Chapter 2: Assessment of the Pacific Cod Stock in the Gulf of Alaska

Grant G. Thompson, James N. Ianelli, and Mark E. Wilkins

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center
7600 Sand Point Way NE., Seattle, WA 98115-6349

EXECUTIVE SUMMARY

Summary of Changes in Assessment Inputs

Relative to the November edition of last year's GOA SAFE report, the following substantive changes have been made in the Pacific cod stock assessment.

Changes in the Input Data

1) Catch data for 1991-2008 were updated, and preliminary catch data for 2009 were incorporated.
2) Commercial fishery size composition data for 2008 were updated, and preliminary size composition data from the 2009 commercial fisheries were incorporated.
3) Age composition and mean-length-at-age data from the 2007 bottom trawl survey were incorporated into some models.
4) Age composition data from the 2008 January-May longline fishery were incorporated into some of the models.
5) Mean length at age data from the 2008 January-May longline fishery were incorporated into some of the models.
6) Size composition data from the 2009 bottom trawl survey were incorporated.
7) The numeric abundance estimate from the 2009 EBS bottom trawl survey was incorporated (the 2009 estimate of 574 million fish was up about 199% from the 2007 estimate).
8) The variances in the ageing error matrix were updated in all of the models that use age data, and possible biases in age data were corrected for in some of the models that use age data.
9) Seasonal catch per unit effort (CPUE) data for the trawl, longline, and pot fisheries from 2008 were updated, and preliminary catch rates for the trawl, longline, and pot fisheries from 2009 were incorporated.

Changes in the Assessment Methodology

Many changes have been made or considered in the stock assessment model since the 2008 assessment. Eleven models were presented in this year's preliminary assessment (Attachment 2.1). The relationships between the eleven models presented in the preliminary assessment are summarized in Table 2.1.1 of Attachment 2.1. The set of eleven models in the preliminary assessment responded to various requests made by either the Plan Team(s) or SSC. Model A in the preliminary assessment was identical to the model accepted for use by the GOA Plan Team and SSC last year, and was the only model from the preliminary assessment recommended by either the Plan Team or SSC to be carried forward for inclusion in this final assessment.

Ten models are included in this final assessment. As with last year's model, all of them split the data from the trawl survey into two portions, one for fish smaller than 27 cm (the "sub-27" survey) and the other for fish 27 cm or larger (the "27-plus" survey). Six of the models include age composition data and four do not. Models whose names end in "1" include age composition data, and models whose names end in "2" do not include age composition data. The one model whose name ends in "3" (Model A3) includes all available age composition data except the 2008 January-May longline fishery data. The one model whose name ends in "4" (Model A4) uses all available age composition data, but uses an ageing error matrix where the standard deviations are doubled for ages 2-4. The ten models are designed to respond to requests made by the Plan Team(s), SSC, and public, as described in Table 2.0.

The ten models presented in this final assessment may be classified into three groups as follows:

<u>Models based on last year's model, with different uses of age composition data</u>. This group includes four versions of the model accepted for use by the Plan Team and SSC last year, differing only with respect to treatment of age composition data. These are labeled A1 (all available age composition data), A2 (no age composition data), A3 (all available age composition data except the 2008 January-May longline fishery data), and A4 (all available age composition, but standard deviations in the ageing error matrix are doubled for ages 2-4). As with last year's model, all models in this group drastically downweight the importance of the age composition data in parameter estimation (Model A2 ignores it entirely). Given the SSC's past endorsement of the survey age composition data and request for inclusion of fishery age composition data (see "Responses to Comments from the Plan Teams and SSC" below), Model A1 is considered the base model. The models in this group all use mean size-at-age data, which was a feature of last year's model.

<u>New models age with composition data.</u> This group includes three models with various new features requested by the Plan Team(s), SSC, and public. All models in this group share the following requested features: Potential bias in age readings is corrected for, survey selectivity is held constant for the most recent two surveys, and growth rates are cohort-specific. Like the models in the first group, the models in this group all use mean size-at-age data. Use of such data is particularly important for models that estimate cohort-specific growth. Because trawl survey size composition data are not used for any year in which trawl survey age composition data are used (to avoid double counting), and because fishery size composition data give almost no information about ages 1 or 2, inclusion of mean size-at-age data is necessary for meaningful estimation of cohort-specific growth.

Model B1 is the base model for this group. Input standard deviations of all "dev" vectors were set iteratively by matching the standard deviations of the set of estimated "devs," and the standard deviation of length at age was estimated outside the model as a linear function of mean length at age. Selectivity at maximum size or age was treated as a controllable parameter. Catchability for the pre-1996 years of the 27-plus trawl survey was estimated freely, and catchability for the post-1993 years was fixed at the value that sets the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.92 obtained by Nichol et al. (2007). Except for the parameter governing selectivity at age 0, all parameters of the selectivity function for the post-1993 years of the 27-plus trawl survey were allowed to vary in each survey year except for the final year (i.e., the most recent two survey years are forced to have the same selectivity). Potential ageing bias was accounted for in the ageing error matrix by examining alternative bias values in increments of 0.1 for ages 2 and above (age-specific bias values were also examined, but did not improve the fit significantly).

For the remaining models in this group, the input standard deviations for all "dev" vectors and the amount of ageing bias were held constant at the values obtained by Model B1. Differences with respect to Model B1 in the remaining models were as follow:

Model D1 is identical to Model B1 except that selectivity at maximum size or age is removed from the set of controllable parameters (instead, selectivity at maximum size or age becomes a function of other selectivity parameters).

Model E1 is identical to Model B1 except that selectivity at maximum size or age for all non-asymptotic fleets is set equal to a single value that is constant across fleets.

New models without age composition data. This group includes a no-age-composition-data counterpart for each model in the preceding group. Size composition data are included in place of age composition data. The input standard deviations for all "dev" vectors and the amount of ageing bias were held constant at the values obtained by Model B1. These models are labeled B2, D2, and E2.

Table 2.0 shows how the various requests from the Plan Team(s), SSC, and public map into the ten models presented here.

Version 3.03c of SS was used to run all the models in the preliminary assessment and in this final assessment.

Model B1 is the authors' recommended model.

Summary of Results

The principal results of the present assessment, based on the authors' preferred model, are listed in the table below (biomass and catch figures are in units of t) and compared with the corresponding quantities from last year's assessment as specified by the SSC.

	Assessment	
Quantity/Status	Last year	This year
M	0.38	0.38
Specified/recommended Tier	3b	3a
Projected total biomass (ages 0+) for 2010	608,100	738,300
Projected summary biomass (ages 3+) for 2010	571,200	701,200
Projected female spawning biomass for 2010	141,000	117,600
B100%	255,500	291,500
B40%	102,200	116,600
B35%	89,400	102,000
B0	n/a	n/a
FOFL for 2010	n/a	0.60
maxFABC for 2010	0.52	0.49
maxFABC for 2011	0.52	0.49
Specified/recommended *FABC* for 2010	0.39	0.49
Specified/recommended *FABC* for 2011	n/a	0.49
OFL for 2010	126,000	94,100
OFL for 2011 (given recommended ABC for 2010)	n/a	116,700
maxABC for 2010	103,700	79,100
maxABC for 2011	139,300	97,900
Specified/recommended ABC for 2010	79,500	79,100
Specified/recommended ABC for 2011	n/a	97,900
Is the stock being subjected to overfishing?	no	no
Is the stock currently overfished?	no	no
Is the stock approaching a condition of being overfished?	no	no

Responses to Comments from the Plan Teams and SSC

Joint Plan Team Comments

JPT1 (09/08 minutes): "*The Plan Team commented that the assessment author attempted to reduce number of selectivity parameters to the extent possible but this model is still overly complicated as a result of the software being used. A simpler selectivity parameterization was suggested, e.g. exponential-logistic. SS2 notably does not allow for this in the present software. The Plan Teams requested that the selectivity function be further simplified even if it means modifying SS2 accordingly.*" In response to this request, Stock Synthesis (SS) now includes a version of the exponential-logistic selectivity function as an option, and this preliminary assessment considers several new models that use the exponential-logistic selectivity function, as described in the "Analytic Approach" section, under the heading "Model Structure," subheading "Alternative Models." See also comment SSC7.

JPT2 (09/09 minutes): *"Alternatives in modeling Pacific cod growth specifically by cohort may improve the fit to the data, however, other time varying features such as selectivity in the assessment model may be confounded with cohort-specific growth."* Six of the ten models presented in this final assessment (B1, B2, D1, D2, E1, and E2) include cohort-specific growth.

JPT3 (09/09 minutes): *"Research priorities include: Stock assessment model incorporating bias into the existing aging error matrix for ages 2-3 could be employed in the short term to evaluate a process-oriented approach to assessing inconsistency in these data sources."* Six of the ten models presented in this final assessment (B1, B2, D1, D2, E1, and E2) incorporate bias into the ageing error matrix as a short-term means of addressing possible inconsistencies between size composition and age composition data.

JPT4 (09/09 minutes): *"The Teams requested ... some model fits that do not attempt to fit the age data in both regions."* Four of the ten models presented in this final assessment (A2, B2, D2, and E2) do not attempt to fit the age composition data.

GOA Plan Team Comments

GPT1 (11/08 minutes): *"The Team's primary concerns regarding the model are the following: 1. Fits to the survey time series. 2. The age composition sample size needs to be decreased in order to fit the length data. There appears to be an inconsistency between data sets in the assessment. 3. Age-specific selectivity."* Fits to the survey time series, the effects of decreasing the emphasis on the age composition data, and inconsistency between data sets were all addressed in the preliminary assessment, included here as Attachment 2.1 (specifically, in the "Results" section, under the heading, "The Problem of Residual Patterns in the Fits to the 27-Plus Trawl Survey Abundance Data"). Also in the preliminary assessment, Plan Team concerns regarding use of age-based selectivity for the 27-plus survey were addressed by considering two new models that use *size*-based selectivity for the 27-plus survey, as described in Attachment 2.1 to this final assessment (specifically, in the "Analytic Approach" section, under the heading "Model Structure," subheading "Alternative Models").

GPT2 (11/08 minutes): *"The Team requests the assessment include a specific discussion of selectivity outside of the discussion of the model. For example, does the available information on habitat use of Pacific cod, the response to fishing gear, seasonal or ontogentic changes in distributions, changes in natural mortality with age, etc. help explain the selectivity patterns obtained from the model?"* This request is addressed in the "Introduction" section ("Review of Life History" subsection) of the present assessment.

GPT3 (11/08 minutes): *"The Team questioned to what extent the software being employed is limiting the ability to address many issues in the assessment."* The GOA and BSAI Pacific cod assessments both use the SS software package. Although *any* software is necessarily limited in what it can accomplish, SS must surely rank as one of the most flexible stock assessment packages available. Because SS is revised so frequently in response to requests for inclusion of additional features (e.g., see the response to comment JPT1), a completely up-to-date user manual is currently not available. However, Methot (2009) provides an *almost* up-to-date list of available features. In the interest of efficiency, this list is not repeated here.

GPT4 (11/08 minutes): *"The Team had extensive discussions of several model issues. The model does not allow for any catch over age 12. There is a fundamental inconsistency between the size and age compositions from the survey and the biomass from the survey. Thus, the author downweights the age composition data to fit the trend better. Both size and age data have to be downweighted substantially however to fit the observed survey data."* Except for the second sentence, this comment elaborates on comment GPT1. See comment GPT1 for a response. With respect to the second sentence, this assertion may need some qualification. With respect to the fisheries, the assertion made in the second sentence is not true. For example, the January-May trawl fishery exhibited asymptotic selectivity. Specifically, all fish above a length of about 75 cm (approximately age 8 or so) were estimated to be fully selected by that fishery. Because the model explicitly accounted for fish aged 0-19 (with age 20 as a "plus" group), the model clearly did allow for catch of fish over age 12. With respect to the trawl survey, it is true that the estimated selectivity beyond age 12 in last year's model was virtually zero. However, it may be important to keep in mind that, of the 4,942 survey otoliths aged prior to the 2008 assessment, only 1 was older than 12 years of age.

GPT5 (11/08 minutes): *"The Team would like to see additional examination of the selectivity patterns and other issues as noted regarding model configuration."* The only "issues" identified in the Plan Team minutes are those listed under comments GPT3 and GPT4. See comments GPT3 and GPT4 for responses.

GPT6 (2008 SAFE report): *"A number of issues were noted by the Plan Team and authors regarding fit to survey data and estimation of selectivity. The fit of the preferred model to the 27-plus survey abundance was problematic in that each of the model estimates was an underestimate of the observed survey abundance estimate. The fit to this time series improved as the age and length compositions were downweighted, which indicates some inconsistency in the input data which should be explored in more detail. Some of the fishery and survey selectivity curves show sharp reductions at older ages or larger sizes which seem implausible."* Except for the last sentence, this comment elaborates on parts of comment GPT1. See comment GPT1 for a response. The last sentence was addressed in the preliminary assessment (included here as Attachment 2.1) by considering several new models that use the exponential-logistic selectivity function (see Comment JPT1), which appeared to be less prone to sharp changes in selectivity at older ages or larger sizes (but see Comment SSC5). Another suggestion that might pertain to sharp reductions in selectivity is found in Comment SSC7.

GPT7 (2008 SAFE report): *"The Team also requests that the assessment include more information and discussion on the biology and life-history of Pacific cod. This material is requested for background information and to help understand how the behavior and distribution patterns of Pacific cod interact with the fishery and survey processes."* This request elaborates on comment GPT2, and is addressed in the "Introduction" section ("Review of Life History" subsection) of the present assessment.

GPT8 (09/09 minutes): *"A serious conflict between the survey trend and the age/size composition data continues."* As noted in response to Comment GPT1, an explanation for this conflict, together with several models that achieved some level of success in resolving the conflict, were provided in the preliminary assessment, included in the present assessment as Attachment 2.1. In addition, the present assessment includes six models that do not downweight the age data at all (Models B1, B2, D1, D2, E1, and E2) and that produce a better residual pattern in the fit to the survey time series than last year's model.

GPT9 (09/09 minutes): *"Assessment authors should include the information needed to do the status determination criteria on an annual basis in their assessments."* The present assessment includes this information in the "Summary of Results" above and in the "Projections and Status Determination" section.

SSC Comments on Assessments in General

SSC1 (12/08 minutes): *"The BSAI Plan Team recommended that all authors of stocks managed in Tiers 1 through 3 should estimate the probability of the spawning stock biomass falling below $B_{20\%}$. The recommended time frame for this projection was 3-5 years. The SSC agrees with this recommendation and encourages authors to provide estimates of the probability of falling below biologically relevant thresholds such as $B_{20\%}$."* The probability of the spawning biomass falling below $B_{20\%}$ in 2012, 2013, and 2014 under any of the ten models is virtually zero, as reported in Table 2.xx. It should be understood that these estimates of probability are conditional on the data currently available and on the structures of the respective models.

SSC2 (06/09 minutes): *"The SSC recommends to stock assessment authors that if harvest strategies are modified to explicitly incorporate uncertainty in the buffer between OFL and ABC, then authors should strive to select the "best estimate" for parameterizing models and not the most precautionary estimate."* For all ten models presented in this final assessment, best estimates (based in part on SSC and Plan Team input and conditional on the structure of the respective model) are used.

SSC Comments Specific to the GOA Pacific Cod Assessment

SSC3 (12/08 minutes): *"The model fits are so troubled that this stock is a candidate for Tier 5...."* Given that the average ratio of effective sample size to input sample size exceeded unity for the size composition data from all nine fisheries in the 2008 model, it will be assumed here that the "fits" referenced by the SSC consist of the fits to the 27-plus trawl survey abundance data and the age composition data. See comments GPT1 and GPT8 for responses.

SSC4 (10/09 minutes): *"The basic problem of a conflict between age/length data and survey data was not resolved by any of the models [in the preliminary assessment] and the model estimates of survey biomass continue to be much higher than survey biomass in most years."* Actually, the model estimates of survey biomass were consistently lower, not higher, than the observed survey biomass, both in last year's model and in this year's preliminary assessment. See Comments GPT1 and GPT8 for responses.

SSC5 (10/09 minutes): *"Contrary to our previous guidance, we would like to see alternative models that constrain selectivity parameters to preserve a reasonable shape, for example by fixing selectivity at maximum age."* Two of the ten models presented in this final assessment (E1 and E2) fix selectivity at maximum size or age.

SSC6 (10/09 minutes): *"The SSC recommends that alternatives that keep selectivity deviations in the last several years of the time series at 'base' values."* All but four of the ten models presented in this final assessment (A1, A2, A3, and A4) force the two most recent surveys to share the same selectivity schedule.

SSC7 (10/09 minutes): *"We agree with PT recommendations to abandon the use of exponential logistic selectivities for this assessment."* Exponential-logistic selectivity is not used in any of the ten models presented in this final assessment (see also Comments JPT1 and GPT6).

INTRODUCTION

General

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34° N latitude, with a northern limit of about 63° N latitude. Pacific cod is distributed widely over Gulf of Alaska (GOA), as well as the eastern Bering Sea (EBS) and the Aleutian Islands (AI) area. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and GOA. Although at least one previous genetic study (Grant et al. 1987) failed to show significant evidence of stock structure within these areas, current genetic research underway at the Alaska Fisheries Science Center is shedding additional light on the issue of stock structure of Pacific cod within the BSAI (M. Canino, AFSC, pers. commun.). Pacific cod is not known to exhibit any special life history characteristics that would require it to be assessed or managed differently from other groundfish stocks in the GOA.

Review of Life History

Pacific cod eggs are demersal and adhesive. Eggs hatch in about 15 to 20 days. Spawning takes place in the sublittoral-bathyal zone (40 to 290 m) near bottom. Eggs sink to the bottom after fertilization and are somewhat adhesive. Optimal temperature for incubation is 3° to 6°C, optimal salinity is 13 to 23 parts per thousand (ppt), and optimal oxygen concentration is from 2 to 3 ppm to saturation. Little is known about the optimal substrate type for egg incubation.

Little is known about the distribution of Pacific cod larvae, which undergo metamorphosis at about 25 to 35 mm. Larvae are epipelagic, occurring primarily in the upper 45 m of the water column shortly after hatching, moving downward in the water column as they grow.

Juveniles occur mostly over the inner continental shelf at depths of 60 to 150 m. Adults occur in depths from the shoreline to 500 m, although occurrence in depths greater than 300 m is fairly rare. Preferred substrate is soft sediment, from mud and clay to sand. Average depth of occurrence tends to vary directly with age for at least the first few years of life. However, in the GOA trawl survey, the percentage of fish residing in waters less than 100 m tends to increase with length beyond about 90 cm. The GOA trawl survey also indicates that fish occupying depths of 200-300 m are typically in the 40-90 cm size range.

It is conceivable that mortality rates, both fishing and natural, may vary with age in Pacific cod. In particular, very young fish likely have higher natural mortality rates than older fish (note that this may not be particularly important from the perspective of single-species stock assessment, so long as these higher natural mortality rates do not occur at ages or sizes that are present in substantial numbers in the data). For example, Leslie matrix analysis of a Pacific cod stock occurring off Korea estimated the instantaneous natural mortality rate of 0-year-olds at 910% per year (Jung et al. 2009). This may be compared to a mean estimate for age 0 Atlantic cod (*Gadus morhua*) in Newfoundland of 4.42% per day, with a 95% confidence interval ranging from about 3.32% to 5.52% (Gregory et al. in review); and age 0 Greenland cod (*Gadus ogac*) of 2.12% per day, with a 95% confidence interval ranging from about 1.56% to 2.68% (Robert Gregory and Corey Morris, *pers. commun.*).

Although little is known about the likelihood of age-dependent natural mortality in adult Pacific cod, it has been suggested that Atlantic cod may exhibit increasing natural mortality with age (Greer-Walker 1970).

At least one study (Ueda et al. 2006) indicates that age 2 Pacific cod may congregate more, relative to age 1 Pacific cod, in areas where trawling efficiency is reduced (e.g., areas of rough substrate), causing their selectivity to decrease. Also, Atlantic cod have been shown to dive in response to a passing vessel (Ona and Godø 1990), which may complicate attempts to estimate catchability or selectivity. It is not known whether Pacific cod undertake a similar response.

As noted above, Pacific cod are known to undertake seasonal migrations, the timing and duration of which may be variable (Savin 2008).

Fishery

During the two decades prior to passage of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1976, the fishery for Pacific cod in the GOA was small, averaging around 3,000 t per year. Most of the catch during this period was taken by the foreign fleet, whose catches of Pacific cod were usually incidental to directed fisheries for other species. By 1976, catches had increased to 6,800 t. Catches of Pacific cod since 1978 are shown in Tables 2.1a and 2.1b. In Table 2.1a, catches for 1978-1990 are broken down by year, fleet sector, and gear type. In Table 2.1b, catches for 1991-2009 are broken down by year, jurisdiction, and gear type. The foreign fishery peaked in 1981 at a catch of nearly 35,000 t. A small joint venture fishery existed through 1988, averaging a catch of about 1,400 t per year. The domestic fishery increased steadily through 1986, then increased more than three-fold in 1987 to a catch of nearly 31,000 t as the foreign fishery was eliminated. Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components. Trawl gear took the largest share of the catch in every year but one from 1991-2002, although pot gear has taken the largest single-gear share of the catch in each year since 2003. Figures 2.1a-2.1c show areas in which sampled hauls or sets for each of the three main gear types (trawl, longline, and pot) were concentrated during January-May, June-August, and September-December, 2008. Figures 2.1d-2.1e show the corresponding information for January-May and June-August, 2009 (preliminary data). To create these figures, the EEZ off Alaska was divided into 20 km × 20 km squares. For each gear type, a square is shaded if hauls/sets containing Pacific cod from more than two distinct vessels were sampled in it during the respective gear/season/year.

The chapters entitled "Profile for Pacific cod Fleet" and "Pacific Cod Market Analysis" in the economic section of the SAFE Report (Hiatt et al., 2007) provide additional information on the Pacific cod fishery.

The history of acceptable biological catch (ABC) and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate commercial catches in Table 2.2. For the first year of management under the MFCMA (1977), the catch limit for GOA Pacific cod was established at slightly less than the 1976 total reported landings. During the period 1978-1981, catch limits varied between 34,800 and 70,000 t, settling at 60,000 t in 1982. Prior to 1981 these limits were assigned for "fishing years" rather than calendar years. In 1981 the catch limit was raised temporarily to 70,000 t and the fishing year was extended until December 31 to allow for a smooth transition to management based on calendar years, after which the catch limit returned to 60,000 t until 1986, when ABC began to be set on an annual basis. Changes in ABC over time are typically attributable to three factors: 1) changes in resource abundance, 2) changes in management strategy, and 3) changes in the stock assessment model. From 1986 (the first year in which an ABC was set) through 1996, TAC averaged about 83% of ABC and catch averaged about 81% of TAC. In 8 of those 11 years, TAC equaled ABC exactly. In 2 of those 11 years (1992 and 1996), catch exceeded TAC. To understand the relationships between ABC, TAC, and catch for the period since 1997, it is important to understand that a substantial fishery for Pacific cod has been conducted during these years inside State of Alaska waters, mostly in the Western and Central Regulatory Areas. To accommodate the State-managed fishery, the Federal TAC was set well below ABC in each of those years (15% in 1997 and 1998; 20% in 1999; 23% in 2000-2003; and 24% in 2004-2009). Thus, although total (Federal plus State) catch has exceeded the Federal TAC in all but three years since 1997, this is basically an artifact of the bi-jurisdictional nature of the fishery and is not evidence of overfishing. At no time since the separate State waters fishery began in 1997 has total catch exceeded ABC.

Historically, the majority of the GOA catch has come from the Central regulatory area. To some extent the distribution of effort within the GOA is driven by regulation, as catch limits within this region have been apportioned by area throughout the history of management under the MFCMA. Changes in area-specific allocation between years have usually been traceable to changes in biomass distributions estimated by Alaska Fisheries Science Center trawl surveys or management responses to local concerns. Currently, the ABC allocation follows the average biomass distribution estimated by the three most recent trawl surveys, and the TAC allocation is within one percent of this distribution on an area-by-area basis. The complete history of allocation (in percentage terms) by regulatory area within the GOA is shown in Table 2.3.

In addition to area allocations, GOA Pacific cod is also allocated on the basis of processor component (inshore/offshore) and season. The inshore component is allocated 90% of the TAC and the remainder is allocated to the offshore component. Within the Central and Western Regulatory Areas, 60% of each component's portion of the TAC is allocated to the A season (January 1 through June 10) and the remainder is allocated to the B season (June 11 through December 31, although the B season directed fishery does not open until September 1). The longline and trawl fisheries are also associated with a Pacific halibut mortality limit which sometimes constrains the magnitude and timing of harvests taken by these two gear types.

The catches shown in Tables 2.1a-b and 2.2 include estimated discards for all years since 1980. Discard rates of Pacific cod in the various GOA target fisheries are shown for each year 1991-2002 in Table 2.4a, for each year 2003-2004 in Table 2.4b, and for each year 2005-2009 in Table 2.4c (2009 data are partial).

DATA

This section describes data used in the current assessment model. It does not attempt to summarize all available data pertaining to Pacific cod in the GOA.

Commercial Catch Data

Catch Biomass

Catches (including estimated discards) taken in the GOA since 1977 are shown in Table 2.5, broken down by the three main gear types and the following within-year time intervals, or "seasons": January-May, June-August, and September-December. This particular division, which was suggested by participants in the BSAI fishery, is intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning season may be different than at other times of year). In years for which estimates of the distribution by gear or season were not available, proxies based on other years' distributions were used.

Catch Size Composition

Fishery size compositions are presently available, by gear, for the years 1977 through the first part of 2009. For ease of representation and analysis, length frequency data for Pacific cod can usefully be grouped according to the following set of 25 intervals or "bins," with the upper and lower boundaries shown in cm:

Bin Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Lower Bound:	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
Upper Bound:	11	14	17	20	23	26	29	32	35	38	41	44	49	54	59	64	69	74	79	84	89	94	99	104	115

The collections of relative length frequencies are shown by year and size bin for the trawl fishery in Tables 2.6a, 2.6b, and 2.6c; the longline fishery in Tables 2.7a, 2.7b, and 2.7c; and the pot fishery in Tables 2.8a, 2.8b, and 2.8c. Pot fishery length frequencies since 1997 include samples from the State-managed fishery.

Catch Per Unit Effort

Fishery catch per unit effort data are available by gear and season for the years 1991-2009 and are shown below (units are kg/hr for trawl gear, kg/hook for longline gear, and kg/pot for pot gear; season 3 data for 2009 data are partial):

	Trawl fishery			Longline fishery			Pot fishery		
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1991	107.18	20.51	63.12	0.94	0.48		53.33		
1992	67.93	22.19	27.81	0.97	0.37	0.54	55.89	93.65	33.14
1993	78.07	25.95	14.85	0.81	0.51		71.11		
1994	97.17	29.49	37.70	0.73			61.31		48.26
1995	129.89	24.70	53.43	0.91	0.22	0.66	59.60		57.19
1996	104.61	21.64	24.59	0.77			54.53	80.57	
1997	67.84	35.52	68.64	0.96			55.26		73.88
1998	60.87	230.89	204.47	0.65	0.96		64.87		58.15
1999	44.72	237.30	209.30	0.78	0.44		66.95	52.76	28.89
2000	44.72	174.22	28.62	0.76			42.36		
2001	47.36	171.22	51.21	0.65			53.03		46.51
2002	40.76	196.63	38.76	0.80		0.71	50.06		63.63
2003	60.71	152.06	185.81	0.79	0.88		76.83		61.88
2004	62.39	292.58	88.72	0.64	0.83	0.39	68.20		51.11
2005	62.19	99.06	145.48	0.63		0.39	69.63		45.22
2006	45.57	198.80	66.73	0.67		0.53	59.38		43.92
2007	39.50	171.68	57.00	0.69		0.59	53.69		38.78
2008	44.42	192.67	81.24	0.53		0.42	53.11		57.87
2009	92.17	66.37	135.02	0.66		0.47	55.49		

Fishery Age Composition Data

This year marks the first time that fishery age composition data have become available since production ageing of Pacific cod resumed several years ago (Roberson 2001, Roberson et al. 2005). An estimate of age composition from the 2008 January-May longline fishery is now available, as shown in Table 2.10a.

Survey Data

Survey Size Composition

The relative size compositions from trawl surveys of the GOA conducted by the Alaska Fisheries Science Center since 1984 are shown in Tables 2.9a and 2.9b, using the same length bins defined above for the commercial catch size compositions.

Survey Age Composition

Age compositions from each survey except 1984 and 2009 are available. The age compositions and sample sizes (scaled so that the average across all age compositions, including the 2008 January-May longline fishery age composition, equals 300) are shown in Tables 2.10b (for the 27-plus portion of the survey) and 2.10c (for the sub-27 portion of the survey).

Mean Size at Age

Mean size-at-age data are available for all of the years in which age compositions are available (note that age composition data are not available for the earliest years in the time series for the sub-27 survey). These are shown, along with sample sizes, in Table 2.10d. This table also includes mean size at age for the single record of fishery age composition data currently available (2008 Jan-May longline fishery).

Abundance Estimates

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.11, together with their respective coefficients of variation.

The highest biomass ever observed by the survey was the 2009 estimate of 752,651 t, and the low point was the preceding (2007) estimate of 233,310 t. The 2009 biomass estimate represented a 223% increase over the 2007 estimate.

In terms of population numbers, the record high was observed in 2009, when the population was estimated to include over 573 million fish. The 2005 estimate of 140 million fish was the low point in the time series. The 2009 abundance estimate represented a 199% increase over the 2007 estimate.

ANALYTIC APPROACH

Model Structure

History of Previous Model Structures Developed Under Stock Synthesis

Beginning with the 1994 SAFE report (Thompson and Zenger 1994), a model using the Stock Synthesis 1 (SS1) assessment program (Methot 1986, 1990, 1998, 2000) and based largely on length-structured data formed the primary analytical tool used to assess the GOA Pacific cod stock.

SS1 is a program that used the parameters of a set of equations governing the assumed dynamics of the stock (the “model parameters”) as surrogates for the parameters of statistical distributions from which the data are assumed to be drawn (the “distribution parameters”), and varies the model parameters systematically in the direction of increasing likelihood until a maximum is reached. The overall likelihood is the product of the likelihoods for each of the model components. In part because the overall likelihood can be a very small number, SS1 uses the logarithm of the likelihood as the objective function. Each likelihood component is associated with a set of data assumed to be drawn from statistical distributions of the same general form (e.g., multinomial, lognormal, etc.). Typically, likelihood components are associated with data sets such as catch size (or age) composition, survey size (or age) composition, and survey biomass (either relative or absolute).

SS1 permits each data time series to be divided into multiple segments, resulting in a separate set of parameter estimates for each segment. In the base model for the GOA Pacific cod assessment, for example, possible differences in selectivity between the mostly foreign (also joint venture) and mostly domestic fisheries have were accommodated by splitting the fishery size composition time series into pre-1987 and post-1986 segments during the era of SS1-based assessments.

In the both the EBS and GOA Pacific cod models, each year has traditionally been partitioned into three seasons: January-May, June-August, and September-December (these seasonal boundaries were suggested by industry participants in the EBS fishery). Four fisheries were traditionally defined during the era of SS1-based assessments: The January-May trawl fishery, the June-December trawl fishery, the longline fishery, and the pot fishery.

Following a series of modifications from 1993 through 1997, the base model for GOA Pacific cod remained completely unchanged from 1997 through 2001. During the late 1990s, a number of attempts were made to estimate the natural mortality rate *M* and the shelf bottom trawl survey catchability coefficient *Q*, but these were not particularly successful and the Plan Team and SSC always opted to retain the base model in which *M* and *Q* were fixed at their traditional values of 0.37 and 1.0, respectively.

A minor modification of the base model was suggested by the SSC in 2001, namely, that consideration be given to dividing the domestic era into pre-2000 and post-1999 segments. This modification was tested in the 2002 assessment (Thompson et al. 2002), where it was found to result in a statistically significant improvement in the model's ability to fit the data.

A major change took place in the 2005 assessment (Thompson and Dorn 2005), as the model was migrated to the newly developed Stock Synthesis 2 (SS2) program, which made use of the ADMB modeling architecture (Fournier 2005) currently used in most age-structured assessments of BSAI and GOA groundfish. The move to SS2 facilitated improved estimation of model parameters as well as statistical characterization of the uncertainty associated with parameter estimates and derived quantities such as spawning biomass. Technical details of SS2 were described by Methot (2005, 2007).

The 2006 assessment model (Thompson et al. 2006) was structured similarly to the 2005 assessment model; the primary change being external estimation of growth parameters.

A technical workshop was convened in April, 2007 to consider a wide range of issues pertaining to both the BSAI and GOA Pacific cod assessments (Thompson and Conners 2007).

The 2007 assessment model (Thompson et al. 2007b) for Pacific cod in the GOA was patterned after the model used in that year's assessment of the BSAI Pacific cod stock (Thompson et al. 2007a), with several changes as described in the assessment document. However, the 2007 assessment model was not accepted by the Plan Team or the SSC.

For the 2008 assessment, the recommended model for the GOA was based largely on the recommended model from the 2008 BSAI Pacific cod assessment. Among other things, this model used an explicit algorithm to determine which fleets (including surveys as well as fisheries) would be forced to exhibit asymptotic selectivity, and another explicit algorithm to determine which selectivity parameters would be allowed to vary periodically in "blocks" of years and to determine the appropriate block length for each such time-varying parameter. One other significant change in the recommended model from the 2008 GOA assessment, which was not shared by the BSAI assessment, was a substantial downweighting of the age composition data. This downweighting was instituted as a means of keeping the root mean squared error of the fit to the survey abundance data close to the sampling variability of those data.

Model Structures Considered in This Year's Assessment

Ten models are included in this final assessment. Six of the models include age composition data and four do not. Models whose names end in "1" include age composition data, and models whose names end in "2" do not include age composition data. The one model whose name ends in "3" (Model A3) includes all available age composition data except the 2008 January-May longline fishery data. The one model whose name ends in "4" (Model A4) uses all available age composition data, but uses an ageing error matrix where the standard deviations are doubled for ages 2-4. The ten models are designed to respond to requests made by the Plan Team(s), SSC, and public, as described in Table 2.0.

The ten models presented in this final assessment may be classified into three groups as follows:

<u>Models based on last year's model, with different uses of age composition data</u>. This group includes four versions of the model accepted for use by the Plan Team and SSC last year, differing only with respect to treatment of age composition data. These are labeled A1 (all available age composition data), A2 (no age composition data), A3 (all available age composition data except the 2008 January-May longline fishery data), and A4 (all available age composition, but standard deviations in the ageing error matrix are doubled for ages 2-4). These models do not use the age composition data from the sub-27 survey because

these data were not used in last year's assessment and because, unlike the fishery age composition data, the SSC did not request that it be added.

As with last year's model, all models in this group drastically downweight the importance of the age composition data in parameter estimation (Model A2 ignores it entirely). Given the SSC's past endorsement of the survey age composition data and request for inclusion of fishery age composition data (see "Responses to Comments from the Plan Teams and SSC" below), Model A1 is considered the base model. The models in this group all use mean size-at-age data, which was a feature of last year's model.

New models with age composition data. This group includes three models with various new features requested by the Plan Team(s), SSC, and public. All models in this group share the following requested features: Potential bias in age readings is corrected for, survey selectivity is held constant at base values for the most recent survey (i.e., no selectivity "devs" are estimated for the most recent survey), and growth rates are cohort-specific. Like the models in the first group, the models in this group all use mean size-at-age data. Use of such data is particularly important for models that estimate cohort-specific growth. Because trawl survey size composition data are not used for any year in which trawl survey age composition data are used (to avoid double counting), and because fishery size composition data give almost no information about ages 1 or 2, inclusion of mean size-at-age data is necessary for meaningful estimation of cohort-specific growth. Models in this group ignore the 1987 survey age composition data, because the number of otoliths read from this year of the survey was very small (110), and because 37% of the length samples did not correspond to a length in the age-length key.

Model B1 is the base model for this group. Input standard deviations of all "dev" vectors were set iteratively by matching the standard deviations of the set of estimated "devs," and the coefficient of variation of length at age was estimated outside the model as a linear function of mean length at age. Selectivity at maximum size or age was treated as a controllable parameter. Catchability for the pre-1996 years of the 27-plus trawl survey was estimated freely, and catchability for the post-1993 years was fixed at the value that sets the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.92 obtained by Nichol et al. (2007). Except for the parameter governing selectivity at age 0, all parameters of the selectivity function for the post-1993 years of the 27-plus trawl survey were allowed to vary in each survey year. Potential ageing bias was accounted for in the ageing error matrix by examining alternative bias values in increments of 0.1 for ages 2 and above (age-specific bias values were also examined, but did not improve the fit significantly).

For the remaining models in this group, the input standard deviations for all "dev" vectors and the amount of ageing bias were held constant at the values obtained by Model B1. Differences with respect to Model B1 in the remaining models were as follow:

Model D1 is identical to Model B1 except that selectivity at maximum size or age is removed from the set of controllable parameters (instead, selectivity at maximum size or age becomes a function of other selectivity parameters).

Model E1 is identical to Model B1 except that selectivity at maximum size or age for all non-asymptotic fleets is set equal to a single value that is constant across fleets.

New models without age composition data. This group includes a no-age-composition-data counterpart for each model in the preceding group. Size composition data are included in place of age composition data. The input standard deviations for all "dev" vectors and the amount of ageing bias were held constant at the values obtained by Model B1. These models are labeled B2, D2, and E2.

Table 2.0 shows how the various requests from the Plan Team(s), SSC, and public map into the ten models presented here.

Version 3.03c of SS was used to run all the models in this assessment.

Parameters Estimated Independently

Natural Mortality

In the 1993 BSAI Pacific cod assessment (Thompson and Methot 1993), the natural mortality rate *M* was estimated using SS1 at a value of 0.37. All subsequent assessments of the BSAI and GOA Pacific cod stocks (except the 1995 GOA assessment) have used this value for *M*, until the 2007 assessments, at which time the BSAI assessment adopted a value of 0.34 and the GOA assessment adopted a value of 0.38. Both of these were accepted by the respective Plan Teams and the SSC. The new values were based on Equation 7 of Jensen (1996) and ages at 50% maturity reported by (Stark 2007; see "Maturity" subsection below). In response to a request from the SSC, the 2008 BSAI assessment included further discussion and justification for these values.

For historical completeness, other published estimates of *M* for Pacific cod are shown below:

Area	Author	Year	Value
Eastern Bering Sea	Low	1974	0.30-0.45
	Wespestad et al.	1982	0.70
	Bakkala and Wespestad	1985	0.45
	Thompson and Shimada	1990	0.29
	Thompson and Methot	1993	0.37
Gulf of Alaska	Thompson and Zenger	1993	0.27
	Thompson and Zenger	1995	0.50
British Columbia	Ketchen	1964	0.83-0.99
	Fournier	1983	0.65

All of the models in this assessment estimate *M* independently at the SSC-approved value of 0.38.

Trawl Survey Catchability

Models A1, A2, A3, and A4 fix the catchability coefficient (*Q*) for the 27-plus trawl survey at a value of 0.92, in an attempt to approximate the finding of Nichol et al. (2007) that the product of trawl survey catchability and selectivity for Pacific cod in the GOA was approximately 0.92 for fish in the 60-81 cm size range. This value is held constant for the entire time series.

Model B1 estimates catchability for the 27-plus trawl survey iteratively, using a weighted average to estimate the product of catchability and selectivity for fish in the 60-81 cm size range. Models B2, D1, D2, E1, and E2 all fix catchability at the value estimated iteratively for Model B1. Another difference with respect to the "A" series of models is that the other models fix catchability only for the post-1993 portion of the time series, and allow catchability to be estimated freely for the pre-1996 portion. The reason for allowing *Q* to take on a different value for 1984-1993 is that the survey used 30-minute tows during that period, but 15-minute tows thereafter.

Catchability for the sub-27 survey is estimated as a free "random walk" parameter in Models A1, A2, A3, and A4; and as an unconstrained random deviate in the other models.

Variability in Estimated Age

Variability in estimated age in SS is based on the standard deviation of estimated age. Weighted least squares regression has been used in the past several assessments to estimate a linear relationship between standard deviation and age. The regression was recomputed this year, yielding an estimated intercept of

0.019 and an estimated slope of 0.068 (i.e, the standard deviation of estimated age was modeled as 0.019 + 0.068 × age).

Variability in Length at First Survey Age

In the 2008 assessment, the parameters defining the distribution of length at age 1.5417 (age 1 incremented to reflect the timing of the trawl survey) were estimated independently. This was done by computing the long-term survey size composition of fish 12 to 35 cm in length and fitting a mixture of two normal distributions (assuming that fish in this size range are all ages 1 or 2). The mixture model gave an excellent fit (coefficient of determination = 0.96), and estimated the mean and standard deviation of length at age 1.5417 at values of 20.94 cm and 3.806 cm, respectively. Variability in length at age 20 was estimated conditionally in the 2008 assessment. The same procedure was used in the present assessment for Models A1, A2, A3, and A4.

For the other models in the present assessment, however, it was necessary to relax these assumptions, because the other models estimate cohort-specific growth. As described in the SS user manual (Methot 2009), problems can arise when estimating cohort-specific growth unless the first reference age in the length-at-age equation is set at true age 0. Because no data are available to describe the standard deviation of length at true age 0 (which is mostly a theoretical extrapolation anyway), a regression approach was used, based on the outside-the-model estimates of standard deviation of length at age from the survey age data. The best fit was obtained by assuming that the standard deviation is a linear function of length at age, with an intercept of 2.10 and a slope of 0.045.

Use of this regression required an iterative, “quasi-conditional” procedure for specifying the standard deviations of length at ages 0 and 20, because the regression is a function of length at age, and length at age is estimated conditionally (i.e., inside the model).

Weight at Length

Parameters governing weight at length were re-estimated in the 2008 assessment. All weight-length records from the observer database (both shore-based and at-sea samples) were used to estimate seasonally varying values of the weight-at-length parameters. Values of α and β, together with sample sizes, were as follow:

Season:	1	2	3	Annual
α:	8.626×10^{-6}	1.015×10^{-5}	1.434×10^{-5}	8.837×10^{-6}
β:	3.080	3.023	2.948	3.072
Samples:	68,568	4,701	12,309	85,578

The seasonal model gave a statistically significant improvement (AIC = 67,829 for the annual model; AIC = 66,978 for the seasonal model).

The above parameters were also used in the present assessment.

Maturity

A detailed history and evaluation of parameter values used to describe the maturity schedule for BSAI Pacific cod was presented in the 2005 assessment (Thompson and Dorn 2005). A length-based maturity schedule has been used for many years. The parameter values used for this schedule in the 2005 and 2006 assessments were set on the basis of a study by Stark (2007) at the following values: length at 50% maturity = 50 cm and slope of linearized logistic equation = -0.222. However, in 2007, changes in SS allowed for use of either a length-based or an age-based maturity schedule. Beginning with the 2007 assessment, an age-based schedule with intercept = 4.3 years and slope = –1.963 (Stark 2007) was used. The use of an age-based rather than a length-based schedule follows a recommendation from James Stark (Alaska Fisheries Science Center, personal communication).

Parameters Estimated Conditionally

Parameters estimated conditionally (i.e., within individual SS runs, based on the data and the parameters estimated independently) in all models include the Brody growth coefficient *K*, log mean recruitment before and since the 1976-1977 regime shift, initial fishing mortality, selectivity parameters, year-specific values for the ascending "width" parameter governing the 27-plus trawl survey selectivity schedule (see below), year-specific values for catchability of the sub-27 trawl survey, and annual recruitment deviations.

Parameters estimated conditionally in some but not all models include: mean length at age 0 (all Models except A1, A2, A3, and A4), mean length at age 20 (Models A1, A2, A3, and A4), asymptotic length (all models except A1, A2, A3, and A4), the parameter governing variability in length at age 20 (Models A1, A2, A3, and A4), 27-plus trawl survey catchability for the pre-1996 portion of the time series (all models except A1, A2, A3, and A4), year-specific values for all parameters governing the 27-plus trawl survey selectivity schedule except selectivity at age 0 (all models except A1, A2, A3, and A4), and annual deviations in growth (all models except A1, A2, A3, and A4).

The same functional form (pattern 24 for length-based selectivity, pattern 20 for age-based selectivity) used to define the selectivity schedules in last year's assessments was used again this year. This functional form is constructed from two underlying and rescaled normal distributions, with a horizontal line segment joining the two peaks. This form uses the following six parameters (selectivity parameters are referenced by these numbers in several of the tables in this assessment):

1. Beginning of peak region (where the curve first reaches a value of 1.0)
2. Width of peak region (where the curve first departs from a value of 1.0)
3. Ascending "width" (equal to twice the variance of the underlying normal distribution)
4. Descending width
5. Initial selectivity (at minimum length/age)
6. Final selectivity (at maximum length/age)

All but the "beginning of peak region" parameter are transformed: The widths are log-transformed and the other parameters are logit-transformed.

Uniform prior distributions are used for all parameters, except that "dev" vectors are constrained by input standard deviations ("sigma"), which imply a type of joint prior distribution. These input standard deviations were determined iteratively by matching the standard deviations of the estimates for all "dev" vectors in Model B1. Models B2, D1, D2, E1, and E2 use the same values for the input standard deviations as Model B1. In Models A1, A2, A3, and A4, the procedure of matching input and output standard deviations was followed for the recruitment "dev" vector, but the input standard deviation for the random walk "dev" vector for catchability in the sub-27 survey was set at a value of 0.2 by assumption.

For all parameters estimated within individual SS runs, the estimator used is the mode of the logarithm of the joint posterior distribution, which is in turn calculated as the sum of the logarithms of the parameter-specific prior distributions and the logarithm of the likelihood function.

In addition to the above, the full set of year-, season-, and gear-specific fishing mortality rates are also estimated conditionally, but not in the same sense as the above parameters. The fishing mortality rates are determined exactly rather than estimated statistically because SS assumes that the input total catch data are true values rather than estimates, so the fishing mortality rates can be computed algebraically given the other parameter values and the input catch data.

Likelihood Components

All ten models included likelihood components for trawl survey relative abundance, fishery and survey size composition, mean size at age, recruitment, parameter deviations, and "softbounds" (equivalent to an extremely weak prior distribution used to keep parameters from hitting bounds). In addition, Models A1, A3, A4, B1, D1, and E1 included likelihood components for age composition; and Models A1, A2, A3, and A4 had a "prior" component (by virtue of assuming that catchability for the sub-27 survey followed a random walk rather than independent yearly deviations).

In SS, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in previous assessments, likelihood components were generally given an emphasis of 1.0 in the present assessment. Exceptions were those cases where one or more types of data were included in the data file but ignored (e.g., the models that ignore age composition data). In such cases, zero emphasis was placed on the ignored data rather than removing the ignored data from the file, thus enabling a measure of how well the model fit the ignored data.

Use of Size Composition Data in Parameter Estimation

Size composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear, and season within the year. In the parameter estimation process, SS weights a given size composition observation (i.e., the size frequency distribution observed in a given year, gear, and season) according to the emphasis associated with the respective likelihood component and the sample size specified for the multinomial distribution from which the data are assumed to be drawn. In developing the model upon which SS was originally based, Fournier and Archibald (1982) suggested truncating the multinomial sample size at a value of 400 in order to compensate for contingencies which cause the sampling process to depart from the process that gives rise to the multinomial distribution. For many years, the Pacific cod assessments assumed a multinomial sample size equal to the square root of the true length sample size, rather than the true length sample size itself. Given the true length sample sizes observed in the GOA Pacific cod data, this procedure tended to give values somewhat below 400 while still providing SS with usable information regarding the appropriate effort to devote to fitting individual length samples.

Although the "square root rule" for specifying multinomial sample sizes gave reasonable values, the rule itself was largely *ad hoc*. In an attempt to move toward a more statistically based specification, the 2007 BSAI assessment (Thompson et al. 2007a) used the harmonic means from a bootstrap analysis of the available fishery length data from 1990-2006. The harmonic means were smaller than the actual sample sizes, but still ranged well into the thousands. A multinomial sample size in the thousands would likely overemphasize the size composition data. As a compromise, the harmonic means were rescaled proportionally in the 2007 BSAI assessment so that the average value (across all samples) was 300. However, the question then remained of what to do about years not covered by the bootstrap analysis (2007 and pre-1990) and what to do about the survey samples. The solution adopted in the 2007 BSAI assessment was based on the consistency of the ratios between the harmonic means (the raw harmonic means, not the rescaled harmonic means) and the actual sample sizes. For the years prior to 1999, the ratio was very consistently close to 0.16, and for the years after 1998, the ratio was very consistently close to 0.34. This consistency was used to specify the missing values as follows: For fishery data, the sample sizes for length compositions from years prior to 1999 were tentatively set at 16% of the actual sample size, and the sample sizes for length compositions from 2007 were tentatively set at 34% of the actual sample size. For the trawl survey, sample sizes were tentatively set at 34% of the actual sample size. Then, with sample sizes for fishery length compositions from 1990-2007 tentatively set at their bootstrap harmonic means (not rescaled), all sample sizes were adjusted proportionally so that the average was 300.

The same procedure was used in the 2008 assessment and the present assessment as well. The resulting set of multinomial sample sizes is shown in Table 2.12.

Use of Age Composition Data in Parameter Estimation

Like the size composition data, the age composition data are assumed to be drawn from a multinomial distribution specific to a particular gear, year, and season within the year.

Specification of sample sizes for the age composition multinomial distributions differed between the first group of models (A1, A2, A3, and A4) and the other two groups. The first group followed the procedure used in the 2008 assessment, in which the actual number of otoliths read in each year was rescaled proportionally such that the average was equal to 100, then these values were multiplied by 0.12 (giving an average input sample size of 12). The other models used the same procedure followed in the BSAI Pacific cod assessment, where the actual number of otoliths read in each year was scaled proportionally such that the average of the input sample sizes was equal to 300. Thus, the age composition data in Models A1, A2, A3, and A4 were downweighted 96% relative to the other models. (Note that the age composition data are included in all data files, regardless of whether they are used or ignored by any given model.)

To avoid double counting of the same data, Models A1, A3, A4, B1, D1, and E1 ignore size composition data from each gear/year/season combination in which age composition data are available. Models A2, B2, D2, and E2, which ignore the age composition data, use all the available size composition data.

Use of Fishery CPUE and Survey Relative Abundance Data in Parameter Estimation

Fishery CPUE data are included in the models for comparative purposes only. Their respective catchabilities are estimated analytically, not statistically.

For the trawl surveys, each year's survey abundance datum is assumed to be drawn from a lognormal distribution specific to that year. The model's estimate of survey abundance in a given year serves as the geometric mean for that year's lognormal distribution, and the ratio of the survey abundance datum's standard error to the survey abundance datum itself serves as the distribution's coefficient of variation, which is then transformed into the "sigma" parameter for the lognormal distribution.

Use of Recruitment Deviation "Data" in Parameter Estimation

The recruitment deviations likelihood component is different from traditional likelihoods because it does not involve "data" in the same sense that traditional likelihoods do. Instead, the log-scale recruitment deviation plays the role of the datum and the log-scale recruitment mean and input standard deviation are related to the parameters of a normal distribution, but, of course, all of these are treated as parameters by SS (although the input standard deviation is estimated iteratively rather than internally).

MODEL EVALUATION

As described above, ten models are evaluated in the present assessment. All models appeared to converge successfully and the Hessian matrices from all models were positive definite. At several points during the model development process, sets of (typically about 50) additional runs were made for most models with initial parameter values displaced randomly from their converged values to provide additional assurance that another (better) solution did not exist. In the cases of Models B2 and D2, the best value of the objective function could be obtained only by starting the models from their fully converged values (including elements of "dev" vectors).

Comparing and Contrasting the Models

Tables 2.13-2.18 and Figures 2.2-2.9 present summaries of some key results from the ten models.

Table 2.13 pertains to statistical goodness of fit.

The first page of Table 2.13a is structured as follows:

> Section 1: Total negative log-likelihood, parameter counts (internally estimated parameters only), and Akaike Information Criterion (AIC). The use of AIC in this context may not be strictly correct, as some of the terms in the log-likelihood may be more properly viewed as priors. Nevertheless, it may still provide information useful for model selection.
>
> Section 2: Aggregate likelihood components. In general, lower values are better than higher values, but this rule must be interpreted in light of other factors, such as the number of parameters used to achieve a given likelihood value. Furthermore, models in different groups use different data sets, different input standard deviations for "dev" vectors, or both. In general, log-likelihoods of models within the first group are difficult to compare, while log-likelihoods of models within the second group can be compared, as can log-likelihoods of models within the third group.

The second page of Table 2.13a is structured as follows:

> Section 1: Relative abundance log-likelihoods. The only log-likelihoods that are actually used in this section are the trawl survey likelihoods. The others are shown for comparative purposes only.
>
> Section 2: Size composition log-likelihoods. The aggregate size composition log-likelihood is broken down by gear and season in the case of fisheries, and by individual survey types.
>
> Section 3: Age composition log-likelihoods. The aggregate age composition log-likelihood is broken down into the single (2008) record from the January-May longline fishery and the two portions (27-plus and sub-27) of the the trawl survey. Note that the first group of models (A1, A2, A3, and A4) does not use age composition data from the sub-27 survey.
>
> Section 4: Mean size at age. Similar to the above.

Tables 2.13b and 2.13c provide alternative measures of how well the models are fitting the fishery CPUE and survey relative abundance data. Table 2.13b shows root mean squared errors (lower values are better) and Table 2.13c shows correlations between observed and estimated values. Note that none of the models actually attempts to fit the fishery CPUE data; these results are shown for information only.

Table 2.13d shows the average of the ratios between output "effective" sample size (McAllister and Ianelli 1997) and input sample size for size composition data, thus providing an alternative measure of how well the models are these data (higher values are better). Rows in this table correspond to different fisheries or surveys.

Table 2.13e provides a similar analysis for the age composition, except that the rows in the main part of this table correspond to individual records rather than fisheries or surveys. The bottom two rows show weighted averages for the trawl survey and for all records combined (i.e., including the single record from the January-May longline fishery).

Table 2.14 pertains to estimates of parameters other than selectivity parameters.

Table 2.14a lists key parameters that are estimated internally by at least one of the ten models. If a parameter in this table is estimated internally by one of the models, the estimated value is shown along with its standard deviation. If a parameter is estimated externally, just the estimated value is shown. The parameters listed in this table are mean lengths at reference age 1 and 2 (as noted in the legend, these reference ages may be different between models), the Brody growth coefficient *K*, a parameter governing the spread of the age-specific length-at-age distributions (either CV_2 or SD_2, the coefficient of variation or the standard deviation of length at age 20), log mean recruitments for the post-1976 and pre-1977 environmental regimes (R_0 and R_1, where the latter expresses the log of the ratio between the two means), the fishing mortality rate in the initial year, the log ratio of pre-1996 27-plus survey catchability to post-1993 27-plus survey catchability, the base value of log catchability of the sub-27 survey, and the year-specific deviations in catchability of the sub-27 survey (either as a random walk in Models A1-A4 or as independent, unconstrained deviations in the other models).

Table 2.14b lists estimates and standard deviations of annual growth deviations for the second and third groups of models (the first group does not make use of annual growth deviations).

Tables 2.14c-2.16e list estimates and standard deviations of annual log recruitment deviations given by the three groups of models. Note that these are deviations, not log recruitments *per se*, and are computed with respect to their regime-specific (pre-1977, post-1976) log medians. It should also be noted that the number of recruitments differs between the first group of models (A1-A4) and the other two groups. In the 2008 assessment, the optimal number of recruitments to estimate before the initial year (1977) was determined to be 3, on the basis of AIC. Thus, for Models A1-A4, the recruitment time series starts 3 years before the initial year, in 1974. In developing Model B1, however, estimation of a much larger number of early recruitments proved to be optimal. Specifically, 13 early recruitments was determined to be optimal in Model B1 on the basis of AIC, so the recruitment time series starts 13 years before the initial year, in 1964. The remaining models in the second and third groups also estimate 13 recruitments prior to the initial year.

Table 2.15 pertains to model estimates of selectivity parameters.

Tables 2.15a-2.15c list base fishery selectivity parameters for the three groups. Note that these base parameters may be over-written by block-specific parameters. Block-specific selectivity parameters for the first group of models are shown in Tables 2.15d-2.15f, block-specific selectivity parameters for the second group of models are shown in Tables 2.15g-2.15i, and block-specific selectivity parameters for the third group of models are shown in Tables 2.15j-2.15l. Tables 2.15m-2.15o list base survey selectivity parameters for the three groups. Similar to the base fishery selectivity parameters, some of these may be adjusted by block-specific values. The time series of block-specific survey selectivity parameters for the three groups of models are shown in Tables 2.15p-2.15r.

Parameters not listed in Tables 2.14-2.15 include those that have already been identified as being estimated independently (i.e., outside of the stock assessment model), and those that are estimated by trial and error. The parameters in the latter category include the input standard deviations for the various “dev” vectors (recruitment, sub-27 survey catchability, and perhaps growth, depending on the model), and the amount of ageing error bias in all models except A1, A2, A3, and A4. For Models A1, A2, A3, A4, and B1, the values of the input standard deviations were determined as follows ("estimated" means that the value was determined iteratively by matching the standard deviations of the set of "dev" parameters):

	Growth		Recruitment		Sub-27 catchability	
Model	value	method	value	method	value	method
A1	n/a	n/a	0.75	estimated	0.20	assumed
A2	n/a	n/a	0.73	estimated	0.20	assumed
A3	n/a	n/a	0.75	estimated	0.20	assumed
A4	n/a	n/a	0.69	estimated	0.20	assumed
B1	0.09	estimated	0.41	estimated	n/a	n/a

For all other models, the input standard deviations were set at the values determined for Model B1. Note that these models treat the sub-27 catchabilities as independent, unconstrained parameters, so no input standard deviation is specified.

Another parameter that was estimated by trial and error was the amount of bias to include in the ageing error matrix. Model B1 was used for this estimation. Initially, different ranges of ages were examined, with potentially different amounts of bias for each age in the range, but the results of these initial tests indicated that a constant amount of bias for all ages 2 and above performed nearly as well (in terms of log-likelihood), with fewer parameters. The final estimate of the amount of bias was 0.4. Except for Models A1, A2, A3, and A4, all models used this bias value.

The final parameter that was estimated by trial and error in Model B1 was catchability for the post-1993 portion of the 27-plus survey. A catchability of 1.04 set the average product of catchability and selectivity for the 60-81 cm size range equal to 0.92, which is the value determined for the GOA trawl survey by Nichol et al. (2007).

In addition to the parameters estimated by trial and error in Model B1, Models E1 and E2 also required estimation of single fixed values for selectivity at maximum size or age, which was the distinguishing characteristic of those two models (see Comment SSC5). These fixed values were determined by trying different a range of fixed values, in increments of 0.1, and choosing the one that gave the best log-likelihood. For Model E1, this fixed value was 0.3, and for Model E2 it was 0.4. These values were used for all fisheries and surveys that were not constrained to exhibit asymptotic selectivity.

Tables 2.16a and 2.16b shows how estimated size (cm) at ages 1 and 2 under each of the models compare with the observed values from the trawl survey for the years in which data are available. The results for age 1 are disappointing, because the models in which cohort-specific growth is estimated produce mean sizes at age 1 that are either basically uncorrelated or, worse, very negatively correlated with the observed mean sizes at age 1. On the other hand, the models in which cohort-specific growth is estimated appear to do very well in terms of mean size at age 2, because the correlations for all such models are at least 0.75. If the favorable results observed at age 2 tend to hold at other ages also, it would indicate that the estimated growth deviations really are being used largely to fit the mean size-at-age data, rather than being absorbed mostly into fitting other data sets.

Table 2.17 contains selected output from the standard projection model, based on SS parameter estimates from the ten models.

> Section 1: Spawning biomass reference points. Equilibrium spawning biomass under zero fishing (B100%), and the reference points corresponding to 40% and 30% of that value are shown.
>
> Section 2: Projected spawning biomasses. Values for 2010 and 2011 are shown, with the value for 2011 predicated on the assumption that the 2010 catch will equal the 2010 maximum permissible ABC.

Section 3: The ratio of projected spawning biomass to B100%. Values for 2010 and 2011 are shown.

Section 4: Fishing mortality rates that, in equilibrium, result in spawning biomass equal to B40% and B35% respectively.

Section 5: Maximum permissible values of the fishing mortality rate used to compute ABC under the Tier 3 harvest control rules. Values for 2010 and 2011 are shown.

Section 6: Maximum permissible values for ABC corresponding to the fishing mortality rates shown in Section 5.

Section 7: Fishing mortality rate corresponding to the overfishing limit for 2010 under the Tier 3 harvest control rules.

Section 8: Overfishing limits for 2010 and 2011. The value for 2011 assumes that catch in 2010 equals the maximum permissible ABC.

Section 9: Probability that spawning biomass will fall below 20% of B100% in 2012, 2013, or 2014 if catch equals maximum permissible ABC in each year from now until then. Because Pacific cod are a key prey item of endangered Steller sea lions (*Eumetopias jubatus*), current regulations require directed fishing to cease in the event that the spawning biomass falls below 20% of B100%.

Figure 2.2 shows the models' fits to the time trend of survey abundance, measured in numbers of fish. The second and third groups of models have a somewhat better residual pattern. However, this is due in part to extremely high estimates of catchability (in the 2.1-2.5 range) for the 27-plus survey in the pre-1996 years. On the other hand, it should be noted that these models do nearly as well as the first group (Models A1-A4) without drastically downweighting the age composition data.

Figure 2.3 (one page for each model) shows the models' fits to the age composition data. Models A1, A3, and A4 clearly have trouble fitting the age composition data. Ironically, Model A2, which ignores the age composition data entirely (but substitutes the corresponding size composition data), fits the age composition data than the other models in the first group.

Figure 2.4 shows the models' estimated time series of recruitment deviations. The trends produced by Models A1-A4 are noticeably different from those produced by the second and third groups of models. This may be due to a combination of factors, including larger input standard deviations for the recruitment deviations in Models A1-A4, and the estimation of cohort-specific growth in the second and third groups of models.

Figure 2.5 shows the models' estimated time series of relative spawning biomass (i.e., relative to B100%). Once more, the trends are exhibited by Models A1-A4 are noticeably different from those exhibited by the models in the second and third groups.

Figure 2.6 shows the models' estimated time series of total (age 0+) biomass, and shows the time series of trawl survey biomass for comparison. Model A2 estimates a much higher level of biomass than any other model for the last 20 years or so of the time series.

Figure 2.7 shows the models' estimated 27-plus trawl survey schedules. All models show a marked decline in selectivity of old fish, except for Model D2, which estimates that survey selectivity has been approximately asymptotic since 2001.

Figure 2.8 (one page for each model) shows fishery selectivity for each of the nine (3 gears × 3 seasons) fisheries. The numbers and lengths of these blocks were determined in the 2008 assessment on the basis of AIC. The January-May trawl fishery is forced to exhibit asymptotic selectivity in all models.

Evaluation Criteria

The criteria used for selecting the final model were as follow:

1) Does the model respond to current Plan Team and SSC understanding about the usefulness of the age composition data? The Plan Team and SSC have consistently endorsed continued use of the age composition data.
2) Does the model respond appropriately to recent requests? This criterion is a bit more difficult to evaluate, in part because some requests are in conflict with one another. However, the joint Plan Teams have asked that potential ageing bias be corrected for in the ageing error matrix "in the short term" (Comment JPT3), the SSC has asked for refinements in the estimation of "dev" vectors (Comment SSC6), and the joint Plan Teams have asked for inclusion of cohort-specific growth (Comment JPT2, also requested by a member of the public).
3) Of the models that satisfy criteria #1 and #2, are there any that can be selected on purely statistical grounds? If the models all use the same data and the same standard deviations for the various "dev" vectors, they can be ranked by AIC.

Selection of Final Model

The ten models can be evaluated by the three criteria as follows:

1) The only models that meet this criterion are Model A1, the second group of models (B1, D1, and E1), and perhaps Models A3 (which uses all available age composition data except for the 2008 January-May longline fishery record) and A4 (which uses the age composition data but doubles the amount of allowed ageing error for ages 2-4).
2) All the models in the second and third groups satisfy these requests.
3) The only models that satisfy both criteria #1 and #2 are the models in the second group (B1, D1, and E1). Because these models all use the same data and the same standard deviations for the various "dev" vectors, they can be ranked by AIC. Of this group of models, the one with the best AIC is Model B1.

Model B1 is therefore selected as the final model.

Final Parameter Estimates and Associated Schedules

As noted previously, estimates of all statistically estimated parameters in Model B1 are shown in Tables 2.14a, 2.14b, 2.14d, 2.15b, 2.15g, 2.15h, 2.15i, 2.15n, and 2.15q.

Estimates of year-, gear-, and season-specific fishing mortality rates from Model B1 are shown in Table 2.18.

Schedules of selectivity at length for the commercial fisheries from Model B1 are shown in Table 2.19a, and schedules of selectivity at age for the 27-plus trawl survey from Model B1 are shown in Table 2.19b. Post-1981 trawl survey and fishery selectivity schedules are plotted in Figures 2.8 and 2.9B1, respectively.

Schedules of length at age and weight at age for the population, each gear-and-season-specific fishery, and each survey from Model B1 are shown in Tables 2.20a and 2.20b, respectively.

TIME SERIES RESULTS

Note: Because the preferred model differs substantively from last year's model (A1), the tables and figures referenced in this section are reproduced using Model A1 in Attachment 2.2.

Definitions

The biomass estimates presented here will be defined in two ways: 1) age 0+ biomass, consisting of the biomass of all fish aged 0 years or greater in January of a given year; and 2) spawning biomass, consisting of the biomass of all spawning females in a given year. The recruitment estimates presented here will be defined as numbers of age 0 fish in a given year.

Biomass

Table 2.21a shows the time series of Pacific cod age 0+ and female spawning biomass for the years 1977-2010 as estimated last year and this year under Model B1. The estimated spawning biomass time series are accompanied by their respective standard deviations.

The estimated time series of age 0+ biomass and female spawning biomass from Model B1 are shown, together with the observed time series of trawl survey biomass (assuming a catchability of 1.0), in Figure 2.9. Confidence intervals are shown for the model estimates of female spawning biomass and for the trawl survey biomass estimates.

Recruitment and Numbers at Age

Table 2.21b shows the time series of Pacific cod age 0 recruitment (1000s of fish) for the years 1977-2008 as estimated last year and this year under Model B1. Both estimated time series are accompanied by their respective standard deviations.

Model B1's recruitment estimates for the entire time series (1977-2008) are shown in Figure 2.10, along with their respective 95% confidence intervals. For the time series as a whole, the two largest year classes currently appear to be the 2008 and 2007 cohorts, respectively. However, it must be emphasized that the estimated sizes of these cohorts are based entirely on the 2009 survey, and the estimates are accompanied by extremely large confidence intervals. The fact that cohort-specific growth is also being estimated for these cohorts probably adds, appropriately, to the size of these confidence intervals. The 2006 cohort, which was estimated to be enormous in the 2008 assessment, is still estimated to be very strong, but not as strong as estimated in the 2008 assessment. The fact that selectivity at age 1 was being estimated along with the strength of the incoming year class in last year' assessment may have resulted in an overly optimistic estimate of year class strength (this is the main reason that Model B1 does not allow selectivity at age 1 to change in the final year of the survey time series).

To date, it has not been possible to estimate a reliable stock-recruitment relationship for this stock.

The time series of numbers at age as estimated by Model B1 is shown in Table 2.22.

Exploitation

Figure 2.11 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2009 based on Model B1, overlaid with the current harvest control rules (fishing mortality rates in the figure are standardized relative to $F_{35\%}$ and biomasses are standardized relative to $B_{35\%}$, per SSC request). The entire trajectory lies underneath the $maxF_{ABC}$ control rule. While the ratio of $F_{40\%}$ to $F_{35\%}$ shown in Figure 2.11 is based on output from the standard projection model, the trajectory itself is based on SS output, which may not match the estimates obtained by the standard projection program exactly.

PROJECTIONS AND HARVEST ALTERNATIVES

Note: Because the preferred model differs substantively from last year's model (A1), the tables referenced in this section are reproduced using Model A1 in Attachment 2.2.

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific cod in the GOA have generally been managed under Tier 3 of Amendment 56 (with the exception of the current year, when the stock is being managed under Tier 5). Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing. The following formulae apply under Tier 3:

3a) Stock status: $B/B_{40\%} > 1$

$F_{OFL} = F_{35\%}$

$F_{ABC} \leq F_{40\%}$

3b) Stock status: $0.05 < B/B_{40\%} \leq 1$

$F_{OFL} = F_{35\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

$F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

3c) Stock status: $B/B_{40\%} \leq 0.05$

$F_{OFL} = 0$

$F_{ABC} = 0$

Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. These reference points are estimated as follows, based on Model B1:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
Spawning biomass:	102,000 t	116,600 t	291,400 t

For a stock exploited by multiple gear types, estimation of $F_{35\%}$ and $F_{40\%}$ requires an assumption regarding the apportionment of fishing mortality among those gear types. For this assessment, the apportionment was based on Model 1's estimates of fishing mortality by gear for the five most recent complete years of data (2004-2008). The average fishing mortality rates for those years implied that total fishing mortality was divided among the three main gear types according to the following percentages:

trawl 28.3%, longline 21.3%, and pot 50.4%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.60 and 0.49, respectively.

Specification of OFL and Maximum Permissible ABC

Spawning biomass for 2010 is estimated by Model B1, using the standard projection model, at a value of 117,600 t. This is about 1% above the $B_{40\%}$ value of 116,600 t, thereby placing Pacific cod in sub-tier "a" of Tier 3. Given this, Model B1 estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2010 and 2011 as follows (2011 values are predicated on the assumption that 2010 catch will equal 2010 maximum permissible ABC; catches in t):

Year	Overfishing Level	Maximum Permissible ABC
2010	94,100 t	79,100 t
2011	116,700 t	97,900 t
2010	0.60	0.49
2011	n/a	0.49

The age 0+ biomass projections for 2010 and 2011 from Model B1 (using SS) are 738,000 t and 716,000 t.

For comparison, the age 3+ projections for 2010 and 2011 from Model B1 (using SS) are 701,000 t and 684,000 t.

ABC Recommendation

Review of Past Approaches

In 2005, the SSC used a two-year stair-step approach to recommend a 2006 ABC of 68,859 t.

In 2006, the GOA Plan Team and SSC recommended keeping ABC at the 2006 level for 2007 (68,859 t).

In 2007, the GOA Plan Team and SSC adopted a Tier 5 approach, resulting in a recommended 2008 ABC of 66,493 t.

In 2008, the GOA Plan Team and SSC recommended setting 2009 ABC at the maximum permissible level (Tier 3b) of 55,300.

Recommendation for 2010-2011

Based on Model B1, the maximum permissible ABC (Tier 3a) for 2010 is 79,100 t. This is very close to the current 2010 specification of 79,500 t. *The recommended ABC for 2010 is 79,100 t.* For 2011, Model B1 predicts a substantially higher maximum permissible ABC (97,900 t). This increase is fueled largely by the 2006 year class, which has now been observed in the 2007 and 2009 surveys. Although the estimated strength of the 2006 year class is less in the present assessment than in last year's assessment, the 2006 year class is still estimated to be very strong. *The recommended ABC for 2011 is 97,900 t.*

Area Allocation of Harvests

For the past several years, ABC has been allocated among regulatory areas on the basis of the three most recent surveys. The current proportions are 39% Western, 57% Central, and 4% Eastern. If a weighted average of the 2005, 2007, and 2009 surveys were used, the proportions would be 35% Western, 62% Central, and 3% Eastern.

Standard Harvest and Recruitment

Scenarios and Projection Methodology

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 an estimated vector of 2009 numbers at age. This vector is then projected forward to the beginning of 2010 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2009. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2010, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2010 recommended in the assessment to the *max* F_{ABC} for 2010. (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 the 2004-2008 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 4*: In all future years, the upper bound on F_{ABC} is set at $F_{60\%}$. (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 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (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 1) above its MSY level in 2009 or 2) above 1/2 of its MSY level in 2009 and above its MSY level in 2019 under this scenario, then the stock is not overfished.)

Scenario 7: In 2010 and 2011, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2022 under this scenario, then the stock is not approaching an overfished condition.)

Projections and Status Determination

Scenario Projections and Two-Year Ahead Overfishing Level

Projections corresponding to the standard scenarios are shown for Model B1 in Tables 2.23-2.28 (Scenarios 1 and 2 are the same in this assessment).

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2010, it does not provide the best estimate of OFL for 2011, because the mean 2010 catch under Scenario 6 is predicated on the 2010 catch being equal to the 2009 OFL, whereas the actual 2010 catch will likely be less than the 2009 OFL. Table 2.17 contains the appropriate one- and two-year ahead projections for both ABC and OFL under either of the two models considered in the present assessment.

Status Determination

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

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2008) is 58,974 t. This is less than the 2008 OFL of 88,660 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2009:

a. If spawning biomass for 2009 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2009 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2009 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 2.30). If the mean spawning biomass for 2019 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

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

a. If the mean spawning biomass for 2012 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2012 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2012 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2022. If the mean spawning biomass for 2022 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Tables 2.27 and 2.28, the stock is not overfished and is not approaching an overfished condition.

ECOSYSTEM CONSIDERATIONS

This section is largely unchanged from last year's assessment, except for the subsection on "Bycatch of Target and Nontarget Species."

Ecosystem Effects on the Stock

A primary ecosystem phenomenon affecting the Pacific cod stock seems to be the occurrence of periodic "regime shifts," in which central tendencies of key variables in the physical environment change on a scale spanning several years to a few decades (Boldt (ed.), 2005). One well-documented example of such a regime shift occurred in 1977, and shifts occurring in 1989 and 1999 have also been suggested (e.g., Hare and Mantua 2000). In the present assessment, an attempt was made to estimate the change in median recruitment of GOA Pacific cod associated with the 1977 regime shift. According to this year's model, pre-1977 median recruitment was only about 32% of post-1976 median recruitment. Establishing a link between environment and recruitment within a particular regime is more difficult. In the 2004 assessment (Thompson et al. 2004), for example, the correlations between age 1 recruits spawned since 1977 and monthly values of the Pacific Decadal Oscillation (Mantua et al. 1997) were computed and found to be very weak.

The prey and predators of Pacific cod have been described or reviewed by Albers and Anderson (1985), Livingston (1989, 1991), Lang et al. (2003), Westrheim (1996), and Yang (2004). The composition of Pacific cod prey varies to some extent by time and area. In terms of percent occurrence, some of the most important items in the diet of Pacific cod in the BSAI and GOA have been polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, some of the most important dietary items have been euphausids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, some of the most important dietary items have been walleye pollock, fishery offal, yellowfin sole, and crustaceans. Small Pacific cod feed mostly on invertebrates, while large Pacific cod are mainly piscivorous. Predators of Pacific cod include Pacific cod, halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffin. Major trends in the most important prey or predator species could be expected to affect the dynamics of Pacific cod to some extent.

Fishery Effects on the Ecosystem

Potentially, fisheries for Pacific cod can have effects on other species in the ecosystem through a variety of mechanisms, for example by relieving predation pressure on shared prey species (i.e., species which serve as prey for both Pacific cod and other species), by reducing prey availability for predators of Pacific cod, by altering habitat, by imposing bycatch mortality, or by "ghost fishing" caused by lost fishing gear.

Bycatch of Target and Nontarget Species

Bycatch (discards) of target and nontarget species are shown in Table 2.29.

It is not clear how much bycatch of a particular species constitutes "too much" in the context of ecosystem concerns. Only five species or species groups amounts to more than 1% of the average Pacific cod catch over the same period: arrowtooth flounder—2.0%, "skate (other)"—1.6%, "other species"—1.1%, sea stars—1.1%, and walleye pollock—1.0%. Only one of these species or species groups (arrowtooth flounder) accounts for an average of more than 1,000 t of discards on average over the 2005-2009 period (1,029 t).

Steller Sea Lions

Sinclair and Zeppelin (2002) showed that Pacific cod was one of the four most important prey items of Steller sea lions in terms of frequency of occurrence averaged over years, seasons, and sites, and was especially important in winter. Pitcher (1981) and Calkins (1998) also showed Pacific cod to be an important winter prey item in the GOA and BSAI, respectively. Furthermore, the size ranges of Pacific cod harvested by the fisheries and consumed by Steller sea lions overlap, and the fishery operates to some extent in the same geographic areas used by Steller sea lion as foraging grounds (Livingston (ed.), 2002).

The Fisheries Interaction Team of the Alaska Fisheries Science Center has been engaged in research to determine the effectiveness of recent management measures designed to mitigate the impacts of the Pacific cod fisheries (among others) on Steller sea lions. Results from studies conducted in 2002-2003 were summarized by Conners et al. (2004). These studies included a tagging feasibility study, which may evolve into an ongoing research effort capable of providing information on the extent and rate to which Pacific cod move in and out of various portions of Steller sea lion critical habitat. Nearly 6,000 cod with spaghetti tags were released, of which approximately 1,000 had been returned as of September, 2003.

Seabirds

The following is a summary of information provided by Livingston (ed., 2002): In both the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, which occurs primarily in the longline fisheries, including the hook and line fishery for Pacific cod (Tables 2.30b and 2.30b). Shearwater (*Puffinus* spp.) distribution overlaps with the Pacific cod longline fishery in the Bering Sea, and with trawl fisheries in general in both the Bering Sea and GOA. Black-footed albatross (*Phoebastria nigripes*) is taken in much greater numbers in the GOA longline fisheries than the Bering Sea longline fisheries, but is not taken in the trawl fisheries. The distribution of Laysan albatross (*Phoebastria immutabilis*) appears to overlap with the longline fisheries in the central and western Aleutians. The distribution of short-tailed albatross (*Phoebastria albatrus*) also overlaps with the Pacific cod longline fishery along the Aleutian chain, although the majority of the bycatch has taken place along the northern portion of the Bering Sea shelf edge (in contrast, only two takes have been recorded in the GOA). Some success has been obtained in devising measures to mitigate fishery-seabird interactions. For example, on vessels larger than 60 ft. LOA, paired streamer lines of specified performance and material standards have been found to reduce seabird incidental take significantly.

Fishery Usage of Habitat

The following is a summary of information provided by Livingston (ed., 2002): The longline and trawl fisheries for Pacific cod each comprise an important component of the combined fisheries associated with the respective gear type in each of the three major management regions (BS, AI, and GOA). Looking at each gear type in each region as a whole (i.e., aggregating across all target species) during the period 1998-2001, the total number of observed sets was as follows:

Gear	BS	AI	GOA
Trawl	240,347	43,585	68,436
Longline	65,286	13,462	7,139

In the BS, both longline and trawl effort was concentrated north of False Pass (Unimak Island) and along the shelf edge represented by the boundary of areas 513, 517 (in addition, longline effort was concentrated along the shelf edge represented by the boundary of areas 521-533). In the AI, both longline and trawl effort were dispersed over a wide area along the shelf edge. The catcher vessel longline fishery in the AI occurred primarily over mud bottoms. Longline catcher-processors in the AI tended to fish more over rocky bottoms. In the GOA, fishing effort was also dispersed over a wide area along the shelf, though pockets of trawl effort were located near Chirikof, Cape Barnabus, Cape Chiniak and Marmot Flats. The GOA longline fishery for Pacific cod generally took place over gravel, cobble, mud, sand, and rocky bottoms, in depths of 25 fathoms to 140 fathoms.

Impacts of the Pacific cod fisheries on essential fish habitat were further analyzed in an environmental impact statement by NMFS (2005).

Data Gaps and Research Priorities

Understanding of the above ecosystem considerations would be improved if future research were directed toward closing certain data gaps. Such research would have several foci, including the following: 1) determinants of trawl survey selectivity; 2) ecology of the Pacific cod stock, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment; 3) behavior of the Pacific cod fishery, including spatial dynamics; 4) ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and 5) ecology of species that interact with Pacific cod, including estimation of biomass, carrying capacity, and resilience.

ACKNOWLEDGMENTS

Chris Johnston and Delsa Anderl provided age data. Michael Martin provided survey data. Josh Keaton and Kally Spalinger provided fishery data. Angie Greig and Ren Narita provided fishery data and produced Figure 2.1. Olav Ormseth and Terry Hiatt provided incidental catch and bycatch data, and Teresa A'mar produced the incidental catch and bycatch tables. Rick Methot developed the SS software used to conduct this assessment, and answered numerous questions about SS. Anne Hollowed, Teresa A'mar, and the GOA Groundfish Plan Team provided reviews of this assessment. Many NMFS survey personnel and countless fishery observers collected most of the raw data that were used in this assessment.

REFERENCES

Albers, W. D., and P. J. Anderson. 1985. Diet of Pacific cod, *Gadus macrocephalus*, and predation on the northern pink shrimp, *Pandalus borealis*, in Pavlof Bay, Alaska. Fish. Bull., U.S. 83:601-610.

Bakkala, R. G., and V. G. Wespestad. 1985. Pacific cod. *In* R. G. Bakkala and L. L. Low (editors),

Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1984, p. 37-49. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-83.

Boldt, J. (editor). 2005. Ecosystem Considerations for 2006. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Calkins, D. G. 1998. Prey of Steller sea lions in the Bering Sea. Biosphere Conservation 1:33-44.

Dorn, M. W., S. Barbeaux, S. Gaichas, M. Guttormsen, B. Megrey, K. Spalinger, and M. Wilkins. 2004. Assessment of walleye pollock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. p. 35-129. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Dorn, M. W., A. B. Hollowed, E. Brown, B. Megrey, C. Wilson, and J. Blackburn. 2001. Assessment of the walleye Pollock stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Fournier, D. 1983. An analysis of the Hecate Strait Pacific cod fishery using an age-structured model incorporating density-dependent effects. Can. J. Fish. Aquat. Sci. 40:1233-1243.

Fournier, D. 2005. An introduction to AD Model Builder Version 6.0.2 for use in nonlinear modeling and statistics. Otter Research Ltd. P.O. Box 2040, Sidney BC V8L3S3.

Fournier, D., and C. P. Archibald. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. 38:1195-1207.

Fulton, T. W. 1911. The Sovereignty of the Sea; an Historical Account of the Claims of England to the Dominion of the British Seas, and of the Evolution of the Territorial Waters: With Special Reference to the Rights of Fishing and the Naval Salute. William Blackwood and Sons, Edinburgh and London. 799 p.

Grant, W. S., C. I. Zhang, and T. Kobayashi. 1987. Lack of genetic stock discretion in Pacific cod (*Gadus macrocephalus*). Can. J. Fish. Aquat. Sci. 44:490-498.

Greer-Walker, M. 1970. Growth and development of the skeletal muscle fibres of the cod (*Gadus morhua L.*). Journal du Conseil 33:228-244.

Gregory, R. S., C. Morris, and B. Newton. In review. Relative strength of the 2007 and 2008 year-classes, from nearshore surveys of demersal age 0 Atlantic cod in Newman Sound, Bonavista Bay. Can. Sci. Advis. Sec. Res. Doc. 2009/xxx.

Hare, S. R., and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography 47:103-146.

Hiatt, T., R. Felthoven, M. Dalton, B. Garber-Yonts, A. Haynie, K. Herrmann, D. Lew, J. Sepez, C. Seung, L. Sievanen, and the staff of Northern Economics. 2007. Stock Assessment and Fishery Evaluation Report for the Groundfish Fisheries of the Gulf of Alaska and Bering Sea/Aleutian

Islands Area: Economic Status of the Groundfish Fisheries off Alaska, 2006. Economic and Social Sciences Research Program, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, Washington 98115-6349. 353 p.

Jung, S., I. Choi, H. Jin, D.-w. Lee, H.-k. Cha, Y. Kim, and J.-y. Lee. 2009. Size-dependent mortality formulation for isochronal fish species based on their fecundity: an example of Pacific cod (*Gadus macrocephalus*) in the eastern coastal areas of Korea. Fisheries Research 97:77-85.

Ketchen, K.S. 1964. Preliminary results of studies on a growth and mortality of Pacific cod (*Gadus macrocephalus*) in Hecate Strait, British Columbia. J. Fish. Res. Bd. Canada 21:1051-1067.

Lang, G. M., C. W. Derrah, and P. A. Livingston. 2003. Groundfish food habits and predation on commercially important prey species in the Eastern Bering Sea from 1993 through 1996. Alaska Fisheries Science Center Processed Report 2003-04. Alaska Fisheries Science Center, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 351 p.

Livingston, P. A. 1989. Interannual trends in Pacific cod, Gadus macrocephalus, predation on three commercially important crab species in the eastern Bering Sea. Fish. Bull., U.S. 87:807-827.

Livingston, P. A. 1991. Pacific cod. *In* P. A. Livingston (editor), Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1984 to 1986, p. 31-88. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-207.

Livingston, P. A. (editor). 2003. Ecosystem Considerations for 2003. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Low, L. L. 1974. A study of four major groundfish fisheries of the Bering Sea. Ph.D. Thesis, Univ. Washington, Seattle, WA 240 p.

Mantua, N. J., Hare, S. R., Zhang, Y., Wallace, J. M., & Francis, R. C.. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society 78, 1069-1079.

McAllister, M. K., and J. N. Ianelli. 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. Can. J. Fish. Aquat. Sci. 54:284-300.

Methot, R. D. 1986. Synthetic estimates of historical abundance and mortality for northern anchovy, *Engraulis mordax*. NMFS, Southwest Fish. Cent., Admin. Rep. LJ 86-29, La Jolla, CA.

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

Methot, R. D. 1998. Application of stock synthesis to NRC test data sets. *In* V. R. Restrepo (editor), Analyses of simulated data sets in support of the NRC study on stock assessment methods, p. 59-80. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-30.

Methot, R. D. 2000. Technical description of the stock synthesis assessment program. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-43, 46 p.

Methot, R. D. 2005a. Technical description of the Stock Synthesis II Assessment Program. Unpubl. manuscr. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 54 p.

Methot, R. D. 2005b. User manual for the assessment program Strock Synthesis 2 (SS2), Model Version 1.19. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 47 p.

Methot, R. D. 2007. User manual for the integrated analysis program Stock Synthesis 2 (SS2), Model Version 2.00c. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 47 p.

Methot, R. D. 2009. User Manual for Stock Synthesis, Model Version 3.03a. Unpublished manuscript, available from NOAA Fisheries Stock Assessment Toolbox website: http://nft.nefsc.noaa.gov/. 143 p.

National Marine Fisheries Service (NMFS). 2004. Alaska Groundfish Fisheries Final Programmatic Supplemental Environmental Impact Statement. National Marine Fisheries Service, Alaska Region. PO Box 21668, Juneau, AK 99802-1668.

National Marine Fisheries Service (NMFS). 2005. Final environmental impact statement for essential fish habitat identification and conservation in Alaska. National Marine Fisheries Service, Alaska Region. P.O. Box 21668, Juneau, AK 99802-1668.

Nichol, D. G., T. Honkalehto, and G. G. Thompson. 2007. Proximity of Pacific cod to the sea floor: Using archival tags to estimate fish availability to research bottom trawls. *Fisheries Research* 86:129-135.

Ona, E., and O. R. Godø. 1990. Fish reaction to trawling noise: the significance for trawl sampling. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer 189: 159–166.

Pitcher, K. W. 1981. Prey of Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. Fishery Bulletin 79:467-472.

Ricker, W. E. 1954. Stock and recruitment. J. Fish. Res. Board Can. 11:559-63.

Ricker. W. E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Bulletin 191. Department of the Environment, Canada. 382 p.

Roberson, N. E. 2001. Age determination of Pacific cod (*Gadus macrocephalus*). MS thesis, University of Washington, Seattle, WA. 44 p.

Roberson, N. E., D. K. Kimura, D. R. Gunderson, and A. M. Shimada. 2005. Indirect validation of the age-reading method for Pacific cod (Gadus macrocephalus) using otoliths from marked and recaptured fish. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 103:153-160.

Savin, A. B. 2008. Seasonal distribution and Migrations of Pacific cod *Gadus macrocephalus* (Gadidae) in Anadyr Bay and adjacent waters. Journal of Ichythyology 48:610-621.

Shimada, A. M., and D. K. Kimura. 1994. Seasonal movements of Pacific cod (*Gadus macrocephalus*) in the eastern Bering Sea and adjacent waters based on tag-recapture data. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 92:800-816.

Sinclair, E.S. and T. K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). Journal of Mammalogy 83(4).

Somerton, D. A. 2004. Do Pacific cod (*Gadus macrocephalus*) and walleye pollock *(Theregra chalcogramma*) lack a herding response to the doors, bridles, and mudclouds of survey trawls? ICES Journal of Marine Science 61:1186-1189.

Stark, J. W. 2005. Length and age at maturity, seasonal maturation and growth of Pacific cod (*Gadus macrocephalus*) in the Gulf of Alaska and southeastern Bering Sea. Unpubl. manuscr. Alaska Fisheries Science Center, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 23 p.

Thompson, G. G., and M. E. Conners. 2007. Report of the Pacific cod technical workshop held at the Alaska Fisheries Science Center, April 24-25, 2007. Unpubl. manuscr., Alaska Fisheries Science

Center, Resource Ecology and Fisheries Management Division, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 56 p.

Thompson, G. G., and M. W. Dorn. 1997. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 121-158. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 1998. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 113-181. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 1999. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 151-230. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 2003. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 127-222. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 2005. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 155-244. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., M. Dorn, and D. Nichol. 2006. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 147-220. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, D. Nichol, S. Gaichas, and K. Aydin. 2007a. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 209-327. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, and M. Wilkins. 2007b. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 169-194. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and R. D. Methot. 1993. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region as projected for 1994, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and A. M. Shimada. 1990. Pacific cod. *In* L. L. Low and R. E. Narita (editors), Condition of groundfish resources of the eastern Bering Sea-Aleutian Islands region as assessed in 1988, p. 44-66. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-178.

Thompson, G. G, and H. H. Zenger. 1993. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1994, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G, and H. H. Zenger. 1994. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1995, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and H. H. Zenger. 1995. Pacific cod. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1996, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. W. Dorn. 1997. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 121-163. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. W. Dorn. 1998. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 91-155. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. W. Dorn. 1999. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 105-184. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. K. Dorn. 2000. Pacific cod. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska p. 91-110. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. K. Dorn. 2002. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska p. 89-167. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. K. Dorn. 2003. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska p. 149-241. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. K. Dorn. 2004. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska p. 131-232. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Ueda, Y., Y. Narimatsu, T. Hattori, M. Ito, D. Kitagawa, N. Tomikawa, and T. Matsuishi. 2006. Fishing efficiency estimated based on the abundance from virtual population analysis and bottom-trawl surveys of Pacific cod (Gadus macrocephalus) in the waters off the Pacific coast of northern Honshu, Japan. Nippon Suisan Gakkaishi 72:201-209.

Wespestad, V., R. Bakkala, and J. June. 1982. Current abundance of Pacific cod (*Gadus macrocephalus*) in the eastern Bering Sea and expected abundance in 1982-1986. NOAA Tech. Memo. NMFS F/NWC-25, 26 p.

Westrheim, S. J. 1996. On the Pacific cod (*Gadus macrocephalus*) in British Columbia waters, and a comparison with Pacific cod elsewhere, and Atlantic cod (*G. morhua*). Can. Tech. Rep. Fish. Aquat. Sci. 2092. 390 p.

Yang, M-S. 2004. Diet changes of Pacific cod (Gadus macrocephalus) in Pavlof Bay associated with climate changes in the Gulf of Alaska between 1980 and 1995. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 102:400-405.

Tables

Table 2.0—List of models, showing how requests made by the Plan Team(s), SSC, and public have been incorporated. Models whose names end in “2” include the same features as the corresponding model whose name ends in “1,” except for omission of age composition data.

Model	Description	Proposals included	Proposer(s)
A1	Base model	Use Model B1 from 2008 assessment as base model	SSC
		Do not use exponential-logistic selectivity	SSC
		Include age data, but give it low emphasis	Teresa A'mar
A2	Base model without age data	Include a "no agecomps" counterpart to every model	Mark Maunder
A3	Base model without Jan-May longline fishery age data from 2008	n/a	n/a
A4	Base model with increased ageing error at ages 2-4	Increase ageing error at ages 2-4	Teresa A'mar
B1	Preferred model	Include bias in ageing error matrix	Joint Plan Teams
		Turn off variable survey selectivity in recent years	SSC
		Include cohort-specific growth	Joint Plan Teams, Mark Maunder
		Do not use exponential-logistic selectivity	SSC
B2	Preferred model without age data	Include a "no agecomps" counterpart to every model	Mark Maunder
D1	Preferred model with "-999" selectivity option	Use "-999" selectivity option	Mark Maunder
D2	Preferred model with "-999" selectivity option and without age data	Include a "no agecomps" counterpart to every model	Mark Maunder
E1	Preferred model with selectivity fixed at max. size/age	Fix selectivity at maximum size/age	SSC
E2	Preferred model with selectivity fixed at max. size/age and without age data	Include a "no agecomps" counterpart to every model	Mark Maunder

Table 2.1a—Summary of catches (t) of Pacific cod by fleet sector and gear type, 1964-1990. All catches since 1980 include discards. Jt. Vent. = joint venture.

	Fleet Sector			Gear Type				
Year	Foreign	Jt. Vent.	Domestic	Trawl	Longline	Pot	Other	Total
1964	196	0	0	56	140	0	0	196
1965	599	0	0	172	427	0	0	599
1966	1,376	0	0	396	980	0	0	1,376
1967	2,225	0	0	640	1,585	0	0	2,225
1968	1,046	0	0	301	745	0	0	1,046
1969	1,335	0	0	384	951	0	0	1,335
1970	1,805	0	0	519	1,286	0	0	1,805
1971	523	0	0	150	373	0	0	523
1972	3,513	0	0	1,010	2,503	0	0	3,513
1973	5,963	0	0	1,715	4,248	0	0	5,963
1974	5,182	0	0	1,491	3,691	0	0	5,182
1975	6,745	0	0	1,940	4,805	0	0	6,745
1976	6,764	0	0	1,946	4,818	0	0	6,764
1977	2,267	0	0	652	1,615	0	0	2,267
1978	11,370	7	813	4,547	6,800	0	843	12,190
1979	13,173	711	1,020	3,629	9,545	0	1,730	14,904
1980	34,245	466	634	6,464	27,780	0	1,101	35,345
1981	34,969	58	1,104	10,484	25,472	0	175	36,131
1982	26,937	193	2,335	6,679	22,667	0	119	29,465
1983	29,777	2,426	4,337	9,512	26,756	0	272	36,540
1984	15,896	4,649	3,353	8,805	14,844	0	249	23,898
1985	9,086	2,266	3,076	4,876	9,411	2	139	14,428
1986	15,211	1,357	8,444	6,850	17,619	141	402	25,012
1987	0	1,978	30,961	22,486	8,261	642	1,550	32,939
1988	0	1,661	32,141	27,145	3,933	1,422	1,302	33,802
1989	0	0	43,293	37,637	3,662	376	1,618	43,293
1990	0	0	72,517	59,188	5,919	5,661	1,749	72,517

Table 2.1b—Summary of catches (t) of Pacific cod since 1991 by management jurisdiction and gear type. Longl. = longline, Subt. = subtotal. All entries include discards. Catches for 2009 are complete through early October.

	Federal					State				
Year	Trawl	Longl.	Pot	Other	Subt.	Longl.	Pot	Other	Subt.	Total
1991	58,093	7,656	10,464	115	76,328	0	0	0	0	76,328
1992	54,593	15,675	10,154	325	80,747	0	0	0	0	80,747
1993	37,806	8,963	9,708	11	56,488	0	0	0	0	56,488
1994	31,447	6,778	9,161	100	47,485	0	0	0	0	47,485
1995	41,875	10,978	16,055	77	68,985	0	0	0	0	68,985
1996	45,991	10,196	12,040	53	68,280	0	0	0	0	68,280
1997	48,406	10,978	9,065	26	68,476	0	7,224	1,319	8,542	77,018
1998	41,570	10,012	10,510	29	62,121	0	9,088	1,316	10,404	72,525
1999	37,167	12,363	19,015	70	68,614	0	12,075	1,096	13,171	81,785
2000	25,458	11,667	17,351	54	54,529	0	10,388	1,643	12,031	66,560
2001	24,383	9,914	7,171	155	41,622	0	7,836	2,084	9,920	51,542
2002	19,810	14,666	7,694	176	42,346	0	10,423	1,714	12,137	54,483
2003	18,885	9,470	12,675	161	41,191	115	8,031	3,242	11,388	52,579
2004	17,593	10,327	14,889	345	43,154	53	10,678	2,820	13,551	56,705
2005	14,549	5,731	14,752	203	35,236	27	9,650	2,673	12,350	47,585
2006	13,131	10,229	14,495	118	37,973	52	9,183	645	9,881	47,854
2007	14,795	11,501	13,523	39	39,857	186	10,886	573	11,645	51,501
2008	20,287	12,052	11,308	62	43,709	259	13,438	1,568	15,265	58,974
2009	11,951	11,588	10,119	121	33,779	344	10,082	2,441	12,867	46,646

Table 2.2—History of Pacific cod ABC, TAC, total catch, and type of stock assessment model used to recommend ABC. ABC was not used in management of GOA groundfish prior to 1986. Catch for 2009 is current through early October. The values in the column labeled "TAC" correspond to "optimum yield" for the years 1980-1986, "target quota" for the year 1987, and true TAC for the years 1988-2009. "SS1" refers to Stock Synthesis 1, and "SS2" refers to Stock Synthesis 2; after 2007, the program is referred to simply as "SS." Each cell in the "Stock Assessment Model" column lists the type of model used to recommend the ABC in the corresponding row, meaning that the model was produced in the year previous to the one listed in the corresponding row.

Year	ABC	TAC	Catch	Stock Assessment Model (from previous year)
1980	n/a	60,000	35,345	n/a
1981	n/a	70,000	36,131	n/a
1982	n/a	60,000	29,465	n/a
1983	n/a	60,000	36,540	n/a
1984	n/a	60,000	23,898	n/a
1985	n/a	60,000	14,428	n/a
1986	136,000	75,000	25,012	survey biomass
1987	125,000	50,000	32,939	survey biomass
1988	99,000	80,000	33,802	survey biomass
1989	71,200	71,200	43,293	stock reduction analysis
1990	90,000	90,000	72,517	stock reduction analysis
1991	77,900	77,900	76,328	stock reduction analysis
1992	63,500	63,500	80,747	stock reduction analysis
1993	56,700	56,700	56,488	stock reduction analysis
1994	50,400	50,400	47,485	stock reduction analysis
1995	69,200	69,200	68,985	SS1 model (length-based data)
1996	65,000	65,000	68,280	SS1 model (length-based data)
1997	81,500	69,115	77,018	SS1 model (length-based data)
1998	77,900	66,060	72,525	SS1 model (length-based data)
1999	84,400	67,835	81,785	SS1 model (length-based data)
2000	76,400	58,715	66,560	SS1 model (length-based data)
2001	67,800	52,110	51,542	SS1 model (length-based data)
2002	57,600	44,230	54,483	SS1 model (length-based data)
2003	52,800	40,540	52,579	SS1 model (length-based data)
2004	62,810	48,033	56,705	SS1 model (length-based data)
2005	58,100	44,433	47,585	SS1 model (length-based data)
2006	68,859	52,264	47,854	SS2 model (length- and age-based data)
2007	68,859	52,264	51,501	SS2 model (length- and age-based data)
2008	66,493	50,269	58,974	survey biomass
2009	55,300	41,807	46,646	SS model (length- and age-based data)

Table 2.3—History of GOA Pacific cod allocations by regulatory area.

	Regulatory Area		
Year(s)	Western	Central	Eastern
1977-1985	28	56	16
1986	40	44	16
1987	27	56	17
1988-1989	19	73	8
1990	33	66	1
1991	33	62	5
1992	37	61	2
1993-1994	33	62	5
1995-1996	29	66	5
1997-1999	35	63	2
2000-2001	36	57	7
2002 (ABC)	39	55	6
2002 (TAC)	38	56	6
2003 (ABC)	39	55	6
2003 (TAC)	38	56	6
2004 (ABC)	36	57	7
2004 (TAC)	35.3	56.5	8.2
2005 (ABC)	36	57	7
2005 (TAC)	35.3	56.5	8.2
2006 (ABC)	39	55	6
2006 (TAC)	38.54	54.35	7.11
2007 (ABC)	39	55	6
2007 (TAC)	38.54	54.35	7.11
2008 (ABC)	39	57	4
2008 (TAC)	38.69	56.55	4.76
2009 (ABC)	39	57	4
2009 (TAC)	38.69	56.55	4.76

Table 2.4a—Pacific cod discard rates by area, target species/group, and year for the period 1991-2002 (see Table 2.4b for the period 2003-2004 and Table 2.4c for the period 2005-2009). The discard rate is the ratio of discarded Pacific cod catch to total Pacific cod catch for a given area/target/year combination. An empty cell indicates that no Pacific cod were caught in that area/target/year combination. Note that the absolute amount of discards may be small even if the discard rate is large.

Target species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Arrowtooth flounder		0.98	0.59	0.00	0.10	0.09	0.00	1.00	0.63	0.06		0.00
Atka mackerel				0.81	1.00	0.00						
Deepwater Flat	1.00			0.43	0.00	0.68	0.53	0.00	0.36	0.00	0.75	
Flathead sole				1.00		0.07	0.99	0.00		0.29	0.75	0.00
Other species	1.00	0.15	0.63		0.10	0.91	0.00	0.00	0.96	0.01	0.00	0.00
Pacific cod	0.05	0.03	0.03	0.02	0.03	0.02	0.02	0.01	0.01	0.00	0.02	0.02
Pollock	0.82	0.59	0.15	0.15	0.95	0.17	0.98	0.75	0.89	0.44	0.00	1.00
Rex sole					0.16	0.25	0.61	0.57				1.00
Rockfish	0.15	0.11	0.13	0.16	0.11	0.13	0.14	0.17	0.17	0.17	0.00	0.04
Sablefish	0.84	0.72	0.72	0.77	0.55	0.78	0.54	0.66	0.52	0.25	0.27	0.22
Shallow-water flatfish	0.43	0.00	0.00	0.87	0.00	0.97	0.00	1.00	0.74	0.28		1.00
Unknown	0.01					1.00	1.00	1.00		1.00		
All targets	0.03	0.03	0.04	0.02	0.03	0.02	0.03	0.01	0.02	0.00	0.02	0.02

Table 2.4b—Pacific cod discard rates by area, target species/group, and year for the period 2003-2004 (see Table 2.4a for the period 1991-2002 and Table 2.4c for the period 2005-2009). The discard rate is the ratio of discarded Pacific cod catch to total Pacific cod catch for a given area/target/year combination. An empty cell indicates that no Pacific cod were caught in that area/target/year combination. Note that the absolute amount of discards may be small even if the discard rate is large.

Target species/group	2003	2004
Arrowtooth flounder	0.40	0.27
Atka mackerel		
Deepwater flatfish	0.01	0.25
Flathead sole	0.25	0.33
IFQ halibut	0.61	0.59
Other species	0.16	0.07
Pacific cod	0.01	0.01
Pollock	0.05	0.26
Rex sole	0.22	0.15
Rockfish	0.14	0.04
Sablefish	0.64	0.23
Shallowwater flatfish	0.61	0.53
Unknown		
All targets	0.05	0.02

Table 2.4c—Pacific cod discard rates by area, target species/group, and year for the period 2005-2009 (see Table 2.4a for the period 1991-2002 and Table 2.4b for the period 2003-2004). The discard rate is the ratio of discarded Pacific cod catch to total Pacific cod catch for a given area/target/year combination. An empty cell indicates that no Pacific cod were caught in that area/target/year combination. Note that the absolute amount of discards may be small even if the discard rate is large.

Target fishery	2005	2006	2007	2008	2009
Arrowtooth Flounder	0.29	0.18	0.07	0.48	0.05
Atka Mackerel			0.00		
Deep Water Flatfish	0.00	0.00			
Flathead Sole	0.12	0.09	0.10	0.16	0.06
Halibut	0.28	0.25	0.24	0.16	0.47
Other Species	0.06	0.05		0.00	0.00
Pacific Cod	0.00	0.03	0.01	0.01	0.01
Pollock - bottom	0.00	0.01	0.04	0.04	0.09
Pollock - midwater	0.00	0.01	0.00	0.00	0.00
Rex Sole	0.12	0.05	0.12	0.04	0.14
Rockfish	0.04	0.14	0.02	0.08	0.04
Sablefish	0.53	0.28	0.20	0.17	0.23
Shallow Water Flatfish	0.39	0.30	0.38	0.60	0.64
Unknown			1.00		
Total	0.02	0.04	0.03	0.06	0.06

Table 2.5—Catch of Pacific cod by year, gear, and season as used in the stock assessment model. Because direct estimates of gear- and period-specific catches are not available for the years 1977-1980, the figures shown here are estimates derived by distributing each year's total catch according to the average proportion observed for each gear/period combination during the years 1981-1988. The small amounts of catch from "other" gear types have been merged into the gear types listed below proportionally. Sea. 1 = Jan-May, Sea. 2 = Jun-Aug, Sea. 3 = Sep-Dec. Sea. 3 catches for 2009 are extrapolated.

	Trawl fishery			Longline fishery			Pot fishery		
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3
1977	183	158	311	943	190	482	0	0	0
1978	916	790	1558	4720	950	2413	0	0	0
1979	1063	917	1809	5480	1103	2801	0	0	0
1980	2764	2384	4702	14245	2868	7282	0	0	0
1981	387	3532	6565	10504	5312	9656	0	0	0
1982	1143	2041	3495	9912	2890	9865	0	0	0
1983	2861	2844	3807	10960	4651	11145	0	0	0
1984	3429	2008	3368	11840	425	2579	0	0	0
1985	2427	571	1878	9127	6	280	0	0	0
1986	2999	431	3420	15927	460	1373	0	0	0
1987	5377	7928	9181	5343	983	1935	219	141	282
1988	16021	6569	4555	2979	507	447	1081	23	318
1989	24614	12857	166	2378	356	928	241	103	32
1990	43279	7514	8395	5557	109	253	2577	1008	2076
1991	56005	636	1528	7264	327	72	9596	0	899
1992	52088	1220	1501	12736	770	2242	9705	15	470
1993	33638	2625	1550	8476	307	181	9691	18	0
1994	29164	1422	926	6681	48	55	8746	0	444
1995	38519	807	2597	10603	161	227	15436	44	592
1996	41484	3048	1494	9947	152	105	12024	27	0
1997	40738	1640	6044	10407	196	379	14521	1245	1848
1998	34706	3680	3200	9553	199	264	19477	311	1135
1999	30147	1501	5554	11946	268	158	25981	3662	2568
2000	22152	2574	750	11456	114	107	28230	477	699
2001	15240	2035	7221	9682	96	142	14558	603	1964
2002	15830	2705	1301	11478	92	3157	15086	250	4584
2003	12037	2616	5271	9172	411	765	19251	0	3057
2004	9853	2122	6398	8884	119	2045	22889	0	4394
2005	10387	1849	3159	4102	115	1875	20959	0	5139
2006	10346	1715	1332	6285	165	3955	21682	0	2375
2007	10203	1696	3159	7268	264	4266	20631	17	3997
2008	11752	3358	6106	9551	423	2619	20565	0	4599
2009	8751	2300	3533	10183	605	3613	19328	0	3657

Table 2.6a—Length frequencies for the January-May trawl fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1984	0	0	0	0	0	0	2	6	5	12	110	291	852	740	567	554	558	439	249	138	60	19	6	0	0
1985	0	0	0	0	1	1	0	2	1	47	149	174	261	87	203	268	257	202	200	108	56	23	1	0	0
1986	0	0	0	0	0	0	0	10	23	17	4	3	14	64	56	55	59	55	42	27	16	4	3	0	0
1988	0	0	0	0	0	0	2	6	11	15	33	76	332	764	615	435	381	355	276	177	116	44	27	22	13
1989	0	0	0	0	0	0	0	0	0	0	0	0	5	52	175	248	141	30	5	3	1	0	0	0	0
1990	2	0	1	1	12	7	15	76	119	163	214	231	607	1346	3197	4899	4678	3355	2563	1572	1312	754	256	66	25
1991	0	1	2	2	2	7	63	142	163	226	235	346	1905	3794	4421	5618	6609	5126	3629	2613	1621	1016	618	273	82
1992	0	0	0	1	4	13	21	78	261	567	921	1084	1796	3160	4966	6796	5825	4257	3355	2548	1734	1143	749	280	124
1993	0	0	1	4	2	5	4	58	234	469	547	544	2077	3445	3613	4744	4817	2832	1430	846	491	345	214	87	35
1994	0	0	0	0	0	0	0	7	31	83	115	138	499	1022	1734	2551	2642	1659	944	490	347	167	82	44	24
1995	0	0	0	0	0	0	1	8	60	91	204	316	1000	2363	3475	4628	5820	4040	1903	993	533	300	164	74	66
1996	0	0	0	1	6	28	39	64	105	187	250	230	290	690	1575	2924	3744	2948	1949	1237	793	437	217	96	48
1997	0	0	3	8	12	12	5	44	123	300	357	276	807	2271	2841	2945	4449	3874	2247	1140	562	288	174	67	17
1998	0	0	0	1	5	7	9	57	293	746	989	832	2009	4345	5676	9100	10443	8205	4970	2379	1278	652	327	98	27
1999	0	0	1	4	4	4	4	21	73	144	184	215	453	1052	1797	2194	2226	1644	851	397	173	61	30	14	4
2000	0	0	0	0	0	0	2	10	29	74	84	99	250	787	1091	1429	1310	806	475	243	163	72	20	6	1
2001	0	1	2	2	1	1	4	7	37	97	158	146	287	694	947	1166	1183	803	336	147	63	22	8	1	2
2002	0	0	0	0	1	3	5	7	36	118	232	298	497	441	756	975	1123	936	508	218	80	36	8	5	2
2003	0	0	0	0	0	1	4	13	34	99	150	130	214	609	963	645	433	358	221	133	85	20	10	6	1
2004	0	0	1	0	2	1	0	6	24	52	65	74	179	433	525	518	413	167	86	35	11	4	2	0	0
2005	0	0	0	0	0	0	0	2	5	7	26	24	58	98	177	318	437	300	143	75	51	21	8	8	2
2006	0	0	0	0	0	1	0	1	3	14	42	27	64	180	228	397	424	342	206	124	63	35	25	11	3
2007	1	0	2	15	37	29	7	4	12	46	165	236	274	378	571	471	435	381	187	99	57	47	19	14	1
2008	0	0	0	1	0	0	1	13	54	125	181	171	183	296	370	376	332	174	75	45	13	4	3	1	0
2009	0	0	0	0	0	1	1	1	15	31	35	48	209	491	385	197	191	137	35	9	4	1	0	0	0

Table 2.6b—Length frequencies for the June-August trawl fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1980	0	0	0	0	0	0	0	0	0	0	1	6	49	139	86	65	91	133	91	48	16	2	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	12	9	52	146	110	96	56	33	20	4	6	2	2	1	0
1983	0	0	0	0	0	0	1	1	0	3	6	34	155	201	180	208	184	151	121	64	37	11	5	3	0
1984	0	0	0	0	0	0	5	18	29	50	121	305	1148	1706	1157	828	804	527	376	233	113	35	9	2	0
1985	0	0	0	0	0	0	0	1	2	23	61	134	292	399	975	1160	691	312	195	146	95	54	9	0	0
1988	0	0	0	0	0	0	0	1	2	17	56	70	229	571	640	378	113	51	8	6	3	0	1	0	0
1990	62	36	15	0	0	1	0	1	3	31	81	169	419	954	1898	2583	2568	1325	510	181	88	24	3	4	0
1998	0	0	1	3	0	0	1	1	0	2	13	49	196	310	656	854	720	419	148	60	26	1	4	0	1
2000	0	0	0	0	0	0	0	3	1	0	9	21	31	30	56	88	100	48	20	14	4	0	0	0	0
2001	0	0	0	0	0	5	5	5	0	2	6	18	48	45	68	144	147	99	31	20	16	6	0	0	0
2002	0	0	0	0	0	0	0	1	3	1	5	24	145	195	101	114	117	55	24	19	3	1	0	0	0
2003	0	0	0	2	1	2	10	8	7	19	27	59	193	170	162	220	136	101	37	26	5	1	1	0	0
2004	0	0	0	0	0	0	0	2	0	0	1	6	9	24	83	124	106	62	30	16	5	2	1	0	0
2005	0	0	0	0	2	2	2	2	4	8	21	22	8	10	52	144	150	91	40	13	8	2	0	0	0
2007	0	0	0	1	0	17	21	12	6	3	7	23	94	121	61	96	105	77	47	14	3	1	0	0	0
2008	0	0	0	0	0	0	0	0	13	54	125	160	191	66	50	134	180	90	45	13	10	4	0	0	0

Table 2.6c—Length frequencies for the September-December trawl fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1977	0	0	0	0	0	0	0	0	2	15	56	82	95	66	37	32	10	14	6	4	0	0	0	0	0
1978	0	0	0	0	0	1	1	5	13	14	11	28	88	130	163	121	112	66	41	25	5	1	1	0	0
1982	0	0	0	0	0	0	0	0	1	3	14	30	66	109	170	198	118	78	32	10	9	3	0	0	0
1983	0	0	0	0	0	0	0	1	1	8	18	78	184	197	241	234	195	162	131	79	39	12	2	0	0
1984	0	1	1	0	8	2	1	29	50	64	106	264	581	665	590	318	172	127	57	38	17	11	5	3	1
1985	0	0	0	0	0	0	8	42	111	137	107	132	484	506	672	746	352	115	68	42	36	12	4	3	0
1987	0	0	0	0	0	0	0	1	1	4	9	22	67	138	189	112	37	15	1	1	1	0	0	0	0
1990	0	0	0	1	2	0	7	13	39	62	180	427	1447	1239	1240	1740	1717	1253	1082	842	429	131	66	18	19
1992	0	0	0	0	0	1	8	21	18	7	64	214	479	502	415	211	145	77	63	28	2	0	0	0	0
1995	0	0	0	0	0	1	14	14	16	14	12	7	51	140	222	583	642	470	153	50	9	3	1	0	0
1997	0	0	0	1	3	8	29	49	100	62	56	96	318	374	477	823	589	342	262	100	46	10	1	0	0
1998	3	4	0	0	5	35	112	133	209	209	146	225	1027	1139	906	1048	747	438	214	112	45	4	1	1	0
1999	0	0	0	0	0	1	0	2	3	6	2	9	14	31	59	271	281	213	124	54	19	10	2	0	0
2001	0	0	0	0	1	0	10	45	100	154	123	80	303	633	669	783	677	496	301	122	46	14	3	0	0
2003	0	0	0	0	0	1	9	5	9	11	12	43	193	303	291	405	249	139	53	25	8	4	1	0	0
2004	0	0	0	0	0	0	4	9	7	1	4	30	156	284	383	465	532	405	166	70	20	9	0	0	0
2005	0	0	0	0	0	0	3	2	5	4	15	34	34	21	57	275	485	420	229	113	44	14	4	0	0
2007	0	0	0	0	2	3	17	27	30	31	21	21	86	201	213	172	146	54	30	13	4	0	0	0	0
2008	0	1	0	1	5	12	17	34	43	56	64	168	580	567	254	289	335	234	91	37	17	5	2	2	0

Table 2.7a—Length frequencies for the January-May longline fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1979	0	0	0	0	0	0	0	6	33	93	146	94	191	427	669	973	1025	764	433	245	110	31	6	0	0
1980	0	0	0	0	0	0	0	1	2	37	237	996	2510	1328	971	927	1325	1425	1145	493	195	72	17	2	1
1981	0	0	0	0	0	0	0	0	2	17	53	122	929	2398	1887	840	575	389	318	239	117	44	14	6	0
1982	0	0	0	0	0	0	0	5	37	103	221	237	1243	2105	2639	2468	1777	1001	462	173	89	44	14	3	0
1983	0	0	0	0	0	0	0	2	18	105	230	908	4274	4322	6004	7674	8689	7453	4419	1919	760	237	99	31	1
1984	0	0	0	0	1	7	1	4	21	72	221	858	4324	6783	7637	7503	9547	9996	7612	4602	2351	883	213	45	6
1985	0	0	0	0	0	0	0	3	28	96	438	1118	3608	4677	5341	4955	6271	7723	6625	4556	2659	1364	464	94	13
1986	0	0	0	0	0	0	0	10	138	397	509	724	3093	7348	12279	12702	11312	13262	12110	7969	4127	2268	1033	349	82
1990	0	0	0	0	0	0	2	1	6	26	77	53	180	407	728	1215	1920	1587	1120	823	542	183	70	30	3
1991	0	0	0	0	0	0	0	1	3	8	56	155	670	1351	1839	2473	2486	1740	909	411	229	119	49	23	29
1992	0	0	0	0	0	2	3	8	20	57	137	333	1078	2326	4103	5900	4910	3817	2585	1598	906	580	306	103	45
1993	0	0	0	1	3	6	9	5	8	18	43	67	357	924	1503	2077	1959	1226	1036	947	856	413	163	75	52
1994	0	0	0	0	0	0	0	0	0	1	4	20	166	500	630	1000	1065	788	450	213	167	93	61	26	17
1995	0	0	0	0	1	0	3	2	3	24	96	173	692	1662	2521	4264	5252	4025	2628	1606	874	421	212	117	59
1996	0	0	0	0	0	0	1	4	21	42	54	79	260	516	1268	2763	3858	3178	1627	583	265	109	48	26	4
1997	0	0	0	0	0	0	0	0	3	3	10	12	159	559	925	1267	1575	1431	791	317	118	46	16	6	1
1998	0	0	0	0	0	0	0	0	2	9	18	53	277	748	1015	1458	1548	1197	833	473	243	78	27	2	0
1999	0	0	0	0	0	0	0	0	3	6	20	60	254	707	1385	1802	1679	1243	881	474	268	132	62	22	15
2000	0	0	0	0	0	0	0	1	2	3	2	25	197	797	1697	2548	2714	1747	946	422	179	97	36	10	3
2001	0	0	0	0	0	0	1	1	3	6	33	82	296	915	1969	2850	3074	1919	906	358	126	60	34	6	3
2002	0	0	0	0	1	0	0	5	3	13	32	77	246	542	1250	1849	2208	1712	939	447	161	69	21	7	1
2003	0	0	0	0	0	0	0	0	5	7	30	92	385	800	1337	1415	1523	1097	626	382	149	58	26	9	0
2004	0	0	0	0	0	0	0	0	0	1	4	16	149	654	1188	1563	1367	803	434	257	129	55	19	7	1
2005	0	0	0	0	0	0	0	0	0	1	2	7	75	386	917	1466	1428	796	410	235	152	75	26	2	0
2006	0	0	0	0	0	1	0	0	2	6	17	27	156	569	960	1685	1864	1177	529	248	185	104	69	35	11
2007	0	0	0	0	0	0	0	1	0	6	18	37	112	511	1093	1508	1357	1029	504	203	102	82	66	15	6
2008	0	0	0	0	0	0	1	3	2	25	43	75	198	797	1586	1838	2139	1551	847	436	166	82	44	37	17
2009	0	0	0	0	0	0	1	1	5	23	58	128	496	1173	1668	2363	2284	1352	607	281	126	50	43	14	13

Table 2.7b—Length frequencies for the June-August longline fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1978	0	0	0	0	0	0	0	0	1	15	36	102	530	791	1007	1187	681	350	260	122	35	5	0	0	0
1979	1	0	0	0	0	0	1	0	2	9	19	21	59	100	188	248	307	254	131	51	20	5	1	0	0
1980	0	0	0	0	0	0	0	0	0	7	15	148	784	878	448	289	249	316	273	173	57	21	2	0	0
1981	0	0	0	0	0	0	0	0	0	2	12	51	274	1032	1949	1162	343	134	81	51	45	21	5	1	0
1982	0	0	0	0	0	0	0	0	1	0	9	28	131	443	565	547	408	210	88	35	22	10	4	1	0
1983	0	0	0	0	0	0	0	0	1	25	88	153	1258	2344	2531	2217	1376	888	520	230	97	29	22	4	0
1984	0	0	0	0	0	0	0	0	0	4	8	13	197	691	1003	804	430	291	245	184	96	57	28	3	2
1992	0	0	0	0	0	0	0	0	1	2	6	8	13	76	84	119	145	71	28	11	11	2	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	7	28	34	80	116	79	48	8	6	3	0	1	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	2	14	57	99	92	54	40	33	17	18	12	7	0
2007	0	0	0	0	0	0	0	0	0	0	0	0	8	11	55	142	173	131	84	32	22	16	3	3	1
2008	0	0	0	0	0	0	0	0	0	0	0	0	1	14	94	168	231	249	173	63	36	16	14	11	3

Table 2.7c—Length frequencies for the September-December longline fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1978	0	0	0	0	0	0	0	0	6	22	55	174	626	1435	2050	2847	2670	1773	986	557	188	43	6	1	0
1979	0	0	0	0	0	0	0	0	0	11	120	360	875	802	887	928	1202	1241	837	355	141	39	5	0	0
1980	0	0	0	0	0	0	0	0	0	0	4	46	494	1001	580	345	299	279	233	133	28	6	0	0	0
1981	0	0	0	0	0	0	0	0	7	10	18	90	344	1213	1955	1233	563	320	171	89	37	36	9	1	0
1982	0	0	0	0	0	0	0	0	2	3	50	233	571	1444	1897	1571	930	518	265	143	70	26	8	2	0
1983	0	0	0	0	0	0	0	1	5	33	411	1597	5995	14381	16151	12362	7588	4808	2914	1727	784	324	113	29	7
1984	0	0	0	0	0	1	1	5	33	111	277	644	2940	7080	8092	5473	2209	983	545	426	304	154	68	10	2
1992	0	0	0	0	0	0	0	1	2	0	11	7	68	185	466	986	1130	541	142	43	15	1	2	2	1
2002	0	0	0	0	1	2	9	24	16	16	18	38	103	279	424	618	622	440	263	95	31	8	0	2	0
2003	0	0	0	0	0	0	0	0	0	0	3	16	47	224	378	500	468	276	182	102	59	29	12	4	1
2004	0	0	0	0	0	0	0	0	0	0	4	4	31	203	505	694	633	407	230	96	62	23	10	3	1
2005	0	0	0	0	0	0	0	0	0	2	2	8	39	153	394	719	845	563	236	139	83	65	48	12	4
2006	0	0	0	0	0	0	0	0	4	4	8	39	207	741	1529	2428	2411	1439	525	228	113	94	48	31	4
2007	1	0	0	0	0	0	0	0	0	1	3	14	216	599	831	1632	1674	1225	618	359	99	29	7	3	3
2008	0	0	0	0	0	0	0	0	0	5	6	25	83	349	539	770	1028	685	365	165	82	54	31	4	2

Table 2.8a—Length frequencies for the January-May pot fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1990	0	0	0	0	0	0	0	0	0	0	0	0	9	52	115	247	268	144	57	10	3	1	2	0	0
1991	0	0	0	0	0	0	0	1	2	16	44	87	799	2413	5253	11348	13970	9321	4071	1403	487	180	49	8	1
1992	0	0	0	0	0	0	0	1	10	29	58	148	700	2092	5494	9467	9042	5461	2671	1248	509	190	45	11	1
1993	0	0	0	0	0	0	0	0	0	0	13	51	319	1173	2529	4897	5815	3641	1546	566	201	78	28	7	2
1994	0	0	0	0	0	0	0	0	0	0	3	26	196	943	2218	4052	4217	2759	1228	428	160	71	28	13	0
1995	0	0	0	0	0	0	0	0	1	4	12	33	607	2329	4778	9405	12541	8610	4502	2120	1026	403	170	59	25
1996	0	0	0	0	0	0	0	2	4	6	5	23	174	954	3199	6690	9720	8399	3889	1431	489	184	67	15	5
1997	6	0	1	1	4	9	12	18	43	45	43	53	263	969	2843	6289	7541	5200	2299	750	268	151	50	19	3
1998	0	0	0	0	0	0	0	2	0	1	14	19	281	1081	2513	6362	8088	6459	4003	1699	660	257	97	24	9
1999	0	0	0	0	0	0	0	0	1	1	15	51	392	1769	4157	7042	8712	6480	2980	1313	586	216	102	42	17
2000	0	0	0	0	0	3	2	0	3	1	9	41	464	1839	3998	6894	6987	4694	2237	1055	454	203	73	25	9
2001	1	0	0	0	0	0	0	1	0	4	13	62	310	1339	3324	6205	6366	3540	1202	525	222	106	49	16	5
2002	0	0	0	0	0	0	0	0	0	0	15	39	323	1192	2507	3864	4315	3048	1245	427	159	68	24	8	1
2003	0	0	0	0	0	1	0	2	3	9	46	82	369	1203	2059	2566	2267	1750	945	442	167	63	28	14	3
2004	0	0	0	0	0	0	0	0	0	1	2	26	422	1629	3197	3869	3233	1952	1132	599	344	177	64	29	0
2005	0	0	0	0	0	0	0	0	0	1	3	10	249	1298	2984	4337	3695	2123	1010	662	340	253	113	33	13
2006	0	0	0	0	0	0	0	0	0	0	5	21	216	1156	2725	4676	4931	3368	1583	767	424	312	181	62	18
2007	0	0	0	0	0	0	0	3	2	4	8	30	229	1127	2769	4172	4653	3645	1743	811	413	305	203	81	37
2008	0	0	0	0	0	0	0	0	1	4	15	25	238	1091	2439	3329	3494	2512	1359	648	274	158	89	34	19
2009	0	0	0	0	0	0	0	1	0	1	8	26	247	1013	1944	2970	3107	1750	777	294	123	43	37	21	4

Table 2.8b—Length frequencies for the June-August pot fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1990	0	0	0	0	0	0	0	0	0	0	0	0	6	38	169	252	253	177	84	42	7	2	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	1	10	45	81	118	164	118	71	34	12	5	4	0	1
1996	0	0	0	0	0	0	0	0	0	0	0	0	7	24	105	130	55	36	31	20	12	8	1	2	1
1999	0	0	0	0	0	0	0	0	0	0	0	0	7	56	317	653	720	838	626	306	131	48	11	5	1
2000	0	0	0	0	0	0	0	0	0	0	0	0	1	7	76	374	316	104	17	5	0	2	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	9	144	717	1682	2186	2040	1421	689	281	113	39	15	5	2

Table 2.8c—Length frequencies for the September-December pot fishery by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1990	0	0	0	0	0	0	0	0	0	1	7	53	113	215	583	1122	1301	957	549	254	102	56	15	0	0
1992	0	0	0	0	0	0	0	0	0	1	7	24	91	191	489	1073	1337	898	545	222	93	35	7	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	8	51	200	394	274	152	74	40	26	8	5	1	0
1997	0	0	0	0	0	0	0	0	0	0	0	4	18	46	90	228	440	390	206	64	29	16	5	1	0
1998	0	0	0	0	0	0	0	3	2	7	7	9	62	126	259	477	623	640	362	184	74	33	15	18	1
1999	0	0	0	1	0	0	0	1	0	1	0	8	65	188	402	824	858	648	339	166	75	48	24	6	2
2001	0	0	0	0	0	0	0	0	0	0	3	10	104	389	730	956	954	553	134	56	26	3	4	1	2
2002	0	0	0	0	0	0	0	1	0	2	2	17	133	312	580	926	982	841	479	217	106	53	16	6	1
2003	0	0	0	0	0	0	0	0	0	0	2	15	204	744	1232	1416	1093	768	392	181	78	35	7	0	1
2004	0	0	0	0	0	0	0	0	0	0	6	11	130	502	1147	1144	812	485	269	157	85	40	18	9	2
2005	0	0	0	0	0	0	0	0	0	0	0	4	67	321	1108	1794	1588	896	479	277	179	94	49	10	1
2006	0	0	0	0	0	0	0	0	0	0	6	21	190	471	749	1245	1191	750	254	111	67	39	16	7	1
2007	0	0	0	0	0	0	0	0	0	0	0	7	59	306	486	821	726	424	244	81	41	17	10	2	1
2008	0	0	0	0	0	0	0	1	1	2	4	12	184	616	719	876	819	461	203	87	37	15	4	2	1

Table 2.9a—Length frequencies for the 27-plus cm trawl survey by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1984	0	0	0	0	0	0	425	462	599	559	990	1145	2466	3643	2880	1661	788	358	281	237	97	34	11	2	0
1987	0	0	0	0	0	0	130	536	1127	1650	1820	1253	1717	3305	2943	2194	1297	558	309	96	57	14	7	6	1
1990	0	0	0	0	0	0	78	120	233	288	432	573	1718	1894	2015	1706	976	555	245	143	74	36	14	6	2
1993	0	0	0	0	0	0	192	263	448	516	806	1282	2011	2554	3100	2119	1487	675	321	110	60	22	16	11	3
1996	0	0	0	0	0	0	292	110	234	381	558	556	888	1257	1672	2010	1686	666	339	104	50	36	19	9	8
1999	0	0	0	0	0	0	70	134	294	333	381	551	1037	1079	1369	1141	747	374	178	55	27	7	5	7	1
2001	0	0	0	0	0	0	226	183	180	306	447	428	736	740	714	751	525	284	145	51	18	15	6	4	1
2003	0	0	0	0	0	0	66	65	160	296	496	753	1281	1319	1624	1309	700	354	208	112	36	15	4	0	0
2005	0	0	0	0	0	0	70	103	190	244	205	219	426	856	1541	1272	489	221	101	73	46	89	89	57	6
2007	0	0	0	0	0	0	282	235	283	498	732	855	1021	675	835	808	528	261	156	37	12	8	8	3	5
2009	0	0	0	0	0	0	167	351	712	1145	1147	1074	1885	2571	3124	2181	1024	421	186	55	17	28	3	4	1

Table 2.9b—Length frequencies for the sub-27 cm trawl survey by length bin.

Year	5	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1984	516	10	9	28	59	153	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	130	23	37	133	137	110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	151	1	6	37	80	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	43	19	282	341	213	260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	2	15	97	360	480	363	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	2	29	117	262	284	166	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	6	63	116	213	259	356	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	1	5	28	76	136	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	9	9	94	162	172	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	2	29	467	793	371	192	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	16	646	683	74	65	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2.10a—Age compositions observed in the 2008 January-May longline fishery. N = actual sample size rescaled so that the average across all age composition records (including those from Tables 2.10b and 2.10c) is 300.

Year	N	1	2	3	4	5	6	7	8	9	10	11	12+
2008	632	0.0000	0.0016	0.1358	0.2415	0.2791	0.1706	0.0890	0.0519	0.0176	0.0087	0.0000	0.0041

Table 2.10b—Age compositions observed by the 27-plus GOA bottom trawl survey, 1987-2007. N = actual sample size rescaled so that average across all age composition records is 300.

Year	N	1	2	3	4	5	6	7	8	9	10	11	12+
1987	83	0.0000	0.2175	0.3676	0.2630	0.1142	0.0377	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1990	359	0.0056	0.0652	0.2690	0.2585	0.2045	0.1305	0.0456	0.0154	0.0046	0.0011	0.0000	0.0000
1993	567	0.0072	0.0849	0.2109	0.2918	0.2142	0.1294	0.0351	0.0242	0.0020	0.0003	0.0000	0.0000
1996	509	0.0088	0.0406	0.1457	0.2038	0.2661	0.2077	0.1079	0.0121	0.0070	0.0000	0.0000	0.0002
1999	443	0.0000	0.0283	0.1666	0.2549	0.3180	0.1560	0.0386	0.0263	0.0078	0.0035	0.0000	0.0000
2001	474	0.0090	0.1191	0.2549	0.2237	0.1875	0.1299	0.0523	0.0196	0.0034	0.0007	0.0000	0.0000
2003	495	0.0013	0.0408	0.1916	0.3266	0.2574	0.1044	0.0557	0.0201	0.0002	0.0000	0.0005	0.0015
2005	356	0.0000	0.0644	0.1158	0.2109	0.2937	0.2307	0.0584	0.0174	0.0053	0.0006	0.0000	0.0029
2007	286	0.0225	0.2095	0.3413	0.1798	0.1244	0.0531	0.0356	0.0284	0.0040	0.0000	0.0013	0.0000

Table 2.10c—Age compositions observed by the sub-27 GOA bottom trawl survey, 1993-2007. N = actual sample size rescaled so that average across all age composition records is 300.

Year	N	1	2	3	4	5	6	7	8	9	10	11	12+
1993	144	0.9767	0.0233	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1996	140	0.8985	0.1015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1999	137	0.9690	0.0310	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2001	175	0.9223	0.0777	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2003	80	0.9071	0.0929	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2005	91	0.7999	0.2001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2007	130	0.9825	0.0175	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2.10d—Mean length (cm) at age, with sample sizes.

Average length (cm) at age:

Year	Fleet	1	2	3	4	5	6	7	8	9	10	11	12
2008	Jan-May longline fishery	0	41.26	52.55	59.63	65.73	69.60	74.65	76.88	85.22	79.04	0	87.68
1987	27-plus trawl survey	0	35.51	42.64	52.12	59.05	63.00	0	0	0	0	0	0
1990	27-plus trawl survey	0	35.24	45.96	53.41	59.98	64.98	70.96	77.48	83.54	88.42	96.03	102.00
1993	27-plus trawl survey	0	34.22	44.24	52.26	59.05	65.79	70.79	74.79	85.24	92.64	96.47	0
1996	27-plus trawl survey	0	32.01	41.76	52.47	59.46	64.54	68.99	76.17	80.57	86.21	100.00	85.00
1999	27-plus trawl survey	0	32.57	41.23	48.74	58.17	64.38	70.98	70.75	75.55	76.77	79.20	0
2001	27-plus trawl survey	0	32.84	42.65	52.15	58.81	65.61	70.62	74.80	83.90	85.71	85.00	78.57
2003	27-plus trawl survey	0	32.73	43.84	48.97	57.85	64.92	71.56	75.05	83.87	82.69	75.50	74.79
2005	27-plus trawl survey	0	33.29	41.25	51.23	57.54	62.57	67.49	73.44	80.69	94.14	90.00	87.00
2007	27-plus trawl survey	0	35.98	43.85	56.26	60.17	64.24	69.95	70.40	74.19	96.00	74.78	0
1993	Sub-27 trawl survey	20.85	0	0	0	0	0	0	0	0	0	0	0
1996	Sub-27 trawl survey	21.12	0	0	0	0	0	0	0	0	0	0	0
1999	Sub-27 trawl survey	20.58	0	0	0	0	0	0	0	0	0	0	0
2001	Sub-27 trawl survey	21.16	0	0	0	0	0	0	0	0	0	0	0
2003	Sub-27 trawl survey	21.13	0	0	0	0	0	0	0	0	0	0	0
2005	Sub-27 trawl survey	19.58	0	0	0	0	0	0	0	0	0	0	0
2007	Sub-27 trawl survey	19.24	0	0	0	0	0	0	0	0	0	0	0

Number of samples:

Year	Fleet	1	2	3	4	5	6	7	8	9	10	11	12
2008	Jan-May longline fishery	0	2	110	236	247	132	55	30	15	6	0	2
1987	27-plus trawl survey	0	20	56	22	11	1	0	0	0	0	0	0
1990	27-plus trawl survey	0	50	95	81	78	59	41	36	20	7	2	1
1993	27-plus trawl survey	0	103	127	124	116	117	66	53	23	10	2	0
1996	27-plus trawl survey	0	45	146	123	100	107	92	34	17	3	1	1
1999	27-plus trawl survey	0	26	83	124	141	103	58	30	11	5	2	0
2001	27-plus trawl survey	0	88	121	106	83	85	70	35	16	8	3	2
2003	27-plus trawl survey	0	40	119	141	140	91	62	41	12	2	2	2
2005	27-plus trawl survey	0	64	87	83	78	85	40	21	6	4	1	1
2007	27-plus trawl survey	0	47	86	73	65	34	36	25	4	1	2	0
1993	Sub-27 trawl survey	101	0	0	0	0	0	0	0	0	0	0	0
1996	Sub-27 trawl survey	92	0	0	0	0	0	0	0	0	0	0	0
1999	Sub-27 trawl survey	95	0	0	0	0	0	0	0	0	0	0	0
2001	Sub-27 trawl survey	117	0	0	0	0	0	0	0	0	0	0	0
2003	Sub-27 trawl survey	52	0	0	0	0	0	0	0	0	0	0	0
2005	Sub-27 trawl survey	50	0	0	0	0	0	0	0	0	0	0	0
2007	Sub-27 trawl survey	92	0	0	0	0	0	0	0	0	0	0	0

Table 2.11—Pacific cod abundance measured in biomass (t) and numbers of fish (1000s), as assessed by the GOA bottom trawl survey. Point estimates are shown along with coefficients of variation. The two right-hand sections show the total abundance divided into fish 27 cm or larger and fish smaller than 27 cm (totals are very slightly different in the first four years due to exclusion of tows with no length data from the strata extrapolations).

	All lengths				27-plus		sub-27	
Year	Biomass	CV	Abundance	CV	Abundance	CV	Abundance	CV
1984	550971	0.146	320525	0.156	296057	0.175	19526	0.596
1987	394987	0.130	247020	0.185	238165	0.234	6772	0.374
1990	416788	0.153	212132	0.208	193577	0.243	14739	0.412
1993	409848	0.179	231963	0.190	214244	0.210	17021	0.372
1996	538154	0.200	319068	0.215	234528	0.172	84540	0.615
1999	306413	0.126	166584	0.112	157019	0.118	9565	0.272
2001	257614	0.204	158424	0.180	137041	0.203	21384	0.270
2003	297402	0.150	159749	0.129	153895	0.134	5854	0.231
2005	308091	0.262	139852	0.208	127282	0.221	12570	0.388
2007	233310	0.139	192025	0.175	134261	0.163	57764	0.425
2009	752651	0.303	573509	0.286	422370	0.239	151139	0.867

Table 2.12—Input sample sizes associated with size composition data. Sea. 1 = January-May, Sea. 2 = June-August, Sea. 3 = September-December. Trawl survey is divided into fish 27 cm and larger ("27-plus") and fish smaller than 27 cm ("Sub-27").

	Trawl fishery			Longline fishery			Pot fishery			Trawl survey	
Year	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	Sea. 1	Sea. 2	Sea. 3	27-plus	Sub-27
1977			9								
1978			17		108	284					
1979				111	30	165					
1980		15		247	77	73					
1981				168	109	129					
1982		12	18	266	53	163					
1983		29	33	995	249	1461					
1984	97	158	66	1323	86	620				746	35
1985	43	96	75	1056							
1986	9			1893							
1987			13							853	26
1988	78	45									
1989	14										
1990	537	231	252	189			19	22	112	498	15
1991	813			265			1044				
1992	837		48	608	12	76	785	14	106		
1993	567			248			440			717	52
1994	266			110			345				
1995	549		51	520			984		26		
1996	377			310			744	9		488	59
1997	482		79	153			567		32		
1998	1107	73	143	168	9		666		61		
1999	518		49	404			1519	167	164	349	39
2000	312	19		512			1300	40			
2001	274	30	204	567			1045		176	258	45
2002	282	36		430		135	773		210		
2003	185	53	79	356		103	539	419	277	395	15
2004	116	21	114	298		130	748		216		
2005	79	26	79	268	20	149	768		308	282	25
2006	98			343		442	917		230		
2007	156	32	48	298	31	328	907		145	325	83
2008	108	51	126	443	48	188	705		181		
2009	80			479			555			722	68

Table 2.13a (page 1 of 2)—Comparison of negative log-likelihoods across models. Log-likelihoods within the first group (Models A1, A2, A3, A4) are not comparable with each other. Log-likelihoods within the second group (Models B1, D1, E1) are comparable with one another, as are models within the third group (Models B2, D2, E2). Green = within-group minimum (by row), pink = within-group maximum (by row). AIC = Akaike Information Criterion. Blank cells indicate that the log-likelihood for that row is not defined in the model for that column.

	Last year's model with different data sets				New models					
					Models with age composition data			Models without age composition data		
Item	A1	A2	A3	A4	B1	D1	E1	B2	D2	E2
Total -ln(likelihood)	1455.23	1660.63	1458.41	1466.71	1484.67	1650.21	1592.67	1530.39	1732.99	1703.23
Number of parameters	214	215	216	218	282	244	242	277	244	240
AIC	3338.46	3751.26	3348.82	3369.42	3533.34	3788.42	3669.34	3614.78	3953.98	3886.46
Likelihood component										
Equilibrium catch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Survey CPUE (numbers)	10.47	27.93	10.34	12.46	-4.81	-0.65	-2.43	-5.52	0.55	-5.11
Size composition	1195.31	1368.36	1199.61	1198.96	1047.86	1214.24	1176.20	1249.30	1460.35	1410.63
Age composition	25.05	0.00	23.91	30.93	109.87	128.78	112.50			
Mean size at age	207.88	250.29	208.05	209.53	329.28	308.98	300.10	271.43	264.80	299.09
Recruitment	14.34	11.41	14.34	12.78	-14.08	-17.17	-9.98	-17.35	-24.97	-12.72
Priors (random walks)	2.13	2.60	2.12	2.01						
"Softbounds"	0.04	0.04	0.05	0.05	0.05	0.05	0.04	0.05	0.06	0.04
Deviations					16.49	15.97	16.23	32.48	32.20	11.31

Table 2.13a (page 2 of 2)—Log likelihoods broken down by individual fleet. For the CPUE component, only the trawl survey values are counted in the total; the other rows are shown for comparison only. Likewise, log-likelihoods are shown for age composition data in models that do not use these data, simply for purposes of comparison. For the second and third groups of models, green = within-group minimum (by row), pink = within-group maximum (by row).

	Last year's model with different data sets				New models					
					Models with age composition data			Models without age composition data		
	A1	A2	A3	A4	B1	D1	E1	B2	D2	E2
CPUE										
Jan-May trawl fishery	182.19	308.93	188.48	159.95	130.75	120.59	129.24	128.59	131.11	138.05
Jun-Aug trawl fishery	100.24	86.05	99.27	103.79	113.89	128.60	124.78	114.08	126.59	120.65
Sep-Dec trawl fishery	107.89	91.64	106.82	113.08	118.14	117.13	128.07	125.19	114.31	124.41
Jan-May longline fishery	-2.24	27.52	-3.80	-5.85	-15.86	-9.32	-11.72	-27.26	-22.49	-22.00
Jun-Aug longline fishery	-0.60	-2.11	-0.72	-0.26	0.08	2.82	2.19	-0.15	2.47	1.60
Sep-Dec longline fishery	-0.14	1.59	-0.29	-0.36	0.54	2.27	1.21	-0.73	2.67	-3.30
Jan-May pot fishery	5.62	37.72	6.72	1.92	-1.46	-0.40	1.94	-5.64	-4.14	-2.52
Jun-Aug pot fishery	-3.95	-2.30	-3.92	-4.08	-3.79	-4.30	-3.63	-3.64	-4.24	-3.66
Sep-Dec pot fishery	-1.45	-0.53	-1.42	-1.29	-0.63	-2.00	1.66	-1.37	-2.31	0.79
27-plus cm trawl survey	9.44	25.23	9.38	10.24	4.32	8.52	6.67	2.60	8.75	3.46
Sub-27 cm trawl survey	1.03	2.70	0.96	2.22	-9.12	-9.17	-9.10	-8.11	-8.20	-8.57
Size composition										
Jan-May trawl fishery	239.78	275.49	240.59	243.40	253.12	245.75	252.27	284.72	273.97	270.30
Jun-Aug trawl fishery	79.01	78.46	78.91	79.35	74.81	84.85	83.34	81.29	94.13	83.88
Sep-Dec trawl fishery	126.35	128.29	126.60	127.55	129.80	134.31	132.08	146.12	149.53	135.48
Jan-May longline fishery	246.00	248.90	251.45	242.53	201.02	269.08	254.24	197.88	273.53	255.99
Jun-Aug longline fishery	27.37	29.07	27.34	27.84	27.84	26.66	29.14	26.88	26.35	27.59
Sep-Dec longline fishery	98.59	95.96	96.75	96.90	92.32	120.02	111.23	88.24	117.32	92.41
Jan-May pot fishery	142.57	139.09	142.04	142.80	130.04	165.21	154.00	134.06	166.81	153.95
Jun-Aug pot fishery	13.16	12.88	13.16	13.39	12.39	13.91	12.46	12.59	14.67	13.75
Sep-Dec pot fishery	42.33	42.95	42.39	41.93	36.48	45.12	42.12	37.72	46.46	40.90
27-plus cm trawl survey	51.96	185.66	52.17	51.51	39.78	51.59	47.35	142.84	181.41	144.36
Sub-27 cm trawl survey	128.18	131.61	128.22	131.77	50.27	57.74	57.97	96.96	116.18	192.02
Age composition										
Jan-May longline fishery	1.09	2.07	1.27	1.30	39.89	34.47	40.32	108.21	97.92	78.11
27-plus cm trawl survey	23.97	9.79	23.91	29.63	54.04	77.14	55.80	170.42	161.06	125.23
Sub-27 cm trawl survey	0.00	0.00	0.00	0.00	15.94	17.18	16.38	17.53	16.79	21.33
Mean size at age										
Jan-May longline fishery	21.62	21.83	21.60	22.49	36.84	28.58	32.83	65.99	53.45	54.58
27-plus cm trawl survey	186.26	228.45	186.45	187.03	237.79	238.78	220.90	189.80	197.77	190.12
Sub-27 cm trawl survey	0.00	0.00	0.00	0.00	54.65	41.62	46.37	15.65	13.59	54.38

Table 2.13b—Root mean squared errors for fishery CPUE and survey relative abundance time series. For the second and third groups of models, green = row minimum, pink = row maximum.

		Last year's model with diff. data sets				New models					
						Models w/ agecomps			Models w/o agecomps		
Fleet	Records	A1	A2	A3	A4	B1	D1	E1	B2	D2	E2
Jan-May trawl fishery	19	0.39	0.50	0.39	0.36	0.31	0.31	0.31	0.31	0.32	0.31
Jun-Aug trawl fishery	19	0.98	0.90	0.98	1.00	1.05	1.11	1.10	1.05	1.10	1.08
Sep-Dec trawl fishery	19	0.84	0.78	0.84	0.86	0.86	0.86	0.90	0.87	0.85	0.88
Jan-May longline fishery	19	0.19	0.25	0.19	0.19	0.16	0.17	0.17	0.13	0.14	0.14
Jun-Aug longline fishery	8	0.55	0.46	0.54	0.57	0.60	0.73	0.70	0.58	0.71	0.68
Sep-Dec longline fishery	9	0.34	0.37	0.34	0.34	0.35	0.37	0.36	0.33	0.37	0.30
Jan-May pot fishery	19	0.22	0.27	0.22	0.22	0.22	0.22	0.23	0.20	0.21	0.21
Jun-Aug pot fishery	3	0.14	0.28	0.14	0.11	0.15	0.06	0.16	0.16	0.08	0.16
Sep-Dec pot fishery	14	0.27	0.30	0.27	0.26	0.24	0.25	0.26	0.24	0.25	0.25
27-plus trawl survey	11	0.43	0.54	0.43	0.45	0.37	0.40	0.39	0.36	0.40	0.37
Sub-27 trawl survey	11	0.87	0.90	0.87	0.90	0.36	0.35	0.36	0.48	0.47	0.43

Table 2.13c—Correlations between observed data and model estimates for fishery CPUE and survey relative abundance time series. For the second and third groups of models, green = row minimum, pink = row maximum.

		Last year's model with diff. data sets				New models					
						Models w/ agecomps			Models w/o agecomps		
Fleet	Records	A1	A2	A3	A4	B1	D1	E1	B2	D2	E2
Jan-May trawl fishery	19	0.20	-0.18	0.17	0.31	0.56	0.71	0.56	0.55	0.63	0.69
Jun-Aug trawl fishery	19	0.05	0.26	0.07	-0.02	-0.26	-0.34	-0.52	-0.51	-0.48	-0.55
Sep-Dec trawl fishery	19	-0.29	-0.06	-0.29	-0.32	-0.24	-0.23	-0.24	-0.21	-0.33	-0.31
Jan-May longline fishery	19	0.21	-0.40	0.22	0.32	0.53	0.70	0.42	0.60	0.52	0.61
Jun-Aug longline fishery	8	-0.74	0.34	-0.73	-0.75	-0.70	-0.70	-0.69	-0.69	-0.67	-0.69
Sep-Dec longline fishery	9	-0.31	-0.43	-0.32	-0.27	-0.05	0.04	-0.04	-0.04	0.02	0.11
Jan-May pot fishery	19	-0.29	-0.17	-0.29	-0.32	-0.41	-0.46	-0.35	-0.40	-0.37	-0.44
Jun-Aug pot fishery	3	0.99	0.93	0.99	1.00	1.00	1.00	0.99	0.99	0.99	0.99
Sep-Dec pot fishery	14	0.08	0.02	0.06	0.09	0.28	0.31	0.18	0.15	0.23	0.21
27-plus cm trawl survey	11	0.50	0.60	0.48	0.24	0.65	0.51	0.65	0.60	0.63	0.62
Sub-27 cm trawl survey	11	0.31	0.28	0.31	0.29	0.71	0.58	0.72	0.59	0.71	0.63

Table 2.13d—Average ratio of effective multinomial sample size to input sample size for each fishery and survey size composition time series. Note that size composition records from gear/year/season combinations are turned off if age composition records are available and used. For the second and third groups of models, green = within-group row minimum, pink = within-group row maximum.

			Last year's model w/ diff. data sets				New models					
							Models w/ age comp. data			Models w/o age comp. data		
Fleet	Records	Ave. N	A1	A2	A3	A4	B1	D1	E1	B2	D2	E2
Jan-May trawl fishery	25	319	1.20	1.12	1.20	1.20	1.24	1.21	1.13	1.51	1.26	1.10
Jun-Aug trawl fishery	16	58	2.42	2.60	2.42	2.36	2.61	1.88	1.95	2.69	1.95	2.04
Sep-Dec trawl fishery	19	79	1.85	1.88	1.86	1.85	1.67	1.47	1.40	1.64	1.46	1.42
Jan-May longline fishery	28	465	1.67	1.65	1.60	1.71	1.77	1.87	1.82	1.44	1.63	1.68
Jun-Aug longline fishery	12	69	3.80	3.65	3.83	3.99	3.60	4.11	4.79	3.83	4.42	4.97
Sep-Dec longline fishery	15	296	2.40	1.94	2.03	2.05	2.94	2.63	1.55	2.73	2.47	2.24
Jan-May pot fishery	20	769	1.28	1.42	1.30	1.30	1.71	1.23	1.50	1.57	1.23	1.45
Jun-Aug pot fishery	6	112	4.57	4.88	4.57	4.79	4.65	4.32	4.67	4.48	3.88	4.46
Sep-Dec pot fishery	14	160	2.70	2.72	2.71	2.74	3.34	2.76	2.81	3.12	2.87	3.28
27-plus trawl survey	11	774	0.17	0.58	0.17	0.17	0.47	0.30	0.35	0.78	0.57	0.72
Sub-27 trawl survey	11	36	0.85	0.72	0.85	0.66	1.54	0.61	0.78	0.67	0.73	0.50
Weighted average		316	1.89	1.89	1.85	1.87	2.10	1.86	1.85	2.02	1.86	1.94

Table 2.13e— Average ratio of effective multinomial sample size to input sample size for each survey and fishery age composition record. For the second and third groups of models, green = within-group row minimum, pink = within-group row maximum. Note that the 1987 record from the 27-plus trawl survey was turned off in the second and third groups of models, because the number of otoliths read was small and 37% of the length samples did not correspond to a length in the age-length key.

		Last year's model w/ diff. data sets					New models						
								Models w/ agecomps			Models w/o agecomps		
Fleet	Year	Input N	A1	A2	A3	A4	Input N	B1	D1	E1	B2	D2	E2
Jan-May longline fishery	2008	18.0	5.49	2.63	4.50	3.02	632	0.17	0.18	0.17	0.05	0.06	0.07
27-plus cm trawl survey	1987	2.4	4.65	2.23	4.66	2.26	83	0.09	0.18	0.20	0.31	0.15	0.16
27-plus cm trawl survey	1990	10.2	1.02	2.62	1.02	2.49	359	0.51	0.85	1.07	0.11	0.19	0.17
27-plus cm trawl survey	1993	16.2	0.52	2.58	0.52	0.63	567	0.88	0.83	0.77	0.22	0.23	0.16
27-plus cm trawl survey	1996	14.5	0.55	4.81	0.55	0.41	509	1.01	0.73	0.89	0.90	0.55	0.67
27-plus cm trawl survey	1999	12.6	0.70	1.43	0.70	0.51	443	0.29	0.31	0.30	0.08	0.08	0.09
27-plus cm trawl survey	2001	13.6	12.56	7.05	12.60	2.36	474	2.32	1.31	2.08	0.38	0.34	0.47
27-plus cm trawl survey	2003	14.2	0.35	3.86	0.35	0.48	495	0.69	0.11	0.63	0.66	1.06	0.70
27-plus cm trawl survey	2005	10.2	1.30	6.02	1.31	0.66	356	1.05	0.53	1.23	0.46	0.42	0.89
27-plus cm trawl survey	2007	8.2	1.54	2.72	1.61	29.88	286	0.36	0.44	0.38	0.27	0.31	0.49
Sub-27 cm trawl survey	1993						144	0.16	0.18	0.17	0.26	0.14	0.10
Sub-27 cm trawl survey	1996						140	1.83	1.44	2.00	0.29	6.18	23.44
Sub-27 cm trawl survey	1999						137	0.80	1.14	0.86	1.48	0.41	0.19
Sub-27 cm trawl survey	2001						175	6.93	79.14	9.54	0.32	6.27	2.13
Sub-27 cm trawl survey	2003						80	8.81	4.30	4.26	2.57	789.53	0.58
Sub-27 cm trawl survey	2005						91	0.04	0.03	0.03	0.03	0.04	0.09
Sub-27 cm trawl survey	2007						130	0.45	0.51	0.47	0.68	0.28	0.15
27-plus cm trawl survey	Ave.	11	2.58	3.70	2.59	4.41	436	0.89	0.64	0.92	0.38	0.40	0.46
Sub-27 cm trawl survey	Ave.	n/a					128	2.72	12.39	2.48	0.80	114.69	3.81
All	Ave.	12	2.87	3.59	2.78	4.27	314	1.64	5.75	1.55	0.55	50.38	1.90

Table 2.14a (page 1 of 2)— Key parameters as specified/estimated by Models A1, A2, A3, and A4. "Value" = point estimate, "SD" = standard deviation. A blank under "SD" indicates that the parameter was fixed.

	Model A1		Model A2		Model A3		Model A4	
Parm.	Value	SD	Valule	SD	Value	SD	Value	SD
L1	20.94		20.94		20.94		20.94	
L2	99.34	1.33	96.65	1.22	99.28	1.34	100.08	1.33
K	0.15	0.00	0.16	0.00	0.15	0.00	0.15	0.00
CV2	0.03	0.01	0.03	0.01	0.03	0.01	0.02	0.01
R0	12.55	0.05	12.88	0.07	12.56	0.05	12.46	0.05
R1	-1.37	0.15	-1.18	0.16	-1.37	0.15	-1.35	0.14
Init. F	0.05	0.01	0.03	0.00	0.04	0.01	0.05	0.01
lnQoffset	0.00		0.00		0.00		0.00	
lnQsub27	-1.76	0.31	-2.32	0.30	-1.76	0.31	-1.77	0.30
lnQdev1987	-0.17	0.19	-0.15	0.19	-0.17	0.19	-0.18	0.19
lnQdev1990	-0.08	0.18	0.01	0.18	-0.08	0.18	-0.04	0.18
lnQdev1993	-0.01	0.18	0.04	0.18	-0.01	0.18	0.02	0.18
lnQdev1996	-0.01	0.18	-0.05	0.18	-0.01	0.18	0.01	0.18
lnQdev1999	-0.16	0.17	-0.22	0.17	-0.16	0.17	-0.16	0.17
lnQdev2001	-0.13	0.17	-0.15	0.17	-0.13	0.17	-0.12	0.17
lnQdev2003	-0.21	0.17	-0.24	0.17	-0.20	0.17	-0.19	0.17
lnQdev2005	0.06	0.18	0.04	0.17	0.06	0.18	0.08	0.18
lnQdev2007	0.15	0.19	0.16	0.18	0.15	0.19	0.15	0.18
lnQdev2009	0.16	0.20	0.16	0.20	0.16	0.20	0.16	0.20

Legend:
L1 = mean Jan. 1 length at age a1 (a1 = 1.5417 in Models A1-A4)
L2 = mean Jan. 1 length at age 20 in Models A1-A4
K = Brody's growth coefficient
CV2 = coefficient of variation of length at age 20
R0 = log mean recruitment for post-1976 environmental regime
R1 = log ratio of pre-1977 mean recruitment to post-1976 mean recruitment
Init. F = equilibrium fishing mortality rate in initial year (1977)
lnQoffset = log ratio of pre-1996 27-plus survey catchability to post-1993 27-plus survey catchability
lnQsub27 = log sub-27 survey catchability in 1984
lnQdev(year) = log ratio of sub-27 survey catchability in (year) to sub-27 survey catchability in previous survey year

Table 2.14a (page 2 of 2)— Key parameters as specified/estimated by the second and third groups. “Value” = point estimate, “SD” = standard deviation. A blank under “SD” indicates that the parameter was fixed. Green = within-group row minimum, pink = within-group row maximum.

	Model B1		Model D1		Model E1		Model B2		Model D2		Model E2	
Parm.	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
L1	-5.16	0.49	-2.04	0.46	-3.53	0.48	-3.86	0.37	-2.05	0.36	-5.82	0.41
L2	101.90	0.81	111.84	1.23	105.79	0.97	100.86	0.73	109.41	1.07	102.40	0.76
K	0.18	0.00	0.15	0.00	0.16	0.00	0.18	0.00	0.16	0.00	0.18	0.00
SD2	6.53		6.53		6.53		6.53		6.53		6.53	
R0	12.47	0.03	12.34	0.03	12.42	0.03	12.42	0.04	12.34	0.03	12.44	0.03
R1	-0.65	0.12	-0.69	0.13	-0.94	0.10	-0.47	0.12	-0.58	0.13	-0.99	0.10
Init. F	0.02	0.00	0.02	0.00	0.03	0.00	0.02	0.00	0.02	0.00	0.03	0.00
lnQoffset	0.87	0.12	0.82	0.11	0.71	0.11	0.79	0.12	0.80	0.11	0.72	0.11
lnQsub27	-2.19	0.14	-2.09	0.14	-2.17	0.14	-2.01	0.15	-2.03	0.14	-2.15	0.14
lnQdev1984	0.04	0.52	0.21	0.52	0.21	0.52	1.08	0.56	0.17	0.52	0.14	0.52
lnQdev1987	-0.72	0.36	-0.91	0.35	-0.92	0.36	-1.10	0.36	-0.90	0.36	-0.95	0.36
lnQdev1990	-0.43	0.38	-0.41	0.38	-0.48	0.38	-0.65	0.39	-0.47	0.38	-0.53	0.38
lnQdev1993	-0.03	0.35	-0.05	0.35	-0.08	0.35	-0.18	0.36	-0.08	0.35	-0.09	0.35
lnQdev1996	1.54	0.53	1.58	0.53	1.54	0.53	1.43	0.53	1.58	0.53	1.55	0.53
lnQdev1999	-0.48	0.28	-0.55	0.28	-0.48	0.28	-0.67	0.28	-0.58	0.28	-0.45	0.28
lnQdev2001	0.14	0.28	0.25	0.28	0.19	0.28	-0.12	0.28	0.02	0.28	0.09	0.28
lnQdev2003	-0.47	0.25	-0.50	0.25	-0.46	0.25	-0.45	0.27	-0.46	0.26	-0.39	0.26
lnQdev2005	-0.09	0.37	-0.12	0.37	-0.07	0.37	-0.19	0.37	-0.18	0.37	-0.10	0.37
lnQdev2007	0.45	0.40	0.45	0.40	0.49	0.40	0.78	0.40	0.82	0.40	0.66	0.40

Legend:

L1 = mean Jan. 1 length at age a1 (a1 = 0, except in Models A1-A4)
L2 = mean asymptotic length (except in Models A1-A4)
K = Brody's growth coefficient
SD2 = coefficient of variation of length at age 20
R0 = log mean recruitment for post-1976 environmental regime
R1 = log ratio of pre-1977 mean recruitment to post-1976 mean recruitment
Init. F = equilibrium fishing mortality rate in initial year (1977)
lnQoffset = log ratio of pre-1996 27-plus survey catchability to post-1993 27-plus survey catchability
lnQsub27 = base value of log sub-27 survey catchability
lnQdev(year) = log ratio of sub-27 survey catchability in (year) to base value

Table 2.14b— Growth deviations (not applicable for Models A1-A4). "Value" = point estimate, "SD" = standard deviation.

	Model B1		Model D1		Model E1		Model B2		Model D2		Model E2	
Cohort	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
1977	0.073	0.017	0.055	0.017	0.080	0.017	0.064	0.017	0.058	0.017	0.078	0.017
1978	0.059	0.034	-0.032	0.018	0.009	0.020	0.051	0.036	-0.032	0.019	0.003	0.020
1979	0.080	0.037	-0.087	0.020	-0.047	0.024	0.073	0.035	-0.087	0.021	-0.063	0.022
1980	0.078	0.025	-0.091	0.022	-0.039	0.032	0.063	0.024	-0.089	0.024	-0.061	0.026
1981	0.075	0.020	-0.034	0.025	0.016	0.027	0.049	0.021	-0.028	0.027	0.002	0.027
1982	0.059	0.018	0.018	0.018	0.051	0.019	0.020	0.020	0.020	0.019	0.045	0.019
1983	-0.007	0.018	-0.014	0.017	0.023	0.019	0.021	0.030	-0.012	0.018	0.011	0.019
1984	-0.153	0.017	-0.060	0.023	-0.001	0.028	0.139	0.022	-0.063	0.023	-0.026	0.024
1985	0.128	0.022	0.067	0.017	0.089	0.018	0.087	0.017	0.049	0.018	0.088	0.018
1986	0.038	0.019	0.032	0.017	0.061	0.018	0.039	0.018	0.013	0.018	0.057	0.019
1987	0.019	0.017	0.008	0.016	0.037	0.017	0.010	0.017	0.003	0.017	0.034	0.017
1988	0.046	0.018	0.023	0.017	0.057	0.018	0.038	0.018	0.023	0.018	0.065	0.018
1989	0.011	0.017	0.000	0.016	0.027	0.017	-0.002	0.017	-0.003	0.017	0.025	0.017
1990	0.001	0.018	-0.013	0.017	0.015	0.018	-0.025	0.018	-0.027	0.017	-0.001	0.018
1991	-0.005	0.017	-0.021	0.016	0.012	0.017	-0.015	0.017	-0.017	0.017	0.020	0.017
1992	-0.006	0.018	-0.029	0.017	0.006	0.018	-0.017	0.018	-0.026	0.018	0.019	0.018
1993	0.002	0.018	-0.015	0.017	0.019	0.018	-0.021	0.018	-0.024	0.018	0.002	0.018
1994	-0.026	0.017	-0.044	0.016	-0.009	0.017	-0.034	0.018	-0.040	0.017	-0.004	0.018
1995	-0.022	0.017	-0.042	0.017	-0.007	0.017	-0.018	0.018	-0.030	0.017	0.021	0.018
1996	-0.025	0.018	-0.035	0.017	-0.007	0.018	-0.021	0.018	-0.020	0.018	0.005	0.018
1997	0.015	0.019	-0.002	0.018	0.029	0.019	0.003	0.018	0.002	0.017	0.030	0.019
1998	-0.006	0.017	-0.023	0.017	0.008	0.018	-0.037	0.017	-0.037	0.017	0.003	0.018
1999	-0.030	0.017	-0.051	0.016	-0.014	0.017	-0.046	0.017	-0.050	0.017	-0.005	0.017
2000	-0.030	0.017	-0.049	0.016	-0.017	0.017	-0.051	0.017	-0.058	0.017	-0.012	0.017
2001	-0.027	0.018	-0.033	0.017	-0.012	0.018	-0.049	0.019	-0.050	0.018	-0.011	0.018
2002	0.049	0.020	0.024	0.018	0.060	0.020	0.027	0.022	0.016	0.020	0.047	0.021
2003	0.076	0.018	0.066	0.017	0.092	0.018	0.065	0.018	0.064	0.017	0.099	0.018
2004	0.168	0.019	0.150	0.018	0.185	0.019	0.097	0.018	0.095	0.017	0.137	0.018
2005	0.173	0.018	0.164	0.017	0.193	0.018	0.117	0.018	0.120	0.017	0.152	0.018
2006	0.206	0.017	0.204	0.017	0.228	0.017	-0.126	0.017	-0.130	0.018	0.172	0.018
2007	0.159	0.019	0.153	0.018	0.178	0.019	0.582	0.019	0.578	0.018	0.159	0.019
2008	-0.233	0.026	-0.308	0.028	-0.250	0.028	-0.287	0.026	-0.315	0.027	-0.195	0.025

Table 2.14c—Recruitment deviations for Models A1-A4. “Value” = point estimate, “SD” = standard deviation. Note that deviations are relative to their regime-specific (pre-1977, post-1976) log medians.

	Model A1		Model A2		Model A3		Model A4	
Cohort	Value	SD	Value	SD	Value	SD	Value	SD
1974	1.040	0.266	0.815	0.265	1.036	0.267	1.022	0.245
1975	-0.515	0.586	-0.514	0.436	-0.511	0.586	-0.416	0.470
1976	-0.524	0.502	-0.301	0.368	-0.525	0.501	-0.606	0.406
1977	1.230	0.095	1.159	0.102	1.230	0.095	1.208	0.095
1978	-1.435	0.436	-1.697	0.415	-1.440	0.436	-1.164	0.395
1979	-0.849	0.277	-1.200	0.303	-0.856	0.278	-0.819	0.273
1980	0.562	0.102	0.364	0.108	0.560	0.102	0.508	0.100
1981	-0.707	0.217	-0.709	0.222	-0.712	0.217	-0.586	0.188
1982	0.676	0.102	0.549	0.104	0.674	0.102	0.660	0.099
1983	-2.327	0.381	-1.954	0.355	-2.328	0.381	-2.265	0.376
1984	0.512	0.151	0.542	0.110	0.510	0.151	0.344	0.150
1985	0.294	0.181	-0.314	0.267	0.289	0.182	0.392	0.169
1986	-0.963	0.305	-0.364	0.207	-0.964	0.305	-0.602	0.255
1987	0.248	0.114	-0.157	0.145	0.245	0.114	0.020	0.123
1988	-0.054	0.155	0.089	0.130	-0.057	0.155	0.104	0.123
1989	0.090	0.143	0.023	0.132	0.088	0.143	0.052	0.127
1990	0.381	0.122	0.084	0.135	0.379	0.122	0.285	0.117
1991	-0.027	0.168	0.220	0.121	-0.029	0.168	0.099	0.141
1992	-0.048	0.154	-0.342	0.154	-0.048	0.154	-0.064	0.137
1993	0.044	0.141	-0.089	0.147	0.042	0.142	-0.123	0.138
1994	-0.048	0.151	0.124	0.137	-0.046	0.151	0.125	0.117
1995	0.401	0.103	0.382	0.102	0.404	0.103	0.209	0.103
1996	-0.098	0.134	-0.089	0.139	-0.095	0.134	0.028	0.107
1997	-0.252	0.143	-0.330	0.160	-0.247	0.143	-0.295	0.127
1998	-0.462	0.146	-0.235	0.146	-0.457	0.146	-0.476	0.124
1999	0.230	0.107	0.264	0.110	0.239	0.108	0.122	0.096
2000	0.398	0.103	0.565	0.112	0.408	0.104	0.385	0.093
2001	-0.155	0.169	-0.207	0.176	-0.133	0.170	-0.177	0.140
2002	-0.312	0.183	-0.051	0.192	-0.306	0.190	-0.384	0.154
2003	0.247	0.153	0.094	0.183	0.247	0.158	0.265	0.124
2004	0.402	0.146	0.750	0.163	0.369	0.149	0.198	0.144
2005	0.987	0.162	0.854	0.181	0.965	0.162	0.953	0.156
2006	1.569	0.223	1.792	0.228	1.598	0.219	1.516	0.218
2007	-0.616	0.549	-0.338	0.560	-0.614	0.550	-0.515	0.554
2008	0.080	0.671	0.222	0.619	0.085	0.672	-0.003	0.595

Table 2.14d—Recruitment deviations for Models B1, D1, E1. "Value" = point estimate, "SD" = standard deviation. Note that deviations are relative to their regime-specific (pre-1977, post-1976) log medians.

	Model B1		Model D1		Model E1	
Cohort	Value	SD	Value	SD	Value	SD
1964	-0.059	0.353	0.135	0.375	-0.016	0.347
1965	-0.124	0.344	0.090	0.367	-0.093	0.337
1966	-0.193	0.335	0.027	0.357	-0.176	0.327
1967	-0.253	0.328	-0.048	0.346	-0.253	0.318
1968	-0.287	0.323	-0.119	0.336	-0.302	0.312
1969	-0.265	0.322	-0.152	0.327	-0.289	0.310
1970	-0.150	0.326	-0.114	0.318	-0.179	0.310
1971	0.082	0.340	-0.026	0.305	0.044	0.317
1972	0.534	0.314	0.161	0.269	0.547	0.265
1973	0.978	0.198	0.554	0.169	0.702	0.195
1974	0.065	0.205	-0.094	0.172	0.002	0.188
1975	-0.099	0.171	-0.254	0.160	-0.054	0.163
1976	-0.229	0.231	-0.161	0.202	0.067	0.225
1977	0.801	0.105	0.515	0.076	0.598	0.075
1978	-0.177	0.182	0.117	0.076	0.072	0.092
1979	-0.490	0.153	-0.013	0.096	-0.099	0.149
1980	-0.318	0.083	-0.193	0.123	-0.278	0.141
1981	-0.271	0.079	-0.628	0.152	-0.468	0.150
1982	0.136	0.078	-0.012	0.083	0.058	0.082
1983	0.032	0.103	-0.030	0.094	-0.053	0.119
1984	0.175	0.113	-0.578	0.117	-0.528	0.112
1985	-0.145	0.123	0.064	0.083	0.095	0.088
1986	-0.329	0.097	-0.118	0.067	-0.109	0.075
1987	-0.024	0.082	0.032	0.068	0.054	0.075
1988	-0.115	0.076	-0.144	0.070	-0.079	0.074
1989	0.244	0.068	0.226	0.063	0.310	0.065
1990	0.223	0.067	0.227	0.061	0.248	0.068
1991	0.092	0.072	0.127	0.065	0.131	0.071
1992	-0.053	0.078	-0.022	0.073	0.003	0.077
1993	-0.015	0.082	-0.019	0.074	0.008	0.080
1994	0.234	0.065	0.230	0.057	0.257	0.062
1995	0.058	0.068	0.021	0.065	0.059	0.066
1996	-0.226	0.082	-0.220	0.078	-0.228	0.081
1997	-0.506	0.081	-0.431	0.073	-0.491	0.078
1998	-0.203	0.066	-0.128	0.058	-0.200	0.063
1999	0.040	0.057	0.104	0.050	0.025	0.056
2000	0.071	0.065	-0.058	0.058	0.036	0.061
2001	-0.522	0.090	-0.468	0.084	-0.550	0.088
2002	-0.767	0.110	-0.734	0.104	-0.770	0.106
2003	-0.350	0.087	-0.392	0.081	-0.396	0.085
2004	-0.422	0.096	-0.391	0.089	-0.445	0.094
2005	0.286	0.100	0.295	0.099	0.255	0.100
2006	0.715	0.116	0.699	0.117	0.680	0.117
2007	0.835	0.163	0.886	0.163	0.809	0.163
2008	0.991	0.246	1.036	0.243	0.999	0.244

Table 2.14e—Recruitment deviations for Models B2, D2, E2. “Value” = point estimate, “SD” = standard deviation. Note that deviations are relative to their regime-specific (pre-1977, post-1976) log medians.

	Model B2		Model D2		Model E2	
Cohort	Value	SD	Value	SD	Value	SD
1964	-0.088	0.356	0.101	0.375	-0.009	0.347
1965	-0.145	0.348	0.060	0.368	-0.084	0.336
1966	-0.204	0.340	0.005	0.359	-0.163	0.327
1967	-0.255	0.333	-0.057	0.350	-0.237	0.318
1968	-0.280	0.330	-0.110	0.342	-0.284	0.313
1969	-0.250	0.330	-0.122	0.335	-0.273	0.311
1970	-0.131	0.336	-0.069	0.328	-0.171	0.313
1971	0.100	0.351	0.024	0.317	0.047	0.321
1972	0.516	0.332	0.220	0.280	0.534	0.280
1973	1.016	0.201	0.587	0.177	0.731	0.197
1974	0.074	0.214	-0.120	0.180	-0.016	0.194
1975	-0.071	0.173	-0.269	0.165	-0.088	0.168
1976	-0.282	0.231	-0.250	0.211	0.014	0.225
1977	0.973	0.110	0.616	0.080	0.584	0.074
1978	-0.084	0.190	0.177	0.082	0.081	0.086
1979	-0.336	0.161	0.034	0.106	0.006	0.116
1980	-0.170	0.086	-0.177	0.141	-0.201	0.145
1981	-0.167	0.084	-0.602	0.163	-0.498	0.158
1982	0.088	0.099	0.009	0.089	0.100	0.085
1983	-1.213	0.321	-0.001	0.102	0.013	0.108
1984	-0.366	0.113	-0.354	0.191	-0.438	0.120
1985	0.355	0.080	0.108	0.090	-0.018	0.107
1986	0.066	0.073	-0.090	0.080	-0.027	0.075
1987	0.054	0.085	0.015	0.077	0.025	0.083
1988	0.023	0.078	-0.098	0.075	-0.059	0.077
1989	0.446	0.070	0.328	0.065	0.399	0.065
1990	0.339	0.074	0.241	0.068	0.256	0.072
1991	0.159	0.089	0.116	0.079	0.032	0.090
1992	0.066	0.090	0.030	0.082	0.036	0.080
1993	0.131	0.091	0.054	0.081	0.093	0.082
1994	0.221	0.086	0.179	0.074	0.070	0.087
1995	0.139	0.082	0.042	0.076	0.072	0.075
1996	-0.168	0.087	-0.269	0.083	-0.155	0.085
1997	-0.262	0.079	-0.281	0.070	-0.403	0.081
1998	-0.013	0.074	-0.038	0.063	-0.181	0.072
1999	0.074	0.075	0.031	0.066	-0.035	0.065
2000	0.283	0.066	0.207	0.059	0.133	0.065
2001	-0.489	0.135	-0.526	0.124	-0.449	0.107
2002	-0.822	0.155	-0.742	0.138	-0.846	0.147
2003	-0.198	0.091	-0.249	0.089	-0.348	0.092
2004	-0.223	0.102	-0.174	0.098	-0.302	0.095
2005	-0.041	0.148	0.039	0.146	0.252	0.106
2006	0.383	0.122	0.399	0.125	0.557	0.124
2007	0.249	0.134	0.373	0.143	0.506	0.166
2008	0.502	0.261	0.603	0.255	0.746	0.254

Table 2.15a—Base fishery selectivity parameters for Models A1-A4. A blank under "SD" means the parameter was fixed. Fixed parameters may be over-written by block-specific values (see Tables 2.15d-2.15f). See text for parameter definitions.

		Model A1		Model A2		Model A3		Model A4	
Fishery	Parm.	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May trawl	1	0.000		0.000		0.000		0.000	
Jan-May trawl	2	0.000		0.000		0.000		0.000	
Jan-May trawl	3	5.797	0.032	5.740	0.032	5.796	0.032	5.807	0.032
Jan-May trawl	4	0.000		0.000		0.000		0.000	
Jan-May trawl	5	-999.000		-999.000		-999.000		-999.000	
Jan-May trawl	6	10.000		10.000		10.000		10.000	
Jun-Aug trawl	1	0.000		0.000		0.000		0.000	
Jun-Aug trawl	2	-9.523	12.456	-9.550	11.858	-9.522	12.480	-9.516	12.609
Jun-Aug trawl	3	0.000		0.000		0.000		0.000	
Jun-Aug trawl	4	3.681	0.638	3.659	0.572	3.678	0.638	3.656	0.649
Jun-Aug trawl	5	-999.000		-999.000		-999.000		-999.000	
Jun-Aug trawl	6	0.000		0.000		0.000		0.000	
Sep-Dec trawl	1	0.000		0.000		0.000		0.000	
Sep-Dec trawl	2	0.000		0.000		0.000		0.000	
Sep-Dec trawl	3	0.000		0.000		0.000		0.000	
Sep-Dec trawl	4	-8.911	25.913	-9.412	8.681	-8.792	27.306	-9.591	9.486
Sep-Dec trawl	5	-999.000		-999.000		-999.000		-999.000	
Sep-Dec trawl	6	-0.883	0.320	-1.043	0.296	-0.873	0.319	-0.857	0.319
Jan-May longline	1	0.000		0.000		0.000		0.000	
Jan-May longline	2	0.000		0.000		0.000		0.000	
Jan-May longline	3	0.000		0.000		0.000		0.000	
Jan-May longline	4	2.682	0.907	3.939	0.389	2.785	0.781	2.552	0.980
Jan-May longline	5	-999.000		-999.000		-999.000		-999.000	
Jan-May longline	6	0.000		0.000		0.000		0.000	
Jun-Aug longline	1	0.000		0.000		0.000		0.000	
Jun-Aug longline	2	-8.963	23.275	-9.241	18.238	-8.969	23.182	-9.003	22.579
Jun-Aug longline	3	0.000		0.000		0.000		0.000	
Jun-Aug longline	4	5.641	0.488	5.529	0.601	5.641	0.487	5.627	0.482
Jun-Aug longline	5	-999.000		-999.000		-999.000		-999.000	
Jun-Aug longline	6	0.000		0.000		0.000		0.000	
Sep-Dec longline	1	0.000		0.000		0.000		0.000	
Sep-Dec longline	2	-1.865	0.172	-1.890	1.105	-1.935	0.238	-1.976	0.226
Sep-Dec longline	3	0.000		0.000		0.000		0.000	
Sep-Dec longline	4	0.000		0.000		0.000		0.000	
Sep-Dec longline	5	-999.000		-999.000		-999.000		-999.000	
Sep-Dec longline	6	0.000		0.000		0.000		0.000	
Jan-May pot	1	0.000		0.000		0.000		0.000	
Jan-May pot	2	-14.110	79.348	-14.326	77.182	-14.112	79.323	-14.088	79.560
Jan-May pot	3	0.000		0.000		0.000		0.000	
Jan-May pot	4	0.000		0.000		0.000		0.000	
Jan-May pot	5	-999.000		-999.000		-999.000		-999.000	
Jan-May pot	6	0.000		0.000		0.000		0.000	
Jun-Aug pot	1	0.000		0.000		0.000		0.000	
Jun-Aug pot	2	-8.529	30.246	-8.820	25.681	-8.537	30.121	-8.462	31.252
Jun-Aug pot	3	0.000		0.000		0.000		0.000	
Jun-Aug pot	4	4.744	0.575	4.734	0.467	4.744	0.573	4.744	0.586
Jun-Aug pot	5	-999.000		-999.000		-999.000		-999.000	
Jun-Aug pot	6	-1.270	0.701	-1.579	0.625	-1.277	0.699	-1.228	0.707
Sep-Dec pot	1	0.000		0.000		0.000		0.000	
Sep-Dec pot	2	-8.939	23.683	-9.204	18.937	-8.947	23.542	-8.917	24.061
Sep-Dec pot	3	0.000		0.000		0.000		0.000	
Sep-Dec pot	4	4.143	0.495	4.294	0.382	4.148	0.491	4.116	0.509
Sep-Dec pot	5	-999.000		-999.000		-999.000		-999.000	
Sep-Dec pot	6	0.000		0.000		0.000		0.000	

Table 2.15b—Base fishery selectivity parameters for Models B1, D1, and E1. A blank under "SD" means the parameter was fixed. Fixed parameters may be over-written by block-specific values (see Tables 2.15g-2.15i). See text for parameter definitions.

		Model B1		Model D1		Model E1	
Fishery	Parm.	Value	SD	Value	SD	Value	SD
Jan-May trawl	1	0.000		0.000		0.000	
Jan-May trawl	2	0.000		0.000		0.000	
Jan-May trawl	3	5.896	0.034	5.957	0.034	5.907	0.033
Jan-May trawl	4	0.000		0.000		0.000	
Jan-May trawl	5	-10.000		-10.000		-10.000	
Jan-May trawl	6	10.000		10.000		10.000	
Jun-Aug trawl	1	0.000		0.000		0.000	
Jun-Aug trawl	2	-9.493	13.126	-9.347	16.159	-9.260	17.886
Jun-Aug trawl	3	0.000		0.000		0.000	
Jun-Aug trawl	4	4.250	0.532	5.985	0.237	4.296	0.514
Jun-Aug trawl	5	-10.000		-10.000		-10.000	
Jun-Aug trawl	6	0.000		-999.000		-0.847	
Sep-Dec trawl	1	0.000		0.000		0.000	
Sep-Dec trawl	2	0.000		0.000		0.000	
Sep-Dec trawl	3	0.000		0.000		0.000	
Sep-Dec trawl	4	3.820	0.671	5.464	0.355	-10.000	
Sep-Dec trawl	5	-10.000		-10.000		-10.000	
Sep-Dec trawl	6	-1.009	0.358	-999.000		-0.847	
Jan-May longline	1	0.000		0.000		0.000	
Jan-May longline	2	0.000		0.000		0.000	
Jan-May longline	3	0.000		0.000		0.000	
Jan-May longline	4	-1.344	149.736	5.600	0.151	-10.000	
Jan-May longline	5	-10.000		-10.000		-10.000	
Jan-May longline	6	0.000		-999.000		-0.847	
Jun-Aug longline	1	0.000		0.000		0.000	
Jun-Aug longline	2	-9.084	21.157	-9.250	18.069	-9.298	17.143
Jun-Aug longline	3	0.000		0.000		0.000	
Jun-Aug longline	4	4.143	0.577	6.397	0.184	5.755	0.384
Jun-Aug longline	5	-10.000		-10.000		-10.000	
Jun-Aug longline	6	0.000		-999.000		-0.847	
Sep-Dec longline	1	0.000		0.000		0.000	
Sep-Dec longline	2	-9.770	6.565	-10.000		-9.621	10.242
Sep-Dec longline	3	0.000		0.000		0.000	
Sep-Dec longline	4	0.000		0.000		0.000	
Sep-Dec longline	5	-10.000		-10.000		-10.000	
Sep-Dec longline	6	0.000		-999.000		-0.847	
Jan-May pot	1	0.000		0.000		0.000	
Jan-May pot	2	-13.494	85.567	-14.207	78.360	-13.968	80.767
Jan-May pot	3	0.000		0.000		0.000	
Jan-May pot	4	0.000		0.000		0.000	
Jan-May pot	5	-10.000		-10.000		-10.000	
Jan-May pot	6	0.000		-999.000		-0.847	
Jun-Aug pot	1	0.000		0.000		0.000	
Jun-Aug pot	2	-8.710	27.458	-9.040	21.936	-8.289	33.718
Jun-Aug pot	3	0.000		0.000		0.000	
Jun-Aug pot	4	4.555	0.609	5.900	0.336	4.350	0.477
Jun-Aug pot	5	-10.000		-10.000		-10.000	
Jun-Aug pot	6	-1.046	0.598	-999.000		-0.847	
Sep-Dec pot	1	0.000		0.000		0.000	
Sep-Dec pot	2	-8.226	34.595	-8.937	23.722	-9.242	18.228
Sep-Dec pot	3	0.000		0.000		0.000	
Sep-Dec pot	4	4.254	0.578	6.946	0.346	5.547	0.346
Sep-Dec pot	5	-10.000		-10.000		-10.000	
Sep-Dec pot	6	0.000		-999.000		-0.847	

Table 2.15c—Base fishery selectivity parameters for Models B2, D2, and E2. A blank under "SD" means the parameter was fixed. Fixed parameters may be over-written by block-specific values (see Tables 2.15j-2.15l). See text for parameter definitions.

		Model B2		Model D2		Model E2	
Fishery	Parm.	Value	SD	Value	SD	Value	SD
Jan-May trawl	1	0.000		0.000		0.000	
Jan-May trawl	2	0.000		0.000		0.000	
Jan-May trawl	3	5.887	0.035	5.960	0.034	5.909	0.034
Jan-May trawl	4	0.000		0.000		0.000	
Jan-May trawl	5	-10.000		-10.000		-10.000	
Jan-May trawl	6	10.000		10.000		10.000	
Jun-Aug trawl	1	0.000		0.000		0.000	
Jun-Aug trawl	2	-9.530	12.315	-9.395	15.183	-9.077	21.284
Jun-Aug trawl	3	0.000		0.000		0.000	
Jun-Aug trawl	4	4.155	0.517	5.966	0.232	3.632	0.681
Jun-Aug trawl	5	-10.000		-10.000		-10.000	
Jun-Aug trawl	6	0.000		-999.000		-0.405	
Sep-Dec trawl	1	0.000		0.000		0.000	
Sep-Dec trawl	2	0.000		0.000		0.000	
Sep-Dec trawl	3	0.000		0.000		0.000	
Sep-Dec trawl	4	-10.000		5.483	0.348	-10.000	
Sep-Dec trawl	5	-10.000		-10.000		-10.000	
Sep-Dec trawl	6	-0.889	0.245	-999.000		-0.405	
Jan-May longline	1	0.000		0.000		0.000	
Jan-May longline	2	0.000		0.000		0.000	
Jan-May longline	3	0.000		0.000		0.000	
Jan-May longline	4	-2.988	95.745	5.732	0.163	-6.061	6.385
Jan-May longline	5	-10.000		-10.000		-10.000	
Jan-May longline	6	0.000		-999.000		-0.405	
Jun-Aug longline	1	0.000		0.000		0.000	
Jun-Aug longline	2	-9.108	20.719	-9.338	16.348	-9.261	17.849
Jun-Aug longline	3	0.000		0.000		0.000	
Jun-Aug longline	4	4.098	0.556	6.379	0.182	5.319	0.543
Jun-Aug longline	5	-10.000		-10.000		-10.000	
Jun-Aug longline	6	0.000		-999.000		-0.405	
Sep-Dec longline	1	0.000		0.000		0.000	
Sep-Dec longline	2	-9.787	6.123	-10.000		-2.220	0.295
Sep-Dec longline	3	0.000		0.000		0.000	
Sep-Dec longline	4	0.000		0.000		0.000	
Sep-Dec longline	5	-10.000		-10.000		-10.000	
Sep-Dec longline	6	0.000		-999.000		-0.405	
Jan-May pot	1	0.000		0.000		0.000	
Jan-May pot	2	-13.558	84.915	-14.206	78.384	-12.647	94.375
Jan-May pot	3	0.000		0.000		0.000	
Jan-May pot	4	0.000		0.000		0.000	
Jan-May pot	5	-10.000		-10.000		-10.000	
Jan-May pot	6	0.000		-999.000		-0.405	
Jun-Aug pot	1	0.000		0.000		0.000	
Jun-Aug pot	2	-8.805	25.926	-9.140	20.140	-4.370	8.613
Jun-Aug pot	3	0.000		0.000		0.000	
Jun-Aug pot	4	4.473	0.605	5.834	0.323	3.909	0.879
Jun-Aug pot	5	-10.000		-10.000		-10.000	
Jun-Aug pot	6	-1.037	0.569	-999.000		-0.405	
Sep-Dec pot	1	0.000		0.000		0.000	
Sep-Dec pot	2	-8.416	31.886	-9.045	21.850	-9.198	19.065
Sep-Dec pot	3	0.000		0.000		0.000	
Sep-Dec pot	4	4.165	0.542	6.914	0.333	4.802	0.420
Sep-Dec pot	5	-10.000		-10.000		-10.000	
Sep-Dec pot	6	0.000		-999.000		-0.405	

Table 2.15d—Block-specific values of trawl fishery selectivity parameters in Models A1-A4. See text for parameter definitions. “Block” refers to first year in the time block.

			Model A1		Model A2		Model A3		Model A4	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May trawl	1	1977	66.933	1.273	65.412	1.256	66.897	1.273	66.914	1.261
Jan-May trawl	1	1990	74.142	0.680	72.684	0.652	74.114	0.680	74.233	0.674
Jan-May trawl	1	1995	76.546	0.690	74.696	0.658	76.525	0.690	76.654	0.684
Jan-May trawl	1	2000	71.624	0.788	69.527	0.738	71.594	0.788	71.846	0.788
Jan-May trawl	1	2005	71.617	1.000	69.370	0.973	71.470	1.003	71.789	1.001
Jun-Aug trawl	1	1977	54.789	1.766	54.355	1.800	54.769	1.764	54.617	1.733
Jun-Aug trawl	1	1985	62.466	1.743	62.278	1.689	62.465	1.744	62.486	1.686
Jun-Aug trawl	1	1990	67.336	1.337	67.112	1.252	67.337	1.337	67.721	1.354
Jun-Aug trawl	1	2000	70.081	2.419	68.911	2.226	70.058	2.410	70.219	2.451
Jun-Aug trawl	1	2005	75.244	3.107	73.206	2.836	75.024	3.059	75.335	3.157
Jun-Aug trawl	3	1977	4.399	0.270	4.351	0.275	4.397	0.270	4.379	0.269
Jun-Aug trawl	3	1985	4.994	0.229	4.994	0.224	4.995	0.229	4.989	0.223
Jun-Aug trawl	3	1990	5.084	0.152	5.088	0.147	5.084	0.152	5.137	0.151
Jun-Aug trawl	3	2000	5.726	0.176	5.699	0.175	5.724	0.176	5.734	0.177
Jun-Aug trawl	3	2005	6.121	0.167	6.078	0.168	6.114	0.166	6.125	0.168
Jun-Aug trawl	6	1977	8.388	32.362	2.318	2.161	8.364	32.716	8.018	37.543
Jun-Aug trawl	6	1985	-0.626	0.514	-0.761	0.492	-0.629	0.514	-0.691	0.503
Jun-Aug trawl	6	1990	-1.703	0.562	-1.762	0.530	-1.702	0.561	-1.737	0.571
Jun-Aug trawl	6	2000	-0.397	0.937	-0.709	0.770	-0.401	0.932	-0.346	0.950
Jun-Aug trawl	6	2005	-1.386	1.763	-1.491	1.351	-1.375	1.709	-1.321	1.756
Sep-Dec trawl	1	1977	44.846	4.597	45.165	4.641	44.848	4.598	44.743	4.582
Sep-Dec trawl	1	1980	55.608	3.018	55.134	2.943	55.723	3.034	55.666	3.012
Sep-Dec trawl	1	1985	64.480	0.237	64.512	0.220	64.479	0.251	64.512	0.223
Sep-Dec trawl	1	1990	63.500	3.499	61.025	3.338	63.476	3.499	62.370	2.981
Sep-Dec trawl	1	1995	79.462	0.315	77.977	4.150	79.461	0.324	79.462	0.321
Sep-Dec trawl	1	2000	71.754	2.381	69.829	2.216	71.723	2.377	72.028	2.411
Sep-Dec trawl	1	2005	79.466	0.720	76.252	3.402	79.305	4.234	79.474	0.538
Sep-Dec trawl	2	1977	0.369	0.133	0.360	0.136	0.369	0.134	0.373	0.132
Sep-Dec trawl	2	1980	0.887	0.092	0.017	0.121	0.418	0.107	0.422	0.105
Sep-Dec trawl	2	1985	-8.698	27.643	-8.647	28.441	-8.684	27.852	-8.633	28.656
Sep-Dec trawl	2	1990	0.619	0.137	0.711	0.119	0.620	0.137	0.662	0.112
Sep-Dec trawl	2	1995	-7.988	37.936	-2.783	2.812	-7.968	38.186	-7.971	38.155
Sep-Dec trawl	2	2000	-1.132	0.310	-0.911	0.231	-1.128	0.309	-1.167	0.325
Sep-Dec trawl	2	2005	-7.356	45.720	-2.004	1.057	-4.917	24.209	-7.566	43.296
Sep-Dec trawl	3	1977	3.695	0.912	3.767	0.908	3.695	0.912	3.681	0.917
Sep-Dec trawl	3	1980	4.888	0.367	4.849	0.367	4.897	0.366	4.896	0.366
Sep-Dec trawl	3	1985	5.753	0.145	5.740	0.140	5.754	0.145	5.784	0.149
Sep-Dec trawl	3	1990	5.405	0.292	5.213	0.310	5.403	0.292	5.321	0.265
Sep-Dec trawl	3	1995	6.339	0.062	6.322	0.187	6.339	0.062	6.344	0.062
Sep-Dec trawl	3	2000	5.847	0.143	5.783	0.144	5.846	0.143	5.866	0.143
Sep-Dec trawl	3	2005	6.174	0.070	6.087	0.167	6.169	0.184	6.172	0.067

Table 2.15e—Block-specific values of longline fishery selectivity parameters in Models A1-A4. See text for parameter definitions. "Block" refers to first year in the time block.

			Model A1		Model A2		Model A3		Model A4	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May longline	1	1977	70.665	1.598	67.263	1.439	70.603	1.606	69.811	1.630
Jan-May longline	1	1985	80.978	1.654	79.148	1.548	80.919	1.655	80.627	1.614
Jan-May longline	1	1990	70.544	1.032	70.170	0.970	70.532	1.032	70.658	1.031
Jan-May longline	1	1995	74.888	1.116	73.587	0.881	74.882	1.114	74.936	1.120
Jan-May longline	1	2000	69.767	0.754	69.258	0.784	69.748	0.753	69.898	0.757
Jan-May longline	1	2005	70.016	0.946	68.835	0.627	70.350	0.845	70.146	0.954
Jan-May longline	2	1977	-0.095	0.216	-0.408	0.213	-0.112	0.205	-0.024	0.212
Jan-May longline	2	1985	-0.080	0.467	-4.780	16.893	-0.103	0.473	-0.068	0.425
Jan-May longline	2	1990	-0.516	0.519	-8.670	28.088	-0.526	0.543	-0.512	0.439
Jan-May longline	2	1995	-4.032	7.570	-8.980	22.993	-4.524	12.193	-3.810	6.212
Jan-May longline	2	2000	-1.494	0.377	-3.963	2.618	-1.528	0.364	-1.471	0.377
Jan-May longline	2	2005	-8.335	33.220	-9.581	11.155	-8.503	30.716	-8.208	35.074
Jan-May longline	3	1977	5.579	0.092	5.401	0.096	5.576	0.092	5.534	0.098
Jan-May longline	3	1985	6.048	0.072	5.971	0.071	6.046	0.072	6.049	0.072
Jan-May longline	3	1990	5.286	0.086	5.273	0.083	5.285	0.086	5.295	0.086
Jan-May longline	3	1995	5.417	0.081	5.362	0.072	5.416	0.081	5.423	0.081
Jan-May longline	3	2000	5.070	0.069	5.064	0.073	5.069	0.069	5.077	0.069
Jan-May longline	3	2005	5.022	0.086	4.951	0.063	5.035	0.073	5.029	0.086
Jan-May longline	6	1977	-1.123	0.493	-1.138	0.586	-1.142	0.500	-1.164	0.475
Jan-May longline	6	1985	0.571	0.935	1.382	0.708	0.544	0.931	0.422	0.840
Jan-May longline	6	1990	1.379	0.829	1.417	0.556	1.365	0.832	1.230	0.729
Jan-May longline	6	1995	1.262	0.614	0.529	0.396	1.252	0.612	1.303	0.632
Jan-May longline	6	2000	-0.012	0.307	-0.410	0.266	-0.023	0.307	0.052	0.316
Jan-May longline	6	2005	0.473	0.326	-0.125	0.240	0.421	0.285	0.534	0.339
Jun-Aug longline	1	1977	62.992	2.730	62.510	2.671	62.977	2.725	62.997	2.700
Jun-Aug longline	1	1980	58.132	0.965	57.470	0.964	58.122	0.964	58.024	0.952
Jun-Aug longline	1	1990	69.792	4.552	69.141	4.174	69.783	4.549	69.991	4.574
Jun-Aug longline	1	2000	71.596	2.677	69.990	2.631	71.451	2.692	71.806	2.690
Jun-Aug longline	3	1977	5.034	0.285	5.015	0.292	5.033	0.285	5.038	0.284
Jun-Aug longline	3	1980	4.322	0.157	4.271	0.165	4.322	0.157	4.319	0.157
Jun-Aug longline	3	1990	5.072	0.492	5.040	0.483	5.071	0.492	5.087	0.492
Jun-Aug longline	3	2000	4.626	0.327	4.509	0.352	4.620	0.331	4.648	0.325
Jun-Aug longline	6	1977	-8.123	36.049	-4.739	13.605	-8.124	36.037	-8.136	35.861
Jun-Aug longline	6	1980	0.002	0.629	-0.409	0.592	-0.010	0.628	-0.105	0.605
Jun-Aug longline	6	1990	-3.755	13.329	-3.699	10.606	-3.758	13.343	-3.792	13.709
Jun-Aug longline	6	2000	7.210	48.033	1.342	2.566	7.106	49.283	7.451	45.048
Sep-Dec longline	1	1977	66.105	1.908	65.061	2.230	66.168	1.907	66.192	1.825
Sep-Dec longline	1	1980	58.213	0.574	57.700	0.523	58.204	0.574	58.112	0.566
Sep-Dec longline	1	1990	70.036	0.772	69.460	0.801	70.277	0.815	70.446	0.819
Sep-Dec longline	3	1977	5.125	0.169	5.077	0.201	5.131	0.168	5.135	0.163
Sep-Dec longline	3	1980	4.407	0.082	4.360	0.079	4.406	0.082	4.399	0.082
Sep-Dec longline	3	1990	4.976	0.074	4.968	0.078	4.996	0.076	5.005	0.075
Sep-Dec longline	4	1977	5.097	0.355	5.174	0.622	5.128	0.350	5.135	0.338
Sep-Dec longline	4	1980	-3.093	9.799	-0.522	14.455	-1.112	4.380	-0.303	2.777
Sep-Dec longline	4	1990	-10.000	_	-1.121	14.914	-7.583	47.346	-7.779	39.938
Sep-Dec longline	6	1977	-7.406	36.424	-6.627	28.599	-7.771	37.203	-8.058	35.343
Sep-Dec longline	6	1980	-0.115	0.172	-0.394	0.153	-0.121	0.172	-0.189	0.166
Sep-Dec longline	6	1990	-0.057	0.229	-0.394	0.197	-0.040	0.233	0.023	0.241

Table 2.15f—Block-specific values of pot fishery selectivity parameters in Models A1-A4. See text for parameter definitions. "Block" refers to first year in the time block.

			Model A1		Model A2		Model A3		Model A4	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD
Jan-May pot	1	1977	68.889	0.457	68.525	0.446	68.884	0.457	68.858	0.457
Jan-May pot	1	1995	71.811	0.396	71.200	0.390	71.807	0.396	71.846	0.396
Jan-May pot	1	2000	68.806	0.492	67.901	0.421	68.791	0.491	68.901	0.501
Jan-May pot	1	2005	68.512	0.474	67.705	0.434	68.446	0.473	68.575	0.477
Jan-May pot	3	1977	4.740	0.054	4.727	0.054	4.740	0.054	4.744	0.054
Jan-May pot	3	1995	4.877	0.041	4.849	0.042	4.876	0.041	4.883	0.041
Jan-May pot	3	2000	4.862	0.050	4.816	0.047	4.861	0.050	4.866	0.050
Jan-May pot	3	2005	4.709	0.052	4.669	0.051	4.707	0.052	4.715	0.052
Jan-May pot	4	1977	4.273	0.226	4.241	0.206	4.273	0.226	4.325	0.223
Jan-May pot	4	1995	3.754	0.379	3.847	0.300	3.756	0.377	3.737	0.385
Jan-May pot	4	2000	3.857	0.396	4.153	0.269	3.864	0.394	3.790	0.411
Jan-May pot	4	2005	3.335	0.475	3.751	0.313	3.364	0.464	3.260	0.512
Jan-May pot	6	1977	-1.931	0.280	-1.956	0.257	-1.932	0.280	-1.985	0.291
Jan-May pot	6	1995	-0.443	0.225	-0.770	0.197	-0.446	0.225	-0.421	0.226
Jan-May pot	6	2000	-0.207	0.218	-0.704	0.193	-0.215	0.217	-0.144	0.219
Jan-May pot	6	2005	0.641	0.248	0.043	0.184	0.610	0.245	0.728	0.260
Jun-Aug pot	1	1977	67.744	3.051	67.595	2.882	67.744	3.049	67.944	3.061
Jun-Aug pot	1	1995	77.351	1.963	75.914	1.820	77.339	1.960	77.600	1.921
Jun-Aug pot	1	2000	67.462	1.026	66.566	1.003	67.446	1.029	67.506	1.008
Jun-Aug pot	3	1977	4.620	0.468	4.614	0.461	4.620	0.468	4.641	0.465
Jun-Aug pot	3	1995	5.090	0.190	5.033	0.193	5.090	0.190	5.113	0.183
Jun-Aug pot	3	2000	4.551	0.137	4.490	0.141	4.550	0.138	4.552	0.135
Sep-Dec pot	1	1977	71.262	1.393	70.760	1.335	71.251	1.392	71.521	1.402
Sep-Dec pot	1	1995	73.066	1.587	72.038	1.484	73.058	1.585	73.071	1.603
Sep-Dec pot	1	2000	66.995	0.909	66.286	0.869	66.981	0.907	67.059	0.916
Sep-Dec pot	1	2005	66.800	0.812	66.007	0.789	66.731	0.814	66.829	0.816
Sep-Dec pot	3	1977	5.002	0.161	4.981	0.161	5.001	0.161	5.028	0.161
Sep-Dec pot	3	1995	5.072	0.160	5.027	0.161	5.071	0.160	5.073	0.161
Sep-Dec pot	3	2000	4.808	0.106	4.769	0.107	4.806	0.106	4.815	0.107
Sep-Dec pot	3	2005	4.692	0.098	4.651	0.100	4.690	0.099	4.694	0.099
Sep-Dec pot	6	1977	-1.291	0.699	-1.431	0.696	-1.296	0.700	-1.336	0.709
Sep-Dec pot	6	1995	0.464	0.878	-0.113	0.665	0.457	0.876	0.538	0.908
Sep-Dec pot	6	2000	0.028	0.410	-0.480	0.342	0.017	0.409	0.105	0.423
Sep-Dec pot	6	2005	0.021	0.355	-0.459	0.303	-0.002	0.352	0.087	0.362

Table 2.15g—Block-specific values of trawl fishery selectivity parameters in Models B1, D1, and E1. See text for parameter definitions. "Block" refers to first year in the time block.

			Model B1		Model D1		Model E1	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD
Jan-May trawl	1	1977	65.431	1.297	68.074	1.305	67.227	1.265
Jan-May trawl	1	1990	75.193	0.716	77.586	0.726	76.244	0.685
Jan-May trawl	1	1995	77.177	0.724	79.724	0.749	77.437	0.683
Jan-May trawl	1	2000	71.630	0.793	74.565	0.811	71.915	0.749
Jan-May trawl	1	2005	72.044	1.077	74.662	1.043	72.888	1.002
Jun-Aug trawl	1	1977	55.048	1.718	60.464	2.236	60.867	1.938
Jun-Aug trawl	1	1985	61.665	1.541	61.509	1.789	61.912	1.647
Jun-Aug trawl	1	1990	67.183	1.388	65.146	1.308	66.465	1.373
Jun-Aug trawl	1	2000	69.560	2.566	71.156	2.835	69.717	2.298
Jun-Aug trawl	1	2005	78.073	5.722	80.267	5.382	78.246	4.828
Jun-Aug trawl	3	1977	4.483	0.267	5.090	0.257	5.090	0.228
Jun-Aug trawl	3	1985	4.913	0.217	4.914	0.239	4.936	0.223
Jun-Aug trawl	3	1990	5.127	0.155	4.907	0.160	5.042	0.156
Jun-Aug trawl	3	2000	5.780	0.193	5.821	0.197	5.773	0.181
Jun-Aug trawl	3	2005	6.382	0.255	6.401	0.224	6.360	0.221
Jun-Aug trawl	6	1977	-0.040	0.456				
Jun-Aug trawl	6	1985	-1.397	0.492				
Jun-Aug trawl	6	1990	-2.169	0.793				
Jun-Aug trawl	6	2000	-0.761	1.102				
Jun-Aug trawl	6	2005	-2.445	6.103				
Sep-Dec trawl	1	1977	44.166	3.892	45.675	4.446	47.038	4.672
Sep-Dec trawl	1	1980	57.071	2.809	55.879	3.325	56.794	3.248
Sep-Dec trawl	1	1985	61.115	2.235	61.776	2.903	64.526	0.210
Sep-Dec trawl	1	1990	62.460	2.870	66.488	3.414	65.406	3.494
Sep-Dec trawl	1	1995	75.994	2.061	77.270	2.685	79.467	0.355
Sep-Dec trawl	1	2000	72.006	1.630	72.711	1.765	72.191	2.503
Sep-Dec trawl	1	2005	79.966	2.726	81.979	3.627	84.028	5.635
Sep-Dec trawl	2	1977	0.063	0.634	-0.713	0.684	-1.258	0.375
Sep-Dec trawl	2	1980	-6.363	50.991	-1.196	0.825	-0.981	0.255
Sep-Dec trawl	2	1985	-8.991	22.797	-8.933	23.799	-8.665	28.152
Sep-Dec trawl	2	1990	-0.063	0.378	-0.296	0.681	0.550	0.145
Sep-Dec trawl	2	1995	-8.817	25.732	-8.836	25.428	-7.892	39.224
Sep-Dec trawl	2	2000	-8.449	31.456	-8.967	23.219	-1.192	0.346
Sep-Dec trawl	2	2005	-8.231	34.643	-8.316	33.439	-3.771	12.989
Sep-Dec trawl	3	1977	3.703	0.907	3.863	0.926	3.955	0.890
Sep-Dec trawl	3	1980	5.032	0.323	4.954	0.386	5.021	0.370
Sep-Dec trawl	3	1985	5.573	0.243	5.601	0.280	5.765	0.153
Sep-Dec trawl	3	1990	5.363	0.259	5.625	0.251	5.564	0.270
Sep-Dec trawl	3	1995	6.328	0.122	6.317	0.139	6.458	0.069
Sep-Dec trawl	3	2000	5.934	0.114	5.915	0.116	5.936	0.151
Sep-Dec trawl	3	2005	6.329	0.132	6.344	0.155	6.448	0.210

Table 2.15h—Block-specific values of longline fishery selectivity parameters in Models B1, D1, and E1. See text for parameter definitions. "Block" refers to first year in the time block.

			Model B1		Model D1		Model E1	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD
Jan-May longline	1	1977	57.860	1.237	66.605	1.424	64.555	1.465
Jan-May longline	1	1985	73.581	1.574	78.635	1.150	77.597	1.039
Jan-May longline	1	1990	71.304	1.095	72.759	1.092	71.901	1.056
Jan-May longline	1	1995	75.270	1.208	76.687	1.118	74.727	1.059
Jan-May longline	1	2000	69.252	0.756	70.749	0.769	69.687	0.757
Jan-May longline	1	2005	71.395	0.871	71.737	0.756	70.750	0.755
Jan-May longline	2	1977	0.308	2.497	-1.491	0.295	0.580	0.059
Jan-May longline	2	1985	-1.500	7.966	-9.371	15.684	1.716	0.048
Jan-May longline	2	1990	0.193	5.522	0.149	0.575	1.975	0.077
Jan-May longline	2	1995	-2.315	56.304	1.915	7.287	2.252	39.517
Jan-May longline	2	2000	-0.919	5.373	-0.973	0.521	-0.889	0.077
Jan-May longline	2	2005	-2.510	23.454	6.780	52.811	2.297	33.663
Jan-May longline	3	1977	4.670	0.150	5.376	0.101	5.230	0.122
Jan-May longline	3	1985	5.754	0.092	5.917	0.061	5.897	0.061
Jan-May longline	3	1990	5.367	0.089	5.415	0.084	5.380	0.085
Jan-May longline	3	1995	5.498	0.086	5.532	0.078	5.462	0.081
Jan-May longline	3	2000	5.084	0.073	5.147	0.070	5.104	0.072
Jan-May longline	3	2005	5.196	0.069	5.183	0.062	5.138	0.064
Jan-May longline	6	1977	-0.431	0.307				
Jan-May longline	6	1985	0.714	0.280				
Jan-May longline	6	1990	0.795	0.742				
Jan-May longline	6	1995	2.094	0.923				
Jan-May longline	6	2000	0.124	0.320				
Jan-May longline	6	2005	1.243	0.479				
Jun-Aug longline	1	1977	55.712	2.742	56.070	2.044	57.108	2.377
Jun-Aug longline	1	1980	57.042	1.021	57.249	0.983	57.047	0.967
Jun-Aug longline	1	1990	71.069	4.378	70.828	5.382	69.998	5.109
Jun-Aug longline	1	2000	74.267	3.388	78.891	3.602	76.867	3.144
Jun-Aug longline	3	1977	4.393	0.426	4.371	0.344	4.490	0.364
Jun-Aug longline	3	1980	4.310	0.175	4.269	0.172	4.247	0.172
Jun-Aug longline	3	1990	5.193	0.471	5.151	0.537	5.122	0.537
Jun-Aug longline	3	2000	4.870	0.348	5.183	0.295	5.059	0.292
Jun-Aug longline	6	1977	0.520	0.845				
Jun-Aug longline	6	1980	-0.707	0.246				
Jun-Aug longline	6	1990	-1.320	2.263				
Jun-Aug longline	6	2000	8.131	36.047				
Sep-Dec longline	1	1977	57.387	1.706	61.858	2.063	60.635	2.433
Sep-Dec longline	1	1980	56.476	0.491	56.267	0.512	57.650	0.468
Sep-Dec longline	1	1990	70.718	0.921	70.571	0.775	73.139	1.405
Sep-Dec longline	3	1977	4.423	0.243	4.880	0.221	4.727	0.271
Sep-Dec longline	3	1980	4.247	0.080	4.197	0.085	4.358	0.075
Sep-Dec longline	3	1990	5.060	0.085	5.015	0.077	5.206	0.111
Sep-Dec longline	4	1977	8.362	2.504	6.123	0.314	6.630	0.828
Sep-Dec longline	4	1980	4.089	0.197	6.195	0.102	4.016	0.232
Sep-Dec longline	4	1990	2.505	0.836	7.532	0.795	0.997	2.234
Sep-Dec longline	6	1977	-8.643	28.531				
Sep-Dec longline	6	1980	-1.295	0.125				
Sep-Dec longline	6	1990	0.464	0.314				

Table 2.15i—Block-specific values of pot fishery selectivity parameters in Models B1, D1, and E1. See text for parameter definitions. "Block" refers to first year in the time block.

			Model B1		Model D1		Model E1	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD
Jan-May pot	1	1977	68.873	0.470	68.830	0.428	69.443	0.576
Jan-May pot	1	1995	72.788	0.592	72.123	0.444	71.716	0.419
Jan-May pot	1	2000	68.470	0.471	68.896	0.456	68.340	0.431
Jan-May pot	1	2005	69.301	0.568	70.066	0.568	69.406	0.554
Jan-May pot	3	1977	4.761	0.056	4.722	0.053	4.800	0.063
Jan-May pot	3	1995	4.998	0.055	4.909	0.046	4.905	0.045
Jan-May pot	3	2000	4.883	0.051	4.877	0.049	4.859	0.049
Jan-May pot	3	2005	4.829	0.058	4.857	0.057	4.820	0.057
Jan-May pot	4	1977	4.520	0.221	5.246	0.109	3.695	0.311
Jan-May pot	4	1995	1.552	0.806	6.105	0.179	4.442	0.255
Jan-May pot	4	2000	3.832	0.361	6.526	0.222	4.606	0.230
Jan-May pot	4	2005	2.707	1.296	10.000		10.000	
Jan-May pot	6	1977	-2.169	0.352				
Jan-May pot	6	1995	0.002	0.154				
Jan-May pot	6	2000	-0.146	0.203				
Jan-May pot	6	2005	1.583	0.486				
Jun-Aug pot	1	1977	68.738	3.276	67.695	3.356	69.138	3.258
Jun-Aug pot	1	1995	77.611	2.000	78.656	2.207	77.434	1.988
Jun-Aug pot	1	2000	66.921	1.037	67.480	1.045	67.226	1.029
Jun-Aug pot	3	1977	4.767	0.459	4.595	0.490	4.770	0.446
Jun-Aug pot	3	1995	5.151	0.195	5.151	0.195	5.135	0.197
Jun-Aug pot	3	2000	4.523	0.143	4.559	0.142	4.549	0.141
Sep-Dec pot	1	1977	72.024	1.536	69.891	1.646	70.125	1.533
Sep-Dec pot	1	1995	73.094	1.692	74.793	1.904	73.231	1.653
Sep-Dec pot	1	2000	66.699	0.969	66.844	0.969	66.055	0.914
Sep-Dec pot	1	2005	67.172	0.930	68.289	0.977	68.069	0.937
Sep-Dec pot	3	1977	5.097	0.167	4.891	0.189	4.918	0.179
Sep-Dec pot	3	1995	5.133	0.171	5.206	0.173	5.142	0.170
Sep-Dec pot	3	2000	4.821	0.115	4.807	0.115	4.746	0.114
Sep-Dec pot	3	2005	4.781	0.110	4.851	0.109	4.848	0.107
Sep-Dec pot	6	1977	-1.552	0.841				
Sep-Dec pot	6	1995	0.731	1.045				
Sep-Dec pot	6	2000	-0.012	0.404				
Sep-Dec pot	6	2005	0.768	0.545				

Table 2.15j—Block-specific values of trawl fishery selectivity parameters in Models B2, D2, and E2. See text for parameter definitions. “Block” refers to first year in the time block.

			Model B2		Model D2		Model E2	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD
Jan-May trawl	1	1977	64.490	1.322	67.666	1.310	67.188	1.275
Jan-May trawl	1	1990	75.301	0.716	77.690	0.733	76.115	0.689
Jan-May trawl	1	1995	76.779	0.724	79.581	0.766	76.922	0.667
Jan-May trawl	1	2000	71.489	0.784	74.414	0.818	71.523	0.748
Jan-May trawl	1	2005	70.515	1.114	73.685	1.069	71.848	1.032
Jun-Aug trawl	1	1977	55.049	1.682	60.046	2.248	60.890	1.823
Jun-Aug trawl	1	1985	61.111	1.557	61.049	1.744	62.269	1.705
Jun-Aug trawl	1	1990	67.256	1.299	65.265	1.318	66.983	1.385
Jun-Aug trawl	1	2000	69.469	2.523	70.621	2.719	69.303	2.180
Jun-Aug trawl	1	2005	76.055	4.315	78.659	5.683	76.667	4.210
Jun-Aug trawl	3	1977	4.535	0.263	5.068	0.264	5.088	0.216
Jun-Aug trawl	3	1985	4.913	0.225	4.878	0.239	4.991	0.225
Jun-Aug trawl	3	1990	5.109	0.148	4.924	0.160	5.101	0.156
Jun-Aug trawl	3	2000	5.768	0.192	5.785	0.195	5.763	0.177
Jun-Aug trawl	3	2005	6.377	0.221	6.404	0.250	6.350	0.210
Jun-Aug trawl	6	1977	-0.129	0.419				
Jun-Aug trawl	6	1985	-1.512	0.463				
Jun-Aug trawl	6	1990	-2.082	0.728				
Jun-Aug trawl	6	2000	-0.769	1.035				
Jun-Aug trawl	6	2005	-1.643	2.705				
Sep-Dec trawl	1	1977	44.117	3.888	45.326	4.380	46.504	4.671
Sep-Dec trawl	1	1980	55.591	3.773	55.517	3.333	55.616	3.188
Sep-Dec trawl	1	1985	62.653	4.151	61.005	2.813	64.493	0.610
Sep-Dec trawl	1	1990	64.226	3.787	66.703	3.434	65.412	3.694
Sep-Dec trawl	1	1995	76.390	3.303	76.977	2.674	77.377	3.469
Sep-Dec trawl	1	2000	74.500	0.594	72.395	1.794	73.019	2.855
Sep-Dec trawl	1	2005	80.615	4.748	81.386	3.691	80.915	4.585
Sep-Dec trawl	2	1977	0.394	0.114	-0.747	0.830	-1.220	0.362
Sep-Dec trawl	2	1980	-1.479	0.427	-1.277	0.810	-0.425	0.169
Sep-Dec trawl	2	1985	-3.053	2.258	-8.970	23.167	-7.839	39.679
Sep-Dec trawl	2	1990	0.589	0.152	-0.356	0.686	0.546	0.156
Sep-Dec trawl	2	1995	-0.845	0.407	-8.839	25.378	-2.415	1.623
Sep-Dec trawl	2	2000	-7.631	42.049	-9.040	21.935	-2.978	1.941
Sep-Dec trawl	2	2005	-1.579	1.218	-8.327	33.273	-1.684	1.315
Sep-Dec trawl	3	1977	3.682	0.902	3.818	0.927	3.916	0.915
Sep-Dec trawl	3	1980	4.966	0.446	4.938	0.393	4.942	0.387
Sep-Dec trawl	3	1985	5.794	0.322	5.550	0.277	5.804	0.158
Sep-Dec trawl	3	1990	5.492	0.303	5.640	0.249	5.580	0.282
Sep-Dec trawl	3	1995	6.373	0.166	6.320	0.139	6.406	0.168
Sep-Dec trawl	3	2000	6.045	0.066	5.897	0.119	5.988	0.162
Sep-Dec trawl	3	2005	6.424	0.205	6.368	0.164	6.388	0.191

Table 2.15k—Block-specific values of longline fishery selectivity parameters in Models B2, D2, and E2. See text for parameter definitions. "Block" refers to first year in the time block.

			Model B2		Model D2		Model E2	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD
Jan-May longline	1	1977	57.333	0.753	65.562	1.649	65.549	1.260
Jan-May longline	1	1985	71.311	2.440	77.741	1.195	78.942	1.157
Jan-May longline	1	1990	71.176	1.073	72.944	1.119	71.971	1.068
Jan-May longline	1	1995	75.139	1.208	76.608	1.132	74.276	1.028
Jan-May longline	1	2000	68.992	0.734	70.348	0.767	69.076	0.732
Jan-May longline	1	2005	73.798	1.137	73.746	0.841	71.072	0.749
Jan-May longline	2	1977	0.346	0.707	-1.512	0.325	0.535	0.056
Jan-May longline	2	1985	-1.109	1.703	-9.425	14.555	1.674	0.544
Jan-May longline	2	1990	-0.364	0.558	0.052	0.629	2.417	41.088
Jan-May longline	2	1995	-1.836	6.448	5.520	66.371	2.360	42.860
Jan-May longline	2	2000	-0.855	1.447	-1.369	0.768	-0.839	0.073
Jan-May longline	2	2005	-4.496	53.143	6.726	53.461	2.463	41.130
Jan-May longline	3	1977	4.632	0.098	5.317	0.122	5.303	0.102
Jan-May longline	3	1985	5.714	0.145	5.894	0.064	5.955	0.064
Jan-May longline	3	1990	5.342	0.088	5.425	0.085	5.396	0.086
Jan-May longline	3	1995	5.499	0.087	5.535	0.079	5.454	0.081
Jan-May longline	3	2000	5.060	0.072	5.118	0.071	5.072	0.073
Jan-May longline	3	2005	5.353	0.082	5.288	0.068	5.100	0.067
Jan-May longline	6	1977	-0.392	0.310				
Jan-May longline	6	1985	0.780	0.289				
Jan-May longline	6	1990	1.269	0.730				
Jan-May longline	6	1995	1.960	1.087				
Jan-May longline	6	2000	0.072	0.310				
Jan-May longline	6	2005	1.387	0.548				
Jun-Aug longline	1	1977	55.639	2.719	55.759	2.060	56.950	2.451
Jun-Aug longline	1	1980	56.941	1.016	56.948	0.987	57.382	0.997
Jun-Aug longline	1	1990	70.872	4.205	70.733	5.320	69.849	4.985
Jun-Aug longline	1	2000	73.858	3.423	78.952	3.802	75.492	3.182
Jun-Aug longline	3	1977	4.382	0.426	4.343	0.353	4.486	0.375
Jun-Aug longline	3	1980	4.315	0.177	4.243	0.175	4.282	0.172
Jun-Aug longline	3	1990	5.170	0.463	5.143	0.535	5.121	0.533
Jun-Aug longline	3	2000	4.897	0.363	5.240	0.311	4.991	0.317
Jun-Aug longline	6	1977	0.559	0.842				
Jun-Aug longline	6	1980	-0.740	0.234				
Jun-Aug longline	6	1990	-1.298	2.160				
Jun-Aug longline	6	2000	8.033	37.405				
Sep-Dec longline	1	1977	57.432	1.710	61.135	2.155	59.559	2.628
Sep-Dec longline	1	1980	56.329	0.503	55.982	0.527	57.704	0.526
Sep-Dec longline	1	1990	70.354	0.928	70.234	0.777	71.342	0.917
Sep-Dec longline	3	1977	4.434	0.244	4.819	0.238	4.623	0.312
Sep-Dec longline	3	1980	4.258	0.081	4.171	0.088	4.381	0.081
Sep-Dec longline	3	1990	5.061	0.087	5.012	0.079	5.110	0.083
Sep-Dec longline	4	1977	8.678	3.523	6.210	0.326	6.069	0.778
Sep-Dec longline	4	1980	4.075	0.194	6.162	0.100	1.630	1.133
Sep-Dec longline	4	1990	2.687	0.784	7.488	0.747	-9.385	17.378
Sep-Dec longline	6	1977	-8.554	29.895				
Sep-Dec longline	6	1980	-1.336	0.118				
Sep-Dec longline	6	1990	0.392	0.300				

Table 2.15l—Block-specific values of pot fishery selectivity parameters in Models B2, D2, and E2. See text for parameter definitions. "Block" refers to first year in the time block.

			Model B2		Model D2		Model E2	
Fishery	Parm.	Block	Value	SD	Value	SD	Value	SD
Jan-May pot	1	1977	69.014	0.472	68.934	0.438	69.388	0.581
Jan-May pot	1	1995	72.688	0.597	72.025	0.454	73.275	0.660
Jan-May pot	1	2000	68.274	0.454	68.506	0.441	68.188	0.437
Jan-May pot	1	2005	69.222	0.578	69.894	0.566	68.457	0.515
Jan-May pot	3	1977	4.762	0.056	4.735	0.054	4.814	0.064
Jan-May pot	3	1995	4.997	0.056	4.909	0.047	5.043	0.059
Jan-May pot	3	2000	4.861	0.050	4.844	0.049	4.859	0.050
Jan-May pot	3	2005	4.844	0.060	4.852	0.058	4.767	0.057
Jan-May pot	4	1977	4.342	0.236	5.254	0.112	3.396	0.326
Jan-May pot	4	1995	1.663	0.774	6.144	0.186	0.869	1.170
Jan-May pot	4	2000	3.864	0.337	6.488	0.213	4.073	0.259
Jan-May pot	4	2005	2.835	0.953	10.000		10.000	
Jan-May pot	6	1977	-1.968	0.305				
Jan-May pot	6	1995	-0.033	0.150				
Jan-May pot	6	2000	-0.206	0.196				
Jan-May pot	6	2005	1.337	0.396				
Jun-Aug pot	1	1977	68.609	3.138	67.884	3.341	68.987	3.425
Jun-Aug pot	1	1995	77.439	2.042	78.653	2.221	77.077	2.000
Jun-Aug pot	1	2000	67.011	1.036	67.482	1.025	67.027	1.292
Jun-Aug pot	3	1977	4.719	0.453	4.610	0.483	4.761	0.464
Jun-Aug pot	3	1995	5.154	0.201	5.168	0.196	5.120	0.201
Jun-Aug pot	3	2000	4.540	0.142	4.569	0.138	4.556	0.163
Sep-Dec pot	1	1977	71.803	1.458	70.056	1.657	70.683	1.518
Sep-Dec pot	1	1995	72.912	1.657	74.664	1.912	73.124	1.592
Sep-Dec pot	1	2000	66.799	0.942	66.668	0.950	66.269	0.934
Sep-Dec pot	1	2005	66.650	0.946	67.870	0.968	67.560	0.875
Sep-Dec pot	3	1977	5.054	0.164	4.899	0.189	4.970	0.175
Sep-Dec pot	3	1995	5.131	0.170	5.211	0.175	5.147	0.167
Sep-Dec pot	3	2000	4.824	0.112	4.781	0.114	4.778	0.115
Sep-Dec pot	3	2005	4.766	0.113	4.843	0.110	4.833	0.105
Sep-Dec pot	6	1977	-1.402	0.757				
Sep-Dec pot	6	1995	0.652	0.959				
Sep-Dec pot	6	2000	-0.067	0.380				
Sep-Dec pot	6	2005	0.673	0.494				

Table 2.15m—Base survey selectivity parameters for Models A1-A4. A blank under "SD" means the parameter was fixed. Fixed parameters may be over-written by block-specific values (see Table 2.15p). See text for parameter definitions.

		Model A1		Model A2		Model A3		Model A4	
Survey	Parm.	Value	SD	Value	SD	Value	SD	Value	SD
27-plus	1	0		0		0		0	
27-plus	2	0		0		0		0	
27-plus	3	0		0		0		0	
27-plus	4	0		0		0		0	
27-plus	5	0		0		0		0	
27-plus	6	0		0		0		0	
Sub-27	Logit sel at age 0	-1.812	0.250	-1.517	0.247	-1.811	0.251	-1.714	0.235
Sub-27	Logit sel at age 1	10		10		10		10	
Sub-27	Logit sel at age 2	-2.613	0.713	-2.204	0.736	-2.603	0.712	-2.695	0.756
Sub-27	Logit sel at age 3	-10		-10		-10		-10	
Sub-27	Logit sel at age 4	-10		-10		-10		-10	
Sub-27	Logit sel at age 5	-10		-10		-10		-10	
Sub-27	Logit sel at age 6	-10		-10		-10		-10	
Sub-27	Logit sel at age 7	-10		-10		-10		-10	
Sub-27	Logit sel at age 8	-10		-10		-10		-10	
Sub-27	Logit sel at age 9	-10		-10		-10		-10	
Sub-27	Logit sel at age 10	-10		-10		-10		-10	
Sub-27	Logit sel at age 11	-10		-10		-10		-10	
Sub-27	Logit sel at age 12	-10		-10		-10		-10	
Sub-27	Logit sel at age 13	-10		-10		-10		-10	
Sub-27	Logit sel at age 14	-10		-10		-10		-10	
Sub-27	Logit sel at age 15	-10		-10		-10		-10	
Sub-27	Logit sel at age 16	-10		-10		-10		-10	
Sub-27	Logit sel at age 17	-10		-10		-10		-10	
Sub-27	Logit sel at age 18	-10		-10		-10		-10	
Sub-27	Logit sel at age 19	-10		-10		-10		-10	
Sub-27	Logit sel at age 20	-10		-10		-10		-10	

Table 2.15n—Base survey selectivity parameters for Models B1, D1, and E1. A blank under "SD" means the parameter was fixed. Fixed parameters may be over-written by block-specific values (see Table 2.15q). See text for parameter definitions.

		Model B1		Model D1		Model E1	
Survey	Parm.	Value	SD	Value	SD	Value	SD
27-plus	1	0		0		0	
27-plus	2	0		0		0	
27-plus	3	0		0		0	
27-plus	4	0		0		0	
27-plus	5	0		0		0	
27-plus	6	0		-999		-0.847	
Sub-27	Logit sel at age 0	-1.005	0.144	-0.804	0.144	-0.854	0.145
Sub-27	Logit sel at age 1	10		10		10	
Sub-27	Logit sel at age 2	-1.005	0.153	-0.998	0.154	-0.981	0.154
Sub-27	Logit sel at age 3	-10		-10		-10	
Sub-27	Logit sel at age 4	-10		-10		-10	
Sub-27	Logit sel at age 5	-10		-10		-10	
Sub-27	Logit sel at age 6	-10		-10		-10	
Sub-27	Logit sel at age 7	-10		-10		-10	
Sub-27	Logit sel at age 8	-10		-10		-10	
Sub-27	Logit sel at age 9	-10		-10		-10	
Sub-27	Logit sel at age 10	-10		-10		-10	
Sub-27	Logit sel at age 11	-10		-10		-10	
Sub-27	Logit sel at age 12	-10		-10		-10	
Sub-27	Logit sel at age 13	-10		-10		-10	
Sub-27	Logit sel at age 14	-10		-10		-10	
Sub-27	Logit sel at age 15	-10		-10		-10	
Sub-27	Logit sel at age 16	-10		-10		-10	
Sub-27	Logit sel at age 17	-10		-10		-10	
Sub-27	Logit sel at age 18	-10		-10		-10	
Sub-27	Logit sel at age 19	-10		-10		-10	
Sub-27	Logit sel at age 20	-10		-10		-10	

Table 2.15o—Base survey selectivity parameters for Models B2, D2, and E2. A blank under "SD" means the parameter was fixed. Fixed parameters may be over-written by block-specific values (see Table 2.15r). See text for parameter definitions.

		Model B2		Model D2		Model E2	
Survey	Parm.	Value	SD	Value	SD	Value	SD
27-plus	1	0		0		0	
27-plus	2	0		0		0	
27-plus	3	0		0		0	
27-plus	4	0		0		0	
27-plus	5	0		0		0	
27-plus	6	0		-999		-0.405	
Sub-27	Logit sel at age 0	-1.782	0.164	-1.638	0.160	-1.578	0.147
Sub-27	Logit sel at age 1	10		10		10	
Sub-27	Logit sel at age 2	-1.260	0.451	-0.849	0.381	-0.516	0.323
Sub-27	Logit sel at age 3	-10		-10		-10	
Sub-27	Logit sel at age 4	-10		-10		-10	
Sub-27	Logit sel at age 5	-10		-10		-10	
Sub-27	Logit sel at age 6	-10		-10		-10	
Sub-27	Logit sel at age 7	-10		-10		-10	
Sub-27	Logit sel at age 8	-10		-10		-10	
Sub-27	Logit sel at age 9	-10		-10		-10	
Sub-27	Logit sel at age 10	-10		-10		-10	
Sub-27	Logit sel at age 11	-10		-10		-10	
Sub-27	Logit sel at age 12	-10		-10		-10	
Sub-27	Logit sel at age 13	-10		-10		-10	
Sub-27	Logit sel at age 14	-10		-10		-10	
Sub-27	Logit sel at age 15	-10		-10		-10	
Sub-27	Logit sel at age 16	-10		-10		-10	
Sub-27	Logit sel at age 17	-10		-10		-10	
Sub-27	Logit sel at age 18	-10		-10		-10	
Sub-27	Logit sel at age 19	-10		-10		-10	
Sub-27	Logit sel at age 20	-10		-10		-10	

Table 2.15p— Block-specific values of survey selectivity parameters for Models A1-A4. "Block" refers to first year in the time block. See text for parm. definitions.

			Model A1		Model A2		Model A3		Model A4	
Survey	Parm.	Block	Value	SD	Value	SD	Value	SD	Value	SD
27-plus	1	1977	2.420	0.389	4.154	0.102	2.420	0.389	2.661	0.399
27-plus	1	1996	3.068	0.018	4.473	0.157	3.071	0.018	3.063	0.018
27-plus	2	1977	-1.658	0.386	-3.613	1.473	-1.659	0.377	-1.775	0.229
27-plus	2	1996	-2.077	0.554	-2.234	3.889	-2.107	0.584	-2.151	0.423
27-plus	3	1977	-3.034	1.975	0.352	0.123	-3.030	1.967	-2.099	1.232
27-plus	3	1987	-4.279	28.192	0.482	0.146	-4.278	28.177	-3.996	43.522
27-plus	3	1990	-2.591	1.952	-0.099	0.175	-2.588	1.945	-1.115	1.302
27-plus	3	1993	-1.898	1.747	0.088	0.107	-1.897	1.740	-0.356	0.592
27-plus	3	1996	0.376	0.476	0.399	0.234	0.371	0.474	1.053	0.527
27-plus	3	1999	-0.257	0.490	0.684	0.178	-0.270	0.470	0.702	0.460
27-plus	3	2001	-0.731	0.122	0.875	0.141	-0.727	0.122	0.100	0.216
27-plus	3	2003	-0.582	0.189	0.305	0.154	-0.584	0.188	0.289	0.327
27-plus	3	2005	-0.743	0.434	0.466	0.187	-0.742	0.424	0.256	0.372
27-plus	3	2007	-1.156	0.224	0.651	0.147	-1.149	0.228	-0.643	0.227
27-plus	3	2009	-7.816	15.170	0.268	0.246	-7.728	15.468	-7.894	15.257
27-plus	4	1977	-7.258	9.216	0.014	0.779	-7.297	9.231	-2.584	37.661
27-plus	4	1996	2.291	0.656	-4.122	80.666	2.282	0.657	1.916	0.554
27-plus	5	1977	-6.412	2.219	-9.767	6.544	-6.415	2.223	-6.122	1.877
27-plus	5	1987	-1.706	1.290	-10.000		-1.719	1.302	-0.778	0.656
27-plus	5	1990	-10.000		-10.000		-10.000		-6.902	1.940
27-plus	5	1993	-10.000		-10.000		-10.000		-9.768	6.619
27-plus	5	1996	-5.572	3.214	-5.559	0.666	-5.595	3.221	-9.466	13.695
27-plus	5	1999	-10.000		-10.000		-10.000		-9.720	7.853
27-plus	5	2001	-10.000		-6.776	1.021	-10.000		-10.000	
27-plus	5	2003	-10.000		-10.000		-10.000		-10.000	
27-plus	5	2005	-8.464	30.517	-10.000		-8.548	29.430	-9.600	10.729
27-plus	5	2007	-10.000		-7.454	1.771	-10.000		-6.754	1.580
27-plus	5	2009	-10.000		-10.000		-9.778	6.293	-10.000	
27-plus	6	1977	-0.346	0.360	-2.204	0.369	-0.354	0.359	-0.635	0.350
27-plus	6	1996	-9.711	8.071	-1.196	0.327	-9.727	7.684	-10.000	

Table 2.15q— Block-specific values of survey selectivity parameters for Models B1, D1, and E1. "Block" refers to first year in the time block. See text for parm. definitions.

			Model B1		Model D1		Model E1	
Survey	Parm.	Block	Value	SD	Value	SD	Value	SD
27-plus	1	1977	3.943	0.063	4.027	0.163	4.229	0.231
27-plus	1	1987	2.986	0.003	2.838	0.279	2.049	0.012
27-plus	1	1990	4.055	0.262	3.797	0.177	3.779	0.194
27-plus	1	1993	4.669	0.305	4.750	0.288	4.560	0.329
27-plus	1	1996	5.213	0.224	5.075	0.170	5.219	0.221
27-plus	1	1999	3.759	0.227	3.833	0.219	3.742	0.227
27-plus	1	2001	3.747	0.189	3.850	0.211	3.733	0.210
27-plus	1	2003	4.018	0.232	2.113	0.021	3.967	0.196
27-plus	1	2005	5.017	0.306	4.868	0.331	5.080	0.295
27-plus	1	2007	2.772	0.100	2.812	0.101	2.772	0.099
27-plus	2	1977	-9.608	10.523	-10.000		-3.833	2.571
27-plus	2	1987	-8.531	29.118	-6.579	21.103	-1.727	0.649
27-plus	2	1990	-6.400	27.156	-9.364	15.823	-1.891	5.178
27-plus	2	1993	-1.871	0.802	-1.690	0.142	-2.148	1.223
27-plus	2	1996	-2.928	2.919	-9.613	10.429	-3.100	1.242
27-plus	2	1999	-1.287	0.070	-1.426	0.463	-1.415	1.088
27-plus	2	2001	-8.693	27.673	-0.950	0.206	-1.980	2.115
27-plus	2	2003	-1.634	0.647	-0.685	0.336	-1.607	0.600
27-plus	2	2005	-4.544	9.195	-9.459	13.840	-6.139	27.059
27-plus	2	2007	-1.430	0.587	-2.502	1.610	-1.352	1.501
27-plus	3	1977	0.541	0.083	0.699	0.157	0.837	0.197
27-plus	3	1987	-10.000		-0.715	0.648	-10.000	
27-plus	3	1990	0.530	0.230	0.379	0.195	0.363	0.209
27-plus	3	1993	1.185	0.213	1.200	0.198	1.122	0.234
27-plus	3	1996	1.337	0.142	1.252	0.121	1.346	0.140
27-plus	3	1999	0.375	0.277	0.413	0.259	0.361	0.278
27-plus	3	2001	0.551	0.190	0.657	0.204	0.552	0.207
27-plus	3	2003	0.555	0.257	-6.569	22.721	0.509	0.227
27-plus	3	2005	1.481	0.204	1.377	0.228	1.500	0.189
27-plus	3	2007	-0.415	0.157	-0.369	0.155	-0.415	0.156
27-plus	4	1977	-7.991	16.133	1.101	0.258	-4.142	28.110
27-plus	4	1987	1.043	0.320	2.494	0.255	-4.173	30.740
27-plus	4	1990	-6.075	29.500	2.412	0.323	-3.428	76.902
27-plus	4	1993	-1.896	5.778	-7.364	26.313	-6.398	18.590
27-plus	4	1996	-5.759	68.278	1.260	0.432	-5.163	38.371
27-plus	4	1999	-10.000		-2.198	8.173	-10.000	
27-plus	4	2001	2.355	0.332	-7.249	51.930	-1.589	15.469
27-plus	4	2003	-3.732	29.731	-2.040	8.639	-3.775	29.770
27-plus	4	2005	-0.673	3.164	2.511	0.613	-5.395	38.804
27-plus	4	2007	-2.227	23.819	2.668	1.360	-4.211	55.825
27-plus	6	1977	-2.123	0.228				
27-plus	6	1987	-2.947	0.561				
27-plus	6	1990	-1.136	0.336				
27-plus	6	1993	-5.410	1.917				
27-plus	6	1996	-1.548	0.584				
27-plus	6	1999	-10.000					
27-plus	6	2001	-9.661	9.286				
27-plus	6	2003	-1.784	0.610				
27-plus	6	2005	-1.602	0.678				
27-plus	6	2007	-1.745	0.813				

Table 2.15r— Block-specific values of survey selectivity parameters for Models B2, D2, and E2. "Block" refers to first year in the time block. See text for parm. definitions.

			Model B2		Model D2		Model E2	
Survey	Parm.	Block	Value	SD	Value	SD	Value	SD
27-plus	1	1977	3.951	0.057	3.984	0.169	4.172	0.215
27-plus	1	1987	2.035	0.010	3.451	0.282	2.048	0.015
27-plus	1	1990	3.994	0.002	4.097	0.131	4.104	0.149
27-plus	1	1993	4.772	0.255	4.619	0.208	4.746	0.242
27-plus	1	1996	5.497	0.276	5.296	0.209	5.320	0.234
27-plus	1	1999	2.537	0.828	2.601	0.794	3.444	0.290
27-plus	1	2001	4.136	0.246	4.247	0.263	4.080	0.242
27-plus	1	2003	4.420	0.391	4.478	0.348	3.940	0.194
27-plus	1	2005	5.015	0.041	5.274	0.319	5.013	0.020
27-plus	1	2007	2.314	0.142	2.391	0.131	2.804	0.115
27-plus	2	1977	-9.743	7.260	-10.000		-3.694	2.002
27-plus	2	1987	-2.046	0.178	-9.672	9.023	-1.759	0.565
27-plus	2	1990	-10.000		-9.603	10.647	-2.718	0.164
27-plus	2	1993	-2.897	2.176	-9.538	12.129	-3.943	0.908
27-plus	2	1996	-4.725	11.331	-9.157	19.833	-3.994	4.659
27-plus	2	1999	-1.001	0.193	-1.326	0.244	-1.389	0.538
27-plus	2	2001	-8.638	28.589	3.349	112.756	-2.078	7.501
27-plus	2	2003	-1.097	0.280	3.895	102.592	-1.827	0.389
27-plus	2	2005	-9.579	11.206	4.077	98.734	-9.655	9.421
27-plus	2	2007	-1.082	0.464	3.893	102.995	-1.359	1.454
27-plus	3	1977	0.630	0.100	0.686	0.165	0.779	0.190
27-plus	3	1987	-10.000		0.236	0.324	-10.000	
27-plus	3	1990	0.312	0.082	0.436	0.148	0.425	0.161
27-plus	3	1993	1.084	0.181	0.934	0.163	1.031	0.177
27-plus	3	1996	1.578	0.159	1.443	0.138	1.453	0.150
27-plus	3	1999	-1.429	3.081	-1.279	2.626	0.299	0.342
27-plus	3	2001	0.865	0.223	0.905	0.229	0.801	0.225
27-plus	3	2003	0.811	0.381	0.794	0.335	0.242	0.284
27-plus	3	2005	1.521	0.092	1.616	0.193	1.459	0.084
27-plus	3	2007	-0.853	0.238	-0.742	0.215	-0.305	0.177
27-plus	4	1977	-8.340	14.254	1.075	0.250	-4.128	27.736
27-plus	4	1987	0.241	0.746	2.136	0.252	-3.974	29.839
27-plus	4	1990	-10.000		2.799	0.346	-10.000	
27-plus	4	1993	-1.524	5.955	2.959	0.577	-10.000	
27-plus	4	1996	-4.323	30.514	3.331	1.376	-4.171	29.546
27-plus	4	1999	-10.000		-1.210	0.633	-10.000	
27-plus	4	2001	3.428	0.753	2.549	155.480	-2.756	80.703
27-plus	4	2003	-6.885	56.933	3.488	129.509	-2.554	38.566
27-plus	4	2005	-10.000		3.944	117.697	-10.000	
27-plus	4	2007	-3.877	30.656	3.339	134.388	-4.573	37.364
27-plus	6	1977	-2.179	0.224				
27-plus	6	1987	-2.840	0.575				
27-plus	6	1990	-1.510	0.349				
27-plus	6	1993	-1.888	0.501				
27-plus	6	1996	-0.428	0.449				
27-plus	6	1999	-10.000					
27-plus	6	2001	-6.901	51.795				
27-plus	6	2003	-10.000					
27-plus	6	2005	0.633	0.705				
27-plus	6	2007	-1.206	0.720				

Table 2.16a—Time series of mean length (cm) at age 1 as estimated by the ten models. Years 1993-2007 are shown, to correspond with the range for which observations are available. Mean = average, SE = standard error of the mean, correl. = correlation between estimates and data. For the second and third groups of models, green = within-group minimum (by row) and pink = within-group maximum (by row).

		Last year's model with different data sets				New models					
						Models with age composition data			Models w/o age composition data		
Year	Data	A1	A2	A3	A4	B1	D1	E1	B2	D2	E2
1993	20.85	20.94	20.94	20.94	20.94	20.44	21.01	20.78	21.17	21.21	20.21
1996	21.12	20.94	20.94	20.94	20.94	20.08	20.73	20.50	21.14	21.11	20.25
1999	20.58	20.94	20.94	20.94	20.94	20.43	21.13	20.83	20.73	20.98	19.86
2001	21.16	20.94	20.94	20.94	20.94	19.89	20.59	20.29	20.42	20.54	19.51
2003	21.13	20.94	20.94	20.94	20.94	21.70	22.13	21.97	22.16	22.10	20.87
2005	19.58	20.94	20.94	20.94	20.94	24.63	25.00	24.93	23.79	23.87	23.04
2007	19.24	20.94	20.94	20.94	20.94	25.63	26.31	26.02	18.86	19.12	23.94
Mean:	20.52	20.94	20.94	20.94	20.94	21.83	22.42	22.19	21.18	21.28	21.10
SE:	0.30	0.00	0.00	0.00	0.00	0.89	0.87	0.88	0.58	0.55	0.64
Correl:	n/a	0.00	0.00	0.00	0.00	-0.93	-0.94	-0.94	0.08	0.04	-0.92

Table 2.16b—Time series of mean length (cm) at age 2 as estimated by the ten models. Years 1987-2007 are shown, to correspond with the range for which observations are available. Mean = average, SE = standard error of the mean, correl. = correlation between estimates and data. For the second and third groups of models, green = within-group minimum (by row) and pink = within-group maximum (by row).

		Last year's model with different data sets				New models					
						Models with age composition data			Models w/o age composition data		
Year	Data	A1	A2	A3	A4	B1	D1	E1	B2	D2	E2
1987	35.51	32.75	32.82	32.75	32.97	38.01	36.34	36.17	37.38	35.90	35.89
1990	35.24	32.75	32.82	32.75	32.97	35.32	34.97	35.17	35.79	35.11	35.12
1993	34.22	32.75	32.82	32.75	32.97	33.70	33.64	33.75	34.16	33.90	33.69
1996	32.01	32.75	32.82	32.75	32.97	33.05	32.96	33.12	33.58	33.21	32.94
1999	32.57	32.75	32.82	32.75	32.97	34.32	34.21	34.28	34.72	34.47	33.99
2001	32.84	32.75	32.82	32.75	32.97	32.91	32.74	32.96	33.22	32.92	32.90
2003	32.73	32.75	32.82	32.75	32.97	33.03	33.27	33.05	33.14	32.93	32.71
2005	33.29	32.75	32.82	32.75	32.97	36.28	36.31	36.27	36.67	36.36	36.24
2007	35.98	32.75	32.82	32.75	32.97	39.53	39.47	39.59	38.34	38.14	38.02
Mean:	33.82	32.75	32.82	32.75	32.97	35.13	34.88	34.93	35.22	34.77	34.61
SE:	0.49	0.00	0.00	0.00	0.00	0.79	0.73	0.72	0.64	0.59	0.61
Correl:	n/a	0.00	0.00	0.00	0.00	0.82	0.76	0.77	0.80	0.75	0.78

Table 2.17—Summary of key management reference points from the standard projection algorithm. All biomass figures are in t. For the second and third groups of models, green = within-group row minimum, pink = within-group row maximum.

	Last year's model with different data sets				New models					
					Models with age composition data			Models without age composition data		
Quantity	A1	A2	A3	A4	B1	D1	E1	B2	D2	E2
B100%	263,176	363,195	264,709	253,436	291,492	272,697	280,188	277,592	268,508	268,373
B40%	105,270	145,278	105,884	101,375	116,597	109,079	112,075	111,037	107,403	107,349
B35%	92,112	127,118	92,648	88,703	102,022	95,444	98,066	97,157	93,978	93,931
B2010	207,392	361,079	208,109	186,952	117,585	95,506	100,383	109,286	97,659	103,168
B2011	229,087	386,095	231,800	213,041	148,073	130,270	132,618	116,041	112,995	124,081
B2010/B100%	0.79	0.99	0.79	0.74	0.40	0.35	0.36	0.39	0.36	0.38
B2011/B100%	0.87	1.06	0.88	0.84	0.51	0.48	0.47	0.42	0.42	0.46
F40%	0.55	0.55	0.55	0.54	0.49	0.48	0.52	0.53	0.54	0.49
F35%	0.69	0.67	0.69	0.66	0.60	0.60	0.64	0.64	0.66	0.60
maxFABC2010	0.55	0.55	0.55	0.54	0.49	0.42	0.46	0.52	0.49	0.47
maxFABC2011	0.55	0.55	0.55	0.54	0.49	0.48	0.52	0.53	0.54	0.49
maxABC2010	158,707	276,528	159,564	143,551	79,111	54,304	57,908	75,119	62,620	64,260
maxABC2011	164,235	274,889	166,063	152,410	97,865	81,238	82,912	81,700	78,806	79,198
FOFL2010	0.69	0.67	0.69	0.66	0.60	0.51	0.56	0.63	0.59	0.57
OFL2010	191,319	331,529	192,331	172,851	94,149	64,835	68,859	88,107	74,010	76,182
OFL2011	197,072	328,264	199,244	182,685	116,725	97,528	99,211	96,686	93,797	94,621
Pr(B2012<B20%)	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0
Pr(B2013<B20%)	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0
Pr(B2014<B20%)	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0

Legend:
B100% = equilibrium unfished spawning biomass
B40% = 40% of B100% (the inflection point of the harvest control rules in Tier 3)
B35% = 35% of B100% (the BMSY proxy for Tier 3)
B2010 = projected spawning biomass for 2010
B2011 = projected spawning biomass for 2011 (assuming 2010 catch = maximum permissible ABC)
B2010/B100% = ratio of 2010 spawning biomass to B100%
B2011/B100% = ratio of 2011 spawning biomass to B100%
F40% = fishing mortality rate that reduces equilibrium spawning per recruit to 40% of unfished level
F35% = fishing mortality rate that reduces equilibrium spawning per recruit to 35% of unfished level
maxFABC2010 = maximum permissible ABC fishing mortality rate for 2010 under Tier 3
maxFABC2011 = maximum permissible ABC fishing mortality rate for 2011 under Tier 3
maxABC2010 = maximum permissible ABC for 2010 under Tier 3
maxABC2011 = maximum permissible ABC for 2011 under Tier 3
FOFL2010 = OFL fishing mortality rate for 2010 under Tier 3
OFL2010 = OFL for 2010 under Tier 3
OFL2011 = OFL for 2011 under Tier 3 assuming 2010 catch = maxABC2010
Pr(B2012<B20%) = probability that spawning biomass will fall below 20% of B100% in 2012
Pr(B2013<B20%) = probability that spawning biomass will fall below 20% of B100% in 2013
Pr(B2014<B20%) = probability that spawning biomass will fall below 20% of B100% in 2014

Table 2.18—Estimates of Pacific cod fishing mortality rates, expressed on an annual time scale (Model B1). Rates are expressed as catch (in weight) divided by gear- and season-specific available biomass.

	Trawl fishery			Longline fishery			Pot fishery		
Year	Jan-May	Jun-Aug	Sep-Dec	Jan-May	Jun-Aug	Sep-Dec	Jan-May	Jun-Aug	Sep-Dec
1977	0.001	0.001	0.001	0.003	0.001	0.002	0	0	0
1978	0.003	0.003	0.005	0.014	0.004	0.008	0	0	0
1979	0.003	0.004	0.005	0.017	0.005	0.010	0	0	0
1980	0.007	0.009	0.017	0.042	0.013	0.032	0	0	0
1981	0.001	0.011	0.022	0.025	0.019	0.036	0	0	0
1982	0.003	0.007	0.014	0.023	0.011	0.044	0	0	0
1983	0.006	0.011	0.018	0.026	0.021	0.059	0	0	0
1984	0.008	0.008	0.016	0.030	0.002	0.014	0	0	0
1985	0.006	0.003	0.008	0.029	0.000	0.001	0	0	0
1986	0.007	0.002	0.014	0.051	0.002	0.007	0	0	0
1987	0.013	0.038	0.038	0.017	0.005	0.010	0.001	0.001	0.001
1988	0.039	0.032	0.018	0.010	0.002	0.002	0.005	0.000	0.002
1989	0.059	0.059	0.001	0.008	0.002	0.005	0.001	0.000	0.000
1990	0.134	0.040	0.027	0.018	0.001	0.001	0.012	0.005	0.011
1991	0.194	0.004	0.005	0.026	0.002	0.000	0.050	0.000	0.006
1992	0.201	0.008	0.006	0.051	0.005	0.013	0.054	0.000	0.003
1993	0.140	0.016	0.005	0.036	0.002	0.001	0.056	0.000	0.000
1994	0.117	0.008	0.003	0.027	0.000	0.000	0.047	0.000	0.002
1995	0.156	0.004	0.011	0.046	0.001	0.001	0.080	0.000	0.003
1996	0.170	0.016	0.006	0.043	0.001	0.001	0.062	0.000	0.000
1997	0.171	0.009	0.027	0.047	0.001	0.002	0.077	0.010	0.010
1998	0.156	0.022	0.015	0.046	0.001	0.002	0.112	0.003	0.007
1999	0.142	0.009	0.028	0.060	0.002	0.001	0.157	0.033	0.016
2000	0.091	0.015	0.004	0.056	0.001	0.001	0.149	0.003	0.004
2001	0.067	0.012	0.041	0.050	0.001	0.001	0.082	0.004	0.012
2002	0.073	0.017	0.008	0.063	0.001	0.023	0.092	0.002	0.030
2003	0.058	0.017	0.032	0.055	0.004	0.006	0.127	0.000	0.021
2004	0.048	0.013	0.039	0.053	0.001	0.015	0.150	0.000	0.028
2005	0.052	0.012	0.021	0.026	0.001	0.013	0.128	0.000	0.032
2006	0.052	0.012	0.009	0.039	0.001	0.029	0.131	0.000	0.015
2007	0.049	0.010	0.019	0.045	0.002	0.028	0.124	0.000	0.023
2008	0.049	0.016	0.028	0.052	0.003	0.014	0.109	0.000	0.021
2009	0.027	0.008	0.011	0.041	0.003	0.012	0.078	0.000	0.011

Table 2.19a—Schedules of Pacific cod selectivities at length in the commercial fisheries as defined by final parameter estimates under Model B1 (page 1 of 4). Lengths (cm) correspond to mid-points of size bins. Years correspond to beginnings of blocks.

	Jan-May trawl fishery					Jun-Aug trawl fishery				
Len.	1977	1990	1995	2000	2005	1977	1985	1990	2000	2005
8.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13.5	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
16.5	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
19.5	0.003	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.003
22.5	0.006	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.005
25.5	0.012	0.001	0.001	0.003	0.003	0.000	0.000	0.000	0.003	0.009
28.5	0.023	0.003	0.002	0.006	0.005	0.000	0.000	0.000	0.005	0.015
31.5	0.042	0.005	0.003	0.012	0.011	0.002	0.001	0.001	0.011	0.025
34.5	0.072	0.011	0.007	0.023	0.021	0.009	0.004	0.002	0.022	0.040
37.5	0.117	0.020	0.013	0.041	0.038	0.031	0.014	0.005	0.042	0.062
40.5	0.181	0.036	0.025	0.070	0.065	0.092	0.037	0.015	0.074	0.092
43.5	0.266	0.063	0.044	0.113	0.106	0.222	0.088	0.036	0.123	0.132
47.5	0.413	0.121	0.089	0.202	0.191	0.525	0.229	0.100	0.222	0.206
52.5	0.631	0.242	0.187	0.365	0.350	0.929	0.539	0.278	0.407	0.331
57.5	0.841	0.423	0.345	0.577	0.559	1.000	0.880	0.573	0.638	0.489
62.5	0.977	0.642	0.553	0.795	0.778	0.875	1.000	0.878	0.857	0.663
67.5	1.000	0.850	0.773	0.954	0.945	0.633	0.913	1.000	0.987	0.828
72.5	1.000	0.980	0.942	1.000	1.000	0.516	0.532	0.934	1.000	0.949
77.5	1.000	1.000	1.000	1.000	1.000	0.492	0.275	0.521	0.800	0.999
82.5	1.000	1.000	1.000	1.000	1.000	0.490	0.207	0.206	0.485	0.974
87.5	1.000	1.000	1.000	1.000	1.000	0.490	0.199	0.115	0.347	0.590
92.5	1.000	1.000	1.000	1.000	1.000	0.490	0.198	0.103	0.321	0.223
97.5	1.000	1.000	1.000	1.000	1.000	0.490	0.198	0.103	0.319	0.099
102.5	1.000	1.000	1.000	1.000	1.000	0.490	0.198	0.103	0.319	0.081
107.5	1.000	1.000	1.000	1.000	1.000	0.490	0.198	0.103	0.318	0.080

Table 2.19a—Schedules of Pacific cod selectivities at length in the commercial fisheries as defined by final parameter estimates under Model B1 (page 2 of 4). Lengths (cm) correspond to mid-points of size bins. Years correspond to beginnings of blocks.

	Sep-Dec trawl fishery							Jan-May longline fishery					
Len.	1977	1980	1985	1990	1995	2000	2005	1977	1985	1990	1995	2000	2005
8.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13.5	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16.5	0.000	0.000	0.001	0.000	0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
19.5	0.000	0.000	0.001	0.000	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
22.5	0.000	0.000	0.003	0.001	0.006	0.002	0.003	0.000	0.000	0.000	0.000	0.000	0.000
25.5	0.000	0.002	0.008	0.002	0.010	0.003	0.005	0.000	0.001	0.000	0.000	0.000	0.000
28.5	0.002	0.005	0.018	0.005	0.018	0.007	0.009	0.000	0.002	0.000	0.000	0.000	0.000
31.5	0.019	0.014	0.036	0.011	0.029	0.013	0.015	0.002	0.004	0.001	0.000	0.000	0.000
34.5	0.100	0.036	0.068	0.026	0.046	0.024	0.025	0.006	0.008	0.002	0.001	0.001	0.001
37.5	0.334	0.082	0.120	0.054	0.071	0.043	0.040	0.021	0.016	0.005	0.003	0.002	0.002
40.5	0.718	0.167	0.199	0.104	0.105	0.072	0.062	0.059	0.031	0.012	0.007	0.006	0.005
43.5	0.989	0.301	0.308	0.186	0.151	0.116	0.093	0.145	0.057	0.027	0.016	0.016	0.013
47.5	1.000	0.550	0.495	0.350	0.234	0.204	0.152	0.366	0.116	0.071	0.043	0.053	0.042
52.5	1.000	0.873	0.754	0.628	0.373	0.365	0.260	0.764	0.245	0.192	0.120	0.176	0.138
57.5	1.000	1.000	0.952	0.891	0.543	0.573	0.406	0.999	0.441	0.411	0.275	0.425	0.343
62.5	1.000	0.916	1.000	1.000	0.722	0.787	0.580	1.000	0.678	0.696	0.513	0.754	0.645
67.5	1.000	0.491	0.838	1.000	0.879	0.948	0.758	1.000	0.889	0.935	0.781	0.981	0.919
72.5	1.000	0.293	0.424	1.000	0.978	1.000	0.905	1.000	0.996	1.000	0.969	1.000	1.000
77.5	1.000	0.268	0.282	1.000	1.000	0.907	0.989	1.000	1.000	1.000	1.000	1.000	0.811
82.5	0.712	0.267	0.268	1.000	0.827	0.481	1.000	1.000	0.810	1.000	0.890	0.710	0.776
87.5	0.357	0.267	0.267	0.926	0.417	0.291	0.735	0.748	0.671	1.000	0.890	0.531	0.776
92.5	0.273	0.267	0.267	0.502	0.281	0.268	0.367	0.394	0.671	0.771	0.890	0.531	0.776
97.5	0.267	0.267	0.267	0.295	0.268	0.267	0.274	0.394	0.671	0.689	0.890	0.531	0.776
102.5	0.267	0.267	0.267	0.268	0.267	0.267	0.267	0.394	0.671	0.689	0.890	0.531	0.776
107.5	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.394	0.671	0.689	0.890	0.531	0.776

Table 2.19a—Schedules of Pacific cod selectivities at length in the commercial fisheries as defined by final parameter estimates under Model B1 (page 3 of 4). Lengths (cm) correspond to mid-points of size bins. Years correspond to beginnings of blocks.

	Jun-Aug longline fishery				Sep-Dec LL fishery			Jan-May pot fishery			
Len.	1977	1980	1990	2000	1977	1980	1990	1977	1995	2000	2005
8.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31.5	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34.5	0.004	0.001	0.001	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000
37.5	0.017	0.006	0.002	0.000	0.009	0.006	0.001	0.000	0.000	0.001	0.000
40.5	0.057	0.025	0.006	0.000	0.033	0.026	0.003	0.001	0.001	0.003	0.001
43.5	0.158	0.085	0.015	0.001	0.099	0.090	0.009	0.004	0.003	0.009	0.005
47.5	0.435	0.294	0.046	0.004	0.310	0.316	0.033	0.020	0.013	0.036	0.022
52.5	0.880	0.758	0.147	0.026	0.751	0.798	0.122	0.101	0.062	0.145	0.105
57.5	1.000	1.000	0.359	0.116	1.000	1.000	0.330	0.331	0.206	0.402	0.328
62.5	0.924	0.939	0.665	0.346	0.997	0.889	0.652	0.706	0.489	0.763	0.691
67.5	0.737	0.608	0.932	0.704	0.971	0.482	0.936	0.984	0.828	0.993	0.974
72.5	0.645	0.387	1.000	0.976	0.917	0.261	1.000	0.996	0.999	0.988	1.000
77.5	0.629	0.336	0.866	1.000	0.837	0.218	0.734	0.738	0.769	0.707	0.858
82.5	0.627	0.331	0.467	1.000	0.733	0.215	0.615	0.365	0.500	0.502	0.830
87.5	0.627	0.330	0.256	1.000	0.610	0.215	0.614	0.165	0.500	0.466	0.830
92.5	0.627	0.330	0.214	1.000	0.471	0.215	0.614	0.111	0.500	0.464	0.830
97.5	0.627	0.330	0.211	1.000	0.320	0.215	0.614	0.103	0.500	0.464	0.830
102.5	0.627	0.330	0.211	1.000	0.162	0.215	0.614	0.103	0.500	0.464	0.830
107.5	0.627	0.330	0.211	1.000	0.000	0.215	0.614	0.103	0.500	0.464	0.830

Table 2.19a—Schedules of Pacific cod selectivities at length in the commercial fisheries as defined by final parameter estimates under Model B1 (page 4 of 4). Lengths (cm) correspond to mid-points of size bins. Years correspond to beginnings of blocks.

	Jun-Aug pot fishery			Sep-Dec pot fishery			
Len.	1977	1995	2000	1977	1995	2000	2005
8.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37.5	0.000	0.000	0.000	0.001	0.001	0.001	0.001
40.5	0.001	0.000	0.001	0.002	0.002	0.004	0.003
43.5	0.004	0.001	0.003	0.007	0.006	0.013	0.009
47.5	0.022	0.005	0.017	0.025	0.021	0.051	0.039
52.5	0.106	0.026	0.105	0.097	0.082	0.197	0.164
57.5	0.342	0.096	0.381	0.275	0.238	0.506	0.456
62.5	0.718	0.267	0.809	0.574	0.516	0.868	0.833
67.5	0.987	0.553	1.000	0.882	0.832	1.000	1.000
72.5	0.996	0.860	0.950	1.000	0.998	0.947	0.977
77.5	0.782	1.000	0.665	0.932	0.991	0.709	0.831
82.5	0.479	0.973	0.400	0.549	0.857	0.546	0.720
87.5	0.314	0.709	0.289	0.266	0.726	0.503	0.687
92.5	0.268	0.427	0.263	0.186	0.682	0.497	0.683
97.5	0.261	0.297	0.260	0.175	0.676	0.497	0.683
102.5	0.260	0.264	0.260	0.175	0.675	0.497	0.683
107.5	0.260	0.260	0.260	0.175	0.675	0.497	0.683

Table 2.19b—Schedules of Pacific cod selectivities at age in the 27-plus bottom trawl surveys as defined by final parameter estimates under Model B1. The selectivity schedule for 2009 is constrained to be equal to the schedule for 2007.

Age	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.006	0.000	0.004	0.015	0.009	0.005	0.013	0.005	0.022	0.009
2	0.111	0.000	0.083	0.112	0.066	0.119	0.172	0.096	0.123	0.406
3	0.596	0.574	0.520	0.426	0.276	0.673	0.725	0.551	0.394	0.998
4	0.999	1.000	0.999	0.872	0.679	0.999	0.999	1.000	0.790	1.000
5	0.336	0.713	0.867	1.000	0.989	1.000	0.994	1.000	1.000	1.000
6	0.107	0.279	0.243	1.000	1.000	1.000	0.862	1.000	0.998	1.000
7	0.107	0.089	0.243	0.999	0.329	1.000	0.618	0.998	0.378	0.881
8	0.107	0.053	0.243	0.272	0.175	0.574	0.367	0.144	0.169	0.149
9	0.107	0.050	0.243	0.004	0.175	0.000	0.180	0.144	0.168	0.149
10	0.107	0.050	0.243	0.004	0.175	0.000	0.073	0.144	0.168	0.149
11	0.107	0.050	0.243	0.004	0.175	0.000	0.025	0.144	0.168	0.149
12	0.107	0.050	0.243	0.004	0.175	0.000	0.007	0.144	0.168	0.149
13	0.107	0.050	0.243	0.004	0.175	0.000	0.002	0.144	0.168	0.149
14	0.107	0.050	0.243	0.004	0.175	0.000	0.000	0.144	0.168	0.149
15	0.107	0.050	0.243	0.004	0.175	0.000	0.000	0.144	0.168	0.149
16	0.107	0.050	0.243	0.004	0.175	0.000	0.000	0.144	0.168	0.149
17	0.107	0.050	0.243	0.004	0.175	0.000	0.000	0.144	0.168	0.149
18	0.107	0.050	0.243	0.004	0.175	0.000	0.000	0.144	0.168	0.149
19	0.107	0.050	0.243	0.004	0.175	0.000	0.000	0.144	0.168	0.149
20	0.107	0.050	0.243	0.004	0.175	0.000	0.000	0.144	0.168	0.149

Table 2.20a—Schedules of Pacific cod length (cm) by season and age as estimated by Model B1. Sea1 = Jan-May, Sea2 = Jul-Aug, Sea3 = Sep-Dec.

	Population			Trawl fishery			Longline fishery			Pot fishery			Survey
Age	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea2
0	-1.26	4.69	9.62	3.05	7.88	11.98	3.05	7.77	9.41	3.05	7.77	9.41	5.46
1	11.58	15.72	19.19	17.80	22.50	26.77	15.44	20.57	25.42	15.42	20.57	25.03	20.57
2	34.51	39.06	42.79	32.35	35.80	39.50	33.71	36.69	42.79	32.00	39.16	43.49	33.86
3	49.04	52.78	55.83	44.20	46.98	49.96	46.30	51.33	52.36	47.45	51.19	52.59	45.11
4	58.14	61.13	63.58	53.47	55.91	58.44	55.10	59.30	59.84	55.83	58.36	59.60	54.28
5	66.32	68.74	70.72	61.06	63.30	65.42	62.09	65.45	65.73	62.33	63.93	65.27	62.05
6	69.52	71.53	73.19	58.90	60.68	62.52	60.11	63.30	63.32	60.49	61.95	62.89	59.27
7	74.17	75.85	77.23	78.34	79.11	80.53	77.86	80.07	80.32	77.96	77.62	80.51	79.87
8	76.14	77.59	78.79	84.31	83.04	84.58	84.08	85.58	86.17	84.13	83.30	86.16	85.54
9	80.11	81.33	82.35	86.78	84.51	86.22	86.65	87.83	88.42	86.69	85.90	88.38	87.82
10	83.58	84.60	85.45	89.54	86.20	88.26	89.48	90.38	90.94	89.49	88.95	90.89	90.38
11	87.21	88.05	88.75	89.54	86.15	88.14	89.47	90.31	90.80	89.49	88.86	90.75	90.30
12	90.15	90.84	91.41	91.03	87.11	89.34	90.99	91.69	92.13	91.00	90.50	92.08	91.68
13	91.14	91.74	92.25	91.08	87.12	89.31	91.04	91.69	92.10	91.05	90.50	92.05	91.69
14	92.92	93.43	93.85	92.71	88.28	90.76	92.69	93.22	93.58	92.69	92.30	93.54	93.22
15	94.27	94.70	95.06	94.15	89.42	92.16	94.14	94.58	94.89	94.14	93.87	94.86	94.58
16	95.99	96.33	96.61	95.78	90.88	93.86	95.77	96.11	96.37	95.77	95.61	96.34	96.11
17	96.83	97.12	97.37	97.03	92.15	95.23	97.02	97.29	97.49	97.02	96.91	97.47	97.29
18	97.67	97.91	98.11	97.26	92.38	95.46	97.25	97.50	97.68	97.25	97.14	97.66	97.50
19	98.43	98.63	98.80	97.97	93.18	96.26	97.96	98.16	98.32	97.96	97.86	98.30	98.16
20	99.10	99.26	99.40	98.45	93.61	96.73	98.45	98.62	98.75	98.45	98.33	98.73	98.62

Table 2.20b—Schedules of Pacific cod weight (kg) by season and age as estimated by Model B1. Sea1 = Jan-May, Sea2 = Jul-Aug, Sea3 = Sep-Dec.

	Population			Trawl fishery			Longline fishery			Pot fishery			Survey
Age	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea2
0	0.00	0.00	0.01	0.00	0.01	0.03	0.00	0.01	0.01	0.00	0.01	0.01	0.00
1	0.04	0.10	0.19	0.07	0.13	0.24	0.04	0.10	0.21	0.04	0.10	0.20	0.10
2	0.31	0.44	0.63	0.40	0.52	0.75	0.45	0.57	0.94	0.40	0.69	0.99	0.44
3	0.86	1.04	1.32	1.03	1.17	1.48	1.18	1.52	1.70	1.27	1.50	1.71	1.04
4	1.64	1.81	2.15	1.84	1.97	2.35	2.01	2.34	2.51	2.09	2.23	2.48	1.81
5	2.58	2.70	3.08	2.77	2.87	3.27	2.90	3.16	3.30	2.93	2.94	3.24	2.70
6	2.27	2.36	2.66	2.48	2.52	2.86	2.63	2.85	2.96	2.68	2.67	2.90	2.36
7	5.93	5.78	6.16	5.95	5.59	6.00	5.84	5.81	5.98	5.86	5.29	6.02	5.78
8	7.45	7.10	7.44	7.45	6.46	6.93	7.39	7.11	7.35	7.41	6.57	7.35	7.10
9	8.14	7.68	7.99	8.14	6.81	7.34	8.11	7.69	7.93	8.12	7.22	7.92	7.68
10	8.96	8.38	8.64	8.96	7.24	7.88	8.95	8.38	8.61	8.95	8.01	8.59	8.38
11	8.96	8.36	8.60	8.96	7.23	7.84	8.94	8.36	8.57	8.95	7.99	8.55	8.36
12	9.43	8.75	8.96	9.43	7.48	8.17	9.42	8.75	8.94	9.42	8.44	8.93	8.75
13	9.44	8.75	8.95	9.44	7.48	8.16	9.43	8.75	8.93	9.44	8.44	8.92	8.75
14	9.97	9.19	9.37	9.97	7.79	8.57	9.96	9.20	9.36	9.96	8.95	9.35	9.19
15	10.45	9.60	9.76	10.45	8.11	8.97	10.45	9.60	9.75	10.45	9.41	9.74	9.60
16	11.01	10.08	10.20	11.01	8.53	9.46	11.01	10.08	10.19	11.01	9.94	10.19	10.08
17	11.45	10.45	10.55	11.45	8.91	9.88	11.45	10.45	10.54	11.45	10.34	10.54	10.45
18	11.54	10.52	10.61	11.54	8.98	9.95	11.54	10.52	10.60	11.54	10.41	10.60	10.52
19	11.79	10.73	10.80	11.79	9.22	10.19	11.79	10.73	10.80	11.79	10.64	10.80	10.73
20	11.98	10.88	10.95	11.98	9.36	10.34	11.98	10.88	10.94	11.98	10.80	10.94	10.88

Table 2.21a—Time series of GOA Pacific cod age 0+ biomass, female spawning biomass (t), and standard deviation of spawning biomass as estimated by the model presented in last year's assessment and this year under Model B1.

	Last year's assessment			This year's assessment		
Year	Age 0+ bio.	Spawn. bio.	Std. dev.	Age 0+ bio.	Spawn. bio.	Std. dev.
1977	130,021	42,383	6,941	403,489	136,186	17,735
1978	146,875	46,819	6,636	422,637	160,132	18,307
1979	180,466	49,013	6,156	461,997	163,907	17,896
1980	225,141	48,282	5,842	516,504	159,027	16,905
1981	247,593	58,523	6,530	537,465	164,605	17,036
1982	266,290	84,423	8,325	535,727	190,837	18,580
1983	287,676	90,265	8,656	528,201	198,042	18,106
1984	305,012	91,090	8,523	515,566	187,314	16,174
1985	330,223	103,996	8,888	519,256	181,428	14,328
1986	364,116	120,116	8,830	530,368	185,445	12,648
1987	390,721	131,660	8,481	534,174	191,279	11,334
1988	400,823	132,230	7,560	528,339	190,263	10,680
1989	405,770	142,571	7,081	519,241	187,462	9,966
1990	401,025	143,190	6,361	504,318	181,049	8,258
1991	374,683	124,241	5,645	475,188	159,824	6,978
1992	356,112	111,780	5,329	459,088	143,723	6,431
1993	340,730	100,449	5,226	447,949	134,387	6,229
1994	346,463	104,843	5,366	457,855	143,630	6,321
1995	358,082	116,013	5,540	470,308	156,502	6,244
1996	351,127	112,578	5,249	462,568	154,448	5,949
1997	347,741	107,972	4,950	455,565	149,001	5,600
1998	335,431	101,303	4,872	434,853	141,599	5,393
1999	321,952	99,278	5,181	409,637	139,263	5,514
2000	295,611	96,551	5,613	371,951	128,932	5,603
2001	282,343	91,471	5,481	352,131	118,369	5,482
2002	285,445	86,583	5,260	351,396	111,469	5,340
2003	284,783	81,476	5,456	345,473	107,626	5,557
2004	281,936	86,338	6,529	334,355	110,265	6,217
2005	272,978	89,380	7,881	319,165	108,929	7,051
2006	280,114	87,240	9,024	325,306	103,100	7,597
2007	311,870	83,482	10,492	370,128	96,839	8,273
2008	405,367	81,473	13,201	475,523	98,512	9,846
2009	520,192	90,702	18,532	615,610	115,196	13,441

Table 2.21b—Time series of GOA Pacific cod age 0 recruitment (1000s of fish), with standard deviations, as estimated by the model presented in last year's assessment and this year under Model B1.

	Last year's assessment		This year's assessment	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	567,138	44,304	533,640	57,186
1978	32,837	15,458	200,794	37,044
1979	119,124	21,179	146,871	22,856
1980	293,252	28,322	174,402	15,043
1981	129,061	25,049	182,684	14,717
1982	346,825	32,317	274,476	20,988
1983	14,781	5,739	247,450	25,293
1984	366,314	45,688	285,355	32,364
1985	257,969	42,834	207,324	24,676
1986	76,987	24,534	172,402	15,861
1987	286,070	25,914	234,053	18,410
1988	178,270	28,735	213,655	15,690
1989	222,709	30,118	306,007	19,661
1990	313,815	32,146	299,631	18,670
1991	183,246	31,097	262,718	17,793
1992	204,701	29,483	227,272	17,048
1993	229,405	28,101	236,014	18,627
1994	193,258	26,979	302,847	18,760
1995	313,337	26,919	253,921	16,859
1996	158,432	22,125	191,267	15,825
1997	165,827	21,266	144,517	11,916
1998	118,999	18,474	195,679	13,704
1999	248,282	26,517	249,443	15,969
2000	263,090	29,099	257,218	19,475
2001	121,909	27,668	142,246	14,313
2002	160,355	27,373	111,348	13,642
2003	158,588	36,337	168,890	17,594
2004	192,790	37,478	157,187	17,735
2005	273,494	93,599	318,968	38,970
2006	1,333,990	450,529	489,736	67,522
2007			552,154	101,439
2008			645,932	168,209
Average	250,828		262,066	

Table 2.22—Numbers (1000s) at age as estimated by Model B1.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	533640	68280	53162	42822	72628	31483	13470	7165	4287	2811	1950	1389	997	714	552	370	248	167	112	75	153
1978	200794	364936	46694	36339	29209	49376	21376	9147	4867	2913	1911	1326	945	679	486	376	252	169	114	76	155
1979	146871	137315	249556	31859	24533	19406	32608	14125	6053	3226	1936	1273	886	633	455	326	253	170	114	76	156
1980	174402	100439	93901	169988	21469	16214	12734	21414	9293	3991	2133	1283	847	590	422	304	218	169	114	76	155
1981	182684	119267	68679	63870	110172	13377	10019	7997	13581	5919	2551	1370	828	548	383	275	198	142	110	74	151
1982	274476	124930	81552	46620	41397	68286	8340	6386	5161	8807	3849	1664	896	543	360	252	181	131	94	73	149
1983	247450	187704	85428	55438	30250	25958	43429	5359	4148	3366	5759	2524	1094	590	358	238	167	120	86	62	147
1984	285355	169221	128351	57963	35273	18319	16005	27515	3415	2659	2165	3715	1633	709	383	233	155	109	78	56	136
1985	207324	195144	115718	87408	38261	22581	11762	10348	17860	2219	1732	1414	2435	1073	467	253	154	102	72	52	127
1986	172402	141781	133447	79028	59163	25534	14917	7741	6812	11788	1466	1146	938	1616	713	310	168	102	68	48	119
1987	234053	117899	96927	91173	53262	38777	16458	9559	4965	4384	7625	949	744	610	1052	464	202	109	67	44	108
1988	213655	160060	80589	65387	61353	33566	24010	10396	6133	3212	2847	4965	618	485	398	686	303	132	71	43	100
1989	306007	146111	109431	54821	42740	40311	20946	15053	6595	3918	2060	1829	3194	398	312	256	442	195	85	46	92
1990	299631	209267	99908	74595	36254	26236	25116	12741	9342	4131	2464	1298	1153	2014	251	197	162	279	123	54	87
1991	262718	204906	143097	68069	49727	22594	14613	14552	6887	5110	2291	1380	732	652	1144	142	112	92	159	70	81
1992	227272	179663	140122	97717	45645	31611	12831	7436	7718	3486	2635	1195	725	386	345	607	76	60	49	85	80
1993	236014	155422	122859	95685	65612	28226	17472	6317	3551	3700	1686	1304	598	365	196	175	309	38	30	25	84
1994	302847	161401	106284	83928	64597	42133	16263	9454	3335	1916	1957	919	722	333	204	110	98	174	22	17	61
1995	253921	207105	110373	72627	56867	42196	25565	9202	5275	1873	1098	1102	529	419	194	119	64	57	101	13	46
1996	191267	173647	141615	75378	49159	37039	25116	13673	4641	2659	955	567	562	273	217	101	62	33	30	53	30
1997	144517	130800	118741	96757	50988	31945	22069	13531	6965	2352	1356	491	293	289	141	112	52	32	17	15	43
1998	195679	98830	89425	81010	65242	32602	18499	11384	6526	3334	1146	666	243	146	143	71	56	26	16	9	29
1999	249443	133817	67573	61062	54747	42223	18738	9460	5452	3119	1626	569	333	122	74	71	36	28	13	8	19
2000	257218	170584	91485	46078	41174	35114	24052	8905	4148	2386	1405	752	268	158	58	35	34	17	14	6	13
2001	142246	175901	116650	62468	30963	26247	19701	12060	4335	2080	1239	748	406	146	86	32	19	19	9	7	11
2002	111348	97276	120274	79565	41831	19381	15131	10490	6315	2335	1150	699	428	234	84	50	18	11	11	5	10
2003	168890	76147	66519	82132	53583	26253	10653	7773	5281	3252	1248	626	385	237	130	47	28	10	6	6	9
2004	157187	115497	52063	45384	55183	33934	14564	5355	3875	2712	1729	685	348	216	134	73	27	16	6	4	8
2005	318968	107494	78962	35460	30445	34710	18773	7161	2620	1949	1424	934	378	194	121	75	41	15	9	3	7
2006	489736	218130	73481	53825	23745	19605	20310	10021	3689	1362	1021	753	497	202	104	65	40	22	8	5	5
2007	552154	334912	149132	50035	36030	14919	11481	10818	5146	1907	713	537	399	264	108	55	35	22	12	4	5
2008	645932	377597	228932	101431	32766	22175	8257	6039	5494	2626	988	373	282	210	140	57	29	18	11	6	5
2009	260674	441728	258094	155305	66306	19243	12189	4278	3096	2825	1366	521	199	150	113	75	31	16	10	6	6

Table 2.23—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2010-2022 (Scenarios 1-2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	79,100	79,100	79,100	79,100	0
2011	97,900	97,900	97,900	97,900	2
2012	118,000	118,000	118,000	118,000	75
2013	127,000	128,000	128,000	129,000	939
2014	106,000	112,000	112,000	121,000	4,838
2015	99,100	112,000	113,000	132,000	10,765
2016	80,500	93,400	95,100	116,000	11,165
2017	61,600	83,700	84,700	109,000	14,365
2018	52,500	79,100	78,800	106,000	16,157
2019	50,400	76,700	76,000	102,000	15,847
2020	49,100	76,200	75,300	101,000	15,828
2021	49,600	75,300	74,700	101,000	15,471
2022	50,000	75,500	74,900	102,000	15,905

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	118,000	118,000	118,000	118,000	0
2011	148,000	148,000	148,000	148,000	2
2012	182,000	182,000	182,000	182,000	78
2013	199,000	200,000	200,000	202,000	1,002
2014	173,000	179,000	181,000	192,000	6,465
2015	154,000	172,000	174,000	201,000	15,556
2016	125,000	146,000	148,000	178,000	17,350
2017	106,000	131,000	133,000	169,000	19,994
2018	97,600	123,000	126,000	163,000	20,549
2019	95,200	119,000	122,000	157,000	19,379
2020	94,100	119,000	121,000	156,000	19,056
2021	94,700	117,000	121,000	155,000	18,568
2022	95,000	117,000	121,000	155,000	19,225

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.49	0.49	0.49	0.49	0.00
2011	0.49	0.49	0.49	0.49	0.00
2012	0.49	0.49	0.49	0.49	0.00
2013	0.49	0.49	0.49	0.49	0.00
2014	0.49	0.49	0.49	0.49	0.00
2015	0.49	0.49	0.49	0.49	0.00
2016	0.49	0.49	0.49	0.49	0.00
2017	0.45	0.49	0.49	0.49	0.02
2018	0.41	0.49	0.48	0.49	0.03
2019	0.40	0.49	0.47	0.49	0.03
2020	0.39	0.49	0.47	0.49	0.03
2021	0.40	0.49	0.47	0.49	0.03
2022	0.40	0.49	0.47	0.49	0.03

Table 2.24—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that the upper bound on F_{ABC} is set the most recent five-year average fishing mortality rate in 2010-2022 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	21,100	21,100	21,100	21,100	0
2011	29,500	29,500	29,500	29,500	1
2012	39,300	39,300	39,300	39,300	18
2013	48,000	48,200	48,200	48,600	232
2014	47,600	49,000	49,200	51,400	1,250
2015	49,900	53,600	54,000	59,400	3,128
2016	44,400	48,200	48,800	54,600	3,356
2017	38,100	44,000	44,600	53,100	4,769
2018	34,200	41,300	41,800	51,600	5,448
2019	31,700	39,100	39,700	49,500	5,495
2020	30,000	38,100	38,600	48,800	5,589
2021	29,500	37,100	37,700	47,500	5,550
2022	29,000	36,600	37,200	47,100	5,667

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	122,000	122,000	122,000	122,000	0
2011	175,000	175,000	175,000	175,000	2
2012	237,000	237,000	237,000	237,000	78
2013	290,000	291,000	292,000	293,000	1,008
2014	293,000	301,000	302,000	313,000	6,694
2015	296,000	316,000	319,000	349,000	17,614
2016	266,000	290,000	293,000	329,000	20,905
2017	231,000	266,000	270,000	317,000	28,076
2018	209,000	249,000	253,000	310,000	31,899
2019	192,000	237,000	240,000	298,000	32,500
2020	182,000	230,000	233,000	290,000	33,006
2021	179,000	224,000	228,000	285,000	32,810
2022	176,000	221,000	225,000	282,000	33,340

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.12	0.12	0.12	0.12	0.00
2011	0.12	0.12	0.12	0.12	0.00
2012	0.12	0.12	0.12	0.12	0.00
2013	0.12	0.12	0.12	0.12	0.00
2014	0.12	0.12	0.12	0.12	0.00
2015	0.12	0.12	0.12	0.12	0.00
2016	0.12	0.12	0.12	0.12	0.00
2017	0.12	0.12	0.12	0.12	0.00
2018	0.12	0.12	0.12	0.12	0.00
2019	0.12	0.12	0.12	0.12	0.00
2020	0.12	0.12	0.12	0.12	0.00
2021	0.12	0.12	0.12	0.12	0.00
2022	0.12	0.12	0.12	0.12	0.00

Table 2.25—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that the upper bound on F_{ABC} is set at $F_{60\%}$ in 2010-2022 (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	39,100	39,100	39,100	39,100	0
2011	52,600	52,600	52,600	52,600	1
2012	67,800	67,900	67,900	68,000	35
2013	79,600	80,000	80,100	80,900	439
2014	75,000	77,600	77,900	82,100	2,339
2015	75,800	82,300	83,200	92,800	5,650
2016	65,100	71,900	72,900	83,600	5,994
2017	54,900	64,700	65,900	79,800	7,993
2018	49,100	60,400	61,400	77,700	8,870
2019	45,600	57,500	58,500	73,900	8,785
2020	43,500	56,500	57,100	73,100	8,896
2021	43,000	55,100	55,900	71,300	8,796
2022	42,700	54,500	55,500	71,100	9,029

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	120,000	120,000	120,000	120,000	0
2011	166,000	166,000	166,000	166,000	2
2012	218,000	219,000	219,000	219,000	78
2013	258,000	259,000	260,000	261,000	1,007
2014	249,000	256,000	257,000	269,000	6,627
2015	242,000	261,000	264,000	293,000	16,983
2016	209,000	232,000	235,000	269,000	19,761
2017	178,000	210,000	213,000	257,000	25,290
2018	160,000	196,000	199,000	250,000	27,901
2019	148,000	186,000	189,000	236,000	27,908
2020	140,000	182,000	184,000	233,000	28,176
2021	138,000	178,000	181,000	230,000	27,873
2022	138,000	176,000	179,000	227,000	28,449

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.23	0.23	0.23	0.23	0.00
2011	0.23	0.23	0.23	0.23	0.00
2012	0.23	0.23	0.23	0.23	0.00
2013	0.23	0.23	0.23	0.23	0.00
2014	0.23	0.23	0.23	0.23	0.00
2015	0.23	0.23	0.23	0.23	0.00
2016	0.23	0.23	0.23	0.23	0.00
2017	0.23	0.23	0.23	0.23	0.00
2018	0.23	0.23	0.23	0.23	0.00
2019	0.23	0.23	0.23	0.23	0.00
2020	0.23	0.23	0.23	0.23	0.00
2021	0.23	0.23	0.23	0.23	0.00
2022	0.23	0.23	0.23	0.23	0.00

Table 2.26—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = 0 in 2010-2022 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0	0	0	0	0
2011	0	0	0	0	0
2012	0	0	0	0	0
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	0	0	0	0	0
2022	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	123,000	123,000	123,000	123,000	0
2011	185,000	185,000	185,000	185,000	2
2012	260,000	260,000	260,000	260,000	79
2013	333,000	334,000	334,000	336,000	1,010
2014	355,000	363,000	364,000	376,000	6,770
2015	376,000	397,000	400,000	431,000	18,345
2016	353,000	380,000	383,000	421,000	22,297
2017	317,000	357,000	361,000	415,000	31,737
2018	292,000	339,000	344,000	411,000	37,536
2019	270,000	325,000	328,000	398,000	39,338
2020	257,000	315,000	319,000	392,000	40,464
2021	249,000	307,000	311,000	386,000	40,615
2022	246,000	303,000	306,000	379,000	41,173

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.00	0.00	0.00	0.00	0.00
2011	0.00	0.00	0.00	0.00	0.00
2012	0.00	0.00	0.00	0.00	0.00
2013	0.00	0.00	0.00	0.00	0.00
2014	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00
2019	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00
2021	0.00	0.00	0.00	0.00	0.00
2022	0.00	0.00	0.00	0.00	0.00

Table 2.27—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2010-2022 (Scenario 6), with random variability in future recruitment.

Catch projections:					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	94,100	94,100	94,100	94,100	0
2011	113,000	113,000	113,000	113,000	3
2012	132,000	132,000	132,000	133,000	92
2013	138,000	139,000	139,000	141,000	1,145
2014	111,000	117,000	118,000	128,000	5,815
2015	101,000	115,000	117,000	139,000	12,521
2016	73,400	95,700	96,200	122,000	14,536
2017	55,600	83,200	83,900	114,000	18,563
2018	50,400	78,200	79,300	112,000	19,266
2019	50,300	76,800	77,900	109,000	18,278
2020	50,200	77,400	78,100	107,000	18,201
2021	51,300	76,000	77,800	109,000	17,899
2022	51,000	76,300	78,100	109,000	18,452
Biomass projections:					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	116,000	116,000	116,000	116,000	0
2011	141,000	141,000	141,000	141,000	2
2012	169,000	169,000	169,000	169,000	78
2013	180,000	181,000	181,000	183,000	1,001
2014	150,000	157,000	158,000	169,000	6,399
2015	130,000	147,000	150,000	175,000	15,006
2016	105,000	123,000	126,000	155,000	16,321
2017	91,700	112,000	115,000	148,000	17,543
2018	87,100	108,000	111,000	143,000	17,196
2019	87,000	107,000	109,000	140,000	15,937
2020	86,800	107,000	109,000	138,000	15,813
2021	87,300	107,000	109,000	138,000	15,477
2022	87,600	107,000	109,000	139,000	16,214
Fishing mortality projections:					
Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.60	0.60	0.60	0.60	0.00
2011	0.60	0.60	0.60	0.60	0.00
2012	0.60	0.60	0.60	0.60	0.00
2013	0.60	0.60	0.60	0.60	0.00
2014	0.60	0.60	0.60	0.60	0.00
2015	0.60	0.60	0.60	0.60	0.00
2016	0.54	0.60	0.59	0.60	0.02
2017	0.47	0.58	0.56	0.60	0.05
2018	0.44	0.55	0.55	0.60	0.06
2019	0.44	0.55	0.54	0.60	0.06
2020	0.44	0.55	0.54	0.60	0.06
2021	0.44	0.55	0.54	0.60	0.05
2022	0.44	0.55	0.54	0.60	0.05

Table 2.28—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2010-2011 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	79,100	79,100	79,100	79,100	0
2011	97,900	97,900	97,900	97,900	2
2012	140,000	140,000	140,000	140,000	92
2013	144,000	145,000	145,000	147,000	1,145
2014	114,000	121,000	122,000	132,000	5,815
2015	102,000	117,000	119,000	141,000	12,522
2016	74,800	96,600	97,300	122,000	14,328
2017	56,000	83,700	84,400	115,000	18,553
2018	50,400	78,300	79,500	112,000	19,290
2019	50,400	76,800	77,900	109,000	18,297
2020	50,200	77,400	78,100	107,000	18,207
2021	51,300	76,000	77,800	109,000	17,901
2022	51,000	76,300	78,100	109,000	18,452

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	118,000	118,000	118,000	118,000	0
2011	148,000	148,000	148,000	148,000	2
2012	180,000	180,000	180,000	180,000	78
2013	188,000	189,000	189,000	191,000	1,001
2014	155,000	162,000	163,000	174,000	6,399
2015	133,000	150,000	152,000	178,000	15,006
2016	106,000	124,000	127,000	156,000	16,341
2017	91,900	112,000	115,000	148,000	17,614
2018	87,200	108,000	111,000	143,000	17,246
2019	87,000	107,000	109,000	140,000	15,962
2020	86,800	107,000	109,000	138,000	15,821
2021	87,300	107,000	109,000	138,000	15,479
2022	87,600	107,000	109,000	139,000	16,214

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.49	0.49	0.49	0.49	0.00
2011	0.49	0.49	0.49	0.49	0.00
2012	0.60	0.60	0.60	0.60	0.00
2013	0.60	0.60	0.60	0.60	0.00
2014	0.60	0.60	0.60	0.60	0.00
2015	0.60	0.60	0.60	0.60	0.00
2016	0.54	0.60	0.59	0.60	0.02
2017	0.47	0.58	0.56	0.60	0.05
2018	0.44	0.56	0.55	0.60	0.06
2019	0.44	0.55	0.54	0.60	0.06
2020	0.44	0.55	0.54	0.60	0.06
2021	0.44	0.55	0.54	0.60	0.05
2022	0.44	0.55	0.54	0.60	0.05

Table 2.29—Discarded catch (t) of species groups by GOA Pacific cod fisheries, 2005-2009.

Species group	2005	2006	2007	2008	2009
Arrowtooth flounder	620	821	945	2225	536
Atka mackerel	24	18	10	331	45
Benthic urochordata		0	0	1	3
Birds	0	1	0	1	0
Bivalves	1	2	1	2	4
Brittle star unidentified	0	0	0	0	0
Capelin				0	
Corals Bryozoans	0	0	0	0	1
Dark Rockfish				0	1
Deep-water flatfish	15	4	4	16	1
Eelpouts	0	0		0	0
Eulachon	0	2	0	0	
Flathead sole	18	90	78	71	13
Giant Grenadier	0	22	82	31	39
Greenlings	1	4	1	7	1
Grenadier		1		66	5
Gunnels				0	
Hermit crab unidentified	0	1	2	3	4
Invertebrate unidentified	0	13	2	1	0
Large Sculpins	294	351	437	740	487
Misc crabs	2	1	7	2	1
Misc crustaceans					0
Misc fish	153	176	539	211	98
Misc inverts (worms etc)		0	0		
Northern rockfish	7	128	21	91	8
Octopus	139	151	250	326	230
Other osmerids			0		
Other rockfish	13	6	9	19	10
Other Sculpins	26	10	7	4	10
Other species	452	427	572	946	393
Pacific cod	181	1082	293	332	262
Pacific ocean perch	5	78	1	4	2
Pacific Sand lance		0			0
Pandalid shrimp	0		0	0	0
Pelagic rockfish	20	45	26	28	27
Rex sole	4	7	9	35	0
Rougheye rockfish	1	2	0	7	1
Sablefish	8	14	20	297	9
Scypho jellies	1	5	0	0	0
Sea anemone unidentified	1	0	5	6	6
Sea pens whips	0	3	1		3
Sea star	938	703	301	316	439
Shallow-water flatfish	86	162	219	794	41
Shark, Other	1	12	39	2	2
Shark, pacific sleeper	134	14	9	13	4
Shark, salmon	1	1			
Shark, spiny dogfish	28	113	250	290	50
Shortraker rockfish	0	8	1	4	3
Skate, big	224	440	662	620	497
Skate, longnose	142	196	409	386	266
Skate, other	243	1209	782	1197	636
Snails	5	3	1	1	2
Sponge unidentified	1	1	0	1	1
Squid	0	0	0	0	0
Stichaeidae	0				2
Surf smelt	0				
Thornyhead rockfish	0	0	0	1	0
urchins dollars cucumbers	1	1	3	1	1
Walleye pollock	19	73	221	2125	119
Total	3810	6397	6221	11558	4267

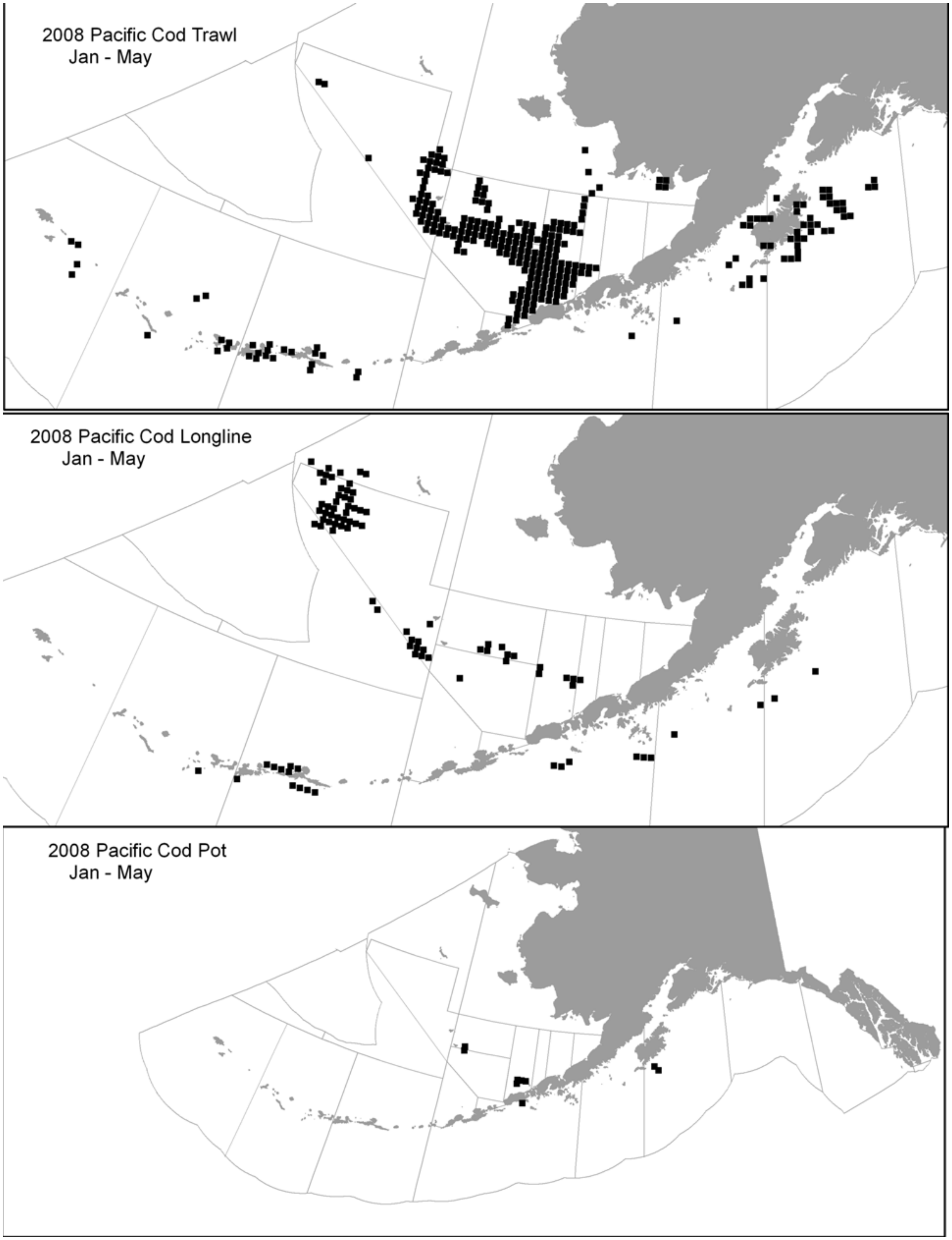


Figure 2.1a—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, January-May 2008, by gear type, overlaid against NMFS 3-digit statistical areas.

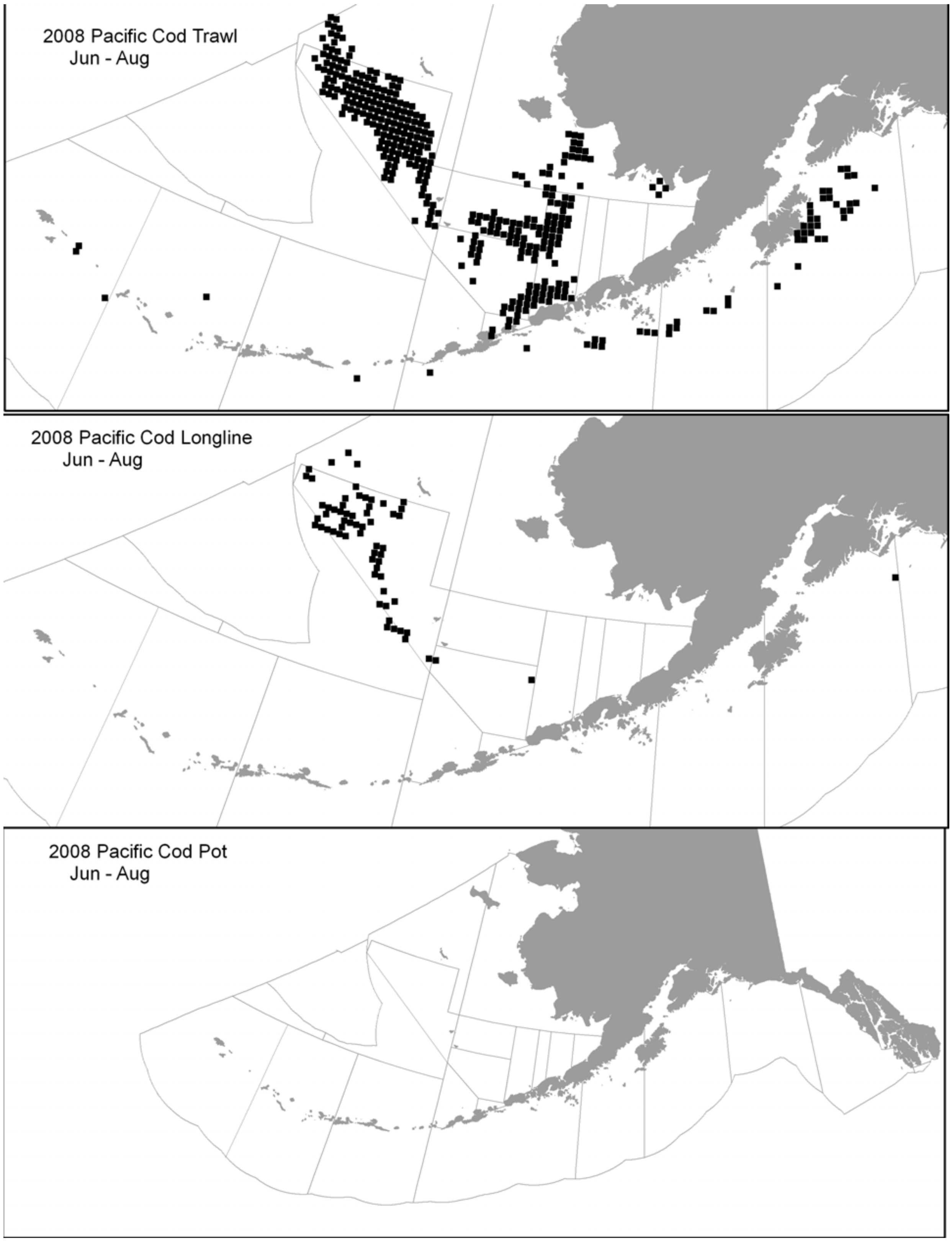


Figure 2.1b—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, June-August 2008, by gear type, overlaid against NMFS 3-digit statistical areas.

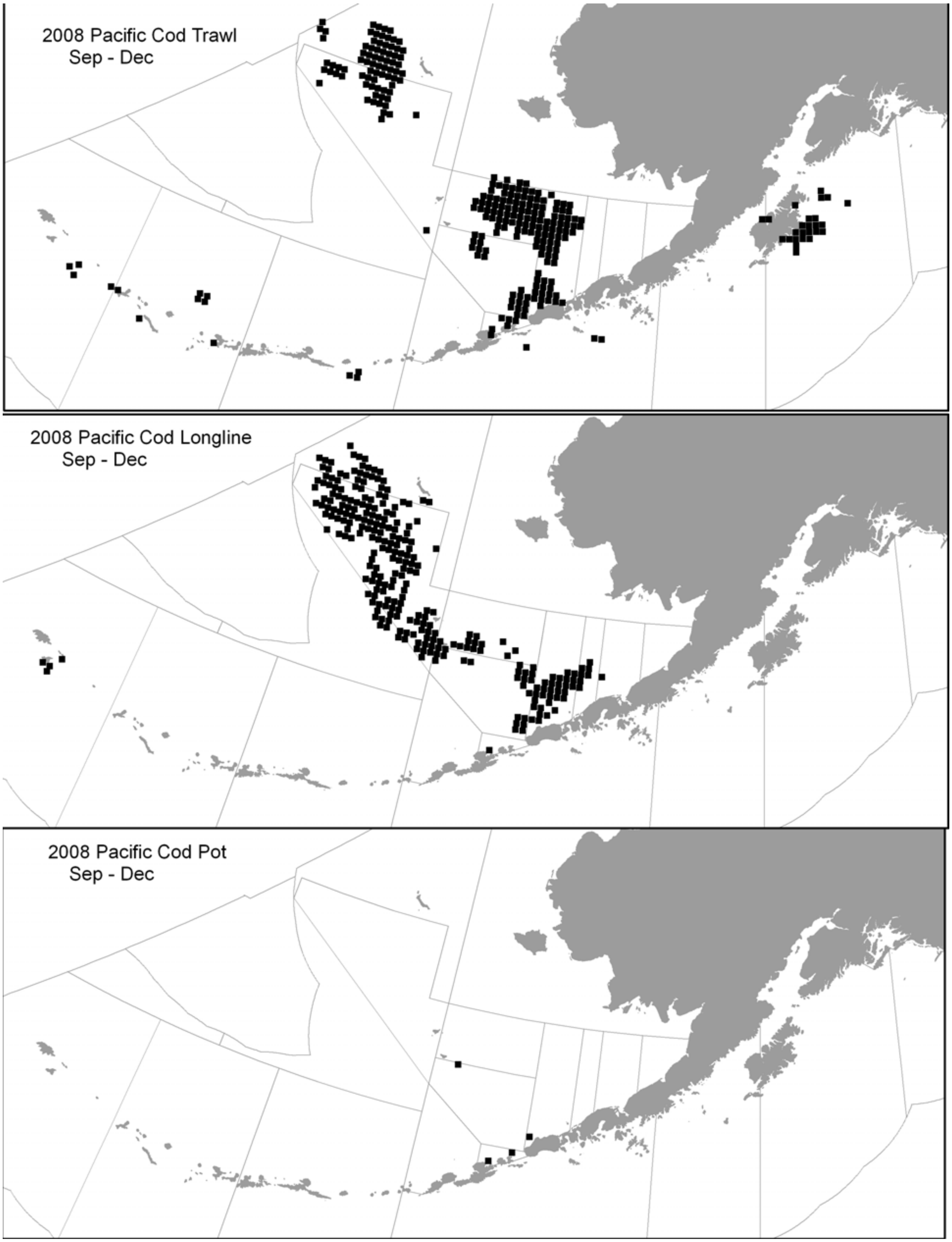


Figure 2.1c—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, Sept.-Dec. 2008, by gear type, overlaid against NMFS 3-digit statistical areas.

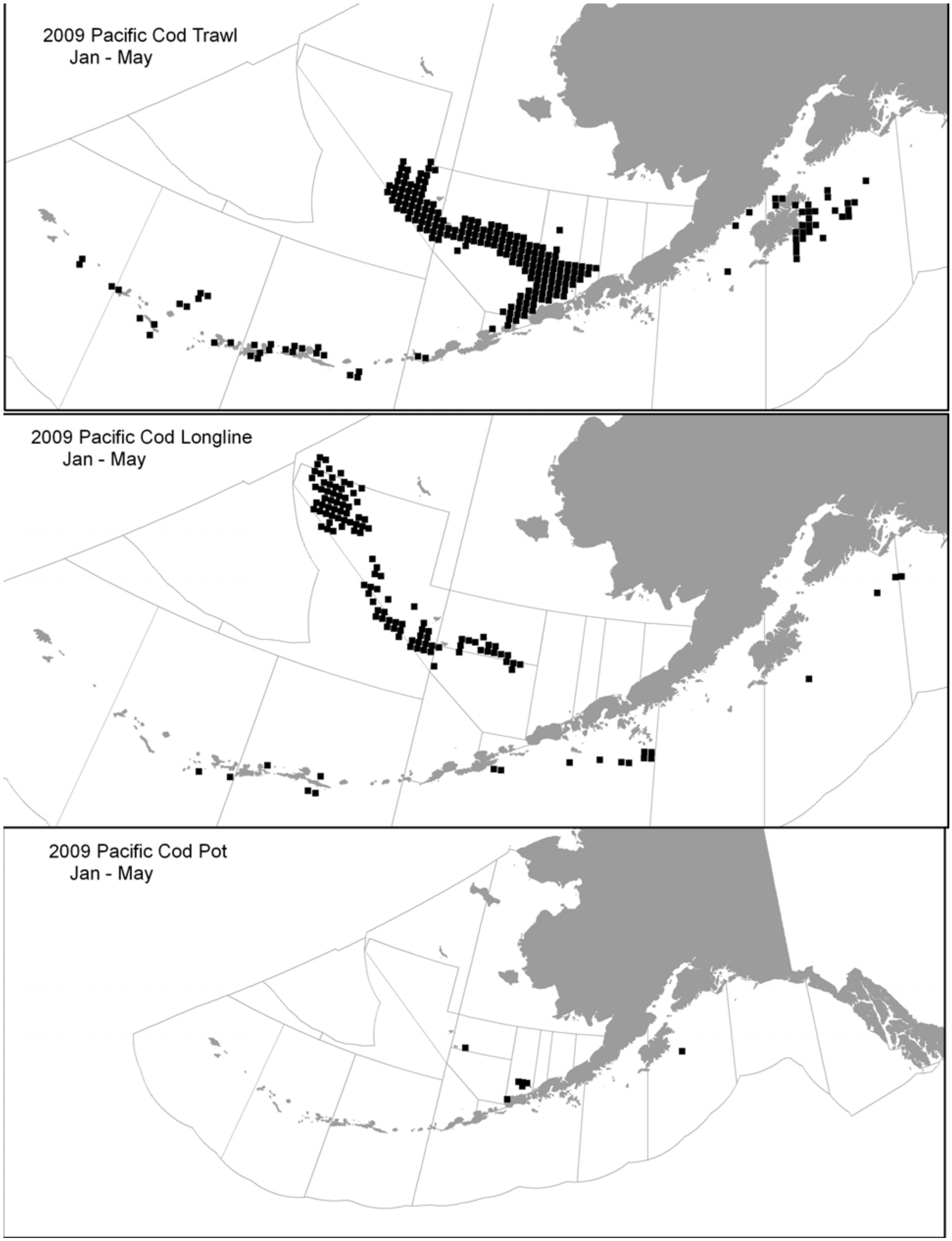


Figure 2.1d—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, January-May 2009, by gear type, overlaid against NMFS 3-digit statistical areas.

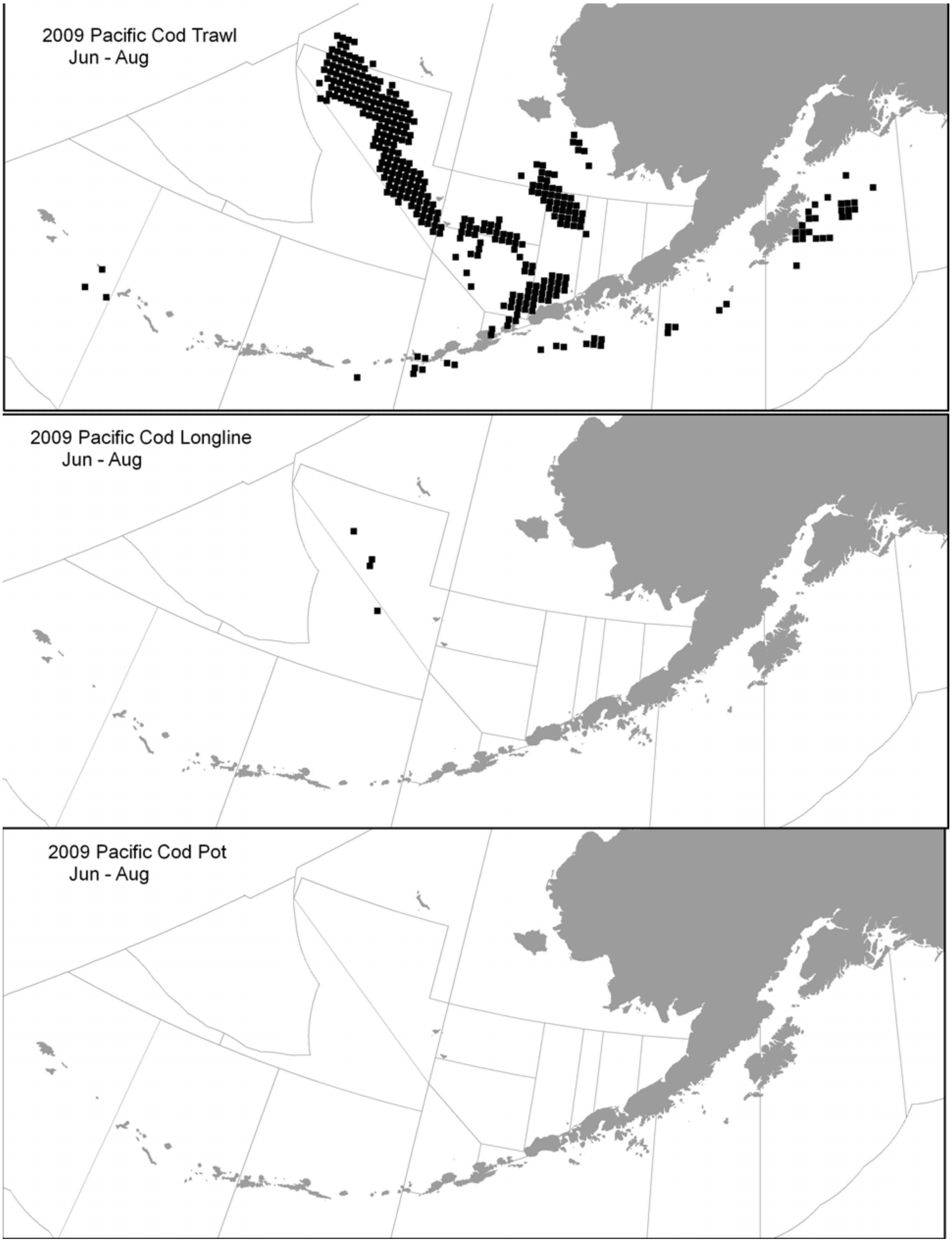


Figure 2.1e—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, June-August 2009, by gear type, overlaid against NMFS 3-digit statistical areas.

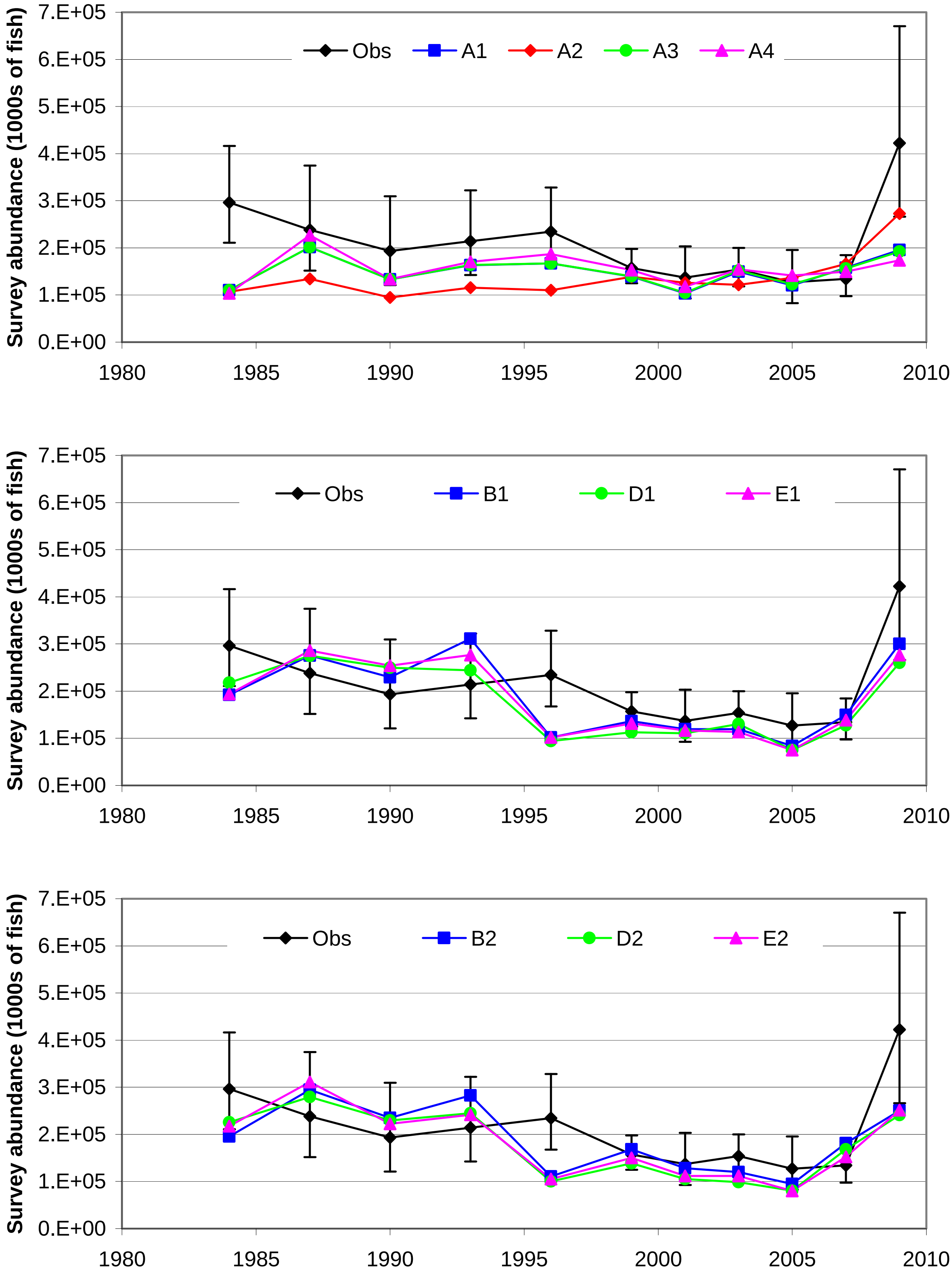


Figure 2.2—Fits of the ten models to the trawl survey abundance time series.

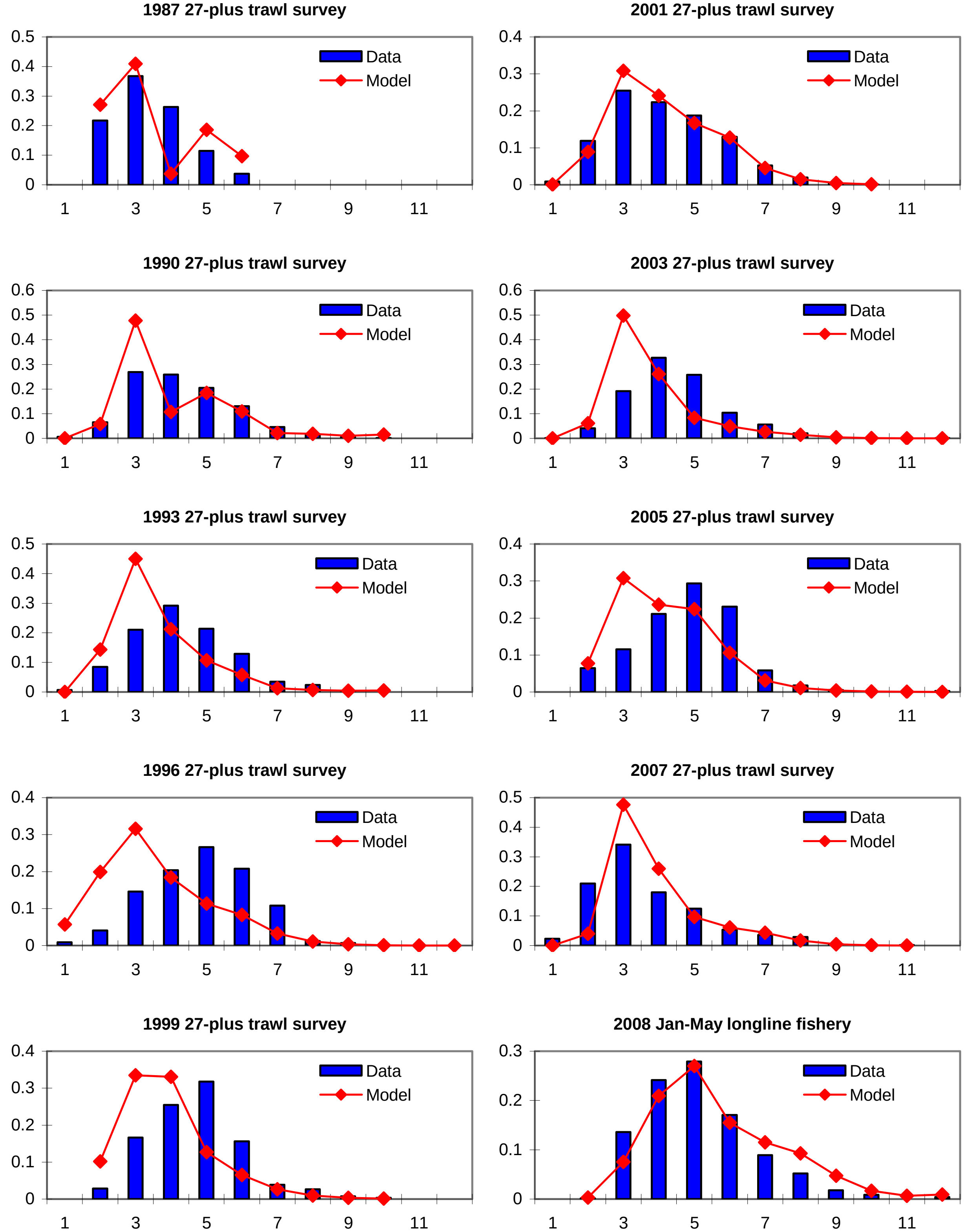


Figure 2.3A1—Fit to trawl survey age composition data obtained by Model A1.

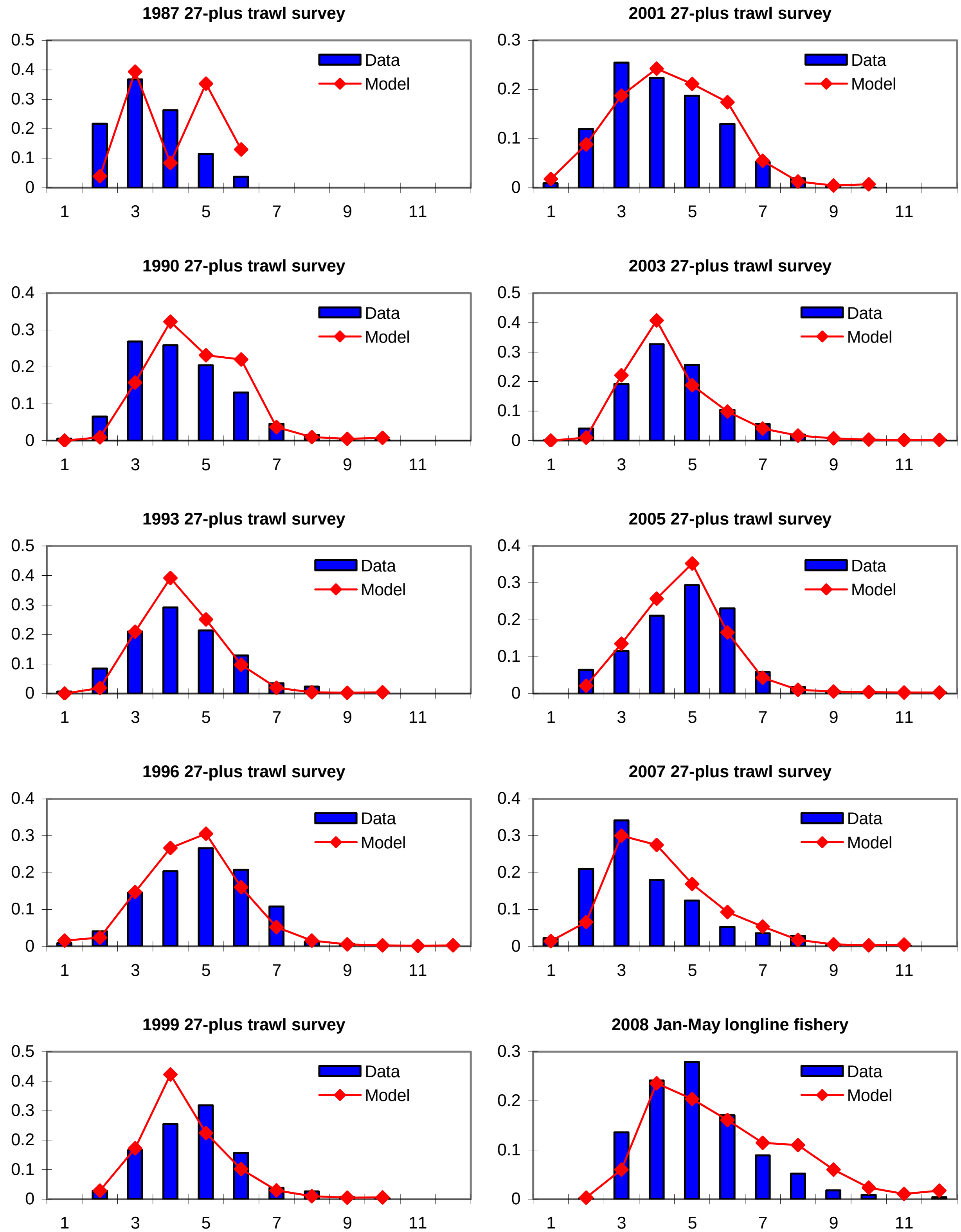


Figure 2.3A2—Fit to trawl survey age composition data obtained by Model A2.

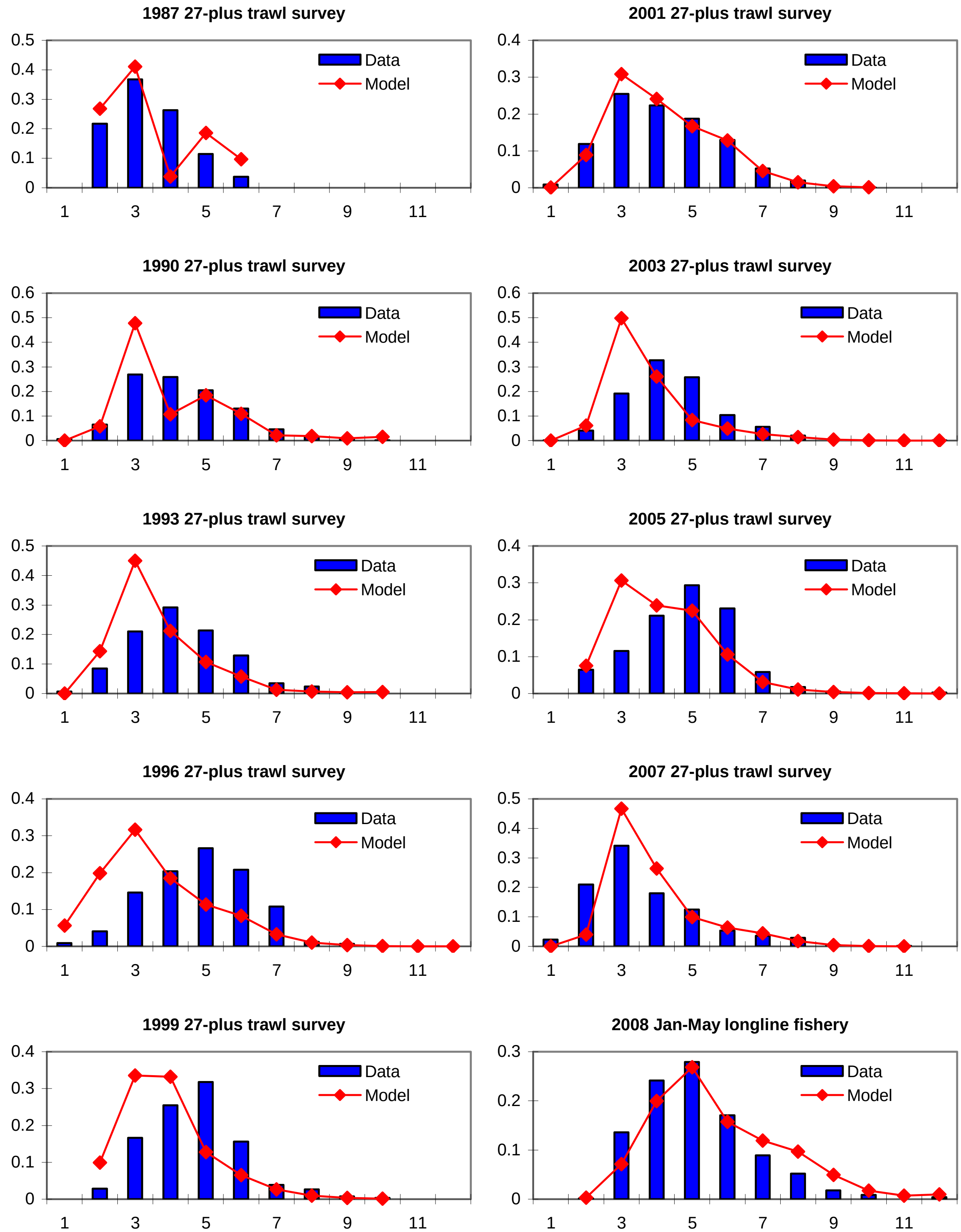


Figure 2.3A3—Fit to trawl survey age composition data obtained by Model A3.

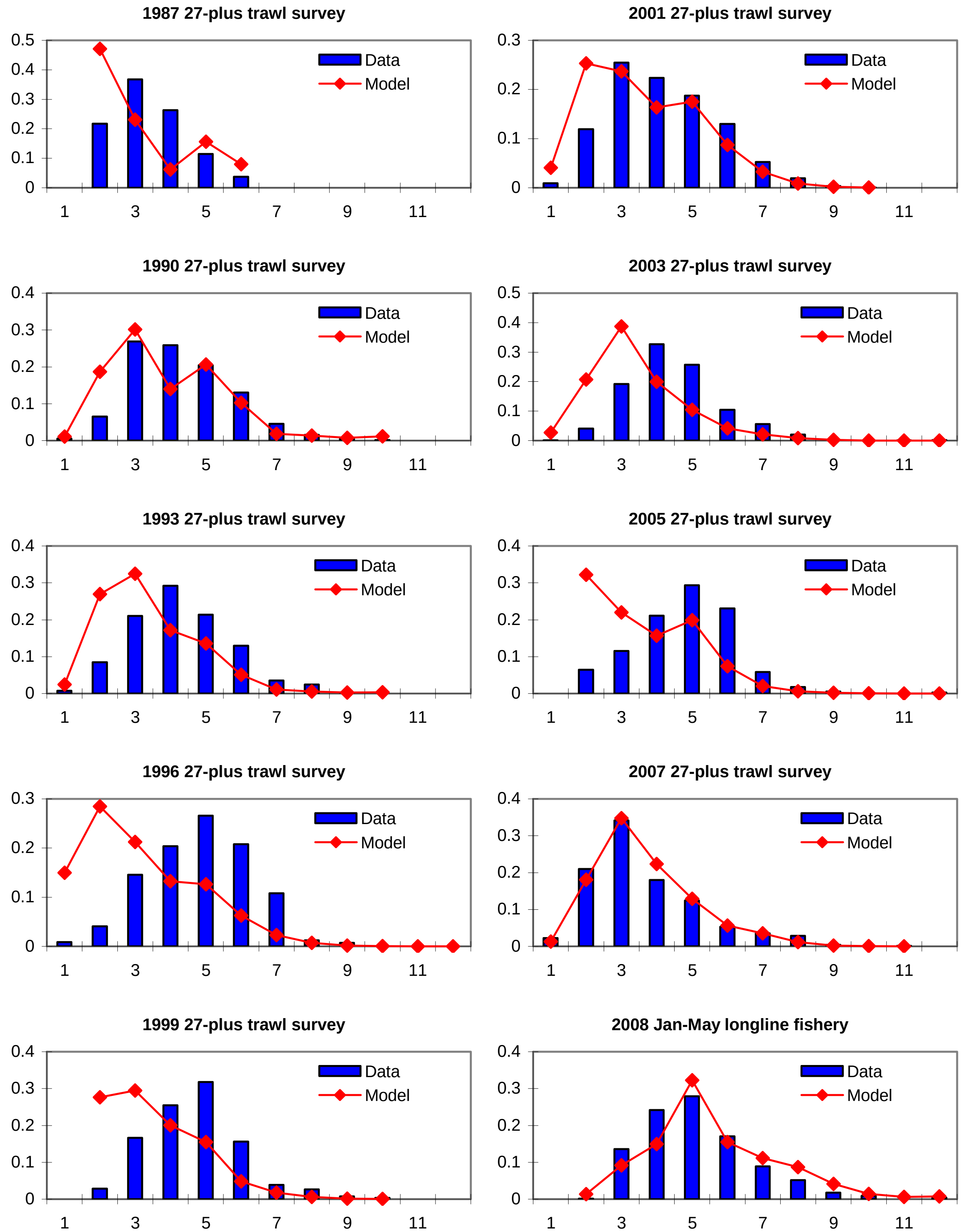


Figure 2.3A4—Fit to trawl survey age composition data obtained by Model A4.

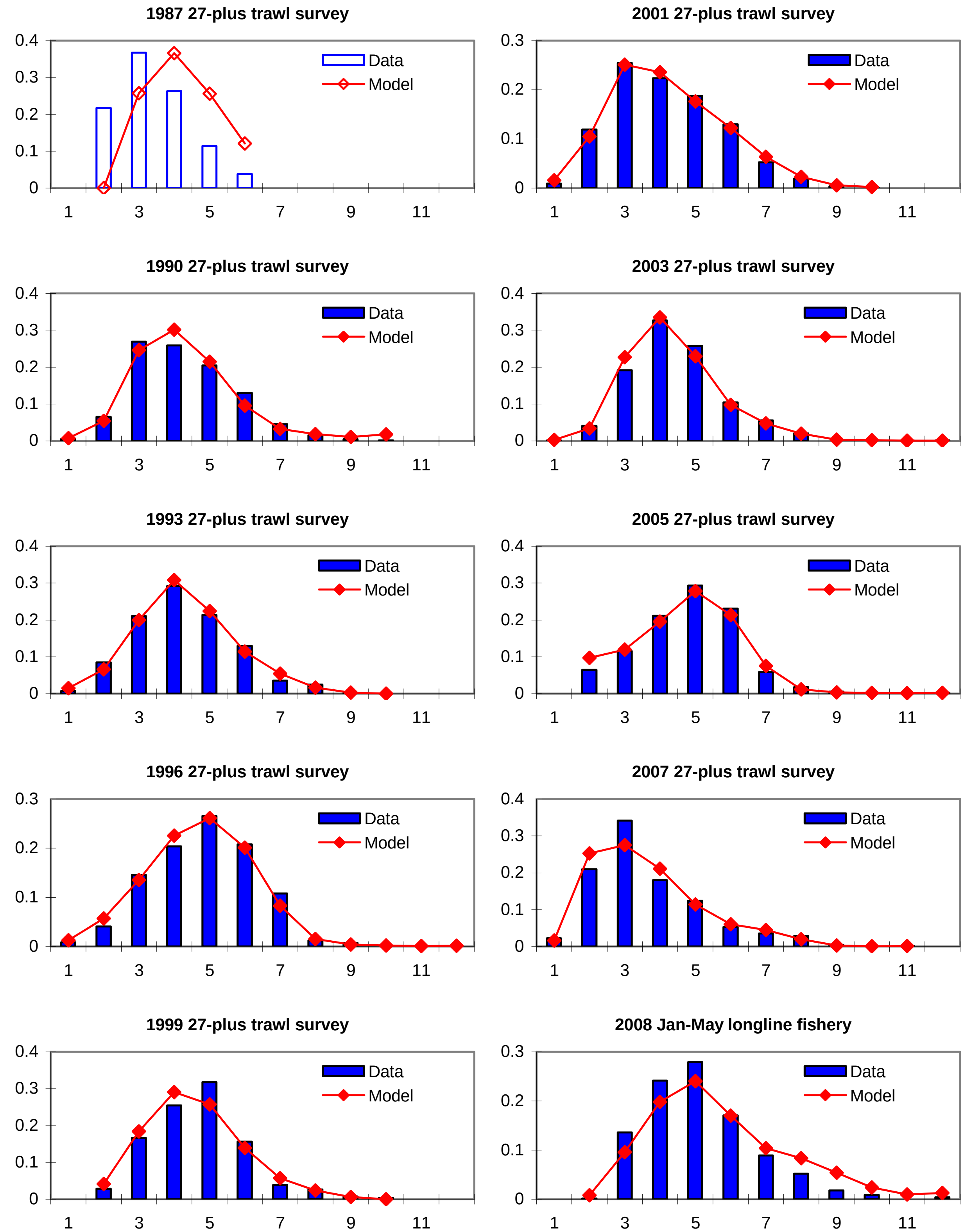


Figure 2.3B1—Fit to trawl survey age composition data obtained by Model B1 (1987 data not fit).

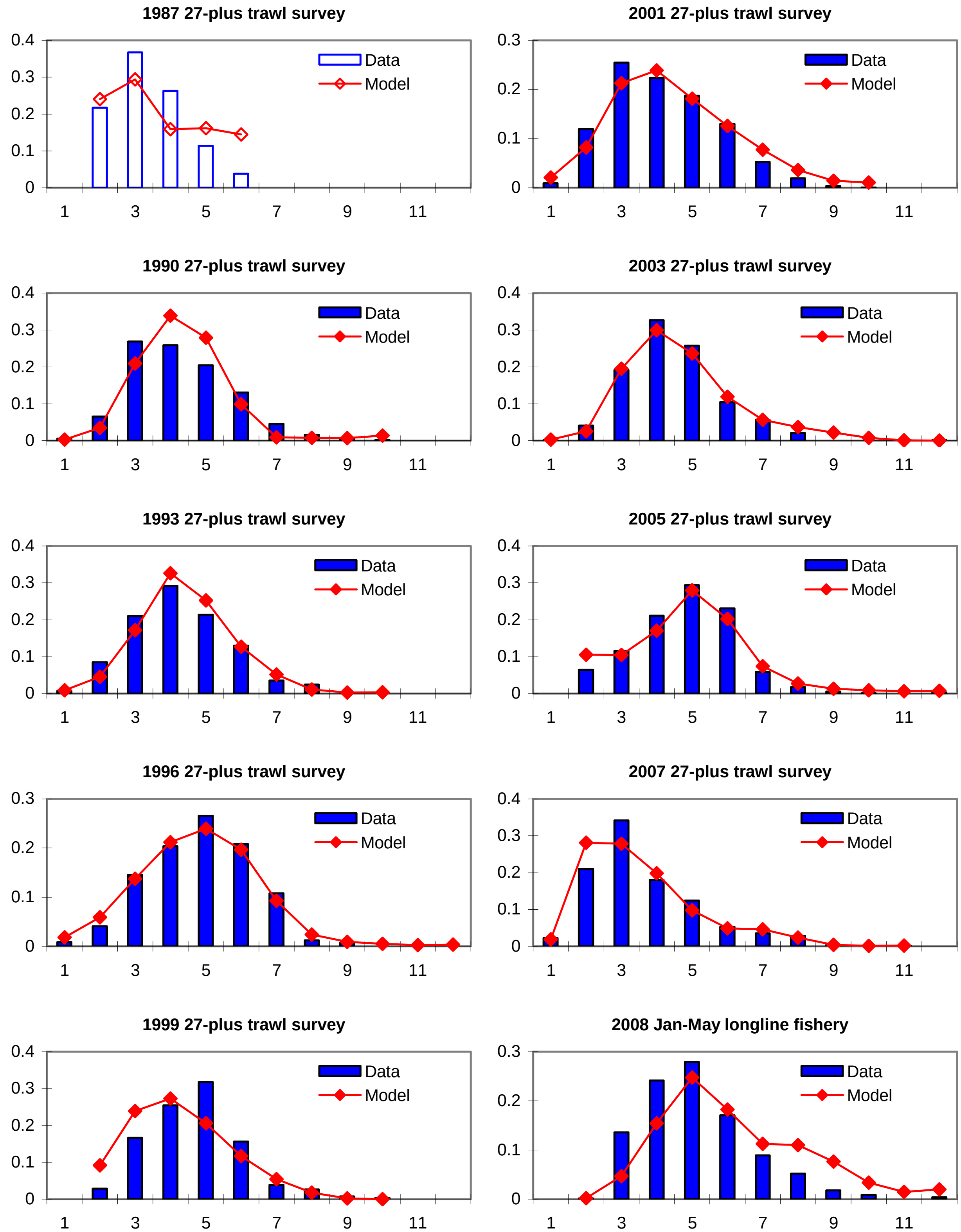


Figure 2.3B2—Fit to trawl survey age composition data obtained by Model B2 (1987 data not fit).

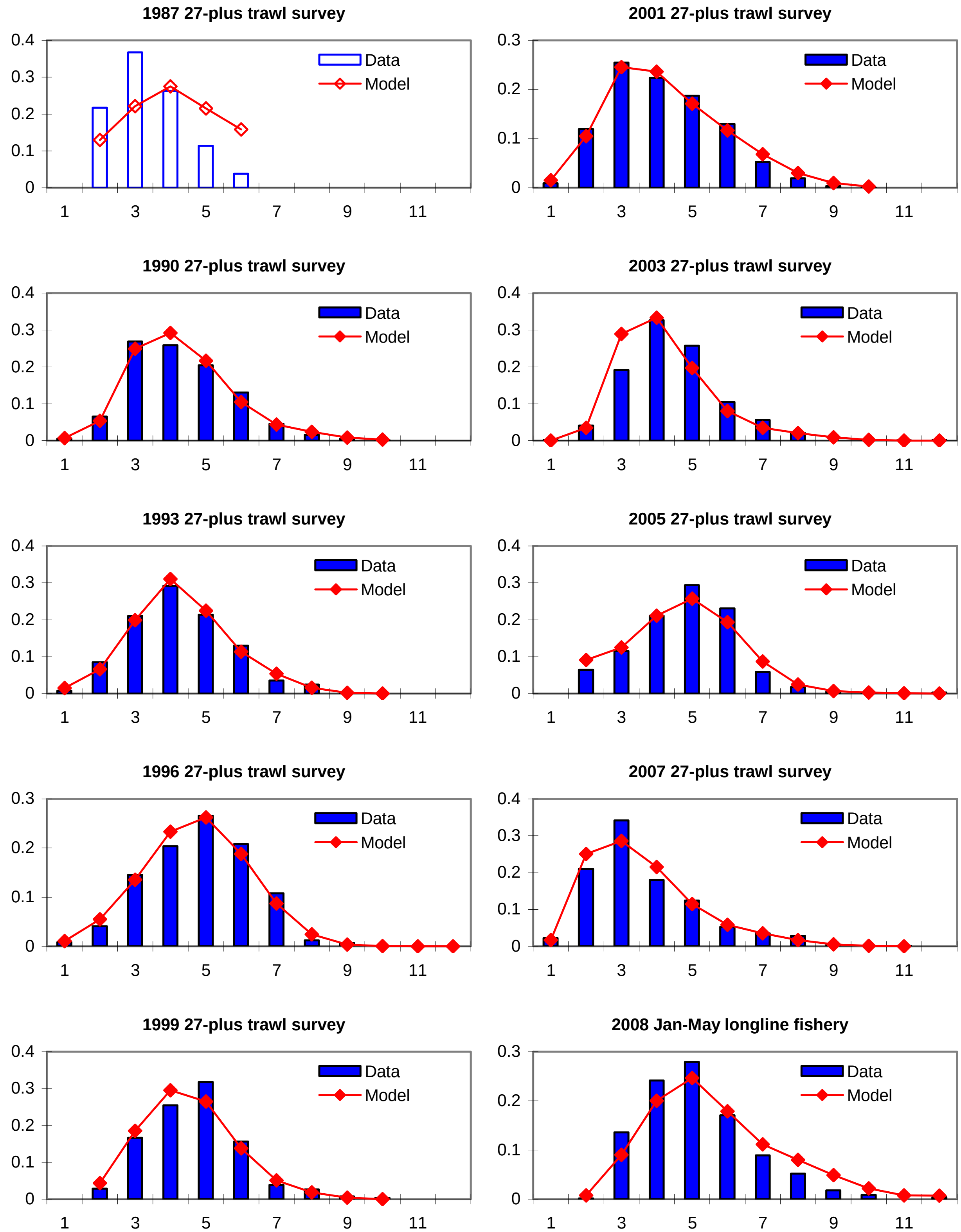


Figure 2.3D1—Fit to trawl survey age composition data obtained by Model D1 (1987 data not fit).

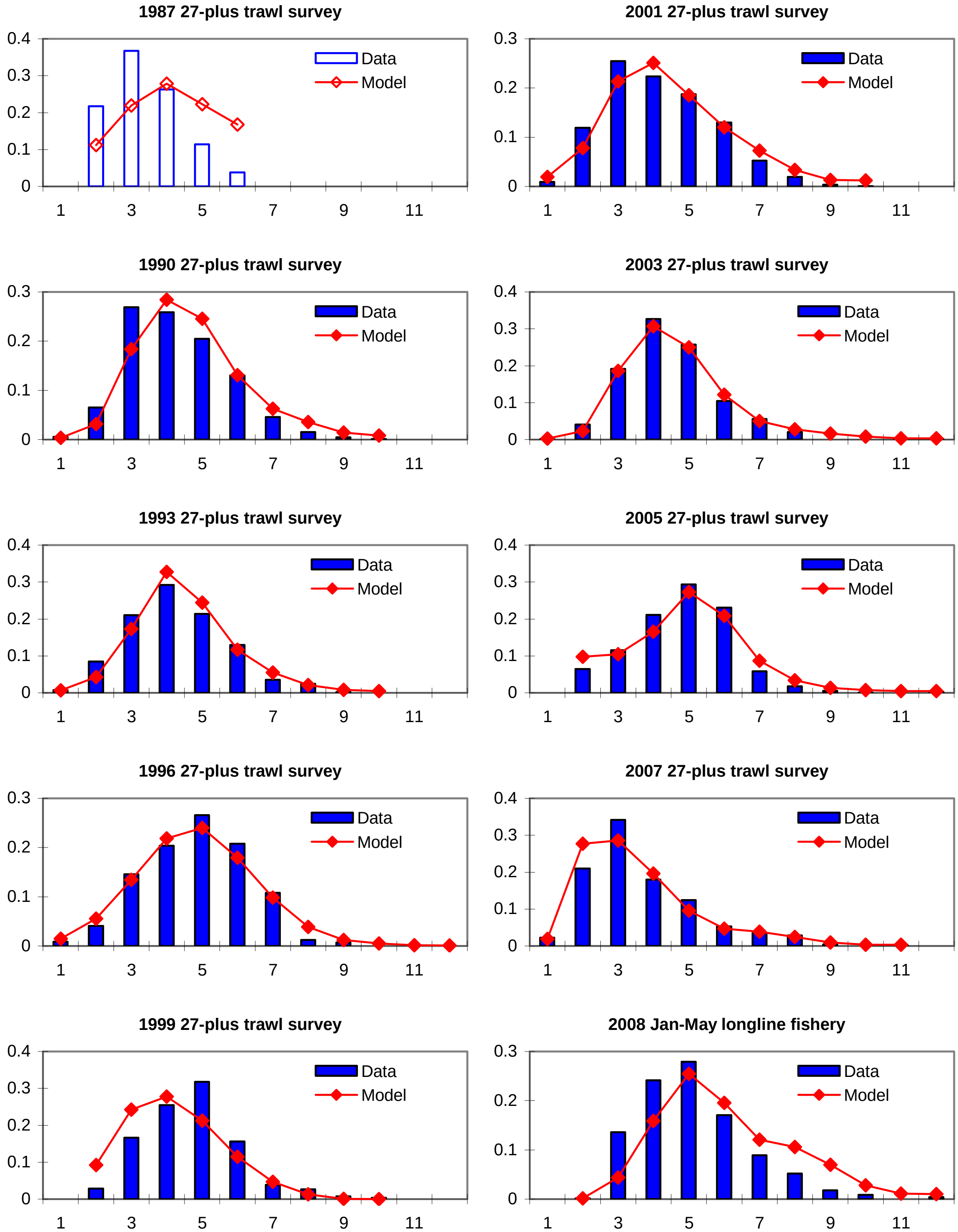


Figure 2.3D2—Fit to trawl survey age composition data obtained by Model D2 (1987 data not fit).

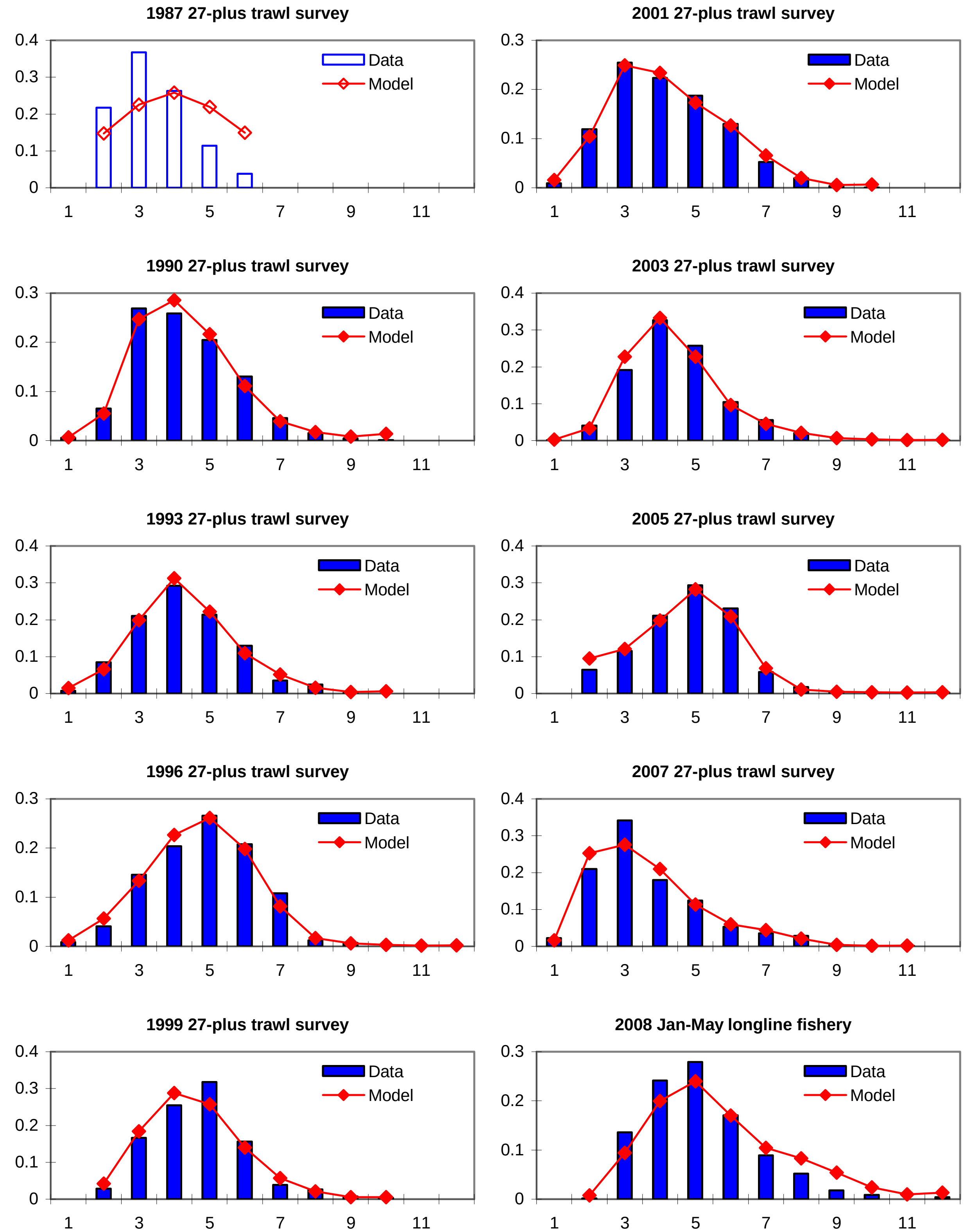


Figure 2.3E1—Fit to trawl survey age composition data obtained by Model E1 (1987 data not fit).

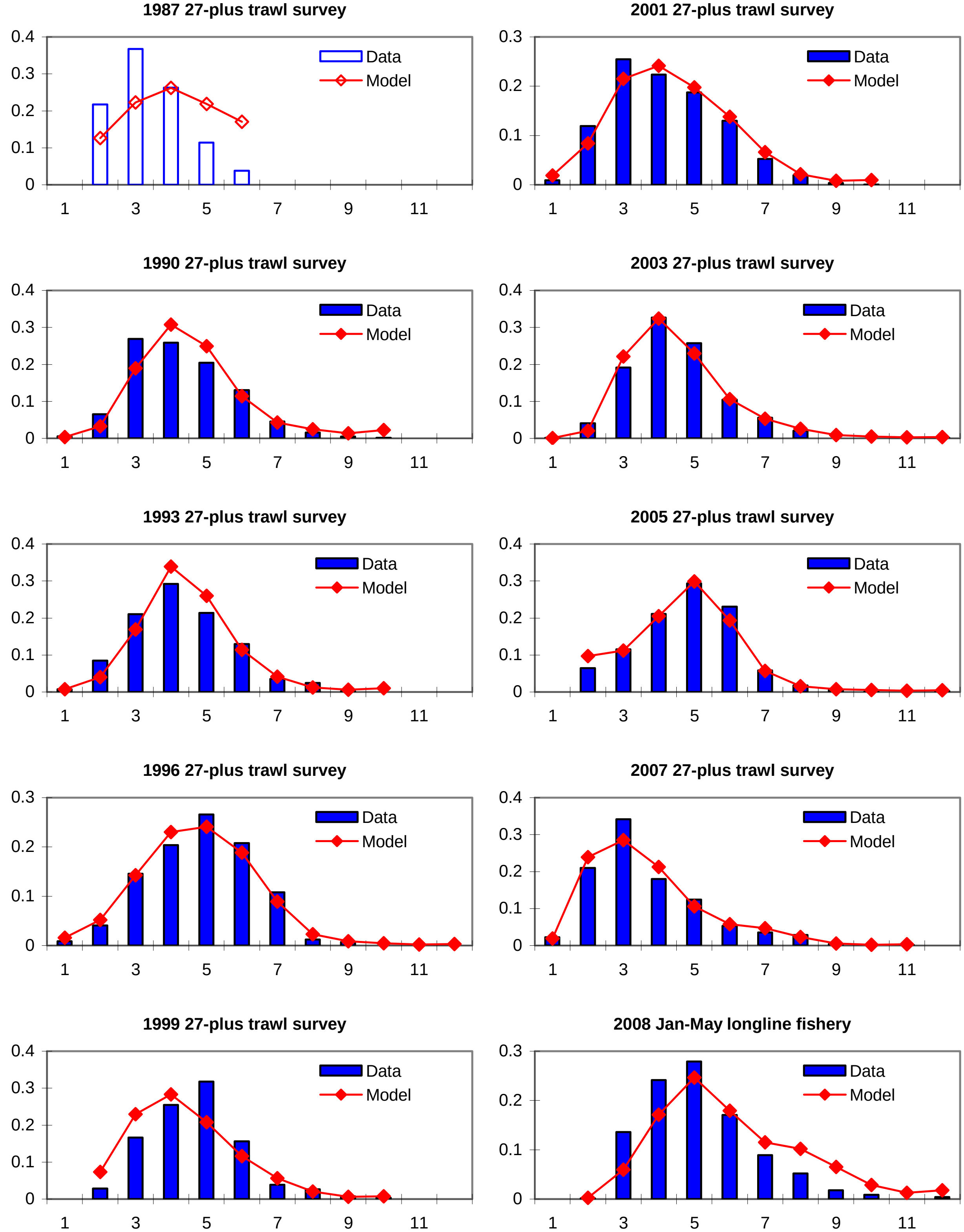


Figure 2.3E2—Fit to trawl survey age composition data obtained by Model E2 (1987 data not fit).

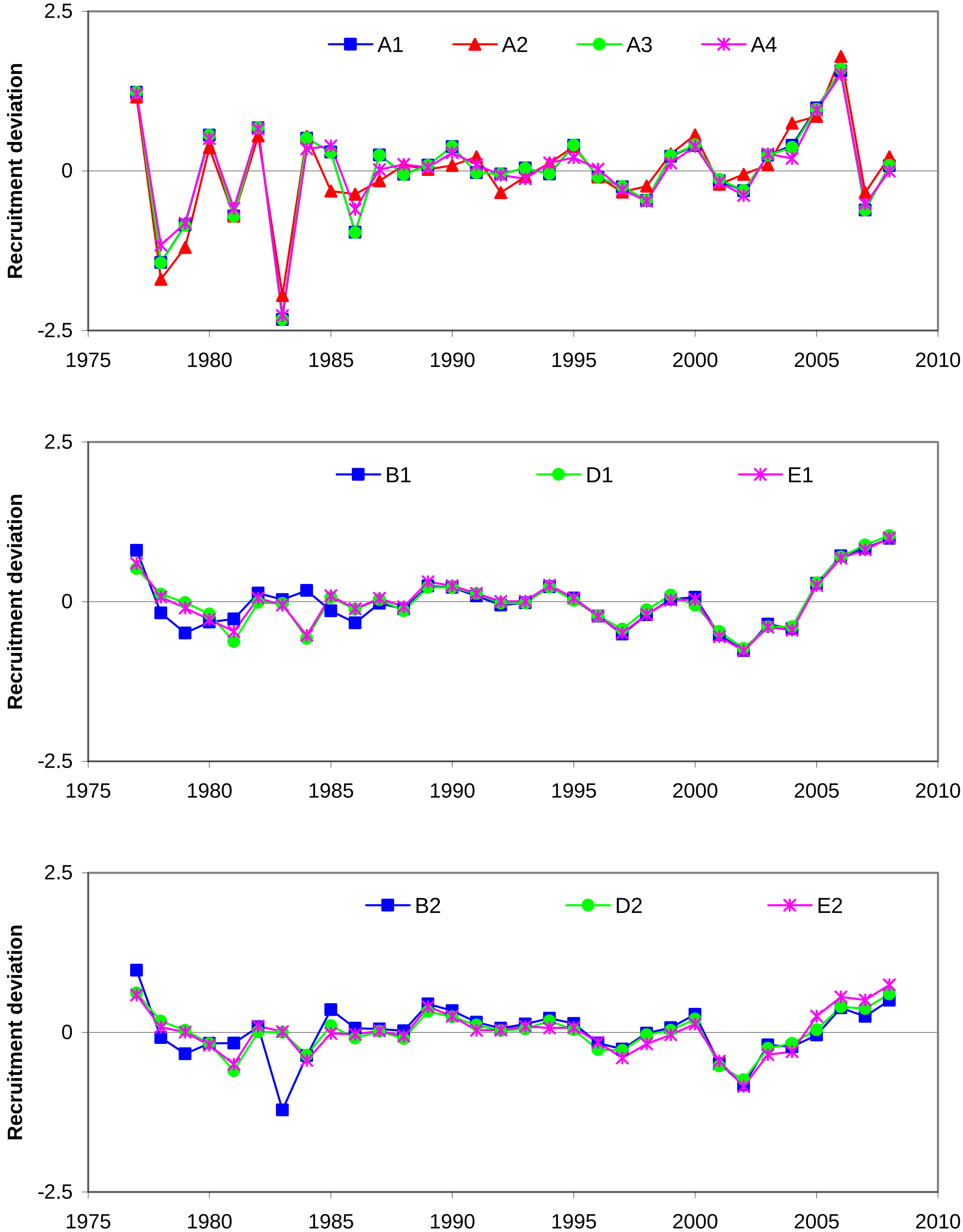


Figure 2.4—Time series of estimated recruitment deviations from the 14 models. Note that the pre-1977 deviations are with respect to the pre-1977 log median.

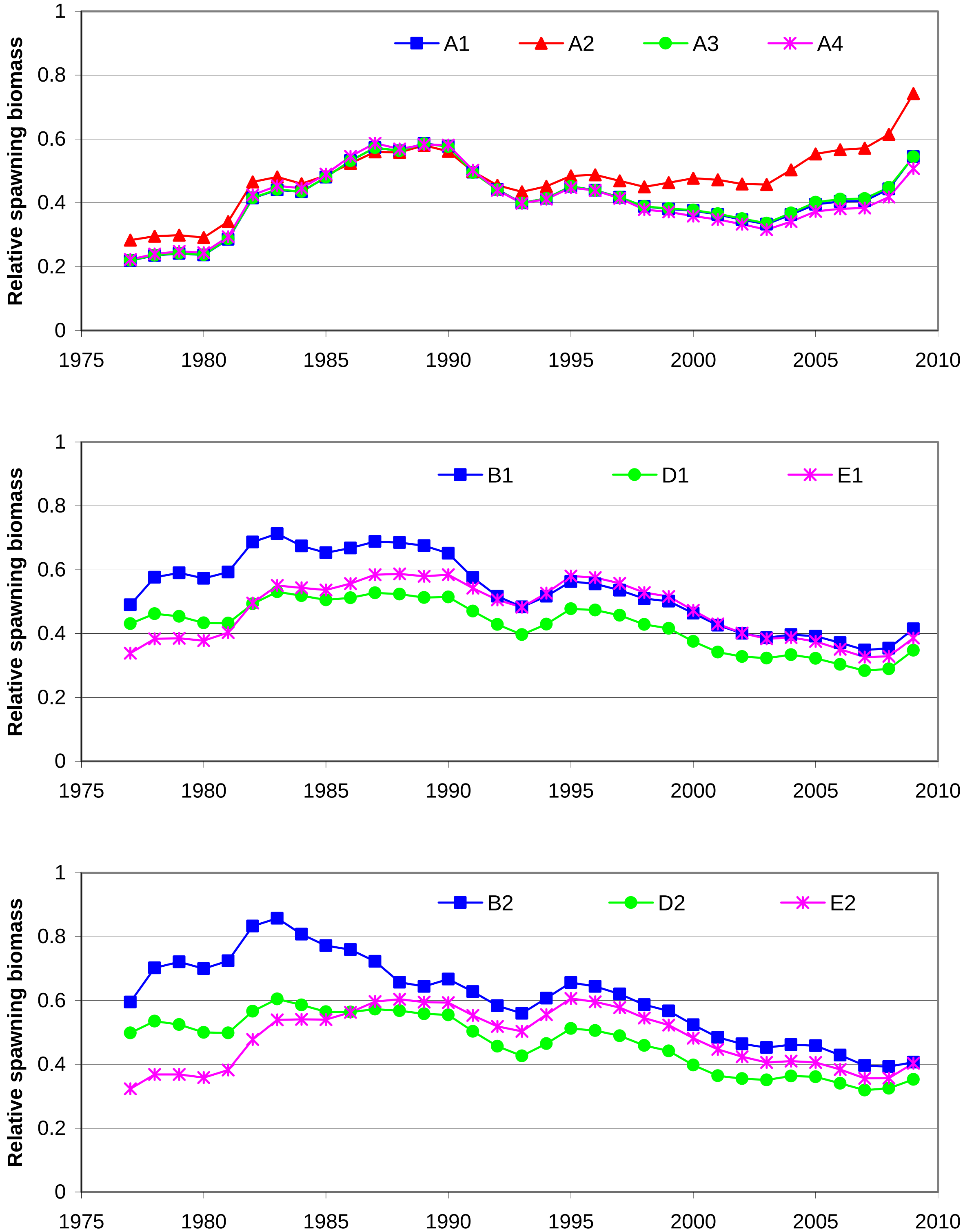
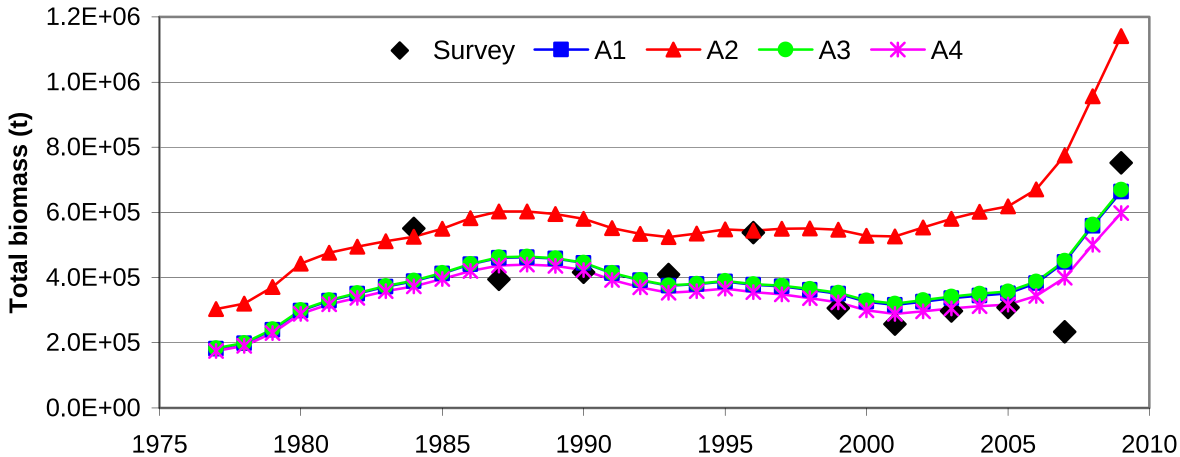
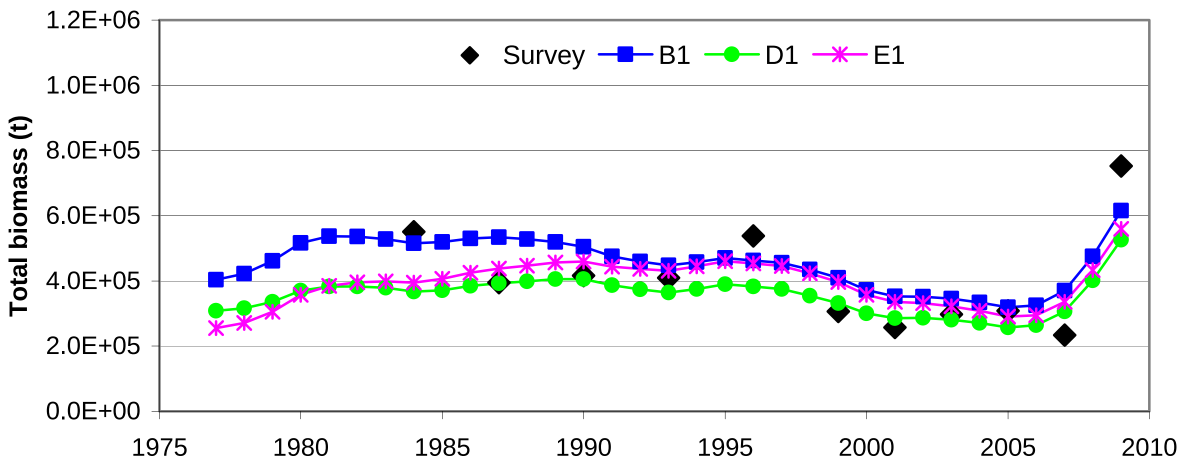


Figure 2.5—Time series of relative spawning biomass as estimated by the ten models.





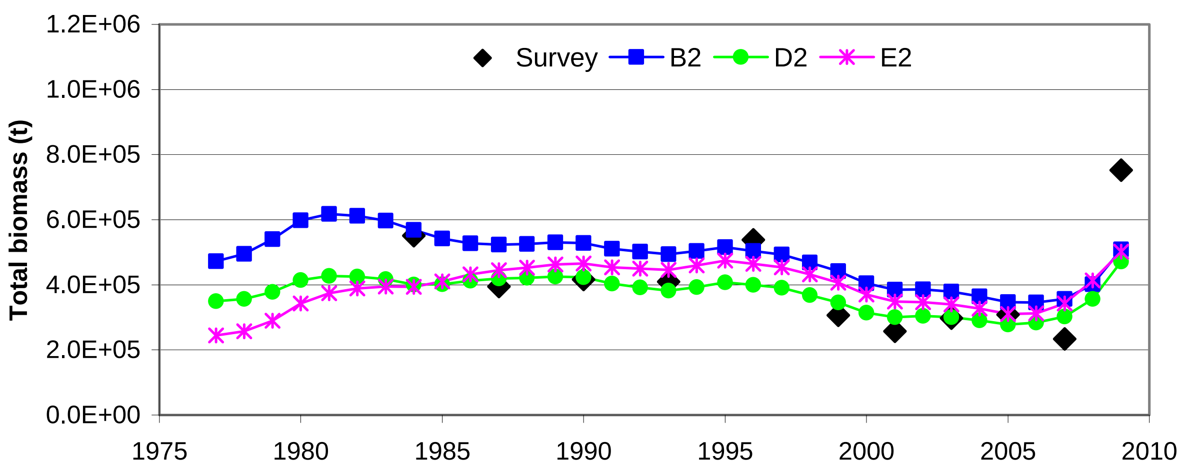


Figure 2.6—Time series of total (age 0+) biomass as estimated by the ten models. Survey biomass is shown for comparison.

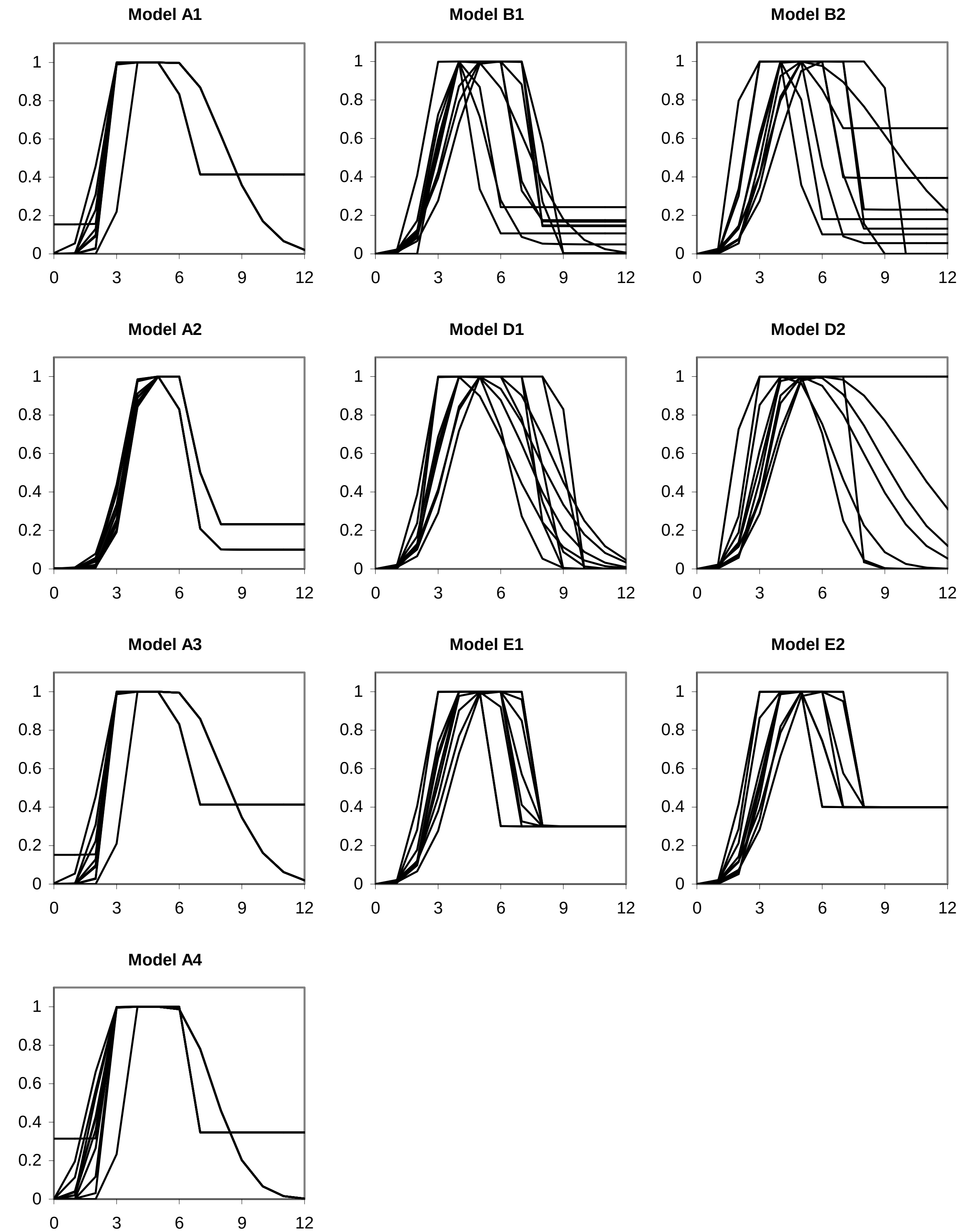


Figure 2.7—27-plus trawl survey selectivity as estimated by the ten models.

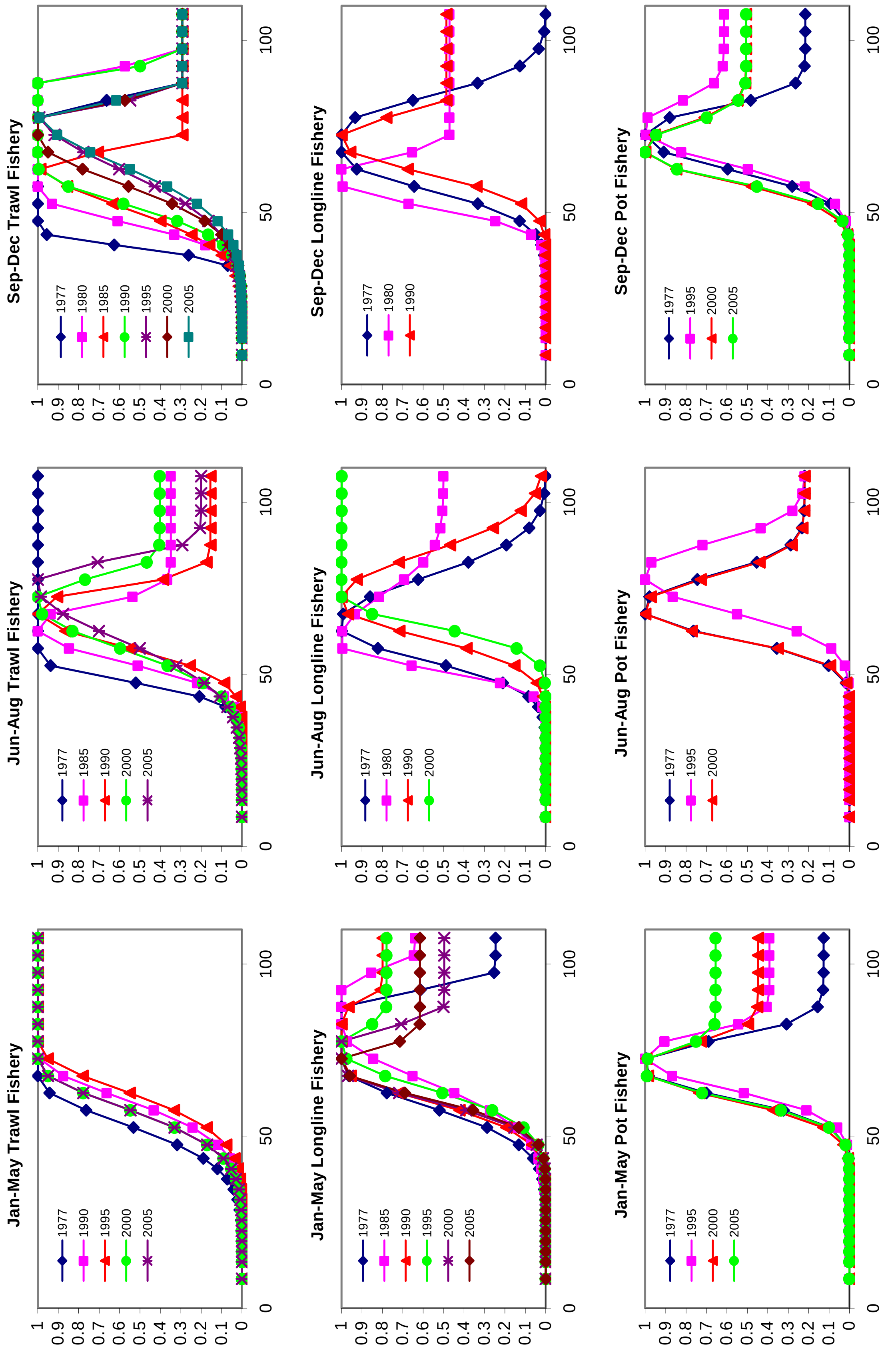


Figure 2.8A1—Fishery selectivities as estimated by Model A1.

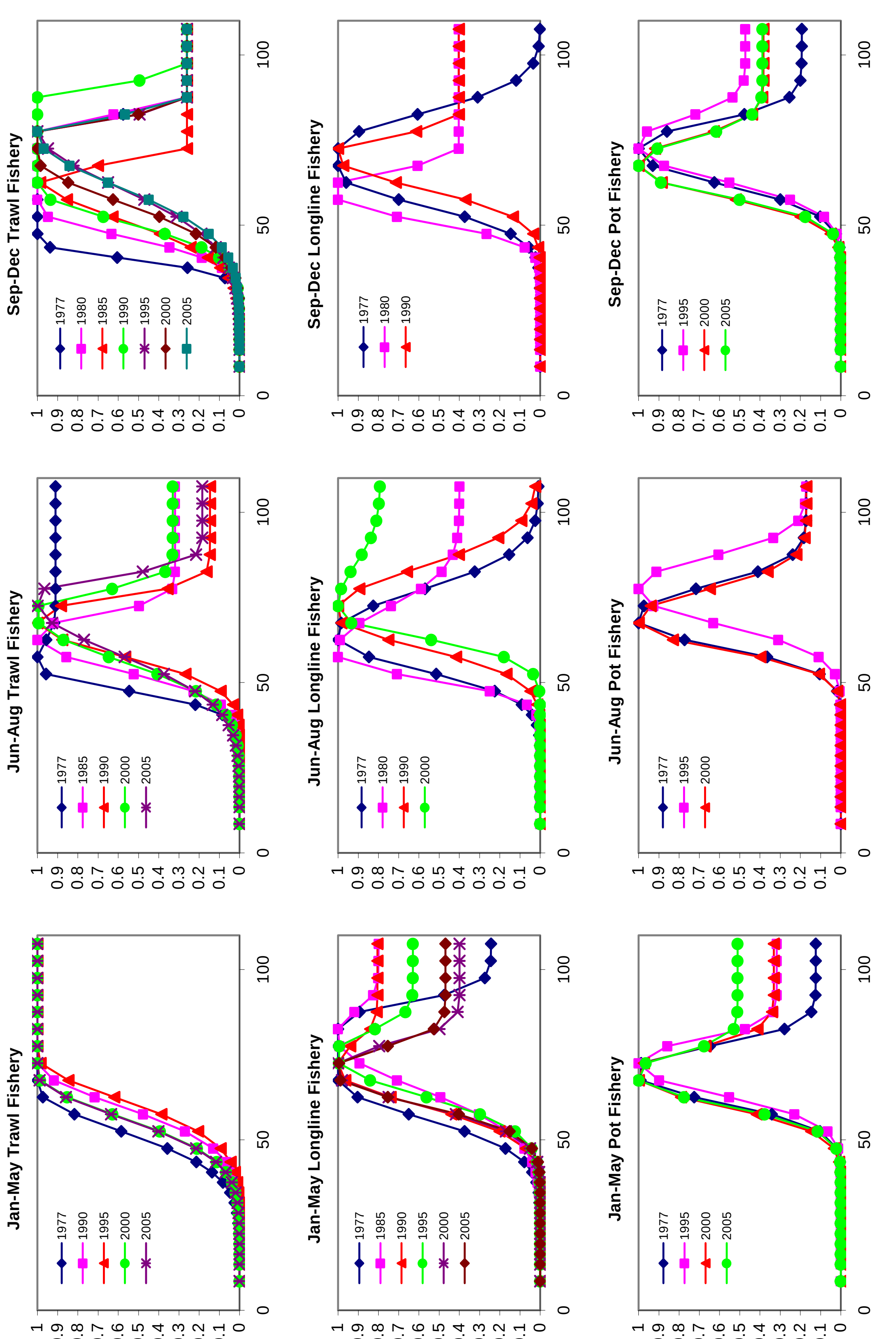


Figure 2.8A2—Fishery selectivities as estimated by Model A2.

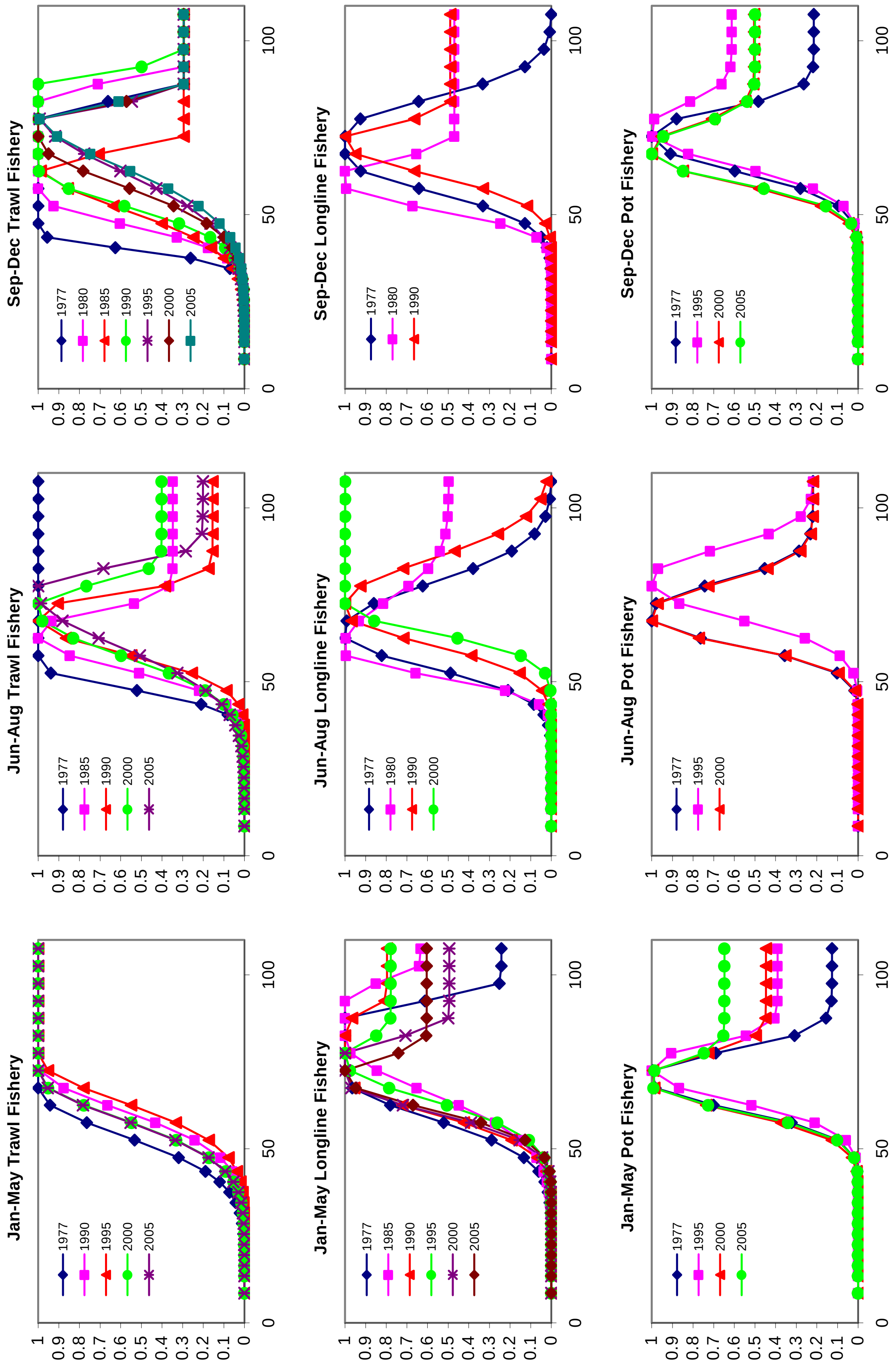


Figure 2.8A3—Fishery selectivities as estimated by Model A3.

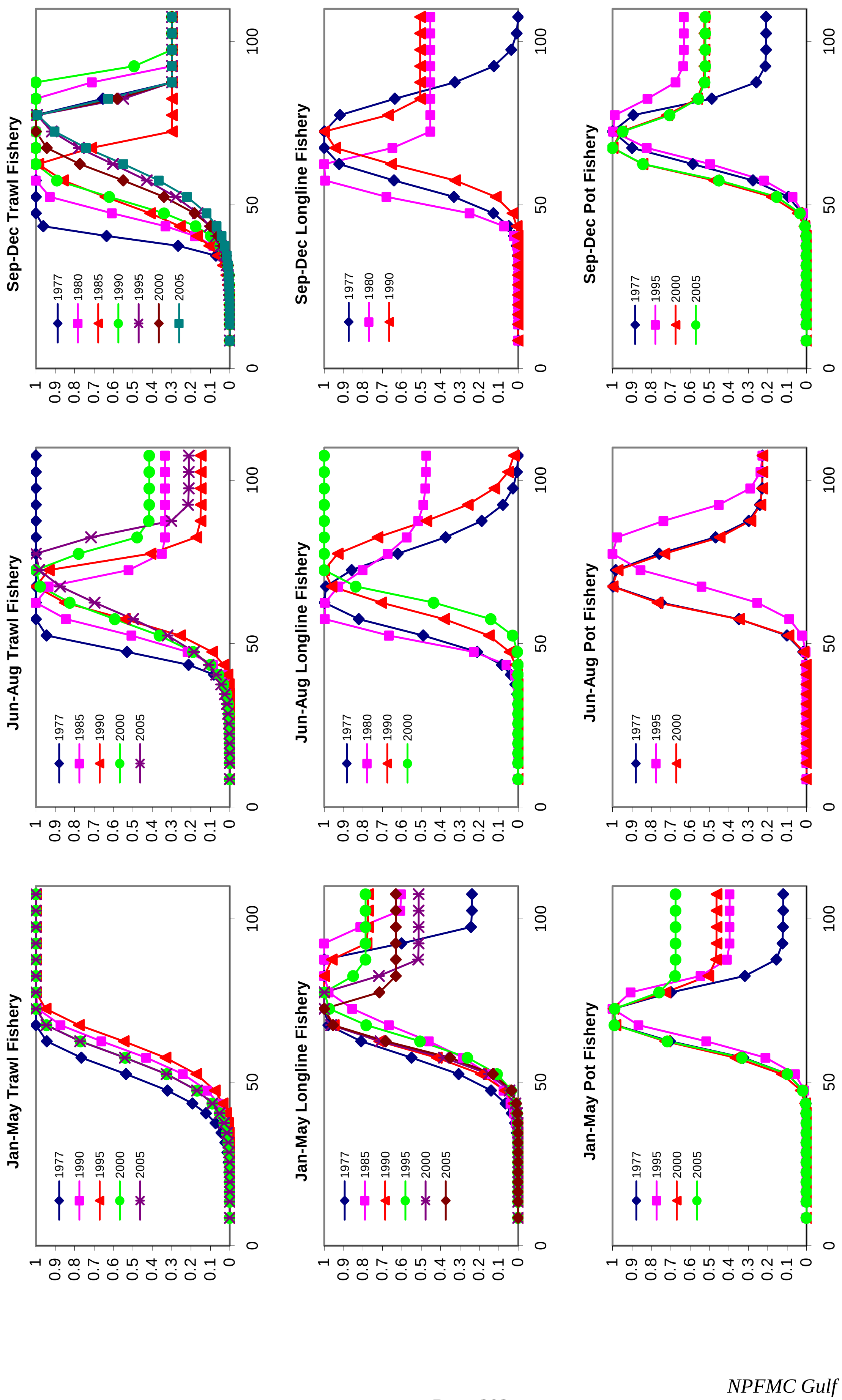


Figure 2.8A4—Fishery selectivities as estimated by Model A4.

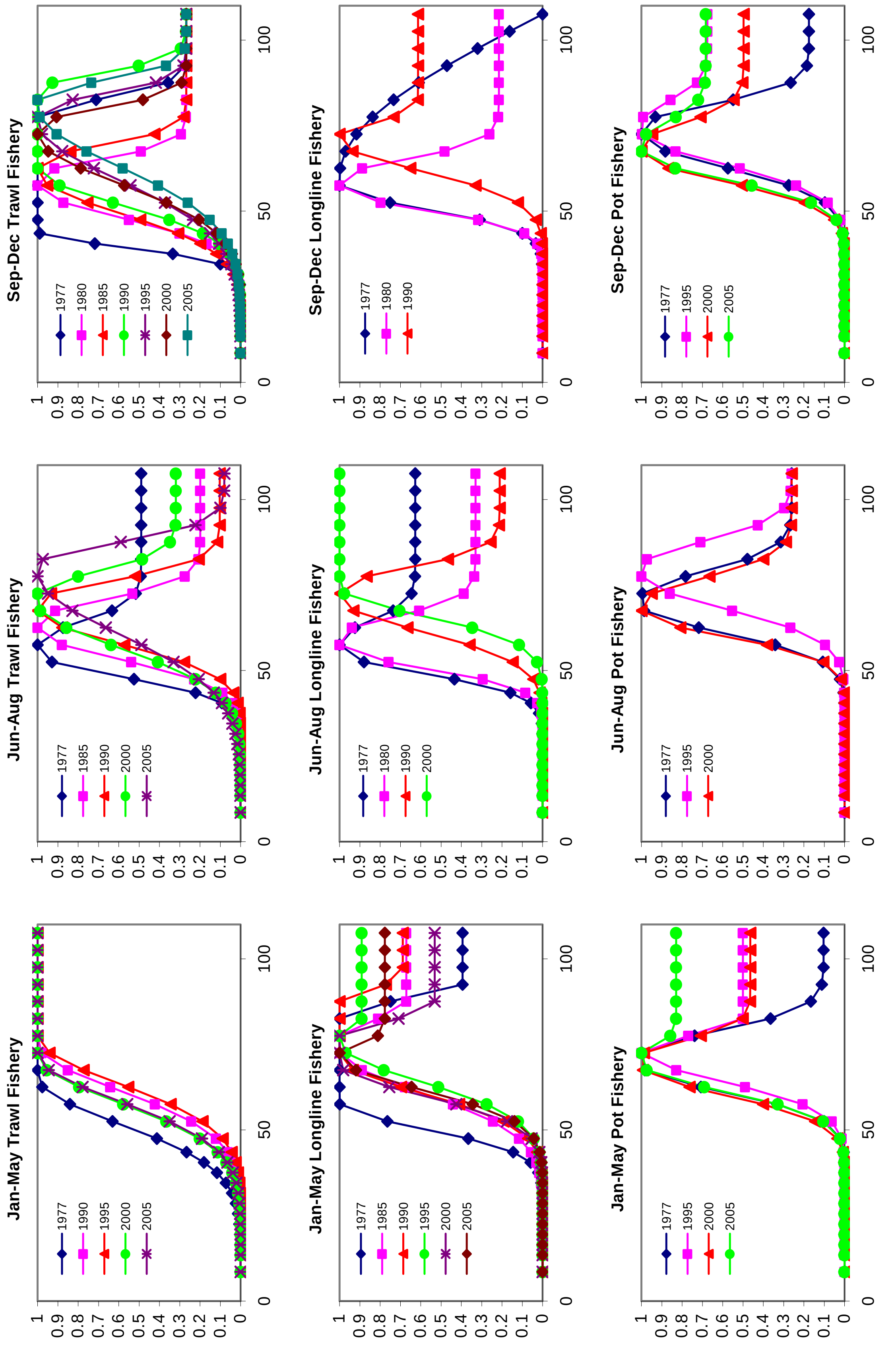


Figure 2.8B1—Fishery selectivities as estimated by Model B1.

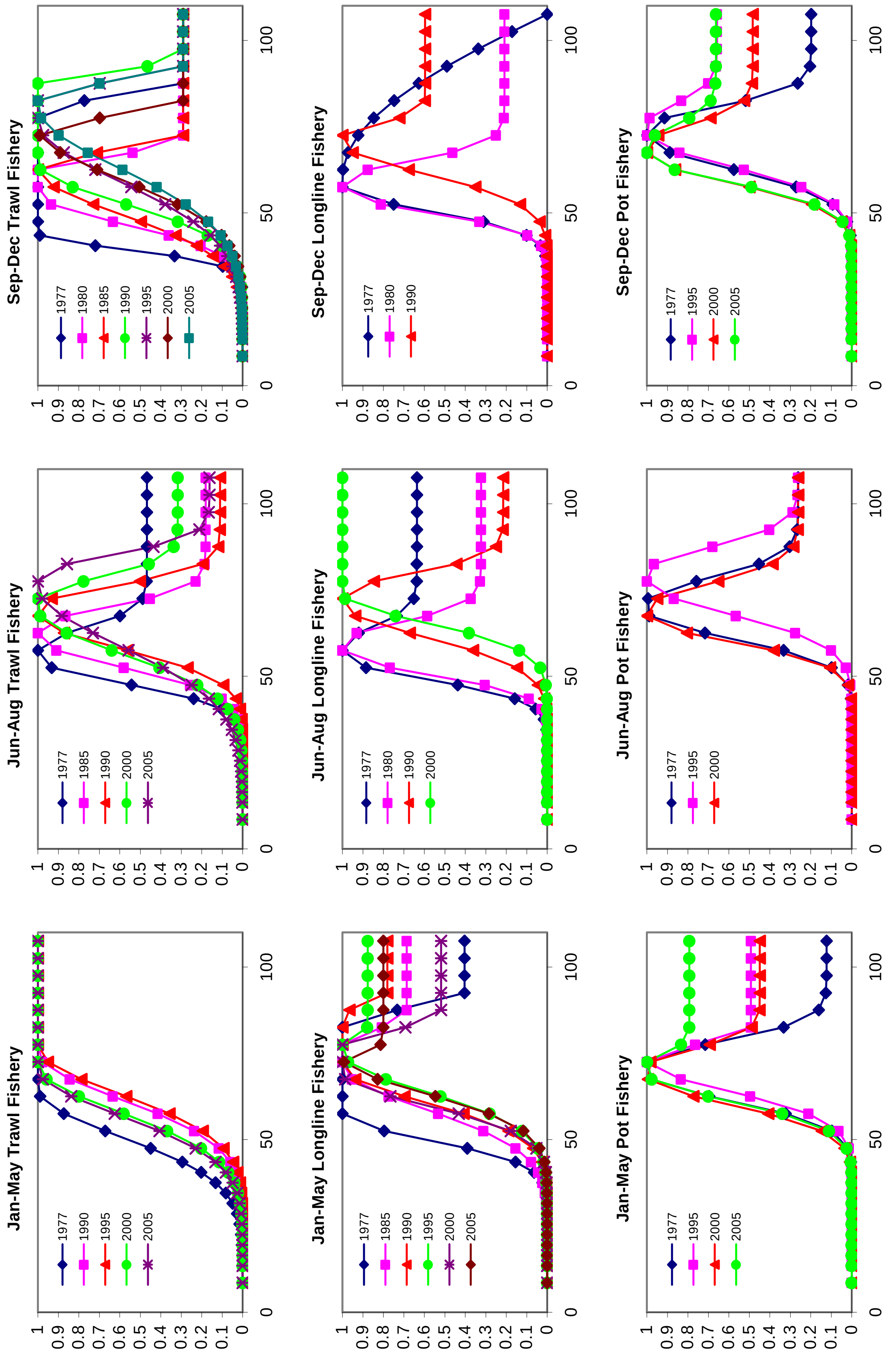


Figure 2.8B2—Fishery selectivities as estimated by Model B2.

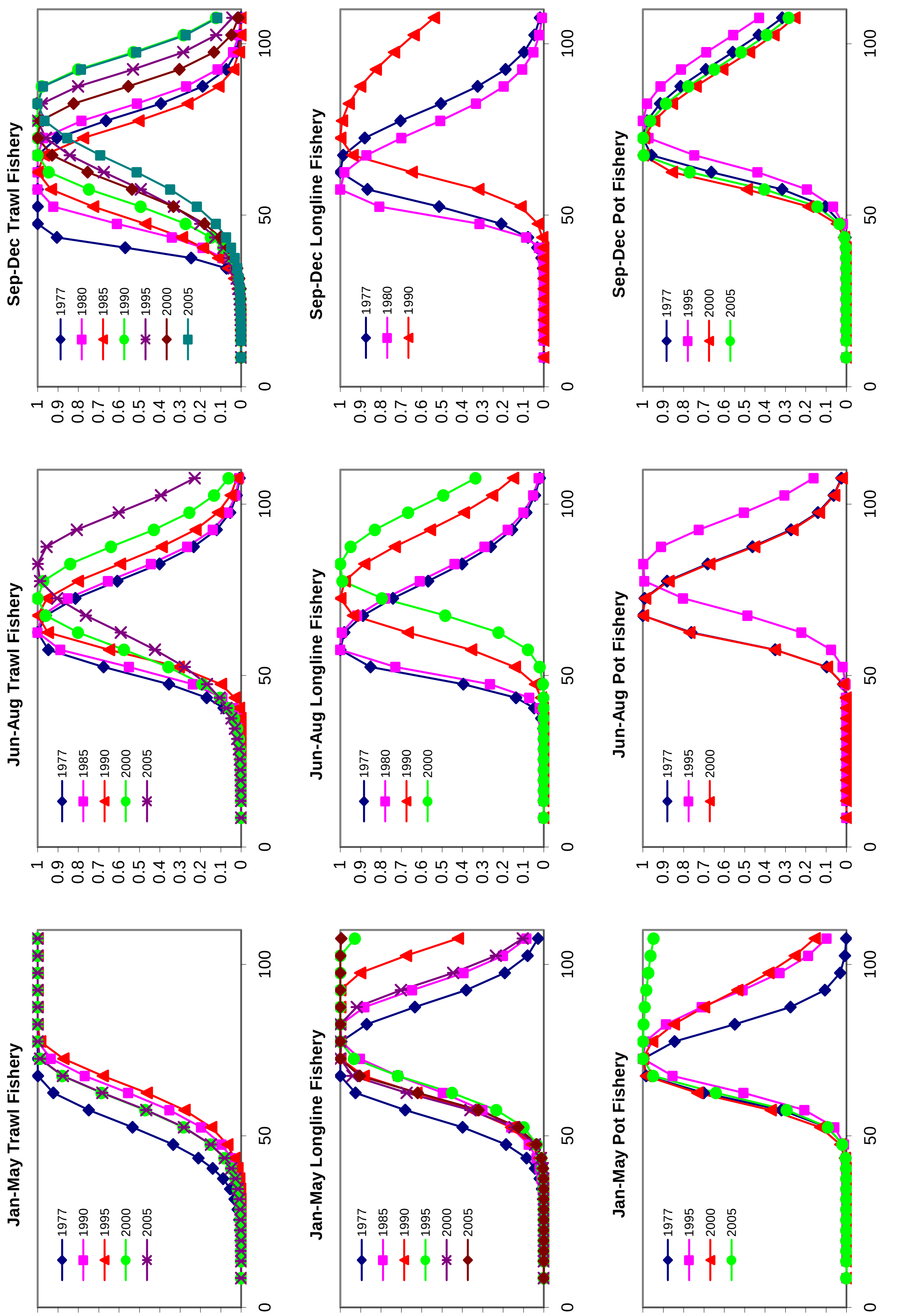


Figure 2.8D1—Fishery selectivities as estimated by Model D1.

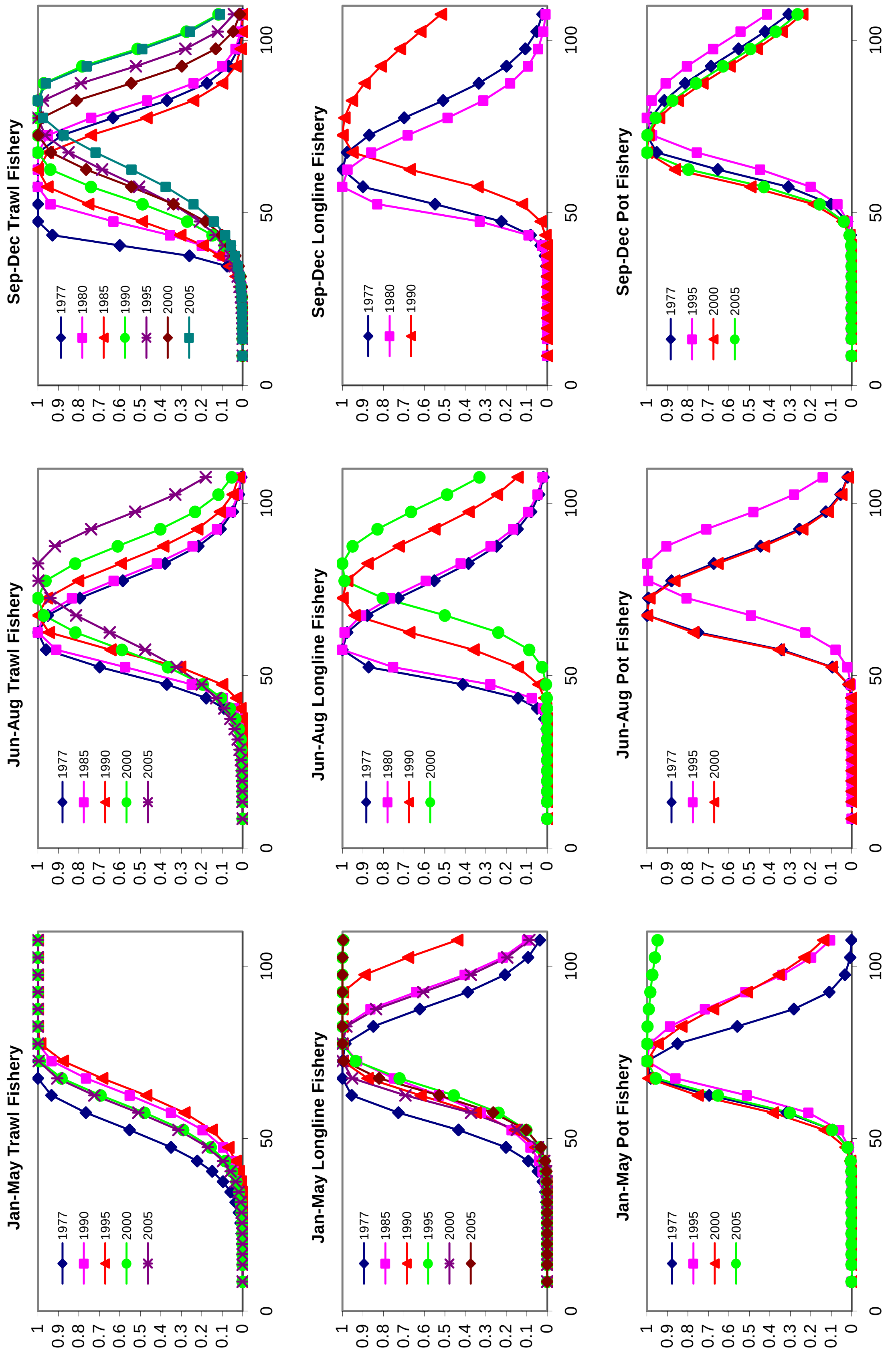


Figure 2.8D2—Fishery selectivities as estimated by Model D2.

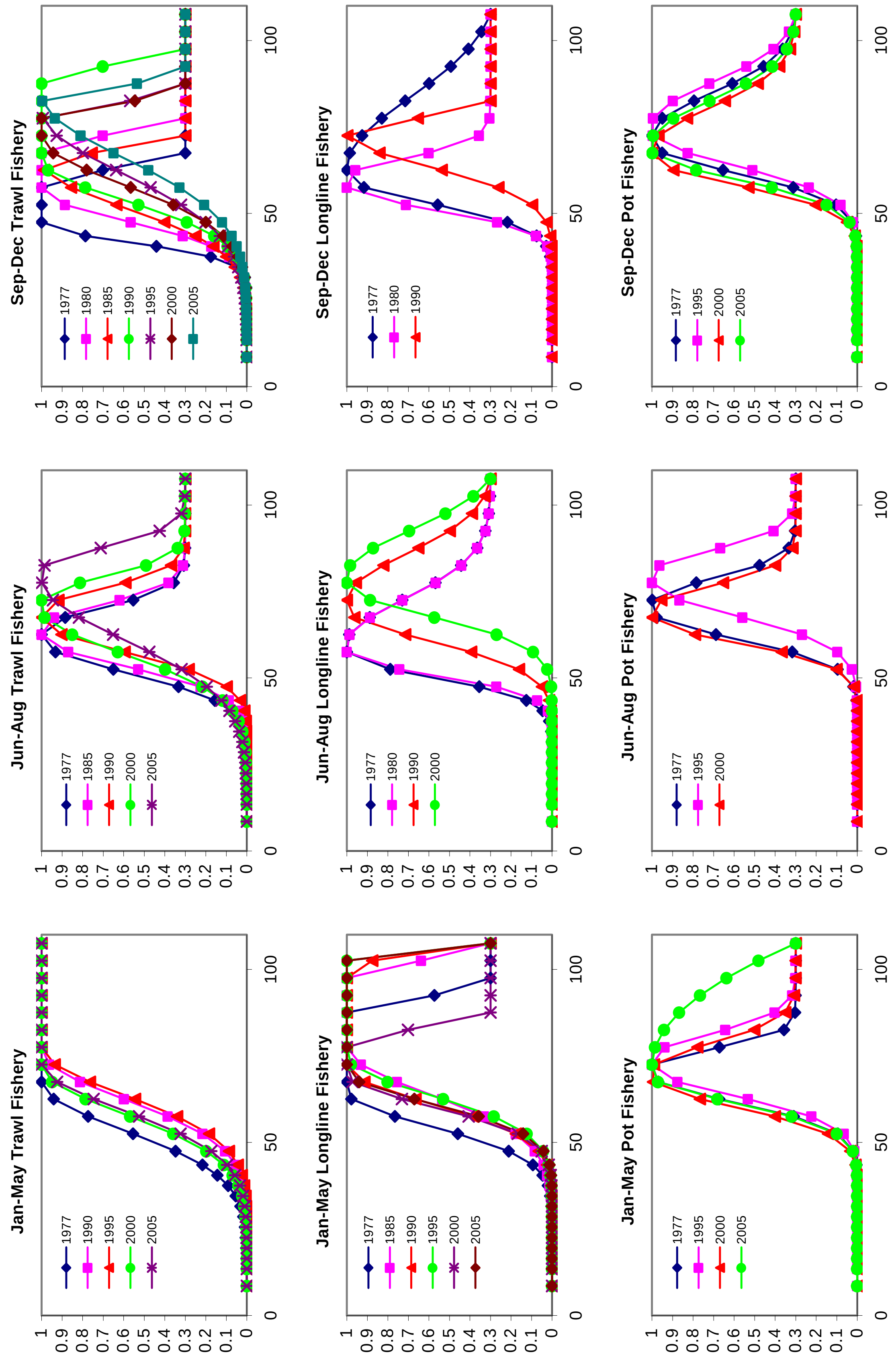


Figure 2.8E1—Fishery selectivities as estimated by Model E1.

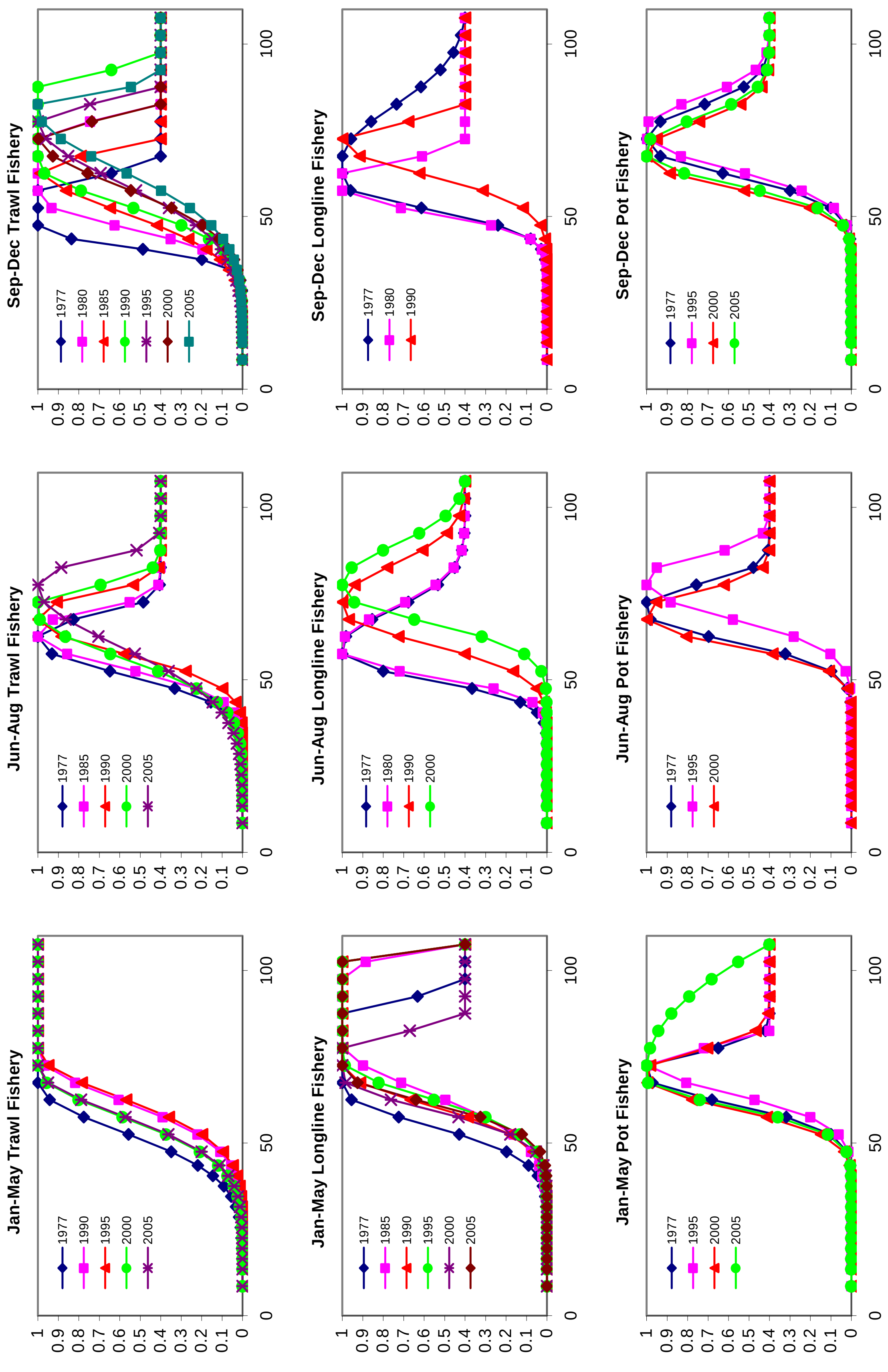


Figure 2.8E2—Fishery selectivities as estimated by Model E2.

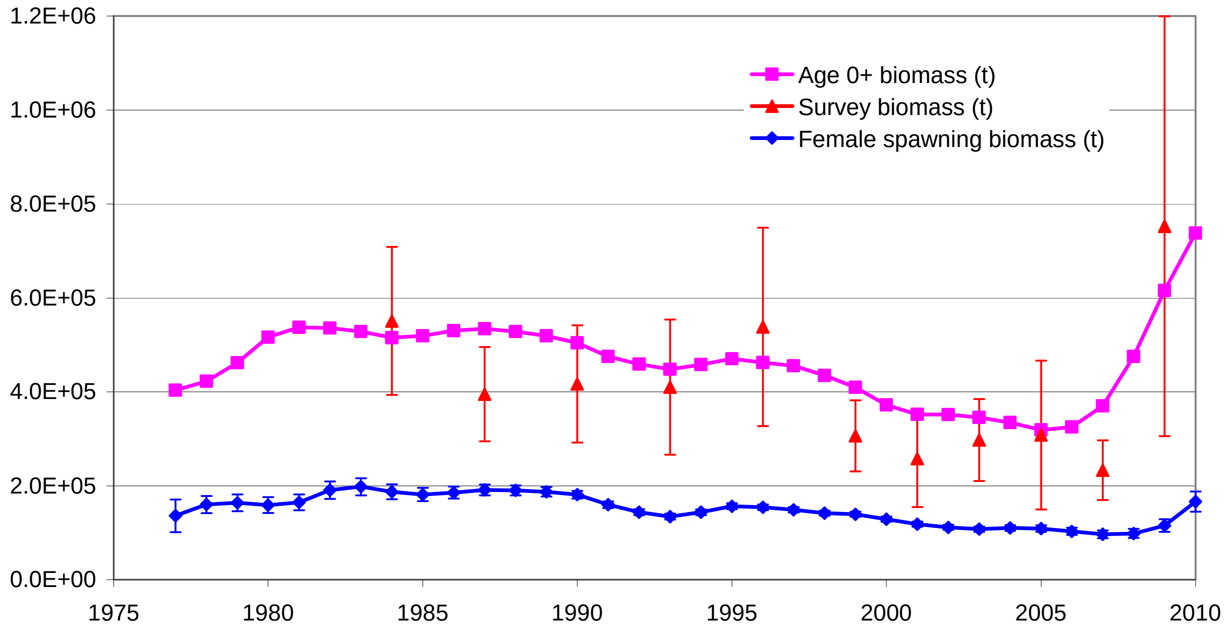


Figure 2.9—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) as estimated by Model B1. Female spawning biomass and survey biomass show 95% CI.

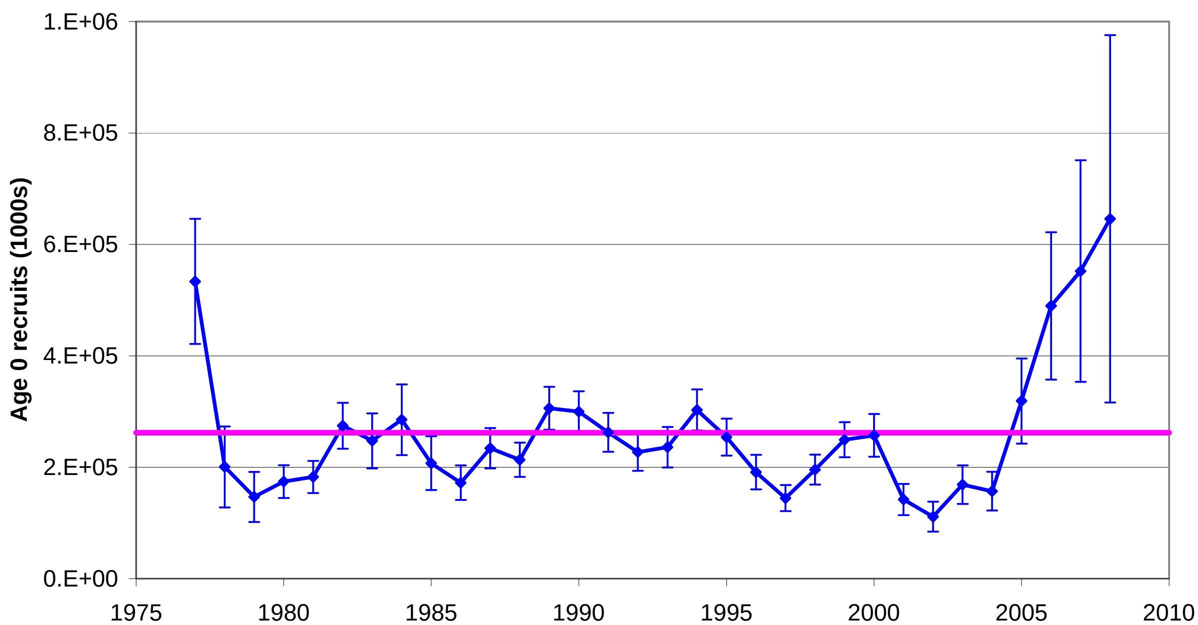


Figure 2.10—Time series of recruitment at age 0, with 95% confidence intervals, as estimated by Model B1. Magenta line = 1977-2008 average.

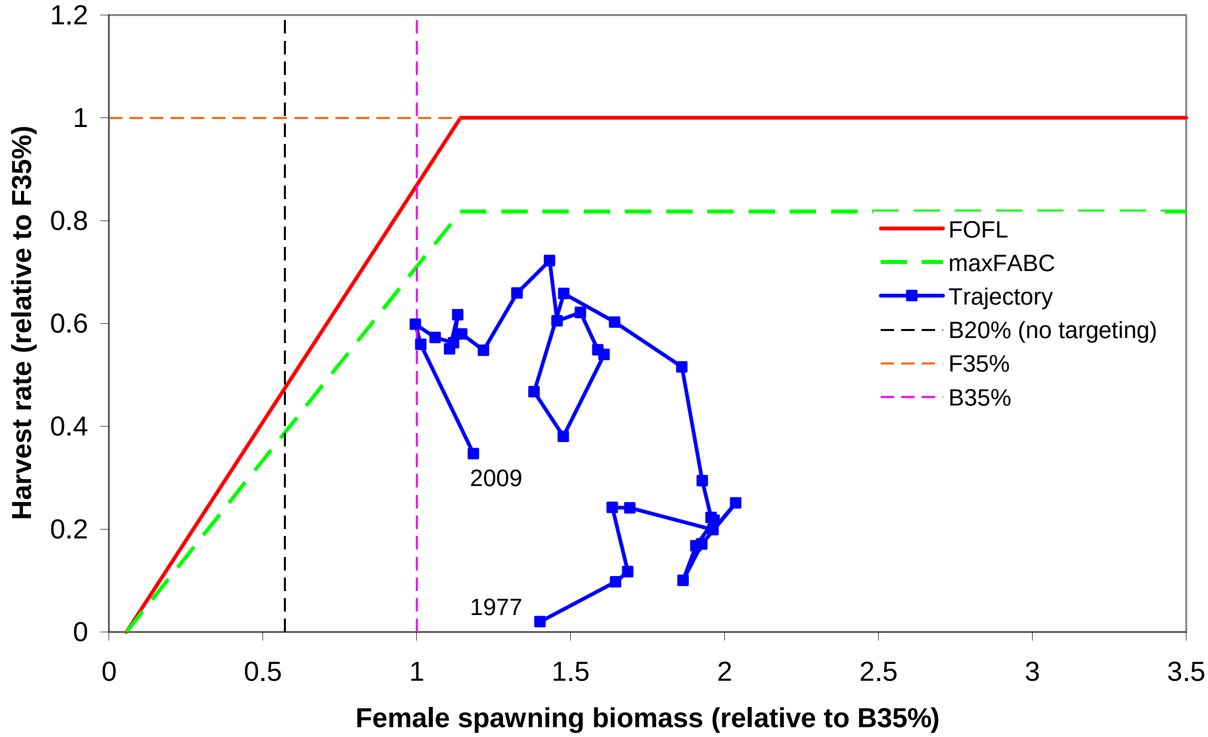


Figure 2.11—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model B1, 1977-present. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.

Attachment 2.1:
An exploration of alternative models of the Gulf of Alaska Pacific cod stock

Grant G. Thompson, James N. Ianelli, and Mark E. Wilkins

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center
7600 Sand Point Way NE., Seattle, WA 98115-6349

Introduction

This document represents an effort to respond to comments made by the joint BSAI and GOA Plan Teams, the GOA Plan Team, and the SSC on the 2008 assessment of the Pacific cod (*Gadus macrocephalus*) stock in the Gulf of Alaska (Thompson et al. 2008).

Eleven models are presented here. These include the model that was recommended in the 2008 assessment and adopted by the GOA Plan Team and the SSC ("Model A"), plus 10 alternative models.

Joint Plan Team Comments from the September, 2008 Minutes

JPT1: "*The Plan Team commented that the assessment author attempted to reduce number of selectivity parameters to the extent possible but this model is still overly complicated as a result of the software being used. A simpler selectivity parameterization was suggested, e.g. exponential-logistic. SS2 notably does not allow for this in the present software. The Plan Teams requested that the selectivity function be further simplified even if it means modifying SS2 accordingly.*" In response to this request, Stock Synthesis (SS) now includes a version of the exponential-logistic selectivity function (Thompson 1994) as an option, and this preliminary assessment considers several new models that use the exponential-logistic selectivity function, as described in the "Analytic Approach" section, under the heading "Model Structure," subheading "Alternative Models."

GOA Plan Team Comments from the November, 2008 Minutes

GPT1: "*The Team's primary concerns regarding the model are the following:*

1. *Fits to the survey time series.*
2. *The age composition sample size needs to be decreased in order to fit the length data. There appears to be an inconsistency between data sets in the assessment.*
3. *Age-specific selectivity*"

Fits to the survey time series, the effects of decreasing the emphasis on the age composition data, and inconsistency between data sets are all addressed in the "Results" section, under the heading, "The Problem of Residual Patterns in the Fits to the 27-Plus Trawl Survey Abundance Data." Plan Team concerns regarding use of age-based selectivity for the 27-plus survey is addressed by considering two new models that use *size*-based selectivity for the 27-plus survey, as described in the "Analytic Approach" section, under the heading "Model Structure," subheading "Alternative Models."

GPT2: *"The Team requests the assessment include a specific discussion of selectivity outside of the discussion of the model. For example, does the available information on habitat use of Pacific cod, the response to fishing gear, seasonal or ontogentic changes in distributions, changes in natural mortality with age, etc. help explain the selectivity patterns obtained from the model?"* This request will be addressed in the final assessment.

GPT3: *"The Team questioned to what extent the software being employed is limiting the ability to address many issues in the assessment."* The GOA and BSAI Pacific cod assessments both use the SS software package. Although *any* software is necessarily limited in what it can accomplish, SS must surely rank as one of the most flexible stock assessment packages available. Because SS is revised so frequently in response to requests for inclusion of additional features (e.g., see the response to comment JPT1), a completely up-to-date user manual is currently not available. However, Methot (2009) provides an *almost* up-to-date list of available features. In the interest of efficiency, this list is not repeated here.

GPT4: *"The Team had extensive discussions of several model issues. The model does not allow for any catch over age 12. There is a fundamental inconsistency between the size and age compositions from the survey and the biomass from the survey. Thus, the author downweights the age composition data to fit the trend better. Both size and age data have to be downweighted substantially however to fit the observed survey data."* Except for the second sentence, this comment elaborates on comment GPT1. See comment GPT1 for a response. With respect to the second sentence, this assertion may need some qualification. With respect to the fisheries, the assertion made in the second sentence is not true. For example, the January-May trawl fishery exhibited asymptotic selectivity. Specifically, all fish above a length of about 75 cm (approximately age 8 or so) were estimated to be fully selected by that fishery. Because the model explicitly accounted for fish aged 0-19 (with age 20 as a "plus" group), the model clearly did allow for catch of fish over age 12. With respect to the trawl survey, it is true that the estimated selectivity beyond age 12 was virtually zero. However, it may be important to keep in mind that, of the 4,942 survey otoliths aged prior to the 2008 assessment, only 1 was older than 12 years of age.

GPT5: *"The Team would like to see additional examination of the selectivity patterns and other issues as noted regarding model configuration."* The only "issues" identified in the Plan Team minutes are those listed under comments GPT3 and GPT4. See comments GPT3 and GPT4 for responses.

GOA Plan Team Comments from the 2008 GOA SAFE Report Introduction

GPT6: *"A number of issues were noted by the Plan Team and authors regarding fit to survey data and estimation of selectivity. The fit of the preferred model to the 27-plus survey abundance was problematic in that each of the model estimates was an underestimate of the observed survey abundance estimate. The fit to this time series improved as the age and length compositions were downweighted, which indicates some inconsistency in the input data which should be explored in more detail. Some of the fishery and survey selectivity curves show sharp reductions at older ages or larger sizes which seem implausible."* Except for the last sentence, this comment elaborates on parts of comment GPT1. See comment GPT1 for a response. The last sentence is addressed here by considering several new models that use the exponential-logistic selectivity function, which appears to be less prone to sharp changes in selectivity at older ages or larger sizes (see also the response to comment JPT1).

GPT7: *"The Team also requests that the assessment include more information and discussion on the biology and life-history of Pacific cod. This material is requested for background information and to help* *understand how the behavior and distribution patterns of Pacific cod interact with the fishery and survey processes."* This request elaborates on comment GPT2, and will be addressed in the final assessment.

SSC Comments on Assessments in General

SSC1: *"The BSAI Plan Team recommended that all authors of stocks managed in Tiers 1 through 3 should estimate the probability of the spawning stock biomass falling below $B_{20\%}$. The recommended time frame for this projection was 3-5 years. The SSC agrees with this recommendation and encourages authors to provide estimates of the probability of falling below biologically relevant thresholds such as $B_{20\%}$."* This request will be addressed in the final assessment.

SSC Comments Specific to the GOA Pacific Cod Assessment

SSC2: *"The model fits are so troubled that this stock is a candidate for Tier 5...."* Given that the average ratio of effective sample size to input sample size exceeded unity for all nine fisheries in the 2008 model, it will be assumed here that the "fits" referenced by the SSC consist of the fit to the 27-plus trawl survey abundance data. See comment GPT1 for a response.

Data

The basic data sources in the 11 models examined here are the NMFS bottom trawl survey and the fisheries. In all models, fisheries are structured by gear (trawl, longline, and pot) and season (Jan-May, Jun-Aug, Sep-Dec). Data types include relative abundance from the survey, catch from the fisheries, size composition from the survey and fisheries, age composition from the survey, and mean size at age from the survey. Catch per unit effort data from the fisheries are included for purposes of comparison, but are not used in parameter estimation.

The data set for Model A was described in the 2008 assessment. One feature of the data set that was new in the 2008 assessment was the division of the trawl survey data into a pair of size-based partitions: one partition for all fish smaller than 27 cm (the "sub-27" trawl survey), and another partition for all fish at least 27 cm in length (the "27-plus" trawl survey). This was undertaken in an attempt to accommodate what appeared to be a bimodality in the size composition data, wherein age 2 fish seemed to be less fully selected than either age 1 or age 3 fish.

The data set for each of the other 10 models is identical to the Model A data set, except that the size-at-age data from the trawl survey have been modified in two ways:

1. In the data set for Model A, size-at-age data were included for the years 1996, 1999, 2001, 2003, and 2005. In the data sets for the other 10 models, size-at-age data from 1987, 1990, and 1993 have also been included.
2. In the data set for Model A, mean size at age was computed by averaging the lengths at each age in the otolith sample. In the data sets for the other 10 models, mean size at age was computed by applying the age-length key. The SSC requested this change for the BSAI assessment. Given that size-at-age data are not used in the BSAI assessment, it seems even more important that this change be made in the GOA assessment, where size-at-age data *are* used.

Analytic Approach

Model Structure

Assessment Software

The 2008 assessment used SS V3.01-f. In this preliminary assessment, SS V3.03-c was used.

Base Model

The model recommended by the authors and adopted by the GOA Plan Team and SSC in 2008 was described by Thompson et al. (2008). Briefly, the main features that characterized the 2008 model were as follows:

1. The 2008 model used an algorithm developed in the 2007 BSAI Pacific cod assessment (Thompson et al. 2007) to set the input sample size for the size composition data.
2. The 2008 model set the input sample size for the age composition data proportional to the number of fish aged, with the proportionality constant chosen so as to result in an average input sample size of 100.
3. The 2008 model set an emphasis of 0.12 on the age composition data.
4. The 2008 model treated the coefficient of variation of length at age as a linear function of length at age.
5. The 2008 model specified seasonal weight-at-length relationships.
6. The 2008 model estimated log recruitment variability, iteratively, as the standard deviation of the recruitment “devs” from 1977 to 2007.
7. The 2008 model specified separate recruitment “dev” vectors for the pre-1977 and post-1976 environmental regimes.
8. The 2008 model fixed catchability of the 27-plus survey at a value of 0.92 over the entire time series, based on Nichol et al. (2007).
9. The 2008 model estimated catchability of the sub-27 survey internally as a random walk, with $\sigma = 0.2$.
10. The 2008 model allowed individual fishery selectivity parameters to vary between blocks of years only if the cost of the additional parameters was outweighed by a sufficient improvement in the model’s fit to the data (this resulted in some parameters being held constant over all years, while others varied at 5-year, 10-year, and 20-year intervals).
11. The 2008 model estimated individual year class strengths in the initial numbers at age vector only if the cost of the additional parameters was outweighed by a sufficient improvement in the model’s fit to the data (this resulted in three individual year class strengths being estimated).
12. The 2008 model forced the January-May trawl fishery to exhibit asymptotic selectivity during all time blocks, based on an algorithm described in the 2008 assessment (Thompson et al. 2008).
13. The 2008 model estimated age-specific selectivities for the three ages covered by the sub-27 survey (ages 0, 1, and 2), which was more efficient than estimating the six parameters used by the usual “double normal” selectivity function.
14. The 2008 model treated selectivity of the 27-plus survey as a function of age, to be consistent with the Bering Sea Pacific cod model.
15. The 2008 model defined a survey selectivity block for each survey year, and estimated the parameters of the ascending limb separately for each block.

16. The 2008 model treated the years 1984-1993 and 1996-2007 as the only two time blocks for the remaining parameters of the 27-plus survey selectivity schedule, to coincide with the switch from 30-minute to 15-minute tows in the survey design.

As the new base model in this preliminary assessment, the 2008 model is labeled Model A (not to be confused with the model with the same label in the 2008 assessment).

Alternative Models

Ten alternatives to the base model are presented here. They are labeled Models B, C, D1, D2, D3, D4, D5, D6, E1, and E2. Their distinguishing features are summarized in Table 2.1.1, and described in hierarchical fashion along with their respective motivations below:

Models B-E2 all share a common data set, incorporating the revised size-at-age data described in the "Data" section (Model A uses the data set described in the 2008 assessment). Except for this difference, Model B is identical to Model A. Consideration of models using the revised size-at-age data was motivated by a request from the SSC (albeit directed at the BSAI Pacific cod assessment), as described in the "Data" section.

Models C-E2 all use an emphasis of 1.00 for the age composition data (Models A-B use an emphasis of 0.12). Except for this assumption, Model C is identical to Model B. Consideration of models using the conventional assumption of unit emphasis was motivated by comments GPT1, GPT4, GPT5, GPT6, and SSC2.

Models D1-E2 all use a catchability of 1.00 for the pre-1996 portion of the 27-plus trawl survey (Models A-C use a catchability of 0.92 for all years). Except for this assumption, Model D1 is identical to Model C. Consideration of models using unit catchability was motivated primarily by the fact that such models tended to fit the data better and the fact that the SSC endorsed the use of fixed values for catchability in the BSAI Pacific cod assessment (SSC minutes, December 2008).

Models D1-D6 comprise a factorial design of models focusing on the functional form of the selectivity curve and the choice of fleet(s) constrained to exhibit asymptotic selectivity. More specifically, the factors are as follow:

1. Does selectivity follow the double normal form or the exponential-logistic form?
2. Is selectivity for the January-May trawl fishery free or constrained to be asymptotic?
3. Is selectivity for the 27-plus trawl survey free or constrained to be asymptotic?

In forming the factorial design for Models D1-D6, it was assumed that selectivities for the January-May trawl fishery and the 27-plus trawl surveys could not *both* be free (i.e., at least one had to be asymptotic). Consideration of models with exponential-logistic selectivity was motivated by comments JPT1 and GPT6. Consideration of models with asymptotic trawl survey selectivity was motivated by a comment from the BSAI Plan Team in the introduction to the 2008 BSAI SAFE report: "The authors describe a reasonable method for selecting which fisheries should exhibit asymptotic selectivity.... The Plan Team recommends that the authors apply this method in next year's model(s) and examine whether assuming asymptotic selectivity also is appropriate for the shelf bottom trawl survey."

Models E1 and E2 use size-based, rather than age-based, selectivity for the 27-plus trawl survey (Models A-D6 use age-based selectivity). Model E1 uses double normal selectivity and Model E2 uses exponential-logistic selectivity. Consideration of models with size-based selectivity for the 27-plus trawl survey was motivated by comment GPT1.

To keep the base model and the alternative models as comparable as possible (given the differences listed above), the σ parameter constraining the amount of recruitment variability and the time blocks governing time-varying selectivity parameters were held constant across all models to the extent possible.

Other Models Evaluated but not Carried Forward

A total of 168 other models (not counting hundreds of "jitter" runs) were evaluated but not carried forward into the present document. Many of these contained one or more of the following features (list is not exhaustive):

- Decreasing size composition emphasis
- Decreasing age composition emphasis (including zero emphasis)
- Decreasing size-at-age emphasis (including zero emphasis)
- Adding a constant to the 27-plus trawl survey "sigma"
- Decreasing the 27-plus trawl survey "sigma"
- Turning off size composition data for various blocks of years
- Turning off size composition data one year at a time
- Turning off size composition data one fleet at a time
- Freeing catchability for the 27-plus trawl survey
- Freeing pre-1996 catchability for the 27-plus trawl survey
- Imposing an informative normal prior on pre-1996 catchability for the 27-plus trawl survey
- Allowing catchability in the 27-plus trawl survey to follow a random walk
- Allowing all double normal selectivity parameters to change in each survey year
- Introducing cohort-specific length at age, with varying amounts of freedom
- Changing the age range from 0-20+ to 1-12+ or 1-13+
- Doubling the amount ageing error
- Setting the natural mortality rate equal to 0.40
- Freeing the natural mortality rate
- Freeing the natural mortality rate at ages 0 and 1
- Forcing the natural mortality rate at ages 0 and 1 to be higher than at ages 2 and above.
- Imposing symmetric beta priors on exponential-logistic selectivity parameters
- Relaxing the assumption that at least one fishery or survey must exhibit asymptotic selectivity
- Changing from size-based to age-based selectivity for fisheries
- Estimating a separate, *time-invariant*, selectivity for each age in the 27-plus trawl survey
- Estimating a separate, *time-variant*, selectivity for each age in the 27-plus trawl survey

Parameters Estimated Independently

All parameters estimated independently are fixed at the values used in the 2008 assessment. These include the natural mortality rate, mean length at age 1 in July, the coefficient of variation in length at age 1 in July, parameters of the seasonal weight-at-length relationship, parameters of the maturity-at-age relationship, stock-recruitment "steepness," and catchability of the 27-plus trawl survey for the years 1996-2007 (and also for the years 1984-1993, in Models A-C).

Parameters Estimated Conditionally

Parameters estimated within SS include the Brody growth coefficient, mean length at age 20 in July, the coefficient of variation in length at age 20 in July, log mean recruitment under two environmental regimes (pre-1977 and post-1976), annual log recruitment deviations, annual fishing mortality rates, log catchability in the sub-27 trawl survey, and all selectivity parameters except those used to force at least one fleet to exhibit asymptotic selectivity.

Three selectivity patterns were used in the suite of models considered here:

I. For the fisheries and the 27-plus trawl survey in Models A-D3 and E1, double normal selectivity was assumed. As configured in SS, double normal selectivity uses the following six parameters:
   1. Beginning of the peak region (where the curve first reaches a value of 1.0)
   2. Width of the peak region (where the curve first departs from a value of 1.0)
   3. Ascending "width" (equal to twice the variance of the underlying normal distribution)
   4. Descending width
   5. Selectivity at minimum length (or age)
   6. Selectivity at maximum length (or age)

   All but parameter #1 are transformed: The widths are log-transformed and the other parameters are logit-transformed. Selectivity at minimum length (or age) was fixed at 0 for all fisheries.

II. For the fisheries and the 27-plus trawl survey in Models D4-D6 and E2, exponential-logistic selectivity was assumed. As configured in SS, exponential-logistic selectivity uses the following three parameters:
   1. Inverse scale (ranging from $-\infty$ to $+\infty$)
   2. Location of peak (the single point at which the curve reaches a value of 1.0)
   3. Shape (ranging from 0 to 1; to achieve a curve with selectivities close to unity for sizes/ages greater than the location of the peak, set the shape close to 0 if the scale is positive and close to 1 if the scale is negative)

   Parameter #2 is transformed by scaling it relative to the minimum and maximum length (or age).

III. For the sub-27 trawl survey in all models, age-specific selectivities were estimated for ages 0-2 and selectivity was assumed to equal zero for ages 3-20+.

As in the 2008 assessment, uniform prior distributions were used for all parameters except for log catchability in the sub-27 survey, which was estimated as a normal random walk.

Results

Goodness of Fit

Table 2.1.2 shows number of parameters, Akaike information criterion (AIC), and likelihoods for the 11 models. Log likelihoods and AIC values for Models A and B are not comparable with log likelihoods and AIC values for the other 9 models, because Models A and B use different data or emphases than the others. It should also be noted that log likelihood values for the fishery CPUE data (shown under "CPUE –ln(likelihood)") are provided for information only; these data are not used in parameter estimation.

Of the nine comparable models (C-E2), the following overall extrema can be identified from Table 2.1.2: Model D3 has the most parameters and Model D5 the fewest (note that annual fishing mortality rates do not count as parameters), Model D3 has the lowest total negative log likelihood and Model E2 the highest, and Model D1 has the lowest AIC value and Model E2 the highest.

On a component-by-component basis, and using log likelihood as the measure of goodness of fit, Table 2.1.2 indicates that Model D6 has the best fit to the survey abundance data and Model E1 the worst, Model D3 has the best fit to the size composition data and Model D5 the worst, Model C has the best fit to the age composition data and Model E2 the worst, and Model D6 has the best fit to the size-at-age data and Model E2 the worst. (Models A and B are excluded from these comparisons.)

In terms of fitting the size composition data on a fleet-by-fleet basis (9 fisheries plus 2 surveys = 11 fleets), and again using log likelihood as the measure of goodness of fit, Table 2.1.2 indicates that Models C, D4, and E1 each performed the best in two instances; and Models D1, D3, D5, D6, and E2 each performed the best in one instance. Model D4 performed the worst in four instances; Model E2 performed the worst in three instances; and Models D3, D5, D6, and E1 each performed the worst in one instance. (Models A and B are excluded from these comparisons.)

Table 2.1.3 provides an alternative way of evaluating goodness of fit for the size composition data, based on the relationship between input sample size and effective sample size. Four measures are presented: mean effective sample size, harmonic mean effective sample size, the mean of the ratio between effective sample size and input sample size, and the ratio between mean effective sample size and mean input sample size. Some of the performances are fairly robust across these four measures. For example, of the nine comparable models (C-E2), the following results emerge:

- Model C does the best job of fitting the June-August pot fishery data under three of the four measures.
- Model D4 does the best job of fitting the sub-27 trawl survey data under all four measures.
- Model D6 does the best job of fitting the January-May trawl fishery data under three of the four measures.
- Model E1 does the best job of fitting the January-May longline fishery data under three of the four measures and the best job of fitting the September-December longline fishery data and the January-May pot fishery data under all four measures.
- Model E2 does the best job of fitting the June-August trawl fishery data, the September-December pot fishery data, and the 27-plus trawl survey data under all four measures.

Similarly, Table 2.1.4 evaluates goodness of fit for the age composition data based on the relationship between input sample size and effective sample size. Models C-D6 tend to perform much better than Models A and B (which are not strictly comparable) and Models E1-E2 (which use size-based selectivity for the only fleet with age data), with Model D4 providing the best fit overall.

The Problem of Residual Patterns in the Fits to the 27-Plus Trawl Survey Abundance Data

As noted in comments GPT1, GPT4, GPT5, GPT6, and SSC2, Model A's fit to the 27-plus trawl survey abundance data is less than ideal, and apparently would have been worse had the age composition data not been heavily downweighted. The age composition data in Model A were given an emphasis of only 0.12 (compared to the conventional value of 1.00). This value was determined by adjusting the emphasis iteratively until the average root mean squared deviation from the model approximated the average input "sigma" (roughly equivalent to a coefficient of variation) from the surveys in years where age data were available. Thus, the *magnitudes* of the residuals from the fit to the survey abundance data under Model A are close to what would be expected (although at considerable cost to the fit to the age composition data). However, as the Plan Team has noted, these residuals are all of the same sign, whereas the expectation is that approximately half should be positive and half negative.

Tables 2.1.5-2.1.9 help to explain what happens when the emphasis on the age composition data increases from 0.12 (Model B) to 1.00 (Model C).

Table 2.1.5 shows negative log likelihoods for age composition, by year and age, for Models B and C. Because Model B uses an emphasis of 0.12 for the age composition data while Model C uses an emphasis of 1.00, values for Model B have been divided by 0.12 to make the results comparable. Differences in negative log likelihoods (Model C minus Model B) are shown in the bottom section of the table. As expected, Model C provides a better fit to the age composition data: For ages 4-8, negative log likelihoods are decreased (i.e., the fit is improved) under Model C in all years. Only at ages 2 and 3 (and perhaps age 10) does Model B tend to provide a better fit to the age composition data than Model C.

Although increasing the emphasis on the age data from 0.12 (Model B) to 1.00 (Model C) improves the overall fit to the age composition data, it also tends to degrade the fit to the 27-plus survey abundance data. Tables 2.1.6-2.1.9 demonstrate how this occurs.

Table 2.1.6 shows population numbers (1000s) at age in July of each survey year as estimated by Models B and C, along with the differences between the respective estimates (Model C minus Model B). With very few exceptions, estimated numbers at each age increase by at least 10% in each year when moving from Model B (age composition emphasis = 0.12) to Model C (age composition emphasis = 1.00). Because the estimates of 27-plus survey abundance produced by Model B are uniformly lower than the data obtained from the survey itself, the fact that Model C tends to produce higher population sizes might suggest that Model C's fit to the survey abundance data would be better. However, this is not the case, as Tables 2.1.7-2.1.9 illustrate.

Table 2.1.7 shows selectivity at age in the 27-plus trawl survey as estimated by Models B and C, along with the differences between the respective estimates (Model C minus Model B). In moving from Model B to Model C, selectivities at ages 2 and 3 decrease dramatically in most years, and selectivities at ages 8-10 likewise decrease dramatically in the post-1993 portion of the time series. In contrast, there are relatively few instances of increasing selectivity in moving from Model B to Model C, and the few increases tend to be smaller (on a proportional scale) than the decreases.

To obtain survey numbers at age, it is necessary to multiply catchability (= 0.92 in both Models B and C), selectivity at age, and population numbers at age. The results for Models B and C, along with the differences between the two models (Model C minus Model B) are shown in Table 2.1.8. In terms of frequency, there are more increases than decreases, but the decreases tend to be much larger. The biggest changes occur at ages 2 and 3, where very large decreases occur in nearly all years. Increases tend to occur at ages 4 and above, but they tend to be much smaller than the decreases at ages 2 and 3.

The end result is shown in Table 2.1.9, which compares goodness of fit for the aggregated abundance data. Even though Model C tends to estimate more fish in the population at each age, most of these increases occur at the youngest ages, which tend to be more than offset by lower estimated selectivity. Although Model C did produce two small negative deviations at the end of the time series, the positive deviations produced under Model B increased by more than 10% in six out of the ten survey years under Model C. Overall, the square root of the mean squared deviation (RMSD) for Model B is 0.392, and the RMSD for Model C is 0.461. The mean of the differences between the two models' respective squared deviations (Model C minus Model B) is 0.059, which is equal to the difference between the squared RMSDs.

In summary, the apparent inconsistency between the age composition data and the 27-plus survey abundance data arises because SS achieves a better fit to the age composition data by greatly reducing selectivity at younger ages, which in turn tends to decrease the estimated survey (though not population) abundance.

It might be wondered whether the problem is inaccurate age data. This does not appear to be the case, because a similar pattern results if the age data are removed entirely and different levels of emphasis between the size composition data and the survey abundance data are explored.

In the process of producing this preliminary assessment, many approaches were explored in an attempt to improve the residual pattern with respect to the 27-plus survey abundance data without simultaneously making the RMSD much larger. Several of these approaches succeeded in improving the residual pattern, but seemed difficult to justify and were not pursued further. These include the following: Freeing the natural mortality rate (this tended to produce values much higher than the value of 0.38 currently used), freeing the 27-plus survey catchability (this also tended to produce values much higher than the value currently used), increasing the amount of ageing error, increasing the emphasis on the survey abundance data, and further decreasing the emphasis on the age (or size) data.

As Figure 2.1.1 indicates, some of the models that *were* carried forward did succeed in introducing some negative residuals, but these tended to be small compared to the positive residuals. (Note that the residuals in Figure 2.1.1 have been standardized by expressing them relative to the standard error.)

Table 2.1.10 provides several statistics that can be used to evaluate these residual patterns:

- One way of characterizing a residual pattern is to count the number of "runs" (strings of consecutive positive or consecutive negative values). Models A, B, E1, and E2 all resulted in only a single run (all residuals positive); Models C, D1, and D2 all resulted in two runs; and Models D3-D6 all resulted in four runs.
- Assuming that residuals are distributed randomly about zero with no autocorrelation, the column labeled "Pr(runs)" shows the probability of observing the number of runs generated by each model. For comparison, in a sample size of 10 (the total number of survey years), the most likely number of runs is 5 or 6, with a probability of 0.246.
- The column labeled "AveSign" shows the average value of the signs of the residuals for each model (an average of zero means that half the residuals were positive and half were negative, while an average of unity means that all the residuals were positive). Models A, B, E1, and E2 had an average sign of 1.0; Models D1 and D2 had an average sign of 0.8; Models C, D3, D5, and D6 had an average sign of 0.6, and Model D4 had an average sign of 0.2.
- The column labeled "Abs(cor)" shows the absolute value of the correlation between year and residual. All models exhibited negative correlations. Model C had the strongest correlation, and Model D6 the weakest.
- The column labeled "AveRelDev" shows the average standardized deviation (deviation divided by standard error). Model E1 had the highest average standardized deviation, and Model D6 had the lowest.
- The column labeled "Sum(-lnL)" shows the negative log likelihood associated with the 27-plus survey abundance data. By this criterion, Model E1 had the worst fit, and Model D6 the best.

Estimates of Length at Age, Catchability, and Selectivity at Length or Age

Table 2.1.11 shows estimated mean length (cm) at age and standard deviation of length at age for each model. Values correspond to July, the approximate mid-point of the survey season. With respect to mean length at age, the range of values across models C-E2 is no more than 3 cm for ages 0-8. If Model A is included in the comparison, the range is slightly larger. Model A exhibits the largest mean lengths at ages 5-11. If Model A is ignored, then Model D4 has the largest mean lengths at ages 2-5 and Model E1 has the largest mean lengths at ages 8 and above. Model E1 has the smallest mean lengths at ages 2-4, while Model E2 has the smallest mean lengths at ages 5-10. With respect to the standard deviation of length at age, Model D2 has the largest values for all ages ≥ 2, while Model E1 has the smallest values for all ages ≥ 2.

Figure 2.1.2 shows estimated catchability in the sub-27 trawl survey for each model (catchability is fixed in the 27-plus trawl survey). All models show a generally declining trend. All models with age-based selectivity for the 27-plus trawl survey (Models A-D6) are almost uniformly declining, with an accelerated decline after 1996; while the two models with size-based selectivity for the 27-plus trawl survey (Models E1-E2) show a U-shaped pattern for the years 1984-1996, and higher catchabilities than the other models after the 2001 survey.

Figure 2.1.3 shows estimated selectivity at age (or length) in the 27-plus trawl survey for each model. Models A and B both exhibit drops in selectivity from 1 to 0 between adjacent ages (between ages 11 and 12 in Model A, and between ages 10 and 11 in Model B), which was a concern to the GOA Plan Team last year (comment GPT6). Because the ascending and descending limbs of the exponential-logistic selectivity function are not independent (in contrast to the double normal selectivity function), it was not possible to restrict flexibility in the descending limbs of the curves in Model D4 without also restricting flexibility in the ascending limbs, so the curves in Model D4 exhibit greater variability than their counterparts in Models A-D1 (which use double normal selectivity). It is curious that Models E1 and E2 show significant selectivity at sizes smaller than 27 cm in several years, given that there are no fish smaller than 27 cm in the 27-plus trawl survey data (by definition).

Figure 2.1.4 shows estimated selectivity at ages 0-2 in the sub-27 trawl survey for each model. There is very little contrast between the models, with ages 0 and 2 having selectivities close to 0.07 and 0.05, respectively, in all models (selectivity at age 1 was fixed at 1.0, to avoid confounding with catchability).

Figures 2.1.5A-2.1.5E2 show estimated selectivity at length for all time blocks in all nine fisheries (3 gears × 3 seasons), with one figure for each model. Some of the curves for the models using double normal selectivity (Models A-D3 and E1) drop abruptly at large sizes, then level off just as abruptly. The models using exponential-logistic selectivity (Models D4-D6 and E2) are also capable of rapid declines at large sizes, but without any subsequent abrupt leveling.

Estimates of Time Series

Figure 2.1.6 shows estimated spawning biomass relative to the model-specific estimate of $B_{100\%}$ for each model. The time trends are similar for all models except Models D4 and E2. Models D4 and E2 peak earlier than the other models (1982-1983 for Models D4 and E2, versus 1987-1989 for the others), and at much higher values (0.95-0.99 for Models D4 and E2, versus 0.50-0.67 for the others). The range of relative spawning biomass for 2008 extends from 0.22 (Model E1) to 0.51 (Model D4).

Figure 2.1.7 shows estimated total (ages 0+) biomass for each model. Aggregate survey biomass (i.e., not divided into sub-27 and 27-plus segments) is shown for comparison. However, it should be emphasized that survey biomass is a different quantity than total biomass, involving not only the total population biomass but the effects of catchability and selectivity as well. As with the relative spawning biomass trajectories in Figure 2.1.6, Models D4 and E2 are noticeably different from the other models, in ways similar to those described in the preceding paragraph. Also noteworthy is the rapid increase indicated by nearly all models (Models E1 and E2 being the main exceptions) at the end of the time series.

Figure 2.1.8 shows log recruitment (numbers of age 0 fish, in 1000s) for each model. Considerable agreement is evident among all models, particularly during the first several years of the time series and again at the end of the time series. All models agree that the 2006 year class appears to be very large, although it should be emphasized that this conclusion is based almost entirely upon the cohort’s single appearance in the 2007 survey. The estimated large size of the 2006 year class accounts for the upturn in total biomass at the end of the time series in Figure 2.1.7.

Discussion

This preliminary assessment is intended to illustrate the behavior of alternative model structures. The authors welcome comment on any issue pertaining to model structure.

One feature that merits special consideration is the choice between double normal and exponential-logistic selectivity. On the one hand, double normal selectivity offers far more flexibility than exponential-logistic selectivity. On the other hand, the additional flexibility afforded by double normal selectivity often appears to lead to behaviors that are difficult to rationalize (e.g., rapid drop-offs in selectivity at old ages or large sizes, followed by abrupt leveling). Furthermore, in the limited experience obtained during the process of developing this preliminary assessment, models using exponential-logistic selectivity appeared to be much more stable, on average, than models using double normal selectivity. The procedure used to develop the models presented here was to work with a model until it appeared to have converged (positive definite Hessian), then create 50 "jitter" runs with random starting values displaced slightly from the allegedly converged values. In the case of most models using exponential-logistic selectivity, the vast majority of "jitter" runs converged at the same place as the initial run. In the case of most models using double normal selectivity, however, it was typical for nearly all "jitter" runs to converge in different places.

A related issue is the use of informative priors. For BSAI Pacific cod, the SSC has now endorsed the use of informative priors for catchability (SSC minutes, December 2008), but not for selectivity parameters. Use of informative priors for selectivity parameters might help to alleviate some of the convergence problems that appear to plague models based on double normal selectivity.

References

Nichol, D. G., T. Honkalehto, and G. G. Thompson. 2007. Proximity of Pacific cod to the sea floor: Using archival tags to estimate fish availability to research bottom trawls. *Fisheries Research* 86:129-135.

Methot, R. D. 2009. *User Manual for Stock Synthesis, Model Version 3.03a.* Unpublished manuscript, available from NOAA Fisheries Stock Assessment Toolbox website: http://nft.nefsc.noaa.gov/. 143 p.

Thompson, G. G. 1994. Confounding of gear selectivity and the natural mortality rate in cases where the former is a nonmonotone function of age. *Canadian Journal of Fisheries and Aquatic Sciences* 51:2654-2664.

Thompson, G. G., J. N. Ianelli, M. W. Dorn, S. Gaichas, and K. Aydin. 2007. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. In Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 209-327. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., J. N. Ianelli, and M. Wilkins. 2008. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 169-301. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Table 2.1.1. List of models. Colors indicate hierarchical classification of models (Models B-E1 all use new size-at-age data, Models C-E2 all use an emphasis of 1 for age composition data, and Models D1-E2 all use a value of 1 for catchability in the pre-1996 years of the 27-plus trawl survey). Form of selectivity schedule is either double normal ("dbl. nor.") or exponential-logistic ("exp.-log.").

				27-plus survey select.		Forced asymptotic or free?	
Model	Size-age data	Agecomp wt.	Pre-96 Q	Basis	Form	Jan-May trawl	27-plus survey
A	old	0.12	0.92	age	dbl. nor.	asymptotic	free
B	new	0.12	0.92	age	dbl. nor.	asymptotic	free
C	new	1	0.92	age	dbl. nor.	asymptotic	free
D1	new	1	1	age	dbl. nor.	asymptotic	free
D2	new	1	1	age	dbl. nor.	asymptotic	asymptotic
D3	new	1	1	age	dbl. nor.	free	asymptotic
D4	new	1	1	age	exp.-log.	asymptotic	free
D5	new	1	1	age	exp.-log.	asymptotic	asymptotic
D6	new	1	1	age	exp.-log.	free	asymptotic
E1	new	1	1	size	dbl. nor.	asymptotic	free
E2	new	1	1	size	exp.-log.	asymptotic	free

Table 2.1.2. Number of parameters, Akaike information criterion (AIC), and likelihoods for the 11 models. Note that Models A and B use different data or emphases from the other 9 models. "Prior –ln(like.)" and "Total –ln(likelihood)" are misnomers, as prior distributions are not likelihoods. Log likelihood values for the fishery CPUE data (shown under "CPUE –ln(likelihood)") are provided for information only; these data are not used in parameter estimation. Fits to the size composition data are broken down by fleet under the heading "Length –ln(likelihood)." Pink = row maximum (excluding Models A and B), green = row minimum (excluding Models A and B).

	A	B	C	D1	D2	D3	D4	D5	D6	E1	E2
Total no. parameters	224	217	217	217	211	230	199	189	194	217	199
Bound parameters	0	1	5	5	7	6	10	13	8	1	9
Net no. parameters	224	216	212	212	204	224	189	176	186	216	190
Total -ln(likelihood)	1252.5	1257.8	1328.8	1325.8	1345.9	1315.7	1496.0	1553.5	1455.1	1456.3	1675.0
AIC	2952.9	2947.6	3081.5	3075.6	3099.8	3079.5	3369.9	3458.9	3282.2	3344.5	3729.9
Survey nos. -ln(like.)	43.7	31.3	38.7	37.6	37.2	23.2	25.0	22.1	18.1	53.8	26.3
Size comp. -ln(like.)	1071.0	1078.5	1097.2	1094.3	1108.8	1089.8	1250.3	1318.9	1231.9	1104.4	1287.2
Age comp. -ln(like.)	22.9	20.8	46.9	53.6	61.7	67.3	55.8	70.0	72.4	120.8	178.3
Size-at-age -ln(like.)	84.8	101.6	119.9	114.5	108.9	107.9	144.7	117.7	107.3	144.7	162.4
Recruitment -ln(like.)	28.3	23.7	23.7	23.4	26.8	25.5	18.2	23.1	24.3	31.7	20.3
Prior -ln(like.)	1.8	1.8	2.3	2.4	2.4	1.9	1.8	1.5	1.1	0.8	0.5
"Softbounds" -ln(like.)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1
<u>CPUE -ln(likelihood)</u>											
Jan-May trawl fishery	196.0	192.0	303.1	276.7	292.1	201.8	234.2	206.1	170.7	183.2	128.9
Jun-Aug trawl fishery	124.6	123.8	103.8	107.3	106.7	117.5	105.4	112.3	121.2	138.6	140.7
Sep-Dec trawl fishery	145.0	148.5	129.9	130.6	130.1	142.4	144.5	150.1	164.4	155.7	182.0
Jan-May longl. fishery	17.8	18.0	45.7	43.0	48.8	26.2	40.0	30.4	22.2	15.1	27.1
Jun-Aug longl. fishery	13.5	13.0	18.9	18.7	19.5	16.1	20.2	18.4	15.9	7.7	8.8
Sep-Dec longl. fishery	8.1	8.8	8.8	8.5	9.1	7.4	8.7	8.0	7.9	17.0	18.6
Jan-May pot fishery	41.1	41.1	68.2	62.1	68.1	42.4	87.5	69.5	49.8	56.4	54.0
Jun-Aug pot fishery	0.4	0.4	1.4	1.0	0.9	1.3	2.3	1.7	1.8	0.3	1.3
Sep-Dec pot fishery	19.5	19.3	22.2	22.6	23.6	23.1	19.9	18.3	20.3	19.3	22.2
27plus trawl survey	38.1	26.1	32.5	31.4	30.9	17.1	19.8	16.8	12.6	47.1	20.9
Sub27 trawl survey	5.5	5.2	6.2	6.2	6.3	6.1	5.2	5.2	5.5	6.7	5.4
<u>Length -ln(likelihood)</u>											
Jan-May trawl fishery	229.9	236.2	248.8	244.0	237.7	215.3	311.3	305.0	213.4	227.3	299.9
Jun-Aug trawl fishery	78.9	79.1	79.5	79.5	81.2	82.0	76.0	79.3	80.6	80.8	74.3
Sep-Dec trawl fishery	114.2	112.5	112.2	112.7	112.0	113.7	108.1	107.3	109.3	115.4	109.4
Jan-May longl. fishery	244.4	245.3	248.3	248.0	252.6	250.1	276.4	315.4	315.1	266.8	322.1
Jun-Aug longl. fishery	27.1	26.4	26.6	26.7	25.6	25.5	32.7	30.9	30.7	31.6	36.8
Sep-Dec longl. fishery	88.4	86.1	86.4	87.0	85.2	85.2	117.1	111.2	113.2	83.6	112.8
Jan-May pot fishery	130.7	130.7	130.1	130.5	130.7	131.7	164.0	161.5	160.7	128.7	159.7
Jun-Aug pot fishery	13.0	13.1	13.2	13.3	13.3	13.3	18.8	19.1	19.9	13.4	19.1
Sep-Dec pot fishery	39.3	39.3	39.2	39.2	39.6	39.8	47.1	46.6	46.8	40.4	45.8
27plus trawl survey	25.5	32.7	31.0	31.7	48.8	51.2	19.7	61.9	60.2	32.3	22.2
Sub27 trawl survey	79.5	77.3	81.7	81.9	81.9	82.0	79.2	80.7	81.9	84.1	85.0

Table 2.1.3. Goodness of fit with respect to size composition, as measured by the relationship between input sample size and effective sample size. "Rec." = number of records. Fleets are indexed as follows: 1 = Jan-May trawl fishery, 2 = Jun-Aug trawl fishery, 3 = Sep-Dec trawl fishery, 4 = Jan-May longline fishery, 5 = Jun-Aug longline fishery, 6 = Sep-Dec longline fishery, 7 = Jan-May pot fishery, 8 = Jun-Aug pot fishery, 9 = Sep-Dec pot fishery, 10 = 27-plus trawl survey, 11 = sub-27 trawl survey. Pink = row maximum (excluding Models A and B), green = row minimum (excluding Models A and B).

Mean effective sample size

Fleet	Rec.	Input	A	B	C	D1	D2	D3	D4	D5	D6	E1	E2
1	24	330	268	255	240	245	252	282	178	188	354	272	187
2	16	58	133	128	127	127	117	122	162	163	170	122	197
3	18	77	94	95	92	95	97	91	93	96	94	97	93
4	27	465	649	629	572	582	582	568	471	468	483	619	467
5	12	68	167	173	162	160	166	170	150	160	165	155	136
6	14	305	470	477	448	445	485	493	352	320	319	579	348
7	19	778	1097	959	930	928	934	962	599	614	595	1315	633
8	6	112	417	424	407	401	389	395	141	139	132	389	136
9	13	159	495	506	501	497	487	499	493	502	482	453	519
10	2	511	196	170	174	175	135	132	227	140	140	192	320
11	10	54	32	31	29	29	29	29	30	28	28	28	28

Harmonic mean effective sample size

Fleet	Rec.	Input	A	B	C	D1	D2	D3	D4	D5	D6	E1	E2
1	24	330	88	86	85	86	87	89	67	71	84	88	70
2	16	58	44	44	44	44	43	42	44	43	42	46	48
3	18	77	48	51	52	52	51	51	60	59	59	45	54
4	27	465	251	248	247	248	242	240	240	221	223	214	202
5	12	68	106	104	101	100	104	104	94	99	101	88	82
6	14	305	190	190	188	188	191	189	147	157	155	202	149
7	19	778	481	470	445	447	447	438	447	440	435	495	452
8	6	112	30	31	31	30	30	30	31	30	30	30	31
9	13	159	153	154	153	153	152	153	155	154	153	153	157
10	2	511	195	168	170	172	132	130	214	114	117	190	279
11	10	54	17	17	17	17	17	17	17	17	17	16	16

Mean (effective sample size / input sample size)

Fleet	Rec.	Input	A	B	C	D1	D2	D3	D4	D5	D6	E1	E2
1	24	330	1.19	1.15	1.11	1.13	1.11	1.15	0.94	0.93	1.30	1.14	0.93
2	16	58	2.50	2.47	2.53	2.52	2.36	2.42	2.92	2.76	2.85	2.30	3.42
3	18	77	1.84	1.97	1.91	1.97	1.96	1.93	2.05	2.14	2.15	1.67	1.81
4	27	465	1.95	1.89	1.75	1.78	1.77	1.73	1.37	1.38	1.42	1.86	1.32
5	12	68	4.15	4.15	3.86	3.83	3.89	3.95	4.11	4.29	4.44	3.91	4.10
6	14	305	2.13	2.15	2.10	2.09	2.15	2.19	1.73	1.60	1.61	2.41	1.66
7	19	778	1.75	1.54	1.48	1.48	1.49	1.53	1.38	1.33	1.31	1.94	1.34
8	6	112	4.40	4.64	4.69	4.66	4.53	4.60	3.21	3.14	3.07	4.38	3.00
9	13	159	2.91	2.96	2.85	2.86	2.82	2.82	3.23	3.21	3.05	2.74	3.39
10	2	511	0.46	0.43	0.39	0.40	0.34	0.34	0.49	0.41	0.40	0.48	0.66
11	10	54	1.00	0.95	0.89	0.88	0.88	0.89	0.90	0.84	0.84	0.85	0.85

(Mean effective sample size) / (mean input sample size)

Fleet	Rec.	Input	A	B	C	D1	D2	D3	D4	D5	D6	E1	E2
1	24	330	0.81	0.77	0.73	0.74	0.76	0.85	0.54	0.57	1.07	0.82	0.57
2	16	58	2.30	2.23	2.20	2.20	2.03	2.12	2.80	2.83	2.94	2.12	3.41
3	18	77	1.23	1.24	1.19	1.25	1.26	1.18	1.22	1.25	1.22	1.26	1.21
4	27	465	1.40	1.35	1.23	1.25	1.25	1.22	1.01	1.01	1.04	1.33	1.01
5	12	68	2.45	2.54	2.39	2.36	2.44	2.50	2.20	2.35	2.43	2.27	1.99
6	14	305	1.54	1.56	1.47	1.46	1.59	1.62	1.16	1.05	1.05	1.90	1.14
7	19	778	1.41	1.23	1.20	1.19	1.20	1.24	0.77	0.79	0.77	1.69	0.81
8	6	112	3.72	3.78	3.63	3.57	3.47	3.52	1.26	1.24	1.18	3.47	1.22
9	13	159	3.11	3.18	3.15	3.12	3.06	3.13	3.10	3.15	3.03	2.85	3.26
10	2	511	0.38	0.33	0.34	0.34	0.26	0.26	0.44	0.27	0.27	0.38	0.63
11	10	54	0.59	0.57	0.53	0.53	0.53	0.54	0.55	0.52	0.52	0.51	0.52

Table 2.1.4. Goodness of fit with respect to age composition, as measured by the relationship between input sample size and effective sample size. Note that the input sample sizes listed here do not apply directly to Models A and B (the input sample sizes were multiplied by 0.12 in those two cases). Pink = row maximum (excluding Models A and B), green = row minimum (excluding Models A and B).

		Effective sample size												
Year	Input	A	B	C	D1	D2	D3	D4	D5	D6	E1	E2
1987	22	6	8	10	10	9	8	6	8	7	8	9
1990	80	10	12	145	151	102	83	63	34	36	52	23
1993	138	12	6	42	43	42	48	114	75	82	56	27
1996	124	10	10	59	52	47	60	61	64	75	9	12
1999	110	10	11	24	22	22	26	17	15	21	16	11
2001	122	60	93	232	293	326	261	345	399	355	21	10
2003	117	6	5	25	21	21	21	32	22	22	16	14
2005	87	10	12	82	64	60	57	147	105	90	11	9
Ave.	100	15	20	77	82	79	71	98	90	86	23	14

		Effective sample size / input sample size										
Year	Input	A	B	C	D1	D2	D3	D4	D5	D6	E1	E2
1987	22	0.27	0.37	0.44	0.44	0.39	0.36	0.28	0.35	0.32	0.37	0.42
1990	80	0.12	0.15	1.81	1.88	1.27	1.04	0.79	0.42	0.45	0.65	0.28
1993	138	0.08	0.04	0.30	0.31	0.30	0.35	0.83	0.54	0.59	0.40	0.20
1996	124	0.08	0.08	0.47	0.42	0.38	0.49	0.49	0.52	0.60	0.07	0.09
1999	110	0.09	0.10	0.22	0.20	0.20	0.24	0.15	0.14	0.19	0.14	0.10
2001	122	0.49	0.76	1.90	2.40	2.67	2.14	2.83	3.27	2.91	0.17	0.09
2003	117	0.05	0.05	0.21	0.18	0.18	0.18	0.27	0.19	0.19	0.14	0.12
2005	87	0.11	0.14	0.94	0.74	0.69	0.65	1.69	1.21	1.03	0.13	0.10
Ave.	100	0.16	0.21	0.79	0.82	0.76	0.68	0.92	0.83	0.79	0.26	0.17

Table 2.1.5. Negative log likelihoods for age composition, by year and age, for Models B and C. Because Model B uses an emphasis of 0.12 for the age composition data while Model C uses an emphasis of 1.00, values for Model B have been divided by 0.12 to make the results comparable. Differences in negative log likelihoods (Model C minus Model B) are shown in the bottom section. Pink = positive differences (i.e., Model B gives a better fit), green = negative differences (i.e., Model C gives a better fit).

Model	Age	1987	1990	1993	1996	1999	2001	2003	2005
B	2	-2.163	-0.027	1.005	-9.739	-5.213	-7.721	-4.636	-5.558
B	3	-0.165	-11.595	-25.864	-14.302	-9.958	0.611	-19.669	-9.332
B	4	13.411	16.281	13.992	-1.562	-8.581	0.947	4.138	0.923
B	5	-0.547	2.289	19.808	18.262	27.096	5.237	43.393	11.026
B	6	-0.726	1.052	13.739	21.753	16.468	1.847	16.590	15.619
B	7		2.856	5.296	17.109	3.991	2.404	3.436	3.243
B	8		0.708	2.965	0.586	1.484	0.473	0.315	1.099
B	9		-0.113	-0.165	-0.140	0.010	-0.261	-0.411	-0.255
B	10		-0.202	-0.093	-0.112	-0.121	-0.092	-0.145	-0.184
B	11		-0.072	-0.064	-0.019	0.005	-0.027	0.000	-0.061
B	12		-0.034		0.020		0.366	0.293	0.724
C	2	-0.994	1.237	4.225	-0.342	-1.290	-2.616	0.304	0.232
C	3	-0.470	-1.533	-12.725	-5.866	-2.570	6.889	-8.877	-3.256
C	4	11.588	4.751	-1.478	-6.620	-11.905	0.918	-6.796	-3.546
C	5	-1.143	0.330	7.010	1.570	11.419	-0.986	18.646	0.532
C	6	-0.773	-2.983	6.702	9.021	9.413	-2.030	8.044	8.058
C	7		1.242	2.856	9.313	2.113	-0.592	-0.033	0.426
C	8		0.139	2.118	-0.478	0.649	-0.211	-0.838	0.436
C	9		-0.301	-0.369	-0.258	-0.035	-0.177	-0.530	-0.247
C	10		-0.244	-0.165	-0.112	-0.081	-0.003	-0.149	-0.111
C	11		-0.081	-0.072	-0.028	-0.015	-0.028	-0.002	-0.047
C	12		-0.037		-0.014		0.149	0.128	0.454
Diff.	2	1.170	1.264	3.219	9.397	3.923	5.104	4.940	5.791
Diff.	3	-0.305	10.063	13.140	8.436	7.388	6.278	10.792	6.076
Diff.	4	-1.823	-11.530	-15.471	-5.058	-3.323	-0.028	-10.934	-4.469
Diff.	5	-0.597	-1.958	-12.798	-16.692	-15.676	-6.223	-24.747	-10.494
Diff.	6	-0.047	-4.035	-7.037	-12.732	-7.055	-3.877	-8.546	-7.561
Diff.	7		-1.614	-2.439	-7.796	-1.878	-2.996	-3.469	-2.817
Diff.	8		-0.568	-0.847	-1.064	-0.836	-0.684	-1.154	-0.662
Diff.	9		-0.189	-0.204	-0.118	-0.045	0.084	-0.119	0.009
Diff.	10		-0.042	-0.073	0.000	0.040	0.089	-0.004	0.072
Diff.	11		-0.009	-0.009	-0.010	-0.019	-0.001	-0.002	0.014
Diff.	12		-0.003		-0.035		-0.217	-0.165	-0.269

Table 2.1.6. Population numbers (1000s) at age (columns) in July of each survey year as estimated by Models B and C, and the difference between the respective estimates (Model C minus Model B). Pink = increase of at least 10%, green = decrease of at least 10%.

Model	Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
B	1984	288648	8741	152415	41151	59364	11296	2536	25196	592	306	1090	307	201	134	91	62	43	29	20	14	28
B	1987	213141	50997	108458	91478	2703	45372	11689	16147	2979	655	6432	150	77	275	78	51	34	23	16	11	24
B	1990	285457	109840	85413	67242	15157	28581	20993	561	8995	2304	3216	601	134	1325	31	16	57	16	11	7	16
B	1993	187515	117422	71011	90029	32434	21383	13012	2227	3409	2237	58	932	245	353	68	15	156	4	2	7	6
B	1996	133860	189752	74936	59298	35193	18502	18632	5195	2803	1523	250	383	257	7	112	30	44	9	2	20	2
B	1999	208548	67298	66068	42305	56074	18349	10629	4441	1760	1503	395	214	121	21	33	23	1	10	3	4	3
B	2001	101986	164475	97438	31075	28746	15904	17237	4760	2524	1037	421	373	102	57	33	6	9	6	0	3	3
B	2003	138573	84165	47654	75933	41984	11339	8526	4049	4117	1140	625	268	113	103	29	16	9	2	3	2	2
B	2005	201296	111667	64754	38932	20801	28641	13064	3039	2138	1013	1062	305	174	77	33	30	9	5	3	0	2
B	2007	227847	882688	94069	51691	28358	14824	6591	7871	3354	771	551	268	287	84	48	22	9	9	2	1	1
C	1984	348419	14025	174956	41034	69879	11015	2758	30244	895	408	1357	432	285	191	129	88	60	41	28	19	39
C	1987	224151	83561	92148	110541	4356	52551	11831	19401	2977	733	7949	234	106	353	113	74	50	34	23	16	34
C	1990	298531	136671	99936	70819	25040	24848	26441	955	11079	2480	4102	637	158	1729	51	23	78	25	16	11	24
C	1993	212283	115851	99211	94363	40882	26047	14904	4199	3513	3410	119	1392	318	538	85	22	239	7	3	11	11
C	1996	184170	210450	112471	67247	35101	26826	21246	7542	4126	2170	593	497	491	18	209	48	83	13	3	37	5
C	1999	267391	119427	71825	58350	63301	29335	13907	5618	3507	2476	844	465	252	71	62	63	2	28	6	11	8
C	2001	157149	240163	124959	55317	31827	23244	21878	9039	4049	1623	1032	749	263	148	82	23	21	21	1	9	9
C	2003	232610	119588	73449	111309	55219	21840	10956	7255	6572	2729	1254	518	339	251	90	51	28	8	7	7	7
C	2005	337277	241116	108724	55529	32863	45410	20008	7246	3507	2329	2155	919	432	182	121	90	32	19	10	3	8
C	2007	291452	1283646	157660	112073	48921	23054	12305	15738	6700	2419	1185	800	752	325	154	65	43	33	12	7	8
Diff.	1984	73431	6492	27695	-181	12968	-438	260	6258	389	129	336	160	107	72	49	33	22	15	10	7	15
Diff.	1987	13527	40008	-20059	23472	2058	8841	99	4041	-26	94	1896	106	36	98	44	29	20	13	9	6	13
Diff.	1990	16061	32965	17845	4339	12547	-5496	7069	550	2693	163	1172	27	30	541	28	10	27	12	8	5	11
Diff.	1993	30428	-1930	34657	5159	10478	5675	1965	2834	-157	1622	91	631	91	255	21	8	115	5	2	6	7
Diff.	1996	61807	25427	46129	9735	-520	10755	2500	3102	1758	832	528	128	344	17	139	25	56	6	2	25	4
Diff.	1999	72292	64044	7067	19755	8286	14210	3581	984	2542	1263	668	371	190	79	39	60	3	25	5	10	7
Diff.	2001	67771	92987	33809	29923	3434	9113	5133	5675	1931	731	830	496	217	122	65	24	15	19	1	8	8
Diff.	2003	115529	43519	31694	43477	15920	13440	2446	4071	2945	2137	814	319	303	194	81	46	25	9	6	7	6
Diff.	2005	167059	159037	54027	20363	14811	20438	8215	5476	1630	1698	1378	807	334	135	116	78	32	18	10	3	8
Diff.	2007	78141	492600	78127	74342	25243	9748	6985	9716	4110	2173	788	693	595	317	137	57	45	32	12	7	8

Table 2.1.7. Selectivity at age (columns) in the 27-plus trawl survey as estimated by Models B and C, and the difference between the respective estimates (Model C minus Model B). Pink = increase of at least 10%, green = decrease of at least 10%.

Model	Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
B	1984	0.01	0.01	0.01	0.63	1.00	1.00	1.00	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
B	1987	0.01	0.16	0.64	1.00	1.00	1.00	1.00	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
B	1990	0.00	0.00	0.10	1.00	1.00	1.00	1.00	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
B	1993	0.00	0.00	0.16	1.00	1.00	1.00	1.00	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
B	1996	0.00	0.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	1999	0.00	0.00	0.29	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	2001	0.00	0.00	0.27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	2003	0.00	0.00	0.35	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	2005	0.00	0.00	0.35	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	2007	0.00	0.00	0.04	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	1984	0.00	0.00	0.04	0.42	0.99	1.00	1.00	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
C	1987	0.01	0.16	0.45	0.81	1.00	1.00	1.00	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
C	1990	0.00	0.00	0.06	0.46	1.00	1.00	1.00	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
C	1993	0.00	0.00	0.07	0.48	1.00	1.00	1.00	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
C	1996	0.00	0.01	0.09	0.41	0.90	1.00	1.00	0.92	0.73	0.48	0.27	0.13	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
C	1999	0.00	0.01	0.09	0.41	0.90	1.00	1.00	0.92	0.73	0.48	0.27	0.13	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
C	2001	0.00	0.02	0.12	0.47	0.91	1.00	1.00	0.92	0.73	0.48	0.27	0.13	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
C	2003	0.00	0.00	0.05	0.33	0.88	1.00	1.00	0.92	0.73	0.48	0.27	0.13	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
C	2005	0.00	0.01	0.08	0.40	0.90	1.00	1.00	0.92	0.73	0.48	0.27	0.13	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
C	2007	0.00	0.00	0.05	0.35	0.88	1.00	1.00	0.92	0.73	0.48	0.27	0.13	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Diff.	1984	-0.01	-0.01	0.03	-0.21	-0.01	0.00	0.00	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Diff.	1987	0.00	0.00	-0.19	-0.19	0.00	0.00	0.00	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Diff.	1990	0.00	0.00	-0.05	-0.54	0.00	0.00	0.00	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Diff.	1993	0.00	0.00	-0.09	-0.52	0.00	0.00	0.00	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Diff.	1996	0.00	0.01	-0.41	-0.59	-0.10	0.00	0.00	-0.08	-0.27	-0.52	-0.73	0.13	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Diff.	1999	0.00	0.01	-0.20	-0.59	-0.10	0.00	0.00	-0.08	-0.27	-0.52	-0.73	0.13	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Diff.	2001	0.00	0.02	-0.14	-0.53	-0.09	0.00	0.00	-0.08	-0.27	-0.52	-0.73	0.13	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Diff.	2003	0.00	0.00	-0.30	-0.67	-0.12	0.00	0.00	-0.08	-0.27	-0.52	-0.73	0.13	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Diff.	2005	0.00	0.01	-0.27	-0.60	-0.10	0.00	0.00	-0.08	-0.27	-0.52	-0.73	0.13	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Diff.	2007	0.00	0.00	0.01	-0.65	-0.12	0.00	0.00	-0.08	-0.27	-0.52	-0.73	0.13	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00

Table 2.1.8. 27-plus trawl survey numbers (1000s) at age (columns) in July of each survey year as estimated by Models B and C, and the difference between the respective estimates (Model C minus Model B). Pink = increase of at least 10%, green = decrease of at least 10%.

Model	Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
B	1984	1,592	48	848	23,717	54,612	10,392	2,333	10,533	247	128	455	128	84	56	38	26	18	12	8	6	12
B	1987	1,343	7,358	64,014	84,150	2,487	41,742	10,754	6,750	1,245	274	2,689	63	32	115	33	21	14	10	7	5	10
B	1990	12	13	8,034	61,825	13,944	26,293	19,314	234	3,760	963	1,344	251	56	554	13	7	24	7	4	3	7
B	1993	19	67	10,296	82,786	29,838	19,672	11,971	931	1,425	935	24	389	102	148	28	6	65	2	1	3	3
B	1996	48	82	34,339	54,533	32,377	17,022	17,141	4,779	2,579	1,401	230	0	0	0	0	0	0	0	0	0	0
B	1999	29	10	17,769	38,904	51,588	16,881	9,779	4,086	1,619	1,383	363	0	0	0	0	0	0	0	0	0	0
B	2001	32	52	23,960	28,577	26,446	14,632	15,858	4,379	2,322	954	387	0	0	0	0	0	0	0	0	0	0
B	2003	21	13	15,144	69,829	38,625	10,431	7,844	3,725	3,788	1,048	575	0	0	0	0	0	0	0	0	0	0
B	2005	44	25	21,115	35,802	19,137	26,350	12,019	2,796	1,967	932	977	0	0	0	0	0	0	0	0	0	0
B	2007	278	1,083	3,419	47,535	26,089	13,638	6,064	7,241	3,086	710	507	0	0	0	0	0	0	0	0	0	0
C	1984	21	13	6,577	15,757	63,931	10,134	2,537	11,187	331	151	502	160	105	71	48	33	22	15	10	7	15
C	1987	2,060	12,130	38,228	82,172	4,002	48,346	10,884	7,176	1,101	271	2,940	86	39	131	42	27	18	13	9	6	13
C	1990	13	241	5,193	29,715	22,922	22,859	24,326	353	4,098	917	1,517	236	59	640	19	9	29	9	6	4	9
C	1993	22	301	6,124	41,495	37,434	23,962	13,712	1,553	1,299	1,261	44	515	118	199	32	8	88	3	1	4	4
C	1996	8	1,569	8,901	25,320	29,062	24,676	19,546	6,414	2,754	966	150	60	24	0	1	0	0	0	0	0	0
C	1999	45	963	5,884	22,242	52,487	26,984	12,794	4,778	2,341	1,102	213	56	12	1	0	0	0	0	0	0	0
C	2001	7	3,548	14,197	23,784	26,768	21,382	20,127	7,686	2,703	722	260	91	13	3	0	0	0	0	0	0	0
C	2003	10	288	3,209	33,725	44,561	20,090	10,080	6,169	4,387	1,214	316	63	17	4	0	0	0	0	0	0	0
C	2005	254	1,739	8,082	20,391	27,128	41,772	18,407	6,162	2,341	1,037	543	111	21	3	1	0	0	0	0	0	0
C	2007	12	3,972	7,855	35,624	39,703	21,207	11,320	13,383	4,472	1,077	299	97	37	6	1	0	0	0	0	0	0
Diff.	1984	-1,571	-35	5,729	-7,960	9,318	-259	204	654	84	23	47	31	21	14	10	7	4	3	2	1	3
Diff.	1987	717	4,773	-25,785	-1,978	1,515	6,604	130	426	-144	-3	251	24	7	15	9	6	4	3	2	1	3
Diff.	1990	1	227	-2,841	-32,110	8,978	-3,434	5,012	119	338	-46	173	-16	3	86	6	2	5	2	2	1	2
Diff.	1993	3	234	-4,172	-41,292	7,596	4,290	1,740	622	-125	326	20	125	15	51	3	2	23	1	0	1	1
Diff.	1996	-40	1,487	-25,438	-29,213	-3,315	7,654	2,405	1,634	176	-436	-81	60	24	0	1	0	0	0	0	0	0
Diff.	1999	16	953	-11,885	-16,661	899	10,104	3,015	692	722	-281	-150	56	12	1	0	0	0	0	0	0	0
Diff.	2001	-25	3,496	-9,763	-4,793	322	6,750	4,269	3,307	381	-232	-127	91	13	3	0	0	0	0	0	0	0
Diff.	2003	-11	275	-11,934	-36,104	5,936	9,658	2,236	2,444	599	166	-259	63	17	4	0	0	0	0	0	0	0
Diff.	2005	210	1,714	-13,033	-15,411	7,990	15,422	6,388	3,366	374	104	-434	111	21	3	1	0	0	0	0	0	0
Diff.	2007	-265	2,889	4,435	-11,911	13,614	7,568	5,257	6,143	1,386	367	-209	97	37	6	1	0	0	0	0	0	0

Table 2.1.9. Goodness of fit to the time series of 27-plus trawl survey total numbers (1000s) obtained by Models B and C, and differences between the two models (Model C minus Model B). Obs. = number observed by the survey, Exp. = number expected by the respective model, Dev. = log scale deviation, Sq. Dev. = squared log scale deviation. Pink = increase of at least 10%, green = decrease of at least 10%. The square root of the mean squared deviation (RMSD) for Model B is 0.392, and the RMSD for Model C is 0.461. The mean of the differences between the two models' respective squared deviations (Model C minus Model B) is 0.059, which is equal to the difference between the squared RMSDs.

Model	Year	Obs.	Exp.	Dev.	Sq. Dev.
B	1984	300,682	105,295	1.049	1.101
B	1987	240,186	223,114	0.074	0.005
B	1990	197,131	136,663	0.366	0.134
B	1993	214,893	158,712	0.303	0.092
B	1996	234,524	164,531	0.354	0.126
B	1999	157,046	142,411	0.098	0.010
B	2001	137,062	117,598	0.153	0.023
B	2003	153,902	151,043	0.019	0.000
B	2005	127,261	121,166	0.049	0.002
B	2007	134,327	109,649	0.203	0.041
C	1984	300,682	111,626	0.991	0.982
C	1987	240,186	209,693	0.136	0.018
C	1990	197,131	113,171	0.555	0.308
C	1993	214,893	128,178	0.517	0.267
C	1996	234,524	119,452	0.675	0.455
C	1999	157,046	129,904	0.190	0.036
C	2001	137,062	121,290	0.122	0.015
C	2003	153,902	124,134	0.215	0.046
C	2005	127,261	127,991	-0.006	0.000
C	2007	134,327	139,065	-0.035	0.001
Diff.	1984	0	6,331	-0.058	-0.119
Diff.	1987	0	-13,421	0.062	0.013
Diff.	1990	0	-23,492	0.189	0.174
Diff.	1993	0	-30,534	0.214	0.175
Diff.	1996	0	-45,079	0.320	0.330
Diff.	1999	0	-12,507	0.092	0.026
Diff.	2001	0	3,692	-0.031	-0.009
Diff.	2003	0	-26,909	0.196	0.046
Diff.	2005	0	6,826	-0.055	-0.002
Diff.	2007	0	29,415	-0.238	-0.040

Table 2.1.10. Summary of statistics pertaining to residuals and goodness of fit with respect to 27-plus trawl survey abundance (measured in numbers of fish). Runs = number of strings of consecutive positive or consecutive negative residuals. Pr(runs) = binomial probability of observing the given number of runs (maximum possible value is 0.246, achieved under either 5 or 6 runs). AveSign = average value of the signs of residuals. Abs(cor) = absolute value of the correlation between year and residual. AveRelDev = average ratio between deviation and standard error. Sum(-lnL) = sum of negative log likelihoods. Pink = column maximum (excluding Models A and B), green = column minimum (excluding Models A and B).

Model	Runs	Pr(runs)	AveSign	Abs(cor)	AveRelDev	Sum(-lnL)
A	1	0.002	1.00	0.576	1.707	38.133
B	1	0.002	1.00	0.638	1.455	26.140
C	2	0.018	0.60	0.732	1.850	32.517
D1	2	0.018	0.80	0.698	1.868	31.357
D2	2	0.018	0.80	0.634	1.912	30.906
D3	4	0.164	0.60	0.569	1.286	17.077
D4	4	0.164	0.20	0.633	1.167	19.838
D5	4	0.164	0.60	0.384	1.269	16.826
D6	4	0.164	0.60	0.237	1.060	12.601
E1	1	0.002	1.00	0.476	2.570	47.107
E2	1	0.002	1.00	0.336	1.746	20.896

Table 2.1.11. Estimated mean length (cm) at age and standard deviation of length at age. Values correspond to July, the approximate mid-point of the survey season. Pink = row maximum (excluding Models A and B; also ages 0 and 1, which are identical across models), green = row minimum (excluding Models A and B; also ages 0 and 1, which are identical across models).

	Mean length in July										
Age	A	B	C	D1	D2	D3	D4	D5	D6	E1	E2
0	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
1	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9
2	32.2	32.6	32.5	32.5	32.4	32.5	33.0	32.7	32.6	31.1	31.8
3	42.2	42.6	42.5	42.5	42.3	42.4	43.1	42.7	42.6	40.4	41.1
4	51.0	51.3	51.1	51.1	50.9	51.0	51.6	51.2	51.2	48.8	49.3
5	58.8	58.8	58.5	58.5	58.4	58.4	58.7	58.5	58.6	56.5	56.3
6	65.6	65.2	64.8	64.9	64.8	64.8	64.6	64.8	64.9	63.4	62.5
7	71.7	70.8	70.3	70.4	70.4	70.3	69.6	70.1	70.4	69.7	67.8
8	77.0	75.6	75.0	75.2	75.2	75.1	73.7	74.6	75.1	75.4	72.4
9	81.8	79.8	79.0	79.3	79.4	79.2	77.2	78.5	79.1	80.6	76.4
10	86.0	83.4	82.5	82.8	83.0	82.7	80.1	81.8	82.5	85.3	79.9
11	89.6	86.5	85.5	85.8	86.1	85.8	82.6	84.6	85.5	89.6	82.9
12	92.9	89.1	88.1	88.5	88.8	88.4	84.6	87.0	88.1	93.5	85.5

	Standard deviation of length in July										
Age	A	B	C	D1	D2	D3	D4	D5	D6	E1	E2
0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
1	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
2	5.5	5.7	5.7	5.7	5.6	5.7	5.8	5.7	5.7	5.4	5.6
3	6.8	7.1	7.1	7.0	7.0	7.1	7.3	7.2	7.1	6.6	6.9
4	7.8	8.1	8.1	8.1	8.1	8.1	8.4	8.2	8.2	7.4	7.9
5	8.4	8.8	8.8	8.8	8.8	8.9	9.1	9.0	9.0	8.0	8.7
6	8.7	9.2	9.2	9.2	9.3	9.3	9.7	9.5	9.5	8.4	9.2
7	8.8	9.4	9.4	9.4	9.5	9.6	9.9	9.8	9.8	8.6	9.5
8	8.7	9.5	9.5	9.4	9.6	9.7	10.1	9.9	9.9	8.5	9.6
9	8.4	9.4	9.4	9.3	9.5	9.6	10.0	9.8	9.9	8.3	9.6
10	8.0	9.1	9.1	9.1	9.3	9.4	9.9	9.7	9.7	8.0	9.5
11	7.5	8.7	8.8	8.7	9.0	9.1	9.7	9.4	9.5	7.5	9.2
12	6.8	8.3	8.3	8.2	8.6	8.7	9.3	9.0	9.2	6.9	8.9

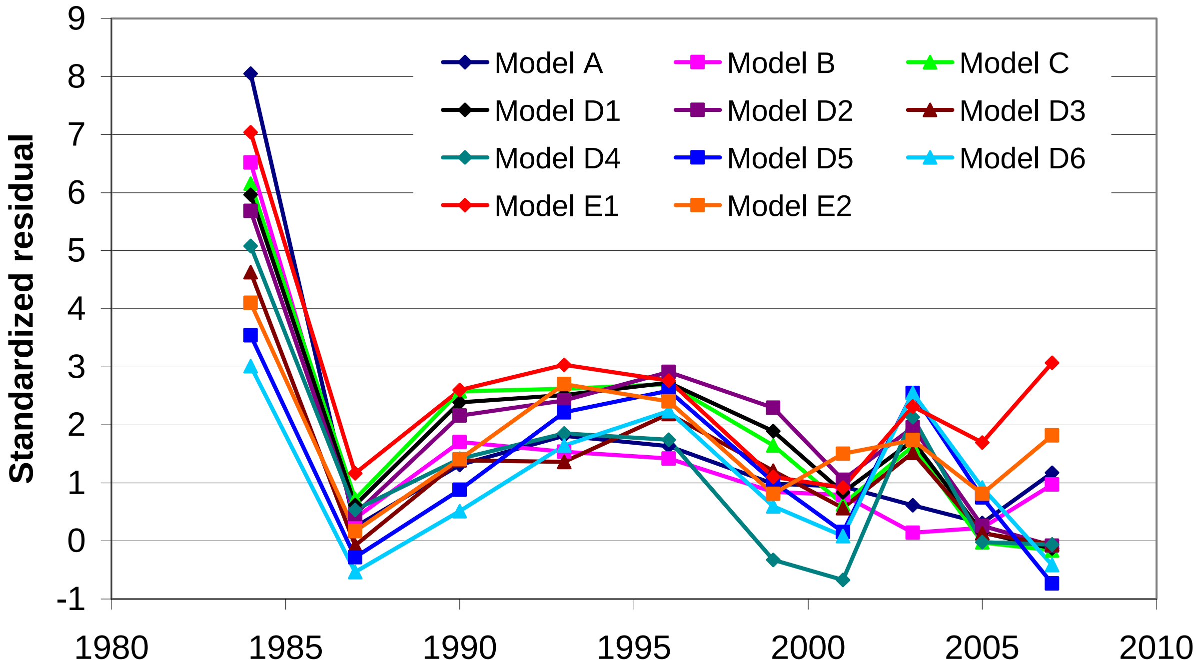


Figure 2.1.1. Standardized residuals from fits to 27-plus trawl survey abundance.

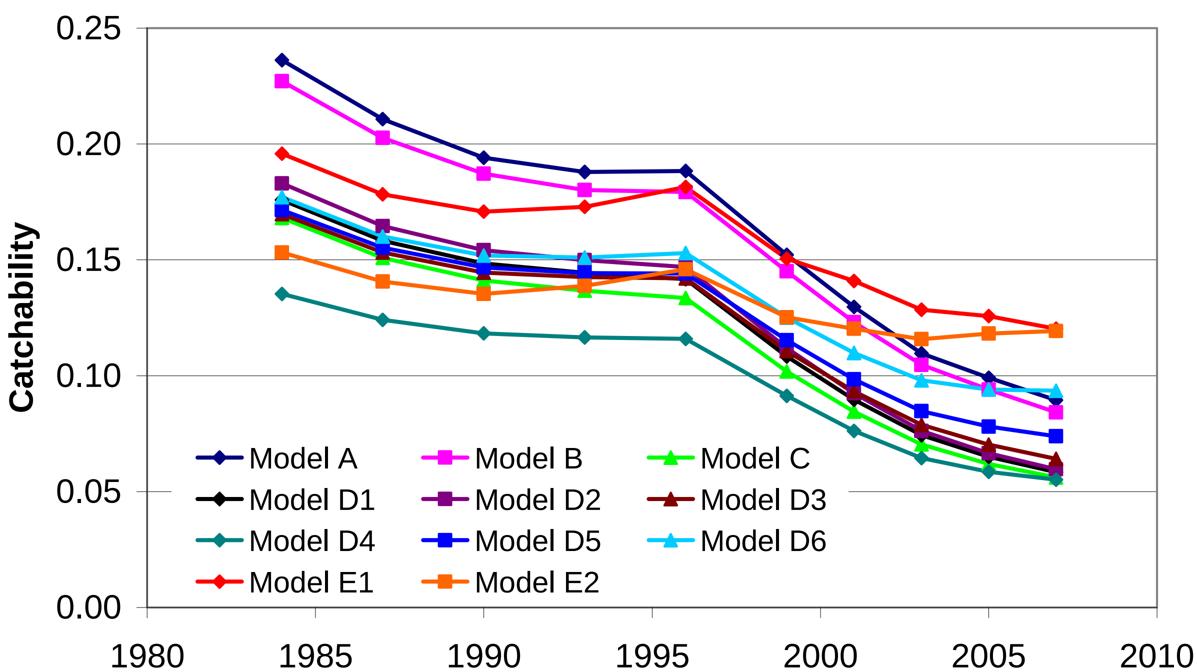


Figure 2.1.2. Catchability in the sub-27 trawl survey.

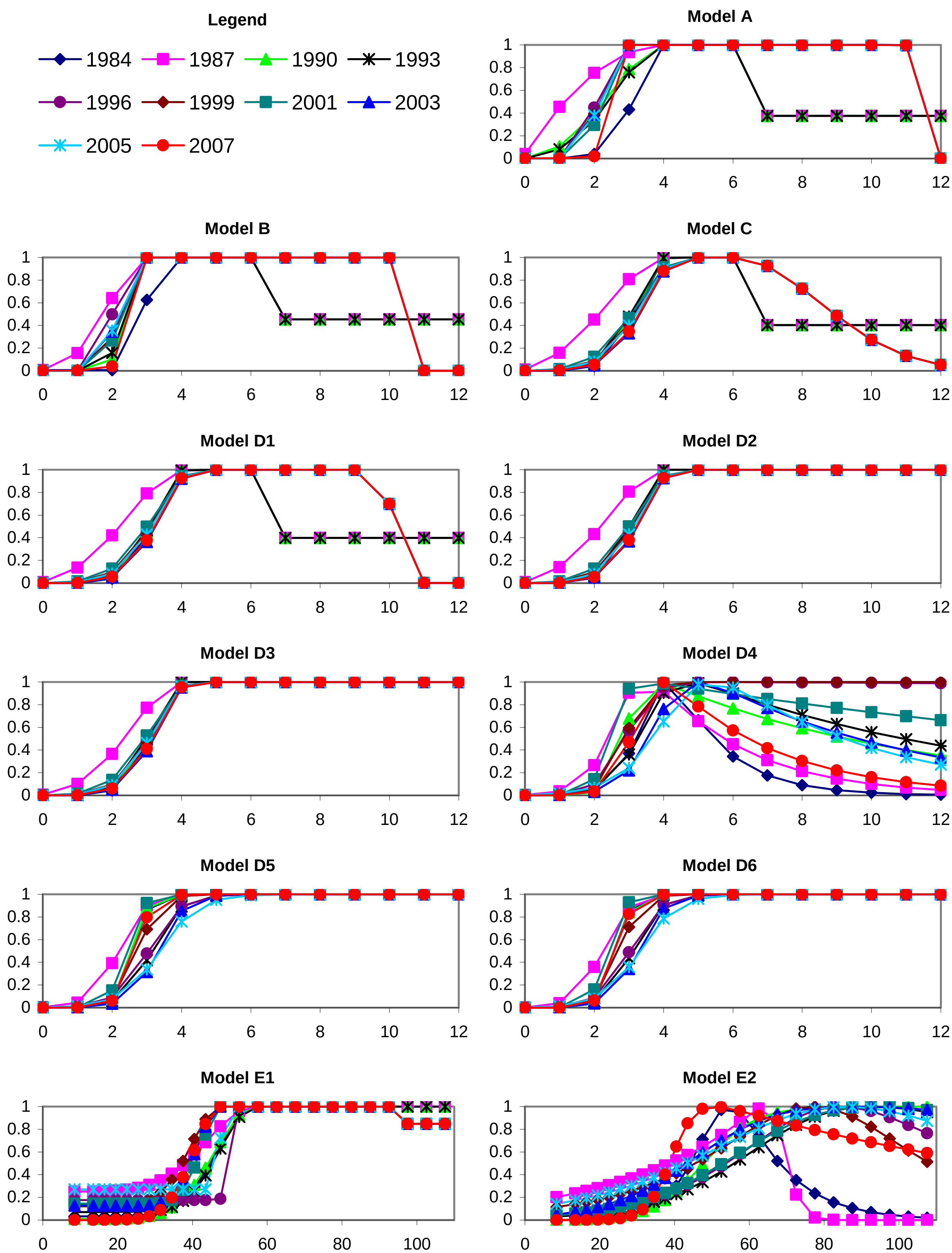


Figure 2.1.3. 27-plus trawl survey selectivities.

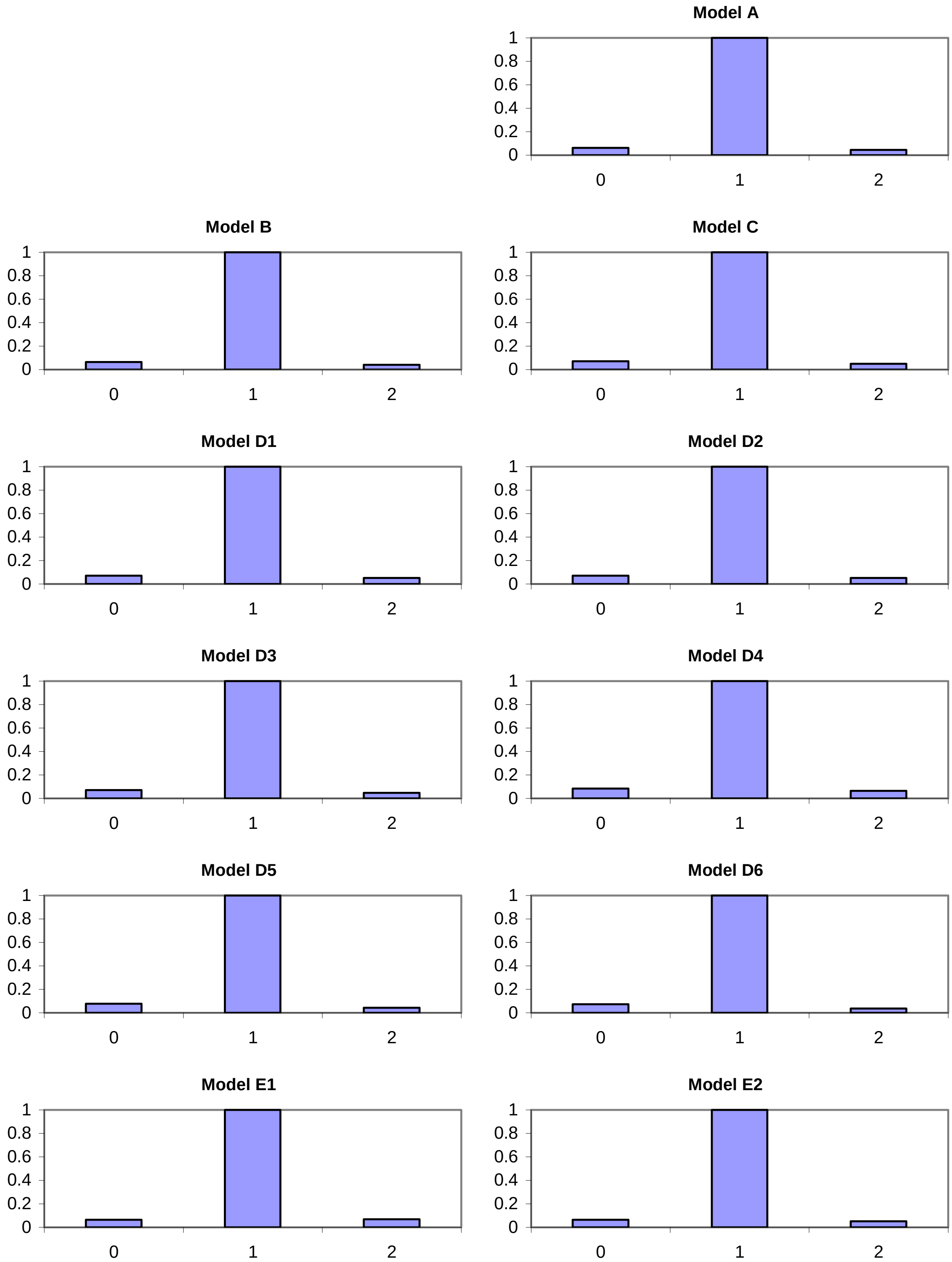


Figure 2.1.4. Sub-27 trawl survey selectivities.

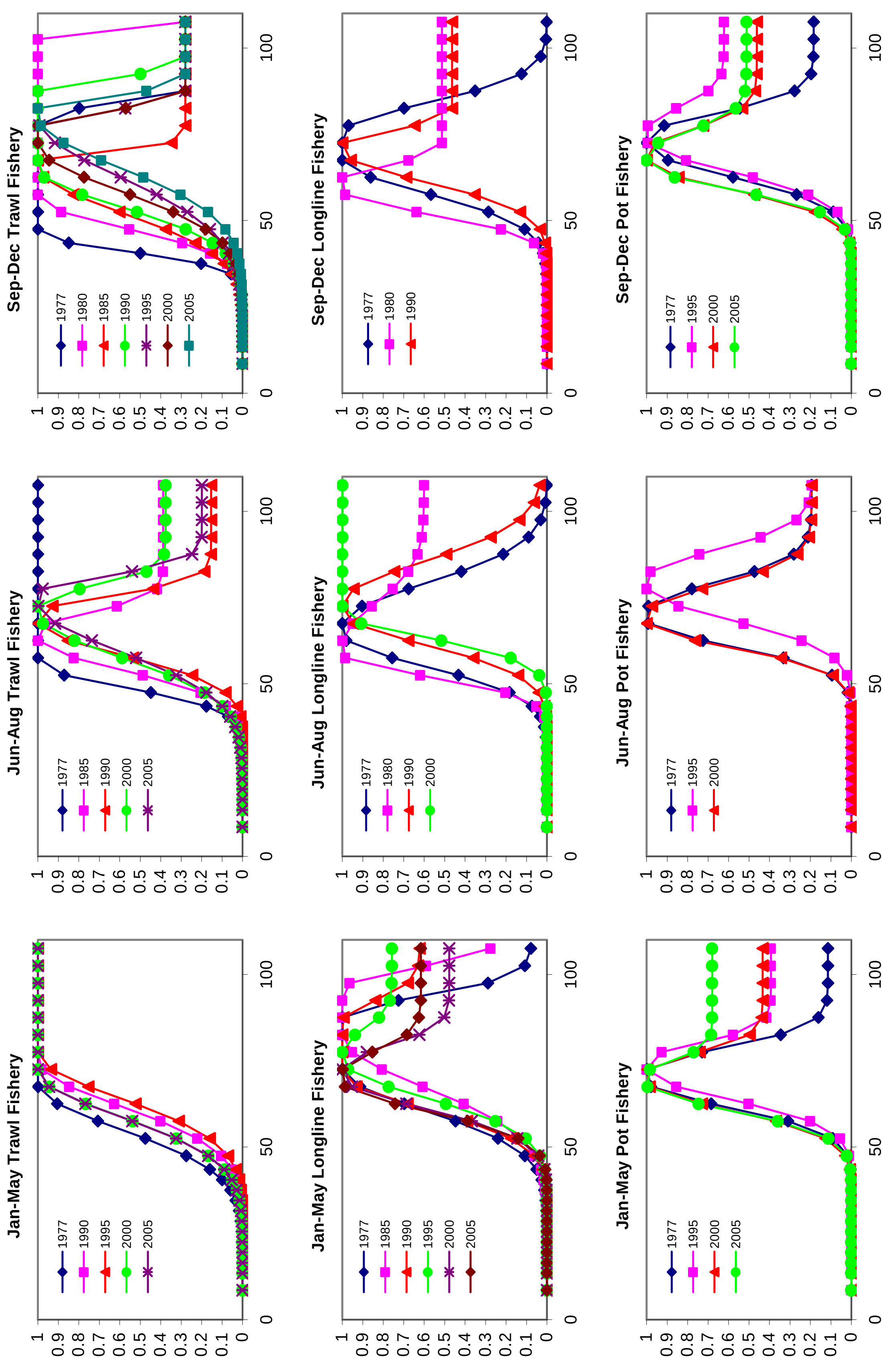


Figure 2.1.5A. Fishery selectivities as estimated by Model A.

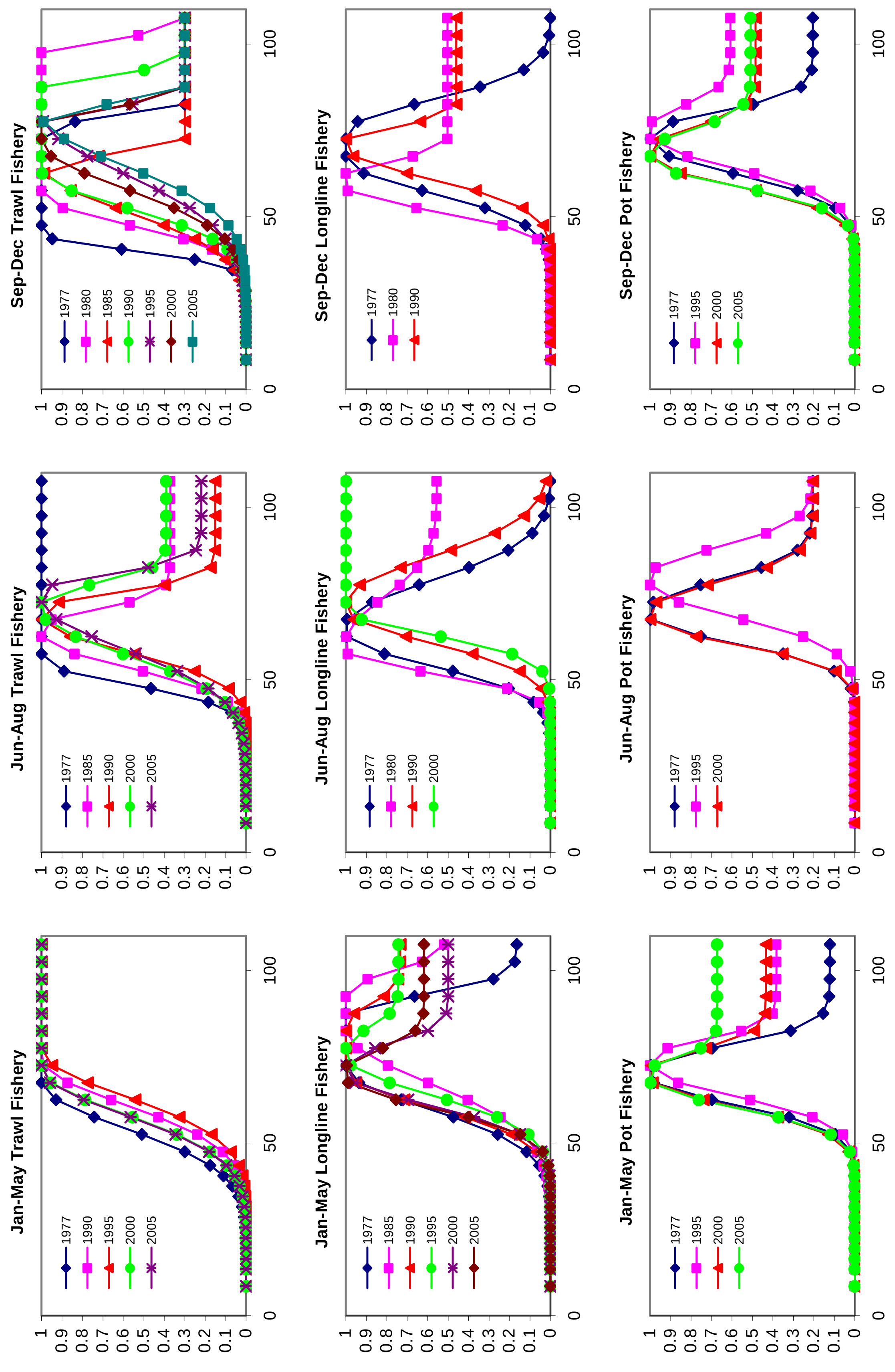


Figure 2.1.5B. Fishery selectivities as estimated by Model B.

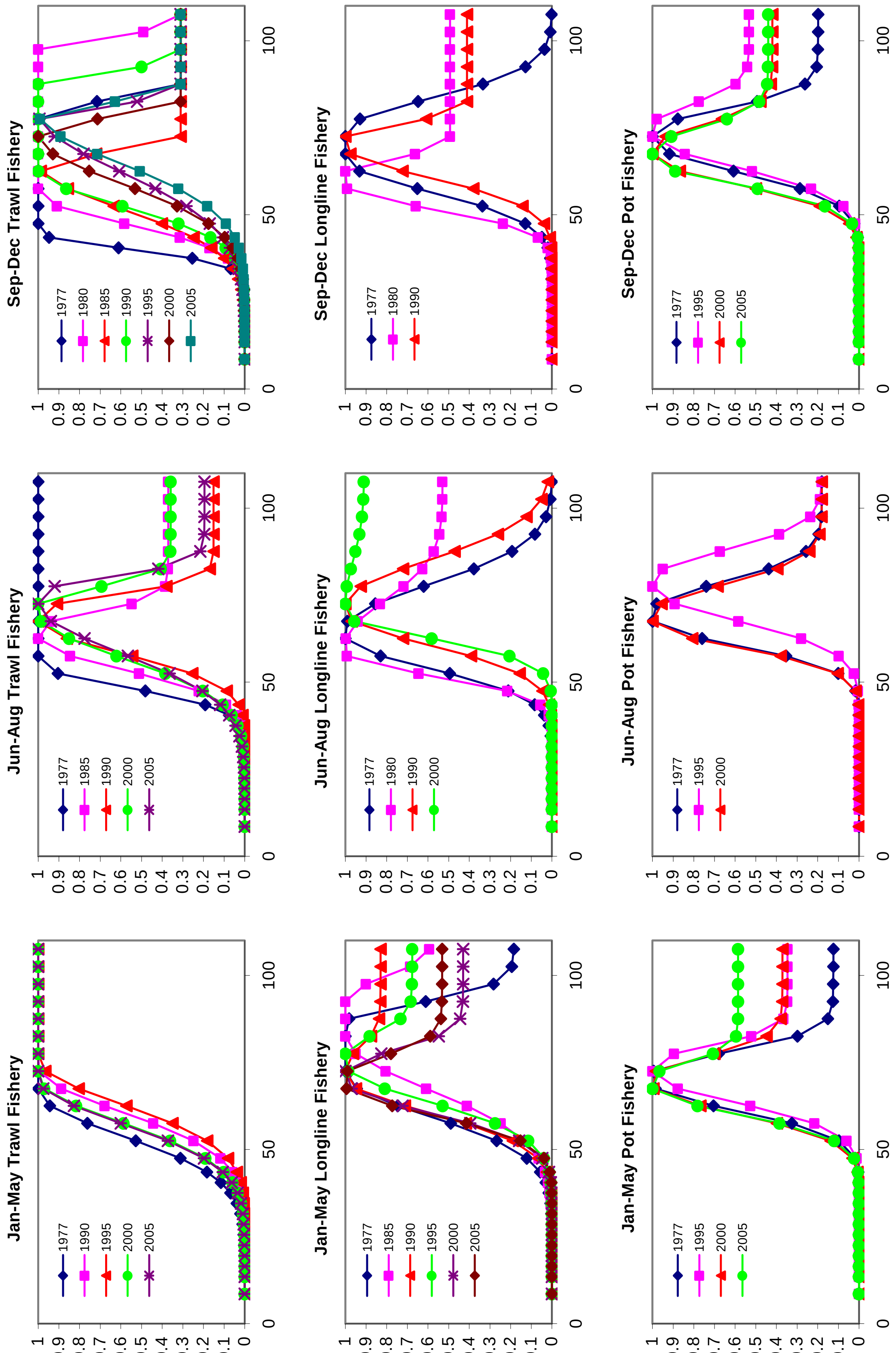


Figure 2.1.5C. Fishery selectivities as estimated by Model C.

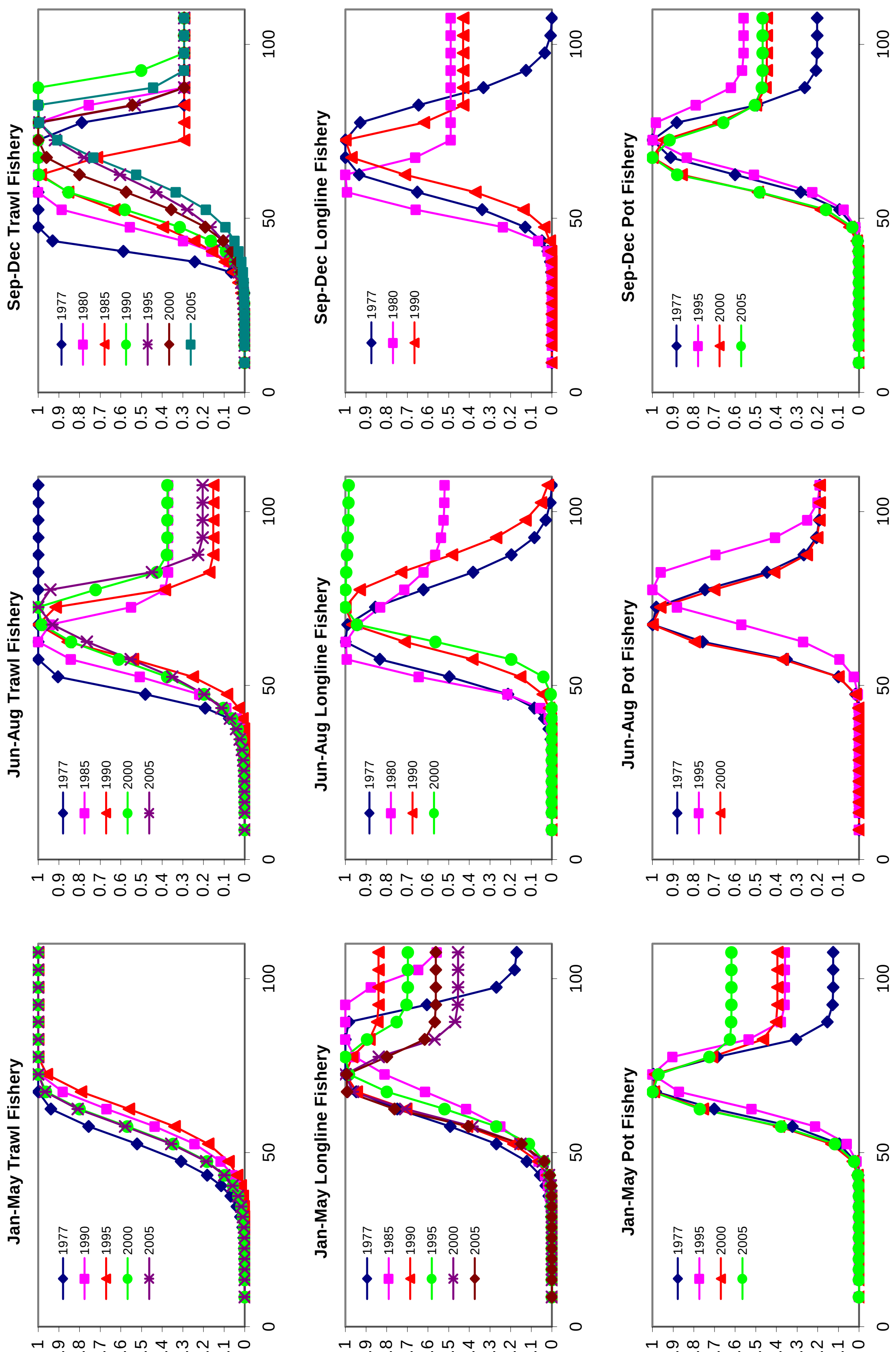


Figure 2.1.5D1. Fishery selectivities as estimated by Model D1.

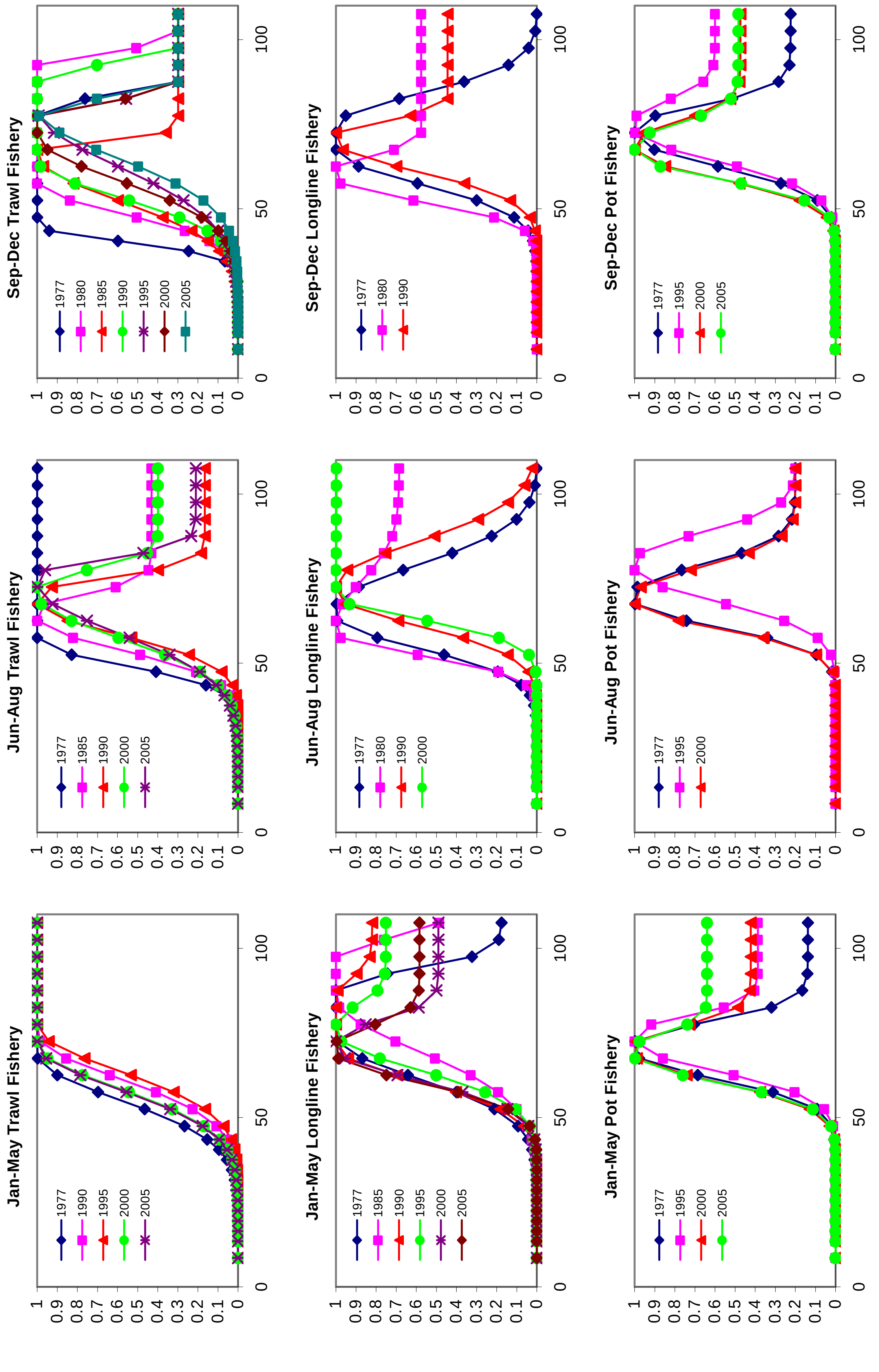


Figure 2.1.5D2. Fishery selectivities as estimated by Model D2.

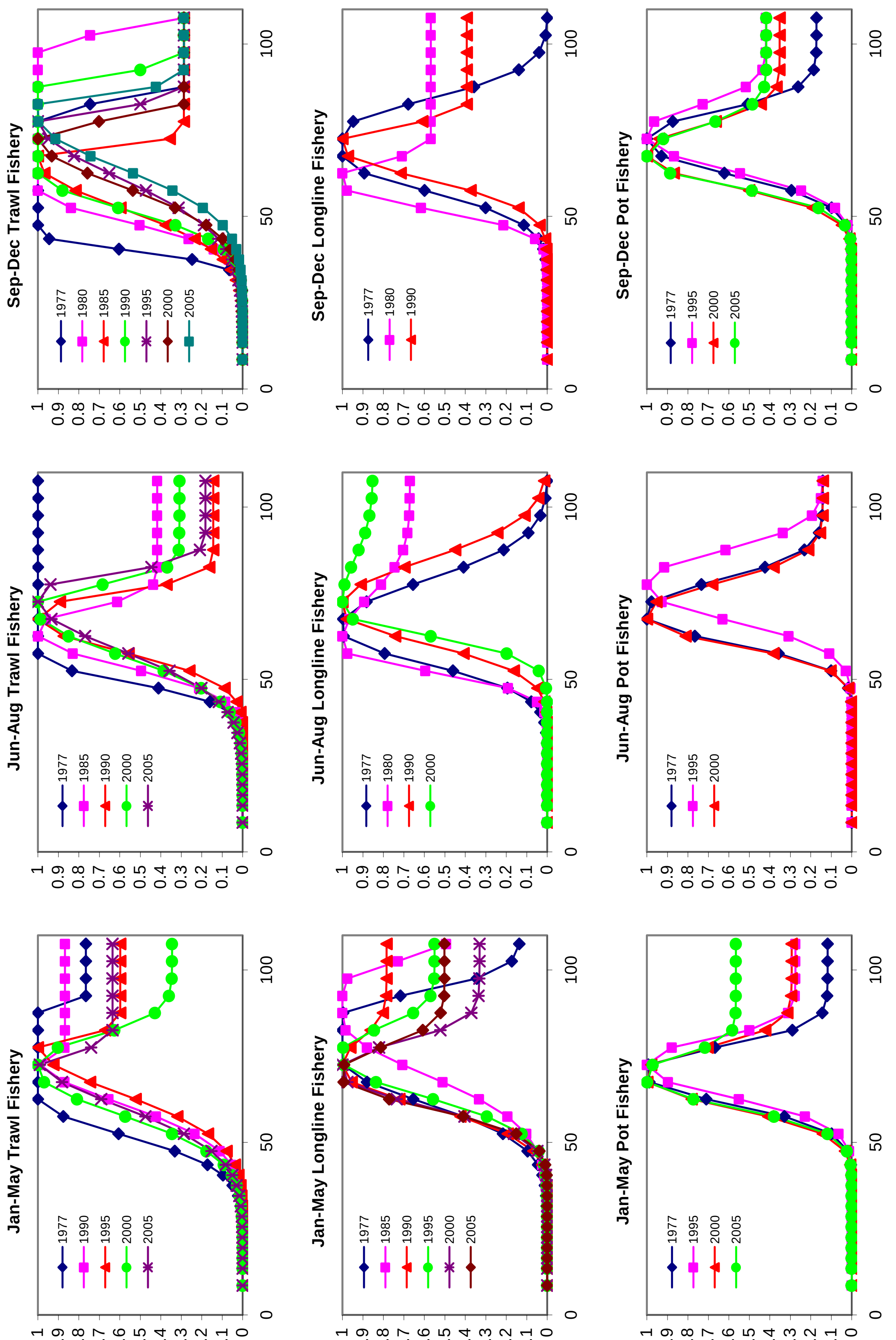


Figure 2.1.5D3. Fishery selectivities as estimated by Model D3.

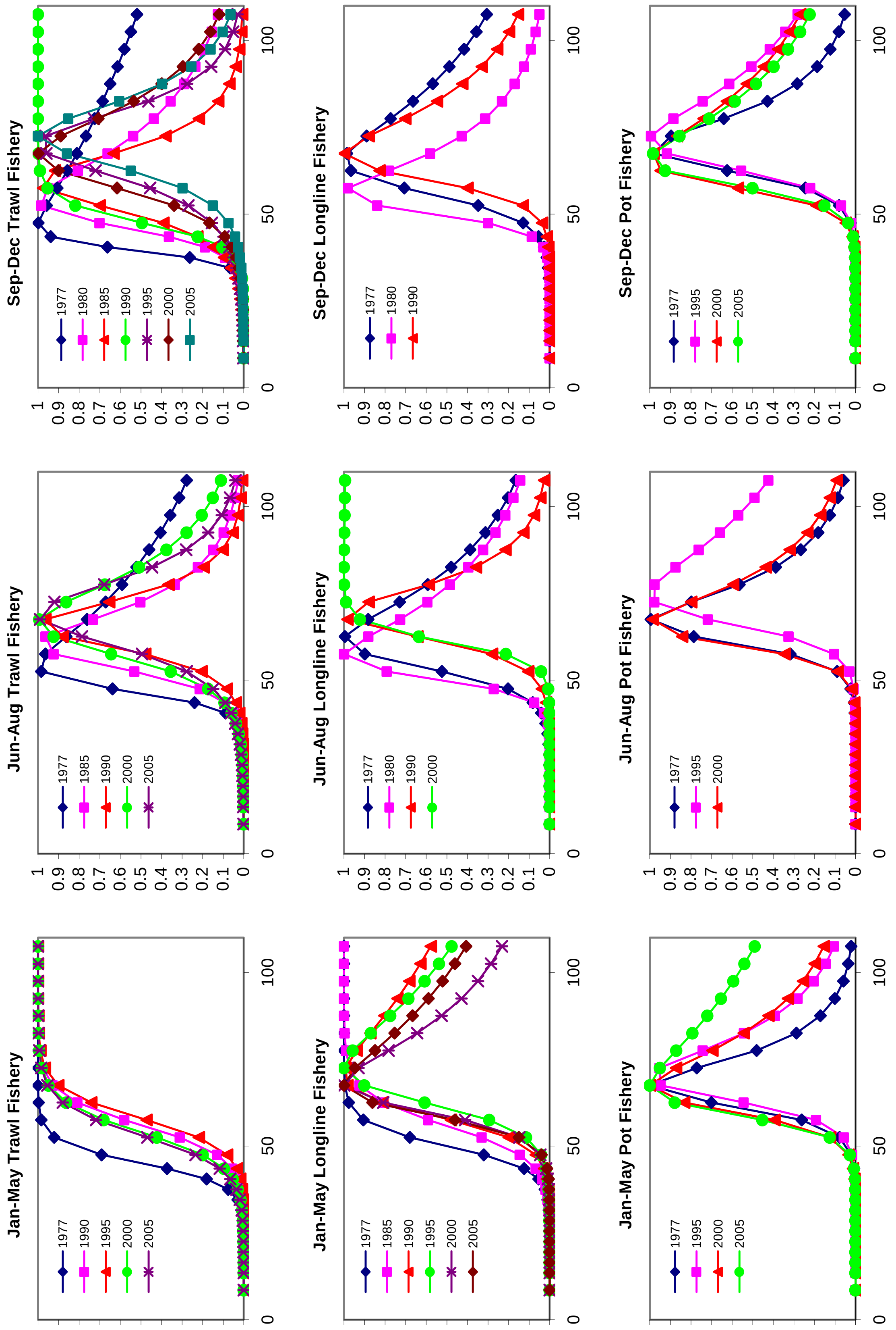


Figure 2.1.5D4. Fishery selectivities as estimated by Model D4.

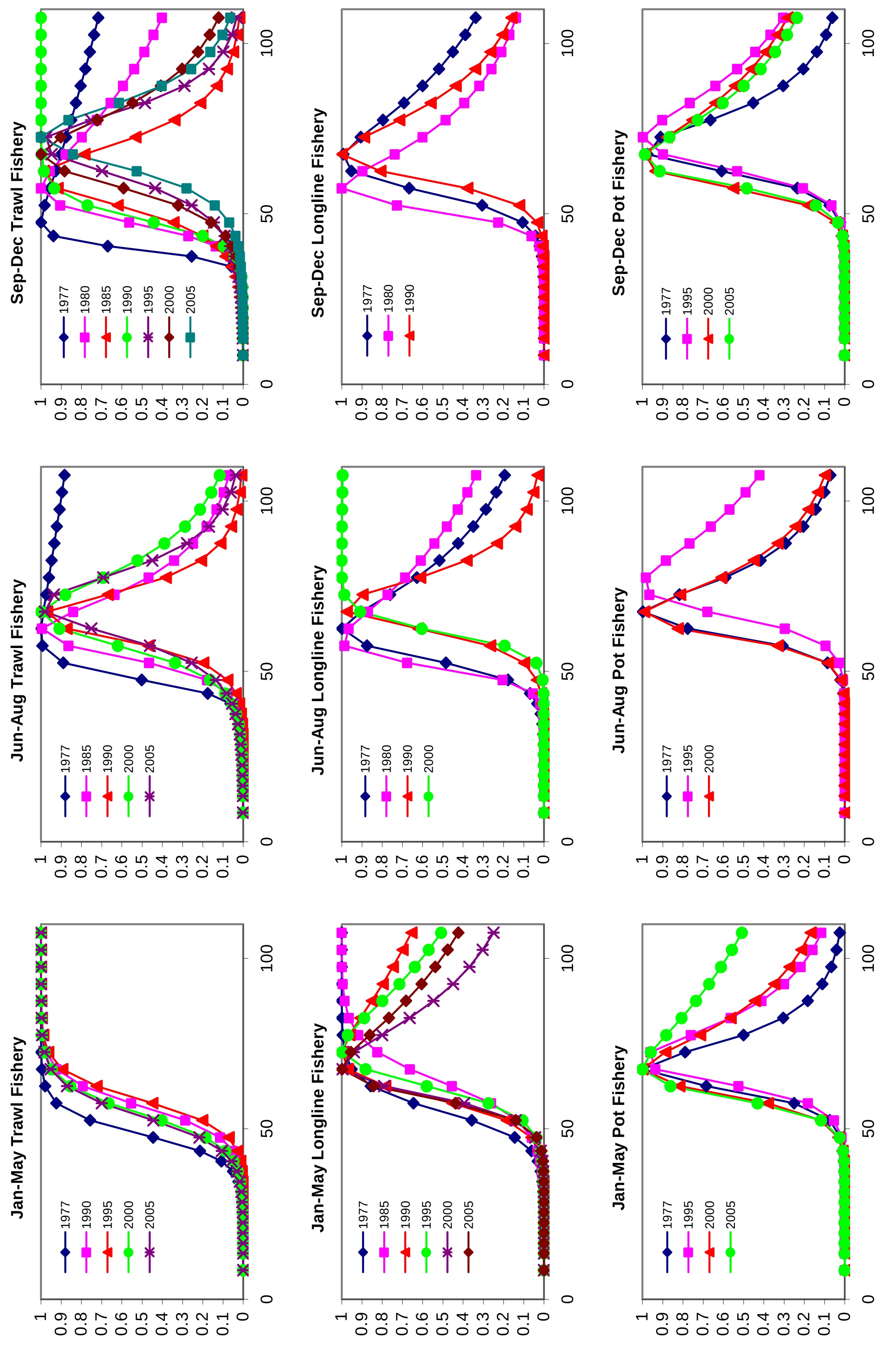


Figure 2.1.5D5. Fishery selectivities as estimated by Model D5.

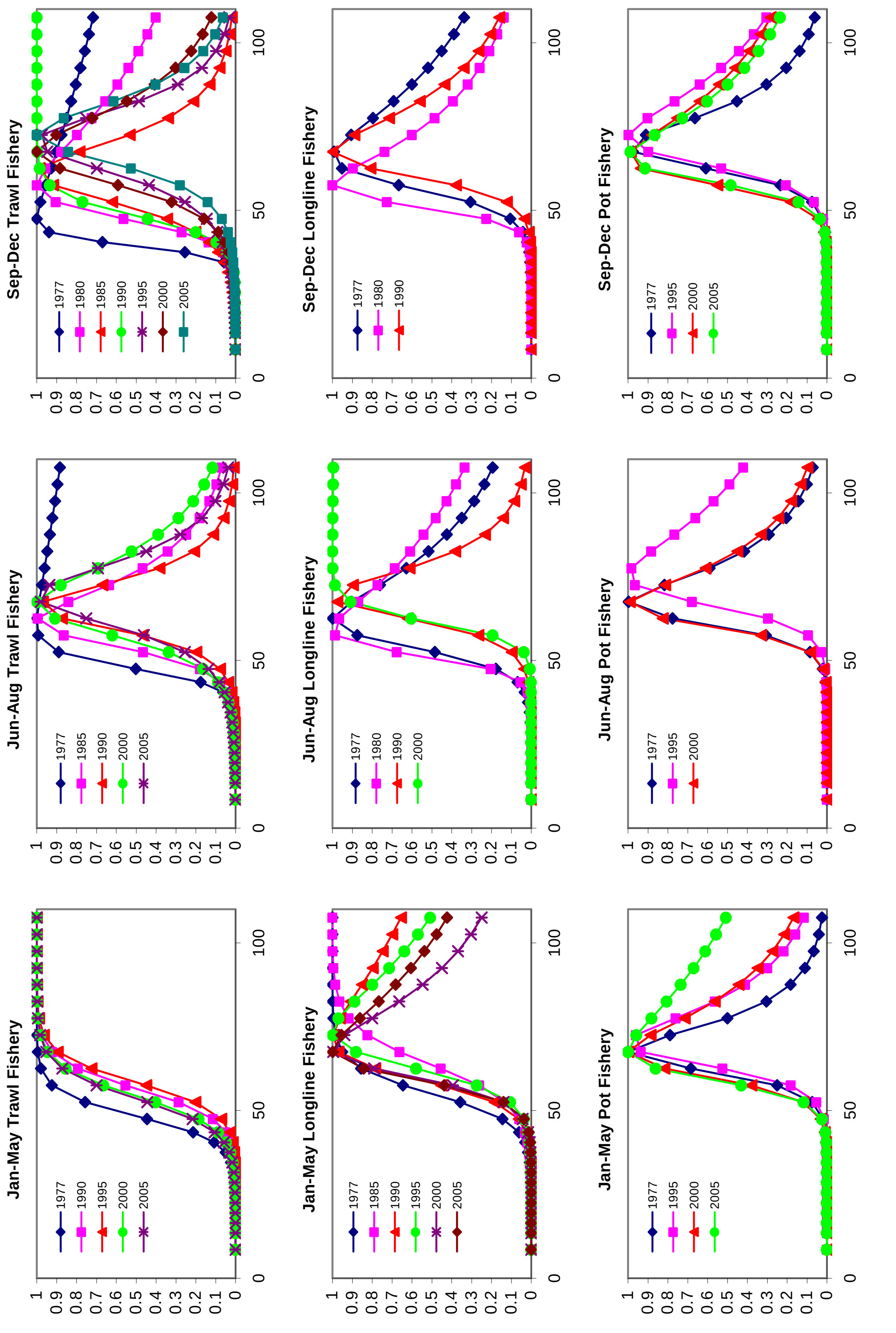


Figure 2.1.5D6. Fishery selectivities as estimated by Model D6.

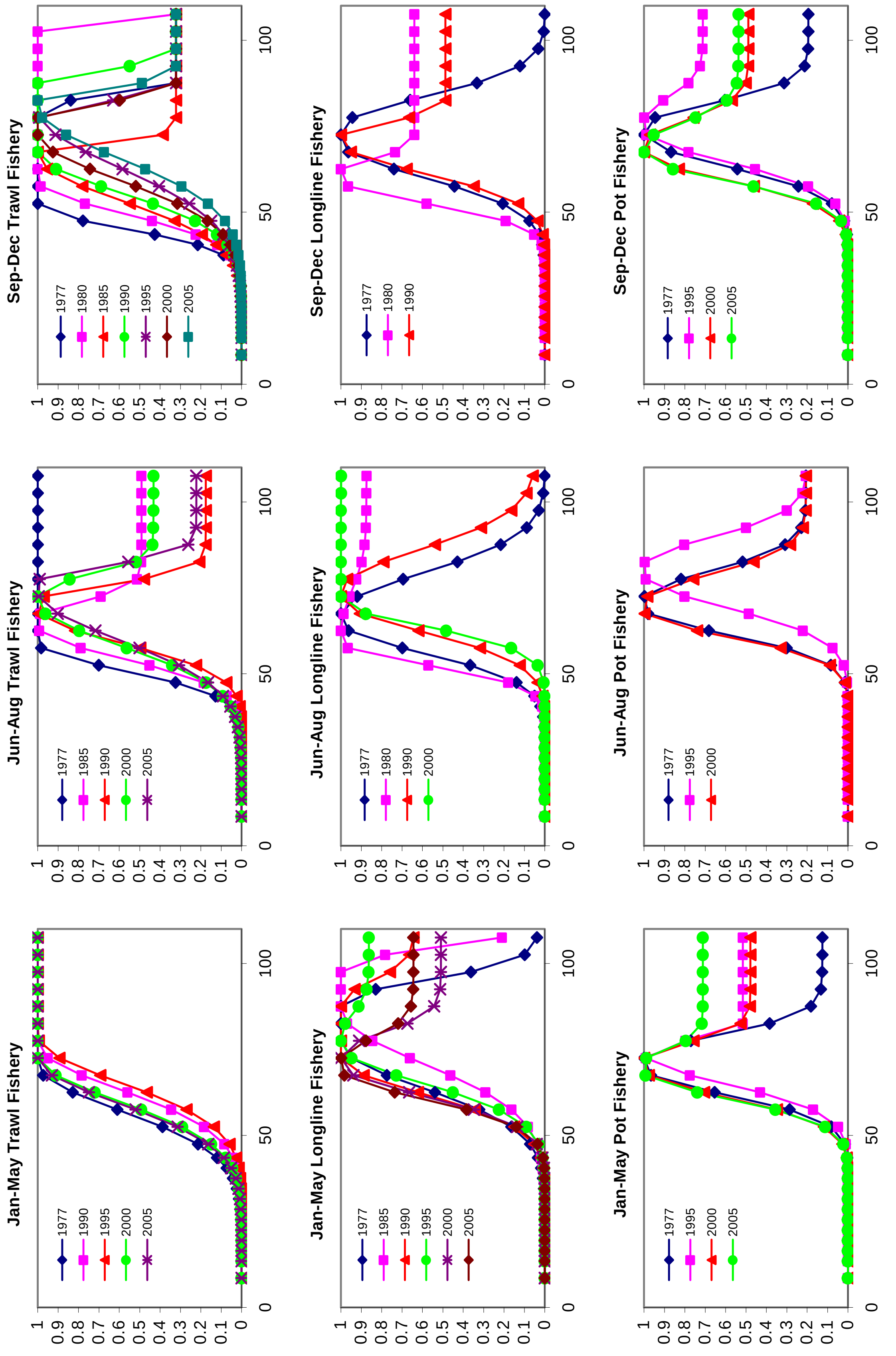


Figure 2.1.5E1. Fishery selectivities as estimated by Model E1.

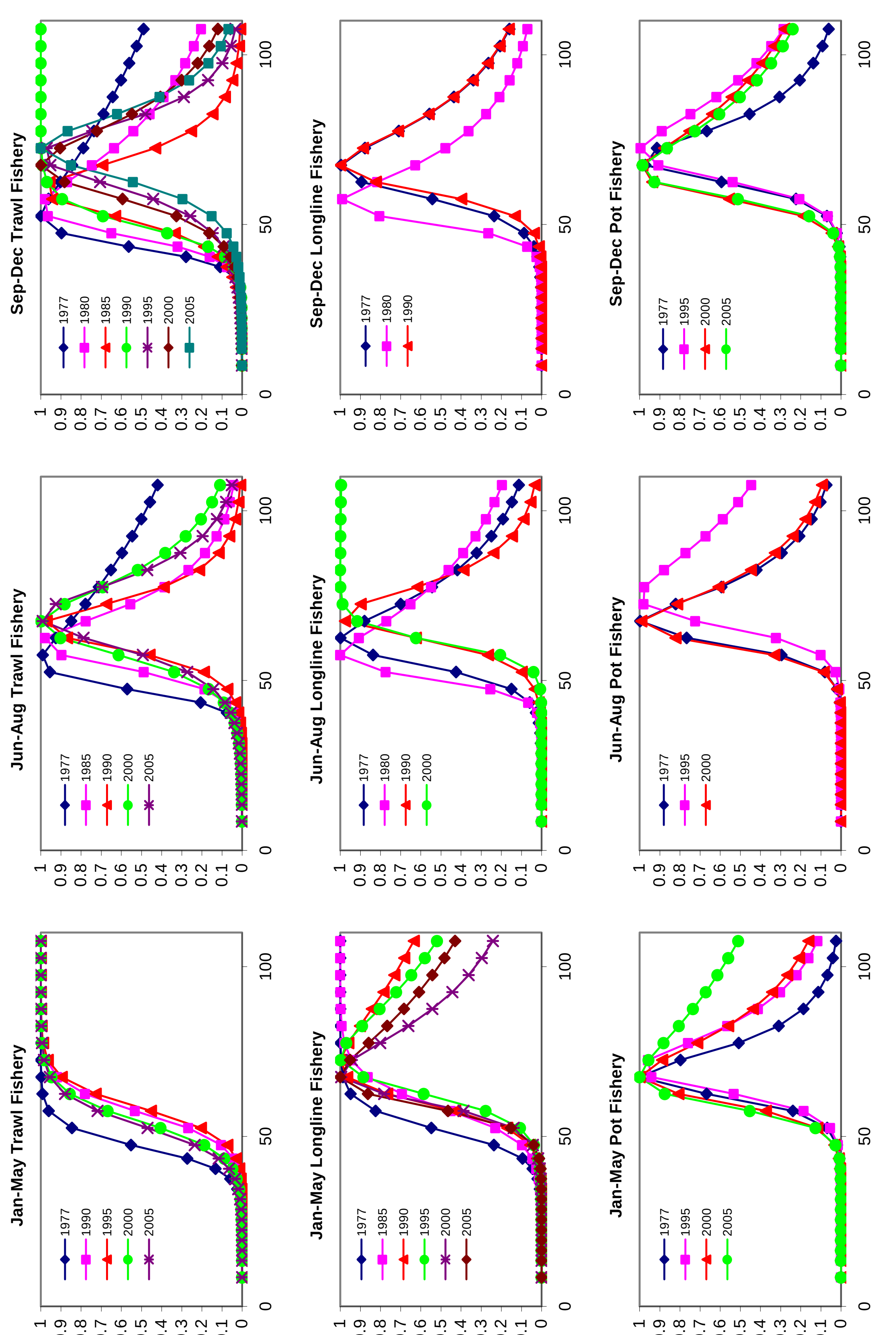


Figure 2.1.5E2. Fishery selectivities as estimated by Model E2.

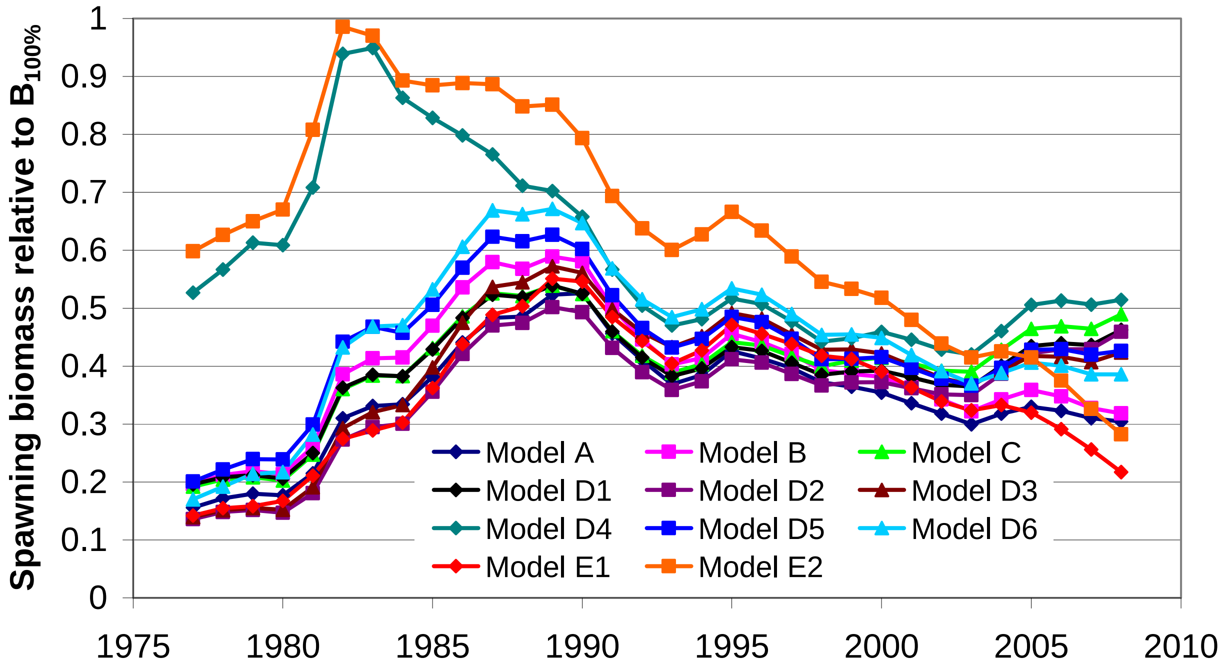


Figure 2.1.6. Comparison of estimated relative spawning biomass time series.

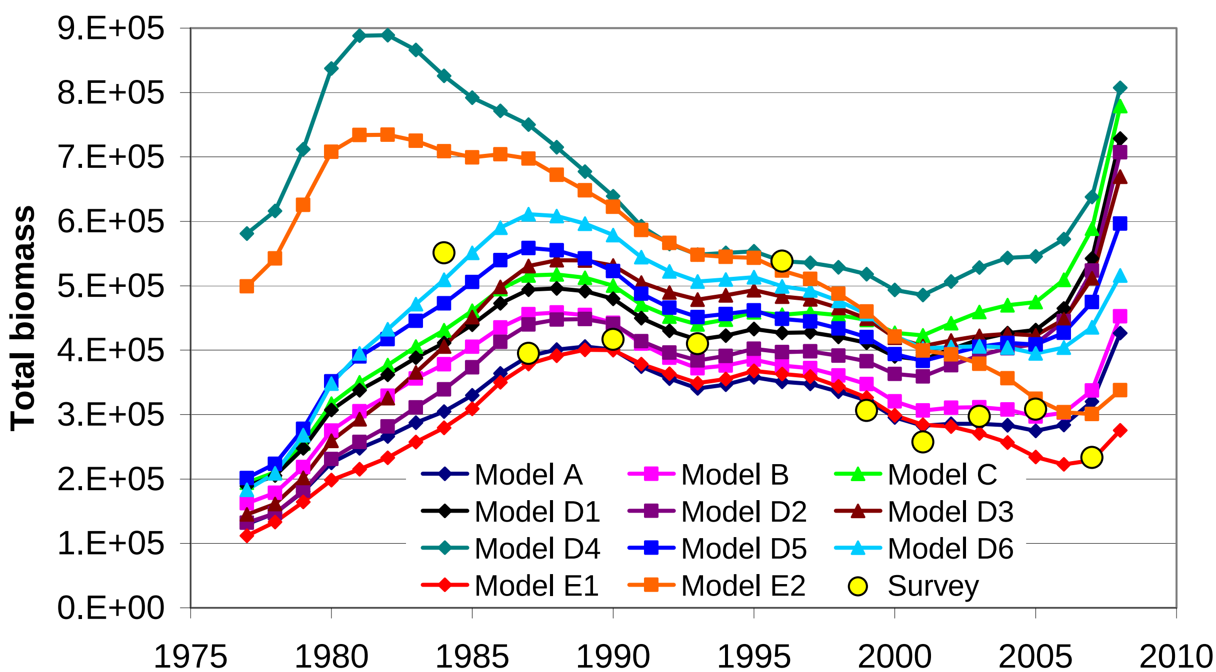


Figure 2.1.7. Comparison of estimated total biomass time series.

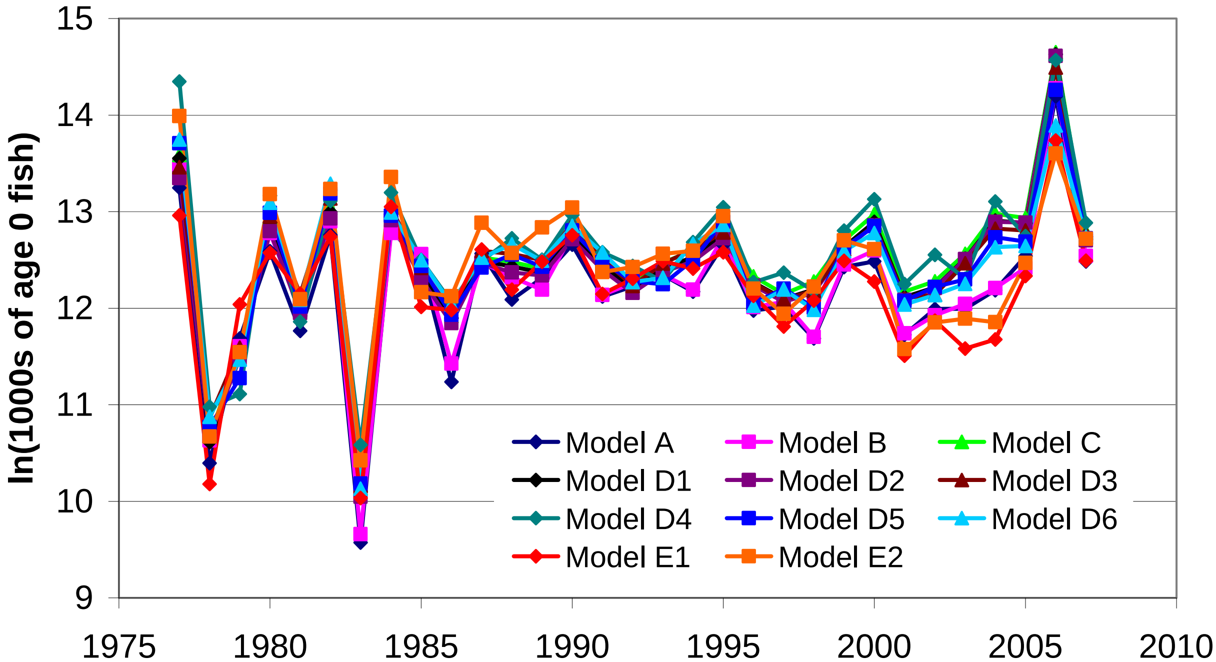


Figure 2.1.8. Comparison of estimated log recruitment time series.

Attachment 2.2:

Tables and figures for the "Time Series Results" and "Projections and Harvest Alternatives" sections based on the SSC's reference model (Model A1)

The tables and figures contained in the "Time Series Results" and "Projections and Harvest Alternatives" sections in the main text are based on Model B1. This attachment reproduces those tables and figures, but based on the SSC's reference model (A1).

Table 2.2.21a—Time series of GOA Pacific cod age 0+ biomass, female spawning biomass (t), and standard deviation of spawning biomass as estimated by the model presented in last year's assessment and this year under Model A1.

	Last year's assessment			This year's assessment		
Year	Age 0+ bio.	Spawn. bio.	Std. dev.	Age 0+ bio.	Spawn. bio.	Std. dev.
1977	130,021	42,383	6,941	181,922	61,243	10,447
1978	146,875	46,819	6,636	198,262	65,633	10,051
1979	180,466	49,013	6,156	239,503	67,551	9,605
1980	225,141	48,282	5,842	298,717	66,071	9,282
1981	247,593	58,523	6,530	328,706	79,952	10,361
1982	266,290	84,423	8,325	350,405	115,994	13,306
1983	287,676	90,265	8,656	372,131	123,196	13,476
1984	305,012	91,090	8,523	388,744	121,542	12,607
1985	330,223	103,996	8,888	412,518	134,368	12,565
1986	364,116	120,116	8,830	440,705	148,783	12,054
1987	390,721	131,660	8,481	460,808	160,260	11,491
1988	400,823	132,230	7,560	462,950	157,523	10,260
1989	405,770	142,571	7,081	458,200	163,756	9,555
1990	401,025	143,190	6,361	445,102	161,241	8,531
1991	374,683	124,241	5,645	413,187	138,651	7,454
1992	356,112	111,780	5,329	391,700	123,472	6,895
1993	340,730	100,449	5,226	375,337	111,691	6,711
1994	346,463	104,843	5,366	379,605	115,798	6,858
1995	358,082	116,013	5,540	388,235	126,380	7,009
1996	351,127	112,578	5,249	378,435	122,760	6,633
1997	347,741	107,972	4,950	373,593	116,776	6,183
1998	335,431	101,303	4,872	362,633	108,596	6,004
1999	321,952	99,278	5,181	350,936	106,438	6,388
2000	295,611	96,551	5,613	326,399	105,001	6,994
2001	282,343	91,471	5,481	316,237	101,619	6,915
2002	285,445	86,583	5,260	326,400	97,012	6,615
2003	284,783	81,476	5,456	336,880	93,104	6,726
2004	281,936	86,338	6,529	345,021	101,577	7,770
2005	272,978	89,380	7,881	351,723	110,498	9,086
2006	280,114	87,240	9,024	382,901	112,913	9,903
2007	311,870	83,482	10,492	447,862	113,523	10,806
2008	405,367	81,473	13,201	558,610	124,068	13,328
2009	520,192	90,702	18,532	663,545	152,317	18,829

Table 2.2.21b—Time series of GOA Pacific cod age 0 recruitment (1000s of fish), with standard deviations, as estimated by the model presented in last year's assessment and this year under Model A1.

	Last year's assessment		This year's assessment	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	567,138	44,304	730,729	64,506
1978	32,837	15,458	50,848	22,556
1979	119,124	21,179	91,402	25,242
1980	293,252	28,322	374,605	35,970
1981	129,061	25,049	105,323	23,336
1982	346,825	32,317	420,126	39,157
1983	14,781	5,739	20,852	8,148
1984	366,314	45,688	356,280	52,523
1985	257,969	42,834	286,458	48,953
1986	76,987	24,534	81,542	25,297
1987	286,070	25,914	273,829	28,016
1988	178,270	28,735	202,436	30,831
1989	222,709	30,118	233,717	32,400
1990	313,815	32,146	312,739	35,801
1991	183,246	31,097	207,903	33,976
1992	204,701	29,483	203,612	30,524
1993	229,405	28,101	223,091	30,042
1994	193,258	26,979	203,665	30,147
1995	313,337	26,919	318,933	31,276
1996	158,432	22,125	193,696	25,342
1997	165,827	21,266	166,079	23,194
1998	118,999	18,474	134,623	19,667
1999	248,282	26,517	268,773	28,964
2000	263,090	29,099	318,151	33,825
2001	121,909	27,668	182,918	31,986
2002	160,355	27,373	156,347	29,348
2003	158,588	36,337	273,377	44,591
2004	192,790	37,478	319,382	50,065
2005	273,494	93,599	572,846	99,854
2006	1,333,990	450,529	1,025,410	246,257
2007			115,405	66,001
2008			231,410	161,271
Average	250,828		270,516	

Table 2.2.22—Numbers (1000s) at age as estimated by Model A1.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	730729	21949	15148	48992	15586	10458	6934	4561	2988	1953	1276	833	544	355	232	152	99	65	42	28	52
1978	50848	499718	15010	10349	33361	10558	7049	4659	3061	2006	1313	859	562	367	240	157	103	67	44	29	54
1979	91402	34773	341715	10214	6928	21779	6729	4426	2910	1914	1261	831	547	361	237	156	103	67	44	29	55
1980	374605	62506	23778	232628	6833	4502	13761	4178	2730	1797	1189	789	524	348	231	153	101	67	44	29	55
1981	105323	256178	42741	16167	152199	4190	2612	7721	2307	1502	992	661	443	298	200	134	90	60	40	27	52
1982	420126	72026	175174	29061	10604	94598	2508	1535	4512	1350	882	586	394	266	180	122	82	56	37	25	49
1983	20852	287308	49253	119308	19256	6743	58510	1532	935	2751	826	542	362	244	166	113	77	52	35	24	48
1984	356280	14260	196466	33525	78584	12066	4088	34978	913	558	1649	497	328	220	149	102	70	48	33	22	45
1985	286458	243646	9751	134002	22522	51480	7725	2577	21877	570	348	1032	312	207	140	95	65	45	31	21	44
1986	81542	195897	166601	6658	90965	15124	34157	5073	1679	14180	368	225	665	201	134	90	61	42	29	20	42
1987	273829	55763	133940	113635	4495	60335	9849	21903	3215	1056	8871	230	140	415	126	83	56	39	26	18	39
1988	202436	187261	38115	91012	75383	2878	37770	6132	13679	2018	666	5611	146	89	263	80	53	36	25	17	37
1989	233717	138438	128025	25959	60848	48803	1815	23541	3813	8522	1261	417	3521	91	56	166	50	33	23	15	34
1990	312739	159830	94665	87313	17330	38912	30087	1100	14220	2309	5176	768	254	2152	56	34	101	31	20	14	30
1991	207903	213870	109290	64531	58260	10936	22822	16630	588	7508	1219	2747	411	137	1165	30	19	56	17	11	24
1992	203612	142177	146251	74620	43376	37076	6358	12147	8343	287	3629	590	1339	202	68	579	15	9	28	8	18
1993	223091	139242	97225	99834	49976	27138	20724	3184	5655	3751	128	1624	267	611	93	31	270	7	4	13	12
1994	203665	152564	95219	66393	67191	31921	15907	11206	1637	2848	1886	65	830	138	318	49	16	142	4	2	13
1995	318933	139279	104330	65049	44856	43574	19341	9041	6119	879	1526	1015	35	453	76	175	27	9	79	2	9
1996	193696	218106	95236	71246	43924	28931	25706	10320	4466	2895	409	710	475	17	216	36	84	13	4	38	5
1997	166079	132462	149143	65050	48083	28249	17008	13693	5099	2114	1346	190	331	223	8	102	17	40	6	2	21
1998	134623	113575	90559	101705	43633	30408	16037	8579	6318	2240	913	582	83	146	100	4	46	8	18	3	10
1999	268773	92064	77657	61812	68389	27643	17208	8017	3912	2748	962	394	255	37	66	45	2	21	4	8	6
2000	318151	183803	62941	52964	41464	42888	15148	8084	3354	1545	1071	380	159	105	16	28	20	1	9	2	6
2001	182918	217571	125689	42972	35557	25995	23861	7545	3790	1551	723	512	186	79	53	8	14	10	0	5	4
2002	156347	125090	148762	85675	28714	22379	14967	12753	3886	1940	803	381	274	101	44	29	4	8	6	0	5
2003	273377	106920	85539	101533	57355	17975	12644	7757	6328	1913	966	407	197	144	53	23	16	2	4	3	3
2004	319382	186952	73109	58339	67937	35999	10205	6590	3875	3144	964	497	214	105	78	29	13	9	1	2	3
2005	572846	218413	127832	49861	39030	42606	20418	5321	3301	1936	1596	500	263	115	57	43	16	7	5	1	3
2006	1025410	391747	149348	87269	33588	25058	25328	11366	2863	1762	1039	865	274	145	64	32	24	9	4	3	2
2007	115405	701236	267883	102006	58925	21668	14977	14162	6136	1531	947	563	473	151	81	36	18	13	5	2	3
2008	231410	78921	479502	182901	68727	37780	12820	8271	7548	3243	814	509	306	259	83	45	20	10	7	3	3
2009	282964	158252	53963	327206	123014	43939	22262	7041	4380	3963	1713	435	275	167	142	46	25	11	5	4	3

Table 2.2.23—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2010-2022 (Scenarios 1-2), with random variability in future recruitment under Model A1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	159,000	159,000	159,000	159,000	0
2011	164,000	164,000	164,000	164,000	4
2012	137,000	137,000	137,000	138,000	198
2013	107,000	108,000	109,000	114,000	2,790
2014	81,800	90,200	93,400	116,000	12,243
2015	52,900	80,200	84,200	129,000	25,639
2016	38,300	75,500	79,400	139,000	33,318
2017	33,900	76,100	78,400	140,000	34,507
2018	31,700	74,200	77,400	139,000	33,694
2019	31,300	74,900	76,500	136,000	32,651
2020	31,600	74,500	76,400	135,000	32,570
2021	32,100	73,000	77,100	140,000	33,451
2022	31,200	74,800	77,700	142,000	34,536

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	207,000	207,000	207,000	207,000	0
2011	229,000	229,000	229,000	229,000	7
2012	190,000	190,000	191,000	191,000	166
2013	148,000	149,000	150,000	153,000	1,987
2014	117,000	125,000	128,000	152,000	12,569
2015	88,300	110,000	118,000	174,000	30,105
2016	74,200	103,000	114,000	188,000	38,840
2017	69,800	104,000	114,000	189,000	40,133
2018	67,600	103,000	113,000	189,000	38,543
2019	66,800	103,000	111,000	183,000	36,702
2020	67,400	103,000	111,000	178,000	36,442
2021	68,300	102,000	112,000	185,000	37,986
2022	67,200	103,000	112,000	190,000	39,255

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.55	0.55	0.55	0.55	0.00
2011	0.55	0.55	0.55	0.55	0.00
2012	0.55	0.55	0.55	0.55	0.00
2013	0.55	0.55	0.55	0.55	0.00
2014	0.55	0.55	0.55	0.55	0.00
2015	0.46	0.55	0.53	0.55	0.03
2016	0.38	0.54	0.50	0.55	0.06
2017	0.36	0.55	0.50	0.55	0.07
2018	0.34	0.54	0.49	0.55	0.08
2019	0.34	0.54	0.49	0.55	0.08
2020	0.34	0.54	0.49	0.55	0.08
2021	0.35	0.53	0.49	0.55	0.07
2022	0.34	0.54	0.49	0.55	0.08

Table 2.2.24—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that the upper bound on F_{ABC} is set the most recent five-year average fishing mortality rate in 2010-2022 (Scenario 3), with random variability in future recruitment under Model A1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	37,800	37,800	37,800	37,800	0
2011	46,900	46,900	46,900	46,900	1
2012	47,800	47,900	47,900	48,000	43
2013	44,000	44,400	44,600	45,700	613
2014	38,500	40,400	41,200	46,300	2,825
2015	32,500	37,000	38,700	49,200	6,006
2016	27,700	34,900	37,000	52,500	8,527
2017	24,600	33,800	35,900	53,500	9,815
2018	22,300	33,000	35,000	54,400	10,172
2019	20,800	32,400	34,300	53,000	10,082
2020	20,300	32,100	33,800	52,400	10,019
2021	20,000	31,800	33,600	53,000	10,211
2022	19,900	31,700	33,600	53,600	10,535

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	215,000	215,000	215,000	215,000	0
2011	283,000	283,000	283,000	283,000	7
2012	286,000	286,000	286,000	287,000	166
2013	266,000	267,000	267,000	271,000	1,999
2014	239,000	247,000	251,000	276,000	13,044
2015	204,000	229,000	238,000	302,000	34,356
2016	174,000	216,000	229,000	321,000	50,177
2017	155,000	209,000	222,000	327,000	58,231
2018	140,000	204,000	216,000	332,000	60,699
2019	130,000	200,000	211,000	323,000	60,505
2020	127,000	197,000	207,000	320,000	60,118
2021	122,000	196,000	206,000	324,000	61,344
2022	123,000	194,000	205,000	325,000	63,117

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.12	0.12	0.12	0.12	0.00
2011	0.12	0.12	0.12	0.12	0.00
2012	0.12	0.12	0.12	0.12	0.00
2013	0.12	0.12	0.12	0.12	0.00
2014	0.12	0.12	0.12	0.12	0.00
2015	0.12	0.12	0.12	0.12	0.00
2016	0.12	0.12	0.12	0.12	0.00
2017	0.12	0.12	0.12	0.12	0.00
2018	0.12	0.12	0.12	0.12	0.00
2019	0.12	0.12	0.12	0.12	0.00
2020	0.12	0.12	0.12	0.12	0.00
2021	0.12	0.12	0.12	0.12	0.00
2022	0.12	0.12	0.12	0.12	0.00

Table 2.2.25—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that the upper bound on F_{ABC} is set at $F_{60\%}$ in 2010-2022 (Scenario 4), with random variability in future recruitment under Model A1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	76,000	76,000	76,000	76,000	0
2011	89,200	89,200	89,200	89,200	2
2012	85,500	85,600	85,600	85,700	89
2013	74,300	75,100	75,500	77,800	1,261
2014	61,900	65,900	67,300	77,800	5,730
2015	50,100	59,100	62,300	82,900	11,809
2016	41,700	55,300	59,500	89,000	16,144
2017	36,800	53,900	57,700	90,300	17,939
2018	33,500	52,500	56,300	90,600	18,109
2019	31,500	52,100	55,100	88,400	17,677
2020	31,000	51,600	54,500	86,300	17,545
2021	31,300	51,000	54,500	88,200	17,976
2022	30,400	51,100	54,600	91,600	18,583

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	213,000	213,000	213,000	213,000	0
2011	265,000	265,000	265,000	265,000	7
2012	253,000	253,000	253,000	253,000	166
2013	221,000	223,000	223,000	227,000	1,995
2014	190,000	198,000	202,000	226,000	12,902
2015	154,000	179,000	187,000	249,000	33,091
2016	128,000	166,000	178,000	264,000	46,757
2017	112,000	161,000	173,000	268,000	52,511
2018	101,000	157,000	168,000	271,000	53,294
2019	95,400	155,000	164,000	263,000	52,177
2020	93,000	153,000	162,000	255,000	51,569
2021	92,600	152,000	161,000	261,000	52,840
2022	92,200	150,000	162,000	268,000	54,470

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.25	0.25	0.25	0.25	0.00
2011	0.25	0.25	0.25	0.25	0.00
2012	0.25	0.25	0.25	0.25	0.00
2013	0.25	0.25	0.25	0.25	0.00
2014	0.25	0.25	0.25	0.25	0.00
2015	0.25	0.25	0.25	0.25	0.00
2016	0.25	0.25	0.25	0.25	0.00
2017	0.25	0.25	0.25	0.25	0.00
2018	0.25	0.25	0.25	0.25	0.00
2019	0.25	0.25	0.25	0.25	0.00
2020	0.25	0.25	0.25	0.25	0.00
2021	0.25	0.25	0.25	0.25	0.00
2022	0.25	0.25	0.25	0.25	0.00

Table 2.2.26—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = 0$ in 2010-2022 (Scenario 5), with random variability in future recruitment under Model A1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0	0	0	0	0
2011	0	0	0	0	0
2012	0	0	0	0	0
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	0	0	0	0	0
2022	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	217,000	217,000	217,000	217,000	0
2011	300,000	300,000	300,000	300,000	7
2012	322,000	322,000	323,000	323,000	166
2013	317,000	319,000	319,000	323,000	2,002
2014	301,000	309,000	313,000	338,000	13,179
2015	271,000	297,000	306,000	372,000	35,596
2016	241,000	286,000	299,000	399,000	53,726
2017	219,000	278,000	293,000	408,000	64,564
2018	201,000	273,000	287,000	412,000	69,481
2019	187,000	269,000	281,000	414,000	71,021
2020	180,000	265,000	276,000	410,000	71,519
2021	175,000	262,000	274,000	414,000	73,050
2022	171,000	260,000	273,000	414,000	75,081

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.00	0.00	0.00	0.00	0.00
2011	0.00	0.00	0.00	0.00	0.00
2012	0.00	0.00	0.00	0.00	0.00
2013	0.00	0.00	0.00	0.00	0.00
2014	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00
2019	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00
2021	0.00	0.00	0.00	0.00	0.00
2022	0.00	0.00	0.00	0.00	0.00

Table 2.2.27—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2010-2022 (Scenario 6), with random variability in future recruitment under Model A1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	191,000	191,000	191,000	191,000	0
2011	188,000	188,000	188,000	188,000	5
2012	149,000	149,000	149,000	149,000	245
2013	111,000	113,000	114,000	120,000	3,445
2014	78,000	93,200	95,800	125,000	16,234
2015	46,900	75,600	84,100	142,000	32,763
2016	36,900	73,500	82,500	150,000	38,962
2017	33,600	76,000	82,900	154,000	39,375
2018	32,600	75,100	82,200	153,000	38,196
2019	32,800	75,800	81,400	149,000	36,976
2020	33,000	74,600	81,300	149,000	37,234
2021	33,600	74,900	82,200	154,000	38,443
2022	32,400	75,500	83,000	155,000	39,528

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	205,000	205,000	205,000	205,000	0
2011	215,000	215,000	215,000	215,000	7
2012	169,000	169,000	169,000	170,000	166
2013	126,000	127,000	128,000	131,000	1,983
2014	97,600	105,000	109,000	132,000	12,305
2015	74,800	93,800	102,000	155,000	28,245
2016	65,400	91,900	101,000	167,000	34,948
2017	62,800	93,300	102,000	167,000	35,482
2018	61,500	92,700	101,000	169,000	33,874
2019	61,400	93,300	100,000	164,000	32,277
2020	62,000	92,600	99,700	160,000	32,378
2021	62,500	92,800	101,000	168,000	33,898
2022	61,700	93,200	102,000	172,000	34,923

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.69	0.69	0.69	0.69	0.00
2011	0.69	0.69	0.69	0.69	0.00
2012	0.69	0.69	0.69	0.69	0.00
2013	0.69	0.69	0.69	0.69	0.00
2014	0.63	0.68	0.67	0.69	0.02
2015	0.48	0.61	0.60	0.69	0.08
2016	0.41	0.59	0.58	0.69	0.10
2017	0.39	0.60	0.58	0.69	0.10
2018	0.39	0.60	0.58	0.69	0.11
2019	0.38	0.60	0.58	0.69	0.11
2020	0.39	0.60	0.58	0.69	0.11
2021	0.39	0.60	0.58	0.69	0.10
2022	0.39	0.60	0.58	0.69	0.11

Table 2.2.28—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2010-2011 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment under Model A1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	159,000	159,000	159,000	159,000	0
2011	164,000	164,000	164,000	164,000	4
2012	164,000	164,000	164,000	165,000	245
2013	119,000	121,000	122,000	129,000	3,445
2014	85,100	97,500	101,000	129,000	15,244
2015	48,200	78,500	86,100	143,000	32,820
2016	37,100	74,400	83,100	151,000	39,092
2017	33,700	76,300	83,100	154,000	39,436
2018	32,600	75,000	82,300	153,000	38,216
2019	32,700	75,800	81,400	149,000	36,982
2020	32,900	74,600	81,300	149,000	37,236
2021	33,600	74,900	82,200	154,000	38,444
2022	32,400	75,500	83,000	155,000	39,528

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	207,000	207,000	207,000	207,000	0
2011	229,000	229,000	229,000	229,000	7
2012	188,000	188,000	188,000	188,000	166
2013	136,000	137,000	138,000	141,000	1,984
2014	102,000	110,000	113,000	137,000	12,394
2015	75,900	95,900	104,000	157,000	28,594
2016	65,600	92,500	102,000	168,000	35,179
2017	62,900	93,600	102,000	167,000	35,580
2018	61,500	92,700	101,000	169,000	33,905
2019	61,400	93,300	100,000	164,000	32,286
2020	62,000	92,600	99,700	160,000	32,381
2021	62,500	92,800	101,000	168,000	33,899
2022	61,700	93,200	102,000	172,000	34,923

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2010	0.55	0.55	0.55	0.55	0.00
2011	0.55	0.55	0.55	0.55	0.00
2012	0.69	0.69	0.69	0.69	0.00
2013	0.69	0.69	0.69	0.69	0.00
2014	0.66	0.69	0.68	0.69	0.01
2015	0.48	0.62	0.61	0.69	0.07
2016	0.41	0.60	0.58	0.69	0.10
2017	0.39	0.61	0.58	0.69	0.10
2018	0.39	0.60	0.58	0.69	0.11
2019	0.38	0.60	0.58	0.69	0.11
2020	0.39	0.60	0.58	0.69	0.11
2021	0.39	0.60	0.58	0.69	0.10
2022	0.39	0.60	0.58	0.69	0.11

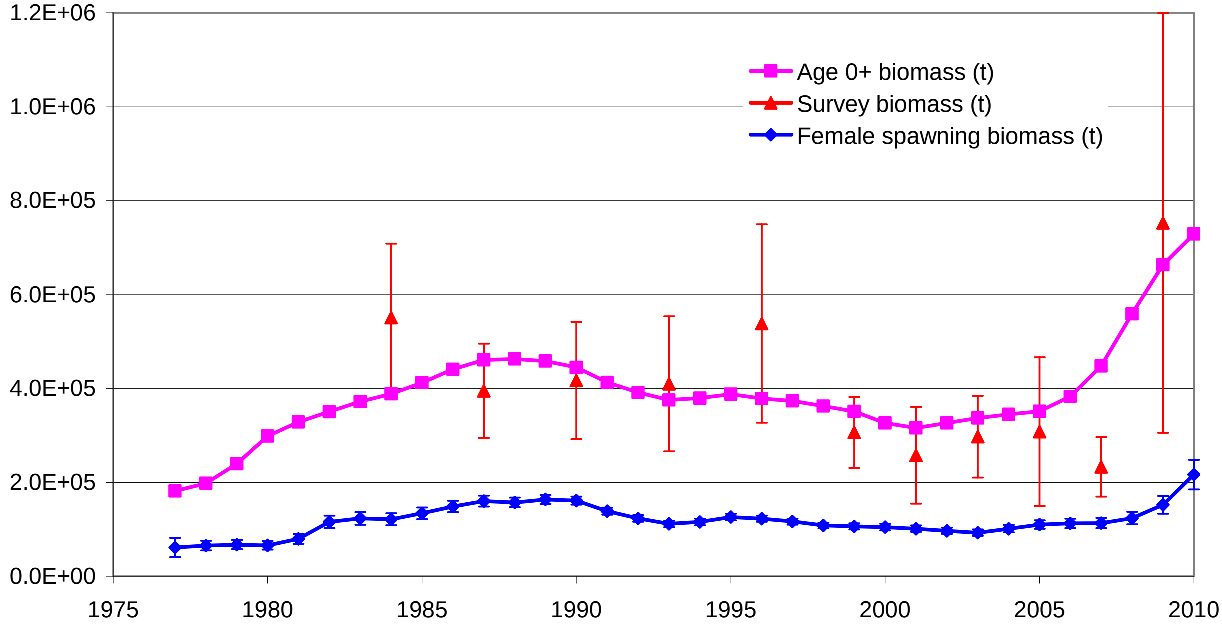


Figure 2.2.9—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) as estimated by Model A1. Female spawning biomass and survey biomass show 95% CI.

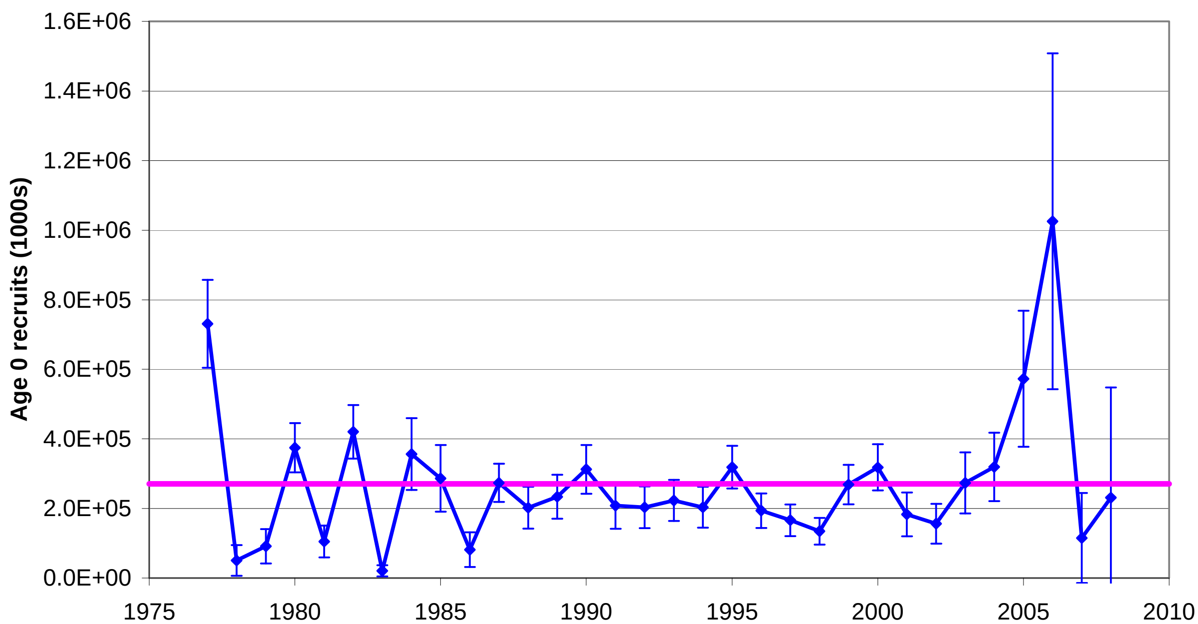


Figure 2.2.10—Time series of recruitment at age 0, with 95% confidence intervals, as estimated by Model A1. Magenta line = 1977-2008 average.

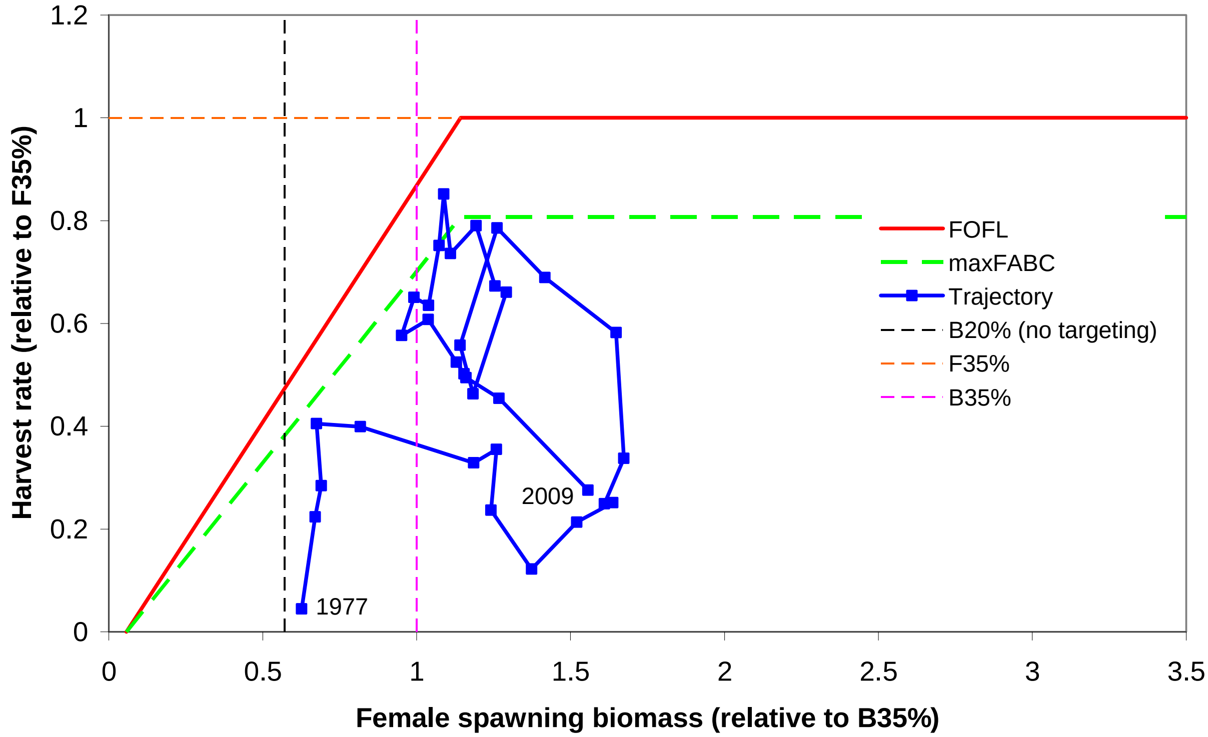


Figure 2.2.11—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model A1, 1977-present. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.

(This page intentionally left blank)