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

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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 2004-2009 were updated, and preliminary catch data for 2010 were incorporated.
2) Commercial fishery size composition data for 2009 were updated, and preliminary size composition data from the 2010 commercial fisheries were incorporated.
3) Age composition and mean-length-at-age data from the 2009 bottom trawl survey were incorporated into some models.
4) Age composition data from the 2008 January-May longline fishery were removed from two of the models.
5) Mean length at age data from the 2008 January-May longline fishery were removed from two of the models.
6) Seasonal catch per unit effort (CPUE) data for the trawl, longline, and pot fisheries from 2009 were updated, and preliminary catch rates for the trawl, longline, and pot fisheries from 2010 were incorporated.
7) Size composition data from the State-managed Pacific cod fishery for 1997-2009 were updated, and preliminary size composition data from the 2010 State-managed fishery were incorporated.

Changes in the Assessment Methodology

Many changes have been made or considered in the stock assessment model since the 2009 assessment (Thompson et al. 2009). Five models were presented in this year's preliminary assessment (Attachment 2.1). The relationships between the five models presented in the preliminary assessment are summarized in Table 2.1.1 of Attachment 2.1. The set of five models in the preliminary assessment was requested by the Plan Teams in May of this year, with subsequent concurrence (given two minor modifications) by the SSC in June. Following review in September and October, three of these models, or modifications thereof, were requested by the Plan Teams or SSC to be included in the final assessment.

Model 1 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 without modification for inclusion in the final assessment, where it is labeled Model A.

Model 2 in the preliminary assessment included three changes in data or data structure: 1) exclude the single record (each) of fishery age composition and mean length-at-age data, 2) use a finer length bin structure than previous models, and 3) re-evaluate the existing seasonal structure used in the model and revise it as appropriate. The length bin structure adopted in Model 2 consisted of 1-cm bins, replacing the combination of 3-cm and 5-cm bins used in previous assessments. The seasonal structure adopted in Model 2 consisted of five catch seasons defined as January-February, March-April, May-August, September-October, and November-December; and three selectivity seasons defined as January-April, May-August, and September-December; with spawning identified as occurring at the beginning of the second catch season (March).

Model 4 in the preliminary assessment included all of the changes in Model 2, plus disuse of all mean length-at-age data and all age composition data, and a change from age-based to length-based maturity.

The Plan Teams and SSC requested that modified forms of preliminary Models 2 and 4 be included in the final assessment. The requested modification in each case was removal of cohort-specific growth rates (use of cohort-specific growth rates was new in last year's assessment). The modified Models 2 and 4 from the preliminary assessment are labeled here as Models B and C, respectively.

Version 3.11b of Stock Synthesis (SS) was used to run all the models in the preliminary assessment and in the final assessment up until the very last stages of the analysis, at which point version 3.11c was used.

Model B 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.

Quantity/Status	Last year 2010	2011	This year **2011**	2012
M (natural mortality)	0.38	0.38	**0.38**	0.38
Specified/recommended Tier	3a	3a	**3a**	3a
Projected biomass (ages 3+)	701,200	684,200	**428,000**	401,300
Female spawning biomass (t)				
Projected	117,600	148,100	**124,100**	111,900
$B_{100\%}$	291,500	291,500	**256,300**	256,300
$B_{40\%}$	116,600	116,600	**102,500**	102,500
$B_{35\%}$	102,000	102,000	**89,700**	89,700
F_{OFL}	0.60	0.60	**0.51**	0.51
$maxF_{ABC}$	0.49	0.49	**0.42**	0.42
Specified/recommended F_{ABC}	0.49	0.49	**0.42**	0.42
Specified/recommended OFL (t)	94,100	116,700	**102,600**	92,300
Specified/recommended ABC (t)	79,100	97,900	**86,800**	78,200
Is the stock being subjected to overfishing?	No	n/a	**No**	n/a
Is the stock currently overfished?	No	No	**No**	No
Is the stock approaching a condition of being overfished?	No	n/a	**No**	n/a

Responses to Comments from the Plan Teams and SSC

A total of 23 comments specific to the Pacific cod assessments from the November, 2009 meetings of the BSAI Plan Team (1 comment) and the GOA Plan Team (2 comments); the December, 2009 meeting of the SSC (7 comments); the May, 2010 meeting of the Joint Plan Teams (11 comments); and the June, 2010 meeting of the SSC (2 comments) were previously addressed in the preliminary assessment (included here as Attachment 2.1). In the interest of efficiency, these comments and responses are not repeated in this section. Joint Plan Team and SSC comments from the September, 2010 and October, 2010 meetings, respectively, are addressed below, followed by a single comment on GOA assessments in general from the December, 2009 meeting of the SSC.

Joint Plan Team Comments

JPT1 (09/10 minutes): *"Do not iterate to obtain estimates for penalties associated with dev vectors (see also next paragraph* [Comment JPT5] *below)."* See response to Comment JPT5.

JPT2 (09/10 minutes): *"Use finer (1-cm vs. 3 to 5-cm) length bins and seasons (5 rather than 3) as done for Models 2-6."* Models B and C exhibit the requested characteristics. However, Model A, which was requested by the SSC (see Comment SSC1), does not.

JPT3 (09/10 minutes): *"Continue to apply the catchability values (Q) derived by Dan Nichol (based on archival tag data on Pacific cod depth distribution)."* The trawl survey catchability coefficient (for the post-1993 portion of the time series) in last year's preferred model was tuned iteratively so that the weighted average product of selectivity and catchability across the 60-81 cm size range matched the results of the study by Nichol et al. (2007). The value obtained in last year's preferred model was retained for all three models in this final assessment (see also response to Comment JPT5).

JPT4 (09/10 minutes): *"Use constant growth rather than annually-varying or cohort-specific growth."* Models B and C exhibit the requested characteristic. However, Model A, which was requested by the SSC (see Comment SSC1), does not.

JPT5 (09/10 minutes): *"Several quantities have traditionally been estimated iteratively in the Pacific cod assessments, for example, the catchability coefficient and the input standard deviations for all deviation* *("dev") vectors. To make the process of tuning the models less cumbersome, the Teams encouraged the authors to consider external weighting (i.e., setting such quantities on the basis of common sense) or one-time reweighting of likelihood components."* A total of seven quantities were estimated iteratively in last year's preferred model:

1. ageing error bias (assumed constant across ages 2-20; units = years)
2. input standard deviation of length at length-at-age-0 (units = cm)
3. input standard deviation of length at length-at-age-20 (units = cm)
4. input standard deviation for cohort-specific growth devs (lognormal, multiplicative)
5. input standard deviation for log recruitment devs (normal, additive)
6. number of pre-1977 recruitment devs to estimate (1977 = model start year)
7. catchability for 27-plus trawl survey (assumed constant since 1996)

To make sure that comment JPT5 was not misinterpreted by the assessment authors, ten Plan Team members with experience in developing age-structured models were invited to provide advice on how this comment should be applied. Four responses were received. None of the responses contained any suggestions as to how any of the quantities listed above could be estimated by one-time reweighting of likelihood components. However, several suggestions, sometimes with multiple options, were offered regarding "common sense" methods of setting one or more of the quantities listed above. Of these, the only option mentioned in a majority of the responses was to keep all of the quantities fixed at last year's values, the rationale being that this would facilitate comparison of models across years. Based on majority opinion, this approach was adopted for all models in the final assessment. See also Comment SSC3.

JPT6 (09/10 minutes): *"Prior to the 2009 assessment, constant growth was assumed in the model. Cohort-specific growth was estimated in the 2009 model and Models 1-5 and annually varying growth was tested in Model 6. The Plan Team recommends returning to a constant growth assumption for this year's assessment until there is evidence for either time-varying or cohort-specific growth in the Pacific cod age or length data."* See response to Comment JPT4.

JPT7 (09/10 minutes): *"The Team recommended that the author prepare two models for November, with these features: one with, and one without, age data, along the lines of Model 2 and Model 4."* Models B and C correspond to this request.

SSC Comments

SSC1 (10/10 minutes): *"The SSC agrees with the GPTs recommendations to bring forward models 2 and 4 in November, but to modify the models to include constant growth over time. However, the SSC requests that the authors include results from the previously approved Model 1 (last year's model) for comparison. Models 5 and 6 appear to either overfit the data and/or resulted in unreasonable estimates of the standard deviation of length-at-age."* Models B and C correspond to the request in the first sentence of this comment, and Model A corresponds to the request in the second sentence.

SSC2 (10/10 minutes): *"The SSC agreed with the use of the 1 cm bin structure, but had concerns about possible artifacts arising from the large number of length bin / year / season combinations and the likely presence of a large number of zero entries. Therefore, we recommend that the authors explore an intermediate bin size in next year's assessment that results in fewer zeros and faster run times."* As requested, this suggestion will be considered next year. For now, however, it may be noted that the extremely long run times experienced during the preliminary assessment (several hours) did not arise during the final assessment, presumably due to the omission of cohort-specific growth rates from the two models using the more complicated bin and seasonal structures (Models B and C).

SSC3 (10/10 minutes): *"With respect to iterative estimation of input standard deviations (for 'deviation vectors') and other quantities, the SSC recommends that the author use his judgment in determining a* *reasonable approach for setting these quantities."* The authors' judgment is that keeping the quantities listed in the response to Comment JPT5 fixed at last year's values is a prudent course of action given Comment JPT5 and subsequent clarification thereof by Plan Team members.

SSC4 (10/10 minutes): *"The SSCs recommends that an examination of maturity-at-length (instead of maturity-at-age) in the 'age-free' models, as suggested in public comments, would be appropriate but should be deferred to next year."* This comment may reflect poor communication on the part of the authors in presenting the preliminary assessment. Models 4-5 in the preliminary assessment already included use of length rather than age as the basis of the maturity schedule. The issue raised in the preliminary assessment was whether the estimate of the natural mortality rate, which is presently based on Jensen's (1996) Equation 7, should be revised in models which do not use age data and which describe maturity as a function of length (by using the age corresponding to the length at the inflection of the length-based maturity schedule, rather than the age at the inflection of the age-based maturity schedule). Model C in the final assessment, which is based on Model 4 in the preliminary assessment, continues to use length as the basis of the maturity schedule.

SSC Comments on GOA Assessments in General

SSC5 (12/09 minutes): *"The methods for area apportionment of the ABC that are used in the specific chapters are different from those given in the general introductory material to the SAFE on page 4. The SSC suggests that the table be updated. Also, a different number of years are used for various species (e.g., 5 years for Sablefish, 4 years for pollock, 3 surveys, most recent survey). SSC members recall extensive discussions about these issues but the rationale for the decision is not given in the SAFE chapters. The SSC suggests that description of the apportionment rationale in each SAFE chapter of area-apportioned species would be helpful to the reader."* For many years, the GOA Plan Team has based its recommendation for allocating the Pacific cod ABC on the average of the three most recent trawl surveys. The original rationale for this choice of methods is unknown. In the 2004 BSAI and GOA Pacific cod assessments (Thompson and Dorn 2004, Thompson et al. 2004), a wide range of alternative allocation algorithms was analyzed, such as different numbers of years to include in the time series, various exponential weighting systems, unweighted systems, and a simple Kalman filter. For the BSAI Pacific cod stock, this analysis prompted the SSC to adopt the simple Kalman filter approach. For the GOA Pacific cod stock, however, the Plan Team concluded that the traditional approach was satisfactory.

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 1991-2010 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, 2009. Figures 2.1d-2.1e show the corresponding information for January-May and June-August, 2010 (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), overfishing level (OFL, 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. 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 (between 15% and 25%) ABC in each of those years. Thus, while the combined Federal and State catch has exceeded the Federal TAC in all but three years since 1997, the overall target catch (Federal TAC plus State GHL) was not exceeded. At no time since the separate State waters fishery began in 1997 has total catch exceeded ABC, and total catch has never exceeded OFL.

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. Assessments conducted prior to 1988 were based on survey biomass alone. From 1988-1993, the assessment was based on stock reduction analysis (Kimura et al. 1984). From 1994-2004, the assessment was conducted using the Stock Synthesis 1 modeling software (Methot 1986, 1990) with length-based data. The assessment was migrated to Stock Synthesis 2 in 2005 (Methot 2005), at which time age-based data began to enter the assessment. Several changes have been made to the model within the SS2 framework (renamed "Stock Synthesis," without a numeric modifier, in 2008) each year since then.

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 2005-2010 in Table 2.4c (2010 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 for the period 1977-2010 are shown for the three main gear types and two different seasonal configurations in Tables 2.5a and 2.5b. The seasons used in Table 2.5a are January-May, June-August, and September-December. This particular division, which was suggested in the early 1990s by fishery participants, was intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning period may be different than at other times of year), and is used by Model A in the present assessment.

Table 2.5b makes use of two different types of season: catch seasons and selectivity seasons. The catch seasons are defined as January-February, March-April, May-August, September-October, and November-December. Three selectivity seasons are defined by combining catch seasons 1 and 2 into selectivity season 1, equating catch season 3 with selectivity season 2, and combining catch seasons 4 and 5 into selectivity season 3. The catch seasons used in Table 2.5b were the result of a statistical analysis described in this year's preliminary assessment (see Attachment 2.1), and the selectivity seasons were chosen to correspond as closely as possible to the traditional seasons used in Table 2.5a given the revised catch seasons. This seasonal structure is used by Models B and C in the present assessment.

In years for which estimates of the distribution by gear or period were not available, proxies based on other years' distributions were used to create Tables 2.5a and 2.5b. Catches for the years 1977-1980 may or may not include discards.

Catch Per Unit Effort

Fishery catch per unit effort data are available by gear and season for the years 1991-2010 and are shown in Table 2.5c for the seasonal structure used by Model A and Table 2.5d for the seasonal structure used by Models B and C. Units are kg/minute for trawl gear, kg/hook for longline gear, and kg/pot for pot gear; data for 2010 are partial. The "sigma" values shown in the tables are intended only to give an idea of the relative variability of the respective point estimates, and are not actually used in any of the analyses presented here.

Catch Size Composition

Fishery size compositions are presently available, by gear, for at least one gear type in every year from 1977 through the first part of 2010. For ease of representation and analysis, length frequency data for Pacific cod have traditionally been 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
Low. 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. These are the size composition data used by Model A. Models B and C use a finer scale consisting of 1-cm bins ranging from 4 to 120 cm. Because displaying these data would add approximately 40 pages to the present document, they are not shown here but are available on request by contacting the senior author.

Fishery Age Composition Data

The 2008 assessment marked the first time that fishery age composition data were used since production ageing of Pacific cod resumed several years ago (Roberson 2001, Roberson et al. 2005). Specifically, the estimate of age composition from the 2008 January-May longline fishery shown in Table 2.10a was used. These data continue to be used in Model A in the present assessment, but not in Models B or C.

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 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 was 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 were 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 was the product of the likelihoods for each of the model components. In part because the overall likelihood could be a very small number, SS1 used the logarithm of the likelihood as the objective function. Each likelihood component was 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 were associated with data sets such as catch size (or age) composition, survey size (or age) composition, and survey abundance (either biomass or numbers, either relative or absolute).

SS1 permitted 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 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.

The 2009 assessment (Thompson et al. 2009) featured a total of ten models reflecting a great many alternative assumptions and use or non-use of certain data, particularly age composition data. Relative to the 2008 assessment, the main changes in the model accepted by the Plan Team and SSC were as follow: 1) input standard deviations of all "dev" vectors were set iteratively by matching the standard deviations of the set of estimated "devs;" 2) the standard deviation of length at age was estimated outside the model as a linear function of mean length at age; 3) catchability for the pre-1996 trawl survey was estimated freely while catchability for the post-1993 trawl survey 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); 4) 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, resulting in a positive bias of 0.4 years for these ages (age-specific bias values were also examined, but did not improve the fit significantly); 5) weighting of the age composition data was returned to its traditional level; 6) 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 most recent; and 7) cohort-specific growth devs were estimated for all years through 2008.

Model Structures Considered in This Year's Assessment

Many changes have been made or considered in the stock assessment model since the 2009 assessment (Thompson et al. 2009). Five models were presented in this year's preliminary assessment (Attachment 2.1). The relationships between the five models presented in the preliminary assessment are summarized in Table 2.1.1 of Attachment 2.1. The set of five models in the preliminary assessment was requested by the Plan Teams in May of this year, with subsequent concurrence (given two minor modifications) by the SSC in June. Following review in September and October, three of these models, or modifications thereof, were requested by the Plan Teams or SSC to be included in the final assessment.

Model 1 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 without modification for inclusion in the final assessment, where it is labeled Model A.

Model 2 in the preliminary assessment included three changes in data or data structure: 1) exclude the single record (each) of fishery age composition and mean length-at-age data, 2) use a finer length bin structure than previous models, and 3) re-evaluate the existing seasonal structure used in the model and revise it as appropriate. The length bin structure adopted in Model 2 consisted of 1-cm bins, replacing the combination of 3-cm and 5-cm bins used in previous assessments. The seasonal structure adopted in Model 2 consisted of five catch seasons defined as January-February, March-April, May-August, September-October, and November-December; and three selectivity seasons defined as January-April, May-August, and September-December; with spawning identified as occurring at the beginning of the second catch season (March).

Model 4 in the preliminary assessment included all of the changes in Model 2, plus disuse of all mean length-at-age data and all age composition data, and a change from age-based to length-based maturity.

The Plan Teams and SSC requested that modified forms of preliminary Models 2 and 4 be included in the final assessment. The requested modification in each case was removal of cohort-specific growth rates (this feature was new in last year's assessment). The modified Models 2 and 4 from the preliminary assessment are labeled here as Models B and C, respectively.

Version 3.11b of Stock Synthesis (SS) was used to run all the models in the preliminary assessment and in the final assessment up until the very last stages of the analysis, at which point version 3.11c was used. The most recent user manual is for version 3.11a (Methot 2010).

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 set *M* independently at the SSC-approved value of 0.38.

Catchability

In the 2009 assessment (Thompson et al. 2009), catchability for the post-1993 27-plus trawl survey was estimated iteratively by matching 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). The resulting value of 1.04 was retained for all models in the present assessment.

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 last recomputed in the 2009 assessment (Thompson et al. 2009), 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). This regression was retained for all models in the present assessment.

Variability in Length at First Survey Age

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), the 2009 assessment used a regression approach to extrapolate the parameters of the schedule of variability in length at age, based on the outside-the-model estimates of standard deviation of length at age from the survey age data (Thompson et al. 2009). 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). The resulting standard deviations were 1.87 (for length at age 0) and 6.53 (for length at age 20). These values were retained for all models in the present assessment.

Weight at Length

Weight-at-length parameters specific to each of the three seasons used in Model A were estimated in the 2008 assessment (Thompson et al. 2008). These were determined from all weight-length records present in the observer database (both shore-based and at-sea samples) as of the 2008 assessment, giving the following values:

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

In the 2008 assessment, the seasonal model gave a statistically significant improvement (AIC = 67,829 for the annual model; AIC = 66,978 for the seasonal model).

For Models B and C, new season-specific parameters were computed from the same data set in order to comply with the new seasonal structure of those models, giving the following values:

Season:	Jan-Feb	Mar-Apr	May-Aug	Sep-Oct	Nov-Dec
α:	8.799×10^{-6}	8.013×10^{-6}	1.147×10^{-5}	1.791×10^{-5}	7.196×10^{-6}
β:	3.084	3.088	2.990	2.893	3.120
Samples:	36,566	29,753	6,950	9,352	2,957

The weight-length parameters for the new seasonal structure give a better (lower) AIC than the weight-length parameters for the old seasonal structure.

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). In the present assessment, Models A and B use the age-based schedule and Model C uses the length-based schedule.

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 (i.e., within individual SS runs, based on the data and the parameters estimated independently) in all models include the von Bertalanffy growth parameters, log mean recruitment, annual recruitment deviations, initial fishing mortality, gear-season-and-block-specific fishery selectivity parameters, survey selectivity parameters (a unique value for each survey year except 2009), catchability for the pre-1996 27-plus trawl survey (constant), and catchability for the sub-27 trawl survey (a unique value for each survey year except 2009). In addition, Model A estimates cohort-specific deviations in growth rates.

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.

Fishery selectivities are length-based and trawl survey selectivities are age-based in all models considered in this assessment.

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 in the 2009 assessment (Thompson et al. 2009) by matching the standard deviations of the estimated devs. The same input standard deviations were used in all models in the present assessment.

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 three models included likelihood components for trawl survey relative abundance, fishery and survey size composition, recruitment, parameter deviations, and "softbounds" (equivalent to an extremely weak prior distribution used to keep parameters from hitting bounds), and initial (equilibrium) catch. In addition, Models A and B included likelihood components for age composition and mean size at age.

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 given an emphasis of 1.0 in the present assessment.

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 input sample sizes for size composition data in all GOA assessments since 2007 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, all sample sizes were adjusted proportionally so that the average was 300. For this year's assessment, the resulting set of multinomial sample sizes is shown in Tables 2.12a (Model A) and 2.12b (Models B and C).

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. Input sample sizes for the multinomial distributions were computed by scaling the actual number of otoliths read in each year proportionally such that the average of the input sample sizes was equal to 300.

To avoid double counting of the same data, Models A and B ignore size composition data from each gear/year/season combination in which age composition data are available. Model C, which ignores the age composition data, uses 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).

RESULTS

Model Evaluation

As described above, three 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. If a better solution was found, the process was repeated.

Comparing and Contrasting the Models

Tables 2.13-2.19 and Figures 2.2-2.9 present summaries of some key results from the ten models.

Tables 2.13-2.15 pertain to statistical goodness of fit.

Table 2.13 shows negative log-likelihoods and numbers of parameters for each of the three models. It should be emphasized that, although the negative log-likelihood values for the three models are displayed next to one another, they are not strictly comparable, because the data sets are different for every model. The first part of Table 2.13 shows negative log-likelihoods for the aggregate data components. The second part shows the number of parameters. Model A has 282 parameters, while Models B and C (which do not estimate cohort-specific growth *dev*s) have 250. The third part breaks down the CPUE and size composition components into fleet-specific values. For the CPUE component, the fishery values are shown for completeness, but only the trawl survey values count toward the total negative log-likelihood. The final part of Table 2.13 breaks down the age composition and mean size at age components into fleet-specific values. The season 1 longline fishery age composition data and mean size at age components are not included in the data for Models B and C, so no values are reported for those two models.

Table 2.14 provides two alternative measures of how well the models are fitting the fishery CPUE and survey relative abundance data: root mean squared errors (lower values are better) and correlations between observed and estimated values (higher values are better). Note that none of the models actually attempts to fit the fishery CPUE data; these results are shown for information only. Most important are the two rows for the trawl survey. For the 27-plus survey, Model C has the lowest RMSE (0.29) and Model B has the highest (0.39), while Model A has the highest correlation (0.62) and Model B has the lowest (0.40). For the sub-27 survey, Model A has the lowest RMSE (0.51) and Model B has the highest (0.73), while Model again has the highest correlation (0.55) and Model B again has the lowest (0.41).

Figures 2.2a and 2.2b show the fits of the three models to the 27-plus and sub-27 trawl survey abundance data, respectively. All models stay within the 95% confidence intervals for most years, although none of the models come close to matching the large increases observed in both portions of the survey in 2009 (paradoxically, all three models estimate *decreases* for the sub-27 survey in 2009).

Table 2.15a shows the average of the ratio and the ratio of the average between output "effective" sample size (McAllister and Ianelli 1997) and input sample size for the 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. Models B and C tend to do better by this measure than Model A, but it should be remembered that, because of the finer seasonal structure used by Models B and C, they have many more records of size composition data than Model A and, because the average input sample size is constrained to equal 300 for both data sets, the overall emphasis (number of records × average input sample size) on size composition data is much greater for Models B and C than Model A.

Table 2.15b 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 the overall average of ratios and ratio of averages for the 27-plus trawl survey age compositions. In general, Model B tends to better here than Model A, and both Models A and B do much better than Model C, which does not attempt to fit these data at all. The three models' fits to the age composition data from the 27-plus survey are shown in Figures 2.3a, 2.3b, and 2.3c, respectively; and their fits to the age composition data from the sub-27 survey are shown in Figures 2.3d, 2.3e, and 2.3f, respectively. Figure 2.4 shows Model A's fit to the single record of fishery age composition data (Models B and C do not include this record).

Table 2.16 displays all of the quantities listed in the "parameters" section of the SS report file, including quantities whose values are set externally. Each quantity that is estimated internally is given a parameter number ("par. no."); and the phase in which it is estimated, its value, and its standard deviation are reported. For quantities estimated externally, values are reported, but the other columns are not applicable. A blank row for a given quantity/model combination indicates that the given quantity is not used by that model. Most labels are either fairly straightforward to interpret or probably correspond to quantities that are not essential to understanding the analysis. It should be noted that the post-1976 recruitment mean *R0* and all catchability coefficients are reported on natural log scales and that the *R1 offset* parameter describes the log ratio of the recruitment means before and after the 1976-1977 regime shift. Labels for selectivity parameters include the fleet number (e.g., in the order given in Table 2.13) followed by a "P," then the parameter number (see "Parameters Estimated Conditionally"). Note that many selectivity parameters get overwritten by other selectivity parameters specific to blocks of years (the labels for these end in "*block* YEAR," where YEAR is the first year in the block).

Tables 2.17a, 2.17b, and 2.17c show estimates of full-selection fishing mortality rates for Models A, B, and C, respectively (note that these are not counted as parameters in SS).

Figure 2.5 shows the time series of recruitment devs as estimated by the three models. Models A and B show some synchrony, with a correlation of 0.45. Models A and C are slightly less similar, with a correlation of 0.37, and Models B and C are negatively correlated (-0.11).

Figure 2.6 shows the time series of spawning biomass relative to $B_{35\%}$ as estimated by the three models (the year coordinates of the three time series have been offset from one another slightly in order to reduce overplotting). Model C has the highest ratio throughout the time series and Model A tends to have the lowest, although Models A and B are very close by 2010. The ratios estimated by Model C are truly immense in the early part of the time series, implying that spawning biomass was five times $B_{35\%}$ for the better part of the first decade.

Figure 2.7 shows the time series of total (age 0+) biomass as estimated by the three models, with the trawl survey biomass estimates included for comparison. Model C estimates the highest biomass, by far, throughout all of the time series, while Models A and B are much closer to one another than to Model C. The biomass estimates obtained by Models A and B are roughly comparable to the biomass estimates from the survey, consistent with the catchability of 1.04 assumed for the post-1993 portion of the 27-plus survey. The biomass estimates obtained by Model C exceed the survey point estimates by a factor of 2.5 on average from 1984 through 2007, and they intersect the upper 95% confidence interval from the survey in 2009 only, where the survey point estimate is extremely high and the 95% confidence interval is extremely wide.

Figure 2.8 shows 27-plus trawl survey selectivity as estimated by the three models. The red line in each figure corresponds to 2007. Selectivity for 2009 is held constant at the 2007 level to avoid confounding the ascending slope with incoming recruitment. In general, the survey selectivity schedules estimated by Model C tend to reach unity at an older age (typically about age 6) than Models A and B (typically about ages 4-5).

Figures 2.9a, 2.9b, and 2.9c show fishery selectivity as estimated by all three models. Visually, there does not appear to be a great deal of difference between the curves estimated by the various models. In general, selectivities that are not forced to be asymptotic tend to show decreasing selectivity at large size.

Table 2.18 shows how estimated size (cm) at age 1 under each of the models compares with the observed values from the trawl survey for the years in which data are available. Model A is the only model that does not assume constant growth, and it succeeds in producing a positive correlation between observed and expected values, although the root-mean-squared-errors are about the same for all three models (Model C does slightly better than the other two). Model B estimates an age 1 size that appears to be about 2 cm high on average (assuming that the age data are correct), which may be the result of the assumed ageing bias. Model C estimates an age 1 size that is very close to the observed average.

Because the catchability coefficient for the post-1993 portion of the 27-plus trawl survey was held constant for all models at the value estimated in the 2009 assessment (1.04), it may be wondered how well this value continues to achieve the intended result of matching the value of 0.92 obtained by Nichol et al. (2007) for the weighted average of the product of trawl survey catchability and selectivity across the 60-81 cm size range. This weighted average product was computed for each year in the period 1996-2010, which resulted in the following statistics:

Statistic	Model A	Model B	Model C
Average:	0.96	0.91	0.87
Minimum:	0.82	0.83	0.78
Maximum:	1.04	1.01	0.98
Standard deviation:	0.08	0.07	0.06
Coefficient of variation:	0.08	0.08	0.07

Model B comes closest to achieving the desired average of 0.92, while Model A is a bit high and Model C is a bit low.

Table 2.19 contains selected output from the standard projection model, based on SS parameter estimates from the three models, along with the probability that the stock will fall below $B_{20\%}$ in each of the next five years (these probabilities are given by SS rather than the standard projection model). Model B tends to produce the lowest values of all quantities, and Model C the highest (except for relative spawning biomass in 2012, where Model A gives the highest value). All three models agree that the probability of spawning biomass falling below $B_{20\%}$ within the next five years is negligible.

Evaluation Criteria

The following criteria were used to select the final model:

1. Does the model make full use of the information in the size composition data?
2. Has the seasonal structure of the model been justified statistically?
3. Is the model sufficiently parsimonious?
4. Does the model estimate plausible estimates of biomass?

Selection of Final Model

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

1. The raw size composition data are expressed in 1-cm intervals. It is possible that some amount of binning would not diminish the information content of the raw data, but the acceptable amount of binning has yet to be determined. All else being equal, the 1-cm intervals used in Models B and C guard against loss of information content.
2. The seasonal structure used in Model A has been a consistent feature of the Pacific cod assessment for over 15 years. However, its original rationale was never made explicit, and the statistical analysis conducted in this year's preliminary assessment indicated that the seasonal structure used in Models B and C is superior in terms of defining seasons within which the fishing mortality is relatively constant. On the other hand, it should be acknowledged that the optimality of combining some of the five new catch seasons to yield three selectivity seasons has not been evaluated.
3. Model A, with cohort-specific growth *dev*s, has 32 more parameters than Models B or C. At their September meeting, the Plan Teams expressed a preference for models with constant growth.
4. Models A and B give estimates of total biomass on the same order as the estimates produced by the survey. Model C, on the other hand, produces estimates of total biomass that are higher on average by a factor of about 2.5 from 1984 through 2007, with a biomass in the late 1970s exceeding 2 million t. Models A and B indicate that the ratio of spawning biomass to $B_{35\%}$ has ranged from slightly less than 1 to as high as 2 or 3, while Model C indicates that this ratio was above 5 for several years in the late 1970s and early 1980s. If the biomass of Pacific cod were truly enormous during the late 1970s, it seems likely that the fishery would have expanded much more rapidly than it did.

On the basis of the above, Model B is selected as the final model.

Final Parameter Estimates and Associated Schedules

As noted previously, estimates of all statistically estimated parameters in Model B are shown in Table 2.16. Estimates of year-, gear-, and season-specific fishing mortality rates from Model B are shown in Table 2.17b.

Schedules of selectivity at length for the commercial fisheries from Model B are shown in Table 2.20a, and schedules of selectivity at age for the trawl surveys from Model B are shown in Table 2.20b. The 27-plus trawl survey schedule and all fishery selectivity schedules for Model B are plotted in Figures 2.8 and 2.9b, respectively.

Schedules of length at age and weight at age for the population, length at age for each gear-and-season-specific fishery and each survey, and weight at age for each gear-and-season-specific fishery and each survey from Model B are shown in Tables 2.21, and 2.22a, and 2.22b, respectively.

Time Series Results

Note: Because the preferred model differs substantively from last year's model (Model A), the tables and figures referenced in this section are reproduced using Model A 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. To supplement the full-selection fishing mortality rates already shown in Table 2.17b, an alternative "effective" fishing mortality rate will be provided here, defined for each age and time by $-\ln(N_{a+1,t+1}/N_{a,t})-M$, where N = number of fish, a = age measured in years, t = time measured in years, and M = instantaneous natural mortality rate. In addition, the ratio of full-selection fishing mortality to $F_{35\%}$ will be provided.

Biomass

Table 2.23a shows the time series of Pacific cod age 0+ and female spawning biomass for the years 1977-2011 as estimated last year and this year under Model B. 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 B are shown, together with the observed time series of trawl survey biomass (assuming a catchability of 1.0), in Figure 2.10. 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 2.23b 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 B. Both estimated time series are accompanied by their respective standard deviations. For the time series as a whole, the largest year class appears to have been the 1977 cohort. The 2005 year class currently ranks second. However, it should be noted that, of the nine cohorts produced immediately prior to 2005, only one (2000) was above average. The 2006 year class, while still estimated to be above average, does not appear to be as strong as estimated in last year's assessment. The strengths of the 2007 and 2008 cohorts have been downgraded considerably since last year's assessment.

Model B's recruitment estimates for the entire time series (1977-2008) are shown in Figure 2.11, along with their respective 95% confidence intervals. 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 B is shown in Table 2.23c.

Fishing Mortality

Table 2.24 shows "effective" fishing mortality by age and year for ages 1-19 and years 1977-2010.

Figure 2.12 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2010 based on Model B, 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 2.12 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 (Model A), the tables referenced in this section are reproduced using Model A 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:	89,700 t	102,500 t	256,300 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 B's estimates of fishing mortality by gear for the five most recent complete years of data (2005-2009). 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 25%, longline 23%, and pot 52%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.51 and 0.42, respectively.

Specification of OFL and Maximum Permissible ABC

Spawning biomass for 2011 is estimated by Model B, using the standard projection model, at a value of 124,100 t. This is well above the $B_{40\%}$ value of 102,500 t, thereby placing Pacific cod in sub-tier "a" of Tier 3. Given this, Model B estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2011 and 2012 as follows (2012 values are predicated on the assumption that 2011 catch will equal 2011 maximum permissible ABC):

Year	Overfishing Level	Maximum Permissible ABC
2011	102,600 t	86,800 t
2012	92,300 t	78,200 t
2011	0.56	0.42
2012	0.56	0.42

The age 0+ biomass projections for 2010 and 2011 from Model B (using SS) are 471,000 t and 444,000 t.

For comparison, the age 3+ projections for 2010 and 2011 from Model B (using SS) are 428,000 t and 401,000 t.

ABC Recommendation

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.

In 2009, the GOA Plan Team and SSC recommended setting the 2010 and 2011 ABCs at the maximum permissible levels (79,100 t and 97,900 t, respectively).

Following recent practice, this year's ABC recommendations for 2011 and 2012 are at their respective maximum permissible levels of 86,800 t and 78,200 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. From the 2005, 2007, and 2009 surveys, the averages of the area-specific proportions are 39% Western, 57% Central, and 4% Eastern; the proportions of the average area-specific biomasses are 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 2011 numbers at age. 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 TACs for 2011 and 2012, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

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

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2011 recommended in the assessment to the *max* F_{ABC} for 2011. (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 2005-2009 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 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 2010 or 2) above 1/2 of its MSY level in 2010 and above its MSY level in 2020 under this scenario, then the stock is not overfished.)

Scenario 7: In 2011 and 2012, 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 2023 under this scenario, then the stock is not approaching an overfished condition.)

Projections and Status Determination

Projections corresponding to the standard scenarios are shown for Model B in Tables 2.25-2.30 (Scenarios 1 and 2 are the same in this assessment, because the recommended ABC is equal to the maximum permissible ABC).

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 2011, it does not provide the best estimate of OFL for 2012, because the mean 2012 catch under Scenario 6 is predicated on the 2011 catch being equal to the 2011 OFL, whereas the actual 2011 catch will likely be less than the 2011 OFL. Table 2.19 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.

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 (2009) is 52,922 t. This is less than the 2009 OFL of 66,000 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 2010 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2010 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2010 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 2.29). If the mean spawning biomass for 2020 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 2013 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2013 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2013 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2023. If the mean spawning biomass for 2023 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 2.29 and 2.30, 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 in each year 2003-2010 are shown in Table 2.31.

It is not clear how much bycatch of a particular species constitutes "too much" in the context of ecosystem concerns. No species group accounts for an average of more than 1,000 t of discards over the 2003-2010 period. The only species groups accounting for an average of more than 100 t of discards are "other" skates (696 t), sea star (630 t), big skate (508 t), large sculpins (427 t), octopus (230 t), longnose skate (220 t), miscellaneous fish (186 t), and spiny dogfish (118 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) ecology of the Pacific cod stock, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment; 2) behavior of the Pacific cod fishery, including spatial dynamics; 3) determinants of trawl survey catchability and selectivity; 4) age determination; 5) ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and 6) ecology of species that interact with Pacific cod, including estimation of biomass, carrying capacity, and resilience.

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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 2010 are complete through October 13.

	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	18,474	9,470	12,675	572	41,191	115	8,031	3,242	11,388	52,579
2004	17,089	10,380	14,965	824	43,258	0	10,602	2,765	13,367	56,625
2005	14,137	5,758	14,749	616	35,260	0	9,653	2,673	12,326	47,585
2006	12,448	10,274	14,795	801	38,319	0	8,890	646	9,536	47,854
2007	14,370	11,677	13,515	443	40,004	0	10,885	573	11,458	51,462
2008	19,930	12,366	11,220	442	43,957	0	13,438	1,568	15,005	58,963
2009	13,618	14,066	11,576	559	39,820	312	10,293	2,497	13,102	52,922
2010	19,401	16,253	20,135	1,663	57,452	313	14,316	4,090	18,719	76,171

Table 2.2—History of Pacific cod catch (includes catch from State waters), Federal TAC (does *not* include State guideline harvest level), ABC, OFL, and age 3+ biomass (from the previous year's assessment). ABC was not used in management of GOA groundfish prior to 1986. Catch for 2010 is current through October 13. 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. The ABC value listed for 1987 is the upper bound of the range. Source: NPFMC staff.

Year	Catch	TAC	ABC	OFL	Biomass
1980	35,345	60,000	-	-	-
1981	36,131	70,000	-	-	-
1982	29,465	60,000	-	-	-
1983	36,540	60,000	-	-	-
1984	23,898	60,000	-	-	-
1985	14,428	60,000	136,000	-	-
1986	25,012	75,000	125,000	-	-
1987	32,939	50,000	185,000*	-	-
1988	33,802	80,000	99,000	-	481,700
1989	43,293	71,200	71,200	-	558,700
1990	72,517	90,000	90,000	-	498,044
1991	76,328	77,900	77,900	-	424,100
1992	80,747	63,500	63,500	87,600	363,000
1993	56,488	56,700	56,700	78,100	324,000
1994	47,485	50,400	50,400	71,100	296,000
1995	68,985	69,200	69,200	126,000	573,000
1996	68,280	65,000	65,000	88,000	557,000
1997	77,018	69,115	81,500	180,000	650,000
1998	72,525	66,060	77,900	141,000	785,000
1999	81,785	67,835	84,400	134,000	648,000
2000	66,560	59,800	76,400	102,000	567,000
2001	51,542	52,110	67,800	91,200	526,000
2002	54,483	44,230	57,600	77,100	428,000
2003	52,579	40,540	52,800	70,100	428,000
2004	56,625	48,033	62,810	102,000	484,000
2005	47,585	44,433	58,100	86,200	472,000
2006	47,854	52,264	68,859	95,500	453,000
2007	51,462	52,264	68,859	97,600	375,000
2008	58,963	50,269	64,493	88,660	233,310
2009	52,922	41,807	55,300	66,000	520,000
2010	76,171	59,563	79,100	94,100	701,200

Table 2.3—History of GOA Pacific cod allocations by regulatory area (in percent).

	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
2010 (ABC)	35	62	3
2010 (TAC)	34.86	61.75	3.39

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—Gulf of Alaska Pacific cod discard rates by area, target species/group, and year for the period 2005-2010 (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	2010	Ave.
Arrowtooth Flounder	0.29	0.18	0.07	0.48	0.05	0.28	0.22
Atka Mackerel			0.00				0.00
Deep Water Flatfish	0.00	0.00				0.00	0.00
Flathead Sole	0.12	0.09	0.10	0.16	0.03	0.11	0.10
Halibut	0.28	0.25	0.24	0.16	0.43	0.22	0.26
Other Species	0.06	0.05		0.00	0.00	0.00	0.02
Pacific Cod	0.00	0.03	0.01	0.01	0.01	0.01	0.01
Pollock - bottom	0.00	0.01	0.04	0.04	0.06	0.03	0.03
Pollock - midwater	0.00	0.01	0.00	0.00	0.00	0.01	0.00
Rex Sole	0.12	0.05	0.12	0.04	0.15	0.10	0.10
Rockfish	0.04	0.14	0.02	0.08	0.05	0.05	0.06
Sablefish	0.53	0.28	0.20	0.17	0.29	0.09	0.26
Shallow Water Flatfish	0.39	0.30	0.38	0.60	0.64	0.74	0.51
Unknown			1.00				1.00
Total	0.02	0.04	0.03	0.08	0.09	0.04	0.05

Table 2.5a—Catch of Pacific cod by year, gear, and season for the years 1977-2010 as used in Model A. 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 2010 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	11920	2611	5176	9209	416	784	19330	0	3133
2004	9686	2119	6261	8908	123	2089	22951	0	4488
2005	10294	1846	2990	4117	118	1920	21036	0	5263
2006	10295	1696	951	6297	184	4185	21722	0	2524
2007	10088	1696	2954	7298	261	4351	20715	17	4081
2008	11709	3355	5958	9625	424	2677	20513	0	4702
2009	8663	2218	3757	10331	895	4020	19383	0	3655
2010	12591	2087	6331	12707	366	4808	31734	0	5548

Table 2.5b (p. 1 of 4)—Catch (t) of Pacific cod by year, gear, and season for the years 1977-2010 as configured in Models B and C.

		Trawl fishery			Longline fishery			Pot fishery		
Year	Season	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec
1977	Jan-Feb	73	0	0	377	0	0	0	0	0
1977	Mar-Apr	73	0	0	377	0	0	0	0	0
1977	May-Aug	0	195	0	0	379	0	0	0	0
1977	Sep-Oct	0	0	156	0	0	241	0	0	0
1977	Nov-Dec	0	0	156	0	0	241	0	0	0
1978	Jan-Feb	366	0	0	1888	0	0	0	0	0
1978	Mar-Apr	366	0	0	1888	0	0	0	0	0
1978	May-Aug	0	973	0	0	1894	0	0	0	0
1978	Sep-Oct	0	0	779	0	0	1207	0	0	0
1978	Nov-Dec	0	0	779	0	0	1207	0	0	0
1979	Jan-Feb	425	0	0	2192	0	0	0	0	0
1979	Mar-Apr	425	0	0	2192	0	0	0	0	0
1979	May-Aug	0	1130	0	0	2199	0	0	0	0
1979	Sep-Oct	0	0	905	0	0	1401	0	0	0
1979	Nov-Dec	0	0	905	0	0	1401	0	0	0
1980	Jan-Feb	1106	0	0	5698	0	0	0	0	0
1980	Mar-Apr	1106	0	0	5698	0	0	0	0	0
1980	May-Aug	0	2937	0	0	5717	0	0	0	0
1980	Sep-Oct	0	0	2351	0	0	3641	0	0	0
1980	Nov-Dec	0	0	2351	0	0	3641	0	0	0
1981	Jan-Feb	155	0	0	4202	0	0	0	0	0
1981	Mar-Apr	155	0	0	4202	0	0	0	0	0
1981	May-Aug	0	3609	0	0	7413	0	0	0	0
1981	Sep-Oct	0	0	3283	0	0	4828	0	0	0
1981	Nov-Dec	0	0	3283	0	0	4828	0	0	0
1982	Jan-Feb	457	0	0	3965	0	0	0	0	0
1982	Mar-Apr	457	0	0	3965	0	0	0	0	0
1982	May-Aug	0	2270	0	0	4872	0	0	0	0
1982	Sep-Oct	0	0	1748	0	0	4933	0	0	0
1982	Nov-Dec	0	0	1748	0	0	4933	0	0	0
1983	Jan-Feb	1144	0	0	4384	0	0	0	0	0
1983	Mar-Apr	1144	0	0	4384	0	0	0	0	0
1983	May-Aug	0	3416	0	0	6843	0	0	0	0
1983	Sep-Oct	0	0	1904	0	0	5573	0	0	0
1983	Nov-Dec	0	0	1904	0	0	5573	0	0	0
1984	Jan-Feb	1372	0	0	4736	0	0	0	0	0
1984	Mar-Apr	1372	0	0	4736	0	0	0	0	0
1984	May-Aug	0	2694	0	0	2793	0	0	0	0
1984	Sep-Oct	0	0	1684	0	0	1290	0	0	0
1984	Nov-Dec	0	0	1684	0	0	1290	0	0	0
1985	Jan-Feb	971	0	0	3651	0	0	0	0	0
1985	Mar-Apr	971	0	0	3651	0	0	0	0	0
1985	May-Aug	0	1056	0	0	1831	0	0	0	0
1985	Sep-Oct	0	0	939	0	0	140	0	0	0
1985	Nov-Dec	0	0	939	0	0	140	0	0	0

Table 2.5b (p. 2 of 4)—Catch (t) of Pacific cod by year, gear, and season for the years 1977-2010 as configured in Models B and C.

		Trawl fishery			Longline fishery			Pot fishery		
Year	Season	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec
1986	Jan-Feb	1200	0	0	6371	0	0	0	0	0
1986	Mar-Apr	1200	0	0	6371	0	0	0	0	0
1986	May-Aug	0	1031	0	0	3645	0	0	0	0
1986	Sep-Oct	0	0	1710	0	0	687	0	0	0
1986	Nov-Dec	0	0	1710	0	0	687	0	0	0
1987	Jan-Feb	2151	0	0	2137	0	0	88	0	0
1987	Mar-Apr	2151	0	0	2137	0	0	88	0	0
1987	May-Aug	0	9003	0	0	2052	0	0	185	0
1987	Sep-Oct	0	0	4591	0	0	968	0	0	141
1987	Nov-Dec	0	0	4591	0	0	968	0	0	141
1988	Jan-Feb	6408	0	0	1192	0	0	432	0	0
1988	Mar-Apr	6408	0	0	1192	0	0	432	0	0
1988	May-Aug	0	9773	0	0	1103	0	0	239	0
1988	Sep-Oct	0	0	2278	0	0	224	0	0	159
1988	Nov-Dec	0	0	2278	0	0	224	0	0	159
1989	Jan-Feb	9846	0	0	951	0	0	96	0	0
1989	Mar-Apr	9846	0	0	951	0	0	96	0	0
1989	May-Aug	0	17780	0	0	832	0	0	151	0
1989	Sep-Oct	0	0	83	0	0	464	0	0	16
1989	Nov-Dec	0	0	83	0	0	464	0	0	16
1990	Jan-Feb	17312	0	0	2223	0	0	1031	0	0
1990	Mar-Apr	17312	0	0	2223	0	0	1031	0	0
1990	May-Aug	0	16170	0	0	1220	0	0	1523	0
1990	Sep-Oct	0	0	4198	0	0	127	0	0	1038
1990	Nov-Dec	0	0	4198	0	0	127	0	0	1038
1991	Jan-Feb	12061	0	0	1289	0	0	2503	0	0
1991	Mar-Apr	43801	0	0	5763	0	0	6910	0	0
1991	May-Aug	0	778	0	0	540	0	0	183	0
1991	Sep-Oct	0	0	1492	0	0	44	0	0	28
1991	Nov-Dec	0	0	1	0	0	28	0	0	906
1992	Jan-Feb	17072	0	0	6058	0	0	2586	0	0
1992	Mar-Apr	34407	0	0	6487	0	0	7112	0	0
1992	May-Aug	0	1828	0	0	966	0	0	19	0
1992	Sep-Oct	0	0	1386	0	0	2168	0	0	470
1992	Nov-Dec	0	0	114	0	0	75	0	0	0
1993	Jan-Feb	9116	0	0	3937	0	0	2936	0	0
1993	Mar-Apr	24521	0	0	4062	0	0	6448	0	0
1993	May-Aug	0	2625	0	0	784	0	0	326	0
1993	Sep-Oct	0	0	734	0	0	134	0	0	0
1993	Nov-Dec	0	0	817	0	0	47	0	0	0
1994	Jan-Feb	10235	0	0	3958	0	0	5213	0	0
1994	Mar-Apr	18915	0	0	2473	0	0	3501	0	0
1994	May-Aug	0	1433	0	0	299	0	0	33	0
1994	Sep-Oct	0	0	852	0	0	50	0	0	5
1994	Nov-Dec	0	0	25	0	0	2	0	0	491
1995	Jan-Feb	5994	0	0	5458	0	0	9033	0	0
1995	Mar-Apr	32204	0	0	5095	0	0	6377	0	0
1995	May-Aug	0	1117	0	0	214	0	0	76	0
1995	Sep-Oct	0	0	2597	0	0	180	0	0	416
1995	Nov-Dec	0	0	0	0	0	47	0	0	176

Table 2.5b (p. 3 of 4)—Catch (t) of Pacific cod by year, gear, and season for the years 1977-2010 as configured in Models B and C.

		Trawl fishery			Longline fishery			Pot fishery		
Year	Season	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec
1996	Jan-Feb	10154	0	0	5880	0	0	7481	0	0
1996	Mar-Apr	30352	0	0	4005	0	0	4544	0	0
1996	May-Aug	0	4023	0	0	215	0	0	27	0
1996	Sep-Oct	0	0	932	0	0	59	0	0	0
1996	Nov-Dec	0	0	562	0	0	47	0	0	0
1997	Jan-Feb	12168	0	0	6707	0	0	8331	0	0
1997	Mar-Apr	28239	0	0	3506	0	0	5080	0	0
1997	May-Aug	0	1970	0	0	390	0	0	2356	0
1997	Sep-Oct	0	0	4862	0	0	261	0	0	917
1997	Nov-Dec	0	0	1182	0	0	118	0	0	931
1998	Jan-Feb	17009	0	0	7786	0	0	11899	0	0
1998	Mar-Apr	17363	0	0	1521	0	0	5753	0	0
1998	May-Aug	0	4014	0	0	444	0	0	2137	0
1998	Sep-Oct	0	0	3200	0	0	183	0	0	568
1998	Nov-Dec	0	0	0	0	0	81	0	0	568
1999	Jan-Feb	14236	0	0	7773	0	0	13883	0	0
1999	Mar-Apr	15886	0	0	4035	0	0	8910	0	0
1999	May-Aug	0	1520	0	0	403	0	0	6859	0
1999	Sep-Oct	0	0	5550	0	0	96	0	0	1940
1999	Nov-Dec	0	0	0	0	0	62	0	0	632
2000	Jan-Feb	13420	0	0	9432	0	0	19229	0	0
2000	Mar-Apr	8159	0	0	1969	0	0	6539	0	0
2000	May-Aug	0	3148	0	0	170	0	0	2938	0
2000	Sep-Oct	0	0	551	0	0	90	0	0	307
2000	Nov-Dec	0	0	199	0	0	17	0	0	392
2001	Jan-Feb	8621	0	0	9234	0	0	6971	0	0
2001	Mar-Apr	5901	0	0	410	0	0	5304	0	0
2001	May-Aug	0	2753	0	0	135	0	0	2885	0
2001	Sep-Oct	0	0	7220	0	0	127	0	0	1106
2001	Nov-Dec	0	0	8	0	0	15	0	0	852
2002	Jan-Feb	7264	0	0	7978	0	0	7490	0	0
2002	Mar-Apr	7202	0	0	3432	0	0	5559	0	0
2002	May-Aug	0	4069	0	0	161	0	0	2288	0
2002	Sep-Oct	0	0	1106	0	0	2070	0	0	2569
2002	Nov-Dec	0	0	203	0	0	1089	0	0	2004
2003	Jan-Feb	8941	0	0	6619	0	0	12827	0	0
2003	Mar-Apr	1739	0	0	2348	0	0	6653	0	0
2003	May-Aug	0	3234	0	0	463	0	0	0	0
2003	Sep-Oct	0	0	5716	0	0	890	0	0	3109
2003	Nov-Dec	0	0	0	0	0	13	0	0	27
2004	Jan-Feb	7923	0	0	8059	0	0	13932	0	0
2004	Mar-Apr	1216	0	0	223	0	0	9462	0	0
2004	May-Aug	0	2284	0	0	241	0	0	278	0
2004	Sep-Oct	0	0	6393	0	0	2119	0	0	3643
2004	Nov-Dec	0	0	0	0	0	10	0	0	843
2005	Jan-Feb	8769	0	0	3629	0	0	12008	0	0
2005	Mar-Apr	790	0	0	222	0	0	9439	0	0
2005	May-Aug	0	1876	0	0	167	0	0	255	0
2005	Sep-Oct	0	0	3247	0	0	1443	0	0	4064
2005	Nov-Dec	0	0	0	0	0	484	0	0	1192

Table 2.5b (p. 4 of 4)—Catch (t) of Pacific cod by year, gear, and season for the years 1977-2010 as configured in Models B and C.

		Trawl fishery			Longline fishery			Pot fishery		
Year	Season	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec
2006	Jan-Feb	8762	0	0	5394	0	0	11988	0	0
2006	Mar-Apr	1214	0	0	773	0	0	9470	0	0
2006	May-Aug	0	1385	0	0	193	0	0	301	0
2006	Sep-Oct	0	0	1643	0	0	2483	0	0	1240
2006	Nov-Dec	0	0	0	0	0	1759	0	0	1250
2007	Jan-Feb	7702	0	0	5619	0	0	9049	0	0
2007	Mar-Apr	1797	0	0	1515	0	0	11090	0	0
2007	May-Aug	0	1763	0	0	357	0	0	564	0
2007	Sep-Oct	0	0	3261	0	0	3315	0	0	2210
2007	Nov-Dec	0	0	288	0	0	1085	0	0	1847
2008	Jan-Feb	9875	0	0	7897	0	0	8575	0	0
2008	Mar-Apr	1222	0	0	1438	0	0	11854	0	0
2008	May-Aug	0	2514	0	0	606	0	0	0	0
2008	Sep-Oct	0	0	6882	0	0	2719	0	0	3429
2008	Nov-Dec	0	0	623	0	0	67	0	0	1261
2009	Jan-Feb	5797	0	0	8708	0	0	10631	0	0
2009	Mar-Apr	974	0	0	895	0	0	8490	0	0
2009	May-Aug	0	3871	0	0	1067	0	0	0	0
2009	Sep-Oct	0	0	4198	0	0	3440	0	0	3172
2009	Nov-Dec	0	0	273	0	0	896	0	0	511
2010	Jan-Feb	9491	0	0	10968	0	0	18981	0	0
2010	Mar-Apr	1039	0	0	821	0	0	12377	0	0
2010	May-Aug	0	4606	0	0	679	0	0	1	0
2010	Sep-Oct	0	0	6671	0	0	4943	0	0	5593
2010	Nov-Dec	0	0	394	0	0	683	0	0	1207

Table 2.5c—Fishery catch per unit effort as configured in Model A. Effort units are kg/minute (trawl), kg/hook (longline), and kg/pot (pot). "Sigma" is a proxy for the log-scale standard error. It was computed by first calculating the reciprocal of the number of hauls associated with each CPUE value, then rescaling such that the average across all records was 0.2. Records with fewer than three distinct vessels are excluded.

	Trawl fishery						Longline fishery						Pot fishery					
	Jan-May		Jun-Aug		Sep-Dec		Jan-May		Jun-Aug		Sep-Dec		Jan-May		Jun-Aug		Sep-Dec	
Year	CPUE	Sigma	CPUE	Sigma	CPUE	Sigma	CPUE	Sigma	CPUE	Sigma	CPUE	Sigma	CPUE	Sigma	CPUE	Sigma	CPUE	Sigma
1991	107.18	0.04	20.51	0.43	63.12	0.38	0.935	0.108	0.479	0.351			53.33	0.06				
1992	67.93	0.04	22.19	0.41	27.81	0.22	0.966	0.067	0.369	0.359	0.543	0.182	55.89	0.06	93.65	0.23	33.14	0.11
1993	78.07	0.06	25.95	0.31	14.85	0.22	0.811	0.097	0.513	0.607			71.11	0.08				
1994	97.17	0.09	29.49	0.35	37.70	0.31	0.733	0.110					61.31	0.08			48.26	0.66
1995	129.89	0.06	24.70	0.36	53.43	0.16	0.910	0.075	0.222	0.568	0.657	0.484	59.60	0.05			57.19	0.28
1996	104.61	0.06	21.64	0.21	24.59	0.25	0.767	0.103					54.53	0.08	80.57	0.51		
1997	67.84	0.06	35.52	0.24	68.64	0.14	0.965	0.141					55.26	0.11			73.88	0.40
1998	60.87	0.06	230.89	0.15	204.47	0.18	0.649	0.192	0.955	0.803			64.87	0.09			58.15	0.19
1999	44.72	0.07	237.30	0.39	209.30	0.25	0.779	0.117	0.444	0.718			66.95	0.09	52.76	0.11	28.89	0.15
2000	44.72	0.09	174.22	0.25	28.62	0.57	0.761	0.143					42.36	0.07				
2001	47.36	0.08	171.22	0.25	51.21	0.12	0.648	0.105					53.03	0.11			46.51	0.13
2002	40.76	0.08	196.63	0.23	38.76	0.36	0.804	0.095			0.708	0.153	50.06	0.13			63.63	0.11
2003	60.71	0.11	152.06	0.20	185.81	0.17	0.794	0.096	0.883	0.415			76.83	0.16			61.88	0.12
2004	62.39	0.13	292.58	0.24	88.72	0.14	0.642	0.124	0.835	0.927	0.388	0.170	68.20	0.13			51.11	0.12
2005	62.19	0.14	99.06	0.33	145.48	0.21	0.631	0.188			0.389	0.237	69.63	0.12			45.22	0.12
2006	45.57	0.15	198.80	0.57	66.73	0.39	0.673	0.130			0.529	0.082	59.38	0.10			43.92	0.13
2007	39.50	0.08	171.68	0.16	57.00	0.15	0.685	0.095			0.587	0.072	53.69	0.07			38.78	0.11
2008	44.42	0.13	192.67	0.21	81.24	0.13	0.529	0.088			0.424	0.206	53.11	0.11			57.87	0.22
2009	92.17	0.14	65.61	0.23	98.30	0.16	0.665	0.084			0.492	0.128	55.50	0.15				
2010	87.54	0.11	110.12	0.27	132.19	0.30	0.726	0.093					75.44	0.16				

Table 2.5d (page 1 of 3)— Fishery CPUE as configured in Models B and C. See Table 2.5c for details.

Jan-Apr trawl fishery				May-Aug trawl fishery				Sep-Dec trawl fishery			
Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma
1991	Jan-Feb	74.23	0.067	1991	May-Aug	19.20	0.354	1991	Sep-Oct	63.12	0.333
1992	Jan-Feb	60.41	0.051	1992	May-Aug	22.19	0.365	1992	Sep-Oct	27.81	0.193
1993	Jan-Feb	43.00	0.100	1993	May-Aug	25.95	0.272	1993	Sep-Oct	15.02	0.272
1994	Jan-Feb	56.35	0.129	1994	May-Aug	29.49	0.309	1994	Sep-Oct	37.70	0.272
1995	Jan-Feb	67.22	0.094	1995	May-Aug	18.59	0.221	1995	Sep-Oct	53.43	0.138
1996	Jan-Feb	52.59	0.088	1996	May-Aug	25.73	0.153	1996	Sep-Oct	23.55	0.263
1997	Jan-Feb	44.17	0.080	1997	May-Aug	30.92	0.189	1997	Sep-Oct	70.38	0.121
1998	Jan-Feb	38.18	0.078	1998	May-Aug	223.12	0.132	1998	Sep-Oct	204.47	0.157
1999	Jan-Feb	45.75	0.083	1999	May-Aug	237.30	0.343	1999	Sep-Oct	209.30	0.218
2000	Jan-Feb	42.16	0.091	2000	May-Aug	147.61	0.200	2001	Sep-Oct	51.21	0.105
2001	Jan-Feb	31.72	0.095	2001	May-Aug	169.12	0.191	2002	Sep-Oct	39.87	0.325
2002	Jan-Feb	37.39	0.101	2002	May-Aug	115.75	0.149	2003	Sep-Oct	185.81	0.151
2003	Jan-Feb	65.48	0.103	2003	May-Aug	147.54	0.167	2004	Sep-Oct	88.72	0.128
2004	Jan-Feb	72.40	0.131	2004	May-Aug	264.53	0.198	2005	Sep-Oct	145.48	0.186
2005	Jan-Feb	71.38	0.139	2005	May-Aug	85.58	0.263	2006	Sep-Oct	66.73	0.343
2006	Jan-Feb	49.07	0.144	2006	May-Aug	176.86	0.472	2007	Sep-Oct	62.05	0.141
2007	Jan-Feb	38.63	0.077	2007	May-Aug	139.79	0.127	2008	Sep-Oct	90.74	0.123
2008	Jan-Feb	32.93	0.127	2008	May-Aug	184.70	0.170	2009	Sep-Oct	101.97	0.147
2009	Jan-Feb	77.79	0.153	2009	May-Aug	111.02	0.167	2010	Sep-Oct	132.19	0.267
2010	Jan-Feb	67.53	0.111	2010	May-Aug	166.42	0.175	1993	Nov-Dec	14.65	0.289
1991	Mar-Apr	122.97	0.046					1996	Nov-Dec	27.31	0.427
1992	Mar-Apr	77.74	0.058					1997	Nov-Dec	21.33	0.633
1993	Mar-Apr	89.45	0.057					2007	Nov-Dec	25.48	0.354
1994	Mar-Apr	119.65	0.096					2008	Nov-Dec	11.60	0.333
1995	Mar-Apr	157.65	0.058					2009	Nov-Dec	49.50	0.535
1996	Mar-Apr	136.50	0.064								
1997	Mar-Apr	86.48	0.068								
1998	Mar-Apr	82.78	0.077								
1999	Mar-Apr	43.69	0.083								
2000	Mar-Apr	54.66	0.159								
2001	Mar-Apr	61.07	0.122								
2002	Mar-Apr	50.05	0.109								
2003	Mar-Apr	30.44	0.233								
2004	Mar-Apr	19.92	0.309								
2005	Mar-Apr	23.24	0.325								
2006	Mar-Apr	19.03	0.427								
2007	Mar-Apr	66.48	0.258								
2008	Mar-Apr	48.35	0.365								
2009	Mar-Apr	37.39	0.283								
2010	Mar-Apr	42.94	0.283								

Table 2.5d (page 2 of 3)— Fishery CPUE as configured in Models B and C. See Table 2.5c for details.

Jan-Apr longline fishery			
Year	Season	CPUE	Sigma
1991	Jan-Feb	0.803	0.183
1992	Jan-Feb	1.099	0.071
1993	Jan-Feb	0.909	0.119
1994	Jan-Feb	0.769	0.161
1995	Jan-Feb	0.871	0.121
1996	Jan-Feb	0.879	0.127
1997	Jan-Feb	0.958	0.132
1998	Jan-Feb	0.639	0.206
1999	Jan-Feb	0.620	0.272
2000	Jan-Feb	0.727	0.134
2001	Jan-Feb	0.647	0.093
2002	Jan-Feb	0.863	0.103
2003	Jan-Feb	0.745	0.117
2004	Jan-Feb	0.648	0.114
2005	Jan-Feb	0.723	0.191
2006	Jan-Feb	0.680	0.121
2007	Jan-Feb	0.724	0.100
2008	Jan-Feb	0.534	0.083
2009	Jan-Feb	0.670	0.075
2010	Jan-Feb	0.735	0.084
1991	Mar-Apr	0.989	0.112
1992	Mar-Apr	0.697	0.104
1993	Mar-Apr	0.750	0.131
1994	Mar-Apr	0.727	0.125
1995	Mar-Apr	0.935	0.079
1996	Mar-Apr	0.667	0.135
1998	Mar-Apr	0.551	0.365
1999	Mar-Apr	0.826	0.113
2000	Mar-Apr	1.112	0.408
2002	Mar-Apr	0.693	0.148
2003	Mar-Apr	0.861	0.125
2004	Mar-Apr	0.415	0.578
2005	Mar-Apr	0.358	0.354
2006	Mar-Apr	0.635	0.392
2007	Mar-Apr	0.592	0.154
2008	Mar-Apr	0.496	0.213
2009	Mar-Apr	0.695	0.535
2010	Mar-Apr	0.638	0.378

May-Aug longline fishery			
Year	Season	CPUE	Sigma
1991	May-Aug	0.472	0.302
1992	May-Aug	0.347	0.289
1993	May-Aug	0.453	0.283
1994	May-Aug	0.451	0.535
1995	May-Aug	0.231	0.408
1996	May-Aug	0.406	0.427
1997	May-Aug	0.656	0.535
1998	May-Aug	0.913	0.408
1999	May-Aug	0.362	0.427
2002	May-Aug	0.625	0.472
2003	May-Aug	0.787	0.325
2004	May-Aug	0.726	0.427
2009	May-Aug	0.306	0.472

Sep-Dec longline fishery			
Year	Season	CPUE	Sigma
1992	Sep-Oct	0.543	0.160
1995	Sep-Oct	0.620	0.500
2002	Sep-Oct	0.664	0.202
2004	Sep-Oct	0.392	0.155
2005	Sep-Oct	0.389	0.209
2006	Sep-Oct	0.505	0.102
2007	Sep-Oct	0.582	0.064
2008	Sep-Oct	0.424	0.181
2009	Sep-Oct	0.491	0.114
2002	Nov-Dec	0.743	0.181
2006	Nov-Dec	0.553	0.102

Table 2.5d (page 3 of 3)— Fishery CPUE as configured in Models B and C. See Table 2.5c for details.

Jan-Apr pot fishery				May-Aug pot fishery				Sep-Dec pot fishery			
Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma
1991	Jan-Feb	45.15	0.081	1992	May-Aug	95.04	0.174	1992	Sep-Oct	33.14	0.098
1992	Jan-Feb	80.38	0.116	1995	May-Aug	62.95	0.427	1994	Sep-Oct	48.26	0.578
1993	Jan-Feb	62.13	0.172	1996	May-Aug	63.05	0.295	1995	Sep-Oct	56.15	0.246
1994	Jan-Feb	83.45	0.120	1997	May-Aug	58.00	0.354	1998	Sep-Oct	35.07	0.365
1995	Jan-Feb	58.24	0.060	1998	May-Aug	34.68	0.707	1999	Sep-Oct	30.51	0.142
1996	Jan-Feb	57.23	0.098	1999	May-Aug	53.21	0.084	2001	Sep-Oct	36.77	0.147
1997	Jan-Feb	46.27	0.126	2000	May-Aug	45.80	0.141	2002	Sep-Oct	62.09	0.110
1998	Jan-Feb	66.84	0.088	2001	May-Aug	35.33	0.272	2003	Sep-Oct	63.04	0.106
1999	Jan-Feb	69.83	0.098					2004	Sep-Oct	49.46	0.107
2000	Jan-Feb	42.27	0.066					2005	Sep-Oct	43.64	0.110
2001	Jan-Feb	38.81	0.141					2006	Sep-Oct	35.57	0.150
2002	Jan-Feb	57.97	0.167					2007	Sep-Oct	42.76	0.118
2003	Jan-Feb	78.75	0.144					2008	Sep-Oct	57.87	0.198
2004	Jan-Feb	68.20	0.117					1997	Nov-Dec	76.60	0.378
2005	Jan-Feb	69.63	0.108					1998	Nov-Dec	64.68	0.194
2006	Jan-Feb	62.31	0.099					1999	Nov-Dec	21.59	0.302
2007	Jan-Feb	53.14	0.061					2002	Nov-Dec	67.94	0.184
2008	Jan-Feb	51.87	0.100					2004	Nov-Dec	66.30	0.325
2009	Jan-Feb	55.50	0.129					2005	Nov-Dec	54.56	0.267
2010	Jan-Feb	75.44	0.145					2006	Nov-Dec	57.45	0.191
1991	Mar-Apr	58.98	0.068					2007	Nov-Dec	30.09	0.174
1992	Mar-Apr	49.33	0.054								
1993	Mar-Apr	73.68	0.075								
1994	Mar-Apr	51.06	0.087								
1995	Mar-Apr	61.20	0.071								
1996	Mar-Apr	52.26	0.095								
1997	Mar-Apr	68.99	0.159								
1998	Mar-Apr	59.33	0.168								
1999	Mar-Apr	73.53	0.209								
2000	Mar-Apr	40.31	0.147								
2001	Mar-Apr	78.03	0.164								
2002	Mar-Apr	41.92	0.169								
2006	Mar-Apr	43.72	0.229								

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

Fleet	Sea.	Year	N	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
1	1	1984	96	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
1	1	1985	43	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
1	1	1986	9	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
1	1	1988	77	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
1	1	1989	14	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
1	1	1990	532	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
1	1	1991	789	0	1	2	2	2	7	63	142	162	221	226	333	1827	3693	4341	5520	6425	5055	3587	2578	1612	1008	616	273	85
1	1	1992	837	0	0	0	1	4	13	21	78	261	566	923	1083	1800	3167	4992	6893	5897	4303	3386	2589	1749	1156	756	282	130
1	1	1993	564	0	0	1	4	2	5	4	60	236	469	558	550	2090	3466	3628	4770	4839	2848	1440	853	495	351	215	89	37
1	1	1994	267	0	0	0	0	0	0	0	7	31	83	117	145	505	1048	1771	2593	2665	1682	951	491	348	168	82	44	30
1	1	1995	544	0	0	0	0	0	0	1	8	60	91	204	316	1000	2363	3475	4628	5820	4040	1902	993	533	298	165	74	78
1	1	1996	371	0	0	0	1	6	28	39	64	105	187	250	227	278	662	1562	2917	3736	2936	1944	1230	791	435	216	96	48
1	1	1997	471	0	0	3	8	11	8	3	32	111	284	352	270	793	2226	2810	2896	4413	3842	2230	1128	563	286	176	67	17
1	1	1998	1081	0	0	0	1	5	7	9	60	293	750	996	829	2027	4372	5659	8967	10078	7996	4952	2411	1234	621	308	115	37
1	1	1999	523	2	0	1	4	4	4	4	21	73	144	184	215	455	1065	1817	2229	2281	1691	884	414	182	65	31	14	4
1	1	2000	310	0	0	0	0	0	0	2	10	29	73	84	99	249	788	1094	1432	1329	816	478	243	164	74	20	6	1
1	1	2001	277	0	1	2	2	1	1	4	7	37	98	160	151	292	714	965	1194	1202	814	341	149	67	22	8	1	2
1	1	2002	276	0	0	0	0	1	3	5	7	35	115	234	298	485	433	745	962	1118	928	509	218	80	36	7	5	2
1	1	2003	183	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
1	1	2004	115	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
1	1	2005	78	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
1	1	2006	97	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
1	1	2007	153	1	0	2	15	37	29	7	4	12	43	160	231	271	373	568	464	431	374	185	98	56	47	19	14	1
1	1	2008	107	0	0	0	1	0	0	1	14	56	130	188	173	180	300	367	370	322	170	74	45	13	4	3	1	0
1	1	2009	82	0	0	0	0	0	1	1	1	15	31	35	48	209	501	394	209	203	143	38	10	4	1	0	0	0
1	1	2010	126	0	0	0	0	0	0	0	18	38	70	59	69	215	460	505	658	475	181	65	28	2	3	0	0	0

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

Fleet	Sea.	Year	N	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
2	2	1980	15	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
2	2	1982	11	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
2	2	1983	28	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
2	2	1984	156	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
2	2	1985	95	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
2	2	1988	45	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
2	2	1990	229	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
2	2	1998	72	0	0	1	3	0	0	1	1	0	2	13	49	196	310	656	854	720	419	148	62	26	2	0	0	0
2	2	2000	19	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
2	2	2001	29	0	0	0	0	0	5	5	5	0	2	6	16	48	44	68	143	145	98	31	19	14	6	0	0	0
2	2	2002	36	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
2	2	2003	53	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
2	2	2004	21	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
2	2	2005	26	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
2	2	2007	31	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
2	2	2008	46	0	0	0	0	0	0	0	0	13	54	123	159	179	55	34	115	172	77	34	11	8	3	0	0	0
2	2	2009	24	0	0	0	0	0	0	0	0	0	5	13	19	52	78	114	113	75	38	10	4	6	3	0	1	0
2	2	2010	18	0	0	0	0	0	0	0	0	0	4	8	13	29	33	79	116	83	20	10	7	6	0	3	1	1

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

Fleet	Sea.	Year	N	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
3	3	1977	9	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
3	3	1978	17	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
3	3	1982	18	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
3	3	1983	33	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
3	3	1984	65	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
3	3	1985	75	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
3	3	1987	13	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
3	3	1990	250	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
3	3	1992	47	0	0	0	0	0	1	8	21	18	7	64	214	479	502	415	211	145	77	63	28	2	1	0	0	0
3	3	1995	51	0	0	0	0	0	1	14	14	16	14	12	7	51	140	227	591	662	492	153	50	9	5	0	0	0
3	3	1997	79	0	0	0	1	3	8	29	49	100	62	56	96	320	376	481	835	599	351	273	101	47	10	1	0	0
3	3	1998	120	3	4	0	0	2	23	79	109	175	181	122	174	763	932	780	939	703	432	185	102	31	5	1	1	1
3	3	1999	49	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
3	3	2001	202	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
3	3	2003	78	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
3	3	2004	113	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
3	3	2005	78	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
3	3	2007	39	0	0	0	0	2	3	16	18	20	21	19	16	70	174	178	140	127	41	25	13	3	0	0	0	0
3	3	2008	127	0	1	0	1	5	12	17	34	43	57	65	175	611	578	260	284	335	237	92	37	17	5	2	2	0
3	3	2009	58	0	0	0	0	0	1	27	27	12	3	18	29	108	105	205	355	233	131	37	9	2	1	1	0	0

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

Fleet	Sea.	Year	N	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
4	1	1979	110	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
4	1	1980	244	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
4	1	1981	166	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
4	1	1982	264	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
4	1	1983	985	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
4	1	1984	1310	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
4	1	1985	1045	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
4	1	1986	1874	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
4	1	1990	227	0	0	0	0	0	0	2	2	6	28	84	58	227	564	1059	1726	2387	1811	1218	858	553	187	70	30	3
4	1	1991	312	0	0	0	0	0	0	0	1	3	10	57	160	793	1583	2117	2891	2980	2126	1163	538	263	132	53	25	31
4	1	1992	568	0	0	0	0	0	2	3	8	17	38	109	265	841	2033	3665	5556	4843	3747	2536	1580	897	578	305	105	47
4	1	1993	248	0	0	0	1	3	6	9	5	8	18	44	75	355	914	1535	2089	2015	1240	1046	942	859	416	165	76	55
4	1	1994	173	0	0	0	0	0	0	0	0	0	1	4	21	178	625	1232	1994	1776	1160	601	284	188	102	62	27	18
4	1	1995	577	0	0	0	0	1	0	3	2	3	25	101	178	677	1597	2570	4671	6341	4901	3048	1769	927	434	214	116	61
4	1	1996	311	0	0	0	0	0	0	1	4	20	41	55	81	252	494	1256	2785	3941	3250	1665	591	268	111	49	26	6
4	1	1997	169	0	0	0	0	0	0	0	0	3	3	11	15	205	695	1087	1329	1652	1597	888	376	138	56	21	7	1
4	1	1998	230	0	0	0	0	0	0	0	0	2	10	32	73	345	1014	1394	1992	2115	1634	1192	676	371	94	40	9	1
4	1	1999	400	1	0	0	0	0	0	0	0	3	6	20	60	254	707	1385	1802	1679	1243	881	474	268	132	62	22	20
4	1	2000	507	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
4	1	2001	561	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
4	1	2002	425	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
4	1	2003	353	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
4	1	2004	295	3	0	0	0	0	0	0	0	0	1	4	16	149	654	1188	1563	1367	803	434	257	129	55	19	7	1
4	1	2005	265	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
4	1	2006	339	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
4	1	2007	295	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
4	1	2008	-446	0	0	0	0	0	0	1	3	2	25	46	76	202	819	1617	1869	2165	1568	861	446	171	83	44	37	17
4	1	2009	479	0	0	0	0	0	0	1	1	5	23	58	128	501	1185	1699	2383	2308	1356	608	283	127	50	43	14	13
4	1	2010	390	0	0	0	0	0	0	1	2	4	7	14	83	322	840	1566	2297	1930	1053	408	156	61	25	11	3	2

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

Fleet	Sea.	Year	N	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
5	2	1978	107	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
5	2	1979	30	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
5	2	1980	77	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
5	2	1981	108	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
5	2	1982	52	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
5	2	1983	246	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
5	2	1984	85	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
5	2	2005	20	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
5	2	2007	31	0	0	0	0	0	0	0	0	0	0	0	0	8	11	56	143	179	138	87	33	22	16	3	3	1
5	2	2008	48	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.

Fleet	Sea.	Year	N	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
6	3	1978	281	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
6	3	1979	163	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
6	3	1980	72	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
6	3	1981	127	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
6	3	1982	162	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
6	3	1983	1446	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
6	3	1984	613	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
6	3	1992	78	0	0	0	0	0	0	0	1	2	0	11	8	82	213	503	1022	1152	547	148	44	16	1	2	2	0
6	3	2002	134	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
6	3	2003	102	1	0	0	0	0	0	0	0	0	0	3	16	47	224	378	500	468	276	182	102	59	29	12	4	1
6	3	2004	129	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
6	3	2005	147	1	0	0	0	0	0	0	0	0	2	2	8	39	153	394	719	845	563	236	139	83	65	48	12	4
6	3	2006	437	1	0	0	0	0	0	0	0	4	4	8	39	207	741	1529	2428	2411	1439	525	228	113	94	48	31	4
6	3	2007	334	1	0	0	0	0	0	0	0	0	1	4	18	236	620	879	1671	1703	1247	636	364	103	31	9	4	3
6	3	2008	207	0	0	0	0	0	0	0	0	0	5	7	25	95	399	605	861	1144	763	390	175	86	58	33	5	2
6	3	2009	243	0	0	0	0	0	0	0	0	0	2	4	13	73	432	955	1351	1266	779	334	164	62	22	10	2	0
6	3	2010	55	0	0	0	0	0	0	0	1	1	1	1	7	42	126	288	389	235	108	26	18	6	1	0	0	0

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

Fleet	Sea.	Year	N	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
7	1	1990	73	0	0	0	0	0	0	0	0	0	0	0	0	34	167	439	857	1004	538	264	96	59	35	14	6	1
7	1	1991	1017	0	0	0	0	0	0	0	1	2	15	48	120	900	2454	5156	10982	13595	9147	4064	1434	509	177	53	8	1
7	1	1992	709	0	0	0	0	0	0	0	1	10	29	57	139	631	1898	5019	8699	8168	4915	2462	1170	484	187	47	12	2
7	1	1993	476	0	0	0	0	0	0	0	0	0	0	13	51	311	1205	2679	5288	6503	4085	1696	620	220	84	28	7	2
7	1	1994	322	0	0	0	0	0	0	0	0	0	0	3	26	194	889	2109	3819	3972	2610	1149	382	151	58	23	12	1
7	1	1995	1078	0	0	0	0	0	0	0	4	2	6	16	43	666	2493	5066	10231	14153	9769	5031	2333	1087	428	185	59	26
7	1	1996	766	0	0	0	0	0	0	0	3	4	8	7	27	198	1036	3413	6989	10046	8616	4006	1484	525	192	70	17	6
7	1	1997	678	5	0	1	1	4	9	12	18	43	46	46	66	371	1327	3534	7154	8688	6456	3054	1008	341	184	59	22	5
7	1	1998	833	0	0	0	0	0	0	0	2	1	4	15	26	352	1418	3329	8132	10183	8001	5019	2151	773	297	116	30	10
7	1	1999	1505	1	0	0	0	0	0	0	0	1	1	15	51	393	1769	4162	7048	8714	6483	2982	1313	586	217	102	42	17
7	1	2000	1786	0	0	0	0	0	3	2	0	3	1	11	52	715	2726	5819	9494	9505	6371	3035	1434	623	277	105	41	17
7	1	2001	1039	1	0	0	0	0	0	0	0	0	4	13	63	312	1354	3341	6229	6392	3554	1210	530	222	106	49	16	5
7	1	2002	761	0	0	0	0	0	0	0	0	0	0	15	39	322	1191	2503	3839	4290	3022	1240	425	157	68	24	8	1
7	1	2003	522	0	0	0	0	0	1	0	2	3	9	46	81	352	1166	2001	2489	2233	1724	929	436	167	65	30	14	3
7	1	2004	748	0	0	0	0	0	0	0	0	0	1	2	26	424	1646	3208	3899	3276	1973	1155	612	345	177	64	29	0
7	1	2005	807	1	0	0	0	0	0	0	0	0	1	3	10	262	1387	3258	4647	3910	2208	1047	678	346	259	113	33	13
7	1	2006	920	0	0	0	0	0	0	0	0	0	0	5	22	219	1169	2766	4734	5006	3421	1605	772	427	312	181	62	18
7	1	2007	898	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
7	1	2008	707	0	0	0	0	0	0	0	0	1	4	15	26	239	1096	2474	3385	3542	2548	1367	652	276	159	89	34	19
7	1	2009	547	0	0	0	0	0	0	0	1	0	1	8	26	234	1000	1938	2968	3103	1749	777	294	123	43	37	21	4
7	1	2010	563	0	0	0	0	0	0	0	0	0	1	2	3	199	921	2073	3328	2863	1836	902	368	117	57	14	3	1

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

Fleet	Sea.	Year	N	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
8	2	1990	61	0	0	0	0	0	0	0	0	0	0	1	3	39	144	525	845	748	382	151	62	14	4	1	3	0
8	2	1992	15	0	0	0	0	0	0	0	0	0	0	0	1	10	45	82	122	168	121	82	44	14	6	3	0	0
8	2	1996	8	0	0	0	0	0	0	0	0	0	0	0	0	7	24	98	122	52	34	30	19	10	9	1	1	0
8	2	1999	165	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
8	2	2000	40	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
9	3	1990	251	0	0	0	0	0	0	0	0	0	2	43	186	457	656	1322	2305	2723	1951	1249	618	327	129	23	0	0

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

Fleet	Sea.	Year	N	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
9	3	1992	113	0	0	0	0	0	0	0	0	0	1	7	24	92	196	528	1138	1442	971	626	239	101	36	14	1	0
9	3	1994	14	0	0	0	0	0	0	0	0	0	0	0	3	35	103	141	141	96	62	36	19	4	6	2	2	0
9	3	1995	26	0	0	0	0	0	0	0	0	0	0	0	0	8	51	200	394	274	152	74	41	26	8	4	2	0
9	3	1997	64	0	0	0	0	0	0	0	0	0	0	0	7	25	86	254	681	924	589	294	104	53	27	8	3	0
9	3	1998	65	0	0	0	0	0	0	0	3	2	7	7	9	64	138	292	511	671	679	383	198	77	34	15	19	3
9	3	1999	162	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
9	3	2001	174	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
9	3	2002	207	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
9	3	2003	267	0	0	0	0	0	0	0	0	0	0	2	15	201	732	1207	1379	1060	746	379	179	74	34	6	0	1
9	3	2004	214	0	0	0	0	0	0	0	0	0	0	6	11	130	502	1147	1144	812	485	269	157	85	40	18	9	3
9	3	2005	305	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
9	3	2006	227	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
9	3	2007	148	0	0	0	0	0	0	0	0	0	0	1	8	60	307	497	828	754	451	261	84	42	17	10	2	1
9	3	2008	186	0	0	0	0	0	0	0	1	1	2	4	11	197	626	724	888	870	492	216	99	42	16	5	2	1
9	3	2009	96	0	0	0	0	0	0	0	0	0	0	0	7	94	234	449	605	386	238	89	30	18	2	1	0	0

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

Fleet	Sea.	Year	N	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
10	2	1984	703	0	0	0	0	0	0	424	462	599	560	990	1145	2465	3643	2879	1661	787	335	304	238	98	34	12	1	1
10	2	1987	804	0	0	0	0	0	0	130	535	1127	1649	1820	1252	1718	3305	2943	2193	1298	596	272	96	57	14	10	3	2
10	2	1990	469	0	0	0	0	0	0	78	119	233	288	433	573	1719	1893	2015	1705	976	584	217	143	73	36	14	7	1
10	2	1993	676	0	0	0	0	0	0	192	263	448	516	806	1283	2012	2555	3099	2119	1486	699	296	110	59	22	17	10	1
10	2	1996	459	0	0	0	0	0	0	292	110	234	381	557	556	889	1258	1672	2010	1685	733	273	104	49	36	18	15	3
10	2	1999	329	0	0	0	0	0	0	71	134	294	333	381	550	1037	1080	1369	1141	748	393	159	55	26	7	9	3	0
10	2	2001	243	0	0	0	0	0	0	226	184	180	305	447	429	737	740	714	752	525	297	131	51	18	14	5	5	0
10	2	2003	372	0	0	0	0	0	0	66	65	160	296	496	753	1281	1320	1625	1309	699	372	190	113	36	15	3	0	0
10	2	2005	266	0	0	0	0	0	0	70	103	190	244	206	219	426	857	1541	1271	491	216	104	73	45	89	99	46	7
10	2	2007	306	0	0	0	0	0	0	281	235	283	498	732	855	1022	675	835	807	528	284	133	38	13	8	7	5	3
10	2	2009	680	0	0	0	0	0	0	167	351	712	1145	1147	1075	1885	2572	3126	2182	1024	419	187	56	16	28	4	2	1

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

Fleet	Sea.	Year	N	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
11	2	1984	33	416	13	13	39	81	212	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	1987	24	118	23	38	137	141	113	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	1990	14	110	1	7	45	98	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	1993	49	0	19	292	355	221	270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	1996	56	0	15	97	361	481	364	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	1999	36	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
11	2	2001	43	6	64	116	213	259	355	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	2003	14	0	5	28	76	137	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	2005	23	0	9	96	164	176	102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	2007	78	2	29	467	793	372	192	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	2009	64	13	647	684	74	66	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. Nact = actual sample size (these get rescaled in Model A so that the average across all age composition records, including those from Tables 2.10b and 2.10c, equals 300).

Year	N	1	2	3	4	5	6	7	8	9	10	11	12+
2008	835	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 EBS shelf bottom trawl survey, 1994-2009. Nact = actual sample size (in Model A, these get rescaled so that the average across the age compositions from Tables 2.10a, 2.10b, and 2.10c combined equals 300; in Models B and C, these get rescaled so that the average across all age compositions in Table 2.10b and 2.10c equals 300).

Year	N	1	2	3	4	5	6	7	8	9	10	11	12+
1987	110	0.0032	0.2064	0.2409	0.2488	0.1776	0.0781	0.0273	0.0134	0.0030	0.0008	0.0003	0.0003
1990	493	0.0035	0.0721	0.2533	0.2496	0.2040	0.1289	0.0516	0.0256	0.0085	0.0026	0.0002	0.0001
1993	860	0.0045	0.0906	0.2237	0.2819	0.2129	0.1271	0.0346	0.0195	0.0038	0.0012	0.0001	0.0000
1996	771	0.0026	0.0588	0.1754	0.1978	0.2202	0.2100	0.1058	0.0207	0.0062	0.0019	0.0002	0.0005
1999	682	0.0010	0.0582	0.1645	0.2412	0.2808	0.1594	0.0562	0.0255	0.0097	0.0023	0.0010	0.0001
2001	751	0.0126	0.1144	0.2509	0.2246	0.1683	0.1313	0.0632	0.0238	0.0069	0.0028	0.0001	0.0011
2003	711	0.0013	0.0325	0.1868	0.2763	0.2824	0.1372	0.0514	0.0250	0.0041	0.0010	0.0009	0.0011
2005	536	0.0000	0.0661	0.1221	0.1953	0.2950	0.1912	0.0560	0.0353	0.0232	0.0097	0.0029	0.0031
2007	471	0.0183	0.2369	0.3205	0.1561	0.1234	0.0551	0.0295	0.0207	0.0209	0.0148	0.0024	0.0014
2009	548	0.0003	0.0972	0.3485	0.3070	0.1755	0.0507	0.0106	0.0069	0.0013	0.0020	0.0000	0.0000

Table 2.10c—Age compositions observed by the sub-27 GOA bottom trawl survey, 1993-2009. Nact = actual sample size (in Model A, these get rescaled so that the average across the age compositions from Tables 2.10a, 2.10b, and 2.10c combined equals 300; in Models B and C, these get rescaled so that the average across all age compositions in Table 2.10b and 2.10c equals 300).

Year	N	1	2	3	4	5	6	7	8	9	10	11	12+
1987	28	0.9276	0.0701	0.0023	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1990	20	0.9778	0.0222	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1993	103	0.9812	0.0188	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1996	100	0.9354	0.0646	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1999	98	0.9691	0.0309	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2001	125	0.9224	0.0776	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2003	57	0.9070	0.0930	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2005	65	0.8336	0.1664	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2007	93	0.9961	0.0039	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2009	85	0.9903	0.0084	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2.10d— Mean size (cm) at age from age-length key applied to respective size compositions, and sample sizes. Mean lengths for samples of size zero result from application of area-specific long-term average age-length keys. Green = column minimum, pink = column maximum.

Average length (cm) at age:

Year	Fleet	1	2	3	4	5	6	7	8	9	10	11	12
2008	Jan-May longline fishery	n/a	41.26	52.55	59.63	65.73	69.60	74.65	76.88	85.22	79.04	n/a	87.68
1987	27-plus trawl survey	n/a	34.26	43.17	52.68	58.92	64.66	n/a	n/a	n/a	n/a	n/a	n/a
1990	27-plus trawl survey	27.27	35.07	45.92	53.46	59.92	65.13	70.78	77.15	83.98	89.18	98.32	102.31
1993	27-plus trawl survey	27.55	34.31	44.04	52.12	58.89	65.61	70.36	74.71	87.64	94.81	97.41	n/a
1996	27-plus trawl survey	27.12	32.32	41.56	52.39	59.24	64.13	68.51	75.55	82.94	93.91	97.31	85.00
1999	27-plus trawl survey	27.42	32.94	41.03	48.71	58.17	64.39	71.13	71.91	77.90	80.16	83.68	n/a
2001	27-plus trawl survey	27.44	32.84	42.65	52.15	58.81	65.61	70.62	74.94	84.30	86.75	85.00	78.72
2003	27-plus trawl survey	29.29	32.65	43.83	48.97	57.85	64.94	71.73	75.50	84.10	83.41	75.69	75.96
2005	27-plus trawl survey	n/a	33.35	41.20	51.27	57.14	62.27	67.95	78.36	90.90	95.88	95.08	90.54
2007	27-plus trawl survey	27.47	35.21	43.36	55.49	59.64	63.47	70.06	69.86	99.57	103.75	94.10	n/a
2009	27-plus trawl survey	27.00	33.71	44.70	55.50	61.95	65.66	74.05	74.25	84.82	92.46	n/a	n/a
1987	Sub-27 trawl survey	20.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1990	Sub-27 trawl survey	21.83	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1993	Sub-27 trawl survey	20.38	25.65	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1996	Sub-27 trawl survey	20.44	25.37	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1999	Sub-27 trawl survey	20.57	26.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2001	Sub-27 trawl survey	21.14	25.01	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2003	Sub-27 trawl survey	21.13	25.04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2005	Sub-27 trawl survey	18.94	24.49	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2007	Sub-27 trawl survey	17.38	26.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2009	Sub-27 trawl survey	15.20	24.65	25.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

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	3	50	95	81	78	59	41	36	20	7	2	1
1993	27-plus trawl survey	9	103	127	124	116	117	66	53	23	10	2	0
1996	27-plus trawl survey	2	45	146	123	100	107	92	34	17	3	1	1
1999	27-plus trawl survey	1	26	83	124	141	103	58	30	11	5	2	0
2001	27-plus trawl survey	9	88	121	106	83	85	70	35	16	8	3	2
2003	27-plus trawl survey	2	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	5	47	86	73	65	34	36	25	4	1	2	0
2009	27-plus trawl survey	1	60	120	105	86	47	19	16	5	4	0	0
1987	Sub-27 trawl survey	28	0	0	0	0	0	0	0	0	0	0	0
1990	Sub-27 trawl survey	20	0	0	0	0	0	0	0	0	0	0	0
1993	Sub-27 trawl survey	101	2	0	0	0	0	0	0	0	0	0	0
1996	Sub-27 trawl survey	92	8	0	0	0	0	0	0	0	0	0	0
1999	Sub-27 trawl survey	95	3	0	0	0	0	0	0	0	0	0	0
2001	Sub-27 trawl survey	117	8	0	0	0	0	0	0	0	0	0	0
2003	Sub-27 trawl survey	52	5	0	0	0	0	0	0	0	0	0	0
2005	Sub-27 trawl survey	50	15	0	0	0	0	0	0	0	0	0	0
2007	Sub-27 trawl survey	92	1	0	0	0	0	0	0	0	0	0	0
2009	Sub-27 trawl survey	79	5	1	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 2.12a—Input multinomial sample sizes associated with length composition data (Model A). 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			Survey	
Year	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec	27-plus	Sub-27
1977			9								
1978			17		107	281					
1979				110	30	163					
1980		15		244	77	72					
1981				166	108	127					
1982		11	18	264	52	162					
1983		28	33	985	246	1446					
1984	96	156	65	1310	85	613				703	33
1985	43	95	75	1045							
1986	9			1874							
1987			13							804	24
1988	77	45									
1989	14										
1990	532	229	250	227			73	61	251	469	14
1991	789			312			1017				
1992	837		47	568		78	709	15	113		
1993	564			248			476			676	49
1994	267			173			322		14		
1995	544		51	577			1078		26		
1996	371			311			766	8		459	56
1997	471		79	169			678		64		
1998	1081	72	120	230			833		65		
1999	523		49	400			1505	165	162	329	36
2000	310	19		507			1786	40			
2001	277	29	202	561			1039		174	243	43
2002	276	36		425		134	761		207		
2003	183	53	78	353		102	522		267	372	14
2004	115	21	113	295		129	748		214		
2005	78	26	78	265	20	147	807		305	266	23
2006	97			339		437	920		227		
2007	153	31	39	295	31	334	898		148	306	78
2008	107	46	127	446	48	207	707		186		
2009	82	24	58	479		243	547		96	680	64
2010	126	18		390		55	563				

Table 2.12b (page 1 of 3)—Input multinomial sample sizes for length compositions (Models B and C).

		Trawl fishery			Longline fishery			Pot fishery			Survey	
Year	Season	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec	27-plus	Sub-27
1977	Sep-Oct			13								
1978	May-Aug					167						
1978	Sep-Oct						293					
1978	Nov-Dec			18			136					
1979	Jan-Feb				46							
1979	Mar-Apr				109							
1979	May-Aug					57						
1979	Sep-Oct						109					
1979	Nov-Dec						140					
1980	Jan-Feb				233							
1980	Mar-Apr				103							
1980	May-Aug		23			154						
1980	Sep-Oct						110					
1981	Jan-Feb				61							
1981	Mar-Apr				184							
1981	May-Aug					173						
1981	Sep-Oct						101					
1981	Nov-Dec						94					
1982	Jan-Feb				92							
1982	Mar-Apr				220							
1982	May-Aug		22			170						
1982	Sep-Oct			27			127					
1982	Nov-Dec						120					
1983	Jan-Feb				474							
1983	Mar-Apr				915							
1983	May-Aug		43			490						
1983	Sep-Oct			48			613					
1983	Nov-Dec						1595					
1984	Jan-Feb	26			1475							
1984	Mar-Apr	33			507							
1984	May-Aug		326			145					1127	53
1984	Sep-Oct			82			716					
1984	Nov-Dec			17			220					
1985	Jan-Feb				788							
1985	Mar-Apr	14			807							
1985	May-Aug		195									
1985	Sep-Oct			114								
1986	Jan-Feb				1407							
1986	Mar-Apr				1453							
1987	May-Aug										1288	39
1987	Sep-Oct			19								
1988	Jan-Feb	47										
1988	Mar-Apr	71										
1988	May-Aug		68									
1989	Mar-Apr	21										
1990	Jan-Feb	64			78							
1990	Mar-Apr	719			214			85				
1990	May-Aug		379			55			110		752	22
1990	Sep-Oct			363						314		
1990	Nov-Dec			18						69		
1991	Jan-Feb	358			61			477				
1991	Mar-Apr	846			410			1075				

Table 2.12b (page 2 of 3)—Input multinomial sample sizes for length compositions (Models B and C).

		Trawl fishery			Longline fishery			Pot fishery			Survey	
Year	Season	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec	27-plus	Sub-27
1992	Jan-Feb	572			428			397				
1992	Mar-Apr	705			438			684				
1992	May-Aug								23			
1992	Sep-Oct			72			120			173		
1993	Jan-Feb	160			151			116				
1993	Mar-Apr	701			211			583				
1993	May-Aug					16			27		1084	79
1994	Jan-Feb	131			85			271				
1994	Mar-Apr	276			179			213				
1994	Nov-Dec									18		
1995	Jan-Feb	302			369			971				
1995	Mar-Apr	525			512			670				
1995	Sep-Oct			78						39		
1996	Jan-Feb	199			266			717				
1996	Mar-Apr	366			209			429				
1996	May-Aug								35		737	89
1997	Jan-Feb	367			196			434				
1997	Mar-Apr	348			50			400				
1997	May-Aug					15			209			
1997	Sep-Oct			121						60		
1997	Nov-Dec									37		
1998	Jan-Feb	928			286			533				
1998	Mar-Apr	712			55			737				
1998	May-Aug		120			17						
1998	Sep-Oct			183						36		
1998	Nov-Dec									63		
1999	Jan-Feb	424			300			609				
1999	Mar-Apr	375			303			1507				
1999	May-Aug								432		528	58
1999	Sep-Oct			75						172		
1999	Nov-Dec									76		
2000	Jan-Feb	375			662			1299				
2000	Mar-Apr	92			100			1267				
2000	May-Aug		35						221			
2001	Jan-Feb	280			837			410				
2001	Mar-Apr	125						1088				
2001	May-Aug		62						87		390	69
2001	Sep-Oct			309						171		
2001	Nov-Dec									95		
2002	Jan-Feb	243			453			342				
2002	Mar-Apr	163			187			758				
2002	May-Aug		70						62			
2002	Sep-Oct						113			254		
2002	Nov-Dec						91			63		
2003	Jan-Feb	252			334			412				
2003	Mar-Apr				169			384				
2003	May-Aug		90			60					596	23
2003	Sep-Oct			119			154			397		
2004	Jan-Feb	157			391			702				
2004	Mar-Apr				42			437				
2004	May-Aug		44			41						
2004	Sep-Oct			172			197			298		

Table 2.12b (page 3 of 3)—Input multinomial sample sizes for length compositions (Models B and C).

		Trawl fishery			Longline fishery			Pot fishery			Survey	
Year	Season	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec	Jan-Apr	May-Aug	Sep-Dec	27-plus	Sub-27
2004	Nov-Dec									28		
2005	Jan-Feb	111			315			728				
2005	Mar-Apr				82			502				
2005	May-Aug		39			38					427	37
2005	Sep-Oct			119			195			400		
2005	Nov-Dec						30			65		
2006	Jan-Feb	138			459			679				
2006	Mar-Apr				38			725				
2006	May-Aug					32						
2006	Sep-Oct						360			276		
2006	Nov-Dec						308			71		
2007	Jan-Feb	213			382			652				
2007	Mar-Apr				61			709				
2007	May-Aug		52			55					491	126
2007	Sep-Oct			53			475			160		
2007	Nov-Dec						35			65		
2008	Jan-Feb	142			601			565				
2008	Mar-Apr				68			514				
2008	May-Aug		80			85						
2008	Sep-Oct			167			308			257		
2008	Nov-Dec			27								
2009	Jan-Feb	92			683			577				
2009	Mar-Apr							258				
2009	May-Aug		58			56					1091	103
2009	Sep-Oct			86			345			134		
2010	Jan-Feb	138			551			579				
2010	Mar-Apr							281				
2010	May-Aug		63			36						
2010	Sep-Oct						85					

Table 2.13— Negative log-likelihoods and parameter numbers for Models A, B, and C. Note that the data sets for each model are different, so log-likelihoods are not comparable. Note that selectivity seasons are defined differently between Model A (Jan-May, Jun-Aug, Sep-Dec) and Models B and C (Jan-Apr, May-Aug, Sep-Dec). Shaded cells indicate values that are not used in computing the total.

	Aggregate -lnL		
Component	Model A	Model B	Model C
Equilibrium catch	0.00	0.00	0.00
Survey CPUE (numbers)	-0.04	1.51	-11.81
Size composition	1041.95	2951.24	3437.26
Age composition	131.76	110.28	n/a
Mean size at age	607.35	734.30	n/a
Recruitment	-10.77	-22.93	-16.94
"Softbounds"	0.05	0.05	0.05
Deviations	31.77	0.02	0.02
Total	1802.08	3774.47	3408.57

	Model A	Model B	Model C
Number of parameters	282	250	250

	Fleet CPUE -lnL			Size composition -lnL		
Fleet	Model A	Model B	Model C	Model A	Model B	Model C
Season 1 trawl fishery	96.82	440.89	364.06	261.16	687.03	677.32
Season 2 trawl fishery	119.43	163.84	185.27	80.70	171.63	167.02
Season 3 trawl fishery	135.66	180.20	202.53	140.52	275.42	280.14
Season 1 longline fishery	-13.03	-42.18	-24.89	197.12	588.92	629.83
Season 2 longline fishery	-3.07	-3.94	-1.77	27.77	112.69	116.85
Season 3 longline fishery	1.80	-10.36	-8.07	102.34	251.95	247.23
Season 1 pot fishery	5.14	12.56	20.25	143.97	436.09	440.57
Season 2 pot fishery	-4.17	-5.54	-8.14	14.35	70.62	67.21
Season 3 pot fishery	6.00	5.65	13.84	45.33	173.59	172.06
27-plus trawl survey	7.75	6.63	-4.98	15.94	112.39	283.36
Sub-27 trawl survey	-7.79	-5.12	-6.83	12.76	70.92	355.66
Total	-0.04	1.51	-11.81	1041.95	2951.24	3437.26

	Age composition -lnL			Mean size at age -lnL		
Fleet:	Model A	Model B	Model C	Model A	Model B	Model C
Season 1 longline fishery	34.26	n/a	n/a	91.49	n/a	n/a
27-plus trawl survey	83.24	91.84	n/a	344.54	510.91	n/a
Sub-27 trawl survey	14.27	18.44	n/a	171.33	223.39	n/a
Total	131.76	110.28	n/a	607.35	734.30	n/a

Table 2.14— Root mean squared errors (RMSE) and observed:predicted correlations for fishery CPUE and survey relative abundance time series. Green = within-section row minimum, pink = within-section row maximum. Note that selectivity seasons are defined differently between Model A (Jan-May, Jun-Aug, Sep-Dec) and Models B and C (Jan-Apr, May-Aug, Sep-Dec). Only the trawl survey data are used in fitting the models (shown in bold box); other results are displayed for comparison only.

	No. records		RMSE			Correlation		
Fleet	A	B/C	A	B	C	A	B	C
Sea. 1 trawl fishery	20	40	0.27	0.50	0.45	0.67	0.21	0.40
Sea. 2 trawl fishery	20	20	1.06	0.98	1.04	-0.40	-0.21	-0.66
Sea. 3 trawl fishery	20	25	0.91	1.01	1.06	-0.35	-0.39	-0.38
Sea. 1 longline fishery	20	38	0.19	0.21	0.24	0.63	0.55	0.54
Sea. 2 longline fishery	8	13	0.41	0.44	0.48	0.57	-0.43	-0.46
Sea. 3 longline fishery	9	11	0.29	0.21	0.24	0.26	0.27	0.25
Sea. 1 pot fishery	20	33	0.23	0.24	0.26	0.07	-0.04	0.04
Sea. 2 pot fishery	3	8	0.12	0.28	0.24	0.95	0.65	0.86
Sea. 3 pot fishery	14	21	0.27	0.34	0.35	0.16	0.13	0.07
27-plus trawl survey	11	11	0.39	0.39	0.29	0.62	0.40	0.53
Sub-27 trawl survey	11	11	0.51	0.73	0.60	0.55	0.41	0.48

Table 2.15a—Number of records, average input sample size (N), average ratio of effective multinomial sample size (Neff) to input sample size, and ratio of average Neff to average N 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. Green = within-section row minimum, pink = within-section row maximum. Note that selectivity seasons are defined differently between Model A (Jan-May, Jun-Aug, Sep-Dec) and Models B and C (Jan-Apr, May-Aug, Sep-Dec).

	No. records			Ave. input N			Ave(Neff/N)			Ave(Neff)/Ave(N)		
Fleet	A	B	C	A	B	C	A	B	C	A	B	C
Sea. 1 trawl fishery	26	40	40	309	295	295	1.25	2.76	2.62	0.94	2.42	2.30
Sea. 2 trawl fishery	18	18	18	53	98	98	2.99	6.02	5.90	2.40	6.12	5.74
Sea. 3 trawl fishery	20	23	23	76	100	100	1.45	4.47	4.63	1.03	3.00	2.99
Sea. 1 longline fishery	29	55	55	469	365	365	1.77	5.90	5.28	1.32	3.78	3.44
Sea. 2 longline fishery	10	19	19	80	98	98	2.89	6.85	7.02	2.17	4.19	4.22
Sea. 3 longline fishery	17	27	27	278	266	266	2.32	4.76	4.91	1.80	3.75	3.92
Sea. 1 pot fishery	21	41	41	798	604	604	1.31	4.21	3.75	1.11	3.71	3.33
Sea. 2 pot fishery	5	9	9	58	134	134	1.70	7.32	7.00	2.27	3.99	3.86
Sea. 3 pot fishery	16	26	26	157	146	146	4.44	5.86	5.97	5.65	5.60	5.99
27-plus trawl survey	2	2	11	754	1208	774	0.95	0.57	1.42	0.99	0.55	1.27
Sub-27 trawl survey	2	2	11	29	46	63	2.09	0.27	0.78	1.79	0.25	0.67

Table 2.15b— Input sample size (input N), effective multinomial sample size (effective N), and ratio of effective N to input N for each record of age composition data. Average of ratios and ratio of averages are shown for the 27-plus trawl survey in the bottom two rows. Green = within-section row minimum, pink = within-section row maximum. Note that selectivity seasons are defined differently between Model A (Jan-May, Jun-Aug, Sep-Dec) and Models B and C (Jan-Apr, May-Aug, Sep-Dec).

		Input N		Effective N			Effective N / Input N		
Fleet	Year	A	B/C	A	B	C	A	B	C
Sea. 1 longline fishery	2008	697	n/a	148	n/a	n/a	0.21	n/a	n/a
27-plus trawl survey	1990	412	441	174	764	11	0.42	1.73	0.03
27-plus trawl survey	1993	718	769	326	424	14	0.45	0.55	0.02
27-plus trawl survey	1996	644	690	968	231	24	1.50	0.33	0.03
27-plus trawl survey	1999	570	610	134	124	31	0.24	0.20	0.05
27-plus trawl survey	2001	627	672	680	2308	28	1.08	3.43	0.04
27-plus trawl survey	2003	594	636	200	106	23	0.34	0.17	0.04
27-plus trawl survey	2005	448	479	206	286	18	0.46	0.60	0.04
27-plus trawl survey	2007	393	421	128	101	9	0.33	0.24	0.02
27-plus trawl survey	2009	458	490	134	226	8	0.29	0.46	0.02
Sub-27 trawl survey	1990	17	18	193	316	29	11.38	17.54	1.60
Sub-27 trawl survey	1993	86	92	26	48	43	0.31	0.53	0.47
Sub-27 trawl survey	1996	84	89	108961	152	5494	1297.15	1.71	61.73
Sub-27 trawl survey	1999	82	88	910	353	229	11.10	4.02	2.60
Sub-27 trawl survey	2001	104	112	46	27	5479	0.44	0.24	48.92
Sub-27 trawl survey	2003	48	51	89	17	19	1.85	0.33	0.37
Sub-27 trawl survey	2005	54	58	3	2	2	0.06	0.04	0.04
Sub-27 trawl survey	2007	78	83	26	21	29	0.34	0.25	0.35
Sub-27 trawl survey	2009	71	76	22	25	54	0.32	0.33	0.71
Ave(effective N / input N)--27-plus trawl survey:							0.57	0.86	0.03
Ave(effective N)/ave(input N)--27-plus trawl survey:							0.61	0.88	0.03

Table 2.16 (page 1 of 10)—All of the quantities listed in the "parameters" section of the SS report file. Quantities with a value listed but no standard deviation were fixed externally. A blank value means that the quantity was not used in the respective model. See text for other details.

	Model A				Model B				Model C			
Label	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.
M	0.38	_	-3	_	0.38	_	-3	_	0.38	_	-3	_
L-at-age-0	-6.52459	1	3	0.469754	1.32094	1	3	0.271378	3.04261	1	3	0.250685
Linf	99.3371	2	3	0.646425	101.697	2	3	0.660851	102.319	2	3	0.762835
K	0.215383	3	3	0.004683	0.173053	3	3	0.002272	0.135312	3	3	0.002163
SD_of_len_at_L-at-age-0	1.87	_	-3	_	1.87	_	-3	_	1.87	_	-3	_
SD_of_len_at_L-at-age-20	6.53	_	-3	_	6.53	_	-3	_	6.53	_	-3	_
Wtlen_1	8.80E-06	_	-1	_	8.84E-06	_	-1	_	8.84E-06	_	-1	_
Wtlen_2	3.07181	_	-1	_	3.07181	_	-1	_	3.07181	_	-1	_
Maturity_inflection	4.35	_	-1	_	4.35	_	-1	_	50.2	_	-1	_
Maturity_slope	-1.9632	_	-1	_	-1.9632	_	-1	_	-0.222	_	-1	_
Eggs/kg_intercept	1	_	-1	_	1	_	-1	_	1	_	-1	_
Eggs/kg_slope	0	_	-1	_	0	_	-1	_	0	_	-1	_
RecrDist_growpattern_1	0	_	-1	_	0	_	-1	_	0	_	-1	_
RecrDist_Area_1	0	_	-1	_	0	_	-1	_	0	_	-1	_
RecrDist_Seas_1	0	_	-1	_	0	_	-1	_	0	_	-1	_
RecrDist_Seas_2	0	_	-1	_	0	_	-1	_	0	_	-1	_
RecrDist_Seas_3	0	_	-1	_	0	_	-1	_	0	_	-1	_
RecrDist_Seas_4					0	_	-1	_	0	_	-1	_
RecrDist_Seas_5					0	_	-1	_	0	_	-1	_
CohortGrowDev	1	_	-1	_	1	_	-1	_	1	_	-1	_
WL1_offsetseas_1	-0.02418	_	-1	_	-0.004274	_	-1	_	-0.004274	_	-1	_
WL1_offsetseas_2	0.138649	_	-1	_	-0.097812	_	-1	_	-0.097812	_	-1	_
WL1_offsetseas_3	0.48434	_	-1	_	0.260771	_	-1	_	0.260771	_	-1	_
WL1_offsetseas_4					0.706346	_	-1	_	0.706346	_	-1	_
WL1_offsetseas_5					-0.205349	_	-1	_	-0.205349	_	-1	_
WL2_offsetseas_1	0.002609	_	-1	_	0.004059	_	-1	_	0.004059	_	-1	_
WL2_offsetseas_2	-0.01617	_	-1	_	0.005264	_	-1	_	0.005264	_	-1	_
WL2_offsetseas_3	-0.041207	_	-1	_	-0.026835	_	-1	_	-0.026835	_	-1	_
WL2_offsetseas_4					-0.059968	_	-1	_	-0.059968	_	-1	_
WL2_offsetseas_5					0.015615	_	-1	_	0.015615	_	-1	_
CohortGrow_dev_1977	-0.022865	4	1	0.01875								
CohortGrow_dev_1978	0.094623	5	1	0.025693								
CohortGrow_dev_1979	0.051765	6	1	0.020487								
CohortGrow_dev_1980	-0.00252	7	1	0.018361								
CohortGrow_dev_1981	-0.020915	8	1	0.018119								
CohortGrow_dev_1982	-0.055417	9	1	0.018044								
CohortGrow_dev_1983	-0.122275	10	1	0.018354								
CohortGrow_dev_1984	-0.283909	11	1	0.016742								
CohortGrow_dev_1985	0.132043	12	1	0.029091								
CohortGrow_dev_1986	-0.100817	13	1	0.022077								

Table 2.16 (page 2 of 10)—All of the quantities listed in the “parameters” section of the SS report file. Quantities with a value listed but no standard deviation were fixed externally. A blank value means that the quantity was not used in the respective model. See text for other details.

	Model A				Model B				Model C			
Label	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.
CohortGrow_dev_1987	-0.112878	14	1	0.017514								
CohortGrow_dev_1988	-0.069369	15	1	0.017745								
CohortGrow_dev_1989	-0.122327	16	1	0.017075								
CohortGrow_dev_1990	-0.130479	17	1	0.017501								
CohortGrow_dev_1991	-0.146303	18	1	0.018033								
CohortGrow_dev_1992	-0.090343	19	1	0.020624								
CohortGrow_dev_1993	-0.120547	20	1	0.017179								
CohortGrow_dev_1994	-0.17325	21	1	0.017427								
CohortGrow_dev_1995	-0.155125	22	1	0.017266								
CohortGrow_dev_1996	-0.147167	23	1	0.018642								
CohortGrow_dev_1997	-0.089275	24	1	0.0183								
CohortGrow_dev_1998	-0.136511	25	1	0.017209								
CohortGrow_dev_1999	-0.169774	26	1	0.017422								
CohortGrow_dev_2000	-0.146229	27	1	0.01639								
CohortGrow_dev_2001	-0.163258	28	1	0.020462								
CohortGrow_dev_2002	-0.043842	29	1	0.024105								
CohortGrow_dev_2003	-0.054158	30	1	0.017396								
CohortGrow_dev_2004	0.019709	31	1	0.017774								
CohortGrow_dev_2005	-0.028976	32	1	0.017004								
CohortGrow_dev_2006	-0.060129	33	1	0.019196								
CohortGrow_dev_2007	-0.14292	34	1	0.020719								
CohortGrow_dev_2008	-0.269742	35	1	0.038123								
SR_R0	12.3995	36	1	0.037413	12.4309	4	1	0.034707	13.1151	4	1	0.049439
SR_steep	1	_	-1	_	1	_	-1	_	1	_	-1	_
SR_sigmaR	0.41	_	-1	_	0.41	_	-1	_	0.41	_	-1	_
SR_envlink	0	_	-1	_	0	_	-1	_	0	_	-1	_
SR_R1_offset	-0.721049	37	3	0.135797	-0.398954	5	3	0.126001	0.326553	5	3	0.129253
SR_autocorr	0	_	-1	_	0	_	-1	_	0	_	-1	_
InitialAge_dev_13	-0.159167	38	_	0.381182	-0.277118	6	_	0.364268	-0.290662	6	_	0.3616
InitialAge_dev_12	-0.214926	39	_	0.372842	-0.349753	7	_	0.354964	-0.299854	7	_	0.359397
InitialAge_dev_11	-0.281299	40	_	0.363893	-0.418407	8	_	0.346729	-0.254172	8	_	0.362637
InitialAge_dev_10	-0.355354	41	_	0.354613	-0.470901	9	_	0.340304	-0.154292	9	_	0.37073
InitialAge_dev_9	-0.426362	42	_	0.346263	-0.480131	10	_	0.337057	0.038402	10	_	0.386018
InitialAge_dev_8	-0.475662	43	_	0.339939	-0.405746	11	_	0.338407	0.259117	11	_	0.394777
InitialAge_dev_7	-0.47232	44	_	0.336583	-0.205593	12	_	0.343413	0.381276	12	_	0.427406
InitialAge_dev_6	-0.377617	45	_	0.335216	0.089917	13	_	0.350999	0.904102	13	_	0.319389
InitialAge_dev_5	-0.160456	46	_	0.339769	0.465781	14	_	0.2842	0.706438	14	_	0.263901
InitialAge_dev_4	0.563041	47	_	0.251465	0.906529	15	_	0.215736	-0.003537	15	_	0.272525
InitialAge_dev_3	0.471996	48	_	0.20815	0.132777	16	_	0.188307	0.240363	16	_	0.180246
InitialAge_dev_2	-0.153606	49	_	0.185757	-0.044659	17	_	0.165533	0.181402	17	_	0.18453

Table 2.16 (page 3 of 10)—All of the quantities listed in the "parameters" section of the SS report file. Quantities with a value listed but no standard deviation were fixed externally. A blank value means that the quantity was not used in the respective model. See text for other details.

	Model A				Model B				Model C			
Label	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.
InitialAge_dev_1	-0.442428	50	_	0.20066	0.506604	18	_	0.14321	1.16443	18	_	0.122959
Recr_dev_1977	0.421089	51	_	0.180763	1.05146	19	_	0.068762	-0.566899	19	_	0.195132
Recr_dev_1978	-0.017789	52	_	0.16863	-0.303089	20	_	0.096386	0.060637	20	_	0.093253
Recr_dev_1979	-0.125961	53	_	0.093786	-0.205695	21	_	0.068059	0.182432	21	_	0.073631
Recr_dev_1980	-0.252927	54	_	0.07492	-0.087207	22	_	0.056721	0.143005	22	_	0.077106
Recr_dev_1981	-0.239296	55	_	0.078985	-0.059584	23	_	0.060984	0.217626	23	_	0.078306
Recr_dev_1982	0.159991	56	_	0.088751	0.264921	24	_	0.060403	0.35209	24	_	0.079792
Recr_dev_1983	-0.181711	57	_	0.124082	-0.107351	25	_	0.077492	-0.920198	25	_	0.153857
Recr_dev_1984	0.967794	58	_	0.099905	-0.098318	26	_	0.069583	0.68594	26	_	0.063966
Recr_dev_1985	-0.508933	59	_	0.161451	0.312627	27	_	0.055459	-0.608395	27	_	0.129421
Recr_dev_1986	-0.461027	60	_	0.107953	-0.28829	28	_	0.062803	0.363684	28	_	0.066734
Recr_dev_1987	-0.084146	61	_	0.093897	0.195463	29	_	0.045988	0.105685	29	_	0.071288
Recr_dev_1988	-0.004213	62	_	0.077042	-0.060764	30	_	0.053033	0.331917	30	_	0.064257
Recr_dev_1989	0.329754	63	_	0.071464	0.28801	31	_	0.047695	0.166873	31	_	0.067983
Recr_dev_1990	0.30587	64	_	0.069675	0.155812	32	_	0.049916	0.16996	32	_	0.064542
Recr_dev_1991	0.090436	65	_	0.078715	0.124683	33	_	0.047467	-0.100301	33	_	0.077884
Recr_dev_1992	-0.283021	66	_	0.099174	-0.037052	34	_	0.051334	0.026243	34	_	0.068021
Recr_dev_1993	0.26776	67	_	0.069616	0.06329	35	_	0.046503	0.047834	35	_	0.062914
Recr_dev_1994	0.328665	68	_	0.067965	0.115716	36	_	0.043484	-0.024436	36	_	0.060166
Recr_dev_1995	0.042597	69	_	0.075705	0.056825	37	_	0.042986	-0.136293	37	_	0.058822
Recr_dev_1996	-0.368027	70	_	0.083314	-0.063618	38	_	0.047435	-0.470526	38	_	0.069514
Recr_dev_1997	-0.430132	71	_	0.074575	-0.336662	39	_	0.046456	-0.390999	39	_	0.068508
Recr_dev_1998	-0.140393	72	_	0.06562	-0.332296	40	_	0.045512	-0.094703	40	_	0.055817
Recr_dev_1999	-0.059726	73	_	0.06161	-0.080641	41	_	0.043404	0.036991	41	_	0.05304
Recr_dev_2000	0.008927	74	_	0.065855	0.074306	42	_	0.043885	-0.282695	42	_	0.070099
Recr_dev_2001	-0.545952	75	_	0.088164	-0.296874	43	_	0.051118	-0.420961	43	_	0.079172
Recr_dev_2002	-0.925023	76	_	0.110754	-0.314459	44	_	0.053978	-0.135914	44	_	0.074796
Recr_dev_2003	-0.329347	77	_	0.077811	-0.159639	45	_	0.059375	-0.043187	45	_	0.085786
Recr_dev_2004	-0.426331	78	_	0.085575	-0.101437	46	_	0.069152	0.47804	46	_	0.088264
Recr_dev_2005	0.630852	79	_	0.102766	0.432715	47	_	0.085624	0.203187	47	_	0.121717
Recr_dev_2006	0.742143	80	_	0.124406	0.256873	48	_	0.10678	0.679227	48	_	0.132303
Recr_dev_2007	0.745289	81	_	0.191529	0.060104	49	_	0.15046	-0.245758	49	_	0.19833
Recr_dev_2008	0.342789	82	_	0.32913	-0.519828	50	_	0.196465	0.189893	50	_	0.213909
Late_RecrDev_2009	0	_	_	_	0	_	_	_	0	_	_	_
Late_RecrDev_2010	0	_	_	_	0	_	_	_	0	_	_	_
ForeRecr_2011	0	_	_	_	0	_	_	_	0	_	_	_
ForeRecr_2012	0	_	_	_	0	_	_	_	0	_	_	_
ForeRecr_2013	0	_	_	_	0	_	_	_	0	_	_	_
ForeRecr_2014	0	_	_	_	0	_	_	_	0	_	_	_
ForeRecr_2015	0	_	_	_	0	_	_	_	0	_	_	_

Table 2.16 (page 4 of 10)—All of the quantities listed in the “parameters” section of the SS report file. Quantities with a value listed but no standard deviation were fixed externally. A blank value means that the quantity was not used in the respective model. See text for other details.

	Model A				Model B				Model C			
Label	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.
InitF_1	0.041841	83	1	0.006319	0.081231	51	1	0.011389	0.03021	51	1	0.004353
InitF_2	0	_	-1	_	0	_	-1	_	0	_	-1	_
InitF_3	0	_	-1	_	0	_	-1	_	0	_	-1	_
InitF_4	0	_	-1	_	0	_	-1	_	0	_	-1	_
InitF_5	0	_	-1	_	0	_	-1	_	0	_	-1	_
InitF_6	0	_	-1	_	0	_	-1	_	0	_	-1	_
InitF_7	0	_	-1	_	0	_	-1	_	0	_	-1	_
InitF_8	0	_	-1	_	0	_	-1	_	0	_	-1	_
InitF_9	0	_	-1	_	0	_	-1	_	0	_	-1	_
Q_envlink_10	0.962991	84	4	0.12195	0.528437	52	4	0.111597	-0.008198	52	4	0.122032
Q_base_10	0.039221	_	-4	_	0.039221	_	-4	_	0.039221	_	-4	_
Q_base_11	-1.99686	85	4	0.140955	-2.21715	53	4	0.140564	-2.8652	53	4	0.146332
Q_dev_11y_1984	0.051128	86	4	0.51924	0.234226	54	4	0.514171	0.710919	54	4	0.520135
Q_dev_11y_1987	-0.612036	87	4	0.362459	-0.841897	55	4	0.353587	-1.22542	55	4	0.356485
Q_dev_11y_1990	-0.559134	88	4	0.384212	-0.446797	56	4	0.381252	-0.311467	56	4	0.383609
Q_dev_11y_1993	0.083581	89	4	0.356302	-0.054758	57	4	0.350726	-0.020582	57	4	0.353292
Q_dev_11y_1996	1.52783	90	4	0.527501	1.5836	58	4	0.524942	1.82544	58	4	0.526214
Q_dev_11y_1999	-0.559687	91	4	0.279051	-0.386891	59	4	0.275408	-0.498808	59	4	0.277055
Q_dev_11y_2001	0.139214	92	4	0.277855	0.133103	60	4	0.27417	0.479664	60	4	0.276484
Q_dev_11y_2003	-0.372681	93	4	0.255687	-0.882791	61	4	0.246236	-0.951965	61	4	0.249339
Q_dev_11y_2005	-0.159496	94	4	0.367802	-0.387172	62	4	0.365156	-0.730367	62	4	0.36804
Q_dev_11y_2007	0.38619	95	4	0.405906	0.943248	63	4	0.39977	0.634987	63	4	0.405625
Q_dev_11y_2009	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_1P_1	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_1P_2	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_1P_3	5.89284	96	4	0.034804	5.86318	64	4	0.028352	5.84396	64	4	0.027263
SizeSel_1P_4	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_1P_5	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
SizeSel_1P_6	10	_	-4	_	10	_	-4	_	10	_	-4	_
SizeSel_2P_1	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_2P_2	-9.49593	97	4	13.0534	-9.67679	65	4	8.90441	-9.70261	65	4	8.27216
SizeSel_2P_3	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_2P_4	4.21913	98	4	0.570708	4.43791	66	4	0.440341	4.08064	66	4	0.49909
SizeSel_2P_5	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
SizeSel_2P_6	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_3P_1	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_3P_2	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_3P_3	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_3P_4	-9.98469	99	4	0.485761	3.74764	67	4	0.622025	3.6164	67	4	0.606088
SizeSel_3P_5	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_

Table 2.16 (page 5 of 10)—All of the quantities listed in the "parameters" section of the SS report file. Quantities with a value listed but no standard deviation were fixed externally. A blank value means that the quantity was not used in the respective model. See text for other details.

	Model A				Model B				Model C			
Label	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.
SizeSel_3P_6	-0.933075	100	4	0.28142	-1.05761	68	4	0.279364	-0.939421	68	4	0.258277
SizeSel_4P_1	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_4P_2	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_4P_3	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_4P_4	-1.10774	101	4	62.8935	4.06632	69	4	0.389602	3.83343	69	4	0.54888
SizeSel_4P_5	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
SizeSel_4P_6	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_5P_1	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_5P_2	-9.12129	102	4	20.4803	-9.01233	70	4	22.4113	-9.25276	70	4	18.0123
SizeSel_5P_3	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_5P_4	4.52045	103	4	0.623043	4.65999	71	4	0.553486	4.48359	71	4	0.578803
SizeSel_5P_5	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
SizeSel_5P_6	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_6P_1	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_6P_2	-9.65588	104	4	9.41218	-13.6506	72	4	83.9731	-13.6685	72	4	83.7891
SizeSel_6P_3	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_6P_4	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_6P_5	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
SizeSel_6P_6	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_7P_1	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_7P_2	-13.2379	105	4	80.4461	-14.3183	73	4	77.254	-14.2811	73	4	77.6265
SizeSel_7P_3	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_7P_4	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_7P_5	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
SizeSel_7P_6	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_8P_1	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_8P_2	-0.103096	106	4	1.86241	-9.07225	74	4	21.3589	-9.09245	74	4	20.9952
SizeSel_8P_3	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_8P_4	-0.754797	107	4	53.1064	5.10252	75	4	0.481223	5.08256	75	4	0.512103
SizeSel_8P_5	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
SizeSel_8P_6	-1.62953	108	4	0.895121	-1.19157	76	4	0.60016	-1.08149	76	4	0.607007
SizeSel_9P_1	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_9P_2	-8.90103	109	4	24.3198	-7.74324	77	4	38.3257	-8.98183	77	4	22.9276
SizeSel_9P_3	0	_	-4	_	0	_	-4	_	0	_	-4	_
SizeSel_9P_4	4.35651	110	4	0.581043	4.68018	78	4	0.365381	4.61613	78	4	0.408066
SizeSel_9P_5	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
SizeSel_9P_6	0	_	-4	_	0	_	-4	_	0	_	-4	_
AgeSel_10P_1	0	_	-4	_	0	_	-4	_	0	_	-4	_
AgeSel_10P_2	0	_	-4	_	0	_	-4	_	0	_	-4	_
AgeSel_10P_3	0	_	-4	_	0	_	-4	_	0	_	-4	_

Table 2.16 (page 6 of 10)—All of the quantities listed in the “parameters” section of the SS report file. Quantities with a value listed but no standard deviation were fixed externally. A blank value means that the quantity was not used in the respective model. See text for other details.

	Model A				Model B				Model C			
Label	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.
AgeSel_10P_4	0	_	-4	_	0	_	-4	_	0	_	-4	_
AgeSel_10P_5	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_10P_6	0	_	-4	_	0	_	-4	_	0	_	-4	_
AgeSel_11P_1	-1.43557	111	4	0.170466	-0.560346	79	4	0.131707	-1.57342	79	4	0.163918
AgeSel_11P_2	10	_	-4	_	10	_	-4	_	10	_	-4	_
AgeSel_11P_3	-1.47081	112	4	0.204346	-1.39911	80	4	0.193523	-1.174	80	4	0.247109
AgeSel_11P_4	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_5	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_6	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_7	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_8	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_9	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_10	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_11	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_12	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_13	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_14	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_15	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_16	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_17	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_18	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_19	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_20	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_11P_21	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
SizeSel_1P_1_block_1977	65.3346	113	4	1.33387	62.8916	81	4	1.26794	63.4248	81	4	1.23517
SizeSel_1P_1_block_1990	74.6647	114	4	0.727613	74.4375	82	4	0.602782	75.3585	82	4	0.605839
SizeSel_1P_1_block_1995	76.7838	115	4	0.721168	75.9522	83	4	0.596374	76.2839	83	4	0.592753
SizeSel_1P_1_block_2000	71.1143	116	4	0.788706	70.5132	84	4	0.652168	71.8087	84	4	0.629414
SizeSel_1P_1_block_2005	71.843	117	4	0.980858	69.9356	85	4	0.849132	72.5457	85	4	0.834064
SizeSel_2P_1_block_1977	55.0135	118	4	1.82863	55.163	86	4	1.42741	55.0854	86	4	1.41778
SizeSel_2P_1_block_1985	62.3707	119	4	1.69867	62.6856	87	4	1.28664	62.5449	87	4	1.27393
SizeSel_2P_1_block_1990	66.8705	120	4	1.38538	67.2159	88	4	1.11324	68.1818	88	4	1.06925
SizeSel_2P_1_block_2000	69.0701	121	4	2.53294	69.0035	89	4	1.68858	70.0983	89	4	1.71866
SizeSel_2P_1_block_2005	75.672	122	4	3.74362	72.2663	90	4	1.96262	74.357	90	4	2.17518
SizeSel_2P_3_block_1977	4.47832	123	4	0.284381	4.52471	91	4	0.21033	4.52409	91	4	0.210716
SizeSel_2P_3_block_1985	5.0338	124	4	0.226583	5.1399	92	4	0.155699	5.10815	92	4	0.152643
SizeSel_2P_3_block_1990	5.13425	125	4	0.155584	5.16058	93	4	0.116863	5.17398	93	4	0.107228
SizeSel_2P_3_block_2000	5.77397	126	4	0.196295	5.79871	94	4	0.131193	5.76955	94	4	0.126633
SizeSel_2P_3_block_2005	6.21311	127	4	0.190671	6.07452	95	4	0.122477	6.01254	95	4	0.121289
SizeSel_2P_6_block_1977	-0.154573	128	4	0.447095	0.182303	96	4	0.404107	0.3201	96	4	0.386391

Table 2.16 (page 7 of 10)—All of the quantities listed in the "parameters" section of the SS report file. Quantities with a value listed but no standard deviation were fixed externally. A blank value means that the quantity was not used in the respective model. See text for other details.

	Model A				Model B				Model C			
Label	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.
SizeSel_2P_6_block_1985	-1.47659	129	4	0.508353	-0.955753	97	4	0.375335	-0.891977	97	4	0.333272
SizeSel_2P_6_block_1990	-2.08486	130	4	0.774866	-2.47537	98	4	0.737503	-2.17041	98	4	0.580719
SizeSel_2P_6_block_2000	-0.762282	131	4	1.05574	-1.09326	99	4	0.769376	-0.787045	99	4	0.723335
SizeSel_2P_6_block_2005	-0.571998	132	4	1.83335	-1.26514	100	4	0.969638	-0.798816	100	4	0.996233
SizeSel_3P_1_block_1977	44.3984	133	4	5.63351	45.2458	101	4	3.60653	49.0513	101	4	6.84355
SizeSel_3P_1_block_1980	54.3715	134	4	3.04828	57.0273	102	4	3.67407	57.2281	102	4	3.59
SizeSel_3P_1_block_1985	62.8578	135	4	3.52982	62.1682	103	4	1.75161	61.9188	103	4	1.66178
SizeSel_3P_1_block_1990	59.9721	136	4	3.46021	64.4196	104	4	2.89345	68.0733	104	4	2.91983
SizeSel_3P_1_block_1995	79.428	137	4	3.43579	75.6298	105	4	1.69956	75.8826	105	4	1.73572
SizeSel_3P_1_block_2000	71.515	138	4	2.56549	71.6638	106	4	2.36575	72.715	106	4	1.20065
SizeSel_3P_1_block_2005	81.5703	139	4	4.20096	76.9911	107	4	1.85212	78.8583	107	4	1.98675
SizeSel_3P_2_block_1977	-0.661632	140	4	0.280543	-0.209084	108	4	0.551853	-2.37721	108	4	2.30393
SizeSel_3P_2_block_1980	-0.81134	141	4	0.202892	-3.74366	109	4	4.66257	-4.35304	109	4	7.88867
SizeSel_3P_2_block_1985	-1.66556	142	4	0.56563	-9.17979	110	4	19.3998	-9.02258	110	4	22.2395
SizeSel_3P_2_block_1990	0.746495	143	4	0.119069	-0.603939	111	4	0.287777	-0.823782	111	4	0.336615
SizeSel_3P_2_block_1995	-5.63265	144	4	40.1474	-9.25754	112	4	17.9277	-9.22245	112	4	18.6001
SizeSel_3P_2_block_2000	-1.1023	145	4	0.324362	-4.96754	113	4	11.3302	-8.53111	113	4	30.1585
SizeSel_3P_2_block_2005	-1.88131	146	4	1.46356	-9.14528	114	4	20.0436	-8.95766	114	4	23.3801
SizeSel_3P_3_block_1977	3.79211	147	4	1.09582	3.98282	115	4	0.736986	4.26219	115	4	1.03409
SizeSel_3P_3_block_1980	4.83873	148	4	0.405876	5.05431	116	4	0.352356	5.06297	116	4	0.342163
SizeSel_3P_3_block_1985	5.71769	149	4	0.268505	5.66056	117	4	0.186213	5.60926	117	4	0.174512
SizeSel_3P_3_block_1990	5.16627	150	4	0.348099	5.55281	118	4	0.224942	5.70642	118	4	0.194489
SizeSel_3P_3_block_1995	6.42644	151	4	0.159979	6.25495	119	4	0.1018	6.21297	119	4	0.100747
SizeSel_3P_3_block_2000	5.94079	152	4	0.157291	5.93697	120	4	0.134253	5.88385	120	4	0.080705
SizeSel_3P_3_block_2005	6.35769	153	4	0.171479	6.21021	121	4	0.101457	6.14007	121	4	0.098058
SizeSel_4P_1_block_1977	57.6526	154	4	1.06992	57.9294	122	4	0.89536	57.9868	122	4	0.896136
SizeSel_4P_1_block_1985	72.8541	155	4	1.48134	73.179	123	4	1.26902	70.0678	123	4	1.33953
SizeSel_4P_1_block_1990	70.2933	156	4	1.01427	70.8017	124	4	1.14164	70.9651	124	4	0.819937
SizeSel_4P_1_block_1995	75.0837	157	4	1.13168	74.3216	125	4	0.792601	74.604	125	4	0.801804
SizeSel_4P_1_block_2000	69.5791	158	4	0.838911	69.3651	126	4	0.780551	69.6971	126	4	0.691338
SizeSel_4P_1_block_2005	71.3759	159	4	0.83015	69.4455	127	4	0.543421	70.3414	127	4	0.542436
SizeSel_4P_2_block_1977	0.309942	160	4	1.23873	-0.455266	128	4	0.111548	-0.513337	128	4	0.131912
SizeSel_4P_2_block_1985	-1.38817	161	4	3.47833	-3.96224	129	4	2.72544	-1.76938	129	4	0.531508
SizeSel_4P_2_block_1990	-0.335706	162	4	1.53343	-4.58707	130	4	16.7008	-1.25125	130	4	0.668026
SizeSel_4P_2_block_1995	-2.3284	163	4	36.5758	-9.04639	131	4	21.8274	-8.84629	131	4	25.2564
SizeSel_4P_2_block_2000	-1.88712	164	4	3.78804	-4.5321	132	4	5.0212	-3.42359	132	4	1.53434
SizeSel_4P_2_block_2005	-2.53466	165	4	11.0881	-9.76195	133	4	6.77528	-9.69449	133	4	8.47207
SizeSel_4P_3_block_1977	4.66388	166	4	0.131213	4.7102	134	4	0.10287	4.71781	134	4	0.101387
SizeSel_4P_3_block_1985	5.74088	167	4	0.085003	5.72924	135	4	0.073809	5.5413	135	4	0.090409
SizeSel_4P_3_block_1990	5.27619	168	4	0.087862	5.3083	136	4	0.084511	5.27304	136	4	0.067869

Table 2.16 (page 8 of 10)—All of the quantities listed in the "parameters" section of the SS report file. Quantities with a value listed but no standard deviation were fixed externally. A blank value means that the quantity was not used in the respective model. See text for other details.

	Model A				Model B				Model C			
Label	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.
SizeSel_4P_3_block_1995	5.48331	169	4	0.082238	5.45264	137	4	0.060559	5.436	137	4	0.059826
SizeSel_4P_3_block_2000	5.12024	170	4	0.077756	5.12068	138	4	0.067595	5.08969	138	4	0.061068
SizeSel_4P_3_block_2005	5.1731	171	4	0.067757	5.07558	139	4	0.050448	5.05323	139	4	0.048081
SizeSel_4P_6_block_1977	-0.585916	172	4	0.294354	-1.00291	140	4	0.455959	-0.325904	140	4	0.41233
SizeSel_4P_6_block_1985	0.494991	173	4	0.243898	0.730092	141	4	0.27231	1.4868	141	4	0.492002
SizeSel_4P_6_block_1990	0.917209	174	4	0.550191	1.18567	142	4	0.436178	0.82137	142	4	0.572774
SizeSel_4P_6_block_1995	1.74814	175	4	0.650428	1.12997	143	4	0.473	1.2825	143	4	0.520001
SizeSel_4P_6_block_2000	0.332868	176	4	0.249322	-0.142197	144	4	0.231031	0.051238	144	4	0.264446
SizeSel_4P_6_block_2005	1.05669	177	4	0.422747	0.099852	145	4	0.224223	0.752276	145	4	0.297258
SizeSel_5P_1_block_1977	57.0526	178	4	2.75512	57.1119	146	4	3.04292	58.8277	146	4	2.24951
SizeSel_5P_1_block_1980	56.5611	179	4	1.12302	56.3041	147	4	0.887932	56.0771	147	4	0.909244
SizeSel_5P_1_block_1990	68.0425	180	4	10.0404	70.8	148	4	2.22117	71.3949	148	4	2.20425
SizeSel_5P_1_block_2000	74.0672	181	4	3.3804	72.2606	149	4	1.54525	73.1564	149	4	1.71302
SizeSel_5P_3_block_1977	4.62072	182	4	0.404457	4.5533	150	4	0.391732	4.66426	150	4	0.280227
SizeSel_5P_3_block_1980	4.24626	183	4	0.187361	4.31113	151	4	0.140912	4.30557	151	4	0.143745
SizeSel_5P_3_block_1990	-3.48194	184	4	51.7875	5.048	152	4	0.254885	5.05423	152	4	0.245533
SizeSel_5P_3_block_2000	4.83531	185	4	0.352505	5.0253	153	4	0.151273	5.01477	153	4	0.155632
SizeSel_5P_6_block_1977	-0.211516	186	4	0.758101	0.429226	154	4	0.812525	0.744684	154	4	0.815182
SizeSel_5P_6_block_1980	-0.865107	187	4	0.284358	-0.502229	155	4	0.22919	-0.4144	155	4	0.210474
SizeSel_5P_6_block_1990	-6.85762	188	4	52.5273	-1.66962	156	4	1.28212	-1.51572	156	4	1.20697
SizeSel_5P_6_block_2000	8.21975	189	4	34.8097	1.06698	157	4	1.02667	3.92124	157	4	12.8137
SizeSel_6P_1_block_1977	57.4391	190	4	1.79355	60.6497	158	4	2.56994	63.972	158	4	2.5394
SizeSel_6P_1_block_1980	56.2317	191	4	0.487313	57.0258	159	4	0.377148	57.0224	159	4	0.384958
SizeSel_6P_1_block_1990	70.5291	192	4	0.835485	69.3719	160	4	0.563723	70.0234	160	4	0.577831
SizeSel_6P_3_block_1977	4.47673	193	4	0.254177	4.81919	161	4	0.265995	5.09876	161	4	0.226169
SizeSel_6P_3_block_1980	4.2044	194	4	0.0836	4.33669	162	4	0.058731	4.3234	162	4	0.059686
SizeSel_6P_3_block_1990	5.04133	195	4	0.07783	4.97782	163	4	0.056846	4.94969	163	4	0.055509
SizeSel_6P_4_block_1977	7.13265	196	4	0.670782	7.24766	164	4	0.796171	7.4074	164	4	1.21549
SizeSel_6P_4_block_1980	4.18746	197	4	0.191167	4.14991	165	4	0.148507	3.95244	165	4	0.16328
SizeSel_6P_4_block_1990	2.51987	198	4	0.794713	3.6329	166	4	0.460339	3.27159	166	4	0.668815
SizeSel_6P_6_block_1977	-8.9189	199	4	24.0428	-8.61602	167	4	28.9455	-8.09044	167	4	36.6254
SizeSel_6P_6_block_1980	-1.38822	200	4	0.124857	-1.35538	168	4	0.10282	-1.2632	168	4	0.0982
SizeSel_6P_6_block_1990	0.545662	201	4	0.309218	-0.158556	169	4	0.204281	0.369515	169	4	0.241225
SizeSel_7P_1_block_1977	68.9307	202	4	0.487385	69.1199	170	4	0.376585	69.5204	170	4	0.384025
SizeSel_7P_1_block_1995	72.6561	203	4	0.578492	71.7653	171	4	0.355867	71.7707	171	4	0.354335
SizeSel_7P_1_block_2000	68.2724	204	4	0.448757	68.0047	172	4	0.372883	68.4506	172	4	0.366888
SizeSel_7P_1_block_2005	69.2226	205	4	0.519884	68.4466	173	4	0.405835	69.1769	173	4	0.420277
SizeSel_7P_3_block_1977	4.79606	206	4	0.057426	4.78801	174	4	0.044193	4.79256	174	4	0.043502
SizeSel_7P_3_block_1995	5.0032	207	4	0.053659	4.9369	175	4	0.036136	4.91509	175	4	0.035753
SizeSel_7P_3_block_2000	4.88805	208	4	0.049331	4.86413	176	4	0.039744	4.85919	176	4	0.038334

Table 2.16 (page 9 of 10)—All of the quantities listed in the "parameters" section of the SS report file. Quantities with a value listed but no standard deviation were fixed externally. A blank value means that the quantity was not used in the respective model. See text for other details.

	Model A				Model B				Model C			
Label	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.
SizeSel_7P_3_block_2005	4.81615	209	4	0.053788	4.76762	177	4	0.042343	4.7608	177	4	0.041669
SizeSel_7P_4_block_1977	4.41141	210	4	0.233344	4.57075	178	4	0.16484	4.58593	178	4	0.172523
SizeSel_7P_4_block_1995	1.71007	211	4	0.738645	4.21882	179	4	0.254078	4.27887	179	4	0.271105
SizeSel_7P_4_block_2000	3.83707	212	4	0.328913	4.32739	180	4	0.221675	4.22713	180	4	0.24667
SizeSel_7P_4_block_2005	2.97991	213	4	0.948028	4.03789	181	4	0.289585	3.70995	181	4	0.458353
SizeSel_7P_6_block_1977	-1.99154	214	4	0.309956	-2.14477	182	4	0.254457	-2.13573	182	4	0.269314
SizeSel_7P_6_block_1995	-0.050083	215	4	0.1427	-0.6174	183	4	0.189105	-0.572947	183	4	0.201229
SizeSel_7P_6_block_2000	-0.130017	216	4	0.189562	-0.485849	184	4	0.157184	-0.303404	184	4	0.161294
SizeSel_7P_6_block_2005	1.54342	217	4	0.445408	0.369128	185	4	0.200354	1.17924	185	4	0.305942
SizeSel_8P_1_block_1977	63.4073	218	4	2.85397	64.7599	186	4	1.54163	65.4774	186	4	1.48289
SizeSel_8P_1_block_1995	76.0352	219	4	2.64761	71.1457	187	4	1.08947	71.1019	187	4	1.07934
SizeSel_8P_1_block_2000	63.036	220	4	1.7687	65.5247	188	4	0.887432	65.8399	188	4	0.899379
SizeSel_8P_3_block_1977	4.29238	221	4	0.482122	4.42605	189	4	0.251004	4.46704	189	4	0.231808
SizeSel_8P_3_block_1995	5.05318	222	4	0.25632	4.8868	190	4	0.127243	4.85912	190	4	0.126148
SizeSel_8P_3_block_2000	3.13269	223	4	0.621711	4.27022	191	4	0.159984	4.27642	191	4	0.157272
SizeSel_9P_1_block_1977	72.2318	224	4	1.38496	72.0918	192	4	1.05521	72.8674	192	4	1.06001
SizeSel_9P_1_block_1995	71.7048	225	4	1.53177	70.9788	193	4	1.18857	70.9965	193	4	1.1684
SizeSel_9P_1_block_2000	66.2754	226	4	1.00384	66.113	194	4	0.817543	66.6519	194	4	0.805762
SizeSel_9P_1_block_2005	67.4563	227	4	0.858967	66.4536	195	4	0.695293	67.411	195	4	0.721804
SizeSel_9P_3_block_1977	5.33203	228	4	0.132011	5.2885	196	4	0.101565	5.28543	196	4	0.097944
SizeSel_9P_3_block_1995	5.01325	229	4	0.168769	4.97147	197	4	0.1343	4.94316	197	4	0.132043
SizeSel_9P_3_block_2000	4.79388	230	4	0.120928	4.80378	198	4	0.097136	4.79172	198	4	0.092643
SizeSel_9P_3_block_2005	4.81074	231	4	0.100556	4.7501	199	4	0.083436	4.76732	199	4	0.080376
SizeSel_9P_6_block_1977	-1.25383	232	4	0.758071	-1.62775	200	4	0.633173	-1.63782	200	4	0.687622
SizeSel_9P_6_block_1995	0.573215	233	4	0.866506	0.219233	201	4	0.599971	0.325908	201	4	0.613058
SizeSel_9P_6_block_2000	-0.059448	234	4	0.40255	-0.439122	202	4	0.308832	-0.093219	202	4	0.341241
SizeSel_9P_6_block_2005	0.724959	235	4	0.531107	-0.098421	203	4	0.311587	0.562569	203	4	0.418598
AgeSel_10P_1_block_1977	3.58711	236	4	0.201338	4.05962	204	4	0.039418	5.54106	204	4	0.24272
AgeSel_10P_1_block_1987	3.07882	237	4	0.011991	2.04713	205	4	0.008277	3.02246	205	4	0.009371
AgeSel_10P_1_block_1990	4.02473	238	4	0.050556	3.90618	206	4	0.182824	5.51442	206	4	0.199289
AgeSel_10P_1_block_1993	4.73923	239	4	0.35793	3.84703	207	4	0.178652	5.70859	207	4	0.262366
AgeSel_10P_1_block_1996	5.01966	240	4	0.185451	5.22679	208	4	0.253279	7.08716	208	4	0.132876
AgeSel_10P_1_block_1999	2.84075	241	4	0.162341	4.04551	209	4	0.45594	5.3043	209	4	0.422055
AgeSel_10P_1_block_2001	3.7708	242	4	0.184185	3.30653	210	4	0.194767	5.26346	210	4	0.45542
AgeSel_10P_1_block_2003	4.29364	243	4	0.284589	4.07439	211	4	0.232178	5.97325	211	4	0.302426
AgeSel_10P_1_block_2005	4.72533	244	4	0.315458	5.08699	212	4	0.213594	6.35279	212	4	0.340484
AgeSel_10P_1_block_2007	2.99151	245	4	0.150925	2.9472	213	4	0.120672	6.08808	213	4	0.285361
AgeSel_10P_2_block_1977	-8.25295	246	4	33.8183	-13.6351	214	4	84.1285	-7.49459	214	4	43.5615
AgeSel_10P_2_block_1987	-9.46412	247	4	13.7701	-2.09476	215	4	0.221151	-2.28695	215	4	0.776122
AgeSel_10P_2_block_1990	-9.73944	248	4	7.35409	-9.03412	216	4	22.0795	-8.32628	216	4	33.267

Table 2.16 (page 10 of 10)—All of the quantities listed in the "parameters" section of the SS report file. Quantities with a value listed but no standard deviation were fixed externally. A blank value means that the quantity was not used in the respective model. See text for other details.

	Model A				Model B				Model C			
Label	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.	Par. no.	Phase	Value	St. Dev.
AgeSel_10P_2_block_1993	-1.83107	249	4	0.426606	-1.86764	217	4	0.819317	-1.60787	217	4	6.93935
AgeSel_10P_2_block_1996	-8.77485	250	4	26.1729	-2.90845	218	4	3.06402	-8.7494	218	4	26.6972
AgeSel_10P_2_block_1999	-0.50966	251	4	0.075302	-1.02281	219	4	0.120766	-0.970195	219	4	0.114051
AgeSel_10P_2_block_2001	-8.58055	252	4	29.3263	-2.84769	220	4	1.26947	-1.85977	220	4	2.41342
AgeSel_10P_2_block_2003	-2.01503	253	4	0.233567	-1.85784	221	4	1.02146	-2.42501	221	4	0.325025
AgeSel_10P_2_block_2005	-0.82966	254	4	0.339139	-8.2705	222	4	34.1051	-8.32051	222	4	33.79
AgeSel_10P_2_block_2007	0.011195	255	4	1.22449	-2.15102	223	4	0.725952	-2.51356	223	4	0.914
AgeSel_10P_3_block_1977	0.252283	256	4	0.23103	0.615248	224	4	0.068094	1.39861	224	4	0.142012
AgeSel_10P_3_block_1987	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_10P_3_block_1990	0.407383	257	4	0.094724	0.480682	225	4	0.192624	1.06624	225	4	0.142876
AgeSel_10P_3_block_1993	1.28758	258	4	0.244653	0.58356	226	4	0.184486	1.4586	226	4	0.152693
AgeSel_10P_3_block_1996	1.23987	259	4	0.128211	1.44854	227	4	0.153496	2.05089	227	4	0.080519
AgeSel_10P_3_block_1999	-0.70548	260	4	0.341492	0.804609	228	4	0.419324	1.32097	228	4	0.275367
AgeSel_10P_3_block_2001	0.624189	261	4	0.179127	0.206722	229	4	0.227156	1.36592	229	4	0.283494
AgeSel_10P_3_block_2003	0.725793	262	4	0.274222	0.448353	230	4	0.252499	1.45119	230	4	0.173756
AgeSel_10P_3_block_2005	1.31735	263	4	0.221057	1.404	231	4	0.146143	1.56646	231	4	0.166894
AgeSel_10P_3_block_2007	-0.255612	264	4	0.231614	-0.168172	232	4	0.194404	1.70793	232	4	0.1324
AgeSel_10P_4_block_1977	-4.37712	265	4	26.9505	-7.86861	233	4	16.5691	-4.12118	233	4	29.1313
AgeSel_10P_4_block_1987	0.137947	266	4	0.309135	1.08064	234	4	0.593825	2.13678	234	4	0.767196
AgeSel_10P_4_block_1990	-9.35161	267	4	9.45134	1.87227	235	4	0.595849	1.2528	235	4	0.580399
AgeSel_10P_4_block_1993	-2.10456	268	4	4.04344	-2.35289	236	4	20.0565	-5.15235	236	4	318.656
AgeSel_10P_4_block_1996	-0.211585	269	4	0.740886	-5.81787	237	4	76.515	-6.73395	237	4	25.7783
AgeSel_10P_4_block_1999	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_10P_4_block_2001	2.7977	270	4	0.343544	2.74921	238	4	0.589478	-4.7839	238	4	11.5661
AgeSel_10P_4_block_2003	-2.29956	271	4	46.4413	-6.03664	239	4	3.39613	-9.61375	239	4	9.13245
AgeSel_10P_4_block_2005	-0.904094	272	4	11.3353	3.57568	240	4	0.604572	-4.02107	240	4	40.4203
AgeSel_10P_4_block_2007	-5.89639	273	4	204.636	-4.30361	241	4	29.5404	-7.28334	241	4	5.87378
AgeSel_10P_6_block_1977	-2.05718	274	4	0.22508	-1.9843	242	4	0.174934	-1.9762	242	4	0.176205
AgeSel_10P_6_block_1987	-3.08642	275	4	0.430518	-2.60739	243	4	0.520368	-2.9969	243	4	0.800235
AgeSel_10P_6_block_1990	-1.21112	276	4	0.248244	-2.19176	244	4	0.992707	-1.53174	244	4	0.394639
AgeSel_10P_6_block_1993	-7.58302	277	4	1.95287	-1.5481	245	4	0.424561	-1.33196	245	4	0.494843
AgeSel_10P_6_block_1996	-1.33282	278	4	0.515278	-1.46337	246	4	0.444904	-0.997925	246	4	0.40732
AgeSel_10P_6_block_1999	-10	_	-4	_	-10	_	-4	_	-10	_	-4	_
AgeSel_10P_6_block_2001	-8.5518	279	4	29.9678	-8.64094	247	4	28.5556	-0.709165	247	4	0.668066
AgeSel_10P_6_block_2003	-1.39247	280	4	0.517825	-1.5696	248	4	0.476138	-0.738422	248	4	0.455674
AgeSel_10P_6_block_2005	-0.93112	281	4	3.52208	-7.43641	249	4	45.2574	0.578095	249	4	0.60341
AgeSel_10P_6_block_2007	-6.99005	282	4	50.8215	0.523939	250	4	0.404476	-1.04552	250	4	0.445203

Table 2.17a—Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model A). Sea1=Jan-May, Sea2=Jun-Aug, Sea3=Sep-Dec. Rates must be multiplied by relative season length before summing to get total.

	Trawl fishery			Longline fishery			Pot fishery			
Year	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Sea1	Sea2	Sea3	Total
1977	0.002	0.003	0.004	0.009	0.004	0.006	0	0	0	0.010
1978	0.007	0.016	0.025	0.040	0.019	0.031	0	0	0	0.047
1979	0.008	0.021	0.025	0.047	0.024	0.038	0	0	0	0.056
1980	0.021	0.043	0.052	0.119	0.064	0.115	0	0	0	0.141
1981	0.002	0.049	0.063	0.070	0.083	0.121	0	0	0	0.124
1982	0.007	0.030	0.034	0.060	0.046	0.142	0	0	0	0.106
1983	0.016	0.045	0.044	0.066	0.086	0.189	0	0	0	0.145
1984	0.020	0.034	0.041	0.075	0.009	0.045	0	0	0	0.079
1985	0.014	0.012	0.024	0.072	0.000	0.004	0	0	0	0.048
1986	0.018	0.009	0.044	0.127	0.009	0.023	0	0	0	0.087
1987	0.032	0.161	0.112	0.043	0.019	0.031	0.003	0.002	0.004	0.127
1988	0.091	0.117	0.049	0.024	0.008	0.006	0.013	0.000	0.004	0.105
1989	0.137	0.217	0.002	0.019	0.006	0.013	0.003	0.001	0.000	0.127
1990	0.318	0.151	0.076	0.043	0.006	0.003	0.028	0.016	0.029	0.242
1991	0.486	0.015	0.015	0.066	0.022	0.001	0.126	0.000	0.015	0.302
1992	0.511	0.030	0.016	0.130	0.060	0.037	0.140	0.000	0.008	0.369
1993	0.345	0.060	0.015	0.090	0.023	0.003	0.139	0.000	0.000	0.266
1994	0.286	0.030	0.009	0.067	0.003	0.001	0.116	0.000	0.007	0.209
1995	0.399	0.017	0.036	0.121	0.011	0.003	0.206	0.001	0.009	0.326
1996	0.440	0.067	0.022	0.115	0.010	0.002	0.163	0.001	0.000	0.326
1997	0.451	0.038	0.092	0.126	0.013	0.006	0.207	0.035	0.031	0.391
1998	0.410	0.089	0.051	0.124	0.015	0.005	0.300	0.009	0.020	0.401
1999	0.377	0.038	0.097	0.165	0.023	0.003	0.423	0.120	0.048	0.497
2000	0.245	0.061	0.013	0.159	0.004	0.002	0.405	0.013	0.013	0.366
2001	0.177	0.049	0.126	0.141	0.003	0.003	0.219	0.016	0.038	0.296
2002	0.197	0.072	0.025	0.182	0.003	0.073	0.249	0.008	0.098	0.348
2003	0.159	0.073	0.102	0.161	0.016	0.019	0.354	0.000	0.070	0.367
2004	0.132	0.060	0.127	0.160	0.005	0.052	0.430	0.000	0.100	0.410
2005	0.150	0.056	0.077	0.078	0.005	0.048	0.378	0.000	0.117	0.348
2006	0.156	0.053	0.025	0.122	0.008	0.109	0.403	0.000	0.058	0.363
2007	0.150	0.049	0.071	0.143	0.011	0.108	0.389	0.001	0.089	0.388
2008	0.153	0.081	0.117	0.172	0.016	0.056	0.354	0.000	0.086	0.393
2009	0.087	0.040	0.055	0.144	0.027	0.060	0.262	0.000	0.047	0.276
2010	0.097	0.030	0.076	0.129	0.008	0.057	0.310	0.000	0.058	0.297

Table 2.17b—Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model B). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Aug, Sea4=Sep-Oct, Sea5=Nov-Dec. Rates must be multiplied by relative season length before summing to get total.

	Trawl fishery					Longline fishery					Pot fishery					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.001	0.001	0.002	0.002	0.002	0.006	0.006	0.004	0.004	0.004	0	0	0	0	0	0.006
1978	0.005	0.005	0.010	0.011	0.010	0.026	0.028	0.017	0.020	0.019	0	0	0	0	0	0.030
1979	0.005	0.006	0.011	0.011	0.010	0.030	0.033	0.021	0.024	0.022	0	0	0	0	0	0.034
1980	0.013	0.014	0.024	0.043	0.040	0.074	0.079	0.058	0.082	0.076	0	0	0	0	0	0.097
1981	0.002	0.002	0.026	0.054	0.054	0.047	0.049	0.060	0.089	0.089	0	0	0	0	0	0.093
1982	0.005	0.005	0.018	0.034	0.035	0.042	0.046	0.043	0.111	0.113	0	0	0	0	0	0.085
1983	0.012	0.013	0.030	0.045	0.044	0.049	0.054	0.070	0.154	0.153	0	0	0	0	0	0.121
1984	0.015	0.016	0.025	0.041	0.040	0.058	0.063	0.031	0.038	0.036	0	0	0	0	0	0.070
1985	0.011	0.012	0.012	0.020	0.020	0.056	0.062	0.020	0.004	0.004	0	0	0	0	0	0.042
1986	0.013	0.015	0.011	0.036	0.035	0.101	0.110	0.038	0.018	0.017	0	0	0	0	0	0.074
1987	0.024	0.026	0.100	0.099	0.096	0.034	0.037	0.022	0.027	0.026	0.002	0.002	0.002	0.003	0.003	0.105
1988	0.075	0.082	0.114	0.050	0.049	0.020	0.021	0.012	0.006	0.006	0.011	0.012	0.003	0.004	0.004	0.099
1989	0.117	0.128	0.210	0.002	0.002	0.016	0.018	0.009	0.013	0.013	0.002	0.003	0.002	0.000	0.000	0.126
1990	0.277	0.311	0.242	0.073	0.070	0.039	0.044	0.018	0.003	0.003	0.027	0.030	0.021	0.029	0.027	0.249
1991	0.214	0.914	0.013	0.029	0.000	0.025	0.133	0.009	0.001	0.001	0.072	0.233	0.003	0.001	0.026	0.283
1992	0.342	0.811	0.032	0.028	0.002	0.133	0.168	0.018	0.069	0.002	0.081	0.261	0.000	0.016	0.000	0.336
1993	0.195	0.595	0.043	0.014	0.015	0.092	0.107	0.014	0.004	0.001	0.095	0.234	0.005	0.000	0.000	0.246
1994	0.215	0.442	0.021	0.015	0.000	0.089	0.062	0.005	0.001	0.000	0.157	0.116	0.000	0.000	0.013	0.194
1995	0.126	0.779	0.017	0.062	0.000	0.128	0.137	0.003	0.005	0.001	0.246	0.199	0.001	0.012	0.004	0.290
1996	0.218	0.752	0.062	0.023	0.013	0.140	0.110	0.004	0.002	0.001	0.205	0.144	0.000	0.000	0.000	0.290
1997	0.272	0.731	0.032	0.125	0.029	0.166	0.101	0.007	0.008	0.003	0.239	0.170	0.041	0.028	0.026	0.343
1998	0.410	0.483	0.068	0.086	0.000	0.209	0.047	0.008	0.006	0.002	0.374	0.210	0.039	0.018	0.017	0.349
1999	0.355	0.461	0.027	0.158	0.000	0.217	0.131	0.008	0.003	0.002	0.451	0.337	0.133	0.066	0.020	0.422
2000	0.297	0.208	0.049	0.017	0.006	0.276	0.067	0.003	0.003	0.001	0.587	0.231	0.056	0.010	0.012	0.322
2001	0.197	0.151	0.044	0.229	0.000	0.277	0.014	0.002	0.005	0.001	0.219	0.187	0.056	0.038	0.028	0.258
2002	0.173	0.195	0.070	0.038	0.007	0.254	0.125	0.003	0.084	0.042	0.251	0.213	0.049	0.096	0.071	0.299
2003	0.226	0.050	0.057	0.198	0.000	0.232	0.093	0.010	0.037	0.001	0.476	0.280	0.000	0.118	0.001	0.308
2004	0.201	0.035	0.039	0.217	0.000	0.284	0.009	0.005	0.086	0.000	0.518	0.394	0.006	0.132	0.029	0.334
2005	0.218	0.022	0.032	0.115	0.000	0.124	0.008	0.003	0.057	0.018	0.417	0.365	0.005	0.144	0.040	0.268
2006	0.220	0.034	0.024	0.058	0.000	0.183	0.030	0.004	0.101	0.067	0.413	0.370	0.007	0.046	0.043	0.273
2007	0.195	0.051	0.030	0.116	0.010	0.195	0.060	0.008	0.138	0.043	0.320	0.445	0.013	0.083	0.066	0.304
2008	0.248	0.034	0.042	0.236	0.020	0.281	0.058	0.013	0.112	0.003	0.313	0.489	0.000	0.126	0.043	0.346
2009	0.136	0.025	0.056	0.127	0.008	0.295	0.033	0.022	0.122	0.029	0.373	0.325	0.000	0.099	0.015	0.291
2010	0.199	0.024	0.062	0.191	0.011	0.320	0.027	0.012	0.157	0.020	0.571	0.413	0.000	0.159	0.032	0.379

Table 2.17c—Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model C). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Aug, Sea4=Sep-Oct, Sea5=Nov-Dec. Rates must be multiplied by relative season length before summing to get total.

	Trawl fishery					Longline fishery					Pot fishery					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0	0	0	0	0	0.002
1978	0.001	0.002	0.003	0.006	0.006	0.008	0.009	0.005	0.007	0.006	0	0	0	0	0	0.010
1979	0.002	0.002	0.004	0.006	0.006	0.010	0.010	0.006	0.008	0.007	0	0	0	0	0	0.012
1980	0.004	0.005	0.008	0.016	0.015	0.024	0.026	0.019	0.029	0.028	0	0	0	0	0	0.034
1981	0.001	0.001	0.010	0.023	0.023	0.017	0.019	0.024	0.038	0.038	0	0	0	0	0	0.038
1982	0.002	0.002	0.007	0.015	0.015	0.017	0.019	0.018	0.048	0.049	0	0	0	0	0	0.036
1983	0.005	0.006	0.013	0.019	0.019	0.021	0.023	0.030	0.067	0.067	0	0	0	0	0	0.052
1984	0.007	0.007	0.011	0.019	0.018	0.025	0.028	0.014	0.017	0.017	0	0	0	0	0	0.031
1985	0.005	0.006	0.006	0.010	0.010	0.024	0.026	0.010	0.002	0.002	0	0	0	0	0	0.019
1986	0.007	0.007	0.006	0.019	0.019	0.045	0.049	0.020	0.010	0.009	0	0	0	0	0	0.036
1987	0.013	0.014	0.056	0.053	0.052	0.016	0.018	0.012	0.015	0.014	0.001	0.001	0.001	0.002	0.002	0.057
1988	0.042	0.046	0.066	0.028	0.027	0.010	0.011	0.007	0.004	0.003	0.006	0.007	0.002	0.002	0.002	0.056
1989	0.068	0.075	0.124	0.001	0.001	0.008	0.009	0.005	0.007	0.007	0.001	0.002	0.001	0.000	0.000	0.074
1990	0.172	0.192	0.145	0.045	0.043	0.023	0.026	0.011	0.002	0.002	0.016	0.018	0.012	0.018	0.017	0.152
1991	0.132	0.549	0.008	0.017	0.000	0.015	0.075	0.005	0.001	0.000	0.043	0.134	0.002	0.001	0.016	0.169
1992	0.207	0.475	0.018	0.017	0.001	0.076	0.093	0.010	0.038	0.001	0.047	0.147	0.000	0.009	0.000	0.195
1993	0.117	0.351	0.025	0.009	0.009	0.052	0.060	0.008	0.002	0.001	0.054	0.132	0.003	0.000	0.000	0.143
1994	0.133	0.271	0.013	0.010	0.000	0.052	0.036	0.003	0.001	0.000	0.093	0.069	0.000	0.000	0.008	0.118
1995	0.080	0.486	0.010	0.039	0.000	0.081	0.086	0.002	0.003	0.001	0.154	0.123	0.001	0.007	0.003	0.182
1996	0.142	0.478	0.040	0.015	0.008	0.091	0.070	0.002	0.001	0.001	0.131	0.090	0.000	0.000	0.000	0.185
1997	0.179	0.472	0.021	0.081	0.019	0.109	0.065	0.004	0.005	0.002	0.154	0.107	0.026	0.018	0.017	0.222
1998	0.272	0.315	0.045	0.057	0.000	0.138	0.031	0.005	0.004	0.002	0.242	0.133	0.025	0.012	0.011	0.228
1999	0.242	0.309	0.018	0.107	0.000	0.147	0.087	0.005	0.002	0.001	0.301	0.221	0.088	0.044	0.014	0.283
2000	0.210	0.145	0.033	0.012	0.004	0.187	0.044	0.002	0.002	0.000	0.400	0.155	0.038	0.007	0.008	0.220
2001	0.142	0.109	0.031	0.164	0.000	0.192	0.010	0.002	0.003	0.000	0.152	0.130	0.039	0.026	0.019	0.182
2002	0.127	0.141	0.048	0.027	0.005	0.178	0.086	0.002	0.058	0.029	0.176	0.148	0.034	0.065	0.048	0.209
2003	0.165	0.036	0.039	0.141	0.000	0.160	0.064	0.007	0.026	0.000	0.330	0.192	0.000	0.081	0.001	0.215
2004	0.149	0.025	0.028	0.157	0.000	0.199	0.006	0.004	0.061	0.000	0.364	0.275	0.004	0.093	0.020	0.237
2005	0.171	0.017	0.024	0.089	0.000	0.089	0.006	0.003	0.041	0.013	0.296	0.257	0.004	0.101	0.028	0.195
2006	0.172	0.026	0.018	0.045	0.000	0.131	0.021	0.003	0.071	0.047	0.293	0.258	0.005	0.031	0.030	0.196
2007	0.150	0.039	0.022	0.087	0.007	0.138	0.042	0.006	0.096	0.030	0.224	0.307	0.009	0.057	0.045	0.215
2008	0.188	0.026	0.029	0.174	0.015	0.196	0.040	0.010	0.076	0.002	0.216	0.331	0.000	0.084	0.029	0.242
2009	0.102	0.019	0.040	0.094	0.006	0.203	0.023	0.016	0.085	0.020	0.254	0.220	0.000	0.068	0.010	0.203
2010	0.148	0.018	0.043	0.136	0.008	0.224	0.018	0.009	0.107	0.014	0.397	0.283	0.000	0.106	0.021	0.264

Table 2.18—Time series of mean length (cm) at age 1 as estimated by Models A, B, and C. Years 1994-2009 are shown, to correspond with the range for which observations are available. Mean = average, RMSE = root mean squared error, Corr. = correlation between estimates and data.

Year	Data	Model A	Model B	Model C
1987	20.00	20.88	22.00	19.43
1990	21.83	20.37	22.00	19.43
1993	20.38	21.14	22.00	19.43
1996	20.44	19.61	22.00	19.43
1999	20.57	20.04	22.00	19.43
2001	21.14	19.82	22.00	19.43
2003	21.13	22.28	22.00	19.43
2005	18.94	23.90	22.00	19.43
2007	17.38	21.87	22.00	19.43
2009	15.20	17.09	22.00	19.43
Mean:	19.70	20.70	22.00	19.43
RMSE:		2.36	2.99	1.93
Corr:		0.31	0	0

Table 2.19—Summary of key management reference points from the standard projection algorithm (last five rows are from SS). All biomass figures are in t. Green = row minimum, pink = row maximum.

Quantity	Model A	Model B	Model C
B100%	267,767	256,252	339,537
B40%	107,107	102,501	135,815
B35%	93,718	89,688	118,838
B2011	163,092	124,064	217,410
B2012	176,554	111,866	189,286
B2011/B100%	0.61	0.48	0.64
B2012/B100%	0.66	0.44	0.56
F40%	0.45	0.42	0.58
F35%	0.56	0.51	0.74
maxFABC2011	0.45	0.42	0.58
maxFABC2012	0.45	0.42	0.58
maxABC2011	122,429	86,845	179,754
maxABC2012	130,327	78,202	159,954
FOFL2011	0.56	0.51	0.74
OFL2011	145,398	102,640	218,857
OFL2012	154,482	92,349	194,553
Pr(B2011<B20%)	~0	~0	~0
Pr(B2012<B20%)	~0	~0	~0
Pr(B2013<B20%)	~0	~0	~0
Pr(B2014<B20%)	~0	~0	~0
Pr(B2015<B20%)	~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)
B2011 = projected spawning biomass for 2011 (assuming 2011 catch = maxABC)
B2012 = projected spawning biomass for 2012 (assuming 2011-2012 catch = maxABC)
B2011/B100% = ratio of 2011 spawning biomass to B100%
B2012/B100% = ratio of 2012 spawning biomass to B100%
F40% = fishing mortality that reduces equilibrium spawning per recruit to 40% of unfished
F35% = fishing mortality that reduces equilibrium spawning per recruit to 35% of unfished
maxFABC2011 = maximum permissible ABC fishing mortality rate for 2011 under Tier 3
maxFABC2012 = maximum permissible ABC fishing mortality rate for 2012 under Tier 3
maxABC2011 = maximum permissible ABC for 2011 under Tier 3
maxABC2012 = maximum permissible ABC for 2012 under Tier 3
FOFL2011 = OFL fishing mortality rate for 2011 under Tier 3
OFL2011 = OFL for 2011 under Tier 3
OFL2012 = OFL for 2012 under Tier 3 assuming 2011 catch = maxABC2011
Pr(B2011<B20%) = probability that spawning biomass will fall below 20% of B100% in 2011
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
Pr(B2015<B20%) = probability that spawning biomass will fall below 20% of B100% in 2015

Table 2.20a (page 1 of 7)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries survey as defined by parameter estimates under Model B. Years correspond to beginnings of blocks.

	January-April trawl fishery					May-August trawl fishery				
Len.	1977	1990	1995	2000	2005	1977	1985	1990	2000	2005
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
16	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
17	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
18	0.003	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001
19	0.004	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.001
20	0.005	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.002
21	0.007	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.002
22	0.009	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.003
23	0.011	0.001	0.000	0.002	0.002	0.000	0.000	0.000	0.002	0.004
24	0.014	0.001	0.001	0.002	0.003	0.000	0.000	0.000	0.002	0.005
25	0.017	0.001	0.001	0.003	0.003	0.000	0.000	0.000	0.003	0.006
26	0.021	0.001	0.001	0.004	0.004	0.000	0.000	0.000	0.004	0.007
27	0.026	0.002	0.001	0.005	0.005	0.000	0.001	0.000	0.005	0.009
28	0.031	0.002	0.001	0.006	0.007	0.000	0.001	0.000	0.006	0.011
29	0.038	0.003	0.002	0.008	0.009	0.001	0.001	0.000	0.008	0.013
30	0.046	0.004	0.003	0.009	0.011	0.001	0.002	0.000	0.010	0.016
31	0.056	0.005	0.003	0.012	0.013	0.002	0.003	0.001	0.013	0.020
32	0.066	0.006	0.004	0.015	0.017	0.003	0.004	0.001	0.016	0.024
33	0.079	0.008	0.005	0.018	0.021	0.005	0.006	0.001	0.020	0.029
34	0.093	0.010	0.007	0.023	0.026	0.008	0.008	0.002	0.024	0.034
35	0.110	0.012	0.009	0.028	0.031	0.012	0.011	0.003	0.030	0.041
36	0.128	0.015	0.011	0.034	0.038	0.019	0.015	0.004	0.037	0.049
37	0.149	0.019	0.013	0.041	0.046	0.028	0.021	0.005	0.045	0.057
38	0.172	0.023	0.017	0.050	0.055	0.041	0.028	0.008	0.054	0.067
39	0.197	0.028	0.021	0.059	0.066	0.059	0.037	0.010	0.065	0.078
40	0.226	0.034	0.025	0.071	0.078	0.083	0.049	0.014	0.078	0.091
41	0.256	0.042	0.031	0.084	0.093	0.114	0.064	0.019	0.093	0.106
42	0.289	0.050	0.038	0.099	0.109	0.153	0.082	0.026	0.110	0.122
43	0.325	0.060	0.046	0.116	0.127	0.201	0.103	0.035	0.129	0.139
44	0.363	0.072	0.055	0.136	0.148	0.259	0.129	0.045	0.150	0.159
45	0.403	0.085	0.066	0.157	0.171	0.327	0.160	0.059	0.174	0.181
46	0.444	0.100	0.078	0.181	0.196	0.403	0.196	0.076	0.201	0.204
47	0.488	0.118	0.092	0.208	0.224	0.486	0.237	0.096	0.230	0.230
48	0.532	0.137	0.109	0.237	0.255	0.573	0.283	0.120	0.263	0.258
49	0.578	0.159	0.127	0.268	0.288	0.663	0.334	0.149	0.297	0.288
50	0.624	0.183	0.147	0.302	0.323	0.749	0.390	0.183	0.335	0.320
51	0.669	0.210	0.170	0.339	0.361	0.829	0.449	0.221	0.374	0.353
52	0.714	0.239	0.196	0.378	0.401	0.897	0.512	0.265	0.416	0.389
53	0.757	0.271	0.224	0.418	0.443	0.951	0.577	0.314	0.460	0.426
54	0.799	0.305	0.254	0.461	0.486	0.985	0.643	0.367	0.505	0.464
55	0.838	0.342	0.287	0.505	0.530	1.000	0.707	0.425	0.552	0.504
56	0.874	0.381	0.323	0.550	0.576	1.000	0.770	0.486	0.599	0.544
57	0.906	0.421	0.360	0.595	0.622	0.996	0.827	0.549	0.646	0.585
58	0.934	0.464	0.400	0.641	0.667	0.982	0.879	0.614	0.693	0.626
59	0.958	0.508	0.442	0.686	0.712	0.959	0.924	0.679	0.738	0.667
60	0.977	0.553	0.485	0.730	0.755	0.928	0.959	0.742	0.782	0.707
61	0.990	0.599	0.530	0.773	0.797	0.890	0.983	0.801	0.824	0.747
62	0.998	0.644	0.575	0.814	0.836	0.849	0.997	0.855	0.862	0.785

Table 2.20a (page 2 of 7)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries survey as defined by parameter estimates under Model B. Years correspond to beginnings of blocks.

	January-April trawl fishery					May-August trawl fishery				
Len.	1977	1990	1995	2000	2005	1977	1985	1990	2000	2005
63	1.000	0.690	0.621	0.852	0.872	0.807	1.000	0.903	0.897	0.821
64	1.000	0.734	0.666	0.886	0.905	0.766	0.999	0.942	0.927	0.855
65	1.000	0.776	0.711	0.917	0.933	0.726	0.985	0.972	0.953	0.886
66	1.000	0.817	0.755	0.944	0.957	0.690	0.956	0.992	0.973	0.914
67	1.000	0.855	0.796	0.966	0.976	0.659	0.912	1.000	0.988	0.938
68	1.000	0.889	0.836	0.982	0.989	0.632	0.858	1.000	0.997	0.959
69	1.000	0.919	0.872	0.994	0.998	0.610	0.795	0.993	1.000	0.976
70	1.000	0.946	0.904	0.999	1.000	0.593	0.729	0.966	1.000	0.988
71	1.000	0.967	0.933	1.000	1.000	0.579	0.662	0.919	0.991	0.996
72	1.000	0.983	0.957	1.000	1.000	0.569	0.597	0.857	0.966	1.000
73	1.000	0.994	0.976	1.000	1.000	0.561	0.537	0.782	0.925	1.000
74	1.000	0.999	0.989	1.000	1.000	0.556	0.483	0.699	0.871	0.995
75	1.000	1.000	0.997	1.000	1.000	0.552	0.437	0.613	0.809	0.973
76	1.000	1.000	1.000	1.000	1.000	0.550	0.398	0.529	0.741	0.934
77	1.000	1.000	1.000	1.000	1.000	0.548	0.367	0.448	0.671	0.882
78	1.000	1.000	1.000	1.000	1.000	0.547	0.342	0.375	0.603	0.819
79	1.000	1.000	1.000	1.000	1.000	0.546	0.323	0.311	0.539	0.749
80	1.000	1.000	1.000	1.000	1.000	0.546	0.309	0.256	0.481	0.677
81	1.000	1.000	1.000	1.000	1.000	0.546	0.299	0.211	0.431	0.605
82	1.000	1.000	1.000	1.000	1.000	0.546	0.291	0.175	0.388	0.537
83	1.000	1.000	1.000	1.000	1.000	0.546	0.287	0.147	0.353	0.475
84	1.000	1.000	1.000	1.000	1.000	0.545	0.283	0.126	0.325	0.420
85	1.000	1.000	1.000	1.000	1.000	0.545	0.281	0.111	0.304	0.373
86	1.000	1.000	1.000	1.000	1.000	0.545	0.280	0.100	0.287	0.335
87	1.000	1.000	1.000	1.000	1.000	0.545	0.279	0.092	0.276	0.304
88	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.087	0.267	0.280
89	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.083	0.262	0.262
90	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.081	0.258	0.249
91	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.080	0.255	0.239
92	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.079	0.253	0.232
93	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.252	0.228
94	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.252	0.225
95	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.223
96	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.222
97	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.221
98	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.221
99	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
100	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
101	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
102	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
103	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
104	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
105	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
106	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
107	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
108	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
109	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
110	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
111	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
112	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
113	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
114	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
115	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
116	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
117	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
118	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
119	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220
120	1.000	1.000	1.000	1.000	1.000	0.545	0.278	0.078	0.251	0.220

Table 2.20a (page 3 of 7)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries survey as defined by parameter estimates under Model B. Years correspond to beginnings of blocks.

	September-December trawl fishery							January-April longline fishery					
Len.	1977	1980	1985	1990	1995	2000	2005	1977	1985	1990	1995	2000	2005
4	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
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
6	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
7	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
8	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
9	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
10	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
11	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
12	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	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
14	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
15	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	0.000	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.001	0.000	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.002	0.000	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.002	0.001	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.003	0.001	0.003	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.004	0.001	0.004	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.001	0.005	0.001	0.005	0.002	0.003	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	0.001	0.006	0.002	0.006	0.003	0.004	0.000	0.000	0.000	0.000	0.000	0.000
25	0.001	0.001	0.008	0.002	0.007	0.003	0.004	0.000	0.001	0.000	0.000	0.000	0.000
26	0.001	0.002	0.011	0.003	0.009	0.004	0.005	0.000	0.001	0.000	0.000	0.000	0.000
27	0.002	0.003	0.014	0.004	0.011	0.005	0.007	0.000	0.001	0.000	0.000	0.000	0.000
28	0.004	0.005	0.017	0.006	0.013	0.007	0.008	0.000	0.001	0.000	0.000	0.000	0.000
29	0.007	0.007	0.022	0.008	0.015	0.008	0.010	0.001	0.002	0.000	0.000	0.000	0.000
30	0.013	0.009	0.027	0.010	0.018	0.010	0.012	0.001	0.002	0.000	0.000	0.000	0.000
31	0.023	0.013	0.034	0.013	0.022	0.013	0.014	0.002	0.003	0.000	0.000	0.000	0.000
32	0.038	0.018	0.042	0.017	0.026	0.016	0.017	0.002	0.004	0.001	0.001	0.000	0.000
33	0.061	0.025	0.052	0.022	0.030	0.019	0.021	0.004	0.005	0.001	0.001	0.000	0.000
34	0.095	0.034	0.063	0.028	0.036	0.024	0.024	0.006	0.007	0.001	0.001	0.001	0.000
35	0.141	0.045	0.077	0.035	0.042	0.029	0.029	0.009	0.009	0.002	0.001	0.001	0.001
36	0.203	0.060	0.092	0.044	0.049	0.035	0.034	0.013	0.011	0.003	0.002	0.001	0.001
37	0.282	0.077	0.110	0.054	0.057	0.042	0.040	0.019	0.014	0.004	0.003	0.002	0.001
38	0.376	0.099	0.131	0.067	0.066	0.050	0.047	0.028	0.018	0.005	0.004	0.003	0.002
39	0.483	0.126	0.154	0.082	0.076	0.060	0.055	0.040	0.023	0.007	0.005	0.004	0.003
40	0.599	0.157	0.181	0.099	0.087	0.071	0.064	0.055	0.028	0.009	0.006	0.006	0.004
41	0.715	0.194	0.210	0.119	0.100	0.084	0.074	0.076	0.035	0.012	0.009	0.008	0.006
42	0.822	0.237	0.243	0.143	0.114	0.098	0.085	0.102	0.043	0.017	0.011	0.011	0.009
43	0.910	0.285	0.278	0.169	0.129	0.114	0.098	0.134	0.052	0.022	0.015	0.016	0.013
44	0.971	0.339	0.317	0.199	0.146	0.133	0.112	0.174	0.063	0.029	0.019	0.021	0.018
45	0.999	0.397	0.359	0.232	0.165	0.153	0.128	0.222	0.076	0.037	0.025	0.029	0.024
46	1.000	0.460	0.403	0.268	0.185	0.176	0.145	0.278	0.091	0.048	0.032	0.038	0.032
47	1.000	0.526	0.449	0.308	0.207	0.201	0.164	0.341	0.108	0.061	0.041	0.050	0.043
48	1.000	0.595	0.497	0.352	0.231	0.228	0.185	0.412	0.127	0.076	0.051	0.066	0.057
49	1.000	0.663	0.547	0.398	0.256	0.258	0.207	0.488	0.150	0.095	0.064	0.084	0.073
50	1.000	0.730	0.597	0.447	0.283	0.290	0.231	0.568	0.175	0.117	0.079	0.107	0.094
51	1.000	0.793	0.648	0.498	0.312	0.324	0.257	0.649	0.202	0.144	0.097	0.133	0.119
52	1.000	0.851	0.698	0.550	0.342	0.360	0.285	0.729	0.233	0.174	0.118	0.165	0.149
53	1.000	0.902	0.746	0.603	0.374	0.399	0.315	0.804	0.266	0.208	0.143	0.202	0.185
54	1.000	0.943	0.793	0.656	0.407	0.439	0.346	0.870	0.303	0.247	0.170	0.244	0.225
55	1.000	0.974	0.836	0.709	0.442	0.480	0.379	0.926	0.342	0.291	0.202	0.292	0.272
56	1.000	0.993	0.876	0.760	0.477	0.523	0.413	0.967	0.383	0.338	0.237	0.344	0.323
57	1.000	1.000	0.911	0.808	0.513	0.567	0.448	0.992	0.427	0.389	0.276	0.401	0.380
58	1.000	1.000	0.941	0.852	0.550	0.611	0.485	1.000	0.473	0.444	0.319	0.462	0.441
59	1.000	1.000	0.966	0.892	0.588	0.655	0.522	1.000	0.520	0.502	0.366	0.526	0.506
60	1.000	0.994	0.984	0.927	0.625	0.698	0.560	1.000	0.569	0.561	0.415	0.592	0.573
61	1.000	0.958	0.995	0.956	0.663	0.741	0.598	1.000	0.618	0.622	0.467	0.658	0.640
62	1.000	0.893	1.000	0.978	0.700	0.782	0.637	1.000	0.666	0.681	0.522	0.723	0.707

Table 2.20a (page 4 of 7)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries survey as defined by parameter estimates under Model B. Years correspond to beginnings of blocks.

	September-December trawl fishery							January-April longline fishery					
Len.	1977	1980	1985	1990	1995	2000	2005	1977	1985	1990	1995	2000	2005
63	1.000	0.808	1.000	0.992	0.736	0.820	0.675	1.000	0.714	0.740	0.577	0.785	0.771
64	1.000	0.712	0.988	0.999	0.771	0.856	0.712	1.000	0.761	0.795	0.634	0.842	0.831
65	1.000	0.615	0.944	1.000	0.805	0.889	0.749	1.000	0.805	0.847	0.689	0.892	0.884
66	1.000	0.526	0.873	1.000	0.837	0.919	0.785	1.000	0.846	0.892	0.743	0.935	0.929
67	1.000	0.450	0.783	1.000	0.867	0.944	0.818	1.000	0.883	0.931	0.795	0.967	0.963
68	1.000	0.389	0.686	1.000	0.894	0.965	0.850	1.000	0.917	0.962	0.843	0.989	0.987
69	1.000	0.344	0.591	1.000	0.919	0.981	0.880	1.000	0.945	0.984	0.886	0.999	0.999
70	1.000	0.311	0.505	1.000	0.941	0.993	0.906	1.000	0.968	0.997	0.923	1.000	1.000
71	1.000	0.289	0.433	1.000	0.960	0.999	0.930	1.000	0.985	1.000	0.954	1.000	0.998
72	1.000	0.276	0.376	1.000	0.975	1.000	0.951	1.000	0.995	1.000	0.977	0.989	0.981
73	1.000	0.267	0.334	1.000	0.987	1.000	0.969	1.000	1.000	0.998	0.993	0.960	0.950
74	1.000	0.263	0.305	1.000	0.995	0.982	0.982	1.000	1.000	0.988	1.000	0.918	0.908
75	1.000	0.260	0.285	1.000	0.999	0.932	0.992	1.000	1.000	0.972	1.000	0.865	0.858
76	1.000	0.259	0.273	1.000	1.000	0.857	0.998	1.000	0.995	0.950	0.998	0.806	0.805
77	1.000	0.258	0.266	1.000	0.998	0.765	1.000	1.000	0.979	0.926	0.989	0.746	0.753
78	1.000	0.258	0.262	1.000	0.968	0.668	1.000	1.000	0.954	0.899	0.972	0.689	0.704
79	0.999	0.258	0.260	1.000	0.908	0.574	0.983	1.000	0.922	0.874	0.950	0.637	0.661
80	0.973	0.258	0.259	1.000	0.826	0.490	0.933	1.000	0.887	0.850	0.924	0.593	0.624
81	0.916	0.258	0.258	1.000	0.731	0.421	0.858	1.000	0.851	0.829	0.896	0.557	0.595
82	0.836	0.258	0.258	1.000	0.634	0.367	0.766	1.000	0.816	0.812	0.870	0.529	0.573
83	0.742	0.258	0.258	1.000	0.543	0.327	0.669	0.991	0.784	0.799	0.845	0.508	0.557
84	0.645	0.258	0.258	1.000	0.464	0.300	0.575	0.959	0.756	0.788	0.823	0.493	0.545
85	0.553	0.258	0.258	0.991	0.400	0.282	0.491	0.906	0.734	0.781	0.805	0.482	0.538
86	0.472	0.258	0.258	0.950	0.352	0.271	0.422	0.837	0.716	0.775	0.790	0.475	0.532
87	0.407	0.258	0.258	0.882	0.317	0.265	0.368	0.759	0.703	0.772	0.779	0.471	0.529
88	0.356	0.258	0.258	0.794	0.293	0.261	0.328	0.677	0.693	0.769	0.771	0.468	0.527
89	0.320	0.258	0.258	0.697	0.278	0.260	0.300	0.597	0.686	0.768	0.766	0.466	0.526
90	0.295	0.258	0.258	0.602	0.269	0.259	0.283	0.524	0.682	0.767	0.762	0.466	0.526
91	0.279	0.258	0.258	0.514	0.263	0.258	0.272	0.460	0.679	0.767	0.759	0.465	0.525
92	0.270	0.258	0.258	0.440	0.261	0.258	0.265	0.408	0.677	0.766	0.758	0.465	0.525
93	0.264	0.258	0.258	0.382	0.259	0.258	0.261	0.366	0.676	0.766	0.757	0.465	0.525
94	0.261	0.258	0.258	0.338	0.258	0.258	0.260	0.335	0.675	0.766	0.756	0.465	0.525
95	0.259	0.258	0.258	0.307	0.258	0.258	0.259	0.312	0.675	0.766	0.756	0.465	0.525
96	0.258	0.258	0.258	0.287	0.258	0.258	0.258	0.296	0.675	0.766	0.756	0.465	0.525
97	0.258	0.258	0.258	0.274	0.258	0.258	0.258	0.285	0.675	0.766	0.756	0.465	0.525
98	0.258	0.258	0.258	0.267	0.258	0.258	0.258	0.278	0.675	0.766	0.756	0.465	0.525
99	0.258	0.258	0.258	0.262	0.258	0.258	0.258	0.274	0.675	0.766	0.756	0.465	0.525
100	0.258	0.258	0.258	0.260	0.258	0.258	0.258	0.272	0.675	0.766	0.756	0.465	0.525
101	0.258	0.258	0.258	0.259	0.258	0.258	0.258	0.270	0.675	0.766	0.756	0.465	0.525
102	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.269	0.675	0.766	0.756	0.465	0.525
103	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.269	0.675	0.766	0.756	0.465	0.525
104	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.269	0.675	0.766	0.756	0.465	0.525
105	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
106	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
107	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
108	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
109	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
110	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
111	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
112	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
113	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
114	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
115	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
116	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
117	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
118	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
119	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525
120	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.268	0.675	0.766	0.756	0.465	0.525

Table 2.20a (page 5 of 7)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries survey as defined by parameter estimates under Model B. Years correspond to beginnings of blocks.

	May-August longline fishery				Sep-Dec longline fish.			January-April pot fishery				May-August pot fishery		
Len.	1977	1980	1990	2000	1977	1980	1990	1977	1995	2000	2005	1977	1995	2000
4	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	0.000
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	0.000
6	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	0.000
7	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	0.000
8	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	0.000
9	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	0.000
10	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	0.000
11	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	0.000
12	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	0.000
13	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	0.000
14	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	0.000
15	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	0.000
16	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	0.000
17	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	0.000
18	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	0.000
19	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	0.000
20	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	0.000
21	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	0.000
22	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	0.000
23	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	0.000
24	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	0.000
25	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	0.000
26	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	0.000
27	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	0.000
28	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	0.000
29	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	0.000
30	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	0.000
31	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
33	0.002	0.001	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34	0.004	0.001	0.000	0.000	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
35	0.006	0.002	0.000	0.000	0.005	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36	0.009	0.004	0.000	0.000	0.007	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	0.014	0.007	0.001	0.000	0.011	0.005	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000
38	0.021	0.011	0.001	0.000	0.016	0.009	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000
39	0.032	0.018	0.002	0.001	0.023	0.014	0.002	0.001	0.000	0.002	0.001	0.000	0.000	0.000
40	0.046	0.028	0.002	0.001	0.032	0.023	0.003	0.001	0.001	0.002	0.001	0.001	0.001	0.000
41	0.065	0.043	0.003	0.002	0.044	0.035	0.004	0.001	0.001	0.004	0.002	0.001	0.001	0.000
42	0.090	0.064	0.005	0.002	0.060	0.052	0.006	0.002	0.002	0.005	0.003	0.002	0.002	0.000
43	0.123	0.093	0.007	0.004	0.081	0.076	0.008	0.003	0.003	0.008	0.004	0.004	0.003	0.001
44	0.164	0.131	0.010	0.005	0.107	0.109	0.012	0.005	0.004	0.012	0.006	0.006	0.004	0.002
45	0.213	0.180	0.014	0.008	0.138	0.151	0.017	0.008	0.006	0.017	0.009	0.009	0.006	0.003
46	0.272	0.241	0.019	0.011	0.177	0.204	0.023	0.012	0.009	0.024	0.014	0.015	0.009	0.005
47	0.341	0.313	0.026	0.015	0.222	0.269	0.032	0.017	0.012	0.033	0.020	0.023	0.012	0.008
48	0.417	0.396	0.036	0.021	0.275	0.345	0.043	0.024	0.017	0.046	0.029	0.035	0.018	0.014
49	0.500	0.489	0.047	0.029	0.334	0.431	0.057	0.034	0.024	0.062	0.040	0.051	0.025	0.022
50	0.587	0.587	0.062	0.039	0.400	0.524	0.075	0.048	0.033	0.082	0.055	0.074	0.034	0.034
51	0.675	0.686	0.081	0.051	0.472	0.622	0.098	0.065	0.045	0.107	0.075	0.104	0.047	0.052
52	0.759	0.780	0.103	0.067	0.547	0.719	0.125	0.087	0.061	0.139	0.100	0.143	0.063	0.078
53	0.837	0.864	0.131	0.087	0.624	0.809	0.158	0.115	0.080	0.176	0.132	0.191	0.083	0.112
54	0.903	0.931	0.163	0.112	0.700	0.887	0.196	0.149	0.104	0.220	0.170	0.250	0.109	0.156
55	0.954	0.977	0.201	0.141	0.773	0.948	0.241	0.190	0.133	0.271	0.215	0.320	0.140	0.213
56	0.987	0.999	0.245	0.176	0.840	0.986	0.292	0.238	0.168	0.329	0.268	0.399	0.177	0.281
57	1.000	1.000	0.294	0.217	0.898	1.000	0.348	0.294	0.209	0.393	0.328	0.487	0.221	0.362
58	1.000	0.997	0.349	0.263	0.945	1.000	0.410	0.357	0.257	0.462	0.395	0.579	0.271	0.453
59	0.997	0.983	0.409	0.315	0.978	0.988	0.477	0.426	0.311	0.535	0.468	0.672	0.329	0.552
60	0.987	0.959	0.473	0.373	0.997	0.953	0.546	0.500	0.370	0.610	0.545	0.763	0.392	0.653
61	0.970	0.925	0.540	0.435	1.000	0.897	0.617	0.577	0.435	0.685	0.624	0.844	0.460	0.751
62	0.948	0.883	0.608	0.501	1.000	0.825	0.688	0.656	0.504	0.757	0.702	0.913	0.532	0.841

Table 2.20a (page 6 of 7)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries survey as defined by parameter estimates under Model B. Years correspond to beginnings of blocks.

	May-August longline fishery				Sep-Dec longline fish.			January-April pot fishery				May-August pot fishery		
Len.	1977	1980	1990	2000	1977	1980	1990	1977	1995	2000	2005	1977	1995	2000
63	0.920	0.836	0.677	0.569	0.999	0.743	0.756	0.732	0.576	0.824	0.777	0.964	0.606	0.915
64	0.890	0.785	0.743	0.639	0.996	0.658	0.820	0.804	0.649	0.884	0.845	0.993	0.680	0.968
65	0.858	0.733	0.806	0.707	0.991	0.574	0.877	0.868	0.720	0.933	0.904	1.000	0.752	0.996
66	0.825	0.682	0.862	0.773	0.985	0.497	0.925	0.922	0.788	0.969	0.950	1.000	0.819	1.000
67	0.793	0.633	0.911	0.834	0.978	0.428	0.962	0.963	0.850	0.992	0.982	0.993	0.878	0.999
68	0.762	0.588	0.951	0.888	0.969	0.371	0.987	0.990	0.903	1.000	0.998	0.977	0.928	0.990
69	0.734	0.548	0.979	0.933	0.959	0.324	0.999	1.000	0.947	1.000	1.000	0.953	0.966	0.972
70	0.709	0.513	0.996	0.967	0.947	0.288	1.000	1.000	0.978	0.992	0.998	0.921	0.990	0.946
71	0.688	0.483	1.000	0.990	0.934	0.261	0.994	0.993	0.996	0.968	0.983	0.882	1.000	0.912
72	0.669	0.458	1.000	1.000	0.919	0.242	0.963	0.968	1.000	0.931	0.956	0.839	1.000	0.872
73	0.654	0.438	0.989	1.000	0.904	0.228	0.910	0.926	0.999	0.882	0.918	0.791	0.997	0.828
74	0.642	0.422	0.963	0.999	0.887	0.219	0.841	0.871	0.986	0.826	0.875	0.741	0.984	0.779
75	0.632	0.409	0.923	0.993	0.869	0.213	0.767	0.804	0.954	0.766	0.829	0.690	0.963	0.729
76	0.625	0.400	0.871	0.983	0.850	0.210	0.694	0.731	0.907	0.705	0.783	0.639	0.934	0.678
77	0.619	0.393	0.810	0.968	0.831	0.208	0.629	0.653	0.849	0.647	0.741	0.589	0.898	0.627
78	0.615	0.388	0.744	0.951	0.810	0.206	0.576	0.576	0.784	0.594	0.704	0.542	0.856	0.578
79	0.612	0.384	0.674	0.932	0.788	0.206	0.536	0.501	0.717	0.546	0.673	0.497	0.810	0.531
80	0.610	0.382	0.604	0.911	0.766	0.205	0.507	0.431	0.651	0.506	0.649	0.457	0.760	0.487
81	0.608	0.380	0.537	0.889	0.743	0.205	0.488	0.368	0.590	0.474	0.630	0.420	0.709	0.448
82	0.607	0.379	0.473	0.868	0.720	0.205	0.476	0.313	0.536	0.447	0.617	0.387	0.658	0.412
83	0.607	0.378	0.415	0.848	0.696	0.205	0.468	0.266	0.489	0.428	0.607	0.359	0.608	0.380
84	0.606	0.378	0.364	0.830	0.672	0.205	0.464	0.227	0.452	0.413	0.601	0.335	0.560	0.353
85	0.606	0.377	0.320	0.814	0.647	0.205	0.462	0.195	0.422	0.402	0.597	0.314	0.514	0.329
86	0.606	0.377	0.283	0.799	0.622	0.205	0.461	0.171	0.400	0.395	0.595	0.297	0.472	0.309
87	0.606	0.377	0.253	0.787	0.597	0.205	0.461	0.152	0.383	0.389	0.593	0.282	0.434	0.293
88	0.606	0.377	0.229	0.777	0.572	0.205	0.461	0.138	0.372	0.386	0.592	0.271	0.399	0.279
89	0.606	0.377	0.210	0.769	0.547	0.205	0.461	0.127	0.364	0.384	0.592	0.262	0.369	0.269
90	0.606	0.377	0.195	0.762	0.522	0.205	0.460	0.120	0.359	0.383	0.591	0.255	0.343	0.260
91	0.606	0.377	0.184	0.757	0.497	0.205	0.460	0.115	0.355	0.382	0.591	0.249	0.321	0.253
92	0.606	0.377	0.176	0.753	0.472	0.205	0.460	0.111	0.353	0.381	0.591	0.245	0.303	0.248
93	0.606	0.377	0.170	0.750	0.448	0.205	0.460	0.109	0.352	0.381	0.591	0.241	0.288	0.244
94	0.606	0.377	0.166	0.748	0.424	0.205	0.460	0.107	0.351	0.381	0.591	0.239	0.275	0.241
95	0.606	0.377	0.164	0.747	0.400	0.205	0.460	0.106	0.351	0.381	0.591	0.237	0.265	0.239
96	0.606	0.377	0.162	0.746	0.377	0.205	0.460	0.106	0.351	0.381	0.591	0.236	0.257	0.237
97	0.606	0.377	0.161	0.745	0.354	0.205	0.460	0.105	0.350	0.381	0.591	0.235	0.251	0.236
98	0.606	0.377	0.160	0.745	0.331	0.205	0.460	0.105	0.350	0.381	0.591	0.234	0.246	0.235
99	0.606	0.377	0.159	0.745	0.309	0.205	0.460	0.105	0.350	0.381	0.591	0.234	0.243	0.234
100	0.606	0.377	0.159	0.744	0.288	0.205	0.460	0.105	0.350	0.381	0.591	0.234	0.240	0.234
101	0.606	0.377	0.159	0.744	0.267	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.238	0.234
102	0.606	0.377	0.159	0.744	0.247	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.236	0.233
103	0.606	0.377	0.159	0.744	0.228	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.235	0.233
104	0.606	0.377	0.159	0.744	0.209	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.235	0.233
105	0.606	0.377	0.159	0.744	0.191	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.234	0.233
106	0.606	0.377	0.158	0.744	0.173	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.234	0.233
107	0.606	0.377	0.158	0.744	0.157	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
108	0.606	0.377	0.158	0.744	0.141	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
109	0.606	0.377	0.158	0.744	0.125	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
110	0.606	0.377	0.158	0.744	0.111	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
111	0.606	0.377	0.158	0.744	0.097	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
112	0.606	0.377	0.158	0.744	0.083	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
113	0.606	0.377	0.158	0.744	0.071	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
114	0.606	0.377	0.158	0.744	0.059	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
115	0.606	0.377	0.158	0.744	0.048	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
116	0.606	0.377	0.158	0.744	0.037	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
117	0.606	0.377	0.158	0.744	0.027	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
118	0.606	0.377	0.158	0.744	0.017	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
119	0.606	0.377	0.158	0.744	0.009	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233
120	0.606	0.377	0.158	0.744	0.000	0.205	0.460	0.105	0.350	0.381	0.591	0.233	0.233	0.233

Table 2.20a (page 7 of 7)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries survey as defined by parameter estimates under Model B. Years correspond to beginnings of blocks.

	Sep-Dec pot fishery			
Len.	1977	1995	2000	2005
4	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000
25	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000
27	0.000	0.000	0.000	0.000
28	0.000	0.000	0.000	0.000
29	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000
31	0.000	0.000	0.000	0.000
32	0.000	0.000	0.000	0.000
33	0.000	0.000	0.000	0.000
34	0.001	0.000	0.000	0.000
35	0.001	0.000	0.000	0.000
36	0.001	0.000	0.001	0.000
37	0.002	0.000	0.001	0.001
38	0.003	0.001	0.002	0.001
39	0.004	0.001	0.002	0.002
40	0.006	0.001	0.004	0.002
41	0.008	0.002	0.006	0.004
42	0.010	0.003	0.009	0.006
43	0.014	0.004	0.013	0.009
44	0.019	0.006	0.018	0.013
45	0.025	0.009	0.026	0.019
46	0.032	0.013	0.036	0.027
47	0.042	0.019	0.050	0.038
48	0.053	0.026	0.068	0.053
49	0.068	0.035	0.091	0.072
50	0.085	0.047	0.119	0.096
51	0.106	0.063	0.154	0.127
52	0.130	0.082	0.195	0.164
53	0.159	0.106	0.244	0.209
54	0.192	0.136	0.300	0.261
55	0.229	0.170	0.363	0.321
56	0.271	0.211	0.432	0.389
57	0.317	0.258	0.506	0.462
58	0.367	0.311	0.583	0.539
59	0.421	0.370	0.660	0.618
60	0.478	0.434	0.736	0.697
61	0.537	0.501	0.807	0.773
62	0.598	0.572	0.870	0.842
63	0.659	0.643	0.924	0.902
64	0.718	0.713	0.964	0.949
65	0.776	0.781	0.990	0.982
66	0.829	0.842	1.000	0.998
67	0.877	0.896	1.000	1.000
68	0.919	0.940	0.996	0.999
69	0.953	0.973	0.981	0.989
70	0.978	0.993	0.955	0.970
71	0.994	1.000	0.921	0.943
72	1.000	1.000	0.880	0.909
73	1.000	0.996	0.834	0.871
74	0.994	0.984	0.785	0.829
75	0.973	0.964	0.735	0.786
76	0.938	0.939	0.685	0.743
77	0.891	0.908	0.638	0.702
78	0.834	0.874	0.595	0.663
79	0.770	0.837	0.557	0.628
80	0.702	0.801	0.523	0.598
81	0.633	0.765	0.494	0.572
82	0.566	0.731	0.470	0.550
83	0.502	0.700	0.451	0.531
84	0.442	0.672	0.435	0.517
85	0.389	0.647	0.423	0.506
86	0.343	0.627	0.414	0.497
87	0.304	0.610	0.408	0.491
88	0.271	0.596	0.403	0.486
89	0.244	0.585	0.399	0.483
90	0.223	0.577	0.397	0.480
91	0.207	0.570	0.395	0.479
92	0.195	0.565	0.394	0.477
93	0.185	0.562	0.393	0.477
94	0.179	0.560	0.393	0.476
95	0.174	0.558	0.392	0.476
96	0.171	0.557	0.392	0.476
97	0.168	0.556	0.392	0.476
98	0.167	0.555	0.392	0.476
99	0.166	0.555	0.392	0.475
100	0.165	0.555	0.392	0.475
101	0.165	0.555	0.392	0.475
102	0.165	0.555	0.392	0.475
103	0.164	0.555	0.392	0.475
104	0.164	0.555	0.392	0.475
105	0.164	0.555	0.392	0.475
106	0.164	0.555	0.392	0.475
107	0.164	0.555	0.392	0.475
108	0.164	0.555	0.392	0.475
109	0.164	0.555	0.392	0.475
110	0.164	0.555	0.392	0.475
111	0.164	0.555	0.392	0.475
112	0.164	0.555	0.392	0.475
113	0.164	0.555	0.392	0.475
114	0.164	0.555	0.392	0.475
115	0.164	0.555	0.392	0.475
116	0.164	0.555	0.392	0.475
117	0.164	0.555	0.392	0.475
118	0.164	0.555	0.392	0.475
119	0.164	0.555	0.392	0.475
120	0.164	0.555	0.392	0.475

Table 2.20b—Schedules of Pacific cod selectivities at age in the sub-27 and 27-plus bottom trawl surveys as defined by final parameter estimates under Model B (sub-27 survey does not vary with time; 27-plus selectivity schedule for 2009 is constrained to be equal to the schedule for 2007.

	Sub-27	27-plus									
Age	All	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007-9
0	0.174	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	1.000	0.006	0.000	0.005	0.011	0.013	0.015	0.013	0.002	0.015	0.011
2	0.083	0.101	0.289	0.106	0.149	0.085	0.153	0.249	0.064	0.095	0.346
3	0.000	0.545	1.000	0.602	0.670	0.311	0.613	0.927	0.478	0.342	0.999
4	0.000	0.999	1.000	0.999	0.999	0.702	0.999	1.000	0.997	0.748	1.000
5	0.000	0.785	0.996	0.999	1.000	0.988	1.000	1.000	1.000	0.998	1.000
6	0.000	0.121	0.679	0.849	1.000	1.000	1.000	0.955	1.000	1.000	0.629
7	0.000	0.121	0.272	0.559	0.834	0.476	1.000	0.804	0.843	0.977	0.628
8	0.000	0.121	0.103	0.307	0.175	0.188	1.000	0.596	0.172	0.903	0.628
9	0.000	0.121	0.072	0.169	0.175	0.188	0.270	0.389	0.172	0.788	0.628
10	0.000	0.121	0.069	0.117	0.175	0.188	0.000	0.223	0.172	0.651	0.628
11	0.000	0.121	0.069	0.103	0.175	0.188	0.000	0.113	0.172	0.507	0.628
12	0.000	0.121	0.069	0.101	0.175	0.188	0.000	0.050	0.172	0.374	0.628
13	0.000	0.121	0.069	0.101	0.175	0.188	0.000	0.020	0.172	0.260	0.628
14	0.000	0.121	0.069	0.100	0.175	0.188	0.000	0.007	0.172	0.170	0.628
15	0.000	0.121	0.069	0.100	0.175	0.188	0.000	0.002	0.172	0.105	0.628
16	0.000	0.121	0.069	0.100	0.175	0.188	0.000	0.001	0.172	0.060	0.628
17	0.000	0.121	0.069	0.100	0.175	0.188	0.000	0.000	0.172	0.032	0.628
18	0.000	0.121	0.069	0.100	0.175	0.188	0.000	0.000	0.172	0.015	0.628
19	0.000	0.121	0.069	0.100	0.175	0.188	0.000	0.000	0.172	0.006	0.628
20	0.000	0.121	0.069	0.100	0.175	0.188	0.000	0.000	0.172	0.001	0.628

Table 2.21—Schedules of population length (cm) and weight (kg) by season and age as estimated by Model B. Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Aug, Sea4=Sep-Oct, Sea5=Nov=Dec. Lengths and weights correspond to season mid-points. Survey weights and lengths correspond to population values for Sea3.

	Population length (cm)					Population weight (kg)				
Age	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5
1	16.05	18.48	22.00	25.38	27.55	0.04	0.06	0.09	0.19	0.21
2	29.66	31.70	34.67	37.51	39.33	0.28	0.32	0.40	0.61	0.65
3	41.10	42.83	45.32	47.71	49.24	0.80	0.84	0.94	1.25	1.34
4	50.73	52.18	54.28	56.29	57.58	1.56	1.58	1.67	2.04	2.20
5	58.83	60.05	61.81	63.50	64.59	2.49	2.46	2.50	2.91	3.18
6	65.64	66.67	68.15	69.57	70.48	3.52	3.42	3.39	3.81	4.19
7	71.37	72.23	73.48	74.68	75.44	4.57	4.40	4.29	4.70	5.20
8	76.19	76.92	77.97	78.97	79.62	5.61	5.35	5.15	5.53	6.17
9	80.24	80.85	81.74	82.58	83.13	6.60	6.26	5.96	6.31	7.07
10	83.65	84.17	84.91	85.62	86.08	7.52	7.10	6.71	7.02	7.89
11	86.52	86.95	87.58	88.17	88.56	8.36	7.86	7.38	7.65	8.64
12	88.93	89.29	89.82	90.32	90.65	9.11	8.54	7.98	8.21	9.30
13	90.96	91.27	91.71	92.13	92.40	9.77	9.15	8.51	8.70	9.88
14	92.67	92.92	93.29	93.65	93.88	10.36	9.68	8.97	9.13	10.39
15	94.10	94.32	94.63	94.93	95.12	10.87	10.14	9.37	9.50	10.83
16	95.31	95.49	95.75	96.00	96.17	11.31	10.54	9.71	9.82	11.21
17	96.32	96.48	96.70	96.91	97.05	11.69	10.88	10.01	10.09	11.54
18	97.18	97.31	97.49	97.67	97.78	12.02	11.18	10.27	10.32	11.82
19	97.90	98.00	98.16	98.31	98.41	12.30	11.43	10.49	10.52	12.05
20	99.17	99.24	99.35	99.45	99.51	12.80	11.89	10.88	10.89	12.49

Table 2.22a—Schedules of 2010 fleet-specific length (cm) by season and age as estimated by Model B. Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Aug, Sea4=Sep-Oct, Sea5=Nov=Dec. See Table 2.21 for survey lengths.

	Trawl fishery					Longline fishery					Pot fishery				
Age	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5
1	17.79	20.39	23.80	27.17	29.38	16.05	18.51	22.03	26.00	29.17	16.05	18.48	22.00	25.73	28.73
2	31.86	33.92	36.60	39.42	41.24	33.10	35.72	39.04	42.16	43.94	31.23	34.89	38.19	42.62	44.36
3	43.21	44.89	47.10	49.50	51.00	45.28	46.90	49.84	51.67	53.03	46.29	47.87	51.38	51.82	53.12
4	52.46	53.83	55.71	57.80	59.03	54.08	55.35	57.84	59.07	60.14	54.78	55.99	58.16	58.87	59.89
5	60.00	61.12	62.77	64.63	65.64	61.01	62.02	64.16	64.90	65.74	61.34	62.29	63.44	64.50	65.35
6	66.22	67.16	68.49	70.21	71.02	66.55	67.37	69.29	69.52	70.22	66.59	67.38	68.10	69.34	70.09
7	71.56	72.39	72.93	74.55	75.16	71.13	71.83	73.73	73.55	74.21	71.12	71.83	72.32	73.72	74.42
8	76.24	76.95	76.41	77.83	78.30	75.22	75.88	77.71	77.56	78.23	75.35	76.04	76.12	77.79	78.44
9	80.26	80.86	79.40	80.50	80.92	79.12	79.74	81.28	81.48	82.09	79.39	80.03	79.62	81.53	82.11
10	83.66	84.17	82.22	82.99	83.39	82.73	83.29	84.42	84.92	85.43	83.03	83.58	82.84	84.81	85.31
11	86.52	86.95	84.92	85.43	85.83	85.88	86.35	87.14	87.76	88.18	86.12	86.58	85.75	87.59	88.01
12	88.93	89.30	87.45	87.78	88.16	88.51	88.91	89.46	90.08	90.43	88.68	89.07	88.29	89.91	90.26
13	90.96	91.27	89.71	89.94	90.27	90.69	91.01	91.42	91.99	92.27	90.81	91.12	90.46	91.84	92.12
14	92.67	92.92	91.65	91.83	92.12	92.49	92.75	93.06	93.56	93.80	92.57	92.83	92.27	93.44	93.67
15	94.10	94.32	93.28	93.43	93.67	93.98	94.20	94.44	94.87	95.07	94.04	94.26	93.79	94.77	94.97
16	95.31	95.49	94.64	94.77	94.97	95.22	95.41	95.60	95.96	96.13	95.26	95.45	95.05	95.88	96.04
17	96.32	96.48	95.76	95.87	96.04	96.26	96.41	96.56	96.88	97.02	96.29	96.44	96.10	96.81	96.95
18	97.18	97.31	96.69	96.79	96.93	97.13	97.26	97.38	97.65	97.76	97.15	97.28	96.97	97.58	97.70
19	97.90	98.00	97.47	97.55	97.66	97.85	97.96	98.06	98.29	98.39	97.87	97.98	97.70	98.24	98.34
20	99.17	99.24	98.77	98.82	98.89	99.14	99.21	99.26	99.43	99.50	99.16	99.23	98.96	99.39	99.45

Table 2.22b—Schedules of 2010 fleet-specific weight (kg) by season and age as estimated by Model B. Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Aug, Sea4=Sep-Oct, Sea5=Nov=Dec. See Table 2.21 for survey weights.

	Trawl fishery					Longline fishery					Pot fishery				
Age	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5
1	0.07	0.09	0.16	0.26	0.28	0.05	0.07	0.13	0.23	0.28	0.05	0.07	0.12	0.23	0.27
2	0.39	0.44	0.56	0.76	0.81	0.44	0.51	0.68	0.92	0.98	0.38	0.49	0.65	0.94	1.01
3	1.00	1.04	1.18	1.46	1.56	1.15	1.18	1.39	1.64	1.76	1.23	1.26	1.52	1.66	1.77
4	1.81	1.81	1.94	2.27	2.46	1.98	1.97	2.16	2.42	2.60	2.06	2.03	2.20	2.39	2.56
5	2.73	2.67	2.77	3.14	3.42	2.87	2.79	2.95	3.17	3.43	2.91	2.82	2.85	3.11	3.37
6	3.70	3.57	3.59	3.98	4.37	3.75	3.60	3.71	3.87	4.21	3.75	3.60	3.52	3.84	4.19
7	4.70	4.50	4.33	4.73	5.20	4.60	4.39	4.47	4.56	5.01	4.60	4.39	4.22	4.59	5.06
8	5.71	5.44	4.97	5.35	5.91	5.47	5.20	5.24	5.32	5.92	5.51	5.24	4.92	5.37	5.97
9	6.69	6.33	5.58	5.91	6.55	6.40	6.08	5.99	6.14	6.89	6.47	6.14	5.64	6.15	6.88
10	7.60	7.17	6.20	6.46	7.21	7.35	6.95	6.71	6.92	7.79	7.43	7.02	6.35	6.89	7.75
11	8.42	7.92	6.84	7.04	7.91	8.25	7.77	7.38	7.61	8.60	8.32	7.83	7.05	7.56	8.54
12	9.17	8.60	7.48	7.62	8.61	9.05	8.49	7.98	8.20	9.29	9.10	8.54	7.69	8.15	9.24
13	9.83	9.20	8.07	8.18	9.27	9.75	9.13	8.51	8.70	9.89	9.78	9.16	8.26	8.67	9.84
14	10.40	9.72	8.60	8.69	9.87	10.35	9.67	8.98	9.14	10.40	10.38	9.69	8.77	9.11	10.36
15	10.91	10.18	9.07	9.13	10.40	10.87	10.14	9.38	9.51	10.85	10.89	10.16	9.20	9.48	10.81
16	11.34	10.57	9.46	9.51	10.85	11.32	10.55	9.72	9.83	11.23	11.33	10.56	9.57	9.81	11.20
17	11.72	10.91	9.80	9.83	11.23	11.70	10.89	10.02	10.10	11.55	11.71	10.90	9.89	10.08	11.53
18	12.04	11.20	10.08	10.10	11.55	12.03	11.19	10.27	10.34	11.83	12.03	11.19	10.16	10.32	11.81
19	12.32	11.45	10.32	10.33	11.82	12.30	11.44	10.49	10.53	12.07	12.31	11.44	10.39	10.52	12.05
20	12.82	11.91	10.74	10.72	12.30	12.81	11.90	10.88	10.89	12.50	12.81	11.90	10.79	10.88	12.48

Table 2.23a—Time series of GOA Pacific cod age 0+ biomass, female spawning biomass (t), and standard deviation of spawning biomass as estimated last year under the Plan Team's and SSC's preferred model and this year under Model B. Values for 2011 listed under this year's assessment represent Stock Synthesis projections, and may not correspond exactly to values generated by the standard projection model.

	Last year's assessment			This year's assessment		
Year	Age 0+ bio.	Spawn. bio.	Std. dev.	Age 0+ bio.	Spawn. bio.	Std. dev.
1977	403,489	136,186	17,735	537,214	158,247	18,298
1978	422,637	160,132	18,307	584,201	186,593	19,999
1979	461,997	163,907	17,896	650,385	194,541	19,925
1980	516,504	159,027	16,905	713,082	196,358	18,802
1981	537,465	164,605	17,036	728,761	215,009	18,752
1982	535,727	190,837	18,580	715,356	242,461	19,612
1983	528,201	198,042	18,106	695,164	240,658	18,671
1984	515,566	187,314	16,174	668,973	223,085	16,781
1985	519,256	181,428	14,328	658,371	213,126	14,785
1986	530,368	185,445	12,648	658,605	211,306	12,913
1987	534,174	191,279	11,334	653,493	212,431	11,268
1988	528,339	190,263	10,680	639,902	203,905	9,846
1989	519,241	187,462	9,966	628,407	197,412	8,816
1990	504,318	181,049	8,258	611,117	187,446	7,967
1991	475,188	159,824	6,978	577,245	169,320	7,203
1992	459,088	143,723	6,431	554,076	150,715	6,696
1993	447,949	134,387	6,229	535,341	144,140	6,462
1994	457,855	143,630	6,321	539,574	148,816	6,470
1995	470,308	156,502	6,244	549,595	156,929	6,387
1996	462,568	154,448	5,949	537,665	151,639	6,182
1997	455,565	149,001	5,600	527,015	144,069	5,986
1998	434,853	141,599	5,393	504,428	132,668	5,999
1999	409,637	139,263	5,514	479,797	129,351	6,256
2000	371,951	128,932	5,603	439,671	117,910	6,489
2001	352,131	118,369	5,482	417,246	117,221	6,558
2002	351,396	111,469	5,340	413,776	111,480	6,520
2003	345,473	107,626	5,557	407,624	102,852	6,629
2004	334,355	110,265	6,217	401,492	103,224	7,142
2005	319,165	108,929	7,051	390,737	105,580	7,863
2006	325,306	103,100	7,597	395,661	103,394	8,370
2007	370,128	96,839	8,273	418,804	102,792	8,964
2008	475,523	98,512	9,846	451,683	101,898	10,109
2009	615,610	115,196	13,441	475,665	109,328	12,474
2010				490,165	122,871	16,437
2011				470,608	123,640	17,729

Table 2.23b—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 B.

	Last year's assessment		This year's assessment	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	533,640	57,186	658,920	48,397
1978	200,794	37,044	170,043	16,672
1979	146,871	22,856	187,438	13,303
1980	174,402	15,043	211,016	12,578
1981	182,684	14,717	216,926	13,576
1982	274,476	20,988	300,084	18,063
1983	247,450	25,293	206,808	15,683
1984	285,355	32,364	208,685	14,453
1985	207,324	24,676	314,747	16,047
1986	172,402	15,861	172,579	10,498
1987	234,053	18,410	279,948	11,851
1988	213,655	15,690	216,671	11,154
1989	306,007	19,661	307,094	14,263
1990	299,631	18,670	269,066	12,780
1991	262,718	17,793	260,819	11,848
1992	227,272	17,048	221,870	11,224
1993	236,014	18,627	245,288	11,515
1994	302,847	18,760	258,490	12,092
1995	253,921	16,859	243,707	11,608
1996	191,267	15,825	216,053	11,415
1997	144,517	11,916	164,429	8,726
1998	195,679	13,704	165,149	9,035
1999	249,443	15,969	212,406	11,888
2000	257,218	19,475	248,005	15,008
2001	142,246	14,313	171,103	11,481
2002	111,348	13,642	168,121	12,162
2003	168,890	17,594	196,272	15,826
2004	157,187	17,735	208,035	18,859
2005	318,968	38,970	354,908	38,594
2006	489,736	67,522	297,679	38,266
2007	552,154	101,439	244,508	41,571
2008	645,932	168,209	136,909	28,520
Average	262,066		241,681	

Table 2.23c—Numbers (1000s) at age at time of spawning (March) as estimated by Model B.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	658920	175351	69095	56379	83226	36293	16833	8452	4668	2924	1991	1416	1023	742	719	485	327	221	149	100	208
1978	170043	450609	119909	47198	38357	56405	24576	11401	5727	3165	1983	1352	962	696	505	489	330	223	150	101	210
1979	187438	116286	308127	81766	31850	25564	37477	16349	7596	3822	2116	1329	907	647	468	340	330	222	150	101	210
1980	211016	128181	79510	209840	54822	20994	16783	24640	10769	5014	2530	1405	885	605	432	313	228	221	149	101	209
1981	216926	144306	87648	54141	138407	34753	13359	10849	16058	7042	3287	1662	925	584	400	286	207	151	146	99	206
1982	300084	148347	98671	59646	35612	87531	22138	8666	7102	10551	4637	2168	1098	612	387	265	190	138	100	97	202
1983	206808	205215	101431	67166	39299	22616	55989	14400	5684	4674	6957	3064	1435	728	406	257	176	126	92	67	199
1984	208685	141427	140305	68944	43644	24238	14087	35717	9297	3687	3040	4536	2001	939	477	266	169	116	83	60	175
1985	314747	142711	96697	95594	45953	28272	15692	9201	23448	6119	2431	2007	3000	1325	622	316	177	112	77	55	156
1986	172579	215242	97567	65944	64521	30502	18595	10312	6060	15486	4050	1612	1332	1992	881	414	210	118	74	51	140
1987	279948	118019	147134	66466	44256	42337	19855	12132	6753	3981	10200	2673	1065	881	1317	582	274	139	78	49	127
1988	216671	191440	80614	99619	43639	27882	26351	12526	7773	4367	2587	6643	1743	695	575	860	380	179	91	51	115
1989	307094	148166	130747	54589	65668	27696	17400	16559	7967	4985	2813	1670	4294	1127	450	372	557	246	116	59	107
1990	269066	210008	101291	88923	35987	40756	16538	10389	10030	4882	3074	1741	1035	2663	699	279	231	345	153	72	103
1991	260819	184003	143571	68930	58925	22257	23323	9144	5796	5730	2847	1819	1039	622	1606	423	169	140	210	93	106
1992	221870	178362	125791	97693	45648	36277	12403	12120	4654	2969	2969	1489	957	549	329	851	224	90	74	111	106
1993	245288	151727	121949	85718	65092	28418	20487	6552	6305	2449	1586	1604	810	523	301	181	468	123	49	41	119
1994	258490	167742	103737	83103	57209	40900	16444	11248	3567	3478	1371	898	914	464	300	173	104	269	71	28	92
1995	243707	176771	114700	70796	55886	36747	24632	9490	6435	2059	2029	807	531	542	275	178	103	62	160	42	72
1996	216053	166661	120857	78181	47327	35222	21194	13234	4960	3370	1090	1084	434	286	293	149	97	56	34	87	62
1997	164429	147749	113945	82360	52138	29582	20074	11282	6886	2593	1783	582	583	234	155	159	81	52	30	18	81
1998	165149	112446	100989	77461	54315	31567	15896	9902	5424	3346	1285	897	296	298	120	80	82	42	27	16	51
1999	212406	112938	76870	68745	51342	33253	17310	8097	4968	2769	1747	682	482	160	162	65	43	45	23	15	36
2000	248005	145253	77170	52108	44614	29787	16897	8166	3803	2402	1383	893	354	252	84	86	35	23	24	12	27
2001	171103	169599	99288	52473	34423	27411	16900	9301	4556	2174	1400	815	530	211	150	50	51	21	14	14	24
2002	168121	117009	115918	67428	34460	20886	15336	9204	5161	2604	1271	830	486	318	127	91	30	31	12	8	23
2003	196272	114969	79975	78714	43961	20187	10950	7761	4775	2780	1442	716	471	278	182	73	52	17	18	7	18
2004	208035	134221	78578	54283	51298	25901	10753	5654	4115	2634	1579	833	417	276	163	107	43	31	10	10	15
2005	354908	142264	91728	53350	35622	30804	14121	5663	3038	2286	1500	913	485	244	162	96	63	25	18	6	15
2006	297679	242703	97229	62333	35175	21646	17085	7554	3064	1683	1291	857	525	280	141	94	55	36	15	10	12
2007	244508	203568	165891	66139	41303	21671	12249	9332	4169	1729	966	749	500	307	164	83	55	33	21	9	13
2008	136909	167206	139114	112631	43407	24724	11644	6284	4845	2227	945	536	418	281	173	93	47	31	18	12	12
2009	250433	93625	114276	94524	74034	25973	13218	5918	3229	2568	1213	524	300	236	159	98	53	27	18	10	14
2010	250433	171258	63986	77607	61865	43790	13753	6710	3050	1715	1397	670	292	168	132	89	55	30	15	10	14

Table 2.24—Estimates of "effective" fishing mortality (= $-\ln(N_{a+1,t+1}/N_{a,t})-M$) at age and year for Model B.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.000	0.000	0.002	0.005	0.006	0.006	0.005	0.005	0.005	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003
1978	0.000	0.002	0.010	0.023	0.028	0.027	0.025	0.024	0.022	0.020	0.019	0.017	0.016	0.015	0.015	0.014	0.014	0.013	0.013
1979	0.000	0.002	0.012	0.027	0.032	0.031	0.029	0.027	0.026	0.024	0.022	0.020	0.019	0.018	0.017	0.016	0.016	0.016	0.015
1980	0.000	0.003	0.033	0.077	0.078	0.063	0.055	0.051	0.049	0.046	0.044	0.041	0.039	0.037	0.036	0.035	0.035	0.034	0.034
1981	0.000	0.004	0.035	0.076	0.071	0.053	0.044	0.041	0.039	0.037	0.035	0.033	0.032	0.031	0.030	0.030	0.029	0.029	0.029
1982	0.000	0.003	0.032	0.069	0.064	0.048	0.039	0.036	0.035	0.033	0.031	0.030	0.029	0.028	0.027	0.027	0.026	0.026	0.026
1983	0.000	0.004	0.045	0.098	0.091	0.068	0.056	0.051	0.049	0.047	0.045	0.043	0.042	0.041	0.040	0.040	0.039	0.039	0.038
1984	0.000	0.003	0.024	0.055	0.057	0.048	0.042	0.040	0.039	0.037	0.034	0.032	0.031	0.029	0.029	0.028	0.027	0.027	0.026
1985	0.000	0.002	0.009	0.022	0.030	0.031	0.030	0.029	0.027	0.025	0.024	0.024	0.023	0.023	0.023	0.023	0.023	0.023	0.023
1986	0.000	0.003	0.016	0.040	0.051	0.053	0.052	0.049	0.046	0.043	0.041	0.040	0.040	0.039	0.039	0.039	0.039	0.039	0.039
1987	0.001	0.007	0.033	0.072	0.085	0.072	0.058	0.049	0.045	0.042	0.041	0.040	0.040	0.040	0.039	0.039	0.039	0.039	0.039
1988	0.000	0.005	0.027	0.064	0.084	0.079	0.067	0.059	0.054	0.051	0.050	0.049	0.049	0.049	0.049	0.048	0.048	0.048	0.048
1989	0.000	0.004	0.030	0.082	0.110	0.105	0.090	0.078	0.072	0.070	0.068	0.068	0.067	0.067	0.067	0.067	0.067	0.067	0.067
1990	0.000	0.003	0.024	0.087	0.166	0.210	0.209	0.189	0.170	0.156	0.147	0.141	0.137	0.134	0.133	0.131	0.130	0.130	0.129
1991	0.000	0.002	0.016	0.069	0.157	0.231	0.257	0.254	0.243	0.234	0.227	0.224	0.221	0.220	0.219	0.219	0.218	0.218	0.218
1992	0.000	0.002	0.018	0.080	0.187	0.274	0.302	0.294	0.279	0.266	0.259	0.254	0.251	0.249	0.248	0.248	0.247	0.247	0.247
1993	0.000	0.001	0.013	0.059	0.138	0.201	0.220	0.211	0.196	0.186	0.179	0.174	0.172	0.170	0.169	0.169	0.168	0.168	0.168
1994	0.000	0.001	0.010	0.044	0.105	0.157	0.174	0.169	0.158	0.150	0.144	0.141	0.139	0.138	0.137	0.137	0.137	0.136	0.136
1995	0.000	0.002	0.012	0.054	0.136	0.218	0.258	0.260	0.249	0.237	0.229	0.224	0.221	0.219	0.218	0.217	0.217	0.217	0.216
1996	0.000	0.001	0.013	0.057	0.139	0.218	0.255	0.256	0.246	0.235	0.228	0.224	0.221	0.220	0.219	0.219	0.218	0.218	0.218
1997	0.000	0.003	0.018	0.070	0.168	0.261	0.304	0.303	0.287	0.271	0.260	0.254	0.249	0.247	0.246	0.245	0.244	0.243	0.243
1998	0.000	0.002	0.014	0.065	0.166	0.263	0.305	0.300	0.280	0.261	0.249	0.241	0.237	0.234	0.232	0.231	0.231	0.230	0.229
1999	0.000	0.003	0.017	0.075	0.199	0.321	0.372	0.363	0.332	0.305	0.286	0.275	0.267	0.263	0.260	0.258	0.257	0.256	0.255
2000	0.000	0.002	0.017	0.080	0.198	0.278	0.282	0.249	0.219	0.199	0.188	0.182	0.179	0.178	0.177	0.176	0.176	0.175	0.175
2001	0.000	0.003	0.022	0.080	0.170	0.225	0.222	0.193	0.167	0.150	0.141	0.136	0.134	0.132	0.131	0.131	0.130	0.130	0.130
2002	0.000	0.002	0.021	0.090	0.197	0.259	0.254	0.222	0.193	0.175	0.165	0.160	0.157	0.156	0.155	0.154	0.154	0.154	0.154
2003	0.000	0.003	0.021	0.087	0.196	0.266	0.262	0.225	0.192	0.171	0.159	0.153	0.150	0.148	0.147	0.147	0.147	0.146	0.146
2004	0.000	0.003	0.022	0.093	0.213	0.288	0.282	0.240	0.202	0.179	0.166	0.160	0.156	0.154	0.153	0.153	0.152	0.152	0.152
2005	0.000	0.002	0.015	0.068	0.164	0.229	0.234	0.212	0.190	0.176	0.168	0.164	0.162	0.160	0.159	0.159	0.158	0.158	0.158
2006	0.000	0.002	0.013	0.065	0.164	0.232	0.238	0.215	0.194	0.180	0.173	0.169	0.167	0.166	0.165	0.165	0.165	0.165	0.164
2007	0.000	0.002	0.017	0.078	0.187	0.260	0.264	0.237	0.212	0.196	0.187	0.182	0.180	0.178	0.177	0.176	0.176	0.176	0.176
2008	0.000	0.004	0.022	0.091	0.212	0.296	0.303	0.274	0.245	0.225	0.213	0.206	0.202	0.200	0.198	0.198	0.197	0.197	0.196
2009	0.000	0.002	0.016	0.072	0.174	0.247	0.253	0.227	0.201	0.184	0.174	0.169	0.165	0.164	0.163	0.162	0.162	0.161	0.161
2010	0.000	0.003	0.022	0.095	0.228	0.323	0.330	0.296	0.263	0.240	0.227	0.220	0.216	0.214	0.213	0.212	0.211	0.211	0.211

Table 2.25—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2011-2023 (Scenarios 1-2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	86,800	86,800	86,800	86,800	0
2012	78,200	78,200	78,200	78,200	0
2013	67,800	67,800	67,800	67,800	6
2014	65,100	65,300	65,300	65,500	130
2015	67,000	68,700	68,900	71,300	1,364
2016	63,700	70,600	70,900	78,300	4,587
2017	57,200	71,100	70,800	84,500	8,429
2018	54,100	71,900	71,100	87,900	10,446
2019	53,700	72,800	71,600	89,300	11,031
2020	53,400	72,500	71,900	90,900	11,036
2021	53,300	72,200	71,800	89,200	10,985
2022	53,400	72,600	71,700	88,400	10,890
2023	54,000	72,500	71,500	88,400	10,923

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	124,000	124,000	124,000	124,000	0
2012	112,000	112,000	112,000	112,000	0
2013	99,100	99,100	99,100	99,100	2
2014	97,400	97,400	97,400	97,500	49
2015	99,000	99,700	99,700	101,000	570
2016	96,400	101,000	101,000	108,000	3,585
2017	91,100	101,000	102,000	118,000	8,236
2018	88,800	102,000	103,000	122,000	10,456
2019	88,200	102,000	104,000	124,000	11,323
2020	88,100	102,000	104,000	128,000	11,584
2021	88,200	102,000	104,000	125,000	11,507
2022	87,900	102,000	104,000	125,000	11,322
2023	88,500	102,000	104,000	123,000	11,281

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	0.42	0.42	0.42	0.42	0.00
2012	0.42	0.42	0.42	0.42	0.00
2013	0.41	0.41	0.41	0.41	0.00
2014	0.40	0.40	0.40	0.40	0.00
2015	0.41	0.41	0.41	0.42	0.00
2016	0.40	0.42	0.41	0.42	0.01
2017	0.37	0.42	0.41	0.42	0.02
2018	0.36	0.42	0.41	0.42	0.02
2019	0.36	0.42	0.41	0.42	0.02
2020	0.36	0.42	0.41	0.42	0.02
2021	0.36	0.42	0.41	0.42	0.02
2022	0.36	0.42	0.41	0.42	0.02
2023	0.36	0.42	0.41	0.42	0.02

Table 2.26—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 2011-2023 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	64,000	64,000	64,000	64,000	0
2012	61,700	61,700	61,700	61,700	0
2013	57,700	57,700	57,700	57,700	3
2014	56,900	57,000	57,000	57,200	74
2015	57,800	58,700	58,800	60,100	733
2016	56,900	60,100	60,500	65,000	2,558
2017	54,200	60,900	61,400	70,500	5,029
2018	52,200	61,400	62,000	74,000	6,695
2019	51,600	62,100	62,400	75,400	7,427
2020	51,400	61,900	62,700	76,700	7,645
2021	51,100	61,800	62,700	76,100	7,622
2022	50,800	62,100	62,600	75,500	7,528
2023	51,100	62,000	62,500	75,000	7,500

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	127,000	127,000	127,000	127,000	0
2012	123,000	123,000	123,000	123,000	0
2013	115,000	115,000	115,000	115,000	2
2014	114,000	114,000	114,000	115,000	53
2015	117,000	117,000	118,000	119,000	631
2016	115,000	120,000	120,000	127,000	3,950
2017	109,000	121,000	122,000	140,000	9,511
2018	105,000	122,000	123,000	147,000	12,782
2019	103,000	124,000	124,000	149,000	14,358
2020	103,000	123,000	125,000	153,000	14,974
2021	103,000	123,000	125,000	152,000	15,043
2022	102,000	124,000	125,000	151,000	14,890
2023	102,000	124,000	125,000	150,000	14,834

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	0.30	0.30	0.30	0.30	0.00
2012	0.30	0.30	0.30	0.30	0.00
2013	0.30	0.30	0.30	0.30	0.00
2014	0.30	0.30	0.30	0.30	0.00
2015	0.30	0.30	0.30	0.30	0.00
2016	0.30	0.30	0.30	0.30	0.00
2017	0.30	0.30	0.30	0.30	0.00
2018	0.30	0.30	0.30	0.30	0.00
2019	0.30	0.30	0.30	0.30	0.00
2020	0.30	0.30	0.30	0.30	0.00
2021	0.30	0.30	0.30	0.30	0.00
2022	0.30	0.30	0.30	0.30	0.00
2023	0.30	0.30	0.30	0.30	0.00

Table 2.27—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 2011-2023 (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	44,100	44,100	44,100	44,100	0
2012	45,000	45,000	45,000	45,000	0
2013	43,900	43,900	43,900	43,900	2
2014	44,100	44,200	44,200	44,300	50
2015	45,300	45,900	46,000	46,800	493
2016	45,200	47,400	47,600	50,700	1,748
2017	43,600	48,300	48,700	55,100	3,552
2018	42,100	48,900	49,300	58,100	4,895
2019	41,900	49,500	49,800	59,300	5,557
2020	41,500	49,500	50,100	60,500	5,800
2021	41,400	49,600	50,200	60,400	5,829
2022	41,200	49,700	50,200	60,300	5,775
2023	41,500	49,900	50,200	60,000	5,750

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	130,000	130,000	130,000	130,000	0
2012	133,000	133,000	133,000	133,000	0
2013	130,000	130,000	130,000	130,000	2
2014	133,000	133,000	133,000	133,000	53
2015	137,000	138,000	138,000	139,000	633
2016	137,000	142,000	143,000	150,000	4,020
2017	132,000	145,000	146,000	164,000	9,991
2018	128,000	147,000	148,000	174,000	13,858
2019	127,000	150,000	150,000	177,000	15,945
2020	126,000	150,000	151,000	182,000	16,913
2021	127,000	150,000	152,000	183,000	17,183
2022	126,000	151,000	152,000	182,000	17,110
2023	126,000	151,000	152,000	181,000	17,064

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	0.20	0.20	0.20	0.20	0.00
2012	0.20	0.20	0.20	0.20	0.00
2013	0.20	0.20	0.20	0.20	0.00
2014	0.20	0.20	0.20	0.20	0.00
2015	0.20	0.20	0.20	0.20	0.00
2016	0.20	0.20	0.20	0.20	0.00
2017	0.20	0.20	0.20	0.20	0.00
2018	0.20	0.20	0.20	0.20	0.00
2019	0.20	0.20	0.20	0.20	0.00
2020	0.20	0.20	0.20	0.20	0.00
2021	0.20	0.20	0.20	0.20	0.00
2022	0.20	0.20	0.20	0.20	0.00
2023	0.20	0.20	0.20	0.20	0.00

Table 2.28—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = 0 in 2011-2023 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2023	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	135,000	135,000	135,000	135,000	0
2012	157,000	157,000	157,000	157,000	0
2013	170,000	170,000	170,000	170,000	2
2014	185,000	185,000	185,000	185,000	53
2015	199,000	200,000	200,000	201,000	638
2016	208,000	213,000	213,000	221,000	4,165
2017	208,000	222,000	224,000	244,000	11,048
2018	208,000	231,000	232,000	262,000	16,464
2019	209,000	237,000	238,000	273,000	20,154
2020	211,000	242,000	243,000	283,000	22,460
2021	212,000	244,000	247,000	289,000	23,697
2022	211,000	246,000	249,000	292,000	24,205
2023	213,000	249,000	250,000	293,000	24,448

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2023	0.00	0.00	0.00	0.00	0.00

Table 2.29—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2011-2023 (Scenario 6), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	103,000	103,000	103,000	103,000	0
2012	88,000	88,000	88,000	88,000	0
2013	67,800	67,800	67,800	67,800	6
2014	66,700	66,900	66,900	67,200	143
2015	69,700	71,600	71,800	74,500	1,518
2016	66,200	73,800	74,700	86,200	6,159
2017	59,200	74,200	75,400	94,400	10,868
2018	56,400	74,700	75,500	96,400	12,728
2019	55,700	74,900	75,800	98,100	13,225
2020	55,300	74,700	75,900	98,900	13,195
2021	55,200	74,500	75,700	96,800	13,080
2022	55,400	74,500	75,300	96,500	12,937
2023	55,800	74,000	75,200	96,300	13,079

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	122,000	122,000	122,000	122,000	0
2012	104,000	104,000	104,000	104,000	0
2013	90,000	90,000	90,000	90,000	2
2014	89,400	89,500	89,500	89,600	48
2015	91,600	92,300	92,300	93,400	564
2016	89,200	93,400	93,900	99,900	3,386
2017	84,100	93,600	94,500	108,000	7,338
2018	82,000	93,900	94,700	111,000	8,911
2019	81,400	94,300	95,000	112,000	9,460
2020	81,300	93,900	95,200	113,000	9,552
2021	81,400	93,800	95,000	112,000	9,388
2022	81,400	94,000	94,700	111,000	9,252
2023	81,600	93,600	94,600	110,000	9,255

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	0.51	0.51	0.51	0.51	0.00
2012	0.51	0.51	0.51	0.51	0.00
2013	0.45	0.45	0.45	0.45	0.00
2014	0.44	0.44	0.44	0.45	0.00
2015	0.46	0.46	0.46	0.47	0.00
2016	0.44	0.47	0.47	0.50	0.02
2017	0.42	0.47	0.47	0.51	0.03
2018	0.41	0.47	0.47	0.51	0.04
2019	0.40	0.47	0.47	0.51	0.04
2020	0.40	0.47	0.47	0.51	0.04
2021	0.40	0.47	0.47	0.51	0.04
2022	0.40	0.47	0.47	0.51	0.04
2023	0.40	0.47	0.47	0.51	0.04

Table 2.30—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2011-2012 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	86,800	86,800	86,800	86,800	0
2012	78,200	78,200	78,200	78,200	0
2013	79,100	79,100	79,100	79,100	7
2014	70,800	71,000	71,000	71,300	148
2015	70,800	72,700	73,000	75,700	1,530
2016	66,400	73,900	74,900	86,400	6,152
2017	59,200	74,200	75,300	94,400	10,860
2018	56,400	74,600	75,400	96,400	12,728
2019	55,700	74,900	75,800	98,100	13,226
2020	55,300	74,700	75,800	98,900	13,196
2021	55,100	74,500	75,700	96,800	13,080
2022	55,400	74,500	75,300	96,500	12,937
2023	55,800	74,000	75,200	96,300	13,079

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	124,000	124,000	124,000	124,000	0
2012	112,000	112,000	112,000	112,000	0
2013	97,600	97,600	97,600	97,600	2
2014	92,400	92,400	92,400	92,500	48
2015	92,500	93,200	93,300	94,300	563
2016	89,400	93,600	94,100	100,000	3,384
2017	84,100	93,700	94,500	108,000	7,337
2018	82,000	93,900	94,600	111,000	8,911
2019	81,400	94,200	95,000	112,000	9,460
2020	81,300	93,900	95,200	113,000	9,551
2021	81,400	93,800	94,900	112,000	9,387
2022	81,400	94,000	94,700	111,000	9,252
2023	81,600	93,600	94,600	110,000	9,255

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	0.42	0.42	0.42	0.42	0.00
2012	0.42	0.42	0.42	0.42	0.00
2013	0.49	0.49	0.49	0.49	0.00
2014	0.46	0.46	0.46	0.46	0.00
2015	0.46	0.46	0.46	0.47	0.00
2016	0.44	0.47	0.47	0.50	0.02
2017	0.42	0.47	0.47	0.51	0.03
2018	0.40	0.47	0.47	0.51	0.04
2019	0.40	0.47	0.47	0.51	0.04
2020	0.40	0.47	0.47	0.51	0.04
2021	0.40	0.47	0.47	0.51	0.04
2022	0.40	0.47	0.47	0.51	0.04
2023	0.40	0.47	0.47	0.51	0.04

Table 2.31—Discarded catch (t) of species groups by GOA Pacific cod fisheries, 2003-2010.

Species group	2003	2004	2005	2006	2007	2008	2009	2010
Benthic urochordata		0		0	0	1	3	0
Birds	0	0	0	1	0	1	0	0
Bivalves	1	0	1	2	1	2	4	2
Brittle star unidentified	0	0	0	0	0	0	0	0
Capelin						0		
Corals Bryozoans	0	0	0	0	0	0	2	0
Dark Rockfish						0	3	6
Eelpouts	0	0	0	0		0	0	0
Eulachon	0		0	2	0	0		0
Giant Grenadier				22	82	31	51	136
Greenlings	3	6	1	4	1	7	1	1
Grenadier	5	0		1		66	7	0
Gunnels						0		
Hermit crab unidentified	1	0	0	1	2	3	4	2
Invertebrate unidentified	1	4	0	13	2	1	0	1
Large Sculpins	64	412	294	351	437	741	552	562
Misc crabs	1	0	2	1	7	2	2	4
Misc crustaceans		0					0	
Misc fish	86	137	153	176	539	211	99	85
Misc inverts (worms etc)				0	0		0	
Octopus	189	250	139	151	242	326	297	249
Other osmerids		0			0			
Other Sculpins	318	19	26	10	7	4	10	5
Pacific Sand lance		0		0			0	
Pandalid shrimp			0		0	0	0	
Scypho jellies	9	2	1	5	0	0	0	2
Sea anemone unidentified	1	2	1	0	5	6	7	7
Sea pens whips	0	0	0	3	1		3	3
Sea star	468	1009	938	703	301	316	472	833
Shark, Other	6	3	1	12	39	2	3	0
Shark, pacific sleeper	56	26	134	14	9	13	4	3
Shark, salmon		2	1	1				
Shark, spiny dogfish	44	20	28	113	252	290	115	80
Skate, Alaska								26
Skate, Big		331	222	417	537	586	550	911
Skate, Longnose	10	83	139	165	306	361	325	368
Skate, Other	806	490	175	981	529	958	689	942
Snails	5	1	5	3	1	1	2	1
Sponge unidentified	0	1	1	1	0	1	2	0
Squid	14	0	0	0	0	0	0	0
Stichaeidae	0		0				2	0
Surf smelt			0					
Urchins, dollars, cucumbers	1	1	1	1	3	1	1	1
Grand total	2089	2796	2264	3153	3303	3933	3210	4230

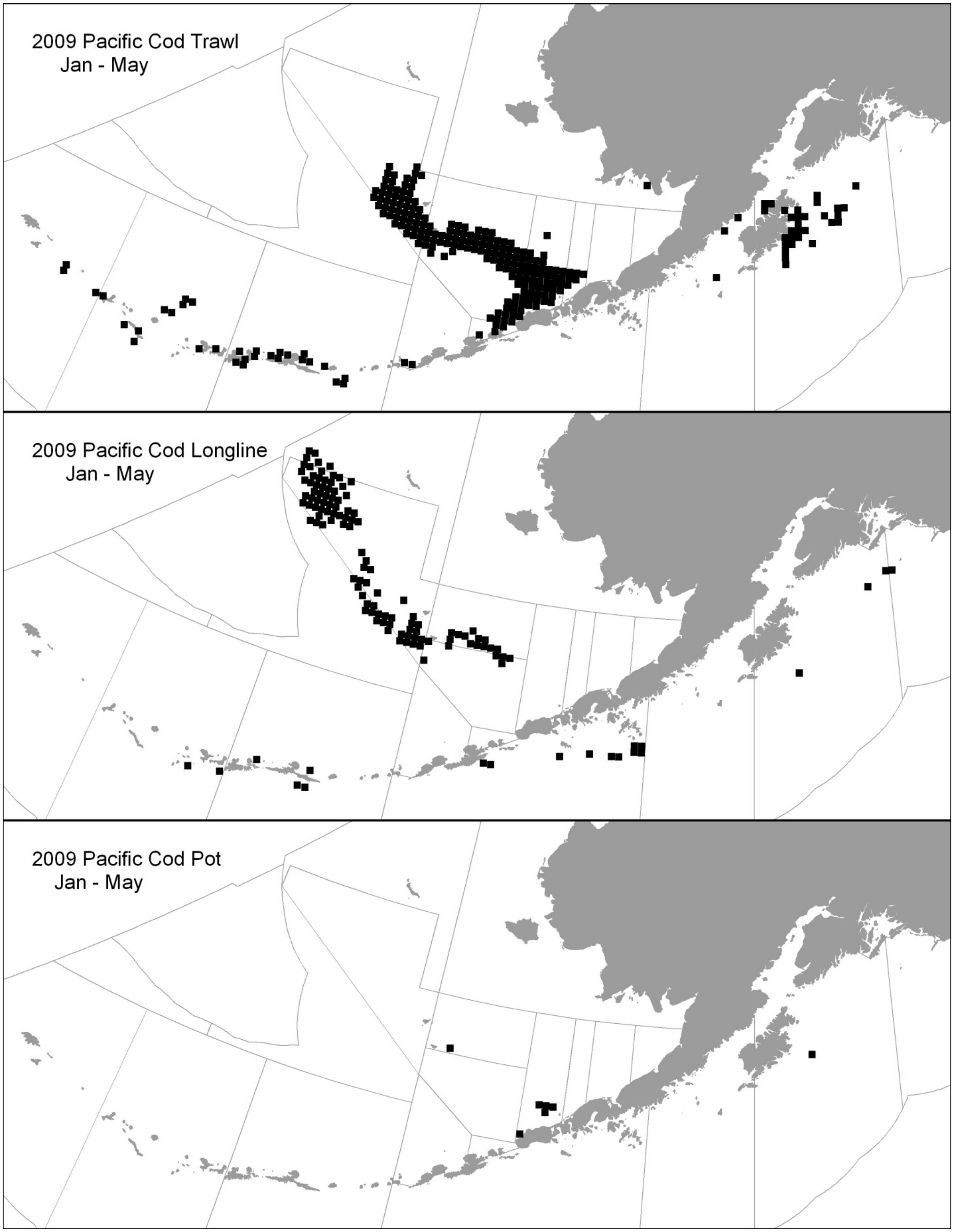


Figure 2.1a—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, January-May 2009, by gear type, overlaid against NMFS 3-digit statistical areas.

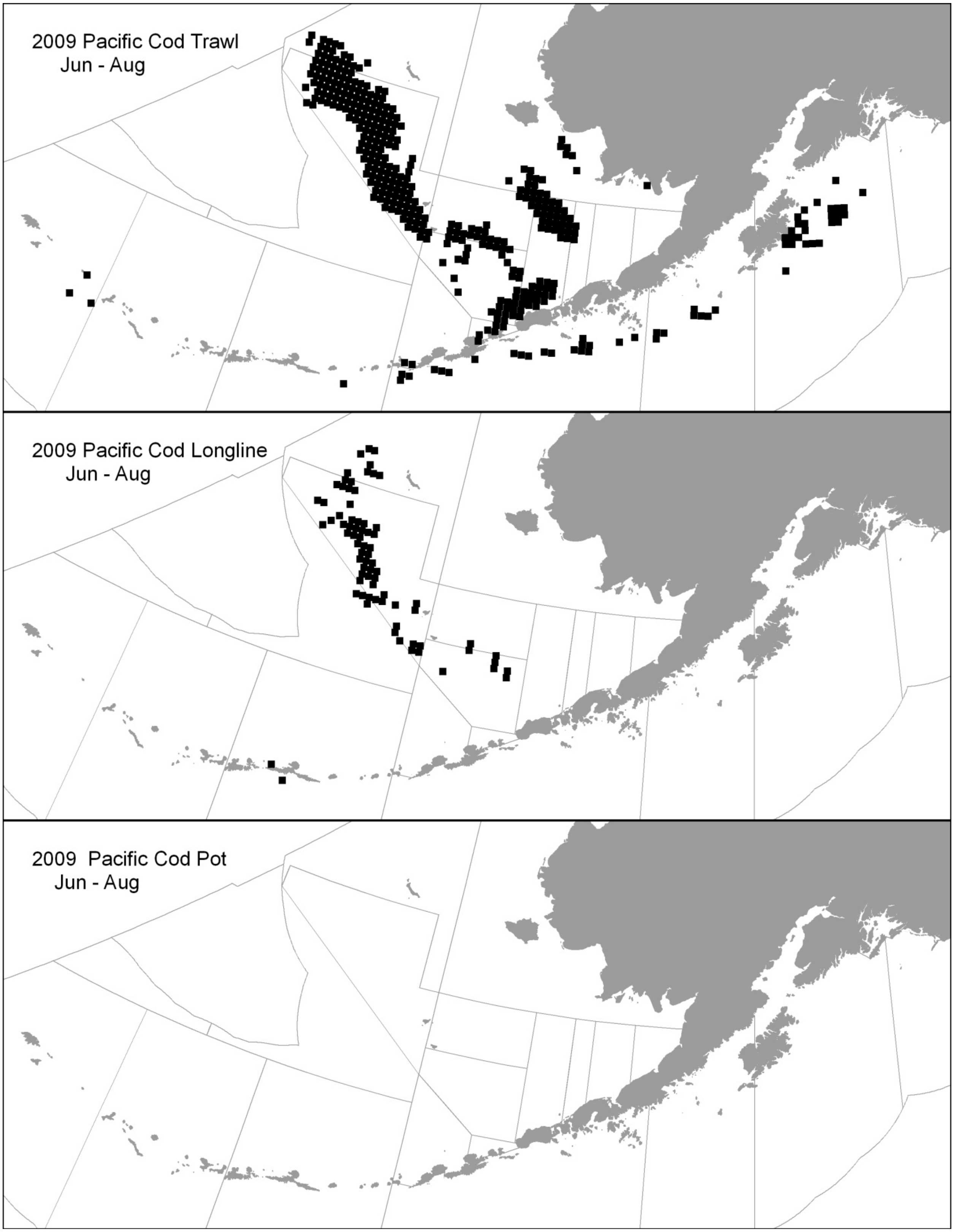


Figure 2.1b—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, June-August 2009, by gear type, overlaid against NMFS 3-digit statistical areas.

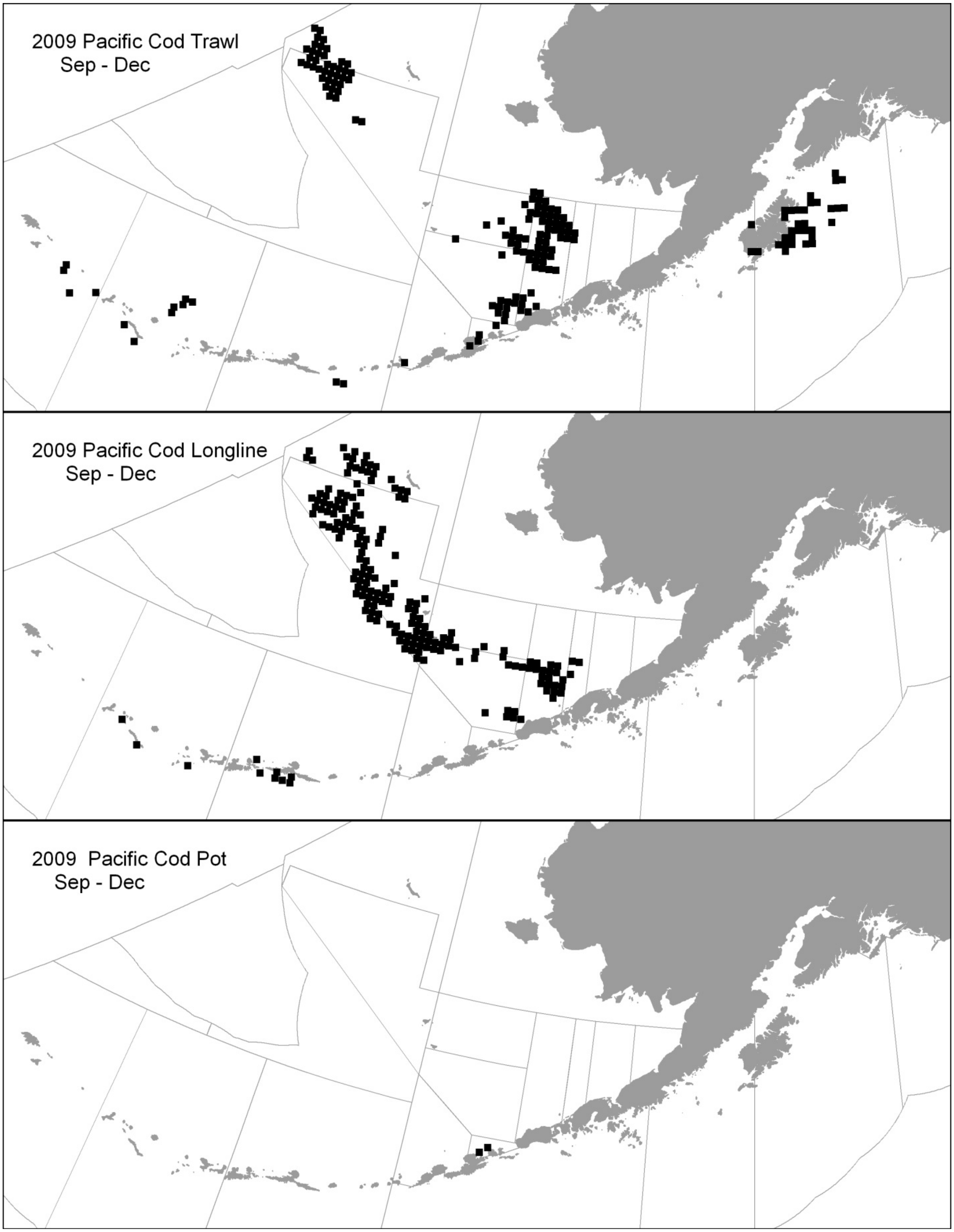


Figure 2.1c—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, Sept.-Dec. 2009, by gear type, overlaid against NMFS 3-digit statistical areas.

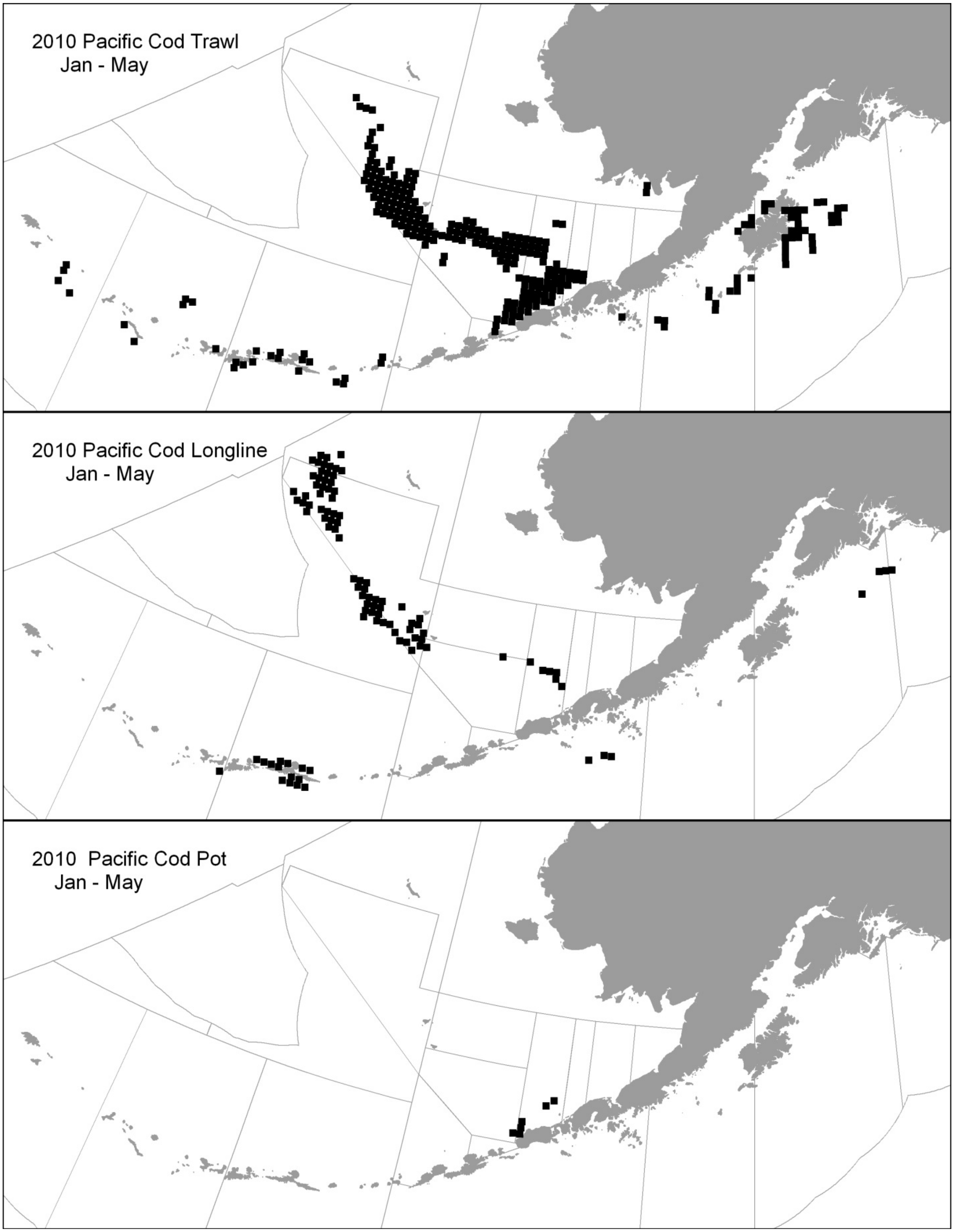


Figure 2.1d—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, January-May 2010, by gear type, overlaid against NMFS 3-digit statistical areas.

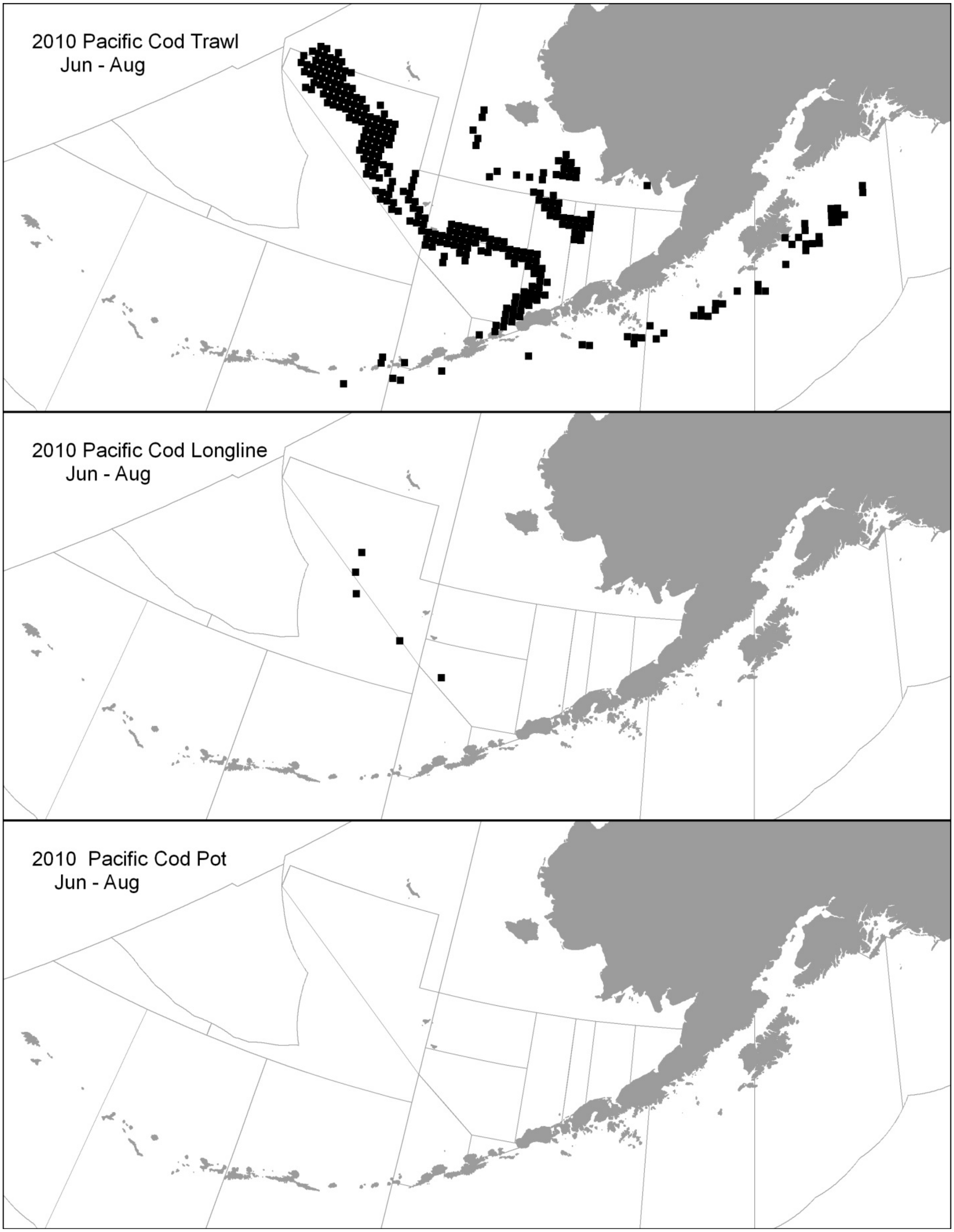


Figure 2.1e—Maps showing each 400 square kilometer cell with hauls/sets containing Pacific cod from at least 3 distinct vessels, June-August 2010, by gear type, overlaid against NMFS 3-digit statistical areas.

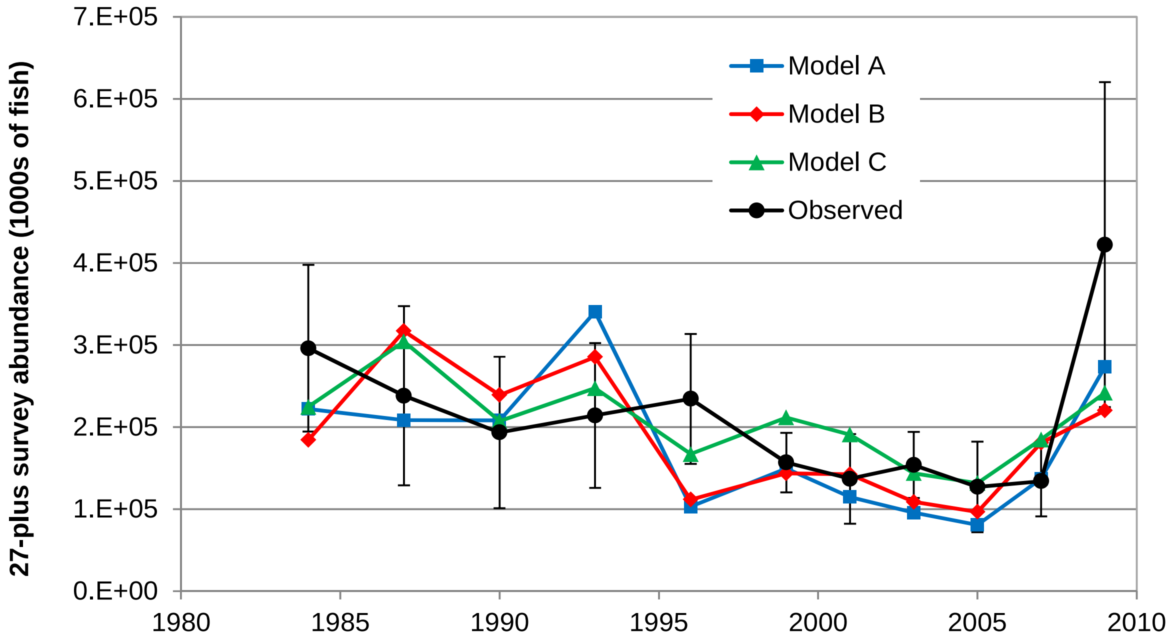


Figure 2.2a—Fits of the three models to the 27-plus trawl survey abundance time series.

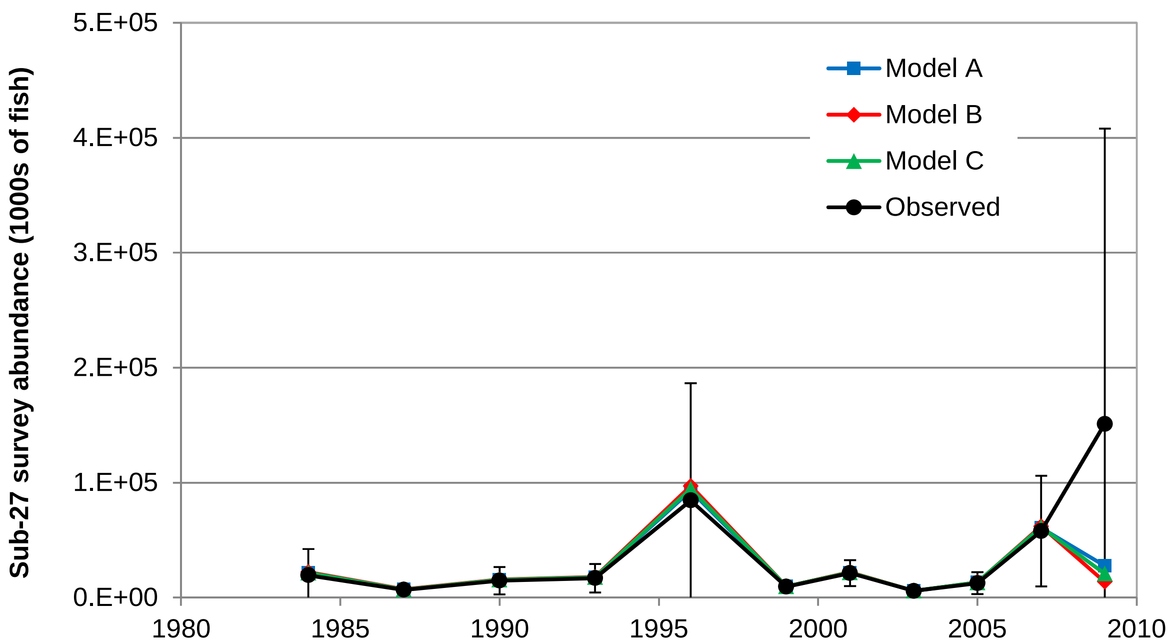


Figure 2.2b—Fits of the three models to the sub-27 trawl survey abundance time series.

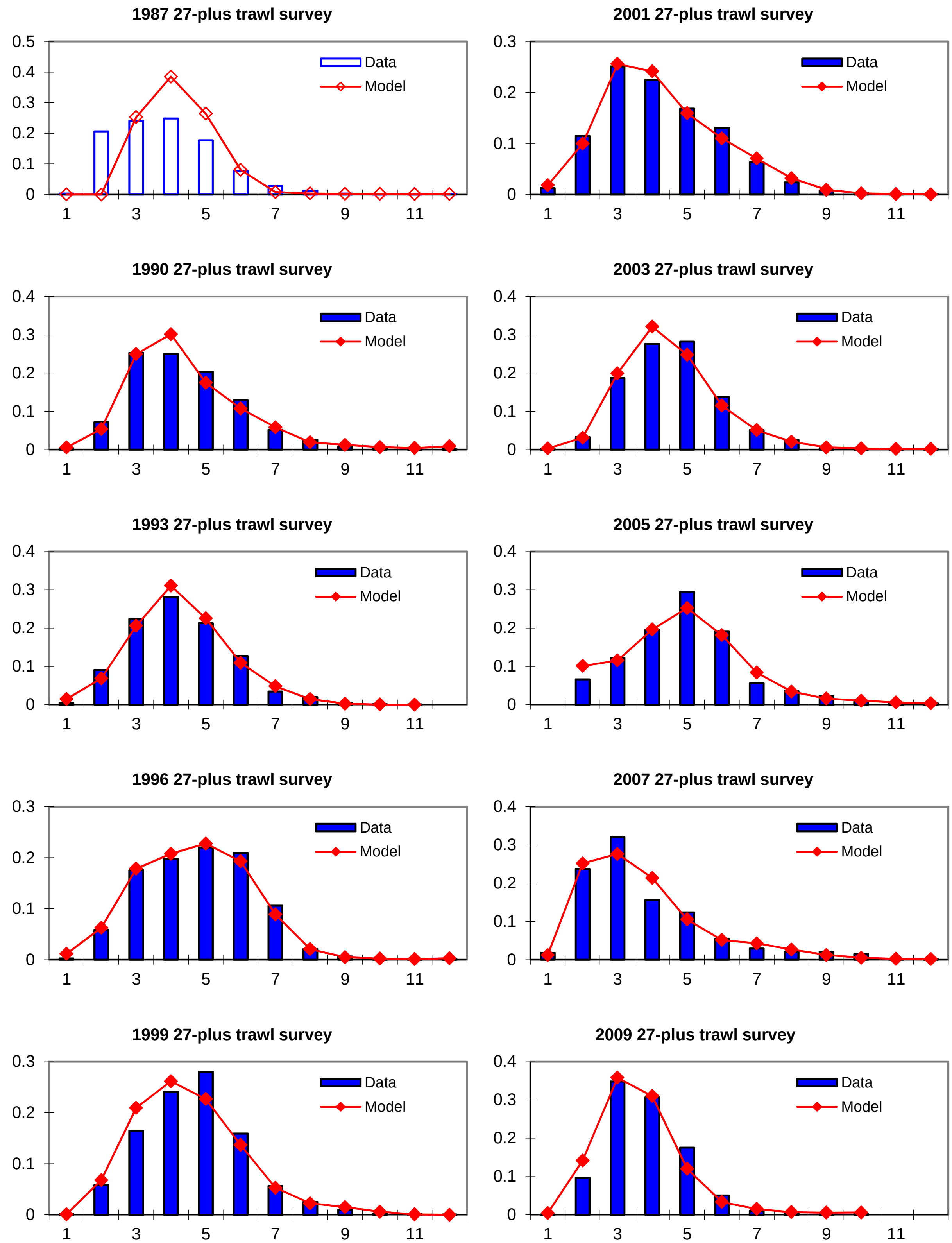


Figure 2.3a—Fit to 27-plus survey age composition data obtained by Model A (1987 data are turned off).

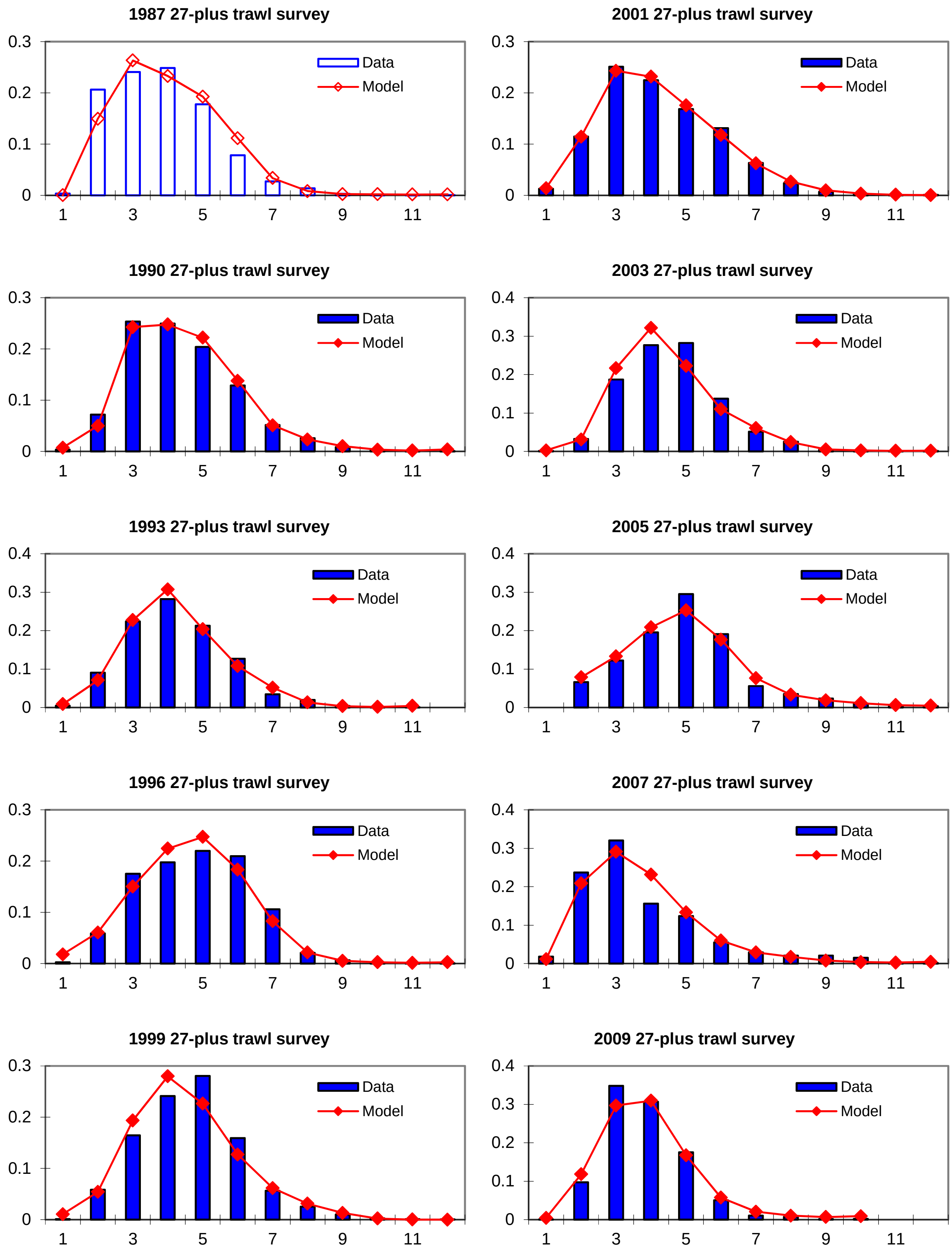


Figure 2.3b—Fit to 27-plus survey age composition data obtained by Model B (1987 data are turned off).

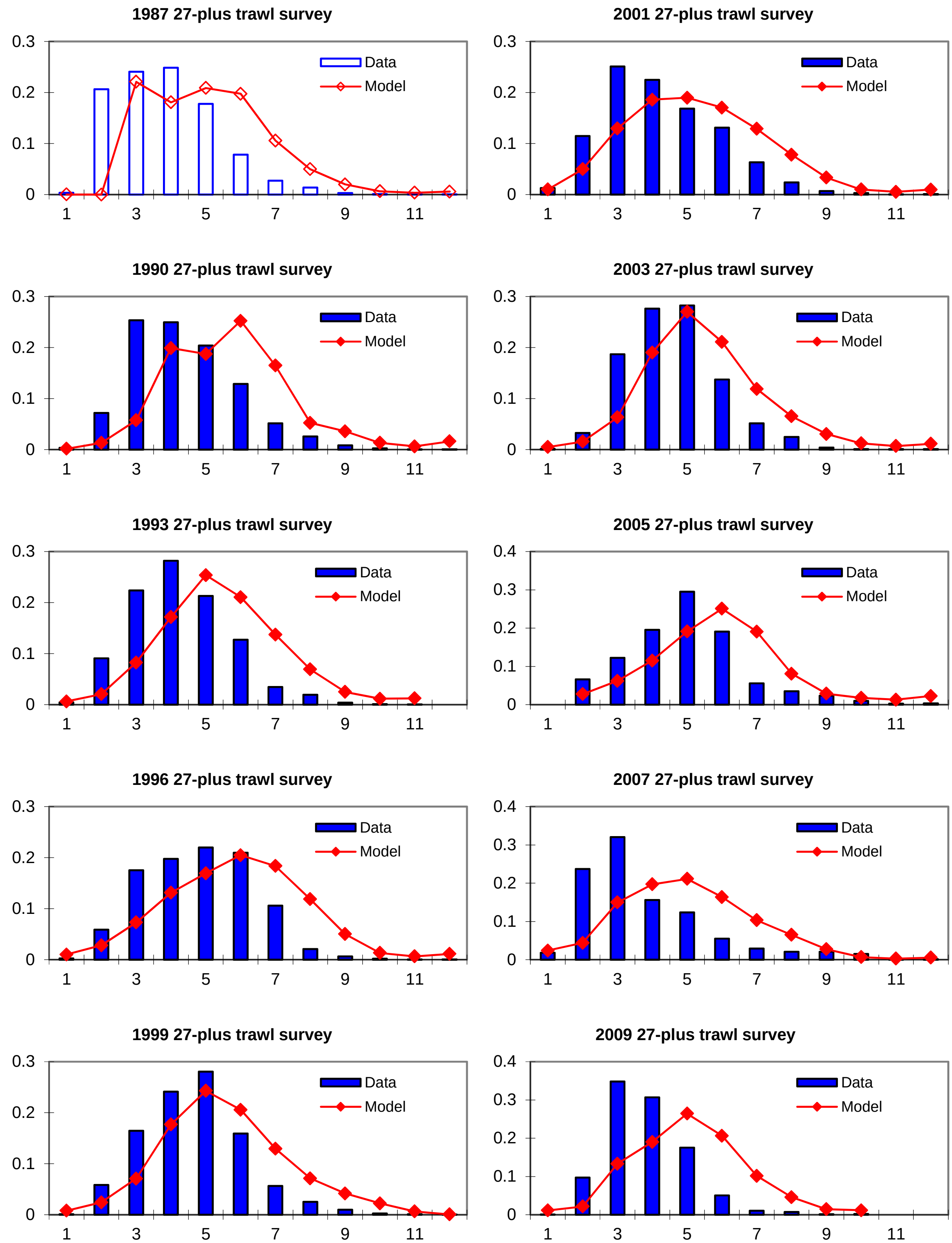


Figure 2.3c—Fit to 27-plus survey age composition data obtained by Model C (1987 data are turned off).

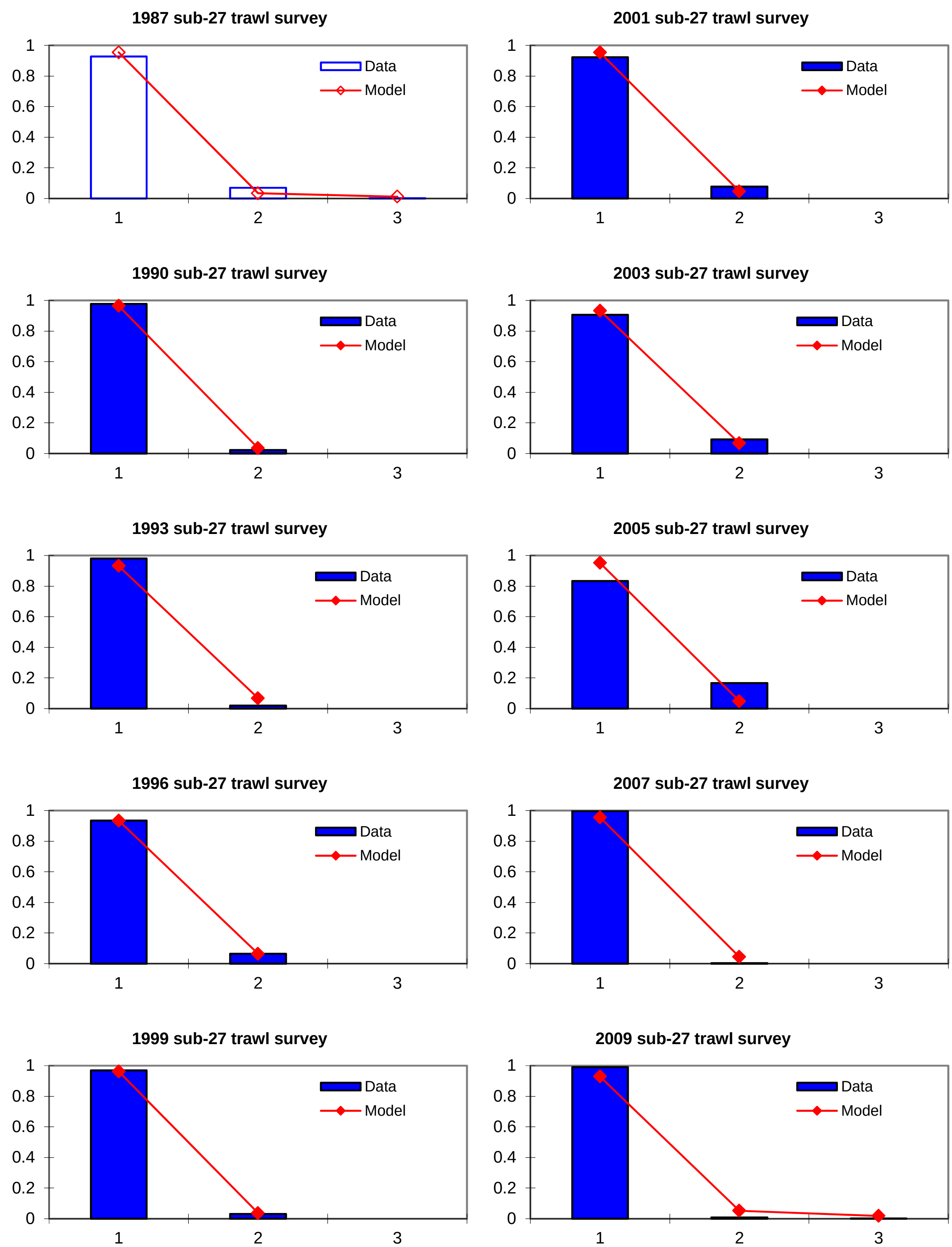


Figure 2.3d—Fit to sub-27 survey age composition data obtained by Model A (1987 data are turned off).

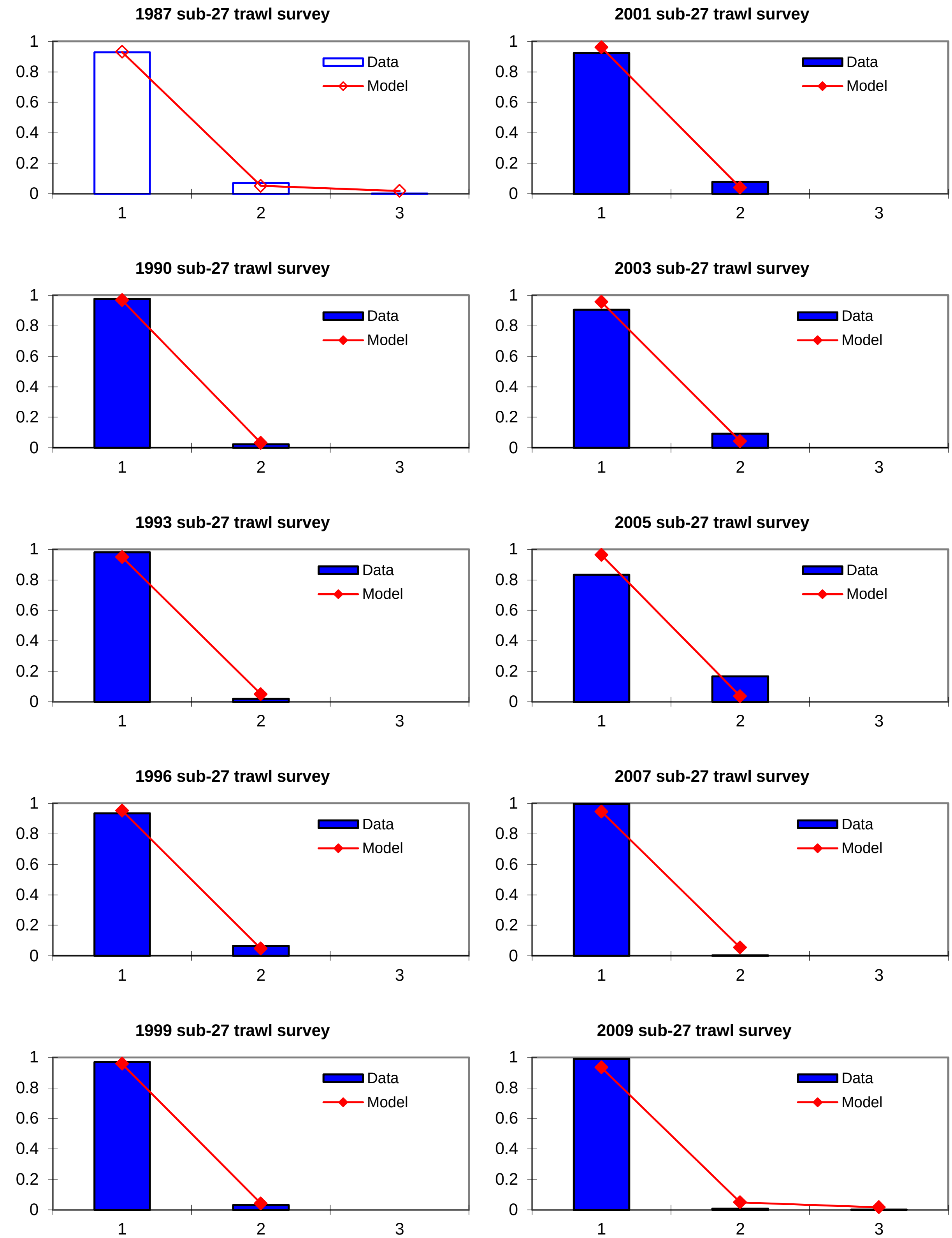


Figure 2.3e—Fit to sub-27 survey age composition data obtained by Model B (1987 data are turned off).

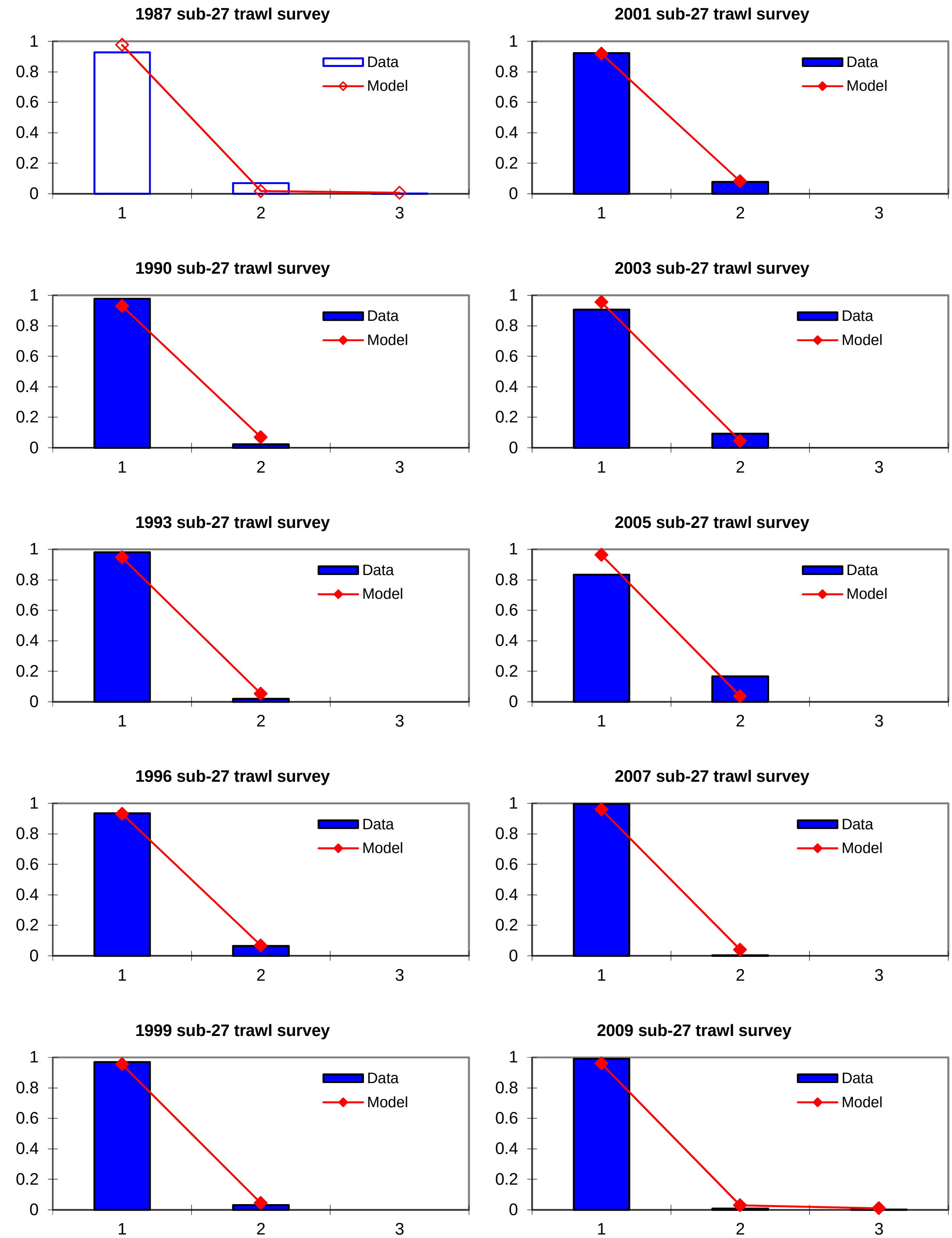
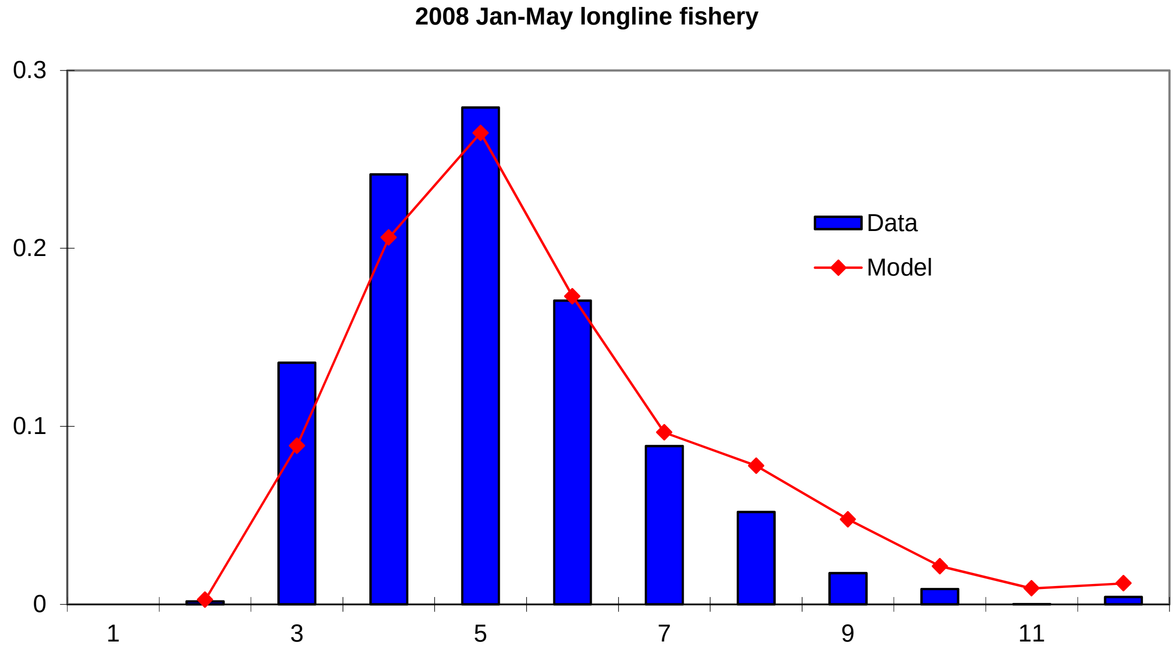


Figure 2.3f—Fit to sub-27 survey age composition data obtained by Model C (1987 data are turned off).



F

igure 2.4—Fit to 2008 January-May longline fishery age composition data obtained by Model A.

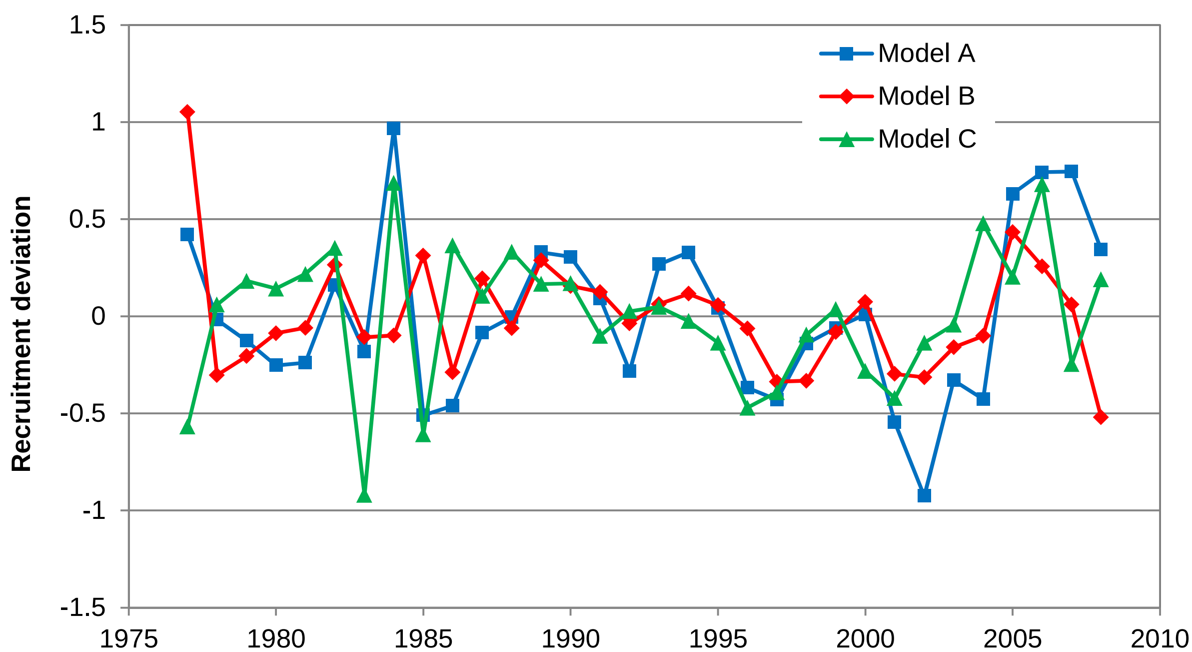


Figure 2.5—Time series of estimated recruitment deviations from the three models. Note that the pre-1977 deviations are with respect to the pre-1977 log median.

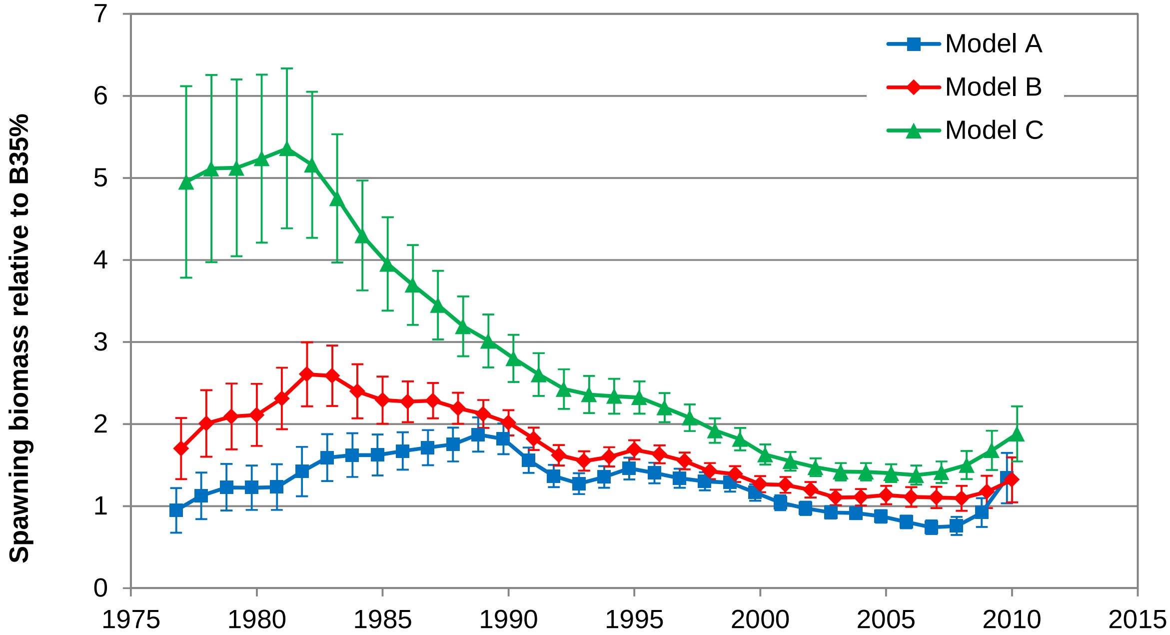


Figure 2.6—Time series of spawning biomass relative to $B_{35\%}$ as estimated by the three models.

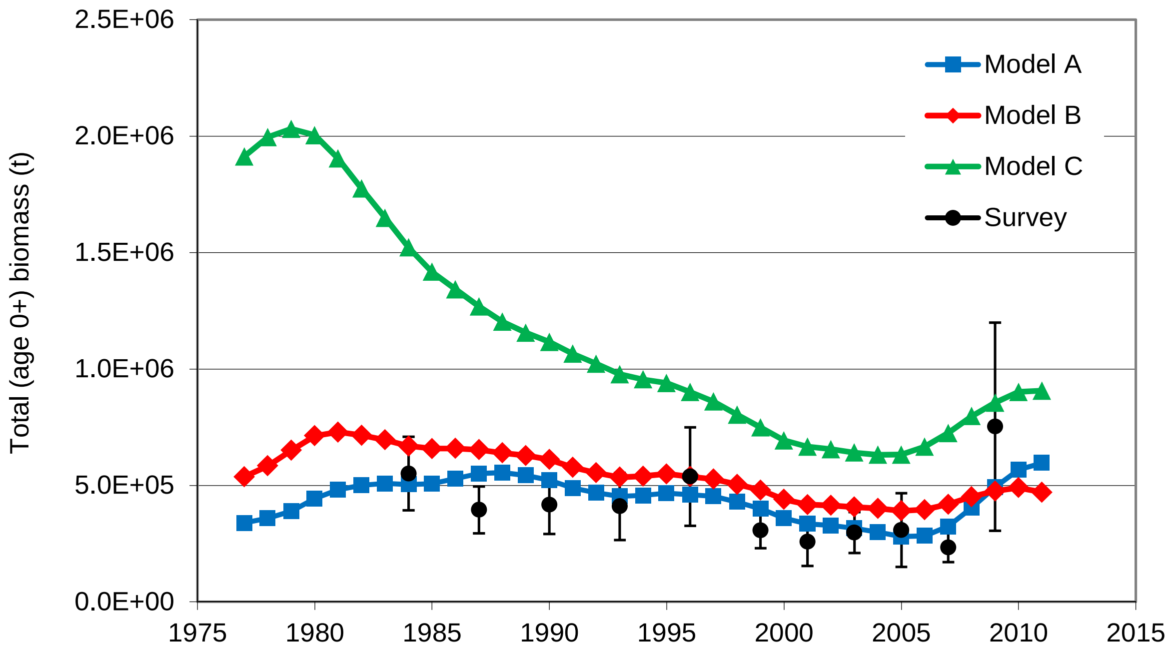


Figure 2.7—Time series of total (age 0+) biomass as estimated by the three models. Survey biomass is shown for comparison.

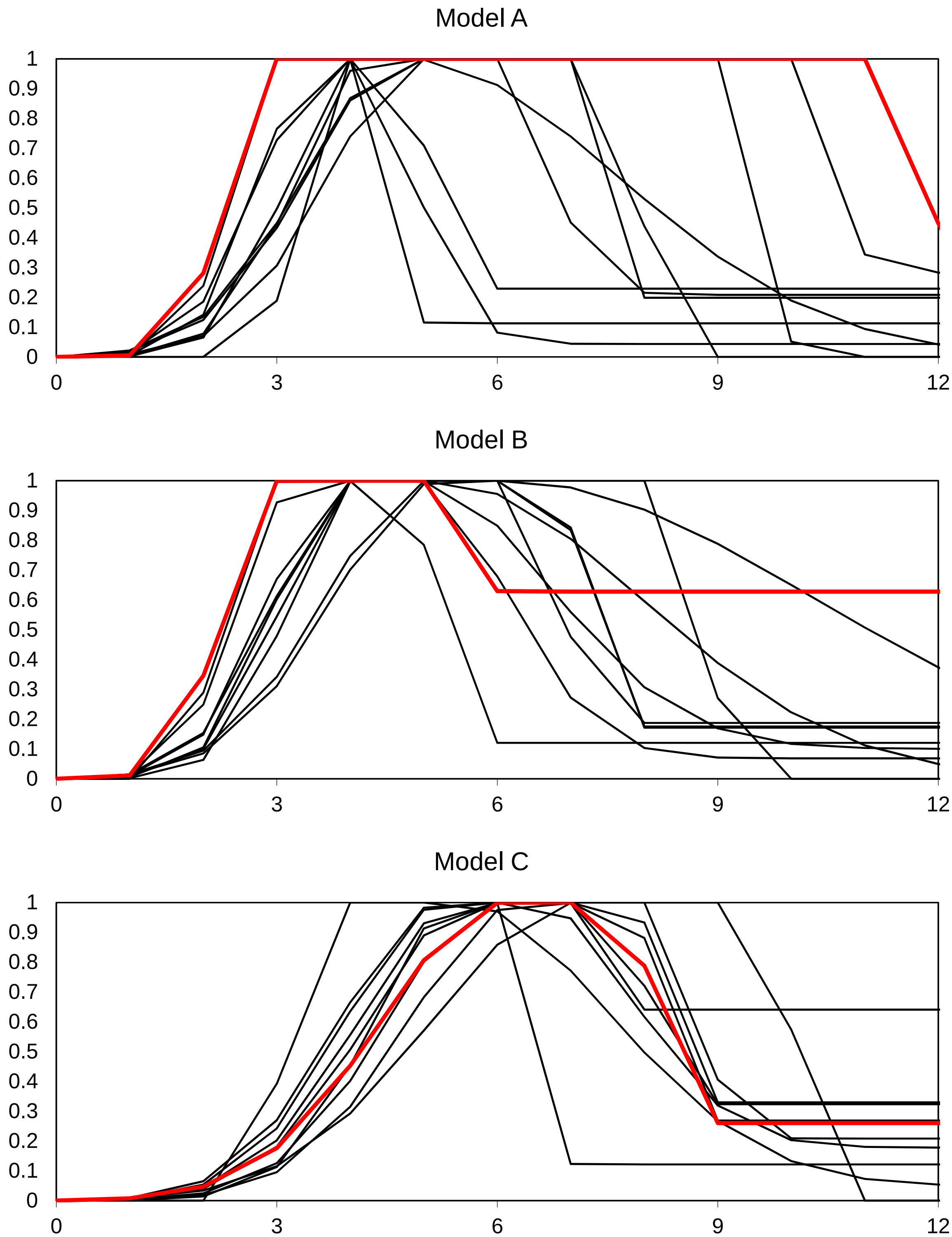


Figure 2.8—27-plus trawl survey selectivity at age as estimated by the three models. Selectivity for 2007 is shown in red. Selectivity for 2009 is held constant at the 2007 value.

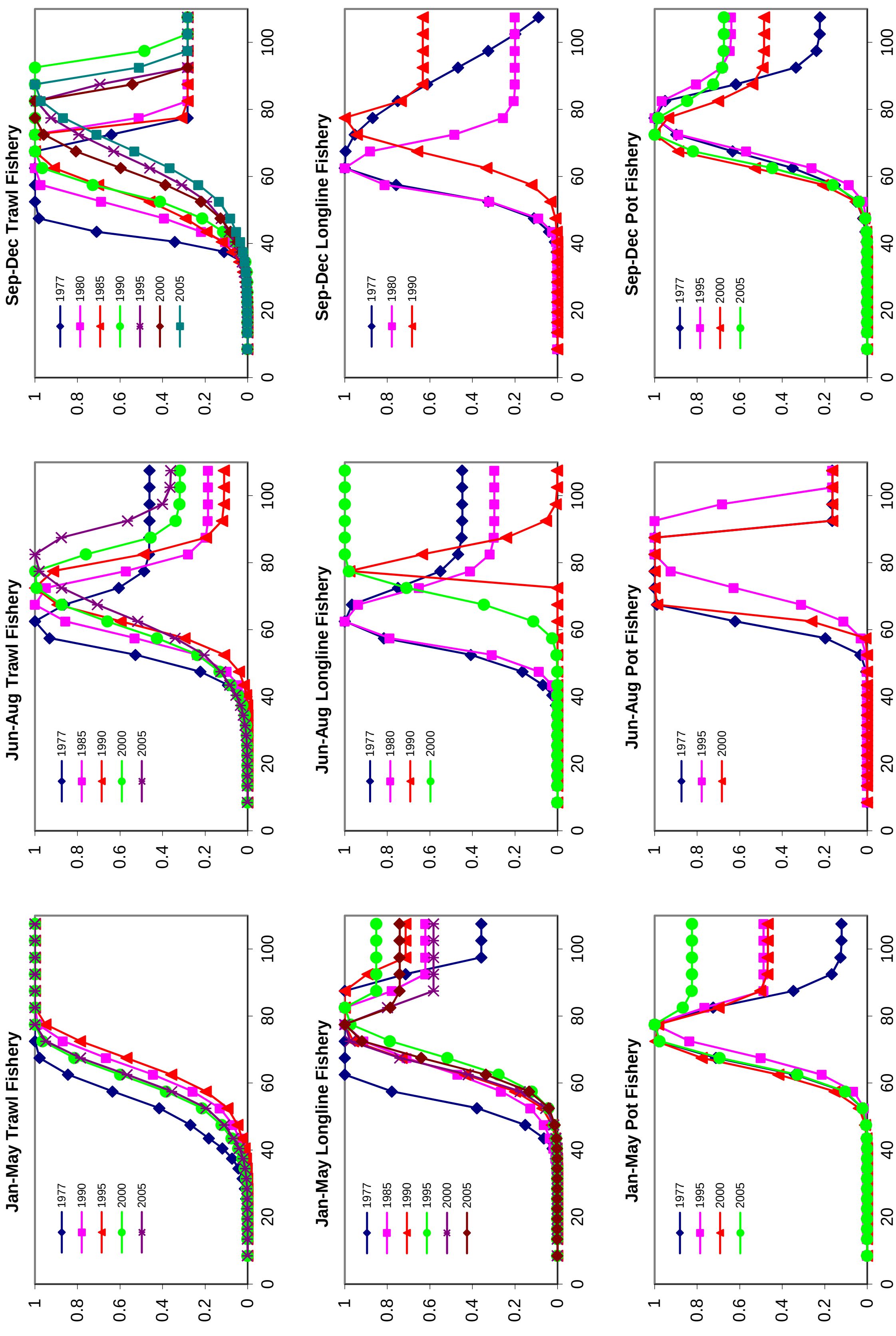
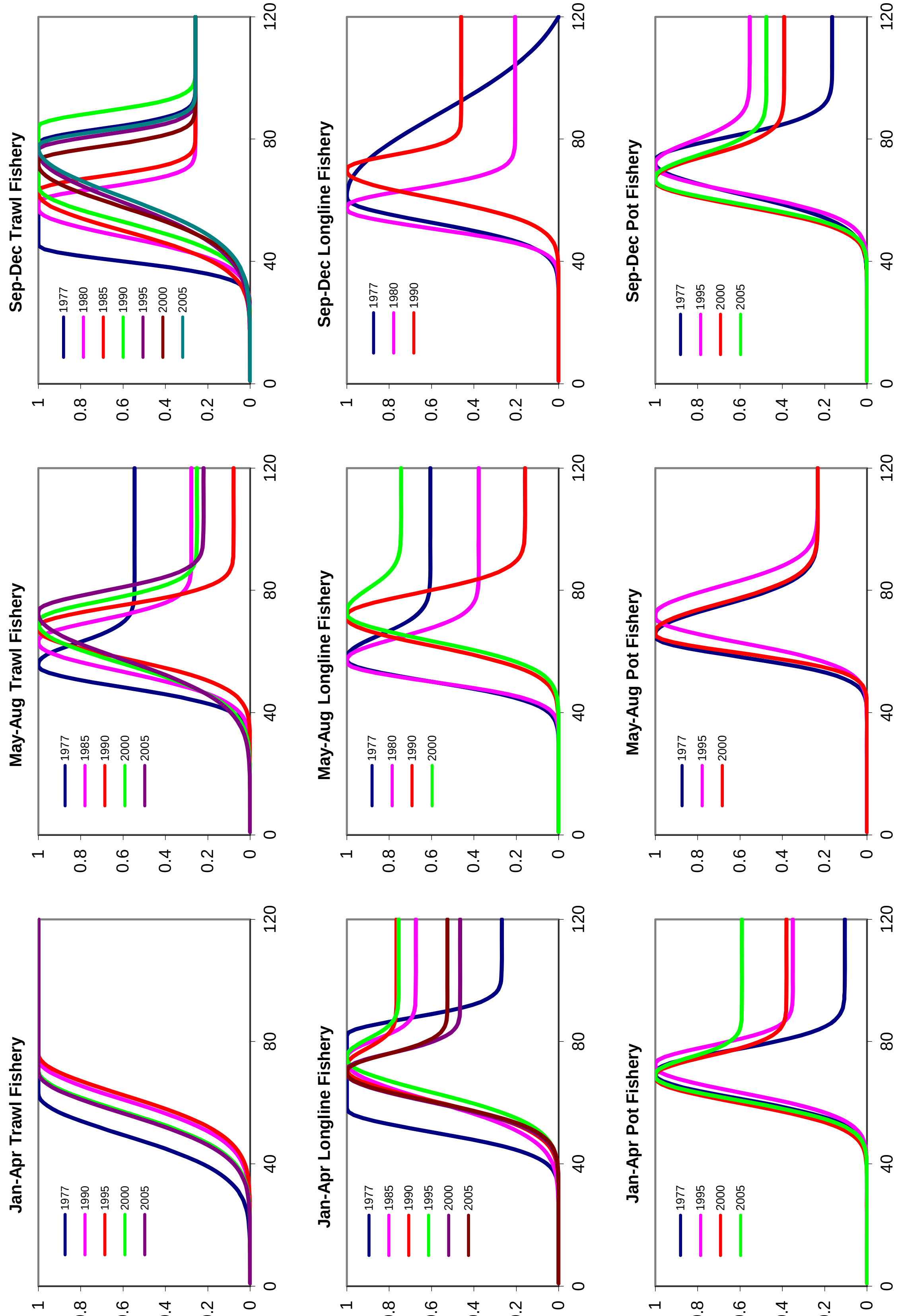
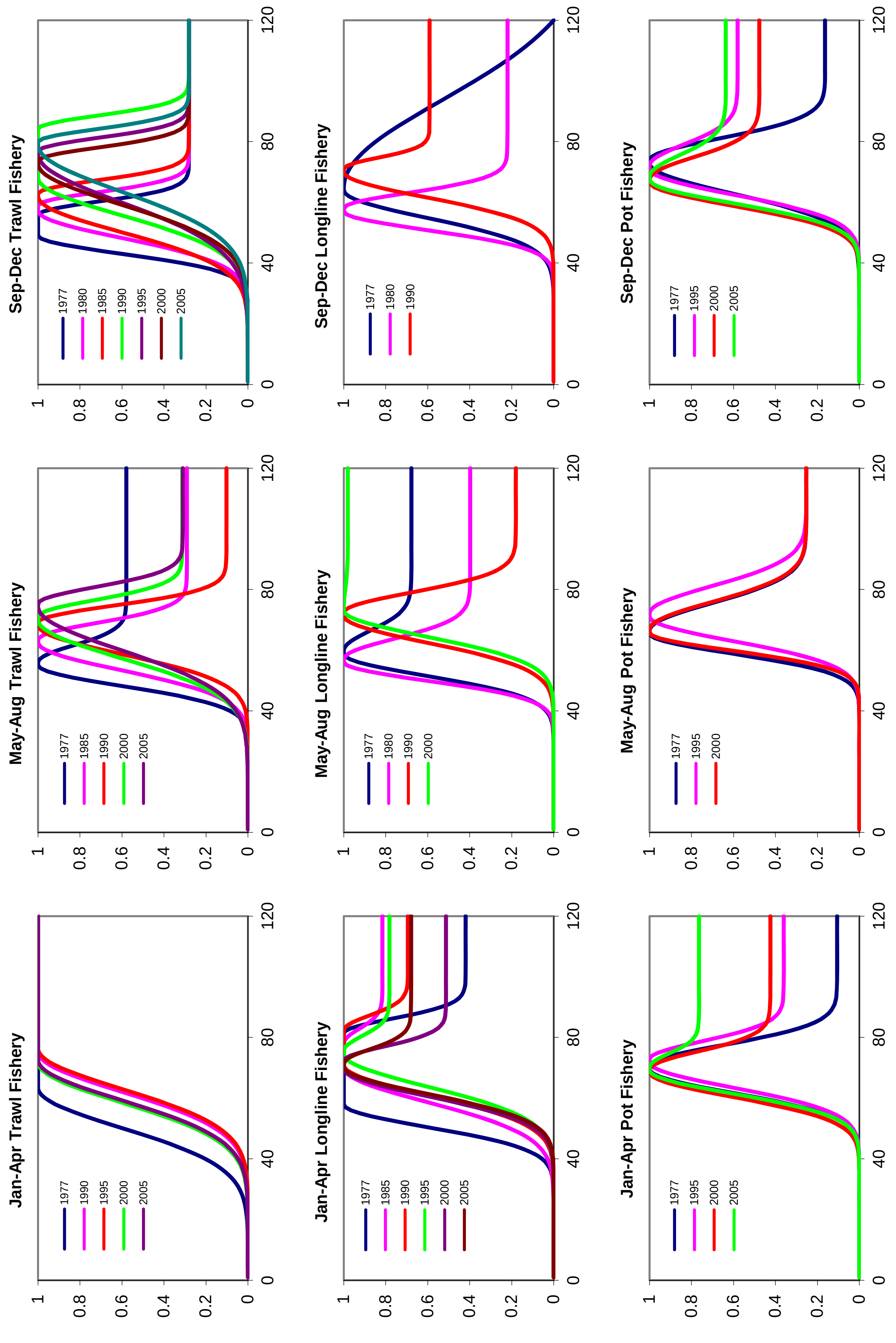


Figure 2.9a—Fishery selectivity at length (cm) as estimated by Model A.



F igure 2.9b—Fishery selectivity at length (cm) as estimated by Model B.



F
igure 2.9c—Fishery selectivity at length (cm) as estimated by Model C.

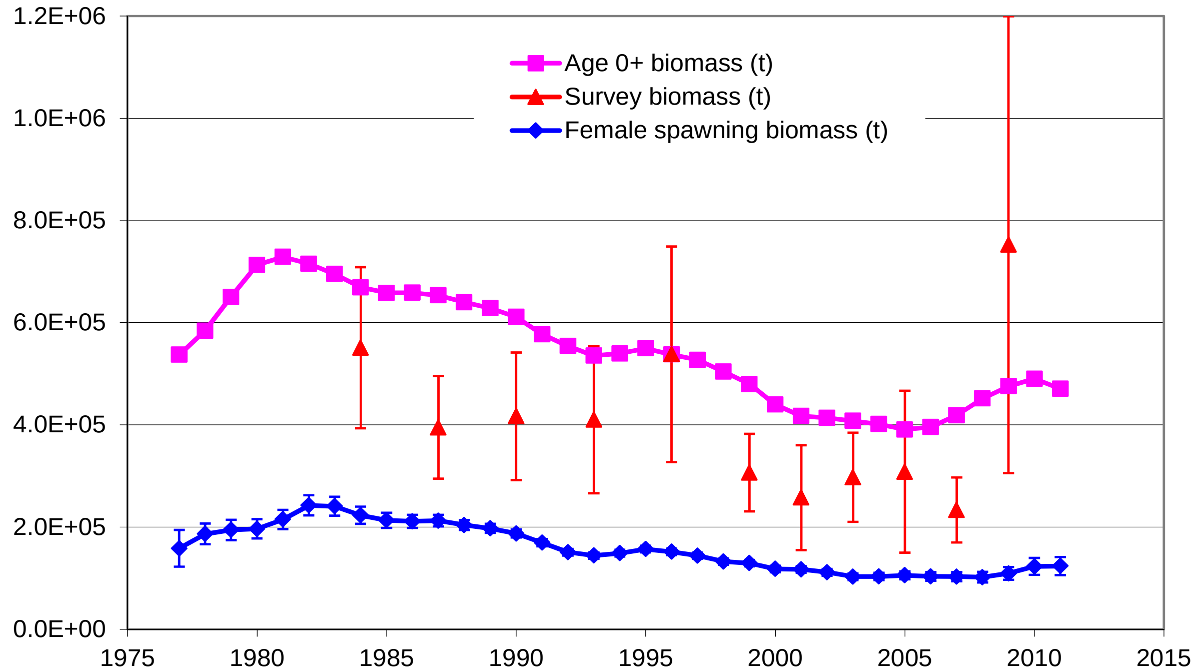


Figure 2.10—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) of Pacific cod as estimated by Model B. Female spawning biomass and survey biomass show 95% CI.

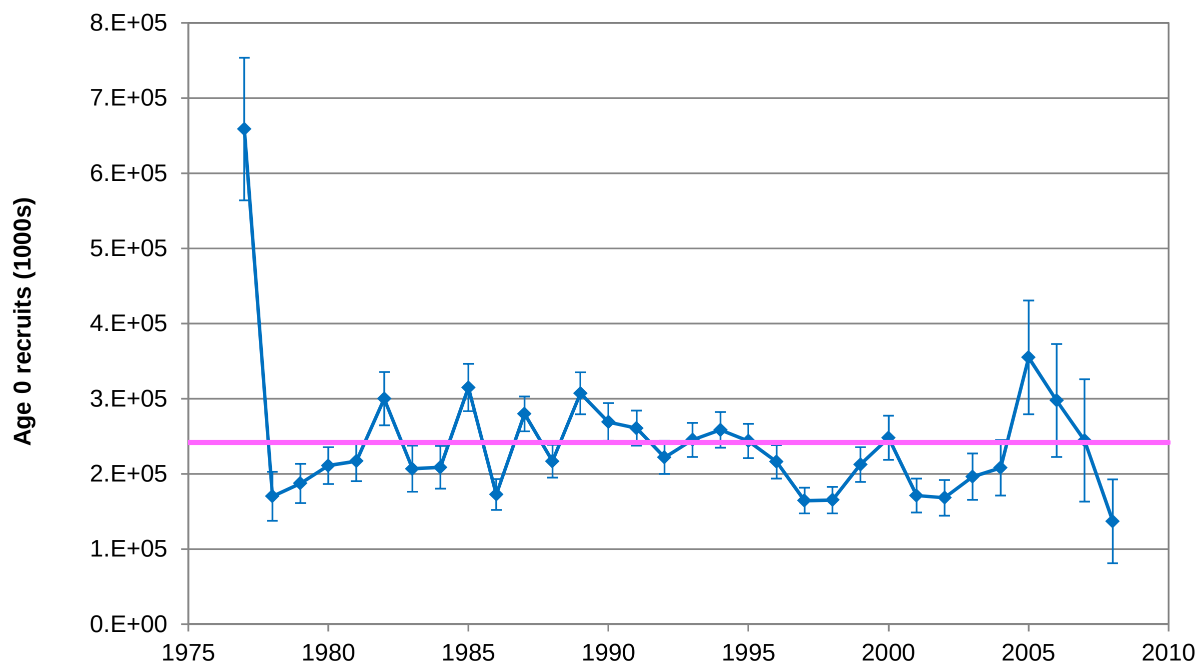


Figure 2.11—Time series of Pacific cod recruitment at age 0, with 95% confidence intervals, as estimated by Model B. Magenta line = 1977-2008 average.

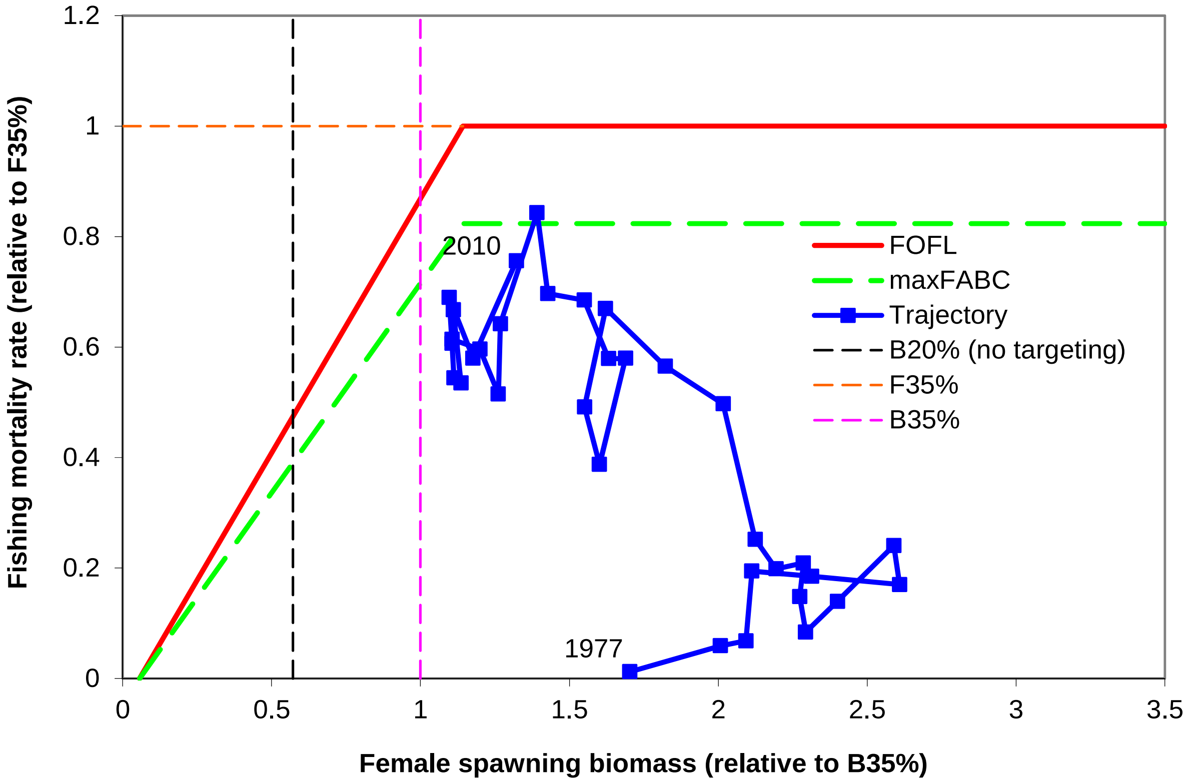


Figure 2.12—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model B, 1977-present. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$.

Attachment 2.1

An exploration of alternative models of the Gulf of Alaska Pacific cod stock

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Introduction

This document represents an effort to respond to comments made by the BSAI Plan Team, the GOA Plan Team, the joint BSAI and GOA Plan Teams, and the SSC on the 2009 assessment of the Pacific cod (*Gadus macrocephalus*) stock in the Gulf of Alaska (Thompson et al. 2009b).

Five models are presented here. These include the model that was recommended in the 2009 assessment and adopted by the GOA Plan Team and the SSC ("Model 1"), plus four alternative models.

BSAI Plan Team Comments from the November, 2009 Minutes

BPT1: *"The Team requested that the lead author analyze three alternative models for the September 2009 meeting: 1) current Model B1, 2) Model B1 with data-based estimates of aging bias from the radiocarbon study if available, and 3) Model B2 without mean length at age data and with maturity a function of length rather than age."* This request was addressed by the joint Plan Teams at their May, 2010 meeting (see comments JPT1 and JPT6), and by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

GOA Plan Team Comments from the November, 2009 Minutes

GPT1: *"Include a model run without age data. It was noted that developing a totally age-free model may be difficult and that some things may require constraining (e.g., variability in length-at-age)."* This request was addressed by the joint Plan Teams at their May, 2010 meeting (see comment JPT1 and JPT2) and by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

GPT2: *"As a low priority, it may be useful to evaluate a model run from the preferred configuration but only advanced by one year for comparison with projections. For example, for the preferred 2010 assessment model, re-run with (expected) catch for 2010 and 2011 as new data inputs as if the assessment was being conducted in 2011. The idea being to compare projected numbers at age (for the same catch assumptions) with modeled numbers at age in 2011."* This request was addressed by the joint Plan Teams at their May, 2010 meeting (see comment JPT10) and by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

SSC Comments Specific to the Pacific Cod Assessments from the December, 2009 Minutes

SSC1: *"The SSC encourages studies to evaluate the causes for the mismatch between survey length modes and estimated mean length at age of younger fish in the Bering Sea and difficulty of fitting age* *compositions in the Gulf of Alaska."* A progress report on this topic by the AFSC Age and Growth Unit is scheduled for the September, 2010 Plan Team meeting.

SSC2: *"The SSC recommends that proposals for model configurations be submitted to the assessment author in April. These proposals will be reviewed the Plan Team(s) and recommendations for future model runs will be vetted by the SSC in June. During the summer months, the stock assessment authors will run the selected models and will present preliminary results to the Plan Team(s) in September. The Plan Teams will then select their preferred suite of models for October SSC review and selection based on model performance. The authors can reserve the right to bring forward additional models for the final SAFE as needed."* The steps described in the first three sentences of the above have been completed, and the remaining steps are scheduled to be completed as described. A total of 20 proposals for model configurations were submitted to the senior assessment author by the April, 2010 deadline. These proposals were reviewed by the Plan Teams in May, 2010 (see comments JPT1-JPT11) and by the SSC in June, 2010 (see comment SSC8). A set of six model requests resulted. These were analyzed over the course of the summer and are presented in this preliminary assessment. See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

SSC3: *"Evaluate incorporating age conditioned on length rather than age composition and mean size-at-age."* This request was addressed by the joint Plan Teams at their May, 2010 meeting (see comment JPT4) and by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

SSC4: *"Evaluate the use of informative priors on selectivities to alleviate convergence problems and constrain selectivity parameters to preserve a reasonable shape."* This request was addressed by the joint Plan Teams at their May, 2010 meeting (see comment JPT7) and by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

SSC5: *"Exclude fishery age composition data unless a reasonable spatial distribution of samples becomes available."* This request was inadvertently overlooked by the joint Plan Teams at their May, 2010 meeting. However, it was reviewed by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

SSC6: *"The IPHC survey does not appear to inform the model and should be removed."* This request, which applied only to the BSAI Pacific cod assessment, was addressed by the joint Plan Teams at their May, 2010 meeting (see comment JPT8) and by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

SSC7: *"Evaluate spatial temporal variation in fishery CPUE trends for next year (time permitting)."* This request was addressed by the joint Plan Teams at their May, 2010 meeting (see comment JPT9) and by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

Joint Plan Team Comments from the May, 2010 Minutes

JPT1: *"Exclude mean length-at-age data and exclude age composition data: The teams recommended adding this component to models 4, 5, and 6."* This refers to proposals made in comments BPT1 and GPT1 and by members of the public. This recommendation was further considered by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

JPT2: *"Estimate the two parameters describing variation in length-at-age: The Teams recommended adding this component to models 5 and 6."* This refers to a proposal made by members of the public and, perhaps, to the proposal made in comment GPT1 (depending on whether these parameters are among those, if any, that "require constraining"). This recommendation was further considered by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

JPT3: *"Eliminate cohort-specific growth and add time-varying growth: The teams recommended adding this component to Model 6 (BSAI only)."* This refers to a proposal made by members of the public. This recommendation was further considered by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

JPT4: *"Age conditioned on length: The Teams did not recommend adding this component to any of the models until age determination issues are resolved."* This refers to a proposal made in comment SSC3. This recommendation was further considered by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

JPT5: *"Finer length bins: After some discussion the teams felt this was a routine housekeeping change to the model. The teams agreed that the author was free to test and implement minor changes to the model as he felt appropriate. The Teams recorded this as a change to models 2 through 6."* This refers to a proposal made by the senior assessment author. This recommendation was further considered by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

JPT6: *"Maturity as a function of length rather than age and ageing bias from radiocarbon study: The Teams recommended adding maturity as a function of length rather than age to models 4, 5, and 6. The teams recommended no change related to the radiocarbon study."* This refers to a pair of proposals made in comment BPT1. This recommendation was further considered by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

JPT7: *"Priors on selectivity, estimate catchability: The Teams recommended adding these components as the main new features of Model 3."* This refers to proposals made in comment SSC4, by the senior assessment author, and by another AFSC assessment scientist. This recommendation was further considered by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

JPT8: *"Exclude IPHC data: The Teams rejected the proposal and recommended that the IPHC data be considered for use in both the BSAI and GOA model as well."* This refers to the proposal made in comment SSC6. This recommendation was further considered by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

JPT9: *"Evaluate spatial-temporal variation in fishery CPUE: The Teams recommended that the SSC proposal to evaluate spatial-temporal variation in fishery CPUE be included in the next set of research priorities."* This refers to the proposal made in comment SSC7. This recommendation was further considered by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

JPT10: *"Advance model one year, compare with projections: No action was taken."* This refers to the proposal made in comment GPT2. This recommendation was further considered by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and "Model Structures" under "Data and Analytic Approach."

JPT11: *"Other GOA proposals: The Team recommended to treat the seasonal proposal under models 2 through 6, but not to address the plus group proposal. The catchability and selectivity-at-age proposals are treated under Model 3 (see 'prior' proposals). No recommendations were made on the remaining two proposals (weight, lower bound)."* The "seasonal proposal" and the "catchability and selectivity-at-age proposals" refer to proposals made by the senior assessment author and another AFSC assessment scientist. The “remaining two proposals” refer to proposals made by an AFSC assessment scientist. These recommendations were further considered by the SSC at its June, 2010 meeting (see comment SSC8). See Table 2.1.1 and “Model Structures” under “Data and Analytic Approach.”

SSC Comments from the June, 2010 Minutes

SSC8: *“The SSC supports* ... the Plan Teams’ *suite of models, with two modifications.* One *SSC proposal ... is to exclude fishery age composition data because of concerns about the spatial distribution and having only one year of data.* Another *SSC proposal ... is to exclude IPHC survey data in the BSAI because of its conflict with other data series. The SSC requests that these two proposals be included in the housekeeping category, because achieving stability in the data sources used in a stock assessment is desirable. The conclusion may be that excluding these data sources is not a good idea, but at least an evaluation will have been done.” (Terms in* non-italicized font *added.)* For the Plan Teams’ suite of models, see comments JPT1-JPT11. The SSC proposals referenced here with respect to exclusion of fishery age composition data and IPHC survey data are given in comments SSC5 and SSC6. See Table 2.1.1 and “Model Structures” under “Data and Analytic Approach.”

SSC9: *“The SSC encourages continued ageing of the Pacific cod winter fishery age samples and acquisition of length composition from the IPHC survey. The assessment author is encouraged to evaluate these data for inclusion in the model after a sufficient time series has been acquired.”* The requests for continued ageing of winter fishery age samples and acquisition of length composition data from the IPHC survey will be communicated to the responsible parties.

SSC Comments on GOA Assessments in General from the December, 2009 Minutes

SSC10: *“The methods for area apportionment of the ABC that are used in the specific chapters are different from those given in the general introductory material to the SAFE on page 4. The SSC suggests that the table be updated. Also, a different number of years are used for various species (e.g., 5 years for Sablefish, 4 years for pollock, 3 surveys, most recent survey). SSC members recall extensive discussions about these issues but the rationale for the decision is not given in the SAFE chapters. The SSC suggests that description of the apportionment rationale in each SAFE chapter of area-apportioned species would be helpful to the reader.”* This comment will be addressed in the final assessment.

Data and Analytic Approach

Model Structures

Five models were requested by the Plan Teams. The SSC adopted the Plan Team requests, with three revisions, as shown in Table 2.1.1 (Model 6 in Table 2.1.1 was requested for the BSAI assessment only). The models are described in more detail below. The software used to run these models was SS V3.10b (Methot 2010); V3.03c was used in the 2009 assessment.

The Plan Teams and SSC developed their list of models by considering all 20 proposals that had been submitted, accepting some and rejecting others, grouping the accepted proposals into categories, then subdividing the categories into separate models if appropriate. In addition to last year’s model (Model 1), the categories were “data and data structure” (Model 2), “selectivity and catchability” (Model 3) and “age and growth” (Models 4-5). To simplify the analysis and make models more comparable for this preliminary assessment, input standard deviations of all *dev* vectors appearing in Model 1 were held constant in all other models using those same vectors. Similarly, catchabilities in all models were held constant at the values used in Model 1, except for Model 3, where estimation of catchability was an explicit feature of the model.

Model 1 is the basis for Model 2, and Model 2 is the basis for Models 3-5.

Data for all models were the same as those used in last year's assessment, including the division of survey data into sub-27 (cm) and 27-plus (cm) components, with the following exceptions:

1) Size composition data were re-assembled for Models 2-5 (see description under Model 2 below)
2) A minor error in last year's data file was corrected and the size composition data from the 2007 27-plus trawl survey were used instead of the age composition data from that survey (see description under Model 2 below).
3) *Fishery* age data (both age composition and mean size at age) were not used in Models 2-5.
4) *Survey* age data (both age composition and mean size at age) were not used in Models 3-5.

Model 1 (last year's model)

Model 1 is the model recommended by the authors and adopted by the GOA Plan Team and SSC in 2009 (Thompson et al. 2009b). Briefly, some features that characterized last year's model were as follow:

1) Growth rates were cohort-specific.
2) The standard deviation of length at age was estimated outside the model as a linear function of mean length at age.
3) 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 and choosing the value (0.4) that gave the highest log-likelihood (age-specific bias values were also examined, but did not improve the fit significantly).
4) Mean size-at-age data were included (because trawl survey size composition data were not used for any year in which trawl survey age composition data are used, and because fishery size composition data give almost no information about ages 1 or 2, inclusion of mean size-at-age data was necessary for meaningful estimation of cohort-specific growth).
5) Sub-27 trawl catchability was allowed to vary freely with each survey year except for 2009.
6) Pre-1996 27-plus trawl survey catchability was treated as a free parameter.
7) Catchability for the post-1993 27-plus trawl survey was fixed at the value that set 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).
8) Fishery selectivity was modeled as a function of length and was defined separately for various combinations of gear, season, and block of years (blocks of years come in 5, 10, or 20-year increments).
9) Trawl survey selectivity was modeled as a function of age.
10) All parameters of the 27-plus survey selectivity schedule were allowed to vary freely with each survey year except for selectivity at age 0 (which was forced to approximate zero) and except that survey selectivity was held constant at base values for the two most recent survey years (i.e., no selectivity *devs* were estimated for those years).
11) Input standard deviations of all *dev* vectors were set iteratively by matching the standard deviations of the set of estimated *devs*.

Model 2 (data and data structure)

Model 2 deals with changes in data and data structure (except for changes in use of trawl survey age data, which are dealt with in Models 4-5). These changes were: to make minor corrections to last year's data file, to exclude the fishery age data (this was an SSC request), to use a finer length bin structure, and to re-evaluate the seasonal structure. The SSC's reason for wishing to exclude the fishery age data (which consist of a single record of age composition data and a single record of mean size-at-age data, both from the 2008 January-May longline fishery) was that these data seemed to be at odds with the rest of the data in last year's assessment. For example, the mean lengths at ages 2-7 from the 2008 January-May longline fishery are higher than the mean lengths at those ages in any of the 9 years of survey age data, exceeding the survey averages by 2.0-2.6 standard deviations, despite the fact that the fishery data were collected earlier in the year than the survey data.

In Plan Team discussions, the features of Model 2 were described as "incremental," the idea being that individual features would be explored separately, then combined as appropriate. Therefore, the development of Model 2 described below goes beyond a description of model structure and ventures into the realm of model results, so that the effects of individual features and combinations of features can be evaluated.

Model 2 was developed as follows: The first step was to make minor corrections to last year's data file, resulting in Model 2.1. The corrections were as follow: The first correction was to turn "off" the 2008 January-May longline fishery size composition data, which had inadvertently been left "on" in last year's model (thus resulting in some amount of double-counting, given that age composition data from the same year and fishery were also turned "on"). The second correction was to change the year of the corresponding size-at-age record from 2009 (incorrect) to 2008 (correct). The third correction was to turn "on" the size composition data from the 2007 sub-27 trawl survey and to turn "off" the corresponding age composition data (this did not correct an error *per se*, but several trial runs indicated that using the size composition data rather than the age composition data for this particular year of the sub-27 trawl survey greatly improved the model's ability to track mean size at age).

The second step was to remove the fishery age data (both age composition and mean size at age) from Model 2.1, resulting in Model 2.2.

Values of the objective function, spawning biomass (t) in 2009, spawning biomass in 2009 relative to $B_{35\%}$, and age 0 recruits in 2006 are shown below, along with the proportional change in each estimate relative to Model 1:

		Spawning biomass 2009		SB2009 per $B_{35\%}$		Recruits 2006 (1000s)	
Model	Obj. func.	Estimate	Change	Estimate	Change	Estimate	Change
1	1483.51	115,877	0.000	1.188	0.000	493,028	0.000
2.1	1599.48	116,143	0.002	1.201	0.011	440,494	-0.107
2.2	1356.88	150,144	0.296	1.527	0.285	364,380	-0.261

Time series of spawning biomass, spawning biomass relative to $B_{35\%}$, and age 0 recruits for Models 1, 2.1, and 2.2 are plotted in Figure 2.1.1. Throughout the time series, the spawning biomass estimates from Model 2.1 are within +/– 7% of those from Model 1, being about 7% higher in 1977, about 7% lower by 2007, and almost identical in 2009. Between 1983 and 1998, the spawning biomass estimates from Model 2.2 are within 10% of those from Model 1, but they are higher at both ends of the time series (about 20% higher in 1977 and about 30% higher in 2009).

Model 2.2 then formed the baseline for a factorial design involving various aspects of season structure and bin structure. Factors and options within factors are shown in italics in the following paragraphs.

Season structure in the GOA Pacific cod model has traditionally consisted of three seasons defined as January-May, June-August, and September-December. This structure was borrowed from the BSAI Pacific cod model. In the BSAI model, the structure dates from the 1993 assessment, and was suggested by industry representatives. It did not have an explicit statistical basis. In an attempt to develop a statistically derived seasonal structure, the catch data from 2003-2008 were averaged by month across years. For a given putative season (e.g., January-May), monthly average catches were assumed to be drawn from a lognormal distribution with season-specific μ and σ. All possible numbers of seasons and all possible combinations of monthly starting and ending dates for each season were considered (note that no more than six seasons per year are possible, because at least two observations (months) are required to compute the maximum likelihood estimate of a season-specific σ). The optimal season structure, as determined by minimum AIC, was five seasons defined as January-February, March-April, May-August, September-October, and November-December (Figure 2.1.2). *The factorial design includes two options with respect to seasonal structure per se: 1) the old, three-season structure; and 2) the new, five-season structure.*

Changing from three to five seasons requires two additional decisions. First is whether the catch data alone will be partitioned accordingly, or whether survey selectivity schedules will also follow the new partition. To simplify matters, this preliminary assessment retains the old pattern of three selectivity seasons, but the beginning and ending dates were changed slightly in some cases so that the catch seasons would be subsets of the selectivity seasons. This was done by combining catch seasons 1 and 2 into the first selectivity season (January-April), equating the second selectivity season with catch season 3 (May-August), and combining catch seasons 4 and 5 into the third selectivity season (September-December). The resulting set of selectivity seasons is close to the old set, with starting or ending points differing by one month in selectivity seasons 1 and 2, and the new selectivity season 3 being identical to the old selectivity season 3. *All models using the new, five-season structure for catch in the factorial design retain the use of three selectivity seasons, but with starting and ending dates adjusted as described here.*

The second decision related to the change from three to five seasons is the timing of each year's spawning event. Prior to the 2005 assessment, spawning was specified to occur in March, which was estimated to be the month of peak spawning based on maturity data. However, with the move to SS2 in the 2006 assessment, the month of peak spawning was constrained to coincide with the start of one of the specified seasons. Given that seasons 1 and 2 were specified to begin in January and June and that January seemed to be a more biologically realistic choice than June, the 2006-2009 assessments specified the beginning of season 1 (January) as the time when spawning would occur in the model. However, under the new season structure, season 2 begins in March, which would allow the model to compute spawning biomass in the month where spawning is estimated to peak in the real population. *The factorial design includes two options with respect to timing of annual spawning for all models using the new, five-season structure: 1) beginning of season 1 (January), and 2) beginning of season 2 (March).*

The length bin structure in the GOA Pacific cod model has remained almost entirely unchanged since the 1994 assessment, and was borrowed initially from the BSAI Pacific cod model. As of last year's GOA assessment, this structure consisted of a length range spanning 5 cm to 105 cm (where the 105 cm bin constitutes a "plus" group), with a single bin for fish between 5 and 11 cm in length, 3 cm bins for fish between 12 and 44 cm in length, and 5 cm bins for fish 45 cm and larger, for a total of 25 bins. This structure was adopted in part due to computational limits associated with the desktop computers used in the 1994 assessment. To take advantage of the greater computational power afforded by today's computers, an alternative bin structure was devised. The first step in doing so was to reconsider the bounds of the length range. The new lower bound of the overall range was set at 4 cm, corresponding to the smallest fish observed in the trawl survey; and the new lower bound of the "plus" group was set at 120 cm, corresponding approximately to the upper 99.9^{th} percentile of observations in the fishery observer database. The second step was to reconsider the bin size. Lengths in both trawl survey and observer databases are recorded to the nearest cm, so bins smaller than 1 cm would not be expected to improve parameter estimates. To provide the maximum amount of contrast with the current bin structure, the new bin size was set at 1 cm throughout the length range. *The factorial design includes two options with respect to bin structure: 1) the old structure, with a combination of 7 cm, 3 cm, and 5 cm bins spanning the 5-105+ cm range; and 2) the new structure, with 1 cm bins spanning the 4-120+ cm range.*

Use of the new bin structure required re-assembling the fishery size composition data from the observer database, because the existing size composition data were not stored in 1 cm bins. Re-assembling the data involved the following changes: 1) various small changes resulting from routine corrections to the observer database, and 2) incorporation of a large number of 2009 data that were not available in time for use in the 2009 assessment. *The factorial design includes two options with respect to use of re-assembled ("new") fishery size composition data: 1) new data in all years except 2009, and 2) new data in all years.*

The full factorial design is shown below (shaded cells highlight differences within each 4-model group):

Model	Season structure	Sizecomp data	Bin structure	Spawning season
2.2	old	old	old	1
2.3.1	old	new except 2009	old	1
2.3.2	old	new except 2009	new	1
2.3.2	old	new	old	1
2.3.4	old	new	new	1
2.4.1	new	new except 2009	old	1
2.4.2	new	new except 2009	old	2
2.4.3	new	new except 2009	new	1
2.4.4	new	new except 2009	new	2
2.5.1	new	new	old	1
2.5.2	new	new	old	2
2.5.3	new	new	new	1
2.5.4	new	new	new	2

Note that use of season 2 to define the time of peak spawning in the "old" season structure is not biologically reasonable, which is why the factorial design includes only 12 models rather than 16.

Values of the objective function, spawning biomass (t) in 2009, spawning biomass in 2009 relative to $B_{35\%}$, and age 0 recruits in 2006 (the most recent year class observed in at least two survey years) are shown below, along with the proportional change in each estimate relative to Model 2.2 (rows shaded yellow correspond to models with spawning at the start of new season 2 (March) to emphasize that spawning biomass values for these models are not strictly comparable to values for models with spawning at the start of season 1; pink cells indicate relative changes with absolute value greater than 10%):

Model	Obj. func.	Spawning biomass 2009		SB2009 per B35%		Recruits 2006 (1000s)	
		Estimate	Change	Estimate	Change	Estimate	Change
2.2	1356.88	150,144	0.000	1.527	0.000	364,380	0.000
2.3.1	1329.94	148,787	-0.009	1.512	-0.009	361,905	-0.007
2.3.2	1704.56	145,861	-0.029	1.544	0.011	424,140	0.164
2.3.2	1364.28	151,096	0.006	1.535	0.005	372,885	0.023
2.3.4	1732.37	153,365	0.021	1.562	0.023	442,189	0.214
2.4.1	2521.65	128,364	-0.145	1.364	-0.106	177,128	-0.514
2.4.2	2536.11	128,364	-0.145	1.364	-0.106	177,128	-0.514
2.4.3	3267.58	168,670	0.123	1.538	0.007	475,237	0.304
2.4.4	3321.48	140,199	-0.066	1.484	-0.028	445,628	0.223
2.5.1	2556.59	148,783	-0.009	1.411	-0.076	187,521	-0.485
2.5.2	2572.10	127,141	-0.153	1.350	-0.116	176,905	-0.515
2.5.3	3309.69	172,040	0.146	1.561	0.022	489,855	0.344
2.5.4	3363.83	142,931	-0.048	1.504	-0.014	457,724	0.256

Some patterns are evident from the above table:

1) For 2009 spawning biomass and 2009 spawning biomass relative to $B_{35\%}$, the only changes greater than 10% in absolute value occur under the new seasonal structure.
2) For 2006 recruitment, all but two of the factorial models are associated with changes greater than 10% in absolute value.
3) All of the models with spawning in season 2 show a decrease in both spawning biomass and spawning biomass relative to $B_{35\%}$.

Time series of spawning biomass, spawning biomass relative to $B_{35\%}$, and age 0 recruits for Models 2.2-2.5.4 are plotted in Figure 2.1.3.

It should be noted that Hessian matrices were not computed for any of the models in the 2.x series except for Model 2.5.4.

Model 2.5.4 is the final version of Model 2 in this preliminary assessment. This should not be taken to imply that all of the changes leading from Model 1 to Model 2.5.4 are insignificant (in fact, some of them are substantial). Rather, justification for their use is as follows:

1) The new catch seasons are a better representation of catch patterns than the old catch seasons, statistically speaking.
2) The new (1 cm) bin structure corresponds to the actual resolution of the observations, and therefore provides maximum ability to infer selectivity and growth patterns from size composition data.
3) March appears to be the peak spawning time for Pacific cod, so it is biologically more reasonable to specify spawning as taking place at the start of new season 2 (March) than the start of season 1 (January).

Model 2 is identical to Model 1 except for the minor corrections described under Model 2.1 above, use of the new season structure, and use of the new bin structure.

Model 3 (selectivity and catchability)

Model 3 deals with use of informative prior distributions to the estimation of selectivity parameters and catchability. In last year's assessment, all selectivity parameters had uniform prior distributions, catchability for the post-1993 portion of the 27-plus trawl survey time series was estimated iteratively by setting 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).

Inclusion of Model 3 in this preliminary assessment was prompted by the following considerations:

1) As in previous assessments, some of the selectivity curves estimated in last year's assessment featured fairly abrupt and difficult-to-rationalize changes, and surprisingly low values for large fish. Moreover, minor changes in starting values of parameters often led to large changes in ending values of the objective function. These features suggest that incorporation of prior knowledge regarding likely values of selectivity parameters might improve model behavior.
2) The point estimate obtained by Nichol et al. was based on only 11 fish, and the distribution of this quantity was shown in last year's assessment to be extremely diffuse (Thompson et al. 2009a, p. 428). This makes it desirable to examine how the estimate of catchability might change if catchability were not assumed to be known with certainty.

Before discussing suitable prior distributions for selectivity parameters, it will prove worthwhile to review the functional form of the selectivity curve and its parameterization. The functional form (SS pattern 24 for length-based selectivity, SS pattern 20 for age-based selectivity) is constructed from two underlying and linearly rescaled normal distributions, with a horizontal line segment joining the two peaks. This form uses the following six parameters:

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* (equal to twice the variance of the underlying normal distribution)
5) *initial_selectivity* (at minimum length/age)
6) *final_selectivity* (at maximum length/age)

All but *beginning_of_peak_region* are transformed: The *ascending_width* and *descending_width* are log-transformed and the other three parameters are logit-transformed.

The candidate prior distributions were all assumed to be normal except for the *beginning_of_peak_region*. This parameter was assumed to have a symmetric beta prior distribution instead, because the bounds placed on the *beginning_of_peak_region* would cause a normal prior distribution to behave awkwardly unless the standard deviation were set at a very small value.

Development of candidate prior means for the selectivity parameters proceeded as follows:

1) The (logit-transformed) *width_of_peak_region* was set at 0.0. This results in the selectivity curve being flat between *beginning_of_peak_region* and the midpoint between *beginning_of_peak_region* and the maximum size/age.
2) The (logit-transformed) *initial_selectivity* was set at -5.0. This results in selectivity equaling approximately 0.0 at the minimum size/age.
3) Provisionally, the (log-transformed) *descending_width* was set at 10.0 and the (logit-transformed) *final_selectivity* was set at 5.0 (these provisional values get changed in steps 5 and 6 below). This results in a provisional selectivity curve equaling approximately 1.0 for all sizes/ages above the *beginning_of_peak_region*.

4) The *beginning_of_peak_region* and *ascending_width* were then set by forcing the provisional selectivity curve to match the maturity curve (in units of size or age, as appropriate) as closely as possible, using least squares as the criterion.
5) Given the values of *width_of_peak_region* and *beginning_of_peak_region* obtained in steps 1 and 4 respectively, the (log-transformed) *descending_width* was then re-set (from the provisional value used in step 3) so as to locate the descending inflection point midway between the end of the peak region and the maximum size/age.
6) The (logit-transformed) *final_selectivity* was then re-set (from the provisional value used in step 3) to a value of 0.0. This results in selectivity equaling 0.5 at the maximum size/age.

If all parameters are set at their respective means as defined above, it is worth noting that the portion of the selectivity curve to the right of the *beginning_of_peak_region* is dependent on the specified maximum size/age (actually the lower bound of the "plus" group). For this preliminary assessment, the lower bound of the age+ group was kept at the value of 20 years that has been used since the 2005 assessment (note that the Plan Teams and SSC rejected a proposal to reduce this to 15 years—Table 2.1.1). As discussed under Model 2 above, the lower bound of the length+ group was set at 120 cm, based on the approximate 99.9th percentile of the lengths in the observer database. These values are thus not arbitrary, but it should be emphasized that other values could have been chosen.

Candidate prior standard deviations were specified so as to satisfy a desired coefficient of variation for each of the following "natural scale" quantities:

1) the *beginning_of_peak_region*
2) the logistic transform of the *width_of_peak_region* (i.e., the actual width of the peak region)
3) the square root of the *ascending_width*/2 (i.e., the standard deviation of the ascending normal)
4) the square root of the *descending_width*/2 (i.e., the standard deviation of the descending normal)
5) the logistic transform of the *initial_selectivity* (i.e., the actual initial selectivity)
6) the logistic transform of the *final_selectivity* (i.e., the actual final selectivity)

For this preliminary assessment, the desired coefficient of variation was set at 50%.

One difficulty with the double-normal selectivity curve is that it is sometimes difficult to infer how prior distributions of the parameters translate into prior distributions on selectivity itself. To make this inference easier, the prior distributions specified above were used to simulate a large number of selectivity curves by drawing parameter values randomly from the prior distributions. Figures 2.1.4 and 2.1.5 show some results of this exercise, for length-based and age-based selectivity, respectively. In each of these figures, the red curve shows the selectivity corresponding to the means of the prior distributions, the blue diamonds show the median selectivity resulting from the simulations, and the blue error bars show the inter-quartile range resulting from the simulations.

A possible shortcoming of Figures 2.1.4 and 2.1.5 is that the inter-quartile range is based on the distribution of selectivities at each size/age taken one at a time, and thus may not provide sufficient information about how selectivities tend to change *across* size/age. To mitigate this possible shortcoming, Figures 2.1.6 and 2.1.7 show the distributions of the multiplicative inverse (reciprocal) of the slope at the ascending inflection point, a quantity which indicates how many units of size/age would be needed to move from a selectivity of 0.0 to a selectivity of 1.0 if the slope of the ascending limb were held constant at the inflection slope. The inter-quartile range for length-based selectivity (Figure 2.1.6) extends from 12.1 to 23.4 cm, and the inter-quartile range for age-based selectivity (Figure 2.1.7) extends from 1.5 to 2.9 years.

For survey catchability (which is log-transformed in SS), a normal prior distribution was specified, with mean 0.0 and standard deviation 0.472. When back-transformed, this corresponds to a lognormal prior with mean 1.0 and a 50% coefficient of variation. A mean of 1.0 (on the natural scale) was viewed as appropriate because the relative magnitudes of typical off-bottom distribution and possible dive response to an oncoming vessel are not precisely quantified, and the effects of these two behaviors would tend to move catchability in opposite directions. The 50% coefficient of variation was chosen to match the value used for the selectivity prior distributions.

Except for the selectivity and catchability prior distributions (and treating post-1993 27-plus catchability as a free parameter), Model 3 is identical to Model 2.

Model 4 (age and growth)

Model 4 is the first of the three models in the "age and growth" group, all of which exclude all age data (both age composition and mean size at age) and all of which describe maturity as a function of length rather than age.

Except for excluding all age data and describing maturity as a function of length rather than age, Model 4 is identical to Model 2.

Model 5 (age and growth)

Model 5 is the second of the three models in the "age and growth" group. It is distinguished from Models 1-4 by internal estimation of the two parameters governing conditional variability in length at age. The term "conditional variability" is used here to distinguish "between-individuals" variability in length at age *given a set of von Bertalanffy growth parameters* from "between-cohorts" or "between-years" variability *in the von Bertalanffy growth parameters themselves*. In all models in this preliminary assessment, the conditional standard deviation of length at age is modeled as a linear function of length at age.

Except for internal estimation of the two parameters governing conditional variability in length at age, Model 5 is identical to Model 4.

Parameters Estimated Independently

Natural mortality

The natural mortality rate is fixed at a value of 0.38 in all models.

Variability in estimated age

The standard deviation of estimated age was modeled as 0.019 + 0.068 × age.

Variability in length at age

Models 1-4 set the standard deviation of length corresponding to length-at-age-0 at a value of 1.87 and the standard deviation of length corresponding to length-at-age-20 at a value of 6.53. Model 5 estimated these parameters internally.

Weight at Length

For Model 1, the season-specific weight-at-length parameters estimated in the 2008 assessment are used. These were determined from all weight-length records present in the observer database (both shore-based and at-sea samples) as of the 2008 assessment, giving the following values:

Season:	Jan-May	Jun-Aug	Sep-Dec	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

For Models 2-5, new season-specific parameters were computed from the same data set in order to comply with the new seasonal structure of the models, giving the following values:

Season:	Jan-Feb	Mar-Apr	May-Aug	Sep-Oct	Nov-Dec
α:	8.799×10^{-6}	8.013×10^{-6}	1.147×10^{-5}	1.791×10^{-5}	7.196×10^{-6}
β:	3.084	3.088	2.990	2.893	3.120
Samples:	36,566	29,753	6,950	9,352	2,957

The weight-length parameters for the new seasonal structure give a better (lower) AIC than the weight-length parameters for the old seasonal structure.

Maturity

Models 1-3 use an age-based logistic maturity schedule with intercept = 4.35 years and slope = -1.963. Models 4-5 use a length-based logistic maturity schedule with intercept = 50.2 cm and slope = -0.222. Both schedules are taken from Stark (2007).

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 mean length at age 0, the Brody growth coefficient *K*, asymptotic length, log mean recruitment before and after the 1977 regime shift, initial fishing mortality, fishery selectivity parameters for various combinations of gear, season, and block of years; sub-27 and 27-plus trawl survey selectivity parameters; annual recruitment deviations, annual deviations in the 27-plus trawl survey selectivity curve (except for initial selectivity), and cohort-specific deviations in growth.

Additional parameters estimated conditionally in Model 3 consist of the post-1993 27-plus trawl survey catchability.

Additional parameters estimated conditionally in Model 5 consist of the standard deviation of length at length-at-age-0 and the standard deviation of length at length-at-age-20.

No additional parameters were estimated conditionally in Models 1, 2, or 4.

Results

Goodness of Fit

Table 2.1.2 shows the number of parameters along with values of the objective function (both in aggregate and broken down by category) for Models 1-5.

Differences in number of parameters can be explained as follows: Model 3 has one more parameters than Models 1, 2, and 4 because it estimates post-1993 27-plus trawl survey catchability. Model 5 has two more parameters than Models 1, 2, and 4 because it estimates conditional variability in length at age internally.

It is important to emphasize that the log likelihood values shown in Table 2.1.2 are comparable across Models 4-5 only. Model 1 uses a different data file; and Models 2-3, while they use the same data file as Models 4-5, do not assign zero weight to the age data like Models 4-5 do. Also, Model 3 uses informative prior distributions for selectivity parameters and survey catchabilities. Because the log likelihoods for Models 4-5 are comparable, AIC can be used to evaluate the performance of these three models relative to one another. Based simply on AIC, Model 5 performs better than Model 4.

Table 2.1.3 shows the ratio of mean effective sample size to mean input sample size for the size composition data. Here, the results from Model 1 are not comparable to the others, because Model 1 uses a different set of input sample sizes. Even Models 2-5 are not perfectly comparable, however, because Models 2 and 3 do not attempt to fit the size composition data from the trawl survey in years where age composition data are available. It is also probably important to remember that Models 4 and 5 are able to focus more attention on fitting the size composition data because they ignore the age composition data and the mean size-at-age data. With these caveats in mind, Models 2 and 5 tend to produce the highest values in Table 2.1.3.

Table 2.1.4 shows the ratio of effective sample size to means input sample size for each record of age composition data, and overall for the 27-plus and sub-27 trawl survey age composition data. Model 3 tends to do the best for the 27-plus age composition data, although Models 1 and 2 do nearly as well (both Models 2 and 3 exhibit a ratio greater than unity for the 27-plus age composition data). Model 1 tends to do the best for the sub-27 age composition data, but is probably important to remember that the simpler seasonal structure used in Model 1 results in many fewer records of size composition data, which, because the *average* input sample size is fixed at 300 for all models, means that Model 1 can focus more attention on fitting the age composition data than Models 2 or 3 (Models 4-5 ignore the age composition data entirely).

Figure 2.1.8 shows how well Models 1-8 fit the trawl survey time series of population numbers. The upper panel shows the observed and estimated abundances, and the lower panel shows the time series of standardized residuals. The means and standard deviations of the standardized residual time series are shown below:

Quantity	Model 1	Model 2	Model 3	Model 4	Model 5
Mean:	0.96	0.75	0.08	-0.22	-0.30
Standard deviation:	1.88	1.64	1.23	1.84	1.41

Model 3 comes closest to achieving a mean of 0.0 and a standard deviation of 1.0.

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

Figure 2.1.9 shows three ways of comparing the length at age estimates produced by the five models. Each model produces a mean length at each age in each year, meaning that each model produces a distribution of mean lengths at each age. The upper panel compares the medians of these distributions across models. Given the thickness of the lines in the graph and the height of the vertical axis, the five curves might appear to be fairly close. The middle panel shows a different way of comparing these data, by expressing the medians for each model in terms of their differences from the medians for Model 1. Here, the medians may not appear so similar as in the upper panel. For example, the medians for Models 2-5 at age 0 are all within 1 cm of the median for Model 1 at age 0. The medians for Models 2 and 3 are more than 1 cm below the median for Model 1 after ages 6-7 and more than 2 cm below the median for Model 1 after ages 13-14. The medians for Models 4 and 5 even farther removed from the median for Model 1. For example, the medians for Models 4 and 5 are 7-10 cm below the median for Model 1 at ages 7-8.

The lower panel shows the range of mean lengths at age for the six models. Except for Model 4, the curves are fairly similar. The range for Model 1 peaks at a value of about 13 cm, with the peak occurring at age 3. The peaks for Models 2, 3, and 5 all occur at ages 5-6, and range from a low of 12 cm (Model 5) to a high of 14 cm (Model 2). The curve for Model 4 is much higher than the others, peaking at a value of 22 cm at age 5.

Figure 2.1.10 plots standard deviation of length at age versus mean length at age in the data and as estimated by Models 1-5. The black dots ("data") represent 8 years' worth of mean lengths and standard deviations of length at ages 1-8, and the solid black line represents the least-squares regression through those data. Models 1-4 approximate the regression fairly closely. Models 5 tends to exceed the regression by an average of about 1.7 cm.

Finally, model performance in terms of matching size at age can be measured by comparing annual estimates of size at age 1 against annual mean size at age 1 against observed size at age 1, as shown in Table 2.1.5. In terms of RMSE, Models 2 and 3 do the best job of matching observed size at age 1 (RMSE=1.10), while Model 1 does the worst (RMSE=3.15; this is probably due to the fact that Model 1 uses the age composition data from the 2007 sub-27 survey, while Models 2-5 use the size composition data instead). Annual sizes at age 1 estimated by Models 2-5 all have positive correlations with observed mean sizes at age 1, while Model 1 produces a negative correlation. The correlations for Models 2-5 are all in the range 0.46-0.50.

Catchability for the pre-1996 portion of the 27-plus trawl survey time series and for each year of the sub-27 trawl survey time series were free parameters in all models. Catchability for the post-1993 portion of the 27-plus trawl survey time series was a free parameter in Model 3 and fixed at 1.040 in all other models. A summary of catchability values, assumed and estimated, is shown below:

Catchability	Model 1	Model 2	Model 3	Model 4	Model 5
27-plus pre-1996	2.478	2.058	1.954	1.284	1.242
27-plus post-1993	1.040	1.040	1.469	1.040	1.040
sub-27 (average)	0.139	0.145	0.147	0.091	0.124

Models 4 and 5 give the lowest estimates for the pre-1996 portion of the 27-plus time series. Model 3's estimate of catchability for the post-1993 portion is much higher than the value assumed by the other models.

Selectivity at age for the 27-plus portion of the trawl survey time series is shown for each model in Figure 2.1.11. Models 1-3 seem noticeably different from Models 4-5, but differences within either of these groups appear to be fairly subtle. Models 4 and 5 each estimate survey selectivity to be approximately asymptotic in one or two years.

Fishery selectivities at length for Models 1-5 are shown in Figures 2.1.12.1-2.1.12.5, respectively. Visually, the curves appear very similar across the six models. The informative prior distributions used in Model 3 may have helped to smooth out the kinks in the January-April longline fishery estimated by the other models, but other impacts of these prior distributions are not particularly obvious.

Estimates of Time Series

Time series of estimated spawning biomass, spawning biomass relative to $B_{35\%}$, and age 0 recruits are shown for each of the six models in Figures 2.1.13, 2.1.14, and 2.1.15, respectively. The upper panel in each figure shows the point estimates, and the lower panel shows the coefficients of variation associated with those estimates.

In Figure 2.1.13, Models 4 and 5 result in the highest spawning biomass throughout the time series. Models 1-3 are close throughout most of the time series, although by 2009 they are starting to diverge, with Model 3 giving the lowest spawning biomass. Model 5 has the largest coefficients of variation throughout most of the time series.

In Figure 2.1.14, the 2009 ratios of spawning biomass to $B_{35\%}$ are closer to one another than the 2009 spawning biomasses themselves. Model 5 again has the largest coefficients of variation throughout most of the time series, but the differences between models are smaller than in Figure 2.1.13.

In Figure 2.1.15, the age 0 recruitment trajectories are fairly similar between Models 1-3 and between Models 4-5 but the estimates from Models 4-5 tend to be much higher and more variable than the estimates from Models 1-3. The pair-wise correlations between the time series estimated by the five models range from a low of 0.31 (Model 1 versus Model 4) to a high of 0.88 (Model 2 versus Model 3).

Discussion

The five models requested by the Plan Teams and SSC are broadly similar in some respects. For example, the estimated time series of spawning biomass, spawning biomass relative to $B_{35\%}$, and age 0 recruitment for the most part show at least qualitatively similar shapes.

Each of the features associated with Models 2-5 presents a decision point for the Plan Teams and the SSC in developing model requests for the final assessment. Some (all?) of them can also be subdivided into multiple decision points.

One obvious decision point is whether to use the age data for none, some, or all of the models in the final assessment. If one or more totally “age-free” models is desired, a related decision is whether to keep the current natural mortality rate, which is based on the age at 50% maturity, or use a natural mortality rate derived from a length-based maturity schedule.

Another decision point that is worth discussing in some detail is whether the new season structure and bin structure used in Models 2-5 should be retained or modified for the final assessment. Although the new season structure has a more explicit statistical justification than the old season structure, and although the new bin structure makes the fullest possible use of the information contained in the size composition data, one cost of adopting these two new data structures is that models take much longer to run. For example, when starting from a converged parameter file, computing the Hessian matrix for Model 1 took about 16 minutes. In contrast, when starting from converged parameter files, computing the Hessian matrices for Models 2-5 took an average of about 7 hours and 40 minutes, more than 28 times as long as Model 1.

When starting from something other than a converged parameter file, run times under the new data structures can be much longer still.

Another decision point is whether to keep fixing survey catchability at the level 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 obtained by Nichol et al. (2007). When catchability is estimated (rather than fixed) in Model 3, resulting biomass estimates are lower than in the other models, but still much higher than survey biomass estimates.

Because of the much longer run times associated with Models 2-5, little testing for global minimization of the objective function was done in this preliminary assessment. This is in sharp contrast to previous assessments in recent years (both preliminary and final), when many hundreds of “jitter” runs were conducted to test whether SS had found the global minimum of the objective function.

The simplicity of the old data structures and the resulting short run times, contrasted with the complexity of the new data structures and the resulting long run times, imply a dilemma: On the one hand, finding the global minimum of the objective function is more likely under the old data structures, but it is also more likely that the global minimum will give inaccurate parameter estimates (because the coarseness of the old data structures can mask the true behavior of the system). On the other hand, finding the global minimum of the objective function is less likely under the new data structures, but it is more likely that the global minimum (if found) would give accurate parameter estimates.

As with the other new features of Models 2-5, the issue of data structures is not necessarily a binomial one, as many possible data structures of intermediate complexity can be imagined. In the case of bin structure, for example, bins could be 2 cm wide throughout the length range rather than 1 cm, or bins could be 1 cm wide up to lengths of 40 cm and 2 cm wide for all larger lengths. Many other intermediate structures are also possible.

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Table 2.1.1. Proposed model features and final model requests. "Group" is a designation intended to combine related proposals. Column colors are intended to help match models or sets of models with groups of proposals.

		Model(s) where proposal is used					
Group	Proposal	1	2	3	4	5	6 [1]
Last year's model	Keep all features of last year's model	x					
Data and data structure[2]	Exclude IPHC data[3]		x	x	x	x	x
	Exclude fishery (but not survey) age data[4]		x	x	x	x	x
	Use finer length bin structure		x	x	x	x	x
	Re-evaluate seasonal structure		x	x	x	x	x
Selectivity and Q	Use informative priors or other constraints on selectivity			x			
	Estimate catchability internally			x			
Age and growth	Exclude all mean length-at-age data				x	x	x
	Exclude all age composition data				x	x	x
	Describe maturity as a function of length, not age				x	x	x
	Estimate variation in length-at-age internally					x	x
	Omit cohort-specific growth, add time-varying growth						x
Considered but rejected	Use age conditioned on length						
	Estimate ageing bias from radiocarbon study						
	Decrease emphasis on season 1 fishery sizecomps						
	Reduce "plus" age from 20 to 15						
	Put a cap on catchability for sub-27 survey in the GOA						
	Decrease lower bound for selectivity parameters						
	Examine spatial-temporal variation in fishery CPUE						
	Advance model one year, compare with projections						

Footnotes:
1. Model 6 is to be used only in the BSAI assessment.
2. This group does not include proposals relating to exclusion of survey age data (see "Age and growth" group).
3. Plan Teams recommended rejecting this proposal (note that the GOA assessment already excludes IPHC data).
4. Plan Teams inadvertently omitted this proposal from their discussion.

Table 2.1.2. Objective function values and components thereof for Models 1-5. Shaded cells represent values that have zero weight in the objective function and are shown for comparison only. Likelihoods for Models 4-5 are directly comparable; likelihoods for other models are not. Only one set of initial parameter values was considered for most models, so the potential for reaching a solution other than the global minimum is greater than in recent assessments.

Parameters	Model 1	Model 2	Model 3	Model 4	Model 5
Unbound	282	281	283	277	280
Bound	0	1	0	5	4
ALL	282	282	283	282	284
Negative log likelihoods and priors	Model 1	Model 2	Model 3	Model 4	Model 5
Survey	-4.83	-9.50	-18.38	-8.37	-15.91
Age Composition	109.77	78.33	81.52	n/a	n/a
Size at Age	329.13	347.93	365.06	n/a	n/a
Length Composition	1047.83	2937.20	2957.92	3043.71	2911.26
Recruitment	-14.37	-17.81	-17.38	-18.47	5.49
Parameter Priors	n/a	n/a	181.23	n/a	n/a
Parameter Softbounds	0.05	0.06	0.02	0.07	0.07
Parameter *devs*	15.93	27.61	24.89	47.33	20.91
ALL	1483.51	3363.83	3574.87	3064.27	2921.82
Akaike Information Criterion	Model 1	Model 2	Model 3	Model 4	Model 5
ALL (including priors for Model 3)	3531.02	7291.66	7715.74	6692.54	6411.64
CPUE negative log likelihoods	Model 1	Model 2	Model 3	Model 4	Model 5
Jan-Apr Trawl Fishery	132.10	132.82	96.48	101.41	121.72
May-Aug Trawl Fishery	113.70	101.67	113.83	111.24	104.49
Sep-Dec Trawl Fishery	117.79	113.88	127.38	139.36	126.65
Jan-Apr Longline Fishery	-15.48	-28.00	-23.58	-22.57	-27.84
May-Aug Longline Fishery	0.05	-1.53	-0.14	-0.94	-1.03
Sep-Dec Longline Fishery	0.63	-6.83	-6.75	-6.63	-7.15
Jan-Apr Pot Fishery	-1.40	-9.18	3.38	1.40	-5.40
May-Aug Pot Fishery	-3.79	-2.65	-3.04	-3.28	-3.39
Sep-Dec Pot Fishery	-0.65	-3.38	-0.06	-0.80	-3.27
27plus Trawl Survey	4.31	-1.93	-10.96	-1.33	-8.11
Sub27 Trawl Survey	-9.13	-7.56	-7.42	-7.05	-7.80
ALL	-4.83	-9.50	-18.38	-8.37	-15.91
Agecomp negative log likelihoods	Model 1	Model 2	Model 3	Model 4	Model 5
Jan-Apr Longline Fishery	39.87	n/a	n/a	n/a	n/a
27plus Trawl Survey	53.96	55.83	59.38	n/a	n/a
Sub27 Trawl Survey	15.94	22.50	22.14	n/a	n/a
ALL	109.77	78.33	81.52	n/a	n/a
Size-at-age negative log likelihoods	Model 1	Model 2	Model 3	Model 4	Model 5
Jan-Apr Longline Fishery	36.76	n/a	n/a	n/a	n/a
27plus Trawl Survey	237.72	301.14	317.14	n/a	n/a
Sub27 Trawl Survey	54.64	46.79	47.92	n/a	n/a
ALL	329.13	347.93	365.06	n/a	n/a
Sizecomp negative log likelihoods	Model 1	Model 2	Model 3	Model 4	Model 5
Jan-Apr Trawl Fishery	252.71	636.26	636.18	612.94	597.49
May-Aug Trawl Fishery	74.83	108.67	110.69	106.15	105.25
Sep-Dec Trawl Fishery	129.79	294.38	299.38	299.74	292.16
Jan-Apr Longline Fishery	201.43	575.21	552.73	569.10	548.79
May-Aug Longline Fishery	27.85	77.04	80.76	74.26	75.91
Sep-Dec Longline Fishery	92.25	248.16	262.57	251.65	249.08
Jan-Apr Pot Fishery	129.96	415.13	424.83	415.59	406.80
May-Aug Pot Fishery	12.38	68.30	69.69	68.87	69.46
Sep-Dec Pot Fishery	36.48	183.41	182.91	177.17	178.35
27plus Trawl Survey	39.90	145.59	151.06	282.83	255.63
Sub27 Trawl Survey	50.23	185.04	187.12	185.41	132.36
ALL	1047.83	2937.20	2957.92	3043.71	2911.26

Table 2.1.3. Ratios of mean effective sample size to input sample size for size composition data. Cells under Model 1 are shaded yellow to indicate that different input sample sizes were used for that model. Pink = row maximum for Models 2-5, green = row minimum for Models 2-5.

	Mean effective sample size / mean input sample size				
Fleet	Model 1	Model 2	Model 3	Model 4	Model 5
Jan-Apr Trawl Fishery	0.92	2.66	2.65	2.62	2.58
May-Aug Trawl Fishery	2.72	6.63	6.11	6.09	7.27
Sep-Dec Trawl Fishery	1.10	3.21	3.19	3.28	3.48
Jan-Apr Longline Fishery	1.26	3.36	3.63	3.43	3.49
May-Aug Longline Fishery	2.53	6.34	5.92	6.33	6.24
Sep-Dec Longline Fishery	1.75	5.53	4.41	4.30	4.02
Jan-Apr Pot Fishery	1.10	3.82	3.64	3.62	3.67
May-Aug Pot Fishery	5.22	4.34	4.14	4.26	4.19
Sep-Dec Pot Fishery	3.77	5.08	5.08	5.52	5.38
27plus trawl Survey	0.48	0.79	0.78	1.34	1.38
Sub27 trawl Survey	1.14	0.19	0.19	1.18	1.23

Table 2.1.4. Ratios of effective sample size to input sample size for age composition data. Cells shaded yellow indicate that the corresponding data (row) were given zero weight in the corresponding model (column). Pink = row maximum, green = row minimum.

		Effective sample size / input sample size				
Fleet	Year	Model 1	Model 2	Model 3	Model 4	Model 5
Jan-Apr Longline Fishery	2008	0.17	0.04	0.04	0.01	0.01
27plus Trawl Survey	1987	0.09	0.09	0.08	0.08	0.03
27plus Trawl Survey	1990	0.51	0.67	1.56	0.07	0.04
27plus Trawl Survey	1993	0.88	0.76	0.77	0.13	0.04
27plus Trawl Survey	1996	1.00	1.26	0.83	0.06	0.04
27plus Trawl Survey	1999	0.29	0.29	0.40	0.23	0.21
27plus Trawl Survey	2001	2.31	2.10	2.50	0.07	0.05
27plus Trawl Survey	2003	0.70	0.98	1.24	0.03	0.02
27plus Trawl Survey	2005	1.05	2.13	1.15	0.05	0.03
27plus Trawl Survey	2007	0.36	0.21	0.20	0.04	0.05
27plus Trawl Survey	All	0.93	1.07	1.11	0.09	0.06
Sub27 Trawl Survey	1993	0.16	0.20	0.19	0.91	0.52
Sub27 Trawl Survey	1996	1.84	0.51	0.51	0.03	0.01
Sub27 Trawl Survey	1999	0.80	1.98	1.67	0.59	0.06
Sub27 Trawl Survey	2001	6.91	0.76	0.67	0.26	0.04
Sub27 Trawl Survey	2003	8.73	2.00	2.58	0.02	0.01
Sub27 Trawl Survey	2005	0.04	0.01	0.02	0.00	0.00
Sub27 Trawl Survey	2007	0.46	0.14	0.14	71.78	0.83
Sub27 Trawl Survey	All	2.63	0.87	0.85	0.35	0.12

Table 2.1.5. Comparison of annual lengths at age 1 as in the age data and as estimated by Models 1-5 ("SE" = squared error). Pink = row maximum, green = row minimum.

		Model 1		Model 2		Model 3		Model 4		Model 5	
Year	Data	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE
1993	20.8	20.4	0.2	20.7	0.0	20.6	0.1	16.6	18.3	17.4	11.8
1996	21.1	20.1	1.1	20.5	0.4	20.5	0.4	19.0	4.6	18.8	5.2
1999	20.6	20.4	0.0	20.7	0.0	20.7	0.0	17.8	7.6	17.4	10.2
2001	21.2	19.9	1.6	20.1	1.1	20.0	1.3	17.6	12.5	18.0	10.2
2003	21.1	21.7	0.3	21.0	0.0	20.9	0.0	19.1	4.2	18.8	5.4
2005	19.6	24.6	25.5	21.5	3.7	21.5	3.6	18.0	2.6	18.6	0.9
2007	19.2	25.6	41.0	17.5	3.1	17.5	3.1	16.5	7.3	16.7	6.3
RMSE:			3.15		1.10		1.10		2.85		2.67
Correl:			-0.93		0.49		0.48		0.50		0.46

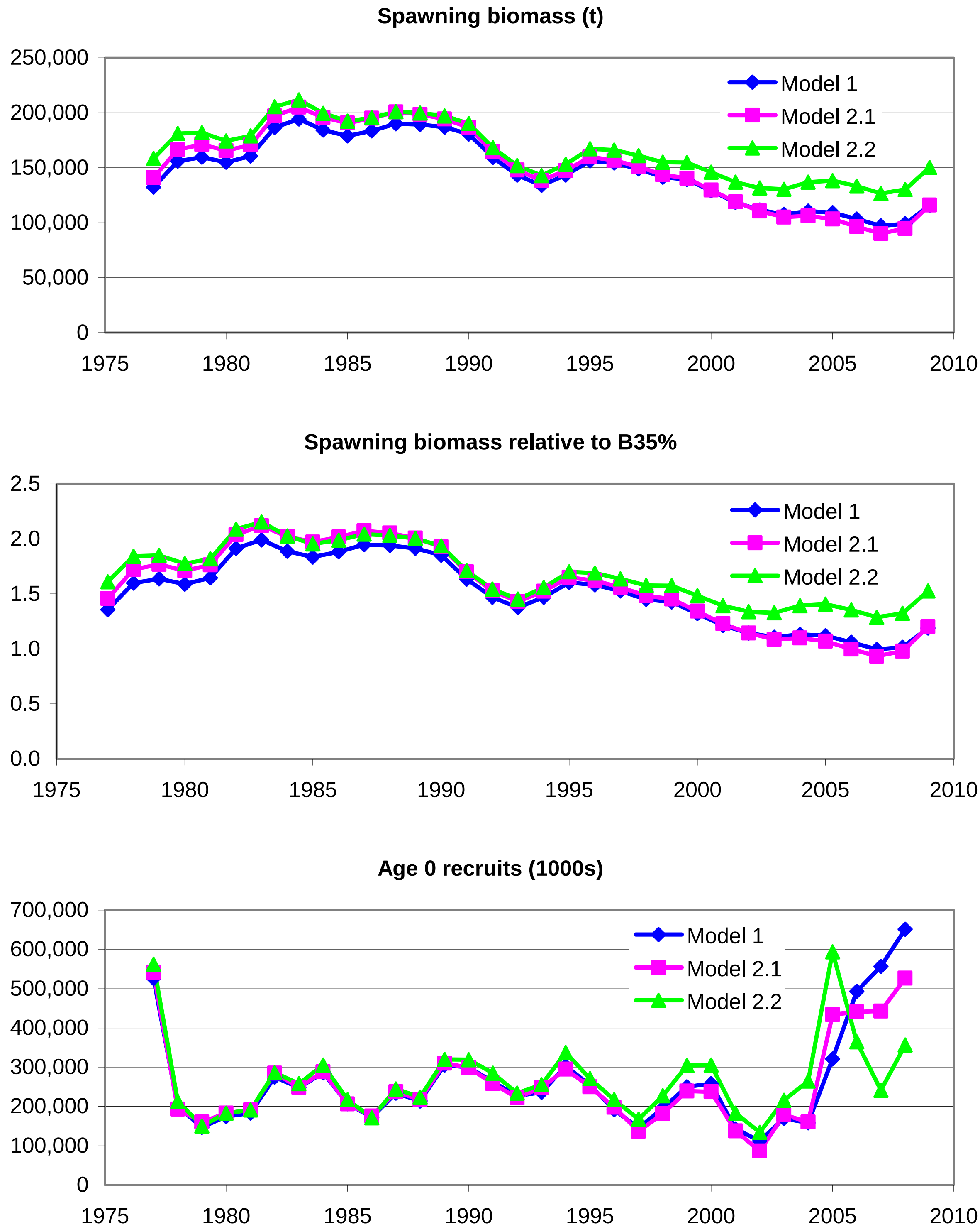


Figure 2.1.1. Time series of spawning biomass (t), spawning biomass relative to $B_{35\%}$, and age 0 recruits (1000s of fish) for Models 1, 2.1, and 2.2.

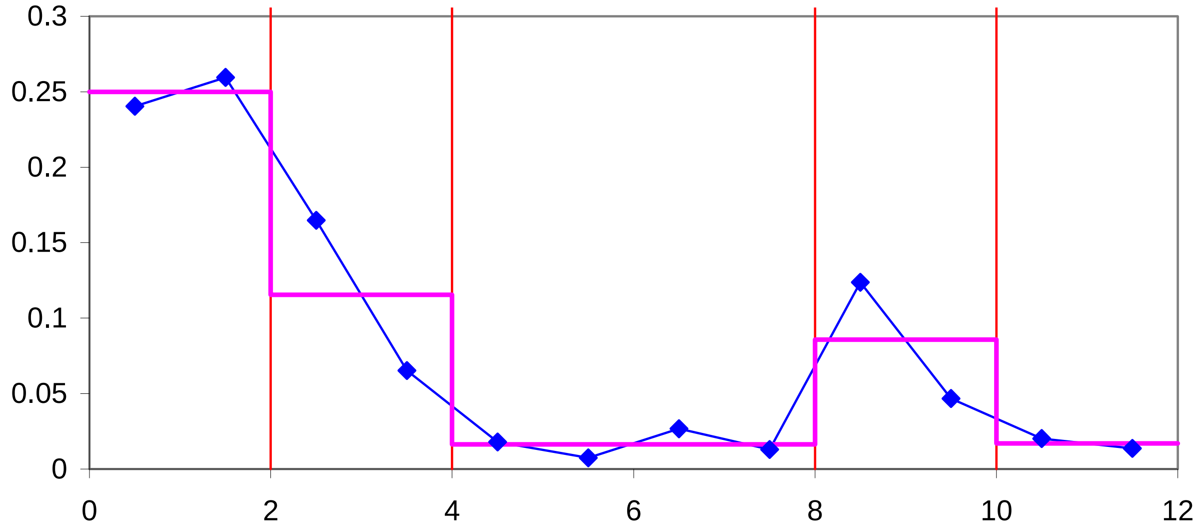
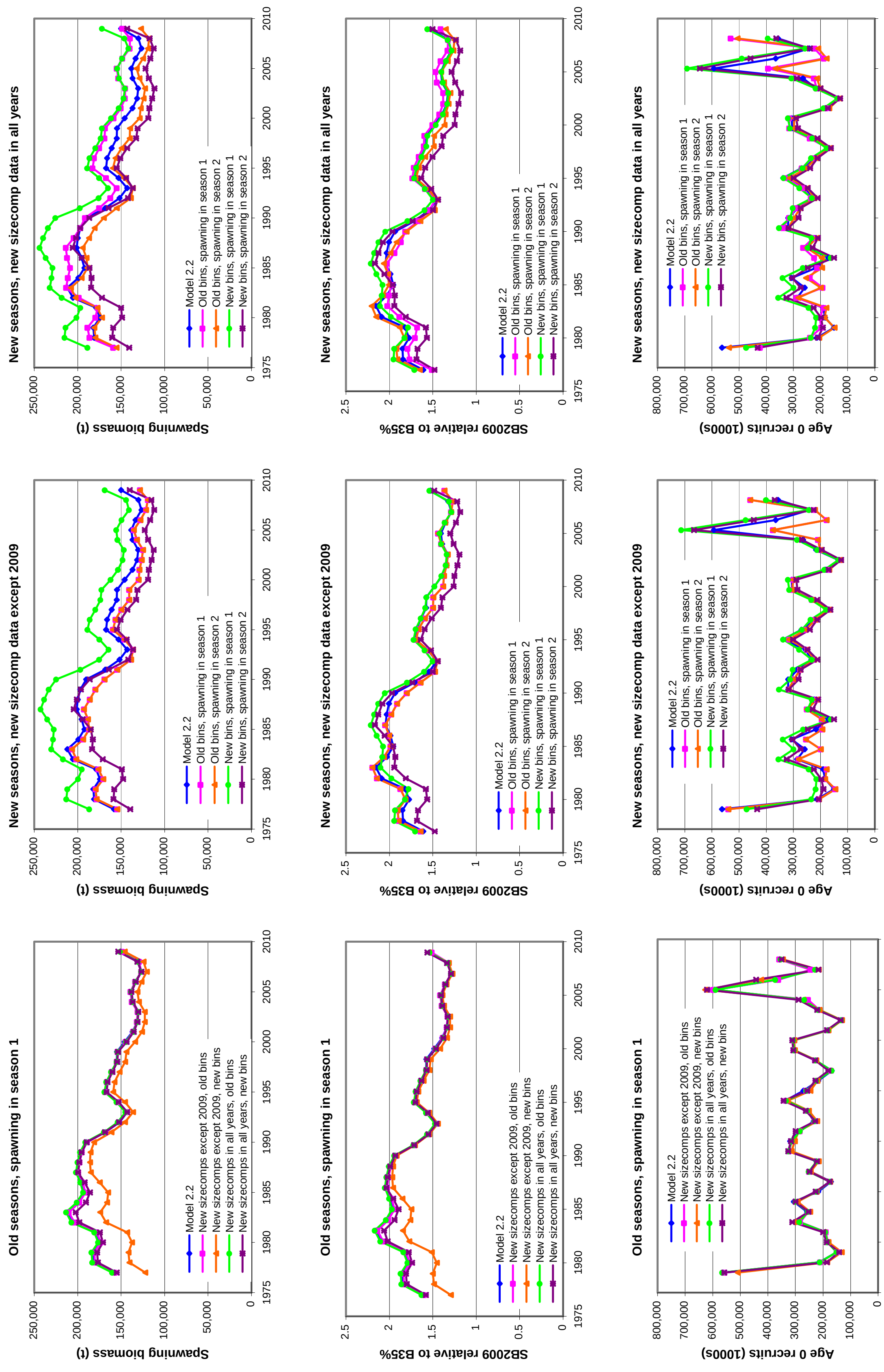


Figure 2.1.2. New season structure. Average monthly catch proportions are shown by the blue diamonds, average seasonal catch proportions are shown by the magenta stair-step, and season ending boundaries are shown by the red vertical lines



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igure 2.1.3. Time series of spawning biomass (t), spawning biomass relative to $B_{35\%}$, and age 0 recruits (1000s of fish) for Models 2.2-2.5.4.

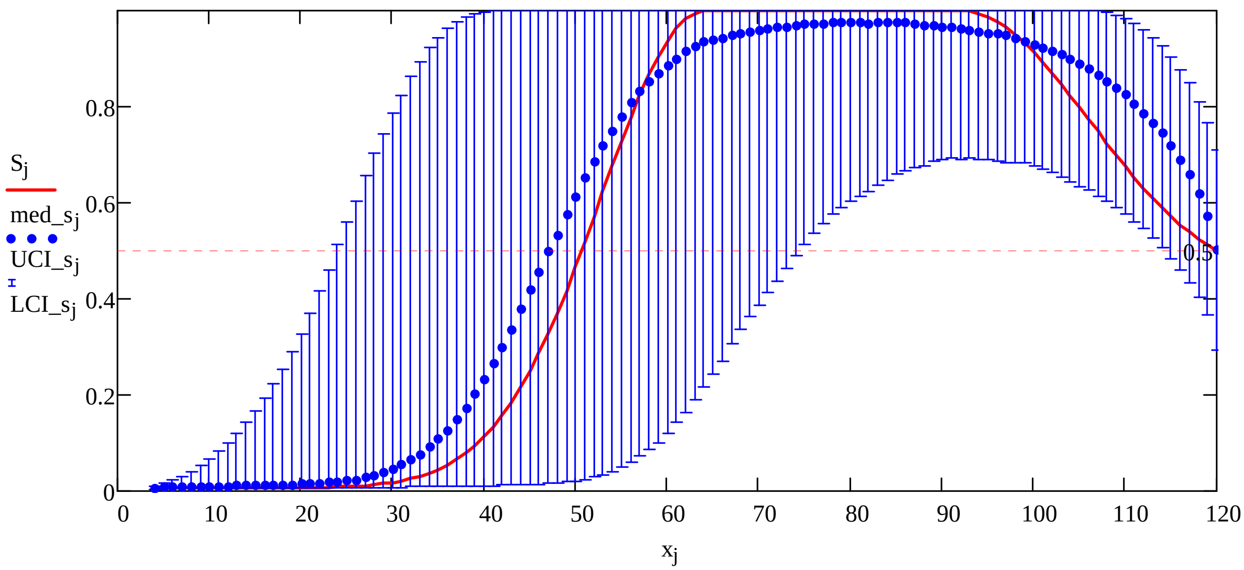


Figure 2.1.4. Selectivity at length implied by prior distributions. Red = curve corresponding to means of prior distributions, blue dots = median of simulations, blue error bars = inter-quartile range.

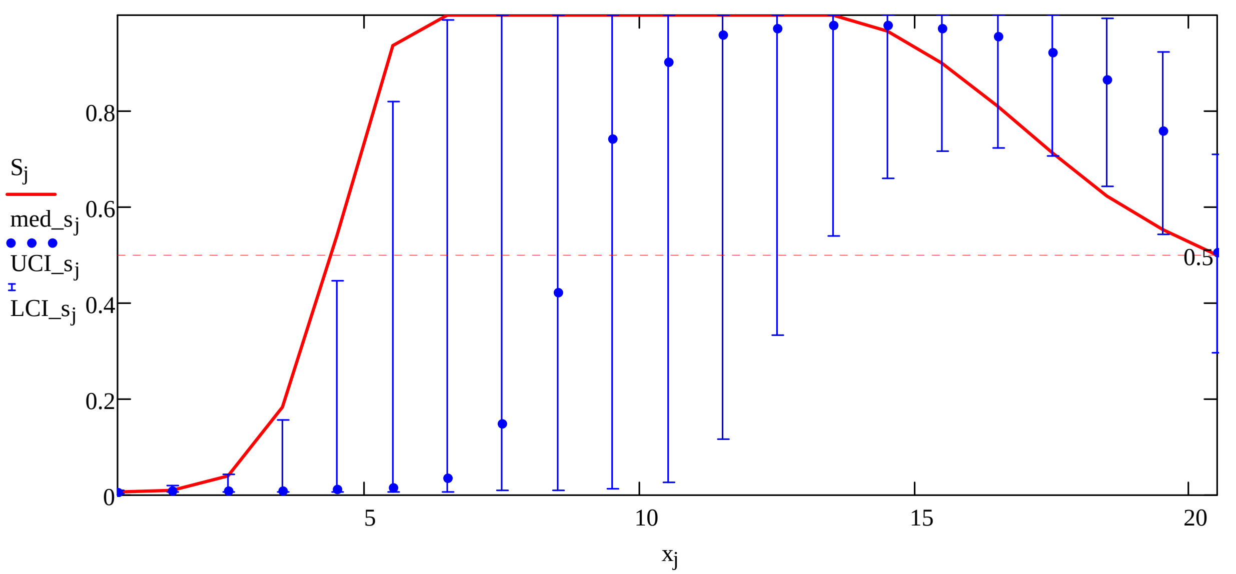


Figure 2.1.5. Selectivity at age implied by prior distributions. Red = curve corresponding to means of prior distributions, blue dots = median of simulations, blue error bars = inter-quartile range.

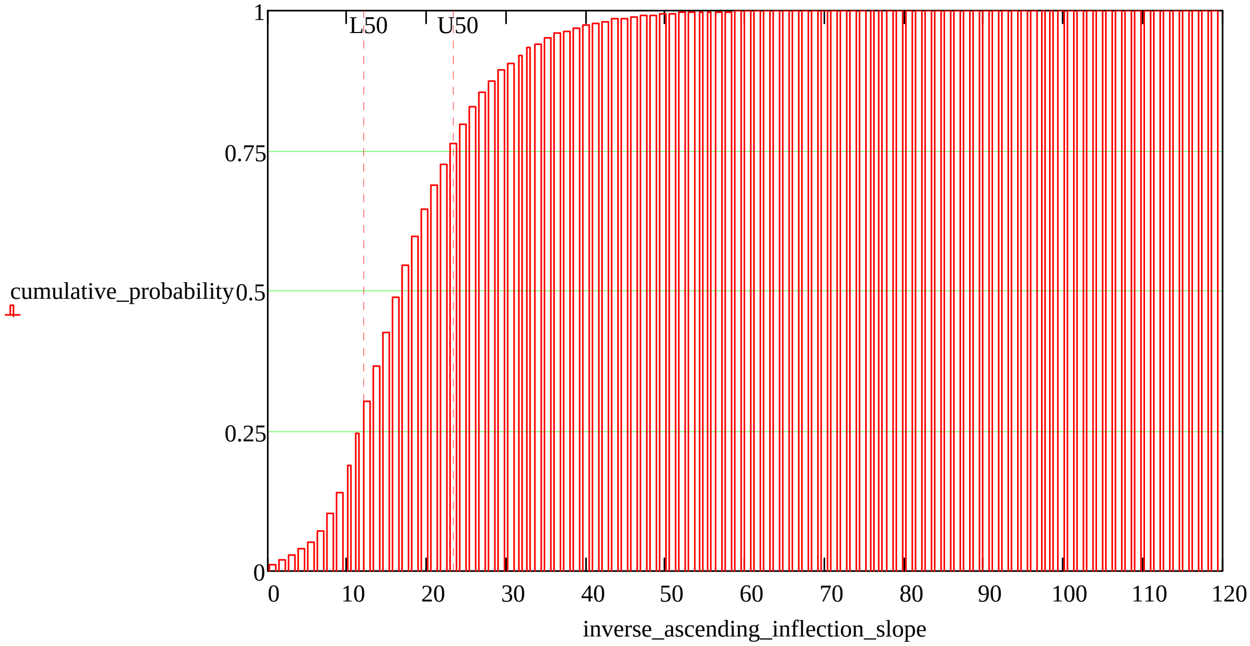


Figure 2.1.6. Distribution of the reciprocal of the slope at the length-based ascending inflection point. L50 and U50 represent limits of inter-quartile range

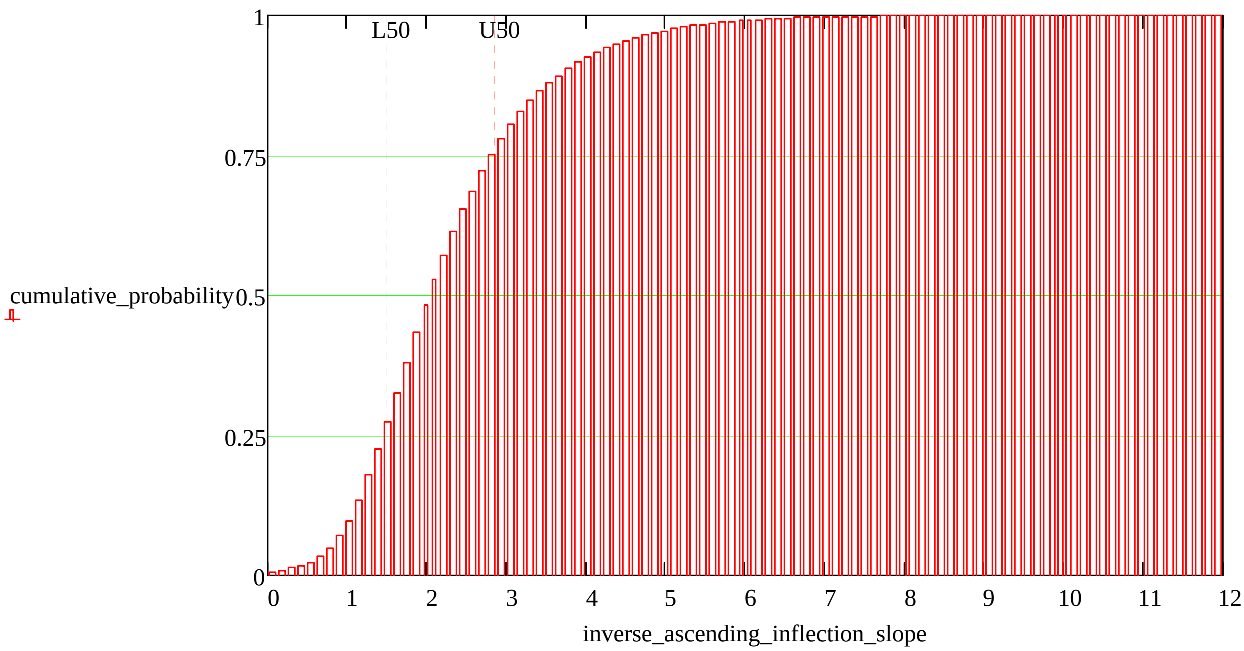


Figure 2.1.7. Distribution of the reciprocal of the slope at the age-based ascending inflection point. L50 and U50 represent limits of inter-quartile range.

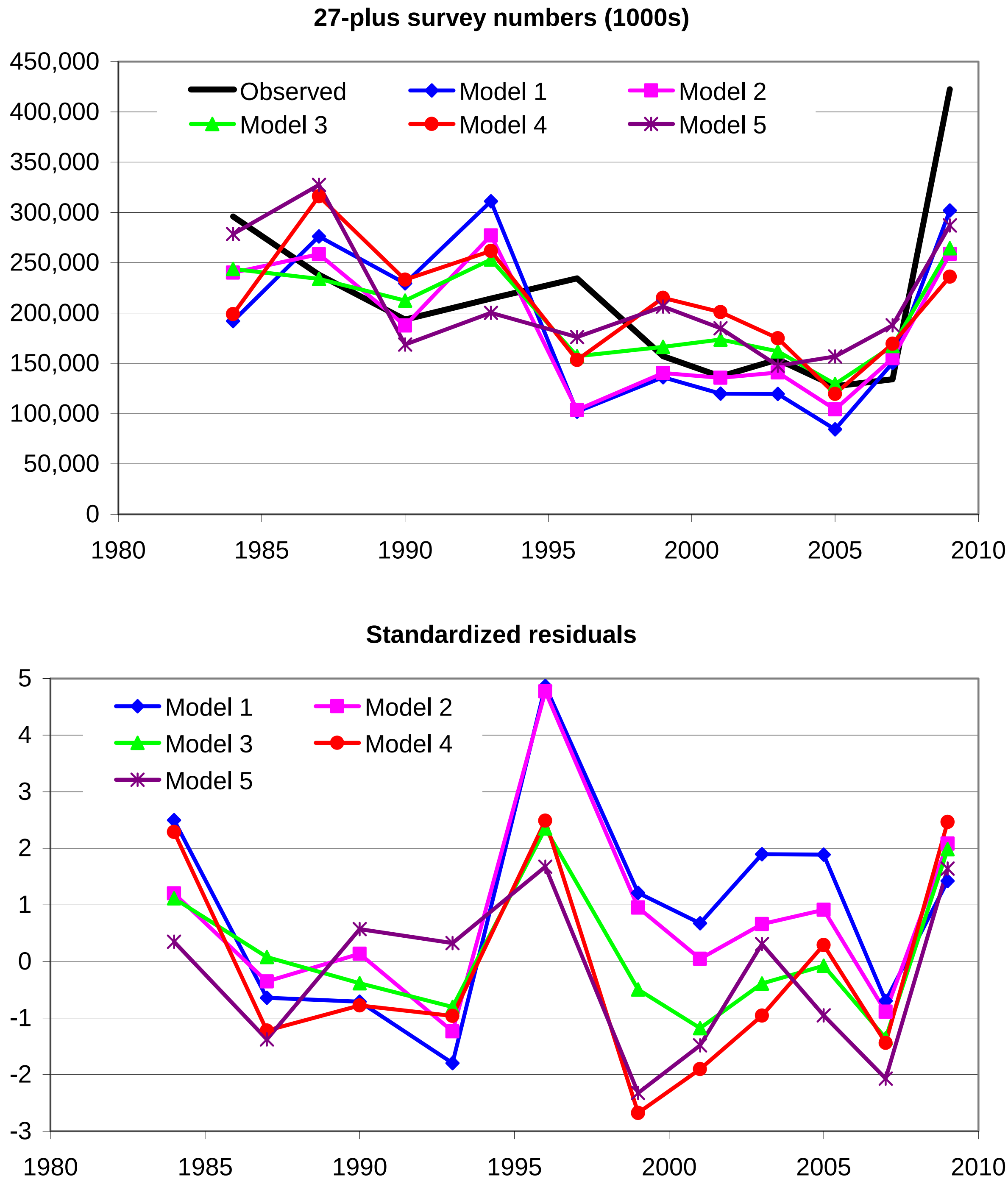


Figure 2.1.8. Model fits to the time series of trawl survey population numbers. The upper panel shows the observed and estimated abundances, and the lower panel shows the time series of standardized residuals.

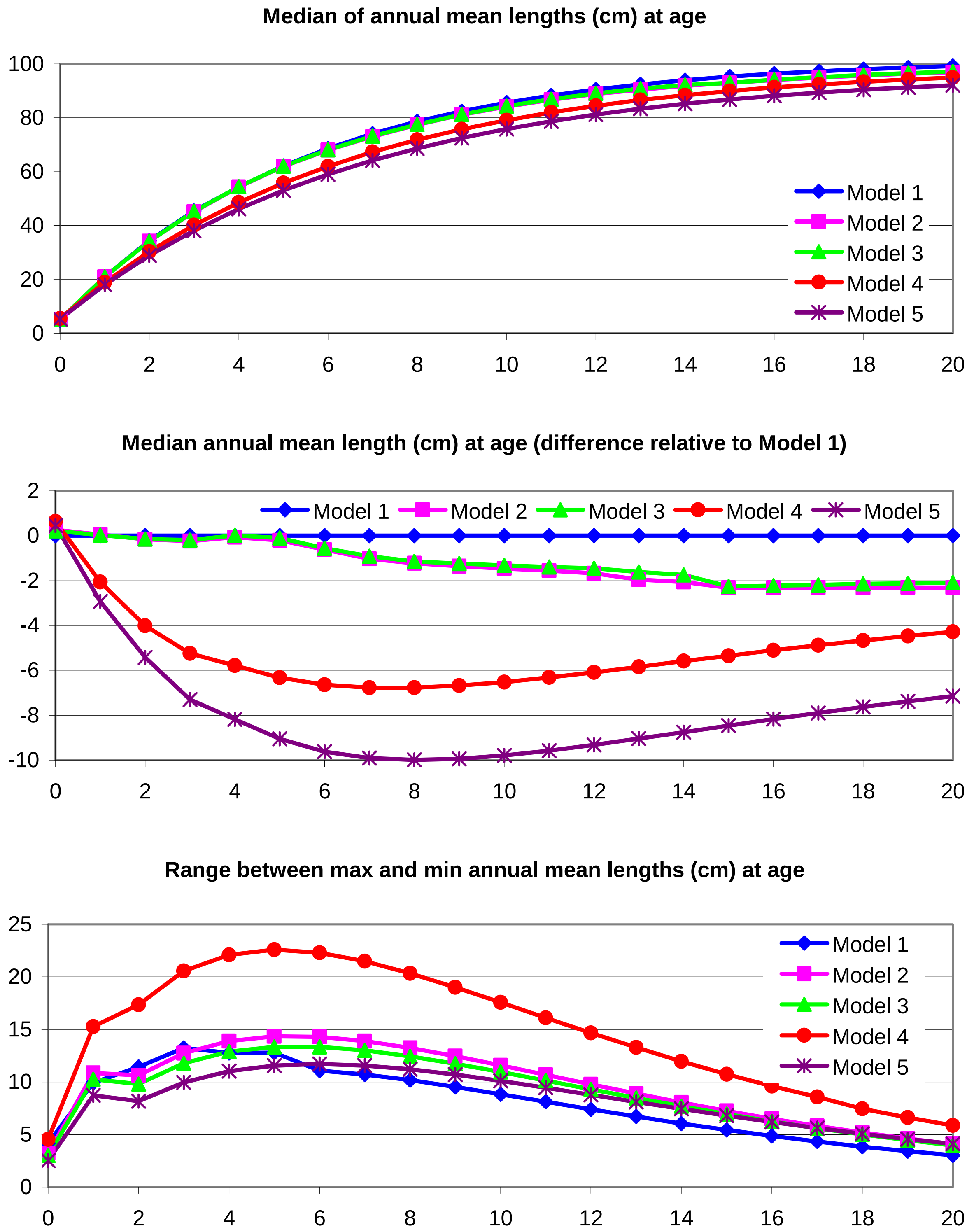


Figure 2.1.9. Three ways of looking at the pattern of mean lengths at age. The upper panel shows the median of each distribution, the middle panel shows the difference between the median for a given model and the corresponding median for Model 1, and the bottom panel shows the range of each distribution.

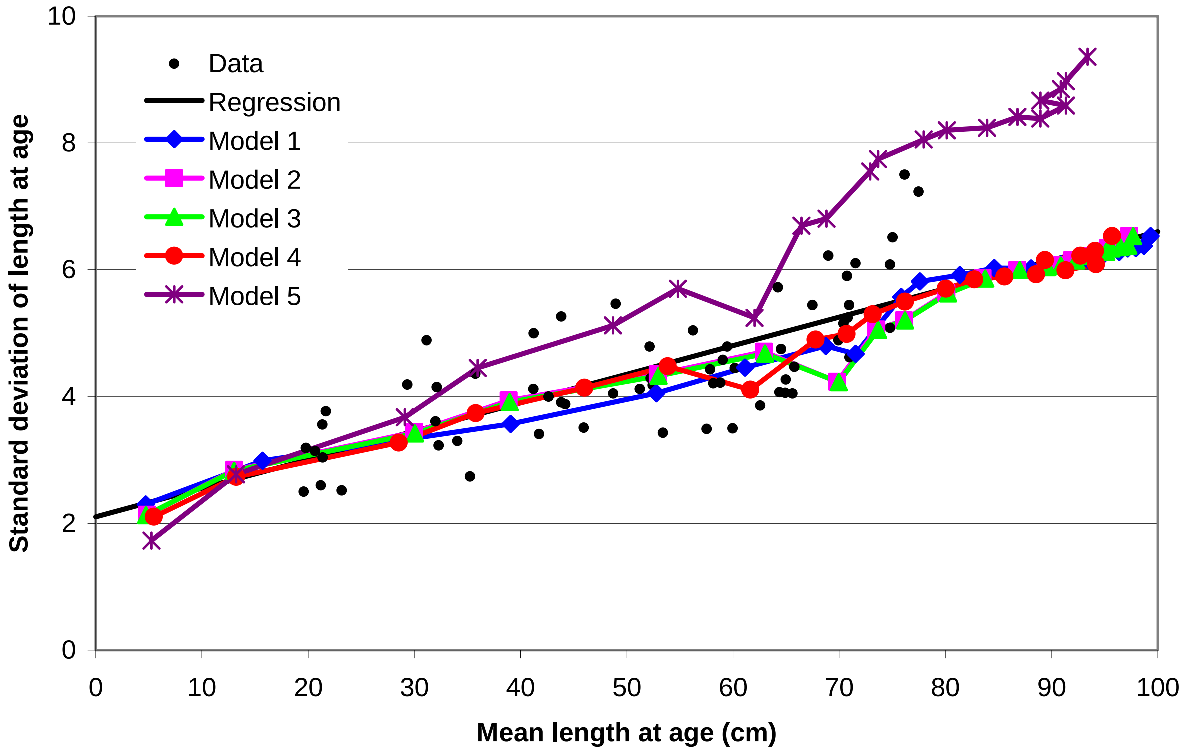


Figure 2.1.10. Standard deviation of length at age versus mean length at age in the data and as estimated by Models 1-5. The black dots (“data”) represent 8 years’ worth of mean lengths and standard deviations of length at ages 1-8, and the solid black line represents the least-squares regression through those data. Colored lines with symbols represent model estimates.

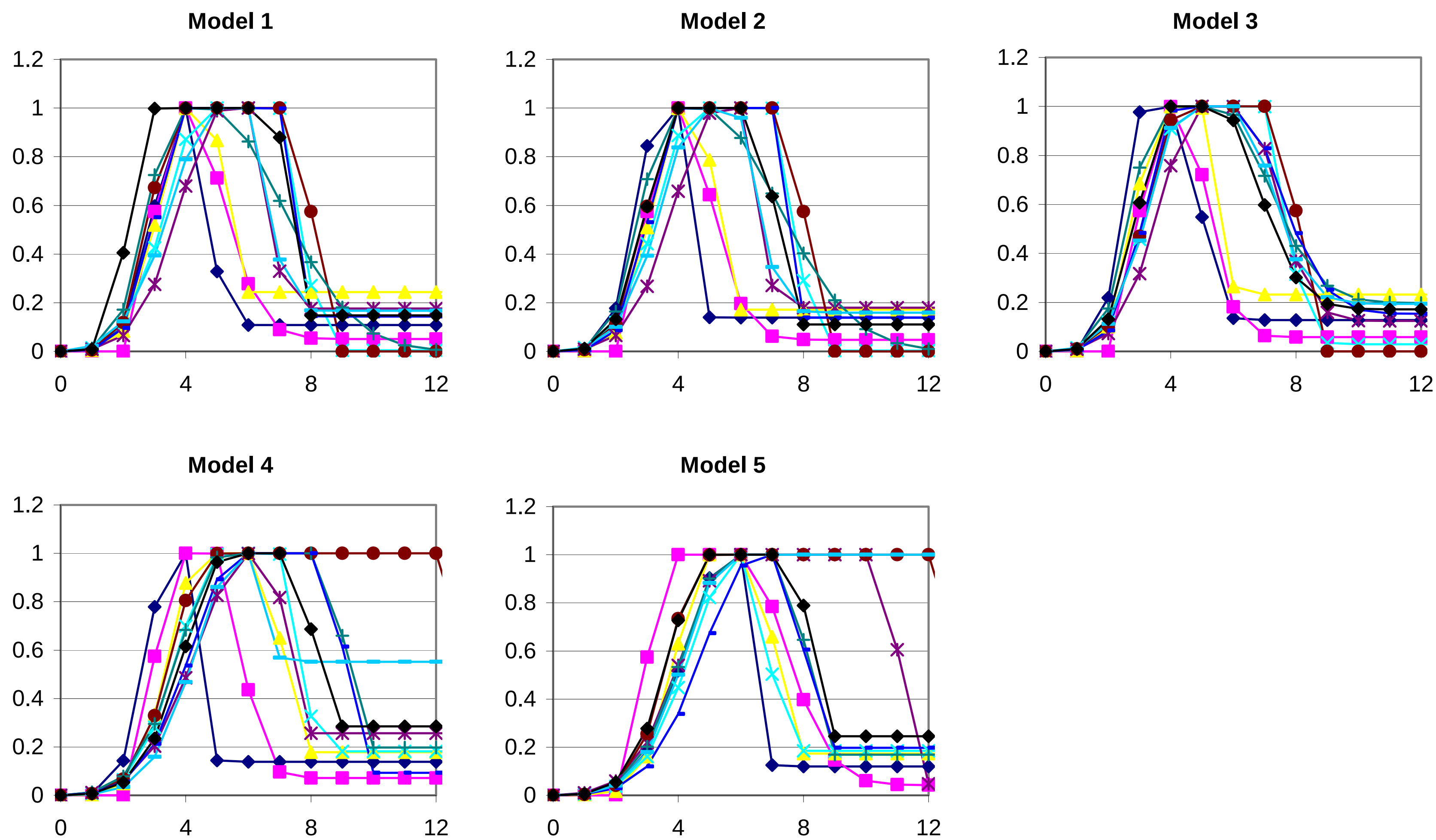


Figure 2.1.11. Estimated 27-plus trawl survey selectivity at age in each model. The actual age range extends to age 20+, but the graphs here have been truncated at age 12 to make differences easier to identify.

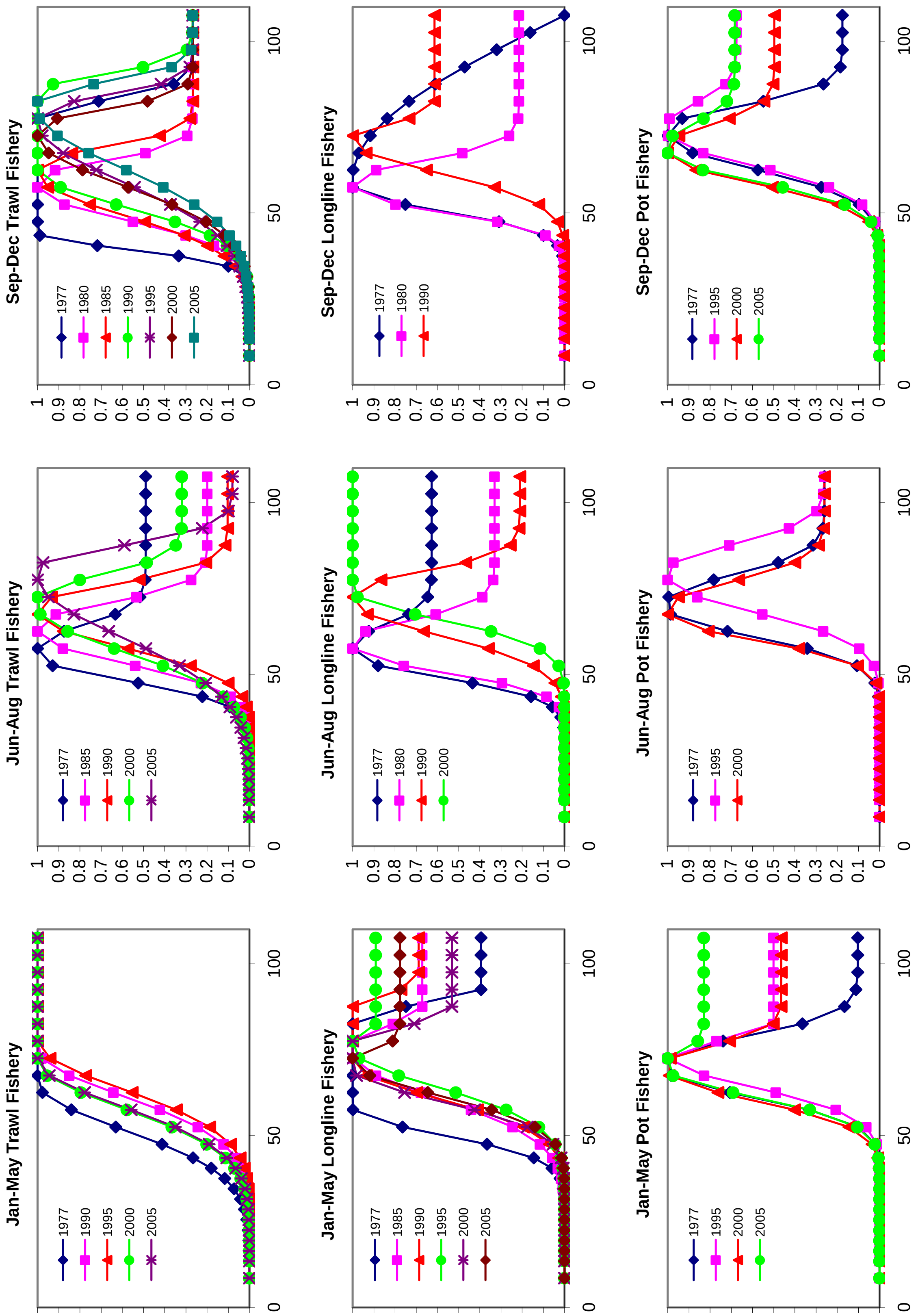
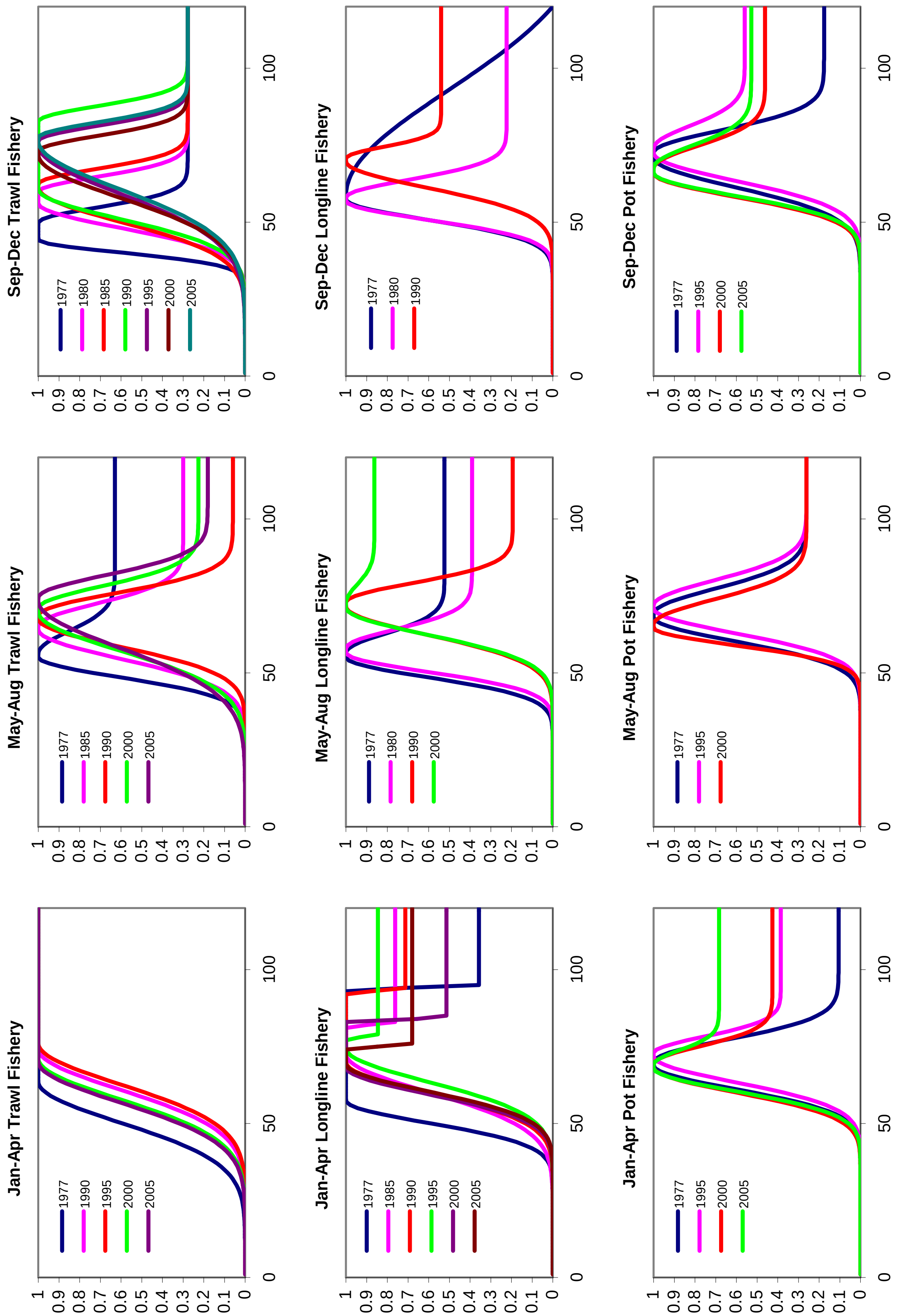
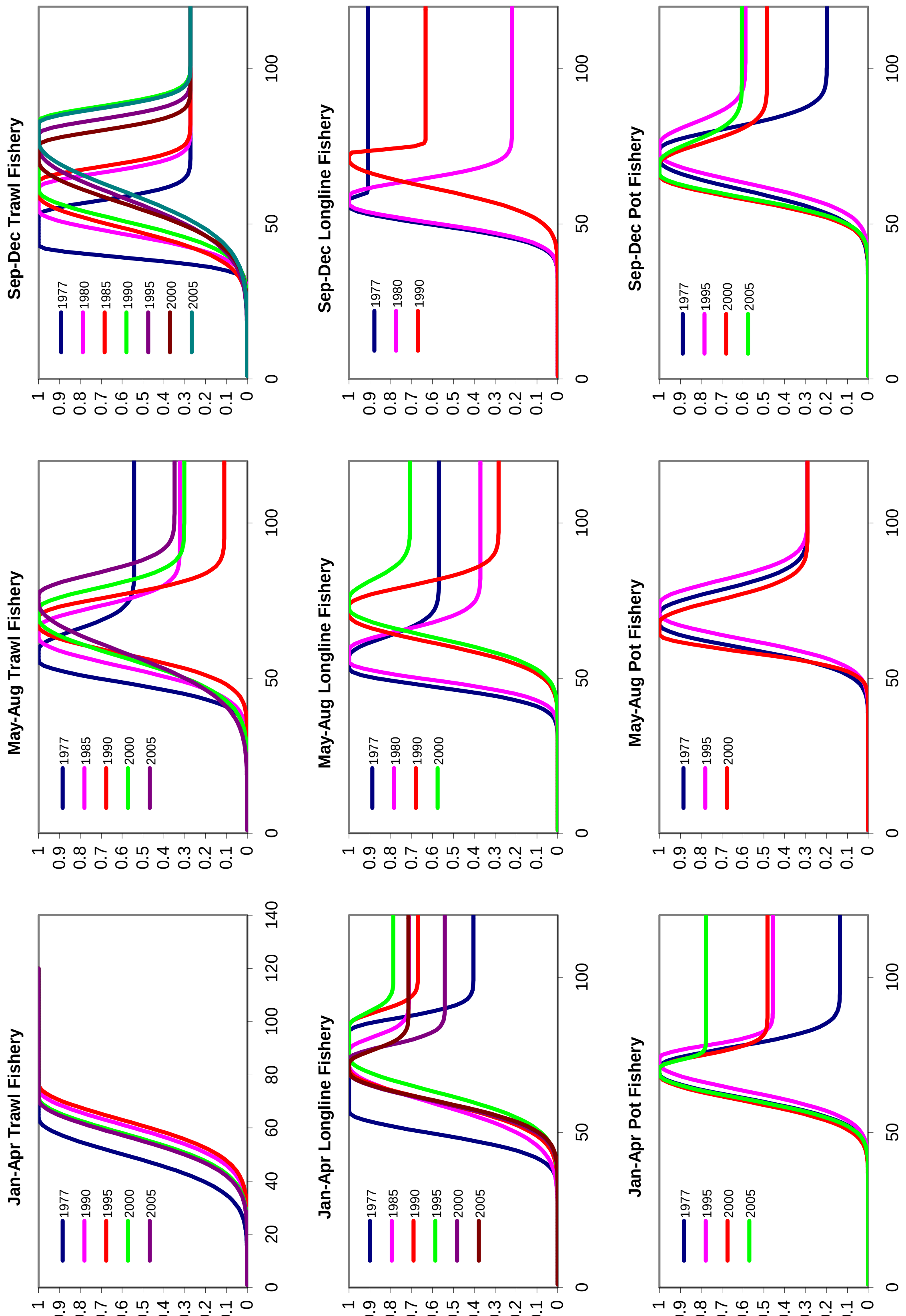


Figure 2.1.12.1. Fishery selectivity at length as estimated by Model 1.



F

ishery 2.1.12.2. Fishery selectivity at length as estimated by Model 2.



F

ishery 2.1.12.3. Fishery selectivity at length as estimated by Model 3.

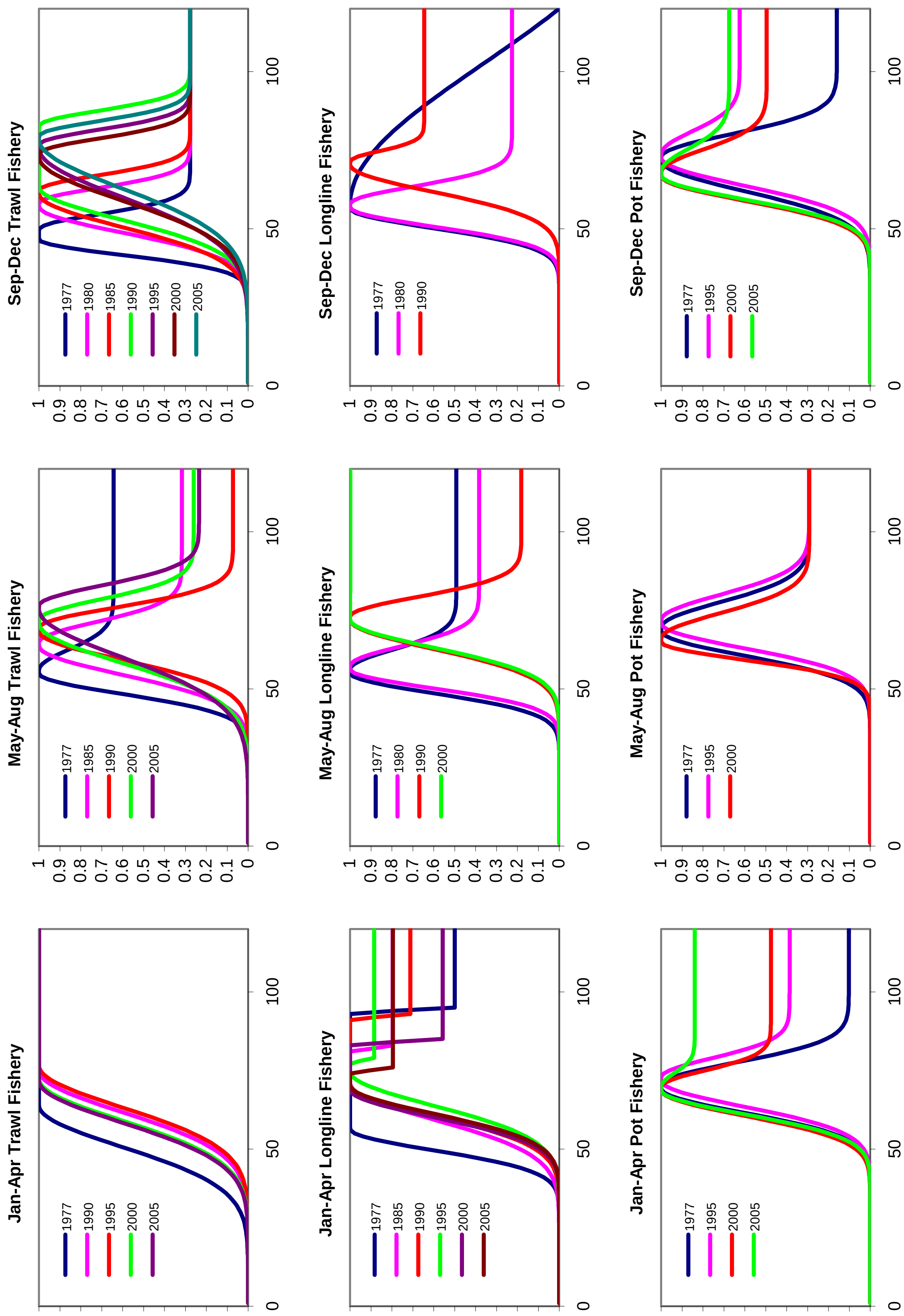


Figure 2.1.12.4. Fishery selectivity at length as estimated by Model 4.

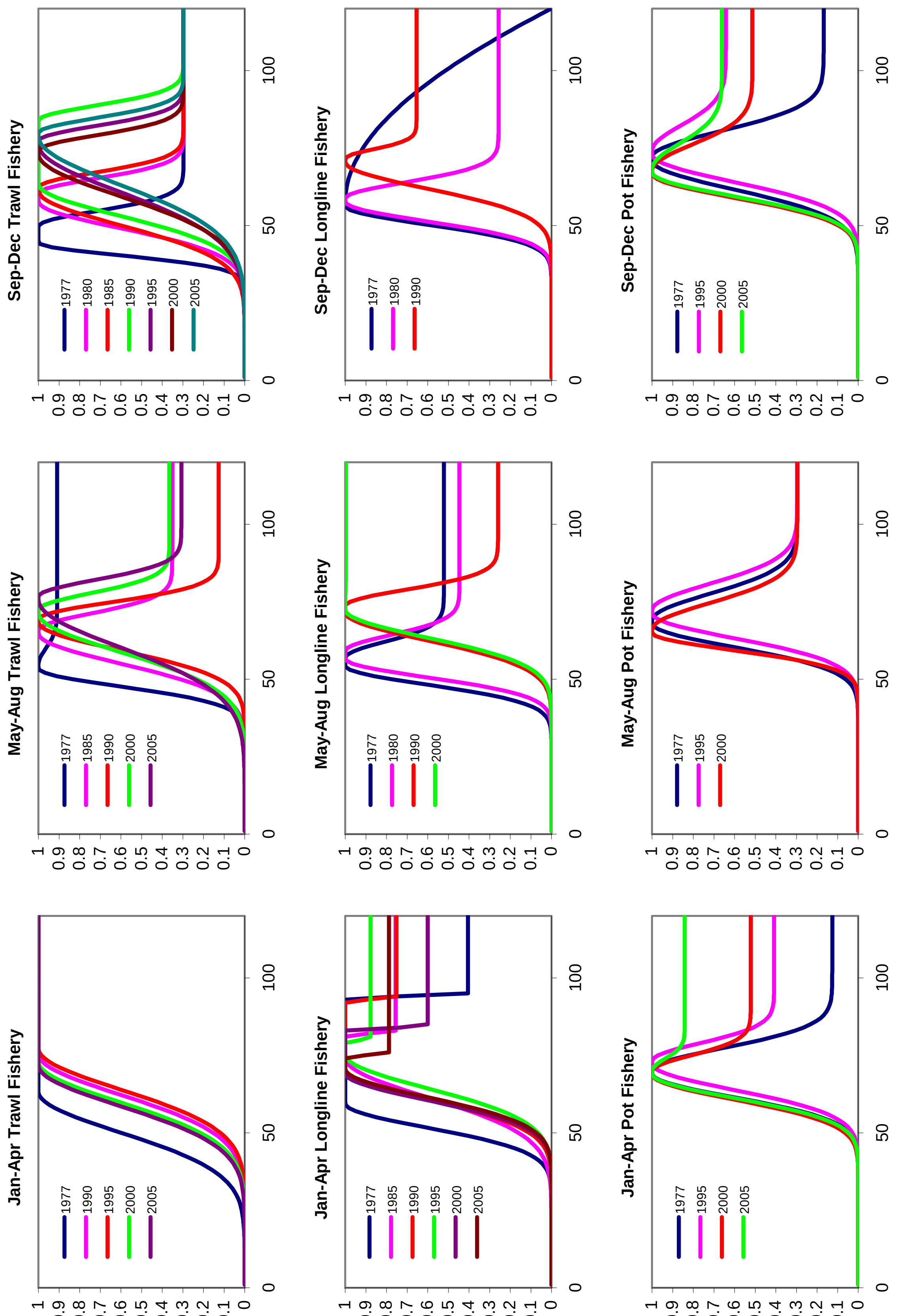
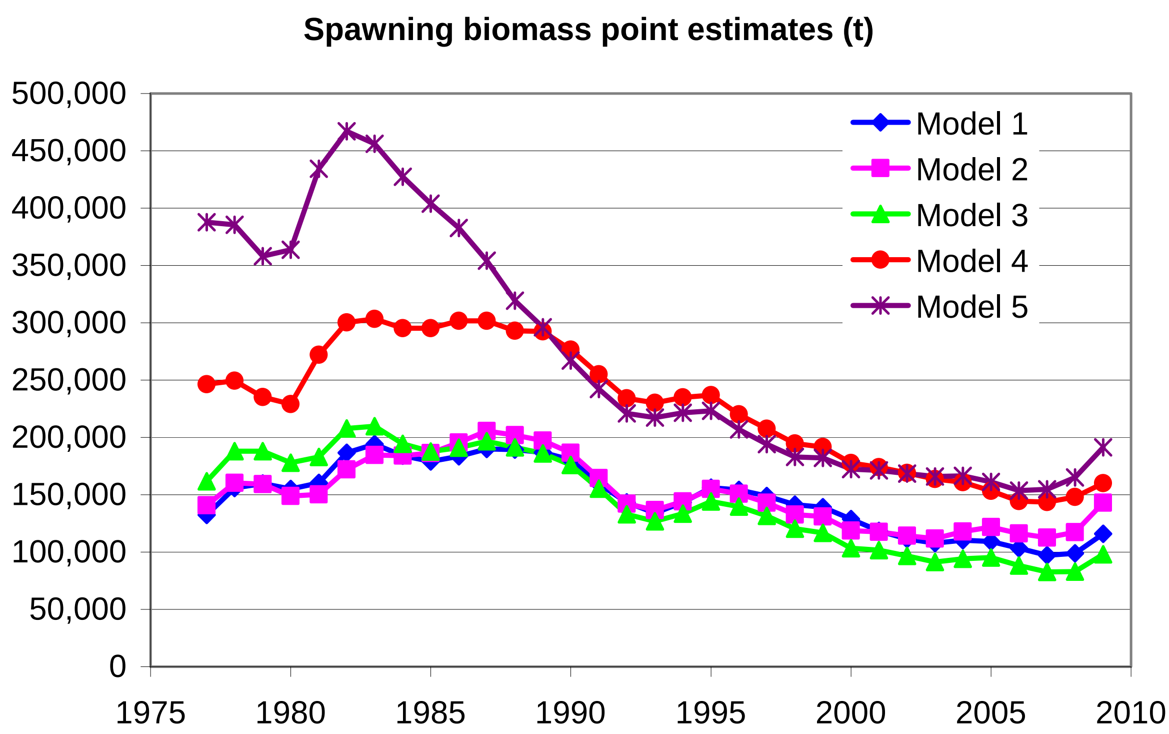


Figure 2.1.12.5. Fishery selectivity at length as estimated by Model 5.



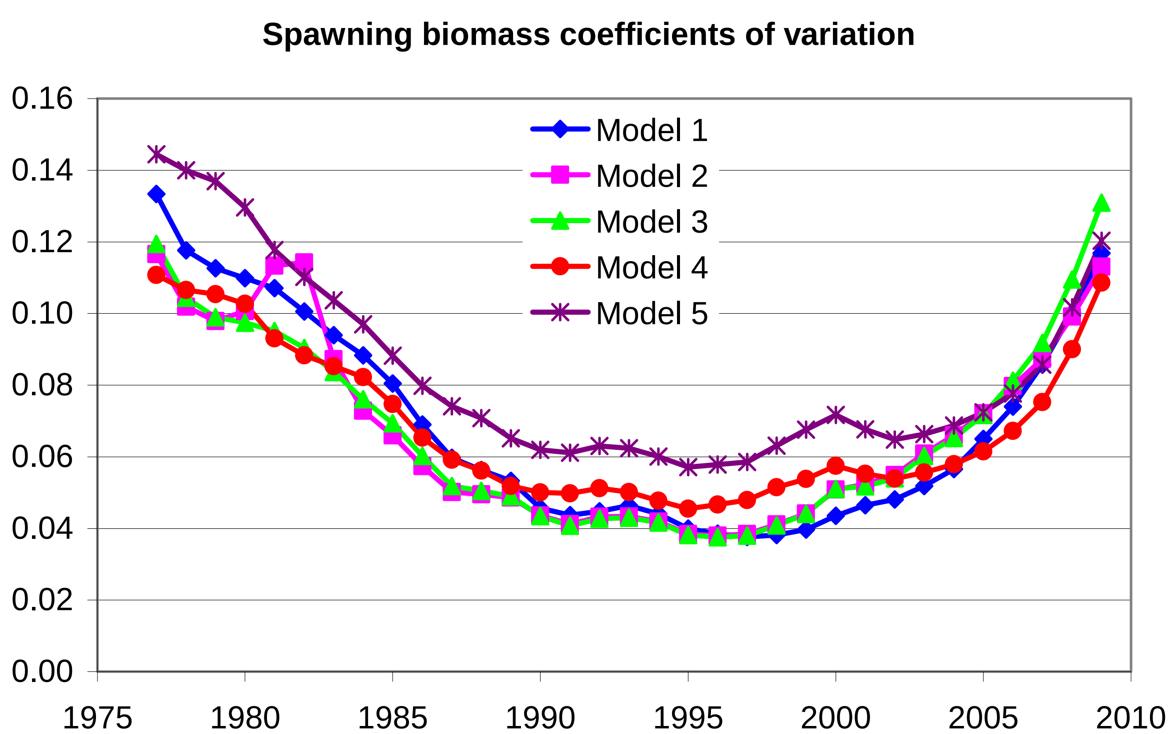
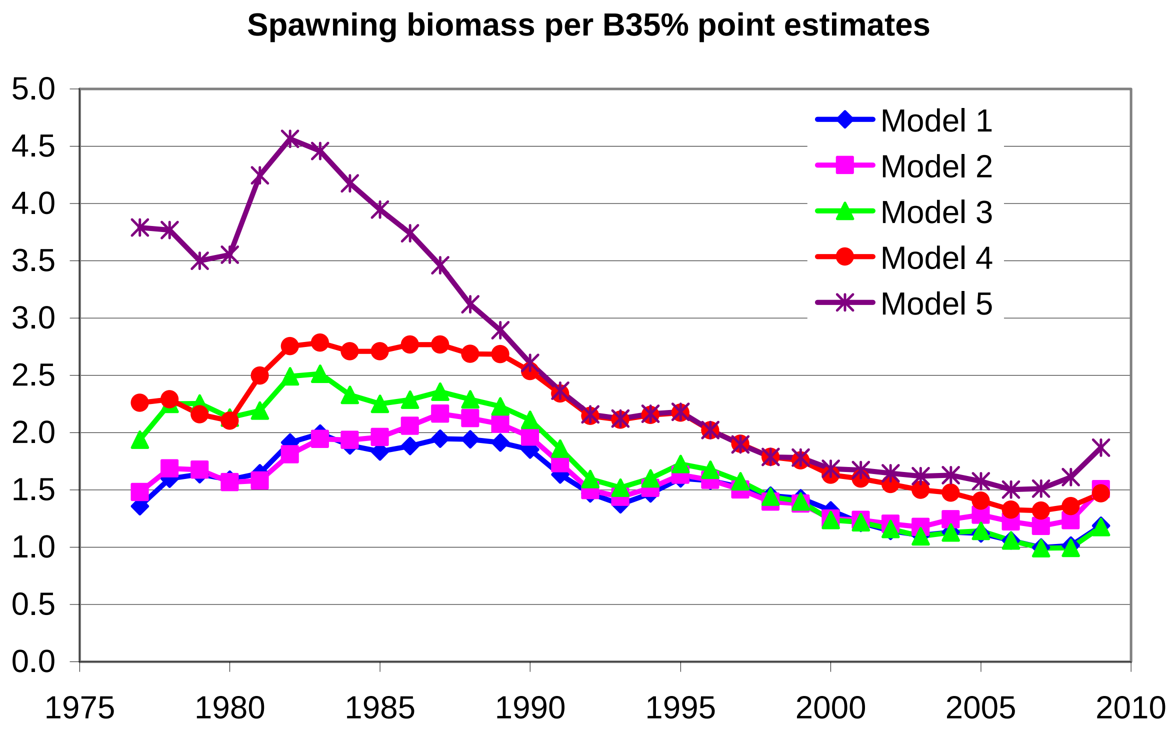


Figure 2.1.13. Time series of spawning biomass estimates for Models 1-5. The upper panel shows the estimates, and the lower panel shows the coefficients of variation corresponding to the estimates.



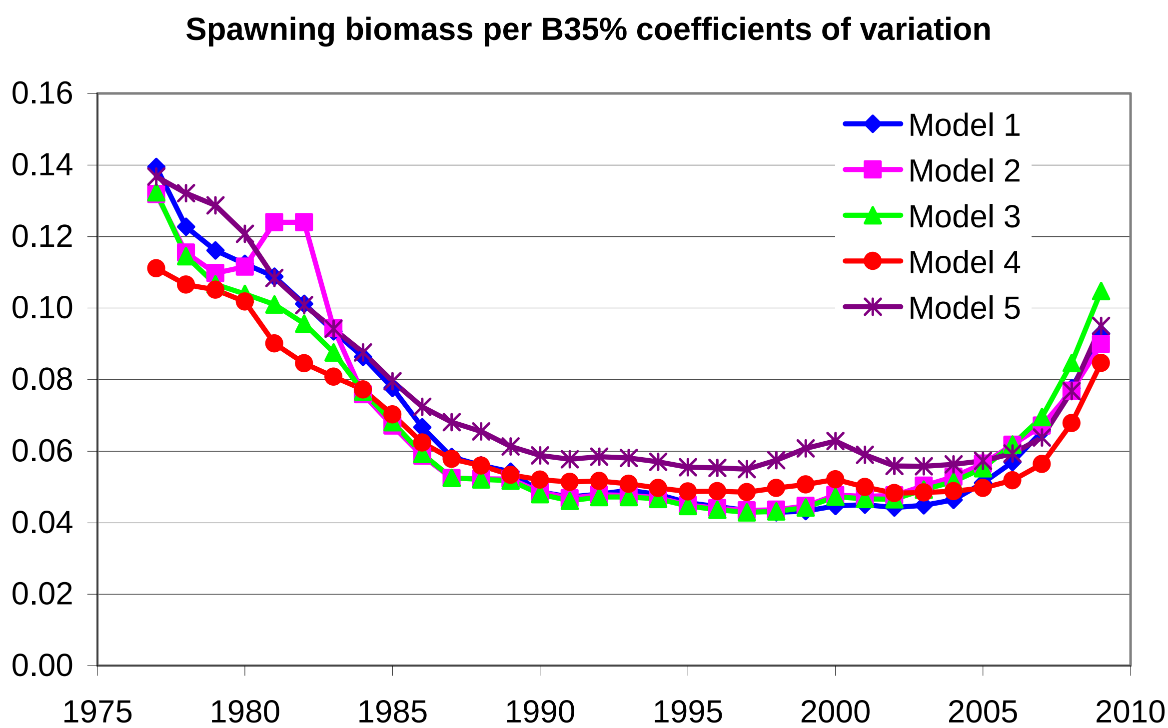


Figure 2.1.14. Time series of spawning biomass relative to $B_{35\%}$ for Models 1-5. The upper panel shows the estimates, and the lower panel shows the coefficients of variation corresponding to the estimates.

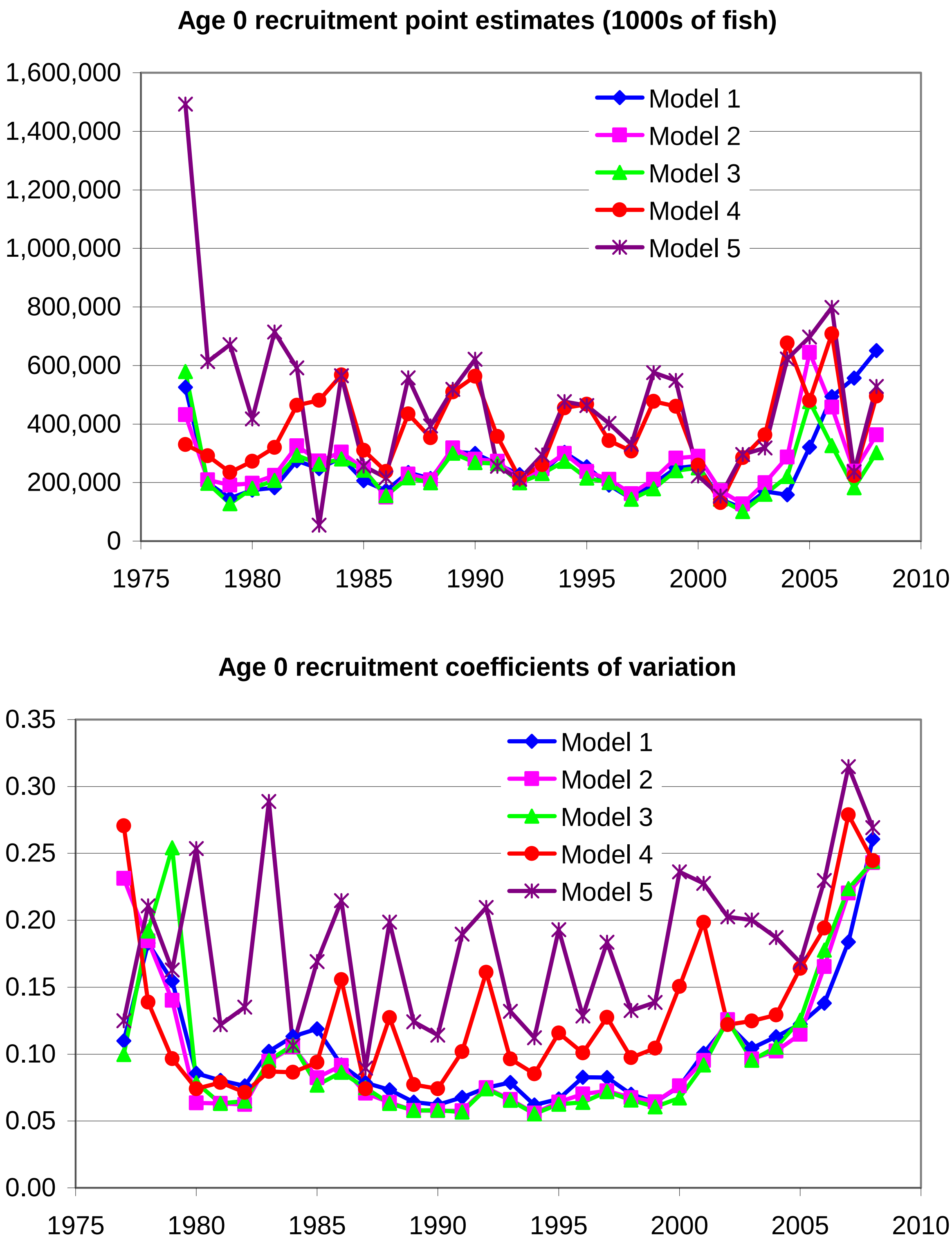


Figure 2.1.15. Time series of age 0 recruitment estimates for Models 1-5. The upper panel shows the estimates, and the lower panel shows the coefficients of variation corresponding to the estimates.

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 A)

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

Table 2.2.23a—Time series of GOA Pacific cod age 0+ biomass, female spawning biomass (t), and standard deviation of spawning biomass as estimated estimated last year under the Plan Team's and SSC's preferred model and this year under Model A. Values for 2011 listed under this year's assessment represent Stock Synthesis projections, and may not correspond exactly to values generated by the standard projection model.

	Last year's assessment			This year's assessment		
Year	Age 0+ bio.	Spawn. bio.	Std. dev.	Age 0+ bio.	Spawn. bio.	Std. dev.
1977	403,489	136,186	17,735	338,379	102,364	14,778
1978	422,637	160,132	18,307	359,826	121,527	15,270
1979	461,997	163,907	17,896	389,141	132,512	15,297
1980	516,504	159,027	16,905	442,993	132,045	14,759
1981	537,465	164,605	17,036	481,068	132,885	15,131
1982	535,727	190,837	18,580	500,656	153,329	16,583
1983	528,201	198,042	18,106	508,728	171,395	15,964
1984	515,566	187,314	16,174	503,526	174,751	15,213
1985	519,256	181,428	14,328	507,101	174,959	14,231
1986	530,368	185,445	12,648	529,166	180,153	13,019
1987	534,174	191,279	11,334	550,947	184,644	12,027
1988	528,339	190,263	10,680	554,962	188,889	11,314
1989	519,241	187,462	9,966	543,504	201,790	10,932
1990	504,318	181,049	8,258	522,185	196,172	9,472
1991	475,188	159,824	6,978	487,849	168,165	7,838
1992	459,088	143,723	6,431	468,522	147,339	6,966
1993	447,949	134,387	6,229	453,360	137,294	6,610
1994	457,855	143,630	6,321	456,583	146,119	6,564
1995	470,308	156,502	6,244	466,516	157,302	6,331
1996	462,568	154,448	5,949	459,579	151,522	5,893
1997	455,565	149,001	5,600	452,672	144,364	5,424
1998	434,853	141,599	5,393	428,825	140,485	5,195
1999	409,637	139,263	5,514	400,026	138,831	5,201
2000	371,951	128,932	5,603	359,647	125,774	5,118
2001	352,131	118,369	5,482	335,007	112,390	4,834
2002	351,396	111,469	5,340	327,633	104,969	4,495
2003	345,473	107,626	5,557	315,366	99,648	4,459
2004	334,355	110,265	6,217	298,927	98,582	4,786
2005	319,165	108,929	7,051	280,053	94,497	5,335
2006	325,306	103,100	7,597	282,712	87,153	5,729
2007	370,128	96,839	8,273	323,958	80,223	6,378
2008	475,523	98,512	9,846	404,371	81,779	8,106
2009	615,610	115,196	13,441	493,019	99,232	12,345
2010				566,999	144,790	20,941
2011				596,130	183,477	31,576

Table 2.2.23b—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 A.

	Last year's assessment		This year's assessment	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	533,640	57,186	339,950	62,005
1978	200,794	37,044	219,186	37,416
1979	146,871	22,856	196,714	19,010
1980	174,402	15,043	173,258	13,599
1981	182,684	14,717	175,636	14,207
1982	274,476	20,988	261,832	23,024
1983	247,450	25,293	186,047	22,960
1984	285,355	32,364	587,282	55,864
1985	207,324	24,676	134,126	21,542
1986	172,402	15,861	140,708	14,821
1987	234,053	18,410	205,114	18,721
1988	213,655	15,690	222,182	16,354
1989	306,007	19,661	310,277	20,721
1990	299,631	18,670	302,954	18,889
1991	262,718	17,793	244,239	18,007
1992	227,272	17,048	168,122	16,196
1993	236,014	18,627	291,626	18,725
1994	302,847	18,760	309,939	19,356
1995	253,921	16,859	232,830	16,733
1996	191,267	15,825	154,421	12,552
1997	144,517	11,916	145,123	10,533
1998	195,679	13,704	193,895	12,590
1999	249,443	15,969	210,184	13,546
2000	257,218	19,475	225,121	16,365
2001	142,246	14,313	129,251	12,522
2002	111,348	13,642	88,472	10,696
2003	168,890	17,594	160,511	15,675
2004	157,187	17,735	145,675	15,431
2005	318,968	38,970	419,290	54,169
2006	489,736	67,522	468,649	70,500
2007	552,154	101,439	470,126	101,775
2008	645,932	168,209	314,348	109,548
Average	262,066		244,597	

Table 2.2.23c—Numbers (1000s) at age as estimated by Model A.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	290170	40687	37136	47343	35143	11494	6220	3803	2548	1800	1299	940	676	480	412	277	186	125	84	56	116
1978	187090	198434	27811	25177	31700	23455	7677	4160	2547	1710	1210	875	634	456	324	278	187	126	84	57	116
1979	167908	127941	135628	18709	16523	20664	15360	5051	2747	1688	1137	806	584	424	305	217	186	125	84	57	116
1980	147887	114822	87199	90339	11872	10357	13017	9734	3221	1764	1091	739	526	382	278	200	143	122	82	55	114
1981	149917	101134	78437	57300	56946	7343	6546	8371	6315	2101	1155	716	486	346	252	183	132	94	81	54	112
1982	223490	102522	69111	51922	35185	34893	4615	4196	5418	4109	1372	756	470	319	228	165	120	87	62	53	109
1983	158803	152834	70052	46218	32308	22003	22018	2967	2719	3528	2685	899	496	309	210	150	109	79	57	41	107
1984	501283	108598	104436	46754	28262	19491	13801	13874	1894	1746	2275	1737	582	322	201	136	97	71	52	37	96
1985	114485	342807	74236	70752	30552	18146	12616	9024	9076	1245	1149	1499	1145	384	212	132	90	64	47	34	88
1986	120103	78287	234380	50445	46904	19730	11632	8137	5865	5897	812	751	980	749	251	139	87	59	42	31	80
1987	175078	82132	53368	159829	33652	30561	12858	7637	5373	3881	3902	538	498	650	496	167	92	57	39	28	73
1988	189647	119722	56043	34676	106026	20551	18409	7967	4817	3420	2478	2490	343	318	415	317	107	59	37	25	65
1989	264841	129679	81662	37603	21535	68040	12626	11447	5015	3049	2170	1573	1581	218	202	264	202	68	37	23	57
1990	258591	181111	88579	55224	24197	12089	40548	7106	6536	2895	1768	1263	917	921	127	118	154	118	39	22	47
1991	208474	176835	123697	59123	34550	13355	5934	20779	3508	3316	1498	925	667	487	488	68	63	82	63	21	37
1992	143503	142563	120780	83153	36454	19446	6867	2989	10448	1766	1699	775	482	349	255	255	35	33	43	33	30
1993	248922	98133	97419	81661	53564	21019	10662	3658	1644	5567	967	945	434	271	197	144	144	20	19	24	36
1994	264553	170224	67048	66058	53265	32491	11902	5973	2059	955	3145	559	551	254	159	115	85	85	12	11	35
1995	198736	180914	116333	45303	43144	31777	17673	6155	3088	1073	505	1641	295	292	135	84	61	45	45	6	25
1996	131809	135905	123649	78683	29038	25888	17308	9147	3157	1591	557	265	852	155	153	71	44	32	24	24	16
1997	123872	90137	92881	83896	50733	16670	13891	8742	4580	1602	812	286	137	437	80	79	37	23	17	12	21
1998	165502	84709	61592	62903	54686	29091	8377	6737	4183	2222	794	404	144	69	219	40	40	19	12	8	17
1999	179406	113178	57873	41724	40730	31995	14363	3879	3126	1984	1076	391	200	71	35	108	20	20	9	6	13
2000	192155	122684	77281	38686	26260	22556	15930	6764	1870	1530	998	551	203	104	37	18	57	11	11	5	10
2001	110324	131404	83836	52263	24569	15602	12543	8684	3747	1060	872	574	319	118	61	22	11	33	6	6	9
2002	75517	75444	89762	56658	33103	13483	8091	6341	4440	1990	578	478	318	177	66	34	12	6	18	3	8
2003	137007	51641	51556	60711	36485	18501	6701	3991	3193	2295	1066	314	260	174	97	36	19	7	3	10	6
2004	124343	93690	35261	34896	38526	20599	9172	3270	1984	1640	1208	577	172	143	96	54	20	10	4	2	9
2005	357891	85030	63981	23640	22575	22019	10687	4512	1632	1000	839	624	301	90	75	50	28	11	5	2	6
2006	400022	244738	58022	42997	14551	13073	11237	5224	2194	806	496	420	314	152	46	38	26	14	5	3	4
2007	401283	273551	167127	38630	26742	7828	6809	5547	2574	1096	408	252	214	160	78	23	19	13	7	3	3
2008	268316	274415	186829	111963	22869	14322	3822	3308	2683	1257	543	205	126	108	81	40	12	10	7	4	3
2009	207147	183489	187553	126144	70057	12413	7500	1971	1707	1398	660	289	110	68	58	44	21	6	5	4	4
2010	207147	141655	125451	127409	80279	39334	6524	3937	1043	904	747	355	156	60	37	32	24	12	4	3	4

Table 2.24—Estimates of "effective" fishing mortality (= $-\ln(N_{a+1,t+1}/N_{a,t})-M$) at age and year for Model A.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.000	0.002	0.006	0.009	0.008	0.008	0.007	0.007	0.006	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004
1978	0.000	0.008	0.028	0.042	0.040	0.036	0.033	0.031	0.028	0.025	0.023	0.022	0.021	0.020	0.019	0.019	0.019	0.018	0.018
1979	0.001	0.008	0.033	0.050	0.047	0.042	0.039	0.036	0.033	0.030	0.028	0.026	0.024	0.024	0.023	0.022	0.022	0.022	0.021
1980	0.000	0.026	0.075	0.121	0.106	0.090	0.082	0.076	0.070	0.065	0.061	0.057	0.055	0.054	0.053	0.052	0.052	0.051	0.051
1981	0.000	0.020	0.098	0.108	0.086	0.067	0.059	0.054	0.050	0.047	0.044	0.042	0.041	0.040	0.040	0.039	0.039	0.039	0.038
1982	0.000	0.010	0.076	0.082	0.074	0.056	0.049	0.046	0.043	0.040	0.037	0.036	0.035	0.034	0.033	0.033	0.033	0.033	0.032
1983	0.000	0.012	0.090	0.117	0.081	0.077	0.066	0.061	0.057	0.054	0.052	0.050	0.049	0.048	0.047	0.047	0.047	0.046	0.046
1984	0.000	0.005	0.042	0.068	0.060	0.053	0.052	0.048	0.045	0.041	0.039	0.037	0.035	0.034	0.034	0.033	0.033	0.033	0.032
1985	0.000	0.002	0.012	0.028	0.037	0.039	0.035	0.035	0.032	0.030	0.029	0.029	0.028	0.028	0.028	0.028	0.028	0.028	0.028
1986	0.001	0.001	0.017	0.047	0.064	0.066	0.061	0.054	0.054	0.051	0.049	0.048	0.048	0.048	0.047	0.047	0.047	0.047	0.047
1987	0.001	0.028	0.017	0.084	0.101	0.078	0.062	0.052	0.049	0.049	0.048	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.046
1988	0.000	0.005	0.064	0.038	0.086	0.082	0.070	0.063	0.059	0.058	0.058	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
1989	0.000	0.003	0.032	0.111	0.085	0.108	0.090	0.081	0.077	0.075	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074
1990	0.000	0.005	0.028	0.092	0.214	0.159	0.216	0.205	0.192	0.183	0.175	0.170	0.172	0.169	0.168	0.167	0.167	0.166	0.165
1991	0.000	0.002	0.025	0.079	0.179	0.276	0.237	0.274	0.259	0.248	0.242	0.238	0.236	0.236	0.235	0.235	0.234	0.234	0.233
1992	0.000	0.002	0.021	0.115	0.210	0.303	0.314	0.324	0.316	0.296	0.286	0.280	0.276	0.274	0.275	0.274	0.273	0.273	0.272
1993	0.000	0.001	0.015	0.067	0.174	0.219	0.238	0.205	0.236	0.210	0.197	0.191	0.188	0.186	0.185	0.185	0.184	0.184	0.184
1994	0.000	0.001	0.010	0.050	0.119	0.181	0.189	0.184	0.159	0.181	0.162	0.155	0.152	0.151	0.150	0.149	0.150	0.149	0.149
1995	0.000	0.001	0.016	0.052	0.144	0.237	0.286	0.285	0.276	0.260	0.275	0.262	0.260	0.259	0.258	0.258	0.258	0.258	0.258
1996	0.000	0.001	0.014	0.073	0.141	0.235	0.280	0.283	0.278	0.271	0.263	0.272	0.264	0.263	0.262	0.262	0.262	0.262	0.262
1997	0.000	0.002	0.014	0.078	0.206	0.275	0.334	0.340	0.323	0.317	0.309	0.298	0.311	0.300	0.298	0.297	0.297	0.296	0.296
1998	0.000	0.002	0.013	0.058	0.189	0.309	0.336	0.339	0.323	0.305	0.301	0.296	0.290	0.298	0.292	0.290	0.290	0.290	0.290
1999	0.000	0.003	0.017	0.073	0.184	0.362	0.425	0.422	0.399	0.377	0.358	0.354	0.348	0.337	0.351	0.340	0.337	0.336	0.334
2000	0.000	0.002	0.026	0.087	0.209	0.298	0.325	0.290	0.277	0.255	0.243	0.235	0.234	0.232	0.230	0.234	0.231	0.230	0.230
2001	0.000	0.003	0.025	0.111	0.186	0.252	0.267	0.239	0.209	0.202	0.190	0.183	0.179	0.178	0.177	0.175	0.178	0.176	0.175
2002	0.000	0.002	0.018	0.101	0.249	0.296	0.308	0.291	0.253	0.233	0.230	0.223	0.220	0.218	0.217	0.217	0.216	0.217	0.216
2003	0.000	0.003	0.024	0.089	0.231	0.325	0.324	0.298	0.271	0.237	0.222	0.220	0.215	0.213	0.211	0.211	0.210	0.210	0.211
2004	0.000	0.006	0.024	0.112	0.236	0.352	0.348	0.326	0.290	0.267	0.242	0.232	0.231	0.228	0.226	0.225	0.225	0.224	0.224
2005	0.000	0.004	0.033	0.073	0.193	0.274	0.315	0.305	0.299	0.290	0.284	0.276	0.272	0.272	0.270	0.269	0.268	0.268	0.268
2006	0.000	0.004	0.028	0.129	0.185	0.295	0.325	0.321	0.305	0.302	0.297	0.294	0.290	0.289	0.289	0.288	0.288	0.287	0.287
2007	0.000	0.004	0.051	0.135	0.282	0.307	0.349	0.346	0.329	0.314	0.312	0.308	0.305	0.302	0.300	0.300	0.300	0.299	0.298
2008	0.000	0.005	0.041	0.186	0.276	0.350	0.352	0.349	0.338	0.321	0.309	0.307	0.304	0.301	0.298	0.296	0.296	0.295	0.294
2009	0.000	0.001	0.020	0.103	0.221	0.243	0.246	0.245	0.234	0.228	0.220	0.215	0.215	0.214	0.213	0.212	0.211	0.211	0.211
2010	0.000	0.001	0.013	0.097	0.219	0.268	0.265	0.253	0.254	0.243	0.238	0.233	0.229	0.229	0.228	0.227	0.226	0.226	0.225

Table 2.2.25—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2011-2023 (Scenarios 1-2), with random variability in future recruitment under Model A.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	122,000	122,000	122,000	122,000	0
2012	130,000	130,000	130,000	130,000	0
2013	119,000	119,000	119,000	119,000	13
2014	102,000	102,000	102,000	103,000	410
2015	89,600	90,300	90,300	91,300	530
2016	78,900	83,300	84,100	91,600	4,069
2017	58,300	79,000	79,000	102,000	13,283
2018	50,900	77,400	76,500	105,000	17,079
2019	48,800	78,000	76,600	106,000	18,176
2020	48,900	77,900	77,300	110,000	18,266
2021	49,100	77,200	77,100	108,000	18,124
2022	48,700	77,800	76,700	105,000	17,886
2023	49,200	76,900	76,400	106,000	17,690

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	163,000	163,000	163,000	163,000	0
2012	177,000	177,000	177,000	177,000	0
2013	164,000	164,000	164,000	164,000	2
2014	143,000	143,000	143,000	143,000	76
2015	125,000	126,000	126,000	127,000	513
2016	110,000	115,000	116,000	126,000	4,984
2017	93,300	109,000	111,000	137,000	13,890
2018	87,000	107,000	110,000	143,000	17,539
2019	85,100	107,000	110,000	143,000	18,975
2020	84,900	107,000	110,000	148,000	19,366
2021	85,200	106,000	110,000	147,000	19,233
2022	85,000	107,000	110,000	143,000	18,810
2023	85,100	106,000	109,000	144,000	18,408

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	0.45	0.45	0.45	0.45	0.00
2012	0.45	0.45	0.45	0.45	0.00
2013	0.45	0.45	0.45	0.45	0.00
2014	0.45	0.45	0.45	0.45	0.00
2015	0.45	0.45	0.45	0.45	0.00
2016	0.45	0.45	0.45	0.45	0.00
2017	0.39	0.45	0.44	0.45	0.02
2018	0.36	0.45	0.43	0.45	0.03
2019	0.36	0.45	0.43	0.45	0.04
2020	0.35	0.45	0.43	0.45	0.03
2021	0.36	0.45	0.43	0.45	0.04
2022	0.35	0.45	0.43	0.45	0.04
2023	0.36	0.45	0.43	0.45	0.04

Table 2.2.26—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 2011-2023 (Scenario 3), with random variability in future recruitment under Model A.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	97,600	97,600	97,600	97,600	0
2012	110,000	110,000	110,000	110,000	0
2013	104,000	104,000	104,000	105,000	10
2014	92,300	92,600	92,700	93,300	317
2015	82,400	82,900	83,000	83,800	410
2016	73,300	76,700	77,300	83,200	3,194
2017	62,100	72,800	74,200	91,200	9,148
2018	56,200	71,200	72,400	94,800	12,003
2019	52,800	70,800	71,800	94,700	13,324
2020	52,600	70,100	71,800	97,800	13,783
2021	51,700	69,300	71,400	96,700	13,743
2022	51,100	69,300	71,000	94,500	13,498
2023	51,800	69,400	70,700	95,000	13,272

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	165,000	165,000	165,000	165,000	0
2012	189,000	189,000	189,000	189,000	0
2013	184,000	184,000	184,000	184,000	2
2014	166,000	166,000	166,000	166,000	76
2015	148,000	148,000	149,000	150,000	514
2016	131,000	137,000	138,000	147,000	5,030
2017	112,000	129,000	131,000	158,000	14,616
2018	101,000	125,000	128,000	165,000	19,866
2019	94,300	125,000	126,000	164,000	22,567
2020	92,900	123,000	126,000	171,000	23,558
2021	91,400	122,000	126,000	169,000	23,639
2022	90,900	122,000	125,000	167,000	23,255
2023	91,600	122,000	124,000	165,000	22,815

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	0.35	0.35	0.35	0.35	0.00
2012	0.35	0.35	0.35	0.35	0.00
2013	0.35	0.35	0.35	0.35	0.00
2014	0.35	0.35	0.35	0.35	0.00
2015	0.35	0.35	0.35	0.35	0.00
2016	0.35	0.35	0.35	0.35	0.00
2017	0.35	0.35	0.35	0.35	0.00
2018	0.35	0.35	0.35	0.35	0.00
2019	0.35	0.35	0.35	0.35	0.00
2020	0.35	0.35	0.35	0.35	0.00
2021	0.35	0.35	0.35	0.35	0.00
2022	0.35	0.35	0.35	0.35	0.00
2023	0.35	0.35	0.35	0.35	0.00

Table 2.2.27—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 2011-2023 (Scenario 4), with random variability in future recruitment under Model A.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	61,000	61,000	61,000	61,000	0
2012	74,000	74,000	74,000	74,000	0
2013	75,200	75,200	75,200	75,200	6
2014	69,900	70,100	70,100	70,400	190
2015	64,100	64,400	64,500	64,900	246
2016	58,200	60,300	60,700	64,300	1,951
2017	50,500	57,300	58,300	69,200	5,906
2018	45,700	55,800	56,800	72,300	8,141
2019	42,800	55,400	56,200	71,800	9,313
2020	41,900	54,700	55,900	74,900	9,804
2021	41,300	54,200	55,600	74,100	9,891
2022	41,000	54,100	55,200	72,100	9,767
2023	41,000	54,000	54,900	72,300	9,597

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	168,000	168,000	168,000	168,000	0
2012	208,000	208,000	208,000	208,000	0
2013	217,000	217,000	217,000	217,000	2
2014	206,000	206,000	206,000	206,000	76
2015	190,000	191,000	191,000	192,000	517
2016	173,000	178,000	179,000	189,000	5,095
2017	151,000	169,000	171,000	200,000	15,395
2018	137,000	164,000	167,000	208,000	21,991
2019	128,000	162,000	164,000	209,000	25,902
2020	124,000	160,000	163,000	216,000	27,597
2021	122,000	158,000	162,000	216,000	28,097
2022	121,000	158,000	161,000	210,000	27,833
2023	121,000	158,000	160,000	209,000	27,334

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	0.21	0.21	0.21	0.21	0.00
2012	0.21	0.21	0.21	0.21	0.00
2013	0.21	0.21	0.21	0.21	0.00
2014	0.21	0.21	0.21	0.21	0.00
2015	0.21	0.21	0.21	0.21	0.00
2016	0.21	0.21	0.21	0.21	0.00
2017	0.21	0.21	0.21	0.21	0.00
2018	0.21	0.21	0.21	0.21	0.00
2019	0.21	0.21	0.21	0.21	0.00
2020	0.21	0.21	0.21	0.21	0.00
2021	0.21	0.21	0.21	0.21	0.00
2022	0.21	0.21	0.21	0.21	0.00
2023	0.21	0.21	0.21	0.21	0.00

Table 2.2.28—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = 0$ in 2011-2023 (Scenario 5), with random variability in future recruitment under Model A.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2023	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	172,000	172,000	172,000	172,000	0
2012	240,000	240,000	240,000	240,000	0
2013	279,000	279,000	279,000	279,000	2
2014	293,000	293,000	293,000	293,000	76
2015	290,000	290,000	290,000	291,000	520
2016	279,000	284,000	285,000	295,000	5,192
2017	258,000	277,000	280,000	311,000	16,638
2018	242,000	273,000	277,000	325,000	25,858
2019	229,000	272,000	275,000	333,000	32,739
2020	223,000	270,000	274,000	340,000	36,514
2021	218,000	268,000	272,000	344,000	38,624
2022	213,000	267,000	271,000	340,000	39,142
2023	211,000	266,000	269,000	340,000	38,958

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2023	0.00	0.00	0.00	0.00	0.00

Table 2.2.29—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2011-2023 (Scenario 6), with random variability in future recruitment under Model A.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	145,000	145,000	145,000	145,000	0
2012	147,000	147,000	147,000	147,000	0
2013	129,000	129,000	129,000	129,000	16
2014	107,000	108,000	108,000	109,000	501
2015	93,700	94,500	94,600	95,800	647
2016	73,800	82,000	83,400	97,200	7,358
2017	56,000	77,300	79,900	110,000	16,948
2018	51,100	77,100	79,500	113,000	20,020
2019	50,300	78,800	80,400	115,000	21,030
2020	49,600	78,300	81,200	119,000	21,106
2021	50,400	78,300	81,000	115,000	20,945
2022	49,800	78,500	80,600	116,000	20,597
2023	50,700	77,700	80,200	114,000	20,573

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	161,000	161,000	161,000	161,000	0
2012	165,000	165,000	165,000	165,000	0
2013	147,000	147,000	147,000	147,000	2
2014	124,000	124,000	124,000	125,000	76
2015	108,000	108,000	108,000	109,000	511
2016	94,800	99,800	101,000	109,000	4,701
2017	82,900	96,700	98,800	122,000	12,220
2018	79,100	96,400	98,700	126,000	14,969
2019	78,300	97,600	99,400	128,000	16,184
2020	77,900	97,100	100,000	133,000	16,524
2021	78,400	97,200	100,000	131,000	16,352
2022	78,400	97,200	99,600	128,000	15,970
2023	78,600	96,800	99,300	128,000	15,708

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	0.56	0.56	0.56	0.56	0.00
2012	0.56	0.56	0.56	0.56	0.00
2013	0.56	0.56	0.56	0.56	0.00
2014	0.56	0.56	0.56	0.56	0.00
2015	0.56	0.56	0.56	0.56	0.00
2016	0.49	0.52	0.52	0.56	0.02
2017	0.42	0.50	0.50	0.56	0.04
2018	0.40	0.50	0.49	0.56	0.05
2019	0.40	0.50	0.49	0.56	0.06
2020	0.40	0.50	0.50	0.56	0.05
2021	0.40	0.50	0.50	0.56	0.05
2022	0.40	0.50	0.50	0.56	0.05
2023	0.40	0.50	0.49	0.56	0.05

Table 2.2.30—Projections for GOA Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2011-2012 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment under Model A.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	122,000	122,000	122,000	122,000	0
2012	130,000	130,000	130,000	130,000	0
2013	141,000	141,000	141,000	141,000	16
2014	113,000	114,000	114,000	115,000	501
2015	96,700	97,500	97,500	98,800	647
2016	76,300	84,600	85,900	98,600	7,139
2017	56,500	77,800	80,400	110,000	16,950
2018	51,200	77,100	79,500	113,000	20,047
2019	50,200	78,800	80,400	115,000	21,040
2020	49,600	78,300	81,200	119,000	21,109
2021	50,400	78,300	81,000	115,000	20,945
2022	49,800	78,500	80,600	116,000	20,597
2023	50,700	77,700	80,200	114,000	20,573

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	163,000	163,000	163,000	163,000	0
2012	177,000	177,000	177,000	177,000	0
2013	162,000	162,000	162,000	162,000	2
2014	132,000	132,000	132,000	133,000	76
2015	112,000	112,000	112,000	113,000	511
2016	96,600	102,000	102,000	111,000	4,724
2017	83,300	97,100	99,200	122,000	12,316
2018	79,200	96,400	98,700	126,000	15,020
2019	78,200	97,600	99,400	128,000	16,198
2020	77,900	97,100	100,000	133,000	16,527
2021	78,400	97,200	100,000	131,000	16,353
2022	78,400	97,200	99,600	128,000	15,970
2023	78,600	96,800	99,300	128,000	15,708

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2011	0.45	0.45	0.45	0.45	0.00
2012	0.45	0.45	0.45	0.45	0.00
2013	0.56	0.56	0.56	0.56	0.00
2014	0.56	0.56	0.56	0.56	0.00
2015	0.56	0.56	0.56	0.56	0.00
2016	0.50	0.53	0.53	0.56	0.02
2017	0.43	0.50	0.50	0.56	0.04
2018	0.40	0.50	0.49	0.56	0.05
2019	0.40	0.50	0.49	0.56	0.06
2020	0.40	0.50	0.50	0.56	0.05
2021	0.40	0.50	0.50	0.56	0.05
2022	0.40	0.50	0.50	0.56	0.05
2023	0.40	0.50	0.49	0.56	0.05

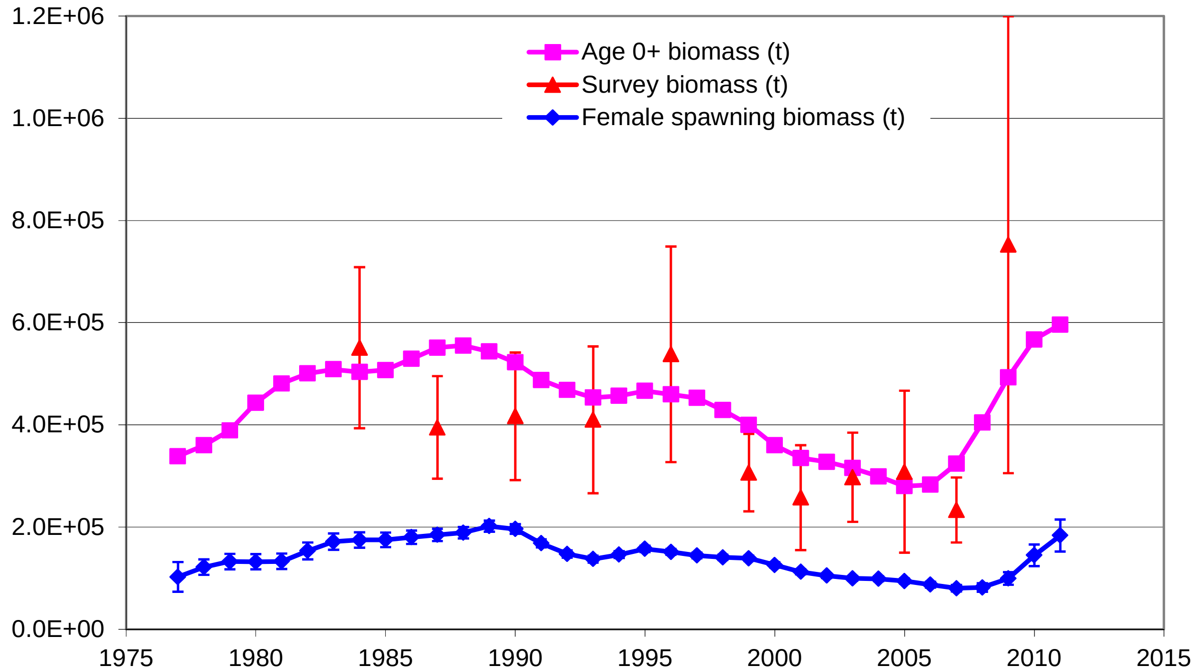


Figure 2.2.10—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) as estimated by Model A. Female spawning biomass and survey biomass show 95% CI.

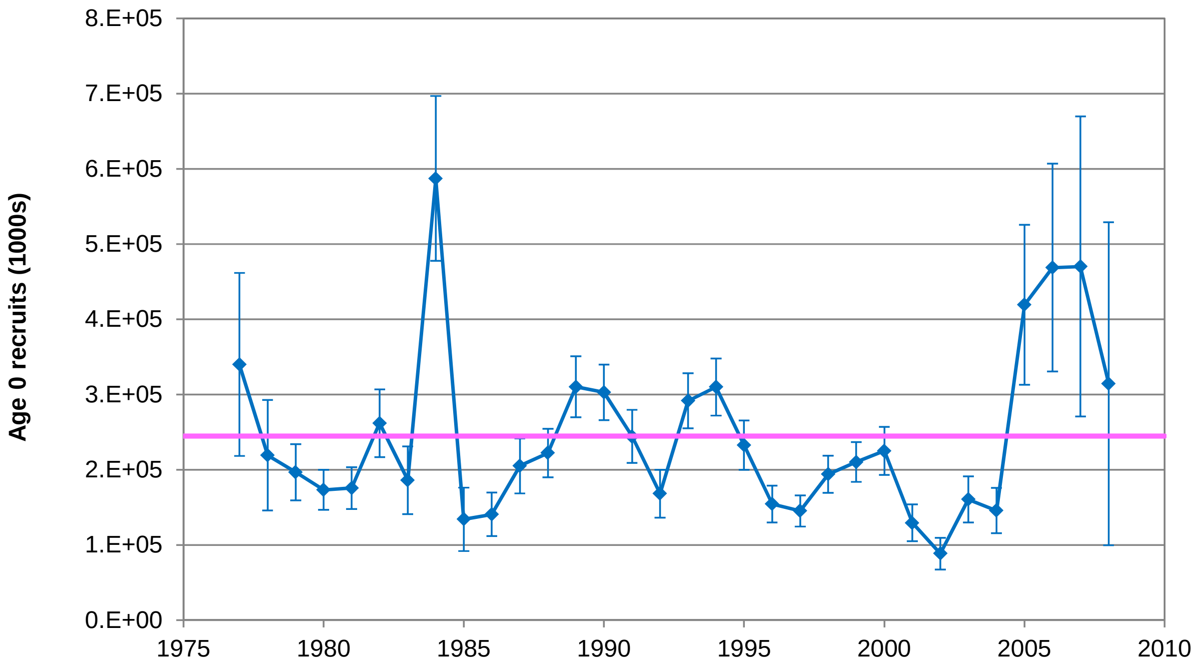


Figure 2.2.11—Time series of recruitment at age 0, with 95% confidence intervals, as estimated by Model A. Magenta line = 1977-2008 average.

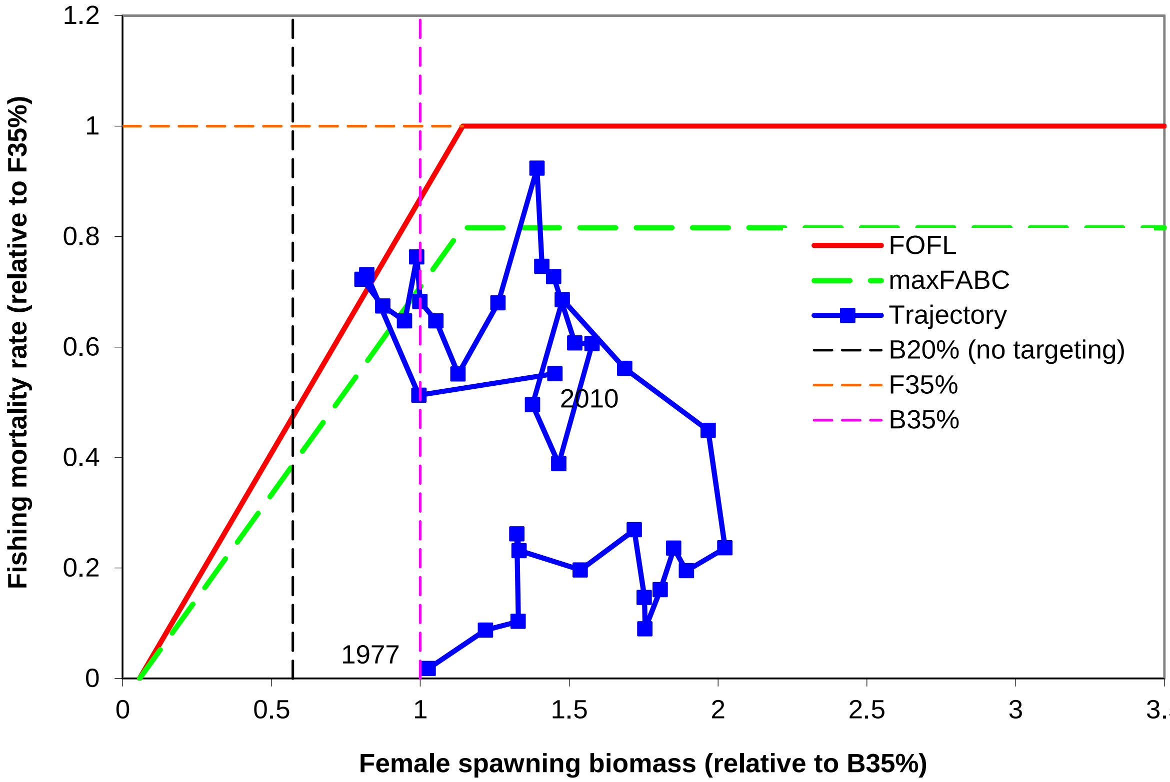


Figure 2.2.12—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model A, 1977-present. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below $B_{20\%}$. Note that $B_{35\%}$ is defined by 2010 parameter values for purposes of this graph (with cohort-specific growth rates, the value of $B_{35\%}$ changes every year).

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