Chapter 2A: Assessment of the Pacific Cod Stock in the Aleutian Islands

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EXECUTIVE SUMMARY

Note: Due to a shutdown of the Federal government during the dates October 1-16, 2013, some customary features are missing from this stock assessment, including:

1. Responses to some SSC and Plan Team comments
2. Retrospective analyses

For the same reason, certain tables have not been updated, including:

1. Discards of Pacific cod in the Pacific cod fishery
2. Incidental catch of FMP species in the Pacific cod fishery
3. Incidental catch of non-target species in the Pacific cod fishery
4. Incidental catch of prohibited species in the Pacific cod fishery

Unrelated to the government shutdown, the former BSAI Pacific cod SAFE chapter has been split into two chapters this year: Chapter 2 pertains to the eastern Bering Sea (EBS) stock, and Chapter 2A pertains to the Aleutian Islands (AI) stock. This change has been anticipated for several years, but was precipitated this year by the likelihood that separate harvest specifications will be set for the EBS and AI Pacific cod stocks beginning with the 2014 fishery.

Summary of Changes in Assessment Inputs

Relative to the November edition of last year's BSAI SAFE report (where the AI Pacific cod stock assessment appeared as an exploratory analysis in Attachment 2.2), the following substantive changes have been made in the AI Pacific cod stock assessment.

Changes in the Input Data

1) Catch data for 1991-2012 were updated, and preliminary catch data for 2013 were incorporated.
2) Commercial fishery size composition data for 2012 were updated, and preliminary size composition data from the 2013 commercial fisheries were incorporated.
3) Age composition data from the 2012 AI bottom trawl survey were incorporated.

Changes in the Assessment Methodology

Although no model or method has yet been approved for recommending harvest specifications for AI Pacific cod, age-structured models of this stock have been explored in both the preliminary and final 2012 BSAI Pacific cod assessments (Thompson and Lauth 2012) and the preliminary 2013 AI Pacific cod assessment (Appendix 2A.1). Three models were presented in this year's preliminary assessment. After reviewing this year's preliminary assessment, the Plan Team and SSC requested two models for inclusion in the final assessment: Team/SSC Model 1 is similar to Model 1 from the preliminary assessment, except that survey catchability is fixed at unity. Team/SSC Model 2 is similar to Model 2 from the preliminary assessment, except that survey selectivity is forced to be asymptotic.

The SSC also requested that this year's assessment include "reference points based on Tier 5 considerations," so two methods for managing this stock under Tier 5 are also presented: the Kalman filter that has been used since 2004 to expand EBS-based reference points into BSAI equivalents, along with the random effects model recommended by the Survey Averaging Working Group.

Tier 5 management based on the random effects model is the authors' recommendation for setting 2014-2015 harvest specifications.

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 (**note that last year's assessment was for the combined EBS and AI (BSAI) region, but this year's assessment is for the AI only; also note that the projected total (age 0+) biomass listed for 2013 and 2014 in last year's summary table was incorrect, but has been corrected below**):

Quantity	As estimated or *specified last* year for: 2013	2014	As estimated or *recommended this* year for: 2014	2015
M (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	3a	3a	5	5
Projected total (age 0+) biomass (t)	1,720,000	1,840,000	n/a	n/a
Female spawning biomass (t)				
Projected				
Upper 95% confidence interval	470,000	495,000	n/a	n/a
Point estimate	422,000	447,000	n/a	n/a
Lower 95% confidence interval	373,000	399,000	n/a	n/a
$B_{100\%}$	896,000	896,000	n/a	n/a
$B_{40\%}$	358,000	358,000	n/a	n/a
$B_{35\%}$	314,000	314,000	n/a	n/a
Biomass (t)				
Upper 95% confidence interval	n/a	n/a	76,700	76,700
Point estimate	n/a	n/a	59,000	59,000
Lower 95% confidence interval	n/a	n/a	45,400	45,400
F_{OFL}	0.34	0.34	0.34	0.34
$maxF_{ABC}$	0.29	0.29	0.26	0.26
F_{ABC}	0.29	0.29	0.26	0.26
OFL (t)	359,000	379,000	20,100	20,100
maxABC (t)	307,000	323,000	15,100	15,100
ABC (t)	307,000	323,000	15,100	15,100
Status	As determined *last* year for: 2011	2012	As determined *this* year for: 2012	2013
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	n/a
Approaching overfished	n/a	No	n/a	n/a

Responses to SSC and Plan Team Comments on Assessments in General

Six comments on assessments in general (including comments on Aleutian Islands assessments in general) were addressed in the preliminary assessment (Appendix 2A.1). In the interest of efficiency, they are not repeated in this section. Joint Plan Team (JPT) and SSC comments that were developed following completion of the preliminary assessment are shown below. Due to the October government shutdown, Alaska Fisheries Science Center (AFSC) leadership has determined that responses to Plan Team and SSC comments are not required for this year's stock assessments. However, the circumstances surrounding the assessment of AI Pacific cod are unusual, in that the SSC is committed to recommending harvest specifications this year but no accepted model or other method of determining harvest specifications or other biological reference points exists. Because of these unusual circumstances, two of the following Plan Team and SSC comments (JPT4 and SSC2) will be addressed in this assessment. Responses to the others will be deferred to a future assessment.

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."*

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."*

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."*

JPT4 (9/13 minutes): *"The Teams recommended that Tier 5 stock authors compute and present both random effects and status quo methods this year in their assessments, specifically using by-year survey variances for the random effects model, with the author to evaluate which method is preferred."* Results from the Kalman filter that has been used since 2004 to expand EBS-based reference points into BSAI equivalents are presented, along with results from the random effects model recommended by the Survey Averaging Working Group (see "Results").

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."*

SSC2 (10/13 minutes): *"The SSC agrees with the Plan Teams' recommendation that authors should compare their method of survey averaging with the random effects approach."* See response to comment JPT4.

Responses to SSC and Plan Team Comments Specific to this Assessment

Four comments specific to this assessment were addressed in the preliminary assessment. 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. As with comments JPT4 and SSC2 in the preceding section, the unusual circumstances surrounding AI Pacific cod merit responses to these comments in this year's assessment, despite the October government shutdown.

BPT1 (9/13 minutes): *"The Team recommended two models: 1. M fixed, Q fixed at 1, freely estimated selectivities; 2. M fixed, Q estimated with a prior as in Model 2, survey selectivity forced to be asymptotic."* The Team's recommended models are included in this assessment (see "Model Structure").

SSC3 (10/13 minutes): *"The SSC concurs with the Plan Team to drop Model 3 from consideration in the December assessment because of the unrealistic value for catchability estimated in the model. Hence we recommend bringing forward results from Models 1 and 2 (and any others at the authors discretion), as well as reference points based on Tier 5 considerations in the December assessment as the SSC has notified the Council that it intends to set separate ABCs for the Aleutians and the Eastern Bering Sea."* Subsequent communication with SSC members clarified that "Models 1 and 2" in the above comment are the Plan Team's recommended models, not Models 1 and 2 from the preliminary assessment. As noted in the response to comment BPT1, the Plan Team's recommended models are included in this assessment (see "Model Structure"). In addition, two sets of Tier 5 reference points are provided (see "Results," also comments JPT4 and SSC2).

INTRODUCTION

General

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34° N latitude, with a northern limit of about 63° N latitude. Pacific cod is distributed widely over the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. 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 has traditionally been managed as a single unit, the SSC has indicated that it intends to set separate 2014-2015 harvest specifications 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 (Q) or selectivity. It is not known whether Pacific cod exhibit a similar response.

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

FISHERY

Description of the Directed Fishery

During the early 1960s, Japanese vessels began harvesting Pacific cod in the AI. However, these catches were not particularly large, and by the time that the Magnuson Fishery Conservation and Management Act went into effect in 1977, foreign catches of Pacific cod in the AI had never exceeded 4,200 t. Joint venture fisheries began operations in the AI in 1981, and peaked in 1987, with catches totaling over 10,000 t. Foreign fishing for AI Pacific cod ended in 1986, followed by an end to joint venture fishing in 1990. Domestic fishing for AI Pacific cod began in 1981, with a peak catch of over 43,000 t in 1992.

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 30 t since 1992). The breakdown of catch by gear during the most recent complete five-year period (2008-2012) is as follows: trawl gear accounted for an average of 71% of the catch, longline gear accounted for an average of 20%, and pot gear accounted for an average of 9%.

Historically, Pacific cod were caught throughout the AI. For the last five years prior to enactment of additional Steller sea lion (*Eumetopias jubatus*) protective regulations in 2011, the proportions of Pacific cod catch in NMFS statistical areas 541, 542, and 543 averaged 58%, 19%, and 23%, respectively. For the period 2011-2013, the average distribution has been 82%, 18%, and 0%, respectively (bearing in mind that 2013 data are not yet complete).

Catches of Pacific cod taken in the AI for the periods 1964-1980, 1981-1990, and 1991-2013 are shown in Tables 2A.1a, 2A.1b, and 2A.1c, respectively. The catches in Tables 2A.1a and 2A.1b are broken down by fleet sector (foreign, joint venture, domestic annual processing). The catches in Table 2A.1b are also broken down by gear to the extent possible. The catches in Table 2A.1c are broken down by gear. Table 2A.1d breaks down catches from 1994-2013 by NMFS 3-digit statistical area (area breakdowns not available prior to 1994), both in absolute terms and as proportions of the yearly totals.

Excerpts from then-current regulations governing the BSAI Pacific cod fisheries, including license limitation permits, prohibitions, allocations, closures, and seasons, were given in Attachment 2.3 of last year's assessment (Thompson and Lauth 2012). The major change for 2014 is that 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 equal to 3 percent of the Pacific cod ABC in the BSAI (this supplements the corresponding 3% GHL that has been set aside for the Aleutian Islands area since 2006). In the event that separate subarea (EBS and AI) ABCs replace the BSAI-wide ABC in 2014, the State will sum the two subarea ABCs, then set a GHL in each subarea equal to 3% of the total.

Effort and CPUE

Figures 2A.1 and 2A.2 show, subject to confidentiality restrictions, the approximate locations in which hauls or sets sampled during 2012 and 2013 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 2A.1 shows locations of sampled AI hauls/sets containing Pacific cod for trawl and longline gear (no data passed the confidentiality threshold for pot gear), for the January-April, May-July, and August-December seasons used in the EBS Pacific cod assessment. Figure 2A.2 shows locations of sampled AI hauls/sets for the same gear types, but aggregated across seasons. More squares are shaded in Figure 2A.2 than in Figure 2A.1 because aggregating across seasons increases the number of squares that satisfy the confidentiality constraint.

Gear-specific time series of fishery catch per unit effort (CPUE) are plotted, along with linear regression lines, in Figure 2A.3. Both CPUE time series appear to be decreasing overall. The slope of the regression for longline gear is statistically significant at the 5% level, but the slope for trawl gear is not.

Discards

The catches shown in Tables 2.1b and 2.1c include estimated discards. Discard rates of Pacific cod in the AI Pacific cod fisheries are shown for each year 1991-2012 in Table 2A.2. Implementation of Amendment 49, which mandated increased retention and utilization, resulted in an average reduction of 87% in discards of Pacific cod between 1991-1997 and 1998-2012.

Management History

The history of acceptable biological catch (ABC), overfishing level (OFL), and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate (i.e., all-gear, combined area) commercial catches in Table 2A.3. Note that this time series pertains to the combined BSAI region, so the catch time series differs from that shown in Table 2A.1, which pertains to the AI 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 91% of TAC (remembering that 2013 catch data are not yet final). In 10 of these 33 years (29%), 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 (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 (BSAI) 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. Because ABC for all years through 2013 were based on the EBS assessment model (with an expansion factor for the AI), readers are referred to Chapter 2 for a history of changes in that model.

Table 2A.4 lists all amendments to the BSAI Groundfish FMP that reference Pacific cod explicitly.

DATA

This section describes data used in the models presented in this stock assessment, of which two are of the Tier 3 variety and two are of the Tier 5 variety. This section does not attempt to summarize all available data pertaining to Pacific cod in the AI.

The following table summarizes the sources, types, and years of data included in the data file for the two Tier 3 stock assessment models:

Source	Type	Years
Fishery	Catch biomass	1977-2012
Fishery	Size composition	1978-1979, 1982-1985, 1990-
AI bottom trawl survey	Numerical abundance	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012
AI bottom trawl survey	Size composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012
AI bottom trawl survey	Age composition	2012

The following table summarizes the sources, types, and years of data included in the data file for the two Tier 5 stock assessment models:

Source	Type	Years
AI bottom trawl survey	Biomass	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012

Fishery

Catch Biomass

The catch data used in the model consist of the totals for 1977-2013 shown in Tables 2A.1. These are “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 available at: http://www.afsc.noaa.gov/REFM/Docs/2013/AI_Pcod_other_removals.xlsx.

Catch Size Composition

Fishery size compositions with at least 400 observations are presently available for nearly every year from 1977 through the first part of 2013 (the exceptions are the periods 1980-1981 and 1986-1989). As used in the assessment model, size composition data are based on 1-cm bins ranging from 4 to 120 cm, as shown in Table 2A.5.

These data suggest that larger fish have become relatively more common during the years covered by the time series. Figure 2A.4 shows the time trends in mean length at age and the 50th, 60th, 70th, 80th, and 90th percentiles. Simple linear regressions through the various time series plotted in Figure 2A.4 estimate positive slope coefficients for all six measures, with all estimates significant at the 5% level. If the time series are started in 1991 instead of 1978, all slope estimates are still positive, and the estimates for all measures but two (the 50th and 60th percentiles) are still significant at the 5% level.

Survey

Biomass and Numerical Abundance

The time series of trawl survey biomass and numerical abundance are shown for Areas 541-543, together with their respective coefficients of variation, in Table 2A.6. These estimates pertain to the Aleutian *management* area, and so are smaller than the estimates pertaining to the Aleutian *survey* area that have been reported in past BSAI Pacific cod stock assessments.

Both the biomass and numerical abundance data indicate very consistent declines throughout the time series. Simple linear regressions on both time series estimate negative slope coefficients that are significant at the 1% level.

As in recent assessments of Pacific cod in the EBS, the Tier 3 models developed here use survey estimates of population size measured in units of individual fish rather than biomass. The Tier 5 models, on the other hand, use survey biomass.

Survey Size Composition

Table 2A.7 shows the total number of fish measured at each 1 cm interval from 4-120+ cm, by year, in the survey.

These data suggest that larger fish have become relatively more common during the years covered by the time series, although the evidence is not as strong as in the fishery size composition data. Figure 2A.5 shows the time trends in mean length at age and the 50th, 60th, 70th, 80th, and 90th percentiles. Simple linear regressions through the various time series plotted in Figure 2A.5 estimate positive slope coefficients for all but one of the six measures (the estimate for the 90th percentile is negative). However, none of the estimates is statistically significant at the 5% level.

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

Year:	1991	1994	1997	2000	2002	2004	2006	2010	2012
N:	7125	7497	4635	5178	3914	3721	2784	3521	3278

Survey Age Composition

A small sample of age data (n=603) for AI Pacific cod became available following completion of this year's preliminary assessment. These data are all from the 2012 AI bottom trawl survey, and indicate the following proportions ("Prop.") at age:

Age:	0	1	2	3	4	5	6	7	8	9	10	11	12+
Prop.:	0.0000	0.0721	0.0893	0.0901	0.2515	0.2834	0.1544	0.0412	0.0120	0.0021	0.0026	0.0013	0.0000

ANALYTIC APPROACH

Model Structure

Tier 3 Models

Two Tier 3 models are presented in this assessment, both of which are estimated using Stock Synthesis (SS, Methot and Wetzel 2013). When exploration of age-structured models for the AI Pacific cod stock began prior to last year's preliminary assessment (Thompson and Lauth 2012, Annex 2.2.1), the models were based, at least conceptually, on the accepted 2011 EBS Pacific cod model (Thompson and Lauth 2011). However, as the exploratory AI models have evolved over the last year and a half (Thompson and Lauth 2012, Attachment 2.2; also Appendix 2A in this assessment), they have come to differ from the EBS model in several respects, due to differences in data characteristics and other features of the two stocks. For the two Tier 3 models presented in this assessment, some of the differences relative to the EBS model are as follow:

1. In the data file, length bins (1 cm each) are extended out to 150 cm instead of 120 cm, because of the higher proportion of large fish observed in the AI.
2. Each year consists of a single season instead of five.
3. A single fishery is defined instead of nine season-and-gear-specific fisheries.
4. The survey samples age 1 fish at true age 1.5 instead of 1.41667.
5. Initial abundances are estimated for the first ten age groups instead of the first three.
6. Selectivity for both the fishery and survey is modeled using a random walk with respect to age instead of the usual double normal (SS selectivity-at-age pattern #17; see Appendix 2A for details).

Another difference from the EBS model is that the following quantities are tuned iteratively in the two Tier 3 models presented here (see Appendix 2A for details):

1. Potentially, length and age composition input sample sizes are tuned so that the harmonic mean effective sample size is at least as large as the arithmetic mean input sample size.
2. Parameters of a normal prior distribution for each selectivity pattern are tuned so that the prior mean is consistent with logistic selectivity and the prior standard deviation is consistent with apparent departures from logistic selectivity.
3. Potentially, each selectivity parameter can be time-varying with annual additive *dev*s, where the sigma term is tuned to match the standard deviation of the estimated *dev*s.

The two Tier 3 models presented here are distinguished from one another by their respective treatments of *Q* and survey selectivity:

- In Model 1, *Q* is fixed at unity, and the functional form of survey selectivity is unconstrained (although prior distributions are placed on the logarithms of between-age changes).
- In Model 2, ln(*Q*) is estimated internally with a normal prior distribution, and survey selectivity is constrained to be asymptotic. The prior distribution for ln(*Q*) was derived by averaging the parameters (or transformed parameters) of the prior distributions used in the other age-structured assessments of AI stocks, giving $\mu = 0.00$ and $\sigma = 0.11$ (see Appendix 2A.1).

Except for the ln(*Q*) parameter in Model 2 and the selectivity and *dev* parameters in all models, all parameters were estimated with uniform prior distributions.

Version 3.24q (compiled on 05/20/13) of SS was used to run the model 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.

Tier 5 Models

Two Tier 5 models are also presented in this assessment. The first is the Kalman filter model that has been used since 2004 to estimate the expansion factor for converting results from the EBS Pacific cod model into BSAI equivalents (Thompson and Dorn 2004). The second is the random effects model recommended by the Survey Averaging Working Group (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/SAWG_2013_draft.pdf).

Both of these are very simple, state-space models of the "random walk" variety. Both models have a parameter related to the variance of the process errors. In the Kalman filter, this parameter takes the form of the process error standard deviation, and in the random effects model, it is the log of the process error coefficient of variation (CV). When used to implement the Tier 5 harvest control rules, both models also require an estimate of the natural mortality rate. The only other parameter in the Kalman filter is the biomass of the initial (1991) state. The random effects model has no other parameters.

The two Tier 5 models both assume that the observation error variances are equal to the sampling variances estimated from the haul-by-haul survey data. In terms of observation errors, the main difference between the two models is that the Kalman filter assumes that these errors are normal, while the random effects model assumes that they are lognormal.

Parameters Estimated Outside the Assessment Model

Natural Mortality (Tier 3 and Tier 5)

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

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

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

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

All of the models in this assessment (both Tier 3 and Tier 5) fix M at the value of 0.34 used for BSAI Pacific cod since 2007.

Variability in Estimated Age (Tier 3 Only)

Variability in estimated age in SS is based on the standard deviation of estimated age between "reader" and "tester" age determinations. The same weighted least squares regression that has been used in the past several assessments of EBS Pacific cod was used here to estimate a proportional relationship between standard deviation and age. The regression for the small reader-tester sample (n=366) of AI Pacific cod age data yielded an estimated slope of 0.08550 (i.e, the standard deviation of estimated age was modeled as 0.09292 × age) and a weighted R^2 of 0.81. This regression corresponds to a standard deviation at age 1 of 0.093 and a standard deviation at age 20 of 1.858. These parameter estimates, which are very close to those estimated for the EBS stock, were used for the models in the present assessment.

Weight at Length (Tier 3 Only)

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

Maturity (Tier 3 Only)

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 from the EBS Pacific cod assessment were retained for the model in the present assessment.

Catchability (Tier 3 Only)

As noted above, Q was fixed at unity in Model 1, but was estimated internally in Model 2.

Parameters Estimated Inside the Assessment Model (Tier 3 Only)

Parameters estimated inside SS for the models used in this assessment 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. standard deviation of log recruitment
6. offset for log-scale mean recruitment prior to the 1976-1977 regime shift
7. *dev*s for log-scale initial (i.e., 1977) abundance at ages 1 through 10
8. annual log-scale recruitment *dev*s for 1977-2011
9. initial (equilibrium) fishing mortality
10. log survey catchability (Model 2 only)
11. base values of fishery selectivity parameters for ages 1 through 10
12. base values of survey selectivity parameters for ages 1 through 10
13. annual *dev*s for the age 2 and age 3 parameters of the survey selectivity function
14. annual *dev*s for the age 5 parameter of the fishery selectivity function (Model 2 only)

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

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

In addition to the above, the full set of year-, season-, and gear-specific fishing mortality rates 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 (Tier 3)

The Tier 3 models in this assessment includes likelihood components for initial (equilibrium) catch, trawl survey relative abundance, fishery and survey size composition, survey age composition, recruitment, "softbounds" (equivalent to an extremely weak prior distribution used to keep parameters from hitting bounds), and parameter deviations.

In SS, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. 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 fleet (fishery or survey) and year. In the parameter estimation process, SS weights a given size composition observation according to the emphasis associated with the respective likelihood component and the sample size specified for the multinomial distribution from which the data are assumed to be drawn. The steps used to scale the sample sizes here were similar to those used in the EBS Pacific cod assessment (Thompson and Lauth 2012): 1) Records with fewer than 400 observations were omitted. 2) The sample sizes for fishery length compositions from years prior to 1999 were tentatively set at 16% of the actual sample size, and the sample sizes for fishery length compositions after 1998 and all survey length compositions were tentatively set at 34% of the actual sample size. 3) All sample sizes were adjusted proportionally to achieve an overall average sample size of 300.

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

Year:	1978	1979	1982	1983	1984	1985	1990	1991	1992	1993	1994	1995
N:	15	16	39	45	49	32	37	200	907	413	262	273

Year:	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
N:	376	210	656	639	984	1084	440	445	450	390	384	517

Year:	2008	2009	2010	2011	2012	2013
N:	493	412	644	167	221	118

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

Year:	1991	1994	1997	2000	2002	2004	2006	2010	2012
N:	134	141	87	97	73	70	52	66	62

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 year and gear. To date, only one set of age composition data is available, namely the 2012 survey. As in the EBS Pacific cod assessment, the average input sample size for the age composition data was fixed at 300. Because there is only one record of age composition data for AI Pacific cod, the input sample size for that record was therefore set at 300.

Use of Survey Relative Abundance Data in Parameter Estimation

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.

Likelihood Components (Tier 5)

The Tier 5 models in this assessment feature use the survey biomass time series as the only data, but, because they are state-space models, they incorporate both process error and observation error in the likelihood. The Kalman filter assumes that both errors are normal, while the random effects model assumes that they are both lognormal. Both models "integrate out" the states (i.e, the individual points in the biomass time series), so that the likelihood is a function of the parameters only.

RESULTS

Model Evaluation

The models used in this assessment are described under "Model Structure" above.

Goodness of Fit (Tier 3)

Objective function values are shown for the two Tier 3 models below (lower values are better, all else being equal; objective function components with a value less than 0.001 for all models are omitted for brevity; color scale extends from red (minimum) to green (maximum)):

Objective function component	Model 1	Model 2
Survey abundance	2.097	-6.889
Fishery size composition	248.795	228.454
Survey size composition	105.736	88.244
Age composition	7.261	7.249
Recruitment	20.555	21.162
Priors	8.530	7.420
Parameter *devs*	7.993	26.492
Total	400.968	372.132

Model 1 has a better (lower) value for the recruitment and parameter devs components, but Model 2 has a better value for all other components and for the overall objective function. Also, it should be noted that Model 2 has 36 more devs (for the age 5 fishery selectivity parameter) than Model 1, so the values for the parameter *dev*s component are not strictly comparable.

The table below shows the number of size composition records (Nrec) that are available for the fishery and survey, and it also shows how the output "effective" sample sizes (Neff, McAllister and Ianelli 1997) of the Tier 3 models compare to the input sample sizes (Ninp) for these data. Two sets of ratios are provided, with the arithmetic mean input sample size used as the denominator for both sets. The *arithmetic* mean effective sample size is used as the numerator for the first set, and the *harmonic* mean effective sample size is used for the second (values greater than unity are preferred in both measures, all else being equal).

			Mean(Neff)/mean(Ninp)		Harm(Neff)/mean(Ninp)	
Fleet	Nrec	Mean(Ninp)	Model 1	Model 2	Model 1	Model 2
Fishery	30	364	5.45	6.10	2.15	2.18
Survey	9	87	5.44	6.63	3.86	4.60

Both Tier 3 models give ratios much greater than unity for all cases, with Model 2's ratios consistently greater than those of Model 1.

Figures 2A.6 and 2A.7 show the Tier 3 models' fits to the fishery size composition and survey size composition data, respectively.

The table below shows the Tier 3 models' ratios of effective sample size to input sample size for the single record of age composition data:

			Neff/Ninp	
Fleet	Nrec	Ninp	Model 1	Model 2
Survey	1	300	1.41	1.12

Both Tier 3 models give a ratio greater than 1.0, with Model 1's ratio being greater than that of Model 2.

Figure 2A.8 shows the Tier 3 models' fits to the one available year of survey age composition data.

The table below shows four statistics related to the Tier 3 models' goodness of fit with respect to the survey abundance data (color scale extends from red (minimum) to green (maximum)). Relative values of the four statistics can be interpreted as follows: correlation—higher values indicate a better fit, root mean squared error—lower values indicate a better fit, average of standardized residuals—values closer to zero indicate a better fit, standard deviation of standardized residuals (and root mean squared standardized residual)—values closer to unity indicate a fit more consistent with the sampling variability in the data.

Statistic	Model 1	Model 2
Correlation (observed:expected)	0.90	0.81
Root mean squared error	0.31	0.27
Average of standardized residuals	-1.09	-0.18
Standard deviation of standardized residuals	1.76	1.46
Root mean squared standardized residual	1.98	1.39

Model 1 fits these data better than Model 2 in terms of correlation, but Model 2 fits them better by any of the other measures.

Figure 2A.9a shows the fits of the Tier 3 models to the trawl survey abundance data. Model 1's estimates are higher (although sometimes just slightly) than the observed values in all years prior to 2010. Model 2 has a better residual pattern than Model 1, although, as the above text table indicates, it is not ideal, either. The point estimates from Model 1 falls within the 95% confidence intervals of the observations in 6 of the 9 years, compared to 8 of 9 for Model 2 (both models miss the 95% confidence interval in 2002).

Goodness of Fit (Tier 5)

Statistics related to the Tier 5 models' goodness of fit with respect to the survey biomass data are shown below (KF = Kalman filter, RE = random effects):

Statistic	KF	RE
Correlation (observed:expected)	0.98	0.98
Root mean squared error	0.13	0.10
Average of standardized residuals	0.27	0.06
Standard deviation of standardized residuals	0.73	0.62
Root mean squared standardized residual	0.74	0.59

The performances of the two Tier 5 models are fairly similar by almost any of the above measures, although the random effects model gave an average standard residual much closer to zero.

Figure 2A.9b shows the fits of the Tier 5 models to the trawl survey biomass data. Note that the Tier 3 models use numbers of fish as the survey index, while the Tier 5 models use biomass.

Iterative Tuning (Tier 3)

For both of the Tier 3 models, the fishery size composition, survey size composition, and survey age composition components had harmonic mean effective sample sizes greater than the average input sample sizes when the multiplier for each was set to unity, so no tuning of sample sizes was necessary.

The tuned parameters of the normal prior distributions for the selectivity parameters are shown in Table 2A.8. In Model 1, the parameters for fishery ages 7-10 were "tuned out," because the estimated fishery selectivity schedule was strongly asymptotic, and the tuned values were essentially zero after age 6. In Model 2, survey selectivity was forced to be asymptotic by design. This was achieved by turning off the parameters for ages 8-10.

In terms of time-varying selectivity, all but five *dev* vectors were tuned out (i.e., selectivity parameters ended up being time-invariant): In Model 2, the selectivity parameter for age 5 in the fishery retained a *dev* vector with a tuned sigma of 0.009, and, in both Tier 3 models, the selectivity parameters for ages 2 and 3 in the survey retained *dev* vectors with sigmas as shown below:

Age	Model 1	Model 2
2	0.124	0.113
3	0.051	0.048

Parameter Estimates (Tier 3)

Table 2A.9 displays all of the parameters (except fishing mortality rates) estimated internally in either of the Tier 3 models, along with the standard deviations of those estimates. Table 2A.9a shows growth, ageing bias, recruitment (except annual *dev*s), log catchability, initial fishing mortality, initial age composition, and selectivity parameters (except annual *dev*s); Table 2A.9b shows annual log-scale recruitment *dev*s (these are plotted in Figure 2A.10), Table 2A.9c shows survey selectivity *dev*s, and Table 2A.9d shows fishery selectivity *dev*s (Model 2 only). The estimate of log catchability for Model 2 corresponds to Q=0.78, which, coincidentally, is very close to the value of 0.77 that is hard-wired into the assessment model for the EBS stock based on Nichol et al. (2007). Catchability is fixed externally at a value of 1.0 in Model 1.

Table 2A.10 shows estimates of full-selection seasonal fishing mortality rates as estimated by the Tier 3 models (note that these are not counted as parameters in SS, and so do not have estimated standard deviations).

Parameter Estimates (Tier 5)

The two internally estimated parameters in the Kalman filter are the process error standard deviation and the initial state. The random effects model has a single internally estimated parameter, the log of the process error coefficient of variation CV. The point estimates and standard deviations of these parameters are shown below:

Model	Parameter	Estimate	St. Dev.
Kalman filter	Initial (1991) biomass (t)	1.570E+05	2.630E+04
Kalman filter	Process error standard deviation (t)	1.626E+04	6.839E+03
Random effects	Log process error CV	-1.681E+00	3.852E-01

To make the process error terms in the above table more comparable, process error CVs can be computed for the two models by dividing the process error standard deviation from the Kalman filter by the mean biomass for the time series as estimated by the Kalman filter, and by exponentiating the log process CV from the random effects model. This gives process error CVs of 0.174 and 0.186 for the Kalman filter and random effects model, respectively.

Other Derived Quantities

Figure 2A.11 shows the time series of spawning biomass relative to $B_{100\%}$ as estimated by the Tier 3 models.

Figure 2A.12 shows trawl survey selectivity as estimated by the Tier 3 models. Selectivity for Model 1 is sharply peaked at age 4; no other age has a selectivity greater than 0.53, and all ages greater than 9 have selectivity = 0.19, meaning that, according to Model 1, the survey misses 81% of all fish greater than 9 years of age. Model 2, which is forced to exhibit asymptotic selectivity for the survey, reaches 0.67 selection by age 3 and 100% selection by age 7. Because Q is estimated at a value of 0.78 in Model 2, this means that, according to Model 2, the survey misses 22% of all fish greater than 6 years of age.

Figure 2A.13 shows fishery selectivity as estimated by the Tier 3 models. Both models estimate asymptotic selectivity for the fishery, with a small amount of time variability in Model 2.

Table 2A.11 contains selected management reference points. For all models (Tiers 3 and 5), the values in the first upper portion of this table (everything above the probabilities shown in the last seven rows) come from the standard projection model, based on parameter estimates from the respective SS model. The last seven rows (Tier 3 only) come directly from SS rather than the standard projection model. The entries in these rows show 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.

Selection of Final Model

The development of criteria for selecting the final model was influenced to some extent by the unusual circumstances surrounding the assessment, in particular the fact that no model, either Tier 3 or Tier 5, has previously been accepted for use in setting harvest specifications or other biological reference points. The Tier 5 Kalman filter does have some claim to prior acceptance, but it has been used only to estimate the BSAI/EBS expansion factor for converting results of the EBS Pacific cod model to BSAI equivalents.

The following criteria were considered in selecting the final model:

1. Has the model been sufficiently reviewed?
2. Does the model fit the data sufficiently well?
3. Are the quantities estimated by the model reasonable?
4. Is there an immediate need to move to an age-structured model?

The models (Tier 3 and Tier 5) were evaluated against the above criteria as follows:

Criterion #1: Many features of the two Tier 3 models have been reviewed numerous times, both in the context of exploratory assessments of the AI Pacific cod stock and also as features of previous EBS Pacific cod assessments. However, some other significant features have had comparatively little review. Two features that stand out in this regard are the use of SS selectivity-at-age pattern #17 (random walk with respect to age) and the particular method used here to specify parameters of the prior distribution for each age-specific selectivity parameter. Although these two features were both included in this year's preliminary assessment (Appendix 2A), it might be advisable to explore them further before incorporating them into a final model used for setting harvest specifications.

Regarding the two Tier 5 models, both have been reviewed over at least two assessment cycles; the Kalman filter having been used, although not for the purpose of setting separate AI specifications, since the 2004 assessment (Thompson and Dorn 2004); and the random effects model having been evaluated in the annual report of the Survey Averaging Working Group for the last two years. This year's Working Group report concluded, "We recommend that the RE model be applied to obtain the 'reliable biomass' estimate required for Tier 5 stocks…."

Criterion #2: Both of the Tier 3 models fit most, or even all, of the data components well. Both models achieved harmonic mean effective sample sizes greater than 300 for the fishery size composition, survey size composition, and survey age composition data. Model 2 also exhibited a reasonably good fit to the survey abundance data, whereas Model 1 did not fare so well in this regard (poor residual pattern, somewhat large absolute value for the average standardized residual). However, both of the Tier 3 models had trouble reconciling the downward time trend in the survey abundance data with the trend toward larger mean lengths (and relatively more large fish in general) in the fishery size composition (Figures 2A.4), as the log likelihoods for the fishery size compositions tend to decrease over time for both of these models (i.e., as larger fish became more dominant, the fit became worse). It is possible that the fishery has changed its behavior so as to target large fish more effectively; however, both of the models "tuned out" time variability in fishery selectivity (except for a very small amount of time variability at age 5 in Model 2), indicating that, if the fishery did indeed change its behavior in this way, the Tier 3 models were unable to detect it.

Regarding the two Tier 5 models, both did a good job of fitting the survey biomass time series. The point estimates from both models were within the 95% confidence intervals of the data in all years, and both models gave correlations (with respect to the data) of 0.98. Of the two Tier 5 models, the random effects model did a bit better, especially in terms of the average standardized residual (0.06 for the RE model versus 0.27 for KF).

Criterion #3: The two Tier 3 models both estimate that total (age 0+) biomass increased very dramatically during the 1980s (see "Time Series Results" below). For the period 1980-1991, Model 1 estimates that the stock grew fairly consistently at an average (discrete) rate of 25% per year, and Model 2 estimates an average rate of 20% per year for the same period. While it is mathematically possible for the stock to sustain rates of this magnitude for over a decade, it would be advisable to investigate this matter further before accepting such results. On a related subject, both Tier 3 models estimate extremely high exploitation rates during the early 1980s. Model 1 estimates that fishing mortality was more than $2\times F_{35\%}$ in 1982, and Model 2 estimates that fishing mortality was more than $3\times F_{35\%}$ throughout the period 1982-

1984. Again, this is mathematically possible, but it would be advisable to investigate further, to see if there are additional data indicative of such a massive level of fishing effort during these years. Finally, the extremely "pointy" survey selectivity curve estimated by Model 1 is very different from the survey selectivity curves estimated for most, if not all, other AI groundfish stocks. As with the other features mentioned in this paragraph, such a selectivity curve is not out of the question, but probably merits further investigation before being accepted for use in management.

The two Tier 5 models had a much simpler task than the Tier 3 models, needing only to fit the survey biomass time series and to estimate the variability in process error. These estimates all seem reasonable.

Criterion #4: The two Tier 3 models project that spawning biomass in 2014-2015 will range from 27-29% (Model 1) or 32-36% (Model 2) of $B_{100\%}$. The projections from Model 1 are well below the B_{MSY} proxy of $B_{35\%}$, while the projections from Model 2 are in the neighborhood of the B_{MSY} proxy. Although the Model 1 projections are lower than would be expected if the stock had been consistently exploited according to the Tier 3 control rules, they do not indicate that the stock is overfished (see "Projections and Status Determination" below). Given that the two Tier 3 models project biomasses either near B_{MSY} or lower than expected but not overfished, there does not seem to be an immediate need to adopt an age-structured model at this point, particularly if major features of the model are still being debated. It may also be noted that the maximum permissible ABCs from all four models (Tiers 3 and 5) are fairly similar, ranging from 13,500-17,400 t in 2014 and 12,000-15,200 t in 2015; suggesting that immediate adoption of either of the Tier 3 models will likely have little impact on actual harvests during the next year or two.

On the basis of the above, the random effects model (Tier 5) is recommended for use in setting final harvest specifications for 2014 and preliminary harvest specifications for 2015.

Final Parameter Estimates and Associated Schedules

For typical stock assessments, this subsection of the chapter would summarize the parameter estimates and associated schedules associated with the final model. However, due to the unusual circumstances associated with AI Pacific cod this year, an attempt will be made to present information for all of the models, thereby giving the Plan Team and SSC maximum flexibility in developing their own recommended harvest specifications.

As noted previously, estimates of all statistically estimated parameters in the Tier 3 models are shown in Table 2A.9. Estimates of fishing mortality rates from the Tier 3 models are shown in Table 2A.10. Estimates of statistically estimated parameters in the Tier 5 models are shown in the main text, under "Parameter Estimates (Tier 5)."

Schedules of selectivity at length for the fishery from the Tier 3 models are shown in Table 2A.12, and schedules of selectivity at age for the trawl surveys from the Tier 3 models are shown in Table 2A.13. The fishery selectivity schedule and the survey selectivity schedule for the Tier 3 models are plotted in Figures 2A.12 and 2A.13, respectively.

Schedules of length at age and weight at age for the population, fishery, and survey are shown in Table 2A.14.

Time Series Results

As in the previous subsection, results for all four models (Tiers 3 and 5) will be presented here to the extent possible.

Definitions

The biomass estimates presented here will be defined in three ways for the Tier 3 models: 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. For the Tier 5 models, biomass will be defined as survey biomass.

For the remaining quantities (recruitment and fishing mortality), Tier 5 estimates do not exist, so only Tier 3 estimates will be given. 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 2A.10, 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 2A.15a shows the time series of age 0+, age 3+, and female spawning biomass for the years 1977-2013 as estimated by the Tier 3 models (projections through 2014 are also shown for this year's assessment). The estimated spawning biomass time series are accompanied by their respective standard deviations. Table 2A.15b shows the time series of survey biomass with 95% confidence intervals as estimated by the Tier 5 models (because these are random walk models, projected biomass for 2014 is the same as estimated biomass for 2013).

The time series of total (age 0+) biomass as estimated by the Tier 3 models are shown, together with the observed time series of trawl survey biomass, in Figure 2A.14a. The time series of female spawning biomass as estimated by the Tier 3 models are shown, together with the observed time series of trawl survey biomass, in Figure 2A.14b. The time series of survey biomass as estimated by the Tier 5 models were shown previously (Figure 2A.9b).

Recruitment and Numbers at Age

Table 2A.16 shows the time series of age 0 recruitment (1000s of fish) for the years 1977-2011 as estimated by the Tier 3 models. Both estimated time series are accompanied by their respective standard deviations.

For the time series as a whole, Model 1 estimates that 1987 was the largest cohort (which Model 2 ranked 3rd), while Model 2 estimates that 1996 was the largest cohort (which Model 1 ranked 7th). Of the last ten cohorts, Model 1 estimates that none were more than 10% above average, and Model 2 estimates that only the 2007 cohort (53% above average) was more than 10% above average.

Tier 3 model estimates of recruitment for the entire time series (1977-2011) are shown in Figure 2A.15, along with their respective 95% confidence intervals.

Both Tier 3 models estimated a high degree of autocorrelation in recruitment (0.72 and 0.62 for Models 1 and 2, respectively).

Estimation of a reliable stock-recruitment relationship was not attempted in this assessment.

The time series of numbers at age as estimated by the Tier 3 models is shown in Table 2A.17.

Fishing Mortality

Table 2A.18 shows "effective" fishing mortality by age and year for ages 1-19 and years 1977-2013 as estimated by the Tier 3 models.

For each of the Tier 3 models, Figure 2A.16 plots the estimated trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2013, overlaid with the current harvest control rules (fishing mortality rates in the figure are standardized relative to $F_{35\%}$ and biomasses are standardized relative to $B_{35\%}$, per SSC request). For both models, the first portion of the trajectory lies well above both control rules, as does the point for 2010, although the point for 2013 lies below both control rules. It should be noted that this trajectory is based on SS output, which may not match the estimates obtained by the standard projection program exactly.

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater.

Tier 3 of the Amendment 56 control rules 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 only parameter used in the Tier 5 reference points is M.

If the SSC determines that the estimates of 2014-15 spawning biomass and the Tier 3 reference points from either of the Tier 3 models are all reliable, then AI Pacific cod will be managed under Tier 3. If the SSC determines that neither of the Tier 3 models produces reliable estimates of all of these quantities, then AI Pacific cod will be managed under Tier 5.

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

$F_{OFL} = 0$

$F_{ABC} = 0$

The following formulae apply under Tier 5:

$F_{OFL} = M$

$F_{ABC} \leq 0.75 \times M$

Estimates of projected biomass and all Tier 3 and Tier 5 reference points are shown for the respective models in Table 2A.11. For the authors' recommended model (Tier 5, random effects), the estimates are as follow:

Quantity	2014	2015
Biomass (t)	59,000	59,000
F_{OFL}	0.34	0.34
$maxF_{ABC}$	0.26	0.26

Specification of OFL and Maximum Permissible ABC

As shown in Table 2A.11, both of the Tier 3 models project that female spawning biomass will be below $B_{40\%}$ in both 2014 and 2015. Thus, if either of those models is accepted for use in setting harvest specifications, harvest specifications for AI Pacific cod will be based on sub-tier "b" of Tier 3 for both 2014 and 2015. Tier 5 has no sub-tiers.

Estimates of OFL, maximum permissible ABC, and the associated fishing mortality rates for 2014 and 2015 are shown for the respective models in Table 2A.11. For the authors' recommended model (Tier 5, random effects), the estimates are as follow:

Quantity	2014	2015
OFL (t)	20,100	20,100
maxABC (t)	15,100	15,100
F_{OFL}	0.34	0.34
$maxF_{ABC}$	0.26	0.26

The age 0+ biomass projections for 2014 and 2015 from the Tier 3 models (using SS rather than the standard projection model) are 108,000 t and 116,000 t, respectively (Model 1); and 103,000 t and 104,000 t, respectively (Model 2).

ABC Recommendation

The authors' recommended ABCs for 2014 and 2015 are the maximum permissible values from the Tier 5 random effects model: 15,100 t in both years.

Area Allocation of Harvests

No recommendations for area allocation of harvests (beyond what is already specified in the Steller sea lion protection measures) are made at this time.

Standard Harvest and Recruitment Scenarios and Projection Methodology (Tier 3 Only)

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 2014 numbers at age. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios are sometimes used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TACs for 2014 and 2015, 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 2014 recommended in the assessment to the *max* F_{ABC} for 2014. (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 2008-2012 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 2013 or 2) above 1/2 of its MSY level in 2013 and expected to be above its MSY level in 2023 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2014 and 2015, 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 2015 or 2) above 1/2 of its MSY level in 2015 and expected to be above its MSY level in 2025 under this scenario, then the stock is not approaching an overfished condition.)

Projections and Status Determination (Tier 3 Only)

Projections corresponding to the standard scenarios are shown for the Tier 3 models in Tables 2A.19-2A.24 (note that Scenarios 1 and 2 are identical in these cases, assuming that the recommended ABC would be equal to the maximum permissible ABC). Each of these tables consists of two pages, with the first corresponding to Model 1 and the second corresponding to Model 2.

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 2014, it does not provide the best estimate of OFL for 2015, because the mean 2015 catch under Scenario 6 is predicated on the 2014 catch being equal to the 2014 OFL, whereas the actual 2014 catch will likely be less than the 2014 OFL. Table 2A.11 contains the appropriate one- and two-year ahead projections for both ABC and OFL under the model considered in the present assessment.

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

Is the stock being subjected to overfishing? The official BSAI catch estimate for the most recent complete year (2012) is 251,055 t. This is less than the 2012 BSAI OFL of 369,000 t. Therefore, the stock is not being subjected to overfishing (recall that AI Pacific cod did not have separate harvest specifications in 2012).

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 2013:

a. If spawning biomass for 2013 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2013 is estimated to be above $B_{35\%}$, the stock is above its MSST.

c. If spawning biomass for 2013 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 2A.32). If the mean spawning biomass for 2023 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 2A.33):

a. If the mean spawning biomass for 2015 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2015 is above $B_{35\%}$, the stock is not approaching an overfished condition.

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

Based on the above criteria and Tables 2A.23 and 2A.24, if either of the Tier 3 models is accepted for use in status determination, 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 each of the Tier 3 models in present assessment, an attempt was made to estimate the change in mean recruitment of AI Pacific cod associated with the 1977 regime shift. According to Models 1 and 2, pre-1977 mean recruitment was only about 17% and 15% of post-1976 mean recruitment, respectively.

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

Note: The tables referenced in this subsection have not been updated since last year's BSAI assessment.

Incidental catches taken in the Pacific cod fisheries for the period 2003-2012 are summarized in Tables 2A.25-2A.29. Table 2A.25 shows incidental catch of FMP species, other than squid and members of the former "other species" complex, taken in the AI. Table 2A.26 shows incidental catch of squid and members of the former "other species" complex taken in the AI. Table 2A.27 shows incidental catch of non-target species groups taken in the AI. Table 2A.28 shows incidental catches of prohibited species taken in the AI. Table 2A.29 shows halibut mortality (as distinguished from catch).

Steller Sea Lions

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

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

Seabirds

The following is a summary of information provided by Livingston (ed., 2002): In both the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, which occurs primarily in the longline fisheries, including the hook and line fishery for Pacific cod (Tables 2.33b and 2.36b). Shearwater (*Puffinus* spp.) distribution overlaps with the Pacific cod longline fishery in the Bering Sea, and with trawl fisheries in general in both the Bering Sea and GOA. Black-footed albatross (*Phoebastria nigripes*) is taken in much greater numbers in the GOA longline fisheries than the Bering Sea longline fisheries, but is not taken in the trawl fisheries. The distribution of Laysan albatross (*Phoebastria immutabilis*) appears to overlap with the longline fisheries in the central and western Aleutians. The distribution of short-tailed albatross (*Phoebastria albatrus*) also overlaps with the Pacific cod longline fishery along the Aleutian chain, although the majority of the bycatch has taken place along the northern portion of the Bering Sea shelf edge (in contrast, only two takes have been recorded in the GOA). Some success has been obtained in devising measures to mitigate fishery-seabird interactions. For example, on vessels larger than 60 ft. LOA, paired streamer lines of specified performance and material standards have been found to reduce seabird incidental take significantly.

Fishery Usage of Habitat

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

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

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

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

DATA GAPS AND RESEARCH PRIORITIES

Note: This section has not been updated since last year's BSAI assessment.

Significant improvements in the quality of this assessment could be made if future research were directed toward closing certain data gaps. Such research would have several foci, including the following: 1) ecology of the Pacific cod stock, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment; 2) behavior of the Pacific cod fishery, including spatial dynamics; 3) determinants of trawl survey catchability and selectivity; 4) age determination; 5) ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and 6) ecology of species that interact with Pacific cod, including estimation of biomass, carrying capacity, and resilience.

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Table 2A.1a—Summary of 1964-1980 catches (t) of Pacific cod in the AI 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.

	Aleutian Islands			
Year	For.	JV	Dom.	Total
1964	241	0	0	241
1965	451	0	0	451
1966	154	0	0	154
1967	293	0	0	293
1968	289	0	0	289
1969	220	0	0	220
1970	283	0	0	283
1971	2,078	0	0	2,078
1972	435	0	0	435
1973	977	0	0	977
1974	1,379	0	0	1,379
1975	2,838	0	0	2,838
1976	4,190	0	0	4,190
1977	3,262	0	0	3,262
1978	3,295	0	0	3,295
1979	5,593	0	0	5,593
1980	5,788	0	0	5,788

Table 2A.1b—Summary of 1981-1990 catches (t) of Pacific cod in the AI 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	LL+pot	Subt.	Total
1981	2,680	235	2,915	1,749	1,749	n/a	n/a	2,770	7,434
1982	1,520	476	1,996	4,280	4,280	n/a	n/a	2,121	8,397
1983	1,869	402	2,271	4,700	4,700	n/a	n/a	1,459	8,430
1984	473	804	1,277	6,390	6,390	n/a	n/a	314	7,981
1985	10	829	839	5,638	5,638	n/a	n/a	460	6,937
1986	5	0	5	6,115	6,115	n/a	n/a	786	6,906
1987	0	0	0	10,435	10,435	n/a	n/a	2,772	13,207
1988	0	0	0	3,300	3,300	1,698	167	1,865	5,165
1989	0	0	0	6	6	4,233	303	4,536	4,542
1990	0	0	0	0	0	6,932	609	7,541	7,541

Table 2A.1c—Summary of 1991-2013 catches (t) of Pacific cod in the AI. To avoid confidentiality problems, longline and pot catches have been combined. 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 12.

	Federal			State	
Year	Trawl	Long.+pot	Subtotal	Subtotal	Total
1991	3,414	6,383	9,798		9,798
1992	14,587	28,481	43,068		43,068
1993	17,328	16,876	34,205		34,205
1994	14,383	7,156	21,539		21,539
1995	10,574	5,960	16,534		16,534
1996	21,179	10,430	31,609		31,609
1997	17,411	7,753	25,164		25,164
1998	20,531	14,196	34,726		34,726
1999	16,478	11,653	28,130		28,130
2000	20,379	19,306	39,685		39,685
2001	15,836	18,372	34,207		34,207
2002	27,929	2,872	30,801		30,801
2003	31,478	980	32,459		32,459
2004	25,770	3,103	28,873		28,873
2005	19,624	3,075	22,699		22,699
2006	16,963	3,535	20,498	3,712	24,210
2007	25,714	4,495	30,209	3,836	34,045
2008	19,405	7,192	26,597	4,462	31,059
2009	20,277	6,222	26,500	2,081	28,580
2010	16,757	8,407	25,164	3,836	29,000
2011	9,359	1,238	10,597	260	10,858
2012	9,789	3,201	12,991	5,232	18,223
2013	6,912	1,709	8,620	4,793	13,414

Table 2A.1d—Summary of 1994-2013 catches (t) of Pacific cod in the AI, by NMFS 3-digit statistical area (area breakdowns not available prior to 1994). Catches for 2013 are through October 12.

	Amount			Proportion		
Year	541	542	543	541	542	543
1994	12,039	7,441	2,059	0.559	0.345	0.096
1995	9,735	5,086	1,713	0.589	0.308	0.104
1996	23,077	4,509	4,023	0.730	0.143	0.127
1997	19,830	4,440	894	0.788	0.176	0.036
1998	21,940	9,299	3,487	0.632	0.268	0.100
1999	20,532	5,276	2,322	0.730	0.188	0.083
2000	21,812	8,799	9,073	0.550	0.222	0.229
2001	14,082	7,358	12,767	0.412	0.215	0.373
2002	21,408	7,133	2,259	0.695	0.232	0.073
2003	22,748	6,713	2,997	0.701	0.207	0.092
2004	18,391	6,825	3,657	0.637	0.236	0.127
2005	14,879	3,552	4,268	0.655	0.157	0.188
2006	14,967	4,661	4,583	0.618	0.193	0.189
2007	24,377	4,660	5,008	0.716	0.137	0.147
2008	18,185	5,555	7,319	0.586	0.179	0.236
2009	13,752	6,899	7,929	0.481	0.241	0.277
2010	14,496	6,291	8,213	0.500	0.217	0.283
2011	9,066	1,768	24	0.835	0.163	0.002
2012	15,377	2,816	29	0.844	0.155	0.002
2013	10,491	2,869	53	0.782	0.214	0.004

Table 2A.2—Discards (t) of Pacific cod in the AI Pacific cod fishery, by gear and year for the period 1991-2012. To avoid confidentiality problems, longline and pot catches have been combined. 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. **This table has not been updated since the 2012 assessment.**

Year	Trawl	Long.+pot	Total
1991	293	233	526
1992	1,781	455	2,236
1993	3,693	2,196	5,889
1994	3,263	221	3,484
1995	1,872	1,308	3,180
1996	2,566	571	3,137
1997	1,438	669	2,107
1998	154	484	638
1999	287	226	514
2000	168	524	692
2001	219	252	471
2002	585	148	734
2003	247	87	334
2004	223	94	317
2005	237	258	494
2006	152	158	310
2007	410	142	553
2008	33	171	204
2009	92	116	208
2010	47	158	205
2011	51	29	80
2012	41	70	111

Table 2A.3—History of **BSAI** Pacific cod catch, TAC, ABC, and OFL (t). Catch for 2013 is through October 12. Note that specifications through 2013 were for the combined BSAI region, so BSAI catch is shown rather than the AI catches from Table 1. Source for historical specifications: NPFMC staff.

Year	Catch	TAC	ABC	OFL
1977	36,597	58,000	-	-
1978	45,838	70,500	-	-
1979	39,354	70,500	-	-
1980	51,649	70,700	148,000	-
1981	63,941	78,700	160,000	-
1982	69,501	78,700	168,000	-
1983	103,231	120,000	298,200	-
1984	133,084	210,000	291,300	-
1985	150,384	220,000	347,400	-
1986	142,511	229,000	249,300	-
1987	163,110	280,000	400,000	-
1988	208,236	200,000	385,300	-
1989	182,865	230,681	370,600	-
1990	179,608	227,000	417,000	-
1991	220,038	229,000	229,000	-
1992	207,278	182,000	182,000	188,000
1993	167,391	164,500	164,500	192,000
1994	193,802	191,000	191,000	228,000
1995	245,033	250,000	328,000	390,000
1996	240,676	270,000	305,000	420,000
1997	257,765	270,000	306,000	418,000
1998	193,256	210,000	210,000	336,000
1999	173,998	177,000	177,000	264,000
2000	191,060	193,000	193,000	240,000
2001	176,749	188,000	188,000	248,000
2002	197,356	200,000	223,000	294,000
2003	210,969	207,500	223,000	324,000
2004	212,161	215,500	223,000	350,000
2005	205,635	206,000	206,000	265,000
2006	193,016	194,000	194,000	230,000
2007	174,125	170,720	176,000	207,000
2008	170,853	170,720	176,000	207,000
2009	175,732	176,540	182,000	212,000
2010	171,854	168,780	174,000	205,000
2011	220,102	227,950	235,000	272,000
2012	251,055	261,000	314,000	369,000
2013	211,867	260,000	307,000	359,000

Table 2A.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 2A.5 (page 1 of 3)—Fishery size composition, by year and cm.

Year	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	1	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	5
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1999	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	4	5	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
2003	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2004	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
2005	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
2007	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Year	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
1978	0	0	1	0	0	0	0	0	2	0	0	2	1	1	5	3	7	4	9	18
1979	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1	1
1982	0	0	0	1	0	0	0	0	0	0	5	4	2	6	7	7	9	15	19	14
1983	2	1	2	5	8	6	16	16	23	25	45	70	64	68	66	60	58	69	86	103
1984	0	0	1	0	2	0	0	1	2	2	7	12	13	17	31	28	21	22	6	6
1985	0	0	0	0	0	0	0	0	0	0	0	3	1	1	7	12	25	21	37	61
1990	0	0	0	0	0	0	0	0	1	0	1	0	1	1	4	2	5	7	15	17
1991	0	0	0	2	0	0	1	2	8	2	4	9	13	11	15	7	9	21	28	39
1992	0	0	0	0	0	0	0	3	4	4	9	21	27	46	40	62	116	153	226	310
1993	0	0	0	0	1	4	7	11	9	12	17	20	30	29	33	39	45	67	76	113
1994	0	0	0	0	1	2	4	7	5	3	8	3	14	8	19	19	26	33	52	73
1995	14	22	34	38	59	51	49	54	66	56	51	33	22	19	11	12	11	23	20	30
1996	0	2	0	2	5	15	6	9	8	14	18	15	12	29	39	39	50	63	108	136
1997	0	0	0	0	2	2	0	7	4	5	9	12	6	9	17	22	17	25	25	32
1998	1	1	4	1	8	9	25	28	43	51	47	88	92	94	87	122	183	200	212	296
1999	0	1	1	3	0	1	3	3	7	6	8	25	21	19	30	32	38	62	75	131
2000	0	1	0	0	0	4	6	5	6	13	7	6	7	20	30	52	62	98	140	169
2001	0	0	0	1	3	10	5	11	12	15	15	23	34	64	72	93	130	163	211	230
2002	0	1	0	1	2	5	3	9	11	12	8	24	22	33	37	48	71	65	68	65
2003	0	1	0	0	1	3	5	5	12	16	22	15	21	25	21	17	33	50	53	64
2004	1	0	1	1	2	2	5	5	14	22	17	44	43	49	69	71	81	94	81	86
2005	0	0	0	0	3	2	1	1	2	5	2	6	12	4	7	11	16	20	30	30
2006	0	1	0	1	0	0	1	3	4	0	4	3	5	0	3	6	14	11	31	33
2007	3	0	1	0	5	3	5	7	12	12	12	20	15	19	17	20	27	31	31	50
2008	0	1	1	2	0	1	3	0	3	2	7	5	10	9	19	21	43	41	47	67
2009	0	0	0	3	0	0	1	4	3	4	10	14	15	20	20	39	52	53	67	86
2010	1	0	0	2	0	0	2	1	0	6	12	14	13	22	40	45	72	87	120	143
2011	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	1	2	3	15
2012	0	0	0	0	0	0	0	0	2	2	1	3	2	4	5	1	12	4	2	7
2013	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	3	4	4	5

Table 2A.5 (page 2 of 3)—Fishery size composition, by year and cm.

Year	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
1978	26	29	39	35	41	39	46	38	25	25	27	32	31	32	44	26	46	44	42	51
1979	4	2	8	10	9	26	25	28	40	47	60	62	71	81	82	84	71	79	64	67
1982	26	31	50	56	57	67	100	98	110	125	112	151	149	155	146	154	180	207	144	166
1983	130	138	149	181	170	171	191	182	182	143	133	146	127	121	123	118	115	116	127	101
1984	9	15	27	27	36	61	73	94	136	145	186	191	186	183	195	164	161	161	138	150
1985	58	74	75	68	85	85	63	60	36	37	32	35	49	52	59	73	96	85	120	122
1990	11	8	9	11	9	16	19	31	52	24	41	35	63	33	39	67	50	70	75	105
1991	24	36	56	63	62	76	62	92	103	141	140	186	214	255	252	312	285	324	359	360
1992	463	550	587	621	705	792	820	872	826	886	898	962	990	1025	1183	1297	1328	1454	1522	1752
1993	121	218	240	274	321	433	573	674	751	827	861	957	985	937	846	857	793	754	764	775
1994	101	83	139	160	161	223	233	257	291	297	333	359	389	466	512	572	632	654	720	750
1995	26	29	33	55	83	81	83	107	137	181	186	195	254	269	308	318	385	404	430	451
1996	168	197	268	249	296	334	335	362	416	423	508	453	502	583	534	558	572	685	800	926
1997	43	56	83	78	110	103	165	147	191	227	248	298	348	351	329	366	440	426	397	371
1998	359	455	483	523	639	629	793	723	718	804	822	798	867	808	882	931	1092	1143	1176	1298
1999	118	173	183	215	305	292	317	366	374	380	400	436	471	464	541	516	516	595	592	646
2000	170	246	286	291	362	375	367	462	488	559	582	658	752	825	841	855	875	946	971	968
2001	296	321	347	424	466	495	563	643	741	772	762	851	951	948	1041	1078	1195	1312	1324	1493
2002	74	89	102	110	122	152	164	179	156	147	154	174	165	139	172	164	198	218	224	255
2003	62	110	105	141	140	164	199	228	232	229	229	253	271	290	239	239	311	279	274	304
2004	84	82	112	116	145	174	186	237	264	307	320	362	381	348	398	371	367	405	399	439
2005	51	51	79	67	79	87	118	127	145	154	193	172	229	253	249	258	297	309	334	340
2006	41	49	70	108	121	137	154	163	199	186	215	211	261	298	315	314	395	395	378	388
2007	30	65	56	64	71	92	112	153	197	201	229	271	331	352	409	468	483	491	496	544
2008	88	96	128	172	209	235	299	308	341	323	316	338	300	310	331	301	308	335	316	358
2009	65	90	78	100	104	121	133	154	167	167	190	234	318	324	359	337	407	414	482	485
2010	184	226	232	307	370	399	444	490	459	519	530	496	490	499	504	531	502	493	509	531
2011	16	18	31	37	47	61	49	72	72	94	102	93	118	132	150	145	187	168	191	212
2012	5	11	10	15	19	32	28	26	51	45	56	76	100	115	126	174	168	214	256	292
2013	7	7	16	20	22	16	21	25	13	33	29	33	27	23	45	54	66	57	64	95

Year	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83
1978	59	72	58	69	73	62	71	62	48	51	47	45	50	45	25	18	28	20	12	9
1979	54	52	53	53	44	57	59	40	62	54	51	31	42	35	35	22	25	27	13	10
1982	173	151	155	122	131	126	106	116	77	86	89	67	60	64	52	47	32	41	51	41
1983	107	82	74	78	66	72	70	66	65	52	55	60	46	58	45	48	37	35	20	17
1984	178	154	201	155	175	166	144	157	143	117	116	111	73	90	84	79	78	61	59	59
1985	131	142	136	147	129	103	118	73	75	56	51	48	58	37	45	50	43	29	34	35
1990	128	167	179	174	158	157	168	140	170	113	132	162	155	122	150	153	140	106	85	92
1991	380	428	463	565	575	544	698	648	732	801	852	829	852	827	753	829	856	703	774	707
1992	1800	2141	2134	2337	2558	2797	2940	2871	3149	3267	3427	3578	3478	3549	3297	3289	3169	2878	2726	2644
1993	783	828	829	856	775	903	891	866	922	938	992	1035	972	1105	1007	1162	1105	1184	1208	1162
1994	762	853	800	865	828	881	827	808	780	804	766	730	617	655	598	545	550	520	535	498
1995	554	556	590	642	635	686	782	748	735	733	782	890	778	857	837	864	880	821	776	736
1996	914	1040	1158	1030	1056	965	1062	977	992	1071	1042	1125	1010	933	926	931	1037	954	1006	982
1997	363	352	349	317	362	371	351	355	402	383	407	489	458	445	513	582	608	572	548	531
1998	1407	1664	1689	1616	1766	1826	2306	1998	1888	1881	1781	2067	1667	1564	1513	1483	1604	1368	1262	1249
1999	621	616	628	560	717	715	702	664	735	783	829	797	773	808	906	800	836	826	820	808
2000	972	991	977	1054	1028	1040	1124	1002	1133	1112	1053	1053	1012	1050	990	1002	1053	972	1084	988
2001	1383	1452	1495	1607	1693	1659	1697	1651	1631	1558	1564	1361	1349	1263	1122	1076	973	962	898	924
2002	279	324	370	451	447	481	571	637	744	718	738	768	809	790	814	779	757	702	726	671
2003	277	272	357	337	307	366	408	415	372	398	349	420	418	432	469	500	547	580	593	688
2004	416	437	460	483	496	481	530	552	515	491	578	510	552	591	523	537	544	518	532	537
2005	340	366	319	362	408	405	464	454	460	518	534	561	559	561	563	637	685	632	623	598
2006	440	429	364	392	449	361	377	368	389	394	447	411	435	411	479	477	500	457	503	472
2007	461	498	466	532	488	493	456	453	428	440	473	458	491	472	519	502	523	532	531	539
2008	408	460	438	427	481	493	521	515	473	524	498	468	471	437	429	403	422	438	425	372
2009	491	452	486	447	486	404	475	406	414	453	434	457	413	451	413	390	379	400	359	363
2010	577	618	531	583	634	668	821	620	695	775	809	822	825	759	764	763	770	687	618	605
2011	210	210	208	228	195	214	217	155	162	147	145	172	135	179	155	161	221	182	184	201
2012	330	327	307	315	351	386	407	384	427	374	391	345	376	343	354	293	297	261	272	208
2013	72	97	110	104	120	149	126	139	159	156	138	142	151	195	172	210	200	174	204	187

Table 2A.5 (page 3 of 3)—Fishery size composition, by year and cm.

Year	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
1978	8	8	3	4	1	2	4	2	0	1	0	0	0	0	1	0	0	0	0	0
1979	15	9	7	13	5	2	0	4	4	1	2	4	0	1	0	0	0	0	0	1
1982	32	37	32	22	24	20	27	17	6	10	12	6	3	6	4	3	0	4	3	3
1983	22	21	14	17	28	14	20	19	18	11	12	20	4	4	3	6	9	4	4	2
1984	55	52	36	52	48	37	48	25	33	33	28	26	22	17	31	21	18	17	12	9
1985	35	39	34	37	35	33	44	51	27	23	24	27	28	9	9	21	10	15	6	6
1990	82	64	58	55	40	55	38	21	13	28	15	11	8	9	7	10	5	8	1	2
1991	642	619	600	515	463	393	311	263	259	212	174	171	115	133	103	72	60	28	42	29
1992	2441	2466	2071	1887	1768	1679	1534	1265	1227	1047	982	879	750	690	635	592	406	314	270	237
1993	1165	1170	1104	1048	955	913	780	728	713	609	548	567	498	423	407	364	298	279	252	213
1994	533	480	480	516	499	564	573	423	391	388	344	395	293	255	276	271	269	178	143	145
1995	741	736	683	646	580	525	629	499	552	620	709	623	496	383	334	330	403	236	263	253
1996	936	903	876	791	761	750	747	524	607	522	564	459	427	428	376	392	409	299	273	267
1997	511	563	509	484	523	492	611	491	480	528	476	465	408	429	394	335	361	287	264	239
1998	1122	1276	1163	1043	1227	1098	1286	1038	910	1028	1066	1076	969	903	924	846	964	726	640	618
1999	775	747	738	655	640	581	569	514	473	413	382	354	362	330	357	328	360	300	287	249
2000	1066	1006	1139	991	1064	1102	1210	1008	1027	906	890	760	769	636	624	566	574	520	468	458
2001	834	722	678	662	653	677	655	611	543	546	525	509	534	481	460	492	527	408	371	384
2002	648	603	574	496	495	412	377	322	328	309	280	257	237	197	182	143	224	165	153	142
2003	669	748	731	710	685	675	699	604	560	556	485	430	406	362	319	282	320	201	213	160
2004	472	439	415	408	366	351	394	347	359	361	329	327	313	321	317	233	269	245	216	178
2005	485	516	466	445	387	421	408	336	311	340	296	261	240	238	202	205	188	182	158	155
2006	478	461	525	468	492	457	442	406	366	362	325	279	249	233	210	190	197	168	170	131
2007	596	559	634	593	662	659	689	640	611	662	585	606	544	550	518	474	418	363	357	315
2008	447	431	449	433	445	485	480	470	484	516	454	518	505	497	503	445	515	470	412	459
2009	346	322	322	279	322	301	304	342	336	318	342	341	309	314	320	323	343	286	318	326
2010	580	480	457	502	427	433	429	388	383	396	354	340	398	392	353	383	436	364	446	458
2011	210	216	213	198	182	179	157	164	152	153	125	116	123	113	97	97	87	80	72	55
2012	186	188	202	156	171	128	165	145	159	118	140	128	131	107	97	102	104	84	99	81
2013	186	190	179	183	158	160	154	132	128	110	114	82	86	94	76	71	64	74	69	60

Year	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120+
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	2	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1983	2	3	0	1	0	1	0	1	0	0	0	0	0	1	0	0	1
1984	14	7	7	4	1	1	1	0	0	0	1	0	0	0	0	0	0
1985	3	1	9	0	0	0	0	3	0	0	0	0	1	0	0	0	0
1990	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	22	16	9	5	2	1	2	0	0	1	1	1	0	0	0	0	0
1992	211	147	128	115	82	59	67	49	26	16	14	5	3	0	6	1	1
1993	172	142	120	70	78	41	40	29	20	14	7	3	4	2	1	0	1
1994	107	81	59	40	34	27	44	18	11	16	5	9	5	4	3	1	1
1995	218	203	113	90	82	66	112	40	47	26	11	25	9	3	0	1	2
1996	239	247	191	166	120	98	123	50	55	18	18	6	4	5	1	0	5
1997	210	196	145	137	120	99	77	51	37	28	22	26	14	4	6	2	9
1998	586	619	419	331	299	250	244	134	99	74	50	48	24	14	4	9	24
1999	260	223	188	144	124	88	86	49	42	33	24	12	2	6	2	5	13
2000	406	384	343	338	244	177	194	126	93	46	27	29	17	8	3	3	14
2001	306	294	254	224	218	167	193	81	86	54	33	42	16	14	12	16	21
2002	140	111	102	81	64	53	46	27	29	12	5	1	4	1	1	1	0
2003	153	108	98	84	73	49	48	25	29	13	6	4	6	0	5	2	2
2004	193	128	117	98	78	72	64	30	29	16	10	4	4	1	5	3	2
2005	136	126	100	92	70	46	46	26	24	17	9	5	6	3	1	4	9
2006	130	115	94	94	79	65	57	34	26	25	15	12	1	2	4	2	6
2007	263	209	196	171	145	113	86	50	36	28	19	11	10	3	3	2	0
2008	357	328	287	231	209	169	156	89	63	35	21	18	15	10	7	5	67
2009	280	273	261	251	222	151	130	95	74	40	30	24	9	3	0	2	2
2010	387	391	343	316	306	257	218	148	117	62	51	47	20	13	4	1	8
2011	72	58	55	42	41	27	24	26	12	10	3	6	4	3	1	2	4
2012	74	73	61	37	48	37	38	25	27	12	15	12	6	6	3	4	8
2013	45	35	29	25	23	14	11	7	3	2	3	0	2	0	0	1	0

Table 2A.6— Total biomass and abundance, with coefficients of variation, as estimated by AI shelf bottom trawl surveys, 1991-2012.

Biomass:

	Western Aleutians (543)		Central Aleutians (542)		Eastern Aleutians (541)		Aleutian management area	
Year	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV
1991	75,514	0.09	39,729	0.11	64,926	0.37	180,170	0.14
1994	23,797	0.29	51,538	0.39	78,081	0.30	153,416	0.21
1997	14,357	0.26	30,252	0.21	28,239	0.23	72,848	0.13
2000	44,261	0.42	36,456	0.27	47,117	0.22	127,834	0.18
2002	23,623	0.25	24,687	0.26	25,241	0.33	73,551	0.16
2004	9,637	0.17	20,731	0.21	51,851	0.30	82,219	0.20
2006	19,734	0.23	21,823	0.19	43,348	0.54	84,905	0.29
2010	21,341	0.41	11,207	0.26	23,277	0.22	55,826	0.19
2012	13,514	0.26	14,804	0.20	30,592	0.24	58,911	0.15

Abundance (1000s of fish):

	Western Aleutians (543)		Central Aleutians (542)		Eastern Aleutians (541)		Aleutian management area	
Year	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV
1991	18,679	0.15	13,138	0.13	33,669	0.44	65,486	0.23
1994	4,491	0.24	12,425	0.20	37,284	0.44	54,201	0.31
1997	4,000	0.25	12,014	0.28	8,859	0.16	24,873	0.15
2000	13,899	0.54	10,661	0.30	18,819	0.29	43,379	0.23
2002	6,840	0.30	6,704	0.17	12,579	0.28	26,123	0.16
2004	3,220	0.17	5,755	0.17	13,040	0.24	22,016	0.15
2006	6,521	0.32	6,243	0.16	8,882	0.33	21,646	0.17
2010	5,323	0.34	5,169	0.17	9,577	0.22	20,068	0.14
2012	4,100	0.14	5,596	0.20	9,480	0.21	19,176	0.12

Table 2A.7—Trawl survey size composition, by year and cm.

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

Year	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
1991	3	2	4	9	26	81	114	147	216	249	293	321	299	242	224	150	139	85	92	54
1994	7	4	4	4	3	3	9	18	24	34	40	44	48	43	47	38	30	44	59	46
1997	102	82	42	19	2	12	7	15	27	32	36	51	61	60	60	58	45	32	31	34
2000	1	4	7	4	3	14	10	13	13	15	26	12	32	14	17	4	27	24	21	52
2002	19	9	9	21	22	28	22	37	45	99	92	103	134	142	119	93	85	63	52	62
2004	5	1	1	1	0	0	0	3	1	5	6	17	25	30	24	28	26	40	41	38
2006	23	13	3	2	1	2	0	1	6	1	5	3	8	13	11	20	12	19	14	9
2010	0	3	1	1	2	10	15	26	22	27	23	23	27	16	23	28	25	28	35	44
2012	9	5	1	0	3	2	2	11	7	32	23	18	32	55	38	18	41	29	31	20

Year	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
1991	80	52	64	72	73	68	54	76	63	58	68	60	98	94	82	115	116	110	121	139
1994	60	63	90	90	102	83	102	67	68	66	72	62	53	93	78	76	84	93	95	123
1997	34	25	35	47	52	59	82	70	73	79	96	103	106	127	150	125	172	165	121	148
2000	96	134	93	117	110	131	123	154	131	136	125	119	130	125	175	183	165	187	156	151
2002	56	59	62	77	81	87	63	62	76	68	95	69	97	72	74	61	64	41	39	40
2004	32	48	56	60	84	83	97	86	84	91	67	98	81	92	83	66	109	80	60	89
2006	21	27	38	39	44	62	63	69	75	57	61	49	49	56	29	45	37	35	51	45
2010	63	84	92	114	117	126	113	121	138	146	135	118	112	116	93	69	93	81	65	45
2012	26	30	34	31	32	42	44	64	58	49	70	56	66	62	86	90	88	86	79	104

Year	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83
1991	86	119	163	157	162	131	136	119	136	117	119	99	89	109	115	81	84	75	63	61
1994	119	124	102	125	114	128	109	118	124	111	133	77	79	86	78	50	71	47	72	62
1997	135	106	85	103	112	80	63	50	59	50	49	58	49	34	27	27	33	31	31	23
2000	154	148	168	115	112	97	84	86	77	86	70	82	88	59	46	49	42	28	27	36
2002	44	33	33	34	31	34	34	33	36	34	42	45	48	42	35	39	49	49	50	55
2004	102	90	89	100	92	83	84	83	88	61	81	68	72	65	62	48	38	55	52	40
2006	35	39	54	29	42	39	44	30	47	47	39	35	41	34	38	42	47	46	46	30
2010	54	56	56	69	78	58	47	43	35	35	31	33	33	24	23	13	9	23	19	19
2012	157	105	97	85	95	80	63	47	56	49	67	59	43	40	39	49	37	36	32	19

Year	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
1991	65	46	56	50	22	31	30	43	30	20	11	14	6	12	4	12	4	1	5	0
1994	52	72	46	59	44	54	93	60	66	48	38	42	50	27	18	27	9	10	8	8
1997	25	19	23	24	23	18	22	31	26	9	25	8	20	13	16	20	9	10	22	7
2000	19	27	18	26	22	15	12	17	13	6	12	10	8	6	10	8	5	2	4	5
2002	39	44	38	38	32	15	30	29	10	21	16	12	9	7	8	4	5	3	6	13
2004	35	40	37	37	11	18	21	15	21	17	14	15	11	8	8	15	7	2	8	8
2006	54	32	28	41	37	39	47	28	17	17	13	28	19	15	10	14	13	5	10	4
2010	12	4	16	12	10	15	9	11	9	8	10	6	7	9	5	7	10	15	5	6
2012	20	11	14	13	15	7	10	8	7	9	5	16	9	5	4	5	6	6	5	4

Year	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120+
1991	3	3	1	6	0	1	0	0	0	0	0	1	0	0	0	0	0
1994	7	5	5	2	0	2	0	0	0	2	2	0	0	0	0	0	0
1997	3	10	8	1	3	3	2	0	0	0	0	0	0	0	0	0	0
2000	3	4	6	1	11	2	1	2	0	0	0	1	0	0	0	0	0
2002	1	6	2	2	2	0	1	0	3	0	0	1	0	0	0	0	0
2004	5	6	3	2	3	1	0	1	0	0	0	0	0	0	0	0	0
2006	15	3	3	6	8	3	0	1	3	2	1	0	1	0	0	0	0
2010	3	8	3	6	6	4	3	5	1	1	0	1	0	0	0	0	0
2012	7	1	1	1	1	1	0	1	0	0	0	0	1	0	0	0	0

Table 2A.8—Iteratively tuned parameters (μ_d = mean, σ_d = standard deviation) of normal prior distributions for selectivity parameters in the Tier 3 models. In Model 1, the parameters for fishery ages 7-10 were "tuned out," because the estimated fishery selectivity schedule was strongly asymptotic, and the tuned values were essentially zero after age 6. In Model 2, survey selectivity was forced to be asymptotic by design. This was achieved by turning off the parameters for ages 8-10. Values were tuned to two significant digits; i.e., one digit beyond the decimal point in scientific notation).

		Model 1		Model 2	
Fleet	Age	μ_d	σ_d	μ_d	σ_d
Fishery	1	4.1E+00	4.2E-01	5.3E+00	1.7E+00
Fishery	2	4.1E+00	4.4E-01	5.3E+00	2.2E+00
Fishery	3	3.6E+00	8.4E-01	3.6E+00	2.5E+00
Fishery	4	8.9E-01	9.1E-01	1.9E-01	2.2E+00
Fishery	5	2.4E-02	1.7E-01	1.0E-03	1.4E+00
Fishery	6	4.1E-04	7.0E-03	5.1E-06	7.2E-01
Fishery	7	n/a	n/a	2.5E-08	2.8E-01
Fishery	8	n/a	n/a	1.3E-10	8.4E-02
Fishery	9	n/a	n/a	6.3E-13	1.7E-02
Fishery	10	n/a	n/a	3.1E-15	4.8E-03
Survey	1	1.4E+00	1.0E+00	1.3E+00	2.0E-03
Survey	2	1.2E+00	9.8E-01	1.1E+00	1.9E-03
Survey	3	7.5E-01	8.4E-01	7.0E-01	1.2E-03
Survey	4	2.9E-01	5.8E-01	2.9E-01	5.6E-04
Survey	5	7.7E-02	3.4E-01	8.6E-02	2.6E-04
Survey	6	1.8E-02	2.2E-01	2.2E-02	1.0E-04
Survey	7	4.1E-03	1.9E-01	5.6E-03	3.5E-05
Survey	8	9.1E-04	1.9E-01	n/a	n/a
Survey	9	2.0E-04	1.9E-01	n/a	n/a
Survey	10	4.5E-05	1.9E-01	n/a	n/a

Table 2A.9a—Growth, ageing bias, recruitment (except annual *dev*s), catchability, initial fishing mortality, initial age composition parameters, and selectivity parameters (except annual *dev*s) as estimated internally the models.

	Model 1		Model 2	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.
Length at age 1 (cm)	1.697E+01	5.887E-01	1.797E+01	4.775E-01
Asymptotic length (cm)	1.113E+02	9.775E-01	1.215E+02	2.823E+00
Brody growth coefficient	2.372E-01	5.696E-03	1.943E-01	8.128E-03
SD of length at age 1 (cm)	5.575E+00	5.074E-01	4.465E+00	4.387E-01
SD of length at age 20 (cm)	5.740E+00	5.062E-01	6.677E+00	7.679E-01
Ageing bias at age 1 (years)	4.638E-01	5.043E-02	4.383E-01	6.301E-02
Ageing bias at age 20 (years)	1.000E+00	4.958E-01	-9.274E-01	6.706E-01
ln(mean post-1976 recruitment)	1.099E+01	1.173E-01	1.071E+01	1.123E-01
σ(recruitment)	9.089E-01	1.049E-01	9.049E-01	1.046E-01
ln(pre-1977 recruitment offset)	-1.757E+00	2.460E-01	-1.921E+00	2.416E-01
Initial fishing mortality rate	1.950E-02	4.766E-03	3.988E-02	1.033E-02
ln(catchability)	0.000E+00	_	-2.494E-01	8.473E-02
Initial age 1 ln(abundance) dev	-8.863E-02	5.622E-01	1.528E-01	6.383E-01
Initial age 2 ln(abundance) dev	3.705E-01	4.202E-01	7.565E-01	4.262E-01
Initial age 3 ln(abundance) dev	-9.932E-02	4.952E-01	1.920E-01	5.013E-01
Initial age 4 ln(abundance) dev	-5.659E-01	5.930E-01	-2.728E-01	5.842E-01
Initial age 5 ln(abundance) dev	-1.036E+00	6.344E-01	-9.908E-01	6.357E-01
Initial age 6 ln(abundance) dev	-1.068E+00	6.413E-01	-1.141E+00	6.275E-01
Initial age 7 ln(abundance) dev	-9.702E-01	6.584E-01	-1.084E+00	6.384E-01
Initial age 8 ln(abundance) dev	-8.389E-01	6.802E-01	-9.424E-01	6.596E-01
Initial age 9 ln(abundance) dev	-7.043E-01	7.045E-01	-7.980E-01	6.839E-01
Initial age 10 ln(abundance) dev	-5.776E-01	7.302E-01	-6.604E-01	7.100E-01
Fishery age 1 selectivity parameter	4.100E+00	4.180E-01	5.300E+00	1.740E+00
Fishery age 2 selectivity parameter	4.223E+00	3.985E-01	5.495E+00	1.595E+00
Fishery age 3 selectivity parameter	3.277E+00	1.932E-01	3.228E+00	1.787E-01
Fishery age 4 selectivity parameter	9.308E-01	5.777E-02	1.085E+00	6.552E-02
Fishery age 5 selectivity parameter	4.246E-01	5.204E-02	5.556E-01	7.128E-02
Fishery age 6 selectivity parameter	2.668E-03	6.960E-03	1.805E-01	9.944E-02
Fishery age 7 selectivity parameter	0.000E+00	_	3.646E-01	1.424E-01
Fishery age 8 selectivity parameter	0.000E+00	_	2.252E-01	7.464E-02
Fishery age 9 selectivity parameter	0.000E+00	_	1.027E-02	1.723E-02
Fishery age 10 selectivity parameter	0.000E+00	_	4.866E-04	4.803E-03
Survey age 1 selectivity parameter	1.420E+00	1.030E+00	1.310E+00	1.960E-03
Survey age 2 selectivity parameter	1.268E+00	4.272E-01	1.110E+00	1.880E-03
Survey age 3 selectivity parameter	7.533E-01	2.327E-01	7.000E-01	1.230E-03
Survey age 4 selectivity parameter	6.424E-01	1.253E-01	2.880E-01	5.620E-04
Survey age 5 selectivity parameter	-6.981E-01	1.331E-01	8.580E-02	2.590E-04
Survey age 6 selectivity parameter	-2.003E-01	1.634E-01	2.230E-02	1.020E-04
Survey age 7 selectivity parameter	-2.489E-01	1.630E-01	5.580E-03	3.460E-05
Survey age 8 selectivity parameter	-1.967E-01	1.689E-01	0.000E+00	_
Survey age 9 selectivity parameter	-1.752E-01	1.736E-01	0.000E+00	_
Survey age 10 selectivity parameter	-1.482E-01	1.770E-01	0.000E+00	_

Table 2A.9b—Annual log-scale recruitment *dev*s estimated by the 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	-1.776E+00	4.526E-01	-1.376E+00	4.344E-01
1978	-1.125E+00	2.738E-01	-9.123E-01	2.501E-01
1979	-1.223E+00	2.753E-01	-1.173E+00	2.495E-01
1980	-4.108E-01	2.426E-01	-5.114E-01	1.918E-01
1981	-4.283E-01	3.019E-01	-8.071E-01	2.742E-01
1982	-3.302E-01	3.613E-01	-7.752E-01	3.209E-01
1983	-5.890E-01	6.969E-01	-1.055E+00	6.106E-01
1984	-9.149E-02	6.546E-01	-3.751E-01	4.724E-01
1985	8.352E-01	2.836E-01	3.440E-01	2.381E-01
1986	8.058E-01	1.958E-01	5.073E-01	1.596E-01
1987	9.546E-01	1.112E-01	7.657E-01	9.535E-02
1988	3.425E-01	1.220E-01	8.837E-02	1.231E-01
1989	6.699E-01	1.051E-01	5.300E-01	1.013E-01
1990	8.513E-01	9.460E-02	6.671E-01	9.066E-02
1991	4.870E-01	1.183E-01	3.344E-01	1.121E-01
1992	3.006E-01	1.328E-01	1.547E-01	1.270E-01
1993	7.208E-01	9.468E-02	7.482E-01	8.407E-02
1994	5.002E-01	1.007E-01	2.878E-01	1.056E-01
1995	4.576E-01	8.642E-02	3.823E-01	8.651E-02
1996	6.997E-01	7.520E-02	7.997E-01	7.581E-02
1997	9.364E-01	6.887E-02	7.870E-01	7.048E-02
1998	4.131E-01	9.820E-02	2.913E-01	9.334E-02
1999	3.277E-01	1.058E-01	5.118E-01	1.004E-01
2000	5.673E-01	9.862E-02	7.218E-01	8.829E-02
2001	2.524E-01	1.099E-01	3.510E-01	1.055E-01
2002	-2.221E-01	1.268E-01	2.993E-02	1.146E-01
2003	-2.589E-03	1.010E-01	1.488E-01	9.373E-02
2004	-4.782E-01	1.345E-01	-2.535E-01	1.222E-01
2005	7.113E-02	9.801E-02	2.610E-01	9.186E-02
2006	-5.682E-01	1.386E-01	-2.291E-01	1.328E-01
2007	2.349E-01	1.072E-01	6.011E-01	1.042E-01
2008	-2.143E-01	1.424E-01	1.874E-01	1.585E-01
2009	-1.089E+00	2.543E-01	-8.469E-01	2.155E-01
2010	-1.210E+00	3.448E-01	-7.504E-01	3.512E-01
2011	-6.689E-01	6.332E-01	-4.355E-01	6.446E-01

Table 2A.9c—Survey selectivity *dev*s estimated by the models.

	Model 1		Model 2	
Parameter	Estimate	St. Dev.	Estimate	St. Dev.
Survey age 2 selectivity dev 1991	2.533E-01	7.398E-02	2.451E-01	6.184E-02
Survey age 2 selectivity dev 1992	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 1993	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 1994	-1.910E-01	5.196E-02	-1.614E-01	3.215E-02
Survey age 2 selectivity dev 1995	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 1996	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 1997	-3.445E-02	5.864E-02	-1.501E-02	4.228E-02
Survey age 2 selectivity dev 1998	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 1999	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 2000	-2.253E-02	6.663E-02	8.669E-03	5.472E-02
Survey age 2 selectivity dev 2001	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 2002	8.438E-02	6.956E-02	7.909E-02	5.742E-02
Survey age 2 selectivity dev 2003	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 2004	6.472E-02	7.998E-02	6.217E-02	6.958E-02
Survey age 2 selectivity dev 2005	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 2006	-8.164E-02	6.241E-02	-7.156E-02	4.926E-02
Survey age 2 selectivity dev 2007	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 2008	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 2009	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 2010	-3.225E-02	7.636E-02	-3.344E-02	6.655E-02
Survey age 2 selectivity dev 2011	0.000E+00	1.240E-01	0.000E+00	1.130E-01
Survey age 2 selectivity dev 2012	-3.142E-02	7.895E-02	-3.044E-02	7.247E-02
Survey age 3 selectivity dev 1991	-1.114E-01	2.597E-02	-9.751E-02	1.909E-02
Survey age 3 selectivity dev 1992	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 1993	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 1994	3.926E-03	3.284E-02	1.601E-02	2.910E-02
Survey age 3 selectivity dev 1995	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 1996	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 1997	2.233E-02	3.127E-02	2.051E-02	2.718E-02
Survey age 3 selectivity dev 1998	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 1999	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 2000	5.178E-02	3.472E-02	5.357E-02	3.163E-02
Survey age 3 selectivity dev 2001	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 2002	-3.953E-02	2.811E-02	-2.744E-02	2.311E-02
Survey age 3 selectivity dev 2003	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 2004	3.935E-02	3.654E-02	4.943E-02	3.330E-02
Survey age 3 selectivity dev 2005	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 2006	3.170E-02	3.807E-02	3.278E-02	3.506E-02
Survey age 3 selectivity dev 2007	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 2008	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 2009	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 2010	2.514E-02	3.415E-02	4.284E-02	3.088E-02
Survey age 3 selectivity dev 2011	0.000E+00	5.100E-02	0.000E+00	4.800E-02
Survey age 3 selectivity dev 2012	-2.318E-02	3.708E-02	-6.712E-03	3.440E-02

Table 2A.9d—Fishery selectivity *dev*s as estimated by the Model 2 (Model 1 does not use fishery selectivity *dev*s).

Parameter	Estimate	St. Dev.
Fishery age 5 selectivity dev 1978	-2.120E-03	8.957E-03
Fishery age 5 selectivity dev 1979	-2.022E-03	8.978E-03
Fishery age 5 selectivity dev 1980	1.580E-05	8.999E-03
Fishery age 5 selectivity dev 1981	1.010E-04	8.992E-03
Fishery age 5 selectivity dev 1982	-2.572E-03	8.921E-03
Fishery age 5 selectivity dev 1983	-5.968E-03	8.875E-03
Fishery age 5 selectivity dev 1984	2.433E-04	8.867E-03
Fishery age 5 selectivity dev 1985	-8.409E-04	8.936E-03
Fishery age 5 selectivity dev 1986	-1.619E-05	9.000E-03
Fishery age 5 selectivity dev 1987	3.132E-04	8.991E-03
Fishery age 5 selectivity dev 1988	2.557E-04	8.998E-03
Fishery age 5 selectivity dev 1989	1.428E-04	8.999E-03
Fishery age 5 selectivity dev 1990	4.136E-03	8.805E-03
Fishery age 5 selectivity dev 1991	1.715E-02	8.185E-03
Fishery age 5 selectivity dev 1992	4.098E-03	7.355E-03
Fishery age 5 selectivity dev 1993	5.209E-04	7.586E-03
Fishery age 5 selectivity dev 1994	-4.277E-03	8.014E-03
Fishery age 5 selectivity dev 1995	7.828E-03	8.091E-03
Fishery age 5 selectivity dev 1996	-5.834E-03	7.759E-03
Fishery age 5 selectivity dev 1997	8.593E-03	7.985E-03
Fishery age 5 selectivity dev 1998	-1.320E-02	7.281E-03
Fishery age 5 selectivity dev 1999	1.176E-03	7.163E-03
Fishery age 5 selectivity dev 2000	2.142E-02	6.685E-03
Fishery age 5 selectivity dev 2001	-2.503E-02	6.921E-03
Fishery age 5 selectivity dev 2002	1.237E-02	7.708E-03
Fishery age 5 selectivity dev 2003	1.730E-02	7.580E-03
Fishery age 5 selectivity dev 2004	-3.569E-03	7.855E-03
Fishery age 5 selectivity dev 2005	-6.192E-04	7.952E-03
Fishery age 5 selectivity dev 2006	-1.713E-02	7.841E-03
Fishery age 5 selectivity dev 2007	-1.233E-02	7.613E-03
Fishery age 5 selectivity dev 2008	-9.056E-03	7.685E-03
Fishery age 5 selectivity dev 2009	-4.448E-03	7.682E-03
Fishery age 5 selectivity dev 2010	4.603E-03	7.541E-03
Fishery age 5 selectivity dev 2011	9.798E-03	8.222E-03
Fishery age 5 selectivity dev 2012	-4.295E-04	8.504E-03
Fishery age 5 selectivity dev 2013	-5.248E-04	8.813E-03

Table 2A.10—Annual "full selection" fishing mortality rates as estimated by the two models. Color scale extends from red (low) to green (high) in each **column**.

Year	Model 1	Model 2
1977	1.616E-01	3.152E-01
1978	1.791E-01	4.031E-01
1979	3.141E-01	8.077E-01
1980	3.522E-01	9.650E-01
1981	5.084E-01	1.446E+00
1982	6.003E-01	1.816E+00
1983	5.175E-01	1.851E+00
1984	3.427E-01	1.534E+00
1985	2.000E-01	1.030E+00
1986	1.480E-01	8.442E-01
1987	2.362E-01	1.591E+00
1988	6.924E-02	4.856E-01
1989	3.819E-02	2.264E-01
1990	4.201E-02	2.163E-01
1991	4.228E-02	1.904E-01
1992	1.706E-01	6.881E-01
1993	1.374E-01	5.587E-01
1994	8.301E-02	3.220E-01
1995	6.107E-02	2.252E-01
1996	1.185E-01	4.098E-01
1997	9.659E-02	3.254E-01
1998	1.358E-01	4.371E-01
1999	1.137E-01	3.768E-01
2000	1.616E-01	5.517E-01
2001	1.375E-01	4.337E-01
2002	1.238E-01	4.108E-01
2003	1.365E-01	4.303E-01
2004	1.267E-01	3.573E-01
2005	1.040E-01	2.728E-01
2006	1.207E-01	2.858E-01
2007	1.968E-01	4.331E-01
2008	2.150E-01	4.664E-01
2009	2.353E-01	5.210E-01
2010	2.757E-01	6.302E-01
2011	1.071E-01	2.356E-01
2012	1.760E-01	3.366E-01
2013	1.569E-01	2.636E-01

Table 2A.11—Summary of key management reference points. Tier 3 values come from the standard projection algorithm (except the last seven rows, which come from SS). All biomass figures are in t. Color scale extends from red (low) to green (high) in each **row**.

	Tier 3		Tier 5	
Quantity	Model 1	Model 2	KF	RE
B100%	115,000	89,500	n/a	n/a
B40%	46,100	35,800	n/a	n/a
B35%	40,300	31,300	n/a	n/a
B(2014)	33,900	31,800	58,800	59,000
B(2015)	31,200	29,000	58,800	59,000
B(2014)/B100%	0.29	0.36	n/a	n/a
B(2015)/B100%	0.27	0.32	n/a	n/a
F40%	0.23	0.37	n/a	n/a
F35%	0.28	0.45	n/a	n/a
maxFABC(2014)	0.17	0.16	0.26	0.26
maxFABC(2015)	0.15	0.14	0.26	0.26
maxABC(2014)	13,500	17,400	15,000	15,100
maxABC(2015)	12,000	15,200	15,000	15,100
FOFL(2014)	0.17	0.20	0.34	0.34
FOFL(2015)	0.16	0.18	0.34	0.34
OFL(2014)	15,800	20,700	20,000	20,100
OFL(2015)	14,100	18,000	20,000	20,100
Pr(maxABC(2014)>truOFL(2014))	0.28	0.28	n/a	n/a
Pr(maxABC(2015)>truOFL(2015))	0.32	0.32	n/a	n/a
Pr(B(2014)<B20%)	0.05	0.01	n/a	n/a
Pr(B(2015)<B20%)	0.07	0.01	n/a	n/a
Pr(B(2016)<B20%)	0.03	0.00	n/a	n/a
Pr(B(2017)<B20%)	0.00	0.00	n/a	n/a
Pr(B(2018)<B20%)	0.00	0.00	n/a	n/a

Table 2A.12—Schedules of Pacific cod selectivity at length (cm) in the fishery as estimated by the models. Note that fishery selectivity is time-invariant in Model 1 (first row).

		Age												
Model	Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1	All	0.000	0.000	0.010	0.257	0.652	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	1974	0.000	0.000	0.004	0.089	0.264	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1977	0.000	0.000	0.004	0.089	0.263	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1978	0.000	0.000	0.004	0.091	0.268	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1979	0.000	0.000	0.004	0.091	0.268	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1980	0.000	0.000	0.004	0.089	0.263	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1981	0.000	0.000	0.004	0.089	0.262	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1982	0.000	0.000	0.004	0.091	0.270	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1983	0.000	0.000	0.004	0.094	0.279	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1984	0.000	0.000	0.004	0.089	0.262	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1985	0.000	0.000	0.004	0.089	0.265	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1986	0.000	0.000	0.004	0.089	0.263	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1987	0.000	0.000	0.004	0.088	0.262	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1988	0.000	0.000	0.004	0.089	0.262	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1989	0.000	0.000	0.004	0.089	0.262	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1990	0.000	0.000	0.003	0.085	0.252	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1991	0.000	0.000	0.003	0.075	0.221	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1992	0.000	0.000	0.003	0.085	0.252	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1993	0.000	0.000	0.004	0.088	0.261	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1994	0.000	0.000	0.004	0.093	0.274	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1995	0.000	0.000	0.003	0.082	0.243	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1996	0.000	0.000	0.004	0.094	0.278	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1997	0.000	0.000	0.003	0.081	0.241	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1998	0.000	0.000	0.004	0.101	0.300	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	1999	0.000	0.000	0.003	0.088	0.260	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2000	0.000	0.000	0.003	0.072	0.212	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2001	0.000	0.000	0.005	0.114	0.337	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2002	0.000	0.000	0.003	0.078	0.232	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2003	0.000	0.000	0.003	0.075	0.221	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2004	0.000	0.000	0.004	0.092	0.272	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2005	0.000	0.000	0.004	0.089	0.264	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2006	0.000	0.000	0.004	0.105	0.312	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2007	0.000	0.000	0.004	0.100	0.297	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2008	0.000	0.000	0.004	0.097	0.288	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2009	0.000	0.000	0.004	0.093	0.275	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2010	0.000	0.000	0.003	0.085	0.251	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2011	0.000	0.000	0.003	0.080	0.238	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2012	0.000	0.000	0.004	0.089	0.264	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000
2	2013	0.000	0.000	0.004	0.089	0.264	0.458	0.549	0.790	0.989	1.000	1.000	1.000	1.000

Table 2A.13—Schedules of Pacific cod selectivity at length (cm) in the survey as estimated by the models. Note that survey selectivity is time-variant in both models.

		Age												
Model	Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1	1991	0.000	0.020	0.753	0.526	1.000	0.498	0.407	0.318	0.261	0.219	0.189	0.189	0.189
1	1994	0.000	0.449	0.238	0.526	1.000	0.498	0.407	0.318	0.261	0.219	0.189	0.189	0.189
1	1997	0.000	0.078	0.198	0.526	1.000	0.498	0.407	0.318	0.261	0.219	0.189	0.189	0.189
1	2000	0.000	0.052	0.148	0.526	1.000	0.498	0.407	0.318	0.261	0.219	0.189	0.189	0.189
1	2002	0.000	0.046	0.367	0.526	1.000	0.498	0.407	0.318	0.261	0.219	0.189	0.189	0.189
1	2004	0.000	0.025	0.168	0.526	1.000	0.498	0.407	0.318	0.261	0.219	0.189	0.189	0.189
1	2006	0.000	0.114	0.181	0.526	1.000	0.498	0.407	0.318	0.261	0.219	0.189	0.189	0.189
1	2010	0.000	0.075	0.193	0.526	1.000	0.498	0.407	0.318	0.261	0.219	0.189	0.189	0.189
1	2012	0.000	0.120	0.312	0.526	1.000	0.498	0.407	0.318	0.261	0.219	0.189	0.189	0.189
2	1991	0.000	0.029	0.880	0.669	0.893	0.973	0.994	1.000	1.000	1.000	1.000	1.000	1.000
2	1994	0.000	0.467	0.283	0.669	0.893	0.973	0.994	1.000	1.000	1.000	1.000	1.000	1.000
2	1997	0.000	0.104	0.271	0.669	0.893	0.973	0.994	1.000	1.000	1.000	1.000	1.000	1.000
2	2000	0.000	0.059	0.195	0.669	0.893	0.973	0.994	1.000	1.000	1.000	1.000	1.000	1.000
2	2002	0.000	0.066	0.437	0.669	0.893	0.973	0.994	1.000	1.000	1.000	1.000	1.000	1.000
2	2004	0.000	0.036	0.204	0.669	0.893	0.973	0.994	1.000	1.000	1.000	1.000	1.000	1.000
2	2006	0.000	0.161	0.240	0.669	0.893	0.973	0.994	1.000	1.000	1.000	1.000	1.000	1.000
2	2010	0.000	0.100	0.217	0.669	0.893	0.973	0.994	1.000	1.000	1.000	1.000	1.000	1.000
2	2012	0.000	0.158	0.355	0.669	0.893	0.973	0.994	1.000	1.000	1.000	1.000	1.000	1.000

Table 2A.14—Schedules of population length (cm) and weight (kg) by age as estimated by the models. Lengths and weights correspond to mid-point of the year.

	Population				Fishery				Survey			
	Length		Weight		Length		Weight		Length		Weight	
Age	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
0	5.99	6.32	0.01	0.01	6.55	6.58	0.01	0.01	6.55	6.58	0.01	0.01
1	16.97	17.97	0.06	0.07	16.97	17.97	0.06	0.07	16.97	17.97	0.06	0.07
2	36.88	36.25	0.59	0.55	36.88	36.25	0.59	0.55	36.88	36.25	0.59	0.55
3	52.59	51.31	1.75	1.61	52.59	51.31	1.75	1.61	52.59	51.31	1.75	1.61
4	64.98	63.70	3.39	3.18	64.98	63.70	3.39	3.18	64.98	63.70	3.39	3.18
5	74.76	73.91	5.26	5.08	74.76	73.91	5.26	5.08	74.76	73.91	5.26	5.08
6	82.47	82.31	7.17	7.13	82.47	82.31	7.17	7.13	82.47	82.31	7.17	7.13
7	88.55	89.23	8.97	9.20	88.55	89.23	8.97	9.20	88.55	89.23	8.97	9.20
8	93.35	94.93	10.59	11.19	93.35	94.93	10.59	11.19	93.35	94.93	10.59	11.19
9	97.13	99.62	12.01	13.04	97.13	99.62	12.01	13.04	97.13	99.62	12.01	13.04
10	100.12	103.49	13.22	14.70	100.12	103.49	13.22	14.70	100.12	103.49	13.22	14.70
11	102.47	106.67	14.22	16.18	102.47	106.67	14.22	16.18	102.47	106.67	14.22	16.18
12	104.33	109.29	15.05	17.47	104.33	109.29	15.05	17.47	104.33	109.29	15.05	17.47
13	105.79	111.44	15.73	18.59	105.79	111.44	15.73	18.59	105.79	111.44	15.73	18.59
14	106.95	113.22	16.28	19.54	106.95	113.22	16.28	19.54	106.95	113.22	16.28	19.54
15	107.86	114.68	16.72	20.35	107.86	114.68	16.72	20.35	107.86	114.68	16.72	20.35
16	108.58	115.89	17.08	21.04	108.58	115.89	17.08	21.04	108.58	115.89	17.08	21.04
17	109.15	116.88	17.36	21.61	109.15	116.88	17.36	21.61	109.15	116.88	17.36	21.61
18	109.60	117.69	17.59	22.09	109.60	117.69	17.59	22.09	109.60	117.69	17.59	22.09
19	109.95	118.36	17.77	22.50	109.95	118.36	17.77	22.50	109.95	118.36	17.77	22.50
20	110.45	119.46	18.02	23.16	110.45	119.46	18.02	23.16	110.45	119.46	18.02	23.16

Table 2A.15a—Time series of age 0+ biomass, age 3+ biomass, female spawning biomass (t), and standard deviation of spawning biomass ("SB SD") as estimated by the models. Spawning biomass for 2014 represents output from the standard projection model.

	Model 1				Model 2			
Year	Age 0+	Age 3+	Spawn.	SB SD	Age 0+	Age 3+	Spawn.	SB SD
1977	27,188	25,852	10,213	2,474	18,568	17,355	6,660	1,611
1978	25,663	24,759	8,427	2,153	17,919	17,171	5,302	1,411
1979	25,462	24,399	7,675	1,924	18,559	17,444	4,918	1,255
1980	24,111	22,291	6,849	1,755	18,102	16,490	4,430	1,091
1981	24,558	22,634	6,298	1,594	18,801	17,379	4,184	884
1982	26,297	22,578	5,652	1,440	19,264	16,874	3,720	597
1983	31,606	27,906	5,679	1,577	20,369	18,527	3,503	515
1984	40,557	36,621	7,104	2,186	21,997	20,151	3,774	671
1985	51,905	48,449	10,213	3,298	23,889	22,262	4,546	1,027
1986	65,861	59,715	14,713	4,636	27,346	24,132	5,652	1,467
1987	87,625	74,710	19,950	5,695	34,890	28,939	6,850	1,810
1988	119,364	106,596	24,593	6,359	44,253	37,180	6,737	2,024
1989	173,332	159,590	36,420	7,526	70,550	62,232	11,656	2,724
1990	232,917	224,585	55,198	9,405	103,372	98,551	20,745	3,782
1991	281,618	270,398	77,410	11,440	132,530	125,414	32,303	4,875
1992	319,676	307,063	97,991	12,874	157,860	150,128	44,101	5,730
1993	318,768	309,794	101,238	13,404	148,769	143,114	41,757	6,199
1994	319,017	310,935	103,584	13,513	145,811	140,526	41,058	6,598
1995	324,821	313,579	108,969	13,333	153,602	145,303	45,134	6,872
1996	333,151	323,917	113,977	12,874	166,698	161,120	50,535	6,930
1997	324,689	315,466	110,748	12,188	163,937	157,504	49,281	6,778
1998	322,823	311,179	109,586	11,502	168,490	159,360	50,643	6,628
1999	316,595	303,043	104,983	10,837	167,707	159,101	48,634	6,487
2000	322,647	314,230	104,104	10,345	175,850	170,158	49,880	6,535
2001	314,435	306,392	101,087	9,951	171,016	163,955	48,207	6,723
2002	306,245	296,719	101,354	9,554	170,141	162,006	49,766	6,934
2003	297,626	290,745	101,057	9,009	171,910	166,260	50,914	7,048
2004	281,541	276,920	97,376	8,286	168,813	164,510	50,562	6,972
2005	261,620	256,272	93,209	7,444	163,822	159,232	51,460	6,576
2006	242,403	238,616	89,150	6,592	159,659	156,201	53,088	5,873
2007	218,672	212,977	81,655	5,819	150,195	145,088	51,478	5,047
2008	186,986	183,316	68,557	5,197	130,940	127,140	43,729	4,327
2009	161,809	155,070	57,015	4,780	117,320	110,147	36,767	3,880
2010	144,939	140,756	48,086	4,583	111,140	106,577	31,890	3,745
2011	128,971	127,092	41,005	4,616	104,986	103,190	28,622	3,956
2012	126,600	124,633	42,297	4,853	111,399	109,271	33,773	4,486
2013	113,177	108,991	40,038	5,073	105,202	101,560	35,214	5,049
2014	107,519	99,032	33,922	5,180	102,688	96,486	31,816	5,476

Table 2A.15b—Time series of survey biomass (t) and 95% confidence intervals for the Kalman filter and random effects model.

	Kalman filter			Random effects		
Year	Mean	U95%CI	L95%CI	Mean	U95%CI	L95%CI
1991	157,038	182,083	131,993	172,531	225,071	132,255
1992	147,569	182,134	113,004	159,866	232,627	109,863
1993	138,100	175,409	100,791	148,130	218,510	100,419
1994	128,631	163,544	93,718	137,256	188,877	99,743
1995	112,633	148,800	76,466	115,954	169,205	79,462
1996	96,635	128,373	64,896	97,958	140,742	68,180
1997	80,636	98,437	62,836	82,755	107,292	63,829
1998	86,116	116,971	55,262	89,490	127,817	62,656
1999	91,596	125,259	57,933	96,773	140,031	66,879
2000	97,076	126,409	67,744	104,649	142,608	76,794
2001	87,982	118,072	57,892	92,040	128,873	65,734
2002	78,888	99,114	58,662	80,949	105,138	62,325
2003	79,506	108,142	50,871	80,706	113,231	57,524
2004	80,125	104,789	55,461	80,463	107,900	60,003
2005	78,697	110,845	46,548	78,706	114,554	54,076
2006	77,268	108,515	46,022	76,987	111,145	53,326
2007	72,456	109,358	35,554	72,158	111,310	46,778
2008	67,643	104,843	30,442	67,632	105,507	43,354
2009	62,830	95,120	30,540	63,390	95,090	42,258
2010	58,017	76,406	39,628	59,414	79,927	44,166
2011	58,408	84,463	32,352	59,222	83,284	42,112
2012	58,798	74,967	42,630	59,031	76,711	45,425

Table 2A.16—Time series of EBS Pacific cod age 0 recruitment (1000s of fish), with standard deviations, as estimated by the models. Color scale extends from red (low) to green (high) in each **column**.

	Model 1		Model 2	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	6,628	3,109	7,546	3,324
1978	12,711	3,632	12,000	2,933
1979	11,525	3,375	9,244	2,313
1980	25,969	7,003	17,919	3,506
1981	25,518	8,274	13,333	3,728
1982	28,147	10,725	13,765	4,561
1983	21,729	15,375	10,409	6,531
1984	35,737	23,901	20,536	10,014
1985	90,272	27,227	42,153	10,887
1986	87,664	19,614	49,631	8,966
1987	101,727	12,747	64,262	7,129
1988	55,157	7,249	32,644	4,289
1989	76,523	10,761	50,768	6,867
1990	91,737	9,680	58,229	6,031
1991	63,734	8,665	41,749	5,316
1992	52,895	7,661	34,883	4,829
1993	80,518	9,622	63,145	6,701
1994	64,577	6,416	39,848	4,213
1995	61,882	6,796	43,799	5,020
1996	78,840	8,165	66,486	7,326
1997	99,892	7,597	65,647	5,340
1998	59,190	5,176	39,987	4,470
1999	54,347	6,876	49,853	6,537
2000	69,062	5,809	61,502	5,045
2001	50,403	5,003	42,448	3,937
2002	31,360	3,766	30,791	3,303
2003	39,059	3,991	34,677	3,378
2004	24,277	3,243	23,191	3,022
2005	42,048	4,217	38,796	3,937
2006	22,187	3,025	23,765	3,565
2007	49,530	5,896	54,507	6,695
2008	31,606	4,013	36,041	5,626
2009	13,180	3,323	12,811	2,824
2010	11,672	4,169	14,111	5,134
2011	24,662	16,012	23,723	15,790
Average	48,456		35,549	

Table 2A.17a—Numbers (1000s) at age at the beginning of the year 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	6628	4402	4959	2206	980	430	291	224	178	142	113	212	148	103	72	50	35	25	17	12	28
1978	12711	4718	3133	3524	1506	628	261	176	136	108	86	68	128	90	63	44	30	21	15	10	24
1979	11525	9047	3358	2226	2396	954	374	155	105	81	64	51	41	76	53	37	26	18	13	9	20
1980	25969	8203	6439	2383	1462	1389	496	194	81	55	42	33	27	21	40	28	19	14	9	7	15
1981	25518	18484	5838	4568	1549	827	696	248	97	40	27	21	17	13	11	20	14	10	7	5	11
1982	28147	18163	13155	4135	2853	791	354	298	106	42	17	12	9	7	6	5	9	6	4	3	7
1983	21729	20035	12927	9309	2522	1373	310	138	116	42	16	7	5	4	3	2	2	3	2	2	4
1984	35737	15466	14259	9155	5800	1281	583	131	59	49	18	7	3	2	1	1	1	1	1	1	2
1985	90272	25436	11008	10115	5966	3301	648	295	66	30	25	9	3	1	1	1	1	0	0	1	2
1986	87664	64253	18104	7820	6839	3727	1925	377	172	39	17	15	5	2	1	1	0	0	0	0	1
1987	101727	62396	45732	12868	5358	4420	2289	1182	232	105	24	11	9	3	1	1	0	0	0	0	1
1988	55157	72406	44410	32476	8619	3269	2486	1287	664	130	59	13	6	5	2	1	0	0	0	0	1
1989	76523	39259	51536	31589	22708	5864	2172	1651	854	441	86	39	9	4	3	1	0	0	0	0	1
1990	91737	54467	27943	36668	22264	15765	4018	1488	1131	585	302	59	27	6	3	2	1	0	0	0	0
1991	63734	65296	38768	19881	25819	15419	10761	2742	1015	772	400	206	40	18	4	2	2	1	0	0	0
1992	52895	45364	46475	27582	13998	17877	10521	7342	1871	693	527	273	141	28	13	3	1	1	0	0	0
1993	80518	37649	32288	33025	18790	8914	10734	6314	4406	1123	416	316	164	84	17	8	2	1	1	0	0
1994	64577	57310	26797	22951	22690	12228	5532	6659	3917	2734	697	258	196	101	52	10	5	1	0	0	0
1995	61882	45964	40791	19058	15991	15299	8012	3624	4362	2566	1791	456	169	128	66	34	7	3	1	0	0
1996	78840	44046	32715	29017	13353	10937	10246	5365	2427	2921	1718	1199	306	113	86	45	23	5	2	0	1
1997	99892	56116	31350	23259	20033	8798	6917	6478	3392	1534	1847	1086	758	193	72	54	28	15	3	1	1
1998	59190	71100	39941	22293	16149	13389	5687	4470	4186	2192	991	1193	702	490	125	46	35	18	9	2	1
1999	54347	42130	50606	28391	15323	10520	8323	3534	2778	2601	1362	616	742	436	304	78	29	22	11	6	2
2000	69062	38683	29986	35980	19626	10127	6685	5287	2245	1765	1653	865	391	471	277	193	49	18	14	7	5
2001	50403	49157	27533	21310	24567	12571	6135	4048	3202	1359	1069	1001	524	237	285	168	117	30	11	8	7
2002	31360	35875	34988	19571	14641	15986	7801	3806	2511	1986	843	663	621	325	147	177	104	73	19	7	10
2003	39059	22321	25534	24873	13494	9613	10057	4906	2393	1579	1249	530	417	390	204	92	111	65	46	12	10
2004	24277	27801	15887	18151	17093	8786	5971	6245	3046	1486	981	776	329	259	242	127	57	69	41	28	14
2005	42048	17279	19788	11294	12505	11201	5511	3744	3916	1910	932	615	486	206	162	152	80	36	43	25	26
2006	22187	29928	12299	14070	7827	8317	7187	3535	2402	2512	1225	598	394	312	132	104	98	51	23	28	33
2007	49530	15792	21302	8744	9709	5149	5249	4534	2230	1515	1585	773	377	249	197	84	66	62	32	15	39
2008	31606	35254	11240	15133	5916	6078	3012	3068	2651	1304	886	926	452	220	145	115	49	38	36	19	31
2009	13180	22497	25092	7984	10192	3660	3491	1729	1761	1522	748	508	532	259	127	84	66	28	22	21	29
2010	11672	9381	16012	17819	5349	6222	2060	1964	973	991	856	421	286	299	146	71	47	37	16	12	28
2011	24662	8308	6677	11366	11815	3181	3364	1113	1061	525	535	462	227	155	162	79	38	25	20	9	22
2011	59188	17554	5913	4747	7870	7842	2035	2151	712	679	336	342	296	145	99	103	50	25	16	13	19
2013	59188	42128	12494	4202	3230	4994	4683	1214	1284	425	405	201	204	177	87	59	62	30	15	10	19

Table 2A.17b—Numbers (1000s) at age at the beginning of the year as estimated by Model 2.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	7546	3628	4723	1911	852	293	176	130	103	81	64	128	87	60	41	28	19	13	9	6	13
1978	12000	5371	2583	3358	1323	558	180	105	72	54	42	33	66	45	31	21	14	10	7	5	10
1979	9244	8542	3823	1836	2304	845	330	103	54	34	26	20	16	31	22	15	10	7	5	3	7
1980	17919	6580	6080	2713	1214	1320	415	151	39	17	11	8	6	5	10	7	5	3	2	1	3
1981	13333	12755	4683	4313	1772	670	603	174	50	11	5	3	2	2	1	3	2	1	1	1	1
1982	13765	9490	9078	3316	2698	861	245	193	39	8	2	1	0	0	0	0	0	0	0	0	0
1983	10409	9797	6754	6419	1998	1172	265	64	32	5	1	0	0	0	0	0	0	0	0	0	0
1984	20536	7409	6973	4774	3832	845	355	68	10	4	1	0	0	0	0	0	0	0	0	0	0
1985	42153	14617	5273	4937	2964	1819	296	108	14	2	1	0	0	0	0	0	0	0	0	0	0
1986	49631	30003	10404	3740	3202	1602	804	119	34	4	0	0	0	0	0	0	0	0	0	0	0
1987	64262	35326	21355	7383	2468	1822	772	359	43	10	1	0	0	0	0	0	0	0	0	0	0
1988	32644	45740	25143	15115	4559	1154	622	228	72	6	1	0	0	0	0	0	0	0	0	0	0
1989	50768	23235	32556	17865	10301	2854	656	338	110	31	3	1	0	0	0	0	0	0	0	0	0
1990	58229	36135	16538	23154	12461	6906	1830	412	201	62	18	2	0	0	0	0	0	0	0	0	0
1991	41749	41446	25720	11763	16177	8395	4449	1156	247	115	36	10	1	0	0	0	0	0	0	0	0
1992	34883	29716	29500	18296	8253	11036	5473	2850	707	145	68	21	6	1	0	0	0	0	0	0	0
1993	63145	24829	21151	20948	12275	4931	5717	2663	1173	253	52	24	7	2	0	0	0	0	0	0	0
1994	39848	44945	17672	15025	14187	7541	2712	2988	1215	478	103	21	10	3	1	0	0	0	0	0	0
1995	43799	28363	31990	12564	10378	9239	4627	1616	1646	627	246	53	11	5	2	0	0	0	0	0	0
1996	66486	31175	20188	22753	8777	6990	5927	2908	961	936	356	140	30	6	3	1	0	0	0	0	0
1997	65647	47323	22189	14347	15580	5571	4121	3366	1495	455	442	168	66	14	3	1	0	0	0	0	0
1998	39987	46726	33683	15777	9943	10247	3413	2451	1850	770	234	227	86	34	7	1	1	0	0	0	0
1999	49853	28462	33258	23932	10740	6203	5963	1909	1233	852	353	107	104	39	15	3	1	0	0	0	0
2000	61502	35484	20258	23641	16478	6929	3712	3448	1007	603	415	172	52	51	19	8	2	0	0	0	0
2001	42448	43775	25256	14396	16171	10426	3826	1949	1584	414	247	170	70	21	21	8	3	1	0	0	0
2002	30791	30213	31157	17941	9750	9934	6076	2143	983	732	191	113	78	32	10	10	4	1	0	0	0
2003	34677	21916	21505	22149	12363	6305	5853	3448	1101	465	345	90	53	37	15	5	4	2	1	0	0
2004	23191	24682	15599	15287	15263	7996	3681	3286	1744	511	215	159	41	25	17	7	2	2	1	0	0
2005	38796	16507	17568	11088	10527	9850	4827	2151	1760	869	254	107	79	21	12	8	3	1	1	0	0
2006	23765	27614	11749	12492	7701	6968	6183	2956	1232	955	470	137	58	43	11	7	5	2	1	1	0
2007	54507	16916	19655	8352	8627	5012	4349	3759	1677	660	510	251	73	31	23	6	4	2	1	0	0
2008	36041	38797	12040	13965	5691	5395	2923	2437	1897	776	304	235	116	34	14	11	3	2	1	0	0
2009	12811	25653	27614	8554	9497	3539	3097	1608	1198	849	345	135	105	51	15	6	5	1	1	0	0
2010	14111	9119	18259	19617	5800	5854	1982	1654	757	508	358	146	57	44	22	6	3	2	1	0	0
2011	23723	10044	6490	12969	13233	3522	3119	997	714	288	192	135	55	22	17	8	2	1	1	0	0
2011	45001	16886	7149	4616	9056	8902	2249	1949	589	402	162	108	76	31	12	9	5	1	1	0	0
2013	45001	32031	12019	5082	3188	5896	5427	1330	1062	300	204	82	55	39	16	6	5	2	1	0	0

Table 2A.18a—"Effective" fishing mortality (= -ln($N_{a+1,t+1}/N_{a,t}$)-M) at age and year, as estimated by Model 1.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.000	0.002	0.042	0.105	0.161	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162
1978	0.000	0.002	0.046	0.117	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179
1979	0.000	0.003	0.081	0.205	0.313	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
1980	0.000	0.003	0.091	0.230	0.351	0.352	0.352	0.352	0.352	0.352	0.352	0.352	0.352	0.352	0.352	0.352	0.352	0.352	0.352
1981	0.000	0.005	0.131	0.332	0.507	0.508	0.508	0.508	0.508	0.508	0.508	0.508	0.508	0.508	0.508	0.508	0.508	0.508	0.508
1982	0.000	0.006	0.154	0.392	0.599	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
1983	0.000	0.005	0.133	0.338	0.516	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518
1984	0.000	0.003	0.088	0.224	0.342	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343
1985	0.000	0.002	0.051	0.130	0.199	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
1986	0.000	0.001	0.038	0.097	0.148	0.148	0.148	0.148	0.148	0.148	0.148	0.148	0.148	0.148	0.148	0.148	0.148	0.148	0.148
1987	0.000	0.002	0.061	0.154	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236
1988	0.000	0.001	0.018	0.045	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069
1989	0.000	0.000	0.010	0.025	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
1990	0.000	0.000	0.011	0.027	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
1991	0.000	0.000	0.011	0.028	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
1992	0.000	0.002	0.044	0.111	0.170	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171	0.171
1993	0.000	0.001	0.035	0.090	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137
1994	0.000	0.001	0.021	0.054	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
1995	0.000	0.001	0.016	0.040	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
1996	0.000	0.001	0.030	0.077	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118
1997	0.000	0.001	0.025	0.063	0.096	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097
1998	0.000	0.001	0.035	0.089	0.135	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136
1999	0.000	0.001	0.029	0.074	0.113	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114
2000	0.000	0.002	0.042	0.105	0.161	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162	0.162
2001	0.000	0.001	0.035	0.090	0.137	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
2002	0.000	0.001	0.032	0.081	0.123	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124
2003	0.000	0.001	0.035	0.089	0.136	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137
2004	0.000	0.001	0.033	0.083	0.126	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127
2005	0.000	0.001	0.027	0.068	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104
2006	0.000	0.001	0.031	0.079	0.120	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121
2007	0.000	0.002	0.051	0.128	0.196	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197
2008	0.000	0.002	0.055	0.140	0.214	0.215	0.215	0.215	0.215	0.215	0.215	0.215	0.215	0.215	0.215	0.215	0.215	0.215	0.215
2009	0.000	0.002	0.061	0.153	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235
2010	0.000	0.003	0.071	0.180	0.275	0.276	0.276	0.276	0.276	0.276	0.276	0.276	0.276	0.276	0.276	0.276	0.276	0.276	0.276
2011	0.000	0.001	0.028	0.070	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107
2012	0.000	0.002	0.045	0.115	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176
2013	0.000	0.002	0.040	0.102	0.156	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157

Table 2A.18b—"Effective" fishing mortality (= $-\ln(N_{a+1,t+1}/N_{a,t})-M$) at age and year, as estimated by Model 2.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.000	0.001	0.028	0.083	0.145	0.173	0.249	0.312	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316
1978	0.000	0.001	0.037	0.108	0.185	0.222	0.319	0.400	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404
1979	0.000	0.003	0.073	0.217	0.371	0.444	0.640	0.801	0.809	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810
1980	0.000	0.003	0.086	0.254	0.444	0.531	0.765	0.958	0.968	0.969	0.969	0.969	0.969	0.969	0.969	0.969	0.969	0.969	0.969
1981	0.000	0.005	0.129	0.382	0.666	0.798	1.150	1.440	1.455	1.455	1.455	1.455	1.455	1.455	1.455	1.455	1.455	1.455	1.455
1982	0.000	0.007	0.167	0.493	0.838	1.004	1.446	1.811	1.830	1.831	1.831	1.831	1.831	1.831	1.831	1.831	1.831	1.831	1.831
1983	0.000	0.007	0.176	0.521	0.855	1.025	1.475	1.848	1.867	1.868	1.868	1.868	1.868	1.868	1.868	1.868	1.868	1.868	1.868
1984	0.000	0.005	0.137	0.405	0.708	0.848	1.221	1.529	1.545	1.545	1.545	1.545	1.545	1.545	1.545	1.545	1.545	1.545	1.545
1985	0.000	0.004	0.093	0.275	0.476	0.570	0.821	1.028	1.039	1.039	1.039	1.039	1.039	1.039	1.039	1.039	1.039	1.039	1.039
1986	0.000	0.003	0.076	0.224	0.390	0.468	0.673	0.843	0.852	0.852	0.852	0.852	0.852	0.852	0.852	0.852	0.852	0.852	0.852
1987	0.000	0.006	0.142	0.420	0.735	0.880	1.268	1.588	1.604	1.605	1.605	1.605	1.605	1.605	1.605	1.605	1.605	1.605	1.605
1988	0.000	0.002	0.043	0.128	0.225	0.269	0.387	0.485	0.490	0.490	0.490	0.490	0.490	0.490	0.490	0.490	0.490	0.490	0.490
1989	0.000	0.001	0.020	0.060	0.105	0.125	0.180	0.226	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228
1990	0.000	0.001	0.019	0.055	0.100	0.120	0.172	0.216	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218
1991	0.000	0.001	0.014	0.042	0.088	0.105	0.151	0.190	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192
1992	0.000	0.002	0.059	0.175	0.318	0.380	0.548	0.686	0.693	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694
1993	0.000	0.002	0.050	0.147	0.258	0.309	0.445	0.557	0.563	0.563	0.563	0.563	0.563	0.563	0.563	0.563	0.563	0.563	0.563
1994	0.000	0.001	0.030	0.089	0.149	0.178	0.256	0.321	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324
1995	0.000	0.001	0.019	0.055	0.104	0.124	0.179	0.224	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227
1996	0.000	0.002	0.039	0.115	0.188	0.226	0.325	0.407	0.411	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412
1997	0.000	0.001	0.027	0.079	0.150	0.180	0.259	0.324	0.327	0.327	0.327	0.327	0.327	0.327	0.327	0.327	0.327	0.327	0.327
1998	0.000	0.002	0.045	0.132	0.201	0.241	0.347	0.435	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440
1999	0.000	0.001	0.033	0.098	0.173	0.208	0.299	0.375	0.379	0.379	0.379	0.379	0.379	0.379	0.379	0.379	0.379	0.379	0.379
2000	0.000	0.002	0.040	0.118	0.254	0.304	0.438	0.548	0.554	0.554	0.554	0.554	0.554	0.554	0.554	0.554	0.554	0.554	0.554
2001	0.000	0.002	0.050	0.147	0.200	0.240	0.345	0.432	0.436	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437
2002	0.000	0.001	0.032	0.096	0.189	0.226	0.326	0.408	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413
2003	0.000	0.001	0.032	0.096	0.198	0.237	0.342	0.428	0.433	0.433	0.433	0.433	0.433	0.433	0.433	0.433	0.433	0.433	0.433
2004	0.000	0.001	0.033	0.098	0.165	0.197	0.284	0.356	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360
2005	0.000	0.001	0.025	0.073	0.126	0.151	0.217	0.272	0.274	0.274	0.274	0.274	0.274	0.274	0.274	0.274	0.274	0.274	0.274
2006	0.000	0.001	0.030	0.090	0.132	0.158	0.227	0.284	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287
2007	0.000	0.002	0.044	0.129	0.199	0.239	0.344	0.431	0.435	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436	0.436
2008	0.000	0.002	0.046	0.135	0.215	0.257	0.371	0.464	0.469	0.469	0.469	0.469	0.469	0.469	0.469	0.469	0.469	0.469	0.469
2009	0.000	0.002	0.049	0.144	0.240	0.287	0.414	0.518	0.523	0.524	0.524	0.524	0.524	0.524	0.524	0.524	0.524	0.524	0.524
2010	0.000	0.002	0.054	0.159	0.290	0.347	0.500	0.626	0.633	0.633	0.633	0.633	0.633	0.633	0.633	0.633	0.633	0.633	0.633
2011	0.000	0.001	0.019	0.056	0.108	0.130	0.187	0.234	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237
2012	0.000	0.001	0.030	0.089	0.155	0.185	0.267	0.335	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338
2013	0.000	0.001	0.024	0.070	0.121	0.146	0.210	0.262	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265

Table 2A.19a—Projections for AI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2014-2026 (Scenarios 1 and 2), with random variability in future recruitment, based on Model 1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	13,500	13,500	13,500	13,500	0
2015	12,000	12,000	12,000	12,000	0
2016	14,700	14,700	14,700	14,700	3
2017	20,900	20,900	21,000	21,100	90
2018	25,800	27,000	27,500	30,800	1,722
2019	25,000	29,600	30,400	38,600	4,448
2020	20,700	29,100	30,100	44,100	7,407
2021	17,200	28,900	29,500	45,700	9,054
2022	15,100	28,700	29,200	45,900	9,889
2023	14,300	28,600	29,100	47,200	10,252
2024	14,300	28,400	28,900	46,500	10,265
2025	14,400	28,100	28,700	47,000	10,079
2026	14,300	28,200	28,600	45,600	9,902

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	33,900	33,900	33,900	33,900	0
2015	31,200	31,200	31,200	31,200	0
2016	32,100	32,100	32,100	32,100	7
2017	36,700	36,800	36,800	37,000	130
2018	41,500	42,200	42,500	44,300	966
2019	42,900	45,500	46,300	52,400	3,232
2020	40,700	46,000	47,800	60,700	6,615
2021	37,500	46,000	48,100	66,700	9,426
2022	34,800	45,900	48,100	68,700	11,061
2023	33,500	45,400	48,100	69,100	11,842
2024	33,400	45,500	48,000	70,300	12,117
2025	33,200	45,300	47,900	70,600	12,006
2026	33,300	45,100	47,700	71,000	11,707

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0.17	0.17	0.17	0.17	0.00
2015	0.15	0.15	0.15	0.15	0.00
2016	0.16	0.16	0.16	0.16	0.00
2017	0.18	0.18	0.18	0.19	0.00
2018	0.21	0.21	0.22	0.23	0.00
2019	0.22	0.23	0.23	0.23	0.01
2020	0.21	0.23	0.23	0.23	0.01
2021	0.19	0.23	0.22	0.23	0.02
2022	0.17	0.23	0.22	0.23	0.02
2023	0.17	0.23	0.22	0.23	0.02
2024	0.17	0.23	0.22	0.23	0.02
2025	0.17	0.23	0.22	0.23	0.02
2026	0.17	0.23	0.22	0.23	0.02

Table 2A.19b—Projections for AI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2014-2026 (Scenarios 1 and 2), with random variability in future recruitment, based on Model 2.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	17,400	17,400	17,400	17,400	0
2015	15,200	15,200	15,200	15,200	0
2016	14,700	14,700	14,700	14,700	2
2017	17,100	17,100	17,200	17,200	49
2018	20,300	20,900	21,000	22,400	652
2019	21,300	23,000	23,300	26,300	1,602
2020	19,200	23,400	23,800	30,300	3,372
2021	16,500	23,400	23,400	32,200	4,816
2022	13,900	22,900	22,800	33,000	5,983
2023	12,700	22,300	22,400	33,100	6,512
2024	12,200	22,200	22,200	33,900	6,574
2025	12,300	22,000	22,100	33,200	6,464
2026	12,400	21,700	21,900	33,000	6,303

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	31,800	31,800	31,800	31,800	0
2015	29,000	29,000	29,000	29,000	0
2016	28,300	28,300	28,300	28,400	4
2017	30,700	30,800	30,800	31,000	79
2018	34,000	34,500	34,600	35,700	569
2019	35,100	36,900	37,300	41,100	1,998
2020	33,300	37,200	38,300	46,600	4,385
2021	30,400	36,800	38,100	51,300	6,554
2022	27,800	36,000	37,600	52,500	7,887
2023	26,700	35,400	37,300	52,000	8,469
2024	26,200	35,400	37,100	53,500	8,560
2025	26,300	35,300	36,900	52,500	8,319
2026	26,400	35,200	36,700	52,400	8,007

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0.33	0.33	0.33	0.33	0.00
2015	0.30	0.30	0.30	0.30	0.00
2016	0.29	0.29	0.29	0.29	0.00
2017	0.31	0.32	0.32	0.32	0.00
2018	0.35	0.36	0.36	0.37	0.01
2019	0.36	0.37	0.37	0.37	0.00
2020	0.34	0.37	0.36	0.37	0.01
2021	0.31	0.37	0.35	0.37	0.02
2022	0.28	0.37	0.35	0.37	0.03
2023	0.27	0.37	0.34	0.37	0.03
2024	0.27	0.37	0.34	0.37	0.04
2025	0.27	0.36	0.34	0.37	0.04
2026	0.27	0.36	0.34	0.37	0.04

Table 2A.20a—Projections for AI 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 2014-2026 (Scenario 3), with random variability in future recruitment, based on Model 1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	15,700	15,700	15,700	15,700	0
2015	14,900	14,900	14,900	14,900	0
2016	17,300	17,300	17,300	17,300	0
2017	21,400	21,400	21,400	21,500	19
2018	23,500	24,300	24,600	26,500	1,053
2019	22,600	25,400	26,300	33,200	3,535
2020	20,200	25,600	27,000	38,800	6,060
2021	18,400	26,200	27,400	41,200	7,300
2022	17,300	26,400	27,700	41,700	7,948
2023	16,900	26,500	27,800	43,100	8,300
2024	16,600	26,500	27,700	42,300	8,345
2025	16,800	26,400	27,600	43,200	8,183
2026	16,700	26,200	27,500	42,300	8,020

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	33,800	33,800	33,800	33,800	0
2015	30,200	30,200	30,200	30,200	0
2016	30,200	30,200	30,200	30,200	7
2017	34,100	34,200	34,300	34,500	134
2018	39,100	39,900	40,100	42,100	1,023
2019	41,500	44,300	45,200	51,900	3,496
2020	40,400	46,600	48,400	62,100	7,185
2021	37,600	48,000	50,000	71,200	10,461
2022	34,700	48,700	50,800	74,200	12,604
2023	32,900	48,800	51,200	74,800	13,788
2024	32,100	49,200	51,300	76,300	14,324
2025	31,900	49,100	51,200	77,400	14,365
2026	31,600	49,000	51,000	78,100	14,136

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0.20	0.20	0.20	0.20	0.00
2015	0.20	0.20	0.20	0.20	0.00
2016	0.20	0.20	0.20	0.20	0.00
2017	0.20	0.20	0.20	0.20	0.00
2018	0.20	0.20	0.20	0.20	0.00
2019	0.20	0.20	0.20	0.20	0.00
2020	0.20	0.20	0.20	0.20	0.00
2021	0.20	0.20	0.20	0.20	0.00
2022	0.20	0.20	0.20	0.20	0.00
2023	0.20	0.20	0.20	0.20	0.00
2024	0.20	0.20	0.20	0.20	0.00
2025	0.20	0.20	0.20	0.20	0.00
2026	0.20	0.20	0.20	0.20	0.00

Table 2A.20b—Projections for AI 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 2014-2026 (Scenario 3), with random variability in future recruitment, based on Model 2.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	22,600	22,600	22,600	22,600	0
2015	20,000	20,000	20,000	20,000	0
2016	18,800	18,800	18,800	18,800	0
2017	19,800	19,800	19,800	19,800	9
2018	21,300	21,700	21,800	22,700	475
2019	21,700	23,300	23,800	27,400	1,883
2020	20,500	23,900	24,700	32,000	3,607
2021	18,900	24,100	24,900	34,200	4,713
2022	16,900	23,700	24,600	34,900	5,702
2023	15,700	23,200	24,200	35,200	6,206
2024	15,300	23,000	23,900	35,900	6,267
2025	15,000	23,000	23,700	34,700	6,128
2026	15,100	22,700	23,600	34,900	5,954

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	31,400	31,400	31,400	31,400	0
2015	26,600	26,600	26,600	26,600	0
2016	24,400	24,400	24,400	24,400	5
2017	25,900	25,900	25,900	26,100	83
2018	28,700	29,200	29,400	30,500	601
2019	29,900	31,700	32,200	36,200	2,086
2020	28,300	32,400	33,400	41,700	4,388
2021	25,300	32,300	33,300	46,200	6,467
2022	22,600	31,700	32,900	47,200	7,808
2023	21,000	31,200	32,500	46,900	8,444
2024	20,300	31,000	32,200	47,800	8,576
2025	20,200	30,700	31,900	47,300	8,374
2026	20,100	30,400	31,600	47,000	8,119

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0.44	0.44	0.44	0.44	0.00
2015	0.44	0.44	0.44	0.44	0.00
2016	0.44	0.44	0.44	0.44	0.00
2017	0.44	0.44	0.44	0.44	0.00
2018	0.44	0.44	0.44	0.44	0.00
2019	0.44	0.44	0.44	0.44	0.00
2020	0.44	0.44	0.44	0.44	0.00
2021	0.44	0.44	0.44	0.44	0.00
2022	0.44	0.44	0.44	0.44	0.00
2023	0.44	0.44	0.44	0.44	0.00
2024	0.44	0.44	0.44	0.44	0.00
2025	0.44	0.44	0.44	0.44	0.00
2026	0.44	0.44	0.44	0.44	0.00

Table 2A.21a—Projections for AI 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 2014-2026 (Scenario 4), with random variability in future recruitment, based on Model 1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	9,510	9,510	9,510	9,510	0
2015	9,560	9,560	9,560	9,560	0
2016	11,500	11,500	11,500	11,500	0
2017	14,400	14,400	14,400	14,400	11
2018	16,300	16,700	16,900	18,000	620
2019	16,200	17,900	18,500	22,700	2,152
2020	15,100	18,500	19,400	26,900	3,864
2021	14,100	19,100	19,900	29,200	4,815
2022	13,400	19,500	20,400	29,700	5,370
2023	13,200	19,700	20,600	30,800	5,700
2024	13,000	19,800	20,700	30,900	5,807
2025	13,000	19,800	20,600	31,200	5,748
2026	12,900	19,700	20,600	31,200	5,652

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	34,200	34,200	34,200	34,200	0
2015	32,900	32,900	32,900	32,900	0
2016	34,500	34,500	34,500	34,500	7
2017	40,100	40,200	40,200	40,500	135
2018	47,100	47,900	48,200	50,100	1,027
2019	51,800	54,700	55,600	62,500	3,599
2020	52,400	58,900	60,900	75,600	7,751
2021	50,300	61,900	64,200	88,200	11,886
2022	47,600	63,800	66,200	94,500	14,921
2023	45,300	64,600	67,400	96,500	16,799
2024	44,600	65,600	68,100	98,800	17,809
2025	44,300	65,500	68,300	100,000	18,139
2026	43,400	65,900	68,300	102,000	18,023

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0.12	0.12	0.12	0.12	0.00
2015	0.12	0.12	0.12	0.12	0.00
2016	0.12	0.12	0.12	0.12	0.00
2017	0.12	0.12	0.12	0.12	0.00
2018	0.12	0.12	0.12	0.12	0.00
2019	0.12	0.12	0.12	0.12	0.00
2020	0.12	0.12	0.12	0.12	0.00
2021	0.12	0.12	0.12	0.12	0.00
2022	0.12	0.12	0.12	0.12	0.00
2023	0.12	0.12	0.12	0.12	0.00
2024	0.12	0.12	0.12	0.12	0.00
2025	0.12	0.12	0.12	0.12	0.00
2026	0.12	0.12	0.12	0.12	0.00

Table 2A.21b—Projections for AI 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 2014-2026 (Scenario 4), with random variability in future recruitment, based on Model 2.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	9,500	9,500	9,500	9,500	0
2015	9,990	9,990	9,990	9,990	0
2016	10,400	10,400	10,400	10,400	0
2017	11,300	11,300	11,300	11,300	4
2018	12,500	12,600	12,700	13,000	185
2019	13,300	14,000	14,200	15,600	765
2020	13,500	15,000	15,400	18,400	1,576
2021	13,300	15,700	16,000	20,500	2,205
2022	12,500	15,800	16,300	21,700	2,909
2023	11,600	15,800	16,300	22,400	3,428
2024	11,200	15,700	16,300	23,200	3,649
2025	10,900	15,800	16,200	23,200	3,705
2026	10,900	15,600	16,100	22,700	3,659

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	32,400	32,400	32,400	32,400	0
2015	32,500	32,500	32,500	32,500	0
2016	33,500	33,500	33,500	33,500	5
2017	36,900	37,000	37,000	37,200	83
2018	41,800	42,300	42,400	43,600	604
2019	45,200	47,200	47,700	51,800	2,159
2020	45,600	50,000	51,200	60,400	4,847
2021	43,600	51,500	53,000	68,600	7,751
2022	40,600	52,200	53,700	72,600	10,054
2023	38,300	52,100	53,900	73,700	11,531
2024	37,100	52,000	53,800	76,400	12,266
2025	36,100	52,300	53,600	77,000	12,399
2026	35,700	51,700	53,300	75,800	12,202

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0.17	0.17	0.17	0.17	0.00
2015	0.17	0.17	0.17	0.17	0.00
2016	0.17	0.17	0.17	0.17	0.00
2017	0.17	0.17	0.17	0.17	0.00
2018	0.17	0.17	0.17	0.17	0.00
2019	0.17	0.17	0.17	0.17	0.00
2020	0.17	0.17	0.17	0.17	0.00
2021	0.17	0.17	0.17	0.17	0.00
2022	0.17	0.17	0.17	0.17	0.00
2023	0.17	0.17	0.17	0.17	0.00
2024	0.17	0.17	0.17	0.17	0.00
2025	0.17	0.17	0.17	0.17	0.00
2026	0.17	0.17	0.17	0.17	0.00

Table 2A.22a—Projections for AI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = 0 in 2014-2026 (Scenario 5), with random variability in future recruitment, based on Model 1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	0	0	0	0	0
2022	0	0	0	0	0
2023	0	0	0	0	0
2024	0	0	0	0	0
2025	0	0	0	0	0
2026	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	34,900	34,900	34,900	34,900	0
2015	37,100	37,100	37,100	37,100	0
2016	41,900	41,900	41,900	41,900	7
2017	50,900	51,000	51,000	51,300	135
2018	62,400	63,200	63,500	65,400	1,033
2019	72,200	75,200	76,200	83,300	3,748
2020	77,400	84,600	86,900	103,000	8,634
2021	78,300	91,900	94,900	123,000	14,325
2022	77,200	97,400	101,000	138,000	19,207
2023	75,300	101,000	105,000	146,000	22,745
2024	75,000	104,000	108,000	151,000	25,065
2025	74,500	106,000	110,000	157,000	26,338
2026	74,500	108,000	111,000	158,000	26,789

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00
2019	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00
2021	0.00	0.00	0.00	0.00	0.00
2022	0.00	0.00	0.00	0.00	0.00
2023	0.00	0.00	0.00	0.00	0.00
2024	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00
2026	0.00	0.00	0.00	0.00	0.00

Table 2A.22b—Projections for AI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = 0$ in 2014-2026 (Scenario 5), with random variability in future recruitment, based on Model 2.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	0	0	0	0	0
2022	0	0	0	0	0
2023	0	0	0	0	0
2024	0	0	0	0	0
2025	0	0	0	0	0
2026	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	33,100	33,100	33,100	33,100	0
2015	37,000	37,000	37,000	37,000	0
2016	41,500	41,500	41,500	41,600	5
2017	48,200	48,300	48,300	48,400	83
2018	56,200	56,700	56,800	58,000	606
2019	62,900	64,900	65,400	69,600	2,206
2020	66,600	71,300	72,500	82,300	5,164
2021	67,200	76,000	77,700	95,400	8,726
2022	66,100	79,500	81,300	105,000	11,945
2023	64,500	81,600	83,800	110,000	14,445
2024	63,500	83,200	85,500	114,000	16,142
2025	62,900	84,600	86,500	118,000	17,044
2026	62,700	85,000	87,100	119,000	17,343

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00
2019	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00
2021	0.00	0.00	0.00	0.00	0.00
2022	0.00	0.00	0.00	0.00	0.00
2023	0.00	0.00	0.00	0.00	0.00
2024	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00
2026	0.00	0.00	0.00	0.00	0.00

Table 2A.23a—Projections for AI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2014-2026 (Scenario 6), with random variability in future recruitment, based on Model 1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	15,800	15,800	15,800	15,800	0
2015	13,400	13,400	13,400	13,400	0
2016	16,100	16,100	16,100	16,100	4
2017	22,700	22,800	22,800	23,000	102
2018	27,600	29,000	29,500	33,200	1,977
2019	26,200	31,200	32,700	43,600	5,722
2020	21,300	30,400	32,200	49,300	8,923
2021	17,600	29,900	31,300	49,800	10,511
2022	15,300	29,100	30,900	49,800	11,283
2023	14,900	28,900	30,700	51,000	11,596
2024	14,700	28,900	30,400	50,600	11,561
2025	14,600	28,800	30,200	51,000	11,344
2026	14,800	28,700	30,000	50,200	11,152

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	33,800	33,800	33,800	33,800	0
2015	30,200	30,200	30,200	30,200	0
2016	30,800	30,800	30,800	30,800	7
2017	35,000	35,100	35,100	35,300	129
2018	39,300	40,000	40,300	42,100	956
2019	40,200	42,700	43,500	49,400	3,117
2020	37,800	42,900	44,400	56,100	6,086
2021	34,700	42,400	44,200	60,800	8,394
2022	32,100	42,000	44,000	61,600	9,648
2023	31,100	41,800	43,800	61,900	10,215
2024	30,900	41,600	43,600	62,600	10,386
2025	30,700	41,400	43,400	63,600	10,229
2026	30,900	41,400	43,300	63,300	9,938

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0.20	0.20	0.20	0.20	0.00
2015	0.18	0.18	0.18	0.18	0.00
2016	0.18	0.18	0.18	0.18	0.00
2017	0.21	0.21	0.21	0.21	0.00
2018	0.24	0.24	0.24	0.25	0.01
2019	0.24	0.26	0.26	0.28	0.01
2020	0.23	0.26	0.26	0.28	0.02
2021	0.21	0.26	0.25	0.28	0.03
2022	0.19	0.25	0.25	0.28	0.03
2023	0.18	0.25	0.25	0.28	0.03
2024	0.18	0.25	0.25	0.28	0.03
2025	0.18	0.25	0.24	0.28	0.03
2026	0.18	0.25	0.24	0.28	0.03

Table 2A.23b—Projections for AI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2014-2026 (Scenario 6), with random variability in future recruitment, based on Model 2.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	20,700	20,700	20,700	20,700	0
2015	16,600	16,600	16,600	16,600	0
2016	15,700	15,700	15,700	15,700	2
2017	18,200	18,300	18,300	18,400	55
2018	21,700	22,300	22,500	24,000	806
2019	22,300	25,000	25,400	29,900	2,447
2020	19,700	24,800	25,600	33,900	4,413
2021	16,700	24,100	24,700	35,300	5,858
2022	14,100	23,000	23,900	35,800	6,945
2023	13,000	22,300	23,500	36,000	7,365
2024	12,700	22,300	23,200	36,300	7,350
2025	12,700	22,100	23,100	35,200	7,209
2026	12,900	22,100	22,900	35,300	7,032

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	31,500	31,500	31,500	31,500	0
2015	27,600	27,600	27,600	27,600	0
2016	26,600	26,600	26,600	26,600	4
2017	28,800	28,900	28,900	29,000	79
2018	31,900	32,300	32,500	33,500	560
2019	32,700	34,400	34,800	38,500	1,909
2020	30,700	34,200	35,200	43,000	4,004
2021	27,800	33,400	34,600	46,600	5,812
2022	25,400	32,600	34,000	46,700	6,852
2023	24,600	32,200	33,700	46,100	7,268
2024	24,200	32,300	33,500	47,300	7,292
2025	24,200	32,000	33,400	46,800	7,037
2026	24,600	32,000	33,200	46,800	6,771

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0.40	0.40	0.40	0.40	0.00
2015	0.34	0.34	0.34	0.34	0.00
2016	0.33	0.33	0.33	0.33	0.00
2017	0.36	0.36	0.36	0.36	0.00
2018	0.40	0.41	0.41	0.42	0.01
2019	0.41	0.43	0.43	0.45	0.01
2020	0.39	0.43	0.43	0.45	0.02
2021	0.35	0.42	0.41	0.45	0.04
2022	0.31	0.41	0.40	0.45	0.05
2023	0.30	0.41	0.40	0.45	0.05
2024	0.30	0.41	0.40	0.45	0.05
2025	0.30	0.40	0.40	0.45	0.05
2026	0.30	0.40	0.40	0.45	0.05

Table 2A.24a—Projections for AI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2014-2015 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment, based on Model 1.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	13,500	13,500	13,500	13,500	0
2015	12,000	12,000	12,000	12,000	0
2016	17,200	17,200	17,200	17,200	4
2017	23,500	23,500	23,600	23,700	103
2018	28,000	29,300	29,900	33,600	1,986
2019	26,200	31,200	32,700	43,600	5,703
2020	21,300	30,400	32,200	49,300	8,923
2021	17,500	29,900	31,300	49,800	10,515
2022	15,300	29,100	30,900	49,800	11,286
2023	14,800	28,900	30,700	51,000	11,598
2024	14,700	28,900	30,400	50,600	11,561
2025	14,600	28,800	30,200	51,000	11,344
2026	14,800	28,700	30,000	50,200	11,152

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	33,900	33,900	33,900	33,900	0
2015	31,200	31,200	31,200	31,200	0
2016	31,900	32,000	32,000	32,000	7
2017	35,700	35,800	35,800	36,100	129
2018	39,700	40,400	40,600	42,400	955
2019	40,300	42,800	43,600	49,500	3,116
2020	37,800	42,900	44,400	56,100	6,089
2021	34,600	42,400	44,200	60,700	8,396
2022	32,100	42,000	43,900	61,600	9,647
2023	31,100	41,800	43,800	61,900	10,214
2024	30,900	41,600	43,600	62,500	10,384
2025	30,700	41,400	43,400	63,600	10,228
2026	30,900	41,400	43,300	63,300	9,937

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0.17	0.17	0.17	0.17	0.00
2015	0.15	0.15	0.15	0.15	0.00
2016	0.19	0.19	0.19	0.19	0.00
2017	0.21	0.21	0.21	0.22	0.00
2018	0.24	0.24	0.24	0.26	0.01
2019	0.24	0.26	0.26	0.28	0.01
2020	0.23	0.26	0.26	0.28	0.02
2021	0.21	0.26	0.25	0.28	0.03
2022	0.19	0.25	0.25	0.28	0.03
2023	0.18	0.25	0.25	0.28	0.03
2024	0.18	0.25	0.25	0.28	0.03
2025	0.18	0.25	0.24	0.28	0.03
2026	0.18	0.25	0.24	0.28	0.03

Table 2A.24b—Projections for AI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2014-2015 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment, based on Model 2.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	17,400	17,400	17,400	17,400	0
2015	15,200	15,200	15,200	15,200	0
2016	17,600	17,600	17,600	17,600	3
2017	19,200	19,200	19,200	19,300	56
2018	22,000	22,700	22,900	24,400	810
2019	22,400	25,000	25,500	29,900	2,437
2020	19,700	24,800	25,500	33,800	4,419
2021	16,700	24,100	24,700	35,300	5,862
2022	14,000	23,000	23,900	35,800	6,946
2023	13,000	22,300	23,400	36,000	7,365
2024	12,700	22,300	23,200	36,300	7,350
2025	12,700	22,100	23,100	35,200	7,208
2026	12,900	22,100	22,900	35,300	7,031

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	31,800	31,800	31,800	31,800	0
2015	29,000	29,000	29,000	29,000	0
2016	28,100	28,100	28,100	28,100	4
2017	29,600	29,600	29,600	29,800	79
2018	32,100	32,600	32,700	33,800	560
2019	32,700	34,400	34,900	38,500	1,908
2020	30,700	34,200	35,200	43,000	4,006
2021	27,700	33,400	34,600	46,600	5,811
2022	25,400	32,600	34,000	46,700	6,850
2023	24,600	32,200	33,700	46,100	7,267
2024	24,200	32,300	33,500	47,300	7,291
2025	24,200	32,000	33,400	46,800	7,037
2026	24,600	32,000	33,200	46,800	6,771

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2014	0.33	0.33	0.33	0.33	0.00
2015	0.30	0.30	0.30	0.30	0.00
2016	0.35	0.35	0.35	0.35	0.00
2017	0.37	0.37	0.37	0.37	0.00
2018	0.40	0.41	0.41	0.43	0.01
2019	0.41	0.43	0.44	0.45	0.01
2020	0.39	0.43	0.43	0.45	0.02
2021	0.35	0.42	0.41	0.45	0.04
2022	0.31	0.41	0.40	0.45	0.05
2023	0.30	0.41	0.40	0.45	0.05
2024	0.30	0.41	0.40	0.45	0.05
2025	0.30	0.40	0.40	0.45	0.05
2026	0.30	0.40	0.40	0.45	0.05

Table 2A.25—Incidental catch (t) of FMP species, other than squid and members of the former "other species" complex, taken in the AI fisheries for Pacific cod, 2003-2012. **This table has not been updated since the 2012 assessment.**

Trawl fishery:

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

Longline and pot fishery:

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

Table 2A.26—Incidental catch (t) of squid and members of the former “other species” complex taken in the AI fisheries for Pacific cod, 2003-2012. **This table has not been updated since the 2012 assessment.**

Trawl fishery:

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

Longline and pot fishery:

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

Table 2A.27—Incidental catch (t) of non-target species groups by AI Pacific cod fisheries, 2003-2012, sorted in order of descending average. **This table has not been updated since the 2012 assessment.**

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

Table 2A.28—Catches of prohibited species by AI fisheries for Pacific cod, 2003-2012. Halibut and herring are in t, salmon and crab are in number of individuals. **This table has not been updated since the 2012 assessment.**

Trawl fishery:

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

Longline and pot fishery:

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

Table 2A.29—Halibut mortality (t) resulting from AI Pacific cod fisheries, 2003-2012. **This table has not been updated since the 2012 assessment.**

Year	Trawl	Long.+pot	Total
2003	46	13	58
2004	29	31	60
2005	56	22	79
2006	57	25	82
2007	66	82	148
2008	18	70	88
2009	29	71	101
2010	15	64	79
2011	17	19	35
2012	37	19	56

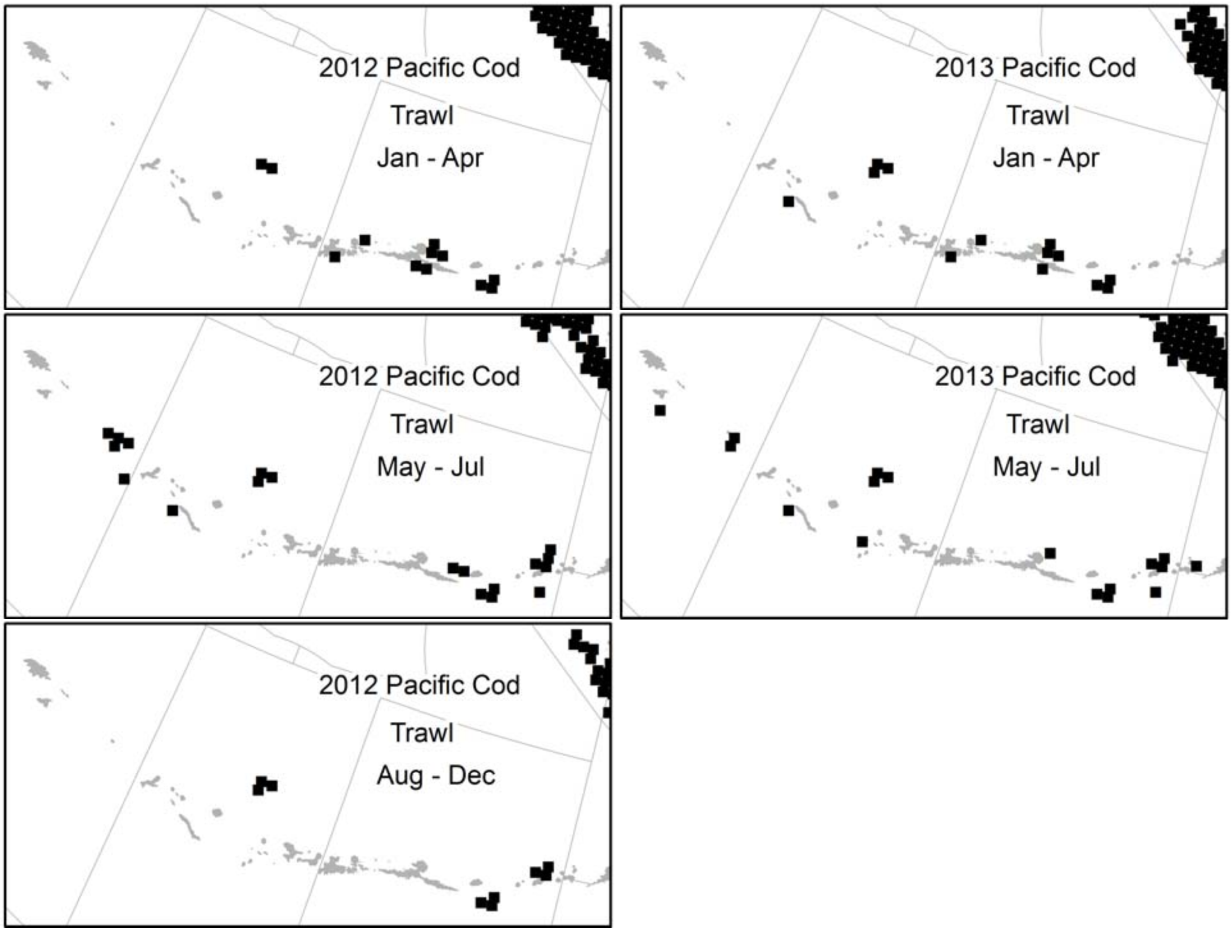


Figure 2A.1a—AI maps showing each 400 square km cell with **trawl hauls** containing Pacific cod from at least 3 distinct vessels **by season** in 2012-2013, overlaid against NMFS 3-digit statistical areas.

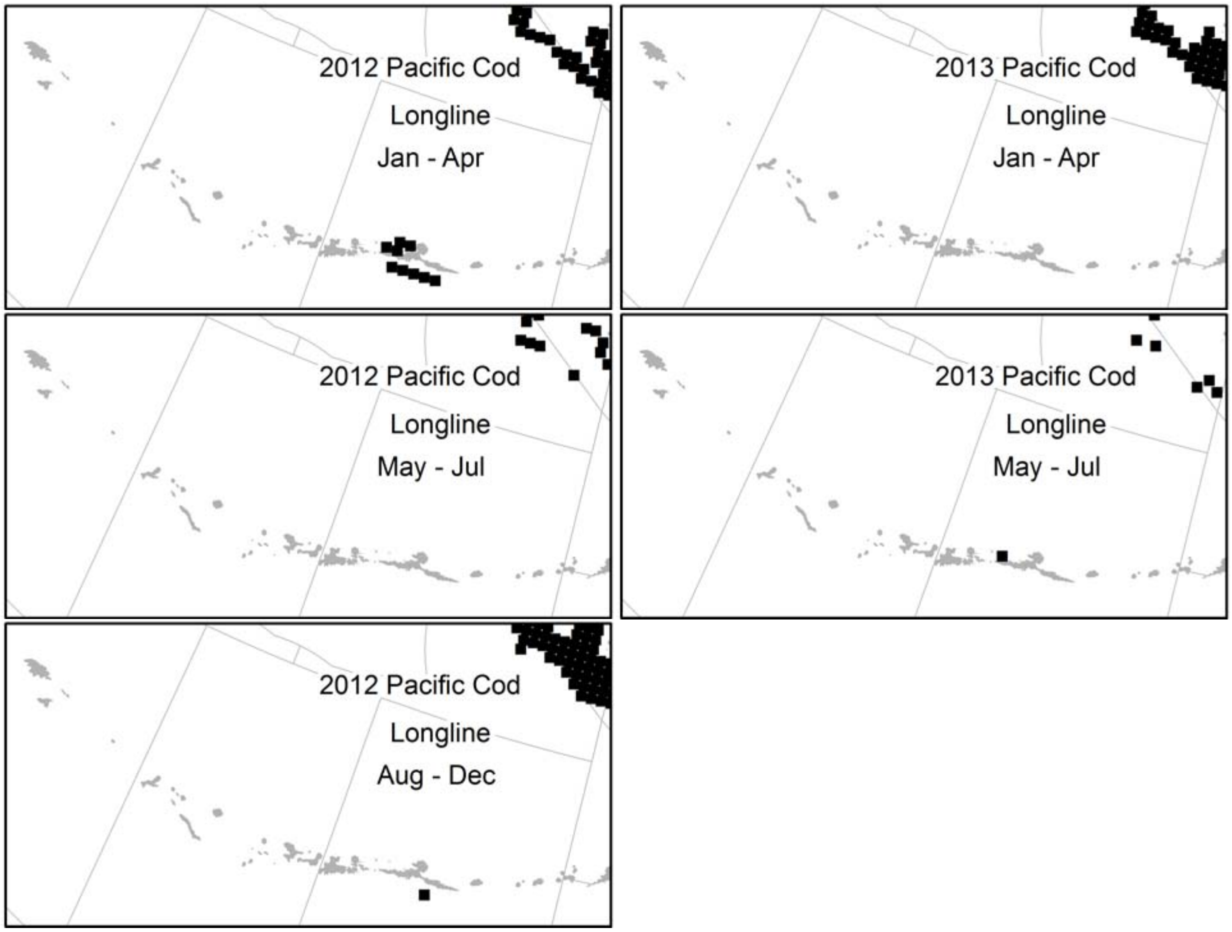


Figure 2A.1b—AI maps showing each 400 square km cell with **longline sets** containing Pacific cod from at least 3 distinct vessels **by season** in 2012-2013, overlaid against NMFS 3-digit statistical areas.

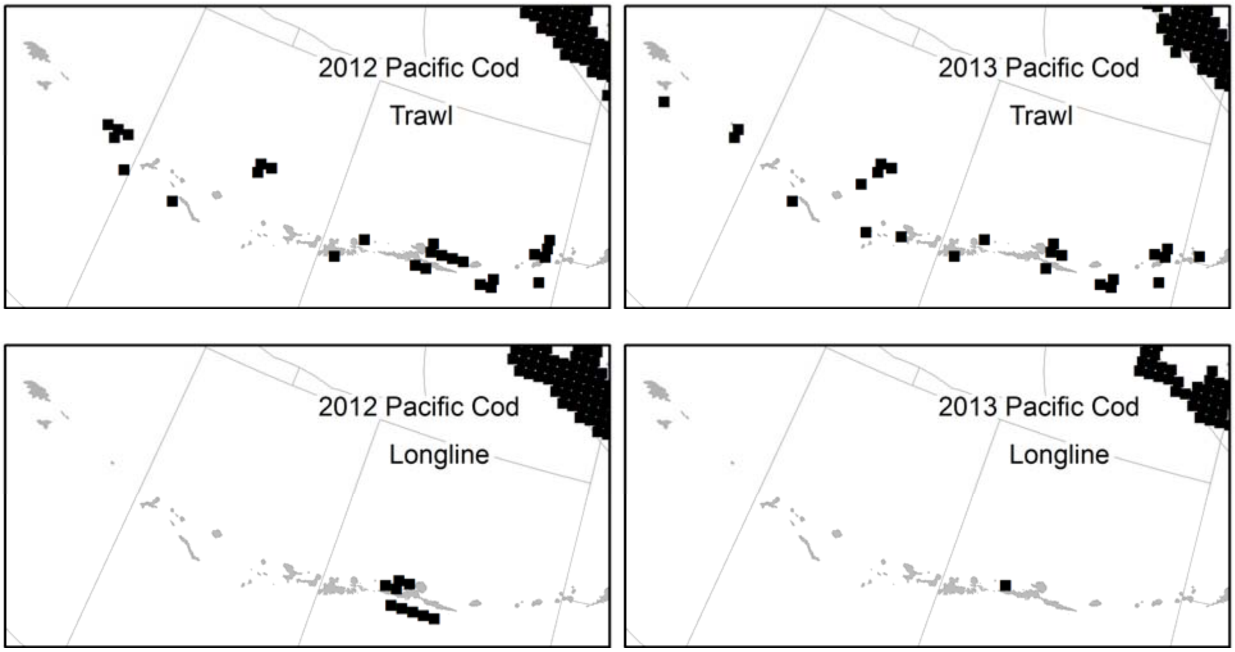
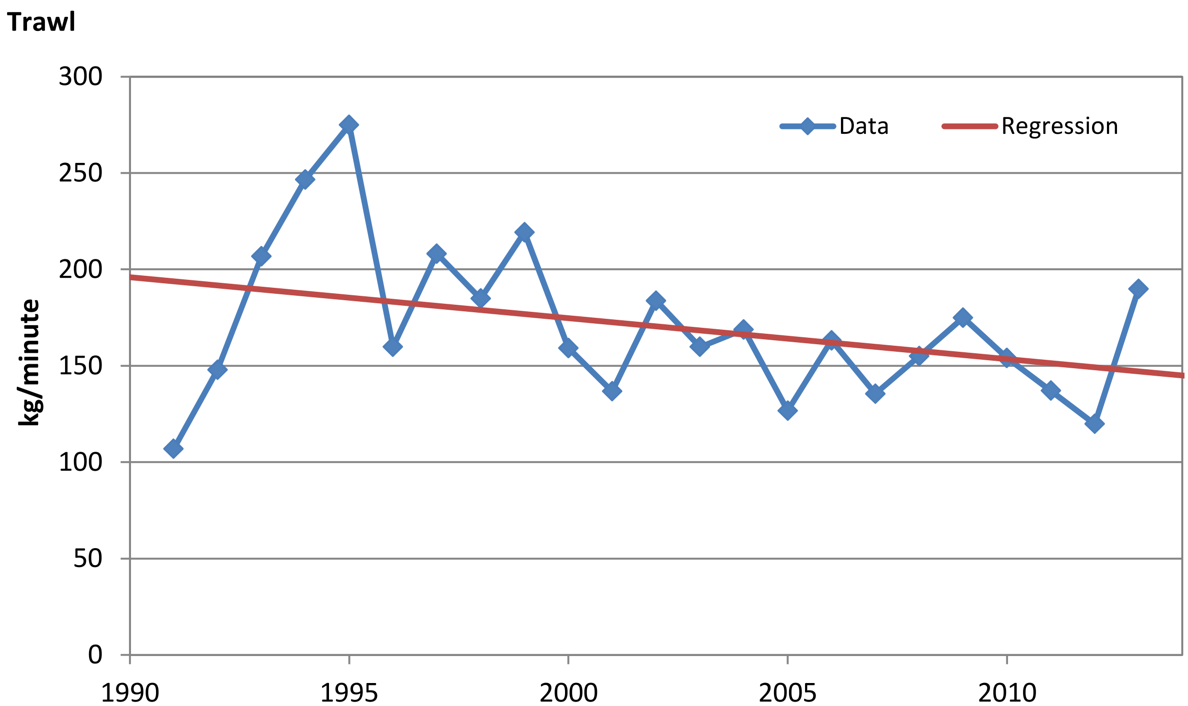


Figure 2A.2—AI maps showing each 400 square km cell with hauls/sets containing Pacific cod from at least 3 distinct vessels **by gear** in 2011-2012, overlaid against NMFS 3-digit statistical areas.



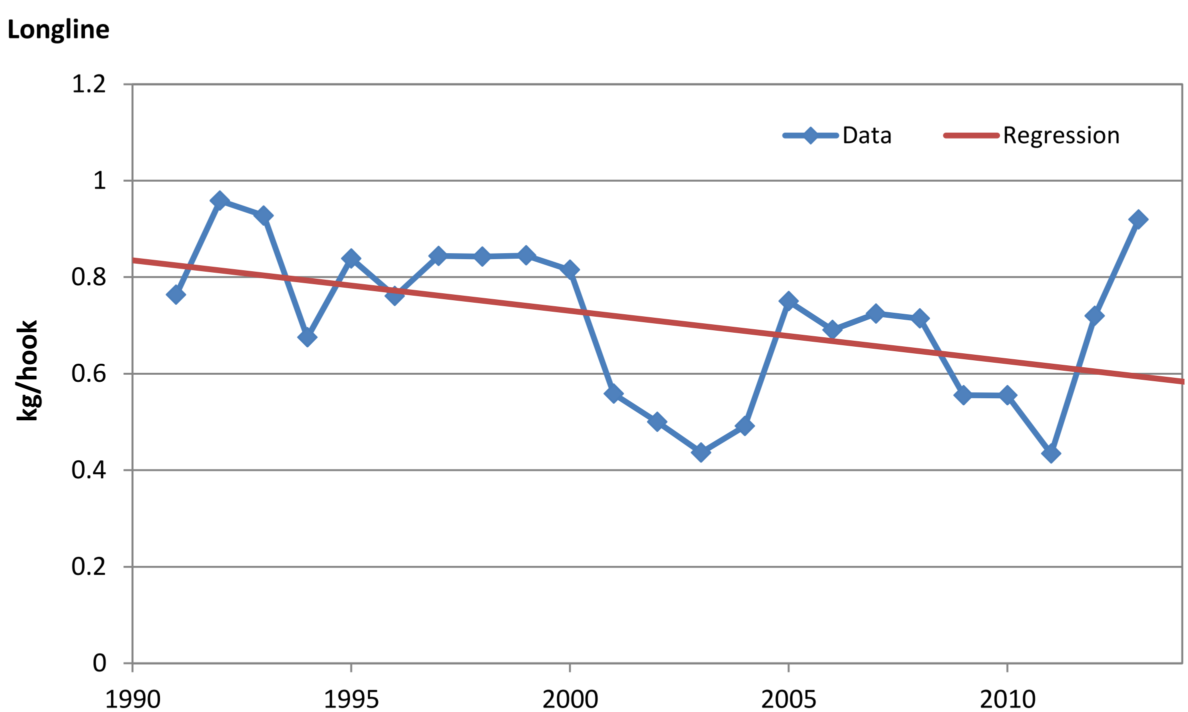


Figure 2A.3—Catch per unit effort for the trawl and longline fisheries, 1991-2013.

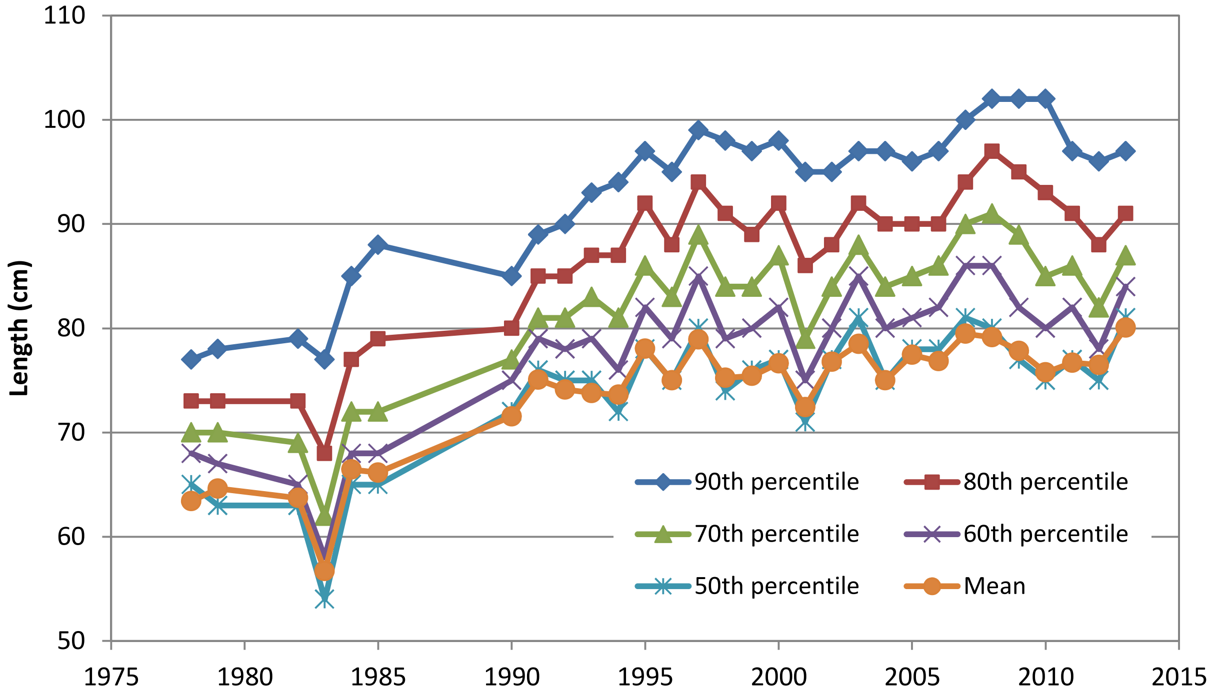


Figure 2A.4—Time series of the mean and five percentiles from the fishery size composition data.

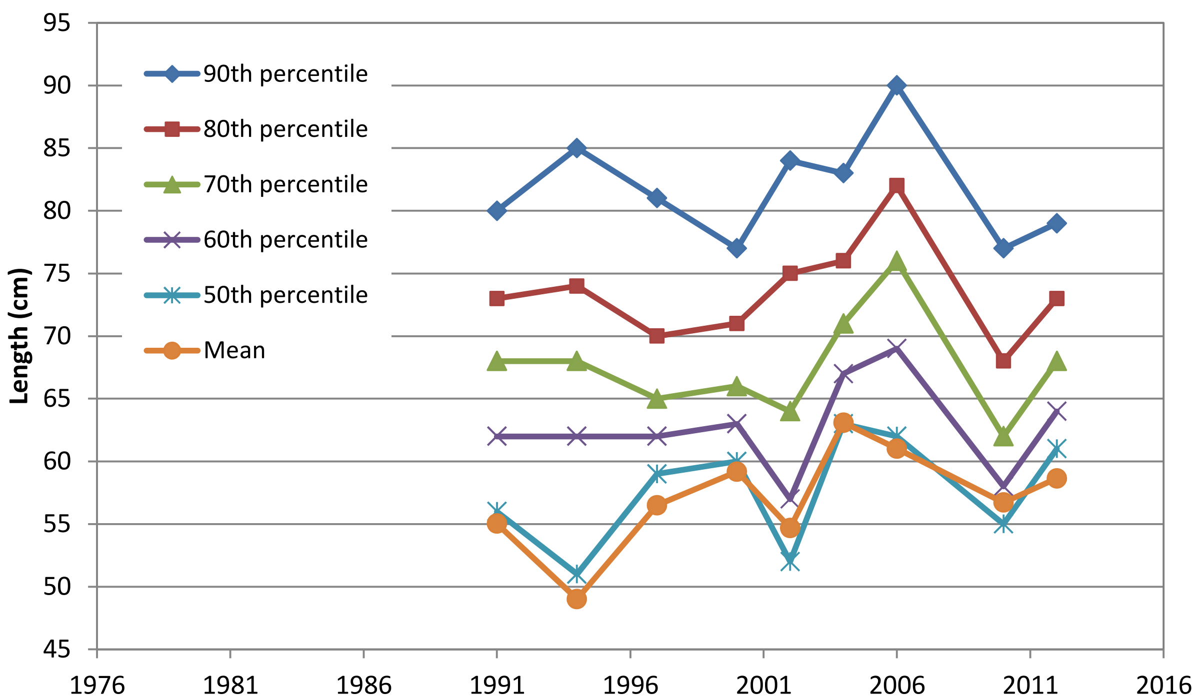


Figure 2A.5—Time series of the mean and five percentiles from the survey size composition data.

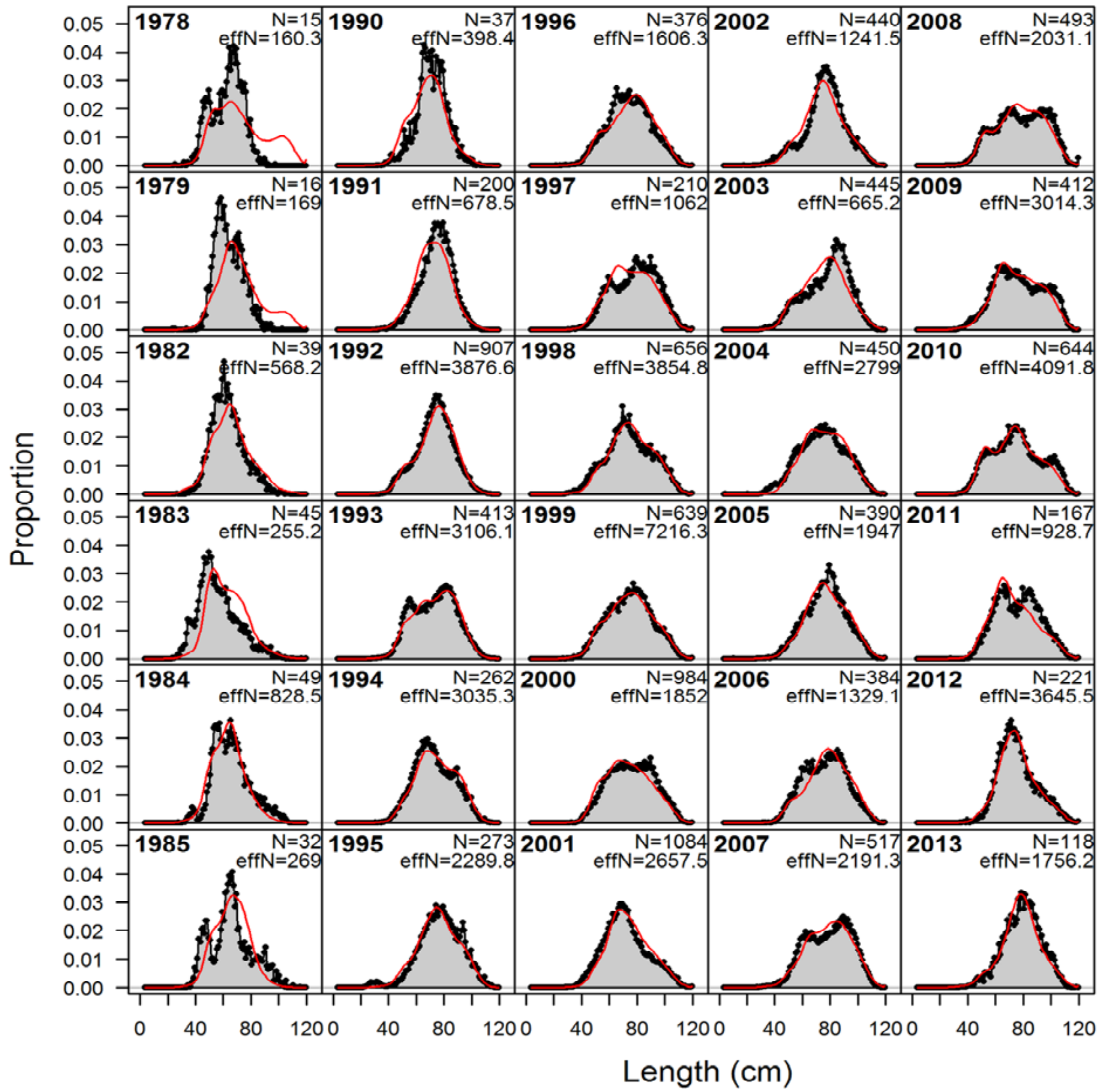


Figure 2A.6a—Fit to fishery size composition data obtained by Model 1 (grey = observed, red = estimated).

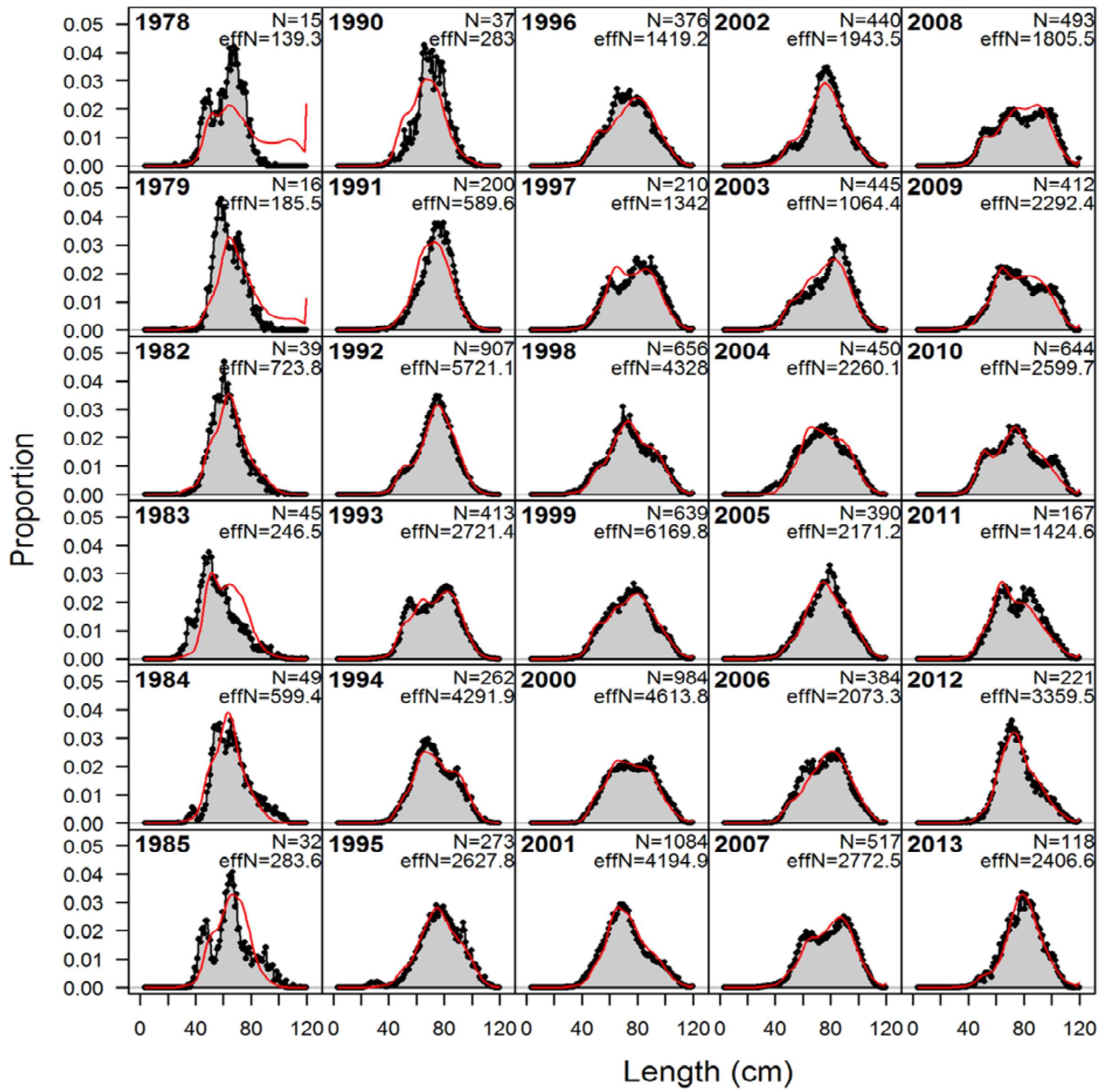


Figure 2A.6b—Fit to fishery size composition data obtained by Model 2 (grey = observed, red = estimated).

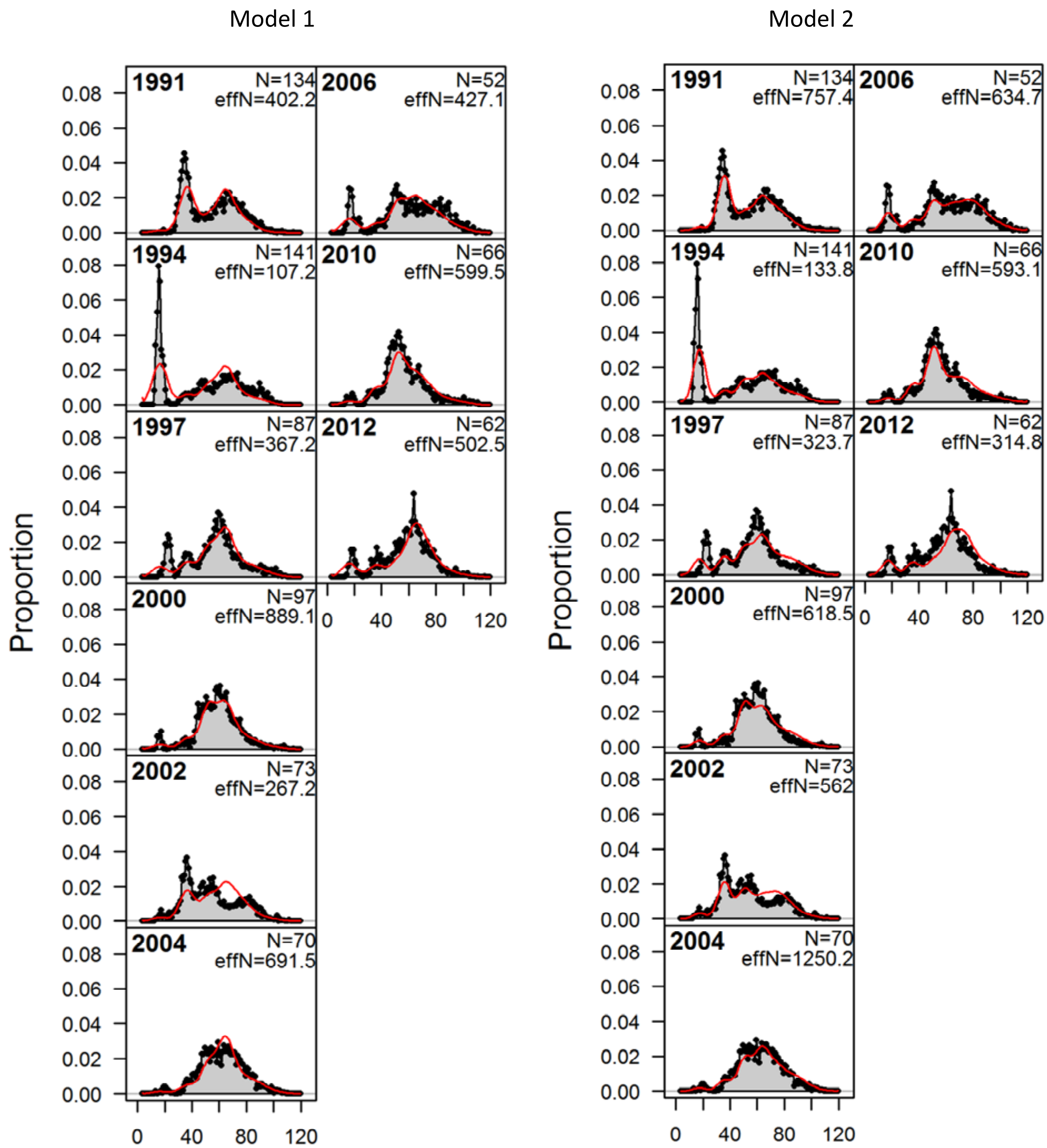
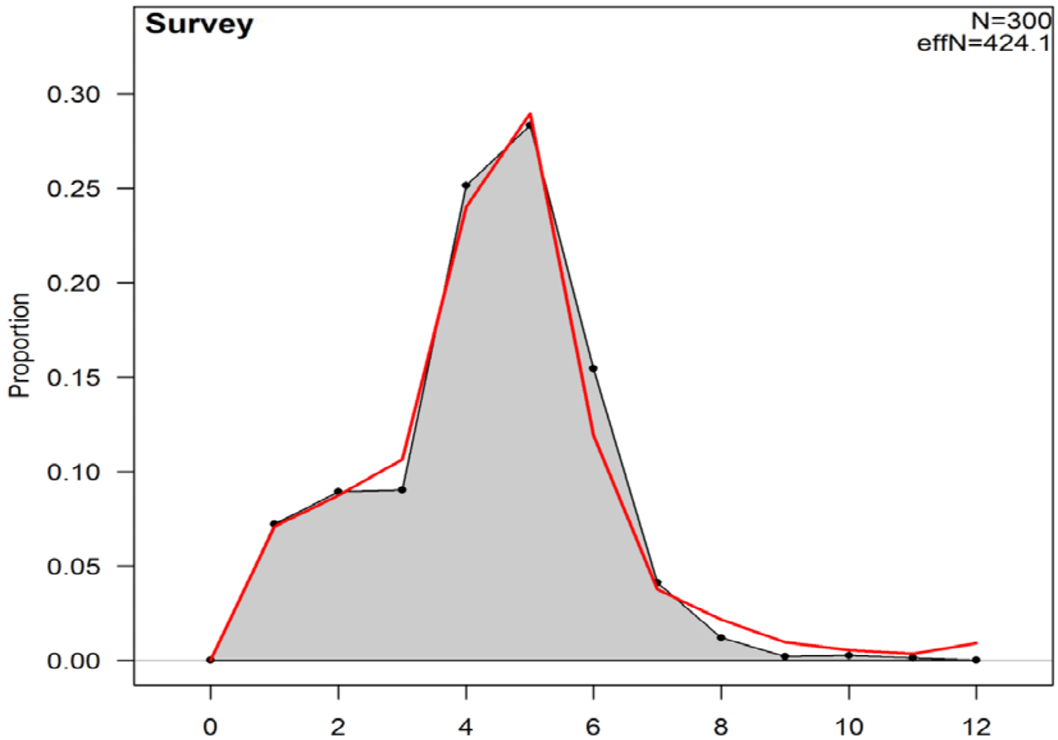


Figure 2A.7—Fits to survey size composition data obtained by the models (grey = observed, red = estimated).

Model 1



Model 2

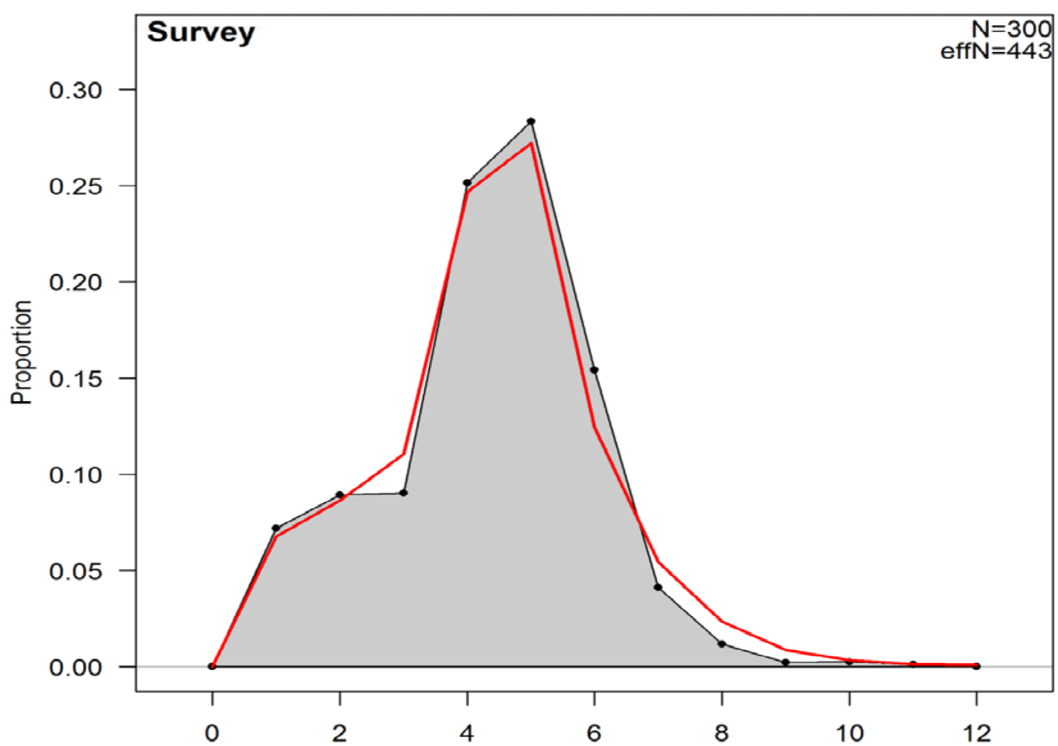


Figure 2A.8—Fits to age composition data obtained by the models (grey = observed, red = estimated).

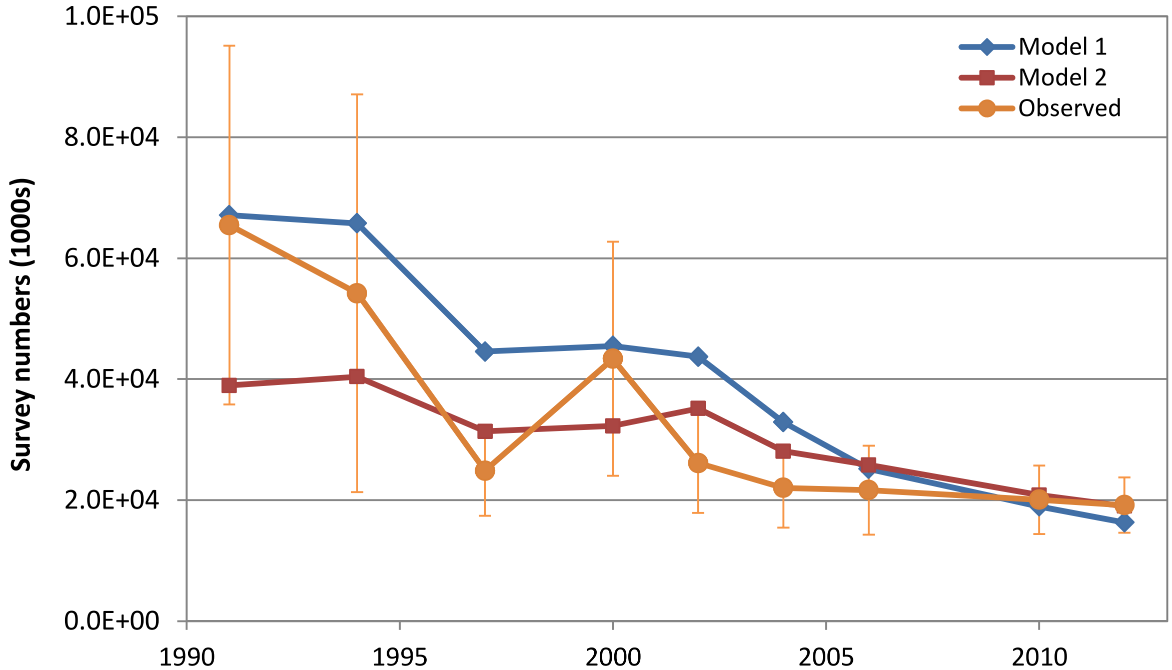


Figure 2A.9a—Tier 3 model fits to the survey abundance time series, with 95% confidence intervals for the observations.

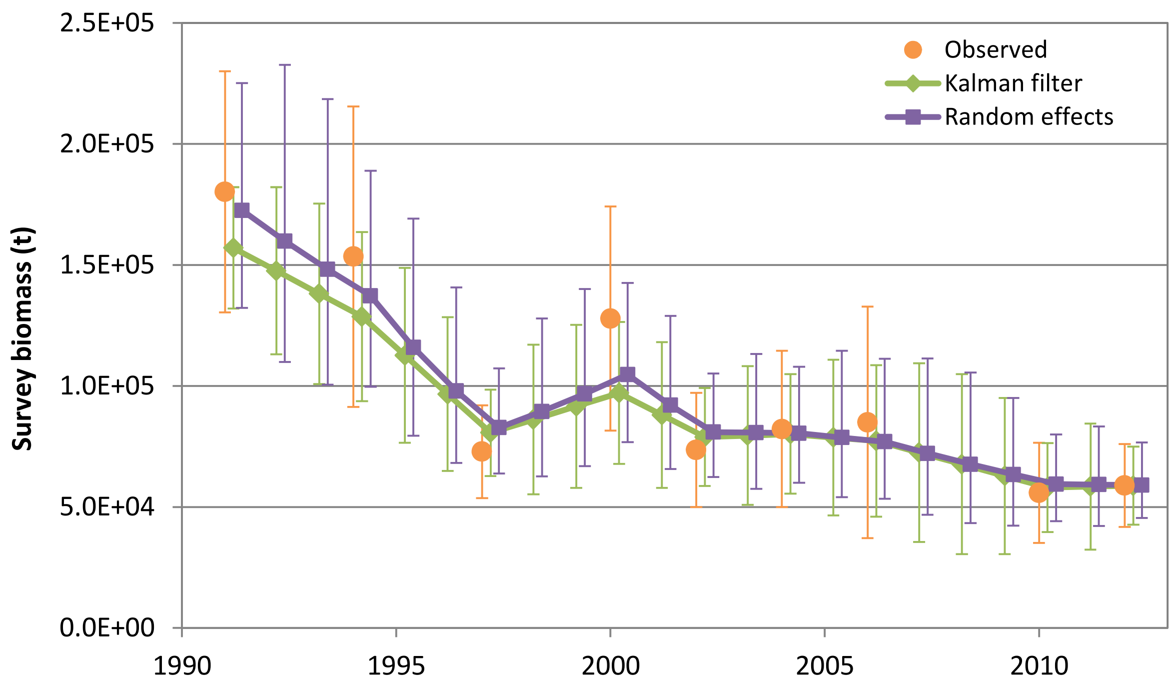


Figure 2A.9b—Tier 5 model fits to the survey biomass time series, with 95% confidence intervals for the observations and estimates. Horizontal axis values have been offset to avoid over-plotting.

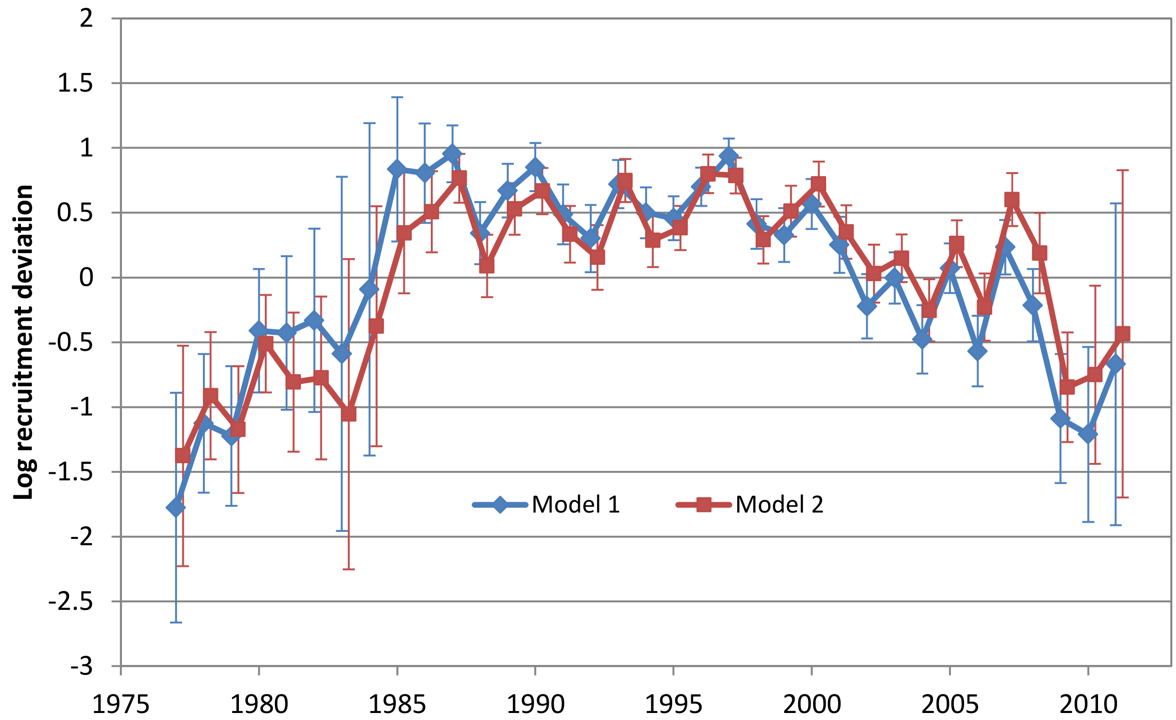


Figure 2A.10—Time series of estimated log recruitment deviations from the models, with 95% confidence intervals (horizontal axis values have been offset slightly to prevent over-plotting).

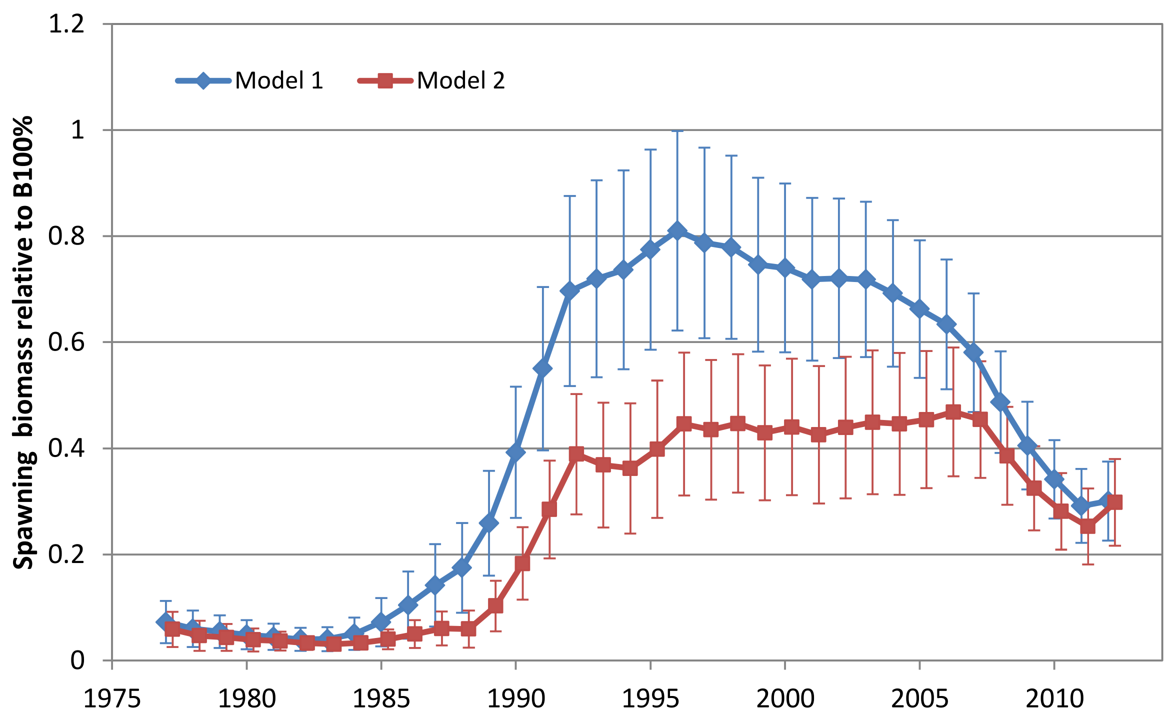
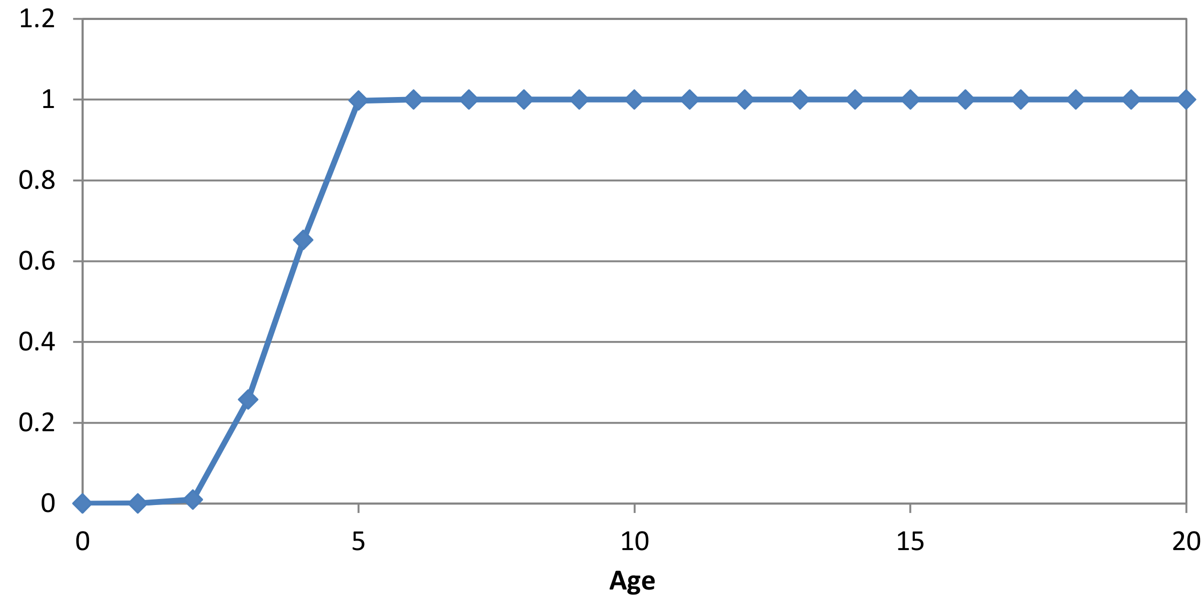


Figure 2A.11—Time series of spawning biomass relative to $B_{100\%}$ as estimated by the models (horizontal axis values have been offset slightly to prevent over-plotting).

Model 1



Model 2

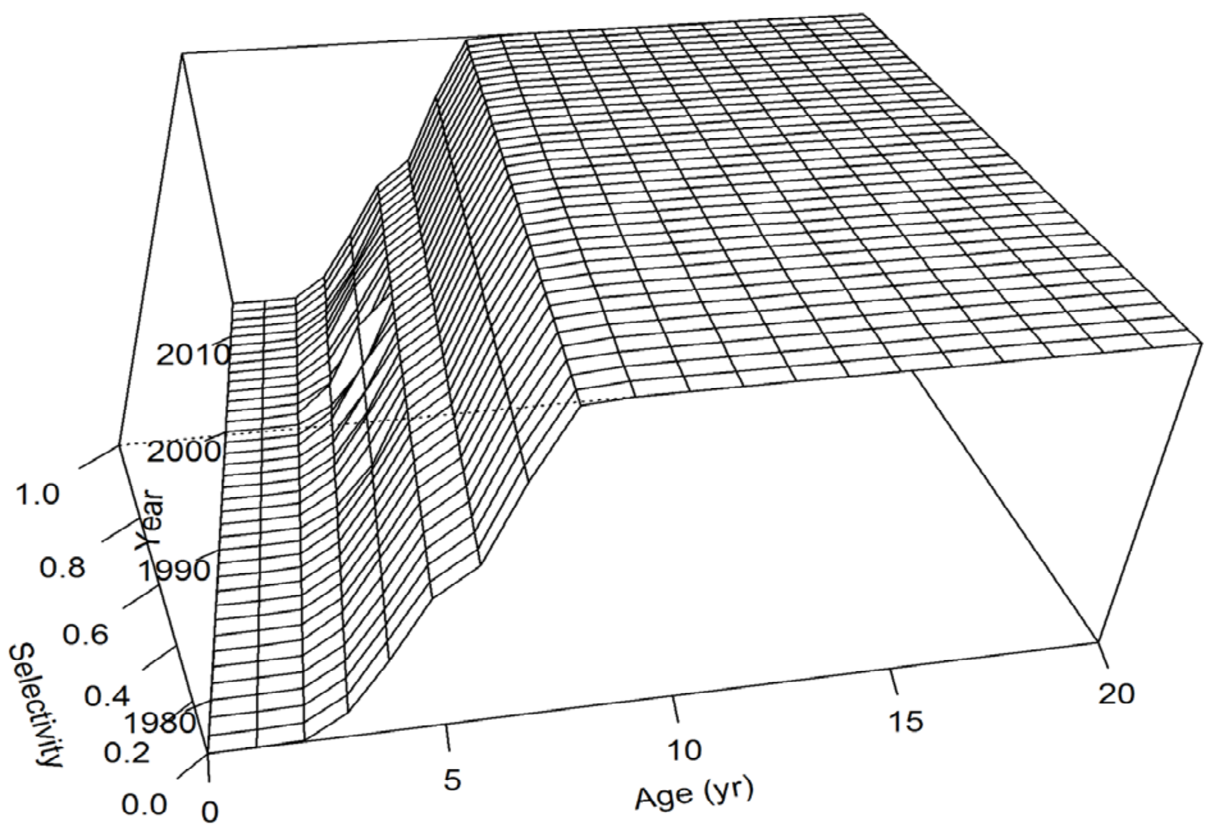
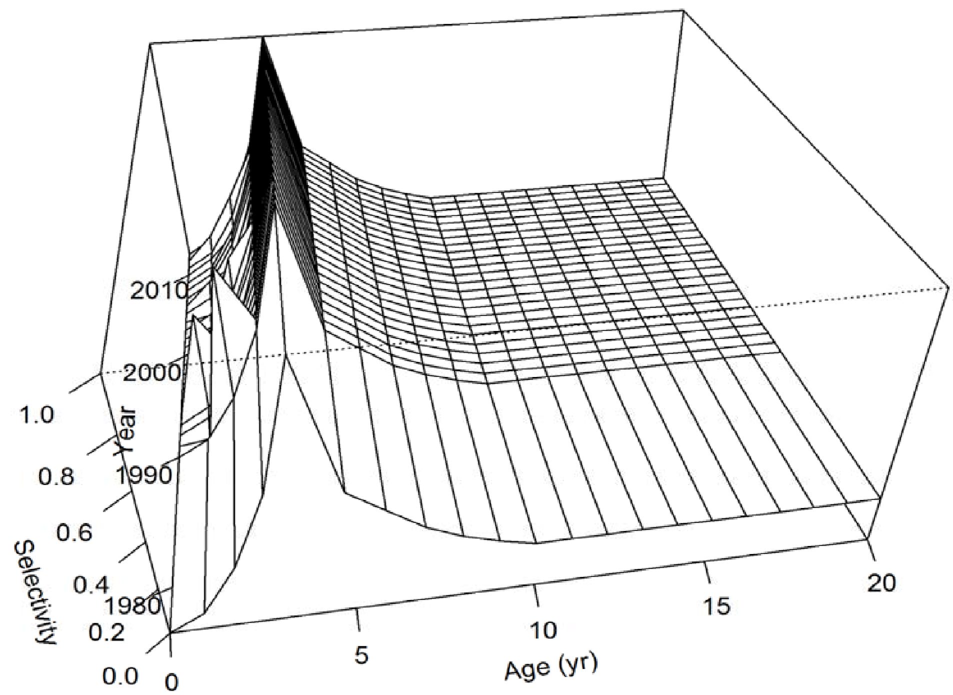


Figure 2A.12—Fishery selectivity at length (cm) as estimated by the models. "*Dev*" parameters affect the ascending limb in Model 2 only.

Model 1



Model 2

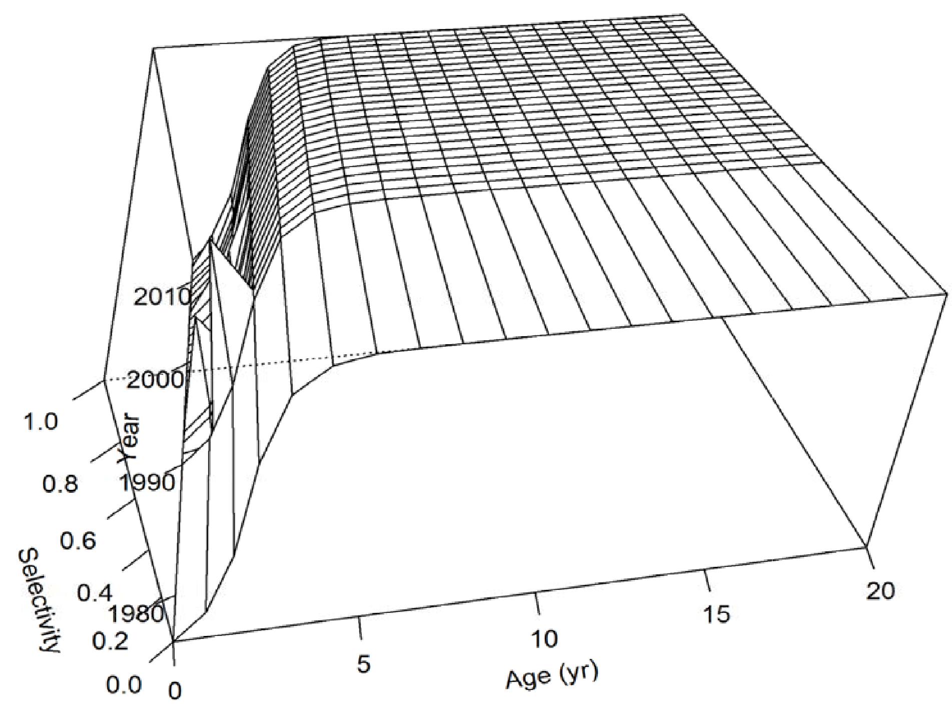


Figure 2A.13—Trawl survey selectivity at age as estimated by the models. "*Dev*" parameters affect the ascending limb in both models.

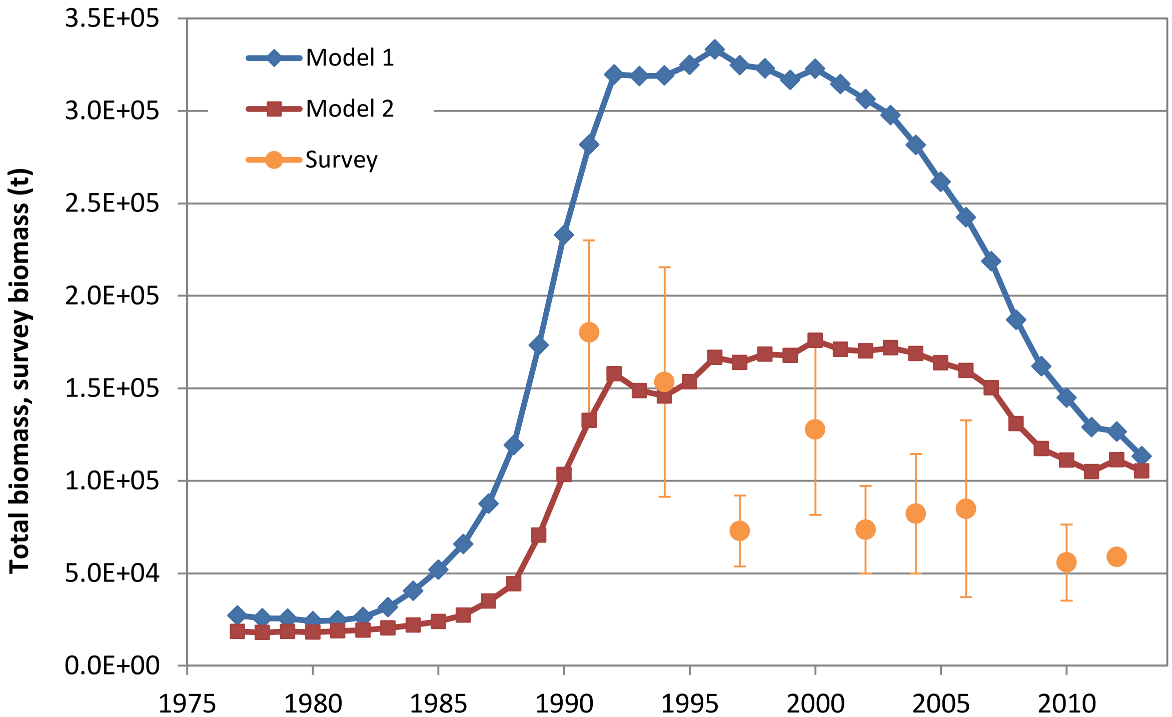


Figure 2A.14a—Time series of age 0+ biomass as estimated by the models. Survey biomass is shown for comparison.

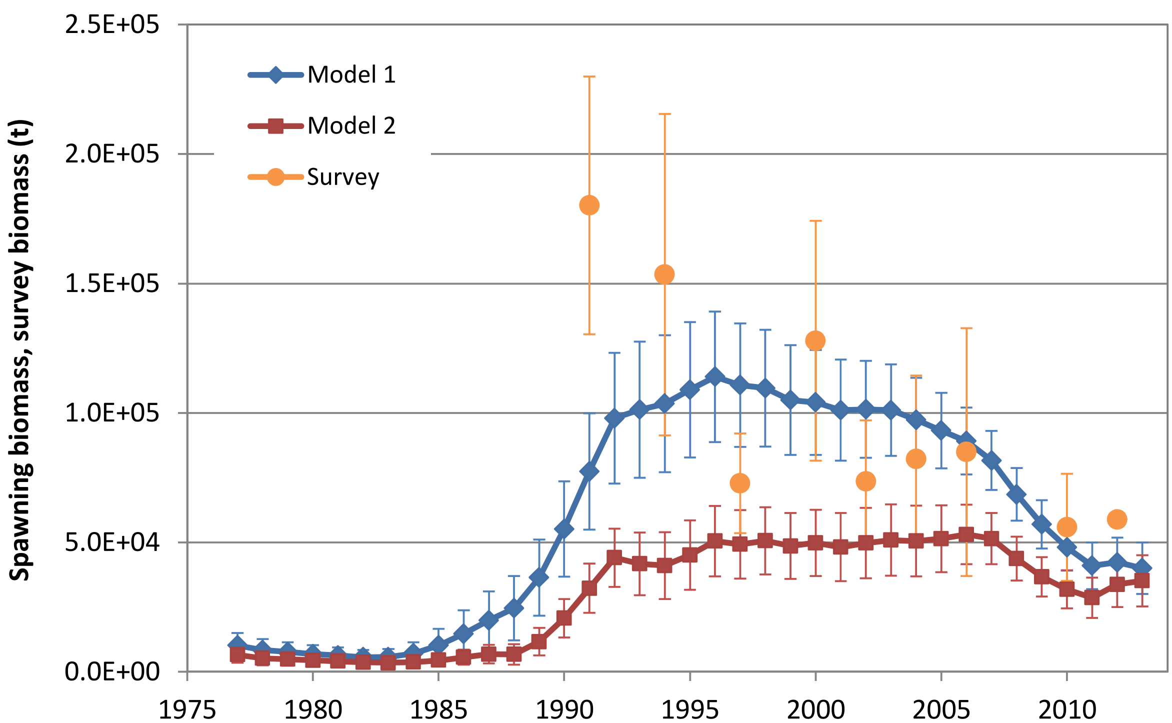


Figure 2A.14b—Time series of female spawning biomass as estimated by the models, with 95% confidence intervals. Survey biomass is shown for comparison.

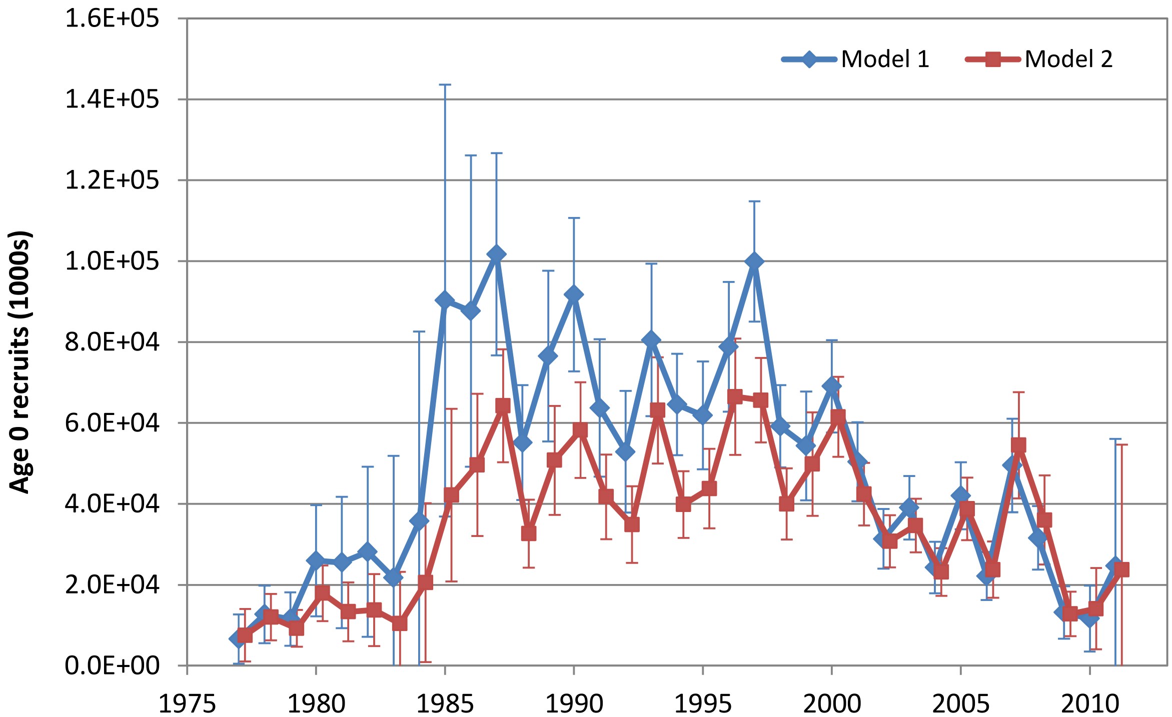


Figure 2A.15—Time series of recruitment at age 0 as estimated by the stock assessment model (horizontal axis values have been offset slightly to prevent over-plotting).

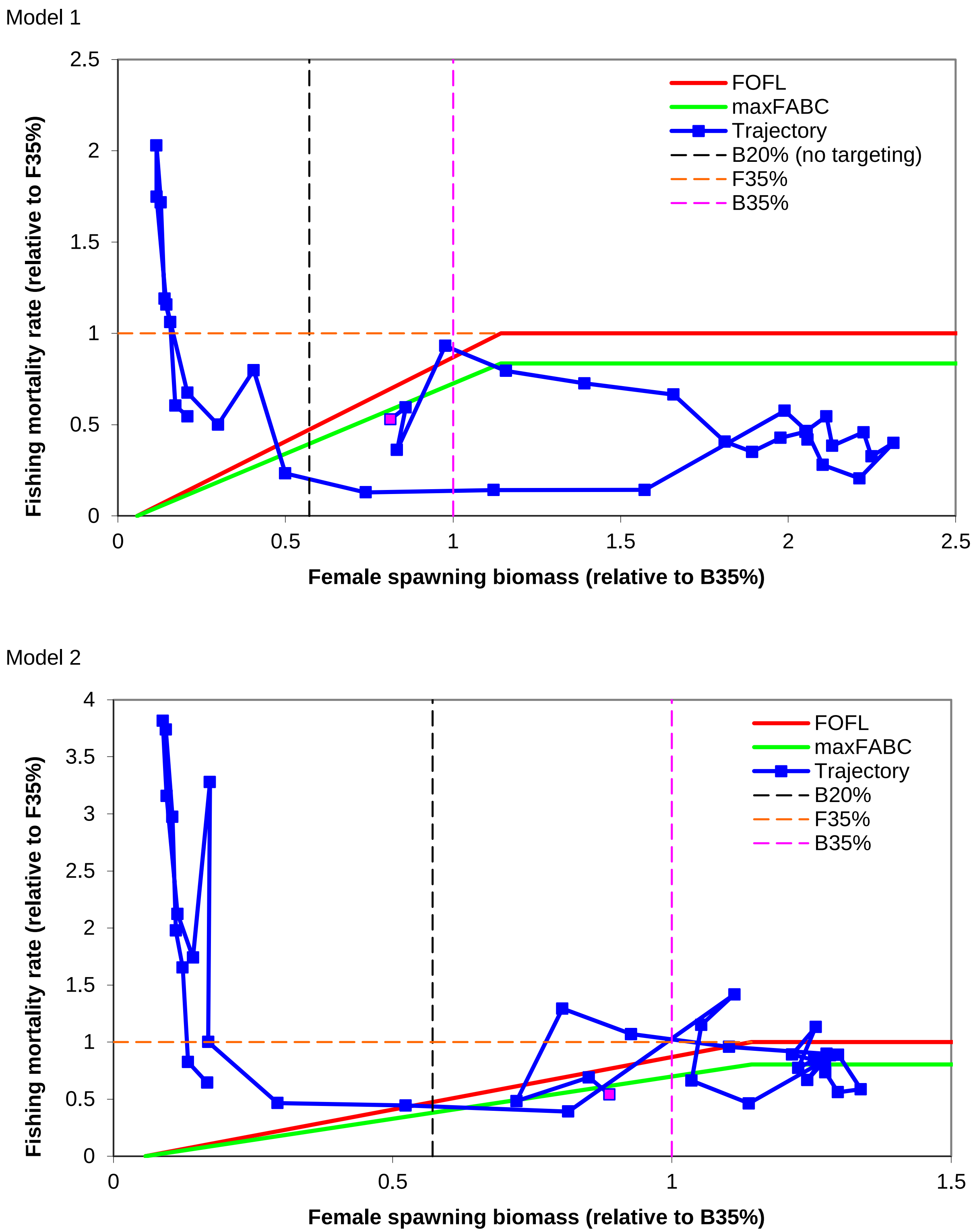


Figure 2A.16—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by the models, 1977-present (magenta square = 2013). Note that the upper limits of the axes in the two panels are different.

Appendix 2A.1:

Preliminary assessment of the Pacific cod stock in the Aleutian Islands

Introduction

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

The importance of recognizing stock distinctions in management of gadids in general has received attention in recent years (e.g., Fu and Fanning 2004, Hutchinson 2008). In particular, several white papers and a stock structure report provide various lines of evidence suggesting that Pacific cod in the EBS and AI should be viewed as separate stocks. Recent studies provide evidence for genetic distinctiveness and lack of gene flow between the Aleutian Islands and Eastern Bering Sea (e.g., Canino et al. (2005), Cunningham et al. (2009), Canino et al. (2010), Spies (2012)).

In light of this evidence, in 2010 the SSC requested that a separate assessment be prepared for Pacific cod in the AI. In response, the 2011 assessment contained a Tier 5 assessment of Pacific cod in the AI (Thompson and Lauth 2011). However, in December 2011, the SSC determined that it would be preferable to wait until an age-structured model was accepted for AI Pacific cod before splitting the BSAI harvest specifications. In response, the 2012 assessment contained a set of alternative age-structured models for AI Pacific cod (Thompson and Lauth 2012). In December 2012, the SSC did not accept any of these models for use in setting harvest specifications. Although the SSC did not split the harvest specifications at that time, it determined that it would begin splitting the harvest specifications in December 2013, regardless of whether an age-structured model is accepted at that time.

Responses to SSC and Plan Team Comments on Assessments in General

SSC minutes (June, 2012)

SSC1: “We note that stock assessment authors are free to develop and bring forward an alternative model or models in both the preliminary and final assessment.” All of the models in this preliminary assessment are new models developed by the authors (see also comment JPT1).

SSC minutes (December, 2012)

SSC2: “The SSC recommends that the authors consider whether it is possible to estimate M with at least two significant digits in all future stock assessments to increase validity of the estimated OFL.” The natural mortality rate M is reported to two significant digits in this preliminary assessment.

Joint Plan Team minutes (May, 2013)

JPT1: “For the last two years, the Teams have reserved the right to request that the author’s preferred model be excluded from the final assessment. Upon further reflection and consideration of the SSC’s

June 2012 minute stating that authors are free to include their own models in both the preliminary and final assessments, the Teams decided to abandon their previous policy. The Teams recommend that authors feel free to include their own models in both the preliminary and final assessments." See comment SSC1.

Responses to SSC and Plan Team Comments on Aleutian Islands Assessments in General

SSC minutes (December, 2012)

SSC3: "The SSC requests that all assessment authors of AI species evaluate AI survey information to ensure that the same standardized survey time series is used." See comments SSC4 and SSC5.

SSC minutes (April, 2013)

SSC4: "Aleutian Islands groundfish stock assessment authors asked for a clarification from the SSC about its December 2012 recommendation for AI assessments to use the same set of years in the AI survey time series. The SSC was asked to comment on whether it would be acceptable for assessment authors to deviate from this recommendation if there was a strong rationale for doing so. The SSC had a brief discussion on this matter and determined that it would be acceptable for assessments to use different sets of years in the AI survey time series if this was accompanied by a scientific rationale for doing so." The authors of all AI assessments containing age-structured models discussed the SSC request for standardization of the years included in the time series. These authors noted the following difficulties with the pre-1991 surveys:

- The dimensions and configurations of the nets used in the pre-1991 surveys varied among nations and years.
- Data from the Japanese vessels were excluded from the 1980 biomass estimate, but the two U.S. vessels in that year used two different nets: one used an Eastern trawl, the other a Noreastern trawl very similar to the one used in recent surveys (high rise Polynoreastern).
- In 1983 and 1986, data from both Japanese and U.S. vessels are used in the estimates, but the Japanese used different gears in those two years.
- For both 1983 and 1986, the U.S. vessels used the Noreastern net.

Because of these difficulties, the authors recommended omitting the pre-1991 survey data from the standard time series (see also comments SSC3 and SSC5).

SSC minutes (June, 2013)

SSC5: "The SSC agrees with the Team and the AI authors that pre-1991 survey data should be omitted from the assessment." Pre-1991 survey data are omitted from this preliminary assessment (see also comments SSC3 and SSC4).

Responses to SSC and Plan Team Comments Specific to Aleutian Islands Pacific Cod

SSC minutes (December, 2012)

SSC6: "The SSC encourages further model development but had no specific suggestions beyond those identified in Plan Team discussions and the possibility of obtaining additional age composition data from archived otoliths." Age data from the entire AI bottom trawl survey time series were requested this year. Data from the 2006, 2010, and 2012 surveys were identified as "mission critical," and were originally scheduled to be available in time for this year's final assessment. However, an unexpected loss of personnel in the Alaska Fisheries Science Center's Age and Growth Program has resulted in the removal of the 2006 and 2010 collections from this list. Age data from the 2012 AI bottom trawl are still scheduled to be available in time for use in this year's final assessment.

Joint Plan Team minutes (May, 2013)

JPT2: **"**For the preliminary AI assessment, the Teams recommend that the author have discretion over any and all models to be included. The Teams noted that no model for this stock has been accepted by the SSC and that a significant amount of development and analysis still needs to occur before a model for this stock can be recommended with confidence. The Teams understand that the SSC will recommend separate EBS and AI harvest specifications for 2014 regardless of whether a model is accepted this year. Although the Teams are not recommending any specific models for the AI stock, one member suggested that the author might consider starting the model in 1977 but omitting survey data prior to 1991, as was done in last year's AI Model 4." The authors have used their best judgment in arriving at a set of alternative models for this preliminary assessment, in the hope that these will provide a sound basis for Team and SSC recommendations regarding a set of models to be included in the final assessment (see also comment SSC7). As noted under comments SSC4 and SSC5, survey data prior to 1991 have been omitted from the models.

SSC minutes (June, 2013)

SSC7: "For the preliminary AI assessment, the SSC has no additional suggestions at this time and is looking forward to a revised and updated assessment model." See response to comment JPT2.

SSC8: "To improve biomass estimates in the Aleutians, we further encourage an examination of existing longline survey data (sablefish and IPHC) to determine if a cooperative, cost-effective longline survey could be developed in the Aleutians and to determine if these data should be incorporated into the AI Assessment." Existing longline survey data were not examined for use in this preliminary assessment, in part because there was insufficient time to do so, and in part because previous experiences with use of longline survey data in the EBS Pacific cod model were not encouraging. Here is a brief history of the use of longline survey data in the EBS Pacific cod model:

- Data from the sablefish longline survey were included in some of the models explored in the 2006 assessment, but the authors concluded that these were unhelpful: "While it may be possible to develop usable indices from these surveys in the future, the present indices seem too problematic, for the following reasons: 1) the available abundance indices for Pacific cod (unlike those for sablefish) do not include appropriate area expansion factors, 2) the interannual variability in the available abundance indices from the Japanese longline survey is extreme, and 3) the sample size in the U.S. longline survey is small (only 11 stations have been successfully sampled in every year)" (Thompson et al., 2006, p. 258). The SSC concurred: "With regard to the longline data, the SSC suggests excluding them from future assessments" (December 2006 minutes).
- Data from the IPHC longline survey were included in at least one model in all assessments from 2007-2010. In the 2009 assessment, the observed values of the IPHC survey index were negatively correlated with the estimated values from all 14 models included in that assessment (Thompson et al. 2009, p. 301). As a result, the SSC concluded, "The IPHC survey does not appear to inform the model and should be removed" (December 2009 minutes). The SSC reiterated this conclusion the following June: "(One) SSC proposal … is to exclude IPHC survey data in the BSAI, because it conflicts with other data series" (June 2010 minutes).

Although previous experiences with use of longline survey data in the EBS model were not encouraging, it should be noted that one of the previous problems with use of the sablefish longline survey data (*viz*., lack of area expansion factors) has since been resolved. Also, the fact that use of longline survey data did not appear to be helpful in the EBS Pacific cod model does not preclude the possibility that use of such data would be helpful in the AI Pacific cod model, so this possibility will be explored in the future, with a particular eye toward whether the usefulness of the existing data merit development of an entire new longline survey.

Data

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

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

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

Fishery

Catch biomass

Total catch data are shown in Tables 2A.1.1a, 2A.1.1b, and 2A.1.1c for the years 1964-2012. The catch data used in the models begin in 1977.

Compared to earlier years, catches dropped sharply in 2011 and remained low in 2012, which may have been due, at least in part, to recent management measures designed to protect Steller sea lions.

Size Composition

Table 2A.1.2 shows the total number of fish measured at each 1 cm interval from 4-120+ cm, by year, in the fishery. Overall, the AI fishery size compositions reflect a higher proportion of fish 100 cm or greater than is the case in the EBS fishery (6.7% in the AI versus 0.6% in the EBS).

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

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

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

Survey

Biomass and Numerical Abundance

The time series of trawl survey biomass and numerical abundance are shown for Areas 541-543, together with their respective coefficients of variation, in Table 2A.1.3. These estimates pertain to the Aleutian *management* area, and so are smaller than the estimates pertaining to the Aleutian *survey* area that have been reported in past BSAI Pacific cod stock assessments.

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

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

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

Size Composition

Table 2A.1.4 shows the total number of fish measured at each 1 cm interval from 4-120+ cm, by year, in the survey. As with the fishery, the overall AI survey size compositions reflect a higher proportion of fish 100 cm or greater than is the case in the EBS survey (0.8% in the AI versus 0.1% in the EBS).

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

Year:	1991	1994	1997	2000	2002	2004	2006	2010	2012
N:	7125	7497	4635	5178	3914	3721	2784	3521	3278

Analytic Approach

Model Structure

Three models are presented in this assessment, all of which are estimated using Stock Synthesis (SS, Methot and Wetzel 2013). All three models differ from last year's accepted EBS model (Thompson and Lauth 2012) in the following respects:

1. In the data file, length bins (1 cm each) are extended out to 150 cm instead of 120 cm, because of the higher proportion of large fish observed in the AI.
2. Each year consists of a single season instead of five.
3. A single fishery is defined instead of nine season-and-gear-specific fisheries.
4. The survey samples age 1 fish at true age 1.5 instead of 1.41667.
5. Ageing bias is not estimated (because there are no age data) instead of estimated.

6. Selectivity for both the fishery and survey is modeled using a random walk with respect to age (SS selectivity-at-age pattern #17, described below) instead of the usual double normal (SS selectivity-at-length pattern #24 for the fisheries and SS selectivity-at-age pattern #20 for the survey).

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 (*d*). 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 three models presented here. As with other parameters in SS, each parameter in this selectivity pattern is associated with a prior distribution (which can be uniform, if desired).

The three models presented here are, to some extent, hybrids of last year's AI Models 1 and 4 (Attachment 2.2 in Thompson and Lauth 2012). Like last year's AI Model 1, survey catchability (*Q*) is constant, and survey selectivity is not constrained to be asymptotic. Like last year's AI Model 4, pre-1991 survey data are excluded, the standard deviation of log-scale age 0 recruitment is estimated internally, length composition sample sizes are (potentially) tuned iteratively, and fishery selectivity is (potentially) time-varying.

The three models are distinguished from one another by their respective treatments of the natural mortality rate (*M*) and *Q*:

- Model 1 (fixed *M*, tuned *Q*): The natural mortality rate is fixed at the accepted EBS value of 0.34. Catchability is tuned so that the average of the product of *Q* and selectivity across the 60-81 cm size range matches the value of 0.92 estimated by Nichol et al. (2007) for the AI survey net. These two assumptions match those used in all four of last year's AI models, and are similar to the assumptions used in the accepted EBS model (except that the EBS model uses a value of 0.47 to tune *Q* rather than 0.92, due to the use of a survey net with a lower headrope in the EBS).
- Model 2 (fixed *M*, constrained *Q*): As in Model 1, *M* is fixed at the accepted EBS value of 0.34. A meta-analytic prior distribution for ln(*Q*) was derived by averaging the parameters (or transformed parameters) of the prior distributions used in the other age-structured assessments of AI stocks. These are shown below:

Stock	Form	Mean	CV	Equivalent lognormal sigma
Atka mackerel	Normal	1	0.2	0.198042
Blackspotted/rougheye	Lognormal	1	0.05	0.049969
Northern rockfish	Lognormal	1	0.001	0.001000
Pacific ocean perch	Lognormal	1	0.45	0.429421
Pollock	Fixed	1	0	0.000000
Shortraker	Fixed	1	0	0.000000
Average		1	0.12	0.11

  Because SS requires *Q* to be modeled on a log scale, Model 2 uses a normal prior distribution for ln(*Q*) with $\mu = 0.00$ (=ln(1.0)) and $\sigma = 0.11$.
- Model 3 (free *M*, free *Q*): Both *M* and *Q* are estimated with non-constraining uniform prior distributions.

Development of the final versions of all models included calculation of the Hessian matrix. These models also passed a "jitter" test of 50 runs with a jitter parameter (equal to half the standard deviation of the logit-scale distribution from which initial values are drawn) of 0.01. 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 the ln(*Q*) parameter in Model 2 and the selectivity and *dev* parameters in all models, all parameters were estimated with uniform prior distributions. Bounds were non-constraining in all cases.

The software used to run all models was SS V3.24q, as compiled on 5/20/2013 (the most recent user manual is for SS V3.24f, Methot 2012). Stock Synthesis is programmed using the ADMB software package (Fournier et al. 2012).

Iterative Tuning Procedures Used for Model 2

Because this preliminary assessment is only an exploration of alternative models, and in the interest of time, the following procedures were applied to Model 2 only (i.e., Models 1 and 3 used the tuned quantities from Model 2, rather than retuning these quantities individually for Models 1 and 3).

Length Composition Sample Sizes

The following procedure was used to allow for the possibility of downweighting the length composition sample sizes:

1. Initially, set the "multiplier" (a weight applied to the input sample sizes specified in the data file) for the fishery and survey length compositions to unity.
2. Compute the arithmetic mean input sample size for each year in the fishery and survey (*ave_inp*).
3. Run SS to obtain the harmonic mean effective sample size for the fishery and survey (*har_eff*).
4. For both the fishery and the survey, compute a new value for the multiplier as min(1.0, multiplier× *har_eff*/*ave_inp*). The idea behind setting an upper value of unity on the multiplier is that obtaining a better-than-expected fit is not particularly undesirable, but obtaining a worse-than-expected fit indicates that some tuning is appropriate.
5. Return to step 3. Repeat until the multipliers (fishery and survey) stop changing.

Parameters of Selectivity Prior Distributions

As noted above, each age-specific parameter $d(a)$ in SS selectivity-at-age pattern #17 is associated with a prior distribution. One special case consists of a normal prior distribution with a constant mean and variance. If the constant variance is specified *a priori* and the constant mean is estimated iteratively, this special case should be equivalent to the second-difference approach used in some other BSAI groundfish stock assessments, and will tend as a default (i.e. in the absence of information to the contrary) to produce a selectivity curve that increases (for positive mean) exponentially with age (assuming that the second differences are computed with respect to the logarithm of selectivity rather than selectivity itself). As an alternative to exponential selectivity, the models presented here utilized logistic selectivity as the default form. This was accomplished as follows:

Setup:

1. Choose a value for the age above which selectivity is not expected to change (*amax*, which was set equal to age 10 here), and fix SS selectivity parameters for all $a>amax$ at 0.
2. Parameterize the default selectivity equation as $s(a|\alpha,\beta)=(1+\exp(\alpha\cdot(a-\beta)))^{-1}$ and the corresponding log-scale first differences as $d(a|\alpha,\beta)=\ln(s(a|\alpha,\beta))-\ln(s(a-1|\alpha,\beta))$, where a

represents age, and α and β are parameters. A negative value of α causes selectivity to increase with age in this default equation, but note that this does *not* necessarily imply that the final selectivity schedule (i.e., as estimated by SS) will be monotone increasing.

3. Uncertainty in the values of α and β are represented by a pair of normal distributions. Set initial guesses as to the mean values of α and β (μ_α, μ_β) and a common standard deviation ($\sigma_{\alpha\beta}$). The quantities μ_α, μ_β, and $\sigma_{\alpha\beta}$ serve a role akin to the hyper-parameters in a hierarchical Bayes approach.
4. Set initial guesses as to the prior mean and standard deviation of each (age-specific) SS selectivity parameter.

Start of "big" loop:

5. Run SS to obtain a vector of selectivity parameter estimates δ.
6. Set a new prior mean for each SS selectivity parameter equal to $d(a|\mu_\alpha,\mu_\beta)$.
7. Determine new values for μ_α and μ_β by minimizing the sum (across age) of squared differences between the estimated value of d and the corresponding prior mean.

Start of "small" loop:

8. Generate a large sample of $N(\mu_\alpha,\sigma_{\alpha\beta}^2)$ and $N(\mu_\beta,\sigma_{\alpha\beta}^2)$ random values for α and β.
9. For each pair of α and β values generated above and each age 1 through *amax*, compute $d(a|\alpha,\beta)$. This will result in a vector (**d**) of values for d at each age (with each element in the vector corresponding to one random (α,β) pair).
10. Set the prior standard deviation for each parameter (i.e., age) in SS equal to the standard deviation (σ_d) of the corresponding age-specific **d** vector.
11. Form a vector of standardized residuals as $(\delta(a)-\mu_d(a))/\sigma_d(a)$ for each age 1 through *amax*.
12. Compute root-mean-squared-standardized residual (RMSSR).
13. Interpolate or extrapolate a new guess value of $\sigma_{\alpha\beta}$ based on the difference of RMSSR from unity, then return to Step 8, and repeat until RMSSR=1.

End of "small" loop.

14. Return to step 5, repeating until the values of μ_α, μ_β, and $\sigma_{\alpha\beta}$ stop changing.

End of "big" loop.

15. Fix (i.e., turn off estimation of) any parameters with prior standard deviations so small that estimation is superfluous.

As indicated in step 2 above, the fact that the default selectivity curve is logistic does *not* necessarily imply that the final selectivity schedule (i.e., as estimated by SS) will be logistic, or even monotone increasing. This is one of the potential advantages of SS selectivity-at-age pattern #17: Because the parameters describe *changes in selectivity between ages*, rather than *selectivity at age*, it is possible to specify prior distributions that are *consistent* with logistic selectivity without *forcing* the estimated selectivity schedule to be logistic. This is not the case, for example, with double-normal selectivity, because it is impossible to specify a prior mean of unity for selectivity at the maximum age unless the prior standard deviation is zero, because it is impossible for selectivity at any age to exceed unity.

Time-Varying Selectivity

The following procedure was used to allow for the possibility of time-varying selectivity:

1. Initially, allow additive *dev*s for each selectivity parameter, and specify a moderate standard deviation for each.
2. Run SS to obtain a vector of estimated *dev*s for each selectivity parameter.
3. Compute the standard deviation of the estimated *dev*s for each selectivity parameter.
4. Change each specified standard deviation in the SS control file to the value computed in step 3.
5. Return to step 2. Repeat until the specified standard deviations stop changing.
6. Remove *dev* vectors for any parameter where the *dev*s are so small as to have negligible effect.

To keep the selectivity parameters from becoming too small or large to exponentiate accurately once *dev*s were added the *d* vector (recall that *d* is expressed on a logarithmic scale), an option in SS was invoked to scale the *dev*s using a logistic transform as follows:

$$par_{a,y} = \frac{(d_a - lo)\cdot hi + (hi - d_a)\cdot lo \cdot \exp(-2\cdot dev_{a,y})}{(d_a - lo) + (hi - d_a)\cdot \exp(-2\cdot dev_{a,y})} \quad ,$$

where *par* is the *dev*-adjusted selectivity parameter, *a* is age, *y* is year, and *lo* and *hi* are the user-specified lower and upper bounds on admissible values of *par*.

Parameters Estimated Outside the Assessment Model

Some parameters were fixed externally at values borrowed from the EBS Pacific cod model:

1. The natural mortality rate was fixed at 0.34 in Models 1 and 2 (*M* was estimated in Model 3).
2. The parameters of the logistic maturity-at-age relationship were set at values of 4.88 years (age at 50% maturity) and –0.965 (slope) in all models.

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

Parameters Estimated Inside the Assessment Model

Parameters estimated inside SS for all models include the von Bertalanffy growth parameters, standard deviation of length at ages 1 and 20, log mean recruitment since the 1976-1977 regime shift, offset for log-scale mean recruitment prior to the 1976-1977 regime shift, *dev*s for log-scale initial (i.e., 1977) abundance at ages 1 through 3, annual log-scale recruitment *dev*s for 1977-2011, initial (equilibrium) fishing mortality, base values for all fishery and survey selectivity parameters, and annual *dev*s for the parameters corresponding to ages 2 and 3 in the survey selectivity function (all fishery *dev*s, and survey *dev*s at all ages other than 2 and 3, were “tuned out” during the iterative tuning process).

Log-scale survey catchability was estimated iteratively in Model 1 by matching the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.92 obtained by Nichol et al. (2007). Log-scale survey catchability was estimated internally in Models 2 and 3.

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

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

Likelihood Components

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

In SS, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in the EBS Pacific cod assessment, 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 fleet (fishery or survey) and year. In the parameter estimation process, SS weights a given size composition observation according to the emphasis associated with the respective likelihood component and the sample size specified for the multinomial distribution from which the data are assumed to be drawn. The steps used to scale the sample sizes here were nearly identical to those used in the EBS Pacific cod assessment: 1) Records with fewer than 400 observations were omitted. 2) The sample sizes for fishery length compositions from years prior to 1999 were tentatively set at 16% of the actual sample size, and the sample sizes for fishery length compositions after 1998 and all survey length compositions were tentatively set at 34% of the actual sample size. 3) All sample sizes were adjusted proportionally to achieve an overall average sample size of 300.

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

Year:	1978	1979	1982	1983	1984	1985	1990	1991	1992	1993	1994	1995
N:	15	16	39	44	49	31	37	198	897	409	260	270
Year:	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
N:	372	208	649	632	973	1072	435	440	445	385	379	511
Year:	2008	2009	2010	2011	2012							
N:	488	407	637	165	166							

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

Year:	1991	1994	1997	2000	2002	2004	2006	2010	2012
N:	132	139	86	96	73	69	52	65	61

Use of Survey Relative Abundance Data in Parameter Estimation

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

Use of Recruitment Deviation "Data" in Parameter Estimation

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

Results

Overview

The following table summarizes the status of the stock as estimated by the three models ("Estimate" is the point estimate, "CV" is the ratio of the standard deviation to the point estimate, "SB(2012)" is female spawning biomass in 2012 (t), and "Bratio(2012)" is the ratio of SB(2012) to $B_{100\%}$):

	Model 1		Model 2		Model 3	
	Estimate	CV	Estimate	CV	Estimate	CV
SB(2012)	62,715	0.123	114,456	0.147	1,021,380	0.528
Bratio(2012)	0.247	0.135	0.336	0.133	0.599	0.099

The estimates of both absolute and relative spawning biomass in 2012 are lowest in Model 1 and highest in Model 3. The CVs associated with these estimates are not dramatically different between models, except for Model 3's estimate of absolute spawning biomass in 2012, which has a much higher CV than the estimates of the other two models (in contrast, the CV of Model 3's estimate of relative spawning biomass in 2012 is slightly lower than those of the other two models).

Model 2 has one more free parameter (ln(Q)) than Model 1, and Model 3 has one more free parameter (M) than Model 2, giving totals of 114, 115, and 116 parameters for Models 1, 2, and 3, respectively. Other differences are that Model 1 tunes ln(Q) iteratively to satisfy a criterion external to the maximum likelihood criterion used to estimate other parameters and Model 2 has a prior distribution on ln(Q).

Here are the values of ln(Q), Q, and M assumed or estimated in the three models:

Parameter	Model 1	Model 2	Model 3
ln(Q)	0.29	-0.43	-2.67
Q	1.33	0.65	0.07
M	0.34	0.34	0.36

Note that the Q values differ by about an order of magnitude between Model 2 and Model 1 and again between Model 3 and Model 2, but Model 3's internal estimate of M is very close to the value assumed for the other two models.

Goodness of Fit

Objective function values are shown for each model below (lower values are better, all else being equal; objective function components with a value less than 0.0005 for all models are omitted for brevity; color scale extends from red (minimum) to green (maximum)):

Obj. func. component	Model 1	Model 2	Model 3
Survey abundance	9.502	-3.388	-10.252
Size composition	358.911	336.031	336.888
Recruitment	19.382	18.964	0.575
Priors	12.282	17.249	8.525
Deviations	8.902	8.086	7.467
Total	408.979	376.942	343.204

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

Statistic	Model 1	Model 2	Model 3
Correlation (observed:expected)	0.882	0.900	0.932
Root mean squared error	0.375	0.253	0.176
Average of standardized residuals	-1.467	-0.663	0.023
Root mean squared standardized residual	2.361	1.647	1.089

By any of the above measures, Model 3 fits the survey abundance data best and Model 1 fits them worst.

Figure 2A.1.1 shows the fits of the three models to the trawl survey abundance data. Model 1's estimates are higher than the observed values in all years prior to 2010. Model 2's estimates are also higher than the observed values on average, but not by as much as Model 1's estimates. Model 3 has a fairly good residual pattern. The point estimates from Models 1 and 2 fall within the 95% confidence intervals of the observations in 6 of the 9 years, while the point estimates from Model 3 do so in 8 of the 9 years (all three models miss the 95% confidence interval in 1997). All three models estimate a 2012 survey biomass lower than the observed value.

The table below shows the mean of the ratios between the harmonic mean effective sample size and average input sample size (*ave_inp*) for the size composition data, thus providing an alternative measure of how well the models are fitting these data (higher values are better, all else being equal). All three models give ratios much greater than unity for both the fleet and survey.

Fleet	*ave_inp*	Model 1	Model 2	Model 3
Fishery	366.5	2.06	2.07	1.82
Survey	85.9	3.49	4.58	5.45

Figures 2A.1.2 and 2A.1.3 show the three models' fits to the fishery size composition and survey size composition data, respectively.

Iterative Tuning of Model 2 and Parameter Estimates From All Models

Both the fishery and survey length composition components in Model 2 had harmonic mean effective sample sizes greater than the average input sample sizes with each multiplier set to unity, so no tuning of sample sizes was necessary.

In tuning the parameters of the selectivity prior distributions, the parameters for ages 7-10 in the fishery were "tuned out," because the estimated fishery selectivity schedule was strongly asymptotic, and the tuned values of σ_d were essentially zero after age 6. The tuned values of μ_d and σ_d are shown for both the fishery and survey below (values were tuned to two significant digits; i.e., one digit beyond the decimal point in scientific notation):

		Age					
Fleet	Parameter	1	2	3	4	5	6
Fishery	μ_d	4.0E+00	4.0E+00	3.5E+00	8.9E-01	2.6E-02	4.9E-04
Fishery	σ_d	3.8E-01	4.0E-01	7.5E-01	8.1E-01	1.3E-01	4.9E-03
Survey	μ_d	1.5E+00	1.3E+00	8.0E-01	2.8E-01	6.9E-02	1.4E-02
Survey	σ_d	9.8E-01	9.3E-01	7.9E-01	5.3E-01	2.7E-01	1.5E-01

		Age			
Fleet	Parameter	7	8	9	10
Survey	μ_d	2.9E-03	6.0E-04	1.2E-04	2.4E-05
Survey	σ_d	1.3E-01	1.3E-01	1.3E-01	1.3E-01

In terms of time-varying selectivity, all fishery dev vectors were tuned out (i.e., the fishery ended up exhibiting constant selectivity over time at all ages), and all survey dev vectors except those at ages 2 and 3 were tuned out. The tuned values of the sigma parameters for ages 2 and 3 in the survey were 0.114 and 0.045, respectively.

Table 2A.1.4 displays all of the parameters (except fishing mortality rates) estimated internally in any of the models. Table 2A.1.4a shows natural mortality, growth, recruitment (except annual *dev*s), initial fishing mortality, catchability, and initial age composition parameters as estimated internally by at least one of the models. Table 2A.1.4b shows annual log-scale recruitment *dev*s as estimated by all of the models. These are plotted in Figure 2A.1.4, where it is apparent that all models show a high degree of synchrony, particularly during the years covered by the survey. Table 2A.1.4c shows selectivity parameters and *dev*s for the age 2 and 3 survey selectivity parameters as estimated by all of the models.

The parameter estimates in Table 2A.1.4 imply the following values for the average of the product of catchability and survey selectivity across the 60-81 cm size range (note that the value corresponding to the height of the headrope in the AI bottom trawl survey net is 0.92, compared to 0.47 for the EBS bottom trawl survey net; the ln(*Q*) parameter in Model 1 was tuned explicitly to achieve a value of 0.92):

Model 1	Model 2	Model 3
0.92	0.48	0.06

Table 2A.1.5 shows estimates of average fishing mortality rates across ages 5-8 for the three models (note that these are not counted as parameters in SS, and so do not have estimated standard deviations).

Estimates of Time Series

Figure 2A.1.5 shows the time series of spawning biomass relative to $B_{100\%}$ as estimated by the three models (note that SS measures spawning biomass at the start of the year and uses a different estimator of mean recruitment than the AFSC's standard projection model). All of the models show a peak ratio in either 1994 or 1996, followed by a monotonic decline through 2012. Model 3 peaks at a ratio of about 1.4, but the ratios for Models 1 and 2 never reach unity.

Figure 2A.1.6 shows the time series of total (age 0+) biomass as estimated by the three models, with the trawl survey biomass estimates included for comparison. All models estimate biomasses much higher than observed by the survey. The biomasses estimated by Model 3 are truly immense, due to that model's very low estimate of survey catchability.

Figure 2A.1.7 shows fishery selectivity as estimated by the three models. The three curves are virtually indistinguishable, and indicate an asymptotic pattern with full selection occurring at age 5.

Figure 2A.1.8 shows time-varying trawl survey selectivity as estimated by the three models. The plots are qualitatively similar across models, with the largest change in age 1 selectivity occurring in 1994 and the largest change in age 2 selectivity occurring in 1991. All three models show a very sharp peak at age 4, followed by declines through age 10 (selectivity is constrained to be constant at ages 10 and above). The selectivities at age 10 are 0.26, 0.31, and 0.37 in Models 1, 2, and 3, respectively.

Discussion

The three models presented here provide good fits to the length composition data, but, except for Model 3, the fits to the survey abundance data are not particularly good, with a very strong residual pattern for Model 1 and a fairly strong residual pattern for Model 2.

Age data from the 2012 AI bottom trawl survey are expected to become available in time for use in this year's final assessment. It is possible that these data will help to inform whatever models are included in the final assessment, but it should be stressed that these will be the only age data available, and such a small dataset may not be sufficient to improve model performance appreciably.

This preliminary assessment provides the first exploration of SS selectivity-at-age pattern #17 (random walk with age) for Pacific cod. This exploration was undertaken for the following reasons:

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 parameters of the prior distributions provides a way to specify these priors 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).

This preliminary assessment 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 this year's CAPAM selectivity workshop (Crone et al., 2013) seemed to favor allowing selectivity to vary over time. Time-varying survey catchability was also explored during the process of developing this preliminary assessment. However, unless catchability was estimated freely (as in Model 3), the primary effect of allowing time variability in catchability seemed to be compensation for an overall lack of fit resulting from a constrained (or fixed) base value for ln(*Q*), rather than estimating true time variability, so this feature was not included in the final models.

It should be emphasized that iterative tuning of the selectivity prior distributions and the sigma parameters for time-varying selectivity was applied only to Model 2, with Models 1 and 3 simply "borrowing" the resulting tuned quantities. If these iterative tuning procedures were also applied to Models 1 and 3, the performance of the latter models would likely change somewhat.

Finally, it may be noted that several of the questions raised in last year's AI Pacific cod assessment (Attachment 2.2 in Thompson and Lauth 2012) remain germane:

1. Correlations between recruitment in the AI and EBS are negative (= -0.38, -0.34, and -0.26 for Models 1, 2, and 3, respectively). Is this because recruitment dynamics are truly different in the AI, or is this evidence that the AI models are not giving good estimates?
2. Relative to Pacific cod in the EBS, Pacific cod in the AI have much larger survey CVs, much smaller length composition sample sizes, and virtually no age data. Is a reliable age-structured model of the AI stock possible under these conditions?
3. Unless constrained to be asymptotic, survey selectivity peaks sharply at age 4, with abrupt drops on either side of the peak. Is this reasonable?
4. Should catchability be tuned so that the average product of *Q* and selectivity across the 60-81 cm range matches the value of 0.92 estimated by Nichol et al. (2007)?

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Table 2A.1.1a—Summary of 1964-1980 catches (t) of Pacific cod in the AI. All catches are foreign reported. Catches by gear are not available for these years. Catches may not always include discards.

Year	Total
1964	241
1965	451
1966	154
1967	293
1968	289
1969	220
1970	283
1971	2078
1972	435
1973	977
1974	1379
1975	2838
1976	4190
1977	3262
1978	3295
1979	5593
1980	5788

Table 2A.1.1b—Summary of 1981-1990 catches (t) of Pacific cod in the AI by fleet sector and gear type. All catches include discards. "LLine" = longline, "Subt." = sector subtotal. Breakdown of domestic annual processing by gear is not available prior to 1988. Longline and pot gear have been combined ("LL+pot") under Domestic Annual Processing.

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

Table 2A.1.1c— Summary of 1991-2012 catches (t) of Pacific cod in the AI. The small catches taken by "other" gear types have been merged proportionally with the catches of the gear types shown. Longline and pot gear have been combined ("Long.+pot") due to confidentiality restrictions. Catches for 2012 are through September 29.

	Federal			State	Grand
Year	Trawl	Long.+pot	Subtotal	Subtotal	Total
1991	3,414	6,383	9,798		9,798
1992	14,587	28,481	43,068		43,068
1993	17,328	16,876	34,205		34,205
1994	14,383	7,156	21,539		21,539
1995	10,574	5,960	16,534		16,534
1996	21,179	10,430	31,609		31,609
1997	17,411	7,753	25,164		25,164
1998	20,531	14,196	34,726		34,726
1999	16,478	11,653	28,130		28,130
2000	20,379	19,306	39,685		39,685
2001	15,836	18,372	34,207		34,207
2002	27,929	2,872	30,801		30,801
2003	31,478	980	32,459		32,459
2004	25,770	3,103	28,873		28,873
2005	19,624	3,075	22,699		22,699
2006	16,963	3,530	20,493	3,717	24,210
2007	25,721	4,495	30,216	3,829	34,045
2008	19,405	7,192	26,597	4,462	31,059
2009	20,284	6,222	26,507	2,074	28,580
2010	16,757	8,365	25,122	3,878	29,000
2011	9,379	1,242	10,621	241	10,862
2012	9,516	2,777	12,294	5,229	17,523

Table 2A.1.2 (page 1 of 3)—Fishery size composition, by year and cm.

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

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

Table 2A.1.2 (page 2 of 3)—Fishery size composition, by year and cm.

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

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

Table 2A.1.2 (3 of 3)—Fishery size composition, by year and cm.

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

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

Table 2A.1.3—Total biomass (t) and abundance, with coefficients of variation (CV), by subarea and year, as estimated by bottom trawl surveys.

Biomass:

	Western Aleutians (543)		Central Aleutians (542)		Eastern Aleutians (541)		Aleutian management area	
Year	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV
1991	75,514	0.09	39,729	0.11	64,926	0.37	180,170	0.14
1994	23,797	0.29	51,538	0.39	78,081	0.30	153,416	0.21
1997	14,357	0.26	30,252	0.21	28,239	0.23	72,848	0.13
2000	44,261	0.42	36,456	0.27	47,117	0.22	127,834	0.18
2002	23,623	0.25	24,687	0.26	25,241	0.33	73,551	0.16
2004	9,637	0.17	20,731	0.21	51,851	0.30	82,219	0.20
2006	19,734	0.23	21,823	0.19	43,348	0.54	84,905	0.29
2010	21,341	0.41	11,207	0.26	23,277	0.22	55,826	0.19
2012	13,514	0.26	14,804	0.20	30,592	0.24	58,911	0.15

Abundance (1000s of fish):

	Western Aleutians (543)		Central Aleutians (542)		Eastern Aleutians (541)		Aleutian management area	
Year	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV
1991	18,679	0.15	13,138	0.13	33,669	0.44	65,486	0.23
1994	4,491	0.24	12,425	0.20	37,284	0.44	54,201	0.31
1997	4,000	0.25	12,014	0.28	8,859	0.16	24,873	0.15
2000	13,899	0.54	10,661	0.30	18,819	0.29	43,379	0.23
2002	6,840	0.30	6,704	0.17	12,579	0.28	26,123	0.16
2004	3,220	0.17	5,755	0.17	13,040	0.24	22,016	0.15
2006	6,521	0.32	6,243	0.16	8,882	0.33	21,646	0.17
2010	5,323	0.34	5,169	0.17	9,577	0.22	20,068	0.14
2012	4,100	0.14	5,596	0.20	9,480	0.21	19,176	0.12

Table 2A.1.4 (page 1 of 2)—Trawl survey size composition, by year and cm.

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

Year	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
1991	3	2	4	9	26	81	114	147	216	249	293	321	299	242	224	150	139	85	92	54
1994	7	4	4	4	3	3	9	18	24	34	40	44	48	43	47	38	30	44	59	46
1997	102	82	42	19	2	12	7	15	27	32	36	51	61	60	60	58	45	32	31	34
2000	1	4	7	4	3	14	10	13	13	15	26	12	32	14	17	4	27	24	21	52
2002	19	9	9	21	22	28	22	37	45	99	92	103	134	142	119	93	85	63	52	62
2004	5	1	1	1	0	0	0	3	1	5	6	17	25	30	24	28	26	40	41	38
2006	23	13	3	2	1	2	0	1	6	1	5	3	8	13	11	20	12	19	14	9
2010	0	3	1	1	2	10	15	26	22	27	23	23	27	16	23	28	25	28	35	44
2012	9	5	1	0	3	2	2	11	7	32	23	18	32	55	38	18	41	29	31	20

Year	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
1991	80	52	64	72	73	68	54	76	63	58	68	60	98	94	82	115	116	110	121	139
1994	60	63	90	90	102	83	102	67	68	66	72	62	53	93	78	76	84	93	95	123
1997	34	25	35	47	52	59	82	70	73	79	96	103	106	127	150	125	172	165	121	148
2000	96	134	93	117	110	131	123	154	131	136	125	119	130	125	175	183	165	187	156	151
2002	56	59	62	77	81	87	63	62	76	68	95	69	97	72	74	61	64	41	39	40
2004	32	48	56	60	84	83	97	86	84	91	67	98	81	92	83	66	109	80	60	89
2006	21	27	38	39	44	62	63	69	75	57	61	49	49	56	29	45	37	35	51	45
2010	63	84	92	114	117	126	113	121	138	146	135	118	112	116	93	69	93	81	65	45
2012	26	30	34	31	32	42	44	64	58	49	70	56	66	62	86	90	88	86	79	104

Year	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83
1991	86	119	163	157	162	131	136	119	136	117	119	99	89	109	115	81	84	75	63	61
1994	119	124	102	125	114	128	109	118	124	111	133	77	79	86	78	50	71	47	72	62
1997	135	106	85	103	112	80	63	50	59	50	49	58	49	34	27	27	33	31	31	23
2000	154	148	168	115	112	97	84	86	77	86	70	82	88	59	46	49	42	28	27	36
2002	44	33	33	34	31	34	34	33	36	34	42	45	48	42	35	39	49	49	50	55
2004	102	90	89	100	92	83	84	83	88	61	81	68	72	65	62	48	38	55	52	40
2006	35	39	54	29	42	39	44	30	47	47	39	35	41	34	38	42	47	46	46	30
2010	54	56	56	69	78	58	47	43	35	35	31	33	33	24	23	13	9	23	19	19
2012	157	105	97	85	95	80	63	47	56	49	67	59	43	40	39	49	37	36	32	19

Table 2A.1.4 (page 2 of 2)—Trawl survey size composition, by year and cm.

Year	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
1991	65	46	56	50	22	31	30	43	30	20	11	14	6	12	4	12	4	1	5	0
1994	52	72	46	59	44	54	93	60	66	48	38	42	50	27	18	27	9	10	8	8
1997	25	19	23	24	23	18	22	31	26	9	25	8	20	13	16	20	9	10	22	7
2000	19	27	18	26	22	15	12	17	13	6	12	10	8	6	10	8	5	2	4	5
2002	39	44	38	38	32	15	30	29	10	21	16	12	9	7	8	4	5	3	6	13
2004	35	40	37	37	11	18	21	15	21	17	14	15	11	8	8	15	7	2	8	8
2006	54	32	28	41	37	39	47	28	17	17	13	28	19	15	10	14	13	5	10	4
2010	12	4	16	12	10	15	9	11	9	8	10	6	7	9	5	7	10	15	5	6
2012	20	11	14	13	15	7	10	8	7	9	5	16	9	5	4	5	6	6	5	4

Year	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120+
1991	3	3	1	6	0	1	0	0	0	0	0	1	0	0	0	0	0
1994	7	5	5	2	0	2	0	0	0	2	2	0	0	0	0	0	0
1997	3	10	8	1	3	3	2	0	0	0	0	0	0	0	0	0	0
2000	3	4	6	1	11	2	1	2	0	0	0	1	0	0	0	0	0
2002	1	6	2	2	2	0	1	0	3	0	0	1	0	0	0	0	0
2004	5	6	3	2	3	1	0	1	0	0	0	0	0	0	0	0	0
2006	15	3	3	6	8	3	0	1	3	2	1	0	1	0	0	0	0
2010	3	8	3	6	6	4	3	5	1	1	0	1	0	0	0	0	0
2012	7	1	1	1	1	1	0	1	0	0	0	0	1	0	0	0	0

Table 2A.1.4a— Natural mortality, growth, recruitment (except annual *dev*s), initial fishing mortality, catchability, and initial age composition parameters as estimated internally by at least one of the assessment models; "n/a" means that the parameter is fixed (i.e., not estimated internally) in that particular model. "Est." = point estimate, "SD" = standard deviation.

	Model 1		Model 2		Model 3	
Parameter	Est.	SD	Est.	SD	Est.	SD
M	3.40E-01	n/a	3.40E-01	n/a	3.64E-01	1.72E-02
L_at_age01	1.67E+01	6.64E-01	1.74E+01	5.34E-01	1.80E+01	4.35E-01
L_at_age20	1.12E+02	1.01E+00	1.10E+02	1.02E+00	1.07E+02	1.12E+00
VonBert_K	2.42E-01	6.23E-03	2.34E-01	5.70E-03	2.29E-01	5.58E-03
SD_of_length_at_age01	6.15E+00	6.03E-01	4.98E+00	4.56E-01	3.93E+00	3.55E-01
SD_of_length_at_age20	5.48E+00	5.31E-01	6.04E+00	4.93E-01	6.86E+00	4.78E-01
Log_mean_post76_recruits	1.09E+01	1.15E-01	1.12E+01	1.31E-01	1.31E+01	5.50E-01
SD_of_log_recruitment	8.89E-01	1.02E-01	8.82E-01	1.09E-01	6.07E-01	9.78E-02
Pre1977_log_mean_offset	-1.73E+00	2.40E-01	-1.74E+00	2.70E-01	-9.92E-01	2.79E-01
Initial_F	2.11E-02	5.04E-03	1.56E-02	4.27E-03	1.37E-03	8.09E-04
log_Q	2.85E-01	n/a	-4.27E-01	8.77E-02	-2.67E+00	5.24E-01
InitAge_10	-5.64E-01	7.17E-01	-5.77E-01	7.09E-01	-2.98E-01	5.40E-01
InitAge_09	-6.90E-01	6.92E-01	-7.03E-01	6.85E-01	-3.85E-01	5.26E-01
InitAge_08	-8.25E-01	6.68E-01	-8.35E-01	6.62E-01	-4.83E-01	5.12E-01
InitAge_07	-9.59E-01	6.46E-01	-9.62E-01	6.41E-01	-5.80E-01	5.00E-01
InitAge_06	-1.07E+00	6.28E-01	-1.05E+00	6.26E-01	-6.47E-01	4.89E-01
InitAge_05	-1.06E+00	6.20E-01	-9.99E-01	6.20E-01	-6.08E-01	4.82E-01
InitAge_04	-6.58E-01	5.92E-01	-5.12E-01	5.71E-01	-3.17E-01	4.51E-01
InitAge_03	-1.03E-01	4.86E-01	-1.75E-01	4.93E-01	-2.27E-01	4.23E-01
InitAge_02	3.46E-01	4.19E-01	3.00E-01	4.13E-01	1.50E-01	3.62E-01
InitAge_01	-9.12E-03	5.44E-01	-2.72E-01	5.61E-01	-4.77E-01	4.44E-01

Table 2A.1.4b— Annual log-scale recruitment *dev*s estimated by the three models. "Est." = point estimate, "SD" = standard deviation.

	Model 1		Model 2		Model 3	
Parameter	Est.	SD	Est.	SD	Est.	SD
RecrDev_1977	-1.75E+00	4.56E-01	-1.81E+00	4.41E-01	-1.06E+00	4.08E-01
RecrDev_1978	-1.12E+00	2.74E-01	-1.14E+00	2.93E-01	-4.85E-01	3.11E-01
RecrDev_1979	-1.21E+00	2.63E-01	-1.20E+00	3.08E-01	-4.87E-01	3.10E-01
RecrDev_1980	-4.69E-01	2.30E-01	-3.13E-01	2.77E-01	4.34E-01	2.38E-01
RecrDev_1981	-4.83E-01	2.96E-01	-3.43E-01	3.14E-01	7.34E-02	3.06E-01
RecrDev_1982	-4.21E-01	3.58E-01	-2.29E-01	3.65E-01	1.31E-01	3.42E-01
RecrDev_1983	-6.67E-01	6.63E-01	-5.44E-01	6.97E-01	-3.29E-01	5.16E-01
RecrDev_1984	-2.51E-01	6.42E-01	4.51E-02	6.52E-01	1.57E-01	5.76E-01
RecrDev_1985	6.98E-01	2.86E-01	9.50E-01	2.91E-01	1.28E+00	2.61E-01
RecrDev_1986	7.59E-01	1.93E-01	8.21E-01	2.07E-01	7.82E-01	2.43E-01
RecrDev_1987	9.25E-01	1.10E-01	9.31E-01	1.19E-01	8.18E-01	1.50E-01
RecrDev_1988	3.84E-01	1.17E-01	2.15E-01	1.35E-01	-6.14E-02	1.67E-01
RecrDev_1989	6.11E-01	1.06E-01	6.90E-01	1.06E-01	6.94E-01	1.08E-01
RecrDev_1990	8.45E-01	9.21E-02	7.99E-01	1.02E-01	5.89E-01	1.26E-01
RecrDev_1991	4.88E-01	1.17E-01	4.08E-01	1.24E-01	2.05E-01	1.38E-01
RecrDev_1992	3.22E-01	1.28E-01	2.21E-01	1.41E-01	-2.45E-02	1.60E-01
RecrDev_1993	6.56E-01	9.88E-02	7.32E-01	9.38E-02	6.36E-01	9.81E-02
RecrDev_1994	5.57E-01	9.68E-02	3.53E-01	1.16E-01	-5.73E-02	1.40E-01
RecrDev_1995	4.38E-01	8.66E-02	4.20E-01	8.90E-02	2.83E-01	9.70E-02
RecrDev_1996	6.51E-01	7.84E-02	6.81E-01	7.60E-02	5.26E-01	8.27E-02
RecrDev_1997	9.58E-01	6.75E-02	8.23E-01	8.19E-02	4.76E-01	9.30E-02
RecrDev_1998	4.43E-01	1.00E-01	3.12E-01	1.07E-01	9.13E-03	1.12E-01
RecrDev_1999	3.00E-01	1.10E-01	2.52E-01	1.11E-01	1.83E-03	1.19E-01
RecrDev_2000	5.88E-01	9.71E-02	4.65E-01	1.12E-01	1.35E-01	1.16E-01
RecrDev_2001	3.15E-01	1.10E-01	8.44E-02	1.27E-01	-2.93E-01	1.31E-01
RecrDev_2002	-2.19E-01	1.29E-01	-3.07E-01	1.34E-01	-5.36E-01	1.38E-01
RecrDev_2003	-4.23E-03	1.02E-01	-1.04E-01	1.14E-01	-3.47E-01	1.24E-01
RecrDev_2004	-4.86E-01	1.35E-01	-5.64E-01	1.47E-01	-7.44E-01	1.56E-01
RecrDev_2005	3.65E-02	9.95E-02	2.40E-03	1.16E-01	-1.56E-01	1.25E-01
RecrDev_2006	-6.39E-01	1.45E-01	-6.43E-01	1.55E-01	-6.91E-01	1.59E-01
RecrDev_2007	8.27E-02	1.17E-01	1.79E-01	1.28E-01	1.64E-01	1.28E-01
RecrDev_2008	-3.24E-01	1.74E-01	-3.12E-01	1.95E-01	-4.87E-01	2.05E-01
RecrDev_2009	-1.04E+00	2.97E-01	-9.90E-01	2.96E-01	-9.73E-01	2.67E-01
RecrDev_2010	-6.48E-01	4.51E-01	-6.09E-01	4.53E-01	-5.23E-01	3.98E-01
RecrDev_2011	-3.13E-01	7.19E-01	-2.83E-01	7.16E-01	-1.38E-01	5.40E-01

Table 2A.1.4c—Selectivity parameters and annual additive *dev*s applied to selectivity parameters as estimated by the three models. "Est." = point estimate, "SD" = standard deviation.

	Model 1		Model 2		Model 3	
Parameter	Est.	SD	Est.	SD	Est.	SD
Selparm_age01_fishery	4.00E+00	3.80E-01	4.00E+00	3.80E-01	4.00E+00	3.80E-01
Selparm_age02_fishery	4.13E+00	3.67E-01	4.13E+00	3.67E-01	4.12E+00	3.69E-01
Selparm_age03_fishery	3.34E+00	2.08E-01	3.18E+00	1.80E-01	3.10E+00	1.76E-01
Selparm_age04_fishery	9.13E-01	5.81E-02	9.48E-01	5.90E-02	1.01E+00	6.35E-02
Selparm_age05_fishery	3.92E-01	5.24E-02	4.16E-01	5.12E-02	4.10E-01	5.49E-02
Selparm_age06_fishery	1.59E-03	4.89E-03	1.48E-03	4.89E-03	9.26E-04	4.89E-03
Selparm_age01_survey	1.50E+00	9.80E-01	1.50E+00	9.80E-01	1.50E+00	9.80E-01
Selparm_age02_survey	1.37E+00	4.05E-01	1.28E+00	4.03E-01	1.23E+00	4.02E-01
Selparm_age03_survey	7.40E-01	2.20E-01	8.27E-01	2.19E-01	9.35E-01	2.22E-01
Selparm_age04_survey	7.17E-01	1.23E-01	4.30E-01	1.34E-01	1.41E-01	1.57E-01
Selparm_age05_survey	-9.27E-01	1.32E-01	-6.17E-01	1.41E-01	-2.75E-01	1.60E-01
Selparm_age06_survey	-1.07E-01	1.30E-01	-1.40E-01	1.30E-01	-1.95E-01	1.30E-01
Selparm_age07_survey	-9.63E-02	1.19E-01	-1.25E-01	1.17E-01	-1.65E-01	1.17E-01
Selparm_age08_survey	-8.54E-02	1.22E-01	-1.07E-01	1.20E-01	-1.39E-01	1.19E-01
Selparm_age09_survey	-7.27E-02	1.24E-01	-9.03E-02	1.22E-01	-1.15E-01	1.21E-01
Selparm_age10_survey	-5.67E-02	1.26E-01	-7.61E-02	1.24E-01	-1.06E-01	1.22E-01
Seldev_age02_survey_1991	2.35E-01	6.98E-02	2.31E-01	6.96E-02	2.19E-01	6.99E-02
Seldev_age02_survey_1994	-2.02E-01	4.94E-02	-1.85E-01	4.92E-02	-1.74E-01	4.94E-02
Seldev_age02_survey_1997	-3.77E-02	5.72E-02	-3.84E-02	5.52E-02	-3.94E-02	5.43E-02
Seldev_age02_survey_2000	-2.45E-02	6.43E-02	-2.18E-02	6.37E-02	-2.13E-02	6.35E-02
Seldev_age02_survey_2002	8.07E-02	6.74E-02	6.67E-02	6.59E-02	5.85E-02	6.53E-02
Seldev_age02_survey_2004	6.17E-02	7.68E-02	5.69E-02	7.53E-02	5.18E-02	7.48E-02
Seldev_age02_survey_2006	-8.15E-02	5.94E-02	-8.18E-02	5.91E-02	-8.29E-02	5.91E-02
Seldev_age02_survey_2010	-1.98E-02	7.44E-02	-2.34E-02	7.33E-02	-1.69E-02	7.23E-02
Seldev_age02_survey_2012	-1.72E-03	8.19E-02	-6.38E-03	8.14E-02	-6.08E-03	7.33E-02
Seldev_age03_survey_1991	-1.10E-01	2.46E-02	-1.00E-01	2.47E-02	-9.09E-02	2.48E-02
Seldev_age03_survey_1994	1.55E-03	3.06E-02	2.57E-03	3.08E-02	1.29E-03	3.14E-02
Seldev_age03_survey_1997	2.01E-02	2.93E-02	2.17E-02	2.93E-02	2.34E-02	2.94E-02
Seldev_age03_survey_2000	4.60E-02	3.20E-02	4.54E-02	3.22E-02	4.37E-02	3.26E-02
Seldev_age03_survey_2002	-3.37E-02	2.65E-02	-4.10E-02	2.68E-02	-5.39E-02	2.73E-02
Seldev_age03_survey_2004	3.55E-02	3.36E-02	3.42E-02	3.38E-02	3.30E-02	3.42E-02
Seldev_age03_survey_2006	2.69E-02	3.47E-02	2.47E-02	3.50E-02	2.32E-02	3.54E-02
Seldev_age03_survey_2010	1.70E-02	3.20E-02	1.95E-02	3.25E-02	1.86E-02	3.33E-02
Seldev_age03_survey_2012	-5.44E-03	3.85E-02	-5.81E-03	3.86E-02	6.00E-03	3.71E-02

Table 2A.1.5—Average fishing mortality rates across ages 5-8 as estimated by the three models.

Year	Model 1	Model 2	Model 3
1977	0.1760	0.1234	0.0075
1978	0.1970	0.1341	0.0076
1979	0.3481	0.2331	0.0124
1980	0.3952	0.2559	0.0125
1981	0.5794	0.3542	0.0155
1982	0.7062	0.3909	0.0157
1983	0.6297	0.3190	0.0128
1984	0.4242	0.2080	0.0092
1985	0.2514	0.1223	0.0063
1986	0.1876	0.0921	0.0055
1987	0.3071	0.1470	0.0098
1988	0.0905	0.0439	0.0034
1989	0.0485	0.0254	0.0023
1990	0.0518	0.0293	0.0031
1991	0.0508	0.0308	0.0036
1992	0.2039	0.1262	0.0155
1993	0.1647	0.1012	0.0124
1994	0.0992	0.0615	0.0078
1995	0.0722	0.0461	0.0061
1996	0.1394	0.0903	0.0124
1997	0.1134	0.0738	0.0102
1998	0.1593	0.1040	0.0146
1999	0.1332	0.0874	0.0123
2000	0.1897	0.1241	0.0175
2001	0.1612	0.1061	0.0150
2002	0.1447	0.0965	0.0139
2003	0.1596	0.1068	0.0155
2004	0.1478	0.0997	0.0145
2005	0.1205	0.0827	0.0122
2006	0.1395	0.0967	0.0144
2007	0.2296	0.1566	0.0224
2008	0.2557	0.1681	0.0226
2009	0.2871	0.1800	0.0226
2010	0.3515	0.2060	0.0240
2011	0.1413	0.0798	0.0091
2012	0.2280	0.1266	0.0146

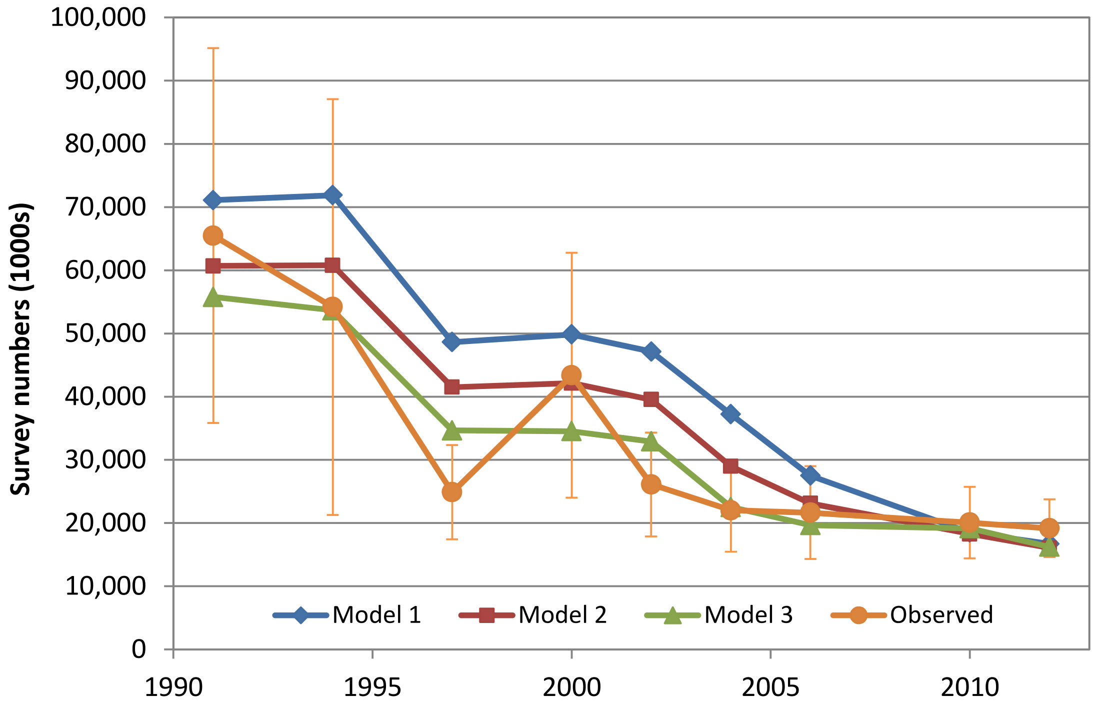


Figure 2A.1.1—Fit of the three models to the trawl survey abundance time series.

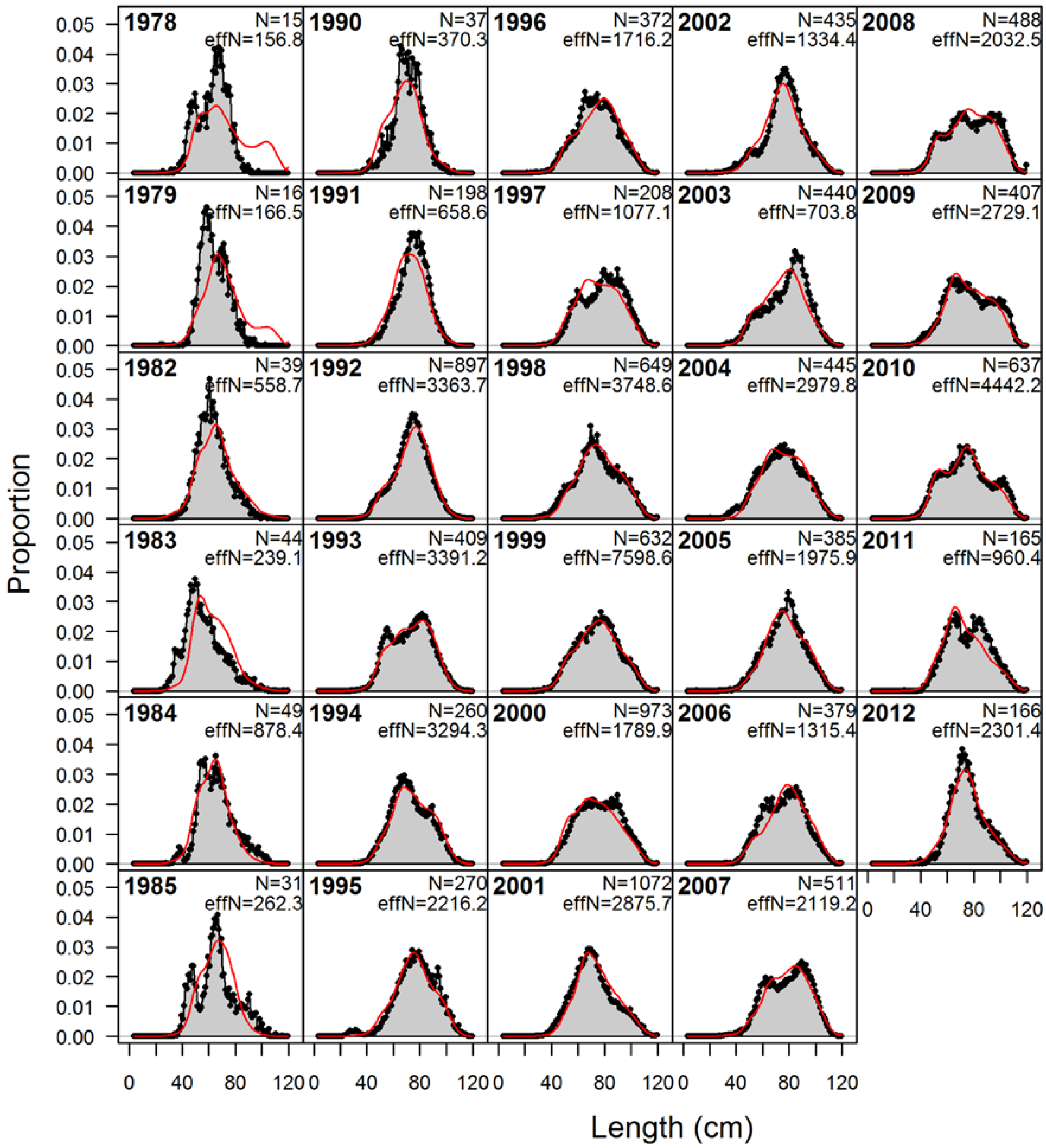


Figure 2A.1.2a—Fit to fishery size composition data obtained by Model 1 (grey = observed, red = estimated).

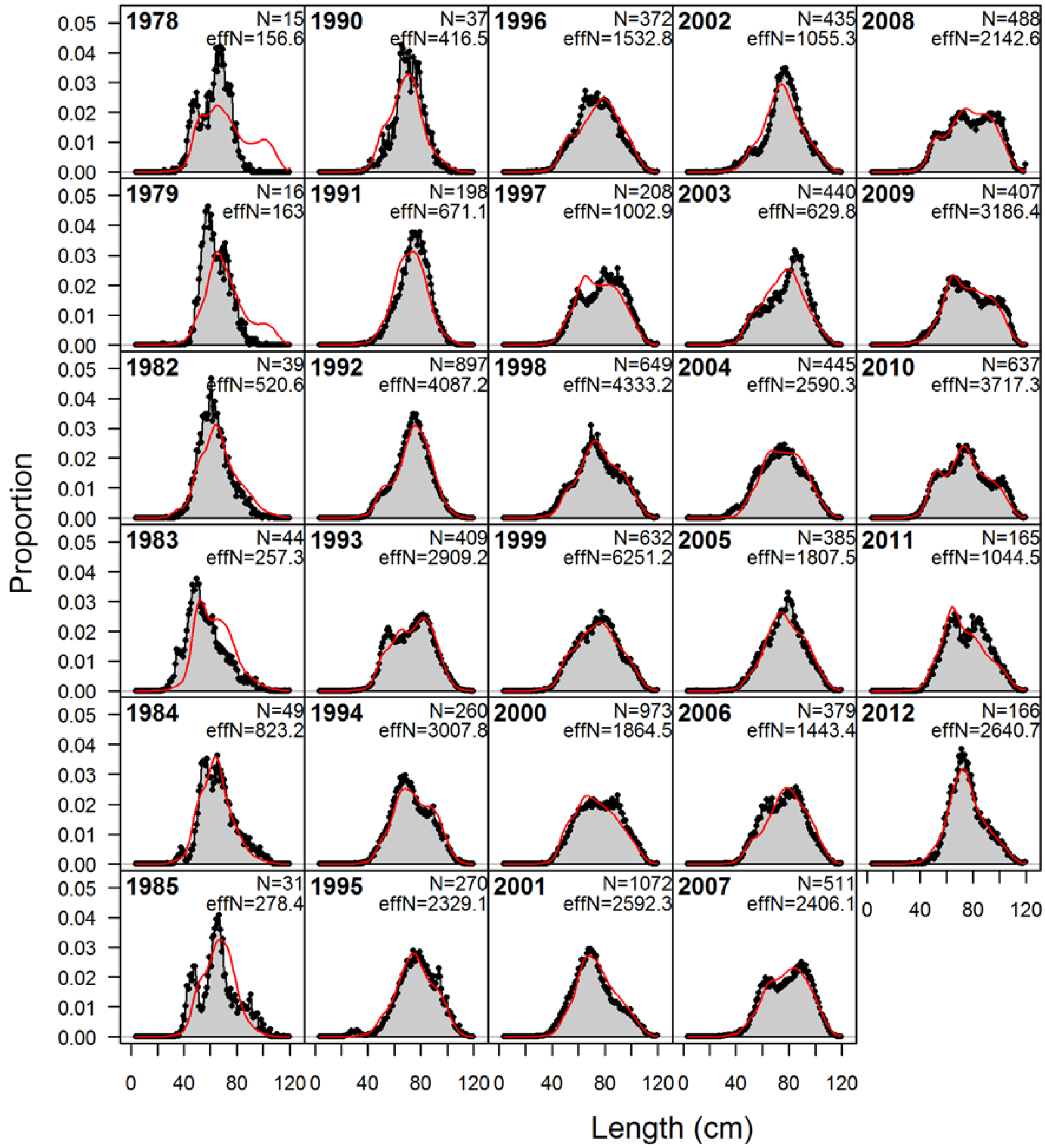


Figure 2A.1.2b—Fit to fishery size composition data obtained by Model 2 (grey = observed, red = estimated).

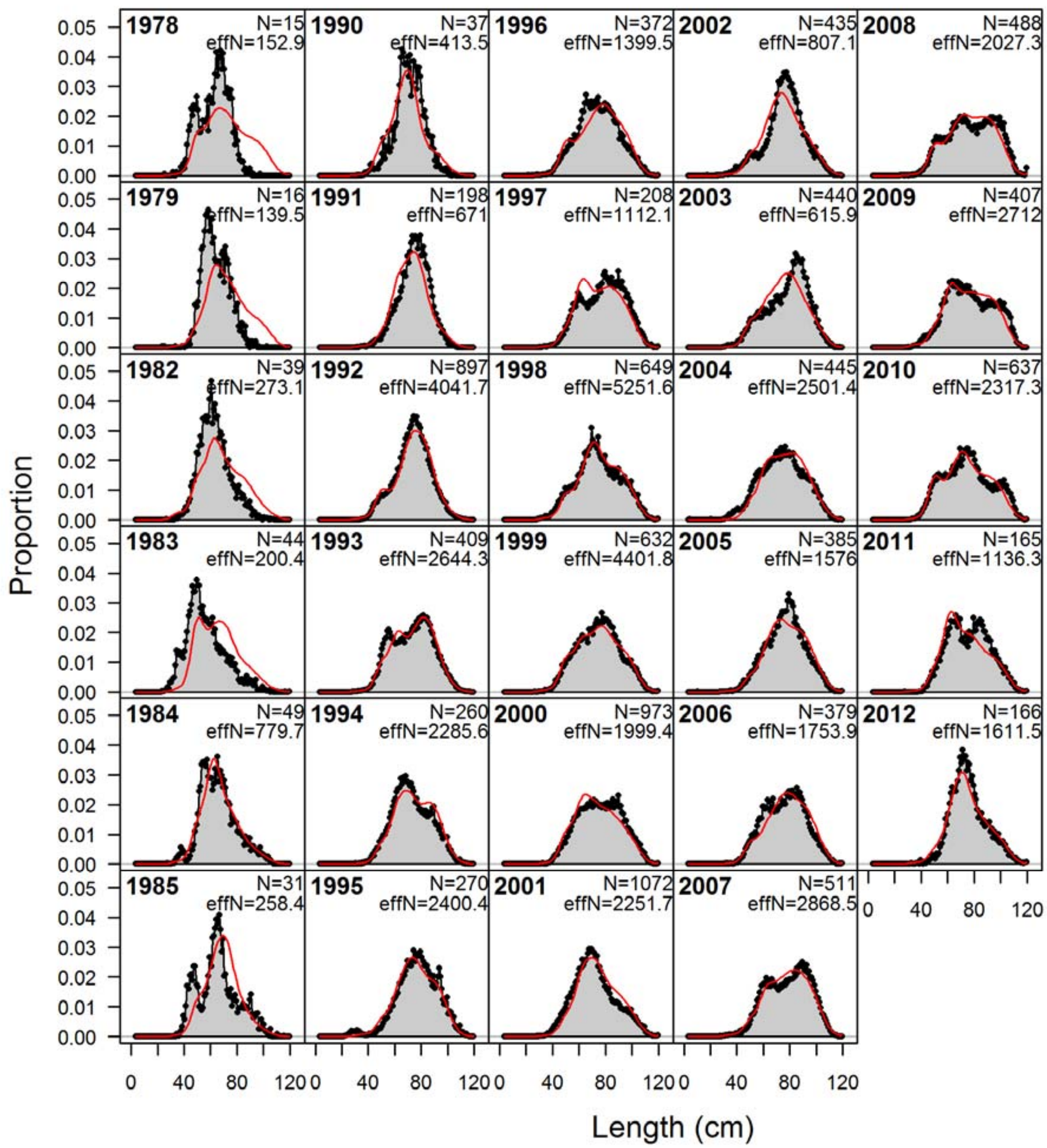


Figure 2A.1.2c—Fit to fishery size composition data obtained by Model 3 (grey = observed, red = estimated).

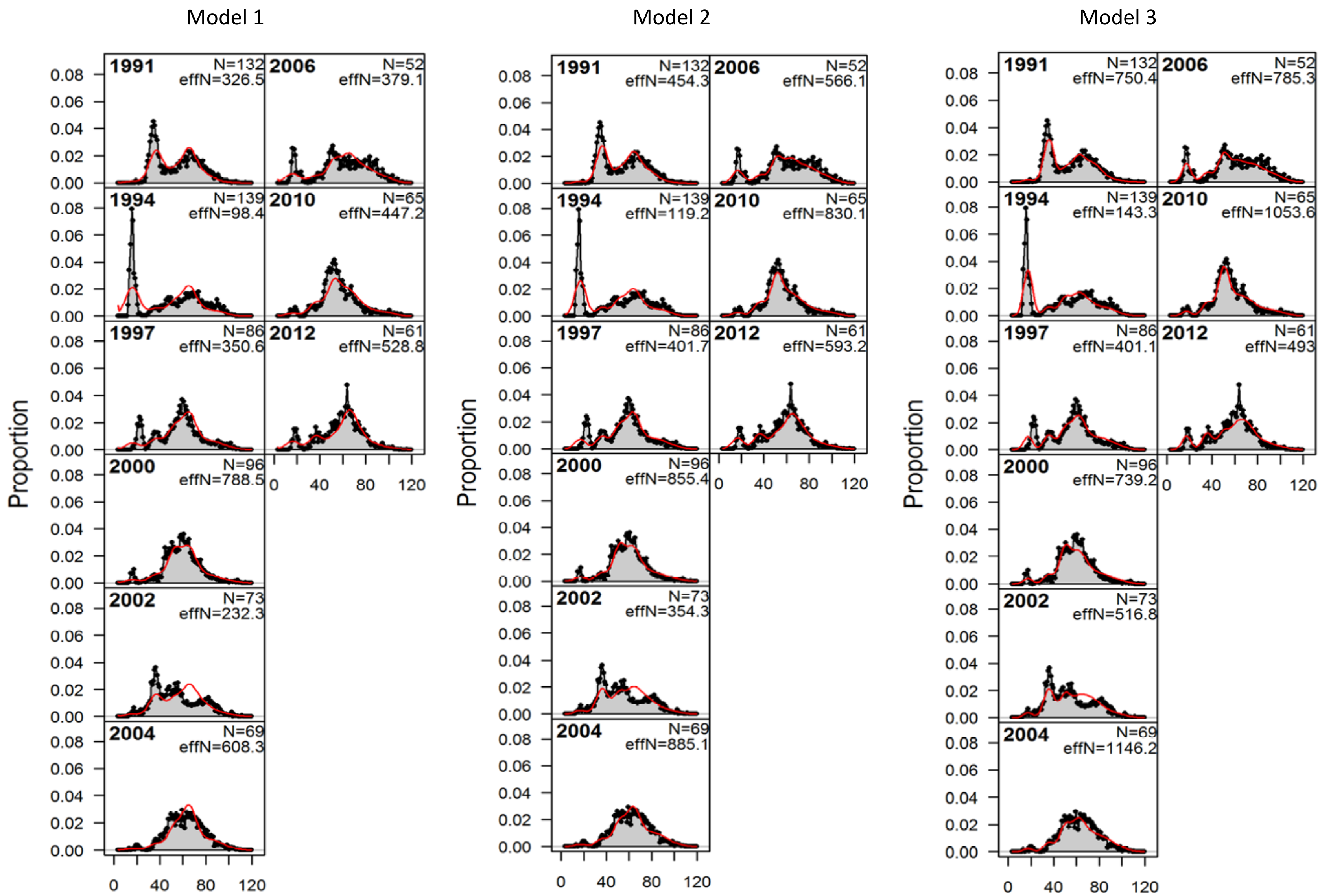


Figure 2A.1.3—Fits of the four models to the survey size composition data (grey = observed, red = estimated).

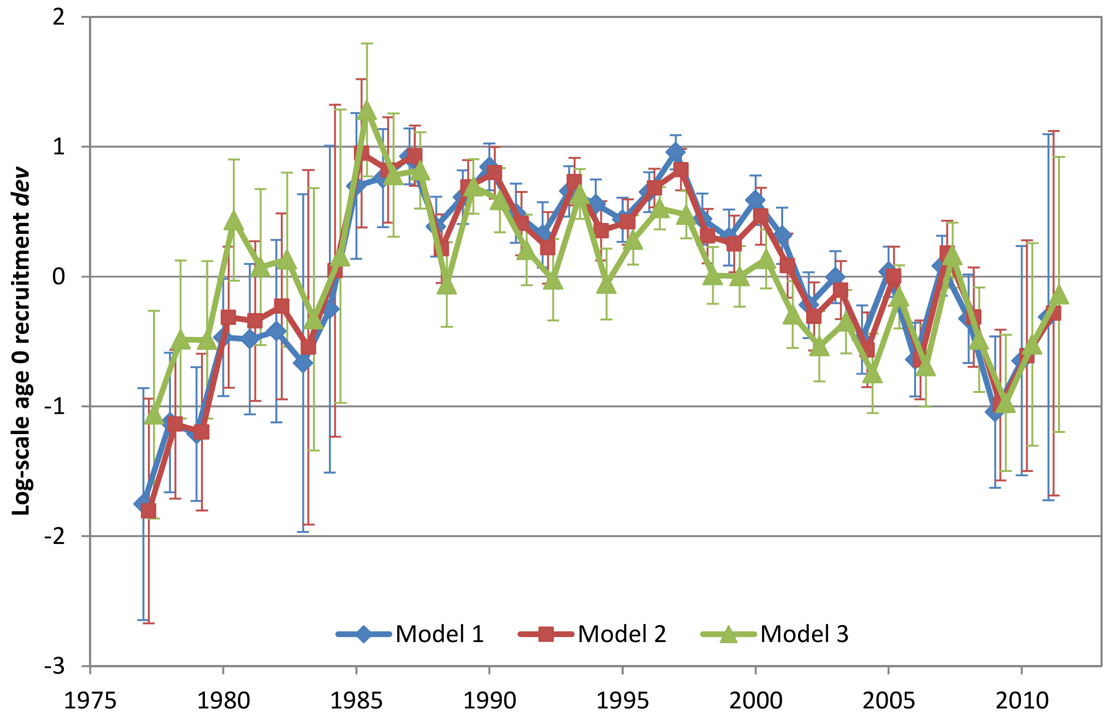


Figure 2A.1.4—Time series of log recruitment deviations estimated by the three models. Horizontal axis values have been offset slightly between models to improve visibility.

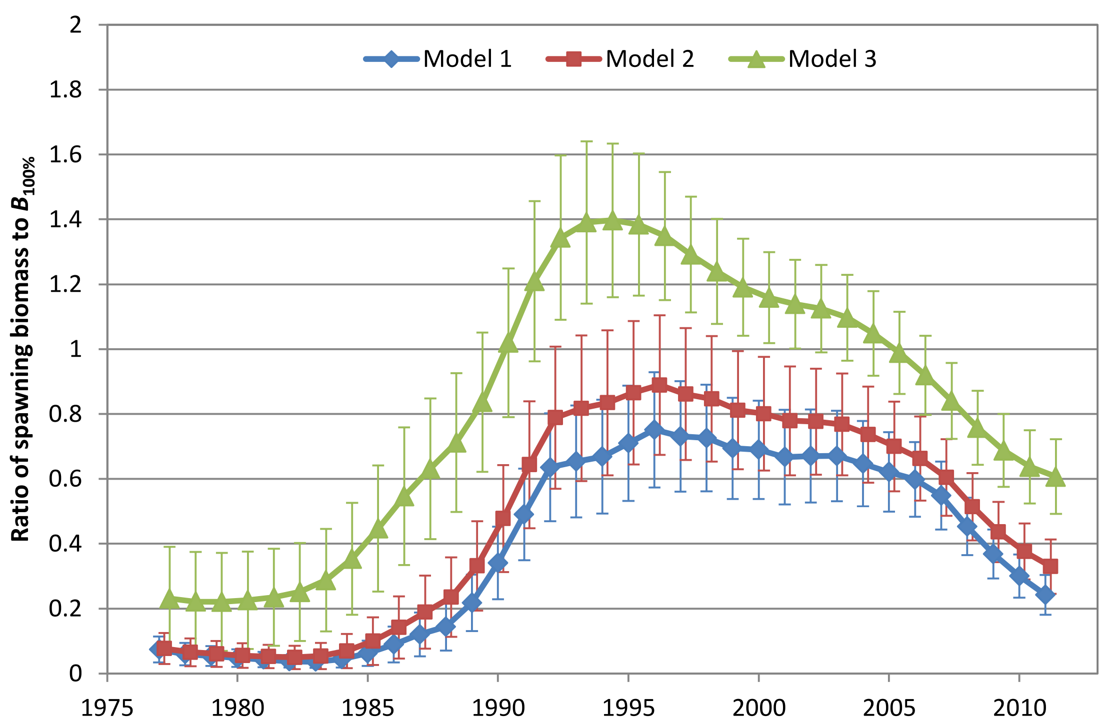


Figure 2A.1.5—Time series of spawning biomass relative to $B_{100\%}$ as estimated by the three models.

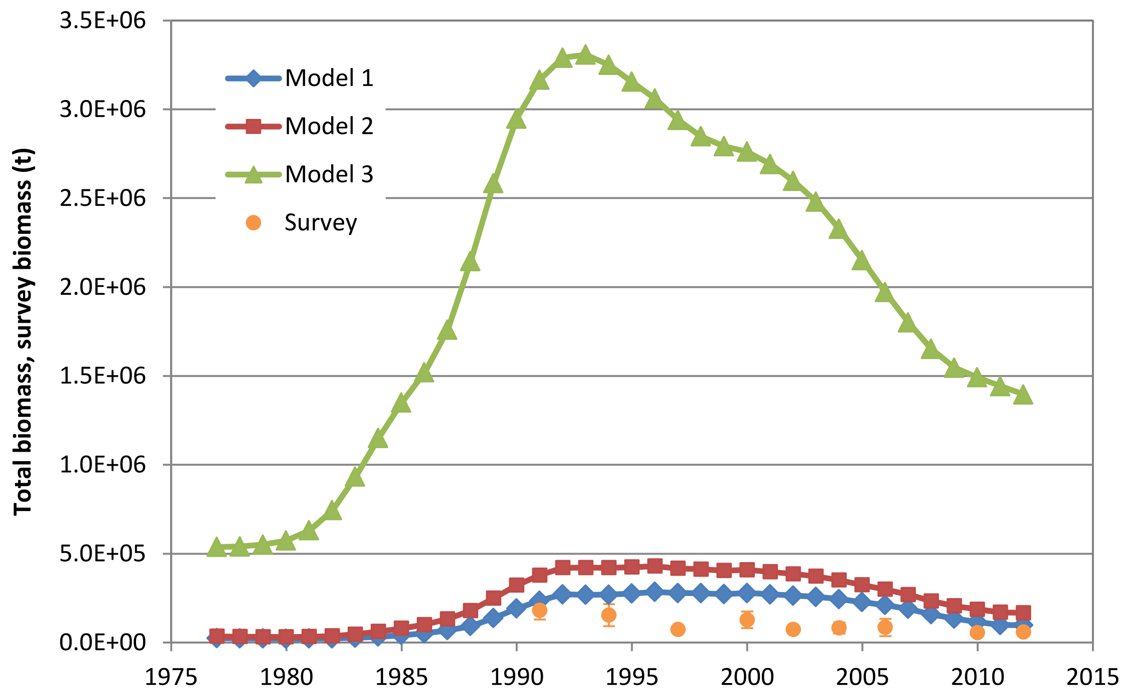


Figure 2A.1.6— Time series of total (age 0+) biomass as estimated by the three models. Survey biomass is shown for comparison.

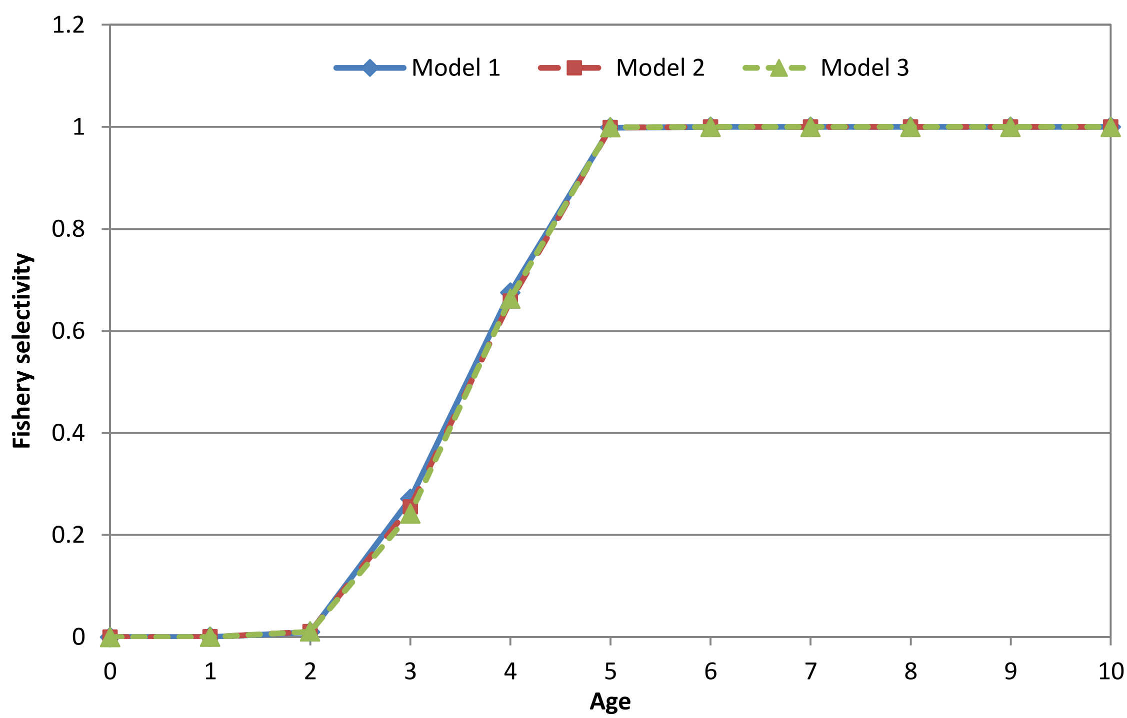
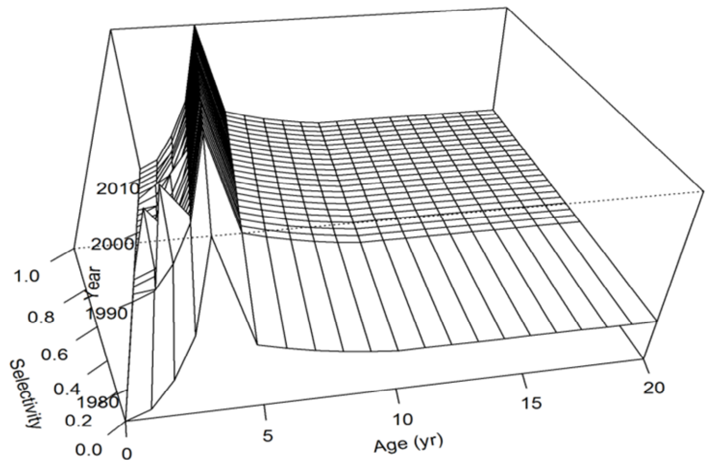
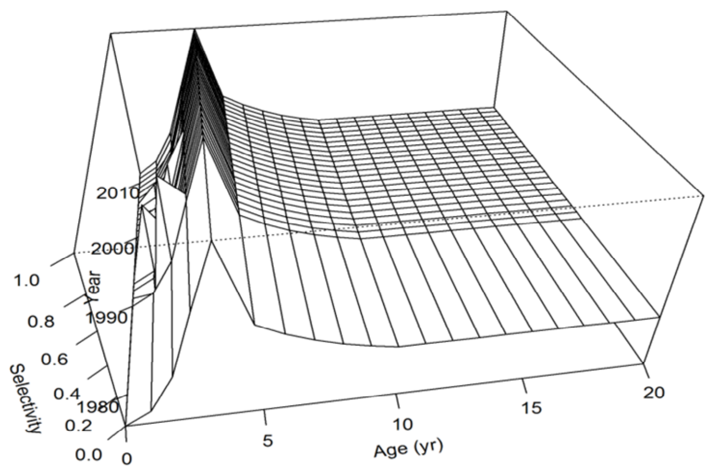


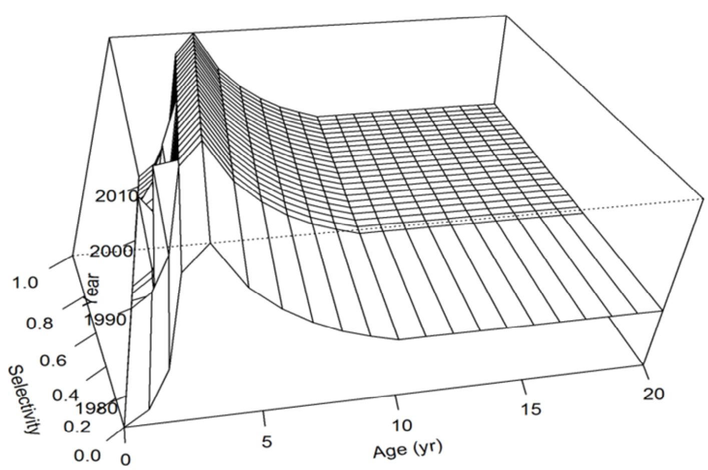
Figure 2A.1.7—Fishery selectivity at age as defined by parameters estimated by the four models.



Model 1



Model 2



Model 3

Figure 2A.1.8—Survey selectivity at age as estimated by the three models.

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