Chapter 2: Assessment of the Pacific Cod Stock in the Eastern Bering Sea and Aleutian Islands Area

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EXECUTIVE SUMMARY

Summary of Changes in Assessment Inputs

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

Changes in the Input Data

1) Catch data for 1991-2011 were updated, and preliminary catch data for 2012 were incorporated.
2) Commercial fishery size composition data for 2011 were updated, and preliminary size composition data from the 2012 commercial fisheries were incorporated.
3) Size composition data from the 2012 EBS shelf bottom trawl survey were incorporated.
4) The numeric abundance estimate from the 2012 EBS shelf bottom trawl survey was incorporated (the 2012 estimate of 988 million fish was up about 18% from the 2011 estimate).
5) Age composition data from the 2011 EBS shelf bottom trawl survey were incorporated.
6) Mean length at age data from the 2011 EBS shelf bottom trawl survey were incorporated.
7) Seasonal catch per unit effort (CPUE) data for the trawl, longline, and pot fisheries from 2011 were updated, and preliminary catch rates for the trawl, longline, and pot fisheries from 2012 were incorporated.

Changes in the Assessment Methodology

Many changes have been made or considered in the stock assessment model since the 2011 assessment (Thompson and Lauth 2011). Five primary models and nine secondary models were presented in this year's preliminary assessment (Attachment 2.1). Four of the primary models and three of the secondary models in the preliminary assessment were requested by the Plan Teams in May of this year, with subsequent concurrence by the SSC in June. Following review in September and October, four of these models were requested by the Plan Teams or SSC to be included in the final assessment.

Model 1 is identical to the model accepted for use by the BSAI Plan Team and SSC last year, except for inclusion of new data.

Model 2 is identical to Model 1, except that the survey catchability coefficient was estimated as a free parameter.

Model 3 is also identical to Model 1, except that ageing bias was not estimated internally and the fit to the age composition data was not included in the log-likelihood function.

Model 4 is an exploratory model that differs from Model 1 in several respects (see “Analytic Approach, Model Structure” below for details).

Version 3.23b (compiled on 11/05/11) of Stock Synthesis (SS) was used to run all the models in this assessment.

Model 1 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	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2012	2013	2013	2014
M (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	3a	3a	3a	3a
Projected total (age 0+) biomass (t)	1,690,000	1,720,000	1,600,000	1,710,000
Female spawning biomass (t)				
Projected	410,000	437,000	422,000	447,000
$B_{100\%}$	889,000	889,000	896,000	896,000
$B_{40\%}$	355,000	355,000	358,000	358,000
$B_{35\%}$	311,000	311,000	314,000	314,000
F_{OFL}	0.36	0.36	0.34	0.34
$maxF_{ABC}$	0.30	0.30	0.29	0.29
F_{ABC}	0.30	0.30	0.29	0.29
OFL (t)	369,000	374,000	359,000	379,000
maxABC (t)	314,000	319,000	307,000	323,000
ABC (t)	314,000	319,000	307,000	323,000
Status	As determined *last* year for:		As determined *this* year for:	
	2010	2011	2011	2012
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Responses to SSC and Plan Team Comments on Assessments in General

SSC1 (12/11 minutes): “*We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year’s assessments.*” A retrospective analysis is presented in Figure 2.15 (see also Comments JPT2 and SSC2).

JPT1 (9/12 minutes): *"Total catch accounting—The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented."* "Other" removals are included in Attachment 2.4. For the purpose of exploring possible impacts of these removals, alternative estimates of ABC are provided in that attachment. It should be noted that these alternative estimates are not recommended for use in the current specifications cycle.

JPT2 (9/12 minutes): *"Retrospective analysis—For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous years."* The retrospective analysis shown in Figure 2.15 follows the Teams' recommended protocol (see also Comments SSC1 and SSC2).

JPT3 (9/12 minutes): *"Methods for averaging surveys—The Plan Teams recommend that assessment authors retain status quo assessment approaches for the November 2012 SAFE report but also apply the Kalman filter or random effects survey averaging methods for Tier 5 stocks and summarize the analytical results for comparison purposes only. ADMB code for implementing the random effects method will be made available."* Although BSAI Pacific cod is currently managed as a single Tier 3 stock, a Kalman filter has been used to estimate the relative biomasses of Pacific cod in the separate EBS and AI areas since 2004, for the purpose of expanding the results of the EBS model to the full BSAI region. The same approach was used in the present assessment. See also Comment SSC3.

SSC2 (10/12 minutes): *"The SSC concurs with the working group and the Groundfish Plan Team (GPT) recommendation that for Alaska groundfish assessment with Tiers 1-3 age-structured models, a retrospective analysis should be done as part of the model evaluation."* See Comments JPT2 and SSC1.

SSC3 (10/12 minutes): *"The SSC concurs with the Team that stock assessment authors for Tier 5 stocks should continue to use status quo methods for survey averaging, and that they should also calculate alternate RE estimates, so that experience can be gained over time in how similar or different the estimates are from the two approaches."* See Comment JPT3.

Responses to SSC and Plan Team Comments Specific to this Assessment

A total of 20 comments specific to BSAI Pacific cod from the November 2011 and May 2012 meetings of the Joint Plan Teams (12 comments), the November 2011 meeting of the BSAI Plan Team (1 comment), and the December 2011 and June 2012 meetings of the SSC (7 comments) were addressed in the preliminary EBS and AI assessments (included here as Attachment 2.1 and Annex 2.2.1, respectively). In the interest of efficiency, they are not repeated in this section.

Plan Team and SSC comments from the September 2012 and October 2012 meetings that relate to the assessment of EBS Pacific cod are shown below. Comments from the September 2012 and October 2012 meetings that relate to the assessment of AI Pacific cod are listed in Attachment 2.2. However, in the interest of providing some context for interpreting the results shown here (i.e., in the main text), it should be noted that one of the comments listed in Attachment 2.2 indicates that the results given in that attachment will *not* be used for recommending 2013 harvest specifications.

BPT1 (9/12 minutes): *"Regarding candidate models for November, the Plan Team recommends including Model 1 (because it is the currently accepted model, inclusion of Model 1 should be considered* *automatic), and also Model 5 because it is very parsimonious and includes a number of features that Grant showed to improve the fit."* Models 1 and 5 from the preliminary assessment are included in this assessment (Model 5 is renamed Model 4 here). See also Comment SSC4.

BPT2 (9/12 minutes): "*There was also a lot of interest in a model intermediate between Model 1 and Model 5, such as a version of Model 5 in which the commercial fishery data are still broken out by gear and season, with selectivity parameters estimated by time block. The Team recommends that the author investigate a model like that and bring it forward on his own if it looks worthwhile."* This optional model was not included in the present assessment due to the fact that developing the Team's four requested models (see Comments BPT1 and BPT3) left insufficient time for developing additional models such as this one. See also Comment SSC4.

BPT3 (9/12 minutes): "*While they are not candidates for the specifications, we think that Models 1.1 and 4 provide a useful check on the candidate models and recommend that they be reported in November (and next September)."* Models 1.1 and 4 are included in this assessment (renamed Models 2 and 3, respectively). These two models will be included in the list of proposals for consideration by the Team and SSC next spring. Following review of all model proposals next spring, if these two are recommended by the Team and SSC, they will be included in next year's preliminary assessment also. See also Comment SSC5.

SSC4 (10/12 minutes): "*For the BS Pacific cod stock, the Plan Team recommends including the currently accepted model (Model 1) and Model 5 because it is parsimonious and includes a number of features that improve fit to the data. The Plan Team recommended the author bring forward a version of Model 5 that incorporates time varying selectivity for the fishery, if time permits and is worthwhile. The SSC supports Plan Team recommendations and encourages the author - if time permits - to bring forward a model that considers time varying survey Q to see if that produces better fit to the survey data."* Models 1 and 5 from the preliminary assessment are included in this assessment (Model 5 is renamed Model 4 here). The two optional models suggested by the SSC were not included in the present assessment due to the fact that developing the SSC's four requested models left insufficient time for developing additional models such as these two. See also Comments BPT1, BPT2, BPT3, and SSC5.

SSC5 (10/12 minutes): "*The SSC also agrees with the Plan Team request for the author to bring forward Models 1.1 and 4 to provide a check on the candidate models."* See Comment BPT3.

SSC6 (10/12 minutes): "*In response to a previous SSC request, the author completely re-parameterized the inter- and intra-annual weight-length relationship in a way that follows an explicit phenological process and is biologically reasonable. This change is incorporated in Model 5. The SSC believes this provides a significant improvement in the fit to the data that should be carried forward in Model 5. The approach could also serve as a model for other assessments."* The new weight-length relationship is carried forward in Model 5 from the preliminary assessment (renamed Model 4).

Organization of This Chapter

Main text
Attachment 2.1: Preliminary EBS assessment (presented to the Plan Team in September)
    Annex 2.1.1: Estimating the standard deviation in a random effects model
    Annex 2.1.2: A trigonometric model of seasonally varying weight at length
Attachment 2.2: AI assessment
    Annex 2.2.1: Preliminary AI assessment (presented to the Plan Team in September)
Attachment 2.3: Current regulations specific to the Pacific cod fishery in the BSAI
Attachment 2.4: Supplemental catch data

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 the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. The resource in these two areas (BSAI) is managed as a single unit. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (GOA). Recent research indicates the existence of discrete stocks in the EBS and AI (Canino et al. 2005, Cunningham et al. 2009, Canino et al. 2010, Spies 2012). 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 EBS or AI areas.

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.

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 2.49% per day (Jung et al. 2009). This may be compared to a mean estimate for age 0 Atlantic cod (*Gadus morhua*) in Newfoundland of 4.17% per day, with a 95% confidence interval ranging from about 3.31% to 5.03% (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 exhibit 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

Description of the Directed Fishery

During the early 1960s, a Japanese longline fishery harvested BSAI Pacific cod for the frozen fish market. Beginning in 1964, the Japanese trawl fishery for walleye pollock (*Theragra chalcogramma*) expanded and cod became an important bycatch species and an occasional target species when high concentrations were detected during pollock operations. By the time that the Magnuson Fishery Conservation and Management Act went into effect in 1977, foreign catches of Pacific cod had consistently been in the 30,000-70,000 t range for a full decade. In 1981, a U.S. domestic trawl fishery and several joint venture fisheries began operations in the BSAI. The foreign and joint venture sectors dominated catches through 1988, but by 1989 the domestic sector was dominant and by 1991 the foreign and joint venture sectors had been displaced entirely. A State-managed fishery for Pacific cod in the Aleutian Islands began in 2006.

Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components (although catches by jig gear are very small in comparison to the other three main gear types). The breakdown of catch by gear during the most recent complete five-year period (2007-2011) is as follows: in the EBS, longline gear accounted for an average of 57% of the catch, trawl gear accounted for an average of 30%, and pot gear accounted for an average of 13%; in the AI, trawl gear accounted for an average of 74% of the catch, longline gear accounted for an average of 19%, and pot gear accounted for an average of 7%; in the BSAI overall, longline gear accounted for an average of 52% of the catch, trawl gear accounted for an average of 36%, and pot gear accounted for an average of 12%.

Historically, the great majority of the BSAI catch has come from the EBS area. During the most recent complete five-year period (2007-2011), the EBS accounted for an average of about 85% of the BSAI catch. In the EBS, Pacific cod are caught throughout much of the continental shelf, with NMFS statistical areas 521, 509, 517, 513, 524, and 519 each accounting for catches of at least 10,000 t on average from 2006-2011, and more than 95% of the total catch from that same time period. In the AI, the majority of the Pacific cod catch has been taken in NMFS statistical area 541 in 9 out of the last 10 years. Concentration of the AI fishery in area 541 has increased even more since area 543 was closed to directed fishing for Pacific cod in 2011 (over 95% of the AI catch to date in 2012 was taken from area 541).

Catches of Pacific cod taken in the BSAI for the periods 1964-1980, 1981-1990, and 1991-2012 are shown in Tables 2.1a, 2.1b, and 2.1c, respectively. The catches in Tables 2.1a and 2.1b are broken down by area and fleet sector (foreign, joint venture, domestic annual processing). The catches in Table 2.1b are also broken down by gear to the extent possible. The catches in Table 2.1c are broken down by area, gear, and—in the Aleutian Islands—management jurisdiction (Federal and State).

Excerpts from the current regulations governing the BSAI Pacific cod fisheries, including license limitation permits, prohibitions, allocations, closures, and seasons, are given in Attachment 2.3.

Effort and CPUE

Figures 2.1 and 2.2 show, subject to confidentiality restrictions, the approximate locations in which hauls or sets sampled during 2011 and 2012 contained Pacific cod. To create these figures, the areas managed under the FMP were 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. Figures 2.1a-d pertain to the EBS and Figures 2.2a-c pertain to the AI. Figures 2.1a-c show locations of sampled EBS hauls/sets containing Pacific cod for trawl, longline, and pot gear, for the January-April, May-July, and August-December seasons. Figure 2.1d shows locations of sampled EBS hauls/sets for the same gear types, but aggregated across seasons. Figures 2.2a-b show locations of sampled AI hauls/sets containing Pacific cod for trawl gear and longline and pot gear combined, for the January-April, May-July, and August-December seasons. Figure 2.1c shows locations of AI sampled hauls/sets for the same gear types, but aggregated across seasons. More squares are shaded in Figures 2.1d and 2.2c than in the other parts of Figures 2.1 and 2.2 because aggregating across seasons increases the number of squares that satisfy the confidentiality constraint.

Various gear-specific time series of fishery catch per unit effort (CPUE) are plotted in Figures 2.3a and 2.3b. Figure 2.3a shows gear-specific CPUE by season for the EBS, while Figure 2.3b shows gear-specific CPUE aggregated across the entire year for the AI. In the EBS, most CPUE time series are either flat or increasing since about the middle of the last decade. In the AI, both CPUE trends seem to be decreasing since about the mid-1990s.

Discards

The catches shown in Tables 2.1b and 2.1c include estimated discards. Discard rates of Pacific cod in the EBS and AI Pacific cod fisheries are shown for each year 1991-2012 in Table 2.2. Implementation of Amendment 49, which mandated increased retention and utilization, resulted in an average reduction of 90% in discards of Pacific cod between 1991-1997 and 1998-2012.

Management History

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 (i.e., all-gear, combined area) commercial catches in Table 2.3.

From 1980 through 2012 TAC averaged about 83% of ABC (ABC was not specified prior to 1980), and from 1980 through 2012 aggregate commercial catch averaged about 91% of TAC (remembering that 2012 catch data are not yet final). In 10 of these 33 years (30%), TAC equaled ABC exactly, and in 8 of these 33 years (24%), catch exceeded TAC (by an average of 3%). However, three of those overages occurred in 2007, 2008, and 2010, when TAC was reduced by 3% to account for a small, State-managed fishery inside State of Alaska waters (similar reductions have been made in all years since 2006); thus, while the combined Federal and State catch exceeded the Federal TAC in 2007, 2008, and 2010 by 2% or less, the overall target catch (Federal TAC plus State GHL) was not exceeded.

Total catch has been less than OFL in every year since 1993.

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 1985 consisted of simple projections of survey numbers at age. In 1985, the assessment was expanded to consider all survey numbers at age from 1979-1985. From 1985-1991, the assessment was conducted using an *ad hoc* separable age-structured model. In 1992, the assessment was conducted using the Stock Synthesis 1 modeling software (Methot 1986, 1990) with age-based data. All assessments from 1992 through 2003 continued to use the Stock Synthesis 1 modeling software, but with length-based data. Age data based on a revised ageing protocol were added to the model in the 2004 assessment. The assessment was migrated to Stock Synthesis 2 in 2005 (Methot 2005), and several changes have been made to the model within the SS framework (renamed "Stock Synthesis," without a numeric modifier, in 2008) each year since then.

Table 2.4 lists all amendments to the BSAI Groundfish FMP that reference Pacific cod explicitly.

DATA

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

The following table summarizes the sources, types, and years of data included in the data file for one or more of the stock assessment models:

Source	Type	Years
Fishery	Catch biomass	1977-2012
Fishery	Catch size composition	1977-2012
Fishery	Catch per unit effort	1991-2012
EBS shelf bottom trawl survey	Numerical abundance	1982-2012
EBS shelf bottom trawl survey	Size composition	1982-2012
EBS shelf bottom trawl survey	Age composition	1994-2011
EBS shelf bottom trawl survey	Mean size at age	1994-2011

Fishery

Catch Biomass

Catches taken in the EBS for the period 1977-2012 are shown for the three main gear types in Tables 2.5a and 2.5b. Table 2.5a makes use of two different types of season: catch seasons and selectivity seasons (Table 2.5b uses catch seasons only). The catch seasons are defined as January-February, March-April, May-July, August-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 Tables 2.5a and 2.5b were the result of a statistical analysis described in the 2010 preliminary assessment (Thompson et al. 2010), and the selectivity seasons were chosen to correspond as closely as possible to the traditional seasons used in assessments prior to 2010 (given the revised catch seasons).

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 Table 2.5a. Catches for the years 1977-1980 may or may not include discards.

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 2012. Beginning with the 2010 assessment (Thompson et al. 2010), size composition data are based on 1-cm bins ranging from 4 to 120 cm. Because displaying these data would add a large number of pages to the present document, they are not shown here but are available at: http://www.afsc.noaa.gov/REFM/Docs/2012/EBS_Pcod_fishery_sizecomp_data.xlsx.

Catch Per Unit Effort

Fishery catch per unit effort data are available by gear and season for the years 1991-2012 and are shown in Table 2.6. Units are kg/minute for trawl gear, kg/hook for longline gear, and kg/pot for pot gear; data for 2012 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.

Survey

EBS Shelf Bottom Trawl Survey

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.7, together with their respective standard errors. Upper and lower 95% confidence intervals are also shown for the biomass estimates. Survey results indicate that biomass increased steadily from 1979 through 1983, and then remained relatively constant from 1983 through 1988. The highest biomass ever observed by the survey was the 1994 estimate of 1,368,120 t. Following the high observation in 1994, the survey biomass estimate declined steadily through 1998. The survey biomass estimates remained in the 596,000-619,000 t range from 2002 through 2005. However, the survey biomass estimates dropped after 2005, producing an all-time low in 2007 and again in 2008. Estimated biomass more than doubled between 2009 and 2010, and has remained approximately constant since then.

Numerical abundance has shown more variability than biomass. With the exception of 2008, numerical abundance estimates since 2007 have all been at least 15% above the pre-2007 average. The 2012 estimate is the second highest in the time series.

The relative size compositions from the EBS shelf bottom trawl survey for the years 1982-2012 are shown in Table 2.8 (actual numbers of fish measured are shown in column 2). The 1982-2012 time series is shown according to the 1-cm bins described above for fishery size composition data. Rows in Table 2.8 sum to the actual number of fish measured in each year.

Age compositions from the 1994-2011 surveys are available. The age compositions and actual sample sizes are shown in Table 2.9.

Mean size-at-age data are available for all of the years in which age compositions are available. These are shown, along with sample sizes, in Table 2.10.

This year's preliminary assessment (Attachment 2.1) describes a detailed reanalysis of the available weight-at-length data. The data set is too large to include here (over 100,000 fishery weight-at-length data were collected from 1974 through 2011), but means and standard deviations of weight at each sampled length are shown for each month and year at:
http://www.afsc.noaa.gov/REFM/Docs/2012/EBS_Pcod_weight-length_data.xlsx.

Aleutian Bottom Trawl Survey

Biomass estimates for the Aleutian Islands region were derived from U.S.-Japan cooperative bottom trawl surveys conducted during the summers of 1980, 1983, and 1986, and by U.S. bottom trawl surveys of the same area in 1991, 1994, 1997, 2000, 2002, 2004, 2006, and 2010. These surveys covered both the Aleutian management area (170 degrees east to 170 degrees west) and a portion of the Bering Sea management area ("Southern Bering Sea") not covered by the EBS shelf bottom trawl surveys. The time series of biomass estimates (t) from the overall Aleutian survey area are shown below, together with their respective coefficients of variation (CV):

Year	Survey Type	Biomass	CV
1980	U.S.-Japan	146,093	0.20
1983	U.S.-Japan	215,823	0.14
1986	U.S.-Japan	254,698	0.26
1991	U.S.	188,456	0.14
1994	U.S.	184,499	0.18
1997	U.S.	83,590	0.13
2000	U.S.	136,991	0.17
2002	U.S.	83,152	0.15
2004	U.S.	114,183	0.17
2006	U.S.	92,316	0.27
2010	U.S.	68,576	0.16
2012	U.S.	65,868	0.14

The 2010 and 2012 estimates are the lowest in the time series.

For many years, the assessments of Pacific cod in the BSAI have used a weighted average formed from EBS and AI survey biomass estimates to provide a conversion factor which is used to translate model projections of EBS catch and biomass into BSAI equivalents. Prior to the 2004 assessment, the weighted average was based on the sums of the biomass estimates from the EBS shelf and AI survey biomass time series. However, in December of 2003 the SSC requested that alternative methods of estimating relative biomass between the EBS and AI be explored. Following a presentation of some possible alternatives (Thompson and Dorn 2004), the SSC recommended that an approach based on a simple Kalman filter be used. Applying this approach to the updated (through 2012) time series indicates that the best estimate of the current biomass distribution is 93% EBS and 7% AI, replacing the previous proportions of 91% and 9% respectively.

ANALYTIC APPROACH

Model Structure

History of Previous Model Structures Developed Under Stock Synthesis

Stock Synthesis 1 (SS1, Methot 1986, 1990, 1998, 2000) was first applied to the EBS Pacific cod stock in the 1992 assessment (Thompson 1992). This first application used age-structured data. Beginning with the 1993 SAFE report (Thompson and Methot 1993) and continuing through the 2004 SAFE report (Thompson and Dorn 2004), SS1 continued to be used, but based largely on length-structured data. It should be emphasized that the model has always been intended to assess only the EBS portion of the BSAI stock. Conversion of model estimates of EBS biomass and catch to BSAI equivalents has traditionally been accomplished by application of an expansion factor based on the relative survey biomasses between the EBS and AI.

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. The EBS Pacific cod assessments, for example, usually divided the shelf bottom trawl survey size composition time series into pre-1982 and post-1981 segments to account for the effects of a change in the trawl survey gear instituted in 1982. Also, to account for possible differences in selectivity between the mostly foreign (also joint venture) and mostly domestic fisheries, the fishery size composition time series was split into pre-1989 and post-1988 segments during the era of SS1-based assessments.

Until 2010, each year was partitioned into three seasons defined as January-May, June-August, and September-December (these seasonal boundaries were suggested by industry participants). Four fisheries were 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 EBS 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 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 and Dorn 2002), where it was found to result in a statistically significant improvement in the model’s ability to fit the data. In the 2004 assessment (Thompson and Dorn 2004), further modifications were made to the base model. The 2004 model included a set of selectivity parameters for the EBS slope bottom trawl survey and added new likelihood components for the age compositions and length-at-age data from the 1998-2003 EBS shelf bottom trawl surveys and the size composition and biomass data from the 2002 and 2004 EBS slope bottom trawl surveys. Incorporation of age data and slope survey data had been suggested by the SSC (SSC minutes, December 2003).

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 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 Stock Synthesis 2 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 Stock Synthesis 2 were described by Methot (2005).

The 2006 assessment (Thompson et al. 2006) explored alternative functional forms for selectivity, use of Pacific cod incidental catch data from the NMFS sablefish longline survey, and the influence of prior distributions.

In 2007, SS introduced a six-parameter double-normal selectivity curve. This functional form is constructed from two underlying and linearly rescaled normal distributions, with a horizontal line segment joining the two peaks. As configured in SS, the equation 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.

A technical workshop was held in April of 2007 to address possible improvements to the assessment model (Thompson and Conners 2007). Based on suggestions received at the workshop, several alternative models were considered in a preliminary 2007 assessment (Thompson et al. 2007a), and four models were advanced during the final 2007 assessment (Thompson et al. 2007b). The recommended model from the final 2007 assessment (Model 1) included a number of features that distinguished it from the model used in the 2006 assessment, including:

1. A fixed value of 0.34 was adopted for the natural mortality rate, based on life history theory.
2. The six parameter double-normal function was used for all selectivities.
3. The maturity schedule modeled as a function of age rather than length.
4. Trawl survey selectivity modeled as a function of age rather than length.
5. Fishery selectivity was assumed to be constant across all years.
6. Annual *dev*s were estimated in the *ascending_width* parameter of the trawl survey selectivity schedule, with an assumed standard deviation of 0.2.
7. The standard deviation of length at age modeled as a linear function of length at age.
8. Survey abundance was measured in numbers of fish (rather than biomass).
9. The input sample sizes for multinomial distributions were set on the basis of a scaled bootstrap harmonic mean.

Relative to the 2007 assessment, the model accepted by the Plan Team and SSC from the 2008 assessment (Thompson et al. 2008) featured two main changes:

1. An explicit algorithm was used to determine which fleets (including surveys as well as fisheries) would be forced to exhibit asymptotic selectivity.
2. An explicit algorithm was used 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.

The 2009 assessment (Thompson et al. 2009) featured a total of 14 models reflecting 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 *dev*s.
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 post-1981 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 0.47 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. Cohort-specific growth *dev*s were estimated for all years through 2008.

Many changes were made or considered in the 2010 stock assessment model (Thompson et al. 2010). Six models were presented in the preliminary assessment, as requested by the Plan Teams in May, 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. Relative to the 2009 assessment, the main changes in the model that was ultimately accepted by the Plan Team and SSC in 2010 were as follow:

1. Relative abundance data and the two records of size composition data from the IPHC longline survey were excluded.
2. The single available record (each) of fishery age composition and mean length-at-age data was excluded.
3. A new length structure consisting of 1-cm bins was adopted, replacing the combination of 3-cm and 5-cm bins used in previous assessments.
4. A new seasonal structure was adopted, consisting of five catch seasons defined as January-February, March-April, May-July, August-October, and November-December; and three selectivity seasons defined as January-April, May-July, and August-December; with spawning identified as occurring at the beginning of the second catch season (March).
5. Cohort-specific growth rates were removed (these were introduced for the first time in the 2009 assessment).

Per request from the Plan Teams, quantities that were estimated iteratively in the 2009 assessment were not re-estimated in the 2010 assessment.

Following a review by the Center for Independent Experts earlier in the year that resulted in a total of 128 unique recommendations from the three reviewers, the 2011 stock assessment (Thompson and Lauth 2011) again considered several possible model changes. A set of seven models was requested for inclusion in the preliminary by the Plan Teams in May, with subsequent concurrence by the SSC in June. Following review in August and September, four of these models were requested by the Plan Teams or SSC to be included in the final assessment. In addition, the SSC requested one new model, which was ultimately accepted by both the BSAI Plan Team and the SSC. Relative to the 2010 assessment, the main changes in the accepted model were as follow:

1. The pre-1982 portion of the AFSC bottom trawl time series was omitted.
2. The 1977-1979 and 1980-1984 time blocks for the January-April trawl fishery selectivity parameters were combined. This change was made because the selectivity curve for the 1977-1979 time block tended to have a very difficult-to-rationalize shape (almost constant across length, even at very small sizes), which led to very high and also difficult-to-rationalize initial fishing mortality rates.
3. The age corresponding to the *L1* parameter in the length-at-age equation was increased from 0 to 1.4167, to correspond to the age of a 1-year-old fish at the time of the survey, which is when the age data are collected. This change was adopted to prevent mean size at age from going negative (as sometimes happened for age 0 fish in previous assessments, and as happened even for age 1 fish in one of the models from the 2010 assessment), and to facilitate comparison of estimated and observed length at age and variability in length at age.
4. A column for age 0 fish was added to the age composition and mean-size-at-age portions of the data file. Even though there are virtually no age 0 fish represented in these two portions of the data file, unless a column for age 0 is included, SS will interpret age 1 fish as being ages 0 and 1 combined, which can bias the estimates of year class strength.
5. Ageing bias was estimated internally.
6. The parameters governing variability in length were estimated internally.
7. All size composition records were included in the log-likelihood function.

8. The fit to the mean-size-at-age data was not included in the log-likelihood function.

It should also be noted that, consistent with the Plan Team request made in 2010, quantities that were estimated iteratively in the 2009 assessment were not re-estimated in the 2011 assessment.

Model Structures Considered in This Year's Assessment

Many model changes have been considered in this year's stock assessment. Five primary models and nine secondary models were presented in this year's preliminary assessment (Attachment 2.1). Of these, four of the primary models and three of the secondary models were requested by the Plan Teams in May of this year, with subsequent concurrence by the SSC in June. Following review in September and October, four of the models from the preliminary assessment were requested by the Plan Teams or SSC to be included in the final assessment:

Model 1 is identical to the model accepted for use by the BSAI Plan Team and SSC last year, except for inclusion of new data.

Model 2 is identical to Model 1, except that the survey catchability coefficient was estimated as a free parameter.

Model 3 is also identical to Model 1, except that ageing bias was not estimated internally and the fit to the age composition data was not included in the log-likelihood function.

Model 4 is an exploratory model that differs from Model 1 in several respects:

1. A new, inter- and intra-annually varying weight-length representation developed in the preliminary assessment (Attachment 2.1, Annex 2.1.2) was used.
2. "Tail compression" was turned off. This feature aggregates size composition bins with few or zero data on a record-by-record basis, which improves computational speed, but which also makes some of the graphs in the R4SS package difficult to interpret. In Models 1-3, tail compression is turned on.
3. Fishery CPUE data were omitted. In Models 1-3, fishery CPUE data are included for purposes of comparison, but are not used in estimation.
4. A new population length bin was added for fish in the 0-0.5 cm range, which was used for extrapolating the length-at age curve below the first reference age. In Models 1-3, the lower bound of the first population length bin is 0.5 cm.
5. Mean-size-at-age data were eliminated. In Models 1-3, mean-size-at-age data are included, but not used in estimation.
6. The number of estimated year class strengths in the initial numbers-at-age vector was set at 10. In Models 1-3, only 3 elements of the initial numbers-at-age vector are estimated, which causes an automatic warning in SS.
7. The Richards growth equation (Richards 1959, Schnute 1981, Schnute and Richards 1990) was used, which adds one more parameter. In Models 1-3, the von Bertalanffy equation—a special case of the Richards equation—was used.
8. The log-scale standard deviation of recruitment was estimated internally (i.e., as a free parameter estimated by ADMB). In Models 1-3, this parameter was held constant at the value of 0.57 that was estimated in the final 2009 assessment by matching the standard deviation of the recruitment *dev*s, per Plan Team request.
9. Survey selectivity was modeled as a function of length. In Models 1-3, survey selectivity was modeled as a function of age.

10. Fisheries were defined with respect to each of the five seasons, but not with respect to gear. In Models 1-3, fisheries were defined with respect to both season and gear.
11. Fishery selectivity curves were defined for each of the five seasons, but were not stratified by gear type. In Models 1-3, seasons 1-2 and 4-5 were lumped into a pair of "super" seasons for the purpose of defining fishery selectivity curves, and fishery selectivities were also *gear*-specific (3 super-seasons × 3 gears = 9 selectivity curves).
12. The selectivity curve for the fishery that came closest to being asymptotic on its own (in this case, the season 3 fishery) was forced to be asymptotic by fixing both *width_of_peak_region* and *final_selectivity* at a value of 10.0 and *descending_width* at a value of 0.0. In Models 1-3, six of the nine super-season × gear fisheries were forced to exhibit asymptotic selectivity.
13. Survey catchability was tuned iteratively to set the average of the product of catchability and survey selectivity across the 60-81 cm range equal to 0.47, corresponding to the Nichol et al. (2007) estimate. In Models 1-3, *Q* was left at the value of 0.77 estimated by a similar procedure in the final 2009 assessment, per Plan Team request.
14. The age composition sample size multiplier was tuned iteratively to set the mean of the ratio of effective sample size to input sample size equal to 1.0. In Models 1-3, the variance adjustment was fixed at 1.0.
15. The two parameters governing the ascending limb of the survey selectivity schedule were given annual additive *dev*s with each σ_{dev} tuned to match the estimate that would be appropriate for a univariate linear-normal model with random effects integrated out (see Attachment 2.1, Annex 2.1.1). In Models 1-3, no *dev* vector corresponding to the *initial_selectivity* parameter is used, because it was "tuned out" in the 2009 final assessment; and σ_{dev} for the *ascending_width* parameter was left at the value of 0.07 estimated iteratively in the final 2009 assessment, per Plan Team request.

Version 3.23b (as compiled on 11/05/11) of Stock Synthesis was used to run all the models in this assessment (Methot 2011). An updated version of the technical description of SS given by Methot (2005) should appear shortly (Methot and Wetzel, in press). Stock Synthesis is programmed using the ADMB software package (Fournier et al. 2012).

Parameters Estimated Outside the Assessment Model

Natural Mortality

A value of 0.34 has been used for the natural mortality rate M in all BSAI Pacific cod stock assessments since 2007. This value was based on Equation 7 of Jensen (1996) and an age at maturity of 4.9 years (Stark 2007). In response to a request from the SSC, the 2008 assessment included a discussion of alternative values and a justification for the value chosen (Thompson et al. 2008). However, it should be emphasized that, even if Jensen's Equation 7 is exactly right, variability in the estimate of the age at maturity implies that the point of estimate of 0.34 is accompanied by a level of uncertainty. Using the variance for the age at 50% maturity published by Stark (0.0663), the 95% confidence interval for *M* extends from about 0.30 to 0.38.

The value of 0.34 adopted in 2007 replaced the value of 0.37 that had been used in all BSAI Pacific cod stock assessments from 1993 through 2006.

For historical completeness, some 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 fix *M* at the value of 0.34 used since 2007.

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 proportional relationship between standard deviation and age. The regression was recomputed this year, yielding an estimated slope of 0.08649 (i.e, the standard deviation of estimated age was modeled as 0.08649 × age) and a weighted R^2 of 0.93. This regression corresponds to a standard deviation at age 1 of 0.086 and a standard deviation at age 20 of 1.73. These parameters were used for all models in the present assessment.

Weight at Length

Parameters governing the weight-at-length schedule were re-estimated for this year's assessment, based on fishery data collected from 1974 through 2011.

Using the functional form weight = $\alpha \times \text{length}^{\beta}$, where weight is measured in kg and length is measured in cm, long-term base values for the parameters were estimated as $\alpha = 6.358 \times 10^{-6}$ and $\beta = 3.157$.

In this year's preliminary assessment, a new approach for computing both inter- and intra-annual variability in weight at length was described (Attachment 2.1, Annex 2.2.1). Seasonal additive offsets from the base parameter values, as estimated by the new approach, are shown below:

Season:	Jan-Feb	Mar-Apr	May-Jul	Aug-Oct	Nov-Dec
α:	-2.312×10^{-2}	2.769×10^{-3}	1.946×10^{-2}	2.343×10^{-3}	-1.433×10^{-2}
β:	5.344×10^{-2}	-6.503×10^{-2}	-4.617×10^{-2}	-5.500×10^{-2}	3.329×10^{-2}

The above values for the base parameters and seasonal offsets were used for all models in the present assessment. In addition to the *seasonal* offsets, Model 4 also used the *annual* offsets resulting from the new approach. These are shown in Table 2.11.

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 was 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 = 58 cm and slope of linearized logistic equation = –0.132. 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, the accepted model has used an age-based schedule with intercept = 4.88 years and slope =

–0.965 (Stark 2007). The use of an age-based rather than a length-based schedule follows a recommendation from the maturity study's author (James Stark, Alaska Fisheries Science Center, personal communication). The age-based parameters were retained for all models in the present assessment.

Standard Deviation of Log Recruitment

The standard deviation specified for log-scale age 0 recruitment was estimated iteratively in the 2009 assessment, by matching the input value to the standard deviation of the estimated *dev*s. The resulting value of 0.57 was retained for Models 1-3 in the present assessment. Model 4 estimates this parameter internally.

Catchability

In the 2009 assessment (Thompson et al. 2009), catchability for the post-1981 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 0.47 obtained by Nichol et al. (2007). The resulting value of 0.77 was retained for Models 1 and 3 in the present assessment. Model 2 estimates catchability internally. Model 4 re-estimates catchability iteratively, using the 2009 procedure.

Parameters Estimated Inside the Assessment Model

Parameters estimated inside SS for all models include the von Bertalanffy growth parameters, standard deviation of length at ages 1 and 20, log mean recruitment since the 1976-1977 regime shift, offset for log-scale mean recruitment prior to the 1976-1977 regime shift, *dev*s for log-scale initial (i.e., 1977) abundance at ages 1 through 3, annual log-scale recruitment *dev*s for 1977-2011, base values for all survey selectivity parameters, and annual *dev*s for the *ascending_width* parameter of the survey selectivity function. (It should be noted that annual *dev*s for the *ascending_width* parameter were not included in Model 4 when it was developed in the preliminary assessment (Attachment 2.1, where it was labeled "Model 5"), because these *dev*s were "tuned out" during the iterative estimation phase of the algorithm described in Annex 2.1.1.)

Ageing bias at ages 1 and 20 is estimated in Models 1, 2, and 4 only.

Log-scale survey catchability is estimated internally in Model 2 only.

Initial (equilibrium) fishing mortality for the Jan-Apr trawl fishery is estimated internally for Models 1-3, and initial (equilibrium) fishing mortality for the Jan-Feb fishery (not stratified by gear) is estimated internally for Model 4.

Gear-season-and-block-specific selectivity parameters are estimated for nine super-season × gear fisheries in Models 1-3. Time-invariant selectivity parameters are estimated for five seasonal fisheries in Model 4.

A fourth ("Richards") growth parameter, the standard deviation of log-scale recruitment *dev*s, *dev*s for log-scale initial (i.e., 1977) abundance at ages 4 through 10, and annual *dev*s for the *initial_selectivity* parameter of the survey selectivity schedule are estimated for Model 4 only.

Fishery selectivities are length-based in all models. Trawl survey selectivity is age-based in Models 1-3 and length-based in Model 4.

Uniform prior distributions are used for all parameters, except that *dev* vectors are constrained by input standard deviations (“sigma”), which are somewhat analogous to a joint prior distribution.

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 (just year- and season-specfic in the case of Model 4) are also estimated internally, 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 four models include likelihood components for initial (equilibrium) catch, trawl survey relative abundance, fishery and survey size composition, survey age composition, recruitment, “softbounds” (equivalent to an extremely weak prior distribution used to keep parameters from hitting bounds), and parameter deviations.

In SS, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in previous assessments, likelihood components were given an emphasis of 1.0 in the present assessment, except that the age composition component was given zero emphasis in Model 3.

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 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 EBS 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 assessment used the harmonic means from a bootstrap analysis of the available fishery length data from 1990-2006 (Thompson et al. 2007b). 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 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 assessment was based on an observed consistency in the ratios between the harmonic means (the raw harmonic means, not the rescaled harmonic means) and the actual sample sizes. For the years prior to 1999, the ratio was very consistently close to 0.16, and for the years after 1998, the ratio was very consistently close to 0.34.

This consistency was used to specify the missing values as follows: For fishery data, the sample sizes for length compositions from years prior to 1999 were tentatively set at 16% of the actual sample size, and the sample sizes for length compositions from 2007 were tentatively set at 34% of the actual sample size. For the pre-1982 trawl survey, length compositions were tentatively set at 16% of an assumed sample size of 10,000. For the post-1981 trawl survey length compositions, sample sizes were tentatively set at 34% of the actual sample size. Then, with sample sizes for fishery length compositions from 1990-2007 tentatively set at their bootstrap harmonic means (not rescaled), all sample sizes were adjusted proportionally so that the average was 300.

The same procedure was used in the 2008 and 2009 assessments. For the 2010 assessment, however, this procedure had to be modified somewhat, because the bootstrap values for the 1990-2006 size composition data did not match the new bin and seasonal structures. To be as consistent as possible with the approach used to set sample sizes in the 2008 and 2009 assessments, the 2010 and 2011 assessments set sample sizes by applying the 16/34% rule for *all* size composition records (not just those lying outside the set of 1990-2006 fishery data), then rescaling proportionally to achieve an average sample size of 300. The same procedure was used for all models in the present assessment, except that the pre-1982 trawl survey data are no longer used. Input sample sizes for all size composition records are shown in Tables 2.12a (Models 1-3) and 2.12b (Model 4).

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 (Table 2.9, column 2) proportionally such that the average of the input sample sizes was equal to 300, giving the following:

Year:	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
N:	208	174	207	209	184	250	251	276	275	395	302	372	378

Year:	2007	2008	2009	2010	2011
N:	419	352	410	375	364

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 likelihood component for recruitment is different from traditional likelihoods because it does not involve "data" in the same sense that traditional likelihoods do. Instead, the log-scale recruitment *dev* plays the role of the datum in a normal distribution with mean zero and specified (or estimated) standard deviation; but, of course, the *dev*s are parameters, not data.

RESULTS

Model Evaluation

The four models included in this assessment are described above under “Analytic Approach,” “Model Structure,” “Model Structures Considered in This Year’s Assessment.”

Comparing and Contrasting the Models

Table 2.13 shows numbers of parameters and negative log-likelihoods for each of the models. It should be emphasized that, although the negative log-likelihood values for the models are displayed next to one another, except for Models 1 and 2 they are not strictly comparable, because the data sets for Models 1-2, 3, and 4 are all different. The first part of Table 2.13 shows the number of parameters for each model, which range from a low of 143 for Model 4 to a high of 185 for Model 2. The second part shows negative log-likelihoods for the aggregate data components. The value for the age composition component is shaded under Model 3, because this value does not count toward the total for Model 3. The third and fourth parts of the table break down the CPUE and size composition components into fleet-specific values. For the CPUE component, the fishery values under Models 1-3 are shown for completeness, but they are shaded to indicate that they do not count toward the respective totals. Model 4 did not include fishery CPUE in the data set.

Tables 2.14 and 2.15 provide alternative measures of how well the models are fitting the fishery CPUE and survey relative abundance data. Table 2.14 shows root mean squared errors (lower values are better) and correlations between observed and estimated values (higher values are better). The most important parts of this table are the rows for the shelf trawl survey, where all five models give an RMSE between 0.19 and 0.26 and a correlation between 0.65 and 0.77. Although none of the models actually attempts to fit the fishery CPUE data (only the survey CPUE are used), of the 27 correlations with fishery CPUE data (9 fleets × 3 models), all but 5 are positive. Table 2.15 shows the means and standard deviations of the normalized residuals. For the shelf trawl survey, all models have a positive value for mean normalized residual (ranging from 0.16 to 0.97), and the standard deviations tend to be quite a bit larger than unity (ranging from 1.78 to 2.17).

Figure 2.4 shows the fits of the four models to the trawl survey abundance data. The four models’ estimates fall within the 95% confidence intervals between 74% and 77% of the time.

Table 2.16 shows the mean of the ratios 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 fitting these data (higher values are better, all else being equal). All four models give mean ratios much greater than unity. Between Models 1-3, Model 3 tends to give the highest mean ratios (Model 4 is hard to compare to Models 1-3, because the fisheries are defined differently). However, as with the likelihood table, such comparisons are problematic, because different data sets are used for the different models. For example, Model 3 does not attempt to fit the age composition data, so it might be expected to do a better job of fitting the size composition data than the other models.

Table 2.17 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 (all age composition data come from the survey). The bottom row shows the overall mean of the ratios. Model 4 gives an overall ratio of approximately 1.0, which is one of the defining features of that model. Models 1-2 give overall ratios in the 0.78-0.86 range, while Model 3, which does not attempt to fit the age composition data, gives an overall ratio of 0.22.

The models' fits to the age composition data are shown in Figure 2.5 (four pages, one for each model). Estimates of mean sizes at age 1 (at the time of the survey) from each model are compared to the long-term average survey size composition (through 50 cm) in Figure 2.6. All models tend to undershoot the first two modes, but only by about 1 cm (or 2 cm in the case of Model 4's estimate of mean length at age 2). The fits to the mean-size-at-age data for Models 1-3 are shown in Figure 2.7 (recall that none of the models actually attempt to fit these data, and Model 4 does not even include these data).

Table 2.18 displays all of the parameters (except fishing mortality rates) estimated internally in any of the models. Table 2.18a shows growth, ageing bias, recruitment (except annual *dev*s), catchability, initial fishing mortality, and initial age composition parameters as estimated internally by at least one of the assessment models. Table 2.18b shows annual log-scale recruitment *dev*s, Table 2.18c shows fishery selectivity parameters as estimated by Models 1-3, Table 2.18d shows fishery selectivity parameters as estimated by Model 4, Table 2.18e shows survey selectivity parameters as estimated by Models 1-3, and Table 2.18f shows survey selectivity parameters as estimated by Model 4.

Table 2.19 (five pages, one for each model) show estimates of full-selection fishing mortality rates (note that these are not counted as parameters in SS, and so do not have estimated standard deviations).

Figure 2.8 shows the time series of log recruitment *dev*s as estimated by the four models. All models show a high degree of synchrony throughout the time series.

Figure 2.9 shows the time series of spawning biomass relative to $B_{100\%}$ as estimated by the four models. Qualitatively, all models exhibit approximately the same trend. The time series estimated by Model 2 tends to be lower than those estimated by the other models except for the years 1996-2004, where the time series estimated by Model 4 is lower than that estimated by Model 2.

Figure 2.10 shows the time series of total (age 0+) biomass as estimated by the four models, with the trawl survey biomass estimates included for comparison. All four models estimate a higher total biomass than the survey in nearly all years. The average ratio of model biomass to survey biomass ranges from 1.41 (Model 2) to 2.08 (Model 4). Given that the post-1981 catchability coefficient is fixed at 0.77 for all models, estimation of a higher biomass (on average) than observed by the survey is expected.

Figure 2.11 shows trawl survey selectivity as estimated by the four models (recall that Models 1-3 assume age-based selectivity for the survey, whereas Model 4 assumes length-based selectivity). The overall shapes are similar for the four models, although the variability of the ascending limb in Model 4, as would be expected given: 1) both *initial_selectivity* and *ascending_width* are allowed to vary in Model 4, whereas only *ascending_width* is allowed to vary in Models 1-3; and 2) the "sigma" parameters governing the degree of variability in the selectivity *dev*s for Model 4 are 2.21 and 1.28, respectively, whereas the single "sigma" parameter in Models 1-4 is 0.07.

Figure 2.12 (four pages, one for each model) shows fishery selectivity as estimated by all four models. Visually, there does not appear to be a great deal of difference between the curves estimated by Models 1-3. Fishery selectivities estimated by Model 4 are not comparable to those estimated by Models 1-3, because the fisheries are defined differently. In general, selectivities that are not forced to be asymptotic tend to show decreasing selectivity at large size.

Because the catchability coefficient for the trawl survey was held constant for all models at the value estimated in the 2009 assessment (0.77), it may be wondered how well this value continues to achieve the intended result of matching the value of 0.47 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 of the post-1981 survey (i.e., 1982-2011), which resulted in the following statistics:

Statistic	Model 1	Model 2	Model 3	Model 4
Average:	0.54	0.77	0.48	0.47
Minimum:	0.45	0.67	0.38	0.44
Maximum:	0.61	0.85	0.58	0.50
Standard deviation:	0.04	0.04	0.05	0.02
Coefficient of variation:	0.08	0.06	0.10	0.03

Models 3 and 4 either match or almost match the target value exactly, Model 1 is high by 0.07, and Model 2 is high by 0.30. The range bracketed by Model 1 includes the target value, but the range bracketed by Model 2 does not.

Table 2.20 contains selected output from the standard projection model, based on SS parameter estimates from the four assessment models, along with the probability that the maximum permissible ABC in each of the next two years will exceed the corresponding true-but-unknown OFL and the probability that the stock will fall below $B_{20\%}$ in each of the next five years (probabilities are given by SS rather than the standard projection model). Recruitments, numbers at age, and biomasses have been divided by the conversion factor of 0.93 described in the "Aleutian Bottom Trawl Survey" subsection, so as to represent quantities relevant to the entire BSAI management region, rather than the EBS area on the basis of which the models are configured. With the exceptions of the probability of exceeding the true-but-unknown OFL in 2013 and 2014, Model 2 produces the lowest values of all reference points shown and Model 4 produces the highest.

All models converged successfully and the Hessian matrices from all models were positive definite. Once each model appeared to have converged, a set of (typically 50) "jitter" runs were made 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 until such time as no further improvement was obtained. No model was considered final until a set of 50 jitter runs failed to find a better value of the objective function.

In the table below, the row labeled "Success" shows the proportion of jitters that ran successfully (i.e., that returned a numeric value for the objective function). The row labeled "Match" shows the proportion of successful jitters that matched the final version. The two rows labeled "-lnL 'RMSE'" show a statistic for the objective function that is similar to a root-mean-squared-error, but in which the squared difference is taken with respect to the *minimum* value (across jitters) rather than the *mean*; this statistic is reported in units of log-likelihood. Finally, the two rows labeled "SB2012 'CV'" show a statistic for 2012 spawning biomass that is similar to a coefficient of variation, but in which (as with the preceding statistic) the mean is replaced by the value corresponding to the final (i.e., best case) version of the model. The label "first 25 jitters" in Performance measures #3 and #5 refers to the first 25 jitters *after sorting* in order from lowest to highest objective function value. Color scale in the table extends from red (minimum) to green (maximum).

Performance Measure	Model 1	Model 2	Model 3	Model 4
Success	1.000	1.000	1.000	0.800
Match	0.520	0.420	0.360	0.525
-lnL "RMSE" (first 25 jitters)	0.000	0.028	0.116	0.089
-lnL "RMSE" (all 50 jitters)	131.808	1894.643	91.652	3211.854
SB2012 "CV" (first 25 jitters)	0.000	0.000	0.002	0.005
SB2012 "CV" (all 50 jitters)	0.033	0.478	0.050	0.043

Models 1-3 all had a perfect success rate, while Model 4 had a success rate of 0.80. "Match" rates ranged from 0.420 (Model 2) to 0.525 (Model 4). In terms of the final four performance measures, Model 1 tended to perform the best, although Models 2 and 3 each performed at least as well as Model 1 for one of the performance measures. All four models exhibited very low relative variability for SB2012 in the first 25 (sorted) jitters.

Figure 2.13 sorts the jitter runs for each model in order of decreasing log likelihood, and shows how the running (cumulative) value of –lnL "RMSE" changes with each additional (sorted) jitter run. This figure is included to address previous Plan Teams concerns that the reported value of –lnL "RMSE" may be due to a small number of outliers.

Evaluation Criteria

The following criteria were considered in selecting the final model:

1. Would selection of the model be consistent with current Plan Team recommendations?
2. Has the model been sufficiently tested?

Selection of Final Model

The four models can be evaluated by the above criteria as follows:

1. The September 2012 Plan Team minutes indicate that Models 2 and 3 "are not candidates for the specifications," and are to be included in the final assessment only as "a useful check on the candidate models" (i.e., Models 1 and 4). This would seem to rule out Models 2 and 3. Moreover, the Plan Team expressed support for tuning survey catchability so as to approximate the results of Nichol et al. (2007): "For the time being we favor continuing to tune survey catchability in this fashion in order to limit the variability of abundance estimates…. We have discussed this issue at length in the past and for now do not see a strong reason to abandon this tuning mechanism, which is extremely valuable for stabilizing the abundance estimates." This confirms that choosing Model 2 would be inconsistent with the Plan Team's current understanding of the best available science.
2. Models 1 and 3 are identical to models that have been reviewed through two assessment cycles (counting the present cycle), and can reasonably be viewed as incremental steps in the long-term evolution of the EBS Pacific cod stock assessment. Model 2 constitutes a fairly significant departure from the accepted practice (over the last few years) for tuning survey catchability; on the other hand, perhaps one full assessment cycle is sufficient to test this single change. In contrast to Models 1-3, Model 4 includes 15 changes from last year's accepted model, several of which are major. One of the changes associated with Model 4 that bears further investigation is the sensitivity of the estimated "sigma" parameters governing selectivity *dev*s. As noted above in "Parameters Estimated Inside the Assessment Model," annual *dev*s for the *ascending_width* parameter of the survey selectivity schedule were "tuned out" when Model 4 was developed

during the preliminary assessment (where it was labeled “Model 5”), but not in the final assessment. While it is possible to imagine circumstances under which making such a large number of changes would be advisable within a single assessment cycle, the results of Model 4 do not indicate that immediate adoption of that model is necessary.

On the basis of the above, Model 1 is selected as the final model.

Final Parameter Estimates and Associated Schedules

As noted previously, estimates of all statistically estimated parameters in Model 1 are shown in Table 2.18. Estimates of year-, gear-, and season-specific fishing mortality rates from Model 1 are shown in Table 2.19a.

Schedules of selectivity at length for the commercial fisheries from Model 1 are shown in Table 2.21, and schedules of selectivity at age for the trawl surveys from Model 1 are shown in Table 2.22. The trawl survey selectivity schedule and all fishery selectivity schedules for Model 1 are plotted in Figures 2.11 and 2.12a, 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 1 are shown in Tables 2.23, and 2.24, and 2.25, respectively.

Time Series Results

Definitions

The biomass estimates presented here will be defined in three ways: 1) age 0+ biomass, consisting of the biomass of all fish aged 0 years or greater in January of a given year; 2) age 3+ biomass, consisting of the biomass of all fish aged 3 years or greater in January of a given year; and 3) 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 2.19a, an alternative “effective” fishing mortality rate will be provided here, defined for each age and time as $-\ln(N_{a+1,t+1}/N_{a,t})-M$, 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 2.26 shows the time series of EBS (not expanded to BSAI) Pacific cod age 0+, age 3+, and female spawning biomass for the years 1977-2013 as estimated last year and this year under Model 1. These biomass estimates can be expanded to BSAI equivalents by dividing by 0.93, as described under “Data,” “Survey,” “Aleutian Bottom Trawl Survey.” The estimated spawning biomass time series are accompanied by their respective standard deviations.

The estimated time series of EBS age 0+ biomass and female spawning biomass from Model 1 are shown, together with the observed time series of trawl survey biomass, in Figure 2.14. Confidence intervals are shown for the model estimates of female spawning biomass and for the trawl survey biomass estimates.

The SSC and Plan Teams have requested that a 10-year retrospective analysis of the final model be conducted, using spawning biomass and relative changes in spawning biomass as the performance measures (see Comments SSC1, JPT2, and SSC2 in the Executive Summary). Figure 2.15 is included to satisfy this request. Figure 2.15a plots retrospective spawning biomass in absolute terms, while Figure 2.15b plots the same results in terms of proportional changes relative to the terminal (2012) run. With the exception of the one-year retrospective run (labeled “2011”), these figures indicate a positive retrospective bias (i.e., initial estimates of spawning biomass tend to be high relative to later estimates as new data are added). Whether this outcome is dependent on the particular time series of data used in this analysis or is a general feature of Model 1 is unknown.

Recruitment and Numbers at Age

Table 2.27 shows the time series of EBS (not expanded to BSAI) Pacific cod age 0 recruitment (1000s of fish) for the years 1977-2011 as estimated last year and this year under Model 1. 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. Based on current estimates, the six most recent year classes include four of the top nine year classes of all time (2006, 2008, 2010, and 2011). However, it should be emphasized that the estimate of the 2011 year class is based entirely on the 2012 survey.

Model 1’s recruitment estimates for the entire time series (1977-2011) are shown in Figure 2.16, along with their respective 95% confidence intervals.

To date, it has not been possible to estimate a reliable stock-recruitment relationship for this stock. A possible (and very preliminary) relationship between recruitment and an environmental index is discussed under “Ecosystem Considerations,” “Ecosystem Effects on the Stock.”

The time series of numbers at age as estimated by Model 1 is shown in Table 2.28.

Fishing Mortality

Table 2.29 shows “effective” fishing mortality by age and year for ages 1-19 and years 1977-2011 as estimated by Model 1.

Figure 2.17 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2012 based on Model 1, 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). Nearly the entire trajectory lies underneath the $maxF_{ABC}$ control rule. It should be noted that this trajectory is based on SS output, which may not match the estimates obtained by the standard projection program exactly.

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the BSAI 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 BSAI have generally been managed under Tier 3 of Amendment 56. 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 1:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
BSAI:	314,000 t	358,000 t	896,000 t
EBS:	292,000 t	333,000 t	833,000 t

For a stock exploited by multiple gear types, estimation of $F_{35\%}$ and $F_{40\%}$ requires an assumption regarding the apportionment of fishing mortality among those gear types. For this assessment, the apportionment was based on Model 1's estimates of fishing mortality by gear for the five most recent complete years of data (2007-2011). 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 25.9%, longline 60.5%, and pot 13.6%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.34 and 0.29, respectively.

Specification of OFL and Maximum Permissible ABC

BSAI female spawning biomass for 2013 is estimated by Model 1 at a value of 422,000 t. This is about 7% above the BSAI $B_{40\%}$ value of 358,000 t, thereby placing Pacific cod in sub-tier "a" of Tier 3. Given this, Model 1 estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2013 and 2014 as follows (2014 values are predicated on the assumption that 2013 catch will equal 2013 maximum permissible ABC; catches are for the entire BSAI):

Year	Overfishing Level	Maximum Permissible ABC
2013	Catch = 359,000 t	Catch = 307,000 t
2014	Catch = 379,000 t	Catch = 323,000 t
2013	$F = 0.34$	$F = 0.29$
2014	$F = 0.34$	$F = 0.29$

The age 0+ biomass BSAI projections for 2013 and 2014 from Model 1 (using SS) are 1,600,000 t and 1,710,000 t.

For comparison, the age 3+ BSAI projections for 2013 and 2014 from Model 1 (using SS) are 1,510,000 t and 1,670,000 t.

ABC Recommendation

Since 2005, the SSC has set ABC at the maximum permissible level every year with the exception of the 2007 assessment cycle, when the SSC held the 2008-2009 ABCs constant at the 2007 level. Specifications for 2006-2011 were set under Tier 3b, and specifications for 2012-2013 were set under Tier 3a.

In the present assessment, spawning biomass is estimated to be well above $B_{40\%}$, and is projected to increase further. These increases are fueled largely by the 2006, 2008, and 2010 year classes, whose strengths have now been confirmed by multiple surveys. In addition, the 2011 year class also appears to be very strong, although this estimate must be regarded as highly preliminary.

Based on the precedents of the last several years and the evidence of multiple strong year classes in the population, the maximum permissible values of 307,000 t and 323,000 t are the recommended ABCs for 2013 and 2014, respectively.

At the same time, a couple of concerns should be noted:

1. The estimate of survey catchability upon which these projections depend is based on an extremely small sample size (Nichol et al. 2007), implying that there is considerable uncertainty surrounding the point estimate. When catchability was estimated freely in Model 2, the estimate went up substantially, and the maximum permissible ABC for 2013 dropped by 47%. Nevertheless, the catchability estimate assumed in Model 1 has been subjected to multiple peer reviews and remains the best scientific information available.
2. The retrospective analysis shown in Figure 2.15 indicates that Model 1, if it had been used without modification throughout the last decade, would very consistently have tended to project overly optimistic levels of spawning biomass. However, it is not clear whether this is an inherent characteristic of the model or is simply due to unique features of the data time series from the last decade.

An alternative ABC based on inclusion of removals other than those made by fisheries prosecuted under the BSAI Groundfish FMP is provided in Attachment 2.4. However, this alternative is provided for purposes of comparison only.

Area Allocation of Harvests

At present, ABC of BSAI Pacific cod is not allocated by area. However, the Council is presently considering the possibility of specifying separate harvests in the EBS and AI. An age-structured assessment of the AI stock is presented here as Attachment 2.2, for purposes of evaluation only.

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 2013 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 are sometimes 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 2013 and 2014, 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 2013 recommended in the assessment to the *max* F_{ABC} for 2012. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)
>
> *Scenario 3*: In all future years, F is set equal to the 2007-2011 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 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 1) above its MSY level in 2012 or 2) above 1/2 of its MSY level in 2012 and expected to be above its MSY level in 2022 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2013 and 2014, 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 2025 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 1 in Tables 2.30-2.35 (note that Scenarios 1 and 2 are identical in this case, 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 2012, it does not provide the best estimate of OFL for 2013, because the mean 2013 catch under Scenario 6 is predicated on the 2012 catch being equal to the 2012 OFL, whereas the actual 2012 catch will likely be less than the 2012 OFL. Table 2.20 contains the appropriate one- and two-year ahead projections for both ABC and OFL under any of the four 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 (2011) is 220,134 t. This is less than the 2011 OFL of 272,000 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 2012:

a. If spawning biomass for 2012 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2012 is estimated to be above $B_{35\%}$, the stock is above its MSST.
c. If spawning biomass for 2012 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 2.34). If the mean spawning biomass for 2022 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 (Table 2.35):

a. If the mean spawning biomass for 2015 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2015 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2015 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2025. If the mean spawning biomass for 2025 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 2.34 and 2.35, the stock is not overfished and is not approaching an overfished condition.

ECOSYSTEM CONSIDERATIONS

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 (Zador, 2011). 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 mean recruitment of EBS Pacific cod associated with the 1977 regime shift. According to Model 1, pre-1977 mean recruitment was only about 30% of post-1976 mean recruitment. Establishing a link between environment and recruitment within a particular regime is more difficult. In the 2004 assessment (Thompson and Dorn 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.

For this year's assessment, annual log-scale recruitment *dev*s estimated by Model 1 were regressed against each of several environmental indices summarized by Zador (2011). The highest univariate correlation was obtained for the spring-summer North Pacific Index (NPI), which was developed by Trenberth and Hurrell (1994). The NPI is the area-weighted sea level pressure over the region 30°N-65°N, 160°E-140°W. Further investigations were conducted with monthly NPI data from the Climate Analysis Section of the National Center for Atmospheric Research. The best univariate model obtained so far is a linear regression of recruitment *dev*s from 1977-2011 against the October-December average NPI (from the same year), which gives a correlation of 0.52. The data, regression line, and 95% confidence intervals are shown in Figure 2.18.

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.

Incidental Catch Taken in the Pacific Cod Fisheries

Incidental catches taken in the Pacific cod fisheries for the period 2003-2012 are summarized in Tables 2.36-2.40. Table 2.36a shows incidental catch of FMP species, other than squid and members of the former "other species" complex, taken in the EBS. Table 2.37a shows incidental catch of squid and members of the former "other species" complex taken in the EBS. Table 2.38a shows incidental catch of non-target species groups taken in the EBS. Table 2.38b shows analogous data for the AI. Table 2.39a shows incidental catches of prohibited species taken in the EBS. Tables 2.36b, 2.37b, 2.38b, and 2.39b show analogous data for the AI. Table 2.40 shows halibut mortality (as distinguished from catch).

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 2.33b and 2.36b). 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

Significant improvements in the quality of this assessment could be made 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.

ACKNOWLEDGMENTS

Chris Johnston and Delsa Anderl provided age data. Camille Kohler, Ingrid Spies, Olav Ormseth, and Jason Gasper provided catch data. Angie Greig provided fishery size composition data and fishery CPUE data and produced Figures 2.1 and 2.2. Mary Furuness provided text of current regulations. Rick Methot developed the SS software used to conduct this assessment, and answered numerous questions about SS. Anne Hollowed and the BSAI Groundfish Plan Team provided reviews of this assessment. Many NMFS survey personnel and countless fishery observers collected most of the raw data that were used in this assessment.

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Table 2.1a—Summary of 1964-1980 catches (t) of Pacific cod in the BSAI by area and fleet sector. “For.” = foreign, “JV” = joint venture processing, “Dom.” = domestic annual processing. Catches by gear are not available for these years. Catches may not always include discards.

	Bering Sea				Aleutian Islands				Bering Sea and Aleutians			
Year	For.	JV	Dom.	Subt.	For.	JV	Dom.	Subt.	For.	JV	Dom.	Total
1964	13408	0	0	13408	241	0	0	241	13649	0	0	13649
1965	14719	0	0	14719	451	0	0	451	15170	0	0	15170
1966	18200	0	0	18200	154	0	0	154	18354	0	0	18354
1967	32064	0	0	32064	293	0	0	293	32357	0	0	32357
1968	57902	0	0	57902	289	0	0	289	58191	0	0	58191
1969	50351	0	0	50351	220	0	0	220	50571	0	0	50571
1970	70094	0	0	70094	283	0	0	283	70377	0	0	70377
1971	43054	0	0	43054	2078	0	0	2078	45132	0	0	45132
1972	42905	0	0	42905	435	0	0	435	43340	0	0	43340
1973	53386	0	0	53386	977	0	0	977	54363	0	0	54363
1974	62462	0	0	62462	1379	0	0	1379	63841	0	0	63841
1975	51551	0	0	51551	2838	0	0	2838	54389	0	0	54389
1976	50481	0	0	50481	4190	0	0	4190	54671	0	0	54671
1977	33335	0	0	33335	3262	0	0	3262	36597	0	0	36597
1978	42512	0	31	42543	3295	0	0	3295	45807	0	31	45838
1979	32981	0	780	33761	5593	0	0	5593	38574	0	780	39354
1980	35058	8370	2433	45861	5788	0	0	5788	40846	8370	2433	51649

Table 2.1b—Summary of 1981-1990 catches (t) of Pacific cod in the BSAI by area, fleet sector, and gear type. All catches include discards. “LLine” = longline, “Subt.” = sector subtotal. Breakdown of domestic annual processing by gear is not available prior to 1988. Longline and pot gear have been combined in the AI (“LL+pot”).

Bering Sea only:

	Foreign			Joint Venture		Domestic Annual Processing				
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Subt.	Total
1981	30347	5851	36198	7410	7410	n/a	n/a	n/a	12899	56507
1982	23037	3142	26179	9312	9312	n/a	n/a	n/a	25613	61104
1983	32790	6445	39235	9662	9662	n/a	n/a	n/a	45904	94801
1984	30592	26642	57234	24382	24382	n/a	n/a	n/a	43487	125103
1985	19596	36742	56338	35634	35634	n/a	n/a	n/a	51475	143447
1986	13292	26563	39855	57827	57827	n/a	n/a	n/a	37923	135605
1987	7718	47028	54746	47722	47722	n/a	n/a	n/a	47435	149903
1988	0	0	0	106592	106592	93706	2474	299	96479	203071
1989	0	0	0	44612	44612	119631	13935	145	133711	178323
1990	0	0	0	8078	8078	115493	47114	1382	163989	172067

Aleutian Islands only:

	Foreign			Joint Venture		Domestic Annual Processing			
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LL+pot	Subt.	Total
1981	2680	235	2915	1749	1749	n/a	n/a	2770	7434
1982	1520	476	1996	4280	4280	n/a	n/a	2121	8397
1983	1869	402	2271	4700	4700	n/a	n/a	1459	8430
1984	473	804	1277	6390	6390	n/a	n/a	314	7981
1985	10	829	839	5638	5638	n/a	n/a	460	6937
1986	5	0	5	6115	6115	n/a	n/a	786	6906
1987	0	0	0	10435	10435	n/a	n/a	2772	13207
1988	0	0	0	3300	3300	1698	167	1865	5165
1989	0	0	0	6	6	4233	303	4536	4542
1990	0	0	0	0	0	6932	609	7541	7541

Bering Sea and Aleutian Islands:

	Foreign			Joint Venture		Domestic Annual Processing			
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LL+pot	Subt.	Total
1981	33027	6086	39113	9159	9159	n/a	n/a	15669	63941
1982	24557	3618	28175	13592	13592	n/a	n/a	27734	69501
1983	34659	6847	41506	14362	14362	n/a	n/a	47363	103231
1984	31065	27446	58511	30772	30772	n/a	n/a	43801	133084
1985	19606	37571	57177	41272	41272	n/a	n/a	51935	150384
1986	13297	26563	39860	63942	63942	n/a	n/a	38709	142511
1987	7718	47028	54746	58157	58157	n/a	n/a	50207	163110
1988	0	0	0	109892	109892	95404	2940	98344	208236
1989	0	0	0	44618	44618	123864	14383	138247	182865
1990	0	0	0	8078	8078	122425	49105	171530	179608

Table 2.1c—Summary of 1991-2012 catches (t) of Pacific cod in the BSAI. The small catches taken by "other" gear types have been merged proportionally with the catches of the gear types shown. Catches for 2012 are through September 29.

	Bering Sea				Aleutian Islands					
	Federal				Federal			State	AI	BSAI
Year	Trawl	Longline	Pot	Subtotal	Trawl	Long.+pot	Subtotal	Subtotal	Total	Total
1991	129,393	77,505	3,343	210,241	3,414	6,383	9,798		9,798	220,038
1992	77,276	79,420	7,514	164,210	14,587	28,481	43,068		43,068	207,278
1993	81,792	49,296	2,098	133,186	17,328	16,876	34,205		34,205	167,391
1994	85,294	78,898	8,071	172,263	14,383	7,156	21,539		21,539	193,802
1995	111,250	97,923	19,326	228,498	10,574	5,960	16,534		16,534	245,033
1996	92,029	88,996	28,042	209,067	21,179	10,430	31,609		31,609	240,676
1997	93,995	117,097	21,509	232,601	17,411	7,753	25,164		25,164	257,765
1998	60,855	84,426	13,249	158,529	20,531	14,196	34,726		34,726	193,256
1999	51,939	81,520	12,408	145,867	16,478	11,653	28,130		28,130	173,998
2000	53,841	81,678	15,856	151,376	20,379	19,306	39,685		39,685	191,060
2001	35,670	90,394	16,478	142,542	15,836	18,372	34,207		34,207	176,749
2002	51,118	100,371	15,067	166,555	27,929	2,872	30,801		30,801	197,356
2003	47,758	108,774	21,978	178,511	31,478	980	32,459		32,459	210,969
2004	57,867	108,157	17,264	183,288	25,770	3,103	28,873		28,873	212,161
2005	52,638	113,184	17,114	182,936	19,624	3,075	22,699		22,699	205,635
2006	53,235	96,606	18,966	168,806	16,963	3,530	20,493	3,717	24,210	193,017
2007	45,700	77,148	17,232	140,079	25,721	4,495	30,216	3,829	34,045	174,124
2008	33,497	88,928	17,368	139,794	19,405	7,192	26,597	4,462	31,059	170,853
2009	36,959	96,606	13,587	147,152	20,284	6,222	26,507	2,074	28,580	175,732
2010	41,297	81,852	19,702	142,852	16,757	8,365	25,122	3,878	29,000	171,851
2011	64,085	117,129	28,058	209,272	9,379	1,242	10,621	241	10,862	220,134
2012	70,837	97,851	25,960	194,647	9,516	2,777	12,294	5,229	17,523	212,170

Table 2.2—Discards (t) of Pacific cod in the Pacific cod fishery, by area, gear, and year for the period 1991-2012. The small amounts of discards taken by other gear types have been merged proportionally into the gear types shown. Discards from longline and pot gear in the AI have been combined to preserve confidentiality. Note that Amendment 49, which mandated increased retention and utilization, was implemented in 1998.

	Bering Sea				Aleutian Islands			BSAI
Year	Trawl	Longline	Pot	Subtotal	Trawl	Long.+pot	Subtotal	Total
1991	15,216	1,543	10	16,770	293	233	526	17,296
1992	21,405	1,970	59	23,435	1,781	455	2,236	25,670
1993	28,898	2,258	25	31,182	3,693	2,196	5,889	37,070
1994	26,282	2,923	168	29,373	3,263	221	3,484	32,857
1995	35,689	4,100	222	40,011	1,872	1,308	3,180	43,191
1996	22,376	2,899	394	25,669	2,566	571	3,137	28,806
1997	16,556	3,218	79	19,853	1,438	669	2,107	21,960
1998	962	2,487	52	3,501	154	484	638	4,139
1999	1,677	1,322	52	3,051	287	226	514	3,565
2000	883	2,310	72	3,265	168	524	692	3,957
2001	861	1,539	52	2,452	219	252	471	2,923
2002	1,317	2,159	97	3,573	585	148	734	4,307
2003	827	1,789	176	2,791	247	87	334	3,126
2004	545	1,823	49	2,417	223	94	317	2,733
2005	455	2,663	64	3,182	237	258	494	3,677
2006	813	1,544	63	2,420	152	158	310	2,730
2007	588	1,385	31	2,004	410	142	553	2,557
2008	493	1,362	157	2,011	33	171	204	2,215
2009	534	1,503	16	2,053	92	116	208	2,261
2010	1,305	1,413	19	2,737	47	158	205	2,942
2011	487	1,853	34	2,374	51	29	80	2,455
2012	954	1,276	52	2,282	41	70	111	2,393

Table 2.3—History of BSAI Pacific cod catch, TAC, ABC, and OFL (t). Catch for 2012 is through September 29. Source for historical specifications: NPFMC staff.

Year	Catch	TAC	ABC	OFL
1977	36,597	58,000	-	-
1978	45,838	70,500	-	-
1979	39,354	70,500	-	-
1980	51,649	70,700	148,000	-
1981	63,941	78,700	160,000	-
1982	69,501	78,700	168,000	-
1983	103,231	120,000	298,200	-
1984	133,084	210,000	291,300	-
1985	150,384	220,000	347,400	-
1986	142,511	229,000	249,300	-
1987	163,110	280,000	400,000	-
1988	208,236	200,000	385,300	-
1989	182,865	230,681	370,600	-
1990	179,608	227,000	417,000	-
1991	220,038	229,000	229,000	-
1992	207,278	182,000	182,000	188,000
1993	167,391	164,500	164,500	192,000
1994	193,802	191,000	191,000	228,000
1995	245,033	250,000	328,000	390,000
1996	240,676	270,000	305,000	420,000
1997	257,765	270,000	306,000	418,000
1998	193,256	210,000	210,000	336,000
1999	173,998	177,000	177,000	264,000
2000	191,060	193,000	193,000	240,000
2001	176,749	188,000	188,000	248,000
2002	197,356	200,000	223,000	294,000
2003	210,969	207,500	223,000	324,000
2004	212,161	215,500	223,000	350,000
2005	205,635	206,000	206,000	265,000
2006	193,017	194,000	194,000	230,000
2007	174,124	170,720	176,000	207,000
2008	170,853	170,720	176,000	207,000
2009	175,732	176,540	182,000	212,000
2010	171,851	168,780	174,000	205,000
2011	220,134	227,950	235,000	272,000
2012	212,170	261,000	314,000	369,000

Table 2.4—Amendments to the BSAI Fishery Management Plan (FMP) that reference Pacific cod explicitly (excerpted from Appendix A of the FMP).

Amendment 2, implemented January 12, 1982:

For Pacific cod, decreased maximum sustainable yield to 55,000 t from 58,700 t, increased equilibrium yield to 160,000 t from 58,700 t, increased acceptable biological catch to 160,000 t from 58,700 t, increased optimum yield to 78,700 t from 58,700 t, increased reserves to 3,935 t from 2,935 t, increased domestic annual processing (DAP) to 26,000 t from 7,000 t, and increased DAH to 43,265 t from 24,265 t.

Amendment 4, implemented May 9, 1983, supersedes Amendment 2:

For Pacific Cod, increased equilibrium yield and acceptable biological catch to 168,000 t from 160,000 t, increased optimum yield to 120,000 t from 78,700 t, increased reserves to 6,000 t from 3,935 t, and increased TALFF to 70,735 t from 31,500 t.

Amendment 10, implemented March 16, 1987:

Established Bycatch Limitation Zones for domestic and foreign fisheries for yellowfin sole and other flatfish (including rock sole); an area closed to all trawling within Zone 1; red king crab, C. bairdi Tanner crab, and Pacific halibut PSC limits for DAH yellowfin sole and other flatfish fisheries; a C. bairdi PSC limit for foreign fisheries; and a red king crab PSC limit and scientific data collection requirement for U.S. vessels fishing for Pacific cod in Zone 1 waters shallower than 25 fathoms.

Amendment 24, implemented February 28, 1994, and effective through December 31, 1996:

1. Established the following gear allocations of BSAI Pacific cod TAC as follows: 2 percent to vessels using jig gear; 44.1 percent to vessels using hook-and-line or pot gear, and 53.9 percent to vessels using trawl gear.
2. Authorized the seasonal apportionment of the amount of Pacific cod allocated to gear groups. Criteria for seasonal apportionments and the seasons authorized to receive separate apportionments will be set forth in regulations.

Amendment 46, implemented January 1, 1997, superseded Amendment 24:

Replaced the three year Pacific cod allocation established with Amendment 24, with the following gear allocations in BSAI Pacific cod: 2 percent to vessels using jig gear; 51 percent to vessels using hook-and-line or pot gear; and 47 percent to vessels using trawl gear. The trawl apportionment will be divided 50 percent to catcher vessels and 50 percent to catcher processors. These allocations as well as the seasonal apportionment authority established in Amendment 24 will remain in effect until amended.

Amendment 49, implemented January 3, 1998:

Implemented an Increased Retention/Increased Utilization Program for pollock and Pacific cod beginning January 1, 1998 and rock sole and yellowfin sole beginning January 1, 2003.

Amendment 64, implemented September 1, 2000, revised Amendment 46:

Allocated the Pacific cod Total Allowable Catch to the jig gear (2 percent), fixed gear (51 percent), and trawl gear (47 percent) sectors.

Amendment 67, implemented May 15, 2002, revised Amendment 39:

Established participation and harvest requirements to qualify for a BSAI Pacific cod fishery endorsement for fixed gear vessels.

Amendment 77, implemented January 1, 2004, revised Amendment 64:

Implemented a Pacific cod fixed gear allocation between hook and line catcher processors (80 percent), hook and line catcher vessels (0.3 percent), pot catcher processors (3.3 percent), pot catcher vessels (15 percent), and catcher vessels (pot or hook and line) less than 60 feet (1.4 percent).

Amendment 85, partially implemented on March 5, 2007, superseded Amendments 46 and 77:

Implemented a gear allocation among all non-CDQ fishery sectors participating in the directed fishery for Pacific cod. After deduction of the CDQ allocation, the Pacific cod TAC is apportioned to vessels using jig gear (1.4 percent); catcher processors using trawl gear listed in Section 208(e)(1)-(20) of the AFA (2.3 percent); catcher processors using trawl gear as defined in Section 219(a)(7) of the Consolidated Appropriations Act, 2005 (Public Law 108-447) (13.4 percent); catcher vessels using trawl gear (22.1 percent); catcher processors using hook-and-line gear (48.7 percent); catcher vessels ≥60’ LOA using hook-and-line gear (0.2 percent); catcher processors using pot gear (1.5 percent); catcher vessels ≥60’ LOA using pot gear (8.4 percent); and catcher vessels <60’ LOA that use either hook-and-line gear or pot gear (2.0 percent).

Table 2.5a (p. 1 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2011 as configured in Models 1-3. 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. Aug-Oct and Nov-Dec catches for 2012 are extrapolated.

		Trawl fishery			Longline fishery			Pot fishery		
Year	Season	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec
1977	Jan-Feb	5974	0	0	740	0	0	0	0	0
1977	Mar-Apr	5974	0	0	740	0	0	0	0	0
1977	May-Jul	0	7080	0	0	544	0	0	0	0
1977	Aug-Oct	0	0	5475	0	0	1733	0	0	0
1977	Nov-Dec	0	0	3429	0	0	1646	0	0	0
1978	Jan-Feb	7884	0	0	977	0	0	0	0	0
1978	Mar-Apr	7884	0	0	977	0	0	0	0	0
1978	May-Jul	0	9343	0	0	717	0	0	0	0
1978	Aug-Oct	0	0	7226	0	0	2286	0	0	0
1978	Nov-Dec	0	0	4526	0	0	2172	0	0	0
1979	Jan-Feb	6452	0	0	800	0	0	0	0	0
1979	Mar-Apr	6452	0	0	800	0	0	0	0	0
1979	May-Jul	0	7646	0	0	587	0	0	0	0
1979	Aug-Oct	0	0	5914	0	0	1871	0	0	0
1979	Nov-Dec	0	0	3704	0	0	1778	0	0	0
1980	Jan-Feb	7355	0	0	912	0	0	0	0	0
1980	Mar-Apr	7355	0	0	912	0	0	0	0	0
1980	May-Jul	0	8716	0	0	669	0	0	0	0
1980	Aug-Oct	0	0	6741	0	0	2133	0	0	0
1980	Nov-Dec	0	0	4222	0	0	2027	0	0	0
1981	Jan-Feb	6027	0	0	514	0	0	0	0	0
1981	Mar-Apr	6027	0	0	514	0	0	0	0	0
1981	May-Jul	0	12405	0	0	673	0	0	0	0
1981	Aug-Oct	0	0	15439	0	0	2179	0	0	0
1981	Nov-Dec	0	0	10743	0	0	1971	0	0	0
1982	Jan-Feb	8697	0	0	145	0	0	0	0	0
1982	Mar-Apr	8697	0	0	145	0	0	0	0	0
1982	May-Jul	0	16449	0	0	389	0	0	0	0
1982	Aug-Oct	0	0	14224	0	0	1312	0	0	0
1982	Nov-Dec	0	0	8174	0	0	1154	0	0	0
1983	Jan-Feb	16303	0	0	1176	0	0	0	0	0
1983	Mar-Apr	16303	0	0	1176	0	0	0	0	0
1983	May-Jul	0	24351	0	0	1087	0	0	0	0
1983	Aug-Oct	0	0	19453	0	0	1627	0	0	0
1983	Nov-Dec	0	0	11353	0	0	1378	0	0	0
1984	Jan-Feb	19295	0	0	2005	0	0	0	0	0
1984	Mar-Apr	19295	0	0	2005	0	0	0	0	0
1984	May-Jul	0	26290	0	0	2421	0	0	0	0
1984	Aug-Oct	0	0	20844	0	0	10463	0	0	0
1984	Nov-Dec	0	0	12523	0	0	9754	0	0	0
1985	Jan-Feb	22269	0	0	5481	0	0	0	0	0
1985	Mar-Apr	22269	0	0	5481	0	0	0	0	0
1985	May-Jul	0	30250	0	0	3881	0	0	0	0
1985	Aug-Oct	0	0	20713	0	0	11260	0	0	0
1985	Nov-Dec	0	0	11155	0	0	10690	0	0	0

Table 2.5a (p. 2 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2012 as configured in Models 1-3.

		Trawl fishery			Longline fishery			Pot fishery		
Year	Season	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec
1986	Jan-Feb	23914	0	0	3558	0	0	0	0	0
1986	Mar-Apr	23914	0	0	3558	0	0	0	0	0
1986	May-Jul	0	29689	0	0	2071	0	0	0	0
1986	Aug-Oct	0	0	20057	0	0	8785	0	0	0
1986	Nov-Dec	0	0	11191	0	0	8639	0	0	0
1987	Jan-Feb	25765	0	0	8379	0	0	0	0	0
1987	Mar-Apr	25765	0	0	8379	0	0	0	0	0
1987	May-Jul	0	23285	0	0	4671	0	0	0	0
1987	Aug-Oct	0	0	15932	0	0	13617	0	0	0
1987	Nov-Dec	0	0	10731	0	0	13376	0	0	0
1988	Jan-Feb	50988	0	0	214	0	0	0	0	0
1988	Mar-Apr	50988	0	0	214	0	0	0	0	0
1988	May-Jul	0	42602	0	0	571	0	0	0	0
1988	Aug-Oct	0	0	32137	0	0	1005	0	0	0
1988	Nov-Dec	0	0	23583	0	0	773	0	0	0
1989	Jan-Feb	50984	0	0	1524	0	0	13	0	0
1989	Mar-Apr	50984	0	0	1524	0	0	13	0	0
1989	May-Jul	0	36816	0	0	4074	0	0	49	0
1989	Aug-Oct	0	0	15561	0	0	4235	0	0	46
1989	Nov-Dec	0	0	9899	0	0	2579	0	0	25
1990	Jan-Feb	40658	0	0	5268	0	0	0	0	0
1990	Mar-Apr	40658	0	0	5268	0	0	0	0	0
1990	May-Jul	0	27930	0	0	13730	0	0	657	0
1990	Aug-Oct	0	0	9063	0	0	14197	0	0	526
1990	Nov-Dec	0	0	5262	0	0	8650	0	0	198
1991	Jan-Feb	35012	0	0	8232	0	0	1	0	0
1991	Mar-Apr	65705	0	0	12398	0	0	12	0	0
1991	May-Jul	0	16403	0	0	20115	0	0	410	0
1991	Aug-Oct	0	0	12271	0	0	21276	0	0	2306
1991	Nov-Dec	0	0	2	0	0	15484	0	0	614
1992	Jan-Feb	23287	0	0	13646	0	0	50	0	0
1992	Mar-Apr	32239	0	0	22401	0	0	149	0	0
1992	May-Jul	0	11784	0	0	27051	0	0	5321	0
1992	Aug-Oct	0	0	8182	0	0	16319	0	0	1992
1992	Nov-Dec	0	0	1788	0	0	0	0	0	0
1993	Jan-Feb	28010	0	0	22406	0	0	1	0	0
1993	Mar-Apr	35659	0	0	21656	0	0	1010	0	0
1993	May-Jul	0	6095	0	0	5208	0	0	1086	0
1993	Aug-Oct	0	0	9943	0	0	3	0	0	0
1993	Nov-Dec	0	0	2084	0	0	23	0	0	0
1994	Jan-Feb	13856	0	0	22458	0	0	0	0	0
1994	Mar-Apr	44222	0	0	29481	0	0	3179	0	0
1994	May-Jul	0	4453	0	0	6210	0	0	1792	0
1994	Aug-Oct	0	0	20070	0	0	20718	0	0	3133
1994	Nov-Dec	0	0	2691	0	0	0	0	0	0
1995	Jan-Feb	31919	0	0	29918	0	0	62	0	0
1995	Mar-Apr	58159	0	0	34516	0	0	7715	0	0
1995	May-Jul	0	1145	0	0	4161	0	0	7342	0
1995	Aug-Oct	0	0	19770	0	0	21305	0	0	2927
1995	Nov-Dec	0	0	108	0	0	8039	0	0	1413

Table 2.5a (p. 3 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2012 as configured in Models 1-3.

		Trawl fishery			Longline fishery			Pot fishery		
Year	Season	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec
1996	Jan-Feb	21160	0	0	28848	0	0	4	0	0
1996	Mar-Apr	50436	0	0	29471	0	0	12571	0	0
1996	May-Jul	0	8398	0	0	3755	0	0	10423	0
1996	Aug-Oct	0	0	10543	0	0	23629	0	0	4347
1996	Nov-Dec	0	0	1475	0	0	3278	0	0	728
1997	Jan-Feb	25706	0	0	31962	0	0	46	0	0
1997	Mar-Apr	52321	0	0	30578	0	0	9639	0	0
1997	May-Jul	0	5049	0	0	8211	0	0	7411	0
1997	Aug-Oct	0	0	9321	0	0	21323	0	0	3780
1997	Nov-Dec	0	0	1585	0	0	25011	0	0	658
1998	Jan-Feb	16120	0	0	30359	0	0	31	0	0
1998	Mar-Apr	26963	0	0	19925	0	0	5550	0	0
1998	May-Jul	0	4180	0	0	4022	0	0	5770	0
1998	Aug-Oct	0	0	12586	0	0	16155	0	0	1890
1998	Nov-Dec	0	0	999	0	0	13928	0	0	53
1999	Jan-Feb	18354	0	0	31749	0	0	5	0	0
1999	Mar-Apr	24661	0	0	20876	0	0	4937	0	0
1999	May-Jul	0	3028	0	0	3283	0	0	5420	0
1999	Aug-Oct	0	0	5658	0	0	20571	0	0	2054
1999	Nov-Dec	0	0	231	0	0	5040	0	0	0
2000	Jan-Feb	18935	0	0	30652	0	0	11647	0	0
2000	Mar-Apr	23194	0	0	8195	0	0	4105	0	0
2000	May-Jul	0	4588	0	0	1683	0	0	0	0
2000	Aug-Oct	0	0	6540	0	0	23325	0	0	107
2000	Nov-Dec	0	0	590	0	0	17816	0	0	0
2001	Jan-Feb	8588	0	0	19639	0	0	150	0	0
2001	Mar-Apr	13895	0	0	16568	0	0	11279	0	0
2001	May-Jul	0	3687	0	0	4089	0	0	611	0
2001	Aug-Oct	0	0	8701	0	0	30261	0	0	3878
2001	Nov-Dec	0	0	807	0	0	19831	0	0	558
2002	Jan-Feb	13410	0	0	35198	0	0	1845	0	0
2002	Mar-Apr	21130	0	0	14486	0	0	8407	0	0
2002	May-Jul	0	7772	0	0	1811	0	0	1013	0
2002	Aug-Oct	0	0	8594	0	0	34463	0	0	2997
2002	Nov-Dec	0	0	263	0	0	14360	0	0	804
2003	Jan-Feb	16424	0	0	35441	0	0	13712	0	0
2003	Mar-Apr	16459	0	0	17106	0	0	1661	0	0
2003	May-Jul	0	7074	0	0	2879	0	0	0	0
2003	Aug-Oct	0	0	7794	0	0	35121	0	0	5143
2003	Nov-Dec	0	0	70	0	0	18183	0	0	1444
2004	Jan-Feb	21886	0	0	37436	0	0	9023	0	0
2004	Mar-Apr	17432	0	0	16627	0	0	2854	0	0
2004	May-Jul	0	9773	0	0	2914	0	0	946	0
2004	Aug-Oct	0	0	8766	0	0	30938	0	0	3841
2004	Nov-Dec	0	0	75	0	0	20181	0	0	596
2005	Jan-Feb	27360	0	0	46935	0	0	9034	0	0
2005	Mar-Apr	15119	0	0	6612	0	0	3114	0	0
2005	May-Jul	0	7191	0	0	3509	0	0	0	0
2005	Aug-Oct	0	0	2892	0	0	35344	0	0	4549
2005	Nov-Dec	0	0	113	0	0	20756	0	0	407

Table 2.5a (p. 4 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2012 as configured in Models 1-3.

		Trawl fishery			Longline fishery			Pot fishery		
Year	Season	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec	Jan-Apr	May-Jul	Aug-Dec
2006	Jan-Feb	28595	0	0	45149	0	0	10608	0	0
2006	Mar-Apr	13917	0	0	6017	0	0	3297	0	0
2006	May-Jul	0	6345	0	0	1903	0	0	363	0
2006	Aug-Oct	0	0	4357	0	0	42489	0	0	3885
2006	Nov-Dec	0	0	49	0	0	1025	0	0	808
2007	Jan-Feb	15851	0	0	42910	0	0	10686	0	0
2007	Mar-Apr	16398	0	0	1917	0	0	1139	0	0
2007	May-Jul	0	10225	0	0	1213	0	0	479	0
2007	Aug-Oct	0	0	3190	0	0	30304	0	0	4922
2007	Nov-Dec	0	0	68	0	0	777	0	0	0
2008	Jan-Feb	15514	0	0	41629	0	0	8850	0	0
2008	Mar-Apr	7159	0	0	3657	0	0	1951	0	0
2008	May-Jul	0	3868	0	0	2633	0	0	225	0
2008	Aug-Oct	0	0	6306	0	0	33040	0	0	6218
2008	Nov-Dec	0	0	655	0	0	7966	0	0	124
2009	Jan-Feb	12194	0	0	44713	0	0	9387	0	0
2009	Mar-Apr	9602	0	0	3726	0	0	1722	0	0
2009	May-Jul	0	4271	0	0	2292	0	0	108	0
2009	Aug-Oct	0	0	10490	0	0	35381	0	0	1288
2009	Nov-Dec	0	0	403	0	0	10494	0	0	1081
2010	Jan-Feb	16326	0	0	40592	0	0	10692	0	0
2010	Mar-Apr	8172	0	0	2050	0	0	1726	0	0
2010	May-Jul	0	4291	0	0	2551	0	0	308	0
2010	Aug-Oct	0	0	10941	0	0	23936	0	0	5162
2010	Nov-Dec	0	0	1601	0	0	12702	0	0	1801
2011	Jan-Feb	21217	0	0	28984	0	0	15345	0	0
2011	Mar-Apr	20796	0	0	26311	0	0	2297	0	0
2011	May-Jul	0	6982	0	0	13494	0	0	1456	0
2011	Aug-Oct	0	0	13351	0	0	30923	0	0	8949
2011	Nov-Dec	0	0	1728	0	0	17437	0	0	0
2012	Jan-Feb	39025	0	0	33164	0	0	19236	0	0
2012	Mar-Apr	14807	0	0	24916	0	0	2318	0	0
2012	May-Jul	0	9104	0	0	21545	0	0	133	0
2012	Aug-Oct	0	0	11594	0	0	30080	0	0	5133
2012	Nov-Dec	0	0	1244	0	0	13544	0	0	961

Table 2.5b— EBS catch (t) of Pacific cod by year and season for the years 1977-2012 as configured in Model 4. Aug-Oct and Nov-Dec catches for 2012 are extrapolated.

Year	Jan-Feb	Mar-Apr	May-Jul	Aug-Oct	Nov-Dec
1977	6714	6714	7624	7208	5075
1978	8861	8861	10060	9512	6698
1979	7252	7252	8233	7785	5482
1980	8267	8267	9385	8874	6249
1981	6541	6541	13078	17618	12714
1982	8842	8842	16838	15536	9328
1983	17479	17479	25438	21080	12731
1984	21300	21300	28711	31307	22277
1985	27750	27750	34131	31973	21845
1986	27472	27472	31760	28842	19830
1987	34144	34144	27956	29549	24107
1988	51202	51202	43173	33142	24356
1989	52521	52521	40939	19842	12503
1990	45926	45926	42317	23786	14110
1991	43245	78114	36927	35853	16101
1992	36983	54790	44155	26494	1788
1993	50417	58325	12390	9946	2108
1994	36314	76882	12455	43921	2691
1995	61899	100390	12647	44002	9561
1996	50012	92479	22577	38518	5481
1997	57714	92538	20671	34424	27253
1998	46509	52437	13971	30632	14980
1999	50108	50474	11732	28283	5271
2000	61234	35493	6272	29972	18405
2001	28376	41742	8387	42841	21196
2002	50452	44023	10597	46055	15428
2003	65576	35226	9953	48058	19697
2004	68345	36913	13633	43544	20853
2005	83329	24846	10700	42785	21276
2006	84352	23231	8611	50731	1881
2007	69447	19454	11916	38417	845
2008	65992	12767	6726	45564	8745
2009	66294	15050	6671	47159	11978
2010	67610	11948	7151	40038	16104
2011	65546	49405	21933	53223	19166
2012	91425	42042	30782	46807	15749

Table 2.6 (page 1 of 3)— Fishery CPUE as configured in the stock assessment models. Units are kg/minute for trawl gear, kg/hook for longline gear, and kg/pot for pot gear.

Jan-Apr trawl fishery				May-Jul trawl fishery				Aug-Dec trawl fishery			
Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma
1991	Jan-Feb	55.864	0.091	1991	May-Jul	36.761	0.202	1991	Aug-Oct	71.702	0.600
1992	Jan-Feb	60.427	0.161	1992	May-Jul	38.568	0.289	1992	Aug-Oct	57.517	0.769
1993	Jan-Feb	62.047	0.156	1993	May-Jul	39.902	0.467	1993	Aug-Oct	113.970	0.501
1994	Jan-Feb	51.965	0.221	1994	May-Jul	26.767	0.247	1994	Aug-Oct	56.308	0.388
1995	Jan-Feb	88.482	0.122	1995	May-Jul	59.393	1.661	1995	Aug-Oct	60.164	0.322
1996	Jan-Feb	48.331	0.132	1996	May-Jul	29.174	0.312	1996	Aug-Oct	34.896	0.289
1997	Jan-Feb	75.605	0.121	1997	May-Jul	24.880	0.257	1997	Aug-Oct	62.619	0.564
1998	Jan-Feb	59.920	0.158	1998	May-Jul	26.245	0.302	1998	Aug-Oct	38.995	0.303
1999	Jan-Feb	42.399	0.119	1999	May-Jul	15.672	0.424	1999	Aug-Oct	20.611	0.365
2000	Jan-Feb	34.522	0.122	2000	May-Jul	32.694	0.292	2000	Aug-Oct	15.070	0.525
2001	Jan-Feb	25.452	0.165	2001	May-Jul	60.120	0.297	2001	Aug-Oct	16.662	0.248
2002	Jan-Feb	35.892	0.140	2002	May-Jul	39.985	0.208	2002	Aug-Oct	15.141	0.195
2003	Jan-Feb	24.642	0.168	2003	May-Jul	49.493	0.209	2003	Aug-Oct	19.171	0.155
2004	Jan-Feb	62.609	0.137	2004	May-Jul	34.588	0.163	2004	Aug-Oct	21.519	0.153
2005	Jan-Feb	43.993	0.115	2005	May-Jul	24.100	0.171	2005	Aug-Oct	15.932	0.831
2006	Jan-Feb	36.397	0.107	2006	May-Jul	30.653	0.185	2006	Aug-Oct	26.772	0.375
2007	Jan-Feb	30.849	0.094	2007	May-Jul	39.485	0.114	2007	Aug-Oct	18.147	0.678
2008	Jan-Feb	24.385	0.151	2008	May-Jul	40.650	0.249	2008	Aug-Oct	60.047	0.334
2009	Jan-Feb	37.853	0.170	2009	May-Jul	33.932	0.291	2009	Aug-Oct	54.154	0.225
2010	Jan-Feb	41.949	0.136	2010	May-Jul	32.031	0.334	2010	Aug-Oct	73.484	0.197
2011	Jan-Feb	50.737	0.110	2011	May-Jul	49.228	0.257	2011	Aug-Oct	56.918	0.201
2012	Jan-Feb	97.338	0.099	2012	May-Jul	117.809	0.247	2012	Aug-Oct	50.420	0.587
1991	Mar-Apr	61.454	0.058					1993	Nov-Dec	32.678	0.910
1992	Mar-Apr	48.269	0.069					1996	Nov-Dec	29.543	0.480
1993	Mar-Apr	48.840	0.073					1997	Nov-Dec	31.309	1.088
1994	Mar-Apr	52.428	0.053					1998	Nov-Dec	16.891	0.643
1995	Mar-Apr	55.463	0.061					1999	Nov-Dec	12.994	0.959
1996	Mar-Apr	33.954	0.051					2009	Nov-Dec	28.369	1.175
1997	Mar-Apr	45.985	0.062					2010	Nov-Dec	40.079	0.678
1998	Mar-Apr	31.809	0.071					2011	Nov-Dec	20.796	1.175
1999	Mar-Apr	35.675	0.086								
2000	Mar-Apr	31.397	0.085								
2001	Mar-Apr	21.213	0.105								
2002	Mar-Apr	26.640	0.102								
2003	Mar-Apr	28.131	0.095								
2004	Mar-Apr	42.816	0.115								
2005	Mar-Apr	48.932	0.113								
2006	Mar-Apr	56.188	0.140								
2007	Mar-Apr	45.097	0.092								
2008	Mar-Apr	40.343	0.195								
2009	Mar-Apr	55.557	0.182								
2010	Mar-Apr	55.766	0.265								
2011	Mar-Apr	76.788	0.148								
2012	Mar-Apr	79.219	0.153								

Table 2.6 (page 2 of 3)— Fishery CPUE as configured in the stock assessment models. Units are kg/minute for trawl gear, kg/hook for longline gear, and kg/pot for pot gear.

Jan-Apr longline fishery			
Year	Season	CPUE	Sigma
1991	Jan-Feb	1.124	0.155
1992	Jan-Feb	0.873	0.088
1993	Jan-Feb	0.654	0.066
1994	Jan-Feb	0.728	0.067
1995	Jan-Feb	0.895	0.069
1996	Jan-Feb	0.878	0.068
1997	Jan-Feb	0.989	0.072
1998	Jan-Feb	0.888	0.073
1999	Jan-Feb	0.743	0.067
2000	Jan-Feb	0.730	0.069
2001	Jan-Feb	0.586	0.079
2002	Jan-Feb	0.680	0.061
2003	Jan-Feb	0.517	0.052
2004	Jan-Feb	0.562	0.060
2005	Jan-Feb	0.626	0.055
2006	Jan-Feb	0.747	0.062
2007	Jan-Feb	0.734	0.045
2008	Jan-Feb	0.794	0.068
2009	Jan-Feb	0.893	0.068
2010	Jan-Feb	0.781	0.066
2011	Jan-Feb	0.716	0.082
2012	Jan-Feb	0.774	0.081
1991	Mar-Apr	0.993	0.110
1992	Mar-Apr	0.858	0.070
1993	Mar-Apr	0.669	0.061
1994	Mar-Apr	0.735	0.060
1995	Mar-Apr	0.841	0.061
1996	Mar-Apr	0.756	0.066
1997	Mar-Apr	0.829	0.078
1998	Mar-Apr	0.619	0.075
1999	Mar-Apr	0.617	0.067
2000	Mar-Apr	0.617	0.096
2001	Mar-Apr	0.539	0.072
2002	Mar-Apr	0.676	0.082
2003	Mar-Apr	0.530	0.068
2004	Mar-Apr	0.579	0.075
2005	Mar-Apr	0.678	0.112
2006	Mar-Apr	0.796	0.112
2007	Mar-Apr	0.693	0.154
2008	Mar-Apr	0.774	0.145
2009	Mar-Apr	1.159	0.171
2010	Mar-Apr	0.829	0.194
2011	Mar-Apr	0.703	0.072
2012	Mar-Apr	0.597	0.082

May-Jul longline fishery			
Year	Season	CPUE	Sigma
1991	May-Jul	0.771	0.075
1992	May-Jul	0.530	0.052
1993	May-Jul	0.551	0.175
1994	May-Jul	0.713	0.132
1995	May-Jul	0.760	0.178
1996	May-Jul	0.669	0.177
1997	May-Jul	0.657	0.120
1998	May-Jul	0.496	0.183
1999	May-Jul	0.637	0.142
2000	May-Jul	0.610	0.168
2001	May-Jul	0.514	0.106
2002	May-Jul	0.405	0.136
2003	May-Jul	0.376	0.109
2004	May-Jul	0.367	0.115
2005	May-Jul	0.385	0.106
2006	May-Jul	0.366	0.161
2007	May-Jul	0.406	0.142
2008	May-Jul	0.366	0.140
2009	May-Jul	0.384	0.150
2010	May-Jul	0.419	0.155
2011	May-Jul	0.374	0.088
2012	May-Jul	0.442	0.090

Aug-Dec longline fishery			
Year	Season	CPUE	Sigma
1991	Aug-Oct	0.595	0.062
1992	Aug-Oct	0.512	0.069
1994	Aug-Oct	0.576	0.068
1995	Aug-Oct	0.587	0.069
1996	Aug-Oct	0.542	0.060
1997	Aug-Oct	0.580	0.064
1998	Aug-Oct	0.398	0.063
1999	Aug-Oct	0.481	0.060
2000	Aug-Oct	0.404	0.053
2001	Aug-Oct	0.398	0.051
2002	Aug-Oct	0.372	0.046
2003	Aug-Oct	0.342	0.044
2004	Aug-Oct	0.312	0.047
2005	Aug-Oct	0.330	0.045
2006	Aug-Oct	0.391	0.047
2007	Aug-Oct	0.402	0.038
2008	Aug-Oct	0.307	0.048
2009	Aug-Oct	0.348	0.049
2010	Aug-Oct	0.352	0.060
2011	Aug-Oct	0.369	0.058
2012	Aug-Oct	0.340	0.206
1991	Nov-Dec	0.551	0.092
1995	Nov-Dec	0.648	0.109
1996	Nov-Dec	0.590	0.276
1997	Nov-Dec	0.577	0.072
1998	Nov-Dec	0.501	0.072
1999	Nov-Dec	0.541	0.119
2000	Nov-Dec	0.416	0.066
2001	Nov-Dec	0.432	0.065
2002	Nov-Dec	0.394	0.072
2003	Nov-Dec	0.365	0.059
2004	Nov-Dec	0.441	0.065
2005	Nov-Dec	0.385	0.064
2006	Nov-Dec	0.433	0.213
2007	Nov-Dec	0.449	0.330
2008	Nov-Dec	0.449	0.086
2009	Nov-Dec	0.428	0.090
2010	Nov-Dec	0.447	0.087
2011	Nov-Dec	0.447	0.086

Table 2.6 (page 3 of 3)— Fishery CPUE as configured in the stock assessment models. Units are kg/minute for trawl gear, kg/hook for longline gear, and kg/pot for pot gear.

Jan-Apr pot fishery				May-Jul pot fishery				Aug-Dec pot fishery			
Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma
2000	Jan-Feb	56.553	0.151	1991	May-Jul	64.037	0.249	1991	Aug-Oct	88.556	0.132
2001	Jan-Feb	72.207	0.501	1992	May-Jul	66.730	0.076	1992	Aug-Oct	30.252	0.112
2002	Jan-Feb	81.893	0.263	1993	May-Jul	90.669	0.227	1994	Aug-Oct	97.172	0.151
2003	Jan-Feb	73.858	0.138	1994	May-Jul	75.421	0.172	1995	Aug-Oct	57.783	0.153
2004	Jan-Feb	78.980	0.169	1995	May-Jul	72.065	0.098	1996	Aug-Oct	49.758	0.136
2005	Jan-Feb	85.328	0.167	1996	May-Jul	55.819	0.089	1997	Aug-Oct	47.938	0.166
2006	Jan-Feb	83.292	0.153	1997	May-Jul	46.843	0.114	1998	Aug-Oct	32.057	0.279
2007	Jan-Feb	64.671	0.108	1998	May-Jul	49.999	0.128	1999	Aug-Oct	37.675	0.212
2008	Jan-Feb	81.642	0.207	1999	May-Jul	47.466	0.123	2001	Aug-Oct	46.493	0.168
2009	Jan-Feb	92.345	0.188					2002	Aug-Oct	42.331	0.188
2010	Jan-Feb	88.535	0.167					2003	Aug-Oct	57.632	0.174
2011	Jan-Feb	130.718	0.152					2004	Aug-Oct	48.802	0.209
2012	Jan-Feb	138.766	0.147					2005	Aug-Oct	45.872	0.191
1992	Mar-Apr	86.412	0.420					2006	Aug-Oct	55.342	0.185
1993	Mar-Apr	84.191	0.135					2007	Aug-Oct	65.356	0.150
1994	Mar-Apr	89.313	0.107					2008	Aug-Oct	57.252	0.163
1995	Mar-Apr	91.679	0.094					2009	Aug-Oct	72.836	0.265
1996	Mar-Apr	73.485	0.076					2010	Aug-Oct	82.936	0.209
1997	Mar-Apr	93.226	0.120					2011	Aug-Oct	81.445	0.147
1998	Mar-Apr	77.558	0.183					2012	Aug-Oct	46.287	0.575
1999	Mar-Apr	67.604	0.194					1991	Nov-Dec	91.633	0.261
2000	Mar-Apr	45.310	0.162					1995	Nov-Dec	53.251	0.187
2001	Mar-Apr	69.247	0.136					1996	Nov-Dec	46.456	0.420
2002	Mar-Apr	61.628	0.175					1997	Nov-Dec	41.829	0.411
2004	Mar-Apr	65.936	0.388					1998	Nov-Dec	41.138	0.798
2006	Mar-Apr	116.202	0.420					2001	Nov-Dec	40.740	0.628
								2002	Nov-Dec	55.955	0.415
								2003	Nov-Dec	60.093	0.332
								2004	Nov-Dec	66.375	0.449
								2006	Nov-Dec	37.187	0.420
								2010	Nov-Dec	104.985	0.371

Table 2.7— Total biomass and abundance, with standard deviations, as estimated by EBS shelf bottom trawl surveys, 1982-2012. For biomass, lower and upper 95% confidence intervals are also shown.

	Biomass (t)				Abundance (1000s of fish)	
Year	Estimate	Std. deviation	L95% CI	U95% CI	Estimate	Std. deviation
1982	1,012,856	73,588	867,151	1,158,562	583,716	38,041
1983	1,185,419	120,868	941,146	1,429,692	751,067	80,441
1984	1,048,595	63,643	922,583	1,174,608	680,915	49,914
1985	1,001,108	55,845	890,536	1,111,681	841,108	113,438
1986	1,117,774	69,604	979,957	1,255,590	838,123	83,854
1987	1,104,868	68,304	969,627	1,240,109	728,974	48,488
1988	959,401	76,118	808,688	1,110,114	507,104	35,468
1989	833,314	62,709	709,150	957,477	292,168	19,986
1990	691,255	51,455	589,375	793,136	423,835	36,466
1991	514,498	38,038	439,183	589,813	488,869	51,109
1992	551,369	45,780	460,725	642,013	601,795	70,551
1993	691,311	54,581	583,240	799,383	852,288	106,918
1994	1,368,120	250,044	868,032	1,868,209	1,237,758	153,120
1995	1,002,850	91,622	821,437	1,184,262	757,827	75,473
1996	892,377	87,532	719,064	1,065,690	609,987	88,407
1997	604,439	68,120	468,199	740,678	485,643	70,802
1998	558,419	45,182	468,960	647,879	537,278	48,428
1999	584,762	50,591	484,592	684,932	501,496	46,613
2000	531,171	43,160	445,714	616,627	483,808	44,188
2001	833,626	76,247	681,133	986,119	985,569	94,981
2002	618,680	69,082	480,516	756,845	566,471	57,676
2003	593,258	62,153	468,951	717,564	499,366	62,355
2004	596,279	35,216	526,552	666,007	424,662	36,140
2005	606,394	43,047	521,160	691,628	450,918	63,358
2006	517,698	28,341	461,583	573,813	394,051	23,784
2007	423,703	34,811	354,080	493,326	733,374	195,955
2008	403,125	26,822	350,018	456,232	476,697	49,413
2009	421,290	34,969	352,051	490,528	716,590	62,700
2010	859,642	102,265	657,157	1,062,127	887,457	117,009
2011	896,039	66,843	763,690	1,028,388	836,794	79,204
2012	890,665	100,473	689,718	1,091,612	987,973	91,589

Table 2.8 (page 1 of 3)—Trawl survey size composition, by year and cm (sample size in column 2).

Year	N	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1982	10546	0	0	0	0	0	1	8	9	19	26	52	59	109	66	51	52	46
1983	13149	0	0	0	0	0	7	96	291	455	458	484	461	433	395	253	250	120
1984	12135	0	0	0	0	0	7	26	37	56	45	28	26	26	31	47	31	63
1985	16881	0	0	0	0	0	4	56	102	179	145	216	287	304	372	503	507	526
1986	15378	0	0	0	0	1	23	38	93	133	130	202	175	177	150	93	34	27
1987	10601	0	0	0	0	0	0	14	3	7	24	38	60	80	110	122	122	154
1988	9995	0	0	0	0	0	0	1	8	7	28	13	27	26	23	42	27	18
1989	9999	0	0	0	0	0	3	3	19	47	37	70	86	108	105	101	66	39
1990	5631	0	0	0	0	0	26	71	104	154	150	185	236	259	205	149	117	89
1991	7225	0	0	0	0	0	6	31	94	112	140	137	163	133	136	128	107	135
1992	9602	0	0	0	0	0	0	1	17	82	184	190	173	148	196	218	232	248
1993	10403	0	0	0	0	1	3	30	82	194	433	296	409	356	322	321	346	314
1994	13923	0	0	0	0	0	3	10	5	27	42	76	92	100	100	116	136	111
1995	9212	0	0	0	0	0	3	12	15	13	19	41	37	42	56	59	81	68
1996	9349	0	0	0	0	0	1	2	11	9	23	33	48	64	53	66	69	63
1997	9173	0	0	0	0	0	8	17	65	114	167	193	192	196	212	284	226	218
1998	9578	0	0	0	0	0	1	4	24	56	87	119	106	137	91	45	23	6
1999	11699	0	0	0	0	0	1	15	54	101	110	122	94	113	79	42	30	41
2000	12548	0	0	0	4	10	23	51	99	137	298	478	582	442	278	274	141	87
2001	19746	0	0	0	0	5	6	27	62	127	205	314	452	661	714	768	681	663
2002	12239	0	0	0	0	1	3	6	22	45	65	81	102	160	112	168	111	72
2003	12358	0	0	1	0	1	3	5	11	56	93	138	203	231	205	247	252	280
2004	10803	0	2	0	0	0	1	4	19	44	84	149	106	193	186	218	212	136
2005	11292	0	0	0	0	0	0	1	4	22	43	87	138	201	248	304	284	301
2006	12133	0	1	0	4	7	40	101	336	405	427	453	401	343	330	359	280	243
2007	12816	0	0	0	0	7	7	129	481	1163	1425	1398	1141	731	715	511	326	400
2008	12975	0	0	1	0	0	6	54	168	350	379	390	350	313	227	151	75	40
2009	16675	1	0	0	7	36	106	401	971	1057	1087	878	744	651	485	460	318	220
2010	7570	0	0	0	0	0	1	5	18	24	29	50	50	56	46	31	15	17
2011	20744	0	0	0	0	0	8	20	76	142	257	307	385	413	598	627	905	887
2012	13075	0	0	6	0	0	74	379	686	732	563	424	417	310	410	396	208	129

Year	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1982	19	8	9	2	8	18	25	40	67	87	123	193	221	240	305	317	237	197
1983	74	44	29	9	5	18	34	46	56	100	125	145	173	166	212	145	127	108
1984	71	89	123	229	310	381	465	580	608	656	577	480	395	349	297	222	156	107
1985	647	559	555	321	212	130	91	100	106	159	220	216	272	300	309	311	288	343
1986	20	22	72	114	218	360	449	697	629	616	638	653	580	557	448	402	349	332
1987	125	81	61	46	63	76	118	123	200	273	302	324	292	281	205	232	202	173
1988	26	35	48	68	77	88	86	110	84	124	122	137	179	191	269	216	196	211
1989	19	21	30	4	15	16	35	13	34	30	24	33	37	70	33	107	109	134
1990	57	35	41	42	33	47	76	77	96	103	97	92	118	124	80	113	96	67
1991	86	72	72	78	100	97	166	192	265	285	325	289	373	308	251	261	196	173
1992	216	228	113	119	134	182	262	288	303	349	375	351	310	304	242	217	177	149
1993	324	217	136	97	62	55	67	85	95	175	207	232	292	316	239	245	226	195
1994	103	91	132	120	171	154	205	320	430	552	638	732	766	672	643	471	362	288
1995	34	24	19	37	47	89	108	158	194	228	218	245	225	198	155	217	249	239
1996	54	36	20	22	23	58	64	130	162	193	229	276	236	251	190	199	168	158
1997	226	177	105	58	41	41	34	70	109	103	154	223	231	222	174	159	155	138
1998	4	17	24	57	72	181	275	382	494	598	626	612	514	538	343	261	229	165
1999	49	39	53	109	110	196	227	222	311	269	296	309	241	228	198	191	239	289
2000	33	9	12	25	39	77	119	170	197	220	258	305	222	197	184	188	174	199
2001	441	350	219	136	112	160	225	313	364	506	655	828	825	916	802	697	509	407
2002	52	35	17	42	62	105	159	240	266	433	473	553	552	519	379	400	313	293
2003	251	235	198	217	154	119	67	57	59	79	58	115	145	318	216	320	241	275
2004	143	113	64	55	73	90	102	186	195	219	236	273	301	318	311	341	313	326
2005	290	362	362	387	376	289	210	136	135	141	115	158	178	197	197	207	231	288
2006	146	105	65	54	56	55	64	86	115	168	189	246	243	264	245	303	263	298
2007	230	121	122	42	44	65	86	124	117	154	122	140	147	124	114	93	93	76
2008	21	40	70	162	307	479	550	707	745	719	681	559	461	341	281	200	161	151
2009	114	35	28	33	82	94	173	253	336	397	468	436	339	306	221	214	215	225
2010	9	13	31	60	126	193	242	355	431	417	394	394	323	269	183	165	106	95
2011	851	536	286	110	34	37	55	48	56	72	121	136	188	164	232	229	272	287
2012	48	31	10	28	37	59	84	178	259	269	358	352	390	279	309	190	158	98

Table 2.8 (page 2 of 3)—Trawl survey size composition, by year and cm.

Year	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
1982	144	146	126	137	180	202	282	302	272	328	328	280	284	270	254	239	278	258	267	225	260
1983	61	62	86	94	143	157	212	269	301	287	298	316	254	248	246	225	299	277	258	263	245
1984	102	89	58	94	76	92	93	95	108	135	105	108	95	108	140	128	155	164	194	198	153
1985	351	389	413	514	500	514	482	470	359	323	244	192	168	128	96	93	103	101	104	86	86
1986	220	194	138	126	136	163	185	216	205	246	218	248	269	258	275	288	299	226	252	251	175
1987	186	222	209	297	328	334	332	319	323	251	250	262	157	156	134	120	146	140	98	122	92
1988	141	184	165	239	222	197	318	277	294	277	247	308	266	230	250	250	260	220	214	226	194
1989	115	125	101	115	114	139	176	165	176	183	176	200	253	235	260	247	234	326	293	219	222
1990	57	67	51	47	38	38	31	35	48	39	41	25	51	31	62	53	66	58	74	72	75
1991	143	118	84	68	64	61	51	61	53	61	74	49	61	42	71	89	58	75	40	34	42
1992	125	179	147	216	187	219	240	186	185	160	143	153	119	108	88	78	57	63	29	42	51
1993	150	159	179	180	217	218	229	266	204	183	190	157	150	128	112	117	107	87	63	64	78
1994	196	115	133	114	221	188	164	233	256	264	299	173	189	230	189	181	175	219	251	252	162
1995	314	378	371	417	421	394	343	335	293	199	189	153	142	115	98	108	95	88	93	86	72
1996	168	155	175	214	240	290	263	292	323	300	299	324	273	282	283	243	253	205	166	151	132
1997	145	136	125	127	135	135	171	194	228	152	172	134	150	180	187	160	167	124	213	164	173
1998	146	134	100	117	116	133	125	168	118	114	134	111	94	88	82	82	72	61	78	90	76
1999	307	379	484	508	585	557	505	395	409	312	234	199	165	142	145	117	117	93	104	93	86
2000	223	256	267	303	306	347	308	355	321	391	342	351	262	315	239	256	194	202	183	159	159
2001	299	217	189	176	152	157	187	229	281	229	266	251	230	264	274	257	236	219	225	189	208
2002	249	287	256	405	357	453	393	387	278	330	189	228	184	167	137	162	130	157	90	109	123
2003	291	320	361	343	390	457	426	461	415	391	278	276	235	246	260	198	185	167	149	124	144
2004	254	244	213	208	188	181	156	149	152	176	172	207	201	162	182	172	186	167	192	142	157
2005	252	204	194	203	207	216	167	205	168	193	132	170	127	144	129	134	111	111	101	99	100
2006	253	244	209	200	161	171	145	151	127	157	147	191	169	175	145	174	137	182	105	128	90
2007	61	73	77	74	68	82	76	85	79	80	60	75	74	82	68	72	59	54	48	52	47
2008	133	130	117	143	129	138	138	139	113	135	121	124	127	134	114	108	101	111	90	113	103
2009	302	303	361	380	379	347	334	280	289	247	181	147	144	117	103	93	82	75	78	85	88
2010	64	75	78	124	132	231	154	165	159	156	123	134	106	148	114	155	151	139	95	140	112
2011	403	457	673	801	859	925	872	790	634	511	347	349	278	265	185	230	225	265	184	276	241
2012	81	61	46	63	59	85	81	130	111	196	188	239	285	379	323	408	309	316	218	198	168

Year	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1982	264	261	225	227	202	193	190	198	122	172	124	132	73	73	72	64	45	34	37	30	20
1983	262	245	201	224	196	200	191	166	188	176	145	180	126	122	78	81	79	68	59	39	48
1984	212	167	196	199	187	159	195	181	177	168	151	143	82	118	96	104	74	81	56	66	45
1985	90	85	148	110	110	113	171	124	134	146	147	136	134	120	138	107	135	99	95	60	75
1986	171	120	146	111	81	99	76	84	70	87	105	99	89	70	90	86	69	81	71	62	84
1987	141	136	124	132	121	133	123	132	134	111	115	94	59	90	53	55	54	24	43	34	34
1988	198	165	206	164	116	123	99	138	106	105	81	116	84	83	56	79	71	48	41	55	71
1989	197	290	186	228	242	184	167	241	213	136	201	105	184	198	167	154	143	107	151	108	63
1990	85	89	89	78	78	54	80	55	60	34	64	43	53	52	53	49	33	38	38	25	37
1991	41	34	52	44	43	26	45	41	47	46	48	32	31	25	40	32	27	14	16	19	22
1992	50	66	45	36	25	32	31	47	35	32	24	14	21	23	21	15	24	15	18	25	29
1993	66	56	57	52	36	67	36	37	62	28	28	14	15	15	14	16	12	12	11	12	12
1994	219	153	204	164	180	160	126	84	133	62	102	49	67	30	41	20	29	13	21	9	9
1995	93	99	104	100	87	70	54	60	72	71	69	50	54	45	36	28	22	37	20	25	21
1996	141	98	95	86	78	57	60	59	56	56	45	56	62	32	44	36	27	29	34	22	21
1997	122	130	107	111	115	101	99	92	80	69	56	61	53	29	18	31	20	28	16	11	10
1998	66	77	88	86	75	65	98	59	64	48	46	52	55	38	52	29	37	21	21	25	13
1999	72	116	86	93	80	95	63	69	48	61	70	49	45	51	37	28	28	23	26	27	25
2000	149	112	101	90	85	54	65	58	52	36	50	33	38	31	34	29	22	12	14	22	22
2001	185	149	198	132	155	151	106	82	106	68	78	57	51	33	38	26	19	27	20	31	17
2002	125	101	113	107	99	57	107	72	64	66	57	48	35	36	31	25	31	24	13	10	20
2003	138	116	96	71	94	64	72	69	66	67	76	47	56	40	40	36	35	27	28	16	18
2004	166	148	141	138	121	102	100	86	104	81	63	72	58	57	33	49	44	42	44	31	27
2005	117	84	118	83	127	104	112	101	101	77	83	74	70	59	72	51	72	54	65	49	44
2006	97	105	95	106	90	88	98	61	96	51	71	60	58	64	67	57	59	42	57	44	58
2007	61	50	60	49	49	45	46	32	43	40	31	24	32	23	38	21	19	14	12	17	17
2008	113	91	81	81	88	62	71	64	71	44	53	35	39	23	43	19	23	21	23	13	16
2009	72	84	77	53	65	71	52	38	48	30	40	29	21	24	13	17	14	15	14	4	13
2010	100	71	90	60	67	41	42	29	22	16	19	18	10	7	7	9	10	3	7	2	2
2011	301	228	294	184	249	172	205	152	159	115	126	61	78	51	50	27	25	21	15	14	18
2012	164	97	120	86	104	78	79	63	66	46	72	37	47	24	29	21	20	19	18	6	10

Table 2.8 (page 3 of 3)—Trawl survey size composition, by year and cm.

Year	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
1982	27	24	12	8	7	9	3	6	4	1	2	3	0	2	0	1	2	1	0
1983	32	29	24	18	12	1	7	8	3	12	1	1	2	4	0	3	0	1	0
1984	39	31	32	26	21	27	12	16	18	12	9	4	7	6	0	4	3	2	1
1985	59	50	48	21	37	22	22	16	14	10	8	7	8	4	1	3	7	2	4
1986	56	53	43	29	26	35	18	21	18	30	10	16	13	5	4	6	2	7	2
1987	45	28	29	29	29	9	7	15	9	10	13	6	10	10	2	4	6	3	1
1988	62	53	30	30	11	27	15	6	15	2	16	2	6	6	6	5	1	4	8
1989	53	85	61	74	88	43	60	41	14	43	30	19	24	28	32	14	10	21	11
1990	39	10	24	19	23	19	10	11	18	11	6	5	5	7	11	10	3	1	1
1991	33	24	21	12	13	8	13	7	8	6	3	5	4	1	6	8	3	2	3
1992	14	16	15	11	13	14	6	10	8	13	6	7	7	4	7	8	3	9	1
1993	11	9	4	12	10	4	7	7	8	4	3	4	7	3	7	5	5	4	3
1994	10	12	5	9	8	9	7	4	6	34	13	9	3	1	3	6	4	2	1
1995	20	18	12	13	10	7	8	7	7	4	11	3	4	4	10	1	3	2	3
1996	24	25	15	25	10	13	22	17	9	3	3	7	10	3	5	5	3	2	2
1997	9	12	17	12	10	8	9	9	4	3	8	7	2	6	3	2	4	0	1
1998	16	9	15	11	8	10	7	4	3	5	5	10	3	6	3	1	2	2	1
1999	19	13	17	15	12	11	17	16	6	16	6	5	5	5	2	5	6	6	3
2000	12	18	19	8	9	5	9	26	7	7	7	4	4	10	2	8	5	3	1
2001	17	12	11	13	5	10	6	6	5	7	5	4	2	4	6	1	2	1	5
2002	14	6	6	3	7	2	4	5	2	2	4	5	5	1	3	2	3	6	1
2003	21	22	11	14	7	9	6	7	5	4	4	3	2	1	0	1	1	0	0
2004	23	23	16	22	10	25	13	19	14	13	6	4	8	4	3	4	4	2	2
2005	40	40	32	25	17	28	20	23	14	10	14	10	8	4	9	5	3	4	0
2006	50	51	37	42	39	34	20	35	16	23	15	18	10	10	6	11	9	1	7
2007	18	10	10	9	25	11	8	9	15	10	13	8	3	8	4	6	2	3	2
2008	12	16	14	12	8	20	11	10	8	12	5	10	10	10	9	3	8	9	2
2009	6	8	4	4	7	6	6	3	4	5	1	1	1	2	3	5	2	3	1
2010	5	2	2	1	3	4	0	2	1	2	1	1	2	0	0	2	1	1	1
2011	7	14	10	7	3	4	4	4	4	1	5	3	4	7	2	1	0	1	0
2012	4	7	6	6	4	4	4	1	1	2	2	1	3	3	2	0	0	1	2

Year	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118+
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	4	3	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	1	2	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	3	1	3	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
1989	10	22	1	22	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	5	0	6	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	6	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1992	4	3	3	3	2	1	1	1	0	0	0	0	0	0	0	0	0	1	0
1993	1	2	2	1	8	3	0	1	0	0	0	0	0	0	0	2	0	0	0
1994	2	9	6	3	1	7	0	0	1	0	1	0	0	0	0	0	0	0	0
1995	5	1	3	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0
1996	4	1	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
1997	2	0	0	1	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0
1998	1	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	2	1	0	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
2000	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	1	1	0	2	1	3	1	0	1	0	0	0	0	0	0	0	0	0	0
2002	1	0	0	1	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0
2003	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	1	0	5	0	1	0	0	2	0	1	0	0	0	0	0	0	0	0
2005	4	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	5	3	2	3	2	0	1	0	0	2	0	0	0	0	0	0	0	0	0
2007	3	2	8	1	2	1	2	0	1	0	0	0	1	0	0	0	0	0	0
2008	4	3	7	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2009	2	1	1	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0
2010	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	2	2	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2.9—Age compositions observed by the EBS shelf bottom trawl survey, 1994-2010. "Nact" = actual sample size (these get rescaled so that the average across all age compositions equals 300).

Year	Nact	0	1	2	3	4	5	6	7	8	9	10	11	12+
1994	715	0.0000	0.0884	0.3829	0.1713	0.1217	0.1182	0.0807	0.0211	0.0074	0.0048	0.0016	0.0010	0.0009
1995	599	0.0000	0.0507	0.2624	0.4231	0.0989	0.0788	0.0486	0.0172	0.0101	0.0064	0.0016	0.0010	0.0012
1996	711	0.0000	0.0538	0.2079	0.2041	0.2939	0.1347	0.0564	0.0286	0.0116	0.0047	0.0019	0.0014	0.0009
1997	719	0.0000	0.2502	0.1698	0.1829	0.1577	0.1210	0.0785	0.0231	0.0108	0.0034	0.0013	0.0010	0.0004
1998	635	0.0000	0.0775	0.4405	0.2027	0.1118	0.0570	0.0594	0.0286	0.0165	0.0042	0.0008	0.0007	0.0003
1999	860	0.0000	0.0791	0.2000	0.3019	0.2320	0.0803	0.0569	0.0278	0.0127	0.0057	0.0013	0.0015	0.0006
2000	864	0.0000	0.2336	0.1268	0.1514	0.2417	0.1466	0.0611	0.0136	0.0144	0.0062	0.0028	0.0014	0.0005
2001	950	0.0000	0.2874	0.2358	0.1936	0.0915	0.0835	0.0679	0.0269	0.0084	0.0024	0.0015	0.0009	0.0003
2002	947	0.0001	0.0808	0.1872	0.3168	0.2332	0.0719	0.0585	0.0343	0.0109	0.0040	0.0011	0.0006	0.0005
2003	1360	0.0000	0.1732	0.1564	0.2514	0.2099	0.1190	0.0410	0.0300	0.0138	0.0038	0.0005	0.0006	0.0005
2004	1040	0.0000	0.1430	0.1656	0.2715	0.1299	0.1266	0.0900	0.0405	0.0190	0.0086	0.0022	0.0025	0.0005
2005	1280	0.0000	0.1830	0.2444	0.2094	0.1212	0.0659	0.0793	0.0545	0.0235	0.0109	0.0036	0.0037	0.0006
2006	1300	0.0000	0.3243	0.1428	0.1650	0.1214	0.0928	0.0633	0.0463	0.0285	0.0101	0.0030	0.0016	0.0010
2007	1441	0.0000	0.6993	0.0959	0.0674	0.0415	0.0462	0.0177	0.0143	0.0084	0.0051	0.0017	0.0016	0.0010
2008	1213	0.0001	0.2138	0.4448	0.1449	0.0829	0.0485	0.0328	0.0100	0.0104	0.0060	0.0026	0.0016	0.0017
2009	1412	0.0006	0.4543	0.1895	0.2309	0.0641	0.0288	0.0146	0.0094	0.0040	0.0021	0.0009	0.0006	0.0003
2010	1292	0.0000	0.0462	0.4805	0.1786	0.2029	0.0648	0.0143	0.0078	0.0027	0.0014	0.0004	0.0005	0.0001
2011	1253	0.0000	0.2904	0.0730	0.3882	0.1111	0.0956	0.0278	0.0069	0.0034	0.0017	0.0010	0.0006	0.0004

Table 2.10—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.

Average length (cm) at age:

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
1994	11.00	18.45	27.75	41.50	55.39	60.90	65.04	72.50	81.08	87.11	90.94	89.54	95.81
1995	11.00	17.39	28.73	42.03	56.81	62.74	69.45	74.51	81.86	85.63	90.62	90.24	81.28
1996	11.00	17.93	29.29	39.15	54.83	61.95	68.91	75.71	81.04	88.99	89.69	80.15	80.03
1997	n/a	16.68	30.47	39.86	51.69	60.07	70.68	74.79	80.47	86.18	90.70	91.83	93.91
1998	11.00	15.66	27.69	38.79	48.67	59.68	70.44	73.48	78.51	88.47	89.04	91.74	92.21
1999	11.00	15.96	28.57	43.52	49.63	59.77	67.04	73.09	79.99	83.66	90.83	91.36	90.74
2000	11.00	15.26	28.53	38.55	49.22	61.80	66.41	74.43	76.07	81.00	69.93	84.44	79.05
2001	11.00	15.85	31.37	37.98	47.94	62.15	66.66	69.22	78.22	82.84	84.04	85.90	94.88
2002	11.00	14.90	28.46	39.19	47.64	61.58	66.37	71.05	74.53	81.24	91.16	90.20	95.10
2003	11.00	15.69	29.84	39.58	48.28	58.23	70.45	74.43	80.32	83.97	86.19	72.48	95.90
2004	11.00	15.97	27.27	37.64	48.44	60.75	70.15	75.47	78.63	84.45	87.55	90.26	94.84
2005	n/a	15.81	27.02	38.43	48.55	57.13	69.01	79.41	82.47	86.21	89.57	90.77	92.68
2006	n/a	14.52	30.90	38.55	47.56	56.93	69.65	76.22	84.25	86.81	91.37	93.81	97.37
2007	n/a	14.50	31.00	42.31	50.98	59.49	65.96	73.71	67.70	65.75	92.85	90.62	89.02
2008	11.00	15.91	26.90	41.32	53.38	61.28	71.04	75.48	83.03	86.57	86.74	94.38	93.93
2009	11.00	13.07	28.98	42.51	51.65	61.38	66.57	76.92	79.63	85.88	90.42	92.05	74.50
2010	n/a	15.48	28.56	43.53	53.85	64.88	72.78	76.18	83.13	86.21	90.94	92.54	79.14
2011	11.00	13.81	32.03	43.94	53.86	64.73	64.71	76.65	80.07	86.00	86.55	85.01	92.01

Number of samples at age (0 indicates mean length inferred from long-term average age-length key):

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
1994	0	40	213	143	109	89	73	26	12	7	1	2	0
1995	0	25	153	202	90	57	38	14	9	6	1	1	2
1996	0	34	143	138	183	101	65	37	5	2	0	1	2
1997	0	94	92	109	125	120	110	38	21	5	3	2	0
1998	0	56	145	97	94	73	88	47	28	6	0	1	0
1999	0	84	167	195	162	105	77	44	17	8	0	1	0
2000	0	112	102	131	204	177	83	21	20	7	6	1	0
2001	0	173	161	159	135	127	119	43	15	7	4	5	1
2002	1	114	165	206	189	85	91	70	16	6	2	0	2
2003	0	193	222	205	198	206	129	114	68	17	1	4	0
2004	0	150	134	205	133	160	136	62	35	17	4	4	0
2005	0	141	218	238	171	112	146	121	73	30	18	10	0
2006	0	205	176	179	168	155	140	133	93	36	10	4	1
2007	0	268	206	191	155	211	108	119	75	62	21	12	7
2008	0	141	262	244	188	134	97	45	45	28	13	8	6
2009	0	222	259	325	187	133	100	82	47	23	13	12	4
2010	0	105	344	229	296	144	71	48	30	13	5	7	0
2011	0	186	148	315	178	218	107	40	20	12	11	8	1

Table 2.11—Annual offsets to weight-length parameters used in Model 4.

Year	α offset	β offset
1977	1.357E-06	-4.548E-02
1978	-3.171E-06	1.665E-01
1979	6.182E-07	-2.191E-02
1980	-9.815E-07	3.355E-02
1981	-3.713E-08	-6.535E-03
1982	1.954E-06	-5.945E-02
1983	-3.956E-07	2.234E-02
1984	1.069E-05	-2.511E-01
1985	-1.740E-06	8.375E-02
1986	-2.963E-06	1.566E-01
1987	9.523E-07	-2.880E-02
1988	-2.888E-06	1.592E-01
1989	-1.982E-06	1.070E-01
1990	4.484E-07	-4.204E-03
1991	9.273E-07	-3.577E-02
1992	-5.052E-07	8.191E-03
1993	1.900E-06	-4.713E-02
1994	-2.472E-07	8.373E-03
1995	-1.693E-06	7.442E-02
1996	6.784E-06	-1.739E-01
1997	3.844E-07	-2.733E-02
1998	8.578E-07	-4.503E-02
1999	1.113E-06	-4.315E-02
2000	1.353E-06	-3.848E-02
2001	3.210E-06	-9.671E-02
2002	6.381E-07	-2.316E-02
2003	-1.058E-06	4.122E-02
2004	1.306E-06	-4.658E-02
2005	-7.270E-07	3.024E-02
2006	2.029E-07	-7.837E-03
2007	-2.620E-07	1.343E-02
2008	3.499E-06	-1.056E-01
2009	-1.490E-06	6.575E-02
2010	4.596E-07	-2.035E-02
2011	7.164E-08	-1.039E-02

Table 2.12a—Input multinomial sample sizes for length composition data as specified in Models 1-3 (S1…S5 = seasons 1-5, Srv. = shelf trawl survey).

	Trawl fishery					Longline fishery					Pot fishery					Srv.
Year	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	
1977			10	13												
1978				35		8	24		43	18						
1979			17		6	76	25	32	12	20						
1980	24	65				8	6	30	13	19						
1981			52		16	7	5	27		12						
1982		26	20	5	14		12	16	35	20						247
1983	20	73	28	11	155	85	89	49	55	60						308
1984	80	100	93	22	35	69	93	84	196	754						284
1985	76	253	10	16	6	323	69	8	386	1111						396
1986	87	206	81	46		236	29	101	208	976			12	14		361
1987	263	183	106	157	83	713	207	103	637	1306			5	15		248
1988	747	329	35	6	36	12										234
1989	643		70		12				39					9		234
1990	228	584	283	6		14	84	640	644	316			7	73		132
1991	442	1057	55			171	254	576	948	296			17	123	13	169
1992	110	757	58			407	751	1068	556		6	10	253	120		225
1993	171	937				506	746	86				94	37			244
1994	113	1394	85			614	885	187	455			211	109	71		326
1995	92	924		8		623	799	104	511	225	7	278	351	99	63	216
1996	68	1336	99	42	14	766	766	107	770	38		450	474	183	21	219
1997	131	1140	30			780	826	276	861	735		279	356	131	23	215
1998	78	975	33	39	5	669	596	115	1025	890		219	249	52		225
1999	247	587	13	16		769	819	248	1014	255		123	304	86		274
2000	206	547	37			710	410	135	1313	861	315	174				294
2001	77	317	43	54		579	696	339	1474	887	28	302	20	144	10	463
2002	168	328	93	126		1018	570	218	1780	726	83	168	17	130	17	287
2003	126	430	104	155		1326	832	335	1968	1044	274	13		141	41	290
2004	152	265	139	88		1083	693	288	1726	864	164	36	14	121	19	253
2005	213	283	116			1262	311	327	1723	850	149	23		141		265
2006	289	163	85	14		997	306	157	1723	85	207	51	12	143	30	284
2007	195	219	150			915	78	92	1264	58	219	24		104		300
2008	171	95	33	22		836	197	215	1610	480	125	27		128		304
2009	88	59	28	69		748	120	169	1540	448	126	21		54	15	391
2010	169	38	18	60		805	78	153	997	451	148			118	38	177
2011	252	144	38	87		511	692	435	1058	458	170			175		486
2012	340	129	47	10		595	563	441	88		210	30				307

Table 2.12b—Input multinomial sample sizes for length composition data as specified in Model 4.

Year	Fishery Season 1	Season 2	Season 3	Season 4	Season 5	Survey
1977			8	11		
1978	7	19		30	14	
1979	61	20	15	10	8	
1980	18	47	24	11	15	
1981	6	4	41		12	
1982		21	16	6	12	199
1983	19	59	23	12	117	249
1984	64	80	74	65	282	229
1985	100	175	8	118	441	319
1986	86	148	67	77	787	291
1987	301	152	85	305	614	200
1988	600	265	28	5	29	189
1989	518		56	31	10	189
1990	164	424	318	313	254	106
1991	315	750	273	699	230	137
1992	177	607	565	410		181
1993	258	686	63			197
1994	341	927	112	326		263
1995	281	671	211	208	162	174
1996	380	833	220	407	24	177
1997	395	763	197	606	578	173
1998	374	605	118	451	670	181
1999	466	514	172	602	206	221
2000	386	381	51	1058	694	237
2001	342	373	150	859	696	373
2002	611	304	87	1099	555	231
2003	649	488	137	1192	782	234
2004	535	355	131	1011	677	204
2005	642	208	150	1244	685	213
2006	530	148	79	1173	49	229
2007	519	156	116	888	47	242
2008	471	92	86	958	387	245
2009	434	57	63	945	328	315
2010	441	37	55	506	322	143
2011	280	363	242	537	369	392
2012	327	307	261	53		247

Table 2.13—Number of parameters and negative log-likelihoods. The data used by Models 1 and 2 are the same, but the data used by Models 1-2, 3, and 4 are all different, so likelihoods are comparable only between Models 1 and 2. Shaded cells indicate values that are not used in computing the total; "n/a" indicates that the data are not included in the file for the respective model.

	Model 1	Model 2	Model 3	Model 4
Number of parameters	184	185	182	143

Obj. func. component	Model 1	Model 2	Model 3	Model 4
Equilibrium catch	0.00	0.02	0.00	0.00
Catch per unit effort	-6.27	-23.13	-9.21	13.93
Size composition	4442.11	4412.66	4427.41	2565.36
Age composition	127.75	131.80	377.05	125.62
Recruitment	22.49	26.11	23.19	16.25
"Softbounds"	0.04	0.04	0.04	0.01
Deviations	19.54	19.67	15.53	19.90
Total	4605.67	4567.18	4456.96	2741.07

CPUE component	Model 1	Model 2	Model 3	Model 4
Jan-Apr trawl fishery	110.25	145.06	110.68	n/a
May-Jul trawl fishery	-5.54	-0.70	-5.27	n/a
Aug-Dec trawl fishery	53.91	64.46	52.09	n/a
Jan-Apr longline fishery	176.18	230.11	168.57	n/a
May-Jul longline fishery	3.51	4.19	0.74	n/a
Aug-Dec longline fishery	79.78	129.28	68.73	n/a
Jan-Apr pot fishery	-16.35	-4.80	-17.05	n/a
May-Jul pot fishery	-8.54	-7.54	-8.75	n/a
Aug-Dec pot fishery	6.69	12.98	6.96	n/a
Shelf trawl survey	-6.27	-23.13	-9.21	13.93

Sizecomp component	Model 1	Model 2	Model 3	Model 4
Jan-Apr trawl fishery	986.43	986.85	977.62	n/a
May-Jul trawl fishery	187.76	192.20	187.28	n/a
Aug-Dec trawl fishery	237.08	239.36	237.30	n/a
Jan-Apr longline fishery	676.45	688.24	675.01	n/a
May-Jul longline fishery	215.35	201.30	215.16	n/a
Aug-Dec longline fishery	944.60	914.43	936.56	n/a
Jan-Apr pot fishery	124.83	126.95	124.33	n/a
May-Jul pot fishery	70.05	70.54	71.05	n/a
Aug-Dec pot fishery	205.53	200.44	205.15	n/a
Shelf trawl survey	794.05	792.35	797.95	508.60
Season 1 fishery	n/a	n/a	n/a	545.81
Season 2 fishery	n/a	n/a	n/a	360.13
Season 3 fishery	n/a	n/a	n/a	409.24
Season 4 fishery	n/a	n/a	n/a	461.02
Season 5 fishery	n/a	n/a	n/a	280.55

Table 2.14—Root mean squared errors and observed:expected correlations for fishery CPUE and survey relative abundance time series. Color scale extends from red (minimum) to green (maximum). Fishery CPUE data are not used in fitting the models; fishery CPUE results are shown for comparison only.

	Root mean squared error			
Fleet	Model 1	Model 2	Model 3	Model 4
Jan-Apr trawl fishery	0.38	0.41	0.37	n/a
May-Jul trawl fishery	0.36	0.39	0.36	n/a
Aug-Dec trawl fishery	0.69	0.71	0.68	n/a
Jan-Apr longline fishery	0.30	0.33	0.30	n/a
May-Jul longline fishery	0.25	0.25	0.24	n/a
Aug-Dec longline fishery	0.21	0.22	0.21	n/a
Jan-Apr pot fishery	0.26	0.30	0.26	n/a
May-Jul pot fishery	0.22	0.22	0.21	n/a
Aug-Dec pot fishery	0.35	0.38	0.35	n/a
Shelf trawl survey	0.22	0.19	0.22	0.26
	Correlation (observed versus expected)			
Fleet	Model 1	Model 2	Model 3	Model 4
Jan-Apr trawl fishery	0.32	0.21	0.33	n/a
May-Jul trawl fishery	0.53	0.30	0.52	n/a
Aug-Dec trawl fishery	0.19	0.17	0.20	n/a
Jan-Apr longline fishery	-0.08	-0.10	-0.06	n/a
May-Jul longline fishery	0.43	0.43	0.47	n/a
Aug-Dec longline fishery	0.25	0.30	0.33	n/a
Jan-Apr pot fishery	0.19	-0.06	0.21	n/a
May-Jul pot fishery	0.15	0.10	0.17	n/a
Aug-Dec pot fishery	0.05	-0.05	0.07	n/a
Shelf trawl survey	0.72	0.77	0.73	0.65

Table 2.15—Average and standard deviation of normalized residuals for fishery CPUE and survey relative abundance time series. Color scale extends from red (minimum) to green (maximum). Fishery CPUE data are not used in fitting the models; fishery CPUE results are shown for comparison only.

	Average of normalized residuals			
Fleet	Model 1	Model 2	Model 3	Model 4
Jan-Apr trawl fishery	0.38	0.44	0.40	n/a
May-Jul trawl fishery	-0.12	-0.10	-0.13	n/a
Aug-Dec trawl fishery	0.32	0.33	0.31	n/a
Jan-Apr longline fishery	0.22	0.28	0.22	n/a
May-Jul longline fishery	0.07	0.03	0.08	n/a
Aug-Dec longline fishery	0.22	0.31	0.22	n/a
Jan-Apr pot fishery	0.09	0.12	0.10	n/a
May-Jul pot fishery	0.03	0.02	0.03	n/a
Aug-Dec pot fishery	-0.01	-0.02	-0.01	n/a
Shelf trawl survey	0.80	0.16	0.73	0.97
	Standard deviation of normalized residuals			
Fleet	Model 1	Model 2	Model 3	Model 4
Jan-Apr trawl fishery	3.07	3.32	3.07	n/a
May-Jul trawl fishery	1.48	1.63	1.48	n/a
Aug-Dec trawl fishery	2.30	2.45	2.27	n/a
Jan-Apr longline fishery	3.65	3.98	3.61	n/a
May-Jul longline fishery	2.16	2.18	2.10	n/a
Aug-Dec longline fishery	3.09	3.47	2.99	n/a
Jan-Apr pot fishery	1.52	1.80	1.50	n/a
May-Jul pot fishery	1.56	1.64	1.54	n/a
Aug-Dec pot fishery	1.84	1.95	1.84	n/a
Shelf trawl survey	1.91	1.78	1.89	2.17

Table 2.16—Number of records ("Nrec"), average input sample size ("Input N"), and average ratio of effective multinomial sample size to input sample size for each fishery and survey size composition time series. Note that the average input sample size for the trawl survey differs between Models 1-3 (N=279) and Model 4 (N=225). Color scale extends from red (minimum) to green (maximum).

Fleet	Nrec	Input N	Model 1	Model 2	Model 3	Model 4
Jan-Apr trawl fishery	60	323	5.567	5.522	5.586	n/a
May-Jul trawl fishery	31	66	9.142	9.208	9.113	n/a
Aug-Dec trawl fishery	34	43	12.768	12.643	12.770	n/a
Jan-Apr longline fishery	64	468	8.878	8.816	8.915	n/a
May-Jul longline fishery	31	224	9.551	9.978	9.486	n/a
Aug-Dec longline fishery	59	671	6.702	6.614	6.853	n/a
Jan-Apr pot fishery	32	140	13.260	13.059	13.415	n/a
May-Jul pot fishery	16	140	18.035	17.948	17.898	n/a
Aug-Dec pot fishery	33	78	10.328	10.244	10.380	n/a
Trawl survey	30	279/225	2.087	2.110	2.083	3.264
Jan-Feb fishery	33	326	n/a	n/a	n/a	7.827
Mar-Apr fishery	33	325	n/a	n/a	n/a	6.936
May-Jul fishery	34	123	n/a	n/a	n/a	8.087
Aug-Oct fishery	33	477	n/a	n/a	n/a	9.910
Nov-Dec fishery	30	324	n/a	n/a	n/a	8.779

Table 2.17—Input sample size ("Input N") and ratio of effective multinomial sample size to input N for each record of age composition data. Averages are shown in the bottom row. Color scale extends from red (minimum) to green (maximum).

	Models 1-3				Model 4	
Year	Input N	M1 ratio	M2 ratio	M3 ratio	Input N	M4 ratio
1994	208	2.075	1.731	0.180	177	2.219
1995	174	0.205	0.212	1.183	148	0.226
1996	207	1.477	1.123	0.320	176	1.714
1997	209	0.806	0.930	0.238	178	1.149
1998	184	4.730	3.910	0.146	156	4.760
1999	250	0.513	0.490	0.072	213	0.386
2000	251	0.464	0.317	0.143	213	0.270
2001	276	0.396	0.432	0.110	235	0.238
2002	275	0.327	0.263	0.072	234	0.363
2003	395	0.736	1.114	0.360	336	1.317
2004	302	0.108	0.114	0.040	257	0.144
2005	372	1.386	1.236	0.224	316	2.372
2006	378	0.376	0.337	0.106	321	0.398
2007	419	0.176	0.164	0.171	356	0.330
2008	352	0.563	0.724	0.059	299	0.772
2009	410	0.211	0.217	0.135	349	0.324
2010	375	0.545	0.477	0.050	319	0.877
2011	364	0.308	0.229	0.277	309	0.247
All	300	0.856	0.779	0.216	255	1.006

Table 2.18a—Growth, ageing bias, recruitment (except annual *devs*), catchability, initial fishing mortality, and initial age composition parameters as estimated internally by at least one of the assessment models. Shaded cells indicate that the parameter was not estimated internally in that particular model; "n/a" means that the parameter is not applicable to that particular model.

	Model 1		Model 2		Model 3		Model 4	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
Length at age 1 (cm)	14.117	0.107	14.143	0.109	14.117	0.108	13.763	0.159
Asymptotic length (cm)	91.972	0.533	95.906	0.761	91.333	0.535	90.002	0.878
Brody growth coefficient	0.243	0.003	0.231	0.003	0.246	0.003	0.285	0.013
Richards growth coefficient	n/a	n/a	n/a	n/a	n/a	n/a	0.812	0.058
SD of length at age 1 (cm)	3.512	0.069	3.634	0.074	3.525	0.070	3.410	0.085
SD of length at age 20 (cm)	10.146	0.166	9.849	0.188	10.147	0.165	10.236	0.212
Ageing bias at age 1 (years)	0.341	0.013	0.328	0.014	n/a	n/a	0.333	0.015
Ageing bias at age 20 (years)	0.457	0.160	0.733	0.171	n/a	n/a	0.581	0.183
ln(mean post-1976 recruitment)	13.224	0.019	13.025	0.024	13.236	0.021	13.442	0.077
σ(recruitment)	0.570	_	0.570	_	0.570	_	0.814	0.091
ln(pre-1977 recruitment offset)	-1.202	0.132	-1.517	0.108	-1.129	0.132	-1.287	0.216
ln(trawl survey catchability)	-0.261	_	0.045	0.031	-0.261	_	-0.288	_
Initial F (Jan-Apr trawl fishery)	0.671	0.146	1.744	0.600	0.591	0.123	n/a	n/a
Initial F (Jan-Feb fishery)	n/a	n/a	n/a	n/a	n/a	n/a	0.706	0.193
Initial age 10 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	-0.468	0.680
Initial age 9 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	-0.576	0.658
Initial age 8 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	-0.676	0.638
Initial age 7 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	-0.735	0.622
Initial age 6 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	-0.697	0.611
Initial age 5 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	-0.535	0.576
Initial age 4 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	-0.579	0.571
Initial age 3 ln(abundance) dev	1.283	0.189	1.267	0.173	1.306	0.191	1.380	0.254
Initial age 2 ln(abundance) dev	-0.718	0.418	-0.663	0.412	-0.695	0.421	-0.389	0.576
Initial age 1 ln(abundance) dev	1.316	0.217	1.240	0.205	1.335	0.221	1.623	0.269

Table 2.18b—Annual log-scale recruitment *dev*s estimated by Models 1-4. "Est." = point estimate, "SD" = standard deviation.

	Model 1		Model 2		Model 3		Model 4	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	1.333	0.108	1.074	0.106	1.450	0.111	1.292	0.144
1978	0.477	0.208	0.419	0.173	0.491	0.218	1.057	0.179
1979	0.651	0.111	0.652	0.093	0.671	0.114	0.421	0.183
1980	-0.394	0.133	-0.319	0.116	-0.379	0.134	-0.266	0.154
1981	-0.995	0.147	-1.020	0.140	-0.992	0.150	-0.769	0.161
1982	0.955	0.041	0.898	0.039	0.975	0.042	0.915	0.048
1983	-0.566	0.113	-0.503	0.100	-0.562	0.116	-0.768	0.150
1984	0.746	0.046	0.745	0.043	0.764	0.047	0.725	0.051
1985	-0.094	0.071	-0.016	0.065	-0.081	0.072	0.086	0.075
1986	-0.856	0.096	-0.698	0.087	-0.856	0.097	-0.854	0.118
1987	-1.213	0.112	-1.040	0.096	-1.230	0.116	-1.295	0.146
1988	-0.265	0.057	-0.282	0.054	-0.251	0.058	-0.273	0.071
1989	0.504	0.039	0.495	0.036	0.525	0.041	0.373	0.051
1990	0.320	0.044	0.392	0.040	0.343	0.046	0.312	0.054
1991	-0.338	0.062	-0.277	0.057	-0.320	0.065	-0.410	0.081
1992	0.598	0.032	0.606	0.030	0.624	0.035	0.477	0.039
1993	-0.431	0.058	-0.324	0.052	-0.519	0.071	-0.524	0.070
1994	-0.359	0.051	-0.325	0.047	-0.331	0.056	-0.581	0.063
1995	-0.293	0.054	-0.310	0.050	-0.301	0.060	-0.560	0.067
1996	0.663	0.032	0.636	0.031	0.681	0.035	0.483	0.038
1997	-0.230	0.051	-0.108	0.046	-0.215	0.057	-0.191	0.057
1998	-0.269	0.050	-0.196	0.046	-0.272	0.055	-0.205	0.059
1999	0.436	0.032	0.466	0.030	0.430	0.035	0.556	0.036
2000	-0.033	0.037	0.063	0.036	0.021	0.042	0.091	0.044
2001	-0.842	0.059	-0.748	0.054	-1.042	0.081	-0.721	0.068
2002	-0.285	0.039	-0.279	0.036	-0.199	0.042	-0.304	0.050
2003	-0.478	0.047	-0.490	0.043	-0.530	0.057	-0.451	0.058
2004	-0.598	0.053	-0.610	0.048	-0.514	0.058	-0.490	0.063
2005	-0.469	0.051	-0.555	0.048	-0.445	0.060	-0.401	0.067
2006	0.843	0.035	0.717	0.034	0.875	0.039	0.879	0.040
2007	-0.360	0.069	-0.417	0.065	-0.518	0.086	-0.114	0.080
2008	1.171	0.049	1.000	0.053	1.199	0.052	1.086	0.054
2009	-1.017	0.150	-1.082	0.142	-1.156	0.201	-1.265	0.170
2010	0.625	0.080	0.483	0.082	0.597	0.086	0.589	0.095
2011	1.064	0.127	0.958	0.129	1.067	0.129	1.101	0.153

Table 2.18c (page 1 of 2)—Fishery selectivity parameters estimated by Models 1-3.

	Model 1		Model 2		Model 3	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
P3_May-Jul_Trawl_Fishery	5.634	0.103	5.749	0.103	5.610	0.106
P2_Jan-Apr_Longline_Fishery	-4.924	2.122	-8.812	25.162	-4.664	1.617
P4_Jan-Apr_Longline_Fishery	5.084	0.141	5.154	0.104	5.063	0.140
P3_May-Jul_Longline_Fishery	5.008	0.052	5.076	0.050	4.993	0.052
P2_Aug-Dec_Longline_Fishery	-2.159	0.274	-2.166	0.280	-2.127	0.264
P4_Aug-Dec_Longline_Fishery	5.141	0.328	5.245	0.348	5.112	0.327
P2_Jan-Apr_Pot_Fishery	-9.295	17.184	-9.408	14.906	-9.264	17.790
P3_Jan-Apr_Pot_Fishery	5.008	0.050	5.023	0.049	5.007	0.050
P4_Jan-Apr_Pot_Fishery	4.441	0.286	4.428	0.315	4.436	0.283
P3_May-Jul_Pot_Fishery	4.920	0.082	4.956	0.078	4.912	0.082
P1_Jan-Apr_Trawl_Fishery_1977	68.941	3.106	71.321	2.980	68.308	3.074
P1_Jan-Apr_Trawl_Fishery_1985	76.402	1.675	78.351	1.590	75.555	1.710
P1_Jan-Apr_Trawl_Fishery_1990	68.576	1.084	71.616	1.069	68.039	1.098
P1_Jan-Apr_Trawl_Fishery_1995	73.803	0.933	75.260	0.938	73.334	0.935
P1_Jan-Apr_Trawl_Fishery_2000	78.235	1.184	79.649	1.215	78.134	1.191
P1_Jan-Apr_Trawl_Fishery_2005	75.385	0.842	76.221	0.867	75.265	0.844
P3_Jan-Apr_Trawl_Fishery_1977	6.167	0.174	6.204	0.157	6.153	0.176
P3_Jan-Apr_Trawl_Fishery_1985	6.627	0.076	6.639	0.069	6.608	0.079
P3_Jan-Apr_Trawl_Fishery_1990	6.075	0.058	6.191	0.052	6.052	0.060
P3_Jan-Apr_Trawl_Fishery_1995	6.288	0.046	6.322	0.044	6.278	0.046
P3_Jan-Apr_Trawl_Fishery_2000	6.300	0.060	6.311	0.059	6.302	0.061
P3_Jan-Apr_Trawl_Fishery_2005	6.018	0.051	6.035	0.051	6.017	0.051
P1_May-Jul_Trawl_Fishery_1977	50.262	1.695	52.743	1.827	49.684	1.692
P1_May-Jul_Trawl_Fishery_1985	51.294	1.737	53.649	1.782	50.824	1.758
P1_May-Jul_Trawl_Fishery_1990	61.894	1.519	64.338	1.671	61.391	1.542
P1_May-Jul_Trawl_Fishery_2000	53.087	1.505	55.019	1.591	52.692	1.530
P1_May-Jul_Trawl_Fishery_2005	58.749	1.444	60.485	1.534	58.480	1.454
P1_Aug-Dec_Trawl_Fishery_1977	62.524	3.992	63.915	4.294	62.501	3.976
P1_Aug-Dec_Trawl_Fishery_1980	81.941	5.601	85.763	6.032	80.840	5.796
P1_Aug-Dec_Trawl_Fishery_1985	86.656	5.326	88.058	5.017	85.676	5.244
P1_Aug-Dec_Trawl_Fishery_1990	45.637	14.856	44.559	11.235	45.683	15.172
P1_Aug-Dec_Trawl_Fishery_1995	102.470	0.941	102.466	1.081	102.471	0.915
P1_Aug-Dec_Trawl_Fishery_2000	57.417	2.021	59.312	2.349	57.059	2.060
P3_Aug-Dec_Trawl_Fishery_1977	5.554	0.327	5.584	0.324	5.553	0.327
P3_Aug-Dec_Trawl_Fishery_1980	6.661	0.227	6.722	0.220	6.646	0.240
P3_Aug-Dec_Trawl_Fishery_1985	6.615	0.229	6.609	0.208	6.592	0.232
P3_Aug-Dec_Trawl_Fishery_1990	3.223	4.256	3.013	3.746	3.244	4.308
P3_Aug-Dec_Trawl_Fishery_1995	7.015	0.091	6.981	0.090	7.025	0.091
P3_Aug-Dec_Trawl_Fishery_2000	5.267	0.204	5.410	0.214	5.244	0.211
P1_Jan-Apr_Longline_Fishery_1977	58.830	2.066	58.834	2.232	58.806	2.063
P1_Jan-Apr_Longline_Fishery_1980	72.432	2.475	73.747	2.547	71.848	2.530
P1_Jan-Apr_Longline_Fishery_1985	75.174	0.911	75.893	0.865	74.779	0.917
P1_Jan-Apr_Longline_Fishery_1990	66.033	0.474	67.055	0.474	65.869	0.477
P1_Jan-Apr_Longline_Fishery_1995	65.705	0.426	66.168	0.388	65.528	0.428
P1_Jan-Apr_Longline_Fishery_2000	63.529	0.445	64.227	0.392	63.457	0.447
P1_Jan-Apr_Longline_Fishery_2005	67.436	0.391	68.077	0.349	67.294	0.393
P3_Jan-Apr_Longline_Fishery_1977	5.142	0.210	5.117	0.217	5.141	0.209
P3_Jan-Apr_Longline_Fishery_1980	5.911	0.179	5.912	0.174	5.901	0.185
P3_Jan-Apr_Longline_Fishery_1985	5.859	0.067	5.856	0.063	5.850	0.068
P3_Jan-Apr_Longline_Fishery_1990	5.222	0.046	5.276	0.044	5.212	0.047
P3_Jan-Apr_Longline_Fishery_1995	5.300	0.040	5.317	0.037	5.293	0.040

Table 2.18c (page 2 of 2)—Fishery selectivity parameters estimated by Models 1-3.

	Model 1		Model 2		Model 3	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
P3_Jan-Apr_Longline_Fishery_2000	5.361	0.042	5.388	0.037	5.361	0.042
P3_Jan-Apr_Longline_Fishery_2005	5.339	0.034	5.375	0.031	5.333	0.034
P6_Jan-Apr_Longline_Fishery_1977	-1.329	0.798	-0.849	0.913	-1.325	0.791
P6_Jan-Apr_Longline_Fishery_1980	0.374	1.055	0.780	1.444	0.413	1.031
P6_Jan-Apr_Longline_Fishery_1985	-1.281	0.462	-1.532	0.525	-1.216	0.438
P6_Jan-Apr_Longline_Fishery_1990	-0.499	0.137	-0.455	0.147	-0.506	0.135
P6_Jan-Apr_Longline_Fishery_1995	-0.717	0.140	-0.635	0.146	-0.726	0.138
P6_Jan-Apr_Longline_Fishery_2000	-1.194	0.146	-1.152	0.151	-1.187	0.144
P6_Jan-Apr_Longline_Fishery_2005	-0.946	0.150	-0.975	0.156	-0.911	0.147
P1_May-Jul_Longline_Fishery_1977	63.269	2.223	64.457	2.209	63.143	2.212
P1_May-Jul_Longline_Fishery_1980	62.424	1.365	64.229	1.365	62.042	1.377
P1_May-Jul_Longline_Fishery_1985	63.292	1.122	64.456	1.123	62.965	1.123
P1_May-Jul_Longline_Fishery_1990	63.519	0.522	64.743	0.545	63.278	0.522
P1_May-Jul_Longline_Fishery_2000	59.809	0.562	60.815	0.580	59.626	0.564
P1_May-Jul_Longline_Fishery_2005	64.396	0.548	65.375	0.563	64.197	0.547
P1_Aug-Dec_Longline_Fishery_1977	60.535	2.171	60.969	2.364	60.490	2.163
P1_Aug-Dec_Longline_Fishery_1980	69.691	1.599	70.588	1.625	69.091	1.615
P1_Aug-Dec_Longline_Fishery_1985	64.449	0.753	65.630	0.764	64.026	0.757
P1_Aug-Dec_Longline_Fishery_1990	67.036	0.715	68.105	0.732	66.847	0.728
P1_Aug-Dec_Longline_Fishery_1995	69.394	0.692	70.568	0.693	68.985	0.695
P1_Aug-Dec_Longline_Fishery_2000	63.585	0.427	64.459	0.439	63.442	0.434
P1_Aug-Dec_Longline_Fishery_2005	62.843	0.394	63.794	0.406	62.765	0.398
P3_Aug-Dec_Longline_Fishery_1977	4.519	0.321	4.541	0.329	4.512	0.321
P3_Aug-Dec_Longline_Fishery_1980	5.410	0.134	5.434	0.131	5.380	0.138
P3_Aug-Dec_Longline_Fishery_1985	4.878	0.086	4.962	0.081	4.842	0.089
P3_Aug-Dec_Longline_Fishery_1990	5.032	0.076	5.086	0.073	5.022	0.077
P3_Aug-Dec_Longline_Fishery_1995	5.499	0.053	5.548	0.050	5.478	0.054
P3_Aug-Dec_Longline_Fishery_2000	5.179	0.041	5.226	0.040	5.173	0.042
P3_Aug-Dec_Longline_Fishery_2005	4.937	0.040	5.009	0.040	4.933	0.041
P6_Aug-Dec_Longline_Fishery_1977	-2.652	2.253	-2.137	2.324	-2.622	2.191
P6_Aug-Dec_Longline_Fishery_1980	0.417	0.767	0.499	0.919	0.462	0.735
P6_Aug-Dec_Longline_Fishery_1985	0.206	0.253	0.057	0.283	0.174	0.242
P6_Aug-Dec_Longline_Fishery_1990	2.416	0.888	2.481	1.033	2.349	0.828
P6_Aug-Dec_Longline_Fishery_1995	9.449	14.049	9.530	12.306	9.412	14.834
P6_Aug-Dec_Longline_Fishery_2000	-0.386	0.193	-0.380	0.226	-0.365	0.189
P6_Aug-Dec_Longline_Fishery_2005	9.752	7.035	9.818	5.288	9.767	6.654
P1_Jan-Apr_Pot_Fishery_1977	68.758	0.918	69.412	0.944	68.683	0.917
P1_Jan-Apr_Pot_Fishery_1995	68.486	0.550	68.883	0.552	68.385	0.552
P1_Jan-Apr_Pot_Fishery_2000	68.139	0.521	68.665	0.528	68.096	0.522
P1_Jan-Apr_Pot_Fishery_2005	68.660	0.520	69.118	0.526	68.590	0.521
P6_Jan-Apr_Pot_Fishery_1977	0.210	0.552	0.384	0.639	0.190	0.542
P6_Jan-Apr_Pot_Fishery_1995	-0.260	0.249	-0.147	0.265	-0.273	0.246
P6_Jan-Apr_Pot_Fishery_2000	-0.573	0.235	-0.506	0.251	-0.577	0.233
P6_Jan-Apr_Pot_Fishery_2005	0.198	0.231	0.276	0.246	0.207	0.230
P1_May-Jul_Pot_Fishery_1977	67.231	0.857	68.109	0.846	67.072	0.852
P1_May-Jul_Pot_Fishery_1995	65.929	0.721	66.633	0.716	65.741	0.718
P1_Aug-Dec_Pot_Fishery_1977	68.416	1.173	69.389	1.176	68.182	1.171
P1_Aug-Dec_Pot_Fishery_2000	63.063	0.708	63.607	0.733	62.988	0.728
P3_Aug-Dec_Pot_Fishery_1977	5.186	0.119	5.230	0.114	5.177	0.120
P3_Aug-Dec_Pot_Fishery_2000	4.545	0.105	4.583	0.105	4.541	0.108

Table 2.18d—Fishery selectivity parameters estimated by Model 4.

Parameter	Estimate	St. Dev.
P1_Season1_Fishery	68.894	0.494
P2_Season1_Fishery	-9.432	14.418
P3_Season1_Fishery	5.711	0.033
P4_Season1_Fishery	5.018	0.223
P6_Season1_Fishery	-0.224	0.159
P1_Season2_Fishery	69.074	0.575
P2_Season2_Fishery	-9.359	15.917
P3_Season2_Fishery	5.908	0.034
P4_Season2_Fishery	4.766	0.282
P6_Season2_Fishery	0.165	0.158
P1_Season3_Fishery	66.114	0.749
P3_Season3_Fishery	5.696	0.054
P1_Season4_Fishery	64.536	0.425
P2_Season4_Fishery	-1.784	0.328
P3_Season4_Fishery	5.100	0.039
P4_Season4_Fishery	1.534	2.210
P6_Season4_Fishery	2.068	0.325
P1_Season5_Fishery	63.632	0.542
P2_Season5_Fishery	-1.971	0.452
P3_Season5_Fishery	5.168	0.049
P4_Season5_Fishery	5.097	0.641
P6_Season5_Fishery	0.268	0.271

Table 2.18e—Survey selectivity parameters as estimated by Models 1-3.

	Model 1		Model 2		Model 3	
Parameter	Estimate	St. dev.	Estimate	St. dev.	Estimate	St. dev.
P1	1.292	0.062	1.291	0.061	1.344	0.086
P2	-3.749	0.853	-12.659	94.244	-2.505	0.420
P3	-1.991	0.455	-2.064	0.452	-1.685	0.527
P4	3.033	0.307	3.201	0.235	1.109	0.807
P5	-9.986	0.425	-9.988	0.363	-9.995	0.158
P6	-1.383	0.420	-1.074	0.421	-0.499	0.185
P3_dev_1982	-0.049	0.034	-0.052	0.032	-0.047	0.033
P3_dev_1983	-0.056	0.017	-0.054	0.016	-0.057	0.016
P3_dev_1984	-0.091	0.028	-0.095	0.025	-0.089	0.027
P3_dev_1985	-0.012	0.021	-0.015	0.019	-0.013	0.020
P3_dev_1986	-0.060	0.022	-0.065	0.020	-0.057	0.022
P3_dev_1987	0.025	0.042	-0.005	0.034	0.025	0.041
P3_dev_1988	-0.084	0.033	-0.099	0.028	-0.080	0.032
P3_dev_1989	-0.129	0.018	-0.126	0.018	-0.125	0.018
P3_dev_1990	-0.044	0.020	-0.048	0.019	-0.044	0.020
P3_dev_1991	-0.056	0.022	-0.062	0.020	-0.055	0.021
P3_dev_1992	0.077	0.042	0.068	0.039	0.077	0.041
P3_dev_1993	0.035	0.029	0.034	0.028	0.035	0.029
P3_dev_1994	-0.055	0.021	-0.060	0.019	-0.048	0.027
P3_dev_1995	-0.105	0.019	-0.103	0.019	-0.090	0.024
P3_dev_1996	-0.126	0.017	-0.119	0.017	-0.116	0.021
P3_dev_1997	-0.081	0.015	-0.075	0.014	-0.078	0.017
P3_dev_1998	-0.088	0.018	-0.095	0.017	-0.086	0.022
P3_dev_1999	-0.091	0.017	-0.092	0.016	-0.086	0.020
P3_dev_2000	-0.055	0.015	-0.054	0.015	-0.052	0.017
P3_dev_2001	0.137	0.037	0.115	0.034	0.111	0.038
P3_dev_2002	-0.030	0.023	-0.034	0.021	0.000	0.035
P3_dev_2003	-0.017	0.019	-0.010	0.018	-0.013	0.024
P3_dev_2004	-0.039	0.019	-0.033	0.018	-0.024	0.025
P3_dev_2005	0.023	0.025	0.028	0.024	0.038	0.034
P3_dev_2006	0.130	0.037	0.138	0.037	0.107	0.039
P3_dev_2007	0.181	0.037	0.193	0.037	0.135	0.039
P3_dev_2008	0.098	0.038	0.088	0.035	0.091	0.042
P3_dev_2009	-0.003	0.017	0.010	0.017	-0.014	0.018
P3_dev_2010	-0.015	0.036	-0.021	0.032	0.002	0.051

Table 2.18f—Survey selectivity parameters as estimated by Model 4.

Par.	Estimate	St. dev.	P3 dev	Estimate	St. dev.	P5 dev	Estimate	St. dev.
P1	27.376	1.167	1982	-3.080	1.416	1982	-0.649	0.475
P2	-1.526	0.184	1983	-2.987	1.181	1982	-0.158	0.300
P3	4.042	0.477	1984	-0.378	0.597	1982	-0.767	0.577
P4	6.749	0.271	1985	0.598	0.418	1982	-1.673	0.661
P5	-0.396	0.216	1986	-1.593	0.641	1982	-0.625	0.356
P6	-1.184	0.328	1987	0.924	0.717	1982	-0.690	0.999
			1988	-0.301	0.757	1982	-0.996	0.727
			1989	-2.702	1.320	1982	-1.480	0.360
			1990	-1.780	1.115	1982	0.067	0.350
			1991	-0.943	0.829	1982	-0.391	0.383
			1992	1.683	1.010	1982	-0.281	1.095
			1993	1.473	0.898	1982	-0.422	1.023
			1994	0.240	0.578	1982	-1.063	0.756
			1995	-0.361	0.629	1982	-1.264	0.597
			1996	-0.855	0.857	1982	-1.517	0.542
			1997	-0.302	0.491	1982	-1.132	0.400
			1998	-2.079	0.810	1982	-1.033	0.331
			1999	-1.367	0.610	1982	-1.113	0.324
			2000	-3.293	1.051	1982	-0.560	0.263
			2001	2.260	0.881	1982	-0.811	0.942
			2002	-2.678	1.190	1982	-0.094	0.347
			2003	0.832	0.465	1982	-1.348	0.811
			2004	0.444	0.541	1982	-1.109	0.792
			2005	0.938	0.441	1982	-1.609	0.805
			2006	-1.751	2.173	1982	1.846	0.532
			2007	2.219	1.387	1982	2.591	0.765
			2008	-1.678	0.853	1982	0.912	0.395
			2009	-2.374	0.952	1982	0.728	0.294
			2010	-1.346	1.260	1982	0.538	0.574

Table 2.19a— Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model 1). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov-Dec. Rates have been 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	0.087	0.090	0.056	0.049	0.043	0.017	0.017	0.006	0.024	0.032	0	0	0	0	0	0.081
1978	0.099	0.103	0.067	0.057	0.050	0.017	0.017	0.006	0.026	0.035	0	0	0	0	0	0.093
1979	0.072	0.074	0.044	0.040	0.034	0.013	0.013	0.005	0.019	0.025	0	0	0	0	0	0.066
1980	0.064	0.063	0.031	0.042	0.035	0.010	0.010	0.004	0.014	0.017	0	0	0	0	0	0.056
1981	0.034	0.033	0.032	0.064	0.061	0.004	0.004	0.002	0.009	0.011	0	0	0	0	0	0.051
1982	0.035	0.035	0.036	0.045	0.036	0.001	0.001	0.001	0.004	0.005	0	0	0	0	0	0.040
1983	0.054	0.057	0.051	0.053	0.044	0.005	0.005	0.003	0.004	0.005	0	0	0	0	0	0.056
1984	0.062	0.066	0.057	0.056	0.049	0.007	0.008	0.006	0.028	0.038	0	0	0	0	0	0.075
1985	0.078	0.084	0.066	0.065	0.051	0.024	0.026	0.010	0.034	0.047	0	0	0	0	0	0.096
1986	0.088	0.093	0.066	0.065	0.053	0.017	0.019	0.005	0.027	0.038	0	0	0	0	0	0.092
1987	0.096	0.103	0.052	0.053	0.052	0.042	0.045	0.013	0.042	0.060	0	0	0	0	0	0.107
1988	0.194	0.209	0.101	0.113	0.120	0.001	0.001	0.002	0.003	0.004	0	0	0	0	0	0.143
1989	0.206	0.224	0.098	0.059	0.054	0.008	0.009	0.012	0.015	0.013	0.000	0.000	0.000	0.000	0.000	0.132
1990	0.174	0.191	0.092	0.029	0.025	0.031	0.034	0.047	0.051	0.047	0.000	0.000	0.002	0.002	0.001	0.139
1991	0.179	0.378	0.067	0.048	0.000	0.061	0.105	0.087	0.099	0.108	0.000	0.000	0.002	0.010	0.004	0.217
1992	0.147	0.223	0.055	0.033	0.010	0.133	0.240	0.141	0.091	0.000	0.000	0.002	0.030	0.011	0.000	0.216
1993	0.187	0.256	0.028	0.037	0.011	0.223	0.229	0.027	0.000	0.000	0.000	0.011	0.006	0.000	0.000	0.177
1994	0.085	0.293	0.019	0.075	0.014	0.188	0.263	0.029	0.103	0.000	0.000	0.031	0.009	0.016	0.000	0.208
1995	0.210	0.422	0.005	0.193	0.002	0.241	0.308	0.020	0.106	0.057	0.001	0.076	0.039	0.015	0.010	0.316
1996	0.141	0.367	0.037	0.105	0.021	0.235	0.260	0.018	0.118	0.023	0.000	0.126	0.054	0.022	0.005	0.285
1997	0.175	0.396	0.024	0.097	0.024	0.262	0.279	0.042	0.113	0.193	0.000	0.097	0.040	0.020	0.005	0.323
1998	0.122	0.224	0.022	0.136	0.016	0.287	0.208	0.023	0.093	0.116	0.000	0.062	0.034	0.011	0.000	0.252
1999	0.147	0.214	0.016	0.063	0.004	0.329	0.236	0.019	0.121	0.042	0.000	0.062	0.034	0.013	0.000	0.239
2000	0.164	0.215	0.019	0.027	0.003	0.291	0.081	0.008	0.126	0.136	0.132	0.049	0.000	0.001	0.000	0.223
2001	0.068	0.116	0.015	0.035	0.005	0.165	0.148	0.018	0.156	0.149	0.001	0.114	0.003	0.018	0.004	0.190
2002	0.103	0.174	0.031	0.035	0.002	0.307	0.137	0.008	0.184	0.110	0.018	0.087	0.005	0.015	0.006	0.226
2003	0.126	0.136	0.028	0.031	0.000	0.312	0.161	0.013	0.183	0.137	0.136	0.018	0.000	0.024	0.010	0.243
2004	0.169	0.146	0.041	0.038	0.000	0.328	0.159	0.013	0.171	0.165	0.088	0.030	0.005	0.019	0.004	0.254
2005	0.223	0.136	0.036	0.014	0.001	0.455	0.071	0.020	0.191	0.167	0.087	0.033	0.000	0.025	0.003	0.268
2006	0.267	0.146	0.036	0.025	0.000	0.521	0.078	0.013	0.267	0.009	0.121	0.042	0.002	0.025	0.008	0.291
2007	0.169	0.194	0.066	0.020	0.001	0.568	0.028	0.009	0.213	0.008	0.140	0.017	0.004	0.036	0.000	0.274
2008	0.184	0.094	0.027	0.042	0.006	0.608	0.059	0.021	0.253	0.089	0.129	0.031	0.002	0.050	0.001	0.299
2009	0.157	0.134	0.026	0.059	0.003	0.698	0.062	0.019	0.254	0.103	0.151	0.030	0.001	0.010	0.012	0.317
2010	0.189	0.098	0.021	0.050	0.010	0.512	0.026	0.016	0.133	0.098	0.150	0.025	0.002	0.031	0.015	0.251
2011	0.194	0.199	0.028	0.049	0.009	0.272	0.258	0.073	0.143	0.110	0.158	0.025	0.008	0.045	0.000	0.291
2012	0.294	0.117	0.032	0.038	0.006	0.253	0.197	0.093	0.115	0.073	0.164	0.021	0.001	0.021	0.005	0.263

Table 2.19b—Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model 2). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov-Dec. Rates have been 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	0.211	0.217	0.121	0.111	0.095	0.033	0.033	0.014	0.049	0.063	0	0	0	0	0	0.182
1978	0.226	0.233	0.141	0.123	0.109	0.032	0.033	0.014	0.050	0.068	0	0	0	0	0	0.199
1979	0.159	0.164	0.091	0.084	0.071	0.024	0.025	0.010	0.037	0.049	0	0	0	0	0	0.138
1980	0.136	0.133	0.059	0.090	0.074	0.022	0.021	0.008	0.028	0.034	0	0	0	0	0	0.116
1981	0.066	0.063	0.055	0.127	0.118	0.007	0.007	0.004	0.016	0.019	0	0	0	0	0	0.097
1982	0.061	0.061	0.057	0.081	0.063	0.001	0.001	0.002	0.006	0.008	0	0	0	0	0	0.069
1983	0.088	0.090	0.076	0.089	0.073	0.007	0.008	0.004	0.006	0.008	0	0	0	0	0	0.089
1984	0.094	0.099	0.083	0.089	0.077	0.011	0.012	0.009	0.041	0.055	0	0	0	0	0	0.113
1985	0.117	0.125	0.096	0.098	0.077	0.035	0.038	0.015	0.049	0.068	0	0	0	0	0	0.141
1986	0.129	0.137	0.094	0.097	0.078	0.025	0.027	0.008	0.038	0.054	0	0	0	0	0	0.134
1987	0.139	0.148	0.073	0.077	0.075	0.061	0.065	0.018	0.059	0.083	0	0	0	0	0	0.152
1988	0.275	0.296	0.137	0.162	0.172	0.002	0.002	0.002	0.004	0.005	0	0	0	0	0	0.201
1989	0.288	0.312	0.132	0.083	0.076	0.011	0.012	0.016	0.020	0.017	0.000	0.000	0.000	0.000	0.000	0.182
1990	0.237	0.261	0.124	0.038	0.033	0.041	0.045	0.063	0.069	0.063	0.000	0.000	0.003	0.003	0.001	0.189
1991	0.243	0.519	0.093	0.064	0.000	0.080	0.138	0.119	0.136	0.149	0.000	0.000	0.003	0.015	0.006	0.296
1992	0.205	0.316	0.078	0.044	0.013	0.177	0.324	0.198	0.129	0.000	0.001	0.002	0.043	0.016	0.000	0.300
1993	0.265	0.367	0.039	0.048	0.014	0.302	0.312	0.038	0.000	0.000	0.000	0.016	0.009	0.000	0.000	0.246
1994	0.118	0.405	0.026	0.096	0.018	0.245	0.344	0.039	0.138	0.000	0.000	0.040	0.013	0.021	0.000	0.278
1995	0.281	0.572	0.007	0.266	0.002	0.307	0.398	0.028	0.144	0.077	0.001	0.099	0.052	0.020	0.014	0.421
1996	0.190	0.500	0.050	0.145	0.029	0.303	0.339	0.025	0.160	0.031	0.000	0.165	0.074	0.030	0.007	0.382
1997	0.237	0.543	0.033	0.134	0.033	0.339	0.366	0.057	0.155	0.265	0.001	0.128	0.055	0.028	0.007	0.435
1998	0.169	0.312	0.030	0.192	0.022	0.379	0.278	0.031	0.130	0.162	0.000	0.084	0.047	0.015	0.001	0.346
1999	0.205	0.303	0.022	0.090	0.005	0.442	0.320	0.027	0.172	0.059	0.000	0.084	0.048	0.018	0.000	0.331
2000	0.235	0.309	0.025	0.036	0.005	0.388	0.109	0.011	0.167	0.180	0.181	0.067	0.000	0.001	0.000	0.306
2001	0.095	0.162	0.019	0.047	0.006	0.214	0.192	0.024	0.203	0.194	0.002	0.151	0.004	0.024	0.005	0.251
2002	0.140	0.240	0.040	0.046	0.002	0.393	0.176	0.011	0.237	0.142	0.023	0.114	0.007	0.019	0.007	0.296
2003	0.171	0.186	0.036	0.040	0.001	0.396	0.205	0.017	0.234	0.175	0.177	0.023	0.000	0.032	0.013	0.314
2004	0.227	0.197	0.053	0.049	0.001	0.411	0.200	0.017	0.216	0.209	0.112	0.039	0.006	0.024	0.006	0.325
2005	0.294	0.181	0.047	0.019	0.001	0.583	0.092	0.026	0.251	0.219	0.112	0.043	0.000	0.033	0.004	0.349
2006	0.359	0.199	0.049	0.033	0.001	0.684	0.104	0.017	0.362	0.013	0.159	0.056	0.003	0.034	0.011	0.389
2007	0.234	0.273	0.091	0.028	0.001	0.769	0.039	0.012	0.297	0.011	0.190	0.023	0.005	0.050	0.000	0.377
2008	0.263	0.136	0.038	0.060	0.009	0.848	0.083	0.031	0.365	0.130	0.180	0.045	0.003	0.072	0.002	0.425
2009	0.235	0.206	0.039	0.089	0.005	1.021	0.093	0.029	0.385	0.157	0.221	0.045	0.001	0.015	0.018	0.473
2010	0.296	0.155	0.032	0.076	0.015	0.773	0.040	0.025	0.202	0.149	0.230	0.038	0.003	0.047	0.023	0.383
2011	0.304	0.318	0.044	0.078	0.014	0.412	0.399	0.116	0.228	0.176	0.241	0.039	0.013	0.071	0.000	0.455
2012	0.482	0.195	0.052	0.063	0.010	0.402	0.320	0.154	0.189	0.120	0.264	0.034	0.001	0.034	0.009	0.429

Table 2.19c—Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model 3). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov-Dec. Rates have been 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	0.076	0.079	0.050	0.044	0.038	0.015	0.015	0.005	0.022	0.028	0	0	0	0	0	0.072
1978	0.087	0.090	0.060	0.051	0.045	0.015	0.016	0.006	0.023	0.031	0	0	0	0	0	0.082
1979	0.063	0.065	0.039	0.035	0.030	0.011	0.012	0.004	0.017	0.022	0	0	0	0	0	0.058
1980	0.056	0.055	0.028	0.036	0.030	0.009	0.009	0.003	0.012	0.015	0	0	0	0	0	0.049
1981	0.030	0.029	0.029	0.055	0.052	0.003	0.003	0.002	0.008	0.009	0	0	0	0	0	0.045
1982	0.031	0.031	0.032	0.039	0.031	0.001	0.001	0.001	0.003	0.004	0	0	0	0	0	0.035
1983	0.049	0.051	0.046	0.047	0.039	0.004	0.004	0.002	0.004	0.005	0	0	0	0	0	0.050
1984	0.056	0.060	0.052	0.050	0.044	0.007	0.007	0.005	0.025	0.035	0	0	0	0	0	0.068
1985	0.071	0.076	0.061	0.059	0.046	0.022	0.024	0.009	0.032	0.044	0	0	0	0	0	0.087
1986	0.080	0.086	0.062	0.059	0.048	0.016	0.017	0.005	0.025	0.036	0	0	0	0	0	0.085
1987	0.089	0.095	0.049	0.049	0.048	0.040	0.042	0.012	0.040	0.057	0	0	0	0	0	0.099
1988	0.181	0.194	0.095	0.104	0.111	0.001	0.001	0.001	0.003	0.003	0	0	0	0	0	0.133
1989	0.193	0.209	0.093	0.054	0.050	0.008	0.008	0.011	0.014	0.012	0.000	0.000	0.000	0.000	0.000	0.123
1990	0.164	0.180	0.087	0.028	0.024	0.030	0.033	0.044	0.049	0.044	0.000	0.000	0.002	0.002	0.001	0.132
1991	0.170	0.358	0.064	0.045	0.000	0.058	0.100	0.082	0.094	0.102	0.000	0.000	0.002	0.010	0.004	0.206
1992	0.139	0.211	0.052	0.031	0.010	0.126	0.228	0.133	0.087	0.000	0.000	0.001	0.028	0.010	0.000	0.205
1993	0.176	0.241	0.026	0.035	0.010	0.212	0.217	0.025	0.000	0.000	0.000	0.011	0.006	0.000	0.000	0.168
1994	0.081	0.277	0.018	0.071	0.014	0.179	0.250	0.028	0.098	0.000	0.000	0.029	0.009	0.015	0.000	0.198
1995	0.198	0.397	0.005	0.182	0.001	0.230	0.293	0.019	0.100	0.054	0.001	0.073	0.037	0.014	0.010	0.299
1996	0.133	0.345	0.035	0.099	0.020	0.223	0.247	0.017	0.111	0.022	0.000	0.119	0.051	0.021	0.005	0.269
1997	0.166	0.374	0.023	0.091	0.022	0.251	0.267	0.040	0.107	0.183	0.000	0.092	0.038	0.019	0.005	0.306
1998	0.116	0.213	0.021	0.129	0.015	0.276	0.200	0.022	0.089	0.111	0.000	0.060	0.033	0.011	0.000	0.241
1999	0.140	0.204	0.015	0.060	0.003	0.318	0.227	0.018	0.116	0.040	0.000	0.059	0.033	0.012	0.000	0.229
2000	0.157	0.206	0.018	0.026	0.003	0.280	0.078	0.008	0.121	0.131	0.128	0.047	0.000	0.001	0.000	0.215
2001	0.065	0.111	0.014	0.034	0.005	0.159	0.143	0.018	0.151	0.144	0.001	0.110	0.003	0.018	0.004	0.183
2002	0.099	0.168	0.030	0.033	0.001	0.296	0.132	0.008	0.177	0.106	0.017	0.084	0.005	0.014	0.005	0.218
2003	0.122	0.131	0.027	0.030	0.000	0.302	0.156	0.012	0.177	0.133	0.132	0.017	0.000	0.024	0.010	0.235
2004	0.163	0.141	0.040	0.037	0.000	0.317	0.153	0.013	0.165	0.160	0.085	0.029	0.005	0.018	0.004	0.245
2005	0.216	0.132	0.035	0.014	0.001	0.440	0.069	0.019	0.186	0.162	0.084	0.032	0.000	0.025	0.003	0.260
2006	0.259	0.141	0.035	0.024	0.000	0.505	0.075	0.012	0.259	0.009	0.117	0.041	0.002	0.025	0.008	0.282
2007	0.163	0.187	0.064	0.019	0.001	0.547	0.027	0.009	0.206	0.008	0.135	0.016	0.004	0.035	0.000	0.265
2008	0.177	0.090	0.025	0.040	0.006	0.583	0.056	0.020	0.242	0.085	0.124	0.030	0.002	0.048	0.001	0.287
2009	0.149	0.127	0.025	0.056	0.003	0.660	0.059	0.018	0.241	0.098	0.143	0.029	0.001	0.010	0.011	0.301
2010	0.179	0.093	0.020	0.048	0.010	0.481	0.025	0.016	0.126	0.093	0.142	0.023	0.002	0.029	0.014	0.237
2011	0.184	0.189	0.027	0.047	0.008	0.259	0.247	0.069	0.138	0.106	0.151	0.024	0.008	0.043	0.000	0.278
2012	0.282	0.112	0.031	0.037	0.006	0.244	0.190	0.090	0.111	0.071	0.158	0.020	0.001	0.020	0.005	0.253

Table 2.19d—Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model 4). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov-Dec. Rates have been multiplied by relative season length before summing to get total.

Year	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.229	0.218	0.131	0.128	0.123	0.159
1978	0.222	0.207	0.127	0.118	0.116	0.152
1979	0.132	0.125	0.080	0.075	0.069	0.093
1980	0.107	0.095	0.058	0.052	0.045	0.069
1981	0.046	0.041	0.045	0.057	0.053	0.049
1982	0.036	0.034	0.038	0.034	0.028	0.034
1983	0.055	0.055	0.048	0.040	0.036	0.047
1984	0.074	0.076	0.061	0.071	0.079	0.071
1985	0.095	0.099	0.069	0.069	0.074	0.079
1986	0.103	0.105	0.066	0.063	0.069	0.078
1987	0.136	0.138	0.062	0.070	0.089	0.094
1988	0.199	0.202	0.094	0.076	0.087	0.124
1989	0.210	0.216	0.095	0.048	0.048	0.115
1990	0.209	0.219	0.115	0.070	0.068	0.129
1991	0.257	0.499	0.134	0.144	0.108	0.214
1992	0.293	0.450	0.199	0.131	0.014	0.209
1993	0.389	0.448	0.051	0.042	0.013	0.165
1994	0.266	0.569	0.052	0.190	0.018	0.203
1995	0.438	0.747	0.055	0.199	0.064	0.272
1996	0.373	0.714	0.103	0.181	0.039	0.259
1997	0.470	0.809	0.109	0.191	0.234	0.327
1998	0.456	0.548	0.086	0.200	0.152	0.264
1999	0.545	0.571	0.075	0.190	0.051	0.261
2000	0.617	0.356	0.035	0.168	0.149	0.238
2001	0.257	0.378	0.044	0.230	0.168	0.202
2002	0.438	0.389	0.054	0.241	0.116	0.231
2003	0.538	0.290	0.046	0.227	0.134	0.229
2004	0.515	0.284	0.061	0.201	0.145	0.223
2005	0.638	0.201	0.051	0.212	0.163	0.233
2006	0.745	0.218	0.046	0.289	0.017	0.247
2007	0.683	0.201	0.069	0.237	0.008	0.225
2008	0.731	0.146	0.043	0.310	0.091	0.250
2009	0.748	0.169	0.041	0.295	0.104	0.254
2010	0.647	0.109	0.036	0.197	0.110	0.203
2011	0.487	0.362	0.093	0.225	0.112	0.240
2012	0.552	0.253	0.108	0.164	0.079	0.215

Table 2.20—Summary of key management reference points from the standard projection algorithm (last seven rows are from SS). All biomass figures are in t. Color scale extends from red (minimum) to green (maximum).

Quantity	Model 1	Model 2	Model 3	Model 4
B100%	896,000	755,000	916,000	958,000
B40%	358,000	302,000	366,000	383,000
B35%	314,000	264,000	321,000	335,000
B(2013)	422,000	258,000	435,000	487,000
B(2014)	447,000	299,000	456,000	491,000
B(2013)/B100%	0.47	0.34	0.47	0.51
B(2014)/B100%	0.50	0.40	0.50	0.51
F40%	0.29	0.28	0.28	0.30
F35%	0.34	0.34	0.34	0.35
maxFABC(2013)	0.29	0.24	0.28	0.30
maxFABC(2014)	0.29	0.28	0.28	0.30
maxABC(2013)	307,000	163,000	316,000	339,000
maxABC(2014)	323,000	215,000	330,000	336,000
FOFL(2013)	0.34	0.29	0.34	0.35
FOFL(2014)	0.34	0.33	0.34	0.35
OFL(2013)	359,000	190,000	370,000	396,000
OFL(2014)	379,000	250,000	387,000	394,000
Pr(maxABC(2013)>truOFL(2013))	0.005	0.178	0.007	0.008
Pr(maxABC(2014)>truOFL(2014))	0.014	0.181	0.017	0.022
Pr(B(2013)<B20%)	~0	~0	~0	~0
Pr(B(2014)<B20%)	~0	~0	~0	~0
Pr(B(2015)<B20%)	~0	~0	~0	~0
Pr(B(2016)<B20%)	~0	~0	~0	~0
Pr(B(2017)<B20%)	~0	~0	~0	~0

Legend:
B100% = equilibrium unfished spawning biomass
B40% = 40% of B100% (the inflection point of the harvest control rules in Tier 3)
B35% = 35% of B100% (the BMSY proxy for Tier 3)
B(year) = projected spawning biomass for year (assuming catch = maxABC)
B(year)/B100% = ratio of 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
maxFABC(year) = maximum permissible ABC fishing mortality rate under Tier 3
maxABC(year) = maximum permissible ABC under Tier 3
FOFL(year) = OFL fishing mortality rate under Tier 3
OFL(year) = OFL under Tier 3 (second year assumes catch = maxABC in first year)
Pr(maxABC(year)>truOFL(year)) = probability that maxABC is greater than the "true" OFL
Pr(B(year)<B20%) = probability that spawning biomass is less than 20% of unfished

Table 2.21 (page 1 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 1. Years correspond to beginnings of blocks.

	January-April trawl fishery						May-July trawl fishery				
Len.	1977	1985	1990	1995	2000	2005	1977	1985	1990	2000	2005
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
6	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000
7	0.000	0.002	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.000
8	0.000	0.002	0.000	0.000	0.000	0.000	0.002	0.001	0.000	0.001	0.000
9	0.001	0.002	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.001	0.000
10	0.001	0.003	0.000	0.001	0.000	0.000	0.003	0.002	0.000	0.001	0.000
11	0.001	0.003	0.000	0.001	0.000	0.000	0.004	0.003	0.000	0.002	0.000
12	0.001	0.004	0.001	0.001	0.000	0.000	0.005	0.004	0.000	0.002	0.000
13	0.001	0.005	0.001	0.001	0.000	0.000	0.007	0.005	0.000	0.003	0.001
14	0.002	0.006	0.001	0.001	0.001	0.000	0.009	0.007	0.000	0.004	0.001
15	0.002	0.007	0.001	0.002	0.001	0.000	0.012	0.009	0.000	0.006	0.001
16	0.003	0.008	0.002	0.002	0.001	0.000	0.015	0.012	0.001	0.007	0.001
17	0.003	0.009	0.002	0.002	0.001	0.000	0.019	0.015	0.001	0.010	0.002
18	0.004	0.011	0.003	0.003	0.001	0.000	0.024	0.019	0.001	0.012	0.003
19	0.005	0.013	0.004	0.004	0.002	0.000	0.030	0.024	0.001	0.016	0.004
20	0.007	0.015	0.004	0.005	0.002	0.001	0.038	0.030	0.002	0.020	0.005
21	0.008	0.017	0.005	0.006	0.002	0.001	0.047	0.038	0.003	0.025	0.006
22	0.010	0.020	0.007	0.007	0.003	0.001	0.058	0.047	0.003	0.032	0.008
23	0.012	0.023	0.008	0.008	0.004	0.001	0.070	0.057	0.004	0.039	0.010
24	0.014	0.026	0.010	0.010	0.005	0.002	0.085	0.070	0.006	0.049	0.013
25	0.017	0.030	0.013	0.012	0.005	0.002	0.102	0.084	0.008	0.060	0.017
26	0.021	0.035	0.015	0.014	0.007	0.003	0.122	0.102	0.010	0.073	0.022
27	0.025	0.039	0.019	0.017	0.008	0.003	0.145	0.121	0.013	0.088	0.027
28	0.030	0.045	0.023	0.020	0.010	0.004	0.170	0.144	0.016	0.105	0.034
29	0.035	0.051	0.027	0.024	0.012	0.005	0.199	0.169	0.021	0.126	0.042
30	0.042	0.058	0.033	0.028	0.014	0.007	0.231	0.198	0.026	0.149	0.052
31	0.049	0.065	0.039	0.033	0.017	0.008	0.265	0.229	0.033	0.175	0.064
32	0.057	0.073	0.046	0.039	0.020	0.010	0.304	0.264	0.041	0.204	0.078
33	0.067	0.082	0.054	0.045	0.023	0.013	0.345	0.302	0.051	0.236	0.093
34	0.077	0.092	0.064	0.053	0.027	0.015	0.389	0.343	0.062	0.272	0.112
35	0.089	0.103	0.075	0.061	0.032	0.019	0.435	0.387	0.075	0.311	0.133
36	0.103	0.115	0.087	0.070	0.038	0.023	0.483	0.433	0.091	0.352	0.157
37	0.118	0.128	0.101	0.081	0.044	0.028	0.533	0.482	0.109	0.397	0.184
38	0.134	0.142	0.116	0.092	0.051	0.033	0.584	0.532	0.130	0.443	0.215
39	0.153	0.157	0.134	0.105	0.059	0.040	0.636	0.583	0.154	0.492	0.248
40	0.173	0.173	0.153	0.120	0.068	0.047	0.686	0.634	0.180	0.542	0.285
41	0.194	0.190	0.174	0.135	0.078	0.056	0.736	0.685	0.210	0.593	0.324
42	0.218	0.209	0.197	0.153	0.090	0.066	0.784	0.734	0.243	0.644	0.367
43	0.244	0.228	0.222	0.172	0.102	0.078	0.828	0.782	0.279	0.695	0.412
44	0.271	0.249	0.249	0.192	0.116	0.091	0.869	0.827	0.318	0.744	0.460
45	0.300	0.271	0.278	0.214	0.131	0.106	0.906	0.868	0.361	0.792	0.509
46	0.332	0.294	0.310	0.238	0.148	0.122	0.937	0.905	0.405	0.836	0.559
47	0.364	0.318	0.343	0.263	0.167	0.141	0.963	0.936	0.453	0.876	0.611
48	0.399	0.344	0.378	0.290	0.187	0.161	0.982	0.962	0.502	0.912	0.662
49	0.434	0.370	0.414	0.319	0.208	0.183	0.994	0.981	0.552	0.942	0.712
50	0.471	0.397	0.452	0.349	0.231	0.208	1.000	0.994	0.603	0.967	0.761
51	0.509	0.425	0.491	0.381	0.256	0.235	1.000	1.000	0.654	0.985	0.807
52	0.548	0.454	0.531	0.414	0.282	0.264	1.000	1.000	0.705	0.996	0.850
53	0.587	0.484	0.572	0.448	0.310	0.295	1.000	1.000	0.754	1.000	0.889
54	0.626	0.514	0.613	0.483	0.340	0.328	1.000	1.000	0.800	1.000	0.923
55	0.665	0.545	0.654	0.519	0.371	0.363	1.000	1.000	0.844	1.000	0.951
56	0.704	0.576	0.695	0.555	0.403	0.400	1.000	1.000	0.883	1.000	0.973
57	0.741	0.607	0.735	0.592	0.437	0.439	1.000	1.000	0.918	1.000	0.989
58	0.778	0.639	0.773	0.629	0.471	0.479	1.000	1.000	0.947	1.000	0.998
59	0.813	0.670	0.810	0.666	0.507	0.520	1.000	1.000	0.971	1.000	1.000
60	0.846	0.700	0.844	0.702	0.543	0.562	1.000	1.000	0.987	1.000	1.000

Table 2.21 (page 2 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 1. Years correspond to beginnings of blocks.

	January-April trawl fishery						May-July trawl fishery				
Len.	1977	1985	1990	1995	2000	2005	1977	1985	1990	2000	2005
61	0.876	0.730	0.876	0.737	0.579	0.604	1.000	1.000	0.997	1.000	1.000
62	0.904	0.760	0.905	0.772	0.616	0.646	1.000	1.000	1.000	1.000	1.000
63	0.929	0.788	0.931	0.805	0.653	0.688	1.000	1.000	1.000	1.000	1.000
64	0.950	0.816	0.953	0.837	0.689	0.729	1.000	1.000	1.000	1.000	1.000
65	0.968	0.842	0.971	0.866	0.725	0.769	1.000	1.000	1.000	1.000	1.000
66	0.982	0.866	0.985	0.893	0.760	0.807	1.000	1.000	1.000	1.000	1.000
67	0.992	0.890	0.994	0.918	0.793	0.843	1.000	1.000	1.000	1.000	1.000
68	0.998	0.911	0.999	0.939	0.825	0.876	1.000	1.000	1.000	1.000	1.000
69	1.000	0.930	1.000	0.958	0.855	0.905	1.000	1.000	1.000	1.000	1.000
70	1.000	0.947	1.000	0.973	0.883	0.932	1.000	1.000	1.000	1.000	1.000
71	1.000	0.962	1.000	0.986	0.908	0.954	1.000	1.000	1.000	1.000	1.000
72	1.000	0.975	1.000	0.994	0.931	0.972	1.000	1.000	1.000	1.000	1.000
73	1.000	0.985	1.000	0.999	0.951	0.986	1.000	1.000	1.000	1.000	1.000
74	1.000	0.992	1.000	1.000	0.968	0.995	1.000	1.000	1.000	1.000	1.000
75	1.000	0.997	1.000	1.000	0.981	1.000	1.000	1.000	1.000	1.000	1.000
76	1.000	1.000	1.000	1.000	0.991	1.000	1.000	1.000	1.000	1.000	1.000
77	1.000	1.000	1.000	1.000	0.997	1.000	1.000	1.000	1.000	1.000	1.000
78	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
79	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
80	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
81	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
82	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
83	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
84	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
85	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
86	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
87	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
88	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
89	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
90	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
91	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
92	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
93	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
94	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
95	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
96	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
97	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
98	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
99	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
101	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
102	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
103	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
104	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
105	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
106	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
107	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
108	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
109	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
110	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
111	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
112	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
113	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
114	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
115	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
116	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
117	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
118	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
119	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
120	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 2.21 (page 3 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 1. Years correspond to beginnings of blocks.

	August-December trawl fishery						January-April longline fishery						
Len.	1977	1980	1985	1990	1995	2000	1977	1980	1985	1990	1995	2000	2005
1	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
2	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
3	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
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	0.001	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	0.001	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	0.001	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	0.001	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	0.001	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	0.001	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	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.002	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.002	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	0.003	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	0.000	0.003	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.004	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.005	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.005	0.002	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.001	0.006	0.002	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.001	0.007	0.003	0.000	0.002	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
21	0.001	0.009	0.003	0.000	0.003	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
22	0.002	0.010	0.004	0.000	0.003	0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.000
23	0.002	0.012	0.004	0.000	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000
24	0.003	0.014	0.005	0.000	0.004	0.003	0.001	0.002	0.001	0.000	0.000	0.001	0.000
25	0.004	0.016	0.006	0.000	0.005	0.004	0.001	0.002	0.001	0.000	0.000	0.001	0.000
26	0.006	0.018	0.007	0.000	0.005	0.006	0.002	0.003	0.001	0.000	0.000	0.001	0.000
27	0.008	0.021	0.008	0.000	0.006	0.008	0.003	0.004	0.001	0.000	0.001	0.002	0.000
28	0.010	0.024	0.010	0.000	0.007	0.012	0.004	0.005	0.002	0.000	0.001	0.003	0.001
29	0.013	0.028	0.012	0.000	0.008	0.016	0.006	0.006	0.002	0.001	0.001	0.004	0.001
30	0.017	0.032	0.014	0.000	0.009	0.021	0.008	0.008	0.003	0.001	0.002	0.005	0.001
31	0.021	0.036	0.016	0.000	0.010	0.027	0.011	0.010	0.004	0.001	0.002	0.007	0.002
32	0.027	0.041	0.018	0.001	0.012	0.036	0.015	0.012	0.005	0.002	0.003	0.009	0.002
33	0.034	0.047	0.021	0.002	0.013	0.046	0.020	0.015	0.006	0.003	0.005	0.013	0.003
34	0.043	0.053	0.024	0.005	0.015	0.059	0.027	0.018	0.008	0.004	0.007	0.017	0.005
35	0.053	0.060	0.028	0.011	0.017	0.075	0.036	0.022	0.010	0.006	0.009	0.022	0.006
36	0.066	0.067	0.032	0.025	0.019	0.094	0.048	0.027	0.013	0.008	0.012	0.028	0.009
37	0.080	0.075	0.037	0.051	0.021	0.117	0.062	0.033	0.016	0.011	0.016	0.037	0.012
38	0.097	0.084	0.042	0.098	0.024	0.143	0.079	0.040	0.019	0.014	0.022	0.047	0.016
39	0.117	0.094	0.048	0.173	0.027	0.174	0.100	0.048	0.024	0.019	0.028	0.059	0.021
40	0.140	0.105	0.054	0.282	0.030	0.209	0.126	0.058	0.029	0.026	0.037	0.074	0.027
41	0.166	0.117	0.061	0.425	0.034	0.249	0.156	0.069	0.036	0.034	0.048	0.092	0.035
42	0.196	0.130	0.069	0.591	0.037	0.294	0.191	0.081	0.043	0.044	0.061	0.113	0.045
43	0.228	0.143	0.078	0.758	0.042	0.342	0.231	0.096	0.052	0.057	0.076	0.138	0.057
44	0.265	0.158	0.087	0.899	0.046	0.395	0.276	0.112	0.062	0.073	0.095	0.167	0.072
45	0.304	0.174	0.098	0.984	0.051	0.452	0.327	0.130	0.074	0.092	0.118	0.199	0.089
46	0.347	0.191	0.109	1.000	0.057	0.511	0.382	0.151	0.088	0.115	0.144	0.236	0.110
47	0.393	0.209	0.121	1.000	0.063	0.571	0.441	0.173	0.104	0.142	0.175	0.277	0.135
48	0.442	0.229	0.135	1.000	0.070	0.633	0.504	0.199	0.121	0.173	0.209	0.322	0.163
49	0.492	0.249	0.149	1.000	0.077	0.694	0.568	0.226	0.141	0.209	0.248	0.371	0.196
50	0.545	0.271	0.165	1.000	0.084	0.753	0.634	0.256	0.164	0.250	0.292	0.423	0.233
51	0.598	0.294	0.182	1.000	0.093	0.809	0.699	0.288	0.189	0.295	0.340	0.478	0.274
52	0.651	0.317	0.200	1.000	0.101	0.860	0.761	0.323	0.216	0.345	0.392	0.536	0.319
53	0.704	0.342	0.219	1.000	0.111	0.904	0.820	0.360	0.246	0.400	0.447	0.594	0.368
54	0.755	0.368	0.239	1.000	0.121	0.942	0.873	0.398	0.278	0.458	0.505	0.653	0.421
55	0.803	0.395	0.261	1.000	0.132	0.970	0.918	0.439	0.313	0.518	0.565	0.711	0.476
56	0.848	0.422	0.284	1.000	0.144	0.990	0.954	0.481	0.350	0.581	0.625	0.766	0.534
57	0.889	0.451	0.308	1.000	0.156	0.999	0.981	0.525	0.389	0.644	0.685	0.819	0.593
58	0.924	0.480	0.333	1.000	0.169	1.000	0.996	0.569	0.431	0.706	0.744	0.866	0.652
59	0.953	0.510	0.359	1.000	0.183	1.000	1.000	0.613	0.474	0.766	0.799	0.908	0.711
60	0.976	0.540	0.386	1.000	0.198	1.000	1.000	0.658	0.518	0.822	0.850	0.943	0.767

Table 2.21 (page 4 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 1. Years correspond to beginnings of blocks.

	August-December trawl fishery						January-April longline fishery						
Len.	1977	1980	1985	1990	1995	2000	1977	1980	1985	1990	1995	2000	2005
61	0.991	0.570	0.414	1.000	0.213	1.000	0.997	0.702	0.564	0.872	0.895	0.970	0.820
62	0.999	0.601	0.443	1.000	0.230	1.000	0.985	0.745	0.609	0.916	0.934	0.989	0.868
63	1.000	0.632	0.472	1.000	0.247	1.000	0.964	0.786	0.655	0.952	0.964	0.999	0.910
64	1.000	0.662	0.503	1.000	0.265	1.000	0.934	0.825	0.700	0.978	0.986	1.000	0.945
65	1.000	0.692	0.533	1.000	0.283	1.000	0.897	0.861	0.744	0.994	0.998	1.000	0.972
66	1.000	0.722	0.564	1.000	0.303	1.000	0.854	0.894	0.786	1.000	1.000	0.994	0.990
67	1.000	0.751	0.596	1.000	0.323	1.000	0.806	0.923	0.826	1.000	1.000	0.980	0.999
68	1.000	0.780	0.627	1.000	0.344	1.000	0.755	0.948	0.863	0.999	0.996	0.956	1.000
69	1.000	0.807	0.658	1.000	0.366	1.000	0.702	0.969	0.897	0.990	0.985	0.925	1.000
70	1.000	0.833	0.689	1.000	0.388	1.000	0.648	0.984	0.926	0.975	0.965	0.887	0.994
71	1.000	0.858	0.720	1.000	0.411	1.000	0.596	0.994	0.951	0.952	0.939	0.843	0.979
72	1.000	0.881	0.750	1.000	0.434	1.000	0.546	0.999	0.972	0.924	0.906	0.795	0.956
73	1.000	0.903	0.779	1.000	0.458	1.000	0.498	1.000	0.987	0.890	0.869	0.745	0.925
74	1.000	0.922	0.807	1.000	0.483	1.000	0.455	1.000	0.996	0.853	0.828	0.693	0.889
75	1.000	0.940	0.834	1.000	0.508	1.000	0.415	0.996	1.000	0.813	0.784	0.642	0.847
76	1.000	0.956	0.859	1.000	0.533	1.000	0.380	0.988	1.000	0.772	0.739	0.591	0.802
77	1.000	0.969	0.883	1.000	0.558	1.000	0.349	0.974	0.999	0.730	0.693	0.543	0.755
78	1.000	0.980	0.904	1.000	0.584	1.000	0.322	0.957	0.989	0.688	0.649	0.499	0.706
79	1.000	0.989	0.924	1.000	0.610	1.000	0.299	0.936	0.970	0.648	0.607	0.457	0.658
80	1.000	0.995	0.942	1.000	0.635	1.000	0.280	0.913	0.942	0.611	0.567	0.420	0.611
81	1.000	0.999	0.958	1.000	0.661	1.000	0.264	0.887	0.907	0.576	0.530	0.387	0.566
82	1.000	1.000	0.971	1.000	0.686	1.000	0.252	0.860	0.865	0.544	0.497	0.359	0.524
83	1.000	1.000	0.982	1.000	0.711	1.000	0.241	0.833	0.819	0.516	0.468	0.334	0.486
84	1.000	1.000	0.991	1.000	0.736	1.000	0.233	0.805	0.769	0.491	0.442	0.313	0.452
85	1.000	1.000	0.996	1.000	0.760	1.000	0.227	0.779	0.717	0.469	0.420	0.296	0.421
86	1.000	1.000	0.999	1.000	0.784	1.000	0.222	0.754	0.664	0.451	0.401	0.281	0.395
87	1.000	1.000	1.000	1.000	0.807	1.000	0.219	0.730	0.612	0.435	0.386	0.270	0.372
88	1.000	1.000	1.000	1.000	0.829	1.000	0.216	0.709	0.561	0.423	0.373	0.261	0.353
89	1.000	1.000	1.000	1.000	0.850	1.000	0.214	0.689	0.514	0.412	0.362	0.254	0.337
90	1.000	1.000	1.000	1.000	0.870	1.000	0.213	0.672	0.470	0.404	0.354	0.248	0.324
91	1.000	1.000	1.000	1.000	0.889	1.000	0.212	0.657	0.430	0.398	0.347	0.244	0.314
92	1.000	1.000	1.000	1.000	0.906	1.000	0.211	0.644	0.393	0.392	0.342	0.241	0.305
93	1.000	1.000	1.000	1.000	0.923	1.000	0.210	0.634	0.362	0.388	0.339	0.238	0.299
94	1.000	1.000	1.000	1.000	0.938	1.000	0.210	0.625	0.334	0.385	0.336	0.237	0.294
95	1.000	1.000	1.000	1.000	0.951	1.000	0.210	0.617	0.311	0.383	0.333	0.235	0.290
96	1.000	1.000	1.000	1.000	0.963	1.000	0.210	0.612	0.291	0.382	0.332	0.234	0.287
97	1.000	1.000	1.000	1.000	0.973	1.000	0.210	0.607	0.275	0.380	0.331	0.234	0.285
98	1.000	1.000	1.000	1.000	0.982	1.000	0.209	0.603	0.262	0.380	0.330	0.233	0.283
99	1.000	1.000	1.000	1.000	0.989	1.000	0.209	0.600	0.251	0.379	0.329	0.233	0.282
100	1.000	1.000	1.000	1.000	0.995	1.000	0.209	0.598	0.243	0.379	0.329	0.233	0.281
101	1.000	1.000	1.000	1.000	0.998	1.000	0.209	0.597	0.236	0.378	0.329	0.233	0.281
102	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.595	0.231	0.378	0.328	0.233	0.280
103	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.595	0.227	0.378	0.328	0.233	0.280
104	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.594	0.225	0.378	0.328	0.233	0.280
105	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.593	0.222	0.378	0.328	0.233	0.280
106	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.593	0.221	0.378	0.328	0.233	0.280
107	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.593	0.220	0.378	0.328	0.232	0.280
108	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.593	0.219	0.378	0.328	0.232	0.280
109	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.593	0.219	0.378	0.328	0.232	0.280
110	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.593	0.218	0.378	0.328	0.232	0.280
111	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.593	0.218	0.378	0.328	0.232	0.280
112	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.593	0.218	0.378	0.328	0.232	0.280
113	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.593	0.218	0.378	0.328	0.232	0.280
114	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.592	0.218	0.378	0.328	0.232	0.280
115	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.592	0.217	0.378	0.328	0.232	0.280
116	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.592	0.217	0.378	0.328	0.232	0.280
117	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.592	0.217	0.378	0.328	0.232	0.280
118	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.592	0.217	0.378	0.328	0.232	0.280
119	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.592	0.217	0.378	0.328	0.232	0.280
120	1.000	1.000	1.000	1.000	1.000	1.000	0.209	0.592	0.217	0.378	0.328	0.232	0.280

Table 2.21 (page 5 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 1. Years correspond to beginnings of blocks.

	May-July longline fishery						August-December longline fishery						
Len.	1977	1980	1985	1990	2000	2005	1977	1980	1985	1990	1995	2000	2005
1	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
2	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
3	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
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	0.000	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
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
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
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
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
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
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
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
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
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
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
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
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
27	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000
28	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000
29	0.000	0.001	0.000	0.000	0.002	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.000
30	0.001	0.001	0.001	0.001	0.003	0.000	0.000	0.001	0.000	0.000	0.002	0.002	0.000
31	0.001	0.001	0.001	0.001	0.004	0.001	0.000	0.001	0.000	0.000	0.002	0.003	0.001
32	0.001	0.002	0.001	0.001	0.006	0.001	0.000	0.002	0.000	0.000	0.003	0.004	0.001
33	0.002	0.003	0.002	0.002	0.008	0.001	0.000	0.002	0.001	0.001	0.004	0.005	0.002
34	0.003	0.005	0.003	0.003	0.012	0.002	0.000	0.003	0.001	0.001	0.006	0.007	0.003
35	0.005	0.007	0.005	0.004	0.016	0.003	0.001	0.005	0.001	0.001	0.008	0.010	0.004
36	0.007	0.009	0.007	0.006	0.023	0.005	0.001	0.006	0.002	0.002	0.010	0.014	0.006
37	0.010	0.013	0.010	0.009	0.031	0.007	0.002	0.008	0.003	0.003	0.014	0.019	0.008
38	0.014	0.019	0.014	0.013	0.042	0.009	0.004	0.011	0.005	0.004	0.018	0.025	0.012
39	0.019	0.026	0.019	0.018	0.055	0.013	0.006	0.015	0.007	0.006	0.023	0.033	0.017
40	0.027	0.035	0.027	0.025	0.073	0.019	0.010	0.019	0.011	0.008	0.029	0.044	0.024
41	0.036	0.046	0.036	0.034	0.094	0.026	0.016	0.025	0.015	0.012	0.037	0.056	0.033
42	0.049	0.061	0.048	0.045	0.120	0.035	0.024	0.032	0.022	0.017	0.046	0.072	0.044
43	0.064	0.080	0.064	0.060	0.151	0.047	0.035	0.041	0.030	0.023	0.058	0.092	0.059
44	0.084	0.103	0.083	0.078	0.188	0.062	0.051	0.052	0.041	0.031	0.072	0.115	0.078
45	0.107	0.131	0.107	0.101	0.231	0.081	0.072	0.066	0.056	0.042	0.088	0.143	0.102
46	0.136	0.165	0.135	0.128	0.279	0.104	0.100	0.081	0.075	0.056	0.107	0.175	0.130
47	0.170	0.204	0.170	0.161	0.334	0.132	0.136	0.100	0.098	0.073	0.129	0.212	0.165
48	0.210	0.249	0.209	0.200	0.394	0.166	0.180	0.122	0.127	0.094	0.154	0.254	0.206
49	0.256	0.300	0.255	0.244	0.458	0.205	0.234	0.147	0.162	0.120	0.183	0.302	0.253
50	0.308	0.356	0.307	0.295	0.526	0.250	0.298	0.177	0.204	0.151	0.215	0.354	0.306
51	0.366	0.418	0.364	0.351	0.595	0.301	0.371	0.210	0.252	0.187	0.251	0.410	0.365
52	0.428	0.484	0.426	0.412	0.665	0.358	0.452	0.247	0.307	0.229	0.290	0.469	0.430
53	0.494	0.552	0.493	0.477	0.733	0.420	0.539	0.288	0.369	0.277	0.333	0.532	0.499
54	0.563	0.622	0.561	0.546	0.798	0.486	0.628	0.333	0.435	0.330	0.379	0.596	0.570
55	0.633	0.692	0.632	0.616	0.857	0.554	0.716	0.381	0.507	0.389	0.429	0.660	0.643
56	0.702	0.759	0.701	0.685	0.908	0.624	0.799	0.433	0.581	0.452	0.480	0.723	0.715
57	0.769	0.821	0.767	0.753	0.949	0.694	0.873	0.487	0.655	0.518	0.534	0.783	0.783
58	0.831	0.877	0.829	0.816	0.978	0.761	0.932	0.543	0.729	0.587	0.588	0.839	0.845
59	0.885	0.925	0.884	0.872	0.996	0.823	0.975	0.600	0.798	0.656	0.643	0.888	0.899
60	0.931	0.961	0.930	0.921	1.000	0.879	0.997	0.657	0.860	0.724	0.697	0.930	0.944

Table 2.21 (page 6 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 1. Years correspond to beginnings of blocks.

	May-July longline fishery						August-December longline fishery						
Len.	1977	1980	1985	1990	2000	2005	1977	1980	1985	1990	1995	2000	2005
61	0.966	0.987	0.966	0.958	1.000	0.926	1.000	0.713	0.913	0.788	0.750	0.963	0.976
62	0.989	0.999	0.989	0.985	1.000	0.962	1.000	0.768	0.955	0.847	0.800	0.986	0.995
63	1.000	1.000	0.999	0.998	1.000	0.987	1.000	0.819	0.984	0.899	0.846	0.998	1.000
64	1.000	1.000	1.000	1.000	1.000	0.999	1.000	0.865	0.998	0.942	0.888	1.000	1.000
65	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.906	1.000	0.973	0.924	1.000	1.000
66	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.941	1.000	0.993	0.954	1.000	1.000
67	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.968	1.000	1.000	0.977	1.000	1.000
68	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.987	1.000	1.000	0.992	1.000	1.000
69	1.000	1.000	1.000	1.000	1.000	1.000	0.987	0.998	1.000	1.000	0.999	1.000	1.000
70	1.000	1.000	1.000	1.000	1.000	1.000	0.965	1.000	1.000	1.000	1.000	1.000	1.000
71	1.000	1.000	1.000	1.000	1.000	1.000	0.934	1.000	1.000	1.000	1.000	0.998	1.000
72	1.000	1.000	1.000	1.000	1.000	1.000	0.894	1.000	0.997	1.000	1.000	0.989	1.000
73	1.000	1.000	1.000	1.000	1.000	1.000	0.847	1.000	0.989	1.000	1.000	0.973	1.000
74	1.000	1.000	1.000	1.000	1.000	1.000	0.793	1.000	0.977	1.000	1.000	0.952	1.000
75	1.000	1.000	1.000	1.000	1.000	1.000	0.736	1.000	0.959	0.999	1.000	0.925	1.000
76	1.000	1.000	1.000	1.000	1.000	1.000	0.676	1.000	0.938	0.997	1.000	0.894	1.000
77	1.000	1.000	1.000	1.000	1.000	1.000	0.614	0.996	0.914	0.994	1.000	0.859	1.000
78	1.000	1.000	1.000	1.000	1.000	1.000	0.554	0.988	0.887	0.990	1.000	0.822	1.000
79	1.000	1.000	1.000	1.000	1.000	1.000	0.494	0.975	0.859	0.986	1.000	0.783	1.000
80	1.000	1.000	1.000	1.000	1.000	1.000	0.438	0.959	0.830	0.981	1.000	0.744	1.000
81	1.000	1.000	1.000	1.000	1.000	1.000	0.385	0.939	0.800	0.976	1.000	0.705	1.000
82	1.000	1.000	1.000	1.000	1.000	1.000	0.337	0.917	0.772	0.971	1.000	0.668	1.000
83	1.000	1.000	1.000	1.000	1.000	1.000	0.293	0.893	0.744	0.965	1.000	0.633	1.000
84	1.000	1.000	1.000	1.000	1.000	1.000	0.254	0.867	0.718	0.960	1.000	0.600	1.000
85	1.000	1.000	1.000	1.000	1.000	1.000	0.220	0.841	0.693	0.955	1.000	0.570	1.000
86	1.000	1.000	1.000	1.000	1.000	1.000	0.191	0.816	0.671	0.950	1.000	0.543	1.000
87	1.000	1.000	1.000	1.000	1.000	1.000	0.166	0.790	0.651	0.945	1.000	0.519	1.000
88	1.000	1.000	1.000	1.000	1.000	1.000	0.145	0.766	0.634	0.941	1.000	0.498	1.000
89	1.000	1.000	1.000	1.000	1.000	1.000	0.128	0.743	0.618	0.937	1.000	0.480	1.000
90	1.000	1.000	1.000	1.000	1.000	1.000	0.114	0.722	0.605	0.934	1.000	0.465	1.000
91	1.000	1.000	1.000	1.000	1.000	1.000	0.102	0.703	0.594	0.931	1.000	0.452	1.000
92	1.000	1.000	1.000	1.000	1.000	1.000	0.093	0.686	0.585	0.929	1.000	0.442	1.000
93	1.000	1.000	1.000	1.000	1.000	1.000	0.086	0.671	0.578	0.926	1.000	0.433	1.000
94	1.000	1.000	1.000	1.000	1.000	1.000	0.081	0.658	0.572	0.925	1.000	0.426	1.000
95	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.647	0.567	0.923	1.000	0.421	1.000
96	1.000	1.000	1.000	1.000	1.000	1.000	0.074	0.638	0.563	0.922	1.000	0.417	1.000
97	1.000	1.000	1.000	1.000	1.000	1.000	0.072	0.631	0.560	0.921	1.000	0.414	1.000
98	1.000	1.000	1.000	1.000	1.000	1.000	0.070	0.624	0.558	0.920	1.000	0.411	1.000
99	1.000	1.000	1.000	1.000	1.000	1.000	0.069	0.619	0.556	0.920	1.000	0.409	1.000
100	1.000	1.000	1.000	1.000	1.000	1.000	0.068	0.615	0.555	0.919	1.000	0.408	1.000
101	1.000	1.000	1.000	1.000	1.000	1.000	0.067	0.612	0.554	0.919	1.000	0.407	1.000
102	1.000	1.000	1.000	1.000	1.000	1.000	0.067	0.610	0.553	0.919	1.000	0.406	1.000
103	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.608	0.553	0.918	1.000	0.406	1.000
104	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.606	0.552	0.918	1.000	0.405	1.000
105	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.605	0.552	0.918	1.000	0.405	1.000
106	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.605	0.552	0.918	1.000	0.405	1.000
107	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.604	0.552	0.918	1.000	0.405	1.000
108	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.604	0.552	0.918	1.000	0.405	1.000
109	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.603	0.552	0.918	1.000	0.405	1.000
110	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.603	0.551	0.918	1.000	0.405	1.000
111	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.603	0.551	0.918	1.000	0.405	1.000
112	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.603	0.551	0.918	1.000	0.405	1.000
113	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.603	0.551	0.918	1.000	0.405	1.000
114	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.603	0.551	0.918	1.000	0.405	1.000
115	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.603	0.551	0.918	1.000	0.405	1.000
116	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.603	0.551	0.918	1.000	0.405	1.000
117	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.603	0.551	0.918	1.000	0.405	1.000
118	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.603	0.551	0.918	1.000	0.405	1.000
119	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.603	0.551	0.918	1.000	0.405	1.000
120	1.000	1.000	1.000	1.000	1.000	1.000	0.066	0.603	0.551	0.918	1.000	0.405	1.000

Table 2.21 (page 7 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 1. Years correspond to beginnings of blocks.

	January-April pot fishery				May-July pot		Sep-Dec pot	
Len.	1977	1995	2000	2005	1977	1995	1977	2000
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	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
6	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
8	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
10	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
12	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
14	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
16	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
18	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
20	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
22	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
24	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
26	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
28	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
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
33	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
34	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000
35	0.000	0.001	0.001	0.001	0.001	0.001	0.002	0.000
36	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.000
37	0.001	0.001	0.002	0.001	0.001	0.002	0.004	0.001
38	0.002	0.002	0.002	0.002	0.002	0.003	0.006	0.001
39	0.003	0.003	0.003	0.003	0.003	0.005	0.008	0.002
40	0.004	0.004	0.005	0.004	0.004	0.007	0.011	0.004
41	0.006	0.006	0.007	0.006	0.007	0.011	0.015	0.006
42	0.008	0.009	0.010	0.009	0.010	0.015	0.020	0.009
43	0.012	0.013	0.015	0.012	0.014	0.022	0.027	0.014
44	0.017	0.018	0.020	0.017	0.019	0.030	0.036	0.021
45	0.023	0.025	0.028	0.024	0.027	0.041	0.047	0.031
46	0.031	0.034	0.038	0.032	0.037	0.055	0.060	0.045
47	0.042	0.046	0.050	0.043	0.050	0.073	0.077	0.065
48	0.056	0.060	0.066	0.058	0.067	0.096	0.097	0.090
49	0.074	0.079	0.086	0.075	0.088	0.123	0.121	0.122
50	0.095	0.102	0.111	0.098	0.115	0.157	0.150	0.163
51	0.121	0.129	0.140	0.124	0.146	0.197	0.183	0.213
52	0.153	0.163	0.175	0.156	0.184	0.243	0.222	0.273
53	0.190	0.201	0.216	0.194	0.228	0.295	0.265	0.341
54	0.233	0.246	0.263	0.238	0.279	0.354	0.313	0.418
55	0.282	0.296	0.315	0.287	0.336	0.418	0.365	0.501
56	0.337	0.353	0.373	0.343	0.398	0.487	0.422	0.589
57	0.397	0.414	0.436	0.403	0.466	0.559	0.482	0.677
58	0.461	0.479	0.503	0.468	0.537	0.632	0.545	0.762
59	0.529	0.548	0.572	0.536	0.610	0.704	0.609	0.839
60	0.599	0.618	0.642	0.606	0.683	0.774	0.673	0.905

Table 2.21 (page 8 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates under Model 1. Years correspond to beginnings of blocks.

	January-April pot fishery				May-July pot		Sep-Dec pot	
Len.	1977	1995	2000	2005	1977	1995	1977	2000
61	0.669	0.688	0.711	0.676	0.753	0.837	0.735	0.956
62	0.737	0.755	0.777	0.743	0.819	0.893	0.794	0.988
63	0.801	0.818	0.838	0.807	0.878	0.939	0.849	1.000
64	0.860	0.874	0.892	0.865	0.927	0.973	0.897	1.000
65	0.910	0.922	0.936	0.914	0.964	0.994	0.937	1.000
66	0.950	0.960	0.970	0.954	0.989	1.000	0.968	1.000
67	0.980	0.985	0.991	0.982	1.000	1.000	0.989	1.000
68	0.996	0.998	1.000	0.997	1.000	1.000	0.999	1.000
69	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
70	1.000	0.998	0.995	0.999	1.000	1.000	1.000	1.000
71	0.992	0.985	0.975	0.991	1.000	1.000	1.000	1.000
72	0.974	0.960	0.941	0.972	1.000	1.000	1.000	1.000
73	0.948	0.924	0.897	0.945	1.000	1.000	1.000	1.000
74	0.915	0.880	0.845	0.910	1.000	1.000	1.000	1.000
75	0.876	0.830	0.787	0.872	1.000	1.000	1.000	1.000
76	0.835	0.778	0.728	0.830	1.000	1.000	1.000	1.000
77	0.794	0.726	0.670	0.788	1.000	1.000	1.000	1.000
78	0.754	0.676	0.614	0.748	1.000	1.000	1.000	1.000
79	0.716	0.630	0.564	0.711	1.000	1.000	1.000	1.000
80	0.683	0.589	0.520	0.677	1.000	1.000	1.000	1.000
81	0.653	0.554	0.483	0.649	1.000	1.000	1.000	1.000
82	0.629	0.525	0.452	0.624	1.000	1.000	1.000	1.000
83	0.609	0.501	0.427	0.605	1.000	1.000	1.000	1.000
84	0.593	0.483	0.408	0.589	1.000	1.000	1.000	1.000
85	0.581	0.469	0.394	0.578	1.000	1.000	1.000	1.000
86	0.572	0.458	0.383	0.569	1.000	1.000	1.000	1.000
87	0.566	0.451	0.375	0.562	1.000	1.000	1.000	1.000
88	0.561	0.445	0.370	0.558	1.000	1.000	1.000	1.000
89	0.558	0.442	0.367	0.555	1.000	1.000	1.000	1.000
90	0.556	0.439	0.364	0.553	1.000	1.000	1.000	1.000
91	0.555	0.438	0.363	0.551	1.000	1.000	1.000	1.000
92	0.554	0.437	0.362	0.551	1.000	1.000	1.000	1.000
93	0.553	0.436	0.361	0.550	1.000	1.000	1.000	1.000
94	0.553	0.436	0.361	0.550	1.000	1.000	1.000	1.000
95	0.553	0.436	0.361	0.550	1.000	1.000	1.000	1.000
96	0.552	0.436	0.361	0.549	1.000	1.000	1.000	1.000
97	0.552	0.436	0.361	0.549	1.000	1.000	1.000	1.000
98	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
99	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
100	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
101	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
102	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
103	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
104	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
105	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
106	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
107	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
108	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
109	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
110	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
111	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
112	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
113	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
114	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
115	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
116	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
117	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
118	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
119	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000
120	0.552	0.435	0.361	0.549	1.000	1.000	1.000	1.000

Table 2.22—Schedules of Pacific cod selectivity at age in the bottom trawl survey as defined by final parameter estimates under Model 1.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1982	0.000	0.375	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1983	0.000	0.351	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1984	0.000	0.237	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1985	0.000	0.500	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1986	0.000	0.338	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1987	0.000	0.617	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1988	0.000	0.260	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1989	0.000	0.135	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1990	0.000	0.392	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1991	0.000	0.352	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1992	0.000	0.747	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1993	0.000	0.645	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1994	0.000	0.355	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1995	0.000	0.196	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1996	0.000	0.142	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1997	0.000	0.269	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1998	0.000	0.246	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
1999	0.000	0.237	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2000	0.000	0.357	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2001	0.000	0.845	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2002	0.000	0.442	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2003	0.000	0.484	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2004	0.000	0.412	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2005	0.000	0.611	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2006	0.000	0.836	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2007	0.000	0.887	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2008	0.000	0.786	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2009	0.000	0.531	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2010	0.000	0.492	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2011	0.000	0.540	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201
2012	0.000	0.540	1.000	0.996	0.937	0.820	0.673	0.528	0.407	0.318	0.262	0.229	0.213	0.205	0.202	0.201	0.201	0.201	0.201	0.201	0.201

Table 2.23—Schedules of population length (cm) and weight (kg) by season and age as estimated by Model 1. Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov=Dec. Lengths and weights correspond to season mid-points.

	Population length (cm)					Population weight (kg)				
Age	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5
1	9.31	10.91	12.92	16.45	20.18	0.01	0.02	0.03	0.05	0.10
2	23.04	25.78	29.05	32.77	35.69	0.15	0.20	0.28	0.42	0.56
3	37.93	40.08	42.65	45.56	47.85	0.69	0.78	0.91	1.16	1.39
4	49.61	51.29	53.30	55.59	57.39	1.59	1.67	1.83	2.15	2.46
5	58.76	60.08	61.66	63.45	64.86	2.70	2.74	2.87	3.26	3.61
6	65.94	66.97	68.21	69.61	70.72	3.87	3.85	3.93	4.35	4.74
7	71.56	72.37	73.34	74.44	75.31	5.01	4.91	4.93	5.37	5.78
8	75.97	76.61	77.37	78.23	78.91	6.05	5.87	5.83	6.27	6.69
9	79.43	79.93	80.52	81.20	81.73	6.96	6.70	6.60	7.05	7.47
10	82.14	82.53	83.00	83.53	83.94	7.74	7.41	7.25	7.70	8.13
11	84.26	84.57	84.94	85.35	85.68	8.39	8.00	7.80	8.24	8.67
12	85.93	86.17	86.46	86.78	87.04	8.92	8.48	8.24	8.68	9.11
13	87.23	87.42	87.65	87.90	88.10	9.36	8.88	8.60	9.04	9.46
14	88.26	88.41	88.58	88.78	88.94	9.71	9.19	8.89	9.32	9.75
15	89.06	89.18	89.31	89.47	89.59	9.99	9.45	9.12	9.55	9.97
16	89.69	89.78	89.89	90.01	90.11	10.21	9.65	9.30	9.73	10.16
17	90.18	90.25	90.34	90.43	90.51	10.39	9.81	9.45	9.88	10.30
18	90.57	90.62	90.69	90.77	90.83	10.53	9.93	9.57	9.99	10.41
19	90.87	90.92	90.97	91.03	91.07	10.64	10.03	9.66	10.08	10.50
20	91.29	91.32	91.35	91.39	91.42	10.80	10.18	9.79	10.21	10.63

Table 2.24—Schedules of fleet-specific length (cm) by season and age as estimated by Model 1. Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov=Dec.

	Trawl fishery					Longline fishery					Pot fishery					Survey
Age	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	
1	13.09	14.59	16.65	21.57	25.55	15.47	16.92	20.15	24.14	28.28	12.56	16.05	20.24	25.32	31.14	16.45
2	27.33	30.26	33.24	38.00	40.66	29.68	32.60	37.36	40.97	43.62	32.02	34.96	38.31	43.57	46.06	32.77
3	42.82	44.95	45.90	48.96	50.78	44.66	46.64	49.63	51.71	53.42	46.89	48.80	50.58	53.44	54.97	45.56
4	54.06	55.60	54.93	56.99	58.50	54.80	56.15	57.71	58.98	60.28	56.55	57.80	58.53	59.92	61.10	55.59
5	62.21	63.35	62.24	63.89	65.20	61.79	62.75	63.84	64.94	66.10	63.01	63.89	64.43	65.40	66.50	63.45
6	68.30	69.17	68.40	69.75	70.83	66.85	67.56	69.18	70.23	71.23	67.74	68.43	69.53	70.44	71.42	69.61
7	73.07	73.77	73.41	74.49	75.35	70.70	71.25	73.78	74.71	75.54	71.61	72.21	73.98	74.81	75.63	74.44
8	76.93	77.49	77.40	78.25	78.93	73.78	74.24	77.58	78.36	79.02	74.99	75.51	77.70	78.41	79.07	78.23
9	80.06	80.52	80.54	81.21	81.74	76.37	76.76	80.64	81.27	81.80	77.95	78.41	80.71	81.30	81.82	81.20
10	82.57	82.94	83.00	83.53	83.95	78.56	78.89	83.07	83.57	83.98	80.49	80.87	83.11	83.59	84.00	83.53
11	84.58	84.88	84.94	85.35	85.68	80.41	80.69	84.98	85.38	85.71	82.60	82.91	85.01	85.39	85.72	85.35
12	86.18	86.41	86.46	86.78	87.04	81.96	82.19	86.49	86.80	87.06	84.31	84.56	86.51	86.81	87.07	86.78
13	87.44	87.62	87.65	87.90	88.10	83.23	83.42	87.67	87.92	88.12	85.69	85.89	87.69	87.93	88.13	87.90
14	88.43	88.57	88.58	88.78	88.94	84.27	84.42	88.60	88.79	88.95	86.78	86.94	88.62	88.80	88.96	88.78
15	89.21	89.32	89.31	89.47	89.59	85.10	85.22	89.33	89.48	89.60	87.64	87.77	89.34	89.49	89.61	89.47
16	89.82	89.91	89.89	90.01	90.11	85.76	85.86	89.90	90.02	90.11	88.32	88.42	89.91	90.02	90.12	90.01
17	90.30	90.37	90.34	90.43	90.51	86.29	86.37	90.35	90.44	90.52	88.86	88.93	90.36	90.44	90.52	90.43
18	90.68	90.74	90.69	90.76	90.82	86.71	86.77	90.70	90.77	90.83	89.27	89.34	90.71	90.77	90.83	90.76
19	90.98	91.02	90.96	91.02	91.07	87.04	87.09	90.98	91.03	91.08	89.60	89.65	90.99	91.03	91.08	91.02
20	91.39	91.42	91.34	91.38	91.41	87.51	87.50	91.36	91.39	91.42	90.06	90.07	91.37	91.39	91.42	91.38

Table 2.25—Schedules of fleet-specific weight (kg) by season and age as estimated by Model 1. Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov=Dec.

	Trawl fishery					Longline fishery					Pot fishery					Survey
Age	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	
1	0.03	0.04	0.05	0.11	0.19	0.04	0.05	0.09	0.16	0.26	0.03	0.05	0.09	0.19	0.35	0.05
2	0.24	0.32	0.42	0.64	0.82	0.31	0.40	0.59	0.81	1.02	0.39	0.49	0.64	0.98	1.20	0.42
3	0.98	1.09	1.13	1.42	1.65	1.12	1.22	1.43	1.68	1.92	1.29	1.40	1.51	1.85	2.09	1.16
4	2.05	2.12	1.98	2.30	2.59	2.12	2.18	2.29	2.54	2.82	2.33	2.37	2.39	2.66	2.93	2.15
5	3.19	3.20	2.94	3.31	3.66	3.10	3.09	3.15	3.46	3.80	3.28	3.25	3.24	3.53	3.86	3.26
6	4.28	4.22	3.96	4.37	4.76	3.98	3.90	4.08	4.45	4.83	4.14	4.05	4.13	4.48	4.86	4.35
7	5.31	5.17	4.94	5.38	5.78	4.76	4.62	5.00	5.42	5.82	4.96	4.82	5.04	5.43	5.83	5.37
8	6.25	6.05	5.83	6.28	6.69	5.46	5.27	5.86	6.30	6.71	5.77	5.57	5.89	6.31	6.72	6.27
9	7.11	6.83	6.60	7.05	7.47	6.11	5.87	6.62	7.06	7.48	6.55	6.30	6.64	7.07	7.49	7.05
10	7.84	7.50	7.26	7.70	8.13	6.71	6.42	7.27	7.71	8.14	7.27	6.96	7.28	7.71	8.14	7.70
11	8.47	8.07	7.80	8.24	8.67	7.25	6.92	7.81	8.25	8.67	7.90	7.54	7.81	8.25	8.68	8.24
12	8.99	8.54	8.24	8.68	9.11	7.71	7.34	8.25	8.69	9.11	8.44	8.03	8.25	8.69	9.11	8.68
13	9.41	8.92	8.60	9.04	9.46	8.11	7.71	8.61	9.04	9.47	8.89	8.44	8.61	9.04	9.47	9.04
14	9.75	9.23	8.89	9.33	9.75	8.45	8.01	8.89	9.33	9.75	9.25	8.77	8.90	9.33	9.75	9.32
15	10.03	9.48	9.12	9.55	9.97	8.72	8.26	9.13	9.56	9.98	9.55	9.03	9.13	9.56	9.98	9.55
16	10.25	9.68	9.31	9.74	10.16	8.95	8.46	9.31	9.74	10.16	9.78	9.25	9.31	9.74	10.16	9.73
17	10.42	9.84	9.45	9.88	10.30	9.13	8.62	9.45	9.88	10.30	9.97	9.42	9.46	9.88	10.30	9.88
18	10.56	9.96	9.57	9.99	10.41	9.27	8.75	9.57	9.99	10.41	10.12	9.55	9.57	10.00	10.41	9.99
19	10.67	10.06	9.66	10.08	10.50	9.38	8.86	9.66	10.08	10.50	10.24	9.66	9.66	10.09	10.50	10.08
20	10.82	10.20	9.79	10.21	10.63	9.55	9.00	9.79	10.21	10.63	10.40	9.80	9.79	10.21	10.63	10.21

Table 2.26—Time series of EBS (not expanded to BSAI) Pacific cod age 0+ biomass, age 3+ biomass, female spawning biomass (t), and standard deviation of spawning biomass ("SB SD") as estimated last year under the Plan Team's and SSC's preferred model and this year under Model 1. Values for 2013 listed under this year's assessment represent Stock Synthesis projections, and may not correspond exactly to values generated by the standard projection model (even after correcting for the BSAI expansion).

	Last year's assessment				This year's assessment			
Year	Age 0+	Age 3+	Spawn.	SB SD	Age 0+	Age 3+	Spawn.	SB SD
1977	603,325	596,205	167,932	32,923	569,478	561,480	159,465	31,807
1978	678,315	638,632	184,828	32,986	646,691	600,575	176,360	31,849
1979	838,368	720,987	211,489	34,053	814,516	693,807	203,132	32,830
1980	1,222,200	1,170,000	265,442	36,480	1,189,870	1,134,690	256,656	35,146
1981	1,678,620	1,620,000	371,918	40,280	1,621,340	1,560,720	360,543	38,792
1982	2,059,300	2,040,000	527,065	45,111	1,974,690	1,952,970	510,580	43,367
1983	2,260,620	2,240,000	674,910	47,832	2,157,450	2,138,000	654,455	46,003
1984	2,275,930	2,200,000	749,745	46,103	2,170,450	2,089,410	729,415	44,486
1985	2,251,210	2,230,000	743,760	41,277	2,151,230	2,127,280	726,290	39,989
1986	2,197,870	2,140,000	704,810	35,677	2,103,880	2,036,710	690,300	34,714
1987	2,178,530	2,150,000	679,380	30,800	2,088,340	2,059,250	666,580	30,110
1988	2,111,080	2,100,000	658,570	26,952	2,021,390	2,007,490	646,360	26,462
1989	1,908,730	1,900,000	621,130	23,800	1,822,510	1,811,030	609,270	23,442
1990	1,665,820	1,640,000	572,130	20,943	1,590,520	1,561,920	561,860	20,670
1991	1,445,410	1,390,000	492,812	17,975	1,387,960	1,333,140	485,065	17,764
1992	1,293,070	1,250,000	396,146	15,222	1,252,640	1,208,390	390,787	15,065
1993	1,280,630	1,260,000	346,825	13,358	1,246,770	1,219,300	342,683	13,228
1994	1,331,190	1,280,000	361,202	12,711	1,297,640	1,240,110	357,309	12,552
1995	1,364,360	1,340,000	366,660	12,836	1,328,740	1,306,730	361,860	12,592
1996	1,314,450	1,290,000	362,738	13,167	1,274,300	1,250,640	356,939	12,836
1997	1,239,070	1,210,000	354,144	13,276	1,196,590	1,167,730	347,429	12,868
1998	1,137,180	1,080,000	327,975	13,114	1,097,170	1,035,460	320,396	12,639
1999	1,171,350	1,150,000	314,810	12,871	1,129,590	1,102,940	306,593	12,330
2000	1,229,130	1,200,000	318,443	12,819	1,180,400	1,152,230	309,081	12,188
2001	1,264,600	1,220,000	351,344	13,016	1,209,090	1,158,890	340,418	12,249
2002	1,311,320	1,280,000	364,353	12,935	1,248,060	1,217,200	351,400	12,013
2003	1,316,290	1,300,000	362,894	12,547	1,241,430	1,225,920	347,580	11,464
2004	1,270,660	1,250,000	364,881	12,216	1,171,460	1,146,570	341,634	10,939
2005	1,164,770	1,140,000	341,597	11,974	1,061,770	1,041,140	314,994	10,525
2006	1,046,930	1,030,000	304,374	11,635	943,742	924,993	275,854	10,078
2007	946,021	921,028	271,623	11,212	845,398	819,008	242,782	9,602
2008	921,565	851,553	248,405	11,001	825,138	752,091	219,414	9,332
2009	1,015,500	985,311	238,735	11,424	918,703	887,286	208,925	9,615
2010	1,174,880	1,090,000	261,659	13,178	1,079,660	980,157	230,371	11,065
2011	1,404,570	1,390,000	323,273	16,861	1,330,430	1,313,520	291,406	14,373
2012	1,536,900	1,470,000	373,130	20,349	1,474,330	1,408,210	344,516	19,306
2013					1,600,230	1,508,140	391,961	22,806

Table 2.27—Time series of EBS (not expanded to BSAI) Pacific cod age 0 recruitment (1000s of fish), with standard deviations, as estimated last year under the Plan Team’s and SSC’s preferred model and this year under Model 1.

	Last year's values		This year's values	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	2,156,140	148,905	1,783,510	197,998
1978	853,573	94,534	758,050	160,459
1979	879,621	68,296	902,112	98,971
1980	369,786	36,636	317,104	42,618
1981	366,820	31,794	173,945	26,280
1982	1,124,690	43,085	1,222,410	49,941
1983	421,601	29,106	267,130	31,242
1984	938,090	37,907	991,872	44,000
1985	458,257	26,528	428,088	30,838
1986	235,807	17,205	199,925	19,059
1987	210,155	14,446	139,907	15,654
1988	471,870	20,293	360,918	20,832
1989	836,105	28,830	778,663	31,833
1990	640,243	24,776	647,798	28,864
1991	509,156	21,039	335,431	21,360
1992	819,039	23,776	855,563	28,123
1993	359,016	15,411	305,627	18,064
1994	361,842	14,958	328,665	16,966
1995	502,339	19,694	350,896	19,802
1996	854,923	24,513	913,070	30,856
1997	449,847	16,353	373,892	19,092
1998	442,972	15,866	359,370	17,798
1999	719,361	20,223	727,158	23,208
2000	438,710	15,003	455,028	16,863
2001	266,319	11,109	202,745	12,067
2002	379,147	13,955	353,813	14,410
2003	330,055	14,141	291,552	14,625
2004	311,786	14,559	258,775	14,376
2005	445,026	22,163	294,313	16,355
2006	947,211	45,498	1,092,540	44,523
2007	463,752	30,689	328,097	23,944
2008	1,128,900	74,744	1,516,810	80,964
2009	224,345	32,711	170,090	26,420
2010	913,889	119,700	878,979	74,498
2011			1,362,850	179,946
Average	612,659		592,191	

Table 2.28—Numbers (1000s) at age at time of spawning (March) as estimated by Model 1.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	1783510	375350	34934	182999	41510	27888	18200	11702	7479	4770	3039	1935	1232	785	499	318	202	129	82	52	91
1978	758050	1269430	267044	24666	125845	27776	18431	11998	7721	4942	3155	2012	1282	817	520	331	211	134	85	54	95
1979	902112	539552	903176	188527	16935	83942	18285	12100	7883	5081	3256	2081	1328	847	540	344	219	139	89	57	99
1980	317104	642091	383917	639136	130812	11503	56440	12265	8120	5296	3416	2191	1401	894	570	364	232	148	94	60	105
1981	173945	225704	456891	272142	447799	90419	7873	38427	8331	5511	3593	2318	1487	951	607	387	247	157	100	64	112
1982	1222410	123808	160593	323702	190511	309475	61902	5361	26094	5650	3735	2435	1570	1007	644	411	262	167	106	68	119
1983	267130	870068	88092	113760	226607	131883	212654	42364	3662	17806	3854	2547	1660	1071	687	439	280	179	114	73	127
1984	991872	190134	619020	62316	79231	155512	89624	143753	28566	2466	11986	2594	1714	1117	720	462	295	189	120	77	134
1985	428088	705957	135244	437411	43206	53780	103943	59420	94983	18853	1627	7910	1712	1132	738	476	305	195	125	79	140
1986	199925	304687	502162	95577	302779	29171	35657	68233	38830	61965	12294	1061	5160	1117	739	481	311	199	127	81	143
1987	139907	142294	216719	354727	66089	204207	19318	23374	44518	25289	40338	8004	691	3361	728	481	314	202	130	83	146
1988	360918	99572	101170	152835	244227	44126	133277	12455	14988	28494	16180	25814	5124	443	2153	466	308	201	130	83	147
1989	778663	256864	70775	71053	103906	160611	28292	84056	7781	9315	17656	10010	15953	3165	273	1329	288	190	124	80	142
1990	647798	554222	182694	49801	48376	68383	103350	17985	53120	4904	5864	11109	6296	10034	1990	172	836	181	120	78	140
1991	335431	461077	394327	129087	33951	31399	43004	64233	11146	32916	3040	3638	6895	3909	6232	1236	107	519	112	74	135
1992	855563	238747	328068	278663	87109	21214	18583	24935	37087	6440	19054	1763	2112	4007	2274	3626	720	62	302	66	122
1993	305627	608956	169864	231661	187966	54186	12442	10681	14312	21367	3726	11061	1026	1231	2339	1328	2120	421	36	177	110
1994	328665	217535	433347	120278	158800	122487	34040	7724	6636	8928	13383	2341	6965	647	778	1478	840	1342	267	23	182
1995	350896	233929	154767	305775	80661	98706	72025	19629	4451	3841	5194	7816	1371	4088	380	458	871	495	791	157	121
1996	913070	249754	166435	109388	207609	50365	57326	40476	10937	2480	2145	2905	4378	769	2294	214	257	489	278	445	156
1997	373892	649885	177688	117566	74070	129052	29127	32136	22545	6104	1389	1205	1635	2469	434	1296	121	145	277	157	340
1998	359370	266122	462404	125546	79288	45432	73213	15986	17517	12313	3345	764	664	903	1364	240	717	67	81	153	276
1999	727158	255785	189344	326710	85120	49792	26886	42301	9196	10095	7116	1938	443	386	525	794	140	418	39	47	250
2000	455028	517566	182012	133764	221149	53332	29457	15594	24533	5361	5917	4188	1144	262	228	311	471	83	248	23	177
2001	202745	323874	368338	128800	91315	143112	33425	18305	9719	15381	3380	3746	2660	728	167	146	199	301	53	159	128
2002	353813	144307	230481	260015	86455	56854	85407	19815	10950	5882	9401	2081	2318	1652	454	104	91	124	189	33	180
2003	291552	251832	102690	162531	173368	53011	33241	49521	11591	6483	3518	5665	1261	1410	1008	277	64	56	76	116	131
2004	258775	207517	179200	72379	108132	106053	31022	19335	29074	6885	3888	2125	3441	769	862	617	170	39	34	47	152
2005	294313	184188	147680	126440	48018	64994	60130	17366	10909	16609	3977	2265	1246	2026	454	511	366	101	23	20	118
2006	1092540	209483	131082	104356	84256	28885	36660	33239	9601	6067	9293	2236	1278	705	1149	258	290	208	58	13	79
2007	328097	777640	149089	92688	69771	50940	16388	20412	18539	5394	3433	5287	1278	733	405	661	149	167	120	33	53
2008	1516810	233529	553437	105355	61847	42194	28996	9163	11427	10445	3058	1956	3025	733	421	233	381	86	97	69	50
2009	170090	1079620	166202	390870	69681	36530	23302	15740	4994	6285	5794	1708	1098	1703	414	238	132	216	49	55	68
2010	878979	121065	768358	117442	259955	41773	20554	12865	8698	2777	3516	3258	964	621	966	235	135	75	123	28	70
2011	1362850	625630	86162	543865	79561	163429	25066	12146	7594	5149	1649	2094	1944	576	372	579	141	81	45	74	59
2012	553388	970032	445245	60931	364911	48185	91844	13689	6607	4148	2828	910	1160	1080	321	207	323	79	45	25	74

Table 2.29—Estimates of "effective" fishing mortality (= $-\ln(N_{a+1,t+1}/N_{a,t})-M$) at age and year for Model 1.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.000	0.005	0.028	0.055	0.070	0.074	0.074	0.072	0.071	0.070	0.070	0.069	0.069	0.068	0.068	0.068	0.068	0.068	0.068
1978	0.000	0.006	0.032	0.064	0.081	0.085	0.085	0.083	0.082	0.081	0.080	0.080	0.079	0.079	0.079	0.079	0.079	0.079	0.079
1979	0.000	0.004	0.022	0.045	0.057	0.060	0.060	0.059	0.058	0.057	0.056	0.056	0.056	0.056	0.055	0.055	0.055	0.055	0.055
1980	0.000	0.003	0.015	0.030	0.043	0.049	0.052	0.053	0.054	0.054	0.054	0.054	0.054	0.053	0.053	0.053	0.053	0.053	0.053
1981	0.000	0.004	0.015	0.028	0.038	0.044	0.047	0.049	0.049	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
1982	0.000	0.003	0.013	0.023	0.031	0.035	0.037	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
1983	0.000	0.005	0.018	0.032	0.043	0.049	0.052	0.054	0.054	0.054	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
1984	0.000	0.005	0.022	0.042	0.058	0.066	0.070	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.070	0.070	0.070	0.070
1985	0.000	0.005	0.024	0.048	0.067	0.079	0.084	0.086	0.087	0.087	0.087	0.086	0.086	0.086	0.086	0.085	0.085	0.085	0.085
1986	0.000	0.005	0.023	0.046	0.065	0.076	0.082	0.084	0.085	0.085	0.085	0.085	0.085	0.085	0.084	0.084	0.084	0.084	0.084
1987	0.000	0.005	0.023	0.051	0.074	0.088	0.094	0.096	0.096	0.095	0.095	0.094	0.093	0.093	0.093	0.092	0.092	0.092	0.092
1988	0.001	0.009	0.037	0.069	0.097	0.115	0.126	0.132	0.135	0.137	0.138	0.139	0.140	0.140	0.140	0.140	0.140	0.140	0.141
1989	0.000	0.008	0.035	0.067	0.093	0.110	0.119	0.123	0.125	0.126	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127
1990	0.000	0.003	0.031	0.078	0.114	0.129	0.134	0.135	0.134	0.134	0.134	0.133	0.133	0.133	0.133	0.133	0.132	0.132	0.132
1991	0.000	0.003	0.040	0.114	0.173	0.199	0.206	0.206	0.205	0.204	0.203	0.202	0.202	0.201	0.201	0.201	0.200	0.200	0.200
1992	0.000	0.003	0.032	0.104	0.168	0.194	0.199	0.196	0.193	0.190	0.187	0.186	0.184	0.184	0.183	0.182	0.182	0.182	0.181
1993	0.000	0.002	0.027	0.082	0.135	0.157	0.159	0.155	0.150	0.146	0.143	0.141	0.140	0.139	0.138	0.138	0.137	0.137	0.136
1994	0.000	0.003	0.036	0.101	0.160	0.185	0.188	0.184	0.179	0.175	0.172	0.170	0.168	0.167	0.167	0.166	0.165	0.165	0.165
1995	0.000	0.003	0.031	0.115	0.202	0.246	0.259	0.259	0.257	0.254	0.253	0.251	0.250	0.250	0.249	0.249	0.249	0.248	0.248
1996	0.000	0.003	0.029	0.108	0.190	0.229	0.239	0.237	0.234	0.230	0.228	0.226	0.225	0.224	0.223	0.222	0.222	0.222	0.222
1997	0.000	0.003	0.036	0.128	0.220	0.264	0.275	0.274	0.270	0.267	0.264	0.262	0.261	0.260	0.259	0.258	0.258	0.258	0.257
1998	0.000	0.002	0.026	0.095	0.165	0.199	0.207	0.206	0.203	0.200	0.198	0.197	0.196	0.195	0.194	0.194	0.194	0.193	0.193
1999	0.000	0.002	0.023	0.092	0.163	0.196	0.201	0.197	0.192	0.187	0.184	0.182	0.180	0.179	0.178	0.177	0.177	0.176	0.176
2000	0.000	0.003	0.033	0.101	0.160	0.182	0.180	0.171	0.162	0.155	0.150	0.147	0.144	0.142	0.141	0.140	0.139	0.138	0.137
2001	0.000	0.003	0.034	0.099	0.147	0.160	0.155	0.145	0.136	0.129	0.125	0.121	0.119	0.117	0.115	0.114	0.114	0.113	0.113
2002	0.000	0.004	0.038	0.113	0.172	0.189	0.184	0.172	0.162	0.154	0.149	0.145	0.142	0.140	0.138	0.137	0.136	0.136	0.135
2003	0.000	0.004	0.039	0.119	0.183	0.202	0.196	0.183	0.172	0.163	0.157	0.152	0.149	0.147	0.145	0.144	0.143	0.142	0.141
2004	0.000	0.004	0.044	0.127	0.192	0.212	0.206	0.194	0.183	0.174	0.168	0.164	0.161	0.158	0.157	0.155	0.154	0.154	0.153
2005	0.000	0.002	0.032	0.111	0.190	0.229	0.238	0.234	0.228	0.223	0.219	0.215	0.213	0.211	0.210	0.209	0.208	0.208	0.207
2006	0.000	0.002	0.030	0.114	0.201	0.246	0.256	0.252	0.245	0.238	0.233	0.230	0.227	0.225	0.223	0.222	0.221	0.221	0.220
2007	0.000	0.002	0.030	0.108	0.190	0.232	0.241	0.236	0.229	0.222	0.217	0.214	0.211	0.209	0.208	0.207	0.206	0.205	0.204
2008	0.000	0.002	0.035	0.125	0.213	0.256	0.264	0.258	0.250	0.242	0.237	0.232	0.229	0.227	0.225	0.224	0.223	0.223	0.222
2009	0.000	0.003	0.037	0.131	0.225	0.271	0.279	0.271	0.261	0.253	0.246	0.242	0.238	0.236	0.234	0.232	0.231	0.230	0.229
2010	0.000	0.002	0.029	0.100	0.175	0.212	0.220	0.215	0.208	0.202	0.197	0.194	0.191	0.190	0.188	0.187	0.186	0.186	0.185
2011	0.000	0.002	0.034	0.119	0.205	0.247	0.257	0.254	0.247	0.242	0.237	0.234	0.232	0.230	0.228	0.227	0.227	0.226	0.226
2012	0.000	0.002	0.029	0.103	0.181	0.222	0.232	0.230	0.225	0.220	0.216	0.213	0.211	0.209	0.208	0.207	0.207	0.206	0.206

Table 2.30—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2013-2025 (Scenarios 1 and 2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	307,000	307,000	307,000	307,000	0
2014	323,000	323,000	323,000	323,000	0
2015	340,000	340,000	340,000	340,000	2
2016	339,000	339,000	340,000	342,000	1,091
2017	306,000	316,000	320,000	345,000	13,764
2018	257,000	286,000	295,000	360,000	34,227
2019	214,000	266,000	276,000	383,000	52,339
2020	160,000	255,000	260,000	381,000	68,690
2021	133,000	245,000	249,000	377,000	77,797
2022	124,000	242,000	244,000	382,000	80,669
2023	122,000	239,000	242,000	381,000	80,279
2024	123,000	236,000	239,000	379,000	78,728
2025	124,000	236,000	238,000	380,000	77,779

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	422,000	422,000	422,000	422,000	0
2014	447,000	447,000	447,000	447,000	0
2015	468,000	468,000	468,000	468,000	50
2016	485,000	486,000	487,000	489,000	1,138
2017	472,000	478,000	480,000	495,000	8,105
2018	423,000	446,000	452,000	504,000	26,324
2019	361,000	409,000	421,000	521,000	52,214
2020	309,000	384,000	398,000	540,000	73,584
2021	278,000	369,000	384,000	540,000	84,806
2022	266,000	358,000	378,000	533,000	89,434
2023	263,000	356,000	374,000	540,000	90,278
2024	261,000	352,000	372,000	542,000	88,391
2025	263,000	351,000	370,000	541,000	85,928

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	0.29	0.29	0.29	0.29	0.00
2014	0.29	0.29	0.29	0.29	0.00
2015	0.29	0.29	0.29	0.29	0.00
2016	0.29	0.29	0.29	0.29	0.00
2017	0.29	0.29	0.29	0.29	0.00
2018	0.29	0.29	0.29	0.29	0.00
2019	0.29	0.29	0.29	0.29	0.00
2020	0.24	0.29	0.28	0.29	0.01
2021	0.22	0.29	0.27	0.29	0.02
2022	0.21	0.29	0.27	0.29	0.03
2023	0.21	0.28	0.26	0.29	0.03
2024	0.20	0.28	0.26	0.29	0.03
2025	0.21	0.28	0.26	0.29	0.03

Table 2.31—Projections for BSAI 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 2013-2025 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	310,000	310,000	310,000	310,000	0
2014	326,000	326,000	326,000	326,000	0
2015	343,000	343,000	343,000	343,000	2
2016	341,000	342,000	342,000	344,000	1,106
2017	307,000	318,000	322,000	348,000	13,946
2018	258,000	288,000	296,000	362,000	34,639
2019	215,000	267,000	278,000	385,000	52,729
2020	185,000	256,000	266,000	384,000	63,486
2021	166,000	248,000	260,000	380,000	69,055
2022	159,000	245,000	255,000	384,000	71,360
2023	156,000	241,000	252,000	383,000	70,986
2024	155,000	238,000	249,000	381,000	69,482
2025	153,000	239,000	248,000	379,000	68,620

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	422,000	422,000	422,000	422,000	0
2014	445,000	445,000	445,000	445,000	0
2015	465,000	466,000	466,000	466,000	50
2016	482,000	483,000	483,000	485,000	1,138
2017	468,000	474,000	476,000	491,000	8,103
2018	419,000	441,000	448,000	500,000	26,288
2019	357,000	405,000	417,000	517,000	52,073
2020	303,000	380,000	393,000	536,000	73,863
2021	263,000	365,000	378,000	535,000	87,035
2022	243,000	353,000	368,000	528,000	94,037
2023	231,000	349,000	362,000	535,000	96,687
2024	227,000	344,000	357,000	534,000	96,004
2025	223,000	340,000	354,000	537,000	94,278

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	0.29	0.29	0.29	0.29	0.00
2014	0.29	0.29	0.29	0.29	0.00
2015	0.29	0.29	0.29	0.29	0.00
2016	0.29	0.29	0.29	0.29	0.00
2017	0.29	0.29	0.29	0.29	0.00
2018	0.29	0.29	0.29	0.29	0.00
2019	0.29	0.29	0.29	0.29	0.00
2020	0.29	0.29	0.29	0.29	0.00
2021	0.29	0.29	0.29	0.29	0.00
2022	0.29	0.29	0.29	0.29	0.00
2023	0.29	0.29	0.29	0.29	0.00
2024	0.29	0.29	0.29	0.29	0.00
2025	0.29	0.29	0.29	0.29	0.00

Table 2.32—Projections for BSAI 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 2013-2025 (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	159,000	159,000	159,000	159,000	0
2014	182,000	182,000	182,000	182,000	0
2015	203,000	203,000	203,000	203,000	1
2016	213,000	213,000	213,000	214,000	542
2017	204,000	209,000	211,000	224,000	6,952
2018	181,000	197,000	201,000	236,000	18,031
2019	158,000	187,000	192,000	252,000	29,017
2020	139,000	180,000	186,000	256,000	36,742
2021	126,000	175,000	181,000	253,000	41,342
2022	119,000	171,000	178,000	255,000	43,734
2023	114,000	169,000	175,000	255,000	44,356
2024	113,000	167,000	173,000	255,000	43,873
2025	111,000	166,000	171,000	253,000	43,348

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	434,000	434,000	434,000	434,000	0
2014	507,000	507,000	507,000	507,000	0
2015	573,000	573,000	573,000	573,000	50
2016	630,000	631,000	631,000	633,000	1,139
2017	651,000	657,000	659,000	675,000	8,204
2018	621,000	645,000	652,000	705,000	27,690
2019	561,000	614,000	628,000	738,000	58,512
2020	495,000	587,000	603,000	781,000	88,932
2021	441,000	566,000	582,000	788,000	110,807
2022	400,000	549,000	568,000	782,000	124,391
2023	380,000	539,000	557,000	786,000	131,567
2024	368,000	529,000	549,000	787,000	133,469
2025	356,000	525,000	542,000	789,000	132,444

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	0.14	0.14	0.14	0.14	0.00
2014	0.14	0.14	0.14	0.14	0.00
2015	0.14	0.14	0.14	0.14	0.00
2016	0.14	0.14	0.14	0.14	0.00
2017	0.14	0.14	0.14	0.14	0.00
2018	0.14	0.14	0.14	0.14	0.00
2019	0.14	0.14	0.14	0.14	0.00
2020	0.14	0.14	0.14	0.14	0.00
2021	0.14	0.14	0.14	0.14	0.00
2022	0.14	0.14	0.14	0.14	0.00
2023	0.14	0.14	0.14	0.14	0.00
2024	0.14	0.14	0.14	0.14	0.00
2025	0.14	0.14	0.14	0.14	0.00

Table 2.33—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that F = 0 in 2013-2025 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2024	0	0	0	0	0
2025	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	447,000	447,000	447,000	447,000	0
2014	575,000	575,000	575,000	575,000	0
2015	703,000	703,000	703,000	703,000	50
2016	827,000	828,000	828,000	830,000	1,140
2017	912,000	918,000	920,000	936,000	8,302
2018	933,000	958,000	965,000	1,020,000	29,109
2019	900,000	958,000	974,000	1,100,000	65,584
2020	839,000	946,000	967,000	1,180,000	107,195
2021	776,000	933,000	955,000	1,230,000	142,470
2022	719,000	918,000	942,000	1,250,000	168,139
2023	684,000	905,000	931,000	1,250,000	184,961
2024	656,000	894,000	921,000	1,270,000	193,801
2025	639,000	890,000	911,000	1,250,000	196,734

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2024	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00

Table 2.34—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2013-2025 (Scenario 6), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	359,000	359,000	359,000	359,000	0
2014	368,000	368,000	368,000	368,000	0
2015	380,000	380,000	380,000	380,000	2
2016	371,000	372,000	372,000	374,000	1,301
2017	328,000	340,000	344,000	375,000	16,308
2018	270,000	305,000	314,000	390,000	39,913
2019	195,000	279,000	285,000	414,000	67,499
2020	150,000	257,000	265,000	411,000	84,034
2021	129,000	245,000	257,000	405,000	90,502
2022	124,000	241,000	255,000	414,000	92,007
2023	126,000	242,000	253,000	409,000	90,894
2024	125,000	241,000	252,000	418,000	89,118
2025	128,000	243,000	251,000	413,000	88,233

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	417,000	417,000	417,000	417,000	0
2014	426,000	426,000	426,000	426,000	0
2015	434,000	434,000	434,000	434,000	50
2016	441,000	442,000	442,000	444,000	1,137
2017	420,000	426,000	428,000	443,000	8,068
2018	368,000	390,000	397,000	448,000	25,821
2019	312,000	355,000	367,000	461,000	49,240
2020	273,000	335,000	349,000	478,000	65,621
2021	250,000	326,000	341,000	473,000	73,011
2022	242,000	323,000	338,000	473,000	75,965
2023	242,000	323,000	337,000	477,000	76,315
2024	241,000	322,000	336,000	482,000	74,479
2025	244,000	322,000	335,000	485,000	72,461

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	0.34	0.34	0.34	0.34	0.00
2014	0.34	0.34	0.34	0.34	0.00
2015	0.34	0.34	0.34	0.34	0.00
2016	0.34	0.34	0.34	0.34	0.00
2017	0.34	0.34	0.34	0.34	0.00
2018	0.34	0.34	0.34	0.34	0.00
2019	0.29	0.34	0.33	0.34	0.02
2020	0.26	0.32	0.31	0.34	0.03
2021	0.23	0.31	0.30	0.34	0.04
2022	0.22	0.31	0.30	0.34	0.04
2023	0.22	0.31	0.30	0.34	0.04
2024	0.22	0.30	0.30	0.34	0.04
2025	0.23	0.30	0.30	0.34	0.04

Table 2.35—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2013-2014 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	307,000	307,000	307,000	307,000	0
2014	323,000	323,000	323,000	323,000	0
2015	399,000	399,000	399,000	399,000	2
2016	384,000	385,000	386,000	388,000	1,301
2017	336,000	349,000	353,000	383,000	16,308
2018	275,000	310,000	319,000	395,000	39,913
2019	201,000	283,000	290,000	417,000	66,252
2020	152,000	260,000	267,000	413,000	83,836
2021	130,000	246,000	258,000	406,000	90,534
2022	125,000	242,000	255,000	415,000	92,067
2023	126,000	242,000	253,000	409,000	90,938
2024	124,000	240,000	252,000	418,000	89,144
2025	128,000	243,000	251,000	413,000	88,246

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	422,000	422,000	422,000	422,000	0
2014	447,000	447,000	447,000	447,000	0
2015	463,000	463,000	463,000	463,000	50
2016	463,000	463,000	464,000	466,000	1,137
2017	435,000	441,000	443,000	458,000	8,068
2018	378,000	400,000	406,000	457,000	25,821
2019	317,000	361,000	373,000	467,000	49,364
2020	275,000	338,000	352,000	482,000	66,027
2021	251,000	327,000	342,000	475,000	73,372
2022	242,000	323,000	339,000	474,000	76,196
2023	242,000	323,000	338,000	477,000	76,437
2024	241,000	322,000	336,000	482,000	74,537
2025	243,000	322,000	335,000	485,000	72,485

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	0.29	0.29	0.29	0.29	0.00
2014	0.29	0.29	0.29	0.29	0.00
2015	0.34	0.34	0.34	0.34	0.00
2016	0.34	0.34	0.34	0.34	0.00
2017	0.34	0.34	0.34	0.34	0.00
2018	0.34	0.34	0.34	0.34	0.00
2019	0.30	0.34	0.33	0.34	0.01
2020	0.26	0.32	0.31	0.34	0.03
2021	0.23	0.31	0.30	0.34	0.04
2022	0.23	0.31	0.30	0.34	0.04
2023	0.22	0.31	0.30	0.34	0.04
2024	0.22	0.30	0.30	0.34	0.04
2025	0.23	0.30	0.30	0.34	0.04

Table 2.36a (1 of 2)—Incidental catch (t) of FMP species, other than squid and members of the former "other species" complex, taken in the Bering Sea fisheries for Pacific cod, 2003-2012.

Trawl fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Alaska Plaice	265	372	389	342	404	54	55	73	502	159
Arrowtooth Flounder	4151	7859	3788	4297	1923	585	448	417	218	201
Atka Mackerel	3470	4442	652	367	123	10	28	46	69	51
Flathead Sole	1467	2817	1350	2899	3941	358	479	167	222	232
Greenland Turbot	71	76	10	20	82	8	1	5	0	1
Kamchatka Flounder									6	6
Northern Rockfish	12	51	22	48	4	1	1	3	6	5
Other Flatfish	897	2069	1331	600	463	76	28	63	73	71
Other Rockfish	34	63	18	12	5	5	2	8	2	16
Pacific Ocean Perch	31	64	80	50	25	2	1	0	4	30
Pollock	8840	13301	9926	12081	16913	4275	3332	2241	3481	3605
Rex Sole										
Rock Sole	5185	8650	7461	4528	3864	974	750	848	1329	1118
Rougheye Rockfish		1	1			0		0		
Sablefish	56	73	28	2	1	1	0	1	0	
Shortraker Rockfish		1		1	0		0			
Shortraker/Rougheye	3									
Yellowfin Sole	1007	1840	1266	1438	645	321	306	469	1141	635
Total	25488	41677	26322	26685	28393	6669	5432	4341	7054	6131

Longline fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Alaska Plaice	0	0	0	4	0	0	0	0	0	0
Arrowtooth Flounder	1295	1333	1670	1322	1265	1622	1646	1510	1333	893
Atka Mackerel	6	25	5	0	4	1	0	1	6	1
Flathead Sole	372	586	618	539	352	334	248	265	334	236
Greenland Turbot	182	218	169	65	115	72	79	122	173	91
Kamchatka Flounder									25	70
Northern Rockfish	6	5	6	6	5	4	4	11	13	6
Other Flatfish	80	187	253	145	59	28	56	91	50	35
Other Rockfish	10	28	19	10	22	18	6	47	34	18
Pacific Ocean Perch	1	3	1	0	0	0	1	1	2	1
Pollock	7162	5300	4172	3040	3372	5230	4530	4168	5478	3977
Rex Sole	0									
Rock Sole	45	37	48	21	14	20	25	5	20	22
Rougheye Rockfish	0	2	4	2	2	6	2	7	7	7
Sablefish	66	18	22	22	14	4	2	3	16	3
Shortraker Rockfish	0	26	19	10	22	15	29	56	16	10
Shortraker/Rougheye	18									
Yellowfin Sole	631	615	717	485	264	507	653	198	674	669
Total	9875	8382	7723	5671	5509	7861	7282	6487	8180	6040

Table 2.36a (2 of 2)—Incidental catch (t) of FMP species, other than squid and members of the former "other species" complex, taken in the Bering Sea fisheries for Pacific cod, 2003-2012.

Pot fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Alaska Plaice	0	0	0	0	0					0
Arrowtooth Flounder	5	4	5	12	2	7	0	1	1	1
Atka Mackerel	205	141	236	341	58	60	2	27	29	9
Flathead Sole	0	1	1	0	2	1	0	0	0	0
Greenland Turbot	0		0	1	0	0	0		0	
Kamchatka Flounder										0
Northern Rockfish	1	1	1	1	1	2	0	0	1	1
Other Flatfish	1	1	1	1	1	0	0	0	0	0
Other Rockfish	5	3	3	4	1	1	0	2	2	1
Pacific Ocean Perch	1	0	0	1	0	0	0	0	0	0
Pollock	20	9	8	26	12	11	17	8	7	6
Rex Sole										
Rock Sole	3	2	1	2	3	1	0	1	0	1
Rougheye Rockfish		0	0							
Sablefish	0	1	0	4					0	
Shortraker Rockfish								0		
Shortraker/Rougheye	0									
Yellowfin Sole	90	78	76	47	209	131	35	2	29	25
Total	332	241	332	439	289	214	56	41	69	44

Table 2.36b—Incidental catch (t) of FMP species, other than squid and members of the former "other species" complex, taken in the Aleutian Islands fisheries for Pacific cod, 2003-2012.

Trawl fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Alaska Plaice		0	0	0	0	0	0			0
Arrowtooth Flounder	230	199	244	206	134	24	35	35	16	20
Atka Mackerel	1075	549	482	447	361	456	359	124	101	384
Flathead Sole	39	34	24	33	27	10	14	17	3	9
Greenland Turbot	8	6	5	1	7	1	1			0
Kamchatka Flounder									3	3
Northern Rockfish	215	129	210	185	89	51	59	29	21	9
Other Flatfish	8	10	6	11	11	13	3	2	0	7
Other Rockfish	13	12	8	7	9	9	7	4	4	9
Pacific Ocean Perch	185	160	180	134	98	106	32	5	2	43
Pollock	785	537	669	314	413	54	51	18	57	78
Rex Sole										
Rock Sole	802	699	437	449	585	258	433	427	196	217
Rougheye Rockfish		2	3	1	0	0	0	0	1	0
Sablefish	1	1	0	1	1		0			0
Shortraker Rockfish		3	1	2	0	0		0		0
Shortraker/Rougheye	7									
Yellowfin Sole	0	9	2	3	0	0	0	0	0	0
Grand Total	3368	2348	2272	1792	1736	982	993	661	404	779

Longline and pot fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Alaska Plaice										
Arrowtooth Flounder	14	18	34	37	66	60	76	94	14	20
Atka Mackerel	14	12	19	21	25	47	92	94	14	15
Flathead Sole	0	0	0	1	2	2	3	3	0	1
Greenland Turbot	12	3	1	11	15	4	4	5	1	2
Kamchatka Flounder									1	7
Northern Rockfish	18	27	19	8	33	54	56	119	7	11
Other Flatfish		10	0	0	0	1	16	1	3	6
Other Rockfish	12	55	12	21	50	46	79	78	14	17
Pacific Ocean Perch	1	0	2	1	4	4	1	1	0	1
Pollock	9	15	3	8	6	9	29	47	7	8
Rex Sole										
Rock Sole	1	2	4	4	3	2	2	3	0	2
Rougheye Rockfish	0	26	2	3	28	54	33	49	5	33
Sablefish	14	2	1	37	20	23	2	30	6	13
Shortraker Rockfish		3	6	9	12	7	7	27	3	7
Shortraker/Rougheye	12									
Yellowfin Sole				0	2	0	0			
Total	108	174	102	161	266	314	399	551	74	142

Table 2.37a—Incidental catch (t) of squid and members of the former “other species” complex taken in the Bering Sea fisheries for Pacific cod, 2003-2012.

Trawl fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Octopus	21	64	17	22	10	11	1	4	18	1
Sculpins, large	520	1448	920	892	1102	286	221	214	330	327
Sculpins, other	775	96	59	109	194	27	17	1	3	6
Shark, Pacific sleeper	11	30	14	8	5	0	0	0		
Shark, salmon			1	0						
Shark, spiny dogfish	0	1	0	0	0	1	0			
Shark, other	0	1		0						
Skate, Alaska								222	188	162
Skate, Aleutian									2	3
Skate, big		33	68	120	31	20	16	16	49	26
Skate, longnose	0	9	20	18	1			3	1	1
Skate, whiteblotched									1	0
Skate, other	1228	1485	625	1435	2392	420	309	56	7	4
Squid	5	4	1	0	1	0		0	0	0
Total	2561	3170	1724	2605	3736	764	563	517	598	531

Longline fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Octopus	41	49	25	13	8	10	4	8	30	11
Sculpins, large	195	1189	1214	760	765	811	745	647	1133	874
Sculpins, other	996	239	278	267	138	240	192	62	141	214
Shark, Pacific sleeper	110	198	175	115	39	12	11	8	19	8
Shark, salmon	1	0	1	1						
Shark, spiny dogfish	10	8	11	6	2	6	17	13	7	3
Shark, other	20	20	10	4	2	1	3	1	1	0
Skate, Alaska								1272	1968	1903
Skate, Aleutian									101	174
Skate, big		125	107	123	43	30	47	101	84	159
Skate, longnose		3	1	2	0	1	1	2	3	1
Skate, whiteblotched									12	21
Skate, other	13521	16194	18224	12995	10343	13267	11578	8961	14128	12223
Squid	0	0	0			0	0		0	
Total	14894	18025	20046	14284	11339	14377	12597	11074	17629	15589

Pot fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Octopus	139	151	257	233	122	153	32	101	506	106
Sculpins, large	122	191	114	268	243	292	105	181	168	298
Sculpins, other	133	13	2	6	7	9	1	3	2	0
Shark, Pacific sleeper				0						
Shark, spiny dogfish								0	0	0
Skate, other	0	0	0	0					0	0
Squid			1		0			0		
Total	394	356	374	508	372	454	138	285	676	403

Table 2.37b—Incidental catch (t) of squid and members of the former “other species” complex taken in the Aleutian Islands fisheries for Pacific cod, 2003-2012.

Trawl fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Octopus	6	6	8	5	4	4	1	1	2	2
Sculpins, large	78	161	88	174	201	90	111	59	27	40
Sculpins, other	122	1	3	16	9	2	9	0	1	0
Shark, Pacific sleeper	0	2	2		0			0		
Shark, salmon							0		0	
Shark, spiny dogfish	0			0				0	0	
Shark, other										
Skate, Alaska								22	9	12
Skate, Aleutian									1	4
Skate, big		0	0	3	0	0	0			2
Skate, longnose		0	0				0			0
Skate, whiteblotched									1	2
Skate, other	95	84	72	91	102	43	46	13	3	6
Squid	3	2	1	1	0	0	0	0	0	0
Total	304	257	176	290	317	139	167	95	44	69

Longline and pot fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Octopus	9	8	4	59	22	15	19	47	9	6
Sculpins, large	28	133	118	133	172	280	292	484	72	316
Sculpins, other	31	63	3	53	20	24	68	205	5	11
Shark, Pacific sleeper			0	0	0	0	0			
Shark, salmon										
Shark, spiny dogfish	0	0	0	1	0	3	1	1	0	0
Shark, other		0								
Skate, Alaska								185	30	48
Skate, Aleutian									5	21
Skate, big				2	0		0	0		
Skate, longnose		0	0	0		0	0	0	0	0
Skate, whiteblotched									1	3
Skate, other	105	401	332	320	545	533	703	590	114	211
Squid		0								
Total	174	606	459	568	760	856	1083	1512	236	616

Table 2.38a—Incidental catch (t) of non-target species groups by Bering Sea Pacific cod fisheries, 2003-2012, sorted in order of descending average.

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Ave.
Sea star	442	420	439	316	235	180	144	134	191	303	280
Giant Grenadier	2	15	143	101	95	133	203	335	1083	268	238
Scypho jellies	669	709	399	66	112	41	87	42	185	53	237
Misc fish	231	226	205	93	88	37	46	43	92	83	114
Sea anemone unidentified	92	114	113	87	37	53	114	84	144	133	97
Grenadier	239	224	192	25	84	15	0	80	12	29	90
Invertebrate unidentified	19	5	3	17	20	2	13	35	55	30	20
Snails	26	20	12	16	16	18	25	17	23	14	19
Sea pens whips	6	12	30	16	7	9	34	22	25	24	18
Eelpouts	48	35	42	17	18	7	2	2	4	4	18
Benthic urochordata	14	4	10	5	1	2	0	10	35	32	11
Misc crabs	8	4	4	16	28	5	1	5	3	3	8
Sponge unidentified	6	8	6	11	2	2	11	5	12	12	7
Bivalves	5	16	6	5	2	11	9	2	11	8	7
Urchins dollars cucumbers	11	11	13	4	13	3	1	1	4	2	6
Corals Bryozoans	1	1	1	1	2	2	4	1	3	21	4
Hermit crab unidentified	5	3	2	2	2	1	1	1	1	0	2
Greenlings	6	3	2	2	0	1	0	0	0	0	2
Brittle star unidentified	1	1	0	1	0	0	0	0	1	0	1
Dark Rockfish						1	0	0	0	0	0
Misc crustaceans	0	0	0	1	1	0	0	0	0	0	0
Other osmerids	0	0	0	0	0		0	0	0	0	0
Pandalid shrimp	0	0	0	0	0	0	0	0	0	0	0
Eulachon		0	0	0	0	0		0	0	0	0
Pacific Sand lance	0	0	0	0	0	0		0	0	0	0
Misc inverts (worms etc)	0	0	0	0	0	0	0	0	0	0	0
Polychaete unidentified	0	0	0	0	0	0	0	0	0	0	0
Capelin		0			0	0		0	0	0	0
Stichaeidae	0	0	0	0	0	0	0	0			0
Lanternfishes (myctophidae)		0									0
Gunnels		0	0		0						0
Birds	0	0	0	0	0	0	0	0	0	0	0
Grand Total	1832	1834	1624	800	763	523	696	820	1885	1021	1180

Table 2.38b—Incidental catch (t) of non-target species groups by Aleutian Islands Pacific cod fisheries, 2003-2012, sorted in order of descending average.

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Ave.
Giant Grenadier	0	0	1	94	31	26	9	186	18	39	40
Misc fish	29	18	20	17	26	17	18	17	9	9	18
Sponge unidentified	25	23	26	28	19	4	14	9	3	7	16
Grenadier	46	13	1	26	10	0	2	36	0	8	14
Corals Bryozoans	25	13	12	12	16	11	10	10	6	4	12
Sea star	6	9	6	7	9	11	20	19	2	5	9
Invertebrate unidentified	0	1	0	14	2	4	0	10	0	0	3
Bivalves	15	1	1	3	2	1	0	0	0	0	2
Dark Rockfish						2	4	4	0	0	2
Snails	1	1	0	1	1	1	3	1	0	1	1
Greenlings	1	0	0	4	1	1	0	1	0	0	1
Scypho jellies	0	0	1	2	0	0	0	0	0	2	1
Misc crabs	1	1	0	1	1	1	1	1	0	0	1
Urchins dollars cucumbers	1	1	0	1	1	0	1	0	0	0	1
Sea anemone unidentified	0	0	1	1	1	0	1	1	0	1	1
Sea pens whips	0	0	0	0	0	0	1	1	0	0	0
Eelpouts	0	1	0	0	0	0	0	0	0	0	0
Benthic urochordata	0	0	0	0	1	0	0	0	0	0	0
Misc crustaceans	0	0	0	0	0	0	0	0	0	0	0
Hermit crab unidentified	0	0	0	0	0	0	0	0	0	0	0
Brittle star unidentified	0	0	0	0	1	0	0	0	0	0	0
Pandalid shrimp	0	0	0	0	0	0	0	0	0	0	0
Polychaete unidentified	0	0	0	0	0	0	0	0	0	0	0
Pacific Sand lance	0		0	0	0	0		0			0
Misc inverts (worms etc)		0	0	0	0	0	0	0	0	0	0
Eulachon			0	0	0	0				0	0
Stichaeidae	0		0	0	0		0				0
Capelin					0	0				0	0
Other osmerids			0	0	0					0	0
Gunnels		0	0		0						0
Birds	0	0	0	0	0	0	0	0	0	0	0
Lanternfishes (myctophidae)											
Grand Total	152	84	70	209	122	79	85	296	39	76	121

Table 2.39a—Catches of prohibited species by Bering Sea fisheries for Pacific cod, 2003-2012. Halibut and herring are in t, salmon and crab are in number of individuals.

Trawl fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Halibut	1989	2328	2023	2048	1432	463	328	390	346	630
Herring	14	9	18	8	1	0	0	0	0	6
Chinook salmon	2131	4888	3091	2888	4970	571	180	472	54	597
Non-chinook salmon	992	6672	596	7288	618	138	0	0	61	24
Bairdi tanner crab	159969	214318	153997	185871	140988	36264	14210	26705	14648	9699
Blue king crab	1266	2134	0	1488	2537	0	148	0	8	0
Golden king crab	66	0	22	98	69	0	0	0	1	127
Opilio tanner crab	79065	94964	59816	101285	298407	22169	15112	5433	9877	6610
Red king crab	1147	756	1705	5968	1585	1281	1298	366	2125	313

Longline fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Halibut	4707	4337	5871	4229	4592	6713	6560	6170	5968	4147
Herring	0	0	0	0	0	0	0	0	0	0
Chinook salmon	0	49	48	23	43	10	11	13	40	46
Non-chinook salmon	13	118	81	449	250	60	51	26	119	137
Bairdi tanner crab	11559	11831	13409	14958	16290	32416	34241	25782	20452	13154
Blue king crab	1641	1001	831	2101	296	8776	12620	425	986	811
Golden king crab	247	45	273	167	165	305	495	405	222	223
Opilio tanner crab	63887	49722	56584	44979	46991	96688	66865	61018	60036	25036
Red king crab	13404	15199	16093	7995	7584	8146	6972	1989	5174	3338

Pot fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Halibut	27	33	35	52	11	65	4	27	63	47
Herring	0	0	0	0	0	0	0	0	0	0
Chinook salmon	0	0	0	0	19	0	0	0	0	0
Non-chinook salmon	0	0	0	0	0	0	0	0	0	0
Bairdi tanner crab	100738	31749	123551	387420	465273	1340375	396107	369175	285448	65019
Blue king crab	147	16	492	135	211286	54	1762	35580	0	0
Golden king crab	0	0	0	29	29	0	188	5	147	0
Opilio tanner crab	21803	75208	77669	190198	568301	530634	481870	270878	131946	13559
Red king crab	59	320	3169	5238	23281	36087	2927	2435	16519	4680

Table 2.39b—Catches of prohibited species by Aleutian Islands fisheries for Pacific cod, 2003-2012. Halibut and herring are in t, salmon and crab are in number of individuals.

Trawl fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Halibut	68	43	83	83	95	27	42	21	23	54
Herring	0	0	0	0	0	0	0	0	0	0
Chinook salmon	1859	711	673	732	1329	1492	873	784	392	300
Non-chinook salmon	42	75	290	228	954	65	51	17	83	5
Bairdi tanner crab	10836	7759	2641	3487	1294	790	1316	949	30	429
Blue king crab	0	0	0	0	2	0	0	0	2	0
Golden king crab	110	0	33	297	382	6	79	9	63	102
Opilio tanner crab	195	29	113	255	959	278	322	0	29	84
Red king crab	7090	768	3037	19	36	120	516	523	132	3

Longline and pot fishery:

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Halibut	106	286	223	248	841	669	672	738	188	190
Herring	0	0	0	0	0	0	0	0	0	0
Chinook salmon	0	0	0	0	0	0	0	0	4	0
Non-chinook salmon	0	0	0	0	1	8	0	0	8	0
Bairdi tanner crab	4	0	55	3264	18515	188576	40166	9622	808	7284
Blue king crab	0	0	11	32	8761	31	475	18065	1	2
Golden king crab	4	0	2	93	220	683	1114	530	897	122
Opilio tanner crab	33	2	260	11886	49803	102404	125437	34331	742	1424
Red king crab	4	0	13	34	1601	5458	172	46	766	493

Table 2.40—Halibut mortality (t) resulting from BSAI Pacific cod fisheries, 2003-2012.

	Bering Sea				Aleutian Islands			BSAI
Year	Trawl	Longline	Pot	Subtotal	Trawl	Long.+pot	Subtotal	Total
2003	1333	558	2	1893	46	13	58	1951
2004	1583	477	3	2063	29	31	60	2123
2005	1376	588	3	1967	56	22	79	2045
2006	1393	414	4	1811	57	25	82	1893
2007	1002	449	1	1451	66	82	148	1600
2008	321	647	5	972	18	70	88	1060
2009	229	645	0	874	29	71	101	975
2010	277	553	2	832	15	64	79	911
2011	244	529	5	777	17	19	35	813
2012	442	373	4	819	37	19	56	874

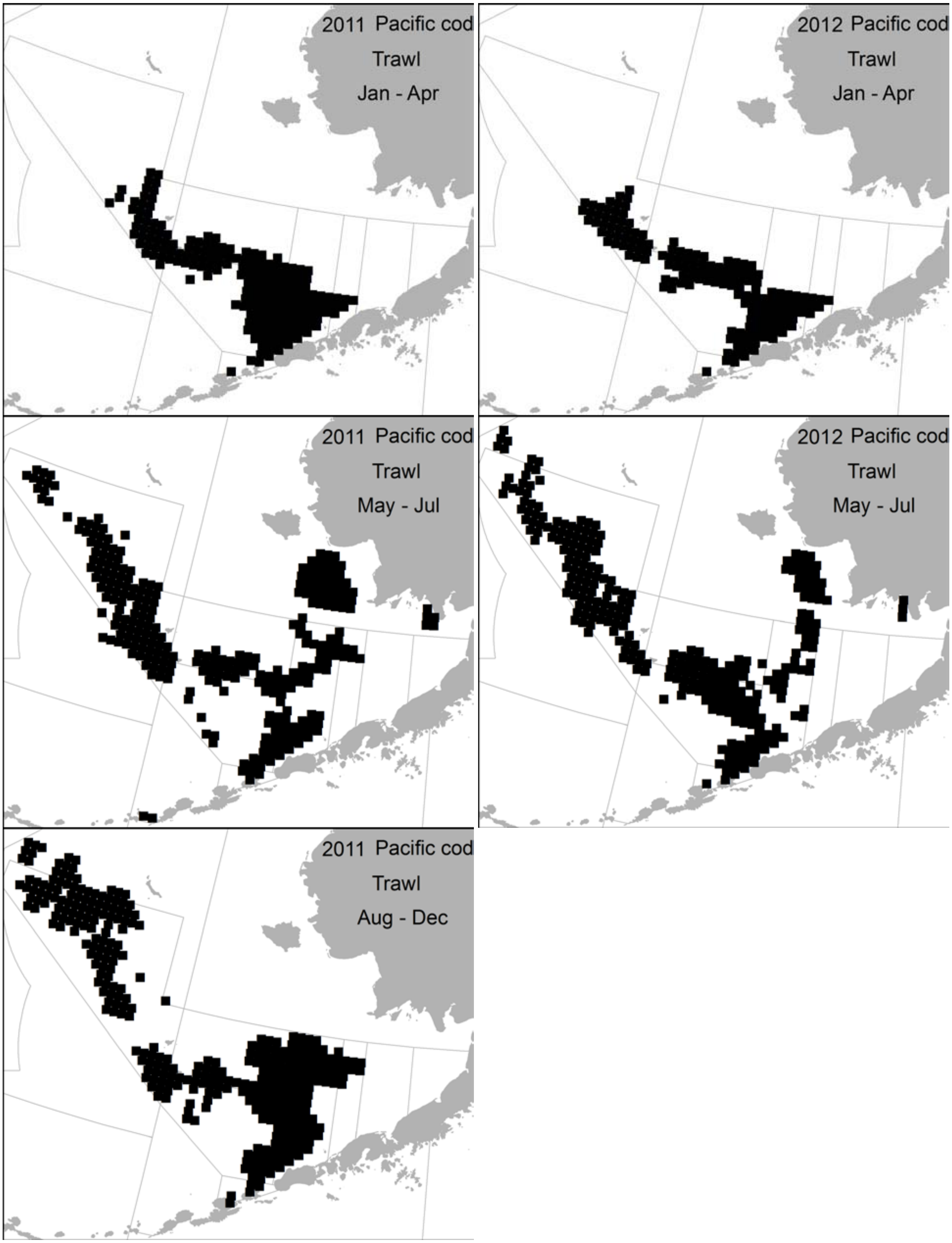

Figure 2.1a—EBS maps showing each 400 square km cell with **trawl hauls** containing Pacific cod from at least 3 distinct vessels **by season** in 2011-2012, overlaid against NMFS 3-digit statistical areas.

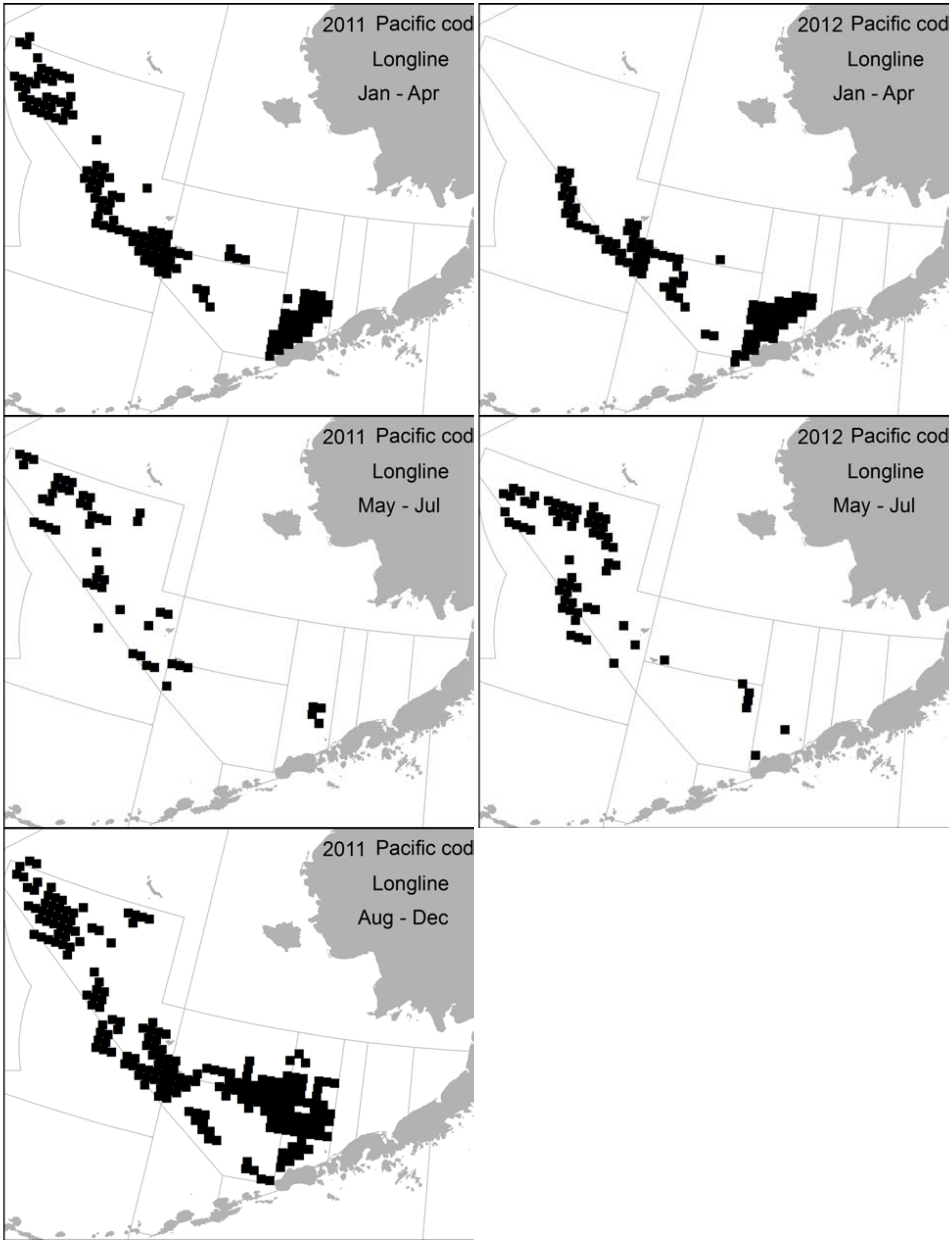

Figure 2.1b—EBS maps showing each 400 square km cell with **longline sets** containing Pacific cod from at least 3 distinct vessels **by season** in 2011-2012, overlaid against NMFS 3-digit statistical areas.

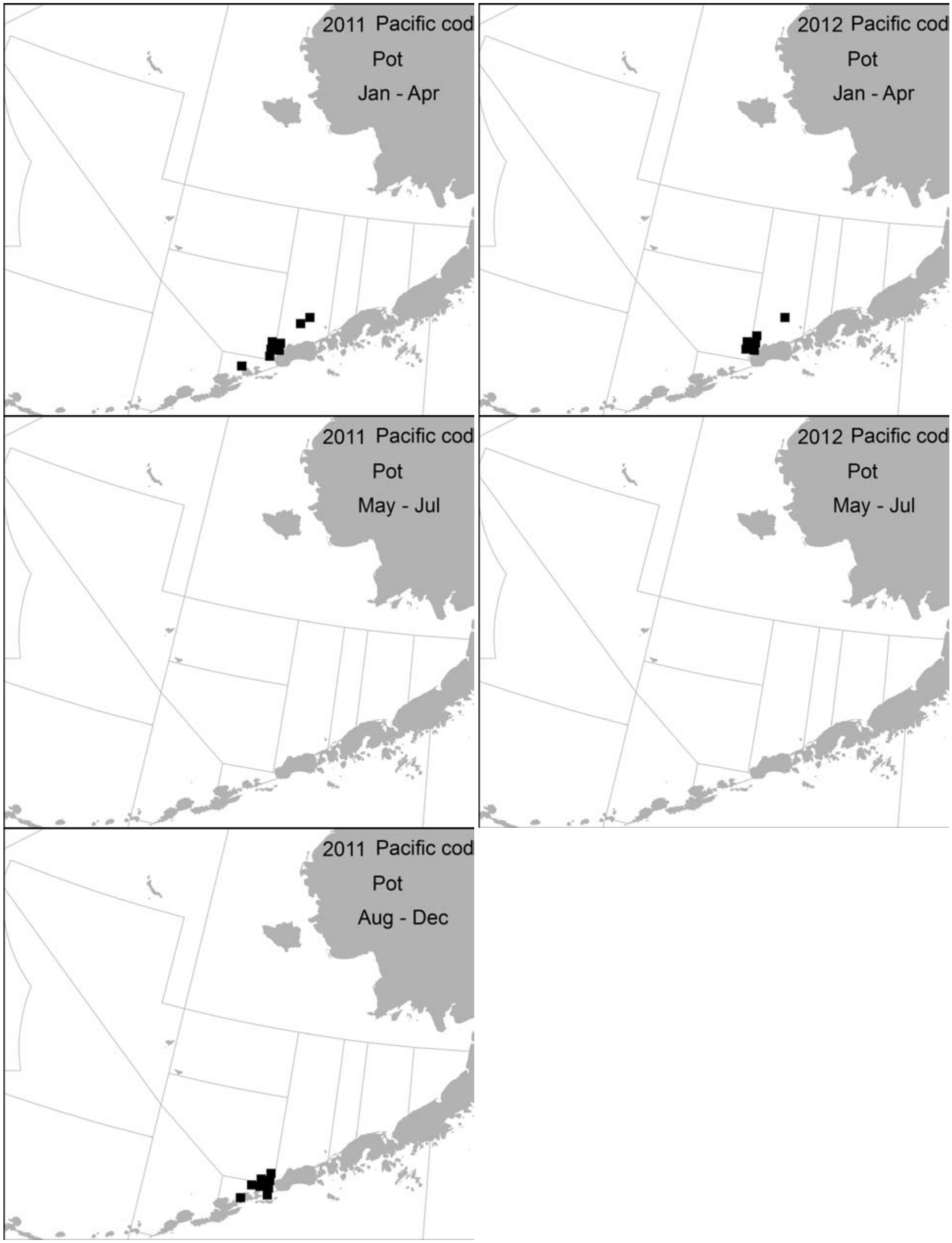

Figure 2.1c—EBS maps showing each 400 square km cell with **pot sets** containing Pacific cod from at least 3 distinct vessels **by season** in 2011-2012, overlaid against NMFS 3-digit statistical areas.

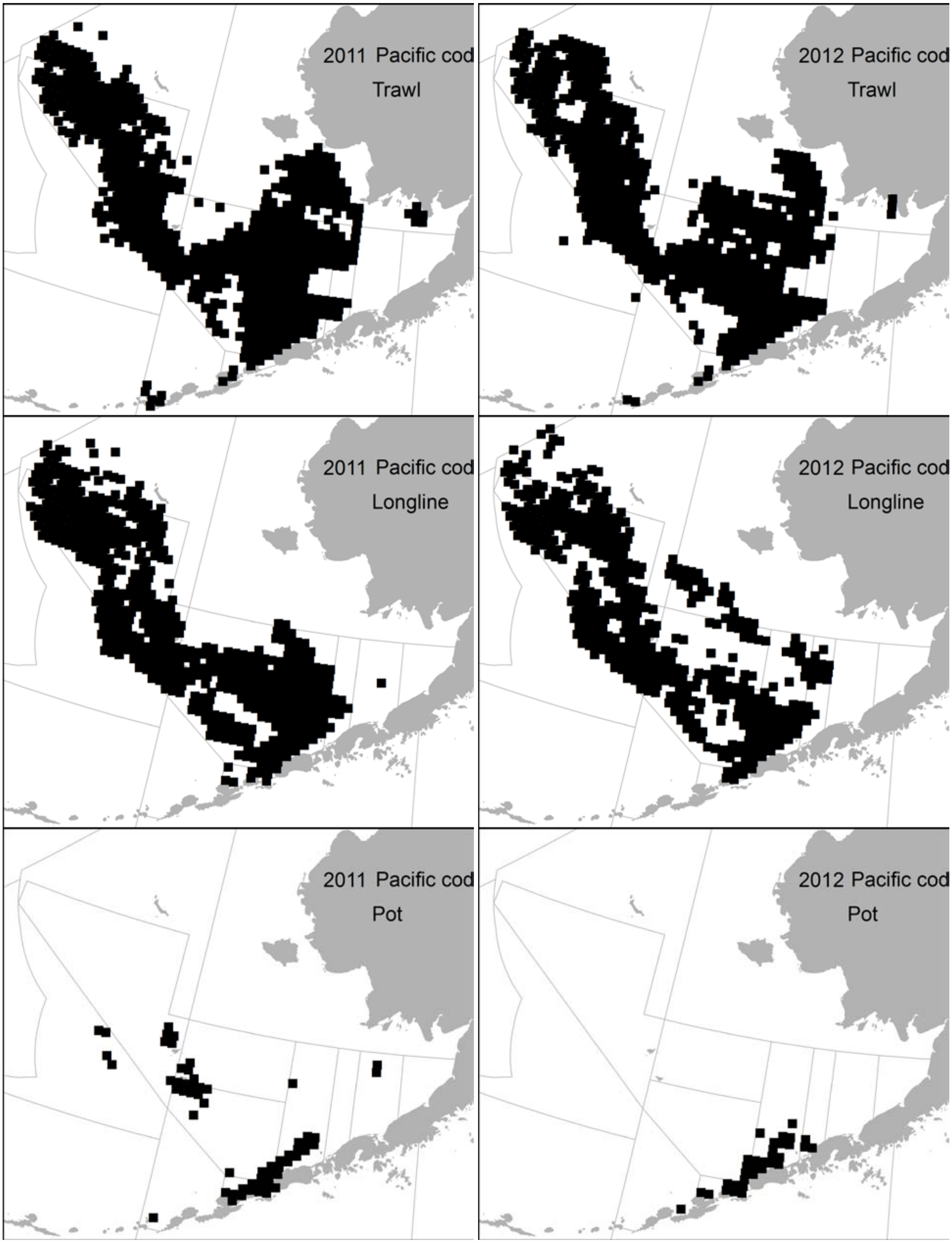

Figure 2.1d—EBS maps showing each 400 square km cell with hauls/sets containing Pacific cod from at least 3 distinct vessels **by gear** in 2011-2012, overlaid against NMFS 3-digit statistical areas.

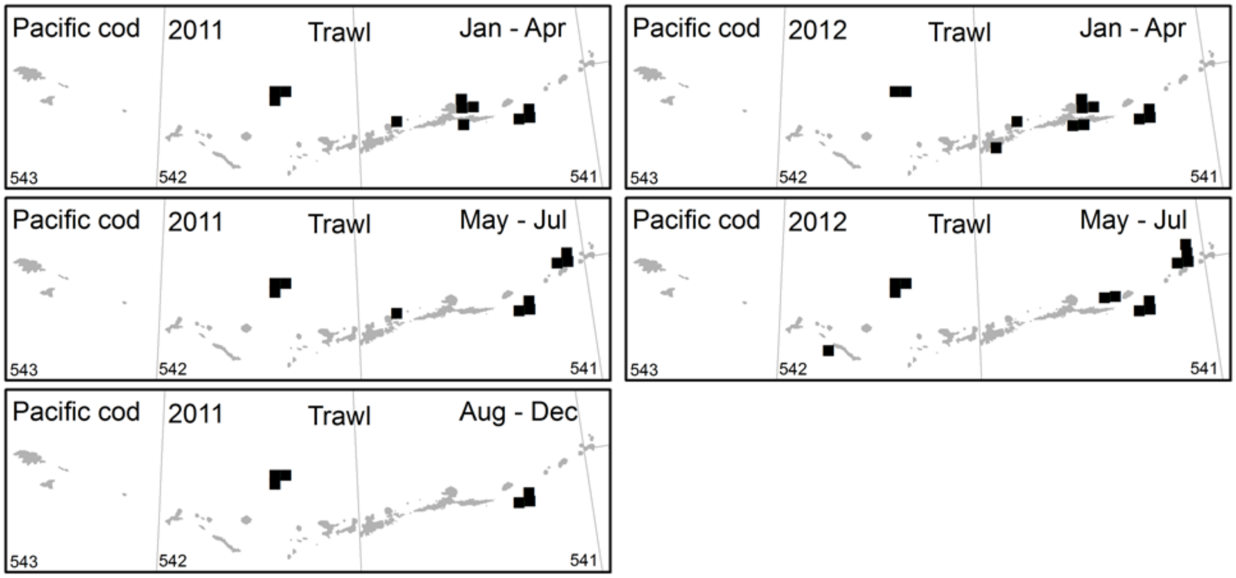

Figure 2.2a—AI maps showing each 400 square km cell with **trawl hauls** containing Pacific cod from at least 3 distinct vessels **by season** in 2011-2012, overlaid against NMFS 3-digit statistical areas.

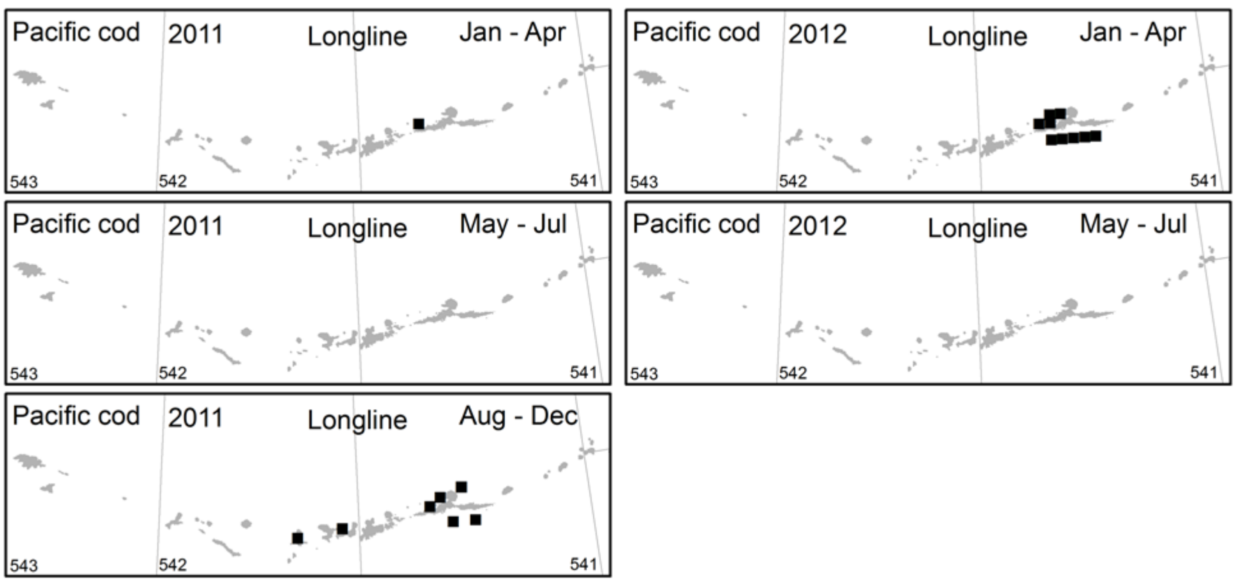

Figure 2.2b—AI maps showing each 400 square km cell with **longline sets** containing Pacific cod from at least 3 distinct vessels **by season** in 2011-2012, overlaid against NMFS 3-digit statistical areas.

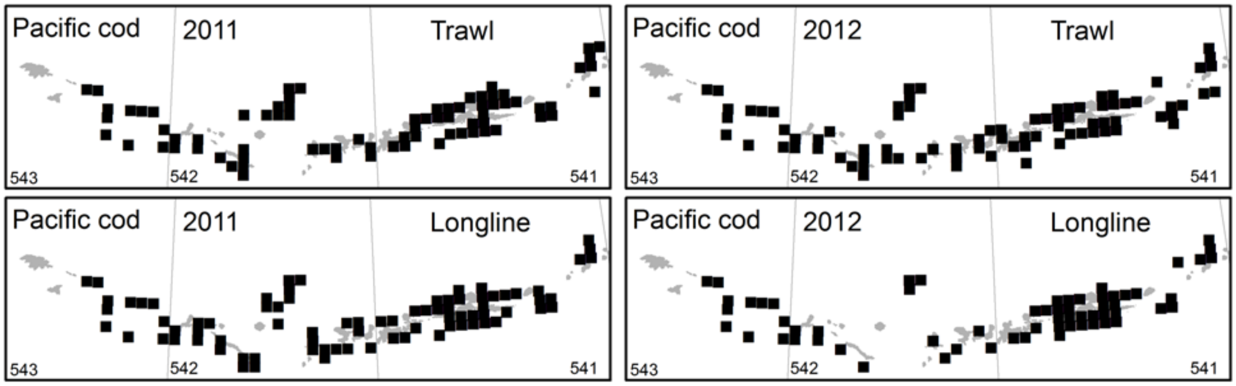

Figure 2.2c—AI maps showing each 400 square km cell with hauls/sets containing Pacific cod from at least 3 distinct vessels **by gear** in 2011-2012, overlaid against NMFS 3-digit statistical areas.

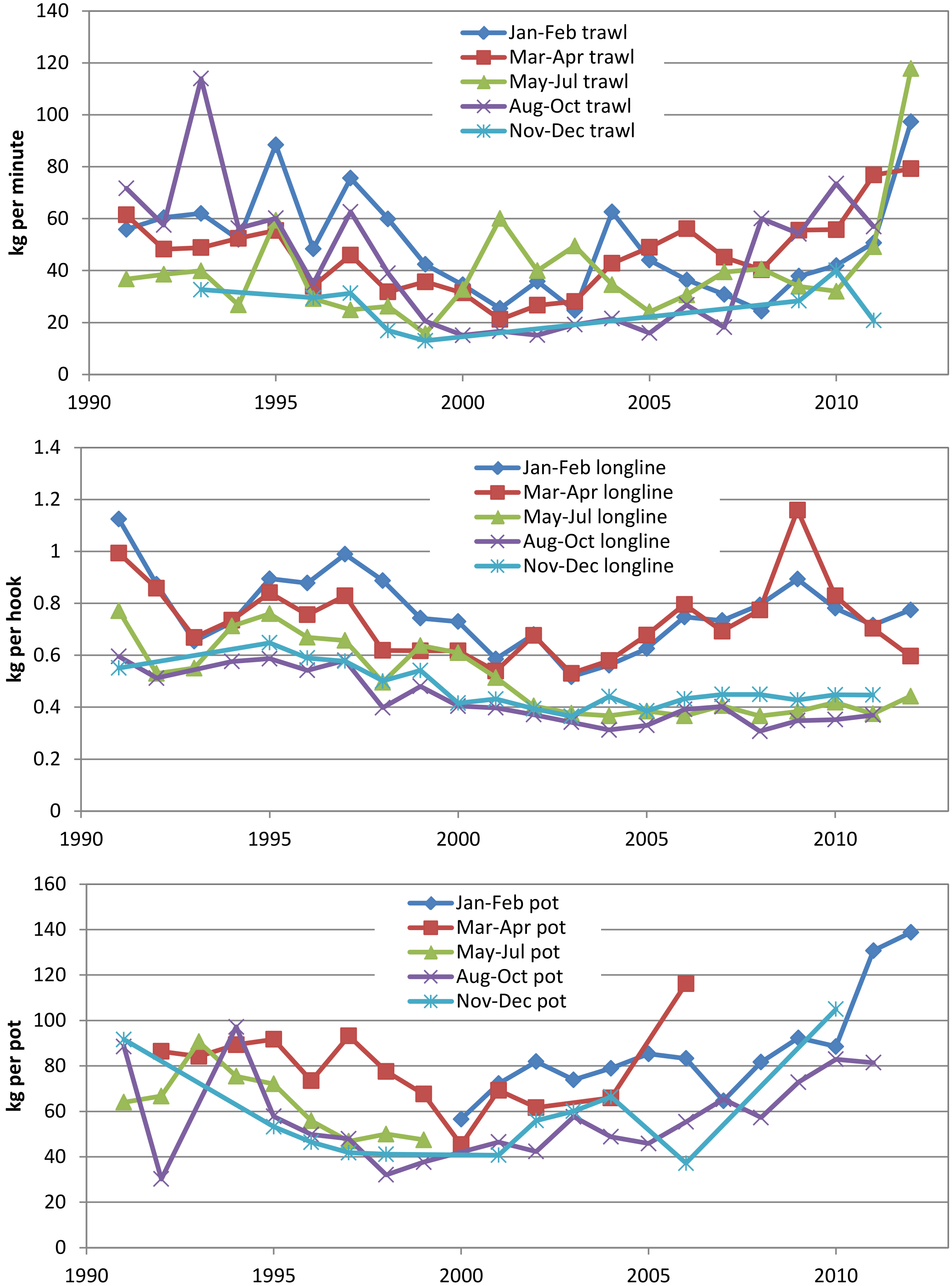

Figure 2.3a—Time series of fishery catch per unit effort, by gear and season, in the EBS.

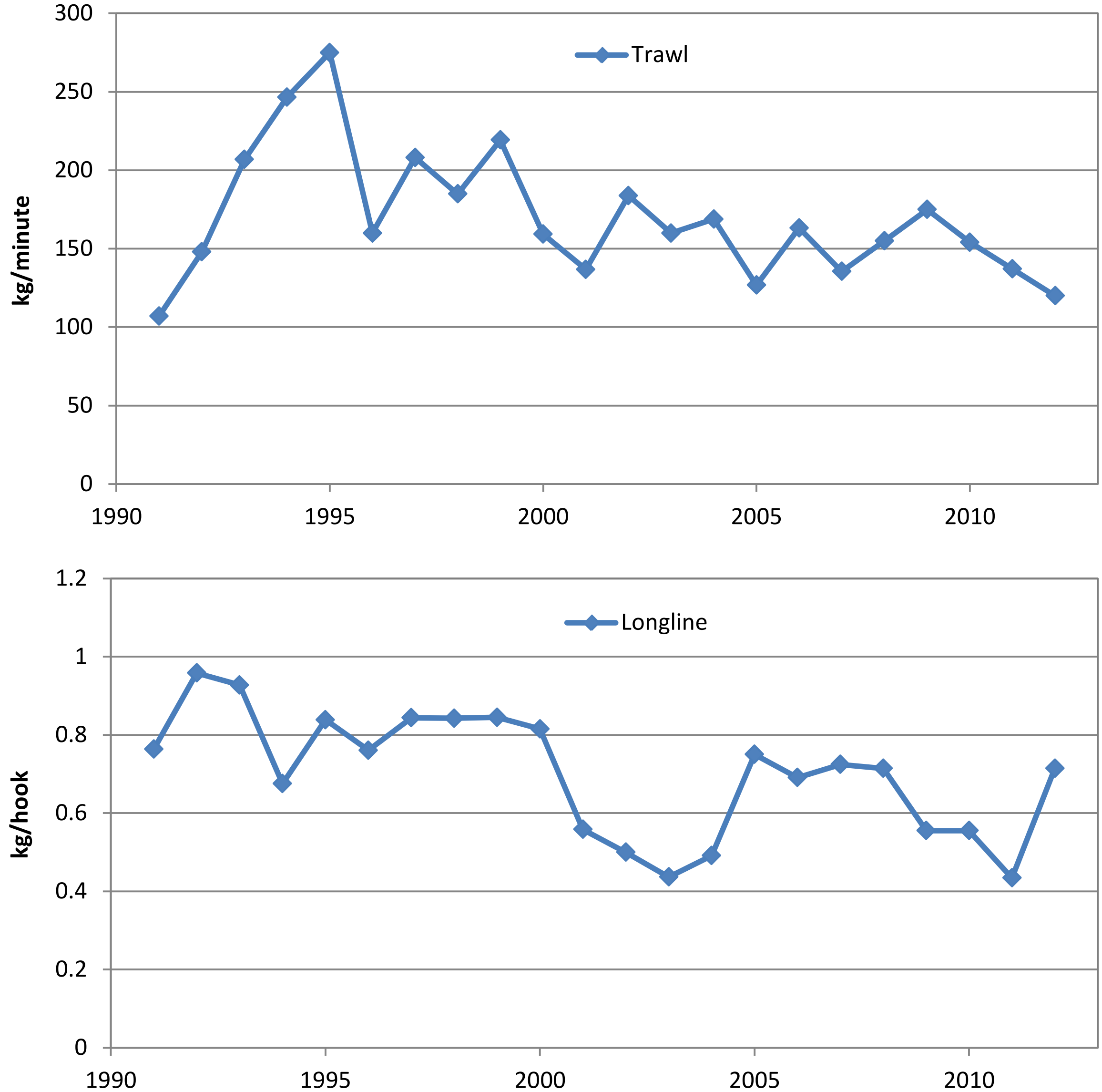

Figure 2.3b—Time series of fishery catch per unit effort, by gear, in the AI.

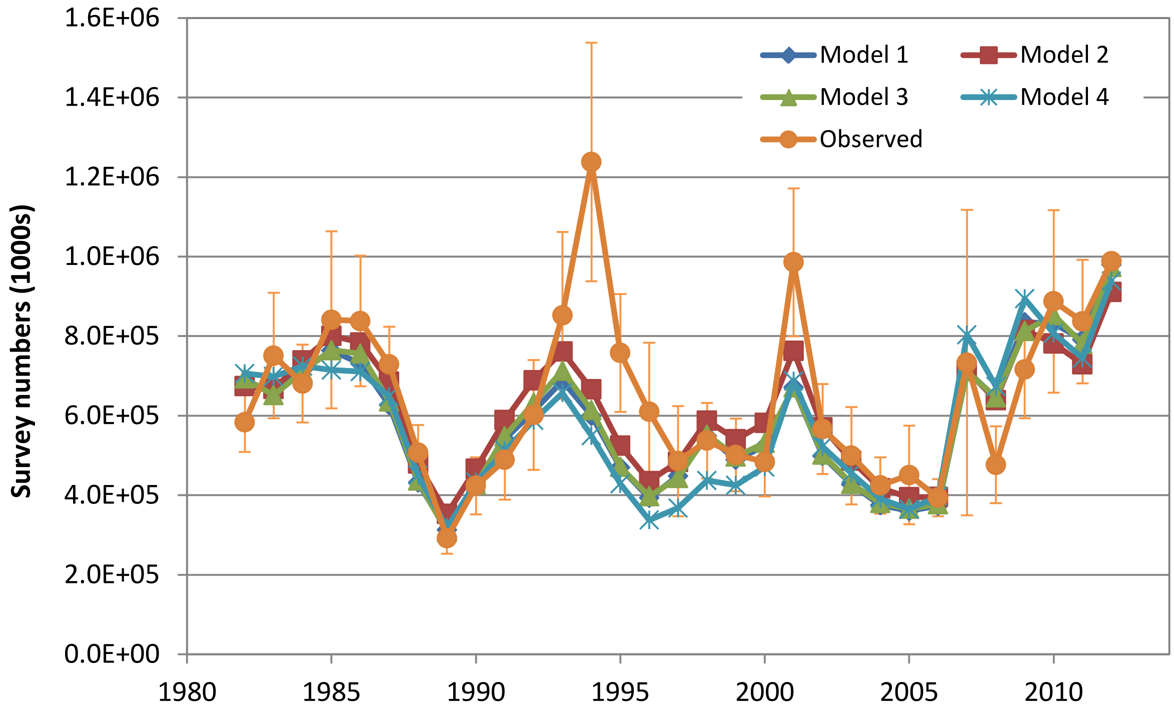

Figure 2.4—Fits of the four models to the trawl survey abundance time series.

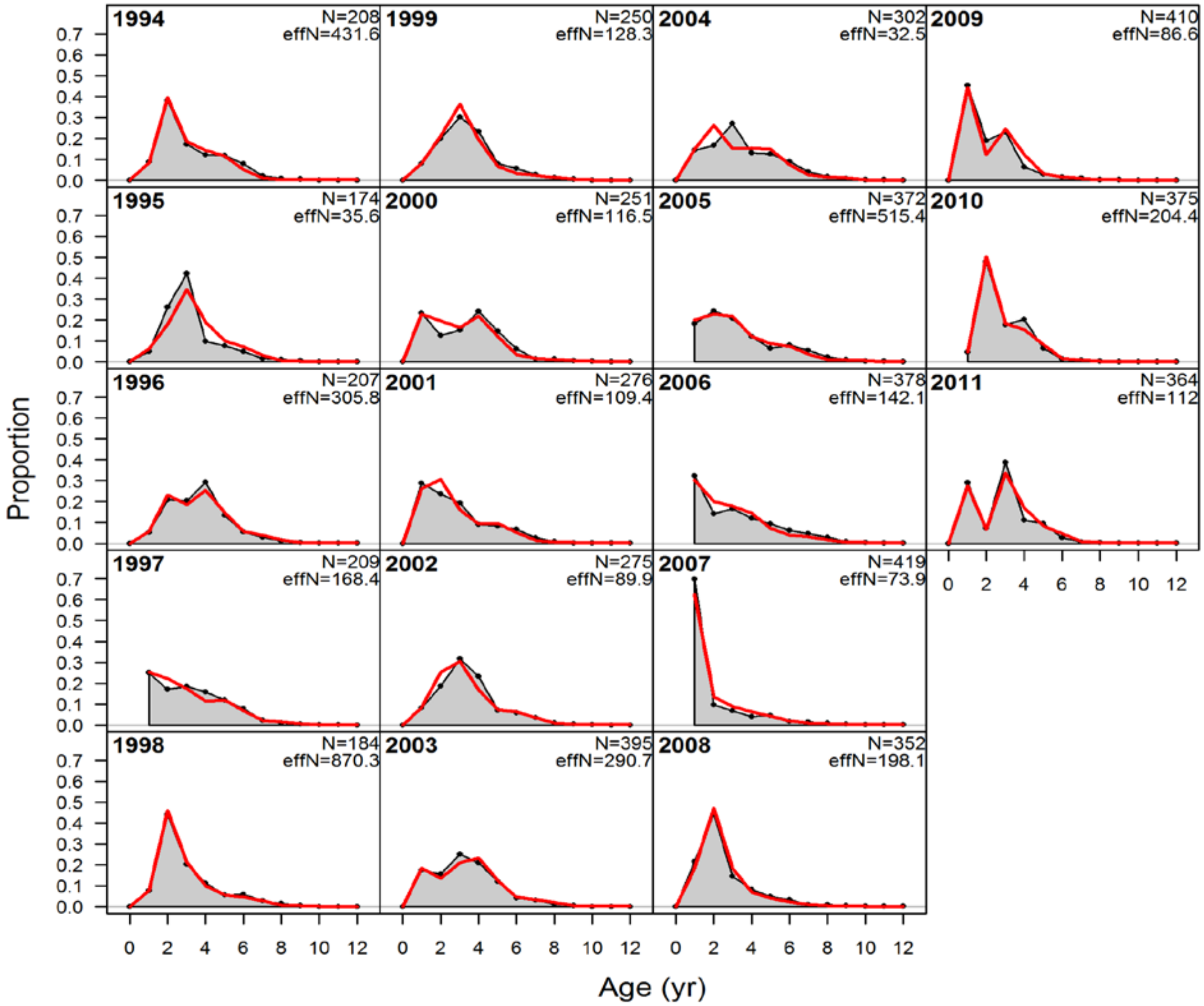

Figure 2.5a—Fit to trawl survey age composition data obtained by Model 1 (grey = observed, red = estimated).

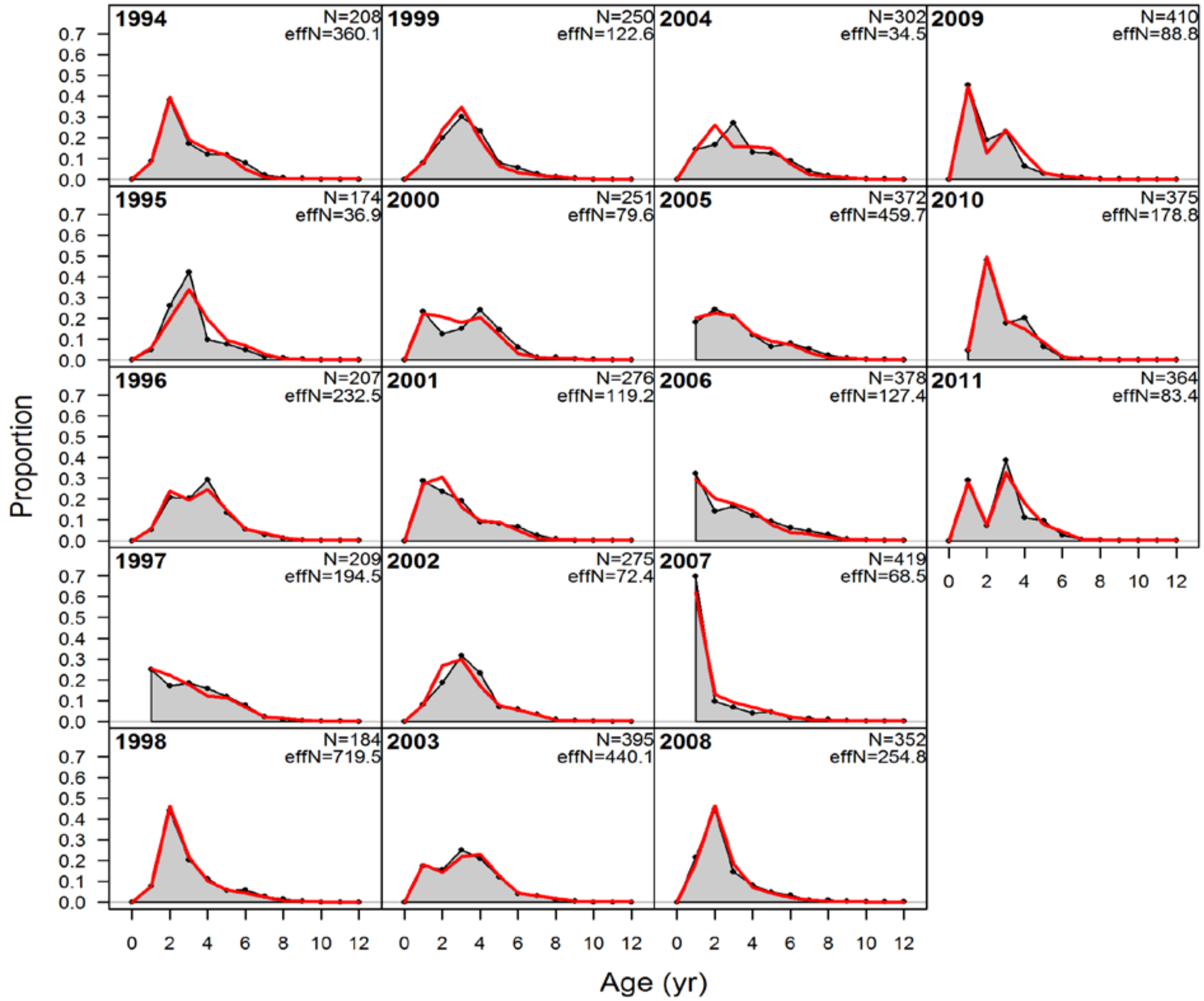

Figure 2.5b—Fit to trawl survey age composition data obtained by Model 2 (grey = observed, red = estimated).

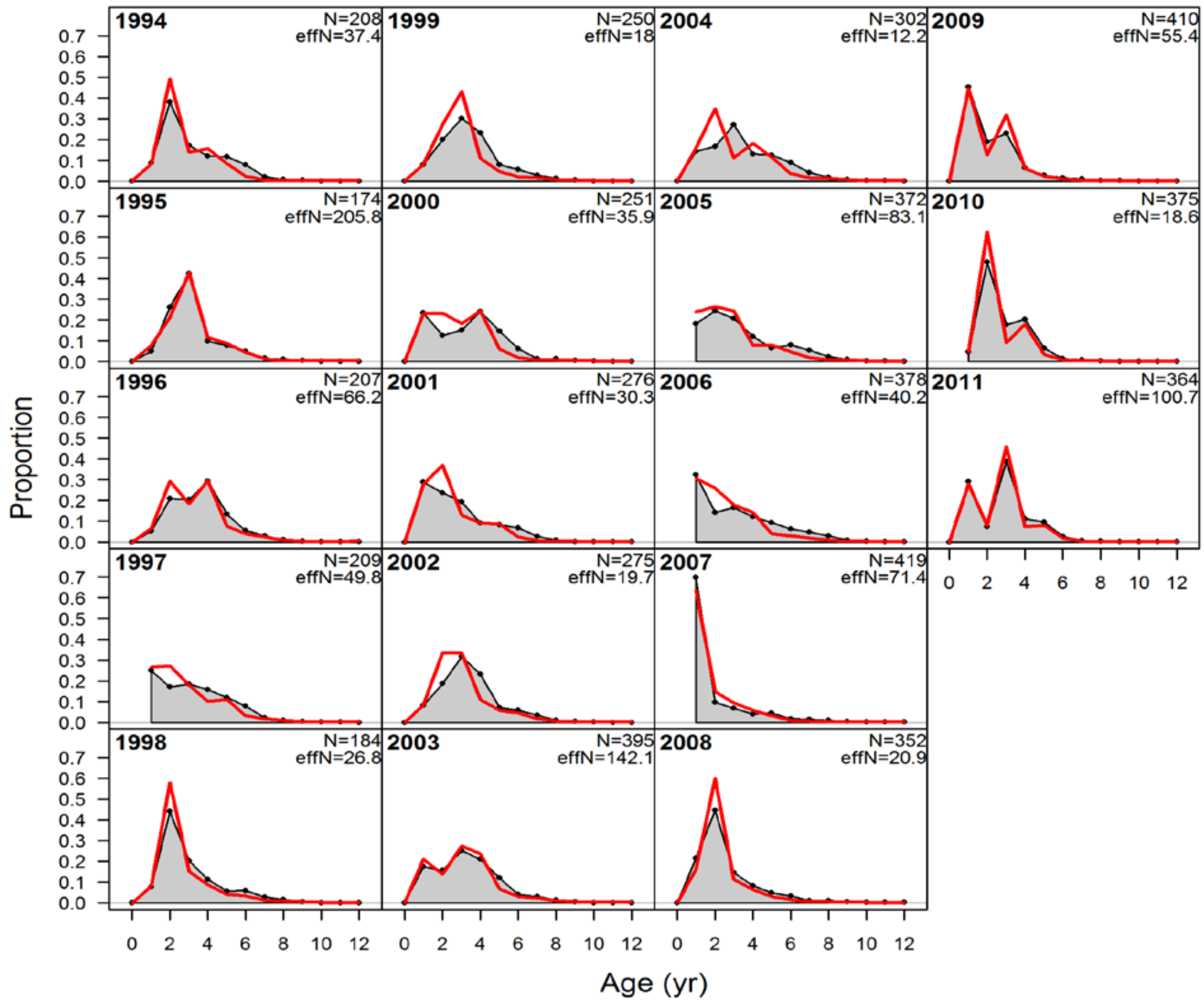

Figure 2.5c—Fit to trawl survey age composition data obtained by Model 3 (grey = observed, red = estimated).

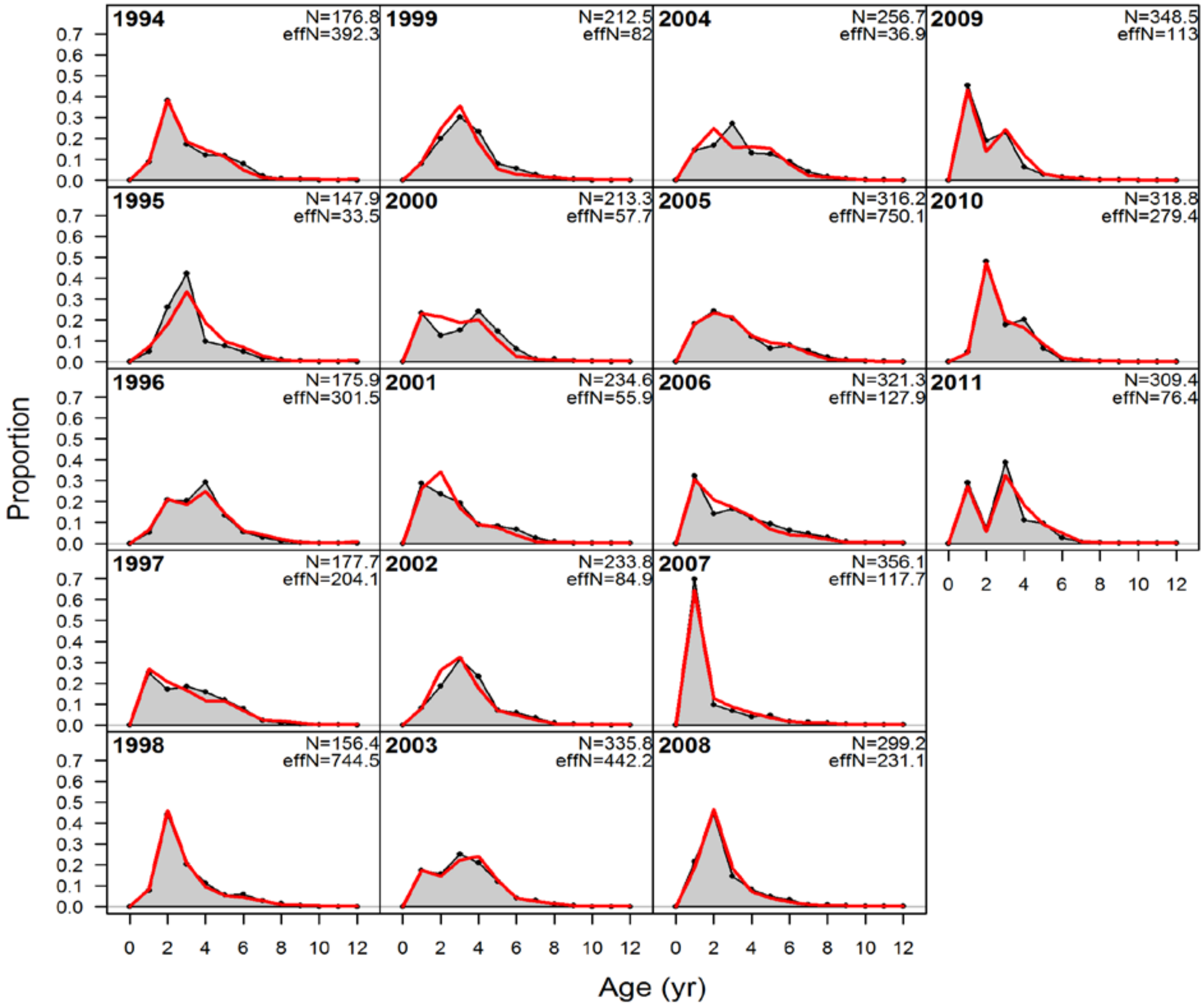

Figure 2.5d—Fit to trawl survey age composition data obtained by Model 4 (grey = observed, red = estimated).

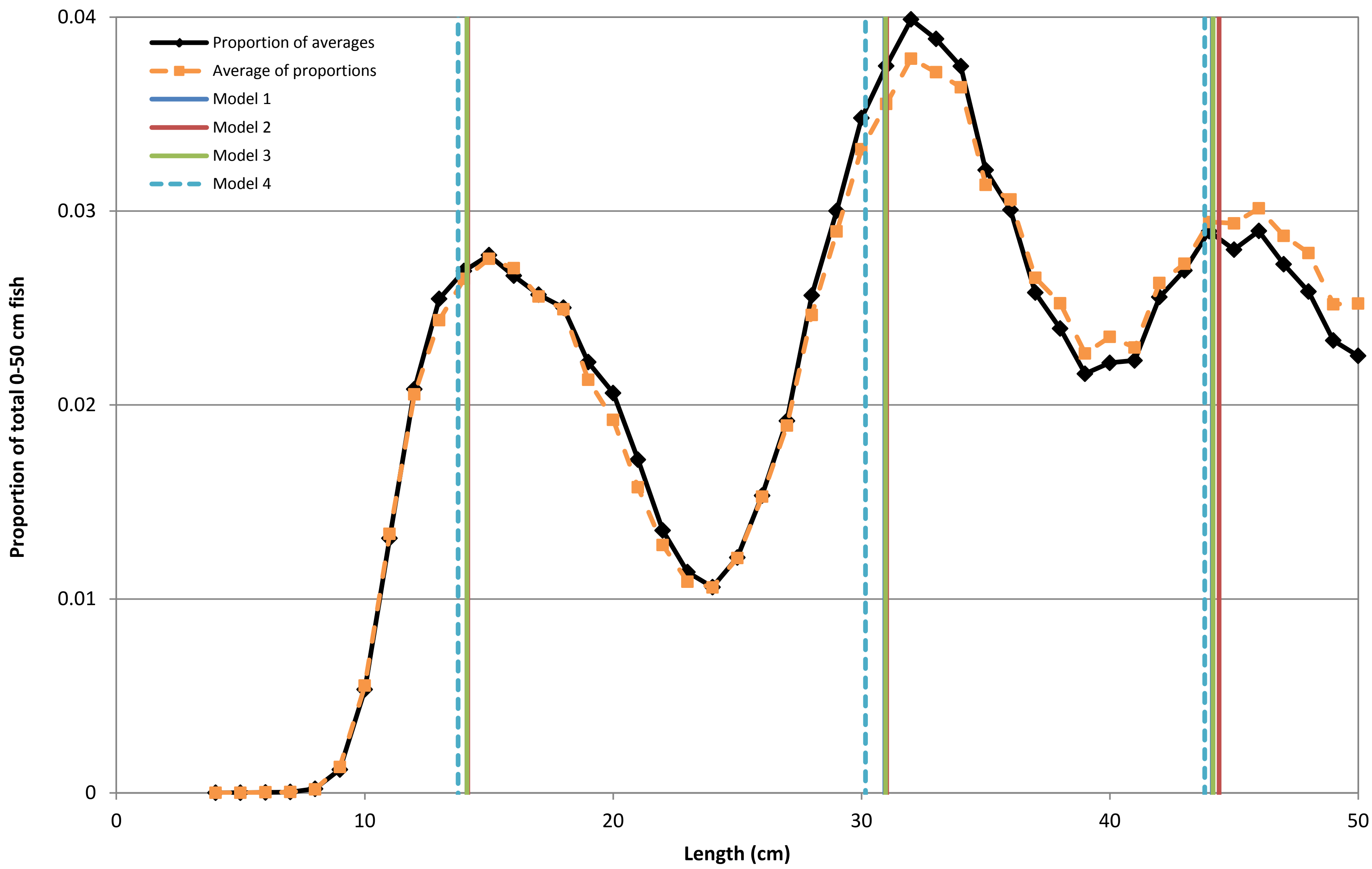

Figure 2.6—Estimates of mean size at ages 1-3 from each of the models, compared to long-term average survey size (0-50 cm) composition.

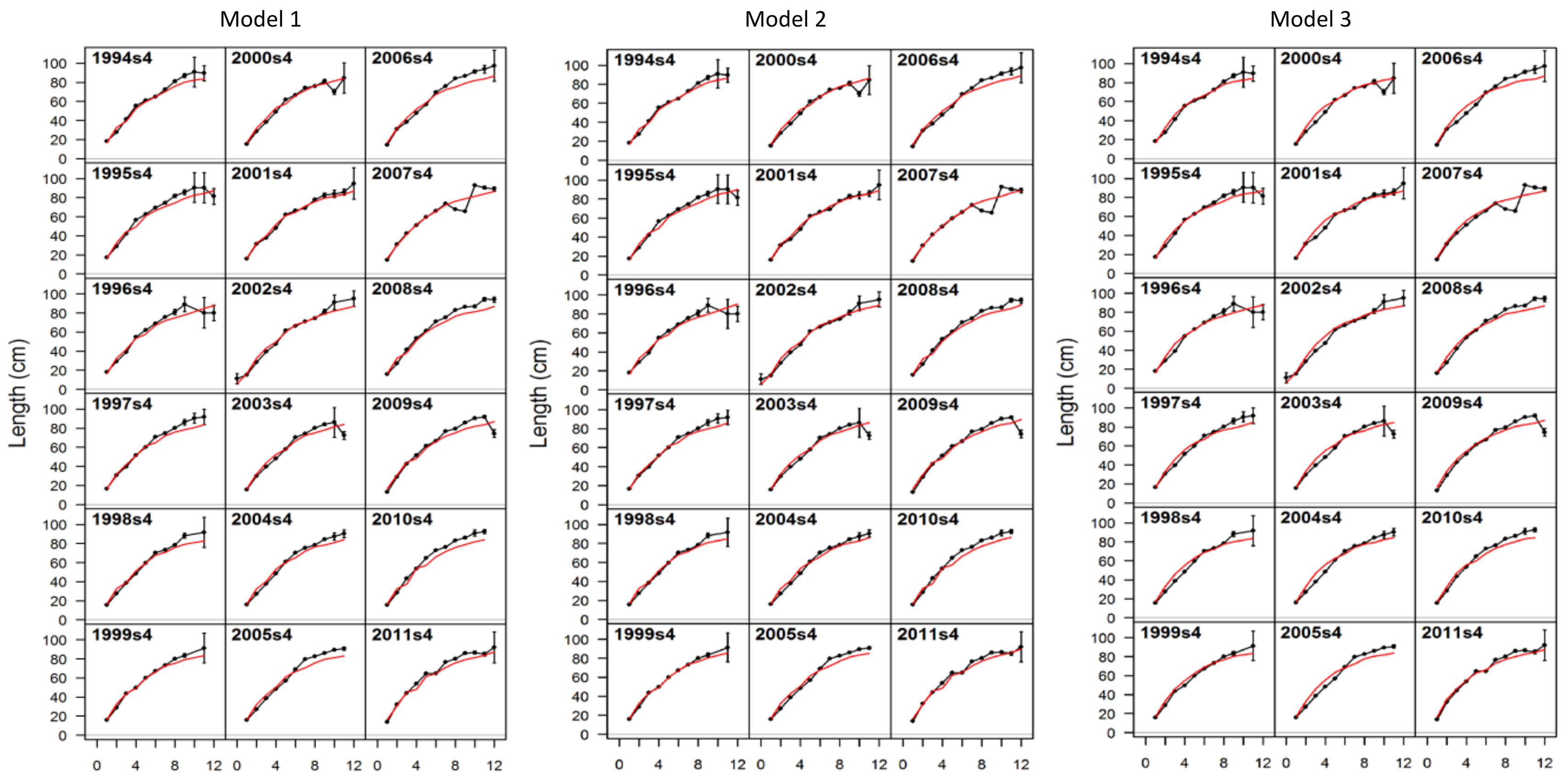

Figure 2.7—Fit to mean-size-at-age data from Models 1-3 (black = observed, red = estimated). Model 4 does not use mean-size-at-age data.

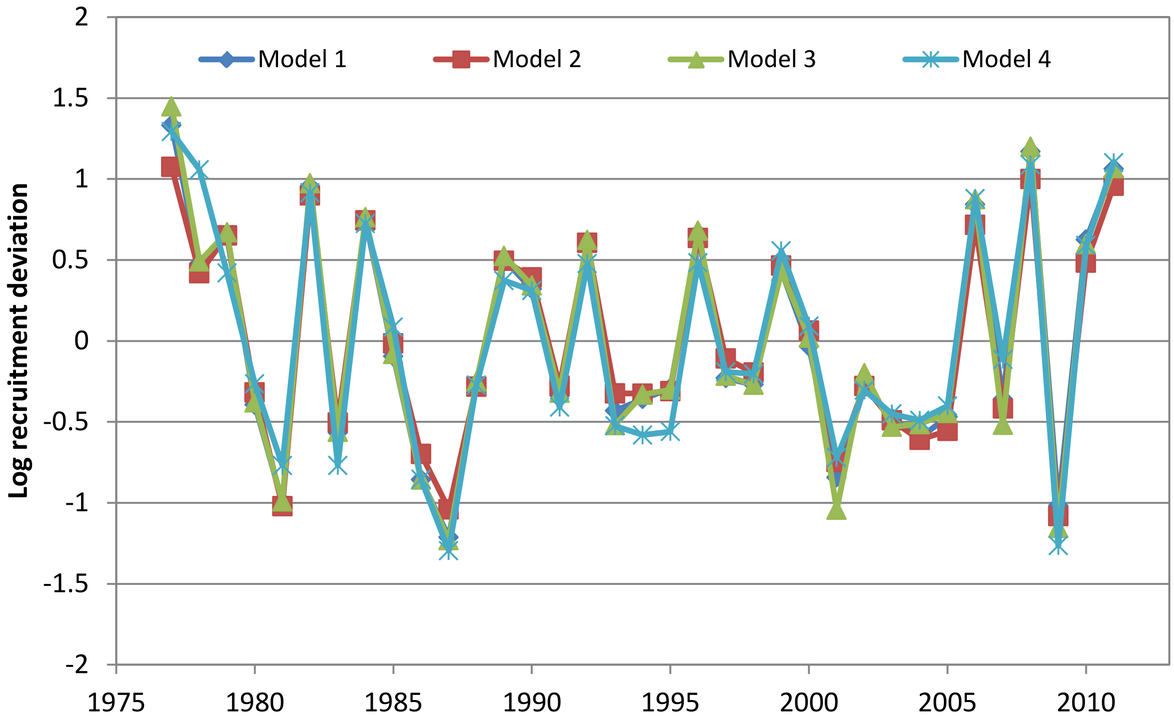

Figure 2.8—Time series of estimated log recruitment deviations from the four models.

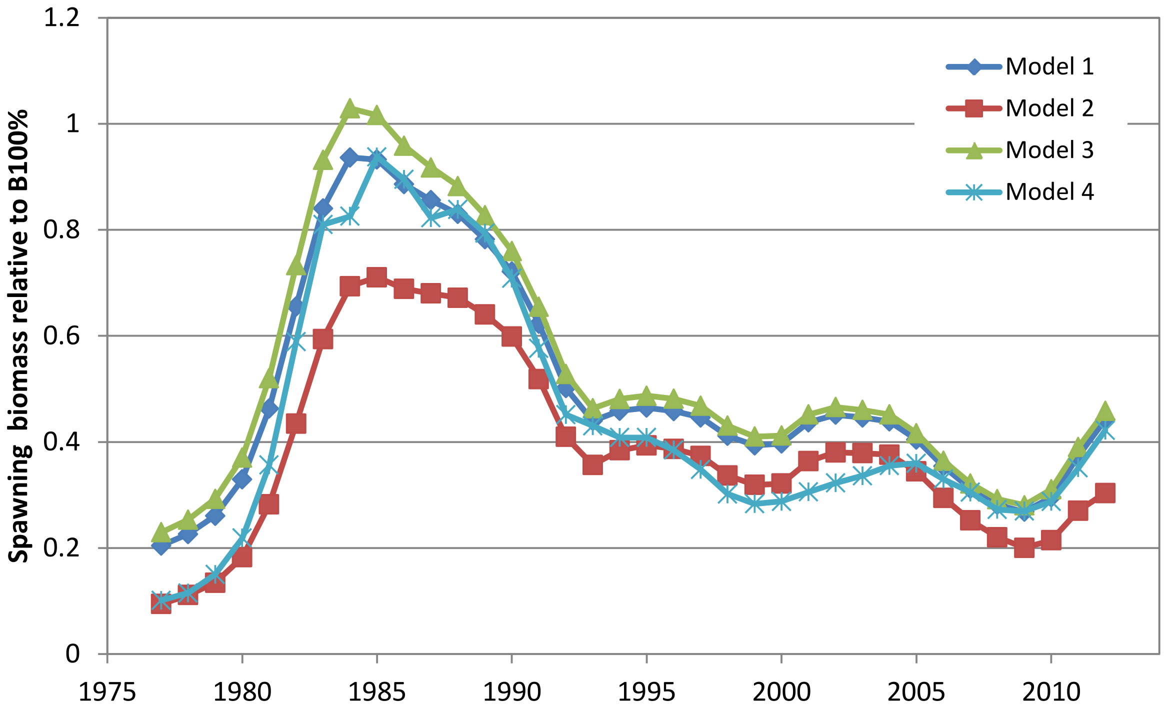

Figure 2.9—Time series of spawning biomass relative to $B_{100\%}$ as estimated by the four models.

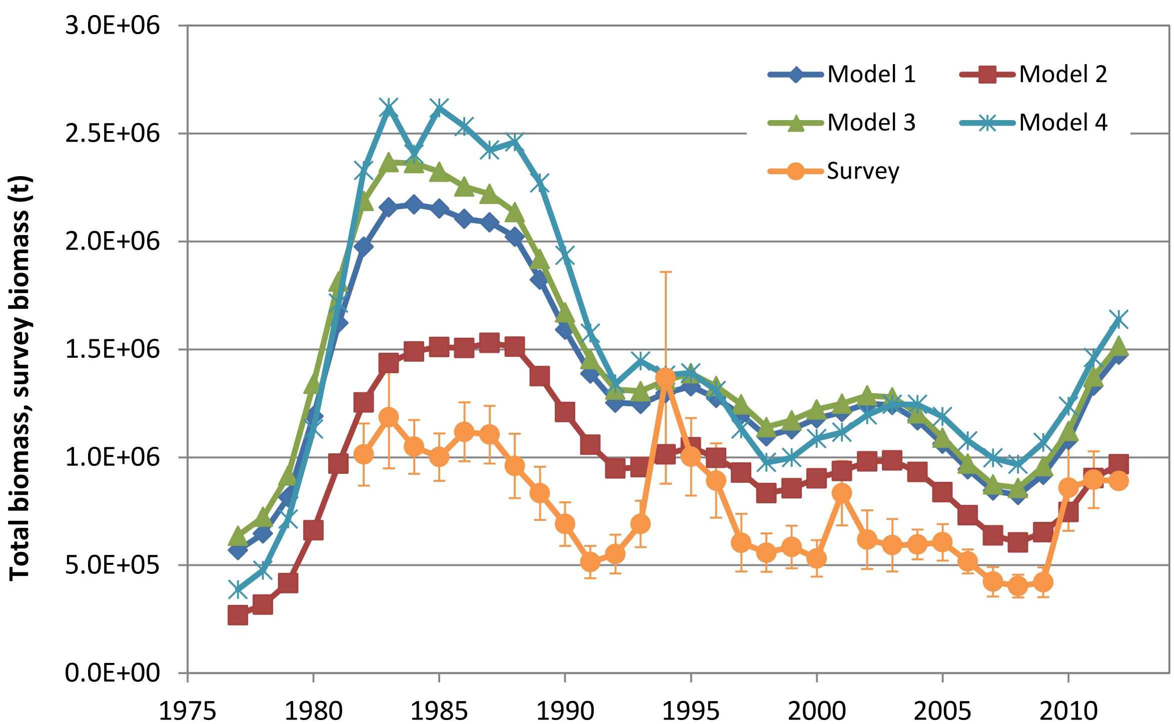

Figure 2.10—Time series of total (age 0+) biomass as estimated by the four models. Survey biomass is shown for comparison.

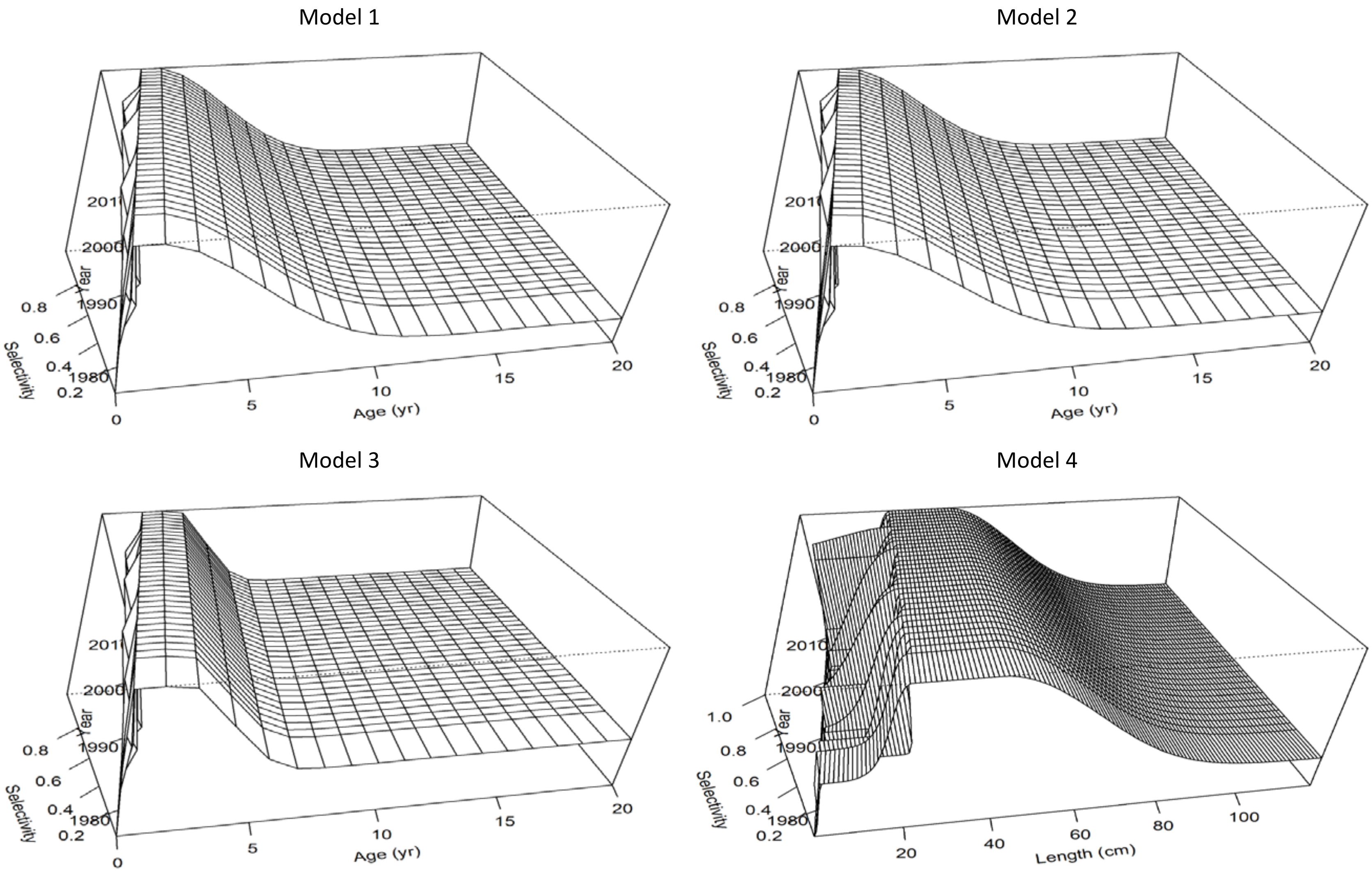

Figure 2.11—Trawl survey selectivity at age as estimated by the four models. "*Dev*" parameters affect the ascending limb annually in all models. Selectivity is age-based in Models 1-3, but length-based in Model 4.

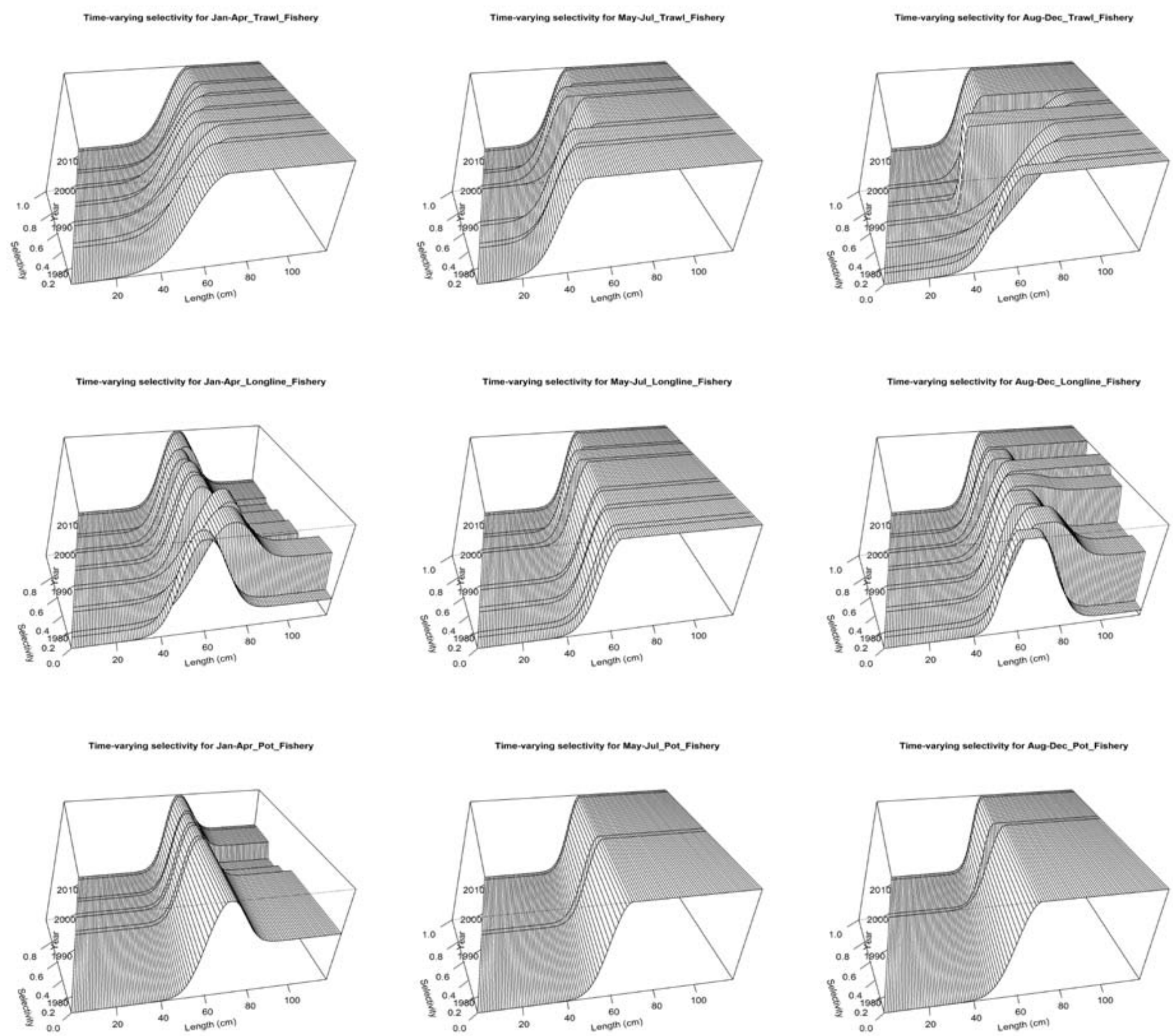

Figure 2.12a—Fishery selectivity at length (cm) as estimated by Model 1. Rows represent gear types (trawl, longline, and pot, respectively), and columns represent seasons (Jan-Apr, May-Jul, and Aug-Dec, respectively).

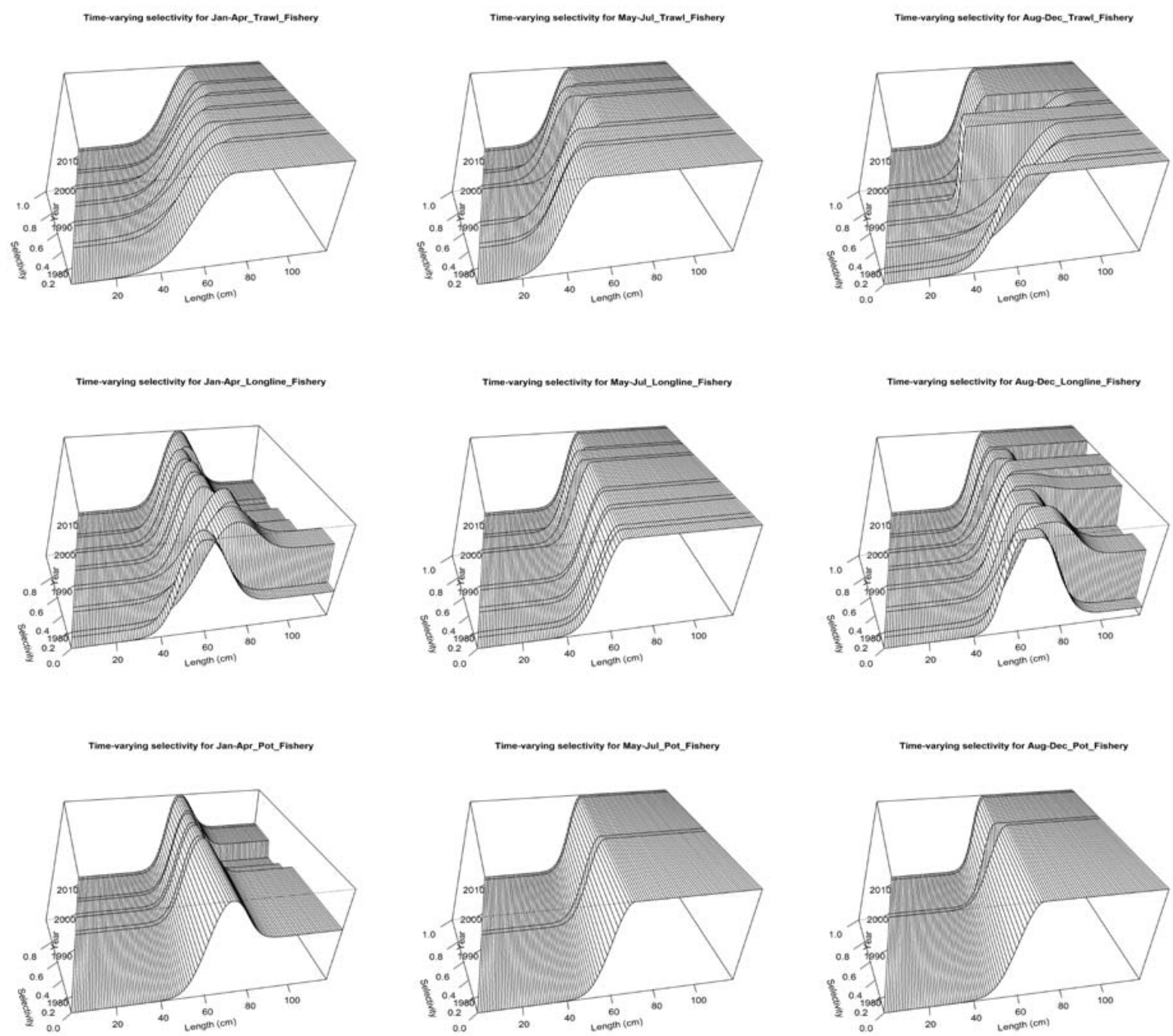

Figure 2.12b—Fishery selectivity at length (cm) as estimated by Model 2. Rows represent gear types (trawl, longline, and pot, respectively), and columns represent seasons (Jan-Apr, May-Jul, and Aug-Dec, respectively).

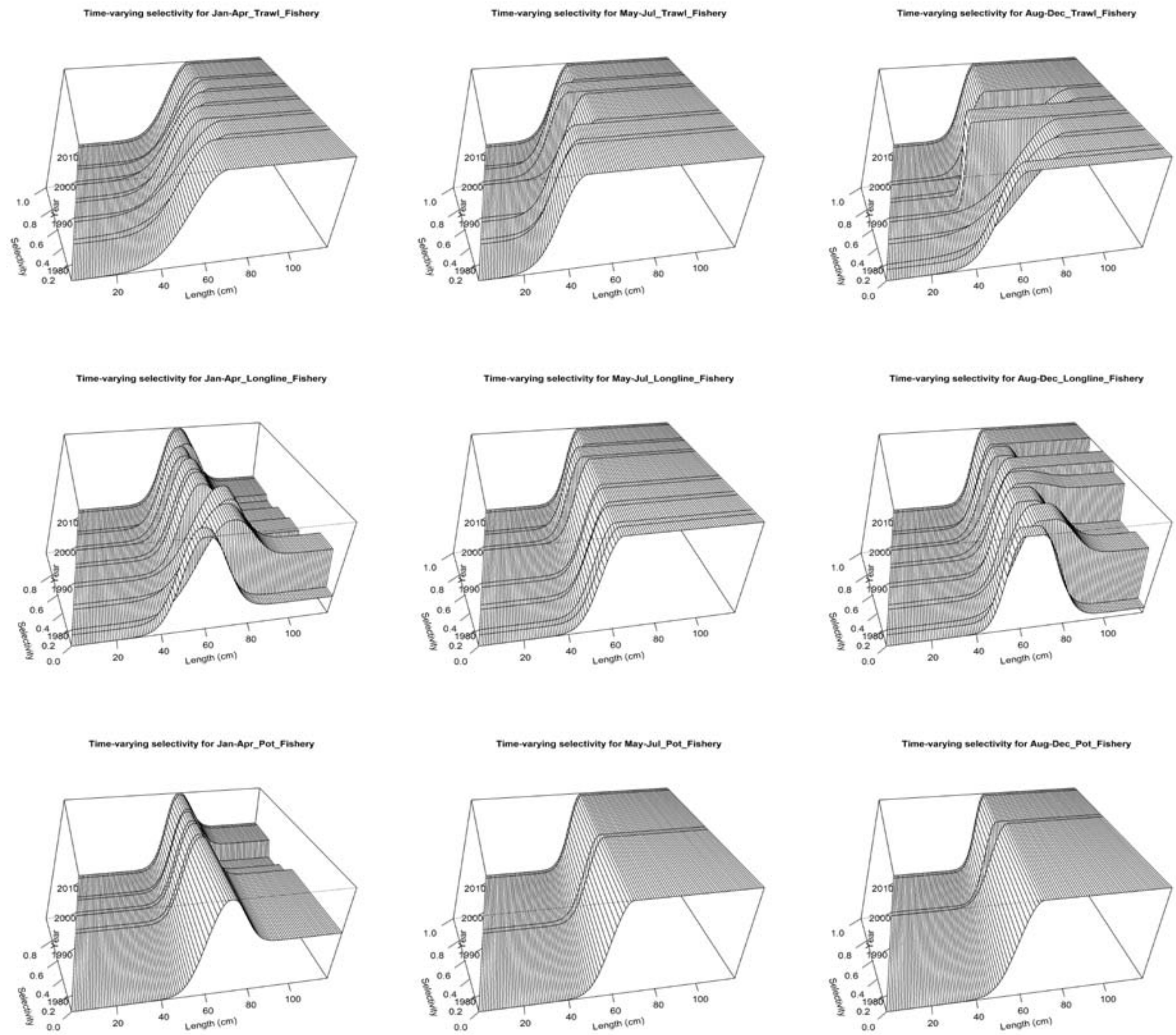

Figure 2.12c—Fishery selectivity at length (cm) as estimated by Model 3. Rows represent gear types (trawl, longline, and pot, respectively), and columns represent seasons (Jan-Apr, May-Jul, and Aug-Dec, respectively).

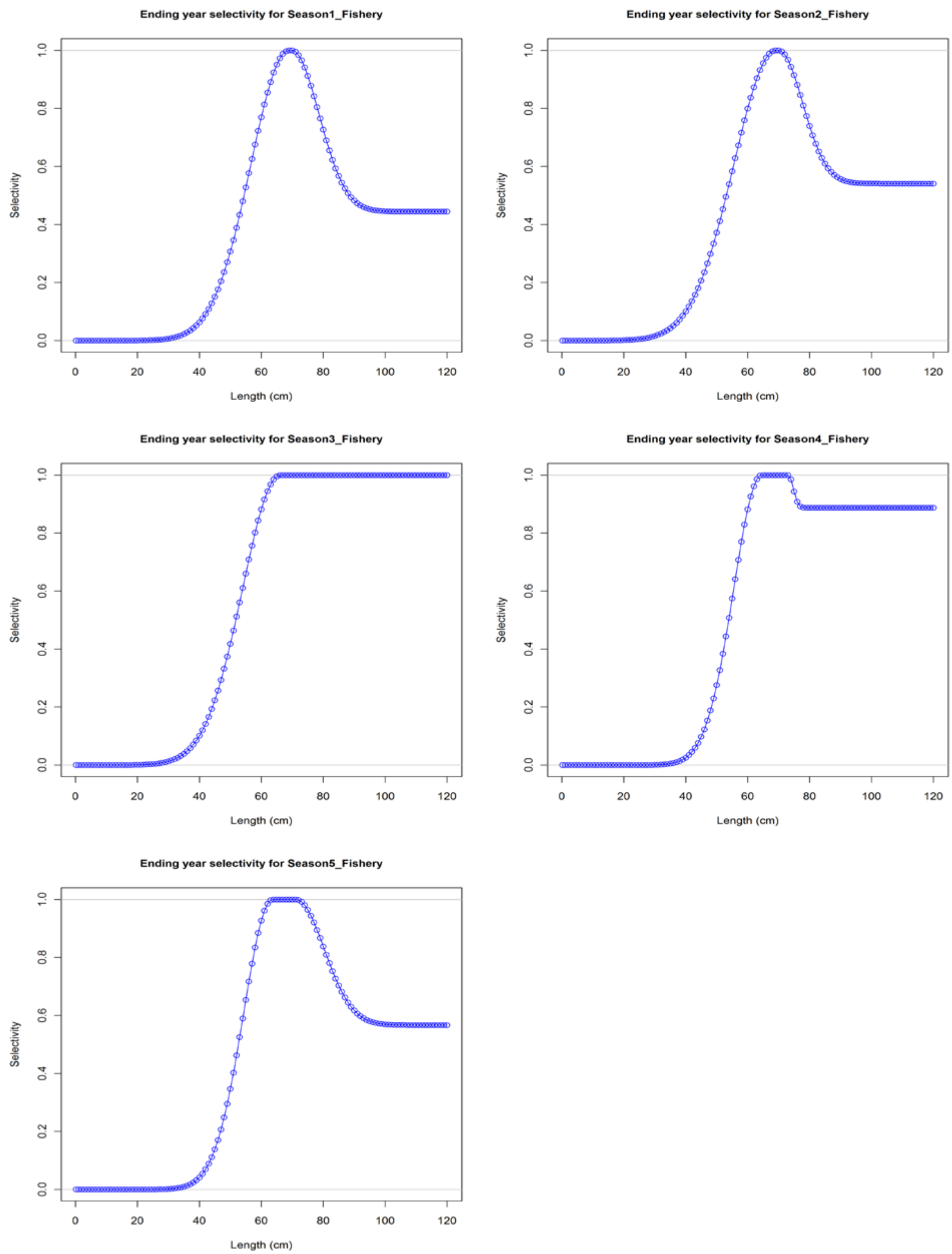

Figure 2.12d—Fishery selectivity at length (cm) as estimated by Model 4; one panel per season.

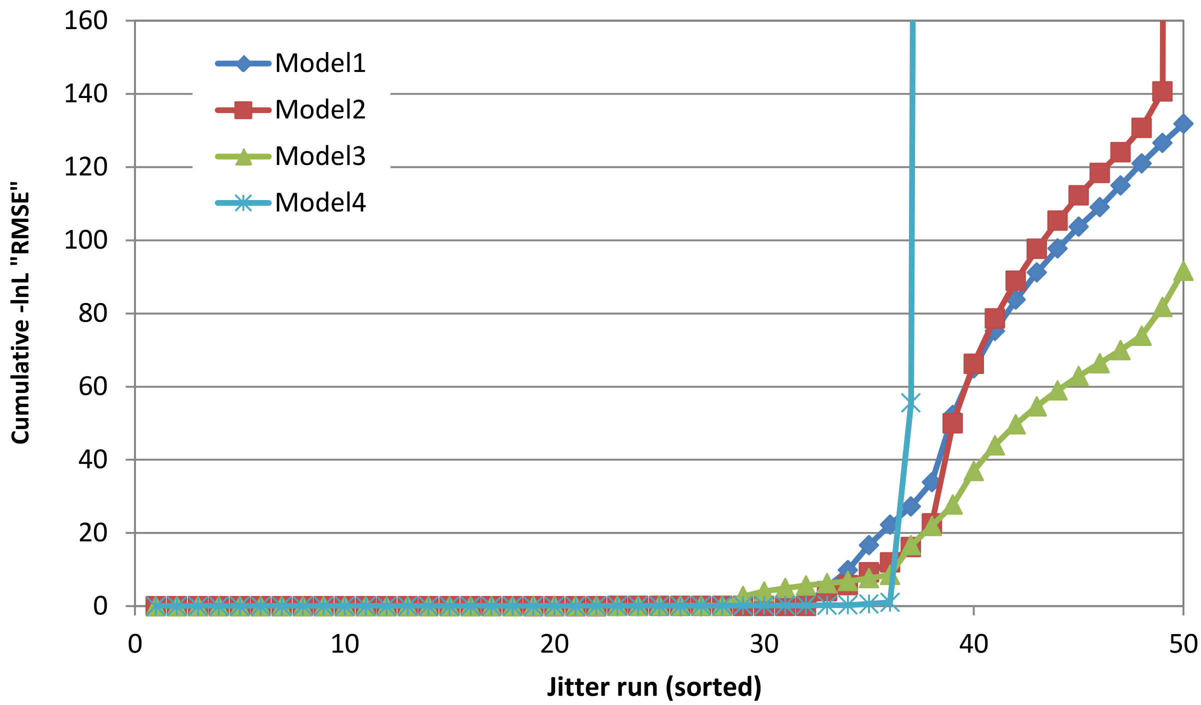

Figure 2.13—Variability in objective function value for each of the four models. See text for details.

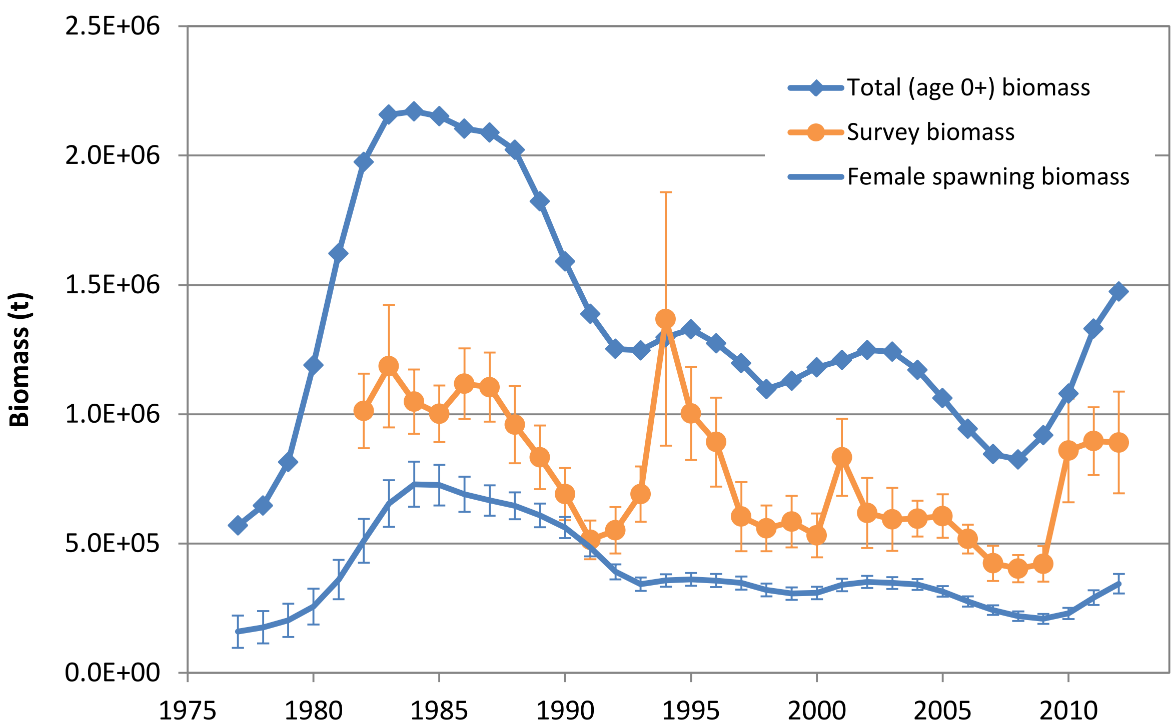

Figure 2.14—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by Model 1. Spawning biomass and survey biomass show 95% CI.

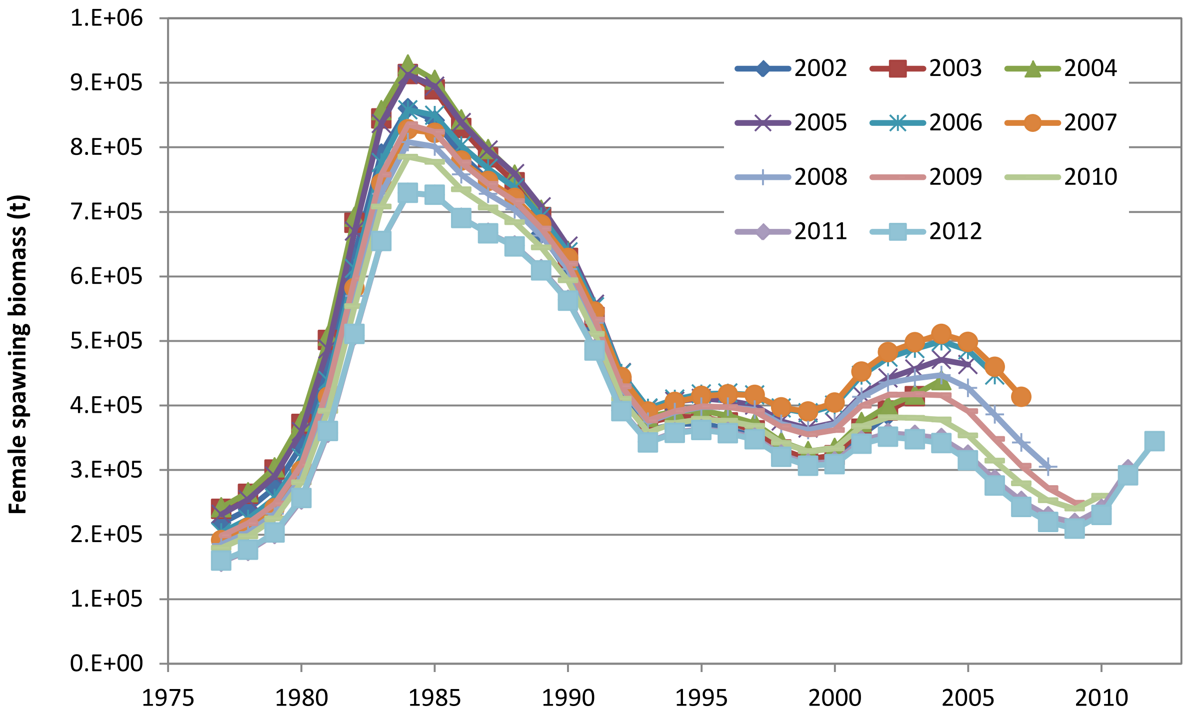

Figure 2.15a—Retrospective plots of spawning biomass for Model 1.

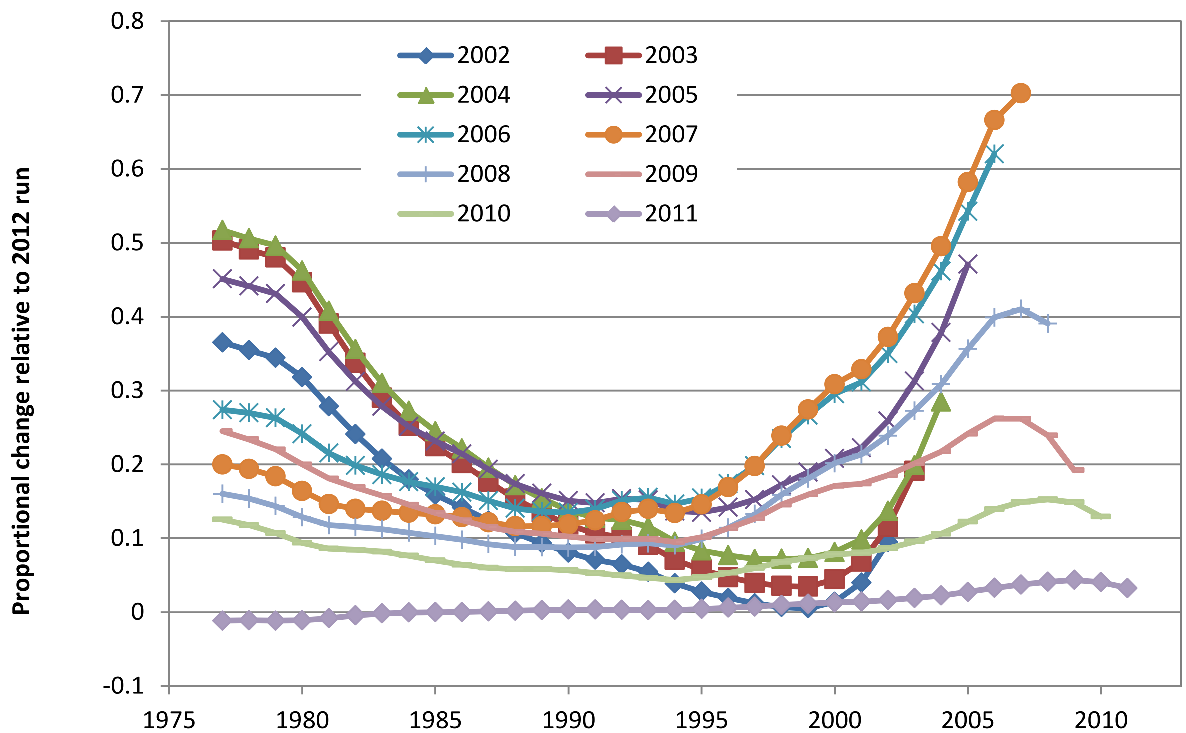

Figure 2.15b—Same retrospective results shown in Figure 2.15a, but plotted as proportional changes relative to the terminal (2012) run.

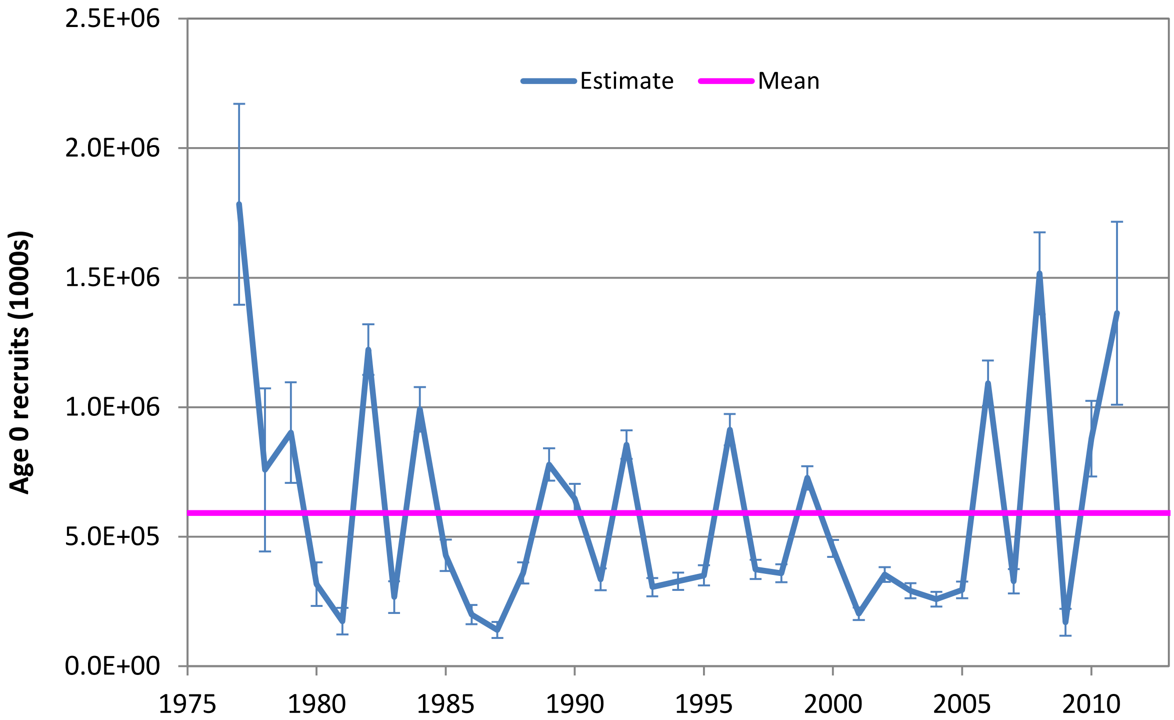

Figure 2.16—Time series of EBS Pacific cod recruitment at age 0 as estimated by Model 1.

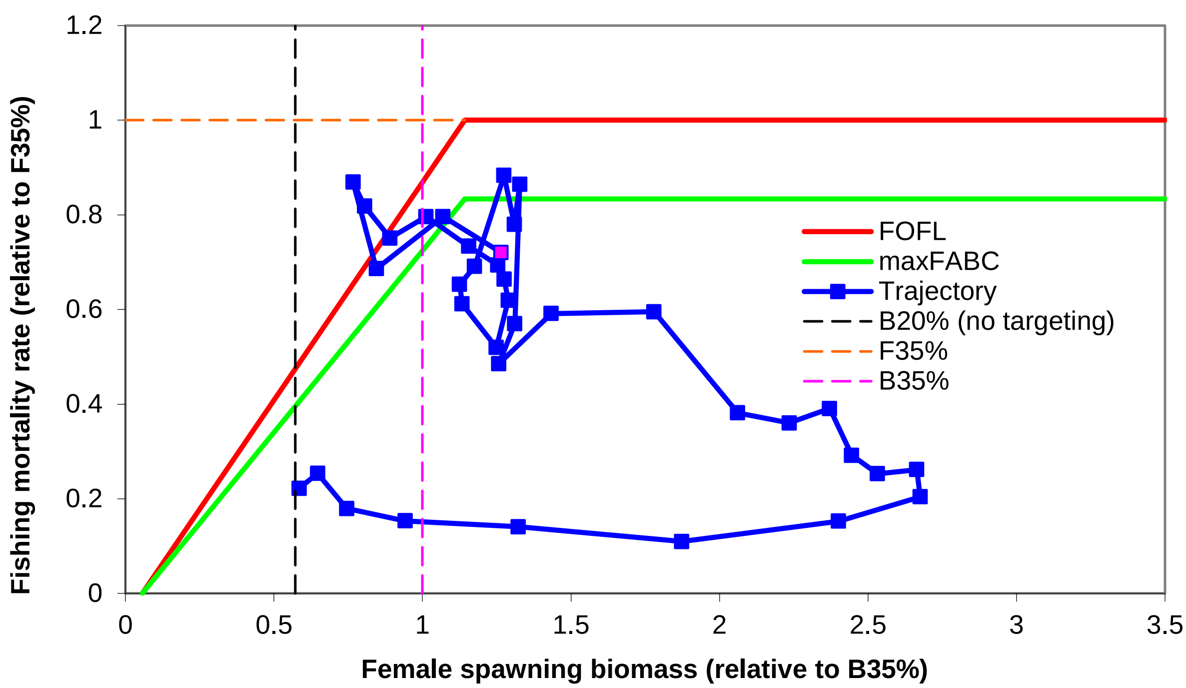

Figure 2.17—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model 1, 1977-present (magenta square = 2012).

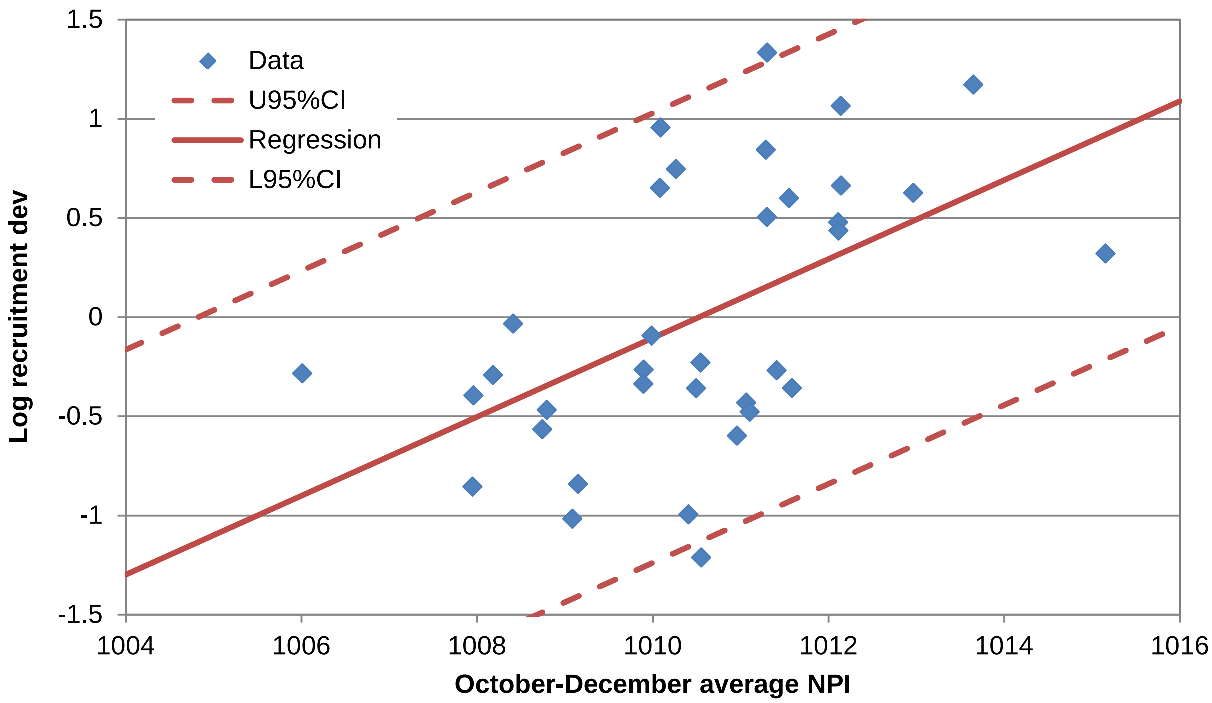

Figure 2.18—Log recruitment *dev*s (age 0) estimated by Model 1 versus same-year October-December average of the North Pacific Index (see text for details).

Attachment 2.1:

An exploration of alternative assessment models for Pacific cod in the eastern Bering Sea

Introduction

This document represents an effort to respond to comments made by the BSAI Plan Team, the joint BSAI and GOA Plan Teams, and the SSC on the 2011 assessment of the Pacific cod (*Gadus macrocephalus*) stock in the eastern Bering Sea (EBS, Thompson and Lauth 2011), and to explore additional models.

Comments from the Plan Teams and SSC

Note: Comments directed exclusively at the assessments for Pacific cod in the Aleutian Islands or Gulf of Alaska are not included here.

Joint Plan Team (September, 2011)

JPT1: *"In Model A …, the catchability and selectivity deviations are treated as random effects but they are not properly integrated out. The MLEs are therefore suspect, and the iterative tuning may produce pathological results."* This is correct, and appears to be a problem with all age-structured assessments of BSAI and GOA groundfish. However, there is no reason to believe that a subjectively specified σ, as used in most or all other assessments, is any less suspect or any less likely to produce pathological results. In a univariate linear-normal model, iterative tuning of σ will tend to under-estimate the true variability. Model 5 in this preliminary assessment attempts to address this problem by applying a method that adjusts σ upward to the value that would be correct for a univariate linear-normal model after random effects are properly integrated out (see Annex 2.1.1).

JPT2: *"Allowing survey catchability to vary from year to year, perhaps substantially, achieves a better fit to the data but at the expense of discounting the relative abundance data. Some members felt strongly that this was a mistake."* The reason for allowing survey catchability to vary in last year's Model A was precisely to *avoid* discounting the survey. Either the confidence intervals derived from the survey data are accurate or they are not. Surely it *would* be discounting the survey to claim that there is no need for model estimates to be generally consistent with the survey confidence intervals. If variable catchability is the only way for the model to estimate a time series that is consistent with the survey confidence intervals, then allowing catchability to vary is the only way *not* to discount the survey. Alternatively, if "discounting" means simply that the influence of a given survey datum on model estimates is less than it would have otherwise been, then the Plan Teams' premise is valid, but the same argument could be made for including many other standard parameters or data sets (e.g., allowing selectivity to be less than unity for some range of ages or lengths, allowing recruitment to vary with time, or including size composition data from the fishery would cause the survey abundance data to be "discounted" under this definition). The objective of allowing survey catchability to vary under last year's Model A was to fit the survey abundance data in a manner consistent with those data (both the means and the confidence intervals), not to maximize the impact of those data.

JPT3: *"The great variability of survey selectivity estimates from Model A is a clear indication that the model is overfitting the data."* This comment is difficult to interpret for three reasons:

First, comment JPT3 suggests that the problem consists of allowing selectivity to vary *too much*, whereas comment JPT1 (above) suggests just the opposite (because the iterative tuning that was used in last year's Model A tends to *under*estimate the true variability). Because it would be unreasonable to criticize a model for allowing *too little* variability in selectivity and at the same time criticize the same model for allowing *too much* variability in selectivity, comments JPT1 and JPT3 will be reconciled here as follows: Comment JPT1 will be interpreted as implying that the amount of variability allowed in last year's Model A *for any given time-varying selectivity parameter* was too small, while comment JPT3 will be interpreted as implying that the *overall number of time-varying selectivity parameters* in last year's Model A was too large.

Second, comment JPT3 sheds very little light on what constitutes "great" variability. In an effort to address this issue more quantitatively, last year's final assessment introduced a statistic (the selectivity coefficient of variation, SCV) designed to measure the extent to which estimated selectivity varies. In last year's final assessment, the SCV for the accepted model (Model 3b) was 0.208, compared to a value of 0.330 for Model A in last year's preliminary assessment. Given the lack of any Team comment to the contrary, it will be assumed here that the SCV is an appropriate measure of variability in selectivity, and that the break between "great" and "less than great" variability therefore falls somewhere between 0.208 and 0.330. An explicit statement from the Plan Team as to exactly where the break occurs within this range, preferably accompanied by a logical rationale, would be welcome.

Third, comment JPT3 does not mention why great variability between point estimates in a time series constitutes a clear indication of overfitting. A customary goal in statistics is to obtain point estimates that reflect the true variability in the time series, but comment JPT3 suggests that the model should be systematically constrained to *under*estimate the true variability in the time series whenever the latter is "great." Again, an explicit rationale for this claim would be welcome.

JPT4: *"In view of the many new features in Model A and several concerns about it, the Teams do not favor including it … as one of the candidates in November."* In deference to the Teams, Model A was not included in last year's final assessment. However, several features of Model A are considered again in this preliminary assessment.

Joint Plan Team (November, 2011)

JPT5: *"The Teams encouraged the author to try estimating survey catchability internally again. It is possible that with the other improvements made in this assessment, catchability will be estimable, at least in the EBS assessment."* Catchability is estimated internally in Model 1.1 (see "Model Structures" below; also comment JPT9).

BSAI Plan Team (November, 2011)

BPT1: *"The BSAI team recommends that the author check for any poor fits to commercial length frequencies that might indicate a change in selectivity resulting from the implementation of Amendment 80 in 2008 and the creation of longline cooperatives in 2010."* A new fishery selectivity period beginning in 2008 is incorporated in Model 3 (see "Model Structures" below; also comments JPT6 and SSC4).

SSC (December, 2011)

SSC1: *"We agree with a recommendation from the CIE review that the number of explorations and new model configurations for upcoming assessments should be reduced to allow for a thorough evaluation of the performance of the current model over several assessment cycles."* Five primary models are presented in this preliminary assessment, down from six in last year's preliminary assessment. A small subset of results is also presented for nine secondary models (see "Model Structures" below; also comments JPT6, SSC4, and SSC5).

SSC2: *"The SSC notes that weight-at-age in both regions was lowest in May-Aug. or Sept.-Oct. and highest in Jan.-Feb. These patterns seem somewhat counter-intuitive and we encourage the authors to evaluate the biological basis for these patterns."* For the past few years, the parameters of the seasonal weight-length relationships have been estimated independently of one another. Although the resulting estimates gave a better fit to the data than the alternative of assuming no intra-annual variability in weight at length, they did not necessarily follow any explicit phenological process, and counter-intuitive results (such as multiple intra-annual maxima or minima in the seasonal schedule of weight for a given length) could occur. In this preliminary assessment, the inter- and intra-annual weight-length relationship has been completely re-parameterized in a way that follows an explicit phenological process and that prevents such counter-intuitive patterns from arising, while still providing an excellent fit to the data. This re-parameterized relationship is used in Model 1.3, all of the "Pre5" models, and Model 5 (see "Model Structures" and Annex 2.1.2 below; also comments JPT8, SSC4, and SSC5).

SSC3: *"The recommended models for both regions estimate ageing bias as a linear function of age, but the estimated patterns in bias by age differs by region increasing from approximately 0.34 at the youngest age to 0.85 at the oldest age in the BSAI assessment (Model 3b), but decreases from 0.36 to 0 at the oldest age in the GOA assessment (Model 3)."* The effects of these contrasting patterns are examined in Model 1.2 (see "Model Structures" below; also comment JPT7).

Joint Plan Team (May, 2012)

JPT6: *"For the EBS, the Teams recommend that the preliminary assessment include the following four models, which are in addition to any models that the authors wish to propose: Model 1 is last year's final model, Model 2 is last year's final model with re-tuned catchability, Model 3 is last year's final model with a new fishery selectivity period beginning in 2008 or 2010, and Model 4 is last year's final model without age data. For Model 3, the Teams acknowledge that estimating a full set of selectivity parameters with only 2-4 years of data may be challenging."* All four of the Teams' requested models are included in this preliminary assessment (see "Model Structures" below; also comment SSC4).

JPT7: *"For both the EBS and GOA, the Teams recommend that the authors attempt to explore the divergent ageing bias trends in the two regions and the impacts thereof"* (this was a "non-model" proposal, meaning that it *"can be explored sufficiently without developing and presenting a full set of results for an additional model"*). See response to comment SSC3.

JPT8: *"For both the EBS and GOA, the Teams recommend that the authors attempt to evaluate the biological basis for estimated patterns of seasonal weight at length"* (this was a "non-model" proposal, meaning that it *"can be explored sufficiently without developing and presenting a full set of results for an additional model"*). See response to comment SSC2.

JPT9: *"For both the EBS and GOA, the Teams recommend that the authors attempt to estimate catchability internally"* (this was a "non-model" proposal, meaning that it *"can be explored sufficiently without developing and presenting a full set of results for an additional model"*). See response to comment JPT5.

JPT10: *"The Teams recommend that Stock Synthesis be modified so that a prior distribution can be placed on the average, across the 60-81 cm size range, of the product of catchability and selectivity at age, where the average is weighted by long-term average numbers at length."* This comment has been forwarded to Richard Methot, who develops and maintains the code for Stock Synthesis (SS). He agreed to attempt to make this modification, although it may not be ready in time for this year's assessment.

SSC (June, 2012)

SSC4: *"The SSC agrees with the selection of last year's final model as the baseline and with the proposed suite of alternative models. However, we note that there are limited data to assess any effects resulting from the creation of longline cooperatives in 2010 on fishery selectivity (Model 3).* ***Hence, the SSC recommends evaluation of a change in fishery selectivity in 2008 (in response to Amendment 80), but no change in 2010"*** (emphasis original). See response to comment BPT1.

SSC5: *"In addition, we note that stock assessment authors are free to develop and bring forward an alternative model or models in both the preliminary and final assessment. However, given the Plan Team's (and SSC's) reluctance in previous years to consider a new author-recommended model in the fall that incorporates a large number of potentially influential changes in a single model (for example changes in growth, selectivities, and catchability), the SSC encourages the authors to evaluate changes in one or a few structural elements at a time."* Some of the features of last year's Model A are brought forward here in a new model, labeled Model 5. Other features of last year's Model A were not included in the new Model 5 in an attempt to avoid introducing too many changes. Some transitional steps between last year's accepted model and the new Model 5 are provided in Models 1.3 and Pre5.1 through Pre5.6 (see "Model Structures" below; also responses to comments JPT1 through JPT4).

Model Structures

As mentioned above, four primary models and three secondary models were requested by the Plan Team and SSC. A fifth primary model and six more secondary models are also presented here. A brief description of each model is shown below, with more detailed descriptions in the next subsections:

Model	Description
1	Last year's accepted model (same as last year's Model 3b)
1.1	Same as Model 1, except survey catchability estimated internally
1.2	Same as Model 1, except ageing bias parameters fixed at GOA values
1.3	Same as Model 1, except with revised weight-length representation
2	Same as Model 1, except survey catchability re-tuned to match Nichol et al. (2007)
3	Same as Model 1, except new fishery selectivity period beginning in 2008
4	Same as Model 1, except no age data used (same as last year's Model 4)
Pre5.1	Same as Model 1.3, except for three minor changes to the data file
Pre5.2	Same as Model Pre5.1, except ages 1-10 in the initial vector estimated individually
Pre5.3	Same as Model Pre5.2, except Richards growth curve used
Pre5.4	Same as Model Pre5.3, except σ for recruitment *dev*s estimated internally as a free parameter
Pre5.5	Same as Model Pre5.4, except survey selectivity modeled as a function of length
Pre5.6	Same as Model Pre5.5, except fisheries defined by season only (not season-and-gear)
5	Same as Model Pre5.6, except four quantities estimated iteratively

The five primary models are Models 1, 2, 3, 4, and 5. The nine secondary models are Models 1.1-1.3 and Pre5.1-Pre5.6. The purpose of including Models Pre5.1-Pre5.6 is to provide a reasonably smooth transition between Model 1.3 and Model 5. The main differences between primary and secondary models are: 1) full results are presented for primary models, but only a small subset of results is presented for secondary models, and 2) some of the secondary models (specifically, Models Pre5.1-Pre5.6) were subjected to less rigorous tests for convergence than the other models.

Development of the final versions of all primary models and Models 1.1-1.3 included calculation of the Hessian matrix, and—with one exception—all primary models and Models 1.1-1.3 also passed a "jitter" test of 50 runs with a jitter parameter (equal to half the standard deviation of the logit-scale distribution from which initial values are drawn) of 0.1. The one exception was that the jitter parameter for Model 5 was reduced to 0.01, because most runs failed if the jitter parameter was set at 0.1. In the event that a jitter run produced a better value for the objective function than the base run, then: 1) the model was re-run starting from the final parameter file from the best jitter run, 2) the resulting new control file became the new base run, and 3) the entire process (starting with a new set of jitter runs) was repeated until no jitter run produced a better value for the objective function than the most recent base run.

Development of the final versions of Models Pre5.1-Pre5.6 did not include calculation of the Hessian matrix, and they were not subjected to a jitter test. As a weak test for convergence, each of these models was re-run from its respective ending values (in the control file, not the parameter file), and confirmed to return the same objective function value.

Each model had its own control file, but some groups of models shared a common data file. Specifically, Models 1, 1.1, 1.2, 2, and 3 shared a common data file ("BSbase.dat"); Models Pre5.1-Pre5.5 shared a common data file ("BSmodelPre5.dat"); and Models Pre5.6 and 5 shared a common data file ("BSmodel5.dat"). Models 1.3 and 4 each had their own data file ("BSmodel1_3.dat" and "BSmodel4.dat," respectively).

Except for *dev* parameters, all parameters were estimated with uniform prior distributions. Bounds were non-constraining except in a very few unimportant cases.

All of the models use a double-normal curve to model selectivity. This functional form is constructed from two underlying and linearly rescaled normal distributions, with a horizontal line segment joining the two peaks. As configured in SS, the equation uses the following six parameters:

7) *beginning_of_peak_region* (where the curve first reaches a value of 1.0)
8) *width_of_peak_region* (where the curve first departs from a value of 1.0)
9) *ascending_width* (equal to twice the variance of the underlying normal distribution)
10) *descending_width* (equal to twice the variance of the underlying normal distribution)
11) *initial_selectivity* (at minimum length/age)
12) *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 data used in this preliminary assessment were the same data used in last year's final assessment, except that the weight-length data used in Models 1.3, Pre5.1-Pre5.6, and 5 were updated.

The software used to run all models was SS V3.23b, as compiled on 11/5/2011 (Methot 2005, Methot 2011, Methot and Wetzel *in press*). Stock Synthesis is programmed using the ADMB software package (Fournier et al. 2012).

Model 1

The details of last year's final model (labeled Model 3b in last year's assessment) were described by Thompson and Lauth (2011). That model, in turn, was identical to the final model from the 2010 assessment (Thompson et al. 2010), except for the following features:

- The pre-1982 portion of the AFSC bottom trawl time series was removed from the data file.
- The 1977-1979 and 1980-1984 time blocks for the January-April trawl fishery selectivity parameters were combined. This change was made because the selectivity curve for the 1977-1979 time block tended to have a very difficult-to-rationalize shape (almost constant across length, even at very small sizes), which led to very high and also difficult-to-rationalize initial fishing mortality rates.
- The age corresponding to the *L1* parameter in the length-at-age equation was increased from 0 to 1.4167, to correspond to the age of a 1-year-old fish at the time of the survey, which is when the age data are collected. This change was adopted to prevent mean size at age from going negative (as sometimes happened for age 0 fish in previous assessments, and as happened even for age 1 fish in one of the models from the 2010 assessment), and to facilitate comparison of estimated and observed length at age and variability in length at age.
- A column for age 0 fish was added to the age composition and mean-size-at-age portions of the data file. Even though there are virtually no age 0 fish represented in these two portions of the data file, unless a column for age 0 is included, SS will interpret age 1 fish as being ages 0 and 1 combined, which can bias the estimates of year class strength.
- Ageing bias was estimated internally.
- The parameters governing variability in length (i.e., the distribution of length at age for a given set of von Bertalanffy parameters) were estimated internally.
- All size composition records were included in the log-likelihood function, regardless of whether an age composition record existed for the same year.
- The fit to the mean-size-at-age data was not included in the log likelihood function.

No changes to last year's control file or data file were necessary in order for the code to run under SS V3.23b.

Model 1.1

Model 1.1 is the same as Model 1, except that survey catchability (*Q*) was estimated internally as a free parameter. In Model 1, *Q* was fixed at a value of 0.77 (note that SS estimates *Q* in log space, so this means that ln(*Q*) was fixed at a value of -0.261365 in Model 1). The value of *Q* used in Model 1 was determined iteratively in the 2009 assessment (Thompson et al. 2009) by finding the value that matched the average of the product of catchability and selectivity at age with the value of 0.47 obtained by Nichol et al. (2007). This average was computed across the 60-81 cm size range, weighted by annual numbers at length, and across all years in the post-1981 survey time series. For the 2010 assessment, the Plan Team requested that *Q* be held constant at the value used in the 2009 assessment. None of the models requested for the 2011 assessment addressed *Q*, so last year's final model again held *Q* constant at the value used in the 2009 assessment.

Model 1.2

Model 1.2 was the same as Model 1, except that the ageing bias parameters were hard-wired at the values estimated in last year's assessment of Pacific cod in the Gulf of Alaska (Thompson et al. 2011). As noted by the Plan Teams and SSC, the slopes of the relationships between ageing bias and age in last year's EBS and GOA assessments were of opposite sign. In last year's EBS assessment, ageing bias at age 1 was 0.34, increasing to a value of 0.85 at age 20; whereas in last year's GOA assessment, ageing bias at age 1 was 0.36, decreasing to a value of 0.00 at age 20. The purpose of Model 1.2 was to show how much impact the difference in these two relationships has on other results.

Model 1.3

Model 1.3 was the same as Model 1, except that a new method was used to represent variability in weight at length.

The Pacific cod assessments have always used the traditional functional form weight=$\alpha \times$length$^{\beta}$, where length is measured in cm and weight is measured in kg.

The weight-at-age patterns from last year's assessment are shown for ages 1-16 in Figure 2.1.1. It is important to remember that the weight-at-age patterns shown in this figure result from two processes: 1) weight at length varies (perhaps non-monotonically) throughout the year, and 2) length at age increases throughout the year. Thus, a decrease in weight at age necessarily means that weight at length is decreasing faster than length at age is increasing. However, an increase in weight at age could mean either that weight at length is increasing or that it is decreasing, but more slowly than length at age is increasing.

As shown in Figure 2.1.1, weight at age is minimized in January-February for ages 1-5, in March-April for ages 6-7, and in May-July for ages 8+; while weight at age is maximized in November-December for ages 1-12 and in January-February for ages 13+. Although the SSC found these patterns counter-intuitive, one possible explanation is that weight at length for immature fish remains approximately constant or increases throughout the year, and length at age for these fish increases relatively rapidly; whereas weight at length for mature fish decreases rapidly after spawning but otherwise increases throughout the year, and length at age for these fish increases relatively slowly.

However, even if the seasonal weight-at-age patterns from last year's assessment were determined to be biologically reasonable, it does not necessarily follow that estimates of seasonal weight-length parameters in *future* assessments will also be biologically reasonable, because α and β are estimated independently for each season without regard to any underlying phenological model. For example, it is easy for such parameter estimates to imply intra-annual weight-at-length schedules with multiple maxima or minima (see Annex 2.1.2).

Six models were fit to the 100,641 weight-length measurements that have been collected for Pacific cod in the EBS since 1974 (these include data through the first few months of 2012; note that the data used in last year's assessment included years through 2008 only):

A. Single α and β for the entire time series (no inter- or intra-annual variability)
B. Unique α and β for each season, but no inter-annual variability
C. Unique α and β for each year, but no intra-annual variability
D. Unique α and β for each week, but no inter-annual variability
E. Unconstrained trigonometric functions used to describe intra-annual variability in α and β, with annual means equal to the annual α and β values estimated in Model C (see Annex 2.1.2)
F. Same as Model E, except the trigonometric function for α constrained (conditional on β) such that intra-annual variability in weight at length always has a single maximum and minimum (see Annex 2.1.2)

Note that Model B is the model that has been used in the last few assessments.

Some results related to model selection are shown below (R^2 = coefficient of determination, Δ(lnLike) = difference in log likelihood relative to the maximum, Δ(AIC) = difference in Akaike's Information Criterion relative to the minimum):

Model	R^2	Δ(lnLike)	Δ(AIC)
A	0.916	-4325.963	8447.925
B	0.917	-4204.775	8221.551
C	0.919	-2853.194	5730.388
D	0.923	0	0
E	0.923	-182.964	321.928
F	0.923	-312.984	581.968

Note that all six models give nearly identical R^2 values. However, in terms of either log likelihood or AIC, there are clear differences, with the order of preference the same by either measure: Model D performs the best, followed (in order) by Models E, F, C, B, and A.

Note that Model C, which estimates inter-annual variability only, does much better than Model B, which estimates seasonal variability only. Past assessments of the EBS Pacific cod stock have always assumed no inter-annual variability in weight at length.

The performance of each of the four intra-annually varying models (B, D, E, and F) is illustrated for four example lengths (50, 60, 70, and 80 cm) in Figures 2.1.2a-2.1.2d (one figure per model). In each figure, the blue diamonds represent the mean observed weight for the given length during each week of the year, and the red squares represent the model estimates. Model B estimates much less intra-annual variability at these example lengths than is reflected in the data. Model D appears to do the best job of fitting the data, but much of the week-to-week variability does not appear to follow any discernible pattern. Models E and F do almost as well as Model D, but with a clearly discernible pattern between weeks.

Another perspective on the performance of the four intra-annually varying models is provided in Figures 2.1.3a-2.1.3e. Whereas each figure in Figures 2.1.2 shows four example lengths for a single model, each figure in Figures 2.1.3 compares all four models for each of two example lengths (10 and 20 cm, 30 and 40 cm, 50 and 60 cm, 70 and 80 cm, and 90 and 100 cm, respectively). The extreme week-to-week variability estimated by Model D is even more apparent in Figures 2.1.3 than in Figures 2.1.2, particularly for small fish (e.g., Figure 2.1.3a). The potential for Model B to produce multiple maxima or minima is also evident in Figures 2.1.3, again especially at smaller lengths. Model E is also capable of exhibiting multiple maxima/minima, although this is illustrated only weakly in the lower panel of Figure 2.1.3a.

Model F was chosen as the basis for the representation of weight at length used in Model 1.3. Summarizing the above, the reasons were as follow:

- Models that incorporate inter-annual variability (C, E, and F) statistically out-performed all models that did not, with the exception of Model D.
- The very complicated week-to-week patterns estimated by Model D are impossible to explain phenologically.
- Of the models that incorporate intra-annual variability (B, D, E, and F), only Models E and F are constrained to exhibit a clear phenological process.
- Of the models that incorporate intra-annual variability (B, D, E, and F), only Model F is constrained to prevent multiple intra-annual maxima/minima.

Given the choice of Model F, the trigonometric functions used to describe the intra-annual variation in α and β were averaged between the endpoints of each season in order to obtain the season-specific values required by SS.

Model 2

Model 2 was the same as Model 1, except that *Q* was re-tuned iteratively by so that the combination of *Q* and the survey selectivity schedule was consistent with the results obtained by Nichol et al. (2007). As described under Model 1.1 above, this involved finding the value of *Q* such that the average product of *Q* and survey selectivity was equal to 0.47. The average was computed across the 60-81 cm size range, weighted by annual numbers at length, and across all years in the post-1981 survey time series. As reported in last year's assessment, Model 3b (the same as Model 1 here) exhibited an average product of 0.51, slightly above the target value of 0.47.

Model 3

Model 3 was the same as Model 1, except that an additional selectivity "time block" was imposed on all fisheries. The new time block began in 2008 and extended through the end of the time series. The purpose of Model 3 was to explore the possibility that selectivity changed as a result of implementing Amendment 80 to the groundfish fishery management plan.

Model 4

Model 4, which was the same as Model 4 in last year's final assessment (Thompson and Lauth 2011), was the same as Model 1, except that ageing bias was not estimated and the fit to the age composition data was not included in the log-likelihood function.

Model 5

For last year's preliminary assessment, the authors were asked by the Plan Teams and SSC to specify their own preferred model, which was labeled Model A. For the reasons listed under "Comments from the Plan Teams and SSC" above (specifically, comments JPT1-JPT4), the Teams then asked the authors not to include Model A in the final assessment.

To avoid a repeat of last year's sequence of events, the SSC has suggested that author-recommended models include fewer new features, and has encouraged the authors to evaluate changes in one or a few structural elements at a time (comment SSC5).

Based on this feedback, the following strategy was used to bring forward an exploratory model (not necessarily the authors' preferred model) in this preliminary assessment, which is labeled Model 5:

- Omit the features of last year's Model A that caused Plan Team concern and that could not be modified so as to eliminate that concern, or that were rendered irrelevant or inappropriate due to the inclusion of other features.
- Retain the features of last year's Model A that already made it into last year's final model.
- Incorporate two new features not included in last year's Model A.
- Incorporate some other features of last year's Model A without modification.
- Incorporate some other features of last year's Model A after modifying them to address Plan Team or other concerns.
- Develop some additional secondary models that provide a reasonably smooth transition from Model 1 to Model 5 by adding one new feature or a few new features at a time.

Here are the features of last year's model A that were omitted:

- In last year's Model A, *Q* was given annual additive *dev*s, with σ_{dev} tuned iteratively to set the root-mean-squared-standardized-residual of the survey abundance estimates equal to 1.0. The Plan Teams felt that this amounted to "discounting" the survey data. By omitting this feature, *Q* is held constant in Model 5. Model 5 is similar to Models 1-4 in this regard.
- In last year's Model A, all estimated fishery selectivity parameters were given annual random walk *dev*s with σ_{dev} tuned iteratively to match the standard deviation of the estimated *dev*s, except that the *dev*s for any selectivity parameter with a tuned σ_{dev} less than 0.005 were removed. The Plan Teams felt that the resulting estimates were suspect because random effects had not been properly integrated out. By omitting this feature, selectivity is held constant for all fisheries in Model 5. This is unlike Models 1-4, where many fishery selectivity parameters are estimated independently in pre-specified blocks of years.
- In last year's Model A, all parameters governing the peak region and descending limb of the survey selectivity function were given annual random walk *dev*s with σ_{dev} tuned iteratively to match the standard deviation of the estimated *dev*s, except that the *dev*s for any selectivity parameter with a tuned σ_{dev} less than 0.005 were removed. The Plan Teams felt that the resulting estimates were suspect because the random effects had not been properly integrated out. By omitting this feature, all parts of the survey selectivity function except the ascending limb are held constant in Model 5. Model 5 is similar to Models 1-4 in this regard.
- In last year's Model A, input sample sizes for size composition data were re-scaled to give a mean of 300 for *each* fishery and the survey. This was done in anticipation of retuning the input sample size for each fishery and the survey in the event that mean effective sample sizes were less than mean input sample sizes. However, this did not turn out to be the case, meaning that the size compositions for each fishery and the survey were weighted equally, even though the true sample sizes were very different. To keep the input sample sizes more proportional to the true sample sizes, Model 5 reverted to the previous practice of scaling the input sample sizes so that the *overall* mean (i.e., across all fisheries and the survey) was 300. Model 5 is similar to Models 1-4 in this regard.
- In last year's Model A, the standard deviation of length at the first reference age was tuned iteratively to match the value from the regression of standard deviation against length at age presented in the 2010 assessment. However, as of last year's final assessment, the parameters governing variability in length at age (i.e., between-individual variability, conditional on a single set of von Bertalanffy parameter values) are estimated internally, so there is no need to include this feature from last year's Model A. Model 5 is similar to Models 1-4 in this regard.

Here are the features of last year's Model A that already made it into last year's final model:

- All size composition records were activated, regardless of whether an age composition record existed for the same year. Model 5 is similar to Models 1-4 in this regard.
- The first reference age in the mean length-at-age relationship was set at 1.41667, to coincide with age 1 at the time of year when the survey takes place. Model 5 is similar to Models 1-4 in this regard.
- Ageing bias was estimated internally. Model 5 is similar to Models 1-3 in this regard (Model 4 does not need to estimate ageing bias, because it does not use age data).

Here are the two new features not included in last year's Model A that were incorporated:

16. The new weight-length representation developed in Model 1.3 was used.
17. "Tail compression" was turned off. This feature aggregates size composition bins with few or zero data on a record-by-record basis, which improves computational speed, but which also makes some of the graphs in the R4SS package difficult to interpret. In Models 1-4, tail compression is turned on.

Here are the other features of last year's Model A that were incorporated without modification:

18. Fishery CPUE data were omitted. In Models 1-4, fishery CPUE data are included for purposes of comparison, but are not used in estimation.
19. A new population length bin was added for fish in the 0-0.5 cm range, which was used for extrapolating the length-at age curve below the first reference age. In Models 1-4, the lower bound of the first population length bin is 0.5 cm.
20. Mean-size-at-age data were eliminated. In Models 1-4, mean-size-at-age data are included, but not used in estimation.
21. The number of estimated year class strengths in the initial numbers-at-age vector was set at 10. In Models 1-4, only 3 elements of the initial numbers-at-age vector are estimated, which causes an automatic warning in SS.
22. The Richards growth equation (Richards 1959, Schnute 1981, Schnute and Richards 1990) was used, which adds one more parameter. In Models 1-4, the von Bertalanffy equation—a special case of the Richards equation—was used.
23. The log-scale standard deviation of recruitment was estimated internally (i.e., as a free parameter estimated by ADMB). In Models 1-4, this parameter was held constant at the value of 0.57 that was estimated in the final 2009 assessment by matching the standard deviation of the recruitment *dev*s, per Plan Team request.
24. Survey selectivity was modeled as a function of length. In Models 1-4, survey selectivity was modeled as a function of age.
25. Fisheries were defined with respect to each of the five seasons, but not with respect to gear. In Models 1-4, fisheries were defined with respect to both season and gear.
26. Fishery selectivity curves were defined for each of the five seasons, but were not stratified by gear type. In Models 1-4, seasons 1-2 and 4-5 were lumped into a pair of "super" seasons for the purpose of defining fishery selectivity curves, and fishery selectivities were also *gear*-specific (3 super-seasons × 3 gears = 9 selectivity curves).
27. The selectivity curve for the fishery that came closest to being asymptotic on its own (in this case, the season 3 fishery) was forced to be asymptotic by fixing both *width_of_peak_region* and *final_selectivity* at a value of 10.0 and *descending_width* at a value of 0.0. In Models 1-4, six of the nine super-season × gear fisheries were forced to exhibit asymptotic selectivity.
28. Survey catchability was tuned iteratively to set the average of the product of catchability and survey selectivity across the 60-81 cm range equal to 0.47, corresponding to the Nichol et al. (2007) estimate. In Models 1-4, Q was left at the value of 0.77 estimated by a similar procedure in the final 2009 assessment, per Plan Team request.

Here are the features of last year's Model A that were incorporated after modifying them to address Plan Team or other concerns.

29. The age composition sample size multiplier was tuned iteratively to set the mean of the ratio of effective sample size to input sample size equal to 1.0. In last year's Model A, tuning was done with respect to the *ratio of the means* rather than the *mean of the ratio*, but examination of results from early runs in the present preliminary assessment seemed to suggest that the *mean of the ratio* usually provided a higher standard. In Models 1-4, the variance adjustment was fixed at 1.0.
30. The two parameters governing the ascending limb of the survey selectivity schedule were given annual additive *dev*s with each σ_{dev} tuned to match the estimate that would be appropriate for a univariate linear-normal model with random effects integrated out (see Annex 2.1.1). In the 2009 final assessment (Thompson et al. 2009), σ_{dev} for each of these two parameters was tuned iteratively to match the standard deviation of the corresponding set of *dev*s. Having previously been accepted, this same method was used in last year's Model A. However, the Plan Teams reconsidered their position with respect to this method and determined it to be invalid because the

random effects had not been properly integrated out, which is why the method has been modified for use in Model 5. In Models 1-4, no *dev* vector corresponding to the *initial_selectivity* parameter is used, because it was "tuned out" in the 2009 final assessment; and σ_{dev} is set at a value of 0.07 for the *dev* vector corresponding to the *ascending_width* parameter, because current Plan Team policy is to keep this quantity constant at the value estimated (by the now-invalid method) in the 2009 final assessment.

Here are the additional secondary models that were developed in order to provide a reasonably smooth transition from Model 1 to Model 5 by adding one new feature or a few new features at a time:

- Pre5.15 Same as Model 1.3, but with the addition of items 2-5 in the above list. All of these items involve minor changes to the data file (half of them simply involve removing data sets that are not used in estimation).
- Pre5.16 Same as Model Pre5.1, but with the addition of item 6 in the above list.
- Pre5.17 Same as Model Pre5.2, but with the addition of item 7 in the above list.
- Pre5.18 Same as Model Pre5.3, but with the addition of item 8 in the above list.
- Pre5.19 Same as Model Pre5.4, but with the addition of item 9 in the above list.
- Pre5.20 Same as Model Pre5.5, but with the addition of items 10-12 in the above list. All of these items involve switching to fisheries defined by super-season and gear to fisheries defined by season alone.

The full Model 5 is the same as Model Pre5.6, but with the addition of items 13-15 in the above list. These last three items all involve iterative "tuning" adjustments.

Results

Model 1 and the three secondary models based on Model 1

Overview

The following table summarizes the status of the stock as estimated by Model 1 and the three secondary models based on Model 1 ("Est." is the point estimate, "SD" is the standard deviation of the estimate, "SB(2011)" is female spawning biomass in 2011 (t), and "Bratio(2011)" is the ratio of SB(2011) to $B_{100\%}$):

	Model 1		Model 1.1		Model 1.2		Model 1.3	
Quantity	Est.	SD	Est.	SD	Est.	SD	Est.	SD
SB(2011)	323,273	33,721	201,003	31,148	311,441	33,240	315,918	33,047
Bratio(2011)	0.426	0.017	0.306	0.019	0.417	0.017	0.411	0.017

The above results are similar for three of the four models listed, with Model 1.1 being the exception, as it lists both a much small 2011 spawning biomass than the other three models, both in absolute and relative terms. Thus, estimating *Q* internally (Model 1.1) had a major impact on stock status, while use of the GOA ageing bias parameter values (Model 1.2) and adoption of the revised weight-length representation (Model 1.3) had only minor impacts.

Estimates of selected parameters

The following table lists some key parameters estimated by Model 1 or at least one of the three secondary models based on Model 1 (grey shading indicates that the parameter was not estimated in the respective model; "Est." = point estimate, "SD" = standard deviation):

	Model 1		Model 1.1		Model 1.2		Model 1.3	
Quantity	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Length at age 1 (cm)	14.243	0.111	14.265	0.112	14.269	0.111	14.243	0.111
Asymptotic length (cm)	91.021	0.525	94.858	0.800	91.230	0.551	90.982	0.523
Brody growth coefficient	0.248	0.003	0.236	0.003	0.246	0.003	0.248	0.003
SD of length at age 1 (cm)	3.498	0.072	3.610	0.077	3.495	0.072	3.496	0.072
SD of length at age 20 (cm)	10.514	0.172	10.241	0.197	10.573	0.175	10.520	0.172
Ageing bias at age 1 (years)	0.335	0.013	0.323	0.014	0.362	_	0.336	0.013
Ageing bias at age 20 (years)	0.849	0.173	1.143	0.188	0.000	_	0.844	0.173
Trawl survey catchability (*Q*)	0.770	_	1.035	0.034	0.770	_	0.770	_

In general, parameters in the above table that were not forced to be different tended to be estimated at similar values. As suggested by the respective estimates of 2011 spawning biomass presented in the preceding section, Model 1.1 estimated a much higher estimate of *Q* than the value that was hard-wired in the other three models in the group.

Goodness of fit

For Model 1 and the three secondary models based on Model 1, Table 2.1.1 shows the data files used, objective function values, and numbers of parameters. The objective function values are broken down by major component, and the size composition component is broken down further by fleet. Parameter numbers are expressed as the number of non-*dev* parameters, number of *dev*s, and total number of parameters.

Note that objective functions are comparable only between models that use the same data file. Of the models listed in Table 2.1.1, all but Model 1.3 use the same data file. Model 1.1, by estimating *Q* internally, achieves an improvement of about 30 log-likelihood units relative to Model 1, mostly in the size composition and survey abundance components. Model 1.2, by substituting the values of the ageing bias parameters from last year's GOA Pacific cod assessment, gives a worse objective function value than Model 1 by about 13 log-likelihood points, mostly in the size composition and age composition components.

The number of parameters for the models in this group varies by at most three. Each of these models estimates 65 *dev*s. Models 1 and 1.3 each estimate 117 non-*dev* parameters. Model 1.1 estimates one additional non-*dev* parameter (*Q*), and Model 1.2 estimates two fewer (the two ageing bias parameters).

The Five Primary Models

Overview

The following table summarizes the status of the stock as estimated by the five primary models:

	Model 1		Model 2		Model 3		Model 4		Model 5	
Quantity	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
SB(2011)	323,273	33,721	353,269	36,223	326,272	34,372	336,429	37,182	368,253	44,207
Bratio(2011)	0.426	0.017	0.450	0.018	0.418	0.017	0.440	0.019	0.381	0.033

For the two quantities listed in the above table, Models 2-4 are all within 10% of Model 1. Model 5's estimate of 2011 spawning biomass is 14% higher than Model 1's estimate, and Model 5's estimate of relative 2011 spawning biomass is 11% lower than Model 1's.

Because Model 5 differs from Model 1 in several ways, the material presented in this section will adhere to the SSC's suggestion to provide results for a series of transitional models that span the range of features included in Models 1 and 5. This range begins with Model 1 as one endpoint, followed in order by Models 1.3 and Pre5.1 through Pre5.6, and concluding with Model 5 as the other endpoint. To facilitate navigation of the document, presentation of such transitional results will be shown as indented paragraphs.

Estimates and derived quantities

Tables 2.1.2-2.1.6 show every parameter estimated by at least one of the five primary models, together with standard deviations (except that standard deviations are not shown for fishing mortalities, because SS does not treat these as true parameters and therefore does not produce standard deviations for them).

Table 2.1.2 shows all of the estimated parameters other than recruitment *dev*s, selectivity parameters, and fishing mortality rates estimated by at least one of the five primary models.

Table 2.1.3 shows recruitment *dev*s estimated by each of the five primary models.

Table 2.1.4a shows fishery selectivity parameters estimated by Models 1-4 and Table 2.1.4b shows fishery selectivity parameters estimated by Model 5 (parameter numbering in these tables follows the order listed in the "Model Structures" section; parameters ending in a 4-digit year correspond to the time block beginning in that year). Fishery selectivity parameters that are not estimated by any of the five primary models are not shown. These consist of *initial_selectivity*, which is set at a very low value for all fisheries in all models, and the parameters governing the descending limb for whatever fisheries are constrained to have asymptotic selectivity. Figures 2.1.4a-e show surface plots of selectivity for each fishery (one figure for each model).

Table 2.1.5 shows survey selectivity parameters estimated by the five primary models (parameter numbering in these tables follows the order listed in the "Model Structures" section; parameters ending in a 4-digit year correspond to the *dev* for that year). Models 1-4 use age-based selectivity while Model 5 uses length-based, and the *dev*s in Models 1-4 are with respect to *ascending_width* while the Model 5 *dev*s are with respect to *initial_selectivity* (the *ascending_width dev*s were initially present in Model 5, but were "tuned out" in the process of developing the model). Figure 2.1.5a shows surface plots of survey selectivity for each model, and Figure 2.1.5b shows contour plots of the same.

Tables 2.1.6a-e show fishing mortality rates by year, gear, and season for the five primary models.

The following table shows *Q* (not estimated internally in any of the primary models), the average product of *Q* and survey selectivity across the 60-81 cm size range, and the survey selectivity coefficient of variation for the five primary models:

Quantity	Model 1	Model 2	Model 3	Model 4	Model 5
Q	0.770	0.730	0.770	0.770	0.723
Mean($Q \times$ selectivity)	0.51	0.47	0.49	0.45	0.47
Survey SCV	0.208	0.198	0.202	0.201	0.242

Models 2 and 5 estimate *Q* iteratively so as to set the average product of *Q* and survey catchability across the 60-81 cm size range equal to the value of 0.47 estimated by Nichol et al. (2007), and they result in *Q* lower than the value of 0.770 that is hard-wired into Models 1, 3, and 4. Models 1 and 3 result in average products slightly higher than the target value, and Model 4 results in an average product slightly lower than the target value.

At last year's September meeting, the Plan Teams concluded that Model A's estimate of survey variability was excessive. Last year's Model A had SCV=0.330, and the model that was ultimately accepted after the final assessment (Model 1 here) had SCV=0.208.

Figures 2.1.6-2.1.8 compare various estimated times series from the five primary models. Figure 2.1.6 shows total (age 0+) biomass, Figure 2.1.7 shows spawning biomass relative to $B_{100\%}$, and Figure 2.1.8 shows age 0 recruits. Qualitatively, the trends for each of these three quantities are similar across all five models. For example, relative estimates of year class strength are very similar for all models and years, with the single exception of Model 5's estimate of the 1978 year class. Quantitatively, the time trends estimated by Model 5 tend to be the most dissimilar, particularly in Figure 2.1.7.

> Transition from Model 1 to Model 5: Table 2.1.7 shows how estimates of selected parameters and results change during the transitional steps. This table is split into two parts: The first shows the estimates themselves ("absolute values"), and the second shows the relative change in the estimates during each transitional step. Grey shading in both parts of the table indicates parameters that were fixed in a particular model. In the second part of the table, green shading indicates a positive change of more than 5% from the previous model, and pink shading indicates a negative change of at least 5% from the previous model. None of the quantities shown change by more than 5% until the transition from Model Pre5.2 to Model Pre5.3. None of the quantities shown change by more than 10% until the transition from Model Pre5.3 to Model Pre5.4, where internal estimation of σ for the recruitment *dev*s causes that parameter to increase from 0.57 to 0.76 and relative 2011 spawning biomass to decrease from 0.412 to 0.364. No other 10% changes occur until the transition from Model Pre5.5 to Model Pre5.6, where switching from the traditional super-season × gear definition of fisheries to fisheries based only on seasons caused the estimate of the Richards growth parameter to decrease from 0.965 to 0.833 and σ for the recruitment *dev*s to increase from 0.759 to 0.860. Iterative tuning of *Q*, the agecomp sample size multiplier, and σ for the selectivity *dev*s in Model 5 caused four of the listed quantities to change by more than 10% relative to Model Pre5.6: Ageing bias at age 1 decreased from 0.330 to 0.283, ageing bias at age 20 increased from 0.864 to 1.059, σ for the selectivity *dev*s increased from 0.07 to 1.01, and the agecomp sample size multiplier decreased from 1.00 to 0.85.

Goodness of fit

For the five primary models, Table 2.1.8 shows the data files used, objective function values, and numbers of parameters, using the same format as Table 2.1.1. Of the three primary models that use BSbase.dat, Model 2 gives a worse fit than Model 1 by about 10 log-likelihood units, mostly in the survey abundance and size composition components; and Model 3 gives a better fit than Model 1 by about 248 log-likelihood units, mostly in the survey abundance, size composition, and age composition components.

Parameter counts can be difficult to interpret, because *dev*s are constrained and are therefore not comparable to non-*dev* parameters. Models 1 and 2 have the same number of parameters, 117 non-*dev* and 65 *dev*. Model 3 has 17 more non-*dev* parameters than Models 1 and 2, because it adds another time block for each estimated selectivity parameter. Model 4 has two fewer non-*dev* parameters than Models 1 and 2, because it does not estimate ageing bias. Model 5 has 77 fewer non-*dev* parameters than Models 1 and 2, because it does not estimate block-specific fishery selectivity parameters, and it has 7 more *dev*s, because it adds 7 individually estimated age groups to the initial numbers-at-age vector. Note again that SS does not count fishing mortality rates as parameters.

> Transition from Model 1 to Model 5: Table 2.1.9 shows objective function values and numbers of parameters for these two models and several transitional models in between, using the same formats as Tables 2.1.1 and 2.1.8, except that data files are listed in the table legend. Models Pre5.1-Pre5.5 all use a common data file, and Models Pre5.6 and 5 use a common data file, while Model 1 and Model 1.3 each use their own unique data file. In the progression from Models Pre5.1-Pre5.5, each successive model gives a better objective function value than its predecessor, with the biggest jump (an improvement of about 55 log-likelihood units) coming when length-based selectivity replaces age-based selectivity for the trawl survey in Model Pre5.5. Although Models Pre5.6 and 5 use the same data file, the objective function values are still not comparable, because the data are weighted differently in these two models.

Figure 2.1.9 shows the fit to the survey abundance time series obtained by the five primary models. None of the fits are particularly good. The estimates from Models 1-3 miss the 95% confidence intervals 30% of the time, and the estimates from Models 4-5 miss the 95% confidence intervals 27% of the time. Table 2.1.10a shows log-scale residuals for the trawl survey index resulting from each of the five primary models. All of the models are biased low, with average residuals ranging from 0.073 (Model 3) to 0.119 (Model 5). Table 2.1.10b shows squared standardized residuals for the trawl survey index resulting from the five primary models. All of the models have root-mean-squared-errors much greater than unity, ranging from 1.987 (Model 3) to 2.460 (Model 5).

> Transition from Model 1 to Model 5: Tables 2.1.11a and 2.1.11b show results analogous to Tables 2.1.10a and 2.1.10b.

Table 2.1.12a shows the number of records, input sample sizes, and the mean of the ratio between effective sample size and input sample size for size composition data from each fleet (fisheries and the trawl survey) for the five primary models. All models have ratios of at least 2.0 for every fleet. Table 2.1.12b shows input sample sizes and the ratio between effective sample size and input sample size for each year of age composition data from the survey for the five primary models. Models 1-4 have average ratios ranging from 0.58 (Model 4, which does not attempt to fit the age composition data) to 0.89 (Model 2). Model 5 was tuned so that the average ratio is approximately 1.0; note that one way it does so is by adjusting the sample size multiplier from 1.0 down to 0.85 (i.e., the model multiplies each input sample size by 0.85, so that the average input sample size is 255 rather than 300).

> Transition from Model 1 to Model 5: Tables 2.1.13a and 2.1.13b show results analogous to Tables 2.1.12a and 2.1.12b, except using a two-part format similar to Table 2.1.7, with the actual ratios shown in the upper part and the relative changes from each preceding model shown in the lower part. In terms of size composition data (Table 2.1.13a), all models have ratios of at least 2.0 for every fleet, and none of the transitional steps results in a change of more than 5% except for the fit to the August-December trawl fishery going from Model 1.3 to Model Pre5.1 (an improvement of 8.9%), and the fit to the trawl survey going from Model Pre5.4 to Model Pre5.5 (an improvement of 15.6%), Model Pre5.5 to Model Pre5.6 (an improvement of 30.4%), and Model Pre5.6 to Model 5 (an improvement of 19.5%). The fit to the age composition data (Table 2.1.13b) does not proceed monotonically during the transition from Model 1 to Model 5; the average ratio stays approximately constant from Model 1 through Model Pre5.4, then decreases in Model Pre5.5 (-12.8%) and again in Model Pre5.6 (-45.6%), then more than doubles in the transition from Model Pre5.6 to Model 5.

Discussion

Review of models and major issues

This preliminary assessment presents all the models requested by the Plan Team and SSC (four primary models and three secondary models), one additional primary model, and six additional secondary models. The Team/SSC primary models are labeled 1 through 4, the Team/SSC secondary models are labeled 1.1 through 1.3, the additional primary model is labeled 5, and the six additional secondary models are labeled Pre5.1 through Pre5.6. The latter group is used, together with Model 1.3, to illustrate *one possible transition* from Model 1 to Model 5. The phrase "one possible transition" is emphasized because the effects of model features are not necessarily additive, which means that the smoothness (or lack thereof) in the transition presented here may be due in part to the ordering of the secondary models in that transition.

Model 5 was based largely on Model A from last year's preliminary assessment, but with some changes suggested by the Plan Team or SSC. As described more fully in the "Model Structures" section, the following strategy was used to develop Model 5:

- Omit the features of last year's Model A that caused Plan Team concern and that could not be modified so as to eliminate that concern, or that were rendered irrelevant or inappropriate due to the inclusion of other features. The features that were omitted because of Team concern were:
  - Annual *dev*s on survey catchability
  - Annual *dev*s on fishery selectivity parameters
  - Annual *dev*s on survey selectivity parameters other than the ascending limb
- Retain the features of last year's Model A that already made it into last year's final model.
- Incorporate two new features not included in last year's Model A.
- Incorporate some other features of last year's Model A without modification. All of these were items to which neither the Plan Team nor SSC objected after last year's preliminary assessment.
- Incorporate some other features of last year's Model A after modifying them to address Plan Team or other concerns. The feature that was modified because of Team concern was the method used to tune the input σ for each vector of survey selectivity *dev*s. In last year's Model A, the input σ was tuned to match the standard deviation of the estimated *dev*s, but this fails to account for the fact that random effects have not been integrated out. In Model 5, this method was replaced by one that is designed to account for such integration (see Annex 2.1.1).

Comments on any of the models are welcome.

Over the years, the Pacific cod assessment models have been able to track general trends with a fair amount of success, particularly in terms of identifying strong and weak year classes. The models have always succeeded in fitting the size composition data very well. However, fitting *all* of the data sets at levels consistent with best estimates of their associated measurement errors has proven to be an elusive task. Two data sets have been especially problematic in this regard: First, the models have been unable to track the survey abundance data with a level of precision consistent with the observed sampling variance. Second, the models have been unable to track the age composition data with an effective sample size consistent with the input sample size.

The historic difficulty of fitting the survey abundance data continues in this preliminary assessment. However, it is difficult to imagine how any of the fits could be improved very much without allowing Q to vary, because the *inter*-annual variability in survey estimates relative to the *intra*-annual variability (standard errors) is so great. For example, the following tables show the relative year-to-year changes in survey estimates of numbers and biomass, together with the coefficients of variation, for every year in which the estimates of numbers or biomass increased by at least 85% over the previous year or decreased by at least 25% from the previous year (tables are sorted in order of increasing relative change):

Numbers				Biomass			
Change	Year	CV(current)	CV(previous)	Change	Year	CV(current)	CV(previous)
-0.43	2002	0.10	0.10	-0.32	1997	0.11	0.10
-0.42	1989	0.07	0.07	-0.27	1995	0.09	0.18
-0.39	1995	0.10	0.12	-0.26	2002	0.11	0.09
-0.35	2008	0.10	0.27	-0.26	1991	0.07	0.07
-0.30	1988	0.07	0.07	0.98	1994	0.18	0.08
0.86	2007	0.27	0.06	1.04	2010	0.12	0.08
1.04	2001	0.10	0.09				

Regarding the fit to the age composition data, it should be noted that some improvement has been achieved in recent years by attempting to estimate the degree of bias in the age data. Nevertheless, the four primary models suggested by the Team/SSC continue to fall short of producing an effective sample size at least as large as the input sample size. Model 5 achieves this goal, in part by reducing the input sample sizes by 15%. Given that the scale of the input sample sizes (average = 300) was chosen subjectively to begin with, it is difficult to argue that the reduction suggested by Model 5 is inappropriate. This raises an important contrast between the two difficult-to-fit data sets: The standard errors of the survey estimates are derived statistically, but the scale of the input sample sizes for the age (or, for that matter, size) composition data is simply assumed.

It may also be noted that Model 5 focuses on achieving an appropriate match to the age composition data while ignoring the better-than-expected fit to the size composition data. This is deliberate, and not inconsistent: The goal of Model 5 is to produce a fit, for each data set, *at least as good* as the typical variance specified for that data set suggests is appropriate. An alternative would be to produce a fit that matches the specified variances exactly, but when this approach has been tried in past Pacific cod assessments, the result has been that the size composition data are so heavily up-weighted that the other data sets contribute very little (or nothing at all), which would run afoul of the Plan Team's desire not to "discount" the survey abundance data.

Over-parameterization has also been a concern regarding the Pacific cod models for many years. As noted in the "Results" section, quantifying the parameterization of these models is challenging, in part because they all use constrained *dev*s, which are not truly free parameters. Model 5 does include seven more *dev*s than Models 1-4 (72 versus 65) because it estimates the abundance of seven more age groups in the initial numbers-at-age vector (10 versus 3). However, it has 75 fewer non-*dev* parameters than Models 1,2, and 4 (40 versus 117); and 94 fewer parameters than Model 3 (40 versus 134). (As noted in the "Results" section, SS does not count fishing mortality rates as parameters.)

Finally, the long-standing issue of catchability has yet to reach an entirely satisfying conclusion. Using the point estimate obtained by Nichol et al. (2007) to tune the model does provide an empirical benchmark, but one that is based on a very small sample (11 fish). The 2009 assessment (Thompson et al. 2009) attempted to calculate the distribution of this point estimate, and obtained a log-scale standard deviation of 0.59, which implies that values fairly far removed from the point estimate are almost as likely to be true. When *Q* was freed in Model 1.1, the estimate went up from the value of 0.77 used in the last few assessments to 1.035. Moreover, Model 2's estimate was very precise, with a standard deviation of 0.034, implying almost no chance that the true value could be as small as 0.77. However, the extents to which the point estimate from Model 2 and its precision are accurate depend on the extent to which the model is correctly specified. All of the primary models are likely mis-specified to some extent, as evidenced, for example, by their inconsistency with the survey abundance standard errors.

Questions for the Plan Team or SSC

1. For each fishery, Model 5 produces an average value for the ratio between effective sample size and input sample size greater than 2.0, even though this model assumes constant selectivity for each fishery. Is it necessary to incorporate time-varying selectivity under these circumstances?
2. In Model 5, the season 3 fishery was constrained to exhibit asymptotic selectivity, because this fishery came the closest to doing so on its own (i.e., when unconstrained) during early stages of model development. No other Model 5 fisheries were constrained in this manner. However, season 3 has the second smallest average catch of any season and the smallest number of length measurements of any season, so the effect of constraining the selectivity for this fishery may have only a very small impact on model stability. In contrast, six of the nine fisheries defined in Models 1-4 were constrained to exhibit asymptotic selectivity. If Model 5, or something like it, is carried forward into the final assessment, should different criteria be used to specify which fishery or fisheries are constrained to exhibit asymptotic selectivity?
3. Should the Team's preferred model continue to estimate Q (either from a previous assessment or re-tuned in this year's final assessment) by matching the average product of Q and survey selectivity across the 60-81 cm size range to the point estimate from Nichol et al. (2007)?
4. If tuning an input σ by matching the standard deviation of the estimated *dev*s "may produce pathological results" and gives MLEs that are "suspect" (see comment JPT1), what does this imply about the Team's primary models (1-4), given that they all rely on input σ values that were estimated using precisely this method?
5. If forcing Q to remain constant makes it impossible for a model to fit the survey abundance time series in a manner consistent with the survey data themselves (point estimates and standard errors), should the Team reconsider what "discounting" the survey means (see comment JPT2)?
6. Regarding the Team's concern over excessive variability in survey selectivity, it may be noted that Models 2-4 all have survey SCV values less than that of Model 1 (0.208). Model 5's SCV (0.242) constitutes a 27% reduction from last year's Model A (0.330), but it is still 16% higher than the SCV from Model 1. Where is the breakpoint between acceptable variability and excessive variability in survey (or other) selectivity (see comment JPT3)?
7. If the Team decides that Model 5 as a whole should not be included in the final assessment, are there any individual features specific to Model 5 that could be carried forward into the final assessment (see comment JPT4)?

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Table 2.1.1. Data files, objective function values, and number of parameters for Model 1 and the three secondary models based on Model 1. Note that objective function values are not comparable between models that use different data files.

	Model 1	Model 1.1	Model 1.2	Model 1.3
Data file:	BSbase	BSbase	BSbase	BSmodel1_3
Component	Model 1	Model 1.1	Model 1.2	Model 1.3
Catch	0.00	0.00	0.00	0.00
Equilibrium catch	0.00	0.02	0.00	0.00
Survey CPUE	-4.20	-19.58	-6.79	-5.70
Size composition	4192.75	4170.04	4198.24	4191.29
Age composition	117.70	121.37	126.46	117.60
Recruitment	20.65	24.72	21.08	20.63
"Softbounds"	0.03	0.04	0.03	0.03
Deviations	16.83	17.27	18.14	16.80
Total	4343.76	4313.87	4357.17	4340.65
Sizecomp component	Model 1	Model 1.1	Model 1.2	Model 1.3
Jan-Apr trawl fishery	932.95	934.74	934.61	932.34
May-Jul trawl fishery	181.97	186.22	182.45	181.77
Aug-Dec trawl fishery	221.46	222.73	221.28	221.33
Jan-Apr longline fishery	638.76	650.21	641.44	639.03
May-Jul longline fishery	206.76	194.61	205.71	206.45
Aug-Dec longline fishery	891.28	865.80	890.94	891.32
Jan-Apr pot fishery	112.19	114.21	112.18	112.28
May-Jul pot fishery	70.60	71.05	70.01	70.53
Aug-Dec pot fishery	191.39	187.56	190.66	191.28
Trawl survey	745.40	742.91	748.97	744.95
Parameter count	Model 1	Model 1.1	Model 1.2	Model 1.3
No. non-*dev* parameters	117	118	115	117
No. *dev* s	65	65	65	65
Total no. parameters	182	183	180	182

Table 2.1.2. All of the parameters other than recruitment *dev*s, selectivity parameters, and fishing mortality rates estimated by at least one of the five primary models. Grey shading and a "_" symbol in the St. Dev. column mean that the parameter was fixed in the respective model, and "n/a" means that the parameter was not used in the respective model.

	Model 1		Model 2		Model 3		Model 4		Model 5	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
Length at age 1 (cm)	14.243	0.111	14.235	0.111	14.254	0.111	14.240	0.112	14.623	0.187
Asymptotic length (cm)	91.021	0.525	90.398	0.508	91.513	0.513	90.379	0.536	89.843	0.892
Brody growth coefficient	0.248	0.003	0.250	0.003	0.247	0.003	0.251	0.003	0.283	0.013
Richards growth coefficient	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.803	0.064
SD of length at age 1 (cm)	3.498	0.072	3.479	0.071	3.546	0.072	3.508	0.072	3.682	0.108
SD of length at age 20 (cm)	10.514	0.172	10.560	0.168	10.269	0.166	10.503	0.170	10.267	0.219
Ageing bias at age 1 (years)	0.335	0.013	0.337	0.013	0.335	0.013	n/a	n/a	0.283	0.018
Ageing bias at age 20 (years)	0.849	0.173	0.814	0.172	0.864	0.175	n/a	n/a	1.059	0.219
ln(mean post-1976 recruitment)	13.224	0.020	13.268	0.021	13.242	0.021	13.241	0.023	13.435	0.080
σ(recruitment)	0.570	_	0.570	_	0.570	_	0.570	_	0.829	0.093
ln(pre-1977 recruitment offset)	-1.159	0.135	-1.101	0.136	-1.248	0.132	-1.086	0.135	-1.412	0.204
Initial F (Jan-Apr trawl fishery)	0.613	0.131	0.533	0.110	0.676	0.147	0.540	0.111	n/a	n/a
Initial F (Jan-Feb fishery)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.813	0.223
Initial age 10 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.485	0.691
Initial age 9 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.594	0.669
Initial age 8 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.688	0.649
Initial age 7 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.726	0.636
Initial age 6 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.629	0.631
Initial age 5 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.374	0.576
Initial age 4 ln(abundance) dev	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.584	0.583
Initial age 3 ln(abundance) dev	1.275	0.195	1.277	0.198	1.268	0.194	1.300	0.197	1.581	0.235
Initial age 2 ln(abundance) dev	-0.684	0.423	-0.687	0.424	-0.662	0.422	-0.662	0.426	-0.351	0.580
Initial age 1 ln(abundance) dev	1.207	0.230	1.212	0.232	1.210	0.227	1.224	0.234	1.680	0.251

Table 2.1.3. Recruitment devs estimated by each of the five primary models.

	Model 1		Model 2		Model 3		Model 4		Model 5	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	1.406	0.109	1.450	0.110	1.347	0.108	1.514	0.112	1.285	0.129
1978	0.518	0.219	0.523	0.227	0.520	0.207	0.564	0.226	1.141	0.161
1979	0.671	0.118	0.668	0.122	0.657	0.114	0.676	0.122	0.386	0.197
1980	-0.385	0.137	-0.395	0.140	-0.377	0.132	-0.365	0.138	-0.252	0.165
1981	-1.047	0.153	-1.045	0.154	-1.051	0.150	-1.040	0.155	-0.802	0.182
1982	0.990	0.042	0.998	0.042	0.966	0.042	1.008	0.043	1.011	0.048
1983	-0.557	0.118	-0.564	0.120	-0.549	0.114	-0.545	0.120	-0.949	0.187
1984	0.777	0.047	0.775	0.048	0.759	0.047	0.789	0.048	0.730	0.052
1985	-0.066	0.073	-0.080	0.074	-0.071	0.071	-0.048	0.074	0.163	0.070
1986	-0.865	0.099	-0.892	0.101	-0.851	0.096	-0.870	0.101	-0.896	0.123
1987	-1.288	0.122	-1.328	0.126	-1.263	0.117	-1.312	0.127	-1.163	0.132
1988	-0.271	0.059	-0.271	0.059	-0.287	0.058	-0.258	0.060	-0.247	0.068
1989	0.526	0.040	0.528	0.041	0.508	0.040	0.547	0.042	0.419	0.048
1990	0.358	0.046	0.347	0.046	0.353	0.045	0.378	0.047	0.346	0.051
1991	-0.349	0.065	-0.359	0.066	-0.341	0.064	-0.328	0.068	-0.453	0.082
1992	0.626	0.033	0.625	0.033	0.628	0.033	0.653	0.036	0.525	0.038
1993	-0.384	0.060	-0.399	0.061	-0.357	0.058	-0.478	0.073	-0.589	0.074
1994	-0.343	0.053	-0.347	0.054	-0.313	0.052	-0.316	0.058	-0.544	0.062
1995	-0.298	0.057	-0.295	0.057	-0.265	0.056	-0.302	0.062	-0.561	0.069
1996	0.713	0.033	0.720	0.033	0.741	0.033	0.733	0.036	0.514	0.041
1997	-0.181	0.053	-0.197	0.054	-0.127	0.052	-0.172	0.059	-0.147	0.066
1998	-0.265	0.053	-0.275	0.054	-0.213	0.052	-0.257	0.058	-0.226	0.071
1999	0.491	0.033	0.491	0.034	0.547	0.034	0.484	0.037	0.591	0.041
2000	0.056	0.039	0.047	0.040	0.099	0.041	0.116	0.044	0.140	0.051
2001	-0.811	0.062	-0.821	0.063	-0.816	0.064	-1.039	0.088	-0.608	0.077
2002	-0.223	0.041	-0.219	0.042	-0.280	0.045	-0.138	0.044	-0.255	0.059
2003	-0.391	0.049	-0.382	0.050	-0.486	0.053	-0.446	0.060	-0.319	0.065
2004	-0.523	0.056	-0.515	0.057	-0.585	0.056	-0.440	0.061	-0.499	0.077
2005	-0.398	0.055	-0.380	0.056	-0.469	0.054	-0.384	0.064	-0.313	0.075
2006	0.896	0.040	0.919	0.040	0.854	0.040	0.919	0.043	0.948	0.048
2007	-0.201	0.076	-0.189	0.076	-0.158	0.078	-0.389	0.094	-0.025	0.093
2008	1.062	0.061	1.081	0.061	1.098	0.063	1.079	0.067	0.967	0.072
2009	-1.027	0.160	-1.016	0.160	-1.015	0.159	-1.123	0.206	-1.091	0.195
2010	0.785	0.130	0.797	0.129	0.795	0.130	0.790	0.135	0.773	0.150

Table 2.1.4a (page 1 of 4). Fishery selectivity parameters estimated by Models 1-4 (Model 5 is shown separately). See text for details.

	Model 1		Model 2		Model 3		Model 4	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
P3_May-Jul_Trawl_Fishery	5.648	0.106	5.628	0.109	5.607	0.110	5.622	0.109
P2_Jan-Apr_Longline_Fishery	-5.158	2.729	-4.938	2.173	-4.848	2.047	-4.770	1.819
P4_Jan-Apr_Longline_Fishery	5.110	0.141	5.098	0.140	5.098	0.140	5.087	0.139
P3_May-Jul_Longline_Fishery	4.999	0.055	4.987	0.055	4.975	0.055	4.984	0.055
P2_Aug-Dec_Longline_Fishery	-2.200	0.237	-2.190	0.237	-2.292	0.196	-2.165	0.236
P4_Aug-Dec_Longline_Fishery	5.241	0.288	5.217	0.288	4.586	0.241	5.209	0.293
P2_Jan-Apr_Pot_Fishery	-8.764	26.446	-8.645	28.262	-8.951	23.418	-8.601	28.892
P3_Jan-Apr_Pot_Fishery	4.994	0.052	4.992	0.053	4.993	0.052	4.994	0.053
P4_Jan-Apr_Pot_Fishery	4.572	0.286	4.573	0.283	4.544	0.269	4.565	0.284
P3_May-Jul_Pot_Fishery	4.918	0.082	4.912	0.082	4.910	0.082	4.910	0.083
P1_Jan-Apr_Trawl_Fishery_1977	68.697	3.055	68.358	3.057	69.039	2.998	68.077	3.024
P1_Jan-Apr_Trawl_Fishery_1985	76.587	1.703	76.277	1.709	76.543	1.699	75.736	1.746
P1_Jan-Apr_Trawl_Fishery_1990	68.186	1.093	67.602	1.122	67.869	1.107	67.609	1.142
P1_Jan-Apr_Trawl_Fishery_1995	73.708	0.926	73.423	0.920	73.482	0.914	73.235	0.930
P1_Jan-Apr_Trawl_Fishery_2000	78.227	1.180	77.974	1.175	77.965	1.176	78.131	1.188
P1_Jan-Apr_Trawl_Fishery_2005	74.221	0.959	74.072	0.957	73.329	1.484	74.064	0.962
P1_Jan-Apr_Trawl_Fishery_2008	n/a	n/a	n/a	n/a	72.682	1.171	n/a	n/a
P3_Jan-Apr_Trawl_Fishery_1977	6.155	0.173	6.151	0.175	6.161	0.169	6.141	0.175
P3_Jan-Apr_Trawl_Fishery_1985	6.642	0.077	6.641	0.078	6.639	0.077	6.625	0.080
P3_Jan-Apr_Trawl_Fishery_1990	6.058	0.059	6.033	0.062	6.043	0.061	6.033	0.062
P3_Jan-Apr_Trawl_Fishery_1995	6.285	0.046	6.279	0.046	6.275	0.046	6.275	0.046
P3_Jan-Apr_Trawl_Fishery_2000	6.300	0.060	6.298	0.060	6.299	0.060	6.304	0.060
P3_Jan-Apr_Trawl_Fishery_2005	6.032	0.058	6.031	0.058	6.153	0.090	6.031	0.059
P3_Jan-Apr_Trawl_Fishery_2008	n/a	n/a	n/a	n/a	5.858	0.077	n/a	n/a
P1_May-Jul_Trawl_Fishery_1977	50.334	1.718	49.937	1.714	50.081	1.716	49.728	1.719
P1_May-Jul_Trawl_Fishery_1985	51.318	1.768	50.913	1.789	50.935	1.777	50.808	1.790
P1_May-Jul_Trawl_Fishery_1990	61.914	1.558	61.504	1.580	61.384	1.577	61.377	1.585
P1_May-Jul_Trawl_Fishery_2000	53.196	1.537	52.864	1.566	52.334	1.566	52.758	1.563
P1_May-Jul_Trawl_Fishery_2005	58.916	1.534	58.587	1.547	57.631	1.616	58.605	1.545
P1_May-Jul_Trawl_Fishery_2008	n/a	n/a	n/a	n/a	57.976	2.088	n/a	n/a

Table 2.1.4a (page 2 of 4). Fishery selectivity parameters estimated by Models 1-4 (Model 5 is shown separately). See text for details.

	Model 1		Model 2		Model 3		Model 4	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
P1_Aug-Dec_Trawl_Fishery_1977	62.324	3.943	62.231	3.918	62.369	3.954	62.316	3.937
P1_Aug-Dec_Trawl_Fishery_1980	81.378	5.431	80.880	5.614	82.305	5.646	80.392	5.641
P1_Aug-Dec_Trawl_Fishery_1985	87.202	5.374	87.147	5.475	87.258	5.446	86.282	5.365
P1_Aug-Dec_Trawl_Fishery_1990	45.799	15.035	46.013	17.091	46.891	18.780	45.891	15.189
P1_Aug-Dec_Trawl_Fishery_1995	102.474	0.827	102.474	0.824	102.474	0.829	102.474	0.810
P1_Aug-Dec_Trawl_Fishery_2000	62.151	2.705	61.720	2.486	73.193	4.732	61.660	2.537
P1_Aug-Dec_Trawl_Fishery_2008	n/a	n/a	n/a	n/a	48.251	2.598	n/a	n/a
P3_Aug-Dec_Trawl_Fishery_1977	5.556	0.326	5.557	0.326	5.552	0.325	5.557	0.326
P3_Aug-Dec_Trawl_Fishery_1980	6.647	0.224	6.639	0.234	6.673	0.226	6.635	0.237
P3_Aug-Dec_Trawl_Fishery_1985	6.637	0.227	6.645	0.231	6.639	0.229	6.618	0.233
P3_Aug-Dec_Trawl_Fishery_1990	3.255	4.249	3.299	4.650	3.482	4.612	3.280	4.245
P3_Aug-Dec_Trawl_Fishery_1995	7.013	0.090	7.020	0.090	7.014	0.090	7.023	0.091
P3_Aug-Dec_Trawl_Fishery_2000	5.631	0.217	5.605	0.205	6.092	0.284	5.607	0.209
P3_Aug-Dec_Trawl_Fishery_2008	n/a	n/a	n/a	n/a	4.611	0.387	n/a	n/a
P1_Jan-Apr_Longline_Fishery_1977	58.582	2.059	58.568	2.050	58.481	2.067	58.539	2.067
P1_Jan-Apr_Longline_Fishery_1980	72.354	2.427	72.152	2.416	72.534	2.502	71.832	2.491
P1_Jan-Apr_Longline_Fishery_1985	75.315	0.909	75.213	0.917	75.222	0.919	74.927	0.918
P1_Jan-Apr_Longline_Fishery_1990	65.935	0.478	65.751	0.475	65.870	0.476	65.754	0.478
P1_Jan-Apr_Longline_Fishery_1995	65.698	0.428	65.601	0.427	65.611	0.426	65.506	0.429
P1_Jan-Apr_Longline_Fishery_2000	63.510	0.448	63.379	0.447	63.368	0.450	63.418	0.450
P1_Jan-Apr_Longline_Fishery_2005	67.471	0.408	67.352	0.407	64.131	0.543	67.301	0.410
P1_Jan-Apr_Longline_Fishery_2008	n/a	n/a	n/a	n/a	69.721	0.507	n/a	n/a
P3_Jan-Apr_Longline_Fishery_1977	5.134	0.208	5.137	0.208	5.119	0.209	5.132	0.209
P3_Jan-Apr_Longline_Fishery_1980	5.912	0.176	5.912	0.177	5.915	0.179	5.906	0.182
P3_Jan-Apr_Longline_Fishery_1985	5.868	0.067	5.870	0.067	5.862	0.067	5.861	0.068
P3_Jan-Apr_Longline_Fishery_1990	5.217	0.047	5.207	0.047	5.213	0.047	5.206	0.047
P3_Jan-Apr_Longline_Fishery_1995	5.299	0.040	5.296	0.040	5.292	0.040	5.291	0.040
P3_Jan-Apr_Longline_Fishery_2000	5.359	0.042	5.353	0.042	5.355	0.042	5.358	0.042
P3_Jan-Apr_Longline_Fishery_2005	5.351	0.036	5.346	0.036	5.240	0.060	5.345	0.036
P3_Jan-Apr_Longline_Fishery_2008	n/a	n/a	n/a	n/a	5.416	0.041	n/a	n/a

Table 2.1.4a (page 3 of 4). Fishery selectivity parameters estimated by Models 1-4 (Model 5 is shown separately). See text for details.

	Model 1		Model 2		Model 3		Model 4	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
P6_Jan-Apr_Longline_Fishery_1977	-1.375	0.792	-1.400	0.787	-1.340	0.791	-1.363	0.785
P6_Jan-Apr_Longline_Fishery_1980	0.284	1.008	0.261	0.982	0.446	1.096	0.334	0.994
P6_Jan-Apr_Longline_Fishery_1985	-1.377	0.481	-1.335	0.472	-1.289	0.468	-1.298	0.455
P6_Jan-Apr_Longline_Fishery_1990	-0.499	0.137	-0.502	0.135	-0.529	0.135	-0.503	0.135
P6_Jan-Apr_Longline_Fishery_1995	-0.747	0.140	-0.762	0.139	-0.760	0.139	-0.755	0.138
P6_Jan-Apr_Longline_Fishery_2000	-1.209	0.147	-1.217	0.145	-1.227	0.145	-1.200	0.145
P6_Jan-Apr_Longline_Fishery_2005	-1.050	0.155	-1.045	0.153	-1.154	0.167	-1.012	0.152
P6_Jan-Apr_Longline_Fishery_2008	n/a	n/a	n/a	n/a	-1.386	0.226	n/a	n/a
P1_May-Jul_Longline_Fishery_1977	63.004	2.224	62.846	2.258	62.851	2.232	62.861	2.252
P1_May-Jul_Longline_Fishery_1980	62.302	1.368	62.026	1.373	62.247	1.358	61.921	1.365
P1_May-Jul_Longline_Fishery_1985	63.188	1.127	62.995	1.127	63.021	1.120	62.852	1.130
P1_May-Jul_Longline_Fishery_1990	63.395	0.544	63.186	0.543	63.149	0.539	63.144	0.545
P1_May-Jul_Longline_Fishery_2000	59.731	0.576	59.559	0.574	59.417	0.571	59.534	0.577
P1_May-Jul_Longline_Fishery_2005	64.076	0.609	63.895	0.610	62.983	0.820	63.851	0.611
P1_May-Jul_Longline_Fishery_2008	n/a	n/a	n/a	n/a	63.800	0.666	n/a	n/a
P1_Aug-Dec_Longline_Fishery_1977	60.183	2.162	60.156	2.148	61.470	2.202	60.153	2.139
P1_Aug-Dec_Longline_Fishery_1980	69.800	1.554	69.691	1.562	69.591	1.696	69.230	1.578
P1_Aug-Dec_Longline_Fishery_1985	64.625	0.751	64.413	0.764	65.336	0.774	64.168	0.775
P1_Aug-Dec_Longline_Fishery_1990	66.975	0.725	66.794	0.729	66.957	0.721	66.773	0.729
P1_Aug-Dec_Longline_Fishery_1995	69.367	0.688	69.142	0.686	69.169	0.681	68.953	0.693
P1_Aug-Dec_Longline_Fishery_2000	63.527	0.426	63.368	0.426	64.008	0.417	63.367	0.436
P1_Aug-Dec_Longline_Fishery_2005	62.342	0.411	62.162	0.408	62.713	0.679	62.235	0.416
P1_Aug-Dec_Longline_Fishery_2008	n/a	n/a	n/a	n/a	61.819	0.462	n/a	n/a
P3_Aug-Dec_Longline_Fishery_1977	4.478	0.327	4.478	0.327	4.623	0.311	4.474	0.325
P3_Aug-Dec_Longline_Fishery_1980	5.416	0.131	5.414	0.132	5.398	0.141	5.388	0.135
P3_Aug-Dec_Longline_Fishery_1985	4.902	0.085	4.887	0.087	4.978	0.084	4.864	0.089
P3_Aug-Dec_Longline_Fishery_1990	5.033	0.077	5.024	0.077	5.030	0.076	5.021	0.077
P3_Aug-Dec_Longline_Fishery_1995	5.499	0.052	5.489	0.053	5.487	0.052	5.477	0.053
P3_Aug-Dec_Longline_Fishery_2000	5.174	0.041	5.165	0.041	5.228	0.039	5.168	0.042
P3_Aug-Dec_Longline_Fishery_2005	4.900	0.043	4.887	0.043	4.990	0.075	4.896	0.044

Table 2.1.4a (page 4 of 4). Fishery selectivity parameters estimated by Models 1-4 (Model 5 is shown separately). See text for details.

	Model 1		Model 2		Model 3		Model 4	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
P3_Aug-Dec_Longline_Fishery_2008	n/a	n/a	n/a	n/a	4.805	0.049	n/a	n/a
P6_Aug-Dec_Longline_Fishery_1977	-2.841	2.526	-2.825	2.445	-1.774	1.241	-2.787	2.425
P6_Aug-Dec_Longline_Fishery_1980	0.164	0.737	0.173	0.722	1.098	0.801	0.241	0.712
P6_Aug-Dec_Longline_Fishery_1985	0.143	0.258	0.181	0.254	0.479	0.228	0.131	0.248
P6_Aug-Dec_Longline_Fishery_1990	2.350	0.853	2.372	0.857	2.207	0.620	2.315	0.817
P6_Aug-Dec_Longline_Fishery_1995	9.379	15.512	9.345	16.203	9.336	16.386	9.335	16.413
P6_Aug-Dec_Longline_Fishery_2000	-0.439	0.195	-0.439	0.191	-0.121	0.136	-0.413	0.191
P6_Aug-Dec_Longline_Fishery_2005	9.772	6.521	9.754	6.973	9.892	3.251	9.783	6.240
P6_Aug-Dec_Longline_Fishery_2008	n/a	n/a	n/a	n/a	-0.068	0.139	n/a	n/a
P1_Jan-Apr_Pot_Fishery_1977	68.513	0.925	68.389	0.924	68.514	0.921	68.434	0.925
P1_Jan-Apr_Pot_Fishery_1995	68.325	0.563	68.250	0.564	68.305	0.559	68.224	0.567
P1_Jan-Apr_Pot_Fishery_2000	67.975	0.535	67.882	0.535	67.919	0.530	67.930	0.538
P1_Jan-Apr_Pot_Fishery_2005	68.103	0.556	68.017	0.558	66.145	0.664	68.014	0.561
P1_Jan-Apr_Pot_Fishery_2008	n/a	n/a	n/a	n/a	69.333	0.650	n/a	n/a
P6_Jan-Apr_Pot_Fishery_1977	0.216	0.563	0.197	0.553	0.167	0.545	0.197	0.553
P6_Jan-Apr_Pot_Fishery_1995	-0.313	0.253	-0.332	0.251	-0.323	0.248	-0.325	0.250
P6_Jan-Apr_Pot_Fishery_2000	-0.620	0.243	-0.631	0.241	-0.629	0.236	-0.622	0.241
P6_Jan-Apr_Pot_Fishery_2005	0.354	0.258	0.340	0.256	0.195	0.292	0.366	0.259
P6_Jan-Apr_Pot_Fishery_2008	n/a	n/a	n/a	n/a	-0.094	0.332	n/a	n/a
P1_May-Jul_Pot_Fishery_1977	67.178	0.852	67.029	0.853	67.065	0.845	67.019	0.857
P1_May-Jul_Pot_Fishery_1995	65.901	0.717	65.772	0.715	65.790	0.711	65.711	0.717
P1_May-Jul_Pot_Fishery_2008	n/a	n/a	n/a	n/a	95.228	67.782	n/a	n/a
P1_Aug-Dec_Pot_Fishery_1977	68.394	1.166	68.225	1.163	68.254	1.158	68.159	1.164
P1_Aug-Dec_Pot_Fishery_2000	62.159	0.775	62.053	0.770	59.945	0.910	62.080	0.774
P1_Aug-Dec_Pot_Fishery_2008	n/a	n/a	n/a	n/a	65.154	1.157	n/a	n/a
P3_Aug-Dec_Pot_Fishery_1977	5.187	0.118	5.180	0.119	5.177	0.118	5.177	0.119
P3_Aug-Dec_Pot_Fishery_2000	4.479	0.121	4.472	0.121	4.284	0.166	4.477	0.121
P3_Aug-Dec_Pot_Fishery_2008	n/a	n/a	n/a	n/a	4.611	0.164	n/a	n/a

Table 2.1.4b. Fishery selectivity parameters estimated by Model 5. See text for details.

	Model 5	
Parameter	Estimate	St. Dev.
P1_Season1_Fishery	69.263	0.569
P2_Season1_Fishery	-8.564	29.566
P3_Season1_Fishery	5.798	0.036
P4_Season1_Fishery	5.191	0.265
P6_Season1_Fishery	-0.038	0.185
P1_Season2_Fishery	69.130	0.587
P2_Season2_Fishery	-8.259	33.647
P3_Season2_Fishery	5.961	0.033
P4_Season2_Fishery	4.840	0.284
P6_Season2_Fishery	0.274	0.159
P1_Season3_Fishery	66.959	0.776
P3_Season3_Fishery	5.760	0.052
P1_Season4_Fishery	65.310	0.463
P2_Season4_Fishery	-1.766	0.401
P3_Season4_Fishery	5.145	0.041
P4_Season4_Fishery	1.268	3.551
P6_Season4_Fishery	2.358	0.425
P1_Season5_Fishery	64.297	0.555
P2_Season5_Fishery	-1.834	0.423
P3_Season5_Fishery	5.190	0.049
P4_Season5_Fishery	4.973	0.697
P6_Season5_Fishery	0.387	0.276

Table 2.1.5. Survey selectivity parameters estimated by the five primary models. Models 1-4 use age-based selectivity while Model 5 uses length-based, and the *dev*s in Models 1-4 are with respect to *ascending_width* while the Model 5 *dev*s are with respect to *initial_selectivity*.

	Model 1		Model 2		Model 3		Model 4			Model 5	
Parameter	Estimate	St. dev.	Estimate	St. dev.	Estimate	St. dev.	Estimate	St. dev.	Parameter	Estimate	St. dev.
P1	1.290	0.065	1.292	0.065	1.292	0.065	1.349	0.095	P1	27.196	1.067
P2	-11.490	107.111	-9.992	122.185	-12.001	101.357	-3.383	0.682	P2	-1.430	0.202
P3	-2.189	0.482	-2.167	0.483	-2.187	0.481	-1.846	0.570	P3	1.748	0.886
P4	3.185	0.175	3.177	0.178	3.106	0.161	1.864	0.438	P4	6.774	0.325
P5	-9.564	1.716	-9.559	1.714	-9.575	1.715	-9.995	0.170	P5	-0.031	0.196
P6	-1.667	0.415	-1.732	0.416	-1.680	0.368	-0.668	0.187	P6	-1.301	0.432
P3_dev_1982	-0.028	0.035	-0.028	0.035	-0.029	0.034	-0.027	0.034	P5_dev_1982	-0.809	0.520
P3_dev_1983	-0.042	0.018	-0.042	0.018	-0.042	0.018	-0.042	0.018	P5_dev_1983	-0.515	0.307
P3_dev_1984	-0.075	0.028	-0.075	0.028	-0.075	0.028	-0.072	0.027	P5_dev_1984	-0.021	0.590
P3_dev_1985	0.003	0.021	0.003	0.021	0.003	0.021	0.004	0.021	P5_dev_1985	0.206	0.361
P3_dev_1986	-0.044	0.023	-0.043	0.023	-0.044	0.023	-0.041	0.022	P5_dev_1986	-0.847	0.370
P3_dev_1987	0.040	0.041	0.044	0.042	0.038	0.040	0.040	0.040	P5_dev_1987	0.756	0.625
P3_dev_1988	-0.062	0.034	-0.058	0.035	-0.064	0.033	-0.057	0.033	P5_dev_1988	-0.549	0.598
P3_dev_1989	-0.110	0.019	-0.110	0.019	-0.109	0.019	-0.105	0.019	P5_dev_1989	-1.726	0.374
P3_dev_1990	-0.028	0.021	-0.028	0.021	-0.027	0.021	-0.028	0.020	P5_dev_1990	-0.242	0.356
P3_dev_1991	-0.041	0.022	-0.041	0.022	-0.041	0.022	-0.040	0.022	P5_dev_1991	-0.542	0.373
P3_dev_1992	0.094	0.041	0.095	0.041	0.092	0.040	0.094	0.040	P5_dev_1992	1.353	0.601
P3_dev_1993	0.047	0.028	0.046	0.028	0.045	0.028	0.046	0.028	P5_dev_1993	0.941	0.488
P3_dev_1994	-0.041	0.021	-0.041	0.022	-0.043	0.021	-0.035	0.027	P5_dev_1994	-0.125	0.397
P3_dev_1995	-0.088	0.020	-0.088	0.020	-0.089	0.020	-0.073	0.024	P5_dev_1995	-0.976	0.393
P3_dev_1996	-0.107	0.019	-0.108	0.019	-0.108	0.018	-0.098	0.022	P5_dev_1996	-1.490	0.355
P3_dev_1997	-0.067	0.016	-0.068	0.016	-0.067	0.016	-0.064	0.018	P5_dev_1997	-0.974	0.268
P3_dev_1998	-0.072	0.019	-0.071	0.019	-0.075	0.019	-0.070	0.022	P5_dev_1998	-1.305	0.334
P3_dev_1999	-0.071	0.018	-0.071	0.018	-0.073	0.018	-0.067	0.021	P5_dev_1999	-1.264	0.316
P3_dev_2000	-0.041	0.016	-0.041	0.016	-0.043	0.016	-0.038	0.018	P5_dev_2000	-0.900	0.258
P3_dev_2001	0.135	0.035	0.137	0.035	0.134	0.035	0.110	0.035	P5_dev_2001	1.476	0.478
P3_dev_2002	-0.012	0.024	-0.011	0.024	-0.006	0.025	0.019	0.035	P5_dev_2002	-0.508	0.352
P3_dev_2003	-0.002	0.019	-0.003	0.019	0.012	0.021	0.001	0.024	P5_dev_2003	0.141	0.326
P3_dev_2004	-0.026	0.019	-0.028	0.019	-0.014	0.020	-0.015	0.024	P5_dev_2004	-0.452	0.307
P3_dev_2005	0.037	0.025	0.036	0.025	0.045	0.026	0.050	0.033	P5_dev_2005	0.620	0.415
P3_dev_2006	0.134	0.036	0.130	0.036	0.144	0.036	0.109	0.037	P5_dev_2006	1.372	0.484
P3_dev_2007	0.197	0.037	0.195	0.037	0.193	0.037	0.150	0.038	P5_dev_2007	2.487	0.536
P3_dev_2008	0.087	0.033	0.088	0.034	0.068	0.030	0.090	0.039	P5_dev_2008	0.550	0.403
P3_dev_2009	0.044	0.022	0.044	0.022	0.033	0.021	0.027	0.022	P5_dev_2009	0.922	0.378

Table 2.1.6a. Fishing mortality rate by year, gear, and season for Model 1. The “total” column weights rates by season length before summing.

	Trawl fishery					Longline fishery					Pot fishery					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.080	0.085	0.052	0.046	0.040	0.016	0.016	0.005	0.023	0.030	0	0	0	0	0	0.076
1978	0.092	0.097	0.064	0.053	0.048	0.016	0.017	0.006	0.024	0.033	0	0	0	0	0	0.087
1979	0.067	0.071	0.042	0.038	0.032	0.012	0.013	0.005	0.018	0.024	0	0	0	0	0	0.062
1980	0.060	0.061	0.030	0.039	0.033	0.010	0.010	0.004	0.014	0.017	0	0	0	0	0	0.053
1981	0.032	0.032	0.031	0.060	0.057	0.004	0.004	0.002	0.008	0.010	0	0	0	0	0	0.048
1982	0.033	0.034	0.034	0.042	0.033	0.001	0.001	0.001	0.004	0.005	0	0	0	0	0	0.038
1983	0.051	0.055	0.049	0.050	0.041	0.004	0.005	0.002	0.004	0.005	0	0	0	0	0	0.053
1984	0.058	0.064	0.055	0.053	0.046	0.007	0.008	0.006	0.027	0.037	0	0	0	0	0	0.072
1985	0.074	0.082	0.064	0.064	0.049	0.023	0.026	0.010	0.033	0.045	0	0	0	0	0	0.092
1986	0.083	0.091	0.064	0.064	0.051	0.016	0.018	0.005	0.026	0.037	0	0	0	0	0	0.089
1987	0.091	0.101	0.051	0.052	0.050	0.040	0.045	0.012	0.041	0.058	0	0	0	0	0	0.103
1988	0.184	0.205	0.098	0.110	0.116	0.001	0.001	0.002	0.003	0.003	0	0	0	0	0	0.138
1989	0.195	0.219	0.096	0.057	0.052	0.008	0.009	0.012	0.014	0.013	0.000	0.000	0.000	0.000	0.000	0.127
1990	0.164	0.187	0.090	0.028	0.024	0.030	0.034	0.046	0.050	0.045	0.000	0.000	0.002	0.002	0.001	0.135
1991	0.169	0.371	0.066	0.047	0.000	0.058	0.103	0.085	0.097	0.104	0.000	0.000	0.002	0.010	0.004	0.212
1992	0.139	0.219	0.054	0.032	0.010	0.126	0.236	0.138	0.089	0.000	0.000	0.002	0.030	0.011	0.000	0.211
1993	0.177	0.250	0.027	0.036	0.011	0.213	0.224	0.026	0.000	0.000	0.000	0.011	0.006	0.000	0.000	0.172
1994	0.081	0.286	0.019	0.073	0.014	0.180	0.258	0.029	0.100	0.000	0.000	0.030	0.009	0.015	0.000	0.203
1995	0.200	0.414	0.005	0.188	0.001	0.233	0.304	0.020	0.103	0.055	0.001	0.075	0.038	0.015	0.010	0.307
1996	0.134	0.359	0.036	0.102	0.020	0.226	0.255	0.018	0.114	0.022	0.000	0.123	0.053	0.021	0.005	0.277
1997	0.166	0.386	0.023	0.093	0.023	0.252	0.274	0.041	0.109	0.185	0.000	0.094	0.039	0.020	0.005	0.312
1998	0.115	0.218	0.021	0.132	0.015	0.274	0.203	0.022	0.090	0.111	0.000	0.061	0.033	0.011	0.000	0.243
1999	0.138	0.208	0.015	0.061	0.003	0.314	0.229	0.019	0.116	0.040	0.000	0.060	0.033	0.012	0.000	0.229
2000	0.154	0.207	0.018	0.027	0.003	0.277	0.078	0.008	0.120	0.130	0.124	0.047	0.000	0.000	0.000	0.213
2001	0.063	0.112	0.014	0.035	0.005	0.157	0.143	0.017	0.149	0.142	0.001	0.109	0.003	0.017	0.004	0.181
2002	0.096	0.168	0.029	0.034	0.002	0.290	0.132	0.008	0.174	0.104	0.016	0.083	0.005	0.014	0.005	0.215
2003	0.116	0.129	0.026	0.029	0.000	0.292	0.097	0.000	0.163	0.106	0.126	0.017	0.000	0.022	0.009	0.209
2004	0.153	0.136	0.038	0.036	0.000	0.301	0.148	0.012	0.157	0.151	0.079	0.028	0.005	0.017	0.004	0.233
2005	0.193	0.122	0.033	0.013	0.001	0.412	0.066	0.018	0.173	0.149	0.076	0.030	0.000	0.023	0.003	0.240
2006	0.228	0.128	0.033	0.023	0.000	0.465	0.071	0.011	0.238	0.008	0.103	0.037	0.002	0.022	0.007	0.257
2007	0.142	0.168	0.059	0.019	0.001	0.502	0.025	0.008	0.187	0.007	0.118	0.014	0.003	0.031	0.000	0.240
2008	0.153	0.080	0.023	0.038	0.006	0.533	0.053	0.019	0.220	0.077	0.107	0.027	0.002	0.043	0.001	0.259
2009	0.128	0.113	0.023	0.056	0.003	0.606	0.055	0.016	0.219	0.089	0.124	0.025	0.001	0.009	0.010	0.273
2010	0.154	0.082	0.019	0.047	0.010	0.448	0.023	0.014	0.116	0.086	0.124	0.021	0.002	0.026	0.013	0.216
2011	0.160	0.169	0.026	0.034	0.005	0.242	0.234	0.064	0.127	0.059	0.134	0.022	0.008	0.028	0.006	0.243

Table 2.1.6b. Fishing mortality rate by year, gear, and season for Model 2. The "total" column weights rates by season length before summing.

	Trawl fishery					Longline fishery					Pot fishery					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.070	0.074	0.046	0.040	0.035	0.014	0.014	0.005	0.020	0.026	0	0	0	0	0	0.067
1978	0.080	0.086	0.056	0.047	0.042	0.014	0.015	0.005	0.022	0.030	0	0	0	0	0	0.077
1979	0.059	0.063	0.037	0.034	0.029	0.011	0.012	0.004	0.016	0.022	0	0	0	0	0	0.055
1980	0.053	0.054	0.026	0.034	0.029	0.009	0.009	0.003	0.012	0.015	0	0	0	0	0	0.047
1981	0.029	0.029	0.028	0.054	0.051	0.003	0.003	0.002	0.008	0.009	0	0	0	0	0	0.043
1982	0.030	0.031	0.031	0.038	0.030	0.001	0.001	0.001	0.003	0.004	0	0	0	0	0	0.034
1983	0.047	0.050	0.045	0.046	0.038	0.004	0.004	0.002	0.004	0.005	0	0	0	0	0	0.049
1984	0.054	0.059	0.051	0.049	0.042	0.007	0.007	0.005	0.025	0.034	0	0	0	0	0	0.066
1985	0.068	0.076	0.060	0.059	0.046	0.021	0.024	0.009	0.031	0.042	0	0	0	0	0	0.086
1986	0.077	0.085	0.060	0.059	0.047	0.015	0.017	0.005	0.024	0.034	0	0	0	0	0	0.083
1987	0.085	0.094	0.048	0.049	0.047	0.038	0.041	0.011	0.038	0.054	0	0	0	0	0	0.096
1988	0.172	0.191	0.092	0.103	0.108	0.001	0.001	0.001	0.003	0.003	0	0	0	0	0	0.129
1989	0.182	0.205	0.090	0.054	0.049	0.007	0.008	0.011	0.013	0.012	0.000	0.000	0.000	0.000	0.000	0.119
1990	0.154	0.175	0.085	0.027	0.023	0.028	0.032	0.043	0.047	0.042	0.000	0.000	0.002	0.002	0.001	0.127
1991	0.159	0.348	0.062	0.044	0.000	0.055	0.097	0.080	0.090	0.097	0.000	0.000	0.002	0.010	0.004	0.198
1992	0.130	0.205	0.051	0.030	0.009	0.119	0.222	0.129	0.083	0.000	0.000	0.001	0.028	0.010	0.000	0.197
1993	0.165	0.233	0.025	0.034	0.010	0.200	0.210	0.024	0.000	0.000	0.000	0.010	0.006	0.000	0.000	0.160
1994	0.076	0.268	0.017	0.069	0.013	0.170	0.243	0.027	0.094	0.000	0.000	0.028	0.009	0.014	0.000	0.190
1995	0.188	0.387	0.005	0.175	0.001	0.221	0.287	0.019	0.097	0.052	0.001	0.071	0.035	0.014	0.009	0.289
1996	0.126	0.336	0.033	0.095	0.019	0.213	0.241	0.016	0.107	0.021	0.000	0.115	0.050	0.020	0.005	0.259
1997	0.156	0.361	0.022	0.087	0.021	0.238	0.258	0.038	0.102	0.172	0.000	0.089	0.037	0.018	0.005	0.292
1998	0.108	0.203	0.019	0.122	0.014	0.257	0.190	0.020	0.083	0.103	0.000	0.057	0.031	0.010	0.000	0.227
1999	0.128	0.193	0.014	0.056	0.003	0.294	0.214	0.017	0.108	0.037	0.000	0.056	0.031	0.011	0.000	0.213
2000	0.143	0.192	0.017	0.025	0.003	0.259	0.073	0.007	0.112	0.122	0.116	0.044	0.000	0.000	0.000	0.199
2001	0.059	0.104	0.013	0.033	0.004	0.148	0.135	0.016	0.140	0.134	0.001	0.102	0.003	0.016	0.003	0.170
2002	0.089	0.156	0.027	0.032	0.001	0.274	0.124	0.007	0.164	0.098	0.015	0.078	0.005	0.013	0.005	0.202
2003	0.108	0.120	0.024	0.028	0.000	0.276	0.091	0.000	0.153	0.100	0.119	0.016	0.000	0.021	0.008	0.196
2004	0.143	0.127	0.036	0.034	0.000	0.284	0.139	0.012	0.148	0.142	0.075	0.026	0.004	0.016	0.004	0.219
2005	0.181	0.114	0.031	0.013	0.001	0.387	0.062	0.017	0.162	0.139	0.071	0.028	0.000	0.021	0.003	0.225
2006	0.213	0.119	0.031	0.021	0.000	0.435	0.066	0.010	0.221	0.008	0.096	0.035	0.002	0.021	0.006	0.240
2007	0.132	0.156	0.054	0.017	0.001	0.467	0.024	0.007	0.173	0.006	0.110	0.013	0.003	0.029	0.000	0.222
2008	0.141	0.074	0.022	0.035	0.005	0.493	0.049	0.017	0.203	0.071	0.099	0.025	0.002	0.040	0.001	0.239
2009	0.117	0.103	0.021	0.051	0.003	0.558	0.051	0.015	0.200	0.081	0.114	0.023	0.001	0.008	0.009	0.251
2010	0.141	0.075	0.017	0.043	0.009	0.412	0.021	0.013	0.107	0.079	0.113	0.019	0.002	0.024	0.012	0.198
2011	0.147	0.154	0.024	0.031	0.004	0.223	0.215	0.059	0.117	0.054	0.123	0.020	0.007	0.025	0.006	0.223

Table 2.1.6c. Fishing mortality rate by year, gear, and season for Model 3. The “total” column weights rates by season length before summing.

	Trawl fishery					Longline fishery					Pot fishery					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.087	0.093	0.057	0.050	0.043	0.017	0.017	0.006	0.026	0.034	0	0	0	0	0	0.083
1978	0.100	0.107	0.069	0.058	0.052	0.017	0.018	0.007	0.028	0.038	0	0	0	0	0	0.096
1979	0.073	0.078	0.045	0.041	0.035	0.013	0.014	0.005	0.021	0.028	0	0	0	0	0	0.068
1980	0.066	0.066	0.031	0.043	0.035	0.011	0.011	0.004	0.014	0.018	0	0	0	0	0	0.057
1981	0.034	0.034	0.032	0.065	0.061	0.004	0.004	0.002	0.009	0.011	0	0	0	0	0	0.052
1982	0.034	0.035	0.035	0.044	0.035	0.001	0.001	0.001	0.004	0.005	0	0	0	0	0	0.040
1983	0.053	0.056	0.050	0.052	0.043	0.004	0.005	0.003	0.004	0.005	0	0	0	0	0	0.055
1984	0.059	0.065	0.056	0.055	0.047	0.007	0.008	0.006	0.027	0.036	0	0	0	0	0	0.073
1985	0.075	0.083	0.065	0.064	0.050	0.023	0.026	0.010	0.034	0.046	0	0	0	0	0	0.093
1986	0.083	0.092	0.065	0.064	0.051	0.016	0.018	0.005	0.026	0.037	0	0	0	0	0	0.090
1987	0.091	0.101	0.051	0.052	0.050	0.040	0.044	0.012	0.041	0.058	0	0	0	0	0	0.103
1988	0.183	0.204	0.097	0.110	0.115	0.001	0.001	0.002	0.003	0.003	0	0	0	0	0	0.138
1989	0.193	0.217	0.095	0.057	0.052	0.008	0.009	0.012	0.014	0.012	0.000	0.000	0.000	0.000	0.000	0.126
1990	0.162	0.184	0.089	0.028	0.024	0.029	0.033	0.045	0.050	0.045	0.000	0.000	0.002	0.002	0.001	0.134
1991	0.166	0.365	0.065	0.046	0.000	0.058	0.102	0.084	0.096	0.103	0.000	0.000	0.002	0.010	0.004	0.209
1992	0.136	0.215	0.053	0.032	0.010	0.125	0.233	0.135	0.088	0.000	0.000	0.002	0.029	0.010	0.000	0.207
1993	0.173	0.244	0.026	0.036	0.011	0.210	0.221	0.026	0.000	0.000	0.000	0.011	0.006	0.000	0.000	0.168
1994	0.079	0.279	0.018	0.072	0.014	0.177	0.253	0.028	0.098	0.000	0.000	0.029	0.009	0.015	0.000	0.198
1995	0.194	0.401	0.005	0.181	0.001	0.228	0.296	0.019	0.100	0.053	0.001	0.073	0.037	0.014	0.010	0.299
1996	0.130	0.346	0.034	0.098	0.019	0.219	0.248	0.017	0.109	0.021	0.000	0.119	0.051	0.021	0.005	0.267
1997	0.159	0.369	0.022	0.089	0.021	0.243	0.263	0.039	0.104	0.175	0.000	0.091	0.037	0.019	0.005	0.299
1998	0.109	0.206	0.020	0.124	0.014	0.261	0.193	0.021	0.085	0.104	0.000	0.058	0.031	0.010	0.000	0.230
1999	0.130	0.195	0.014	0.056	0.003	0.296	0.216	0.017	0.108	0.037	0.000	0.056	0.031	0.011	0.000	0.215
2000	0.142	0.191	0.017	0.030	0.004	0.259	0.073	0.007	0.114	0.123	0.116	0.044	0.000	0.000	0.000	0.201
2001	0.058	0.102	0.013	0.038	0.005	0.146	0.133	0.016	0.141	0.134	0.001	0.101	0.003	0.015	0.003	0.170
2002	0.087	0.152	0.026	0.037	0.002	0.268	0.121	0.007	0.163	0.097	0.015	0.077	0.005	0.012	0.005	0.200
2003	0.104	0.116	0.023	0.031	0.000	0.267	0.088	0.000	0.151	0.098	0.115	0.015	0.000	0.019	0.008	0.191
2004	0.136	0.121	0.034	0.037	0.000	0.272	0.133	0.011	0.145	0.139	0.072	0.025	0.004	0.015	0.003	0.212
2005	0.166	0.104	0.030	0.013	0.001	0.383	0.061	0.016	0.154	0.133	0.068	0.027	0.000	0.020	0.003	0.216
2006	0.196	0.110	0.030	0.023	0.000	0.442	0.067	0.010	0.215	0.008	0.093	0.033	0.002	0.020	0.006	0.234
2007	0.124	0.147	0.054	0.020	0.001	0.488	0.025	0.007	0.174	0.006	0.109	0.013	0.003	0.028	0.000	0.224
2008	0.141	0.074	0.022	0.032	0.005	0.520	0.052	0.018	0.270	0.095	0.109	0.027	0.006	0.043	0.001	0.269
2009	0.122	0.108	0.022	0.045	0.002	0.617	0.057	0.016	0.263	0.106	0.130	0.027	0.003	0.009	0.011	0.286
2010	0.151	0.080	0.018	0.040	0.008	0.483	0.025	0.014	0.133	0.098	0.135	0.023	0.011	0.029	0.014	0.231
2011	0.158	0.167	0.025	0.028	0.004	0.258	0.250	0.063	0.143	0.066	0.145	0.023	0.055	0.030	0.007	0.266

Table 2.1.6d. Fishing mortality rate by year, gear, and season for Model 4. The "total" column weights rates by season length before summing.

	Trawl fishery					Longline fishery					Pot fishery					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.070	0.075	0.046	0.041	0.035	0.014	0.014	0.005	0.020	0.026	0	0	0	0	0	0.067
1978	0.081	0.086	0.056	0.047	0.042	0.014	0.015	0.005	0.022	0.029	0	0	0	0	0	0.077
1979	0.059	0.062	0.037	0.034	0.028	0.011	0.011	0.004	0.016	0.021	0	0	0	0	0	0.055
1980	0.053	0.053	0.026	0.033	0.028	0.009	0.009	0.003	0.012	0.015	0	0	0	0	0	0.046
1981	0.028	0.028	0.027	0.052	0.049	0.003	0.003	0.002	0.007	0.009	0	0	0	0	0	0.042
1982	0.029	0.030	0.031	0.037	0.029	0.001	0.001	0.001	0.003	0.004	0	0	0	0	0	0.033
1983	0.046	0.049	0.044	0.044	0.037	0.004	0.004	0.002	0.004	0.004	0	0	0	0	0	0.048
1984	0.052	0.058	0.050	0.048	0.041	0.006	0.007	0.005	0.024	0.033	0	0	0	0	0	0.065
1985	0.067	0.074	0.059	0.057	0.044	0.021	0.023	0.009	0.030	0.042	0	0	0	0	0	0.084
1986	0.076	0.083	0.060	0.058	0.046	0.015	0.017	0.005	0.024	0.034	0	0	0	0	0	0.082
1987	0.084	0.093	0.048	0.048	0.046	0.037	0.041	0.011	0.038	0.054	0	0	0	0	0	0.095
1988	0.170	0.190	0.092	0.101	0.106	0.001	0.001	0.001	0.003	0.003	0	0	0	0	0	0.128
1989	0.182	0.204	0.091	0.053	0.048	0.007	0.008	0.011	0.013	0.012	0.000	0.000	0.000	0.000	0.000	0.119
1990	0.154	0.176	0.085	0.027	0.023	0.028	0.032	0.043	0.047	0.042	0.000	0.000	0.002	0.002	0.001	0.128
1991	0.159	0.350	0.062	0.044	0.000	0.055	0.098	0.080	0.091	0.098	0.000	0.000	0.002	0.010	0.004	0.200
1992	0.131	0.206	0.051	0.030	0.009	0.120	0.223	0.130	0.084	0.000	0.000	0.001	0.028	0.010	0.000	0.198
1993	0.166	0.235	0.025	0.034	0.010	0.201	0.212	0.025	0.000	0.000	0.000	0.010	0.006	0.000	0.000	0.162
1994	0.076	0.269	0.017	0.069	0.013	0.171	0.244	0.027	0.094	0.000	0.000	0.028	0.009	0.014	0.000	0.191
1995	0.188	0.387	0.005	0.176	0.001	0.221	0.287	0.019	0.097	0.052	0.001	0.071	0.036	0.014	0.009	0.289
1996	0.126	0.336	0.033	0.095	0.019	0.213	0.241	0.017	0.107	0.021	0.000	0.115	0.050	0.020	0.005	0.260
1997	0.156	0.363	0.022	0.087	0.021	0.239	0.260	0.038	0.103	0.174	0.000	0.089	0.037	0.019	0.005	0.294
1998	0.109	0.206	0.020	0.124	0.014	0.262	0.194	0.021	0.085	0.105	0.000	0.058	0.031	0.010	0.000	0.231
1999	0.131	0.196	0.014	0.057	0.003	0.301	0.220	0.018	0.110	0.038	0.000	0.057	0.031	0.011	0.000	0.218
2000	0.146	0.197	0.017	0.026	0.003	0.265	0.075	0.007	0.114	0.124	0.118	0.045	0.000	0.000	0.000	0.203
2001	0.060	0.107	0.013	0.033	0.004	0.150	0.137	0.017	0.143	0.136	0.001	0.105	0.003	0.016	0.003	0.174
2002	0.091	0.160	0.028	0.033	0.001	0.278	0.126	0.008	0.167	0.100	0.016	0.080	0.005	0.013	0.005	0.206
2003	0.111	0.123	0.025	0.028	0.000	0.281	0.093	0.000	0.156	0.102	0.121	0.016	0.000	0.021	0.009	0.200
2004	0.146	0.130	0.037	0.035	0.000	0.289	0.142	0.012	0.151	0.145	0.076	0.027	0.004	0.016	0.004	0.224
2005	0.185	0.117	0.032	0.013	0.001	0.395	0.063	0.017	0.167	0.143	0.073	0.029	0.000	0.022	0.003	0.231
2006	0.219	0.123	0.032	0.022	0.000	0.447	0.068	0.011	0.229	0.008	0.099	0.036	0.002	0.022	0.006	0.247
2007	0.136	0.161	0.056	0.018	0.001	0.481	0.024	0.008	0.180	0.007	0.113	0.014	0.003	0.030	0.000	0.230
2008	0.146	0.077	0.022	0.036	0.005	0.508	0.050	0.018	0.210	0.073	0.102	0.026	0.002	0.041	0.001	0.247
2009	0.121	0.106	0.022	0.053	0.003	0.572	0.052	0.015	0.207	0.084	0.117	0.024	0.001	0.008	0.009	0.258
2010	0.145	0.077	0.018	0.045	0.009	0.422	0.022	0.014	0.111	0.082	0.116	0.020	0.002	0.025	0.012	0.205
2011	0.153	0.162	0.025	0.033	0.004	0.233	0.226	0.062	0.124	0.057	0.128	0.021	0.007	0.027	0.006	0.234

Table 2.1.6e. Fishing mortality rate by year and season for Model 5. The “total” column weights rates by season length before summing.

Year	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.248	0.237	0.148	0.143	0.133	0.176
1978	0.226	0.211	0.136	0.125	0.119	0.158
1979	0.131	0.124	0.083	0.077	0.071	0.094
1980	0.105	0.094	0.060	0.054	0.047	0.070
1981	0.046	0.041	0.047	0.060	0.055	0.050
1982	0.036	0.034	0.039	0.034	0.028	0.035
1983	0.054	0.055	0.049	0.041	0.036	0.047
1984	0.072	0.076	0.062	0.071	0.078	0.071
1985	0.092	0.097	0.070	0.069	0.073	0.078
1986	0.097	0.101	0.066	0.062	0.067	0.076
1987	0.128	0.133	0.062	0.069	0.087	0.091
1988	0.187	0.195	0.094	0.075	0.086	0.120
1989	0.198	0.209	0.094	0.048	0.047	0.111
1990	0.198	0.212	0.115	0.068	0.066	0.125
1991	0.241	0.479	0.133	0.140	0.104	0.206
1992	0.270	0.426	0.196	0.126	0.013	0.199
1993	0.357	0.422	0.050	0.041	0.013	0.155
1994	0.248	0.540	0.051	0.185	0.017	0.193
1995	0.411	0.712	0.054	0.193	0.062	0.259
1996	0.351	0.682	0.101	0.178	0.038	0.248
1997	0.445	0.779	0.108	0.187	0.229	0.316
1998	0.433	0.529	0.085	0.196	0.148	0.255
1999	0.514	0.548	0.075	0.186	0.050	0.250
2000	0.582	0.341	0.035	0.166	0.147	0.228
2001	0.244	0.364	0.044	0.227	0.166	0.197
2002	0.416	0.374	0.054	0.238	0.114	0.224
2003	0.509	0.228	0.033	0.213	0.111	0.203
2004	0.483	0.270	0.060	0.195	0.139	0.212
2005	0.595	0.189	0.049	0.202	0.154	0.219
2006	0.680	0.202	0.044	0.272	0.015	0.228
2007	0.612	0.183	0.065	0.219	0.007	0.205
2008	0.649	0.132	0.040	0.286	0.084	0.226
2009	0.656	0.151	0.038	0.271	0.096	0.228
2010	0.571	0.098	0.033	0.184	0.103	0.183
2011	0.438	0.331	0.088	0.185	0.068	0.208

Table 2.1.7. Selected parameter estimates and results from Models 1 and 5 and the secondary models that constitute a transition between those two primary models. Grey shading indicates parameters that were fixed, green shading indicates a positive change of more than 5% from the previous model, and pink shading indicates a negative change of at least 5% from the previous model.

Absolute values:

Quantity	1	1.3	Pre5.1	Pre5.2	Pre5.3	Pre5.4	Pre5.5	Pre5.6	5
Length at age 1 (cm)	14.243	14.243	14.245	14.246	14.365	14.369	13.622	14.622	14.623
Asymptotic length (cm)	91.021	90.982	90.986	91.059	90.114	90.164	89.235	91.394	89.843
Brody growth coefficient	0.248	0.248	0.248	0.248	0.263	0.263	0.267	0.270	0.283
Richards growth coefficient	1.000	1.000	1.000	1.000	0.926	0.926	0.965	0.833	0.803
SD of length at age 1 (cm)	3.498	3.496	3.497	3.498	3.489	3.491	3.333	3.669	3.682
SD of length at age 20 (cm)	10.514	10.520	10.509	10.503	10.525	10.543	10.641	10.480	10.267
Ageing bias at age 1 (years)	0.335	0.336	0.336	0.335	0.334	0.334	0.340	0.330	0.283
Ageing bias at age 20 (years)	0.849	0.844	0.844	0.844	0.863	0.858	0.830	0.864	1.059
σ(recruitment *dev* s)	0.570	0.570	0.570	0.570	0.570	0.760	0.759	0.860	0.829
Trawl survey catchability (*Q*)	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.723
σ(selectivity *dev* s)	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	1.010
Agecomp sample size multiplier	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.850
Spawning biomass 2011 (t)	323,273	315,918	316,030	316,938	316,271	316,713	343,693	341,604	368,253
SB(2011)/B100%	0.426	0.411	0.411	0.411	0.412	0.364	0.383	0.372	0.381

Relative changes from previous model:

Quantity	1	1.3	Pre5.1	Pre5.2	Pre5.3	Pre5.4	Pre5.5	Pre5.6	5
Length at age 1 (cm)	n/a	0.000	0.000	0.000	0.008	0.000	-0.052	0.073	0.000
Asymptotic length (cm)	n/a	0.000	0.000	0.001	-0.010	0.001	-0.010	0.024	-0.017
Brody growth coefficient	n/a	0.000	0.000	-0.001	0.061	-0.001	0.016	0.014	0.047
Richards growth coefficient	n/a	0.000	0.000	0.000	-0.074	0.000	0.042	-0.137	-0.035
SD of length at age 1 (cm)	n/a	0.000	0.000	0.000	-0.003	0.000	-0.045	0.101	0.004
SD of length at age 20 (cm)	n/a	0.001	-0.001	-0.001	0.002	0.002	0.009	-0.015	-0.020
Ageing bias at age 1 (years)	n/a	0.000	0.000	0.000	-0.004	0.001	0.017	-0.030	-0.143
Ageing bias at age 20 (years)	n/a	-0.006	0.001	0.000	0.022	-0.006	-0.032	0.041	0.226
σ(recruitment *dev* s)	n/a	0.000	0.000	0.000	0.000	0.334	-0.001	0.132	-0.036
Trawl survey catchability (*Q*)	n/a	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.061
σ(selectivity *dev* s)	n/a	0.000	0.000	0.000	0.000	0.000	0.000	0.000	13.429
Agecomp sample size multiplier	n/a	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.150
Spawning biomass 2011 (t)	n/a	-0.023	0.000	0.003	-0.002	0.001	0.085	-0.006	0.078
SB(2011)/B100%	n/a	-0.036	0.000	0.002	0.001	-0.115	0.052	-0.030	0.024

Table 2.1.8. Data files, objective function values, and number of parameters for the five primary models. Note that objective function values are not comparable between models that use different data files.

	Model 1	Model 2	Model 3	Model 4	Model 5
Data file:	BSbase	BSbase	BSbase	BSmodel4	BSmodel5

Component	Model 1	Model 2	Model 3	Model 4	Model 5
Catch	0.00	0.00	0.00	0.00	0.00
Equilibrium catch	0.00	0.00	0.00	0.00	0.00
Survey CPUE	-4.20	-0.72	-9.50	-7.13	22.01
Size composition	4192.75	4199.40	3951.66	4177.78	2590.40
Age composition	117.70	118.06	114.64	n/a	118.15
Recruitment	20.65	20.10	22.36	21.34	17.38
"Softbounds"	0.03	0.03	0.04	0.04	0.01
Deviations	16.83	16.76	16.68	13.08	14.27
Total	4343.76	4353.63	4095.87	4205.10	2762.21

Sizecomp component	Model 1	Model 2	Model 3	Model 4	Model 5
Jan-Apr trawl fishery	932.95	932.85	935.05	924.36	n/a
May-Jul trawl fishery	181.97	181.47	181.15	181.14	n/a
Aug-Dec trawl fishery	221.46	221.29	185.99	222.34	n/a
Jan-Apr longline fishery	638.76	637.23	547.57	636.52	n/a
May-Jul longline fishery	206.76	209.12	210.30	206.22	n/a
Aug-Dec longline fishery	891.28	896.13	783.03	883.24	n/a
Jan-Apr pot fishery	112.19	111.98	103.18	111.04	n/a
May-Jul pot fishery	70.60	70.63	72.06	71.63	n/a
Aug-Dec pot fishery	191.39	192.09	184.89	190.84	n/a
Trawl survey	745.40	746.62	748.44	750.45	406.62
Jan-Feb fishery	n/a	n/a	n/a	n/a	610.40
Mar-Apr fishery	n/a	n/a	n/a	n/a	397.71
May-Jul fishery	n/a	n/a	n/a	n/a	482.94
Aug-Oct fishery	n/a	n/a	n/a	n/a	403.70
Nov-Dec fishery	n/a	n/a	n/a	n/a	289.04

Parameter count	Model 1	Model 2	Model 3	Model 4	Model 5
No. non-*dev* parameters	117	117	134	115	40
No. *dev* s	65	65	65	65	72
Total no. parameters	182	182	199	180	112

Table 2.1.9. Objective function values, and number of parameters for the transition from Model 1 to Model 5. Note that objective function values are not comparable between models that use different data files. Model 1 uses “BSbase.dat,” Model 1.3 uses “BSmodel1_3.dat,” Models Pre5.1-Pre5.5 use “BSmodelPre5.dat,” and Models Pre5.6 and 5 use “BSmodel5.dat.”

Component	1	1.3	Pre5.1	Pre5.2	Pre5.3	Pre5.4	Pre5.5	Pre5.6	5
Catch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Equilibrium catch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Survey CPUE	-4.20	-5.70	-5.74	-5.47	-4.99	-4.79	0.27	32.36	22.01
Size composition	4192.75	4191.29	4208.94	4207.79	4206.15	4201.95	4089.57	2645.18	2590.40
Age composition	117.70	117.60	117.78	117.65	117.27	117.47	140.17	214.09	118.15
Recruitment	20.65	20.63	20.62	12.11	12.08	12.40	12.11	19.85	17.38
"Softbounds"	0.03	0.03	0.04	0.04	0.04	0.04	0.03	0.01	0.01
Deviations	16.83	16.80	16.81	16.77	16.65	16.58	46.20	12.62	14.27
Total	4343.76	4340.65	4358.45	4348.89	4347.20	4343.64	4288.36	2924.12	2762.21

Sizecomp component	1	1.3	Pre5.1	Pre5.2	Pre5.3	Pre5.4	Pre5.5	Pre5.6	5
Jan-Apr trawl fishery	932.95	932.34	934.50	934.15	935.67	935.38	944.19	n/a	n/a
May-Jul trawl fishery	181.97	181.77	183.39	183.85	183.77	184.06	184.94	n/a	n/a
Aug-Dec trawl fishery	221.46	221.33	223.30	223.58	224.40	223.59	224.62	n/a	n/a
Jan-Apr longline fishery	638.76	639.03	640.98	640.98	644.16	644.00	643.53	n/a	n/a
May-Jul longline fishery	206.76	206.45	207.64	207.23	208.23	207.16	207.88	n/a	n/a
Aug-Dec longline fishery	891.28	891.32	892.67	891.98	889.77	888.69	884.63	n/a	n/a
Jan-Apr pot fishery	112.19	112.28	113.82	113.80	114.07	114.09	114.38	n/a	n/a
May-Jul pot fishery	70.60	70.53	71.08	71.10	71.73	71.75	72.43	n/a	n/a
Aug-Dec pot fishery	191.39	191.28	192.83	192.70	193.20	192.98	193.61	n/a	n/a
Trawl survey	745.40	744.95	748.73	748.43	741.15	740.27	619.36	619.99	406.62
Jan-Feb fishery	n/a	n/a	n/a	n/a	n/a	n/a	n/a	403.34	610.40
Mar-Apr fishery	n/a	n/a	n/a	n/a	n/a	n/a	n/a	469.74	397.71
May-Jul fishery	n/a	n/a	n/a	n/a	n/a	n/a	n/a	391.39	482.94
Aug-Oct fishery	n/a	n/a	n/a	n/a	n/a	n/a	n/a	288.93	403.70
Nov-Dec fishery	n/a	n/a	n/a	n/a	n/a	n/a	n/a	471.80	289.04

Parameter count	1	1.3	Pre5.1	Pre5.2	Pre5.3	Pre5.4	Pre5.5	Pre5.6	5
No. non-*dev* parameters	117	117	117	117	118	119	119	40	40
No. *dev* s	65	65	65	72	72	72	100	100	72
Total no. parameters	182	182	182	189	190	191	219	140	112

Table 2.1.10a. Residuals for the trawl survey index resulting from the five primary models. For each year, residual = ln(observed/expected). The bottom row shows the mean for each column. Ideally, this value should be close to zero. A positive mean implies that the model tends to be biased low.

Year	Model 1	Model 2	Model 3	Model 4	Model 5
1982	-0.151	-0.157	-0.136	-0.175	-0.172
1983	0.138	0.136	0.155	0.153	0.070
1984	-0.058	-0.057	-0.046	-0.059	-0.075
1985	0.093	0.096	0.101	0.076	0.094
1986	0.128	0.135	0.134	0.104	0.181
1987	0.148	0.159	0.151	0.129	0.126
1988	0.169	0.183	0.172	0.162	0.125
1989	-0.042	-0.025	-0.041	-0.022	-0.101
1990	-0.002	0.008	-0.001	0.007	-0.026
1991	-0.099	-0.091	-0.098	-0.121	-0.047
1992	-0.022	-0.009	-0.029	-0.059	0.038
1993	0.220	0.231	0.211	0.187	0.262
1994	0.720	0.730	0.707	0.698	0.828
1995	0.471	0.482	0.452	0.462	0.600
1996	0.437	0.446	0.410	0.436	0.619
1997	0.087	0.092	0.053	0.094	0.306
1998	-0.045	-0.043	-0.086	-0.057	0.218
1999	0.001	0.008	-0.049	-0.021	0.181
2000	-0.087	-0.078	-0.140	-0.096	0.035
2001	0.348	0.359	0.286	0.348	0.354
2002	0.085	0.097	0.022	0.069	0.087
2003	0.117	0.128	0.063	0.119	0.069
2004	0.081	0.088	0.061	0.074	0.074
2005	0.168	0.171	0.186	0.148	0.138
2006	-0.002	-0.003	0.035	-0.007	-0.020
2007	-0.026	-0.036	0.010	-0.017	-0.077
2008	-0.362	-0.373	-0.335	-0.358	-0.367
2009	-0.211	-0.223	-0.205	-0.173	-0.250
2010	0.108	0.096	0.079	0.107	0.181
2011	0.085	0.073	0.057	0.094	0.131
Mean	0.083	0.087	0.073	0.077	0.119

Table 2.1.10b. Squared standardized residuals (SSR) for the trawl survey index resulting from the five primary models. For each year, SSR = $(\ln(\text{observed}/\text{expected})/\sigma)^2$. The bottom row shows the root mean squared error. Ideally, this value should be close to unity.

Year	Model 1	Model 2	Model 3	Model 4	Model 5
1982	5.415	5.795	4.373	7.237	6.972
1983	1.681	1.633	2.093	2.060	0.433
1984	0.627	0.615	0.389	0.644	1.053
1985	0.483	0.516	0.567	0.323	0.492
1986	1.643	1.821	1.807	1.092	3.307
1987	4.989	5.758	5.184	3.784	3.583
1988	5.861	6.833	6.052	5.381	3.225
1989	0.381	0.133	0.363	0.102	2.198
1990	0.001	0.008	0.000	0.006	0.093
1991	0.909	0.767	0.890	1.336	0.202
1992	0.036	0.006	0.060	0.259	0.103
1993	3.087	3.409	2.864	2.230	4.413
1994	34.098	35.092	32.881	32.109	45.095
1995	22.483	23.537	20.681	21.589	36.476
1996	9.169	9.582	8.076	9.133	18.429
1997	0.357	0.405	0.132	0.419	4.447
1998	0.249	0.225	0.906	0.400	5.886
1999	0.000	0.007	0.278	0.052	3.818
2000	0.921	0.733	2.345	1.111	0.146
2001	13.133	13.928	8.835	13.103	13.569
2002	0.708	0.903	0.048	0.458	0.729
2003	0.885	1.060	0.258	0.912	0.309
2004	0.905	1.069	0.523	0.763	0.756
2005	1.444	1.491	1.773	1.128	0.970
2006	0.001	0.003	0.343	0.015	0.111
2007	0.010	0.019	0.001	0.004	0.086
2008	12.230	13.044	10.496	11.979	12.571
2009	5.864	6.499	5.530	3.914	8.195
2010	0.679	0.537	0.362	0.666	1.893
2011	0.814	0.596	0.368	0.993	1.935
RMSE	2.074	2.129	1.987	2.027	2.460

Table 2.1.11a. Residuals for the trawl survey index resulting from Models 1 and 5 and the secondary models that constitute a transition between those two primary models. For each year, residual = ln(observed/expected). The bottom row shows the mean for each column. Ideally, this value should be close to zero. A positive mean implies that the model tends to be biased low.

Year	1	1.3	Pre5.1	Pre5.2	Pre5.3	Pre5.4	Pre5.5	Pre5.6	5
1982	-0.151	-0.143	-0.143	-0.140	-0.145	-0.143	-0.133	-0.106	-0.172
1983	0.138	0.146	0.145	0.147	0.144	0.147	0.160	0.050	0.070
1984	-0.058	-0.047	-0.047	-0.045	-0.044	-0.044	-0.057	-0.008	-0.075
1985	0.093	0.104	0.104	0.106	0.106	0.108	0.165	0.173	0.094
1986	0.128	0.137	0.138	0.139	0.138	0.138	0.123	0.153	0.181
1987	0.148	0.156	0.156	0.157	0.155	0.155	0.161	0.190	0.126
1988	0.169	0.173	0.173	0.174	0.172	0.173	0.177	0.119	0.125
1989	-0.042	-0.045	-0.045	-0.045	-0.045	-0.043	-0.041	-0.239	-0.101
1990	-0.002	-0.007	-0.008	-0.007	-0.003	-0.002	-0.002	-0.037	-0.026
1991	-0.099	-0.105	-0.105	-0.103	-0.096	-0.095	-0.115	-0.080	-0.047
1992	-0.022	-0.028	-0.028	-0.026	-0.021	-0.020	-0.006	0.157	0.038
1993	0.220	0.211	0.211	0.212	0.216	0.217	0.245	0.414	0.262
1994	0.720	0.707	0.706	0.708	0.714	0.715	0.721	0.835	0.828
1995	0.471	0.456	0.456	0.457	0.461	0.462	0.463	0.546	0.600
1996	0.437	0.422	0.421	0.422	0.428	0.429	0.442	0.528	0.619
1997	0.087	0.079	0.079	0.080	0.087	0.089	0.097	0.171	0.306
1998	-0.045	-0.045	-0.045	-0.043	-0.035	-0.034	-0.029	0.163	0.218
1999	0.001	0.002	0.002	0.003	0.008	0.009	0.006	0.145	0.181
2000	-0.087	-0.088	-0.088	-0.088	-0.085	-0.084	-0.064	-0.030	0.035
2001	0.348	0.347	0.347	0.347	0.350	0.350	0.385	0.526	0.354
2002	0.085	0.084	0.084	0.084	0.085	0.084	0.080	0.095	0.087
2003	0.117	0.116	0.116	0.115	0.115	0.114	0.139	0.106	0.069
2004	0.081	0.080	0.080	0.080	0.082	0.081	0.083	0.058	0.074
2005	0.168	0.168	0.168	0.167	0.171	0.170	0.201	0.217	0.138
2006	-0.002	-0.002	-0.002	-0.003	0.000	-0.001	-0.016	0.097	-0.020
2007	-0.026	-0.026	-0.026	-0.028	-0.025	-0.028	-0.065	0.177	-0.077
2008	-0.362	-0.362	-0.361	-0.364	-0.362	-0.364	-0.384	-0.402	-0.367
2009	-0.211	-0.211	-0.211	-0.214	-0.214	-0.216	-0.237	-0.261	-0.250
2010	0.108	0.109	0.109	0.106	0.103	0.099	0.112	0.010	0.181
2011	0.085	0.088	0.088	0.084	0.081	0.074	0.082	-0.029	0.131
Mean	0.083	0.082	0.082	0.083	0.085	0.085	0.090	0.125	0.119

Table 2.1.11b. Squared standardized residuals (SSR) for the trawl survey index resulting from Models 1 and 5 and the secondary models that constitute a transition between those two primary models. For each year, SSR = $(\ln(\text{observed}/\text{expected})/\sigma)^2$. The bottom row shows the root mean squared error. Ideally, this value should be close to unity.

Year	1	1.3	Pre5.1	Pre5.2	Pre5.3	Pre5.4	Pre5.5	Pre5.6	5
1982	5.415	4.824	4.848	4.630	4.981	4.855	4.203	2.630	6.972
1983	1.681	1.865	1.856	1.906	1.807	1.907	2.249	0.221	0.433
1984	0.627	0.410	0.412	0.370	0.357	0.355	0.615	0.013	1.053
1985	0.483	0.605	0.604	0.625	0.619	0.643	1.502	1.659	0.492
1986	1.643	1.896	1.900	1.951	1.899	1.901	1.531	2.344	3.307
1987	4.989	5.503	5.500	5.599	5.436	5.467	5.904	8.202	3.583
1988	5.861	6.115	6.108	6.179	6.080	6.104	6.405	2.902	3.225
1989	0.381	0.433	0.438	0.436	0.440	0.399	0.360	12.206	2.198
1990	0.001	0.007	0.008	0.007	0.001	0.001	0.000	0.187	0.093
1991	0.909	1.010	1.014	0.981	0.855	0.827	1.214	0.588	0.202
1992	0.036	0.056	0.057	0.050	0.033	0.028	0.003	1.799	0.103
1993	3.087	2.850	2.841	2.880	2.975	3.016	3.853	10.977	4.413
1994	34.098	32.865	32.839	33.003	33.562	33.651	34.270	45.950	45.095
1995	22.483	21.071	21.044	21.176	21.507	21.633	21.716	30.192	36.476
1996	9.169	8.549	8.535	8.586	8.797	8.842	9.397	13.428	18.429
1997	0.357	0.297	0.294	0.302	0.364	0.376	0.450	1.384	4.447
1998	0.249	0.252	0.254	0.233	0.151	0.141	0.107	3.278	5.886
1999	0.000	0.000	0.000	0.001	0.007	0.009	0.005	2.448	3.818
2000	0.921	0.934	0.939	0.924	0.864	0.852	0.500	0.111	0.146
2001	13.133	12.990	12.987	13.037	13.222	13.226	16.053	29.946	13.569
2002	0.708	0.678	0.678	0.684	0.694	0.689	0.614	0.880	0.729
2003	0.885	0.865	0.864	0.861	0.850	0.847	1.256	0.726	0.309
2004	0.905	0.896	0.895	0.882	0.928	0.911	0.949	0.472	0.756
2005	1.444	1.440	1.437	1.421	1.493	1.480	2.067	2.399	0.970
2006	0.001	0.001	0.001	0.003	0.000	0.000	0.068	2.599	0.111
2007	0.010	0.010	0.010	0.011	0.009	0.011	0.062	0.454	0.086
2008	12.230	12.230	12.225	12.364	12.229	12.401	13.828	15.132	12.571
2009	5.864	5.855	5.852	5.982	5.991	6.140	7.339	8.961	8.195
2010	0.679	0.695	0.694	0.651	0.619	0.564	0.732	0.006	1.893
2011	0.814	0.863	0.865	0.785	0.730	0.608	0.760	0.095	1.935
RMSE	2.074	2.050	2.049	2.054	2.062	2.065	2.145	2.596	2.460

Table 2.1.12a. Number of records, input sample sizes, and mean of the ratio between effective sample size and input sample size for size composition data from each fleet for the five primary models.

Fleet	Nrec	Input N	Model 1	Model 2	Model 3	Model 4	Model 5
Jan-Apr trawl fishery	60	327	5.702	5.704	5.462	5.725	n/a
May-Jul trawl fishery	31	67	9.305	9.287	9.247	9.264	n/a
Aug-Dec trawl fishery	34	42	13.205	13.230	13.819	13.186	n/a
Jan-Apr longline fishery	64	466	9.021	9.020	8.760	9.060	n/a
May-Jul longline fishery	31	211	9.511	9.441	9.127	9.458	n/a
Aug-Dec longline fishery	59	673	6.886	6.916	6.811	7.005	n/a
Jan-Apr pot fishery	32	143	12.998	13.023	14.203	13.147	n/a
May-Jul pot fishery	16	141	17.940	17.995	17.601	17.810	n/a
Aug-Dec pot fishery	33	76	10.942	10.942	11.321	10.982	n/a
Trawl survey	30	281	2.114	2.108	2.072	2.127	3.862
Jan-Feb fishery	33	334	n/a	n/a	n/a	n/a	6.149
Mar-Apr fishery	33	399	n/a	n/a	n/a	n/a	6.340
May-Jul fishery	34	138	n/a	n/a	n/a	n/a	7.474
Aug-Oct fishery	33	430	n/a	n/a	n/a	n/a	8.101
Nov-Dec fishery	30	338	n/a	n/a	n/a	n/a	7.916

Table 2.1.12b. Input sample size and the ratio between effective sample size and input sample size for each year of age composition data from the survey for the five primary models. The last row in the top half of the table is the mean of the ratio of effective N to input N.

Year	Input N	Model 1	Model 2	Model 3	Model 4	Model 5
1994	210	2.242	2.298	1.974	0.610	2.279
1995	176	0.169	0.169	0.175	0.132	0.142
1996	209	1.051	1.070	1.019	1.841	0.798
1997	212	1.027	0.991	0.962	1.508	1.005
1998	187	3.723	3.649	3.227	0.829	3.926
1999	253	0.770	0.746	0.744	0.453	0.427
2000	254	0.556	0.591	0.502	0.715	0.259
2001	280	0.466	0.453	0.438	1.439	0.261
2002	279	0.330	0.337	0.345	0.450	0.314
2003	400	0.599	0.580	0.515	0.261	0.950
2004	306	0.113	0.111	0.118	0.130	0.140
2005	377	1.676	1.764	1.077	0.284	1.289
2006	383	0.409	0.410	0.474	0.322	0.461
2007	424	0.178	0.180	0.205	0.195	0.164
2008	357	0.582	0.566	0.622	0.162	0.644
2009	416	0.199	0.198	0.235	0.096	0.261
2010	378	0.894	0.943	0.623	0.495	0.986
All	300	0.881	0.886	0.780	0.584	0.990

Table 2.1.13a. Number of records, input sample sizes, and mean of the ratio between effective sample size and input sample size for size composition data from each fleet for Models 1 and 5 and the secondary models that constitute a transition between those two primary models. Green shading indicates a positive change of more than 5% from the previous model (there were no instances of a negative change of at least 5% from the previous model).

Absolute values:

Fleet	Nrec	Input N	1	1.3	Pre5.1	Pre5.2	Pre5.3	Pre5.4	Pre5.5	Pre5.6	5
Jan-Apr trawl fishery	60	327	5.702	5.703	5.755	5.780	5.767	5.779	5.764	n/a	n/a
May-Jul trawl fishery	31	67	9.305	9.313	9.456	9.430	9.400	9.364	9.397	n/a	n/a
Aug-Dec trawl fishery	34	42	13.205	13.226	14.405	14.398	14.402	14.419	14.313	n/a	n/a
Jan-Apr longline fishery	64	466	9.021	9.024	9.255	9.260	9.215	9.233	9.237	n/a	n/a
May-Jul longline fishery	31	211	9.511	9.504	9.595	9.624	9.583	9.595	9.636	n/a	n/a
Aug-Dec longline fishery	59	673	6.886	6.886	7.052	7.143	7.190	7.270	7.480	n/a	n/a
Jan-Apr pot fishery	32	143	12.998	12.988	13.047	13.046	13.012	13.012	12.968	n/a	n/a
May-Jul pot fishery	16	141	17.940	17.954	18.798	18.812	18.802	18.822	18.693	n/a	n/a
Aug-Dec pot fishery	33	76	10.942	10.953	11.430	11.436	11.388	11.399	11.335	n/a	n/a
Trawl survey	30	281	2.114	2.116	2.132	2.132	2.144	2.144	2.480	3.233	3.862
Jan-Feb fishery	33	334	n/a	n/a	n/a	n/a	n/a	n/a	n/a	6.201	6.149
Mar-Apr fishery	33	399	n/a	n/a	n/a	n/a	n/a	n/a	n/a	6.247	6.340
May-Jul fishery	34	138	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7.346	7.474
Aug-Oct fishery	33	430	n/a	n/a	n/a	n/a	n/a	n/a	n/a	8.368	8.101
Nov-Dec fishery	30	338	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7.839	7.916

Relative changes from previous model:

Fleet	Nrec	Input N	1	1.3	Pre5.1	Pre5.2	Pre5.3	Pre5.4	Pre5.5	Pre5.6	5
Jan-Apr trawl fishery	60	327	n/a	0.000	0.009	0.004	-0.002	0.002	-0.003	n/a	n/a
May-Jul trawl fishery	31	67	n/a	0.001	0.015	-0.003	-0.003	-0.004	0.003	n/a	n/a
Aug-Dec trawl fishery	34	42	n/a	0.002	0.089	0.000	0.000	0.001	-0.007	n/a	n/a
Jan-Apr longline fishery	64	466	n/a	0.000	0.026	0.001	-0.005	0.002	0.000	n/a	n/a
May-Jul longline fishery	31	211	n/a	-0.001	0.010	0.003	-0.004	0.001	0.004	n/a	n/a
Aug-Dec longline fishery	59	673	n/a	0.000	0.024	0.013	0.007	0.011	0.029	n/a	n/a
Jan-Apr pot fishery	32	143	n/a	-0.001	0.005	0.000	-0.003	0.000	-0.003	n/a	n/a
May-Jul pot fishery	16	141	n/a	0.001	0.047	0.001	-0.001	0.001	-0.007	n/a	n/a
Aug-Dec pot fishery	33	76	n/a	0.001	0.044	0.000	-0.004	0.001	-0.006	n/a	n/a
Trawl survey	30	281	n/a	0.001	0.007	0.000	0.005	0.000	0.156	0.304	0.195
Jan-Feb fishery	33	334	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.008
Mar-Apr fishery	33	399	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.015
May-Jul fishery	34	138	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.017
Aug-Oct fishery	33	430	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.032
Nov-Dec fishery	30	338	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.010

Table 2.1.13b. Input sample size and the ratio between effective sample size and input sample size for each year of age composition data from the survey for Models 1 and 5 and the secondary models that constitute a transition between those two primary models. The last row in the top half of the table is the mean of the ratio of effective N to input N. Green shading indicates a positive change of more than 5% from the previous model, and pink indicates a negative change of at least 5% from the previous model.

Absolute values:

Year	Input N	1	1.3	Pre5.1	Pre5.2	Pre5.3	Pre5.4	Pre5.5	Pre5.6	5
1994	210	2.242	2.229	2.228	2.228	2.223	2.231	1.687	1.690	2.279
1995	176	0.169	0.169	0.169	0.169	0.169	0.168	0.175	0.108	0.142
1996	209	1.051	1.070	1.069	1.069	1.082	1.087	0.908	0.242	0.798
1997	212	1.027	1.067	1.066	1.068	1.108	1.117	0.941	0.159	1.005
1998	187	3.723	3.847	3.859	3.908	4.000	4.013	2.885	0.302	3.926
1999	253	0.770	0.764	0.766	0.768	0.771	0.767	0.644	0.218	0.427
2000	254	0.556	0.553	0.553	0.550	0.546	0.548	0.476	0.161	0.259
2001	280	0.466	0.463	0.464	0.465	0.468	0.467	0.322	0.212	0.261
2002	279	0.330	0.331	0.331	0.330	0.329	0.330	0.262	0.207	0.314
2003	400	0.599	0.596	0.597	0.600	0.606	0.599	0.864	1.020	0.950
2004	306	0.113	0.113	0.113	0.113	0.114	0.113	0.108	0.120	0.140
2005	377	1.676	1.678	1.677	1.675	1.648	1.643	2.197	0.968	1.289
2006	383	0.409	0.408	0.408	0.407	0.414	0.414	0.296	0.183	0.461
2007	424	0.178	0.178	0.177	0.177	0.180	0.181	0.188	0.045	0.164
2008	357	0.582	0.583	0.583	0.584	0.591	0.587	0.441	0.362	0.644
2009	416	0.199	0.199	0.199	0.199	0.198	0.197	0.214	0.142	0.261
2010	378	0.894	0.904	0.902	0.901	0.881	0.857	0.744	1.128	0.986
All	300	0.881	0.891	0.892	0.895	0.902	0.901	0.785	0.427	0.990

Relative changes from previous model:

Year	Input N	1	1.3	Pre5.1	Pre5.2	Pre5.3	Pre5.4	Pre5.5	Pre5.6	5
1994	210	n/a	-0.006	-0.001	0.000	-0.002	0.004	-0.244	0.002	0.349
1995	176	n/a	0.003	0.000	0.000	-0.003	-0.001	0.040	-0.386	0.323
1996	209	n/a	0.018	-0.001	0.000	0.013	0.005	-0.165	-0.734	2.303
1997	212	n/a	0.039	0.000	0.002	0.037	0.008	-0.157	-0.831	5.330
1998	187	n/a	0.033	0.003	0.013	0.024	0.003	-0.281	-0.895	12.016
1999	253	n/a	-0.007	0.002	0.003	0.004	-0.006	-0.160	-0.662	0.958
2000	254	n/a	-0.006	-0.001	-0.005	-0.008	0.005	-0.131	-0.663	0.614
2001	280	n/a	-0.008	0.002	0.004	0.007	-0.003	-0.310	-0.344	0.235
2002	279	n/a	0.004	-0.001	-0.003	-0.004	0.002	-0.206	-0.209	0.518
2003	400	n/a	-0.006	0.002	0.005	0.010	-0.011	0.443	0.180	-0.069
2004	306	n/a	-0.001	0.000	0.001	0.009	-0.003	-0.046	0.107	0.165
2005	377	n/a	0.001	-0.001	-0.001	-0.016	-0.003	0.337	-0.559	0.332
2006	383	n/a	-0.001	-0.001	-0.001	0.017	0.001	-0.285	-0.384	1.523
2007	424	n/a	-0.002	-0.001	-0.001	0.014	0.007	0.039	-0.763	2.687
2008	357	n/a	0.001	0.001	0.002	0.011	-0.005	-0.249	-0.180	0.780
2009	416	n/a	0.001	0.000	0.002	-0.007	-0.003	0.085	-0.335	0.835
2010	378	n/a	0.012	-0.002	-0.001	-0.023	-0.027	-0.133	0.517	-0.125
All	300	n/a	0.011	0.001	0.003	0.008	0.000	-0.128	-0.456	1.317

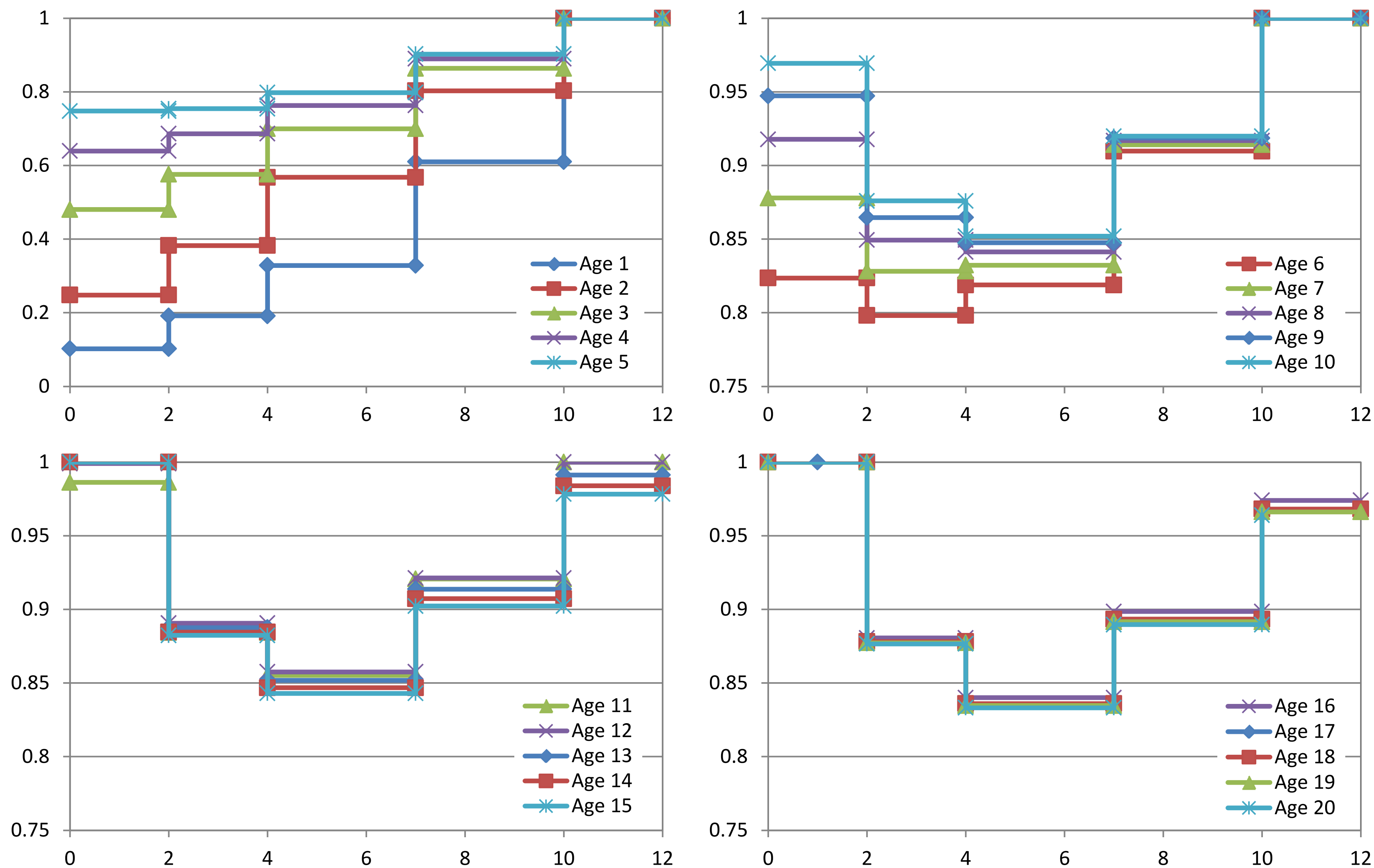


Figure 2.1.1. Relative mean weight at age by time within year for Model 1. Horizontal axis represents months elapsed within the year; vertical axis is mean weight relative to intra-annual maximum mean weight.

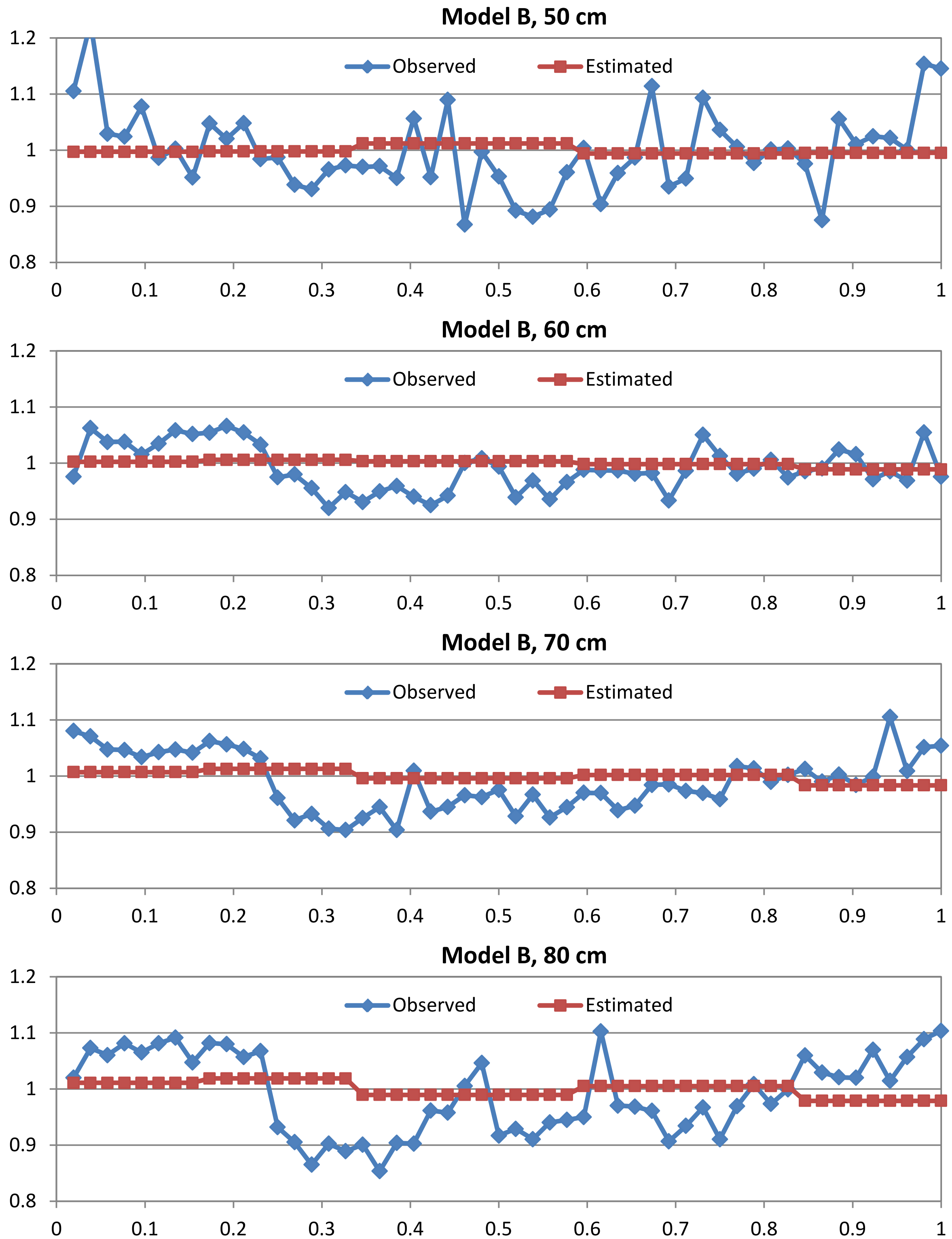


Figure 2.1.2a. Fit of weight-length Model B to weekly relative mean weight-at-length data for four example lengths. Horizontal axis is relative time within the year; vertical axis is mean weekly weight scaled relative to average weight (at that length) for the year.

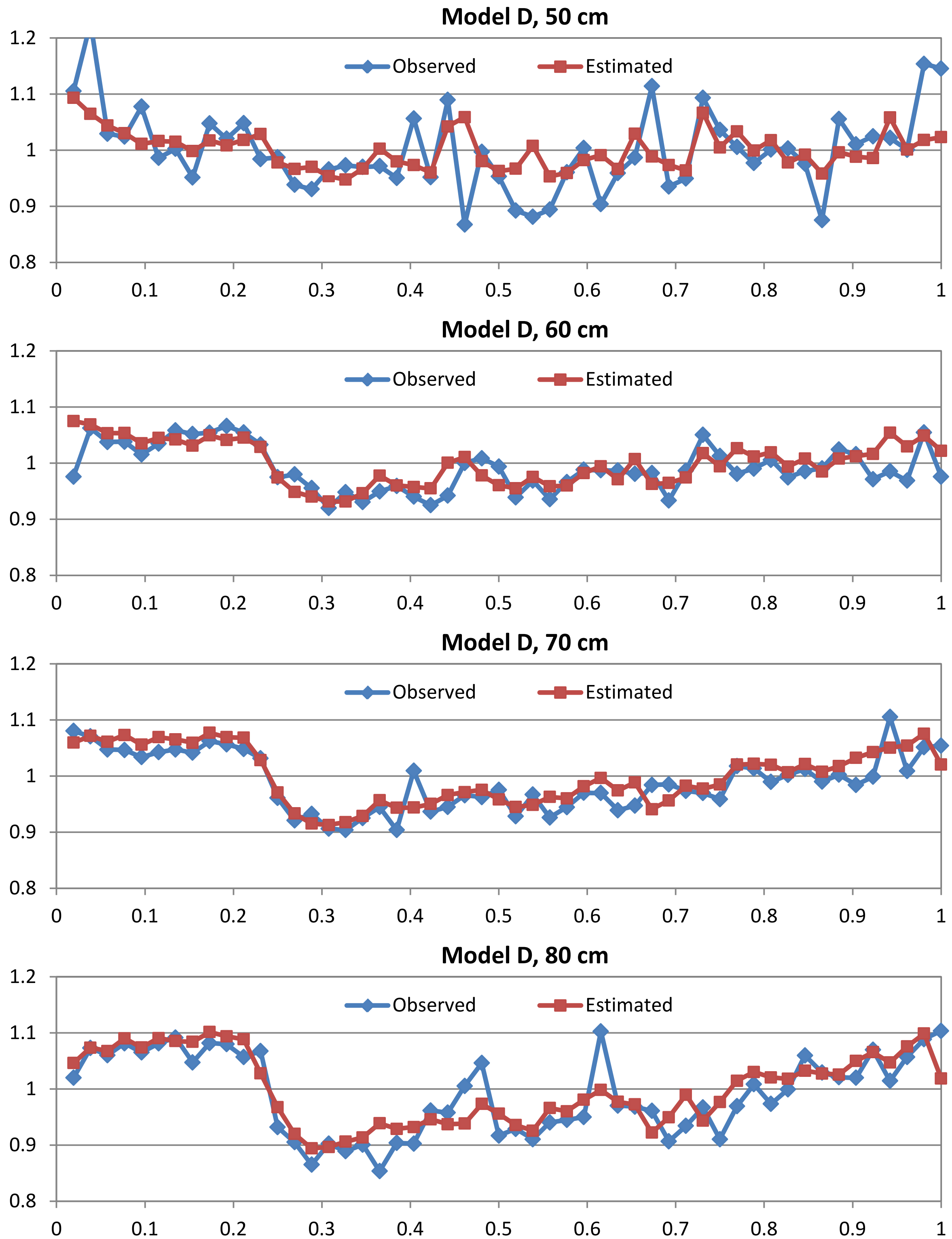


Figure 2.1.2b. Fit of weight-length Model D to weekly mean relative weight-at-length data for four example lengths. Horizontal axis is relative time within the year; vertical axis is mean weekly weight scaled relative to average weight (at that length) for the year.

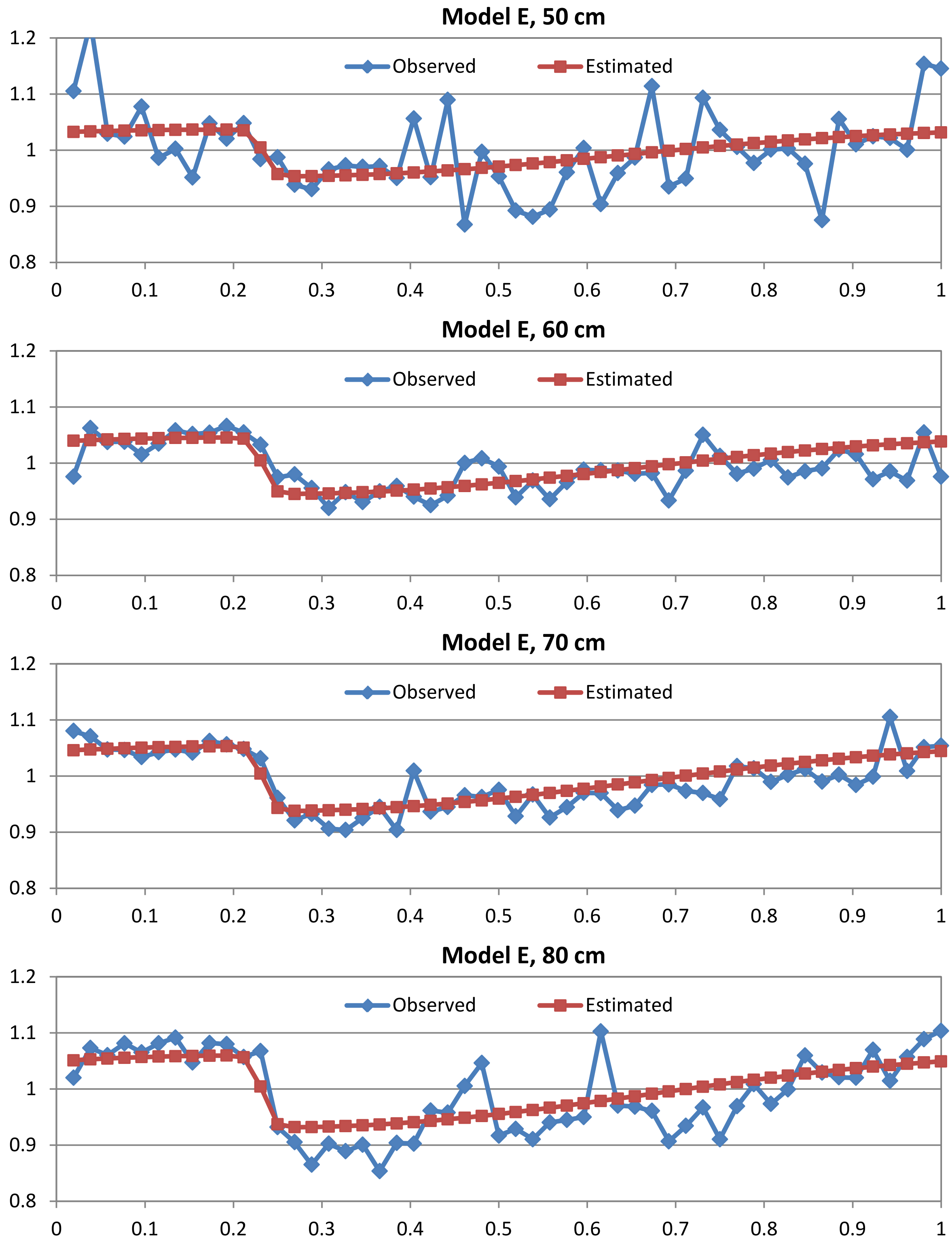


Figure 2.1.2c. Fit of weight-length Model E to weekly mean relative weight-at-length data for four example lengths. Horizontal axis is relative time within the year; vertical axis is mean weekly weight scaled relative to average weight (at that length) for the year.

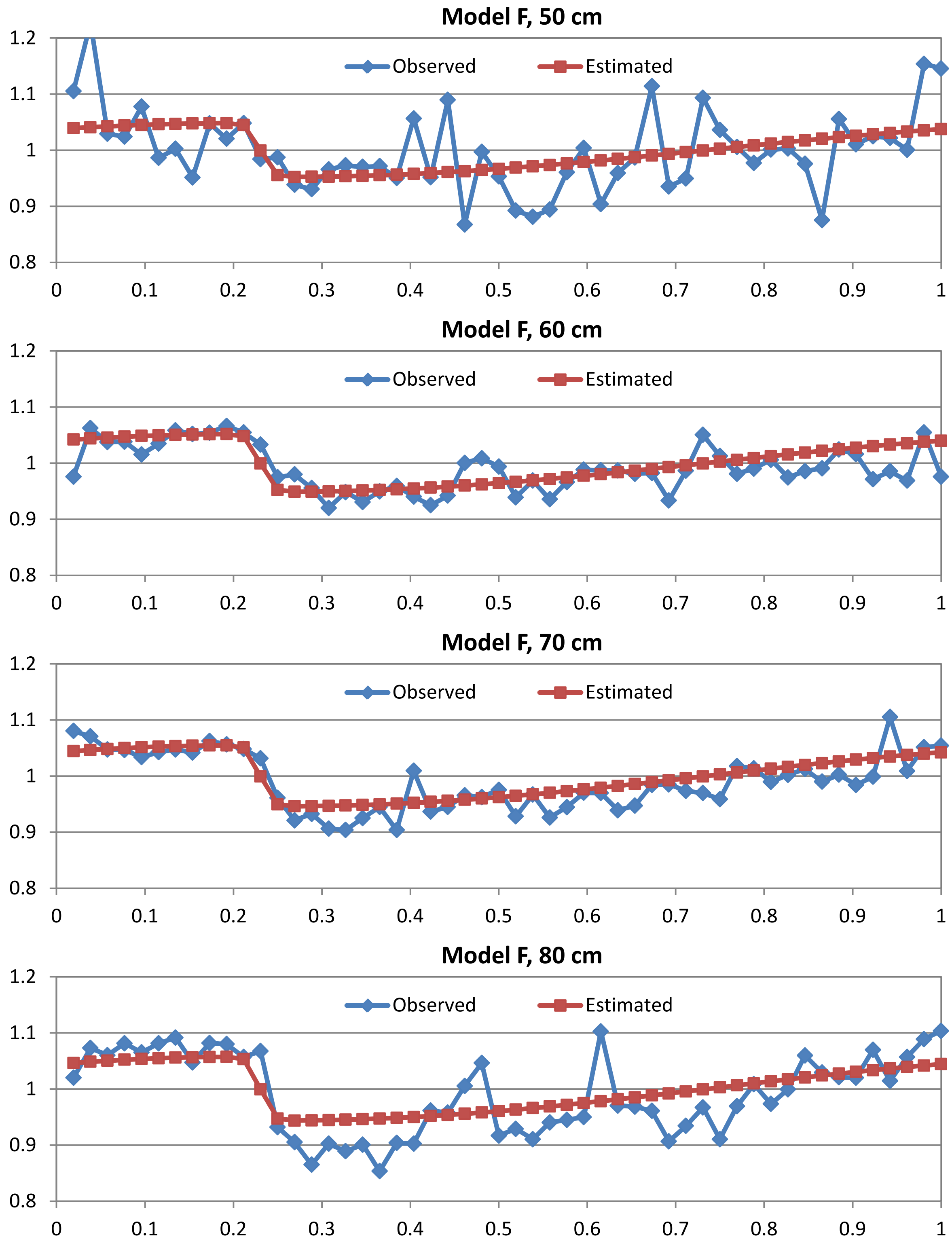
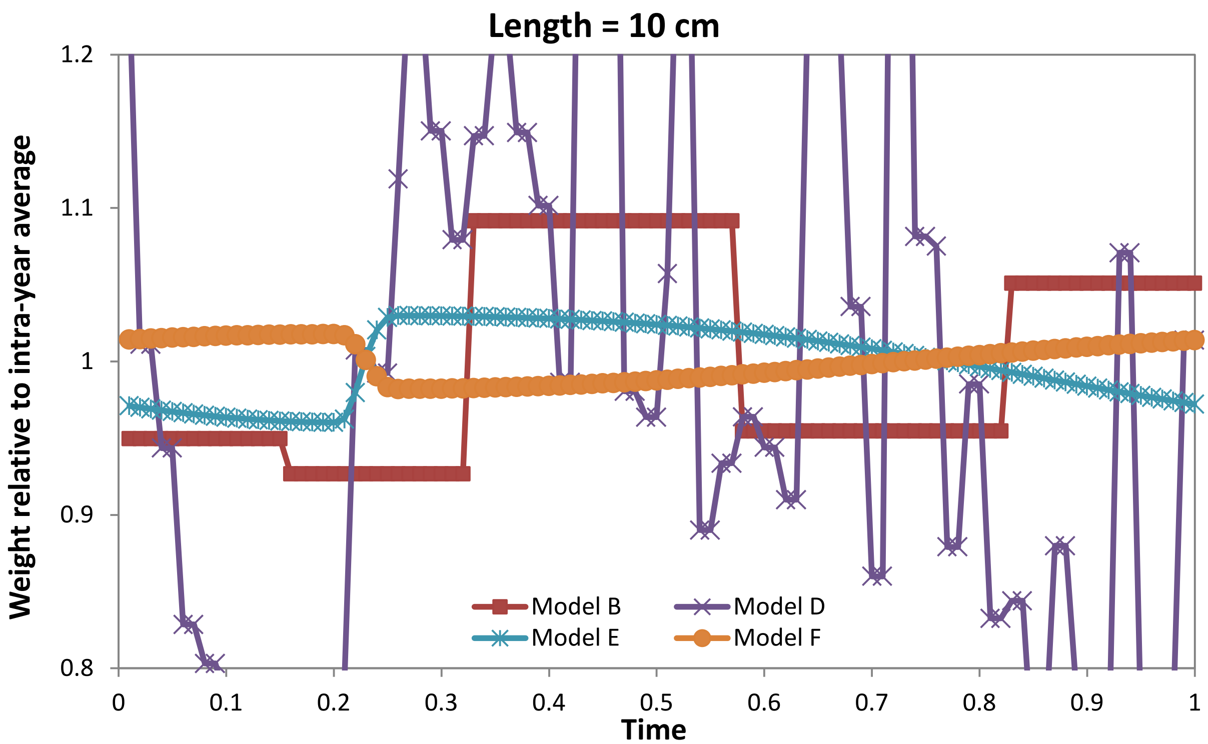


Figure 2.1.2d. Fit of weight-length Model F to weekly relative mean weight-at-length data for four example lengths. Horizontal axis is relative time within the year; vertical axis is mean weekly weight scaled relative to average weight (at that length) for the year.



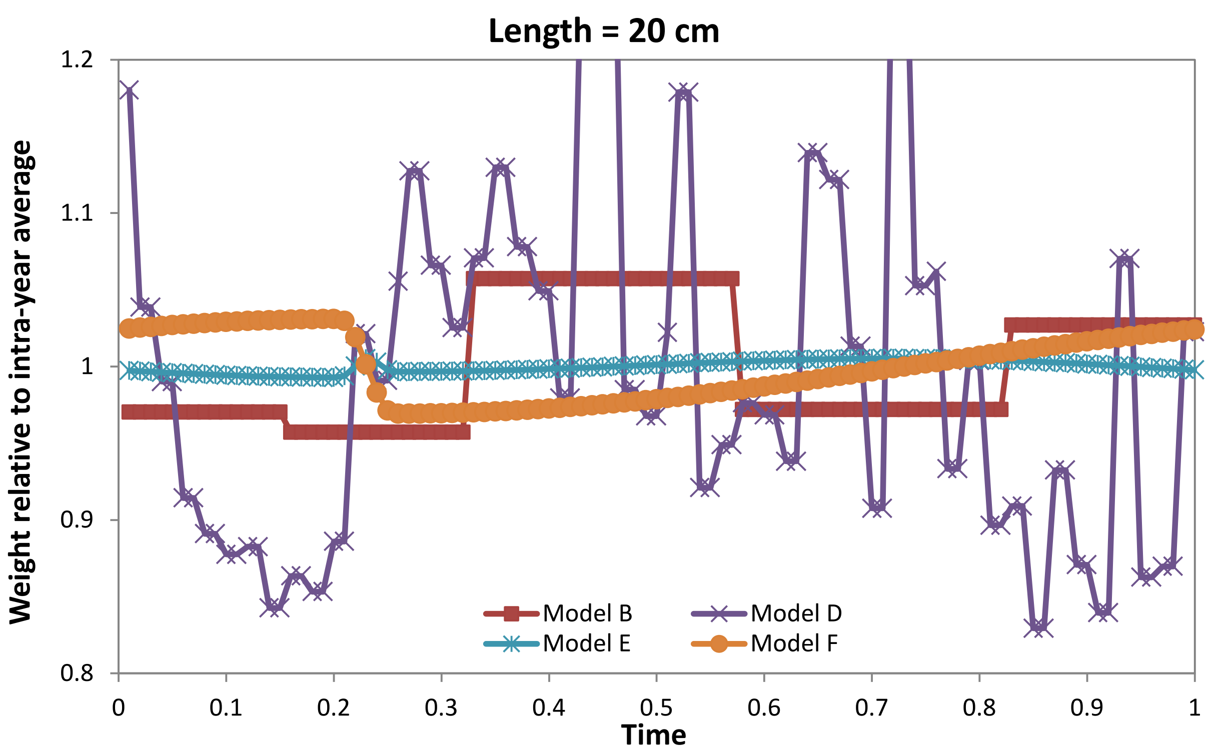


Figure 2.1.3a. Relative intra-annual weight at lengths 10 and 20 cm as estimated by four models.

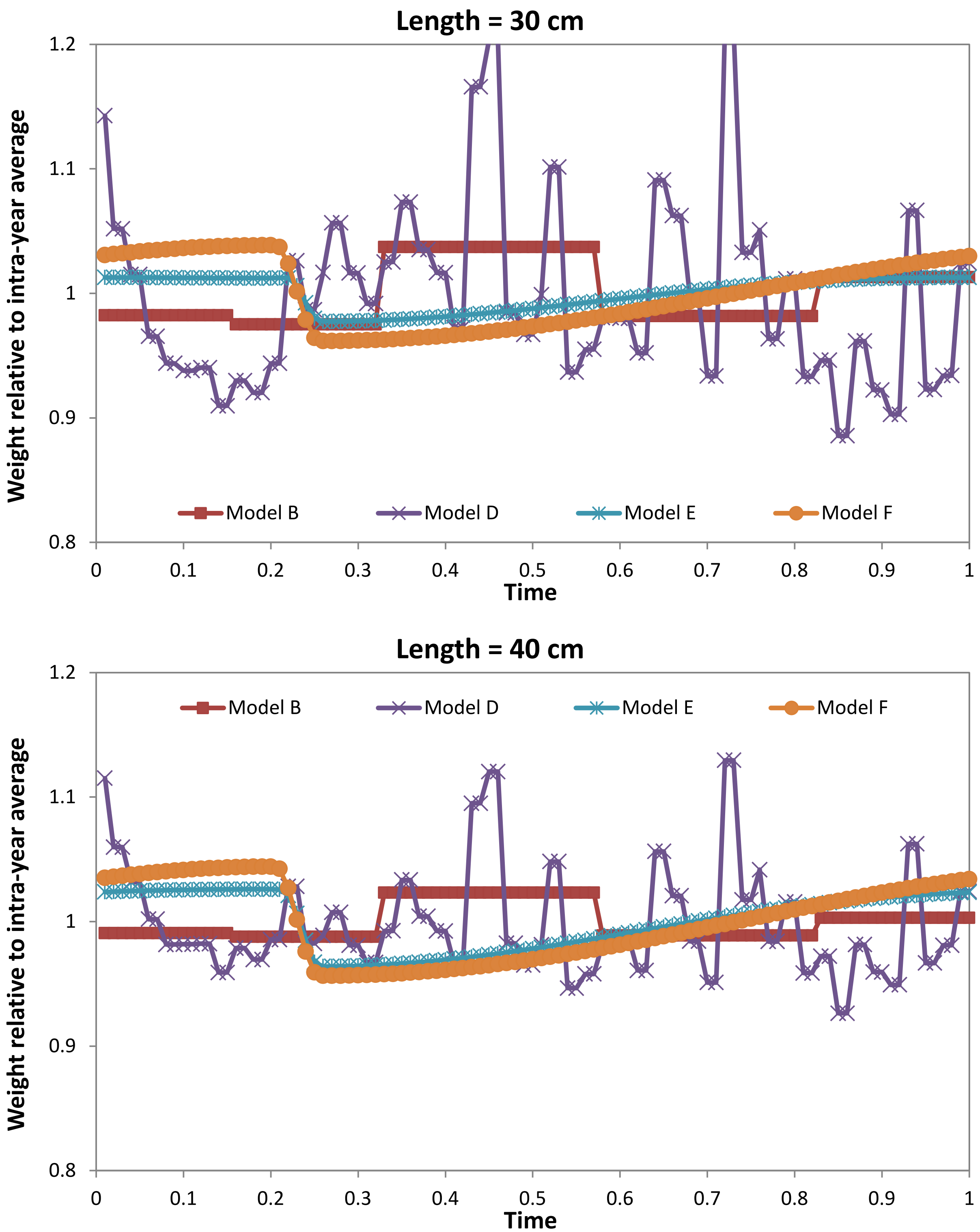


Figure 2.1.3b. Relative intra-annual weight at lengths 30 and 40 cm as estimated by four models.

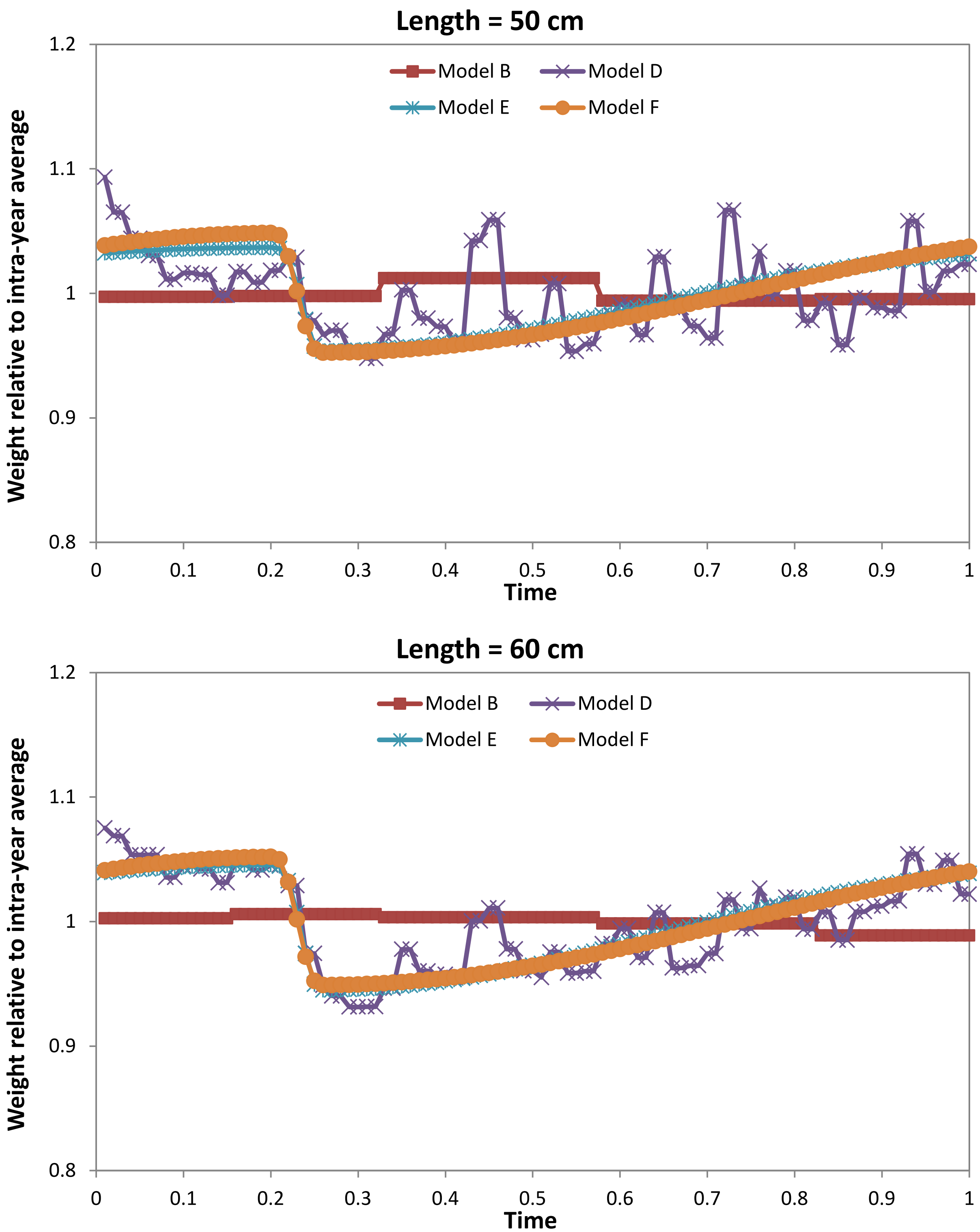


Figure 2.1.3c. Relative intra-annual weight at lengths 50 and 60 cm as estimated by four models.

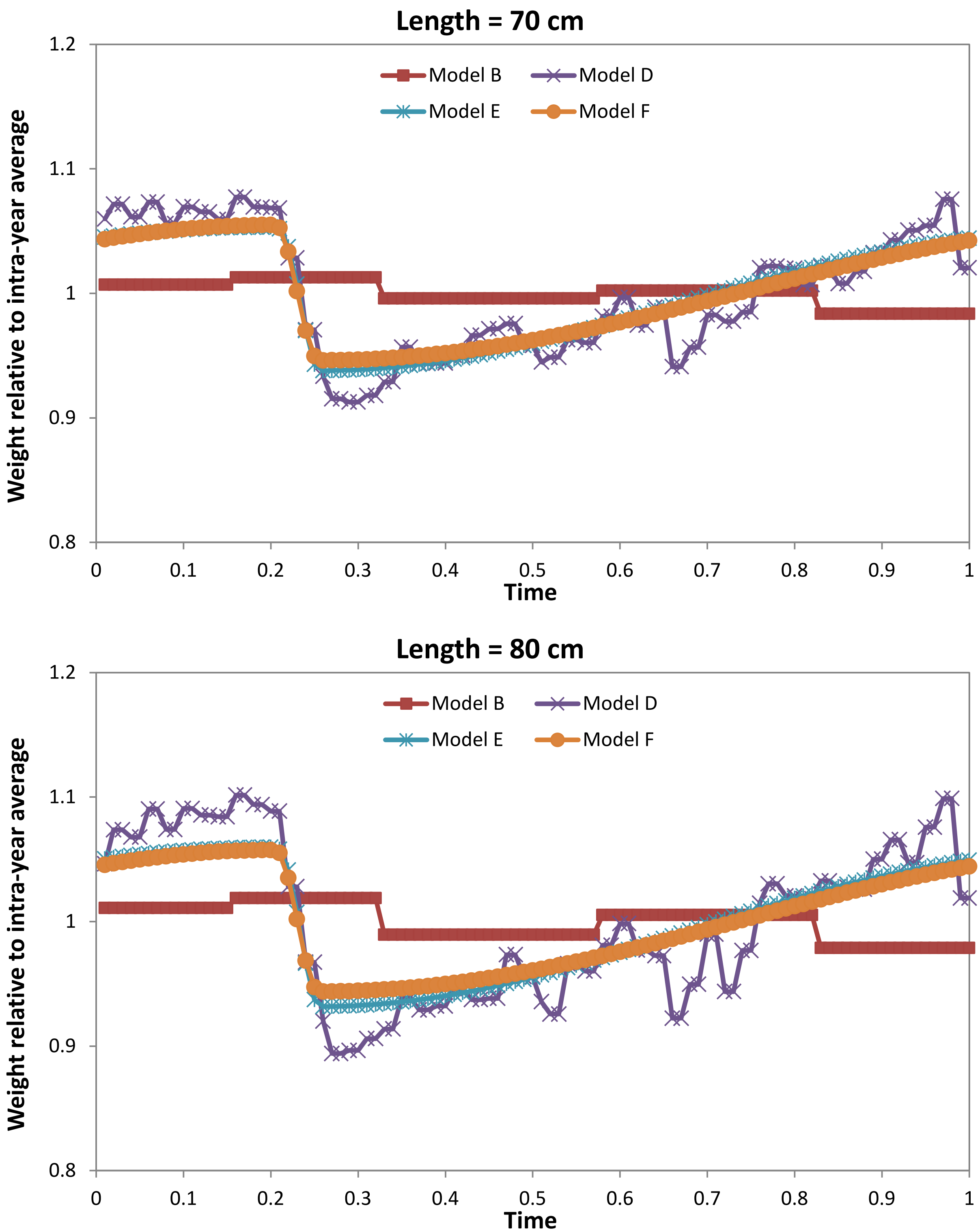


Figure 2.1.3d. Relative intra-annual weight at lengths 70 and 80 cm as estimated by four models.

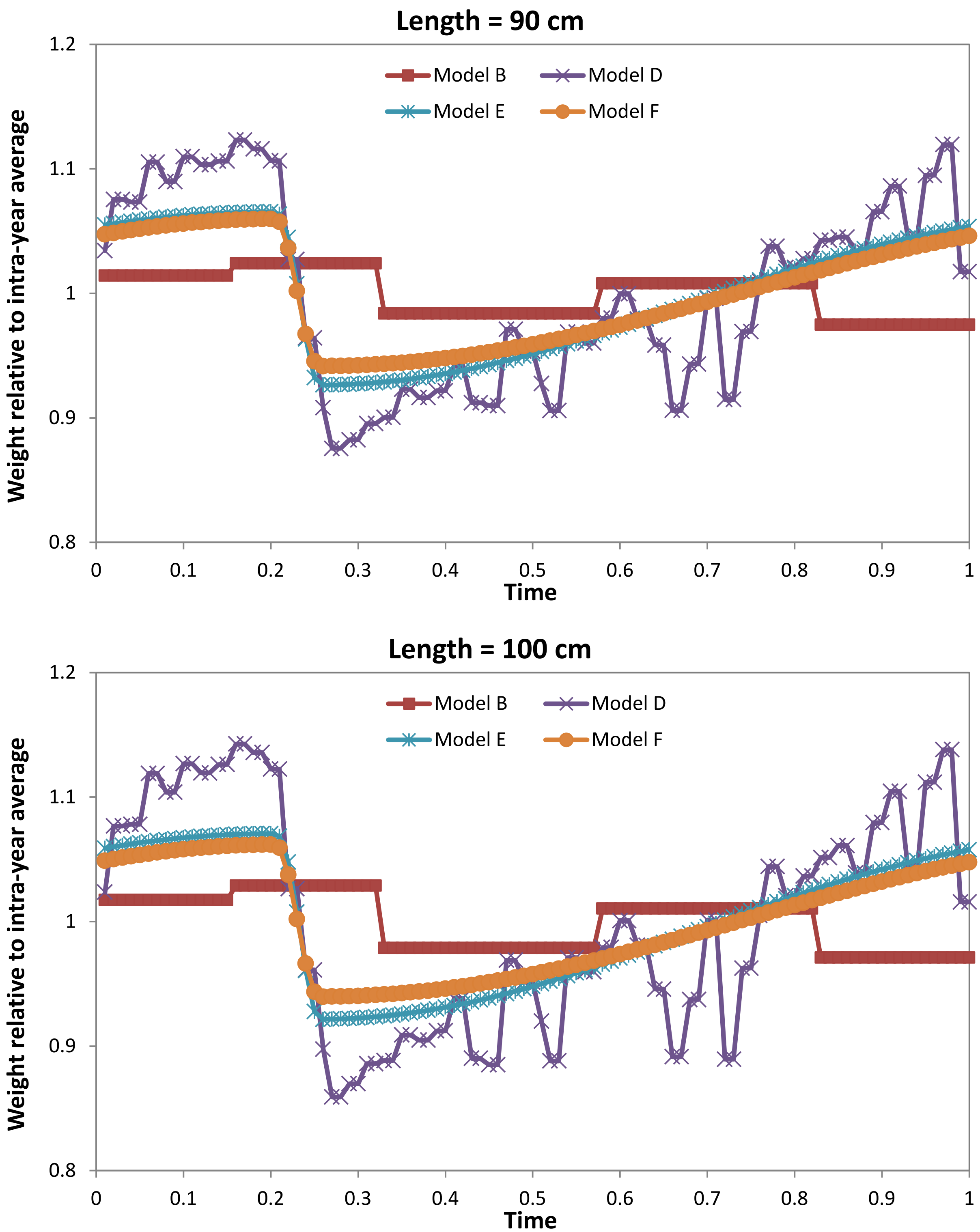


Figure 2.1.3e. Relative intra-annual weight at lengths 90 and 100 cm as estimated by four models.

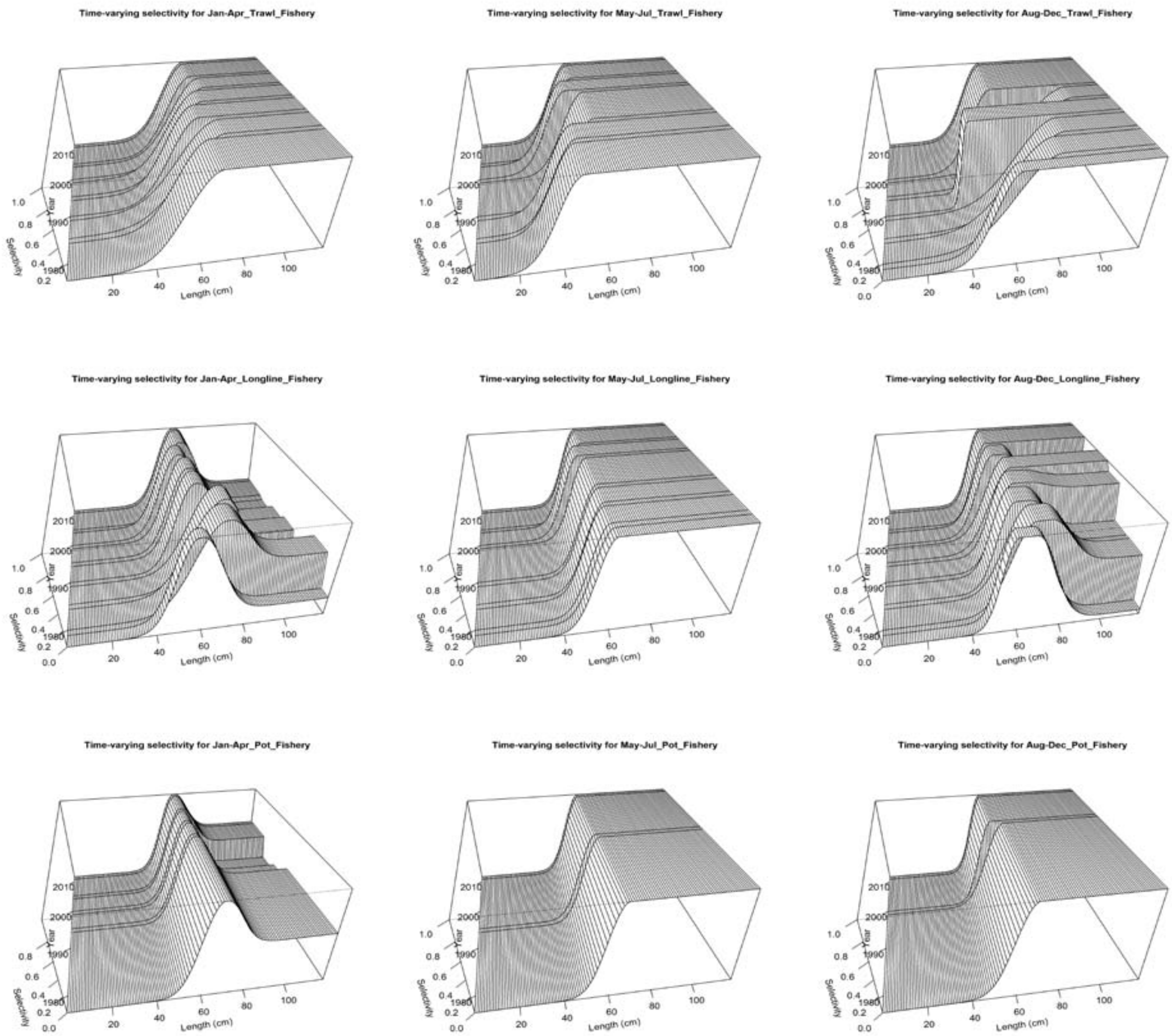


Figure 2.1.4a. Fishery selectivity as estimated by Model 1.

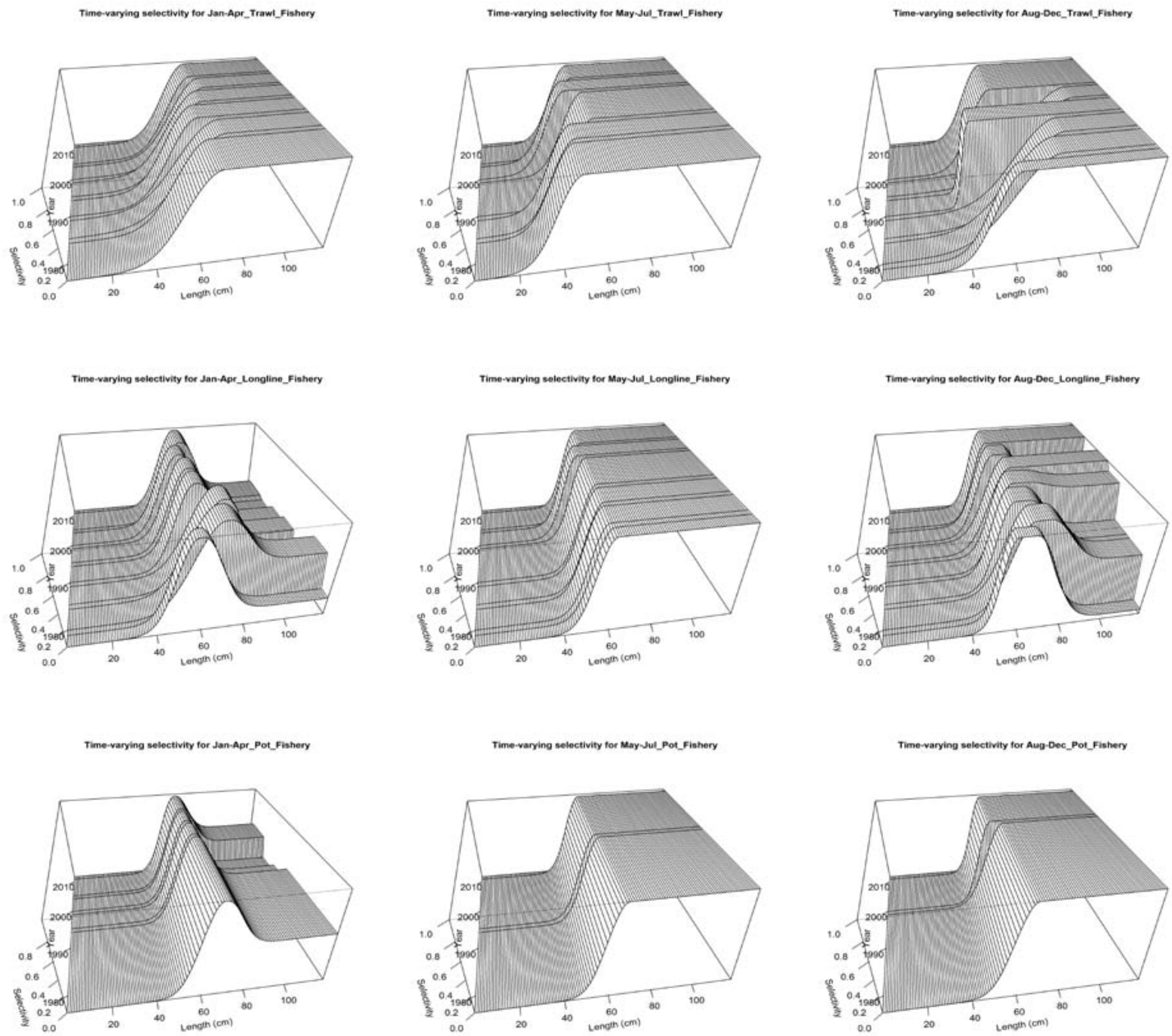


Figure 2.1.4b. Fishery selectivity as estimated by Model 2.

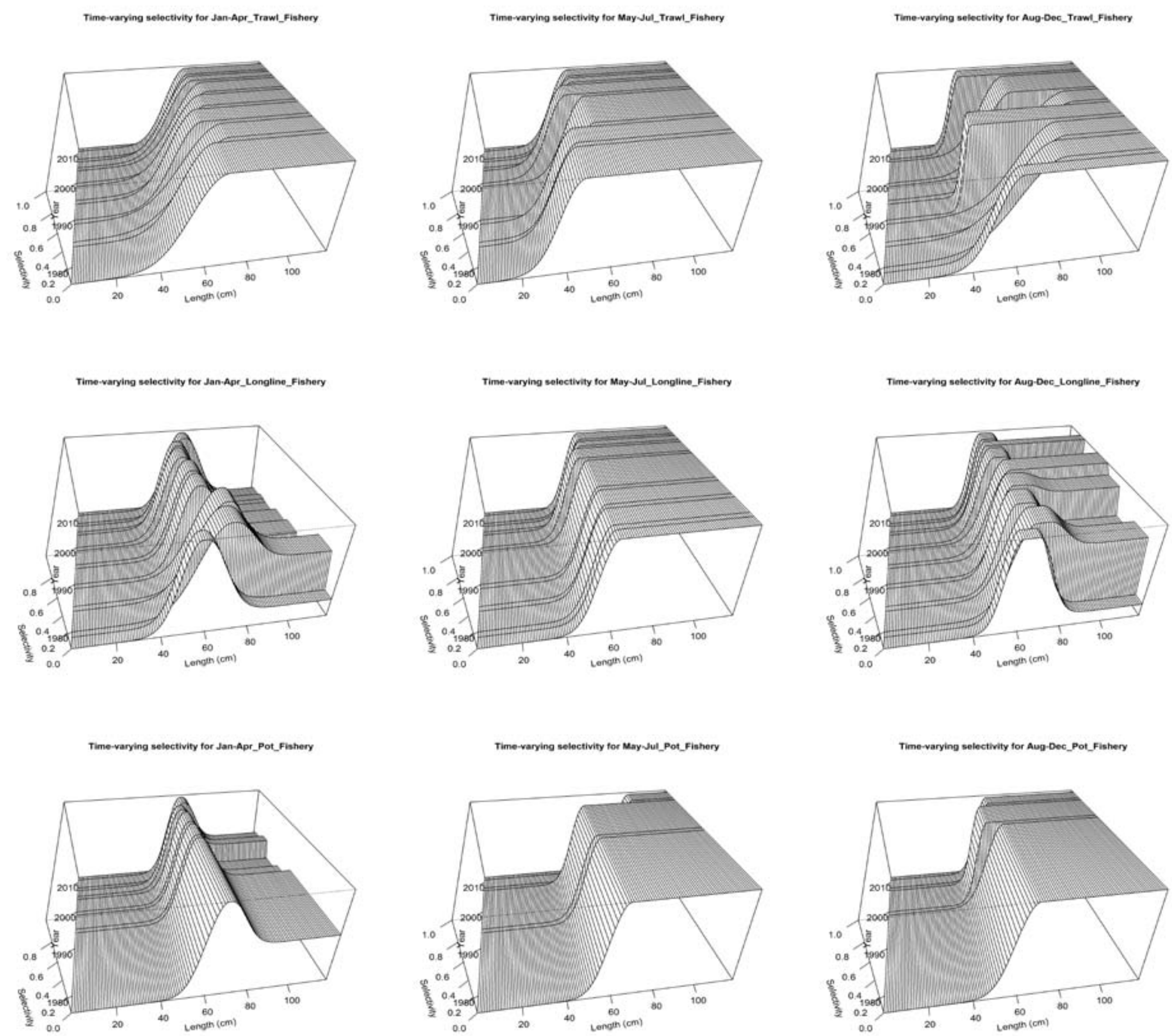


Figure 2.1.4c. Fishery selectivity as estimated by Model 3.

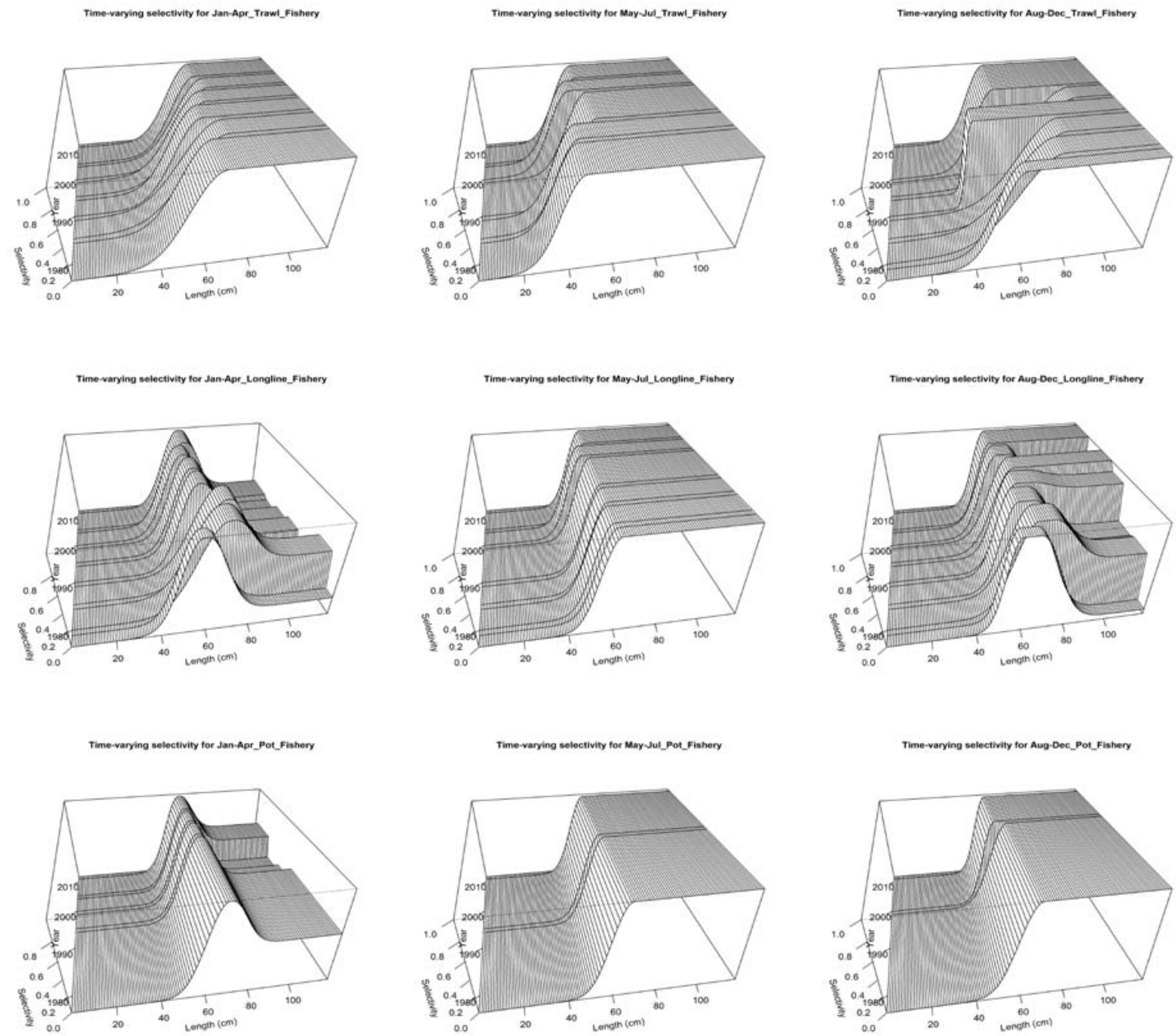


Figure 2.1.4d. Fishery selectivity as estimated by Model 4.

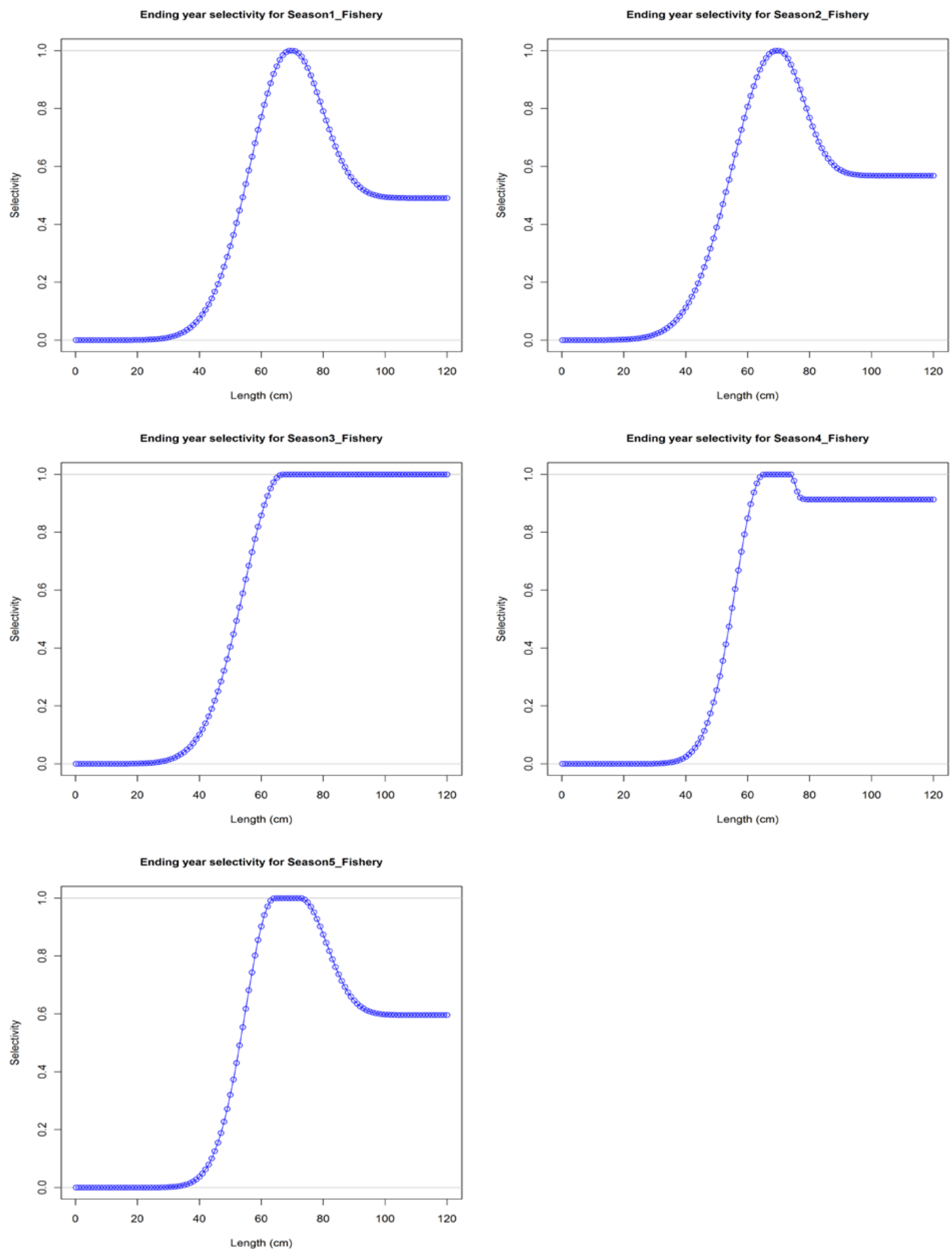


Figure 2.1.4e. Fishery selectivity as estimated by Model 5.

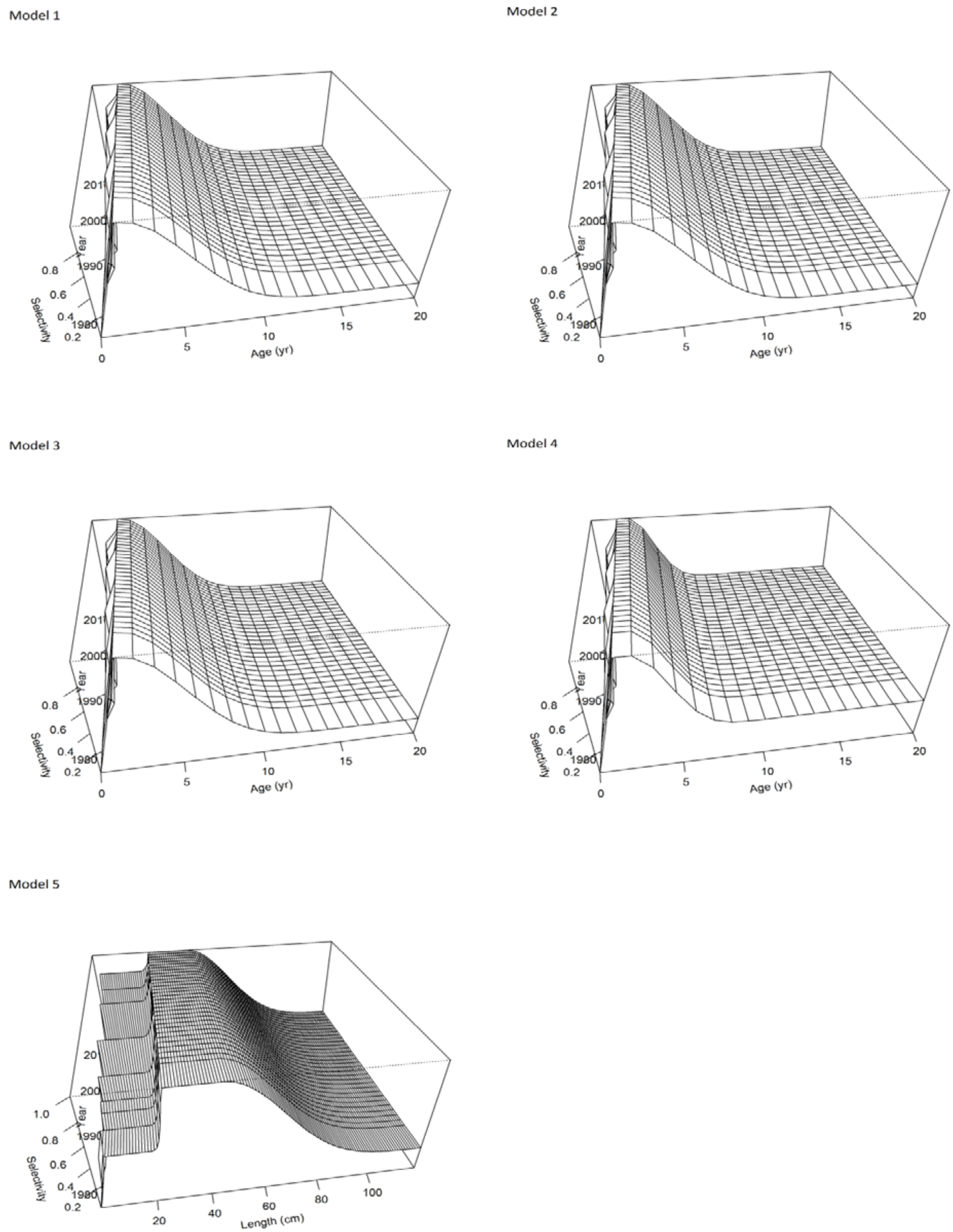


Figure 2.1.5a. Surface plots of time-varying survey selectivity as estimated by five primary models. Note that Models 1-4 use age-based selectivity, while Model 5 uses length-based.

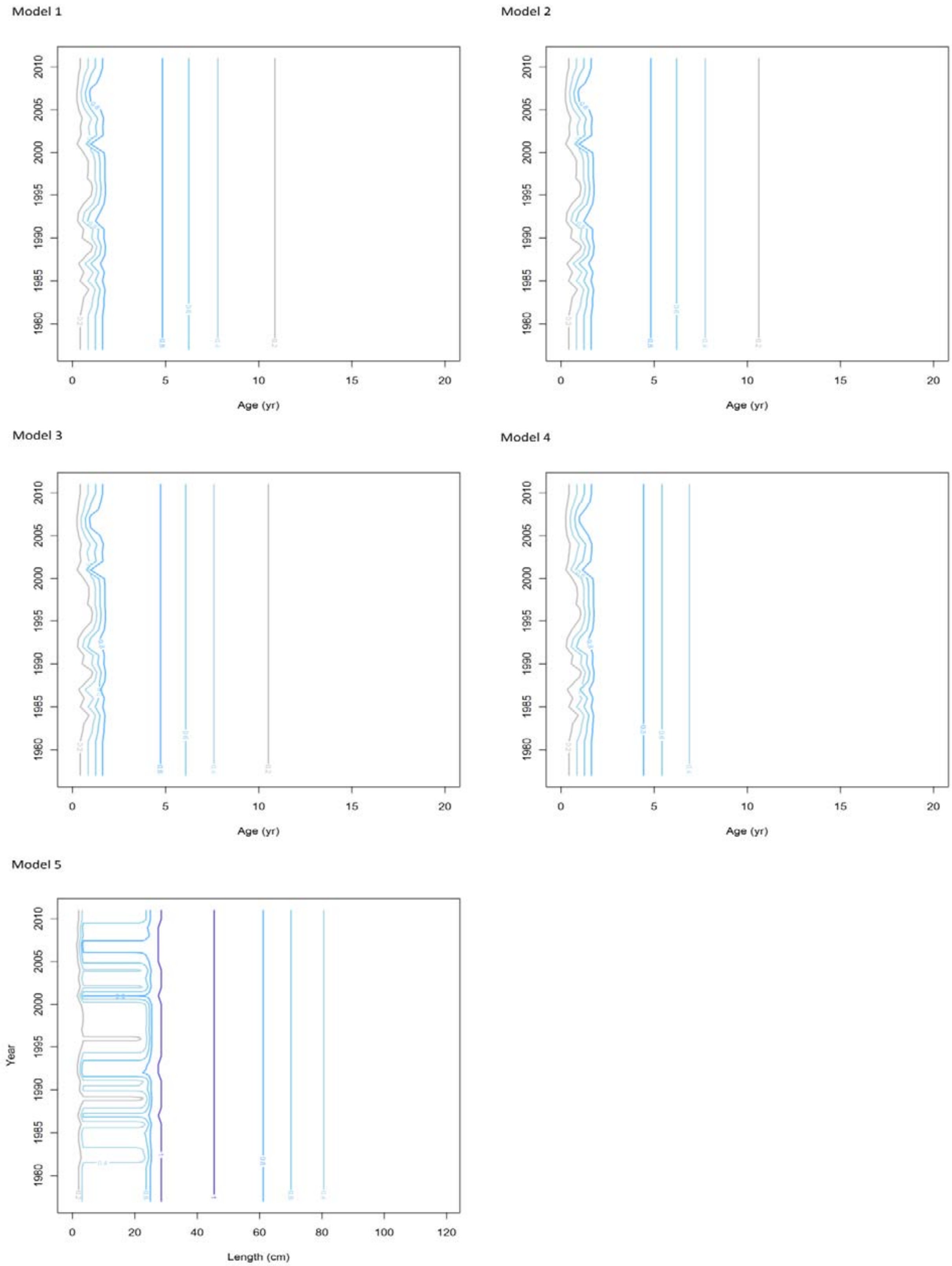


Figure 2.1.5b. Contour plots of time-varying survey selectivity as estimated by five primary models. Note that Models 1-4 use age-based selectivity, while Model 5 uses length-based.

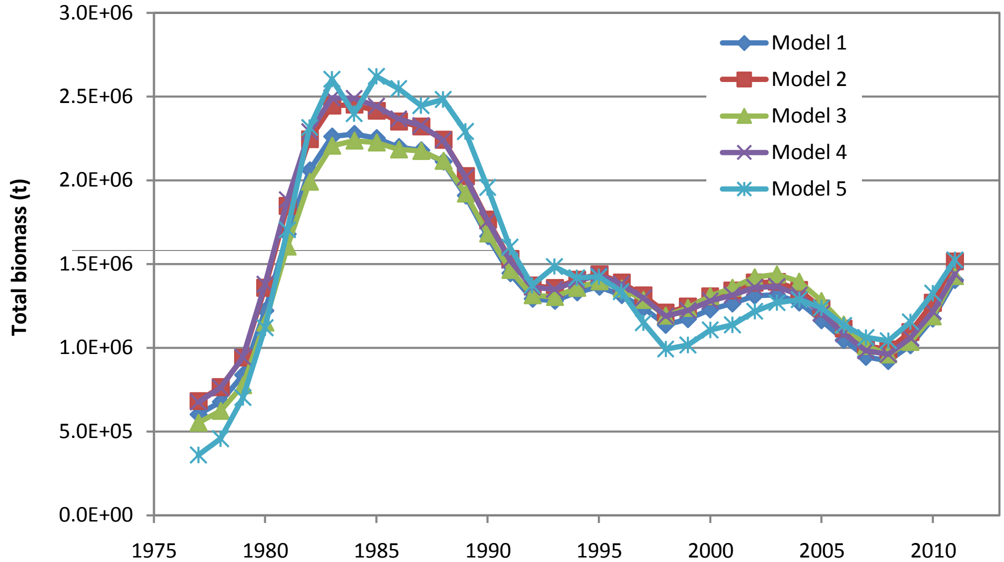


Figure 2.1.6. Time series of total (age 0+) biomass (t) as estimated by the five primary models.

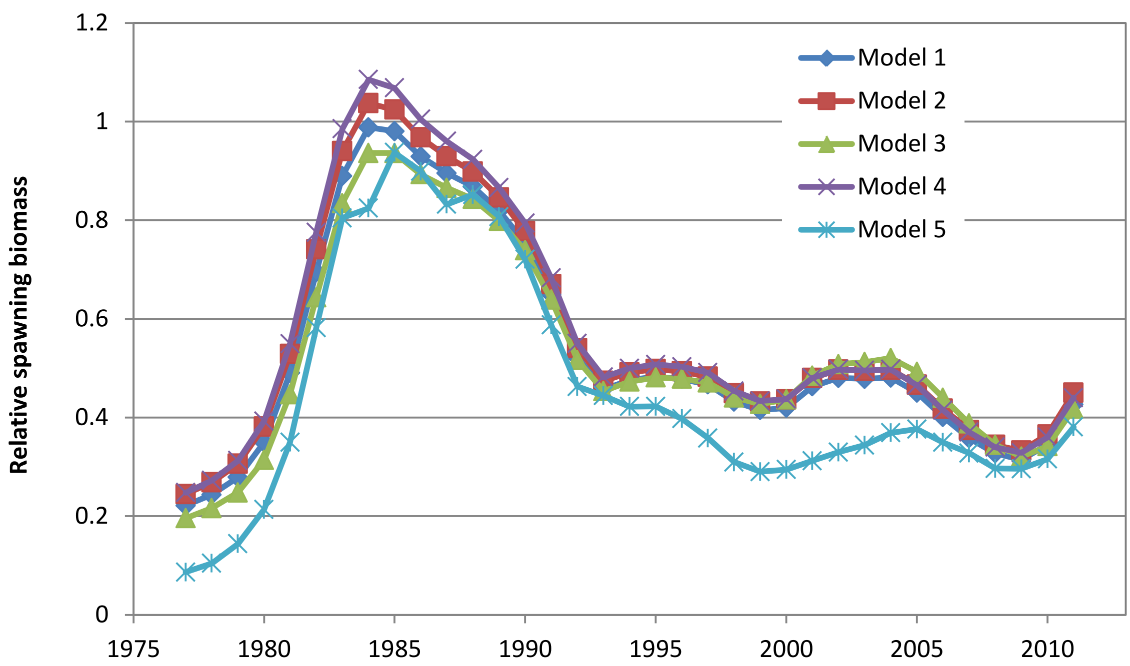


Figure 2.1.7. Time series of spawning biomass relative to $B_{100\%}$ as estimated by the five primary models.

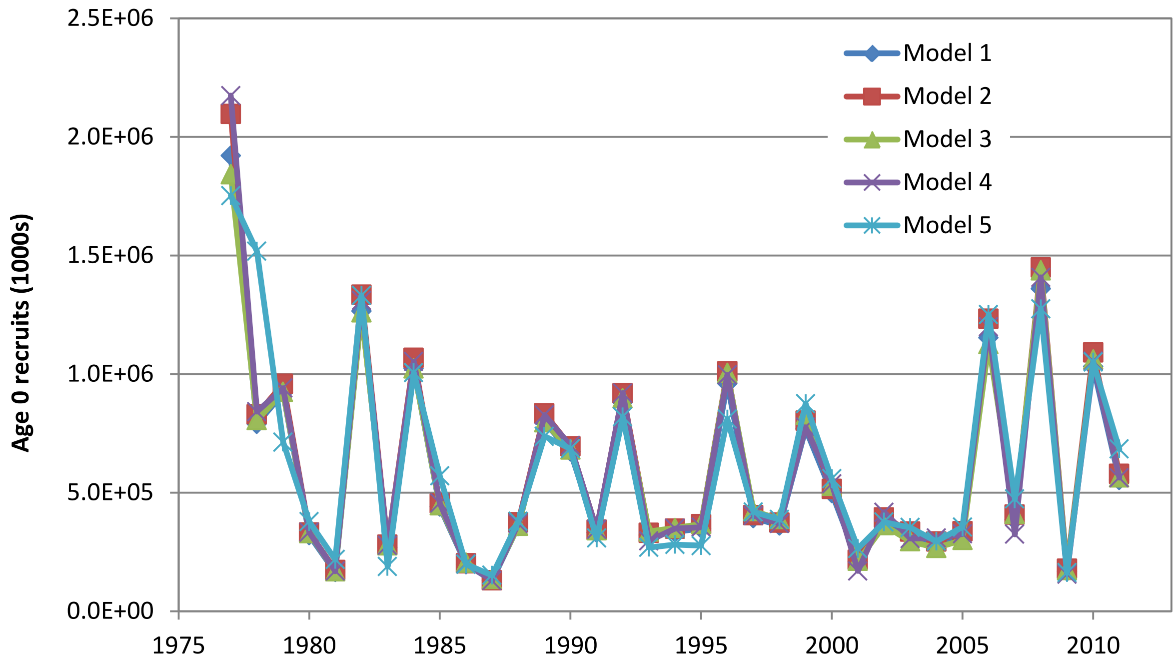


Figure 2.1.8. Time series of age 0 recruits (1000s) as estimated by the five primary models.

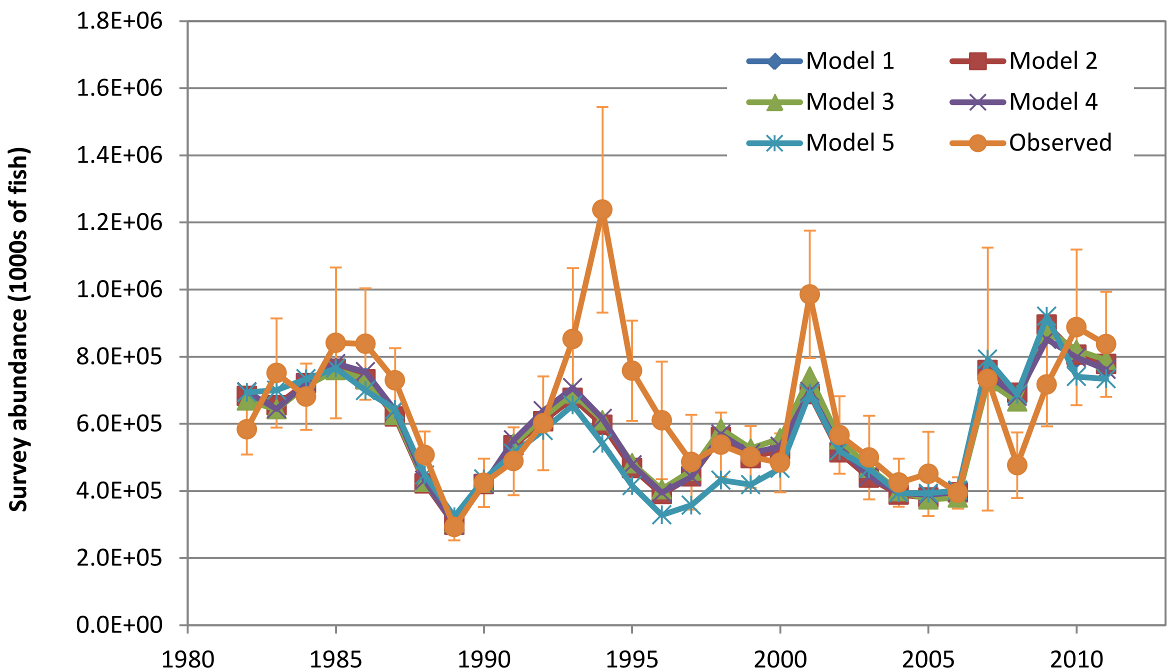


Figure 2.1.9. Estimates of survey abundance (1000s of fish) obtained by the five primary models, with point estimates and 95% confidence intervals from the survey ("Observed").

Annex 2.1.1:

Estimating the standard deviation in a random effects model

Background

To develop the idea of a random effects model, consider first the following univariate, linear-normal, *fixed effects* model:

- $\mathbf{x}$ is an $m \times 1$ variable with *known* realizations at times $j=1,2,\ldots,n$
- α is a constant scalar
- $\boldsymbol{\beta}$ is an $m \times 1$ constant vector
- $ytru_j$ is a scalar related to $\mathbf{x}_j$ by $ytru_j = \alpha + \boldsymbol{\beta}'\mathbf{x}_j$
- $yobs_j$ is related to $ytru_j$ by $yobs_j = ytru_j + \varepsilon_j$, where $\varepsilon_j \sim N(0, \sigma\varepsilon^2)$

Now, suppose that the value of each $\mathbf{x}_j$ is unknown or, worse, that the identities of the m scalar variables comprising the vector $\mathbf{x}$ are unknown. In both of these cases, the fixed effects model is often replaced by a *random effects* model. Two of the assumptions are the same as in the fixed effects model:

- $ytru_j$ is a scalar related to $\mathbf{x}_j$ by $ytru_j = \alpha + \boldsymbol{\beta}'\mathbf{x}_j$
- $yobs_j$ is related to $ytru_j$ by $yobs_j = ytru_j + \varepsilon_j$, where $\varepsilon_j \sim N(0, \sigma\varepsilon^2)$

However, in the random effects model, $\mathbf{x}$ is replaced by a multivariate normal random variable with mean vector $\boldsymbol{\mu}\mathbf{x}$, covariance matrix $\boldsymbol{\Sigma}\mathbf{x}$, and unknown realizations at times $j=1,2,\ldots,n$. Then the following conditions will hold:

- *ytru* is normally distributed with mean $\mu y = \alpha + \boldsymbol{\beta}'\boldsymbol{\mu}\mathbf{x}$ and variance $\sigma y = \boldsymbol{\beta}'\boldsymbol{\Sigma}\mathbf{x}\,\boldsymbol{\beta}$
- *yobs* is normally distributed with the same mean as *ytru*, but variance $\sigma y_{obs}^2 = \sigma y^2 + \sigma\varepsilon^2$

The full log likelihood in the random effects model consists of two parts. One is the distribution of the observed values:

$$lnLik_1 = -\left(\frac{n}{2}\right)\cdot\ln(2\pi) - n\cdot\ln(\sigma\varepsilon) - \left(\frac{1}{2}\right)\cdot\sum_{j=1}^{n}\left(\frac{yobs_j - ytru_j}{\sigma\varepsilon}\right)^2 \quad .$$

The other is the distribution of the true values:

$$lnLik_2 = -\left(\frac{n}{2}\right)\cdot\ln(2\pi) - n\cdot\ln(\sigma y) - \left(\frac{1}{2}\right)\cdot\sum_{j=1}^{n}\left(\frac{ytru_j - \mu y}{\sigma y}\right)^2 \quad .$$

As an aside, the designation of the above as a "likelihood" is somewhat problematic, because the above equation does not contain any data *per se*. Alternatively, it might be referred to as a joint prior distribution, but this is not completely satisfactory either, because σy is a "real" parameter of the model that gives rise to the true states, independent of any modeler's prior beliefs about the distribution of those states. Although these are interesting philosophical issues, the method developed here does not particularly depend on what the above equation is called. Because it is widely referred to as a "likelihood," this term will be used here, too.

In many applications, this model is reparameterized by defining **δ** ≡ **ytru** $-\mu y$ and substituting into the above two equations. Then, after summing, the full log likelihood can be written as:

$$lnLik_{full} = -\left(\frac{n}{2}\right)\cdot\ln(2\pi) - n\cdot\ln(\sigma\varepsilon) - \left(\frac{1}{2}\right)\cdot\sum_{j=1}^{n}\left(\frac{yobs_j - (\mu y + \delta_j)}{\sigma\varepsilon}\right)^2$$
$$-\left(\frac{n}{2}\right)\cdot\ln(2\pi) - n\cdot\ln(\sigma y) - \left(\frac{1}{2}\right)\cdot\sum_{j=1}^{n}\left(\frac{\delta_j}{\sigma y}\right)^2 \quad .$$

The MLE of μy is $\mu yest$ = mean(**yobs**). Note that $\mu yest$ is independent of any estimate of σy.

Given an estimate of σy ($\sigma yest$) the MLE of **ytru** is

$$\mathbf{yest} = \frac{\sigma yest^2\cdot\mathbf{yobs} + \sigma\varepsilon^2\cdot mean(\mathbf{yobs})}{\sigma yest^2 + \sigma\varepsilon^2} \quad . \qquad (2.1.1.1)$$

Note that **yest** is dependent on $\sigma yest$, except for two extreme cases:

- If $\sigma yest$=0, **yest**=mean(**yobs**)
- If $\sigma yest$=∞, **yest**=**yobs**

Differentiating the full log likelihood profile (i.e., the log of the full likelihood with μy and either **ytru** or **δ** set at their MLEs conditional on σy) with respect to σy shows that the partial derivative is zero whenever the following quadratic is zero:

$$sy^2 - \sqrt{\mathrm{var}(\mathbf{yobs})}\cdot sy + s\varepsilon^2 = 0 \quad ,$$

where sy is a surrogate for σy.

The above quadratic has the following roots:

$$sy = \begin{pmatrix} \dfrac{\sqrt{\mathrm{var}(\mathbf{yobs})} - \sqrt{\mathrm{var}(\mathbf{yobs}) - 4\sigma\varepsilon^2}}{2} \\ \dfrac{\sqrt{\mathrm{var}(\mathbf{yobs})} + \sqrt{\mathrm{var}(\mathbf{yobs}) - 4\sigma\varepsilon^2}}{2} \end{pmatrix} \quad . \qquad (2.1.1.2)$$

If var(**yobs**)>$\sigma\varepsilon^2$, the full likelihood profile has a global maximum at 0, a local minimum at sy_1, and a local maximum at sy_2. The latter will be taken to be the MLE for the full likelihood profile, σy_{full}.

The full log likelihood can be written as the sum of a conditional log likelihood and a marginal log likelihood:

$$lnLik_{cond} = -\left(\frac{n}{2}\right)\cdot \ln(2\pi) - n\cdot \ln\left(\frac{\sigma y\cdot\sigma\varepsilon}{\sqrt{\sigma y^2+\sigma\varepsilon^2}}\right) - \left(\frac{1}{2}\right)\cdot\sum_{j=1}^{n}\left(\frac{\delta_j - \frac{\sigma y^2\cdot(yobs_j-\mu y)}{\sigma y^2+\sigma\varepsilon^2}}{\frac{\sigma y\cdot\sigma\varepsilon}{\sqrt{\sigma y^2+\sigma\varepsilon^2}}}\right)^2 \quad ,$$

and

$$lnLik_{m\arg} = -\left(\frac{n}{2}\right)\cdot \ln(2\pi) - n\cdot \ln\left(\sqrt{\sigma y^2+\sigma\varepsilon^2}\right) - \left(\frac{1}{2}\right)\cdot\sum_{j=1}^{n}\left(\frac{yobs_j-\mu y}{\sqrt{\sigma y^2+\sigma\varepsilon^2}}\right)^2 \quad .$$

Because δ appears only as the argument of the conditional log likelihood, integrating it out (i.e., integrating out the random effects) leaves the marginal posterior.

The marginal likelihood profile has a single maximum at

$$\sigma y_{m\arg} = \sqrt{\mathrm{var}(\mathbf{yobs}) - \sigma\varepsilon^2} \quad . \qquad (2.1.1.3)$$

The above is a much more obvious estimator than σy_{full}, because it simply says that the variance of the observed values is equal to the sum of the variance of the true values plus the variance of the observation error.

It can be shown that σy_{marg} is always greater than σy_{full}.

Estimating σy for a vector of *dev*s in Stock Synthesis

Some quantities, such as population density, lend themselves to measurement by statistically designed field experiments from which estimates of precision (e.g., $\sigma\varepsilon$) can be obtained. Others, such as *dev*s associated with a selectivity parameter, do not.

First, note that Equation 2.1.1.2 can be solved for $\sigma\varepsilon$ as follows:

$$\sigma\varepsilon = \sqrt{\sigma y_{full}\cdot\left(\sqrt{\mathrm{var}(\mathbf{yobs})} - \sigma y_{full}\right)} \quad .$$

Substituting the above into Equation 2.1.1.3 gives

$$\sigma y_{m\arg} = \sqrt{\mathrm{var}(\mathbf{yobs}) - \sigma y_{full}\cdot\left(\sqrt{\mathrm{var}(\mathbf{yobs})} - \sigma y_{full}\right)} \quad . \qquad (2.1.1.4)$$

The above shows that σy_{marg} can be computed just from **yobs** and σy_{full}. However, σy_{full} cannot be computed from Equation 2.1.1.2 if $\sigma\varepsilon$ is unknown. Moreover, in cases such as the *dev*s associated with a selectivity parameter, not only will $\sigma\varepsilon$ be unknown, but **yobs** will not even exist (i.e., there are never any direct observations of the *dev*s associated with a selectivity parameter). In other words, in such cases it is necessary to estimate both **yobs** and σy_{full} without knowledge of $\sigma\varepsilon$. This can be accomplished as follows:

1. Recall from Equation 2.1.1.1 that **yest**=**yobs** if $\sigma y=\infty$. Therefore, fix σy initially at a very large value and run SS. The resulting estimated *dev*s should be the equivalent of **yobs**. It may take several tries to find a value of σy sufficiently high that it does not constrain the *dev*s. To avoid getting trapped in a local minimum, it is probably best to start with a reasonably low value of σy and then increase it gradually. It is also possible that one or more *dev*s (particularly *dev*s on selectivity parameters) may want to go to +/– ∞, in which case the assumption of normality is not reasonable. In such cases, the "outlier" *dev*s should not be considered when making the determination that σy is no longer constraining the *dev*s.
2. Estimate σy iteratively by choosing an initial value, running SS, computing the standard deviations of the estimated *dev*s, re-setting σy at that value, and repeating until σy equals the standard deviations of the estimated *dev*s. Because SS uses the full likelihood, the resulting estimate of σy should be the equivalent of σy_{full}. As in Step 1, if one or more *dev*s tends toward +/– ∞, those *dev*s should not be included when computing the standard deviation of the *dev*s.
3. Given the estimate of **yobs** from Step 1 and the estimate of σy_{full} from Step 2, estimate σy_{full} by Equation 2.1.1.4.

Because Equation 2.1.1.2 will result in the estimate of σy_{full} being real only when var(**yobs**)>$\sigma\varepsilon^2$, it is possible that Step 2 in the above algorithm will fail, even when the "true" value of σy is positive. The algorithm should therefore be conservative in the sense of tending to err toward underestimating σy.

It should also be noted that, while the above algorithm is appropriate (given var(**yobs**)>$\sigma\varepsilon^2$) for a univariate linear-normal model, when used in a multivariate nonlinear model such as SS, the properties of the estimator are presently unknown.

Annex 2.1.2: A trigonometric model of seasonally varying weight at length

Trigonometric functions such as sine or cosine are natural choices for describing processes that vary on a cyclical basis. For example, the α and β parameters of the standard weight-length equation $W=\alpha L^{\beta}$ might reasonably be assumed to vary on an annual cycle. However, there are two problems with fitting each of these two parameters to a sine or cosine function as usually formulated.

The first problem is that, while it is reasonable to assume that α and β vary on an annual cycle, it is much less reasonable to assume that the cycle is symmetric (e.g., that the rate of approach *to* the maximum is equal to the rate of descent *from* the maximum). This problem can be overcome by linearly rescaling time between the points corresponding to the minimum and maximum. This can be accomplished by means of the following two functions:

$$a(t,t1,t2)=\left\{\begin{array}{ll}\dfrac{1}{2\left(1-\left|t2-t1\right|\right)} & \text{if} \quad t<\min\left(t1,t2\right) \\ \dfrac{1}{2\left|t2-t1\right|} & \text{if} \quad \min\left(t1,t2\right)\le t\le\max\left(t1,t2\right) \\ \dfrac{1}{2\left(1-\left|t2-t1\right|\right)} & \text{if} \quad t>\max\left(t1,t2\right)\end{array}\right\} \quad ,$$

and

$$b(t,t1,t2)=\left\{\begin{array}{ll}\dfrac{\min\left(t1,t2\right)}{2\left(1-\left|t2-t1\right|\right)}-\dfrac{1}{2}-\dfrac{1}{2}(t1\ge t2) & \text{if} \quad t<\min\left(t1,t2\right) \\ \dfrac{\min\left(t1,t2\right)}{2\left|t2-t1\right|}-\dfrac{1}{2}(t2\ge t1) & \text{if} \quad \min\left(t1,t2\right)\le t\le\max\left(t1,t2\right) \\ \dfrac{\max\left(t1,t2\right)}{2\left(1-\left|t2-t1\right|\right)}-\dfrac{1}{2}(t1\ge t2) & \text{if} \quad t>\max\left(t1,t2\right)\end{array}\right\} \quad ,$$

where notation of the form "($x\le y$)" denotes a Boolean operator that returns 1 if true and 0 if false.

With the above linear rescalings of time, a reasonable formula for intra-annual variation of α or β is:

$$p(t,t1,t2,pmid,prat)=pmid\cdot\left(1+(1-prat)\cdot\cos\left(2\pi\cdot\left(a(t,t1,t2)\cdot t-b(t,t1,t2)\right)\right)\right) \quad ,$$

where time is measured on an annual scale, *pmid* is the midpoint between the minimum and maximum of the curve, and *prat* is the ratio between the minimum and *pmid*. A hypothetical example is shown in Figure 2.1.2.1.

To keep things simple, it may be assumed that *t1* and *t2* for β equal *t2* and *t1* for α, respectively. This causes β to be minimized when α is maximized, and vice-versa.

The second problem is that, if the values of the parameters are left unconstrained (except for the obvious natural boundaries $0\le t1\le 1$, $0\le t2\le 1$, $pmid>0$, and $0\le prat\le 1$), the functions can imply very complicated patterns of intra-annual variability in weight at length that would be difficult to justify biologically. A hypothetical example is shown in Figure 2.1.2.2.

One way to address this problem is to constrain the *prat* parameter for α (αrat) conditionally on the *pmid* and *prat* parameters for β (βmid and βrat, respectively) to be greater than:

$$\alpha rat_{min}(\beta mid,\beta rat)=\frac{1}{1+\beta mid\cdot(1-\beta rat)\cdot\ln(Lmin)} \quad ,$$

where *Lmin* is the minimum length being modeled. When this constraint is satisfied, the resulting intra-annual pattern of weight at length is assured to have only one minimum and one maximum for all modeled lengths.

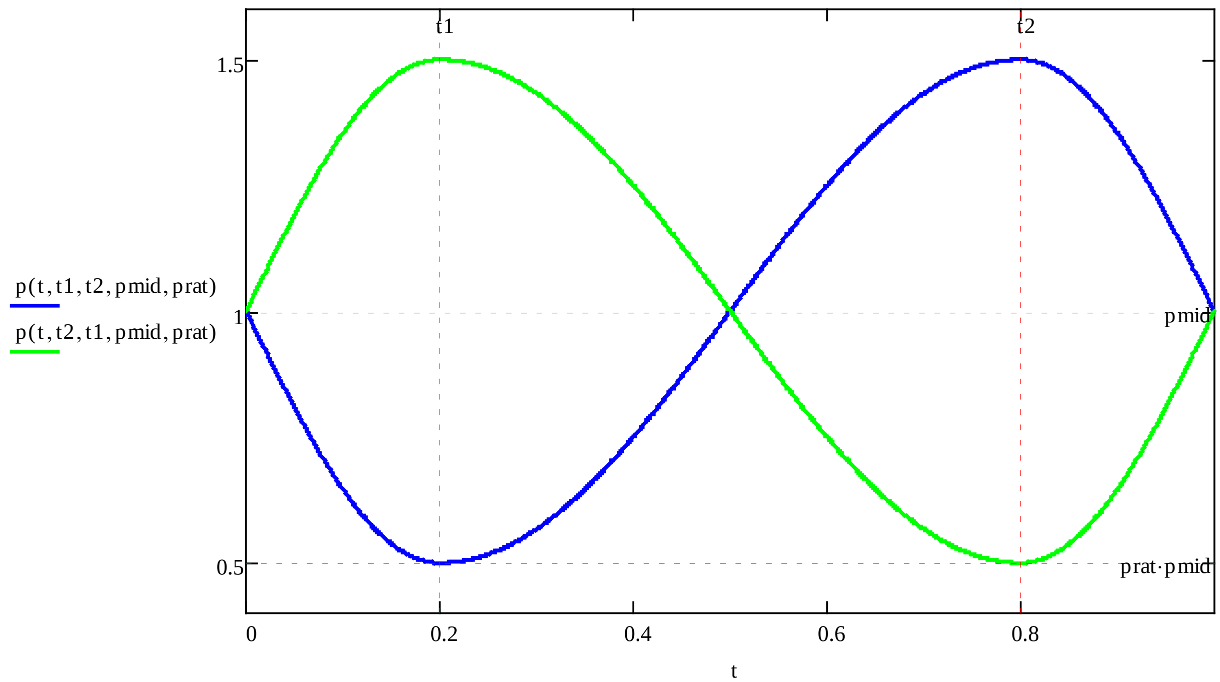


Figure 2.1.2.1. Hypothetical illustration of the trigonometric function with linearly rescaled time used to represent intra-annual variability in weight-length parameters, showing how the curve is flipped about the vertical midpoint when the time parameters are switched. Time is measured in years.

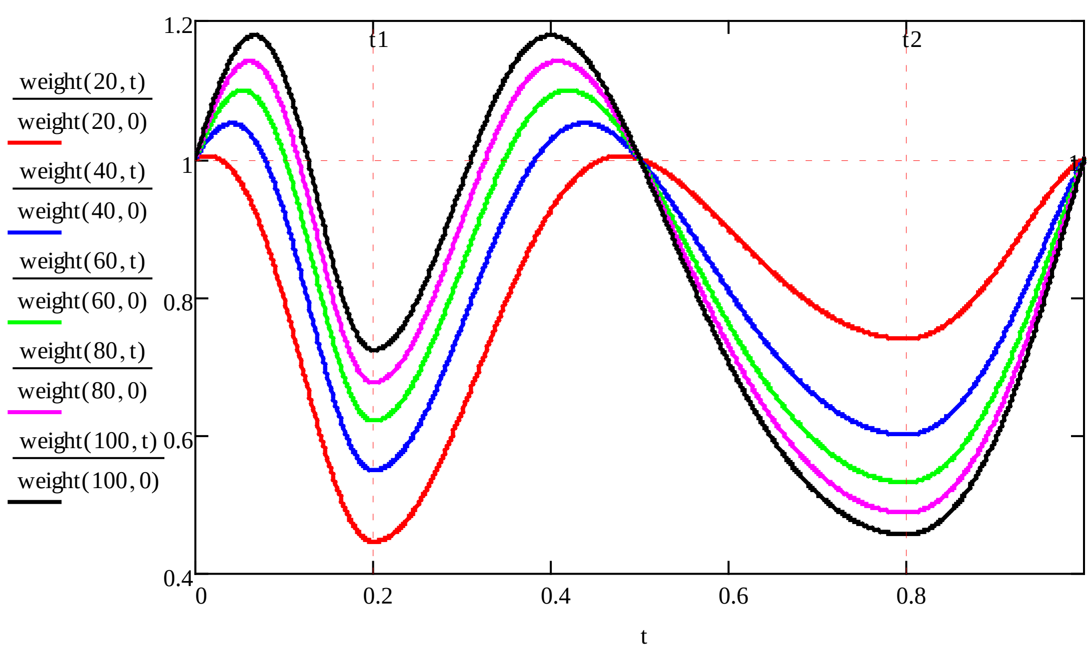


Figure 2.1.2.2. Hypothetical illustration showing how allowing the parameters of the weight-length model to be unconstrained can lead to very complicated intra-annual dynamics. Five example lengths are shown (20,40,60,80,100). Weights for each length are scaled relative to weight at *t*=0.

Attachment 2.2: Continuing the initial exploration of alternative assessment models for Pacific cod in the Aleutian Islands

INTRODUCTION

This document represents an effort to respond to comments made by the BSAI Plan Team, the joint BSAI and GOA Plan Teams, and the SSC regarding the need to develop an age-structured model of the Pacific cod (*Gadus macrocephalus*) stock in the Aleutian Islands (AI). Throughout the history of management under the Magnuson-Stevens Fishery Conservation and Management Act, Pacific cod in the eastern Bering Sea (EBS) and AI have been managed as a unit. Since at least the mid-1980s, harvest specifications for the combined BSAI unit have been extrapolated from an age-structured model for Pacific cod in the EBS.

Several white papers and a stock structure report provide various lines of evidence suggesting that Pacific cod in the EBS and AI should be viewed as separate stocks. Building on earlier genetic studies by Canino et al. (2005), Cunningham et al. (2009), and Canino et al. (2010), Spies (2012) concluded that her study "provides the most comprehensive evidence to date for genetic distinctiveness and lack of gene flow between the Aleutian Islands and Eastern Bering Sea." The importance of recognizing stock distinctions in management of gadids in general has also received attention in recent years (e.g., Fu and Fanning 2004, Hutchinson 2008).

In light of this evidence, in 2010 the SSC requested that a separate assessment be prepared for Pacific cod in the AI. In response, the 2011 assessment contained a Tier 5 assessment of Pacific cod in the AI (Thompson and Lauth 2011). This attachment, including the preliminary assessment (Annex 2.2.1), marks the first time that an age-structured model of Pacific cod in the AI has been presented in the context of the annual BSAI groundfish management cycle.

It should be emphasized that this assessment is a work in progress, and will *not* be used for setting harvest specifications until the next assessment cycle at the earliest (see Comment SSC6 below). As a result, the format of the document differs from that of a full SAFE chapter. Much information pertaining to AI Pacific cod can be found in the main text of the chapter. In particular, the reader is referred to the main text for information relevant to AI Pacific cod in the "Introduction," "Fishery," and "Ecosystem Considerations" sections. Rather than repeating such information, this attachment focuses on the data, structure, and results associated with four exploratory stock assessment models.

Overview of Models Presented

Four models are presented in this attachment, two of which have the same structure as models presented in the preliminary assessment (Annex 2.2.1).

Model 1 is identical to Model 1 from the preliminary assessment. Broadly speaking, it is similar to the model currently accepted by the Plan Team and SSC for EBS Pacific cod, except that it assumes only a single season per year and only a single fishery, does not include any age data, and the catchability coefficient is tuned to a higher value (because of the difference in survey net configurations between the two areas, Nichol et al. 2007).

Model 2 is identical to Model 2 from the preliminary assessment. It is similar to Model 1, except that it allows temporal variability in two of the growth parameters.

Model 3 is identical to Model 1, except that all input sample sizes for length composition data are multiplied by 1/3.

Model 4 is a new model that differs from Model 1 in several respects (see “Analytic Approach,” “Model Structure” for details).

Responses to SSC and Plan Team Comments on Assessments in General

SSC1 (12/11 minutes): “*We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year’s assessments.*” A retrospective analysis is presented in Figure 2.2.13 (see also Comments JPT2 and SSC2).

JPT1 (9/12 minutes): “*Total catch accounting—The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented.*” This information is provided in Attachment 2.4.

JPT2 (9/12 minutes): “*Retrospective analysis—For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author’s recommended model, even if it differs from the accepted model from previous years.*” The retrospective analysis shown in Figure 2.13 follows the Teams’ recommended protocol (see also Comments SSC1 and SSC2).

SSC2 (10/12 minutes): “*The SSC concurs with the working group and the Groundfish Plan Team (GPT) recommendation that for Alaska groundfish assessment with Tiers 1-3 age-structured models, a retrospective analysis should be done as part of the model evaluation.*” See Comments JPT2 and SSC1.

Responses to SSC and Plan Team Comments Specific to this Assessment

A total of four comments specific to BSAI Pacific cod from the December 2011 meeting of the SSC (1 comment), the May 2012 meeting of the Joint Plan Teams (2 comments), and the June 2012 meeting of the SSC (1 comment) were addressed in the preliminary AI assessment (included here as Annex 2.2.1). In the interest of efficiency, they are not repeated in this section.

Plan Team and SSC comments from the September 2012 and October 2012 meetings that relate to the assessment of AI Pacific cod are shown below.

BPT1 (9/12 minutes): “*The Plan Team recommends trying a model with smaller average sample sizes for the length composition data.*” Models 3 and 4 in this attachment use smaller average sample sizes for the length composition data.

BPT2 (9/12 minutes): “*The Plan Team also recommends that the two models presented in the preliminary assessment be updated with the most recent data and presented at the November Plan Team meeting so as to continue progress on development of this assessment.*” Models 1 and 2 from the preliminary assessment have been updated with the most recent development and are included here.

SSC4 (10/12 minutes): “*The Plan Team recommends that the two models presented in the preliminary assessment be updated with the most recent data and be brought forward for presentation at the*

November Plan Team meeting so as to continue progress on development of this assessment. The SSC agrees with Plan Team recommendations and looks forward to further development of the Aleutian Island model." See Comment BPT2. In addition to Models 1 and 2 from the preliminary assessment, two new models are included here.

SSC5 (10/12 minutes): "*The author mentioned that he has requested ageing of historical samples and intends to incorporate these into further assessments. Also, the development of an empirical growth relationship outside of the assessment model would be informative."* Development of an empirical growth relationship outside of the assessment model would be a welcome addition.

SSC6 (10/12 minutes): "*When the SSC judges this assessment as appropriate for setting management benchmarks, it will be used to set separate OFL and ABC for the Aleutian Island Pacific cod stock. This could happen as soon as the next assessment cycle (2014 fishing season)."* Development of the present assessment was guided largely by this comment, which implies that the assessment will *not* be used for recommending harvest specifications during the current cycle.

DATA

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

The following table summarizes the sources, types, and years of data included in the data file for one or more of the stock assessment models:

Source	Type	Years
Fishery	Catch biomass	1977-2012
Fishery	Catch size composition	1978-2012
AI bottom trawl survey	Numerical abundance	1980, 1983, 1986, 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012
AI bottom trawl survey	Size composition	1980, 1983, 1986, 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012

Fishery

Catch biomass

Total catch data are shown in Tables 2.1a, 2.1b, and 2.1c of the main text for the years 1964-2012. In addition to updating the 2011 data and providing preliminary 2012 data, the data in this table correct some errors that were present in the preliminary assessment. The catch data used in the models start with 1977, except for Model 2, which starts with 1976 (see "Analytic Approach," "Model Structure", below).

Compared to earlier years, catches dropped sharply in 2011 and remained low in 2012, which was likely the result of recent management measures designed to protect Steller sea lions (see Attachment 2.3).

Size Composition

Table 2.2.1 shows the total number of fish measured at each 1 cm interval from 4-120+ cm, by year, in the fishery. Overall, the AI fishery size compositions reflect a higher proportion of fish 100 cm or greater than is the case in the EBS fishery (6.7% in the AI versus 0.6% in the EBS).

The actual sample sizes for the fishery size composition data are shown below:

Year:	1978	1979	1982	1983	1984	1985	1990	1991
N:	1729	1814	4437	5072	5565	3602	4206	22653
Year:	1992	1993	1994	1995	1996	1997	1998	1999
N:	102653	46775	29716	30870	42610	23762	74286	34027
Year:	2000	2001	2002	2003	2004	2005	2006	2007
N:	52435	57750	23442	23690	23990	20754	20446	27543
Year:	2008	2009	2010	2011	2012			
N:	26282	21954	34329	8879	8922			

Fishery length composition sample sizes in the AI tend to be much lower than those in the EBS; the average in the AI is 27,000 fish, which is only 13.5% of the 200,000 fish average in the EBS.

It should also be noted that the length composition data in Table 2.2.1 and the sample sizes listed above differ significantly from the corresponding data in Annex 2.2.1, which suffered from a spreadsheet error.

Survey

Biomass and Numerical Abundance

The time series of trawl survey biomass and numerical abundance are shown for Areas 541-543, together with their respective coefficients of variation, in Table 2.2.2. These estimates pertain to the Aleutian *management* area, and so are smaller than the estimates pertaining to the Aleutian *survey* area that are reported in the main text of this chapter. (It should be noted that the preliminary AI assessment inadvertently used abundance estimates from the AI management area rather than the AI survey area.)

As in recent assessments of Pacific cod in the EBS, the models developed here use survey estimates of population size measured in units of individual fish rather than biomass.

Trawl survey estimates of Pacific cod in the AI tend to be much less precise than their EBS counterparts. The table below compares coefficients of variation from the surveys in the two areas, in terms of both biomass and numerical abundance:

	Biomass		Numbers	
Statistic	EBS	AI	EBS	AI
Min.	0.055	0.134	0.060	0.122
Mean	0.085	0.195	0.106	0.189
Max.	0.183	0.288	0.267	0.310

Size Composition

Table 2.2.3 shows the total number of fish measured at each 1 cm interval from 4-120+ cm, by year, in the survey. As with the fishery, the overall AI survey size compositions reflect a higher proportion of fish 100 cm or greater than is the case in the EBS survey (0.8% in the AI versus 0.1% in the EBS).

The actual sample sizes for the survey size composition data are shown below:

Year:	1980	1983	1986	1991	1994	1997
N:	1725	9050	12018	7125	7497	4635

Year:	2000	2002	2004	2006	2010	2012
N:	5178	3914	3721	2784	3521	3278

It should be noted that some of the survey sample sizes reported in Annex 2.2.1 were incorrect.

ANALYTIC APPROACH

Model Structure

Four models are presented in this assessment, all of which are estimated using Stock Synthesis (SS), and three of which are based largely on last year's accepted model for Pacific cod in the EBS (Thompson and Lauth 2011).

All models used a double-normal curve to model selectivity. This functional form is constructed from two underlying and linearly rescaled normal distributions, with a horizontal line segment joining the two peaks. As configured in SS, the equation 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.

Model 1's structure differs from last year's accepted EBS model in the following respects:

1. In the data file, length bins (1 cm each) were extended out to 150 cm instead of the limit of 120 cm that is used in the EBS assessment, because of the higher proportion of large fish observed in the AI.
2. Each year consists of a single season instead of five.
3. A single fishery is defined (with forced asymptotic selectivity) instead of nine season-and-gear-specific fisheries (with forced asymptotic selectivity for six of them).
4. Fishery selectivity is constant over time instead of variable in multiple time blocks.
5. The survey samples age 1 fish at true age 1.5 instead of 1.41667.
6. Ageing bias is not estimated (no age data) instead of estimated.
7. Survey catchability *Q* is tuned to match the value of 0.92 estimated by Nichol et al. (2007) for the AI survey net instead of the value of 0.47 estimated for the EBS survey net.

Model 2 was chosen from a set of seven candidate models, all of which were basically identical to Model 1 except that they each allowed at least one of the three length-at-age parameters (length at age 1, *L1*; asymptotic length, *Linf*; and Brody's growth coefficient, *K*) to vary annually from 1977-2011, using multiplicative *dev*s with $\sigma = 0.1$. The candidate models were structured as follows:

Model	*L1 dev*s	*Linf dev*s	*K dev*s
A	yes	yes	yes
B	yes	yes	no
C	yes	no	yes
D	no	yes	yes
E	yes	no	no
F	no	yes	no
G	no	no	yes

The candidate model with the lowest value of Akaike's information criterion (AIC) was chosen as Model 2 (see "Results," below).

The other difference between Model 2 and Model 1 is that an additional year of catch data (1976) was included in the data file for Model 2. This change was necessitated when it was discovered that SS was estimating $B_{100\%}$ from the length-at-age parameters corresponding to the first year in the catch data, which would normally be 1977. However, it turned out that 1977 had one of the largest estimated growth *dev*s in the time series. The available options were either to turn off the growth *dev*s for 1977 or to add another year to the start of the time series. Given that 1977 appeared to exhibit one of the most non-typical growth patterns in the time series, the latter option seemed preferable.

Model 3 is the same as Model 1, except that all input sample sizes for length composition data were multiplied by 1/3 (see Comment BPT1 in "Executive Summary").

Model 4 differs from Model 1 in several respects:

1. Survey data from the pre-1991 years (i.e., the years of the U.S.-Japan cooperative survey) were removed from the data file.
2. Survey catchability was allowed to vary randomly around a base value (estimated iteratively, using the same approach as the other three models), with the input standard deviation estimated iteratively by matching the standard deviation of the estimated *dev*s.
3. Survey selectivity was forced to be asymptotic.
4. Fishery selectivity was not forced to be asymptotic.
5. Input sample sizes for length composition data were estimated iteratively by setting the root-mean-squared-standardized-residual of the survey abundance time series equal to unity.
6. All fishery selectivity parameters except *initial_selectivity* and the *ascending_width* survey selectivity were allowed (initially) to vary randomly, with the input standard deviations estimated iteratively by matching the respective standard deviations of the estimated *dev*s.
7. The input standard deviation for log-scale recruitment *dev*s was estimated internally (i.e., as a free parameter).

Models 1 and 3 use the same data file. Model 2's data file is the same as that for Models 1 and 3, except for the addition of catch data for 1976 noted above. Model 4's data file is the same as that for Models 1 and 3, except that the survey data from the pre-1991 years were removed.

Development of the final versions of all models included calculation of the Hessian matrix. These models also passed a "jitter" test of 50 runs with a jitter parameter (equal to half the standard deviation of the logit-scale distribution from which initial values are drawn) of 0.1. In the event that a jitter run produced a better value for the objective function than the base run, then: 1) the model was re-run starting from the final parameter file from the best jitter run, 2) the resulting new control file became the new base run, and

3) the entire process (starting with a new set of jitter runs) was repeated until no jitter run produced a better value for the objective function than the most recent base run.

Prior to selection of one of the candidate models A-G to constitute Model 2, development of these models did not include calculation of the Hessian matrix, and they were not subjected to a jitter test. As a weak test for convergence, each of these models was re-run from its respective ending values (in the control file, not the parameter file), and confirmed to return the same objective function value.

Except for *dev* parameters, all parameters in all models were estimated with uniform prior distributions. Bounds were non-constraining except in a very few unimportant cases.

The software used to run all models was SS V3.23b, as compiled on 11/5/2011 (Methot 2005, Methot 2011, Methot and Wetzel *in press*). Stock Synthesis is programmed using the ADMB software package (Fournier et al. 2012).

Parameters Estimated Outside the Assessment Model

Several parameters were fixed externally at values borrowed from the EBS Pacific cod model (see main text):

1. The natural mortality rate was fixed at 0.34 in all models.
2. The parameters of the logistic maturity-at-age relationship were set at values of 4.88 years (age at 50% maturity) and –0.965 (slope) in all models.
3. The standard deviation specified for log-scale age 0 recruitment was set at 0.57 for Models 1-3. Model 4 estimated this parameter internally.

In all four models, weight (kg) at length (cm) was assumed to follow the usual form weight=$\alpha \times$length$^{\beta}$ and to be constant across the time series, with α and β estimated at 5.683×10^{-6} and 3.18, respectively, based on 8,126 samples collected from the AI fishery between 1974 and 2011.

Parameters Estimated Inside the Assessment Model

Parameters estimated inside SS for all models include the von Bertalanffy growth parameters, standard deviation of length at ages 1 and 20, log mean recruitment since the 1976-1977 regime shift, offset for log-scale mean recruitment prior to the 1976-1977 regime shift, *dev*s for log-scale initial (i.e., 1977) abundance at ages 1 through 3, annual log-scale recruitment *dev*s for 1977-2011, initial (equilibrium) fishing mortality, base values for all fishery and survey selectivity parameters, and annual *dev*s for the *ascending_width* parameter of the survey selectivity function.

Log-scale survey catchability was estimated iteratively in all models 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).

Annual *dev*s around selected growth parameters (see “Results”) were estimated in Model 2 only.

The standard deviation specified for log-scale age 0 recruitment was estimated in Model 4 only.

Annual *dev*s around the log-scale base catchability were estimated in Model 4 only.

Fishery selectivity is length-based and trawl survey selectivity is age-based in all models.

Uniform prior distributions are used for all parameters, except that *dev* vectors are constrained by input standard deviations ("sigma"), which are somewhat analogous to a joint prior distribution.

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-specific fishing mortality rates are also estimated internally, 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 four models include likelihood components for initial (equilibrium) catch, trawl survey relative abundance, fishery and survey size composition, recruitment, priors (for Model 4 only due to the use of time-varying catchability), "softbounds" (equivalent to an extremely weak prior distribution used to keep parameters from hitting bounds), and parameter deviations.

In SS, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in the EBS assessment, likelihood components were given an emphasis of 1.0 here.

Use of Size Composition Data in Parameter Estimation

Size composition data are assumed to be drawn from a multinomial distribution specific to a particular fleet (fishery or survey) and year. In the parameter estimation process, SS weights a given size composition observation 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. The steps used to scale the sample sizes were nearly identical to those described for the EBS models in the main text of this chapter: 1) Records with fewer than 400 observations were omitted. 2) The sample sizes for fishery length compositions from years prior to 1999 were tentatively set at 16% of the actual sample size, and the sample sizes for fishery length compositions after 1998 and all survey length compositions were tentatively set at 34% of the actual sample size. 3) All sample sizes were adjusted proportionally.

Relative to the procedure described for the EBS models in the main text, the only difference in the scaling algorithm was an unintentional one, resulting from a spreadsheet error that was detected too late to fix: instead of achieving the intended average of 300, the scaling formula resulted in an average of 357.

The resulting input sample sizes for *fishery* length composition data are shown below:

Year:	1978	1979	1982	1983	1984	1985	1990	1991	1992	1993	1994	1995
N:	16	16	40	46	51	33	38	206	933	425	270	280

Year:	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
N:	387	216	675	657	1012	1115	453	457	463	401	395	532

Year:	2008	2009	2010	2011	2012
N:	507	424	663	171	172

The resulting input sample sizes for *survey* length composition data are shown below:

Year:	1980	1983	1986	1991	1994	1997	2000	2002	2004	2006	2010	2012
N:	96	505	671	398	419	259	289	219	208	156	197	183

Use of Survey Relative Abundance Data in Parameter Estimation

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 likelihood component for recruitment is different from traditional likelihoods because it does not involve "data" in the same sense that traditional likelihoods do. Instead, the log-scale recruitment *dev* plays the role of the datum in a normal distribution with mean zero and specified (or estimated) standard deviation; but, of course, the *dev*s are parameters, not data.

RESULTS

Model Evaluation

The four models included in this assessment are described above under "Analytic Approach," "Model Structure."

Selection of one of the time-varying growth models to constitute Model 2

The seven candidate models with time-varying growth gave the following results ("Δ(−lnLike)" represents the negative log likelihood relative to the model with the lowest negative log likelihood, and "Δ(AIC)" represents the value of Akaike's information criterion relative to the model with the lowest AIC; note that, with respect to both of these measures, lower values are better):

Model	*L1 dev*s	*Linf dev*s	*K dev*s	Parameters	Δ(-lnLike)	Δ(AIC)
A	yes	yes	yes	191	0.00	12.71
B	yes	yes	no	156	28.64	0.00
C	yes	no	yes	156	85.58	113.87
D	no	yes	yes	156	51.57	45.86
E	yes	no	no	121	145.04	162.78
F	no	yes	no	121	69.17	11.06
G	no	no	yes	121	129.13	130.96
1	no	no	no	86	203.63	209.96

Model A has the lowest negative log likelihood overall, followed by Models B and D, respectively. However, Model A's negative log likelihood is only 28.64 units lower than Model B, an improvement which is achieved at a cost of 35 additional parameters. It should be noted, though, that the differences listed in the "parameters" column (above) all represent differences in the number of *dev*s, which, being constrained by σ, are not true parameters, meaning that the differences in number of parameters are overstated to some unknown extent. Unfortunately, use of a more rigorous method of model selection in this preliminary assessment was precluded by time limitations, so AIC will be taken here to represent the best available method. Model B has the lowest AIC overall, followed by Models F and A, respectively, so Model B was chosen to constitute Model 2 in this preliminary assessment.

Comparing and Contrasting the Models

The number of parameters for each model is shown below. Allowing *dev*s for the *ascending_width* survey selectivity parameter causes SS to estimate these parameters even in years when no survey takes place (the estimates are identically zero in all such cases). Therefore, the table below shows both the total number of parameters (first row) and the number of parameters whose estimates are actually influenced by data (third row, obtained by subtracting the second row from the first):

Parameter type	Model 1	Model 2	Model 3	Model 4
All SS parameters	86	156	86	83
Survey *dev*s in non-survey years	20	20	20	12
Parameters influenced by data	66	136	66	71

It should also be noted that, by including *dev*s, the above table overstates the number of free parameters, because the *dev*s are constrained by their respective input standard deviations.

Objective function values are shown for each model below (objective function components with a value of 0.00 for all models are omitted for brevity):

Obj. func. component	Model 1	Model 2	Model 3	Model 4
Survey abundance	99.01	41.04	20.79	-11.14
Size composition	721.23	593.58	292.20	403.13
Recruitment	29.88	24.14	4.66	27.05
Priors	0.00	0.00	0.00	3.87
"Softbounds"	0.01	0.01	0.01	0.01
Deviations	5.58	28.08	3.23	4.21
Total	855.72	686.85	320.90	427.13

The values shown in the above table are not strictly comparable. Values for Models 1 and 2 are *almost* comparable, because the only differences in their respective data files is the inclusion of a 1976 catch datum for Model 2. Models 3 and 4, by adjusting the sample sizes specified for length composition data, imply different weightings for the data components (both from each other and from Models 1 and 2). Also, Model 4 omits the pre-1991 survey data.

The table below shows five statistics related to goodness of fit with respect to the survey abundance data (color scale extends from red (minimum) to green (maximum)). Relative values of the five statistics can be interpreted as follows: correlation—higher values indicate a better fit, root mean squared error—lower values indicate a better fit, average of standardized residuals—values closer to zero indicate a better fit, last two rows—values closer to unity indicate a fit more consistent with the sampling variability in the data.

Statistic	Model 1	Model 2	Model 3	Model 4
Correlation (observed:expected)	0.50	0.81	0.66	0.98
Root mean squared error	0.79	0.56	0.46	0.17
Average of standardized residuals	-2.61	-2.11	-1.40	-0.74
Standard deviation of standardized residuals	3.78	2.52	2.32	0.70
Root mean squared standardized residual	4.46	3.20	2.63	0.99

Figure 2.2.1 shows the fits of the four models to the trawl survey abundance data. Models 1-3 all tend to estimate abundances much higher than the data from 1991 through 2004. In terms of frequency of the estimates falling within the 95% confidence intervals, the models ranked as follow (best to worst): Model 4—100%, Model 3—50%, Model 2—42%, Model 1—25%. All four models' estimates fall within the 95% confidence interval in 2010, and all but Model 1's estimate fall within the 95% confidence interval in 2012 (all four models' estimates fall below the survey datum in 2012).

The table below shows the mean of the ratios between output "effective" sample size and input sample size for the size composition data, thus providing an alternative measure of how well the models are fitting these data (higher values are better, all else being equal). All four models give mean ratios much greater than unity. Note that the input sample sizes are different for Models 1-2, Model 3, and Model 4. For Model 3, the input sample sizes were reduced by 67% (by assumption); while for Model 4, the input sample sizes were reduced by 37% (by iterating).

	Mean (effective N / input N)			
Fleet	Model 1	Model 2	Model 3	Model 4
Fishery	4.773	5.666	12.062	8.50
Survey	2.716	3.035	6.060	3.53

Figures 2.2.2 and 2.2.3 show the four models' fits to the fishery size composition and survey size composition data, respectively.

Table 2.2.4 displays all of the parameters (except fishing mortality rates) estimated internally in any of the models. Table 2.2.4a shows growth (except annual *dev*s for Model 2), recruitment (except annual *dev*s), initial age composition, initial fishing mortality, and base selectivity parameters as estimated internally by at least one of the assessment models. It may be noted that Model 4's estimates of asymptotic length and the standard deviation of length at age 20 are much higher than the other models. Table 2.2.4b shows annual log-scale recruitment *dev*s as estimated by all of the models. These are plotted in Figure 2.2.4, where it is apparent that Models 1-3 show a high degree of synchrony throughout the time series, with Model 4 showing lower recruitments than the other models prior to 1985 and higher recruitments than the other models from 1994-2009. Table 2.2.4c shows survey shows *dev*s for the survey selectivity *ascending_width* parameter as estimated by all of the models. Table 2.2.4d shows *dev*s for growth parameters as estimated by Model 2. Figure 2.2.5 shows the pattern of time-varying length at age estimated by Model 2.

The table below shows the estimates of catchability obtained iteratively by attempting to match the results of Nichol et al. (2007).

Parameter	Model 1	Model 2	Model 3	Model 4
ln(catchability)	0.277632	0.262364	0.157004	0.019803
Catchability (natural scale)	1.32	1.30	1.17	1.02

The value shown above for Model 4 is the base value of catchability, around which annual *dev*s were estimated as follows (recall that Model 4 does not use the pre-1991 survey data; also, note that no *dev* was estimated for 2012, to avoid confounding the estimate of the 2011 year class with catchability):

Year:	1991	1994	1997	2000	2002	2004	2006	2010
Q dev:	1.317	1.149	0.721	1.186	0.706	0.787	0.800	1.032

The above time series is plotted in Figure 2.2.6.

Table 2.2.5 shows estimates of full-selection fishing mortality rates for the four models (note that these are not counted as parameters in SS, and so do not have estimated standard deviations).

Figure 2.2.7 shows the time series of spawning biomass relative to $B_{100\%}$ as estimated by the four models (note that SS measures spawning biomass at the start of the year and uses a different estimator mean recruitment than the AFSC's standard projection model). Models 1-3 all show a peak ratio in 1991 or 1992, followed by a monotonic or near-monotonic decline through 2012. The peaks for Models 1 and 2 are quite high (1.85 and 2.50, respectively). Model 4 estimates extremely low values for the ratio prior to 1991, which is the year of the first survey datum in that model. All four models estimate ratios for 2012 in the range 0.19-0.25. (In Annex 2.2.1, Model 2 estimated a much higher ending value for this ratio. This was due to the problem of SS estimating $B_{100\%}$ from the length-at-age parameters corresponding to the first year in the data, as described previously under "Analytic Approach," "Model Structure.")

Figure 2.2.8 shows the time series of total (age 0+) biomass as estimated by the four models, with the trawl survey biomass estimates included for comparison. As with the survey abundance data, Models 1-3 estimate a much higher total biomass than the survey in nearly all years. Model 4 does much better than the other models for the years 1991 and beyond, but it estimates extremely low values for the period prior to 1991 (where it drops the survey estimates from the data file). On average, Model 1's estimates are 223% higher than the data, Model 2's are 180% higher, Model 3's are 172% higher, and Model 4's are 64% higher (not counting the pre-1991 data).

Figure 2.2.9 shows fishery selectivity as estimated by all four models. Visually, there does not appear to be a great deal of difference between the curves estimated by Models 1-3, all of which force fishery selectivity to be asymptotic. Model 4, which allows dome-shaped fishery selectivity, shows a sharp drop in selectivity for lengths in the 108-119 cm range.

Figure 2.2.10 shows trawl survey selectivity as estimated by the four models. Models 1-3, which allow dome-shaped survey selectivity, all estimate extremely "pointy" selectivity schedules, with selectivity less than 0.35 at ages 6 and higher. Model 4 forces survey selectivity to be asymptotic.

Table 2.2.6 contains selected output from the standard projection model, based on SS parameter estimates from the four assessment models, along with the probability that the maximum permissible ABC in each of the next two years will exceed the corresponding true-but-unknown OFL and the probability that the stock will fall below $B_{20\%}$ in each of the next five years (probabilities are given by SS rather than the standard projection model). Model 1 estimates the highest values of biomass reference points and Model 4 the lowest. The order is reversed for most other quantities in the table, except for the probability of dropping below $B_{20\%}$ in the next few years.

All models converged successfully and the Hessian matrices from all models were positive definite. Once each model appeared to have converged, a set of (typically 50) "jitter" runs were made 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 until such time as no further improvement was obtained. No model was considered final until a set of 50 jitter runs failed to find a better value of the objective function.

In the table below, the row labeled "Success" shows the proportion of jitters that ran successfully (i.e., that returned a numeric value for the objective function). The row labeled "Match" shows the proportion of successful jitters that matched the final version. The two rows labeled "-lnL 'RMSE'" show a statistic for the objective function that is similar to a root-mean-squared-error, but in which the squared difference is taken with respect to the *minimum* value (across jitters) rather than the *mean*; this statistic is reported in units of log-likelihood. Finally, the two rows labeled "SB2012 'CV'" show a statistic for 2012 spawning biomass that is similar to a coefficient of variation, but in which (as with the preceding statistic) the mean is replaced by the value corresponding to the final (i.e., best case) version of the model. The label "first 25 jitters" in Performance measures #3 and #5 refers to the first 25 jitters *after sorting* in order from lowest to highest objective function value. Color scale in the table extends from red (minimum) to green (maximum).

Performance Measure	Model 1	Model 2	Model 3	Model 4
Success	1.000	1.000	1.000	0.900
Match	0.320	0.200	0.340	0.978
-lnL "RMSE" (first 25 jitters)	0.178	3.303	1.058	0.000
-lnL "RMSE" (all 50 jitters)	41.096	29.162	8.353	0.897
SB2012 "CV" (first 25 jitters)	0.004	0.043	0.011	0.000
SB2012 "CV" (all 50 jitters)	0.058	0.117	0.039	0.001

Models 1-3 all had a perfect success rate, while Model 4 had a success rate of 0.9. "Match" rates ranged from 0.2 (Model 2) to 0.978 (Model 4). In terms of the final four performance measures, Model 4 tended to perform the best. All four models exhibited very low (<5%) relative variability for SB2012 in the first 25 (sorted) jitters.

Figure 2.11 sorts the jitter runs for each model in order of decreasing log likelihood, and shows how the running (cumulative) value of –lnL "RMSE" changes with each additional (sorted) jitter run. This figure is included to address previous Plan Teams concerns that the reported value of –lnL "RMSE" may be due to a small number of outliers.

Evaluation Criteria and Selection of Final Model

Given the SSC's determination (see Comment SSC6 in "Introduction") that this assessment will not be used to set harvest specifications, selection of a preferred model is somewhat academic. All of the models presented here should be considered preliminary. However, in the interest of providing further illustration of the modeling work undertaken to date, it is helpful to focus on a single model. Model 3 will be chosen for this purpose. The reasons for selecting Model 3 are as follow:

1. Model 3 is one of the models requested by the Plan Team and SSC.
2. Model 3 does not use time-varying catchability or time-varying growth, both of which have been discouraged in the past by the Plan Team.
3. Model 3 avoids estimating levels of relative spawning biomass that seem extreme (either high or low) in comparison to time series estimated by accepted models of Pacific cod in the EBS and GOA (Figure 2.2.7).
    a. Models 1 and 2 estimate extremely high relative spawning biomasses during the early 1990s (more than 80% above $B_{100\%}$).

b. Model 4 estimates extremely low relative spawning biomasses during the 1980s (less than 10% of $B_{100\%}$).

Final Parameter Estimates and Associated Schedules

As noted previously, estimates of all statistically estimated parameters in Model 3 are shown in Table 2.2.4. Estimates of year-, gear-, and season-specific fishing mortality rates from Model 3 are shown in Table 2.2.5.

Schedules of selectivity at length for the commercial fisheries from Model 3 are shown in Table 2.2.7, and schedules of selectivity at age for the trawl survey from Model 3 are shown in Table 2.2.8. The trawl survey selectivity schedule and all fishery selectivity schedules for Model 3 are plotted in Figures 2.2.9 and 2.2.10, respectively.

Schedules of length and weight at age for the population, fishery, and survey are shown in Table 2.2.9.

Time Series Results

Definitions

The biomass estimates presented here will be defined in three ways: 1) age 0+ biomass, consisting of the biomass of all fish aged 0 years or greater in January of a given year; 2) age 3+ biomass, consisting of the biomass of all fish aged 3 years or greater in January of a given year; and 3) 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 2.2.5, an alternative "effective" fishing mortality rate will be provided here, defined for each age and time as $-\ln(N_{a+1,t+1}/N_{a,t})-M$, 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 2.2.10 shows the time series of age 0+, age 3+, and female spawning biomass for the years 1977-2013 as estimated under Model 3. The estimated spawning biomass time series is accompanied by its respective standard deviations.

The estimated time series of EBS age 0+ biomass and female spawning biomass from Model 3 are shown, together with the observed time series of trawl survey biomass, in Figure 2.2.12. Confidence intervals are shown for the model estimates of female spawning biomass and for the trawl survey biomass estimates.

The SSC and Plan Teams have requested that a 10-year retrospective analysis of the final model be conducted, using spawning biomass and relative changes in spawning biomass as the performance measures (see Comments SSC1, JPT2, and SSC2 in "Introduction"). Figure 2.2.13 is included to satisfy this request. Figure 2.2.13a plots retrospective spawning biomass in absolute terms, while Figure 2.2.13b plots the same results in terms of proportional changes relative to the terminal (2012) run. These figures indicate a negative retrospective bias (i.e., initial estimates of spawning biomass tend to be low relative to later estimates as new data are added). Whether this outcome is dependent on the particular time series of data used in this analysis or is a general feature of Model 3 is unknown.

Recruitment and Numbers at Age

Table 2.2.11 shows the time series of age 0 recruitment (1000s of fish) for the years 1977-2011 as estimated last year and this year under Model 3. The estimated time series is accompanied by its respective standard deviations.

For the time series as a whole, the largest year class appears to have been the 1986 cohort, followed by the 1984 and 1989 cohorts. In the EBS Pacific cod models, the 1977 year class is estimated to have been the strongest in the time series, but here it is estimated to have been below average. Based on Model 3, the last above-average cohort was spawned in 2000. The 11 most recent cohorts (2001-2011) constitute 11 of the 14 weakest cohorts in the time series.

Model 3's recruitment estimates for the entire time series (1977-2011) are shown in Figure 2.2.14, along with their respective 95% confidence intervals.

No stock-recruitment relationship has been estimated for Pacific cod in the AI.

The time series of numbers at age as estimated by Model 3 is shown in Table 2.2.12.

Fishing Mortality

Table 2.2.13 shows "effective" fishing mortality by age and year for ages 1-19 and years 1977-2011 as estimated by Model 3.

Figure 2.2.15 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2012 based on Model 3, 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). Nearly the entire trajectory lies underneath the $maxF_{ABC}$ control rule. It should be noted that this trajectory is based on SS output, which may not match the estimates obtained by the standard projection program.

Harvest Recommendations

Recommendation of harvest specifications based on this assessment would be premature. Information presented in this section is intended only to illustrate the behavior of an example model.

Amendment 56 Reference Points

Amendment 56 to the BSAI 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. These are defined in terms of a set of management tiers. The applicable tier is identified by the level of information that has been determined by the SSC to be "reliable." Because Pacific cod in the AI have so far not been managed as a unit separate from Pacific in the EBS, no such determination has been made for this stock, and the SSC has indicated that the assessment will not be judged "as appropriate for setting management benchmarks" prior to the next assessment cycle" (see Comment SSC6 in "Introduction").

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). Because Pacific cod in the AI are not yet managed under Tiers 1, 2, or 3, results presented in this section should be considered as hypothetical only.

For each scenario, the projections begin with an estimated vector of 2013 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 are sometimes 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 2013 and 2014, 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 2013 recommended in the assessment to the *max* F_{ABC} for 2012. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to the 2007-2011 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 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 1) above its MSY level in 2012 or 2) above 1/2 of its MSY level in 2012 and expected to be above its MSY level in 2022 under this scenario, then the stock is not overfished.)

Scenario 7: In 2013 and 2014, 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 2025 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 3 in Tables 2.2.14-2.2.19 (note that Scenario 2 is not applicable in this assessment, because no ABC recommendation is made).

Because this stock is not managed separately from Pacific cod in the EBS and no assessment model will be accepted by the SSC during the current cycle, status determinations cannot be made.

DATA GAPS AND RESEARCH PRIORITIES

As research on age-structured modeling of AI Pacific cod continues, the following issues will likely emerge as priorities:

1. Models 1-3 all estimate very low levels of current spawning biomass relative to spawning biomass in the early 1990s. If these estimates are accurate, was the high biomass in the early 1990s the result of spawning that took place in the AI, or did a large portion of this biomass originate in the EBS?
2. Recruitment of Pacific cod in the EBS and GOA seem to be highly synchronous, but correlations between recruitment in the AI and EBS or GOA are low. Is this because recruitment dynamics are truly different in the AI, or is this evidence that the AI models are not giving good estimates?
3. Relative to Pacific cod in the EBS, Pacific cod in the AI have much larger survey CVs, much smaller length composition sample sizes, and virtually no age data. Is a reliable age-structured model of the AI stock possible under these conditions?
4. Unless survey selectivity is forced to be asymptotic, it peaks sharply at age 4 or 5 (depending on the model), with abrupt drops on either side of the peak. Is this reasonable?
5. Should catchability be tuned so that the average product of Q and selectivity across the 60-81 cm range matches the value of 0.92 estimated by Nichol et al. (2007)? In exploratory runs based on Models 1 and 3 (not shown here), catchability dropped dramatically when estimated freely (and current levels of relative spawning biomass increased substantially).
6. How should the pre-1991 survey data be treated? The dimensions and configurations of the nets used in the pre-1991 surveys varied among nations and years. Data from the Japanese vessels were excluded from the 1980 biomass estimate, but the two U.S. vessels in that year used two different nets: one used an Eastern trawl, the other a Noreastern trawl very similar to the one used in recent surveys (high rise Polynoreastern). In 1983 and 1986, data from both Japanese and U.S. vessels are used in the estimates, but the Japanese used different gears in those two years. For both 1983 and 1986, the U.S. vessels used the Noreastern net. When the pre-1991 survey data were excluded in Model 4, abundance estimates tended toward unreasonably low values in those years. Another possibility would be to keep the data in the model, but estimate separate selectivity or catchability for the early years. However, three years of data may be insufficient to obtain reliable estimates.
7. Is the negative retrospective bias an inherent feature of Model 3 (a similar bias was found for Model 1, although not shown here), or is it dependent on the particular time series of data used in this analysis?
8. Should projections be based on the AFSC's standard projection model rather than SS? The two approaches differ significantly in two respects (for a single-season model such as those considered in this assessment):
    a. SS computes spawning biomass at the start of the year, whereas the standard projection model computes spawning biomass in the month of peak spawning.
    b. SS estimates mean recruitment together with all other parameters (including recruitment *devs*) in the model; whereas the standard projection model estimates mean recruitment as the sample mean of the estimated recruitments.

Acknowledgments

Camille Kohler and Ingrid Spies provided the catch data. Angie Greig provided the size composition and weight-length data. Jennifer Calahan helped to code the query for the weight-length data. Wayne Palsson provided the survey data and information on the nets used during the pre-1991 surveys. Rick Methot developed the SS software used to conduct this assessment, and answered numerous questions about SS. Anne Hollowed and the BSAI Groundfish Plan Team provided reviews of this assessment. Many NMFS survey personnel and countless fishery observers collected most of the raw data that were used here.

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Table 2.2.1 (page 1 of 3)—Fishery size composition, by year and cm.

Year	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	1	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	5
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1999	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	4	5	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
2003	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2004	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
2005	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
2007	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Year	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
1978	0	0	1	0	0	0	0	0	2	0	0	2	1	1	5	3	7	4	9	18
1979	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1	1
1982	0	0	0	1	0	0	0	0	0	0	5	4	2	6	7	7	9	15	19	14
1983	2	1	2	5	8	6	16	16	23	25	45	70	64	68	66	60	58	69	86	103
1984	0	0	1	0	2	0	0	1	2	2	7	12	13	17	31	28	21	22	6	6
1985	0	0	0	0	0	0	0	0	0	0	0	3	1	1	7	12	25	21	37	61
1990	0	0	0	0	0	0	0	0	1	0	1	0	1	1	4	2	5	7	15	17
1991	0	0	0	2	0	0	1	2	8	2	4	9	13	11	15	7	9	21	28	39
1992	0	0	0	0	0	0	0	3	4	4	9	21	27	46	40	62	116	153	226	310
1993	0	0	0	0	1	4	7	11	9	12	17	20	30	29	33	39	45	67	76	113
1994	0	0	0	0	1	2	4	7	5	3	8	3	14	8	19	19	26	33	52	73
1995	14	22	34	38	59	51	49	54	66	56	51	33	22	19	11	12	11	23	20	30
1996	0	2	0	2	5	15	6	9	8	14	18	15	12	29	39	39	50	63	108	136
1997	0	0	0	0	2	2	0	7	4	5	9	12	6	9	17	22	17	25	25	32
1998	1	1	4	1	8	9	25	28	43	51	47	88	92	94	87	122	183	200	212	296
1999	0	1	1	3	0	1	3	3	7	6	8	25	21	19	30	32	38	62	75	131
2000	0	1	0	0	0	4	6	5	6	13	7	6	7	20	30	52	62	98	140	169
2001	0	0	0	1	3	10	5	11	12	15	15	23	34	64	72	93	130	163	211	230
2002	0	1	0	1	2	5	3	9	11	12	8	24	22	33	37	48	71	65	68	65
2003	0	1	0	0	1	3	5	5	12	16	22	15	21	25	21	17	33	50	53	64
2004	1	0	1	1	2	2	5	5	14	22	17	44	43	49	69	71	81	94	81	86
2005	0	0	0	0	3	2	1	1	2	5	2	6	12	4	7	11	16	20	30	30
2006	0	1	0	1	0	0	1	3	4	0	4	3	5	0	3	6	14	11	31	33
2007	3	0	1	0	5	3	5	7	12	12	12	20	15	19	17	20	27	31	31	50
2008	0	1	1	2	0	1	3	0	3	2	7	5	10	9	19	21	43	41	47	67
2009	0	0	0	3	0	0	1	4	3	4	10	14	15	20	20	39	52	53	67	86
2010	1	0	0	2	0	0	2	1	0	6	12	14	13	22	40	45	72	87	120	143
2011	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	1	2	3	15
2012	0	0	0	0	0	0	0	0	1	2	0	0	1	2	3	0	11	2	1	5

Table 2.2.1 (page 2 of 3)—Fishery size composition, by year and cm.

Year	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
1978	26	29	39	35	41	39	46	38	25	25	27	32	31	32	44	26	46	44	42	51
1979	4	2	8	10	9	26	25	28	40	47	60	62	71	81	82	84	71	79	64	67
1982	26	31	50	56	57	67	100	98	110	125	112	151	149	155	146	154	180	207	144	166
1983	130	138	149	181	170	171	191	182	182	143	133	146	127	121	123	118	115	116	127	101
1984	9	15	27	27	36	61	73	94	136	145	186	191	186	183	195	164	161	161	138	150
1985	58	74	75	68	85	85	63	60	36	37	32	35	49	52	59	73	96	85	120	122
1990	11	8	9	11	9	16	19	31	52	24	41	35	63	33	39	67	50	70	75	105
1991	24	36	56	63	62	76	62	92	103	141	140	186	214	255	252	312	285	324	359	360
1992	463	550	587	621	705	792	820	872	826	886	898	962	990	1025	1183	1297	1328	1454	1522	1752
1993	121	218	240	274	321	433	573	674	751	827	861	957	985	937	846	857	793	754	764	775
1994	101	83	139	160	161	223	233	257	291	297	333	359	389	466	512	572	632	654	720	750
1995	26	29	33	55	83	81	83	107	137	181	186	195	254	269	308	318	385	404	430	451
1996	168	197	268	249	296	334	335	362	416	423	508	453	502	583	534	558	572	685	800	926
1997	43	56	83	78	110	103	165	147	191	227	248	298	348	351	329	366	440	426	397	371
1998	359	455	483	523	639	629	793	723	718	804	822	798	867	808	882	931	1092	1143	1176	1298
1999	118	173	183	215	305	292	317	366	374	380	400	436	471	464	541	516	516	595	592	646
2000	170	246	286	291	362	375	367	462	488	559	582	658	752	825	841	855	875	946	971	968
2001	296	321	347	424	466	495	563	643	741	772	762	851	951	948	1041	1078	1195	1312	1324	1493
2002	74	89	102	110	122	152	164	179	156	147	154	174	165	139	172	164	198	218	224	255
2003	62	110	105	141	140	164	199	228	232	229	229	253	271	290	239	239	311	279	274	304
2004	84	82	112	116	145	174	186	237	264	307	320	362	381	348	398	371	367	405	399	439
2005	51	51	79	67	79	87	118	127	145	154	193	172	229	253	249	258	297	309	334	340
2006	41	49	70	108	121	137	154	163	199	186	215	211	261	298	315	314	395	395	378	388
2007	30	65	56	64	71	92	112	153	197	201	229	271	331	352	409	468	483	491	496	544
2008	88	96	128	172	209	235	299	308	341	323	316	338	300	310	331	301	308	335	316	358
2009	65	90	78	100	104	121	133	154	167	167	190	234	318	324	359	337	407	414	482	485
2010	184	226	232	307	370	399	444	490	459	519	530	496	490	499	504	531	502	493	509	531
2011	16	18	31	37	47	61	49	72	72	94	102	93	118	132	150	145	187	168	191	212
2012	3	9	8	12	16	28	21	16	31	26	31	52	61	81	88	136	118	151	182	212

Year	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83
1978	59	72	58	69	73	62	71	62	48	51	47	45	50	45	25	18	28	20	12	9
1979	54	52	53	53	44	57	59	40	62	54	51	31	42	35	35	22	25	27	13	10
1982	173	151	155	122	131	126	106	116	77	86	89	67	60	64	52	47	32	41	51	41
1983	107	82	74	78	66	72	70	66	65	52	55	60	46	58	45	48	37	35	20	17
1984	178	154	201	155	175	166	144	157	143	117	116	111	73	90	84	79	78	61	59	59
1985	131	142	136	147	129	103	118	73	75	56	51	48	58	37	45	50	43	29	34	35
1990	128	167	179	174	158	157	168	140	170	113	132	162	155	122	150	153	140	106	85	92
1991	380	428	463	565	575	544	698	648	732	801	852	829	852	827	753	829	856	703	774	707
1992	1800	2141	2134	2337	2558	2797	2940	2871	3149	3267	3427	3578	3478	3549	3297	3289	3169	2878	2726	2644
1993	783	828	829	856	775	903	891	866	922	938	992	1035	972	1105	1007	1162	1105	1184	1208	1162
1994	762	853	800	865	828	881	827	808	780	804	766	730	617	655	598	545	550	520	535	498
1995	554	556	590	642	635	686	782	748	735	733	782	890	778	857	837	864	880	821	776	736
1996	914	1040	1158	1030	1056	965	1062	977	992	1071	1042	1125	1010	933	926	931	1037	954	1006	982
1997	363	352	349	317	362	371	351	355	402	383	407	489	458	445	513	582	608	572	548	531
1998	1407	1664	1689	1616	1766	1826	2306	1998	1888	1881	1781	2067	1667	1564	1513	1483	1604	1368	1262	1249
1999	621	616	628	560	717	715	702	664	735	783	829	797	773	808	906	800	836	826	820	808
2000	972	991	977	1054	1028	1040	1124	1002	1133	1112	1053	1053	1012	1050	990	1002	1053	972	1084	988
2001	1383	1452	1495	1607	1693	1659	1697	1651	1631	1558	1564	1361	1349	1263	1122	1076	973	962	898	924
2002	279	324	370	451	447	481	571	637	744	718	738	768	809	790	814	779	757	702	726	671
2003	277	272	357	337	307	366	408	415	372	398	349	420	418	432	469	500	547	580	593	688
2004	416	437	460	483	496	481	530	552	515	491	578	510	552	591	523	537	544	518	532	537
2005	340	366	319	362	408	405	464	454	460	518	534	561	559	561	563	637	685	632	623	598
2006	440	429	364	392	449	361	377	368	389	394	447	411	435	411	479	477	500	457	503	472
2007	461	498	466	532	488	493	456	453	428	440	473	458	491	472	519	502	523	532	531	539
2008	408	460	438	427	481	493	521	515	473	524	498	468	471	437	429	403	422	438	425	372
2009	491	452	486	447	486	404	475	406	414	453	434	457	413	451	413	390	379	400	359	363
2010	577	618	531	583	634	668	821	620	695	775	809	822	825	759	764	763	770	687	618	605
2011	210	210	208	228	195	214	217	155	162	147	145	172	135	179	155	161	221	182	184	201
2012	232	228	219	218	249	280	321	303	343	315	325	281	304	298	251	264	236	210	195	163

Table 2.2.1 (3 of 3)—Fishery size composition, by year and cm.

Year	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
1978	8	8	3	4	1	2	4	2	0	1	0	0	0	0	1	0	0	0	0	0
1979	15	9	7	13	5	2	0	4	4	1	2	4	0	1	0	0	0	0	0	1
1982	32	37	32	22	24	20	27	17	6	10	12	6	3	6	4	3	0	4	3	3
1983	22	21	14	17	28	14	20	19	18	11	12	20	4	4	3	6	9	4	4	2
1984	55	52	36	52	48	37	48	25	33	33	28	26	22	17	31	21	18	17	12	9
1985	35	39	34	37	35	33	44	51	27	23	24	27	28	9	9	21	10	15	6	6
1990	82	64	58	55	40	55	38	21	13	28	15	11	8	9	7	10	5	8	1	2
1991	642	619	600	515	463	393	311	263	259	212	174	171	115	133	103	72	60	28	42	29
1992	2441	2466	2071	1887	1768	1679	1534	1265	1227	1047	982	879	750	690	635	592	406	314	270	237
1993	1165	1170	1104	1048	955	913	780	728	713	609	548	567	498	423	407	364	298	279	252	213
1994	533	480	480	516	499	564	573	423	391	388	344	395	293	255	276	271	269	178	143	145
1995	741	736	683	646	580	525	629	499	552	620	709	623	496	383	334	330	403	236	263	253
1996	936	903	876	791	761	750	747	524	607	522	564	459	427	428	376	392	409	299	273	267
1997	511	563	509	484	523	492	611	491	480	528	476	465	408	429	394	335	361	287	264	239
1998	1122	1276	1163	1043	1227	1098	1286	1038	910	1028	1066	1076	969	903	924	846	964	726	640	618
1999	775	747	738	655	640	581	569	514	473	413	382	354	362	330	357	328	360	300	287	249
2000	1066	1006	1139	991	1064	1102	1210	1008	1027	906	890	760	769	636	624	566	574	520	468	458
2001	834	722	678	662	653	677	655	611	543	546	525	509	534	481	460	492	527	408	371	384
2002	648	603	574	496	495	412	377	322	328	309	280	257	237	197	182	143	224	165	153	142
2003	669	748	731	710	685	675	699	604	560	556	485	430	406	362	319	282	320	201	213	160
2004	472	439	415	408	366	351	394	347	359	361	329	327	313	321	317	233	269	245	216	178
2005	485	516	466	445	387	421	408	336	311	340	296	261	240	238	202	205	188	182	158	155
2006	478	461	525	468	492	457	442	406	366	362	325	279	249	233	210	190	197	168	170	131
2007	596	559	634	593	662	659	689	640	611	662	585	606	544	550	518	474	418	363	357	315
2008	447	431	449	433	445	485	480	470	484	516	454	518	505	497	503	445	515	470	412	459
2009	346	322	322	279	322	301	304	342	336	318	342	341	309	314	320	323	343	286	318	326
2010	580	480	457	502	427	433	429	388	383	396	354	340	398	392	353	383	436	364	446	458
2011	210	216	213	198	182	179	157	164	152	153	125	116	123	113	97	97	87	80	72	55
2012	140	140	152	123	130	113	120	121	127	97	106	80	96	84	72	90	63	66	68	58

Year	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120+
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	2	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1983	2	3	0	1	0	1	0	1	0	0	0	0	0	1	0	0	1
1984	14	7	7	4	1	1	1	0	0	0	1	0	0	0	0	0	0
1985	3	1	9	0	0	0	0	3	0	0	0	0	1	0	0	0	0
1990	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	22	16	9	5	2	1	2	0	0	1	1	1	0	0	0	0	0
1992	211	147	128	115	82	59	67	49	26	16	14	5	3	0	6	1	1
1993	172	142	120	70	78	41	40	29	20	14	7	3	4	2	1	0	1
1994	107	81	59	40	34	27	44	18	11	16	5	9	5	4	3	1	1
1995	218	203	113	90	82	66	112	40	47	26	11	25	9	3	0	1	2
1996	239	247	191	166	120	98	123	50	55	18	18	6	4	5	1	0	5
1997	210	196	145	137	120	99	77	51	37	28	22	26	14	4	6	2	9
1998	586	619	419	331	299	250	244	134	99	74	50	48	24	14	4	9	24
1999	260	223	188	144	124	88	86	49	42	33	24	12	2	6	2	5	13
2000	406	384	343	338	244	177	194	126	93	46	27	29	17	8	3	3	14
2001	306	294	254	224	218	167	193	81	86	54	33	42	16	14	12	16	21
2002	140	111	102	81	64	53	46	27	29	12	5	1	4	1	1	1	0
2003	153	108	98	84	73	49	48	25	29	13	6	4	6	0	5	2	2
2004	193	128	117	98	78	72	64	30	29	16	10	4	4	1	5	3	2
2005	136	126	100	92	70	46	46	26	24	17	9	5	6	3	1	4	9
2006	130	115	94	94	79	65	57	34	26	25	15	12	1	2	4	2	6
2007	263	209	196	171	145	113	86	50	36	28	19	11	10	3	3	2	0
2008	357	328	287	231	209	169	156	89	63	35	21	18	15	10	7	5	67
2009	280	273	261	251	222	151	130	95	74	40	30	24	9	3	0	2	2
2010	387	391	343	316	306	257	218	148	117	62	51	47	20	13	4	1	8
2011	72	58	55	42	41	27	24	26	12	10	3	6	4	3	1	2	4
2012	58	43	42	26	32	25	19	18	19	10	10	7	5	5	2	4	6

Table 2.2.2—Total biomass (t) and abundance, with coefficients of variation (CV), by subarea and year, as estimated by bottom trawl surveys. Surveys prior to 1991 were U.S.-Japan cooperative surveys. The NMFS survey time series begins in 1991.

Biomass:

	Western Aleutians (543)		Central Aleutians (542)		Eastern Aleutians (541)		Aleutian management area	
Year	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV
1980	7,953	0.34	37,934	0.46	33,883	0.21	79,770	0.24
1983	69,613	0.39	66,137	0.07	51,827	0.19	187,577	0.16
1986	48,377	0.31	134,235	0.48	49,641	0.12	232,253	0.28
1991	75,514	0.09	39,729	0.11	64,926	0.37	180,170	0.14
1994	23,797	0.29	51,538	0.39	78,081	0.30	153,416	0.21
1997	14,357	0.26	30,252	0.21	28,239	0.23	72,848	0.13
2000	44,261	0.42	36,456	0.27	47,117	0.22	127,834	0.18
2002	23,623	0.25	24,687	0.26	25,241	0.33	73,551	0.16
2004	9,637	0.17	20,731	0.21	51,851	0.30	82,219	0.20
2006	19,734	0.23	21,823	0.19	43,348	0.54	84,905	0.29
2010	21,341	0.41	11,207	0.26	23,277	0.22	55,826	0.19
2012	13,514	0.26	14,804	0.20	30,592	0.24	58,911	0.15

Abundance (1000s of fish):

	Western Aleutians (543)		Central Aleutians (542)		Eastern Aleutians (541)		Aleutian management area	
Year	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV
1980	3,856	0.24	10,740	0.43	15,161	0.23	29,757	0.20
1983	21,418	0.35	18,322	0.07	19,690	0.19	59,430	0.14
1986	31,154	0.62	44,790	0.35	23,993	0.15	99,937	0.25
1991	18,679	0.15	13,138	0.13	33,669	0.44	65,486	0.23
1994	4,491	0.24	12,425	0.20	37,284	0.44	54,201	0.31
1997	4,000	0.25	12,014	0.28	8,859	0.16	24,873	0.15
2000	13,899	0.54	10,661	0.30	18,819	0.29	43,379	0.23
2002	6,840	0.30	6,704	0.17	12,579	0.28	26,123	0.16
2004	3,220	0.17	5,755	0.17	13,040	0.24	22,016	0.15
2006	6,521	0.32	6,243	0.16	8,882	0.33	21,646	0.17
2010	5,323	0.34	5,169	0.17	9,577	0.22	20,068	0.14
2012	4,100	0.14	5,596	0.20	9,480	0.21	19,176	0.12

Table 2.2.3 (page 1 of 2)—Trawl survey size composition, by year and cm.

Year	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	3	35	12	0	0	0	0	0	0	0	0	0	0	1	0	3	2	1
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	11	1	0	1
1994	0	0	0	0	0	0	0	0	0	62	254	398	595	529	236	211	167	63	12	16
1997	0	0	0	0	0	0	0	0	0	0	0	0	3	12	5	19	35	87	81	111
2000	0	0	0	0	0	0	0	0	0	0	5	38	33	37	51	20	2	6	0	2
2002	0	0	0	0	0	1	0	0	0	0	6	6	12	16	25	9	13	12	13	5
2004	0	0	0	0	0	0	0	0	0	0	5	0	1	3	6	2	14	14	8	8
2006	0	0	0	0	0	0	0	0	0	5	11	13	42	71	69	57	22	21	18	16
2010	0	0	0	0	0	0	0	0	0	0	6	16	12	14	15	23	17	10	3	0
2012	0	0	0	0	0	0	0	0	0	0	1	5	19	24	50	44	50	31	24	8

Year	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
1980	0	0	0	0	0	0	5	4	4	11	12	7	21	26	24	38	18	19	17	30
1983	3	11	19	47	51	68	124	152	73	103	84	73	60	70	61	58	89	141	89	115
1986	30	2	60	45	22	32	87	166	223	319	340	416	462	363	331	239	267	262	248	253
1991	3	2	4	9	26	81	114	147	216	249	293	321	299	242	224	150	139	85	92	54
1994	7	4	4	4	3	3	9	18	24	34	40	44	48	43	47	38	30	44	59	46
1997	102	82	42	19	2	12	7	15	27	32	36	51	61	60	60	58	45	32	31	34
2000	1	4	7	4	3	14	10	13	13	15	26	12	32	14	17	4	27	24	21	52
2002	19	9	9	21	22	28	22	37	45	99	92	103	134	142	119	93	85	63	52	62
2004	5	1	1	1	0	0	0	3	1	5	6	17	25	30	24	28	26	40	41	38
2006	23	13	3	2	1	2	0	1	6	1	5	3	8	13	11	20	12	19	14	9
2010	0	3	1	1	2	10	15	26	22	27	23	23	27	16	23	28	25	28	35	44
2012	9	5	1	0	3	2	2	11	7	32	23	18	32	55	38	18	41	29	31	20

Year	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
1980	41	31	34	78	54	62	80	61	55	48	35	47	35	42	29	22	22	41	35	26
1983	127	92	101	104	156	127	170	184	227	201	208	171	144	166	213	247	242	197	242	326
1986	276	263	333	241	251	234	244	207	259	170	169	214	137	132	140	123	144	142	160	241
1991	80	52	64	72	73	68	54	76	63	58	68	60	98	94	82	115	116	110	121	139
1994	60	63	90	90	102	83	102	67	68	66	72	62	53	93	78	76	84	93	95	123
1997	34	25	35	47	52	59	82	70	73	79	96	103	106	127	150	125	172	165	121	148
2000	96	134	93	117	110	131	123	154	131	136	125	119	130	125	175	183	165	187	156	151
2002	56	59	62	77	81	87	63	62	76	68	95	69	97	72	74	61	64	41	39	40
2004	32	48	56	60	84	83	97	86	84	91	67	98	81	92	83	66	109	80	60	89
2006	21	27	38	39	44	62	63	69	75	57	61	49	49	56	29	45	37	35	51	45
2010	63	84	92	114	117	126	113	121	138	146	135	118	112	116	93	69	93	81	65	45
2012	26	30	34	31	32	42	44	64	58	49	70	56	66	62	86	90	88	86	79	104

Year	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83
1980	38	30	47	51	47	56	37	39	28	31	26	14	14	9	8	18	14	11	16	7
1983	173	256	162	176	250	209	216	175	169	190	170	153	170	168	173	165	87	161	90	80
1986	201	202	221	244	261	277	212	174	231	282	192	175	171	87	122	122	76	67	65	54
1991	86	119	163	157	162	131	136	119	136	117	119	99	89	109	115	81	84	75	63	61
1994	119	124	102	125	114	128	109	118	124	111	133	77	79	86	78	50	71	47	72	62
1997	135	106	85	103	112	80	63	50	59	50	49	58	49	34	27	27	33	31	31	23
2000	154	148	168	115	112	97	84	86	77	86	70	82	88	59	46	49	42	28	27	36
2002	44	33	33	34	31	34	34	33	36	34	42	45	48	42	35	39	49	49	50	55
2004	102	90	89	100	92	83	84	83	88	61	81	68	72	65	62	48	38	55	52	40
2006	35	39	54	29	42	39	44	30	47	47	39	35	41	34	38	42	47	46	46	30
2010	54	56	56	69	78	58	47	43	35	35	31	33	33	24	23	13	9	23	19	19
2012	157	105	97	85	95	80	63	47	56	49	67	59	43	40	39	49	37	36	32	19

Table 2.2.3 (page 2 of 2)—Trawl survey size composition, by year and cm.

Year	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
1980	10	7	2	2	14	5	5	10	0	5	2	5	0	0	2	0	0	0	1	0
1983	46	95	57	28	23	22	78	16	6	11	11	13	4	17	3	2	19	2	0	1
1986	32	35	35	29	26	24	40	10	9	14	16	11	8	12	11	7	11	1	1	1
1991	65	46	56	50	22	31	30	43	30	20	11	14	6	12	4	12	4	1	5	0
1994	52	72	46	59	44	54	93	60	66	48	38	42	50	27	18	27	9	10	8	8
1997	25	19	23	24	23	18	22	31	26	9	25	8	20	13	16	20	9	10	22	7
2000	19	27	18	26	22	15	12	17	13	6	12	10	8	6	10	8	5	2	4	5
2002	39	44	38	38	32	15	30	29	10	21	16	12	9	7	8	4	5	3	6	13
2004	35	40	37	37	11	18	21	15	21	17	14	15	11	8	8	15	7	2	8	8
2006	54	32	28	41	37	39	47	28	17	17	13	28	19	15	10	14	13	5	10	4
2010	12	4	16	12	10	15	9	11	9	8	10	6	7	9	5	7	10	15	5	6
2012	20	11	14	13	15	7	10	8	7	9	5	16	9	5	4	5	6	6	5	4

Year	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120+
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	1	3	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1991	3	3	1	6	0	1	0	0	0	0	0	1	0	0	0	0	0
1994	7	5	5	2	0	2	0	0	0	2	2	0	0	0	0	0	0
1997	3	10	8	1	3	3	2	0	0	0	0	0	0	0	0	0	0
2000	3	4	6	1	11	2	1	2	0	0	0	1	0	0	0	0	0
2002	1	6	2	2	2	0	1	0	3	0	0	1	0	0	0	0	0
2004	5	6	3	2	3	1	0	1	0	0	0	0	0	0	0	0	0
2006	15	3	3	6	8	3	0	1	3	2	1	0	1	0	0	0	0
2010	3	8	3	6	6	4	3	5	1	1	0	1	0	0	0	0	0
2012	7	1	1	1	1	1	0	1	0	0	0	0	1	0	0	0	0

Table 2.2.4a— Growth (except annual *dev*s estimated by Model 2), recruitment (except annual *dev*s), catchability, initial fishing mortality, initial age composition, and base selectivity parameters as estimated internally by at least one of the assessment models. Shaded cells indicate that the parameter was not estimated internally in that particular model; "n/a" means that the parameter is not applicable to that particular model.

	Model 1		Model 2		Model 3		Model 4	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
Length at age 1 (cm)	17.748	0.240	17.932	0.572	17.609	0.431	17.921	0.270
Asymptotic length (cm)	106.841	0.764	100.169	2.061	109.258	1.245	132.936	4.866
Brody growth coefficient	0.227	0.004	0.250	0.008	0.220	0.007	0.147	0.009
SD of length at age 1 (cm)	3.713	0.182	3.019	0.207	3.817	0.352	2.701	0.193
SD of length at age 20 (cm)	7.508	0.359	8.891	0.396	7.440	0.713	15.185	1.422
ln(mean post-1976 recruitment)	11.099	0.045	11.044	0.051	11.070	0.056	10.767	0.134
σ(recruitment)	0.570	_	0.570	_	0.570	_	1.020	0.128
ln(pre-1977 recruitment offset)	-1.113	0.146	-0.597	0.185	-0.641	0.172	-2.290	0.294
Initial age 3 ln(abundance) dev	-0.096	0.437	0.168	0.499	-0.176	0.475	0.307	0.838
Initial age 2 ln(abundance) dev	0.704	0.284	0.768	0.316	0.154	0.383	1.304	0.588
Initial age 1 ln(abundance) dev	0.101	0.331	-0.752	0.360	-0.048	0.411	-0.144	0.876
Initial fishing mortality	0.010	0.002	0.007	0.001	0.006	0.001	0.076	0.021
Fishery selectivity P1	75.665	0.903	76.186	1.285	78.650	1.597	93.072	2.098
Fishery selectivity P2	10.000	_	10.000	_	10.000	_	-1.231	0.208
Fishery selectivity P3	6.088	0.051	6.113	0.065	6.197	0.084	6.583	0.062
Fishery selectivity P4	0.000	223.603	0.000	223.605	0.000	223.603	3.727	0.440
Fishery selectivity P6	10.000	_	10.000	_	10.000	_	-3.630	0.836
Survey selectivity P1	4.014	0.011	3.980	0.017	4.897	0.062	4.970	0.409
Survey selectivity P2	-9.923	2.340	-9.946	1.664	-9.870	3.861	10.000	_
Survey selectivity P3	1.100	0.149	1.094	0.151	1.742	0.178	2.081	0.313
Survey selectivity P4	-9.990	0.310	-9.915	2.259	-7.068	17.463	0.000	_
Survey selectivity P5	-7.788	0.627	-7.621	0.604	-8.035	1.710	-9.981	0.600
Survey selectivity P6	-0.791	0.121	-0.847	0.156	-1.207	0.207	10.000	_

Table 2.2.4b— Annual log-scale recruitment *dev*s estimated by Models 1-4. "Est." = point estimate, "SD" = standard deviation.

	Model 1		Model 2		Model 3		Model 4	
Year	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
1977	-0.094	0.181	-0.073	0.284	0.127	0.275	-1.556	0.558
1978	0.221	0.159	0.728	0.226	0.141	0.231	-0.843	0.340
1979	-0.303	0.148	0.001	0.249	0.044	0.215	-1.075	0.368
1980	-0.113	0.132	0.356	0.177	0.247	0.194	-0.397	0.274
1981	0.971	0.138	1.731	0.184	0.567	0.190	-0.730	0.396
1982	-0.530	0.227	-0.332	0.396	-0.480	0.303	-0.752	0.443
1983	0.472	0.122	1.002	0.155	0.469	0.182	-1.109	0.694
1984	1.675	0.137	2.382	0.184	1.115	0.196	-0.677	0.796
1985	-0.678	0.466	-0.293	0.519	-0.959	0.451	0.899	0.321
1986	1.748	0.110	1.598	0.203	1.291	0.165	0.896	0.272
1987	0.790	0.147	0.051	0.457	0.627	0.213	0.849	0.202
1988	0.187	0.147	-0.061	0.259	0.090	0.218	-0.143	0.285
1989	1.334	0.074	1.472	0.087	1.044	0.112	1.289	0.121
1990	0.520	0.118	-1.128	0.378	0.229	0.195	0.006	0.325
1991	0.588	0.102	0.013	0.190	0.445	0.156	0.698	0.142
1992	-0.293	0.155	-0.304	0.191	-0.492	0.235	-0.781	0.353
1993	1.109	0.066	0.900	0.090	0.871	0.101	1.332	0.109
1994	-0.022	0.138	-0.545	0.284	-0.056	0.200	-0.265	0.353
1995	0.498	0.085	-0.012	0.121	0.319	0.137	0.682	0.141
1996	0.773	0.068	0.457	0.095	0.657	0.108	0.968	0.108
1997	0.640	0.070	0.503	0.088	0.539	0.113	1.033	0.108
1998	0.076	0.095	-0.218	0.131	0.043	0.147	0.268	0.166
1999	0.131	0.091	-0.206	0.118	0.036	0.147	0.647	0.136
2000	0.195	0.084	0.184	0.090	0.247	0.130	0.956	0.118
2001	-0.300	0.102	-0.208	0.113	-0.239	0.160	0.314	0.175
2002	-0.633	0.117	-0.580	0.127	-0.564	0.181	0.081	0.193
2003	-0.444	0.095	-0.607	0.122	-0.372	0.149	0.307	0.148
2004	-1.182	0.152	-0.816	0.127	-0.930	0.209	-0.721	0.302
2005	-0.450	0.087	-0.450	0.115	-0.396	0.137	0.428	0.140
2006	-1.351	0.143	-0.992	0.144	-1.081	0.204	-0.487	0.243
2007	-0.522	0.090	-0.393	0.107	-0.291	0.132	0.615	0.156
2008	-1.288	0.144	-1.042	0.153	-0.927	0.211	-0.577	0.301
2009	-1.721	0.180	-1.396	0.213	-1.139	0.256	-0.697	0.288
2010	-1.546	0.247	-1.352	0.240	-0.922	0.324	-1.056	0.407
2011	-0.457	0.393	-0.371	0.387	-0.301	0.410	-0.404	0.419

Table 2.2.4c—Annual additive *dev*s applied to the *ascending_width* parameter of the survey selectivity schedule, as estimated by Models 1-4.

	Model 1		Model 2		Model 3		Model 4	
Year	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
1980	-0.065	0.020	-0.083	0.022	-0.038	0.025	n/a	n/a
1983	-0.067	0.017	-0.089	0.017	-0.029	0.022	n/a	n/a
1986	-0.026	0.018	-0.048	0.019	0.025	0.030	n/a	n/a
1991	0.039	0.019	0.033	0.021	0.049	0.028	0.008	0.026
1994	0.197	0.034	0.163	0.032	0.152	0.038	0.112	0.034
1997	0.016	0.018	0.037	0.019	-0.019	0.021	-0.020	0.024
2000	-0.011	0.018	-0.011	0.019	-0.020	0.024	-0.058	0.023
2002	0.045	0.021	0.027	0.019	0.011	0.025	0.002	0.027
2004	-0.031	0.019	-0.025	0.019	-0.047	0.023	-0.070	0.025
2006	0.040	0.021	0.039	0.021	0.009	0.026	0.012	0.030
2010	0.007	0.021	0.003	0.021	0.002	0.025	-0.025	0.027

Table 2.2.4d—Annual multiplicative *dev*s applied to the initial and asymptotic lengths, as estimated by Model 2.

	Length at age 1.5		Linf			Length at age 1.5		Linf	
Year	Estimate	St. Dev.	Estimate	St. Dev.	Year	Estimate	St. Dev.	Estimate	St. Dev.
1977	-0.007	0.092	-0.094	0.071	1995	-0.068	0.078	-0.074	0.048
1978	0.066	0.092	-0.101	0.033	1996	0.219	0.038	0.021	0.049
1979	0.029	0.093	-0.091	0.067	1997	-0.062	0.084	0.119	0.039
1980	-0.036	0.090	0.022	0.070	1998	0.011	0.088	-0.027	0.042
1981	-0.101	0.083	0.000	0.068	1999	-0.030	0.052	0.056	0.040
1982	-0.017	0.097	0.010	0.050	2000	-0.183	0.075	0.001	0.047
1983	-0.024	0.087	-0.004	0.055	2001	0.035	0.053	0.021	0.042
1984	0.011	0.083	0.058	0.061	2002	0.021	0.075	0.136	0.037
1985	0.018	0.112	-0.058	0.050	2003	0.047	0.057	0.035	0.022
1986	0.002	0.096	-0.010	0.058	2004	0.039	0.079	0.115	0.043
1987	0.009	0.099	-0.047	0.087	2005	0.020	0.041	0.055	0.022
1988	0.022	0.094	-0.055	0.086	2006	-0.030	0.082	0.186	0.036
1989	0.012	0.067	-0.051	0.077	2007	-0.081	0.128	0.046	0.023
1990	0.046	0.094	0.005	0.065	2008	0.012	0.098	0.147	0.058
1991	-0.075	0.085	-0.050	0.045	2009	0.013	0.058	0.054	0.071
1992	0.047	0.080	-0.352	0.057	2010	0.067	0.069	0.057	0.060
1993	-0.069	0.034	0.032	0.043	2011	0.066	0.047	0.099	0.059
1994	-0.022	0.093	0.092	0.047					

Table 2.2.5—Full-selection fishing mortality rates as estimated by Models 1-4.

Year	Model 1	Model 2	Model 3	Model 4
1977	0.034	0.025	0.021	0.262
1978	0.035	0.027	0.022	0.297
1979	0.059	0.049	0.039	0.581
1980	0.059	0.048	0.041	0.724
1981	0.067	0.052	0.050	1.252
1982	0.065	0.048	0.052	1.911
1983	0.058	0.042	0.047	2.007
1984	0.047	0.032	0.040	1.566
1985	0.034	0.022	0.032	1.019
1986	0.029	0.019	0.029	0.812
1987	0.047	0.031	0.051	1.667
1988	0.014	0.010	0.018	0.536
1989	0.010	0.008	0.014	0.215
1990	0.014	0.012	0.021	0.175
1991	0.017	0.015	0.024	0.140
1992	0.074	0.085	0.107	0.513
1993	0.060	0.080	0.088	0.407
1994	0.039	0.048	0.057	0.242
1995	0.031	0.040	0.045	0.173
1996	0.065	0.090	0.092	0.337
1997	0.055	0.074	0.078	0.281
1998	0.081	0.110	0.114	0.393
1999	0.071	0.100	0.098	0.326
2000	0.104	0.153	0.143	0.467
2001	0.095	0.146	0.127	0.397
2002	0.092	0.136	0.120	0.342
2003	0.106	0.151	0.136	0.358
2004	0.105	0.142	0.131	0.319
2005	0.093	0.118	0.112	0.245
2006	0.115	0.132	0.134	0.265
2007	0.198	0.211	0.225	0.422
2008	0.233	0.235	0.259	0.484
2009	0.279	0.263	0.299	0.572
2010	0.377	0.346	0.384	0.733
2011	0.169	0.143	0.160	0.284
2012	0.316	0.257	0.270	0.423

Table 2.2.6— Summary of key management reference points from the standard projection algorithm (last seven rows are from SS). All biomass figures are in t. Color scale extends from red (minimum) to green (maximum).

Quantity	Model 1	Model 2	Model 3	Model 4
B100%	163,000	157,000	140,000	90,300
B40%	65,200	62,700	56,200	36,100
B35%	57,000	54,900	49,200	31,600
B(2013)	19,300	19,300	24,100	22,800
B(2014)	19,800	20,300	25,400	23,100
B(2013)/B100%	0.118	0.123	0.171	0.253
B(2014)/B100%	0.122	0.129	0.181	0.255
F40%	0.239	0.255	0.248	0.340
F35%	0.285	0.305	0.297	0.410
maxFABC(2013)	0.062	0.069	0.099	0.208
maxFABC(2014)	0.064	0.073	0.105	0.210
maxABC(2013)	2,990	3,410	6,080	8,690
maxABC(2014)	3,260	3,850	6,860	8,620
FOFL(2013)	0.074	0.083	0.118	0.251
FOFL(2014)	0.076	0.088	0.126	0.254
OFL(2013)	3,540	4,050	7,190	10,300
OFL(2014)	3,860	4,570	8,110	10,200
Pr(maxABC(2013)>truOFL(2013))	0.222	0.393	0.253	0.295
Pr(maxABC(2014)>truOFL(2014))	0.236	0.405	0.264	0.305
Pr(B(2013)<B20%)	0.999	0.355	0.661	0.319
Pr(B(2014)<B20%)	1.000	0.539	0.532	0.237
Pr(B(2015)<B20%)	0.986	0.391	0.208	0.211
Pr(B(2016)<B20%)	0.407	0.105	0.050	0.168
Pr(B(2017)<B20%)	0.081	0.032	0.020	0.144

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)
B(year) = projected spawning biomass for year (assuming catch = maxABC)
B(year)/B100% = ratio of 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
maxFABC(year) = maximum permissible ABC fishing mortality rate under Tier 3
maxABC(year) = maximum permissible ABC under Tier 3
FOFL(year) = OFL fishing mortality rate under Tier 3
OFL(year) = OFL under Tier 3 (second year assumes catch = maxABC in first year)
Pr(maxABC(year)>truOFL(year)) = probability that maxABC is greater than the "true" OFL
Pr(B(year)<B20%) = probability that spawning biomass is less than 20% of unfished

Table 2.2.7—Schedule of fishery selectivity at length (cm) as defined by parameter estimates under Model 3.

Len.	Sel.	Len.	Sel.	Len.	Sel.	Len.	Sel.	Len.	Sel.
1	0.000	31	0.010	61	0.530	91	1.000	121	1.000
2	0.000	32	0.012	62	0.569	92	1.000	122	1.000
3	0.000	33	0.014	63	0.607	93	1.000	123	1.000
4	0.000	34	0.017	64	0.646	94	1.000	124	1.000
5	0.000	35	0.021	65	0.684	95	1.000	125	1.000
6	0.000	36	0.025	66	0.722	96	1.000	126	1.000
7	0.000	37	0.029	67	0.759	97	1.000	127	1.000
8	0.000	38	0.035	68	0.794	98	1.000	128	1.000
9	0.000	39	0.041	69	0.827	99	1.000	129	1.000
10	0.000	40	0.048	70	0.859	100	1.000	130	1.000
11	0.000	41	0.056	71	0.888	101	1.000	131	1.000
12	0.000	42	0.065	72	0.914	102	1.000	132	1.000
13	0.000	43	0.075	73	0.937	103	1.000	133	1.000
14	0.000	44	0.087	74	0.957	104	1.000	134	1.000
15	0.000	45	0.100	75	0.973	105	1.000	135	1.000
16	0.000	46	0.114	76	0.986	106	1.000	136	1.000
17	0.000	47	0.130	77	0.994	107	1.000	137	1.000
18	0.001	48	0.148	78	0.999	108	1.000	138	1.000
19	0.001	49	0.167	79	1.000	109	1.000	139	1.000
20	0.001	50	0.188	80	1.000	110	1.000	140	1.000
21	0.001	51	0.211	81	1.000	111	1.000	141	1.000
22	0.001	52	0.235	82	1.000	112	1.000	142	1.000
23	0.002	53	0.262	83	1.000	113	1.000	143	1.000
24	0.002	54	0.290	84	1.000	114	1.000	144	1.000
25	0.003	55	0.320	85	1.000	115	1.000	145	1.000
26	0.004	56	0.352	86	1.000	116	1.000	146	1.000
27	0.004	57	0.385	87	1.000	117	1.000	147	1.000
28	0.005	58	0.420	88	1.000	118	1.000	148	1.000
29	0.007	59	0.456	89	1.000	119	1.000	149	1.000
30	0.008	60	0.492	90	1.000	120	1.000	150	1.000

Table 2.2.8—Schedule of survey selectivity at ages 0-20 as defined by parameter estimates under Model 3.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1980	0.000	0.019	0.117	0.400	0.815	1.000	0.335	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
1983	0.000	0.026	0.140	0.432	0.829	1.000	0.335	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
1986	0.000	0.090	0.288	0.593	0.891	1.000	0.335	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
1991	0.000	0.126	0.352	0.649	0.909	1.000	0.335	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
1994	0.000	0.257	0.532	0.779	0.948	1.000	0.335	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
1997	0.000	0.035	0.165	0.464	0.843	1.000	0.335	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
2000	0.000	0.034	0.163	0.462	0.842	1.000	0.335	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
2002	0.000	0.071	0.251	0.558	0.879	1.000	0.335	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
2004	0.000	0.014	0.096	0.366	0.799	1.000	0.335	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
2006	0.000	0.067	0.243	0.551	0.876	1.000	0.335	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
2010	0.000	0.059	0.225	0.532	0.869	1.000	0.335	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
2012	0.000	0.056	0.218	0.525	0.867	1.000	0.335	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230

Table 2.2.9—Schedules of population, fishery, and survey length (cm) and weight (kg) at age as defined by parameter estimates under Model 3.

	Population		Fishery		Survey	
Age	Length	Weight	Length	Weight	Length	Weight
0	6.20	0.00	10.42	0.01	6.35	0.00
1	17.61	0.06	21.05	0.10	17.61	0.06
2	35.73	0.52	39.06	0.68	35.73	0.52
3	50.27	1.51	53.00	1.78	50.27	1.51
4	61.93	2.92	63.81	3.19	61.93	2.92
5	71.29	4.55	72.26	4.73	71.29	4.55
6	78.80	6.23	79.14	6.31	78.80	6.23
7	84.82	7.87	84.91	7.89	84.82	7.87
8	89.65	9.38	89.68	9.38	89.65	9.38
9	93.53	10.72	93.54	10.72	93.53	10.72
10	96.64	11.89	96.64	11.89	96.64	11.89
11	99.13	12.89	99.13	12.89	99.13	12.89
12	101.14	13.73	101.14	13.73	101.14	13.73
13	102.74	14.43	102.74	14.43	102.74	14.43
14	104.03	15.01	104.03	15.01	104.03	15.01
15	105.06	15.49	105.06	15.49	105.06	15.49
16	105.89	15.88	105.89	15.88	105.89	15.88
17	106.56	16.20	106.56	16.20	106.56	16.20
18	107.09	16.45	107.09	16.45	107.09	16.45
19	107.52	16.66	107.52	16.66	107.52	16.66
20	108.16	16.98	108.16	16.98	108.16	16.98

Table 2.2.10—Time series of age 0+ biomass, age 3+ biomass, female spawning biomass (t), and standard deviation of spawning biomass ("SB SD") as estimated this year under Model 3. Values for 2013 listed under this year's assessment represent Stock Synthesis projections, and may not correspond exactly to values generated by the standard projection model. (Columns under "Last year's assessment" are shown for completeness, even though no previous age-structured assessment exists for this stock.)

	Last year's assessment				This year's assessment			
Year	Age 0+	Age 3+	Spawn.	SB SD	Age 0+	Age 3+	Spawn.	SB SD
1977	n/a	n/a	n/a	n/a	182,798	178,569	68,961	12,717
1978	n/a	n/a	n/a	n/a	178,366	174,334	67,455	12,438
1979	n/a	n/a	n/a	n/a	177,074	169,116	65,638	11,891
1980	n/a	n/a	n/a	n/a	181,616	173,632	63,495	11,145
1981	n/a	n/a	n/a	n/a	193,718	186,195	63,521	10,353
1982	n/a	n/a	n/a	n/a	209,657	200,327	66,424	9,778
1983	n/a	n/a	n/a	n/a	230,056	218,623	72,117	9,602
1984	n/a	n/a	n/a	n/a	252,719	247,548	79,704	9,714
1985	n/a	n/a	n/a	n/a	272,940	260,631	88,538	10,096
1986	n/a	n/a	n/a	n/a	300,345	281,096	97,890	10,810
1987	n/a	n/a	n/a	n/a	336,062	330,766	107,132	11,667
1988	n/a	n/a	n/a	n/a	366,343	342,345	115,936	12,777
1989	n/a	n/a	n/a	n/a	413,265	400,748	131,179	14,665
1990	n/a	n/a	n/a	n/a	455,616	446,568	148,104	16,690
1991	n/a	n/a	n/a	n/a	484,131	465,527	164,191	17,892
1992	n/a	n/a	n/a	n/a	504,642	495,612	177,159	18,234
1993	n/a	n/a	n/a	n/a	482,242	472,048	172,026	17,806
1994	n/a	n/a	n/a	n/a	458,193	452,496	167,446	16,979
1995	n/a	n/a	n/a	n/a	439,355	423,795	164,727	15,871
1996	n/a	n/a	n/a	n/a	427,829	420,845	160,091	14,503
1997	n/a	n/a	n/a	n/a	401,615	391,533	147,596	13,031
1998	n/a	n/a	n/a	n/a	385,967	372,650	139,611	11,715
1999	n/a	n/a	n/a	n/a	369,210	357,757	129,698	10,620
2000	n/a	n/a	n/a	n/a	362,679	355,369	124,551	9,757
2001	n/a	n/a	n/a	n/a	341,440	333,996	117,692	9,030
2002	n/a	n/a	n/a	n/a	321,351	312,798	113,576	8,327
2003	n/a	n/a	n/a	n/a	301,564	296,228	108,462	7,532
2004	n/a	n/a	n/a	n/a	275,336	271,261	100,318	6,631
2005	n/a	n/a	n/a	n/a	247,727	243,133	92,266	5,741
2006	n/a	n/a	n/a	n/a	222,930	219,949	84,939	4,980
2007	n/a	n/a	n/a	n/a	195,164	190,716	75,024	4,353
2008	n/a	n/a	n/a	n/a	159,952	157,253	60,345	3,856
2009	n/a	n/a	n/a	n/a	131,353	126,410	47,619	3,502
2010	n/a	n/a	n/a	n/a	110,009	107,298	37,480	3,285
2011	n/a	n/a	n/a	n/a	90,349	88,035	28,961	3,199
2012	n/a	n/a	n/a	n/a	88,173	85,048	28,633	3,265
2013					81,723	75,796	25,849	3,386

Table 2.2.11— Time series of age 0 recruitment (1000s of fish), with standard deviations, as estimated this year under Model 3. (Columns under "Last year's assessment" are shown for completeness, even though no previous age-structured assessment exists for this stock.)

	Last year's values		This year's values	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	n/a	n/a	61,954	17,898
1978	n/a	n/a	62,869	14,869
1979	n/a	n/a	57,054	12,496
1980	n/a	n/a	69,883	14,300
1981	n/a	n/a	96,227	19,564
1982	n/a	n/a	33,783	10,506
1983	n/a	n/a	87,247	17,656
1984	n/a	n/a	166,389	36,850
1985	n/a	n/a	20,915	9,915
1986	n/a	n/a	198,471	34,120
1987	n/a	n/a	102,186	22,142
1988	n/a	n/a	59,715	13,476
1989	n/a	n/a	155,055	19,265
1990	n/a	n/a	68,650	13,706
1991	n/a	n/a	85,169	13,597
1992	n/a	n/a	33,376	8,056
1993	n/a	n/a	130,415	13,878
1994	n/a	n/a	51,593	10,350
1995	n/a	n/a	75,119	10,805
1996	n/a	n/a	105,320	11,985
1997	n/a	n/a	93,561	9,882
1998	n/a	n/a	56,986	8,291
1999	n/a	n/a	56,590	8,144
2000	n/a	n/a	69,860	8,473
2001	n/a	n/a	42,967	6,616
2002	n/a	n/a	31,054	5,574
2003	n/a	n/a	37,640	5,455
2004	n/a	n/a	21,531	4,546
2005	n/a	n/a	36,726	4,838
2006	n/a	n/a	18,512	3,839
2007	n/a	n/a	40,794	5,316
2008	n/a	n/a	21,608	4,556
2009	n/a	n/a	17,468	4,605
2010	n/a	n/a	21,707	7,366
2011			43,833	18,888
Average	n/a		66,635	

Table 2.2.12—Numbers at age (1000s) at the beginning of each year as estimated by Model 3.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	61954	19498	17000	8692	8667	6147	4351	3078	2177	1539	1089	770	544	385	272	193	136	96	68	48	116
1978	62869	44097	13878	12092	6158	6095	4296	3034	2145	1517	1073	759	536	379	268	190	134	95	67	47	115
1979	57054	44749	31387	9871	8566	4328	4257	2993	2112	1493	1056	747	528	373	264	187	132	93	66	47	113
1980	69883	40609	31850	22314	6967	5963	2980	2918	2049	1446	1022	723	511	361	256	181	128	90	64	45	109
1981	96227	49741	28904	22642	15742	4845	4098	2039	1994	1400	988	698	494	349	247	175	123	87	62	44	105
1982	33783	68492	35403	20542	15942	10889	3304	2779	1380	1350	948	669	473	334	236	167	118	84	59	42	101
1983	87247	24045	48748	25159	14458	11017	7415	2236	1878	933	912	640	452	319	226	160	113	80	56	40	96
1984	166389	62099	17114	34648	17725	10017	7531	5041	1518	1275	633	619	435	307	217	153	108	77	54	38	93
1985	20915	118431	44199	12167	24447	12330	6889	5155	3447	1038	872	433	423	297	210	148	105	74	52	37	90
1986	198471	14886	84293	31430	8601	17092	8543	4756	3556	2378	716	601	299	292	205	145	102	72	51	36	87
1987	102186	141266	10595	59945	22230	6021	11866	5912	3288	2458	1644	495	416	206	202	142	100	71	50	35	85
1988	59715	72733	100545	7530	42195	15366	4102	8036	3998	2223	1662	1111	335	281	140	136	96	68	48	34	82
1989	155055	42503	51769	71527	5339	29731	10773	2870	5620	2796	1555	1162	777	234	196	98	95	67	47	33	81
1990	68650	110363	30252	36832	50757	3770	20912	7565	2015	3945	1962	1091	816	545	164	138	68	67	47	33	80
1991	85169	48863	78552	21519	26100	35707	2637	14592	5276	1405	2751	1368	761	569	380	115	96	48	47	33	79
1992	33376	60621	34779	55870	15236	18320	24891	1833	10137	3665	976	1911	950	528	395	264	80	67	33	32	78
1993	130415	23756	43145	24674	38856	10203	11901	15974	1173	6482	2343	624	1222	608	338	253	169	51	43	21	70
1994	51593	92826	16908	30628	17232	26309	6738	7782	10419	765	4226	1527	407	796	396	220	165	110	33	28	60
1995	75119	36723	66068	12014	21535	11877	17845	4541	5236	7009	514	2842	1027	274	536	266	148	111	74	22	59
1996	105320	53468	26137	46961	8468	14940	8135	12160	3091	3563	4769	350	1934	699	186	364	181	101	75	50	55
1997	93561	74964	38054	18552	32765	5719	9829	5296	7896	2006	2312	3095	227	1255	454	121	236	118	65	49	69
1998	56986	66594	53354	27022	12984	22310	3809	6488	3489	5199	1321	1522	2037	150	826	299	80	156	77	43	77
1999	56590	40561	47396	37845	18766	8662	14409	2428	4124	2216	3302	839	967	1294	95	525	190	50	99	49	76
2000	69860	40279	28868	33635	26373	12633	5671	9330	1568	2661	1430	2131	541	624	835	61	339	122	33	64	81
2001	42967	49724	28666	20459	23214	17309	7963	3517	5763	968	1643	883	1315	334	385	515	38	209	76	20	89
2002	31054	30583	35389	20326	14169	15374	11059	5014	2207	3614	607	1030	553	825	209	241	323	24	131	47	69
2003	37640	22103	21766	25098	14098	9421	9880	7011	3168	1394	2282	383	650	349	521	132	152	204	15	83	73
2004	21531	26791	15731	15429	17346	9287	5971	6166	4359	1969	866	1418	238	404	217	323	82	95	127	9	97
2005	36726	15325	19067	11152	10675	11460	5911	3744	3853	2722	1229	540	885	149	252	135	202	51	59	79	66
2006	18512	26141	10907	13525	7748	7128	7412	3775	2384	2451	1731	782	344	563	95	160	86	128	33	38	92
2007	40794	13176	18604	7732	9352	5109	4525	4633	2351	1484	1525	1077	486	214	350	59	100	54	80	20	81
2008	21608	29036	9377	13152	5242	5855	3001	2590	2636	1336	843	867	612	276	122	199	33	57	30	45	58
2009	17468	15380	20663	6622	8853	3221	3344	1664	1426	1449	734	463	476	336	152	67	109	18	31	17	57
2010	21707	12433	10944	14575	4418	5315	1777	1782	880	753	765	387	244	251	177	80	35	58	10	16	39
2011	43833	15450	8847	7700	9548	2528	2727	872	866	427	365	371	188	118	122	86	39	17	28	5	27
2012	64209	31199	10996	6267	5294	6204	1570	1663	530	525	259	221	225	114	72	74	52	24	10	17	19

Table 2.2.13—Estimates of "effective" fishing mortality (= $-\ln(N_{a+1,t+1}/N_{a,t})-M$) at age and year for Model 3.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.000	0.001	0.005	0.012	0.018	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
1978	0.000	0.001	0.005	0.013	0.019	0.021	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
1979	0.000	0.001	0.008	0.022	0.033	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
1980	0.000	0.001	0.009	0.023	0.035	0.040	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
1981	0.000	0.002	0.011	0.029	0.043	0.049	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
1982	0.000	0.002	0.011	0.030	0.044	0.050	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
1983	0.000	0.001	0.010	0.027	0.040	0.046	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
1984	0.000	0.001	0.009	0.023	0.034	0.039	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
1985	0.000	0.001	0.007	0.018	0.027	0.030	0.031	0.031	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
1986	0.000	0.001	0.006	0.017	0.025	0.028	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
1987	0.000	0.002	0.011	0.029	0.044	0.050	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
1988	0.000	0.001	0.004	0.010	0.015	0.017	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
1989	0.000	0.000	0.003	0.008	0.012	0.013	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
1990	0.000	0.001	0.004	0.012	0.018	0.020	0.020	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
1991	0.000	0.001	0.005	0.014	0.021	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
1992	0.000	0.003	0.023	0.061	0.091	0.104	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107
1993	0.000	0.003	0.019	0.050	0.075	0.085	0.087	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088
1994	0.000	0.002	0.012	0.032	0.048	0.055	0.056	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
1995	0.000	0.001	0.010	0.026	0.038	0.044	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
1996	0.000	0.003	0.020	0.053	0.079	0.089	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092
1997	0.000	0.002	0.017	0.044	0.066	0.075	0.077	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078
1998	0.000	0.003	0.025	0.065	0.097	0.110	0.113	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114
1999	0.000	0.003	0.021	0.056	0.083	0.095	0.097	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
2000	0.000	0.004	0.031	0.081	0.122	0.138	0.142	0.142	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143
2001	0.000	0.004	0.027	0.072	0.108	0.122	0.126	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127
2002	0.000	0.004	0.026	0.068	0.102	0.116	0.119	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120
2003	0.000	0.004	0.029	0.077	0.116	0.131	0.135	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136
2004	0.000	0.004	0.028	0.075	0.112	0.127	0.130	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131
2005	0.000	0.003	0.024	0.064	0.096	0.109	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112
2006	0.000	0.004	0.029	0.076	0.115	0.130	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134
2007	0.000	0.007	0.049	0.128	0.192	0.218	0.224	0.225	0.225	0.225	0.225	0.225	0.225	0.225	0.225	0.225	0.225	0.225	0.225
2008	0.000	0.008	0.056	0.147	0.220	0.250	0.257	0.258	0.258	0.258	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259
2009	0.000	0.009	0.065	0.170	0.255	0.289	0.297	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299
2010	0.000	0.012	0.083	0.219	0.327	0.371	0.382	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384
2011	0.000	0.005	0.035	0.091	0.136	0.155	0.159	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160
2012	0.000	0.008	0.058	0.154	0.230	0.261	0.268	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270

Table 2.2.14—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2013-2025 (Scenario 1), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	6,080	6,080	6,080	6,080	0
2014	6,860	6,860	6,860	6,860	0
2015	8,980	8,980	8,980	8,980	3
2016	13,400	13,500	13,500	13,700	122
2017	18,700	19,800	20,200	23,100	1,534
2018	21,300	25,800	27,300	38,700	5,705
2019	21,100	30,100	32,000	48,900	8,714
2020	20,000	33,300	34,100	51,700	10,115
2021	19,000	34,600	35,200	53,000	10,929
2022	19,200	35,200	35,600	55,300	11,211
2023	18,900	35,600	35,800	54,900	11,078
2024	19,200	35,100	35,600	54,700	10,822
2025	19,600	35,300	35,500	54,300	10,683

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	24,100	24,100	24,100	24,100	0
2014	25,400	25,400	25,400	25,400	0
2015	27,900	27,900	27,900	27,900	7
2016	32,800	32,900	33,000	33,200	146
2017	38,900	39,700	40,000	41,900	1,047
2018	42,900	45,900	46,800	53,300	3,440
2019	43,900	50,200	51,700	65,100	6,774
2020	43,000	53,000	54,700	74,200	9,637
2021	41,800	54,400	56,500	77,500	11,514
2022	41,700	54,800	57,600	79,100	12,570
2023	41,700	55,600	58,000	81,900	12,899
2024	41,700	55,300	57,900	82,200	12,669
2025	42,000	55,200	57,800	81,700	12,321

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	0.10	0.10	0.10	0.10	0.00
2014	0.10	0.10	0.10	0.10	0.00
2015	0.12	0.12	0.12	0.12	0.00
2016	0.14	0.14	0.14	0.14	0.00
2017	0.17	0.17	0.17	0.18	0.00
2018	0.19	0.20	0.20	0.23	0.01
2019	0.19	0.22	0.22	0.25	0.02
2020	0.19	0.23	0.23	0.25	0.02
2021	0.18	0.24	0.23	0.25	0.02
2022	0.18	0.24	0.23	0.25	0.02
2023	0.18	0.25	0.23	0.25	0.02
2024	0.18	0.24	0.23	0.25	0.02
2025	0.18	0.24	0.23	0.25	0.02

Table 2.2.15—Projections for BSAI 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 2013-2025 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	14,500	14,500	14,500	14,500	0
2014	13,900	13,900	13,900	13,900	0
2015	15,600	15,600	15,600	15,600	1
2016	19,400	19,500	19,500	19,700	107
2017	22,600	23,600	24,000	26,500	1,375
2018	23,000	26,900	27,900	36,400	4,403
2019	22,600	29,500	31,000	45,600	7,090
2020	22,000	32,000	33,200	49,400	8,667
2021	21,800	33,200	34,700	51,300	9,581
2022	22,200	34,100	35,700	54,500	9,949
2023	22,300	34,700	36,100	54,500	9,829
2024	23,000	34,700	36,200	54,200	9,548
2025	23,200	34,900	36,200	53,600	9,397

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	23,500	23,500	23,500	23,500	0
2014	21,900	21,900	21,900	21,900	0
2015	22,300	22,300	22,300	22,300	8
2016	25,600	25,700	25,700	26,000	150
2017	30,300	31,100	31,400	33,500	1,089
2018	33,600	36,800	37,700	44,700	3,654
2019	34,600	41,400	43,200	57,700	7,395
2020	34,400	45,700	47,500	68,900	10,644
2021	33,900	48,700	50,600	73,700	12,748
2022	33,900	50,600	52,700	76,400	13,911
2023	34,300	51,800	53,900	79,900	14,276
2024	35,000	52,500	54,500	80,000	14,059
2025	35,100	52,600	54,600	80,300	13,712

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	0.25	0.25	0.25	0.25	0.00
2014	0.25	0.25	0.25	0.25	0.00
2015	0.25	0.25	0.25	0.25	0.00
2016	0.25	0.25	0.25	0.25	0.00
2017	0.25	0.25	0.25	0.25	0.00
2018	0.25	0.25	0.25	0.25	0.00
2019	0.25	0.25	0.25	0.25	0.00
2020	0.25	0.25	0.25	0.25	0.00
2021	0.25	0.25	0.25	0.25	0.00
2022	0.25	0.25	0.25	0.25	0.00
2023	0.25	0.25	0.25	0.25	0.00
2024	0.25	0.25	0.25	0.25	0.00
2025	0.25	0.25	0.25	0.25	0.00

Table 2.2.16—Projections for BSAI 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 2013-2025 (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	6,080	6,080	6,080	6,080	0
2014	6,860	6,860	6,860	6,860	0
2015	8,980	8,980	8,980	8,980	3
2016	11,800	11,800	11,800	11,900	52
2017	14,000	14,500	14,700	16,000	682
2018	14,900	16,900	17,400	21,800	2,284
2019	15,100	18,800	19,700	27,900	3,903
2020	15,100	20,800	21,500	31,300	5,014
2021	15,200	22,100	22,900	32,900	5,742
2022	15,600	22,900	23,900	35,100	6,137
2023	15,900	23,600	24,500	36,100	6,211
2024	16,200	24,000	24,800	35,900	6,113
2025	16,400	24,200	25,000	36,200	6,013

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	24,100	24,100	24,100	24,100	0
2014	25,400	25,400	25,400	25,400	0
2015	27,900	27,900	27,900	27,900	7
2016	32,900	33,000	33,000	33,300	150
2017	39,600	40,500	40,800	42,800	1,097
2018	45,500	48,800	49,700	56,900	3,805
2019	48,700	56,100	58,200	73,800	8,203
2020	50,100	63,100	65,400	90,800	12,655
2021	50,300	68,600	71,100	101,000	16,019
2022	50,600	72,500	75,300	106,000	18,207
2023	52,000	75,300	78,200	114,000	19,315
2024	52,800	77,400	80,000	116,000	19,508
2025	53,300	78,500	81,000	116,000	19,236

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	0.10	0.10	0.10	0.10	0.00
2014	0.10	0.10	0.10	0.10	0.00
2015	0.12	0.12	0.12	0.12	0.00
2016	0.12	0.12	0.12	0.12	0.00
2017	0.12	0.12	0.12	0.12	0.00
2018	0.12	0.12	0.12	0.12	0.00
2019	0.12	0.12	0.12	0.12	0.00
2020	0.12	0.12	0.12	0.12	0.00
2021	0.12	0.12	0.12	0.12	0.00
2022	0.12	0.12	0.12	0.12	0.00
2023	0.12	0.12	0.12	0.12	0.00
2024	0.12	0.12	0.12	0.12	0.00
2025	0.12	0.12	0.12	0.12	0.00

Table 2.2.17— Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = 0 in 2013-2025 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2024	0	0	0	0	0
2025	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	24,400	24,400	24,400	24,400	0
2014	28,000	28,000	28,000	28,000	0
2015	32,900	33,000	33,000	33,000	8
2016	40,700	40,800	40,900	41,200	151
2017	51,100	51,900	52,200	54,300	1,107
2018	61,400	64,800	65,700	73,300	3,957
2019	69,100	77,200	79,500	96,800	9,076
2020	74,200	89,200	92,200	123,000	15,056
2021	77,500	100,000	103,000	142,000	20,305
2022	79,700	108,000	112,000	155,000	24,282
2023	82,900	115,000	119,000	167,000	26,899
2024	85,800	121,000	125,000	177,000	28,192
2025	88,300	125,000	128,000	181,000	28,526

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2024	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00

Table 2.2.18— Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2013-2025 (Scenario 6), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	7,190	7,190	7,190	7,190	0
2014	7,870	7,870	7,870	7,870	0
2015	10,100	10,100	10,100	10,100	3
2016	14,900	15,000	15,100	15,300	140
2017	20,500	21,800	22,300	25,600	1,747
2018	22,900	28,000	29,700	42,500	6,526
2019	22,400	32,200	34,600	55,500	10,220
2020	20,900	35,100	36,700	57,100	11,798
2021	19,900	35,900	37,700	58,200	12,603
2022	19,900	36,200	38,000	60,500	12,781
2023	19,800	36,500	37,800	59,400	12,558
2024	19,700	36,300	37,500	59,700	12,267
2025	20,300	36,200	37,300	58,700	12,137

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	24,000	24,000	24,000	24,000	0
2014	24,900	24,900	24,900	24,900	0
2015	27,100	27,100	27,100	27,200	7
2016	31,700	31,800	31,800	32,100	146
2017	37,300	38,100	38,400	40,300	1,038
2018	40,800	43,800	44,600	51,000	3,368
2019	41,200	47,400	48,800	61,600	6,436
2020	40,200	49,700	51,100	68,600	8,801
2021	38,900	50,600	52,300	70,100	10,210
2022	38,600	50,800	52,900	72,200	10,934
2023	38,900	51,100	52,900	74,000	11,056
2024	38,800	50,700	52,800	73,600	10,734
2025	39,200	50,700	52,500	73,300	10,406

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	0.12	0.12	0.12	0.12	0.00
2014	0.12	0.12	0.12	0.12	0.00
2015	0.14	0.14	0.14	0.14	0.00
2016	0.16	0.16	0.16	0.16	0.00
2017	0.19	0.20	0.20	0.21	0.01
2018	0.21	0.23	0.23	0.27	0.02
2019	0.21	0.25	0.25	0.30	0.03
2020	0.21	0.26	0.26	0.30	0.03
2021	0.20	0.27	0.26	0.30	0.03
2022	0.20	0.27	0.26	0.30	0.03
2023	0.20	0.27	0.26	0.30	0.03
2024	0.20	0.27	0.26	0.30	0.03
2025	0.20	0.27	0.26	0.30	0.03

Table 2.2.19—Projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2013-2014 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	6,080	6,080	6,080	6,080	0
2014	6,860	6,860	6,860	6,860	0
2015	10,600	10,600	10,600	10,600	3
2016	15,300	15,400	15,500	15,700	142
2017	20,800	22,100	22,600	25,800	1,756
2018	23,000	28,100	29,800	42,600	6,529
2019	22,400	32,200	34,600	55,500	10,212
2020	20,900	35,100	36,700	57,100	11,795
2021	19,800	35,900	37,700	58,200	12,603
2022	19,900	36,200	37,900	60,500	12,782
2023	19,800	36,500	37,800	59,400	12,558
2024	19,700	36,300	37,500	59,700	12,268
2025	20,300	36,200	37,300	58,700	12,137

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	24,100	24,100	24,100	24,100	0
2014	25,400	25,400	25,400	25,400	0
2015	27,800	27,800	27,800	27,900	7
2016	32,200	32,300	32,300	32,600	146
2017	37,600	38,400	38,700	40,600	1,038
2018	40,900	43,900	44,700	51,100	3,366
2019	41,300	47,400	48,800	61,600	6,433
2020	40,200	49,700	51,100	68,600	8,799
2021	38,900	50,600	52,300	70,100	10,209
2022	38,600	50,800	52,800	72,200	10,933
2023	38,900	51,000	52,900	74,000	11,055
2024	38,800	50,700	52,700	73,600	10,733
2025	39,200	50,700	52,500	73,300	10,406

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2013	0.10	0.10	0.10	0.10	0.00
2014	0.10	0.10	0.10	0.10	0.00
2015	0.14	0.14	0.14	0.14	0.00
2016	0.16	0.16	0.16	0.17	0.00
2017	0.19	0.20	0.20	0.21	0.01
2018	0.21	0.23	0.23	0.27	0.02
2019	0.21	0.25	0.25	0.30	0.03
2020	0.21	0.26	0.26	0.30	0.03
2021	0.20	0.27	0.26	0.30	0.03
2022	0.20	0.27	0.26	0.30	0.03
2023	0.20	0.27	0.26	0.30	0.03
2024	0.20	0.27	0.26	0.30	0.03
2025	0.20	0.27	0.26	0.30	0.03

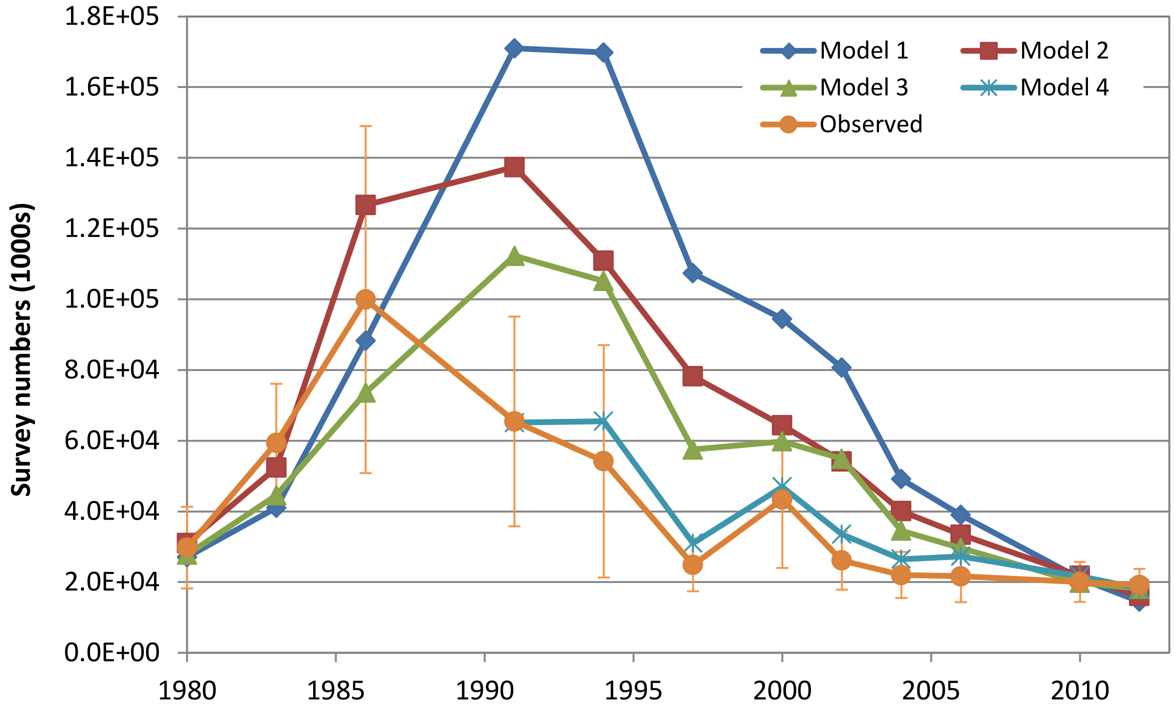

Figure 2.2.1—Fit of the four models to the trawl survey abundance time series.

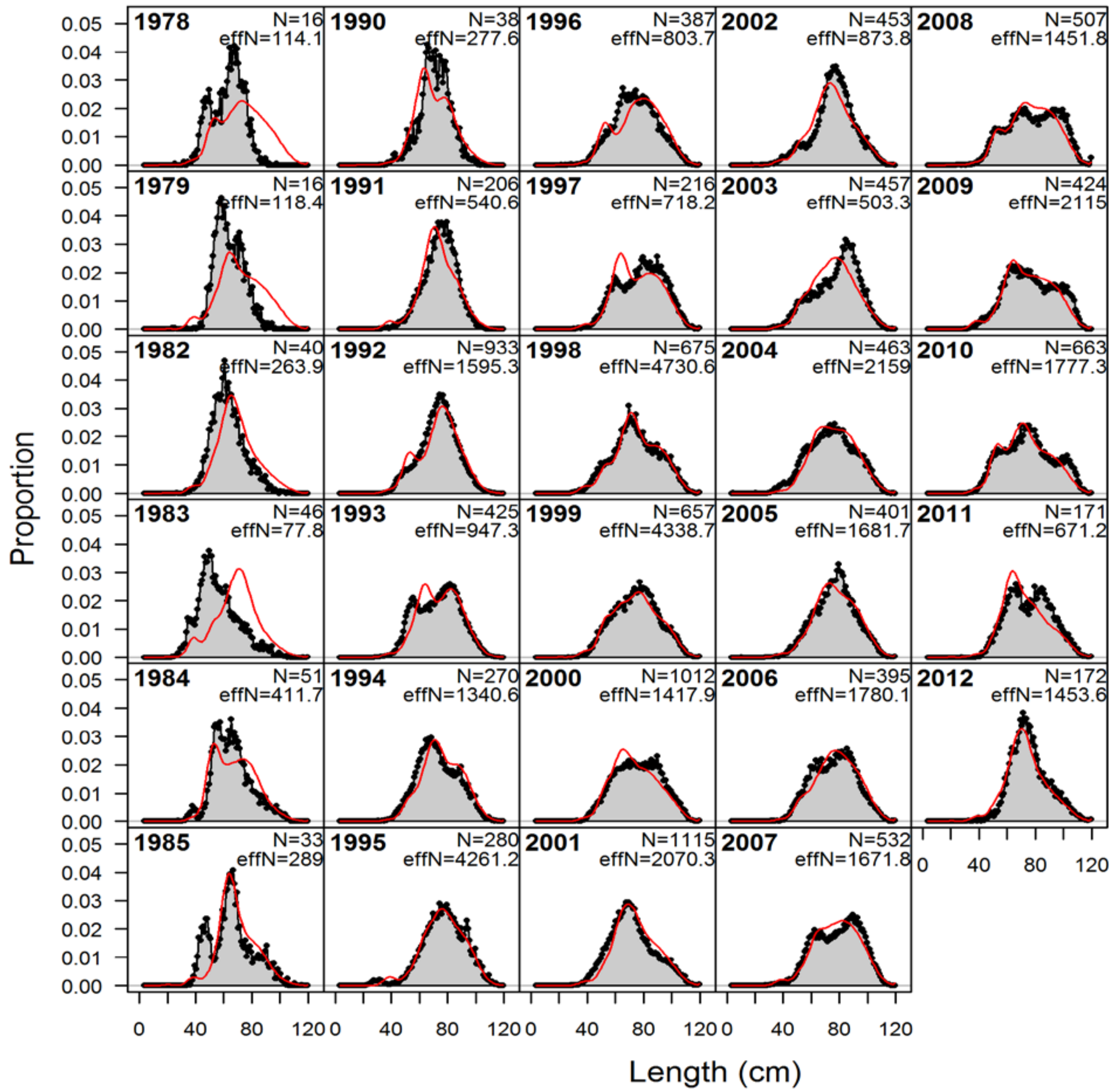

Figure 2.2.2a—Fit to fishery size composition data obtained by Model 1 (grey = observed, red = estimated).

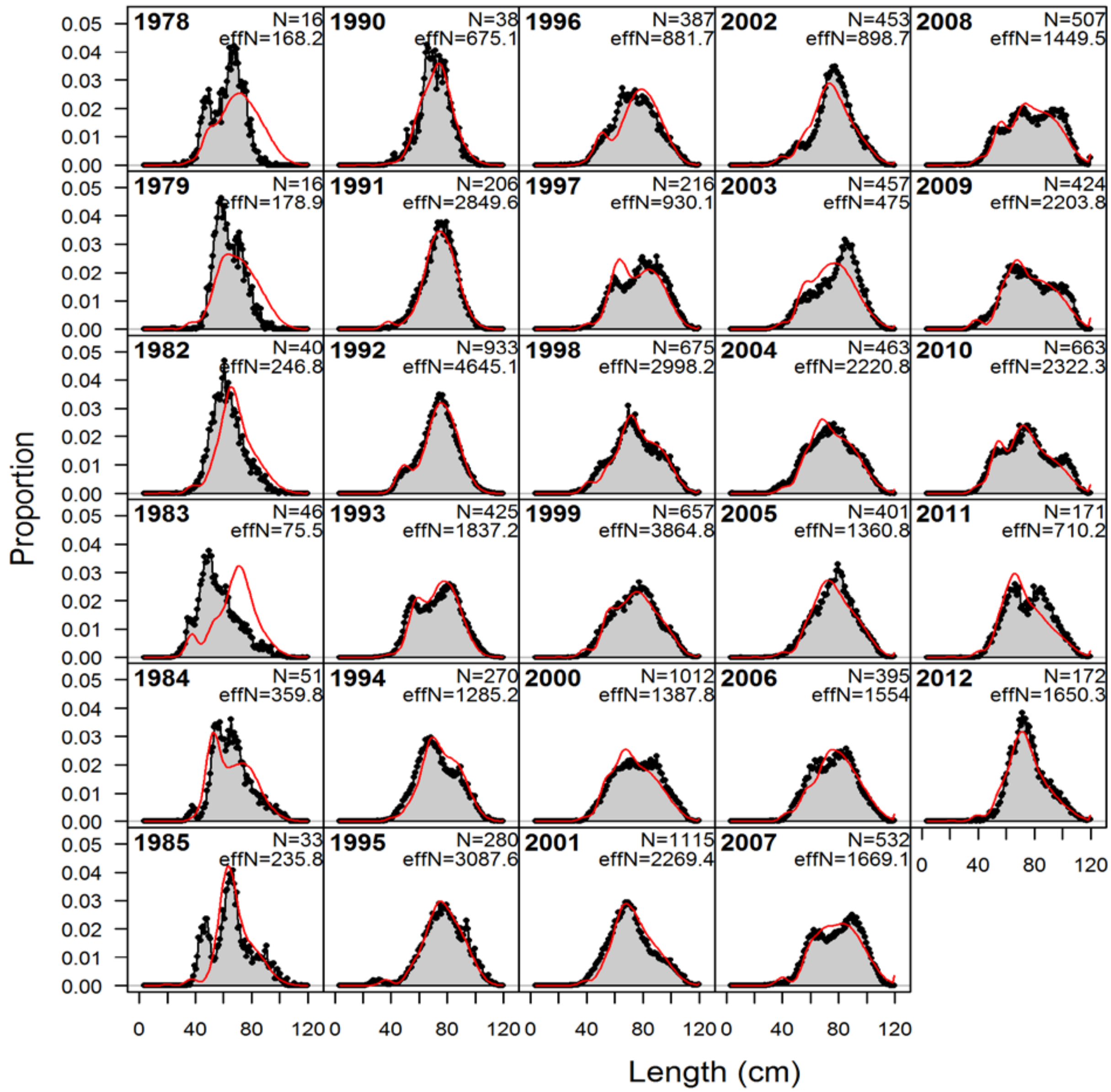

Figure 2.2.2b—Fit to fishery size composition data obtained by Model 2 (grey = observed, red = estimated).

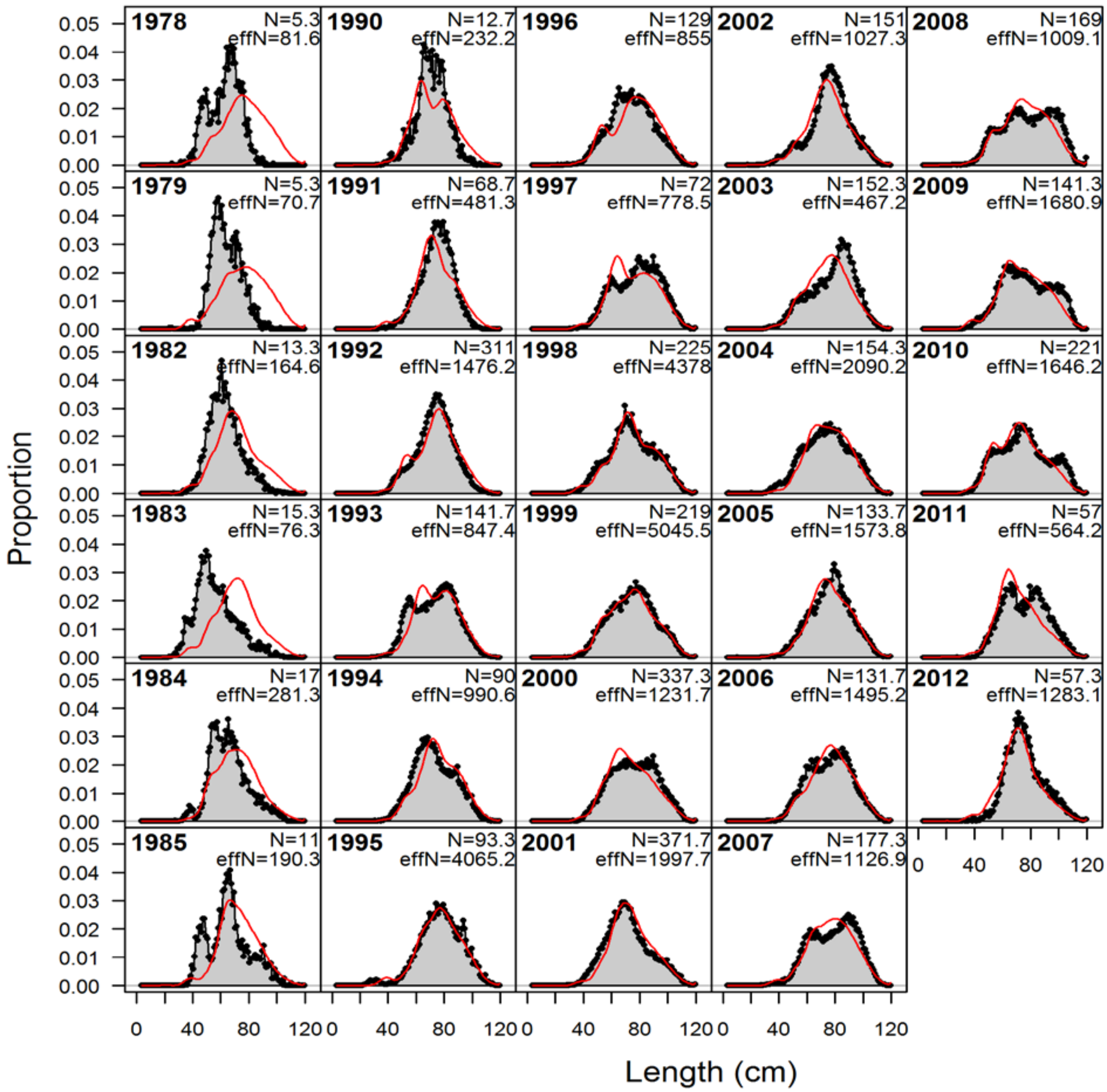

Figure 2.2.2c—Fit to fishery size composition data obtained by Model 3 (grey = observed, red = estimated).

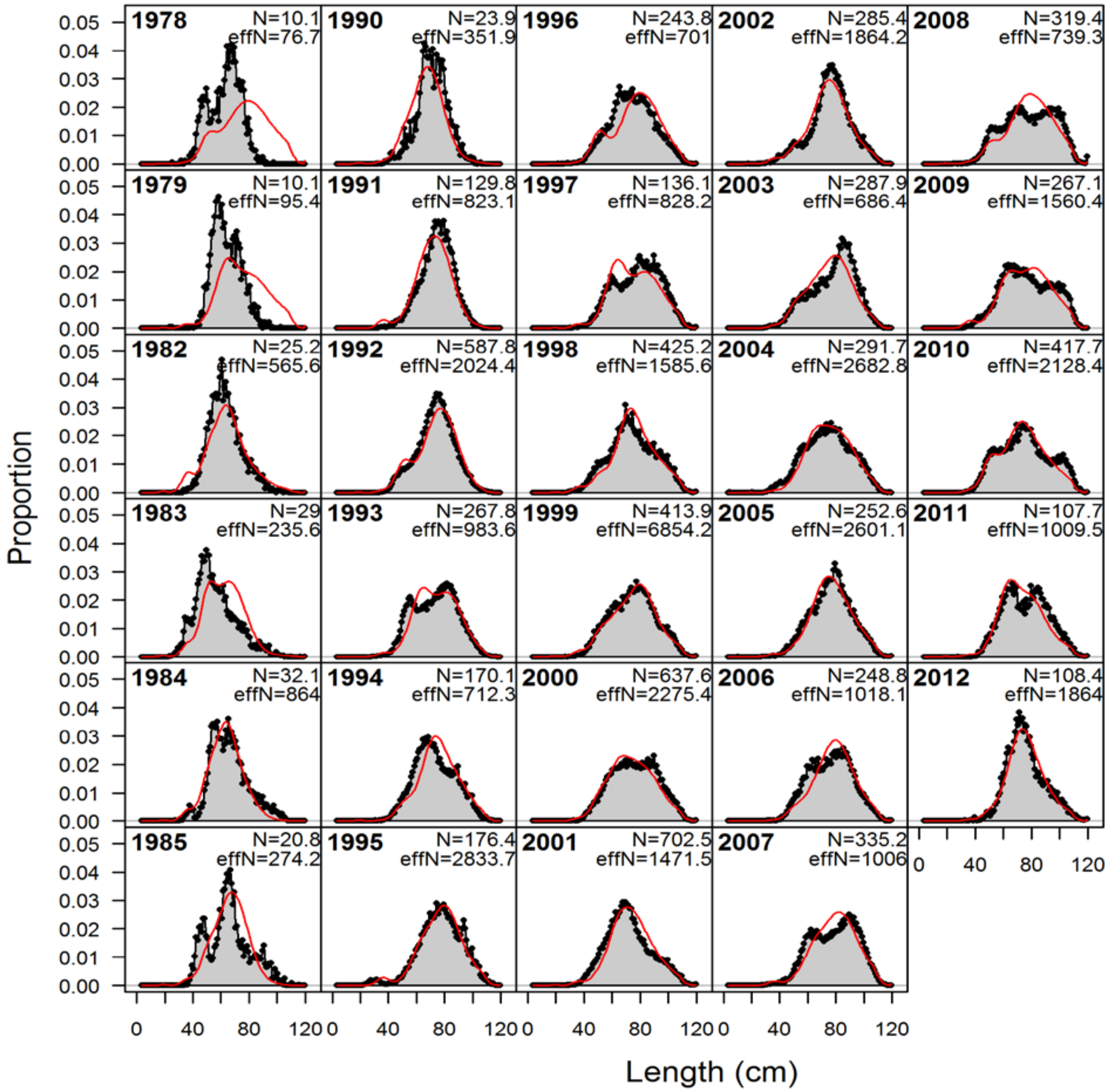

Figure 2.2.2d—Fit to fishery size composition data obtained by Model 4 (grey = observed, red = estimated).

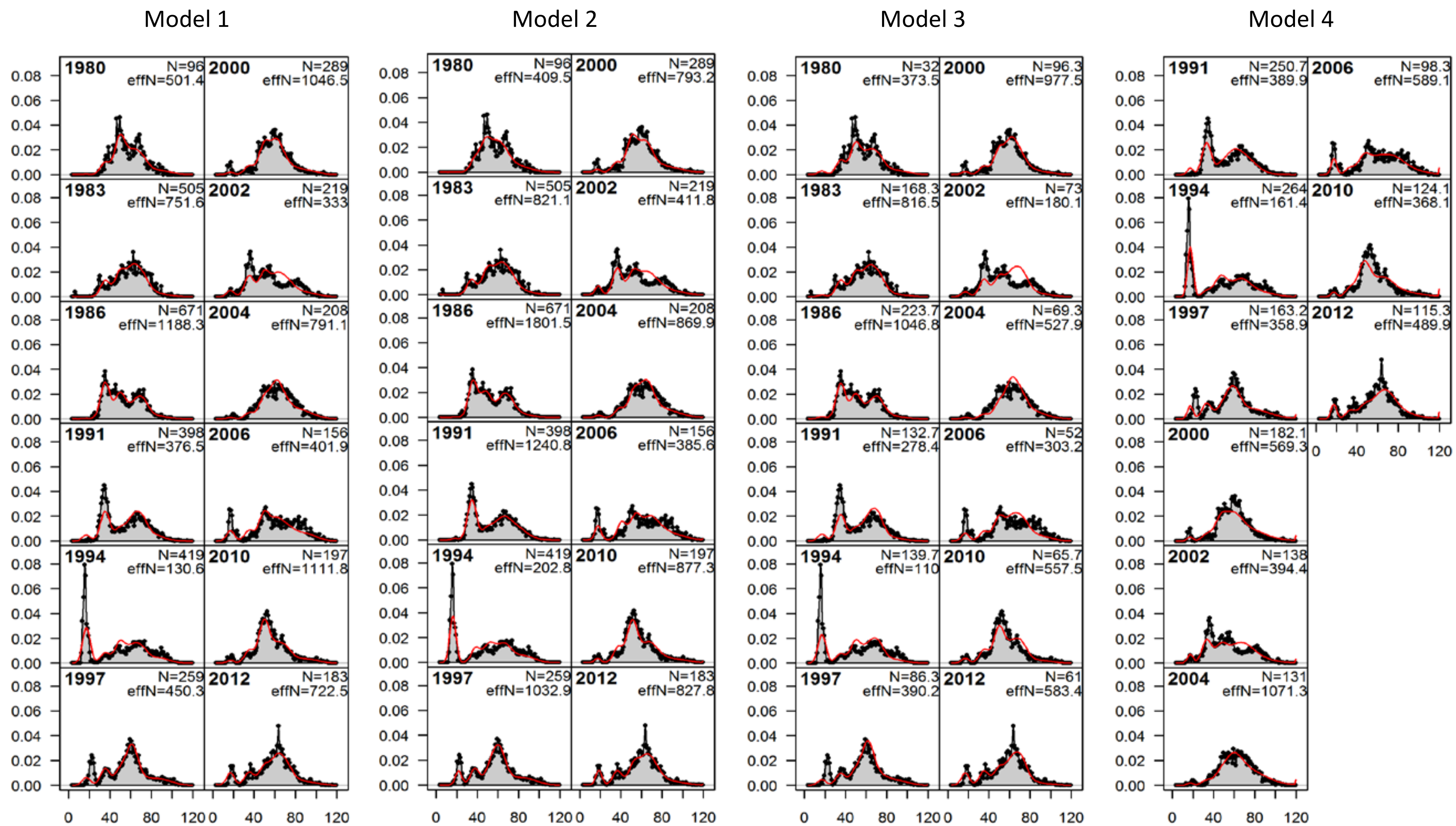

Figure 2.2.3—Fits of the four models to the survey age composition data (grey = observed, red = estimated).

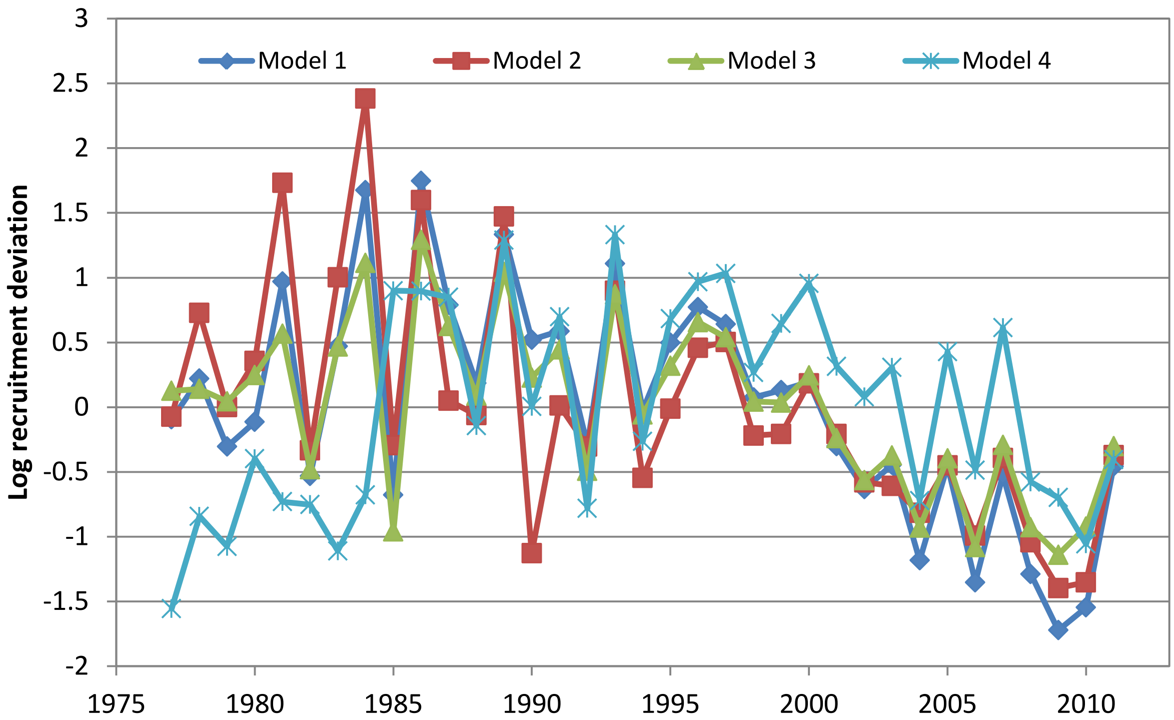

Figure 2.2.4—Time series of log recruitment deviations estimated by the four models.

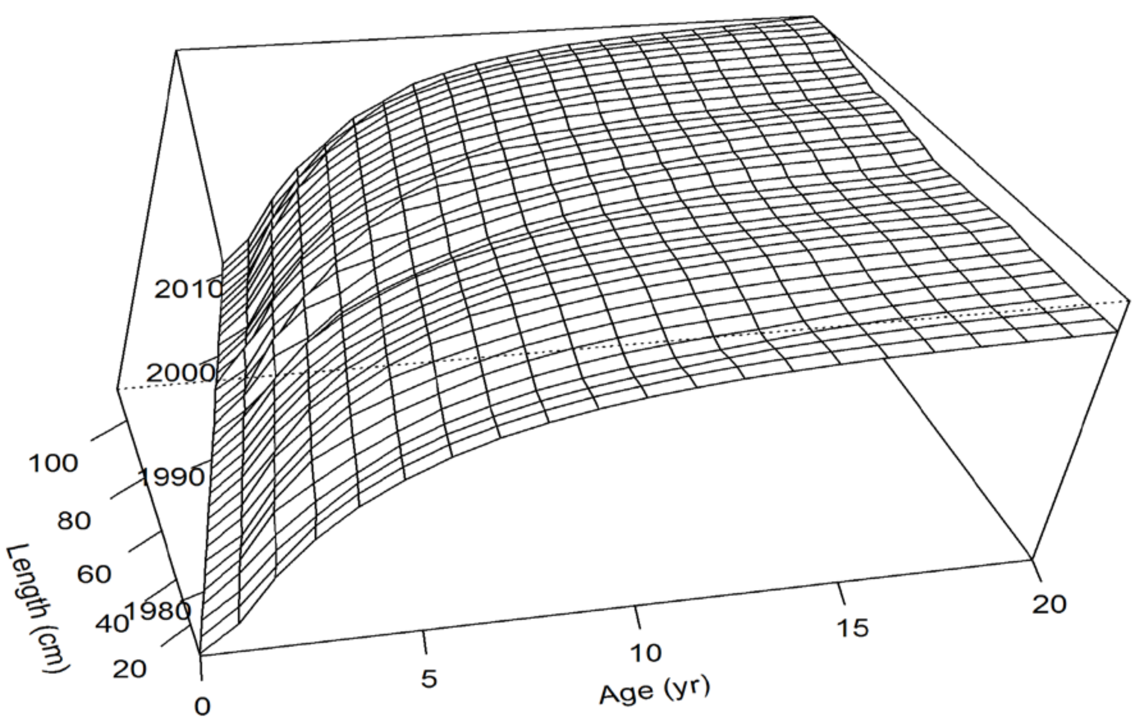

Figure 2.2.5—Surface plot of time-varying length at age estimated by Model 2.

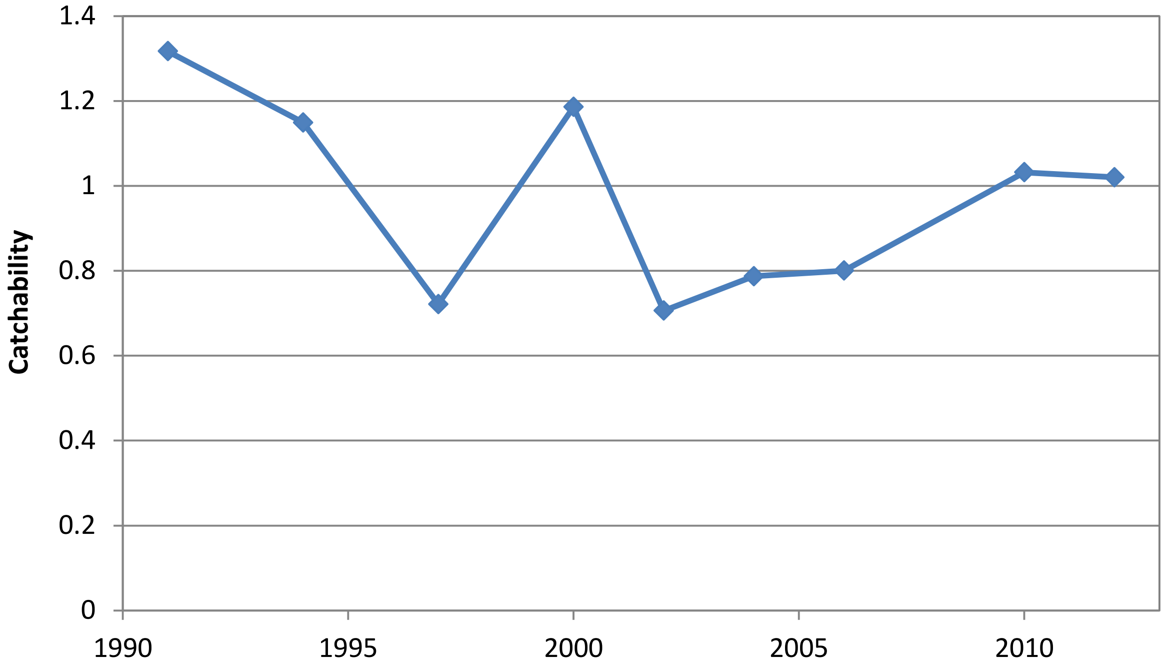

Figure 2.2.6—Time series of survey catchability estimated by Model 4.

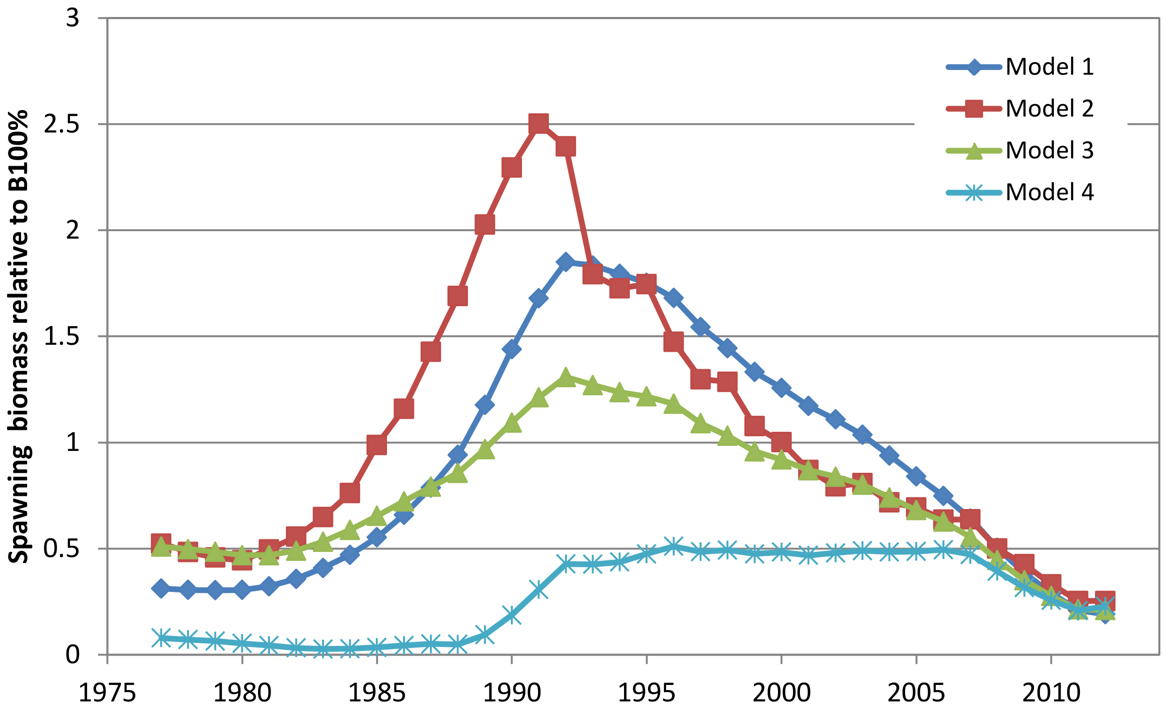

Figure 2.2.7—Time series of spawning biomass relative to $B_{100\%}$ as estimated by the four models.

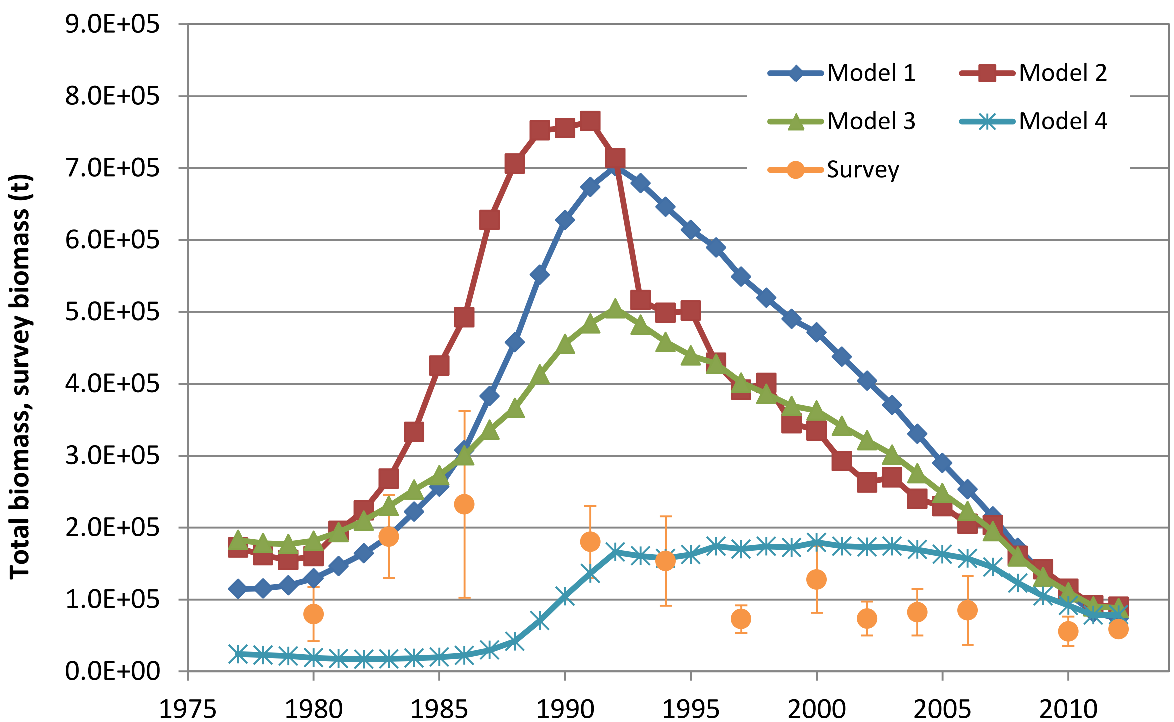

Figure 2.2.8— Time series of total (age 0+) biomass as estimated by the four models. Survey biomass is shown for comparison.

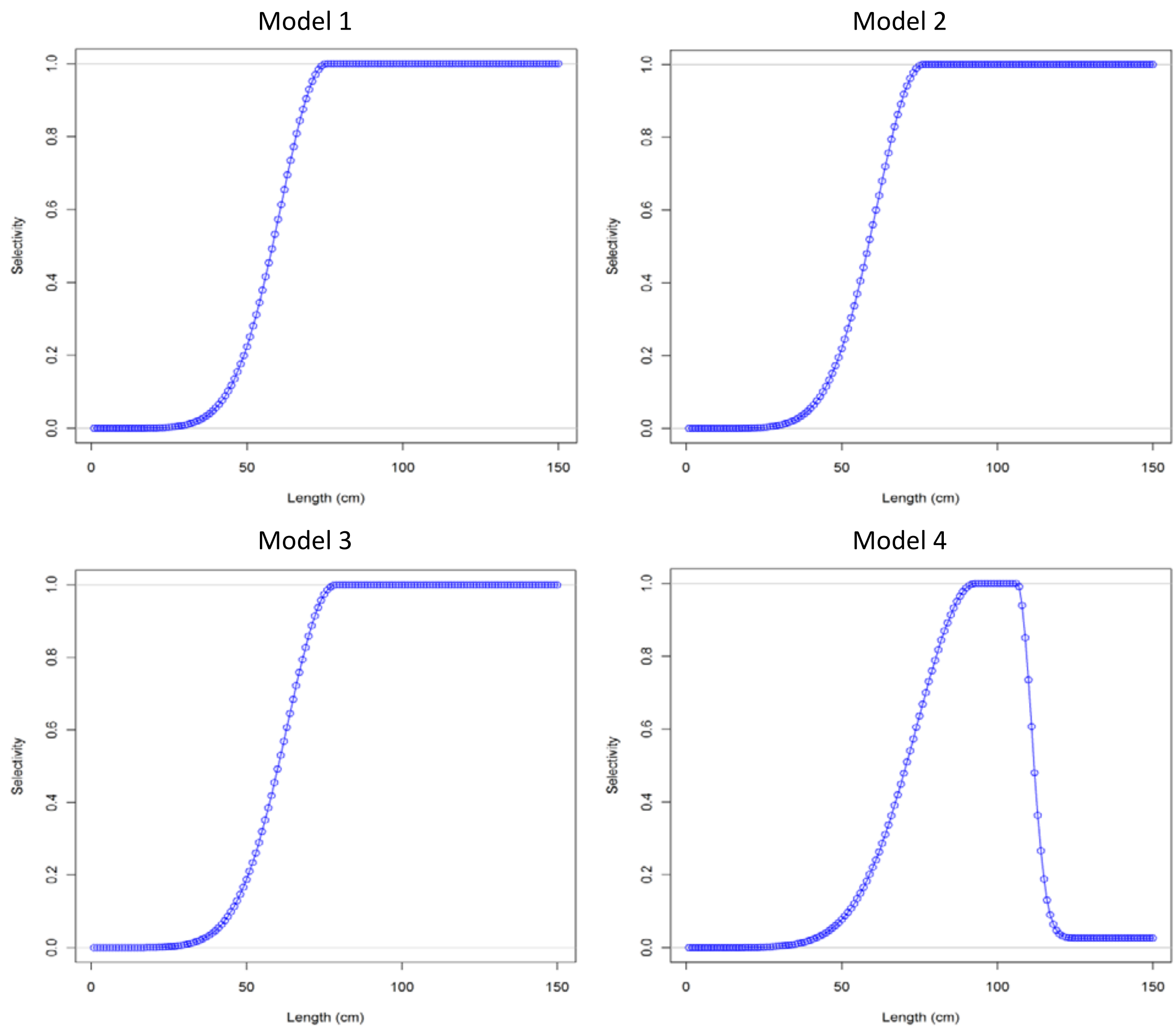

Figure 2.2.9—Fishery selectivity at length (cm) as defined by parameters estimated by the four models.

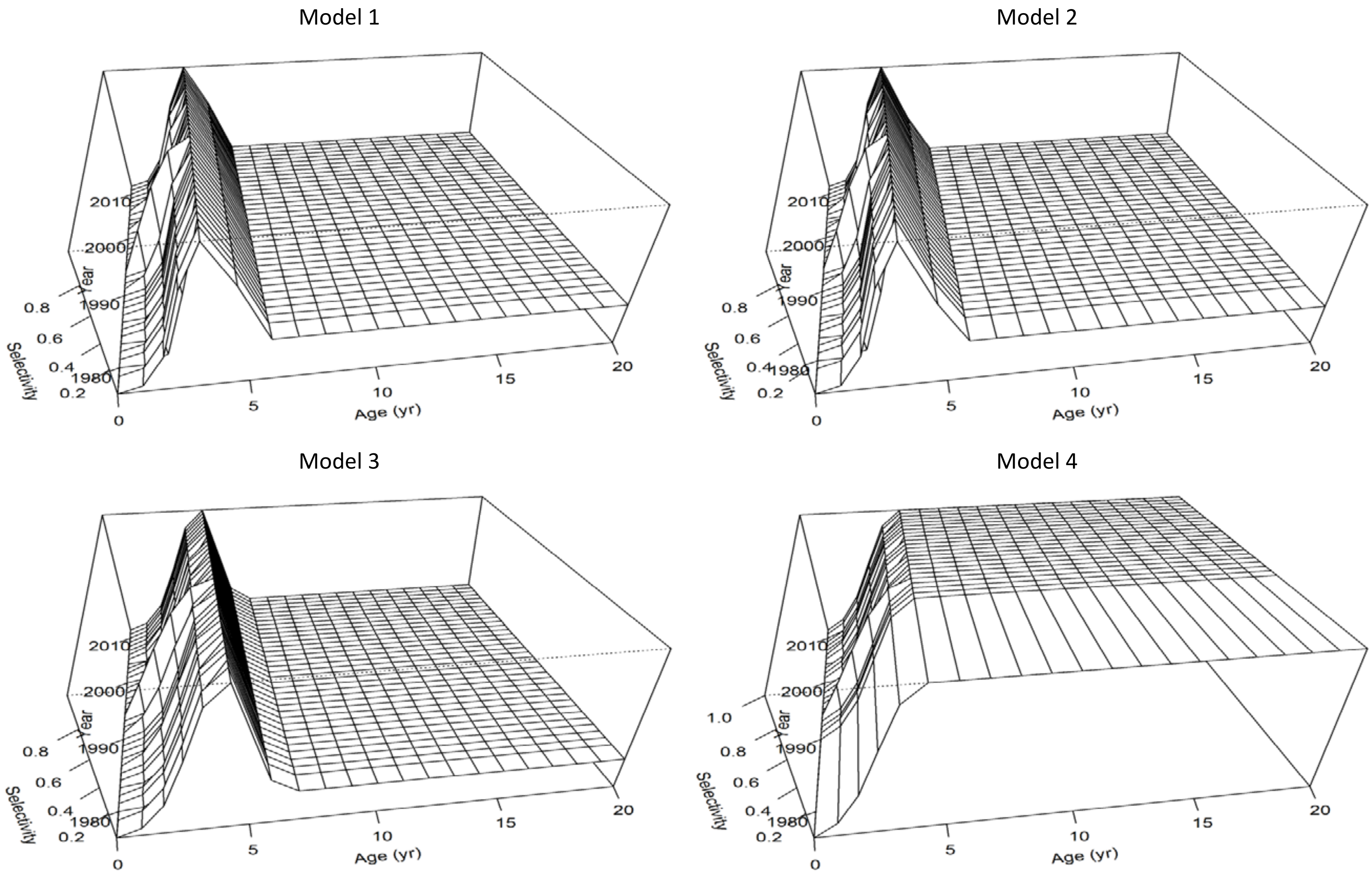

Figure 2.2.10— Survey selectivity at length (cm) as defined by parameters estimated by the four models.

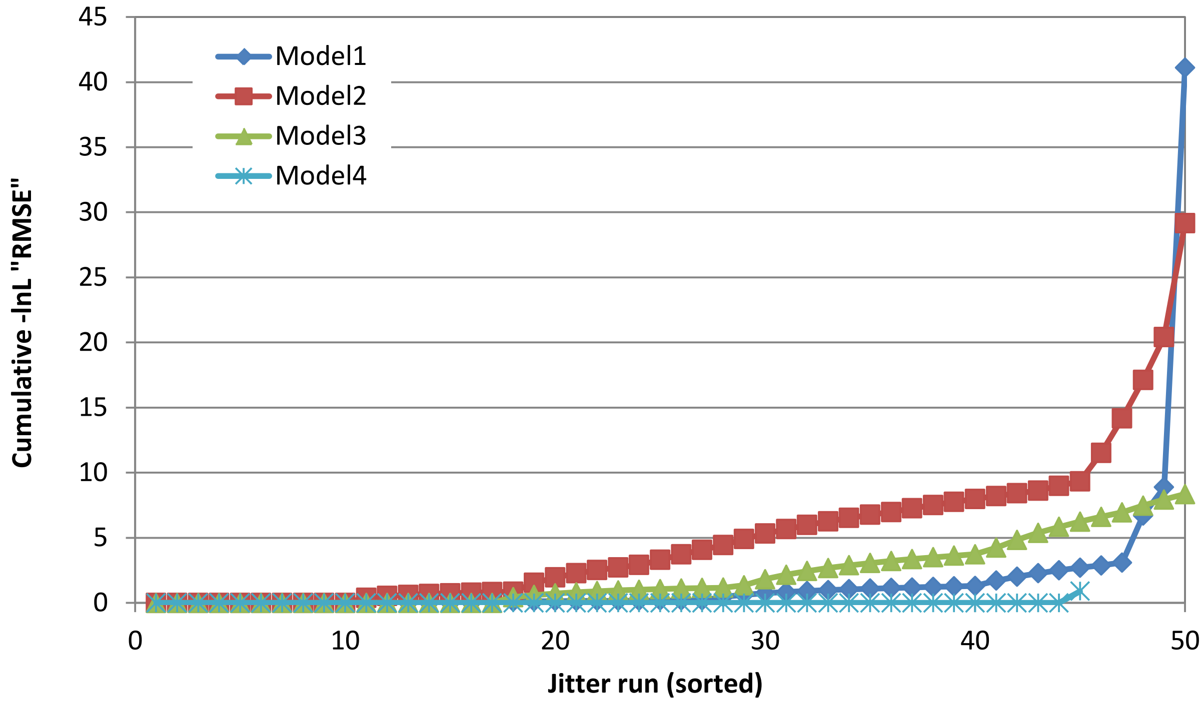

Figure 2.2.11—Variability in objective function value for each of the four models. See text for details.

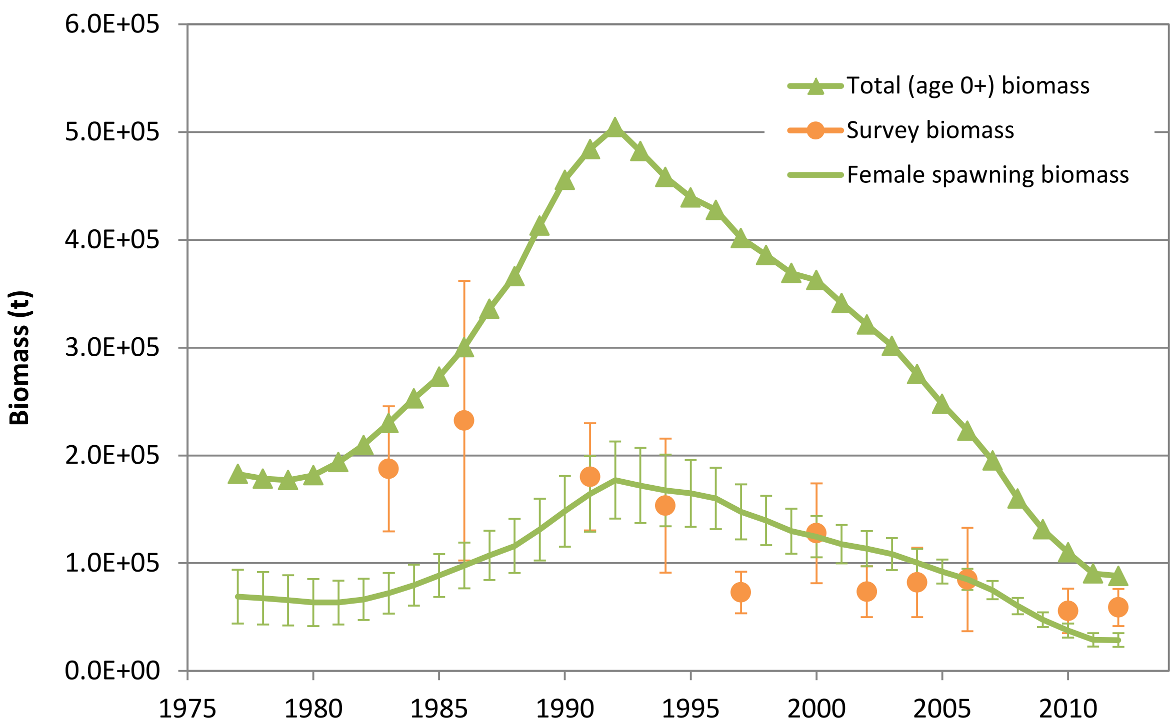

Figure 2.2.12—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by Model 3. Spawning biomass and survey biomass show 95% CI.

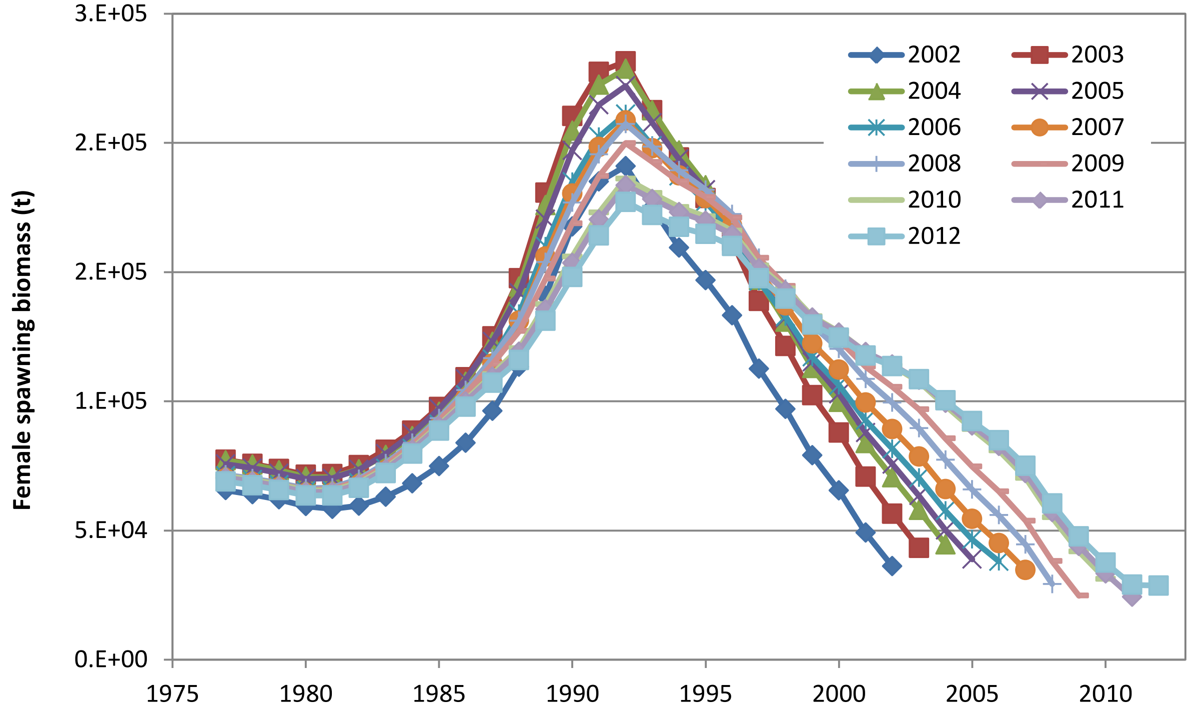

Figure 2.2.13a—Retrospective plots of spawning biomass for Model 3.

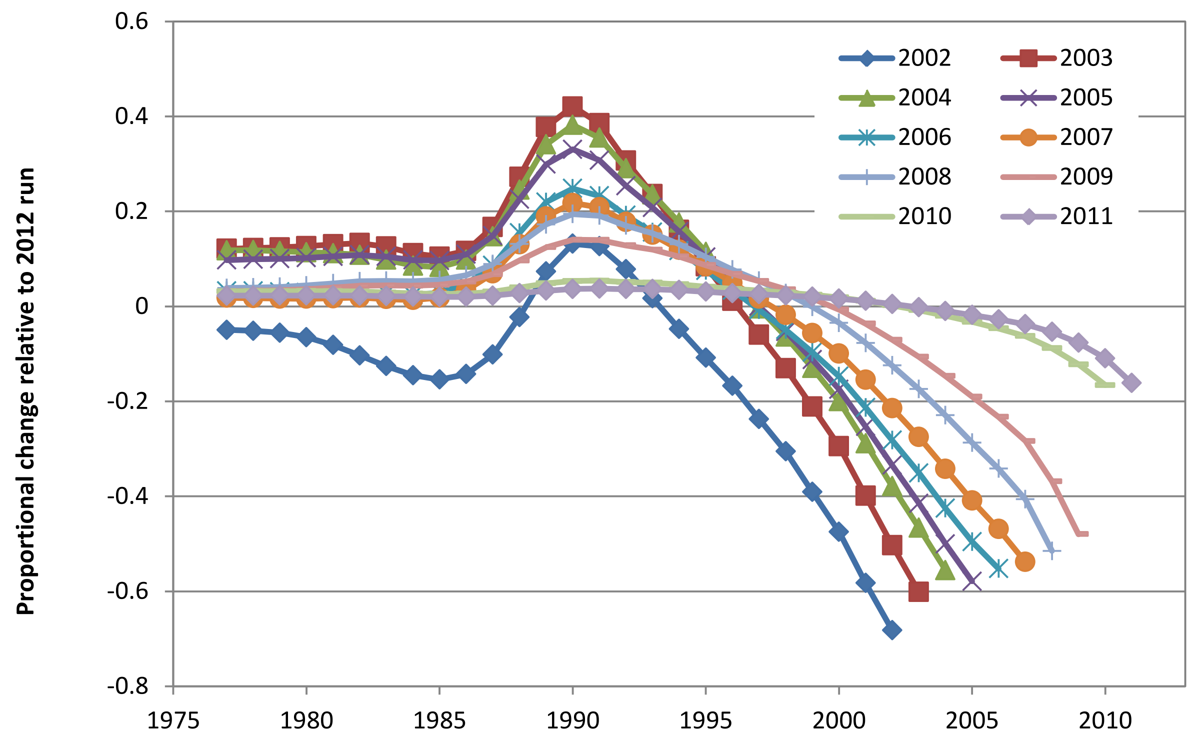

Figure 2.2.13b—Same retrospective results shown in Figure 2.2.13a, but plotted as proportional changes relative to the terminal (2012) run

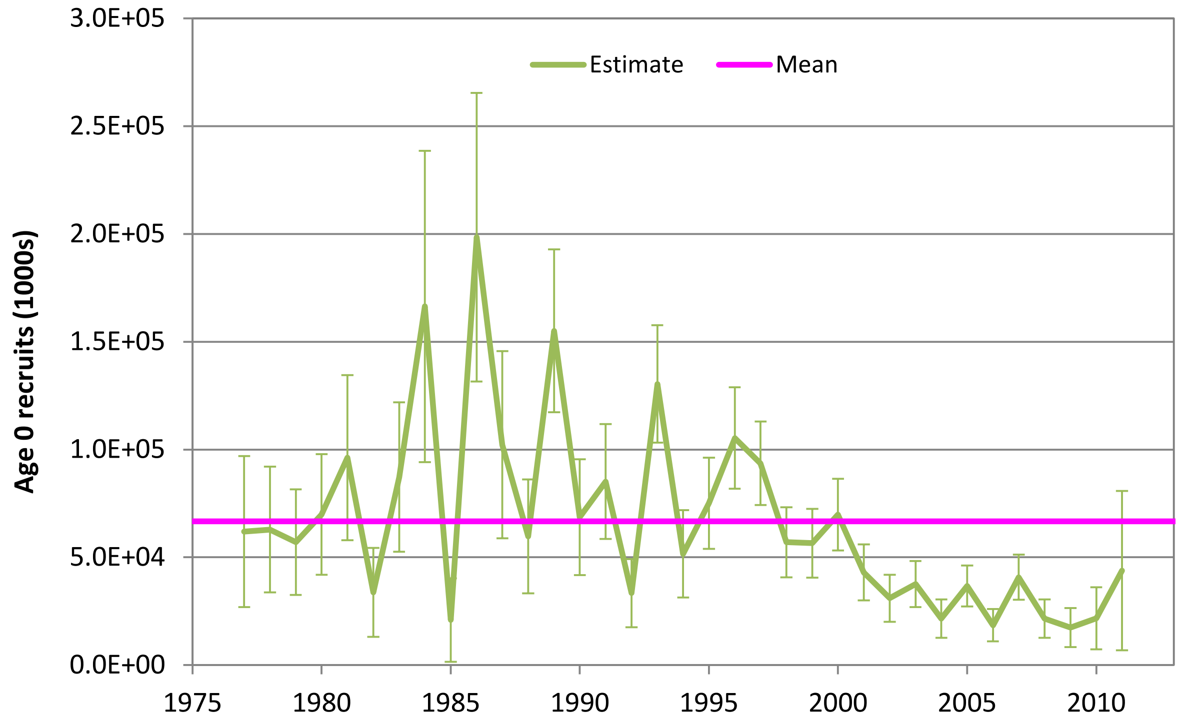

Figure 2.2.14—Time series of recruitment at age 0 as estimated by Model 3.

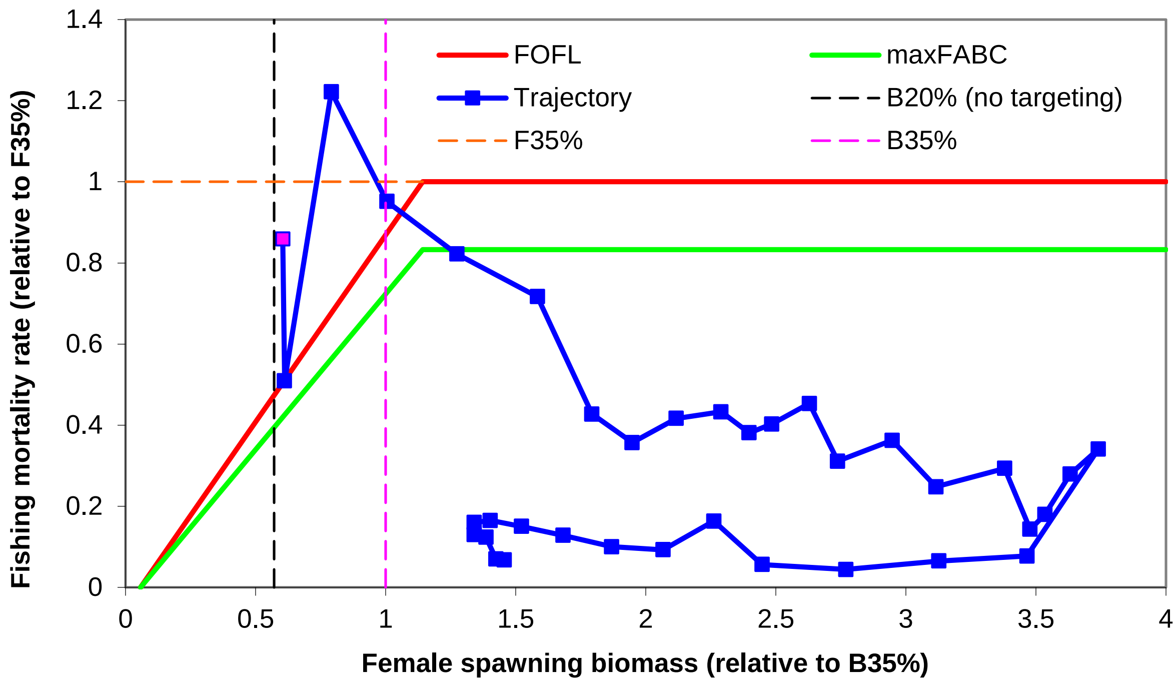

Figure 2.2.15—Trajectory of fishing mortality and female spawning biomass as estimated by Model 3, 1977-present (magenta square = 2012). These results are from SS, and are not exactly comparable to results obtained by the standard projection program.

Annex 2.2.1: An initial exploration of alternative assessment models for Pacific cod in the Aleutian Islands

Introduction

This document represents an effort to respond to comments made by the BSAI Plan Team, the joint BSAI and GOA Plan Teams, and the SSC regarding the need to develop an age-structured model of the Pacific cod (*Gadus macrocephalus*) stock in the Aleutian Islands (AI). Throughout the history of management under the Magnuson-Stevens Fishery Conservation and Management Act, Pacific cod in the eastern Bering Sea (EBS) and AI have been managed as a unit. Since at least the mid-1980s, harvest specifications for the combined BSAI unit have been extrapolated from an age-structured model for Pacific cod in the EBS.

Several white papers and a stock structure report provide various lines of evidence suggesting that Pacific cod in the EBS and AI should be viewed as separate stocks. Building on earlier genetic studies by Canino et al. (2005), Cunningham et al. (2009), and Canino et al. (2010), Spies (*in press*) concluded that her "study provides the most comprehensive evidence to date for genetic distinctiveness and lack of gene flow between the Aleutian Islands and Eastern Bering Sea." The importance of recognizing stock distinctions in management of gadids in general has also received attention in recent years (e.g., Fu and Fanning 2004, Hutchinson 2008).

In light of this evidence, in 2010 the SSC requested that a separate assessment be prepared for Pacific cod in the AI. In response, the 2011 assessment contained a Tier 5 assessment of Pacific cod in the AI (Thompson and Lauth 2011). This preliminary assessment marks the first time that an age-structured model of Pacific cod in the AI has been presented in the context of the annual BSAI groundfish management cycle.

Comments from the Plan Teams and SSC

Note: Comments directed exclusively at the assessments for Pacific cod in the EBS or Gulf of Alaska are not included here.

SSC (December, 2011)

SSC1: *"The SSC requested in its December 2010 minutes that a separate assessment for the AI be brought forward because of concerns over diverging trends in the biomass estimates for the AI and EBS. In response, the author provided a Tier-5 assessment for AI cod as an appendix to the current assessment. The author plans to develop an age-structured model for the Aleutians in 2012. We look forward to reviewing a preliminary model in October 2012."* Two age-structured models are presented here (see "Model Structures" below).

Joint Plan Teams (May, 2012)

JPT1: *"For the AI, the Teams recommend that a preliminary assessment be developed with a simple, age-structured model configured in Stock Synthesis* if there is enough time to do so*. This initial attempt at age-structured modeling of the AI stock may serve largely to determine whether the lack of age data prohibits meaningful parameter estimation at the present time"* (emphasis original). See response to comment SSC1.

JPT2: *"The Teams recommend that the AFSC begin production ageing of AI Pacific cod."* A request for production of age data will be filed in the upcoming cycle.
SSC (June, 2012)

SSC2: *"The SSC agrees with the Plan Team recommendation that the author bring forward a preliminary model for the Aleutian Islands* if there is enough time. *The author noted the lack of age data for the Aleutians Pacific cod stock and the SSC agrees that length data should be used for all years (including for any year with age data). Authors should consider age composition sample size needs for the assessment and request ageing of current sample collections for next year's assessment"* (emphasis original). See responses to comments SSC1 and JPT1.

Data

Catch

Total catch data are shown in Table 2.2.1.1 for the years 1977-2011. These are taken from last year's assessment (Thompson and Lauth 2011), so the 2011 datum is slightly incomplete. These are the catch data that were used in the models described in this preliminary assessment. However, they contain two errors which were discovered too late to be changed in this document: 1) the catches in Table 2.2.1.1 do not include catches from the State-managed fishery in 2006-2011; and 2) the datum for 2003 does not included CDQ catches, which would add another 266 t to the reported amount. These errors will be corrected in the final assessment. Table 2.2.1.2 shows catches broken by year, jurisdiction (Federal and State), and gear for the years 1991-2011. Again, data for 2011 are slightly incomplete. Table 2.2.1.3 shows catches broken down by area, both in volume and as proportions of the yearly total for the years 2003-2012. Unlike Tables 2.2.1.1 and 2.2.1.2, the data for 2011 in Table 2.2.1.3 are complete; however, the data for 2012 are current only through August 16. Catches dropped sharply in 2011, which was likely the result of recent management measures designed to protect Steller sea lions.

Length frequency

Table 2.2.1.4 shows the number of fish actually measured in each year from both the fishery and the survey, along with the scaled sample sizes used in the models described in this preliminary assessment. The steps used to scale the sample sizes were the same as those used in last year's EBS assessment (Thompson and Lauth 2011), which have changed very little since 2007: 1) Records with fewer than 400 observations were omitted. 2) The sample sizes for fishery length compositions from years prior to 1999 were tentatively set at 16% of the actual sample size, and the sample sizes for fishery length compositions after 1998 and all survey length compositions were tentatively set at 34% of the actual sample size. 3) All sample sizes were adjusted proportionally so that the average was 300. It should be noted that the actual fishery sample sizes for Pacific cod in the AI are *much* smaller than the actual fishery sample sizes for Pacific cod in the EBS (average of 1,011 samples per year in the AI versus 210,156 samples per year in the EBS).

Table 2.2.1.5 shows the actual (i.e., not rescaled) number of fish measured at each 1 cm interval from 4-120+ cm in the fishery and the survey. Overall, the AI size compositions reflect a higher proportion of fish 100 cm or greater than is the case in the EBS (AI: 2.5% in the fishery, 0.7% in the survey; EBS: 0.6% in the fishery, 0.1% in the survey).

Trawl survey abundance and biomass estimates

As in recent assessments of Pacific cod in the EBS, the models developed here use survey estimates of population size measured in units of individual fish. These estimates are shown below, along with the coefficient of variation (CV) for each estimate.

Year	Numbers (1000s)	CV
1980	57,036	0.157
1983	70,402	0.131
1986	109,969	0.229
1991	70,557	0.216
1994	62,333	0.271
1997	28,724	0.137
2000	47,231	0.210
2002	30,560	0.140
2004	29,224	0.133
2006	24,649	0.154
2010	24,617	0.121

Table 2.2.1.6 shows the time series of survey biomass estimates, broken down by area, along with coefficients of variation.

In terms of both biomass and numbers, the CVs for the AI surveys tend to be much larger than the CVs for the EBS surveys, as shown below:

	EBS		AI	
Statistic	Biomass	Numbers	Biomass	Numbers
Min.	0.055	0.060	0.126	0.121
Mean	0.084	0.107	0.179	0.173
Max.	0.183	0.267	0.264	0.271

Model Structures

Two models (labeled Model 1 and Model 2) are presented in this preliminary assessment, both estimated using Stock Synthesis (SS), and both based largely on last year's accepted model for Pacific cod in the EBS (Thompson and Lauth 2011). The natural mortality rate was fixed at 0.34 in both models, borrowing the accepted value in the EBS.

In both models, weight (kg) at length (cm) was assumed to follow the usual form weight=$\alpha \times \text{length}^{\beta}$ and to be constant across the time series, with α and β estimated at 5.68×10^{-6} and 3.18, respectively, based on 8,126 samples collected between 1974 and 2011.

In both models, length bins (1 cm each) were extended out to 150 cm instead of the limit of 120 cm that is used in the EBS assessment, because of the higher proportion of large fish observed in the AI.

In addition to differences in the data between the AI and EBS, Model 1 differs from last year's accepted EBS model in the following respects:

- Each year consists of a single season instead of five.
- A single fishery is defined (with forced asymptotic selectivity) instead of nine season-and-gear-specific fisheries (with forced asymptotic selectivity for six of them).
- Fishery selectivity is constant over time instead of variable in multiple time blocks.
- The survey samples age 1 fish at true age 1.5 instead of 1.41667.
- Ageing bias is not estimated (no age data) instead of estimated.
- Survey catchability *Q* is tuned to match the value of 0.92 estimated by Nichol et al. (2007) for the AI survey net instead of the value of 0.47 estimated for the EBS survey net.

Model 2 was chosen from a set of seven candidate models, all of which were identical to Model 1 except that they each allowed at least one of the three length-at-age parameters (length at age 1, *L1*; asymptotic length, *Linf*; and Brody's growth coefficient, *K*) to vary annually from 1977-2010, using multiplicative *dev*s with $\sigma = 0.1$. The candidate models were structured as follows:

Model	*L1 dev*s	*Linf dev*s	*K dev*s
A	yes	yes	yes
B	yes	yes	no
C	yes	no	yes
D	no	yes	yes
E	yes	no	no
F	no	yes	no
G	no	no	yes

The candidate model with the lowest value of Akaike's information criterion (AIC) was chosen as Model 2 (see "Results," below).

All models used the same data file.

Development of the final versions of Models 1 and 2 included calculation of the Hessian matrix. These models also passed a "jitter" test of 50 runs with a jitter parameter (equal to half the standard deviation of the logit-scale distribution from which initial values are drawn) of 0.1. In the event that a jitter run produced a better value for the objective function than the base run, then: 1) the model was re-run starting from the final parameter file from the best jitter run, 2) the resulting new control file became the new base run, and 3) the entire process (starting with a new set of jitter runs) was repeated until no jitter run produced a better value for the objective function than the most recent base run.

Prior to selection of one of the candidate models A-G to constitute Model 2, development of these models did not include calculation of the Hessian matrix, and they were not subjected to a jitter test. As a weak test for convergence, each of these models was re-run from its respective ending values (in the control file, not the parameter file), and confirmed to return the same objective function value.

Except for *dev* parameters, all parameters in all models were estimated with uniform prior distributions. Bounds were non-constraining except in a very few unimportant cases.

All models used a double-normal curve to model selectivity. This functional form is constructed from two underlying and linearly rescaled normal distributions, with a horizontal line segment joining the two peaks. As configured in SS, the equation 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 software used to run all models was SS V3.23b, as compiled on 11/5/2011 (Methot 2005, Methot 2011, Methot and Wetzel *in press*). Stock Synthesis is programmed using the ADMB software package (Fournier et al. 2012).

Results

Selection of one of the time-varying growth models to constitute Model 2

The seven candidate models with time-varying growth gave the following results ("Δ(−lnLike)" represents the negative log likelihood relative to the model with the lowest negative log likelihood, and "Δ(AIC)" represents the value of Akaike's information criterion relative to the model with the lowest AIC; note that, with respect to both of these measures, lower values are better):

Model	*L1 dev*s	*Linf dev*s	*K dev*s	Parameters	Δ(-lnLike)	Δ(AIC)
A	yes	yes	yes	183	0.00	61.09
B	yes	yes	no	149	3.45	0.00
C	yes	no	yes	149	22.31	37.71
D	no	yes	yes	149	101.72	196.52
E	yes	no	no	115	83.10	91.28
F	no	yes	no	115	115.96	157.01
G	no	no	yes	115	147.73	220.55

Model A has the lowest negative log likelihood overall, followed by Models B and C, respectively. However, Model A's negative log likelihood is only 3.45 units lower than Model B, an improvement which is achieved at a cost of 34 additional parameters. It should be noted, though, that the differences listed in the "parameters" column (above) all represent differences in the number of *dev*s, which, being constrained by σ, are not true parameters, meaning that the differences in number of parameters are overstated to some unknown extent. Unfortunately, use of a more rigorous method of model selection in this preliminary assessment was precluded by time limitations, so AIC will be taken here to represent the best available method. Model B has the lowest AIC overall, followed by Models C and A, respectively, so Model B was chosen to constitute Model 2 in this preliminary assessment.

Overview

The following table summarizes the status of the stock as estimated by Models 1 and 2 ("Estimate" is the point estimate, "St. Dev." is the standard deviation of the estimate, "SB(2011)" is female spawning biomass in 2011 (t), and "Bratio(2011)" is the ratio of SB(2011) to $B_{100\%}$):

	Model 1		Model 2	
Quantity	Estimate	St. Dev.	Estimate	St. Dev.
SB(2011)	26,444	6,451	28,171	7,603
Bratio(2011)	0.211	0.021	0.381	0.067

Although 2011 spawning biomass is only 7% higher under Model 2 than Model 1, *relative* spawning biomass in 2011 is 81% higher under Model 2 than Model 1, implying quite a big difference in how stock status is estimated by these two models.

Estimates of parameters and derived quantities

Tables 2.2.1.7-2.2.1.10 show all parameters estimated internally by either Model 1 or Model 2. Table 2.2.1.7 shows parameters other than recruitment *dev*s, growth *dev*s (Model 2 only), and fishing mortality rates, with standard deviations. Table 2.2.1.8 shows recruitment *dev*s, with standard deviations. Table 2.2.1.9 shows growth parameter *dev*s for mid-year length at age 1 (*L1*) and asymptotic length (*Linf*) estimated by Model 2, with standard deviations. These two sets of *dev*s exhibited a correlation of –0.064. Table 2.2.1.10 shows fishing mortality rates (without standard deviations, because SS does not treat fishing mortality rates as true parameters and therefore does not produce standard deviations for them).

In Model 1, *Q* was tuned to a value of 1.01, which set the average product of *Q* and survey selectivity across the 60-81 cm size range equal to the estimate of 0.92 obtained by Nichol et al. (2007). Model 2 did not re-tune *Q*, and exhibited an average product of *Q* and survey selectivity across the 60-81 cm size range equal to 0.98, slightly above the target value.

Figure 2.2.1.1 shows time-varying length at age as estimated by Model 2, both as a surface plot (upper panel) and as a contour plot (lower panel).

Figure 2.2.1.2 shows fishery selectivity as estimated by Model 1 (upper panel) and Model 2 (lower panel). Figures 2.2.1.3a-b show time-varying survey selectivity as estimated by the two models. In both figures, Model 1 is shown in the upper panel and Model 2 in the lower panel. Figure 2.2.1.3a shows time-varying selectivity as a surface plot, while Figure 2.2.1.3b shows it as a contour plot.

Overall, the most obvious differences in parameter estimates between Models 1 and 2 seem to be the growth *dev*s estimated by Model 2 (not present in Model 1) and differences in survey selectivity.

Figures 2.2.1.4-7 show various time series as estimated by the two models. Figure 2.2.1.4 shows the time series of total (age 0+) biomass (t), where both models have similar endpoints, but Model 1 increases to a much higher peak in the middle of the time series than does Model 2. Figure 2.2.1.5 shows the time series of spawning biomass relative to $B_{100\%}$, where Model 2 starts at a much higher initial value, then both models peak at about the same place and height, then both models descend at about the same rate until about 2005, after which Model 2 estimates a higher relative spawning biomass than Model 1 (note also that SS computes a time-varying value for $B_{100\%}$ whenever growth is time varying; however, $B_{100\%}$ for 2011 in Model 2 is within 1% of the value in Model 1). Figure 2.2.1.6 shows the time series of age 0 recruits (1000s), where Model 1 shows much higher variability than Model 2. Figure 2.2.1.7 shows the time series of relative spawning per recruit corresponding to the estimated fishing mortality rates, where the two models have similar endpoints, but Model 2 is at least 10 percentage points less than Model 1 in all years between 1992 and 2005 except for 1995. The abrupt change from 2010 to 2011 which occurs for both models in Figure 2.2.1.7 (the symbol for Model 2 over-plots the symbol for Model 1 in 2011) is due to the fact that catch fell by 58% between 2010 and 2011.

Goodness of fit

Objective function values for the two models, both total and by component, are shown below:

Component	Model 1	Model 2
Survey CPUE	13.96	-9.63
Size composition	699.89	423.87
Recruitment	23.96	6.19
"Softbounds"	0.01	0.01
Deviations	6.33	29.76
Total	744.15	450.20

Model 2 has a lower (better) overall objective function value than Model 1. The only component where Model 2 has a higher value is the "Deviations" component, which would be expected, given that Model 2 has many more *dev*s that Model 1 (see below).

The number of parameters in the two models, both *dev*s and non-*dev*s, are shown below:

Parameter count	Model 1	Model 2
No. non-*dev* parameters	17	17
No. *dev*s	64	132
Total no. parameters	81	149

If *dev*s are counted as true parameters, then Models 1 and 2 have AIC values of 1650.31 and 1198.41.

Figure 2.2.1.8 shows the fits to the survey abundance (1000s of fish) time series. The estimates obtained by Model 1 fall within the 95% confidence interval 73% of the time, compared to 82% for Model 2.

Table 2.2.1.11 shows the fits to survey abundance (measured in 1000s of fish) obtained by Models 1 and 2. The columns labeled "Expected" show the estimates for each model. The columns labeled "Residual" show ln(observed/expected). The bottom row under "Residual" shows the mean for each column. Ideally, this value should be close to zero. Model 2 comes closer to this ideal than Model 1. The columns labeled "Squared std. res." show $(\ln(\text{observed/expected})/\sigma)^2$. The bottom row under "Squared std. res." shows the root mean squared error. Ideally, this value should be close to unity. Again, Model 2 comes closer to this ideal than Model 1.

The following table shows the number of size composition records, the mean of the input sample size, and the mean ratio between effective sample size and input sample size for the fishery and the survey:

			Mean(Neff/Ninput)	
Fleet	Records	Mean(Ninput)	Model 1	Model 2
Fishery	24	44.17	20.30	18.43
Survey	11	883.36	1.48	2.43

Model 1 has a higher ratio than Model 2 for the fishery, while Model 2 has a higher ratio than Model 1 for the survey. However, all ratios are greater than unity.

Discussion

This initial exploration of age-structured modeling for Pacific cod in the AI indicates that model structure can have a large impact on the estimated status of the stock. To some extent, this is characteristic of stock assessment modeling in general. However, it may also be a product of the degree to which the available data for Pacific cod in the AI are uninformative. Relative to Pacific cod in the EBS, Pacific cod in the AI have much larger survey CVs, much smaller length composition sample sizes, and virtually no age data.

Acknowledgments

Mary Furuness and Josh Keaton provided the catch data. Angie Greig provided the size composition and weight-length data. Jennifer Calahan helped to code the query for the weight-length data. Michael Martin provided the survey data. Rick Methot developed the SS software used to conduct this assessment. Anne Hollowed reviewed an earlier draft. Many NMFS survey personnel and countless fishery observers collected most of the raw data that were used here.

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Table 2.2.1.1. Total catch (t) of Pacific cod in the Aleutian Islands as used in Models 1 and 2, 1977-2011 (data for 2011 were current through October 3, 2011). These data do not include catches from the State-managed fishery in 2006-2011 (see Table 2.2.1.2). Failure to include catches from the State-managed fishery in this preliminary assessment was an oversight, which will be corrected in the final assessment. Also, catch for 2003 does not include CDQ, which would add 266 t.

Year	Catch	Year	Catch	Year	Catch	Year	Catch
1977	3,262	1986	6,906	1995	16,534	2004	28,873
1978	3,295	1987	13,207	1996	31,609	2005	22,699
1979	5,593	1988	5,165	1997	25,164	2006	20,493
1980	5,788	1989	4,542	1998	34,726	2007	30,221
1981	7,434	1990	7,541	1999	28,130	2008	26,597
1982	8,397	1991	9,798	2000	39,685	2009	26,507
1983	8,430	1992	43,068	2001	34,207	2010	25,122
1984	7,981	1993	34,205	2002	30,801	2011	10,444
1985	6,937	1994	21,539	2003	32,193		

Table 2.2.1.2. Catches (t) of Pacific cod in the Aleutian Islands by year, jurisdiction, and gear, 1991-2011 (data for 2011 were current through October 3, 2011).

	Federal					State					
Year	Trawl	LLine	Pot	Other	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1991	3,414	3,203	3,180	0	9,798						9,798
1992	14,559	22,108	6,317	84	43,068						43,068
1993	17,312	16,860	0	33	34,205						34,205
1994	14,383	7,009	147	0	21,539						21,539
1995	10,574	4,935	1,025	0	16,534						16,534
1996	21,179	5,819	4,611	0	31,609						31,609
1997	17,349	7,151	575	89	25,164						25,164
1998	20,531	13,771	424	0	34,726						34,726
1999	16,437	7,874	3,750	69	28,130						28,130
2000	20,362	16,183	3,107	33	39,685						39,685
2001	15,827	17,817	544	19	34,207						34,207
2002	27,929	2,865	7	0	30,801						30,801
2003	31,215	976	2	0	32,193						32,193
2004	25,770	3,103	0	0	28,873						28,873
2005	19,613	3,073	0	13	22,699						22,699
2006	16,956	3,128	401	8	20,493	3,106	455	156	0	3,717	24,210
2007	25,725	4,182	313	1	30,221	2,907	529	383	6	3,824	34,045
2008	19,291	5,471	1,679	156	26,597	2,540	234	1,634	53	4,462	31,059
2009	20,284	5,469	754	0	26,507	537	279	1,237	20	2,074	28,580
2010	16,757	7,638	727	0	25,122	2,113	77	1,688	0	3,878	29,000
2011	9,250	1,194	1	0	10,444	4	14	30	0	48	10,492

Table 2.2.1.3. Catches of Pacific cod in Areas 541 (eastern Aleutians), 542 (central Aleutians), and 543 (western Aleutians), in metric tons and as proportions of the yearly total, 2003-2012 (2012 catches are current through August 16, 2012).

	Catch				Proportion of total		
Year	541	542	543	Total	541	542	543
2003	22,748	6,713	2,997	32,459	0.701	0.207	0.092
2004	18,391	6,825	3,657	28,873	0.637	0.236	0.127
2005	14,879	3,552	4,268	22,699	0.655	0.157	0.188
2006	12,902	3,118	4,474	20,493	0.630	0.152	0.218
2007	21,087	4,136	4,998	30,221	0.698	0.137	0.165
2008	15,411	4,025	7,162	26,597	0.579	0.151	0.269
2009	13,208	5,376	7,923	26,507	0.498	0.203	0.299
2010	13,170	3,959	7,993	25,122	0.524	0.158	0.318
2011	8,940	1,657	24	10,621	0.842	0.156	0.002
2012	11,103	420	28	11,551	0.961	0.036	0.002
Average:	15,184	3,978	4,352	23,514	0.646	0.169	0.185

Table 2.2.1.4. True ("Ntrue") and input ("N") sample sizes for length composition data from the fishery and the survey. Input N is scaled so that the average is 300 across all fleets and years.

Year	Fleet	Ntrue	N	Year	Fleet	Ntrue	N
1982	fishery	577	15	2006	fishery	956	52
1983	fishery	438	11	2007	fishery	1,125	61
1984	fishery	571	15	2008	fishery	1,504	82
1991	fishery	1,038	27	2009	fishery	1,116	61
1992	fishery	1,217	31	2010	fishery	1,362	74
1993	fishery	721	18	2011	fishery	536	29
1994	fishery	740	19	2012	fishery	438	24
1995	fishery	1,303	33	1980	survey	30,233	1,641
1996	fishery	1,446	37	1983	survey	28,868	1,567
1997	fishery	701	18	1986	survey	25,399	1,379
1998	fishery	1,289	33	1991	survey	15,603	847
1999	fishery	1,349	73	1994	survey	18,048	980
2000	fishery	1,663	90	1997	survey	11,691	635
2001	fishery	1,407	76	2000	survey	10,767	585
2002	fishery	982	53	2002	survey	13,450	730
2003	fishery	861	47	2004	survey	8,573	465
2004	fishery	993	54	2006	survey	6,598	358
2005	fishery	947	51	2010	survey	9,759	530

Table 2.2.1.5 (page 1 of 4). Number of fish measured at each 1 cm interval from 4-120+ cm in the fishery and the survey.

Year	Fleet	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1982	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	4
1983	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	1	2	3	1	2	2
1984	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	1	1	1	3	1
1991	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	4	2	2	4
1992	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	2	3	4
1993	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	3	2	4	5	4
1994	fish.	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	1	2	3	3	4	2	4	3
1995	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	2	1	3	2	2	2	2	2	3	4	3	3	4
1996	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	2	2	2	3	4	4	3	4
1997	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	4	1	3	4	4
1998	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	1	3	3	4	4	4	5	8	7
1999	fish.	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	2	1	3	3	3
2000	fish.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	3	3	6	6	4
2001	fish.	0	3	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	4	5	6	7	9
2002	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1	1	2	4	3	4	5	7
2003	fish.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	2	2	3	2	3	3	2
2004	fish.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0	1	1	1	2	3	3	4	5	5	5
2005	fish.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1	2	3	2	2
2006	fish.	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	1	2	3	0	3	3
2007	fish.	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	1	0	4	1	2	1	3	5	5	5
2008	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	2	0	3	2	6	4
2009	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	3	4	6	6
2010	fish.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2	0	0	1	1	0	3	2	5
2011	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
2012	fish.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0
1980	surv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	38	35	31	91	100	68
1983	surv.	0	0	7	96	33	4	0	0	0	0	0	0	0	0	0	3	0	7	6	3	8	31	52	126	139	184	335	413	197	280	228	199
1986	surv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	58	4	117	90	43	68	178	352	474	648	691	858
1991	surv.	0	0	0	0	0	0	0	0	0	0	0	5	5	30	29	31	45	33	40	46	34	22	26	23	54	167	231	300	440	511	607	666
1994	surv.	0	0	0	0	0	0	0	0	0	129	533	833	1246	1106	497	445	349	134	26	34	16	8	9	10	8	7	21	50	81	103	119	135
1997	surv.	0	0	0	0	0	0	0	0	0	0	0	0	6	27	11	41	79	190	177	242	222	179	92	42	4	25	18	33	64	79	90	139
2000	surv.	0	0	0	0	0	0	0	0	0	0	12	72	63	72	99	38	6	20	0	3	3	7	14	8	8	27	22	28	33	43	53	38
2002	surv.	0	0	0	0	0	3	0	0	0	0	18	19	34	50	76	41	41	41	43	20	57	28	32	63	69	85	67	115	138	308	279	329
2004	surv.	0	0	0	0	0	0	0	0	0	0	9	0	2	6	10	4	25	24	15	15	11	3	1	3	0	0	0	6	1	11	17	32
2006	surv.	0	0	0	0	0	0	0	0	0	11	22	27	87	156	144	135	46	44	37	33	49	26	9	4	2	5	0	2	14	2	10	9
2010	surv.	0	0	0	0	0	0	0	0	0	0	14	35	28	33	37	64	40	23	7	4	0	7	2	4	5	26	45	63	61	70	68	68

Table 2.2.1.5 (page 2 of 4). Number of fish measured at each 1 cm interval from 4-120+ cm in the fishery and the survey.

Year	Fleet	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
1982	fish.	2	3	4	5	5	8	6	5	6	9	9	9	10	9	9	11	11	11	11	11	11	12	12	12	11	12	12
1983	fish.	3	5	4	3	6	4	4	4	6	8	7	8	8	8	8	8	8	8	8	7	8	8	7	9	7	7	9
1984	fish.	1	2	2	1	3	3	3	3	6	5	5	5	6	7	7	9	9	9	10	9	10	10	12	11	10	9	10
1991	fish.	5	5	4	3	5	6	6	6	8	7	9	10	12	12	11	13	11	13	16	14	16	17	17	17	16	16	18
1992	fish.	6	7	6	11	13	13	15	15	15	15	16	16	17	16	17	16	16	16	16	16	16	16	16	16	16	17	16
1993	fish.	4	4	4	5	3	7	6	6	6	8	9	9	8	9	10	9	9	10	10	10	10	10	10	10	9	10	8
1994	fish.	5	3	3	4	6	7	8	8	8	9	9	9	8	9	9	9	11	10	11	11	10	11	10	11	10	11	10
1995	fish.	2	5	4	4	3	5	7	7	6	10	12	12	13	15	15	14	16	19	17	17	20	19	19	18	20	20	21
1996	fish.	3	5	5	5	9	9	10	12	12	15	15	18	18	20	19	19	21	20	20	21	20	20	20	20	19	20	21
1997	fish.	4	3	4	3	4	5	5	3	4	5	5	7	7	7	8	8	8	8	5	8	9	9	10	9	10	10	10
1998	fish.	10	9	8	9	10	10	12	10	11	11	11	14	13	14	15	14	16	17	15	15	16	16	17	17	17	17	17
1999	fish.	6	6	6	7	10	8	15	14	14	16	15	18	19	17	18	19	20	19	21	20	19	20	19	19	20	20	20
2000	fish.	5	9	12	14	13	13	17	18	19	19	22	21	22	21	22	21	22	22	23	23	22	24	23	23	24	22	25
2001	fish.	8	8	11	12	11	12	13	13	12	13	16	12	13	13	15	16	16	17	15	18	18	17	18	19	19	20	21
2002	fish.	8	11	11	9	10	10	9	11	11	11	10	10	12	10	11	13	12	12	11	15	14	16	14	12	12	13	15
2003	fish.	2	3	5	3	4	7	8	9	10	8	11	11	10	10	10	12	12	13	13	16	16	17	18	17	18	17	17
2004	fish.	6	5	6	7	6	7	7	8	8	9	8	10	11	9	12	11	12	14	11	14	13	13	14	14	14	15	14
2005	fish.	3	3	4	5	7	6	7	7	10	10	10	8	11	12	12	11	13	15	14	14	15	16	14	16	16	15	15
2006	fish.	4	0	2	3	6	5	7	6	7	11	9	11	10	11	11	14	12	12	14	13	13	13	15	13	16	15	14
2007	fish.	6	7	6	7	8	7	8	9	10	12	11	10	13	13	15	13	16	15	14	15	15	16	15	17	18	18	18
2008	fish.	6	6	7	9	12	12	15	12	15	16	15	16	17	19	18	17	17	22	16	20	19	20	19	19	20	21	19
2009	fish.	8	9	7	7	10	8	9	9	9	11	8	9	13	12	11	12	12	14	14	13	14	17	18	14	16	19	18
2010	fish.	7	7	11	9	12	12	11	12	13	12	11	12	15	15	15	15	16	15	14	17	16	18	15	14	16	17	17
2011	fish.	0	0	0	1	1	1	2	4	4	6	5	5	8	8	9	8	9	8	10	10	10	9	10	11	11	11	11
2012	fish.	1	1	2	0	4	2	1	2	1	3	2	3	4	5	2	4	5	4	5	6	6	5	6	7	6	6	7
1980	surv.	197	238	293	452	385	461	477	594	1094	977	1388	1857	1582	1881	1705	1215	1065	810	570	616	572	498	366	282	366	481	360
1983	surv.	168	200	189	175	296	515	301	460	417	362	415	462	572	515	596	719	849	694	726	613	497	561	660	767	707	586	735
1986	surv.	949	760	709	539	577	577	525	537	573	541	672	492	517	473	500	422	525	372	359	476	327	334	350	288	337	317	356
1991	surv.	626	534	502	341	324	215	216	123	179	119	147	157	158	155	126	167	142	138	157	141	216	215	180	256	248	238	261
1994	surv.	121	111	125	94	76	107	148	118	160	172	225	228	242	212	249	186	188	188	200	182	180	259	220	211	231	239	245
1997	surv.	204	215	237	224	134	108	109	113	88	66	99	111	118	135	192	161	177	181	227	242	238	289	382	290	405	379	280
2000	surv.	84	45	39	9	65	52	47	132	207	264	201	253	231	265	262	310	271	284	263	245	290	254	353	374	346	387	329
2002	surv.	448	453	387	325	290	223	207	234	213	229	241	293	305	335	270	231	288	293	338	235	318	242	250	201	208	157	138
2004	surv.	52	64	54	71	58	83	75	76	58	89	117	134	168	171	206	171	171	198	153	188	199	198	197	166	257	205	173
2006	surv.	18	27	24	57	38	74	40	43	58	67	92	116	122	161	169	175	195	149	158	116	117	132	73	111	96	91	122
2010	surv.	88	49	71	68	60	81	93	110	171	221	237	278	299	301	277	315	346	358	352	313	299	312	264	220	280	252	199

Table 2.2.1.5 (page 3 of 4). Number of fish measured at each 1 cm interval from 4-120+ cm in the fishery and the survey.

Year	Fleet	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
1982	fish.	12	11	11	11	11	11	11	11	12	11	10	12	10	11	10	11	8	9	9	9	11	8	10	9	8	8	7	9	7
1983	fish.	8	8	7	8	6	7	9	8	7	7	7	7	8	7	7	6	7	7	8	5	5	4	6	4	4	7	6	4	7
1984	fish.	11	11	11	12	11	11	12	11	11	12	12	10	12	10	10	11	10	11	9	11	9	10	9	8	9	8	8	8	9
1991	fish.	18	18	19	17	19	19	19	20	19	18	20	19	20	20	19	20	18	20	18	19	19	19	18	19	20	18	18	17	16
1992	fish.	16	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	16	16	16	17	17	17	17	17	17	17
1993	fish.	10	10	10	10	10	10	10	10	9	10	10	10	10	10	10	9	10	10	10	10	10	10	10	10	10	9	9	9	10
1994	fish.	9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	11	10	10	10	10	10	10	11	10	10	10	11
1995	fish.	21	19	20	20	21	20	21	20	19	20	21	20	20	20	17	20	19	20	19	19	19	19	20	19	19	20	19	19	19
1996	fish.	20	21	22	20	20	22	21	22	20	21	22	22	22	22	22	21	21	22	22	21	21	22	22	21	21	19	21	20	21
1997	fish.	10	10	10	10	10	9	9	10	10	9	9	10	10	10	10	9	9	9	9	8	9	9	9	10	10	10	9	8	10
1998	fish.	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	16	17	17
1999	fish.	19	20	20	19	19	19	19	19	19	21	21	20	20	19	20	20	19	20	19	17	19	18	20	20	17	18	18	18	17
2000	fish.	25	24	25	25	24	25	24	24	24	24	25	21	22	21	23	21	23	22	21	22	19	23	20	21	20	24	18	23	21
2001	fish.	21	22	21	20	22	23	21	22	20	22	21	22	23	22	23	19	22	21	19	21	21	19	17	18	17	15	16	14	16
2002	fish.	14	14	16	15	18	16	15	16	14	17	16	16	17	16	15	15	13	13	15	17	15	14	14	15	12	12	12	11	11
2003	fish.	18	18	15	18	17	12	17	14	14	15	15	13	15	14	15	13	12	13	11	9	12	10	14	12	10	10	12	10	11
2004	fish.	18	17	16	17	16	15	15	16	16	17	13	17	15	15	15	13	13	15	16	14	13	14	15	15	14	11	13	13	13
2005	fish.	16	16	15	16	16	15	16	14	15	13	16	14	15	15	15	14	16	14	15	16	12	13	14	14	14	13	10	15	13
2006	fish.	14	16	14	18	16	16	16	14	15	16	14	15	13	15	17	12	15	13	15	12	14	14	15	16	14	14	14	13	13
2007	fish.	17	18	17	17	16	18	17	18	17	16	17	16	16	17	16	16	15	15	16	16	16	16	13	14	16	15	16	16	17
2008	fish.	23	20	21	21	23	24	23	20	24	21	21	23	24	21	18	23	22	24	21	21	18	18	20	21	20	20	18	19	20
2009	fish.	16	18	18	18	18	18	18	18	19	15	16	15	15	15	14	14	15	13	16	11	13	14	16	15	14	15	14	14	15
2010	fish.	21	20	20	18	16	17	22	20	21	21	23	21	24	21	21	21	19	22	22	17	21	20	18	18	19	19	20	19	16
2011	fish.	11	10	11	9	10	9	9	10	10	9	7	9	10	8	6	8	8	7	8	9	7	7	7	6	6	6	6	5	6
2012	fish.	8	8	7	7	6	8	8	7	7	6	7	7	6	7	7	8	7	7	7	7	8	8	7	7	7	7	8	6	7
1980	surv.	387	588	320	419	576	443	568	436	451	283	386	355	216	230	164	176	362	352	379	250	208	271	102	42	115	190	148	103	166
1983	surv.	961	576	772	498	535	725	598	623	539	482	582	482	473	511	498	510	505	317	495	294	255	187	275	201	83	76	92	225	53
1986	surv.	515	427	448	472	511	533	569	437	364	487	586	402	365	363	194	248	247	158	139	142	110	65	74	70	60	53	52	80	21
1991	surv.	297	191	263	340	335	335	273	292	253	285	249	250	207	189	229	240	169	172	158	131	127	136	96	115	102	47	66	61	87
1994	surv.	302	297	301	258	293	280	313	270	284	302	265	329	192	206	215	188	131	181	116	170	149	127	184	130	148	109	127	219	158
1997	surv.	359	323	277	228	285	302	241	190	131	180	139	128	140	123	84	62	78	82	74	79	53	58	50	54	59	52	43	50	75
2000	surv.	321	315	308	333	235	228	209	164	180	150	172	143	165	174	120	94	98	86	58	54	71	43	56	39	50	43	29	25	34
2002	surv.	147	153	122	135	119	130	121	112	125	124	115	148	168	160	151	118	130	156	162	159	165	122	141	115	121	96	45	91	90
2004	surv.	199	226	229	241	230	199	178	185	202	208	142	170	163	163	140	147	121	96	149	117	119	97	99	118	90	35	58	61	42
2006	surv.	113	90	98	130	64	100	89	101	73	107	106	88	84	99	80	83	91	102	105	101	63	116	69	62	89	80	82	100	59
2010	surv.	160	168	180	231	245	227	163	135	130	126	119	92	116	87	61	72	60	35	66	42	54	35	13	42	30	29	35	23	25

Table 2.2.1.5 (page 4 of 4). Number of fish measured at each 1 cm interval from 4-120+ cm in the fishery and the survey.

Year	Fleet	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120+
1982	fish.	3	5	6	5	1	4	4	3	0	4	2	2	2	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1983	fish.	3	4	6	4	3	3	2	4	4	3	2	2	1	3	0	1	0	1	0	1	0	0	0	0	0	1	0	0	1
1984	fish.	8	9	6	8	5	3	7	4	5	5	3	3	5	4	4	4	1	1	1	0	0	0	1	0	0	0	0	0	0
1991	fish.	18	17	16	16	13	13	14	10	10	10	9	10	8	6	6	3	2	1	1	0	0	1	1	1	0	0	0	0	0
1992	fish.	17	17	17	17	17	17	16	17	17	15	15	14	16	13	15	12	11	9	10	11	10	5	4	3	3	0	2	1	1
1993	fish.	9	10	10	9	10	9	9	9	9	9	9	9	9	9	8	9	8	7	8	7	6	5	3	2	3	2	1	0	1
1994	fish.	10	11	10	10	10	9	9	10	10	8	11	10	7	9	7	5	6	6	7	4	5	4	3	4	3	2	1	1	1
1995	fish.	19	19	20	19	19	20	19	17	19	17	18	16	16	16	15	12	13	11	11	9	6	8	4	6	3	3	0	1	2
1996	fish.	20	20	21	19	20	20	18	19	19	17	17	17	17	19	18	16	16	12	12	12	7	8	9	3	3	4	1	0	5
1997	fish.	9	10	10	10	9	10	9	9	9	10	8	10	10	9	9	8	8	8	8	8	8	6	9	8	6	2	2	2	5
1998	fish.	17	17	17	16	17	17	17	17	16	17	17	17	17	16	15	16	16	15	13	11	12	10	10	7	6	4	3	4	14
1999	fish.	18	14	15	17	15	17	15	17	15	17	15	15	14	14	13	15	13	12	12	10	10	8	10	6	2	5	2	4	11
2000	fish.	22	19	22	18	20	20	19	20	19	20	18	20	19	19	21	19	18	18	19	15	13	13	11	9	9	5	2	2	12
2001	fish.	16	16	16	16	16	14	17	16	17	15	13	15	15	16	17	15	13	13	13	12	11	11	11	10	8	8	7	8	12
2002	fish.	12	11	12	12	11	11	11	10	12	10	10	11	12	8	8	6	8	6	7	6	7	5	2	1	3	1	1	1	0
2003	fish.	9	9	11	10	9	8	7	9	9	7	6	5	7	5	5	4	6	3	4	3	5	2	2	1	2	0	2	2	2
2004	fish.	12	12	11	13	13	11	12	12	11	12	10	11	12	12	11	11	10	8	9	5	6	4	5	4	4	1	3	2	2
2005	fish.	12	12	13	12	12	12	11	11	11	10	10	10	9	11	9	8	8	7	5	5	4	3	4	2	2	2	1	1	6
2006	fish.	13	12	11	12	13	12	13	13	11	13	12	10	10	12	9	9	10	9	7	7	5	5	4	5	1	1	3	2	5
2007	fish.	15	14	14	15	15	13	14	16	12	14	13	14	12	12	12	13	12	10	6	6	10	8	5	5	4	3	2	1	0
2008	fish.	21	18	21	20	20	18	18	19	19	19	19	19	19	18	17	15	17	16	14	15	14	12	8	7	7	4	5	4	24
2009	fish.	16	16	15	17	14	13	17	14	16	13	14	12	12	13	13	14	13	12	13	11	9	10	10	7	4	2	0	1	1
2010	fish.	16	19	18	16	18	19	17	22	18	17	17	19	15	16	18	16	15	15	14	12	13	9	8	9	8	7	3	1	9
2011	fish.	6	6	6	5	7	6	5	7	5	6	5	6	6	5	5	6	4	3	4	4	3	3	2	4	2	1	1	2	4
2012	fish.	6	7	7	7	6	6	5	6	6	7	6	5	7	7	5	5	5	5	2	2	3	2	1	1	1	1	1	2	4
1980	surv.	30	95	58	55	22	48	18	31	15	15	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	surv.	17	56	36	36	36	47	9	6	54	4	1	5	3	7	4	13	0	3	0	0	0	0	0	0	0	0	0	0	0
1986	surv.	22	29	31	26	16	25	23	14	23	2	3	2	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
1991	surv.	62	43	23	28	13	24	8	25	8	4	10	0	6	7	3	13	1	1	0	0	0	0	0	3	0	0	0	0	0
1994	surv.	159	130	97	103	119	76	58	76	22	33	20	28	20	10	14	5	0	5	3	0	0	5	5	0	0	0	0	0	0
1997	surv.	61	24	61	18	46	30	42	48	26	27	55	18	7	21	17	2	7	6	6	0	3	3	0	0	0	0	0	0	0
2000	surv.	26	12	27	20	17	12	19	16	9	3	8	11	6	8	11	2	22	3	3	3	0	0	0	1	0	0	0	0	0
2002	surv.	31	61	50	34	28	23	24	14	14	11	17	37	2	19	7	7	6	0	4	0	9	0	0	3	0	0	0	0	0
2004	surv.	54	51	38	35	24	31	21	37	21	13	18	15	12	12	4	5	7	2	0	2	0	0	0	0	0	0	0	0	0
2006	surv.	34	36	28	59	40	32	22	31	30	11	20	10	35	6	9	13	17	7	0	3	7	5	2	0	2	0	0	0	0
2010	surv.	23	18	28	15	16	22	12	31	23	41	12	13	7	17	8	12	12	8	6	11	2	1	0	2	0	0	0	0	0

Table 2.2.1.6. Survey biomass (t) by area with coefficients of variation (CV), 1980-2010.

Survey biomass (t)

Year	S. Bering Sea	Eastern	Central	Western	All areas
1980	66,324	33,883	37,934	10,132	148,272
1983	28,246	51,742	66,153	69,613	215,755
1986	22,445	50,015	134,235	48,377	255,072
1991	8,286	64,926	42,323	75,514	191,049
1994	31,084	78,081	51,538	23,365	184,068
1997	10,742	28,239	30,252	14,183	83,416
2000	9,157	47,117	36,456	43,298	136,028
2002	9,601	25,241	24,327	23,802	82,970
2004	31,964	51,851	20,709	9,637	114,161
2006	7,410	43,349	22,033	19,734	92,526
2010	12,608	23,184	11,100	21,269	68,161

Coefficient of variation

Year	S. Bering Sea	Eastern	Central	Western	All areas
1980	0.344	0.215	0.464	0.175	0.201
1983	0.329	0.192	0.069	0.395	0.144
1986	0.295	0.125	0.478	0.314	0.261
1991	0.285	0.370	0.119	0.092	0.134
1994	0.375	0.301	0.390	0.286	0.183
1997	0.354	0.230	0.208	0.263	0.126
2000	0.220	0.222	0.270	0.429	0.173
2002	0.199	0.329	0.266	0.243	0.147
2004	0.355	0.304	0.208	0.169	0.175
2006	0.206	0.545	0.188	0.230	0.264
2010	0.231	0.230	0.258	0.410	0.161

Table 2.2.1.7. Parameters other than recruitment *dev*s, growth *dev*s (Model 2 only), and fishing mortality rates estimated by Models 1 and 2, with standard deviations.

	Model 1		Model 2	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.
Length at age 1 (cm)	17.988	0.155	20.246	0.532
Asymptotic length (cm)	117.274	2.150	125.056	3.597
Brody growth coefficient	0.186	0.005	0.163	0.007
SD of length at age 1 (cm)	2.820	0.105	2.174	0.072
SD of length at age 20 (cm)	11.294	0.455	12.719	0.471
ln(mean post-1976 recruitment)	10.953	0.050	10.768	0.051
ln(pre-1977 recruitment offset)	-0.638	0.146	-0.124	0.177
Initial age 3 ln(abundance) dev	-0.044	0.377	0.042	0.411
Initial age 2 ln(abundance) dev	0.718	0.175	-0.130	0.465
Initial age 1 ln(abundance) dev	-0.843	0.316	-0.008	0.323
Initial fishing mortality	0.009	0.002	0.010	0.003
Fishery beginning_of_peak_region	109.221	8.374	105.764	6.903
Fishery ascending_width	7.611	0.182	7.464	0.163
Survey beginning_of_peak_region	3.495	0.098	3.525	0.119
Survey width_of_peak_region	-9.538	12.118	-1.416	1.068
Survey ascending_width	0.718	0.164	0.791	0.184
Survey descending_width	2.557	0.121	-1.559	10.458
Survey initial_selectivity	-7.342	0.368	-6.952	0.370
Survey final_selectivity	-9.783	6.222	-9.806	5.624
Survey ascending_width dev_1980	-0.113	0.017	-0.102	0.020
Survey ascending_width dev_1983	-0.090	0.015	-0.094	0.017
Survey ascending_width dev_1986	0.014	0.025	0.024	0.030
Survey ascending_width dev_1991	0.082	0.027	0.075	0.030
Survey ascending_width dev_1994	0.166	0.029	0.174	0.033
Survey ascending_width dev_1997	0.004	0.015	0.020	0.016
Survey ascending_width dev_2000	-0.008	0.016	-0.012	0.017
Survey ascending_width dev_2002	0.039	0.018	0.025	0.018
Survey ascending_width dev_2004	-0.048	0.018	-0.041	0.017
Survey ascending_width dev_2006	0.053	0.020	0.056	0.022

Table 2.2.1.8. Recruitment *dev*s estimated my Models 1 and 2, with standard deviations.

	Model 1		Model 2	
Year	Estimate	St. Dev.	Estimate	St. Dev.
1977	0.915	0.113	1.333	0.131
1978	0.169	0.213	0.175	0.284
1979	0.449	0.117	0.543	0.146
1980	0.169	0.125	-0.056	0.224
1981	1.514	0.142	1.396	0.175
1982	0.005	0.257	-0.523	0.431
1983	1.020	0.117	0.800	0.141
1984	1.500	0.152	1.199	0.211
1985	-1.536	0.448	-0.921	0.483
1986	1.543	0.138	0.120	0.928
1987	0.562	0.196	1.017	0.173
1988	-0.074	0.167	-0.088	0.155
1989	1.270	0.083	1.103	0.096
1990	-0.764	0.243	-0.819	0.281
1991	0.045	0.106	-0.163	0.123
1992	-1.016	0.146	-1.064	0.156
1993	0.870	0.086	0.710	0.092
1994	-0.920	0.197	-0.856	0.254
1995	0.242	0.117	-0.132	0.121
1996	0.897	0.097	0.697	0.102
1997	0.095	0.110	0.048	0.129
1998	-0.500	0.153	-0.767	0.174
1999	0.394	0.087	0.261	0.095
2000	0.291	0.089	0.384	0.089
2001	-0.537	0.129	-0.332	0.140
2002	-0.567	0.175	-0.351	0.154
2003	-0.346	0.121	-0.079	0.113
2004	-1.857	0.241	-1.286	0.219
2005	-0.237	0.139	-0.109	0.167
2006	-0.432	0.148	-0.200	0.177
2007	-0.410	0.124	0.002	0.142
2008	-1.402	0.208	-1.024	0.210
2009	-0.803	0.336	-0.604	0.349
2010	-0.548	0.471	-0.415	0.479

Table 2.2.1.9. Growth parameter *dev*s for mid-year length at age 1 (*L1*) and asymptotic length (*Linf*) estimated by Model 2.

	*L1 dev*s		*Linf dev*s	
Year	Estimate	St. Dev.	Estimate	St. Dev.
1977	0.008	0.086	-0.144	0.048
1978	0.022	0.075	0.178	0.050
1979	0.008	0.078	-0.045	0.058
1980	0.000	0.079	-0.037	0.071
1981	-0.090	0.068	-0.109	0.066
1982	0.013	0.101	-0.124	0.061
1983	-0.026	0.068	-0.132	0.067
1984	0.045	0.069	0.050	0.065
1985	0.235	0.042	-0.053	0.053
1986	0.073	0.124	-0.051	0.070
1987	0.191	0.115	-0.175	0.084
1988	-0.001	0.088	-0.113	0.121
1989	-0.010	0.069	0.088	0.068
1990	0.016	0.037	-0.004	0.064
1991	-0.014	0.078	-0.032	0.066
1992	0.018	0.071	-0.039	0.067
1993	-0.191	0.027	-0.004	0.056
1994	-0.017	0.087	-0.035	0.068
1995	0.021	0.075	0.079	0.054
1996	0.121	0.028	0.050	0.066
1997	0.010	0.073	0.068	0.066
1998	-0.049	0.076	-0.026	0.041
1999	-0.153	0.036	-0.010	0.056
2000	-0.106	0.073	-0.044	0.064
2001	-0.042	0.035	0.104	0.037
2002	0.023	0.075	0.098	0.055
2003	0.017	0.044	0.055	0.046
2004	0.061	0.083	0.140	0.059
2005	-0.071	0.031	0.060	0.045
2006	0.005	0.085	0.091	0.068
2007	0.023	0.081	0.097	0.063
2008	-0.018	0.074	0.033	0.069
2009	-0.106	0.038	0.035	0.058
2010	-0.014	0.099	-0.032	0.069

Table 2.2.1.10. Fishing mortality rates as estimated by Models 1 and 2.

	Fishing mortality rate	
Year	Model 1	Model 2
1977	0.029	0.034
1978	0.029	0.028
1979	0.050	0.041
1980	0.050	0.040
1981	0.059	0.050
1982	0.059	0.056
1983	0.052	0.057
1984	0.043	0.049
1985	0.032	0.037
1986	0.027	0.034
1987	0.045	0.066
1988	0.016	0.027
1989	0.013	0.021
1990	0.019	0.030
1991	0.024	0.038
1992	0.108	0.175
1993	0.091	0.152
1994	0.062	0.104

	Fishing mortality rate	
Year	Model 1	Model 2
1995	0.051	0.083
1996	0.110	0.167
1997	0.100	0.146
1998	0.157	0.231
1999	0.143	0.221
2000	0.220	0.366
2001	0.206	0.348
2002	0.199	0.313
2003	0.223	0.336
2004	0.216	0.295
2005	0.183	0.222
2006	0.180	0.200
2007	0.309	0.309
2008	0.337	0.316
2009	0.421	0.378
2010	0.493	0.434
2011	0.226	0.197

Table 2.2.1.11. Fit to survey abundance (1000s of fish, "Observed") obtained by Models 1 and 2. "Expected" shows estimate for each model. "Residual" shows ln(observed/expected). The bottom row under "Residual" shows the mean for each column. Ideally, this value should be close to zero. A positive mean implies that the model tends to be biased low. Squared standardized residuals ("Squared std. res.") shows $(\ln(\text{observed/expected})/\sigma)^2$. The bottom row under "Squared std. res." shows the root mean squared error. Ideally, this value should be close to unity.

			Expected		Residual		Squared std. res.	
Year	Observed	Sigma	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
1980	57,036	0.156	41,040	54,403	0.329	0.047	4.452	0.092
1983	70,402	0.131	56,583	54,408	0.219	0.258	2.804	3.900
1986	109,969	0.226	127,501	90,234	-0.148	0.198	0.429	0.767
1991	70,557	0.214	127,044	87,004	-0.588	-0.210	7.574	0.961
1994	62,333	0.266	86,432	63,933	-0.327	-0.025	1.510	0.009
1997	28,724	0.137	53,822	39,668	-0.628	-0.323	21.071	5.569
2000	47,231	0.207	58,291	39,930	-0.210	0.168	1.030	0.656
2002	30,560	0.139	58,786	42,106	-0.654	-0.320	22.152	5.316
2004	29,224	0.132	36,878	30,542	-0.233	-0.044	3.096	0.111
2006	24,649	0.153	31,430	32,000	-0.243	-0.261	2.523	2.910
2010	24,617	0.121	21,988	25,341	0.113	-0.029	0.875	0.058
					-0.216	-0.049	2.477	1.360

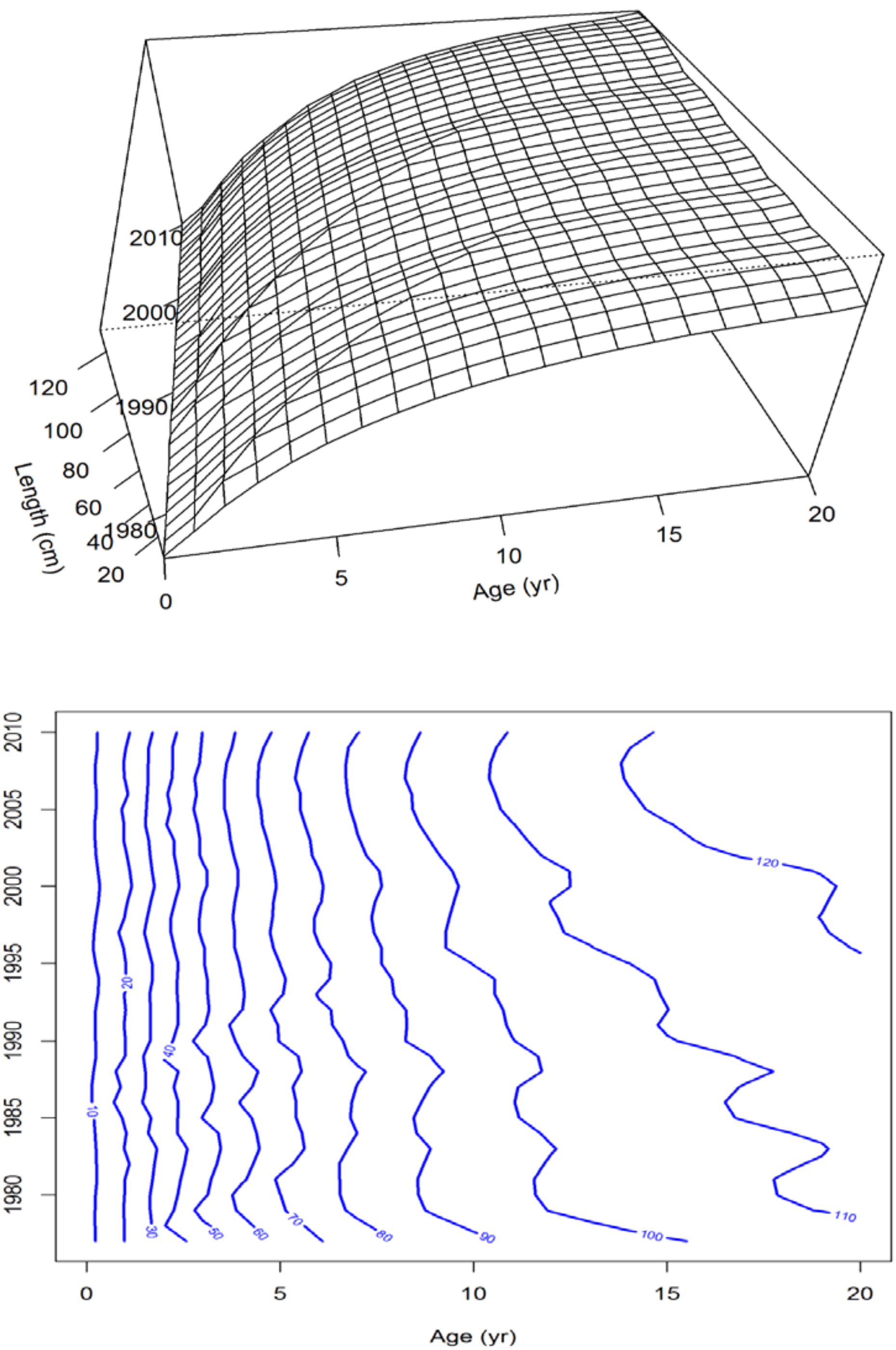

Figure 2.2.1.1. Time-varying length at age as estimated by Model 2, shown as a surface plot (upper panel) and as a contour plot (lower panel).

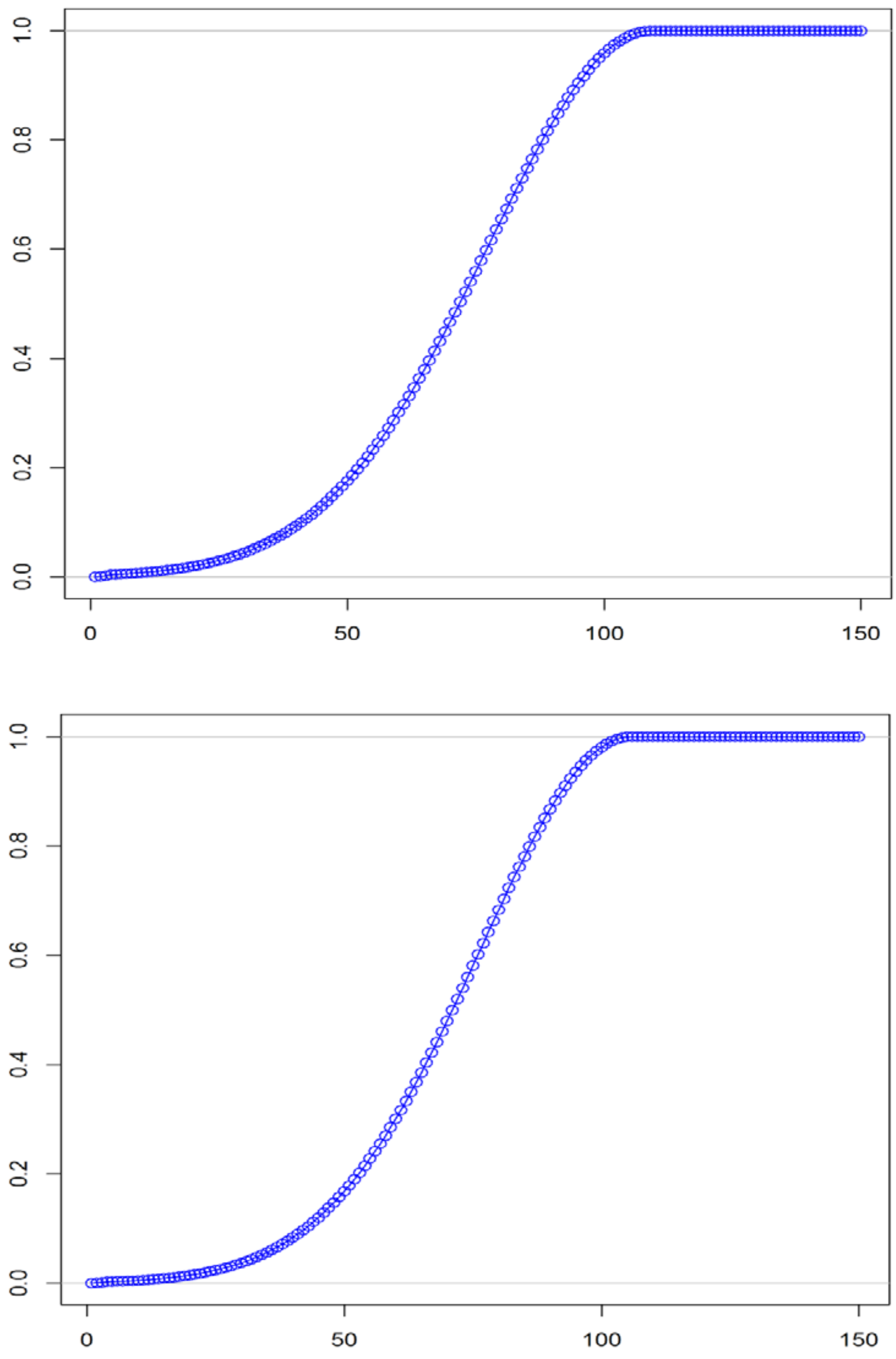

Figure 2.2.1.2. Fishery selectivity as estimated by Model 1 (upper panel) and Model 2 (lower panel).

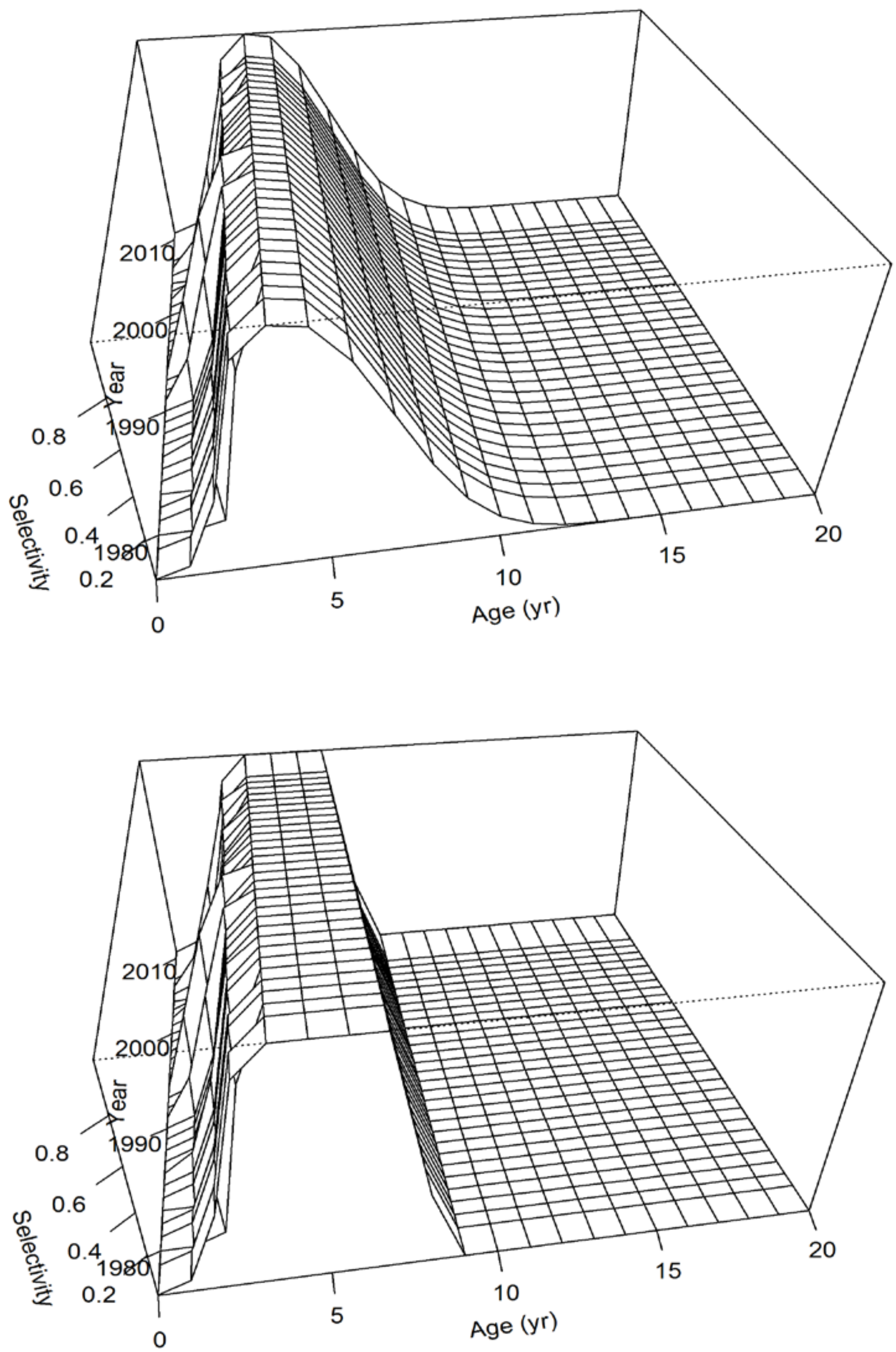

Figure 2.2.1.3a. Time-varying survey selectivity as estimated by Model 1 (upper panel) and Model 2 (lower panel), shown as surface plots.

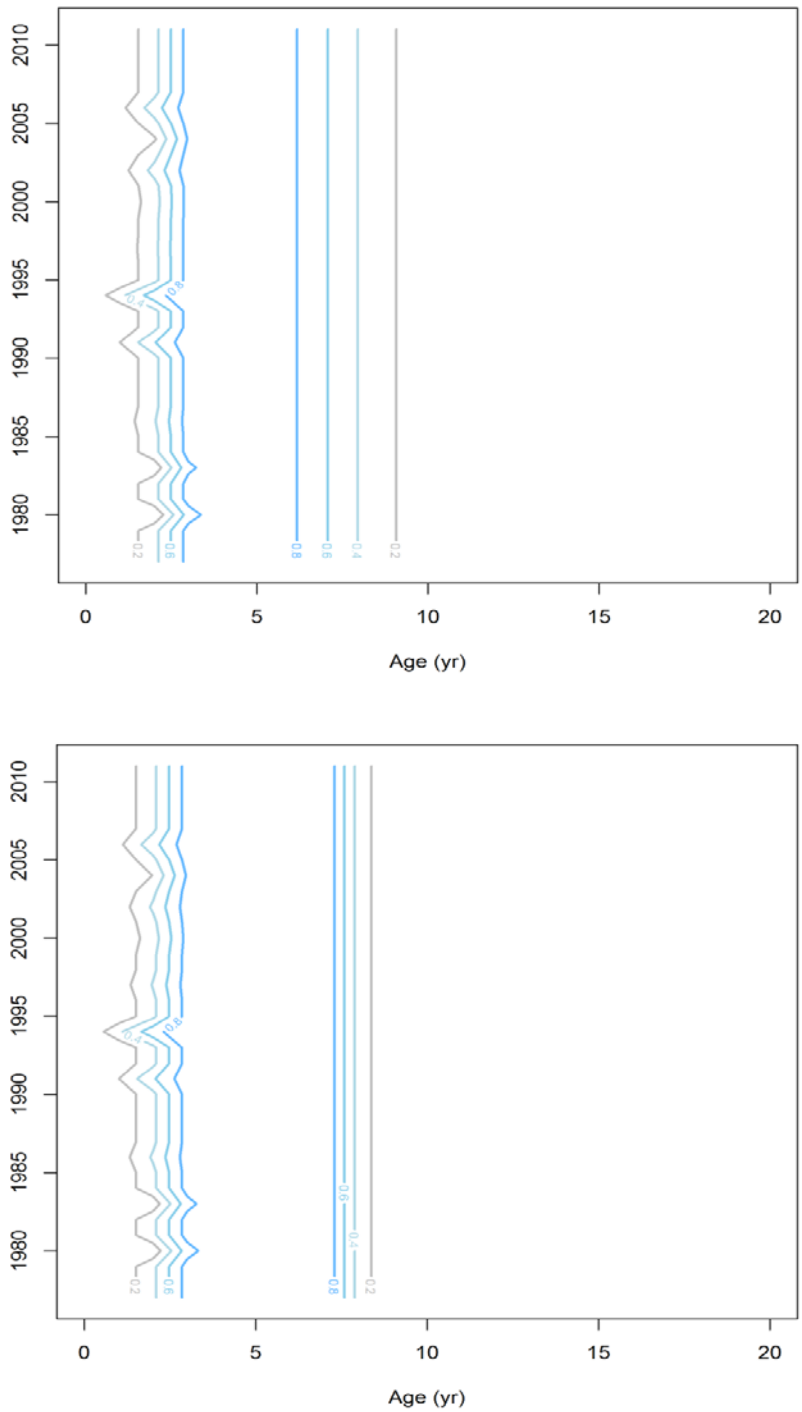

Figure 2.2.1.3b. Time-varying survey selectivity as estimated by Model 1 (upper panel) and Model 2 (lower panel), shown as contour plots.

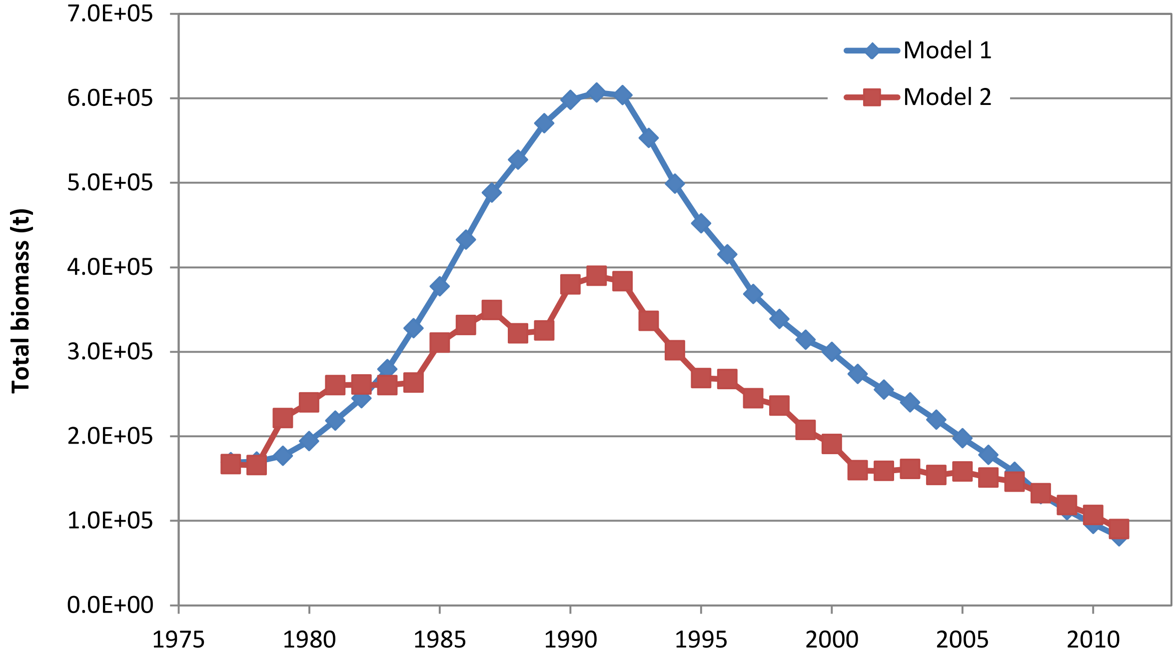

Figure 2.2.1.4. Time series of total (age 0+) biomass (t) as estimated by Models 1 and 2.

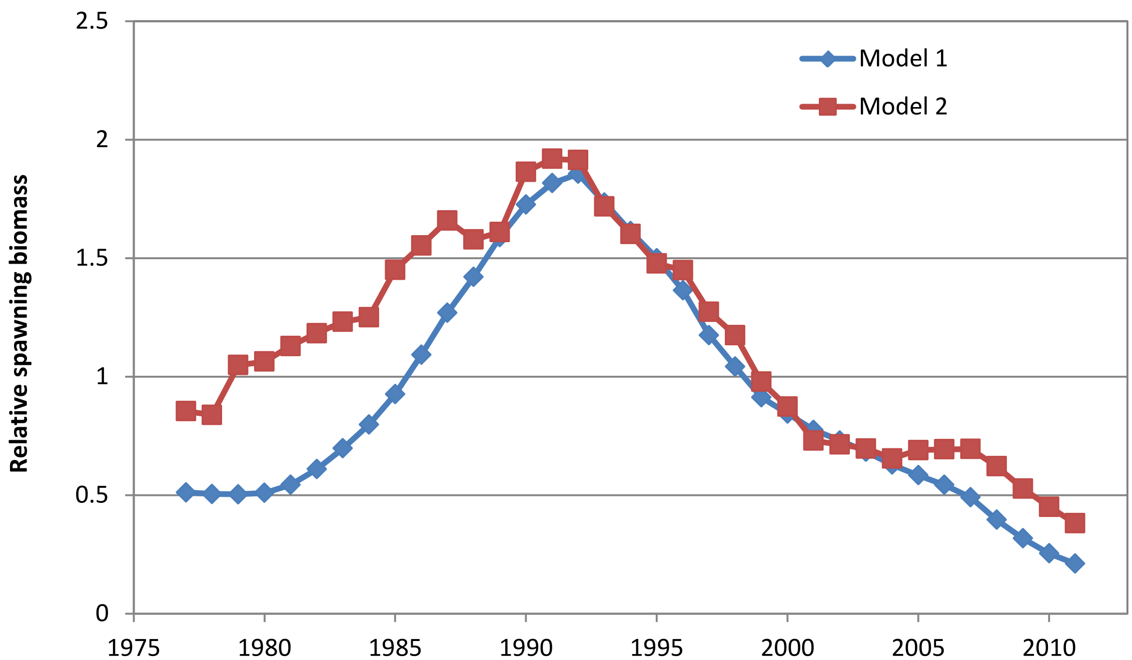

Figure 2.2.1.5. Time series of spawning biomass relative to $B_{100\%}$ as estimated by Models 1 and 2.

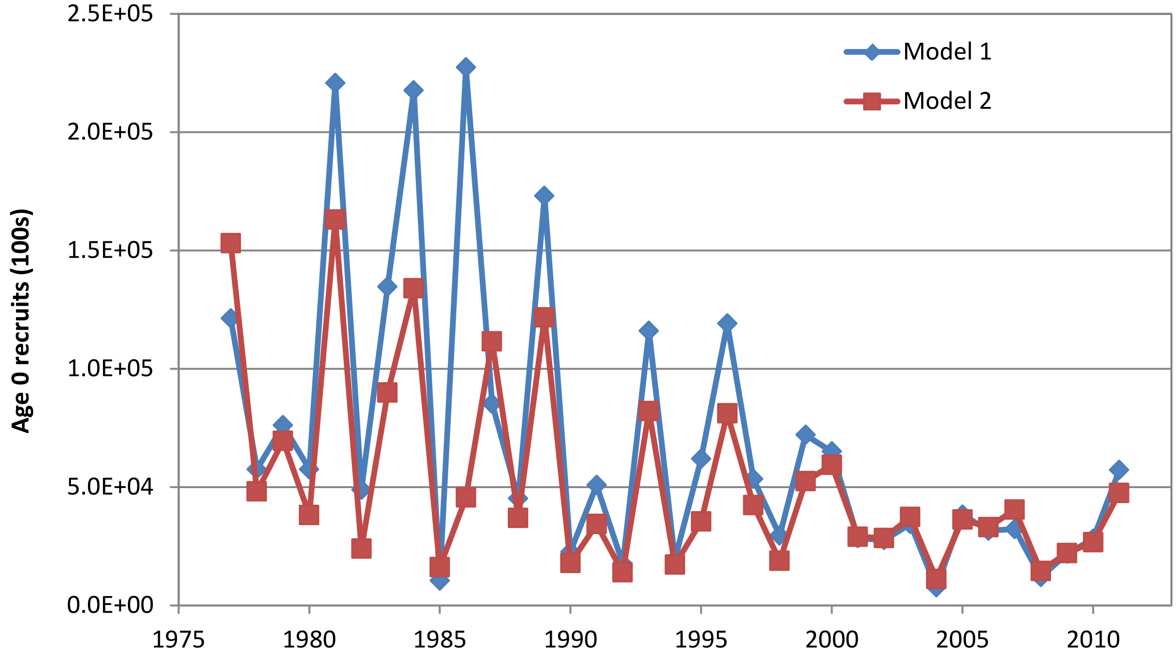

Figure 2.2.1.6. Time series of age 0 recruits (1000s) as estimated by Models 1 and 2.

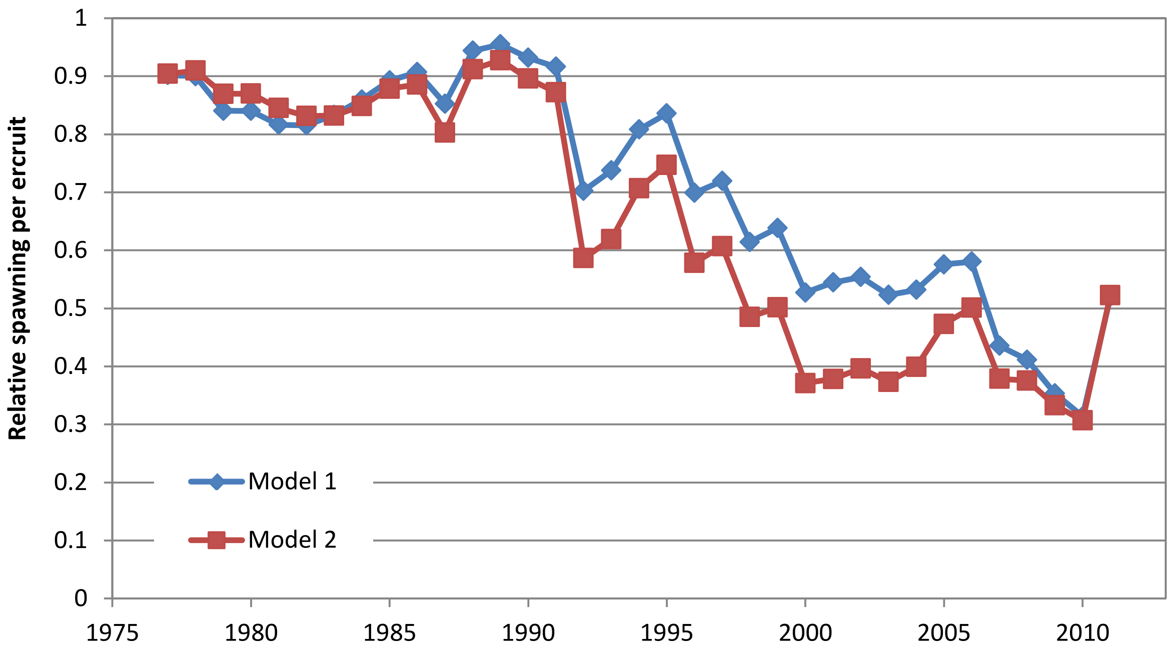

Figure 2.2.1.7. Time series of relative spawning per recruit (RSPR) corresponding to fishing mortality rates as estimated by Models 1 and 2 (higher fishing mortality corresponds to lower RSPR).

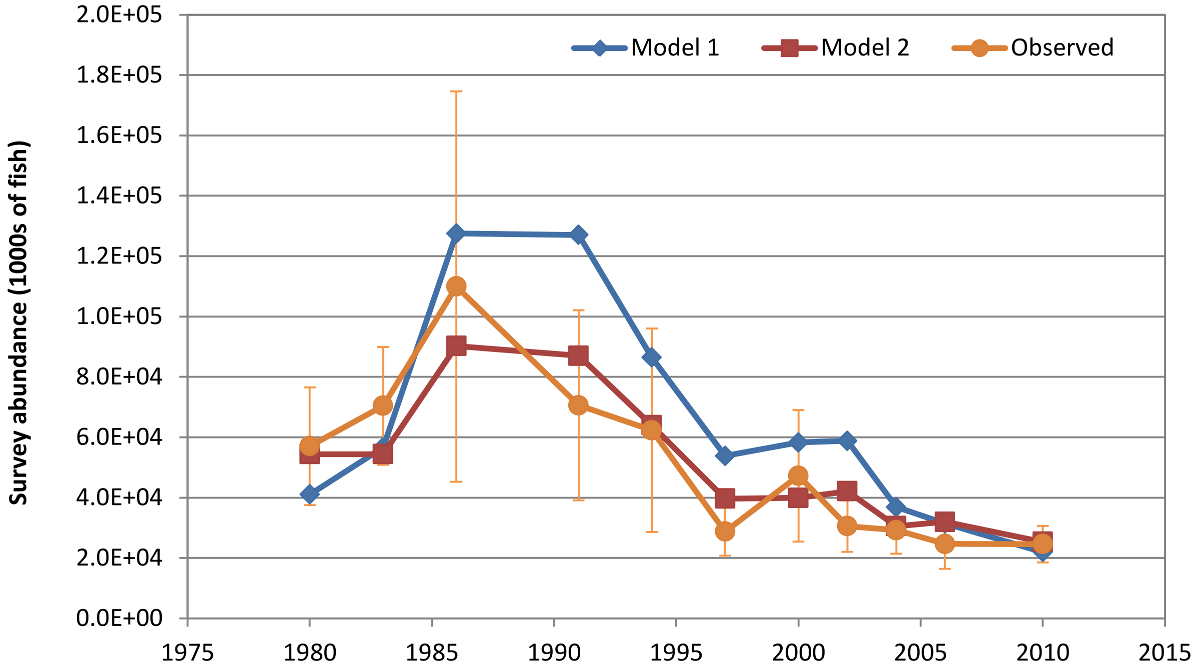

Figure 2.2.1.8. Estimates of survey abundance (1000s of fish) obtained by Models 1 and 2, with point estimates and 95% confidence intervals from the survey ("Observed").

Attachment 2.3: Current regulations specific to the Pacific cod fishery in the BSAI

(from 50 CFR Part 679)

This attachment only provides information on existing regulatory provisions, and should not be relied upon for determining compliance with the regulations. For the purpose of complying with the regulations, please refer to the actual text in the Code of Federal Regulations.

§ 679.4 License Limitation Permits; (k) Licenses for license limitation program (LLP) groundfish or crab species; (9) Pacific cod endorsements in the BSAI

i) General. In addition to other requirements of this part, and unless specifically exempted in paragraph (k)(9)(iv) of this section, a license holder must have a Pacific cod endorsement on his or her groundfish license to conduct directed fishing for Pacific cod with hook-and-line or pot gear in the BSAI. A license holder can only use the specific non-trawl gear(s) indicated on his or her license to conduct directed fishing for Pacific cod in the BSAI.

ii) Eligibility requirements for a Pacific cod endorsement. This table provides eligibility requirements for Pacific cod endorsements on an LLP groundfish license:

If a license holder's license has a …	And the license holder harvested Pacific cod in the BSAI with …	Then the license holder must demonstrate that he or she harvested at least …	In …	To receive a Pacific cod endorsement that authorizes harvest with …
(A) Catcher vessel designation.	Hook-and-line gear or jig gear	7.5 mt of Pacific cod in the BSAI.	In any one of the years 1995, 1996, 1997, 1998, or 1999.	Hook-and-line gear
(B) Catcher vessel designation.	Pot gear or jig gear	100,000 lb of Pacific cod in the BSAI.	In each of any two of the years 1995, 1996, 1997, 1998, or 1999.	Pot gear.
(C) Catcher/ processor vessel designation.	Hook-and-line gear	270 mt of Pacific cod in the BSAI	In any one of the years 1996, 1997, 1998, or 1999.	Hook-and-line gear.
(D) Catcher/ processor vessel designation.	Pot gear	300,000 lb of Pacific cod in the BSAI.	In each of any two of the years 1995, 1996, 1997, or 1998.	Pot gear.

iii) Explanations for Pacific cod endorsements.

A) All eligibility amounts in the table at paragraph (k)(9)(ii) of this section will be determined based on round weight equivalents.

B) Discards will not count toward eligibility amounts in the table at paragraph (k)(9)(ii) of this section.
C) Pacific cod harvested for personal bait use will not count toward eligibility amounts in the table at paragraph (k)(9)(ii) of this section.
D) A legal landing of Pacific cod in the BSAI for commercial bait will count toward eligibility amounts in the table at paragraph (k)(9)(ii) of this section.
E) Harvests within the BSAI will count toward eligibility amounts in the table at paragraph (k)(9)(ii) of this section; however, a license holder will only be able to harvest Pacific cod in the specific areas in the BSAI for which he or she has an area endorsement.
F) Harvests within the BSAI would count toward eligibility amounts in the table at paragraph (k)(9)(ii) of this section if:
   1) Those harvests were made from the vessel that was used as the basis of eligibility for the license holder's LLP groundfish license, or
   2) Those harvests were made from a vessel that was not the vessel used as the basis of eligibility for the license holder's LLP groundfish license, provided that, at the time the endorsement-qualifying Pacific cod harvests were made, the person who owned such Pacific cod endorsement-qualifying fishing history also owned the fishing history of a vessel that satisfied the requirements for the LLP groundfish license.
   3) Notwithstanding the provisions of paragraph (k)(9)(iii)(F)(2) of this section, the LLP groundfish license qualifying history or the Pacific cod qualifying history of any one vessel may not be used to satisfy the requirements for issuance of more than one LLP groundfish license endorsed for the BSAI Pacific cod hook-and-line or pot gear fisheries.
G) Except as provided in paragraph 679.4(k)(9)(iii)(D), only harvests of BSAI Pacific cod in the directed fishery will count toward eligibility amounts.

iv) <u>Exemptions to Pacific cod endorsements</u>.
A) Any vessel exempted from the License Limitation Program at paragraph (k)(2) of this section.
B) Any catcher vessel less than 60 ft (18.3 m) LOA.
C) Any catch of Pacific cod for personal use bait.

v) <u>Combination of landings and hardship provision</u>. Notwithstanding the eligibility requirements in paragraph (k)(9)(ii) of this section, a license holder may be eligible for a Pacific cod endorsement by meeting the following criteria.
A) <u>Combination of landings</u>. A license holder may combine the landings of a sunken vessel and the landings of a vessel obtained to replace a sunken vessel to satisfy the eligibility amounts in the table at paragraph (k)(9)(ii) of this section only if he or she meets the requirements in paragraphs (k)(9)(v)(A)(1) - (4) of this section. No other combination of landings will satisfy the eligibility amounts in the table at paragraph (k)(9)(ii) of this section.
   1) The sunken vessel was used as the basis of eligibility for the license holder's groundfish license;
   2) The sunken vessel sank after January 1, 1995;
   3) The vessel obtained to replace the sunken vessel was obtained by December 31 of the year 2 years after the sunken vessel sank; and
   4) The length of the vessel obtained to replace the sunken vessel does not exceed the MLOA specified on the license holder's groundfish license.
B) <u>Hardship provision</u>. A license holder may be eligible for a Pacific cod endorsement because of unavoidable circumstances if he or she meets the requirements in paragraphs (k)(9)(v)(B)(1) - (4) of this section. For purposes of this hardship provision, the term license holder includes the person who landings were used to meet the eligibility requirements for the license holder's groundfish license, if not the same person.
   1) The license holder at the time of the unavoidable circumstance held a specific intent to conduct directed fishing for BSAI Pacific cod in a manner sufficient to meet the landing

requirements in the table at paragraph (k)(9)(ii) of this section but that this intent was thwarted by a circumstance that was:
(i) Unavoidable;
(ii) Unique to the license holder, or unique to the vessel that was used as the basis of eligibility for the license holder's groundfish license; and
(iii) Unforeseen and reasonably unforeseeable to the license holder.

2) The circumstance that prevented the license holder from conducting directed fishing for BSAI Pacific cod in a manner sufficient to meet the landing requirements in paragraph (k)(9)(ii) actually occurred;
3) The license holder took all reasonable steps to overcome the circumstance that prevented the license holder from conducting directed fishing for BSAI Pacific cod in a manner sufficient to meet the landing requirements in paragraph (k)(9)(ii) of this section; and
4) Any amount of Pacific cod was harvested in the BSAI aboard the vessel that was used as the basis of eligibility for the license holder's groundfish license after the vessel was prevented from participating by the unavoidable circumstance but before April 16, 2000.

§ 679.7 Prohibitions; (a) Groundfish of the GOA and BSAI; (19) Atka mackerel and Pacific cod prohibition in Area 543

[In addition to the general prohibitions specified in § 600.725 of this chapter, it is unlawful for any person to do any of the following:] Retain in Area 543 or in adjacent State waters Pacific cod or Atka mackerel required to be deducted from the Federal TAC specified under § 679.20 on a vessel required to be Federally permitted.

§ 679.7 Prohibitions; (a) Groundfish of the GOA and BSAI; (23) Pacific cod directed fishing prohibition by hook-and-line, pot, or jig vessels in the Aleutian Islands subarea

[In addition to the general prohibitions specified in § 600.725 of this chapter, it is unlawful for any person to do any of the following:] Conduct directed fishing for Pacific cod required to be deducted from the Federal TAC specified under § 679.20 in the Aleutian Islands subarea and adjacent State waters with a vessel required to be Federally permitted using hook-and-line, pot, or jig gear November 1, 1200 hours, A.l.t., to December 31, 2400 hours, A.l.t.

§ 679.20 General limitations; (a) Harvest limits; (7) Pacific cod TAC, BSAI

i) CDQ reserve and seasonal allowances.
   A) A total of 10.7 percent of the annual Pacific cod TAC will be allocated to the CDQ Program in the annual harvest specifications required under paragraph (c) of this section. The Pacific cod CDQ allocation will be deducted from the annual Pacific cod TAC before allocations to the non-CDQ sectors are made under paragraph (a)(7)(ii) of this section.
   B) The BSAI Pacific cod CDQ gear allowances by season, as those seasons are specified under §679.23(e)(5), are as follows:

Gear Type	A season	B season	C season
(1) Trawl	60%	20%	20%
(i) Trawl CV	70%	10%	20%
(ii) Trawl CP	50%	30%	20%

(2) Hook-and-line CP and hook-and-line CV ≥60 ft (18.3 m) LOA	60%	40%	no C season
(3) Jig	40%	20%	40%
(4) All other non-trawl gear	no seasonal allowance	no seasonal allowance	no seasonal allowance

ii) Non-CDQ allocations.

A) Sector allocations. The remainder of the BSAI Pacific cod TAC after subtraction of the CDQ reserve for Pacific cod will be allocated to non-CDQ sectors as follows:

Sector	**% Allocation**
(1) Jig vessels	1.4
(2) Hook-and-line/pot CV <60 ft (18.3 m) LOA	2
(3) Hook-and-line CV ≥60 ft (18.3 m) LOA	0.2
(4) Hook-and-line CP	48.7
(5) Pot CV ≥60 ft (18.3 m) LOA	8.4
(6) Pot CP	1.5
(7) AFA trawl CP	2.3
(8) Amendment 80 sector	13.4
(9) Trawl CV	22.1

B) Incidental catch allowance. During the annual harvest specifications process set forth at paragraph (c) of this section, the Regional Administrator will specify an amount of Pacific cod that NMFS estimates will be taken as incidental catch in directed fisheries for groundfish other than Pacific cod by the hook-and-line and pot gear sectors. This amount will be the incidental catch allowance and will be deducted from the aggregate portion of Pacific cod TAC annually allocated to the hook-and-line and pot gear sectors before the allocations under paragraph (a)(7)(ii)(A) of this section are made to these sectors.

iii) Reallocation among non-CDQ sectors. If, during a fishing year, the Regional Administrator determines that a non-CDQ sector will be unable to harvest the entire amount of Pacific cod allocated to that sector under paragraph (a)(7)(ii)(A) of this section, the Regional Administrator will reallocate the projected unused amount of Pacific cod to other sectors through notification in the Federal Register. Any reallocation decision by the Regional Administrator will take into account the capability of a sector to harvest the reallocated amount of Pacific cod, and the following reallocation hierarchy:

A) Catcher vessel sectors. The Regional Administrator will reallocate projected unharvested amounts of Pacific cod TAC from a catcher vessel sector as follows: first to the jig sector, or to the less than 60 ft (18.3 m) LOA hook-and-line or pot catcher vessel sector, or to both of these sectors; second, to the greater than or equal to 60 ft (18.3 m) LOA hook-and-line or to the greater than or equal to 60 ft (18.3 m) LOA pot catcher vessel sectors; and third to the trawl catcher vessel sector. If the Regional Administrator determines that a projected unharvested amount from the jig sector allocation, the less than 60 ft (18.3 m) LOA hook-and-line or pot catcher vessel sector allocation, or the greater than or equal to 60 ft (18.3 m) LOA hook-and-line catcher vessel sector allocation is unlikely to be harvested through this hierarchy, the Regional Administrator will reallocate that amount to the hook-and-line catcher/processor sector. If the Regional Administrator determines that a projected unharvested amount from a greater than or equal to 60 ft (18.3 m) LOA pot catcher vessel sector allocation is unlikely to be harvested through this hierarchy, the Regional Administrator will reallocate that amount to the pot catcher/processor sector in accordance with the hierarchy set forth in paragraph (a)(7)(iii)(C) of this section. If the Regional Administrator determines that a projected unharvested amount from a trawl catcher vessel sector allocation is unlikely to be harvested through this hierarchy, the Regional Administrator will reallocate that amount to the other trawl sectors in accordance with the hierarchy set forth in paragraph (a)(7)(iii)(B) of this section.

B) Trawl gear sectors. The Regional Administrator will reallocate any projected unharvested amounts of Pacific cod TAC from the trawl catcher vessel or AFA catcher/processor sectors to other trawl sectors before unharvested amounts are reallocated and apportioned to specified gear sectors as follows:

1) 83.1 percent to the hook-and-line catcher/processor sector,
2) 2.6 percent to the pot catcher/processor sector, and
3) 14.3 percent to the greater than or equal to 60 ft (18.3 m) LOA pot catcher vessel sector.

C) Pot gear sectors. The Regional Administrator will reallocate any projected unharvested amounts of Pacific cod TAC from the pot catcher/processor sector to the greater than or equal to 60 ft (18.3 m) LOA pot catcher vessel sector, and from the greater than or equal to 60 ft (18.3 m) LOA pot catcher vessel sector to the pot catcher/processor sector before reallocating it to the hook-and-line catcher/processor sector.

iv) Non-CDQ seasonal allowances.

A) Seasonal allowances by sector. The BSAI Pacific cod sector allowances are apportioned by seasons, as those seasons are specified at § 679.23(e)(5), as follows:

Sector	**Seasonal Allowances**		
	A season	**B season**	**C season**
(1) Trawl			
(i) Trawl CV	74%	11%	15%
(ii) Trawl CP	75%	25%	0%
(2) Hook-and-line CP, hook-and-line CV ≥60 ft (18.3 m) LOA, and pot gear vessels ≥ ft (18.3 m) LOA	51%	49%	No C season
(3) Jig vessels	60%	20%	20%
(4) All other nontrawl vessels	No seasonal allowance	No seasonal allowance	No seasonal allowance

B) Unused seasonal allowances. Any unused portion of a seasonal allowance of Pacific cod from any sector except the jig sector will be reallocated to that sector's next season during the current fishing year unless the Regional Administrator makes a determination under paragraph (a)(7)(iii) of this section that the sector will be unable to harvest its allocation.

C) Jig sector. The Regional Administrator will reallocate any projected unused portion of a seasonal allowance of Pacific cod for the jig sector under this section to the less than 60 ft (18.3 m) LOA hook-and-line or pot catcher vessel sector. The Regional Administrator will reallocate the projected unused portion of the jig sector's C season allowance on or about September 1 of each year.

v) ITAC allocation to the Amendment 80 sector. A percentage of the Pacific cod TAC, after subtraction of the CDQ reserve, will be allocated as ITAC to the Amendment 80 sector as described in Table 33 to this part (http://alaskafisheries.noaa.gov/rr/tables/tabl33.pdf). Separate allocations for each Amendment 80 cooperative and the Amendment 80 limited access fishery are described under § 679.91. The allocation of Pacific cod to the Amendment 80 sector will be further divided into seasonal apportionments as described under paragraph (a)(7)(iv)(A)(1)(ii) of this section.
   A) Use of seasonal apportionments by Amendment 80 cooperatives.
      1) The amount of Pacific cod listed on a CQ permit that is assigned for use in the A season may be used in the B or C season.
      2) The amount of Pacific cod that is listed on a CQ permit that is assigned for use in the B season may not be used in the A season.
      3) The amount of Pacific cod listed on a CQ permit that is assigned for use in the C season may not be used in the A or B seasons.
   B) Harvest of seasonal apportionments in the Amendment 80 limited access fishery.
      1) Pacific cod ITAC assigned for harvest by the Amendment 80 limited access fishery in the A season may be harvested in the B seasons.
      2) Pacific cod ITAC assigned for harvest by the Amendment 80 limited access fishery in the B season may not be harvested in the A season.
      3) Pacific cod ITAC assigned for harvest by the Amendment 80 limited access fishery in the C season may not be harvested in the A or B seasons.

vi) ITAC rollover to Amendment 80 cooperatives. If during a fishing year, the Regional Administrator determines that a portion of the Pacific cod TAC is unlikely to be harvested and is made available for reallocation to the Amendment 80 sector according to the provisions under paragraph (a)(7)(iii) of this section, the Regional Administrator may issue inseason notification in the ***Federal Register*** that reallocates that remaining amount of Pacific cod to Amendment 80 cooperatives, according to the procedures established under § 679.91(f).

§ 679.22 Closures, (a) BSAI, (7) Steller sea lion protection areas, Bering Sea subarea

v) Pacific cod closures. Directed fishing for Pacific cod by vessels named on a Federal Fisheries Permit under § 679.4(b) and using trawl, hook-and-line, or pot gear is prohibited within the Pacific cod no fishing zones around selected sites. These sites and gear types are listed in Table 5 of this part (http://alaskafisheries.noaa.gov/rr/tables/tabl5.pdf) and are identified by "BS" in column 2.

§ 679.23 Seasons; (c) GOA and BSAI trawl groundfish

Notwithstanding other provisions of this part, fishing for groundfish with trawl gear in the GOA and BSAI is prohibited from 0001 hours, A.l.t., January 1, through 1200 hours, A.l.t., January 20.

§ 679.23 Seasons; (e) BSAI groundfish seasons; (4) CDQ fishing seasons

iii) Groundfish CDQ. Fishing for groundfish CDQ species, other than CDQ pollock; hook-and-line, pot, jig, or trawl CDQ Pacific cod; trawl CDQ Atka mackerel; and fixed gear CDQ sablefish under subpart C of this part, is authorized from 0001 hours, A.l.t., January 1 through the end of each fishing year, except as provided under paragraph (c) of this section.

§ 679.23 Seasons; (e) BSAI groundfish seasons; (5) Directed fishing for Pacific cod

i) Hook-and-line gear. Subject to other provisions of this part, directed fishing for CDQ and non-CDQ Pacific cod with vessels equal to or greater than 60 ft (18.3 m) LOA using hook-and-line gear is authorized only during the following two seasons:
   A) A season. From 0001 hours, A.l.t., January 1 through 1200 hours, A.l.t., June 10; and
   B) B season. From 1200 hours, A.l.t., June 10 through 2400 hours, A.l.t., December 31.
ii) Trawl gear. Subject to other provisions of this part, directed fishing for CDQ and non-CDQ Pacific cod with trawl gear in the BSAI is authorized only during the following three seasons:
   A) A season. From 1200 hours, A.l.t., January 20 through 1200 hours, A.l.t., April 1;
   B) B season. From 1200 hours, A.l.t., April 1 through 1200 hours, A.l.t., June 10; and
   C) C season. From 1200 hours, A.l.t., June 10 through 1200 hours, A.l.t., November 1.
iii) Pot gear. Subject to other provisions of this part, non-CDQ directed fishing for Pacific cod with vessels equal to or greater than 60 ft (18.3 m) LOA using pot gear in the BSAI is authorized only during the following two seasons:
   A) A season. From 0001 hours, A.l.t., January 1 through 1200 hours, A.l.t., June 10; and
   B) B season. From 1200 hours, A.l.t., September 1 through 2400 hours, A.l.t., December 31.
iv) Jig gear. Subject to other provisions of this part, directed fishing for CDQ and non-CDQ Pacific cod with jig gear is authorized only during the following three seasons:
   A) A season. From 0001 hours, A.l.t., January 1 through 1200 hours, A.l.t., April 30;
   B) B season. From 1200 hours, A.l.t., April 30 through 1200 hours, A.l.t., August 31; and
   C) C season. From 1200 hours, A.l.t., August 31 through 2400 hours, A.l.t., December 31.

§ 679.27 Improved Retention/Improved Utilization Program

See http://alaskafisheries.noaa.gov/regs/679b27.pdf, pages 211-214.

Attachment 2.4: Supplemental catch data

At their November 2012 meeting, the Plan Teams requested that authors "continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented." This attachment is provided in response to that request.

NMFS Alaska Region has made substantial progress in developing a database documenting many of the removals of FMP species that have resulted from activities outside of fisheries prosecuted under the BSAI Groundfish FMP, including removals resulting from scientific research, subsistence fishing, personal use, recreational fishing, exempted fishing permit activities, and commercial fisheries other than those managed under the BSAI groundfish FMP. Estimates for Pacific cod from this dataset are shown in Table 2.4.1.

Although many sources of removal are documented in Table 2.4.1, the time series is highly incomplete for many of these. In an effort to get a better idea of possible removals for missing years, Table 2.4.2 uses the average for each source listed in Table 2.4.1 to fill in the years with missing values (in the case of surveys, years with missing values were identified from the literature or by contacting individuals knowledgeable about the survey; in the case of fisheries, it was assumed that the activity occurred every year).

To begin to understand how incorporating data on "other" removals such as those shown in Table 2.4.2 might affect the calculation and allocation of ABC, the Bering Sea time series total for each gear type was added to the respective gear-specifc catches in the data file for Model 1 (all of these catches were assumed to occur at the mid-point of the respective year), and Model 1 was re-run with the new data file.

The results were that $F_{40\%}$ increased from 0.29 to 0.30 and the maximum permissible ABCs for 2013 and 2014 decreased from 307,000 t and 323,000 t to 303,000 t and 310,000 t, respectively.

The average of the BSAI "other" removals from the most recent three years in Table 2.4.2 is 3,260 t (3,223 t in the EBS and 27 t in the AI). If this average is taken "off the top," then the maximum permissible ABCs for the groundfish fishery in 2013 and 2014 would decrease further to approximately 300,000 t and 307,000 t, respectively.

It should be emphasized that these calculations are provided purely for purposes of comparison and discussion, as NMFS and the Council continue to refine policy pertaining to treatment of removals from sources other than the directed fishery.

Table 2.4.1—Total removals of Pacific cod (t) from activities not related to directed fishing, since 1986. No records of removals are available for years prior to 1986. Missing years in the table below indicate no records of removals. Source: NMFS Alaska Region.

Area	Source	1986	1990	1992	1994	1996	1997	1998	1999	2000	2001
AI	Aleutian Island bottom trawl survey										
AI	Atka tag recover										
AI	Crab fishery bait										
AI	IPHC longline survey										
AI	NMFS longline survey					17		27		25	
AI	Subsistence				0						
BS	ADFG large-mesh survey										
BS	Aleutian Island bottom trawl survey										
BS	Blue king crab pot survey										
BS	Crab fishery bait										
BS	Eastern Bering Sea acoustic survey										
BS	Eastern Bering Sea shelf trawl survey										
BS	Eastern Bering Sea slope survey										
BS	Gulf of Alaska bottom trawl survey										
BS	IPHC longline survey										
BS	NMFS longline survey						38		30		36
BS	Northern Bering Sea bottom trawl survey										
BS	Pribilof Islands survey - king crab pot										
BS	Subsistence	2	1	0	5			1	0		

Area	Source	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Ave.
AI	Aleutian Island bottom trawl survey									12		12
AI	Atka tag recover										2	2
AI	Crab fishery bait										0	0
AI	IPHC longline survey									9	23	16
AI	NMFS longline survey	19		13		25		13		16		19
AI	Subsistence											0
BS	ADFG large-mesh survey									1	1	1
BS	Aleutian Island bottom trawl survey									2		2
BS	Blue king crab pot survey									9		9
BS	Crab fishery bait									1737	4544	3141
BS	Eastern Bering Sea acoustic survey									0		0
BS	Eastern Bering Sea shelf trawl survey									38	42	40
BS	Eastern Bering Sea slope survey									2		2
BS	Gulf of Alaska bottom trawl survey										0	0
BS	IPHC longline survey									32	20	26
BS	NMFS longline survey		30		23		25		20		24	28
BS	Northern Bering Sea bottom trawl survey									1		1
BS	Pribilof Islands survey - king crab pot										5	5
BS	Subsistence											2

Table 2.4.2 (page 1 of 3)—Total removals of Pacific cod (t) from activities not related to directed fishing, extrapolated to years with no records in the NMFS Alaska Region database. In years where an activity ("Source") is known to have occurred, the average of the available data is inserted.

Area	Gear	Collection	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
AI	n/a	Aleutian Island bottom trawl survey				12			12			12		
AI	n/a	Atka tag recover												
AI	n/a	Crab fishery bait	0	0	0	0	0	0	0	0	0	0	0	0
AI	n/a	IPHC longline survey												
AI	n/a	NMFS longline survey			19	19	19	19	19	19	19	19	19	19
AI	n/a	Subsistence	0	0	0	0	0	0	0	0	0	0	0	0
AI	n/a	Total	0	0	20	32	20	20	32	20	20	32	20	20
BS	Trawl	ADFG large-mesh survey												
BS	Trawl	Aleutian Island bottom trawl survey				2			2			2		
BS	Trawl	Eastern Bering Sea acoustic survey			0			0			0			0
BS	Trawl	Eastern Bering Sea shelf trawl survey	40	40	40	40	40	40	40	40	40	40	40	40
BS	Trawl	Eastern Bering Sea slope survey			2		2	2			2			2
BS	Trawl	Gulf of Alaska bottom trawl survey								0			0	
BS	Trawl	Northern Bering Sea bottom trawl survey			1		1	1			1			1
BS	Trawl	Subtotal	40	40	42	42	42	42	42	40	42	42	40	42
BS	Longline	IPHC longline survey												
BS	Longline	NMFS longline survey						28	28	28	28	28	28	28
BS	Longline	Subsistence	2	2	2	2	2	2	2	2	2	2	2	2
BS	Longline	Subtotal	2	2	2	2	2	30	30	30	30	30	30	30
BS	Pot	Blue king crab pot survey												
BS	Pot	Crab fishery bait	3141	3141	3141	3141	3141	3141	3141	3141	3141	3141	3141	3141
BS	Pot	Pribilof Islands survey - king crab pot												
BS	Pot	Subtotal	3141	3141	3141	3141	3141	3141	3141	3141	3141	3141	3141	3141
BS	All	Total	3182	3182	3185	3185	3185	3213	3213	3211	3213	3213	3211	3213
BSAI	All	Grand Total	3183	3183	3204	3216	3204	3233	3245	3230	3233	3245	3230	3233

Table 2.4.2 (page 2 of 3)—Total removals of Pacific cod (t) from activities not related to directed fishing, extrapolated to years with no records in the NMFS Alaska Region database. In years where an activity ("Source") is known to have occurred, the average of the available data is inserted.

Area	Gear	Collection	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
AI	n/a	Aleutian Island bottom trawl survey			12			12			12			12
AI	n/a	Atka tag recover												2
AI	n/a	Crab fishery bait	0	0	0	0	0	0	0	0	0	0	0	0
AI	n/a	IPHC longline survey										16	16	16
AI	n/a	NMFS longline survey	19	19	19	19	19	19		17		27		25
AI	n/a	Subsistence	0	0	0	0	0	0	0	0	0	0	0	0
AI	n/a	Total	20	20	32	20	20	32	0	18	12	43	16	54
BS	Trawl	ADFG large-mesh survey		1	1			1	1				1	1
BS	Trawl	Aleutian Island bottom trawl survey			2			2			2			2
BS	Trawl	Eastern Bering Sea acoustic survey			0			0		0	0		0	0
BS	Trawl	Eastern Bering Sea shelf trawl survey	40	40	40	40	40	40	40	40	40	40	40	40
BS	Trawl	Eastern Bering Sea slope survey			2									2
BS	Trawl	Gulf of Alaska bottom trawl survey		0			0			0			0	
BS	Trawl	Northern Bering Sea bottom trawl survey			1									
BS	Trawl	Subtotal	40	40	45	40	40	42	40	40	42	40	40	44
BS	Longline	IPHC longline survey										26	26	26
BS	Longline	NMFS longline survey	28	28	28	28	28	28			38		30	
BS	Longline	Subsistence	2	1	2	0	2	5	2	2	2	1	0	2
BS	Longline	Subtotal	30	29	30	28	30	34	2	2	40	27	56	27
BS	Pot	Blue king crab pot survey							9			9		
BS	Pot	Crab fishery bait	3141	3141	3141	3141	3141	3141	3141	3141	3141	3141	3141	3141
BS	Pot	Pribilof Islands survey - king crab pot												
BS	Pot	Subtotal	3141	3141	3141	3141	3141	3141	3149	3141	3141	3149	3141	3141
BS	All	Total	3210	3210	3215	3209	3211	3217	3191	3183	3223	3216	3237	3212
BSAI	All	Grand Total	3230	3230	3247	3229	3230	3248	3191	3200	3235	3259	3253	3266

Table 2.4.2 (page 3 of 3)—Total removals of Pacific cod (t) from activities not related to directed fishing, extrapolated to years with no records in the NMFS Alaska Region database. In years where an activity ("Source") is known to have occurred, the average of the available data is inserted.

Area	Gear	Collection	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
AI	n/a	Aleutian Island bottom trawl survey		12		12		12				12		12
AI	n/a	Atka tag recover	2	2	2	2		2	2				2	2
AI	n/a	Crab fishery bait	0	0	0	0	0	0	0	0	0	0	0	0
AI	n/a	IPHC longline survey	16	16	16	16	16	16	16	16	16	9	23	16
AI	n/a	NMFS longline survey		19		13		25		13		16		19
AI	n/a	Subsistence	0	0	0	0	0	0	0	0	0	0	0	0
AI	n/a	Total	18	49	18	43	16	54	18	29	16	37	25	49
BS	Trawl	ADFG large-mesh survey			1	1	1	1	1	1	1	1	1	1
BS	Trawl	Aleutian Island bottom trawl survey		2		2		2				2		2
BS	Trawl	Eastern Bering Sea acoustic survey		0		0		0	0	0	0	0		0
BS	Trawl	Eastern Bering Sea shelf trawl survey	40	40	40	40	40	40	40	40	40	38	42	40
BS	Trawl	Eastern Bering Sea slope survey		2		2				2		2		2
BS	Trawl	Gulf of Alaska bottom trawl survey	0		0		0		0		0		0	
BS	Trawl	Northern Bering Sea bottom trawl survey										1		
BS	Trawl	Subtotal	40	44	40	44	40	42	40	42	40	43	43	44
BS	Longline	IPHC longline survey	26	26	26	26	26	26	26	26	26	32	20	26
BS	Longline	NMFS longline survey	36		30		23		25		20		24	
BS	Longline	Subsistence	2	2	2	2	2	2	2	2	2	2	2	2
BS	Longline	Subtotal	63	27	57	27	50	27	52	27	48	33	45	27
BS	Pot	Blue king crab pot survey	9			9			9			9		
BS	Pot	Crab fishery bait	3141	3141	3141	3141	3141	3141	3141	3141	3141	1737	4544	3141
BS	Pot	Pribilof Islands survey - king crab pot			5		5			5			5	
BS	Pot	Subtotal	3149	3141	3146	3149	3146	3141	3149	3146	3141	1746	4549	3141
BS	All	Total	3252	3212	3243	3220	3236	3210	3241	3214	3228	1822	4636	3212
BSAI	All	Grand Total	3270	3261	3260	3263	3252	3265	3259	3244	3245	1859	4661	3261