Chapter 2: Assessment of the Pacific Cod Stock in the Eastern Bering Sea

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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 EBS Pacific cod stock assessment.

Changes in the Input Data

1) Catch data for 1991-2014 were updated, and preliminary catch data for 2015 were incorporated.
2) Commercial fishery size composition data for 2014 were updated, and preliminary size composition data from the 2015 commercial fisheries were incorporated.
3) Size composition data from the 2015 EBS shelf bottom trawl survey were incorporated.
4) The numeric abundance estimate from the 2015 EBS shelf bottom trawl survey was incorporated (the 2015 estimate of 982 million fish was down about 12% from the 2014 estimate).
5) Age composition data from the 2014 EBS shelf bottom trawl survey were incorporated.
6) Mean length at age data from the 2014 EBS shelf bottom trawl survey were incorporated.
7) Seasonal catch per unit effort (CPUE) data for the trawl, longline, and pot fisheries from 2014 were updated, and preliminary CPUE data for the trawl, longline, and pot fisheries from 2015 were incorporated.

Changes in the Assessment Methodology

Many changes have been made or considered in the stock assessment model since the 2014 assessment (Thompson 2014). Eight models were presented in this year's preliminary assessment (Appendix 2.1), including four models requested in May and June by the Joint Team Subcomittee on Pacific Cod Models and the SSC, two models requested by members of the public, and two additional models. After reviewing the preliminary assessment, the BSAI Plan Team and SSC requested two models for inclusion in the final assessment: the base model that has been used for setting harvest specifications since the 2011 assessment; and another model that appeared in last year's assessment and this year's preliminary assessment. The author recommends retaining the base model for the purpose of setting final harvest specifications for 2016 and preliminary harvest specifications for 2017.

Summary of Results

The principal results of the present assessment, based on the author's recommended 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: 2015	2016	As estimated or *recommended this* year for: 2016*	2017*
M (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	3a	3a	3a	3a
Projected total (age 0+) biomass (t)	1,680,000	1,770,000	1,830,000	1,780,000
Projected female spawning biomass (t)	409,000	473,000	466,000	530,000
$B_{100\%}$	824,000	824,000	806,000	806,000
$B_{40\%}$	330,000	330,000	323,000	323,000
$B_{35\%}$	288,000	288,000	282,000	282,000
F_{OFL}	0.35	0.35	0.35	0.35
$maxF_{ABC}$	0.29	0.29	0.30	0.30
F_{ABC}	0.25	0.25	0.22	0.22
OFL (t)	346,000	389,000	390,000	412,000
maxABC (t)	295,000	316,000	332,000	329,000
ABC (t)	255,000	255,000	255,000	270,000
Status	As determined *last* year for: 2013	2014	As determined *this* year for: 2014	2015
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on assumed catches of 212,000 t and 221,000 t for 2016 and 2017, respectively.

Responses to SSC and Plan Team Comments on Assessments in General

Two comments on assessments in general were addressed in the preliminary assessment (Appendix 2.1). In the interest of efficiency, they are not repeated in this section. One Joint Plan Team (JPT) comment that was developed following completion of the preliminary assessment is shown below.

JPT1 (9/15 minutes): *"For this year's final assessments, the Teams recommend that each author of an age-structured assessment use one of the following model naming conventions…."* [The remainder of this recommendation consists of a list of options, too lengthy to reproduce here (see link below).] This recommendation was made in response to a request from the SSC that the JPT *"refine the model numbering system to avoid confusion and ensure that the origin of the model can be traced back to the original derivation*" (6/15 minutes). Option 4a in the JPT's list consists of a model naming convention described in the "Team procedures" document that was presented at the September JPT meeting (see link below), and is the option used in this assessment. Names of all final models adopted since the first application of an ADMB-based version of Stock Synthesis in the BSAI Pacific cod assessment (in 2005), and all models included in this year's preliminary assessment, are translated according to the new naming convention in the "Model Structure" subsection of the "Analytic Approach" section.

The minutes from the September JPT meeting can be found at:

https://npfmc.legistar.com/LegislationDetail.aspx?ID=2449669&GUID=BC4E6655-EEF8-480C-BDBC-D5E6B5DD2D8A&Options=&Search= (click on "C2_1. GFPT September 2015 report.pdf")

The "Team procedures" document can be found at: http://legistar2.granicus.com/npfmc/meetings/2015/9/927_A_Groundfish_Plan_Team_15-09-21_Meeting_Agenda.pdf (click on "Team procedures, updated")

Responses to SSC and Plan Team Comments Specific to this Assessment

Seven comments specific to this assessment, some of which contained several parts, were addressed in the preliminary assessment (Appendix 2.1). In the interest of efficiency, they are not repeated in this section. BSAI Plan Team (BPT) and SSC comments that were developed following completion of the preliminary assessment are shown below.

BPT1 (9/15 minutes): *"The Team recommends that Models 0 and 2 be brought forward in November."* The models that were numbered 0 and 2 in the preliminary assessment are included here, now numbered 11.5 and 14.2, following the new model numbering protocol. Note that these are the same two models included in last year's final assessment. See also comment SSC2 (below).

SSC1 (10/15 minutes): *"The SSC has been on record encouraging the development of an alternative model that estimates q, due to the very weak or non-existent evidence for net avoidance, which has been corroborated by recent work. This makes the fixed value for q, which was always based on weak evidence, even less tenable than before. Therefore the SSC agrees with the Plan Team that the author should bring forward one of the model alternatives that estimate q (models 2-6) in December. A related issue is the treatment of survey and fishery selectivity, which displays a pronounced peak and, in one case, two peaks (at intermediate and at the largest size). This pattern implies that the survey detects far fewer large cod than are present in the population. The SSC suggests that at the time of the survey, some of these 'missing cod' may be in the northern Bering Sea (NBS) outside the standard survey area. Pacific cod likely undertake seasonal feeding migrations into the NBS each summer. A simple analysis of the 2010 NBS survey would allow an assessment of the proportion of Pacific cod in the NBS and their size composition relative to Pacific cod sampled in the survey area."* Survey data from the NBS are presented in the "Survey" subsection of the "Data" section, and discussed under "Evaluation Criteria and Choice of Final Model" in the "Model Evaluation" subsection of the "Results" section.

SSC2 (10/15 minutes): *"Based on consideration of the above issues, in particular concerns about catchability and selectivity, the SSC concurs with the Plan Team request to bring forward model 0 (last year's model) and model 2 for harvest specification in December."* See response to comment BPT1.

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 65° N latitude (Lauth 2011). Pacific cod is distributed widely over the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (GOA). However, 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). Although the resource in the combined EBS and AI (BSAI) region had been managed as a single unit from 1977 through 2013, separate harvest specifications have been set for the two areas since the 2014 season.

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.

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. Neidetcher et al. (2014) have identified spawning locations throughout the Bering Sea and Aleutian Islands.

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% (Robert Gregory, DFO, *pers. commun.*); 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, DFO, *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 (Q) 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 EBS 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 EBS. 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.

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, with an average annual catch of less than 200 t since 1992). The breakdown of catch by gear during the most recent complete five-year period (2010-2014) is as follows: longline gear accounted for an average of 55% of the catch, trawl gear accounted for an average of 32%, and pot gear accounted for an average of 13%.

In the EBS, Pacific cod are caught throughout much of the continental shelf, with NMFS statistical areas 509, 513, 517, 519, and 521 each accounting for at least 5% of the average catch over the most recent 5-year period (2010-2014).

Catches of Pacific cod taken in the EBS for the periods 1964-1980, 1981-1990, and 1991-2015 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 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 gear.

Effort and CPUE

Figures 2.1 and 2.2 show, subject to confidentiality restrictions, the approximate locations in which hauls or sets sampled during 2014 and 2015 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 (Figure 2.1) or gear/year (Figure 2.2). Figure 2.1 shows 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 2.2 shows locations of sampled EBS hauls/sets for the same gear types, but aggregated across seasons. More squares are shaded in Figure 2.2 than in Figure 2.1 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 Figure 2.3. Most CPUE time series are either flat or increasing since about the middle of the last decade.

Discards

The catches shown in Tables 2.1b and 2.1c include estimated discards. Discards of Pacific cod in the EBS Pacific cod fisheries are shown for each year 1991-2015 in Table 2.2. Amendment 49, which mandated increased retention and utilization of Pacific cod, was implemented in 1998. From 1991-1997, discard rates in the Pacific cod fishery averaged about 4.7%. Since then, they have averaged about 1.4%.

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. Note that, prior to 2014, this time series pertains to the combined BSAI region, so the catch time series differs from that shown in Table 2.1, which pertains to the EBS only.

From 1980 through 2014, TAC averaged about 84% of ABC (ABC was not specified prior to 1980), and from 1980 through 2014 aggregate commercial catch averaged about 92% of TAC. In 10 of these 34 years, TAC equaled ABC exactly, and in 8 of these 34 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 within the AI subarea (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 current 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 modeling software (Methot 1986, 1990) with age-based data. All assessments from 1993 through 2003 continued to use the Stock Synthesis modeling software, but with length-based data. Age data based on a revised ageing protocol were added to the model in the 2004 assessment. At about that time, a major upgrade in the Stock Synthesis architecture resulted in a substantially new product, at that time labeled “SS2” (Methot 2005). The assessment was migrated to SS2 in 2005. Changes to model structure were made annually through 2011, but the base model has remained constant since then (see Appendix 2.3). A note on software nomenclature: The label “SS2” was dropped in 2008. Since then, the program has been known simply as “Stock Synthesis” or “SS,” with several versions typically produced each year, each given an alpha-numeric label.

Beginning with the 2014 fishery, the Board of Fisheries for the State of Alaska established a guideline harvest level (GHL) in State waters between 164 and 167 degrees west longitude in the EBS subarea (this supplemented a GHL that had been set aside for the Aleutian Islands subarea since 2006). The State’s procedure for setting GHLs for the two subareas is to sum the subarea ABCs, then set a GHL in each subarea equal to 3% of the total.

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 EBS.

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

Source	Type	Years
Fishery	Catch biomass	1977-2015
Fishery	Catch size composition	1977-2015
Fishery	Catch per unit effort	1991-2015
EBS shelf bottom trawl survey	Numerical abundance	1982-2015
EBS shelf bottom trawl survey	Size composition	1982-2015
EBS shelf bottom trawl survey	Age composition	1994-2014
EBS shelf bottom trawl survey	Mean size at age	1994-2014

Fishery

Catch Biomass

Catches taken in the EBS for the period 1977-2015 are shown for the three main gear types in Table 2.5. Table 2.5 makes use of two different types of season: catch seasons and selectivity seasons. 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 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 2.5. Catches for the years 1977-1980 may or may not include discards.

The 2014 assessment included an evaluation of 12 methods for projecting year-end catch for the last year in the time series (Thompson 2014). It turned out that the best estimator was simply to set the current year's catch during seasons 4-5 equal to the previous year's catch during those same seasons (up to the TAC for the current year). In Table 2.5, catches for the August-October and November-December seasons of 2015 were estimated by this method. The other catches shown in Table 2.5 consist of "official" data from the NMFS Alaska Region. However, other removals of Pacific cod are known to have occurred over the years, including removals due to subsistence fishing, scientific research, and fisheries managed under other FMPs. Estimates of such other removals are shown in Appendix 2.2.

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 2015. 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/2015/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 1991-2015 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 2015 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

Strata 1-6 of the EBS shelf bottom trawl survey have been sampled annually since 1982, and comprise the standard survey area used in this assessment. Beginning in 1987, strata 8 and 9, located to the northwest of the standard survey area, have also been sampled annually. Although strata 8 and 9 do contain Pacific cod, the biomass contained in those strata is typically a small fraction of that contained in the overall survey area (i.e., strata 1-6 plus strata 8-9), averaging less than 3% over the time series. Rather than estimate separate catchability and selectivity parameters for the pre-1987 (strata 1-6) and post-1986 (strata 1-6 plus strata 8-9) portions of the time series, the assessment models for EBS Pacific cod have always used data from strata 1-6 only.

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 remained relatively constant from 1982 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, then remained relatively stable for the next three years, followed by another large increase (36%) in 2014. The 2015 estimate is the fourth highest in the time series, being approximately 2% above the 2014 estimate.

Numerical abundance has shown more variability than biomass, with the estimates since 2007 generally well above average pre-2007 levels (with the exception of 2008, estimates since 2007 have all been at least 15% above the pre-2007 average). The 2014 and 2015 estimates were especially large, being the second and fourth largest in the time series, respectively.

The relative size compositions from the EBS shelf bottom trawl survey for the years 1982-2015 are shown in Table 2.8 (actual numbers of fish measured are shown in column 2 in the upper portion of the first page). The 1982-2015 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 1994-2014 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.

NBS Shelf Bottom Trawl Survey

In contrast to the EBS, the NBS has been surveyed only rarely, most recently in 2010. The results of that survey were described by Lauth (2011). Although the 2010 NBS survey data have never been used in the EBS Pacific cod models, the SSC has expressed interest in possible future use of those data (see comment SSC1), so a brief summary is presented here. Unlike the EBS shelf, where Pacific cod are broadly distributed (e.g., they were captured in 91% of the survey stations in 2010), the distribution in the NBS appears to be much patchier (captured in only 41% of the survey stations in 2010). The estimated biomass in the NBS also appears to be much smaller than in the EBS. For 2010, the biomass in strata 1-6 of the EBS shelf survey constituted 96% of the total (EBS+NBS), the biomass in strata 8-9 constituted 1% of the total, and the biomass in the NBS constituted 3% of the total.

The proportion of the overall (EBS+NBS) 2010 population abundance (in numbers of fish) contributed by each of the survey areas is shown below, broken down by 5-cm length bins (the rows labeled "Bin" show the upper ends of the 5-cm bins):

Bin	10	15	20	25	30	35	40	45	50	55	60
Strata 1-6	0.863	0.931	0.982	0.965	0.988	0.987	0.982	0.991	0.993	0.993	0.989
Strata 8-9	0.000	0.000	0.005	0.010	0.007	0.012	0.017	0.009	0.007	0.006	0.010
NBS	0.137	0.069	0.013	0.025	0.005	0.001	0.002	0.001	0.000	0.001	0.000

Bin	65	70	75	80	85	90	95	100	105	110
Strata 1-6	0.979	0.939	0.822	0.688	0.584	0.813	0.810	1.000	1.000	1.000
Strata 8-9	0.009	0.029	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NBS	0.012	0.032	0.160	0.312	0.416	0.187	0.190	0.000	0.000	0.000

For all length bins between 11 and 70 cm and between 96 and 110 cm, strata 1-6 of the EBS survey area contributed at least 93% of the total numbers at length. Strata 8-9 of the EBS survey area did not contribute more than 3% of the total in any bin across the 6-110 cm range. However, the NBS survey area did contribute significantly in the 71-95 cm range, accounting for 16-42% of the total in each of those bins.

ANALYTIC APPROACH

Model Structure (General)

Although Pacific cod in the EBS and AI were managed on a BSAI-wide basis through 2013, the stock assessment model has always been configured for the EBS stock only. Since 1992, the assessment model has always been developed under some version of the SS modeling framework (technical details given in Methot and Wetzel 2013; see especially Appendix A to that paper). Beginning with the 2005 assessment, the EBS Pacific cod models have all used versions of SS based on the ADMB software package (Fournier et al. 2012). A history of previous model structures, including details of the present model, is given in Appendix 2.3.

In response to a request from the Joint Plan Teams (which was, in turn, a response to a request from the SSC), a new protocol for model numbering is adopted in this assessment (see comment JPT1 in the Executive Summary). The goal of the new protocol is to make it easy to distinguish between major and minor changes in models and to identify the years in which major model changes were introduced. Names of models constituting *major* changes get linked to the year that they are introduced (e.g., Model 11.5 is one of at least five models introduced in 2011 that constituted a major change from the then-current base model), while names of models constituting *minor* changes get linked to the model that they modify (e.g., Model 11.5a is the first model that constituted a minor change from Model 11.5).

Names of all final models adopted since the first application of an ADMB-based version of SS (in 2005) are translated according to the new naming convention in Table 2.11. Names of all models included in this year's preliminary assessment (Appendix 2.1) are translated below:

Name	Models included in preliminary assessment							
Original	0	2	3	4	5	6	7	8
New	11.5	14.2	15.3	15.4	15.5	15.6	15.7	11.5a

Per request of the BSAI Plan Team and SSC, two models are presented in this final assessment: Model 11.5, the base model that has been used for the last three years, and Model 14.2, which differs from Model 11.5 in several respects, as detailed below. Note that these are the same two models included in last year's final assessment.

Version 3.24u (compiled on 08/29/14) of SS was used to run the models in this assessment. The current SS user manual is available at: https://drive.google.com/a/noaa.gov/?tab=mo#folders/0Bz1UsDoLaOMLN2FiOTI3MWQtZDQwOS00YWZkLThmNmEtMTk2NTA2M2FjYWVh.

Development of the final versions of both 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 0.10 (or 0.05, in the event that too few runs converged when the jitter parameter was set at 0.10). 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.

Model 11.5: Main Features

Model 11.5 is the model that has been used to recommend harvest specifications for the last four years (2011-2014), and its structure was documented in the assessments for each of those years. Briefly, some of the main features characterizing this model are as follow:

1. Age- and time-invariant natural mortality, estimated outside the model
2. Parameters governing time-invariant mean length at age estimated internally
3. Parameters governing width of length-at-age distribution (for a given mean) estimated internally
4. Ageing bias parameters estimated internally
5. Gear-and-season-specific catch and selectivity for the fisheries
6. Double normal selectivity for the fisheries and survey (see Appendix 2.3 for parameterization)
7. Length-based selectivity for the fisheries
8. Age-based selectivity for the survey
9. Fishery selectivity estimated for "blocks" of years
10. Survey selectivity constant over time, except with annual *dev*s for the *ascending_width* parameter
11. Survey size composition data used in all years, including those years with age composition data (at the request of Plan Team members, inclusion of survey size composition data in all years was instituted in the 2011 assessment and has been retained ever since, based on the view that the costs of double-counting are outweighed by the benefits of including this information for estimation of growth parameters)
12. Fishery CPUE data included but not used for estimation
13. Mean size at age included but not used for estimation

Model 11.5: Iterative Tuning

The values of iteratively tuned parameters used in Model 11.5 have not been updated since the 2009 assessment, per request of the BSAI Plan Team.

Iterative Tuning of Time-Varying Parameters

The standard deviations of the two *dev* vectors in Model 11.5 (the log of age 0 recruitment and the survey *ascending_width* parameter, both additive) were estimated iteratively during the 2009 assessment by tuning the specified σ term for each vector to the standard deviation of the elements in that vector. Although this method is more justifiable than simply guessing at the value of σ, it is known to be biased low, and in the worst case may return a value of zero even when the true value is substantially greater than zero (Maunder and Deriso 2003, Thompson in prep.).

Iterative Tuning of Survey Catchability

Survey catchability was estimated iteratively during the 2009 assessment by tuning Q so that the average of the product of Q and survey selectivity across the 60-81 cm size range matched the point estimate of 0.47 given by Nichol et al. (2007).

Model 14.2: Main Features

Except for procedures related to iterative tuning (see next subsection), the differences between Model 14.2 and Model 11.5 were as follow:

1. Each year consisted of a single season instead of five.
2. A single fishery was defined instead of nine season-and-gear-specific fisheries.
3. The survey was assumed to sample age 1 fish at true age 1.5 instead of 1.41667.
4. Initial abundances were estimated for the first ten age groups instead of the first three.
5. The natural mortality rate was estimated internally.
6. The base value of survey catchability was estimated internally.
7. Survey catchability was allowed to vary annually.
8. Selectivity for both the fishery and the survey were allowed to vary annually.
9. Selectivity for both the fishery and survey was modeled using a random walk with respect to age (SS selectivity-at-age pattern #17) instead of the usual double normal.

Model 14.2: Iterative Tuning

The values of iteratively tuned parameters used in Model 14.2 have not been updated since the preliminary 2014 assessment.

Iterative Tuning of Prior Distributions for Selectivity Parameters

Initially, the model was run with recruitment as the only time-varying quantity, with the standard deviation of log-scale recruitment estimated internally (i.e., as a free parameter), and with large standard deviations in the prior distributions for all selectivity parameters.

Once the initial model converged, a pair of transformed logistic curves was fit to the point estimates of the fishery and survey selectivity schedules (a *transformed* logistic curve was used because the selectivity parameters in pattern #17 consist of the backward first differences of selectivity on the log scale, rather than selectivity itself; Thompson and Palsson 2013). The respective transformed logistic curve (fishery or survey) was then used to specify a new set of means for the selectivity prior distributions (one for each age). A constant (across age) prior standard deviation was then computed such that no age had a prior CV (on the selectivity scale, not the transformed scale) less than 50%, and at least one age had a prior CV of exactly 50%.

The model was then run with the new set of prior means and constant prior standard deviations (one for the fishery, one for the survey), then a new pair of transformed logistic curves was fit to the results, and the process was repeated until convergence was achieved.

Iterative Tuning of Time-Varying Parameters Other than Catchability

Two main loops were involved in the iterative tuning of time-varying parameters other than catchability. These loops were designed to produce the quantities needed in order to use the method of Thompson and Lauth (2012, Annex 2.1.1; also Thompson in prep.) for estimating the standard deviation of a *dev* vector:

1. Compute an "unconstrained" estimate of the standard deviation of the set of year-specific *dev*s associated with each age. The purpose of this loop was to determine the vector of *dev*s that would be obtained if they were completely unconstrained by their respective σ. This was not always a straightforward process, as estimating a large matrix of age×year *dev*s is difficult if the *dev*s are unconstrained. In general, though, the procedure was to begin with a small (constant across age) value of σ; calculate the standard deviation of the estimated *dev*s; then increase the value of σ gradually until the standard deviation of the estimated *dev*s reached an asymptote.
2. Compute an "iterated" estimate of the standard deviation of the set of year-specific *dev*s associated with each age. This loop began with each σ set at the unconstrained value estimated in the first loop. The standard deviation of the estimated *dev*s then became the age-specific σ for the next run, and the process was repeated until convergence was achieved.

The iteration was conducted separately for the fishery and survey.

It was common for some ages to be "tuned" out during the second loop (i.e., the σs converged on zero). For Model 14.2, all ages were tuned out except age 4 for the fishery and ages 2 and 3 for the survey. Unfortunately, given the way that selectivity pattern #17 is implemented in SS, large gradients can result if sufficiently large *dev*s occur at or adjacent to the age of peak selectivity. Because survey selectivity for Model 14.2 tended to peak at age 3, runs that included *dev*s for age 3 resulted in large gradients, so Model 14.2 included survey selectivity *dev*s for age 2 only.

A similar procedure was used to tune σ_R.

All selectivity *dev*s were assumed to be additive (SS automatically assumes log recruitment *dev*s to be additive).

Iterative Tuning of Time-Varying Catchability

Although conceptually similar to a *dev* vector, SS treats each annual deviation in ln(Q) as a true parameter, with its own prior distribution. Because SS works in terms of ln(Q) rather than Q, normal prior distributions were assumed for all annual deviations. To be parsimonious, a single σ was assumed for all such prior distributions.

Unlike the size composition or age composition data sets, the time series of survey abundance data includes not only a series of expected values, but a corresponding series of standard errors as well. This fact formed the basis for the iterative tuning of the σ term for time-varying Q in Model 14.2. The procedure involved iteratively adjusting σ until the root-mean-squared-standardized-residual for survey abundance equaled unity.

Parameters Estimated Outside the Assessment Model

This section does not include parameters that were estimated according to the iterative tuning procedure described above for the respective model. Values of iteratively tuned parameters are listed under "Goodness of Fit, Parameter Estimates, and Derived Quantities," in the "Model Evaluation" subsection of the "Results" section.

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 (Thompson et al. 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 some 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

Model 11.5 in this assessment fixes *M* at the value of 0.34 used since 2007. Model 14.2 estimates *M* internally.

Variability in Estimated Age

Variability in estimated age in SS is based on the standard deviation of estimated age between "reader" and "tester" age determinations. 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 0.0852 (i.e, the standard deviation of estimated age was modeled as 0.0852 × age) and a weighted R^2 of 0.93. This regression corresponds to a standard deviation at age 1 of 0.085 and a standard deviation at age 20 of 1.704. These parameters were used for the models in the present assessment.

Weight at Length

Long-term base values along with annual and seasonal deviations of the parameters governing the weight-at-length schedule were estimated in the 2012 assessment using the method described in Annex 2.1.2 of Thompson and Lauth (2012), based on fishery data collected from 1974 through 2011. The same method was used this year to update all weight-length parameters using fishery data through 2014.

Using the functional form weight = $\alpha \times \text{length}^{\beta}$, where weight is measured in kg and length is measured in cm, the long-term base values for the parameters were estimated as α = 5.76218E-6 and β = 3.1786263.

Seasonal additive log-scale offsets from the base parameter values (used in Model 11.5 only) were re-estimated in this year's preliminary assessment, resulting in the following values:

Season:	Jan-Feb	Mar-Apr	May-Jul	Aug-Oct	Nov-Dec
α:	-2.288E-02	2.884E-03	1.922E-02	2.278E-03	-1.421E-02
β:	5.251E-03	-6.725E-04	-4.528E-03	-5.309E-04	3.280E-03

Model 14.2 allows for *inter*-annual as well as *intra*-annual variability in weight-length parameters (Model 11.5 allows for intra-annual variability only). New values of annual additive offsets from the base values are shown below:

Year:	1977	1978	1979	1980	1981	1982	1983	1984
α offset:	1.95E-06	-2.58E-06	1.21E-06	-3.86E-07	5.58E-07	2.55E-06	2.00E-07	1.13E-05
β offset:	-6.71E-02	1.45E-01	-4.35E-02	1.19E-02	-2.81E-02	-8.11E-02	7.35E-04	-2.73E-01

Year:	1985	1986	1987	1988	1989	1990	1991	1992
α offset:	-1.14E-06	-2.37E-06	-3.42E-07	-2.29E-06	-1.39E-06	1.04E-06	1.52E-06	9.02E-08
β offset:	6.21E-02	1.35E-01	2.06E-02	1.38E-01	8.54E-02	-2.58E-02	-5.74E-02	-1.34E-02

Year:	1993	1994	1995	1996	1997	1998	1999	2000
α offset:	2.50E-06	3.48E-07	-1.10E-06	7.38E-06	9.80E-07	1.45E-06	1.71E-06	1.95E-06
β offset:	-6.87E-02	-1.32E-02	5.28E-02	-1.95E-01	-4.89E-02	-6.66E-02	-6.48E-02	-6.01E-02

Year:	2001	2002	2003	2004	2005	2006	2007	2008
α offset:	3.81E-06	1.23E-06	-4.62E-07	1.90E-06	-1.32E-07	7.98E-07	3.33E-07	4.04E-06
β offset:	-1.18E-01	-4.48E-02	1.96E-02	-6.82E-02	8.63E-03	-2.94E-02	-8.18E-03	-1.26E-01

Year:	2009	2010	2011	2012	2013	2014
α offset:	-8.40E-07	9.75E-07	4.56E-07	2.73E-06	-8.76E-07	-2.04E-06
β offset:	4.16E-02	-3.90E-02	-2.43E-02	-1.01E-01	3.41E-02	9.59E-02

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, *pers. commun.*). The age-based parameters were retained for the models in the present assessment.

Stock-Recruitment "Steepness"

Following the standard Tier 3 approach, both models assume that there is no relationship between stock and recruitment, so the "steepness" parameter is set at 1.0 in each.

Parameters Estimated Inside the Assessment Model

A total of 188 parameters were estimated inside SS for Model 11.5. These include:

1. all three von Bertalanffy growth parameters
2. standard deviation of length at ages 1 and 20
3. mean ageing bias at ages 1 and 20
4. log mean recruitment since the 1976-1977 regime shift
5. offset for log-scale mean recruitment before the 1976-1977 regime shift
6. *dev*s for log-scale initial (i.e., 1977) abundance at ages 1 through 3
7. annual log-scale recruitment *dev*s for 1977-2014
8. initial (equilibrium) fishing mortality for the Jan-Apr trawl fishery
9. gear-, season-, and-block-specific selectivity parameters for nine fisheries
10. base values for all survey selectivity parameters
11. annual *dev*s for the *ascending_width* parameter of the survey selectivity function

A total of 207 parameters were estimated inside SS for Model 14.2. With the exceptions of the initial fising mortality rate, base values for selectivity patterns, and selectivity *dev*s, these included all of the parameters listed above for Model 11.5 (Model 14.2 estimated an initial fishing mortality rate, base values of selectivity parameters, and selectivity *dev*s also, but the nature and number of those parameters was different than in Model 11.5). In addition, Model 14.2 estimated the natural mortality rate, a fourth growth parameter (Richards' growth coefficient), the base value of log-scale survey catchability, and annual catchability offsets.

In Model 11.5, uniform prior distributions were used for all parameters, except that the *dev* vectors were constrained by input standard deviations ("sigma"), which are somewhat analogous to a joint prior distribution.

In Model 14.2, the base selectivity parameters had normal priors, while other non-*dev* parameters had uniform priors (as in Model 11.5).

For all parameters estimated within individual SS runs, the estimator used was the mode of the logarithm of the joint posterior distribution, which was 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 were also estimated internally, but not in the same sense as the above parameters. The fishing mortality rates are determined (almost) exactly as functions of other model parameters, 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. An option does exist in SS for treating the fishing mortality rates as full parameters, but previous explorations have indicated that adding these parameters has almost no effect on other model output (Methot and Wetzell 2013).

Objective Function Components

Both models in this assessment 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 addition, Model 14.2 includes an objective function component for prior distributions (Model 11.5 uses only uniform prior distributions, so does not need an objective function for prior distributions).

In SS, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in previous assessments, all 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 year, gear, and season within the year (Model 11.5) or just year (Model 14.2). 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. 2007). 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: Whenever the actual sample size exceeded about 400 fish, 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, records with actual sample sizes less than 400 were omitted. Then, 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 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 with actual sample sizes greater than 400 (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 the 2012-2014 assessments, except the pre-1982 trawl survey data were no longer used. Model 11.5 in this year's assessment uses the same procedure as the 2012-2014 assessments. Model 14.2 uses a similar procedure, except that the input sample sizes for the fishery and survey scaled so that the average is 300 *for each*, rather than 300 for all size composition data combined. The full sets of input sample sizes are shown in Table 2.12.

Use of Age Composition Data in Parameter Estimation

Like the size composition data, the age composition data are assumed to be drawn from a multinomial distribution specific to a particular gear, year, and season within the year. 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
N:	201	160	200	202	178	241	241	258	244	354	279

Year:	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
N:	359	365	404	340	396	363	352	365	398	399

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

Fishery CPUE data are included in the Model 11.5 for comparative purposes only, and are not included at all in Model 14.2. Their respective catchabilities (in Model 11.5) are estimated analytically, not statistically.

For the trawl surveys, each year's survey abundance estimate 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 estimate's standard error to the survey abundance estimate 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 two models used in this assessment are described under “Model Structure” above.

Goodness of Fit, Parameter Estimates, and Derived Quantities

Table 2.13 shows the objective function value for each data component and sub-component in each model, and compares this year’s values to last year’s for each model. The first part of the table shows negative log-likelihoods (and negative log priors) for the aggregate data components. The second and third parts of the table break down the CPUE (Model 11.5 only) and size composition components into fleet-specific values. For the CPUE component, the fishery values are shown for completeness, but they are shaded to indicate that they do not count toward the total. Because the two models contain very different data in many respects, objective function values are not comparable across models. Table 2.13 also shows parameter counts for the two models, broken down into the following categories: 1) unconstrained parameters (i.e., parameters with non-constraining uniform prior distributions), 2) parameters with priors (other than uniform), and 3) constrained *dev*s.

Table 2.14 provides alternative measures of how well the model fits the fishery CPUE (Model 11.5 only) and survey relative abundance data. The first column shows root mean squared errors (RMSE; values closer to the average log-scale standard error in the data (0.11) are better), mean normalized residuals (MNR; values closer to zero are better), standard deviations of normalized residuals (SDNR; values closer to unity are better), and correlations between observed and estimated values (values to unity are better). The first 9 rows of Table 2.14 pertain to the fishery CPUE data. Although Model 11.5 does not actually attempt to fit these data (only the survey CPUE are used), of the 9 correlations with fishery CPUE, all but one are positive. The most important parts of this table are the entries for the shelf trawl survey (last two rows), which is something that both models actually try to fit. Model 14.2 does much better than Model 11.5 by any of the four measures presented.

Figure 2.4 shows the models’ fits to the trawl survey abundance data. Model 11.5’s estimates fall within the 95% confidence intervals 79% of the time; Model 14.2’s do so 97% of the time.

Table 2.15 shows how output “effective” sample sizes (“Neff,” McAllister and Ianelli 1997) compare to input sample sizes (“Ninp”) for the size composition data. Three sets of ratios are provided for each fleet: 1) the arithmetic mean (“A”) of the Neff/Ninp ratio, 2) the ratio of arithmetic mean Neff to arithmetic mean Ninp, and 3) the ratio of harmonic mean (“H”) Neff to arithmetic mean Ninp. Both models give ratios greater (usually *much* greater) than unity for all cases for all three measures, except for the Aug-Dec longline fishery in Model 11.5, using the measure with the harmonic mean in the numerator (ratio=0.89).

Table 2.16 provides a similar analysis for the age composition data, 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 two rows in the table show the ratios of the means (using the arithmetic mean as the numerator in the next-to-last row and the harmonic mean in the last row). For Model 11.5, both ratios are less than unity. For Model 14.2, the ratio based on the arithmetic mean is greater than unity, but the ratio based on the harmonic mean is less than unity.

The models’ fits to the age composition data are shown in Figure 2.5. Estimates of mean size at ages 1 through 3 (at the time of the survey) from the model are compared to the long-term average survey size composition (through 50 cm) in Figure 2.6. Both models tend to match the modes, within one or two cm.

Model 11.5's fits to the mean-size-at-age data are shown in Figure 2.7 (recall that the model does not actually attempt to fit these data, and Model 14.2 does not include these data at all). Because of the large number of size composition records (n=445 for Model 11.5, n=73 for Model 14.2), figures showing the models' fits to these data are not included in this document, but are available at: http://www.afsc.noaa.gov/REFM/Docs/2015/EBS_Pcod_sizecomp_fits.xlsx.

Table 2.17 displays all of the parameters (except fishing mortality rates, because these are functions of other parameters) estimated internally in the model, along with the standard deviations of those estimates, plus selected constants. Table 2.17 consists of the following parts:

- Table 2.17a shows scalar parameters and initial age composition parameters for both models
- Table 2.17b shows annual log-scale recruitment *dev*s for both models
    - These are plotted in Figure 2.8
- Table 2.17c shows fishery selectivity parameters for Model 11.5
- Table 2.17d shows survey selectivity parameters for Model 11.5
- Table 2.17e shows annual log catchability offsets for Model 14.2
- Table 2.17f shows fishery selectivity parameters for Model 14.2
- Table 2.17g shows survey selectivity parameters for Model 14.2

Table 2.18 shows estimates of fishing mortality. Table 2.18a shows fishing mortality by year in both models, and Table 2.18 b shows full-selection seasonal fishing mortality rates for each gear type and year in Model 11.5 only. In Table 2.18a, two measures of annual fishing mortality are shown for each model. The first is an "average" fishing mortality rate across ages 6-18. This age range was determined in the 2013 assessment as the set of ages for which fishery selectivity was at least 80% on average across all gear types and seasons (ages 19-20 also met this criterion, but SS generates a warning if the last two age groups are included in the average). The second measure of fishing mortality ("Apical F") is the rate corresponding to the length of full selection.

Values of parameters tuned iteratively are shown below (note that the values used in Model 11.5 were last tuned in 2009 and the values used in Model 14.2 were last tuned in 2014):

Tuning parameter	Model 11.5	Model 14.2
Sigma(recruitment)	0.570	0.657
ln(catchability)	-0.261	
Sigma(catchability)		0.089
Sigma(survey double normal *ascending_width*)	0.070	
Sigma(fishery age 4 selectivity parm.)		0.158
Sigma(survey age 2 selectivity parm.)		0.106
Logistic alpha (fishery selectivity prior)		2.940
Logistic beta (fishery selectivity prior)		3.970
Sigma(fishery selectivity prior)		0.350
Logistic alpha (survey selectivity prior)		5.800
Logistic beta (survey selectivity prior)		0.970
Sigma(survey selectivity prior)		0.319

Figure 2.9a shows the time series of female spawning biomass relative to $B_{100\%}$ as estimated by each model, and Figure 2.9b shows the time series of total biomass as estimated by each model, along with the time series of observed survey biomass. On average, observed survey biomass is 42% lower than total biomass as estimated by Model 11.5 and 23% lower than total biomass as estimated by Model 14.2.

Figure 2.10 shows trawl survey selectivity as estimated by the model. Both models show variability over time for selectivity at age 1. For Model 11.5, this is due to the fact that annual *dev*s are estimated for the *ascending_width* parameter. For Model 14.2, it is due to the fact that annual *dev*s are estimated for the age 1 selectivity parameter. The shapes of the profiles are qualitatively similar, although the profile for Model 11.5 declines more at older ages than does the profile for Model 14.2. For example, in Model 11.5, all ages greater than 10 have selectivity estimates between 0.26 and 0.28, whereas in Model 14.2, all ages greater than 10 have selectivity estimates between 0.31 and 0.40.

Figure 2.11 shows fishery selectivity for the two models. Figure 2.11a shows gear-, season-, and block-specific fishery selectivity as estimated by Model 11.5. In general, selectivities that are not forced to be asymptotic tend to show decreasing selectivity at large size in Model 11.5. Figure 2.11b shows the pattern of annually varying fishery selectivity as estimated by Model 14.2. The only time variability occurs at ages less than 4. Model 14.2 exhibits bimodality, with a dominant mode at age 6 and a secondary mode at age 13.

The base value of ln(*Q*) (Table 2.17a) and the annual ln(*Q*) deviations (Table 2.17e) estimated by Model 14.2 imply the following statistics (mean, median, and standard deviation) pertaining to catchability (note that the correlation between the base value and the annual deviation was taken into consideration when computing the standard deviation):

Year:	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Mean:	0.945	1.076	1.030	1.077	1.122	1.062	1.086	0.940	1.004	1.014	1.007	1.092
Med:	0.936	1.066	1.020	1.066	1.112	1.053	1.077	0.932	0.996	1.006	0.999	1.083
Sdev:	0.135	0.151	0.140	0.149	0.153	0.138	0.141	0.121	0.134	0.135	0.134	0.145

Year:	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Mean:	1.331	1.215	1.150	1.065	1.058	1.038	0.989	1.189	1.034	1.045	1.022	1.093
Med:	1.319	1.205	1.140	1.056	1.049	1.030	0.980	1.180	1.026	1.036	1.014	1.084
Sdev:	0.175	0.154	0.155	0.144	0.136	0.132	0.127	0.152	0.131	0.137	0.127	0.145

Year:	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Mean:	1.015	1.084	0.992	0.959	1.113	1.065	1.111	1.051	1.127	1.157
Med:	1.008	1.073	0.984	0.952	1.103	1.057	1.102	1.041	1.116	1.147
Sdev:	0.119	0.156	0.126	0.119	0.147	0.134	0.146	0.145	0.154	0.160

Means and 95% confidence intervals of the catchability time series implied by the Model 14.2 estimates are shown in Figure 2.12.

Figure 2.13 shows likelihood profiles with respect to *M* for each model. The value of survey catchability is also shown (constant for Model 11.5, but co-varying with *M* for Model 14.2, as both parameters were estimated internally for Model 14.2). Model 11.5 assumes a value of 0.34 for *M*, but the likelihood profile indicates that a value of 0.40 would provide a better fit to the data. Model 14.2 estimates *M* internally at a value of 0.337, very close to the value assumed in Model 11.5.

Table 2.19 contains selected output from the standard projection model, based on SS parameter estimates from the two 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). Note that some of the quantities in Table 2.19 are conditional on catches estimated under Scenario 2 ("author's F") in the "Harvest Recommendations" section.

Evaluation Criteria and Choice of Final Model

Five criteria were considered in evaluating the models. The first three are the criteria used last year. The fourth and fifth were added this year.

1. Does the model satisfy the SSC's requests that model changes be kept to a minimum?
2. Does the model contain new features that merit further evaluation before being adopted?
3. Would use of the model for setting harvest specifications pose a significant risk to the stock?
4. Are the model's estimates of *Q* and survey selectivity consistent with all of the relevant data?
5. Would adoption of the model be consistent with respect to the peer review procedures described in the NS2 guidelines?

<u>Criterion #1</u>

The first criterion was suggested by a number of SSC minutes over the last few years:

- From the June 2012 meeting (listed as comment SSC5 in Attachment 2.1 to the 2012 assessment): *"…Given the Plan Team's (and SSC's) reluctance in previous years to consider a new author-recommended model … 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."*
- From the June 2013 meeting (listed as comment SSC6 in Appendix 2.1 to the 2013 assessment): *"The SSC recommends that model changes be kept to a minimum to ensure that we can track model sensitivities to specific changes in model structure."*
- From the December 2013 meeting (listed as comment SSC3 in Appendix 2.1 to the 2014 assessment): *"…The SSC discussed the need for a more incremental approach to implementing changes to the model…."*

Because Model 11.5 is the base model (having been used for the last four years), adopting it for the present harvest specifications cycle would, by definition, keep the number of model changes to a minimum. Model 14.2, in contrast, contains a large number of potentially influential changes, including changes in growth, selectivity, and catchability; and does not satisfy the stated need for a more incremental approach to implementing changes to the base model.

<u>Criterion #2</u>

In the context of the second criterion, two features of Model 14.2 that stand out are its use of SS selectivity pattern #17, which treats selectivity as a random walk with respect to age, and the method used to estimate the "sigma" parameters governing the amount of time-variability in *dev* vectors.

Although selectivity pattern #17 has several benefits (see "Discussion" section in Appendix 2.1), some aspects could benefit from further evaluation, specifically:

- This selectivity pattern involves internal rescaling so that selectivity reaches a peak value of unity at some integer age. Restricting peak selectivity to occur at an integer age means that the function is not entirely differentiable, which is potentially problematic in ADMB.
- Although a substantial improvement in goodness of fit can sometimes be achieved by allowing annual *dev*s at the age of peak selectivity, this is sometimes accompanied by a large final gradient in the objective function (this may be related to the item in the previous bullet), which is usually considered to be symptomatic of a problem with the model.

- In some situations, a substantial improvement in goodness of fit can be achieved by estimating selectivity at unrealistically low values for all ages except for a few that are very close to the age-plus group (e.g., Model 3—now relabeled as Model 15.3—in this year's preliminary assessment).

The method of Thompson and Lauth (2012, Annex 2.1.1) was used to estimate the sigma parameters governing the amount of time-variability in *dev* vectors in Model 14.2. This method was developed as an alternative to estimating the sigma parameters by iteratively tuning each sigma to match the standard deviation of the elements in the respective *dev* vector, which is known to be biased low and is prone to "false negatives" (i.e., returning a zero estimate for σ when the true value is non-zero). For a univariate model (i.e., a model with only one *dev* vector), *if* the method of Thompson and Lauth (2012) returns a non-zero estimate of σ, this estimate will be unbiased (at least in a linear-normal model). However, the method is still prone to false negatives (Thompson in prep.), and generalizations to the multivariate case are awkward at best, with unknown statistical properties.

Two of the models presented in this year's preliminary assessment (Appendix 2.1) use an alternative method that addresses the shortcomings of the method of Thompson and Lauth (2012), at least in a linear-normal model. While its performance in the context of a typical stock assessment model remains to be evaluated, the new method so far shows considerable promise, and it might be worth waiting for further studies of the new method rather than switching to the method of Thompson and Lauth (2012) this year and then switching to a different method in the near future.

Criterion #3

With respect to the third criterion, Model 11.5 estimates a much higher maximum permissible ABC than Model 14.2 (Table 2.19). As discussed below in the "Retrospective Analysis" section, Model 11.5 appears to over-estimate the size of the stock by a substantial amount consistently (ρ = 0.475), in contrast to Model 14.2, which appears to show almost no systematic over- or under-estimation (ρ = -0.038). If ABC were set at the maximum permissible level, and if the stock were at a low level of abundance, this suggests that adoption of Model 11.5 might impose an unacceptable risk to the stock. However, it is not necessary to set ABC at the maximum permissible level (e.g., ABC for 2015 was set 14% below the maximum permissible level), neither model suggests that spawning biomass is dangerously low, and both models suggest that spawning biomass has been increasing steadily since 2009 or 2010. Although adoption of Model 11.5 would result in the seventh-highest OFL in history, catches of Pacific cod have never exceeded ABC during the last 20 years, so OFL may not be much of a consideration in practice.

Criterion #4

In the context of the two model structures, the data used in those models suggest strongly that survey selectivity has a steeply declining right-hand limb, and Model 11.5 assumes that *Q* is substantially less than 1.0 (Model 14.2 estimates *Q* at a value of 1.06). However, various field studies that have attempted to estimate survey efficiency or availability have failed to identify mechanisms that could account for this (with the possible exception of the study by Nichol et al. (2007)—see discussion below). As a result of their estimated survey selectivity schedules (and, in the case of Model 11.5, the assumed value of *Q*), both models provide estimates of total biomass that are, on average, much larger than the average survey biomass. According to the models, the EBS survey misses an average of 42% (Model 11.5) or 23% (Model 14.2) of the total biomass.

The SSC has suggested that the descending limb of the survey selectivity schedule might be explained, at least in part, by fish moving out of the EBS survey area during the summer and into the NBS (see comment SSC1 in the Executive Summary). As shown in the "Data" section, a comparison of size compositions from the 2010 EBS and NBS surveys indicates that, within the 71-95 cm size range, the

NBS accounted for 16-42% of the total (EBS+NBS) numbers at length. Figure 2.14 overlays the relative proportions of numbers-at-length and the survey selectivity schedules from the two models (to create this figure, model estimates of 2010 numbers at age, 2010 selectivity at age, and the distributions of length at age were used to convert selectivity at age into selectivity at length). For lengths in the 21-85 cm range, there does seem to be some resemblance between the proportion of numbers at length occurring in the EBS and estimated EBS survey selectivity. For lengths greater than 85 cm, however, the resemblance disappears, as fish in this size range were relatively uncommon in the 2010 NBS survey.

Additionally, even if summer migration into the NBS were to explain a substantial portion of the descending limb of the EBS survey selectivity schedule, it is not clear that this would explain the bulk of the discrepancy between biomass estimates (survey versus model). The year 2010 was unusual in the EBS survey time series in that it was one of only two years in which the EBS survey biomass exceeded the total biomass estimated by Model 11.5 and one of only six years in which the survey biomass exceeded the total biomass estimated by Model 14.2, so in this year there was no "missing biomass" that needed to be found elsewhere. However, when averaged over the entire time series, the discrepancy between EBS survey biomass and model biomass (42% or 23%, depending on model) is much larger than the 2010 NBS survey biomass, which accounted for only 3% of the overall (EBS+NBS) survey biomass in that year. Additional surveys of the NBS would likely make it easier to determine whether the "missing biomass" estimated by the models can typically be accounted for in the NBS.

The estimate of catchability in Model 11.5 is based on results from 11 archival tags (Nichol et al. 2007) which showed that the probability of a tag (fish) occurring within 2.5 m of the bottom at any given time during daylight hours was 47%. Although the number of data points from those 11 tags is quite large (~17,000), implying that the probability *for that particular group of 11 fish* is estimated very precisely, previous analyses have shown that there is considerable uncertainty regarding this probability *for the stock as a whole* (Thompson et al. 2009, p. 428; Thompson 2013, p. 344). Moreover, when catchability was estimated freely in the 2013 preliminary assessment (Thompson 2013), the estimate went up substantially, and the estimate of 2012 spawning biomass dropped by 56%. It is important to note that the study by Nichol et al. dealt with the behavior of fish in the absence of an interaction with a vessel or trawl. Therefore, the results of that study may be entirely accurate in the context of the study conditions, but they may not provide a good point estimate for use in the stock assessment if Pacific cod undertake a dive response to an oncoming vessel or trawl, as Atlantic cod (*Gadus morhua*) have been shown to do (Handegard and Tjøstheim 2005).

The Team and SSC have suggested several times that the catchability estimate used in Model 11.5 may need to be revised upward:

- From the October 2013 SSC minutes: *"In addition to the recommended model configurations, the SSC would like to see a model or models that fix survey catchability at Q=1…. Our rationale for this request is based on the increasing evidence that catchability is higher and quite possibly much higher than the current standard assumption…. Evidence from an unpublished study conducted in 2012 (Lauth) suggests that there is no difference in catchability between the low-opening (2.5 m) trawl used in the Bering Sea survey and the high opening (7 m) trawl used in the Gulf of Alaska survey. Moreover, observations of acoustic backscatter showed that Pacific cod tended to be near the bottom in the study area, consistent with a dive response to passing vessels commonly observed in other gadids."*
- From the December 2013 SSC minutes: *"The SSC re-iterates its concerns over the best value for the catchability coefficient…. The default assumption in most assessments is that survey catchability is 1, unless there is strong evidence to the contrary. The evidence for a lower Q has been put into question based on recent work…."*

- From the September 2014 Team minutes: *"All of the recent field work done by RACE has indicated that the bulk of the cod are very near the bottom when the survey trawl passes, contradicting the conclusion from the tag data. This suggests that catchability is near 1… The Team believes that the issue of whether to fix survey catchability at a low value (rather than at 1, or near 1…) should be resolved by next year at the latest."*
- From the October 2014 SSC minutes: *"Recent acoustic field work conducted by AFSC/RACE indicates that the bulk of the cod biomass is very near the bottom when the survey trawl passes, which is in contradiction to the archival tag data. This suggests that catchability is near 1…. Additional analysis will be forthcoming in the next assessment cycle that may help resolve this issue."*
- From the September 2015 Team minutes: *"The fixed survey Q (0.77) based on archival tags … has become less and less credible as careful experiments and analysis performed by RACE have produced no evidence that cod in the path of the survey trawl avoid capture by any means (e.g., vertical distribution or outswimming)."*
- From the October 2015 SSC minutes: *"The SSC has been on record encouraging the development of an alternative model that estimates q, due to the very weak or non-existent evidence for net avoidance, which has been corroborated by recent work. This makes the fixed value for q, which was always based on weak evidence, even less tenable than before."*

In summary, neither model is entirely successful in reconciling all of the data that can be brought to bear on the value of *Q* and the shape of the survey selectivity function. However, Model 14.2 comes closer to doing so than Model 11.5.

Criterion #5

The Federal guidelines for National Standard 2 of the Magnuson-Stevens Fishery Conservation and Management Act encourage use of external peer reviewers before adopting major model changes. Although the guidelines do not prohibit making major model changes in the course of a typical assessment cycle, the fact that the Center for Independent Experts is scheduled to review the assessment early next year might suggest that it is appropriate to wait until the next assessment cycle to make a major change in the final model.

Conclusion

Although neither model consistently out-performs the other with respect to each of the above criteria, consideration of the entire set of criteria suggests that Model 11.5 should be chosen as the final model for this assessment.

Final Parameter Estimates and Associated Schedules

As noted previously, estimates of all statistically estimated parameters in the model are shown in Table 2.17. Estimates of both aggregated annual and year-, gear-, and season-specific fishing mortality rates from Model 11.5 are shown in Table 2.18.

Schedules of selectivity at length for the commercial fisheries from Model 11.5 are shown in Table 2.20, and schedules of selectivity at age for the trawl surveys from Model 11.5 are shown in Table 2.21. The trawl survey selectivity schedule and all fishery selectivity schedules for Model 11.5 are plotted in Figures 2.10 and 2.11, 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 the survey from Model 11.5 are shown in Tables 2.22, and 2.23, and 2.24, 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 and numbers-at-age-averaged fishing mortality rates already shown in Table 2.18, 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 2.25 shows the time series of age 0+, age 3+, and female spawning biomass for the years 1977-2015 as estimated last year and this year (projections through 2016 are also shown for this year's assessment). The estimated spawning biomass time series are accompanied by their respective standard deviations.

The estimated time series of EBS age 0+, age 3+, and female spawning biomass are shown, together with the observed time series of trawl survey biomass, in Figure 2.15. Confidence intervals are shown for estimates of female spawning biomass and for the trawl survey biomass estimates. The average ratio of estimated age 0+ biomass to survey biomass over the time series is 1.76. Given that the catchability coefficient is fixed at 0.77, estimation of biomasses at least 30% (on average) higher than observed by the survey is to be expected.

Recruitment and Numbers at Age

Table 2.26 shows the time series of age 0 recruitment (1000s of fish) for the years 1977-2014 as estimated last year and this year. 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, followed by the 2008 cohort. The year classes since 2006 include five of the top ten year classes of all time (2006, 2008, 2010, 2011, and 2013; although it should be emphasized that the estimate of the 2013 cohort's rank is still somewhat preliminary). The set of year classes comprising the top ten is the same this year as last year, except that the 2010 cohort has bumped the 1992 cohort down from #10 to #11.

Recruitment estimates for the entire time series (1977-2014) are shown in Figure 2.16, along with their respective 95% confidence intervals.

The coefficient of autocorrelation for the recruitment time series is –0.11.

To date, it has not been possible to estimate a reliable stock-recruitment relationship for this stock. A possible relationship between recruitment and an environmental index is discussed in the "Ecosystem Considerations" section, under "Ecosystem Effects on the Stock."

The estimated time series of numbers at age is shown in Table 2.27.

Fishing Mortality

Table 2.28 shows "effective" fishing mortality by age and year for ages 1-19 and years 1977-2014.

Figures 2.17a and 2.17b plot the estimated/projected trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2017 based on full-selection fishing mortality for Models 11.5 and 14.2 respectively, overlaid with the current harvest control rules. Ordinarily, a figure of this nature would be presented for the final model only. However, members of the public have expressed particular interest in seeing a corresponding figure for Model 14.2, so it has been included as well.

For Model 11.5, projected values for 2016 and 2017 are from Scenario 2 (with the "author's F" multiplier set equal to 0.75) under "Harvest Recommendations," below. For Model 14.2, projected values for 2016 are computed analogously, except that the "author's F" multiplier is set equal to 1.00. It should be noted that, except for the projection years, these trajectories based on SS output, which may not match the estimates obtained by the standard projection program exactly.

Note that fishing mortality rates for several recent years (2006-2012 in Model 11.5, 1992-2015 in Model 14.2) appear to have been higher than the F_{OFL} control rule. In the case of Model 11.5, some of this may be due to a retrospective bias, as discussed in the next subsection.

Retrospective Analysis

Figure 2.18 shows the retrospective behavior of Model 11.5 with respect to female spawning biomass over the years 2005-2015. This figure was obtained by conducting ten additional model runs, dropping the 2015 data to create the run labeled "2014," dropping the 2014-2015 data to create the run labeled "2013," and so forth (the run labeled "2015" is this year's model run). In an attempt to quantify the results of this type of retrospective analysis, Mohn (1999) introduced a statistic labeled ρ, which has since been redefined to represent the average relative bias in terminal year estimates of a given quantity (in this case, female spawning biomass) across retrospective runs. For Model 11.5, $\rho = 0.475$, indicating that Model 11.5 tends to overestimate spawning biomass in the current year by nearly 50%. This ρ value is higher (in absolute terms) than any of the 20 examples of BSAI and GOA groundfish stocks reported in the 2013 report of the Retrospective Working Group. Not only is the retrospective bias of Model 11.5 high and positive on average, it is positive in all runs shown in Figure 2.18 except one (2014), ranging from 0.026-1.031 for the remaining years.

Determining the cause of a retrospective bias can be difficult. One oft-considered possibility is that certain parameters are constrained in the model to be constant over time, whereas the model would behave better if those parameters were allowed to vary over time. Examining the correlation between estimated parameter values and the number of "peels" (i.e., the number of data years dropped in each sequential run) in a retrospective analysis has been suggested as an appropriate diagnostic tool. For all estimated parameters in Model 11.5 (except those that get eliminated from the model during the peeling process, leaving a total of 168), correlation coefficients with respect to number of peels were computed.

The results are shown in Figure 2.19, in the form of a cumulative distribution function. For example, 36 parameters (21% of the total) had a correlation (in absolute value) of at least 0.90 with respect to number of peels. These are listed below (names of selectivity parameters are given in Appendix 2.3):

- One ageing bias parameter (age 20)
- Two initial age composition *dev*s (ages 1 and 2)
- Eight recruitment *dev*s (1981, 1987, 1988, 1997, 1999, 2000, 2001, 2002)
- Ten block-specific trawl fishery selectivity parameters
    - Five *beginning_of_peak_region* parameters
    - Five *ascending_width* parameters
- Ten block-specific longline fishery selectivity parameters
    - Seven *beginning_of_peak_region* parameters
    - Two *ascending_width* parameters
    - One *final_selectivity* parameter
- Four block-specific pot fishery selectivity parameters
    - Three *beginning_of_peak_region* parameters
    - One *final_selectivity* parameter
- One base survey selectivity parameter (*width_of_peak_region*)

All but two of the parameters in the above list already pertain to a specific year or block of years in the time series, so it is not clear that adding time variability to an existing estimated parameter will solve the problem. Another possibility is that certain quantities that are fixed in the model (i.e., not estimated internally) could be causing the problem, for example ln(Q), which is fixed in Model 11.5 at a value of −0.261. Model 14.2, where ln(Q) is estimated freely at a value of 0.056, has a ρ of only −0.038.

For the time being, the most important result of the retrospective analysis is that there appears to be a significant chance that Model 11.5 overestimates spawning biomass in the current year, perhaps by a considerable amount. It should be noted, however, that only one model run was conducted for each peel in the retrospective analysis (i.e., no "jitter" analysis was conducted), meaning it is possible that some of the retrospective runs may not have converged to the true minimum of the objective function.

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 EBS 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: $B/B_{40\%} \leq 0.05$

$F_{OFL} = 0$

$F_{ABC} = 0$

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 11.5's estimates of fishing mortality by gear for the five most recent complete years of data (2010-2014). 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 32%, longline 53%, and pot 15%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.35 and 0.30, respectively.

Model 11.5's estimates of $B_{100\%}$, $B_{40\%}$, and $B_{35\%}$ are 806,000 t, 323,000 t, and 282,000 t, respectively.

Specification of OFL and Maximum Permissible ABC

Given the assumptions of Scenario 1 (below), female spawning biomass for 2015 and 2016 is estimated by Model 11.5 to be well above the $B_{40\%}$ value of 323,000 t, thereby placing Pacific cod in sub-tier "a" of Tier 3 for both 2016 and 2017. Given this, Model 11.5 estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2016 and 2017 as follows:

Year	Overfishing Level	Maximum Permissible ABC
2016	OFL = 390,000 t	maxABC = 332,000 t
2017	OFL = 412,000 t	maxABC = 329,000 t
2016	*FOFL* = 0.35	*maxFABC* = 0.30
2017	*FOFL* = 0.35	*maxFABC* = 0.30

The age 0+ biomass projections for 2016 and 2017 from Model 11.5 (using SS rather than the standard projection model) are 1,830,000 t and 1,780,000 t.

For comparison, the age 3+ biomass projections for 2016 and 2017 from Model 11.5 (again using SS) are 1,820,000 t and 1,740,000 t.

Standard Harvest Scenarios, Projection Methodology, and Projection Results

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 numbers at age for January 1, 2016. This requires an appropriate estimate of total catch for 2015. Because each year's stock assessment is finalized before complete (i.e., year-long) catch data are available for that year, it is necessary to extrapolate the available catch data through the end of the year. In last year's final assessment, twelve estimators were evaluated to determine the best method of estimating total current-year catch as a function of previous intra-annual fishery performance. This evaluation concluded that the best estimator simply assumed that this year's catch during seasons 4-5 was equal to last year's catch during seasons 4-5. Because management of the EBS Pacific cod fishery has a very strong track record of keeping catch below TAC, however, this estimator was used only in the event that it did not result in a current-year catch greater than current-year TAC. In the case of the 2015 fishery, the estimator resulted in a catch of 229,000 t, which is less than the 2015 TAC of 240,000 t, so 229,000 t was used as the best estimate of the catch for 2015.

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. Except for the first two projection years under Scenario 2 (see paragraph below), 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.

For predicting future catches under Scenario 2, the 2014 assessment also described development of the following estimator for future total catch as a function of future ABC: For ABC≥148,000 t, catch = 59,200 t + 0.6×ABC; for ABC<148,000 t, catch = ABC. This estimator was used again in the present assessment, giving catches of 212,000 t for 2016 and 221,000 t for 2017.

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 2016 and 2017, 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 ("author's F") of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2016 recommended in the assessment to the *max* F_{ABC} for 2016. (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 2010-2014 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 2015 or 2) above 1/2 of its

MSY level in 2015 and expected to be above its MSY level in 2025 under this scenario, then the stock is not overfished.)

Scenario 7: In 2016 and 2017, 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 1) above its MSY level in 2017 or 2) above 1/2 of its MSY level in 2017 and expected to be above its MSY level in 2027 under this scenario, then the stock is not approaching an overfished condition.)

Projections corresponding to the standard scenarios are shown for Model 11.5 in Tables 2.29-2.35.

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 2016, it does not provide the best estimate of OFL for 2017, because the mean 2017 catch under Scenario 6 is predicated on the 2016 catch being equal to the 2016 OFL, whereas the actual 2016 catch will likely be less than the 2016 OFL. Table 2.19 contains the appropriate one- and two-year ahead projections for both ABC and OFL under Model 11.5.

ABC Recommendation

Since 2005, the SSC has set ABC at the maximum permissible level every year with the exception of the 2007 and 2014 assessment cycles, when, in each case, the SSC held the ABCs for the next two years constant at the then-current level. Specifications for 2006-2011 were set under Tier 3b, and specifications for 2012-2016 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, and 2011 year classes, whose strengths have now been confirmed by multiple surveys. The 2013 year class also appears to be strong, although this result is highly preliminary, being based entirely on the results of the 2014 and 2015 surveys.

However, the two concerns that resulted in last year's decision to keep the 2015-2016 ABCs constant at the 2014 level remain.

The first of these is doubt over reliability the sharply declining right-hand limb of the survey selectivity function as estimated by Model 11.5 and the value of catchability assumed in that model (see "Evaluation Criteria and Choice of Final Model" above).

Second, there is the issue of the apparently large and positive retrospective bias in Model 11.5's estimates of current-year spawning biomass (see "Retrospective Analysis" above). The amount of bias, while almost always positive, varies from year to year. Moreover, there does not appear to be a scientific consensus as to the appropriate management response to the existence of a retrospective bias, at least not in very precise terms. However, it is probably fair to conclude that the existence of a positive retrospective bias does not argue in favor of increasing the Pacific cod ABC for 2016.

Because these concerns remain, it does not seem appropriate to recommend an increase in ABC for 2016. The recommended ABC for 2016 is therefore the same as the current (2014-2015) value of 255,000 t. Holding fishing mortality constant at the rate that results in a 2016 ABC of 255,000 t (75% of *max* F_{ABC}; see Scenario 2, Table 2.30) gives a 2017 ABC of 270,000 t, which is the recommended ABC for 2017.

Area Allocation of Harvests

No recommendations are made regarding area allocation of harvests.

Status Determination

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

Is the stock being subjected to overfishing? The official EBS catch estimate for the most recent complete year (2014) is 238,729 t. This is less than the 2014 EBS OFL of 299,000 t. Therefore, the EBS Pacific cod 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 2015:

a. If spawning biomass for 2015 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2015 is estimated to be above $B_{35\%}$, the stock is above its MSST.

c. If spawning biomass for 2015 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 2025 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 2.34):

a. If the mean spawning biomass for 2017 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2017 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2017 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2027. If the mean spawning biomass for 2027 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 the assessment model, pre-1977 mean recruitment was only about 31% 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.

In the 2012 assessment, annual log-scale recruitment *dev*s estimated by the assessment model 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 in the 2012 analysis was a linear regression of recruitment *dev*s from 1977-2011 against the October-December average NPI (from the same year). Vestfals et al. (2014) have also noted a positive correlation between Pacific cod recruitment and the NPI, although not the October-December average NPI in particular.

In each assessment since 2012, the regression analysis has been updated. This year's regression resulted in a correlation of 0.56 (R^2=0.32). The time series, regression line, and 95% confidence interval from this year's regression are shown in the upper panel of Figure 2.20. The data for 2014 (magenta diamond in the upper panel), which is the most recent point in the data set, represents both the fifth-lowest value in the NPI time series and the second-lowest value in the recruitment time series. According to this analysis, the probability of the 2014 year class being higher than the median for the time series is less than 19%.

In each assessment since 2013, the main regression analysis has been accompanied by a cross-validation analysis involving creation of 100,000 "training" data sets, each one obtained by randomly sub-sampling 50% of the data without replacement. A regression was performed on each of the training sets, and then the performance of each regression was computed against the corresponding "test" (i.e., non-training) data set. When the NPI *was not* included as an explanatory variable (i.e., only the intercept of the regression was estimated), the RMSE (computed across all 100,000 test data sets) was 0.67, but when the NPI *was* included as an explanatory variable, the RMSE was reduced to 0.56. The distribution of slope parameter estimates from the cross-validation is shown in the middle panel of Figure 2.20. Note that the entire distribution is well above zero, indicating that the observed correlation is very unlikely to be entirely spurious. Two years, 1990 and 2002 (yellow and green diamonds in the upper panel), turned out to be far more influential than any other year in determining the magnitude of the estimated slope, and both of these influences were negative (lower panel of Figure 2.20). In other words, the positive slope is not due to the influence of outliers; if anything, the outliers are making the relationship appear less strong than would be the case without them.

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 are summarized in Tables 2.36-2.39. Catches for 2015 in each of these tables are incomplete. Table 2.36 shows incidental catch of FMP species, other than squid and the members of the former "other species" complex, taken from 1991-2015 by each of the three main gear types. Table 2.37 shows incidental catch of squid and the members of the former "other species" complex taken from 2003-2015, aggregated across gear types. Table 2.38 shows incidental catch of prohibited species taken from 1991-2015, plus mortality estimates for halibut, aggregated across gear types. Table 2.39 shows incidental catch of non-target species groups taken from 2003-2015, aggregated across gear types.

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 has operated to some extent in the same 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. A study conducted in 2002-2005 using pot fishing gear demonstrated that the local concentration of cod in the Unimak Pass area is very dynamic, so that fishery removals did not create a measurable decline in fish abundance (Conners and Munro 2008). A preliminary tagging study in 2003 – 2004 showed some cod remaining in the vicinity of the release area in the southeast Bering Sea for several months, while other fish moved distances of 150 km or more north-northwest along the shelf, some within a matter of two weeks (Rand et al. 2015). Further work has been planned to determine the overall scale of movement of Pacific cod in the Bering Sea and Aleutian Islands.

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. 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 hauls/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), followed by a 5-year review in 2010 (NMFS 2010). A second 5-year review is currently in progress.

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. At this point, the most critical needs pertain to trawl survey catchability and selectivity, specifically: 1) to understand the factors determining these characteristics, 2) to understand whether/how these characteristics change over time, and 3) to obtain accurate estimates of these characteristics. Additional surveys of the NBS may prove helpful in this regard. Ageing also continues to be an issue, as the assessment models consistently estimate a positive ageing bias. Longer-term research needs include improved understanding of: 1) the ecology of Pacific cod in the EBS, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment; 2) ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and 3) ecology of species that interact with Pacific cod, including estimation of interaction strengths, biomass, carrying capacity, and resilience.

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TABLES

Table 2.1a—Summary of 1964-1980 catches (t) of Pacific cod in the EBS by 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.

Year	For.	JV	Dom.	Total
1964	13,408	0	0	13,408
1965	14,719	0	0	14,719
1966	18,200	0	0	18,200
1967	32,064	0	0	32,064
1968	57,902	0	0	57,902
1969	50,351	0	0	50,351
1970	70,094	0	0	70,094
1971	43,054	0	0	43,054
1972	42,905	0	0	42,905
1973	53,386	0	0	53,386
1974	62,462	0	0	62,462
1975	51,551	0	0	51,551
1976	50,481	0	0	50,481
1977	33,335	0	0	33,335
1978	42,512	0	31	42,543
1979	32,981	0	780	33,761
1980	35,058	8,370	2,433	45,861

Table 2.1b—Summary of 1981-1990 catches (t) of Pacific cod in the EBS 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.

	Foreign			Joint Venture		Domestic Annual Processing				
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Subt.	Total
1981	30,347	5,851	36,198	7,410	7,410	n/a	n/a	n/a	12,899	56,507
1982	23,037	3,142	26,179	9,312	9,312	n/a	n/a	n/a	25,613	61,104
1983	32,790	6,445	39,235	9,662	9,662	n/a	n/a	n/a	45,904	94,801
1984	30,592	26,642	57,234	24,382	24,382	n/a	n/a	n/a	43,487	125,103
1985	19,596	36,742	56,338	35,634	35,634	n/a	n/a	n/a	51,475	143,447
1986	13,292	26,563	39,855	57,827	57,827	n/a	n/a	n/a	37,923	135,605
1987	7,718	47,028	54,746	47,722	47,722	n/a	n/a	n/a	47,435	149,903
1988	0	0	0	106,592	106,592	93,706	2,474	299	96,479	203,071
1989	0	0	0	44,612	44,612	119,631	13,935	145	133,711	178,323
1990	0	0	0	8,078	8,078	115,493	47,114	1,382	163,989	172,067

Table 2.1c—Summary of 1991-2015 catches (t) of Pacific cod in the EBS. The small catches taken by "other" gear types have been merged proportionally with the catches of the gear types shown. Pot catches for 2014-2015 include the State-managed fishery. Catches for 2015 are through September 27.

Year	Trawl	Longline	Pot	Total
1991	129,393	77,505	3,343	210,241
1992	77,276	79,420	7,514	164,210
1993	81,792	49,296	2,098	133,186
1994	85,294	78,898	8,071	172,263
1995	111,250	97,923	19,326	228,498
1996	92,029	88,996	28,042	209,067
1997	93,995	117,097	21,509	232,601
1998	60,855	84,426	13,249	158,529
1999	51,939	81,520	12,408	145,867
2000	53,841	81,678	15,856	151,376
2001	35,670	90,394	16,478	142,542
2002	51,118	100,371	15,067	166,555
2003	46,717	108,764	19,957	175,438
2004	57,866	108,618	17,264	183,748
2005	52,638	113,190	17,112	182,940
2006	53,236	96,613	18,969	168,818
2007	45,700	77,181	17,248	140,129
2008	33,497	88,936	17,368	139,802
2009	36,959	96,606	13,609	147,174
2010	41,297	81,848	19,723	142,868
2011	64,084	117,072	28,063	209,219
2012	75,423	128,513	28,737	232,674
2013	81,619	124,823	30,261	236,703
2014	72,253	127,283	39,193	238,729
2015	63,703	93,460	30,967	188,130

Table 2.2—Discards (t) and discard rates (%) of Pacific cod in the Pacific cod fishery, by area, gear, and year for the period 1991-2015 (2015 data are current through September 27). The small amounts of discards taken by other gear types have been merged proportionally into the gear types shown. Note that Amendment 49, which mandated increased retention and utilization, was implemented in 1998.

	Discard amount (t)				Discard rate (%)			
Year	Trawl	Longline	Pot	Total	Trawl	Longline	Pot	All
1991	1,278	1,493	4	2,774	4.11	2.62	0.26	3.10
1992	3,314	1,768	59	5,141	8.68	2.23	0.78	4.12
1993	5,449	2,234	25	7,708	12.89	4.54	1.21	8.24
1994	4,599	2,917	161	7,677	9.98	3.71	2.01	5.76
1995	7,987	3,669	222	11,879	12.24	3.77	1.15	6.52
1996	19	2,833	391	3,242	1.21	3.19	1.39	2.73
1997	10	3,183	79	3,280	3.48	2.72	0.37	2.36
1998	102	2,456	52	2,610	0.27	2.92	0.39	1.93
1999	353	1,285	52	1,691	0.95	1.58	0.42	1.29
2000	207	2,267	71	2,546	0.56	2.78	0.45	1.90
2001	142	1,531	52	1,726	0.76	1.70	0.32	1.38
2002	557	2,066	91	2,715	1.73	2.06	0.61	1.84
2003	240	1,771	159	2,170	0.79	1.63	0.80	1.36
2004	158	1,814	48	2,019	0.41	1.67	0.28	1.23
2005	86	2,599	61	2,747	0.26	2.30	0.36	1.68
2006	193	1,528	63	1,784	0.54	1.58	0.33	1.18
2007	238	1,373	45	1,656	0.74	1.78	0.26	1.31
2008	13	1,280	156	1,449	0.09	1.44	0.90	1.20
2009	126	1,503	16	1,645	1.02	1.56	0.12	1.34
2010	154	1,402	19	1,575	1.08	1.72	0.10	1.36
2011	121	1,860	32	2,013	0.42	1.59	0.11	1.16
2012	136	1,754	40	1,930	0.39	1.37	0.14	1.00
2013	220	3,066	90	3,376	0.58	2.46	0.30	1.75
2014	192	2,893	155	3,240	0.50	2.28	0.40	1.58
2015	141	1,710	94	1,945	0.43	1.83	0.30	1.24

Table 2.3—History of BSAI (1977-2013) and EBS (2014-2015) Pacific cod catch, TAC, ABC, and OFL (t). Catch for 2015 is through September 27. Note that specifications through 2013 were for the combined BSAI region, so BSAI catch is shown rather than the EBS catches from Table 2.1 for the period 1977-2013. 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	207,907	207,500	223,000	324,000
2004	212,618	215,500	223,000	350,000
2005	205,635	206,000	206,000	265,000
2006	193,025	194,000	194,000	230,000
2007	174,486	170,720	176,000	207,000
2008	171,277	170,720	176,000	207,000
2009	175,756	176,540	182,000	212,000
2010	171,875	168,780	174,000	205,000
2011	220,109	227,950	235,000	272,000
2012	250,899	261,000	314,000	369,000
2013	250,274	260,000	307,000	359,000
2014	238,729	246,897	255,000	299,000
2015	188,129	240,000	255,000	346,000

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 2.5 (p. 1 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2015 as configured in Model 11.5. 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.

		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 2.5 (p. 2 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2015 as configured in Model 11.5.

		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	34996	0	0	8229	0	0	20	0	0
1991	Mar-Apr	65276	0	0	12317	0	0	522	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	6420	0	0	9312	0	0	369
1992	Jan-Feb	23310	0	0	13660	0	0	13	0	0
1992	Mar-Apr	31836	0	0	22121	0	0	833	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	27998	0	0	22396	0	0	24	0	0
1993	Mar-Apr	35294	0	0	21434	0	0	1597	0	0
1993	May-Jul	0	5552	0	0	4744	0	0	2093	0
1993	Aug-Oct	0	0	6944	0	0	3002	0	0	0
1993	Nov-Dec	0	0	1544	0	0	564	0	0	0
1994	Jan-Feb	13856	0	0	22458	0	0	0	0	0
1994	Mar-Apr	43634	0	0	29089	0	0	4159	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	31939	0	0	29936	0	0	23	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	119	0	0	8802	0	0	640

Table 2.5 (p. 3 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2015 as configured in Model 11.5.

		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	21151	0	0	28835	0	0	25	0	0
1996	Mar-Apr	50436	0	0	29471	0	0	12571	0	0
1996	May-Jul	0	6797	0	0	4179	0	0	11600	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	25713	0	0	31971	0	0	30	0	0
1997	Mar-Apr	52321	0	0	30578	0	0	9639	0	0
1997	May-Jul	0	5174	0	0	8145	0	0	7352	0
1997	Aug-Oct	0	0	9321	0	0	21323	0	0	3780
1997	Nov-Dec	0	0	2366	0	0	24250	0	0	637
1998	Jan-Feb	15535	0	0	29256	0	0	1719	0	0
1998	Mar-Apr	27765	0	0	19060	0	0	5613	0	0
1998	May-Jul	0	4940	0	0	3709	0	0	5321	0
1998	Aug-Oct	0	0	12586	0	0	16155	0	0	1890
1998	Nov-Dec	0	0	1330	0	0	13196	0	0	454
1999	Jan-Feb	17660	0	0	30548	0	0	1900	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	229	0	0	4986	0	0	56
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	3800	0	0	1394	0	0	1077	0
2000	Aug-Oct	0	0	6199	0	0	22107	0	0	1667
2000	Nov-Dec	0	0	590	0	0	17816	0	0	0
2001	Jan-Feb	7962	0	0	18208	0	0	2206	0	0
2001	Mar-Apr	13895	0	0	16568	0	0	11279	0	0
2001	May-Jul	0	3500	0	0	3882	0	0	1005	0
2001	Aug-Oct	0	0	8904	0	0	30967	0	0	2970
2001	Nov-Dec	0	0	803	0	0	19752	0	0	641
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	8163	0	0	1903	0	0	531	0
2002	Aug-Oct	0	0	8594	0	0	34463	0	0	2997
2002	Nov-Dec	0	0	291	0	0	14335	0	0	803
2003	Jan-Feb	15389	0	0	35435	0	0	11705	0	0
2003	Mar-Apr	16452	0	0	17100	0	0	1651	0	0
2003	May-Jul	0	6752	0	0	2748	0	0	454	0
2003	Aug-Oct	0	0	7793	0	0	35120	0	0	5141
2003	Nov-Dec	0	0	264	0	0	18004	0	0	1429
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	2919	0	0	946	0
2004	Aug-Oct	0	0	8766	0	0	31394	0	0	3841
2004	Nov-Dec	0	0	75	0	0	20181	0	0	596
2005	Jan-Feb	27361	0	0	46935	0	0	9033	0	0
2005	Mar-Apr	15119	0	0	6612	0	0	3114	0	0
2005	May-Jul	0	7410	0	0	3290	0	0	0	0
2005	Aug-Oct	0	0	2892	0	0	35350	0	0	4550
2005	Nov-Dec	0	0	113	0	0	20756	0	0	407

Table 2.5 (p. 4 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2015 as configured in Model 11.5. Aug-Oct and Nov-Dec catches for 2015 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
2006	Jan-Feb	28611	0	0	45149	0	0	10608	0	0
2006	Mar-Apr	13901	0	0	6017	0	0	3297	0	0
2006	May-Jul	0	6347	0	0	1905	0	0	364	0
2006	Aug-Oct	0	0	4357	0	0	42493	0	0	3887
2006	Nov-Dec	0	0	70	0	0	1013	0	0	799
2007	Jan-Feb	15947	0	0	42943	0	0	10702	0	0
2007	Mar-Apr	16302	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	67	0	0	777	0	0	0
2008	Jan-Feb	15579	0	0	41627	0	0	8850	0	0
2008	Mar-Apr	7093	0	0	3657	0	0	1951	0	0
2008	May-Jul	0	3868	0	0	2665	0	0	225	0
2008	Aug-Oct	0	0	6306	0	0	33019	0	0	6218
2008	Nov-Dec	0	0	655	0	0	7966	0	0	124
2009	Jan-Feb	12194	0	0	44713	0	0	9395	0	0
2009	Mar-Apr	9602	0	0	3726	0	0	1722	0	0
2009	May-Jul	0	4174	0	0	2239	0	0	258	0
2009	Aug-Oct	0	0	10491	0	0	35381	0	0	1301
2009	Nov-Dec	0	0	403	0	0	10494	0	0	1081
2010	Jan-Feb	16351	0	0	40595	0	0	10695	0	0
2010	Mar-Apr	8148	0	0	2050	0	0	1726	0	0
2010	May-Jul	0	3982	0	0	2902	0	0	268	0
2010	Aug-Oct	0	0	9594	0	0	25029	0	0	5418
2010	Nov-Dec	0	0	1601	0	0	12708	0	0	1801
2011	Jan-Feb	21215	0	0	28996	0	0	15345	0	0
2011	Mar-Apr	20797	0	0	26321	0	0	2297	0	0
2011	May-Jul	0	7277	0	0	13983	0	0	594	0
2011	Aug-Oct	0	0	13352	0	0	30924	0	0	8954
2011	Nov-Dec	0	0	1728	0	0	17434	0	0	0
2012	Jan-Feb	39030	0	0	33163	0	0	19238	0	0
2012	Mar-Apr	14802	0	0	24915	0	0	2295	0	0
2012	May-Jul	0	8667	0	0	21090	0	0	791	0
2012	Aug-Oct	0	0	11670	0	0	27629	0	0	6171
2012	Nov-Dec	0	0	1058	0	0	21260	0	0	893
2013	Jan-Feb	35437	0	0	38744	0	0	19229	0	0
2013	Mar-Apr	16951	0	0	21978	0	0	3269	0	0
2013	May-Jul	0	5977	0	0	13881	0	0	0	0
2013	Aug-Oct	0	0	20907	0	0	26494	0	0	5892
2013	Nov-Dec	0	0	1608	0	0	22769	0	0	3567
2014	Jan-Feb	31399	0	0	32476	0	0	21523	0	0
2014	Mar-Apr	22940	0	0	27209	0	0	5187	0	0
2014	May-Jul	0	7057	0	0	21101	0	0	192	0
2014	Aug-Oct	0	0	11014	0	0	25937	0	0	6093
2014	Nov-Dec	0	0	989	0	0	22085	0	0	3528
2015	Jan-Feb	22015	0	0	27883	0	0	20032	0	0
2015	Mar-Apr	25510	0	0	27187	0	0	7904	0	0
2015	May-Jul	0	7869	0	0	20806	0	0	214	0
2015	Aug-Oct	0	0	11014	0	0	25937	0	0	6093
2015	Nov-Dec	0	0	989	0	0	22085	0	0	3528

Table 2.6 (page 1 of 3)— Fishery CPUE as configured in Model 11.5. Units are kg/minute for trawl gear, kg/hook for longline gear, and kg/pot for pot gear.

Jan-Apr trawl fishery			
Year	Season	CPUE	Sigma
1991	Jan-Feb	55.864	0.091
1992	Jan-Feb	60.427	0.160
1993	Jan-Feb	62.047	0.155
1994	Jan-Feb	51.965	0.220
1995	Jan-Feb	88.482	0.121
1996	Jan-Feb	48.331	0.131
1997	Jan-Feb	75.605	0.121
1998	Jan-Feb	59.920	0.157
1999	Jan-Feb	42.399	0.118
2000	Jan-Feb	34.522	0.122
2001	Jan-Feb	25.452	0.164
2002	Jan-Feb	35.892	0.139
2003	Jan-Feb	24.642	0.167
2004	Jan-Feb	62.609	0.137
2005	Jan-Feb	43.993	0.114
2006	Jan-Feb	36.397	0.106
2007	Jan-Feb	30.849	0.094
2008	Jan-Feb	24.385	0.150
2009	Jan-Feb	37.853	0.169
2010	Jan-Feb	41.949	0.135
2011	Jan-Feb	50.737	0.109
2012	Jan-Feb	97.338	0.098
2013	Jan-Feb	67.061	0.081
2014	Jan-Feb	57.039	0.086
2015	Jan-Feb	49.870	0.110
1991	Mar-Apr	61.454	0.058
1992	Mar-Apr	48.269	0.068
1993	Mar-Apr	48.840	0.073
1994	Mar-Apr	52.428	0.053
1995	Mar-Apr	55.463	0.060
1996	Mar-Apr	33.954	0.051
1997	Mar-Apr	45.985	0.062
1998	Mar-Apr	31.809	0.071
1999	Mar-Apr	35.675	0.085
2000	Mar-Apr	31.397	0.084
2001	Mar-Apr	21.213	0.105
2002	Mar-Apr	26.640	0.102
2003	Mar-Apr	28.131	0.094
2004	Mar-Apr	42.816	0.115
2005	Mar-Apr	48.932	0.112
2006	Mar-Apr	56.188	0.139
2007	Mar-Apr	45.097	0.091
2008	Mar-Apr	40.343	0.194
2009	Mar-Apr	55.557	0.181
2010	Mar-Apr	55.766	0.263
2011	Mar-Apr	76.788	0.147
2012	Mar-Apr	76.796	0.152
2013	Mar-Apr	64.027	0.137
2014	Mar-Apr	61.816	0.100
2015	Mar-Apr	72.289	0.099

May-Jul trawl fishery			
Year	Season	CPUE	Sigma
1991	May-Jul	36.761	0.201
1992	May-Jul	38.568	0.288
1993	May-Jul	39.902	0.464
1994	May-Jul	26.767	0.245
1995	May-Jul	59.393	1.652
1996	May-Jul	29.174	0.310
1997	May-Jul	24.880	0.256
1998	May-Jul	26.245	0.300
1999	May-Jul	15.672	0.422
2000	May-Jul	32.694	0.290
2001	May-Jul	60.120	0.295
2002	May-Jul	39.985	0.207
2003	May-Jul	49.493	0.208
2004	May-Jul	34.588	0.162
2005	May-Jul	24.100	0.170
2006	May-Jul	30.653	0.184
2007	May-Jul	39.485	0.113
2008	May-Jul	40.650	0.248
2009	May-Jul	33.932	0.289
2010	May-Jul	32.031	0.333
2011	May-Jul	49.228	0.256
2012	May-Jul	117.192	0.244
2013	May-Jul	39.218	0.288
2014	May-Jul	53.157	0.221
2015	May-Jul	54.315	0.217

Aug-Dec trawl fishery			
Year	Season	CPUE	Sigma
1991	Aug-Oct	71.702	0.597
1992	Aug-Oct	57.517	0.765
1993	Aug-Oct	113.970	0.498
1994	Aug-Oct	56.308	0.386
1995	Aug-Oct	60.164	0.320
1996	Aug-Oct	34.896	0.288
1997	Aug-Oct	62.619	0.561
1998	Aug-Oct	38.995	0.302
1999	Aug-Oct	20.611	0.363
2000	Aug-Oct	15.070	0.522
2001	Aug-Oct	16.662	0.246
2002	Aug-Oct	15.141	0.194
2003	Aug-Oct	19.171	0.154
2004	Aug-Oct	21.519	0.152
2005	Aug-Oct	15.932	0.826
2006	Aug-Oct	26.772	0.372
2007	Aug-Oct	18.147	0.674
2008	Aug-Oct	60.047	0.333
2009	Aug-Oct	54.154	0.223
2010	Aug-Oct	73.484	0.196
2011	Aug-Oct	56.918	0.200
2012	Aug-Oct	52.247	0.252
2013	Aug-Oct	82.463	0.139
2014	Aug-Oct	56.967	0.281
2015	Aug-Oct	126.284	0.360
1993	Nov-Dec	32.678	0.905
1996	Nov-Dec	29.543	0.477
1997	Nov-Dec	31.309	1.081
1998	Nov-Dec	16.891	0.640
1999	Nov-Dec	12.994	0.954
2009	Nov-Dec	28.369	1.168
2010	Nov-Dec	40.079	0.674
2011	Nov-Dec	20.796	1.168
2012	Nov-Dec	52.570	1.279
2013	Nov-Dec	17.174	1.652
2014	Nov-Dec	24.191	1.168

Table 2.6 (page 2 of 3)— Fishery CPUE as configured in Model 11.5. 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	0.154
1992	Jan-Feb	0.873	0.087
1993	Jan-Feb	0.654	0.065
1994	Jan-Feb	0.728	0.067
1995	Jan-Feb	0.895	0.068
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	0.068
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	0.054
2006	Jan-Feb	0.747	0.061
2007	Jan-Feb	0.734	0.045
2008	Jan-Feb	0.794	0.067
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
2013	Jan-Feb	0.736	0.062
2014	Jan-Feb	0.599	0.067
2015	Jan-Feb	0.579	0.072
1991	Mar-Apr	0.993	0.109
1992	Mar-Apr	0.858	0.070
1993	Mar-Apr	0.669	0.061
1994	Mar-Apr	0.735	0.059
1995	Mar-Apr	0.841	0.061
1996	Mar-Apr	0.756	0.066
1997	Mar-Apr	0.829	0.077
1998	Mar-Apr	0.619	0.075
1999	Mar-Apr	0.617	0.066
2000	Mar-Apr	0.617	0.096
2001	Mar-Apr	0.539	0.072
2002	Mar-Apr	0.676	0.081
2003	Mar-Apr	0.530	0.067
2004	Mar-Apr	0.579	0.075
2005	Mar-Apr	0.678	0.111
2006	Mar-Apr	0.796	0.111
2007	Mar-Apr	0.693	0.153
2008	Mar-Apr	0.774	0.144
2009	Mar-Apr	1.159	0.170
2010	Mar-Apr	0.829	0.193
2011	Mar-Apr	0.703	0.072
2012	Mar-Apr	0.597	0.081
2013	Mar-Apr	0.659	0.082
2014	Mar-Apr	0.523	0.070
2015	Mar-Apr	0.572	0.073

May-Jul longline fishery			
Year	Season	CPUE	Sigma
1991	May-Jul	0.771	0.074
1992	May-Jul	0.530	0.052
1993	May-Jul	0.551	0.174
1994	May-Jul	0.713	0.132
1995	May-Jul	0.760	0.177
1996	May-Jul	0.669	0.176
1997	May-Jul	0.657	0.119
1998	May-Jul	0.496	0.182
1999	May-Jul	0.637	0.141
2000	May-Jul	0.610	0.167
2001	May-Jul	0.514	0.106
2002	May-Jul	0.405	0.135
2003	May-Jul	0.376	0.108
2004	May-Jul	0.367	0.114
2005	May-Jul	0.385	0.105
2006	May-Jul	0.366	0.160
2007	May-Jul	0.406	0.141
2008	May-Jul	0.366	0.139
2009	May-Jul	0.384	0.150
2010	May-Jul	0.419	0.154
2011	May-Jul	0.374	0.087
2012	May-Jul	0.429	0.079
2013	May-Jul	0.424	0.090
2014	May-Jul	0.356	0.063
2015	May-Jul	0.462	0.090

Aug-Dec longline fishery			
Year	Season	CPUE	Sigma
1991	Aug-Oct	0.595	0.062
1992	Aug-Oct	0.512	0.068
1994	Aug-Oct	0.576	0.067
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	0.052
2001	Aug-Oct	0.398	0.051
2002	Aug-Oct	0.372	0.045
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	0.046
2007	Aug-Oct	0.402	0.038
2008	Aug-Oct	0.307	0.047
2009	Aug-Oct	0.348	0.048
2010	Aug-Oct	0.352	0.059
2011	Aug-Oct	0.369	0.058
2012	Aug-Oct	0.321	0.060
2013	Aug-Oct	0.355	0.056
2014	Aug-Oct	0.360	0.058
2015	Aug-Oct	0.448	0.186
1991	Nov-Dec	0.551	0.092
1995	Nov-Dec	0.648	0.109
1996	Nov-Dec	0.590	0.274
1997	Nov-Dec	0.577	0.072
1998	Nov-Dec	0.501	0.071
1999	Nov-Dec	0.541	0.118
2000	Nov-Dec	0.416	0.066
2001	Nov-Dec	0.432	0.065
2002	Nov-Dec	0.394	0.071
2003	Nov-Dec	0.365	0.059
2004	Nov-Dec	0.441	0.065
2005	Nov-Dec	0.385	0.063
2006	Nov-Dec	0.433	0.211
2007	Nov-Dec	0.449	0.328
2008	Nov-Dec	0.449	0.086
2009	Nov-Dec	0.428	0.089
2010	Nov-Dec	0.447	0.086
2011	Nov-Dec	0.447	0.085
2012	Nov-Dec	0.476	0.076
2013	Nov-Dec	0.479	0.070
2014	Nov-Dec	0.439	0.066

Table 2.6 (page 3 of 3)— Fishery CPUE as configured in Model 11.5. 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	0.150	1991	May-Jul	64.037	0.248	1991	Aug-Oct	88.556	0.131
2001	Jan-Feb	72.207	0.498	1992	May-Jul	66.730	0.076	1992	Aug-Oct	30.252	0.112
2002	Jan-Feb	81.893	0.261	1993	May-Jul	90.669	0.226	1994	Aug-Oct	97.172	0.150
2003	Jan-Feb	73.858	0.137	1994	May-Jul	75.421	0.171	1995	Aug-Oct	57.783	0.152
2004	Jan-Feb	78.980	0.168	1995	May-Jul	72.065	0.097	1996	Aug-Oct	49.758	0.135
2005	Jan-Feb	85.328	0.166	1996	May-Jul	55.819	0.088	1997	Aug-Oct	47.938	0.165
2006	Jan-Feb	83.292	0.152	1997	May-Jul	46.843	0.113	1998	Aug-Oct	32.057	0.278
2007	Jan-Feb	64.671	0.108	1998	May-Jul	49.999	0.128	1999	Aug-Oct	37.675	0.210
2008	Jan-Feb	81.642	0.206	1999	May-Jul	47.466	0.123	2001	Aug-Oct	46.493	0.167
2009	Jan-Feb	92.345	0.187					2002	Aug-Oct	42.331	0.187
2010	Jan-Feb	88.535	0.166					2003	Aug-Oct	57.632	0.173
2011	Jan-Feb	130.718	0.151					2004	Aug-Oct	48.802	0.208
2012	Jan-Feb	138.710	0.146					2005	Aug-Oct	45.872	0.190
2013	Jan-Feb	128.974	0.141					2006	Aug-Oct	55.342	0.184
2014	Jan-Feb	105.380	0.143					2007	Aug-Oct	65.356	0.150
2015	Jan-Feb	105.052	0.127					2008	Aug-Oct	57.252	0.162
1992	Mar-Apr	86.412	0.417					2009	Aug-Oct	72.836	0.263
1993	Mar-Apr	84.191	0.134					2010	Aug-Oct	82.936	0.208
1994	Mar-Apr	89.313	0.106					2011	Aug-Oct	81.445	0.146
1995	Mar-Apr	91.679	0.093					2012	Aug-Oct	64.934	0.128
1996	Mar-Apr	73.485	0.076					2013	Aug-Oct	87.471	0.127
1997	Mar-Apr	93.226	0.119					2014	Aug-Oct	77.822	0.160
1998	Mar-Apr	77.558	0.182					1991	Nov-Dec	91.633	0.259
1999	Mar-Apr	67.604	0.193					1995	Nov-Dec	53.251	0.186
2000	Mar-Apr	45.310	0.161					1996	Nov-Dec	46.456	0.417
2001	Mar-Apr	69.247	0.135					1997	Nov-Dec	41.829	0.409
2002	Mar-Apr	61.628	0.174					1998	Nov-Dec	41.138	0.793
2004	Mar-Apr	65.936	0.386					2001	Nov-Dec	40.740	0.624
2006	Mar-Apr	116.202	0.417					2002	Nov-Dec	55.955	0.413
2014	Mar-Apr	183.575	0.349					2003	Nov-Dec	60.093	0.330
2015	Mar-Apr	133.103	0.172					2004	Nov-Dec	66.375	0.447
								2006	Nov-Dec	37.187	0.417
								2010	Nov-Dec	104.985	0.369
								2013	Nov-Dec	90.404	0.211
								2014	Nov-Dec	69.205	0.208

Table 2.7— Total biomass and abundance, with standard deviations, as estimated by EBS shelf bottom trawl surveys, 1982-2015. 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	1,013,061	73,621	867,292	1,158,831	583,781	38,064
1983	1,187,096	120,958	942,640	1,431,553	752,456	80,566
1984	1,013,558	62,513	889,782	1,137,334	651,058	47,126
1985	1,001,112	55,845	890,540	1,111,684	841,108	113,438
1986	1,118,006	69,626	980,146	1,255,866	838,217	83,855
1987	1,027,518	63,670	901,452	1,153,584	677,054	44,120
1988	960,962	76,961	808,579	1,113,344	507,560	35,581
1989	833,473	62,713	709,300	957,645	292,247	19,986
1990	691,256	51,455	589,376	793,136	423,835	36,466
1991	514,407	38,039	439,090	589,725	488,892	51,108
1992	529,049	44,616	440,708	617,390	577,560	68,603
1993	663,308	53,143	558,085	768,531	810,608	99,259
1994	1,360,790	247,737	865,316	1,856,263	1,232,175	152,212
1995	1,002,961	91,622	821,550	1,184,372	757,910	75,473
1996	889,366	87,521	716,076	1,062,657	607,198	88,384
1997	604,439	68,120	468,199	740,678	485,643	70,802
1998	534,150	42,937	449,135	619,165	514,339	46,852
1999	569,765	49,471	471,811	667,718	488,337	45,289
2000	531,171	43,160	445,714	616,627	483,808	44,188
2001	811,816	73,211	665,394	958,239	960,917	91,898
2002	584,565	63,820	456,926	712,205	536,342	53,802
2003	590,973	62,121	466,732	715,214	498,873	62,220
2004	562,309	33,739	495,505	629,113	397,948	34,332
2005	606,050	43,056	520,799	691,301	450,705	63,363
2006	517,698	28,341	461,583	573,813	394,024	23,785
2007	423,704	34,811	354,081	493,326	733,402	195,956
2008	403,125	26,822	350,018	456,232	476,697	49,413
2009	421,291	34,969	352,053	490,530	716,637	62,705
2010	860,210	102,307	657,642	1,062,778	887,836	117,022
2011	896,039	66,843	763,690	1,028,388	836,822	79,207
2012	890,665	100,473	689,718	1,091,612	987,973	91,589
2013	791,958	73,952	644,054	939,862	750,889	124,917
2014	1,079,712	153,299	769,895	1,389,528	1,122,144	143,618
2015	1,102,261	150,981	800,299	1,404,223	982,470	113,501

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	290	455	458	484	461	433	394	252	250	120
1984	12135	0	0	0	0	0	6	25	36	55	43	27	25	26	30	46	31	64
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	4	7	24	38	60	81	108	121	121	153
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	81	183	191	175	150	198	221	233	247
1993	10403	0	0	0	0	1	2	29	81	191	423	293	403	354	321	318	343	311
1994	13923	0	0	0	0	0	3	10	5	27	42	76	91	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	64
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	23	53	84	117	104	136	91	45	22	6
1999	11699	0	0	0	0	0	1	15	53	100	109	122	94	113	78	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	63	127	204	312	449	658	710	766	678	662
2002	12239	0	0	0	0	1	3	6	21	43	63	80	101	159	112	166	111	71
2003	12358	0	0	1	0	1	3	5	11	56	92	138	205	232	206	249	254	282
2004	10803	0	2	0	0	0	1	4	20	45	86	152	106	193	187	215	210	135
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	169	350	380	390	350	312	227	151	75	40
2009	16675	1	0	0	7	36	106	401	971	1058	1087	878	744	650	485	460	318	219
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	306	385	413	597	627	905	886
2012	13075	0	0	6	0	0	74	379	686	732	563	424	417	310	410	396	208	129
2013	18699	0	0	0	0	1	9	50	116	147	207	222	283	239	177	127	35	22
2014	17946	0	0	0	1	0	1	9	90	117	239	340	466	519	657	498	608	490
2015	19322	0	0	0	0	0	0	11	42	42	85	77	52	47	57	57	60	74

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	146	173	165	213	145	127	107
1984	72	90	125	230	311	379	460	574	599	646	569	477	394	345	295	220	154	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	124	80	61	47	63	76	117	124	200	274	302	325	291	280	207	235	201	172
1988	26	35	48	68	77	88	86	109	83	124	122	137	179	190	269	216	195	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	372	308	251	261	196	173
1992	215	227	111	119	135	182	264	288	302	349	373	348	310	304	241	215	176	149
1993	321	215	134	97	61	55	66	85	94	173	206	230	290	315	239	246	227	196
1994	103	91	131	120	171	154	205	321	430	552	639	732	767	672	643	472	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	65	129	163	194	229	275	237	251	191	200	168	157
1997	226	177	105	58	41	41	34	70	109	103	154	223	231	222	174	159	155	138
1998	4	17	25	57	72	182	276	381	494	599	628	614	513	538	346	260	228	166
1999	49	39	53	109	110	196	228	222	310	268	295	308	240	227	197	191	240	290
2000	33	9	12	25	39	77	119	170	197	220	258	305	222	197	184	188	174	199
2001	440	349	219	136	112	160	226	314	365	507	657	832	826	921	806	700	512	409
2002	51	35	17	42	63	106	160	240	268	434	474	555	553	520	381	400	312	295
2003	252	237	199	218	154	120	66	57	59	79	57	115	144	316	216	319	240	275
2004	143	111	65	56	72	92	104	188	196	219	238	273	301	317	310	335	313	325
2005	290	362	362	387	376	289	210	137	135	142	115	158	178	197	197	207	231	288
2006	146	105	65	54	56	55	65	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	744	719	681	559	461	341	281	200	161	151
2009	114	35	28	33	82	93	173	253	336	396	467	436	339	306	221	214	215	225
2010	9	13	31	60	126	193	241	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
2013	63	86	268	398	653	786	982	1078	840	908	652	658	415	310	241	180	174	145
2014	521	308	218	111	103	91	72	96	221	247	419	331	484	460	498	349	311	184
2015	85	69	77	76	78	81	122	177	277	385	524	722	906	1055	1115	987	939	767

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	203	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	288	298	316	254	248	246	225	298	277	258	262	245
1984	102	88	59	94	75	91	94	96	108	134	106	109	95	109	142	129	156	167	197	198	154
1985	351	389	413	514	500	514	482	470	359	323	244	192	168	128	96	93	103	101	104	85	87
1986	220	194	138	126	136	163	185	216	205	246	218	248	269	258	275	288	299	226	252	251	175
1987	186	221	210	293	327	330	330	322	323	252	251	266	157	159	133	120	146	140	98	123	92
1988	141	184	165	239	222	197	319	277	294	277	247	308	266	229	250	250	260	220	214	227	194
1989	115	125	101	115	115	139	176	165	176	183	176	200	253	236	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	180	146	216	188	220	242	186	186	160	143	154	119	107	89	78	57	63	29	42	51
1993	153	161	182	183	221	221	234	270	207	185	193	159	151	129	113	118	108	88	64	66	79
1994	196	115	133	114	221	188	164	233	256	264	299	172	189	230	188	181	175	219	251	252	162
1995	314	378	371	417	422	394	343	335	293	199	189	153	142	115	98	108	95	88	93	86	72
1996	168	154	176	214	238	288	261	292	320	301	297	323	272	282	282	244	254	206	167	152	132
1997	145	136	125	127	135	135	171	194	228	152	172	134	150	180	187	160	167	124	213	164	173
1998	147	134	101	119	117	134	127	169	119	115	133	112	94	89	82	82	72	61	79	89	75
1999	308	382	486	509	584	557	505	395	408	311	233	199	165	141	144	117	117	93	104	92	85
2000	223	256	267	303	306	347	308	355	321	391	342	351	262	315	239	256	194	202	183	159	159
2001	301	218	189	176	152	157	186	229	280	230	266	250	230	262	273	257	235	219	225	189	208
2002	250	289	259	407	359	453	393	389	278	330	188	227	183	166	137	162	129	155	89	109	121
2003	291	318	361	342	389	456	425	461	415	390	277	276	234	246	260	198	185	166	148	124	144
2004	254	242	211	208	188	181	155	148	151	174	170	205	198	162	182	171	186	167	189	143	156
2005	252	204	194	203	207	216	167	205	168	193	131	171	126	144	129	135	111	111	101	98	100
2006	252	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	112	90	113	103
2009	302	303	362	380	379	347	334	280	289	247	181	147	144	117	103	93	82	75	78	85	88
2010	64	75	78	124	132	232	154	166	160	157	124	135	106	147	114	156	151	140	95	140	112
2011	403	457	673	801	860	925	872	790	634	511	347	349	278	265	185	230	225	265	185	276	241
2012	81	61	46	63	59	85	81	130	111	196	188	239	285	379	323	408	309	316	218	198	168
2013	126	184	153	230	292	361	431	519	407	386	349	325	258	259	195	210	136	192	142	214	193
2014	190	145	203	282	444	458	656	676	608	559	492	425	285	216	203	206	182	165	192	249	247
2015	575	498	286	268	200	377	373	500	474	469	426	454	320	352	347	318	337	389	337	433	331

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	181	126	122	78	81	79	68	59	39	48
1984	215	169	199	202	188	161	197	183	180	171	153	144	83	119	98	104	75	82	56	68	46
1985	90	85	148	110	110	113	171	123	134	146	147	135	135	120	138	107	135	99	95	59	75
1986	171	120	146	111	81	99	76	84	70	87	105	99	89	70	90	86	69	81	71	62	84
1987	139	136	123	131	121	132	124	133	132	110	116	94	60	91	53	56	55	23	43	33	33
1988	199	166	207	165	116	124	99	138	106	106	81	116	84	84	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	107	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	35	25	31	30	47	35	32	24	14	21	22	21	15	24	15	18	24	28
1993	66	57	58	52	36	66	37	37	61	28	28	14	15	15	14	16	12	12	11	12	12
1994	219	153	204	163	180	160	126	84	133	62	102	49	67	30	40	20	30	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	99	94	86	79	57	60	60	56	56	45	56	62	32	44	36	28	29	35	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	87	85	74	65	97	58	63	47	46	52	55	37	52	29	36	21	21	25	13
1999	71	117	86	94	80	95	63	70	49	62	70	49	45	51	37	28	28	23	26	27	24
2000	149	112	101	90	85	54	65	58	52	36	50	33	38	31	34	29	22	12	14	22	22
2001	184	149	197	131	155	151	107	83	106	67	78	57	51	33	38	26	20	27	20	31	17
2002	125	101	111	107	99	56	106	72	64	66	58	47	35	35	32	24	31	24	13	10	20
2003	138	116	96	70	95	64	72	69	66	67	76	47	56	40	40	36	35	26	28	16	18
2004	167	148	143	139	120	103	101	86	105	82	64	73	59	58	34	50	45	43	46	32	27
2005	117	84	118	82	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	85	77	53	65	71	52	38	48	30	40	29	21	24	13	17	14	15	14	4	13
2010	101	71	90	58	67	40	42	29	22	16	19	17	9	6	7	8	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
2013	234	192	212	203	234	213	194	163	141	136	109	104	92	51	63	44	31	44	29	31	8
2014	198	191	203	135	140	110	106	62	62	52	66	56	53	66	49	43	40	29	28	20	15
2015	300	219	245	158	168	113	107	111	98	81	65	61	62	57	45	55	43	35	24	24	20

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	11	1	1	2	4	0	3	0	1	0
1984	40	32	33	27	22	28	12	16	19	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	44	28	29	29	29	9	7	15	9	10	13	6	10	10	2	4	6	3	1
1988	63	53	31	30	11	27	15	6	15	2	15	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	17	14	11	13	14	7	10	7	13	5	7	7	4	7	8	3	9	1
1993	11	9	5	12	10	4	7	8	8	4	3	4	7	3	7	5	5	4	4
1994	10	12	5	9	8	9	7	4	6	35	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	0	5
2002	14	6	6	2	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	24	23	16	22	11	26	12	19	15	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	4	2	2	1	3	4	0	2	1	2	1	1	2	0	0	2	1	0	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
2013	29	12	24	12	10	7	7	4	3	5	4	4	5	1	2	0	1	0	1
2014	16	8	8	8	4	4	6	3	1	6	2	3	2	0	0	3	1	2	0
2015	23	14	7	12	7	17	9	6	3	4	1	2	2	0	2	1	1	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	3	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	3	1	1	1	0	0	0	0	0	0	0	0	0	1	0
1993	1	2	2	1	8	2	0	1	0	0	0	0	0	0	0	1	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
2013	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	1	0	0	1	1	1	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, 1994-2013. "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	0.0886	0.3829	0.1714	0.1222	0.1180	0.0810	0.0208	0.0072	0.0047	0.0015	0.0009	0.0008
1995	571	0.0000	0.0524	0.2643	0.4207	0.0990	0.0785	0.0495	0.0165	0.0094	0.0061	0.0016	0.0009	0.0012
1996	711	0.0000	0.0559	0.2081	0.2027	0.2930	0.1349	0.0576	0.0286	0.0106	0.0045	0.0020	0.0012	0.0009
1997	719	0.0000	0.2545	0.1690	0.1833	0.1566	0.1201	0.0781	0.0224	0.0103	0.0032	0.0013	0.0009	0.0004
1998	635	0.0000	0.0766	0.4411	0.2037	0.1123	0.0567	0.0596	0.0282	0.0160	0.0042	0.0008	0.0006	0.0002
1999	860	0.0000	0.0793	0.1996	0.3026	0.2317	0.0805	0.0576	0.0274	0.0123	0.0055	0.0013	0.0016	0.0006
2000	860	0.0000	0.2340	0.1270	0.1504	0.2419	0.1473	0.0614	0.0138	0.0140	0.0057	0.0028	0.0013	0.0005
2001	920	0.0000	0.2893	0.2355	0.1936	0.0909	0.0833	0.0680	0.0264	0.0080	0.0023	0.0015	0.0008	0.0003
2002	870	0.0001	0.0800	0.1880	0.3178	0.2333	0.0718	0.0586	0.0339	0.0105	0.0039	0.0012	0.0005	0.0005
2003	1263	0.0000	0.1750	0.1563	0.2506	0.2094	0.1189	0.0410	0.0300	0.0136	0.0037	0.0005	0.0005	0.0005
2004	995	0.0000	0.1437	0.1658	0.2708	0.1282	0.1279	0.0905	0.0397	0.0191	0.0087	0.0022	0.0026	0.0006
2005	1279	0.0000	0.1833	0.2444	0.2093	0.1211	0.0653	0.0794	0.0550	0.0237	0.0105	0.0037	0.0036	0.0006
2006	1300	0.0000	0.3244	0.1428	0.1649	0.1214	0.0929	0.0634	0.0463	0.0284	0.0100	0.0031	0.0014	0.0010
2007	1441	0.0000	0.7004	0.0956	0.0671	0.0414	0.0460	0.0176	0.0143	0.0084	0.0050	0.0017	0.0015	0.0010
2008	1213	0.0001	0.2133	0.4453	0.1449	0.0827	0.0486	0.0330	0.0101	0.0103	0.0058	0.0028	0.0014	0.0018
2009	1412	0.0007	0.4544	0.1895	0.2309	0.0640	0.0288	0.0146	0.0094	0.0039	0.0021	0.0008	0.0006	0.0003
2010	1292	0.0000	0.0465	0.4794	0.1793	0.2032	0.0644	0.0145	0.0077	0.0026	0.0013	0.0004	0.0005	0.0001
2011	1253	0.0000	0.2904	0.0730	0.3881	0.1111	0.0956	0.0278	0.0069	0.0033	0.0017	0.0010	0.0006	0.0005
2012	1301	0.0000	0.3660	0.2343	0.0583	0.2372	0.0617	0.0307	0.0074	0.0020	0.0016	0.0005	0.0002	0.0002
2013	1418	0.0000	0.1072	0.4270	0.1780	0.1084	0.1129	0.0504	0.0109	0.0036	0.0008	0.0002	0.0003	0.0002
2014	1420	0.0000	0.2787	0.1879	0.2381	0.1972	0.0478	0.0358	0.0102	0.0022	0.0009	0.0007	0.0001	0.0003

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. These data are used in Model 11.5 only.

Average length (cm) at age:

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1994	11.00	19.01	31.76	39.93	49.48	58.13	64.17	70.88	81.49	86.42	95.32	90.34	95.68
1995	11.00	17.35	32.35	43.22	53.11	62.09	69.84	74.59	81.72	84.90	91.93	91.28	95.54
1996	11.00	17.66	31.64	41.44	50.30	57.73	67.24	75.75	82.24	88.33	90.09	90.22	95.92
1997	0.00	17.21	31.83	41.99	51.73	59.81	64.94	72.30	79.30	86.53	91.81	92.20	93.75
1998	11.00	15.51	30.77	37.87	49.36	59.06	66.40	70.39	77.59	89.22	88.97	91.92	91.25
1999	11.00	15.82	29.66	40.34	46.25	56.79	65.50	71.46	79.81	82.59	91.86	90.45	96.01
2000	11.00	15.26	30.33	38.99	47.70	53.76	59.87	73.19	74.62	79.93	82.34	81.79	94.13
2001	11.00	17.88	31.36	36.69	48.31	55.35	62.01	65.94	77.00	82.21	78.84	89.04	91.81
2002	11.00	16.54	30.08	36.95	46.92	55.83	62.69	68.79	72.03	79.65	92.54	89.85	94.31
2003	11.00	18.00	29.81	40.87	48.29	56.52	65.35	70.42	75.31	81.55	85.04	84.26	78.93
2004	11.00	17.24	30.21	37.98	49.00	57.04	64.10	71.10	75.64	83.33	88.08	86.25	95.20
2005	0.00	18.59	26.70	39.16	48.56	57.03	64.12	72.34	78.57	81.78	88.33	87.17	94.51
2006	0.00	15.34	30.89	38.56	47.57	55.92	65.01	73.79	82.38	85.67	88.79	94.10	96.68
2007	0.00	15.06	31.03	41.18	50.61	59.35	66.64	74.74	81.58	84.26	94.22	87.84	91.37
2008	11.00	15.37	29.77	41.31	53.38	60.88	66.05	72.70	79.10	84.29	89.82	94.98	91.34
2009	11.00	14.14	31.10	42.51	51.62	59.79	65.93	71.88	75.56	83.65	90.04	88.89	90.44
2010	0.00	15.55	30.51	43.47	53.84	59.23	66.32	70.81	81.39	82.04	89.96	84.21	99.33
2011	11.00	18.19	33.07	43.94	53.86	62.52	67.87	73.09	77.21	85.18	85.85	83.92	95.44
2012	11.00	14.02	32.06	44.55	53.52	61.30	68.51	73.16	81.31	83.57	92.02	93.51	96.95
2012	0.00	16.27	28.90	43.88	50.64	61.98	66.60	74.91	77.35	83.71	88.24	87.24	95.24
2014	11.00	17.65	31.87	44.19	51.75	61.08	67.35	71.02	79.84	86.99	86.13	93.70	89.24

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	23	138	194	89	55	38	14	9	6	1	1	3
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	130	204	177	82	21	19	6	6	1	0
2001	0	163	156	153	132	124	118	42	15	6	4	5	2
2002	1	72	153	202	186	80	88	63	15	6	2	0	2
2003	0	163	197	191	189	193	129	111	66	17	1	4	2
2004	0	141	133	197	128	151	129	59	32	17	4	4	0
2005	0	141	218	238	171	112	146	121	73	29	18	10	2
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	13
2008	0	141	262	244	188	134	97	45	45	28	13	8	8
2009	0	222	259	325	187	133	100	82	47	23	13	12	9
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	10
2012	0	163	289	130	284	161	151	55	30	20	11	3	4
2013	0	133	289	264	171	272	163	81	25	10	3	4	3
2014	0	183	231	307	300	134	166	57	23	9	8	0	2

Table 2.11—Time series of final model names in the BSAI/EBS Pacific cod assessments since 2005. Shading indicates the final model in each year. Note that original model names were recycled over time (e.g., Model 1 in 2007 is not the same as Model 1 in 2005).

	Models included in final assessment (original names)														Final model	
Assessment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Original name	New name
2005	1	2	3												2	05.2
2006	0	A1	A2	B1	B2	C1	C2	D1	D2						B1	06.4
2007	1	2	3	4											1	07.1
2008	A1	A2	B1	B2	C1	D2	E2	F2							B1	08.3
2009	A1	A2	A3	B1	B2	C1	C2	D1	D2	E1	E2	F2	G1	G2	B1	08.3a
2010	A	B	C												B	10.2
2011	1	2b	3	4	3b										3b	11.5
2012	1	2	3	4											1	11.5
2013	n/a														n/a	11.5
2014	1	2													1	11.5

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

	Model 11.5																M. 14.2	
	Trawl fishery					Longline fishery					Pot fishery					Srv.	Fish.	Srv.
Year	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5			
1977			10	13													2	
1978				34		8	23		42	17							12	
1979			17		6	74	24	32	12	20							17	
1980	23	63				8	6	30	13	19							15	
1981			51		15	7	5	26		11							11	
1982		25	20	5	13		12	16	34	19						241	14	253
1983	19	71	27	11	151	83	87	48	54	59						300	57	315
1984	78	98	91	22	34	67	91	82	191	735						277	140	291
1985	74	246	10	16	6	314	68	8	376	1082						386	207	405
1986	85	201	79	45		230	28	98	202	951			11	13		351	180	369
1987	256	178	103	153	81	695	201	101	620	1272			5	15		242	344	254
1988	728	320	34	6	35	12										228	107	240
1989	626		68		12				38					9		228	71	240
1990	222	569	276	5		14	82	623	627	307			7	71		129	264	135
1991	431	1030	53			167	248	561	923	288			17	120	13	165	362	173
1992	107	738	56			396	731	1041	542		6	10	246	117		219	375	230
1993	167	913				493	726	84				92	36			238	236	249
1994	111	1358	83			598	863	182	443			206	106	69		318	378	334
1995	89	901		8		607	779	101	498	219	7	271	342	96	62	210	374	221
1996	66	1301	96	41	14	747	746	104	751	37		438	461	179	20	213	470	224
1997	127	1111	30			760	805	269	839	716		272	347	128	23	210	510	220
1998	76	950	32	38	5	651	580	112	998	867		213	243	51		219	453	230
1999	240	572	12	15		749	798	241	987	248		119	296	84		267	410	281
2000	201	533	36			692	399	131	1279	839	307	170				287	431	301
2001	75	309	42	53		564	678	331	1436	864	27	294	19	140	10	451	455	473
2002	163	320	91	123		992	556	212	1734	707	81	164	16	127	17	279	498	293
2003	123	419	101	151		1292	811	326	1917	1017	267	13		137	40	282	622	296
2004	148	258	135	86		1055	675	281	1681	841	160	35	14	118	18	247	505	259
2005	207	275	113			1230	303	319	1678	828	145	23		137		258	494	271
2006	281	159	83	13		971	298	153	1678	82	202	49	11	139	29	277	390	291
2007	190	213	146			892	76	90	1232	57	213	23		101		293	304	307
2008	167	93	32	21		814	192	209	1569	467	122	26		124		296	361	311
2009	86	58	28	67		729	117	165	1500	436	123	21		53	15	381	319	400
2010	165	37	17	59		784	76	150	971	439	144			115	37	173	281	181
2011	245	140	37	85		497	674	424	1031	446	166			170		474	368	497
2012	331	126	45	28		579	548	562	1032	587	205	29		241		299	406	313
2013	471	170	31	124		900	512	426	1105	700	128	9		197	79	427	511	448
2014	440	353	59	52		769	697	863	1007	777	147	21		115	62	410	504	430
2015	168	277	37	21		661	654	426	96		148	53	14	50		441	245	463

Table 2.13—Objective function components and parameter counts. Shaded cells indicate values not used in computing the total. Color scale extends from red (low) to green (high) in each row.

	Last year		This year	
Obj. func. component	Model 11.5	Model 14.2	Model 11.5	Model 14.2
Equilibrium catch	0.01	0.00	0.01	0.00
Survey abundance index	-3.61	-60.32	-6.87	-62.42
Size composition	4948.11	992.08	5235.34	1034.90
Age composition	141.27	104.30	145.88	110.89
Recruitment	21.62	-0.11	22.19	0.95
Priors	n/a	14.77	n/a	14.52
"Softbounds"	0.03	0.00	0.03	0.00
Deviations	19.85	13.05	20.31	13.26
"F ballpark"	0.00	0.17	0.00	0.01
Total	5127.28	1063.93	5416.88	1112.11
CPUE component	Model 11.5	Model 14.2	Model 11.5	Model 14.2
Jan-Apr trawl fishery	233.86	n/a	269.87	n/a
May-Jul trawl fishery	-1.42	n/a	-0.88	n/a
Aug-Dec trawl fishery	65.58	n/a	66.96	n/a
Jan-Apr longline fishery	302.02	n/a	383.77	n/a
May-Jul longline fishery	16.74	n/a	25.51	n/a
Aug-Dec longline fishery	156.46	n/a	208.17	n/a
Jan-Apr pot fishery	2.16	n/a	5.62	n/a
May-Jul pot fishery	-9.24	n/a	-9.33	n/a
Aug-Dec pot fishery	17.76	n/a	19.77	n/a
Shelf trawl survey	-3.61	-60.32	-6.87	-62.42
Sizecomp component	Model 11.5	Model 14.2	Model 11.5	Model 14.2
Jan-Apr trawl fishery	1098.50	n/a	1181.97	n/a
May-Jul trawl fishery	203.96	n/a	209.66	n/a
Aug-Dec trawl fishery	247.93	n/a	259.01	n/a
Jan-Apr longline fishery	757.87	n/a	773.04	n/a
May-Jul longline fishery	245.71	n/a	250.43	n/a
Aug-Dec longline fishery	1055.81	n/a	1119.37	n/a
Jan-Apr pot fishery	133.02	n/a	168.06	n/a
May-Jul pot fishery	67.89	n/a	71.92	n/a
Aug-Dec pot fishery	245.53	n/a	273.37	n/a
Fishery	n/a	207.04	n/a	210.61
Shelf trawl survey	891.90	785.04	928.51	824.28
Parameter counts	Model 11.5	Model 14.2	Model 11.5	Model 14.2
Unconstrained parameters	115	13	115	13
Parameters with priors	0	73	0	74
Constrained deviations	71	117	73	120
Total	186	203	188	207

Table 2.14—Root mean squared errors (RMSE), mean normalized residuals (MNR), standard deviations of normalized residuals (SDNR), and observed:expected correlations (Corr.) for fishery CPUE and survey relative abundance time series. Fishery CPUE data are not used in fitting Model 11.5 and are not included at all in Model 14.2; fishery CPUE results are shown for comparison only.

Model	Fleet	RMSE	MNR	SDNR	Corr.
11.5	Jan-Apr trawl fishery	0.47	0.57	3.89	0.16
11.5	May-Jul trawl fishery	0.38	-0.16	1.63	0.33
11.5	Aug-Dec trawl fishery	0.69	0.17	2.33	0.25
11.5	Jan-Apr longline fishery	0.38	0.23	4.57	-0.16
11.5	May-Jul longline fishery	0.28	0.35	2.54	0.48
11.5	Aug-Dec longline fishery	0.25	0.12	3.85	0.35
11.5	Jan-Apr pot fishery	0.34	0.18	1.99	0.26
11.5	May-Jul pot fishery	0.21	0.04	1.50	0.22
11.5	Aug-Dec pot fishery	0.39	0.01	2.06	0.11
11.5	Shelf trawl survey	0.23	0.95	1.82	0.78
14.2	Shelf trawl survey	0.11	0.10	0.93	0.93

Table 2.15—Ratios of effective sample size to input sample size for each fishery and survey size composition time series. Mod. = model, Nrec = number of records, Ninp = input sample size, Neff = effective sample size, A(·) = arithmetic mean, H(·) = harmonic mean.

				Ratios		
Model	Fleet	Nrec	A(Ninp)	A(Neff/Ninp)	A(Neff)/A(Ninp)	H(Neff)/A(Ninp)
11.5	Jan-Apr trawl fish.	68	314	4.88	2.92	1.53
11.5	May-Jul trawl fish.	35	62	9.05	7.26	3.32
11.5	Aug-Dec trawl fish.	38	44	12.75	6.00	3.24
11.5	Jan-Apr longl. fish.	72	476	8.44	3.99	1.18
11.5	May-Jul longl. fish.	35	252	9.32	5.16	3.00
11.5	Aug-Dec longl. fish.	67	673	6.42	3.09	0.89
11.5	Jan-Apr pot fish.	40	129	13.79	9.71	3.37
11.5	May-Jul pot fish.	17	129	17.83	7.72	1.72
11.5	Aug-Dec pot fish.	40	84	9.83	7.25	2.75
11.5	Trawl survey	34	286	1.97	1.66	1.03
14.2	Fishery	39	300	13.45	9.22	2.69
14.2	Trawl survey	34	300	2.31	1.94	1.19

Table 2.16—Input sample size, effective sample size, and ratio thereof for each year of age composition data from the bottom trawl survey. Last two rows show arithmetic and harmonic means. Color scale extends from red (low) to green (high) in each row.

		Effective N		Ratio	
Year	Input N	Model 11.5	Model 14.2	Model 11.5	Model 14.2
1994	201	437	273	2.18	1.36
1995	160	37	60	0.23	0.37
1996	200	342	796	1.71	3.98
1997	202	149	452	0.74	2.24
1998	178	1116	1270	6.27	7.13
1999	241	125	84	0.52	0.35
2000	241	115	66	0.48	0.27
2001	258	99	90	0.38	0.35
2002	244	90	106	0.37	0.43
2003	354	266	432	0.75	1.22
2004	279	31	58	0.11	0.21
2005	359	395	329	1.10	0.92
2006	365	147	394	0.40	1.08
2007	404	61	1108	0.15	2.74
2008	340	250	485	0.74	1.43
2009	396	94	383	0.24	0.97
2010	363	94	240	0.26	0.66
2011	352	151	113	0.43	0.32
2012	365	98	114	0.27	0.31
2013	398	122	148	0.31	0.37
2014	399	483	291	1.21	0.73
Mean	300	224	347	0.90	1.31
Harm.	275	109	156	0.37	0.56

Table 2.17a—Biological parameters, ageing bias, recruitment (except annual *dev*s), initial fishing mortality, log catchability (base value only for Model 14.2), and initial age composition parameters used or estimated by the stock assessment models.

	Model 11.5		Model 14.2	
Parameter	Estimate	St. dev.	Estimate	St. dev.
Natural mortality	3.400E-01	_	3.366E-01	3.019E-02
Length at age 1 (cm)	1.424E+01	1.035E-01	1.632E+01	8.620E-02
Asymptotic length (cm)	9.251E+01	4.929E-01	9.633E+01	2.017E+00
Brody growth coefficient	2.399E-01	2.469E-03	2.245E-01	1.472E-02
Richards growth coefficient	n/a	n/a	9.315E-01	5.477E-02
SD of length at age 1 (cm)	3.537E+00	6.615E-02	3.393E+00	5.681E-02
SD of length at age 20 (cm)	9.776E+00	1.524E-01	8.762E+00	2.868E-01
Weight-length α (proportionality)	5.762E-06	_	5.762E-06	_
Weight-length β (exponent)	3.179E+00	_	3.179E+00	_
Age at 50% maturity	4.883E+00	_	4.883E+00	_
Maturity slope	-9.654E-01	_	-9.654E-01	_
Ageing bias at age 1 (years)	3.326E-01	1.315E-02	2.744E-01	2.454E-02
Ageing bias at age 20 (years)	3.544E-01	1.483E-01	7.050E-01	2.210E-01
Ageing error st. dev. at age 1	8.500E-02	_	8.500E-02	_
Ageing error st. dev. at age 20	1.704E+00	_	1.704E+00	_
ln(mean post-1976 recruitment)	1.320E+01	1.868E-02	1.314E+01	2.085E-01
Beverton-Holt "steepness"	1.000E+00	_	1.000E+00	_
σ(recruitment)	5.700E-01	_	6.570E-01	_
ln(pre-1977 recruitment offset)	-1.151E+00	1.297E-01	-7.091E-01	2.273E-01
Initial F (Jan-Apr trawl fishery)	6.566E-01	1.395E-01	n/a	n/a
Initial F (fishery)	n/a	n/a	8.710E-02	2.641E-02
ln(trawl survey catchability)	-2.614E-01	_	5.591E-02	1.125E-01
Initial age 10 ln(abundance) dev	n/a	n/a	-2.651E-01	5.882E-01
Initial age 9 ln(abundance) dev	n/a	n/a	-3.098E-01	5.786E-01
Initial age 8 ln(abundance) dev	n/a	n/a	-3.798E-01	5.649E-01
Initial age 7 ln(abundance) dev	n/a	n/a	-4.800E-01	5.463E-01
Initial age 6 ln(abundance) dev	n/a	n/a	-5.655E-01	5.279E-01
Initial age 5 ln(abundance) dev	n/a	n/a	-5.320E-01	5.210E-01
Initial age 4 ln(abundance) dev	n/a	n/a	-7.053E-02	5.091E-01
Initial age 3 ln(abundance) dev	1.302E+00	1.871E-01	1.770E-01	4.721E-01
Initial age 2 ln(abundance) dev	-7.164E-01	4.172E-01	-2.293E-01	5.508E-01
Initial age 1 ln(abundance) dev	1.415E+00	2.087E-01	7.009E-01	4.704E-01

Table 2.17b—Annual log-scale recruitment *devs* estimated by the stock assessment models. Color scale extends from red (low) to green (high) in each column.

	Model 11.5		Model 14.2	
Year	Estimate	St. dev.	Estimate	St. dev.
1977	1.346E+00	1.084E-01	9.080E-01	2.404E-01
1978	4.748E-01	2.069E-01	6.814E-01	2.154E-01
1979	6.902E-01	1.071E-01	4.780E-01	1.402E-01
1980	-3.689E-01	1.319E-01	-2.681E-01	1.381E-01
1981	-8.989E-01	1.430E-01	-7.965E-01	1.605E-01
1982	9.647E-01	4.102E-02	7.443E-01	6.394E-02
1983	-5.250E-01	1.104E-01	-3.346E-01	1.234E-01
1984	7.580E-01	4.560E-02	6.616E-01	6.591E-02
1985	-8.446E-02	7.108E-02	-8.001E-02	9.615E-02
1986	-7.928E-01	9.326E-02	-6.414E-01	1.147E-01
1987	-1.127E+00	1.055E-01	-1.536E+00	2.112E-01
1988	-2.196E-01	5.607E-02	-1.954E-01	1.004E-01
1989	5.199E-01	3.989E-02	3.803E-01	7.218E-02
1990	3.161E-01	4.513E-02	3.745E-01	6.977E-02
1991	-3.007E-01	6.074E-02	-2.969E-01	9.853E-02
1992	6.045E-01	3.216E-02	6.207E-01	4.817E-02
1993	-4.381E-01	5.767E-02	-1.671E-01	7.317E-02
1994	-3.502E-01	5.034E-02	-3.735E-01	7.523E-02
1995	-2.697E-01	5.305E-02	-3.790E-01	8.070E-02
1996	6.298E-01	3.190E-02	5.044E-01	4.866E-02
1997	-2.645E-01	5.065E-02	-1.062E-01	6.654E-02
1998	-2.852E-01	4.859E-02	-1.953E-01	7.417E-02
1999	3.715E-01	3.140E-02	5.142E-01	4.807E-02
2000	-1.185E-01	3.670E-02	-7.377E-03	5.896E-02
2001	-8.911E-01	5.668E-02	-4.670E-01	6.924E-02
2002	-3.543E-01	3.801E-02	-4.150E-01	6.547E-02
2003	-5.935E-01	4.572E-02	-3.969E-01	6.426E-02
2004	-7.240E-01	4.969E-02	-6.828E-01	8.140E-02
2005	-5.943E-01	4.666E-02	-3.934E-01	7.945E-02
2006	6.617E-01	2.697E-02	5.290E-01	5.023E-02
2007	-5.224E-01	6.004E-02	6.392E-02	6.818E-02
2008	1.123E+00	3.225E-02	9.846E-01	4.572E-02
2009	-6.548E-01	1.012E-01	-7.570E-01	1.231E-01
2010	6.055E-01	5.209E-02	3.860E-01	7.075E-02
2011	1.005E+00	5.587E-02	8.103E-01	7.374E-02
2012	3.463E-01	8.731E-02	2.464E-01	1.020E-01
2013	1.015E+00	8.238E-02	7.277E-01	1.204E-01
2014	-1.053E+00	2.458E-01	-1.126E+00	2.762E-01

Table 2.17c—Fishery selectivity parameters estimated by Model 11.5.

Parameter	Estimate	St. dev.
P3_May-Jul_Trawl	5.607E+00	1.034E-01
P2_Jan-Apr_Longline	-5.299E+00	2.981E+00
P4_Jan-Apr_Longline	5.025E+00	1.421E-01
P3_May-Jul_Longline	5.050E+00	4.376E-02
P2_Aug-Dec_Longline	-2.096E+00	2.616E-01
P4_Aug-Dec_Longline	5.008E+00	3.378E-01
P2_Jan-Apr_Pot	-9.465E+00	1.371E+01
P3_Jan-Apr_Pot	5.031E+00	4.654E-02
P4_Jan-Apr_Pot	4.344E+00	2.889E-01
P3_May-Jul_Pot	4.920E+00	8.319E-02
P1_Jan-Apr_Trawl_1977	6.893E+01	3.172E+00
P1_Jan-Apr_Trawl_1985	7.600E+01	1.688E+00
P1_Jan-Apr_Trawl_1990	6.900E+01	1.081E+00
P1_Jan-Apr_Trawl_1995	7.404E+01	9.373E-01
P1_Jan-Apr_Trawl_2000	7.832E+01	1.209E+00
P1_Jan-Apr_Trawl_2005	7.793E+01	6.955E-01
P3_Jan-Apr_Trawl_1977	6.176E+00	1.781E-01
P3_Jan-Apr_Trawl_1985	6.610E+00	7.798E-02
P3_Jan-Apr_Trawl_1990	6.095E+00	5.747E-02
P3_Jan-Apr_Trawl_1995	6.301E+00	4.611E-02
P3_Jan-Apr_Trawl_2000	6.306E+00	6.138E-02
P3_Jan-Apr_Trawl_2005	6.026E+00	3.852E-02
P1_May-Jul_Trawl_1977	4.991E+01	1.684E+00
P1_May-Jul_Trawl_1985	5.104E+01	1.735E+00
P1_May-Jul_Trawl_1990	6.165E+01	1.525E+00
P1_May-Jul_Trawl_2000	5.277E+01	1.523E+00
P1_May-Jul_Trawl_2005	5.772E+01	1.395E+00
P1_Aug-Dec_Trawl_1977	6.270E+01	4.081E+00
P1_Aug-Dec_Trawl_1980	8.193E+01	5.789E+00
P1_Aug-Dec_Trawl_1985	8.607E+01	5.410E+00
P1_Aug-Dec_Trawl_1990	7.558E+01	3.473E+01
P1_Aug-Dec_Trawl_1995	1.025E+02	_
P1_Aug-Dec_Trawl_2000	5.631E+01	1.448E+00
P3_Aug-Dec_Trawl_1977	5.555E+00	3.318E-01
P3_Aug-Dec_Trawl_1980	6.666E+00	2.344E-01
P3_Aug-Dec_Trawl_1985	6.598E+00	2.357E-01
P3_Aug-Dec_Trawl_1990	6.327E+00	1.965E+00
P3_Aug-Dec_Trawl_1995	7.016E+00	8.932E-02
P3_Aug-Dec_Trawl_2000	5.215E+00	1.509E-01
P1_Jan-Apr_Longline_1977	5.925E+01	2.071E+00
P1_Jan-Apr_Longline_1980	7.233E+01	2.528E+00
P1_Jan-Apr_Longline_1985	7.502E+01	9.218E-01
P1_Jan-Apr_Longline_1990	6.622E+01	4.778E-01
P1_Jan-Apr_Longline_1995	6.583E+01	4.271E-01
P1_Jan-Apr_Longline_2000	6.368E+01	4.400E-01
P1_Jan-Apr_Longline_2005	6.746E+01	3.351E-01
P3_Jan-Apr_Longline_1977	5.164E+00	2.105E-01
P3_Jan-Apr_Longline_1980	5.910E+00	1.824E-01
P3_Jan-Apr_Longline_1985	5.853E+00	6.827E-02
P3_Jan-Apr_Longline_1990	5.236E+00	4.641E-02
P3_Jan-Apr_Longline_1995	5.313E+00	3.981E-02

Parameter	Estimate	St. Dev.
P3_Jan-Apr_Longline_2000	5.376E+00	4.145E-02
P3_Jan-Apr_Longline_2005	5.313E+00	2.853E-02
P6_Jan-Apr_Longline_1977	-1.276E+00	7.988E-01
P6_Jan-Apr_Longline_1980	4.739E-01	1.078E+00
P6_Jan-Apr_Longline_1985	-1.111E+00	4.272E-01
P6_Jan-Apr_Longline_1990	-4.550E-01	1.370E-01
P6_Jan-Apr_Longline_1995	-6.352E-01	1.391E-01
P6_Jan-Apr_Longline_2000	-1.138E+00	1.431E-01
P6_Jan-Apr_Longline_2005	-8.192E-01	1.349E-01
P1_May-Jul_Longline_1977	6.382E+01	2.224E+00
P1_May-Jul_Longline_1980	6.267E+01	1.360E+00
P1_May-Jul_Longline_1985	6.359E+01	1.122E+00
P1_May-Jul_Longline_1990	6.392E+01	4.762E-01
P1_May-Jul_Longline_2000	6.011E+01	5.339E-01
P1_May-Jul_Longline_2005	6.525E+01	4.613E-01
P1_Aug-Dec_Longline_1977	6.092E+01	2.220E+00
P1_Aug-Dec_Longline_1980	6.938E+01	1.661E+00
P1_Aug-Dec_Longline_1985	6.414E+01	7.663E-01
P1_Aug-Dec_Longline_1990	6.713E+01	7.245E-01
P1_Aug-Dec_Longline_1995	6.954E+01	7.069E-01
P1_Aug-Dec_Longline_2000	6.360E+01	4.308E-01
P1_Aug-Dec_Longline_2005	6.383E+01	3.401E-01
P3_Aug-Dec_Longline_1977	4.565E+00	3.203E-01
P3_Aug-Dec_Longline_1980	5.394E+00	1.402E-01
P3_Aug-Dec_Longline_1985	4.844E+00	8.989E-02
P3_Aug-Dec_Longline_1990	5.037E+00	7.663E-02
P3_Aug-Dec_Longline_1995	5.510E+00	5.375E-02
P3_Aug-Dec_Longline_2000	5.182E+00	4.160E-02
P3_Aug-Dec_Longline_2005	4.986E+00	3.338E-02
P6_Aug-Dec_Longline_1977	-2.489E+00	2.035E+00
P6_Aug-Dec_Longline_1980	6.936E-01	8.143E-01
P6_Aug-Dec_Longline_1985	2.717E-01	2.430E-01
P6_Aug-Dec_Longline_1990	2.709E+00	1.146E+00
P6_Aug-Dec_Longline_1995	9.561E+00	1.160E+01
P6_Aug-Dec_Longline_2000	-2.968E-01	1.840E-01
P6_Aug-Dec_Longline_2005	9.407E+00	1.493E+01
P1_Jan-Apr_Pot_1977	6.904E+01	9.192E-01
P1_Jan-Apr_Pot_1995	6.869E+01	5.385E-01
P1_Jan-Apr_Pot_2000	6.833E+01	5.070E-01
P1_Jan-Apr_Pot_2005	6.957E+01	4.911E-01
P6_Jan-Apr_Pot_1977	2.263E-01	5.545E-01
P6_Jan-Apr_Pot_1995	-1.942E-01	2.516E-01
P6_Jan-Apr_Pot_2000	-5.304E-01	2.321E-01
P6_Jan-Apr_Pot_2005	1.919E-01	2.228E-01
P1_May-Jul_Pot_1977	6.727E+01	8.694E-01
P1_May-Jul_Pot_1995	6.591E+01	7.300E-01
P1_Aug-Dec_Pot_1977	6.854E+01	1.196E+00
P1_Aug-Dec_Pot_2000	6.268E+01	6.638E-01
P3_Aug-Dec_Pot_1977	5.195E+00	1.204E-01
P3_Aug-Dec_Pot_2000	4.545E+00	9.519E-02

Table 2.17d—Survey selectivity parameters as estimated by Model 11.5.

Parameter	Estimate	St. dev.
P1	1.269E+00	5.383E-02
P2	-2.688E+00	3.587E-01
P3	-2.361E+00	4.275E-01
P4	2.534E+00	3.961E-01
P5	-9.992E+00	_
P6	-1.018E+00	3.202E-01
P3_dev_1982	-4.439E-02	3.177E-02
P3_dev_1983	-2.687E-02	1.731E-02
P3_dev_1984	-7.416E-02	2.736E-02
P3_dev_1985	9.584E-03	2.064E-02
P3_dev_1986	-3.784E-02	2.268E-02
P3_dev_1987	2.824E-02	3.814E-02
P3_dev_1988	-6.980E-02	3.188E-02
P3_dev_1989	-1.114E-01	1.835E-02
P3_dev_1990	-2.190E-02	2.053E-02
P3_dev_1991	-3.358E-02	2.210E-02
P3_dev_1992	8.987E-02	3.975E-02
P3_dev_1993	5.649E-02	2.896E-02
P3_dev_1994	-3.075E-02	2.165E-02
P3_dev_1995	-8.305E-02	1.967E-02
P3_dev_1996	-1.054E-01	1.749E-02
P3_dev_1997	-5.491E-02	1.477E-02
P3_dev_1998	-6.765E-02	1.865E-02
P3_dev_1999	-7.080E-02	1.702E-02
P3_dev_2000	-2.729E-02	1.550E-02
P3_dev_2001	1.691E-01	3.637E-02
P3_dev_2002	-1.008E-02	2.345E-02
P3_dev_2003	9.227E-03	1.937E-02
P3_dev_2004	-9.878E-03	1.956E-02
P3_dev_2005	5.517E-02	2.658E-02
P3_dev_2006	1.703E-01	3.660E-02
P3_dev_2007	2.084E-01	3.598E-02
P3_dev_2008	1.210E-01	3.640E-02
P3_dev_2009	6.244E-03	1.517E-02
P3_dev_2010	-4.370E-02	2.391E-02
P3_dev_2011	3.330E-02	1.909E-02
P3_dev_2012	4.042E-02	2.007E-02
P3_dev_2013	-4.908E-02	1.702E-02

Table 2.17e—Annual log-scale catchability offsets as estimated by Model 14.2.

Year	Estimate	St. dev.
1982	-1.222E-01	6.538E-02
1983	7.968E-03	7.221E-02
1984	-3.565E-02	6.209E-02
1985	8.374E-03	7.515E-02
1986	4.999E-02	6.837E-02
1987	-4.158E-03	5.826E-02
1988	1.820E-02	5.947E-02
1989	-1.260E-01	6.038E-02
1990	-6.027E-02	6.962E-02
1991	-5.032E-02	7.059E-02
1992	-5.719E-02	7.249E-02
1993	2.367E-02	7.382E-02
1994	2.212E-01	7.244E-02
1995	1.306E-01	6.740E-02
1996	7.532E-02	7.578E-02
1997	-1.809E-03	7.612E-02
1998	-8.040E-03	6.555E-02
1999	-2.680E-02	6.579E-02
2000	-7.563E-02	6.585E-02
2001	1.094E-01	6.674E-02
2002	-3.038E-02	6.747E-02
2003	-2.080E-02	7.267E-02
2004	-4.177E-02	6.415E-02
2005	2.458E-02	7.530E-02
2006	-4.807E-02	5.797E-02
2007	1.432E-02	8.391E-02
2008	-7.230E-02	6.919E-02
2009	-1.049E-01	6.604E-02
2010	4.246E-02	7.390E-02
2011	-5.042E-04	6.746E-02
2012	4.096E-02	6.883E-02
2013	-1.536E-02	7.886E-02
2014	5.427E-02	7.611E-02
2015	8.084E-02	7.688E-02

Table 2.17f—Fishery selectivity parameters as estimated by Model 14.2.

Parameter	Estimate	St. dev.	Parameter	Estimate	St. dev.
Age 1 base	2.940E+00	3.500E-01	Age 4 dev 1977	-2.474E-02	1.506E-01
Age 2 base	3.162E+00	3.085E-01	Age 4 dev 1978	-6.914E-03	1.243E-01
Age 3 base	2.962E+00	1.855E-01	Age 4 dev 1979	-1.577E-01	7.022E-02
Age 4 base	1.882E+00	2.169E-01	Age 4 dev 1980	-1.184E-01	7.033E-02
Age 5 base	9.680E-01	1.030E-01	Age 4 dev 1981	-2.223E-01	7.264E-02
Age 6 base	1.863E-01	1.339E-01	Age 4 dev 1982	-2.393E-02	1.169E-01
Age 7 base	-1.560E-01	1.808E-01	Age 4 dev 1983	-7.497E-02	8.583E-02
Age 8 base	-1.962E-01	2.361E-01	Age 4 dev 1984	-1.828E-01	4.184E-02
Age 9 base	-2.312E-01	2.667E-01	Age 4 dev 1985	-4.382E-02	3.792E-02
Age 10 base	-8.517E-02	2.780E-01	Age 4 dev 1986	-9.863E-02	4.344E-02
Age 11 base	2.793E-01	2.984E-01	Age 4 dev 1987	-1.361E-02	3.648E-02
Age 12 base	2.473E-01	3.218E-01	Age 4 dev 1988	-2.258E-01	3.850E-02
Age 13 base	1.966E-02	3.337E-01	Age 4 dev 1989	-1.800E-01	5.476E-02
Age 14 base	-5.361E-02	3.381E-01	Age 4 dev 1990	-1.114E-01	4.700E-02
Age 15 base	-9.905E-02	3.340E-01	Age 4 dev 1991	-5.561E-02	3.261E-02
Age 16 base	-4.528E-02	3.392E-01	Age 4 dev 1992	-1.402E-02	3.197E-02
Age 17 base	-2.303E-02	3.425E-01	Age 4 dev 1993	-9.575E-02	3.185E-02
Age 18 base	-1.039E-02	3.455E-01	Age 4 dev 1994	-8.454E-02	3.379E-02
Age 19 base	-4.479E-03	3.477E-01	Age 4 dev 1995	-6.324E-02	2.931E-02
Age 20 base	-5.797E-03	3.485E-01	Age 4 dev 1996	9.038E-03	4.320E-02
			Age 4 dev 1997	-6.105E-02	3.338E-02
			Age 4 dev 1998	-2.627E-02	3.533E-02
			Age 4 dev 1999	-3.880E-02	2.914E-02
			Age 4 dev 2000	1.133E-01	6.639E-02
			Age 4 dev 2001	2.683E-02	4.673E-02
			Age 4 dev 2002	-3.542E-02	2.972E-02
			Age 4 dev 2003	6.587E-03	4.109E-02
			Age 4 dev 2004	3.610E-02	5.676E-02
			Age 4 dev 2005	-2.732E-03	4.265E-02
			Age 4 dev 2006	7.433E-02	5.899E-02
			Age 4 dev 2007	9.582E-02	6.643E-02
			Age 4 dev 2008	5.624E-02	4.654E-02
			Age 4 dev 2009	1.218E-01	5.049E-02
			Age 4 dev 2010	2.142E-01	8.125E-02
			Age 4 dev 2011	9.686E-02	4.373E-02
			Age 4 dev 2012	1.443E-01	8.266E-02
			Age 4 dev 2013	-1.181E-02	3.268E-02
			Age 4 dev 2014	1.057E-01	4.534E-02
			Age 4 dev 2015	1.351E-01	7.460E-02

Table 2.17g—Survey selectivity parameters as estimated by Model 14.2.

Parameter	Estimate	St. dev.	Parameter	Estimate	St. dev.
Age 1 base	5.020E+00	3.190E-01	Age 2 dev 1982	3.425E-02	3.649E-02
Age 2 base	8.696E-01	1.590E-01	Age 2 dev 1983	-1.263E-02	2.077E-02
Age 3 base	1.596E-01	4.743E-02	Age 2 dev 1984	8.860E-02	3.686E-02
Age 4 base	-1.217E-01	5.697E-02	Age 2 dev 1985	-2.584E-02	2.068E-02
Age 5 base	-7.063E-02	7.869E-02	Age 2 dev 1986	2.758E-02	2.630E-02
Age 6 base	-1.237E-01	1.196E-01	Age 2 dev 1987	-1.310E-02	2.985E-02
Age 7 base	-5.393E-02	1.660E-01	Age 2 dev 1988	4.165E-02	4.617E-02
Age 8 base	-2.084E-01	2.141E-01	Age 2 dev 1989	1.127E-01	3.058E-02
Age 9 base	-2.056E-01	2.467E-01	Age 2 dev 1990	-9.403E-03	2.387E-02
Age 10 base	-9.345E-02	2.663E-01	Age 2 dev 1991	2.425E-02	2.542E-02
Age 11 base	-5.514E-02	2.858E-01	Age 2 dev 1992	-7.055E-02	2.463E-02
Age 12 base	-3.902E-02	3.007E-01	Age 2 dev 1993	-4.619E-02	2.077E-02
Age 13 base	-5.838E-02	3.073E-01	Age 2 dev 1994	4.454E-02	2.428E-02
Age 14 base	-3.276E-02	3.121E-01	Age 2 dev 1995	7.253E-02	2.876E-02
Age 15 base	-1.707E-02	3.154E-01	Age 2 dev 1996	9.068E-02	2.788E-02
Age 16 base	-1.824E-02	3.161E-01	Age 2 dev 1997	2.266E-02	2.005E-02
Age 17 base	-1.906E-02	3.164E-01	Age 2 dev 1998	7.588E-02	2.535E-02
Age 18 base	-1.592E-02	3.169E-01	Age 2 dev 1999	6.609E-02	2.407E-02
Age 19 base	-1.185E-02	3.174E-01	Age 2 dev 2000	1.852E-02	1.937E-02
Age 20 base	-8.258E-03	3.178E-01	Age 2 dev 2001	-8.468E-02	1.881E-02
			Age 2 dev 2002	2.417E-02	2.331E-02
			Age 2 dev 2003	-4.323E-02	1.992E-02
			Age 2 dev 2004	1.739E-03	2.090E-02
			Age 2 dev 2005	-5.500E-02	2.051E-02
			Age 2 dev 2006	-7.744E-02	1.954E-02
			Age 2 dev 2007	-1.414E-01	1.863E-02
			Age 2 dev 2008	-1.468E-02	1.993E-02
			Age 2 dev 2009	-4.550E-02	1.790E-02
			Age 2 dev 2010	1.905E-02	2.837E-02
			Age 2 dev 2011	-5.884E-02	1.874E-02
			Age 2 dev 2012	-4.665E-02	1.865E-02
			Age 2 dev 2013	3.788E-02	2.148E-02
			Age 2 dev 2014	-3.153E-02	2.059E-02

Table 2.18a—Annual fishing mortality rates as estimated by Models 11.5 and 14.2. "F averaged over 6-18" represents an average rate across the specified age range; "Apical F" represents the fishing mortality rate at the length of peak selectivity. Color scale extends from red (low) to green (high) in each **column**.

	Model 11.5				Model 14.2			
	F averaged over 6-18		Apical F		F averaged over 6-18		Apical F	
Year	Estimate	St. dev.	Estimate	St. dev.	Estimate	St. dev.	Estimate	St. dev.
1977	7.16E-02	1.29E-02	7.97E-02	1.40E-02	9.13E-02	3.31E-02	1.15E-01	3.65E-02
1978	8.18E-02	1.33E-02	9.05E-02	1.45E-02	1.10E-01	3.98E-02	1.37E-01	4.37E-02
1979	5.71E-02	8.47E-03	6.34E-02	9.40E-03	8.00E-02	2.76E-02	9.55E-02	3.00E-02
1980	4.95E-02	6.25E-03	5.44E-02	7.67E-03	9.87E-02	3.13E-02	1.15E-01	3.37E-02
1981	4.71E-02	5.07E-03	5.07E-02	6.60E-03	7.62E-02	2.12E-02	9.19E-02	2.36E-02
1982	3.65E-02	2.86E-03	3.99E-02	4.08E-03	6.27E-02	1.18E-02	7.20E-02	1.30E-02
1983	5.06E-02	3.04E-03	5.58E-02	4.52E-03	7.99E-02	1.18E-02	8.71E-02	1.28E-02
1984	6.90E-02	3.65E-03	7.45E-02	4.77E-03	1.10E-01	1.46E-02	1.25E-01	1.76E-02
1985	8.37E-02	3.98E-03	9.54E-02	5.51E-03	1.24E-01	1.54E-02	1.48E-01	1.94E-02
1986	8.29E-02	3.71E-03	9.25E-02	5.01E-03	1.23E-01	1.54E-02	1.60E-01	2.07E-02
1987	9.52E-02	3.97E-03	1.07E-01	5.04E-03	1.27E-01	1.65E-02	1.77E-01	2.34E-02
1988	1.26E-01	4.56E-03	1.44E-01	7.52E-03	1.79E-01	1.90E-02	2.14E-01	2.25E-02
1989	1.23E-01	4.27E-03	1.33E-01	5.57E-03	1.54E-01	1.67E-02	1.90E-01	2.44E-02
1990	1.35E-01	4.41E-03	1.43E-01	5.90E-03	1.84E-01	1.66E-02	2.13E-01	2.18E-02
1991	2.08E-01	7.09E-03	2.22E-01	9.06E-03	3.10E-01	3.03E-02	3.79E-01	4.52E-02
1992	2.00E-01	7.39E-03	2.23E-01	8.91E-03	3.37E-01	4.08E-02	4.41E-01	5.37E-02
1993	1.58E-01	6.44E-03	1.86E-01	8.31E-03	2.25E-01	3.18E-02	3.12E-01	3.89E-02
1994	1.90E-01	9.06E-03	2.20E-01	1.60E-02	2.94E-01	3.49E-02	3.56E-01	4.07E-02
1995	2.57E-01	8.61E-03	3.24E-01	1.20E-02	3.99E-01	3.98E-02	4.42E-01	4.84E-02
1996	2.41E-01	8.27E-03	2.94E-01	1.07E-02	4.00E-01	3.93E-02	4.44E-01	4.88E-02
1997	2.81E-01	9.81E-03	3.36E-01	1.22E-02	4.38E-01	4.90E-02	5.16E-01	6.58E-02
1998	2.11E-01	7.53E-03	2.64E-01	1.01E-02	3.65E-01	3.94E-02	4.09E-01	4.48E-02
1999	2.08E-01	7.62E-03	2.52E-01	9.48E-03	3.51E-01	4.10E-02	4.14E-01	5.23E-02
2000	1.85E-01	6.58E-03	2.38E-01	8.29E-03	3.36E-01	4.11E-02	4.06E-01	4.98E-02
2001	1.60E-01	4.98E-03	2.05E-01	6.04E-03	2.71E-01	3.25E-02	3.24E-01	4.08E-02
2002	1.98E-01	5.54E-03	2.46E-01	6.88E-03	3.29E-01	3.33E-02	3.64E-01	3.80E-02
2003	2.07E-01	5.54E-03	2.63E-01	6.95E-03	3.38E-01	3.40E-02	3.88E-01	4.50E-02
2004	2.25E-01	5.73E-03	2.87E-01	7.33E-03	3.20E-01	3.25E-02	3.77E-01	4.43E-02
2005	2.68E-01	7.19E-03	3.17E-01	8.72E-03	3.50E-01	3.14E-02	3.95E-01	3.90E-02
2006	2.98E-01	8.75E-03	3.54E-01	1.06E-02	3.89E-01	3.57E-02	4.54E-01	5.04E-02
2007	2.89E-01	9.24E-03	3.43E-01	1.11E-02	3.63E-01	3.67E-02	4.42E-01	5.11E-02
2008	3.25E-01	1.11E-02	3.85E-01	1.33E-02	4.30E-01	4.63E-02	5.23E-01	6.02E-02
2009	3.59E-01	1.37E-02	4.28E-01	1.64E-02	5.34E-01	6.30E-02	6.39E-01	7.65E-02
2010	2.94E-01	1.15E-02	3.51E-01	1.41E-02	4.57E-01	5.62E-02	5.44E-01	6.66E-02
2011	3.46E-01	1.42E-02	4.10E-01	1.72E-02	5.39E-01	6.61E-02	6.13E-01	7.92E-02
2012	3.08E-01	1.37E-02	3.72E-01	1.72E-02	5.20E-01	6.05E-02	5.54E-01	6.63E-02
2013	2.74E-01	1.37E-02	3.19E-01	1.62E-02	4.21E-01	5.43E-02	4.66E-01	6.68E-02
2014	2.51E-01	1.44E-02	3.02E-01	1.76E-02	5.11E-01	6.87E-02	5.45E-01	7.35E-02
2015	2.13E-01	1.39E-02	2.47E-01	1.62E-02	4.00E-01	6.48E-02	4.78E-01	8.09E-02

Table 2.18b— Model 11.5 estimates of seasonal full-selection fishing mortality rates, on an annual time scale. Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov-Dec.

	Trawl fishery					Longline fishery					Pot fishery				
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5
1977	0.085	0.088	0.055	0.048	0.042	0.016	0.017	0.006	0.024	0.031	0	0	0	0	0
1978	0.097	0.100	0.065	0.055	0.049	0.017	0.017	0.006	0.025	0.034	0	0	0	0	0
1979	0.070	0.072	0.042	0.039	0.033	0.012	0.013	0.005	0.018	0.024	0	0	0	0	0
1980	0.062	0.061	0.031	0.040	0.034	0.010	0.010	0.004	0.013	0.017	0	0	0	0	0
1981	0.033	0.033	0.032	0.064	0.060	0.004	0.004	0.002	0.009	0.010	0	0	0	0	0
1982	0.035	0.035	0.036	0.044	0.036	0.001	0.001	0.001	0.004	0.005	0	0	0	0	0
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
1984	0.062	0.066	0.057	0.056	0.049	0.007	0.008	0.006	0.027	0.038	0	0	0	0	0
1985	0.078	0.083	0.066	0.064	0.051	0.024	0.026	0.010	0.034	0.047	0	0	0	0	0
1986	0.088	0.093	0.067	0.065	0.053	0.017	0.019	0.005	0.027	0.038	0	0	0	0	0
1987	0.097	0.103	0.053	0.053	0.052	0.043	0.046	0.013	0.043	0.061	0	0	0	0	0
1988	0.196	0.211	0.102	0.113	0.120	0.001	0.001	0.002	0.003	0.004	0	0	0	0	0
1989	0.209	0.226	0.100	0.059	0.054	0.008	0.009	0.012	0.015	0.013	0.000	0.000	0.000	0.000	0.000
1990	0.177	0.194	0.093	0.033	0.028	0.032	0.035	0.048	0.052	0.047	0.000	0.000	0.002	0.002	0.001
1991	0.182	0.382	0.068	0.056	0.044	0.062	0.106	0.088	0.100	0.066	0.000	0.004	0.002	0.011	0.003
1992	0.150	0.225	0.056	0.044	0.014	0.134	0.240	0.143	0.093	0.000	0.000	0.009	0.030	0.011	0.000
1993	0.191	0.260	0.026	0.036	0.011	0.227	0.231	0.025	0.016	0.004	0.000	0.018	0.013	0.000	0.000
1994	0.088	0.297	0.019	0.100	0.019	0.192	0.265	0.030	0.105	0.000	0.000	0.041	0.010	0.016	0.000
1995	0.216	0.434	0.005	0.199	0.002	0.246	0.315	0.021	0.110	0.065	0.000	0.078	0.040	0.015	0.005
1996	0.146	0.380	0.031	0.109	0.022	0.241	0.268	0.021	0.122	0.024	0.000	0.129	0.063	0.023	0.005
1997	0.182	0.412	0.025	0.101	0.037	0.271	0.289	0.043	0.117	0.195	0.000	0.100	0.041	0.021	0.005
1998	0.123	0.242	0.027	0.143	0.022	0.287	0.207	0.022	0.098	0.116	0.018	0.066	0.033	0.012	0.004
1999	0.149	0.226	0.016	0.067	0.004	0.331	0.247	0.020	0.128	0.044	0.022	0.065	0.036	0.013	0.001
2000	0.174	0.229	0.017	0.027	0.004	0.310	0.087	0.007	0.127	0.145	0.141	0.052	0.007	0.009	0.000
2001	0.067	0.125	0.015	0.039	0.005	0.164	0.159	0.019	0.172	0.160	0.023	0.123	0.006	0.015	0.005
2002	0.111	0.190	0.035	0.037	0.002	0.333	0.149	0.009	0.200	0.120	0.019	0.095	0.003	0.016	0.006
2003	0.130	0.151	0.029	0.034	0.002	0.345	0.178	0.014	0.204	0.152	0.128	0.020	0.003	0.027	0.011
2004	0.190	0.165	0.047	0.043	0.001	0.370	0.180	0.015	0.197	0.188	0.099	0.034	0.006	0.021	0.005
2005	0.275	0.169	0.043	0.016	0.001	0.524	0.083	0.022	0.226	0.198	0.102	0.039	0.000	0.030	0.004
2006	0.338	0.186	0.043	0.029	0.001	0.616	0.093	0.015	0.327	0.012	0.145	0.051	0.003	0.030	0.009
2007	0.223	0.256	0.080	0.025	0.001	0.688	0.034	0.011	0.269	0.010	0.174	0.021	0.005	0.044	0.000
2008	0.251	0.128	0.033	0.053	0.008	0.758	0.074	0.028	0.330	0.117	0.165	0.041	0.002	0.063	0.002
2009	0.225	0.197	0.033	0.076	0.004	0.907	0.082	0.025	0.349	0.143	0.202	0.041	0.003	0.013	0.015
2010	0.290	0.152	0.026	0.057	0.013	0.690	0.036	0.026	0.193	0.136	0.213	0.035	0.003	0.043	0.020
2011	0.299	0.310	0.038	0.063	0.011	0.368	0.352	0.106	0.200	0.152	0.225	0.036	0.005	0.061	0.000
2012	0.452	0.180	0.038	0.048	0.006	0.337	0.262	0.124	0.140	0.150	0.233	0.029	0.005	0.032	0.006
2013	0.334	0.169	0.024	0.080	0.009	0.323	0.196	0.072	0.124	0.152	0.181	0.033	0.000	0.028	0.024
2014	0.264	0.206	0.025	0.036	0.005	0.260	0.234	0.102	0.110	0.129	0.191	0.050	0.001	0.027	0.021
2015	0.162	0.197	0.024	0.032	0.004	0.194	0.197	0.083	0.091	0.109	0.158	0.065	0.001	0.022	0.018

Table 2.19—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: red = row minimum, green = row maximum.

Quantity	Model 11.5	Model 14.2
B100%	806,000	680,000
B40%	323,000	272,000
B35%	282,000	238,000
B(2016)	466,000	261,000
B(2017)	530,000	304,000
B(2016)/B100%	0.58	0.38
B(2017)/B100%	0.66	0.45
F40%	0.30	0.33
F35%	0.35	0.39
maxFABC(2016)	0.30	0.31
maxFABC(2017)	0.30	0.33
maxABC(2016)	332,000	184,000
maxABC(2017)	329,000	218,000
FOFL(2016)	0.35	0.37
FOFL(2017)	0.35	0.39
OFL(2016)	390,000	215,000
OFL(2017)	412,000	260,000
Pr(maxABC(2016)>truOFL(2016))	0.01	0.31
Pr(maxABC(2017)>truOFL(2017))	0.03	0.14
Pr(B(2016)<B20%)	0.00	0.00
Pr(B(2017)<B20%)	0.00	0.00
Pr(B(2018)<B20%)	0.00	0.00
Pr(B(2019)<B20%)	0.00	0.00
Pr(B(2020)<B20%)	0.00	0.00

<u>Legend:</u>
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
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
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 2.20 (page 1 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates. 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	0.000	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	0.001	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	0.002	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	0.006	0.000	0.004	0.001
15	0.002	0.007	0.001	0.002	0.001	0.000	0.011	0.008	0.000	0.005	0.001
16	0.003	0.008	0.002	0.002	0.001	0.000	0.015	0.011	0.000	0.007	0.002
17	0.004	0.009	0.002	0.003	0.001	0.000	0.019	0.014	0.001	0.009	0.002
18	0.005	0.011	0.003	0.003	0.001	0.000	0.024	0.018	0.001	0.012	0.003
19	0.006	0.013	0.004	0.004	0.002	0.000	0.030	0.023	0.001	0.015	0.004
20	0.007	0.015	0.004	0.005	0.002	0.000	0.037	0.029	0.002	0.019	0.005
21	0.008	0.017	0.006	0.006	0.002	0.000	0.046	0.036	0.002	0.025	0.007
22	0.010	0.020	0.007	0.007	0.003	0.001	0.057	0.045	0.003	0.031	0.009
23	0.012	0.023	0.008	0.008	0.004	0.001	0.070	0.056	0.004	0.039	0.012
24	0.015	0.026	0.010	0.010	0.005	0.001	0.085	0.068	0.005	0.048	0.015
25	0.018	0.030	0.013	0.012	0.006	0.001	0.102	0.083	0.007	0.059	0.020
26	0.022	0.034	0.016	0.014	0.007	0.001	0.122	0.100	0.009	0.072	0.025
27	0.026	0.039	0.019	0.017	0.008	0.002	0.145	0.120	0.012	0.087	0.031
28	0.031	0.045	0.023	0.020	0.010	0.002	0.172	0.142	0.016	0.105	0.039
29	0.036	0.051	0.027	0.024	0.012	0.003	0.201	0.168	0.020	0.125	0.048
30	0.043	0.058	0.032	0.028	0.014	0.004	0.233	0.197	0.025	0.149	0.059
31	0.050	0.065	0.039	0.033	0.017	0.005	0.269	0.229	0.032	0.175	0.073
32	0.059	0.074	0.046	0.039	0.020	0.006	0.308	0.264	0.040	0.205	0.088
33	0.068	0.083	0.054	0.045	0.024	0.008	0.350	0.303	0.049	0.238	0.106
34	0.079	0.093	0.063	0.053	0.028	0.009	0.395	0.344	0.060	0.274	0.127
35	0.091	0.104	0.074	0.061	0.032	0.012	0.442	0.389	0.074	0.313	0.150
36	0.105	0.116	0.086	0.070	0.038	0.014	0.491	0.436	0.089	0.356	0.177
37	0.120	0.129	0.099	0.081	0.044	0.017	0.542	0.485	0.107	0.401	0.207
38	0.137	0.143	0.115	0.092	0.051	0.021	0.594	0.535	0.128	0.449	0.240
39	0.155	0.158	0.132	0.105	0.059	0.026	0.646	0.587	0.152	0.498	0.276
40	0.176	0.175	0.150	0.119	0.068	0.031	0.697	0.639	0.179	0.549	0.316
41	0.198	0.192	0.171	0.135	0.079	0.037	0.747	0.691	0.209	0.601	0.358
42	0.222	0.211	0.193	0.152	0.090	0.044	0.795	0.741	0.242	0.653	0.403
43	0.247	0.231	0.218	0.171	0.102	0.052	0.839	0.789	0.279	0.704	0.451
44	0.275	0.252	0.244	0.191	0.116	0.062	0.880	0.834	0.318	0.754	0.501
45	0.304	0.274	0.273	0.213	0.132	0.073	0.915	0.875	0.361	0.801	0.552
46	0.335	0.298	0.304	0.236	0.148	0.085	0.945	0.911	0.407	0.845	0.604
47	0.368	0.322	0.336	0.261	0.167	0.099	0.969	0.942	0.455	0.885	0.656
48	0.402	0.348	0.370	0.288	0.187	0.115	0.987	0.967	0.504	0.920	0.707
49	0.438	0.375	0.406	0.316	0.208	0.132	0.997	0.985	0.556	0.949	0.756
50	0.475	0.402	0.443	0.346	0.231	0.152	1.000	0.996	0.607	0.972	0.803
51	0.513	0.431	0.482	0.377	0.256	0.173	1.000	1.000	0.659	0.989	0.847
52	0.551	0.460	0.521	0.410	0.282	0.197	1.000	1.000	0.710	0.998	0.887
53	0.590	0.490	0.562	0.444	0.310	0.223	1.000	1.000	0.760	1.000	0.921
54	0.629	0.521	0.602	0.479	0.340	0.251	1.000	1.000	0.807	1.000	0.950
55	0.668	0.552	0.643	0.514	0.370	0.281	1.000	1.000	0.850	1.000	0.973
56	0.707	0.583	0.683	0.550	0.403	0.313	1.000	1.000	0.889	1.000	0.989
57	0.744	0.615	0.723	0.587	0.436	0.347	1.000	1.000	0.924	1.000	0.998
58	0.780	0.646	0.761	0.624	0.470	0.383	1.000	1.000	0.952	1.000	1.000
59	0.815	0.678	0.798	0.660	0.506	0.421	1.000	1.000	0.975	1.000	1.000
60	0.847	0.708	0.833	0.696	0.542	0.460	1.000	1.000	0.990	1.000	1.000

Table 2.20 (page 2 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates. 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	0.878	0.739	0.866	0.732	0.578	0.500	1.000	1.000	0.998	1.000	1.000
62	0.905	0.768	0.895	0.766	0.615	0.541	1.000	1.000	1.000	1.000	1.000
63	0.930	0.796	0.922	0.800	0.651	0.583	1.000	1.000	1.000	1.000	1.000
64	0.951	0.824	0.945	0.831	0.688	0.626	1.000	1.000	1.000	1.000	1.000
65	0.968	0.850	0.965	0.861	0.723	0.668	1.000	1.000	1.000	1.000	1.000
66	0.982	0.874	0.980	0.888	0.758	0.709	1.000	1.000	1.000	1.000	1.000
67	0.992	0.897	0.991	0.913	0.791	0.749	1.000	1.000	1.000	1.000	1.000
68	0.998	0.917	0.998	0.935	0.823	0.788	1.000	1.000	1.000	1.000	1.000
69	1.000	0.936	1.000	0.954	0.853	0.825	1.000	1.000	1.000	1.000	1.000
70	1.000	0.953	1.000	0.970	0.881	0.859	1.000	1.000	1.000	1.000	1.000
71	1.000	0.967	1.000	0.983	0.907	0.890	1.000	1.000	1.000	1.000	1.000
72	1.000	0.979	1.000	0.992	0.930	0.918	1.000	1.000	1.000	1.000	1.000
73	1.000	0.988	1.000	0.998	0.950	0.943	1.000	1.000	1.000	1.000	1.000
74	1.000	0.995	1.000	1.000	0.966	0.963	1.000	1.000	1.000	1.000	1.000
75	1.000	0.999	1.000	1.000	0.980	0.979	1.000	1.000	1.000	1.000	1.000
76	1.000	1.000	1.000	1.000	0.990	0.991	1.000	1.000	1.000	1.000	1.000
77	1.000	1.000	1.000	1.000	0.997	0.998	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 2.20 (page 3 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates. 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	0.001	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	0.001	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	0.001	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	0.001	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	0.001	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	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.005	0.002	0.002	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	0.003	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	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.001	0.008	0.003	0.004	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	0.005	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	0.006	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	0.007	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	0.009	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	0.010	0.005	0.005	0.001	0.002	0.001	0.000	0.000	0.001	0.000
26	0.005	0.019	0.007	0.012	0.005	0.007	0.002	0.003	0.001	0.000	0.000	0.001	0.000
27	0.007	0.021	0.009	0.015	0.006	0.009	0.003	0.004	0.001	0.000	0.001	0.002	0.000
28	0.009	0.025	0.010	0.017	0.007	0.013	0.004	0.005	0.002	0.000	0.001	0.003	0.000
29	0.012	0.028	0.012	0.021	0.008	0.017	0.005	0.006	0.002	0.001	0.001	0.004	0.001
30	0.016	0.032	0.014	0.024	0.009	0.023	0.007	0.008	0.003	0.001	0.002	0.005	0.001
31	0.020	0.037	0.016	0.029	0.010	0.031	0.010	0.010	0.004	0.001	0.003	0.007	0.001
32	0.026	0.042	0.019	0.034	0.012	0.040	0.014	0.012	0.005	0.002	0.004	0.010	0.002
33	0.033	0.047	0.022	0.039	0.013	0.052	0.019	0.015	0.006	0.003	0.005	0.013	0.003
34	0.041	0.054	0.025	0.045	0.015	0.067	0.026	0.019	0.008	0.004	0.007	0.017	0.004
35	0.051	0.061	0.029	0.053	0.017	0.085	0.035	0.023	0.010	0.006	0.009	0.022	0.006
36	0.063	0.068	0.033	0.061	0.019	0.106	0.045	0.028	0.013	0.008	0.012	0.029	0.008
37	0.078	0.076	0.038	0.070	0.021	0.132	0.059	0.034	0.016	0.011	0.017	0.037	0.010
38	0.094	0.086	0.043	0.080	0.024	0.162	0.076	0.041	0.020	0.014	0.022	0.047	0.014
39	0.114	0.096	0.049	0.091	0.027	0.196	0.096	0.049	0.024	0.019	0.029	0.060	0.019
40	0.136	0.107	0.055	0.104	0.030	0.236	0.120	0.059	0.030	0.026	0.037	0.075	0.024
41	0.162	0.118	0.063	0.118	0.034	0.280	0.149	0.070	0.036	0.034	0.048	0.093	0.032
42	0.190	0.131	0.071	0.133	0.038	0.329	0.182	0.083	0.044	0.044	0.061	0.114	0.041
43	0.223	0.145	0.080	0.150	0.042	0.382	0.221	0.097	0.053	0.057	0.077	0.138	0.053
44	0.258	0.160	0.090	0.168	0.046	0.439	0.264	0.114	0.063	0.072	0.096	0.167	0.066
45	0.297	0.176	0.100	0.188	0.052	0.499	0.313	0.132	0.075	0.091	0.118	0.199	0.083
46	0.340	0.193	0.112	0.209	0.057	0.561	0.366	0.153	0.089	0.114	0.144	0.236	0.103
47	0.385	0.211	0.125	0.232	0.063	0.625	0.424	0.176	0.105	0.140	0.174	0.276	0.127
48	0.433	0.231	0.139	0.257	0.070	0.687	0.485	0.201	0.123	0.171	0.209	0.321	0.155
49	0.484	0.251	0.154	0.283	0.077	0.748	0.548	0.229	0.143	0.207	0.248	0.369	0.187
50	0.536	0.273	0.170	0.310	0.084	0.806	0.613	0.259	0.166	0.247	0.291	0.421	0.223
51	0.589	0.296	0.187	0.340	0.093	0.858	0.677	0.291	0.191	0.292	0.338	0.476	0.263
52	0.642	0.320	0.206	0.370	0.102	0.904	0.740	0.326	0.218	0.341	0.390	0.532	0.308
53	0.695	0.344	0.225	0.402	0.111	0.942	0.800	0.363	0.249	0.395	0.444	0.590	0.357
54	0.746	0.370	0.246	0.435	0.121	0.971	0.854	0.402	0.281	0.452	0.502	0.648	0.410
55	0.795	0.397	0.268	0.469	0.132	0.991	0.902	0.443	0.316	0.512	0.561	0.706	0.466
56	0.840	0.425	0.292	0.504	0.144	0.999	0.941	0.485	0.354	0.574	0.621	0.761	0.524
57	0.882	0.453	0.316	0.539	0.156	1.000	0.971	0.529	0.394	0.636	0.681	0.814	0.583
58	0.918	0.482	0.342	0.576	0.169	1.000	0.991	0.573	0.435	0.698	0.739	0.862	0.644
59	0.948	0.512	0.368	0.612	0.183	1.000	1.000	0.618	0.479	0.758	0.795	0.904	0.703
60	0.972	0.542	0.396	0.648	0.198	1.000	1.000	0.662	0.523	0.814	0.846	0.939	0.760

Table 2.20 (page 4 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates. 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	0.989	0.572	0.425	0.684	0.214	1.000	0.999	0.706	0.569	0.865	0.891	0.967	0.814
62	0.998	0.603	0.454	0.719	0.230	1.000	0.989	0.749	0.615	0.910	0.930	0.987	0.864
63	1.000	0.634	0.484	0.754	0.247	1.000	0.970	0.790	0.661	0.946	0.961	0.998	0.907
64	1.000	0.664	0.515	0.787	0.265	1.000	0.941	0.829	0.706	0.974	0.984	1.000	0.943
65	1.000	0.694	0.546	0.819	0.284	1.000	0.904	0.865	0.750	0.992	0.997	1.000	0.971
66	1.000	0.724	0.577	0.849	0.303	1.000	0.861	0.897	0.792	1.000	1.000	0.994	0.990
67	1.000	0.753	0.609	0.877	0.323	1.000	0.813	0.926	0.831	1.000	1.000	0.979	0.999
68	1.000	0.781	0.641	0.902	0.344	1.000	0.761	0.951	0.868	0.999	0.996	0.955	1.000
69	1.000	0.808	0.672	0.926	0.366	1.000	0.707	0.970	0.901	0.991	0.985	0.923	1.000
70	1.000	0.834	0.703	0.946	0.388	1.000	0.653	0.985	0.930	0.975	0.965	0.883	0.992
71	1.000	0.859	0.734	0.963	0.411	1.000	0.599	0.995	0.955	0.952	0.938	0.838	0.976
72	1.000	0.882	0.763	0.977	0.435	1.000	0.548	1.000	0.974	0.923	0.904	0.789	0.952
73	1.000	0.903	0.792	0.988	0.459	1.000	0.500	1.000	0.988	0.889	0.866	0.737	0.921
74	1.000	0.923	0.820	0.996	0.483	1.000	0.456	0.999	0.997	0.851	0.824	0.685	0.883
75	1.000	0.941	0.846	0.999	0.508	1.000	0.416	0.995	1.000	0.810	0.780	0.633	0.841
76	1.000	0.956	0.871	1.000	0.533	1.000	0.381	0.985	1.000	0.768	0.734	0.582	0.795
77	1.000	0.970	0.894	1.000	0.559	1.000	0.350	0.971	0.997	0.725	0.689	0.534	0.748
78	1.000	0.981	0.915	1.000	0.584	1.000	0.324	0.953	0.985	0.684	0.645	0.490	0.700
79	1.000	0.989	0.934	1.000	0.610	1.000	0.302	0.932	0.963	0.644	0.604	0.450	0.652
80	1.000	0.995	0.951	1.000	0.636	1.000	0.283	0.908	0.933	0.606	0.565	0.414	0.606
81	1.000	0.999	0.966	1.000	0.661	1.000	0.268	0.883	0.896	0.572	0.530	0.382	0.563
82	1.000	1.000	0.978	1.000	0.686	1.000	0.256	0.856	0.852	0.541	0.498	0.355	0.523
83	1.000	1.000	0.987	1.000	0.711	1.000	0.247	0.830	0.804	0.514	0.470	0.332	0.487
84	1.000	1.000	0.994	1.000	0.736	1.000	0.239	0.804	0.754	0.490	0.446	0.312	0.455
85	1.000	1.000	0.998	1.000	0.760	1.000	0.234	0.778	0.702	0.469	0.426	0.297	0.427
86	1.000	1.000	1.000	1.000	0.784	1.000	0.229	0.755	0.649	0.452	0.409	0.284	0.403
87	1.000	1.000	1.000	1.000	0.807	1.000	0.226	0.733	0.599	0.438	0.395	0.274	0.383
88	1.000	1.000	1.000	1.000	0.829	1.000	0.224	0.714	0.550	0.427	0.383	0.266	0.366
89	1.000	1.000	1.000	1.000	0.850	1.000	0.222	0.696	0.505	0.417	0.374	0.260	0.352
90	1.000	1.000	1.000	1.000	0.870	1.000	0.221	0.681	0.464	0.410	0.367	0.255	0.341
91	1.000	1.000	1.000	1.000	0.889	1.000	0.220	0.668	0.427	0.404	0.362	0.252	0.332
92	1.000	1.000	1.000	1.000	0.906	1.000	0.219	0.657	0.394	0.400	0.357	0.249	0.326
93	1.000	1.000	1.000	1.000	0.923	1.000	0.219	0.648	0.366	0.397	0.354	0.247	0.320
94	1.000	1.000	1.000	1.000	0.938	1.000	0.219	0.641	0.342	0.394	0.352	0.246	0.316
95	1.000	1.000	1.000	1.000	0.951	1.000	0.219	0.635	0.322	0.392	0.350	0.245	0.313
96	1.000	1.000	1.000	1.000	0.963	1.000	0.218	0.630	0.305	0.391	0.349	0.244	0.311
97	1.000	1.000	1.000	1.000	0.973	1.000	0.218	0.627	0.292	0.390	0.348	0.244	0.310
98	1.000	1.000	1.000	1.000	0.982	1.000	0.218	0.624	0.281	0.390	0.348	0.243	0.308
99	1.000	1.000	1.000	1.000	0.989	1.000	0.218	0.622	0.273	0.389	0.347	0.243	0.308
100	1.000	1.000	1.000	1.000	0.995	1.000	0.218	0.620	0.266	0.389	0.347	0.243	0.307
101	1.000	1.000	1.000	1.000	0.998	1.000	0.218	0.619	0.261	0.389	0.347	0.243	0.307
102	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.618	0.257	0.388	0.347	0.243	0.306
103	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.618	0.254	0.388	0.346	0.243	0.306
104	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.617	0.252	0.388	0.346	0.243	0.306
105	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.617	0.251	0.388	0.346	0.243	0.306
106	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.617	0.250	0.388	0.346	0.243	0.306
107	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.617	0.249	0.388	0.346	0.243	0.306
108	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.249	0.388	0.346	0.243	0.306
109	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.248	0.388	0.346	0.243	0.306
110	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.248	0.388	0.346	0.243	0.306
111	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.248	0.388	0.346	0.243	0.306
112	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.248	0.388	0.346	0.243	0.306
113	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.248	0.388	0.346	0.243	0.306
114	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.248	0.388	0.346	0.243	0.306
115	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.248	0.388	0.346	0.243	0.306
116	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.248	0.388	0.346	0.243	0.306
117	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.248	0.388	0.346	0.243	0.306
118	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.248	0.388	0.346	0.243	0.306
119	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.248	0.388	0.346	0.243	0.306
120	1.000	1.000	1.000	1.000	1.000	1.000	0.218	0.616	0.248	0.388	0.346	0.243	0.306

Table 2.20 (page 5 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates. 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	0.001	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	0.002	0.001	0.001	0.004	0.001	0.000	0.001	0.000	0.000	0.002	0.003	0.001
32	0.002	0.002	0.002	0.001	0.006	0.001	0.000	0.002	0.000	0.000	0.003	0.004	0.001
33	0.002	0.004	0.002	0.002	0.009	0.001	0.000	0.002	0.000	0.001	0.005	0.005	0.002
34	0.003	0.005	0.004	0.003	0.013	0.002	0.001	0.003	0.001	0.001	0.006	0.007	0.002
35	0.005	0.007	0.005	0.005	0.018	0.003	0.001	0.005	0.001	0.001	0.008	0.010	0.003
36	0.007	0.010	0.008	0.007	0.024	0.004	0.002	0.006	0.002	0.002	0.011	0.014	0.005
37	0.010	0.015	0.011	0.010	0.033	0.006	0.003	0.009	0.003	0.003	0.014	0.019	0.007
38	0.014	0.020	0.015	0.013	0.044	0.009	0.004	0.011	0.005	0.004	0.018	0.025	0.010
39	0.019	0.028	0.021	0.019	0.058	0.012	0.007	0.015	0.007	0.006	0.023	0.033	0.015
40	0.026	0.037	0.028	0.026	0.075	0.017	0.011	0.020	0.010	0.008	0.029	0.044	0.021
41	0.036	0.049	0.038	0.034	0.096	0.023	0.016	0.026	0.015	0.012	0.037	0.057	0.028
42	0.047	0.065	0.050	0.046	0.122	0.031	0.024	0.033	0.021	0.017	0.046	0.073	0.039
43	0.062	0.084	0.066	0.061	0.153	0.042	0.035	0.042	0.030	0.023	0.058	0.092	0.052
44	0.081	0.107	0.086	0.079	0.190	0.055	0.051	0.054	0.041	0.031	0.071	0.116	0.068
45	0.103	0.135	0.109	0.101	0.232	0.072	0.072	0.067	0.056	0.042	0.087	0.143	0.089
46	0.131	0.168	0.138	0.128	0.279	0.093	0.099	0.083	0.075	0.055	0.106	0.175	0.114
47	0.163	0.207	0.171	0.160	0.333	0.118	0.133	0.103	0.099	0.072	0.128	0.213	0.144
48	0.201	0.252	0.211	0.197	0.391	0.149	0.176	0.125	0.128	0.093	0.153	0.255	0.180
49	0.245	0.302	0.256	0.240	0.454	0.184	0.228	0.152	0.164	0.118	0.181	0.302	0.222
50	0.294	0.357	0.306	0.289	0.520	0.225	0.289	0.182	0.207	0.149	0.213	0.354	0.271
51	0.349	0.418	0.362	0.343	0.588	0.272	0.359	0.216	0.256	0.184	0.249	0.410	0.325
52	0.409	0.482	0.423	0.402	0.656	0.325	0.437	0.254	0.313	0.226	0.288	0.469	0.384
53	0.472	0.549	0.488	0.466	0.723	0.382	0.521	0.296	0.376	0.273	0.331	0.532	0.449
54	0.539	0.618	0.555	0.532	0.787	0.445	0.608	0.342	0.445	0.326	0.376	0.596	0.517
55	0.608	0.686	0.623	0.600	0.846	0.510	0.695	0.391	0.518	0.384	0.425	0.660	0.587
56	0.676	0.752	0.691	0.669	0.898	0.578	0.777	0.443	0.593	0.447	0.476	0.723	0.658
57	0.742	0.814	0.757	0.736	0.940	0.647	0.852	0.499	0.669	0.513	0.529	0.783	0.727
58	0.805	0.869	0.819	0.799	0.972	0.714	0.915	0.555	0.743	0.582	0.583	0.838	0.793
59	0.862	0.917	0.874	0.856	0.992	0.779	0.962	0.613	0.812	0.651	0.638	0.888	0.852
60	0.911	0.955	0.921	0.906	1.000	0.838	0.991	0.671	0.874	0.719	0.692	0.930	0.904

Table 2.20 (page 6 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates. 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	0.950	0.982	0.958	0.947	1.000	0.891	1.000	0.727	0.925	0.783	0.744	0.963	0.947
62	0.979	0.997	0.984	0.977	1.000	0.935	1.000	0.781	0.964	0.843	0.794	0.986	0.977
63	0.996	1.000	0.998	0.995	1.000	0.968	1.000	0.831	0.990	0.895	0.841	0.998	0.995
64	1.000	1.000	1.000	1.000	1.000	0.990	1.000	0.877	1.000	0.938	0.883	1.000	1.000
65	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.917	1.000	0.971	0.920	1.000	1.000
66	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.949	1.000	0.992	0.951	1.000	1.000
67	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.975	1.000	1.000	0.974	1.000	1.000
68	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.991	1.000	1.000	0.990	1.000	1.000
69	1.000	1.000	1.000	1.000	1.000	1.000	0.996	0.999	1.000	1.000	0.999	1.000	1.000
70	1.000	1.000	1.000	1.000	1.000	1.000	0.979	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	0.951	1.000	1.000	1.000	1.000	0.999	1.000
72	1.000	1.000	1.000	1.000	1.000	1.000	0.913	1.000	0.997	1.000	1.000	0.992	1.000
73	1.000	1.000	1.000	1.000	1.000	1.000	0.865	1.000	0.989	1.000	1.000	0.977	1.000
74	1.000	1.000	1.000	1.000	1.000	1.000	0.811	1.000	0.975	1.000	1.000	0.956	1.000
75	1.000	1.000	1.000	1.000	1.000	1.000	0.751	1.000	0.956	0.999	1.000	0.928	1.000
76	1.000	1.000	1.000	1.000	1.000	1.000	0.688	1.000	0.934	0.998	1.000	0.896	1.000
77	1.000	1.000	1.000	1.000	1.000	1.000	0.623	0.996	0.908	0.996	1.000	0.860	1.000
78	1.000	1.000	1.000	1.000	1.000	1.000	0.559	0.988	0.880	0.993	1.000	0.822	1.000
79	1.000	1.000	1.000	1.000	1.000	1.000	0.497	0.976	0.850	0.989	1.000	0.782	1.000
80	1.000	1.000	1.000	1.000	1.000	1.000	0.437	0.961	0.820	0.985	1.000	0.742	1.000
81	1.000	1.000	1.000	1.000	1.000	1.000	0.383	0.943	0.790	0.981	1.000	0.702	1.000
82	1.000	1.000	1.000	1.000	1.000	1.000	0.332	0.922	0.761	0.977	1.000	0.665	1.000
83	1.000	1.000	1.000	1.000	1.000	1.000	0.288	0.900	0.733	0.972	1.000	0.629	1.000
84	1.000	1.000	1.000	1.000	1.000	1.000	0.249	0.877	0.708	0.968	1.000	0.597	1.000
85	1.000	1.000	1.000	1.000	1.000	1.000	0.215	0.853	0.685	0.964	1.000	0.568	1.000
86	1.000	1.000	1.000	1.000	1.000	1.000	0.186	0.830	0.664	0.960	1.000	0.542	1.000
87	1.000	1.000	1.000	1.000	1.000	1.000	0.162	0.808	0.646	0.957	1.000	0.520	1.000
88	1.000	1.000	1.000	1.000	1.000	1.000	0.143	0.788	0.630	0.953	1.000	0.501	1.000
89	1.000	1.000	1.000	1.000	1.000	1.000	0.127	0.769	0.617	0.951	1.000	0.485	1.000
90	1.000	1.000	1.000	1.000	1.000	1.000	0.115	0.751	0.606	0.948	1.000	0.472	1.000
91	1.000	1.000	1.000	1.000	1.000	1.000	0.105	0.736	0.597	0.946	1.000	0.461	1.000
92	1.000	1.000	1.000	1.000	1.000	1.000	0.097	0.723	0.590	0.944	1.000	0.453	1.000
93	1.000	1.000	1.000	1.000	1.000	1.000	0.091	0.712	0.585	0.943	1.000	0.446	1.000
94	1.000	1.000	1.000	1.000	1.000	1.000	0.087	0.702	0.580	0.942	1.000	0.441	1.000
95	1.000	1.000	1.000	1.000	1.000	1.000	0.084	0.694	0.577	0.941	1.000	0.437	1.000
96	1.000	1.000	1.000	1.000	1.000	1.000	0.082	0.688	0.574	0.940	1.000	0.434	1.000
97	1.000	1.000	1.000	1.000	1.000	1.000	0.080	0.683	0.572	0.939	1.000	0.432	1.000
98	1.000	1.000	1.000	1.000	1.000	1.000	0.079	0.679	0.571	0.939	1.000	0.430	1.000
99	1.000	1.000	1.000	1.000	1.000	1.000	0.078	0.676	0.570	0.938	1.000	0.429	1.000
100	1.000	1.000	1.000	1.000	1.000	1.000	0.078	0.673	0.569	0.938	1.000	0.428	1.000
101	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.671	0.569	0.938	1.000	0.428	1.000
102	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.670	0.568	0.938	1.000	0.427	1.000
103	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.669	0.568	0.938	1.000	0.427	1.000
104	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.668	0.568	0.938	1.000	0.427	1.000
105	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.668	0.568	0.938	1.000	0.427	1.000
106	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
107	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
108	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
109	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
110	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
111	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
112	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
113	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
114	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
115	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
116	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
117	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
118	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
119	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000
120	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.667	0.568	0.938	1.000	0.426	1.000

Table 2.20 (page 7 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates. 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	0.001	0.001	0.001	0.000	0.001	0.001	0.002	0.000
36	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.001
37	0.001	0.001	0.002	0.001	0.001	0.002	0.004	0.001
38	0.002	0.002	0.002	0.001	0.002	0.003	0.006	0.002
39	0.003	0.003	0.004	0.002	0.003	0.005	0.008	0.003
40	0.004	0.005	0.005	0.003	0.004	0.007	0.011	0.004
41	0.006	0.007	0.008	0.005	0.007	0.011	0.015	0.007
42	0.008	0.010	0.011	0.007	0.009	0.015	0.020	0.011
43	0.012	0.013	0.015	0.010	0.014	0.022	0.027	0.016
44	0.017	0.019	0.021	0.014	0.019	0.030	0.035	0.025
45	0.023	0.026	0.029	0.019	0.027	0.041	0.046	0.036
46	0.031	0.035	0.039	0.027	0.037	0.055	0.060	0.052
47	0.042	0.046	0.051	0.036	0.050	0.074	0.076	0.073
48	0.056	0.061	0.067	0.048	0.067	0.096	0.096	0.101
49	0.073	0.080	0.087	0.063	0.088	0.124	0.120	0.137
50	0.094	0.102	0.111	0.082	0.113	0.158	0.149	0.181
51	0.119	0.130	0.141	0.105	0.145	0.197	0.182	0.235
52	0.150	0.162	0.175	0.133	0.182	0.244	0.219	0.298
53	0.186	0.201	0.215	0.167	0.226	0.296	0.262	0.370
54	0.228	0.244	0.262	0.206	0.277	0.355	0.310	0.449
55	0.276	0.294	0.313	0.250	0.333	0.420	0.362	0.534
56	0.330	0.350	0.370	0.301	0.396	0.488	0.418	0.622
57	0.388	0.410	0.432	0.357	0.463	0.560	0.478	0.710
58	0.451	0.474	0.498	0.418	0.534	0.634	0.540	0.792
59	0.518	0.542	0.566	0.482	0.607	0.706	0.604	0.866
60	0.587	0.611	0.635	0.550	0.680	0.775	0.667	0.926

Table 2.20 (page 8 of 8)—Schedules of Pacific cod selectivity at length (cm) in the commercial fisheries as defined by parameter estimates. 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	0.656	0.680	0.704	0.619	0.751	0.839	0.730	0.970
62	0.724	0.747	0.770	0.688	0.817	0.895	0.789	0.995
63	0.788	0.810	0.831	0.755	0.876	0.940	0.844	1.000
64	0.847	0.866	0.885	0.817	0.925	0.974	0.892	1.000
65	0.899	0.915	0.930	0.873	0.963	0.994	0.933	1.000
66	0.942	0.954	0.965	0.920	0.988	1.000	0.965	1.000
67	0.973	0.982	0.988	0.958	0.999	1.000	0.987	1.000
68	0.993	0.997	0.999	0.984	1.000	1.000	0.998	1.000
69	1.000	1.000	1.000	0.998	1.000	1.000	1.000	1.000
70	1.000	0.999	0.996	1.000	1.000	1.000	1.000	1.000
71	0.995	0.988	0.978	0.999	1.000	1.000	1.000	1.000
72	0.978	0.963	0.945	0.988	1.000	1.000	1.000	1.000
73	0.952	0.927	0.899	0.967	1.000	1.000	1.000	1.000
74	0.918	0.883	0.845	0.936	1.000	1.000	1.000	1.000
75	0.879	0.832	0.786	0.898	1.000	1.000	1.000	1.000
76	0.836	0.779	0.724	0.856	1.000	1.000	1.000	1.000
77	0.793	0.726	0.664	0.812	1.000	1.000	1.000	1.000
78	0.751	0.675	0.608	0.769	1.000	1.000	1.000	1.000
79	0.713	0.630	0.558	0.728	1.000	1.000	1.000	1.000
80	0.679	0.590	0.514	0.690	1.000	1.000	1.000	1.000
81	0.650	0.556	0.478	0.658	1.000	1.000	1.000	1.000
82	0.626	0.528	0.449	0.631	1.000	1.000	1.000	1.000
83	0.607	0.507	0.426	0.609	1.000	1.000	1.000	1.000
84	0.592	0.490	0.409	0.591	1.000	1.000	1.000	1.000
85	0.581	0.478	0.396	0.578	1.000	1.000	1.000	1.000
86	0.573	0.469	0.388	0.568	1.000	1.000	1.000	1.000
87	0.567	0.463	0.381	0.561	1.000	1.000	1.000	1.000
88	0.563	0.459	0.377	0.557	1.000	1.000	1.000	1.000
89	0.561	0.456	0.375	0.553	1.000	1.000	1.000	1.000
90	0.559	0.454	0.373	0.551	1.000	1.000	1.000	1.000
91	0.558	0.453	0.372	0.550	1.000	1.000	1.000	1.000
92	0.557	0.452	0.371	0.549	1.000	1.000	1.000	1.000
93	0.557	0.452	0.371	0.548	1.000	1.000	1.000	1.000
94	0.557	0.452	0.371	0.548	1.000	1.000	1.000	1.000
95	0.556	0.452	0.371	0.548	1.000	1.000	1.000	1.000
96	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
97	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
98	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
99	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
100	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
101	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
102	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
103	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
104	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
105	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
106	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
107	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
108	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
109	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
110	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
111	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
112	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
113	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
114	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
115	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
116	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
117	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
118	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
119	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000
120	0.556	0.452	0.370	0.548	1.000	1.000	1.000	1.000

Table 2.21—Schedules of Pacific cod selectivity at age in the bottom trawl survey as defined by final parameter estimates.

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	0.322	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1983	0.000	0.381	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1984	0.000	0.228	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1985	0.000	0.503	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1986	0.000	0.344	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1987	0.000	0.562	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1988	0.000	0.241	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1989	0.000	0.131	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1990	0.000	0.398	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1991	0.000	0.358	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1992	0.000	0.727	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1993	0.000	0.644	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1994	0.000	0.368	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1995	0.000	0.202	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1996	0.000	0.145	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1997	0.000	0.288	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1998	0.000	0.248	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
1999	0.000	0.238	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2000	0.000	0.379	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2001	0.000	0.859	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2002	0.000	0.438	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2003	0.000	0.502	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2004	0.000	0.438	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2005	0.000	0.640	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2006	0.000	0.860	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2007	0.000	0.895	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2008	0.000	0.790	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2009	0.000	0.492	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2010	0.000	0.324	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2011	0.000	0.577	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2012	0.000	0.599	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2013	0.000	0.307	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2014	0.000	0.471	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265
2015	0.000	0.471	1.000	1.000	0.978	0.863	0.692	0.526	0.401	0.326	0.288	0.273	0.268	0.266	0.266	0.265	0.265	0.265	0.265	0.265	0.265

Table 2.22—Schedules of population length (cm) and weight (kg) by season and age as defined by final parameter estimates. 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	9.39	11.01	13.03	16.56	20.26	0.01	0.02	0.02	0.05	0.09
2	23.09	25.81	29.06	32.76	35.67	0.14	0.19	0.27	0.41	0.55
3	37.90	40.04	42.60	45.50	47.79	0.67	0.76	0.89	1.13	1.36
4	49.55	51.23	53.24	55.53	57.33	1.55	1.64	1.79	2.12	2.42
5	58.71	60.04	61.62	63.42	64.84	2.65	2.70	2.84	3.22	3.57
6	65.92	66.96	68.21	69.62	70.74	3.83	3.81	3.90	4.32	4.70
7	71.59	72.41	73.39	74.51	75.38	4.97	4.88	4.91	5.34	5.75
8	76.06	76.70	77.47	78.35	79.04	6.03	5.85	5.82	6.26	6.68
9	79.57	80.07	80.68	81.37	81.91	6.95	6.70	6.61	7.06	7.48
10	82.33	82.73	83.20	83.75	84.17	7.75	7.42	7.28	7.73	8.15
11	84.50	84.81	85.19	85.62	85.95	8.42	8.03	7.84	8.29	8.71
12	86.21	86.46	86.75	87.09	87.35	8.97	8.53	8.30	8.74	9.17
13	87.55	87.75	87.98	88.24	88.45	9.42	8.94	8.67	9.11	9.54
14	88.61	88.76	88.95	89.15	89.32	9.79	9.27	8.98	9.41	9.84
15	89.44	89.56	89.71	89.87	90.00	10.08	9.54	9.22	9.66	10.08
16	90.10	90.19	90.31	90.43	90.54	10.32	9.75	9.41	9.85	10.27
17	90.61	90.69	90.78	90.88	90.96	10.50	9.92	9.57	10.00	10.42
18	91.02	91.08	91.15	91.23	91.29	10.65	10.06	9.69	10.12	10.54
19	91.34	91.38	91.44	91.50	91.55	10.77	10.16	9.79	10.22	10.64
20	91.78	91.81	91.85	91.88	91.91	10.94	10.32	9.93	10.36	10.78

Table 2.23—Schedules of fleet-specific length (cm) by season and age as defined by final parameter estimates. 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	13.33	14.85	16.82	21.78	25.66	15.75	17.22	20.21	24.10	28.16	12.46	15.97	20.51	25.86	31.06	13.03
2	27.50	30.40	33.10	37.82	40.43	29.80	32.66	37.12	40.72	43.38	31.96	34.86	38.13	43.19	45.65	29.06
3	42.89	45.03	45.60	48.61	50.43	44.55	46.51	49.43	51.60	53.35	46.70	48.62	50.28	53.01	54.54	42.60
4	54.19	55.75	54.63	56.68	58.22	54.65	56.00	57.66	59.01	60.32	56.46	57.74	58.29	59.55	60.75	53.24
5	62.47	63.62	62.06	63.73	65.08	61.68	62.64	63.85	64.98	66.14	63.08	63.98	64.25	65.14	66.26	61.62
6	68.64	69.52	68.33	69.71	70.81	66.81	67.53	69.20	70.26	71.27	67.90	68.59	69.41	70.30	71.30	68.21
7	73.42	74.11	73.43	74.53	75.41	70.76	71.33	73.83	74.78	75.61	71.78	72.37	73.94	74.78	75.62	73.39
8	77.26	77.82	77.49	78.36	79.05	73.97	74.45	77.68	78.47	79.15	75.16	75.68	77.74	78.47	79.15	77.47
9	80.37	80.83	80.69	81.37	81.92	76.69	77.11	80.79	81.43	81.97	78.14	78.60	80.82	81.43	81.97	80.68
10	82.89	83.26	83.21	83.75	84.17	79.03	79.39	83.27	83.78	84.21	80.71	81.10	83.29	83.78	84.21	83.20
11	84.92	85.21	85.19	85.62	85.95	81.02	81.32	85.23	85.64	85.98	82.87	83.19	85.24	85.64	85.97	85.19
12	86.53	86.77	86.75	87.09	87.35	82.69	82.94	86.78	87.10	87.37	84.64	84.90	86.79	87.10	87.37	86.75
13	87.82	88.00	87.98	88.24	88.45	84.06	84.26	88.00	88.26	88.46	86.06	86.27	88.01	88.26	88.46	87.98
14	88.83	88.98	88.95	89.15	89.32	85.18	85.34	88.96	89.16	89.33	87.19	87.36	88.97	89.16	89.33	88.95
15	89.64	89.75	89.71	89.87	90.00	86.08	86.21	89.72	89.88	90.01	88.09	88.22	89.73	89.88	90.01	89.71
16	90.27	90.36	90.30	90.43	90.53	86.79	86.90	90.32	90.44	90.54	88.80	88.91	90.32	90.44	90.54	90.30
17	90.77	90.84	90.77	90.87	90.95	87.37	87.45	90.78	90.88	90.96	89.36	89.45	90.79	90.88	90.96	90.77
18	91.16	91.22	91.14	91.22	91.29	87.82	87.89	91.15	91.23	91.29	89.81	89.87	91.16	91.23	91.29	91.14
19	91.47	91.52	91.43	91.50	91.55	88.18	88.23	91.44	91.50	91.55	90.15	90.20	91.45	91.50	91.55	91.43
20	91.91	91.94	91.84	91.88	91.91	88.68	88.68	91.85	91.88	91.91	90.64	90.66	91.85	91.88	91.91	91.84

Table 2.24—Schedules of fleet-specific weight (kg) by season and age as defined by final parameter estimates. 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	0.06	0.09	0.15	0.25	0.03	0.05	0.09	0.20	0.34	0.02
2	0.24	0.32	0.40	0.62	0.79	0.31	0.39	0.57	0.78	0.98	0.38	0.48	0.62	0.93	1.15	0.27
3	0.97	1.08	1.09	1.37	1.59	1.09	1.19	1.39	1.64	1.89	1.26	1.36	1.46	1.78	2.01	0.89
4	2.03	2.12	1.92	2.24	2.52	2.08	2.13	2.26	2.52	2.79	2.29	2.34	2.33	2.58	2.85	1.79
5	3.19	3.21	2.89	3.26	3.60	3.05	3.04	3.13	3.43	3.76	3.26	3.24	3.18	3.45	3.78	2.84
6	4.31	4.24	3.92	4.33	4.71	3.94	3.86	4.05	4.42	4.79	4.13	4.05	4.08	4.42	4.80	3.90
7	5.34	5.20	4.91	5.35	5.75	4.73	4.60	4.98	5.39	5.79	4.95	4.81	5.00	5.39	5.79	4.91
8	6.29	6.08	5.82	6.26	6.68	5.47	5.28	5.85	6.29	6.70	5.76	5.57	5.86	6.29	6.70	5.82
9	7.14	6.87	6.61	7.06	7.48	6.16	5.93	6.63	7.07	7.49	6.55	6.30	6.63	7.07	7.49	6.61
10	7.89	7.55	7.28	7.73	8.15	6.80	6.52	7.29	7.74	8.16	7.28	6.98	7.29	7.74	8.16	7.28
11	8.52	8.13	7.84	8.29	8.71	7.38	7.05	7.85	8.29	8.72	7.93	7.58	7.85	8.29	8.72	7.84
12	9.05	8.61	8.30	8.74	9.17	7.89	7.52	8.30	8.75	9.17	8.49	8.09	8.31	8.75	9.17	8.30
13	9.49	9.01	8.67	9.11	9.54	8.33	7.92	8.68	9.12	9.54	8.96	8.51	8.68	9.12	9.54	8.67
14	9.85	9.33	8.98	9.41	9.84	8.70	8.25	8.98	9.42	9.84	9.34	8.86	8.98	9.42	9.84	8.98
15	10.13	9.59	9.22	9.66	10.08	9.00	8.52	9.22	9.66	10.08	9.65	9.14	9.22	9.66	10.08	9.22
16	10.37	9.80	9.41	9.85	10.27	9.24	8.75	9.42	9.85	10.27	9.90	9.37	9.42	9.85	10.27	9.41
17	10.55	9.96	9.57	10.00	10.42	9.44	8.93	9.57	10.00	10.42	10.10	9.55	9.57	10.00	10.42	9.57
18	10.70	10.09	9.69	10.12	10.54	9.60	9.07	9.69	10.12	10.54	10.26	9.69	9.70	10.12	10.54	9.69
19	10.81	10.20	9.79	10.22	10.64	9.73	9.18	9.79	10.22	10.64	10.39	9.80	9.79	10.22	10.64	9.79
20	10.98	10.35	9.93	10.36	10.78	9.91	9.34	9.93	10.36	10.78	10.57	9.96	9.93	10.36	10.78	9.93

Table 2.25—Time series of EBS Pacific cod age 0+ biomass, age 3+ biomass, female spawning biomass (t), and standard deviation of spawning biomass ("SB SD") as estimated last year and this year under Model 11.5. Spawning biomasses listed for 2015 under last year's assessment and for 2016 under this year's assessment represent output from the standard projection model.

	Last year's assessment				This year's assessment			
Year	Age 0+	Age 3+	Spawn.	SB SD	Age 0+	Age 3+	Spawn.	SB SD
1977	591,789	583,189	166,807	32,473	580,639	572,253	163,291	31,819
1978	673,991	623,433	184,303	32,478	662,973	613,704	180,863	31,815
1979	851,180	731,198	212,668	33,417	837,745	721,585	209,322	32,738
1980	1,228,590	1,174,450	268,722	35,685	1,208,950	1,156,370	265,060	34,971
1981	1,654,360	1,593,140	374,761	39,140	1,629,440	1,569,570	369,954	38,337
1982	1,999,880	1,978,410	524,665	43,215	1,972,970	1,951,710	518,100	42,278
1983	2,176,460	2,156,140	666,225	45,293	2,151,420	2,131,750	658,400	44,272
1984	2,186,380	2,105,700	738,585	43,458	2,163,410	2,085,600	730,720	42,467
1985	2,163,030	2,138,880	733,640	38,886	2,139,140	2,115,600	726,420	37,989
1986	2,111,450	2,044,680	696,235	33,637	2,086,050	2,021,450	689,270	32,820
1987	2,090,360	2,061,760	670,945	29,050	2,063,010	2,035,030	663,430	28,260
1988	2,018,010	2,003,880	648,850	25,404	1,990,860	1,976,770	640,555	24,608
1989	1,816,540	1,804,590	609,820	22,403	1,792,190	1,780,400	601,150	21,610
1990	1,585,510	1,556,390	561,175	19,696	1,564,990	1,536,690	552,990	18,953
1991	1,385,830	1,331,370	484,294	16,935	1,367,790	1,314,930	477,333	16,285
1992	1,250,330	1,207,410	390,653	14,374	1,232,480	1,190,500	384,888	13,820
1993	1,240,290	1,212,580	342,483	12,567	1,222,170	1,195,220	337,244	12,072
1994	1,287,640	1,231,000	356,239	11,843	1,269,250	1,214,270	350,966	11,363
1995	1,315,290	1,293,960	359,402	11,818	1,295,990	1,275,180	353,929	11,328
1996	1,256,420	1,233,180	353,375	11,964	1,236,950	1,214,240	347,596	11,460
1997	1,175,170	1,146,310	342,350	11,904	1,156,000	1,128,240	336,292	11,391
1998	1,072,210	1,013,230	313,764	11,599	1,051,930	995,227	307,581	11,089
1999	1,096,100	1,070,880	298,490	11,218	1,072,690	1,048,190	292,121	10,714
2000	1,136,280	1,109,280	298,729	10,955	1,110,350	1,084,210	291,681	10,439
2001	1,154,260	1,107,370	326,584	10,829	1,126,320	1,081,630	318,496	10,281
2002	1,179,400	1,151,480	333,423	10,393	1,148,480	1,121,510	324,413	9,812
2003	1,157,830	1,143,210	326,080	9,653	1,124,710	1,110,720	316,221	9,043
2004	1,080,000	1,057,220	315,006	8,904	1,046,300	1,024,300	304,265	8,256
2005	962,376	944,101	283,523	8,285	929,101	911,637	272,196	7,602
2006	838,791	822,381	241,555	7,719	806,650	790,942	230,281	7,023
2007	734,535	711,516	206,900	7,177	703,317	681,507	196,128	6,482
2008	700,463	639,210	181,597	6,808	667,841	609,888	171,337	6,100
2009	761,111	733,346	166,996	6,820	723,102	696,689	156,561	6,034
2010	886,635	791,937	179,755	7,611	841,372	750,699	168,038	6,599
2011	1,110,430	1,091,380	227,899	9,756	1,057,930	1,037,380	213,789	8,274
2012	1,249,320	1,186,650	270,608	13,301	1,197,200	1,135,900	254,174	11,074
2013	1,373,860	1,286,090	321,496	18,086	1,324,910	1,241,520	304,236	14,942
2014	1,537,190	1,497,620	364,513	23,729	1,494,390	1,445,130	348,402	19,718
2015	1,678,010	1,594,630	409,446	28,093	1,666,970	1,585,980	401,573	25,678
2016					1,831,620	1,817,980	466,000	30,739

Table 2.26—Time series of EBS Pacific cod age 0 recruitment (1000s of fish), with standard deviations, as estimated last year and this year under Model 11.5.

	Last year's values		This year's values	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	1,776,400	197,362	1,756,770	193,401
1978	740,864	157,782	735,150	154,302
1979	913,365	97,721	911,872	95,777
1980	312,227	42,580	316,193	42,086
1981	186,390	27,473	186,119	27,168
1982	1,218,590	49,129	1,199,810	47,679
1983	269,779	31,121	270,491	30,591
1984	987,710	43,239	975,814	42,279
1985	420,795	30,302	420,228	29,856
1986	203,096	19,072	206,951	19,138
1987	146,013	15,693	148,111	15,608
1988	368,834	20,985	367,125	20,676
1989	775,657	31,615	769,057	30,920
1990	627,593	28,343	627,254	27,833
1991	339,745	21,109	338,528	20,762
1992	844,141	26,769	836,942	26,123
1993	295,784	17,305	295,068	16,994
1994	321,890	16,327	322,162	16,048
1995	354,252	19,292	349,179	18,802
1996	874,354	27,935	858,353	26,888
1997	353,606	17,742	350,987	17,271
1998	345,764	16,613	343,807	16,119
1999	681,454	20,277	662,988	19,273
2000	411,301	14,386	406,171	13,814
2001	191,772	10,829	187,567	10,495
2002	324,762	12,418	320,855	11,944
2003	258,661	12,225	252,583	11,704
2004	226,348	11,753	221,685	11,169
2005	259,582	13,073	252,378	12,323
2006	917,211	31,230	886,192	27,543
2007	278,036	18,500	271,215	17,279
2008	1,441,320	62,674	1,405,850	53,534
2009	207,181	24,276	237,580	24,864
2010	831,528	54,924	837,777	48,260
2011	1,305,490	95,353	1,248,580	78,359
2012	482,541	58,491	646,490	59,830
2013	1,230,400	188,607	1,261,180	112,053
2014			159,532	40,506
Average	587,147		574,858	

Table 2.27—Numbers (1000s) at age at time of spawning (March) as estimated by Model 11.5.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	1756770	423912	35788	190992	42489	28577	18676	12028	7703	4922	3143	2006	1280	817	521	333	212	135	86	55	97
1978	735150	1250400	301593	25274	131467	28467	18907	12326	7946	5097	3261	2084	1331	850	543	346	221	141	90	57	101
1979	911872	523253	889640	212970	17374	87847	18771	12433	8114	5239	3365	2155	1378	881	562	359	229	146	93	60	105
1980	316193	649037	372320	629687	147931	11821	59168	12613	8359	5461	3529	2268	1454	930	594	380	242	155	99	63	111
1981	186119	225056	461833	263936	441324	102324	8098	40327	8578	5680	3709	2397	1541	987	632	404	258	165	105	67	118
1982	1199810	132473	160131	327202	184785	305081	70076	5516	27394	5819	3851	2514	1625	1044	669	428	274	175	112	71	126
1983	270491	853983	94256	113428	229048	127919	209632	47957	3768	18693	3969	2626	1714	1108	712	456	292	187	119	76	134
1984	975814	192526	607567	66672	78991	157172	86918	141685	32331	2537	12582	2671	1767	1153	745	479	307	196	126	80	142
1985	420228	694528	136945	429297	46222	53611	105029	57610	93593	21334	1674	8302	1763	1166	762	492	316	203	130	83	147
1986	206951	299093	494033	96779	297127	31194	35523	68902	37628	61038	13909	1091	5415	1150	761	497	321	207	132	85	150
1987	148111	147294	212740	348978	66905	200273	20640	23263	44915	24489	39712	9051	710	3526	749	496	324	209	135	86	153
1988	367125	105411	104725	150018	240176	44625	130516	13285	14896	28712	15652	25389	5789	455	2257	480	318	207	134	86	153
1989	769057	261281	74925	73537	101907	157706	28554	82122	8280	9236	17755	9664	15662	3569	280	1391	295	196	128	83	148
1990	627254	547384	185834	52718	50042	66975	101266	18107	51771	5207	5802	11147	6066	9831	2240	176	873	185	123	80	144
1991	338528	446454	389439	131377	36155	32606	42111	62786	11184	31966	3216	3586	6892	3752	6082	1386	109	540	115	76	139
1992	836942	240951	317636	275140	89148	22693	19293	24339	36093	6432	18414	1855	2071	3985	2171	3521	803	63	313	67	125
1993	295068	595701	171423	224345	186510	55594	13271	11024	13876	20656	3697	10620	1073	1200	2311	1260	2045	467	37	182	111
1994	322162	210019	423896	121430	154665	121859	34812	8185	6799	8593	12845	2306	6641	672	752	1451	792	1285	293	23	184
1995	349179	229300	149405	299172	82210	96626	71377	19891	4665	3891	4942	7416	1336	3854	391	438	845	461	749	171	121
1996	858353	248531	163138	105585	203042	51214	55806	39816	10998	2580	2157	2745	4124	743	2147	218	244	471	257	418	163
1997	350987	610939	176814	115226	71473	125854	29412	30998	21968	6082	1432	1201	1532	2305	416	1202	122	137	264	144	326
1998	343807	249819	434684	124919	77660	43658	70755	15957	16697	11859	3296	779	654	836	1260	228	658	67	75	145	258
1999	662988	244708	177741	307091	84603	48545	25613	40451	9080	9520	6782	1889	447	376	481	725	131	379	38	43	232
2000	406171	471892	174126	125525	207434	52659	28401	14669	23172	5233	5519	3949	1103	262	221	282	426	77	223	23	162
2001	187567	289100	335832	123219	85590	133493	32695	17464	9050	14391	3269	3464	2487	697	165	140	179	270	49	141	117
2002	320855	133504	205730	236925	82361	52730	78499	19089	10304	5411	8699	1992	2123	1530	430	102	86	111	168	30	161
2003	252583	228374	95000	144965	157190	49911	30341	44775	11001	6019	3197	5183	1194	1278	924	260	62	52	67	102	116
2004	221685	179779	162501	66889	95762	94486	28523	17224	25703	6402	3542	1897	3094	716	768	557	157	37	32	41	132
2005	252378	157789	127942	114617	44081	56342	51836	15391	9374	14190	3580	2000	1079	1768	411	442	321	91	22	18	100
2006	886192	179635	112297	90404	75993	25944	30591	27369	8110	4969	7572	1921	1078	583	958	223	240	174	49	12	65
2007	271215	630765	127847	79370	59991	44704	14067	16151	14453	4317	2666	4090	1043	587	318	524	122	132	96	27	42
2008	1405850	193042	448910	90274	52419	35097	24149	7401	8493	7652	2302	1431	2205	564	318	173	285	66	72	52	38
2009	237580	1000640	137388	316663	58804	29510	18012	12074	3715	4311	3926	1191	745	1153	296	167	91	150	35	38	48
2010	837777	169102	712148	96941	207029	33439	15304	9058	6064	1879	2198	2015	614	385	598	154	87	47	78	18	45
2011	1248580	596304	120350	503586	64870	125111	18850	8408	4956	3327	1035	1215	1117	341	214	333	86	49	26	44	35
2012	646490	888702	424376	85011	333037	37372	64598	9290	4104	2428	1641	514	605	558	171	108	167	43	24	13	40
2013	1261180	460152	632488	300167	56941	199455	20536	34296	4905	2176	1295	880	276	327	302	93	58	91	23	13	29
2014	159532	897670	327494	447468	201785	34699	113023	11306	18791	2697	1202	719	490	154	183	169	52	33	51	13	24
2015	537921	113550	638899	232152	304917	126105	20225	63980	6366	10613	1530	685	411	280	88	105	97	30	19	29	21

Table 2.28—Model 11.5 estimates of "effective" fishing mortality (= $-\ln(N_{a+1,t+1}/N_{a,t})-M$) at age and year.

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	0.027	0.054	0.069	0.073	0.073	0.071	0.070	0.069	0.068	0.068	0.067	0.067	0.067	0.067	0.067	0.067	0.066
1978	0.000	0.006	0.031	0.062	0.079	0.083	0.083	0.081	0.080	0.079	0.078	0.078	0.077	0.077	0.077	0.077	0.077	0.077	0.077
1979	0.000	0.004	0.021	0.043	0.055	0.058	0.058	0.057	0.056	0.055	0.055	0.054	0.054	0.054	0.054	0.053	0.053	0.053	0.053
1980	0.000	0.003	0.014	0.029	0.042	0.048	0.051	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
1981	0.000	0.004	0.015	0.028	0.038	0.044	0.047	0.048	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049
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	0.033	0.043	0.050	0.052	0.054	0.054	0.055	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	0.071	0.071	0.071	0.071
1985	0.000	0.005	0.024	0.048	0.068	0.079	0.085	0.087	0.087	0.087	0.087	0.086	0.086	0.086	0.085	0.085	0.085	0.085	0.085
1986	0.000	0.005	0.024	0.047	0.066	0.077	0.082	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.084	0.084	0.084
1987	0.000	0.005	0.023	0.051	0.075	0.089	0.095	0.097	0.097	0.096	0.095	0.094	0.094	0.093	0.093	0.093	0.092	0.092	0.092
1988	0.001	0.009	0.037	0.070	0.098	0.117	0.128	0.134	0.137	0.139	0.140	0.141	0.141	0.141	0.142	0.142	0.142	0.142	0.142
1989	0.000	0.008	0.036	0.069	0.096	0.113	0.121	0.126	0.128	0.128	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129	0.129
1990	0.000	0.003	0.025	0.074	0.114	0.131	0.137	0.138	0.138	0.138	0.137	0.137	0.137	0.137	0.137	0.137	0.136	0.136	0.136
1991	0.000	0.004	0.034	0.109	0.173	0.202	0.210	0.211	0.210	0.209	0.208	0.207	0.207	0.206	0.206	0.206	0.206	0.206	0.205
1992	0.000	0.002	0.027	0.101	0.170	0.200	0.205	0.203	0.199	0.196	0.193	0.192	0.190	0.190	0.189	0.188	0.188	0.188	0.187
1993	0.000	0.002	0.022	0.079	0.138	0.163	0.167	0.163	0.158	0.154	0.151	0.149	0.147	0.146	0.145	0.145	0.144	0.144	0.144
1994	0.000	0.003	0.027	0.095	0.163	0.194	0.199	0.195	0.190	0.186	0.183	0.181	0.179	0.178	0.177	0.177	0.176	0.176	0.175
1995	0.000	0.003	0.031	0.116	0.207	0.253	0.267	0.267	0.264	0.262	0.260	0.259	0.258	0.257	0.257	0.256	0.256	0.256	0.256
1996	0.000	0.003	0.029	0.109	0.195	0.238	0.248	0.246	0.242	0.238	0.236	0.234	0.233	0.232	0.231	0.231	0.230	0.230	0.230
1997	0.000	0.003	0.036	0.131	0.228	0.275	0.287	0.286	0.282	0.278	0.275	0.273	0.272	0.271	0.270	0.270	0.269	0.269	0.269
1998	0.000	0.003	0.026	0.097	0.172	0.209	0.218	0.216	0.213	0.210	0.208	0.207	0.206	0.205	0.204	0.204	0.204	0.204	0.203
1999	0.000	0.002	0.024	0.095	0.171	0.207	0.213	0.208	0.202	0.198	0.194	0.192	0.190	0.189	0.188	0.187	0.187	0.186	0.186
2000	0.000	0.003	0.034	0.106	0.170	0.195	0.193	0.183	0.173	0.166	0.160	0.157	0.154	0.152	0.150	0.149	0.149	0.148	0.147
2001	0.000	0.003	0.036	0.106	0.158	0.173	0.167	0.156	0.146	0.138	0.133	0.129	0.127	0.125	0.123	0.122	0.122	0.121	0.120
2002	0.000	0.004	0.042	0.123	0.187	0.207	0.200	0.187	0.176	0.167	0.161	0.157	0.153	0.151	0.150	0.148	0.148	0.147	0.146
2003	0.000	0.004	0.043	0.131	0.200	0.221	0.214	0.199	0.186	0.176	0.169	0.164	0.161	0.158	0.157	0.155	0.154	0.154	0.153
2004	0.000	0.005	0.050	0.144	0.218	0.241	0.234	0.220	0.207	0.197	0.190	0.185	0.181	0.179	0.177	0.175	0.174	0.174	0.173
2005	0.000	0.002	0.034	0.123	0.215	0.265	0.278	0.276	0.270	0.264	0.259	0.255	0.253	0.251	0.250	0.249	0.248	0.247	0.246
2006	0.000	0.002	0.033	0.128	0.234	0.292	0.308	0.305	0.297	0.290	0.284	0.280	0.277	0.275	0.273	0.272	0.271	0.271	0.270
2007	0.000	0.003	0.034	0.126	0.228	0.284	0.298	0.295	0.286	0.279	0.273	0.269	0.265	0.263	0.262	0.260	0.259	0.259	0.258
2008	0.000	0.003	0.041	0.151	0.266	0.325	0.338	0.332	0.322	0.313	0.306	0.301	0.297	0.294	0.292	0.291	0.290	0.289	0.288
2009	0.000	0.003	0.046	0.165	0.293	0.360	0.374	0.366	0.353	0.342	0.334	0.328	0.323	0.320	0.318	0.316	0.315	0.314	0.313
2010	0.000	0.003	0.036	0.130	0.234	0.291	0.305	0.301	0.292	0.284	0.278	0.273	0.270	0.268	0.266	0.265	0.264	0.263	0.262
2011	0.000	0.003	0.043	0.155	0.275	0.340	0.359	0.356	0.349	0.342	0.336	0.332	0.328	0.326	0.324	0.323	0.322	0.322	0.321
2012	0.000	0.003	0.036	0.134	0.243	0.305	0.324	0.324	0.318	0.312	0.308	0.304	0.301	0.300	0.298	0.297	0.296	0.296	0.295
2013	0.000	0.003	0.036	0.122	0.213	0.264	0.279	0.279	0.273	0.268	0.264	0.261	0.259	0.257	0.256	0.255	0.254	0.253	0.253
2014	0.000	0.002	0.029	0.109	0.198	0.248	0.263	0.262	0.256	0.251	0.247	0.244	0.242	0.240	0.239	0.238	0.237	0.237	0.236
2015	0.000	0.002	0.025	0.091	0.164	0.204	0.216	0.215	0.210	0.206	0.202	0.200	0.198	0.196	0.195	0.195	0.194	0.194	0.193

Table 2.29—Projections for EBS Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2016-2028 (Scenario 1), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	332,000	332,000	332,000	332,000	0
2017	329,000	329,000	329,000	329,000	0
2018	303,000	303,000	303,000	303,000	2
2019	265,000	266,000	267,000	269,000	1,141
2020	229,000	238,000	241,000	265,000	12,390
2021	196,000	221,000	228,000	283,000	28,725
2022	150,000	213,000	217,000	312,000	49,484
2023	122,000	208,000	210,000	321,000	62,641
2024	109,000	206,000	209,000	322,000	68,466
2025	106,000	207,000	210,000	330,000	70,214
2026	107,000	208,000	211,000	330,000	69,726
2027	109,000	207,000	210,000	330,000	68,278
2028	109,000	209,000	210,000	329,000	67,448

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	457,000	457,000	457,000	457,000	0
2017	483,000	483,000	483,000	483,000	0
2018	473,000	473,000	473,000	473,000	44
2019	431,000	432,000	432,000	434,000	996
2020	377,000	383,000	385,000	398,000	7,096
2021	327,000	347,000	353,000	399,000	23,161
2022	284,000	324,000	336,000	424,000	45,963
2023	255,000	317,000	330,000	458,000	63,994
2024	238,000	315,000	330,000	467,000	73,706
2025	233,000	313,000	331,000	467,000	78,320
2026	234,000	316,000	333,000	480,000	79,802
2027	235,000	315,000	333,000	483,000	78,618
2028	235,000	316,000	332,000	484,000	76,667

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	0.30	0.30	0.30	0.30	0.00
2017	0.30	0.30	0.30	0.30	0.00
2018	0.30	0.30	0.30	0.30	0.00
2019	0.30	0.30	0.30	0.30	0.00
2020	0.30	0.30	0.30	0.30	0.00
2021	0.30	0.30	0.30	0.30	0.00
2022	0.26	0.30	0.29	0.30	0.01
2023	0.23	0.29	0.28	0.30	0.02
2024	0.21	0.29	0.27	0.30	0.03
2025	0.21	0.29	0.27	0.30	0.03
2026	0.21	0.29	0.27	0.30	0.03
2027	0.21	0.29	0.27	0.30	0.03
2028	0.21	0.29	0.27	0.30	0.03

Table 2.30—Projections for EBS Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = 0.75 \times max\ F_{ABC}$ in 2016-2028 (Scenario 2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	212,000	212,000	212,000	212,000	0
2017	221,000	221,000	221,000	221,000	0
2018	264,000	264,000	264,000	264,000	2
2019	238,000	238,000	238,000	240,000	857
2020	208,000	215,000	218,000	235,000	9,388
2021	180,000	200,000	205,000	247,000	22,201
2022	157,000	192,000	199,000	271,000	35,128
2023	135,000	189,000	195,000	279,000	44,685
2024	112,000	187,000	192,000	279,000	51,886
2025	106,000	186,000	190,000	283,000	55,231
2026	102,000	185,000	189,000	286,000	55,664
2027	105,000	183,000	188,000	285,000	54,742
2028	104,000	184,000	187,000	286,000	53,995

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	466,000	466,000	466,000	466,000	0
2017	530,000	530,000	530,000	530,000	0
2018	554,000	554,000	554,000	554,000	44
2019	521,000	522,000	522,000	524,000	997
2020	467,000	473,000	475,000	488,000	7,139
2021	411,000	432,000	438,000	484,000	23,746
2022	359,000	403,000	415,000	507,000	49,021
2023	315,000	389,000	402,000	547,000	72,334
2024	284,000	382,000	396,000	560,000	87,383
2025	270,000	377,000	393,000	556,000	95,289
2026	265,000	377,000	392,000	573,000	98,383
2027	265,000	375,000	391,000	574,000	97,814
2028	265,000	373,000	390,000	572,000	95,702

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	0.18	0.18	0.18	0.18	0.00
2017	0.18	0.18	0.18	0.18	0.00
2018	0.22	0.22	0.22	0.22	0.00
2019	0.22	0.22	0.22	0.22	0.00
2020	0.22	0.22	0.22	0.22	0.00
2021	0.22	0.22	0.22	0.22	0.00
2022	0.22	0.22	0.22	0.22	0.00
2023	0.21	0.22	0.22	0.22	0.00
2024	0.19	0.22	0.22	0.22	0.01
2025	0.18	0.22	0.22	0.22	0.01
2026	0.18	0.22	0.22	0.22	0.02
2027	0.18	0.22	0.21	0.22	0.02
2028	0.18	0.22	0.21	0.22	0.02

Table 2.31—Projections for EBS 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 2016-2028 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	360,000	360,000	360,000	360,000	0
2017	351,000	351,000	351,000	351,000	0
2018	318,000	318,000	318,000	318,000	2
2019	276,000	277,000	277,000	279,000	1,248
2020	236,000	246,000	250,000	275,000	13,507
2021	201,000	228,000	236,000	295,000	31,077
2022	173,000	221,000	230,000	326,000	47,436
2023	154,000	219,000	227,000	333,000	57,303
2024	142,000	216,000	227,000	336,000	62,454
2025	139,000	217,000	227,000	344,000	64,542
2026	139,000	217,000	226,000	343,000	64,196
2027	139,000	215,000	224,000	342,000	62,706
2028	138,000	215,000	224,000	341,000	61,902

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	455,000	455,000	455,000	455,000	0
2017	472,000	472,000	472,000	472,000	0
2018	455,000	455,000	455,000	455,000	44
2019	408,000	409,000	409,000	411,000	996
2020	354,000	359,000	361,000	374,000	7,079
2021	304,000	324,000	329,000	375,000	22,945
2022	261,000	302,000	313,000	400,000	45,487
2023	227,000	294,000	306,000	431,000	64,338
2024	203,000	292,000	303,000	438,000	75,476
2025	193,000	288,000	302,000	442,000	81,250
2026	189,000	289,000	301,000	448,000	83,313
2027	188,000	288,000	300,000	453,000	82,450
2028	187,000	286,000	299,000	454,000	80,756

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	0.32	0.32	0.32	0.32	0.00
2017	0.32	0.32	0.32	0.32	0.00
2018	0.32	0.32	0.32	0.32	0.00
2019	0.32	0.32	0.32	0.32	0.00
2020	0.32	0.32	0.32	0.32	0.00
2021	0.32	0.32	0.32	0.32	0.00
2022	0.32	0.32	0.32	0.32	0.00
2023	0.32	0.32	0.32	0.32	0.00
2024	0.32	0.32	0.32	0.32	0.00
2025	0.32	0.32	0.32	0.32	0.00
2026	0.32	0.32	0.32	0.32	0.00
2027	0.32	0.32	0.32	0.32	0.00
2028	0.32	0.32	0.32	0.32	0.00

Table 2.32—Projections for EBS 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 2016-2028 (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	171,000	171,000	171,000	171,000	0
2017	186,000	186,000	186,000	186,000	0
2018	185,000	185,000	185,000	185,000	1
2019	174,000	175,000	175,000	176,000	564
2020	158,000	163,000	165,000	176,000	6,235
2021	141,000	155,000	158,000	187,000	15,057
2022	126,000	150,000	155,000	205,000	24,502
2023	113,000	149,000	153,000	213,000	31,389
2024	105,000	147,000	153,000	215,000	35,662
2025	101,000	146,000	152,000	219,000	37,918
2026	97,900	146,000	152,000	221,000	38,608
2027	98,100	145,000	151,000	222,000	38,206
2028	96,900	146,000	150,000	221,000	37,722

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	469,000	469,000	469,000	469,000	0
2017	546,000	546,000	546,000	546,000	0
2018	587,000	587,000	587,000	587,000	44
2019	581,000	582,000	582,000	584,000	997
2020	544,000	550,000	552,000	565,000	7,184
2021	497,000	517,000	523,000	570,000	24,364
2022	446,000	492,000	505,000	602,000	51,875
2023	398,000	480,000	494,000	656,000	79,305
2024	361,000	473,000	488,000	673,000	99,152
2025	335,000	468,000	486,000	679,000	111,507
2026	325,000	468,000	484,000	697,000	118,078
2027	320,000	465,000	482,000	698,000	119,776
2028	313,000	464,000	480,000	701,000	118,683

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	0.15	0.15	0.15	0.15	0.00
2017	0.15	0.15	0.15	0.15	0.00
2018	0.15	0.15	0.15	0.15	0.00
2019	0.15	0.15	0.15	0.15	0.00
2020	0.15	0.15	0.15	0.15	0.00
2021	0.15	0.15	0.15	0.15	0.00
2022	0.15	0.15	0.15	0.15	0.00
2023	0.15	0.15	0.15	0.15	0.00
2024	0.15	0.15	0.15	0.15	0.00
2025	0.15	0.15	0.15	0.15	0.00
2026	0.15	0.15	0.15	0.15	0.00
2027	0.15	0.15	0.15	0.15	0.00
2028	0.15	0.15	0.15	0.15	0.00

Table 2.33—Projections for EBS Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = 0$ in 2016-2028 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2026	0	0	0	0	0
2027	0	0	0	0	0
2028	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	481,000	481,000	481,000	481,000	0
2017	617,000	617,000	617,000	617,000	0
2018	726,000	726,000	726,000	726,000	44
2019	785,000	785,000	786,000	787,000	998
2020	794,000	800,000	802,000	815,000	7,271
2021	773,000	794,000	801,000	849,000	25,599
2022	732,000	783,000	798,000	907,000	57,917
2023	682,000	778,000	796,000	989,000	94,999
2024	637,000	777,000	796,000	1,040,000	126,618
2025	598,000	775,000	798,000	1,070,000	149,766
2026	578,000	775,000	799,000	1,080,000	165,046
2027	563,000	775,000	799,000	1,110,000	173,088
2028	556,000	779,000	798,000	1,100,000	175,640

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2026	0.00	0.00	0.00	0.00	0.00
2027	0.00	0.00	0.00	0.00	0.00
2028	0.00	0.00	0.00	0.00	0.00

Table 2.34—Projections for EBS Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2016-2028 (Scenario 6), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	390,000	390,000	390,000	390,000	0
2017	374,000	374,000	374,000	374,000	0
2018	333,000	333,000	333,000	333,000	3
2019	286,000	287,000	287,000	289,000	1,363
2020	242,000	253,000	257,000	285,000	14,694
2021	182,000	221,000	230,000	306,000	40,866
2022	143,000	207,000	219,000	338,000	61,689
2023	121,000	207,000	218,000	347,000	73,020
2024	111,000	209,000	220,000	351,000	78,297
2025	109,000	211,000	222,000	360,000	79,607
2026	112,000	213,000	223,000	359,000	78,774
2027	111,000	213,000	222,000	366,000	77,209
2028	114,000	216,000	222,000	360,000	76,499

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	453,000	453,000	453,000	453,000	0
2017	460,000	460,000	460,000	460,000	0
2018	436,000	436,000	436,000	436,000	44
2019	386,000	386,000	387,000	388,000	996
2020	330,000	336,000	337,000	351,000	7,062
2021	284,000	302,000	308,000	352,000	22,051
2022	252,000	288,000	297,000	377,000	41,086
2023	231,000	286,000	296,000	405,000	55,527
2024	218,000	287,000	298,000	412,000	63,171
2025	215,000	289,000	301,000	419,000	66,920
2026	217,000	290,000	302,000	427,000	68,017
2027	217,000	289,000	302,000	432,000	66,695
2028	219,000	290,000	302,000	435,000	64,983

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	0.35	0.35	0.35	0.35	0.00
2017	0.35	0.35	0.35	0.35	0.00
2018	0.35	0.35	0.35	0.35	0.00
2019	0.35	0.35	0.35	0.35	0.00
2020	0.35	0.35	0.35	0.35	0.00
2021	0.31	0.33	0.33	0.35	0.02
2022	0.27	0.31	0.32	0.35	0.03
2023	0.25	0.31	0.31	0.35	0.04
2024	0.23	0.31	0.31	0.35	0.04
2025	0.23	0.32	0.31	0.35	0.04
2026	0.23	0.32	0.31	0.35	0.04
2027	0.23	0.31	0.31	0.35	0.04
2028	0.23	0.32	0.31	0.35	0.04

Table 2.35—Projections for EBS Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2016-2017 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	332,000	332,000	332,000	332,000	0
2017	329,000	329,000	329,000	329,000	0
2018	355,000	355,000	355,000	355,000	3
2019	300,000	301,000	301,000	304,000	1,363
2020	251,000	262,000	266,000	293,000	14,694
2021	192,000	232,000	240,000	311,000	39,065
2022	147,000	211,000	223,000	341,000	61,500
2023	122,000	208,000	219,000	348,000	73,106
2024	111,000	209,000	220,000	351,000	78,387
2025	109,000	211,000	222,000	361,000	79,671
2026	112,000	213,000	223,000	359,000	78,813
2027	111,000	213,000	222,000	366,000	77,230
2028	114,000	216,000	222,000	360,000	76,508

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	457,000	457,000	457,000	457,000	0
2017	483,000	483,000	483,000	483,000	0
2018	469,000	469,000	469,000	469,000	44
2019	409,000	410,000	410,000	412,000	996
2020	346,000	351,000	353,000	366,000	7,062
2021	293,000	312,000	317,000	361,000	22,215
2022	256,000	292,000	302,000	382,000	41,709
2023	232,000	287,000	298,000	408,000	56,079
2024	219,000	287,000	299,000	414,000	63,512
2025	215,000	289,000	301,000	419,000	67,083
2026	217,000	290,000	302,000	427,000	68,083
2027	217,000	289,000	302,000	432,000	66,719
2028	219,000	290,000	302,000	435,000	64,990

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2016	0.30	0.30	0.30	0.30	0.00
2017	0.30	0.30	0.30	0.30	0.00
2018	0.35	0.35	0.35	0.35	0.00
2019	0.35	0.35	0.35	0.35	0.00
2020	0.35	0.35	0.35	0.35	0.00
2021	0.32	0.34	0.34	0.35	0.01
2022	0.28	0.32	0.32	0.35	0.03
2023	0.25	0.31	0.31	0.35	0.04
2024	0.23	0.31	0.31	0.35	0.04
2025	0.23	0.32	0.31	0.35	0.04
2026	0.23	0.32	0.31	0.35	0.04
2027	0.23	0.31	0.31	0.35	0.04
2028	0.23	0.32	0.31	0.35	0.04

Table 2.36a (page 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 trawl fishery for Pacific cod, 1991-2015 (2015 data current through October 11).

Species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Pollock	8595	17525	29180	23805	22637	19154	28775	7234	17200	9658	5663	8697	8744
Sablefish	1	9		2	0	5	3	4	10	13	36	34	56
Atka Mackerel	165	92	2	2	3	52	44	423	62	19	90	230	3470
Alaska Plaice												399	265
Arrowtooth Flounder	869	2603	1650	1994	1600	3088	2197	1488	1137	1039	2037	3229	4139
Flathead Sole					2836	2737	3363	1543	2108	1830	790	1496	1445
Flounder	753	2447	2652	3233									
Greenland Turbot	35	78	53	46	89	64	72	96	22	50	75	46	71
Rock Sole	1746	3681	5509	7560	13681	9924	14501	5542	9794	7666	4981	5989	5134
Yellowfin Sole	33	269	817	3094	702	1812	821	753	425	1208	559	1520	1006
Other Flatfish					874	1035	1119	543	591	849	592	480	893
Northern Rockfish												42	12
Pacific Ocean Perch	620	365	378	118	105	66	149	42	25	137	33	11	31
Rougheye Rockfish													
Sharpchin/Northern Rockfish		83	55								16		
Short/Rough/Sharp/Northern	99	52	17	12	12	20	85	18	29	40	16		
Shortraker Rockfish													
Shortraker/Rougheye Rockfish		2										3	3
Other Rockfish	21	47	18	2	22	8	4	27	8	15	8	28	33
Other	1092	2661	2688	2315	2560	3239	2333	1827	2166	2086	1370	2351	2477

Table 2.36a (page 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 trawl fishery for Pacific cod, 1991-2015 (2014 data current through October 11).

Species/group	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Pollock	13332	9923	12098	16936	4289	3329	2237	3500	3512	3986	5513	2061
Sablefish	73	28	2	1	1					0		0
Atka Mackerel	4442	652	367	123	10	28	46	69	35	10	2	10
Alaska Plaice	373	391	342	404	54	55	73	523	160	577	623	153
Arrowtooth Flounder	7861	3786	4285	1924	584	448	415	219	217	275	221	222
Flathead Sole	2818	1351	2896	3750	360	479	165	220	242	241	220	118
Flounder												
Greenland Turbot	76	10	20	82	8	1	5	0	1	2	2	1
Rock Sole	8669	7464	4533	3867	974	750	842	1336	1134	830	1363	1656
Yellowfin Sole	1842	1267	1426	645	322	306	471	1208	735	2663	1504	566
Other Flatfish	2064	1332	600	383	76	28	62	73	73	29	48	131
Northern Rockfish	51	22	48	4	1	1	3	6	5	0	1	3
Pacific Ocean Perch	64	80	50	25	2	1	0	4	2	2		5
Rougheye Rockfish	1	1										
Sharpchin/Northern Rockfish												
Short/Rough/Sharp/Northern												
Shortraker Rockfish												
Shortraker/Rougheye Rockfish												
Other Rockfish	63	18	12	5	5	2	8	2	16	2	2	5
Other	3178	1694	2592	3805	741	543	511					

Table 2.36b (page 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 longline fishery for Pacific cod, 1991-2015 (2015 data current through October 20).

Species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Pollock	2098	3245	2117	2772	3037	2875	4461	3186	3907	4785	5894	6482	7163
Sablefish	37	117	18	46	40	24	21	14	15	69	60	59	66
Atka Mackerel	0	2	1	0	6	2	0	0	0	1	1	2	6
Alaska Plaice												1	0
Arrowtooth Flounder	1693	1545	700	1422	1754	2113	2182	1506	736	1119	1155	936	1296
Flathead Sole					254	270	338	407	281	318	268	375	372
Flounder	253	274	205	212									
Greenland Turbot	185	523	148	267	326	377	454	294	170	151	161	221	182
Rock Sole	18	29	12	19	38	45	36	39	29	29	28	32	45
Yellowfin Sole	1	93	5	152	60	148	216	260	185	296	648	620	631
Other Flatfish					22	21	33	30	95	129	91	102	80
Northern Rockfish												9	6
Pacific Ocean Perch	2	6	5	1	17	1	0	0	0	1	2	3	1
Rougheye Rockfish													0
Sharpchin/Northern Rockfish		1	2								7		
Short/Rough/Sharp/Northern	14	15	10	21	20	37	13	15	9	31	8		
Shortraker Rockfish													
Shortraker/Rougheye Rockfish		20	18								25	19	18
Other Rockfish	9	35	15	15	14	16	9	10	15	11	28	32	11
Other	5855	10112	6840	10145	10340	8031	12428	12399	9259	11337	12105	14100	14770

Table 2.36b (page 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 longline fishery for Pacific cod, 1991-2015 (2015 data current through October 11).

Species/group	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Pollock	5309	4172	3041	3372	5234	4529	4166	5458	4821	5103	5979	4317
Sablefish	19	22	22	14	4	2	2	16	3	3	3	2
Atka Mackerel	25	5	0	4	1	0	1	6	3	2	3	2
Alaska Plaice	0	0	4	0	0	0	0	0	0	1	1	0
Arrowtooth Flounder	1365	1675	1323	1265	1208	1220	1100	956	960	580	545	391
Flathead Sole	593	619	539	352	334	248	264	330	291	372	560	376
Flounder												
Greenland Turbot	218	169	65	115	72	79	106	172	121	16	16	19
Rock Sole	37	48	22	14	20	25	5	20	26	33	52	44
Yellowfin Sole	616	717	485	264	507	653	198	674	1001	1422	1861	1541
Other Flatfish	187	253	145	59	29	56	96	50	64	10	36	35
Northern Rockfish	5	6	6	5	4	4	11	13	9	18	32	22
Pacific Ocean Perch	3	1	0	0	0	1	1	2	1	2	6	4
Rougheye Rockfish	1	4	2	2	5	1	4	3	2	2	2	4
Sharpchin/Northern Rockfish												
Short/Rough/Sharp/Northern												
Shortraker Rockfish	25	19	10	22	12	22	48	20	14	8	13	22
Shortraker/Rougheye Rockfish												
Other Rockfish	28	20	10	22	18	7	47	36	23	28	46	34
Other	17848	19934	14230	11244	14331	12464	11043					

Table 2.36c(page 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 pot fishery for Pacific cod, 1991-2015 (2015 data current through October 11).

Species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Pollock	2	7		4	15	32	64	43	23	58		29	18
Sablefish													0
Atka Mackerel	1	10		6	80	53	48	15					191
Alaska Plaice													
Arrowtooth Flounder	0	3			18	18	13	2				151	4
Flathead Sole						7			0				0
Flounder		1											
Greenland Turbot					1	0							0
Rock Sole	0	1		0	0	8	2	1	2	1			3
Yellowfin Sole	38	26			81	256	71	107	61	69		38	82
Other Flatfish						3	1						1
Northern Rockfish													1
Pacific Ocean Perch					1	1							1
Rougheye Rockfish													
Sharpchin/Northern Rockfish													
Short/Rough/Sharp/Northern	0				1	1	1						
Shortraker Rockfish													
Shortraker/Rougheye Rockfish													0
Other Rockfish	0	1		0	3	6	3	2					5
Other	45	318	46	194	527	493	364	330	543	740	441	416	355

Table 2.36c (page 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 pot fishery for Pacific cod, 1991-2015 (2015 data current through October 11).

Species/group	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Pollock	9	8	26	12	11	17	8	7	4	7	16	25
Sablefish	1	0	3							0		
Atka Mackerel	141	236	330	41	61	2	27	29	9	3	7	4
Alaska Plaice									0			
Arrowtooth Flounder	4	5	13	3	6	0	1	1	1	2	1	0
Flathead Sole	1	1	0	2	1	0	0	0	0	0	0	0
Flounder												
Greenland Turbot			1					0				
Rock Sole	2	1	2	3	1	0	1	0	1	1	2	0
Yellowfin Sole	78	76	47	206	133	35	2	29	29	298	352	187
Other Flatfish	1	1	1	1	0	0	0	0	0	2	0	0
Northern Rockfish	1	1	1	1	2	0	0	1	1	0	0	1
Pacific Ocean Perch	0	0	1		0	0	0	0	0	0		
Rougheye Rockfish	0	0										
Sharpchin/Northern Rockfish												
Short/Rough/Sharp/Northern												
Shortraker Rockfish							0					
Shortraker/Rougheye Rockfish												
Other Rockfish	3	3	4	1	1	0	2	2	1	5	4	3
Other	333	360	471	305	383	131	247					

Table 2.37—Incidental catch (t) of squid and members of the former "other species" complex taken in the Bering Sea fisheries for Pacific cod, 2003-2015 (2015 data are current through October 18).

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Octopus, North Pacific	209	264	299	267	130	177	37	114	555	118	181	397	283
Sculpins, large	813	2,846	2,245	1,920	2,087	1,401	1,060	1,057	1,647	1,764	1,457	2,090	1,598
Sculpins, other	1,870	350	339	383	337	299	210	66	146	239	33	88	26
Shark, Pacific sleeper	172	228	189	123	44	20	14	15	20	10	20	37	21
Shark, salmon			2	1							0		
Shark, spiny dogfish	13	8	11	6	2	7	17	13	7	19	18	16	4
Shark, other	21	20	10	4	2	2	5	2	3	1	1	2	1
Skate, Alaskan								1,494	504	783	930	971	651
Skate, Aleutian									20	72	42	47	22
Skate, big		158	174	243	74	49	63	117	14	56	60	71	52
Skate, longnose	0	12	21	20	1	1	1	5	1	1	1	1	0
Skate, whiteblotched									2	2	4	2	7
Skate, other	16,518	17,712	18,856	14,436	12,740	13,685	11,886	9,006	15,993	17,227	19,260	20,767	18,406
Squid, majestic	5	4	1		1			0	0	0	0	1	1

Table 2.38—Catches of prohibited species by Bering Sea fisheries for Pacific cod, 1991-2014 (2014 data are current through October 13). Herring and halibut catches (and halibut mortality totals) are in t, salmon and crab are in 1000s of individuals.

Species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Bairdi Tanner Crab	764	439	230	319	330	455	293	152	158	180	155	355	261
Opilio Tanner (Snow) Crab	212	308	291	440	277	377	1019	803	540	404	251	508	217
Red King Crab	52	13	2	2	8	79	28	12	17	44	21	40	14
Blue King Crab													4
Golden (Brown) King Crab													0
Other King Crab	1	13	1	3	2	7	3	25	12	9	18	27	
Herring		8	23	2	8	18	1	1	1	1	5	3	14
Chinook Salmon	4	5	6	7	7	6	5	2	2	1	3	2	2
Non-Chinook Salmon	0	0	0	1	1	0	0	1	0	0	2	1	1

Species/group	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bairdi Tanner Crab	274	336	491	819	1265	528	389	324	115	238	553	501
Opilio Tanner (Snow) Crab	285	281	475	1812	693	550	782	188	48	42	112	128
Red King Crab	14	20	18	47	36	8	3	23	11	99	142	54
Blue King Crab	3	1	4	173	9	15	123	1	1	0	0	0
Golden (Brown) King Crab	0	0	0	0	0	1	0	0	0	0	0	0
Other King Crab												
Herring	9	18	8	2	0	0	0	0	6	0	1	3
Chinook Salmon	5	3	3	5	1	0	0	0	1	1	1	1
Non-Chinook Salmon	7	1	7	1	0	0	0	0	0	0	1	0

Halibut quantity	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Catch	5198	7256	3463	8657	8950	9175	8640	7234	6136	7273	6221	7329	6699
Mortality				2069	2264	2326	2060	1719	1780	1537	1278	1789	1875

Halibut quantity	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Catch	6716	7524	5904	5316	5828	5422	5464	5701	6567	6179	5293	2892
Mortality	2077	1977	1786	1419	902	782	784	781	1039	863	751	496

Table 2.39—Incidental catch of non-target species groups by Bering Sea Pacific cod fisheries, 2003-2015 (2015 data are current through October 18). All units are t, except for birds, which are in numbers of individuals. Results (except birds) have been sorted in descending order of average.

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Ave.
Sea star	437	422	440	317	235	180	139	135	191	453	283	673	636	349
Giant Grenadier	2	15	144	102	95	135	201	292	1124	537	176	148	42	232
Scypho jellies	675	710	399	66	110	47	93	43	183	80	335	84	84	224
Sea anemone unidentified	92	115	113	87	37	54	115	84	144	177	233	242	202	130
Misc fish	224	229	205	92	86	40	51	52	110	129	60	149	115	119
Grenadier	244	223	199	25	84	27	11	98	13	20	105	16	77	88
Sea pens whips	6	12	30	16	7	10	37	25	25	35	53	84	43	29
Benthic urochordata	14	4	10	5	1	2	1	10	35	65	51	57	95	27
Eelpouts	47	35	42	17	18	7	2	2	4	11	24	54	67	25
Snails	25	20	12	16	15	19	25	17	23	21	29	44	36	23
Invertebrate unidentified	19	5	3	17	19	2	15	37	57	35	21	22	4	20
Sponge unidentified	6	8	6	10	2	3	11	6	11	15	19	20	18	10
Misc crabs	8	4	4	16	28	6	2	5	4	5	12	8	5	8
Bivalves	5	16	6	5	2	11	9	3	11	11	12	8	8	8
Urchins dollars cucumbers	11	11	13	4	13	3	1	1	4	3	1	6	6	6
Corals Bryozoans	1	1	1	1	2	2	8	2	3	24	2	2	2	4
Hermit crab unidentified	5	3	2	2	2	1	1	1	1	1	1	1	1	2
Greenlings	6	3	2	2	0	1	0	0	0	0	0	0	0	1
Brittle star unidentified	1	1	0	1	0	0	0	0	1	1	1	1	2	1
Dark Rockfish						1	0	0	0	0	0	0	1	0
Misc crustaceans	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Other osmerids	0	0	0	0	0		0	0	0	0	0		0	0
Pandalid shrimp	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eulachon		0	0	0	0	0		0	0	0				0
Polychaete unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pacific Sand lance	0	0	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	0		0
Capelin		0			0	0		0	0	0	0	0	0	0
Pacific Sandfish								0				0	0	0
Stichaeidae	0	0	0	0	0	0	0	0					0	0
Lanternfishes (myctophidae)		0												0
Gunnels		0	0		0									0
Birds	*4749*	*4678*	*5291*	*4890*	*5894*	*4389*	*8003*	*3042*	*6803*	*4123*	*3301*	*1342*	*1903*	*4493*

FIGURES

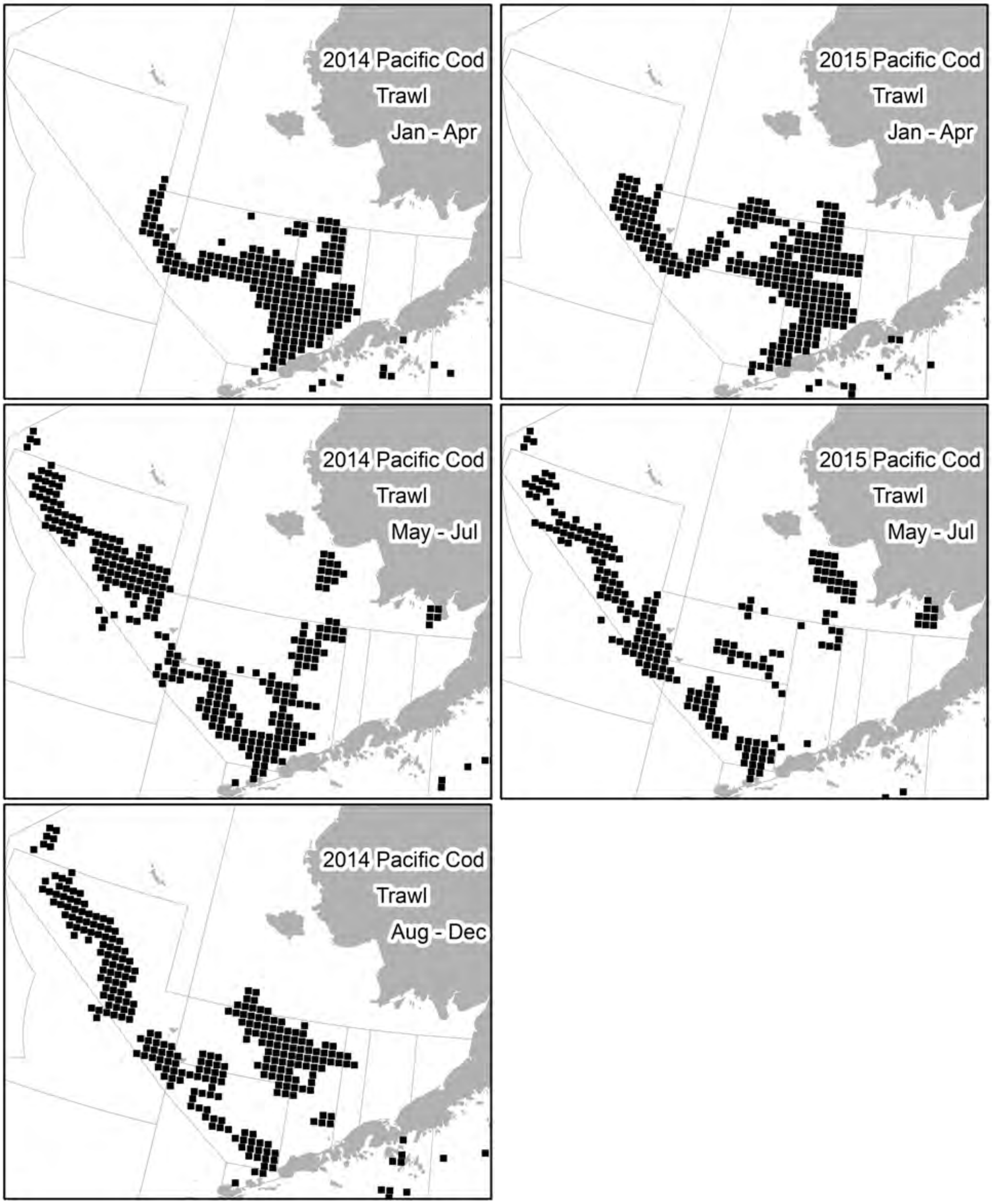


Figure 2.1a. EBS maps showing each 400 square km cell with trawl hauls containing Pacific cod from at least 3 distinct vessels by season in 2014-2015, overlaid against NMFS 3-digit statistical areas.

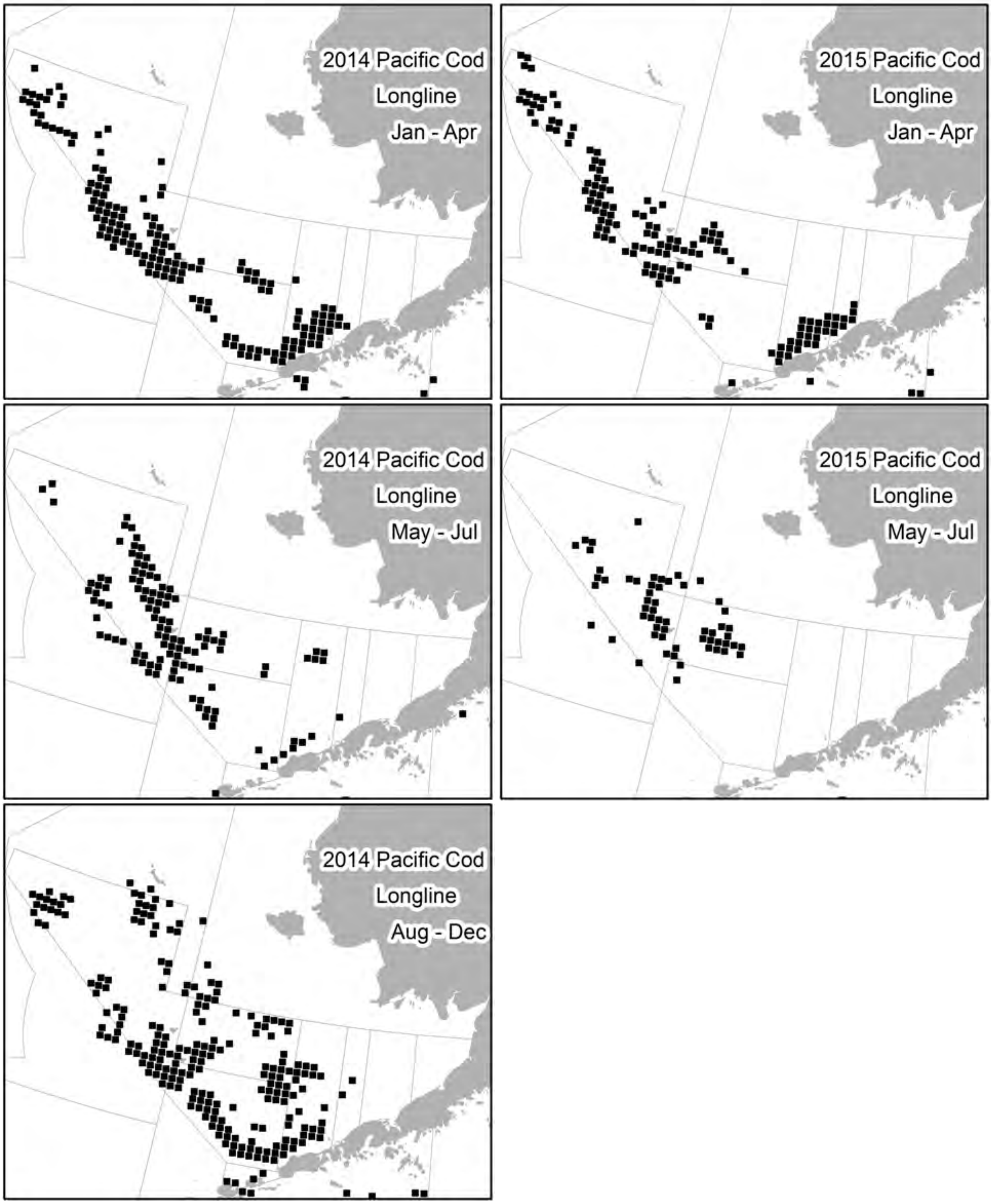


Figure 2.1b. EBS maps showing each 400 square km cell with longline sets containing Pacific cod from at least 3 distinct vessels by season in 2014-2015, overlaid against NMFS 3-digit statistical areas.

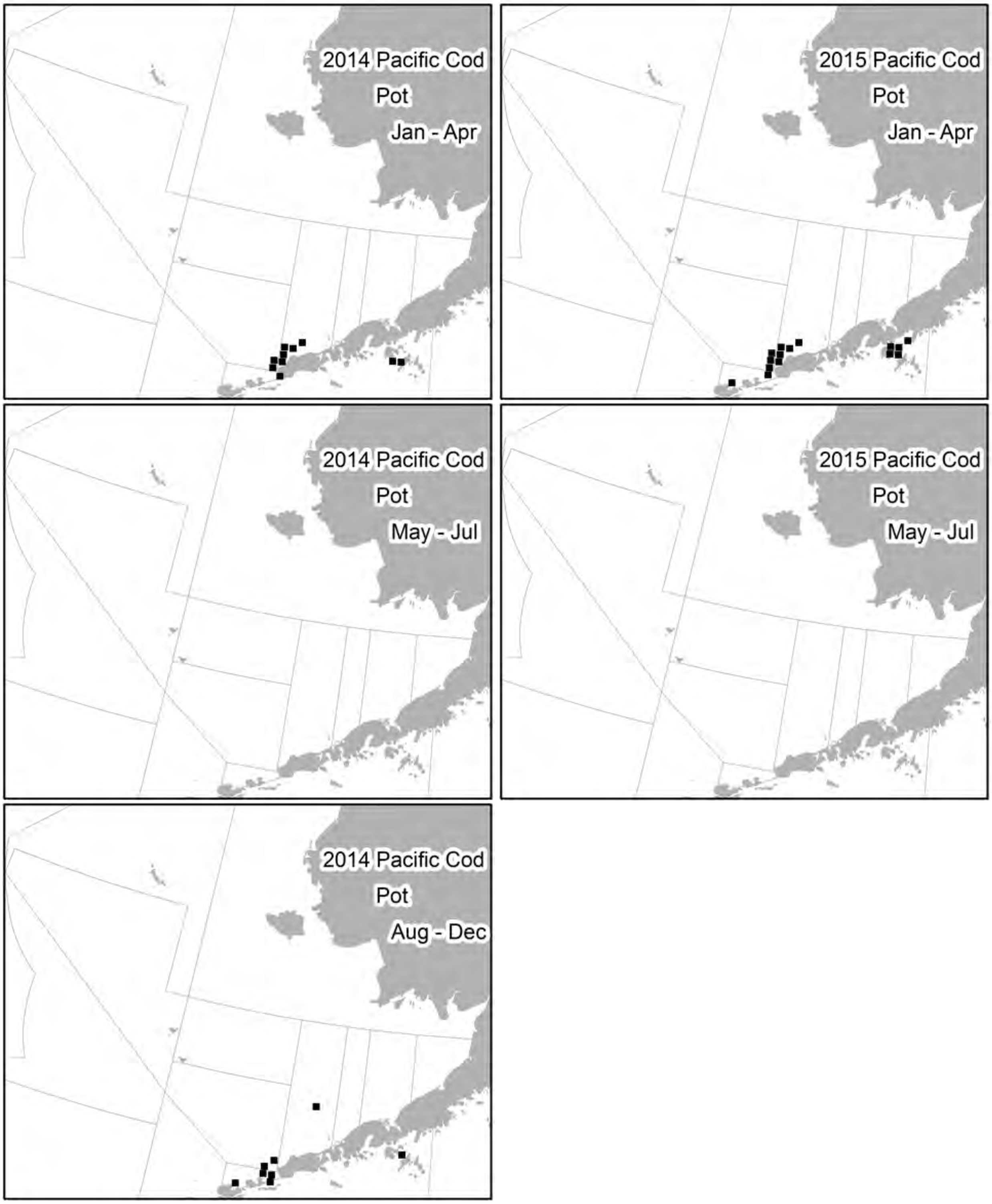


Figure 2.1c. EBS maps showing each 400 square km cell with pot sets containing Pacific cod from at least 3 distinct vessels by season in 2014-2015, overlaid against NMFS 3-digit statistical areas.

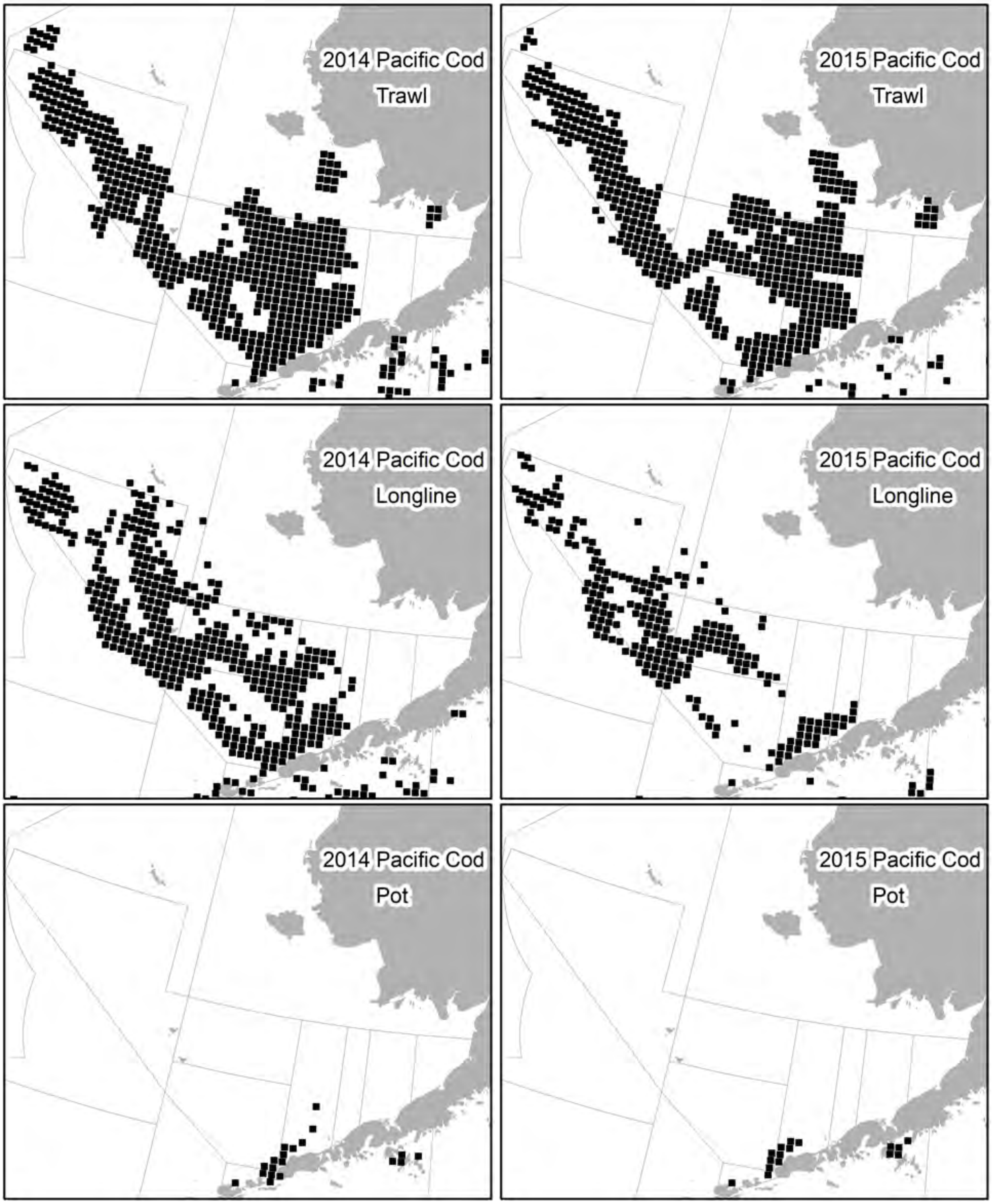


Figure 2.2. Maps showing each 400 square km cell with pot sets containing Pacific cod from at least 3 distinct vessels by season in 2014-2015, overlaid against NMFS 3-digit statistical areas.

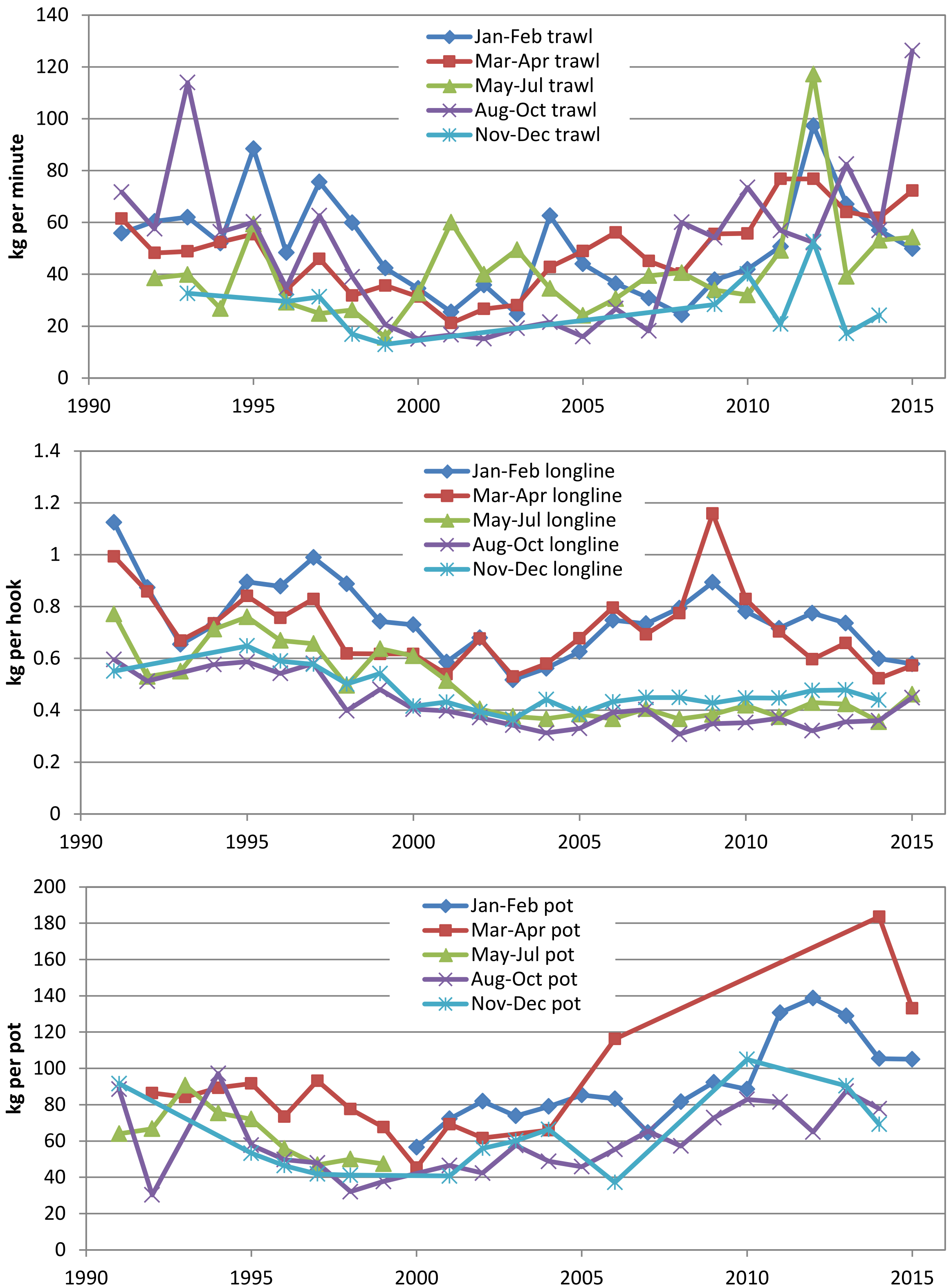


Figure 2.3—Time series of fishery catch per unit effort, by gear and season.

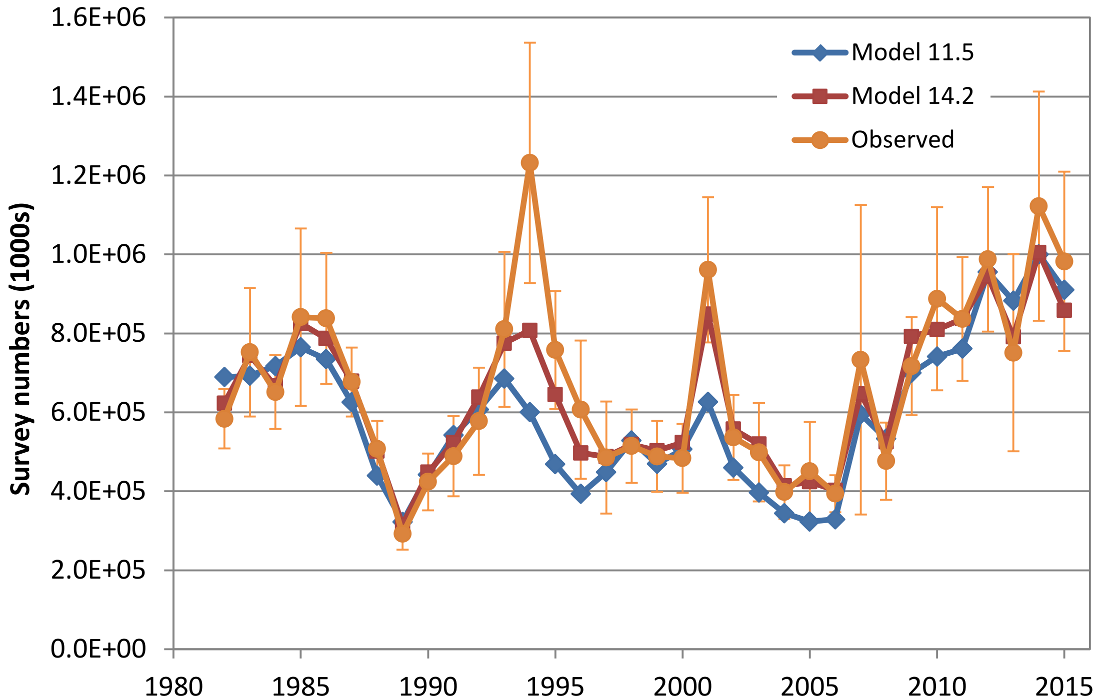


Figure 2.4—Model fits to the trawl survey abundance time series, with 95% confidence intervals for the observations.

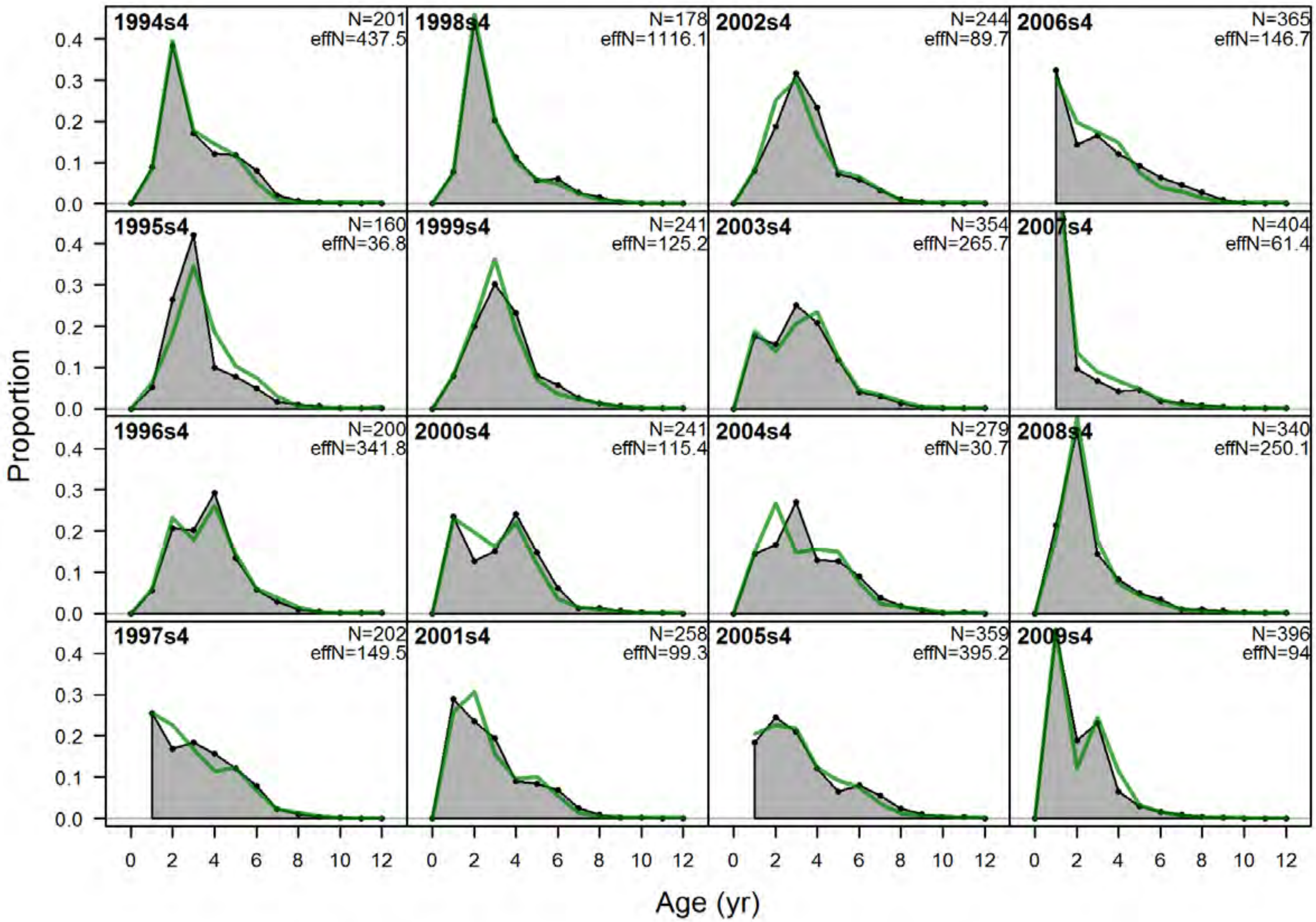


Figure 2.5a (page 1 of 2)—Fit to trawl survey age composition data obtained by Model 11.5 (grey = observed, green = estimated).

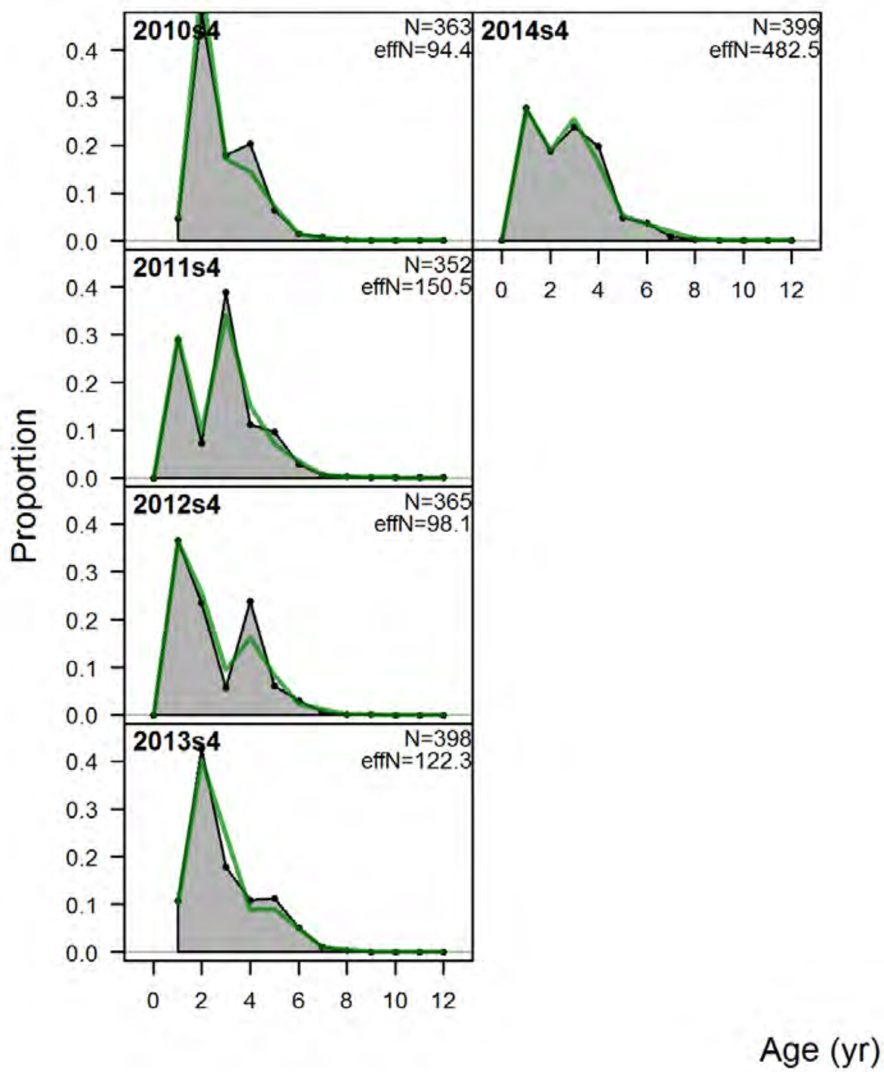


Figure 2.5a (page 2 of 2)—Fit to trawl survey age composition data obtained by Model 11.5 (grey = observed, green = estimated).

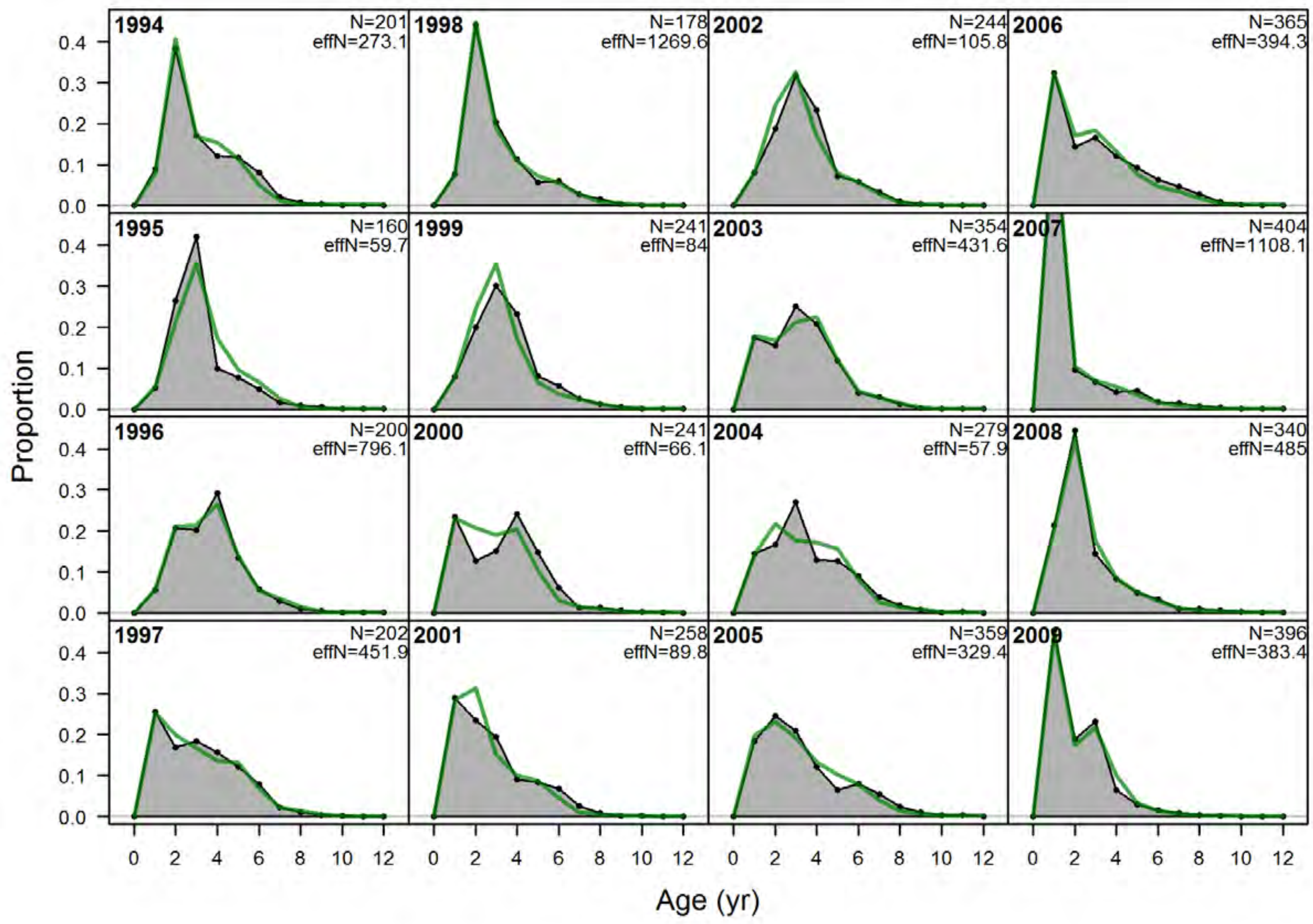


Figure 2.5b (page 1 of 2)—Fit to trawl survey age composition data obtained by Model 14.2 (grey = observed, green = estimated).

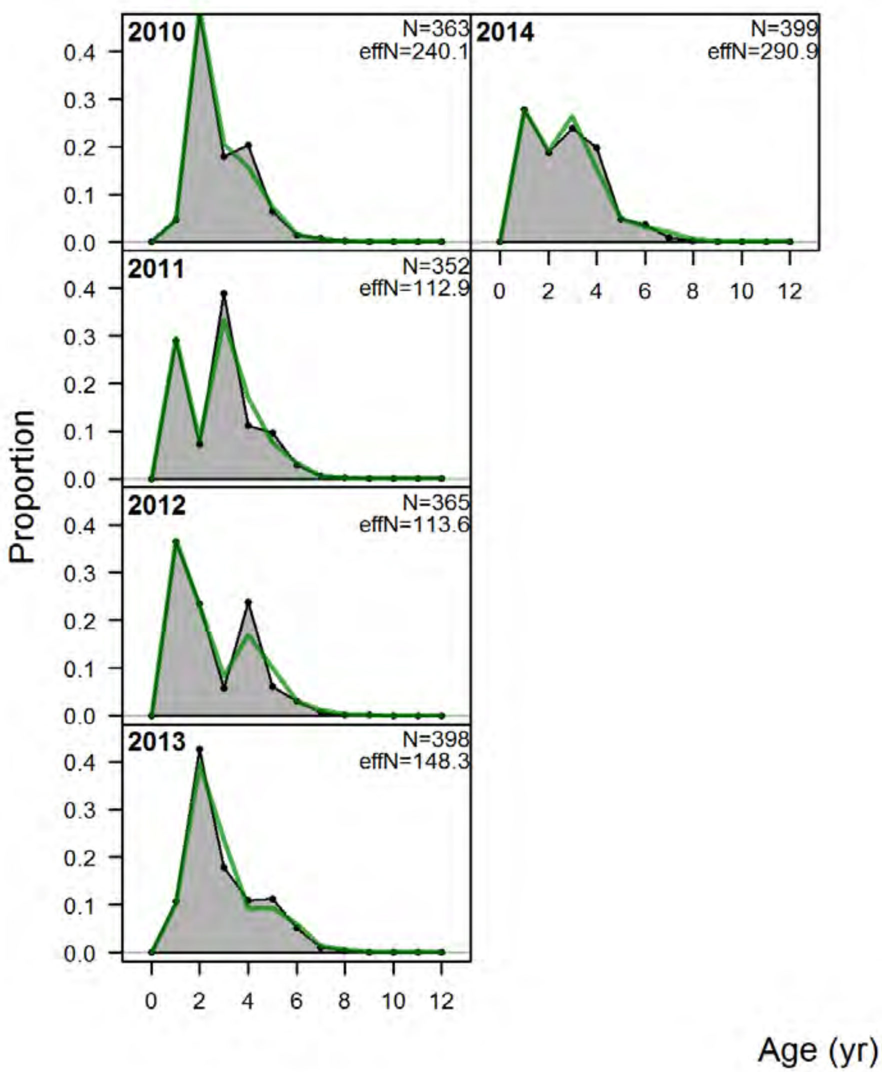


Figure 2.5b (page 2 of 2)—Fit to trawl survey age composition data obtained by Model 14.2 (grey = observed, green = estimated).

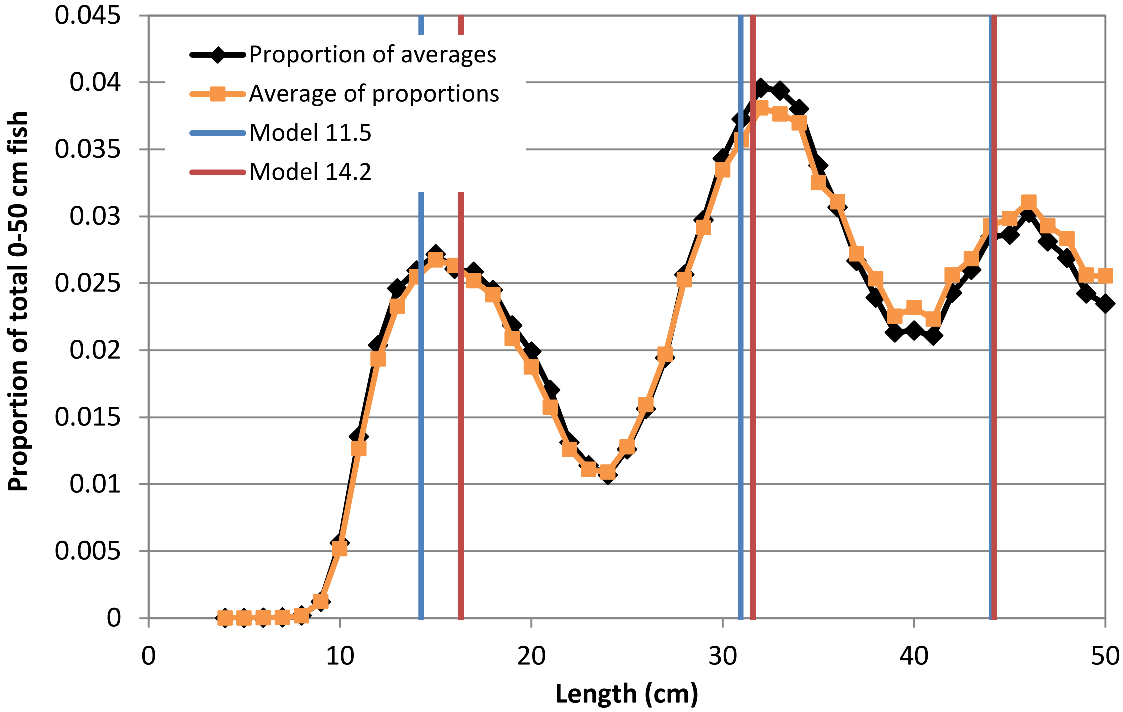


Figure 2.6—Estimates of mean size at ages 1-3 from Models 1 and 2, compared to long-term average survey size (0-50 cm) composition.

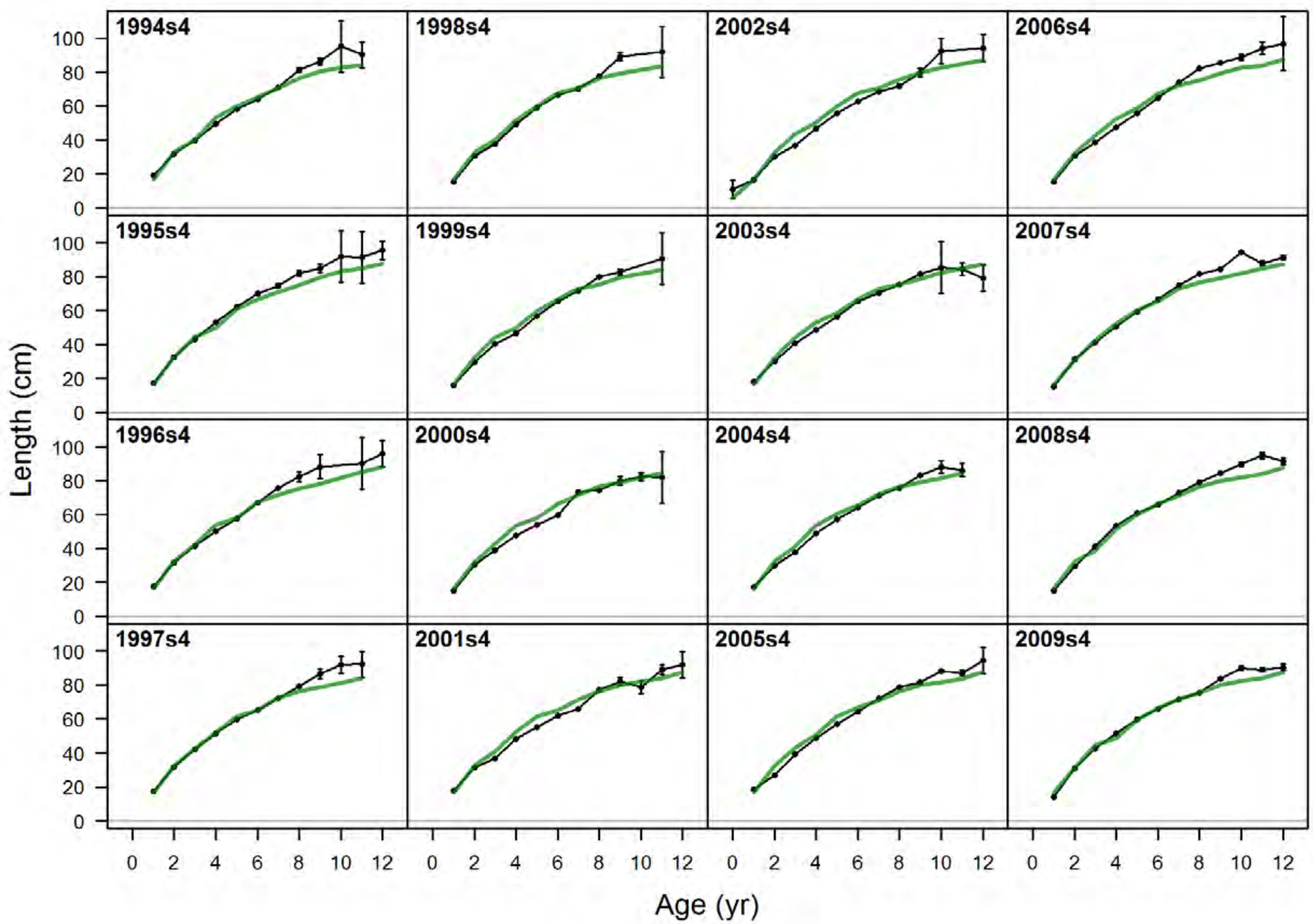


Figure 2.7 (page 1 of 2)—Fit to mean-size-at-age data from Model 11.5 (not used in Model 14.2). Black = observed, green = estimated.

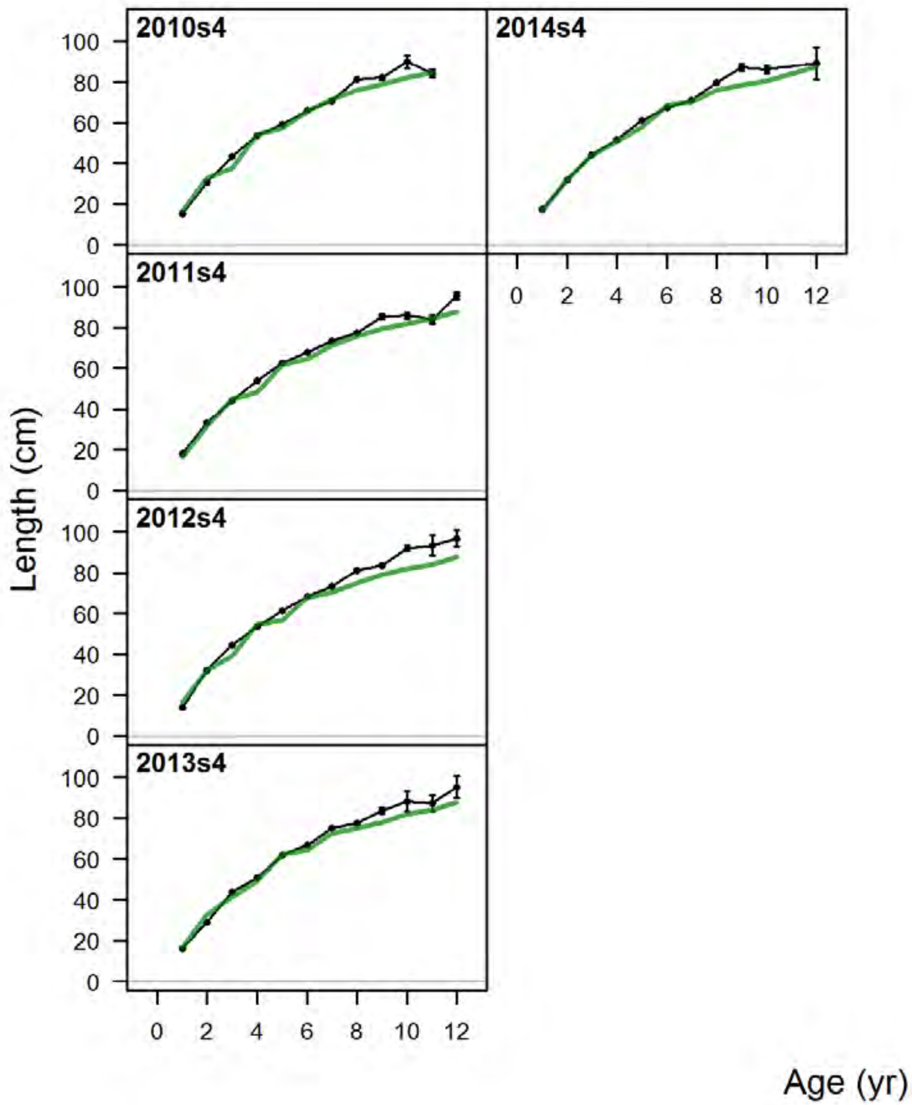


Figure 2.7 (page 2 of 2)—Fit to mean-size-at-age data from Model 11.5 (not used in Model 14.2). Black = observed, green = estimated.

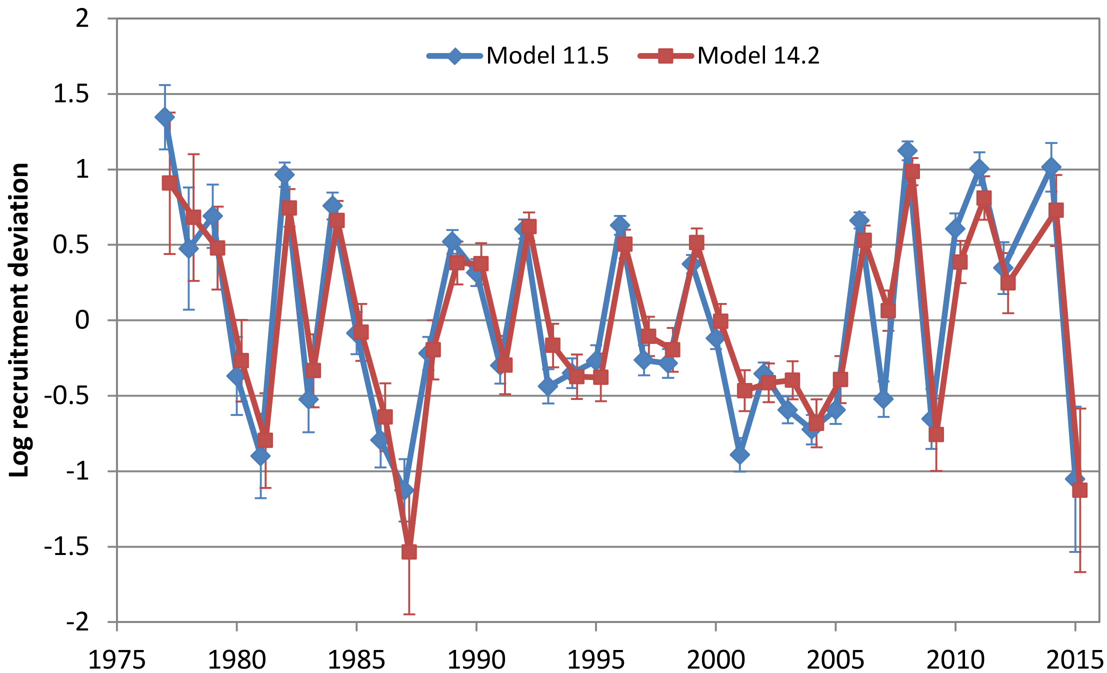


Figure 2.8—Time series of estimated log recruitment deviations as estimated by Models 1 and 2, with 95% confidence intervals.

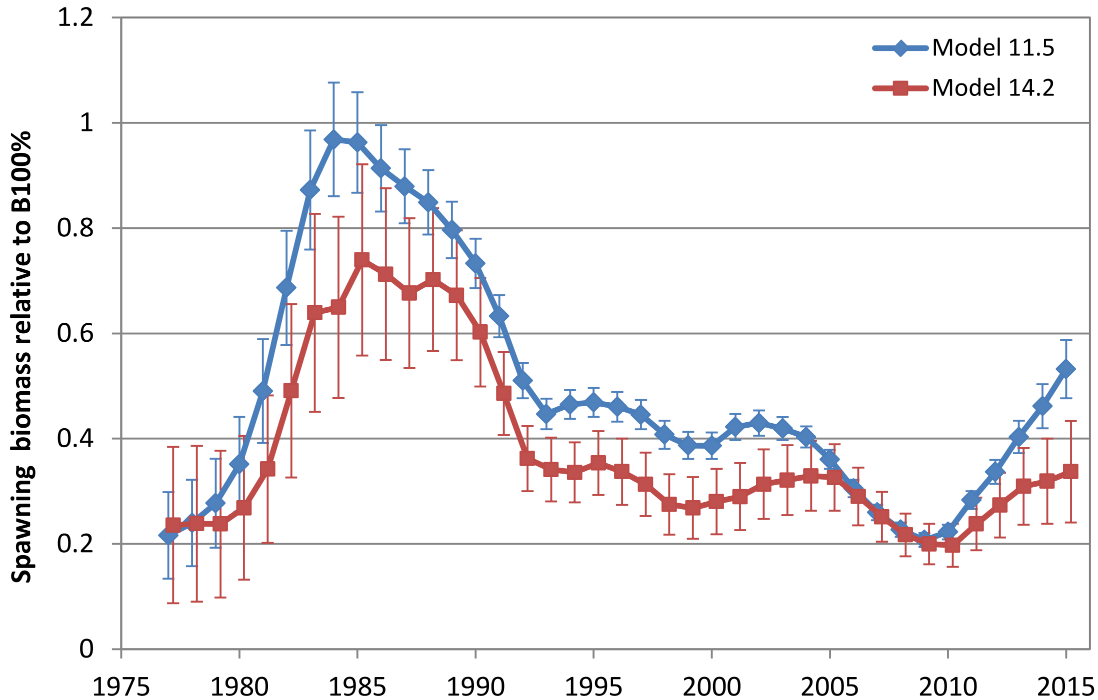


Figure 2.9a—Time series of spawning biomass relative to $B_{100\%}$ as estimated by Models 11.5 and 14.2.

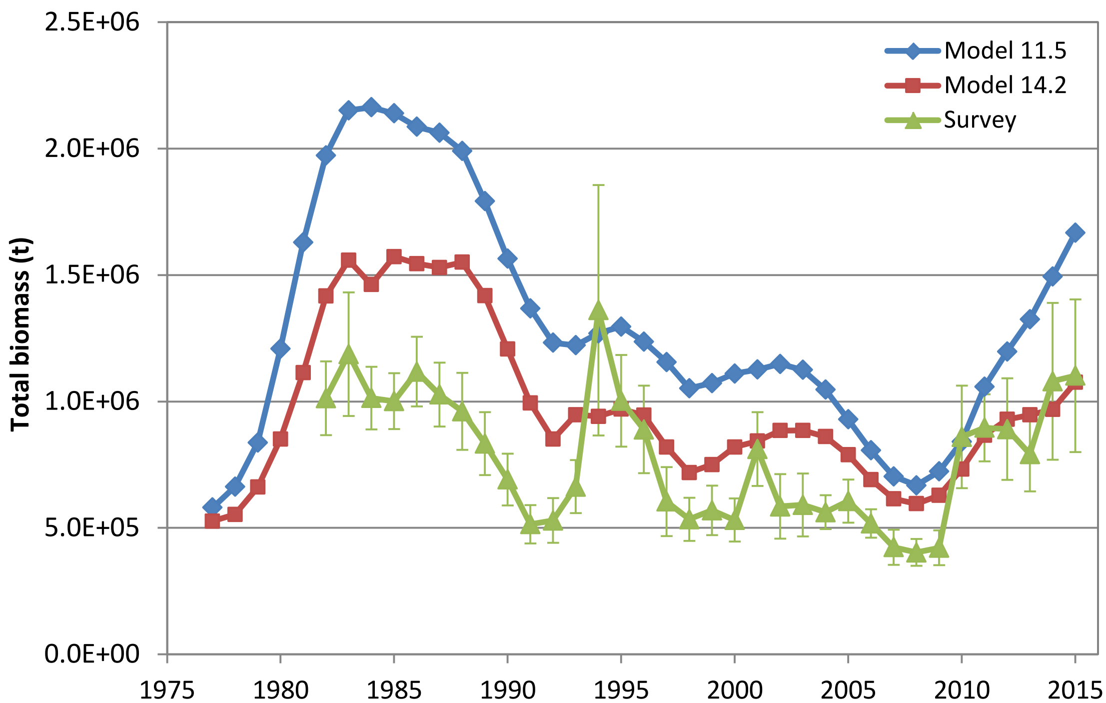
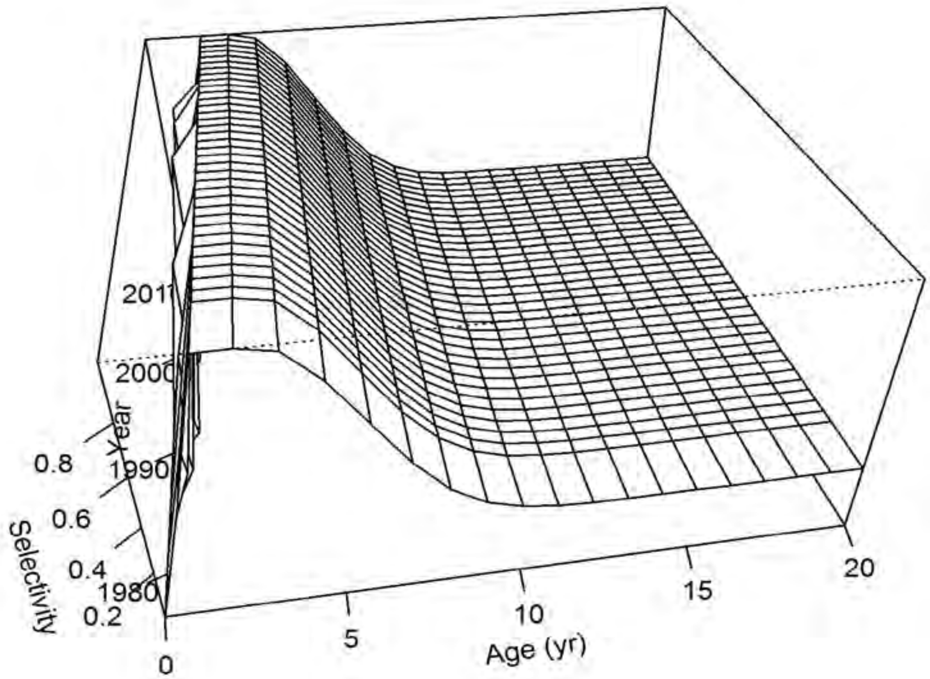


Figure 2.9b—Time series of total biomass (t) as estimated by Models 11.5 and 14.2, with survey biomass shown for comparison.

Model 11.5



Model 14.2

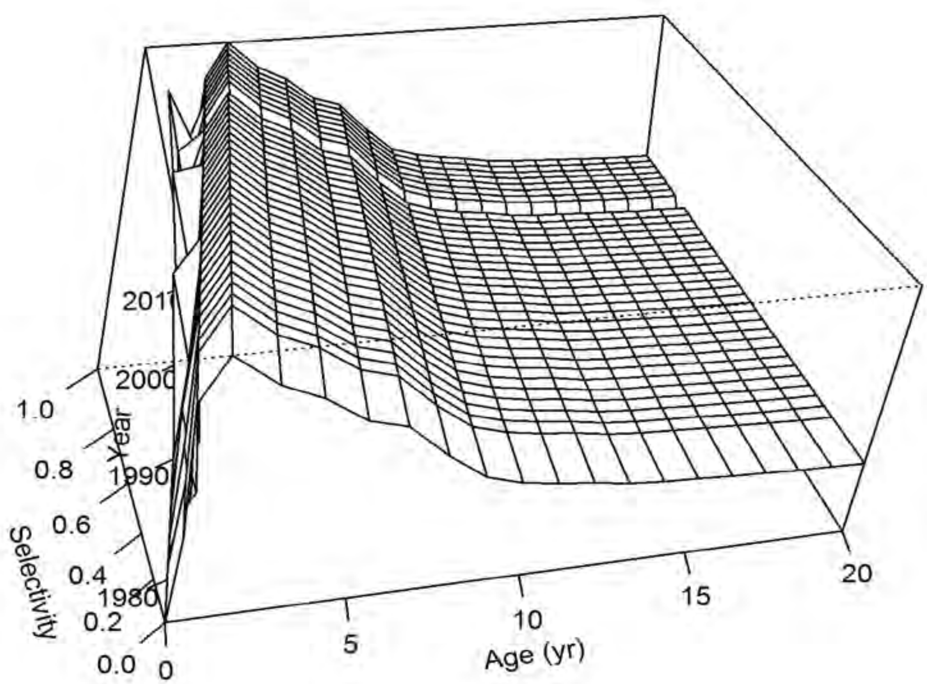


Figure 2.10—Trawl survey selectivity at age as estimated by Models 11.5 and 14.2.

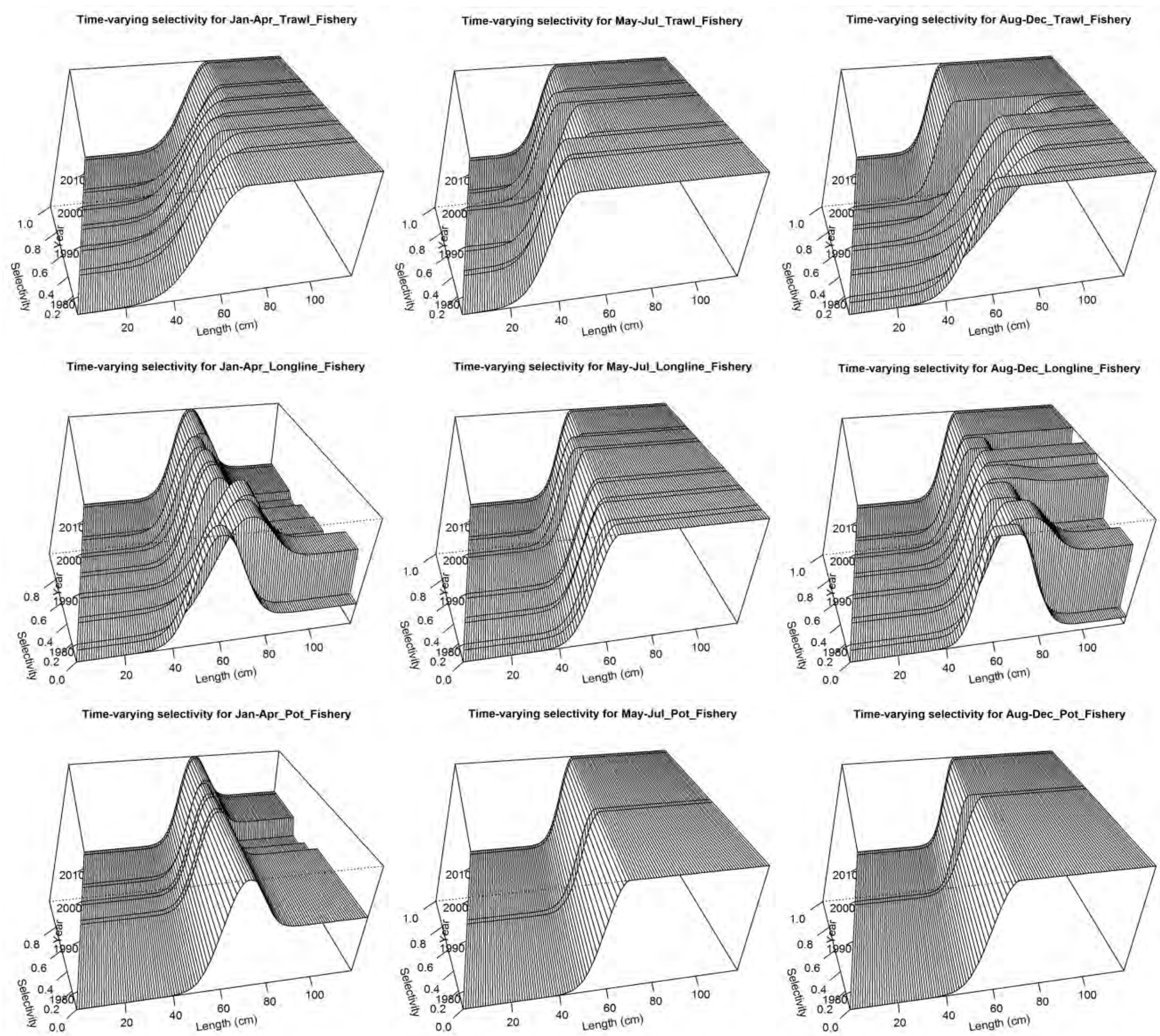


Figure 2.11a—Fishery selectivity at length (cm) as estimated by Model 11.5. Rows represent gear types (trawl, longline, and pot, respectively), and columns represent seasons (Jan-Apr, May-Jul, and Aug-Dec, respectively).

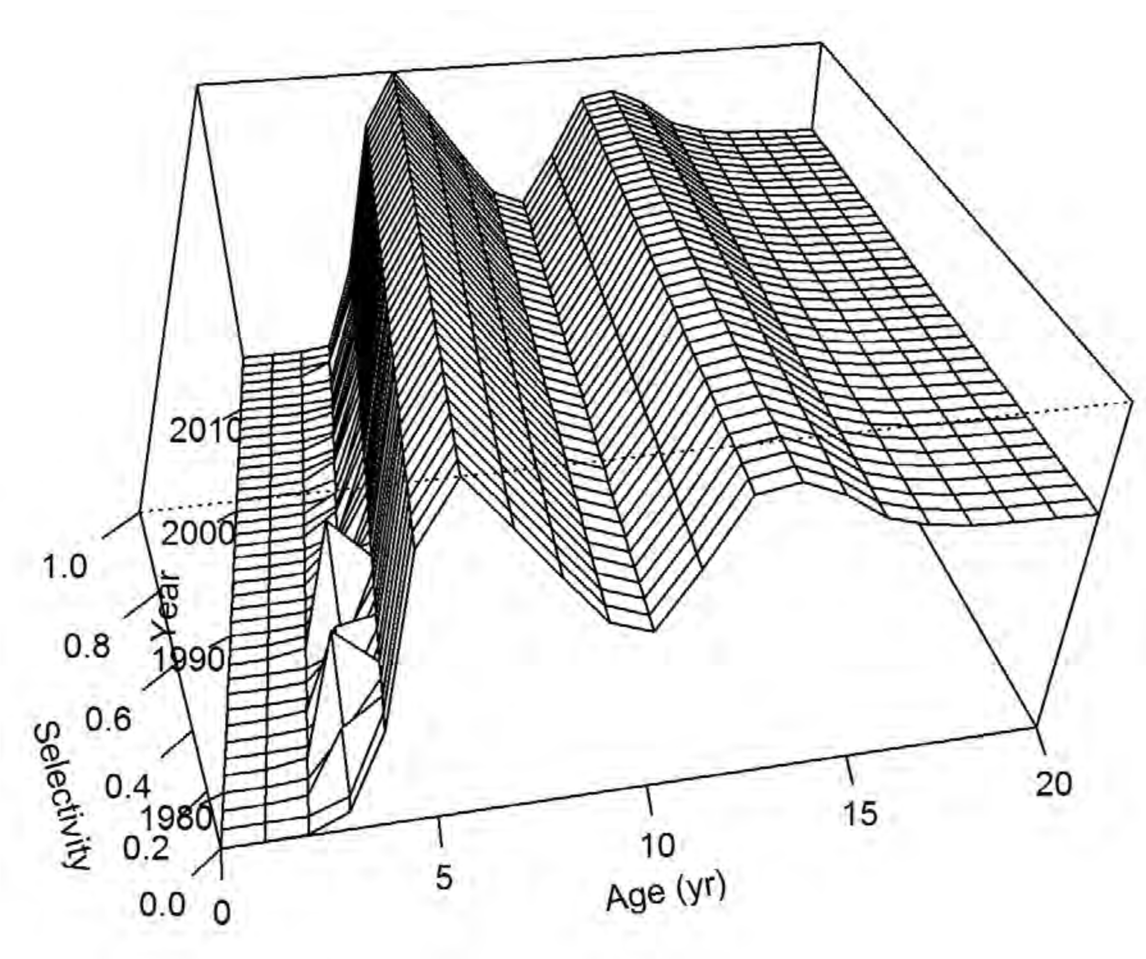


Figure 2.11b—Fishery selectivity at age as estimated by Model 14.2.

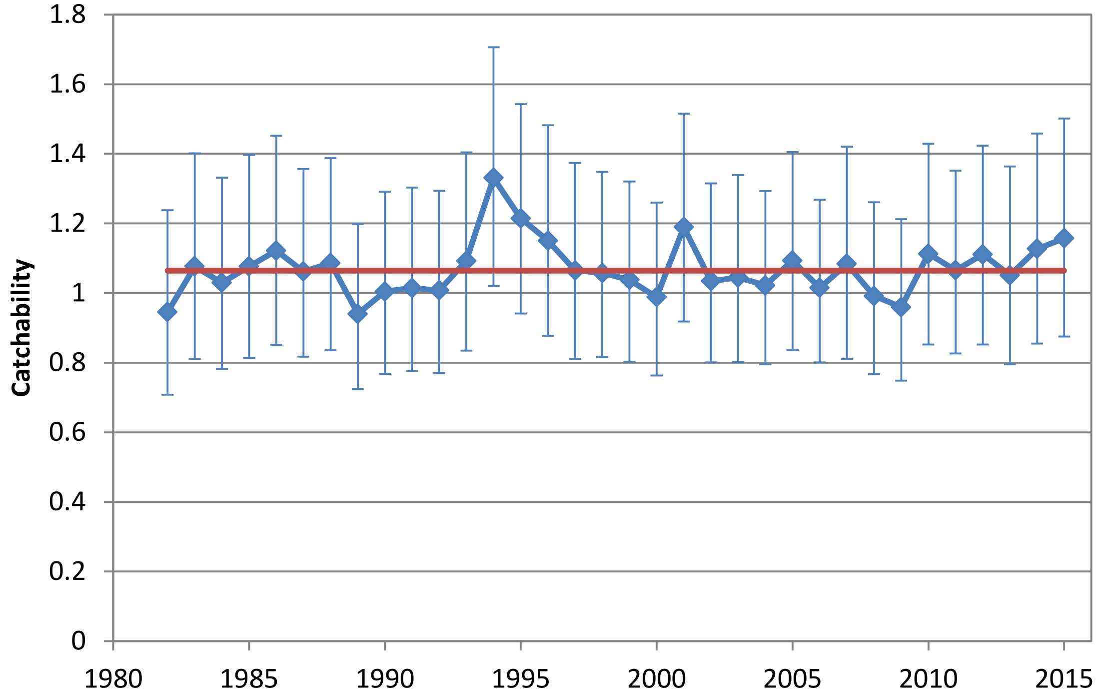


Figure 2.12—EBS bottom trawl survey catchability (*Q*) time series as estimated by Model 14.2. Blue diamonds = lognormal means, error bars = lognormal 95% confidence intervals. Red line = base value.

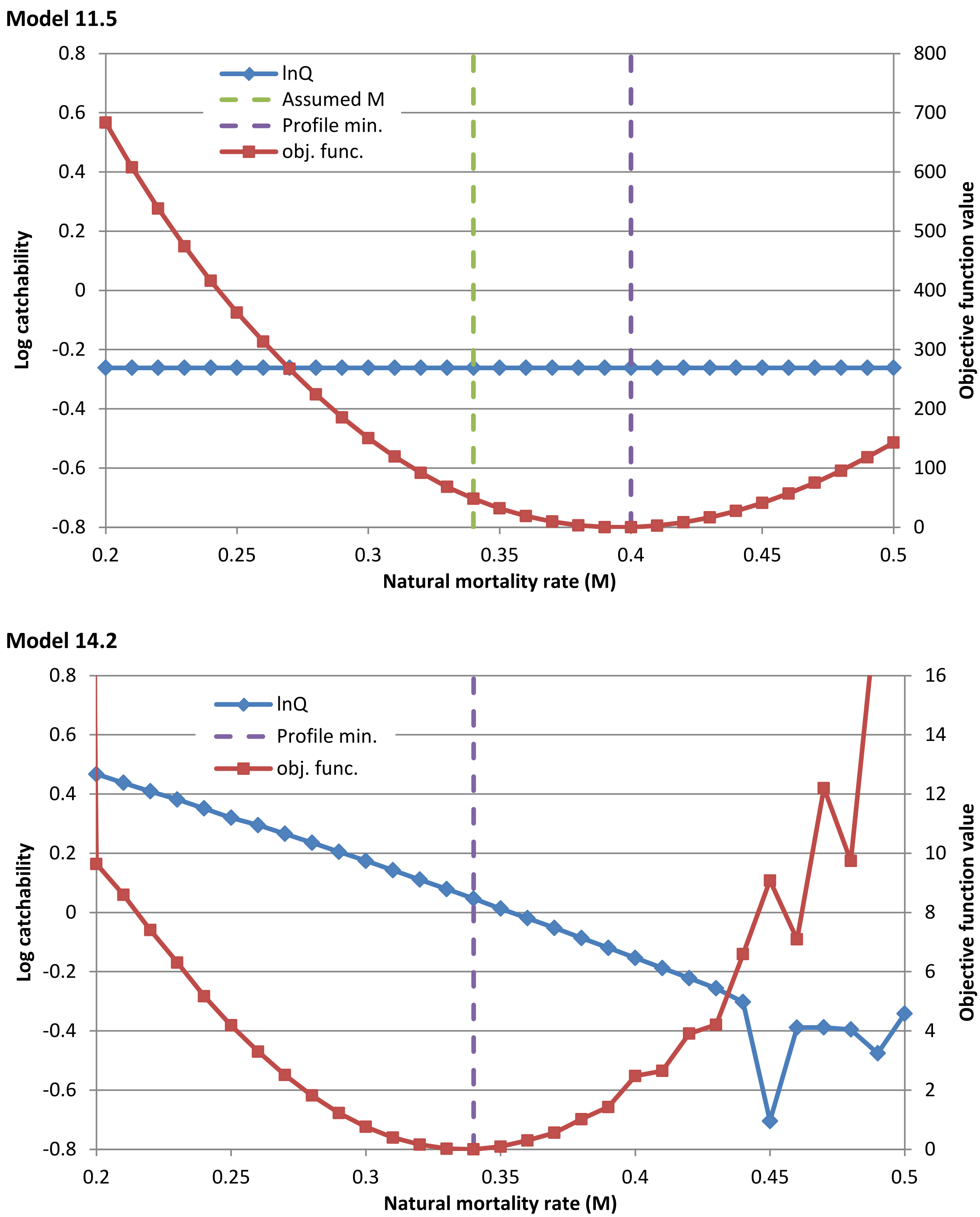


Figure 2.13—Likelihood profiles with respect to the natural mortality rate for Models 11.5 and 14.2. Objective function minima occur at *M*=0.40 (Model 11.5) and *M*=0.34 (Model 14.2). The relationship between *M* and log *Q* is also shown (*Q* is not estimated in Model 11.5). The jagged shapes for high values of *M* in Model 14.2 are likely due to lack of convergence in some runs.

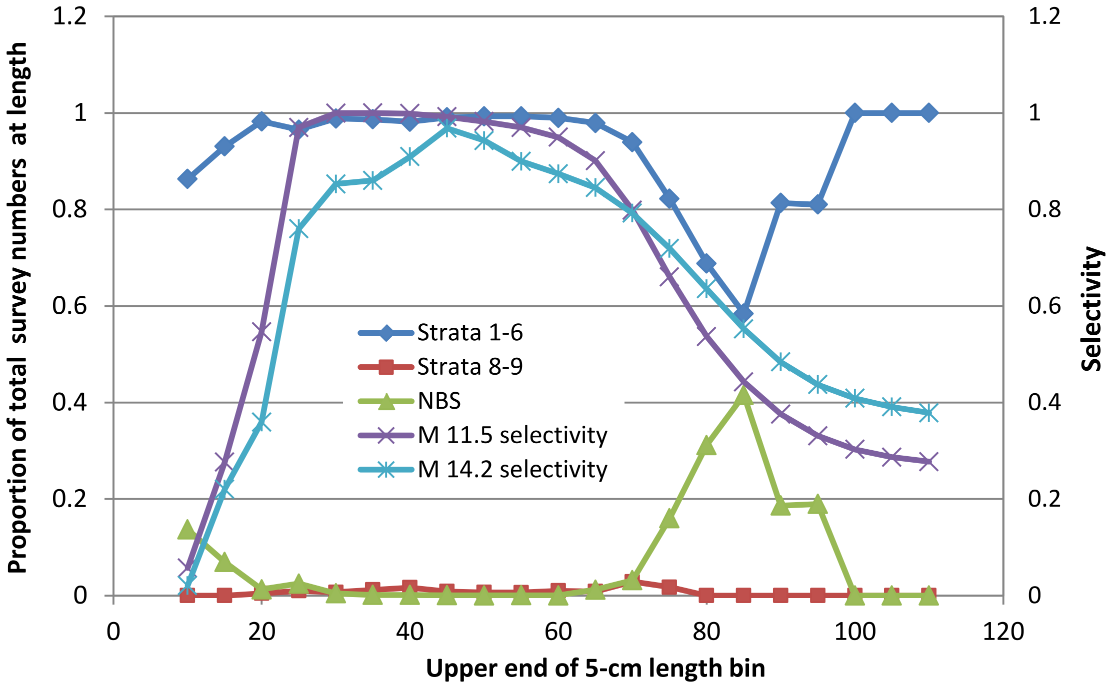


Figure 2.14—Proportion of overall (EBS+NBS) survey numbers at length from the 2010 EBS and NBS shelf surveys, overlaid against each model's estimated schedule of survey selectivity. See text for details.

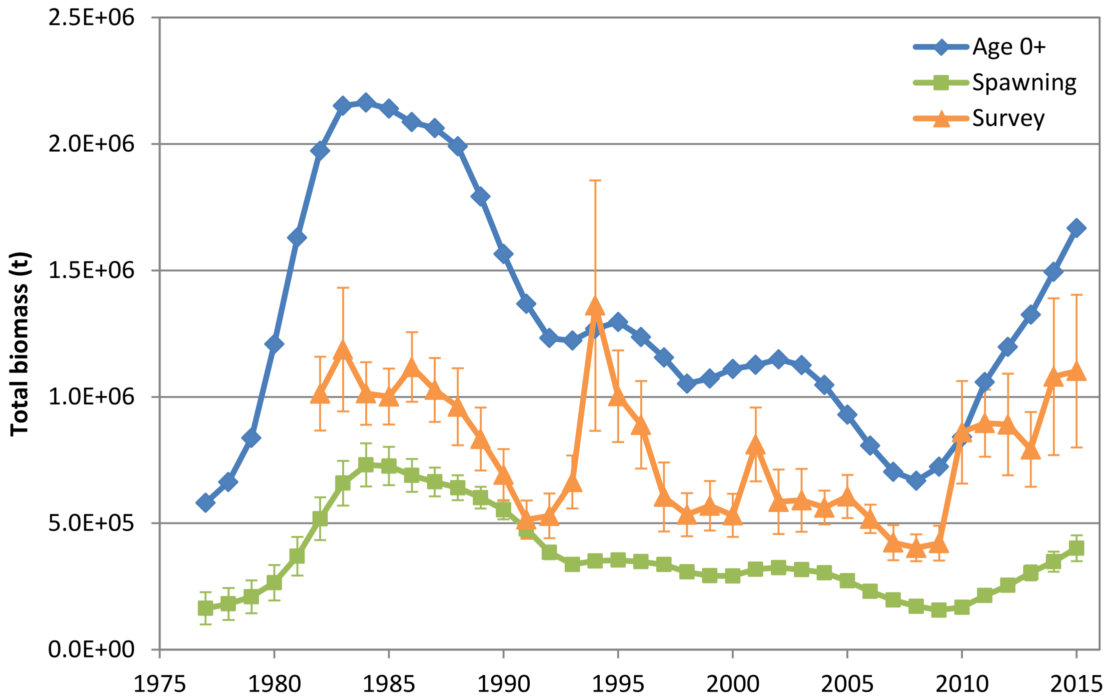


Figure 2.15—Time series of age 0+ and female spawning biomass as estimated by Model 11.5. Survey biomass is shown for comparison.

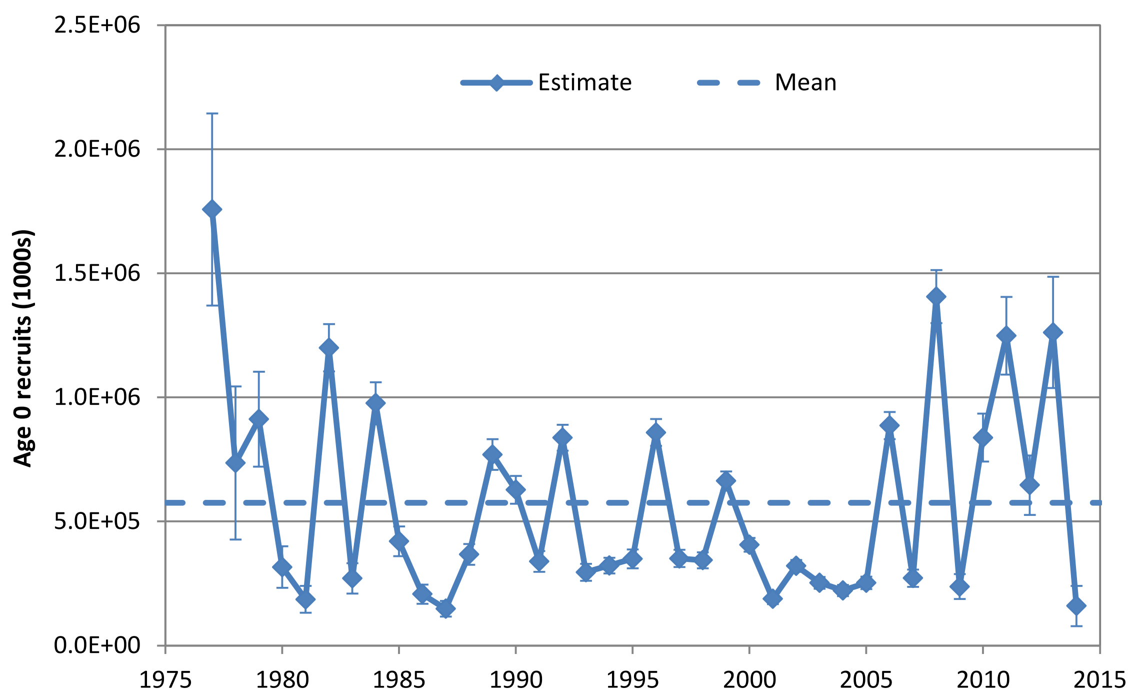


Figure 2.16—Time series of recruitment at age 0 as estimated Model 11.5.

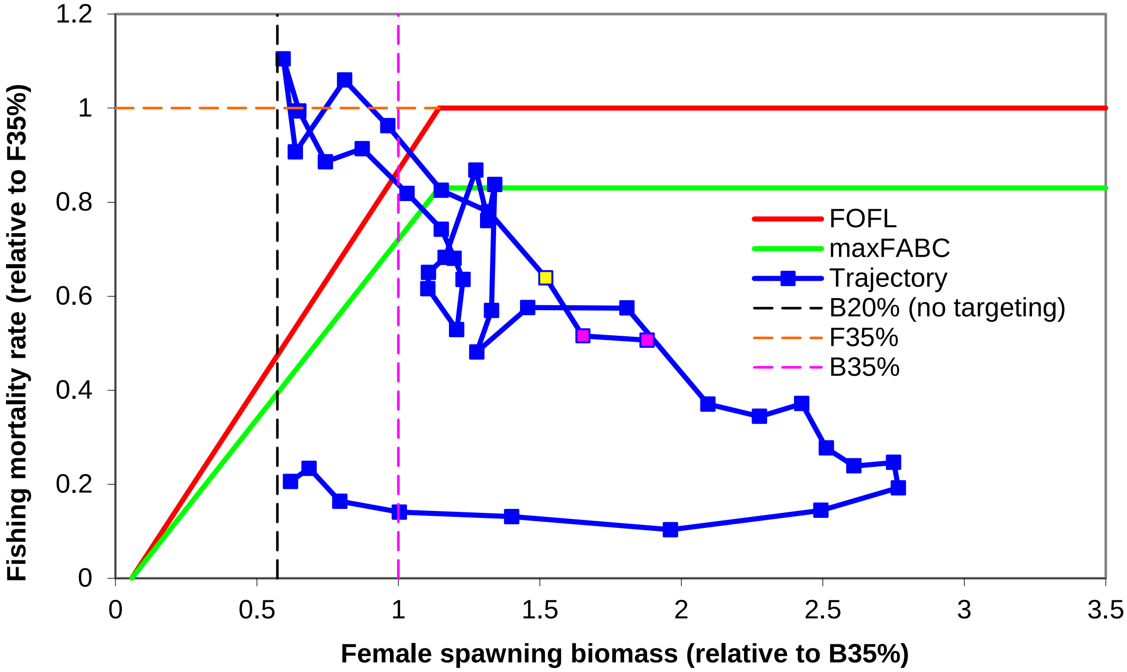


Figure 2.17a—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model 11.5, 1977-2017 (yellow square = current year, magenta squares = first two projection years).

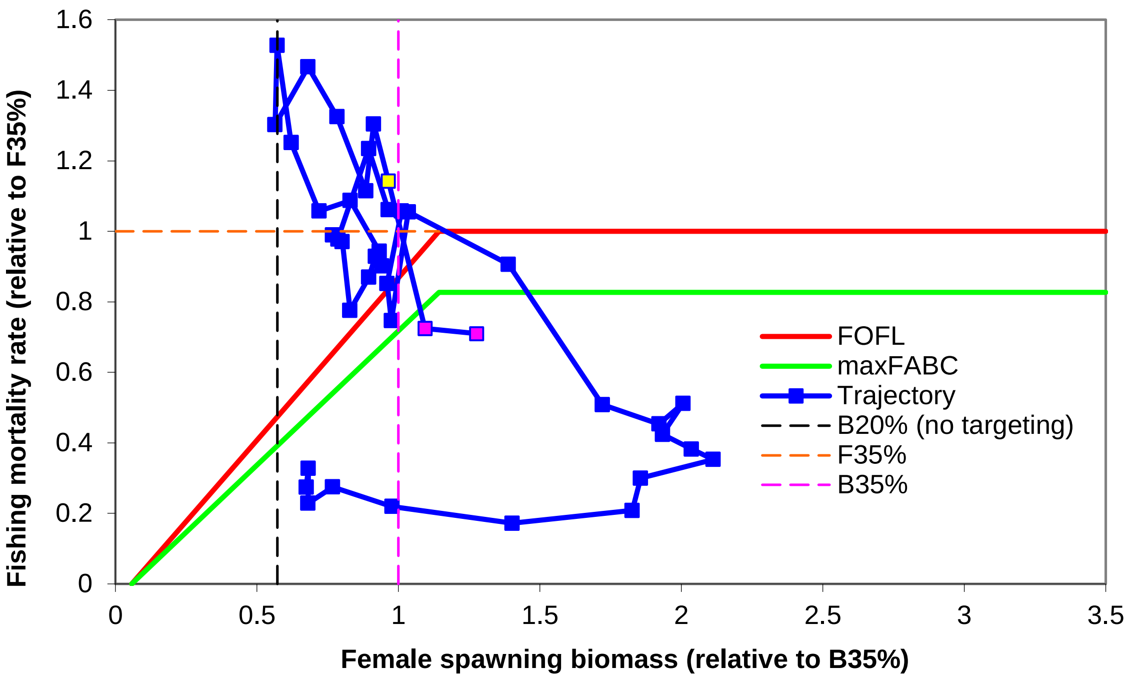
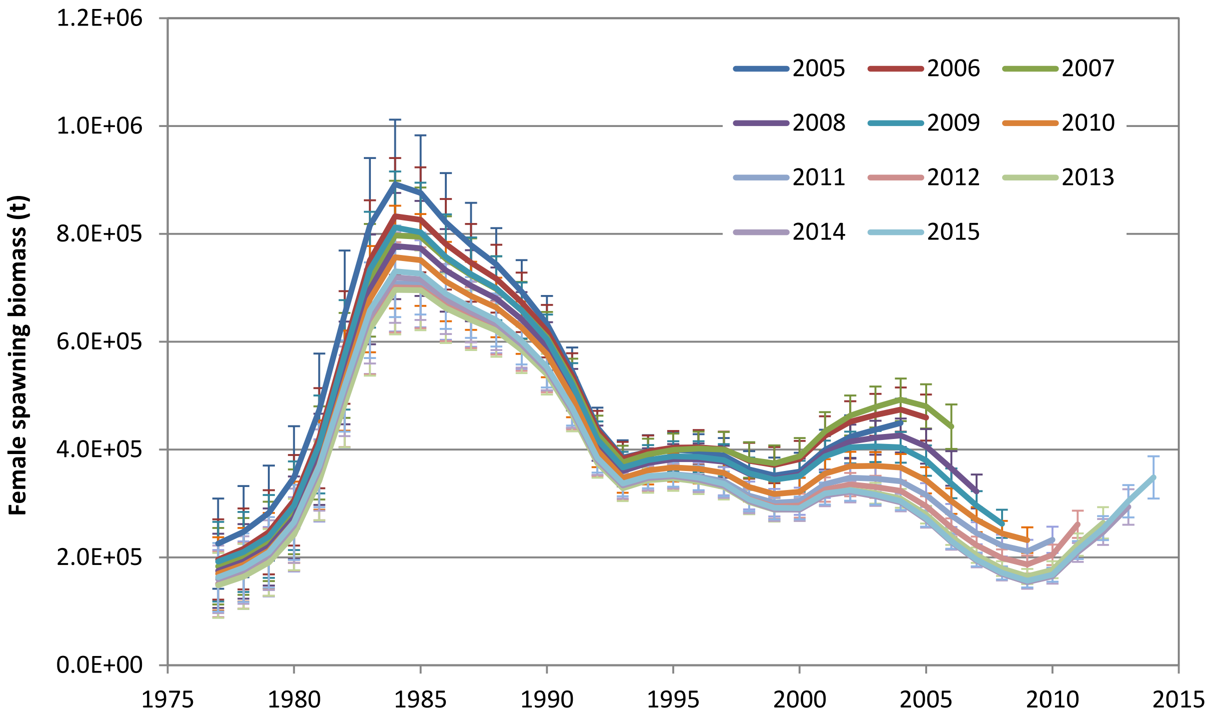


Figure 2.17b—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model 14.2, 1977-2017 (yellow square = current year, magenta squares = first two projection years).



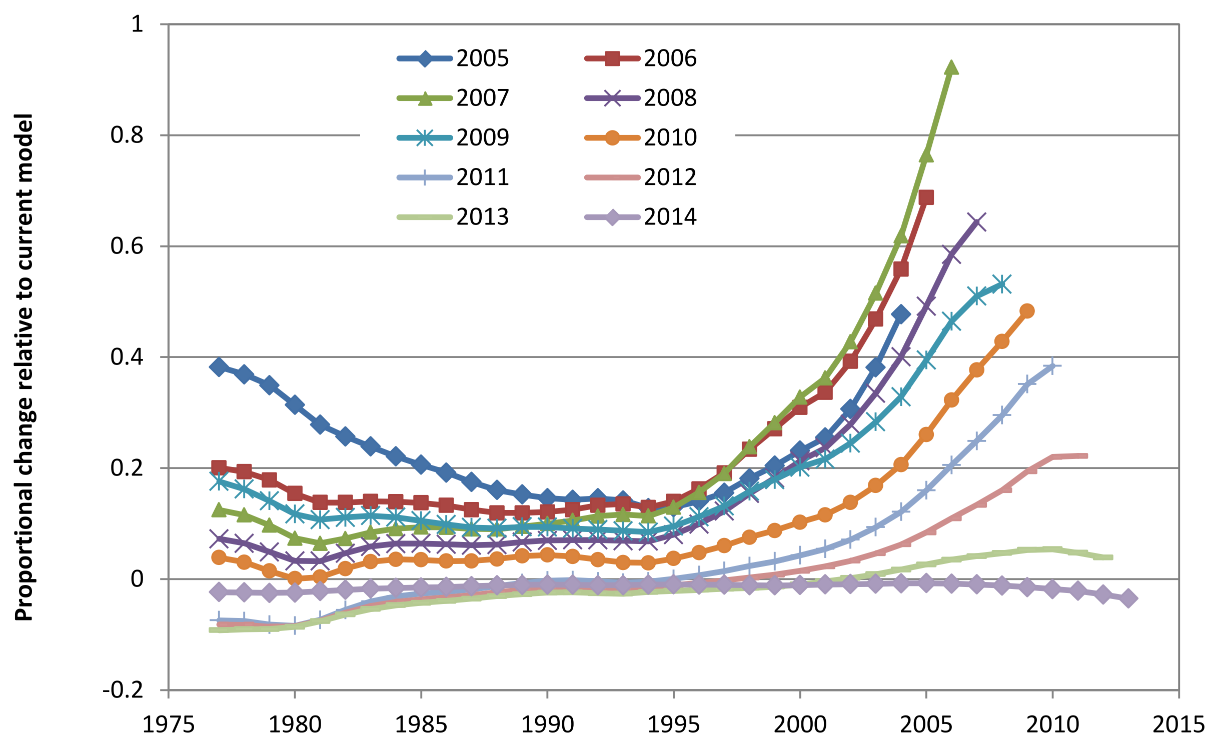


Figure 2.18—Retrospective analysis of spawning biomass estimates from Model 11.5. Top panel: spawning biomass time series with 95% confidence intervals from the current version of Model 11.5 (2015) and 10 retrospective runs (2005-2014) obtained by dropping one year of data at a time. Bottom panel: change in spawning biomass relative to the current version of Model 11.5 for each of 10 retrospective runs.

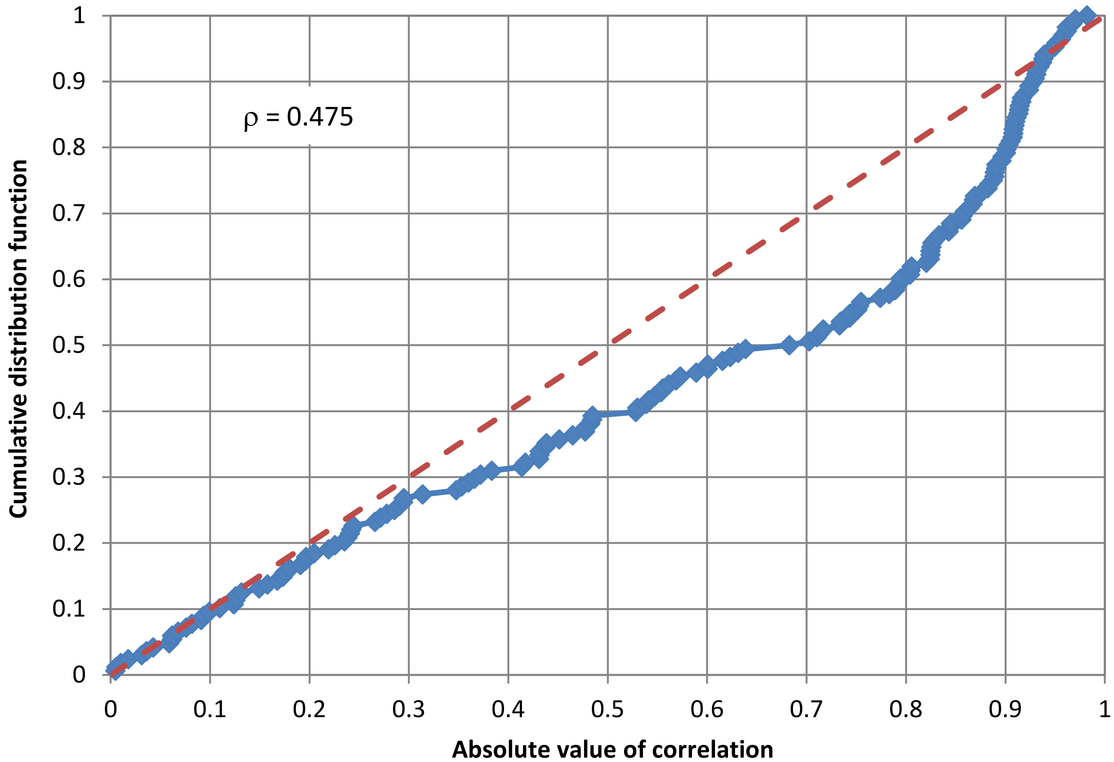


Figure 2.19—Cumulative distribution function (cdf) of correlations (absolute value) between model parameters and number of "peels" in retrospective runs. The diagonal dashed line represents the cdf that would be obtained from a uniform distribution. The statistic ρ represents the average (across peels) relative bias in terminal year estimates of spawning biomass.

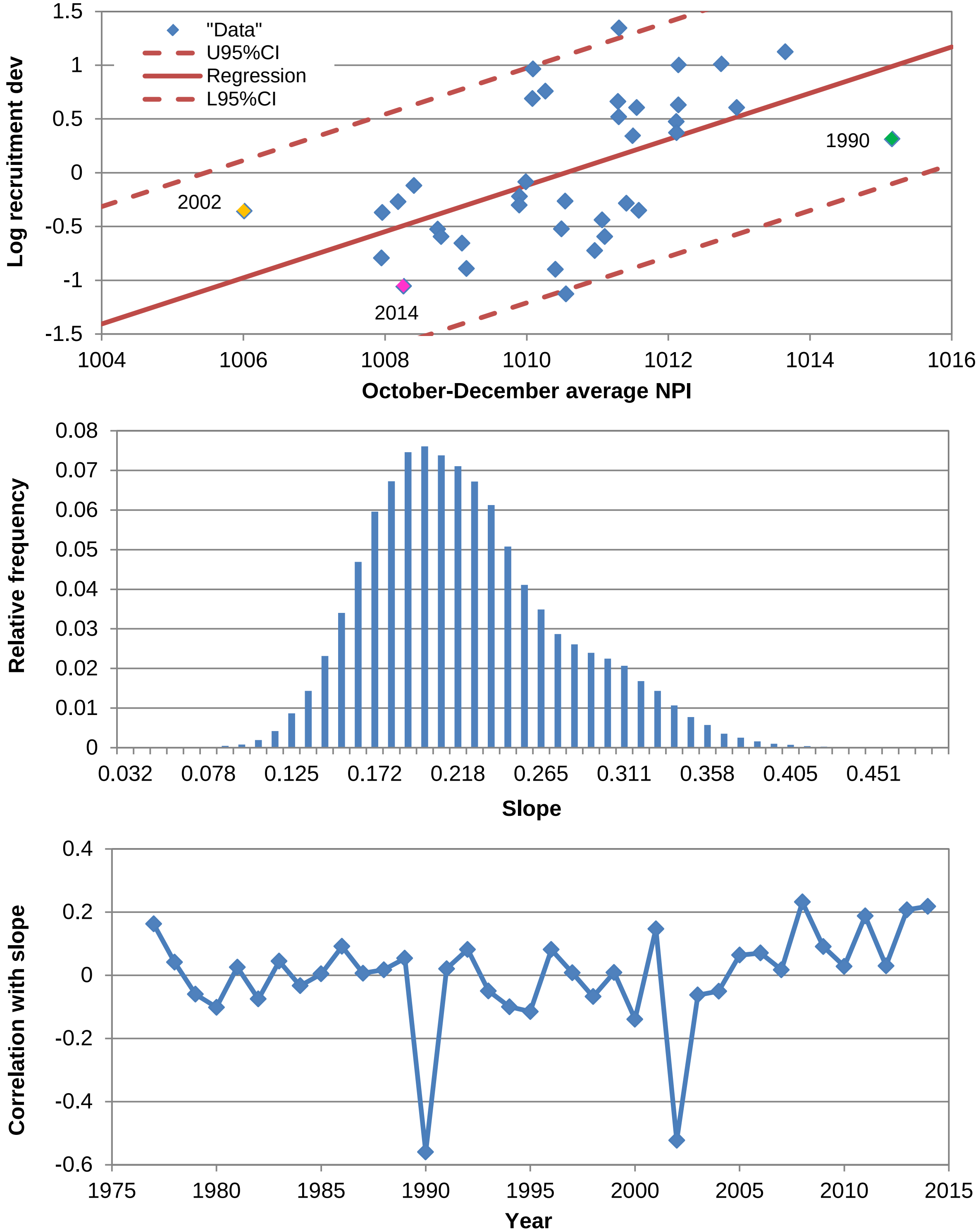


Figure 2.20—Environmental effects on recruitment. Upper panel: Estimated log recruitment *devs* (age 0) versus same-year October-December average of the NPI, with regression line and 95% confidence interval. Middle panel: Distribution of the regression slope, as generated by a cross-validation analysis. Lower panel: Correlation between individual data points and regression slope. See text for details.

APPENDIX 2.1: PRELIMINARY ASSESSMENT OF THE PACIFIC COD STOCK IN THE EASTERN BERING SEA

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Introduction

This document represents an effort to respond to comments made by the BSAI Plan Team, the Joint Team Subcommittee on Pacific cod models (JTS), and the SSC on last year's assessment of the Pacific cod (*Gadus macrocephalus*) stock in the eastern Bering Sea (EBS, Thompson 2014).

Responses to SSC and Plan Team comments on assessments in general

SSC1 (12/14 minutes): *"The SSC requests that stock assessment authors use the following model naming conventions in SAFE chapters:*

- *Model 0: last years' model with no new data,*
- *Model 1: last years' model with updated data, and*
- *Model numbers higher than 1 are for proposed new models."*

Model nomenclature in this preliminary assessment adheres to the above conventions, with the exception that not all model numbers higher than 1 correspond to proposed *new* models (in addition to last year's final model, another of the models presented in this preliminary assessment was also included in last year's assessment).

SSC2 (12/14 minutes): *"The SSC also requests that stock assessment authors use the random effects model for area apportionment of ABCs."* The EBS Pacific cod ABC is not apportioned by area.

Responses to SSC and Plan Team comments specific to Eastern Bering Sea Pacific cod

Note: Following the procedure initiated in 2014, the task of developing recommendations for models to be included in this year's preliminary Pacific cod assessments (subject to review and potential revision by the SSC) was delegated to the JTS rather than the full Joint Plan Teams.

BPT1 (11/14 minutes): *"The Team … recommends … bring[ing] Model 2 back next year as the presumptive reference model for 2016."* This comment was forwarded to the JTS for consideration at its May 2015 meeting.

SSC3 (12/14 minutes): *"The SSC recommends that the author conduct a simulation study to better understand the estimability of the selectivity type 17 in Stock Synthesis and the estimation of annual deviations."* This comment was forwarded to the JTS for consideration at its May 2015 meeting.

SSC4 (12/14 minutes): *"The SSC recommends that a statistical approach be used to weight the composition data (i.e., iterative re-weighting, or other methods outlined in Francis 2011)."* This comment was forwarded to the JTS for consideration at its May 2015 meeting.

JTS1 (5/15 minutes): *"For the EBS, the subcommittee recommended that the following models be developed for this year's preliminary assessment:*

- *Model 0: Final model from 2014 (same as the final models from 2011, 2012, and 2013)*
- *Model 2: Model 2 from the 2014 final assessment*
- *Model 3: Model 2 from the 2014 final assessment, but with:*
    - *composition data weighted either: 1) iteratively, 2) by the method of Francis (2011), or 3) by tuning the harmonic mean of the effective sample sizes to the mean input sample size*
    - *time-varying catchability turned off*
- *Model 4: Model 2 from the 2014 final assessment, but with:*
    - *internal estimation of σ_R replaced by something that attempts to account for the downward bias in the MLE*
    - *estimation of a larger number of age groups in the initial vector"*

The above models are included in this preliminary assessment (see also comment SSC5). For Model 3, of the three options provided, the option of tuning to the harmonic mean was chosen. For Model 4, internal estimation of σ_R had already been replaced (in Model 2) by a procedure that attempts to adjust for the downward bias in the MLE, so the only difference between Models 2 and 4 is the latter's estimation of a larger number of age groups in the initial vector (20 in Model 4, contrasted with 10 in Model 2). In addition, the JTS minutes list a large number of other models, some or all of which could be included at the author's discretion. Most of these were variants on Model 0, and were of special interest to some members of the public. Following the June SSC meeting, the member of the public responsible for proposing these Model 0 variants provided a prioritized list thereof. The first and third priority models are included here (inclusion of the second priority model was precluded by time constraints). In addition, the assessment author has included two of his own models. See section entitled "Model structures."

JTS2 (5/15 minutes): *"For the EBS, the subcommittee recommended that the following non-model analyses be conducted for this year's preliminary assessment:*

- *Analysis 1: R_0 profile using the observed data and using simulated data without error*
- *Analysis 2: Plot the time series of the ratio of catch to survey biomass (or exploitable biomass, time permitting) to determine whether current values are within historic range*
- *Analysis 3: Initialize the composition weighting process by setting sample sizes equal to number of sampled hauls"*

The above analyses are included in this preliminary assessment (see also comments SSC5 and SSC6). Analysis 1 is shown in Figures 2.1.11 and 2.1.12, Analysis 2 is shown in Figure 2.1.8, and Analysis 3 is shown in Figure 2.1.13.

SSC5 (6/15 minutes): *"The SSC agreed that this suite of models was appropriate and practicable and had no suggestions for additional models and analyses."* See comments JST1 and JST2.

SSC6 (6/15 minutes): *"During the first-stage committee review, it was suggested that the time series of the ratio of catch to survey biomass be examined as metric of model suitability. The SSC could not interpret this metric biologically and rather prefers to use the standard metrics of model performance in the stock assessment to guide its selection of useful model(s)."* Because comments JTS2 and SSC5 suggest an interest in Analysis 2, it is included in this preliminary assessment (Figure 2.1.8). However, to address the present comment, Analysis 2 was supplemented by a figure showing the ratio between the full-selection fishing mortality rate and $F_{40\%}$ for each of the models (Figure 2.1.9).

Data

The data used in this preliminary assessment are identical to those used in last year's final assessment (Thompson 2014).

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	1977-2014
Fishery	Catch size composition	1977-2014
Fishery	Catch per unit effort	1991-2014
EBS shelf bottom trawl survey	Numerical abundance	1982-2014
EBS shelf bottom trawl survey	Size composition	1982-2014
EBS shelf bottom trawl survey	Age composition	1994-2013
EBS shelf bottom trawl survey	Mean size at age	1994-2013

Because the models presented in this preliminary assessment include various methods for tuning the input sample sizes for size and age composition data (see next section), a review of the current methods for specifying these input sample sizes is presented here: For the 2007 assessment, the harmonic means from a bootstrap analysis of the available fishery length data from 1990-2006 were computed. The harmonic means were smaller than the actual sample sizes, but still ranged well into the thousands. Analysis of the harmonic means revealed that, except when the actual sample size was very small (less than about 400), they tended to be very nearly proportional to the actual sample sizes, with the coefficient of proportionality dependent on whether the data were collected prior to 1999. For the years prior to 1999 the ratio was consistently very close to 0.16, and for the years after 1998 the ratio was consistently very close to 0.34. Thus, ever since the 2007 assessment (with some minor modifications through the years), input sample sizes have been set according to the following three-step process. First, records with actual sample sizes less than 400 are omitted. Second, sample sizes for fishery length compositions from years prior to 1999 are tentatively set at 16% of the actual sample sizes, and sample sizes for fishery length compositions since 1999 and sample sizes for all survey length compositions are tentatively set at 34% of the actual sample sizes. Third, all sample sizes are adjusted proportionally so that the average is 300. Age composition input sample sizes are obtained by scaling the number of otoliths read so that the average is 300.

Model structures

All of the models presented in this preliminary assessment were developed using Stock Synthesis (SS, Methot and Wetzel 2013). The version used to run all models was SS V3.24u, as compiled on 8/29/2014. Stock Synthesis is programmed using the ADMB software package (Fournier et al. 2012). The current SS user manual is available at: https://drive.google.com/a/noaa.gov/?tab=mo#folders/0Bz1UsDoLaOMLN2FiOTI3MWQtZDQwOS00YWZkLThmNmEtMTk2NTA2M2FjYWVh.

Eight models are presented. Broadly speaking, they may be categorized as follows:

- Group A consists of last year's final model and variants thereof. Last year's final model had the same structure as the final model from 2011, 2012, and 2013. There are three models in Group A (Models 0, 7, and 8). Model 0 was requested by the JTS and SSC. Models 7 and 8 were requested by members of the public.

- Group B consists of Model 2 from last year's final assessment and variants thereof. Model 2 from last year's final assessment used a much simpler data structure than that used in last year's final model, and it used a substantially different representation of selectivity. There are five models in Group B (Models 2, 3, 4, 5, and 6). Group B can be divided into two subgroups:
  - Subgroup B1 consists of the models in Group B that were proposed by the JTS and SSC, all of which use the method of Thompson and Lauth (2012) to tune the parameters governing time-variability in recruitment and selectivity. There are three models in Subgroup B1 (Models 2, 3, and 4).
  - Subgroup B2 consists of models proposed by the assessment author. These use a different method to tune the parameters governing time-variability in recruitment and selectivity. There are two models in Subgroup B2 (Models 5 and 6).

The relationships between Models 0 and 2-8 are described immediately below, and then Models 0, 2, and 5 are described in greater detail in separate sections. Note that there is no "Model 1" in this preliminary assessment, because, per SSC policy, this particular designation is reserved for last year's final model *with updated data*, whereas the models presented in this preliminary assessment all use the same data sets as in last year's final assessment.

Group A:

- Model 0 was the same as Model 1 from the 2014 final assessment (Thompson 2014).
- Model 7 was the same as Model 0, but with composition data weighted by Equation TA1.8 of Francis (2011).
- Model 8 was the same as Model 0, but with Richards growth (Model 0 used von Bertalanffy growth, which is a special case of Richards growth).

Subgroup B1:

- Model 2 was the same as Model 2 from the 2014 final assessment (Thompson 2014).
- Model 3 was the same as Model 2, but with composition data weighted by tuning the mean input sample size to the harmonic mean of the effective sample size, and with time-varying survey catchability (Q) turned off.
- Model 4 was the same as Model 2, but with 20 age groups estimated in the initial numbers-at-age vector (Model 2 estimated 10 age groups in the initial numbers-at-age vector).

For all models in Subgroup B1, selectivity prior distributions and the parameters governing time-variability in recruitment, selectivity, and survey catchability were *not* re-tuned for this preliminary assessment. That is, they were left at the values estimated last year for Model 2, except that time variability in survey catchability was turned off in Model 3. Note that the tuning for Model 2 was performed during last year's *preliminary* assessment (where it was labeled Model 6), and was not updated during last year's final assessment.

Subgroup B2:

- Model 5 was based on Model 2, but had a number of differences (described below under "Model 5: main features"), one of which was that SS runs were accepted even if the gradient was large, so long as the estimated covariance matrix of the parameters appeared reasonable.
- Model 6 was the same as Model 5, except that SS runs were accepted only if the gradient was small.

Development of the final versions of all models included calculation of the Hessian matrix. All models also passed a "jitter" test of 50 runs. The jitter rate (equal to half the standard deviation of the logit-scale distribution from which initial values are drawn) was set at 0.1 for Models 0 and 5-8, and 0.01 for Models 2-4 (a jitter rate of 0.1 for Models 2-4 tended to result in high proportions of failed runs). 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, with the parameter estimates from the best jitter run incorporated as starting values, became the new base run.
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.

Except for selectivity parameters in Models 2-6; annual catchability deviations in Models 2, 4, and 6; and *dev* vectors in all models, all parameters were estimated with uniform prior distributions.

Models 0, 7, and 8 used the same data file as was used for Model 1 in last year's final assessment. Models 2-6 used the same data file as was used for Model 2 in last year's final assessment.

Model 0: main features

Some of the main features characterizing Model 0 are as follow:

1. Age- and time-invariant natural mortality, estimated outside the model
2. Parameters governing time-invariant mean length at age estimated internally
3. Parameters governing width of length-at-age distribution (for a given mean) estimated internally
4. Ageing bias parameters estimated internally
5. Gear-and-season-specific catch and selectivity for the fisheries
6. Double normal selectivity for the fisheries and survey, with parameterization as follows:
    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 parameters except *beginning_of_peak_region* are transformed: The *ascending_width* and *descending_width* are log-transformed and the other three parameters are logit-transformed.
7. Length-based selectivity for the fisheries
8. Age-based selectivity for the survey
9. Fishery selectivity estimated for "blocks" of years
10. Survey selectivity constant over time, except with annual *dev*s for the *ascending_width* parameter
11. Survey size composition data used in all years, including those years with age composition data (at the request of Plan Team members, inclusion of survey size composition data in all years was instituted in the 2011 assessment and has been retained ever since, based on the view that the costs of double-counting are outweighed by the benefits of including this information for estimation of growth parameters)
12. Fishery CPUE data included but not used for estimation
13. Mean size at age included but not used for estimation

Model 0: iterative tuning

Iterative tuning of time-varying parameters

The standard deviations of the two *dev* vectors in Model 0 (the log of age 0 recruitment and the survey *ascending_width* parameter, both additive) were estimated iteratively during the 2009 assessment by tuning the specified σ term for each vector to the standard deviation of the elements in that vector. Although this method is more justifiable than simply guessing at the value of σ, it is known to be biased low, and in the worst case may return a value of zero even when the true value is substantially greater than zero (Maunder and Deriso 2003, Thompson in prep.).

Per request of the BSAI Plan Team, the values of these σ terms (0.57 and 0.07, respectively) have been held constant in Model 0 and its predecessors ever since the 2009 assessment.

Iterative tuning of survey catchability

Survey catchability was estimated iteratively during the 2009 assessment by tuning *Q* so that the average of the product of *Q* and survey selectivity across the 60-81 cm size range matched the point estimate of 0.47 given by Nichol et al. (2007).

Per request of the BSAI Plan Team, this value of *Q* (0.77) has been held constant in Model 0 and its predecessors ever since the 2009 assessment.

Model 2: main features

Except for procedures related to iterative tuning (see next section), the differences between Model 2 and Model 0 were as follow:

1. Each year consisted of a single season instead of five.
2. A single fishery was defined instead of nine season-and-gear-specific fisheries.
3. The survey was assumed to sample age 1 fish at true age 1.5 instead of 1.41667.
4. Initial abundances were estimated for the first ten age groups instead of the first three.
5. The natural mortality rate was estimated internally.
6. The base value of survey catchability was estimated internally.
7. Survey catchability was allowed to vary annually.
8. Selectivity for both the fishery and the survey were allowed to vary annually.
9. Selectivity for both the fishery and survey was modeled using a random walk with respect to age (SS selectivity-at-age pattern #17) instead of the usual double normal.

Model 2: iterative tuning

Iterative tuning of prior distributions for selectivity parameters

Initially, the model was run with recruitment as the only time-varying quantity, with the standard deviation of log-scale recruitment estimated internally (i.e., as a free parameter), and with large standard deviations in the prior distributions for all selectivity parameters.

Once the initial model converged, a pair of transformed logistic curves was fit to the point estimates of the fishery and survey selectivity schedules (a *transformed* logistic curve was used because the selectivity parameters in pattern #17 consist of the backward first differences of selectivity on the log scale, rather than selectivity itself; Thompson and Palsson 2013). The respective transformed logistic curve (fishery or survey) was then used to specify a new set of means for the selectivity prior distributions (one for each age). A constant (across age) prior standard deviation was then computed such that no age had a prior CV (on the selectivity scale, not the transformed scale) less than 50%, and at least one age had a prior CV of exactly 50%.

The model was then run with the new set of prior means and constant prior standard deviations (one for the fishery, one for the survey), then a new pair of transformed logistic curves was fit to the results, and the process was repeated until convergence was achieved.

Iterative tuning of time-varying parameters other than catchability

Two main loops were involved in the iterative tuning of time-varying selectivity parameters. These loops were designed to produce the quantities needed in order to use the method of Thompson and Lauth (2012, Annex 2.1.1; also Thompson in prep.) for estimating the standard deviation of a *dev* vector:

1. Compute an "unconstrained" estimate of the standard deviation of the set of year-specific *dev*s associated with each age. The purpose of this loop was to determine the vector of *dev*s that would be obtained if they were completely unconstrained by their respective σ. This was not always a straightforward process, as estimating a large matrix of age×year *dev*s is difficult if the *dev*s are unconstrained. In general, though, the procedure was to begin with a small (constant across age) value of σ; calculate the standard deviation of the estimated *dev*s; then increase the value of σ gradually until the standard deviation of the estimated *dev*s reached an asymptote.
2. Compute an "iterated" estimate of the standard deviation of the set of year-specific *dev*s associated with each age. This loop began with each σ set at the unconstrained value estimated in the first loop. The standard deviation of the estimated *dev*s then became the age-specific σ for the next run, and the process was repeated until convergence was achieved.

The iteration was conducted separately for the fishery and survey.

It was common for some ages to be "tuned" out during the second loop (i.e., the σs converged on zero). For Model 2, all ages were tuned out except age 4 for the fishery and ages 2 and 3 for the survey. Unfortunately, given the way that selectivity pattern #17 is implemented in SS, large gradients can result if sufficiently large *dev*s occur at or adjacent to the age of peak selectivity. Because survey selectivity for Model 2 tended to peak at age 3, runs that included *dev*s for age 3 resulted in large gradients, so Model 2 included survey selectivity *dev*s for age 2 only.

A similar procedure was used to tune σ_R.

All selectivity *dev*s were assumed to be additive (SS automatically assumes log recruitment *dev*s to be additive).

Iterative tuning of time-varying catchability

Although conceptually similar to a *dev* vector, SS treats each annual deviation in ln(Q) as a true parameter, with its own prior distribution. Because SS works in terms of ln(Q) rather than Q, normal prior distributions were assumed for all annual deviations. To be parsimonious, a single σ was assumed for all such prior distributions.

Unlike the size composition or age composition data sets, the time series of survey abundance data includes not only a series of expected values, but a corresponding series of standard errors as well. This fact formed the basis for the iterative tuning of the σ term for time-varying Q in Model 2. The procedure involved iteratively adjusting σ until the root-mean-squared-standardized-residual for survey abundance equaled unity.

Model 5: main features

Except for some procedures related to iterative tuning (see next section), the differences between Model 5 and Model 2 were as follow:

- Composition data were given a weight of unity if the harmonic mean of the effective sample size was greater than the mean input sample size of 300; otherwise, composition data were weighted by tuning the mean input sample size to the harmonic mean of the effective sample size.
- 20 age groups were estimated in the initial numbers-at-age vector.
- Selectivity at ages 9+ was constrained to equal selectivity at age 8 for both the fishery and the survey.
- A superfluous selectivity parameter was fixed at the mean of the prior (in Model 2, the estimate of this parameter automatically went to the mean of the prior).
- The SS feature known as "Fballpark" was turned off (this feature, which functions something like a very weak prior distribution on the fishing mortality rate in some specified year, did not appear to be providing any benefit in terms of model performance, and what little impact it had on resulting estimates was not easily justified).
- SS runs were accepted even if the gradient was large, so long as the estimated covariance matrix of the parameters appeared reasonable (i.e., all values were numeric, no values were unbelievably large).

Model 5: iterative tuning

Iterative tuning of prior distributions for selectivity parameters and time-varying catchability in Model 5 proceeded as in Model 2, except that all iterative tuning procedures were undertaken simultaneously, rather than in the phased approach used for Model 2.

For time-varying recruitment and selectivity, the approach used in Model 2, which was based on the method of Thompson and Lauth (2012), was not retained in Model 5. For a univariate model, *if* the method of Thompson and Lauth (2012) returns a non-zero estimate of σ, there is reason to believe that this estimate will be unbiased. However, the method carries a fairly high probability of returning a "false negative;" that is, returning a zero estimate for σ when the true value is non-zero (Thompson in prep.). To reduce this bias toward under-parameterization, the following algorithm was used in Model 5 (Thompson in prep.; note that this is a multivariate generalization of one of the methods mentioned by Methot and Taylor (2011, *viz*., the third method listed on p. 1749)):

1. Set initial guesses for the σs.
2. Run SS.
3. Compute the covariance matrix (**V1**) of the set of *dev* vectors (e.g., element $\{i,j\}$ is equal to the covariance between the subsets of the *i*th *dev* vector and the *j*th *dev* vector consisting of years that those two vectors have in common).
4. Compute the covariance matrix of the parameters (the negative inverse of the Hessian matrix).
5. Extract the part of the covariance matrix of the parameters corresponding to the *dev* vectors, using only those years common to all *dev* vectors.
6. Average the values in the matrix obtained in step 5 across years to obtain an "average" covariance matrix (**V2**).
7. Compute the vector of σs corresponding to **V1**+**V2**.

8. Return to step 2 and repeat until the σs converge.

To speed the above algorithm, the σs obtained in step 7 were sometimes substituted with values obtained by extrapolation or interpolation based on previous runs.

As noted above, the procedure used in Model 5 for iterative tuning of time-varying *Q* was the same as that used in Model 2. However, unlike Model 2, this procedure resulted in time-varying *Q* being “tuned out” in Model 5. Model 6, which also used this procedure, ended up retaining time-varying *Q*.

Parameters estimated outside the assessment model

Parameters estimated outside the assessment model were detailed in last year’s final assessment (Thompson 2014). In particular, the natural mortality rate *M* was fixed at 0.34 (Models 0, 7, and 8; estimated internally in Models 2-6), the standard deviations of the ageing error matrix extended linearly from a value of 0.086 at age 1 to a value of 1.712 at age 20 (all models), the parameters of the logistic maturity-at-age relationship were set at values of $age_{50\%}$=4.883 years and slope=–0.965 (all models), and the base value of log survey catchability was fixed at –0.261365 (Models 0, 7, and 8; estimated internally in Models 2-6). Weight at length varied either annually and seasonally (Models 0, 7, and 8) or just annually (Models 2-6).

Parameters estimated inside the assessment model

Parameters estimated inside SS vary to some extent between the eight models. Internally estimated parameters common to all models include the von Bertalanffy growth parameters; standard deviation of length at ages 1 and 20; ageing bias at ages 1 and 20; log mean recruitment since 1977; offset for log mean recruitment prior to 1977; *dev*s for log-scale initial (i.e., 1977) abundance at ages 1 through 3; annual log-scale recruitment *dev*s for 1977-2013; initial (equilibrium) fishing mortality (January-April trawl fishery only, in the case of Models 0, 7, and 8); and base values for all fishery and survey selectivity parameters (although the nature of these parameters varies between models). A complete list of estimated parameters is presented in the “Parameters, schedules, and time series estimates” subsection of the “Results” section.

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 annual fishing mortality rates are also estimated internally, but not in the same sense as the above parameters. The fishing mortality rates are determined (almost) 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. An option does exist in SS for treating the fishing mortality rates as full parameters, but previous explorations have indicated that adding these parameters has almost no effect on other model output (Methot and Wetzel 2013).

Objective function components

All eight models include likelihood components for initial (equilibrium) catch, trawl survey relative abundance, fishery size composition (broken down by gear and season in Models 0, 7, and 8), 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 addition, Models

0, 7, and 8 include a likelihood component for "Fballpark," and Models 2-6 include an objective function component for prior distributions.

In SS, emphasis factors are specified to determine which objective function components receive the greatest weight during the parameter estimation process. All objective function components were given an emphasis of 1.0 in Models 1, 2, 4, and 8. One or more emphasis factors were tuned iteratively in Models 3, 5, 6, and 7.

Results

Overview

The following table summarizes the status of the stock as estimated by the eight models ("Value" is the point estimate, "SD" is the standard deviation of the point estimate, "FSB 2015" is female spawning biomass in 2015 (t), and "Bratio 2015" is the ratio of FSB 2015 to $B_{100\%}$:

	Model 0		Model 2		Model 3		Model 4	
Quantity	Value	SD	Value	SD	Value	SD	Value	SD
FSB 2015	402,931	28,093	230,635	37,456	174,652	22,218	228,697	37,210
Bratio 2015	0.520	0.030	0.308	0.052	0.228	0.030	0.304	0.052

	Model 5		Model 6		Model 7		Model 8	
Quantity	Value	SD	Value	SD	Value	SD	Value	SD
FSB 2015	350,833	67,941	374,668	93,431	406,728	28,258	403,032	28,123
Bratio 2015	0.553	0.095	0.443	0.087	0.522	0.030	0.521	0.030

The eight models span wide ranges for these quantities. Estimates of FSB 2015 range from 175,000 t (Model 3) to 407,000 t (Model 7), and estimates of Bratio 2015 range from 0.228 (Model 3) to 0.522 (Model 7).

Goodness of fit

Objective function values and parameter counts are shown for each model in Table 2.1.1. Objective function values are not directly comparable across models, because different data files are used for some models, different constraints are imposed, and the number and types of parameters vary considerably.

Figure 2.1.1 shows the fits of the eight models to the trawl survey abundance data, with the Group A models shown in the upper panel and the Group B models shown in the lower panel. Table 2.1.2 shows goodness of fit for the fishery CPUE data (Models 0, 7, and 8 only; note that none of the models actually attempts to fit these data) and for the survey abundance data. Four measures are shown: root mean squared error (for comparison, the average log-scale standard error in the data is 0.108), mean normalized residual, standard deviation of normalized residuals, and correlation (observed:estimated).

Sample size ratios for the size composition data are shown in Table 2.1.3 (note that input sample sizes are the same for Models 0, 2, 4, 5, 6, and 8, but different for Models 3 and 7). These results can be summarized as follows:

- Measured either as the arithmetic mean of the ratios or the ratio of the arithmetic means, the models give values well in excess of unity for individual gear-and-season-specific fisheries (Models 0, 7, and 8) or for the overall fishery (Models 2-6), as well as for the survey (all models).

- Measured as the ratio of the *harmonic* mean effective sample size to the arithmetic mean input sample size, all models give noticeably smaller values, but still in excess of unity in all cases except for Model 3, which was tuned by setting this ratio equal to unity.

Sample size ratios for the age composition data are shown in Table 2.1.4 (note that input sample sizes are the same for Models 0, 2, 4, and 8; but different for Models 3, 5, 6, and 7). These results can be summarized as follows:

- Measured as the ratio of the arithmetic means, Models 2-7 all give values greater than unity.
- Measured as the ratio of the *harmonic* mean effective sample size to the arithmetic mean input sample size, Models 3, 5, and 6 give values exactly equal to unity (this was the tuning criterion for those three models), while the other models all give values much less than unity.

In past years, concern has been expressed regarding the extent to which model estimates of mean length at ages 1-3 match the first three modes in the long-term survey size composition data. These are compared for all eight models in Figure 2.1.2.

Parameters, schedules, and time series estimates

Table 2.1.5 lists all the parameters estimated internally in at least one of the eight models, along with their standard deviations. Table 2.1.5 consists of the following parts:

- Table 2.1.5a: scalar parameters
- Table 2.1.5b: initial age structure *dev*s
- Table 2.1.5c: recruitment *dev*s
- Table 2.1.5d: ln(Q) deviations
- Table 2.1.5e: Group A base selectivity parameters
- Table 2.1.5f: Group A trawl and pot fishery selectivity block-specific parameters
- Table 2.1.5g: Group A longline fishery selectivity block-specific parameters
- Table 2.1.5h: Group A survey selectivity *dev*s
- Table 2.1.5i: Group B base selectivity parameters
- Table 2.1.5j: Subgroup B1 fishery selectivity *dev*s
- Table 2.1.5k: Subgroup B2 fishery selectivity *dev*s
- Table 2.1.5l: Group B survey age 2 selectivity *dev*s
- Table 2.1.5m: Model 5 survey ages 3-7 selectivity *dev*s

As noted previously, SS treats fishing mortality rates somewhat differently from other parameters. Estimates of full-selection fishing mortality rates and their corresponding standard deviations are listed in Table 2.1.6.

Table 2.1.7 lists all the parameters involved in iterative tuning.

Selectivity schedules are plotted in Figures 2.1.3 and 2.1.4. Figure 2.1.3 shows the fishery selectivity schedules estimated by the eight models. These schedules are length-based for Models 0, 7, and 8, but age-based for Models 2-6. Figure 2.1.4 shows the survey selectivity schedules estimated by the eight models. These are all age-based.

Time series estimated by the eight models are shown for total biomass, female spawning biomass relative to $B_{100\%}$, and age 0 recruitment in Figures 2.1.5, 2.1.6, and 2.1.7, respectively.

Other diagnostics

In response to requests from the JTS, the SSC, and members of the public, Figures 2.1.8 and 2.1.9 show the ratio of catch to survey biomass and the ratio of full-selection fishing mortality to $F_{40\%}$.

Figure 2.1.10 shows 10-year retrospectives of spawning biomass for each of the eight models. Mohn's rho (revised) values for the eight models are as shown below:

Model 0	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
0.494	-0.049	-0.076	-0.051	0.095	0.032	0.226	0.505

In response to requests from the JTS, the SSC, and members of the public, Figure 2.1.11 shows likelihood profiles with respect to the log of mean post-1976 age 0 recruitment (*R0*) using the actual data, and Figure 2.1.12 shows analogous profiles for "errorless" data generated from each respective model. Use of such profiles as diagnostic tools was discussed by Maunder and Piner (2015). The values of *R0* (to the nearest 0.1) that maximize each component of the objective function for each data type and model are as follow:

Data	Component	M0	M2	M3	M4	M5	M6	M7	M8
Original	Index	13.3	12.9	12.9	12.9	14.4	12.9	13.3	13.3
Original	Size	13.1	12.0	12.0	12.3	14.3	13.4	13.2	13.1
Original	Age	13.1	14.8	14.7	14.7	14.8	14.5	13.2	13.1
Original	Total	13.2	13.2	12.9	13.2	14.1	13.4	13.3	13.2
Errorless	Index	13.2	13.0	13.0	13.0	14.2	13.2	13.3	13.2
Errorless	Size	13.2	13.3	13.0	13.2	14.0	13.4	13.3	13.2
Errorless	Age	13.2	13.2	13.0	13.2	14.0	13.3	13.2	13.2
Errorless	Total	13.2	13.3	13.2	13.3	14.0	13.4	13.3	13.2

Discussion

The models presented here span a wide range of structures, and in many cases the estimates produced by the models are similarly wide ranging. For example, as reported in the "Overview" subsection of the "Results" section, the estimates of female spawning biomass in 2015 range from 175,000 t (Model 3) to 407,000 t (Model 7), and estimates of this quantity relative to $B_{100\%}$ range from 0.23 (Model 3) to 0.52 (Model 7). The natural mortality rate was fixed at a value of 0.34 in Models 0, 7, and 8, but in the other models its estimates ranged from 0.31 (Model 3) to 0.48 (Model 5). Survey catchability was fixed at a value of 0.77 in Models 0, 7, and 8, but in the other models its estimates ranged from 0.87 (Model 6) to 1.65 (Model 3).

All models presented here generally provided good-to-excellent fits to the size composition data. Models 0 and 8 do not do a particularly good job of fitting the age composition data. For the age composition data, the other models all produce an *arithmetic* mean effective sample size larger than the arithmetic mean input sample size, but only Models 3, 5, and 6 produce a *harmonic* mean effective sample size as large as the arithmetic mean input sample size. However, Models 3, 5, and 6 accomplish this, at least in part, by decreasing the input sample sizes.

Appropriate weighting of composition data remains an issue in contemporary stock assessments (Maunder and Piner 2015). Five different procedures were used in this preliminary assessment:

1. Fix the mean input sample size at a value of 300 (Models 0 and 8).

2. Fix the mean input sample size at a value of 300, unless the arithmetic mean effective sample size is less than the mean input sample size, in which case tune the mean input sample size to the arithmetic mean effective sample size (Models 2 and 4).
3. Fix the mean input sample size at a value of 300, unless the harmonic mean effective sample size is less than the mean input sample size, in which case tune the mean input sample size to the harmonic mean effective sample size (Models 5 and 6).
4. Tune the mean input sample size to the harmonic mean effective sample size in all cases (Model 3).
5. Tune all mean input sample sizes by Francis' (2011) Equation TA1.8 (Model 7).

Perhaps foreshadowing possible use of yet another alternative procedure, the JTS and the SSC expressed interest in comparing the number of sampled hauls to the input sample sizes currently used (see description of the latter in the "Data" section). Figure 2.1.13 contains this comparison. The input sample sizes used in Model 0 are very nearly proportional to the number of sampled hauls, with the coefficient of proportionality dependent on whether the data were collected prior to 1999.

Model 5 tended to overfit the survey abundance data (which, according to Francis (2011), should not necessarily be a concern); Models 2, 4, and 6 fit the survey abundance data well (root mean squared errors close to the log-scale standard error in the data, standard deviation of normalized residuals close to unity); whereas Models 0, 7, and 8 tended to underfit the survey abundance data.

Models 2-6 use SS selectivity-at-age pattern #17 (random walk with age). As noted in last year's preliminary assessment, some advantages of pattern #17 are the following:

1. Pattern #17 allows for use of prior distributions that are consistent with a logistic functional form without actually forcing the resulting selectivity schedule to be logistic.
2. Pattern #17 provides an alternative to the somewhat complicated parameterization of the double normal selectivity curve (which has been used in the EBS Pacific cod models for the last several years), in which the effects of some parameters are conditional on the values of other parameters, thus making it difficult to specify appropriate prior distributions.
3. The iterative tuning procedure used here for the means of the prior distributions provides a way to specify these quantities objectively and uniquely for each age.
4. Estimation of individual selectivities at age avoids the problem of mis-specifying a functional form *a priori*, which can have significant consequences (e.g., Kimura 1990, Clark 1999).

Models 2-6 emphasize the potential time-variability of both fishery and survey selectivity, and Models 2, 4, and 6 allow time-variability in survey catchability as well. Although a scientific consensus on how (or whether) to address this phenomenon has yet to be achieved, some of the presentations at the 2013 CAPAM selectivity workshop (Crone et al., 2013) seemed to favor allowing selectivity (or at least fishery selectivity) to vary over time. However, specification of the input standard deviations for *dev* vectors remains a difficult problem; in fact, Maunder and Piner (2015) list this as one of the outstanding problems in contemporary fisheries stock assessment. Models 0, 7, and 8 tune each input standard deviation to the standard deviation of the estimated *dev* vector. This procedure is known to underestimate the true amount of time variability, and is prone to "false negatives" (Maunder and Deriso 2003, Thompson in prep.). Models 2-4 use the method of Thompson and Lauth (2012), but this approach is tedious when more than one parameter is time-varying, and is also prone to false negatives (Thompson in prep.). Models 5 and 6 use an approach that appears to perform well in multivariate linear-normal models, but its performance in stock assessment models has not been thoroughly evaluated (Thompson in prep.).

As has been the case for decades now, most of the models tend to estimate sharply reduced survey selectivity at older ages (Figure 2.1.4). Model 3 estimates a difficult-to-explain increase in survey selectivity at ages greater than 10 years, but these fish are seldom observed in the survey. Otherwise, Model 5 estimates the highest old-age survey selectivity (0.65) of all the models (accompanied by an estimate of M (0.48) that is 38% larger than the estimate from any other model). Except for the study by Nichol et al. (2007), numerous studies by AFSC's RACE Division have failed to verify a mechanism capable of explaining this phenomenon. However, when models with forced asymptotic selectivity have been explored previously, they have never been able to fit the data as well as models without this constraint. This remains a significant issue.

A technical issue that merits further investigation is how to deal with model runs that generate large gradients (much greater than unity), but for which the covariance matrices of the parameters appear to be reasonable. Treatment of this phenomenon is the only methodological difference between Models 5 and 6, but it resulted in substantial differences in the outputs of those two models.

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Tables

Table 2.1.1—Objective function values and parameter counts. Note that fishery CPUE likelihoods are calculated, but not used, in Models 0, 7, and 8.

Obj. func. component	M0	M2	M3	M4	M5	M6	M7	M8
Equilibrium catch	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.01
Survey abundance index	-3.61	-60.32	-29.12	-60.36	-67.23	-58.48	-26.43	-3.28
Size composition	4948.11	992.08	1577.40	991.51	838.03	887.15	1363.75	4947.76
Age composition	141.27	104.30	52.68	104.36	54.24	59.04	95.43	141.20
Recruitment	21.62	-0.11	12.45	-4.39	-18.18	-7.86	5.65	21.57
Priors	n/a	14.77	7.96	14.79	1.52	12.51	n/a	n/a
"Softbounds"	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.03
Deviations	19.85	13.05	16.23	13.06	79.31	51.44	16.74	19.83
"F ballpark"	0.00	0.17	0.05	0.01	n/a	n/a	0.00	0.00
Total	5127.28	1063.93	1637.67	1058.99	887.69	943.81	1455.17	5127.10

CPUE component	M0	M2	M3	M4	M5	M6	M7	M8
Jan-Apr trawl fishery	233.86	n/a	n/a	n/a	n/a	n/a	198.61	233.75
May-Jul trawl fishery	-1.42	n/a	n/a	n/a	n/a	n/a	-4.20	-1.36
Aug-Dec trawl fishery	65.58	n/a	n/a	n/a	n/a	n/a	72.55	65.44
Jan-Apr longline fishery	302.02	n/a	n/a	n/a	n/a	n/a	271.37	302.65
May-Jul longline fishery	16.74	n/a	n/a	n/a	n/a	n/a	19.91	16.90
Aug-Dec longline fishery	156.46	n/a	n/a	n/a	n/a	n/a	162.09	156.80
Jan-Apr pot fishery	2.16	n/a	n/a	n/a	n/a	n/a	-1.41	2.13
May-Jul pot fishery	-9.24	n/a	n/a	n/a	n/a	n/a	-6.98	-9.26
Aug-Dec pot fishery	17.76	n/a	n/a	n/a	n/a	n/a	12.00	17.86
Shelf trawl survey	-3.61	-60.32	-29.12	-60.36	-67.23	-58.48	-26.43	-3.28

Sizecomp component	M0	M2	M3	M4	M5	M6	M7	M8
Jan-Apr trawl fishery	1098.50	n/a	n/a	n/a	n/a	n/a	168.63	1098.95
May-Jul trawl fishery	203.96	n/a	n/a	n/a	n/a	n/a	62.92	203.93
Aug-Dec trawl fishery	247.93	n/a	n/a	n/a	n/a	n/a	33.36	248.18
Jan-Apr longline fishery	757.87	n/a	n/a	n/a	n/a	n/a	106.48	758.95
May-Jul longline fishery	245.71	n/a	n/a	n/a	n/a	n/a	56.74	246.35
Aug-Dec longline fishery	1055.81	n/a	n/a	n/a	n/a	n/a	236.14	1055.46
Jan-Apr pot fishery	133.02	n/a	n/a	n/a	n/a	n/a	66.69	133.14
May-Jul pot fishery	67.89	n/a	n/a	n/a	n/a	n/a	40.98	68.07
Aug-Dec pot fishery	245.53	n/a	n/a	n/a	n/a	n/a	35.43	245.77
Fishery	n/a	207.04	613.41	206.52	114.60	118.98	n/a	n/a
Shelf trawl survey	891.90	785.04	963.99	785.00	723.44	768.17	556.40	888.96

Parameter counts	M0	M2	M3	M4	M5	M6	M7	M8
Unconstrained parameters	115	13	13	13	13	13	115	116
Parameters with priors	0	73	40	73	14	47	0	0
Constrained deviations	71	117	117	127	439	279	71	71
Total	186	203	170	213	466	339	186	187

Table 2.1.2—Various goodness-of-fit measures for fishery CPUE and survey abundance data. Note that fishery CPUE data are included, but not used, in Models 0, 7, and 8; fishery CPUE data are not included in Models 2-6. RMSE = root mean squared error, MNR = mean normalized residual, SDNR = standard deviation of normalized residuals, Corr. = correlation (observed:estimated).

Model	Fleet	RMSE	MNR	SDNR	Corr.
0	Jan-Apr trawl fishery	0.45	0.55	3.76	0.17
0	May-Jul trawl fishery	0.38	-0.15	1.61	0.34
0	Aug-Dec trawl fishery	0.69	0.19	2.37	0.13
0	Jan-Apr longline fishery	0.35	0.23	4.24	-0.10
0	May-Jul longline fishery	0.26	0.31	2.40	0.50
0	Aug-Dec longline fishery	0.23	0.15	3.58	0.35
0	Jan-Apr pot fishery	0.34	0.17	1.93	0.22
0	May-Jul pot fishery	0.21	0.04	1.51	0.21
0	Aug-Dec pot fishery	0.38	0.01	2.03	0.13
7	Jan-Apr trawl fishery	0.43	0.42	3.57	0.13
7	May-Jul trawl fishery	0.37	-0.11	1.53	0.37
7	Aug-Dec trawl fishery	0.72	0.23	2.45	0.02
7	Jan-Apr longline fishery	0.34	0.23	4.09	-0.14
7	May-Jul longline fishery	0.27	0.24	2.47	0.39
7	Aug-Dec longline fishery	0.24	0.23	3.62	0.20
7	Jan-Apr pot fishery	0.33	0.12	1.87	0.20
7	May-Jul pot fishery	0.23	0.02	1.68	-0.06
7	Aug-Dec pot fishery	0.38	-0.01	1.94	0.09
8	Jan-Apr trawl fishery	0.45	0.55	3.76	0.17
8	May-Jul trawl fishery	0.38	-0.15	1.61	0.34
8	Aug-Dec trawl fishery	0.68	0.19	2.36	0.14
8	Jan-Apr longline fishery	0.35	0.23	4.25	-0.10
8	May-Jul longline fishery	0.27	0.31	2.41	0.50
8	Aug-Dec longline fishery	0.23	0.14	3.59	0.35
8	Jan-Apr pot fishery	0.34	0.17	1.93	0.22
8	May-Jul pot fishery	0.21	0.04	1.50	0.21
8	Aug-Dec pot fishery	0.38	0.01	2.03	0.13

Model	Fleet	RMSE	MNR	SDNR	Corr.
0	Shelf trawl survey	0.23	0.99	1.86	0.76
2	Shelf trawl survey	0.11	0.10	0.94	0.93
3	Shelf trawl survey	0.18	0.17	1.66	0.79
4	Shelf trawl survey	0.11	0.10	0.94	0.93
5	Shelf trawl survey	0.08	0.03	0.69	0.95
6	Shelf trawl survey	0.11	0.11	1.00	0.92
7	Shelf trawl survey	0.19	0.40	1.69	0.78
8	Shelf trawl survey	0.23	1.00	1.86	0.76

Table 2.1.3—Statistics related to effective sample sizes (Neff) for length composition data. Nrec = no. records, A(·) = arithmetic mean, H(·) = harmonic mean, Ninp = input sample size. Input sample sizes are adjusted for Models 3 (tuned to H(Neff)) and 7 (tuned by the method of Francis (2011)).

				Ratios		
Mod.	Fleet	Nrec	A(Ninp)	A(Neff/Ninp)	A(Neff)/A(Ninp)	H(Neff)/A(Ninp)
0	Jan-Apr trawl fish.	66	318	5.06	3.00	1.66
0	May-Jul trawl fish.	34	63	9.14	7.31	3.33
0	Aug-Dec trawl fish.	36	44	13.20	6.00	3.35
0	Jan-Apr longline fish.	70	471	8.54	4.00	1.16
0	May-Jul longline fish.	34	244	9.39	5.23	3.02
0	Aug-Dec longline fish.	65	669	6.43	3.15	0.88
0	Jan-Apr pot fish.	38	131	14.30	9.78	3.90
0	May-Jul pot fish.	16	136	18.56	7.79	1.84
0	Aug-Dec pot fish.	38	83	10.15	7.38	2.93
7	Jan-Apr trawl fish.	66	46	34.63	21.57	10.39
7	May-Jul trawl fish.	34	18	30.66	24.31	11.67
7	Aug-Dec trawl fish.	36	5	85.39	45.82	25.50
7	Jan-Apr longline fish.	70	63	60.12	29.19	7.60
7	May-Jul longline fish.	34	50	44.67	23.71	11.60
7	Aug-Dec longline fish.	65	129	27.04	12.51	3.65
7	Jan-Apr pot fish.	38	68	28.62	18.66	7.87
7	May-Jul pot fish.	16	88	29.60	11.94	2.93
7	Aug-Dec pot fish.	38	12	74.06	53.38	20.30
8	Jan-Apr trawl fish.	66	318	5.05	2.99	1.66
8	May-Jul trawl fish.	34	63	9.13	7.31	3.33
8	Aug-Dec trawl fish.	36	44	13.20	5.99	3.34
8	Jan-Apr longline fish.	70	471	8.53	4.00	1.16
8	May-Jul longline fish.	34	244	9.37	5.22	3.02
8	Aug-Dec longline fish.	65	669	6.45	3.16	0.88
8	Jan-Apr pot fish.	38	131	14.29	9.77	3.90
8	May-Jul pot fish.	16	136	18.57	7.85	1.84
8	Aug-Dec pot fish.	38	83	10.15	7.37	2.92
2	Fishery	38	300	13.66	9.50	2.67
3	Fishery	38	1231	4.55	2.90	1.00
4	Fishery	38	300	13.80	9.52	2.71
5	Fishery	38	300	22.24	21.17	3.47
6	Fishery	38	300	21.39	17.83	3.74
0	Trawl survey	33	282	2.01	1.71	1.05
2	Trawl survey	33	300	2.33	1.98	1.23
3	Trawl survey	33	343	1.89	1.62	1.00
4	Trawl survey	33	300	2.33	1.98	1.23
5	Trawl survey	33	300	2.84	2.41	1.34
6	Trawl survey	33	300	2.49	2.11	1.27
7	Trawl survey	33	196	3.27	2.77	1.73
8	Trawl survey	33	282	2.02	1.71	1.06

Table 2.1.4—Statistics related to effective sample size (Eff. N) for age composition data. "In. N" = input sample size, Mean = arithmetic mean, Harm. = harmonic mean, Ratio1 = arithmetic mean effective sample size divided by arithmetic mean input sample size, Ratio2 = harmonic mean effective sample size divided by arithmetic mean input sample size. Input sample sizes are adjusted for Models 3, 5, and 6 (tuned to H(Neff)) and 7 (tuned by the method of Francis (2011)).

	Model 0		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7		Model 8	
Year	In. N	Eff. N	In. N	Eff. N	In. N	Eff. N	In. N	Eff. N	In. N	Eff. N	In. N	Eff. N	In. N	Eff. N	In. N	Eff. N
1994	204	400	204	241	63	323	204	240	160	199	100	189	168	282	204	401
1995	163	39	163	66	50	43	163	67	128	121	80	65	134	53	163	39
1996	203	303	203	588	62	273	203	589	159	492	100	581	167	637	203	305
1997	205	175	205	504	63	317	205	504	161	835	101	684	169	189	205	176
1998	181	1423	181	2042	56	1543	181	2049	142	718	89	1287	149	1438	181	1422
1999	245	112	245	72	75	46	245	72	192	118	121	77	202	104	245	112
2000	245	90	245	58	75	33	245	58	192	170	121	84	202	99	245	90
2001	263	103	263	93	81	87	263	92	206	101	129	106	217	73	263	103
2002	248	82	248	85	76	89	248	85	194	81	122	68	204	76	248	82
2003	360	260	360	523	111	465	360	523	282	989	177	871	297	309	360	260
2004	284	30	284	59	87	41	284	59	223	133	140	48	234	41	284	30
2005	365	401	365	317	112	292	365	317	286	676	180	329	301	427	365	401
2006	371	143	371	405	114	196	371	403	291	783	183	322	306	246	371	143
2007	411	64	411	1496	126	400	411	1488	322	1658	202	952	339	63	411	64
2008	346	249	346	568	106	76	346	567	271	4725	170	527	285	274	346	250
2009	403	100	403	439	124	151	403	439	316	457	198	419	332	188	403	100
2010	369	103	369	263	113	122	369	264	289	450	182	226	304	171	369	103
2011	358	193	358	136	110	44	358	136	281	149	176	112	295	196	358	191
2012	371	112	371	124	114	59	371	124	291	169	183	113	306	152	371	112
2013	405	129	405	229	124	265	405	229	318	770	199	176	334	189	405	130
Mean	300	226	300	415	92	243	300	415	235	690	148	362	247	260	300	226
Harm.	276	107	276	154	85	92	276	154	216	235	136	148	227	126	276	107
Ratio1		0.75		1.38		2.64		1.38		2.93		2.45		1.05		0.75
Ratio2		0.36		0.51		1.00		0.51		1.00		1.00		0.51		0.36

Table 2.1.5a—Scalar parameters estimated by at least one of the eight models. A blank indicates that the parameter (row) was not used in that model (column). A "_" symbol under St. dev. indicates that the parameter (row) was fixed (not estimated) in that model (column).

	Model 0		Model 7		Model 8	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
Natural mortality	3.40E-01	_	3.40E-01	_	3.40E-01	_
Length at age 1 (cm)	1.42E+01	1.04E-01	1.40E+01	1.19E-01	1.42E+01	1.19E-01
Asymptotic length (cm)	9.23E+01	5.02E-01	9.20E+01	8.36E-01	9.21E+01	6.82E-01
Brody growth coefficient	2.40E-01	2.52E-03	2.32E-01	4.08E-03	2.44E-01	7.16E-03
Richards growth coefficient					9.80E-01	3.36E-02
SD of length at age 1 (cm)	3.53E+00	6.71E-02	3.20E+00	7.93E-02	3.53E+00	6.72E-02
SD of length at age 20 (cm)	9.90E+00	1.57E-01	1.07E+01	3.06E-01	9.91E+00	1.56E-01
Ageing bias at age 1 (years)	3.32E-01	1.34E-02	3.23E-01	1.52E-02	3.32E-01	1.34E-02
Ageing bias at age 20 (years)	3.35E-01	1.52E-01	2.56E-01	1.78E-01	3.39E-01	1.53E-01
ln(mean post-1976 recruitment)	1.32E+01	1.91E-02	1.33E+01	2.31E-02	1.32E+01	1.91E-02
ln(pre-1977 recruitment offset)	-1.16E+00	1.31E-01	-5.11E-01	1.74E-01	-1.16E+00	1.31E-01
Initial F (Jan-Apr trawl fishery)	6.44E-01	1.37E-01	2.69E-01	6.18E-02	6.40E-01	1.36E-01
Initial F (fishery)						
ln(trawl survey catchability)	-2.61E-01	_	-2.61E-01	_	-2.61E-01	_

	Model 2		Model 3		Model 4		Model 5		Model 6	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
Natural mortality	3.43E-01	3.05E-02	3.15E-01	1.79E-02	3.39E-01	3.06E-02	4.80E-01	3.88E-02	3.49E-01	3.31E-02
Length at age 1 (cm)	1.63E+01	8.52E-02	1.63E+01	7.96E-02	1.63E+01	8.52E-02	1.63E+01	8.68E-02	1.63E+01	8.58E-02
Asymptotic length (cm)	9.58E+01	1.99E+00	9.50E+01	1.44E+00	9.56E+01	1.97E+00	1.11E+02	3.72E+00	9.59E+01	1.81E+00
Brody growth coefficient	2.34E-01	1.52E-02	2.48E-01	1.23E-02	2.35E-01	1.52E-02	1.63E-01	1.54E-02	2.33E-01	1.42E-02
Richards growth coefficient	8.70E-01	5.63E-02	8.44E-01	4.59E-02	8.69E-01	5.62E-02	1.06E+00	6.01E-02	8.77E-01	5.41E-02
SD of length at age 1 (cm)	3.36E+00	5.61E-02	3.35E+00	5.18E-02	3.36E+00	5.61E-02	3.44E+00	5.78E-02	3.41E+00	5.63E-02
SD of length at age 20 (cm)	8.86E+00	2.86E-01	9.07E+00	2.09E-01	8.85E+00	2.85E-01	8.06E+00	3.57E-01	8.15E+00	2.73E-01
Ageing bias at age 1 (years)	2.57E-01	2.83E-02	2.44E-01	3.94E-02	2.57E-01	2.83E-02	2.70E-01	3.19E-02	2.79E-01	3.06E-02
Ageing bias at age 20 (years)	7.75E-01	2.37E-01	1.33E+00	3.56E-01	7.73E-01	2.37E-01	5.63E-01	2.85E-01	7.42E-01	2.85E-01
ln(mean post-1976 recruitment)	1.32E+01	2.11E-01	1.29E+01	1.20E-01	1.32E+01	2.13E-01	1.41E+01	2.91E-01	1.34E+01	2.72E-01
ln(pre-1977 recruitment offset)	-7.35E-01	2.31E-01	-1.37E+00	1.81E-01	-6.95E-01	2.28E-01	-7.80E-01	2.12E-01	-4.32E-01	2.11E-01
Initial F (Jan-Apr trawl fishery)										
Initial F (fishery)	9.37E-02	2.91E-02	2.86E-01	1.67E-01	8.88E-02	2.69E-02	1.14E-01	3.70E-02	7.31E-02	2.62E-02
ln(trawl survey catchability)	6.51E-02	1.14E-01	5.00E-01	2.63E-01	7.88E-02	1.15E-01	-7.38E-02	1.41E-01	-1.36E-01	1.73E-01

Table 2.1.5b—Initial age structure *dev*s for each of the eight models.

Parameter	Model 0 Estimate	Model 0 St. Dev.	Model 7 Estimate	Model 7 St. Dev.	Model 8 Estimate	Model 8 St. Dev.
Initial age 1 ln(abundance) dev	1.40E+00	2.10E-01	7.74E-01	3.90E-01	1.40E+00	2.10E-01
Initial age 2 ln(abundance) dev	-7.29E-01	4.17E-01	-3.99E-01	4.67E-01	-7.33E-01	4.17E-01
Initial age 3 ln(abundance) dev	1.29E+00	1.88E-01	2.03E-01	4.30E-01	1.29E+00	1.89E-01

Parameter	Model 2 Estimate	Model 2 St. Dev.	Model 3 Estimate	Model 3 St. Dev.	Model 4 Estimate	Model 4 St. Dev.	Model 5 Estimate	Model 5 St. Dev.	Model 6 Estimate	Model 6 St. Dev.
Initial age 1 ln(abundance) dev	6.99E-01	4.70E-01	1.53E+00	2.97E-01	6.67E-01	4.66E-01	6.38E-01	3.58E-01	6.58E-01	4.09E-01
Initial age 2 ln(abundance) dev	-2.33E-01	5.50E-01	-3.71E-01	5.25E-01	-2.59E-01	5.45E-01	-1.74E-01	4.04E-01	-2.62E-01	4.86E-01
Initial age 3 ln(abundance) dev	1.62E-01	4.72E-01	7.90E-01	2.68E-01	1.20E-01	4.71E-01	2.33E-02	3.75E-01	8.20E-02	4.40E-01
Initial age 4 ln(abundance) dev	-7.63E-02	5.09E-01	-7.15E-02	4.18E-01	-1.16E-01	5.06E-01	-1.36E-01	3.95E-01	-1.40E-01	4.84E-01
Initial age 5 ln(abundance) dev	-5.33E-01	5.21E-01	-6.68E-01	4.84E-01	-5.62E-01	5.18E-01	-4.28E-01	4.05E-01	-4.57E-01	4.93E-01
Initial age 6 ln(abundance) dev	-5.58E-01	5.29E-01	-7.24E-01	5.16E-01	-5.83E-01	5.26E-01	-4.02E-01	4.15E-01	-4.09E-01	5.09E-01
Initial age 7 ln(abundance) dev	-4.76E-01	5.47E-01	-6.30E-01	5.44E-01	-4.98E-01	5.44E-01	-3.19E-01	4.30E-01	-3.37E-01	5.25E-01
Initial age 8 ln(abundance) dev	-3.76E-01	5.66E-01	-4.68E-01	5.70E-01	-3.95E-01	5.63E-01	-2.32E-01	4.44E-01	-2.76E-01	5.37E-01
Initial age 9 ln(abundance) dev	-3.04E-01	5.80E-01	-3.50E-01	5.89E-01	-3.22E-01	5.77E-01	-1.56E-01	4.57E-01	-2.19E-01	5.49E-01
Initial age 10 ln(abundance) dev	-2.59E-01	5.90E-01	-3.20E-01	5.95E-01	-2.77E-01	5.86E-01	-1.00E-01	4.67E-01	-1.69E-01	5.60E-01
Initial age 11 ln(abundance) dev					-2.29E-01	5.97E-01	-6.19E-02	4.75E-01	-1.26E-01	5.69E-01
Initial age 12 ln(abundance) dev					-1.70E-01	6.10E-01	-3.73E-02	4.80E-01	-9.28E-02	5.78E-01
Initial age 13 ln(abundance) dev					-1.17E-01	6.23E-01	-2.21E-02	4.84E-01	-6.70E-02	5.84E-01
Initial age 14 ln(abundance) dev					-7.84E-02	6.34E-01	-1.29E-02	4.86E-01	-4.77E-02	5.89E-01
Initial age 15 ln(abundance) dev					-5.24E-02	6.41E-01	-7.43E-03	4.87E-01	-3.36E-02	5.93E-01
Initial age 16 ln(abundance) dev					-3.53E-02	6.46E-01	-4.39E-03	4.88E-01	-2.35E-02	5.96E-01
Initial age 17 ln(abundance) dev					-2.39E-02	6.49E-01	-2.45E-03	4.88E-01	-1.63E-02	5.98E-01
Initial age 18 ln(abundance) dev					-1.61E-02	6.52E-01	-1.30E-03	4.89E-01	-1.13E-02	6.00E-01
Initial age 19 ln(abundance) dev					-1.08E-02	6.54E-01	-7.12E-04	4.89E-01	-7.82E-03	6.01E-01
Initial age 20 ln(abundance) dev					-2.16E-02	6.50E-01	-1.04E-03	4.89E-01	-1.70E-02	5.98E-01

Table 2.1.5c (page 1 of 2)—Log-scale age 0 recruitment *dev*s for Models 0 and 2-4. Shading in each column extends from red (low) to green (high).

	Model 0		Model 2		Model 3		Model 4	
Year	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
1977	1.33E+00	1.09E-01	8.85E-01	2.38E-01	7.13E-01	2.00E-01	8.76E-01	2.39E-01
1978	4.57E-01	2.10E-01	6.86E-01	2.09E-01	6.63E-01	1.62E-01	6.83E-01	2.09E-01
1979	6.66E-01	1.09E-01	4.63E-01	1.38E-01	4.00E-01	1.12E-01	4.58E-01	1.39E-01
1980	-4.07E-01	1.35E-01	-3.08E-01	1.40E-01	-3.78E-01	1.19E-01	-3.12E-01	1.40E-01
1981	-9.23E-01	1.44E-01	-8.05E-01	1.60E-01	-5.39E-01	1.22E-01	-8.09E-01	1.60E-01
1982	9.55E-01	4.14E-02	7.32E-01	6.37E-02	6.43E-01	5.36E-02	7.29E-01	6.39E-02
1983	-5.53E-01	1.12E-01	-3.51E-01	1.23E-01	-3.42E-01	1.00E-01	-3.54E-01	1.23E-01
1984	7.45E-01	4.59E-02	6.48E-01	6.57E-02	5.73E-01	5.54E-02	6.46E-01	6.58E-02
1985	-1.09E-01	7.18E-02	-9.31E-02	9.59E-02	-1.25E-01	7.74E-02	-9.43E-02	9.59E-02
1986	-8.37E-01	9.46E-02	-6.81E-01	1.16E-01	-7.36E-01	9.53E-02	-6.81E-01	1.16E-01
1987	-1.17E+00	1.08E-01	-1.55E+00	2.10E-01	-1.29E+00	1.45E-01	-1.55E+00	2.10E-01
1988	-2.40E-01	5.66E-02	-2.08E-01	9.98E-02	-2.27E-01	7.28E-02	-2.07E-01	9.98E-02
1989	5.03E-01	4.02E-02	3.66E-01	7.21E-02	3.56E-01	5.21E-02	3.66E-01	7.21E-02
1990	2.91E-01	4.57E-02	3.62E-01	6.95E-02	4.12E-01	5.13E-02	3.63E-01	6.95E-02
1991	-3.23E-01	6.13E-02	-2.90E-01	9.70E-02	-3.07E-01	8.09E-02	-2.88E-01	9.70E-02
1992	5.88E-01	3.24E-02	6.11E-01	4.81E-02	5.65E-01	3.87E-02	6.13E-01	4.81E-02
1993	-4.61E-01	5.82E-02	-1.83E-01	7.28E-02	-2.79E-01	6.74E-02	-1.81E-01	7.28E-02
1994	-3.77E-01	5.10E-02	-4.08E-01	7.56E-02	-4.89E-01	6.63E-02	-4.06E-01	7.56E-02
1995	-2.81E-01	5.34E-02	-3.70E-01	7.91E-02	-3.96E-01	6.33E-02	-3.69E-01	7.91E-02
1996	6.23E-01	3.20E-02	4.94E-01	4.85E-02	3.22E-01	4.08E-02	4.95E-01	4.85E-02
1997	-2.83E-01	5.12E-02	-1.19E-01	6.59E-02	8.08E-04	5.11E-02	-1.18E-01	6.59E-02
1998	-3.05E-01	4.95E-02	-2.21E-01	7.44E-02	-1.27E-01	5.81E-02	-2.20E-01	7.45E-02
1999	3.73E-01	3.15E-02	5.05E-01	4.78E-02	5.06E-01	4.00E-02	5.06E-01	4.78E-02
2000	-1.31E-01	3.70E-02	-3.34E-02	5.89E-02	1.88E-02	5.31E-02	-3.23E-02	5.89E-02
2001	-8.94E-01	5.67E-02	-4.60E-01	6.74E-02	-6.22E-01	7.00E-02	-4.59E-01	6.74E-02
2002	-3.68E-01	3.82E-02	-4.48E-01	6.52E-02	-4.13E-01	5.46E-02	-4.46E-01	6.53E-02
2003	-5.95E-01	4.58E-02	-4.20E-01	6.35E-02	-5.00E-01	5.72E-02	-4.18E-01	6.35E-02
2004	-7.29E-01	5.03E-02	-7.03E-01	8.04E-02	-6.43E-01	6.58E-02	-7.00E-01	8.05E-02
2005	-5.92E-01	4.72E-02	-4.11E-01	7.78E-02	-1.53E-01	5.54E-02	-4.08E-01	7.79E-02
2006	6.71E-01	2.83E-02	5.01E-01	4.99E-02	3.05E-01	4.32E-02	5.04E-01	5.00E-02
2007	-5.23E-01	6.17E-02	3.07E-02	6.84E-02	1.57E-01	5.31E-02	3.28E-02	6.84E-02
2008	1.12E+00	3.65E-02	9.29E-01	5.08E-02	8.04E-01	4.25E-02	9.31E-01	5.07E-02
2009	-8.17E-01	1.13E-01	-8.48E-01	1.25E-01	-3.06E-01	9.57E-02	-8.48E-01	1.25E-01
2010	5.73E-01	5.99E-02	2.20E-01	8.32E-02	1.32E-01	7.93E-02	2.20E-01	8.32E-02
2011	1.02E+00	6.60E-02	7.47E-01	8.79E-02	6.58E-01	8.13E-02	7.48E-01	8.78E-02
2012	2.83E-02	1.13E-01	-4.38E-02	1.57E-01	-9.67E-02	1.39E-01	-4.33E-02	1.57E-01
2013	9.64E-01	1.46E-01	7.74E-01	1.95E-01	7.38E-01	1.88E-01	7.75E-01	1.95E-01

Table 2.1.5c (page 2 of 2)— Log-scale age 0 recruitment *dev*s for Models 5-8. Shading in each column extends from red (low) to green (high).

	Model 5		Model 6		Model 7		Model 8	
Year	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
1977	6.36E-01	1.86E-01	9.34E-01	2.27E-01	1.15E+00	2.38E-01	1.33E+00	1.10E-01
1978	4.87E-01	1.71E-01	7.53E-01	1.92E-01	5.76E-01	3.21E-01	4.65E-01	2.09E-01
1979	5.36E-01	1.34E-01	5.35E-01	1.31E-01	5.59E-01	1.81E-01	6.68E-01	1.09E-01
1980	-1.50E-01	1.63E-01	-2.87E-01	1.35E-01	-5.18E-01	2.00E-01	-4.08E-01	1.35E-01
1981	-3.38E-01	1.65E-01	-7.57E-01	1.43E-01	-8.68E-01	1.94E-01	-9.24E-01	1.44E-01
1982	7.25E-01	9.32E-02	7.34E-01	6.53E-02	8.92E-01	6.41E-02	9.55E-01	4.14E-02
1983	-3.47E-01	1.58E-01	-3.67E-01	1.19E-01	-3.74E-01	1.57E-01	-5.51E-01	1.12E-01
1984	4.18E-01	9.60E-02	6.27E-01	6.63E-02	7.49E-01	7.09E-02	7.46E-01	4.60E-02
1985	-8.63E-02	1.17E-01	-4.65E-02	9.32E-02	-1.34E-01	1.18E-01	-1.07E-01	7.19E-02
1986	-4.87E-01	1.37E-01	-6.53E-01	1.13E-01	-7.57E-01	1.36E-01	-8.40E-01	9.49E-02
1987	-8.80E-01	1.71E-01	-1.60E+00	1.89E-01	-1.57E+00	2.16E-01	-1.17E+00	1.07E-01
1988	-2.01E-01	1.24E-01	-3.64E-01	1.12E-01	-1.56E-01	9.78E-02	-2.42E-01	5.66E-02
1989	3.40E-01	8.79E-02	3.12E-01	7.83E-02	4.41E-01	7.52E-02	5.03E-01	4.02E-02
1990	1.75E-01	9.15E-02	3.24E-01	7.68E-02	2.93E-01	8.06E-02	2.91E-01	4.57E-02
1991	-3.51E-01	1.15E-01	-2.60E-01	9.95E-02	-2.72E-01	1.01E-01	-3.22E-01	6.13E-02
1992	4.32E-01	6.54E-02	6.44E-01	5.75E-02	6.35E-01	5.07E-02	5.86E-01	3.24E-02
1993	-3.70E-01	9.58E-02	-1.39E-01	8.53E-02	-2.87E-01	8.46E-02	-4.60E-01	5.82E-02
1994	-4.93E-01	1.06E-01	-3.87E-01	8.80E-02	-3.80E-01	8.56E-02	-3.79E-01	5.11E-02
1995	-2.89E-01	1.03E-01	-4.04E-01	9.16E-02	-2.38E-01	8.91E-02	-2.83E-01	5.35E-02
1996	3.83E-01	7.64E-02	5.45E-01	5.62E-02	6.55E-01	4.92E-02	6.21E-01	3.21E-02
1997	-2.11E-02	9.62E-02	-8.59E-02	7.47E-02	-2.55E-01	7.93E-02	-2.82E-01	5.11E-02
1998	-9.68E-03	9.57E-02	-3.29E-01	8.48E-02	-3.13E-01	8.47E-02	-3.05E-01	4.94E-02
1999	3.55E-01	7.35E-02	4.33E-01	5.62E-02	4.45E-01	4.97E-02	3.73E-01	3.15E-02
2000	-2.60E-01	8.54E-02	-2.24E-02	6.67E-02	-1.07E-01	5.51E-02	-1.31E-01	3.70E-02
2001	-6.40E-01	8.81E-02	-5.73E-01	8.26E-02	-6.74E-01	7.76E-02	-8.93E-01	5.67E-02
2002	-5.59E-01	9.57E-02	-4.32E-01	7.45E-02	-4.74E-01	6.60E-02	-3.70E-01	3.84E-02
2003	-5.77E-01	1.01E-01	-4.31E-01	7.48E-02	-5.14E-01	6.72E-02	-5.97E-01	4.59E-02
2004	-7.01E-01	1.13E-01	-7.40E-01	9.27E-02	-8.08E-01	7.88E-02	-7.30E-01	5.04E-02
2005	-4.12E-01	1.07E-01	-4.62E-01	9.21E-02	-5.45E-01	6.86E-02	-5.93E-01	4.72E-02
2006	3.38E-01	7.86E-02	4.99E-01	5.85E-02	7.04E-01	4.22E-02	6.69E-01	2.84E-02
2007	-1.22E-01	1.07E-01	2.66E-02	7.94E-02	-2.40E-01	8.36E-02	-5.22E-01	6.17E-02
2008	8.18E-01	8.82E-02	9.60E-01	5.82E-02	1.11E+00	4.90E-02	1.12E+00	3.65E-02
2009	-3.70E-01	1.57E-01	-8.74E-01	1.39E-01	-9.49E-01	1.49E-01	-8.12E-01	1.13E-01
2010	4.16E-01	1.43E-01	2.73E-01	8.59E-02	4.57E-01	7.57E-02	5.73E-01	5.99E-02
2011	7.35E-01	1.37E-01	7.70E-01	8.83E-02	9.69E-01	7.91E-02	1.03E+00	6.61E-02
2012	2.71E-02	1.66E-01	-2.81E-02	1.49E-01	-9.11E-02	1.29E-01	2.66E-02	1.14E-01
2013	8.44E-01	1.83E-01	8.72E-01	1.55E-01	8.89E-01	1.61E-01	9.64E-01	1.46E-01

Table 2.1.5d—Log-scale catchabilty (*Q*) devs for Models 2, 4, and 6. The other five models did not include catchability *dev*s.

	Model 2		Model 4		Model 6	
Year	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
1982	-1.34E-01	6.55E-02	-1.31E-01	6.56E-02	-1.54E-01	6.24E-02
1983	1.46E-03	7.22E-02	2.78E-03	7.22E-02	-6.78E-03	6.65E-02
1984	-1.76E-02	6.25E-02	-1.57E-02	6.25E-02	-2.63E-02	5.87E-02
1985	3.36E-03	7.51E-02	4.26E-03	7.52E-02	7.94E-03	6.89E-02
1986	4.33E-02	6.84E-02	4.45E-02	6.84E-02	4.45E-02	6.37E-02
1987	2.80E-02	5.86E-02	2.94E-02	5.86E-02	3.53E-02	5.62E-02
1988	7.38E-03	5.95E-02	8.47E-03	5.95E-02	1.46E-02	5.72E-02
1989	-1.41E-01	6.04E-02	-1.40E-01	6.04E-02	-1.21E-01	5.82E-02
1990	-6.82E-02	6.95E-02	-6.81E-02	6.95E-02	-2.94E-02	6.53E-02
1991	-5.71E-02	7.06E-02	-5.72E-02	7.06E-02	-3.13E-02	6.59E-02
1992	-4.94E-02	7.23E-02	-4.96E-02	7.23E-02	-2.50E-02	6.70E-02
1993	3.12E-02	7.42E-02	3.10E-02	7.42E-02	3.68E-02	6.84E-02
1994	2.14E-01	7.24E-02	2.14E-01	7.24E-02	1.78E-01	6.71E-02
1995	1.17E-01	6.74E-02	1.17E-01	6.74E-02	9.30E-02	6.35E-02
1996	7.04E-02	7.58E-02	7.00E-02	7.58E-02	5.12E-02	6.96E-02
1997	-8.62E-03	7.61E-02	-9.01E-03	7.61E-02	-1.44E-02	6.99E-02
1998	2.53E-03	6.53E-02	1.85E-03	6.53E-02	-2.31E-02	6.17E-02
1999	-2.64E-02	6.58E-02	-2.69E-02	6.58E-02	-4.34E-02	6.20E-02
2000	-8.38E-02	6.59E-02	-8.42E-02	6.59E-02	-7.39E-02	6.21E-02
2001	1.12E-01	6.70E-02	1.12E-01	6.70E-02	1.10E-01	6.30E-02
2002	-1.41E-02	6.80E-02	-1.46E-02	6.80E-02	-1.36E-04	6.37E-02
2003	-2.74E-02	7.27E-02	-2.78E-02	7.27E-02	-7.72E-03	6.72E-02
2004	-1.81E-02	6.39E-02	-1.88E-02	6.39E-02	5.41E-03	6.07E-02
2005	2.20E-02	7.53E-02	2.15E-02	7.53E-02	2.49E-02	6.92E-02
2006	-5.78E-02	5.79E-02	-5.91E-02	5.80E-02	-3.28E-02	5.68E-02
2007	1.11E-02	8.39E-02	1.17E-02	8.39E-02	8.61E-03	7.54E-02
2008	-7.35E-02	6.92E-02	-7.46E-02	6.92E-02	-6.32E-02	6.48E-02
2009	-1.08E-01	6.61E-02	-1.09E-01	6.62E-02	-9.05E-02	6.29E-02
2010	4.72E-02	7.41E-02	4.66E-02	7.41E-02	3.13E-02	6.83E-02
2011	6.39E-03	6.83E-02	5.68E-03	6.83E-02	-1.86E-03	6.42E-02
2012	7.49E-02	7.06E-02	7.45E-02	7.06E-02	4.48E-02	6.57E-02
2013	-5.26E-04	7.95E-02	-6.24E-04	7.95E-02	-1.10E-02	7.20E-02
2014	9.26E-02	7.81E-02	9.26E-02	7.81E-02	6.88E-02	7.08E-02

Table 2.1.5e—Base values of selectivity parameters for Models 0, 7, and 8. These models used the double-normal selectivity function.

	Model 0		Model 7		Model 8	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
P3_May-Jul_Trawl	5.61E+00	1.05E-01	5.68E+00	1.95E-01	5.61E+00	1.06E-01
P2_Jan-Apr_Longline	-4.52E+00	1.41E+00	-5.57E+00	1.09E+01	-4.47E+00	1.33E+00
P4_Jan-Apr_Longline	5.03E+00	1.45E-01	5.11E+00	3.92E-01	5.02E+00	1.45E-01
P3_May-Jul_Longline	5.03E+00	4.60E-02	5.04E+00	1.00E-01	5.02E+00	4.66E-02
P2_Aug-Dec_Longline	-2.12E+00	2.63E-01	-2.31E+00	7.63E-01	-2.11E+00	2.59E-01
P4_Aug-Dec_Longline	5.05E+00	3.32E-01	5.37E+00	7.35E-01	5.05E+00	3.29E-01
P2_Jan-Apr_Pot	-9.24E+00	1.83E+01	-9.02E+00	2.22E+01	-9.23E+00	1.84E+01
P3_Jan-Apr_Pot	5.01E+00	4.85E-02	5.01E+00	6.69E-02	5.01E+00	4.85E-02
P4_Jan-Apr_Pot	4.42E+00	2.86E-01	4.42E+00	4.18E-01	4.42E+00	2.85E-01
P3_May-Jul_Pot	4.93E+00	8.25E-02	4.98E+00	1.02E-01	4.92E+00	8.32E-02
P1_Shelf_Survey	1.27E+00	5.45E-02	1.29E+00	6.62E-02	1.27E+00	5.46E-02
P2_Shelf_Survey	-2.78E+00	4.19E-01	-3.02E+00	7.23E-01	-2.75E+00	4.09E-01
P3_Shelf_Survey	-2.42E+00	4.34E-01	-2.27E+00	4.82E-01	-2.42E+00	4.34E-01
P4_Shelf_Survey	2.68E+00	4.01E-01	2.98E+00	4.89E-01	2.66E+00	4.01E-01
P6_Shelf_Survey	-1.14E+00	3.62E-01	-1.43E+00	5.90E-01	-1.14E+00	3.61E-01

Table 2.1.5f—Block-specific selectivity parameters for the trawl and pot fisheries in Models 0, 7, and 8. Year designations refer to the first year in each time block.

	Model 0		Model 7		Model 8	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
P1_Jan-Apr_Trawl_1977	6.90E+01	3.16E+00	6.82E+01	7.73E+00	6.88E+01	3.16E+00
P1_Jan-Apr_Trawl_1985	7.62E+01	1.67E+00	7.82E+01	3.85E+00	7.60E+01	1.68E+00
P1_Jan-Apr_Trawl_1990	6.88E+01	1.10E+00	7.02E+01	2.49E+00	6.87E+01	1.14E+00
P1_Jan-Apr_Trawl_1995	7.40E+01	9.45E-01	7.61E+01	2.36E+00	7.39E+01	9.73E-01
P1_Jan-Apr_Trawl_2000	7.83E+01	1.21E+00	7.83E+01	3.04E+00	7.82E+01	1.21E+00
P1_Jan-Apr_Trawl_2005	7.74E+01	7.08E-01	7.72E+01	1.81E+00	7.73E+01	7.13E-01
P3_Jan-Apr_Trawl_1977	6.18E+00	1.77E-01	6.17E+00	4.53E-01	6.17E+00	1.78E-01
P3_Jan-Apr_Trawl_1985	6.62E+00	7.69E-02	6.64E+00	1.80E-01	6.61E+00	7.73E-02
P3_Jan-Apr_Trawl_1990	6.09E+00	5.88E-02	6.13E+00	1.34E-01	6.08E+00	6.04E-02
P3_Jan-Apr_Trawl_1995	6.30E+00	4.64E-02	6.35E+00	1.14E-01	6.29E+00	4.75E-02
P3_Jan-Apr_Trawl_2000	6.30E+00	6.13E-02	6.28E+00	1.58E-01	6.30E+00	6.14E-02
P3_Jan-Apr_Trawl_2005	6.01E+00	4.03E-02	6.01E+00	1.05E-01	6.01E+00	4.04E-02
P1_May-Jul_Trawl_1977	5.00E+01	1.71E+00	5.04E+01	3.22E+00	5.00E+01	1.70E+00
P1_May-Jul_Trawl_1985	5.11E+01	1.75E+00	5.27E+01	3.32E+00	5.10E+01	1.75E+00
P1_May-Jul_Trawl_1990	6.17E+01	1.55E+00	6.32E+01	3.08E+00	6.16E+01	1.55E+00
P1_May-Jul_Trawl_2000	5.28E+01	1.54E+00	5.41E+01	2.92E+00	5.28E+01	1.54E+00
P1_May-Jul_Trawl_2005	5.76E+01	1.44E+00	5.82E+01	2.73E+00	5.76E+01	1.44E+00
P1_Aug-Dec_Trawl_1977	6.26E+01	4.06E+00	5.81E+01	1.15E+01	6.26E+01	4.04E+00
P1_Aug-Dec_Trawl_1980	8.19E+01	5.75E+00	8.28E+01	1.39E+01	8.17E+01	5.72E+00
P1_Aug-Dec_Trawl_1985	8.64E+01	5.41E+00	8.76E+01	1.45E+01	8.63E+01	5.42E+00
P1_Aug-Dec_Trawl_1990	7.63E+01	3.50E+01	8.88E+01	1.51E+02	7.55E+01	3.36E+01
P1_Aug-Dec_Trawl_2000	5.61E+01	1.52E+00	5.65E+01	4.30E+00	5.61E+01	1.51E+00
P3_Aug-Dec_Trawl_1977	5.55E+00	3.31E-01	5.40E+00	1.09E+00	5.55E+00	3.31E-01
P3_Aug-Dec_Trawl_1980	6.66E+00	2.33E-01	6.65E+00	5.84E-01	6.66E+00	2.33E-01
P3_Aug-Dec_Trawl_1985	6.61E+00	2.34E-01	6.61E+00	6.13E-01	6.60E+00	2.34E-01
P3_Aug-Dec_Trawl_1990	6.35E+00	1.95E+00	7.00E+00	5.22E+00	6.31E+00	1.92E+00
P3_Aug-Dec_Trawl_1995	7.02E+00	8.92E-02	7.01E+00	2.51E-01	7.02E+00	8.93E-02
P3_Aug-Dec_Trawl_2000	5.22E+00	1.58E-01	5.24E+00	4.42E-01	5.22E+00	1.58E-01
P1_Jan-Apr_Pot_1977	6.88E+01	9.21E-01	6.90E+01	1.25E+00	6.87E+01	9.24E-01
P1_Jan-Apr_Pot_1995	6.85E+01	5.46E-01	6.89E+01	7.72E-01	6.85E+01	5.47E-01
P1_Jan-Apr_Pot_2000	6.81E+01	5.15E-01	6.82E+01	7.20E-01	6.81E+01	5.16E-01
P1_Jan-Apr_Pot_2005	6.91E+01	5.06E-01	6.91E+01	7.05E-01	6.91E+01	5.07E-01
P6_Jan-Apr_Pot_1977	2.25E-01	5.60E-01	1.93E-01	7.68E-01	2.33E-01	5.61E-01
P6_Jan-Apr_Pot_1995	-2.16E-01	2.54E-01	-5.76E-02	3.88E-01	-2.19E-01	2.53E-01
P6_Jan-Apr_Pot_2000	-5.52E-01	2.36E-01	-5.44E-01	3.39E-01	-5.51E-01	2.35E-01
P6_Jan-Apr_Pot_2005	1.86E-01	2.29E-01	1.46E-01	3.19E-01	1.84E-01	2.28E-01
P1_May-Jul_Pot_1977	6.73E+01	8.67E-01	6.78E+01	1.12E+00	6.72E+01	8.72E-01
P1_May-Jul_Pot_1995	6.60E+01	7.26E-01	6.69E+01	9.62E-01	6.60E+01	7.35E-01
P1_Aug-Dec_Pot_1977	6.85E+01	1.19E+00	6.95E+01	3.23E+00	6.85E+01	1.20E+00
P1_Aug-Dec_Pot_2000	6.25E+01	6.70E-01	6.25E+01	1.79E+00	6.25E+01	6.71E-01
P3_Aug-Dec_Pot_1977	5.19E+00	1.20E-01	5.25E+00	3.12E-01	5.19E+00	1.21E-01
P3_Aug-Dec_Pot_2000	4.48E+00	1.01E-01	4.48E+00	2.69E-01	4.47E+00	1.01E-01

Table 2.1.5g—Block-specific selectivity parameters for the longline fishery in Models 0, 7, and 8. Year designations refer to the first year in each time block.

	Model 0		Model 7		Model 8	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
P1_Jan-Apr_Longline_1977	5.91E+01	2.07E+00	5.78E+01	4.40E+00	5.90E+01	2.06E+00
P1_Jan-Apr_Longline_1980	7.23E+01	2.51E+00	7.33E+01	5.43E+00	7.23E+01	2.50E+00
P1_Jan-Apr_Longline_1985	7.50E+01	9.20E-01	7.58E+01	2.29E+00	7.50E+01	9.22E-01
P1_Jan-Apr_Longline_1990	6.61E+01	4.76E-01	6.60E+01	1.26E+00	6.60E+01	4.83E-01
P1_Jan-Apr_Longline_1995	6.57E+01	4.27E-01	6.65E+01	1.14E+00	6.57E+01	4.32E-01
P1_Jan-Apr_Longline_2000	6.35E+01	4.40E-01	6.37E+01	1.15E+00	6.35E+01	4.41E-01
P1_Jan-Apr_Longline_2005	6.71E+01	3.49E-01	6.72E+01	9.28E-01	6.71E+01	3.55E-01
P3_Jan-Apr_Longline_1977	5.15E+00	2.11E-01	5.08E+00	5.47E-01	5.15E+00	2.11E-01
P3_Jan-Apr_Longline_1980	5.91E+00	1.81E-01	5.95E+00	4.15E-01	5.91E+00	1.81E-01
P3_Jan-Apr_Longline_1985	5.85E+00	6.81E-02	5.86E+00	1.74E-01	5.85E+00	6.81E-02
P3_Jan-Apr_Longline_1990	5.23E+00	4.65E-02	5.20E+00	1.26E-01	5.22E+00	4.69E-02
P3_Jan-Apr_Longline_1995	5.30E+00	3.99E-02	5.35E+00	1.05E-01	5.30E+00	4.02E-02
P3_Jan-Apr_Longline_2000	5.36E+00	4.17E-02	5.35E+00	1.11E-01	5.36E+00	4.18E-02
P3_Jan-Apr_Longline_2005	5.30E+00	3.02E-02	5.32E+00	8.17E-02	5.30E+00	3.05E-02
P6_Jan-Apr_Longline_1977	-1.31E+00	8.02E-01	-2.35E+00	2.09E+00	-1.31E+00	7.97E-01
P6_Jan-Apr_Longline_1980	4.30E-01	1.07E+00	-7.37E-01	2.28E+00	4.19E-01	1.06E+00
P6_Jan-Apr_Longline_1985	-1.16E+00	4.39E-01	-1.61E+00	1.44E+00	-1.15E+00	4.35E-01
P6_Jan-Apr_Longline_1990	-4.63E-01	1.38E-01	-3.70E-01	3.77E-01	-4.62E-01	1.37E-01
P6_Jan-Apr_Longline_1995	-6.57E-01	1.40E-01	-6.11E-01	4.05E-01	-6.58E-01	1.39E-01
P6_Jan-Apr_Longline_2000	-1.15E+00	1.44E-01	-1.20E+00	4.05E-01	-1.15E+00	1.44E-01
P6_Jan-Apr_Longline_2005	-8.33E-01	1.38E-01	-9.53E-01	3.90E-01	-8.29E-01	1.37E-01
P1_May-Jul_Longline_1977	6.36E+01	2.22E+00	6.21E+01	5.00E+00	6.35E+01	2.22E+00
P1_May-Jul_Longline_1980	6.25E+01	1.36E+00	6.22E+01	2.90E+00	6.24E+01	1.37E+00
P1_May-Jul_Longline_1985	6.34E+01	1.12E+00	6.41E+01	2.36E+00	6.34E+01	1.12E+00
P1_May-Jul_Longline_1990	6.37E+01	4.88E-01	6.40E+01	1.06E+00	6.36E+01	4.98E-01
P1_May-Jul_Longline_2000	5.99E+01	5.44E-01	6.04E+01	1.17E+00	5.99E+01	5.47E-01
P1_May-Jul_Longline_2005	6.48E+01	4.79E-01	6.48E+01	1.03E+00	6.47E+01	4.86E-01
P1_Aug-Dec_Longline_1977	6.09E+01	2.20E+00	5.81E+01	4.08E+00	6.08E+01	2.19E+00
P1_Aug-Dec_Longline_1980	6.95E+01	1.65E+00	7.23E+01	3.16E+00	6.95E+01	1.65E+00
P1_Aug-Dec_Longline_1985	6.42E+01	7.63E-01	6.50E+01	1.75E+00	6.42E+01	7.72E-01
P1_Aug-Dec_Longline_1990	6.71E+01	7.24E-01	6.78E+01	1.69E+00	6.70E+01	7.30E-01
P1_Aug-Dec_Longline_1995	6.95E+01	7.06E-01	7.11E+01	1.60E+00	6.94E+01	7.17E-01
P1_Aug-Dec_Longline_2000	6.36E+01	4.30E-01	6.43E+01	9.24E-01	6.36E+01	4.34E-01
P1_Aug-Dec_Longline_2005	6.35E+01	3.55E-01	6.31E+01	7.59E-01	6.34E+01	3.63E-01
P3_Aug-Dec_Longline_1977	4.56E+00	3.19E-01	4.25E+00	7.54E-01	4.55E+00	3.19E-01
P3_Aug-Dec_Longline_1980	5.40E+00	1.39E-01	5.59E+00	2.55E-01	5.40E+00	1.39E-01
P3_Aug-Dec_Longline_1985	4.85E+00	8.90E-02	4.91E+00	1.99E-01	4.85E+00	9.01E-02
P3_Aug-Dec_Longline_1990	5.03E+00	7.66E-02	5.10E+00	1.75E-01	5.03E+00	7.71E-02
P3_Aug-Dec_Longline_1995	5.51E+00	5.37E-02	5.60E+00	1.17E-01	5.50E+00	5.43E-02
P3_Aug-Dec_Longline_2000	5.18E+00	4.15E-02	5.21E+00	8.94E-02	5.18E+00	4.18E-02
P3_Aug-Dec_Longline_2005	4.96E+00	3.54E-02	4.94E+00	7.98E-02	4.96E+00	3.60E-02
P6_Aug-Dec_Longline_1977	-2.58E+00	2.13E+00	-4.41E+00	9.77E+00	-2.57E+00	2.11E+00
P6_Aug-Dec_Longline_1980	5.96E-01	8.00E-01	-1.15E+00	2.10E+00	5.86E-01	7.90E-01
P6_Aug-Dec_Longline_1985	2.62E-01	2.47E-01	7.64E-02	6.29E-01	2.65E-01	2.46E-01
P6_Aug-Dec_Longline_1990	2.65E+00	1.09E+00	7.99E+00	3.80E+01	2.63E+00	1.07E+00
P6_Aug-Dec_Longline_1995	9.53E+00	1.23E+01	8.98E+00	2.29E+01	9.53E+00	1.23E+01
P6_Aug-Dec_Longline_2000	-3.28E-01	1.87E-01	-5.29E-01	5.02E-01	-3.24E-01	1.85E-01
P6_Aug-Dec_Longline_2005	9.61E+00	1.04E+01	8.24E+00	3.44E+01	9.60E+00	1.08E+01

Table 2.1.5h—Annual *dev*s for the *ascending_width* parameter of the survey selectivity function in Models 0, 7, and 8.

	Model 0		Model 7		Model 8	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
P3_survey_dev_1982	-3.96E-02	3.20E-02	-5.04E-02	3.41E-02	-3.96E-02	3.20E-02
P3_survey_dev_1983	-2.24E-02	1.81E-02	-1.79E-02	2.06E-02	-2.23E-02	1.81E-02
P3_survey_dev_1984	-6.71E-02	2.82E-02	-8.57E-02	2.89E-02	-6.76E-02	2.82E-02
P3_survey_dev_1985	1.40E-02	2.12E-02	1.69E-03	2.33E-02	1.38E-02	2.12E-02
P3_survey_dev_1986	-3.22E-02	2.33E-02	-3.12E-02	2.73E-02	-3.24E-02	2.33E-02
P3_survey_dev_1987	4.39E-02	3.99E-02	2.36E-02	4.11E-02	4.41E-02	4.00E-02
P3_survey_dev_1988	-6.46E-02	3.23E-02	-3.85E-02	4.42E-02	-6.47E-02	3.23E-02
P3_survey_dev_1989	-1.06E-01	1.93E-02	-1.11E-01	2.06E-02	-1.06E-01	1.93E-02
P3_survey_dev_1990	-1.73E-02	2.11E-02	-1.98E-02	2.33E-02	-1.73E-02	2.12E-02
P3_survey_dev_1991	-2.84E-02	2.27E-02	-3.68E-02	2.46E-02	-2.85E-02	2.27E-02
P3_survey_dev_1992	9.52E-02	3.97E-02	6.47E-02	4.03E-02	9.47E-02	3.96E-02
P3_survey_dev_1993	6.31E-02	2.95E-02	4.90E-02	3.06E-02	6.32E-02	2.95E-02
P3_survey_dev_1994	-2.75E-02	2.21E-02	-3.99E-02	2.31E-02	-2.78E-02	2.21E-02
P3_survey_dev_1995	-7.59E-02	2.05E-02	-6.97E-02	2.31E-02	-7.59E-02	2.05E-02
P3_survey_dev_1996	-9.97E-02	1.84E-02	-9.58E-02	2.01E-02	-9.98E-02	1.84E-02
P3_survey_dev_1997	-4.91E-02	1.59E-02	-4.72E-02	1.73E-02	-4.91E-02	1.59E-02
P3_survey_dev_1998	-6.04E-02	1.96E-02	-6.00E-02	2.14E-02	-6.06E-02	1.96E-02
P3_survey_dev_1999	-6.38E-02	1.81E-02	-6.07E-02	2.01E-02	-6.39E-02	1.81E-02
P3_survey_dev_2000	-2.34E-02	1.64E-02	-2.97E-02	1.74E-02	-2.35E-02	1.64E-02
P3_survey_dev_2001	1.75E-01	3.64E-02	1.64E-01	3.78E-02	1.75E-01	3.64E-02
P3_survey_dev_2002	-4.30E-03	2.40E-02	-2.45E-02	2.37E-02	-4.55E-03	2.40E-02
P3_survey_dev_2003	1.51E-02	2.01E-02	3.71E-02	2.61E-02	1.53E-02	2.02E-02
P3_survey_dev_2004	-2.42E-03	2.05E-02	-9.74E-03	2.17E-02	-2.38E-03	2.05E-02
P3_survey_dev_2005	5.68E-02	2.64E-02	6.75E-02	3.23E-02	5.66E-02	2.64E-02
P3_survey_dev_2006	1.72E-01	3.65E-02	1.49E-01	3.78E-02	1.72E-01	3.65E-02
P3_survey_dev_2007	2.12E-01	3.60E-02	1.97E-01	3.70E-02	2.12E-01	3.60E-02
P3_survey_dev_2008	1.24E-01	3.62E-02	5.90E-02	3.03E-02	1.24E-01	3.62E-02
P3_survey_dev_2009	1.24E-02	1.63E-02	2.11E-02	1.85E-02	1.22E-02	1.63E-02
P3_survey_dev_2010	-2.26E-02	2.71E-02	-5.62E-03	3.34E-02	-2.32E-02	2.70E-02
P3_survey_dev_2011	4.28E-02	2.05E-02	6.47E-02	2.68E-02	4.27E-02	2.05E-02
P3_survey_dev_2012	3.83E-02	2.08E-02	4.03E-02	2.37E-02	3.81E-02	2.08E-02

Table 2.1.5i (page 1 of 2)—Base values of fishery selectivity parameters for Models 2-6. These models use one selectivity parameter for each age rather than the double-normal selectivity function.

	Model 2		Model 3		Model 4		Model 5		Model 6	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
Fishery age 1	2.94E+00	3.50E-01	2.94E+00	3.50E-01	2.94E+00	3.50E-01	3.31E+00	_	3.36E+00	_
Fishery age 2	3.15E+00	3.11E-01	3.51E+00	2.60E-01	3.14E+00	3.11E-01	3.84E+00	5.34E-01	3.80E+00	5.44E-01
Fishery age 3	2.99E+00	1.91E-01	2.94E+00	1.07E-01	2.99E+00	1.91E-01	2.89E+00	2.18E-01	2.89E+00	2.32E-01
Fishery age 4	1.90E+00	2.19E-01	1.90E+00	2.08E-01	1.90E+00	2.19E-01	1.95E+00	1.68E-01	1.82E+00	1.86E-01
Fishery age 5	9.60E-01	1.05E-01	9.89E-01	6.41E-02	9.56E-01	1.05E-01	8.50E-01	1.11E-01	6.31E-01	1.44E-01
Fishery age 6	2.39E-01	1.35E-01	7.86E-02	9.77E-02	2.40E-01	1.35E-01	5.75E-01	1.38E-01	4.27E-01	1.73E-01
Fishery age 7	-2.58E-01	1.89E-01	-2.31E-01	1.48E-01	-2.60E-01	1.89E-01	-3.04E-01	2.19E-01	-5.99E-01	2.81E-01
Fishery age 8	-1.09E-01	2.40E-01	4.03E-02	2.01E-01	-1.15E-01	2.40E-01	6.51E-02	2.29E-01	-3.33E-01	2.82E-01
Fishery age 9	-2.31E-01	2.67E-01	-4.60E-01	2.40E-01	-2.38E-01	2.68E-01	0.00E+00	_	0.00E+00	_
Fishery age 10	-9.23E-02	2.78E-01	-2.08E-01	2.57E-01	-9.57E-02	2.78E-01	0.00E+00	_	0.00E+00	_
Fishery age 11	2.89E-01	2.99E-01	5.56E-01	2.73E-01	2.92E-01	2.99E-01	0.00E+00	_	0.00E+00	_
Fishery age 12	2.58E-01	3.23E-01	4.12E-01	3.00E-01	2.69E-01	3.23E-01	0.00E+00	_	0.00E+00	_
Fishery age 13	2.31E-02	3.35E-01	-1.98E-01	3.22E-01	3.33E-02	3.36E-01	0.00E+00	_	0.00E+00	_
Fishery age 14	-5.14E-02	3.39E-01	-2.43E-01	3.24E-01	-4.55E-02	3.40E-01	0.00E+00	_	0.00E+00	_
Fishery age 15	-9.23E-02	3.35E-01	-2.01E-01	3.19E-01	-9.11E-02	3.35E-01	0.00E+00	_	0.00E+00	_
Fishery age 16	-4.10E-02	3.40E-01	-4.25E-02	3.28E-01	-4.07E-02	3.40E-01	0.00E+00	_	0.00E+00	_
Fishery age 17	-1.97E-02	3.43E-01	3.18E-02	3.38E-01	-1.94E-02	3.43E-01	0.00E+00	_	0.00E+00	_
Fishery age 18	-8.15E-03	3.46E-01	5.59E-02	3.46E-01	-7.11E-03	3.46E-01	0.00E+00	_	0.00E+00	_
Fishery age 19	-3.43E-03	3.48E-01	5.69E-02	3.50E-01	-1.69E-03	3.48E-01	0.00E+00	_	0.00E+00	_
Fishery age 20	-4.95E-03	3.49E-01	3.31E-02	3.51E-01	-3.21E-03	3.49E-01	0.00E+00	_	0.00E+00	_

Table 2.1.5i (page 2 of 2)— Base values of survey selectivity parameters for Models 2-6. These models use one selectivity parameter for each age rather than the double-normal selectivity function.

	Model 2		Model 3		Model 4		Model 5		Model 6	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
Survey age 1	5.02E+00	3.19E-01	5.02E+00	3.19E-01	5.02E+00	3.19E-01	1.51E+00	_	2.09E+00	_
Survey age 2	7.56E-01	1.61E-01	7.88E-01	1.59E-01	7.53E-01	1.61E-01	9.06E-01	1.26E-01	8.56E-01	1.07E-01
Survey age 3	1.85E-01	4.84E-02	1.27E-01	4.21E-02	1.81E-01	4.84E-02	2.74E-01	8.86E-02	1.46E-01	4.96E-02
Survey age 4	-1.34E-01	5.74E-02	-1.96E-01	6.06E-02	-1.38E-01	5.73E-02	6.96E-02	8.65E-02	-1.40E-01	6.50E-02
Survey age 5	-4.54E-02	7.87E-02	-1.42E-02	9.34E-02	-4.80E-02	7.86E-02	7.57E-02	8.52E-02	-7.04E-02	9.16E-02
Survey age 6	-1.29E-01	1.22E-01	-2.29E-01	1.47E-01	-1.30E-01	1.22E-01	-9.50E-02	1.55E-01	-2.61E-01	1.55E-01
Survey age 7	-3.11E-02	1.69E-01	-8.70E-02	1.98E-01	-3.39E-02	1.69E-01	3.18E-01	1.56E-01	-4.36E-02	2.22E-01
Survey age 8	-2.31E-01	2.16E-01	-1.87E-01	2.40E-01	-2.34E-01	2.16E-01	-4.27E-01	2.16E-01	-6.51E-01	2.47E-01
Survey age 9	-2.03E-01	2.47E-01	-1.51E-01	2.60E-01	-2.07E-01	2.47E-01	0.00E+00	_	0.00E+00	_
Survey age 10	-8.32E-02	2.67E-01	-1.50E-02	2.74E-01	-8.63E-02	2.67E-01	0.00E+00	_	0.00E+00	_
Survey age 11	-5.22E-02	2.87E-01	3.05E-02	2.85E-01	-5.34E-02	2.86E-01	0.00E+00	_	0.00E+00	_
Survey age 12	-4.06E-02	3.02E-01	7.81E-02	2.95E-01	-4.02E-02	3.01E-01	0.00E+00	_	0.00E+00	_
Survey age 13	-5.56E-02	3.08E-01	9.80E-02	2.99E-01	-5.37E-02	3.08E-01	0.00E+00	_	0.00E+00	_
Survey age 14	-2.99E-02	3.13E-01	1.22E-01	3.01E-01	-2.70E-02	3.13E-01	0.00E+00	_	0.00E+00	_
Survey age 15	-1.47E-02	3.16E-01	1.44E-01	3.03E-01	-1.11E-02	3.16E-01	0.00E+00	_	0.00E+00	_
Survey age 16	-1.53E-02	3.17E-01	1.40E-01	3.03E-01	-1.11E-02	3.17E-01	0.00E+00	_	0.00E+00	_
Survey age 17	-1.59E-02	3.17E-01	1.30E-01	3.02E-01	-1.22E-02	3.17E-01	0.00E+00	_	0.00E+00	_
Survey age 18	-1.33E-02	3.17E-01	1.25E-01	3.01E-01	-1.06E-02	3.17E-01	0.00E+00	_	0.00E+00	_
Survey age 19	-9.89E-03	3.18E-01	1.23E-01	3.01E-01	-7.99E-03	3.18E-01	0.00E+00	_	0.00E+00	_
Survey age 20	-6.94E-03	3.18E-01	1.25E-01	3.00E-01	-5.72E-03	3.18E-01	0.00E+00	_	0.00E+00	_

Table 2.1.5j—Annual fishery selectivity *dev*s for Models 2-4 (age 4 only; other fishery selectivity parameters did not vary with time in these models).

	Model 2		Model 3		Model 4	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
Age_4_Fishery_1977	-2.36E-02	1.51E-01	-2.38E-04	1.05E-01	-2.31E-02	1.50E-01
Age_4_Fishery_1978	-4.87E-03	1.24E-01	2.57E-02	8.79E-02	-3.84E-03	1.24E-01
Age_4_Fishery_1979	-1.55E-01	7.07E-02	-1.08E-01	4.75E-02	-1.54E-01	7.06E-02
Age_4_Fishery_1980	-1.14E-01	7.10E-02	-1.06E-01	4.99E-02	-1.15E-01	7.09E-02
Age_4_Fishery_1981	-2.16E-01	7.29E-02	-2.62E-01	4.45E-02	-2.17E-01	7.29E-02
Age_4_Fishery_1982	-1.97E-02	1.18E-01	-4.63E-02	7.01E-02	-2.00E-02	1.18E-01
Age_4_Fishery_1983	-7.26E-02	8.79E-02	-9.97E-02	4.62E-02	-7.29E-02	8.78E-02
Age_4_Fishery_1984	-1.81E-01	4.21E-02	-1.66E-01	2.86E-02	-1.81E-01	4.21E-02
Age_4_Fishery_1985	-3.80E-02	3.87E-02	-4.39E-02	2.72E-02	-3.84E-02	3.87E-02
Age_4_Fishery_1986	-9.43E-02	4.41E-02	-1.07E-01	2.88E-02	-9.46E-02	4.41E-02
Age_4_Fishery_1987	-8.31E-03	3.72E-02	-2.89E-02	2.64E-02	-8.44E-03	3.72E-02
Age_4_Fishery_1988	-2.23E-01	3.89E-02	-2.35E-01	2.71E-02	-2.24E-01	3.89E-02
Age_4_Fishery_1989	-1.77E-01	5.58E-02	-2.03E-01	3.26E-02	-1.77E-01	5.58E-02
Age_4_Fishery_1990	-1.12E-01	4.73E-02	-1.00E-01	3.06E-02	-1.13E-01	4.73E-02
Age_4_Fishery_1991	-4.83E-02	3.33E-02	-4.49E-02	2.52E-02	-4.87E-02	3.33E-02
Age_4_Fishery_1992	-8.50E-03	3.26E-02	-1.60E-02	2.46E-02	-8.94E-03	3.25E-02
Age_4_Fishery_1993	-9.06E-02	3.23E-02	-9.84E-02	2.45E-02	-9.08E-02	3.23E-02
Age_4_Fishery_1994	-7.91E-02	3.42E-02	-9.35E-02	2.54E-02	-7.92E-02	3.42E-02
Age_4_Fishery_1995	-5.93E-02	2.98E-02	-7.63E-02	2.36E-02	-5.95E-02	2.98E-02
Age_4_Fishery_1996	1.45E-02	4.43E-02	-1.16E-02	2.83E-02	1.42E-02	4.42E-02
Age_4_Fishery_1997	-5.77E-02	3.40E-02	-7.64E-02	2.50E-02	-5.78E-02	3.40E-02
Age_4_Fishery_1998	-2.17E-02	3.59E-02	-2.50E-02	2.56E-02	-2.18E-02	3.59E-02
Age_4_Fishery_1999	-3.22E-02	2.97E-02	-3.63E-02	2.37E-02	-3.24E-02	2.97E-02
Age_4_Fishery_2000	1.28E-01	6.98E-02	1.36E-01	4.18E-02	1.28E-01	6.98E-02
Age_4_Fishery_2001	3.57E-02	4.90E-02	5.75E-02	3.23E-02	3.57E-02	4.90E-02
Age_4_Fishery_2002	-3.06E-02	3.02E-02	-2.26E-02	2.40E-02	-3.08E-02	3.02E-02
Age_4_Fishery_2003	2.13E-02	4.41E-02	5.23E-03	2.77E-02	2.10E-02	4.41E-02
Age_4_Fishery_2004	4.85E-02	5.94E-02	1.70E-02	3.48E-02	4.84E-02	5.94E-02
Age_4_Fishery_2005	4.48E-03	4.46E-02	-1.67E-02	2.74E-02	4.40E-03	4.46E-02
Age_4_Fishery_2006	8.27E-02	6.12E-02	8.63E-02	3.84E-02	8.26E-02	6.12E-02
Age_4_Fishery_2007	1.03E-01	6.80E-02	1.19E-01	4.22E-02	1.03E-01	6.80E-02
Age_4_Fishery_2008	6.50E-02	4.84E-02	9.15E-02	3.11E-02	6.50E-02	4.84E-02
Age_4_Fishery_2009	1.36E-01	5.38E-02	1.49E-01	4.01E-02	1.36E-01	5.38E-02
Age_4_Fishery_2010	2.18E-01	8.19E-02	2.66E-01	6.45E-02	2.18E-01	8.19E-02
Age_4_Fishery_2011	1.05E-01	4.60E-02	9.85E-02	3.06E-02	1.05E-01	4.60E-02
Age_4_Fishery_2012	1.44E-01	8.41E-02	2.20E-01	6.14E-02	1.44E-01	8.41E-02
Age_4_Fishery_2013	-2.05E-02	3.32E-02	-1.21E-02	2.59E-02	-2.05E-02	3.32E-02
Age_4_Fishery_2014	7.76E-02	4.24E-02	6.90E-02	2.90E-02	7.75E-02	4.24E-02

Table 2.1.5k (page 1 of 3)—Annual fishery selectivity *dev*s for Models 5-6 (ages 3-4).

	Model 5		Model 6			Model 5		Model 6	
Parameter	Model	St. Dev.	Estimate	St. Dev.	Parameter	Estimate	St. Dev.	Estimate	St. Dev.
Age_3_Fishery_1977	-2.02E-03	5.27E-01	-1.82E-03	5.80E-01	Age_4_Fishery_1977	-5.75E-02	7.91E-01	-6.61E-02	8.88E-01
Age_3_Fishery_1978	-2.57E-02	5.21E-01	-3.16E-02	5.73E-01	Age_4_Fishery_1978	1.02E-01	7.15E-01	1.16E-01	7.95E-01
Age_3_Fishery_1979	8.84E-02	5.03E-01	9.79E-02	5.52E-01	Age_4_Fishery_1979	-7.71E-01	5.87E-01	-8.19E-01	6.41E-01
Age_3_Fishery_1980	4.70E-02	5.13E-01	5.05E-02	5.64E-01	Age_4_Fishery_1980	-6.00E-01	5.86E-01	-6.86E-01	6.38E-01
Age_3_Fishery_1981	-7.41E-02	5.32E-01	-7.20E-02	5.87E-01	Age_4_Fishery_1981	-1.13E+00	6.17E-01	-1.32E+00	6.61E-01
Age_3_Fishery_1982	-1.00E-03	5.26E-01	-3.12E-03	5.80E-01	Age_4_Fishery_1982	-2.30E-02	7.06E-01	-8.33E-02	8.04E-01
Age_3_Fishery_1983	-5.68E-02	5.27E-01	-6.38E-02	5.84E-01	Age_4_Fishery_1983	-3.13E-01	6.55E-01	-4.91E-01	7.44E-01
Age_3_Fishery_1984	-4.53E-01	4.59E-01	-4.33E-01	4.88E-01	Age_4_Fishery_1984	-1.11E+00	4.57E-01	-1.40E+00	5.11E-01
Age_3_Fishery_1985	8.18E-02	5.06E-01	1.01E-01	5.52E-01	Age_4_Fishery_1985	3.03E-01	4.41E-01	4.58E-01	4.83E-01
Age_3_Fishery_1986	-3.07E-01	4.83E-01	-3.25E-01	5.20E-01	Age_4_Fishery_1986	-8.47E-01	4.24E-01	-7.75E-01	4.51E-01
Age_3_Fishery_1987	-1.81E-01	4.93E-01	-2.25E-01	5.52E-01	Age_4_Fishery_1987	2.38E-02	3.94E-01	1.71E-01	4.27E-01
Age_3_Fishery_1988	-5.77E-02	5.07E-01	-7.64E-02	5.66E-01	Age_4_Fishery_1988	-1.42E+00	4.09E-01	-1.58E+00	4.31E-01
Age_3_Fishery_1989	-6.54E-02	5.27E-01	-6.25E-02	5.86E-01	Age_4_Fishery_1989	-9.55E-01	5.52E-01	-1.21E+00	6.04E-01
Age_3_Fishery_1990	-5.15E-01	4.89E-01	-5.67E-01	5.19E-01	Age_4_Fishery_1990	-7.05E-01	4.62E-01	-1.13E+00	5.23E-01
Age_3_Fishery_1991	-2.53E-01	4.37E-01	-1.60E-01	4.59E-01	Age_4_Fishery_1991	-2.39E-01	3.94E-01	-1.25E-01	4.52E-01
Age_3_Fishery_1992	1.08E-01	4.49E-01	1.58E-01	4.82E-01	Age_4_Fishery_1992	-9.77E-02	3.22E-01	1.52E-01	3.40E-01
Age_3_Fishery_1993	-3.40E-02	4.70E-01	-4.79E-02	5.20E-01	Age_4_Fishery_1993	-8.29E-01	3.15E-01	-6.39E-01	3.32E-01
Age_3_Fishery_1994	-3.90E-01	4.24E-01	-4.15E-01	4.55E-01	Age_4_Fishery_1994	-4.70E-01	3.55E-01	-5.00E-01	3.84E-01
Age_3_Fishery_1995	1.38E-01	4.63E-01	1.49E-01	5.05E-01	Age_4_Fishery_1995	-1.54E-01	3.26E-01	-6.26E-02	3.59E-01
Age_3_Fishery_1996	-3.86E-01	4.91E-01	-4.64E-01	5.51E-01	Age_4_Fishery_1996	4.03E-02	3.71E-01	5.79E-02	3.97E-01
Age_3_Fishery_1997	-2.76E-01	4.48E-01	-3.94E-01	5.02E-01	Age_4_Fishery_1997	-4.94E-01	3.55E-01	-6.84E-01	3.85E-01
Age_3_Fishery_1998	-4.66E-02	4.27E-01	1.77E-02	4.54E-01	Age_4_Fishery_1998	3.41E-02	3.64E-01	-1.90E-01	4.05E-01
Age_3_Fishery_1999	2.41E-01	4.46E-01	2.13E-01	4.97E-01	Age_4_Fishery_1999	-4.23E-02	3.07E-01	1.13E-01	3.31E-01
Age_3_Fishery_2000	1.20E-01	4.85E-01	5.48E-02	5.46E-01	Age_4_Fishery_2000	5.67E-01	4.26E-01	5.82E-01	4.83E-01
Age_3_Fishery_2001	2.97E-01	4.66E-01	3.92E-01	5.02E-01	Age_4_Fishery_2001	4.08E-01	4.05E-01	1.97E-01	4.63E-01
Age_3_Fishery_2002	8.37E-02	4.72E-01	1.44E-01	5.07E-01	Age_4_Fishery_2002	1.92E-01	3.14E-01	5.74E-01	3.34E-01
Age_3_Fishery_2003	1.89E-01	4.80E-01	1.54E-01	5.35E-01	Age_4_Fishery_2003	1.45E-01	3.62E-01	4.72E-01	3.95E-01
Age_3_Fishery_2004	1.03E-01	4.93E-01	8.48E-02	5.46E-01	Age_4_Fishery_2004	6.18E-01	4.48E-01	6.44E-01	5.09E-01
Age_3_Fishery_2005	1.26E-01	4.84E-01	1.34E-01	5.30E-01	Age_4_Fishery_2005	5.09E-01	4.09E-01	5.21E-01	4.50E-01
Age_3_Fishery_2006	7.66E-02	5.00E-01	5.38E-02	5.56E-01	Age_4_Fishery_2006	8.71E-01	4.52E-01	9.90E-01	4.97E-01
Age_3_Fishery_2007	1.38E-02	4.97E-01	-1.56E-02	5.51E-01	Age_4_Fishery_2007	5.93E-01	4.73E-01	5.34E-01	5.28E-01
Age_3_Fishery_2008	2.91E-01	4.55E-01	3.52E-01	4.92E-01	Age_4_Fishery_2008	6.07E-01	4.11E-01	6.09E-01	4.56E-01
Age_3_Fishery_2009	1.79E-01	4.87E-01	1.89E-01	5.34E-01	Age_4_Fishery_2009	1.41E+00	4.12E-01	1.65E+00	4.46E-01
Age_3_Fishery_2010	1.96E-01	4.83E-01	1.77E-01	5.33E-01	Age_4_Fishery_2010	9.56E-01	4.95E-01	1.10E+00	5.51E-01
Age_3_Fishery_2011	1.21E-01	4.95E-01	6.62E-02	5.59E-01	Age_4_Fishery_2011	8.98E-01	3.78E-01	8.92E-01	4.15E-01
Age_3_Fishery_2012	3.40E-02	4.93E-01	2.34E-03	5.44E-01	Age_4_Fishery_2012	8.47E-01	5.05E-01	6.27E-01	5.98E-01
Age_3_Fishery_2013	3.29E-01	4.45E-01	4.56E-01	4.71E-01	Age_4_Fishery_2013	4.72E-01	3.74E-01	5.02E-01	4.26E-01
Age_3_Fishery_2014	8.41E-02	4.88E-01	7.14E-02	5.40E-01	Age_4_Fishery_2014	4.10E-01	3.65E-01	6.93E-01	3.76E-01

Table 2.1.5k (page 2 of 3)—Annual fishery selectivity *dev*s for Models 5-6 (ages 5-6).

	Model 5		Model 6			Model 5		Model 6	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.	Parameter	Estimate	St. Dev.	Estimate	St. Dev.
Age_5_Fishery_1977	-3.25E-02	3.42E-01	-4.78E-02	4.19E-01	Age_6_Fishery_1977	-2.86E-02	2.43E-01	-5.58E-03	1.15E-01
Age_5_Fishery_1978	-1.18E-01	3.32E-01	-1.64E-01	4.03E-01	Age_6_Fishery_1978	-1.18E-01	2.37E-01	-2.16E-02	1.14E-01
Age_5_Fishery_1979	-1.60E-01	3.23E-01	-1.99E-01	3.92E-01	Age_6_Fishery_1979	-1.04E-01	2.36E-01	-1.87E-02	1.14E-01
Age_5_Fishery_1980	-1.24E-01	3.19E-01	-1.53E-01	3.84E-01	Age_6_Fishery_1980	-4.41E-02	2.36E-01	-8.10E-03	1.14E-01
Age_5_Fishery_1981	-1.81E-01	3.20E-01	-2.34E-01	3.88E-01	Age_6_Fishery_1981	-4.49E-02	2.39E-01	-9.02E-03	1.14E-01
Age_5_Fishery_1982	8.08E-02	3.16E-01	1.08E-01	3.78E-01	Age_6_Fishery_1982	6.79E-02	2.38E-01	1.32E-02	1.14E-01
Age_5_Fishery_1983	1.51E-01	2.86E-01	1.24E-01	3.33E-01	Age_6_Fishery_1983	1.28E-01	2.17E-01	2.25E-02	1.13E-01
Age_5_Fishery_1984	8.13E-02	2.81E-01	-5.79E-04	3.32E-01	Age_6_Fishery_1984	2.47E-01	2.02E-01	2.93E-02	1.12E-01
Age_5_Fishery_1985	-3.33E-01	2.70E-01	-5.50E-01	3.25E-01	Age_6_Fishery_1985	8.46E-02	2.00E-01	-9.72E-03	1.12E-01
Age_5_Fishery_1986	2.98E-01	2.52E-01	4.53E-01	2.80E-01	Age_6_Fishery_1986	-3.03E-02	2.10E-01	6.89E-03	1.13E-01
Age_5_Fishery_1987	-2.56E-01	2.61E-01	-6.02E-02	3.00E-01	Age_6_Fishery_1987	2.40E-01	1.90E-01	4.77E-02	1.13E-01
Age_5_Fishery_1988	-3.08E-01	2.65E-01	-1.89E-01	2.89E-01	Age_6_Fishery_1988	-5.78E-02	2.11E-01	3.49E-03	1.12E-01
Age_5_Fishery_1989	-9.79E-02	2.87E-01	-1.32E-01	3.42E-01	Age_6_Fishery_1989	1.56E-01	2.11E-01	3.30E-02	1.13E-01
Age_5_Fishery_1990	2.52E-01	2.70E-01	2.13E-01	3.07E-01	Age_6_Fishery_1990	3.03E-01	1.95E-01	4.75E-02	1.11E-01
Age_5_Fishery_1991	-8.71E-02	2.67E-01	-3.82E-01	3.37E-01	Age_6_Fishery_1991	2.15E-01	1.95E-01	-4.46E-03	1.12E-01
Age_5_Fishery_1992	3.44E-02	2.44E-01	1.44E-01	2.69E-01	Age_6_Fishery_1992	2.07E-02	2.03E-01	2.27E-03	1.13E-01
Age_5_Fishery_1993	-8.66E-02	2.35E-01	1.58E-01	2.73E-01	Age_6_Fishery_1993	2.11E-02	2.04E-01	5.87E-03	1.13E-01
Age_5_Fishery_1994	-3.70E-02	2.15E-01	2.88E-01	2.29E-01	Age_6_Fishery_1994	-9.01E-04	1.91E-01	2.54E-02	1.11E-01
Age_5_Fishery_1995	-2.03E-01	2.43E-01	-1.20E-01	2.66E-01	Age_6_Fishery_1995	-1.69E-01	1.87E-01	-6.02E-03	1.10E-01
Age_5_Fishery_1996	9.19E-02	2.11E-01	2.02E-01	2.10E-01	Age_6_Fishery_1996	2.97E-02	1.95E-01	1.97E-02	1.11E-01
Age_5_Fishery_1997	1.28E-01	2.22E-01	2.58E-01	2.53E-01	Age_6_Fishery_1997	1.49E-01	1.82E-01	3.85E-02	1.11E-01
Age_5_Fishery_1998	-2.31E-02	2.35E-01	-7.27E-02	2.46E-01	Age_6_Fishery_1998	6.63E-02	1.86E-01	1.51E-02	1.10E-01
Age_5_Fishery_1999	-6.44E-02	2.29E-01	-2.69E-01	2.53E-01	Age_6_Fishery_1999	5.70E-02	1.94E-01	-8.65E-04	1.11E-01
Age_5_Fishery_2000	3.81E-01	2.06E-01	4.70E-01	2.14E-01	Age_6_Fishery_2000	-2.41E-02	1.93E-01	-1.06E-02	1.12E-01
Age_5_Fishery_2001	4.30E-02	2.11E-01	6.30E-02	2.28E-01	Age_6_Fishery_2001	3.97E-02	1.86E-01	1.24E-02	1.11E-01
Age_5_Fishery_2002	-2.44E-01	2.16E-01	-6.45E-01	2.22E-01	Age_6_Fishery_2002	-2.32E-01	1.86E-01	-7.07E-02	1.10E-01
Age_5_Fishery_2003	-1.26E-01	1.95E-01	6.60E-02	1.96E-01	Age_6_Fishery_2003	-1.62E-01	1.88E-01	-1.53E-02	1.11E-01
Age_5_Fishery_2004	-2.08E-01	2.06E-01	7.18E-02	2.19E-01	Age_6_Fishery_2004	-3.05E-01	1.80E-01	-2.13E-02	1.11E-01
Age_5_Fishery_2005	-2.31E-01	2.25E-01	-2.49E-01	2.34E-01	Age_6_Fishery_2005	-2.05E-01	1.83E-01	-8.12E-03	1.09E-01
Age_5_Fishery_2006	-6.77E-02	2.28E-01	-2.10E-01	2.38E-01	Age_6_Fishery_2006	-1.22E-01	1.93E-01	-2.53E-02	1.11E-01
Age_5_Fishery_2007	2.68E-01	2.35E-01	2.69E-01	2.57E-01	Age_6_Fishery_2007	6.78E-03	1.93E-01	-5.43E-03	1.12E-01
Age_5_Fishery_2008	8.86E-02	2.31E-01	-2.82E-02	2.50E-01	Age_6_Fishery_2008	-2.35E-02	1.92E-01	-1.35E-02	1.11E-01
Age_5_Fishery_2009	-1.91E-01	2.23E-01	-2.83E-01	2.35E-01	Age_6_Fishery_2009	-9.74E-03	2.01E-01	-2.61E-03	1.12E-01
Age_5_Fishery_2010	7.03E-01	2.18E-01	9.49E-01	2.35E-01	Age_6_Fishery_2010	-5.88E-02	2.04E-01	-5.25E-03	1.12E-01
Age_5_Fishery_2011	9.52E-03	2.17E-01	1.60E-01	2.40E-01	Age_6_Fishery_2011	1.67E-01	1.99E-01	2.81E-02	1.12E-01
Age_5_Fishery_2012	6.20E-01	2.11E-01	5.98E-01	2.08E-01	Age_6_Fishery_2012	-1.40E-01	2.01E-01	-4.07E-02	1.12E-01
Age_5_Fishery_2013	-1.99E-01	2.31E-01	-4.88E-01	2.93E-01	Age_6_Fishery_2013	7.77E-02	1.93E-01	-7.18E-03	1.11E-01
Age_5_Fishery_2014	2.66E-01	2.48E-01	3.02E-02	2.31E-01	Age_6_Fishery_2014	-1.31E-01	2.07E-01	-2.97E-02	1.12E-01

Table 2.1.5k (page 3 of 3)—Annual fishery selectivity *dev*s for Models 5-6 (age 7).

Parameter	Model 5		Model 6	
	Estimate	St. Dev.	Estimate	St. Dev.
Age_7_Fishery_1977	-2.23E-02	2.13E-01	-8.88E-02	4.62E-01
Age_7_Fishery_1978	-6.95E-02	2.09E-01	-2.71E-01	4.31E-01
Age_7_Fishery_1979	-6.50E-02	2.09E-01	-2.49E-01	4.32E-01
Age_7_Fishery_1980	-1.81E-02	2.11E-01	-7.19E-02	4.45E-01
Age_7_Fishery_1981	-1.62E-02	2.12E-01	-8.42E-02	4.53E-01
Age_7_Fishery_1982	2.20E-02	2.13E-01	8.86E-02	4.63E-01
Age_7_Fishery_1983	8.04E-02	2.08E-01	3.22E-01	4.06E-01
Age_7_Fishery_1984	1.86E-01	1.91E-01	5.29E-01	3.01E-01
Age_7_Fishery_1985	1.46E-01	1.80E-01	2.95E-01	2.69E-01
Age_7_Fishery_1986	-7.29E-02	1.82E-01	-2.16E-01	2.88E-01
Age_7_Fishery_1987	4.67E-02	1.78E-01	3.03E-01	2.34E-01
Age_7_Fishery_1988	3.43E-02	1.94E-01	1.82E-01	3.35E-01
Age_7_Fishery_1989	1.36E-01	1.93E-01	6.04E-01	3.17E-01
Age_7_Fishery_1990	2.95E-01	1.66E-01	8.57E-01	2.25E-01
Age_7_Fishery_1991	2.47E-01	1.68E-01	4.76E-01	2.24E-01
Age_7_Fishery_1992	-1.86E-02	1.74E-01	-3.05E-01	2.54E-01
Age_7_Fishery_1993	1.05E-02	1.86E-01	-7.99E-02	2.82E-01
Age_7_Fishery_1994	-4.14E-02	1.82E-01	-1.47E-01	2.60E-01
Age_7_Fishery_1995	-7.27E-02	1.83E-01	-1.10E-01	2.75E-01
Age_7_Fishery_1996	1.03E-01	1.75E-01	4.42E-01	2.51E-01
Age_7_Fishery_1997	3.64E-02	1.78E-01	4.08E-01	2.35E-01
Age_7_Fishery_1998	6.24E-02	1.75E-01	3.43E-01	2.50E-01
Age_7_Fishery_1999	-3.76E-02	1.80E-01	1.09E-03	2.60E-01
Age_7_Fishery_2000	-4.72E-02	1.80E-01	-2.66E-01	2.53E-01
Age_7_Fishery_2001	-8.35E-02	1.85E-01	-2.65E-01	2.64E-01
Age_7_Fishery_2002	-7.47E-02	1.85E-01	-4.09E-01	2.81E-01
Age_7_Fishery_2003	-1.70E-01	1.78E-01	-6.03E-01	2.56E-01
Age_7_Fishery_2004	-1.65E-01	1.76E-01	-3.60E-01	2.43E-01
Age_7_Fishery_2005	-6.24E-02	1.66E-01	1.27E-01	2.28E-01
Age_7_Fishery_2006	1.33E-02	1.70E-01	3.46E-01	2.35E-01
Age_7_Fishery_2007	3.71E-02	1.74E-01	2.88E-01	2.36E-01
Age_7_Fishery_2008	-2.78E-02	1.78E-01	-1.63E-02	2.47E-01
Age_7_Fishery_2009	-8.88E-02	1.90E-01	-3.76E-01	2.98E-01
Age_7_Fishery_2010	-1.21E-01	1.94E-01	-5.93E-01	3.17E-01
Age_7_Fishery_2011	2.24E-03	1.96E-01	-8.27E-02	3.23E-01
Age_7_Fishery_2012	-6.41E-02	2.01E-01	-4.43E-01	3.52E-01
Age_7_Fishery_2013	-5.10E-02	1.97E-01	-3.31E-01	3.24E-01
Age_7_Fishery_2014	-9.50E-02	1.98E-01	-5.14E-01	3.41E-01

Table 2.1.5l—Age 2 survey selectivity *dev*s for Models 2-5.

Parameter	Model 2 Estimate	Model 2 St. Dev.	Model 3 Estimate	Model 3 St. Dev.	Model 4 Estimate	Model 4 St. Dev.	Model 6 Estimate	Model 6 St. Dev.	Model 5 Estimate	Model 5 St. Dev.
Age_2_Survey_1982	4.64E-02	3.63E-02	8.27E-02	3.33E-02	4.61E-02	3.63E-02	3.50E-01	2.93E-01	4.50E-01	3.66E-01
Age_2_Survey_1983	-6.33E-04	2.08E-02	-8.18E-03	1.99E-02	-8.23E-04	2.08E-02	-8.39E-02	1.64E-01	-4.99E-01	2.74E-01
Age_2_Survey_1984	1.01E-01	3.69E-02	1.03E-01	3.43E-02	1.01E-01	3.69E-02	7.42E-01	2.88E-01	8.34E-01	3.41E-01
Age_2_Survey_1985	-1.28E-02	2.08E-02	-1.81E-02	2.00E-02	-1.30E-02	2.08E-02	-2.00E-01	1.62E-01	-2.33E-01	2.67E-01
Age_2_Survey_1986	4.00E-02	2.63E-02	3.80E-02	2.47E-02	4.00E-02	2.63E-02	3.61E-01	2.16E-01	6.82E-01	2.63E-01
Age_2_Survey_1987	-5.27E-03	2.99E-02	-1.32E-02	2.76E-02	-5.30E-03	2.99E-02	-7.82E-02	2.53E-01	2.35E-01	3.14E-01
Age_2_Survey_1988	5.39E-02	4.59E-02	7.79E-02	4.15E-02	5.37E-02	4.59E-02	3.23E-01	3.53E-01	8.42E-01	3.99E-01
Age_2_Survey_1989	1.24E-01	3.05E-02	1.34E-01	2.84E-02	1.24E-01	3.05E-02	9.18E-01	2.48E-01	9.94E-02	3.52E-01
Age_2_Survey_1990	2.99E-03	2.39E-02	7.22E-03	2.19E-02	2.91E-03	2.39E-02	-4.80E-02	1.96E-01	-2.79E-01	2.80E-01
Age_2_Survey_1991	3.72E-02	2.54E-02	4.33E-02	2.38E-02	3.71E-02	2.54E-02	2.78E-01	2.11E-01	2.10E-01	2.59E-01
Age_2_Survey_1992	-5.64E-02	2.46E-02	-6.04E-02	2.32E-02	-5.64E-02	2.46E-02	-5.34E-01	2.07E-01	-3.73E-01	2.59E-01
Age_2_Survey_1993	-3.51E-02	2.08E-02	-4.27E-02	2.00E-02	-3.51E-02	2.08E-02	-3.45E-01	1.68E-01	-1.66E-01	2.39E-01
Age_2_Survey_1994	5.86E-02	2.44E-02	5.01E-02	2.59E-02	5.85E-02	2.44E-02	5.20E-01	2.18E-01	5.82E-01	2.38E-01
Age_2_Survey_1995	7.99E-02	2.85E-02	6.84E-02	3.04E-02	7.98E-02	2.85E-02	6.25E-01	2.53E-01	9.13E-01	2.92E-01
Age_2_Survey_1996	1.04E-01	2.77E-02	1.06E-01	3.00E-02	1.04E-01	2.77E-02	7.93E-01	2.47E-01	1.09E+00	2.85E-01
Age_2_Survey_1997	3.36E-02	2.01E-02	2.24E-02	2.08E-02	3.35E-02	2.01E-02	2.85E-01	1.68E-01	-1.13E-03	2.26E-01
Age_2_Survey_1998	8.65E-02	2.53E-02	1.05E-01	2.66E-02	8.63E-02	2.53E-02	7.12E-01	2.22E-01	1.04E+00	2.51E-01
Age_2_Survey_1999	7.54E-02	2.40E-02	9.10E-02	2.54E-02	7.52E-02	2.40E-02	5.04E-01	2.13E-01	6.70E-01	2.55E-01
Age_2_Survey_2000	3.06E-02	1.94E-02	3.37E-02	1.97E-02	3.05E-02	1.94E-02	1.70E-01	1.57E-01	-4.07E-01	2.19E-01
Age_2_Survey_2001	-7.41E-02	1.89E-02	-7.25E-02	1.90E-02	-7.42E-02	1.89E-02	-7.57E-01	1.50E-01	-8.30E-01	1.91E-01
Age_2_Survey_2002	3.74E-02	2.33E-02	1.92E-02	2.48E-02	3.73E-02	2.33E-02	2.06E-01	2.08E-01	4.38E-01	2.38E-01
Age_2_Survey_2003	-3.26E-02	2.00E-02	-3.02E-02	2.07E-02	-3.27E-02	2.00E-02	-3.33E-01	1.70E-01	-3.92E-01	2.23E-01
Age_2_Survey_2004	1.16E-02	2.09E-02	5.59E-03	2.19E-02	1.16E-02	2.09E-02	7.43E-02	1.82E-01	4.84E-02	2.34E-01
Age_2_Survey_2005	-4.11E-02	2.06E-02	-4.07E-02	2.12E-02	-4.12E-02	2.06E-02	-5.14E-01	1.79E-01	-2.06E-01	2.32E-01
Age_2_Survey_2006	-6.59E-02	1.95E-02	-3.50E-02	1.89E-02	-6.59E-02	1.95E-02	-7.31E-01	1.63E-01	-7.55E-01	2.28E-01
Age_2_Survey_2007	-1.30E-01	1.87E-02	-1.60E-01	1.94E-02	-1.31E-01	1.87E-02	-1.31E+00	1.51E-01	-1.49E+00	2.11E-01
Age_2_Survey_2008	-2.82E-03	2.00E-02	1.58E-02	2.03E-02	-2.99E-03	2.00E-02	-7.88E-02	1.68E-01	-7.00E-03	2.10E-01
Age_2_Survey_2009	-3.70E-02	1.81E-02	-4.54E-02	1.81E-02	-3.72E-02	1.81E-02	-3.82E-01	1.38E-01	-2.78E-01	2.02E-01
Age_2_Survey_2010	2.62E-02	2.83E-02	7.91E-02	3.17E-02	2.59E-02	2.83E-02	1.21E-01	2.70E-01	7.28E-01	2.84E-01
Age_2_Survey_2011	-5.95E-02	1.91E-02	-6.94E-02	1.93E-02	-5.97E-02	1.91E-02	-6.20E-01	1.51E-01	-1.04E+00	2.65E-01
Age_2_Survey_2012	-3.19E-02	1.90E-02	-4.46E-02	1.96E-02	-3.21E-02	1.90E-02	-4.05E-01	1.51E-01	-5.39E-01	2.29E-01
Age_2_Survey_2013	3.54E-02	2.46E-02	3.31E-02	2.47E-02	3.53E-02	2.46E-02	2.34E-01	2.09E-01	4.10E-01	2.40E-01

Table 2.1.5m (page 1 of 3)—Additional survey selectivity *dev*s for Model 5 (ages 3-4).

	Model 5			Model 5	
Parameter	Estimate	St. Dev.	Parameter	Estimate	St. Dev.
Age_3_Survey_1982	1.87E-01	2.58E-01	Age_4_Survey_1982	3.95E-01	2.01E-01
Age_3_Survey_1983	3.11E-01	2.68E-01	Age_4_Survey_1983	2.86E-01	2.19E-01
Age_3_Survey_1984	-3.99E-01	2.32E-01	Age_4_Survey_1984	3.89E-01	2.26E-01
Age_3_Survey_1985	-1.50E-01	2.33E-01	Age_4_Survey_1985	-1.43E-01	1.88E-01
Age_3_Survey_1986	-4.20E-01	2.29E-01	Age_4_Survey_1986	-2.04E-02	2.19E-01
Age_3_Survey_1987	2.04E-02	2.18E-01	Age_4_Survey_1987	-1.47E-01	1.93E-01
Age_3_Survey_1988	2.22E-01	2.44E-01	Age_4_Survey_1988	-2.48E-02	1.99E-01
Age_3_Survey_1989	7.06E-01	2.83E-01	Age_4_Survey_1989	4.56E-01	2.15E-01
Age_3_Survey_1990	3.09E-02	2.73E-01	Age_4_Survey_1990	2.05E-01	2.41E-01
Age_3_Survey_1991	-3.32E-01	2.34E-01	Age_4_Survey_1991	2.37E-01	2.24E-01
Age_3_Survey_1992	-4.03E-01	2.08E-01	Age_4_Survey_1992	6.28E-02	2.04E-01
Age_3_Survey_1993	-2.04E-01	2.31E-01	Age_4_Survey_1993	-3.16E-01	2.01E-01
Age_3_Survey_1994	-1.20E-01	1.93E-01	Age_4_Survey_1994	-7.08E-02	1.97E-01
Age_3_Survey_1995	-4.05E-02	1.66E-01	Age_4_Survey_1995	-3.70E-01	1.57E-01
Age_3_Survey_1996	2.05E-01	1.83E-01	Age_4_Survey_1996	-1.64E-01	1.38E-01
Age_3_Survey_1997	3.76E-01	2.16E-01	Age_4_Survey_1997	6.18E-03	1.95E-01
Age_3_Survey_1998	-2.62E-01	1.95E-01	Age_4_Survey_1998	7.56E-02	2.02E-01
Age_3_Survey_1999	3.76E-01	1.83E-01	Age_4_Survey_1999	-6.11E-02	1.72E-01
Age_3_Survey_2000	5.75E-01	2.03E-01	Age_4_Survey_2000	9.92E-02	1.77E-01
Age_3_Survey_2001	-2.44E-01	1.85E-01	Age_4_Survey_2001	3.68E-02	1.86E-01
Age_3_Survey_2002	-1.58E-01	1.73E-01	Age_4_Survey_2002	-2.05E-01	1.72E-01
Age_3_Survey_2003	4.42E-01	1.69E-01	Age_4_Survey_2003	-6.65E-01	1.51E-01
Age_3_Survey_2004	3.39E-01	1.67E-01	Age_4_Survey_2004	-5.30E-01	1.50E-01
Age_3_Survey_2005	-5.04E-02	1.93E-01	Age_4_Survey_2005	-2.29E-01	1.81E-01
Age_3_Survey_2006	1.69E-01	2.07E-01	Age_4_Survey_2006	2.68E-02	1.81E-01
Age_3_Survey_2007	-7.04E-04	2.26E-01	Age_4_Survey_2007	1.39E-01	2.10E-01
Age_3_Survey_2008	-4.38E-01	1.90E-01	Age_4_Survey_2008	3.45E-01	1.99E-01
Age_3_Survey_2009	-1.14E-01	1.85E-01	Age_4_Survey_2009	-1.27E-01	1.74E-01
Age_3_Survey_2010	4.84E-02	1.91E-01	Age_4_Survey_2010	1.05E-01	1.94E-01
Age_3_Survey_2011	7.60E-01	2.16E-01	Age_4_Survey_2011	-4.27E-02	1.62E-01
Age_3_Survey_2012	-2.68E-01	2.36E-01	Age_4_Survey_2012	5.79E-01	2.11E-01
Age_3_Survey_2013	-3.50E-01	1.98E-01	Age_4_Survey_2013	3.38E-01	1.97E-01

Table 2.1.5m (page 2 of 3)— Additional survey selectivity *dev*s for Model 5 (ages 5-6).

Parameter	Model 5 Estimate	Model 5 St. Dev.	Parameter	Model 5 Estimate	Model 5 St. Dev.
Age_5_Survey_1982	5.15E-02	1.18E-01	Age_6_Survey_1982	-8.68E-03	7.04E-02
Age_5_Survey_1983	-1.47E-02	1.17E-01	Age_6_Survey_1983	-1.23E-02	7.10E-02
Age_5_Survey_1984	7.04E-02	1.22E-01	Age_6_Survey_1984	7.14E-03	7.07E-02
Age_5_Survey_1985	7.02E-02	1.22E-01	Age_6_Survey_1985	2.78E-02	7.22E-02
Age_5_Survey_1986	1.77E-02	1.15E-01	Age_6_Survey_1986	1.08E-02	7.11E-02
Age_5_Survey_1987	-1.27E-02	1.23E-01	Age_6_Survey_1987	5.36E-03	7.01E-02
Age_5_Survey_1988	-3.43E-02	1.14E-01	Age_6_Survey_1988	-9.99E-03	7.08E-02
Age_5_Survey_1989	6.40E-02	1.17E-01	Age_6_Survey_1989	3.97E-02	6.92E-02
Age_5_Survey_1990	7.30E-02	1.23E-01	Age_6_Survey_1990	2.56E-02	7.18E-02
Age_5_Survey_1991	4.62E-02	1.24E-01	Age_6_Survey_1991	2.30E-02	7.24E-02
Age_5_Survey_1992	6.84E-02	1.21E-01	Age_6_Survey_1992	2.80E-02	7.23E-02
Age_5_Survey_1993	3.08E-02	1.20E-01	Age_6_Survey_1993	1.73E-02	7.18E-02
Age_5_Survey_1994	-7.42E-02	1.15E-01	Age_6_Survey_1994	-6.59E-02	6.52E-02
Age_5_Survey_1995	2.98E-03	1.21E-01	Age_6_Survey_1995	-1.68E-03	7.10E-02
Age_5_Survey_1996	-1.26E-01	1.12E-01	Age_6_Survey_1996	-3.09E-02	7.09E-02
Age_5_Survey_1997	-7.22E-02	1.18E-01	Age_6_Survey_1997	-1.52E-02	7.08E-02
Age_5_Survey_1998	3.63E-02	1.19E-01	Age_6_Survey_1998	1.44E-02	7.13E-02
Age_5_Survey_1999	1.78E-02	1.18E-01	Age_6_Survey_1999	2.70E-03	7.10E-02
Age_5_Survey_2000	1.73E-02	1.11E-01	Age_6_Survey_2000	9.95E-03	7.02E-02
Age_5_Survey_2001	-3.85E-03	1.16E-01	Age_6_Survey_2001	-1.48E-02	7.01E-02
Age_5_Survey_2002	-2.19E-02	1.17E-01	Age_6_Survey_2002	2.35E-02	7.06E-02
Age_5_Survey_2003	-1.01E-01	1.17E-01	Age_6_Survey_2003	-2.13E-02	7.25E-02
Age_5_Survey_2004	-1.82E-02	1.18E-01	Age_6_Survey_2004	-3.42E-03	7.23E-02
Age_5_Survey_2005	1.55E-02	1.17E-01	Age_6_Survey_2005	2.52E-02	7.09E-02
Age_5_Survey_2006	4.56E-02	1.15E-01	Age_6_Survey_2006	1.07E-04	7.02E-02
Age_5_Survey_2007	7.96E-02	1.22E-01	Age_6_Survey_2007	2.18E-02	7.26E-02
Age_5_Survey_2008	4.65E-02	1.19E-01	Age_6_Survey_2008	1.67E-02	7.11E-02
Age_5_Survey_2009	1.10E-01	1.19E-01	Age_6_Survey_2009	3.87E-02	7.13E-02
Age_5_Survey_2010	-1.29E-01	1.15E-01	Age_6_Survey_2010	-3.51E-02	7.13E-02
Age_5_Survey_2011	8.94E-02	1.18E-01	Age_6_Survey_2011	-2.66E-02	7.01E-02
Age_5_Survey_2012	-1.12E-01	1.10E-01	Age_6_Survey_2012	-2.26E-02	7.08E-02
Age_5_Survey_2013	-2.82E-02	1.21E-01	Age_6_Survey_2013	1.78E-03	7.13E-02

Table 2.1.5m (page 3 of 3)— Additional survey selectivity *dev*s for Model 5 (age 7).

Parameter	Model 5 Estimate	Model 5 St. Dev.
Age_7_Survey_1982	-3.55E-02	8.80E-02
Age_7_Survey_1983	-3.07E-02	8.88E-02
Age_7_Survey_1984	1.40E-02	8.70E-02
Age_7_Survey_1985	3.25E-02	9.32E-02
Age_7_Survey_1986	2.21E-02	9.11E-02
Age_7_Survey_1987	6.33E-03	8.75E-02
Age_7_Survey_1988	5.67E-03	8.55E-02
Age_7_Survey_1989	7.97E-02	8.46E-02
Age_7_Survey_1990	5.86E-02	9.01E-02
Age_7_Survey_1991	6.14E-02	9.39E-02
Age_7_Survey_1992	6.26E-02	9.47E-02
Age_7_Survey_1993	3.52E-02	9.38E-02
Age_7_Survey_1994	-1.57E-01	7.52E-02
Age_7_Survey_1995	1.96E-04	8.85E-02
Age_7_Survey_1996	-4.77E-02	9.01E-02
Age_7_Survey_1997	-2.37E-02	9.09E-02
Age_7_Survey_1998	2.01E-02	8.86E-02
Age_7_Survey_1999	-1.70E-03	8.98E-02
Age_7_Survey_2000	3.10E-02	8.81E-02
Age_7_Survey_2001	-4.86E-02	8.79E-02
Age_7_Survey_2002	7.74E-02	8.79E-02
Age_7_Survey_2003	-2.44E-02	9.86E-02
Age_7_Survey_2004	-5.94E-03	9.80E-02
Age_7_Survey_2005	1.85E-02	9.01E-02
Age_7_Survey_2006	-1.90E-02	8.59E-02
Age_7_Survey_2007	3.51E-02	9.68E-02
Age_7_Survey_2008	3.75E-02	9.03E-02
Age_7_Survey_2009	7.62E-02	9.11E-02
Age_7_Survey_2010	-6.31E-02	9.26E-02
Age_7_Survey_2011	-5.97E-02	8.82E-02
Age_7_Survey_2012	-3.94E-02	8.96E-02
Age_7_Survey_2013	1.15E-02	9.33E-02

Table 2.1.6 (page 1 of 2)—Full-selection fishing mortality rates (Models 0 and 2-4).

	Model 0		Model 2		Model 3		Model 4	
Year	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
1977	7.03E-02	1.27E-02	1.24E-01	4.05E-02	4.44E-01	2.43E-01	1.30E-01	4.12E-02
1978	8.06E-02	1.31E-02	1.39E-01	4.53E-02	4.25E-01	2.28E-01	1.44E-01	4.59E-02
1979	5.64E-02	8.42E-03	1.02E-01	3.29E-02	2.36E-01	1.22E-01	1.05E-01	3.29E-02
1980	4.89E-02	6.23E-03	1.22E-01	3.62E-02	2.28E-01	1.08E-01	1.23E-01	3.59E-02
1981	4.66E-02	5.04E-03	9.82E-02	2.53E-02	1.19E-01	4.82E-02	9.89E-02	2.52E-02
1982	3.61E-02	2.85E-03	7.65E-02	1.40E-02	9.75E-02	3.35E-02	7.72E-02	1.40E-02
1983	5.00E-02	3.04E-03	8.98E-02	1.33E-02	1.15E-01	3.78E-02	9.07E-02	1.34E-02
1984	6.83E-02	3.66E-03	1.36E-01	1.92E-02	1.70E-01	5.58E-02	1.37E-01	1.93E-02
1985	8.29E-02	4.00E-03	1.52E-01	2.03E-02	1.88E-01	6.21E-02	1.53E-01	2.05E-02
1986	8.21E-02	3.73E-03	1.60E-01	2.11E-02	1.93E-01	6.37E-02	1.62E-01	2.13E-02
1987	9.41E-02	3.99E-03	1.83E-01	2.46E-02	2.14E-01	7.02E-02	1.85E-01	2.49E-02
1988	1.24E-01	4.59E-03	2.10E-01	2.22E-02	2.52E-01	7.90E-02	2.12E-01	2.25E-02
1989	1.21E-01	4.31E-03	1.94E-01	2.52E-02	2.26E-01	6.67E-02	1.95E-01	2.55E-02
1990	1.33E-01	4.46E-03	2.17E-01	2.23E-02	2.61E-01	7.70E-02	2.19E-01	2.26E-02
1991	2.05E-01	7.19E-03	4.00E-01	4.79E-02	4.99E-01	1.49E-01	4.02E-01	4.83E-02
1992	1.97E-01	7.46E-03	4.59E-01	5.62E-02	5.65E-01	1.78E-01	4.61E-01	5.66E-02
1993	1.56E-01	6.47E-03	3.31E-01	4.16E-02	3.88E-01	1.21E-01	3.33E-01	4.19E-02
1994	1.88E-01	8.97E-03	3.69E-01	4.27E-02	4.24E-01	1.27E-01	3.71E-01	4.29E-02
1995	2.53E-01	8.71E-03	4.47E-01	4.93E-02	5.15E-01	1.55E-01	4.50E-01	4.96E-02
1996	2.37E-01	8.35E-03	4.70E-01	5.16E-02	5.59E-01	1.69E-01	4.72E-01	5.19E-02
1997	2.76E-01	9.89E-03	5.38E-01	6.90E-02	6.50E-01	1.99E-01	5.41E-01	6.94E-02
1998	2.07E-01	7.57E-03	4.22E-01	4.62E-02	5.67E-01	1.77E-01	4.25E-01	4.65E-02
1999	2.03E-01	7.66E-03	4.38E-01	5.54E-02	6.15E-01	1.93E-01	4.41E-01	5.57E-02
2000	1.81E-01	6.60E-03	4.25E-01	5.25E-02	5.99E-01	1.88E-01	4.28E-01	5.29E-02
2001	1.56E-01	5.01E-03	3.43E-01	4.35E-02	4.75E-01	1.47E-01	3.46E-01	4.38E-02
2002	1.92E-01	5.59E-03	3.78E-01	3.98E-02	5.10E-01	1.57E-01	3.80E-01	4.00E-02
2003	2.01E-01	5.60E-03	4.03E-01	4.69E-02	5.05E-01	1.55E-01	4.05E-01	4.72E-02
2004	2.17E-01	5.81E-03	3.96E-01	4.72E-02	4.72E-01	1.43E-01	3.99E-01	4.76E-02
2005	2.57E-01	7.24E-03	4.04E-01	4.01E-02	5.01E-01	1.52E-01	4.07E-01	4.04E-02
2006	2.84E-01	8.77E-03	4.75E-01	5.31E-02	6.22E-01	1.90E-01	4.78E-01	5.34E-02
2007	2.74E-01	9.23E-03	4.60E-01	5.35E-02	6.08E-01	1.87E-01	4.63E-01	5.39E-02
2008	3.08E-01	1.11E-02	5.61E-01	6.57E-02	7.66E-01	2.36E-01	5.65E-01	6.60E-02
2009	3.37E-01	1.36E-02	6.63E-01	8.08E-02	8.68E-01	2.71E-01	6.66E-01	8.12E-02
2010	2.74E-01	1.16E-02	5.76E-01	7.22E-02	7.10E-01	2.22E-01	5.79E-01	7.24E-02
2011	3.23E-01	1.45E-02	6.51E-01	8.77E-02	8.31E-01	2.59E-01	6.55E-01	8.81E-02
2012	2.89E-01	1.45E-02	6.01E-01	7.79E-02	7.92E-01	2.49E-01	6.05E-01	7.82E-02
2013	2.59E-01	1.48E-02	5.06E-01	8.05E-02	6.58E-01	2.08E-01	5.10E-01	8.11E-02
2014	2.47E-01	1.63E-02	6.08E-01	9.93E-02	8.22E-01	2.72E-01	6.13E-01	1.00E-01

Table 2.1.6 (page 2 of 2)— Full-selection fishing mortality rates (Models 5-8).

	Model 5		Model 6		Model 7		Model 8	
Year	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.	Estimate	St. Dev.
1977	1.34E-01	4.57E-02	9.32E-02	3.75E-02	3.88E-02	7.96E-03	7.79E-02	1.38E-02
1978	1.50E-01	5.09E-02	1.09E-01	4.25E-02	5.20E-02	1.06E-02	8.89E-02	1.44E-02
1979	1.15E-01	3.77E-02	8.05E-02	3.04E-02	4.18E-02	8.43E-03	6.25E-02	9.36E-03
1980	1.35E-01	4.19E-02	8.71E-02	3.22E-02	4.21E-02	8.50E-03	5.37E-02	7.63E-03
1981	1.14E-01	3.41E-02	7.34E-02	2.56E-02	4.65E-02	9.95E-03	5.00E-02	6.52E-03
1982	9.58E-02	2.32E-02	6.18E-02	1.72E-02	3.89E-02	6.80E-03	3.93E-02	4.03E-03
1983	1.08E-01	2.07E-02	7.00E-02	1.73E-02	5.61E-02	7.74E-03	5.51E-02	4.49E-03
1984	1.51E-01	2.95E-02	9.73E-02	2.42E-02	7.69E-02	7.92E-03	7.37E-02	4.76E-03
1985	1.42E-01	2.58E-02	1.17E-01	2.77E-02	9.99E-02	9.81E-03	9.45E-02	5.55E-03
1986	1.61E-01	3.16E-02	1.81E-01	4.64E-02	9.78E-02	9.26E-03	9.16E-02	5.04E-03
1987	1.84E-01	3.60E-02	1.55E-01	3.85E-02	1.14E-01	9.01E-03	1.06E-01	5.08E-03
1988	1.87E-01	2.87E-02	1.71E-01	3.59E-02	1.52E-01	1.63E-02	1.42E-01	7.56E-03
1989	2.03E-01	4.07E-02	1.41E-01	3.41E-02	1.39E-01	1.02E-02	1.31E-01	5.61E-03
1990	2.25E-01	3.50E-02	1.84E-01	4.99E-02	1.46E-01	3.15E-02	1.41E-01	5.90E-03
1991	3.60E-01	6.13E-02	2.78E-01	6.23E-02	2.24E-01	4.62E-02	2.19E-01	9.06E-03
1992	4.16E-01	7.53E-02	5.16E-01	1.23E-01	2.25E-01	3.02E-02	2.20E-01	8.94E-03
1993	2.92E-01	5.69E-02	3.33E-01	8.75E-02	1.92E-01	3.02E-02	1.83E-01	8.28E-03
1994	3.51E-01	5.85E-02	3.79E-01	8.00E-02	2.33E-01	8.72E-02	2.17E-01	1.56E-02
1995	4.03E-01	5.97E-02	4.05E-01	8.14E-02	3.37E-01	2.24E-02	3.19E-01	1.21E-02
1996	4.61E-01	7.53E-02	3.61E-01	8.21E-02	3.00E-01	1.92E-02	2.90E-01	1.08E-02
1997	6.16E-01	1.17E-01	4.19E-01	1.05E-01	3.29E-01	2.09E-02	3.30E-01	1.23E-02
1998	4.21E-01	6.38E-02	2.87E-01	6.22E-02	2.49E-01	1.66E-02	2.59E-01	1.01E-02
1999	4.46E-01	8.44E-02	3.20E-01	7.62E-02	2.34E-01	1.48E-02	2.47E-01	9.55E-03
2000	4.41E-01	8.54E-02	3.96E-01	9.22E-02	2.22E-01	1.27E-02	2.33E-01	8.36E-03
2001	3.46E-01	6.54E-02	2.99E-01	6.88E-02	1.90E-01	9.33E-03	2.00E-01	6.11E-03
2002	2.91E-01	4.52E-02	2.80E-01	5.19E-02	2.28E-01	1.10E-02	2.40E-01	6.98E-03
2003	3.23E-01	5.55E-02	4.05E-01	8.39E-02	2.42E-01	1.13E-02	2.56E-01	7.04E-03
2004	3.18E-01	5.34E-02	4.04E-01	9.20E-02	2.59E-01	1.20E-02	2.78E-01	7.42E-03
2005	3.55E-01	5.10E-02	3.33E-01	6.93E-02	2.76E-01	1.35E-02	3.03E-01	8.73E-03
2006	4.42E-01	7.61E-02	3.42E-01	8.17E-02	3.02E-01	1.57E-02	3.37E-01	1.06E-02
2007	4.74E-01	8.57E-02	3.61E-01	8.93E-02	2.91E-01	1.61E-02	3.25E-01	1.10E-02
2008	5.78E-01	1.01E-01	4.61E-01	1.05E-01	3.29E-01	1.90E-02	3.64E-01	1.33E-02
2009	6.26E-01	1.12E-01	5.46E-01	1.26E-01	3.71E-01	2.29E-02	4.01E-01	1.64E-02
2010	6.76E-01	1.32E-01	7.01E-01	1.77E-01	3.10E-01	1.93E-02	3.27E-01	1.41E-02
2011	7.59E-01	1.58E-01	5.66E-01	1.44E-01	3.61E-01	2.21E-02	3.82E-01	1.75E-02
2012	6.50E-01	1.26E-01	5.29E-01	1.28E-01	3.30E-01	2.10E-02	3.47E-01	1.79E-02
2013	5.25E-01	1.27E-01	4.10E-01	1.05E-01	2.92E-01	1.92E-02	3.01E-01	1.74E-02
2014	4.65E-01	1.01E-01	4.42E-01	1.05E-01	2.95E-01	2.10E-02	2.94E-01	1.97E-02

Table 2.1.7—Parameters used in iterative tuning processes by the eight models. A blank indicates that the parameter (row) was not used in that model (column).

Tuning parameter	M0	M2	M3	M4	M5	M6	M7	M8
Sigma(recruitment)	0.570	0.657	0.657	0.657	0.489	0.603	0.570	0.570
Sigma(catchability)		0.089		0.089		0.079		
Sigma(survey double normal P3)	0.070						0.070	0.070
Sigma(fishery age 3 selectivity parm.)					0.527	0.580		
Sigma(fishery age 4 selectivity parm.)		0.158	0.158	0.158	0.808	0.913		
Sigma(fishery age 5 selectivity parm.)					0.345	0.425		
Sigma(fishery age 6 selectivity parm.)					0.245	0.115		
Sigma(fishery age 7 selectivity parm.)					0.214	0.474		
Sigma(survey age 2 selectivity parm.)		0.106	0.106	0.106	0.684	0.555		
Sigma(survey age 3 selectivity parm.)					0.393			
Sigma(survey age 4 selectivity parm.)					0.337			
Sigma(survey age 5 selectivity parm.)					0.134			
Sigma(survey age 6 selectivity parm.)					0.075			
Sigma(survey age 7 selectivity parm.)					0.103			
Logistic alpha (fishery selectivity prior)		2.940	2.940	2.940	3.306	3.364		
Logistic beta (fishery selectivity prior)		3.970	3.970	3.970	3.729	3.587		
Sigma(fishery selectivity prior)		0.350	0.350	0.350	0.722	0.707		
Logistic alpha (survey selectivity prior)		5.800	5.800	5.800	1.778	2.507		
Logistic beta (survey selectivity prior)		0.970	0.970	0.970	1.519	1.208		
Sigma(survey selectivity prior)		0.319	0.319	0.319	0.583	0.559		
Jan-Apr trawl sizecomp multiplier	1.000						0.144	1.000
May-Jul trawl sizecomp multiplier	1.000						0.292	1.000
Aug-Dec trawl sizecomp multiplier	1.000						0.121	1.000
Jan-Apr longline sizecomp multiplier	1.000						0.134	1.000
May-Jul longline sizecomp multiplier	1.000						0.207	1.000
Aug-Dec longline sizecomp multiplier	1.000						0.193	1.000
Jan-Apr pot sizecomp multiplier	1.000						0.519	1.000
May-Jul pot sizecomp multiplier	1.000						0.644	1.000
Aug-Dec pot sizecomp multiplier	1.000						0.140	1.000
Fishery sizecomp multiplier		1.000	4.103	1.000	1.000	1.000		
Survey sizecomp multiplier	1.000	1.000	1.143	1.000	1.000	1.000	0.696	1.000
Survey agecomp multiplier	1.000	1.000	0.307	1.000	0.784	0.492	0.824	1.000

Figures

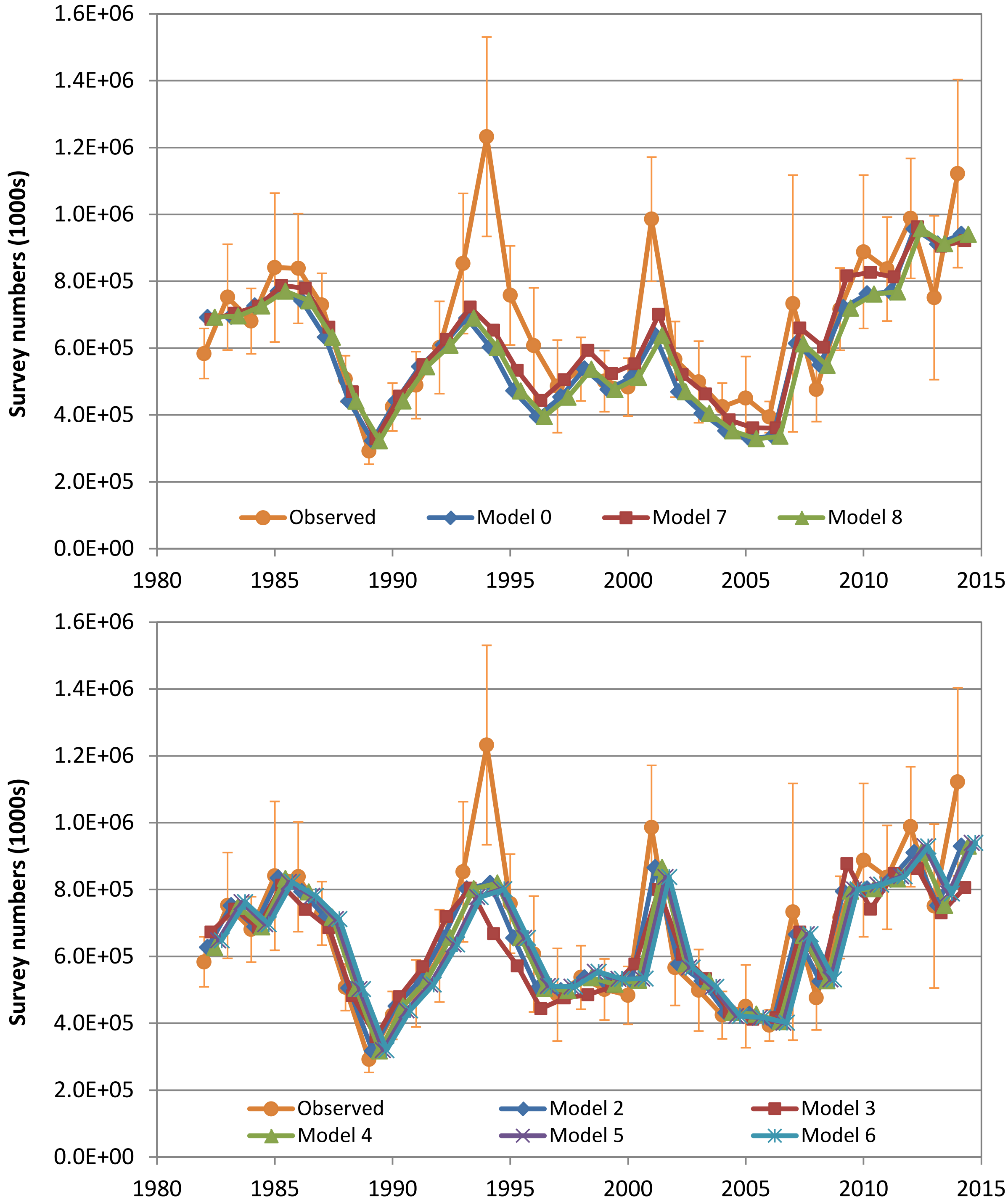


Figure 2.1.1—Fit of each model to the survey abundance time series. Upper panel: Models 0, 7, and8. Lower panel: Models 2-6. Survey abundance time series shows 95% confidence interval.

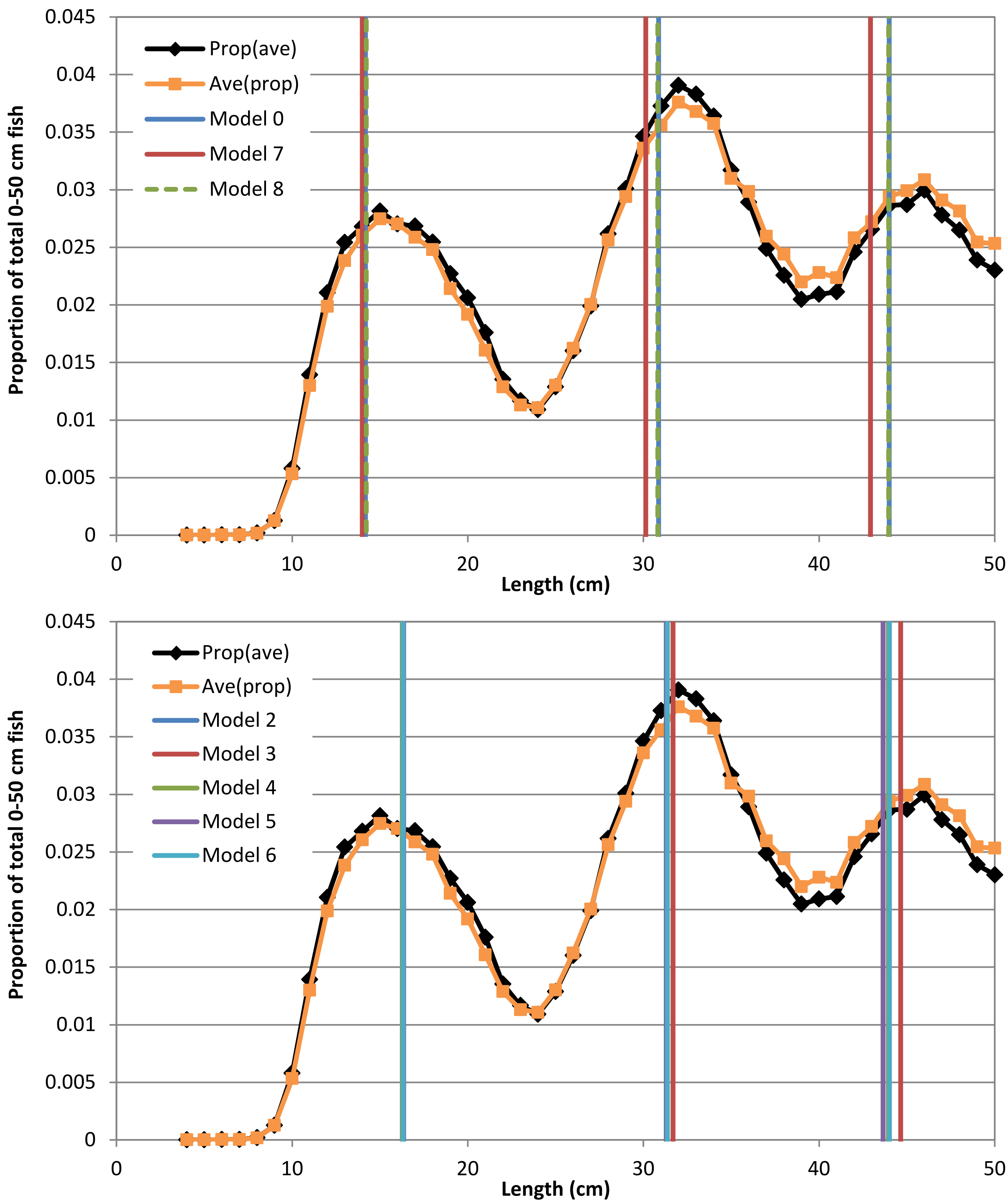


Figure 2.1.2—Comparison of each model's estimated mean length at ages 1, 2, and 3 to the long-term survey size composition (through 50 cm). "Prop(ave)" = proportion of the average numbers at length, "Ave(prop)" = average of the proportion numbers at length. Upper panel: Models 0, 7, and 8. Lower panel: Models 2-6.

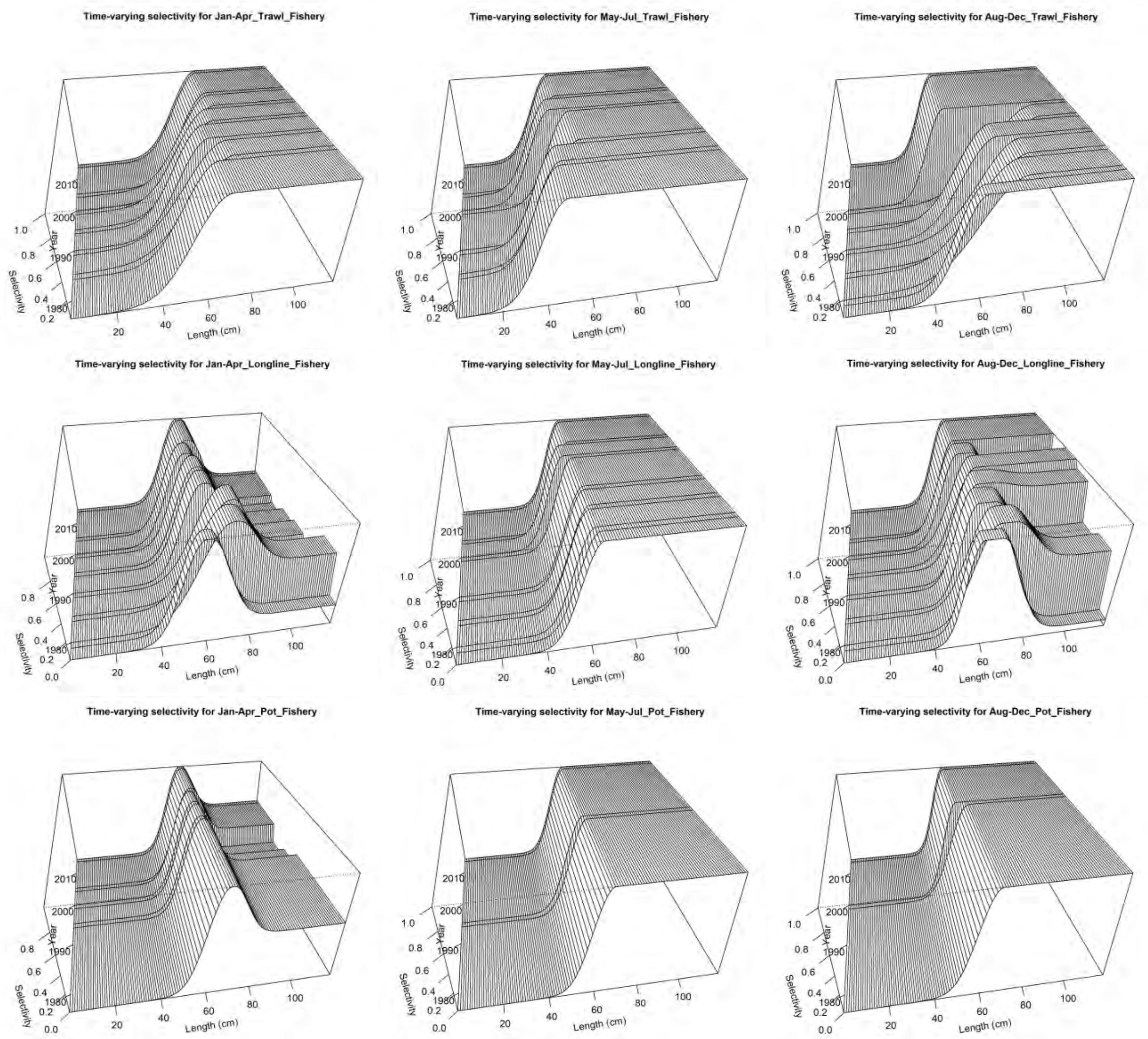


Figure 2.1.3a—Gear-and-season-specific fishery selectivity as estimated by Model 0.

Model 2

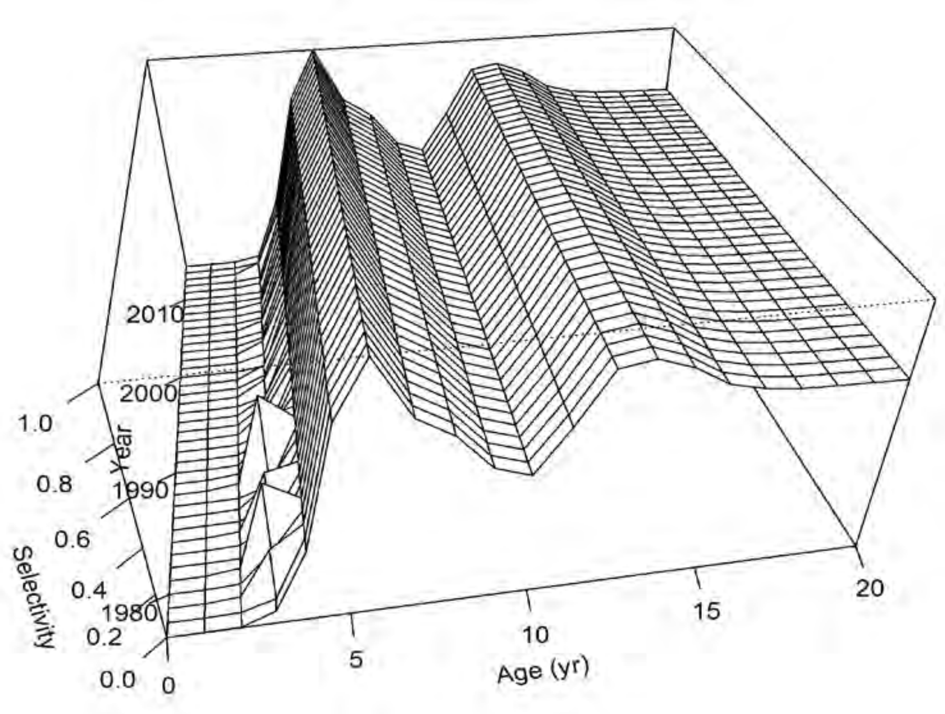
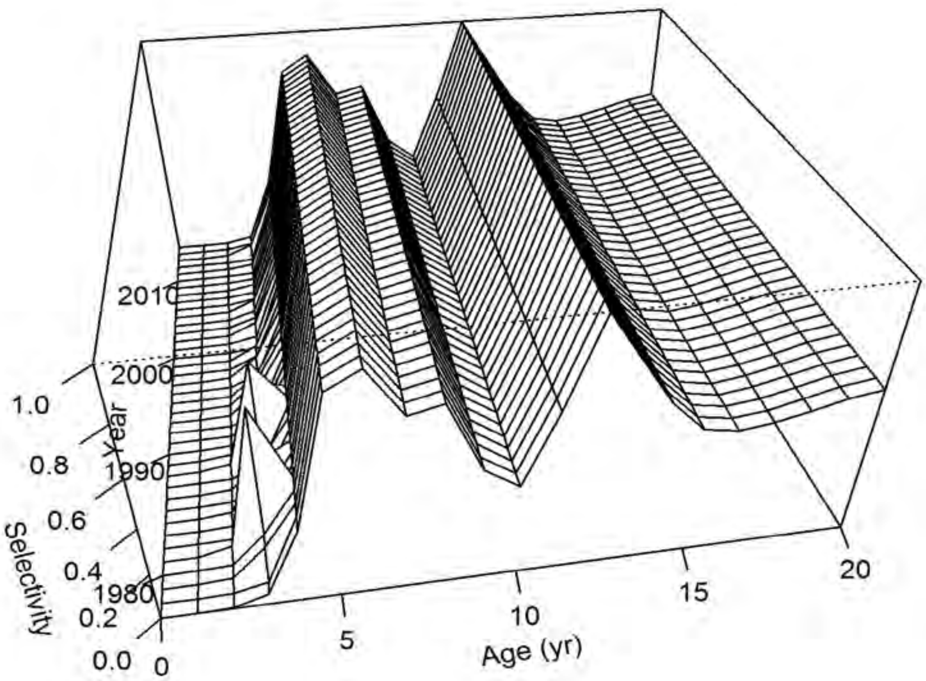


Figure 2.1.3b—Fishery selectivity as estimated by Model 2.

Model 3



Model 4

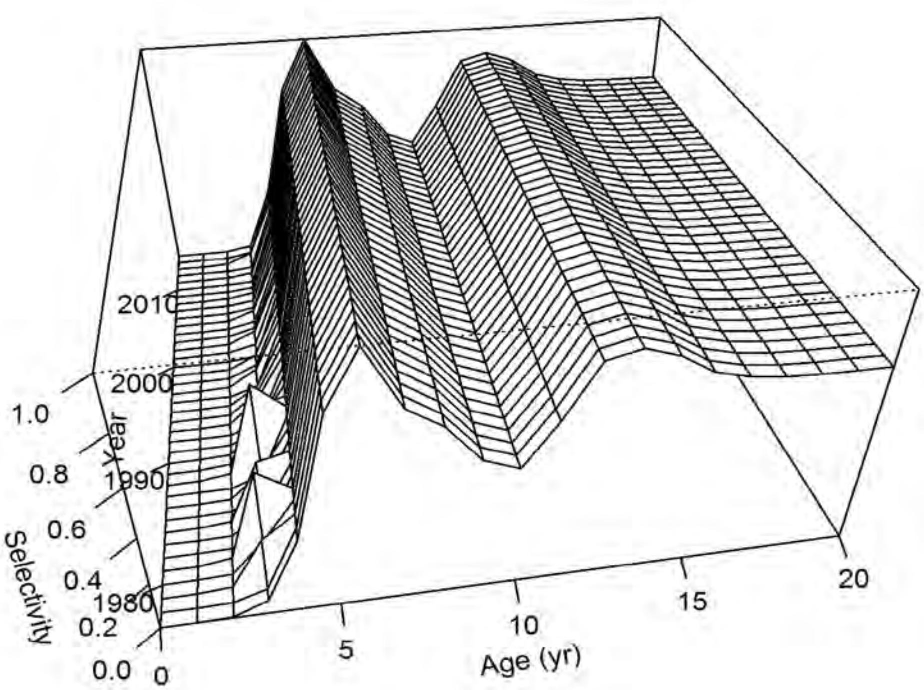
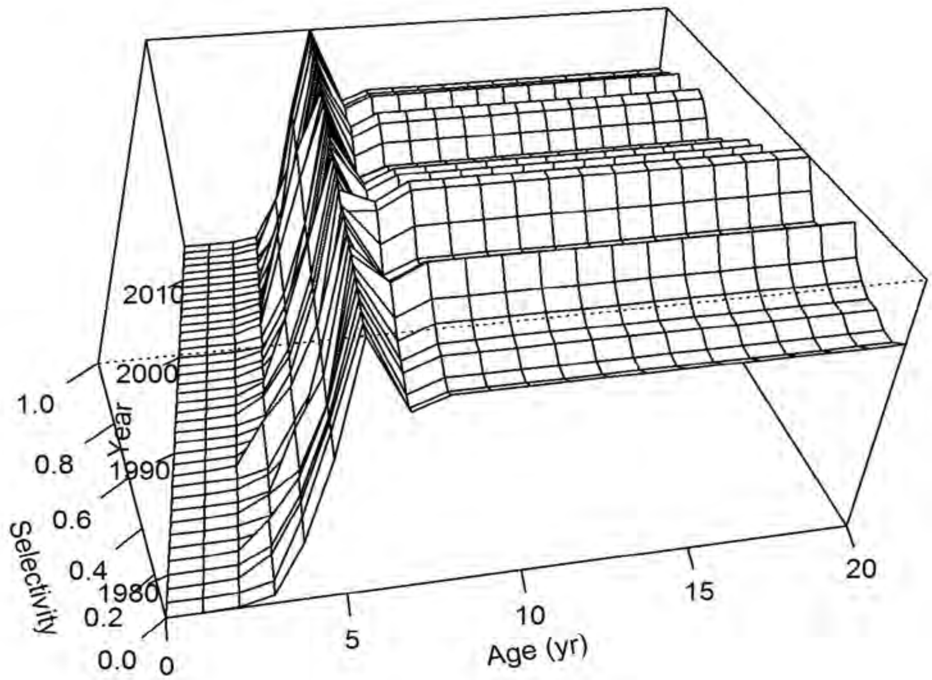


Figure 2.1.3c—Fishery selectivity as estimated by Models 2 and 3.

Model 5



Model 6

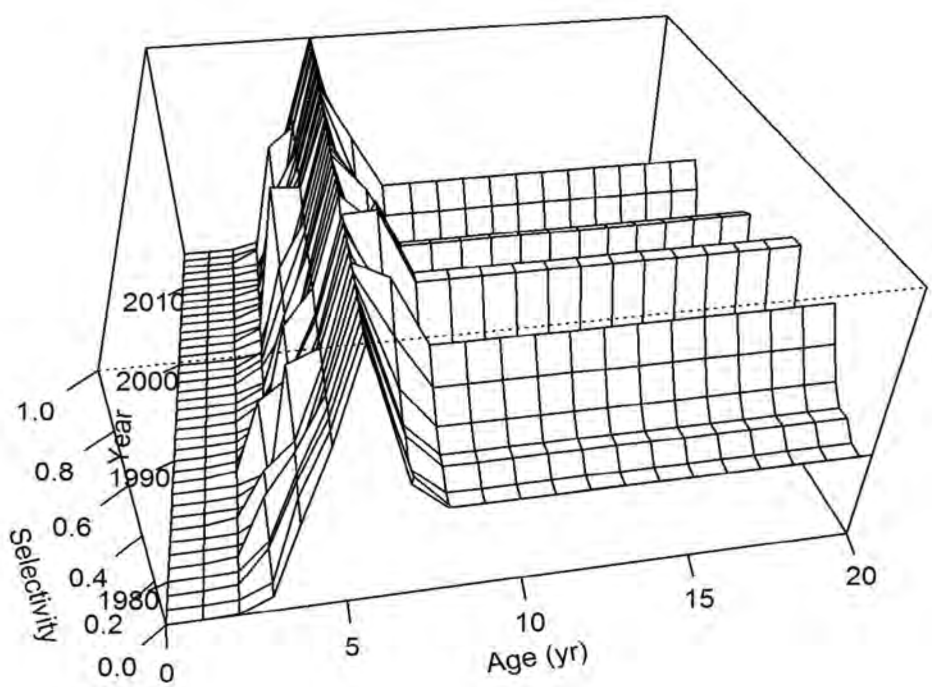


Figure 2.1.3d—Fishery selectivity as estimated by Models 5 and 6.

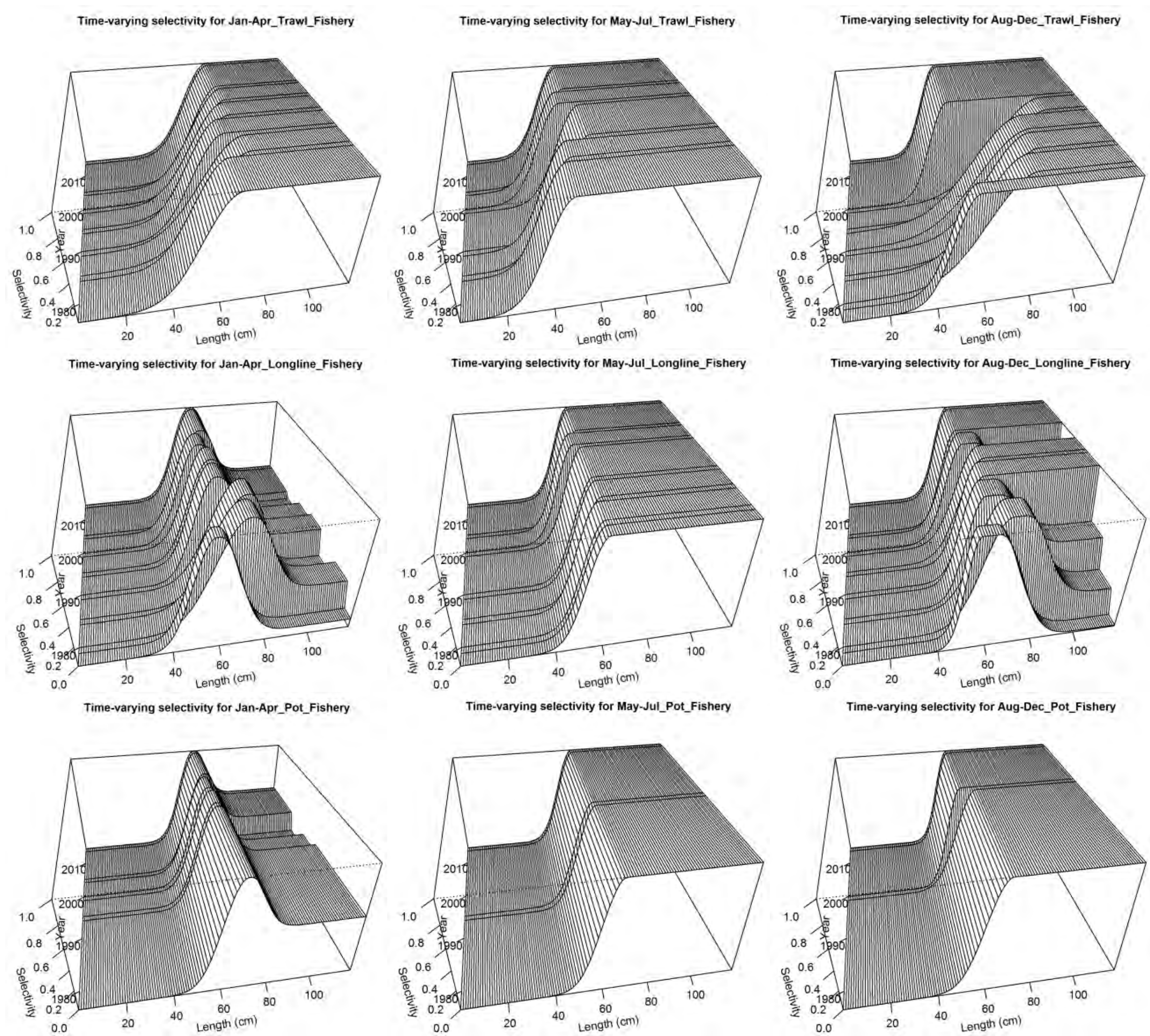


Figure 2.1.3e—Gear-and-season-specific fishery selectivity as estimated by Model 7.

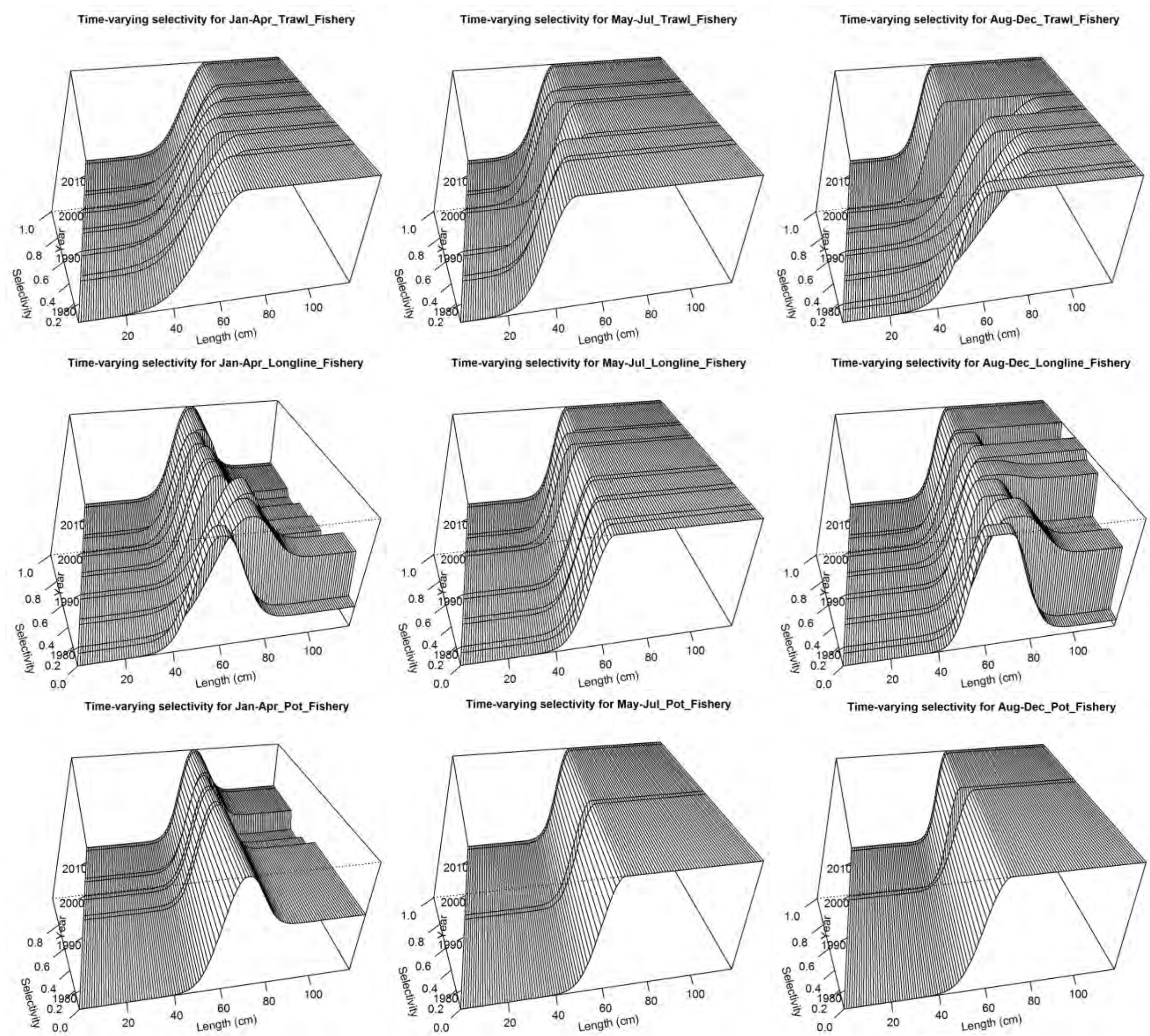
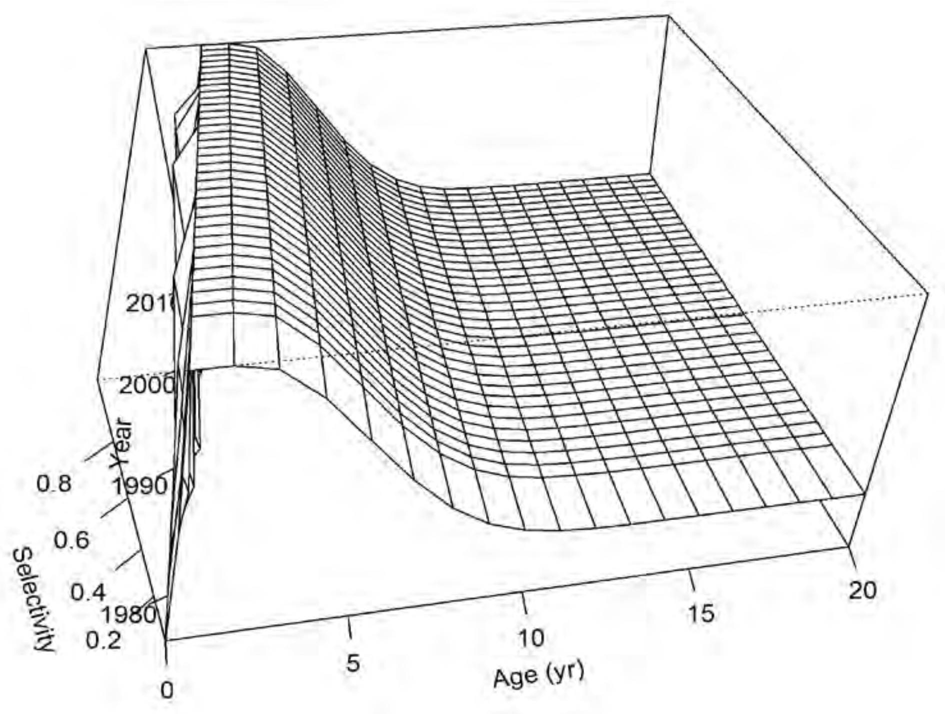


Figure 2.1.3f—Gear-and-season-specific fishery selectivity as estimated by Model 8.

Model 0



Model 2

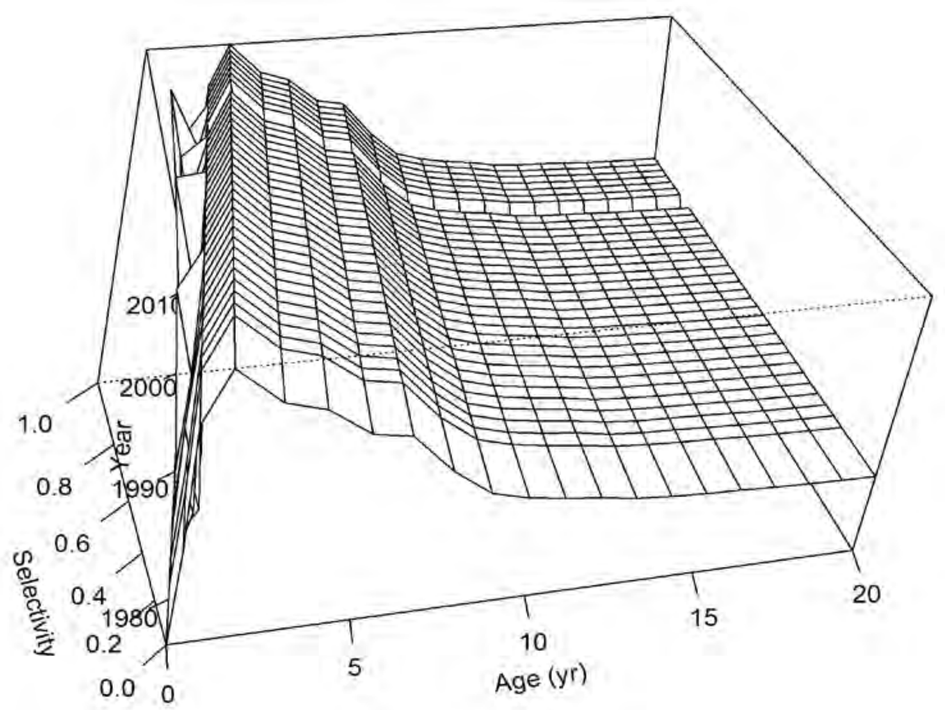
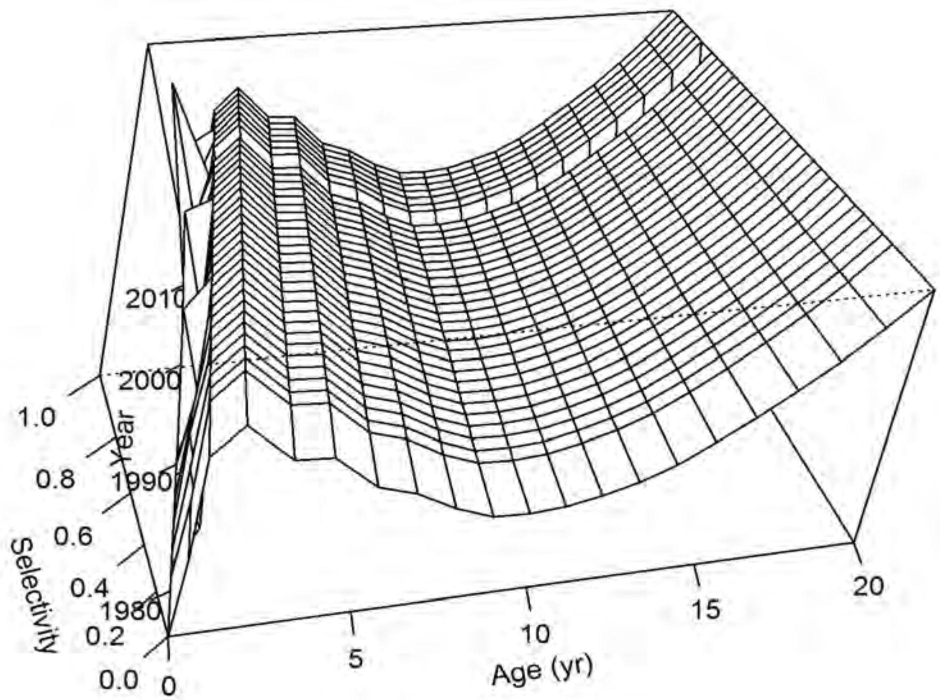


Figure 2.1.4a—Survey selectivity as estimated by Models 0 and 2.

Model 3



Model 4

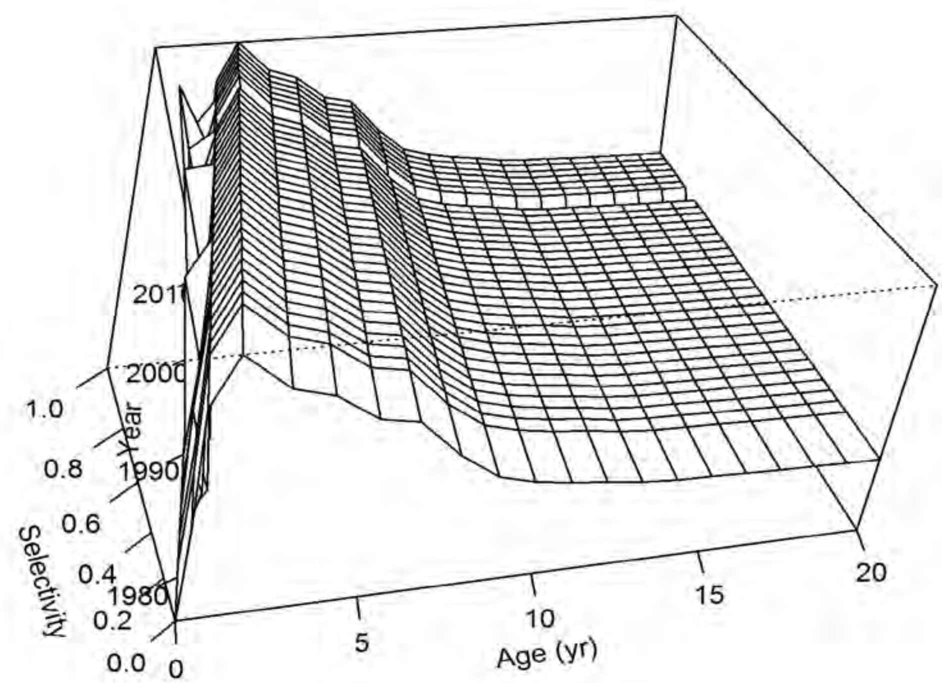
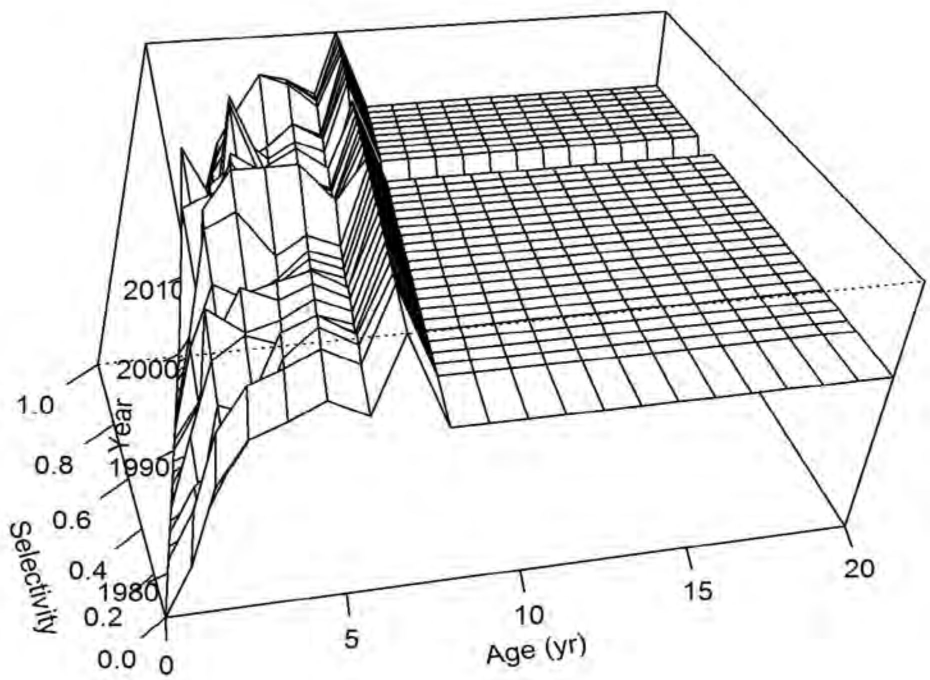


Figure 2.1.4b—Survey selectivity as estimated by Models 3 and 4.

Model 5



Model 6

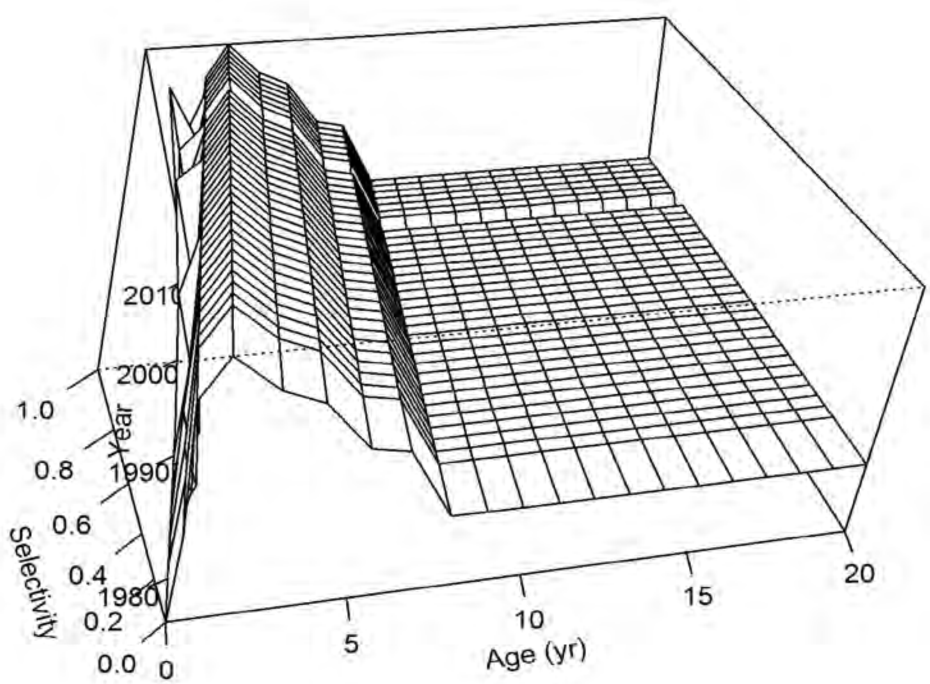
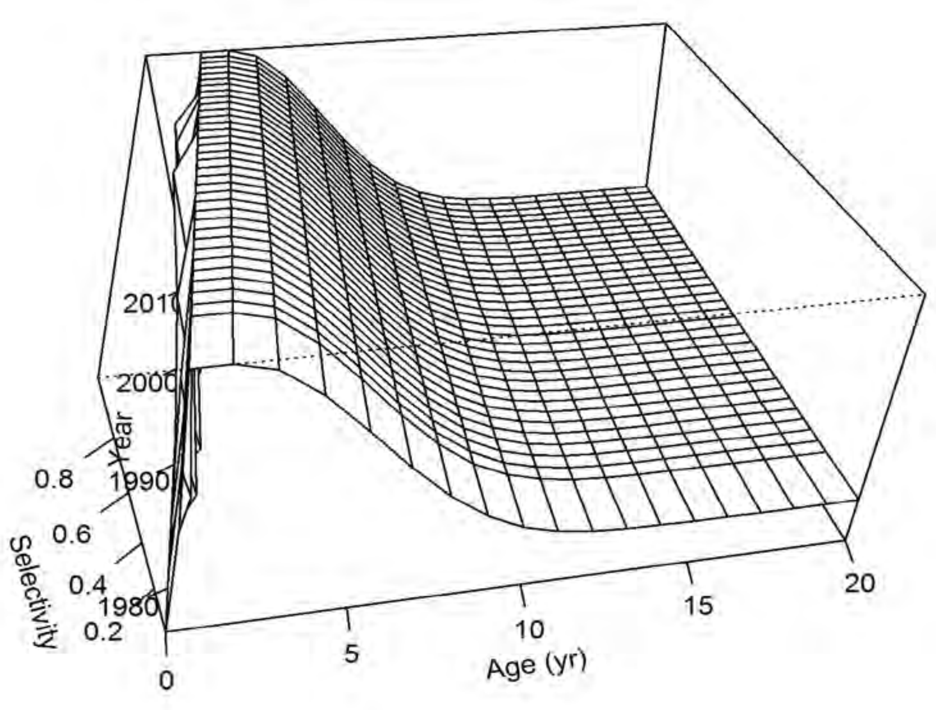


Figure 2.1.4c—Survey selectivity as estimated by Models 5 and 6.

Model 7



Model 8

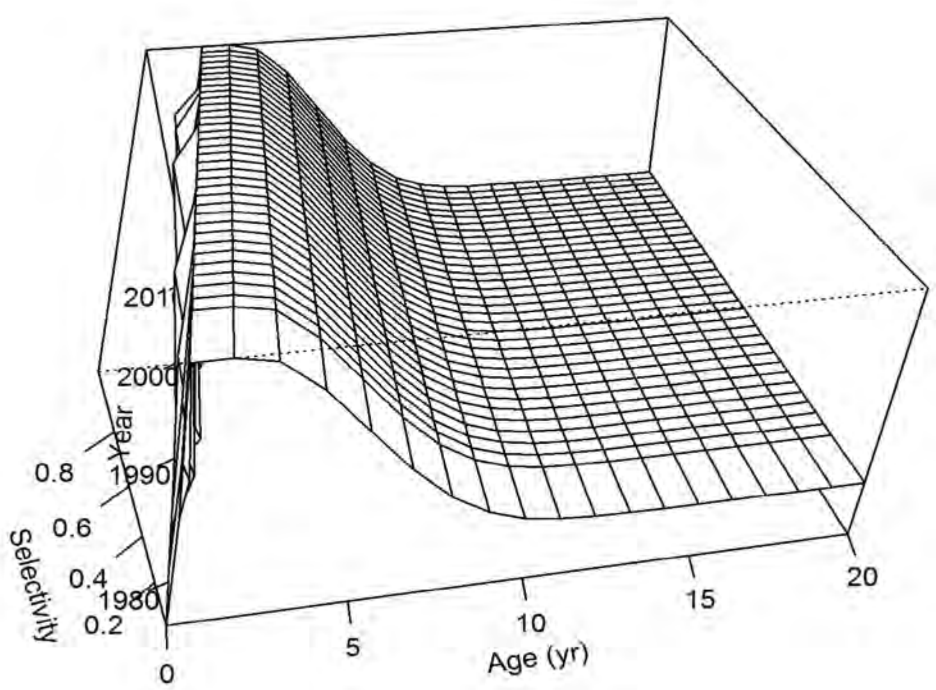


Figure 2.1.4d—Survey selectivity as estimated by Models 7 and 8.

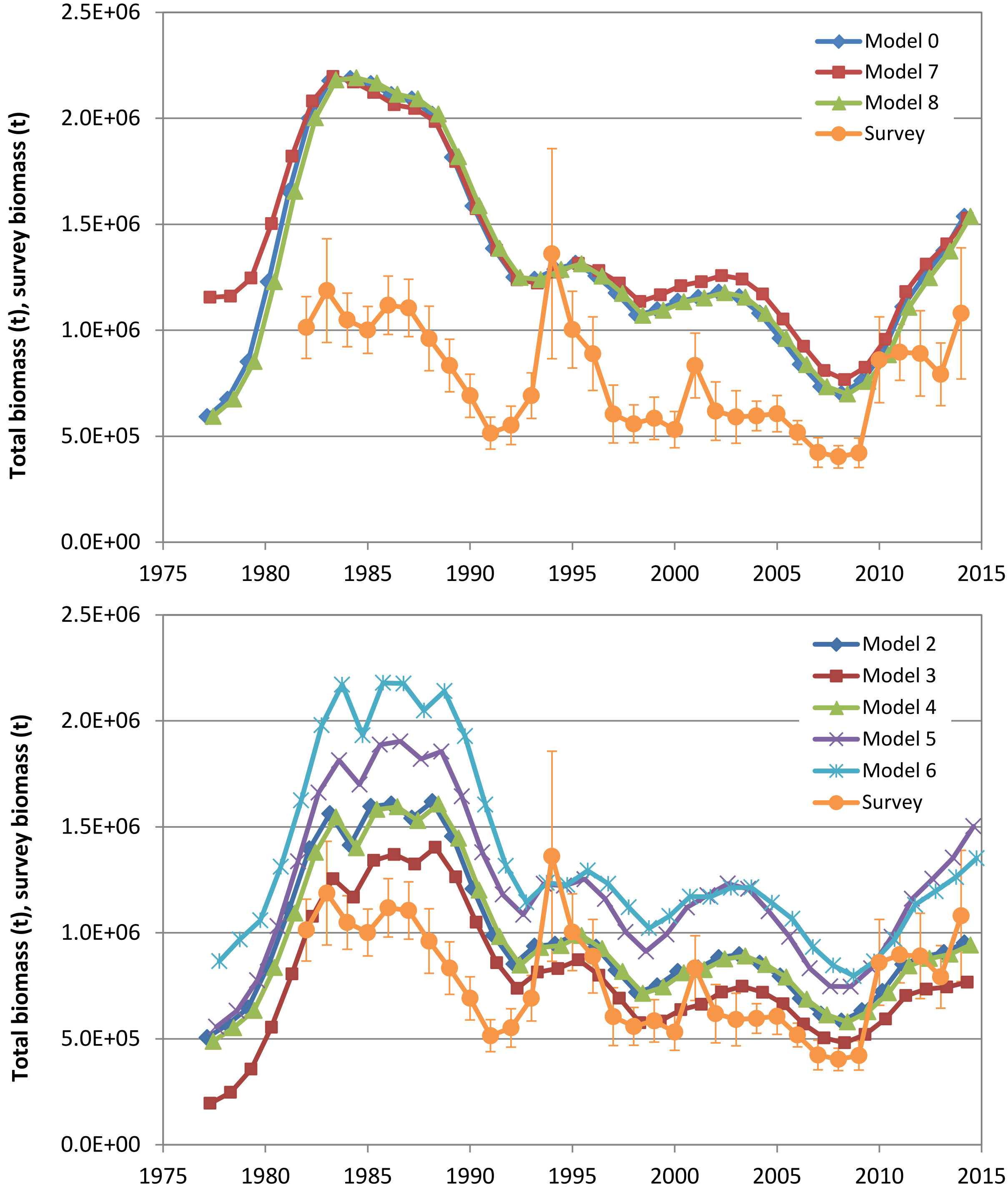


Figure 2.1.5—Total biomass time series as estimated by each of the models. Survey biomass (with 95% confidence interval) shown for comparison. Upper panel: Models 0, 7, and 8. Lower panel: Models 2-6.

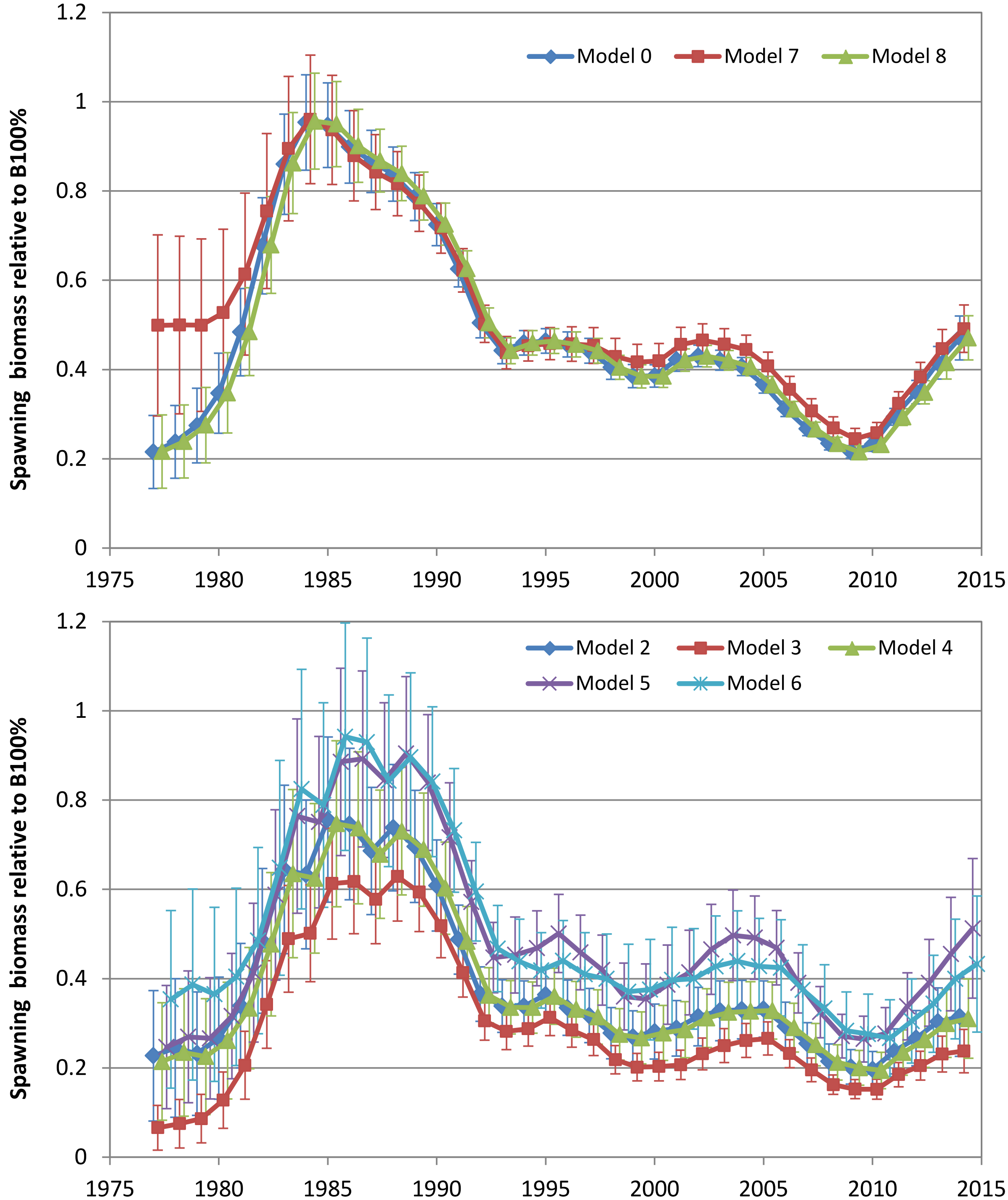


Figure 2.1.6—Time series of spawning biomass relative to $B_{100\%}$ for each of the models, with 95% confidence intervals. Upper panel: Models 0, 7, and 8. Lower panels: Models 2-6.

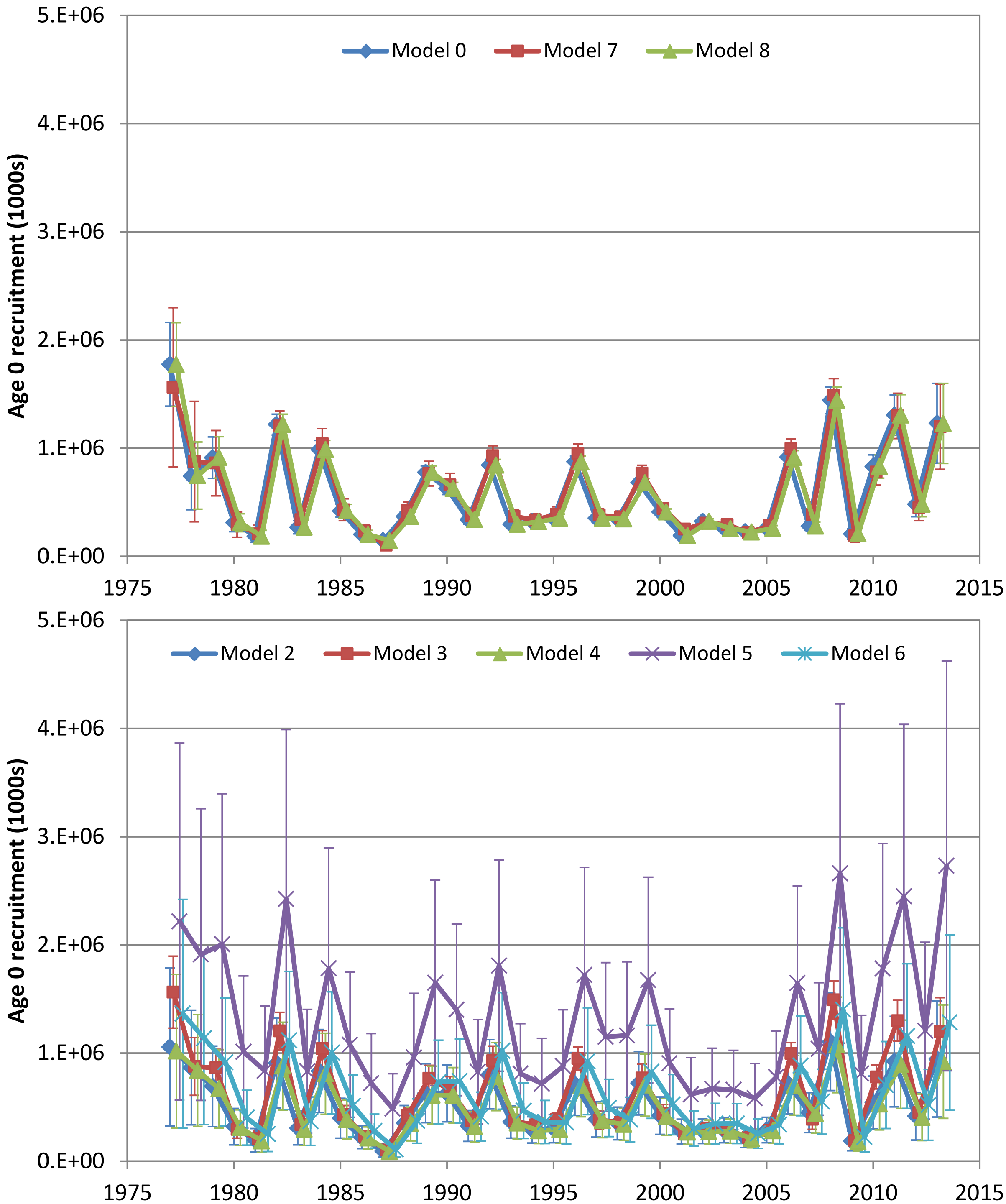


Figure 2.1.7—Age 0 recruitment (1000s of fish) for each model. Upper panel: Models 0, 7, and 8. Lower panel: Models 2-6.

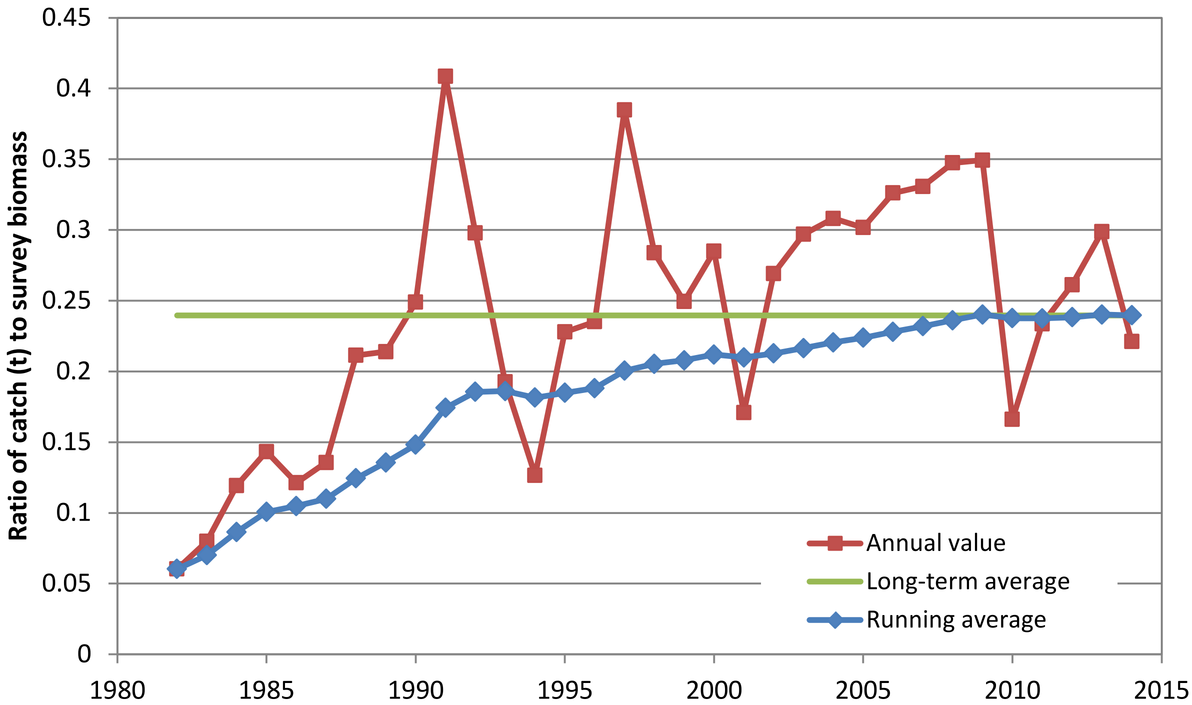


Figure 2.1.8—Time series of the ratio of catch (t) to survey biomass. The long-term average and the running average are also shown.

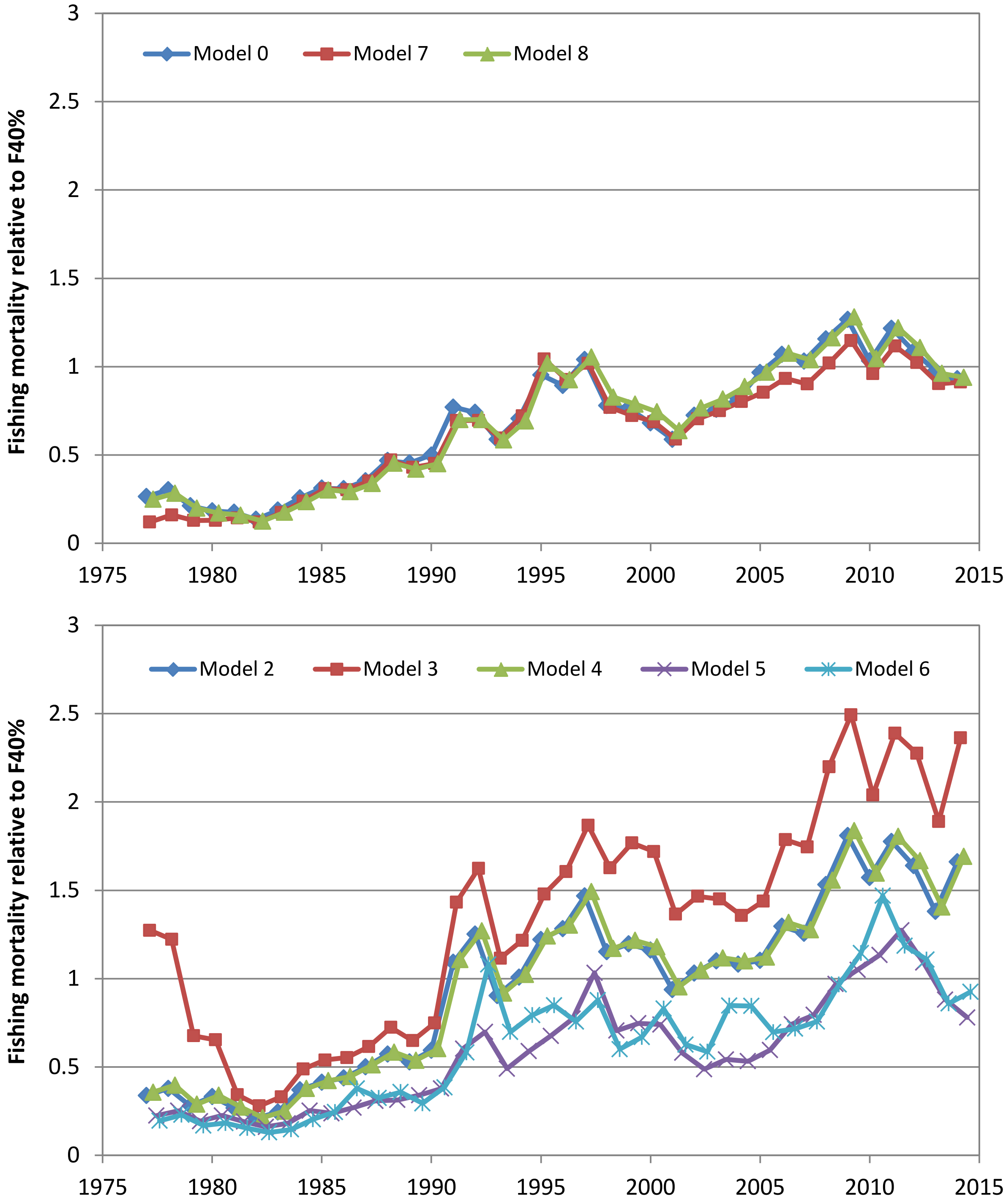


Figure 2.1.9—Time series of the ratio of full-selection fishing morality to $F_{40\%}$. Upper panel: Models 0, 7, and 8. Lower panel: Models 2-6. Note that the vertical scales differ between panels.

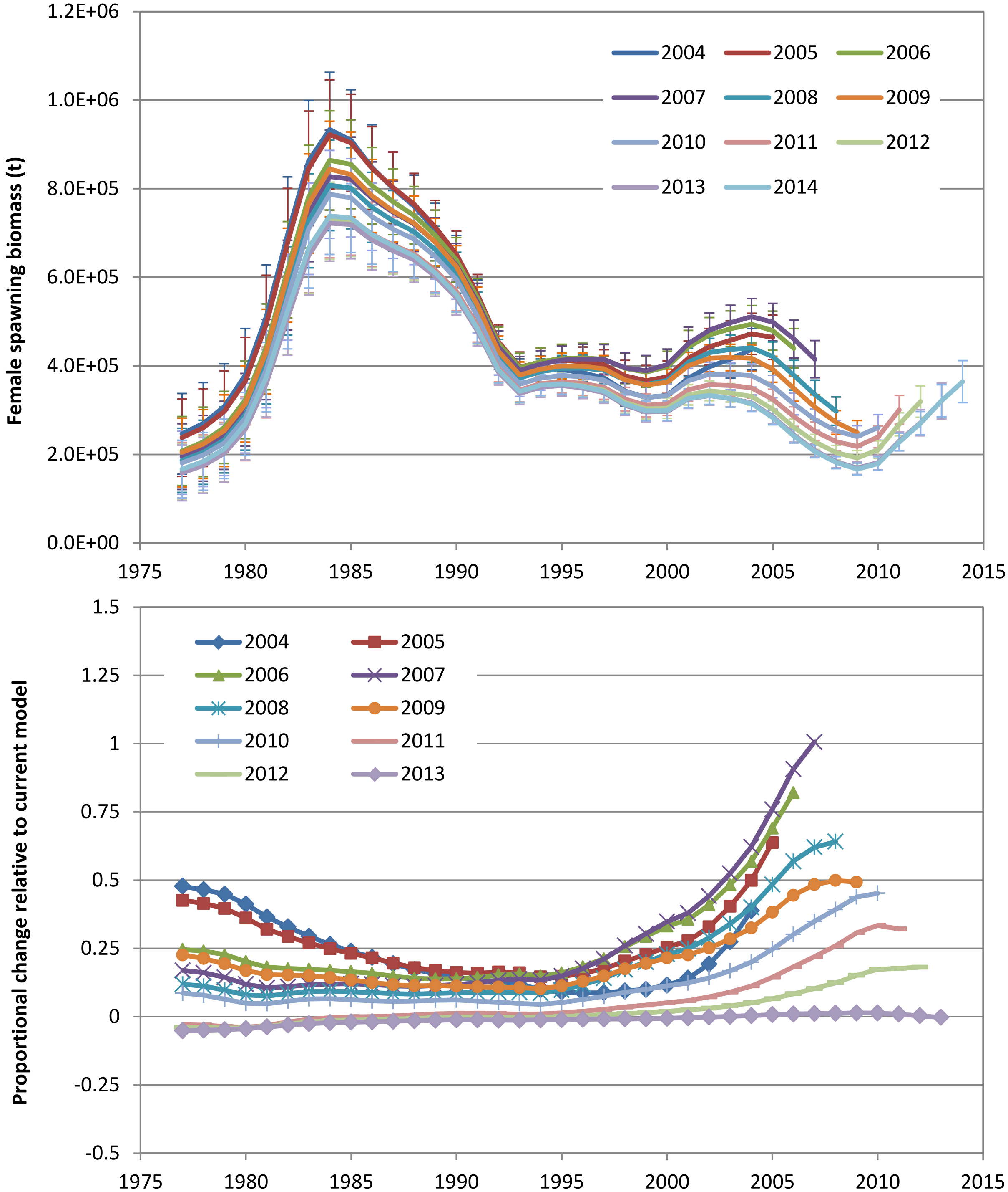


Figure 2.1.10a—Ten-year spawning biomass retrospective analysis of Model 0.

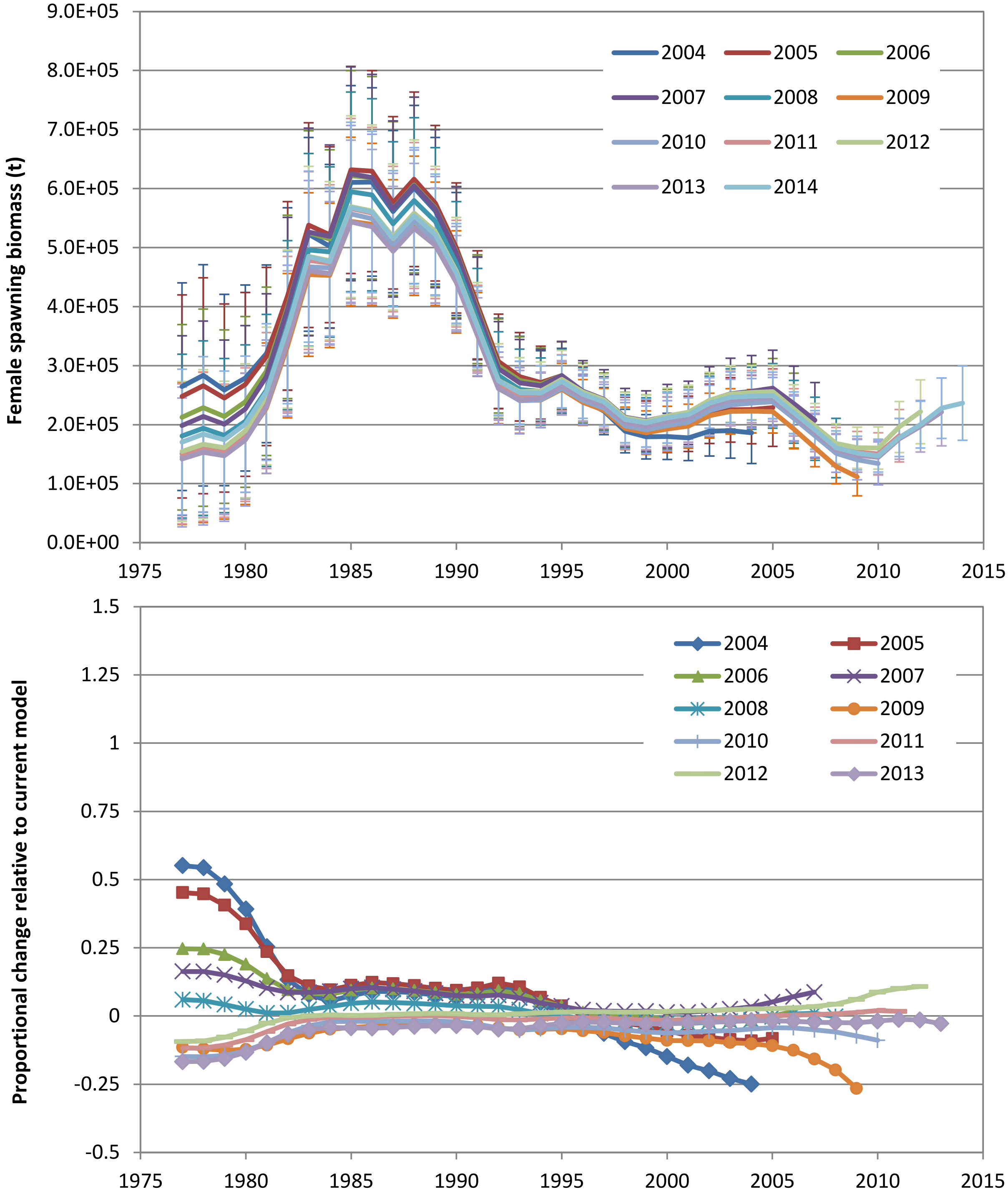


Figure 2.1.10b—Ten-year spawning biomass retrospective analysis of Model 2.

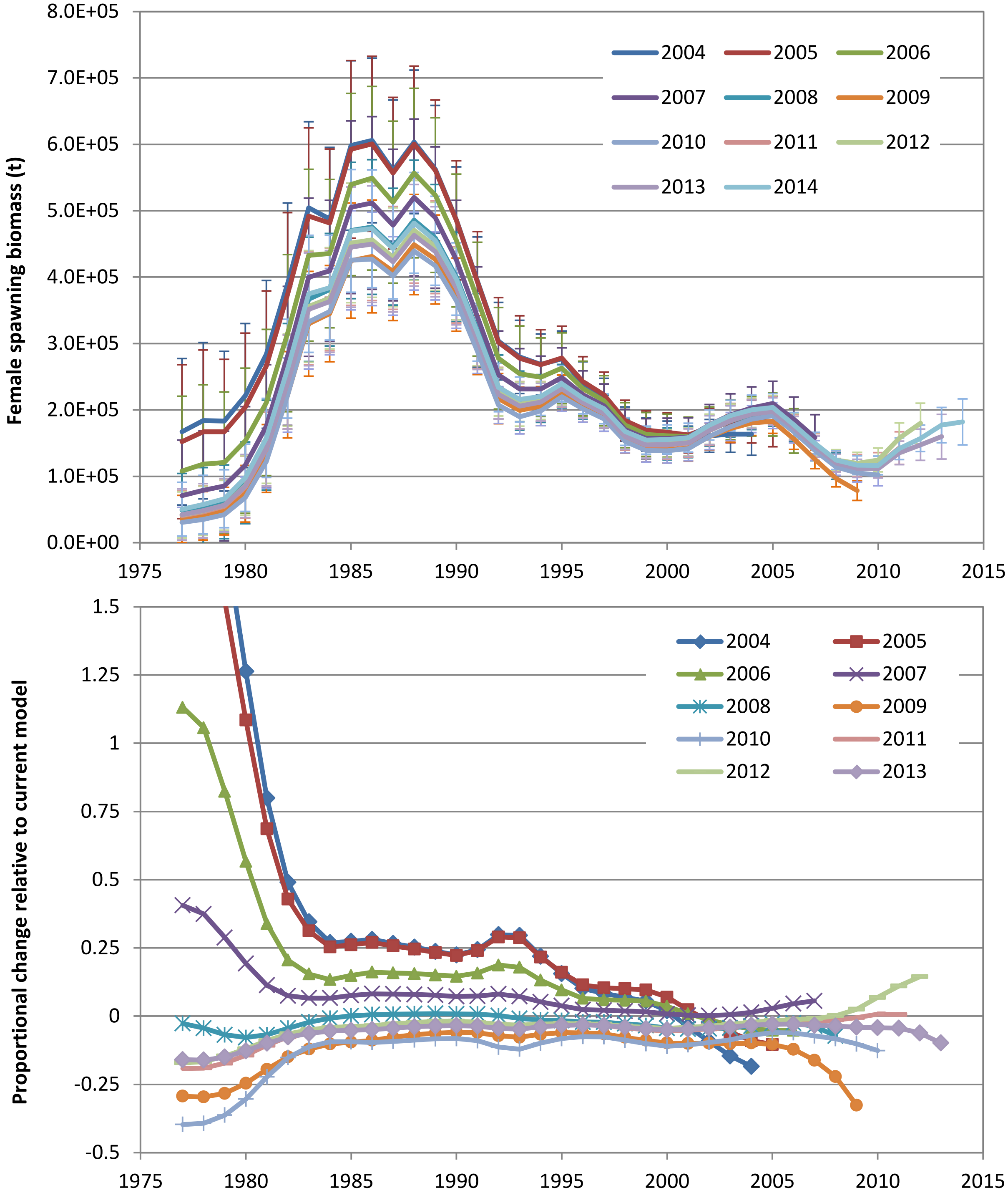


Figure 2.1.10c—Ten-year spawning biomass retrospective analysis of Model 3.

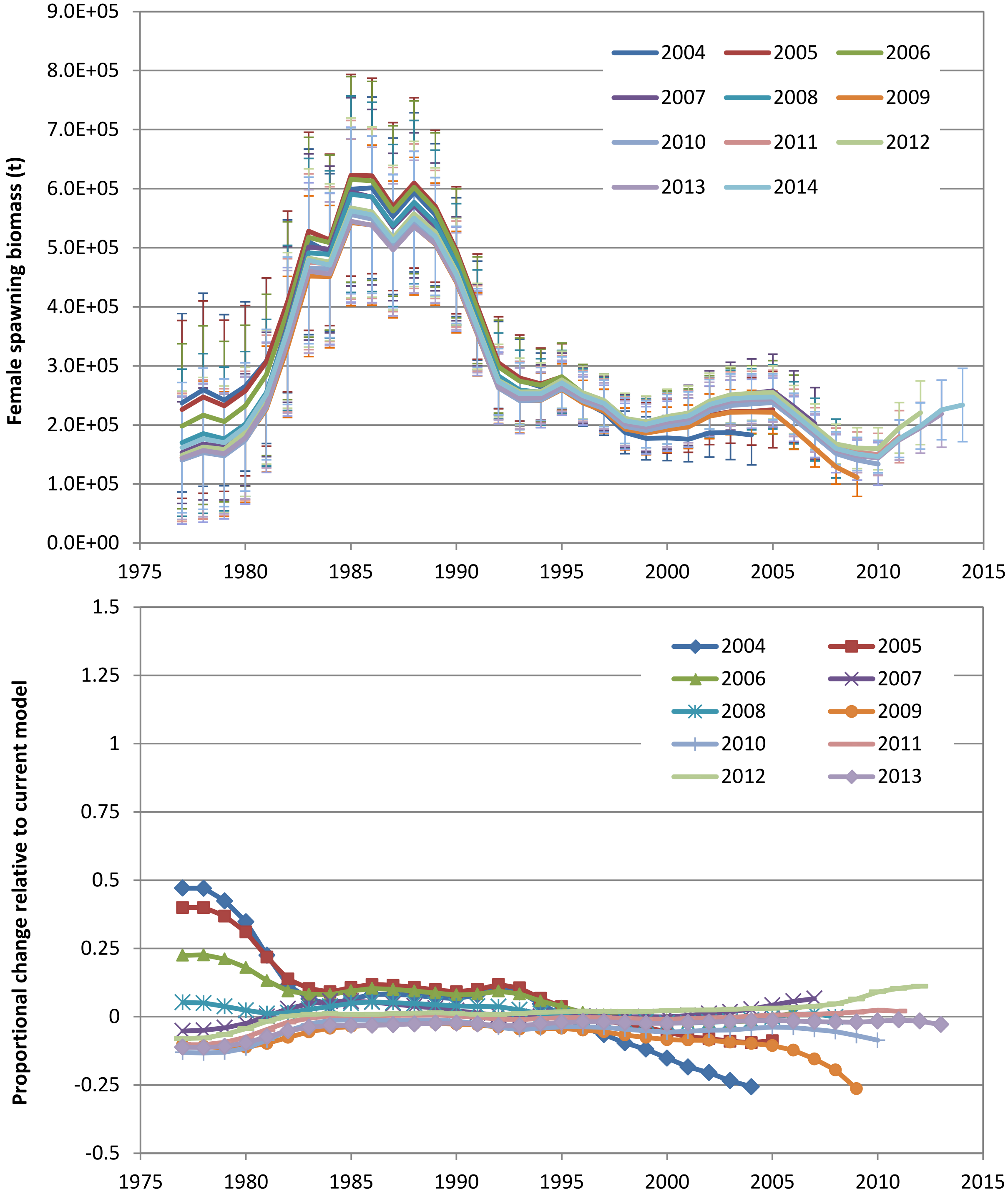


Figure 2.1.10d—Ten-year spawning biomass retrospective analysis of Model 4.

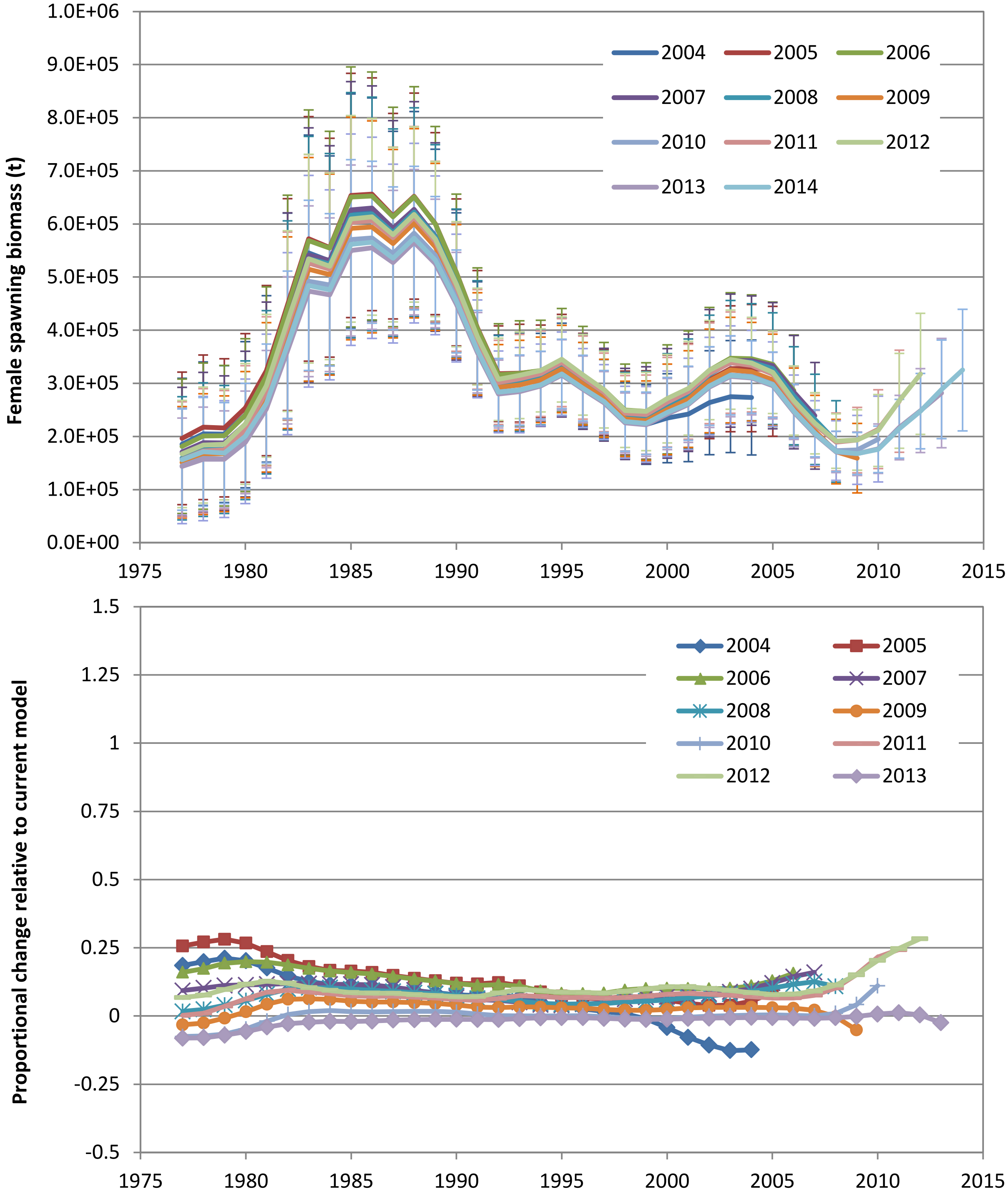


Figure 2.1.10e—Ten-year spawning biomass retrospective analysis of Model 5.

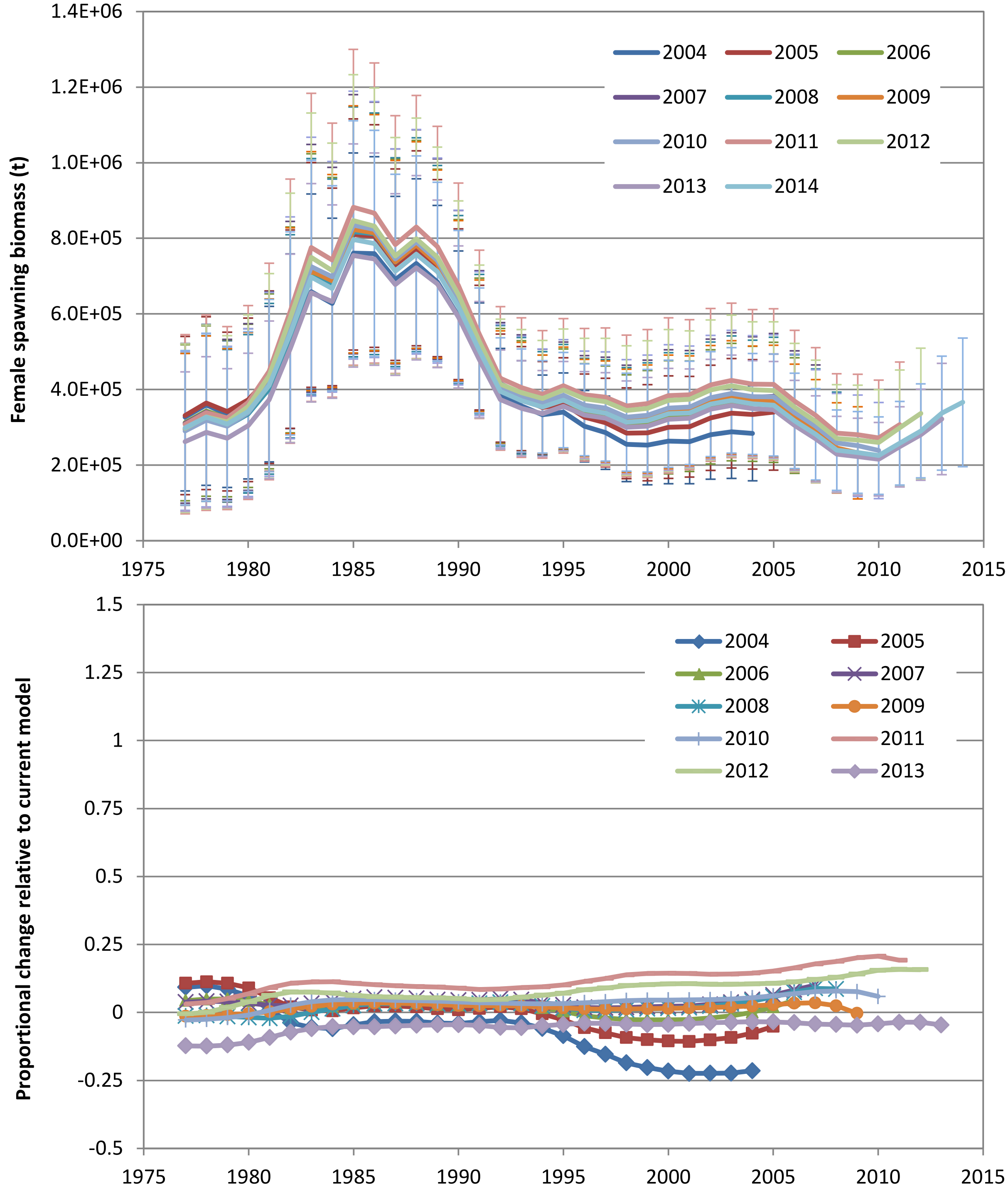


Figure 2.1.10f—Ten-year spawning biomass retrospective analysis of Model 6.

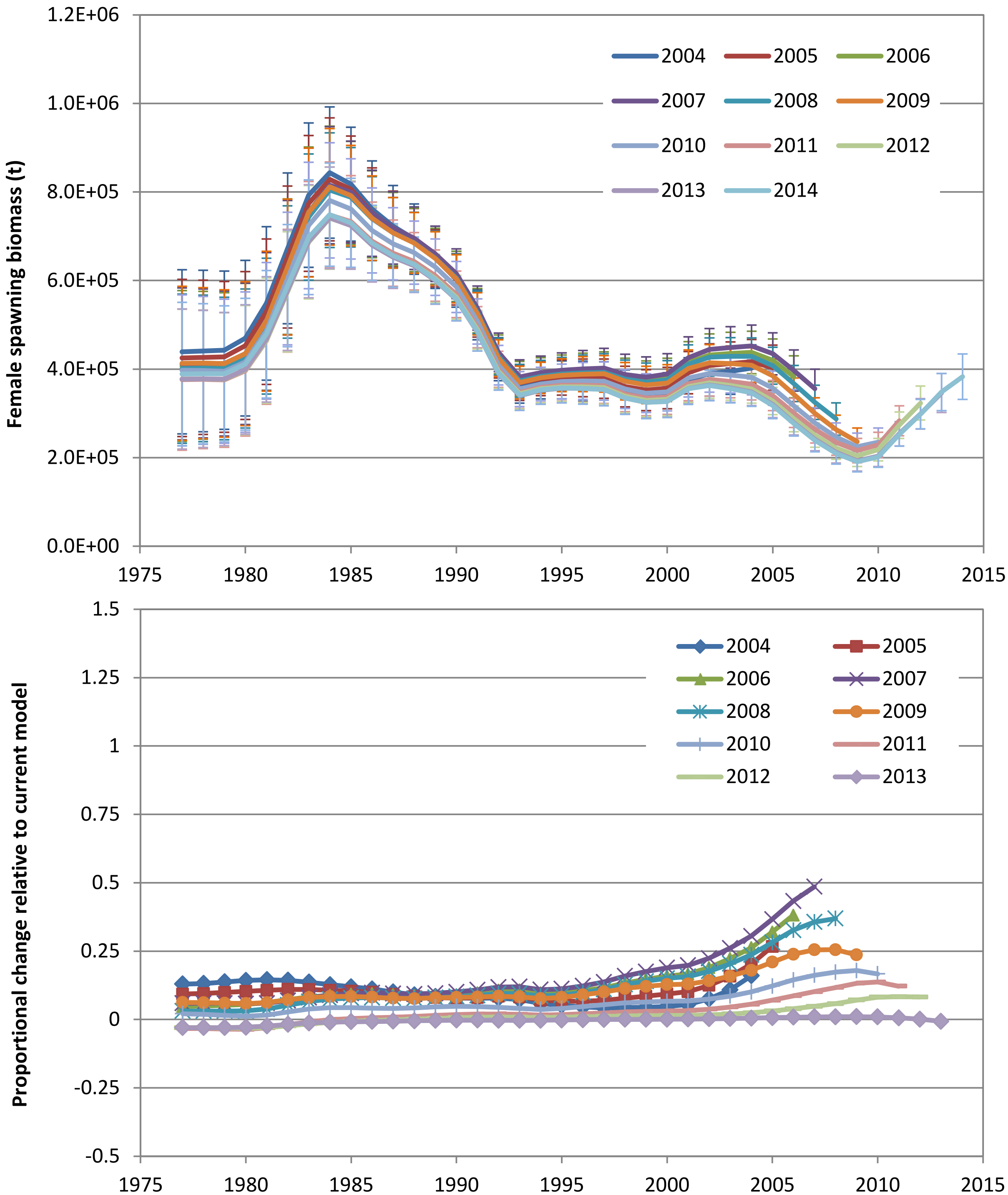


Figure 2.1.10g—Ten-year spawning biomass retrospective analysis of Model 7.

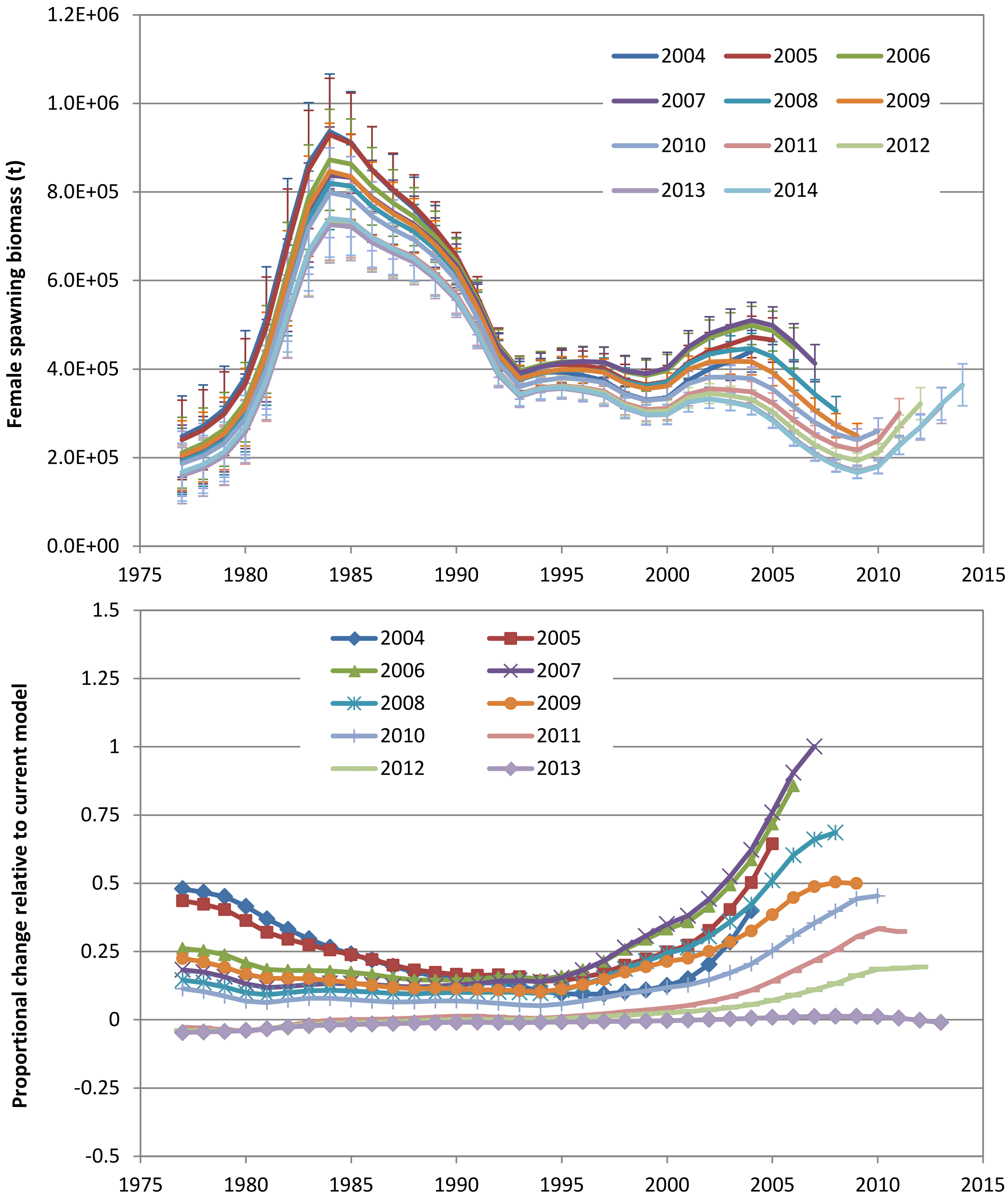


Figure 2.1.10h—Ten-year spawning biomass retrospective analysis of Model 8.

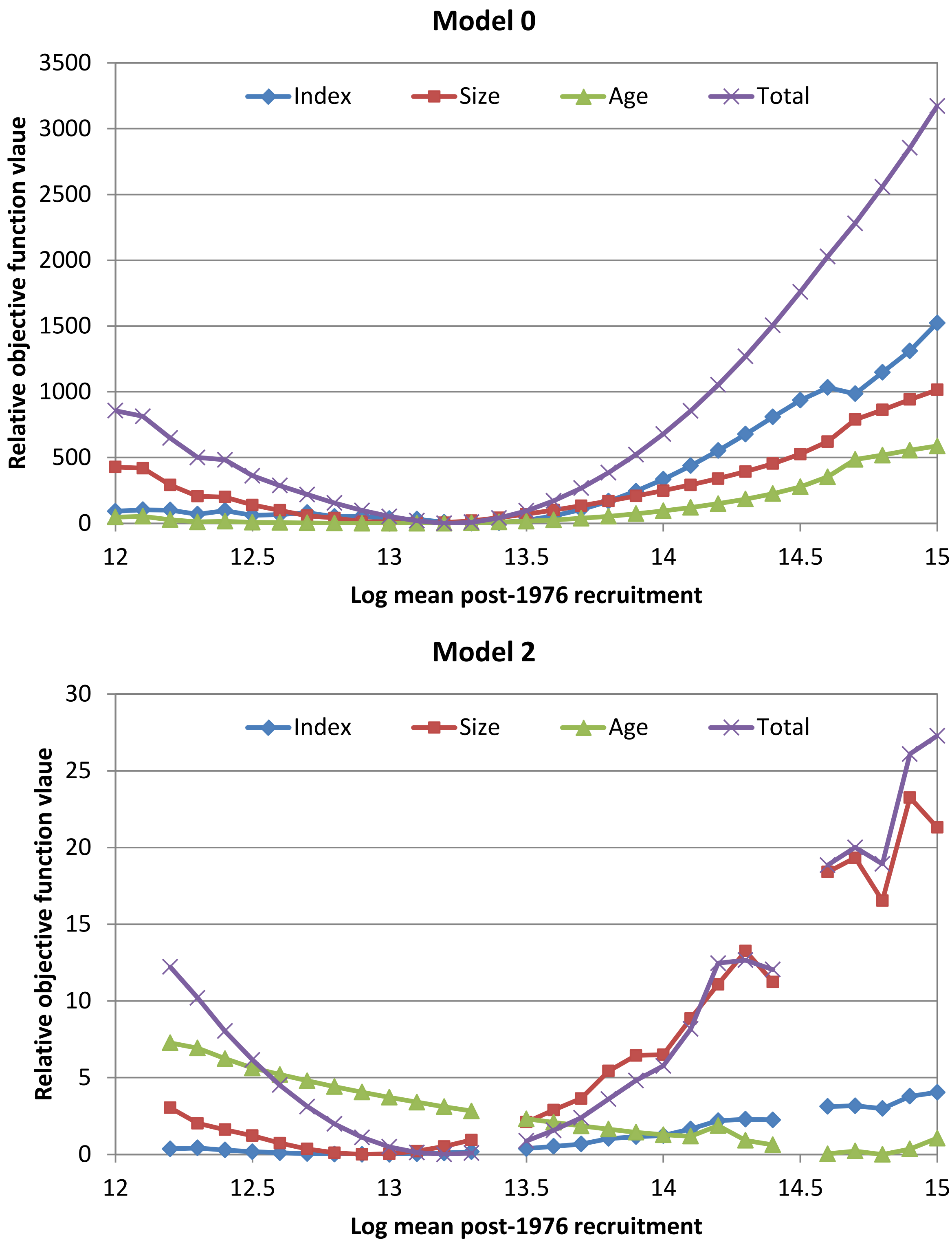
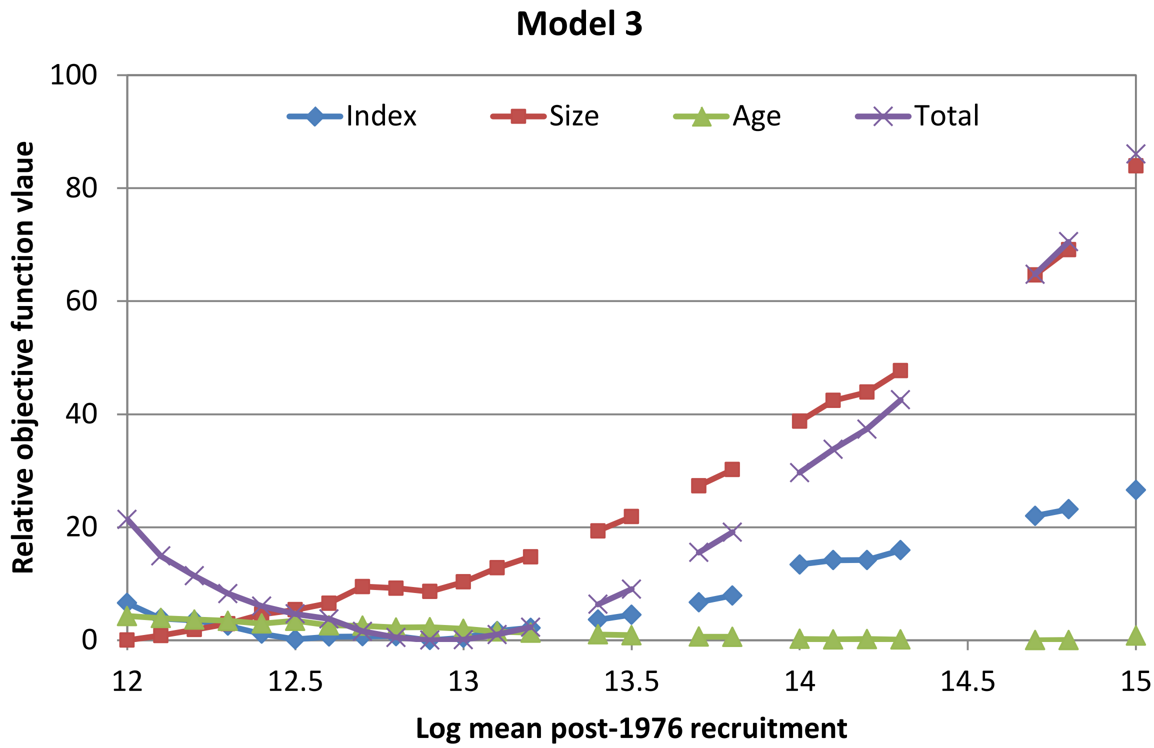


Figure 2.1.11a—Likelihood profile (using observed data) for Models 0 and 2. Missing values indicate runs that failed to converge.



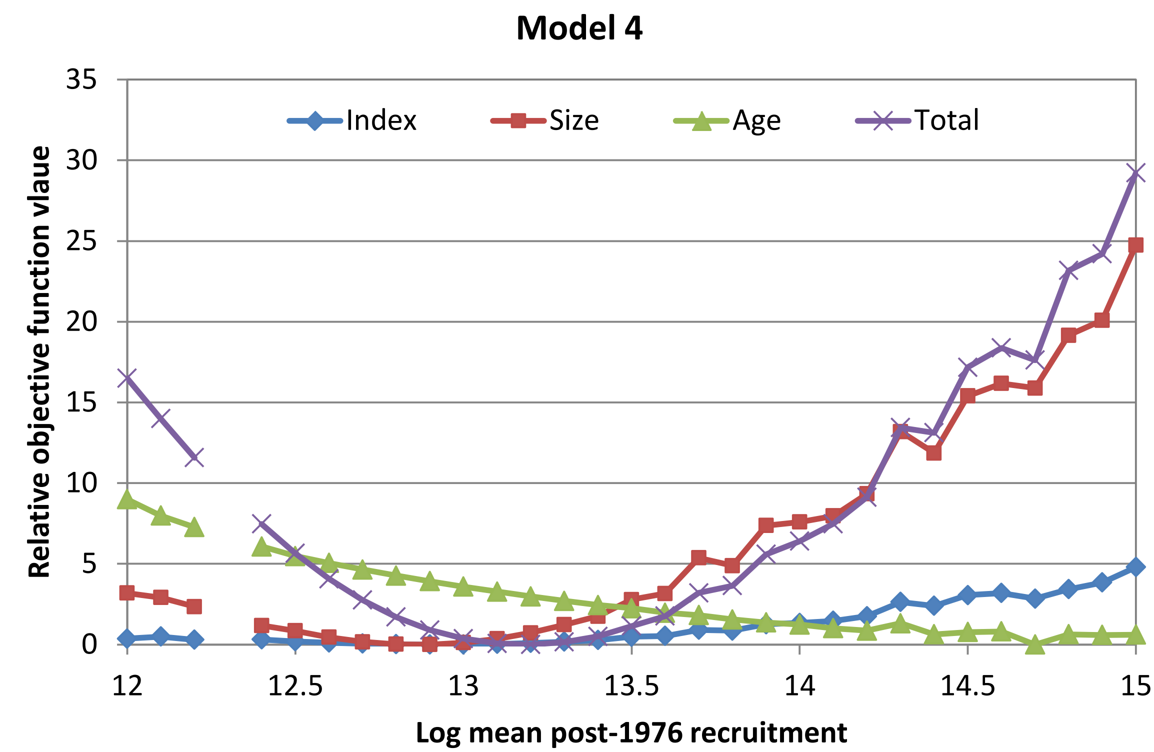


Figure 2.1.11b—Likelihood profile (using observed data) for Models 3 and 4. Missing values indicate runs that failed to converge.

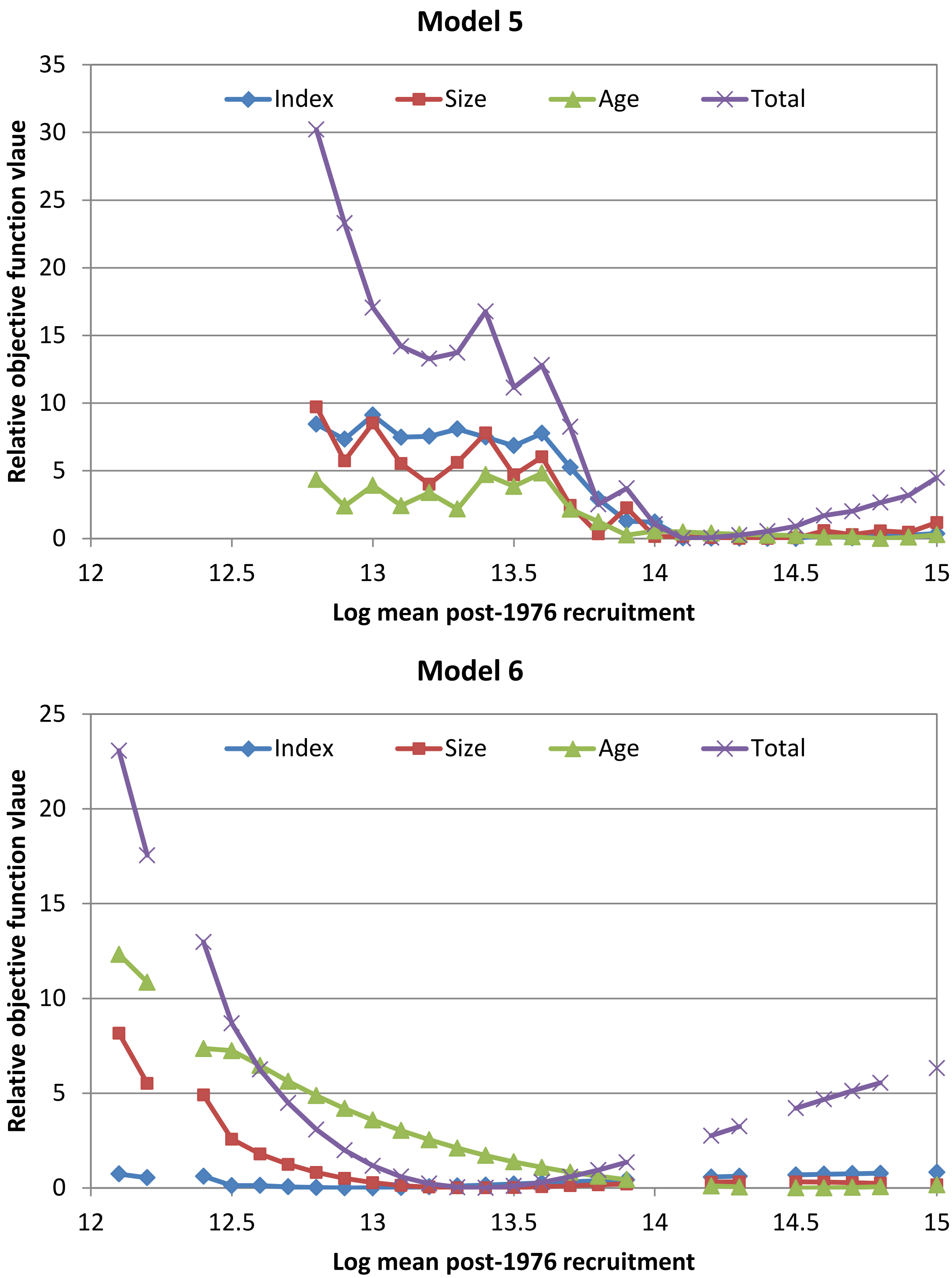


Figure 2.1.11c—Likelihood profile (using observed data) for Models 5 and 6. Missing values indicate runs that failed to converge.

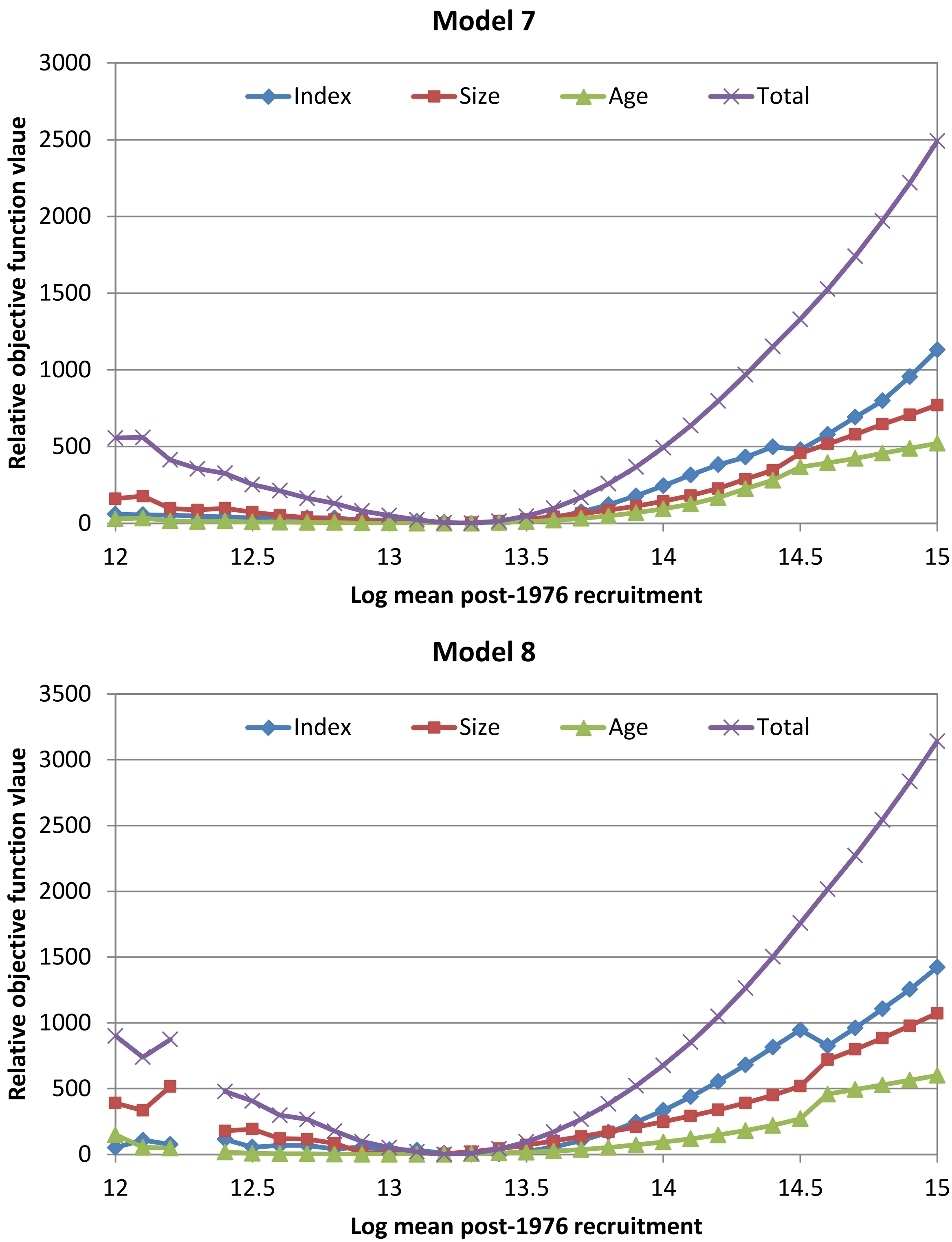


Figure 2.1.11d—Likelihood profile (using observed data) for Models 7 and 8. Missing values indicate runs that failed to converge.

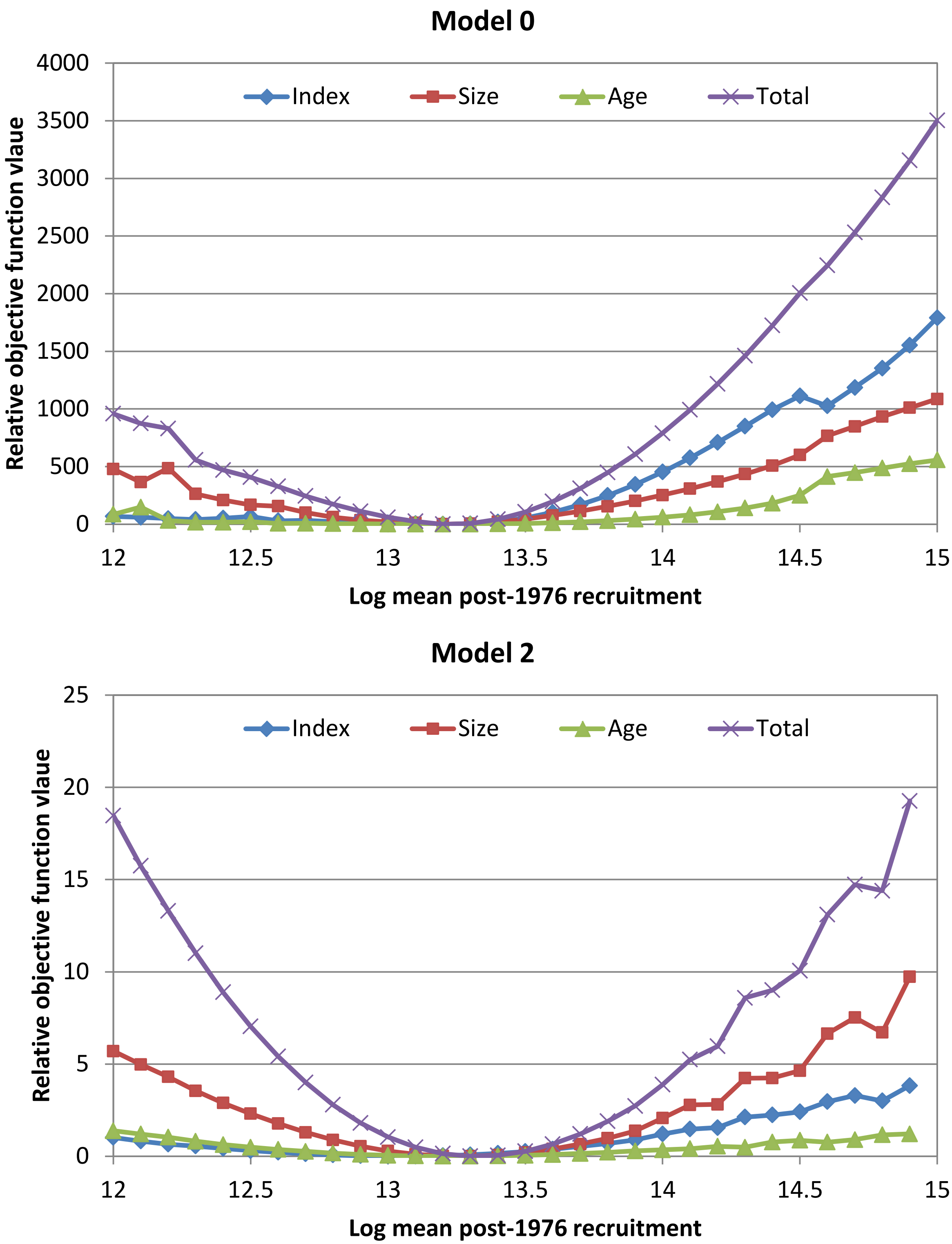


Figure 2.1.12a— Likelihood profile (using "errorless" data) for Models 0 and 2. Missing values indicate runs that failed to converge.

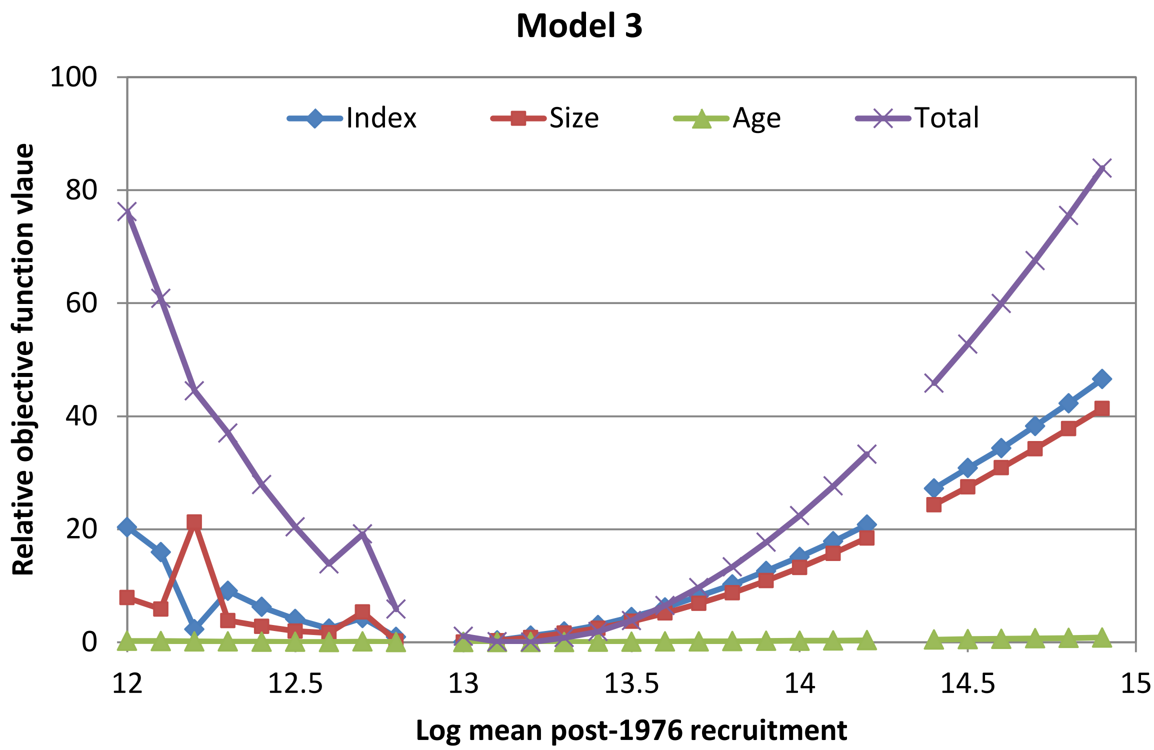


Figure 2.1.12b— Likelihood profile (using "errorless" data) for Models 3 and 4. Missing values indicate runs that failed to converge.

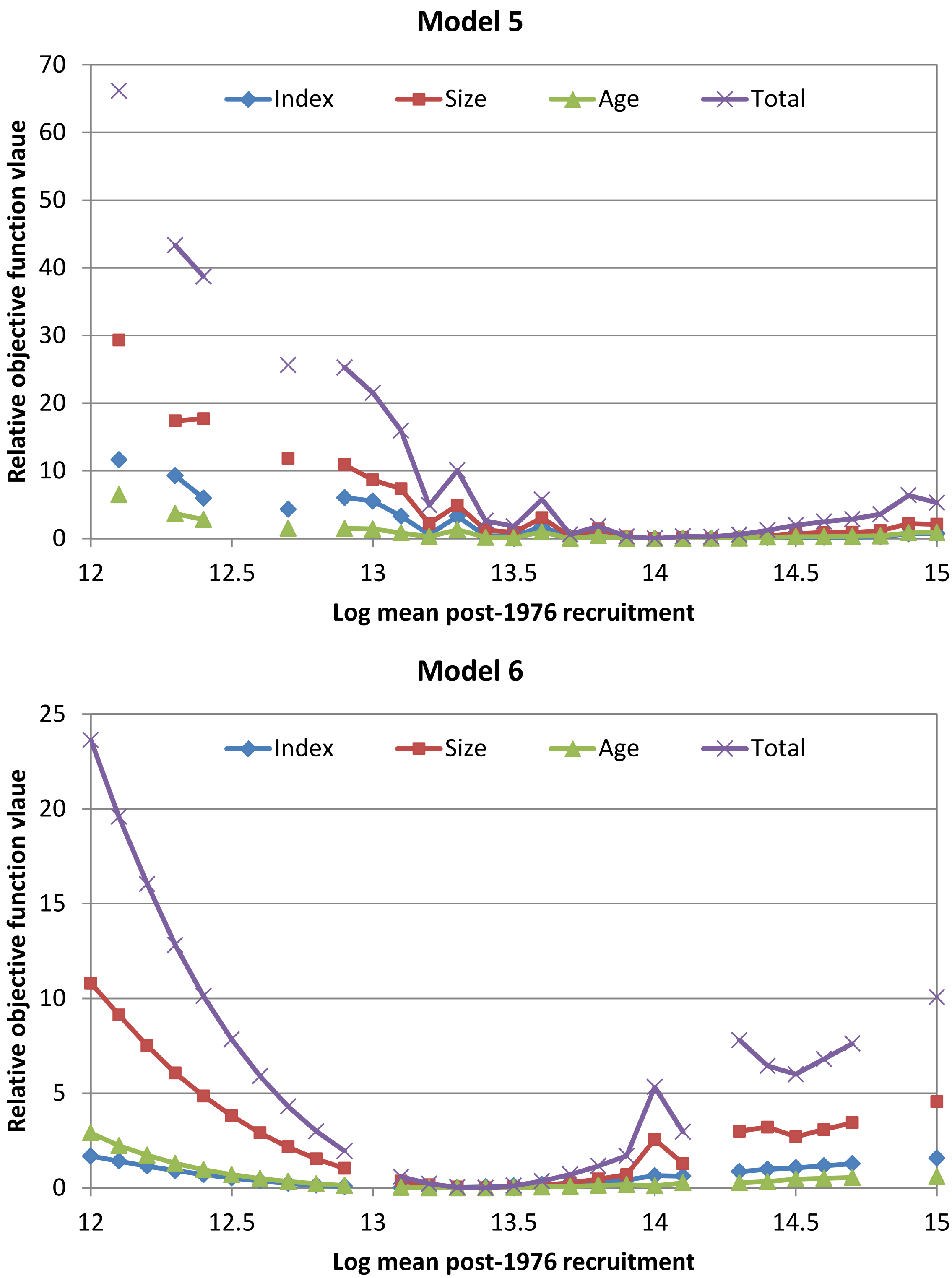


Figure 2.1.12c— Likelihood profile (using “errorless” data) for Models 5 and 6. Missing values indicate runs that failed to converge.

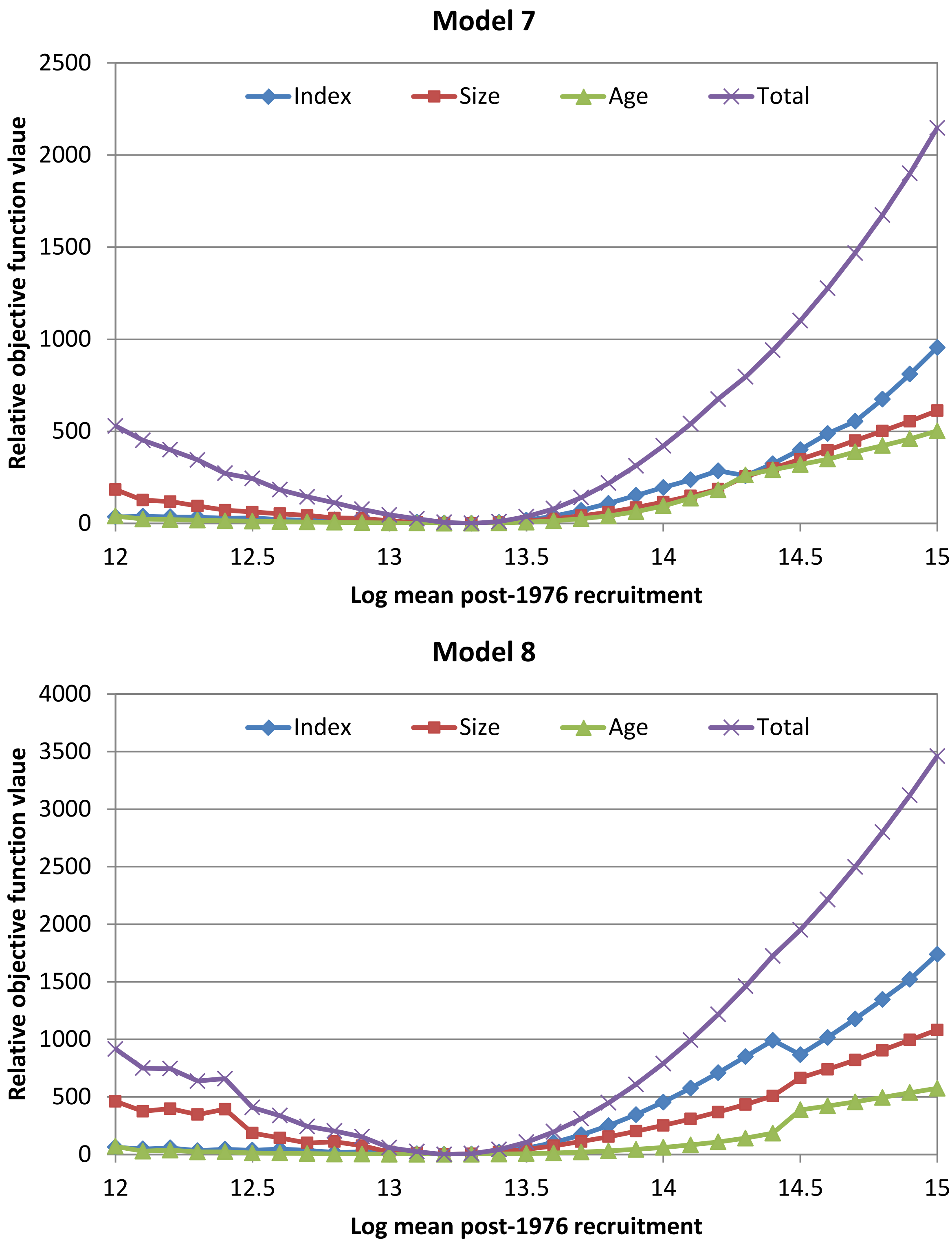


Figure 2.1.12d—Likelihood profile (using "errorless" data) for Models 7 and 8. Missing values indicate runs that failed to converge.

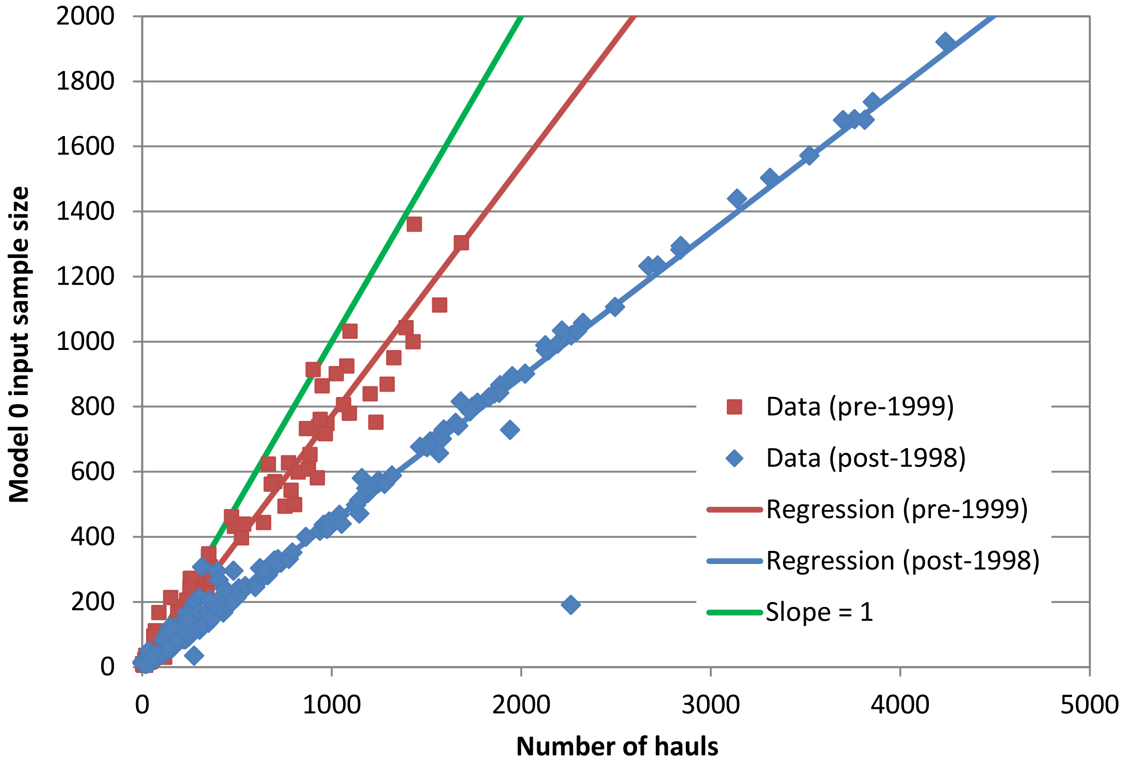


Figure 2.1.13—Comparison of the input sample sizes specified in Model 0 to the number of hauls sampled for lengths (data begin in 1990).

APPENDIX 2.2: SUPPLEMENTAL CATCH DATA

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 EBS Pacific cod from this dataset are shown in Table 2.2.1.

Although many sources of removal are documented in Table 2.2.1, the time series is highly incomplete for many of these. Cells shaded gray represent data contained in the NMFS database. Other entries represent extrapolations for years in which the respective activity was known or presumed to have taken place, where each extrapolated value consists of the time series average of the official data for the corresponding activity. In the case of surveys, years with missing values were identified from the literature or by contacting individuals knowledgeable about the survey (the NMFS database contains names of contact persons for most activities); in the case of fisheries, it was assumed that the activity occurred every year.

In the 2012 analysis (Attachment 2.4 of Thompson and Lauth 2012), the supplemental catch data were used to provide estimates of potential impacts of these data in the event that they were included in the catch time series used in the assessment model. The results of that analysis indicated that $F_{40\%}$ increased by about 0.01 and that the one-year-ahead catch corresponding to harvesting at $F_{40\%}$ decreased by about 4,000 t. Note that this is a separate issue from the effects of taking other removals "off the top" when specifying an ABC for the groundfish fishery; the former accounts for the impact on reference points, while the latter accounts for the fact that "other" removals will continue to occur.

The average of the total removals in Table 2.2.1 for the last three complete years (2012-2014) is 7,782 t.

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 groundfish fishery.

Reference

Thompson, G. G., and R. R. Lauth. 2012. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 245-544. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Table 2.2.1—Total removals of Pacific cod (t) from activities not related to directed fishing. Cells shaded gray represent data contained in the NMFS database. Other entries represent extrapolations for years in which the respective activity was known or presumed to have taken place.

Activity	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Aleutian Island Bottom Trawl Survey				2			2			2					2			2	
Annual Longline Survey						28	28	28	28	28	28	28	28	28	28	28	28	28	
Bait for Crab Fishery	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810
Bering Sea Acoustic Survey			0			0			0			0			0			0	
Bering Sea Slope Survey			1		1	1			1			1			1				
Eastern Bering Sea Bottom Trawl Survey	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
Gulf of Alaska Bottom Trawl Survey								0			0			0			0		
IPHC Annual Longline Survey																			
Large-Mesh Trawl Survey														1	1			1	1
Northern Bering Sea Bottom Trawl Survey			1		1	1			1			1			1				
Pollock EFP 11-01																			
Pribilof Islands Crab Survey																			
St. Mathews Crab Survey																			9
Subsistence Fishery	2	2	2	2	2	2	2	2	2	2	2	2	2	1	0	2	2	5	2
Summer EBS Survey with Russia																		0	

Activity	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Aleutian Island Bottom Trawl Survey		2			2		2		2		2				2		1		2
Annual Longline Survey		38		30		36		30		23		25		20		24		27	
Bait for Crab Fishery	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	5810	1737	4544	6697	6618	9452
Bering Sea Acoustic Survey	0	0		0	0		0		0		0	0	0	0	0		0		
Bering Sea Slope Survey					1		1		1				1		2		1	1	1
Eastern Bering Sea Bottom Trawl Survey	41	41	41	41	41	41	41	41	41	41	41	41	41	41	38	42	52	33	39
Gulf of Alaska Bottom Trawl Survey	0			0		0		0		0		0		0		0		0	
IPHC Annual Longline Survey			30	30	30	30	30	30	30	30	30	30	30	30	32	20	17	29	52
Large-Mesh Trawl Survey				1	1			1	1	1	1	1	1	1	1	1	2	1	1
Northern Bering Sea Bottom Trawl Survey															1				
Pollock EFP 11-01																11	307		
Pribilof Islands Crab Survey								5		5			5			5			
St. Mathews Crab Survey			9			9			9			9			9			9	
Subsistence Fishery	2	2	1	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Summer EBS Survey with Russia							0		0			0	0	0	0		0		

APPENDIX 2.3: HISTORY OF PREVIOUS EBS PACIFIC COD MODEL STRUCTURES DEVELOPED UNDER STOCK SYNTHESIS

For 2005 and beyond, the SSC's accepted model from the final assessment is shown in **bold red**.

Pre-2005

Timeline

- Pre-1985: Simple projections of current survey numbers at age
- 1985: Projections based on 1979-1985 survey numbers at age
- 1986-1991: *ad hoc* separable age-structured FORTRAN model
- 1992: FORTRAN-based Stock Synthesis (SS), with age-based data
    - Strong 1989 cohort "disappears;" production ageing ceased
- 1993-2003: Models continued to be developed using SS, with length-based data only
- 2001: CIE review of code for proposed "ALASKA" (Age-, Length-, and Area-Structured Kalman Assessment) model and methodology for decision-theoretic estimation of OFL and ABC
    - Although review was favorable, use of ALASKA was postponed "temporarily"
- 2004: Models continued to be developed using SS, with length- *and* age-based data
    - New age data, based on revised ageing protocol
    - Agecomp data used in "marginal" form

Main features of the early Stock Synthesis EBS Pacific cod models

- Start year = 1977
- Three seasons (Jan-May, Jun-Aug, Sep-Dec)
- Four fisheries (Jan-May trawl, Jun-Dec trawl, longline, pot)
- M constant at 0.37 in both BS and GOA
- Q constant at 1.00 in both BS and GOA
- Efforts at internal estimation of M, Q unsuccessful
- Double-logistic selectivity for all fleets (fisheries and survey)
- No fleets constrained to exhibit asymptotic selectivity
- Sizecomp input sample size = square root of true sample size
- Survey index standard deviations set to values reported by RACE Division

2005

This assessment marked the first application of ADMB-based Stock Synthesis to EBS Pacific cod

Three models were included:

- Model 1 was identical to the 2004 final model (configured under FORTRAN-based SS), except for use of new maturity schedule developed by Stark
- **Model 2** was configured under ADMB-based SS, and was designed to be as close as possible to Model 1 given the limitations of the respective software packages, except:
    - Nonuniform priors used throughout
    - M fixed at 0.37, Q fixed at 1.00
- Model 3 was identical to Model 2 except that M and Q were estimated internally

Weight-length and length-age data examined for evidence of sexual dimorphism; none found.

2006

Nine models were included, consisting of 2005 final model and a 3-way factorial design of alternative models (the factorial models all differed from the 2005 final model in that they estimated trawl survey Q internally—in the 2005 final model, it was fixed at 1.0; and they estimated all selectivity parameters except for selectivity at the minimum size bin internally—in the 2005 final model, a few selectivity parameters were fixed externally):

- Model 0 was identical to 2005 final model
- Model A1 was identical to Model 0 except as noted above, with:
  - NMFS longline survey data omitted
  - Double logistic selectivity
  - Prior emphasis = 1.0
- Model A2 was identical to Model 0 except as noted above, with:
  - NMFS longline survey data omitted
  - Double logistic selectivity
  - Prior emphasis = 0.5
- **Model B1** was identical to Model 0 except as noted above, with:
  - NMFS longline survey data omitted
  - Double normal (four parameter) selectivity
  - Prior emphasis = 1.0
- Model B2 was identical to Model 0 except as noted above, with:
  - NMFS longline survey data omitted
  - Double normal (four parameter) selectivity
  - Prior emphasis = 0.5
- Model C1 was identical to Model 0 except as noted above, with:
  - NMFS longline survey data included
  - Double logistic selectivity
  - Prior emphasis = 1.0
- Model C2 was identical to Model 0 except as noted above, with:
  - NMFS longline survey data included
  - Double logistic selectivity
  - Prior emphasis = 0.5
- Model D1 was identical to Model 0 except as noted above, with:
  - NMFS longline survey data included
  - Double normal (four parameter) selectivity
  - Prior emphasis = 1.0
- Model D2 was identical to Model 0 except as noted above, with:
  - NMFS longline survey data included
  - Double normal (four parameter) selectivity
  - Prior emphasis = 0.5

2007

Technical workshop

SS introduced a six-parameter form of the double normal selectivity curve (the previous version used only four parameters). 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 0 was prepared ahead of workshop:

- *M* estimated internally
- Length-at-age parameters estimated internally
- Disequilibrium initial age structure
- Regime shift recruitment offset estimated internally
- Start year changed from 1964 to 1976
- New six-parameter double normal selectivity function used
- Prior distributions reflect 50% CV for most parameters

Twenty-one other models were prepared ahead of workshop, each of which was based on Model 0:

- Two models to examine inside/outside growth estimation:
    - Model 1 was identical to Model 0 except length-at-age parameters estimated outside the model
    - Model 2 was identical to Model 0 except standard deviation of length at age 12 estimated internally
- Two models to examine *M* conditional on *Q,* vice-versa:
    - Model 3 was identical to Model 0 except *M* fixed at 0.37 and *Q* free
    - Model 4 was identical to Model 0 except *Q* fixed at 0.75 and *M* free
- Six models to examine effects of prior distributions:
    - Model 5 was identical to Model 0 except 30% CV instead of 50%
    - Model 6 was identical to Model 0 except 40% CV instead of 50%
    - Model 7 was identical to Model 0 except emphasis = 0.2 instead of 1.0
    - Model 8 was identical to Model 0 except emphasis = 0.4 instead of 1.0
    - Model 9 was identical to Model 0 except emphasis = 0.6 instead of 1.0
    - Model 10 was identical to Model 0 except emphasis = 0.8 instead of 1.0
- Four models to examine effects of asymptotic selectivity:
    - Model 11 was identical to Model 0 except Jan-May trawl fishery selectivity forced asymptotic
    - Model 12 was identical to Model 0 except longline fishery selectivity forced asymptotic
    - Model 13 was identical to Model 0 except pot fishery selectivity forced asymptotic
    - Model 14 was identical to Model 0 except shelf trawl survey selectivity forced asymptotic
- One model to examine estimation of stock-recruit relationship:
    - Model 15 was identical to Model 0 except parameters of a Ricker stock-recruitment relationship estimated internally
- Six models to address EBS-specific comments from the public:
    - Model 16 was identical to Model 0 except input *N* determined by iterative re-weighting
    - Model 17 was identical to Model 0 except input *N* for mean-size-at-age data decreased by an order of magnitude
    - Model 18 was identical to Model 0 except standard error from the shelf trawl survey doubled

  - Model 19 was identical to Model 0 except all age data removed
  - Model 20 was identical to Model 0 except slope survey data removed
  - Model 21 was identical to Model 0 except start year changed to 1982

An immense factorial grid of fixed *M*×*Q* models also prepared ahead of workshop, for which only partial results were presented

Eight models were developed during the workshop itself:

- Model 22 was identical to Model 0 except "old" (pre-Stark) maturity schedule used
- Model 23 was identical to Model 0 except priors turned off and separate *M* estimated for ages 1-2
- Model 24 was identical to Model 0 except priors turned off and longline fishery CPUE included as an index of abundance
- Model 25 was identical to Model 0 except priors turned off and Pcod bycatch from IPHC survey included as an index of abundance
- Model 26 was identical to Model 0 except priors turned off and either *Q* (=0.75) or *M* (=0.37) fixed
- Model 27 was identical to Model 0 except all priors turned off other than that for Jan-May trawl selectivity in largest size bin
- Model 28 was identical to Model 0 except survey selectivity forced asymptotic and *Q* fixed at 0.5
- Model 29 was identical to Model 0 except separate *M* estimated for ages 9+

Preliminary assessment

In general:

- Agecomp data presented as "age conditioned on length" (i.e., not marginals)
- Length-at-age SD a linear function of age
- Annual *dev*s for length at age 1, sigma=0.11
- Annual *dev*s for recruitment, sigma=0.6, 1973-2005
- Annual *dev*s for ascending selectivity, sigma=0.4
- All parameters estimated internally
- Except selectivity parameters pinned against bounds
- Uniform priors used exclusively
- Monotone selectivity for Jan-May trawl fishery
- All other selectivities new "double normal" (see next 4 slides)

Four models were included, all of which were identical to the 2006 final model except as specified above and below:

- Model 1:
  - Estimated effect of 1976 regime shift on median recruitment
  - Added a large constant to fishery CPUE sigmas
- Model 2 was identical to Model 1 except age-dependent *M* estimated for ages 8+
- Model 3 was identical to Model 1 except that it did not add the large constant to longline CPUE sigmas
- Model 4 was identical to Model 1 except:
  - Effect of regime shift assumed to be zero
  - Did not add large constant to longline CPUE sigmas
  - Zero emphasis placed on initial catch and age composition
  - Iteratively re-weighted input sigmas and input *N*

Also attempted but not included:

- Simplified model with only a single fishery and no seasons

Final assessment

Four models were included:

- **Model 1** (comparisons to 2006 final model in parentheses):
  - *M* fixed at 0.34 (*M* fixed at 0.37 in 2006)
  - Length-at-age parameters estimated internally (fixed at point estimates from data in 2006)
  - Start year set at 1977 (start year set at 1964 in 2006)
  - Three age groups in initial state vector estimated (initial state vector assumed to be in equilibrium in 2006)
  - 6-parameter double normal selectivity (4-parameter version used in 2006)
  - Uniform priors used exclusively (informative normal priors used for many parameters in 2006)
  - Fishery selectivities constant across all years (approximately decadal "time blocks" used in 2006)
  - Ascending limb of survey selectivity varies annually with σ=0.2 (survey selectivity assumed to be constant in 2006)
  - Survey selectivity based on age (length-based selectivity used in 2006)
  - Some fishery selectivities forced asymptotic (all selectivities free in 2006)
  - Fishery CPUE data included for comparison (not included in 2006)
  - Age-based maturity schedule (length-based schedule used in 2006)
  - All fisheries seasonally structured (trawl partially seasonal, other gears non-seasonal in 2006)
  - Trawl survey abundance measured in numbers (abundance measured in biomass in 2006)
  - Multinomial *N* based on rescaled bootstrap (sample size set equal to square root of actual *N* in 2006)
- Model 2 was identical to Model 1 except *M* fixed at 0.37
- Model 3 was identical to Model 1 except *M* estimated internally
- Model 4 was identical to Model 1 except:
  - *M* estimated internally
  - Survey selectivities forced to be asymptotic
  - Age data ignored
  - Start year set at 1982; 1977 regime shift ignored
  - Length-based maturity used
  - Length-based survey selectivity used
  - Sigma=0.4 for annual deviations in selectivity parameters
  - Initial catch ignored in estimating initial fishing mortality

2008

Preliminary assessment

Five models were included:

- Model 1 was identical to the 2007 final model
- Model 2 was identical to Model 1 except growth parameter *L2* estimated externally
- Model 3 was identical to Model 1 except exponential-logistic selectivity used instead of double normal

- Model 4 was identical to 2007 Model 4
- Model 5 was identical to Model 1 except:
    - Fishery selectivity blocks (5 yr, 10 yr, 20 yr, or no blocks) chosen by AIC
    - Lower bound of descending "width" = 5.0
    - Regime-specific recruitment "dev" vectors
    - "SigmaR" set equal (iteratively) to stdev(dev) from current regime
    - Seasonal weight-length, based on fishery data
    - Number of free initial ages chosen by AIC
    - Size-at-age data used if modes ambiguous

Final assessment

Eight models were included:

- Model A1 was identical to Model 5 from September except lower bound on selectivity descending "width" parameter relaxed so as not to be constraining
- Model A2 was identical to Model A1, except without age data
- **Model B1** was identical to Model A1, except:
    - "Asymptotic algorithm" used to determine which fisheries will be forced to exhibit asymptotic selectivity
    - "Constant-parameters-across-blocks algorithm" used to determine which selectivity parameters can be held constant across blocks
- Model B2 was identical to Model B1, except without age data
- Model C1 was identical to Model B1, except with M estimated internally
- Model D2 was identical to Model B1, except:
    - No age data
    - Maturity modeled as function of length rather than age
    - M estimated iteratively, based on mat. at len and len. at age
- Model E2 was identical to Model B1, except:
    - No age data
    - Post-1981 trawl survey selectivity forced to be asymptotic
    - *M* estimated internally
- Model F2 was identical to Model 4 from the final assessment for 2007, except start year = 1977

2009

Preliminary assessment

Eight models were included, based on factorial design of the following:

- Selectivity functional form: double normal or exponential-logistic?
- Catchability: free or fixed at 1.0?
- Survey selectivity estimation: free or forced asymptotic?

Partial results were presented for a model with a prior distribution for *Q* based on archival tags (the prior had virtually no impact, which was why only partial results were presented)

Other features explored but not included in the above models:

- Fixing trawl survey catchability at the mean of the above normal prior distribution
- Allowing trawl survey catchability to vary as a random walk

- Fixing trawl survey catchability at a value of 1.00 for the pre-1982 portion of the time series, but allowing it to be estimated freely for the post-1981 portion of the time series
- Reducing the number of survey selectivity parameters subject to annual deviations
- Use of additive, rather than multiplicative, deviations for certain survey selectivity parameters
- Decreasing the value of the σ parameter used to constrain annual survey selectivity deviations
- Turning off annual deviations in survey selectivity parameters for the three most recent years
- Turning off all annual deviations in survey selectivity parameters
- Forcing trawl survey selectivity to peak at age 6.5, the approximate mid-point of the size range of 60-81 cm spanned by the results of Nichol et al. (2007)
- Imposing a beta prior distribution on the shape parameter of the exponential-logistic selectivity function in the trawl survey.

Final assessment

Fourteen models were included (all new since the preliminary assessment except for Model A1):

- Models without mean-size-at-age data:
    - Model A1 was identical to the 2008 final model, with the addition of new data, including the first available fishery agecomp data (from the 2008 Jan-May longline fishery)
    - Model A2 was identical to Model A1, except all agecomp data omitted
    - Model A3 was identical to Model A1, except 2008 Jan-May longline fishery agecomp data omitted
    - Model F2 was identical to Model F2 from the final assessment for 2008
- Models with mean-size-at-age data and agecomp data:
    - **Model B1** was identical to Model A1 except:
        - Survey selectivity held constant for most recent two years
        - Cohort-specific growth included
        - Input standard deviations of all “dev” vectors were set iteratively by matching the standard deviations of the set of estimated *dev*s
        - Standard deviation of length at age was estimated outside the model as a linear function of mean length at age
        - Selectivity at maximum size or age was treated as a controllable parameter
        - *Q* for the post-1981 trawl survey was fixed at the value that sets the average (weighted by numbers at length) of the product of *Q* and selectivity for the 60-81 cm size range equal to the point estimate of 0.47 obtained by Nichol et al. (2007)
        - Potential ageing bias was accounted for in the ageing error matrix by examining alternative bias values in increments of 0.1 for ages 2 and above (age-specific bias values were also examined, but did not improve the fit significantly).
    - Model C1 was identical to Model B1 except:
        - Input standard deviations for all “dev” vectors and the amount of ageing bias fixed at the values obtained iteratively in Model B1
        - *Catchability itself* (rather than the average product of catchability and selectivity for the 60-81 cm size range) set equal to 0.47
    - Model D1 was identical to Model B1 except:
        - Input standard deviations for all “dev” vectors and the amount of ageing bias fixed at the values obtained iteratively in Model B1
        - Selectivity at maximum size or age was removed from the set of controllable parameters (instead, selectivity at maximum size or age becomes a function of other selectivity parameters)
    - Model E1 was identical to Model B1 except:

        - Input standard deviations for all "dev" vectors and the amount of ageing bias fixed at the values obtained iteratively in Model B1
        - Selectivity at maximum size or age for all non-asymptotic fleets was set equal to a single value that was constant across fleets
    - Model G1 was identical to Model B1 except:
        - Input standard deviations for all "dev" vectors and the amount of ageing bias fixed at the values obtained iteratively in Model B1
        - Survey selectivity was held constant across all years (i.e., no selectivity *dev*s are estimated for any years)
- Models with mean-size-at-age data and without agecomp data:
    - Models B2, C2, D2, E2, and G2 were identical to their B1, C1, D1, E1, and G1 counterparts except that agecomp data were ignored and the corresponding sizecomp data were active.

2010

Preliminary assessment

Six models were included:

- Model 1 was identical to the 2009 final model
- Model 2 was identical to Model 1 except:
    - Input standard deviations for all "dev" vectors fixed at the values obtained iteratively in Model 1
    - IPHC survey data omitted
    - Fishery age data omitted
    - Traditional 3-or-5 cm size bins replaced with 1 cm size bins
    - Traditional 3-season structure replaced with new, 5-season structure
    - Spawn time changed from beginning of season 1 to beginning of season 2
- Model 3 was identical to Model 2 except:
    - Non-uniform prior distributions used for selectivity parameters and Q
- Model 4 was identical to Model 2 except:
    - All age data omitted
    - Maturity schedule was length-based rather than age-based
- Model 5 was identical to Model 4 except:
    - Parameters governing spread of lengths at age around mean length at age estimated internally
- Model 6 was identical to Model 5 except:
    - Cohort-specific growth replaced by annual variability in each of the three von Bertalanffy parameters

Final assessment

Three models were included:

- Model A was identical to Model 1 from the preliminary assessment
- **Model B** was identical Model 2 from the preliminary assessment, except cohort-specific growth replaced by constant growth
- Model C: same as Model 4 from the preliminary assessment, except cohort-specific growth replaced by constant growth

2011

CIE review

Exploratory model developed prior to review, which was the same as the 2010 final model, except:

- All sizecomp data turned on
- Nine season × gear fisheries consolidated into five seasonal fisheries
- Pre-1982 trawl survey data omitted
- Mean-size-at-age data omitted
- Fishery CPUE data omitted
- Average input *N* set to 100 for all fisheries and the survey
- First reference age for length-at-age relationship set at 0.833333
- Richards growth implemented
- Ageing bias estimated internally
- Selectivities modeled as random walks with age (constant for ages 8+)

Twelve new models were developed during the review itself:

- Model 1 was identical to the 2010 final model except:
  - Length at age 0 constrained to be positive
  - Richards growth implemented
- Model 2 was identical to the 2010 final model except length at age 0 constrained to be positive
- Model 3 was identical to the 2010 final model except:
  - All time blocks removed
  - All selectivity parameters freed except fishery selectivity at initial age
  - All selectivity parameters initialized at mid-point of bounds
- Model 4 was identical to the 2010 final model except:
  - All time blocks removed
  - Emphasis on fishery sizecomps set to 0.001
- Model 5 was identical to the 2010 final model except:
  - Richards growth implemented
  - Ageing bias estimated internally
- Model 6 was identical to Model 4 except time blocks included
- Model 7 was identical to the 2010 final model except *Q* estimated internally
- Model 8 was identical to the 2010 final model except *M* estimated internally with an informative prior
- Model 9 was identical to the 2010 final model except tail compression increased
- Model 10 was identical to the 2010 final model except mean-size-at-age data turned off
- Model 11 was the same the "exploratory" model except:
  - Pre-1982 trawl survey data included
  - All time blocks removed
  - Fishery CPUE data included (but not used for estimation)
  - Input *N* set as in the 2010 final model
  - First reference age for length-at-age relationship set at as in the 2010 final model
- Model 12 was identical to Model 11 except two iterations of survey variance and input *N* re-weighting added

Preliminary assessment

Seven models were included:

- Model 1 was identical to the 2010 final model
- Model 2a was identical to Model 1 except for use of spline-based selectivity
- Model 2b was identical to Model 1 except for omission of pre-1982 survey data
- Model 3 was identical to Model 2b except:
  - Ageing bias estimated internally rather than by trial and error
  - First reference age for length-at-age relationship (*amin*) set at 1.0
  - Standard deviation of length at age *amin* tuned iteratively to match the value predicted externally by regression
- Model 4 was identical to Model 2b except:
  - All agecomp data turned off
  - All sizecomp data turned on
  - First reference age for length-at-age relationship (*amin*) set at 1.0
  - Parameters governing standard deviation of length at age estimated internally
- Model A was identical to Model 2b except:
  - 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 (in Models 1-2b, first reference age was set at 0; in Models 3-4, it was set at 1)
  - Richards growth equation was used (in Models 1-4, von Bertalanffy was used)
  - Ageing bias was estimated internally (as in Model 3; in Models 1-2 and 4, ageing bias was left at the values specified in the 2009 and 2010 assessments—although this was irrelevant for Model 4, which did not attempt to fit the age data)
  - σ_R was estimated internally (in Models 1-4, this parameter was left at the value used in the 2009 and 2010 assessments)
  - 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, and fisheries were also *gear*-specific)
  - Selectivity curve for the fishery that came closest to being asymptotic on its own (in this case, the season 4 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, the Jan-Apr trawl fishery was forced to exhibit asymptotic selectivity)
  - Survey selectivity was modeled as a function of length (in Models 1-4, survey selectivity was modeled as a function of age)
  - Number of estimated year class strengths in the initial numbers-at-age vector was set at 10 (in Models 1-4, only 3 elements were estimated)
  - The following parameters were tuned iteratively:
    - 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 final assessment for 2010 (as in Model 3; in Models 1-2, this parameter was set at 0.01 because the first reference age was 0; in Model 4, it was estimated internally)
    - Base value for *Q* was tuned iteratively to set the average of the product of *Q* 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, the base value was left at the value used in the 2009 and 2010 assessments)
    - *Q* was given annual (but not random walk) *dev*s, with σdev tuned iteratively to set the root-mean-squared-standardized-residual of the survey abundance estimates equal to 1.0 (in Models 1-4, *Q* was constant)
    - All estimated selectivity parameters were given annual random walk *dev*s with *σdev* tuned iteratively to match the standard deviation of the estimated *dev*s, except that the *dev*s for any selectivity parameter with a tuned σdev less than 0.005 were removed (in Models 1-4, certain fishery selectivity parameters were estimated independently in pre-specified blocks of years; the only time-varying selectivity parameter for the

survey was *ascending_width*, which had annual—but not random walk—*dev*s with *σdev* set at the value used in the 2009 and 2010 assessments)
    - Age composition "variance adjustment" multiplier was tuned iteratively to set the mean effective sample size equal to the mean input sample size (in Models 1-4, this multiplier was fixed at 1.0)
- Model 5 was identical to Model A except that it used the time series of selectivity parameters estimated (using random walk *dev*s) in Model A to identify appropriate breakpoints for defining block-specific selectivity parameters

Other model features explored but not included in any of the above:

- Annually varying Brody growth parameter
- Annually varying length at the first reference age
- Internal estimation of standard deviation of length at age
- Ordinary (not random walk) *dev*s for annually varying selectivity parameters
- One selectivity parameter for each age (up to some age-plus group) and fleet, either with ordinary or random walk *dev*s or constant
- Not forcing any fleet to exhibit asymptotic selectivity
- Internal estimation of survey catchability
- Iterative re-weighting of size composition likelihood components
- Internal estimation of the natural mortality rate
- Changing the SS parameter *comp_tail_compression* (the tails of each age or size composition record are compressed until the specified amount was reached; sometimes referred to as "dynamic binning")
- Changing the SS parameter *add_to_comp* (this amount was added to each element of each age or size composition vector—both observed and expected, which avoids taking the logarithm of zero and may also have robustness-related attributes)
- Internal estimation of ageing error variances

Final assessment

Five models were included:

- Model 1 was identical to the 2010 final model (and Model 1 from the preliminary assessment)
- Model 2b was identical to Model 2b from the preliminary assessment
- Model 3 was identical to Model 3 from the preliminary assessment
- Model 4 was identical to Model 4 from the preliminary assessment
- **Model 3b** was identical to Model 3 from the preliminary assessment except:
    - Parameters governing variability in length at age estimated internally
    - All sizecomp data turned on
    - Mean-size-at-age data turned off

2012

Preliminary assessment

Five primary and nine secondary models were included (names of secondary models have decimal points; full results presented for primary models only):

- Model 1 was identical to the 2011 final model
    - Model 1.1: Same as Model 1, except survey catchability estimated internally
    - Model 1.2: Same as Model 1, except ageing bias parameters fixed at GOA values

  - Model 1.3 Same as Model 1, except with revised weight-length representation
- Model 2 was identical to Model 1, except survey catchability re-tuned to match archival tag data
- Model 3 was identical to Model 1, except new fishery selectivity period beginning in 2008
- Model 4 was identical to Model 4 from the final assessment for 2011
  - Model Pre5.1: Same as Model 1.3, except for three minor changes to the data file
  - Model Pre5.2: Same as Model Pre5.1, except ages 1-10 in the initial vector estimated individually
  - Model Pre5.3: Same as Model Pre5.2, except Richards growth curve used
  - Model Pre5.4: Same as Model Pre5.3, except σ for recruitment *dev*s estimated internally as a free parameter
  - Model Pre5.5: Same as Model Pre5.4, except survey selectivity modeled as a function of length
  - Model Pre5.6: Same as Model Pre5.5, except fisheries defined by season only (not season-and-gear)
- Model 5: Same as Model Pre5.6, except four quantities estimated iteratively:
  - Survey catchability tuned to match archival tag data
  - Agecomp *N* tuned to set the mean ratio of effective *N* to input *N* equal to 1
  - Selectivity *dev* sigmas tuned according to the new method described in Annex 2.1.1 of the SAFE chapter

Final assessment

Four models were included:

- **Model 1** was identical to the 2011 final model
- Model 2 was identical to Model 1 except *Q* was estimated freely
- Model 3 was identical to Model 1 except:
  - Ageing bias was not estimated
  - All agecomp data are ignored
- Model 4 was identical to Model 5 from the the preliminary assessment

2013

Preliminary assessment

Four models were included:

- Model 1 was identical to the 2012 final model
- Model 2 was identical to Model 4 from the final 2012 assessment except *Q* estimated internally using a non-constraining uniform prior distribution
- Model 3 was identical to Model 4 from the final 2012 assessment except:
  - *Q* estimated internally using a prior distribution based on archival tagging data
  - Survey selectivity forced asymptotic
- Model 4 was identical to Model 4 from the final 2012 assessment

Final assessment

Due to a protracted government shutdown during the peak of the final assessment season, only one model was presented:

- The **unnumbered model** was identical to the 2012 final model

2014

Preliminary assessment

Six models were included:

- Model 1 was identical to the 2011-2013 final models
- Model 2 was the identical to Model 5 from the 2012 preliminary assessment (also identical to Model 4 in the 2012 final assessment and the 2013 preliminary assessment)
- Model 3 was identical to Model 2, except that survey catchability *Q* was fixed at 1.0
- Model 4 was identical to Model 2, except that *Q* was estimated with a uniform prior and with an internally estimated constant added to each year's log-scale survey abundance standard deviation
- Model 5 was identical to Model 2, except that Q was fixed at 1.0, survey selectivity was forced to be asymptotic, and the natural mortality rate *M* was estimated freely
- Model 6 was a substantially new model, with the following differences from Model 1:
    - Each year consisted of a single season instead of five
    - A single fishery was defined instead of nine season-and-gear-specific fisheries
    - The survey was assumed to sample age 1 fish at true age 1.5 instead of 1.41667
    - Initial abundances were estimated for the first ten age groups instead of the first three
    - The natural mortality rate was estimated internally
    - The base value of survey catchability was estimated internally
    - Length at age 1.5 was allowed to vary annually
    - Survey catchability was allowed to vary annually
    - Selectivity for both the fishery and the survey were allowed to vary annually
    - Selectivity for both the fishery and survey was modeled using a random walk with respect to age (SS selectivity-at-age pattern #17) instead of the usual double normal
    - Several quantities were tuned iteratively: prior distributions for selectivity parameters, catchability, and time-varying parameters other than catchability

Final assessment

Two models were included:

- **Model 1** was identical to the 2011-2013 final models
- Model 2 was identical to Model 2 from the preliminary assessment, except that the *L1* growth parameter was not allowed to vary with time