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

Grant G. Thompson

Resource Ecology and Fisheries Management Division
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7600 Sand Point Way NE., Seattle, WA 98115-6349

EXECUTIVE SUMMARY

Summary of Changes in Assessment Inputs

Relative to the November edition of last year's 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 1991-2013 were updated, and preliminary catch data for 2014 were incorporated.
2) Commercial fishery size composition data for 2013 were updated, and preliminary size composition data from the 2014 commercial fisheries were incorporated.
3) Size composition data from the 2014 EBS shelf bottom trawl survey were incorporated.
4) The numeric abundance estimate from the 2014 EBS shelf bottom trawl survey was incorporated (the 2014 estimate of 1,222 million fish was up about 49% from the 2013 estimate).
5) Age composition data from the 2013 EBS shelf bottom trawl survey were incorporated.
6) Mean length at age data from the 2013 EBS shelf bottom trawl survey were incorporated.
7) Seasonal catch per unit effort (CPUE) data for the trawl, longline, and pot fisheries from 2013 were updated, and preliminary CPUE data for the trawl, longline, and pot fisheries from 2014 were incorporated.

Changes in the Assessment Methodology

Many changes have been made or considered in the stock assessment model since the 2013 assessment (Thompson 2013). Six models were presented in this year's preliminary assessment (Appendix 2.1), as requested in March and April by the Joint Team Subcomittee on Pacific Cod Models and the SSC (including one "optional" model). 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 in 2011, 2012, and 2013; and a slightly modified version of the "optional" model from the preliminary assessment. The author recommends retaining the base model for the purpose of setting final harvest specifications for 2015 and preliminary harvest specifications for 2016.

Summary of Results

The principal results of the present assessment, based on the current 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: 2014	2015	As estimated or *recommended this* year for: 2015*	2016*
M (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	3a	3a	3a	3a
Projected total (age 0+) biomass (t)	1,570,000	1,640,000	1,680,000	1,770,000
Projected female spawning biomass (t)	361,000	389,000	409,000	473,000
$B_{100\%}$	796,000	796,000	824,000	824,000
$B_{40\%}$	318,000	318,000	330,000	330,000
$B_{35\%}$	279,000	279,000	288,000	288,000
F_{OFL}	0.34	0.34	0.35	0.35
$maxF_{ABC}$	0.28	0.28	0.29	0.29
F_{ABC}	0.28	0.28	0.21	0.20
OFL (t)	299,000	319,000	346,000	389,000
maxABC (t)	255,000	272,000	295,000	316,000
ABC (t)	255,000	272,000	255,000	287,000
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
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 estimated catches of 212,000 t and 231,000 t for 2015 and 2016, respectively.

Responses to SSC and Plan Team Comments on Assessments in General

JPT1 (9/13 minutes): *"The Teams recommended that SAFE chapter authors continue to include 'other' removals as an appendix. Optionally, authors could also calculate the impact of these removals on reference points and specifications, but are not required to include such calculations in final recommendations for OFL and ABC."* "Other" removals are presented in Appendix 2.2. Impacts of such removals on reference points and specifications were calculated in Attachment 2.4 of the 2012 assessment (Thompson and Lauth 2012).

JPT2 (9/13 minutes): *"In conformity with the main recommendations of the working group, the Teams recommended the following:*

1. *Assessment authors should routinely do retrospective analyses extending back 10 years, plot spawning biomass estimates and error bars, plot relative differences, and report Mohn's rho (revised).*
2. *If a model exhibits a retrospective pattern, try to investigate possible causes.*
3. *Communicate the uncertainty implied by retrospective variability in biomass estimates.*
4. *For the time being, do not disqualify a model on the grounds of poor retrospective performance alone.*

5. *Do consider retrospective performance as one factor in model selection."*

This comment is addressed in the "Results" section, under "Model Evaluation" and also in a new subsection entitled "Retrospective Analysis," located under "Time Series Results."

JPT3 (9/13 minutes): *"The Teams recommended that each stock assessment model incorporate the best possible estimate of the current year's removals. The Teams plan to inventory how their respective authors address and calculate total current year removals. Following analysis of this inventory, the Teams will provide advice to authors on the appropriate methodology for calculating current year removals to ensure consistency across assessments and FMPs."* This comment is addressed under the "Standard Harvest Scenarios, Projection Methodology, and Projection Results" subsection of the "Results" section.

SSC1 (10/13 minutes): *"We agree with the recommendations of the Plan Team that retrospective analyses extending back 10 years and including Mohn's revised ρ, should routinely be presented in the assessments, and that retrospective patterns should be taken into consideration when selecting a model and when communicating uncertainties associated with biomass estimates. The SSC also notes that a strong retrospective bias should be one of the criteria considered when setting ABCs and could provide justification for recommending a higher or lower ABC."* See response to comment JPT2. Consideration of retrospective bias in the context of ABC is addressed in the "Harvest Recommendations" subsection of the "Results" section.

SSC2 (12/13): *"During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment."* Figure 2.15 includes projected values for the next two years.

JPT4 (9/14): Regarding catch projections, *"the Teams recommend that authors choose a method that appears to be appropriate for their stock, and this method be clearly documented. The Teams recommend authors establish their best available estimate of catch in the current year and the next two years. The Teams recommend that authors should also document how those projected catches were determined in the Harvest Recommendations section (ideally Scenario 2)."* See response to comment JPT3. Estimation of projected catches is addressed in the same subsection, and those estimated catches are used in Scenario 2.

SSC3 (10/14): Regarding comment JPT4, *"The SSC supports these recommendations."* See response to comments JPT3 and JPT4.

Responses to SSC and Plan Team Comments Specific to this Assessment

Nineteen comments specific to this assessment 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 (9/14 minutes): *"The Team recommends that the author present fits of Models 1 and 6 in November. The L1 parameter of Model 6 should be estimated as a single rather than time-varying value to stiffen the fit and eliminate the questionable values in the series of annual estimates of L1."* Models 1 and 6 from the preliminary assessment are included here as Models 1 and 2. The *L1* parameter is now time-invariant in both models.

SSC4 (10/14 minutes): *"The SSC agrees with the Plan Team and also notes that the laborious re-weighting procedure does not need to be repeated for Model 6. The SSC also agrees with the Plan Team regarding estimation of a single L1 parameter for growth instead of the annual estimates."* See response to comment BPT1. The iterative tuning process that was used to estimate certain parameters in Model 6 (now Model 2) during the preliminary assessment was not repeated here.

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 since 1977, last year separate 2014-2015 harvest specifications were set for the two areas.

Pacific cod is not known to exhibit any special life history characteristics that would require it to be assessed or managed differently from other groundfish stocks in the EBS or AI areas.

Review of Life History

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

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

Juveniles occur mostly over the inner continental shelf at depths of 60 to 150 m. Adults occur in depths from the shoreline to 500 m, although occurrence in depths greater than 300 m is fairly rare. Preferred substrate is soft sediment, from mud and clay to sand. Average depth of occurrence tends to vary directly with age for at least the first few years of life.

It is conceivable that mortality rates, both fishing and natural, may vary with age in Pacific cod. In particular, very young fish likely have higher natural mortality rates than older fish (note that this may not be particularly important from the perspective of single-species stock assessment, so long as these higher natural mortality rates do not occur at ages or sizes that are present in substantial numbers in the data). For example, Leslie matrix analysis of a Pacific cod stock occurring off Korea estimated the instantaneous natural mortality rate of 0-year-olds at 2.49% per day (Jung et al. 2009). This may be compared to a mean estimate for age 0 Atlantic cod (*Gadus morhua*) in Newfoundland of 4.17% per day, with a 95% confidence interval ranging from about 3.31% to 5.03% (Gregory et al. in prep.); and age 0 Greenland cod (*Gadus ogac*) of 2.12% per day, with a 95% confidence interval ranging from about 1.56% to 2.68% (Robert Gregory and Corey Morris, *pers. commun.*).

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

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

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

FISHERY

Description of the Directed Fishery

During the early 1960s, a Japanese longline fishery harvested 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 (2009-2013) is as follows: longline gear accounted for an average of 57% of the catch, trawl gear accounted for an average of 31%, and pot gear accounted for an average of 12%.

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 (2009-2013).

Catches of Pacific cod taken in the EBS for the periods 1964-1980, 1981-1990, and 1991-2014 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 2013 and 2014 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 1991-2014 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 3.3%. Since then, they have averaged about 1.8%.

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, with the exception of 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 2013, TAC averaged about 83% of ABC (ABC was not specified prior to 1980), and from 1980 through 2013 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 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, labeled “SS2” (Methot 2005). The assessment was migrated to SS2 in 2005, and several changes have been made to the model in most years since then (see Appendix 2.3). A note on 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	1977-2014
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

Fishery

Catch Biomass

Catches taken in the EBS for the period 1977-2014 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.

Catches for the August-October and November-December seasons of 2014 were estimated by the method described under Scenario 2 in the "Harvest recommendations" subsection of the "Results" section. With these two exceptions, the 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 2014. 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/2014/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 1991-2014 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 2014 are partial. The "sigma" values shown in the tables are intended only to give an idea of the relative variability of the respective point estimates, and are not actually used in any of the analyses presented here.

Survey

EBS Shelf Bottom Trawl Survey

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.7, together with their respective standard errors. Upper and lower 95% confidence intervals are also shown for the biomass estimates. Survey results indicate that biomass 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 (36%) this year. The 2014 estimate is the fifth highest in the time series.

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 2013 estimate was down 24% from the 2012 estimate, but the 2014 estimate is up 49% from the 2013 estimate, and is the second highest estimate in the time series.

The relative size compositions from the EBS shelf bottom trawl survey for the years 1982-2014 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 1982-2014 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 1994-2013 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.

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). A history of previous model structures, including details of the present model, is given in Appendix 2.3.

Two models are presented here: Model 1, the base model that has been used for the last three years, and Model 2, which differs from Model 1 in several respects, as detailed below.

Version 3.24s (compiled on 07/24/13) of SS was used to run the models in this assessment. SS 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.

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 0.01, 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 1: main features

Model 1 is the model that has been used to recommend harvest specifications for the last three years (2011-2013), 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. Standard deviations of *dev* vectors fixed at the values estimated in 2009
6. Survey catchability fixed at the value estimated in 2009 (based on Nichol et al. 2007)
7. Gear-and-season-specific catch and selectivity for the fisheries
8. Double normal selectivity for the fisheries and survey (see Appendix 2.3 for parameterization)
9. Length-based selectivity for the fisheries
10. Age-based selectivity for the survey
11. Fishery selectivity estimated for "blocks" of years
12. Survey selectivity constant over time, except with annual *dev*s for the *ascending_width* parameter
13. 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)

14. Fishery CPUE data included but not used for estimation
15. Mean size at age included but not used for estimation

Model 2: main features

Some of the main differences between Model 2 and Model 1 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. Selectivity-at-age pattern #17 in SS has one parameter for each age in the model. Except for age 0, the parameter for any given age represents the logarithm of the ratio of selectivity at that age to selectivity at the previous age (i.e., the backward first difference on the log scale). Age 0 fish are often expected to have a selectivity of zero, which can be achieved in this selectivity pattern by setting the parameter for age 0 equal to -1000, as was done for all six models presented here. As with other parameters in SS, each parameter in this selectivity pattern is associated with a prior distribution (see "Iterative tuning of prior distributions for selectivity parameters" in the next subsection).

Model 2: iterative tuning

Three types of iterative tuning were involved in the development of Model 2 during this year's preliminary assessment (Appendix 2.1). The first of these applied only to the prior distributions for selectivity parameters, and the second applied to all time-varying parameters except catchability, and the third applied only to time-varying catchability.

Because this type of iterative tuning is time-consuming, it was not possible to redo the analysis for the final assessment; instead, the values resulting from the tuning procedure in the preliminary assessment were retained here (see also Comment SSC4). By way of comparison, a slightly less time-consuming procedure was used to tune some of the same (or analogous) parameters in a precursor to Model 1 from the 2009 assessment (Thompson et al., 2009) and, by request of the Plan Team, those values have not been re-tuned since.

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%.

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. The converged set of prior means for ages 1-12 (on the transformed scale, not the selectivity scale) estimated in the preliminary assessment was as follows (ages 13+ all had prior means of 0 for both the fishery and the survey):

Age:	1	2	3	4	5	6
Fishery:	2.940E+00	2.937E+00	2.887E+00	2.258E+00	6.028E-01	4.471E-02
Survey:	5.020E+00	6.074E-01	2.533E-03	7.680E-06	2.300E-08	0

Age:	7	8	9	10	11	12
Fishery:	2.420E-03	1.280E-04	6.770E-06	3.580E-07	1.900E-08	1.000E-09
Survey:	0	0	0	0	0	0

The converged prior standard deviations were 0.350 for the fishery and 0.319 for the survey (both constant across age).

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) for estimating the standard deviation of a *dev* vector:

1. Estimating "unconstrained" estimates of the standard deviation(s) of the *dev*s for a particular parameter or parameter vector. The purpose of this loop was to determine the vector of *dev*s for an individual parameter or parameter vector that would be obtained if the *dev*s were completely unconstrained by their respective σs. The following individual parameters and parameter vectors were included in this exercise: *L1* (length at age 1.5), age 0 recruitment, the vector of age-specific fishery selectivity parameters, and the vector of age-specific survey selectivity parameters. For parameter vectors especially, 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, in the case of a parameter vector) 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. Estimating "iterated" estimates of the standard deviations for the *dev*s. Again proceeding one parameter or parameter vector fleet at a time, this loop began with σ set at the unconstrained value(s) estimated in the first loop. The standard deviation(s) of the estimated *dev*s then became the age-specific σ(s) for the next run, and the process was repeated until convergence was achieved.

For age 0 recruitment, the final value of σ (after application of the algorithm described by Thompson and Lauth (2012)) obtained in the preliminary assessment was 0.657. Because recruitments are log-transformed, the *dev*s are specified as being normal and additive.

In the case of a vector of age-specific selectivity parameters, it is common for some ages to be "tuned" out during the second loop (i.e., the σs converge on zero). For Model 2, all ages were tuned out except age 4 for the fishery and ages 2 and 3 for the survey. The final values of σ (after application of the algorithm described by Thompson and Lauth (2012)) obtained in the preliminary assessment were 0.158 for fishery age 4 and 0.106 for survey ages 2 and 3 (note that these *dev*s are all normal and additive).

Unfortunately, the way that selectivity pattern #17 is implemented in SS, large gradients tend to result if significant *dev*s occur at the age of peak selectivity. Because survey selectivity for Model 2 tended to peak at age 3, it turned out to be impossible to include *dev*s for age 3, so Model 2 included survey selectivity *dev*s for age 2 only.

Iterative tuning of time-varying catchability

Unlike the size composition or age composition data sets, the time series of survey abundance includes not only a series of expected values, but a corresponding series of standard errors as well. This formed the basis for the iterative tuning of the σ term for time-varying catchability in Model 2. The procedure involved iteratively adjusting σ until the root-mean-squared-standardized-residual equaled unity. The final value of σ obtained in the preliminary assessment was 0.089 (normal and additive, because SS works in terms of ln(Q) rather than Q).

Parameters Estimated Outside the Assessment Model

Natural Mortality

A value of 0.34 has been used for the natural mortality rate M in all BSAI Pacific cod stock assessments since 2007 (Thompson et al. 2007b). 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 1 in this assessment fixes M at the value of 0.34 used since 2007. Model 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 0.08560 (i.e, the standard deviation of estimated age was modeled as 0.08560 × age) and a weighted R^2 of 0.93. This regression corresponds to a standard deviation at age 1 of 0.086 and a standard deviation at age 20 of 1.712. These parameters were used for the models in the present assessment.

Weight at Length

Long-term base values of the parameters governing the weight-at-length schedule were re-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.

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 $\alpha = 6.358 \times 10^{-6}$ and $\beta = 3.157$.

Seasonal additive log-scale offsets from the base parameter values 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:	-2.281E-02	2.768E-03	1.920E-02	2.304E-03	-1.416E-02
β:	5.250E-03	-6.470E-04	-4.535E-03	-5.386E-04	3.276E-03

The above values for the base parameters and seasonal offsets were used for both models in the present assessment.

Model 2 allows for *inter*-annual as well as *intra*-annual variability in weight-length parameters (Model 1 allows for intra-annual variability only). Annual additive offsets from the base values were estimated in this year’s preliminary assessment (values show below) and used for Model 2.

Year:	1977	1978	1979	1980	1981	1982	1983	1984
α offset:	1.72E-06	-2.80E-06	9.84E-07	-6.15E-07	3.29E-07	2.32E-06	-2.94E-08	1.11E-05
β offset:	-5.87E-02	1.53E-01	-3.52E-02	2.03E-02	-1.98E-02	-7.27E-02	9.10E-03	-2.64E-01

Year:	1985	1986	1987	1988	1989	1990	1991	1992
α offset:	-1.37E-06	-2.60E-06	-5.71E-07	-2.52E-06	-1.62E-06	8.15E-07	1.29E-06	-1.39E-07
β offset:	7.05E-02	1.43E-01	2.90E-02	1.46E-01	9.37E-02	-1.74E-02	-4.90E-02	-5.05E-03

Year:	1993	1994	1995	1996	1997	1998	1999	2000
α offset:	2.27E-06	1.19E-07	-1.33E-06	7.15E-06	7.51E-07	1.22E-06	1.48E-06	1.72E-06
β offset:	-6.04E-02	-4.87E-03	6.12E-02	-1.87E-01	-4.06E-02	-5.83E-02	-5.64E-02	-5.17E-02

Year:	2001	2002	2003	2004	2005	2006	2007	2008
α offset:	3.58E-06	1.00E-06	-6.92E-07	1.67E-06	-3.61E-07	5.69E-07	1.04E-07	3.87E-06
β offset:	-1.10E-01	-3.64E-02	2.80E-02	-5.98E-02	1.70E-02	-2.11E-02	1.87E-04	-1.19E-01

Year:	2009	2010	2011	2012	2013
α offset:	-1.12E-06	8.26E-07	4.03E-07	2.52E-06	-1.12E-06
β offset:	5.25E-02	-3.36E-02	-2.24E-02	-9.35E-02	4.30E-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, personal communication). The age-based parameters were retained for the models in the present assessment.

Standard Deviation of Log Recruitment

The standard deviation specified for log-scale age 0 recruitment was estimated iteratively in the 2009 assessment (Thompson et al. 2009), by matching the input value to the standard deviation of the estimated *dev*s. The resulting value of 0.57 was retained for Model 1 in the present assessment. This parameter was set iteratively in Model 2, using the method described in Annex 2.1.1 of Thompson and Lauth (2012).

Catchability

In the 2009 assessment (Thompson et al. 2009), catchability for the post-1981 trawl survey was estimated iteratively by setting the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.47 obtained by Nichol et al. (2007). The resulting value of 0.77 was retained for Model 1 in the present assessment. Catchability was estimated internally in Model 2.

Parameters Estimated Inside the Assessment Model

A total of 186 parameters were estimated inside SS for Model 1. 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 prior to 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 1977-2013
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 203 parameters were estimated inside SS for Model 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 1 (Model 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 1). In addition, Model 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 1, uniform prior distributions were used for all parameters, except that *dev* vectors were constrained by input standard deviations ("sigma"), which are somewhat analogous to a joint prior distribution.

In Model 2, the base selectivity parameters had normal priors, while other non-*dev* parameters had uniform priors (as in Model 1).

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 2 includes an objective function component for prior distributions (Model 1 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 1) or just year (Model 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. 2007b). The harmonic means were smaller than the actual sample sizes, but still ranged well into the thousands. A multinomial sample size in the thousands would likely overemphasize the size composition data. As a compromise, the harmonic means were rescaled proportionally in the 2007 assessment so that the average value (across all samples) was 300. However, the question then remained of what to do about years not covered by the bootstrap analysis (2007 and pre-1990) and what to do about the survey samples. The solution adopted in the 2007 assessment was based on an observed consistency in the ratios between the harmonic means (the raw harmonic means, not the rescaled harmonic means) and the actual sample sizes: 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 2012-2013 assessments, except the pre-1982 trawl survey data were no longer used. Model 1 in this year's assessment uses the same procedure as the 2012-2013 assessments. Model 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 2.11.

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
N:	204	163	203	205	181	245	245	263	248	360

Year:	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
N:	284	365	371	411	346	403	369	358	371	405

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

Fishery CPUE data are included in the Model 1 for comparative purposes only, and are not included at all in Model 2. Their respective catchabilities (in Model 1) 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 2.12 shows the objective function value for each data component and sub-component in the 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 1 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 2.12 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 2.13 provides alternative measures of how well the model fits the fishery CPUE (Model 1 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 2.13 pertain to the fishery CPUE data. Although Model 1 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 2 does much better than Model 1 by any of the four measures presented.

Figure 2.4 shows the model's fit to the trawl survey abundance data. Model 1's estimates fall within the 95% confidence intervals 76% of the time; Model 2's do so 97% of the time.

Table 2.14 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 1, using the the measure with the harmonic mean in the numerator (ratio=0.88).

Table 2.15 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 1, both ratios are less than unity. For Model 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 model's 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 tends to match the modes, within one or two cm. Model 1'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 2 does not include these data at all). Because of the large number of size composition records (n=416), figures showing the model's fits to these data are not included in this document, but are available at:
http://www.afsc.noaa.gov/REFM/Docs/2014/EBS_Pcod_sizecomp fits.xlsx.

Table 2.16 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. Tables 2.16a-b (with a few exceptions) show parameters that are common to both models: Table 2.16a shows biological parameters, ageing bias, recruitment (except annual *dev*s), initial fishing mortality, log catchability (base value only for Model 2), and initial age composition parameters; and Table 2.16b shows annual log-scale recruitment *dev*s (these are plotted in Figure 2.8). Tables 2.16c-d show parameters that are unique to Model 1: Table 2.16c shows fishery selectivity parameters, and Table 2.16d shows survey selectivity parameters. Tables 2.16e-g show parameters that are unique to Model 2: Table 2.16e shows annual log catchability offsets, Table 2.16f shows fishery selectivity parameters, and Table 2.16g shows survey selectivity parameters.

Table 2.17 shows estimates of fishing mortality. Table 2.17a shows fishing mortality by year in both models, and Table 2.17 b shows full-selection seasonal fishing mortality rates for each gear type and year in Model 1 only (Table 2.17b). In Table 2.17a, 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.

Figure 2.9 shows the time series of spawning biomass relative to $B_{100\%}$ as estimated by each model.

Figure 2.10 shows trawl survey selectivity as estimated by the model. Both models show variability aver time for selectivity at age 1. For Model 1, this is due to the fact that annual *dev*s are estimated for the *ascending_width* parameter. For Model 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 1 declines more at older ages than does the profile for Model 2. For example, in Model 1, all ages greater than 10 have selectivity estimates less than about 0.25, whereas in Model 2, all ages greater than 10 have selectivity estimates less than about 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 1. In general, selectivities that are not forced to be asymptotic tend to show decreasing selectivity at large size in Model 1. Figure 2.11b shows the pattern of annually varying fishery selectivity as estimated by Model 2. The only time variability occurs at ages less than 4. Model 2 also exhibits bimodality, with a dominant mode at age 6 and a secondary mode at age 13.

Per request of the SSC (see Comment SSC8 in Appendix 2.1), Figure 2.12 shows likelihood profiles with respect to M for each model. The value of survey catchability is also shown (constant for Model 1, but co-varying with M for Model 2, as both parameters were estimated internally for Model 2). Model 1 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 2 estimates M internally at a value of 0.344, very close to the value assumed in Model 1.

Table 2.18 contains selected output from the standard projection model, based on SS parameter estimates from Models 1 and 2, 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 2.18 are conditional on catches estimated under Scenario 2 (“author’s F”) in the “Harvest Recommendations” section.

Evaluation Criteria

The following criteria were considered in evaluating the model:

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 2015-2016 harvest specifications pose a significant risk to the stock?

The first criterion is suggested by a number of SSC minutes over the last couple of 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 in the fall that incorporates a large number of potentially influential changes in a single model (for example changes in growth, selectivities, and catchability), the SSC encourages the authors to evaluate changes in one or a few structural elements at a time."*
- 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 this year's Appendix 2.1): *"…The SSC discussed the need for a more incremental approach to implementing changes to the model…."*

Because Model 1 is the base model (having been used for the last three years), adopting it for the present harvest specifications cycle would, by definition, keep the number of model changes to a minimum. Model 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.

In the context of the second criterion, one new feature of Model 2 that stands out is its use of SS selectivity pattern #17, which treats selectivity as a random walk with respect to age. Although this pattern has several benefits (see "Discussion" section in Appendix 2.1), some aspects could benefit from further evaluation, specifically:

- Selectivity pattern #17 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 (most likely 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.

With respect to the third criterion, Model 1 estimates a much higher maximum permissible ABC than Model 2 (Table 2.18). As discussed below in the "Retrospective Analysis" section, Model 1 appears to over-estimate the size of the stock by a substantial amount consistently ($\rho = 0.494$), in contrast to Model 2, which appears to show almost no systematic over- or under-estimation ($\rho = -0.049$). 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 1 might impose an unacceptable risk to the stock. However, it is not necessary to set ABC at 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 1 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.

On the basis of the above, Model 1 is recommended for use in setting final harvest specifications for 2015 and preliminary harvest specifications for 2016.

Final Parameter Estimates and Associated Schedules

As noted previously, estimates of all statistically estimated parameters in the model are shown in Table 2.16. Estimates of both aggregated annual and year-, gear-, and season-specific fishing mortality rates from Model 1 are shown in Table 2.17.

Schedules of selectivity at length for the commercial fisheries from Model 1 are shown in Table 2.19, and schedules of selectivity at age for the trawl surveys from Model 1 are shown in Table 2.20. The trawl survey selectivity schedule and all fishery selectivity schedules for Model 1 are plotted in Figures 2.11 and 2.12, 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 1 are shown in Tables 2.21, and 2.22, and 2.23, respectively.

Time Series Results

Definitions

The biomass estimates presented here will be defined in three ways: 1) age 0+ biomass, consisting of the biomass of all fish aged 0 years or greater in January of a given year; 2) age 3+ biomass, consisting of the biomass of all fish aged 3 years or greater in January of a given year; and 3) spawning biomass, consisting of the biomass of all spawning females in a given year. The recruitment estimates presented here will be defined as numbers of age 0 fish in a given year. To supplement the full-selection fishing mortality rates already shown in Table 2.17, 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 2.24 shows the time series of age 0+, age 3+, and female spawning biomass for the years 1977-2014 as estimated last year and this year (projections through 2015 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 2.13. 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 1.79. 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 2.25 shows the time series of age 0 recruitment (1000s of fish) for the years 1977-2013 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 four of the top ten year classes of all time (2006, 2008, 2011, and 2013; although it should be emphasized that the estimate of the 2013 cohort's rank is very preliminary). The set of year classes comprising the top ten is the same this year as last year, except that the 2013 cohort has bumped the 2010 cohort down to #11.

Recruitment estimates for the entire time series (1977-2013) are shown in Figure 2.14, along with their respective 95% confidence intervals.

The coefficient of autocorrelation for the recruitment time series is –0.12.

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 2.26.

Fishing Mortality

Table 2.27 shows "effective" fishing mortality by age and year for ages 1-19 and years 1977-2014.

Figure 2.15 plots the estimated trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2016 based on full-selection fishing mortality, overlaid with the current harvest control rules (projected values for 2015 and 2016 are from Scenario 2 under "Harvest Recommendations," below). It should be noted that, except for the projection years, this trajectory is based on SS output, which may not match the estimates obtained by the standard projection program exactly. Note that fishing mortality rates for the years 2006-2012 appear to have been higher than the F_{OFL} control rule. This may be due to a retrospective bias, as discussed in the next subsection.

Retrospective Analysis

Figure 2.16 shows the retrospective behavior of Model 1 with respect to female spawning biomass over the years 2004-2014. This figure was obtained by conducting ten additional model runs, dropping the 2014 data to create the run labeled "2013," dropping the 2013-2014 data to create the run labeled "2012," and so forth (the run labeled "2014" 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 1, $\rho = 0.494$, indicating that Model 1 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 1 high and positive on average, it is positive in all runs shown in Figure 2.16 except one (2013), ranging from 0.181-1.006 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 1 (except those that get eliminated from the model during the peeling process, leaving a total of 154), correlation coefficients with respect to number of peels were computed.

The results are shown in Figure 2.17, in the form of a cumulative distribution function. For example, 23 parameters (15% of the total) had a correlation (in absolute value) of at least 0.90 with respect to number of peels. These are listed below (naming conventions for selectivity parameters follow Table 2.16):

Init. age 2 ln(abundance) dev	P1_Jan-Apr_Trawl_1977	P3_Aug-Dec_Trawl_2000
Init. F (Jan-Apr trawl fishery)	P1_Jan-Apr_Trawl_1990	P1_Jan-Apr_Longline_1980
Recruitment dev for 1987	P3_Jan-Apr_Trawl_1977	P1_May-Jul_Longline_1980
Recruitment dev for 1991	P3_Jan-Apr_Trawl_1990	P1_May-Jul_Longline_1985
Recruitment dev for 1997	P1_Aug-Dec_Trawl_1980	P1_Aug-Dec_Longline_1990
Recruitment dev for 1999	P1_Aug-Dec_Trawl_2000	P3_Aug-Dec_Longline_1990
Recruitment dev for 2000	P3_Aug-Dec_Trawl_1977	P6_Jan-Apr_Pot_1977
Recruitment dev for 2002	P3_Aug-Dec_Trawl_1980	

All 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. Moreover, Model 2, which had a ρ value of only -0.049, had a CDF fairly similar to that shown in Figure 2.17, indicating that high correlations *per se* might not be a perfect diagnostic. Another possibility is that certain quantities that are fixed in the model (i.e., not estimated internally) could be causing the problem, for example catchability, which is fixed in Model 1 at a value of 0.77. However, there was not sufficient time to investigate this as a possible cause of the retrospective bias in the present assessment.

For the time being, the most important result of the retrospective analysis is that there appears to be a significant chance that Model 1 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 1's estimates of fishing mortality by gear for the five most recent complete years of data (2009-2013). 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 30%, longline 56%, and pot 14%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.35 and 0.29, respectively.

Model 1's estimates of $B_{100\%}$, $B_{40\%}$, and $B_{35\%}$ are 824,000 t, 330,000 t, and 288,000 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 1 to be well above the $B_{40\%}$ value of 330,000 t, thereby placing Pacific cod in sub-tier "a" of Tier 3 for both 2015 and 2016. Given this, Model 1 estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2015 and 2016 as follows:

Year	Overfishing Level	Maximum Permissible ABC
2015	Catch = 346,000 t	Catch = 295,000 t
2016	Catch = 389,000 t	Catch = 316,000 t
2015	$F = 0.35$	$F = 0.29$
2016	$F = 0.35$	$F = 0.29$

The age 0+ biomass projections for 2015 and 2016 from Model 1 (using SS rather than the standard projection model) are 1,680,000 t and 1,770,000 t.

For comparison, the age 3+ biomass projections for 2015 and 2016 from Model 1 (again using SS) are 1,590,000 t and 1,730,000 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, 2015. This requires an appropriate estimate of total catch for 2014. 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.

Twelve estimators were evaluated to determine the best method of estimating total current-year catch as a function of previous intra-annual fishery performance. Typically, current-year catch data are available through the beginning of October. In the seasonal structure used by Model 1, the last two "catch seasons" span the months August-October and November-December, meaning that current-year catch data are missing for part of season 4 and all of season 5. All 12 estimators therefore involved extrapolating the catch for seasons 1-3 through the end of the year. The estimators consisted of two groups of six each. One group was based on the average *absolute* amounts of catch taken in some number of previous years during seasons 4-5, and the other was based on the average *relative* amounts of catch taken in some number of previous years during seasons 4-5. For both groups, averages were taken over a range of previous years spanning 1 to 6. The results of this analysis are shown in Figure 2.18. Although it may be difficult to identify the best estimator by eye, it turned out that all of the "absolute" estimators performed better than any of the "relative" estimators, and the best "absolute" 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 2014 fishery, the estimator resulted in a catch greater than TAC, so TAC was used as the best estimate of the catch for 2014.

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 the first two projection years under Scenario 2, total catch was computed based on two factors: 1) the relationship between previous ABCs and previous catches, and 2) the fact that catch has never exceeded ABC in the last 20 years. Computation of an appropriate estimator is complicated by the fact that, prior to 2014, the Pacific cod ABC applied to the EBS and AI combined, but, as in 2014, future ABCs are anticipated to apply to the EBS only. To adjust for this, a series of "pseudo-ABCs" was computed for the years 1995-2013 by multiplying each BSAI ABC by the corresponding ratio of EBS catch to BSAI catch. Catch for the EBS was then regressed against the EBS pseudo-ABC, giving an intercept of about 59,200 t and a slope of about 0.6. This regression intersects the catch=ABC line at a value of about 148,000 t, meaning that future catch is assumed to equal future ABC whenever the latter is less than 148,000 t, while future catch is assumed to follow the regression whenever ABC is greater than 148,000 t. The data, the catch=ABC line, the regression line, and the estimator are shown in Figure 2.19.

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 2015 and 2016, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2015 recommended in the assessment to the *max* F_{ABC} for 2015. (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 2009-2013 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 2014 or 2) above 1/2 of its MSY level in 2014 and expected to be above its MSY level in 2024 under this scenario, then the stock is not overfished.)

Scenario 7: In 2015 and 2016, 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 2016 or 2) above 1/2 of its MSY level in 2016 and expected to be above its MSY level in 2026 under this scenario, then the stock is not approaching an overfished condition.)

Projections corresponding to the standard scenarios are shown for Model 1 in Tables 2.28-2.34.

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 2015, it does not provide the best estimate of OFL for 2016, because the mean 2016 catch under Scenario 6 is predicated on the 2015 catch being equal to the 2015 OFL, whereas the actual 2015 catch will likely be less than the 2015 OFL. Table 2.18 contains the appropriate one- and two-year ahead projections for both ABC and OFL under Model 1.

ABC Recommendation

Since 2005, the SSC has set ABC at the maximum permissible level every year with the exception of the 2007 assessment cycle, when the SSC held the 2008-2009 ABCs constant at the 2007 level. Specifications for 2006-2011 were set under Tier 3b, and specifications for 2012-2015 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 this year's survey.

At the same time, continuing concerns regarding estimation of survey catchability should be kept in mind. The present estimate, upon which the above projections depend, 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 also suggested that the catchability estimate 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."*

Finally, there is the issue of the apparently large and positive retrospective bias in Model 1'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 2015.

As noted above, there is precedent (*viz*., the 2007 assessment cycle) for holding ABC constant when the assessment involves an inordinate level of uncertainty.

Given all of the above, it does not seem appropriate to recommend an increase in ABC at this time. The recommended ABC for 2015 is therefore the same as the current (2014) value of 255,000 t. Holding fishing mortality constant at the rate that results in a 2015 ABC of 255,000 t (85.4% of *max* F_{ABC}; see Scenario 2, Table 2.29) gives a 2016 ABC of 287,000 t, which is the recommended ABC for 2016.

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 BSAI catch estimate for the most recent complete year (2013) is 250,274 t. This is less than the 2013 BSAI OFL of 359,000 t. Therefore, the combined BSAI 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 2014:

a. If spawning biomass for 2014 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2014 is estimated to be above $B_{35\%}$, the stock is above its MSST.
c. If spawning biomass for 2014 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 2.33). If the mean spawning biomass for 2024 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 2.33):

a. If the mean spawning biomass for 2016 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2016 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2016 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2026. If the mean spawning biomass for 2026 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 2.33 and 2.34, 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), giving a correlation of 0.52 (R^2=0.27). This analysis was updated and expanded for the 2013 assessment, including a cross-validation analysis indicating a very low probability that the correlation is entirely spurious. Vestfals et al. (in press) also noted a positive correlation between Pacific cod recruitment and the NPI, although not the October-December average NPI in particular.

The above analysis was updated again this year, including the cross-validation. The NPI time series was updated through 2013, and this year's estimated time series (1977-2013) of recruitment *dev*s was used, giving a correlation of 0.54 (R^2=0.29). The time series, regression line, and 95% confidence interval are shown in the upper panel of Figure 2.20. The most recent datum (2013, magenta diamond in the upper panel) represents both the fourth-largest value in the NPI time series and the fourth-largest value in the recruitment time series.

As in last year's analysis, the cross-validation involved 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 0.69, but when the NPI *was* included as an explanatory variable, the RMSE was reduced to 0.61. The distribution of slope parameter estimates from the cross-validation is shown in the middle panel of Figure 2.20. 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 2.35-2.38. Catches for 2014 in each of these tables are incomplete. Table 2.35 shows incidental catch of FMP species, other than squid and the members of the former “other species” complex, taken from 1991-2014 by each of the three main gear types. Table 2.36 shows incidental catch of squid and the members of the former “other species” complex taken from 2003-2014, aggregated across gear types. Table 2.37 shows incidental catch of prohibited species taken from 1991-2014, plus mortality estimates for halibut, aggregated across gear types. Table 2.38 shows incidental catch of non-target species groups taken from 2003-2014, 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 operates to some extent in the same geographic areas used by Steller sea lion as foraging grounds (Livingston (ed.), 2002).

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

Seabirds

The following is a summary of information provided by Livingston (ed., 2002): In both the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, which occurs primarily in the longline fisheries, including the hook and line fishery for Pacific cod. 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. 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.

ACKNOWLEDGMENTS

Data or other information new to this year's assessment: Robert Lauth provided survey data. Delsa Anderl, Charles Hutchinson, and Beth Matta provided age data. Angie Greig retrieved the fishery size composition data and fishery CPUE data, and produced Figures 2.1 and 2.2. Mary Furuness assisted with interpreting regulations. Jason Gasper assisted with interpretation of supplemental catch data.

Ongoing contributions: Rick Methot developed the SS software used to conduct the Pacific cod assessments over the last many years. NMFS Alaska Region provided the official catch time series. Numerous AFSC personnel and countless fishery observers collected nearly all of the raw data that were used in this assessment.

Reviewers: Anne Hollowed and the BSAI Groundfish Plan Team provided reviews of this assessment.

REFERENCES

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

Bakkala, R. G., and V. G. Wespestad. 1985. Pacific cod. *In* R. G. Bakkala and L. L. Low (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1984, p. 37-49. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-83.

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

Canino, M. F., I. B. Spies, and L. Hauser. 2005. Development and characterization of novel di- and tetranucleotide microsatellite markers in Pacific cod (*Gadus macrocephalus*). *Molecular Ecology Notes* 5:908-910.

Canino, M. F., I. B. Spies, K. M. Cunningham, L. Hauser, and W. S. Grant. 2010. Multiple ice-age refugia in Pacific cod, *Gadus macrocephalus*. *Molecular Ecology* 19:4339-4351.

Conners, M. E., P. Munro, and S. Neidetcher. 2004. Pacific cod pot studies 2002-2003. Alaska Fisheries Science Center Proc. Rep. 2004-04. 64 p. plus appendices.

Cunningham, K. M., M. F. Canino, I. B. Spies, and L. Hauser. 2009. Genetic isolation by distance and localized fjord population structure in Pacific cod (*Gadus macrocephalus*): limited effective dispersal in the northeastern Pacific Ocean. *Can. J. Fish. Aquat. Sci.* 66:153-166.

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

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

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optimization Methods and Software* 27:233-249.

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

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

Handegard, N.O., and D. Tjøstheim. 2005. When fish meet a trawling vessel: examining the behaviour of gadoids using a free-floating buoy and acoustic split-beam tracking. *Canadian Journal of Fisheries and Aquatic Sciences* 62:2409–2422.

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

Jensen, A. L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. *Can. J. Fish. Aquat. Sci.* 53:820-822.

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

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

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

Lauth, R. R. 2011. Results of the 2010 eastern and northern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate fauna. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-227, 256 p.

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

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

Livingston, P. A. (editor). 2002. Ecosystem Considerations for 2003. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

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

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bull. Amer. Meteor. Soc.* 78:1069-1079.

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

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

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

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

Methot, R. D., and C. R. Wetzel. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research* 142:86-99.

Mohn, R. 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. *ICES J. Mar. Sci.* 56: 473-488.

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

National Marine Fisheries Service (NMFS). 2010. Essential Fish Habitat (EFH) 5-Year Review for 2010 (Final summary report). National Marine Fisheries Service, Alaska Region. P.O. Box 21668, Juneau, AK 99802-1668.

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

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

Pitcher, K. W. 1981. Prey of the Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 79:467-472.

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

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

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

Spies I. 2012. Landscape genetics reveals population subdivision in Bering Sea and Aleutian Islands Pacific cod. *Transactions of the American Fisheries Society* 141:1557-1573.

Stark, J. W. 2007. Geographic and seasonal variations in maturation and growth of female Pacific cod (*Gadus macrocephalus*) in the Gulf of Alaska and Bering Sea. Fish. Bull. 105:396-407.

Thompson, G. G. 2013. Assessment of the Pacific cod stock in the Eastern Bering Sea. *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. 239-380. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 2004. 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. 185-302. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 2005. Assessment of the Pacific cod stock in the 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. 219-330. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, D. Nichol, S. Gaichas, and K. Aydin. 2007b. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for

Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 209-327. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, R. Lauth, S. Gaichas, and K. Aydin. 2008. 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. 221-401. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, and R. Lauth. 2009. 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. 235-439. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, and R. Lauth. 2010. 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. 243-424. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and R. R. Lauth. 2011. 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. 269-476. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

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.

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

Thompson, G. G., and W. A. Palsson. 2013. Assesement of the Pacific cod stock in the Aleutian Islands. In Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions p. 381-507. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

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

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

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

Trenberth, K. E., and J. W. Hurrell. 1994. Decadal atmosphere-ocean variations in the Pacific. *Climate Dynamics* 9:303-319.

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

Vestfals, C. D., L. Ciannelli, J. T. Duffy-Anderson, and C. Ladd. In press. Effects of seasonal and interannual variability in along-shelf and cross-shelf transport on groundfish recruitment in the eastern Bering Sea. Deep Sea Research II (corrected proof published online October 4, 2013: http://www.sciencedirect.com/science/article/pii/S0967064513003573).

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

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

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

Zador, S. (editor). 2011. Ecosystem considerations for 2012. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

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 1991-2014 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. Catches for 2013 are through October 6.

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	108,775	19,959	175,451
2004	57,866	108,614	17,264	183,745
2005	52,638	113,184	17,114	182,936
2006	53,236	96,610	18,969	168,814
2007	45,700	77,181	17,248	140,129
2008	33,497	89,183	17,368	140,048
2009	36,959	96,606	13,609	147,174
2010	41,297	81,855	19,723	142,875
2011	64,085	117,103	28,063	209,250
2012	75,424	128,516	28,737	232,676
2013	81,619	124,823	30,261	236,702
2014	69,921	97,256	33,552	200,729

Table 2.2—Discards (t) of Pacific cod in the Pacific cod fishery, by area, gear, and year for the period 1991-2014 (2014 data are current through October 20). 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. Note also that the version of this table in the 2012 and 2013 assessments inadvertently included discards of Pacific cod in *all* fisheries, not just the Pacific cod fishery.

Year	Trawl	Longline	Pot	Total
1991	1,278	1,493	4	2,774
1992	3,314	1,768	59	5,141
1993	5,449	2,234	25	7,708
1994	4,599	2,917	161	7,677
1995	7,988	3,669	222	11,879
1996	2,971	2,833	391	6,194
1997	3,330	3,187	79	6,596
1998	102	2,456	52	2,610
1999	353	1,285	52	1,691
2000	207	2,267	71	2,546
2001	142	1,531	52	1,726
2002	557	2,066	91	2,715
2003	240	1,772	160	2,171
2004	158	1,814	48	2,019
2005	86	2,600	63	2,750
2006	193	1,528	63	1,784
2007	238	1,373	45	1,656
2008	13	1,280	156	1,449
2009	126	1,503	16	1,645
2010	154	1,402	19	1,574
2011	121	1,860	32	2,013
2012	136	1,754	40	1,930
2013	215	3,060	101	3,377
2014	190	2,373	114	2,678

Table 2.3—History of **BSAI** Pacific cod catch, TAC, ABC, and OFL (t). Catch for 2014 is through October 6. 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	200,729	246,897	255,000	299,000

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 1977-2014 as configured in Model 1. 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 1977-2014 as configured in Model 1.

		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 1977-2014 as configured in Model 1.

		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	7963	0	0	18209	0	0	2205	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	30966	0	0	2970
2001	Nov-Dec	0	0	803	0	0	19751	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	15383	0	0	35435	0	0	11693	0	0
2003	Mar-Apr	16459	0	0	17106	0	0	1661	0	0
2003	May-Jul	0	6752	0	0	2748	0	0	454	0
2003	Aug-Oct	0	0	7794	0	0	35121	0	0	5143
2003	Nov-Dec	0	0	264	0	0	18004	0	0	1430
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	2915	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	27360	0	0	46935	0	0	9034	0	0
2005	Mar-Apr	15119	0	0	6612	0	0	3114	0	0
2005	May-Jul	0	7410	0	0	3289	0	0	0	0
2005	Aug-Oct	0	0	2892	0	0	35344	0	0	4549
2005	Nov-Dec	0	0	113	0	0	20756	0	0	407

Table 2.5 (p. 4 of 4)— EBS catch (t) of Pacific cod by year, gear, and season for the years 1977-2014 as configured in Model 1. Aug-Oct and Nov-Dec catches for 2014 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	28595	0	0	45149	0	0	10608	0	0
2006	Mar-Apr	13917	0	0	6017	0	0	3297	0	0
2006	May-Jul	0	6347	0	0	1905	0	0	364	0
2006	Aug-Oct	0	0	4357	0	0	42490	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	41873	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	257	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	16329	0	0	40595	0	0	10695	0	0
2010	Mar-Apr	8170	0	0	2050	0	0	1726	0	0
2010	May-Jul	0	3980	0	0	2903	0	0	268	0
2010	Aug-Oct	0	0	9596	0	0	25041	0	0	5418
2010	Nov-Dec	0	0	1601	0	0	12702	0	0	1801
2011	Jan-Feb	21217	0	0	28954	0	0	15345	0	0
2011	Mar-Apr	20796	0	0	26321	0	0	2297	0	0
2011	May-Jul	0	7276	0	0	14057	0	0	595	0
2011	Aug-Oct	0	0	13351	0	0	30921	0	0	8954
2011	Nov-Dec	0	0	1728	0	0	17438	0	0	0
2012	Jan-Feb	39029	0	0	33164	0	0	19238	0	0
2012	Mar-Apr	14803	0	0	24916	0	0	2295	0	0
2012	May-Jul	0	8666	0	0	21092	0	0	790	0
2012	Aug-Oct	0	0	11672	0	0	27628	0	0	6171
2012	Nov-Dec	0	0	1058	0	0	21260	0	0	893
2013	Jan-Feb	35435	0	0	38743	0	0	19229	0	0
2013	Mar-Apr	17157	0	0	22243	0	0	2801	0	0
2013	May-Jul	0	5977	0	0	13875	0	0	0	0
2013	Aug-Oct	0	0	20907	0	0	26500	0	0	5891
2013	Nov-Dec	0	0	1608	0	0	22770	0	0	3567
2014	Jan-Feb	31400	0	0	32476	0	0	21523	0	0
2014	Mar-Apr	23274	0	0	27604	0	0	4458	0	0
2014	May-Jul	0	7055	0	0	21136	0	0	230	0
2014	Aug-Oct	0	0	20907	0	0	26500	0	0	5891
2014	Nov-Dec	0	0	1406	0	0	19917	0	0	3120

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

Jan-Apr trawl fishery				May-Jul trawl fishery				Aug-Dec trawl fishery			
Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma
1991	Jan-Feb	55.864	0.091	1991	May-Jul	36.761	0.202	1991	Aug-Oct	71.702	0.597
1992	Jan-Feb	60.427	0.160	1992	May-Jul	38.568	0.288	1992	Aug-Oct	57.517	0.766
1993	Jan-Feb	62.047	0.155	1993	May-Jul	39.902	0.465	1993	Aug-Oct	113.970	0.499
1994	Jan-Feb	51.965	0.220	1994	May-Jul	26.767	0.246	1994	Aug-Oct	56.308	0.386
1995	Jan-Feb	88.482	0.121	1995	May-Jul	59.393	1.654	1995	Aug-Oct	60.164	0.320
1996	Jan-Feb	48.331	0.131	1996	May-Jul	29.174	0.311	1996	Aug-Oct	34.896	0.288
1997	Jan-Feb	75.605	0.121	1997	May-Jul	24.880	0.256	1997	Aug-Oct	62.619	0.562
1998	Jan-Feb	59.920	0.157	1998	May-Jul	26.245	0.300	1998	Aug-Oct	38.995	0.302
1999	Jan-Feb	42.399	0.118	1999	May-Jul	15.672	0.422	1999	Aug-Oct	20.611	0.364
2000	Jan-Feb	34.522	0.122	2000	May-Jul	32.694	0.291	2000	Aug-Oct	15.070	0.523
2001	Jan-Feb	25.452	0.165	2001	May-Jul	60.120	0.295	2001	Aug-Oct	16.662	0.247
2002	Jan-Feb	35.892	0.139	2002	May-Jul	39.985	0.207	2002	Aug-Oct	15.141	0.194
2003	Jan-Feb	24.642	0.167	2003	May-Jul	49.493	0.208	2003	Aug-Oct	19.171	0.154
2004	Jan-Feb	62.609	0.137	2004	May-Jul	34.588	0.162	2004	Aug-Oct	21.519	0.152
2005	Jan-Feb	43.993	0.115	2005	May-Jul	24.100	0.170	2005	Aug-Oct	15.932	0.827
2006	Jan-Feb	36.397	0.106	2006	May-Jul	30.653	0.185	2006	Aug-Oct	26.772	0.373
2007	Jan-Feb	30.849	0.094	2007	May-Jul	39.485	0.113	2007	Aug-Oct	18.147	0.675
2008	Jan-Feb	24.385	0.150	2008	May-Jul	40.650	0.248	2008	Aug-Oct	60.047	0.333
2009	Jan-Feb	37.853	0.169	2009	May-Jul	33.932	0.289	2009	Aug-Oct	54.154	0.224
2010	Jan-Feb	41.949	0.135	2010	May-Jul	32.031	0.333	2010	Aug-Oct	73.484	0.196
2011	Jan-Feb	50.737	0.109	2011	May-Jul	49.228	0.256	2011	Aug-Oct	56.918	0.200
2012	Jan-Feb	97.338	0.098	2012	May-Jul	117.192	0.245	2012	Aug-Oct	52.247	0.252
2013	Jan-Feb	67.061	0.081	2013	May-Jul	39.218	0.288	2013	Aug-Oct	82.463	0.139
2014	Jan-Feb	57.039	0.087	2014	May-Jul	54.974	0.233	2014	Aug-Oct	65.232	0.350
1991	Mar-Apr	61.454	0.058					1993	Nov-Dec	32.678	0.906
1992	Mar-Apr	48.269	0.069					1996	Nov-Dec	29.543	0.477
1993	Mar-Apr	48.840	0.073					1997	Nov-Dec	31.309	1.083
1994	Mar-Apr	52.428	0.053					1998	Nov-Dec	16.891	0.641
1995	Mar-Apr	55.463	0.061					1999	Nov-Dec	12.994	0.955
1996	Mar-Apr	33.954	0.051					2009	Nov-Dec	28.369	1.170
1997	Mar-Apr	45.985	0.062					2010	Nov-Dec	40.079	0.675
1998	Mar-Apr	31.809	0.071					2011	Nov-Dec	20.796	1.170
1999	Mar-Apr	35.675	0.085					2012	Nov-Dec	52.570	1.281
2000	Mar-Apr	31.397	0.084					2013	Nov-Dec	17.174	1.654
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	0.113								
2006	Mar-Apr	56.188	0.140								
2007	Mar-Apr	45.097	0.091								
2008	Mar-Apr	40.343	0.194								
2009	Mar-Apr	55.557	0.182								
2010	Mar-Apr	55.766	0.264								
2011	Mar-Apr	76.788	0.147								
2012	Mar-Apr	76.796	0.153								
2013	Mar-Apr	64.027	0.137								
2014	Mar-Apr	61.848	0.101								

Table 2.6 (page 2 of 3)— Fishery CPUE as configured in Model 1. Units are kg/minute for trawl gear, kg/hook for longline gear, and kg/pot for pot gear.

Jan-Apr longline fishery				May-Jul longline fishery				Aug-Dec longline fishery			
Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma	Year	Season	CPUE	Sigma
1991	Jan-Feb	1.124	0.154	1991	May-Jul	0.771	0.075	1991	Aug-Oct	0.595	0.062
1992	Jan-Feb	0.873	0.088	1992	May-Jul	0.530	0.052	1992	Aug-Oct	0.512	0.068
1993	Jan-Feb	0.654	0.065	1993	May-Jul	0.551	0.174	1994	Aug-Oct	0.576	0.067
1994	Jan-Feb	0.728	0.067	1994	May-Jul	0.713	0.132	1995	Aug-Oct	0.587	0.069
1995	Jan-Feb	0.895	0.068	1995	May-Jul	0.760	0.177	1996	Aug-Oct	0.542	0.060
1996	Jan-Feb	0.878	0.068	1996	May-Jul	0.669	0.176	1997	Aug-Oct	0.580	0.064
1997	Jan-Feb	0.989	0.072	1997	May-Jul	0.657	0.119	1998	Aug-Oct	0.398	0.063
1998	Jan-Feb	0.888	0.073	1998	May-Jul	0.496	0.182	1999	Aug-Oct	0.481	0.060
1999	Jan-Feb	0.743	0.067	1999	May-Jul	0.637	0.141	2000	Aug-Oct	0.404	0.052
2000	Jan-Feb	0.730	0.069	2000	May-Jul	0.610	0.167	2001	Aug-Oct	0.398	0.051
2001	Jan-Feb	0.586	0.079	2001	May-Jul	0.514	0.106	2002	Aug-Oct	0.372	0.045
2002	Jan-Feb	0.680	0.061	2002	May-Jul	0.405	0.136	2003	Aug-Oct	0.342	0.044
2003	Jan-Feb	0.517	0.052	2003	May-Jul	0.376	0.109	2004	Aug-Oct	0.312	0.047
2004	Jan-Feb	0.562	0.060	2004	May-Jul	0.367	0.114	2005	Aug-Oct	0.330	0.045
2005	Jan-Feb	0.626	0.055	2005	May-Jul	0.385	0.105	2006	Aug-Oct	0.391	0.046
2006	Jan-Feb	0.747	0.062	2006	May-Jul	0.366	0.160	2007	Aug-Oct	0.402	0.038
2007	Jan-Feb	0.734	0.045	2007	May-Jul	0.406	0.141	2008	Aug-Oct	0.307	0.047
2008	Jan-Feb	0.794	0.067	2008	May-Jul	0.366	0.139	2009	Aug-Oct	0.348	0.049
2009	Jan-Feb	0.893	0.068	2009	May-Jul	0.384	0.150	2010	Aug-Oct	0.352	0.060
2010	Jan-Feb	0.781	0.066	2010	May-Jul	0.419	0.155	2011	Aug-Oct	0.369	0.058
2011	Jan-Feb	0.716	0.082	2011	May-Jul	0.374	0.087	2012	Aug-Oct	0.321	0.060
2012	Jan-Feb	0.774	0.081	2012	May-Jul	0.429	0.079	2013	Aug-Oct	0.355	0.056
2013	Jan-Feb	0.736	0.062	2013	May-Jul	0.424	0.090	2014	Aug-Oct	0.373	0.108
2014	Jan-Feb	0.604	0.068	2014	May-Jul	0.365	0.067	1991	Nov-Dec	0.551	0.092
1991	Mar-Apr	0.993	0.109					1995	Nov-Dec	0.648	0.109
1992	Mar-Apr	0.858	0.070					1996	Nov-Dec	0.590	0.274
1993	Mar-Apr	0.669	0.061					1997	Nov-Dec	0.577	0.072
1994	Mar-Apr	0.735	0.060					1998	Nov-Dec	0.501	0.071
1995	Mar-Apr	0.841	0.061					1999	Nov-Dec	0.541	0.119
1996	Mar-Apr	0.756	0.066					2000	Nov-Dec	0.416	0.066
1997	Mar-Apr	0.829	0.077					2001	Nov-Dec	0.432	0.065
1998	Mar-Apr	0.619	0.075					2002	Nov-Dec	0.394	0.071
1999	Mar-Apr	0.617	0.066					2003	Nov-Dec	0.365	0.059
2000	Mar-Apr	0.617	0.096					2004	Nov-Dec	0.441	0.065
2001	Mar-Apr	0.539	0.072					2005	Nov-Dec	0.385	0.064
2002	Mar-Apr	0.676	0.082					2006	Nov-Dec	0.433	0.212
2003	Mar-Apr	0.530	0.067					2007	Nov-Dec	0.449	0.329
2004	Mar-Apr	0.579	0.075					2008	Nov-Dec	0.449	0.086
2005	Mar-Apr	0.678	0.112					2009	Nov-Dec	0.428	0.090
2006	Mar-Apr	0.796	0.111					2010	Nov-Dec	0.447	0.086
2007	Mar-Apr	0.693	0.153					2011	Nov-Dec	0.447	0.085
2008	Mar-Apr	0.774	0.144					2012	Nov-Dec	0.476	0.076
2009	Mar-Apr	1.159	0.170					2013	Nov-Dec	0.479	0.070
2010	Mar-Apr	0.829	0.194								
2011	Mar-Apr	0.703	0.072								
2012	Mar-Apr	0.597	0.081								
2013	Mar-Apr	0.659	0.082								
2014	Mar-Apr	0.519	0.072								

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

Jan-Apr pot fishery			
Year	Season	CPUE	Sigma
2000	Jan-Feb	56.553	0.151
2001	Jan-Feb	72.207	0.499
2002	Jan-Feb	81.893	0.262
2003	Jan-Feb	73.858	0.137
2004	Jan-Feb	78.980	0.168
2005	Jan-Feb	85.328	0.167
2006	Jan-Feb	83.292	0.152
2007	Jan-Feb	64.671	0.108
2008	Jan-Feb	81.642	0.206
2009	Jan-Feb	92.345	0.187
2010	Jan-Feb	88.535	0.166
2011	Jan-Feb	130.718	0.151
2012	Jan-Feb	138.710	0.146
2013	Jan-Feb	128.974	0.142
2014	Jan-Feb	105.380	0.144
1992	Mar-Apr	86.412	0.418
1993	Mar-Apr	84.191	0.134
1994	Mar-Apr	89.313	0.106
1995	Mar-Apr	91.679	0.093
1996	Mar-Apr	73.485	0.076
1997	Mar-Apr	93.226	0.119
1998	Mar-Apr	77.558	0.182
1999	Mar-Apr	67.604	0.193
2000	Mar-Apr	45.310	0.161
2001	Mar-Apr	69.247	0.135
2002	Mar-Apr	61.628	0.174
2004	Mar-Apr	65.936	0.386
2006	Mar-Apr	116.202	0.418
2014	Mar-Apr	183.575	0.350

May-Jul pot fishery			
Year	Season	CPUE	Sigma
1991	May-Jul	64.037	0.248
1992	May-Jul	66.730	0.076
1993	May-Jul	90.669	0.226
1994	May-Jul	75.421	0.171
1995	May-Jul	72.065	0.097
1996	May-Jul	55.819	0.088
1997	May-Jul	46.843	0.113
1998	May-Jul	49.999	0.128
1999	May-Jul	47.466	0.123

Aug-Dec pot fishery			
Year	Season	CPUE	Sigma
1991	Aug-Oct	88.556	0.131
1992	Aug-Oct	30.252	0.112
1994	Aug-Oct	97.172	0.150
1995	Aug-Oct	57.783	0.152
1996	Aug-Oct	49.758	0.135
1997	Aug-Oct	47.938	0.165
1998	Aug-Oct	32.057	0.278
1999	Aug-Oct	37.675	0.211
2001	Aug-Oct	46.493	0.167
2002	Aug-Oct	42.331	0.187
2003	Aug-Oct	57.632	0.173
2004	Aug-Oct	48.802	0.208
2005	Aug-Oct	45.872	0.191
2006	Aug-Oct	55.342	0.184
2007	Aug-Oct	65.356	0.150
2008	Aug-Oct	57.252	0.162
2009	Aug-Oct	72.836	0.264
2010	Aug-Oct	82.936	0.208
2011	Aug-Oct	81.445	0.146
2012	Aug-Oct	64.934	0.128
2013	Aug-Oct	87.471	0.127
2014	Aug-Oct	86.671	0.286
1991	Nov-Dec	91.633	0.259
1995	Nov-Dec	53.251	0.186
1996	Nov-Dec	46.456	0.418
1997	Nov-Dec	41.829	0.409
1998	Nov-Dec	41.138	0.795
2001	Nov-Dec	40.740	0.625
2002	Nov-Dec	55.955	0.414
2003	Nov-Dec	60.093	0.331
2004	Nov-Dec	66.375	0.447
2006	Nov-Dec	37.187	0.418
2010	Nov-Dec	104.985	0.370
2013	Nov-Dec	90.404	0.211

Table 2.7— Total biomass and abundance, with standard deviations, as estimated by EBS shelf bottom trawl surveys, 1982-2014. 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	1,048,493	63,632	922,501	1,174,484	680,883	49,913
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	1,104,868	68,304	969,627	1,240,109	728,974	48,488
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	551,369	45,780	460,725	642,013	601,795	70,551
1993	691,494	54,580	583,425	799,562	852,837	106,923
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	558,510	45,182	469,050	647,970	537,342	48,429
1999	584,884	50,616	484,664	685,104	501,554	46,620
2000	531,171	43,160	445,714	616,627	483,808	44,188
2001	833,626	76,247	681,133	986,119	985,569	94,981
2002	618,680	69,082	480,516	756,845	566,471	57,676
2003	590,973	62,121	466,732	715,214	498,873	62,220
2004	596,279	35,216	526,552	666,007	424,662	36,140
2005	606,415	43,047	521,182	691,648	450,918	63,358
2006	517,698	28,341	461,583	573,813	394,051	23,784
2007	423,703	34,811	354,080	493,326	733,374	195,955
2008	403,125	26,822	350,018	456,232	476,697	49,413
2009	421,291	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

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	10547	0	0	0	0	0	1	7	8	18	24	46	54	100	63	46	50	43
1983	13148	0	0	0	0	0	7	101	301	474	473	499	476	449	411	262	258	124
1984	12142	0	0	0	0	0	6	25	36	54	43	27	26	27	32	49	32	67
1985	16884	0	0	0	0	0	4	54	98	174	141	212	282	299	370	498	503	522
1986	15378	0	0	0	0	1	23	38	93	133	130	202	175	177	150	93	34	27
1987	10601	0	0	0	0	0	0	14	3	7	24	38	60	80	110	122	122	154
1988	9994	0	0	0	0	0	0	1	8	7	28	13	27	26	23	42	27	18
1989	9999	0	0	0	0	0	2	2	17	44	35	68	85	109	107	103	66	40
1990	5628	0	0	0	0	0	26	72	105	155	152	187	239	262	207	151	118	90
1991	7222	0	0	0	0	0	6	31	93	111	138	135	161	131	135	127	106	134
1992	9603	0	0	0	0	0	0	1	17	82	184	190	173	148	196	218	232	248
1993	10402	0	0	0	0	1	3	29	82	193	430	296	407	355	322	322	346	315
1994	13924	0	0	0	0	0	3	10	5	27	42	77	92	100	100	116	136	111
1995	9210	0	0	0	0	0	3	12	15	13	19	41	37	42	56	59	81	68
1996	9347	0	0	0	0	0	1	2	11	9	23	33	48	64	53	66	69	64
1997	9175	0	0	0	0	0	8	17	65	114	167	193	192	196	212	284	226	218
1998	9575	0	0	0	0	0	1	4	24	55	86	119	105	137	91	45	22	6
1999	11700	0	0	0	0	0	1	15	55	102	111	123	94	113	78	42	29	41
2000	12548	0	0	0	4	10	23	51	99	137	298	478	582	442	278	274	141	87
2001	19745	0	0	0	0	5	6	27	62	127	205	314	453	662	715	769	681	664
2002	12239	0	0	0	0	1	3	6	22	45	65	81	102	160	112	168	111	72
2003	12357	0	0	1	0	1	3	5	11	56	92	138	205	232	205	249	254	281
2004	10806	0	2	0	0	0	1	4	19	44	84	150	106	194	187	218	213	136
2005	11289	0	0	0	0	0	0	1	4	22	43	87	138	201	248	304	284	301
2006	12132	0	1	0	4	7	40	101	336	405	427	453	401	343	330	359	280	243
2007	12812	0	0	0	0	7	7	129	481	1163	1425	1398	1141	731	715	511	326	400
2008	12981	0	0	1	0	0	6	54	169	350	380	390	350	312	227	151	75	40
2009	16678	1	0	0	7	36	106	401	972	1059	1088	879	744	651	486	460	318	219
2010	7569	0	0	0	0	0	1	5	18	24	29	50	50	56	46	31	15	17
2011	20741	0	0	0	0	0	8	20	76	142	258	306	385	413	597	627	906	887
2012	13074	0	0	6	0	0	74	379	687	732	563	424	417	310	409	395	208	128
2013	18696	0	0	0	0	1	9	50	116	147	207	222	283	240	177	127	35	21
2014	17941	0	0	0	1	0	1	9	90	117	239	341	467	520	658	499	608	490

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	17	24	39	66	87	123	192	221	239	305	320	236	197
1983	77	46	30	9	5	18	35	45	56	97	121	138	169	154	199	131	119	104
1984	75	95	129	234	315	378	455	569	589	637	564	468	388	346	294	221	156	106
1985	641	556	553	320	212	130	92	101	107	160	220	216	273	300	310	314	290	346
1986	20	22	72	114	218	360	449	697	629	616	638	653	580	557	448	402	349	332
1987	125	81	61	46	63	76	118	123	200	273	302	324	292	281	205	232	201	173
1988	26	35	48	68	77	88	87	109	84	124	122	137	179	190	269	215	195	211
1989	19	21	30	4	15	15	36	14	34	31	24	33	37	69	33	107	109	134
1990	57	35	42	43	33	47	77	78	96	104	98	93	119	125	80	114	97	68
1991	86	71	72	78	100	98	167	193	266	286	325	289	372	308	251	262	196	174
1992	216	228	113	119	134	182	262	288	303	349	375	351	310	304	243	217	177	149
1993	325	218	136	97	62	55	67	86	95	175	207	232	291	316	239	245	226	195
1994	103	91	132	121	171	154	206	321	430	552	639	730	766	671	642	471	362	288
1995	34	24	19	37	47	89	108	158	194	228	218	245	225	198	155	217	249	239
1996	54	36	20	22	24	58	65	130	164	195	229	276	237	250	192	201	168	157
1997	226	177	105	58	41	41	34	70	109	103	154	223	231	222	174	159	155	138
1998	4	17	24	57	72	182	275	381	493	598	626	611	513	538	343	261	229	166
1999	49	39	54	110	110	197	227	221	309	268	294	307	240	227	197	191	240	290
2000	33	9	12	25	39	77	119	170	197	220	259	305	222	197	184	188	174	199
2001	442	350	219	136	112	160	226	313	365	507	656	829	826	917	802	697	510	407
2002	52	35	17	42	62	105	159	240	266	433	473	553	552	519	379	400	313	293
2003	252	237	199	218	154	120	66	57	59	79	57	115	145	316	216	319	240	275
2004	143	113	64	55	72	90	102	186	195	219	236	273	301	317	310	341	313	326
2005	289	361	361	387	376	289	210	137	135	141	115	158	178	197	197	207	231	288
2006	146	105	65	54	56	55	64	86	115	168	189	246	243	264	245	303	263	298
2007	230	121	122	42	44	65	86	124	117	154	122	140	147	124	114	93	93	76
2008	21	40	70	162	307	479	550	707	745	719	681	559	461	341	281	200	161	151
2009	114	35	28	33	82	94	173	254	337	397	468	436	339	306	221	213	215	225
2010	9	13	31	60	127	194	242	356	431	418	395	395	324	269	184	165	106	95
2011	851	536	286	110	34	37	55	48	57	72	122	137	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	64	86	268	398	654	785	983	1078	840	908	652	658	415	310	240	180	174	145
2014	521	308	218	111	102	90	71	95	220	245	417	330	483	460	498	349	311	184

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	145	147	127	139	178	203	283	303	272	327	330	285	283	270	251	237	275	259	268	224	259
1983	59	64	81	96	146	156	213	262	291	279	294	315	254	247	246	223	306	284	264	262	248
1984	100	87	59	92	76	91	92	95	108	135	105	110	95	110	144	132	159	168	199	201	156
1985	355	392	418	518	504	518	485	472	361	324	245	194	169	129	97	94	103	102	104	86	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	222	209	297	328	334	332	319	323	251	249	262	157	156	134	120	146	140	98	122	92
1988	141	184	165	239	222	197	318	277	294	277	247	308	266	230	251	250	260	220	214	227	194
1989	117	126	102	116	115	140	177	167	176	184	176	200	254	237	260	246	234	328	293	219	222
1990	58	67	52	47	38	38	31	35	48	38	40	25	51	31	62	53	65	58	73	71	74
1991	144	119	85	68	64	61	52	61	53	61	74	49	62	42	72	90	58	75	40	34	42
1992	125	179	147	216	187	219	240	186	185	160	143	153	119	108	88	78	57	63	29	42	51
1993	150	159	179	180	217	218	229	266	204	183	190	157	150	128	112	117	107	87	63	64	78
1994	196	115	133	114	221	189	164	232	255	264	300	172	189	230	189	181	175	219	251	252	162
1995	314	378	371	417	422	394	342	335	293	199	189	153	142	115	98	108	95	88	93	86	72
1996	168	154	176	214	239	288	261	292	320	301	297	323	272	282	281	244	254	206	166	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	146	134	100	118	117	133	126	168	118	114	134	111	94	89	82	82	72	62	78	90	76
1999	308	380	485	508	584	557	504	394	409	311	233	199	165	142	145	117	117	93	105	93	87
2000	223	256	267	303	306	347	308	355	321	391	342	351	262	315	239	256	194	202	183	159	159
2001	299	217	189	176	152	157	187	229	281	229	265	251	230	263	274	256	235	219	224	188	208
2002	249	287	256	405	357	453	393	387	278	330	189	228	184	167	137	162	130	157	90	109	123
2003	291	318	361	343	390	456	426	461	415	390	277	276	234	246	260	198	185	166	149	124	144
2004	254	244	213	208	188	181	156	149	152	176	172	207	201	162	182	172	185	167	192	142	157
2005	252	204	194	203	207	216	167	205	168	193	132	171	127	144	129	135	111	111	101	99	100
2006	253	244	209	200	161	171	145	151	127	157	147	191	169	175	145	174	137	182	105	128	90
2007	61	73	77	74	68	82	76	85	79	80	60	75	74	82	68	72	59	54	48	52	47
2008	133	130	117	143	128	138	138	139	113	135	121	124	127	134	114	108	101	112	90	113	103
2009	302	304	362	380	379	347	334	279	288	247	180	146	143	116	102	93	82	75	78	85	88
2010	65	75	78	124	132	232	154	165	160	157	124	134	106	147	114	155	151	139	95	139	112
2011	403	458	673	801	859	925	872	790	633	510	346	349	277	265	184	230	225	265	184	276	241
2012	81	61	46	63	59	85	81	130	111	196	188	239	285	379	323	408	309	316	218	198	168
2013	126	184	153	230	292	361	431	519	407	386	349	326	258	259	195	210	136	192	142	214	193
2014	190	145	203	282	444	458	656	676	609	560	492	425	285	216	203	206	182	165	191	249	248

Year	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1982	261	265	228	227	206	197	193	201	123	174	126	135	74	74	74	66	46	35	38	29	21
1983	265	251	199	227	200	200	188	166	181	171	145	179	127	116	76	78	74	63	54	38	44
1984	217	171	200	202	190	164	199	182	177	170	153	147	83	119	97	105	75	84	57	68	46
1985	91	85	148	111	110	113	170	124	134	147	147	136	135	120	138	107	135	100	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	141	136	124	132	121	133	123	132	134	111	115	94	59	90	53	55	54	24	43	34	34
1988	199	166	207	165	116	124	99	138	106	106	82	116	84	84	56	79	71	48	41	55	71
1989	198	290	183	227	243	183	168	241	214	136	200	104	184	197	166	153	142	107	150	106	63
1990	83	88	87	77	77	53	79	54	59	33	62	43	52	51	52	47	32	37	37	24	36
1991	41	34	52	44	43	26	45	41	47	46	48	32	31	25	40	32	27	14	16	19	22
1992	50	66	45	36	25	32	31	47	35	32	24	14	21	23	21	15	24	15	18	25	29
1993	66	56	57	52	36	67	36	37	62	28	28	14	15	15	14	16	12	12	11	12	12
1994	219	153	205	164	180	160	126	84	133	62	102	49	67	30	40	20	29	13	21	9	9
1995	93	99	104	100	87	70	54	60	72	71	69	50	54	45	36	28	22	37	20	25	21
1996	140	99	94	85	79	58	60	60	56	55	45	56	61	31	44	36	27	29	35	22	22
1997	122	130	107	111	115	101	99	92	80	69	56	61	53	29	18	31	20	28	16	11	10
1998	66	77	88	86	75	65	98	59	64	48	46	52	55	38	52	29	37	21	21	25	13
1999	72	117	86	94	80	95	64	70	49	61	70	49	45	51	37	28	28	23	26	27	25
2000	149	112	101	90	85	54	65	58	52	36	50	33	38	31	34	29	22	12	14	22	22
2001	184	148	197	132	154	151	106	82	105	67	77	56	51	33	38	25	19	27	20	31	17
2002	125	101	113	107	99	57	107	72	64	66	57	48	35	36	31	25	31	24	13	10	20
2003	138	116	96	70	95	64	72	69	66	67	76	47	56	40	40	36	35	26	28	16	18
2004	166	148	140	138	121	102	100	86	104	81	63	72	59	57	33	49	44	42	44	31	27
2005	117	84	118	83	127	104	112	101	101	77	83	74	70	59	72	51	72	54	65	49	44
2006	97	105	95	106	90	88	98	61	96	51	71	60	58	64	67	57	59	42	57	44	58
2007	61	50	60	49	49	45	46	32	43	40	31	24	32	23	38	21	19	14	12	17	17
2008	113	91	81	81	88	62	71	64	71	44	53	35	39	23	43	19	23	21	23	13	16
2009	71	84	77	53	64	71	52	38	48	30	40	29	21	24	13	17	14	15	14	4	13
2010	100	71	90	58	67	40	42	29	22	16	19	17	9	6	7	8	10	3	7	2	2
2011	301	227	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	193	163	141	136	109	104	92	51	63	44	31	44	29	31	8
2014	198	191	203	135	139	110	106	62	62	52	66	56	53	65	49	43	40	29	28	20	15

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	25	13	8	7	9	3	6	4	1	3	4	0	3	0	1	2	1	0
1983	25	24	20	14	9	1	7	5	3	9	1	1	2	3	0	2	0	1	0
1984	40	31	33	27	22	28	12	16	19	12	9	4	8	6	0	4	3	2	1
1985	59	50	48	21	37	22	22	16	14	10	8	7	9	4	1	3	7	2	4
1986	56	53	43	29	26	35	18	21	18	30	10	16	13	5	4	6	2	7	2
1987	45	28	29	29	29	9	7	15	9	10	13	6	10	10	2	4	6	3	1
1988	62	53	31	30	11	27	15	6	15	2	15	2	6	6	6	5	1	4	8
1989	53	84	61	74	88	43	60	42	14	42	30	19	24	28	32	14	11	20	11
1990	37	10	23	18	23	19	10	10	19	11	5	5	5	6	11	10	3	1	1
1991	33	24	21	12	13	8	13	7	8	6	3	5	4	1	6	8	3	2	3
1992	14	16	15	11	13	14	6	10	8	13	6	7	7	4	7	8	3	9	1
1993	11	9	4	12	10	4	7	8	8	4	3	4	7	3	7	5	5	4	3
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	24	15	25	10	13	22	17	9	3	3	6	10	3	5	4	3	2	2
1997	9	12	17	12	10	8	9	9	4	3	8	7	2	6	3	2	4	0	1
1998	16	9	15	11	8	10	7	4	3	5	5	10	3	6	3	1	2	2	1
1999	19	13	17	15	12	11	17	16	6	16	6	5	5	5	2	5	6	6	3
2000	12	18	19	8	9	5	9	26	7	7	7	4	4	10	2	8	5	3	1
2001	17	12	11	13	5	10	6	6	5	7	5	4	2	4	6	1	2	1	5
2002	14	6	6	3	7	2	4	5	2	2	4	5	5	1	3	2	3	6	1
2003	21	22	11	14	7	9	6	7	5	4	4	3	2	1	0	1	1	0	0
2004	23	23	16	22	10	25	13	19	14	13	6	4	8	4	3	4	4	2	2
2005	40	40	32	25	17	28	20	23	14	10	14	10	8	4	9	5	3	4	0
2006	50	51	37	42	39	34	20	35	16	23	15	18	10	10	6	11	9	1	7
2007	18	10	10	9	25	11	8	9	15	10	13	8	3	8	4	6	2	3	2
2008	12	16	14	12	8	20	11	10	8	12	5	10	10	10	9	3	8	9	2
2009	6	7	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

Year	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118+
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	4	3	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	1	2	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	3	1	3	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
1989	10	22	1	23	6	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	1	0	6	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1992	4	3	3	3	2	1	1	1	0	0	0	0	0	0	0	0	0	1	0
1993	1	2	2	1	8	3	0	1	0	0	0	0	0	0	0	2	0	0	0
1994	2	9	6	3	1	7	0	0	1	0	1	0	0	0	0	0	0	0	0
1995	5	1	3	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0
1996	4	1	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
1997	2	0	0	1	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0
1998	1	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	2	1	0	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
2000	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	1	1	0	2	1	3	1	0	1	0	0	0	0	0	0	0	0	0	0
2002	1	0	0	1	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0
2003	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	1	0	5	0	1	0	0	2	0	1	0	0	0	0	0	0	0	0
2005	4	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	5	3	2	3	2	0	1	0	0	2	0	0	0	0	0	0	0	0	0
2007	3	2	8	1	2	1	2	0	1	0	0	0	1	0	0	0	0	0	0
2008	4	3	7	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2009	2	1	1	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0
2010	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	2	2	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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

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	0.0847	0.3807	0.1737	0.1186	0.1180	0.0813	0.0207	0.0077	0.0043	0.0016	0.0008	0.0010
1995	571	0.0000	0.0543	0.2593	0.4173	0.1018	0.0765	0.0528	0.0134	0.0073	0.0062	0.0016	0.0016	0.0013
1996	711	0.0000	0.0568	0.2062	0.2019	0.2961	0.1314	0.0598	0.0286	0.0086	0.0038	0.0017	0.0016	0.0013
1997	719	0.0001	0.2538	0.1749	0.1639	0.1523	0.1161	0.0855	0.0224	0.0095	0.0023	0.0016	0.0011	0.0005
1998	635	0.0000	0.0768	0.4475	0.1976	0.1113	0.0576	0.0587	0.0287	0.0160	0.0038	0.0006	0.0007	0.0003
1999	860	0.0000	0.0800	0.1942	0.3021	0.2354	0.0791	0.0577	0.0291	0.0129	0.0061	0.0012	0.0016	0.0006
2000	860	0.0000	0.2339	0.1129	0.1622	0.2402	0.1519	0.0588	0.0133	0.0151	0.0051	0.0034	0.0014	0.0005
2001	920	0.0000	0.2905	0.2390	0.1890	0.0883	0.0862	0.0682	0.0252	0.0076	0.0020	0.0013	0.0010	0.0004
2002	870	0.0005	0.0799	0.1884	0.3066	0.2421	0.0720	0.0590	0.0369	0.0093	0.0031	0.0011	0.0004	0.0005
2003	1263	0.0000	0.1734	0.1615	0.2470	0.2095	0.1155	0.0408	0.0285	0.0152	0.0036	0.0005	0.0005	0.0007
2004	995	0.0000	0.1444	0.1635	0.2744	0.1283	0.1301	0.0918	0.0356	0.0191	0.0078	0.0021	0.0021	0.0005
2005	1279	0.0000	0.1799	0.2438	0.2087	0.1240	0.0639	0.0813	0.0549	0.0242	0.0101	0.0036	0.0042	0.0005
2006	1300	0.0000	0.3251	0.1424	0.1681	0.1168	0.0931	0.0624	0.0468	0.0290	0.0103	0.0032	0.0012	0.0008
2007	1441	0.0000	0.6947	0.0955	0.0677	0.0429	0.0431	0.0178	0.0148	0.0079	0.0052	0.0018	0.0009	0.0008
2008	1213	0.0000	0.2109	0.4473	0.1458	0.0867	0.0490	0.0291	0.0102	0.0098	0.0055	0.0025	0.0020	0.0013
2009	1412	0.0000	0.4547	0.1872	0.2320	0.0655	0.0284	0.0143	0.0086	0.0043	0.0018	0.0009	0.0007	0.0003
2010	1292	0.0000	0.0464	0.4819	0.1786	0.2027	0.0632	0.0144	0.0077	0.0025	0.0013	0.0005	0.0006	0.0001
2011	1253	0.0001	0.2796	0.0700	0.3694	0.1080	0.0903	0.0275	0.0068	0.0028	0.0015	0.0010	0.0005	0.0004
2012	1301	0.0000	0.3659	0.2338	0.0590	0.2358	0.0622	0.0300	0.0074	0.0022	0.0016	0.0006	0.0001	0.0002
2013	1418	0.0000	0.0975	0.4367	0.1804	0.1066	0.1119	0.0501	0.0116	0.0033	0.0009	0.0002	0.0003	0.0002

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 1 only.

Average length (cm) at age:

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
1994	11.00	18.71	31.71	39.84	49.36	58.12	64.30	70.64	79.14	89.16	96.00	92.17	96.06
1995	11.00	17.47	32.36	43.13	52.95	62.32	69.94	76.23	82.88	84.75	93.73	92.67	93.83
1996	11.00	17.69	31.62	41.36	50.29	57.65	67.57	75.89	82.40	89.16	91.06	93.13	94.46
1997	11.00	17.28	32.23	42.20	51.38	59.70	64.57	72.89	78.97	89.31	92.19	92.97	94.75
1998	11.00	15.42	30.80	38.07	49.42	59.05	66.96	70.06	78.32	89.71	90.55	92.14	93.36
1999	0.00	15.80	29.52	40.22	46.13	56.38	65.52	71.48	79.07	81.78	93.50	90.63	97.61
2000	0.00	15.26	30.30	38.21	47.59	54.00	59.29	72.62	73.90	83.33	82.28	81.25	94.73
2001	11.00	17.88	31.36	36.77	48.26	55.42	61.78	66.41	77.18	84.43	77.93	88.73	94.42
2002	11.00	16.53	30.09	36.73	46.78	55.44	63.04	69.02	72.53	81.20	93.92	92.80	95.40
2003	11.00	18.02	29.82	41.05	48.40	56.50	65.19	70.50	74.98	82.61	83.54	83.42	94.09
2004	0.00	17.27	30.16	38.00	49.22	57.08	64.96	70.09	75.15	85.12	88.19	87.26	96.20
2005	11.00	18.51	26.52	39.02	48.42	56.64	64.06	72.19	78.45	82.21	89.65	87.28	96.44
2006	0.00	15.32	30.91	38.69	47.68	55.85	64.85	73.48	82.38	86.64	89.23	94.05	97.36
2007	0.00	15.04	30.97	41.16	50.90	59.63	67.01	74.62	82.30	84.03	94.01	91.10	92.19
2008	0.00	15.26	29.74	41.31	53.69	61.42	66.49	73.30	80.20	82.82	88.67	95.41	97.22
2009	0.00	14.14	31.06	42.44	51.70	59.89	66.22	71.68	77.04	82.67	89.83	88.76	93.00
2010	0.00	15.53	30.53	43.50	53.86	59.42	66.28	70.70	80.80	81.80	90.58	87.27	96.38
2011	11.00	18.21	33.27	43.94	53.81	62.60	67.86	72.93	77.15	85.86	83.77	84.27	90.11
2012	0.00	14.02	32.08	44.64	53.54	61.26	68.52	72.94	80.67	82.64	93.03	94.01	94.82
2013	0.00	15.55	28.78	43.97	50.66	62.09	66.50	75.12	77.07	82.70	89.88	86.78	98.42

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	2
1996	0	34	143	138	183	101	65	37	5	2	0	1	2
1997	0	94	92	109	125	120	110	38	21	5	3	2	0
1998	0	56	145	97	94	73	88	47	28	6	0	1	0
1999	0	84	167	195	162	105	77	44	17	8	0	1	0
2000	0	112	102	130	204	177	82	21	19	6	6	1	0
2001	0	163	156	153	132	124	118	42	15	6	4	5	1
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	0
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	0
2006	0	205	176	179	168	155	140	133	93	36	10	4	1
2007	0	268	206	191	155	211	108	119	75	62	21	12	7
2008	0	141	262	244	188	134	97	45	45	28	13	8	6
2009	0	222	259	325	187	133	100	82	47	23	13	12	4
2010	0	105	344	229	296	144	71	48	30	13	5	7	0
2011	0	186	148	315	178	218	107	40	20	12	11	8	1
2012	0	163	289	130	284	161	151	55	30	20	11	3	2
2013	0	133	289	264	171	272	163	81	25	10	3	4	2

Table 2.11—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 1																Model 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							18	
1980	23	63				8	6	30	13	19							16	
1981			51		15	7	5	26		11							11	
1982		25	20	5	13		12	16	34	19						241	14	257
1983	19	71	28	11	151	83	87	48	54	59						301	59	321
1984	78	98	91	22	34	67	91	82	191	736						278	144	296
1985	74	247	10	16	6	315	68	8	377	1084						386	213	412
1986	85	201	80	45		230	28	98	203	952			12	13		352	186	375
1987	257	178	103	154	81	696	202	101	621	1274			5	15		243	354	258
1988	729	321	34	6	35	12										229	110	244
1989	627		68		12				38					9		229	73	244
1990	223	570	276	5		14	82	624	628	308			7	72		129	271	137
1991	432	1032	54			167	248	562	925	289			17	120	13	165	373	176
1992	107	739	56			397	733	1043	543		6	10	247	117		220	386	234
1993	167	914				494	728	84				92	36			238	243	254
1994	111	1361	83			599	864	182	444			206	107	69		319	389	339
1995	89	902		8		608	780	101	499	219	7	272	342	96	62	211	385	225
1996	67	1304	96	41	14	748	747	105	752	38		439	462	179	20	214	484	228
1997	128	1113	30			761	806	269	840	717		272	348	128	23	210	525	224
1998	76	951	32	38	5	653	582	113	1000	869		214	243	51		219	466	233
1999	241	573	12	15		750	799	242	989	249		120	296	84		268	422	285
2000	201	534	37			693	400	132	1282	841	308	170				287	444	306
2001	75	309	42	53		565	679	331	1439	866	27	295	19	140	10	452	469	481
2002	164	321	91	123		994	557	213	1737	709	81	164	16	127	17	280	513	298
2003	123	419	101	151		1294	812	327	1921	1019	268	13		137	40	283	640	301
2004	148	258	136	86		1058	677	282	1684	843	160	35	14	118	18	247	520	263
2005	207	276	114			1232	304	319	1682	829	145	23		138		258	509	275
2006	282	159	83	13		973	298	153	1681	83	202	50	11	139	29	278	402	296
2007	190	214	147			894	76	90	1234	57	213	23		101		293	313	312
2008	167	93	32	21		816	193	210	1572	468	122	26		125		297	371	316
2009	86	58	28	67		730	117	165	1503	437	123	21		53	15	382	329	407
2010	165	37	17	59		786	76	150	973	440	144			116	37	173	290	184
2011	246	140	37	85		498	676	425	1033	447	166			171		475	379	506
2012	332	126	46	28		581	549	563	1034	588	206	29		241		299	418	319
2013	472	170	31	124		902	513	427	1107	701	129	9		197	79	428	526	456
2014	440	352	54			742	657	729	191		148	22		35		411	420	437

Table 2.12—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.

Obj. func. component	Model 1	Model 2
Equilibrium catch	0.01	0.00
Survey abundance index	-3.61	-60.32
Size composition	4948.11	992.08
Age composition	141.27	104.30
Recruitment	21.62	-0.11
Priors	n/a	14.77
"Softbounds"	0.03	0.00
Deviations	19.85	13.05
"F ballpark"	0.00	0.17
Total	5127.28	1063.93

CPUE component	Model 1	Model 2
Jan-Apr trawl fishery	233.86	n/a
May-Jul trawl fishery	-1.42	n/a
Aug-Dec trawl fishery	65.58	n/a
Jan-Apr longline fishery	302.02	n/a
May-Jul longline fishery	16.74	n/a
Aug-Dec longline fishery	156.46	n/a
Jan-Apr pot fishery	2.16	n/a
May-Jul pot fishery	-9.24	n/a
Aug-Dec pot fishery	17.76	n/a
Shelf trawl survey	-3.61	-60.32

Sizecomp component	Model 1	Model 2
Jan-Apr trawl fishery	1098.50	n/a
May-Jul trawl fishery	203.96	n/a
Aug-Dec trawl fishery	247.93	n/a
Jan-Apr longline fishery	757.87	n/a
May-Jul longline fishery	245.71	n/a
Aug-Dec longline fishery	1055.81	n/a
Jan-Apr pot fishery	133.02	n/a
May-Jul pot fishery	67.89	n/a
Aug-Dec pot fishery	245.53	n/a
Fishery	n/a	207.04
Shelf trawl survey	891.90	785.035

Parameter counts	Model 1	Model 2
Unconstrained parameters	115	13
Parameters with priors	0	73
Constrained deviations	71	117
Total	186	203

Table 2.13—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 1 and are not included at all in Model 2; fishery CPUE results are shown for comparison only.

Model	Fleet	RMSE	MNR	SDNR	Corr.
1	Jan-Apr trawl fishery	0.45	0.55	3.76	0.17
1	May-Jul trawl fishery	0.38	-0.15	1.61	0.34
1	Aug-Dec trawl fishery	0.69	0.19	2.37	0.13
1	Jan-Apr longline fishery	0.35	0.23	4.24	-0.10
1	May-Jul longline fishery	0.26	0.31	2.40	0.50
1	Aug-Dec longline fishery	0.23	0.15	3.58	0.35
1	Jan-Apr pot fishery	0.34	0.17	1.93	0.22
1	May-Jul pot fishery	0.21	0.04	1.51	0.21
1	Aug-Dec pot fishery	0.38	0.01	2.03	0.13
1	Shelf trawl survey	0.23	0.99	1.86	0.76
2	Shelf trawl survey	0.11	0.10	0.94	0.93

Table 2.14—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		
Mod.	Fleet	Nrec	A(Ninp)	A(Neff/Ninp)	A(Neff)/A(Ninp)	H(Neff)/A(Ninp)
1	Jan-Apr trawl fish.	66	318	5.06	3.00	1.66
1	May-Jul trawl fish.	34	63	9.14	7.31	3.33
1	Aug-Dec trawl fish.	36	44	13.20	6.00	3.35
1	Jan-Apr longline fish.	70	471	8.54	4.00	1.16
1	May-Jul longline fish.	34	244	9.39	5.23	3.02
1	Aug-Dec longline fish.	65	669	6.43	3.15	0.88
1	Jan-Apr pot fish.	38	131	14.30	9.78	3.90
1	May-Jul pot fish.	16	136	18.56	7.79	1.84
1	Aug-Dec pot fish.	38	83	10.15	7.38	2.93
1	Trawl survey	33	282	2.01	1.71	1.05
2	Fishery	38	300	13.66	9.50	2.67
2	Trawl survey	33	300	2.33	1.98	1.23

Table 2.15—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 1	Model 2	Model 1	Model 2
1994	204	400	240	1.96	1.18
1995	163	39	67	0.24	0.41
1996	203	303	588	1.50	2.90
1997	205	175	505	0.85	2.46
1998	181	1423	2046	7.86	11.30
1999	245	112	72	0.46	0.29
2000	245	90	58	0.37	0.24
2001	263	103	93	0.39	0.35
2002	248	82	85	0.33	0.34
2003	360	260	523	0.72	1.45
2004	284	30	59	0.11	0.21
2005	365	401	317	1.10	0.87
2006	371	143	405	0.39	1.09
2007	411	64	1494	0.16	3.64
2008	346	249	568	0.72	1.64
2009	403	100	440	0.25	1.09
2010	369	103	262	0.28	0.71
2011	358	193	136	0.54	0.38
2012	371	112	124	0.30	0.33
2013	405	129	229	0.32	0.56
Mean	300	226	416	0.94	1.57
Harm.	272	106	156	0.37	0.58

Table 2.16a—Biological parameters, ageing bias, recruitment (except annual *dev*s), initial fishing mortality, log catchability (base value only for Model 2), and initial age composition parameters used or estimated by the stock assessment models.

	Model 1		Model 2	
Parameter	Estimate	St. dev.	Estimate	St. dev.
Natural mortality	3.400E-01	_	3.440E-01	3.068E-02
Length at age 1 (cm)	1.418E+01	1.037E-01	1.628E+01	8.521E-02
Asymptotic length (cm)	9.234E+01	5.024E-01	9.573E+01	1.987E+00
Brody growth coefficient	2.402E-01	2.520E-03	2.341E-01	1.526E-02
Richards growth coefficient	n/a	n/a	8.699E-01	5.633E-02
SD of length at age 1 (cm)	3.530E+00	6.714E-02	3.360E+00	5.606E-02
SD of length at age 20 (cm)	9.903E+00	1.571E-01	8.859E+00	2.867E-01
Weight-length α (proportionality)	6.358E-06	_	6.358E-06	_
Weight-length β (exponent)	3.157E+00	_	3.157E+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)	3.321E-01	1.340E-02	2.567E-01	2.827E-02
Ageing bias at age 20 (years)	3.350E-01	1.523E-01	7.736E-01	2.369E-01
Ageing error st. dev. at age 1	8.600E-02	_	8.600E-02	_
Ageing error st. dev. at age 20	1.712E+00	_	1.712E+00	_
ln(mean post-1976 recruitment)	1.322E+01	1.907E-02	1.321E+01	2.122E-01
Beverton-Holt "steepness"	1.000E+00	_	1.000E+00	_
σ(recruitment)	5.700E-01	_	6.570E-01	_
ln(pre-1977 recruitment offset)	-1.165E+00	1.308E-01	-7.339E-01	2.325E-01
Initial F (Jan-Apr trawl fishery)	6.436E-01	1.367E-01	n/a	n/a
Initial F (fishery)	n/a	n/a	9.338E-02	2.914E-02
ln(trawl survey catchability)	-2.614E-01	_	6.181E-02	1.147E-01
Initial age 10 ln(abundance) dev	n/a	n/a	-2.584E-01	5.897E-01
Initial age 9 ln(abundance) dev	n/a	n/a	-3.033E-01	5.801E-01
Initial age 8 ln(abundance) dev	n/a	n/a	-3.746E-01	5.661E-01
Initial age 7 ln(abundance) dev	n/a	n/a	-4.744E-01	5.476E-01
Initial age 6 ln(abundance) dev	n/a	n/a	-5.557E-01	5.296E-01
Initial age 5 ln(abundance) dev	n/a	n/a	-5.306E-01	5.216E-01
Initial age 4 ln(abundance) dev	n/a	n/a	-7.424E-02	5.090E-01
Initial age 3 ln(abundance) dev	1.289E+00	1.883E-01	1.638E-01	4.727E-01
Initial age 2 ln(abundance) dev	-7.295E-01	4.170E-01	-2.321E-01	5.500E-01
Initial age 1 ln(abundance) dev	1.403E+00	2.105E-01	7.000E-01	4.698E-01

Table 2.16b—Annual log-scale recruitment *dev*s estimated by the stock assessment models. Color scale extends from red (low) to green (high) in each column.

	Model 1		Model 2	
Year	Estimate	St. dev.	Estimate	St. dev.
1977	1.332E+00	1.093E-01	8.877E-01	2.376E-01
1978	4.571E-01	2.097E-01	6.873E-01	2.091E-01
1979	6.664E-01	1.092E-01	4.645E-01	1.384E-01
1980	-4.070E-01	1.350E-01	-3.076E-01	1.401E-01
1981	-9.229E-01	1.443E-01	-8.042E-01	1.599E-01
1982	9.547E-01	4.142E-02	7.322E-01	6.376E-02
1983	-5.532E-01	1.123E-01	-3.503E-01	1.227E-01
1984	7.446E-01	4.594E-02	6.488E-01	6.570E-02
1985	-1.086E-01	7.181E-02	-9.312E-02	9.597E-02
1986	-8.371E-01	9.461E-02	-6.812E-01	1.158E-01
1987	-1.167E+00	1.075E-01	-1.551E+00	2.099E-01
1988	-2.404E-01	5.656E-02	-2.080E-01	9.989E-02
1989	5.030E-01	4.022E-02	3.659E-01	7.212E-02
1990	2.911E-01	4.567E-02	3.625E-01	6.956E-02
1991	-3.226E-01	6.133E-02	-2.903E-01	9.704E-02
1992	5.876E-01	3.236E-02	6.110E-01	4.814E-02
1993	-4.611E-01	5.825E-02	-1.828E-01	7.280E-02
1994	-3.765E-01	5.102E-02	-4.074E-01	7.559E-02
1995	-2.807E-01	5.344E-02	-3.703E-01	7.914E-02
1996	6.227E-01	3.204E-02	4.937E-01	4.854E-02
1997	-2.826E-01	5.122E-02	-1.193E-01	6.588E-02
1998	-3.050E-01	4.948E-02	-2.214E-01	7.446E-02
1999	3.735E-01	3.152E-02	5.040E-01	4.786E-02
2000	-1.314E-01	3.698E-02	-3.398E-02	5.896E-02
2001	-8.945E-01	5.674E-02	-4.609E-01	6.744E-02
2002	-3.677E-01	3.824E-02	-4.483E-01	6.524E-02
2003	-5.952E-01	4.585E-02	-4.206E-01	6.350E-02
2004	-7.287E-01	5.035E-02	-7.036E-01	8.045E-02
2005	-5.917E-01	4.719E-02	-4.122E-01	7.786E-02
2006	6.706E-01	2.828E-02	5.003E-01	4.994E-02
2007	-5.230E-01	6.172E-02	3.039E-02	6.843E-02
2008	1.123E+00	3.646E-02	9.291E-01	5.086E-02
2009	-8.172E-01	1.126E-01	-8.483E-01	1.252E-01
2010	5.725E-01	5.992E-02	2.198E-01	8.324E-02
2011	1.024E+00	6.603E-02	7.474E-01	8.786E-02
2012	2.831E-02	1.135E-01	-4.361E-02	1.570E-01
2013	9.643E-01	1.455E-01	7.737E-01	1.953E-01

Table 2.16c—Fishery selectivity parameters estimated by Model 1.

Parameter	Estimate	St. dev.
P3_May-Jul_Trawl	5.614E+00	1.052E-01
P2_Jan-Apr_Longline	-4.523E+00	1.405E+00
P4_Jan-Apr_Longline	5.025E+00	1.451E-01
P3_May-Jul_Longline	5.027E+00	4.602E-02
P2_Aug-Dec_Longline	-2.117E+00	2.630E-01
P4_Aug-Dec_Longline	5.051E+00	3.322E-01
P2_Jan-Apr_Pot	-9.240E+00	1.825E+01
P3_Jan-Apr_Pot	5.008E+00	4.845E-02
P4_Jan-Apr_Pot	4.423E+00	2.861E-01
P3_May-Jul_Pot	4.927E+00	8.248E-02
P1_Jan-Apr_Trawl_1977	6.896E+01	3.160E+00
P1_Jan-Apr_Trawl_1985	7.618E+01	1.671E+00
P1_Jan-Apr_Trawl_1990	6.883E+01	1.105E+00
P1_Jan-Apr_Trawl_1995	7.399E+01	9.454E-01
P1_Jan-Apr_Trawl_2000	7.828E+01	1.205E+00
P1_Jan-Apr_Trawl_2005	7.736E+01	7.080E-01
P3_Jan-Apr_Trawl_1977	6.176E+00	1.773E-01
P3_Jan-Apr_Trawl_1985	6.617E+00	7.692E-02
P3_Jan-Apr_Trawl_1990	6.087E+00	5.883E-02
P3_Jan-Apr_Trawl_1995	6.298E+00	4.645E-02
P3_Jan-Apr_Trawl_2000	6.304E+00	6.127E-02
P3_Jan-Apr_Trawl_2005	6.009E+00	4.032E-02
P1_May-Jul_Trawl_1977	5.003E+01	1.706E+00
P1_May-Jul_Trawl_1985	5.110E+01	1.749E+00
P1_May-Jul_Trawl_1990	6.170E+01	1.546E+00
P1_May-Jul_Trawl_2000	5.283E+01	1.541E+00
P1_May-Jul_Trawl_2005	5.765E+01	1.438E+00
P1_Aug-Dec_Trawl_1977	6.263E+01	4.056E+00
P1_Aug-Dec_Trawl_1980	8.194E+01	5.746E+00
P1_Aug-Dec_Trawl_1985	8.638E+01	5.407E+00
P1_Aug-Dec_Trawl_1990	7.628E+01	3.498E+01
P1_Aug-Dec_Trawl_1995	1.025E+02	_
P1_Aug-Dec_Trawl_2000	5.610E+01	1.519E+00
P3_Aug-Dec_Trawl_1977	5.552E+00	3.311E-01
P3_Aug-Dec_Trawl_1980	6.664E+00	2.327E-01
P3_Aug-Dec_Trawl_1985	6.608E+00	2.336E-01
P3_Aug-Dec_Trawl_1990	6.346E+00	1.949E+00
P3_Aug-Dec_Trawl_1995	7.015E+00	8.921E-02
P3_Aug-Dec_Trawl_2000	5.220E+00	1.585E-01
P1_Jan-Apr_Longline_1977	5.908E+01	2.066E+00
P1_Jan-Apr_Longline_1980	7.234E+01	2.513E+00
P1_Jan-Apr_Longline_1985	7.502E+01	9.204E-01
P1_Jan-Apr_Longline_1990	6.606E+01	4.765E-01
P1_Jan-Apr_Longline_1995	6.572E+01	4.268E-01
P1_Jan-Apr_Longline_2000	6.352E+01	4.396E-01
P1_Jan-Apr_Longline_2005	6.711E+01	3.486E-01
P3_Jan-Apr_Longline_1977	5.151E+00	2.112E-01
P3_Jan-Apr_Longline_1980	5.909E+00	1.815E-01
P3_Jan-Apr_Longline_1985	5.851E+00	6.812E-02
P3_Jan-Apr_Longline_1990	5.225E+00	4.654E-02
P3_Jan-Apr_Longline_1995	5.304E+00	3.990E-02

Parameter	Estimate	St. Dev.
P3_Jan-Apr_Longline_2000	5.363E+00	4.166E-02
P3_Jan-Apr_Longline_2005	5.303E+00	3.023E-02
P6_Jan-Apr_Longline_1977	-1.305E+00	8.021E-01
P6_Jan-Apr_Longline_1980	4.299E-01	1.070E+00
P6_Jan-Apr_Longline_1985	-1.160E+00	4.385E-01
P6_Jan-Apr_Longline_1990	-4.633E-01	1.375E-01
P6_Jan-Apr_Longline_1995	-6.573E-01	1.402E-01
P6_Jan-Apr_Longline_2000	-1.152E+00	1.444E-01
P6_Jan-Apr_Longline_2005	-8.331E-01	1.380E-01
P1_May-Jul_Longline_1977	6.359E+01	2.215E+00
P1_May-Jul_Longline_1980	6.248E+01	1.363E+00
P1_May-Jul_Longline_1985	6.344E+01	1.121E+00
P1_May-Jul_Longline_1990	6.370E+01	4.883E-01
P1_May-Jul_Longline_2000	5.994E+01	5.436E-01
P1_May-Jul_Longline_2005	6.480E+01	4.792E-01
P1_Aug-Dec_Longline_1977	6.085E+01	2.197E+00
P1_Aug-Dec_Longline_1980	6.954E+01	1.650E+00
P1_Aug-Dec_Longline_1985	6.423E+01	7.632E-01
P1_Aug-Dec_Longline_1990	6.709E+01	7.241E-01
P1_Aug-Dec_Longline_1995	6.949E+01	7.057E-01
P1_Aug-Dec_Longline_2000	6.360E+01	4.304E-01
P1_Aug-Dec_Longline_2005	6.347E+01	3.548E-01
P3_Aug-Dec_Longline_1977	4.556E+00	3.191E-01
P3_Aug-Dec_Longline_1980	5.404E+00	1.386E-01
P3_Aug-Dec_Longline_1985	4.853E+00	8.898E-02
P3_Aug-Dec_Longline_1990	5.035E+00	7.664E-02
P3_Aug-Dec_Longline_1995	5.506E+00	5.369E-02
P3_Aug-Dec_Longline_2000	5.182E+00	4.152E-02
P3_Aug-Dec_Longline_2005	4.964E+00	3.542E-02
P6_Aug-Dec_Longline_1977	-2.576E+00	2.135E+00
P6_Aug-Dec_Longline_1980	5.958E-01	8.004E-01
P6_Aug-Dec_Longline_1985	2.619E-01	2.474E-01
P6_Aug-Dec_Longline_1990	2.647E+00	1.089E+00
P6_Aug-Dec_Longline_1995	9.532E+00	1.225E+01
P6_Aug-Dec_Longline_2000	-3.277E-01	1.866E-01
P6_Aug-Dec_Longline_2005	9.612E+00	1.044E+01
P1_Jan-Apr_Pot_1977	6.879E+01	9.213E-01
P1_Jan-Apr_Pot_1995	6.849E+01	5.463E-01
P1_Jan-Apr_Pot_2000	6.814E+01	5.154E-01
P1_Jan-Apr_Pot_2005	6.914E+01	5.055E-01
P6_Jan-Apr_Pot_1977	2.247E-01	5.596E-01
P6_Jan-Apr_Pot_1995	-2.156E-01	2.537E-01
P6_Jan-Apr_Pot_2000	-5.518E-01	2.358E-01
P6_Jan-Apr_Pot_2005	1.860E-01	2.286E-01
P1_May-Jul_Pot_1977	6.729E+01	8.667E-01
P1_May-Jul_Pot_1995	6.600E+01	7.259E-01
P1_Aug-Dec_Pot_1977	6.851E+01	1.195E+00
P1_Aug-Dec_Pot_2000	6.249E+01	6.695E-01
P3_Aug-Dec_Pot_1977	5.193E+00	1.204E-01
P3_Aug-Dec_Pot_2000	4.476E+00	1.006E-01

Table 2.16d—Survey selectivity parameters as estimated by Model 1.

Parameter	Estimate	St. dev.
P1	1.269E+00	5.451E-02
P2	-2.778E+00	4.194E-01
P3	-2.419E+00	4.337E-01
P4	2.679E+00	4.005E-01
P5	-9.992E+00	_
P6	-1.142E+00	3.620E-01
P3_dev_1982	-3.959E-02	3.196E-02
P3_dev_1983	-2.239E-02	1.814E-02
P3_dev_1984	-6.714E-02	2.818E-02
P3_dev_1985	1.404E-02	2.124E-02
P3_dev_1986	-3.218E-02	2.332E-02
P3_dev_1987	4.392E-02	3.992E-02
P3_dev_1988	-6.461E-02	3.228E-02
P3_dev_1989	-1.059E-01	1.929E-02
P3_dev_1990	-1.735E-02	2.115E-02
P3_dev_1991	-2.836E-02	2.274E-02
P3_dev_1992	9.523E-02	3.965E-02
P3_dev_1993	6.306E-02	2.950E-02
P3_dev_1994	-2.748E-02	2.214E-02
P3_dev_1995	-7.591E-02	2.048E-02
P3_dev_1996	-9.974E-02	1.842E-02
P3_dev_1997	-4.908E-02	1.590E-02
P3_dev_1998	-6.036E-02	1.962E-02
P3_dev_1999	-6.380E-02	1.806E-02
P3_dev_2000	-2.340E-02	1.644E-02
P3_dev_2001	1.752E-01	3.637E-02
P3_dev_2002	-4.301E-03	2.399E-02
P3_dev_2003	1.514E-02	2.015E-02
P3_dev_2004	-2.416E-03	2.046E-02
P3_dev_2005	5.681E-02	2.643E-02
P3_dev_2006	1.716E-01	3.647E-02
P3_dev_2007	2.121E-01	3.599E-02
P3_dev_2008	1.245E-01	3.623E-02
P3_dev_2009	1.240E-02	1.632E-02
P3_dev_2010	-2.260E-02	2.707E-02
P3_dev_2011	4.285E-02	2.052E-02
P3_dev_2012	3.834E-02	2.083E-02

Table 2.16e—Annual log-scale catchability offsets as estimated by Model 2.

Year	Estimate	St. dev.
1982	-1.347E-01	6.558E-02
1983	1.069E-03	7.222E-02
1984	-1.790E-02	6.246E-02
1985	3.271E-03	7.514E-02
1986	4.319E-02	6.837E-02
1987	2.789E-02	5.862E-02
1988	7.409E-03	5.951E-02
1989	-1.411E-01	6.039E-02
1990	-6.804E-02	6.954E-02
1991	-5.707E-02	7.057E-02
1992	-4.942E-02	7.232E-02
1993	3.126E-02	7.423E-02
1994	2.142E-01	7.244E-02
1995	1.174E-01	6.744E-02
1996	7.039E-02	7.578E-02
1997	-8.659E-03	7.612E-02
1998	2.466E-03	6.531E-02
1999	-2.644E-02	6.582E-02
2000	-8.377E-02	6.586E-02
2001	1.122E-01	6.699E-02
2002	-1.397E-02	6.798E-02
2003	-2.726E-02	7.267E-02
2004	-1.784E-02	6.388E-02
2005	2.222E-02	7.529E-02
2006	-5.731E-02	5.795E-02
2007	1.106E-02	8.391E-02
2008	-7.326E-02	6.920E-02
2009	-1.078E-01	6.616E-02
2010	4.726E-02	7.413E-02
2011	6.428E-03	6.831E-02
2012	7.487E-02	7.058E-02
2013	-5.785E-04	7.946E-02
2014	9.254E-02	7.813E-02

Table 2.16f—Fishery selectivity parameters as estimated by Model 2.

Parameter	Estimate	St. dev.	Parameter	Estimate	St. dev.
Age 1 base	2.940E+00	3.500E-01	Age 4 dev 1977	-2.351E-02	1.505E-01
Age 2 base	3.146E+00	3.106E-01	Age 4 dev 1978	-4.844E-03	1.242E-01
Age 3 base	2.994E+00	1.907E-01	Age 4 dev 1979	-1.554E-01	7.067E-02
Age 4 base	1.899E+00	2.189E-01	Age 4 dev 1980	-1.143E-01	7.104E-02
Age 5 base	9.605E-01	1.049E-01	Age 4 dev 1981	-2.162E-01	7.296E-02
Age 6 base	2.376E-01	1.353E-01	Age 4 dev 1982	-1.980E-02	1.179E-01
Age 7 base	-2.593E-01	1.888E-01	Age 4 dev 1983	-7.268E-02	8.785E-02
Age 8 base	-1.088E-01	2.400E-01	Age 4 dev 1984	-1.807E-01	4.215E-02
Age 9 base	-2.297E-01	2.679E-01	Age 4 dev 1985	-3.788E-02	3.872E-02
Age 10 base	-8.527E-02	2.809E-01	Age 4 dev 1986	-9.415E-02	4.407E-02
Age 11 base	2.887E-01	2.994E-01	Age 4 dev 1987	-8.251E-03	3.716E-02
Age 12 base	2.556E-01	3.239E-01	Age 4 dev 1988	-2.232E-01	3.893E-02
Age 13 base	2.274E-02	3.351E-01	Age 4 dev 1989	-1.771E-01	5.583E-02
Age 14 base	-5.140E-02	3.390E-01	Age 4 dev 1990	-1.124E-01	4.725E-02
Age 15 base	-9.215E-02	3.350E-01	Age 4 dev 1991	-4.815E-02	3.328E-02
Age 16 base	-4.080E-02	3.400E-01	Age 4 dev 1992	-8.397E-03	3.256E-02
Age 17 base	-1.953E-02	3.432E-01	Age 4 dev 1993	-9.054E-02	3.230E-02
Age 18 base	-7.952E-03	3.461E-01	Age 4 dev 1994	-7.911E-02	3.420E-02
Age 19 base	-3.248E-03	3.480E-01	Age 4 dev 1995	-5.930E-02	2.977E-02
Age 20 base	-4.809E-03	3.488E-01	Age 4 dev 1996	1.453E-02	4.426E-02
			Age 4 dev 1997	-5.768E-02	3.398E-02
			Age 4 dev 1998	-2.169E-02	3.590E-02
			Age 4 dev 1999	-3.225E-02	2.967E-02
			Age 4 dev 2000	1.278E-01	6.981E-02
			Age 4 dev 2001	3.550E-02	4.897E-02
			Age 4 dev 2002	-3.068E-02	3.021E-02
			Age 4 dev 2003	2.128E-02	4.408E-02
			Age 4 dev 2004	4.845E-02	5.935E-02
			Age 4 dev 2005	4.517E-03	4.459E-02
			Age 4 dev 2006	8.274E-02	6.122E-02
			Age 4 dev 2007	1.028E-01	6.802E-02
			Age 4 dev 2008	6.501E-02	4.835E-02
			Age 4 dev 2009	1.362E-01	5.380E-02
			Age 4 dev 2010	2.185E-01	8.188E-02
			Age 4 dev 2011	1.053E-01	4.597E-02
			Age 4 dev 2012	1.437E-01	8.412E-02
			Age 4 dev 2013	-2.052E-02	3.320E-02
			Age 4 dev 2014	7.757E-02	4.240E-02

Table 2.16g—Survey selectivity parameters as estimated by Model 2.

Parameter	Estimate	St. dev.	Parameter	Estimate	St. dev.
Age 1 base	5.020E+00	3.190E-01	Age 2 dev 1982	4.634E-02	3.634E-02
Age 2 base	7.568E-01	1.606E-01	Age 2 dev 1983	-6.561E-04	2.080E-02
Age 3 base	1.860E-01	4.855E-02	Age 2 dev 1984	1.014E-01	3.688E-02
Age 4 base	-1.338E-01	5.749E-02	Age 2 dev 1985	-1.280E-02	2.076E-02
Age 5 base	-4.541E-02	7.879E-02	Age 2 dev 1986	4.001E-02	2.628E-02
Age 6 base	-1.294E-01	1.222E-01	Age 2 dev 1987	-5.292E-03	2.995E-02
Age 7 base	-3.186E-02	1.696E-01	Age 2 dev 1988	5.390E-02	4.593E-02
Age 8 base	-2.310E-01	2.156E-01	Age 2 dev 1989	1.243E-01	3.048E-02
Age 9 base	-2.028E-01	2.472E-01	Age 2 dev 1990	3.035E-03	2.389E-02
Age 10 base	-8.219E-02	2.674E-01	Age 2 dev 1991	3.720E-02	2.543E-02
Age 11 base	-5.096E-02	2.868E-01	Age 2 dev 1992	-5.641E-02	2.461E-02
Age 12 base	-3.937E-02	3.016E-01	Age 2 dev 1993	-3.507E-02	2.082E-02
Age 13 base	-5.490E-02	3.081E-01	Age 2 dev 1994	5.859E-02	2.440E-02
Age 14 base	-2.934E-02	3.128E-01	Age 2 dev 1995	7.995E-02	2.854E-02
Age 15 base	-1.431E-02	3.159E-01	Age 2 dev 1996	1.040E-01	2.773E-02
Age 16 base	-1.504E-02	3.166E-01	Age 2 dev 1997	3.362E-02	2.008E-02
Age 17 base	-1.567E-02	3.168E-01	Age 2 dev 1998	8.650E-02	2.529E-02
Age 18 base	-1.314E-02	3.172E-01	Age 2 dev 1999	7.535E-02	2.405E-02
Age 19 base	-9.784E-03	3.176E-01	Age 2 dev 2000	3.060E-02	1.942E-02
Age 20 base	-6.857E-03	3.180E-01	Age 2 dev 2001	-7.407E-02	1.889E-02
			Age 2 dev 2002	3.740E-02	2.326E-02
			Age 2 dev 2003	-3.265E-02	1.999E-02
			Age 2 dev 2004	1.163E-02	2.090E-02
			Age 2 dev 2005	-4.114E-02	2.056E-02
			Age 2 dev 2006	-6.592E-02	1.954E-02
			Age 2 dev 2007	-1.304E-01	1.869E-02
			Age 2 dev 2008	-2.780E-03	1.999E-02
			Age 2 dev 2009	-3.697E-02	1.807E-02
			Age 2 dev 2010	2.617E-02	2.829E-02
			Age 2 dev 2011	-5.947E-02	1.906E-02
			Age 2 dev 2012	-3.186E-02	1.903E-02
			Age 2 dev 2013	3.542E-02	2.462E-02

Table 2.17a—Annual fishing mortality rates as estimated by Models 1 and 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 1				Model 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	7.03E-02	1.27E-02	7.82E-02	1.38E-02	9.65E-02	3.57E-02	1.24E-01	4.05E-02
1978	8.06E-02	1.31E-02	8.92E-02	1.44E-02	1.09E-01	4.02E-02	1.39E-01	4.53E-02
1979	5.64E-02	8.42E-03	6.27E-02	9.37E-03	8.43E-02	2.96E-02	1.02E-01	3.29E-02
1980	4.89E-02	6.23E-03	5.39E-02	7.66E-03	1.02E-01	3.29E-02	1.22E-01	3.62E-02
1981	4.66E-02	5.04E-03	5.02E-02	6.57E-03	7.89E-02	2.20E-02	9.82E-02	2.53E-02
1982	3.61E-02	2.85E-03	3.95E-02	4.06E-03	6.58E-02	1.25E-02	7.65E-02	1.40E-02
1983	5.00E-02	3.04E-03	5.53E-02	4.51E-03	8.12E-02	1.22E-02	8.98E-02	1.33E-02
1984	6.83E-02	3.66E-03	7.40E-02	4.78E-03	1.16E-01	1.54E-02	1.36E-01	1.92E-02
1985	8.29E-02	4.00E-03	9.48E-02	5.56E-03	1.23E-01	1.55E-02	1.52E-01	2.03E-02
1986	8.21E-02	3.73E-03	9.18E-02	5.05E-03	1.19E-01	1.50E-02	1.60E-01	2.11E-02
1987	9.41E-02	3.99E-03	1.06E-01	5.09E-03	1.28E-01	1.68E-02	1.83E-01	2.46E-02
1988	1.24E-01	4.59E-03	1.43E-01	7.58E-03	1.75E-01	1.84E-02	2.10E-01	2.22E-02
1989	1.21E-01	4.31E-03	1.32E-01	5.62E-03	1.51E-01	1.63E-02	1.94E-01	2.52E-02
1990	1.33E-01	4.46E-03	1.41E-01	6.09E-03	1.86E-01	1.67E-02	2.17E-01	2.23E-02
1991	2.05E-01	7.19E-03	2.20E-01	9.30E-03	3.15E-01	3.06E-02	4.00E-01	4.79E-02
1992	1.97E-01	7.46E-03	2.20E-01	9.05E-03	3.41E-01	4.12E-02	4.59E-01	5.62E-02
1993	1.56E-01	6.47E-03	1.83E-01	8.44E-03	2.32E-01	3.29E-02	3.31E-01	4.16E-02
1994	1.88E-01	8.97E-03	2.18E-01	1.64E-02	3.03E-01	3.60E-02	3.69E-01	4.27E-02
1995	2.53E-01	8.71E-03	3.20E-01	1.21E-02	3.98E-01	3.99E-02	4.47E-01	4.93E-02
1996	2.37E-01	8.35E-03	2.90E-01	1.09E-02	4.13E-01	4.06E-02	4.70E-01	5.16E-02
1997	2.76E-01	9.89E-03	3.30E-01	1.23E-02	4.41E-01	4.97E-02	5.38E-01	6.90E-02
1998	2.07E-01	7.57E-03	2.59E-01	1.01E-02	3.72E-01	4.02E-02	4.22E-01	4.62E-02
1999	2.03E-01	7.66E-03	2.46E-01	9.52E-03	3.58E-01	4.19E-02	4.38E-01	5.54E-02
2000	1.81E-01	6.60E-03	2.33E-01	8.32E-03	3.43E-01	4.22E-02	4.25E-01	5.25E-02
2001	1.56E-01	5.01E-03	2.00E-01	6.08E-03	2.81E-01	3.40E-02	3.43E-01	4.35E-02
2002	1.92E-01	5.59E-03	2.39E-01	6.94E-03	3.37E-01	3.45E-02	3.78E-01	3.98E-02
2003	2.01E-01	5.60E-03	2.55E-01	7.01E-03	3.37E-01	3.43E-02	4.03E-01	4.69E-02
2004	2.17E-01	5.81E-03	2.78E-01	7.41E-03	3.27E-01	3.37E-02	3.96E-01	4.72E-02
2005	2.57E-01	7.24E-03	3.03E-01	8.73E-03	3.54E-01	3.20E-02	4.04E-01	4.01E-02
2006	2.84E-01	8.77E-03	3.37E-01	1.06E-02	3.92E-01	3.62E-02	4.75E-01	5.31E-02
2007	2.74E-01	9.23E-03	3.25E-01	1.10E-02	3.68E-01	3.72E-02	4.60E-01	5.35E-02
2008	3.08E-01	1.11E-02	3.64E-01	1.33E-02	4.51E-01	4.90E-02	5.61E-01	6.57E-02
2009	3.37E-01	1.36E-02	4.00E-01	1.63E-02	5.41E-01	6.47E-02	6.63E-01	8.08E-02
2010	2.74E-01	1.16E-02	3.27E-01	1.41E-02	4.72E-01	5.90E-02	5.76E-01	7.22E-02
2011	3.23E-01	1.45E-02	3.82E-01	1.75E-02	5.62E-01	7.19E-02	6.51E-01	8.77E-02
2012	2.89E-01	1.45E-02	3.47E-01	1.79E-02	5.57E-01	7.04E-02	6.01E-01	7.79E-02
2013	2.59E-01	1.48E-02	3.02E-01	1.74E-02	4.43E-01	6.44E-02	5.06E-01	8.05E-02
2014	2.47E-01	1.63E-02	2.95E-01	1.97E-02	5.63E-01	9.15E-02	6.08E-01	9.93E-02

Table 2.17b— Model 1 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	0.083	0.086	0.054	0.047	0.041	0.016	0.016	0.006	0.024	0.031	0	0	0	0	0
1978	0.095	0.099	0.064	0.055	0.049	0.016	0.017	0.006	0.025	0.034	0	0	0	0	0
1979	0.069	0.071	0.042	0.038	0.033	0.012	0.013	0.005	0.018	0.024	0	0	0	0	0
1980	0.061	0.061	0.030	0.040	0.034	0.010	0.010	0.004	0.013	0.017	0	0	0	0	0
1981	0.033	0.032	0.032	0.063	0.059	0.004	0.004	0.002	0.009	0.010	0	0	0	0	0
1982	0.034	0.035	0.035	0.044	0.035	0.001	0.001	0.001	0.004	0.005	0	0	0	0	0
1983	0.054	0.056	0.050	0.053	0.044	0.005	0.005	0.003	0.004	0.005	0	0	0	0	0
1984	0.061	0.065	0.056	0.055	0.048	0.007	0.008	0.006	0.027	0.037	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	0.087	0.093	0.066	0.065	0.053	0.017	0.018	0.005	0.027	0.038	0	0	0	0	0
1987	0.096	0.102	0.052	0.053	0.052	0.042	0.045	0.013	0.042	0.060	0	0	0	0	0
1988	0.194	0.209	0.101	0.112	0.120	0.001	0.001	0.002	0.003	0.004	0	0	0	0	0
1989	0.206	0.224	0.099	0.058	0.054	0.008	0.009	0.012	0.015	0.013	0.000	0.000	0.000	0.000	0.000
1990	0.175	0.192	0.092	0.033	0.028	0.031	0.034	0.047	0.051	0.047	0.000	0.000	0.002	0.002	0.001
1991	0.180	0.376	0.067	0.056	0.043	0.061	0.104	0.087	0.099	0.065	0.000	0.004	0.002	0.011	0.003
1992	0.148	0.221	0.055	0.044	0.014	0.132	0.236	0.141	0.091	0.000	0.000	0.009	0.030	0.011	0.000
1993	0.188	0.256	0.025	0.036	0.011	0.223	0.227	0.025	0.016	0.004	0.000	0.018	0.012	0.000	0.000
1994	0.086	0.292	0.019	0.100	0.019	0.189	0.261	0.030	0.104	0.000	0.000	0.040	0.010	0.016	0.000
1995	0.213	0.428	0.005	0.196	0.002	0.243	0.310	0.021	0.108	0.064	0.000	0.077	0.039	0.015	0.005
1996	0.144	0.374	0.030	0.107	0.021	0.237	0.263	0.021	0.120	0.024	0.000	0.127	0.062	0.023	0.005
1997	0.179	0.405	0.025	0.099	0.037	0.266	0.283	0.043	0.115	0.192	0.000	0.098	0.041	0.021	0.005
1998	0.121	0.237	0.026	0.141	0.021	0.281	0.202	0.021	0.096	0.114	0.018	0.064	0.032	0.011	0.004
1999	0.146	0.222	0.016	0.065	0.004	0.324	0.241	0.020	0.126	0.043	0.022	0.063	0.035	0.013	0.000
2000	0.171	0.224	0.016	0.026	0.004	0.301	0.084	0.007	0.124	0.142	0.137	0.051	0.006	0.009	0.000
2001	0.066	0.122	0.015	0.038	0.005	0.160	0.155	0.018	0.168	0.157	0.022	0.119	0.005	0.015	0.005
2002	0.109	0.185	0.034	0.036	0.002	0.323	0.145	0.009	0.195	0.117	0.019	0.092	0.003	0.015	0.006
2003	0.127	0.146	0.028	0.033	0.002	0.333	0.172	0.013	0.198	0.147	0.124	0.019	0.003	0.026	0.010
2004	0.184	0.160	0.045	0.041	0.001	0.356	0.173	0.015	0.190	0.182	0.096	0.033	0.005	0.021	0.005
2005	0.262	0.161	0.041	0.016	0.001	0.503	0.079	0.021	0.217	0.189	0.098	0.038	0.000	0.028	0.004
2006	0.320	0.176	0.041	0.028	0.001	0.588	0.088	0.014	0.311	0.011	0.139	0.049	0.003	0.029	0.009
2007	0.210	0.240	0.076	0.023	0.001	0.655	0.033	0.011	0.254	0.010	0.165	0.020	0.004	0.042	0.000
2008	0.235	0.120	0.031	0.050	0.007	0.723	0.070	0.026	0.311	0.111	0.155	0.038	0.002	0.060	0.002
2009	0.209	0.182	0.031	0.071	0.004	0.854	0.077	0.024	0.327	0.134	0.189	0.038	0.003	0.013	0.015
2010	0.267	0.140	0.024	0.054	0.012	0.644	0.033	0.024	0.180	0.127	0.198	0.033	0.002	0.041	0.019
2011	0.276	0.285	0.035	0.059	0.011	0.344	0.329	0.099	0.187	0.143	0.209	0.033	0.005	0.057	0.000
2012	0.417	0.165	0.036	0.046	0.006	0.315	0.245	0.115	0.132	0.142	0.216	0.027	0.005	0.030	0.006
2013	0.311	0.159	0.023	0.077	0.008	0.307	0.189	0.068	0.119	0.145	0.170	0.026	0.000	0.027	0.024
2014	0.249	0.197	0.024	0.067	0.006	0.250	0.228	0.098	0.108	0.112	0.182	0.041	0.001	0.025	0.018

Table 2.18—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 1	Model 2
B100%	824,000	714,000
B40%	330,000	286,000
B35%	288,000	250,000
B(2015)	409,000	213,000
B(2016)	473,000	269,000
B(2015)/B100%	0.50	0.30
B(2016)/B100%	0.57	0.38
F40%	0.29	0.34
F35%	0.35	0.41
maxFABC(2015)	0.29	0.25
maxFABC(2016)	0.29	0.32
maxABC(2015)	295,000	112,000
maxABC(2016)	316,000	190,000
FOFL(2015)	0.35	0.30
FOFL(2016)	0.35	0.39
OFL(2015)	346,000	132,000
OFL(2016)	389,000	221,000
Pr(maxABC(2015)>truOFL(2015))	0.01	0.33
Pr(maxABC(2016)>truOFL(2016))	0.03	0.32
Pr(B(2015)<B20%)	0.00	0.02
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

Legend:
B100% = equilibrium unfished spawning biomass
B40% = 40% of B100% (the inflection point of the harvest control rules in Tier 3)
B35% = 35% of B100% (the BMSY proxy for Tier 3)
B(year) = projected spawning biomass for year
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 2.19 (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	0.001	0.005	0.001	0.001	0.000	0.000	0.007	0.005	0.000	0.003	0.001
14	0.002	0.006	0.001	0.001	0.001	0.000	0.009	0.007	0.000	0.004	0.001
15	0.002	0.007	0.001	0.002	0.001	0.000	0.011	0.009	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	0.020	0.006
21	0.008	0.017	0.006	0.006	0.002	0.000	0.046	0.037	0.002	0.025	0.007
22	0.010	0.020	0.007	0.007	0.003	0.001	0.057	0.046	0.003	0.031	0.010
23	0.012	0.023	0.008	0.008	0.004	0.001	0.070	0.056	0.004	0.039	0.013
24	0.015	0.026	0.010	0.010	0.005	0.001	0.084	0.069	0.006	0.048	0.016
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	0.002	0.122	0.100	0.010	0.072	0.026
27	0.026	0.039	0.019	0.017	0.008	0.002	0.144	0.120	0.012	0.088	0.033
28	0.031	0.045	0.023	0.020	0.010	0.003	0.170	0.143	0.016	0.105	0.041
29	0.036	0.051	0.027	0.024	0.012	0.003	0.199	0.168	0.020	0.126	0.050
30	0.043	0.058	0.033	0.028	0.014	0.004	0.231	0.197	0.026	0.149	0.062
31	0.050	0.065	0.039	0.033	0.017	0.005	0.267	0.229	0.032	0.176	0.075
32	0.058	0.073	0.046	0.039	0.020	0.006	0.306	0.264	0.040	0.205	0.091
33	0.068	0.083	0.054	0.045	0.024	0.008	0.347	0.303	0.050	0.238	0.109
34	0.079	0.093	0.064	0.053	0.028	0.010	0.392	0.344	0.061	0.274	0.130
35	0.091	0.103	0.074	0.061	0.032	0.012	0.439	0.388	0.074	0.314	0.154
36	0.104	0.115	0.086	0.070	0.038	0.015	0.488	0.435	0.090	0.356	0.181
37	0.120	0.128	0.100	0.081	0.044	0.018	0.538	0.484	0.108	0.401	0.211
38	0.136	0.142	0.115	0.092	0.051	0.022	0.590	0.535	0.129	0.448	0.245
39	0.155	0.157	0.133	0.105	0.059	0.027	0.642	0.586	0.153	0.498	0.281
40	0.175	0.174	0.151	0.119	0.069	0.032	0.693	0.638	0.179	0.548	0.321
41	0.197	0.191	0.172	0.135	0.079	0.039	0.743	0.689	0.209	0.600	0.364
42	0.221	0.210	0.195	0.152	0.090	0.046	0.790	0.739	0.243	0.652	0.409
43	0.246	0.229	0.220	0.171	0.103	0.055	0.835	0.787	0.279	0.703	0.457
44	0.274	0.250	0.247	0.191	0.117	0.065	0.876	0.832	0.319	0.752	0.507
45	0.303	0.272	0.275	0.213	0.132	0.076	0.912	0.873	0.361	0.800	0.558
46	0.334	0.296	0.306	0.236	0.149	0.089	0.943	0.909	0.407	0.843	0.610
47	0.367	0.320	0.339	0.262	0.167	0.104	0.967	0.940	0.455	0.883	0.661
48	0.401	0.346	0.373	0.288	0.187	0.120	0.985	0.966	0.504	0.918	0.712
49	0.437	0.372	0.409	0.317	0.208	0.139	0.996	0.984	0.555	0.948	0.761
50	0.473	0.400	0.447	0.347	0.232	0.159	1.000	0.996	0.607	0.971	0.808
51	0.511	0.428	0.486	0.378	0.256	0.181	1.000	1.000	0.659	0.988	0.851
52	0.550	0.457	0.526	0.411	0.283	0.206	1.000	1.000	0.709	0.997	0.890
53	0.589	0.487	0.566	0.444	0.311	0.233	1.000	1.000	0.759	1.000	0.924
54	0.628	0.518	0.607	0.479	0.340	0.262	1.000	1.000	0.805	1.000	0.953
55	0.667	0.549	0.648	0.515	0.371	0.293	1.000	1.000	0.849	1.000	0.975
56	0.705	0.580	0.688	0.551	0.403	0.326	1.000	1.000	0.888	1.000	0.990
57	0.743	0.611	0.728	0.588	0.437	0.361	1.000	1.000	0.923	1.000	0.998
58	0.779	0.643	0.766	0.625	0.471	0.398	1.000	1.000	0.951	1.000	1.000
59	0.814	0.674	0.803	0.661	0.507	0.437	1.000	1.000	0.974	1.000	1.000
60	0.846	0.705	0.838	0.698	0.543	0.477	1.000	1.000	0.990	1.000	1.000

Table 2.19 (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	0.877	0.735	0.870	0.733	0.579	0.518	1.000	1.000	0.998	1.000	1.000
62	0.904	0.764	0.900	0.768	0.616	0.560	1.000	1.000	1.000	1.000	1.000
63	0.929	0.793	0.926	0.801	0.652	0.603	1.000	1.000	1.000	1.000	1.000
64	0.950	0.820	0.948	0.832	0.689	0.645	1.000	1.000	1.000	1.000	1.000
65	0.968	0.846	0.967	0.862	0.724	0.687	1.000	1.000	1.000	1.000	1.000
66	0.982	0.871	0.982	0.889	0.759	0.728	1.000	1.000	1.000	1.000	1.000
67	0.992	0.893	0.992	0.914	0.792	0.768	1.000	1.000	1.000	1.000	1.000
68	0.998	0.914	0.998	0.936	0.824	0.806	1.000	1.000	1.000	1.000	1.000
69	1.000	0.933	1.000	0.955	0.854	0.842	1.000	1.000	1.000	1.000	1.000
70	1.000	0.950	1.000	0.971	0.882	0.875	1.000	1.000	1.000	1.000	1.000
71	1.000	0.965	1.000	0.984	0.908	0.905	1.000	1.000	1.000	1.000	1.000
72	1.000	0.977	1.000	0.993	0.930	0.932	1.000	1.000	1.000	1.000	1.000
73	1.000	0.987	1.000	0.998	0.950	0.954	1.000	1.000	1.000	1.000	1.000
74	1.000	0.994	1.000	1.000	0.967	0.973	1.000	1.000	1.000	1.000	1.000
75	1.000	0.998	1.000	1.000	0.980	0.986	1.000	1.000	1.000	1.000	1.000
76	1.000	1.000	1.000	1.000	0.991	0.995	1.000	1.000	1.000	1.000	1.000
77	1.000	1.000	1.000	1.000	0.997	1.000	1.000	1.000	1.000	1.000	1.000
78	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
79	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
80	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
81	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
82	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
83	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
84	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
85	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
86	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
87	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
88	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
89	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
90	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
91	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
92	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
93	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
94	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
95	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
96	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
97	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
98	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
99	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
100	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
101	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
102	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
103	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
104	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
105	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
106	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
107	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
108	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
109	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
110	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
111	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
112	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
113	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
114	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
115	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
116	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
117	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
118	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
119	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
120	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 2.19 (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	0.007	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	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000
24	0.003	0.014	0.005	0.008	0.004	0.004	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	0.018	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	0.014	0.006	0.010	0.003	0.004	0.001	0.000	0.001	0.002	0.000
28	0.010	0.024	0.010	0.017	0.007	0.014	0.004	0.005	0.002	0.000	0.001	0.003	0.000
29	0.012	0.028	0.012	0.020	0.008	0.019	0.005	0.006	0.002	0.001	0.001	0.004	0.001
30	0.016	0.032	0.014	0.023	0.009	0.025	0.007	0.008	0.003	0.001	0.002	0.005	0.001
31	0.021	0.037	0.016	0.027	0.010	0.033	0.010	0.010	0.004	0.001	0.002	0.007	0.002
32	0.026	0.042	0.018	0.032	0.012	0.043	0.014	0.012	0.005	0.002	0.004	0.010	0.002
33	0.033	0.047	0.021	0.037	0.013	0.056	0.019	0.015	0.006	0.003	0.005	0.013	0.003
34	0.042	0.053	0.025	0.044	0.015	0.071	0.026	0.019	0.008	0.004	0.007	0.017	0.004
35	0.052	0.060	0.028	0.050	0.017	0.090	0.035	0.023	0.010	0.006	0.009	0.022	0.006
36	0.064	0.068	0.033	0.058	0.019	0.112	0.046	0.028	0.013	0.008	0.012	0.029	0.008
37	0.078	0.076	0.037	0.067	0.021	0.139	0.059	0.034	0.016	0.011	0.017	0.037	0.011
38	0.095	0.085	0.042	0.077	0.024	0.170	0.076	0.041	0.019	0.014	0.022	0.047	0.015
39	0.115	0.095	0.048	0.087	0.027	0.206	0.097	0.049	0.024	0.019	0.029	0.060	0.020
40	0.137	0.106	0.055	0.099	0.030	0.246	0.122	0.059	0.029	0.026	0.037	0.075	0.026
41	0.163	0.118	0.062	0.113	0.034	0.291	0.151	0.070	0.036	0.034	0.048	0.093	0.034
42	0.192	0.131	0.070	0.127	0.037	0.341	0.185	0.082	0.043	0.044	0.061	0.114	0.043
43	0.224	0.145	0.079	0.143	0.042	0.395	0.224	0.097	0.052	0.057	0.077	0.139	0.055
44	0.260	0.159	0.089	0.161	0.046	0.453	0.268	0.113	0.063	0.073	0.096	0.168	0.070
45	0.299	0.175	0.099	0.180	0.051	0.513	0.317	0.132	0.075	0.092	0.118	0.200	0.088
46	0.342	0.192	0.111	0.200	0.057	0.576	0.371	0.152	0.089	0.115	0.145	0.237	0.109
47	0.387	0.211	0.123	0.222	0.063	0.639	0.430	0.175	0.105	0.142	0.175	0.278	0.134
48	0.436	0.230	0.137	0.246	0.070	0.701	0.491	0.200	0.123	0.173	0.210	0.323	0.162
49	0.486	0.250	0.152	0.271	0.077	0.761	0.555	0.228	0.143	0.209	0.249	0.372	0.195
50	0.538	0.272	0.168	0.298	0.084	0.818	0.621	0.258	0.165	0.250	0.293	0.425	0.233
51	0.592	0.295	0.185	0.326	0.093	0.869	0.685	0.291	0.190	0.295	0.341	0.480	0.275
52	0.645	0.319	0.203	0.356	0.101	0.913	0.748	0.326	0.218	0.345	0.392	0.537	0.321
53	0.698	0.343	0.222	0.387	0.111	0.949	0.807	0.363	0.248	0.399	0.447	0.595	0.371
54	0.749	0.369	0.243	0.419	0.121	0.976	0.861	0.402	0.281	0.457	0.505	0.654	0.425
55	0.798	0.396	0.265	0.452	0.132	0.993	0.908	0.442	0.316	0.518	0.565	0.712	0.482
56	0.843	0.424	0.288	0.486	0.144	1.000	0.947	0.485	0.353	0.580	0.625	0.767	0.541
57	0.884	0.452	0.312	0.521	0.156	1.000	0.975	0.528	0.393	0.643	0.685	0.819	0.601
58	0.920	0.481	0.337	0.557	0.169	1.000	0.993	0.572	0.435	0.705	0.744	0.867	0.661
59	0.950	0.511	0.364	0.592	0.183	1.000	1.000	0.617	0.478	0.765	0.799	0.909	0.721
60	0.973	0.541	0.391	0.628	0.198	1.000	1.000	0.662	0.523	0.821	0.850	0.944	0.777

Table 2.19 (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	0.990	0.571	0.419	0.664	0.213	1.000	1.000	0.706	0.568	0.871	0.895	0.971	0.830
62	0.998	0.602	0.448	0.699	0.230	1.000	0.991	0.748	0.614	0.915	0.934	0.989	0.878
63	1.000	0.633	0.478	0.734	0.247	1.000	0.973	0.789	0.660	0.951	0.964	0.999	0.919
64	1.000	0.663	0.509	0.768	0.265	1.000	0.946	0.828	0.705	0.977	0.985	1.000	0.953
65	1.000	0.693	0.540	0.800	0.283	1.000	0.910	0.864	0.749	0.994	0.997	1.000	0.978
66	1.000	0.723	0.571	0.831	0.303	1.000	0.868	0.897	0.791	1.000	1.000	0.996	0.994
67	1.000	0.752	0.602	0.860	0.323	1.000	0.820	0.926	0.831	1.000	1.000	0.982	1.000
68	1.000	0.780	0.634	0.887	0.344	1.000	0.768	0.950	0.868	0.999	0.998	0.959	1.000
69	1.000	0.808	0.665	0.911	0.366	1.000	0.714	0.970	0.901	0.992	0.987	0.928	0.999
70	1.000	0.834	0.696	0.933	0.388	1.000	0.659	0.985	0.930	0.978	0.969	0.889	0.992
71	1.000	0.858	0.727	0.952	0.411	1.000	0.606	0.995	0.955	0.956	0.943	0.845	0.975
72	1.000	0.881	0.756	0.968	0.434	1.000	0.554	1.000	0.974	0.927	0.910	0.796	0.951
73	1.000	0.903	0.785	0.981	0.458	1.000	0.505	1.000	0.988	0.894	0.872	0.744	0.919
74	1.000	0.923	0.813	0.991	0.483	1.000	0.460	1.000	0.997	0.856	0.831	0.692	0.881
75	1.000	0.940	0.840	0.997	0.508	1.000	0.419	0.996	1.000	0.815	0.786	0.639	0.838
76	1.000	0.956	0.865	1.000	0.533	1.000	0.383	0.988	1.000	0.773	0.741	0.588	0.792
77	1.000	0.969	0.888	1.000	0.558	1.000	0.351	0.975	0.999	0.730	0.695	0.540	0.744
78	1.000	0.980	0.910	1.000	0.584	1.000	0.324	0.957	0.988	0.689	0.651	0.495	0.696
79	1.000	0.989	0.929	1.000	0.610	1.000	0.301	0.936	0.969	0.648	0.608	0.454	0.648
80	1.000	0.995	0.947	1.000	0.635	1.000	0.281	0.913	0.940	0.610	0.569	0.417	0.602
81	1.000	0.999	0.962	1.000	0.661	1.000	0.266	0.887	0.904	0.575	0.532	0.384	0.559
82	1.000	1.000	0.974	1.000	0.686	1.000	0.253	0.860	0.862	0.544	0.500	0.356	0.519
83	1.000	1.000	0.985	1.000	0.711	1.000	0.243	0.833	0.814	0.516	0.471	0.333	0.483
84	1.000	1.000	0.992	1.000	0.736	1.000	0.236	0.805	0.764	0.491	0.446	0.313	0.451
85	1.000	1.000	0.997	1.000	0.760	1.000	0.230	0.779	0.711	0.471	0.425	0.296	0.424
86	1.000	1.000	1.000	1.000	0.784	1.000	0.225	0.755	0.658	0.453	0.407	0.283	0.400
87	1.000	1.000	1.000	1.000	0.807	1.000	0.222	0.732	0.606	0.438	0.392	0.273	0.379
88	1.000	1.000	1.000	1.000	0.828	1.000	0.219	0.711	0.557	0.426	0.381	0.264	0.363
89	1.000	1.000	1.000	1.000	0.850	1.000	0.217	0.693	0.510	0.417	0.371	0.258	0.349
90	1.000	1.000	1.000	1.000	0.870	1.000	0.216	0.676	0.468	0.409	0.363	0.253	0.338
91	1.000	1.000	1.000	1.000	0.888	1.000	0.215	0.663	0.429	0.403	0.358	0.249	0.329
92	1.000	1.000	1.000	1.000	0.906	1.000	0.215	0.651	0.395	0.399	0.353	0.247	0.322
93	1.000	1.000	1.000	1.000	0.923	1.000	0.214	0.641	0.365	0.395	0.350	0.245	0.317
94	1.000	1.000	1.000	1.000	0.938	1.000	0.214	0.633	0.340	0.393	0.347	0.243	0.313
95	1.000	1.000	1.000	1.000	0.951	1.000	0.214	0.627	0.319	0.391	0.346	0.242	0.310
96	1.000	1.000	1.000	1.000	0.963	1.000	0.213	0.621	0.301	0.389	0.344	0.242	0.308
97	1.000	1.000	1.000	1.000	0.973	1.000	0.213	0.617	0.286	0.388	0.343	0.241	0.307
98	1.000	1.000	1.000	1.000	0.982	1.000	0.213	0.614	0.275	0.388	0.343	0.241	0.305
99	1.000	1.000	1.000	1.000	0.989	1.000	0.213	0.612	0.266	0.387	0.342	0.241	0.305
100	1.000	1.000	1.000	1.000	0.995	1.000	0.213	0.610	0.259	0.387	0.342	0.240	0.304
101	1.000	1.000	1.000	1.000	0.998	1.000	0.213	0.609	0.253	0.387	0.342	0.240	0.304
102	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.608	0.249	0.386	0.342	0.240	0.303
103	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.607	0.246	0.386	0.341	0.240	0.303
104	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.607	0.244	0.386	0.341	0.240	0.303
105	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.607	0.242	0.386	0.341	0.240	0.303
106	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.241	0.386	0.341	0.240	0.303
107	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.240	0.386	0.341	0.240	0.303
108	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.240	0.386	0.341	0.240	0.303
109	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.239	0.386	0.341	0.240	0.303
110	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.239	0.386	0.341	0.240	0.303
111	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.239	0.386	0.341	0.240	0.303
112	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.239	0.386	0.341	0.240	0.303
113	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.239	0.386	0.341	0.240	0.303
114	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.239	0.386	0.341	0.240	0.303
115	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.239	0.386	0.341	0.240	0.303
116	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.239	0.386	0.341	0.240	0.303
117	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.239	0.386	0.341	0.240	0.303
118	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.239	0.386	0.341	0.240	0.303
119	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.239	0.386	0.341	0.240	0.303
120	1.000	1.000	1.000	1.000	1.000	1.000	0.213	0.606	0.239	0.386	0.341	0.240	0.303

Table 2.19 (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	0.001	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	0.003	0.002	0.002	0.009	0.001	0.000	0.002	0.000	0.001	0.004	0.005	0.002
34	0.003	0.005	0.003	0.003	0.012	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	0.017	0.003	0.001	0.005	0.001	0.001	0.008	0.010	0.003
36	0.007	0.010	0.007	0.007	0.023	0.004	0.002	0.006	0.002	0.002	0.011	0.014	0.005
37	0.010	0.014	0.010	0.009	0.032	0.006	0.003	0.009	0.003	0.003	0.014	0.019	0.007
38	0.014	0.020	0.014	0.013	0.043	0.009	0.004	0.011	0.005	0.004	0.018	0.025	0.011
39	0.019	0.027	0.020	0.018	0.056	0.013	0.007	0.015	0.007	0.006	0.023	0.033	0.015
40	0.026	0.036	0.027	0.025	0.074	0.018	0.010	0.020	0.010	0.008	0.029	0.044	0.021
41	0.035	0.048	0.037	0.034	0.095	0.024	0.016	0.026	0.015	0.012	0.037	0.057	0.029
42	0.047	0.064	0.049	0.046	0.121	0.033	0.024	0.033	0.021	0.017	0.046	0.073	0.040
43	0.062	0.083	0.065	0.060	0.152	0.044	0.035	0.042	0.030	0.023	0.058	0.092	0.053
44	0.081	0.106	0.084	0.079	0.189	0.059	0.051	0.053	0.041	0.031	0.071	0.116	0.071
45	0.104	0.135	0.108	0.101	0.231	0.077	0.072	0.067	0.056	0.042	0.088	0.143	0.092
46	0.132	0.168	0.136	0.128	0.280	0.099	0.099	0.083	0.075	0.055	0.106	0.175	0.118
47	0.165	0.208	0.170	0.161	0.333	0.125	0.133	0.102	0.098	0.072	0.128	0.213	0.150
48	0.203	0.253	0.209	0.199	0.393	0.157	0.177	0.124	0.128	0.093	0.153	0.255	0.188
49	0.248	0.304	0.255	0.243	0.456	0.195	0.229	0.150	0.163	0.119	0.182	0.302	0.231
50	0.298	0.360	0.306	0.292	0.523	0.238	0.291	0.180	0.206	0.150	0.214	0.354	0.281
51	0.354	0.421	0.363	0.347	0.592	0.287	0.361	0.213	0.255	0.186	0.249	0.410	0.337
52	0.415	0.486	0.424	0.408	0.661	0.342	0.439	0.251	0.311	0.227	0.289	0.470	0.399
53	0.479	0.554	0.489	0.472	0.729	0.401	0.524	0.292	0.374	0.275	0.331	0.532	0.465
54	0.547	0.624	0.557	0.540	0.793	0.466	0.611	0.338	0.442	0.328	0.377	0.596	0.534
55	0.616	0.693	0.627	0.609	0.852	0.533	0.698	0.386	0.514	0.386	0.426	0.660	0.605
56	0.685	0.759	0.696	0.678	0.903	0.602	0.781	0.438	0.589	0.449	0.477	0.723	0.677
57	0.752	0.821	0.762	0.745	0.945	0.671	0.856	0.493	0.665	0.516	0.531	0.783	0.746
58	0.815	0.876	0.824	0.808	0.976	0.739	0.918	0.549	0.739	0.584	0.585	0.838	0.811
59	0.871	0.923	0.879	0.865	0.994	0.802	0.965	0.607	0.808	0.653	0.640	0.888	0.869
60	0.919	0.960	0.925	0.914	1.000	0.860	0.992	0.664	0.870	0.721	0.694	0.930	0.919

Table 2.19 (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	0.957	0.986	0.962	0.953	1.000	0.910	1.000	0.720	0.922	0.786	0.746	0.963	0.958
62	0.984	0.998	0.986	0.981	1.000	0.950	1.000	0.774	0.962	0.845	0.796	0.986	0.985
63	0.998	1.000	0.999	0.997	1.000	0.979	1.000	0.825	0.988	0.897	0.843	0.998	0.998
64	1.000	1.000	1.000	1.000	1.000	0.996	1.000	0.871	1.000	0.940	0.885	1.000	1.000
65	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.911	1.000	0.972	0.921	1.000	1.000
66	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.945	1.000	0.992	0.952	1.000	1.000
67	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.971	1.000	1.000	0.975	1.000	1.000
68	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.989	1.000	1.000	0.991	1.000	1.000
69	1.000	1.000	1.000	1.000	1.000	1.000	0.994	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	0.976	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	0.947	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	0.908	1.000	0.997	1.000	1.000	0.991	1.000
73	1.000	1.000	1.000	1.000	1.000	1.000	0.861	1.000	0.989	1.000	1.000	0.976	1.000
74	1.000	1.000	1.000	1.000	1.000	1.000	0.807	1.000	0.975	1.000	1.000	0.954	1.000
75	1.000	1.000	1.000	1.000	1.000	1.000	0.748	1.000	0.957	0.999	1.000	0.927	1.000
76	1.000	1.000	1.000	1.000	1.000	1.000	0.686	1.000	0.935	0.997	1.000	0.895	1.000
77	1.000	1.000	1.000	1.000	1.000	1.000	0.622	0.996	0.910	0.995	1.000	0.859	1.000
78	1.000	1.000	1.000	1.000	1.000	1.000	0.559	0.988	0.883	0.992	1.000	0.821	1.000
79	1.000	1.000	1.000	1.000	1.000	1.000	0.497	0.976	0.853	0.988	1.000	0.782	1.000
80	1.000	1.000	1.000	1.000	1.000	1.000	0.439	0.961	0.824	0.984	1.000	0.742	1.000
81	1.000	1.000	1.000	1.000	1.000	1.000	0.384	0.942	0.794	0.980	1.000	0.703	1.000
82	1.000	1.000	1.000	1.000	1.000	1.000	0.334	0.921	0.765	0.976	1.000	0.665	1.000
83	1.000	1.000	1.000	1.000	1.000	1.000	0.290	0.898	0.738	0.971	1.000	0.630	1.000
84	1.000	1.000	1.000	1.000	1.000	1.000	0.250	0.874	0.712	0.967	1.000	0.597	1.000
85	1.000	1.000	1.000	1.000	1.000	1.000	0.216	0.850	0.689	0.962	1.000	0.568	1.000
86	1.000	1.000	1.000	1.000	1.000	1.000	0.187	0.825	0.668	0.958	1.000	0.542	1.000
87	1.000	1.000	1.000	1.000	1.000	1.000	0.162	0.802	0.649	0.955	1.000	0.519	1.000
88	1.000	1.000	1.000	1.000	1.000	1.000	0.142	0.780	0.633	0.951	1.000	0.499	1.000
89	1.000	1.000	1.000	1.000	1.000	1.000	0.125	0.760	0.620	0.948	1.000	0.483	1.000
90	1.000	1.000	1.000	1.000	1.000	1.000	0.112	0.741	0.608	0.946	1.000	0.469	1.000
91	1.000	1.000	1.000	1.000	1.000	1.000	0.102	0.725	0.599	0.943	1.000	0.457	1.000
92	1.000	1.000	1.000	1.000	1.000	1.000	0.094	0.710	0.591	0.941	1.000	0.448	1.000
93	1.000	1.000	1.000	1.000	1.000	1.000	0.088	0.697	0.585	0.940	1.000	0.441	1.000
94	1.000	1.000	1.000	1.000	1.000	1.000	0.083	0.687	0.580	0.938	1.000	0.435	1.000
95	1.000	1.000	1.000	1.000	1.000	1.000	0.079	0.678	0.576	0.937	1.000	0.431	1.000
96	1.000	1.000	1.000	1.000	1.000	1.000	0.077	0.670	0.573	0.936	1.000	0.428	1.000
97	1.000	1.000	1.000	1.000	1.000	1.000	0.075	0.664	0.571	0.936	1.000	0.425	1.000
98	1.000	1.000	1.000	1.000	1.000	1.000	0.074	0.660	0.569	0.935	1.000	0.423	1.000
99	1.000	1.000	1.000	1.000	1.000	1.000	0.073	0.656	0.568	0.935	1.000	0.422	1.000
100	1.000	1.000	1.000	1.000	1.000	1.000	0.072	0.653	0.567	0.935	1.000	0.421	1.000
101	1.000	1.000	1.000	1.000	1.000	1.000	0.072	0.651	0.566	0.934	1.000	0.420	1.000
102	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.649	0.566	0.934	1.000	0.420	1.000
103	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.648	0.566	0.934	1.000	0.419	1.000
104	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.647	0.566	0.934	1.000	0.419	1.000
105	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.646	0.565	0.934	1.000	0.419	1.000
106	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.646	0.565	0.934	1.000	0.419	1.000
107	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
108	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
109	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
110	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
111	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
112	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
113	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
114	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
115	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
116	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
117	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
118	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
119	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000
120	1.000	1.000	1.000	1.000	1.000	1.000	0.071	0.645	0.565	0.934	1.000	0.419	1.000

Table 2.19 (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	0.000	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	0.000
37	0.001	0.001	0.002	0.001	0.001	0.002	0.004	0.001
38	0.002	0.002	0.002	0.002	0.002	0.003	0.006	0.001
39	0.003	0.003	0.003	0.002	0.003	0.005	0.008	0.002
40	0.004	0.004	0.005	0.003	0.005	0.007	0.011	0.003
41	0.006	0.006	0.007	0.005	0.007	0.011	0.015	0.005
42	0.008	0.009	0.010	0.007	0.010	0.015	0.020	0.008
43	0.012	0.013	0.015	0.010	0.014	0.022	0.027	0.013
44	0.016	0.018	0.020	0.015	0.020	0.030	0.036	0.020
45	0.023	0.025	0.028	0.020	0.027	0.041	0.046	0.031
46	0.031	0.034	0.038	0.028	0.037	0.055	0.060	0.045
47	0.042	0.046	0.050	0.038	0.051	0.073	0.076	0.065
48	0.056	0.060	0.066	0.050	0.067	0.095	0.097	0.092
49	0.073	0.079	0.086	0.066	0.088	0.123	0.121	0.126
50	0.095	0.102	0.111	0.086	0.114	0.156	0.149	0.170
51	0.121	0.129	0.140	0.111	0.146	0.196	0.182	0.223
52	0.152	0.162	0.175	0.140	0.183	0.242	0.220	0.286
53	0.189	0.201	0.216	0.175	0.227	0.294	0.263	0.359
54	0.232	0.246	0.263	0.216	0.278	0.352	0.310	0.441
55	0.281	0.296	0.315	0.263	0.334	0.416	0.363	0.528
56	0.335	0.352	0.373	0.315	0.397	0.484	0.419	0.619
57	0.395	0.414	0.436	0.374	0.464	0.556	0.479	0.710
58	0.459	0.479	0.503	0.436	0.535	0.629	0.541	0.795
59	0.527	0.548	0.572	0.503	0.607	0.701	0.605	0.871
60	0.597	0.618	0.642	0.572	0.680	0.770	0.669	0.932

Table 2.19 (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	0.667	0.687	0.711	0.642	0.750	0.834	0.731	0.975
62	0.735	0.754	0.777	0.711	0.816	0.891	0.790	0.997
63	0.799	0.817	0.838	0.777	0.875	0.937	0.845	1.000
64	0.858	0.874	0.892	0.838	0.924	0.971	0.893	1.000
65	0.909	0.922	0.936	0.892	0.963	0.993	0.934	1.000
66	0.949	0.959	0.970	0.936	0.988	1.000	0.966	1.000
67	0.979	0.985	0.991	0.970	0.999	1.000	0.987	1.000
68	0.996	0.998	1.000	0.991	1.000	1.000	0.999	1.000
69	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
70	1.000	0.998	0.994	1.000	1.000	1.000	1.000	1.000
71	0.992	0.985	0.974	0.996	1.000	1.000	1.000	1.000
72	0.975	0.960	0.941	0.982	1.000	1.000	1.000	1.000
73	0.948	0.924	0.896	0.958	1.000	1.000	1.000	1.000
74	0.915	0.880	0.844	0.926	1.000	1.000	1.000	1.000
75	0.877	0.831	0.786	0.888	1.000	1.000	1.000	1.000
76	0.836	0.780	0.726	0.847	1.000	1.000	1.000	1.000
77	0.794	0.728	0.668	0.804	1.000	1.000	1.000	1.000
78	0.754	0.679	0.613	0.763	1.000	1.000	1.000	1.000
79	0.716	0.634	0.563	0.723	1.000	1.000	1.000	1.000
80	0.683	0.594	0.520	0.688	1.000	1.000	1.000	1.000
81	0.654	0.559	0.483	0.657	1.000	1.000	1.000	1.000
82	0.630	0.531	0.453	0.630	1.000	1.000	1.000	1.000
83	0.611	0.508	0.429	0.609	1.000	1.000	1.000	1.000
84	0.595	0.491	0.410	0.592	1.000	1.000	1.000	1.000
85	0.584	0.477	0.396	0.578	1.000	1.000	1.000	1.000
86	0.575	0.467	0.386	0.569	1.000	1.000	1.000	1.000
87	0.569	0.460	0.379	0.561	1.000	1.000	1.000	1.000
88	0.564	0.455	0.374	0.556	1.000	1.000	1.000	1.000
89	0.561	0.452	0.371	0.553	1.000	1.000	1.000	1.000
90	0.559	0.450	0.369	0.550	1.000	1.000	1.000	1.000
91	0.558	0.448	0.367	0.549	1.000	1.000	1.000	1.000
92	0.557	0.448	0.367	0.548	1.000	1.000	1.000	1.000
93	0.557	0.447	0.366	0.547	1.000	1.000	1.000	1.000
94	0.556	0.447	0.366	0.547	1.000	1.000	1.000	1.000
95	0.556	0.447	0.366	0.547	1.000	1.000	1.000	1.000
96	0.556	0.446	0.366	0.547	1.000	1.000	1.000	1.000
97	0.556	0.446	0.366	0.546	1.000	1.000	1.000	1.000
98	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
99	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
100	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
101	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
102	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
103	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
104	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
105	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
106	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
107	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
108	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
109	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
110	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
111	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
112	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
113	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
114	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
115	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
116	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
117	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
118	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
119	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000
120	0.556	0.446	0.365	0.546	1.000	1.000	1.000	1.000

Table 2.20—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	0.318	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1983	0.000	0.375	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1984	0.000	0.231	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1985	0.000	0.497	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1986	0.000	0.342	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1987	0.000	0.591	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1988	0.000	0.238	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1989	0.000	0.130	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1990	0.000	0.392	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1991	0.000	0.355	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1992	0.000	0.725	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1993	0.000	0.645	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1994	0.000	0.358	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1995	0.000	0.205	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1996	0.000	0.144	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1997	0.000	0.287	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1998	0.000	0.251	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
1999	0.000	0.241	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2000	0.000	0.372	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2001	0.000	0.859	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2002	0.000	0.436	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2003	0.000	0.501	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2004	0.000	0.443	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2005	0.000	0.628	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2006	0.000	0.855	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2007	0.000	0.893	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2008	0.000	0.785	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2009	0.000	0.492	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2010	0.000	0.375	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2011	0.000	0.588	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2012	0.000	0.574	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2013	0.000	0.451	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242
2014	0.000	0.451	1.000	1.000	0.975	0.863	0.701	0.538	0.408	0.323	0.277	0.255	0.246	0.243	0.242	0.242	0.242	0.242	0.242	0.242	0.242

Table 2.21—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	9.35	10.96	12.97	16.49	20.19	0.01	0.02	0.03	0.05	0.10
2	23.02	25.74	28.99	32.69	35.60	0.15	0.20	0.28	0.41	0.55
3	37.82	39.96	42.52	45.42	47.71	0.68	0.77	0.90	1.15	1.38
4	49.46	51.15	53.16	55.44	57.24	1.57	1.66	1.81	2.13	2.43
5	58.62	59.94	61.52	63.32	64.74	2.67	2.72	2.85	3.23	3.58
6	65.82	66.86	68.10	69.52	70.63	3.84	3.82	3.91	4.32	4.71
7	71.48	72.30	73.28	74.39	75.26	4.98	4.89	4.91	5.35	5.75
8	75.93	76.58	77.35	78.22	78.91	6.02	5.85	5.82	6.26	6.67
9	79.44	79.94	80.55	81.24	81.78	6.94	6.69	6.60	7.05	7.46
10	82.19	82.59	83.07	83.61	84.03	7.73	7.41	7.27	7.71	8.13
11	84.36	84.67	85.05	85.47	85.81	8.39	8.01	7.82	8.26	8.68
12	86.06	86.31	86.60	86.94	87.20	8.94	8.51	8.28	8.71	9.14
13	87.40	87.60	87.83	88.09	88.30	9.38	8.91	8.65	9.08	9.50
14	88.46	88.61	88.79	89.00	89.16	9.75	9.24	8.95	9.38	9.80
15	89.29	89.41	89.55	89.71	89.84	10.04	9.50	9.19	9.62	10.03
16	89.94	90.03	90.15	90.27	90.37	10.27	9.71	9.38	9.80	10.22
17	90.45	90.53	90.61	90.71	90.79	10.45	9.88	9.53	9.96	10.37
18	90.85	90.91	90.98	91.06	91.12	10.60	10.01	9.65	10.08	10.49
19	91.17	91.22	91.27	91.33	91.38	10.72	10.12	9.75	10.17	10.59
20	91.61	91.64	91.68	91.72	91.75	10.88	10.27	9.89	10.31	10.72

Table 2.22—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	13.31	14.82	16.72	21.67	25.56	15.72	17.17	20.21	24.13	28.20	12.16	15.67	20.40	24.92	31.49	12.97
2	27.47	30.38	33.04	37.74	40.35	29.77	32.64	37.16	40.77	43.42	32.03	34.93	38.11	43.62	46.04	28.99
3	42.88	45.02	45.54	48.53	50.34	44.54	46.49	49.42	51.58	53.32	46.76	48.67	50.30	53.24	54.74	42.52
4	54.15	55.71	54.57	56.59	58.14	54.59	55.93	57.57	58.93	60.23	56.45	57.71	58.31	59.62	60.80	53.16
5	62.39	63.54	61.98	63.64	64.98	61.58	62.54	63.73	64.88	66.04	62.98	63.87	64.25	65.12	66.23	61.52
6	68.52	69.40	68.24	69.60	70.70	66.69	67.41	69.08	70.16	71.16	67.76	68.46	69.38	70.24	71.23	68.10
7	73.28	73.98	73.32	74.42	75.29	70.62	71.19	73.71	74.66	75.50	71.64	72.23	73.87	74.69	75.52	73.28
8	77.12	77.68	77.36	78.23	78.92	73.81	74.29	77.55	78.35	79.02	75.02	75.54	77.64	78.36	79.03	77.35
9	80.23	80.69	80.56	81.24	81.78	76.51	76.92	80.66	81.31	81.84	77.99	78.45	80.71	81.31	81.84	80.55
10	82.75	83.12	83.07	83.61	84.04	78.83	79.18	83.13	83.65	84.07	80.56	80.94	83.16	83.65	84.07	83.07
11	84.77	85.06	85.05	85.47	85.81	80.80	81.10	85.09	85.50	85.83	82.70	83.02	85.11	85.50	85.83	85.05
12	86.38	86.62	86.60	86.94	87.20	82.45	82.69	86.63	86.96	87.22	84.46	84.72	86.65	86.96	87.22	86.60
13	87.66	87.85	87.83	88.09	88.30	83.81	84.01	87.85	88.11	88.31	85.87	86.08	87.86	88.11	88.31	87.83
14	88.68	88.82	88.79	89.00	89.16	84.91	85.07	88.81	89.01	89.17	87.00	87.16	88.82	89.01	89.17	88.79
15	89.48	89.59	89.55	89.71	89.84	85.80	85.93	89.56	89.72	89.85	87.89	88.02	89.57	89.72	89.85	89.55
16	90.11	90.20	90.14	90.27	90.37	86.51	86.62	90.16	90.28	90.38	88.60	88.70	90.16	90.28	90.38	90.14
17	90.61	90.68	90.61	90.71	90.79	87.08	87.16	90.62	90.72	90.80	89.15	89.24	90.63	90.72	90.80	90.61
18	91.00	91.06	90.98	91.06	91.12	87.53	87.59	90.99	91.06	91.13	89.59	89.66	91.00	91.06	91.13	90.98
19	91.31	91.35	91.27	91.33	91.38	87.88	87.94	91.28	91.34	91.39	89.94	89.99	91.28	91.34	91.39	91.27
20	91.74	91.77	91.67	91.71	91.74	88.38	88.38	91.68	91.72	91.75	90.42	90.44	91.69	91.72	91.75	91.67

Table 2.23—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	0.05	0.06	0.09	0.16	0.26	0.03	0.05	0.10	0.19	0.36	0.03
2	0.25	0.32	0.41	0.63	0.80	0.31	0.40	0.58	0.80	1.00	0.39	0.49	0.63	0.98	1.19	0.28
3	0.99	1.10	1.10	1.38	1.60	1.10	1.21	1.41	1.66	1.91	1.28	1.38	1.49	1.83	2.06	0.90
4	2.05	2.13	1.94	2.25	2.53	2.09	2.15	2.27	2.53	2.81	2.32	2.36	2.36	2.62	2.88	1.81
5	3.21	3.22	2.90	3.27	3.61	3.06	3.05	3.14	3.45	3.77	3.27	3.25	3.21	3.48	3.80	2.85
6	4.31	4.25	3.93	4.34	4.72	3.94	3.87	4.06	4.43	4.80	4.14	4.05	4.10	4.44	4.81	3.91
7	5.34	5.20	4.92	5.35	5.75	4.73	4.60	4.98	5.39	5.79	4.95	4.81	5.01	5.40	5.80	4.91
8	6.28	6.08	5.82	6.26	6.67	5.46	5.28	5.85	6.28	6.69	5.75	5.57	5.87	6.28	6.70	5.82
9	7.13	6.86	6.60	7.05	7.47	6.14	5.91	6.62	7.06	7.48	6.54	6.30	6.63	7.06	7.48	6.60
10	7.87	7.53	7.27	7.71	8.13	6.77	6.49	7.28	7.72	8.14	7.26	6.97	7.28	7.72	8.14	7.27
11	8.50	8.11	7.82	8.26	8.68	7.34	7.02	7.83	8.27	8.69	7.90	7.56	7.83	8.27	8.69	7.82
12	9.02	8.58	8.28	8.71	9.14	7.84	7.48	8.28	8.72	9.14	8.46	8.06	8.29	8.72	9.14	8.28
13	9.45	8.98	8.65	9.08	9.50	8.27	7.87	8.65	9.09	9.51	8.92	8.48	8.65	9.09	9.51	8.65
14	9.80	9.29	8.95	9.38	9.80	8.63	8.19	8.95	9.38	9.80	9.29	8.82	8.95	9.38	9.80	8.95
15	10.09	9.55	9.19	9.62	10.03	8.93	8.46	9.19	9.62	10.04	9.60	9.10	9.19	9.62	10.04	9.19
16	10.32	9.76	9.38	9.80	10.22	9.17	8.68	9.38	9.81	10.22	9.85	9.32	9.38	9.81	10.22	9.38
17	10.50	9.92	9.53	9.96	10.37	9.36	8.86	9.53	9.96	10.37	10.04	9.50	9.53	9.96	10.37	9.53
18	10.64	10.05	9.65	10.08	10.49	9.52	9.00	9.65	10.08	10.49	10.20	9.64	9.66	10.08	10.49	9.65
19	10.76	10.16	9.75	10.17	10.59	9.64	9.11	9.75	10.17	10.59	10.32	9.75	9.75	10.17	10.59	9.75
20	10.92	10.31	9.89	10.31	10.72	9.82	9.26	9.89	10.31	10.72	10.50	9.91	9.89	10.31	10.72	9.89

Table 2.24—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 1. Spawning biomasses listed for 2014 under last year's assessment and for 2015 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	561,621	553,541	157,153	31,383	591,789	583,189	166,807	32,473
1978	640,257	592,564	174,035	31,397	673,991	623,433	184,303	32,478
1979	810,988	692,685	201,152	32,341	851,180	731,198	212,668	33,417
1980	1,183,740	1,130,020	255,387	34,626	1,228,590	1,174,450	268,722	35,685
1981	1,608,760	1,548,960	359,542	38,170	1,654,360	1,593,140	374,761	39,140
1982	1,955,710	1,934,700	508,370	42,465	1,999,880	1,978,410	524,665	43,215
1983	2,134,940	2,115,170	650,040	44,805	2,176,460	2,156,140	666,225	45,293
1984	2,148,120	2,067,770	723,255	43,170	2,186,380	2,105,700	738,585	43,458
1985	2,129,910	2,106,260	719,565	38,729	2,163,030	2,138,880	733,640	38,886
1986	2,083,990	2,017,450	683,920	33,575	2,111,450	2,044,680	696,235	33,637
1987	2,069,030	2,040,920	660,835	29,068	2,090,360	2,061,760	670,945	29,050
1988	2,001,880	1,988,210	641,025	25,488	2,018,010	2,003,880	648,850	25,404
1989	1,803,710	1,792,190	603,990	22,529	1,816,540	1,804,590	609,820	22,403
1990	1,573,900	1,545,290	556,575	19,836	1,585,510	1,556,390	561,175	19,696
1991	1,374,340	1,320,330	480,137	17,063	1,385,830	1,331,370	484,294	16,935
1992	1,239,610	1,196,890	386,565	14,486	1,250,330	1,207,410	390,653	14,374
1993	1,231,310	1,204,240	338,645	12,666	1,240,290	1,212,580	342,483	12,567
1994	1,280,210	1,223,720	352,954	11,953	1,287,640	1,231,000	356,239	11,843
1995	1,310,130	1,288,940	356,898	11,957	1,315,290	1,293,960	359,402	11,818
1996	1,253,840	1,230,630	351,617	12,139	1,256,420	1,233,180	353,375	11,964
1997	1,174,940	1,146,330	341,393	12,116	1,175,170	1,146,310	342,350	11,904
1998	1,074,320	1,014,680	313,668	11,846	1,072,210	1,013,230	313,764	11,599
1999	1,102,280	1,077,070	299,245	11,502	1,096,100	1,070,880	298,490	11,218
2000	1,146,980	1,119,580	300,649	11,288	1,136,280	1,109,280	298,729	10,955
2001	1,169,800	1,121,990	330,058	11,228	1,154,260	1,107,370	326,584	10,829
2002	1,200,930	1,172,400	338,679	10,851	1,179,400	1,151,480	333,423	10,393
2003	1,185,320	1,170,620	332,244	10,158	1,157,830	1,143,210	326,080	9,653
2004	1,108,780	1,085,570	323,303	9,468	1,080,000	1,057,220	315,006	8,904
2005	994,247	975,421	293,807	8,905	962,376	944,101	283,523	8,285
2006	872,160	855,239	252,761	8,370	838,791	822,381	241,555	7,719
2007	769,195	745,362	218,450	7,846	734,535	711,516	206,900	7,177
2008	738,561	674,191	193,596	7,508	700,463	639,210	181,597	6,808
2009	808,198	780,237	180,024	7,605	761,111	733,346	166,996	6,820
2010	940,591	847,845	195,078	8,612	886,635	791,937	179,755	7,611
2011	1,163,810	1,146,670	246,167	11,188	1,110,430	1,091,380	227,899	9,756
2012	1,232,570	1,169,120	344,516	19,306	1,249,320	1,186,650	270,608	13,301
2013	1,347,910	1,264,450	316,266	20,736	1,373,860	1,286,090	321,496	18,086
2014	1,570,580	1,545,070	360,956	23,324	1,537,190	1,497,620	364,513	23,729
2015					1,678,010	1,594,630	409,446	28,093

Table 2.25—Time series of EBS Pacific cod age 0 recruitment (1000s of fish), with standard deviations, as estimated last year and this year under Model 1.

	Last year's values		This year's values	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	1,767,430	196,764	1,776,400	197,362
1978	743,958	159,596	740,864	157,782
1979	900,256	98,659	913,365	97,721
1980	308,752	42,735	312,227	42,580
1981	180,686	27,113	186,390	27,473
1982	1,225,390	49,555	1,218,590	49,129
1983	265,226	31,477	269,779	31,121
1984	994,261	43,759	987,710	43,239
1985	417,784	30,607	420,795	30,302
1986	198,317	19,072	203,096	19,072
1987	141,601	15,750	146,013	15,693
1988	365,429	21,053	368,834	20,985
1989	776,481	31,931	775,657	31,615
1990	631,381	28,870	627,593	28,343
1991	333,648	21,232	339,745	21,109
1992	849,853	27,220	844,141	26,769
1993	296,575	17,591	295,784	17,305
1994	325,136	16,665	321,890	16,327
1995	353,081	19,679	354,252	19,292
1996	892,906	29,009	874,354	27,935
1997	356,171	18,279	353,606	17,742
1998	354,175	17,206	345,764	16,613
1999	701,237	21,312	681,454	20,277
2000	424,510	15,137	411,301	14,386
2001	194,385	11,269	191,772	10,829
2002	333,977	13,088	324,762	12,418
2003	268,995	13,026	258,661	12,225
2004	235,688	12,624	226,348	11,753
2005	270,182	14,125	259,582	13,073
2006	973,726	35,471	917,211	31,230
2007	287,293	19,704	278,036	18,500
2008	1,427,530	70,863	1,441,320	62,674
2009	177,938	24,410	207,181	24,276
2010	857,525	66,895	831,528	54,924
2011	1,265,700	110,346	1,305,490	95,353
2012	342,104	64,450	482,541	58,491
2013			1,230,400	188,607
Average	567,758		587,147	

Table 2.26—Numbers (1000s) at age at time of spawning (March) as estimated by Model 1.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	1776400	423634	35736	190691	43021	28978	18979	12251	7863	5036	3223	2062	1319	843	539	345	220	141	90	58	102
1978	740864	1264370	301400	25243	131358	28859	19199	12543	8104	5209	3341	2140	1370	876	561	359	229	147	94	60	106
1979	913365	527319	899591	212876	17364	87870	19053	12641	8265	5349	3443	2210	1416	907	581	371	238	152	97	62	110
1980	312227	650100	375217	636811	147927	11823	59228	12812	8504	5566	3605	2322	1491	956	612	392	251	161	103	66	117
1981	186390	222233	462593	266016	446450	102368	8103	40390	8717	5781	3783	2450	1578	1014	650	416	267	171	109	70	124
1982	1218590	132666	158124	327778	186301	308768	70144	5523	27452	5917	3922	2566	1661	1070	687	441	282	181	116	74	131
1983	269779	867350	94395	112020	229523	129023	212267	48027	3774	18742	4038	2676	1750	1133	730	469	301	193	123	79	140
1984	987710	192019	617085	66779	78040	157580	87720	143552	32398	2543	12621	2719	1801	1178	763	491	316	202	130	83	147
1985	420795	702995	136586	436090	46318	53002	105384	58186	94894	21392	1679	8333	1795	1190	778	504	325	209	134	86	152
1986	203096	299496	500060	96538	301979	31286	35155	69204	38039	61935	13957	1095	5439	1172	777	508	329	212	136	87	156
1987	146013	144551	213029	353286	66775	203737	20724	23048	45159	24779	40329	9089	714	3544	764	507	331	215	138	89	158
1988	368834	103918	102776	150250	243308	44594	132972	13359	14779	28903	15855	25811	5819	457	2271	490	325	213	138	89	159
1989	775657	262498	73865	72190	102164	160011	28587	83833	8342	9180	17904	9805	15948	3593	282	1401	302	200	131	85	153
1990	627593	552082	186701	51984	49165	67240	102929	18162	52946	5255	5776	11259	6165	10026	2259	177	881	190	126	82	149
1991	339745	446696	392786	132007	35674	32082	42364	63950	11241	32753	3252	3576	6974	3820	6214	1400	110	546	118	78	144
1992	844141	241818	317812	277550	89651	22439	19041	24563	36873	6483	18918	1881	2071	4043	2216	3606	813	64	317	68	129
1993	295784	600825	172042	224504	188299	56032	13166	10918	14049	21164	3736	10941	1091	1203	2351	1290	2101	474	37	185	115
1994	321890	210529	427546	121880	154860	123209	35165	8139	6747	8716	13184	2335	6853	684	756	1478	811	1322	298	23	189
1995	354252	229107	149770	301812	82597	96973	72407	20160	4653	3872	5025	7630	1355	3986	399	441	863	474	772	174	124
1996	874354	252142	163003	105861	205022	51582	56216	40552	11189	2582	2154	2800	4258	757	2228	223	247	483	265	432	167
1997	353606	622327	179385	115152	71734	127435	29746	31363	22467	6212	1439	1204	1569	2389	425	1252	125	139	272	149	338
1998	345764	251683	442793	126760	77704	43961	71994	16223	16978	12186	3381	786	659	860	1311	234	689	69	76	150	268
1999	681454	246101	179070	312882	85949	48716	25900	41343	9270	9719	6996	1946	453	380	497	758	135	398	40	44	242
2000	411301	485035	175119	126494	211635	53680	28638	14906	23791	5365	5657	4089	1141	266	224	293	447	80	235	24	169
2001	191772	292751	345188	123941	86352	136573	33448	17672	9226	14818	3361	3560	2582	722	169	142	186	284	51	150	123
2002	324762	136497	208330	243588	82992	53419	80726	19625	10472	5537	8988	2055	2189	1594	447	105	88	116	177	32	170
2003	258661	231155	97131	146846	161973	50550	30935	46331	11372	6147	3286	5378	1237	1323	966	272	64	54	71	108	123
2004	226348	184106	164482	68417	97263	97941	29101	17686	26764	6656	3637	1960	3226	745	799	585	165	39	33	43	140
2005	259582	161107	131021	116035	45183	57593	54248	15866	9722	14914	3754	2071	1124	1859	431	463	340	96	23	19	107
2006	917211	184762	114659	92587	77046	26757	31609	29014	8473	5222	8063	2040	1130	615	1020	237	255	187	53	12	70
2007	278036	652843	131497	81048	61550	45646	14684	16928	15547	4575	2842	4415	1123	624	340	565	131	142	104	29	46
2008	1441320	197897	464625	92863	53638	36287	24975	7844	9041	8359	2478	1548	2415	616	343	188	312	73	78	58	42
2009	207181	1025890	140843	327819	60683	30535	18958	12743	4018	4681	4372	1306	821	1286	329	184	101	167	39	42	53
2010	831528	147465	730119	99407	215111	34936	16151	9754	6551	2080	2441	2293	688	434	682	175	98	54	89	21	51
2011	1305490	591856	104951	516404	66700	131160	19980	9024	5431	3658	1166	1373	1293	389	245	386	99	55	30	51	41
2012	482541	929208	421213	74153	342601	38863	69072	10088	4519	2730	1850	593	701	663	200	126	199	51	29	16	47
2013	1230400	343458	661317	297973	49770	206806	21659	37312	5424	2440	1483	1010	325	385	365	110	70	110	28	16	35
2014	551811	875761	244442	467892	200560	30485	118304	12066	20701	3020	1365	832	569	183	218	206	62	40	62	16	29

Table 2.27—Model 1 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	0.026	0.053	0.068	0.072	0.071	0.070	0.069	0.068	0.067	0.066	0.066	0.066	0.066	0.066	0.065	0.065	0.065
1978	0.000	0.006	0.030	0.061	0.078	0.082	0.082	0.080	0.079	0.078	0.077	0.077	0.076	0.076	0.076	0.076	0.076	0.076	0.076
1979	0.000	0.004	0.021	0.042	0.054	0.058	0.057	0.056	0.055	0.054	0.054	0.054	0.053	0.053	0.053	0.053	0.053	0.053	0.053
1980	0.000	0.003	0.014	0.029	0.041	0.048	0.050	0.051	0.052	0.052	0.052	0.052	0.052	0.052	0.051	0.051	0.051	0.051	0.051
1981	0.000	0.004	0.014	0.027	0.037	0.043	0.046	0.048	0.048	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	0.030	0.035	0.037	0.038	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
1983	0.000	0.005	0.018	0.032	0.043	0.049	0.052	0.053	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054
1984	0.000	0.005	0.022	0.042	0.057	0.066	0.069	0.070	0.071	0.071	0.071	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
1985	0.000	0.005	0.023	0.047	0.067	0.078	0.084	0.086	0.086	0.086	0.086	0.086	0.085	0.085	0.085	0.085	0.085	0.085	0.084
1986	0.000	0.005	0.023	0.046	0.065	0.076	0.081	0.084	0.085	0.085	0.085	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084
1987	0.000	0.005	0.023	0.050	0.074	0.088	0.094	0.096	0.096	0.095	0.094	0.094	0.093	0.093	0.092	0.092	0.092	0.092	0.091
1988	0.001	0.009	0.037	0.069	0.097	0.116	0.127	0.133	0.136	0.138	0.139	0.139	0.140	0.140	0.140	0.140	0.140	0.140	0.141
1989	0.000	0.008	0.035	0.067	0.094	0.111	0.120	0.124	0.126	0.127	0.127	0.127	0.128	0.128	0.128	0.128	0.128	0.128	0.128
1990	0.000	0.003	0.024	0.072	0.112	0.129	0.135	0.136	0.136	0.136	0.136	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135
1991	0.000	0.003	0.034	0.107	0.170	0.199	0.207	0.208	0.208	0.206	0.205	0.205	0.204	0.204	0.203	0.203	0.203	0.203	0.203
1992	0.000	0.002	0.027	0.099	0.167	0.196	0.202	0.200	0.196	0.193	0.191	0.189	0.188	0.187	0.187	0.186	0.186	0.185	0.185
1993	0.000	0.002	0.021	0.077	0.135	0.161	0.164	0.160	0.156	0.152	0.149	0.147	0.145	0.144	0.143	0.143	0.142	0.142	0.142
1994	0.000	0.003	0.026	0.093	0.160	0.191	0.196	0.192	0.188	0.184	0.181	0.179	0.177	0.176	0.175	0.175	0.174	0.174	0.173
1995	0.000	0.003	0.031	0.114	0.203	0.249	0.263	0.263	0.261	0.258	0.256	0.255	0.254	0.253	0.253	0.253	0.253	0.252	0.252
1996	0.000	0.003	0.028	0.107	0.192	0.233	0.244	0.242	0.238	0.235	0.232	0.231	0.229	0.228	0.228	0.227	0.227	0.227	0.226
1997	0.000	0.003	0.035	0.128	0.223	0.270	0.282	0.281	0.277	0.273	0.271	0.269	0.267	0.266	0.266	0.265	0.265	0.265	0.264
1998	0.000	0.002	0.026	0.095	0.168	0.204	0.213	0.212	0.209	0.206	0.204	0.203	0.202	0.201	0.201	0.200	0.200	0.200	0.200
1999	0.000	0.002	0.023	0.092	0.167	0.202	0.208	0.204	0.199	0.194	0.190	0.188	0.186	0.185	0.184	0.183	0.183	0.183	0.182
2000	0.000	0.003	0.033	0.103	0.166	0.190	0.189	0.179	0.170	0.162	0.157	0.153	0.151	0.149	0.147	0.146	0.145	0.145	0.144
2001	0.000	0.003	0.035	0.103	0.154	0.169	0.163	0.153	0.143	0.136	0.130	0.127	0.124	0.122	0.121	0.120	0.119	0.118	0.117
2002	0.000	0.004	0.040	0.120	0.182	0.201	0.195	0.183	0.172	0.163	0.157	0.153	0.150	0.148	0.146	0.145	0.144	0.143	0.142
2003	0.000	0.004	0.042	0.126	0.194	0.214	0.208	0.194	0.181	0.171	0.165	0.160	0.157	0.154	0.152	0.151	0.150	0.149	0.148
2004	0.000	0.005	0.048	0.138	0.210	0.233	0.227	0.213	0.200	0.191	0.184	0.179	0.176	0.173	0.171	0.170	0.169	0.168	0.167
2005	0.000	0.002	0.033	0.119	0.208	0.255	0.267	0.264	0.258	0.252	0.248	0.244	0.242	0.240	0.239	0.238	0.237	0.237	0.236
2006	0.000	0.002	0.032	0.124	0.225	0.279	0.294	0.290	0.283	0.276	0.271	0.267	0.264	0.262	0.260	0.259	0.258	0.257	0.256
2007	0.000	0.003	0.033	0.121	0.218	0.270	0.283	0.279	0.271	0.264	0.259	0.254	0.251	0.249	0.248	0.246	0.246	0.245	0.244
2008	0.000	0.003	0.040	0.145	0.254	0.309	0.320	0.314	0.304	0.296	0.289	0.284	0.281	0.278	0.276	0.275	0.274	0.273	0.272
2009	0.000	0.003	0.044	0.157	0.277	0.338	0.351	0.343	0.331	0.321	0.313	0.307	0.303	0.300	0.298	0.296	0.295	0.294	0.293
2010	0.000	0.003	0.034	0.123	0.220	0.273	0.285	0.281	0.272	0.265	0.259	0.255	0.252	0.249	0.248	0.247	0.246	0.245	0.244
2011	0.000	0.003	0.041	0.147	0.259	0.319	0.335	0.332	0.325	0.318	0.313	0.309	0.306	0.304	0.302	0.301	0.300	0.299	0.299
2012	0.000	0.003	0.035	0.127	0.229	0.286	0.303	0.303	0.297	0.292	0.287	0.284	0.281	0.279	0.278	0.277	0.276	0.276	0.275
2013	0.000	0.003	0.036	0.118	0.204	0.251	0.265	0.264	0.259	0.254	0.250	0.247	0.244	0.243	0.242	0.241	0.240	0.240	0.239
2014	0.000	0.003	0.033	0.113	0.198	0.245	0.258	0.257	0.251	0.246	0.242	0.239	0.237	0.236	0.235	0.234	0.233	0.232	0.232

Table 2.28—Projections for EBS Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2015-2027 (Scenario 1), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	295,000	295,000	295,000	295,000	0
2016	316,000	316,000	316,000	316,000	0
2017	320,000	320,000	320,000	320,000	2
2018	309,000	309,000	310,000	312,000	1,168
2019	275,000	285,000	288,000	312,000	12,866
2020	233,000	259,000	266,000	321,000	29,839
2021	195,000	241,000	249,000	342,000	45,794
2022	146,000	230,000	234,000	342,000	60,505
2023	122,000	222,000	225,000	338,000	68,676
2024	114,000	219,000	221,000	343,000	71,118
2025	112,000	217,000	218,000	340,000	70,682
2026	113,000	213,000	216,000	336,000	69,162
2027	113,000	215,000	215,000	335,000	68,341

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	403,000	403,000	403,000	403,000	0
2016	440,000	440,000	440,000	440,000	0
2017	462,000	462,000	462,000	462,000	47
2018	464,000	464,000	465,000	466,000	1,048
2019	439,000	445,000	447,000	460,000	7,415
2020	390,000	410,000	416,000	462,000	24,041
2021	332,000	375,000	387,000	476,000	47,779
2022	284,000	353,000	365,000	499,000	67,233
2023	256,000	338,000	353,000	496,000	77,213
2024	245,000	329,000	347,000	490,000	81,232
2025	242,000	328,000	344,000	494,000	81,829
2026	241,000	325,000	342,000	495,000	79,861
2027	242,000	323,000	340,000	492,000	77,423

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	0.29	0.29	0.29	0.29	0.00
2016	0.29	0.29	0.29	0.29	0.00
2017	0.29	0.29	0.29	0.29	0.00
2018	0.29	0.29	0.29	0.29	0.00
2019	0.29	0.29	0.29	0.29	0.00
2020	0.29	0.29	0.29	0.29	0.00
2021	0.29	0.29	0.29	0.29	0.00
2022	0.25	0.29	0.29	0.29	0.01
2023	0.22	0.29	0.28	0.29	0.02
2024	0.21	0.29	0.27	0.29	0.03
2025	0.21	0.29	0.27	0.29	0.03
2026	0.21	0.29	0.27	0.29	0.03
2027	0.21	0.29	0.27	0.29	0.03

Table 2.29—Projections for EBS Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = 0.854 \times max\ F_{ABC}$ in 2015-2027 (Scenario 2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	212,000	212,000	212,000	212,000	0
2016	231,000	231,000	231,000	231,000	0
2017	303,000	303,000	303,000	303,000	2
2018	293,000	294,000	294,000	296,000	998
2019	263,000	272,000	275,000	295,000	11,054
2020	225,000	247,000	254,000	302,000	25,940
2021	189,000	229,000	237,000	319,000	40,290
2022	161,000	218,000	226,000	319,000	49,915
2023	128,000	212,000	217,000	315,000	58,033
2024	117,000	208,000	211,000	318,000	61,891
2025	110,000	205,000	208,000	316,000	62,320
2026	111,000	202,000	205,000	313,000	61,237
2027	109,000	202,000	204,000	313,000	60,491

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	409,000	409,000	409,000	409,000	0
2016	473,000	473,000	473,000	473,000	0
2017	518,000	518,000	518,000	518,000	47
2018	524,000	525,000	525,000	527,000	1,049
2019	499,000	505,000	507,000	521,000	7,442
2020	447,000	468,000	474,000	520,000	24,399
2021	384,000	428,000	440,000	533,000	49,363
2022	327,000	400,000	414,000	555,000	71,269
2023	287,000	382,000	396,000	554,000	84,596
2024	269,000	370,000	386,000	542,000	90,942
2025	262,000	364,000	380,000	553,000	92,670
2026	259,000	359,000	376,000	547,000	91,049
2027	259,000	357,000	373,000	545,000	88,446

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	0.21	0.21	0.21	0.21	0.00
2016	0.20	0.20	0.20	0.20	0.00
2017	0.25	0.25	0.25	0.25	0.00
2018	0.25	0.25	0.25	0.25	0.00
2019	0.25	0.25	0.25	0.25	0.00
2020	0.25	0.25	0.25	0.25	0.00
2021	0.25	0.25	0.25	0.25	0.00
2022	0.25	0.25	0.25	0.25	0.00
2023	0.22	0.25	0.25	0.25	0.01
2024	0.20	0.25	0.24	0.25	0.02
2025	0.20	0.25	0.24	0.25	0.02
2026	0.19	0.25	0.24	0.25	0.02
2027	0.19	0.25	0.24	0.25	0.02

Table 2.30—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 2015-2027 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	345,000	345,000	345,000	345,000	0
2016	359,000	359,000	359,000	359,000	0
2017	306,000	306,000	306,000	306,000	2
2018	299,000	300,000	300,000	302,000	1,179
2019	269,000	278,000	282,000	306,000	12,988
2020	229,000	255,000	262,000	318,000	30,098
2021	193,000	238,000	247,000	341,000	45,976
2022	167,000	230,000	238,000	342,000	55,503
2023	150,000	223,000	233,000	339,000	60,506
2024	144,000	220,000	230,000	344,000	62,530
2025	141,000	218,000	227,000	340,000	62,162
2026	141,000	215,000	224,000	337,000	60,677
2027	139,000	215,000	223,000	336,000	59,910

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	399,000	399,000	399,000	399,000	0
2016	421,000	421,000	421,000	421,000	0
2017	433,000	433,000	433,000	433,000	47
2018	440,000	441,000	441,000	443,000	1,048
2019	421,000	427,000	429,000	442,000	7,413
2020	377,000	397,000	403,000	449,000	24,017
2021	323,000	366,000	377,000	466,000	47,691
2022	275,000	346,000	358,000	492,000	67,545
2023	241,000	333,000	346,000	490,000	79,365
2024	223,000	324,000	338,000	485,000	85,604
2025	214,000	321,000	333,000	489,000	87,858
2026	210,000	317,000	329,000	490,000	86,967
2027	207,000	314,000	326,000	489,000	85,182

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	0.35	0.35	0.35	0.35	0.00
2016	0.35	0.35	0.35	0.35	0.00
2017	0.30	0.30	0.30	0.30	0.00
2018	0.30	0.30	0.30	0.30	0.00
2019	0.30	0.30	0.30	0.30	0.00
2020	0.30	0.30	0.30	0.30	0.00
2021	0.30	0.30	0.30	0.30	0.00
2022	0.30	0.30	0.30	0.30	0.00
2023	0.30	0.30	0.30	0.30	0.00
2024	0.30	0.30	0.30	0.30	0.00
2025	0.30	0.30	0.30	0.30	0.00
2026	0.30	0.30	0.30	0.30	0.00
2027	0.30	0.30	0.30	0.30	0.00

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 at $F_{60\%}$ in 2015-2027 (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	152,000	152,000	152,000	152,000	0
2016	177,000	177,000	177,000	177,000	0
2017	192,000	192,000	192,000	192,000	1
2018	196,000	196,000	197,000	198,000	578
2019	185,000	190,000	192,000	204,000	6,487
2020	166,000	179,000	183,000	212,000	15,682
2021	145,000	170,000	175,000	227,000	25,347
2022	128,000	164,000	169,000	230,000	32,208
2023	115,000	158,000	164,000	227,000	36,383
2024	109,000	155,000	161,000	233,000	38,531
2025	104,000	154,000	159,000	229,000	39,086
2026	103,000	152,000	157,000	229,000	38,575
2027	101,000	150,000	155,000	226,000	38,082

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	414,000	414,000	414,000	414,000	0
2016	497,000	497,000	497,000	497,000	0
2017	565,000	565,000	565,000	565,000	47
2018	607,000	607,000	608,000	610,000	1,050
2019	611,000	617,000	619,000	633,000	7,508
2020	577,000	598,000	604,000	653,000	25,306
2021	519,000	566,000	579,000	681,000	53,501
2022	457,000	540,000	555,000	720,000	81,147
2023	407,000	519,000	536,000	725,000	100,807
2024	371,000	505,000	523,000	720,000	112,940
2025	353,000	496,000	513,000	730,000	119,239
2026	339,000	488,000	505,000	721,000	120,613
2027	329,000	483,000	499,000	719,000	119,331

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	0.15	0.15	0.15	0.15	0.00
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

Table 2.32—Projections for EBS Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = 0$ in 2015-2027 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	0	0	0	0	0
2022	0	0	0	0	0
2023	0	0	0	0	0
2024	0	0	0	0	0
2025	0	0	0	0	0
2026	0	0	0	0	0
2027	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	424,000	424,000	424,000	424,000	0
2016	559,000	559,000	559,000	559,000	0
2017	692,000	692,000	692,000	692,000	47
2018	799,000	800,000	801,000	802,000	1,051
2019	863,000	869,000	871,000	885,000	7,601
2020	872,000	895,000	901,000	952,000	26,612
2021	837,000	889,000	904,000	1,020,000	59,860
2022	779,000	875,000	894,000	1,090,000	97,554
2023	720,000	861,000	882,000	1,130,000	129,263
2024	666,000	846,000	869,000	1,150,000	152,268
2025	633,000	833,000	858,000	1,150,000	167,257
2026	607,000	824,000	848,000	1,160,000	174,856
2027	592,000	821,000	839,000	1,160,000	177,032

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00
2019	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00
2021	0.00	0.00	0.00	0.00	0.00
2022	0.00	0.00	0.00	0.00	0.00
2023	0.00	0.00	0.00	0.00	0.00
2024	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00
2026	0.00	0.00	0.00	0.00	0.00
2027	0.00	0.00	0.00	0.00	0.00

Table 2.33—Projections for EBS Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2015-2027 (Scenario 6), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	346,000	346,000	346,000	346,000	0
2016	360,000	360,000	360,000	360,000	0
2017	356,000	356,000	356,000	356,000	3
2018	336,000	337,000	338,000	340,000	1,394
2019	294,000	305,000	309,000	337,000	15,251
2020	244,000	274,000	283,000	348,000	34,819
2021	176,000	251,000	256,000	370,000	59,564
2022	137,000	230,000	238,000	368,000	74,178
2023	119,000	221,000	232,000	365,000	79,847
2024	114,000	219,000	230,000	370,000	81,022
2025	115,000	220,000	229,000	365,000	79,951
2026	114,000	218,000	227,000	371,000	78,258
2027	117,000	221,000	227,000	367,000	77,533

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	399,000	399,000	399,000	399,000	0
2016	421,000	421,000	421,000	421,000	0
2017	428,000	428,000	428,000	429,000	47
2018	420,000	420,000	421,000	422,000	1,048
2019	389,000	395,000	396,000	410,000	7,379
2020	338,000	358,000	364,000	409,000	23,574
2021	286,000	325,000	336,000	422,000	45,106
2022	250,000	307,000	320,000	443,000	59,918
2023	230,000	300,000	313,000	434,000	66,366
2024	223,000	297,000	311,000	435,000	68,900
2025	223,000	297,000	310,000	436,000	69,111
2026	222,000	296,000	309,000	440,000	67,243
2027	225,000	297,000	308,000	441,000	65,274

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	0.35	0.35	0.35	0.35	0.00
2016	0.35	0.35	0.35	0.35	0.00
2017	0.35	0.35	0.35	0.35	0.00
2018	0.35	0.35	0.35	0.35	0.00
2019	0.35	0.35	0.35	0.35	0.00
2020	0.35	0.35	0.35	0.35	0.00
2021	0.30	0.35	0.34	0.35	0.02
2022	0.26	0.33	0.32	0.35	0.03
2023	0.24	0.32	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	0.31	0.31	0.35	0.04
2027	0.23	0.31	0.31	0.35	0.04

Table 2.34—Projections for EBS Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2015-2016 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	295,000	295,000	295,000	295,000	0
2016	316,000	316,000	316,000	316,000	0
2017	375,000	375,000	375,000	375,000	3
2018	350,000	351,000	351,000	354,000	1,394
2019	302,000	314,000	318,000	346,000	15,251
2020	249,000	280,000	288,000	353,000	34,819
2021	182,000	256,000	261,000	373,000	58,335
2022	139,000	234,000	240,000	369,000	73,998
2023	119,000	222,000	232,000	366,000	79,891
2024	114,000	220,000	230,000	370,000	81,090
2025	115,000	220,000	229,000	365,000	79,998
2026	114,000	218,000	227,000	371,000	78,284
2027	117,000	221,000	227,000	367,000	77,546

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	403,000	403,000	403,000	403,000	0
2016	440,000	440,000	440,000	440,000	0
2017	457,000	457,000	457,000	458,000	47
2018	441,000	442,000	443,000	444,000	1,048
2019	404,000	410,000	412,000	425,000	7,379
2020	348,000	368,000	374,000	419,000	23,574
2021	291,000	331,000	342,000	428,000	45,218
2022	253,000	310,000	323,000	447,000	60,322
2023	231,000	301,000	314,000	436,000	66,728
2024	223,000	297,000	312,000	436,000	69,130
2025	223,000	297,000	310,000	437,000	69,231
2026	222,000	296,000	309,000	440,000	67,298
2027	225,000	297,000	308,000	441,000	65,296

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2015	0.29	0.29	0.29	0.29	0.00
2016	0.29	0.29	0.29	0.29	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	0.35	0.34	0.35	0.02
2022	0.27	0.33	0.32	0.35	0.03
2023	0.24	0.32	0.31	0.35	0.04
2024	0.23	0.32	0.31	0.35	0.04
2025	0.23	0.32	0.31	0.35	0.04
2026	0.23	0.31	0.31	0.35	0.04
2027	0.23	0.31	0.31	0.35	0.04

Table 2.35a (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, 1991-2014 (2014 data current through October 20).

Trawl fishery

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

Table 2.35a (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, 1991-2014 (2014 data current through October 20).

Trawl fishery

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Pollock	8744	13299	9919	12078	16922	4289	3332	2241	3481	3524	3933	5437
Pacific cod	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sablefish	56	73	28	2	1	1					0	
Yellowfin Sole	1006	1840	1266	1438	645	322	306	469	1141	767	2679	1508
Greenland Turbot	71	76	10	20	82	8	1	5	0	1	2	2
Arrowtooth Flounder	4139	7859	3785	4297	1923	584	448	417	218	216	275	216
Kamchatka Flounder									6	7	16	29
Rock Sole	5134	8647	7461	4528	3864	974	750	848	1329	1146	818	1403
Flathead Sole	1445	2817	1350	2899	3748	360	479	167	222	235	239	215
Alaska Plaice	265	372	389	342	404	53	55	73	502	144	577	625
Other Flatfish	893	2063	1331	600	382	75	28	63	73	71	29	48
Flounder												
Pacific Ocean Perch	31	64	80	50	25	2	1	0	4	2	2	
Northern Rockfish	12	51	22	48	4	1	1	3	6	5	0	1
Rougheye Rockfish		1	1									
Shortraker Rockfish												
Sharpchin/Northern Rockfish												
Shortraker/Rougheye Rockfish	3											
Shortraker/Rougheye/Sharpchin/Northern Rockfish												
Other Rockfish	33	63	18	12	5	5	2	8	2	16	2	2
Atka Mackerel	3470	4442	652	367	123	10	28	46	69	35	10	2

Table 2.35b (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, 1991-2014 (2014 data current through October 20).

Longline fishery

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

Table 2.35b (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, 1991-2014 (2014 data current through October 20).

Longline Fishery

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Pollock	7162	5309	4172	3040	3372	5285	4529	4168	5476	4821	5103	4260
Pacific Cod	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sablefish	66	19	21	22	14	4	2	2	16	3	3	3
Yellowfin Sole	631	616	717	485	264	507	653	198	674	1001	1422	1400
Greenland Turbot	182	218	165	65	115	72	79	106	173	121	15	14
Arrowtooth Flounder	1295	1365	1668	1322	1265	1208	1220	1100	961	961	580	370
Kamchatka Flounder									51	71	47	27
Rock Sole	45	37	48	21	14	20	25	5	20	26	33	50
Flathead Sole	372	593	618	539	352	334	248	265	334	291	372	476
Alaska Plaice	0	0	0	4	0	0	0	0	0	0	1	0
Other Flatfish	80	187	253	145	59	29	56	96	50	64	10	32
Flounder												
Pacific Ocean Perch	1	3	1	0	0	0	1	1	2	1	2	3
Northern Rockfish	6	5	6	6	5	4	4	11	13	9	18	23
Rougheye Rockfish	0	2	4	2	2	5	1	4	3	2	2	1
Shortraker Rockfish		26	19	4	22	12	21	48	20	14	8	9
Sharpchin/Northern Rockfish												
Shortraker/Rougheye Rockfish	18											
Shortraker/Rougheye/Sharpchin/Northern Rockfish												
Other Rockfish	10	28	19	10	22	18	7	47	36	23	28	35
Atka Mackerel	6	25	5	0	4	1	0	1	6	3	2	3

Table 2.35c(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, 1991-2014 (2014 data current through October 20).

Pot fishery

Species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Pollock	2	7		4	15	32	64	43	23	58		29
Pacific Cod	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sablefish												
Yellowfin Sole	38	26			81	256	71	107	61	69		38
Greenland Turbot					1	0						
Alaska Plaice												
Arrowtooth Flounder	0	3			18	18	13	2				151
Kamchatka Flounder												
Rock Sole	0	1		0	0	8	2	1	2	1		
Flathead Sole						7			0			
Other Flatfish						3	1					
Flounder		1										
Pacific Ocean Perch					1	1						
Northern Rockfish												
Rougheye Rockfish												
Shortraker Rockfish												
Sharpchin/Northern Rockfish												
Shortraker/Rougheye Rockfish												
Shortraker/Rougheye/Sharpchin/Northern Rockfish	0				1	1	1					
Other Rockfish	0	1		0	3	6	3	2				
Atka Mackerel	1	10		6	80	53	48	15				

Table 2.35c (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, 1991-2014 (2014 data current through October 20).

Pot fishery

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Pollock	18	9	8	26	12	11	17	8	7	4	7	14
Pacific Cod	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sablefish	0	1	0	4							0	
Yellowfin Sole	82	78	76	47	206	133	35	2	29	29	298	305
Greenland Turbot	0			1					0			
Alaska Plaice										0		
Arrowtooth Flounder	4	4	5	12	3	6	0	1	1	1	2	1
Kamchatka Flounder										0	0	
Rock Sole	3	2	1	2	3	1	0	1	0	1	1	2
Flathead Sole	0	1	1	0	2	1	0	0	0	0	0	0
Other Flatfish	1	1	1	1	1	0	0	0	0	0	2	0
Flounder												
Pacific Ocean Perch	1	0	0	1		0	0		0	0	0	
Northern Rockfish	1	1	1	1	1	2	0	0	1	1	0	0
Rougheye Rockfish		0	0									
Shortraker Rockfish								0				
Sharpchin/Northern Rockfish												
Shortraker/Rougheye Rockfish	0											
Shortraker/Rougheye/Sharpchin/Northern Rockfish												
Other Rockfish	5	3	3	4	1	1	0	2	2	1	5	3
Atka Mackerel	198	141	236	342	41	61	2	27	29	9	3	4

Table 2.36—Incidental catch (t) of squid and members of the former "other species" complex taken in the Bering Sea fisheries for Pacific cod, 2003-2014 (2014 data are current through October 8).

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Octopus	196	264	299	268	130	177	37	114	555	119	181	177
Sculpins, Large	817	2832	2248	1920	2087	1404	1060	1059	1647	1777	1470	1763
Sculpins, Other	1857	349	339	382	337	299	210	66	147	239	33	47
Shark, Other	20	20	10	4	2	2	5	2	3	1	1	1
Shark, Pacific Sleeper	121	228	188	123	44	20	14	15	20	10	20	26
Shark, Salmon	1	0	2	1							0	
Shark, Spiny Dogfish	11	8	11	6	2	7	17	13	7	19	18	6
Skate, Alaska								1493	2156	2676	3251	2642
Skate, Aleutian									103	231	121	106
Skate, Big		158	174	243	74	49	63	117	132	287	218	198
Skate, Longnose	0	12	21	20	1	1	1	5	4	3	9	10
Skate, Other	14742	17708	18843	14432	12740	13685	11886	9007	14133	14919	16684	14101
Skate, Whiteblotched									13	24	12	11
Squid	5	4	1	0	1	0	0	0	0	0	0	1

Table 2.37—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	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Bairdi Tanner Crab	764	439	230	319	330	455	293	152	158	180	155	355
Opilio Tanner (Snow) Crab	212	308	291	440	277	377	1019	803	540	404	251	508
Red King Crab	52	13	2	2	8	79	28	12	17	44	21	40
Blue King Crab												
Golden (Brown) King Crab												
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
Chinook Salmon	4	5	6	7	7	6	5	2	2	1	3	2
Non-Chinook Salmon	0	0	0	1	1	0	0	1	0	0	2	1

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Bairdi Tanner Crab	257	258	291	588	819	1265	528	390	325	120	241	
Opilio Tanner (Snow) Crab	162	222	195	342	1812	693	550	786	192	51	43	
Red King Crab	14	17	21	19	47	36	8	4	23	11	99	
Blue King Crab	3	3	1	4	173	9	15	123	1	1	0	
Golden (Brown) King Crab	0	0	0	0	0	0	1	0	0	0	0	
Other King Crab												
Herring	14	9	18	8	2	0	0	0	0	6	0	
Chinook Salmon	2	5	3	3	5	1	0	0	0	1	1	
Non-Chinook Salmon	1	7	1	7	1	0	0	0	0	0	0	

Halibut quantity	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Catch	5198	7256	3463	8657	8950	9175	8640	7234	6136	7273	6729	7329
Mortality				2069	2264	2326	2060	1719	1780	1537	1278	1789

Halibut quantity	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Catch	6696	6724	7901	6344	5787	6605	6067	6099	6387	7162	6758	3044
Mortality	1870	2065	1963	1812	1418	902	782	784	779	1038	861	481

Table 2.38—Incidental catch (t) of non-target species groups by Bering Sea Pacific cod fisheries, 2003-2014 (2014 data are current through October 8), sorted in order of descending average.

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Ave.
Sea star	438	423	439	316	235	181	139	135	191	454	279	577	317
Giant Grenadier	2	15	143	105	95	135	201	292	1126	494	171	65	237
Scypho jellies	668	709	399	66	110	47	93	43	186	68	338	77	234
Sea anemone unidentified	92	115	113	87	37	54	115	84	144	177	233	202	121
Misc fish	223	226	205	93	86	40	51	52	111	128	61	140	118
Grenadier	238	225	190	25	84	27	11	98	13	20	103	34	89
Sea pens whips	6	12	30	16	7	10	37	25	25	35	53	54	26
Snails	25	20	12	16	15	19	25	17	23	21	29	33	21
Eelpouts	47	35	42	17	18	7	2	2	4	11	24	38	21
Invertebrate unidentified	19	5	3	17	19	2	15	37	57	35	21	8	20
Benthic urochordata	14	4	10	5	1	2	1	10	35	65	51	34	19
Sponge unidentified	6	8	6	11	2	3	11	6	12	15	19	18	10
Misc crabs	8	4	4	16	28	6	2	5	4	5	12	8	9
Bivalves	5	16	6	5	2	11	9	3	11	11	12	7	8
Urchins/dollars/cucumbers	11	11	13	4	13	3	1	1	4	3	1	5	6
Corals Bryozoans	1	1	1	1	2	2	8	2	3	24	2	1	4
Hermit crab unidentified	5	3	2	2	2	1	1	1	1	1	1	1	2
Greenlings	6	3	2	2	0	1	0	0	0	0	0	0	1
Brittle star unidentified	1	1	0	1	0	0	0	0	1	1	1	1	1
Dark Rockfish						1	0	0	0	0	0	0	0
Misc crustaceans	0	0	0	1	1	0	0	0	0	0	0	0	0
Other osmerids	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
Eulachon		0	0	0	0	0		0	0	0			0
Pacific Sand lance	0	0	0	0	0	0		0	0	0		0	0
Polychaete unidentified	0	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
Stichaeidae	0	0	0	0	0	0	0	0					0
Lanternfishes (myctophidae)		0											0
Gunnels		0	0		0								0
Birds	0	0	0	0	0	0	0	0	0	0	0	0	0

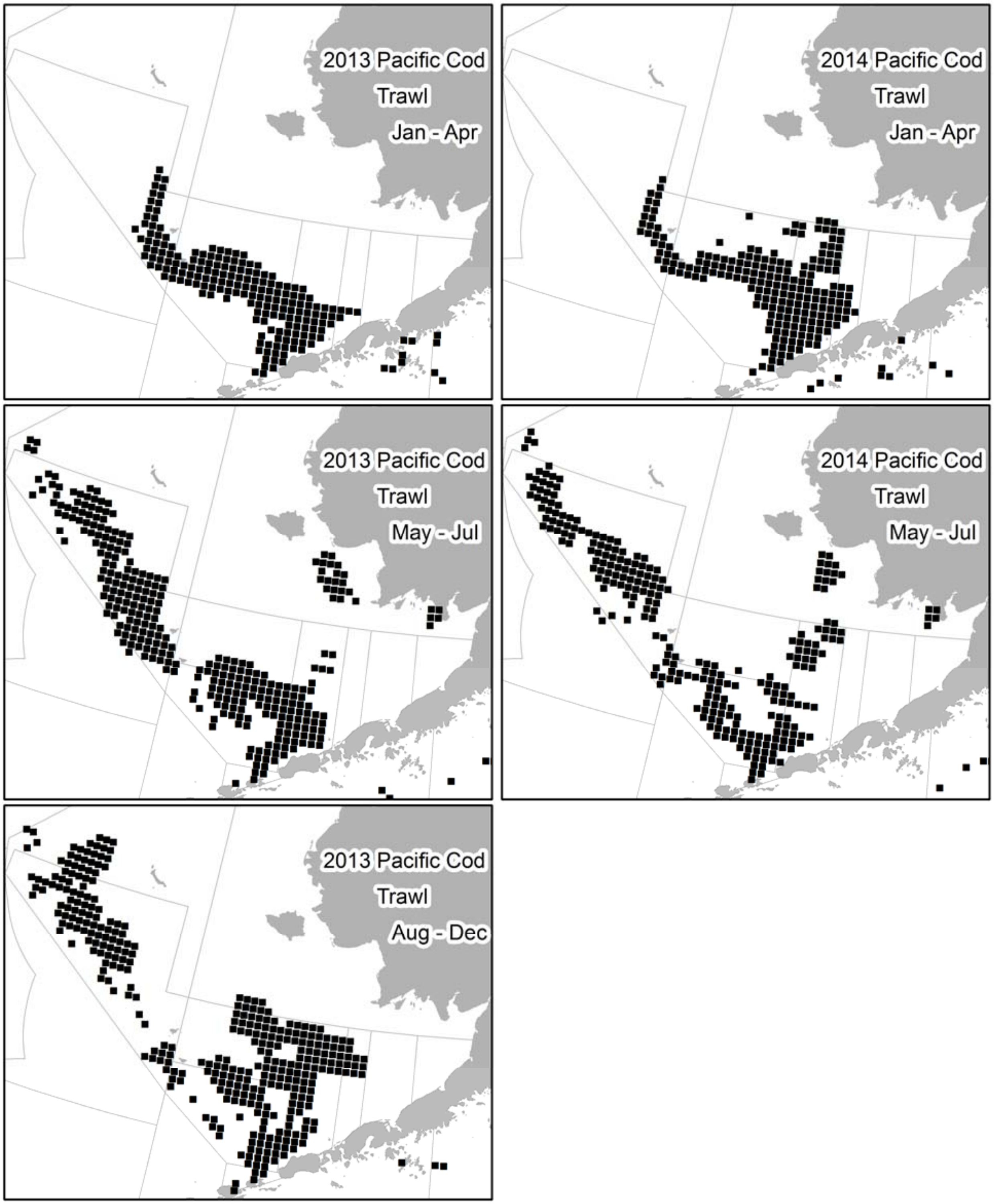


Figure 2.1a. EBS maps showing each 400 square km cell with trawl hauls containing Pacific cod from at least 3 distinct vessels by season in 2013-2014, overlaid against NMFS 3-digit statistical areas.

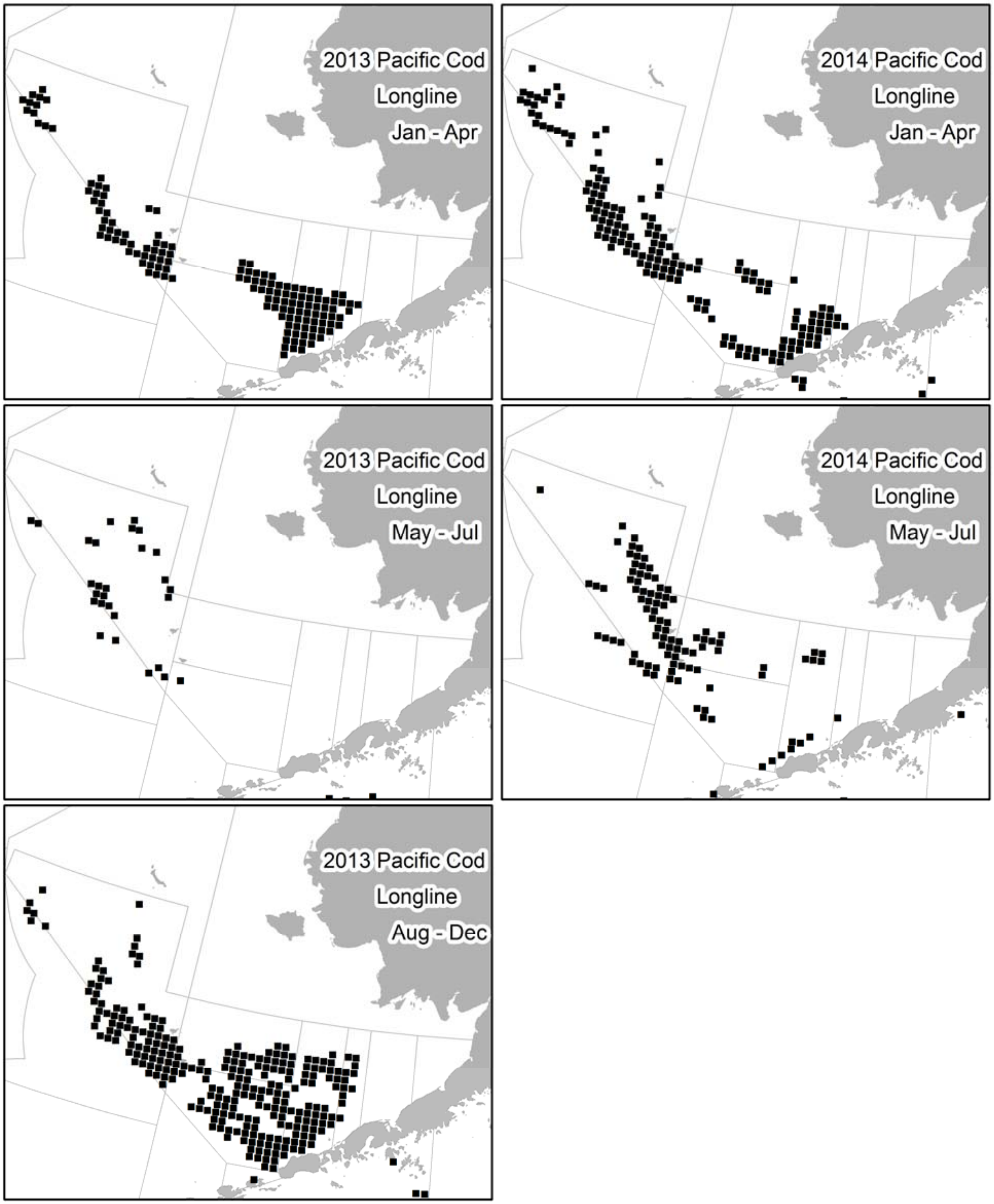


Figure 2.1b. EBS maps showing each 400 square km cell with longline sets containing Pacific cod from at least 3 distinct vessels by season in 2013-2014, overlaid against NMFS 3-digit statistical areas.

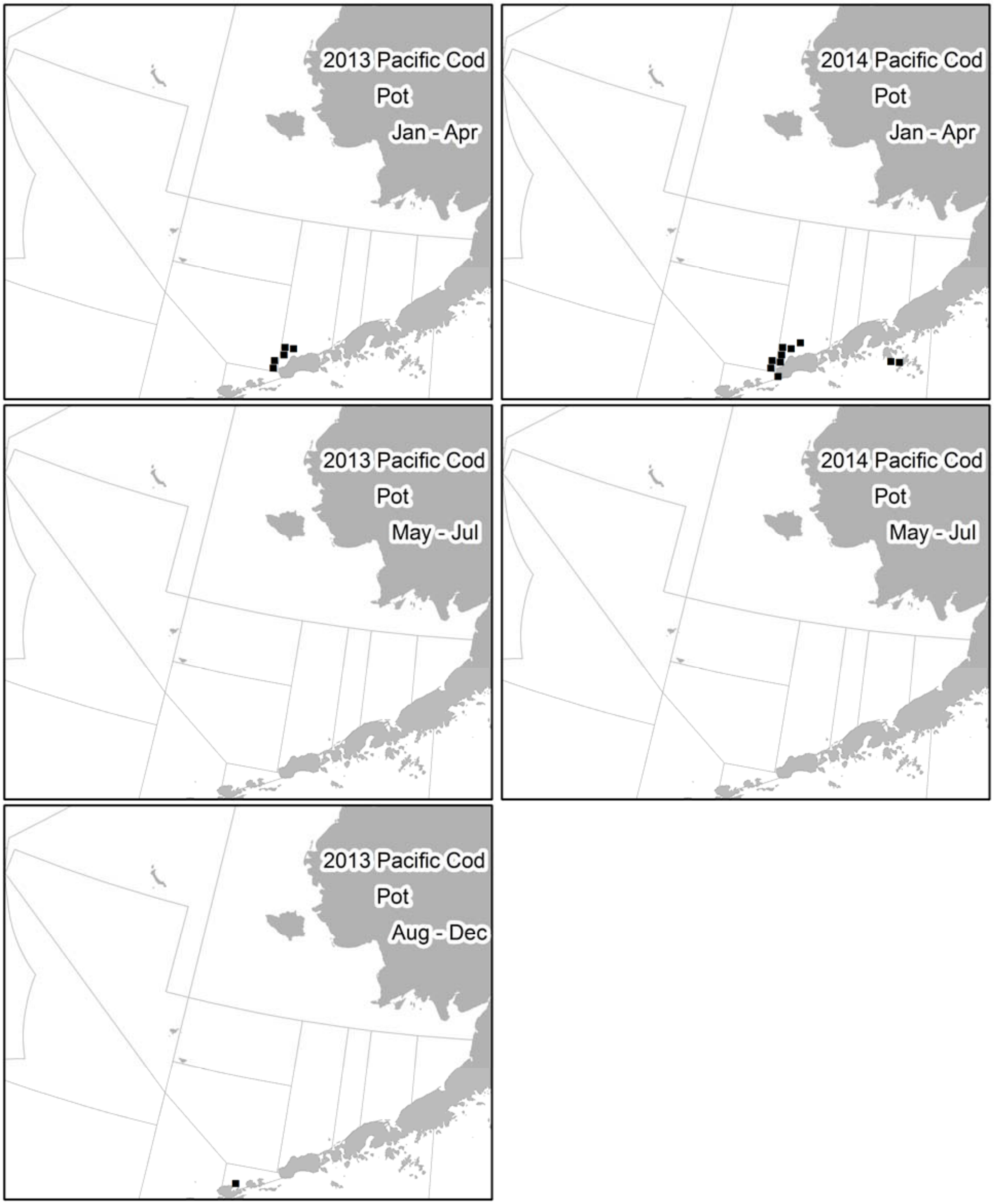


Figure 2.1c. EBS maps showing each 400 square km cell with pot sets containing Pacific cod from at least 3 distinct vessels by season in 2013-2014, overlaid against NMFS 3-digit statistical areas.

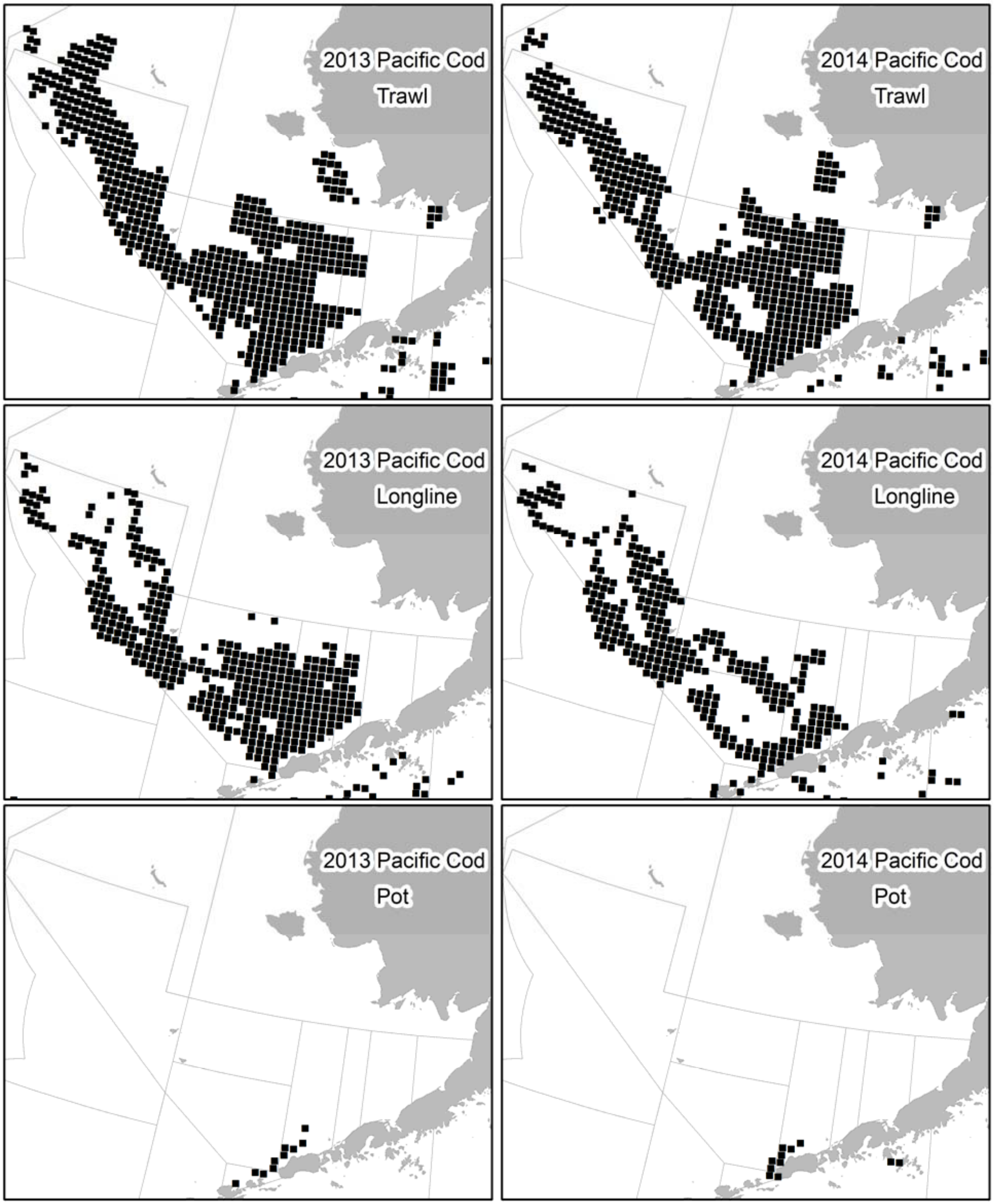


Figure 2.2. Maps showing each 400 square km cell with pot sets containing Pacific cod from at least 3 distinct vessels by season in 2013-2014, overlaid against NMFS 3-digit statistical areas.

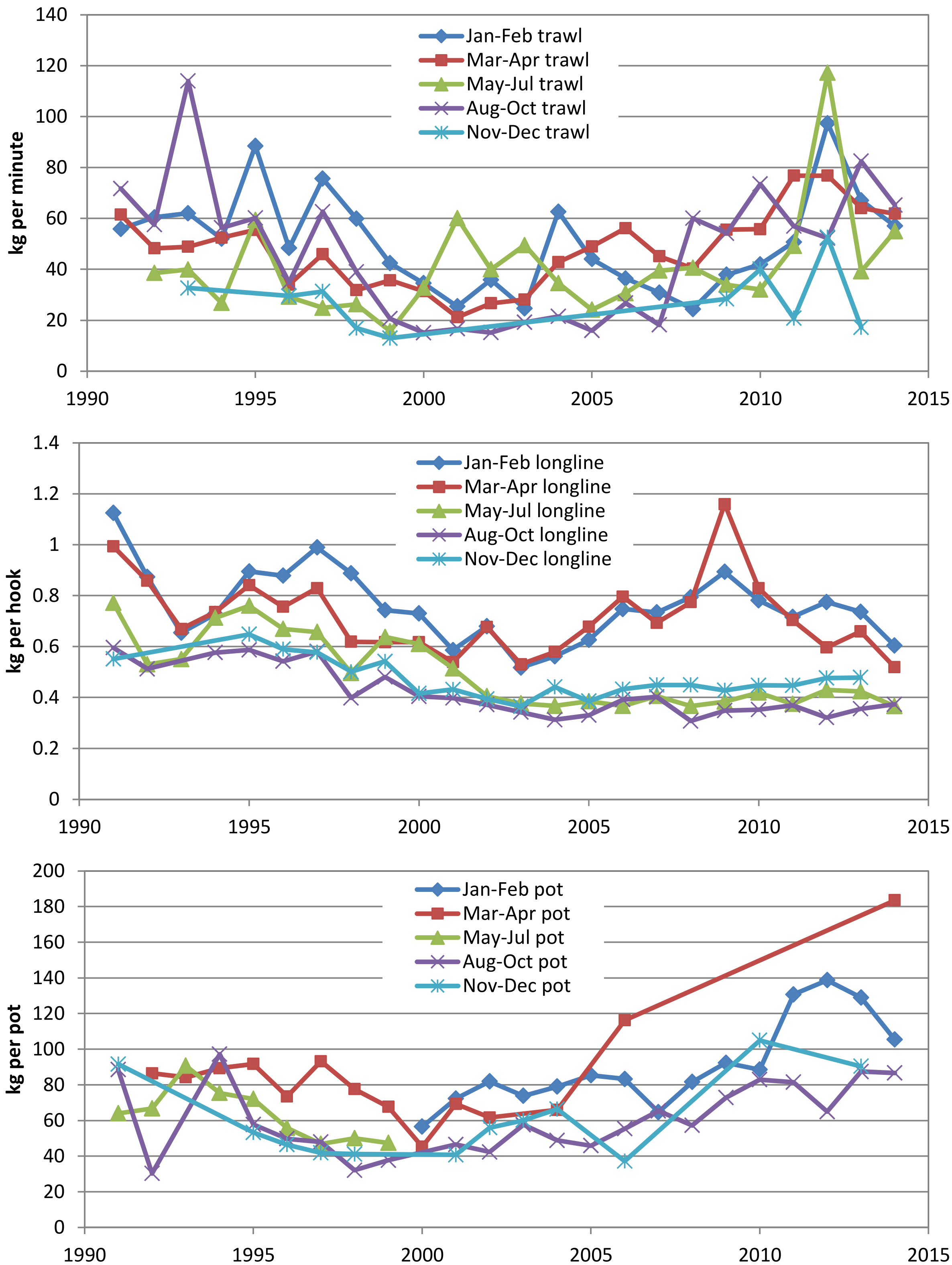


Figure 2.3—Time series of fishery catch per unit effort, by gear and season.

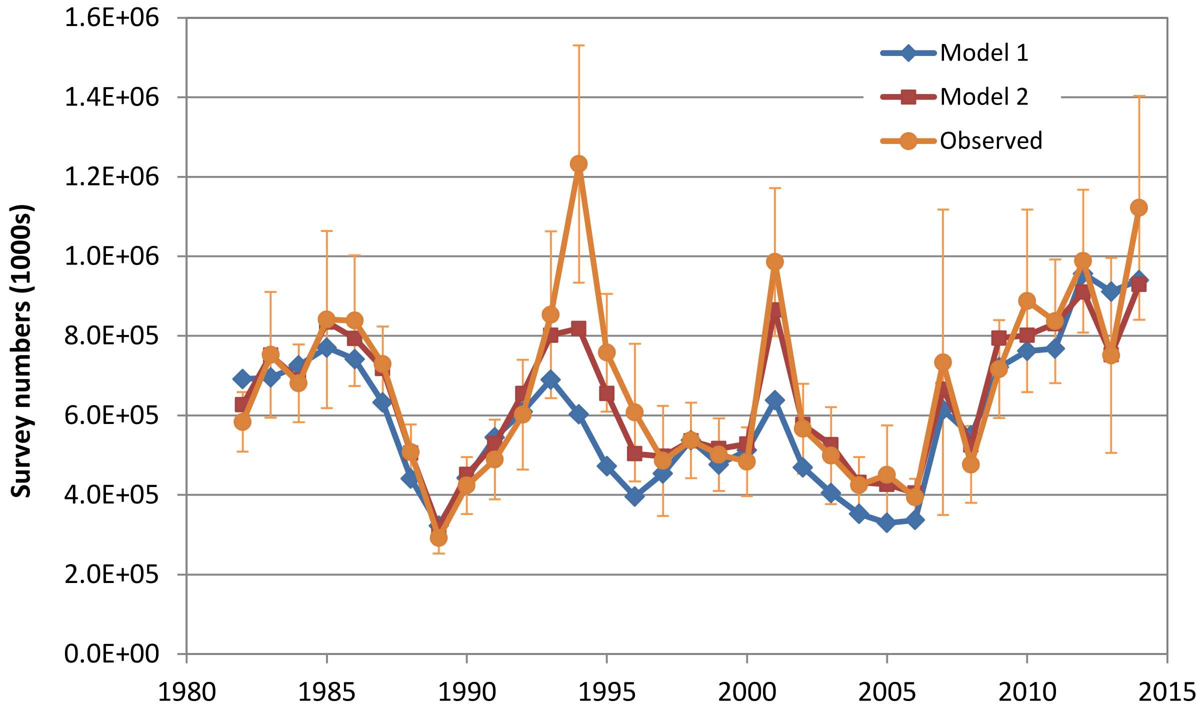


Figure 2.4—Model fits to the trawl survey abundance time series, with 95% confidence intervals for the observations.

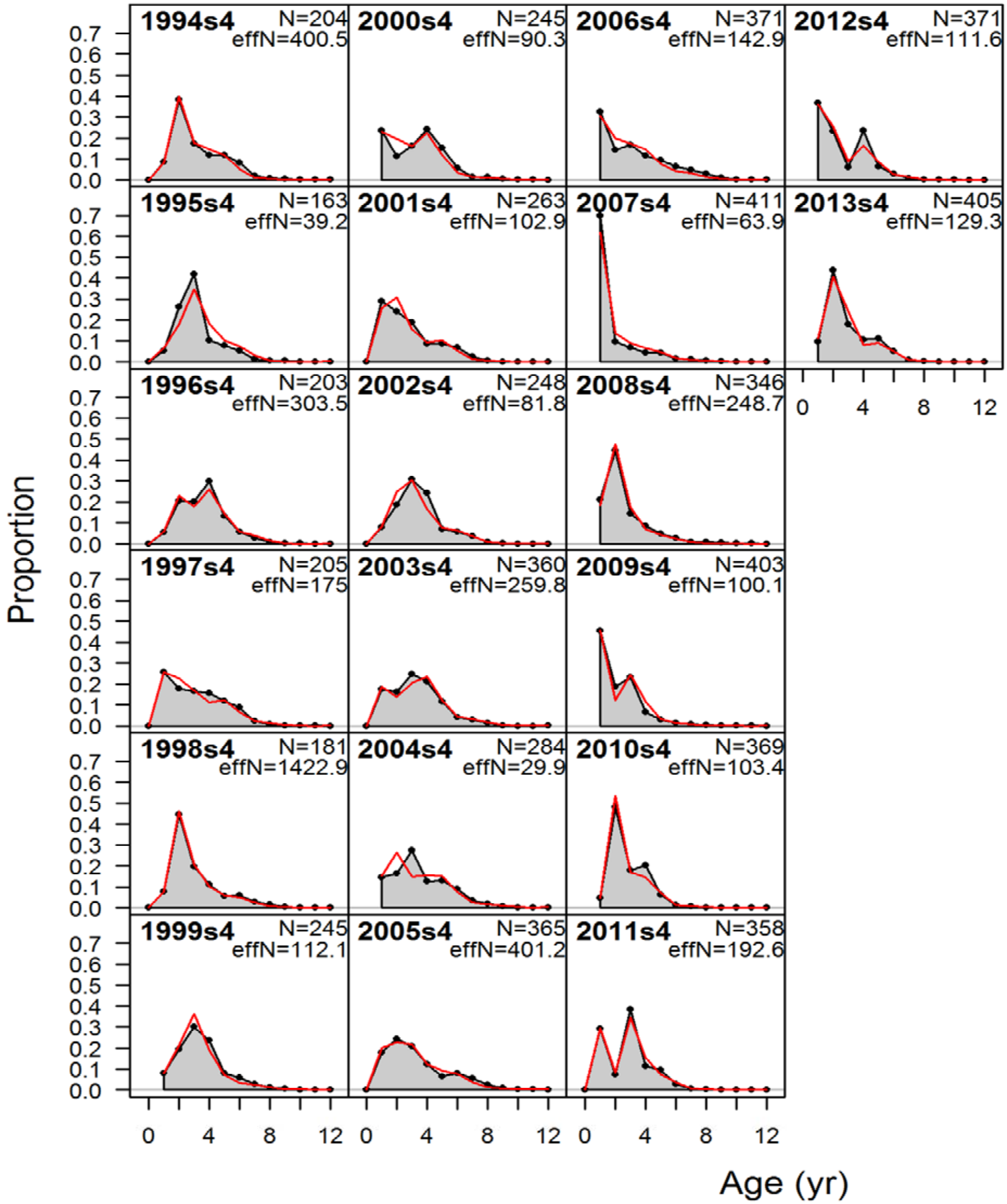


Figure 2.5a—Fit to trawl survey age composition data obtained by Model 1 (grey = observed, red = estimated).

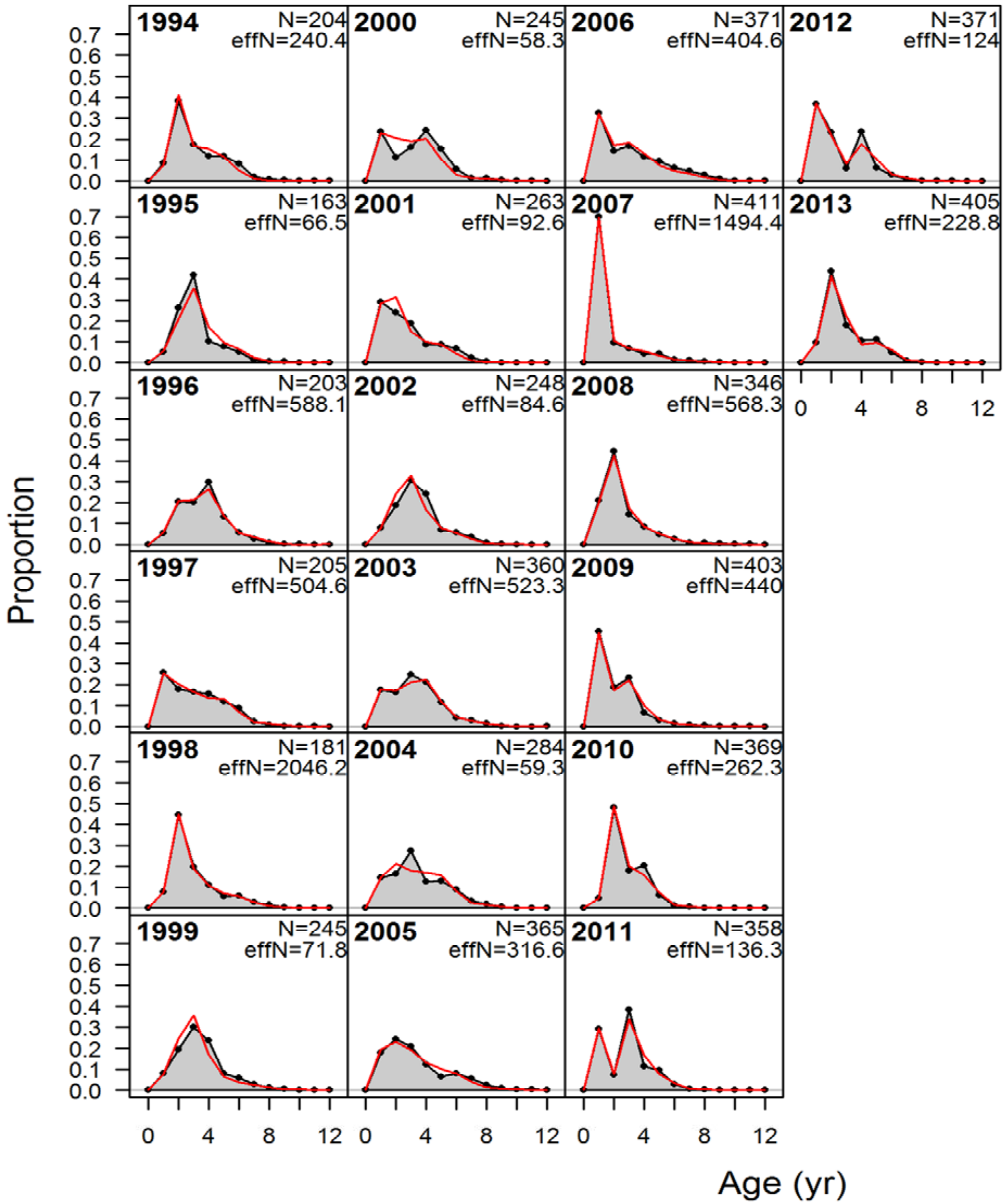


Figure 2.5b—Fit to trawl survey age composition data obtained by Model 2 (grey = observed, red = estimated).

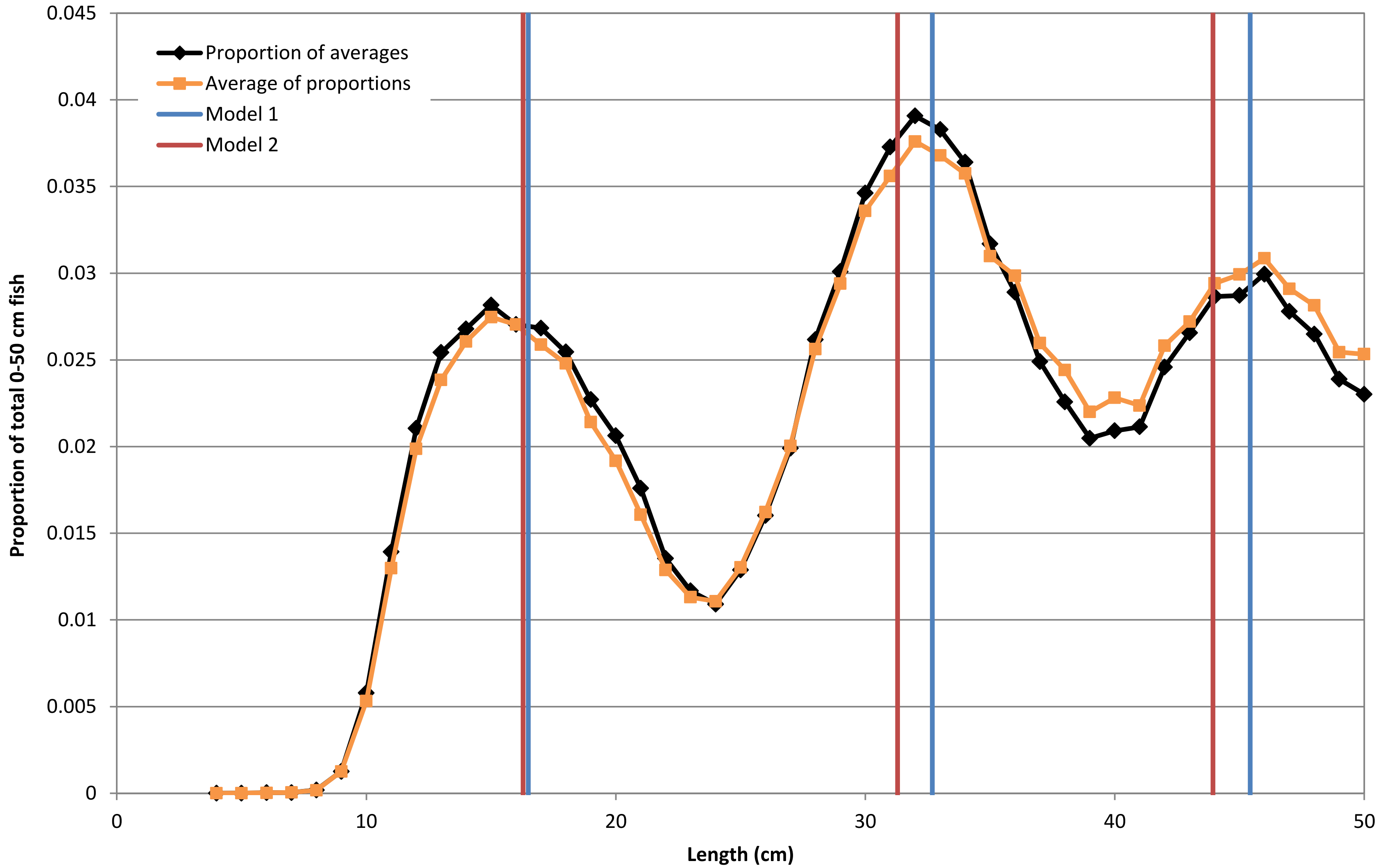


Figure 2.6—Estimates of mean size at ages 1-3 from Models 1 and 2, compared to long-term average survey size (0-50 cm) composition.

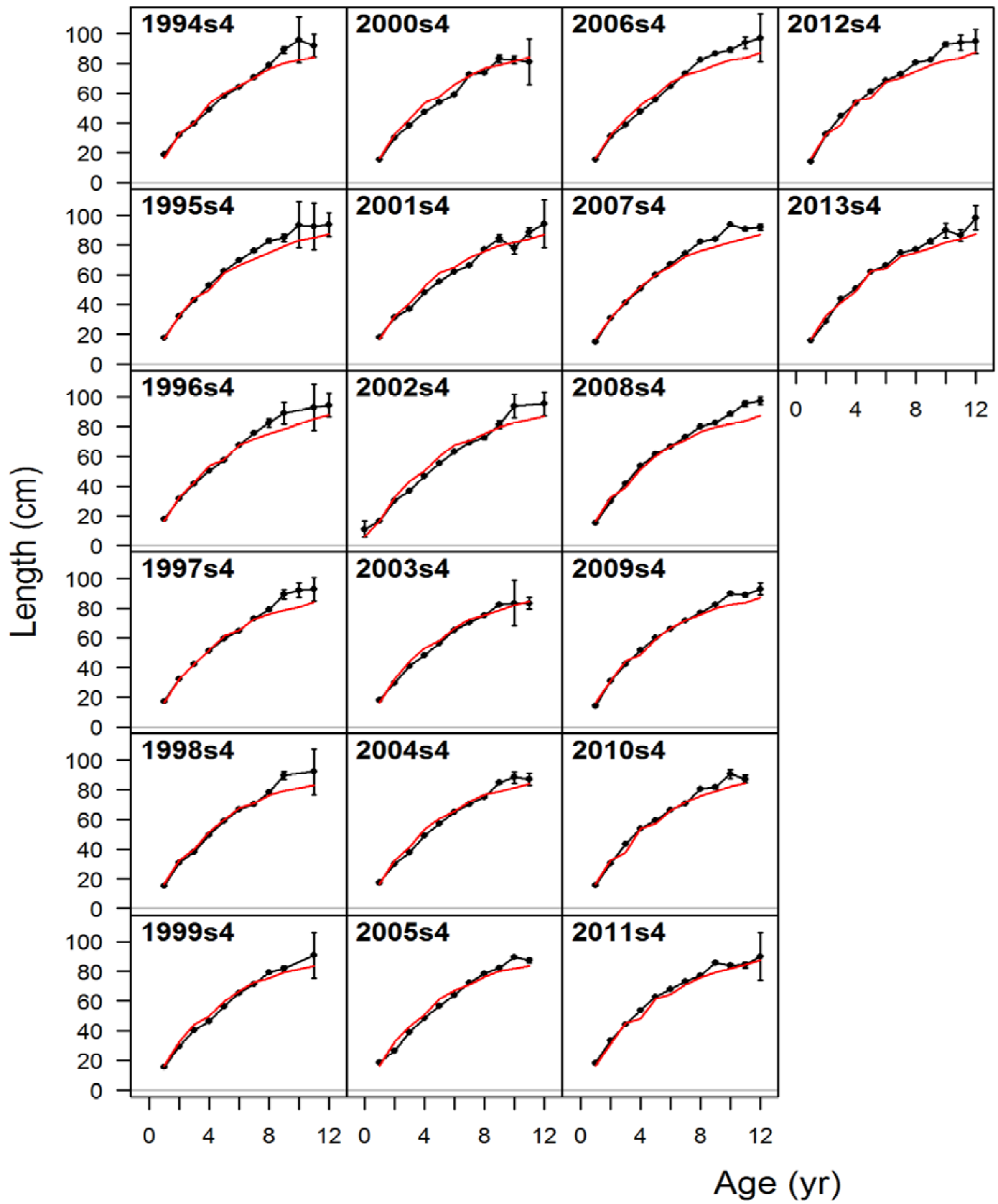


Figure 2.7—Fit to mean-size-at-age data from Model 1 (black = observed, red = estimated). Model 2 does not include mean-size-at-age data.

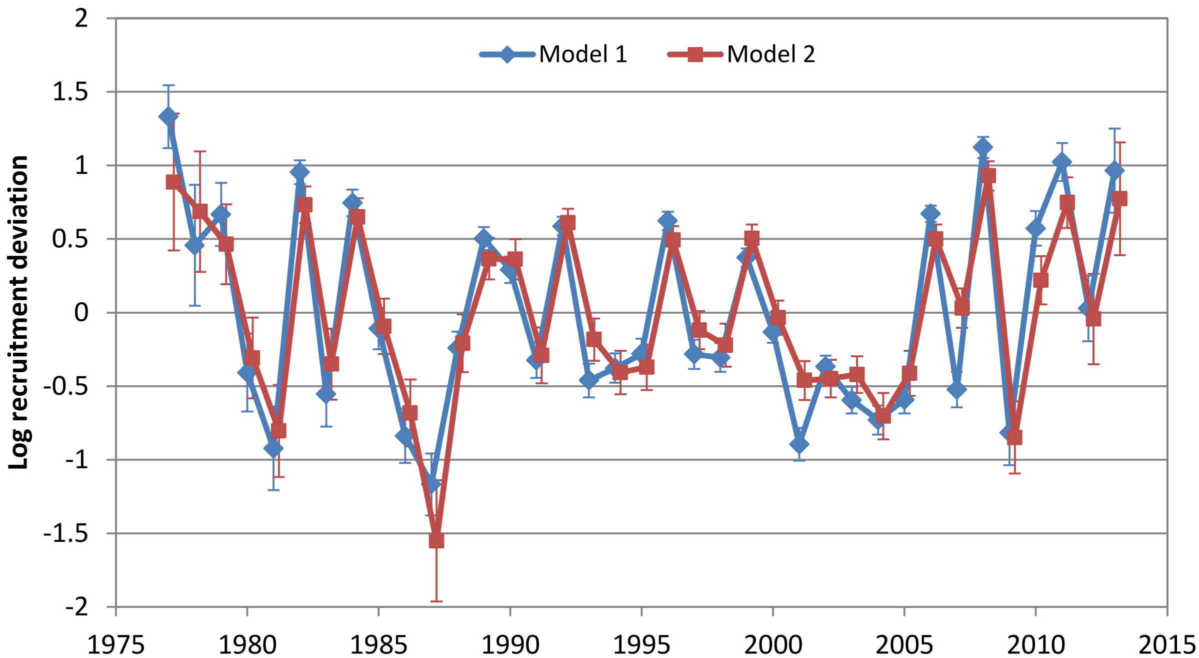


Figure 2.8—Time series of estimated log recruitment deviations as estimated by Models 1 and 2, with 95% confidence intervals.

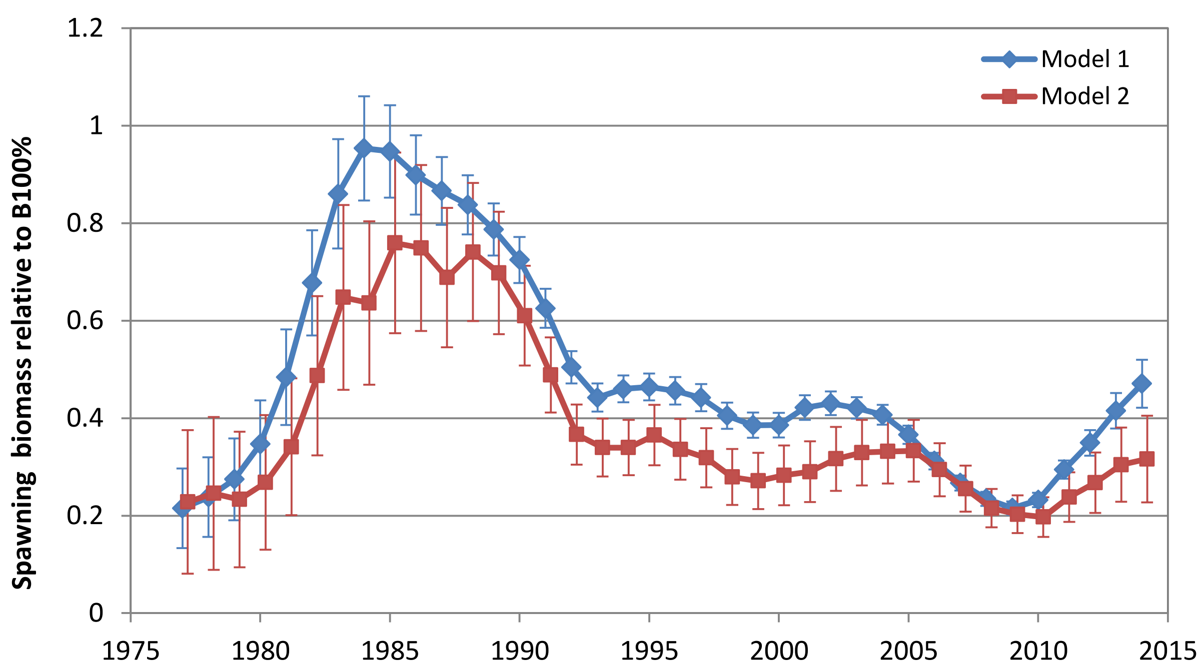
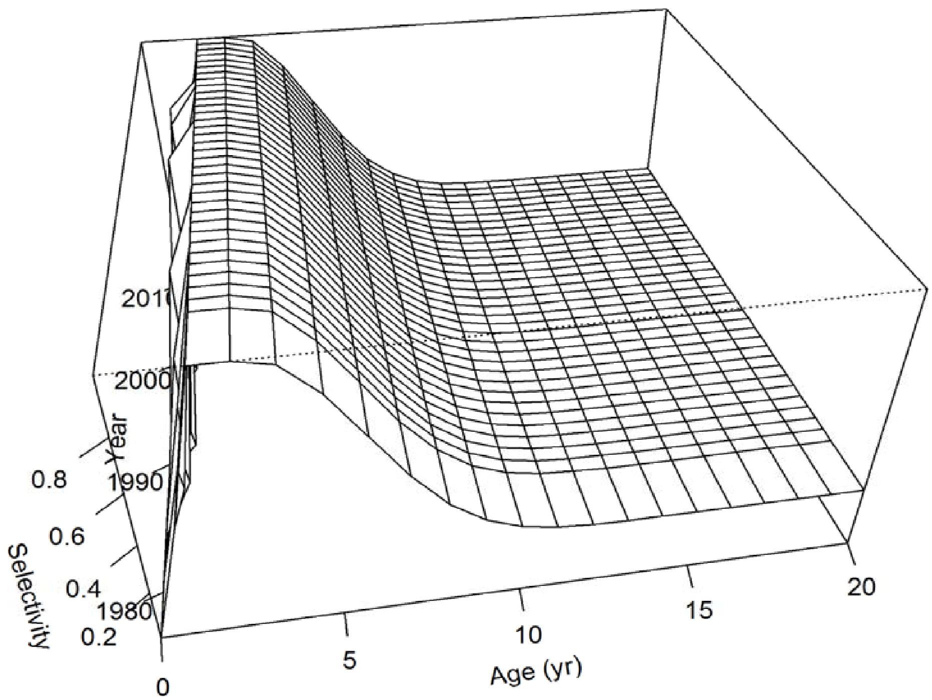


Figure 2.9—Time series of spawning biomass relative to $B_{100\%}$ as estimated by Models 1 and 2.

Model 1



Model 2

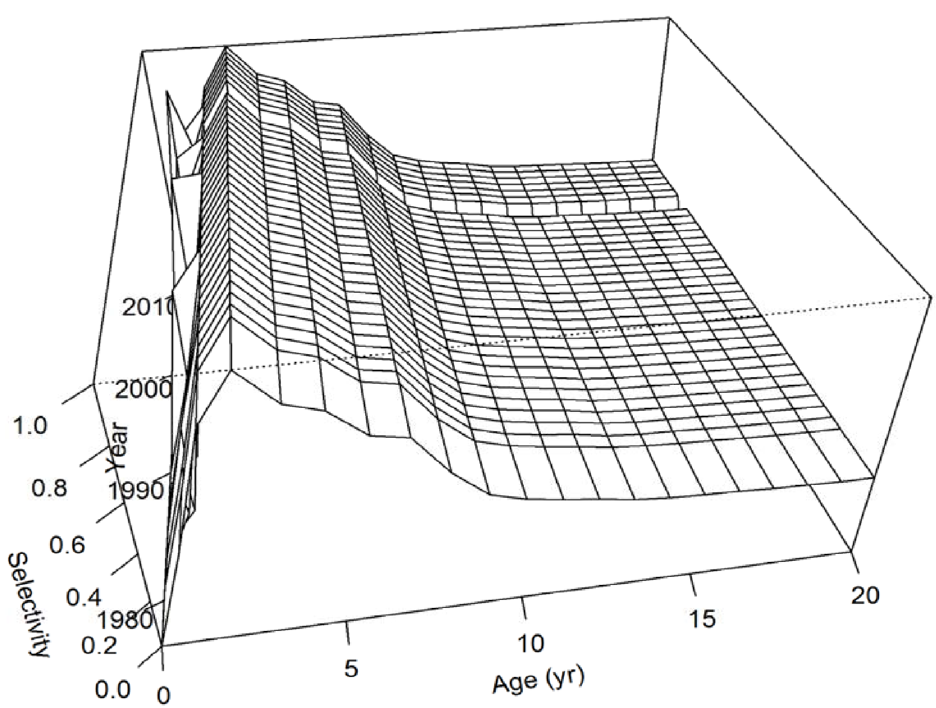


Figure 2.10—Trawl survey selectivity at age as estimated by Models 1 and 2.

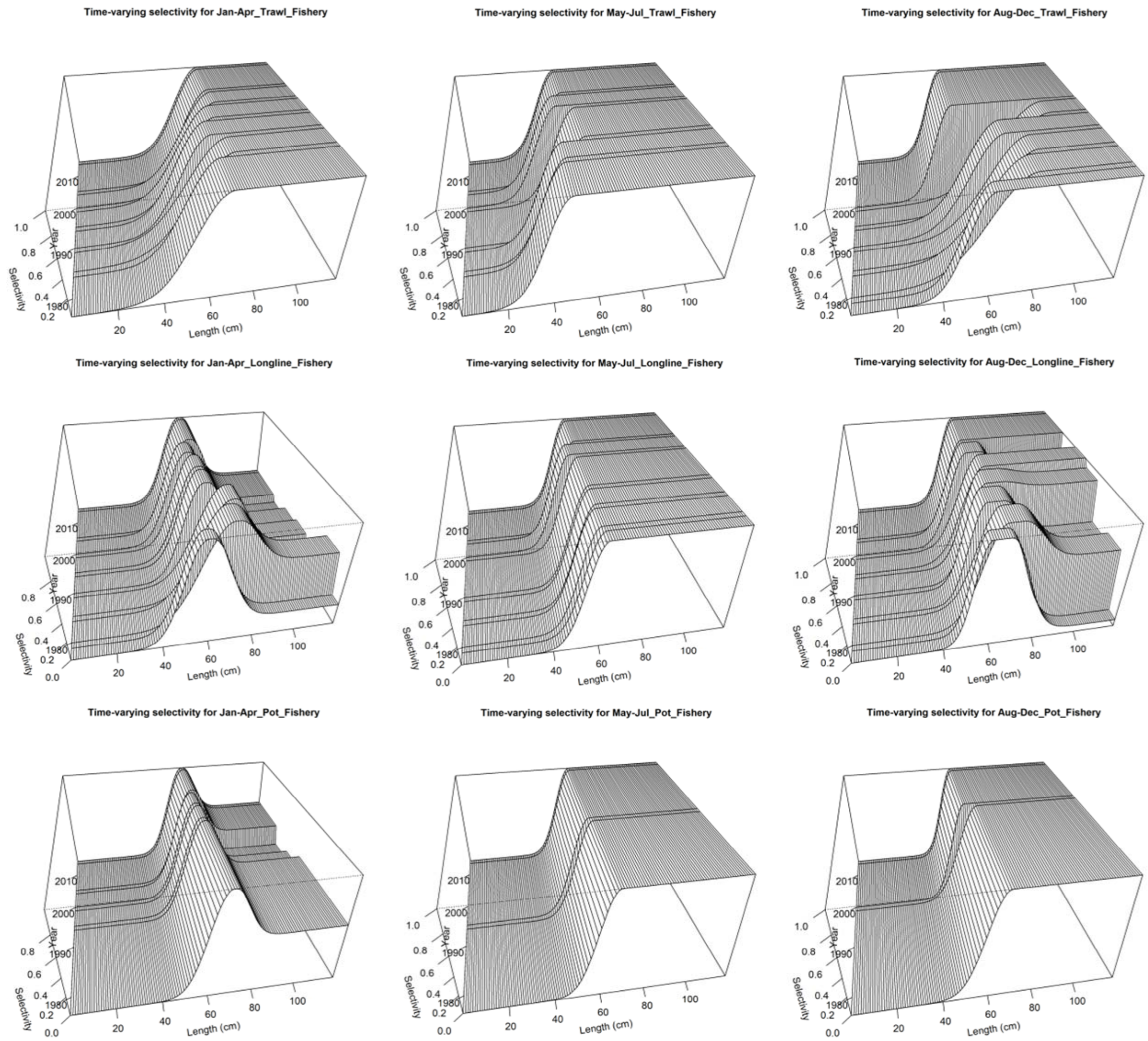


Figure 2.11a—Fishery selectivity at length (cm) as estimated by Model 1. Rows represent gear types (trawl, longline, and pot, respectively), and columns represent seasons (Jan-Apr, May-Jul, and Aug-Dec, respectively).

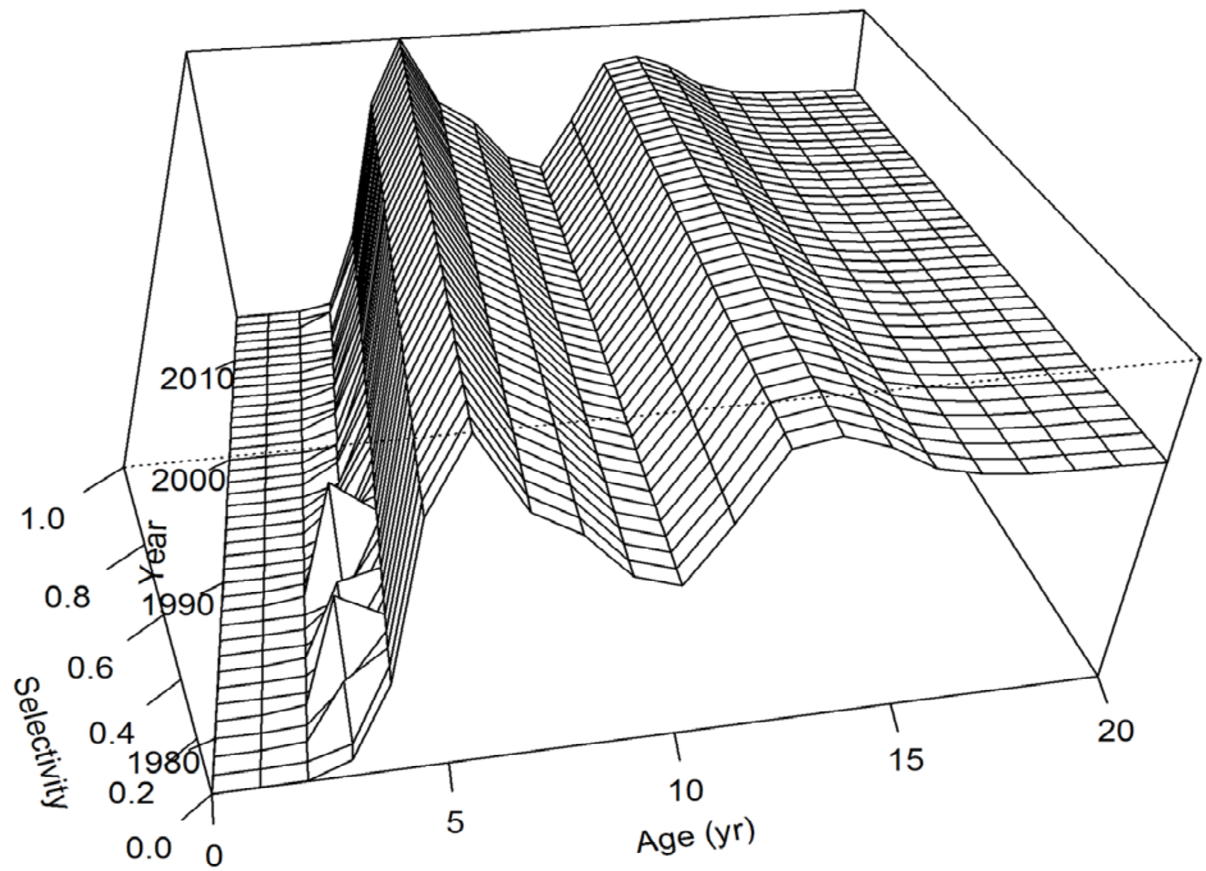
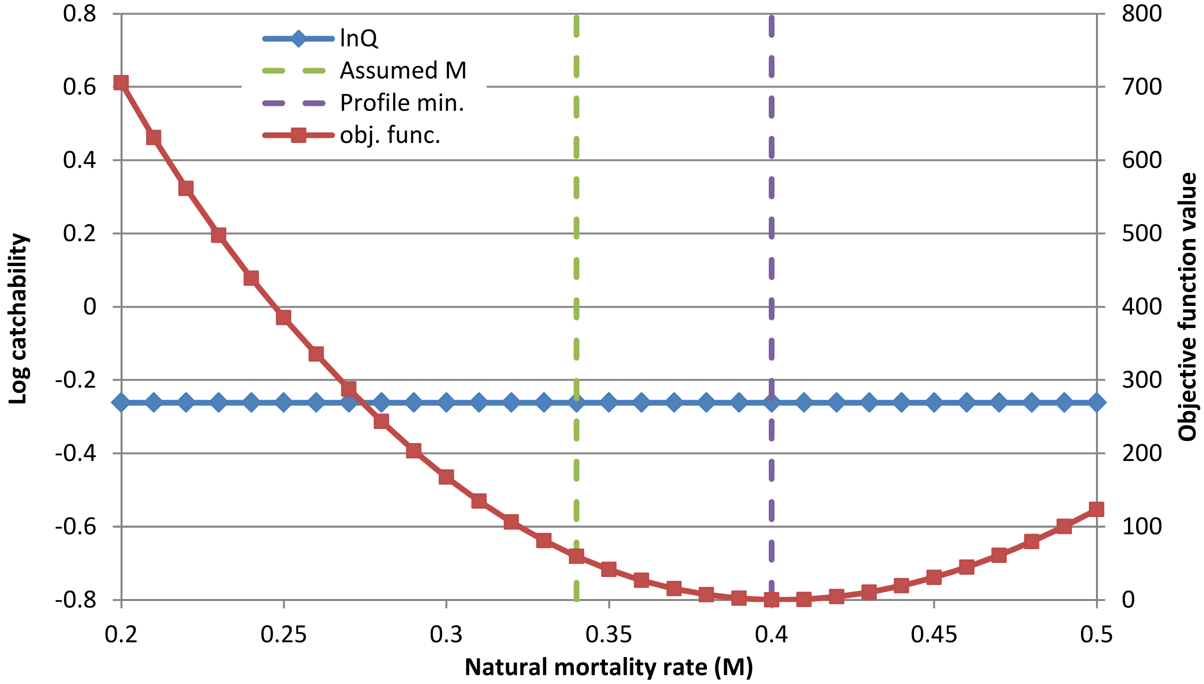


Figure 2.11b—Fishery selectivity at age as estimated by Model 2.

Model 1



Model 2

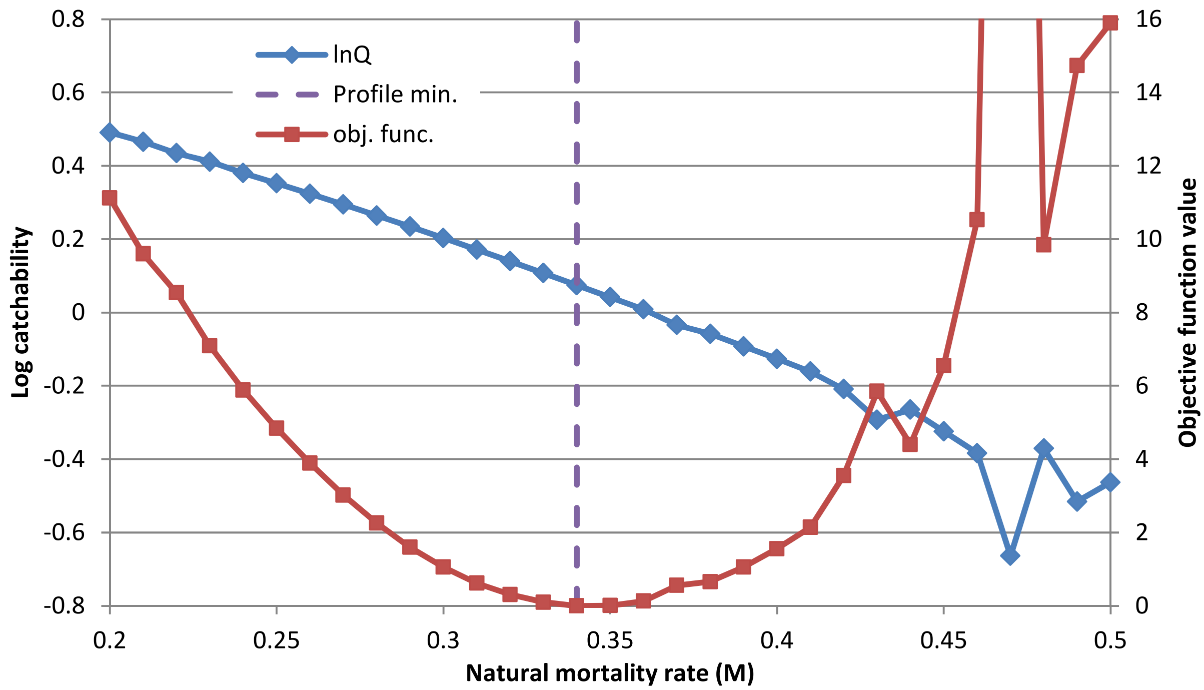


Figure 2.12— Likelihood profiles with respect to the natural mortality rate for Models 1 and 2. Objective function minima occur at *M*=0.40 (Model 1) and *M*=0.34 (Model 3). The relationship between *M* and log *Q* is also shown (*Q* is not estimated in Model 1). The jagged shapes for high values of *M* in Model 2 are likely due to lack of convergence in some runs.

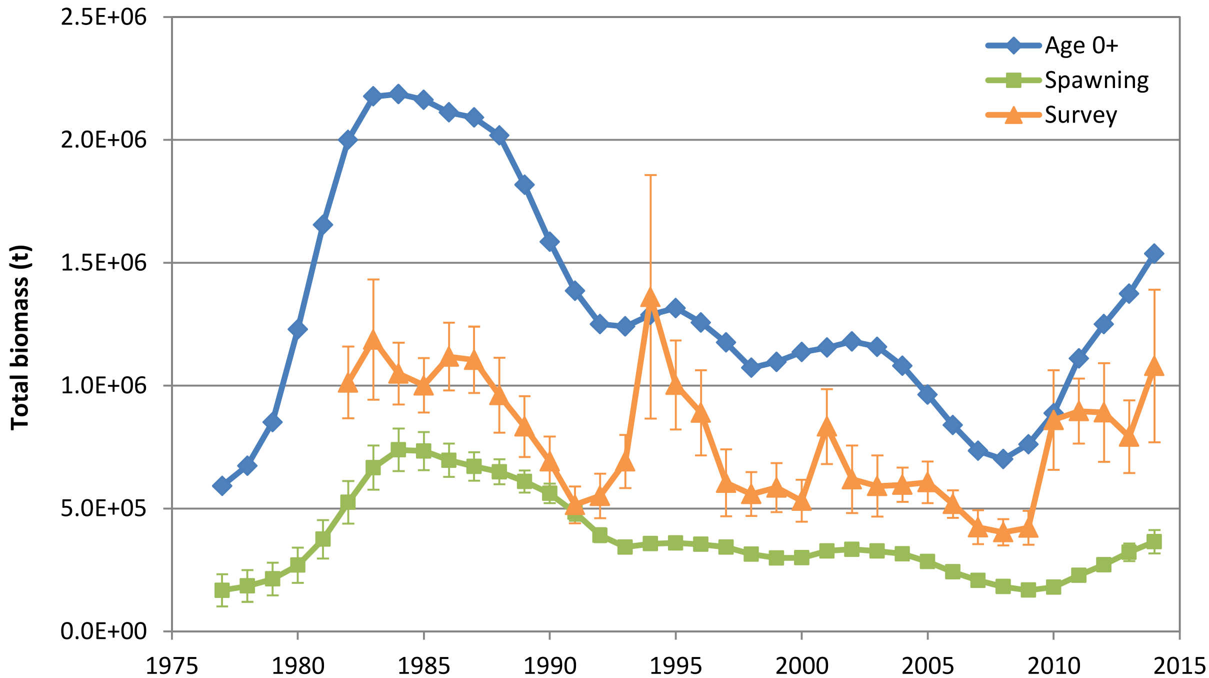


Figure 2.13—Time series of age 0+ and female spawning biomass as estimated by Model 1. Survey biomass is shown for comparison.

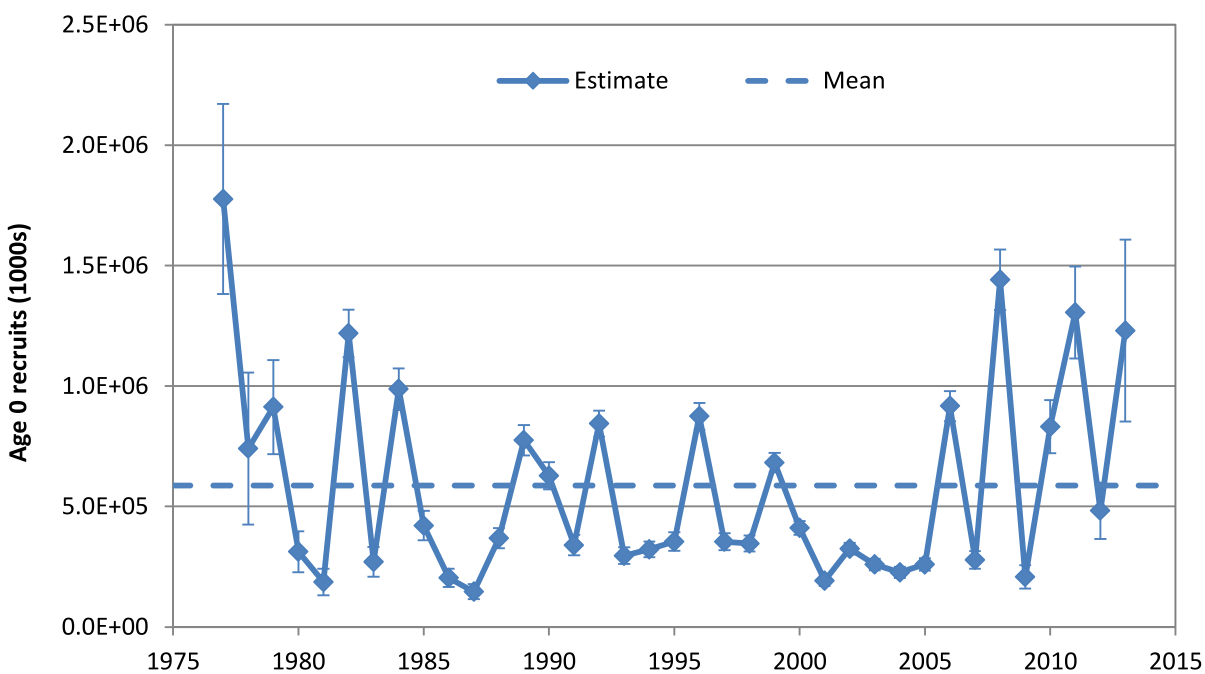


Figure 2.14—Time series of recruitment at age 0 as estimated Model 1.

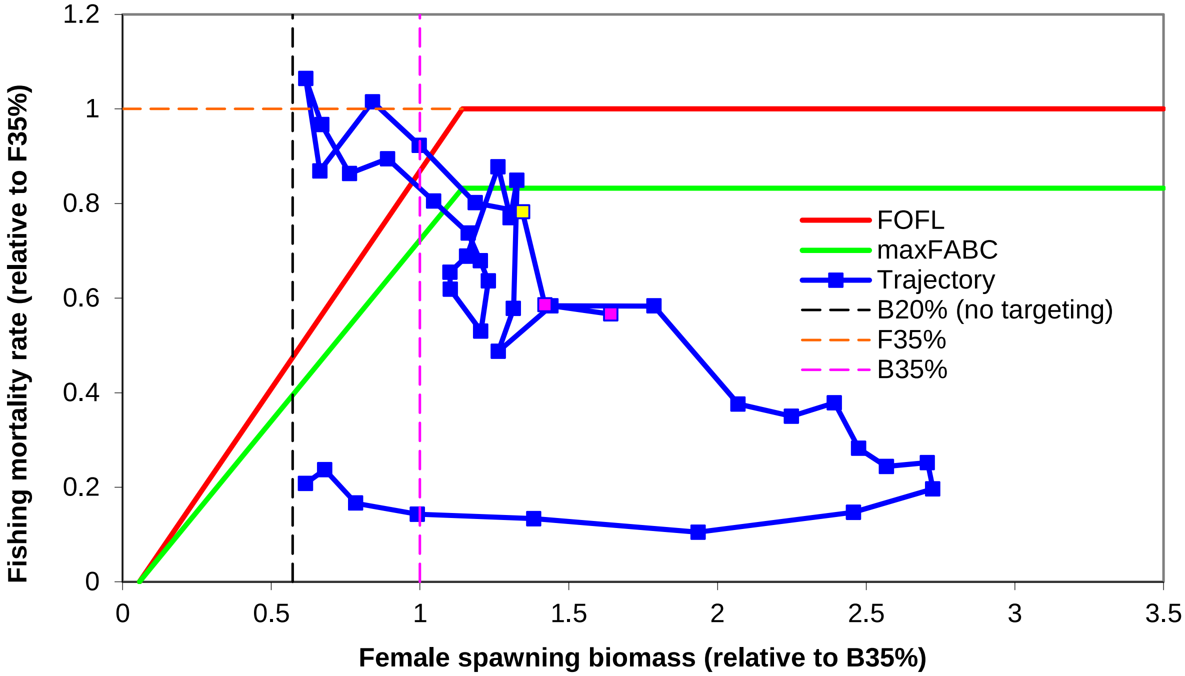
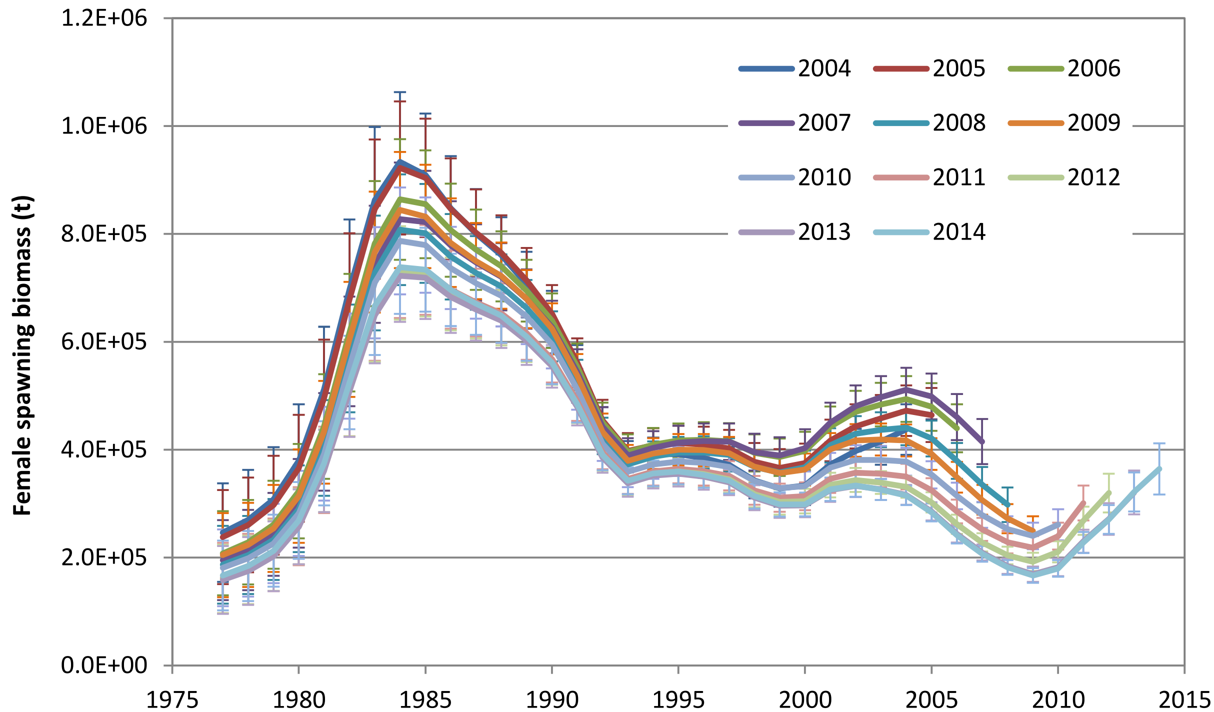


Figure 2.15—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by the stock assessment model, 1977-present (yellow square = current year, magenta squares = first two projection years).



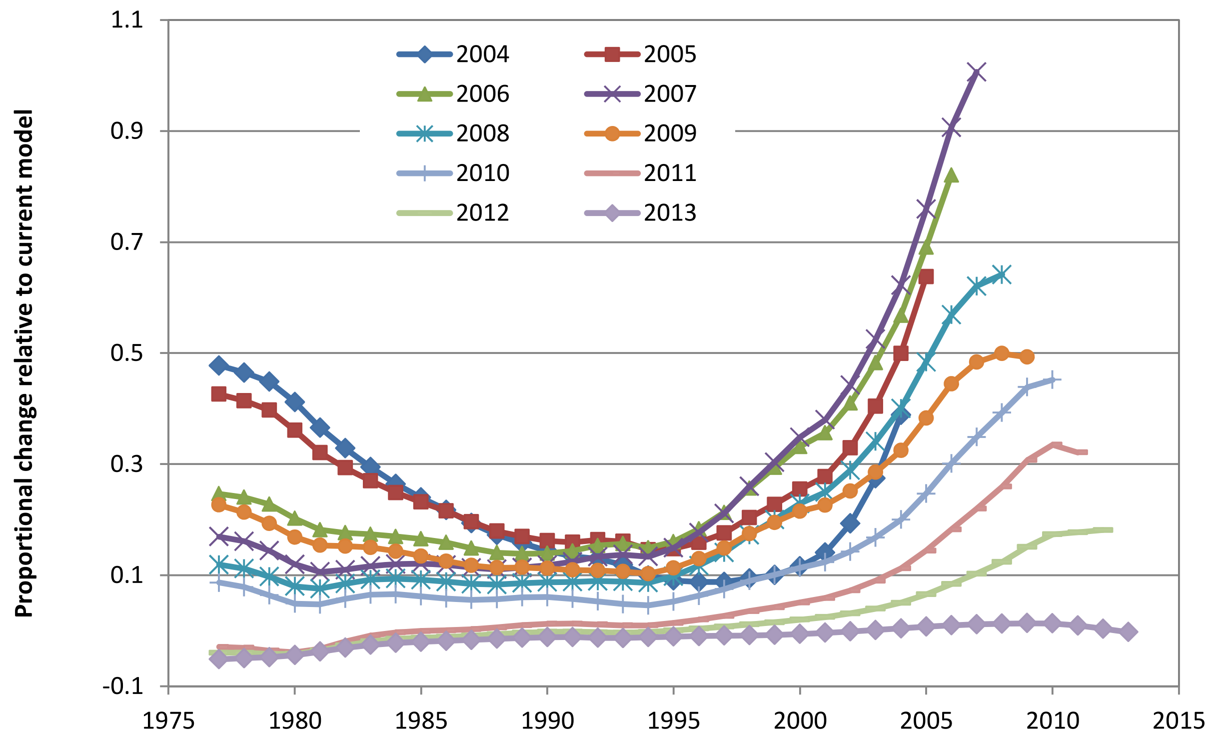


Figure 2.16—Retrospective analysis of spawning biomass estimates from Model 1. Top panel: spawning biomass time series with 95% confidence intervals from the current version of Model 1 (2014) and 10 retrospective runs (2004-2013) obtained by dropping one year of data at a time. Bottom panel: change in spawning biomass relative to the current version of Model 1 for each of 10 retrospective runs.

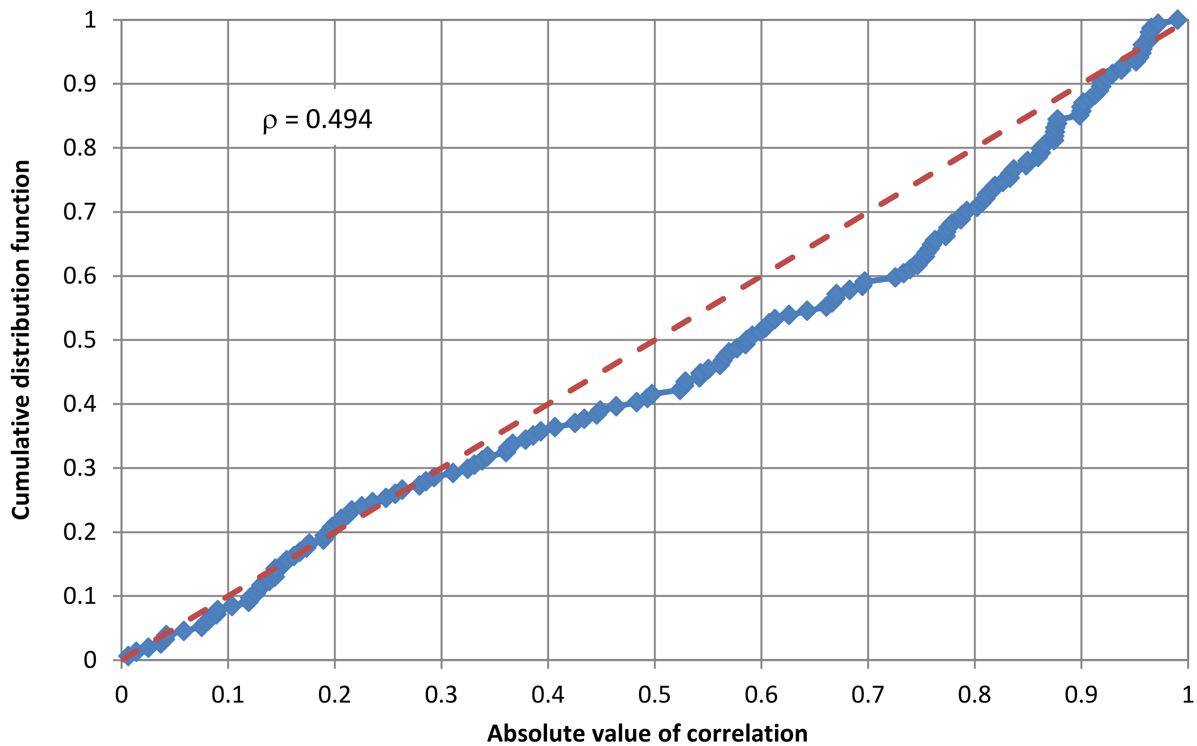
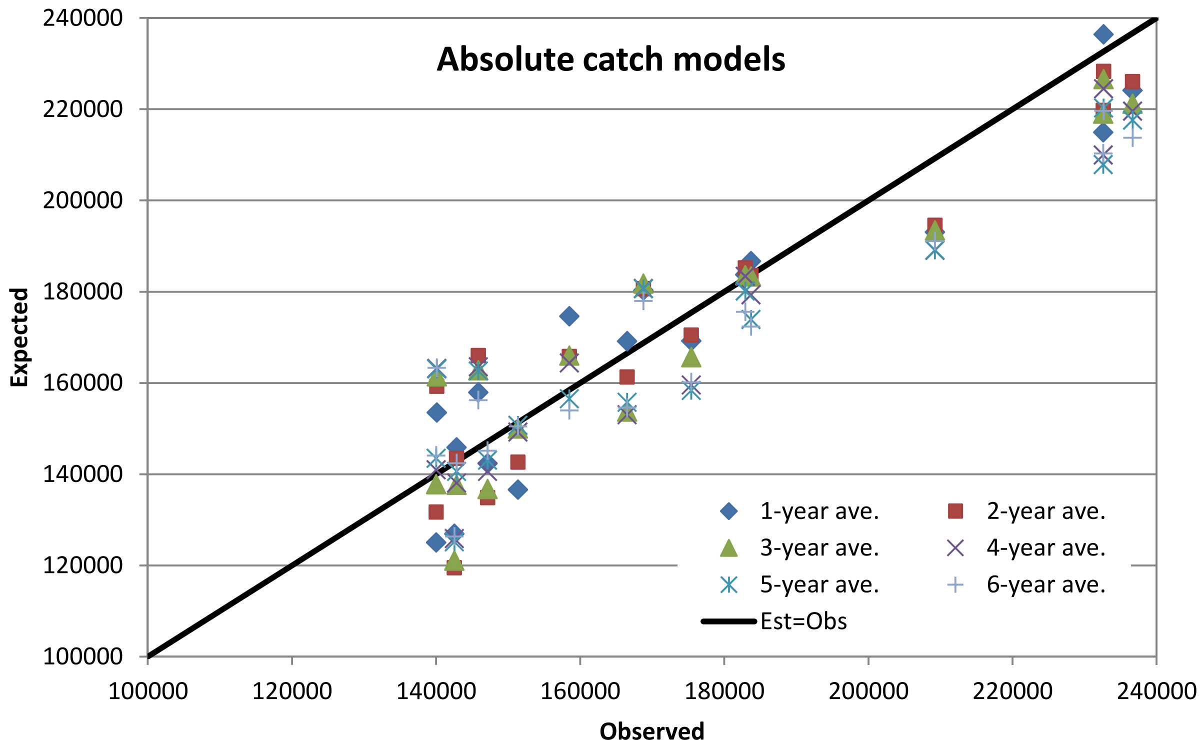


Figure 2.17—Cumulative distribution function (cdf) of correlations (absolute value) between model parameters and number of "peels" in retrospective runs. The diagonal dashed line represents the cdf that would be obtained from a uniform distribution. The statistic ρ represents the average (across peels) relative bias in terminal year estimates of spawning biomass.



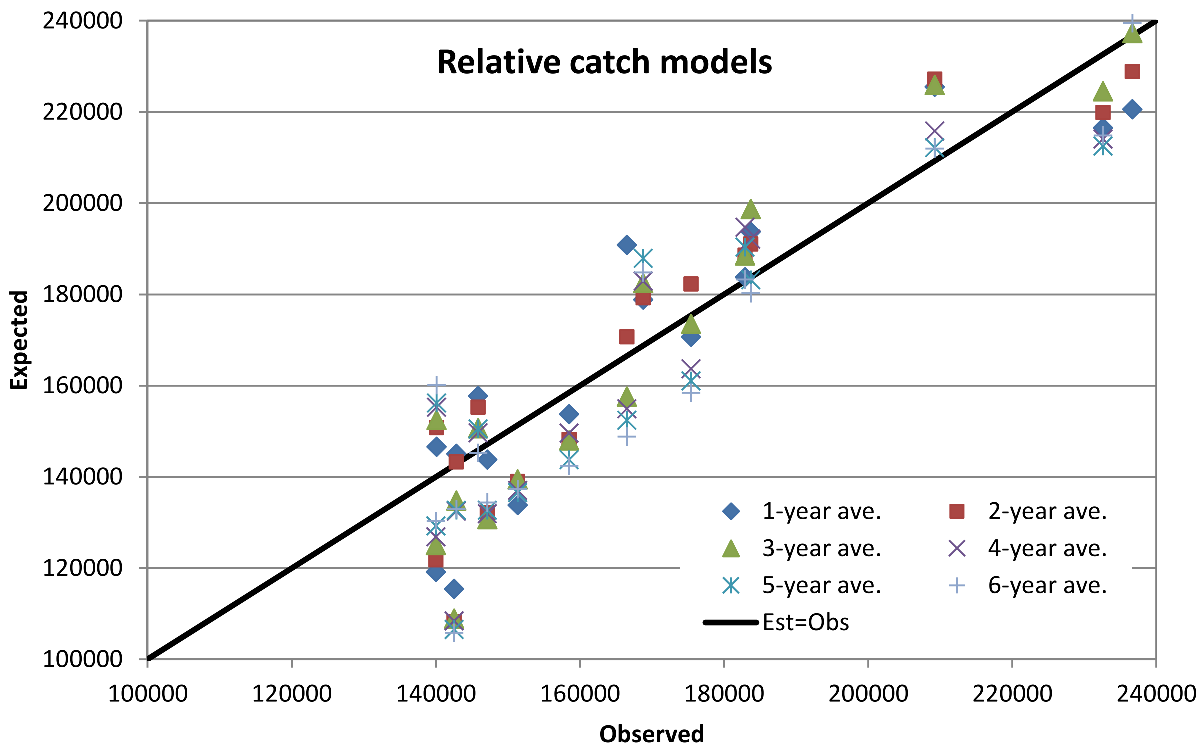


Figure 2.18—Estimators of current-year catch as a function of either absolute or relative August-December catch in some number (1-6) of previous years. Estimators with symbols closer to the diagonal line are better than others.

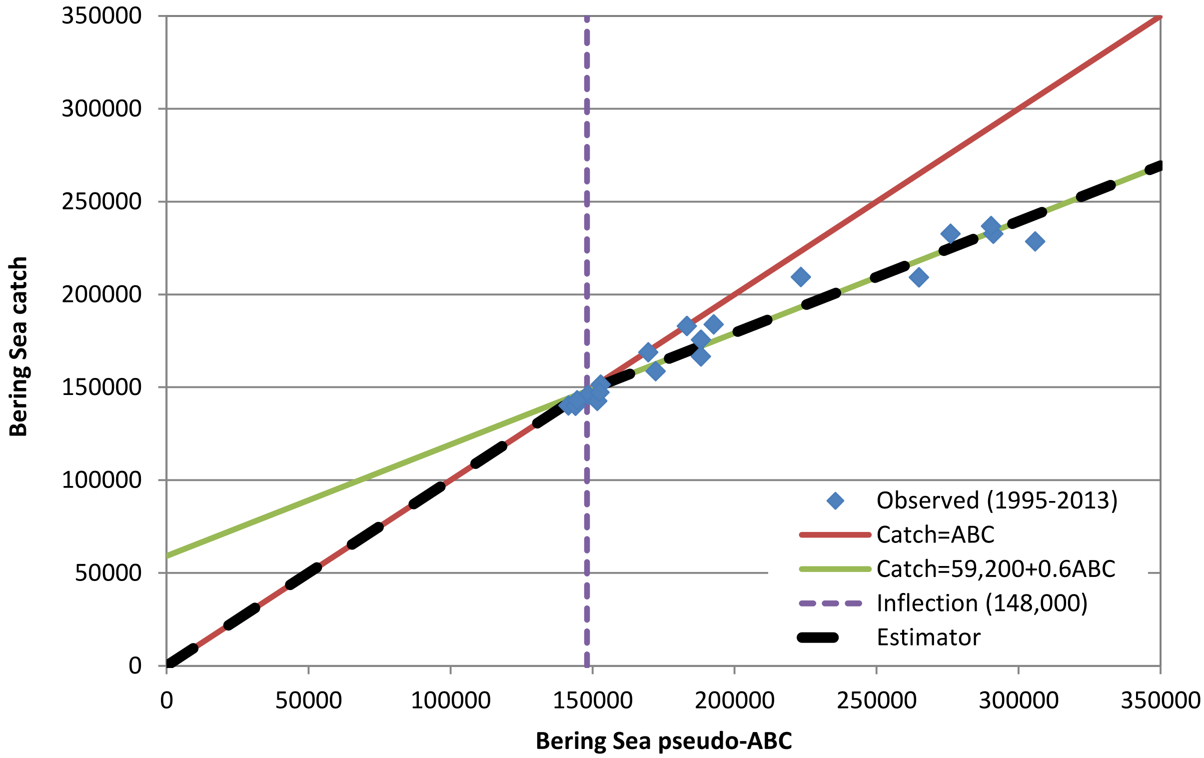


Figure 2.19—Estimation of catch as a function of ABC. Because Pacific cod ABCs through 2013 were specified for the entire BSAI region, "pseudo-ABCs" are shown here, computed by multiplying the overall ABC by the proportion of BSAI catch taken in the EBS. The estimator represented by the dashed black line segments was used to project 2015 and 2016 catch.

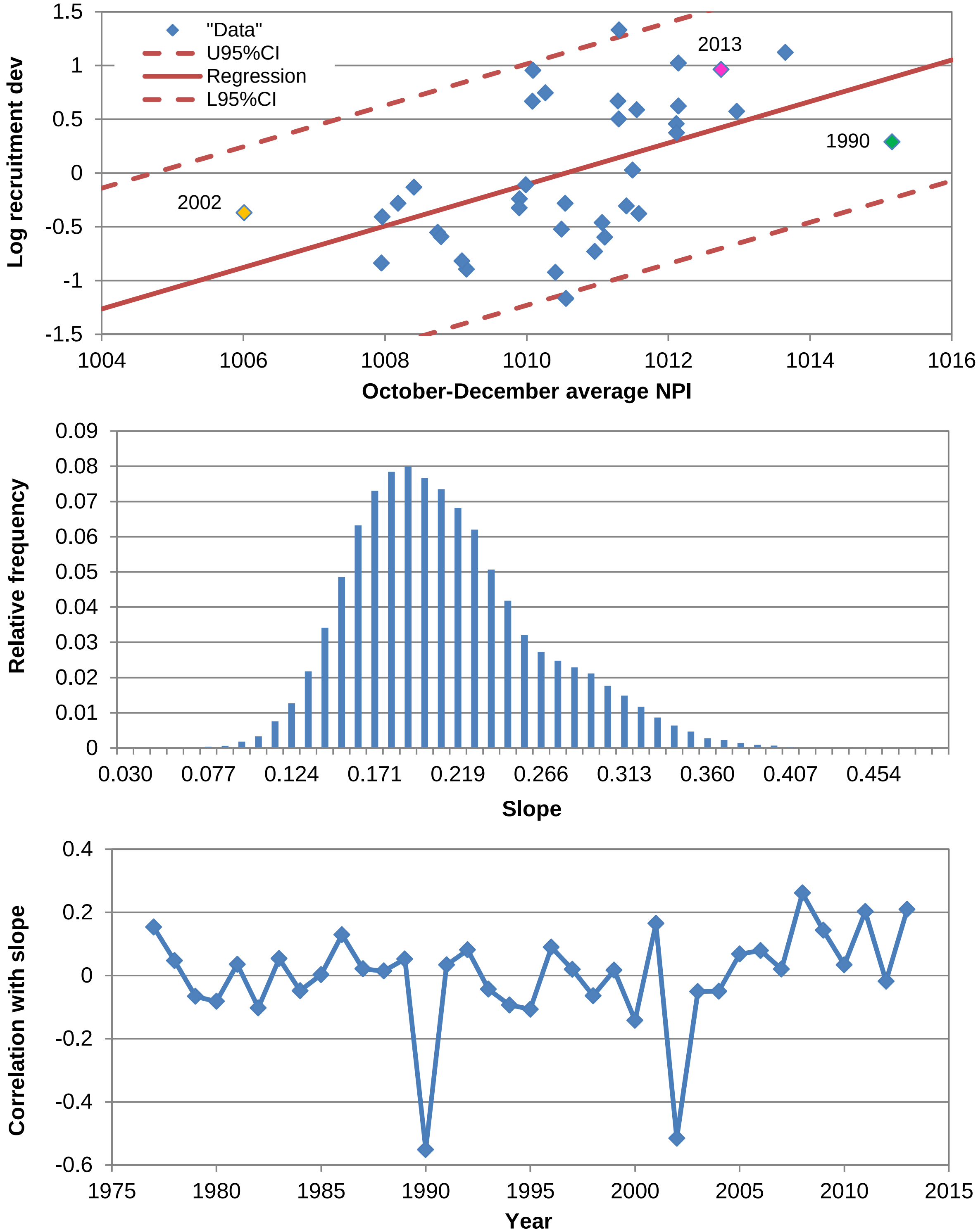


Figure 2.20—Environmental effects on recruitment. Upper panel: Estimated log recruitment *devs* (age 0) versus same-year October-December average of the NPI, with regression line and 95% confidence interval. Middle panel: Distribution of the regression slope, as generated by a cross-validation analysis.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

Grant G. Thompson

Resource Ecology and Fisheries Management Division
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7600 Sand Point Way NE., Seattle, WA 98115-6349

Introduction

This document represents an effort to respond to comments made by the BSAI Plan Team, the Joint BSAI and GOA Plan Teams, and the SSC on last year's assessment of the Pacific cod (*Gadus macrocephalus*) stock in the eastern Bering Sea (EBS, Thompson 2013).

Responses to SSC and Plan Team Comments on Assessments in General

Because last year's SSC and Plan Team comments pertaining to assessments in general all dealt with features of the final SAFE chapters, they will be addressed in this year's final assessment.

Responses to SSC and Plan Team Comments Specific to Eastern Bering Sea Pacific Cod

Note: In previous years, the full Joint Plan Teams have met in the spring to consider recommendations for models to be included in that year's Pacific cod assessments. In 2014, this task was delegated to a Joint Team Subcommittee (JTS) on Pacific Cod Models.

BPT1 (9/13 minutes): *"The Plan Team recommended that studies of the vertical distribution of Pacific cod continue in order to test the previous finding that the average product of survey catchability and selectivity across the 60-81 cm size range is 0.47 (based on vertical distribution from archival tags). These studies should include: 1) analysis of existing fish acoustic data (as recommended by Bob Lauth); and 2) depending on the results of that analysis, repeat the 2012 experiment in an area where Pacific cod are distributed farther off bottom and using an acoustic buoy to measure vertical response to the passing vessel."* When any such studies have been completed, their results will be evaluated for possible use in the assessment. See also comments BPT4 and SSC5.

BPT2 (9/13 minutes): *"The Team recommended the following candidate models for the November meeting, intended to provide a number of alternatives to the present standard Model 1:*

i. Model 1: the standard for the last two years.
ii. Model 2a: Model 2 from the September meeting, with fixed M and freely estimated survey Q.
iii. Model 2b: Model 2 from the September meeting, with fixed M but annually varying survey Q (mean value and dev vector estimated freely).
iv. Model 3a: Model 3 from the September meeting, with asymptotic survey selectivity and a prior on survey Q.
v. Model 3b: Like Model 3a but with M estimated.
vi. Model 4: Same as last year's Model 4.

The Team recommended that the author feel free to apply the iterative tuning procedures to Model 4 only, and use the values of the iteratively tuned quantities from Model 4 for the remaining models (other than Model 1) because all of the models other than Model 1 involve labor-intensive iterative tuning, and given *that all of these iteratively tuned models are based to some extent on Model 4."* Because of last year's October government shutdown, this comment was not addressed in last year's final assessment, but was forwarded to the Joint Team Subcommittee on Pacific Cod Models for consideration at its March 2014 meeting. See comments JTS2, JTS3, and SSC7.

SSC1 (10/13 minutes): *"The SSC notes that all of the Pacific cod models are characterized by a large number of parameters and dome-shaped selectivities, features that were found to be associated with retrospective patterns and a higher risk of overfishing in the meta-analysis by Hanselman et al. (see separate section). The SSC has previously encouraged the authors to simplify the models when possible and appreciates the suggestion by Grant Thompson (AFSC) to consider omitting seasonal structure in one or more of these models in the future."* Because of last year's October government shutdown, this comment was not addressed in last year's final assessment, but was forwarded to the Joint Team Subcommittee on Pacific Cod Models for consideration at its March 2014 meeting. See comments JTS2, JTS3, and SSC7.

SSC2 (10/13 minutes): *"The SSC agrees with Plan Team recommendations regarding models to bring forward in December. In addition to the recommended model configurations, the SSC would like to see a model or models that fix survey catchability at Q=1. We suggest presenting variants of model 2a (or 2b with mean Q=1) and model 3a with 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 that selectivity in the 60-81 cm size range is 0.47, which is based on a limited study by Nichol (2007). 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. We note that the default assumption in most assessments is that survey catchability is 1, unless there is strong evidence to the contrary. The evidence to date consists of the vertical distribution of 11 tagged fish under undisturbed conditions over a period of one month (Nichol et al 2007)."* Because of last year's October government shutdown, this comment was not addressed in last year's final assessment, but was forwarded to the Joint Team Subcommittee on Pacific Cod Models for consideration at its March 2014 meeting. See comments JTS2, JTS3, and SSC7.

BPT3 (11/13 minutes): *"The Team recommended … the following candidate models for next year's September meeting:*

a. Model 1: 2011-2012 standard (rationale: standard practice)
b. Model 2b: Model 4 from the 2012 assessment with fixed M, free survey selectivity, and annually varying survey Q (freely estimated mean and dev vector; rationale: … survey data simply cannot be fitted with a constant survey Q)
c. Model 3a: Model 4 from the 2012 assessment with fixed M, asymptotic survey selectivity, and Q=1 (rationale: an asymptotic candidate, one of the models requested by the SSC)
d. Model 3b: Like Model 3a but with M estimated (rationale: a check on the effect of freeing M)"

This comment was forwarded to the Joint Team Subcommittee on Pacific Cod Models for consideration at its March 2014 meeting. See comments JTS2, JTS3, and SSC7.

BPT4 (11/13 minutes): *"The Team also repeated its previous recommendation that studies of the vertical distribution of Pacific cod continue in order to test the previous finding that the average product of survey catchability and selectivity across the 60-81 cm size range is 0.47 (based on vertical distribution from archival tags). These studies should include: 1) analysis of existing fish acoustic data (as recommended by Bob Lauth); and 2) depending on the results of that analysis, repeat the 2012* *experiment in an area where Pacific cod are distributed farther off bottom and using an acoustic buoy to measure vertical response to the passing vessel."* When any such studies have been completed, their results will be evaluated for possible use in the assessment. See also comments BPT1 and SSC5.

SSC3 (12/13 minutes): *"The SSC re-iterates its concerns over the best value for the catchability coefficient (see December 2012 and October 2013 minutes), which prompted an SSC request additional model runs in October with catchability fixed at 1. In addition to the models already requested by the Plan Team in September 2013, this resulted in a large number of requested models. The Plan Team reduced the suite of models to three models in addition to the current base model, implementing changes to both Q and survey selectivity simultaneously and, secondly, exploring the effect of estimating M freely. The SSC discussed the need for a more incremental approach to implementing changes to the model. The two main issues of concern at this time are the shape of the selectivity function and the appropriate value for catchability (Q). Therefore, the SSC suggests a modeling approach that evaluates changes to selectivity and Q separately and in combination. To limit the number of requested model configurations, the SSC suggests that the Plan Team request for a model that freely estimates M be deferred to a future assessment."* This comment was forwarded to the Joint Team Subcommittee on Pacific Cod Models for consideration at its March 2014 meeting. See comments JTS2, JTS3, and SSC7.

SSC4 (12/13 minutes): *"Therefore, the SSC requests the following models to be brought forward in the 2014 assessment cycle. These recommendations pertain to the overall model structure only and would not preclude updating any of the models with new information. For example, if new estimates of catchability from the proposed analysis of acoustic data become available in time, they should be included in any of the models that are tuned to an empirical estimate of catchability.*

1. *The current base model (same as 2011, 2012) for comparison.*
2. *Model 4 from the 2012 assessment. Rationale: This model implemented a large number of changes relative to the base model and produced a good fit to the data in the 2012 assessment. However, the model was not accepted in 2012 because it had not been fully vetted. Re-fitting the model with 2 years of new data would allow further vetting of the model as a potential new base model and can serve as a basis for exploring the effects of modifying the shape of the survey selectivity function and changing Q.*
3. *Model 4 with annually varying survey Q (freely estimated mean and dev vector). Rationale: This follows a Plan Team recommendation reflecting the senior author's conviction that the survey data cannot be fitted with a constant survey Q. The SSC also notes that time-varying catchability was recognized at a recent international meeting as a possible avenue for improving stock assessments.*
4. *Model 4 with survey catchability fixed at Q=1. Rationale: 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 and is more fully detailed in our October 2013 minutes. This model will allow an evaluation of the effect of fixing Q without also changing the way selectivity is parameterized to help untangle effects of changing Q and changing selectivity.*
5. *Model 4 with fixed Q = 1 and asymptotic survey selectivity. Rationale: This model was previously recommended by the SSC and recommended by the Plan Team in November 2013 to help understand the consequences of using dome-shaped versus asymptotic selectivity in the model."*

This comment was forwarded to the Joint Team Subcommittee on Pacific Cod Models for consideration at its March 2014 meeting. See comments JTS2, JTS3, and SSC7.

SSC5 (12/13 minutes): *"To improve our understanding of survey catchability and provide better empirical estimates of selectivity, the SSC endorses the Plan Team recommendations with regard to survey catchability, specifically studies of the vertical distribution of Pacific cod, including an analysis of existing acoustic data."* When any such studies have been completed, their results will be evaluated for possible use in the assessment. See also comments BPT1 and BPT4.

JTS1 (3/14 minutes): *"The subcommittee discussed the SSC's minute from December 2011 requesting that the final 2011 model for each stock be evaluated over "several amendment cycles," noting that the definition of "several" is unclear. For the EBS, the 2011 model was re-evaluated in 2012 and 2013. For the GOA, the 2011 model was re-evaluated in 2012, but not in 2013 due to the government shutdown in October of that year. For this year, the subcommittee proceeded under the assumption that the SSC wishes to continue re-evaluating the 2011 models. However, the subcommittee recommended that 2014 be the final year for re-evaluation of the 2011 models, unless the 2011 model in one or more regions is chosen as the final model in 2014."* The final 2011 model is included in this preliminary assessment as Model 1. However, see also comment SSC10.

JTS2 (3/14 minutes): *"For the EBS, the subcommittee recommended that the following models be developed for this year's preliminary assessment:*

- *Model 1: Final model from 2011 (same as the final models from 2012 and 2013)*
- *Model 2: Model 5 from the 2012 preliminary assessment (same as Model 4 from the 2012 final and 2013 preliminary assessments)*
- *Model 3: Same as Model 2 in this list, but with:*
    - *survey catchability fixed at 1.0*
- *Model 4: Model 2 from the 2013 preliminary assessment, but with:*
    - *an internally estimated constant added to each year's survey abundance sigma*
- *Model 5: Model 3 from the 2013 preliminary assessment, but with:*
    - *survey catchability fixed at 1.0*
    - *natural mortality estimated freely"*

The above models are included in this preliminary assessment. See also comments JTS3 and SSC7.

JTS3 (3/14 minutes): *"In addition to the models contained in the above lists, the subcommittee expressed special interest in certain other models, but left development of those up to the respective author's discretion rather than including them in the lists of requested models. For the EBS, the discretionary models were as follow:*

- *A new model (author's choice) with no seasonal structure*
- *A new model (author's choice) with gear-specific fisheries and no seasonal structure"*

The first of the above optional models is included in this preliminary assessment as Model 6. See also comments SSC1 and SSC7.

SSC6 (4/14 minutes): *"The process for developing and refining appropriate models for Pacific cod still needs to mature and the SSC recommends that the assessment authors continue to work with the subcommittee to refine this process."* The authors will continue to work with the subcommittee to refine the process of developing appropriate models for Pacific cod. The next meeting of the subcommittee is anticipated to take place in the spring of 2015.

SSC7 (4/14 minutes): *"For 2014, the SSC recommends as an alternative model the use of the time-varying, non-parametric selectivity function described above"* (the reference to "above" in this comment pertains to a recommendation for modeling selectivity as a random walk with respect to age in the GOA Pacific cod assessment). Model 6 in this preliminary assessment includes the time-varying, non-parametric selectivity function.

SSC8 (4/14 minutes): *"Additionally, profiling over the natural mortality rate should be conducted to gain a better understanding of the relationship between global scaling (Q and its associated priors) and natural mortality rate. The mode of the M-profile should not be used as a basis for setting the natural mortality rate in the model as it is conditional on other structural assumptions in the model."* Likelihood profiles with respect to the natural mortality rate are included for all models in this preliminary assessment. The mode is not used for setting the natural mortality rate in Models 1-4, but it is used in Model 5 per request of the Joint Team Subcommittee on Pacific Cod Models (see comment JTS2) and Model 6 ("author's choice," per comment JTS3).

SSC9 (4/14 minutes): *"Lastly, the SSC recommends that as an overarching goal for these three areas, a common model structure be explored and based on the biology of Pacific cod and not devolve over time to address area-specific outliers or retrospective biases"* (the "three areas" referred to in this comment are the EBS, AI, and GOA). The model structures for all three areas already share several features in common. As further steps toward developing a common model structure, Model 6 in this preliminary assessment and all models in the preliminary assessment of the AI stock use the same fleet structure and the same approach to selectivity.

SSC10 (4/14 minutes): *"In light of the presentation, the SSC clarified its intent regarding the use of the base model ('base' being used here to identify the model accepted by the SSC in the previous year) for 'several' years. While the SSC cannot be prescriptive about the exact length of time this would be, the idea is to continue the use of the model until there is general agreement by the stock assessment authors, the Plan Team, and the SSC on discontinuing its use."* The model accepted by the SSC last year is included in this preliminary assessment as Model 1. However, an ambiguity remains: The SSC's request for continued evaluation of the final 2011 model (SSC minutes, December 2011) was not tied to that model being accepted by the SSC as the final model in each subsequent year. The question remains, then, as to how long the final 2011 model needs to be included among the set of candidate models in the event that the SSC chooses some other model as "final."

SSC11 (4/14 minutes): *"The SSC discussed the use of model averaging to ameliorate some of the problems of choosing among competing models with substantially different estimates. Essentially, the SSC agrees with the analyst that this approach should not be used until progress is made regarding issues about the selection of the competing models and averaging over models with nonlinearities in population and fishery processes."* Model averaging is not used in this preliminary assessment.

SSC12 (4/14 minutes): *"The SSC also discussed the nomenclature used to specify models in a historical context (when introduced and the model designator). While the SSC understands that this was useful for the historical presentation, it also notes that the nomenclature is confusing and probably not useful for the assessment in a given year. Furthermore, the use of 'base model' to denote any model that is proposed seems overly inclusive and perhaps should be restricted to the chosen model in a previous assessment year."* Use of the term "base model" will henceforth be restricted to denoting the chosen model in a previous assessment year.

Data

The data used in this preliminary assessment are identical to those used in last year's final assessment, except that estimates of base, seasonal, and annual weight-length parameters were updated using the method described in Thompson and Lauth (2012, Annex 2.1.2).

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	1977-2013
Fishery	Catch size composition	1977-2013
Fishery	Catch per unit effort	1991-2013
EBS shelf bottom trawl survey	Numerical abundance	1982-2013
EBS shelf bottom trawl survey	Size composition	1982-2013
EBS shelf bottom trawl survey	Age composition	1994-2012
EBS shelf bottom trawl survey	Mean size at age	1994-2012

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 V3.24s, as compiled on 7/24/2013 (Methot 2013). Stock Synthesis is programmed using the ADMB software package (Fournier et al. 2012).

Six models are presented. As requested by the Joint Team Subcommittee (comment JTS2), Model 1 in this preliminary assessment is the same as last year's final model (which was also the final model in 2011 and 2012). Model 2 is the same as Model 5 in the 2012 preliminary assessment (which is the same as Model 4 in the 2012 final assessment and the 2013 preliminary assessment). Models 3-5 are all based on Model 2, with the following modifications: Model 3 has survey catchability (Q) fixed at 1.0; Model 4 estimates Q with a uniform prior and adds an internally estimated constant to each year's log-scale survey abundance standard deviation; and Model 5 fixes survey catchability at 1.0 (like Model 3), forces survey selectivity to be asymptotic, and estimates the natural mortality rate (M) freely. Model 6 is a new model, which collapses the season-and-gear-specific fisheries of Model 1 into a single fishery (comments SSC1 and JTS3) with time-varying, non-parametric selectivity (comment SSC7). Model 6 is similar in many respects to the models considered in this year's preliminary assessment of the Aleutian Islands (AI) Pacific cod stock.

All of the models in this preliminary assessment except Model 6 used a double-normal curve to model selectivity (SS selectivity-at-length pattern #24 for the fisheries in all models and for the survey in Models 2-4, and SS selectivity-at-age pattern #20 for the survey in Model 1). 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.

Development of the final versions of all models included calculation of the Hessian matrix. All 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 0.01. 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.

Except for selectivity parameters in Model 6 and *dev* parameters in all models, all parameters were estimated with uniform prior distributions.

Model 1 used a data file with the same structure used for Model 1 in last year's final assessment. Models 2-5 used a common data file with the same structure used for Model 4 in last year's preliminary assessment. Model 6 used a unique data file structured to accommodate the features of that model.

Differences between Model 2 and Model 1, and between Model 6 and Model 1, are detailed below (separate sections are not presented for Models 3-5, because they each differ from Model 2 in only a few respects, as noted above).

Model 2

Some of the main differences between Model 2 and Model 1 were as follow:

1. An inter- and intra-annually varying weight-length representation based on an explicit phenological process (Thompson and Lauth 2012, Annex 2.1.2) was used. Model 1 also used an intra-annually varying weight-length representation, but each set of seasonal parameters was estimated independently of the other seasons, without being constrained by any phenological process.
2. "Tail compression" was turned off. This feature aggregates size composition bins with few or zero data on a record-by-record basis, which improves computational speed, but which also makes some of the graphs in the R4SS package difficult to interpret. In Model 1, tail compression is turned on.
3. Fishery CPUE data were omitted. In Model 1, fishery CPUE data were included for purposes of comparison, but are not used in estimation.
4. A new population length bin was added for fish in the 0-0.5 cm range, which was used for extrapolating the length-at age curve below the first reference age. In Model 1, the lower bound of the first population length bin was 0.5 cm.
5. Mean-size-at-age data were eliminated. In Model 1, mean-size-at-age data were included, but not used in estimation.
6. The number of estimated year class strengths in the initial numbers-at-age vector was set at 10. In Model 1, only 3 elements of the initial numbers-at-age vector were estimated, which causes an automatic warning in SS.
7. The Richards growth equation (Richards 1959, Schnute 1981, Schnute and Richards 1990) was used, which adds one more parameter. In Model 1, the von Bertalanffy equation—a special case of the Richards equation—was used.
8. The log-scale standard deviation of recruitment was estimated internally (i.e., as a free parameter estimated by ADMB). In Model 1, this parameter was held constant at the value of 0.57 that was estimated in the final 2009 assessment by matching the standard deviation of the recruitment *dev*s (normally distributed random deviations added to the base value of their respective parameter), per Plan Team request.
9. Survey selectivity was modeled as a function of length. In Model 1, survey selectivity was modeled as a function of age.
10. Fisheries were defined with respect to each of the five seasons, but not with respect to gear. In Model 1, fisheries were defined with respect to both season and gear.

11. Fishery selectivity curves were defined for each of the five seasons, but were not stratified by gear type. In Model 1, seasons 1-2 and 4-5 were lumped into a pair of "super" seasons for the purpose of defining fishery selectivity curves, and fishery selectivities were also *gear*-specific (3 super-seasons × 3 gears = 9 selectivity curves).
12. The selectivity curve for the fishery that came closest to being asymptotic on its own (in this case, the season 3 fishery) was forced to be asymptotic by fixing both *width_of_peak_region* and *final_selectivity* at a value of 10.0 and *descending_width* at a value of 0.0. In Model 1, six of the nine super-season × gear fisheries were forced to exhibit asymptotic selectivity.
13. The age composition sample size multiplier was tuned iteratively to set the mean of the ratio of effective sample size to input sample size equal to 1.0. In Model 1, the variance adjustment was fixed at 1.0.
14. The two parameters governing the ascending limb of the survey selectivity schedule were given annual additive *dev*s with each σ_{dev} tuned to match the estimate that would be appropriate for a univariate linear-normal model with random effects integrated out (Thompson and Lauth 2012, Annex 2.1.1). In Model 1, no *dev* vector corresponding to the *initial_selectivity* parameter was used, because it was "tuned out" in the 2009 final assessment; and σ_{dev} for the *ascending_width* parameter was left at the value of 0.07 estimated iteratively in the final 2009 assessment, per Plan Team request.
15. The logarithm of survey catchability (ln(Q)) was re-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 Model 1, Q was left at the value of 0.77 estimated by a similar procedure in the final 2009 assessment, per Plan Team request.

As recommended in comment BPT2, quantities that were tuned iteratively in Model 2 (in 2012) were not re-tuned in Models 3-5.

Model 6: main features

Some of the main differences between Model 6 and Model 1 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. Length at age 1.5 was allowed to vary annually.
8. Survey catchability was allowed to vary annually.
9. Selectivity for both the fishery and the survey were allowed to vary annually.
10. 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. Selectivity-at-age pattern #17 in SS has one parameter for each age in the model. Except for age 0, the parameter for any given age represents the logarithm of the ratio of selectivity at that age to selectivity at the previous age (i.e., the backward first difference on the log scale). Age 0 fish are often expected to have a selectivity of zero, which can be achieved in this selectivity pattern by setting the parameter for age 0 equal to -1000, as was done for all six models presented here. As with other parameters in SS, each parameter in this selectivity pattern is associated with a prior distribution (see "Iterative tuning of prior distributions for selectivity parameters" in the next subsection).

Model 6: iterative tuning

Three types of iterative tuning were involved in the development of Model 6. The first of these applied only to the prior distributions for selectivity parameters, and the second applied to all time-varying parameters except catchability, and the third applied only to time-varying catchability.

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%.

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. The converged set of prior means (on the transformed scale, not the selectivity scale) was as follows (ages 8+ all had prior means of 0 for both the fishery and the survey):

Age:	1	2	3	4	5	6	7
Fishery:	2.940	2.937	2.887	2.258	0.603	0.045	0.002
Survey:	5.020	0.607	0.003	0.000	0.000	0.000	0.000

The converged prior standard deviations were 0.350 for the fishery and 0.319 for the survey (both constant across age).

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 to use the method of Thompson and Lauth (2012, Annex 2.1.1) for estimating the standard deviation of a *dev* vector:

1. Estimating "unconstrained" estimates of the standard deviation(s) of the *dev*s for a particular parameter or parameter vector. The purpose of this loop was to determine the vector of *dev*s for an individual parameter or parameter vector that would be obtained if the *dev*s were completely unconstrained by their respective σs. The following individual parameters and parameter vectors were included in this exercise: *L1* (length at age 1.5), age 0 recruitment, the vector of age-specific fishery selectivity parameters, and the vector of age-specific survey selectivity parameters. For parameter vectors especially, 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, in the case of a parameter vector) 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. Estimating "iterated" estimates of the standard deviations for the *dev*s. Again proceeding one parameter or parameter vector fleet at a time, this loop began with σ set at the unconstrained value(s) estimated in the first loop. The standard deviation(s) of the estimated *dev*s then became the age-specific σ(s) for the next run, and the process was repeated until convergence was achieved.

For *L1* and age 0 recruitment, the final values of σ (after application of the algorithm described by Thompson and Lauth (2012, Annex 2.1.1)) were 0.086 and 0.657, respectively (note that the *L1 dev*s are lognormal and multiplicative, while the recruitment *dev*s are normal and additive).

In the case of a vector of age-specific selectivity parameters, it is common for some ages to be "tuned" out during the second loop (i.e., the σs converge on zero). For Model 6, all ages were tuned out except age 4 for the fishery and ages 2 and 3 for the survey. The final values of σ (after application of the algorithm described by Thompson and Lauth (2012, Annex 2.1.1)) were 0.158 for fishery age 4 and 0.106 for survey ages 2 and 3 (note that these *dev*s are all normal and additive).

Unfortunately, the way that selectivity pattern #17 is implemented in SS, large gradients tend to result if significant *dev*s occur at the age of peak selectivity. Because survey selectivity for Model 6 tended to peak at age 3, it turned out to be impossible to include *dev*s for age 3, so Model 6 included survey selectivity *dev*s for age 2 only.

Iterative tuning of time-varying catchability

Unlike the size composition or age composition data sets, the time series of survey abundance includes not only a series of expected values, but a corresponding series of standard errors as well. This formed the basis for the iterative tuning of the σ term for time-varying catchability in Model 6. The procedure involved iteratively adjusting σ until the root-mean-squared-standardized-residual equaled unity. The resulting value of σ was 0.089 (normal and additive, because SS works in terms of ln(*Q*) rather than *Q*).

Parameters Estimated Outside the Assessment Model

Parameters estimated outside the assessment model were detailed in last year's final assessment (Thompson 2013). In particular, the natural mortality rate *M* was fixed at 0.34 in Models 1-4 (*M* was estimated internally in Models 5 and 6), the standard deviations of the ageing error matrix extended linearly from a value of 0.086 at age 1 to a value of 1.73 at age 20, and the parameters of the logistic maturity-at-age relationship were set at values of 4.88 years (age at 50% maturity) and –0.965 (slope) in all models. As noted in the data section, estimates of base, seasonal, and annual weight-length parameters were updated using the method described in Thompson and Lauth (2012, Annex 2.1.2).

Parameters Estimated Inside the Assessment Model

Parameters estimated inside SS vary to some extent between the six 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 the beginning of the time series; offset for log mean recruitment prior to the beginning of the time series; *dev*s for log-scale initial (i.e., 1977) abundance at ages 1 through 3; annual log-scale recruitment *dev*s for 1977-2012; initial (equilibrium) fishing mortality; and base values for all fishery and survey selectivity parameters (although the nature of these parameters varies between models). A complete list of 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 full set of 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 Wetzell 2013).

Likelihood Components

All six models include likelihood components for initial (equilibrium) catch, trawl survey relative abundance, fishery and survey size composition, survey age composition, recruitment, prior distributions (Model 6 only), "softbounds" (equivalent to an extremely weak prior distribution used to keep parameters from hitting bounds), and parameter deviations.

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

Results

Overview

The following table summarizes the status of the stock as estimated by the six models ("Value" is the point estimate, "SD" is the standard deviation to the point estimate, "FSB 2014" is female spawning biomass in 2014 (t), and "Bratio 2014" is the ratio of FSB 2014 to $B_{100\%}$:

	Model 1		Model 2		Model 3	
Quantity	Value	SD	Value	SD	Value	SD
FSB 2014	357,617	23,221	439,474	29,313	243,630	18,391
Bratio 2014	0.478	0.026	0.486	0.042	0.325	0.029

	Model 4		Model 5		Model 6	
Quantity	Value	SD	Value	SD	Value	SD
FSB 2014	95,727	18,881	162,445	14,289	245,145	36,050
Bratio 2014	0.151	0.028	0.290	0.026	0.346	0.053

The six models span wide ranges for these quantities. Estimates of FSB 2014 range from 96,000 t (Model 4) to 439,000 t (Model 2), and estimates of Bratio 2014 range from 0.15 (Model 4) to 0.49 (Model 2).

Goodness of Fit

Objective function values are shown for each model below (lower values are better, all else being equal; color scale extends from red (minimum) to green (maximum); note that the parameter counts include constrained deviations):

Component	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Survey index	-6.25	9.22	-12.25	-30.83	-19.78	-57.16
Size composition (fishery)	3813.17	2143.87	2093.76	2065.55	2094.71	204.11
Size composition (survey)	867.17	556.42	552.57	549.72	564.74	439.28
Age composition	138.69	128.56	124.32	121.30	119.69	117.08
Recruitment	21.38	15.58	17.09	15.08	9.31	0.18
Priors	0.00	0.00	0.00	0.00	0.00	15.50
Parameter *devs*	20.65	22.48	23.54	28.01	24.48	26.95
Other	0.03	0.03	0.21	0.41	0.42	0.17
Total	4854.84	2876.15	2799.24	2749.25	2793.56	746.11
Number of parameters	184	144	144	146	142	230
AIC	10077.68	6040.30	5886.48	5790.50	5871.12	1952.22

Models 2-5 have far fewer parameters than Models 1 or 6 (although many of the parameters in Model 6 are constrained deviations). In addition to the problem of counting constrained deviations as full parameters, the AIC values are not comparable across all models due to the fact that different data files are used for Models 1, 2-5, and 6. Although Models 2-5 all used the same data file, the AIC value for Model 4 probably should not be compared to the values for Models 2, 3, and 5, because Model 4 includes an estimated parameter that inflates the log-scale standard errors for the survey abundance time series specified in the data file, which is equivalent to changing the data file. Among Models 2, 3, and 5, Model 5 has the lowest (best) AIC value. Model 5 also has the lowest (best) value for the overall objective function among this subset of models. Evidently, fixing Q at a value of 1.0 in Model 3, rather than the fixed value of 0.75 used in Model 2, allows Model 3 to fit the data better than Model 2 overall. Given that the only structural differences between Models 3 and 5 are that survey selectivity is forced to be asymptotic and M is estimated internally in Model 5, it is likely that the lower value for the objective function in Model 5 is due to internal estimation of M, because forcing survey selectivity to be asymptotic would be expected to result in a worse fit overall.

Figure 2.1.1a shows the fits of the six models to the trawl survey abundance data, and Figure 2.1.1b shows the same thing in terms of standardized residuals (note that the confidence intervals for the observed values do not account for the "extra" measurement error estimated by Model 4). Models 2, 3, and 6 all estimate a 2013 survey biomass within 10% the observed value (the estimates from Models 1, 4, and 5 are 17% high, 35% low, and 11% low, respectively). All models show a mix of positive and negative residuals. Models 1 and 2 tend to overestimate the survey abundance, although usually not by much. Some summary statistics are shown below, where the values for Model 4 incorporate the estimated "extra" measurement error (for comparison to the root mean squared residual, the average log-scale standard error in the data is 0.108, except for Model 4, where the value is 0.234):

Quantity	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Correlation (observed:expected)	0.929	0.909	0.957	0.963	0.974	0.993
Root mean squared residual	0.221	0.251	0.215	0.234	0.192	0.110
Mean standardized residual	0.913	1.032	0.783	0.045	0.225	0.094
Root mean squared stand. residual	2.042	2.266	1.947	1.001	1.822	0.992

Models 4 (given the estimated "extra" measurement error) and 6 do about as well or better than any of the other models by all of the above measures. Model 2 does the worst of all the models by any of the above measures.

Sample size ratios (effective sample size divided by input sample size) for the size composition data are shown in Table 2.1.1. All six models give values (either the mean of the ratios or the ratio of the means) far in excess of unity for both the fishery and the survey.

Figure 2.1.2 shows the models' fits to the survey age composition data. Effective sample sizes and negative log likelihoods are shown in Tables 2.1.2a and 2.1.2b. Models 3-6 give average effective sample sizes in excess of the average input sample size, while Models 1 and 2 do not. However, it should be noted that the values for Models 2-5 in the last two rows of Table 2.1.2a are not strictly comparable to those for Models 1 and 6, because the input sample sizes for Models 2-5 were all multiplied by a factor of 0.85 (a result of the tuning process used for Model 2).

Parameters, Schedules, and Time Series Estimates

Table 2.1.3 (spanning 14 pages) lists the constants and parameters listed in the SS control files for the six models, along with standard deviations for all estimated parameters. Constants are listed in Table 2.1.3a, main parameters (except recruitment and selectivity) common to most or all models are listed in Table 2.1.3b, recruitment *dev*s are listed in Table 2.1.3c, *L1* *dev*s and ln(*Q*) *dev*s estimated by Model 6 are listed in Table 2.1.3d (transformed to the raw *L1* and *Q* scales and plotted in Figure 2.1.3), base selectivity parameters estimated by Model 1 are listed in Table 2.1.3e, block selectivity parameters and selectivity *dev*s estimated by Model 1 are listed in Table 2.1.3f (spanning 3 pages), base selectivity parameters estimated by Models 2-5 are listed in Table 2.1.3g, annual *dev*s for selectivity parameter #3 estimated by Models 2-5 are listed in Table 2.1.3h (see third paragraph under "Model Structures" for numbering of selectivity parameters), annual *dev*s for selectivity parameter #5 estimated by Models 2-5 are listed in Table 2.1.3i, base selectivity parameters estimated by Model 6 are listed in Table 2.1.3j, annual *dev*s for the age 4 fishery selectivity parameter estimated by Model 6 are shown in Table 2.1.3k, and annual *dev*s for the age 2 survey selectivity parameter estimated by Model 6 are shown in Table 2.1.3l. Quantities with "n/a" listed under "SD" were fixed rather than estimated.

Figure 2.1.4 (spanning six pages) shows the fishery selectivity schedules estimated by the six models. These schedules are time-varying for Models 1 and 6, but time-invariant for Models 2-5. Figure 2.1.5 shows the survey selectivity schedules estimated by the six models. These are all time-varying. All models except Model 5 (where survey was forced to be asymptotic) estimate that survey selectivity decreases substantially at larger sizes (Models 1-4) or older ages (Model 6).

Time series estimated by the six models are shown for female spawning biomass, relative (to $B_{100\%}$) female spawning biomass, and age 0 recruitment in Figures 2.1.6, 2.1.7, and 2.1.8, respectively. In most cases, Figures 2.1.6 and 2.1.7 are very similar except for scale. Models 1 and 2 tend to estimate the highest values of spawning biomass, while Models 4 and 5 tend to estimate the lowest. Figure 2.1.8 indicates a very high degree of synchrony among the estimates of recruitment, except in the first year of the time series (i.e., the 1977 year class). Model 4 tends to estimate the lowest recruitments of the six models.

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 2014 range from 96,000 t (Model 4) to 439,000 t (Model 2), and estimates of this quantity relative to $B_{100\%}$ range from 0.15 (Model 4) to 0.49 (Model 2). Estimates of survey catchability range from 0.75 (Model 2) to 1.42 (Model 4). Other results, however, show greater similarity. For example, all models except Model 5, where survey selectivity was forced to be asymptotic, indicate that survey selectivity decreases substantially at larger sizes (Models 2-4) or older ages (Models 1 and 6).

Although the natural mortality rate *M* is estimated internally in only Models 5 and 6, Figure 2A.1.9 shows the likelihood profiles with respect to *M* for each of the models. If *M* were estimated internally in all models, the estimates would range from a low of 0.36 (Model 6) to a high of 0.44 (Model 2). The entire range lies above the estimate of 0.34 that is hard-wired into Models 1-4, although the lower end of the range is close to that value.

All models presented here generally provided good-to-excellent fits to the size composition and age composition data, although Model 1's fit to the age composition data was a bit lacking, and the acceptable fits to the age composition data achieved by Models 2-5 were accomplished by down-weighting those data. However, none of the models except Models 4 and 6 (the only models that estimated *Q* internally) were able to estimate a survey abundance time series that is consistent with the standard errors in the data. Model 4 was able to do so by inflating the raw standard errors, while Model 6 did so by allowing *Q* to have annual *dev*s (note that the estimates of Q from these two models were quite different: 1.42 for Model 4 and 1.03 for Model 6)

Last year's preliminary assessment of the AI Pacific cod stock provided the first exploration of SS selectivity-at-age pattern #17 (random walk with age) for Pacific cod, and use of this pattern has been included here in Model 6. 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).

Model 6 also emphasized the potential time variability of both fishery and survey selectivity. 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 to vary over time.

Although Model 6 gives excellent fits to the data, various features of the model may require further evaluation before the model is accepted for use in management. For example, the annual values estimated for the *L1* parameter are only mildly consistent with existing data (not included in the data file) on time variability in that parameter. Figure 2.1.10 compares the time series of *L1* values estimated by Model 6 with three other time-varying measures: 1) the mean length at age 1.5 (i.e., age 1 at the time of the survey) estimated by the age readers, 2) the first mode in the survey size composition data, and 3) the mean of a normal distribution fit to the region around the first mode in the size composition data. The correlation between the Model 6 estimates and these three estimators is only 0.28, 0.07, and 0.05, respectively; and only the comparison with the age reader estimates produces a positive R^2 (=0.23). On the other hand, the range of Model 6 estimates is quite consistent with the 95% confidence interval for the time series of normal means (dashed lines in Figure 2.1.10).

It should be emphasized that iterative tuning used for various quantities in Model 2 was conducted two years ago, so the tuned values may no longer be optimal now that more data have been added. Moreover, Models 3-5 simply "borrow" the tuned quantities from Model 2. If these iterative tuning procedures were also applied to Models 3-5, the performance of those models would likely change somewhat.

As has been the case for decades now, the models tend to estimate sharply reduced survey selectivity at older ages (larger sizes) unless constrained to do otherwise (as in Model 5): Estimates of selectivity (ignoring Model 5) for the oldest/largest fish range from 0.21 (Model 1) to 0.35 (Model 6). However, except for the study by Nichol et al. (2007), studies by AFSC's RACE Division have failed to verify a mechanism capable of explaining this phenomenon.

In principle, confounding with *Q* might be an issue: Models 1 and 2 were both tuned (during a previous assessment) so that the average product of catchability and selectivity across the 60-81 cm size range equaled the value of 0.47 estimated by Nichol et al. (2007); Models 3-4 were both based on Model 2, so it is not surprising that they exhibit behavior similar to that of Model 2 in this regard; Model 6 was not tuned in this manner, yet it also estimates that survey selectivity decreases substantially once fish are greater than 3 years of age. Although there is a correlation between survey selectivity of oldest/largest fish and *Q* in Models 1-4 and 6, it is not particularly large (0.42); moreover, it is positive, whereas a negative correlation would be easier to explain (as a tradeoff between catchability and selectivity).

Confounding with *M* might also be an issue: Model 5 gave a better fit to the data than Model 3 (its closest relative) even though it forced survey selectivity to be asymptotic, because it also allowed for a higher value of *M* (about 23% higher than the value assumed in Models 1-4. However, Model 6 estimates *M* (at a value about 17% higher than the fixed value assumed in Models 1-4), *Q*, and all selectivity parameters internally; and it still shows substantially lower survey selectivity at older ages, indicating that the fixed value assumed for *M* in Models 1-4 may not be the main cause of declining selectivity at older ages (larger sizes).

Acknowledgments

Anne Hollowed and the BSAI Groundfish Plan Team provided reviews of this preliminary assessment.

References

Clark, W. G. 1999. Effects of an erroneous natural mortality rate on a simple age-structured stock assessment. *Canadian Journal of Fisheries and Aquatic Sciences* 56:1721-1731.

Crone, P., M. Maunder, J. Valero, J. McDaniel, and B. Semmens (editors). 2013. Selectivity: theory, estimation, and application in fishery stock assessment models. *Workshop Series Report*, available from Center for the Advancement of Population Assessment Methodology (CAPAM), NOAA/NMFS Southwest Fisheries Science Center, 8901 La Jolla Shores Dr., La Jolla, CA 92037, USA. 45 p.

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optimization Methods and Software* 27:233-249.

Kimura, D. K. 1990. Approaches to age-structured separable sequential population analysis. *Canadian Journal of Fisheries and Aquatic Sciences* 47:2364-2374.

Methot, R. D. 2013. User manual for Stock Synthesis, model version 3.24s. Unpubl. manuscr., available from NOAA Fisheries, Seattle, WA. 152 p.

Methot, R. D., and C. R. Wetzel. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research* 142:86-99.

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

Thompson, G. G. 2013. Assessment of the Pacific cod stock in the eastern Bering Sea and Aleutian Islands area. *In* Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 239-380. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

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 the Groundfish Fisheries of the Bering Sea and 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.

Thompson, G. G., and W. A. Palsson. 2013. Assessement of the Pacific cod stock in the Aleutian Islands. In Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions p. 381-507. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Table 2.1.1a—Effective sample size ratioss for size composition fits (Model 1).

	Model 1	
Fleet	Mean(Neff/N)	Mean(Neff)/Mean(N)
Jan-Apr_Trawl_Fishery	5.38	3.21
May-Jul_Trawl_Fishery	9.46	7.47
Aug-Dec_Trawl_Fishery	13.25	6.33
Jan-Apr_Longline_Fishery	8.66	4.06
May-Jul_Longline_Fishery	9.43	5.48
Aug-Dec_Longline_Fishery	6.49	3.21
Jan-Apr_Pot_Fishery	14.35	9.64
May-Jul_Pot_Fishery	18.16	7.63
Aug-Dec_Pot_Fishery	10.87	8.25
Post81_Shelf_Survey	2.03	1.72

Table 2.1.1b—Effective sample size ratios for size composition fits (Models 2-5).

	Mean(Neff/N)				Mean(Neff)/Mean(N)			
Fleet	Model 2	Model 3	Model 4	Model 5	Model 2	Model 3	Model 4	Model 5
Season1_Fishery	8.15	8.01	7.61	7.59	5.20	5.21	4.96	5.01
Season2_Fishery	6.79	6.72	6.62	6.37	4.29	4.24	4.19	4.07
Season3_Fishery	7.91	7.86	7.95	7.88	5.72	5.81	6.06	5.82
Season4_Fishery	9.57	9.78	10.40	9.08	3.50	3.45	3.66	3.06
Season5_Fishery	8.80	8.47	8.49	8.20	3.96	4.04	4.23	4.26
Trawl_Survey	3.12	3.14	3.39	3.17	2.65	2.69	2.88	2.73

Table 2.1.1c—Effective sample size ratiios for size composition fits (Model 6).

	Model 6	
Fleet	Mean(Neff/N)	Mean(Neff)/Mean(N)
Fishery	14.28	9.77
Survey	3.06	2.73

Table 2.1.2a—Effective sample sizes for age composition fits.

Year	N	Effective sample size					
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
1994	205	468	413	421	356	406	424
1995	172	38	36	35	40	36	67
1996	204	316	350	384	449	388	371
1997	206	150	192	266	998	380	453
1998	182	1029	1010	2656	3024	1416	1625
1999	246	104	70	72	73	81	70
2000	248	110	57	52	59	60	63
2001	272	87	48	48	60	45	101
2002	271	87	86	83	82	85	82
2003	390	276	384	447	842	860	662
2004	298	31	36	36	38	36	52
2005	367	448	600	436	442	336	163
2006	372	148	139	151	133	179	243
2007	413	63	105	97	75	110	571
2008	347	212	257	354	705	695	232
2009	404	88	120	119	129	128	327
2010	370	147	224	221	325	204	218
2011	359	162	131	114	98	105	86
2012	374	82	117	105	97	91	103
Mean	300	213	230	321	422	297	311
Mean (Neff/N)		0.86	1.06	1.65	2.14	1.52	1.24
(Mean Neff)/(Mean N)		0.71	0.90	1.26	1.66	1.24	1.04

Table 2.1.2b—Negative log likelihoods for age composition fits.

Year	Negative ln(likelihood)					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
1994	3.15	3.74	3.13	3.08	2.83	3.09
1995	11.01	10.31	9.80	8.33	9.32	6.23
1996	2.07	2.73	1.93	1.45	1.57	1.51
1997	3.92	3.92	2.54	1.13	1.66	1.61
1998	1.05	1.43	0.91	0.90	0.88	0.99
1999	4.99	8.10	7.52	7.59	6.39	7.45
2000	7.27	12.38	12.87	11.89	11.31	12.17
2001	7.09	11.28	11.45	10.36	12.61	8.10
2002	6.75	6.20	6.29	6.96	6.38	6.97
2003	4.65	2.76	1.96	1.76	1.42	1.92
2004	22.40	17.14	17.28	17.07	17.74	13.85
2005	5.73	3.95	4.89	5.74	6.12	8.47
2006	10.50	8.56	7.57	7.36	5.34	6.79
2007	8.89	5.03	5.33	6.84	4.99	3.71
2008	4.52	3.10	2.54	2.05	1.87	3.80
2009	13.80	9.53	9.63	9.11	9.20	5.87
2010	4.07	3.35	3.06	2.67	3.21	3.93
2011	5.10	6.04	6.36	7.40	6.73	9.55
2012	11.74	9.01	9.26	9.61	10.12	11.08
Sum	138.69	128.56	124.32	121.30	119.69	117.08

Table 2.1.3a—Constants listed in the control files for the six models.

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Weight-length a (proportionality)	5.99E-06	6.36E-06	6.36E-06	6.36E-06	6.36E-06	6.36E-06
Weight-length b (exponent)	3.17E+00	3.16E+00	3.16E+00	3.16E+00	3.16E+00	3.16E+00
Age at 50% maturity	4.88E+00	4.88E+00	4.88E+00	4.88E+00	4.88E+00	4.88E+00
Maturity slope	-9.65E-01	-9.65E-01	-9.65E-01	-9.65E-01	-9.65E-01	-9.65E-01
Ageing error st. dev. at age 1	8.50E-02	8.60E-02	8.60E-02	8.60E-02	8.60E-02	8.60E-02
Ageing error st. dev. at age 20	1.71E+00	1.73E+00	1.73E+00	1.73E+00	1.73E+00	1.73E+00
Weight-length a offset--season 1	-2.28E-02	-2.28E-02	-2.28E-02	-2.28E-02	-2.28E-02	n/a
Weight-length a offset--season 2	2.77E-03	2.77E-03	2.77E-03	2.77E-03	2.77E-03	n/a
Weight-length a offset--season 3	1.92E-02	1.92E-02	1.92E-02	1.92E-02	1.92E-02	n/a
Weight-length a offset--season 4	2.30E-03	2.30E-03	2.30E-03	2.30E-03	2.30E-03	n/a
Weight-length a offset--season 5	-1.42E-02	-1.42E-02	-1.42E-02	-1.42E-02	-1.42E-02	n/a
Weight-length b offset--season 1	5.25E-03	5.25E-03	5.25E-03	5.25E-03	5.25E-03	n/a
Weight-length b offset--season 2	-6.47E-04	-6.47E-04	-6.47E-04	-6.47E-04	-6.47E-04	n/a
Weight-length b offset--season 3	-4.54E-03	-4.54E-03	-4.54E-03	-4.54E-03	-4.54E-03	n/a
Weight-length b offset--season 4	-5.39E-04	-5.39E-04	-5.39E-04	-5.39E-04	-5.39E-04	n/a
Weight-length b offset--season 5	3.28E-03	3.28E-03	3.28E-03	3.28E-03	3.28E-03	n/a
Beverton-Holt "steepness"	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00

Table 2.1.3b—Main parameters estimated by the models.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Parameter	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Natural mortality rate	3.40E-01	n/a	3.40E-01	n/a	3.40E-01	n/a	3.40E-01	n/a	4.17E-01	7.54E-03	3.57E-01	3.30E-02
Length at age 1 (cm)	1.41E+01	1.08E-01	1.38E+01	1.47E-01	1.38E+01	1.46E-01	1.41E+01	1.34E-01	1.38E+01	1.44E-01	1.69E+01	2.68E-01
Asymptotic length (cm)	9.22E+01	5.23E-01	9.02E+01	8.43E-01	9.43E+01	1.21E+00	9.45E+01	1.26E+00	1.04E+02	2.18E+00	9.84E+01	2.24E+00
Brody growth coefficient	2.41E-01	2.65E-03	2.83E-01	1.19E-02	2.61E-01	1.29E-02	2.99E-01	1.50E-02	2.25E-01	1.60E-02	2.17E-01	1.47E-02
Richards growth coefficient	n/a	n/a	7.97E-01	5.18E-02	8.16E-01	5.36E-02	5.80E-01	6.00E-02	8.25E-01	6.37E-02	9.38E-01	5.25E-02
SD of length at age 1 (cm)	3.54E+00	7.04E-02	3.44E+00	8.03E-02	3.50E+00	8.31E-02	3.58E+00	8.66E-02	3.55E+00	8.86E-02	3.04E+00	5.12E-02
SD of length at age 20 (cm)	1.01E+01	1.66E-01	1.02E+01	2.13E-01	1.04E+01	2.66E-01	1.02E+01	2.64E-01	1.10E+01	3.91E-01	8.75E+00	3.00E-01
Ageing bias at age 1 (years)	3.40E-01	1.29E-02	3.33E-01	1.48E-02	3.16E-01	1.66E-02	2.61E-01	2.44E-02	2.96E-01	1.87E-02	2.75E-01	2.82E-02
Ageing bias at age 20 (years)	2.80E-01	1.52E-01	3.43E-01	1.73E-01	5.70E-01	1.78E-01	1.01E+00	2.12E-01	7.75E-01	1.91E-01	6.96E-01	2.45E-01
ln(mean post-1976 recruitment)	1.32E+01	1.93E-02	1.34E+01	7.30E-02	1.31E+01	7.04E-02	1.29E+01	6.64E-02	1.34E+01	6.39E-02	1.32E+01	2.26E-01
SD of log recruitment	5.70E-01	n/a	7.97E-01	8.87E-02	8.00E-01	8.49E-02	7.57E-01	8.00E-02	6.97E-01	7.49E-02	6.57E-01	n/a
ln(pre-1977 recruitment offset)	-1.17E+00	1.31E-01	-1.28E+00	2.11E-01	-1.62E+00	1.57E-01	-1.62E+00	1.06E-01	-1.69E+00	1.15E-01	-7.66E-01	2.41E-01
Initial age 10 ln(abundance) dev	n/a	n/a	-4.50E-01	6.71E-01	-2.36E-01	7.39E-01	-5.05E-02	7.48E-01	-3.46E-02	6.88E-01	-2.36E-01	5.95E-01
Initial age 9 ln(abundance) dev	n/a	n/a	-5.58E-01	6.49E-01	-3.41E-01	7.20E-01	-9.76E-02	7.48E-01	-7.48E-02	6.83E-01	-2.92E-01	5.83E-01
Initial age 8 ln(abundance) dev	n/a	n/a	-6.58E-01	6.29E-01	-4.60E-01	6.97E-01	-1.76E-01	7.53E-01	-1.52E-01	6.78E-01	-3.74E-01	5.67E-01
Initial age 7 ln(abundance) dev	n/a	n/a	-7.19E-01	6.12E-01	-5.60E-01	6.70E-01	-2.78E-01	7.55E-01	-2.68E-01	6.67E-01	-4.79E-01	5.47E-01
Initial age 6 ln(abundance) dev	n/a	n/a	-6.82E-01	6.00E-01	-5.66E-01	6.41E-01	-3.32E-01	7.32E-01	-3.53E-01	6.34E-01	-5.64E-01	5.29E-01
Initial age 5 ln(abundance) dev	n/a	n/a	-5.25E-01	5.65E-01	-4.53E-01	5.65E-01	-2.67E-01	6.04E-01	-3.44E-01	5.25E-01	-5.52E-01	5.18E-01
Initial age 4 ln(abundance) dev	n/a	n/a	-5.63E-01	5.59E-01	-6.77E-01	5.42E-01	-6.92E-01	5.02E-01	-7.36E-01	4.62E-01	-1.38E-01	5.09E-01
Initial age 3 ln(abundance) dev	1.29E+00	1.89E-01	1.37E+00	2.48E-01	1.23E+00	2.25E-01	1.07E+00	1.94E-01	9.63E-01	1.97E-01	2.47E-01	4.48E-01
Initial age 2 ln(abundance) dev	-7.31E-01	4.18E-01	-4.70E-01	5.71E-01	-4.31E-01	5.29E-01	-4.24E-01	4.48E-01	-4.41E-01	4.19E-01	-2.31E-01	5.44E-01
Initial age 1 ln(abundance) dev	1.38E+00	2.14E-01	1.67E+00	2.63E-01	1.51E+00	2.38E-01	1.31E+00	2.12E-01	1.20E+00	2.13E-01	7.21E-01	4.52E-01
Initial fishing mortality rate	6.91E-01	1.51E-01	7.83E-01	2.17E-01	2.15E+00	7.99E-01	4.16E+00	2.38E+00	4.36E+00	2.04E+00	1.00E-01	3.32E-02
Survey "extra" SD	n/a	n/a	n/a	n/a	n/a	n/a	1.26E-01	3.35E-02	n/a	n/a	n/a	n/a
Survey ln(catchability)	-2.61E-01	n/a	-2.88E-01	n/a	0.00E+00	n/a	3.50E-01	4.95E-02	0.00E+00	n/a	2.53E-02	1.21E-01

Table 2.1.3c—Recruitment *dev*s estimated by the models.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Year	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
1977	1.36E+00	1.09E-01	1.30E+00	1.46E-01	8.95E-01	1.44E-01	6.44E-01	1.50E-01	5.05E-01	1.39E-01	8.49E-01	2.31E-01
1978	4.95E-01	2.11E-01	1.06E+00	1.81E-01	9.83E-01	1.50E-01	1.02E+00	1.28E-01	9.47E-01	1.19E-01	7.38E-01	1.91E-01
1979	6.86E-01	1.12E-01	4.34E-01	1.83E-01	4.39E-01	1.57E-01	4.14E-01	1.47E-01	4.52E-01	1.33E-01	4.96E-01	1.31E-01
1980	-3.84E-01	1.37E-01	-2.51E-01	1.58E-01	-2.19E-01	1.48E-01	-2.19E-02	1.30E-01	2.80E-02	1.25E-01	-1.93E-01	1.26E-01
1981	-9.20E-01	1.47E-01	-6.97E-01	1.59E-01	-7.26E-01	1.55E-01	-6.85E-01	1.54E-01	-6.60E-01	1.52E-01	-5.25E-01	1.35E-01
1982	9.94E-01	4.16E-02	9.44E-01	4.91E-02	9.16E-01	4.69E-02	9.31E-01	5.04E-02	9.09E-01	4.52E-02	7.93E-01	6.34E-02
1983	-5.36E-01	1.15E-01	-7.54E-01	1.53E-01	-7.18E-01	1.45E-01	-6.06E-01	1.34E-01	-5.94E-01	1.31E-01	-6.47E-01	1.55E-01
1984	7.85E-01	4.63E-02	7.71E-01	5.14E-02	7.90E-01	4.95E-02	8.47E-01	5.09E-02	8.35E-01	4.77E-02	7.07E-01	6.39E-02
1985	-8.09E-02	7.29E-02	8.63E-02	7.69E-02	1.39E-01	7.32E-02	2.40E-01	7.21E-02	2.10E-01	6.84E-02	-2.41E-02	9.39E-02
1986	-8.25E-01	9.68E-02	-8.44E-01	1.20E-01	-7.38E-01	1.15E-01	-6.38E-01	1.12E-01	-6.57E-01	1.06E-01	-6.51E-01	1.25E-01
1987	-1.16E+00	1.11E-01	-1.22E+00	1.43E-01	-1.03E+00	1.27E-01	-6.87E-01	9.78E-02	-7.12E-01	9.46E-02	-1.37E+00	1.99E-01
1988	-2.16E-01	5.72E-02	-2.12E-01	7.13E-02	-1.96E-01	6.91E-02	-1.88E-01	6.91E-02	-2.65E-01	6.84E-02	-1.67E-01	9.56E-02
1989	5.38E-01	4.04E-02	4.26E-01	5.16E-02	4.55E-01	4.90E-02	5.27E-01	4.89E-02	4.56E-01	4.65E-02	4.38E-01	6.99E-02
1990	3.32E-01	4.61E-02	3.35E-01	5.54E-02	4.12E-01	5.18E-02	5.03E-01	5.13E-02	4.46E-01	4.79E-02	3.42E-01	7.30E-02
1991	-3.06E-01	6.26E-02	-3.58E-01	8.17E-02	-2.72E-01	7.80E-02	-1.43E-01	7.29E-02	-2.02E-01	7.12E-02	-3.14E-01	1.01E-01
1992	6.29E-01	3.25E-02	5.18E-01	3.97E-02	5.88E-01	3.78E-02	6.52E-01	3.93E-02	6.00E-01	3.63E-02	6.19E-01	4.98E-02
1993	-4.23E-01	5.88E-02	-5.16E-01	7.09E-02	-4.05E-01	6.64E-02	-2.48E-01	6.36E-02	-3.18E-01	6.05E-02	-1.06E-01	7.26E-02
1994	-3.32E-01	5.14E-02	-5.42E-01	6.36E-02	-4.69E-01	5.98E-02	-3.87E-01	5.92E-02	-4.25E-01	5.47E-02	-3.49E-01	7.51E-02
1995	-2.50E-01	5.44E-02	-5.00E-01	6.72E-02	-4.82E-01	6.33E-02	-3.60E-01	5.95E-02	-4.87E-01	5.78E-02	-3.53E-01	7.95E-02
1996	6.78E-01	3.23E-02	5.10E-01	3.83E-02	4.84E-01	3.69E-02	4.79E-01	3.94E-02	4.01E-01	3.65E-02	5.52E-01	4.79E-02
1997	-2.40E-01	5.20E-02	-1.91E-01	5.81E-02	-1.23E-01	5.35E-02	-1.56E-02	5.15E-02	-9.59E-02	4.90E-02	-4.96E-02	6.55E-02
1998	-2.46E-01	4.98E-02	-1.58E-01	5.86E-02	-9.88E-02	5.48E-02	2.14E-02	5.24E-02	-2.82E-02	4.98E-02	-1.75E-01	7.51E-02
1999	4.37E-01	3.17E-02	5.73E-01	3.61E-02	6.04E-01	3.46E-02	6.67E-01	3.57E-02	5.86E-01	3.43E-02	4.94E-01	4.88E-02
2000	-6.45E-02	3.73E-02	6.72E-02	4.46E-02	1.48E-01	4.17E-02	2.79E-01	4.39E-02	2.34E-01	4.06E-02	4.16E-02	5.76E-02
2001	-8.46E-01	5.78E-02	-7.01E-01	6.68E-02	-6.25E-01	6.26E-02	-5.05E-01	5.92E-02	-5.46E-01	5.70E-02	-4.89E-01	7.06E-02
2002	-3.05E-01	3.88E-02	-3.14E-01	4.98E-02	-2.97E-01	4.71E-02	-2.23E-01	4.65E-02	-2.91E-01	4.42E-02	-3.61E-01	6.46E-02
2003	-5.22E-01	4.65E-02	-4.68E-01	5.71E-02	-4.69E-01	5.34E-02	-4.47E-01	5.19E-02	-4.87E-01	4.97E-02	-4.63E-01	6.82E-02
2004	-6.54E-01	5.16E-02	-5.15E-01	6.15E-02	-5.42E-01	5.75E-02	-5.24E-01	5.36E-02	-5.68E-01	5.30E-02	-5.53E-01	7.55E-02
2005	-5.18E-01	4.87E-02	-4.46E-01	6.07E-02	-4.98E-01	5.65E-02	-4.59E-01	5.20E-02	-5.14E-01	5.40E-02	-2.12E-01	7.07E-02
2006	7.64E-01	3.05E-02	8.51E-01	3.71E-02	7.59E-01	3.33E-02	6.63E-01	2.97E-02	6.36E-01	3.36E-02	5.85E-01	5.13E-02
2007	-4.56E-01	6.36E-02	-1.61E-01	7.74E-02	-2.16E-01	7.21E-02	-2.78E-01	6.50E-02	-2.63E-01	6.59E-02	1.45E-01	7.11E-02
2008	1.15E+00	4.29E-02	1.20E+00	4.71E-02	1.10E+00	4.63E-02	8.25E-01	5.74E-02	9.70E-01	4.87E-02	9.46E-01	6.05E-02
2009	-9.36E-01	1.32E-01	-1.08E+00	1.54E-01	-1.08E+00	1.46E-01	-1.30E+00	1.44E-01	-1.08E+00	1.35E-01	-1.27E+00	1.54E-01
2010	6.35E-01	7.27E-02	4.87E-01	7.12E-02	3.83E-01	7.00E-02	-5.09E-02	1.07E-01	2.29E-01	7.35E-02	2.68E-01	9.48E-02
2011	1.02E+00	8.02E-02	8.87E-01	9.04E-02	7.67E-01	8.76E-02	2.49E-01	1.34E-01	5.83E-01	9.12E-02	7.25E-01	1.17E-01
2012	-2.83E-01	1.81E-01	-5.19E-01	2.11E-01	-6.51E-01	2.06E-01	-1.20E+00	2.33E-01	-8.35E-01	2.03E-01	-4.64E-01	2.28E-01

Table 2.1.3d—Length at age 1.5 (*L1*) *dev*s and ln(*Q*) devs estimated by Model 6.

	L1 dev		ln(*Q*) *dev*	
Year	Value	SD	Value	SD
1982	-1.23E-01	2.18E-02	-1.22E-01	6.60E-02
1983	-9.03E-02	5.64E-02	3.61E-04	7.22E-02
1984	6.12E-02	2.06E-02	-3.08E-02	6.25E-02
1985	-6.71E-02	3.05E-02	5.64E-03	7.52E-02
1986	5.75E-02	3.43E-02	5.36E-02	6.83E-02
1987	9.02E-02	5.75E-02	3.35E-02	5.89E-02
1988	2.00E-02	3.45E-02	1.44E-02	5.97E-02
1989	-4.49E-02	2.62E-02	-1.36E-01	6.07E-02
1990	-6.55E-02	2.91E-02	-6.69E-02	6.94E-02
1991	5.15E-02	2.74E-02	-6.31E-02	7.05E-02
1992	1.15E-02	2.09E-02	-4.85E-02	7.24E-02
1993	4.41E-02	3.19E-02	4.02E-02	7.43E-02
1994	1.82E-02	3.46E-02	2.27E-01	7.26E-02
1995	3.53E-02	3.55E-02	1.30E-01	6.76E-02
1996	-1.06E-02	2.25E-02	7.83E-02	7.57E-02
1997	-1.06E-01	3.23E-02	-2.35E-03	7.61E-02
1998	-5.17E-02	3.45E-02	3.27E-03	6.54E-02
1999	-3.30E-02	2.23E-02	-2.66E-02	6.58E-02
2000	3.59E-02	2.05E-02	-8.28E-02	6.60E-02
2001	-4.11E-03	3.57E-02	1.19E-01	6.71E-02
2002	8.11E-02	2.46E-02	-7.61E-03	6.79E-02
2003	2.70E-02	3.03E-02	-1.95E-02	7.27E-02
2004	1.64E-01	2.34E-02	-9.88E-03	6.39E-02
2005	-6.66E-02	2.34E-02	2.01E-02	7.53E-02
2006	-1.17E-01	1.97E-02	-5.49E-02	5.79E-02
2007	-1.12E-01	2.63E-02	4.87E-03	8.40E-02
2008	-1.45E-01	2.03E-02	-9.82E-02	6.94E-02
2009	-3.06E-02	5.42E-02	-1.34E-01	6.67E-02
2010	8.47E-02	1.96E-02	4.22E-02	7.46E-02
2011	-2.05E-01	2.23E-02	2.52E-02	6.99E-02
2012	-1.22E-01	3.49E-02	9.48E-02	7.27E-02
2013	n/a	n/a	1.09E-02	8.03E-02

Table 2.1.3e—Base selectivity parameters estimated by Model 1 (unlisted parameters were all fixed at 0).

	Model 1	
Parameter	Value	SD
Jan-Apr trawl fishery parameter 5	-999	n/a
Jan-Apr trawl fishery parameter 6	10	n/a
May-Jul trawl fishery parameter 3	5.64E+00	1.04E-01
May-Jul trawl fishery parameter 5	-999	n/a
May-Jul trawl fishery parameter 6	10	n/a
Aug-Dec trawl fishery parameter 5	-999	n/a
Aug-Dec trawl fishery parameter 6	10	n/a
Jan-Apr longline fishery parameter 2	-4.86E+00	2.00E+00
Jan-Apr longline fishery parameter 4	5.08E+00	1.44E-01
Jan-Apr longline fishery parameter 5	-999	n/a
May-Jul longline fishery parameter 3	5.02E+00	4.98E-02
May-Jul longline fishery parameter 5	-999	n/a
May-Jul longline fishery parameter 6	10	n/a
Aug-Dec longline fishery parameter 2	-2.15E+00	2.79E-01
Aug-Dec longline fishery parameter 4	5.13E+00	3.39E-01
Aug-Dec longline fishery parameter 5	-999	n/a
Jan-Apr trawl fishery parameter 2	-9.24E+00	1.82E+01
Jan-Apr trawl fishery parameter 3	5.00E+00	4.92E-02
Jan-Apr trawl fishery parameter 4	4.45E+00	2.88E-01
Jan-Apr trawl fishery parameter 5	-999	n/a
May-Jul trawl fishery parameter 3	4.93E+00	8.12E-02
May-Jul trawl fishery parameter 5	-999	n/a
May-Jul trawl fishery parameter 6	10	n/a
Aug-Dec trawl fishery parameter 5	-999	n/a
Aug-Dec trawl fishery parameter 6	10	n/a
trawl survey parameter 1	1.28E+00	5.58E-02
trawl survey parameter 2	-3.09E+00	5.85E-01
trawl survey parameter 3	-2.11E+00	4.33E-01
trawl survey parameter 4	2.93E+00	3.96E-01
trawl survey parameter 5	-9.99E+00	n/a
trawl survey parameter 6	-1.30E+00	4.47E-01

Table 2.1.3f—Block selectivity parameters and annual selectivity *dev*s estimated by Model 1 (p. 1 of 3).

	Model 1	
Parameter	Value	SD
Jan-Apr trawl fish. par. 1 block 1977	6.92E+01	3.06E+00
Jan-Apr trawl fish. par. 1 block 1985	7.66E+01	1.69E+00
Jan-Apr trawl fish. par. 1 block 1990	6.89E+01	1.11E+00
Jan-Apr trawl fish. par. 1 block 1995	7.41E+01	9.25E-01
Jan-Apr trawl fish. par. 1 block 2000	7.84E+01	1.20E+00
Jan-Apr trawl fish. par. 1 block 2005	7.59E+01	7.55E-01
Jan-Apr trawl fish. par. 3 block 1977	6.18E+00	1.71E-01
Jan-Apr trawl fish. par. 3 block 1985	6.63E+00	7.66E-02
Jan-Apr trawl fish. par. 3 block 1990	6.09E+00	5.88E-02
Jan-Apr trawl fish. par. 3 block 1995	6.30E+00	4.54E-02
Jan-Apr trawl fish. par. 3 block 2000	6.30E+00	6.06E-02
Jan-Apr trawl fish. par. 3 block 2005	5.97E+00	4.52E-02
May-Jul trawl fish. par. 1 block 1977	5.04E+01	1.72E+00
May-Jul trawl fish. par. 1 block 1985	5.15E+01	1.76E+00
May-Jul trawl fish. par. 1 block 1990	6.21E+01	1.57E+00
May-Jul trawl fish. par. 1 block 2000	5.32E+01	1.53E+00
May-Jul trawl fish. par. 1 block 2005	5.91E+01	1.46E+00
Aug-Dec trawl fish. par. 1 block 1977	6.27E+01	4.01E+00
Aug-Dec trawl fish. par. 1 block 1980	8.22E+01	5.64E+00
Aug-Dec trawl fish. par. 1 block 1985	8.70E+01	5.37E+00
Aug-Dec trawl fish. par. 1 block 1990	7.74E+01	3.94E+01
Aug-Dec trawl fish. par. 1 block 1995	1.02E+02	n/a
Aug-Dec trawl fish. par. 1 block 2000	5.74E+01	1.91E+00
Aug-Dec trawl fish. par. 3 block 1977	5.55E+00	3.27E-01
Aug-Dec trawl fish. par. 3 block 1980	6.67E+00	2.27E-01
Aug-Dec trawl fish. par. 3 block 1985	6.62E+00	2.28E-01
Aug-Dec trawl fish. par. 3 block 1990	6.39E+00	2.10E+00
Aug-Dec trawl fish. par. 3 block 1995	7.01E+00	8.80E-02
Aug-Dec trawl fish. par. 3 block 2000	5.25E+00	1.93E-01

Table 2.1.3f—Block selectivity parameters and annual selectivity devs estimated by Model 1 (p. 2 of 3).

	Model 1	
Parameter	Value	SD
Jan-Apr longline fish. par. 1 block 1977	5.91E+01	2.07E+00
Jan-Apr longline fish. par. 1 block 1980	7.25E+01	2.50E+00
Jan-Apr longline fish. par. 1 block 1985	7.52E+01	9.13E-01
Jan-Apr longline fish. par. 1 block 1990	6.61E+01	4.78E-01
Jan-Apr longline fish. par. 1 block 1995	6.58E+01	4.27E-01
Jan-Apr longline fish. par. 1 block 2000	6.35E+01	4.44E-01
Jan-Apr longline fish. par. 1 block 2005	6.71E+01	3.67E-01
Jan-Apr longline fish. par. 3 block 1977	5.15E+00	2.09E-01
Jan-Apr longline fish. par. 3 block 1980	5.91E+00	1.79E-01
Jan-Apr longline fish. par. 3 block 1985	5.86E+00	6.71E-02
Jan-Apr longline fish. par. 3 block 1990	5.23E+00	4.64E-02
Jan-Apr longline fish. par. 3 block 1995	5.30E+00	3.97E-02
Jan-Apr longline fish. par. 3 block 2000	5.36E+00	4.17E-02
Jan-Apr longline fish. par. 3 block 2005	5.32E+00	3.20E-02
Jan-Apr longline fish. par. 6 block 1977	-1.32E+00	8.18E-01
Jan-Apr longline fish. par. 6 block 1980	3.98E-01	1.08E+00
Jan-Apr longline fish. par. 6 block 1985	-1.28E+00	4.67E-01
Jan-Apr longline fish. par. 6 block 1990	-4.78E-01	1.39E-01
Jan-Apr longline fish. par. 6 block 1995	-6.90E-01	1.42E-01
Jan-Apr longline fish. par. 6 block 2000	-1.18E+00	1.48E-01
Jan-Apr longline fish. par. 6 block 2005	-8.83E-01	1.45E-01
May-Jul longline fish. par. 1 block 1977	6.35E+01	2.22E+00
May-Jul longline fish. par. 1 block 1980	6.26E+01	1.36E+00
May-Jul longline fish. par. 1 block 1985	6.35E+01	1.12E+00
May-Jul longline fish. par. 1 block 1990	6.37E+01	5.16E-01
May-Jul longline fish. par. 1 block 2000	5.99E+01	5.59E-01
May-Jul longline fish. par. 1 block 2005	6.46E+01	5.26E-01
Aug-Dec longline fish. par. 1 block 1977	6.07E+01	2.18E+00
Aug-Dec longline fish. par. 1 block 1980	6.98E+01	1.61E+00
Aug-Dec longline fish. par. 1 block 1985	6.45E+01	7.59E-01
Aug-Dec longline fish. par. 1 block 1990	6.71E+01	7.24E-01
Aug-Dec longline fish. par. 1 block 1995	6.96E+01	7.00E-01
Aug-Dec longline fish. par. 1 block 2000	6.37E+01	4.29E-01
Aug-Dec longline fish. par. 1 block 2005	6.34E+01	3.62E-01
Aug-Dec longline fish. par. 3 block 1977	4.54E+00	3.19E-01
Aug-Dec longline fish. par. 3 block 1980	5.42E+00	1.34E-01
Aug-Dec longline fish. par. 3 block 1985	4.88E+00	8.70E-02
Aug-Dec longline fish. par. 3 block 1990	5.04E+00	7.61E-02
Aug-Dec longline fish. par. 3 block 1995	5.51E+00	5.30E-02
Aug-Dec longline fish. par. 3 block 2000	5.18E+00	4.12E-02
Aug-Dec longline fish. par. 3 block 2005	4.97E+00	3.64E-02
Aug-Dec longline fish. par. 6 block 1977	-2.65E+00	2.28E+00
Aug-Dec longline fish. par. 6 block 1980	4.44E-01	7.86E-01
Aug-Dec longline fish. par. 6 block 1985	2.26E-01	2.56E-01
Aug-Dec longline fish. par. 6 block 1990	2.59E+00	1.05E+00
Aug-Dec longline fish. par. 6 block 1995	9.50E+00	1.29E+01
Aug-Dec longline fish. par. 6 block 2000	-3.70E-01	1.96E-01
Aug-Dec longline fish. par. 6 block 2005	9.73E+00	7.55E+00

Table 2.1.3f—Block selectivity parameters and annual selectivity *dev*s estimated by Model 1 (p. 3 of 3).

	Model 1	
Parameter	Value	SD
Jan-Apr pot fish. par. 1 block 1977	6.87E+01	9.22E-01
Jan-Apr pot fish. par. 1 block 1995	6.85E+01	5.48E-01
Jan-Apr pot fish. par. 1 block 2000	6.81E+01	5.18E-01
Jan-Apr pot fish. par. 1 block 2005	6.89E+01	5.12E-01
Jan-Apr pot fish. par. 6 block 1977	2.47E-01	5.67E-01
Jan-Apr pot fish. par. 6 block 1995	-2.27E-01	2.54E-01
Jan-Apr pot fish. par. 6 block 2000	-5.60E-01	2.38E-01
Jan-Apr pot fish. par. 6 block 2005	2.10E-01	2.33E-01
May-Jul pot fish. par. 1 block 1977	6.73E+01	8.59E-01
May-Jul pot fish. par. 1 block 1995	6.60E+01	7.15E-01
Aug-Dec pot fish. par. 1 block 1977	6.86E+01	1.19E+00
Aug-Dec pot fish. par. 1 block 2000	6.20E+01	6.84E-01
Aug-Dec pot fish. par. 1 block 1977	5.19E+00	1.19E-01
Aug-Dec pot fish. par. 1 block 2000	4.45E+00	1.07E-01
Survey par. 3 dev 1982	-5.22E-02	3.35E-02
Survey par. 3 dev 1983	-5.41E-02	1.69E-02
Survey par. 3 dev 1984	-9.10E-02	2.79E-02
Survey par. 3 dev 1985	-1.05E-02	2.07E-02
Survey par. 3 dev 1986	-5.63E-02	2.29E-02
Survey par. 3 dev 1987	2.68E-02	4.22E-02
Survey par. 3 dev 1988	-8.47E-02	3.27E-02
Survey par. 3 dev 1989	-1.29E-01	1.83E-02
Survey par. 3 dev 1990	-4.33E-02	2.04E-02
Survey par. 3 dev 1991	-5.27E-02	2.22E-02
Survey par. 3 dev 1992	7.78E-02	4.16E-02
Survey par. 3 dev 1993	3.80E-02	2.96E-02
Survey par. 3 dev 1994	-5.14E-02	2.16E-02
Survey par. 3 dev 1995	-1.03E-01	1.95E-02
Survey par. 3 dev 1996	-1.25E-01	1.75E-02
Survey par. 3 dev 1997	-7.71E-02	1.48E-02
Survey par. 3 dev 1998	-8.43E-02	1.89E-02
Survey par. 3 dev 1999	-9.02E-02	1.71E-02
Survey par. 3 dev 2000	-5.06E-02	1.53E-02
Survey par. 3 dev 2001	1.52E-01	3.75E-02
Survey par. 3 dev 2002	-2.70E-02	2.36E-02
Survey par. 3 dev 2003	-1.03E-02	1.93E-02
Survey par. 3 dev 2004	-3.07E-02	1.94E-02
Survey par. 3 dev 2005	3.27E-02	2.65E-02
Survey par. 3 dev 2006	1.45E-01	3.76E-02
Survey par. 3 dev 2007	1.90E-01	3.70E-02
Survey par. 3 dev 2008	1.09E-01	3.81E-02
Survey par. 3 dev 2009	-5.12E-03	1.60E-02
Survey par. 3 dev 2010	-2.75E-02	3.13E-02
Survey par. 3 dev 2011	1.11E-02	2.06E-02

Table 2.1.3g—Base selectivity parameters estimated by Models 2-5.

	Model 2		Model 3		Model 4		Model 5	
Parameter	Value	SD	Value	SD	Value	SD	Value	SD
Sea. 1 fish. par. 1	6.90E+01	4.95E-01	7.07E+01	4.79E-01	7.10E+01	4.84E-01	7.25E+01	4.69E-01
Sea. 1 fish. par. 2	-9.44E+00	1.42E+01	-9.48E+00	1.35E+01	-9.46E+00	1.39E+01	-9.56E+00	1.15E+01
Sea. 1 fish. par. 3	5.70E+00	3.27E-02	5.75E+00	3.06E-02	5.75E+00	3.03E-02	5.76E+00	2.85E-02
Sea. 1 fish. par. 4	5.01E+00	2.26E-01	5.10E+00	2.98E-01	5.08E+00	3.12E-01	5.76E+00	4.48E-01
Sea. 1 fish. par. 5	-999	n/a	-999	n/a	-999	n/a	-999	n/a
Sea. 1 fish. par. 6	-2.04E-01	1.60E-01	-9.49E-02	2.11E-01	-4.92E-02	2.17E-01	-5.72E-01	5.37E-01
Sea. 2 fish. par. 1	6.92E+01	5.59E-01	7.10E+01	5.47E-01	7.14E+01	5.53E-01	7.31E+01	5.39E-01
Sea. 2 fish. par. 2	-9.43E+00	1.44E+01	-9.52E+00	1.25E+01	-9.51E+00	1.27E+01	-9.56E+00	1.15E+01
Sea. 2 fish. par. 3	5.89E+00	3.31E-02	5.94E+00	3.11E-02	5.93E+00	3.07E-02	5.94E+00	2.86E-02
Sea. 2 fish. par. 4	4.73E+00	2.89E-01	4.84E+00	4.24E-01	4.80E+00	4.42E-01	6.66E+00	6.70E-01
Sea. 2 fish. par. 5	-999	n/a	-999	n/a	-999	n/a	-999	n/a
Sea. 2 fish. par. 6	2.02E-01	1.59E-01	3.56E-01	2.22E-01	3.96E-01	2.29E-01	-1.30E+00	1.36E+00
Sea. 3 fish. par. 1	6.62E+01	7.20E-01	6.84E+01	7.14E-01	6.89E+01	7.30E-01	7.11E+01	7.21E-01
Sea. 3 fish. par. 2	10	n/a	10	n/a	10	n/a	10	n/a
Sea. 3 fish. par. 3	5.67E+00	5.19E-02	5.74E+00	4.89E-02	5.74E+00	4.86E-02	5.79E+00	4.51E-02
Sea. 3 fish. par. 4	0	n/a	0	n/a	0	n/a	0	n/a
Sea. 3 fish. par. 5	-999	n/a	-999	n/a	-999	n/a	-999	n/a
Sea. 3 fish. par. 6	10	n/a	10	n/a	10	n/a	10	n/a
Sea. 4 fish. par. 1	6.46E+01	4.14E-01	6.62E+01	4.45E-01	6.67E+01	4.61E-01	6.88E+01	4.47E-01
Sea. 4 fish. par. 2	-1.75E+00	3.36E-01	8.14E-01	3.95E-01	8.35E-01	5.01E-01	5.14E-01	3.58E-01
Sea. 4 fish. par. 3	5.09E+00	3.77E-02	5.18E+00	3.68E-02	5.20E+00	3.71E-02	5.30E+00	3.29E-02
Sea. 4 fish. par. 4	1.27E+00	2.54E+00	3.78E+00	2.70E+00	3.69E+00	3.31E+00	4.35E+00	1.53E+00
Sea. 4 fish. par. 5	-999	n/a	-999	n/a	-999	n/a	-999	n/a
Sea. 4 fish. par. 6	2.17E+00	3.49E-01	-2.80E-01	1.70E+00	-1.54E-01	1.81E+00	-1.53E+00	1.55E+00
Sea. 5 fish. par. 1	6.41E+01	5.27E-01	6.59E+01	5.25E-01	6.64E+01	5.33E-01	6.84E+01	5.28E-01
Sea. 5 fish. par. 2	-2.02E+00	4.89E-01	-1.89E+00	5.12E-01	-1.89E+00	5.76E-01	-1.93E+00	5.86E-01
Sea. 5 fish. par. 3	5.20E+00	4.66E-02	5.30E+00	4.30E-02	5.32E+00	4.25E-02	5.40E+00	3.87E-02
Sea. 5 fish. par. 4	5.09E+00	6.67E-01	5.43E+00	9.87E-01	5.46E+00	1.10E+00	7.26E+00	1.02E+00
Sea. 5 fish. par. 5	-999	n/a	-999	n/a	-999	n/a	-999	n/a
Sea. 5 fish. par. 6	2.98E-01	2.77E-01	3.27E-01	5.45E-01	3.22E-01	6.08E-01	-2.72E+00	3.67E+00
Survey par. 1	2.78E+01	6.72E-01	2.87E+01	7.17E-01	3.37E+01	6.93E-01	3.38E+01	5.72E-01
Survey par. 2	-1.36E+00	2.10E-01	-1.45E+00	2.96E-01	-8.93E+00	2.39E+01	1.00E+01	n/a
Survey par. 3	4.83E+00	5.16E-01	5.17E+00	3.91E-01	5.76E+00	3.50E-01	6.01E+00	2.86E-01
Survey par. 4	6.63E+00	3.54E-01	7.10E+00	5.81E-01	7.98E+00	4.99E-01	0.00E+00	n/a
Survey par. 5	-3.98E-01	3.41E-01	-5.57E-01	3.10E-01	-3.43E-01	2.68E-01	-1.01E+00	2.92E-01
Survey par. 6	-1.07E+00	3.50E-01	-7.63E-01	6.16E-01	-9.40E-01	7.53E-01	1.00E+01	n/a

Table 2.1.3h—Annual *dev*s for selectivity parameter #3 estimated by Models 2-5.

	Model 2		Model 3		Model 4		Model 5	
Year	Value	SD	Value	SD	Value	SD	Value	SD
1982	-3.66E+00	1.36E+00	-4.08E+00	1.32E+00	-3.48E+00	7.50E-01	-3.84E+00	6.93E-01
1983	-3.46E+00	1.14E+00	-3.55E+00	1.05E+00	-2.86E+00	7.14E-01	-3.02E+00	6.80E-01
1984	-9.98E-01	6.44E-01	-1.11E+00	5.57E-01	-7.15E-01	4.82E-01	-1.00E+00	4.07E-01
1985	-6.25E-02	4.93E-01	-2.47E-01	3.97E-01	-1.43E-01	3.79E-01	-4.08E-01	3.21E-01
1986	-2.17E+00	6.32E-01	-2.16E+00	5.33E-01	-1.45E+00	4.15E-01	-1.59E+00	3.83E-01
1987	3.46E-01	7.99E-01	-1.52E-02	6.60E-01	-3.20E-01	6.49E-01	-5.30E-01	5.10E-01
1988	-9.13E-01	7.47E-01	-1.20E+00	6.26E-01	-1.18E+00	4.81E-01	-1.41E+00	4.22E-01
1989	-3.25E+00	1.26E+00	-3.70E+00	1.13E+00	-5.26E+00	1.11E+00	-5.93E+00	1.26E+00
1990	-2.33E+00	1.08E+00	-2.53E+00	1.00E+00	-2.11E+00	7.95E-01	-2.40E+00	7.22E-01
1991	-1.53E+00	8.49E-01	-1.76E+00	7.77E-01	-1.47E+00	5.97E-01	-1.67E+00	5.27E-01
1992	1.14E+00	1.10E+00	9.13E-01	1.04E+00	9.27E-01	1.18E+00	5.80E-01	9.10E-01
1993	9.51E-01	9.38E-01	7.34E-01	8.72E-01	4.85E-01	9.46E-01	4.26E-01	7.73E-01
1994	-3.72E-01	6.12E-01	-6.05E-01	5.34E-01	-1.06E+00	5.99E-01	-8.51E-01	4.19E-01
1995	-9.48E-01	6.36E-01	-1.12E+00	5.54E-01	-1.06E+00	4.54E-01	-1.10E+00	3.86E-01
1996	-1.44E+00	7.87E-01	-1.57E+00	7.69E-01	-1.61E+00	6.01E-01	-1.52E+00	4.93E-01
1997	-8.87E-01	5.52E-01	-9.61E-01	4.88E-01	-2.99E+00	7.26E-01	-1.01E+00	4.44E-01
1998	-2.61E+00	7.42E-01	-2.52E+00	6.01E-01	-1.65E+00	4.12E-01	-1.66E+00	3.87E-01
1999	-1.95E+00	6.23E-01	-2.07E+00	5.32E-01	-1.75E+00	4.23E-01	-1.85E+00	3.77E-01
2000	-3.86E+00	1.03E+00	-3.95E+00	9.32E-01	-3.25E+00	6.52E-01	-3.38E+00	5.94E-01
2001	1.94E+00	1.12E+00	1.68E+00	1.05E+00	-3.62E+00	6.88E-01	9.41E-01	7.68E-01
2002	-3.15E+00	1.12E+00	-3.34E+00	9.67E-01	-2.40E+00	5.35E-01	-2.54E+00	4.95E-01
2003	2.37E-01	5.35E-01	1.20E-01	4.67E-01	1.76E-01	4.99E-01	-4.64E-02	4.15E-01
2004	-1.54E-01	5.74E-01	-3.06E-01	5.03E-01	-2.58E+00	7.86E-01	-6.10E-01	4.92E-01
2005	3.34E-01	5.23E-01	2.65E-01	4.66E-01	5.42E-01	5.42E-01	2.95E-01	4.72E-01
2006	1.36E+00	1.59E+00	1.32E+00	1.56E+00	-3.99E+00	1.10E+00	-4.05E+00	1.04E+00
2007	1.77E+00	1.43E+00	1.65E+00	1.44E+00	1.37E+00	1.53E+00	1.34E+00	1.52E+00
2008	-2.22E+00	8.33E-01	-2.18E+00	7.19E-01	-1.37E+00	6.25E-01	-1.60E+00	5.27E-01
2009	-2.91E+00	8.30E-01	-2.84E+00	7.18E-01	-1.83E+00	5.10E-01	-2.10E+00	4.12E-01
2010	-2.23E+00	1.08E+00	-2.19E+00	9.29E-01	-1.28E+00	7.20E-01	-1.47E+00	6.64E-01

Table 2.1.3i—Annual *dev*s for selectivity parameter #5 estimated by Models 2-5.

	Model 2		Model 3		Model 4		Model 5	
Year	Value	SD	Value	SD	Value	SD	Value	SD
1982	-6.95E-01	5.21E-01	-6.02E-01	4.95E-01	-1.00E+00	4.48E-01	-5.97E-01	4.42E-01
1983	-1.28E-01	3.97E-01	-3.09E-02	3.70E-01	-4.80E-01	3.34E-01	1.16E-01	3.42E-01
1984	-7.53E-01	6.24E-01	-7.26E-01	6.20E-01	-1.15E+00	6.85E-01	-8.87E-01	6.94E-01
1985	-1.77E+00	6.95E-01	-1.77E+00	7.13E-01	-2.15E+00	7.09E-01	-1.85E+00	7.50E-01
1986	-5.68E-01	4.37E-01	-5.03E-01	4.12E-01	-9.60E-01	3.92E-01	-3.99E-01	4.07E-01
1987	-6.90E-01	1.02E+00	-8.09E-01	9.71E-01	-9.78E-01	9.22E-01	-8.41E-01	9.42E-01
1988	-1.07E+00	7.57E-01	-1.19E+00	7.19E-01	-1.76E+00	6.67E-01	-1.43E+00	7.01E-01
1989	-1.50E+00	4.38E-01	-1.41E+00	4.15E-01	-1.52E+00	3.79E-01	-1.16E+00	3.82E-01
1990	4.91E-02	4.29E-01	7.43E-02	4.01E-01	-1.57E-01	4.04E-01	1.58E-01	3.70E-01
1991	-3.70E-01	4.57E-01	-3.47E-01	4.32E-01	-6.57E-01	4.20E-01	-2.81E-01	4.24E-01
1992	-3.82E-01	1.08E+00	-4.87E-01	1.05E+00	-5.59E-01	9.97E-01	-6.29E-01	1.01E+00
1993	-5.49E-01	1.01E+00	-6.06E-01	9.98E-01	-6.95E-01	9.48E-01	-6.39E-01	9.83E-01
1994	-1.07E+00	8.00E-01	-1.04E+00	8.05E-01	-1.13E+00	6.34E-01	-1.00E+00	8.12E-01
1995	-1.29E+00	6.47E-01	-1.24E+00	6.54E-01	-1.69E+00	6.14E-01	-1.30E+00	7.18E-01
1996	-1.55E+00	5.88E-01	-1.37E+00	6.12E-01	-1.69E+00	4.83E-01	-1.22E+00	6.33E-01
1997	-1.14E+00	4.87E-01	-1.01E+00	5.31E-01	-7.13E-01	3.14E-01	-8.06E-01	6.70E-01
1998	-9.84E-01	4.17E-01	-9.51E-01	3.92E-01	-1.52E+00	3.73E-01	-9.15E-01	4.13E-01
1999	-1.12E+00	4.11E-01	-1.06E+00	3.87E-01	-1.52E+00	3.56E-01	-9.97E-01	3.80E-01
2000	-5.26E-01	3.70E-01	-4.31E-01	3.41E-01	-8.38E-01	3.03E-01	-2.57E-01	3.19E-01
2001	-5.68E-01	9.48E-01	-7.71E-01	9.29E-01	5.52E-01	3.39E-01	-1.02E+00	9.06E-01
2002	-9.26E-02	4.27E-01	-5.00E-02	3.97E-01	-5.15E-01	3.55E-01	5.89E-03	3.65E-01
2003	-1.33E+00	8.38E-01	-1.25E+00	8.57E-01	-1.40E+00	8.32E-01	-1.17E+00	8.75E-01
2004	-1.13E+00	8.27E-01	-1.04E+00	8.56E-01	-1.55E-01	3.40E-01	-7.48E-01	9.36E-01
2005	-1.57E+00	8.30E-01	-1.45E+00	8.48E-01	-1.62E+00	8.23E-01	-1.36E+00	8.59E-01
2006	1.42E+00	8.66E-01	1.59E+00	8.28E-01	1.19E+00	4.17E-01	1.75E+00	3.91E-01
2007	2.56E+00	7.64E-01	2.76E+00	7.39E-01	2.83E+00	7.12E-01	3.09E+00	6.93E-01
2008	9.81E-01	4.72E-01	1.08E+00	4.42E-01	8.52E-01	4.33E-01	1.10E+00	3.96E-01
2009	4.67E-01	3.76E-01	6.63E-01	3.51E-01	8.73E-01	3.58E-01	8.95E-01	3.28E-01
2010	2.85E-01	5.50E-01	2.67E-01	5.15E-01	-1.26E-01	5.41E-01	1.79E-01	5.50E-01

Table 2.1.3j—Base selectivity parameters estimated by Models 6.

	Model 6	
Parameter	Value	SD
Fishery age 1 selectivity parameter	2.94E+00	3.50E-01
Fishery age 2 selectivity parameter	3.21E+00	3.01E-01
Fishery age 3 selectivity parameter	2.87E+00	1.67E-01
Fishery age 4 selectivity parameter	1.83E+00	2.19E-01
Fishery age 5 selectivity parameter	9.43E-01	9.45E-02
Fishery age 6 selectivity parameter	1.89E-01	1.31E-01
Fishery age 7 selectivity parameter	-2.34E-01	1.83E-01
Fishery age 8 selectivity parameter	-6.25E-02	2.31E-01
Fishery age 9 selectivity parameter	-1.78E-01	2.63E-01
Fishery age 10 selectivity parameter	-1.13E-01	2.79E-01
Fishery age 11 selectivity parameter	2.30E-01	3.00E-01
Fishery age 12 selectivity parameter	1.90E-01	3.25E-01
Fishery age 13 selectivity parameter	-3.03E-02	3.33E-01
Fishery age 14 selectivity parameter	-6.40E-02	3.38E-01
Fishery age 15 selectivity parameter	-8.06E-02	3.36E-01
Fishery age 16 selectivity parameter	-3.61E-02	3.41E-01
Fishery age 17 selectivity parameter	-1.71E-02	3.44E-01
Fishery age 18 selectivity parameter	-6.71E-03	3.47E-01
Fishery age 19 selectivity parameter	-3.54E-03	3.48E-01
Fishery age 20 selectivity parameter	-4.86E-03	3.49E-01
Survey age 1 selectivity parameter	5.02E+00	3.19E-01
Survey age 2 selectivity parameter	8.17E-01	1.62E-01
Survey age 3 selectivity parameter	1.75E-01	4.99E-02
Survey age 4 selectivity parameter	-1.37E-01	5.83E-02
Survey age 5 selectivity parameter	-3.36E-02	8.09E-02
Survey age 6 selectivity parameter	-9.69E-02	1.25E-01
Survey age 7 selectivity parameter	-6.74E-03	1.70E-01
Survey age 8 selectivity parameter	-1.90E-01	2.16E-01
Survey age 9 selectivity parameter	-2.22E-01	2.48E-01
Survey age 10 selectivity parameter	-9.74E-02	2.68E-01
Survey age 11 selectivity parameter	-5.86E-02	2.88E-01
Survey age 12 selectivity parameter	-5.04E-02	3.02E-01
Survey age 13 selectivity parameter	-5.94E-02	3.08E-01
Survey age 14 selectivity parameter	-3.18E-02	3.13E-01
Survey age 15 selectivity parameter	-1.65E-02	3.16E-01
Survey age 16 selectivity parameter	-1.63E-02	3.16E-01
Survey age 17 selectivity parameter	-1.58E-02	3.17E-01
Survey age 18 selectivity parameter	-1.30E-02	3.17E-01
Survey age 19 selectivity parameter	-9.47E-03	3.18E-01
Survey age 20 selectivity parameter	-6.46E-03	3.18E-01

Table 2.1.3k—Annual *dev*s for age 4 fishery selectivity parameter estimated by Model 6.

	Model 6	
Parameter	Value	SD
Fishery age 4 sel. par. dev 1977	-2.20E-02	1.46E-01
Fishery age 4 sel. par. dev 1978	3.80E-04	1.21E-01
Fishery age 4 sel. par. dev 1979	-1.44E-01	6.80E-02
Fishery age 4 sel. par. dev 1980	-1.10E-01	6.78E-02
Fishery age 4 sel. par. dev 1981	-2.08E-01	7.09E-02
Fishery age 4 sel. par. dev 1982	-2.09E-02	1.11E-01
Fishery age 4 sel. par. dev 1983	-6.88E-02	7.75E-02
Fishery age 4 sel. par. dev 1984	-1.48E-01	4.02E-02
Fishery age 4 sel. par. dev 1985	-9.72E-03	3.92E-02
Fishery age 4 sel. par. dev 1986	-1.01E-01	4.40E-02
Fishery age 4 sel. par. dev 1987	-1.58E-02	3.46E-02
Fishery age 4 sel. par. dev 1988	-2.10E-01	3.70E-02
Fishery age 4 sel. par. dev 1989	-1.78E-01	5.28E-02
Fishery age 4 sel. par. dev 1990	-9.69E-02	4.45E-02
Fishery age 4 sel. par. dev 1991	-4.26E-02	3.19E-02
Fishery age 4 sel. par. dev 1992	-3.44E-03	3.09E-02
Fishery age 4 sel. par. dev 1993	-8.80E-02	3.15E-02
Fishery age 4 sel. par. dev 1994	-8.56E-02	3.30E-02
Fishery age 4 sel. par. dev 1995	-6.22E-02	2.84E-02
Fishery age 4 sel. par. dev 1996	6.53E-04	3.90E-02
Fishery age 4 sel. par. dev 1997	-6.02E-02	3.18E-02
Fishery age 4 sel. par. dev 1998	-2.65E-02	3.35E-02
Fishery age 4 sel. par. dev 1999	-3.17E-02	2.82E-02
Fishery age 4 sel. par. dev 2000	1.10E-01	5.71E-02
Fishery age 4 sel. par. dev 2001	4.48E-02	4.75E-02
Fishery age 4 sel. par. dev 2002	-2.64E-02	2.96E-02
Fishery age 4 sel. par. dev 2003	-4.94E-03	3.66E-02
Fishery age 4 sel. par. dev 2004	1.10E-02	4.70E-02
Fishery age 4 sel. par. dev 2005	-2.40E-02	3.71E-02
Fishery age 4 sel. par. dev 2006	3.79E-02	4.73E-02
Fishery age 4 sel. par. dev 2007	6.97E-02	5.69E-02
Fishery age 4 sel. par. dev 2008	4.89E-02	3.75E-02
Fishery age 4 sel. par. dev 2009	1.64E-01	5.41E-02
Fishery age 4 sel. par. dev 2010	2.29E-01	7.96E-02
Fishery age 4 sel. par. dev 2011	1.20E-01	4.67E-02
Fishery age 4 sel. par. dev 2012	1.17E-01	8.35E-02
Fishery age 4 sel. par. dev 2013	-1.54E-02	3.90E-02

Table 2.1.3l—Annual *dev*s for age 2 survey selectivity parameter estimated by Model 6.

	Model 6	
Parameter	Value	SD
Survey age 2 sel. par. dev 1982	5.67E-02	3.41E-02
Survey age 2 sel. par. dev 1983	1.86E-03	2.09E-02
Survey age 2 sel. par. dev 1984	7.75E-02	3.91E-02
Survey age 2 sel. par. dev 1985	-2.19E-02	2.06E-02
Survey age 2 sel. par. dev 1986	3.98E-02	2.60E-02
Survey age 2 sel. par. dev 1987	-1.63E-02	2.95E-02
Survey age 2 sel. par. dev 1988	3.56E-02	4.21E-02
Survey age 2 sel. par. dev 1989	1.17E-01	2.99E-02
Survey age 2 sel. par. dev 1990	3.11E-03	2.38E-02
Survey age 2 sel. par. dev 1991	2.67E-02	2.54E-02
Survey age 2 sel. par. dev 1992	-7.25E-02	2.44E-02
Survey age 2 sel. par. dev 1993	-4.26E-02	2.08E-02
Survey age 2 sel. par. dev 1994	5.12E-02	2.38E-02
Survey age 2 sel. par. dev 1995	7.77E-02	2.80E-02
Survey age 2 sel. par. dev 1996	9.64E-02	2.74E-02
Survey age 2 sel. par. dev 1997	3.27E-02	2.01E-02
Survey age 2 sel. par. dev 1998	8.54E-02	2.52E-02
Survey age 2 sel. par. dev 1999	7.42E-02	2.42E-02
Survey age 2 sel. par. dev 2000	2.20E-02	1.96E-02
Survey age 2 sel. par. dev 2001	-7.54E-02	1.89E-02
Survey age 2 sel. par. dev 2002	2.53E-02	2.30E-02
Survey age 2 sel. par. dev 2003	-3.54E-02	1.99E-02
Survey age 2 sel. par. dev 2004	-2.35E-03	2.10E-02
Survey age 2 sel. par. dev 2005	-5.21E-02	2.02E-02
Survey age 2 sel. par. dev 2006	-5.40E-02	1.94E-02
Survey age 2 sel. par. dev 2007	-1.35E-01	1.88E-02
Survey age 2 sel. par. dev 2008	-3.72E-03	2.01E-02
Survey age 2 sel. par. dev 2009	-4.71E-02	1.84E-02
Survey age 2 sel. par. dev 2010	-2.33E-02	2.95E-02
Survey age 2 sel. par. dev 2011	-6.04E-02	1.96E-02
Survey age 2 sel. par. dev 2012	-3.79E-02	2.05E-02

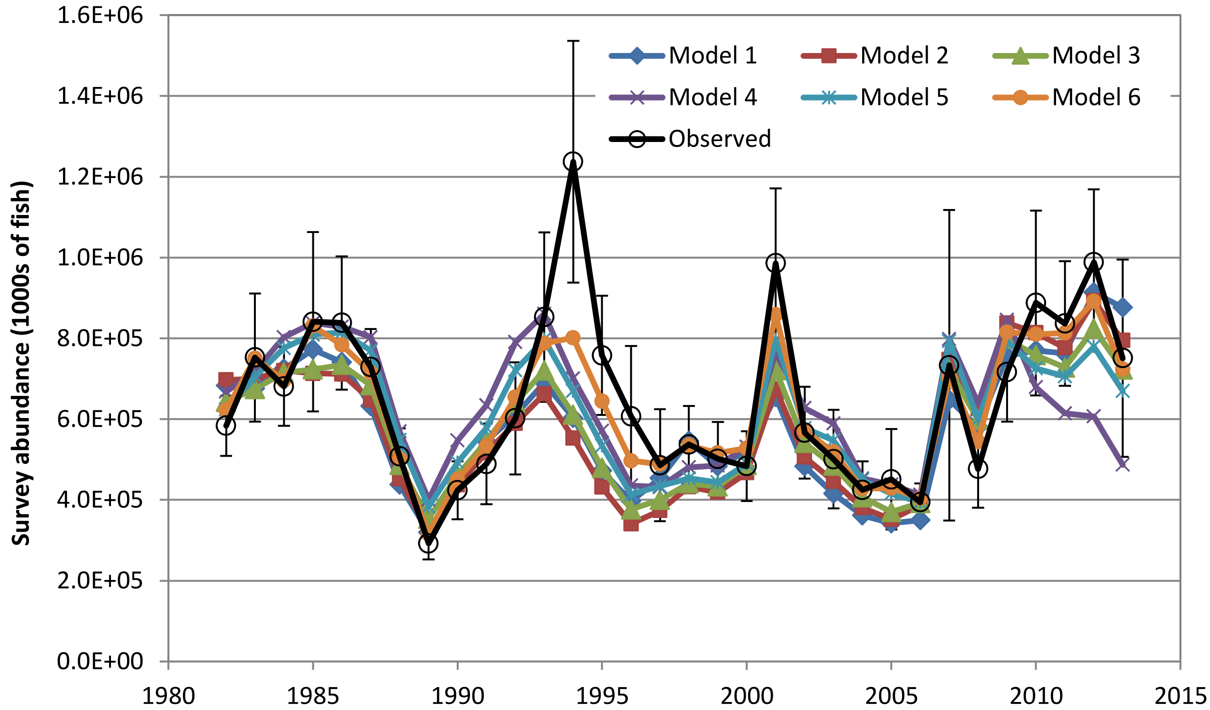


Figure 2.1.1a—Model fits to the survey abundance time series.

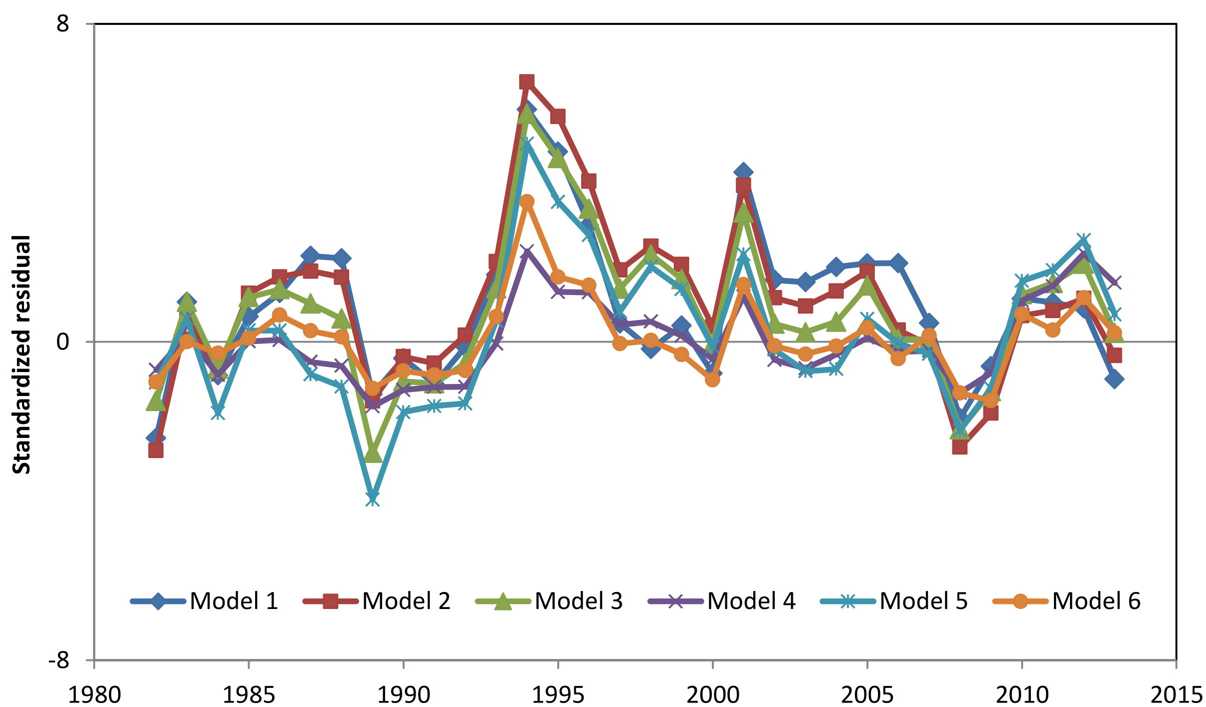


Figure 2.1.1b—Standardized residuals from the model fits to the survey abundance time series.

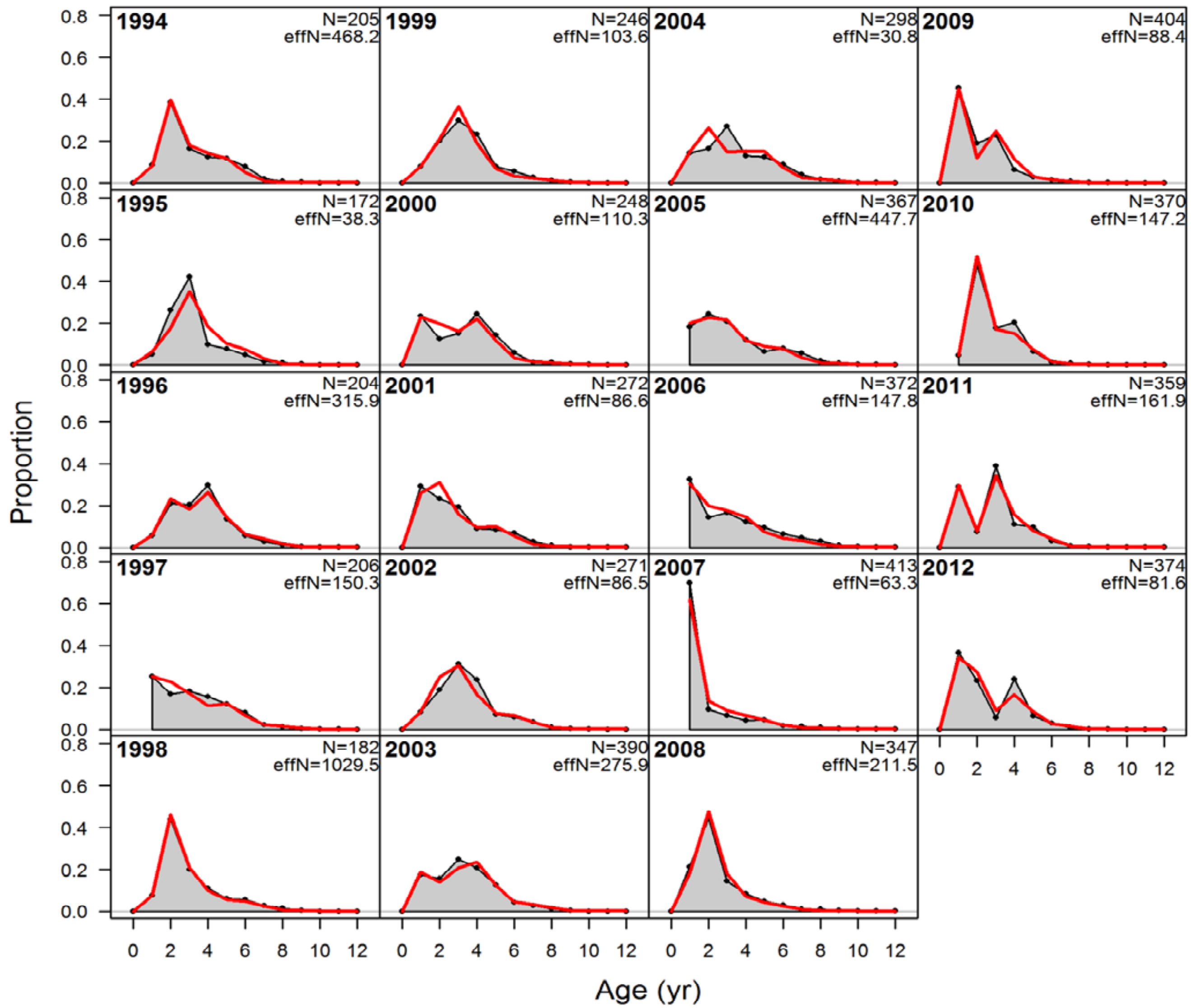


Figure 2.1.2a—Model 1 fits to the fishery age composition data.

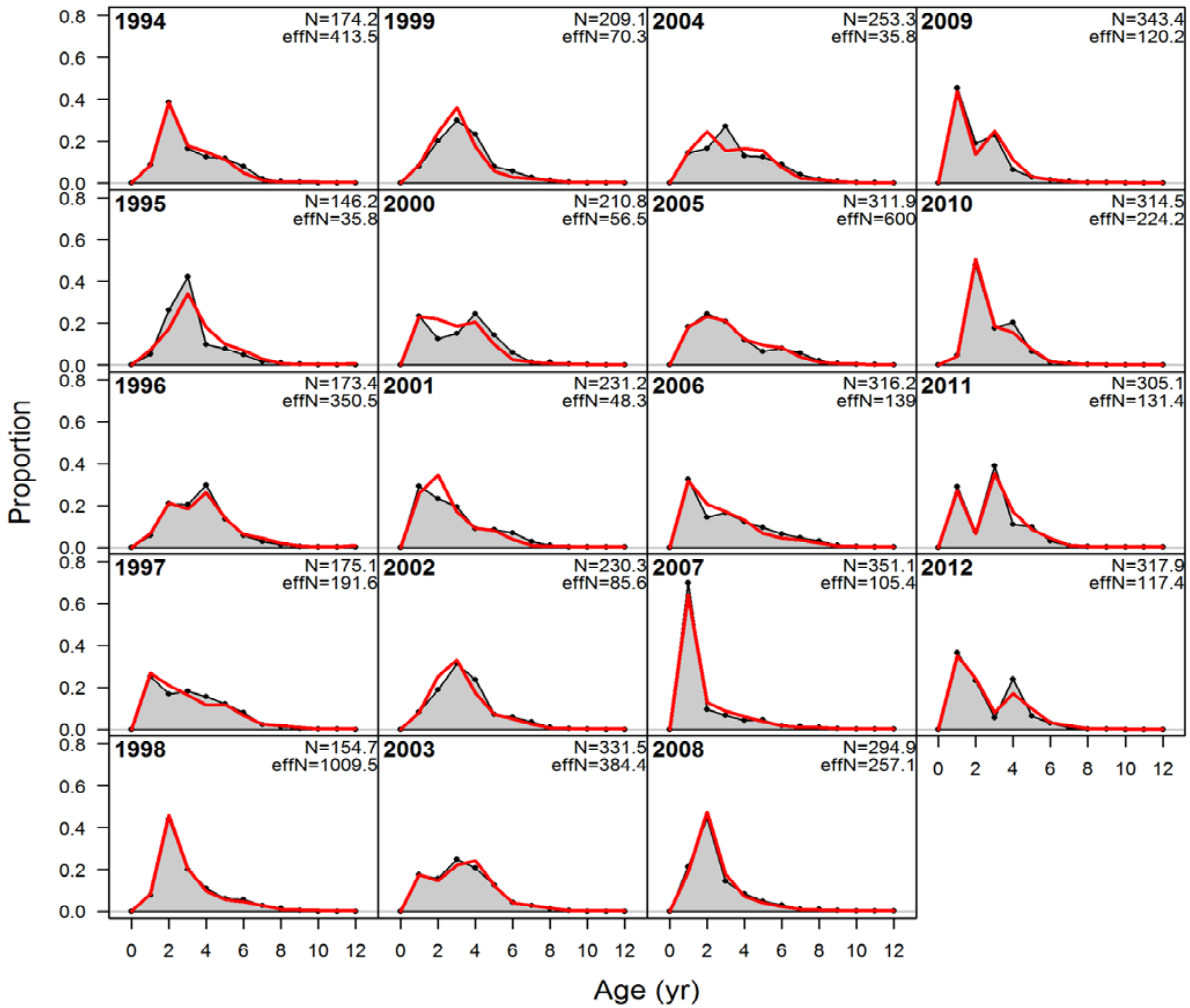


Figure 2.1.2b—Model 2 fits to the fishery age composition data.

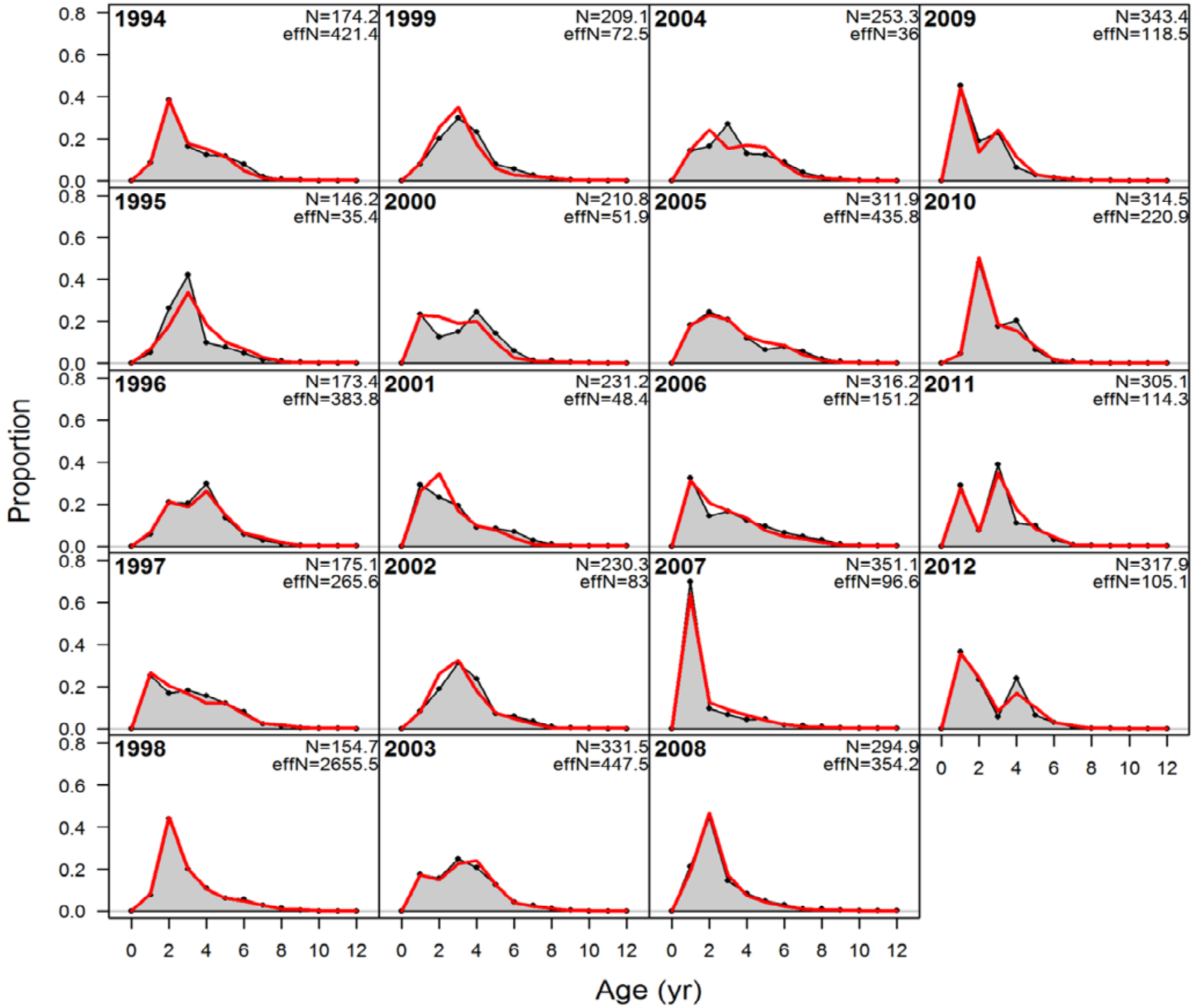


Figure 2.1.2c—Model 3 fits to the fishery age composition data.

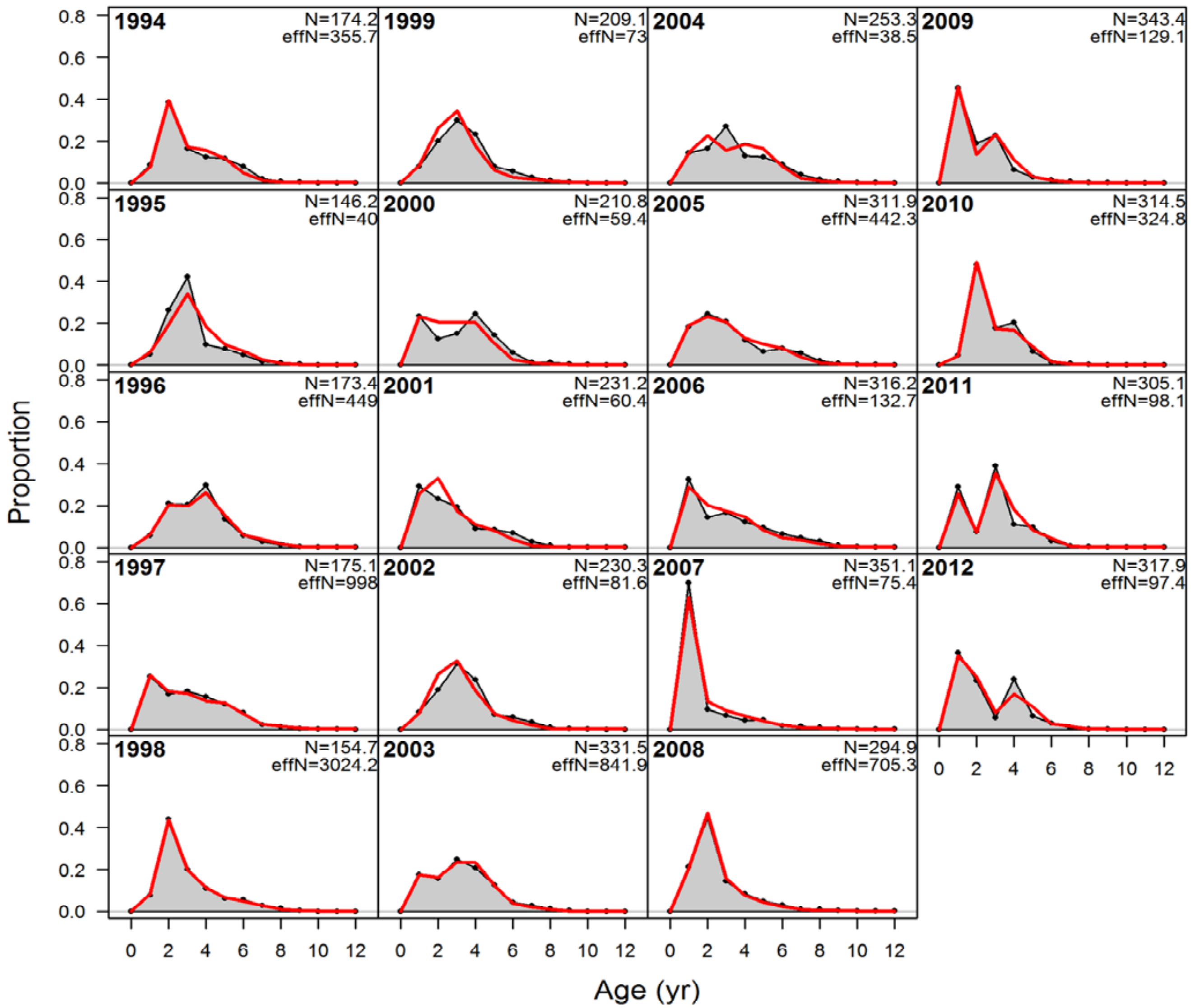


Figure 2.1.2d—Model 4 fits to the fishery age composition data.

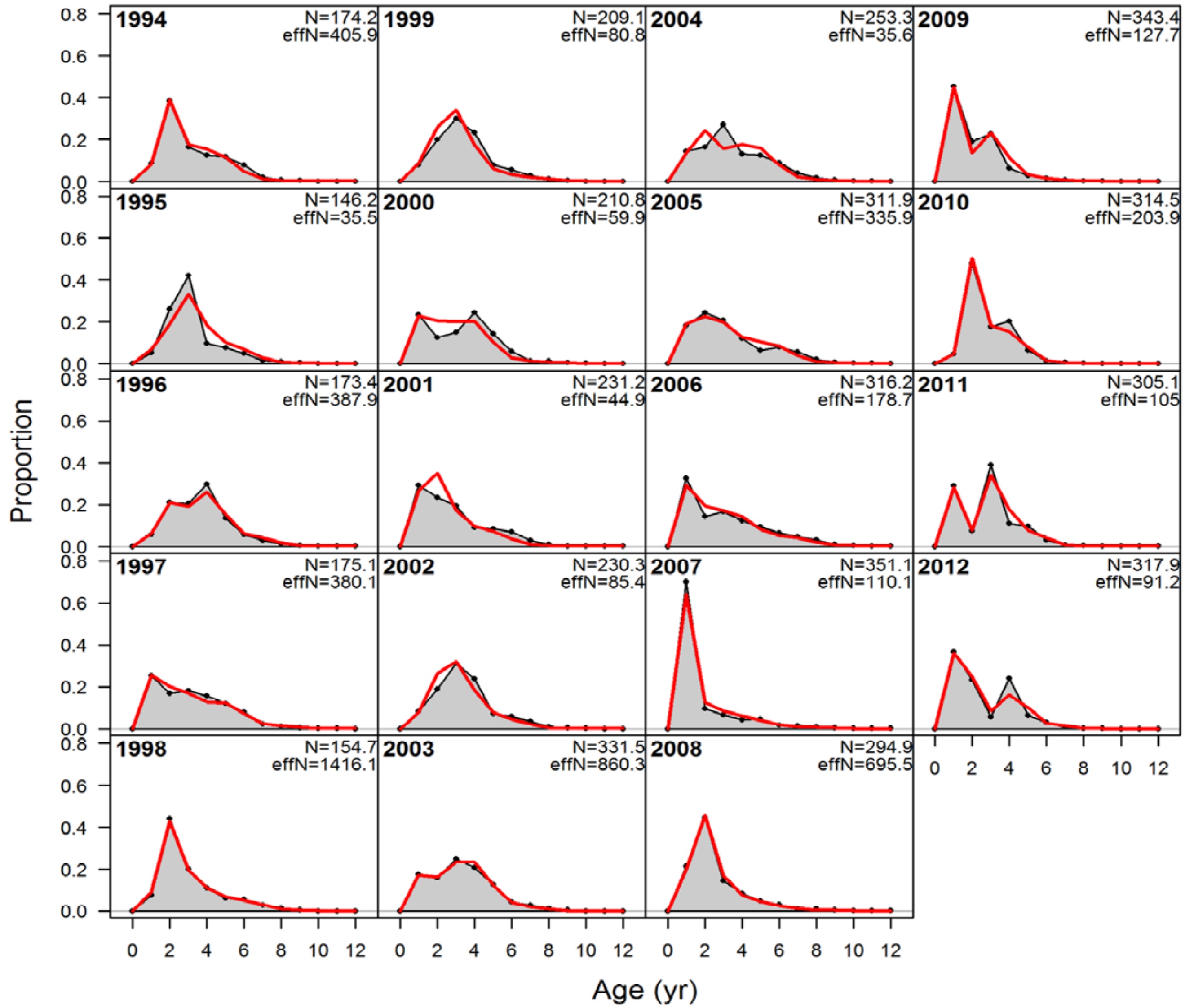


Figure 2.1.2e—Model 5 fits to the fishery age composition data.

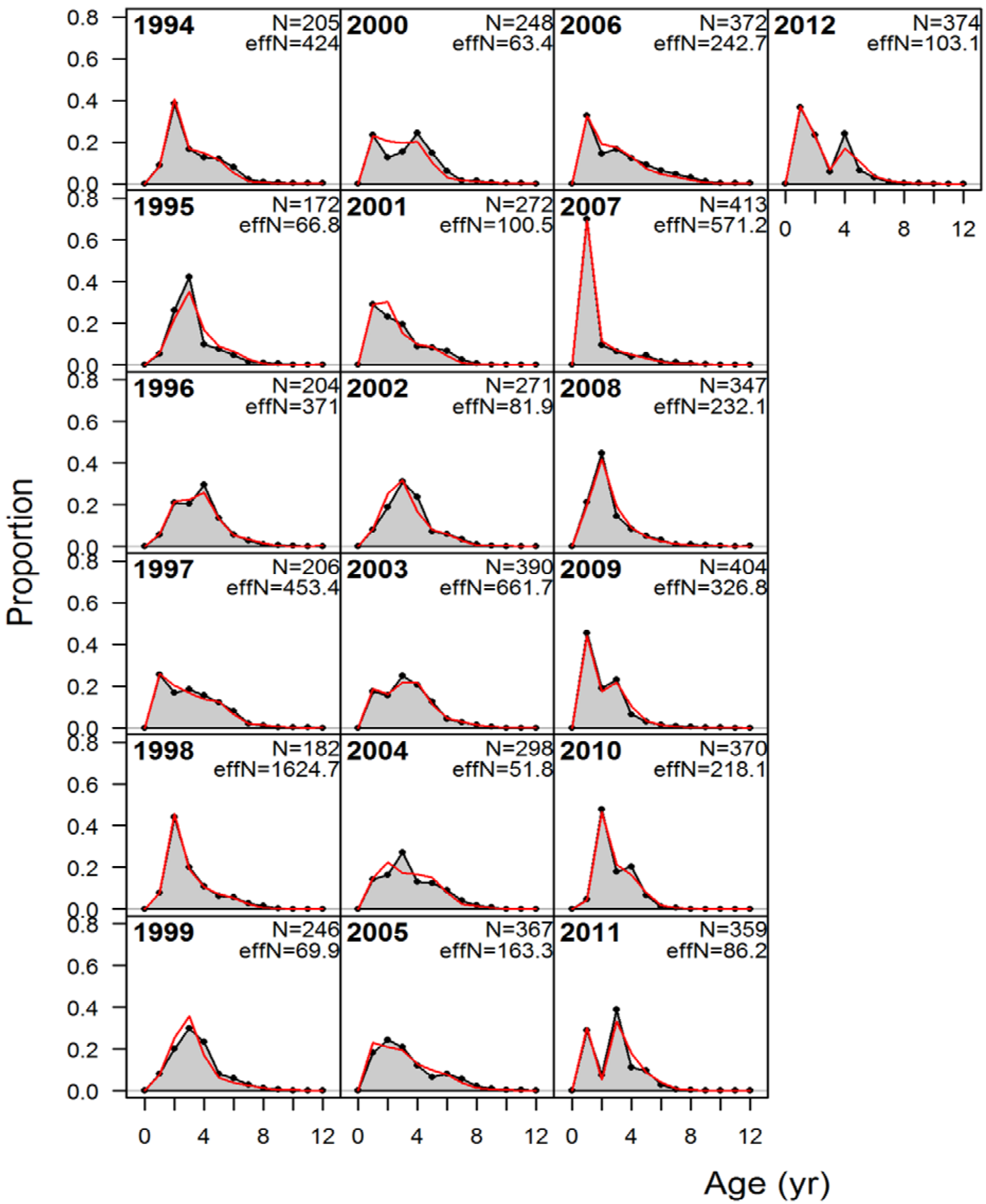
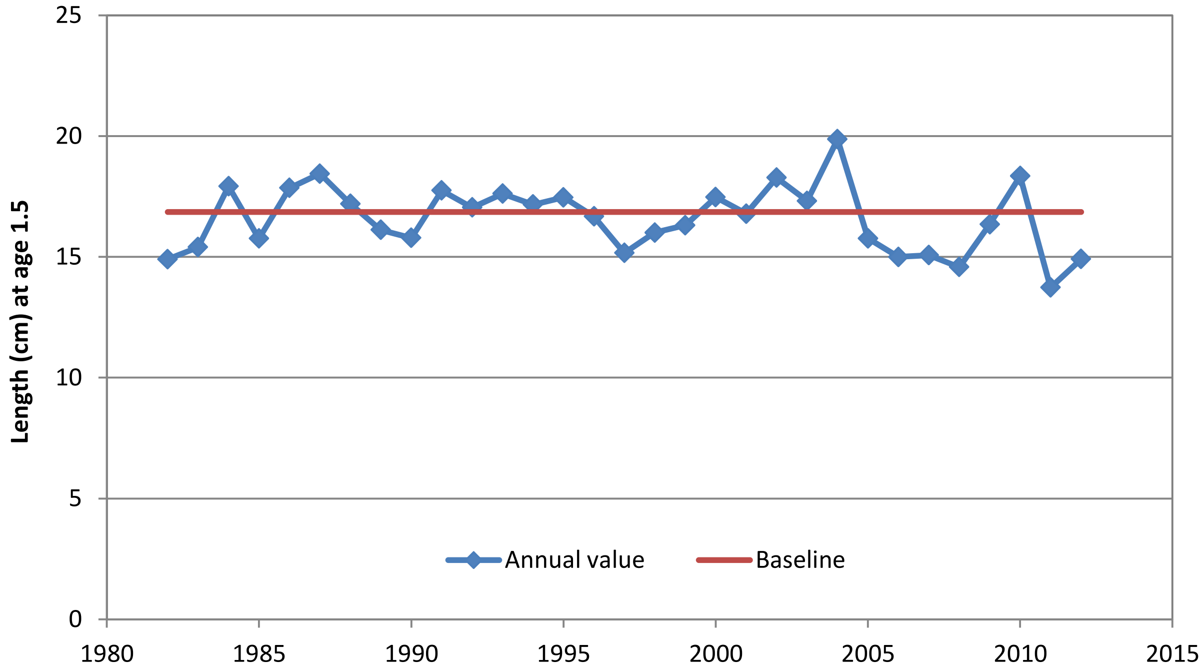


Figure 2.1.2f—Model 6 fits to the fishery age composition data.

Length at age 1.5



Catchability

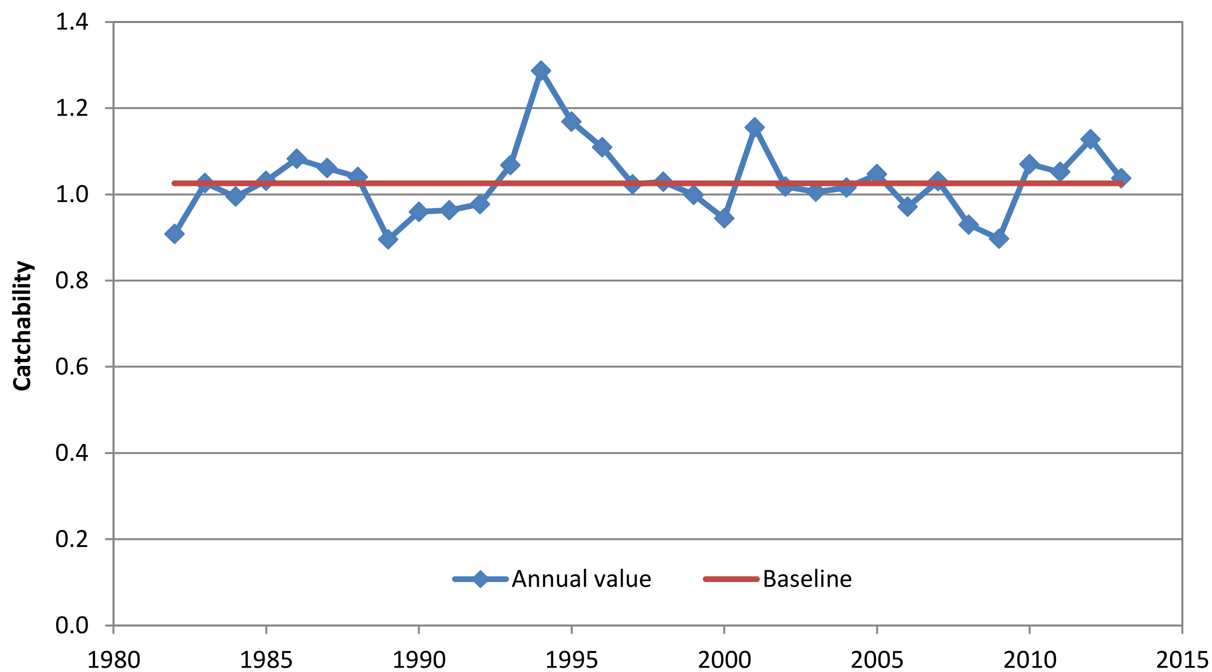


Figure 2.1.3—Time series of length at age 1.5 and survey catchability estimated by Model 6.

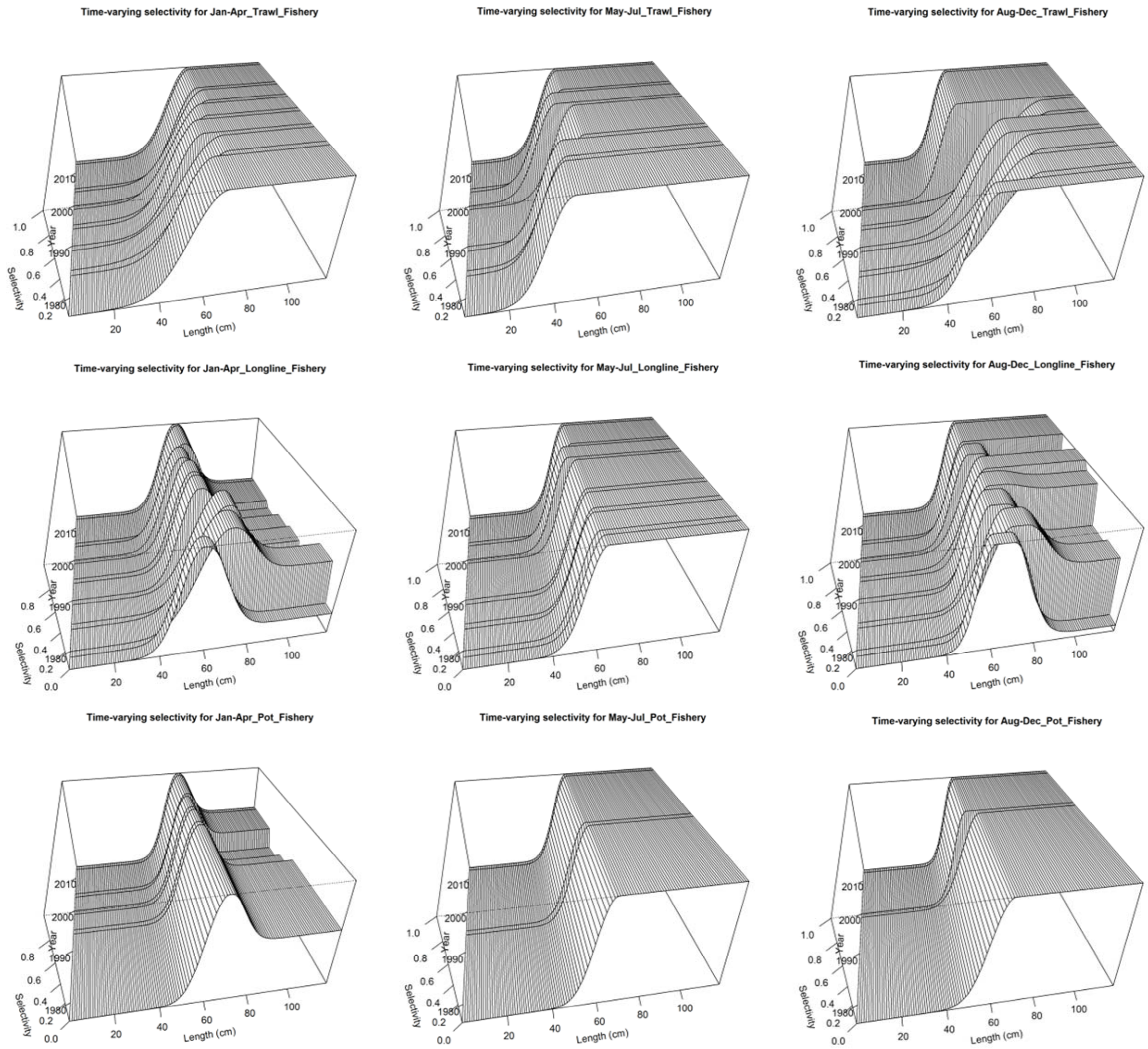


Figure 2.1.4a—Fishery selectivities estimated by Model 1.

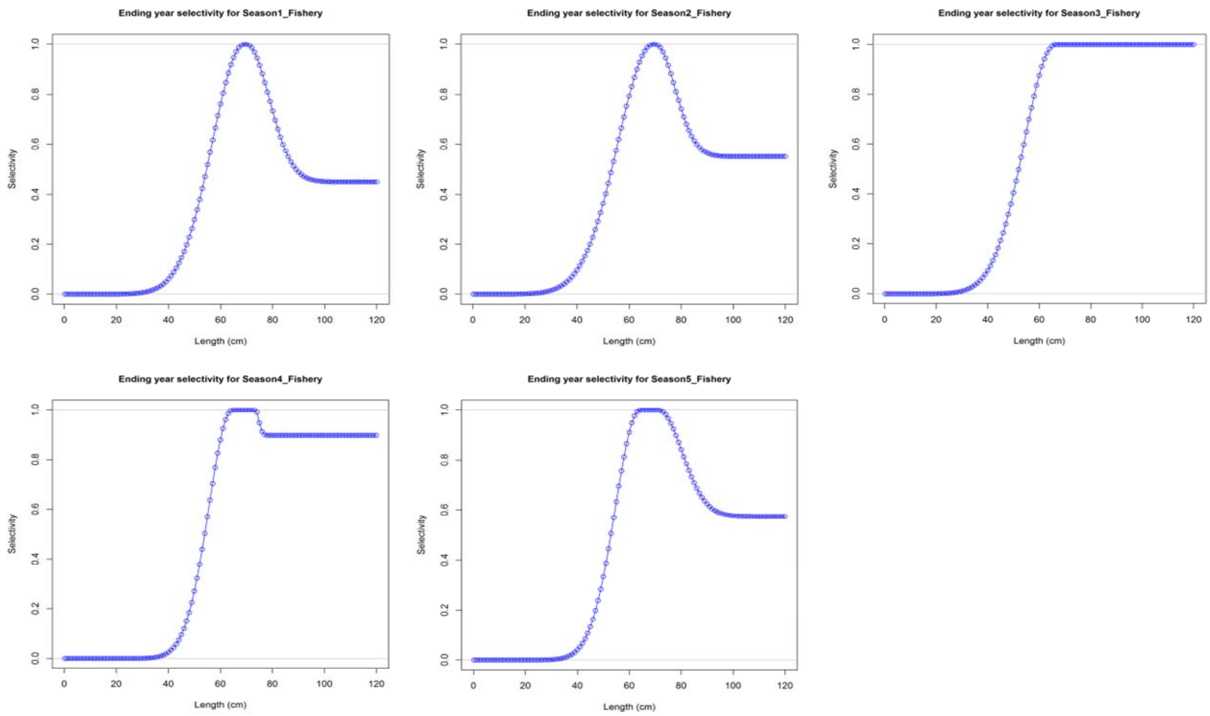


Figure 2.1.4b—Fishery selectivities estimated by Model 2.

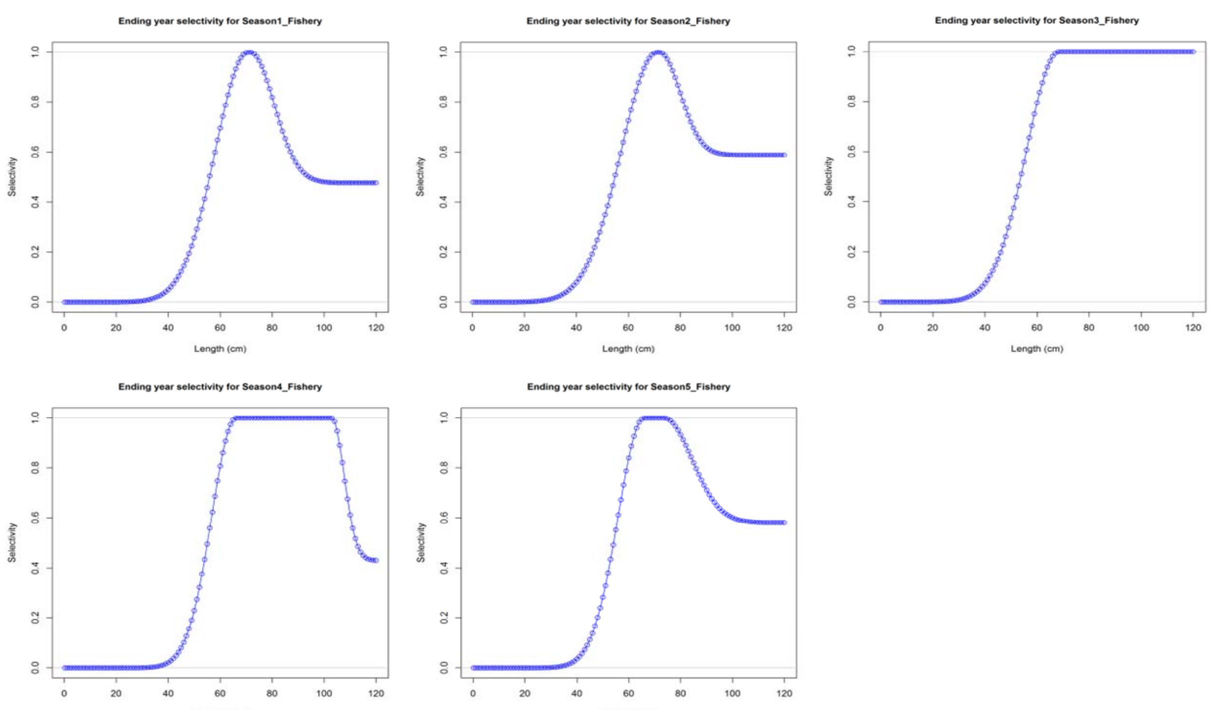


Figure 2.1.4c—Fishery selectivities estimated by Model 3.

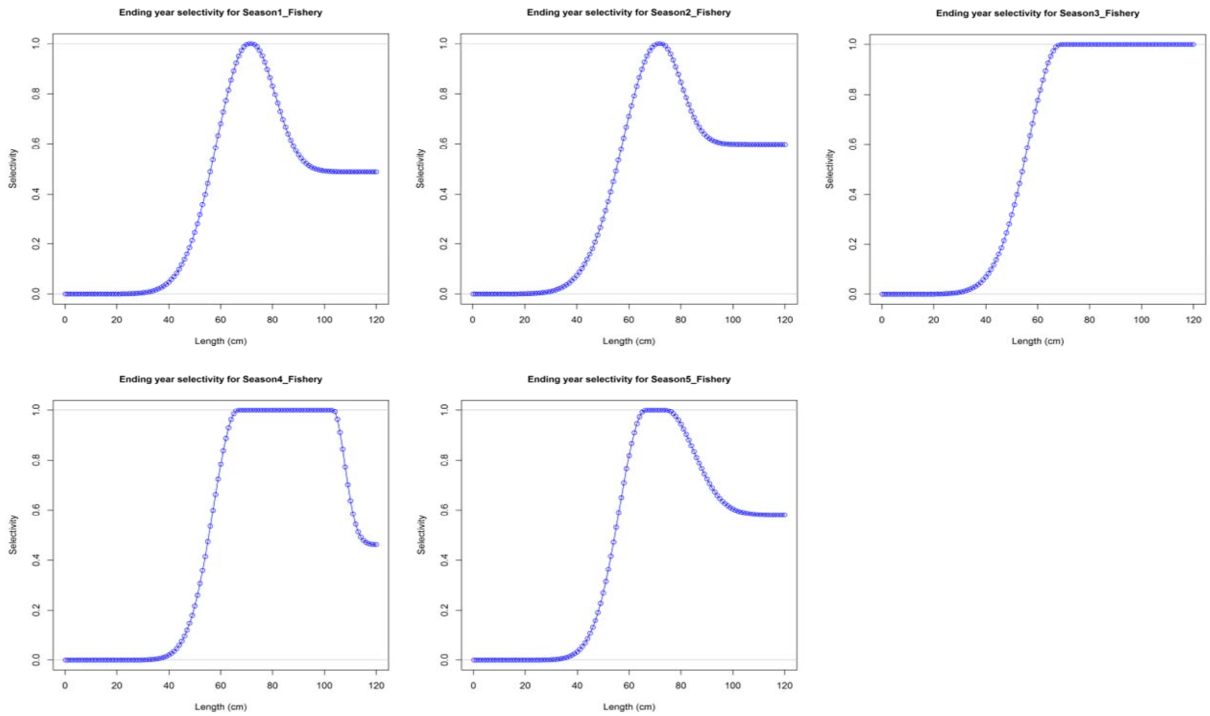


Figure 2.1.4d—Fishery selectivities estimated by Model 4.

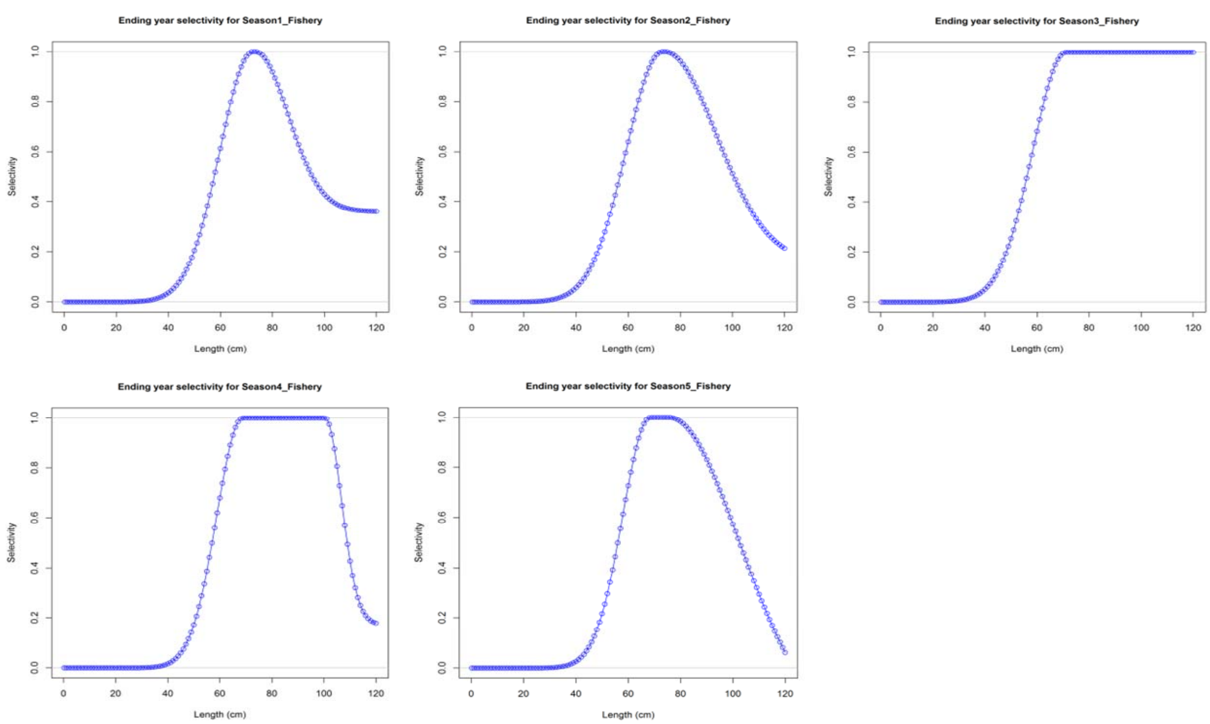


Figure 2.1.4e—Fishery selectivities estimated by Model 5.

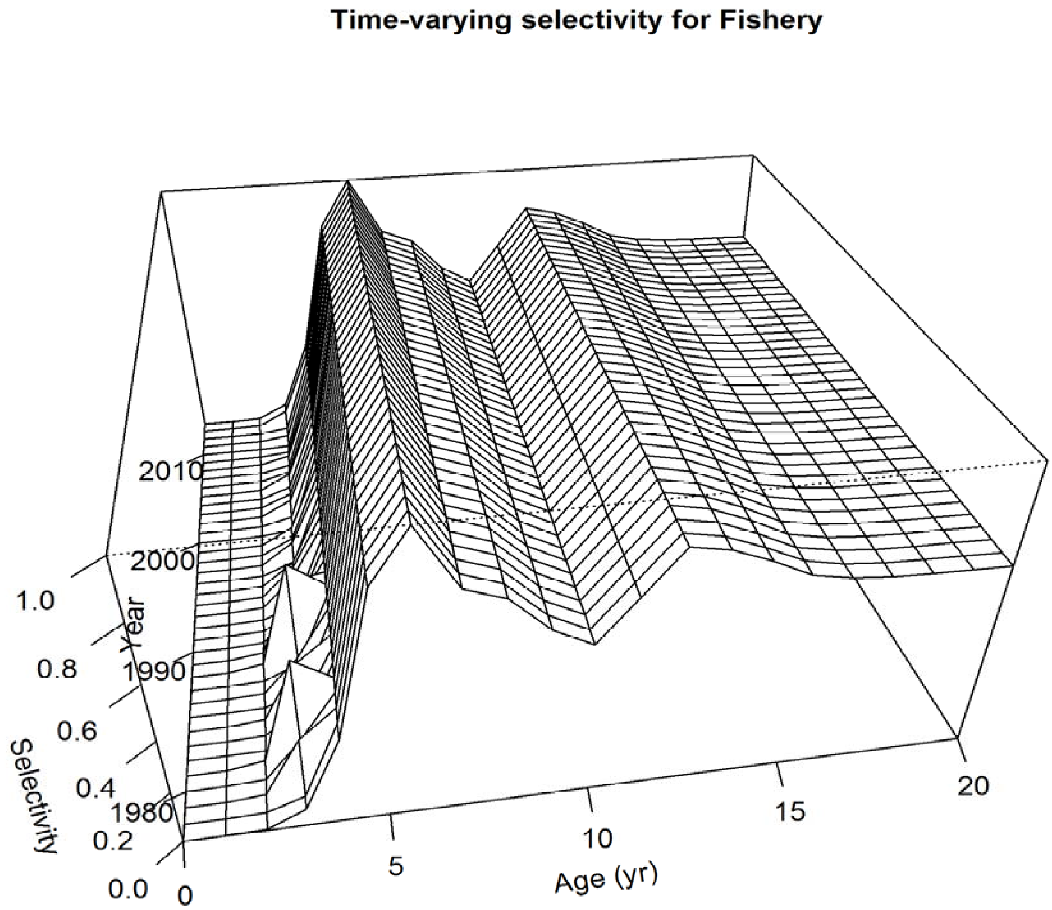


Figure 2.1.4f—Fishery selectivities estimated by Model 6.

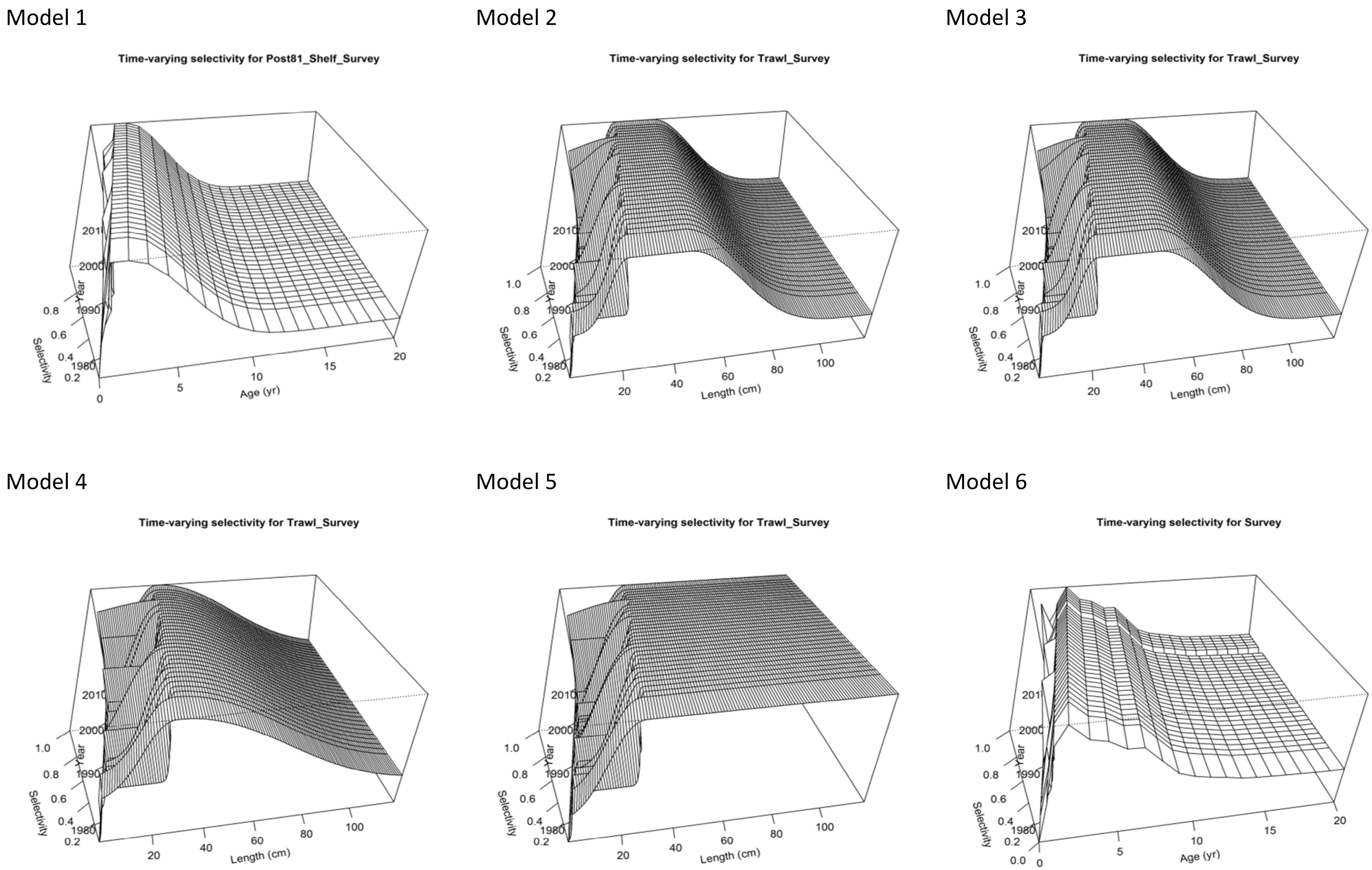


Figure 2.1.5—Survey selectivities estimated by Models 1-6.

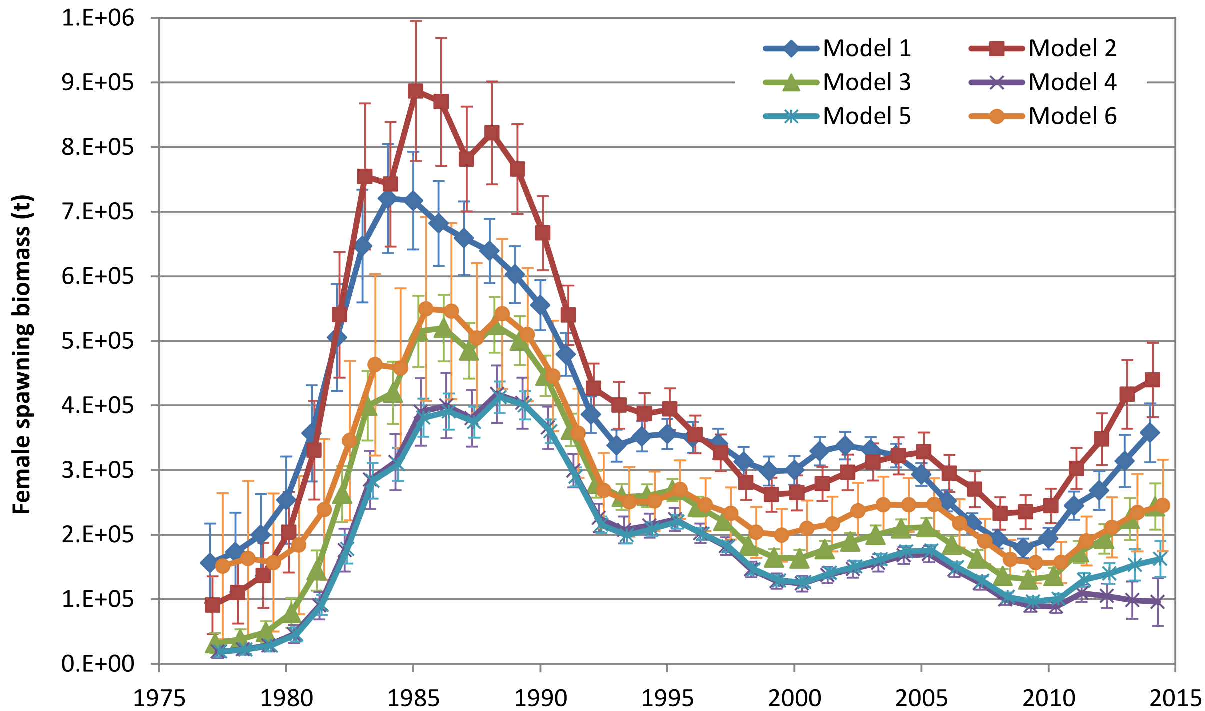


Figure 2.1.6—Model estimates of the female spawning biomass time series.

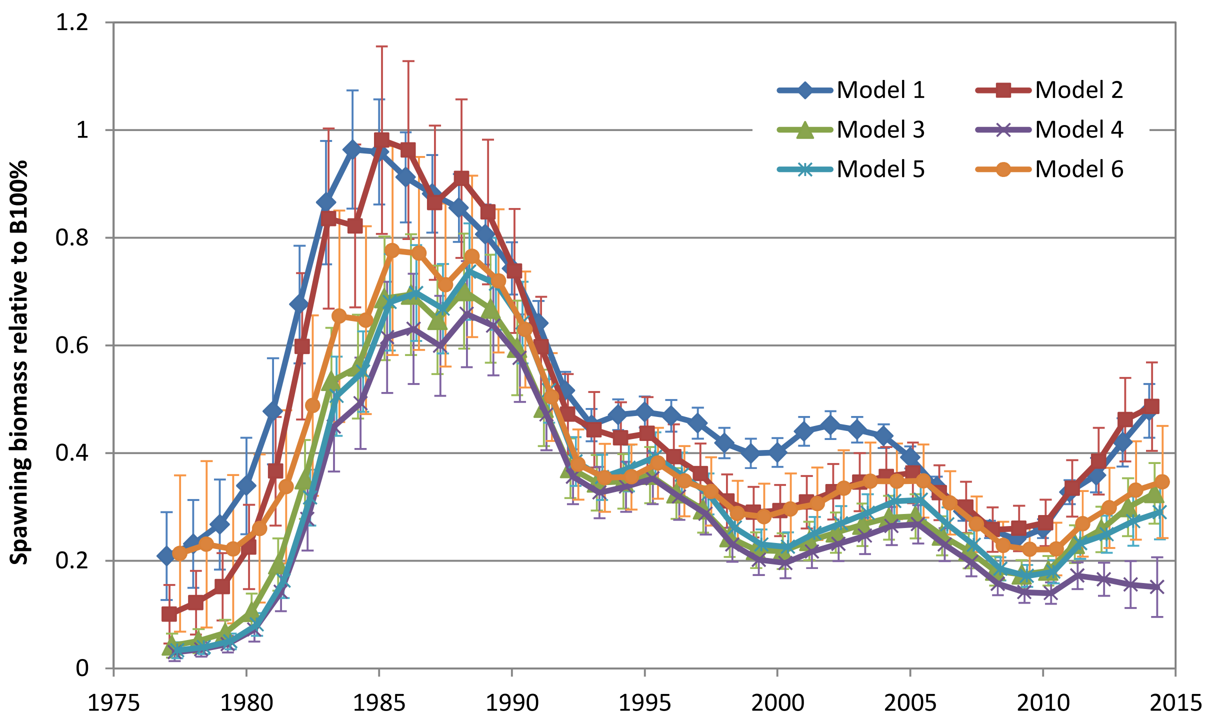


Figure 2.1.7—Model estimates of the relative female spawning biomass time series.

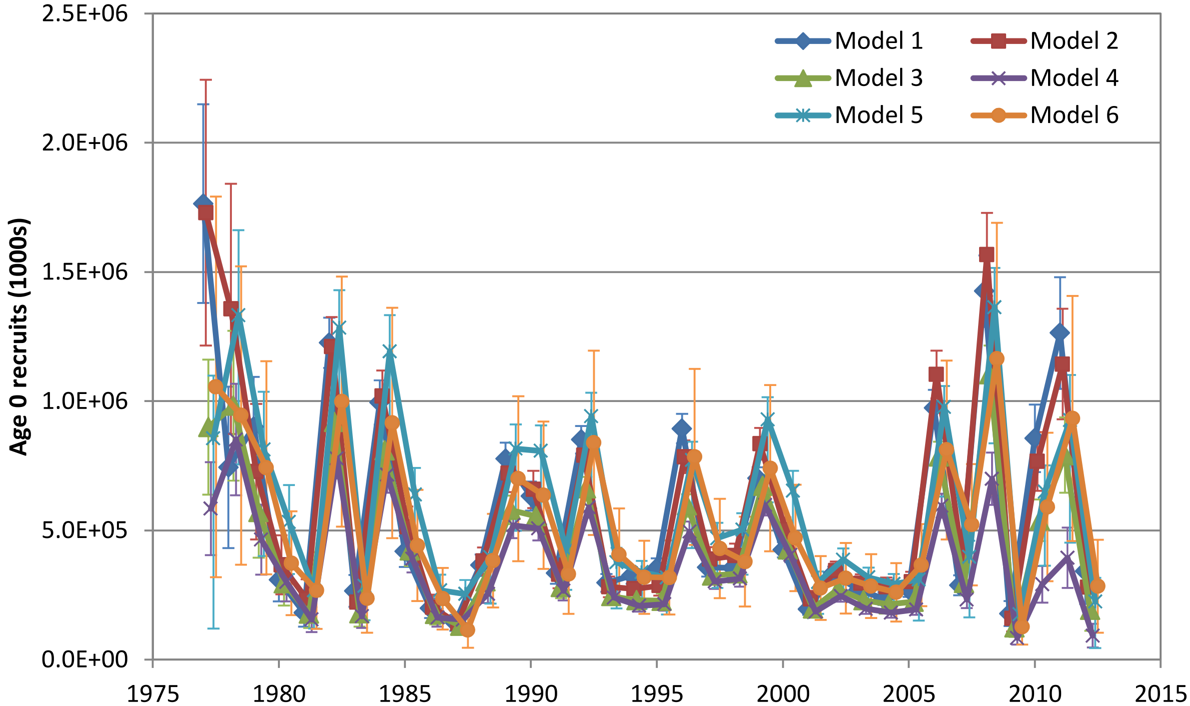


Figure 2.1.8—Model estimates of the age 0 recruitment time series.

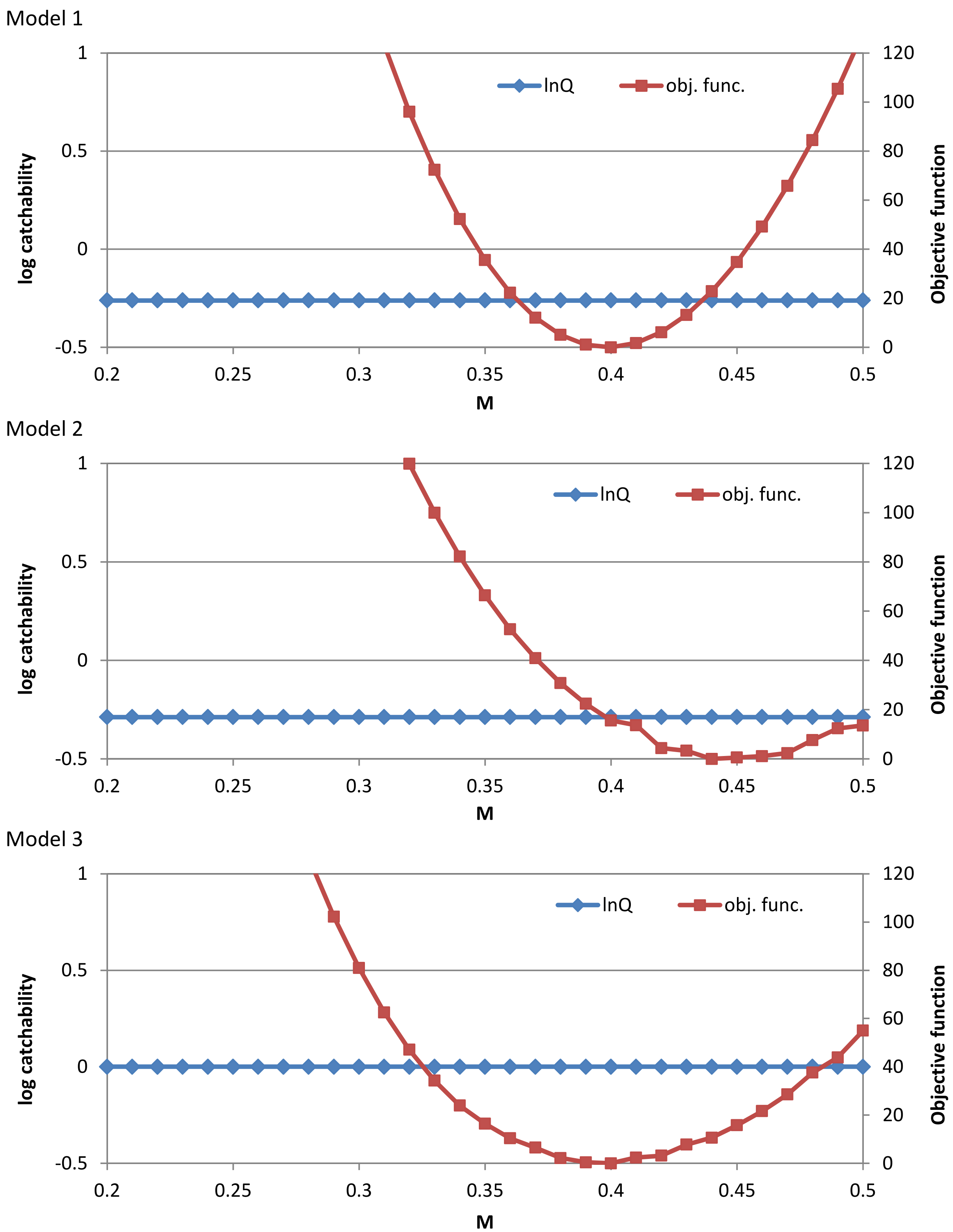


Figure 2.1.9a—Likelihood profiles with respect to the natural mortality rate for Models 1-3. Objective function minima occur at *M*=0.40 (Model 1), *M*=0.44 (Model 2), and *M*=0.40 (Model 3). The relationship between *M* and log *Q* is also shown.

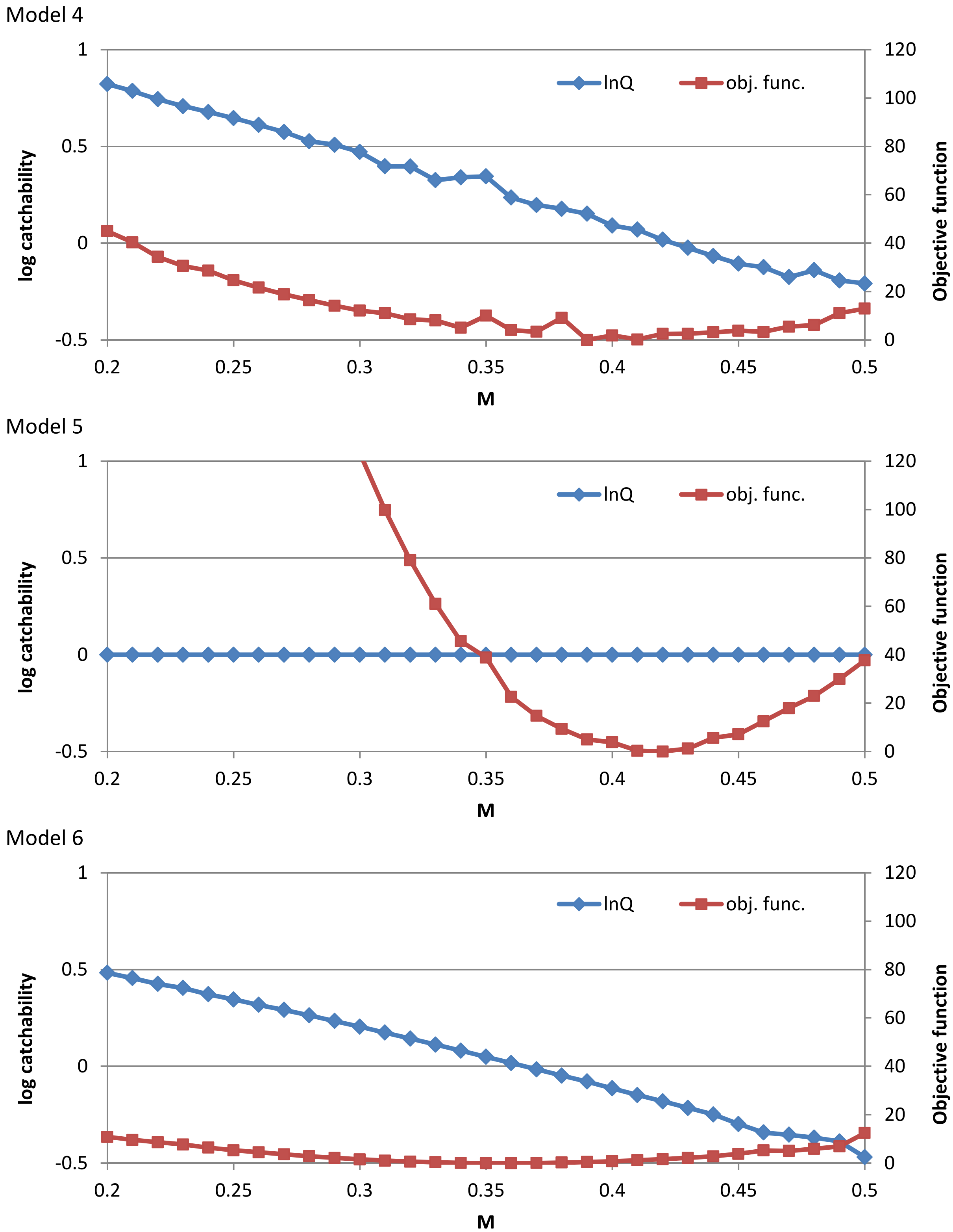


Figure 2.1.9b— Likelihood profiles with respect to the natural mortality rate for Models 4-6. Objective function minima occur at M=0.39 (Model 4), M=0.42 (Model 5), and M=0.36 (Model 3). The relationship between M and log Q is also shown. Jaggedness indicates lack of convergence in some runs.

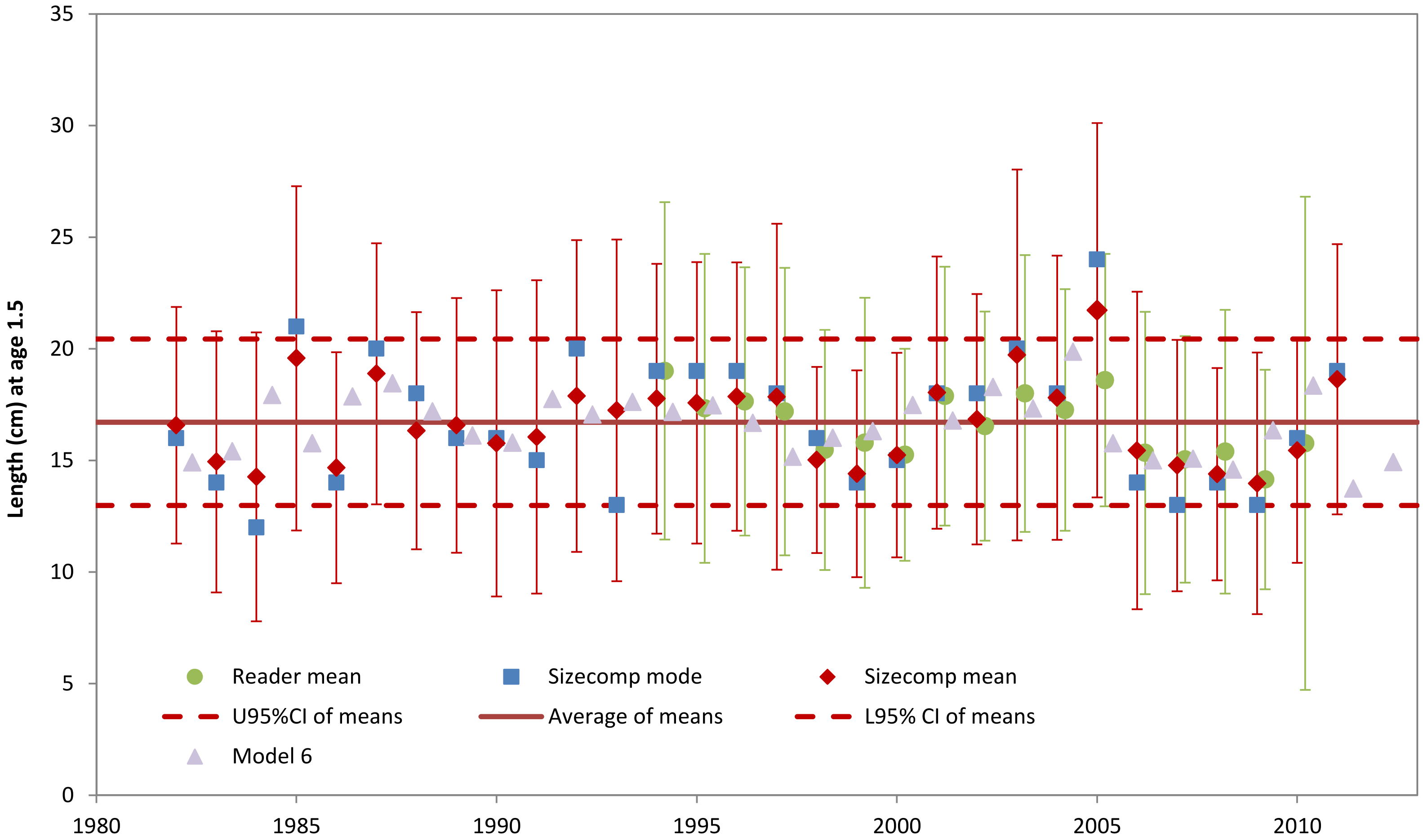


Figure 2.1.10—Various estimators of mean length (cm) at age 1.5.

APPENDIX 2.2: SUPPLEMENTAL CATCH DATA

From the minutes of the September 2013 Joint Plan Team meeting: *"The Teams recommended that SAFE chapter authors continue to include 'other' removals as an appendix. Optionally, authors could also calculate the impact of these removals on reference points and specifications, but are not required to include such calculations in final recommendations for OFL and ABC."*

This appendix is provided in response to the above recommendation. A similar compendium was provided in Attachment 2.4 of the 2012 assessment (Thompson and Lauth 2012).

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 (2011-2013) is 6,149 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.

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	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899
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	2	0	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	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	4899	1737	4544	6697	6618	4899
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			24	24	24	24	24	24	24	24	24	24	24	24	32	20	17	29	24
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

Stock Synthesis 1 (SS1, Methot 1986, 1990, 1998, 2000) was first applied to the EBS Pacific cod stock in the 1992 assessment (Thompson 1992). This first application used age-structured data. Beginning with the 1993 SAFE report (Thompson and Methot 1993) and continuing through the 2004 SAFE report (Thompson and Dorn 2004), SS1 continued to be used, but based largely on length-structured data.

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

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

Until 2010, each year was partitioned into three seasons defined as January-May, June-August, and September-December (these seasonal boundaries were suggested by industry participants). Four fisheries were defined during the era of SS1-based assessments: The January-May trawl fishery, the June-December trawl fishery, the longline fishery, and the pot fishery.

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

A minor modification of the base model was suggested by the SSC in 2001, namely, that consideration be given to dividing the domestic era into pre-2000 and post-1999 segments. This modification was tested in the 2002 assessment (Thompson and Dorn 2002), where it was found to result in a statistically significant improvement in the model’s ability to fit the data. In the 2004 assessment (Thompson and Dorn 2004), further modifications were made to the base model. The 2004 model included a set of selectivity parameters for the EBS slope bottom trawl survey and added new likelihood components for the age compositions and length-at-age data from the 1998-2003 EBS shelf bottom trawl surveys and the size composition and biomass data from the 2002 and 2004 EBS slope bottom trawl surveys. Incorporation of age data and slope survey data had been suggested by the SSC (SSC minutes, December 2003).

A major change took place in the 2005 assessment (Thompson and Dorn 2005), as the model was migrated to the newly developed Stock Synthesis 2 program, which made use of the ADMB modeling architecture (Fournier et al. 2012) currently used in most age-structured assessments of BSAI and GOA groundfish. The move to Stock Synthesis 2 facilitated improved estimation of model parameters as well as statistical characterization of the uncertainty associated with parameter estimates and derived quantities such as spawning biomass. Technical details of Stock Synthesis 2 were described by Methot (2005).

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

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

1. *beginning_of_peak_region* (where the curve first reaches a value of 1.0)
2. *width_of_peak_region* (where the curve first departs from a value of 1.0)
3. *ascending_width* (equal to twice the variance of the underlying normal distribution)
4. *descending_width* (equal to twice the variance of the underlying normal distribution)
5. *initial_selectivity* (at minimum length/age)
6. *final_selectivity* (at maximum length/age)

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

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

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

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

1. An explicit algorithm was used to determine which fleets (including surveys as well as fisheries) would be forced to exhibit asymptotic selectivity.
2. An explicit algorithm was used to determine which selectivity parameters would be allowed to vary periodically in “blocks” of years, and to determine the appropriate block length for each such time-varying parameter.

The 2009 assessment (Thompson et al. 2009) featured a total of 14 models reflecting many alternative assumptions and use or non-use of certain data, particularly age composition data. Relative to the 2008 assessment, the main changes in the model accepted by the Plan Team and SSC were as follow:

1. Input standard deviations of all *dev* vectors were set iteratively by matching the standard deviations of the set of estimated *dev*s.
2. The standard deviation of length at age was estimated outside the model as a linear function of mean length at age.
3. Catchability for the post-1981 trawl survey was fixed at the value that sets the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.47 obtained by Nichol et al. (2007).
4. Potential ageing bias was accounted for in the ageing error matrix by examining alternative bias values in increments of 0.1 for ages 2 and above, resulting in a positive bias of 0.4 years for these ages (age-specific bias values were also examined, but did not improve the fit significantly).
5. Cohort-specific growth *dev*s were estimated for all years through 2008.

Many changes were made or considered in the 2010 stock assessment (Thompson et al. 2010). Six models were presented in the preliminary assessment, as requested by the Plan Teams in May, with subsequent concurrence (given two minor modifications) by the SSC in June. Following review in September and October, three of these models, or modifications thereof, were requested by the Plan Teams or SSC to be included in the final assessment. Relative to the 2009 assessment, the main changes in the model that was ultimately accepted by the Plan Team and SSC in 2010 were as follow:

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

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

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

1. The pre-1982 portion of the bottom trawl time series was omitted.

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

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

Many model changes in the 2012 stock assessment (Thompson and Lauth 2012). Five primary models and nine secondary models were presented in the preliminary assessment. Of these, four of the primary models and three of the secondary models were requested by the Plan Teams, with subsequent concurrence by the SSC. Following review in September and October, four of the models from the preliminary assessment were requested by the Plan Teams or SSC to be included in the final assessment:

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

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

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

Model 4 was an exploratory model that differed from Model 1 in several respects:

1. A new, inter- and intra-annually varying weight-length representation developed in the preliminary assessment was used.
2. "Tail compression" was turned off. This feature aggregates size composition bins with few or zero data on a record-by-record basis, which improves computational speed, but which also makes some of the graphs in the R4SS package difficult to interpret. In Models 1-3, tail compression was turned on.
3. Fishery CPUE data were omitted. In Models 1-3, fishery CPUE data were included for purposes of comparison, but were not used in estimation.
4. A new population length bin was added for fish in the 0-0.5 cm range, which was used for extrapolating the length-at age curve below the first reference age. In Models 1-3, the lower bound of the first population length bin was 0.5 cm.

5. Mean-size-at-age data were eliminated. In Models 1-3, mean-size-at-age data were included, but not used in estimation.
6. The number of estimated year class strengths in the initial numbers-at-age vector was set at 10. In Models 1-3, only 3 elements of the initial numbers-at-age vector were estimated, which causes an automatic warning in SS.
7. The Richards growth equation (Richards 1959, Schnute 1981, Schnute and Richards 1990) was used, which adds one more parameter. In Models 1-3, the von Bertalanffy equation—a special case of the Richards equation—was used.
8. The log-scale standard deviation of recruitment was estimated internally (i.e., as a free parameter estimated by ADMB). In Models 1-3, this parameter was held constant at the value of 0.57 that was estimated in the final 2009 assessment by matching the standard deviation of the recruitment *dev*s, per Plan Team request.
9. Survey selectivity was modeled as a function of length. In Models 1-3, survey selectivity was modeled as a function of age.
10. Fisheries were defined with respect to each of the five seasons, but not with respect to gear. In Models 1-3, fisheries were defined with respect to both season and gear.
11. Fishery selectivity curves were defined for each of the five seasons, but were not stratified by gear type. In Models 1-3, seasons 1-2 and 4-5 were lumped into a pair of "super" seasons for the purpose of defining fishery selectivity curves, and fishery selectivities were also *gear*-specific (3 super-seasons × 3 gears = 9 selectivity curves).
12. The selectivity curve for the fishery that came closest to being asymptotic on its own (in this case, the season 3 fishery) was forced to be asymptotic by fixing both *width_of_peak_region* and *final_selectivity* at a value of 10.0 and *descending_width* at a value of 0.0. In Models 1-3, six of the nine super-season × gear fisheries were forced to exhibit asymptotic selectivity.
13. Survey catchability was tuned iteratively to set the average of the product of catchability and survey selectivity across the 60-81 cm range equal to 0.47, corresponding to the Nichol et al. (2007) estimate. In Models 1-3, Q was left at the value of 0.77 estimated by a similar procedure in the final 2009 assessment, per Plan Team request.
14. The age composition sample size multiplier was tuned iteratively to set the mean of the ratio of effective sample size to input sample size equal to 1.0. In Models 1-3, the variance adjustment was fixed at 1.0.
15. The two parameters governing the ascending limb of the survey selectivity schedule were given annual additive *dev*s with each σ_{dev} tuned to match the estimate that would be appropriate for a univariate linear-normal model with random effects integrated out. In Models 1-3, no *dev* vector corresponding to the *initial_selectivity* parameter was used, because it was "tuned out" in the 2009 final assessment; and σ_{dev} for the *ascending_width* parameter was left at the value of 0.07 estimated iteratively in the final 2009 assessment, per Plan Team request.

Following review of the 2012 final assessment, Model 1 (the same model used in 2011) was accepted by both the BSAI Plan Team and the SSC.

An updated description of the SS framework was published by Methot and Wetzel (2013).

Many changes were considered in the 2013 assessment. Four models were presented in that year's preliminary assessment, as requested in May and June by the Plan Team and SSC. After reviewing the preliminary assessment, the Plan Team requested six models for inclusion in the final assessment. The SSC agreed with this suggestion, and asked for an additional two models, bringing the total number of models requested for inclusion in the final assessment to eight.

However, due to a government shutdown in October 2013, the only model presented in the final assessment was the same model used in 2011 and 2012. This model was accepted by both the BSAI Plan Team and the SSC.

References

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optimization Methods and Software* 27:233-249.

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

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

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

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

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

Methot, R. D., and C. R. Wetzel. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research* 142:86-99.

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

Richards, F. J. 1959. A flexible growth function for empirical use. *Journal of Experimental Botany* 10:290-300.

Schnute, J. 1981. A versatile growth model with statistically stable parameters. *Canadian Journal of Fisheries and Aquatic Sciences* 38:1128-1140.

Schnute, J. T., and L. J. Richards. 1990. A unified approach to the analysis of fish growth, maturity, and survival. *Canadian Journal of Fisheries and Aquatic Sciences* 47:24-40.

Thompson, G. G. 1992. Pacific cod. *In* Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions as Projected for 1993, p. 2-1 through 2-37. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. E. Conners. 2007. Report of the Pacific cod technical workshop held at the Alaska Fisheries Science Center, April 24-25, 2007. Unpubl. manuscr., Alaska Fisheries Science Center, Resource Ecology and Fisheries Management Division, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 56 p.

Thompson, G. G., and M. K. Dorn. 2002. Assessment of the Pacific cod stock in the eastern Bering Sea and Aleutian Islands area. *In* Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish

Resources of the Bering Sea/Aleutian Islands Regions, p. 121-205. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 2004. 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. 185-302. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and M. W. Dorn. 2005. Assessment of the Pacific cod stock in the 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. 219-330. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., M. W. Dorn, S. Gaichas, and K. Aydin. 2006. 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. 237-339. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., J. N. Ianelli, M. W. Dorn, and D. G Nichol. 2007a. An exploration of altnernative models of the Bering Sea Pacific cod stock. Unpubl. manuscr., Alaska Fisheries Science Center, Resource Ecology and Fisheries Management Division, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 29 p.

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

Thompson, G., J. Ianelli, R. Lauth, S. Gaichas, and K. Aydin. 2008. 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. 221-401. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, and R. Lauth. 2009. 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. 235-439. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, and R. Lauth. 2010. 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. 243-424. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and R. R. Lauth. 2011. 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. 269-476. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

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.

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