5. Gulf of Alaska Deepwater Flatfish

By
William T. Stockhausen, Benjamin J. Turnock,
Mark E. Wilkins and Michael H. Martin

Executive Summary

Changes in the Input Data

1) The last full assessment was in 2005. The fishery catch for 2006 and 2007 (through Sept. 22, 2007) was incorporated in the age-structured model for Dover sole.
2) Survey biomass and length composition data for Dover sole from the 2007 GOA groundfish survey were added to the model. Survey biomass decreased from 80,537 t in 2005 to 71,624 t in 2007.
3) Survey age compositions for Dover sole from 2003 and 2005 were added to the model. Corresponding length compositions were substantially de-weighted to avoid “double counting”.

Changes in the Assessment Model

No changes were made to the model structure.

Changes in the Assessment Results

1. The recommended ABCs for the deepwater flatfish complex, based on an $F_{40\%}$ harvest level of 0.137 for Dover sole and 0.75 *x* mean historic catch for Greenland turbot and deepsea sole, are 8,903 t for 2008 and 9,172 t for 2009.
2. The OFLs, based on an $F_{35\%}$ harvest level of 0.176 for Dover sole and mean historic catch for Greenland turbot and deepsea sole, are 11,343 t for 2008 and 11,583 t for 2009.
3. Projected female spawning biomass for Dover sole is estimated at 43,284 t for 2008.
4. Total biomass (age 3+) for Dover sole is estimated at 132,625 t for 2008.

A summary of the recommended ABCs from the 2007 assessment, relative to the 2006 SAFE projections, is as follows:

Species	Quantity	2007 Assessment Recommendations for 2008	2006 Assessment Recommendations for 2008	2006 Assessment Recommendations for 2007
Dover sole	**Tier**	**3a**	**3a**	**3a**
	Total biomass (Age 3+; t)	132,625	135,552	134,196
	Female Spawning Biomass (t)	43,284	43,030	42,398
	ABC (t)	8,720	8,800	8,524
	Overfishing (t)	10,999	11,168	10,817
	$F_{ABC} = F_{40\%}$	0.137	0.142	0.142
	$F_{OFL} = F_{35\%}$	0.176	0.184	0.184
Greenland turbot	**Tier**	**6**	**6**	**6**
	ABC (t)	179	179	179
	Overfishing (t)	238	238	238
Deepsea sole	**Tier**	**6**	**6**	**6**
	ABC (t)	4	4	4
	Overfishing (t)	6	6	6
Entire complex	ABC (t)	8,903	8,983	8,707
	Overfishing (t)	11,243	11,412	11,061

SSC Comments Specific to the Deepwater Flatfish Assessments

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: We felt that the problem with the fishery selectivity curves was a result of misspecification of the functional form for selectivity. We have investigated this issue herein. However, we also recognize that the SSC's suggestion is a good one and we will endeavor to address it prior to the next assessment.

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: This request is being incorporated in a new assessment model that is under development.

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

SSC comment: *The SSC encouraged authors to consider adding more detailed ecosystem consideration information in the flatfish chapters and exploring survey catchability and temperature relationships.*

Author response: We have expanded the ecosystems considerations section of this chapter by incorporating results from the Gulf of Alaska ecosystem model for Dover sole. We are currently developing an assessment model that incorporates environmental covariates (including possible temperature effects on survey catchability) and hope to have it completed for review in the next assessment cycle (i.e., 2008).

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 deep-water 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 deep-water 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 deep-water flatfish fishery was estimated by partitioning the flatfish catch into its component species groups based on historical species composition of observed catch. The deep-water 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.

Deep-water 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 deep-water flatfish-directed fishery. The gross discard rate for deep-water flatfish across all fisheries in 2006 was 60%, similar to that in 2005 (58%; 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 2007 (244 t as of Sept. 22) was the 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 of Greenland turbot the next year. Annual catch has been less than 25 t since 1995. Deepsea sole is the least caught of the three deep-water 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 1 t for 6 out of 9 years.

Annual catches of deep-water 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 deep-water 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 uses fishery catches from 1978 through 22 September, 2007 (Table 5.1; Figure 5.1). ABC and OFL calculations for Greenland turbot and deepsea sole are based on the mean historical catch from 1978-1995. The age-structured model for Dover sole incorporates catch data from 1984-2007, as well as estimates of the proportion of individuals caught by length group and sex for the years 1985-2004 (Table 5.3). Size composition data from 2005-2007 is 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 deep-water flatfish are lightly exploited by the target fishery and are (relatively speaking) often taken incidentally in target fisheries for other species, CPUE 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 deep-water 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 (1999-2007) basis. The survey typically samples depth strata up to 1000 m, although the deepest strata (> 500 m) have not been consistently sampled (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 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 ~85,000 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. The estimated survey biomass was 71,624 in 2007, about 11% smaller than the 2005 estimate (80,537 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 surveys were also incorporated in the age-structured model. Estimates of numbers-at-age by sex were available for surveys conducted from 1993-2005 (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 transition 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 was incorporated in the assessment:

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

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.

Age classes included in the model run 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 99 parameters were estimated in the final model (Table A.5).

Parameters estimated independently

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

Natural mortality

As in the previous assessment (Stockhausen et al., 2005), 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 length-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 length-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 the previous assessment (Stockhausen et al., 2005).

Weight-at-length

The weight-length relationship used for Dover sole was identical to that used in the previous assessment (Stockhausen et al., 2005): $W = 0.0029\ L^{3.3369}$ for both sexes (weight in grams and length in centimeters; Abookire and Macewicz, 2003). Weight-at-age (Table 5.9) was estimated using the 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 the 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 99 parameters were estimated in the base model (Table A.5). These consist primarily of parameters on the recruitment of Dover sole to the population (62 parameters total, including ones determining the initial age composition) and values related to annual fishing mortality (25 parameters total).

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 relative 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.

Alternative models considered in this assessment considered other strategies for incorporating fishery and survey selectivities into the age-structured model. In one form of alternative model, we modeled both fishery and survey selectivities using sex-specific age-based logistic functions (as in the base model), but ignored distinctions in survey depth coverage (thus, we used only a pair of functions to describe survey selectivity, rather than two pair as in the base model). In another form of alternative model, we used sex-specific "free-form" models for both fishery and survey selectivity. The free-form model for sex-specific selectivity consisted of an independent parameter for each model age (thus 74 parameters were required to model fishery selectivities and 148 parameters were required to model selectivities for the "full" and "shallow" surveys). However, we imposed a substantial "roughness" penalty 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. Free-form 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.

Annual recruitment to the age 3 year class was parameterized in the model using one parameter for the log-scale mean recruitment and 61 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 model using one parameter for the log-scale mean and 24 parameters for the annual log-scale deviation from the mean.

Parameters in the model were selected based on minimizing an objective function equivalent to a negative log-likelihood function, hence the parameter estimates are maximum likelihood estimates. Components that contribute to the overall (-log) likelihood include those related to observed fishery catches, fishery size compositions, survey biomass estimates, survey size compositions, survey age composition, and recruitment deviations (Table A.3). The observed fishery catch was assumed to have a lognormal error structure, as was estimated survey biomass. The 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 allows different weights in the likelihood function to be for recruitment estimates that are 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 1984-2004 and "late" recruitment incorporated deviations from 2005-2007. All three components were formulated assuming a lognormal error structure.

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

Weights placed on the various components of the likelihood are given in Table 5.10. 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.

Model evaluation

In performing this assessment, we investigated several alternative model configurations that considered different formulations for survey and fishery selectivity. The base (and final) model configuration was as described above, with the principal features distinguishing it from the alternative models was the use of 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 as was used in the previous full assessment (Stockhausen et al., 2005). The first alternative model also used logistic selectivity functions to describe fishery and survey selectivities, but this model did not distinguish between "shallow" and "full coverage" surveys and thus estimated a single set of selectivity parameters for the survey. The second alternative model used the "free-form" approach to model both fishery and survey selectivities, with separate sets of selectivity parameters estimated for "full coverage" and "shallow" surveys. The final alternative model we investigated also used the "free-form" approach for fishery and survey selectivities, but this model did not distinguish between "full coverage" and "shallow" surveys and thus estimated only a single set of selectivity parameters for the survey. These models are summarized in the following table:

Model	Selectivity Model	# of survey types	# of parameters
base	logistic	2	99
alt 1	logistic	1	95
alt 2	free-form	2	315
alt 3	free-form	1	241

Initial parameter values for the base model are given in Table 5.11. Initial values for the first alternative model were similar, but with only one survey type used. Initial values for the two models that used the "free-form" approach were also similar, except that the initial values for the fishery and survey selectivity parameters were all set to 0 on a natural log scale (1 on an arithmetic scale).

All four models demonstrated good convergence to final parameter estimates. Unfortunately, the Hessian matrix (related to the inverse covariance matrix for parameter estimates) was not positive definite for the two models using free-form selectivities. This was a result of the substantial penalty we placed on smoothness for the age-specific free-form selectivity parameters. This prevented us from estimating variances associated with the parameters and other derived quantities for these two models.

Overall, all four models fit the observed catch history well (Figure 5.7)--not surprising given the relative weight placed on the catch component of the likelihood. The fit of Alternative Model 1 to the catch appears to be the poorest of the four models.

The fishery selectivity curves resulting from the four model fits are shown in Figure 5.8. From the two models that use logistic models for selectivity, the fishery would appear to exhibit knife-edge selectivity in age, with selectivity changing from 0 to 1 as fish grow one year older (the change occurs at 10.5 yrs for males and at 12-13 yrs for females; Fig.s 5.8 a,b). This might occur if, for example, Dover sole exhibited strong spatial segregation of juveniles and young adults from older animals and the fishery only fished in areas with the older fish. However, results from the two models that use free-form approaches for selectivity (Fig.s 5.8 c,d) suggest that this knife-edge selection may instead be a result of misspecification of the functional form of fishery selectivity. Estimated fishery selectivity for females by these models exhibited a dome-like shape, increasing to a maximum at intermediate ages (~19 yrs), then decreasing with increasing age. This might occur if Dover sole exhibited a continual ontogenetic shift into deeper water such that older females moved to depths beyond the reach of the fishery. If fishery selectivity for females actually *were* dome-shaped, a logistic function would be inappropriate as a model for selectivity because it is a strictly increasing (or decreasing) function and cannot exhibit a domed shape.

The survey selectivity curves resulting from the four models are also shown in Figure 5.8. The curves from the models with free-form selectivities (Fig. 5.8c,d) are reasonably monotonically increasing and do not exhibit the strong dome-shapedness that the female fishery selectivity curve exhibited in these models (although the curves for the "shallow" surveys in alternative mode 2 exhibit a small decline at the oldest ages). In both models, the selectivity curves increase rather rapidly at the youngest ages (with the male curves increasing faster than female curves), then level off at intermediate ages, and increase again at older ages. The characteristics of the selectivity curves in the models with logistic selectivity curves (the base model and alternative model 1) appear to reflect competing influences displayed in the free-form curves.

An intriguing contrast between the models with logistic selectivity functions and those with free-form functions is that the selectivity curves for alternative model 1 (logistic selectivity, single survey type) most closely resemble the "shallow" survey selectivity curves from the base model while those from alternative model 3 (free-form selectivity, single survey type) most closely resemble the "full coverage" survey curves from alternative model 2. Thus the "merging" of the selectivity curves appears to go in opposite directions when the model changes from defining two survey types to one survey type.

Alternative model 2 has the best fit to the survey biomass time series, with alternative model 1 exhibiting the worst fit (on the basis of the survey biomass likelihood component; Figure 5.9). The base model and alternative model 3 have fits only slightly worse than the best fit. All four models overestimate the 1984 and 1987 survey biomass estimates, and underestimate the 2003 survey.

The base model was the accepted model in prior assessments (Turnock et al., 2003; Stockhausen et al., 2005), and thus functions as our "null hypothesis". In comparing the three alternative models considered here with the base model, we did not find sufficient evidence to reject continued use of the base model in favor of one of the alternatives. Thus, we regard the base model as the "accepted" model.

Final parameter estimates

The base model described above was considered the "final" model for this assessment. The parameter estimates from this model are given in Table 5.12.

Schedules implied by parameter estimates

The estimated selectivity curves for the fishery and surveys are shown in Figure 5.8a for the base model. For the fishery, the selectivity curves rise extremely steeply and approximate knife-edge selection. The age at 50% selection is 13 yrs for females and 10.5 yrs for males.

The selectivity curves estimated for the two survey types (shallow and full coverage) differ from those of the fishery, as well as from one another. For both survey types, recruits (age 3) of either sex are 20% selected. For the shallow survey type, selectivity for males increases rapidly with age--age at 50% selection is 4.2--while it increases much less rapidly for females. For the full coverage survey type, selectivity increases very slowly with age for both sexes and doesn't even reach the logistic function's inflection point. Similar results were obtained in the 2005 and 2003 assessments (Turnock et al., 2003; Stockhausen et al., 2005).

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 5.10). 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 5.10a). The smoothing inherent in using an age-length transition 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 5.11). Finally, the model also fits the survey age composition reasonably well (Figure 5.12), although more so at younger ages (less than 20). The model appears to mainly underestimate the size fraction at older ages. Part of the lack of fit at older ages may be due to the 5-year age bins used for ages > 20.

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 (~170,000 t) but declined gradually through the 1990's, reaching a low of 115,000 t in 2001 (Table 5.14 and Figure 5.13). Since 2001, total biomass appears to be increasing moderately and is estimated at 132,000 t for 2007. Total biomass estimated in this assessment agrees well with that from the 2005. The biomass estimated in the current assessment is almost identical to that from the 2005 assessment.

Model estimates of spawning biomass show a pattern somewhat different from that of total biomass (Table 5.14, Figure 5.13). Spawning biomass increased somewhat through the 1980's and peaked in 1991 at 64,000 t. Subsequently, spawning biomass has steadily declined; the estimate for 2005 (42,000 t) is the lowest in the model time period, corresponding to a decrease of 34% from the maximum in 1991. The spawning biomass estimated in the current assessment is almost identical to that from the 2005 assessment.

The temporal patterns of recruitment estimated by the model were quite similar to those from the 2005 assessment and average recruitments were nearly identical (17 million individuals). Model estimates of annual recruitment (age 3 numbers) ranged from a low of 8 million in 1995 to a high of 44 million in 2002 (Table 4a.18, Figure 4a.15). 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). There is also evidence of a peak at age 6 in the 2005 survey age composition data that corresponds to recruits entering the model in 2002, providing additional evidence to support Turnock et al.'s (2003) suggestion.

A control rule plot showing the temporal trajectory of estimated fishing mortality and spawning biomass indicates that the GOA Dover sole stock has not been overfished nor has overfishing occurred (Figure 5.15). 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 1981-2003 year classes (1984-2006 age 3 recruits) estimated in this assessment represents a reliable estimate of equilibrium recruitment, then $B_{40\%}$ is 21,077 t. The estimated 2008 spawning stock biomass is 43,284 t. Since reliable estimates of the 2008 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B>B_{40\%}$ (43,284 t > 21,077 t), the Dover sole reference fishing mortality is defined in Tier 3a. For this tier, F_{ABC} is constrained to be $\leq F_{40\%}$, and F_{OFL} is defined to be $F_{35\%}$. The values of these quantities are:

Quantity	Value
2008 SSB estimate (B)	43,284 t
$B_{40\%}$	21,077 t
$F_{40\%}$	0.137
F_{ABC}	0.137
$B_{35\%}$	18,443 t
$F_{35\%}$	0.176
F_{OFL}	0.176

Because the Dover sole stock has not been overfished in recent years and the stock biomass is relatively high, 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 2007 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2007. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch 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 2008, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of $max\ F_{ABC}$, where this fraction is equal to the ratio of the F_{ABC} value for 2006 recommended in the assessment to the $max\ F_{ABC}$ for 2005. (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 2003-2007 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

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 5.16-18.

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 2008, then the stock is not overfished.)

Scenario 7: In 2008 and 2009, F is set equal to $max\ F_{ABC}$, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2020 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that the Dover sole stock is not overfished and is not approaching an overfished condition (Tables 5.16-18). With regard to assessing the current stock level, the expected stock size in the year 2008 of scenario 6 is over twice its $B_{35\%}$ value of 18,443 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 2020 of scenario 7 (20,776 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 estimtates 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)	2008 ABC (t)	2008 OFL (t)	2009 ABC (t)	2009 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 $F_{35\%}$. 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 2008 for Dover sole is 8,720 t and OFL is 10,999 t. For 2008, female spawning biomass is projected to be 43,284 t while total biomass (i.e., age 3+ biomass) is projected to be 132,625 t.

Estimating an ABC and OFL for 2009 is somewhat problematic as these values depend on the catch that will be taken in 2008. The actual catch taken in the GOA Dover sole fishery has been substantially smaller than the TAC for the past several years, and the 2007 catch was the smallest in recent years. To be conservative, we assumed that a reasonable estimate of the catch to be taken in 2008 was the five-year average of recent catches (531 t). Using this value and the estimated population size at the start of 2008, we projected the stock ahead through 2008 and calculated the ABC and OFL for 2009. ABC for 2009 is 8,989 t and OFL is 11,339 t. For 2009, female spawning biomass is projected to be 44,560 t while total biomass (i.e., age 3+ biomass) is projected to be 133,062 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 2007 survey biomass estimated for each area (relative to the total over all areas) to the 2008 and 2009 ABCs. The area-specific allocations for 2008 and 2009 are:

Greenland turbot	Western Gulf	Central Gulf	West Yakutat	Southeast Outside	Total
apportionment	68.2%	22.3%	5.0%	4.5%	100.0%
2008 ABC (t)	122	40	9	8	179
2009 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%
2008 ABC (t)	0	4	0	0	4
2009 ABC (t)	0	4	0	0	4

Dover sole	Western Gulf	Central Gulf	West Yakutat	Southeast Outside	Total
apportionment	6.5%	76.6%	11.0%	5.9%	100.0%
2008 ABC (t)	568	6,677	956	519	8,720
2009 ABC (t)	585	6,884	986	535	8,989

All	Western Gulf	Central Gulf	West Yakutat	Southeast Outside	Total
2008 ABC (t)	690	6,721	965	527	8,903
2009 ABC (t)	707	6,928	995	543	9,172

Ecosystem Considerations

Ecosystem effects on the stock

Based on results from an ecosystem model for the Gulf of Alaska (Aydin et al., in press), Dover sole adults occupy an intermediate trophic level (Figure 5.16). Dover sole commonly feed on brittle stars, polychaetes and other miscellaneous worms (Figure 5.17; 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. 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 Greenland turbot or deepsea sole roles 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, whereas 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 is an important predator of turbot in the Bering Sea, but it is unknown whether this holds in the Gulf, as well.

Fishery effects on ecosystem

Small amounts of protected species such as halibut and crab are taken in the deepwater flatfish-directed fishery. In 2004, the overall halibut PSC rate for the directed fishery was 218 kg halibut/t flatfish--an increase from the 2003 rate of 105. However, apparently no halibut were caught in the directed fishery in 2005 or 2006. The PSC rate for salmon in the 2004 directed fishery was essentially 0 salmon/t flatfish (only 2 salmon were caught), a decrease from 1.92 salmon/t flatfish in 2003 (631 salmon caught). Crabs were not taken in the fishery in either 2003 or 2004. Catches of salmon and crabs were also nonexistent in 2005-2006.

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 (Figure 4a.19). It is unknown whether this level of spatial concentration by the fishery will have any effects on the stock.

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

Data gaps and research priorities

The amount of age data for Dover sole in the Gulf of Alaska available from the groundfish survey is improving, but is nonexistent from the fishery. Additional age data should improve future stock assessments by allowing improved estimates of individual growth and age-length transition matrices, and by filling in missing years with age composition data.

Further modeling research should address the use of length-based approaches to fishery and survey selectivity in the assessment model, as well as alternative forms for the selectivity function. In addition, spatially-explicit approaches that incorporate the differences in survey depth coverage among years should be considered. The utility of potential environmental predictors of recruitment (e.g., temperature) should also be investigated.

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.

Summary

Tier 6 Species	Mean catch (t)	2008 ABC (t)	2008 OFL (t)	2009 ABC (t)	2009 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	
$F_{35\%}$	0.176	
$F_{40\%}$	0.137	
Equilibrium female spawning biomass		
$B_{100\%}$	52,693 t	
$B_{40\%}$	21,077 t	
$B_{35\%}$	18,443 t	
Fishing rates		
F_{OFL}	0.176	
F_{ABC} (maximum permissible)	0.137	
F_{ABC} (recommended)	0.137	
2007 biomass		
Age 3+ biomass (t)	131,720 t	
Female spawning biomass (t)	42,280 t	
Projected biomass	**2008**	**2009**
Age 3+ biomass (t)	132,625	133,062
Female spawning biomass (t)	43,284	44,560
Harvest limits	**2008**	**2009**
OFL (t)	10,999	11,339
ABC (maximum permissible; t)	8,720	8,989
ABC (recommended; t)	8,720	8,989

Literature Cited

Abookire, A. A. and B. J. Macewicz. 2003. Latitudinal variation in reproductive biology and growth of female Dover sole (Microstomus pacificus) in the Nort Pacific, with emphasis on the Gulf of Alaska stock. J. Sea Res. 50: 187-197.

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. In press. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA NMFS Tech Memo. 298 p.

Buckley, T.W., G.E. Tyler, D.M. Smith and P.A. Livingston. Food habits of some commercially important groundfish off the costs of California, Oregon, Washington, and British Columbia. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-102, 173 p.

Demory, R.L., J.T. Golden and E.K. Pikitch. 1984. Status of Dover sole (*Microstomus pacificus*) in INPFC Columbia and Vancouver areas in 1984. Status f Pacific Coast Groundfish Fishery and Recommendations for Management in 1985. Pacific Fishery Management Council. Portland, Oregon 97201.

Fournier, D.A. and C.P. Archibald. 1982. A general theory for analyzing catch-at-age data. Can. J. Fish. Aquat. Sci. 39:1195-1207.

Greiwank, A. and G.F. Corliss (ed.s). 1991. Automatic differentiation of algorithms: theory, implementation and application. Proceedings of the SIAM Workshop on the Automatic Differentiation of Algorithms, held Jan 6-8, Breckenridge, CO. Soc., Induust. and Applied Mathematics, Philadelphia.

Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Canada, Bull. No. 180. 740 p.

Hirschberger, W.A. and G.B. Smith. 1983. Spawning of twelve groundfish species in the Alaska and Pacific coast regions. 50 p. NOAA Tech. Mem. NMFS F/NWC-44. U.S> Dep. Commer., NOAA, Natl. Mar. Fish. Serv.

Hoenig, J. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82:898-903.

Hunter, J.R., B.J. Macewicz, N.C.-H. Lo and C.A. Kimbrell. 1992. Fecundity, spawning, and maturity of female Dover sole, *Microstomus pacificus*, with an evaluation of assumptions and precision. Fish. Bull. 90:101-128.

Ianelli, J.N. T.K. Wilderbuer and D. Nichol. 2006. 5. Assessment of Greenland Turbot in the Eastern Bering Sea and Aleutian Islands. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Gulf of Alaska as Projected for 2007. pp. 492-540. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage AK 99510.

Kendall, A.W. Jr. and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. NOAA Tech. Rep. NMFS 20, U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv.

Markle, D.F., P.M. Harris and C.L. Toole. 1992. Metamorphosis and an overview of early life-history stages in Dover sole *Microstomus pacificus*. Fish. Bull. 90:285-301.

Martin, M.H. and D.M. Clausen. 1995. Data report: 1993 Gulf of Alaska Bottom Trawl Survey. U.S. Dept. Commer., NOAA, Natl. Mar. Fish. Serv., NOAA Tech. Mem. NMFS-AFSC-59, 217p.

Methot, R.D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. Intl. N. Pac. Fish. Comm. Bull. 50:259-277.

Miller, D.J. and R.N. Lea. 1972.Guide to the coastal marine fishes pf California. Calif. Dept. Fish. Game, Fish. Bull. 157, 235 p.

Press, W.H., A.A. Teukolsky, W.T. Vetterling and B.P. Flannery. 1992. Numerical Recipes in C. Second Ed. Cambrige Univ. Press. 994 p.

Stockhausen, W.T., B.J. Turnock, Z.T. A'mar, M.E. Wilkins and M.H. Martin. 2005. 4a. Gulf of Alaska Dover Sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Gulf of Alaska as Projected for 2006. pp. 351-397. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage AK 99510.

Turnock, B.J., T.K. Wilderbuer and E. S. Brown. 2003. Gulf of Alaska Dover sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Gulf of Alaska as Projected for 2004. pp. 341-368. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage AK 99510.

Westrheim, S.J., W.H. Barss, E.K. Pikitch, and L.F. Quirollo. 1992. Stock Delineation of Dover Sole in the California-British Columbia Region, Based on Tagging Studies Conducted during 1948-1979. North American Journal of Fisheries Management 12:172-181.

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. 2007 catch is through Sept. 22.

Year	Greenland turbot (t)	Dover sole (t)	Deep-sea sole (t)	Total (t)
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	244	0	245

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

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	245	97	148	40%

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

Year	Dates	Status
2005	Jan 20-Mar 23	open
	Mar 23-Apr 1	halibut bycatch status
	Apr 1-Apr 8	open
	Apr 8-Apr 24	halibut bycatch status
	Apr 24-May 3	open
	May 3-Jul 5	halibut bycatch status
	Jul 5-Jul 24	open
	Jul 24-Sep 1	halibut bycatch status
	Sep 1-Sep 4	open
	Sep 4-Sep 8	halibut bycatch status
	Sep 8-Sep 10	open
	Sep 10-Oct 1	halibut bycatch status
	Oct 1-Oct 1	open
	Oct 1-Dec31	halibut bycatch status
2006	Jan 20-Apr 27	open
	Apr 27-Jul 1	halibut bycatch status
	Jul 1-Sep 5	open
	Sep 5-Oct 1	halibut bycatch status
	Oct 1-Oct 8	open
	Oct. 8-Dec 31	halibut bycatch status
2007	Jan 20-May 17	open
	May 17-Jul 1	halibut bycatch status
	Jul 1-Aug 10	open
	Aug 10-Sep 1	halibut bycatch status
	Sep 1-Oct 8	open
	Oct 8-Oct 10	halibut bycatch status
	Oct 10-Oct 15	open
	Oct 15-Oct 22	halibut bycatch status
	Oct 22-	open

Table 5.3. Annual fishery length compositions for Dover sole (only) from the domestic fishery. The 2007 composition is based on observer reports through Sept. 22.

a) Females

	Length cutpoints (cm)																								
year	**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**
1991	0	0	0	0	0	0	0	1	1	4	25	69	97	79	80	41	29	9	7	1	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	5	9	12	16	29	30	35	19	19	9	5	6	3	0	0	0
1993	0	0	0	0	0	0	0	2	22	69	76	83	64	78	77	49	31	32	17	11	13	2	5	0	0
1994	0	0	0	0	0	0	0	0	2	5	15	41	61	93	89	71	26	18	3	4	3	1	1	0	0
1995	0	0	0	0	0	0	1	3	2	8	31	76	104	128	101	36	44	7	12	6	1	1	0	0	0
1996	0	0	0	0	0	0	0	0	5	20	40	42	62	135	140	138	78	46	17	5	0	0	2	0	0
1997	0	0	0	0	0	1	0	0	4	10	44	61	94	138	149	132	79	70	36	25	12	7	2	1	1
1998	0	0	0	0	0	0	0	0	4	7	17	27	46	87	151	203	145	87	60	18	8	2	1	0	0
1999	0	0	0	0	0	0	1	4	12	17	41	54	66	74	66	92	78	49	21	18	12	7	7	2	4
2000	0	0	0	0	0	0	1	1	1	3	5	9	11	31	44	69	58	28	35	14	6	3	1	0	0
2001	0	0	0	0	0	0	0	0	1	1	8	17	19	19	20	36	45	34	38	22	12	4	2	2	0
2002	0	0	0	0	0	0	0	1	0	0	2	0	3	2	7	3	16	14	8	8	3	0	0	2	0
2003	0	0	0	0	0	0	1	0	1	2	2	9	9	8	9	17	30	20	14	10	4	2	2	0	0
2004	0	0	0	0	0	0	0	1	0	0	5	7	8	16	26	25	32	38	24	14	12	16	2	3	1

b) Males.

	Length cutpoints (cm)																								
year	**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**
1991	0	0	0	0	0	0	7	8	38	69	117	184	109	59	30	13	2	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	1	1	6	2	11	33	27	32	32	12	7	4	1	2	0	0	0	0	0	0
1993	0	0	0	0	0	0	1	6	104	223	197	117	62	43	19	27	10	4	3	5	2	0	0	0	0
1994	0	0	0	0	0	0	1	9	120	328	363	242	138	85	25	32	10	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	1	1	1	40	160	259	179	137	72	41	10	1	2	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	1	3	37	127	129	157	131	65	25	9	6	1	1	1	0	0	0	0	0
1997	0	0	0	0	0	1	1	6	58	184	259	251	256	201	145	77	15	3	2	0	0	1	0	0	0
1998	0	0	0	0	0	0	0	5	43	99	205	240	261	197	84	40	10	4	2	0	0	0	2	1	0
1999	0	0	1	0	1	2	4	10	32	58	99	87	98	78	72	32	12	5	2	1	0	0	0	1	0
2000	0	0	0	0	0	1	1	1	4	27	73	107	95	88	59	28	13	3	3	1	1	0	0	0	0
2001	0	0	0	0	0	0	1	1	4	6	27	71	97	65	70	46	20	12	5	5	1	2	0	0	0
2002	0	0	0	0	1	0	0	2	1	0	6	31	30	40	44	27	11	11	3	1	0	0	0	0	0
2003	0	0	0	0	0	0	0	3	5	26	50	47	48	33	39	15	3	3	1	2	0	0	0	0	0
2004	0	0	0	0	0	0	1	0	0	14	44	43	51	77	81	53	18	5	7	1	0	0	0	0	0

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

a). Fishery length compositions.

	Males		Females	
year	# of hauls	# of individuals	# of hauls	# of individuals
1990	2	225	2	24
1991	20	636	20	443
1992	10	171	10	197
1993	24	823	27	631
1994	26	1,353	26	433
1995	23	904	23	561
1996	21	693	23	730
1997	41	1,460	41	866
1998	47	1,193	46	863
1999	56	595	62	625
2000	48	556	47	347
2001	43	433	42	280
2002	15	208	15	69
2003	25	275	23	140
2004	31	395	33	230
2005	1	2	2	10
2006	4	30	5	18
2007	2	20	2	20

b). GOA groundfish surveys.

	Survey biomass	Size compositions				Age compositions			
		Males		Females		Males		Females	
year	# of hauls	# of hauls	# of individuals	# of hauls	# of individuals	# of hauls	# of individuals	# of hauls	# of individuals
1984	929	204	6,271	211	3,828	13	255	13	209
1987	783	80	2,872	79	2,308				
1990	708	188	3,401	194	4,034				
1993	775	283	5,316	306	4,866	23	105	31	147
1996	807	308	3,886	373	3,239	49	170	55	213
1999	764	287	3,961	319	2,573	39	148	46	162
2001	489	130	975	161	965	81	239	102	296
2003	809	317	3,785	326	2,893	65	238	86	266
2005	839	358	4,269	379	3,003	79	241	84	273
2007	820	333	3,461	375	2,466				

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. "Corrected" Dover sole biomass is adjusted for incomplete survey coverage (i.e., total Gulf biomass divided by the assumed availability to the survey).

1) Dover sole.

Year	Western Gulf (t)	Central Gulf (t)	West Yakutat (t)	Southeast (t)	Total Gulf (t)	Std. Dev (t)	Max Depth (m)	Assumed availability	"corrected" Total Gulf (t)
1984	4,460	52,469	7,516	4,076	68,521	6,136	1000	1	68,521
1987	2,623	34,577	21,067	5,127	63,394	7,388	1000	1	63,394
1990	1,649	71,109	18,699	5,140	96,597	12,375	500	0.82	117,801
1993	2,371	43,515	26,877	12,787	85,549	6,441	500	0.82	104,329
1996	1,458	37,144	29,766	11,162	79,531	5,624	500	0.82	96,989
1999	1,442	34,155	25,647	13,001	74,245	5,236	1000	1	74,245
2001	895	31,529	**	**	32,424	3,758	500	0.42	77,200
2003	3,149	49,283	31,609	15,256	99,297	10,544	700	1	99,297
2005	2,832	38,881	25,177	13,647	80,538	6,794	1000	1	80,538
2007	2,325	43,490	13,690	12,120	71,624	7,112	1000	1	71,624

2) Greenland turbot

Year	Western Gulf (t)	Central Gulf (t)	West Yakutat (t)	Southeast (t)	Total Gulf (t)	Std. Dev (t)
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

3) Deepsea sole.

Year	Western Gulf (t)	Central Gulf (t)	West Yakutat (t)	Southeast (t)	Total Gulf (t)	Std. Dev (t)
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

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.

	Depth strata (m)					
year	**1-100**	**100-200**	**200-300**	**300-500**	**500-700**	**700-1000**
1984	2,829	30,220	7,928	6,822	8,166	12,557
1987	4,401	25,831	12,039	8,934	10,542	1,647
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	6,049	1,323
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	3,134	2,689
2007	2,814	29,709	19,598	11,335	5,179	2,989

2) Greenland turbot

	Depth strata (m)					
year	**1-100**	**100-200**	**200-300**	**300-500**	**500-700**	**700-1000**
1984	0	0	1	204	35	52
1987	0	25	0	19	66	33
1990	0	0	0	0	**	**
1993	0	0	0	0	**	**
1996	0	0	0	0	**	**
1999	0	0	0	0	0	0
2001	0	0	0	0	**	**
2003	0	0	0	109	0	**
2005	0	0	0	0	0	0
2007	0	0	0	0	122	0

3) Deepsea sole.

	Depth strata (m)					
year	**1-100**	**100-200**	**200-300**	**300-500**	**500-700**	**700-1000**
1984	0	0	0	0	195	23
1987	0	0	0	0	160	0
1990	0	0	0	0	**	**
1993	0	0	0	0	**	**
1996	0	0	0	0	**	**
1999	0	0	0	0	66	31
2001	0	0	0	52	**	**
2003	0	0	0	0	180	**
2005	0	0	0	0	242	20
2007	0	0	0	8	144	122

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
1993	175,468	589,597	1,987,286	1,334,975	1,500,052	897,501	1,883,943	2,547,864	2,467,711	2,367,420	2,738,483	3,073,772	2,300,861	63,879	1,204,741	1,307,452	140,334	5,952,348	7,116,675	6,941,040	2,988,844	420,415
1996	306,730	500,830	2,116,609	506,687	543,968	1,224,424	2,313,215	643,320	1,853,676	2,663,814	2,178,534	751,068	2,755,962	1,695,299	1,228,467	1,091,717	1,665,235	8,557,422	4,226,370	4,169,151	2,463,610	1,966,931
1999	114,907	1,052,940	3,131,470	1,609,283	750,687	1,085,458	1,384,174	524,448	1,591,697	762,811	1,816,584	992,802	2,729,421	2,762,499	1,186,373	852,452	853,313	5,355,809	3,374,473	3,159,376	1,496,633	4,462,199
2001	162,773	631,557	1,053,997	1,096,961	676,309	779,114	125,722	369,652	0	0	175,367	182,634	457,045	0	877,147	685,463	180,299	1,568,113	1,822,027	2,281,102	2,052,032	949,628
2003	2,009,165	5,285,311	4,851,258	4,605,596	2,516,427	3,176,347	1,384,941	2,121,125	1,849,151	1,623,932	1,063,179	1,358,827	1,180,452	1,082,689	250,292	972,694	1,219,331	6,669,126	4,692,529	2,542,372	2,485,394	5,979,459
2005	1,586,021	991,647	3,370,298	5,720,930	2,695,481	3,717,988	839,127	1,642,353	1,927,716	366,682	810,826	1,029,912	462,039	686,250	356,274	921,532	1,296,247	6,458,981	2,803,131	2,012,104	2,389,745	5,200,515

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
1993	1,547,990	2,407,719	4,087,338	2,708,632	4,725,480	5,211,767	2,819,716	3,362,262	1,104,988	2,325,228	1,318,480	1,149,482	2,193,285	1,167,653	968,468	663,149	595,469	6,226,585	1,703,156	1,868,705	1,631,736	0
1996	275,501	1,125,039	3,362,010	2,317,514	2,125,828	2,167,404	2,813,505	1,522,745	1,380,784	4,437,499	5,055,895	3,899,908	2,832,262	2,450,190	629,467	1,551,937	1,792,496	4,054,522	2,601,717	0	752,381	324,873
1999	550,609	2,912,338	3,421,018	2,455,500	806,259	2,020,493	876,111	749,541	1,020,575	1,239,225	534,099	1,447,501	75,987	1,388,766	624,807	2,539,544	75,987	9,438,144	5,527,949	4,911,877	6,258,749	6,020,747
2001	352,700	1,015,131	1,538,281	1,792,614	1,624,724	765,731	337,948	456,200	378,793	104,682	0	280,038	0	593,322	228,101	0	528,946	1,773,053	1,490,781	1,764,407	1,756,096	201,249
2003	1,745,838	7,903,065	5,281,651	7,926,014	4,847,125	4,342,535	1,027,321	2,932,513	1,662,527	1,469,835	2,486,877	1,762,958	1,502,471	0	2,298,418	640,299	1,665,892	6,474,497	7,991,987	4,025,888	3,097,519	9,062,224
2005	1,236,125	999,765	6,882,427	8,561,828	3,912,919	1,675,903	2,898,252	1,667,415	1,846,653	584,146	1,878,429	946,950	1,141,008	1,389,089	976,089	702,043	304,939	7,121,664	4,058,083	2,072,639	3,471,983	6,775,685

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

a) Females.

	Length cutpoints (cm)																								
year	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	57,202	102,501	769,663	1,380,492	2,521,239	3,523,128	4,471,698	5,530,032	6,600,259	5,515,142	4,126,363	3,204,886	2,297,298	1,616,048	917,909	697,263	184,003	158,947	52,658	36,393	0	0
1987	0	45,016	235,938	68,955	148,167	307,091	495,005	1,026,637	1,906,843	2,767,360	4,771,983	6,097,976	6,139,135	6,027,697	4,393,082	3,057,823	1,740,018	1,376,400	523,549	278,789	202,238	0	0	0	0
1990	22,956	22,956	22,956	13,598	41,030	172,944	499,540	808,258	1,177,712	2,346,800	3,233,110	5,506,590	7,594,986	10,100,104	8,524,664	7,073,956	6,797,642	2,907,377	1,249,981	845,502	218,833	69,827	129,991	1,992	0
1993	0	0	11,462	73,326	182,567	246,836	649,643	968,351	1,386,912	1,677,424	2,257,020	3,460,390	5,314,430	6,986,581	8,763,514	6,453,435	5,151,420	3,306,737	1,561,756	999,627	530,696	211,274	87,786	36,040	17,527
1996	92,571	113,077	185,170	300,308	323,831	398,536	521,471	988,802	1,620,893	1,730,806	2,234,114	2,358,219	3,288,388	4,434,603	5,755,202	6,347,051	5,787,072	4,286,438	2,545,825	1,484,355	616,114	257,003	85,136	55,291	0
1999	52,602	132,643	154,499	390,048	613,774	1,361,976	1,878,144	1,437,027	1,803,891	2,043,884	2,296,925	2,770,592	3,315,793	3,514,190	4,080,084	4,118,160	4,774,577	3,327,383	2,138,709	1,283,917	627,980	103,625	41,671	0	0
2001	204,668	146,568	118,026	94,376	472,364	832,618	679,978	761,466	1,205,386	1,513,094	1,306,982	1,002,866	1,010,110	1,569,714	2,234,030	3,178,034	3,167,206	3,740,996	3,433,020	1,907,150	1,685,470	1,479,024	507,480	464,958	198,930
2003	2,261,885	1,400,656	1,701,836	1,415,951	1,551,539	2,242,012	2,755,763	2,283,068	2,536,021	4,030,631	3,668,423	3,983,149	4,001,807	4,705,435	4,302,217	3,893,327	4,461,349	3,477,964	2,885,181	1,806,430	1,032,076	368,932	169,269	114,878	11,639
2005	133,156	161,877	578,168	724,276	908,254	1,856,447	2,413,181	2,591,692	3,675,633	3,828,497	3,337,648	3,709,138	3,238,401	3,031,786	3,193,373	2,884,642	2,682,000	2,824,069	2,295,295	1,748,419	1,320,980	328,535	237,267	78,913	7,473
2007	71,122	138,543	441,874	681,314	920,150	1,024,938	1,127,855	1,219,664	1,873,075	2,363,607	2,240,277	2,910,271	3,581,833	3,474,760	3,224,956	2,820,247	2,647,556	3,198,105	2,276,948	1,588,965	1,194,515	648,158	371,929	113,914	150,427

b) Males.

	Length cutpoints (cm)																								
year	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	42,430	299,982	814,541	1,976,631	3,423,512	7,462,439	13,139,517	13,922,994	9,557,996	5,446,004	2,543,129	1,309,705	428,973	120,474	71,279	142,775	9,682	101,827	0	0	48,493	0	0
1987	0	0	84,329	73,215	303,164	940,394	1,354,051	2,591,737	6,251,352	8,145,509	9,794,006	7,360,218	4,082,985	1,996,811	876,374	430,311	222,466	0	14,051	0	0	0	0	0	0
1990	0	36,985	19,778	42,055	80,222	618,773	917,417	2,263,527	3,832,151	6,827,860	10,361,043	11,751,959	9,519,127	3,740,645	1,410,069	787,375	694,727	325,617	48,987	0	0	0	0	0	0
1993	12,727	36,120	50,185	141,174	200,232	604,950	993,589	1,821,622	4,317,299	6,812,913	9,588,183	10,428,053	7,948,676	4,588,644	1,883,785	920,912	333,622	97,058	66,519	0	20,925	0	0	0	0
1996	24,545	139,728	132,438	325,907	451,555	514,483	1,285,591	2,238,981	3,871,480	6,314,176	8,310,170	9,525,589	7,492,764	4,118,991	1,842,068	674,100	308,558	90,639	22,864	5,269	0	0	0	0	0
1999	90,008	17,651	504,103	840,654	1,265,914	1,964,539	2,607,586	3,365,297	3,774,481	5,707,034	8,411,190	9,447,302	7,077,466	5,435,287	3,222,530	1,217,084	559,618	205,268	26,392	24,250	0	0	0	0	0
2001	97,572	52,142	141,954	222,028	464,794	1,127,876	1,758,868	1,848,306	2,847,824	1,792,226	3,441,596	5,410,218	5,665,180	4,168,432	2,763,100	1,062,102	706,652	365,806	134,594	0	0	0	0	0	34,382
2003	1,658,710	1,430,699	2,125,764	2,007,904	2,682,376	3,400,040	3,539,995	3,972,778	4,961,407	5,980,065	9,086,379	10,931,231	10,659,896	8,671,309	5,368,529	2,966,019	1,568,606	417,111	64,530	65,000	0	27,916	0	0	0
2005	90,948	275,573	656,016	936,960	1,407,411	2,016,909	2,875,520	4,358,413	5,636,146	6,546,388	8,028,912	8,128,357	7,493,406	6,183,898	3,405,760	1,966,610	1,022,764	217,832	104,822	11,924	0	0	0	0	0
2007	37,914	383,046	474,282	685,985	711,685	1,576,707	1,997,659	2,541,432	3,064,529	4,620,222	6,610,659	7,745,264	6,506,845	5,330,849	3,837,366	1,834,400	790,911	326,286	108,076	5,145	10,930	36,559	0	0	99,738

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).

Age	Length (cm) Males	Length (cm) Females	Weight (kg) Males	Weight (kg) Females	Maturity 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. Baseline age-structured assessment model settings for Dover sole.

		Likelihood Component Multipliers							
		Fishery		Survey			Recruitment		
			length		length	age			
Case	**Q**	**catch**	**compositions**	**biomass**	**compositions**	**compositions**	**early**	**ordinary**	**late**
base	1	30	0.5	1	0.5	1	2	1	3

Table 5.11. Initial parameter values for the base mdel.

Case	Recruitment		Fishery						"Full Coverage" Surveys				"Shallow" Surveys			
					slope		A_{50}		slope		A_{50}		slope		A_{50}	
	$\overline{\ln R_0}$	τ_t	$\overline{\ln F}$	ε_t	female	male	female	male	female	male	female	male	female	male	female	male
base	17	0	-6	0	0.4	0.4	5	5	0.8	0.4	4	4	0.8	0.4	4	4

Table 5.12. Final parameter estimates for the base model.

Recruitment										
$\overline{\ln R_0}$	15.986464									
t_t						1947-2007:	-0.88224	-0.134699	-0.142369	-0.150377
	-0.1558161	-0.1612778	-0.16687	-0.172379	-0.1776803	-0.183125	-0.009175	0.003904	0.0193792	0.1106336
	0.1453578	0.15630277	0.1628808	0.2079711	0.4363006	0.602953	0.202587	0.262702	0.3043421	0.0892954
	0.1623181	0.19149508	0.2844847	0.2565381	0.03804	0.2417254	-0.077371	0.358111	0.6198499	0.3411203
	0.4882856	0.1217812	-0.01442	0.2598411	-0.0055071	0.2629896	-0.014056	-0.366492	-0.425466	-0.570847
	-0.5048	-0.7524	-0.6524	-0.2864	-0.6084	-0.3945	-0.0139	0.0802	-0.0773	0.4251
	0.3126	0.9118	0.2519	-0.6645	-0.3524	-0.1127	-0.0828			
Fishing mortality										
$\overline{\ln F}$	-4.6225563									
	1984-2007:			-1.935132	-3.021351	-3.635611	-2.797486	0.059858	0.3659786	0.7733309
	2.1203	2.0414	1.3519	1.1696	0.8287	0.8922	1.3951	0.9574	1.0503	0.2735
e_t	-0.2521	-0.1929	0.3500	0.0577	-0.4383	-0.4792	-0.9351			

Fishery Selectivity

	females	males
slope	23.1474	24.9881
$\mathbf{A_{50}}$	13.1	10.6

Survey Selectivity

	"Full Coverage" Surveys		"Shallow" Surveys	
	females	**males**	**females**	**males**
slope	0.0389	0.0551	0.2045	1.5491
$\mathbf{A_{50}}$	100.0	69.5	9.6	4.2

Table 5.13. Model-estimated catch and survey biomass.

	catch (t)			survey biomass (t)		
year	**estimated**	**std dev**	**observed**	**estimated**	**std dev**	**observed**
1984	141	18	132	88,921	4,465	68,521
1985	48	6	43			
1986	26	3	23			
1987	61	8	56	91,774	4,229	63,394
1988	1,069	135	1,087			
1989	1,472	185	1,521			
1990	2,220	278	2,348	112,850	4,203	96,597
1991	8,178	988	9,741			
1992	7,153	870	8,364			
1993	3,406	419	3,804	95,416	3,716	85,549
1994	2,779	344	3,108			
1995	1,948	243	2,096			
1996	2,024	252	2,177	85,495	3,477	79,531
1997	3,260	400	3,652			
1998	2,020	252	2,230			
1999	2,125	266	2,270	66,257	2,439	74,245
2000	938	118	961			
2001	537	68	800	39,468	1,862	32,424
2002	559	71	554			
2003	930	118	936	68,154	2,532	99,297
2004	678	86	679			
2005	413	52	407	69,099	2,704	80,538
2006	396	50	390			
2007	252	32	244	70,213	2,912	71,624

Table 5.14. Estimated age 3+ population biomass and female spawning biomass.

	Age 3+ Biomass (1000's t)				Female Spawning Stock Biomass (1000's t)			
	2007 Assessment		2005	2003	2007 Assessment		2005	2004
year	mean	std dev	mean	mean	mean	std dev	mean	mean
1984	172	7	172	168	60	3	58	56
1985	172	7	172	169	61	3	59	57
1986	173	7	173	169	62	3	60	59
1987	173	7	173	169	63	3	62	60
1988	172	7	172	167	64	3	63	62
1989	169	7	169	163	64	3	64	63
1990	165	6	166	159	64	3	64	63
1991	160	6	161	153	64	3	64	63
1992	148	6	149	140	60	3	60	58
1993	138	6	139	128	57	3	57	54
1994	133	6	133	121	55	2	56	53
1995	127	6	127	115	54	2	54	51
1996	123	6	123	110	53	2	53	50
1997	120	6	121	107	52	2	52	48
1998	117	6	118	103	50	2	50	45
1999	115	6	116	100	48	2	48	43
2000	115	6	116	98	46	2	46	41
2001	117	7	115	97	45	2	45	40
2002	122	8	121	97	44	2	44	39
2003	126	8	124	97	43	2	43	38
2004	128	9	127		42	2	42	
2005	129	9	130		42	2	42	
2006	131	10			42	2		
2007	132	10			42	2		

Table 5.15. Estimated age 3 recruitment.

	Assessment			
	2007		2005	2003
	Mean	Std Dev	Mean	Mean
Year	(millions)	(millions)	(millions)	(millions)
1984	23	4	23	18
1985	17	3	17	15
1986	23	4	22	19
1987	17	3	17	14
1988	12	2	13	11
1989	11	2	10	9
1990	10	2	10	9
1991	11	2	11	9
1992	8	2	7	5
1993	9	2	8	7
1994	13	2	14	10
1995	10	2	7	5
1996	12	2	13	11
1997	17	3	23	19
1998	19	3	21	17
1999	16	3	15	11
2000	27	5	19	11
2001	24	5	13	12
2002	44	8	45	16
2003	23	5	30	17
2004	9	3	18	
2005	12	3	17	
2006	16	6		
2007	16	6		

Table 5.16. 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**
2007	245	245	245	245	245	245	245
2008	8,720	8,720	4,505	552	0	10,999	8,720
2009	8,011	8,011	4,399	569	0	9,762	8,011
2010	7,806	7,806	4,499	608	0	9,263	9,847
2011	7,447	7,447	4,487	632	0	8,628	9,086
2012	6,944	6,944	4,367	641	0	7,867	8,225
2013	6,874	6,874	4,441	672	0	7,696	7,975
2014	6,420	6,420	4,299	674	0	7,061	7,279
2015	5,811	5,811	4,051	661	0	6,264	6,433
2016	5,399	5,399	3,877	655	0	5,745	5,877
2017	5,128	5,128	3,758	652	0	5,420	5,523
2018	4,921	4,921	3,662	651	0	5,149	5,244
2019	4,767	4,767	3,584	650	0	4,897	4,978
2020	4,633	4,633	3,513	649	0	4,704	4,765

Table 5.17. Female spawning biomass (t) for the seven projection scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 21,077 t and 18,443 t, respectively.

	Female spawning biomass (t)						
year	**scenario 1**	**scenario 2**	**scenario 3**	**scenario 4**	**scenario 5**	**scenario 6**	**scenario 7**
2007	42,280	42,280	42,280	42,280	42,280	42,280	42,280
2008	43,284	43,284	43,284	43,284	43,284	43,284	43,284
2009	40,335	40,335	42,509	44,549	44,834	39,160	40,335
2010	38,325	38,325	42,210	46,088	46,648	36,330	38,325
2011	36,861	36,861	42,083	47,614	48,437	34,310	35,893
2012	35,397	35,397	41,731	48,816	49,901	32,440	33,691
2013	33,709	33,709	40,992	49,559	50,906	30,447	31,430
2014	31,585	31,585	39,798	49,890	51,515	28,028	28,799
2015	29,530	29,530	38,485	49,977	51,872	25,784	26,387
2016	27,864	27,864	37,291	49,960	52,101	24,063	24,534
2017	26,553	26,553	36,255	49,907	52,270	22,784	23,151
2018	25,516	25,516	35,362	49,844	52,412	21,823	22,108
2019	24,695	24,695	34,593	49,779	52,534	21,118	21,331
2020	24,035	24,035	33,925	49,710	52,637	20,622	20,776

Table 5.18. Fishing mortality for the seven projection scenarios.

	Fishing mortality						
year	**scenario 1**	**scenario 2**	**scenario 3**	**scenario 4**	**scenario 5**	**scenario 6**	**scenario 7**
2007	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
2008	0.1367	0.1367	0.0683	0.0081	0.0000	0.1756	0.1367
2009	0.1367	0.1367	0.0683	0.0081	0.0000	0.1756	0.1367
2010	0.1367	0.1367	0.0683	0.0081	0.0000	0.1756	0.1756
2011	0.1367	0.1367	0.0683	0.0081	0.0000	0.1756	0.1756
2012	0.1367	0.1367	0.0683	0.0081	0.0000	0.1756	0.1756
2013	0.1367	0.1367	0.0683	0.0081	0.0000	0.1756	0.1756
2014	0.1367	0.1367	0.0683	0.0081	0.0000	0.1756	0.1756
2015	0.1367	0.1367	0.0683	0.0081	0.0000	0.1756	0.1756
2016	0.1367	0.1367	0.0683	0.0081	0.0000	0.1756	0.1756
2017	0.1367	0.1367	0.0683	0.0081	0.0000	0.1756	0.1756
2018	0.1367	0.1367	0.0683	0.0081	0.0000	0.1742	0.1749
2019	0.1367	0.1367	0.0683	0.0081	0.0000	0.1705	0.1714
2020	0.1366	0.1366	0.0683	0.0081	0.0000	0.1673	0.1681

Table 5.19. Prohibited species catch (PSC) in the deep-water flatfish target fishery. The “deeepwater flatfish (t)” column lists the catch of deepwater flatfish attributed to the targeted fishery.

year	deepwater flatfish (t)	Halibut kg	Halibut kg/t	Crab #	Crab #/t	Salmon #	Salmon #/t
2003	329	34,519	105.0	0	0.0	0	0.00
2004	464	101,460	218.6	0	0.0	2	0.00
2005	108	0	0.0	0	0.0	0	0.00
2006	66	0	0.0	0	0.0	0	0.00

Table 5.20. Catch of non-prohibited species in the deepwater flatfish target fishery. The “Percent of retained target” gives the species catch as a percentage of the deepwater flatfish catch retained in the targeted fishery.

species	2006 Total (t)	2006 % retained	2006 % of retained target	2005 Total (t)	2005 % retained	2005 % of retained target
arrowtooth	1	84%	1%	17	90%	16%
deepwater flatfish	66	100%	100%	108	100%	100%
flathead sole	0	--	--	1	100%	1%
northern rock sole	1	100%	1%	0	--	--
other rockfish	0	0%	0%	0	100%	0%
Pacific cod	1	100%	1%	6	100%	5%
pelagic rockfish complex	1	100%	1%	0	--	--
pollock	0	--	--	0	100%	0%
POP	0	--	--	0	100%	0%
rex sole	0	--	--	3	100%	3%
rougheye	0	--	--	0	100%	0%
sablefish	3	100%	0	5	100%	5%
shallow-water flatfish	2	100%	3%	2	100%	2%
thornyheads	5	100%	7%	9	100%	9%
longnose skate	0	--	--	1	100%	1%

Figures

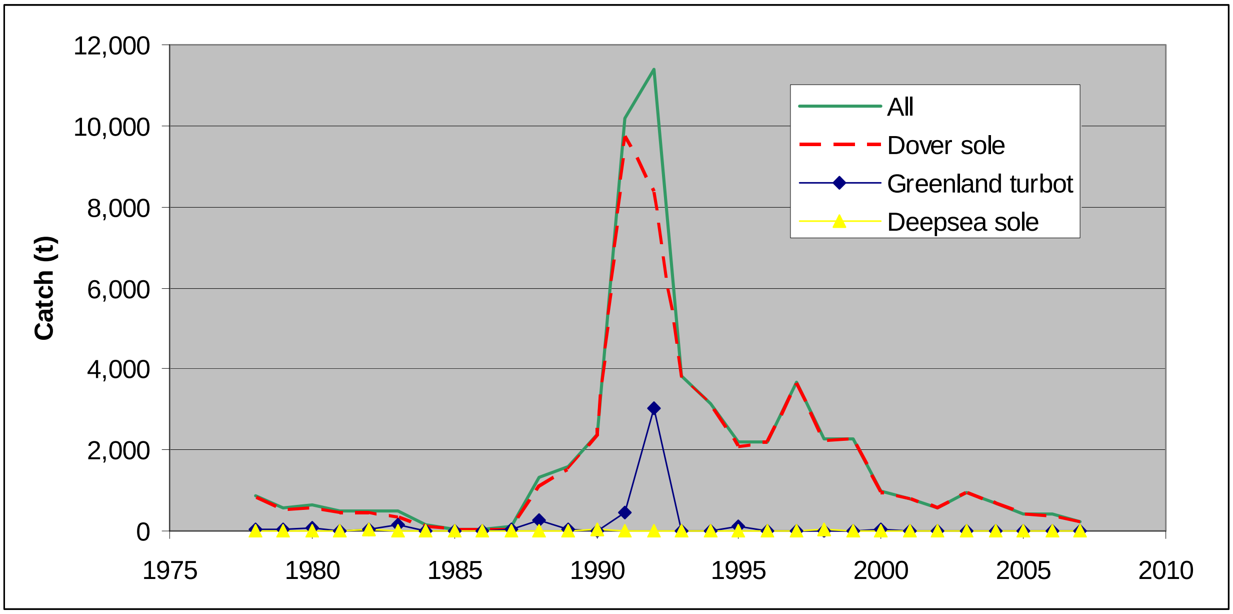


Figure 5.1. Fishery catches for GOA deepwater flatfish (Dover sole, Greenland turbot and deepsea sole), 1978-2007.

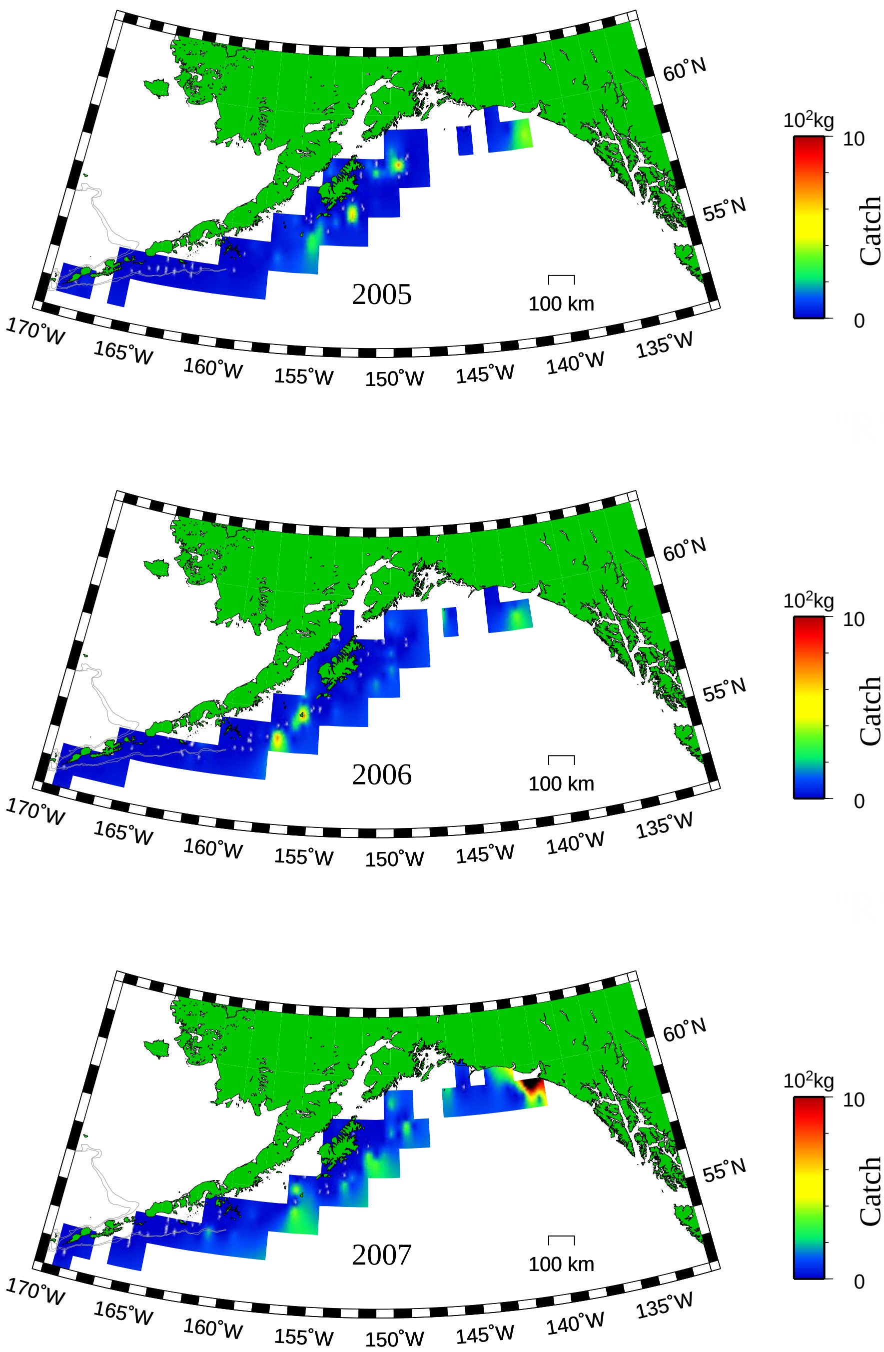


Figure 5.2. Spatial patterns of fishery catches for GOA Dover sole, 2005-2007.

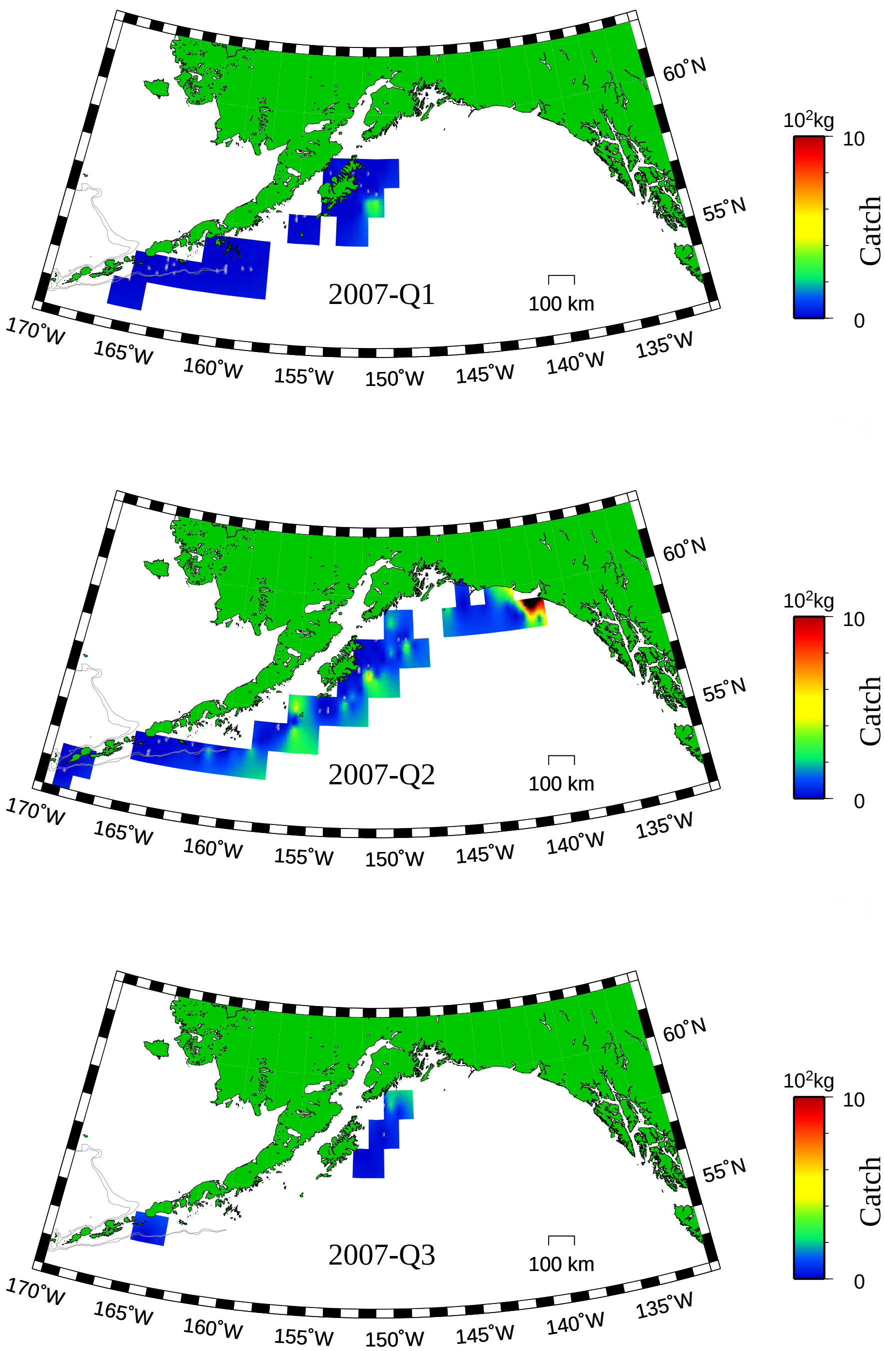


Figure 5.3. Spatial patterns of fishery catches for GOA Dover sole from the first three quarters of 2007.

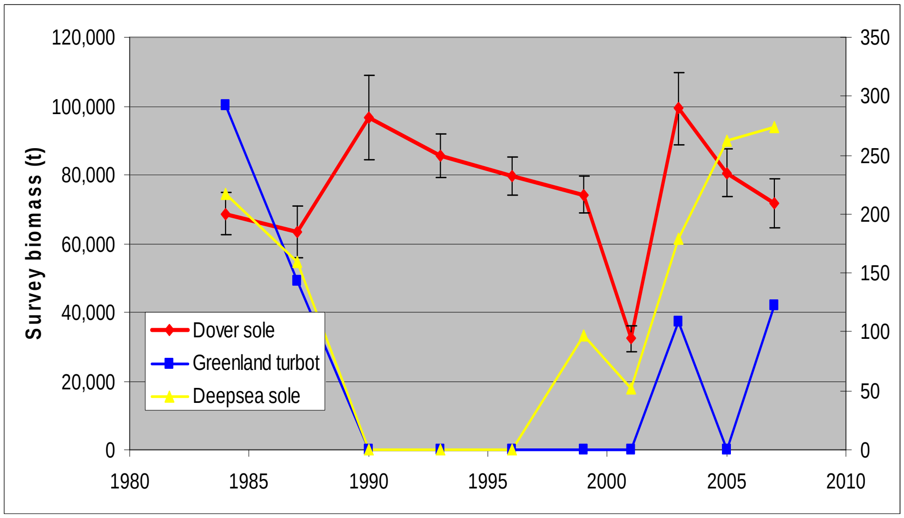


Figure 5.4. GOA survey biomass for the deepwater flatfish. Dover sole is plotted against the left-hand y-axis, while Greenland turbot and deepsea sole are plotted against the righthand y-axis. Error bars are ± 1 standard deviation (shown for Dover sole only). The 2001 GOA survey did not survey the Eastern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

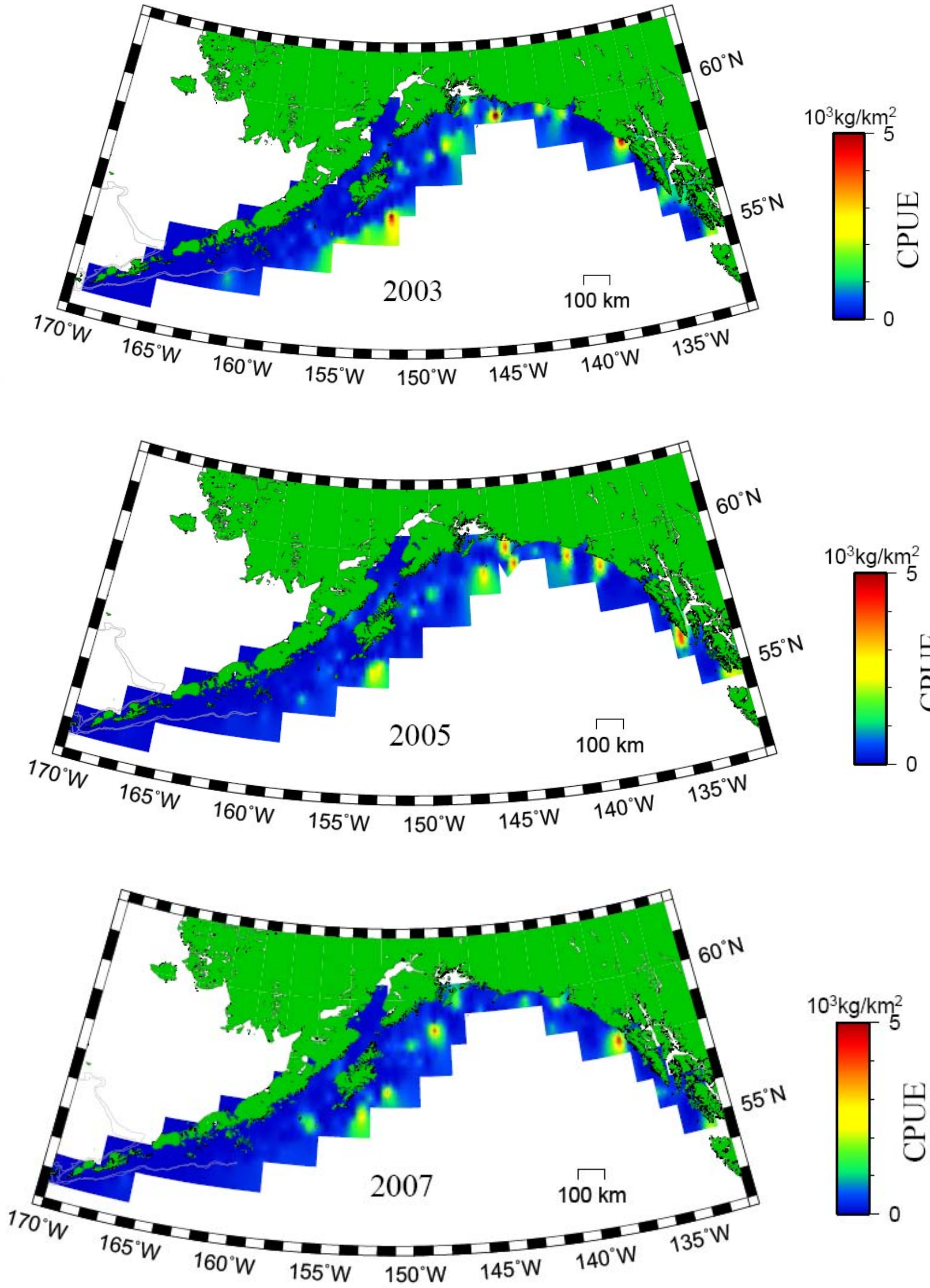
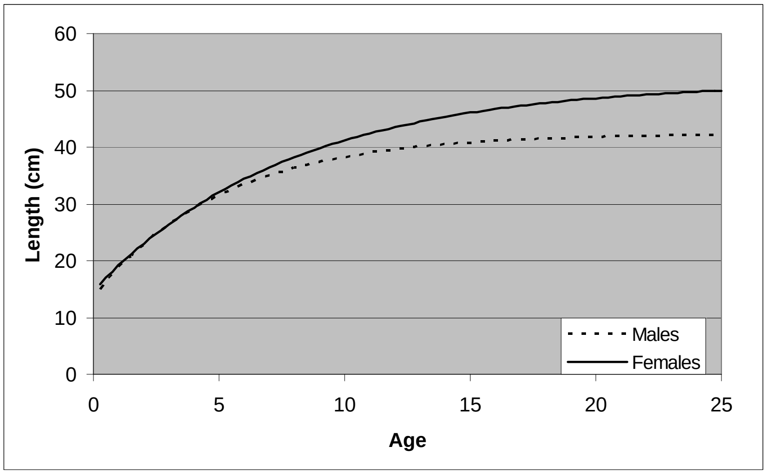
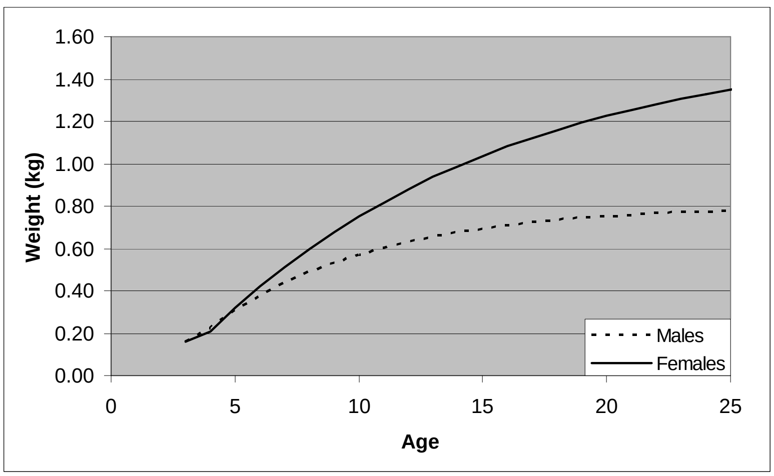


Figure 5.5. Spatial patterns of CPUE for Dover sole in the GOA groundfish surveys for 2003-2007.

a) Length-at-age.



b) Weight-at-age.



c) Maturity-at-age (females).

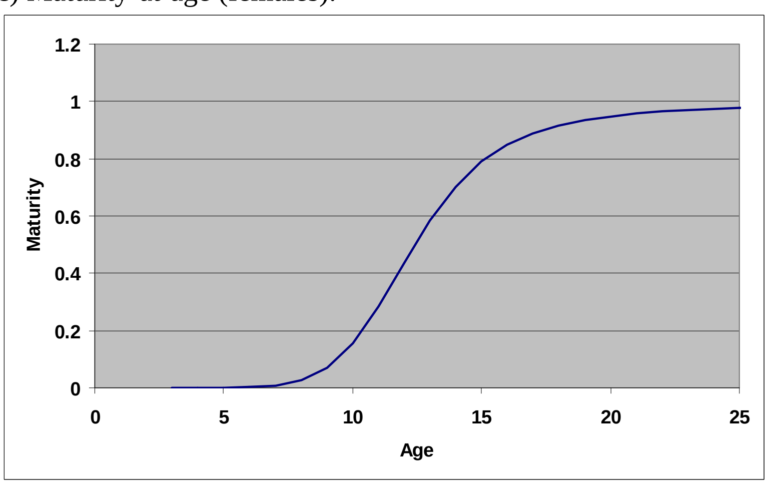


Figure 5.6. Age-specific schedules for GOA Dover sole: females solid line, males dotted line.

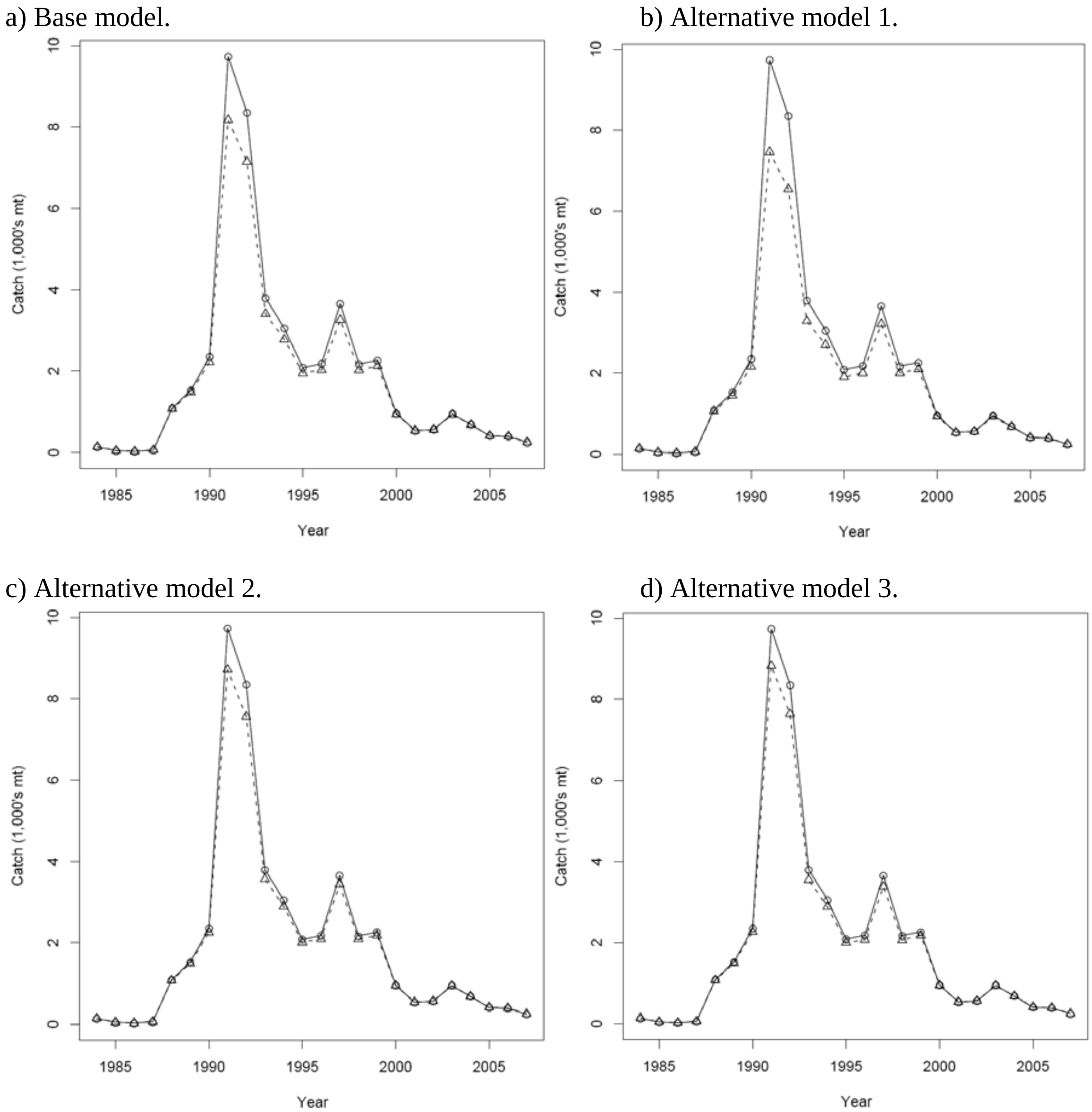


Figure 5.7. Predicted and observed annual catches for GOA Dover sole. Predicted catch = dotted line with circles, observed catch = solid line.

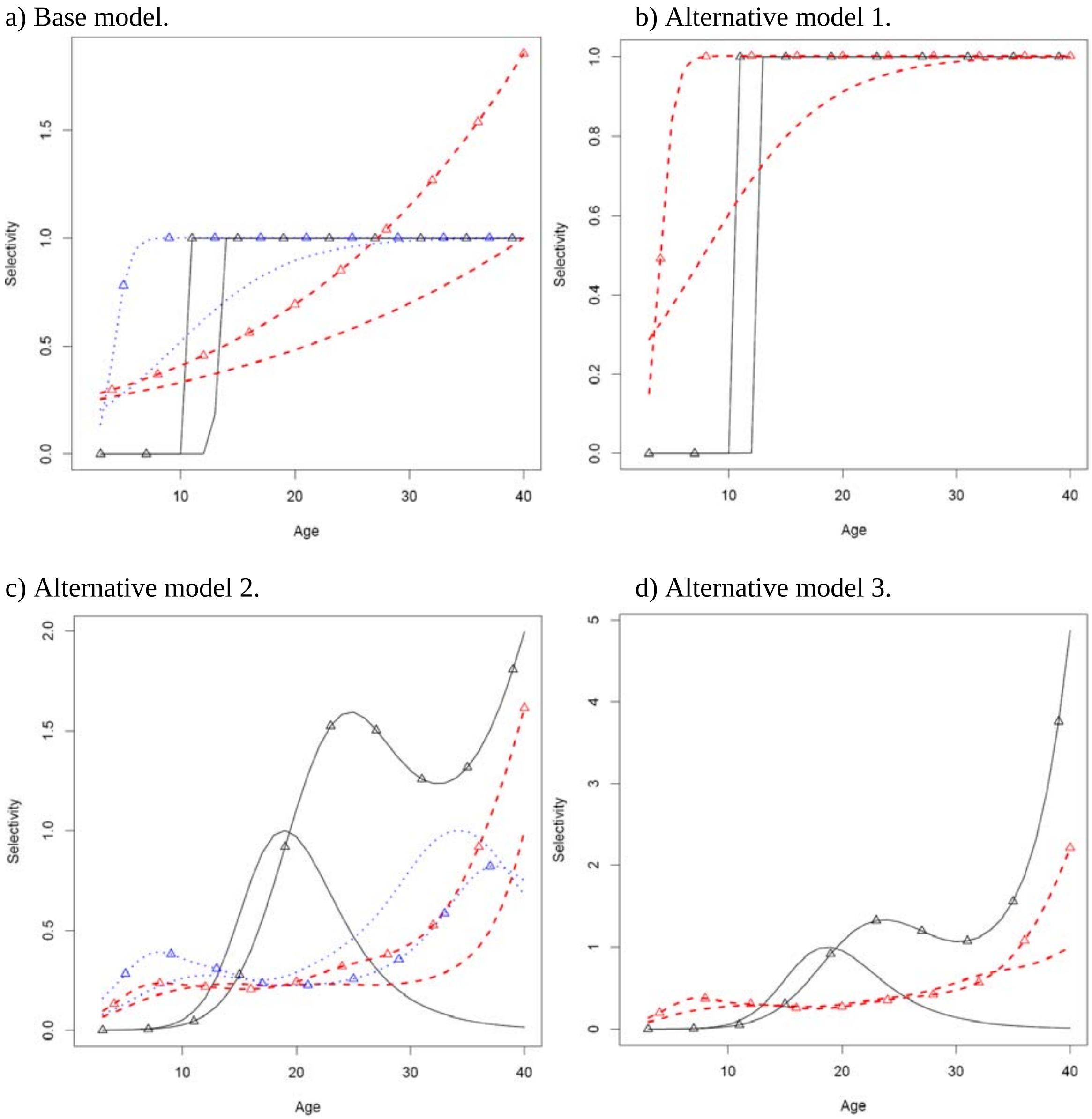
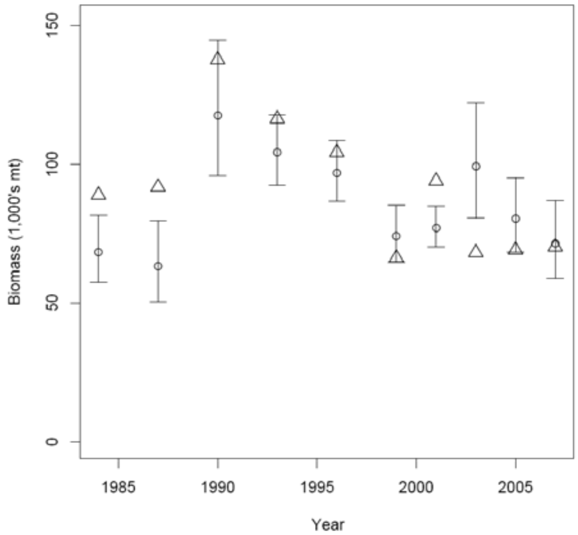
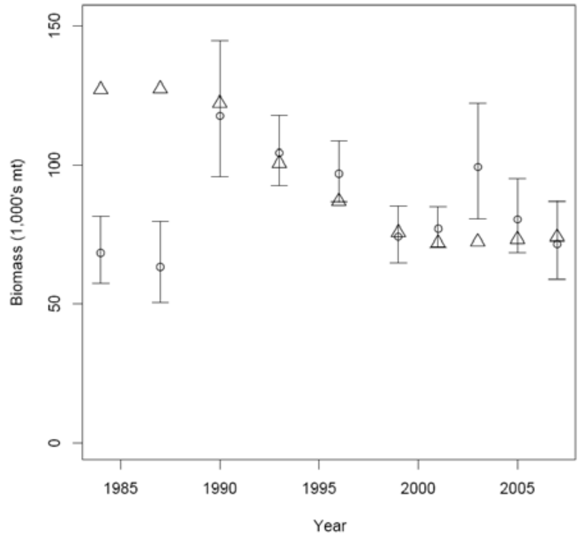


Figure 5.8. Model selectivities for GOA Dover sole. Red dashed line: “full coverage” surveys or “single type” surveys; blue dotted lines: “shallow” surveys; solid black line: fishery. Triangle symbol: males; no symbol: females. Note different y-axis scales.

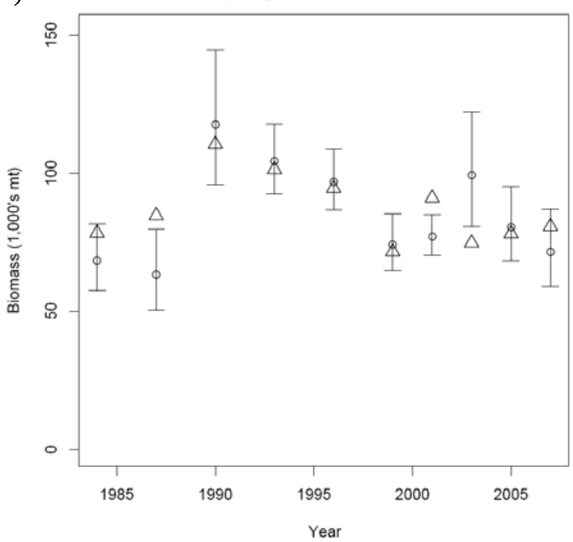
a) Base model.



b) Alternative model 1.



c) Alternative model 2.



c) Alternative model 3.

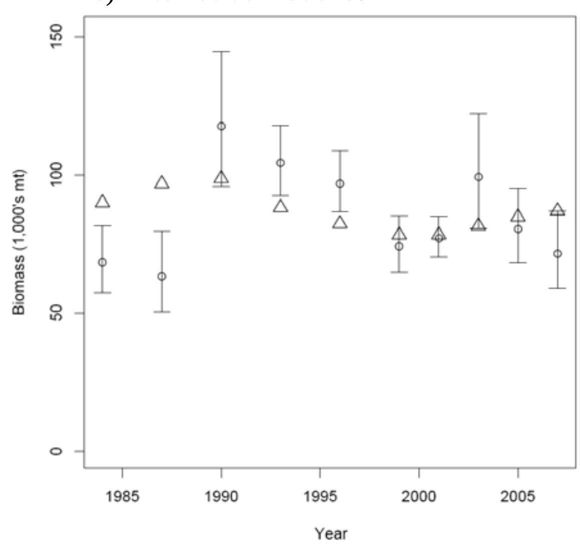


Fig. 5.9. Predicted and observed survey biomass for GOA Dover sole. Predicted survey biomass = triangles, observed survey biomass = circles (error bars are approximate lognormal 95% confidence intervals; survey estimates have been corrected for assumed differences in availability).

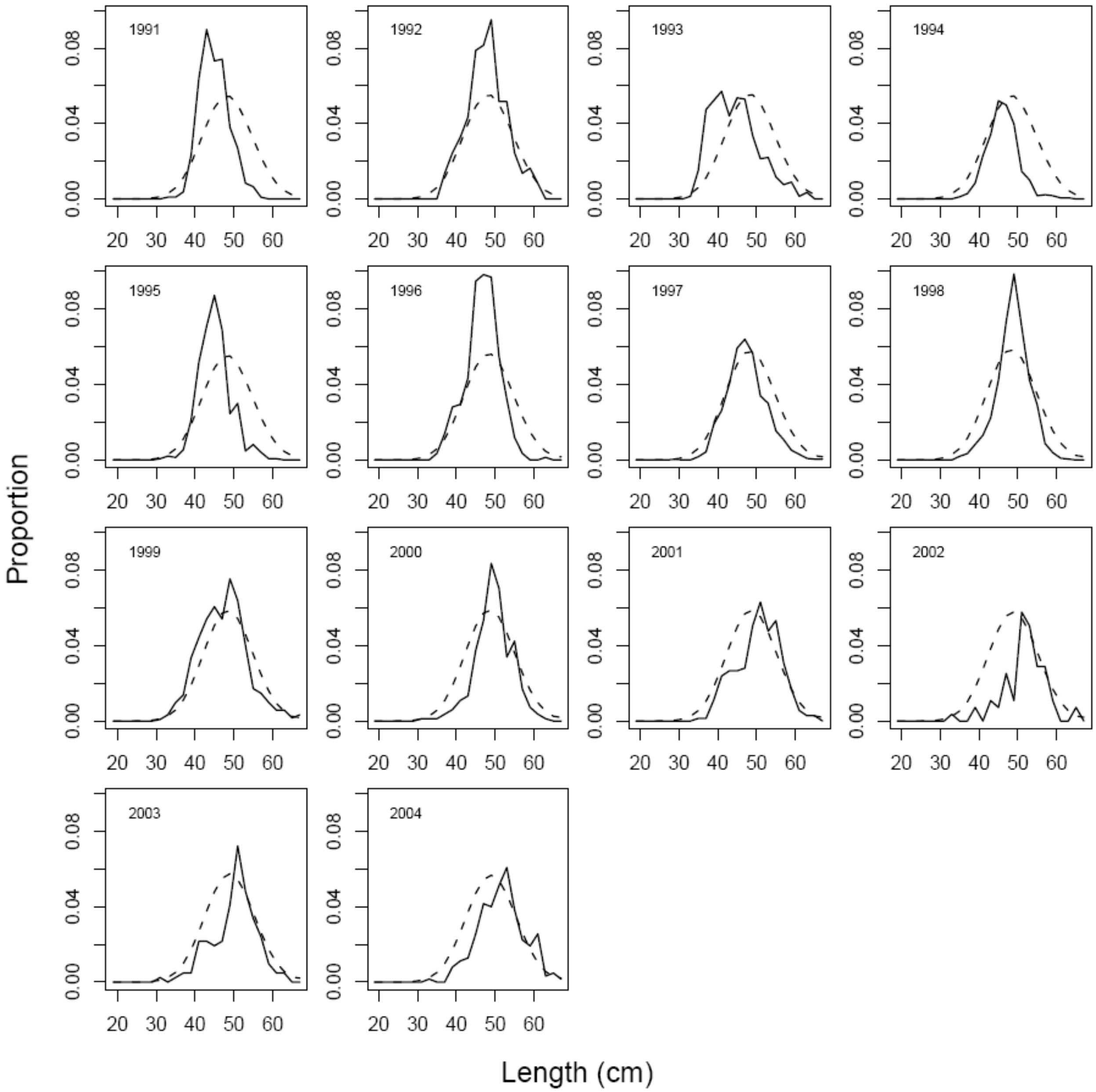


Figure 5.10a. Base model fits to female GOA Dover sole fishery length composition data. Dashed lines represent the model prediction, solid lines represent the data.

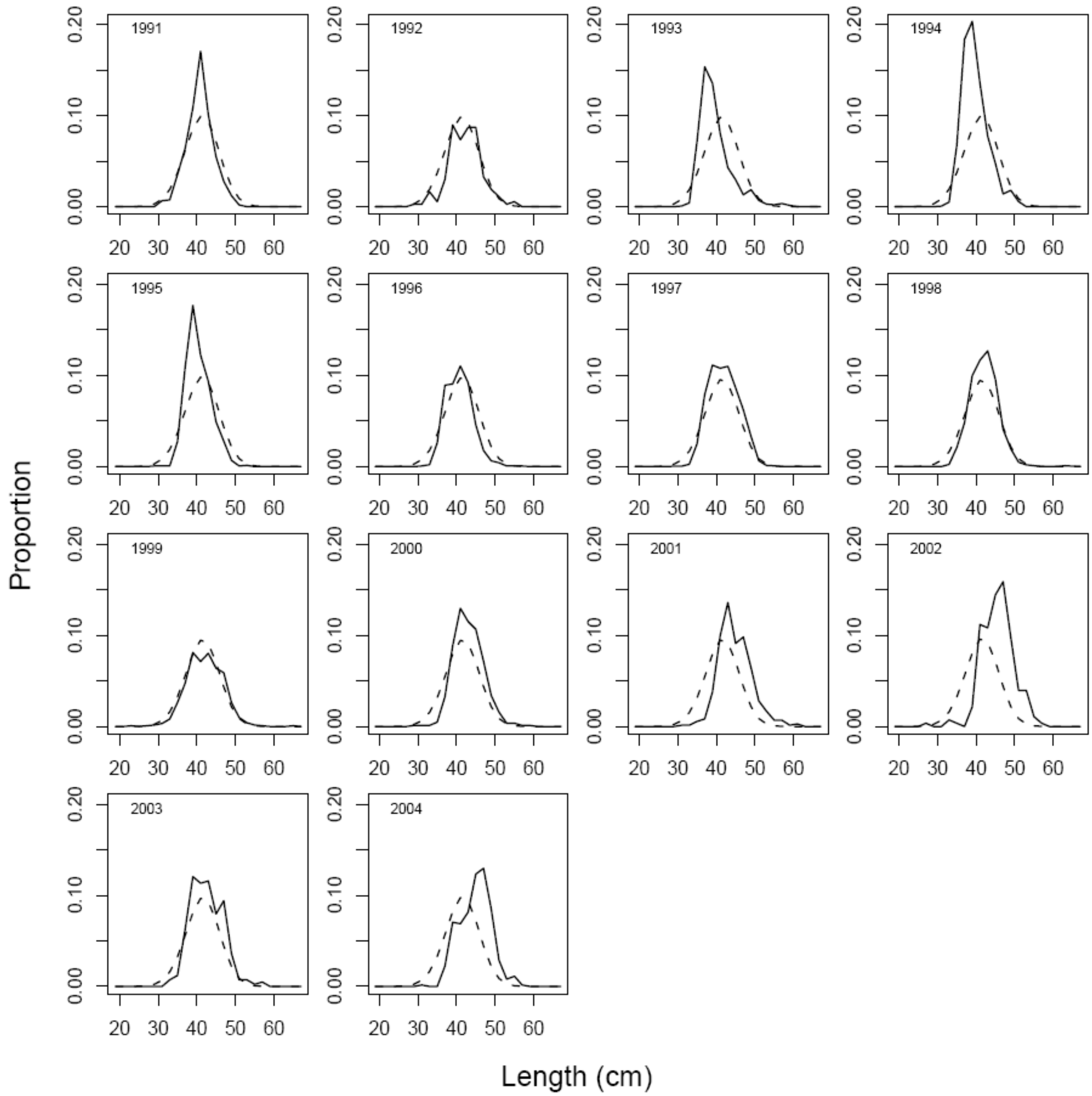


Figure 5.10b. Base model fits to male GOA Dover sole fishery length composition data. Dashed lines represent the model prediction, solid lines represent the data.

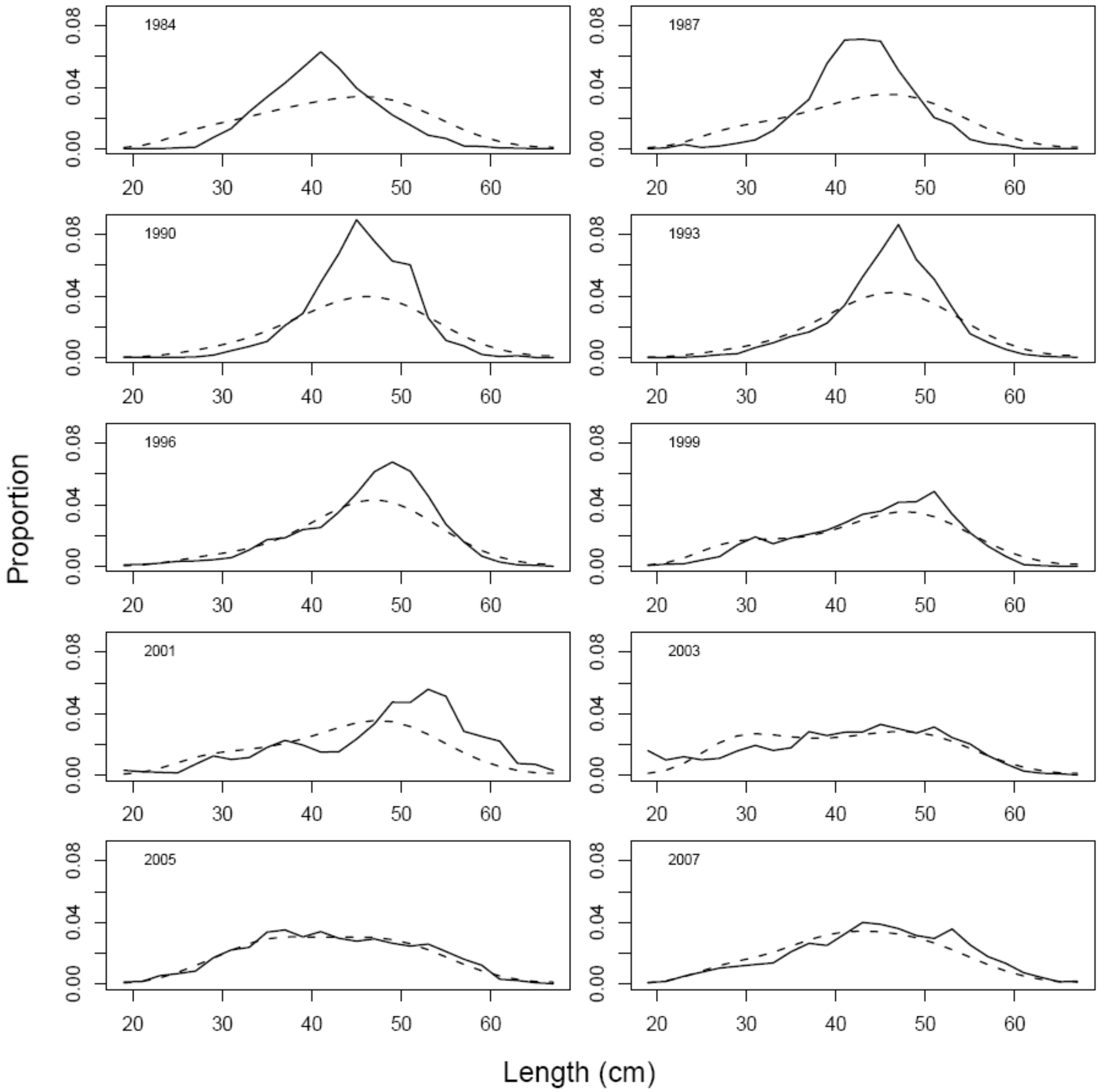


Figure 5.11a. Base model fits to the female GOA Dover sole survey length composition data. Dashed lines represent the model prediction, solid lines represent the data.

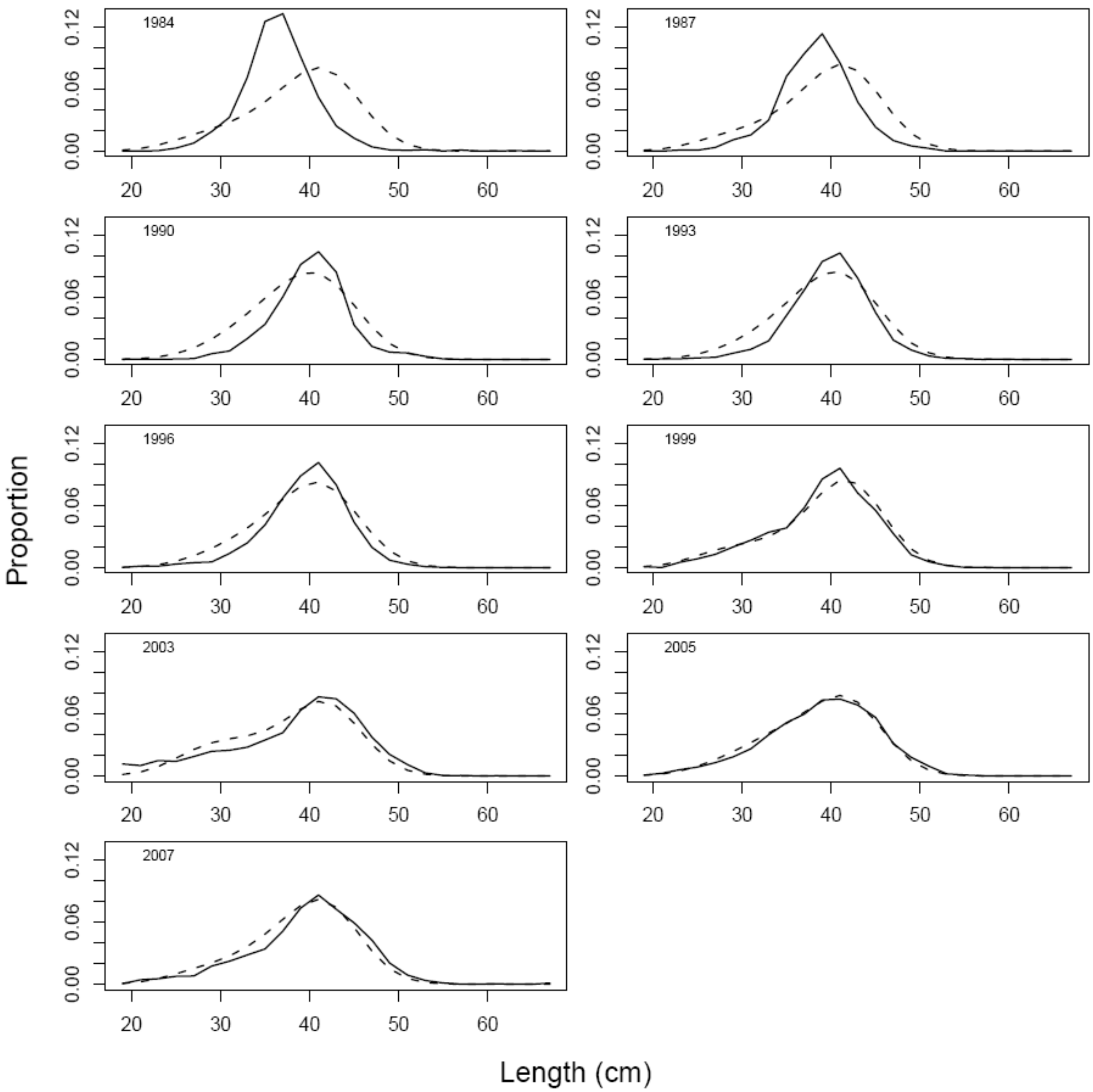


Figure 5.11b. Base model fits to the male GOA Dover sole survey length composition data. Dashed lines represent the model prediction, solid lines represent the data.

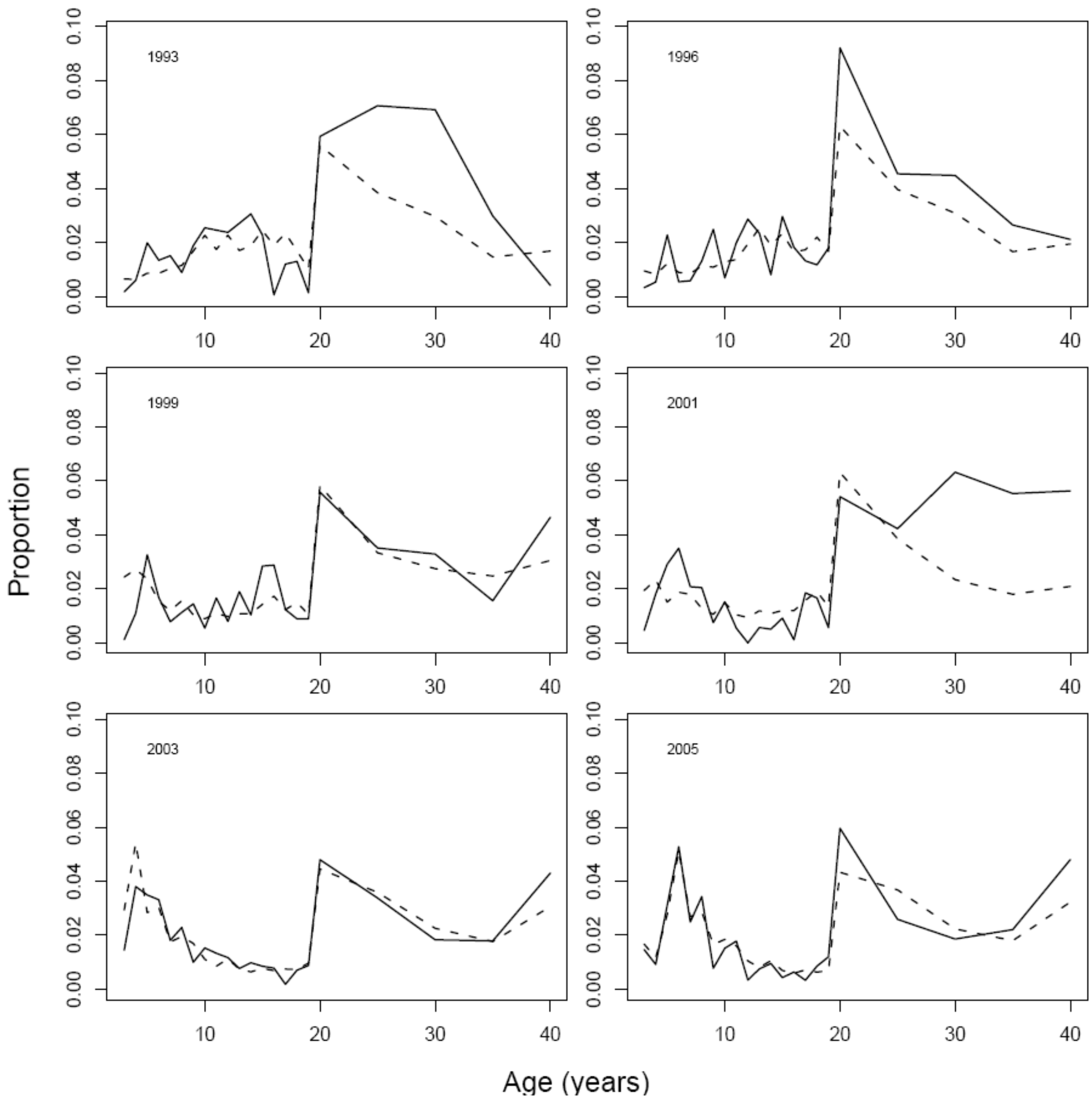


Figure 5.12a. Base model fits to the female survey GOA Dover sole age composition data. Dashed lines represent the model prediction, solid lines represent the data.

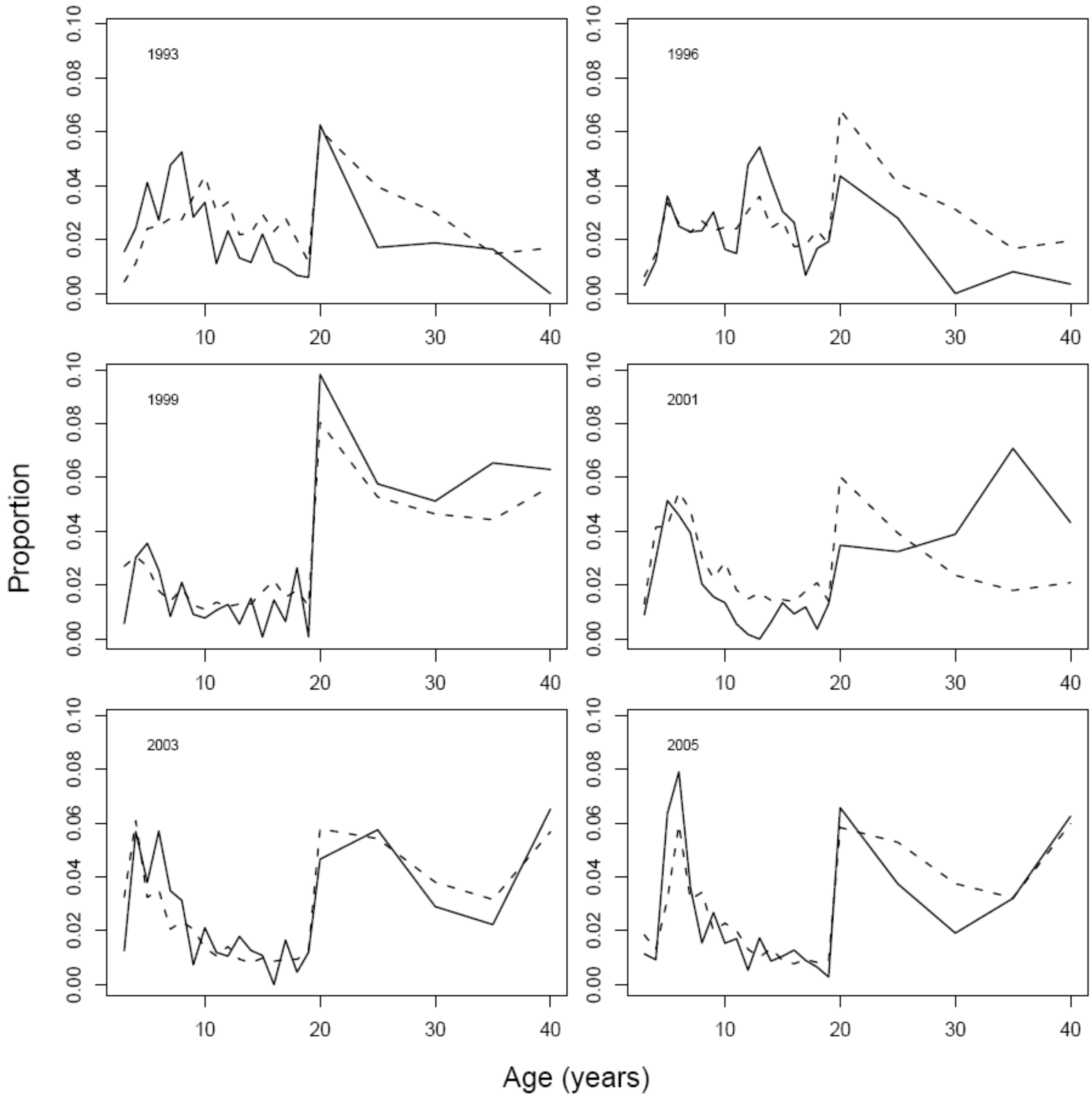


Figure 5.12b. Base model fit to the male survey GOA Dover sole age composition data. Dashed lines represent the model prediction, solid lines represent the data.

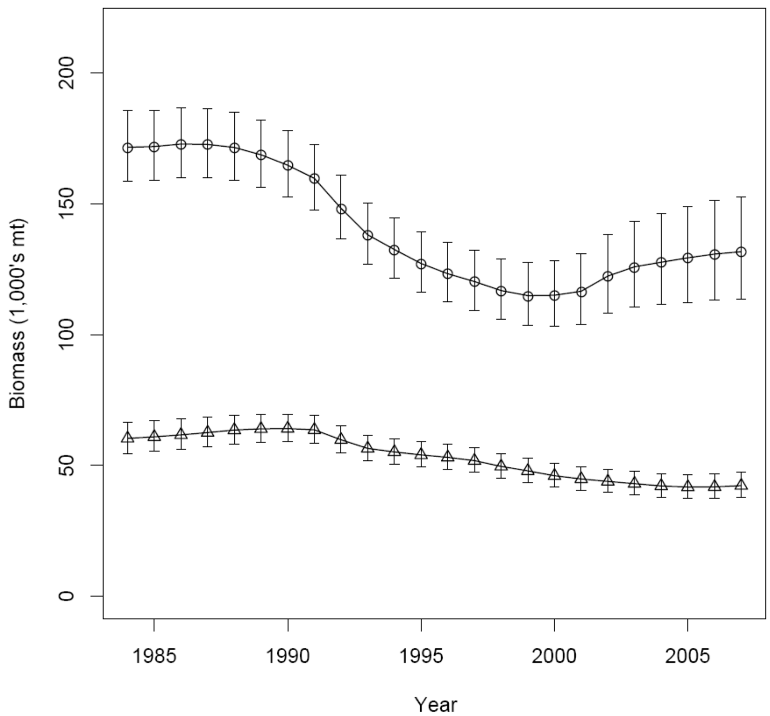


Figure 5.13. Estimated age 3+ biomass (circles) and female spawning biomass (triangles) for GOA Dover sole using the base model. Error bars are approximate lognormal 95% confidence intervals.

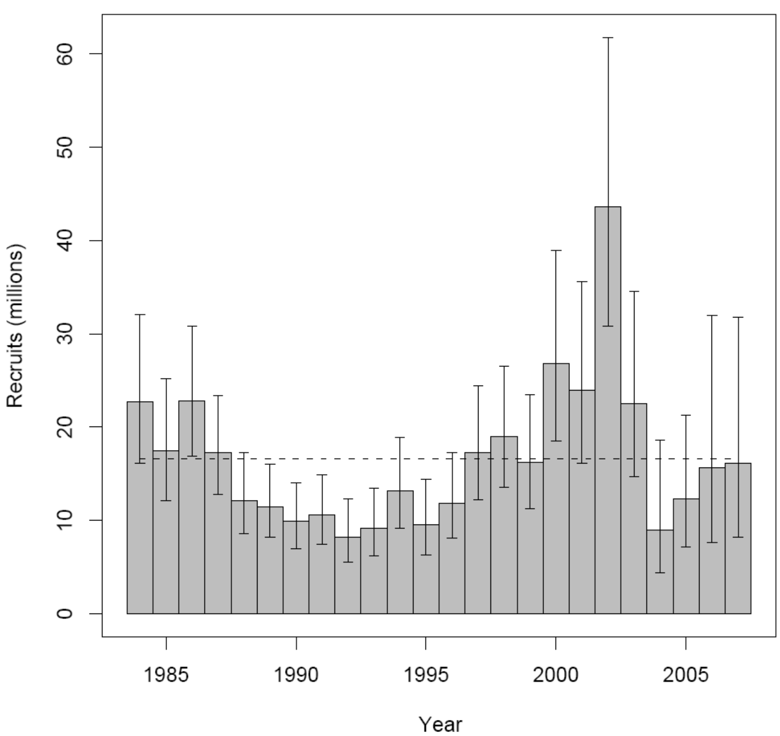


Figure 5.14. Estimated age 3 recruitments of GOA Dover sole using the base model, with approximate 95% lognormal confidence intervals. The horizontal line is mean recruitment.

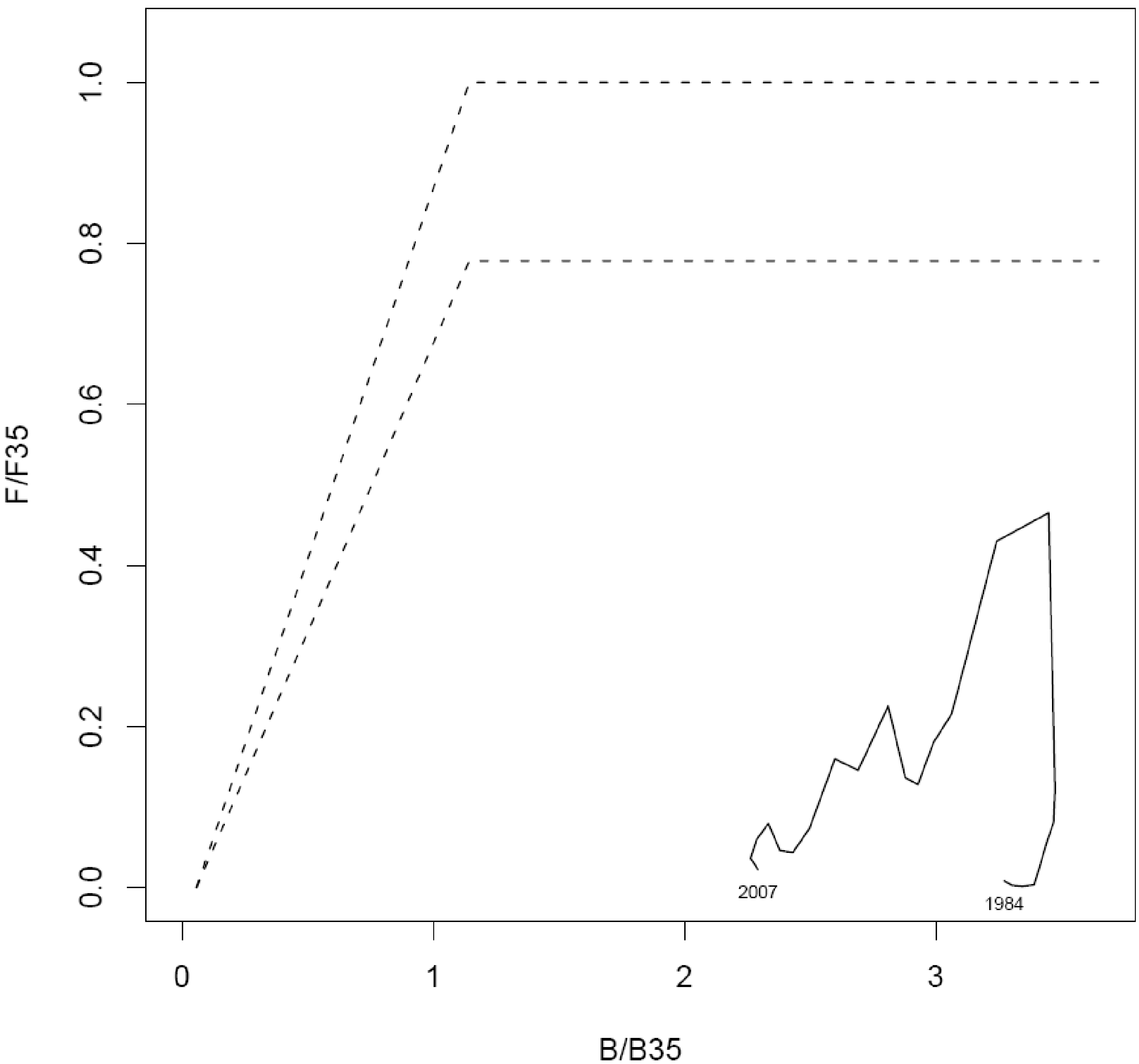


Figure 5.15. Control rule plot of estimated fishing mortality versus estimated female spawning biomass for GOA Dover sole. F_{OFL} = solid line, $F_{max\,ABC}$ = dashed line.

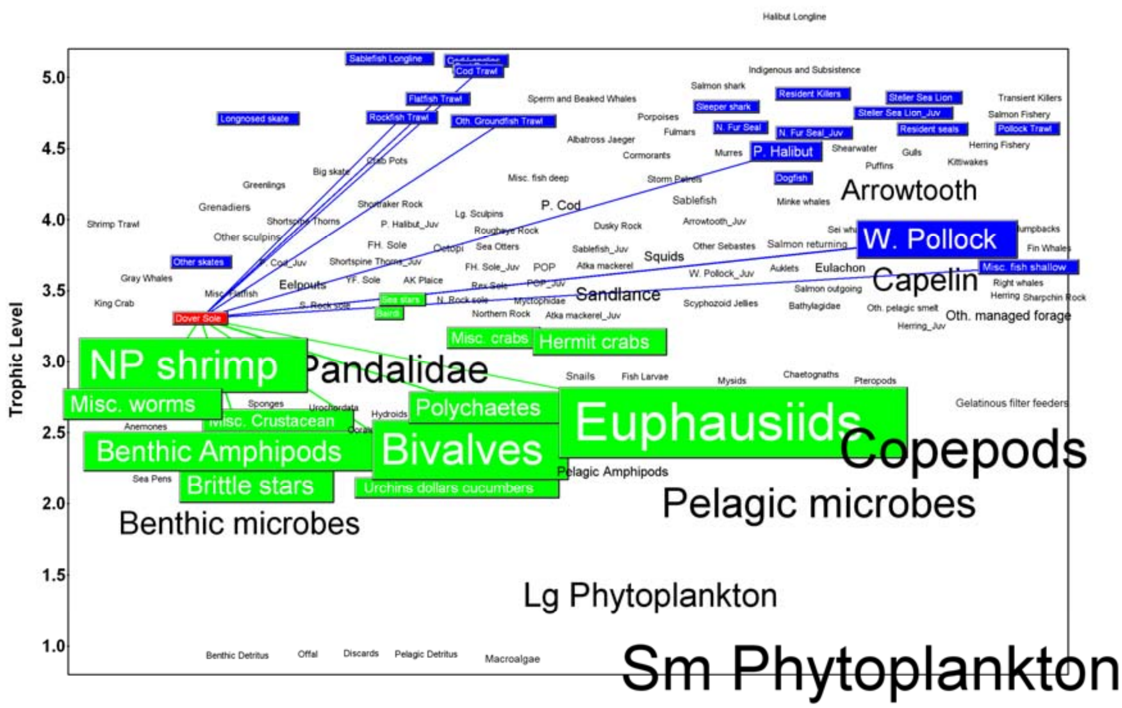


Figure 5.16. Gulf of Alaska food web from the GOA ecosystem model (Aydin et al., in press) highlighting Dover sole links to predators (blue boxes and lines) and prey (green boxes and lines). Box size reflects relative standing stock biomass.

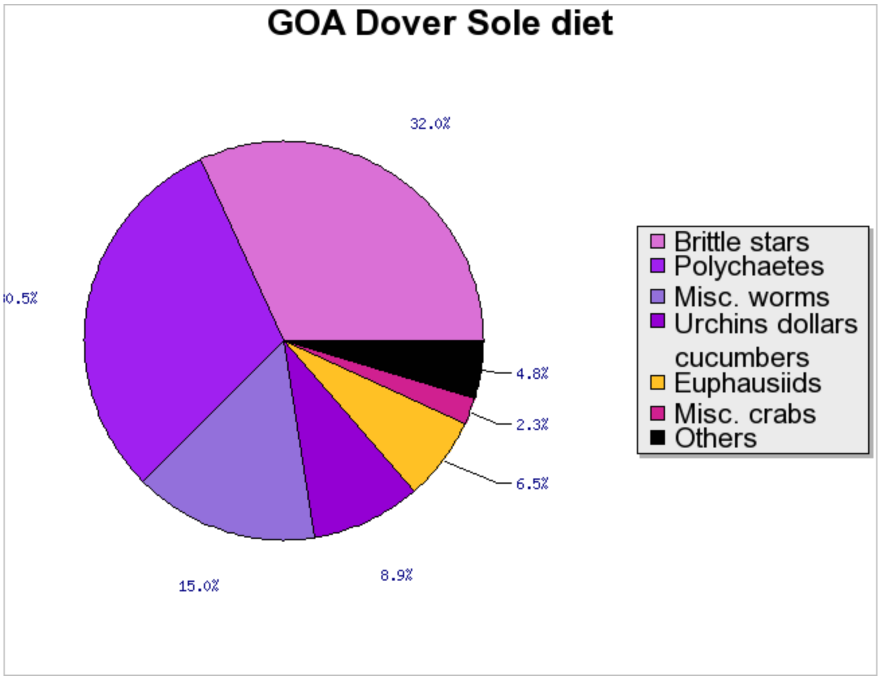


Figure 5.17. Diet composition for Gulf of Alaska Dover sole from the GOA ecosystem model (Aydin et al., in press).

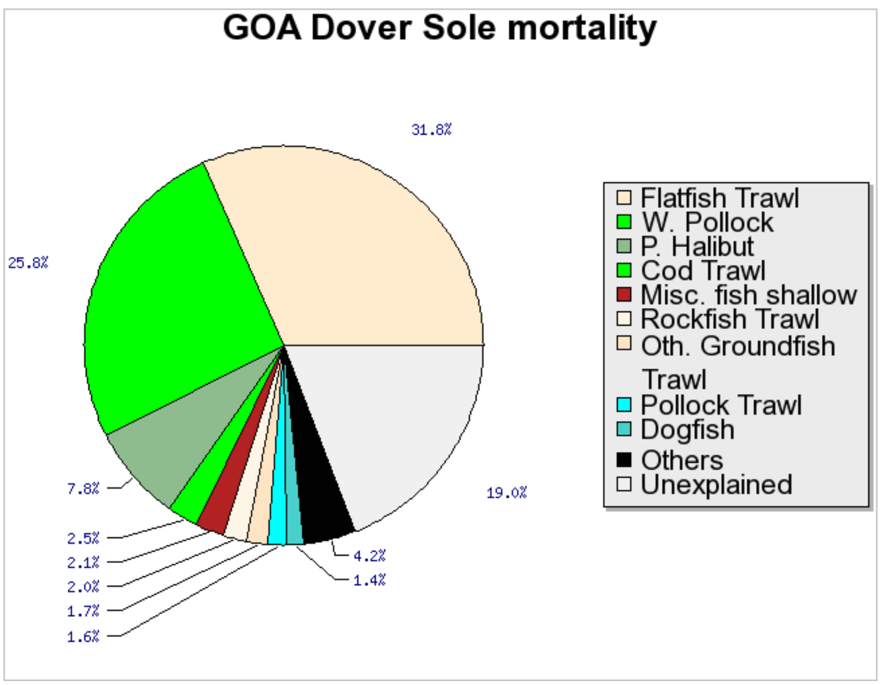


Figure 5.18. Decomposition of natural mortality for Gulf of Alaska Dover sole from the GOA ecosystem model (Aydin et al., in press).

Appendix A.

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

Variable	Definition
T	number of years in the model
A	number of age classes
L	number of length classes
t	time index (1984≤t≤2007)
a	age index (1≤a≤A; a=1 corresponds to age 3)
x	sex index (1≤x≤2; 1=male, 2=female)
l	length index (1≤l≤L)
$\{t^S\}$	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
$L^x_{l,a}$	element of length-age matrix (proportion of sex x fish in age class a that are in length class l)
$w_{x,a}$	mean body weight (kg) of sex x fish in age group a.
ϕ_a	proportion of females mature at age a
R_t	recruitment in year t
$\overline{\ln R_0}$	mean value of log-transformed recruitment
τ_t	recruitment deviation 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 in year t (observed)
Y_t	total yield(tons) in year t
$F_{t,x,a}$	instantaneous fishing mortality rate for sex x and age group a in year t
M	Instantananeous natural mortality rate
$\overline{\ln F}$	mean value of log-transformed fishing mortality
ε_t	deviations in fishing mortality rate in year t
$Z_{t,x,a}$	Instantantaneous total mortality for sex x and age group a in year t
$s^F{}_{x,a}$	fishery selectivity for sex x and age group a
$s^S{}_{x,a}$	survey selectivity for sex x and age group a

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

$\tau_t \sim N(0,\sigma_R^2)$	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.
$C_{t,x,a} = \dfrac{F_{t,x,a}}{Z_{t,x,a}}(1-e^{-Z_{t,x,a}})N_{t,x,a}$	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.
$s_{x,a}^F = \dfrac{1}{1+e^{(-b_x^F(age-{}_{50}A_x^F))}}$	Fishery selectivity- 2 parameter ascending logistic - separate for males and females.
$s_{x,a}^S = \dfrac{1}{1+e^{(-b_x^S(age-{}_{50}A_x^S))}}$	Survey selectivity- 2 parameter ascending logistic - separate for males and females.
$N^S{}_{t,x,a} = Q\, s^S_{x,a} N_{t,x,a}$	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; uses a lognormal distribution.
$\sum_{t\in\{t^{F,A}\}}\sum_{x=1}^{2}\sum_{a=1}^{A} n_{t,x}^{samp}\cdot p_{t,x,a}^{F,A,obs}\cdot\log(p_{t,x,a}^{F,A})$ - offset	Fishery age composition; uses a multinomial distribution. n^{samp} is the observed sample size.
$\sum_{t\in\{t^{F,L}\}}\sum_{x=1}^{2}\sum_{l=1}^{L} n_{t,x}^{samp}\cdot p_{t,x,l}^{F,L,obs}\cdot\log(p_{t,x,l}^{F,L})$ - offset	Fishery length composition; uses a multinomial distribution. n^{samp} is the observed sample size.
$\sum_{t\in\{t^{F,A}\}}\sum_{x=1}^{2}\sum_{a=1}^{A} n_{t,x}^{samp}\cdot p_{t,x,a}^{S,A,obs}\cdot\log(p_{t,x,a}^{S,A})$ - offset	Survey age composition; uses a multinomial distribution. n^{samp} is the observed sample size.
$\sum_{t\in\{t^{F,L}\}}\sum_{x=1}^{2}\sum_{l=1}^{L} n_{t,x}^{samp}\cdot p_{t,x,l}^{S,L,obs}\cdot\log(p_{t,x,l}^{S,L})$ - offset	Survey length composition; uses a multinomial distribution. n^{samp} is the observed sample size.
offset $=\sum_{t}\sum_{x=1}^{2}\sum_{a=1}^{A} n_{t,x}^{samp}\cdot p_{t,x,a}^{obs}\cdot\log(p_{t,x,a}^{obs}))$	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.
$\sum_{t\in\{t^{S}\}}\left[\dfrac{\log\left[\dfrac{SB_t^{obs}}{SB_t}\right]}{\sqrt{2}\cdot s.d.(\log(SB_t^{obs}))}\right]^2$	Survey biomass; uses a lognormal distribution.
$\sum_{t=1984}^{2002}(\tau_t)^2$	Recruitment; uses a lognormal distribution, since τ_t is on a log scale.
$\sum_{t=2003}^{2005}(\tau_t)^2$	"Late" recruitment; uses a lognormal distribution, since τ_t is on a log scale.
$\sum_{t=1967}^{1983}(\tau_t)^2$	"Early" recruitment; uses a lognormal distribution, since τ_t is on a log scale. Determines age composition at starting year of model.

Table A.4. Fixed parameters in the model.

Parameter	Description
M = 0.085	Natural mortality
Q = 1.0	Survey catchability
L_{inf} , t_0 , k , cv of length at age 2 and age 20 for males and females	von Bertalanffy Growth parameters estimated from the 1984-1996 survey length and age data.

Table A.5. Estimated parameters for the model. A total of 99 parameters were estimated in the logistic selectivities 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	$1947 \le t \le 2007$	61 (24 + 37 from initial age composition)	Recruitment deviation in year t (log-scale)
$\ln(f_0)$	NA	1	natural log of the geometric mean value of fishing mortality
ε_t	$1984 \le t \le 2007$	24	deviations in fishing mortality rate in year t
b^F_x , ${}_{50}A^F_x$	$1 \le x \le 2$	4	selectivity parameters (slope and age at 50% selected) for the fishery; for males and females.
b^S_x , ${}_{50}A^S_x$	$1 \le x \le 2$ $1 \le S \le 2$	8	selectivity parameters (slope and age at 50% selected) for the survey data, for (males, females) x (shallow, full) surveys.

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