2. Assessment of the Pacific Cod Stock in the Eastern Bering Sea

Grant G. Thompson

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

EXECUTIVE SUMMARY

Summary of Changes in Assessment Inputs

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

Changes in the Input Data

1) Catch data for 1991-2016 were updated, and preliminary catch data for 2017 were incorporated.
2) Commercial fishery size composition data for 1991-2016 were updated, and preliminary size composition data from the 2017 commercial fishery were incorporated.
3) Size composition data from the 2017 EBS shelf bottom trawl survey were incorporated.
4) The numeric abundance estimate from the 2017 EBS shelf bottom trawl survey was incorporated (the 2017 estimate of 347 million fish was down about 46% from the 2016 estimate).
5) Age composition data from the 2016 EBS shelf bottom trawl survey were incorporated.
6) Age composition data from the 2013-2016 fisheries were incorporated into some of the models.

Changes in the Assessment Methodology

Many changes have been made or considered in the stock assessment model since the 2016 assessment (Thompson 2016). Ten models were reviewed by the BSAI Plan Team Subcommittee on Pacific Cod Models ("Subcommittee") at its June meeting (https://www.npfmc.org/wp-content/PDFdocuments/membership/PlanTeam/Groundfish/BSAIPcod_subcommittee617minutes.pdf), and seven models were presented in this year's preliminary assessment (Appendix 2.1), as requested at the conclusion of the June Subcommittee meeting. After reviewing the preliminary assessment, the BSAI Plan Team and SSC requested that a number of models from the preliminary assessment and one new model be presented in this final assessment. The requested models are as follow:

- Model 16.6: The current base model, exhibiting the following features:
    - One fishery, one gear type, one season per year.
    - Input sample sizes average 300, with season×gear catch-weighted sizecomps.
    - Logistic age-based selectivity for both the fishery and survey.
    - External estimation of time-varying weight-at-length parameters and the standard deviations of ageing error at ages 1 and 20.
    - All parameters constant over time except for recruitment and fishing mortality.
    - Internal estimation of all natural mortality, fishing mortality, length-at-age (including ageing bias), recruitment (conditional on Beverton-Holt recruitment steepness fixed at 1.0), catchability, and selectivity parameters.

- Model 17.1: Same as Model 16.6, but with the following features added:
    - Adjust timing of the fishery and survey in SS.
    - Switch to haul-based input sample size and week×gear×area catch-weighted sizecomps.
    - Do not use old (poorly sampled) fishery agecomps, but do add new fishery agecomps.
    - Develop a prior distribution for natural mortality based on previous estimates.
    - Switch to age-based, flat-topped, double normal selectivity.
    - Allow randomly time-varying selectivity for the fishery and survey, with σs fixed at the restricted MLEs.
- Model 17.2: Same as Model 17.1, but with the following features added:
    - Use harmonic mean weighting of composition data.
    - Allow randomly time-varying selectivity for the fishery but not the survey.
- Model 17.3: Same as Model 17.1, but with the following features added:
    - Use harmonic mean weighting of composition data.
    - Estimate survey index standard error internally ('extra SD' option in SS).
- Model 17.6: Same as Model 17.1, but with the following features added:
    - Use harmonic mean weighting of composition data.
    - Allow randomly time-varying length at age 1.5, with σ fixed at the restricted MLE.
    - Allow randomly time-varying trawl survey catchability
- Model 17.7: Same as Model 17.6, but with the following feature added:
    - All sizecomp and agecomp multipliers capped at a value of 1.0.

The author recommends using Model 17.2 to set harvest specifications for 2018 and 2019.

Summary of Results

The principal results of the present assessment, based on the author's **new recommended model**, are listed in the table below (biomass and catch figures are in units of t) and compared with the corresponding quantities from last year's assessment as specified by the SSC:

Quantity	As estimated or *specified last* year for: 2017	2018	As estimated or *recommended this* year for: 2018*	2019*
M (natural mortality rate)	0.36	0.36	0.38	0.38
Tier	3a	3a	3b	3b
Projected total (age 0+) biomass (t)	1,260,000	1,110,000	807,000	690,000
Projected female spawning biomass (t)	327,000	340,000	217,000	211,000
$B_{100\%}$	620,000	620,000	548,000	548,000
$B_{40\%}$	248,000	248,000	219,000	219,000
$B_{35\%}$	217,000	217,000	192,000	192,000
F_{OFL}	0.38	0.38	0.38	0.37
$maxF_{ABC}$	0.31	0.31	0.31	0.30
F_{ABC}	0.31	0.31	0.31	0.30
OFL (t)	284,000	302,000	202,000	173,000
maxABC (t)	239,000	255,000	172,000	148,000
ABC (t)	239,000	255,000	172,000	148,000
Status	As determined *last* year for: 2015	2016	As determined *this* year for: 2016	2017
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on assumed catches of 224,000 t, 162,000 t, and 148,000 t in 2017, 2018, and 2019, respectively.

Responses to SSC and Plan Team Comments on Assessments in General

Since last year's assessment was completed, the SSC has made the following comments on assessments in general (note that numbering of comments here is continuous with numbering of comments in the preliminary assessment; note also that SSC comments directed to the Plan Teams rather than the assessment authors are not included here):

SSC13 (12/16 minutes): "*In an effort improve record keeping as assessment authors formulate various stock status evaluation models, the Plan Team has recommended a systematic cataloging convention.... The SSC recommends this method of model naming and notes that it should reduce confusion and simplify issues associated with tracking model development over time*." The prescribed model naming convention is used in this assessment.

SSC14 (10/17 minutes): "*The SSC recommends that, for those sets of environmental and fisheries observations that support the inference of an impending severe decline in stock biomass, the issue of concern be brought to the SSC, with an integrated analysis of the indices involved. To be of greatest value, to the extent possible this information should be presented at the October Council meeting so that there is sufficient time for the Plan Teams and industry to react to the possible reduction in fishing opportunity. The SSC also recommends explicit consideration and documentation of ecosystem and stock assessment status for each stock... during the December Council meeting to aid in identifying areas of concern*." Once the processes for producing the integrated analysis of indices and explicit consideration and documentation of ecosystem and stock assessment status have been developed, any features of those processes identified for inclusion in the assessment will be added to future assessments.

Responses to SSC and Plan Team Comments Specific to this Assessment

Twenty-five comments specific to this assessment, including 7 comments from the Subcommittee, were addressed either in the minutes of the June 2017 Subcommittee meeting or in the preliminary assessment (Appendix 2.1). In the interest of efficiency, they are not repeated in this section. The two Subcommittee (Sub) comments from the June 2017 meeting that pertained only to the final assessment, along with the BSAI Plan Team (BPT) and SSC comments that were developed following completion of the preliminary assessment, are shown below (as above, numbering of comments here is continuous with numbering of comments in the preliminary assessment; note also that BPT comments are numbered separately from Subcommittee comments).

Sub8 (6/17 minutes): *"Although the Subcommittee feels that it will not be possible to incorporate feature Sub2 ("Examine survey data from the northern Bering Sea") into this year's preliminary EBS assessment due to the fact that there is currently only a single year's worth of data in the modern NBS survey time series and the results from this year's NBS survey will likely not be ready for inclusion until after the preliminary assessment is due, it may be possible to include this feature as a non-model analysis in the final assessment."* Non-model analyses of results from the northern Bering Sea (NBS) and Norton Sound surveys are presented in the "Data" section.

Sub9 (6/17 minutes): *"Although the Subcommittee also feels that features BPT3 ("Continue to compare empirical weight at age with the traditional approach") and GT10 ("Include EBS survey strata 82 and 90 (NW corner of EBS) in the data") should not be included as non-model analyses in this year's preliminary EBS assessment, it may be appropriate to include them as non-model analyses in the final assessment...."* See comment SSC23 regarding empirical weight at age. The background document provided to the Subcommittee in advance of the June meeting (attached to the minutes of that meeting as Appendix A) included a brief comparison of survey indices between the "standard" survey area and the standard area plus strata 82 and 90. An expanded comparison, updated to include this year's survey estimates, is provided in the "Data" section.

BPT7 (9/17 minutes): *"The Team was pleased with the work done on model averaging, but recommends to not use model averaging in the final 2017 Pacific cod assessment."* See comments SSC17, SSC19, SSC20, SSC21, SSC22, and SSC25. In brief, at its October meeting, the SSC advocated multiple times for inclusion of model averaging in this final assessment.

BPT8 (9/17 minutes): *"The Team recommends considering only models 16.6 and 17.6 for the final Pacific cod assessment."* See comments SSC17 and SSC19.

BPT9 (9/17 minutes): *"The Team would like to better understand the effects of the individual changes bridging from Model 16.6 to Model 17.6 and recommends that the analyst present a bridging analysis at the November meeting."* See comment SSC22.

BPT10 (9/17 minutes): *"The Team leaves it up to the analyst to determine the best order of changes/elements to investigate, and will be happy with a linear analysis of sequentially adding in elements. Recompiling existing data or making 'housekeeping' changes in the control file so as to keep Model 16.6 compliant with SS V3.30 do not necessarily constitute substantive changes in Model 16.6 and so do not need to be included as separate steps in the bridging analysis if the impacts of those changes are negligible."* See comment SSC22

SSC16 (10/17 minutes): *"The SSC supported the Plan Team's recommendation to use the lognormal prior distribution from this review, and further recommended removing all estimates from the prior that contained an appreciable amount of the data that is currently used in the stock assessment model, and would therefore be included in the likelihood function."* The prior distribution for the natural mortality rate has been revised along the lines suggested by this comment, and is described in the "Description of Alternative Models" section.

SSC17 (10/17 minutes): *"The SSC disagreed with the Plan Team recommendations to bring forward only models 16.6 and 17.6, and not use model averaging for 2017."* Models 16.6 and 17.6 are not the only models brought forward in this final assessment (see also comments SSC19, SSC21, and SSC26), and model averaging is the subject of Appendix 2.5.

SSC18 (10/17 minutes): *"Drop models 17.4 and 17.5 from the set under consideration."* Models 17.4 and 17.5 are not included in this final assessment.

SSC19 (10/17 minutes): *"Perform further diagnostics and evaluation on models 16.6, 17.1-17.3, and 17.6 in order to determine whether all five may be candidates for inclusion in a model averaged result in December."* All of the requested models are included in this final assessment, along with a new model (Model 17.7; see comment SSC26). Diagnostics that were not provided in the preliminary assessment but which are provided in this final assessment include: mean normalized residuals, standard deviation of normalized residuals, and correlation between observed and expected values (for survey index data); input sample size and effective sample size for each fleet/year age composition record; figures showing fits to all sizecomp and agecomp data (along with time-aggregated fits to those data); retrospective plots of spawning biomass in both absolute and relative terms; and quantitative adjustments to model weightings based on retrospective performance, model convergence behavior and general plausibility (see also comment SSC20). In order to allow the SSC complete flexibility in determining which models to include in the ensemble to be averaged, Appendix 2.5 includes results for every possible subset of models.

SSC20 (10/17 minutes): *"The SSC encourages the author to consider a broader method for model weighting (perhaps subjective in nature) that includes model fit and also retrospective performance, model convergence behavior and general plausibility."* The approaches to model weighting described in Appendix 2.5 (except for the equal weighting approach) account for retrospective performance, model convergence behavior, and general plausibility.

SSC21 (10/17 minutes): *"Bring forward for consideration in December one or more alternatives for model averaged results (based on models 16.6, 17.1-17.3 , and 17.6), which may include equal weighting, individual model averaged results using some other weighting developed per above, and a distribution fit to the model results (similar to the preliminary approach)."* Appendix 2.5 provides a total of 504 alternatives (each) for model-averaged 2018 ABC, 2018 OFL, 2019 ABC, and 2019 OFL. These are based on the models listed above and also Model 17.7, along with all possible subsets of that set (see comments SSC19 and SSC26). Approaches include equal weighting and three weighting systems based on the response to comment SSC20. Sample means, medians, and standard deviations are provided for each alternative and approach, which can be used to fit two-parameter distributions, as in the preliminary assessment (see also comment SSC25).

SSC22 (10/17 minutes): *"The SSC did not support the Plan Team's recommendation to provide further bridging analysis between models 16.6 and 17.6, but instead suggested a focus on model evaluation and diagnosis of 16.6, 17.1-17.3 and 17.6 for potential inclusion in a model-averaged approach in December."* See also comments BPT8, BPT9, and BPT10. Given the Team's request for a bridging analysis between Models 16.6 and 17.6, preliminary steps toward developing such an analysis were undertaken during the time period between the September Team meeting and the October SSC meeting. The results of this exercise are reported in the "Description of Alternative Models" section. In keeping with the SSC's request, however, a full bridging analysis is not provided.

SSC23 (10/17 minutes): *"Following on the December 2016 recommendation, continue exploration of the treatment of weight-at-age using both internally and externally estimated values, and the treatment of ageing bias in the stock assessment."* As with all comments from last year's November Team and December SSC meetings, the SSC's recommendations from December 2016 regarding continued exploration of empirical weight at age and the treatment of ageing bias were vetted at the June 2016 Subcommittee meeting. Appendices A and B of the minutes from that meeting included a summary of recent work that may bear upon the issue of ageing bias and further exploration of empirical weight at age, particularly with respect to empirical weights at age from the survey. With respect to these two SSC recommendations, the Subcommittee recommended that: 1) the requested exploration of empirical weight at age should wait until the final assessment when more data would be available, and 2) the requested exploration of ageing bias does not have to be done this year at all. Noting that the SSC agreed in June 2016 that Subcommittee recommendations would no longer be subject to SSC review, this year's preliminary and final assessments were prepared accordingly. The potential use of empirical weight at age is further addressed in this final assessment in the "Model Evaluation" section.

SSC24 (10/17 minutes): *"Further, conduct an exploratory analysis of recent weight-at-age data for evidence of patterns resembling those seen for GOA Pacific cod."* An analysis of condition factor is provided in the "Data" section, and an analysis of weight at age (including both data and model estimates) is provided in the "Model Evaluation" section.

SSC25 (10/17 minutes): *"Clarify, with the joint Plan Teams, the preferred measure of central tendency (e.g., median or mean) for assessments reporting probabilistic results either via Bayesian posteriors or model-averaged distributions."* This item is on the agenda for the November meeting of the Joint Plan Teams. Because this final assessment was prepared prior to the November meeting, there was no way to know which measure of central tendency would be preferred by the Teams. Therefore, full sets of results for both the mean and median are presented in Appendix 2.5 (see also comment SSC21).

SSC26 (10/17 minutes): *"For models where iterative reweighting is applied, if the initial input sample sizes have been derived based on a boot strapping approach or using the number of hauls, strongly consider tuning these inputs only in a downward direction in order to avoid placing implausibly high weights on certain data sets to the effective exclusion of others."* Of the five models requested by the SSC (Models 16.6, 17.1, 17.2, 17.3, and 17.6), only Models 17.2, 17.3, and 17.6 use iterative reweighting. When reweighting for these three models was completed, there were only two instances of multipliers exceeding a value of 1.0, both of which happened to apply to the survey sizecomp component: This multiplier had values of 1.0237 and 1.5903 in Models 17.3 and 17.6, respectively. The appropriate response to the SSC's comment hinges on whether the SSC intended to *replace* any models with at least one multiplier in excess of 1.0 with new models where all multipliers are capped at a value of 1.0, or to *add* new models where all multipliers are capped at a value of 1.0. Given that comments SSC19, SSC21, and SSC22 all seem to imply that Models 17.2, 17.3, and 17.6 are to be included in the final assessment, the second interpretation was adopted, except that, because the multiplier in Model 17.3 was so close to 1.0, this model was considered to satisfy the spirit of the SSC's recommendation, so a modified version of Model 17.3 was not added. However, because the multiplier in Model 17.6 was well above 1.0, an additional model (17.7) was developed in order to address the SSC's recommendation. Specifically, Model 17.7 was the same as Model 17.6, except that the compositional multipliers and the standard deviations of all *dev* vectors were re-tuned subject to the constraint that no multiplier could exceed a value of 1.0.

INTRODUCTION

General

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34° N latitude, with a northern limit of about 65° N latitude (Lauth 2011). Pacific cod is distributed widely over the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (GOA). However, recent research indicates the existence of discrete stocks in the EBS and AI (Canino et al. 2005, Cunningham et al. 2009, Canino et al. 2010, Spies 2012). Although the resource in the combined EBS and AI (BSAI) region had been managed as a single unit from 1977 through 2013, separate harvest specifications have been set for the two areas since the 2014 season.

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

Review of Life History

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

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

Juveniles occur mostly over the inner continental shelf at depths of 60 to 150 m. Adults occur in depths from the shoreline to 500 m, although occurrence in depths greater than 300 m is fairly rare. Preferred substrate is soft sediment, from mud and clay to sand. Average depth of occurrence tends to vary directly with age for at least the first few years of life. Neidetcher et al. (2014) have identified spawning locations throughout the Bering Sea and Aleutian Islands.

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

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

At least one study (Ueda et al. 2006) indicates that age 2 Pacific cod may congregate more, relative to age 1 Pacific cod, in areas where trawling efficiency is reduced (e.g., areas of rough substrate), causing their selectivity to decrease. Also, Atlantic cod have been shown to dive in response to a passing vessel (Ona and Godø 1990, Handegard and Tjøstheim 2005), which may complicate attempts to estimate catchability (*Q*) or selectivity. It is not known whether Pacific cod exhibit a similar response.

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

FISHERY

Description of the Directed Fishery

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

Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components (although catches by jig gear are very small in comparison to the other three main gear types, with an average annual catch of less than 200 t since 1992). The breakdown of catch by gear during the most recent complete five-year period (2012-2016) is as follows: longline gear accounted for an average of 54% of the catch, trawl gear accounted for an average of 31%, and pot gear accounted for an average of 15%.

In the EBS, Pacific cod are caught throughout much of the continental shelf, with National Marine Fisheries Service (NMFS) statistical areas 509, 513, 517, 519, and 521 each accounting for at least 5% of the average catch over the most recent 5-year period (2012-2016).

Catches of Pacific cod taken in the EBS for the periods 1964-1980, 1981-1990, and 1991-2017 are shown in Tables 2.1a, 2.1b, and 2.1c, respectively. The catches in Tables 2.1a and 2.1b are broken down by fleet sector (foreign, joint venture, domestic annual processing). The catches in Table 2.1b are also broken down by gear to the extent possible. The catches in Table 2.1c are broken down by gear.

Appendix 2.2 contains an economic performance report on the BSAI Pacific cod fishery.

Effort and CPUE

Catch-per-unit-effort (CPUE) data from the 1991-2017 longline fishery were analyzed, after rescaling the data relative to the time series average, using a model that estimates a time series of year and month effects. This enables the average (across months) CPUE for 2017 to be estimated even though data for the last few months of the year are not yet available. The estimated year and month effects are shown in the two upper panels of Figure 2.1 and the overall fit to the time series (inverse-variance-weighted R^2 = 0.92) is shown in the lower panel. The CPUE for 2017 is estimated to be about 14% below average for the time series, and about 8% below the CPUE for 2016.

Discards

The catches shown in Tables 2.1b and 2.1c include estimated discards. Discards of Pacific cod in the EBS Pacific cod fisheries are shown for each year 1991-2017 in Table 2.2. Amendment 49, which mandated increased retention and utilization of Pacific cod, was implemented in 1998. From 1991-1997, discard rates in the Pacific cod fishery averaged about 4.9%. Since then, they have averaged about 1.4%.

Management History

The history of acceptable biological catch (ABC), overfishing level (OFL), and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate (i.e., all-gear, combined area) commercial catches in Table 2.3. Note that, prior to 2014, this time series pertains to the combined BSAI region, so the catch time series differs from that shown in Table 2.1, which pertains to the EBS only.

From 1980 through 2016, TAC averaged about 84% of ABC (ABC was not specified prior to 1980), and from 1980 through 2016, commercial catch averaged about 92% of TAC. In 10 of these 37 years, TAC equaled ABC exactly, and in 9 of these 37 years, catch exceeded TAC (by an average of 3%). However, four of those overages occurred in 2007, 2008, 2010, and 2016, when TAC was reduced by various proportions to account for a small, State-managed fishery inside State of Alaska waters within the AI subarea (such reductions have been made in all years since 2006; see text table below for recent formulae); thus, while the combined Federal and State catch exceeded the Federal TAC in 2007, 2008, 2010 and 2016 by up to 4%, the overall target catch (Federal TAC plus State GHL) was *not* exceeded.

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

Changes in ABC over time are typically attributable to three factors: 1) changes in resource abundance, 2) changes in management strategy, and 3) changes in the stock assessment model. Assessments conducted prior to 1985 consisted of simple projections of current survey numbers at age. In 1985, the assessment was expanded to consider all survey numbers at age from 1979-1985. From 1985-1991, the assessment was conducted using an *ad hoc* separable age-structured model. In 1992, the assessment was conducted using the Stock Synthesis modeling software (Methot 1986, 1990) with age-based data. All assessments from 1993 through 2003 continued to use the Stock Synthesis modeling software, but with length-based data. Age data based on a revised ageing protocol were added to the model in the 2004 assessment. At about that time, a major upgrade in the Stock Synthesis architecture resulted in a substantially new product, at that time labeled “SS2” (Methot 2005). The assessment was migrated to SS2 in 2005. Changes to model structure were made annually through 2011, and then the base model remained constant since through 2015, and a new base model was adopted in 2016 (see Appendix 2.3). A note on software nomenclature: The label “SS2” was dropped in 2008. Since then, the program has been known simply as “Stock Synthesis” or “SS,” with several versions typically produced each year, each given a numeric or alpha-numeric label.

Beginning with the 2014 fishery, the Board of Fisheries for the State of Alaska has established guideline harvest levels (GHLs) in State waters between 164 and 167 degrees west longitude in the EBS subarea (these have supplemented GHLs that had been set aside for the Aleutian Islands subarea since 2006). The table below shows the formulas that have been used to set the State GHL for the EBS (including the formula anticipated for setting the 2018 GHL):

Year	Formula
2014	0.03 × (EBS ABC + AI ABC)
2015	0.03 × (EBS ABC + AI ABC)
2016	0.064 × EBS ABC
2017	0.064 × EBS ABC
2018	0.064 × EBS ABC

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

DATA

The first two subsections below describe fishery and survey data that are used in the current stock assessment models. The third subsection describes survey data that are not used in the current stock assessment models, but that may help to provide some context for the survey data that are used.

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

Source	Type	Years
Fishery	Catch biomass	1977-2017
Fishery	Catch size composition	1977-2017
Fishery	Catch age composition	2013-2016
EBS shelf bottom trawl survey	Numerical abundance	1982-2017
EBS shelf bottom trawl survey	Size composition	1982-2017
EBS shelf bottom trawl survey	Age composition	1994-2016

Fishery

Catch Biomass

Catch estimates for the period 1977-2017 are shown Tables 2.1a, 2.1b, and 2.1c. However, the estimate for 2017 is complete only through October 18. To obtain an estimate of the year-end catch for 2017, the method developed in the 2014 assessment was used (Thompson 2014). After comparing 12 alternative estimators in that assessment, it turned out that the best choice was simply to set the current year's catch during August-December equal to the previous year's catch during those same months, unless this would cause the catch to exceed the TAC, in which case the year-end catch was set equal to the TAC. This procedure resulted in an estimated year-end 2017 catch of 223,704 t, equal to the 2017 TAC.

The catches shown in Tables 2.1a, 2.1b, and 2.1c consist of "official" data from the NMFS Alaska Region. However, other removals of Pacific cod are known to have occurred over the years, including removals due to subsistence fishing, sport fishing, scientific research, and fisheries managed under other FMPs. Estimates of such other removals are shown in Appendix 2.4.

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

Size and Age Composition

Fishery size compositions are presently available from 1977 through the first part of 2017, and are parsed into 1-cm bins for use in the assessment models.

The size composition in data in Model 16.6 are based on the data used in Model 11.5, which was the base model from 2011-2015. Model 11.5 was structured with respect to both gear and season, whereas Model 16.6 is structured with only a single gear and a single season. When Model 16.6 was being developed during the 2016 assessment (Thompson 2016), the gear-and-season-specific catch proportions in each year were used to create a weighted average size composition from the size composition data used in Model 11.5, in an attempt to make the data files for the two models as comparable as possible. The same procedure was retained for the size composition data used in Model 16.6 for this year's assessment, resulting in the values shown in Table 2.5a, where the units for sample size and the remaining columns are number of fish actually sampled.

The size composition data used in the remaining models were completely recompiled, with each year's record computed by using the week/gear/area catch proportions to create a weighted average, as described in Appendix A of the minutes from the June 2017 Subcommittee meeting and again in this year's preliminary assessment (Appendix 2.1), resulting in the values shown in Table 2.5b, where both the specified sample sizes shown in the second column and the values shown in the remaining columns are in units of sampled hauls (rather than individual fish).

A possible concern with using a week/gear/area structure for compiling each year's size composition data is that it is too finely grained, so that, conceivably, a cell that accounts for a large proportion of the catch in a particular year might be sampled poorly for size composition, in which case the sampling error of the size composition from that cell would be magnified in the weighted average. However, this outcome appears to be infrequent in the actual data. For example, a catch proportion greater than 1% in a week/gear/area cell with fewer than 100 length samples occurs in less than 1% of the cases. Overall, catch proportion and length sample size across week/gear/area cells tend to be highly correlated (range across years = 0.64-0.85, mean=0.76).

SSC10: "The SSC recommends that including existing fishery ages in the assessment and ageing additional fishery otoliths for this assessment should be priorities…."

At its December 2016 meeting, the SSC recommended both: 1) using any existing fishery age data and 2) obtaining additional fishery age data. However, the Subcommittee advised against following the first part of this recommendation, because the very early fishery age data were based on age reading methods that have since been invalidated and the more recent fishery age data were considered to be unrepresentative, having been collected from a single gear type and single season. However, the Subcommittee agreed that obtaining additional fishery age data that did not suffer from either of these shortcomings should be a priority. Therefore, approximately 1000 otoliths that were carefully sub-sampled from the fishery were aged for each year between 2013 and 2016. Selection of otoliths for the fishery age composition data proceeded as follows: Given a desired total annual sample size of 1000 otoliths, the objectives were, first, to distribute the sample so as to reflect the proportion of the total catch in each gear/area/week combination as closely as possible, and second, conditional on achieving the first objective, to maximize the number of hauls sampled. The resulting age compositions were as follow, where "Nage" represents the number of otoliths read, "Nhaul" represents the number of hauls (or sets) sampled for length (rows sum to unity; note that ages 0 and 1 were both unrepresented in the otolith collections for all four years):

Year	Nage	Nhaul	2	3	4	5	6	7	8	9	10	11	12+
2013	988	11126	0.012	0.147	0.111	0.489	0.179	0.050	0.012	0.001	0.000	0.000	0.000
2014	987	12165	0.009	0.120	0.292	0.190	0.278	0.083	0.028	0.001	0.001	0.000	0.001
2015	999	11309	0.006	0.067	0.329	0.344	0.132	0.087	0.023	0.009	0.000	0.002	0.002
2016	995	9773	0.002	0.085	0.204	0.409	0.216	0.058	0.026	0.000	0.001	0.000	0.000

EBS Shelf Bottom Trawl Survey

Abundance

Strata 1-6 of the EBS shelf bottom trawl survey have been sampled annually since 1982, and comprise the standard survey area used in this assessment. Area-swept estimates of abundance (in numbers of fish) obtained from the trawl survey are shown in Table 2.6, together with their respective standard errors, log-scale standard deviations ("Sigma"), and lower and upper bounds of the 95% confidence intervals. Abundance estimates, 95% confidence intervals, and the long-term average abundance are shown in Figure 2.2.

The all-time high estimate of 1.232 billion fish occurred in 1994. The 2014 estimate of 1.122 billion fish was the second highest in the time series, but the next three surveys showed decreases of 12%, 35%, and 46%, respectively. The decrease from 2016 to 2017 is the largest proportional decrease in the history of the survey, and the 2017 estimate of 346 million fish is the second lowest value in the time series. A decrease in abundance from 2016 to 2017 was observed in all six strata, with changes ranging from -63% to -17%.

Size and Age Composition

The size compositions from the EBS shelf bottom trawl survey for the years 1982-2017 as used in Model 16.6 and Models 17.x are shown in in Tables 2.7a and 2.7b, respectively. Data are shown in 1-cm bins, and the sample sizes specified in the respective model's data files are shown in the second column (see "Use of Size Composition Data in Parameter Estimation" section for procedure used to obtain the specified sample sizes for Model 16.6; for Models 17.x, the specified sample sizes are equal to the number of hauls sampled for length). In Table 2.7a, the units for the remaining columns are number of fish actually sampled. In Table 2.7b, the units for the remaining columns are number of hauls sampled for length.

The size compositions from the six most recent surveys are shown in Figure 2.3, illustrating the difference between this year's survey and those from recent history.

Age compositions from the 1994-2016 surveys are currently available. The number of otoliths read, the number of hauls from which lengths were sampled, and the age compositions (as proportions) are shown in Table 2.8. For Model 16.6, the specified sample size is equal to the number of otoliths read, rescaled so that the mean is 300. For Models 17.x, the specified sample size is equal to the number of hauls from which lengths were sampled.

Survey Data Provided for Context Only

Results from several other surveys, or additional survey areas, may provide some helpful context for the results provided in the previous section. These include the two "northwest" strata of the EBS shelf survey (strata 82 and 90), the NBS bottom trawl survey, the Norton Sound bottom trawl survey, the NMFS longline survey, and the International Pacific Halibut Commission (IPHC) longline survey. The areas covered by these surveys are shown in Figures 2.4a (EBS shelf bottom trawl survey standard area, EBS shelf bottom trawl survey strata 82 and 90, and the NBS bottom trawl survey), 2.4b (Norton Sound bottom trawl survey), 2.4c (NMFS longline survey), and 2.4d (IPHC longline survey).

EBS Shelf Bottom Trawl Survey: Standard Area Biomass

Standard area biomass estimates from the EBS shelf bottom trawl survey have been positively correlated with the corresponding abundance time series over the years (correlation = 0.64).

Area-swept estimates of biomass obtained from the trawl survey are shown in Table 2.9, together with their respective standard errors, log-scale standard deviations ("Sigma"), and lower and upper bounds of the 95% confidence intervals. Biomass estimates, 95% confidence intervals, and the long-term average biomass are shown in Figure 2.5. The highest biomass ever observed by the survey was the 1994 estimate of 1,368,120 t. Following the high observation in 1994, the survey biomass estimate declined steadily through 1998. The survey biomass estimates remained in the 596,000-619,000 t range from 2002 through 2005. However, the survey biomass estimates dropped after 2005, producing an all-time low in 2007 and again in 2008. Estimated biomass more than doubled between 2009 and 2010, then remained relatively stable for the next three years, followed by another large increase (36%) in 2014, which was sustained through 2015. The 2016 estimate represented a 14% drop relative to 2015, and the 2017 estimate of 598,260 t represents a 37% drop relative to 2016, which is the largest proportional decrease in the time series. A decrease in biomass from 2016 to 2017 was observed in five of the six strata, with changes ranging from -54% to -7%. The remaining stratum, which accounted for only 2-4% of the total biomass in 2016 and 2017, showed an increase of 21%.

Occasionally, the direction of change in survey biomass estimates tends to be fairly constant across species that are considered to be well sampled by the survey. For example, in 2010 and 2014, of the FMP species whose assessments use the EBS survey as a primary index, the survey biomass estimates for all but one increased relative to those of the previous year, which might be interpreted as reflecting some sort of sampling “year effect” in addition to, or instead of, actual changes in the biomass of the species. Thus, it may be helpful to consider whether this year’s very substantial decrease in estimated Pacific cod biomass might be due in part to an across-the-board year effect. Figure 2.6 shows the proportional change in survey biomass from 2016 to 2017 for the 10 species that were present in at least 50% of the hauls in both years. While 8 of the 10 species showed a decrease, none was nearly as large as the decrease in Pacific cod biomass (the decrease in Pacific cod biomass was almost exactly twice as large as the next largest decrease).

EBS Shelf Bottom Trawl Survey: Standard Area Plus Strata 82 and 90
As noted above, the EBS shelf bottom trawl survey has maintained a consistent time series since 1982 in the standard area. Since 1987, strata 82 and 90, located to the northwest of the standard survey area, have also been sampled annually.

Abundance and Biomass
Abundance (1000s of fish) and biomass (t) estimated for strata 82 and 90 are shown below:

Index	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Abundance	20,021	4,535	9,502	14,272	7,873	7,876	3,579	23,370	3,771	7,295	8,017
Biomass	37,081	15,191	35,331	37,740	16,081	9,813	5,997	16,305	5,332	19,767	22,712

Index	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Abundance	8,247	53,892	4,797	13,099	8,260	17,596	6,739	13,942	13,560	20,418	15,946
Biomass	16,354	48,914	6,392	15,360	13,378	34,686	15,755	32,714	26,337	26,633	24,378

Index	2009	2010	2011	2012	2013	2014	2015	2016	2017
Abundance	5,175	8,465	7,642	3,369	9,336	7,111	3,228	20,636	17,435
Biomass	8,793	10,428	15,043	5,736	19,709	15,558	6,854	41,392	45,693

Ratios of abundance and biomass between estimates that include strata 82 and 90 and those that include the standard area only are shown below (minimum, median, mean, and maximum values are shown at the right-hand side of the bottom row).

Index	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Abundance	1.030	1.009	1.033	1.034	1.016	1.014	1.004	1.019	1.005	1.012	1.017	1.016
Biomass	1.036	1.016	1.042	1.055	1.031	1.019	1.009	1.012	1.005	1.022	1.038	1.031
Index	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Abundance	1.110	1.010	1.014	1.015	1.035	1.017	1.031	1.034	1.028	1.033	1.007	1.010
Biomass	1.086	1.012	1.019	1.023	1.059	1.028	1.054	1.051	1.063	1.060	1.021	1.012
Index	2011	2012	2013	2014	2015	2016	2017	min.	med.	mean	max.	
Abundance	1.009	1.003	1.012	1.006	1.003	1.032	1.050	1.003	1.016	1.022	1.110	
Biomass	1.017	1.006	1.025	1.014	1.006	1.044	1.076	1.005	1.025	1.032	1.086	

Condition Factor

Fulton's condition factor (Ricker 1975), defined as the ratio of weight to length cubed, was computed for fish from the EBS shelf bottom trawl survey, including strata 82 and 90. The results, after averaging across age and converting to z-scores, are plotted for the years 2000-2017 in Figure 2.7. The 2016 and 2017 values are virtually identical (reflecting less than a 0.1% relative change in Fulton's condition factor), and are both higher than any other point in the time series except for 2003. However, the z-scores for 7 of the previous 8 years were negative.

Table 2.10 shows condition factor z-scores by both age (1-10) and year (2000-2016; ages for 2017 are not yet available). Negative values are shaded red in the upper part of the figure. The lower part of the table highlights five cohorts that have previously been identified as being exceptionally strong.

NBS Bottom Trawl Survey

Biomass and Abundance

Trawl surveys of the NBS have been conducted in 2010 and 2017. Biomass and abundance estimates, along with coefficients of variation and upper and lower bounds of 95% confidence intervals, are shown below:

	Biomass (t)				Abundance (number of fish)			
Year	Estimate	CV	L95%CI	U95%CI	Estimate	CV	L95%CI	U95%CI
2010	28,425	0.23	15,520	41,330	8,881,464	0.20	5,402,268	12,360,661
2017	286,310	0.13	211,479	361,140	135,064,549	0.13	100,794,138	169,334,960

The differences in the estimates between years are enormous. Biomass increased by 907% and abundance increased by 1421%. Although the origin of the fish in the NBS is unknown (and potentially mixed), as a point of comparison, it may be noted that the 2017 estimate of biomass in the NBS is equal to 83% of the decrease in biomass estimated in the EBS standard area.

Size composition

Size compositions from the two years of the NBS survey, binned into 5-cm intervals, are shown in Figure 2.8. The upper panel shows size composition in terms of estimated abundance, while the lower panel shows size composition in terms of within-year proportions. The two most dominant modes occurred at the 10-15 and 75-80 cm bins in 2010 and the 30-35 and 55-60 cm bins in 2017. In comparison, the two most dominant modes from the EBS shelf bottom trawl survey (standard area) in those same years occurred at the 30-35 and 45-50 cm bins in 2010 and the 20-25 cm and 55-60 cm bins in 2017.

Norton Sound Bottom Trawl Survey

Catch Per Unit Effort

Bottom trawl surveys of Norton Sound were conducted by NMFS in 1976-1991 (3-year intervals); and by the Alaska Department of Fish and Game in 1996, 1999, 2002, 2006, 2008, 2010, 2011, 2014, and 2017.

Area-swept estimates of biomass or abundance are not available for the Norton Sound survey. However, the time series of CPUE (with catch measured in units of biomass) for the "core" and "tier 1" areas (see Figure 2.4b), which are the areas that have been the most consistently sampled, are shown in Figure 2.9. The 1985-2014 average values were 102 and 174 kg/km2 for the core and tier 1 areas, respectively, with the 2017 values jumping all the way to 854 and 1199 kg/km^2, respectively. For comparison, the mean CPUE from the EBS shelf bottom trawl survey, across all years and strata within the standard area, is 1774 kg/km^2.

Size composition
Because density of Pacific cod in the Norton Sound survey is comparatively low in most years, sample sizes have usually been too small to compute meaningful estimates of size composition. Only three years resulted in length sample sizes greater than 100: 2006 (n=133), 2008 (n=157), and 2017 (n=170). Figure 2.10 shows size compositions for these three years along with the long-term average size composition, with lengths binned into 5-cm intervals. For this small sample of years, modal lengths have consistently fallen within the 60-70 cm size range.

NMFS Longline Survey
The NMFS longline survey time series (1982-2017, 2-year intervals after 1997) of relative population number (RPN) and relative population weight (RPW) are shown, after rescaling relative to the respective mean, in Figure 2.11. RPN for 2017 was down 11% from 2015, and RPW was up 2%. Both are 26-30% below the long-term average.

IPHC Longline Survey
The IPHC longline survey time series (1997-2016; 2017 data not yet available) of RPN is shown in Figure 2.12. RPN for 2016 was down 27% from 2015, and is about 11% below the long-term average.

ANALYTIC APPROACH

General Model Structure

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

Version 3.30.08.03 of SS (compiled on 9/29/2017 using ADMB 11.6) was used to run the models in this assessment.

Description of Alternative Models

List of Models
Beginning with the final 2015 assessment, model numbering has followed the protocol given by Option A in the SAFE chapter guidelines. The goal of this protocol is to make it easy to distinguish between major and minor changes in models and to identify the years in which major model changes were introduced. Names of models constituting *major* changes get linked to the year that they are introduced (e.g., Model 16.6 is one of several models introduced in 2016 that constituted a major change from the then-current base model), while names of models constituting *minor* changes from the current base model get linked to the name of the current base model (e.g., Model 16.6a would refer to a model that constituted a minor change from Model 16.6, regardless of the year in which it was introduced, so long as Model 16.6 was still the current base model). Names of all final models adopted between the 2005 assessment (when an ADMB-based version of SS was first used) and the 2015 assessment were translated according to the current naming convention in Table 2.11 of the 2015 assessment (Thompson 2015).

This year’s preliminary assessment included Model 16.6, which was newly adopted as the base model in 2016 (it replaced Model 11.5, which had been the base model since 2011), and six new models (Models 17.1-17.6). For this year’s final assessment, the Team and SSC provided conflicting recommendations: The Team requested inclusion of only Models 16.6 and 17.6 (comment BPT8), accompanied by a "bridging analysis" (comments BPT9 and BPT10), whereas the SSC requested inclusion of those two models plus Models 17.1, 17.2, and 17.3 (comments SSC19, SSC21, and SSC22) and perhaps others (depending on the interpretation of comment SSC26), and recommended against including the Team's requested bridging analysis (comment SSC22). Erring on the side of inclusion, the five models requested explicitly by the SSC are included here and, as discussed in the "Responses to SSC and Plan Team Comments Specific to this Assessment" section, comment SSC26 was interpreted as requiring the addition of a six model, which was designated Model 17.7.

- Model 16.6: The current base model, exhibiting the following features:
    - One fishery, one gear type, one season per year.
    - Input sample sizes average 300, with season×gear catch-weighted sizecomps.
    - Logistic age-based selectivity for both the fishery and survey.
    - External estimation of time-varying weight-at-length parameters and the standard deviations of ageing error at ages 1 and 20.
    - All parameters constant over time except for recruitment and fishing mortality.
    - Internal estimation of all natural mortality, fishing mortality, length-at-age (including ageing bias), recruitment (conditional on Beverton-Holt recruitment steepness fixed at 1.0), catchability, and selectivity parameters.
- Model 17.1: Same as Model 16.6, but with the following features added:
    - Adjust timing of the fishery and survey in SS.
    - Switch to haul-based input sample size and week×gear×area catch-weighted sizecomps.
    - Do not use old (poorly sampled) fishery agecomps, but do add new fishery agecomps.
    - Develop a prior distribution for natural mortality based on previous estimates.
    - Switch to age-based, flat-topped, double normal selectivity.
    - Allow randomly time-varying selectivity for the fishery and survey, with σs fixed at the restricted MLEs.
- Model 17.2: Same as Model 17.1, but with the following features added:
    - Use harmonic mean weighting of composition data.
    - Allow randomly time-varying selectivity for the fishery but not the survey.
- Model 17.3: Same as Model 17.1, but with the following features added:
    - Use harmonic mean weighting of composition data.
    - Estimate survey index standard error internally ('extra SD' option in SS).
- Model 17.6: Same as Model 17.1, but with the following features added:
    - Use harmonic mean weighting of composition data.
    - Allow randomly time-varying length at age 1.5, with σ fixed at the restricted MLE.
    - Allow randomly time-varying trawl survey catchability
- Model 17.7: Same as Model 17.6, but with the following feature added:
    - All sizecomp and agecomp multipliers capped at a value of 1.0.

Selectivity

Models 17.x all feature "age-based, flat-topped, double normal selectivity." There are multiple ways to configure double normal selectivity so as to achieve a flat-topped functional form. As described in the preliminary assessment, the parameter governing the point at which the flat-topped portion of the function begins (parameter "P1") and the "ascending width" parameter (parameter "P2") were the only two parameters estimated internally in the approach adopted here. The others were fixed as follows:

- The parameter defining the length of the flat-topped portion of the curve (as a logit transform between the beginning of the flat-topped portion and the maximum age) was fixed at a value of 10.0, thereby eliminating any descending limb.

- Given the above, the parameters defining the "descending width" and selectivity at the maximum age are rendered essentially superfluous, and were both fixed at a value of 10.0.
- The parameter defining the selectivity at age 0 was fixed at a value of -10.0, corresponding to a selectivity indistinguishable from 0.0.

Initial Steps toward a Bridging Analysis between Models 16.6 and 17.6
As discussed in the response to comment SSC22, given the Team's request for a bridging analysis between Models 16.6 and 17.6, preliminary steps toward developing such an analysis were undertaken during the time period between the September Team meeting and the October SSC meeting. Although a full bridging analysis was not attempted (in keeping with comment SSC22), results of these preliminary steps are presented here.

In principle, the steps consisted of examining each feature distinguishing Model 17.6 from Model 16.6 one at a time (not cumulatively), using the data files from the preliminary assessment (Appendix 2.1), with the objective of determining the impact of each on model results. However, the following exceptions and clarifications should be noted:

- The sizecomp and agecomp multipliers were borrowed from the version of Model 17.6 that was presented in the preliminary assessment, rather than computing them from scratch. Because the multipliers in Model 17.6 were based on using number of hauls as the initial sample size, it did not make sense to apply the same multipliers to the initial sample sizes used in Model 16.6 (which were based on number of length samples); so, for the run in which multipliers were reweighted (relative to the value of 1.0 used for all multipliers in Model 16.6), the switch to haul-based input sample sizes was included also. Note that use of haul-based initial sample sizes is also considered on its own, in a separate run.
- The sigmas for the time-varying selectivity parameters were borrowed from the version of Model 17.6 that was presented in the preliminary assessment. Because those sigmas were estimated under the assumption of double normal selectivity, it did not make sense to assume that the same sigmas would apply to the logistic selectivity used in Model 16.6, so all of the runs involving time-varying selectivity also assumed that selectivity followed the double normal form.

Two measures were chosen to measure the impact of adding any given feature of Model 17.6 to Model 16.6: The first was the average difference in spawning biomass ("ADSB"), defined as the root-mean-squared-proportional-difference in spawning biomass between "Model 16.6 plus the given feature from Model 17.6" and Model 16.6. The second was the absolute value of the relative change in 2016 spawning biomass ("ΔSB16").

The results of this analysis are shown in Table 2.11. However, the feature labeled "Adjust timing of the fishery and survey in SS" listed above under Model 17.1 turned out to of negligible importance, as the ADSB was only 0.0086, so this feature is not presented in the table and, instead, all data files were modified to include it. Results in Table 2.11 are sorted in increasing order of impact. The same four features had the lowest impact under either measure (ADSB < 0.05 and ΔSB16<0.03 for all four):

- Use of the prior distribution for natural mortality (as specified in the preliminary assessment)
- Switching from logistic selectivity to flat-topped, time-invariant, double normal selectivity
- Including random time variability in length at age 1.5
- Including random time variability in survey catchability

The feature exhibiting the greatest impact, under either measure, was switching from input sample sizes based on number of sampled fish and rescaled to a mean of 300 to haul-based input sample sizes without subsequent reweighting, which gave ADSB=0.3705 and ΔSB16=0.5197.

However, a word of caution about Table 2.11 is in order, insofar as the rankings based on *adding* one feature from Model 17.6 at a time (but not cumulatively) to Model 16.6 are not necessarily the same as the rankings based on *removing* one feature at a time from Model 17.6. For example, in Table 2.11, allowing time variability in survey catchability had the least impact of any of the features as measured by ΔSB16. However, in other exploratory runs (not presented here), removing time variability in survey catchability had a bigger impact on ΔSB16 than removing time variability in any of the selectivity parameters other than survey selectivity parameter P1.

Prior Distribution for the Natural Mortality Rate

At its December 2016 meeting, the SSC requested that a prior distribution for the natural mortality (*M*) rate be developed, using "the variety of estimates referenced" in the 2016 EBS, AI, and GOA Pacific cod assessments (comment SSC6, listed in Appendix 2.1). In response, a prior distribution based on all such estimates, including the estimates of *M* derived in the 2016 EBS and GOA Pacific cod assessments themselves, was developed and applied to Models 17.1-17.6 in the preliminary assessment.

At its October 2017 meeting, the SSC clarified that only a subset of the referenced estimates should be used; specifically, those remaining after removing all estimates from studies "that contained an appreciable amount of the data that is currently used in the stock assessment model." The table below lists all values of *M* referenced in the 2016 EBS, AI, and GOA Pacific cod assessments, including the estimates of *M* derived in the 2016 EBS and GOA Pacific cod assessments themselves. The final column indicates whether the respective value was used in developing the prior distribution that was applied to Models 17.x in this final assessment.

Area	Author	Year	Value	Use?
EBS	Low	1974	0.30-0.45	1
EBS	Wespestad et al.	1982	0.7	0
EBS	Bakkala and Wespestad	1985	0.45	0
EBS	Thompson and Shimada	1990	0.29	0
EBS	Thompson and Methot	1993	0.37	0
EBS	Shimada and Kimura	1994	0.96	1
EBS	Shi et al.	2007	0.40-0.50	1
EBS	Thompson et al.	2007	0.34	0
EBS	Thompson	2016	0.36	0
GOA	Thompson and Zenger	1993	0.27	0
GOA	Thompson and Zenger	1995	0.50	0
GOA	Thompson et al.	2007	0.38	0
GOA	Barbeaux et al.	2016	0.47	1
BC	Ketchen	1964	0.56-0.63	1
BC	Fournier	1983	0.65	1
Korea	Jung et al.	2009	0.82	1
Japan	Ueda et al.	2004	0.20	1

Given the data listed above (using only those values with a "1" in the final column, and taking the midpoint of any estimate identified as a range), and assuming a lognormal distribution (see comment

SSC16), the maximum likelihood estimates of μ and σ are -0.6666 and 0.4930, respectively. The resulting distribution has an arithmetic mean of 0.5798, a geometric mean of 0.5134, a harmonic mean of 0.4547, a mode of 0.4027, and a 95% credibility interval extending from 0.1954 to 1.3493 (Figure 2.13).

Time-Varying Parameters
The procedures for tuning the "sigma" terms that constrain time-varying parameters was described in the preliminary assessment (Appendix 2.1, "Model structures" section). Briefly, except for time-varying catchability, the procedure is one that produces the restricted maximum likelihood estimates of the sigma terms in a linear-normal model. For time-varying catchability, the procedure was to choose the sigma value that sets the root-mean-squared-error of the estimated survey abundance equal to the average log-scale standard error specified in the data file.

The deviation "type" (additive or multiplicative), range of years, and models using each of the various time-varying parameters other than recruitment is shown below:

Parameter	Type	Year range	M16.6	M17.1	M17.2	M17.3	M17.6	M17.7
Fishery selectivity P1	mult.	1977-2017		x	x	x	x	x
Fishery selectivity P3	add.	1977-2017		x	x	x	x	x
Survey selectivity P1	mult.	1982-2017		x		x	x	x
Survey selectivity P3	add.	1982-2017		x		x	x	x
Length at age 1.5	mult.	1981-2015					x	x
Catchability	add.	1982-2017					x	x

Note that, for the mean length at age 1.5, each *dev* becomes "active" in the year for which it is estimated, meaning that it governs the parameters of the mean-length-at-age relationship for fish recruiting at age 0 in that year. However, its impact on the mean length of age 1.5 fish does not occur until the *following* year. Thus, the impacts of the deviations estimated for the years 1981-2016 are manifested at age 1.5 in the years 1982-2017, which are the years spanned by the survey data.

Convergence Behavior
As in previous assessments, development of the final versions of all models included calculation of the Hessian matrix and a requirement that all models pass a "jitter" test of 50 runs. Following the procedure established in the 2016 assessment, when running a jitter test, the bounds for each parameter in the model were adjusted to match the 99.9% confidence interval (based on the normal approximation obtained by inverting the Hessian matrix). A jitter rate (equal to half the standard deviation of the logit-scale distribution from which "jittered" parameter values are drawn) was set at 1.0 for all models. Standardizing the jittering process in this manner will not explore parameter space as thoroughly as possible; however, it makes the jitter rate more interpretable, and shows the extent to which the identified minimum (local or otherwise) is well behaved.

In the event that a jitter run produced a better value for the objective function than the base run, then:

1. The model was re-run starting from the final parameter file from the best jitter run.
2. The resulting new control file, with the parameter estimates from the best jitter run incorporated as starting values, became the new base run.
3. The entire process (starting with a new set of jitter runs) was repeated until no jitter run produced a better value for the objective function than the most recent base run.

Parameters Estimated Outside the Assessment Model

Variability in Estimated Age

Variability in estimated age in the assessment models is based on the standard deviation of estimated age between "reader" and "tester" age determinations (note that this is not the same as ageing *bias*, which is estimated internally). Weighted least squares regression, without an intercept, has been used in the past several assessments to estimate a proportional relationship between standard deviation and age. The regression has traditionally been computed over ages 1 through 13, yielding a slope parameter that is used to estimate standard deviation at age as the product of slope and age.

Because Model 16.6 does not use the fishery age data but Models 17.x do use the fishery age data, two versions of the regression were made:

- For the survey-only data, the estimated slope was 0.085, giving a weighted R^2 of 0.98. This regression corresponds to a standard deviation at age 1 of 0.085 and a standard deviation at age 20 of 1.695. These parameters were used for Model 16.6.
- For the combined survey and fishery data, the estimated slope was 0.082, giving a weighted R^2 of 0.97. This regression corresponds to a standard deviation at age 1 of 0.085 and a standard deviation at age 20 of 1.632. These parameters were used for Models 17.x.

Weight at Length

Using the functional form weight = $\alpha \times \text{length}^{\beta}$, where weight is measured in kg and length is measured in cm, the long-term base values for the parameters were estimated this year (using fishery data from 1974 through 2017) as α = 5.66004E-06 and β = 3.185682.

All of the models allow inter-annual, externally estimated, variability in weight-length parameters. Values of annual additive offsets from the base α and β values are shown in Table 2.12. Although values were calculated for 1977 (the initial year in the model), they were not used in the data files, because SS computes $B_{100\%}$ on the basis of the biology in the initial year, and it seemed more important to have $B_{100\%}$ represent a long-term average than to get the weight-length relationship in 1977 exactly right. Schedules of weight at length (up to 100 cm) are shown for the base parameter values and the offset-adjusted parameter values for each year in Figure 2.14.

Maturity

A detailed history and evaluation of parameter values used to describe the maturity schedule for BSAI Pacific cod was presented in the 2005 assessment (Thompson and Dorn 2005). A length-based maturity schedule was used for many years. The parameter values used for the length-based maturity schedule in the 2005 and 2006 assessments were set on the basis of a study by Stark (2007) at the following values: length at 50% maturity = 58 cm and slope of linearized logistic equation = –0.132. However, in 2007, changes in SS allowed for use of either a length-based or an age-based maturity schedule. Beginning with the 2007 assessment, the accepted model has used an age-based schedule with intercept = 4.88 years and slope = –0.965 (Stark 2007). The use of an age-based rather than a length-based schedule follows a recommendation from the maturity study's author (James Stark, Alaska Fisheries Science Center, *pers. commun.*). The age-based parameters were retained for the models in the present assessment.

Stock-Recruitment "Steepness"

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

Parameters Estimated Inside the Assessment Model

A total of 78 parameters were estimated inside SS for Model 16.6. These consist of the following:

1. instantaneous natural mortality rate (*M*)
2. all three von Bertalanffy growth parameters, plus the Richards growth parameter
3. standard deviation of length at ages 1 and 20
4. mean ageing bias at ages 1 and 20
5. log mean recruitment since the 1976-1977 regime shift
6. offset for log-scale mean recruitment before the 1976-1977 regime shift
7. standard deviation of the log-scale recruitment deviations (σ_R)
8. initial (equilibrium) fishing mortality
9. log catchability for the trawl survey
10. deviations for log-scale initial (i.e., 1977) abundance, ages 1-20
11. log-scale recruitment deviations, 1977-2016
12. base values of both selectivity parameters for both the fishery and survey

Parameter counts for Models 17.x were as follow:

Model 17.1	Model 17.2	Model 17.3	Model 17.6	Model 17.7
231	159	232	304	304

All parameters estimated internally in Model 16.6 were also estimated internally in Models 17.x except:

- In Models 17.x, σ_R was estimated by the tuning procedure described in the preliminary assessment (Appendix 2.1, "Model Structures" section).
- The definitions of the selectivity parameters differ (logistic in Model 16.6, flat-topped double normal in Models 17.x), although the number of base values remain the same (4).

In addition, the following parameters were also estimated internally by one or more models in the 17.x series:

- deviations for fishery selectivity parameters, 1977-2017 (Models 17.1, 17.2, 17.3, 17.6, 17.7)
- deviations for survey selectivity parameters, 1982-2017 (Models 17.1, 17.3, 17.6, 17.7)
- "extra" standard error for the log-scale survey standard error (Model 17.3)
- deviations for length at age 1.5, 1981-2016 (Models 17.6, 17.7)
- deviations for log catchability, 1982-2017 (Models 17.6, 17.7)

In all models, uniform prior distributions were used for all parameters except for M in Models 17.x. It should also be noted that vectors of deviations were constrained by input standard deviations, which are somewhat analogous to a joint prior distribution.

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

In addition to the above, the full set of fishing mortality rates were also estimated internally, but not in the same sense as the above parameters. The fishing mortality rates are determined (almost) exactly as functions of other model parameters, because SS assumes that the input total catch data are true values rather than estimates, so the fishing mortality rates can be computed algebraically given the other parameter values and the input catch data. An option does exist in SS for treating the fishing mortality rates as full parameters, but previous explorations have indicated that adding these parameters has almost no effect on other model output (Methot and Wetzel 2013).

Objective Function Components

All models in this assessment include likelihood components for catch, initial (equilibrium) catch, trawl survey relative abundance, recruitment, "softbounds" (analogous to a very weak prior distribution designed to keep parameters from hitting bounds), fishery and survey size composition, and survey age composition. In addition, Models 17.x include components for the prior distribution on *M*, non-recruitment parameter deviations, and fishery age composition.

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

Use of Size Composition Data in Parameter Estimation

Size composition data are assumed to be drawn from a multinomial distribution specific to a particular year and fleet (fishery or survey). 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 (and perhaps adjusted by a multiplier) for the multinomial distribution from which the data are assumed to be drawn. In developing the model upon which SS was originally based, Fournier and Archibald (1982) suggested truncating the multinomial sample size at a value of 400 in order to compensate for contingencies which cause the sampling process to depart from the process that gives rise to the multinomial distribution. For many years, the Pacific cod assessments assumed a multinomial sample size equal to the square root of the true length sample size, rather than the true length sample size itself. Given the true length sample sizes observed in the EBS Pacific cod data, this procedure tended to give values somewhat below 400 while still providing SS with usable information regarding the appropriate effort to devote to fitting individual length samples.

Although the "square root rule" for specifying multinomial sample sizes gave reasonable values, the rule itself was largely *ad hoc*. In an attempt to move toward a more statistically based specification, the 2007 assessment used the harmonic means from a bootstrap analysis of the available fishery length data from 1990-2006 (Thompson et al. 2007). The harmonic means were smaller than the actual sample sizes, but still ranged well into the thousands. A multinomial sample size in the thousands would likely overemphasize the size composition data. As a compromise, the harmonic means were rescaled proportionally in the 2007 assessment so that the average value (across all samples) was 300. However, the question then remained of what to do about years not covered by the bootstrap analysis (2007 and pre-1990) and what to do about the survey samples. The solution adopted in the 2007 assessment was based on an observed consistency in the ratios between the harmonic means (the raw harmonic means, not the rescaled harmonic means) and the actual sample sizes: Whenever the actual sample size exceeded about 400 fish, for the years prior to 1999 the ratio was very consistently close to 0.16, and for the years after 1998 the ratio was very consistently close to 0.34.

This consistency was used to specify the missing values as follows: For fishery data, records with actual sample sizes less than 400 were omitted. Then, the sample sizes for fishery length compositions from years prior to 1999 were tentatively set at 16% of the actual sample size, and the sample sizes for fishery length compositions from 2007 were tentatively set at 34% of the actual sample size. For the pre-1982 trawl survey, length compositions were tentatively set at 16% of an assumed sample size of 10,000. For the post-1981 trawl survey length compositions, sample sizes were tentatively set at 34% of the actual sample size. Then, with sample sizes for fishery length compositions from 1990-2007 tentatively set at their bootstrap harmonic means (not rescaled), all sample sizes were adjusted proportionally so that the average was 300.

The same procedure was used in the 2008 and 2009 assessments. For the 2010 assessment, however, this procedure had to be modified somewhat, because the bootstrap values for the 1990-2006 size composition data did not match the new bin and seasonal structures. To be as consistent as possible with the approach used to set sample sizes in the 2008 and 2009 assessments, the 2010 and 2011 assessments set sample sizes by applying the 16/34% rule for *all* size composition records with actual sample sizes greater than 400 (not just those lying outside the set of 1990-2006 fishery data), then rescaling proportionally to achieve an average sample size of 300. The same procedure was used for the 2012-2016 assessments, except the pre-1982 trawl survey data were no longer used. Model 16.6 in this year's assessment uses the same procedure as the 2012-2016 assessments. Models 17.x, on the other hand, simply set the input sample size equal to the number of hauls (or sets) sampled for length.

Input sample sizes for size composition data are shown for Model 16.6 and the 17.x series in Table 2.13.

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 fleet (fishery or survey). In Model 16.6, input sample sizes were specified by scaling the number of otoliths read in each year such that the average across all years was equal to 300. In Models 17.x, the input sample sizes were set equal to the number of hauls (or sets) sampled for length (see comment SSC3, listed in Appendix 2.1).

Input sample sizes for fishery age composition data (used only in Models 17.x) are shown below:

Year:	2013	2014	2015	2016
Nhaul:	11126	12165	11309	9773

Input sample sizes for survey age composition data (used in all models) are shown below:

Year:	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Nhaul:	346	335	341	351	344	320	343	348	344	345	345	344

Year:	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Nhaul:	344	348	330	347	328	350	343	343	355	341	356

Note that the age compositions for both the fishery and the survey are used in the marginal forms, not in conditional-age-at-length form.

Use of Survey Relative Abundance Data in Parameter Estimation

For the survey, 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 of the lognormal distribution.

The "sigma" parameters are shown in the fourth column of table 2.6.

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 deviation plays the role of the datum in a normal distribution with mean zero and specified (or estimated) standard deviation; but, of course, the deviations are parameters, not data.

RESULTS

Model Evaluation

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

Goodness of Fit, Parameter Estimates, and Derived Quantities

Goodness of Fit

Table 2.14 shows the objective function value for each data component in each model, along with the number of parameters in each model, broken down into “free” parameters, parameters with prior distributions, and constrained deviations. Models 17.x all use the same data file, which is different than the data file used by Model 16.6. However, the data are weighted differently by the various models in the 17.x series, meaning that none of the objective function values are truly comparable.

The table below provides alternative measures of how well the models fit the survey abundance data:

Model	σave	RMSE	MNR	SDNR	Corr.
16.6	0.107	0.189	0.118	1.801	0.815
17.1	0.107	0.197	0.135	1.992	0.800
17.2	0.107	0.207	0.206	1.959	0.796
17.3	0.107	0.196	-0.017	1.959	0.792
17.6	0.107	0.108	0.071	0.968	0.939
17.7	0.107	0.107	0.071	0.971	0.940

The column labeled “σave” shows the average of the log-scale standard errors arising from the sampling variability in the survey data (the same value for all six models). The four right-hand columns show root mean squared errors (RMSE; values closer to σave are better), mean normalized residuals (MNR; values closer to zero are better), standard deviations of normalized residuals (SDNR; values closer to unity are better), and correlations between observed and estimated values (values to unity are better).

Models 17.6 and 17.7 do the best job of matching the RMSE with σave and achieving a value of SDNR close to unity, and they also give the highest correlations with the data. Model 17.3 does the best at achieving a value of MNR close to zero.

Figure 2.15 shows the models’ fits to the trawl survey abundance data. The proportions of years in which each model’s estimate falls within the respective 95% confidence interval are shown below:

Model 16.6	Model 17.1	Model 17.2	Model 17.3	Model 17.6	Model 17.7
0.78	0.72	0.78	0.72	0.97	0.97

Except for Model 16.6, the models’ fits to the fishery age composition data are shown in Figure 2.16. The models’ fits to the survey age composition data are shown in Figure 2.17, and the models’ time-aggregated fits to the fishery and survey age composition data are shown in Figure 2.18.

The models’ fits to the fishery size composition data are shown in Figure 2.19. The models’ fits to the survey size composition data are shown in Figure 2.20, and the models’ time-aggregated fits to the fishery and survey size composition data are shown in Figure 2.21.

Table 2.15 shows effective sample sizes and input and output weights, using the same concepts and methods introduced in the preliminary assessment (Appendix 2.1, "Goodness of Fit" section):

- Cells shaded gray represent data (Note that the data file used for Models 17.x differs from Model 16.6's data file). The quantities in this category consist of:
    - The number of years represented in the particular data type ("Yrs").
    - The average sample size for the particular data type as specified in the data file ("N"), which, in the case of survey index data, consists of the average number of stations (hauls) sampled over the time series.
    - The average standard error of the survey abundance index ("SEave").
- Cells shaded tan represent values that are specified by the modeler, or that show results computed by SS. The quantities in this category consist of:
    - The multiplier ("Mult") that is used to modify sample sizes for the particular data type that are specified in the data file.
    - The product of the multiplier and the average specified sample size ("N×Mult").
    - The harmonic mean of the effective sample size ("Har").
    - The "extra" standard error (if any) estimated by SS for the survey index data ("SEextra").
    - The root-mean-squared-error of the model's survey index estimates ("RMSE").
- Cells shaded green represent a pair of aggregate sample sizes computed outside of SS.
    - For composition data, the quantities in this category consist of:
        - The aggregate effective sample size *assigned* to the particular data type ("ΣNeff1"), computed as Yrs×N×Mult.
        - The aggregate effective sample size *achieved* for the particular data type ("ΣNeff2"), computed as Yrs×Har.
    - For survey index data, this category consists of the same two quantities (ΣNeff1 and ΣNeff2), and ΣNeff1 is computed just as in the case of composition data, but ΣNeff2 is computed as:
        - Yrs×N×((SEave+SEextra)/RMSE)^2.

By expressing ΣNeff1 and ΣNeff2 in units of hauls for both composition data and index data, the values for the two data types are comparable, and the average across data types is a meaningful statistic (see last row under each model).

The ratio ΣNeff2/ΣNeff1 for a given data component provides a measure of how well the model is tuned with respect to that component (specifically, the ratio should equal unity). Only Models 17.3, 17.6, and 17.6 achieve ratios equal (approximately) to unity for all components. Note that these three models achieve a ratio of unity for the survey index by two different methods: Model 17.3 achieves this result by inflating the standard error of the observations, while Models 17.6 and 17.7 achieve the same result by allowing time variability in survey catchability. However, in the process of setting all of the component-specific ratios equal to unity, Models 17.6 and 17.7 achieve a higher average (across components) aggregate effective sample size than Model 17.3 (ΣNeff2=14,217 for Model 17.6 and ΣNeff2=14,029 for Model 17.7, versus ΣNeff2=12,772 for Model 17.3).

Table 2.16 breaks down the effective sample sizes for the age composition data, by providing a value for each year of age composition data and each model rather than just an aggregate value across years for each model. Results for the fishery age composition data are shown in the upper part of the table and results for the survey age composition data are shown in the lower part. Below each part of the table, the row labeled "Arith." gives the arithmetic mean for the input sample sizes, and the row labeled "Harm." gives the harmonic mean for the output effective sample sizes. Ideally, those two values should be approximately equal.

Parameter Estimates

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

- Table 2.17a shows scalar parameters for all models
- Table 2.17b shows initial (1977) age composition deviations for all models
- Table 2.17c shows annual log-scale recruitment deviations for all models
    - These are plotted in Figure 2.22
- Table 2.17d shows fishery selectivity parameter P1 deviations for Models 17.x
- Table 2.17e shows fishery selectivity parameter P3 deviations for Models 17.x
- Table 2.17f shows survey selectivity parameter P1 deviations for Models 17.x, except 17.2
- Table 2.17g shows survey selectivity parameter P3 deviations for Models 17.x, except 17.2
- Table 2.17h shows length at age 1.5 and catchability deviations for Models 17.6 and 17.7

The log-scale trawl survey catchability estimates shown in Table 2.17a (base values in the cases of Models 17.6 and 17.7) imply the following values of survey catchability on the back-transformed (natural) scale:

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.6		Model 17.7	
Scale	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Log	-0.074	0.061	0.177	0.039	0.023	0.059	0.196	0.064	0.169	0.057	0.193	0.061
Natural	0.929	0.057	1.194	0.046	1.023	0.060	1.217	0.078	1.185	0.068	1.213	0.074

Table 2.18 shows estimates of fishing mortality for all models and years.

The final values of the sigma terms that constrain the vectors of parameter deviations are shown below:

Deviation vector	M16.6	M17.1	M17.2	M17.3	M17.6	M17.7
Recruitment	0.6445	0.4910	0.5687	0.5149	0.5792	0.5544
Selectivity begin peak (fishery)		0.1285	0.1121	0.1130	0.1189	0.1177
Selectivity ascend width (fishery)		0.4539	0.3907	0.3672	0.4297	0.4115
Selectivity begin peak (survey)		0.0566		0.0545	0.0545	0.0567
Selectivity ascend width (survey)		0.1594		0.1593	0.1594	0.1594
Length at age 1.5					0.0967	0.0977
ln(Catchability)					0.0892	0.0879

Derived Quantities

Figure 2.23 shows the time series of female spawning biomass relative to $B_{100\%}$ as estimated by each model, and Figure 2.24 shows the time series of total biomass as estimated by each model, along with the time series of observed survey biomass. Average (across years) ratios of total biomass (as estimated by the models) to survey biomass (as specified in the data) are shown below:

Model 16.6	Model 17.1	Model 17.2	Model 17.3	Model 17.6	Model 17.7
1.19	0.96	1.08	0.93	0.95	0.93

Figures 2.25 and 2.26 show fishery selectivity and survey selectivity as estimated by the models.

Figure 2.27 shows the schedules of mid-year length at age implied by the growth parameters as estimated by the models. The upper panel shows the time-invariant schedules corresponding to the growth parameters estimated by Models 16.6, 17.1, 17.2, and 17.3, along with the schedules corresponding to the base values of the growth parameters as estimated by Models 17.6 and 17.7. The middle and lower panels show the time-varying schedules corresponding to the growth parameters (including annual deviations of length at age 1.5) as estimated by Models 17.6 and 17.7, respectively.

Figure 2.28 shows the time series of length at age 1.5 estimated by Models 17.6 and 17.7, together with the time series of mean length at age 1 from the survey age data (collected at mid-year). The correlations with the data for Models 17.6 and 17.7 are 0.83 and 0.84, respectively. Note that these data are not included in the data file used by Models 17.6 and 17.7; the fits arise from the models' attempts to fit the survey compositional data only.

Figure 2.29 shows the time series of survey catchability estimated by Models 17.6 and 17.7. The coefficients of variation for the two time series are 0.107 and 0.104, respectively.

Table 2.19 contains selected output from the standard projection model, based on SS parameter estimates from the models, along with the probability that the maximum permissible ABC in each of the next two years will exceed the corresponding true-but-unknown OFL and the probability that the stock will fall below $B_{20\%}$ in each of the next four years (probabilities are given by SS rather than the standard projection model). Note that some of the quantities in Table 2.19 are conditional on catches estimated under Scenario 2 ("author's F") in the "Harvest Recommendations" section.

Retrospective Performance

Retrospective analyses for all of the models are shown in Figure 2.30. Values of ρ (Mohn 1999, equation corrected in the 2013 Retrospective Working Group report) are shown below for spawning biomass, together with lower and upper bounds on acceptable levels defined as a function of *M*, based on results reported by Hurtado-Ferro et al. (2015):

Model:	16.6	17.1	17.2	17.3	17.6	17.7
ρ:	0.243	0.040	0.255	0.113	0.028	0.079
M:	0.359	0.324	0.385	0.328	0.322	0.317
Min:	-0.206	-0.193	-0.215	-0.195	-0.193	-0.191
Max:	0.279	0.262	0.292	0.264	0.261	0.258

Model 17.6 has the lowest value of ρ (0.028), and Model 17.2 has the highest (0.255), but none are outside the acceptable ranges implied by Hurtado-Ferro et al. (2015).

Choice of Final Model

Model Weighting

(Note: For all tables in this subsection, color shading extends from red = lowest value across models to green = highest value across models.)

Appendix 2.5 describes an attempt to address the SSC's various requests related to model averaging, including the development of multiple sets of model weightings. That analysis begins by updating the model weightings that were developed in the preliminary assessment (Appendix 2.1) and extending them to Model 17.7 (which was not included in the preliminary assessment). The model weightings in the preliminary assessment were based in part on the arithmetic, geometric, and harmonic means of the vector of ΣNeff2 values for each model (Table 2.15). Geometric and harmonic means were provided as alternatives to the arithmetic mean, so as to allow for the possibility of penalizing models that achieved nearly all their success by focusing on a single component while essentially ignoring the others. This first step resulted in the following values, expressed in units of effective sample size per effective parameter:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
Arithmetic:	170.56	335.53	230.37	250.44	171.29	163.13
Geometric:	104.51	123.43	88.20	153.49	104.50	101.46
Harmonic:	61.40	69.56	43.08	93.14	60.63	59.89

At its October 2017 meeting, the SSC requested that model weightings also incorporate three additional factors: retrospective performance, model convergence behavior, and general plausibility (see comment SSC20). Multiplicative adjustments were computed for each of these in Appendix 2.5, resulting in the following adjustment values:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
Retrospective:	0.784	0.960	0.775	0.893	0.972	0.924
Convergence:	1.000	0.895	0.957	0.935	0.880	0.822
Plausibility:	1.000	0.414	0.897	0.223	0.218	0.207

Adjusting the initial weightings by the above and rescaling so that the weightings sum to unity gave the following final weightings:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
Arithmetic:	0.2619	0.2337	0.3001	0.0914	0.0626	0.0503
Geometric:	0.3296	0.1766	0.2360	0.1150	0.0785	0.0642
Harmonic:	0.3447	0.1772	0.2052	0.1243	0.0811	0.0675

Qualitative Considerations

In addition to the development of quantitative of model weights described above, three qualitative considerations may also be noted:

1. Does the given model address shortcomings that have been identified by the Team or SSC?
2. Is the reduction in the maximum permissible ABC (relative to the specified 2017 ABC) resulting from the given model roughly commensurate with the change in survey biomass observed between 2016 and 2017?
3. Given that the cause of the decline in EBS shelf survey biomass from 2016 to 2017 is unknown, but that one plausible hypothesis is that a substantial portion of the biomass simply moved (perhaps temporarily) to the NBS survey area while remaining part of the same spawning population as the fish in the EBS shelf survey area, does the given model impose drastic reductions in ABC that have a significant probability of later being shown to have been unnecessary?

Final Model: Conclusion

From the standpoint of the quantitative model weighting developed in Appendix 2.5, including the SSC's model weighting factors and the additional factor of effective number of parameters, the "best" model depends on whether the arithmetic, geometric, or harmonic mean of the model-specific SNeff2 values is chosen. If the arithmetic mean is chosen, then Model 17.2 is the best model by this criterion (with Model 16.6 as the second best model); but if either the geometric or harmonic mean is chosen, then Model 16.6 is the best model by this criterion (with Model 17.2 as the second best model).

All of the models in the 17.x series address shortcomings that the Team or SSC has identified in Model 16.6. For example, as listed in Appendix 2.1, the Team has recommended allowing time-varying fishery selectivity (comment BPT5), the SSC has recommended allowing for time varying selectivity in the survey and/or the fishery (comment SSC9), the SSC has recommended switching to haul-based initial sample sizes (comment SSC3), the SSC has recommended adoption of a prior distribution for M (comment SSC6, see also comment SSC16 in this final assessment), and the SSC has recommended including fishery age data in the model (comment SSC10). All of the models in the 17.x series address all of these recommendations, but Model 16.6 addresses none of them.

Estimated biomass from the 2017 EBS shelf bottom trawl survey in the standard area was 37% less than estimated biomass in 2016. The specified ABC for 2017 was 239,000 t. The percentage reductions in ABC for 2018 implied by this year's models (assuming that 2018 ABC is set at the maximum permissible level) are shown below:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
2018 ABC:	201,000	75,500	172,000	59,100	57,300	57,600
% change:	-16%	-68%	-28%	-75%	-76%	-76%

The reduction in ABC from 2017 to 2018 implied by Model 17.2 comes the closest to matching the change in survey biomass from 2016 to 2017.

Models 16.6 and 17.2 are the only models that would not require drastic cuts in the ABC. It is possible, of course, that the other models are more accurate reflections of the true state of the stock, and if subsequent investigations reveal this to be the case, then drastic reductions in future ABCs would appear necessary.

Final Parameter Estimates and Associated Schedules

As noted previously, estimates of all statistically estimated parameters (except fishing mortality rates) are shown for all models in Table 2.17. Estimates of annual fishing mortality rates are shown for all models in Table 2.18.

Schedules of begin-year length at age and mid-year length at age from Model 17.2 are shown in Table 2.20. Schedules of selectivity at age (both fishery and trawl survey) from Model 17.2 are shown in Table 2.21.

Time-Varying Weight at Age

Schedules of time-varying weight at age from Model 17.2 are shown in Table 2.22. Note that model-estimated weights at ages 1-6 are lower than average for 2013-2017, although ages 1 and 2 are rarely encountered in the fishery. For ages 3-6, the decreases are all less than 10%. By way of comparison, Fulton's condition factor is mostly positive at ages 1-3 for 2013-2016 (2017 age data are not yet available), and mostly negative at ages 4-6 for those same years (Table 2.10), and the most recent strong year class (2013) does not appear to have experienced a below-average condition factor in any year through the end of the time series (2016, Table 2.10).

The Team and SSC have both expressed interest in comparing model estimates of weight at age against the mean weights at age obtained from the fishery and survey (comments Sub9 and SSC23 in this final assessment; see also comments BPT3 and SSC11 from Appendix 2.1). As noted in the Executive Summary, some issues regarding empirical weights at age from the survey were already addressed in Appendix B of the minutes from the June Subcommittee meeting, so attention here will be focused on empirical weights at age from the fishery (note also that weight at age from the survey is not a particularly relevant factor for the models in this assessment *per se*, because the survey index is measured in numbers of fish rather than biomass; however, weight at age from the survey could become relevant in *future* models if it were used as a proxy for weight at age from the fishery in years for which empirical weight at age data from the fishery do not exist).

Fishery age data that are well-distributed across time within the year, across gear types, and across areas are currently available for only four years: 2013, 2014, 2015, and 2016. Table 2.23 shows the number of otoliths ("N") that were read, the average weight from the fish from which otoliths were taken and read ("Sample"), the average weight obtained by applying the age-length key to the length composition in order to obtain mean lengths at age and standard deviations of length at age and then integrating weight at length across the distribution of length at age ("ALK-int."), and the average weight from Model 17.2. The average weight at age 2 from Model 17.2 is clearly lower than the other two measures of average weight at age 2, although it should be remembered that age 2 fish are relatively rare in fishery catches. At ages 4-6, which make up 79% of the samples in Table 2.23, the average weights at age from Model 17.2 compare quite favorably to the other two measures of average weights at age.

Last year's assessment included a summary of arguments for and against switching from the traditional method of computing weight at age (i.e., by applying externally estimated and annually varying weight-at-length relationships to an internally estimated and constant length-at-age relationship) to using empirical weight at age. Some of the arguments against switching are still relevant, and are paraphrased below (year ranges have been updated):

1. Weight-at-age data exist for only 19 of the 36 years in the survey time series and only 4 of the 40 years in the fishery time series, which raises the question of what values to use in years with no data.
2. Because the trawl survey takes place during the summer, it is necessary to find an accurate method for determining beginning-of-year weights at age from mid-year weights at age.
3. Consistent with the last several assessments, all of the models in this year's assessment estimate a positive ageing bias for the younger ages at least (Table 2.17a), a finding which was recently confirmed by Kastelle et al. (2017) on the basis of stable isotope analysis, meaning that the empirical weights at age are likely biased downward.

Regarding item #3 in the above list, it may be noted that the estimates of ageing error at age 1 have been remarkably consistent over time (with values ranging from 0.32-0.36 in all 7 assessments where this parameter has been estimated internally). The estimates of ageing error at age 20 have been a bit less consistent, but have always been positive up until this year, when all models in the 17.x series estimated a negative bias at age 20. The ages at which the bias switches from positive to negative in Models 17.x range from 6.8 (Model 17.1) to 9.3 (Model 17.3).

Time Series Results

Definitions

The biomass estimates presented here will be defined in three ways: 1) age 0+ biomass, consisting of the biomass of all fish aged 0 years or greater in January of a given year; 2) age 3+ biomass, consisting of the biomass of all fish aged 3 years or greater in January of a given year; and 3) spawning biomass, consisting of the biomass of all spawning females in a given year. The recruitment estimates presented here will be defined as numbers of age 0 fish in a given year. To supplement the full-selection fishing mortality rates already shown in Table 2.18, an alternative "effective" fishing mortality rate will be provided here, defined for each age and time as $-\ln(N_{a+1,t+1}/N_{a,t})-M$, where N = number of fish, a = age measured in years, t = time measured in years, and M = instantaneous natural mortality rate. In addition, the ratio of full-selection fishing mortality to $F_{35\%}$ will be provided.

Biomass
Table 2.24 shows the time series of age 0+, age 3+, and female spawning biomass since 1977 as estimated last year and this year (projections through 2018 are also shown for this year's assessment). The estimated spawning biomass time series are accompanied by their respective standard deviations.

The estimated time series of age 0+ and female spawning biomass are shown, together with the observed time series of trawl survey biomass, in Figure 2.31. Confidence intervals are shown for estimates of female spawning biomass and for the trawl survey biomass estimates.

Recruitment and Numbers at Age
Table 2.25 shows the time series of age 0 recruitment (1000s of fish) for the years since 1977 as estimated last year and this year. Both estimated time series are accompanied by their respective standard deviations. The correlation between last year's estimated recruitment time series and this year's is 0.97.

For the time series as a whole, the largest year class appears to have been the 2008 cohort, and the year classes since 2008 include the top three year classes of all time (2008, 2011, and 2013). The set of year classes comprising the top ten is the same this year as last year, except that the 1978 cohort has replaced the 1977 cohort and the 1999 cohort has replaced the 1996 cohort.

Last year, the 2014 and 2015 cohorts were estimated to be two of the five smallest in the time series. This year, the 2014, 2015, and 2016 cohorts are estimated to be three of the five smallest in the time series.

Recruitment estimates for the entire time series (1977-2015) are shown in Figure 2.32, along with their respective 95% confidence intervals.

The coefficient of autocorrelation for this year's estimated recruitment time series is –0.02.

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

The estimated time series of numbers at age is shown in Table 2.26.

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

Figure 2.33 plots the estimated/projected trajectory of relative fishing mortality ($F/F_{35\%}$) and relative female spawning biomass ($B/B_{35\%}$) from 1977 through 2019 based on full-selection fishing mortality, overlaid with the current harvest control rules. Projected values for 2018 and 2019 are from Scenario 2 under "Harvest Recommendations," below. It should be noted that, except for the projection years, these trajectories are based on SS output, which may not match the estimates obtained by the standard projection program exactly. Last year, the base model changed from Model 11.5 (which had served as the base model from 2011-2015) to Model 16.6, which generally gave lower estimates of relative spawning biomass than Model 11.5. Model 17.2, which is the author's recommendation for the new base model, generally gives even lower estimates of relative spawning biomass than Model 16.6, to the extent that, in hindsight, the stock was being subjected to fishing mortality rates in excess of the retroactively calculated F_{OFL} values (but not the official F_{OFL} values that were calculated at the time) in all years from 1994-2017.

Harvest Recommendations

The results presented in this section are based on Model 17.2. Because the structure of this model differs substantively from Model 16.6 (the model adopted as the base model last year by the SSC), a set of parallel results for the items in this section, based on Model 17.2, is provided in Appendix 2.6.

Amendment 56 Reference Points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific cod in the EBS have generally been managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing. The following formulae apply under Tier 3:

3a) Stock status: $B/B_{40\%} > 1$

$F_{OFL} = F_{35\%}$

$F_{ABC} \leq F_{40\%}$

3b) Stock status: $0.05 < B/B_{40\%} \leq 1$

$F_{OFL} = F_{35\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

$F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

3c) Stock status: $B/B_{40\%} \leq 0.05$

$F_{OFL} = 0$

$F_{ABC} = 0$

Model 17.2's estimates $F_{35\%}$ and $F_{40\%}$ are 0.38 and 0.32, respectively.

Model 17.2's estimates of $B_{100\%}$, $B_{40\%}$, and $B_{35\%}$ are 548,000 t, 219,000 t, and 192,000 t, respectively.

Specification of OFL and Maximum Permissible ABC

Given the assumptions of Scenario 2 (below), female spawning biomass for 2018 and 2019 is estimated by Model 17.2 to be 217,000 t and 211,000 t, respectively, both of which are below the $B_{40\%}$ value of 219,000 t, thereby placing Pacific cod in sub-tier "b" of Tier 3 for both 2018 and 2019. Given this, Model 17.2 estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2018 and 2019 as follows:

Year	Overfishing Level	Maximum Permissible ABC
2018	OFL = 202,000 t	maxABC = 172,000 t
2019	OFL = 173,000 t	maxABC = 148,000 t
2018	*FOFL* = 0.38	*maxFABC* = 0.31
2019	*FOFL* = 0.37	*maxFABC* = 0.30

The age 0+ biomass projections for 2018 and 2019 from Model 17.2 (using SS rather than the standard projection model) are 807,000 t and 690,000 t.

For comparison, the age 3+ biomass projections for 2018 and 2019 from Model 17.2 (again using SS) are 790,000 t and 644,000 t.

Standard Harvest Scenarios, Projection Methodology, and Projection Results

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with an estimated vector of numbers at age for January 1, 2018. This requires an appropriate estimate of total catch for 2017. Because each year's stock assessment is finalized before complete (i.e., year-long) catch data are available for that year, it is necessary to extrapolate the available catch data through the end of the year. Year-end catch for 2017 was estimated to equal the ABC, at a value of 224,000 t, using the method described under "Catch Biomass" in the "Data" section.

In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Except for the first projection year under Scenario 2 (see paragraph below), total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

For predicting future catches under Scenario 2, the 2014 assessment (Thompson 2014) described the development of the following estimator for future total catch as a function of future ABC: For ABC≥148,000 t, catch = 59,200 t + 0.6×ABC; for ABC<148,000 t, catch = ABC. This estimator was used again in the present assessment, giving catches of 162,000 t, and 148,000 t in 2018 and 2019, respectively.

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 2018 and 2019, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction ("author's F") of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2018 recommended in the assessment to the *max* F_{ABC} for 2018, and where catches for 2018 and 2019 are estimated at their most likely values given the 2018 and 2019 maximum permissible ABCs under this scenario. (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; also, catch tends not to equal ABC exactly.)
>
> *Scenario 3*: In all future years, F is set equal to the 2012-2016 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 2017 or 2) above 1/2 of its MSY level in 2017 and expected to be above its MSY level in 2027 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2018 and 2019, 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 2019 or 2) above 1/2 of its MSY level in 2019 and expected to be above its MSY level in 2029 under this scenario, then the stock is not approaching an overfished condition.)

Projections corresponding to the standard scenarios are shown for Model 17.2 in Tables 2.28-2.34.

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2018, it does not provide the best estimate of OFL for 2019, because the mean 2018 catch under Scenario 6 is predicated on the 2018 catch being equal to the 2018 OFL, whereas the actual 2018 catch will likely be less than the 2018 OFL. Table 2.19 contains the appropriate one- and two-year ahead projections for both ABC and OFL under Model 17.2.

ABC Recommendation

Since 2005, the SSC has set ABC at the maximum permissible level every year with the exceptions of the 2007, 2014, and 2015 assessment cycles, when, in each case, the SSC held the ABCs for the next two years constant at the then-current level. Specifications for 2006-2011 were set under Tier 3b, and specifications for 2012-2017 (and preliminary specifications for 2018) were set under Tier 3a.

The recommended ABCs for 2018 and 2019 are 172,000 t and 148,000 t, respectively, representing the maximum permissible levels under Model 17.2. However, see Appendix 2.5 for several alternatives based on model averaging.

Area Allocation of Harvests

No recommendations are made regarding area allocation of harvests.

Status Determination

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

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2016) is 247,605 t. This is less than the 2016 OFL of 390,000 t. Therefore, the EBS Pacific cod stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2017:

a. If spawning biomass for 2017 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2017 is estimated to be above $B_{35\%}$, the stock is above its MSST.

c. If spawning biomass for 2017 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 2.33). If the mean spawning biomass for 2027 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7 (Table 2.34):

a. If the mean spawning biomass for 2019 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2019 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2019 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2029. If the mean spawning biomass for 2029 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Tables 2.33 and 2.34, the stock is not overfished and is not approaching an overfished condition.

ECOSYSTEM CONSIDERATIONS

Ecosystem Effects on the Stock

A primary ecosystem phenomenon affecting the Pacific cod stock seems to be the occurrence of periodic "regime shifts," in which central tendencies of key variables in the physical environment change on a scale spanning several years to a few decades (Zador, 2011). One well-documented example of such a regime shift occurred in 1977, and shifts occurring in 1989 and 1999 have also been suggested (e.g., Hare and Mantua 2000). As in previous assessments, an attempt was made in the present assessment to estimate the change in mean recruitment of EBS Pacific cod associated with the 1977 regime shift. According to Model 17.2, pre-1977 mean recruitment was only about 23% of post-1976 mean recruitment. Establishing a link between environment and recruitment within a particular regime is more difficult. In the 2004 assessment (Thompson and Dorn 2004), for example, the correlations between age 1 recruits spawned since 1977 and monthly values of the Pacific Decadal Oscillation (Mantua et al. 1997) were computed and found to be very weak.

In the 2012 assessment, annual log-scale recruitment deviations estimated by the assessment model were regressed against each of several environmental indices summarized by Zador (2011). The highest univariate correlation was obtained for the spring-summer North Pacific Index (NPI), which was developed by Trenberth and Hurrell (1994). The NPI is the area-weighted sea level pressure over the region 30°N-65°N, 160°E-140°W. Further investigations were conducted with monthly NPI data from the Climate Analysis Section of the National Center for Atmospheric Research. The best univariate model obtained in the 2012 analysis was a linear regression of recruitment deviations from 1977-2011 against the October-December average NPI (from the same year). Vestfals et al. (2014) have also noted a positive correlation between Pacific cod recruitment and the NPI, although not the October-December average NPI in particular.

In each assessment since 2012, the regression analysis has been updated. This year's regression resulted in a correlation of 0.53 (R^2=0.28). The time series, regression line, and 95% confidence interval from this year's regression are shown in the upper panel of Figure 2.34. According to this regression, the probability of the 2016 year class being higher than the median for the time series is 56%. However, the datum for 2016 (magenta diamond in the upper panel) falls quite a bit below the predicted value from the regression; in fact, the error for 2016 is the largest (in absolute value) in the time series.

In each assessment since 2013, the main regression analysis has been accompanied by a cross-validation analysis involving creation of 100,000 "training" data sets, each one obtained by randomly sub-sampling 50% of the data without replacement. A regression was performed on each of the training sets, and then the performance of each regression was computed against the corresponding "test" (i.e., non-training) data set. When the NPI *was not* included as an explanatory variable (i.e., only the intercept of the regression was estimated), the RMSE (computed across all 100,000 test data sets) was 0.59, but when the NPI *was* included as an explanatory variable, the RMSE was reduced to 0.52. The distribution of slope parameter estimates from the cross-validation is shown in the middle panel of Figure 2.34. Note that the entire distribution is well above zero, indicating that the observed correlation is very unlikely to be entirely spurious. Two years, 1990 and 2002 (yellow and green diamonds in the upper panel), turned out to be far more influential than any other year in determining the magnitude of the estimated slope, and both of these influences were negative (lower panel of Figure 2.34). In other words, the positive slope is not due to the influence of outliers; if anything, the outliers are making the relationship appear less strong than would be the case without them.

The prey and predators of Pacific cod have been described or reviewed by Albers and Anderson (1985), Livingston (1989, 1991), Lang et al. (2003), Westrheim (1996), and Yang (2004). The composition of Pacific cod prey varies to some extent by time and area. In terms of percent occurrence, some of the most important items in the diet of Pacific cod in the BSAI and GOA have been polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, some of the most important dietary items have been euphausids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, some of the most important dietary items have been walleye pollock, fishery offal, yellowfin sole, and crustaceans. Small Pacific cod feed mostly on invertebrates, while large Pacific cod are mainly piscivorous. Predators of Pacific cod include Pacific cod, halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffin. Major trends in the most important prey or predator species could be expected to affect the dynamics of Pacific cod to some extent.

Fishery Effects on the Ecosystem

Potentially, fisheries for Pacific cod can have effects on other species in the ecosystem through a variety of mechanisms, for example by relieving predation pressure on shared prey species (i.e., species which serve as prey for both Pacific cod and other species), by reducing prey availability for predators of Pacific cod, by altering habitat, by imposing bycatch mortality, or by "ghost fishing" caused by lost fishing gear.

Incidental Catch Taken in the Pacific Cod Fisheries

Incidental catches taken in the Pacific cod fisheries, expressed as proportions of total incidental EBS catches (i.e., across all targets) for the respective species, are summarized in Tables 2.35-2.38. Catches for 2017 in each of these tables are incomplete. Table 2.35 shows incidental catch of FMP species taken from 1991-2017 by each of the three main gear types. Table 2.36 shows incidental catch of certain species of squid and members of the former "other species" complex taken from 2003-2017, aggregated across gear types. Table 2.37 shows incidental catch of prohibited species taken from 1991-2017, aggregated across gear types. Note that all entries for 2003 are marked "n/a" in Table 2.37 due to problems in the database for that year, which are under investigation. Table 2.38 shows incidental catch of non-target species groups taken from 2003-2017, aggregated across gear types.

Steller Sea Lions

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

One of the main research emphases of the AFSC Fisheries Interaction Team (now disbanded) was to determine the effectiveness of management measures designed to mitigate the impacts of the Pacific cod fisheries (among others) on Steller sea lions. A study conducted in 2002-2005 using pot fishing gear demonstrated that the local concentration of cod in the Unimak Pass area is very dynamic, so that fishery removals did not create a measurable decline in fish abundance (Conners and Munro 2008). A preliminary tagging study in 2003–2004 showed some cod remaining in the vicinity of the release area in the southeast Bering Sea for several months, while other fish moved distances of 150 km or more north-northwest along the shelf, some within a matter of two weeks (Rand et al. 2015).

Seabirds

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

Fishery Usage of Habitat

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

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

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

Impacts of the Pacific cod fisheries on essential fish habitat were further analyzed in an environmental impact statement by NMFS (2005), followed by “5-year reviews” in 2010 and 2017 (NMFS 2010 and 2017, respectively).

DATA GAPS AND RESEARCH PRIORITIES

Significant improvements in the quality of this assessment could be made if future research were directed toward closing certain data gaps. At this point, the most critical needs pertain to trawl survey catchability and selectivity and movement of Pacific cod, specifically: 1) to understand the factors determining these features, 2) to understand whether/how these features change over time, and 3) to obtain accurate estimates of these features. These needs were highlighted in 2017 when the EBS shelf bottom trawl survey showed a 37% drop in estimated biomass relative to 2016 and the NBS bottom trawl survey showed a nearly commensurate increase in estimated biomass relative to the most recent survey in 2010. Additional surveys of the NBS are strongly encouraged, as are genetic analyses and tagging studies. Ageing also continues to be an issue, as the assessment models consistently estimate a positive ageing bias, at least for the first several ages. Longer-term research needs include improved understanding of: 1) the ecology of Pacific cod in the EBS, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment; 2) ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and 3) ecology of species that interact with Pacific cod, including estimation of interaction strengths, biomass, carrying capacity, and resilience.

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

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

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TABLES

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

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

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

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

Table 2.1c—Summary of 1991-2017 catches (t) of Pacific cod in the EBS by gear type. The small catches taken by "other" gear types have been merged proportionally with the catches of the gear types shown. Pot catches for 2014-2017 include the State-managed fishery. Catches for 2017 are through October 8.

Year	Trawl	Longline	Pot	Total
1991	129,393	77,505	3,343	210,241
1992	77,276	79,420	7,514	164,210
1993	81,792	49,296	2,098	133,186
1994	85,294	78,898	8,071	172,263
1995	111,250	97,923	19,326	228,498
1996	92,029	88,996	28,042	209,067
1997	93,995	117,097	21,509	232,601
1998	60,855	84,426	13,249	158,529
1999	51,939	81,520	12,408	145,867
2000	53,841	81,678	15,856	151,376
2001	35,670	90,394	16,478	142,542
2002	51,118	100,371	15,067	166,555
2003	46,717	108,769	19,957	175,443
2004	57,866	108,618	17,264	183,748
2005	52,638	113,190	17,112	182,940
2006	53,236	96,613	18,969	168,818
2007	45,700	77,181	17,248	140,129
2008	33,497	88,936	17,368	139,802
2009	36,959	96,606	13,609	147,174
2010	41,298	81,841	19,723	142,861
2011	64,086	117,075	28,063	209,224
2012	75,534	128,513	28,737	232,784
2013	81,615	124,794	30,261	236,671
2014	72,260	127,216	39,193	238,669
2015	66,677	128,189	37,938	232,803
2016	72,596	127,927	47,082	247,605
2017	67,901	93,654	38,092	199,646

Table 2.2—Discards (t) and discard rates (%) of Pacific cod in the Pacific cod fishery, by area, gear, and year for the period 1991-2017 (2017 data are current through October 8). The small amounts of discards taken by other gear types have been merged proportionally into the gear types shown. Note that Amendment 49, which mandated increased retention and utilization, was implemented in 1998.

	Discard amount (t)				Discard rate (%)			
Year	Trawl	Longline	Pot	Total	Trawl	Longline	Pot	All
1991	1,278	1,493	4	2,774	4.11	2.62	0.26	3.10
1992	3,314	1,768	59	5,141	8.68	2.23	0.78	4.12
1993	5,449	2,234	25	7,708	12.89	4.54	1.21	8.24
1994	4,599	2,917	161	7,677	9.98	3.71	2.01	5.79
1995	7,987	3,669	222	11,877	12.24	3.77	1.15	6.54
1996	2,971	2,833	391	6,194	5.12	3.19	1.39	3.54
1997	3,327	3,183	79	6,590	5.42	2.72	0.37	3.30
1998	102	2,456	52	2,610	0.27	2.92	0.39	1.94
1999	353	1,285	52	1,691	0.95	1.58	0.42	1.29
2000	207	2,267	71	2,546	0.56	2.78	0.45	1.90
2001	142	1,531	52	1,726	0.76	1.70	0.32	1.38
2002	557	2,066	91	2,715	1.73	2.06	0.61	1.84
2003	240	1,771	159	2,170	0.79	1.63	0.80	1.36
2004	158	1,814	48	2,019	0.41	1.67	0.28	1.23
2005	86	2,599	61	2,747	0.26	2.30	0.36	1.68
2006	193	1,528	63	1,784	0.54	1.58	0.33	1.18
2007	238	1,373	45	1,656	0.74	1.78	0.26	1.31
2008	13	1,280	156	1,449	0.09	1.44	0.90	1.20
2009	126	1,503	16	1,645	1.02	1.56	0.12	1.34
2010	154	1,402	20	1,576	1.08	1.72	0.10	1.37
2011	121	1,860	32	2,013	0.42	1.59	0.11	1.16
2012	136	1,759	40	1,934	0.38	1.37	0.14	1.01
2013	220	3,066	90	3,376	0.58	2.46	0.30	1.75
2014	192	2,893	155	3,241	0.50	2.28	0.40	1.59
2015	141	2,374	104	2,618	0.43	1.85	0.27	1.32
2016	119	2,547	86	2,751	0.29	1.99	0.18	1.28
2017	257	1,478	60	1,796	0.67	1.58	0.16	1.06

Table 2.3—History of BSAI (1977-2013) and EBS (2014-2017) Pacific cod catch, TAC, ABC, and OFL (t). Catch for 2017 is through October 1. Note that specifications through 2013 were for the combined BSAI region, so BSAI catch is shown rather than the EBS catches from Table 2.1 for the period 1977-2013. Source for historical specifications: NPFMC staff.

Year	Catch	TAC	ABC	OFL
1977	36,597	58,000	-	-
1978	45,838	70,500	-	-
1979	39,354	70,500	-	-
1980	51,649	70,700	148,000	-
1981	63,941	78,700	160,000	-
1982	69,501	78,700	168,000	-
1983	103,231	120,000	298,200	-
1984	133,084	210,000	291,300	-
1985	150,384	220,000	347,400	-
1986	142,511	229,000	249,300	-
1987	163,110	280,000	400,000	-
1988	208,236	200,000	385,300	-
1989	182,865	230,681	370,600	-
1990	179,608	227,000	417,000	-
1991	220,038	229,000	229,000	-
1992	207,278	182,000	182,000	188,000
1993	167,391	164,500	164,500	192,000
1994	193,802	191,000	191,000	228,000
1995	245,033	250,000	328,000	390,000
1996	240,676	270,000	305,000	420,000
1997	257,765	270,000	306,000	418,000
1998	193,256	210,000	210,000	336,000
1999	173,998	177,000	177,000	264,000
2000	191,060	193,000	193,000	240,000
2001	176,749	188,000	188,000	248,000
2002	197,356	200,000	223,000	294,000
2003	207,907	207,500	223,000	324,000
2004	212,618	215,500	223,000	350,000
2005	205,635	206,000	206,000	265,000
2006	193,025	194,000	194,000	230,000
2007	174,486	170,720	176,000	207,000
2008	171,277	170,720	176,000	207,000
2009	175,756	176,540	182,000	212,000
2010	171,875	168,780	174,000	205,000
2011	220,109	227,950	235,000	272,000
2012	250,899	261,000	314,000	369,000
2013	250,274	260,000	307,000	359,000
2014	238,669	246,897	255,000	299,000
2015	232,803	240,000	255,000	346,000
2016	247,605	238,680	255,000	390,000
2017	207,791	223,704	239,000	284,000

Table 2.4 (page 1 of 2)—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).

(Continued on next page.)

Table 2.4 (page 2 of 2)—Amendments to the BSAI Fishery Management Plan (FMP) that reference Pacific cod explicitly (excerpted from Appendix A of the FMP).

Amendment 85, partially implemented 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).

Amendment 99, implemented January 6, 2014 (effective February 6, 2014):

Allows holders of license limitation program (LLP) licenses endorsed to catch and process Pacific cod in the Bering Sea/Aleutian Islands hook-and-line fisheries to use their LLP license on larger newly built or existing vessels by:

1. Increasing the maximum vessel length limits of the LLP license, and
2. Waiving vessel length, weight, and horsepower limits of the American Fisheries Act.

Amendment 103, implemented November 14, 2014:

Revise the Pribilof Islands Habitat Conservation Zone to close to fishing for Pacific cod with pot gear (in addition to the closure to all trawling).

Amendment 109, implemented May 4, 2016:

Revised provisions regarding the Western Alaska CDQ Program to update information and to facilitate increased participation in the groundfish CDQ fisheries (primarily Pacific cod) by:

1. Exempting CDQ group-authorized catcher vessels greater than 32 ft LOA and less than or equal to 46 ft LOA using hook-and-line gear from License Limitation Program license requirements while groundfish CDQ fishing,
2. Modifying observer coverage category language to allow for the placement of catcher vessels less than or equal to 46 ft LOA using hook-and-line gear into the partial observer coverage category while groundfish CDQ fishing, and
3. Updating CDQ community population information, and making other miscellaneous editorial revisions to CDQ Program-related text in the FMP.

Amendment 113, implemented November 23, 2016:

1. Reserves up to 5,000 mt of TAC in the AI non-CDQ Pacific cod fishery exclusively for harvest by vessels directed fishing for AI Pacific cod for processing by Aleutian Islands shoreplants from January 1 until March 15.
2. Limits the amount of the trawl CV sector’s BSAI Pacific cod A-season allocation that can be caught in the Bering Sea subarea before March 21
3. Imposes the Aleutian Islands Catcher Vessel Harvest Set-Aside if NMFS is notified in advance as specified in regulations implementing the FMP amendment and certain performance measures are met.

Table 2.5a (page 1 of 5)—Fishery survey size composition as used in Model 16.6, by year and cm (number of fish measured in column 2).

Year	N	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
1977	2090	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	5	9	14	9	24
1978	11558	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	2	6	9	39	46	39	39	25	18	16	6	7
1979	17072	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	9	24	44	32	71	105	149	178
1980	14963	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	15	13	31	35	33	54	87	110
1981	10729	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	2	2	2	3	2	9	7	21	46	56	125	230	320	356	420
1982	13423	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	3	1	2	2	4	10	29	56	66	56
1983	56692	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	8	12	14	4	18	28	25	47	88	120	131	114	87	84
1984	138445	0	0	0	0	0	0	0	0	2	0	2	0	3	6	8	13	47	77	86	95	112	83	109	179	246	375	475	518	499	494	480	502	515	528
1985	204686	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	4	4	0	0	1	0	1	2	13	30	36	50	72	140	165	170
1986	178623	0	0	0	0	0	0	0	0	2	2	5	5	12	21	4	6	12	26	24	35	45	59	47	89	129	147	179	306	437	606	723	762	852	820
1987	340561	0	0	0	0	0	0	0	0	0	0	2	1	2	8	18	21	15	15	33	14	23	36	77	84	131	222	309	380	391	431	504	513	507	536
1988	105626	0	1	0	0	0	1	0	0	0	0	0	0	1	1	2	2	1	3	1	4	13	11	7	14	27	59	113	218	303	436	527	648	727	678
1989	70009	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	4	6	3	3	2	1	1	2	9	22	58	113	96	190	203	266	339	322
1990	260939	0	0	0	0	0	0	0	0	0	0	0	0	0	7	4	2	1	6	2	15	49	36	66	132	166	343	363	595	485	574	545	554	547	529
1991	358383	0	0	0	0	0	0	0	0	0	2	0	2	2	6	1	6	6	10	8	11	14	40	86	153	281	424	619	808	904	875	836	808	827	797
1992	371204	0	0	0	0	0	0	0	0	2	0	3	5	6	3	12	2	13	8	16	16	29	28	68	76	117	167	306	379	463	669	784	921	1001	1040
1993	233591	0	0	0	0	1	0	0	0	0	0	0	1	3	4	1	4	5	10	13	9	21	20	37	63	100	179	375	536	642	747	754	782	783	828
1994	373943	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	6	7	17	9	19	45	75	128	220	416	620	948	1167	1473	1687	1740	1743	1459
1995	370204	0	0	0	0	0	0	0	0	0	0	0	0	9	12	14	16	22	23	22	28	40	46	80	77	111	119	151	167	213	239	222	288	344	450
1996	465413	0	0	0	0	0	2	0	0	3	3	3	5	11	5	16	16	8	23	12	5	14	11	53	81	199	289	443	582	684	716	724	729	693	663
1997	504780	0	2	2	0	8	0	2	0	2	5	0	2	8	17	29	50	49	59	47	53	23	42	55	78	154	266	393	665	902	1136	1236	1443	1432	1362
1998	448236	0	0	0	0	0	1	0	0	0	1	0	3	3	4	4	1	1	11	11	15	9	55	107	212	316	474	613	637	685	699	659	625	603	701
1999	191044	0	2	3	2	0	1	1	2	0	0	0	0	1	0	2	5	3	4	0	4	2	4	4	24	43	76	144	204	211	182	197	206	181	253
2000	200868	0	1	2	1	2	1	0	2	0	9	0	0	0	0	1	0	1	1	1	0	2	3	1	4	18	31	51	51	68	60	59	85	106	143
2001	211995	0	1	6	0	1	0	0	0	0	0	0	0	1	1	0	0	2	3	4	2	2	1	3	6	4	9	11	21	37	45	73	102	152	233
2002	232141	0	4	5	4	0	4	0	0	0	0	2	2	0	4	2	3	6	8	5	8	10	10	21	18	38	45	92	134	196	226	294	342	399	490
2003	289554	0	4	7	7	0	0	1	0	0	0	0	3	1	0	0	1	1	3	2	0	1	1	2	3	3	11	13	40	66	121	162	226	291	331
2004	235106	0	0	1	1	1	1	0	0	0	1	1	0	0	0	0	0	2	0	0	4	2	0	4	5	8	9	25	31	40	70	104	125	172	192
2005	230240	0	4	2	5	0	1	0	0	0	0	0	0	1	1	2	2	0	4	3	3	5	3	8	10	5	15	35	55	63	78	126	156	185	205
2006	181719	0	0	2	4	1	0	0	0	0	0	0	0	0	0	2	0	1	4	4	6	1	1	3	2	7	2	10	20	37	54	78	98	107	168
2007	141530	0	0	2	1	1	1	0	0	0	0	1	2	1	0	3	3	2	4	2	6	6	7	11	6	19	20	34	65	57	72	94	103	114	111
2008	168001	0	3	0	0	0	0	0	0	0	0	0	0	1	1	0	3	2	1	4	3	6	18	27	26	45	42	49	43	45	49	65	68	107	146
2009	148728	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	2	1	2	4	4	14	9	9	18	26	43	54
2010	131119	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	3	4	3	5	12	13	15	23	10	20	26	32	57	76
2011	171418	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	3	2	4	19	24	28	0	41	39	39	64	100
2012	188917	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	0	1	3	24	29	42	38	48	60	52	80	83	77	97
2013	237857	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	8	4	9	28	39	59	82	76	127	149	156	236	256	355
2014	234761	0	0	0	0	0	0	0	0	0	0	0	0	1	1	4	0	1	0	2	0	0	0	5	10	18	32	40	47	93	106	109	104	96	131
2015	215764	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	1	3	3	5	18	28	52	81	96	103	154	143	157
2016	187683	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	4	3	4	17	21	20	39	49	69
2017	101220	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	1	2	4	0	0	0	0	0	1	1	4	4	11	11	30

Table 2.5a (page 2 of 5)—Fishery survey size composition as used in Model 16.6, by year and cm.

Year	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1977	25	28	20	15	27	20	10	14	10	6	14	21	35	54	94	80	95	91	77	73	69	62	72
1978	22	19	15	9	13	20	30	46	68	88	124	155	197	274	321	390	505	587	670	759	709	737	724
1979	281	388	380	495	566	560	495	490	472	409	383	284	265	257	307	322	351	372	392	432	482	483	509
1980	182	214	374	451	526	582	545	575	526	561	470	466	384	425	401	373	378	407	404	372	357	394	354
1981	363	277	266	177	167	212	256	305	364	456	421	410	405	392	400	396	358	298	306	263	248	241	224
1982	73	66	42	30	43	81	104	153	123	175	155	155	198	156	257	234	342	344	329	308	339	374	350
1983	73	102	99	161	250	320	380	386	449	435	469	459	414	512	580	677	866	1176	1251	1470	1507	1757	1818
1984	613	547	507	508	532	640	730	875	858	807	841	867	926	957	1040	1028	1350	1568	1861	2341	2448	2764	3150
1985	297	349	553	814	1144	1549	1782	1829	1994	2249	2384	2816	3143	3428	3799	4000	4120	3936	3616	3478	3218	2995	3030
1986	766	735	821	718	776	910	1098	1383	1376	1639	1864	2084	2333	2733	3020	3122	3822	4008	4318	4724	4923	5037	5280
1987	583	705	963	1244	1526	1969	2203	2461	3040	3266	3450	3864	4497	4863	5769	6518	7352	8110	8385	8803	9046	9110	9390
1988	745	667	808	895	1170	1496	1979	2220	2432	2588	2537	2378	2395	2168	2338	2396	2435	2331	2345	2294	2272	2099	2190
1989	411	379	309	344	340	383	495	549	677	778	783	948	1028	973	1095	1125	1164	1162	1162	1186	1203	1225	1282
1990	420	467	443	398	359	389	387	386	506	639	657	951	1091	1662	1787	2081	2300	2682	3137	3553	4006	4604	5057
1991	802	846	872	1017	1127	1423	1782	2148	2805	3162	3446	4116	3862	3821	4129	3971	4053	4106	4392	4428	4905	5206	5906
1992	1248	1445	1974	2584	3480	4098	5186	6016	6236	6613	7094	7309	7687	7506	7760	7670	7535	7703	7387	7599	7546	7671	8136
1993	1052	1657	2406	3230	4071	4489	4941	4973	5205	5038	4940	5282	5574	6022	6632	7078	7476	7720	7867	7797	7538	7180	7198
1994	1214	1098	1037	1189	1565	2087	2615	3673	3995	4805	5622	6408	7799	8180	9370	9922	10571	11707	11662	12491	12553	12456	14184
1995	705	1251	2202	3227	4486	5539	6571	6618	6785	6507	6124	5989	6248	6181	6746	7423	8288	9013	9707	10160	10881	11531	12136
1996	614	674	809	1048	1504	2044	2882	3832	4625	5611	6770	8236	9810	10937	12031	12968	13520	14183	14219	14293	14292	14216	14156
1997	1279	1230	1240	1416	1633	2096	2839	3874	4501	5348	5836	6577	7136	7552	8159	9096	10485	11672	12372	13731	14636	16243	17601
1998	664	843	1217	1607	2095	2585	3207	3948	4342	4655	5178	5569	6089	6624	6992	7612	8152	9143	9411	10132	10689	11163	12626
1999	365	608	1061	1547	2320	2876	3247	3716	3851	3977	4108	4047	4199	4084	4240	4396	4228	4596	4605	4410	4615	4640	5067
2000	216	305	505	749	980	1323	1523	1916	2271	2741	3181	3631	4119	4725	5206	5598	6014	6293	6725	6818	6946	7187	7472
2001	279	441	531	833	1036	1271	1557	1817	2196	2620	2851	3342	3620	4052	4667	5193	5838	6438	6817	7368	7518	7820	8310
2002	518	739	1002	1382	1865	2378	2662	3141	3458	4019	4298	4796	5163	5416	5747	6002	6370	6619	6750	7092	7420	7491	8020
2003	411	564	800	1124	1591	2203	2848	3635	3985	4790	5421	5968	6823	7324	8599	8858	9525	9734	10056	10132	9933	9785	10164
2004	240	251	369	439	621	821	1102	1492	1931	2400	2759	3372	4028	4620	5114	5898	6414	7098	7739	8288	8455	9132	9869
2005	236	309	376	649	727	940	1236	1648	2026	2309	2632	3047	3291	3643	4127	4423	4855	5278	5835	6087	6328	6547	7162
2006	198	221	275	373	467	605	693	969	1273	1577	1967	2324	2820	3178	3667	4033	4398	4813	5038	5203	5274	5199	5551
2007	145	193	219	245	310	424	481	697	870	1055	1315	1538	1949	2129	2465	2741	3024	3351	3590	3837	4128	4249	5015
2008	209	355	556	722	884	1125	1181	1490	1603	1806	1955	2257	2671	2866	3376	3811	4052	4515	4741	5027	5244	5477	5935
2009	151	233	443	638	737	1017	1232	1641	2039	2474	3294	3794	4683	5172	5444	5682	5225	4930	4779	4412	4206	4080	4385
2010	125	199	335	436	552	638	779	871	998	1226	1547	2012	2544	3016	3516	4057	4276	4758	4791	5078	5313	5378	5747
2011	168	314	564	791	1061	1428	1709	2096	2398	2847	3490	4074	4440	4686	4747	4877	4810	4857	4810	5135	5392	5758	6331
2012	106	129	207	383	527	693	817	1139	1221	1444	1822	2559	3648	4571	5428	6162	7003	7609	7791	7961	7930	8278	8833
2013	366	499	663	941	1242	1599	1962	2316	2536	2866	3185	3353	4126	4823	5403	5905	6378	6919	7299	7580	7868	8489	9308
2014	232	377	689	1070	1514	1962	2221	2418	2563	2701	3026	3541	4573	4831	5350	5871	6369	6717	6926	7317	7461	7697	8488
2015	176	194	239	360	489	787	966	1327	1622	2004	2419	2712	3442	4189	4872	5675	6529	7177	8002	8373	8826	8836	9107
2016	72	101	173	309	503	785	1153	1585	2024	2404	2717	2929	3317	3580	3683	3948	4103	4474	4792	5114	5481	5976	6693
2017	47	40	62	70	97	132	151	262	301	448	624	875	1222	1603	1977	2383	2846	3199	3467	3498	3735	3580	3743

Table 2.5a (page 3 of 5)—Fishery survey size composition as used in Model 16.6, by year and cm.

Year	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81
1977	74	79	79	87	86	99	72	59	55	48	46	35	25	18	28	21	20	20	11	12	8
1978	655	604	506	452	364	266	210	212	193	179	146	119	135	122	92	91	75	69	48	40	25
1979	540	578	569	601	593	578	518	493	372	373	347	254	230	208	154	116	122	84	57	44	48
1980	364	288	255	244	227	178	192	215	205	252	236	225	240	216	209	196	192	152	130	107	90
1981	211	176	178	133	143	136	107	105	93	92	76	72	63	56	49	50	35	25	24	14	17
1982	391	440	443	466	517	503	483	503	476	519	482	512	404	374	338	284	289	198	198	150	169
1983	2022	2157	1931	2064	2147	2228	2022	2008	2058	1958	1791	1722	1601	1550	1443	1300	1294	1236	1154	1060	912
1984	3530	3898	4142	4662	4730	4782	5030	5250	5148	5105	4997	4921	4802	4519	4215	4103	3772	3462	3243	2872	2589
1985	2966	3117	3620	4129	4872	5353	6162	6694	7257	7928	7753	8034	7786	7471	7099	6625	6201	5544	4910	4668	3919
1986	5373	5681	5652	5836	5687	5381	5546	4977	4473	4102	3989	3928	3892	4017	4077	3766	3866	3750	3680	3522	3227
1987	8970	9075	9318	9746	9626	10088	10242	10313	9949	10298	9905	9665	9720	9205	9010	8061	7867	7265	6348	6167	5208
1988	2135	1935	1903	2017	2135	2125	2143	2451	2358	2629	2628	2651	2698	2590	2758	2320	2296	2092	1877	1728	1504
1989	1386	1356	1496	1571	1622	1635	1647	1772	1870	2008	1963	1933	2065	2028	2157	1864	1903	1811	1741	1668	1541
1990	5616	6618	6885	7328	8015	8401	8516	8576	9101	8913	8845	9097	8656	8773	8567	8258	7802	7310	7000	6290	6013
1991	6331	7227	7937	8735	9464	9865	10601	11000	11416	11644	11314	11903	11148	11422	11459	10707	9878	9570	9045	8551	7700
1992	8081	8769	8721	9306	9994	9599	9976	10170	9912	9981	8789	9055	8219	8085	8097	7129	6853	6653	6136	6318	5252
1993	6611	6333	5941	5371	5014	4629	4491	4231	3972	3957	3584	3614	3422	3291	3171	2998	2711	2728	2503	2448	2164
1994	13134	13285	13223	13298	13378	12484	12655	12002	10739	10961	8449	7744	7138	6205	5913	4678	4344	3794	3144	3338	2647
1995	12354	13073	13374	12997	13854	13029	13192	12691	11914	11667	9681	8940	7894	7100	6388	5378	4789	4160	3644	3282	2640
1996	13776	13773	13961	13948	14225	13818	13699	13352	13133	13690	11934	11601	10765	10453	9858	8704	8035	7300	6571	6212	5336
1997	17907	19064	19352	19804	19896	19353	18877	18329	17416	16958	14269	13415	12175	10942	10341	8909	8026	7127	6520	5705	4660
1998	13107	14087	15017	15734	16331	16696	17257	16947	16647	17092	15108	14732	13818	12526	11319	10119	8929	7889	6906	6209	5107
1999	4884	5314	5598	5319	5620	5549	5621	5645	5345	5666	5067	5261	4595	4341	4007	3690	3134	2981	2626	2535	2107
2000	7557	7655	7612	7331	6791	6575	6350	5794	5403	5170	4314	4245	3891	3642	3270	2966	2690	2544	2298	2091	1870
2001	8324	8395	8693	8447	8440	8033	7913	7531	7240	7075	5977	5247	4588	4086	3505	2921	2413	2052	1849	1644	1397
2002	8193	8400	8426	8462	8161	8068	7955	7931	7263	6971	6159	5640	4753	4410	3703	3296	2833	2501	2122	1764	1560
2003	9786	9728	9893	9362	9428	9048	8768	8807	7942	8359	6967	6593	5965	5587	5023	4452	3905	3460	3035	2895	2371
2004	9817	9822	9937	9724	9319	8820	8333	7954	7367	7209	6113	5429	4806	4505	3855	3564	2990	2820	2459	2336	2036
2005	7314	7552	7866	8039	8118	8013	8285	8294	7912	8395	7086	6742	6282	5813	5434	4943	4394	4238	3574	3504	3066
2006	5298	5488	5443	5457	5350	5303	5347	5347	5051	5605	4635	4631	4424	4439	4068	3843	3549	3513	3211	3137	2778
2007	4732	4904	4804	4956	4789	4504	4512	4509	3969	4316	3591	3331	3123	2930	2908	2507	2450	2285	2069	2229	2014
2008	5870	5731	6142	6046	5971	6195	5947	5813	5243	5287	4557	4161	3848	3440	2950	2640	2291	2099	1802	1836	1529
2009	4360	4487	4689	4756	4775	4615	4670	4652	4335	4506	3649	3435	3164	2813	2400	2178	1797	1741	1362	1197	1086
2010	5737	5922	5892	5666	5273	4835	4481	4088	3530	3524	2800	2619	2333	2139	1916	1757	1375	1263	1085	1053	868
2011	6505	6894	7259	7275	7444	6684	6417	6043	5600	5255	4056	3558	3024	2739	2372	1921	1508	1384	1185	1155	923
2012	8156	8018	8145	7697	7589	6843	6592	6213	5778	6123	4688	3924	3594	3095	2765	2130	1753	1548	1236	1106	849
2013	9582	10016	10248	10584	10589	10150	9834	9035	8521	8248	6722	6170	5366	4561	3896	3156	2561	2195	1688	1415	1157
2014	8183	8320	8820	8760	9107	8904	9015	8770	8487	8425	7270	6592	6153	5455	4772	3990	3276	2856	2389	2061	1582
2015	8930	8949	8812	8887	8510	7966	7868	7529	6762	6894	5544	5125	4753	4219	3739	3247	2822	2411	2100	1924	1516
2016	6632	7299	7870	8027	8314	8235	8051	7753	7080	7076	5946	5227	4804	4534	3763	3249	2703	2531	2077	1734	1420
2017	3694	3665	3693	3699	3821	3971	3812	3960	3925	4061	3386	3235	3031	2802	2429	2288	1873	1618	1284	1174	874

Table 2.5a (page 4 of 5)—Fishery survey size composition as used in Model 16.6, by year and cm.

Year	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107
1977	7	2	7	1	5	2	0	0	1	0	3	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0
1978	46	36	27	25	16	15	14	9	5	2	4	3	4	4	1	0	0	1	1	0	0	0	0	0	0	0
1979	41	22	22	25	11	13	9	9	6	8	8	4	8	2	2	2	3	0	2	1	1	0	2	0	0	2
1980	74	54	39	36	38	33	34	14	29	17	18	15	5	10	8	5	3	2	2	2	0	2	3	2	0	0
1981	6	12	5	7	7	6	4	2	5	2	2	0	3	0	0	1	0	2	0	0	0	0	0	0	0	0
1982	87	86	75	42	31	43	30	31	37	18	25	12	20	26	12	12	7	10	1	6	0	6	0	1	3	0
1983	714	628	550	490	437	352	296	212	202	159	137	112	62	53	46	37	36	24	24	19	17	5	6	7	4	0
1984	2366	2199	1899	1655	1307	1230	1053	784	689	504	437	318	258	196	130	122	76	54	47	42	33	22	10	10	6	3
1985	3638	3155	2803	2608	2161	1782	1607	1406	1235	929	805	697	596	469	327	265	210	197	114	101	66	63	27	33	23	9
1986	2890	2827	2411	2200	1885	1579	1347	1084	968	750	612	556	444	391	284	240	175	152	148	113	76	56	39	44	25	17
1987	4814	4675	4025	3786	3417	3130	2758	2484	2338	1980	1703	1562	1194	1135	746	731	551	461	398	283	260	200	134	132	64	42
1988	1198	1054	921	890	783	623	557	477	534	406	321	323	245	304	191	141	126	112	103	99	79	49	40	28	23	18
1989	1456	1291	1227	1090	944	903	807	669	593	485	378	413	321	310	197	211	190	177	133	131	73	70	61	49	35	23
1990	5461	5035	4599	4342	3915	3448	3149	3102	2434	2352	2206	2075	1704	1675	1367	1234	1067	891	606	557	463	466	313	233	166	139
1991	7487	6817	6402	6014	5336	4767	4393	4216	3686	3020	2851	2403	2123	1936	1702	1480	1342	1125	898	733	654	569	436	371	252	183
1992	5035	4772	4461	4209	3541	3382	3238	3032	2776	2187	2110	1879	1648	1580	1368	1199	1048	1008	867	662	507	519	386	318	189	169
1993	1969	1935	1726	1553	1460	1234	1155	1023	1019	762	764	677	564	530	448	357	393	322	236	201	184	151	117	90	59	41
1994	2468	2201	2003	1930	1707	1517	1365	1266	1379	916	904	770	715	644	550	498	429	342	369	254	237	182	168	136	110	70
1995	2509	2212	1980	1795	1508	1353	1221	1159	1114	718	757	736	623	538	495	375	358	302	293	231	201	143	128	103	76	47
1996	4850	4313	4032	3498	3097	2746	2442	2233	2139	1587	1545	1347	1216	1109	954	783	621	601	588	428	354	326	241	209	157	142
1997	4275	4055	3675	3383	3073	2756	2539	2352	2055	1672	1477	1271	1073	1067	889	695	610	495	447	335	290	248	219	175	116	112
1998	4621	4189	3541	3034	2591	2199	2011	1669	1760	1315	1166	1101	956	900	741	678	590	507	435	297	267	210	222	150	109	95
1999	1881	1663	1413	1277	1047	854	765	673	640	533	429	379	301	239	234	180	152	161	170	101	95	68	52	61	45	32
2000	1637	1533	1287	1195	1052	971	829	726	696	537	491	410	367	314	295	232	209	156	147	111	103	73	60	53	31	17
2001	1159	974	913	774	703	556	501	436	453	353	335	271	252	225	210	185	147	105	110	93	67	65	40	39	32	22
2002	1299	1120	950	779	673	591	466	420	398	289	270	234	235	216	146	159	113	95	74	67	57	38	35	36	33	13
2003	2001	1731	1428	1290	985	879	756	592	518	418	334	297	241	206	166	156	117	96	83	75	63	43	31	26	18	15
2004	1732	1567	1375	1176	1067	862	792	681	579	502	394	346	272	261	213	154	124	107	104	81	60	53	31	28	16	16
2005	2673	2342	2188	1879	1560	1452	1331	1137	1151	838	756	630	553	463	383	290	263	179	154	99	106	64	74	36	30	13
2006	2737	2551	2391	2012	1891	1733	1504	1443	1375	1045	957	852	768	655	508	481	439	367	308	228	186	140	123	88	79	67
2007	1831	1825	1750	1625	1474	1466	1396	1286	1232	1049	880	871	753	690	592	473	428	366	333	257	185	152	135	92	60	54
2008	1393	1359	1222	1132	1051	952	1023	851	910	795	765	646	592	568	478	441	374	293	297	190	175	138	110	84	36	37
2009	926	707	678	529	493	454	389	370	353	283	266	219	214	194	177	165	137	113	109	83	68	62	47	39	28	20
2010	639	608	514	448	378	299	268	189	207	128	123	101	101	63	48	56	45	35	46	38	25	21	26	15	11	8
2011	759	638	590	486	382	371	308	241	230	174	142	111	99	93	63	76	59	44	49	30	28	24	10	19	13	8
2012	731	566	508	383	349	236	213	223	175	130	111	81	93	59	43	70	36	32	32	23	20	15	10	14	6	5
2013	993	719	558	502	376	323	248	218	192	129	111	103	113	70	51	37	38	28	39	19	20	12	9	11	7	4
2014	1257	1055	843	683	535	457	374	292	277	207	162	147	108	100	74	62	57	50	20	27	19	16	15	5	5	3
2015	1398	1161	979	836	708	593	467	416	343	232	178	168	142	105	69	69	52	42	45	21	20	16	9	2	3	6
2016	1243	987	867	703	637	471	436	347	309	221	203	154	138	120	85	79	39	41	39	24	20	9	14	7	4	3
2017	735	638	593	453	341	307	257	231	185	149	110	101	71	56	61	46	29	33	15	13	23	18	3	5	4	8

Table 2.5a (page 5 of 5)—Fishery survey size composition as used in Model 16.6, by year and cm.

Year	108	109	110	111	112	113	114	115	116	117	118	119	120+
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	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
1980	0	0	0	2	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	1	0	0	0	0	0	0	0	0	0	0
1983	6	0	4	0	0	2	0	0	0	0	0	0	0
1984	1	3	2	0	3	1	0	1	0	0	0	0	0
1985	8	5	5	3	2	4	4	4	0	0	2	0	0
1986	7	9	11	2	1	0	2	1	1	0	2	2	5
1987	25	23	26	14	9	5	7	6	1	3	3	0	0
1988	8	8	7	3	5	0	0	1	0	0	0	0	0
1989	12	21	12	7	7	5	1	1	0	3	0	2	19
1990	114	71	68	39	17	23	18	12	8	5	0	2	0
1991	149	74	64	40	39	17	17	8	2	0	4	1	4
1992	98	88	76	55	26	21	15	14	3	3	0	1	2
1993	36	42	28	5	10	3	5	5	6	7	2	0	4
1994	53	42	62	27	21	15	12	15	8	0	7	1	11
1995	35	24	44	11	16	8	7	10	7	0	2	1	12
1996	90	66	75	54	46	23	22	15	10	3	6	7	27
1997	79	66	62	19	25	12	6	9	5	8	2	1	13
1998	71	59	57	22	21	28	18	3	6	9	6	2	10
1999	28	20	27	12	10	4	1	3	4	2	1	2	16
2000	29	16	26	10	8	6	13	4	1	2	0	2	12
2001	19	14	11	4	5	7	5	3	1	0	0	1	0
2002	10	4	14	3	2	6	0	4	0	1	0	0	0
2003	14	4	9	4	4	0	1	2	1	0	0	1	1
2004	11	9	13	4	4	1	0	1	0	0	1	0	3
2005	10	12	6	4	4	4	0	2	0	0	2	0	0
2006	33	26	26	16	12	11	3	7	3	5	3	0	1
2007	33	25	22	8	10	7	7	5	2	2	0	0	4
2008	30	15	12	9	7	1	0	0	0	0	1	0	4
2009	12	13	10	9	8	0	4	0	0	1	0	0	0
2010	3	9	8	2	0	1	1	1	0	0	0	1	2
2011	6	2	1	2	3	2	0	0	0	0	0	0	3
2012	4	2	2	1	1	2	0	0	0	0	0	0	0
2013	8	3	0	0	1	0	1	1	0	1	0	0	0
2014	1	5	1	0	0	0	0	2	0	0	0	0	1
2015	4	0	0	0	0	0	0	0	0	0	0	0	1
2016	6	4	2	0	0	0	0	0	1	0	0	0	0
2017	2	0	0	0	2	0	0	0	0	0	0	0	0

Table 2.5b (page 1 of 6)—Fishery survey size composition as used in Models 17.x, by year and cm (number of hauls sampled in column 2).

Year	N	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1977	30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	160	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.03	0.08	0.12	0.54
1979	235	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
1980	208	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03
1981	148	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.03	0.03	0.03	0.04	0.03	0.12	0.10
1982	187	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.04	0.01
1983	782	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.11	0.17	0.19	0.06	0.25	0.39
1984	1913	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.00	0.04	0.08	0.11	0.18	0.65	1.06	1.19	1.31	1.55	1.15	1.51	2.47	3.40	5.18
1985	2825	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.01	0.00	0.01	0.03
1986	2496	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.07	0.07	0.17	0.29	0.06	0.08	0.17	0.36	0.34	0.49	0.63	0.82	0.66	1.24	1.80	2.05
1987	4726	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.03	0.11	0.25	0.29	0.21	0.21	0.46	0.19	0.32	0.50	1.07	1.17	1.82	3.08
1988	1458	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.01	0.04	0.01	0.06	0.18	0.15	0.10	0.19	0.37	0.81
1989	966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.06	0.08	0.04	0.04	0.03	0.01	0.01	0.03	0.12	0.30
1990	3601	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.06	0.03	0.01	0.08	0.03	0.21	0.68	0.50	0.91	1.82	2.29	4.73
1991	5188	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.04	0.05	0.01	0.04	0.00	0.15	0.07	0.21	0.38	0.37	0.82	1.46	2.26	3.59
1992	5322	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.10	0.10	0.02	0.20	0.00	0.11	0.07	0.14	0.06	0.21	0.15	0.52	0.84	1.22	2.15
1993	2993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.07	0.02	0.08	0.03	0.13	0.09	0.06	0.11	0.16	0.26	0.53	0.92	1.94
1994	4687	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.01	0.00	0.00	0.04	0.10	0.15	0.36	0.21	0.45	0.88	1.74	3.05	4.95	9.30
1995	5215	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.37	0.43	0.48	0.59	0.69	0.63	0.70	1.13	1.24	2.09	1.83	2.61	2.53
1996	6618	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.08	0.07	0.07	0.13	0.30	0.11	0.40	0.41	0.20	0.54	0.31	0.17	0.26	0.38	1.17	1.97	4.60	6.75
1997	7278	0.00	0.03	0.02	0.00	0.16	0.00	0.03	0.00	0.03	0.07	0.00	0.01	0.13	0.32	0.64	1.16	1.05	1.22	0.97	1.06	0.44	0.84	1.17	1.64	2.99	5.45
1998	6838	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.11	0.07	0.16	0.11	0.00	0.02	0.16	0.21	0.26	0.26	1.45	2.98	5.51	7.70	11.75
1999	9231	0.00	0.00	0.09	0.05	0.13	0.05	0.09	0.07	0.00	0.00	0.00	0.00	0.06	0.00	0.17	0.14	0.09	0.21	0.00	0.15	0.09	0.20	0.34	1.57	2.95	3.88
2000	9731	0.00	0.08	0.12	0.04	0.06	0.04	0.00	0.01	0.00	0.17	0.00	0.00	0.00	0.00	0.06	0.00	0.12	0.02	0.09	0.00	0.10	0.16	0.13	0.36	1.19	2.17
2001	10364	0.00	0.13	0.32	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.10	0.05	0.09	0.20	0.17	0.19	0.07	0.12	0.11	0.32	0.35	0.06	0.12
2002	11472	0.00	0.16	0.24	0.07	0.00	0.15	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.09	0.21	0.12	0.49	0.53	0.44	0.42	0.79	0.76	0.97	1.35	2.42	2.94
2003	14341	0.00	0.06	0.14	0.49	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.23	0.13	0.00	0.01	0.16	0.26	0.04	0.08	0.00	0.09	0.01	0.19	0.07	0.25	0.61
2004	12242	0.00	0.00	0.17	0.06	0.09	0.04	0.00	0.00	0.00	0.17	0.09	0.01	0.00	0.01	0.00	0.01	0.07	0.00	0.02	0.25	0.03	0.01	0.13	0.26	0.45	0.35
2005	11568	0.00	0.15	0.04	0.29	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.16	0.06	0.00	0.03	0.03	0.10	0.41	0.06	0.32	0.35	0.25	1.02
2006	8849	0.00	0.00	0.08	0.17	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.11	0.00	0.12	0.20	0.15	0.18	0.07	0.01	0.01	0.10	0.26	0.08
2007	6901	0.00	0.00	0.12	0.08	0.01	0.01	0.00	0.00	0.00	0.00	0.10	0.21	0.01	0.00	0.29	0.24	0.17	0.40	0.24	0.41	0.58	0.74	0.98	0.90	1.60	1.50
2008	8320	0.00	0.07	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.14	0.17	0.00	0.26	0.24	0.08	0.14	0.37	0.97	1.65	2.97	2.40	4.71	3.64
2009	7482	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.01	0.06	0.03	0.03	0.10	0.07	0.31	0.42
2010	6514	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.09	0.09	0.15	0.24	0.18	0.42	1.09	1.12
2011	8804	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.03	0.26	0.33	0.16	0.63
2012	9287	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.28	0.32	0.01	0.05	0.44	1.23	2.05	2.53
2013	11126	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.14	0.23	0.12	0.32	0.59	1.14	1.21
2014	12165	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.18	0.05	0.38	0.09	0.02	0.00	0.09	0.00	0.00	0.01	0.49	0.64	2.30	1.95
2015	11309	0.00	0.00	0.00	0.18	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.11	0.00	0.00	0.11	0.42	0.36	1.26
2016	9773	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.02	0.51
2017	5334	0.00	0.00	0.00	0.09	0.00	0.00	0.03	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.09	0.01	0.11	0.45	0.00	0.00	0.00	0.00

Table 2.5b (page 2 of 6)—Fishery survey size composition as used in Models 17.x, by year and cm.

Year	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
1977	0.00	0.03	0.03	0.07	0.13	0.20	0.13	0.34	0.36	0.40	0.29	0.22	0.39	0.29	0.14	0.20	0.14	0.09	0.20	0.30	0.50
1978	0.64	0.54	0.54	0.35	0.25	0.22	0.08	0.10	0.30	0.26	0.21	0.12	0.18	0.28	0.42	0.64	0.94	1.22	1.72	2.15	2.73
1979	0.12	0.33	0.61	0.44	0.98	1.45	2.05	2.45	3.87	5.34	5.23	6.81	7.79	7.71	6.81	6.74	6.50	5.63	5.27	3.91	3.65
1980	0.21	0.18	0.43	0.49	0.46	0.75	1.21	1.53	2.53	2.97	5.20	6.27	7.31	8.09	7.58	7.99	7.31	7.80	6.53	6.48	5.34
1981	0.29	0.63	0.77	1.72	3.17	4.41	4.91	5.79	5.01	3.82	3.67	2.44	2.30	2.92	3.53	4.21	5.02	6.29	5.81	5.66	5.59
1982	0.03	0.03	0.06	0.14	0.40	0.78	0.92	0.78	1.02	0.92	0.59	0.42	0.60	1.13	1.45	2.13	1.71	2.44	2.16	2.16	2.76
1983	0.34	0.65	1.21	1.66	1.81	1.57	1.20	1.16	1.01	1.41	1.37	2.22	3.45	4.41	5.24	5.32	6.19	6.00	6.47	6.33	5.71
1984	6.56	7.16	6.90	6.83	6.63	6.94	7.12	7.30	8.47	7.56	7.01	7.02	7.35	8.84	10.09	12.09	11.86	11.15	11.62	11.98	12.80
1985	0.18	0.41	0.50	0.69	0.99	1.93	2.28	2.35	4.10	4.82	7.63	11.23	15.79	21.38	24.59	25.24	27.52	31.04	32.90	38.87	43.38
1986	2.50	4.28	6.11	8.47	10.10	10.65	11.91	11.46	10.70	10.27	11.47	10.03	10.84	12.72	15.34	19.33	19.23	22.90	26.05	29.12	32.60
1987	4.29	5.27	5.43	5.98	6.99	7.12	7.04	7.44	8.09	9.78	13.36	17.26	21.18	27.32	30.57	34.15	42.19	45.32	47.88	53.62	62.41
1988	1.56	3.01	4.18	6.02	7.27	8.94	10.04	9.36	10.28	9.21	11.15	12.35	16.15	20.65	27.32	30.64	33.57	35.72	35.02	32.82	33.06
1989	0.80	1.56	1.32	2.62	2.80	3.67	4.68	4.44	5.67	5.23	4.26	4.75	4.69	5.28	6.83	7.58	9.34	10.74	10.80	13.08	14.18
1990	5.01	8.21	6.69	7.92	7.52	7.65	7.55	7.30	5.80	6.44	6.11	5.49	4.95	5.37	5.34	5.33	6.98	8.82	9.07	13.12	15.06
1991	4.94	6.98	8.95	8.56	9.62	9.60	9.97	9.43	11.76	12.61	14.06	16.42	18.46	22.00	25.73	29.95	40.03	47.34	51.12	61.17	58.24
1992	3.78	4.93	6.18	8.80	9.93	11.72	11.83	11.95	13.70	15.80	22.17	29.85	40.37	49.41	60.86	72.63	76.74	82.00	90.51	94.35	102.85
1993	4.03	6.66	8.14	9.51	9.54	10.05	9.20	9.16	12.13	20.28	29.78	40.63	52.22	56.44	61.17	62.56	64.95	64.72	62.73	64.95	70.41
1994	12.61	19.31	23.13	27.93	32.67	31.64	31.35	25.64	19.77	17.29	15.08	16.78	20.00	28.04	37.11	46.24	54.52	65.70	72.01	84.19	99.41
1995	3.23	3.42	3.97	4.26	3.85	5.08	5.95	7.55	11.51	21.10	34.53	52.16	73.61	89.35	105.87	105.09	108.65	99.33	91.02	84.15	83.69
1996	10.24	12.85	15.04	15.80	15.84	14.48	13.54	13.15	11.23	10.77	12.71	15.93	22.96	29.73	42.82	56.78	68.40	80.38	96.55	116.41	137.50
1997	7.53	12.60	16.72	21.47	22.78	25.46	24.90	24.00	22.33	20.69	19.46	20.96	22.27	27.18	36.87	51.72	59.93	71.88	79.84	87.91	95.79
1998	14.47	14.01	15.65	14.71	13.93	11.83	11.10	11.85	11.43	12.60	16.30	19.79	24.75	30.68	40.14	50.68	56.96	62.87	73.08	80.22	85.08
1999	8.69	12.55	13.95	10.45	12.43	11.08	10.69	12.29	17.00	27.43	45.10	71.26	107.39	135.54	154.86	174.77	180.19	182.36	190.27	185.38	184.80
2000	3.33	3.12	5.40	4.15	3.93	5.81	5.59	9.02	11.74	15.36	25.41	34.81	46.84	62.11	66.88	90.26	107.09	129.40	149.31	175.93	198.36
2001	0.62	0.95	1.78	2.15	3.25	4.83	6.96	10.81	11.06	16.50	19.82	31.61	38.16	49.08	61.27	72.69	91.59	111.92	125.27	148.19	168.33
2002	5.54	8.86	13.98	14.84	20.19	20.86	22.86	27.59	27.79	35.15	42.90	59.00	76.24	96.67	113.41	129.20	146.85	169.54	192.78	209.83	226.43
2003	0.71	2.31	4.57	7.62	9.49	13.60	14.18	16.41	19.40	25.90	38.45	51.80	69.18	96.91	115.84	144.67	158.09	201.38	230.24	257.54	296.59
2004	1.07	1.56	2.42	4.51	6.70	8.16	9.91	9.92	12.47	14.05	19.37	21.18	27.04	34.24	42.13	60.27	79.46	100.86	118.79	153.56	195.83
2005	2.94	3.45	4.19	5.05	8.01	10.29	12.10	10.66	14.84	17.41	23.64	36.77	37.31	46.06	57.37	72.65	89.44	103.64	116.61	139.71	151.72
2006	0.36	1.72	2.22	3.56	4.26	5.63	5.76	8.87	9.76	10.82	12.82	16.02	19.25	26.51	30.01	40.39	55.00	67.17	87.84	106.29	128.64
2007	2.34	4.04	3.63	4.09	5.06	5.60	6.02	6.24	7.53	9.91	10.92	12.50	15.49	17.16	19.40	24.53	34.63	40.67	51.63	62.15	80.90
2008	3.72	2.96	3.01	3.58	4.16	3.78	5.11	6.15	6.68	10.65	15.29	22.05	27.87	32.12	35.45	48.23	57.58	66.38	76.12	90.73	106.13
2009	0.48	0.71	0.74	0.68	1.28	1.46	2.10	2.85	6.28	10.84	17.02	25.81	30.43	38.35	47.20	61.62	72.92	90.39	117.69	133.41	160.14
2010	1.14	1.70	0.58	1.43	1.43	1.92	3.16	3.80	6.16	8.41	15.84	18.22	26.48	27.54	32.96	39.46	48.48	58.41	76.27	90.43	116.01
2011	1.71	1.58	1.90	2.55	2.21	2.21	3.93	7.12	10.69	18.96	32.38	45.01	55.86	74.59	82.73	97.15	108.28	125.27	147.79	167.17	179.59
2012	2.71	3.29	4.27	4.91	6.45	5.68	6.18	6.37	5.13	6.27	9.36	14.77	23.24	27.41	35.42	51.72	55.11	67.90	86.58	119.72	169.69
2013	2.21	1.89	3.56	3.94	4.82	7.52	8.47	11.32	10.84	16.25	23.90	36.51	49.73	67.03	85.88	98.55	109.08	116.65	122.80	126.98	142.18
2014	3.65	4.25	6.30	7.50	8.13	6.55	5.71	7.45	13.63	19.63	38.13	58.62	79.17	99.12	109.06	113.08	117.79	116.40	123.10	136.53	172.56
2015	2.29	4.86	5.64	9.73	6.24	12.49	10.58	11.97	10.75	10.66	10.00	14.24	17.80	35.65	41.66	59.41	80.09	94.32	113.33	127.89	164.41
2016	0.10	0.47	1.60	1.84	1.27	2.20	3.13	4.56	4.66	5.65	9.76	16.07	24.83	39.27	58.11	76.57	102.44	119.29	131.54	142.89	150.15
2017	0.00	0.11	0.21	0.19	0.34	0.51	0.59	1.41	1.86	2.26	3.14	2.43	4.39	5.73	6.62	11.37	13.28	19.92	25.13	37.56	52.77

Table 2.5b (page 3 of 6)—Fishery survey size composition as used in Models 17.x, by year and cm.

Year	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
1977	0.78	1.35	1.15	1.36	1.31	1.11	1.05	0.99	0.89	1.03	1.06	1.13	1.13	1.25	1.23	1.42	1.03	0.85	0.79
1978	3.79	4.44	5.40	6.99	8.13	9.27	10.51	9.81	10.20	10.02	9.07	8.36	7.00	6.26	5.04	3.68	2.91	2.93	2.67
1979	3.54	4.23	4.43	4.83	5.12	5.40	5.95	6.63	6.65	7.01	7.43	7.96	7.83	8.27	8.16	7.96	7.13	6.79	5.12
1980	5.91	5.57	5.19	5.25	5.66	5.62	5.17	4.96	5.48	4.92	5.06	4.00	3.54	3.39	3.16	2.47	2.67	2.99	2.85
1981	5.41	5.52	5.46	4.94	4.11	4.22	3.63	3.42	3.32	3.09	2.91	2.43	2.46	1.83	1.97	1.88	1.48	1.45	1.28
1982	2.17	3.58	3.26	4.76	4.79	4.58	4.29	4.72	5.21	4.88	5.45	6.13	6.17	6.49	7.20	7.01	6.73	7.01	6.63
1983	7.06	8.00	9.34	11.95	16.22	17.26	20.28	20.79	24.24	25.08	27.89	29.75	26.64	28.47	29.62	30.73	27.89	27.70	28.39
1984	13.22	14.37	14.20	18.65	21.67	25.71	32.35	33.83	38.19	43.53	48.78	53.86	57.23	64.42	65.36	66.08	69.50	72.54	71.13
1985	47.31	52.43	55.21	56.86	54.32	49.91	48.00	44.41	41.34	41.82	40.94	43.02	49.96	56.99	67.24	73.88	85.05	92.39	100.16
1986	38.19	42.20	43.63	53.41	56.01	60.34	66.01	68.79	70.38	73.78	75.08	79.38	78.98	81.55	79.47	75.19	77.50	69.55	62.50
1987	67.48	80.06	90.45	102.02	112.54	116.36	122.16	125.53	126.42	130.31	124.48	125.93	129.31	135.25	133.58	139.99	142.13	143.11	138.06
1988	29.93	32.27	33.07	33.61	32.18	32.37	31.67	31.36	28.97	30.23	29.47	26.71	26.27	27.84	29.47	29.33	29.58	33.83	32.55
1989	13.43	15.11	15.52	16.06	16.03	16.03	16.36	16.60	16.90	17.69	19.12	18.71	20.64	21.68	22.38	22.56	22.73	24.45	25.80
1990	22.94	24.66	28.72	31.74	37.01	43.29	49.03	55.28	63.54	69.79	77.50	91.33	95.01	101.13	110.61	115.94	117.52	118.35	125.60
1991	60.84	62.69	61.34	60.94	62.57	65.72	68.35	75.87	81.56	90.74	97.08	111.78	123.51	131.34	143.08	148.42	161.97	162.09	168.83
1992	103.79	109.98	106.57	109.30	110.06	102.56	106.83	105.81	108.69	117.62	116.55	126.41	129.99	137.57	148.25	141.29	148.87	154.21	146.87
1993	75.38	83.75	89.16	93.02	98.60	100.25	100.07	97.99	93.19	91.60	87.17	82.78	77.28	70.12	65.57	60.60	58.00	55.17	52.09
1994	104.78	116.14	127.14	135.39	143.80	146.49	154.13	152.56	156.19	169.17	159.60	158.03	161.25	159.40	158.79	151.69	150.17	143.40	130.10
1995	82.39	85.66	93.00	101.49	109.80	122.16	127.09	135.65	141.46	151.03	153.90	165.64	173.55	169.22	180.12	174.94	179.08	175.24	167.89
1996	156.03	171.01	184.78	192.77	201.30	203.73	200.18	198.03	194.69	192.06	184.00	185.31	185.41	187.40	189.46	184.21	185.25	184.27	183.92
1997	100.79	108.70	121.57	140.64	159.32	169.49	193.59	208.69	232.98	251.96	263.33	280.82	286.64	292.84	297.57	286.51	279.41	272.90	259.95
1998	94.78	100.55	107.41	116.56	129.82	135.46	146.75	155.60	169.54	188.52	200.92	217.61	232.29	245.01	257.76	264.61	272.59	266.76	262.93
1999	185.96	187.47	193.62	183.60	201.18	201.49	194.66	200.44	204.18	231.93	228.93	239.98	258.99	249.73	274.99	271.24	276.39	281.42	269.39
2000	227.34	250.35	269.34	283.62	300.30	318.73	323.63	326.60	339.17	347.47	352.25	355.16	351.59	341.48	319.08	310.70	303.10	277.75	261.88
2001	190.28	222.42	248.13	282.45	307.29	332.06	366.41	382.41	399.35	428.72	431.15	434.91	454.27	437.64	438.28	415.47	397.42	378.74	363.60
2002	244.55	267.37	278.10	298.11	310.28	319.04	337.10	354.27	361.29	387.97	409.09	429.43	437.30	437.82	431.42	423.74	417.67	418.70	384.85
2003	330.80	398.71	412.04	446.18	468.12	487.49	511.33	492.10	488.26	511.82	494.82	498.10	512.63	491.80	496.13	480.18	464.37	462.34	421.45
2004	223.65	252.61	298.02	325.18	372.23	410.28	439.19	461.74	497.42	556.14	550.99	549.41	566.12	532.49	513.49	485.64	451.15	430.37	392.98
2005	164.66	187.87	196.25	221.40	245.03	263.22	278.99	295.47	310.13	352.82	356.27	388.24	414.70	436.76	442.24	443.68	470.05	449.30	436.75
2006	147.43	169.59	184.15	205.64	224.92	239.90	247.49	249.57	250.26	259.40	251.33	263.23	255.86	258.88	255.11	259.92	264.55	261.27	254.24
2007	84.78	101.03	116.35	129.78	147.49	161.87	172.15	197.14	203.08	248.13	237.85	242.82	243.07	246.97	240.07	222.55	223.81	229.43	197.63
2008	114.60	138.50	156.43	165.31	186.99	196.35	223.08	231.56	248.49	285.13	293.84	293.92	329.84	330.38	325.89	335.94	327.40	329.11	296.82
2009	181.64	192.87	198.53	181.92	174.74	175.84	175.00	177.98	181.03	199.96	205.82	227.87	243.56	259.70	272.97	268.10	278.42	291.08	274.31
2010	132.81	154.55	178.05	193.77	225.13	218.67	229.10	235.01	243.15	249.93	254.74	258.53	264.75	261.50	248.47	231.36	233.22	210.98	197.82
2011	186.54	188.79	204.80	207.16	221.94	229.53	255.67	279.49	301.37	329.81	345.49	368.45	397.99	394.45	407.04	366.96	358.08	334.55	307.28
2012	216.65	244.32	274.13	306.26	316.25	325.87	324.69	336.83	349.27	377.79	366.16	378.40	396.40	390.35	396.36	368.97	363.36	350.48	330.56
2013	168.39	189.47	214.60	245.81	273.69	310.01	334.56	362.56	403.98	460.39	469.14	501.51	518.06	528.07	512.56	493.43	469.93	439.07	415.49
2014	183.29	209.98	238.57	271.86	308.21	332.97	358.44	370.71	374.29	415.30	396.02	395.75	434.19	430.29	453.26	456.40	474.56	479.28	487.95
2015	201.91	235.28	275.82	327.57	362.42	397.00	413.26	432.30	426.50	437.17	435.05	443.16	456.39	469.37	465.04	445.11	445.20	422.78	386.15
2016	163.55	168.64	180.20	194.20	213.93	241.27	264.01	281.98	321.84	358.11	352.12	389.37	430.60	435.33	453.80	440.52	433.55	411.47	378.80
2017	70.00	87.21	107.51	128.62	148.01	164.87	164.27	172.35	168.93	174.44	178.06	176.84	183.75	184.13	194.16	205.09	195.74	215.97	215.80

Table 2.5b (page 4 of 6)—Fishery survey size composition as used in Models 17.x, by year and cm.

Year	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
1977	0.69	0.66	0.50	0.36	0.26	0.40	0.30	0.29	0.29	0.16	0.17	0.11	0.10	0.03	0.10	0.01	0.07	0.03	0.00
1978	2.48	2.02	1.65	1.87	1.69	1.27	1.26	1.04	0.96	0.66	0.55	0.35	0.64	0.50	0.37	0.35	0.22	0.21	0.19
1979	5.13	4.78	3.50	3.17	2.86	2.12	1.60	1.68	1.16	0.78	0.61	0.66	0.56	0.30	0.30	0.34	0.15	0.18	0.12
1980	3.50	3.28	3.13	3.34	3.00	2.91	2.72	2.67	2.11	1.81	1.49	1.25	1.03	0.75	0.54	0.50	0.53	0.46	0.47
1981	1.27	1.05	0.99	0.87	0.77	0.68	0.69	0.48	0.34	0.33	0.19	0.23	0.08	0.17	0.07	0.10	0.10	0.08	0.06
1982	7.23	6.71	7.13	5.63	5.21	4.71	3.96	4.03	2.76	2.76	2.09	2.35	1.21	1.20	1.04	0.59	0.43	0.60	0.42
1983	27.01	24.70	23.75	22.08	21.38	19.90	17.93	17.85	17.05	15.92	14.62	12.58	9.85	8.66	7.59	6.76	6.03	4.86	4.08
1984	70.54	69.05	68.00	66.35	62.44	58.24	56.69	52.12	47.84	44.81	39.68	35.77	32.69	30.39	26.24	22.87	18.06	17.00	14.55
1985	109.42	107.00	110.88	107.46	103.11	97.98	91.44	85.58	76.52	67.77	64.43	54.09	50.21	43.54	38.69	35.99	29.83	24.59	22.18
1986	57.32	55.74	54.89	54.39	56.13	56.97	52.62	54.02	52.40	51.42	49.21	45.09	40.38	39.50	33.69	30.74	26.34	22.06	18.82
1987	142.91	137.45	134.12	134.89	127.74	125.03	111.86	109.17	100.82	88.09	85.58	72.27	66.80	64.88	55.86	52.54	47.42	43.44	38.27
1988	36.29	36.28	36.59	37.24	35.75	38.07	32.02	31.69	28.88	25.91	23.85	20.76	16.54	14.55	12.71	12.29	10.81	8.60	7.69
1989	27.71	27.09	26.67	28.49	27.98	29.76	25.72	26.26	24.99	24.02	23.02	21.26	20.09	17.81	16.93	15.04	13.03	12.46	11.14
1990	123.00	122.06	125.54	119.45	121.07	118.23	113.96	107.67	100.88	96.60	86.80	82.98	75.36	69.48	63.47	59.92	54.03	47.58	43.46
1991	169.37	164.29	170.71	160.49	163.10	157.50	152.61	142.28	136.31	125.80	120.95	109.67	104.75	95.44	89.34	83.01	75.82	66.89	61.41
1992	152.80	129.37	136.40	126.20	120.34	121.51	103.74	102.69	99.40	93.01	98.32	81.89	76.81	71.28	69.41	64.19	53.14	53.04	50.36
1993	51.98	45.86	46.66	44.41	43.41	41.47	39.29	35.95	35.68	32.73	31.74	28.14	26.51	24.92	22.75	20.14	18.51	16.38	15.04
1994	130.52	101.94	92.22	85.22	74.08	71.30	56.73	52.92	44.00	38.00	39.40	32.78	28.87	26.98	24.55	23.74	20.32	17.60	16.54
1995	164.40	138.94	131.31	116.27	105.18	96.17	83.02	75.39	67.45	59.46	54.77	43.25	41.90	38.16	34.99	31.31	26.93	24.53	21.84
1996	192.91	172.02	167.14	154.81	150.44	141.19	126.33	117.51	105.14	95.21	90.85	78.98	72.11	62.93	60.90	52.01	46.68	41.93	36.13
1997	250.20	212.43	197.76	179.33	159.45	148.14	129.25	115.83	102.78	95.79	82.30	66.10	61.32	57.21	51.76	46.74	41.65	38.19	34.99
1998	270.39	242.64	234.06	220.55	199.43	178.92	158.57	139.59	122.37	105.09	92.67	77.18	70.75	62.28	53.14	45.16	39.07	31.83	29.74
1999	290.65	261.56	267.48	235.47	233.97	205.93	198.43	166.67	162.76	139.39	134.35	110.67	100.83	89.59	75.66	69.84	54.77	49.70	39.46
2000	256.69	217.47	215.87	196.43	184.14	169.46	152.48	139.61	131.25	113.52	109.69	97.19	85.67	82.48	68.89	64.44	55.22	49.04	44.35
2001	342.68	289.96	250.45	221.99	191.16	168.29	134.76	109.86	97.64	86.42	78.10	65.98	53.88	46.82	44.55	36.39	34.10	26.12	25.28
2002	370.66	334.56	301.05	254.68	240.38	193.83	173.11	144.12	126.59	109.07	88.51	79.06	64.69	52.14	45.30	37.16	32.25	29.52	21.44
2003	451.41	372.41	353.53	318.40	300.24	263.45	234.06	201.05	179.22	160.29	149.10	116.81	102.30	86.55	71.01	60.50	44.55	39.52	33.55
2004	383.03	317.24	272.89	249.16	223.29	198.81	179.09	147.49	143.33	120.43	112.81	94.97	77.90	70.47	64.09	50.36	48.08	37.98	32.52
2005	468.47	387.43	373.29	344.34	302.10	286.19	249.74	214.42	208.36	167.47	166.82	145.02	123.74	107.62	100.54	85.81	71.39	64.35	59.92
2006	276.15	231.36	234.64	225.24	222.78	212.33	197.08	185.69	183.85	166.48	164.13	143.67	141.98	134.12	123.87	101.43	95.54	88.23	75.67
2007	221.12	180.60	164.99	157.52	146.60	145.38	128.89	128.54	116.32	108.44	116.66	108.44	94.88	95.69	93.21	87.13	75.14	76.98	73.48
2008	299.01	259.07	235.56	217.41	190.53	158.12	145.32	126.07	113.52	100.75	103.66	82.01	73.44	74.32	66.54	56.89	55.03	50.74	53.70
2009	295.64	248.89	244.12	225.34	194.68	180.73	160.03	125.42	128.44	102.04	86.17	74.93	59.74	45.97	41.15	31.15	29.64	25.42	24.32
2010	210.44	166.99	160.38	143.03	136.70	127.35	117.19	90.43	85.39	71.93	69.91	59.15	43.07	38.91	33.16	25.66	23.25	17.72	15.09
2011	283.02	226.10	193.36	167.54	151.71	130.48	106.31	87.50	83.21	71.80	69.46	56.57	49.25	39.36	36.48	30.78	24.04	23.66	19.53
2012	339.60	270.52	234.01	215.02	188.05	166.22	130.13	105.85	94.77	70.05	63.64	48.86	41.40	32.16	27.47	20.88	17.69	12.39	11.03
2013	410.06	337.74	320.49	274.81	242.33	203.74	175.06	139.00	134.19	92.53	85.32	68.44	59.37	40.89	32.25	30.85	21.04	17.60	13.78
2014	489.59	433.56	404.52	385.53	339.81	305.80	261.55	211.82	178.47	146.85	132.90	100.42	82.44	70.67	55.06	47.45	34.39	31.08	23.21
2015	394.01	312.27	291.13	273.63	232.75	204.84	180.93	160.99	137.26	119.08	112.68	90.38	81.74	70.34	60.05	47.79	41.27	36.76	27.07
2016	368.02	312.63	270.76	243.16	231.76	197.60	169.83	143.03	137.01	112.37	93.06	78.40	67.89	54.71	46.38	39.77	37.80	28.41	23.80
2017	220.73	194.12	189.10	186.96	171.15	154.35	142.15	119.80	102.91	81.13	77.93	61.42	49.94	44.30	37.79	30.42	23.89	20.72	17.30

Table 2.5b (page 5 of 6)—Fishery survey size composition as used in Models 17.x, by year and cm.

Year	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112
1977	0.00	0.01	0.00	0.04	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.12	0.07	0.03	0.06	0.04	0.06	0.06	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.12	0.08	0.11	0.11	0.06	0.11	0.03	0.03	0.03	0.04	0.00	0.03	0.01	0.01	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
1980	0.19	0.40	0.24	0.25	0.21	0.07	0.14	0.11	0.07	0.04	0.03	0.03	0.03	0.00	0.03	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00
1981	0.03	0.07	0.03	0.03	0.00	0.04	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.43	0.52	0.25	0.35	0.17	0.28	0.36	0.17	0.17	0.10	0.14	0.01	0.08	0.00	0.08	0.00	0.01	0.04	0.00	0.00	0.00	0.01	0.00	0.00
1983	2.92	2.79	2.19	1.89	1.54	0.86	0.73	0.63	0.51	0.50	0.33	0.33	0.26	0.23	0.07	0.08	0.10	0.06	0.00	0.08	0.00	0.06	0.00	0.00
1984	10.83	9.52	6.96	6.04	4.39	3.56	2.71	1.80	1.69	1.05	0.75	0.65	0.58	0.46	0.30	0.14	0.14	0.08	0.04	0.01	0.04	0.03	0.00	0.04
1985	19.41	17.05	12.82	11.11	9.62	8.23	6.47	4.51	3.66	2.90	2.72	1.57	1.39	0.91	0.87	0.37	0.46	0.32	0.12	0.11	0.07	0.07	0.04	0.03
1986	15.15	13.53	10.48	8.55	7.77	6.20	5.46	3.97	3.35	2.45	2.12	2.07	1.58	1.06	0.78	0.54	0.61	0.35	0.24	0.10	0.13	0.15	0.03	0.01
1987	34.47	32.44	27.48	23.63	21.68	16.57	15.75	10.35	10.14	7.65	6.40	5.52	3.93	3.61	2.78	1.86	1.83	0.89	0.58	0.35	0.32	0.36	0.19	0.12
1988	6.58	7.37	5.60	4.43	4.46	3.38	4.20	2.64	1.95	1.74	1.55	1.42	1.37	1.09	0.68	0.55	0.39	0.32	0.25	0.11	0.11	0.10	0.04	0.07
1989	9.23	8.18	6.69	5.22	5.70	4.43	4.28	2.72	2.91	2.62	2.44	1.84	1.81	1.01	0.97	0.84	0.68	0.48	0.32	0.17	0.29	0.17	0.10	0.10
1990	42.81	33.59	32.46	30.44	28.64	23.52	23.12	18.86	17.03	14.72	12.30	8.36	7.69	6.39	6.43	4.32	3.22	2.29	1.92	1.57	0.98	0.94	0.54	0.23
1991	57.58	51.49	40.10	38.15	32.02	26.76	25.85	23.73	21.28	18.06	16.14	12.14	10.24	8.66	7.90	5.91	4.96	3.30	2.55	2.26	1.08	1.06	0.67	0.47
1992	46.46	42.35	32.71	31.58	28.53	25.34	24.59	19.87	18.23	15.34	15.07	13.29	9.57	8.07	7.76	5.89	4.65	2.67	2.52	1.45	1.31	1.25	0.73	0.42
1993	13.73	13.08	10.13	10.03	9.16	7.42	6.96	5.86	4.86	4.72	4.10	3.02	2.66	2.41	2.04	1.46	1.20	0.79	0.48	0.40	0.50	0.27	0.04	0.15
1994	15.66	15.67	11.21	10.77	10.09	9.13	8.30	7.04	6.45	5.67	4.72	4.73	3.62	3.14	2.48	2.27	1.87	1.57	1.06	0.76	0.72	0.79	0.35	0.33
1995	21.19	20.64	12.17	14.01	14.96	12.04	9.58	9.32	6.58	6.83	5.28	5.34	4.23	3.48	2.76	2.22	1.95	1.34	0.72	0.54	0.46	0.66	0.16	0.25
1996	34.00	32.18	23.99	22.80	20.93	18.37	16.04	14.69	12.18	9.34	9.32	9.22	6.76	5.42	4.95	3.65	3.11	2.45	1.95	1.38	1.01	1.01	0.84	0.65
1997	31.24	27.55	22.16	19.59	16.08	13.89	14.01	11.56	8.77	7.92	6.24	5.38	4.20	3.74	3.22	2.92	2.27	1.57	1.13	1.09	0.77	0.88	0.25	0.35
1998	25.41	25.39	18.74	17.31	16.24	14.60	13.47	11.04	10.16	8.38	7.16	6.10	4.34	3.53	2.92	3.06	2.11	1.36	1.14	0.88	0.75	0.71	0.27	0.21
1999	35.89	35.29	30.09	23.61	20.09	15.85	12.94	12.41	10.16	8.44	8.56	8.03	5.71	4.54	2.78	2.44	2.79	2.71	1.25	0.95	1.27	1.31	0.60	0.51
2000	38.72	38.45	27.26	26.51	22.05	19.54	16.85	15.55	13.30	11.91	9.21	8.46	6.24	5.27	3.89	3.15	3.05	1.66	1.13	1.50	0.79	1.46	0.58	0.39
2001	21.16	21.52	17.11	15.08	13.98	12.80	10.67	8.65	8.91	6.74	5.10	5.44	5.20	2.93	3.18	2.41	2.18	1.43	1.24	1.13	0.77	0.68	0.12	0.17
2002	20.18	19.17	15.53	13.98	12.30	12.68	10.43	7.87	8.37	6.37	4.86	4.18	3.52	2.57	2.15	1.85	2.05	1.83	0.81	0.50	0.26	0.50	0.17	0.24
2003	26.16	23.36	18.63	12.91	13.52	9.94	9.59	8.07	5.90	5.10	4.10	4.01	3.58	2.71	2.14	1.72	1.11	1.00	0.83	0.88	0.11	0.40	0.23	0.20
2004	30.70	26.05	19.95	17.59	15.64	11.47	11.39	9.14	7.99	5.06	5.07	4.81	4.96	2.73	2.32	1.66	1.54	0.86	1.22	0.63	0.59	0.91	0.21	0.14
2005	49.85	50.99	37.37	33.51	26.56	23.93	21.16	16.35	13.31	10.40	7.92	6.80	4.76	4.99	3.61	3.22	1.29	1.46	0.57	0.73	0.47	0.14	0.15	0.15
2006	74.33	69.63	52.46	46.86	42.67	34.83	30.95	23.87	24.29	21.11	15.77	14.91	9.09	8.38	6.96	5.18	4.11	3.91	3.10	1.13	0.80	1.06	0.57	0.36
2007	65.65	66.97	52.89	45.82	44.01	37.68	33.38	29.68	23.48	21.83	16.59	15.65	13.48	7.19	7.33	5.78	3.83	3.11	2.05	1.49	0.88	1.24	0.45	0.38
2008	45.87	47.79	43.00	39.17	32.36	30.39	29.18	24.27	20.88	18.87	13.68	14.67	10.18	8.79	6.49	5.73	4.00	1.71	1.74	1.56	1.11	0.64	0.36	0.39
2009	19.02	21.43	17.66	16.28	13.10	13.47	11.83	10.95	9.19	7.51	5.48	5.17	5.72	3.67	3.12	2.56	1.86	2.35	0.44	0.52	0.53	0.39	0.55	0.34
2010	10.69	14.67	7.35	6.74	5.34	4.96	3.87	2.88	2.43	2.72	1.53	1.93	2.09	1.39	0.70	1.08	0.81	0.50	0.38	0.19	0.39	0.27	0.10	0.01
2011	14.95	15.11	10.91	10.27	6.65	6.85	6.13	4.02	4.68	4.41	2.63	3.19	1.43	1.72	0.99	0.62	1.00	0.74	0.41	0.56	0.06	0.09	0.23	0.26
2012	12.87	9.69	7.30	5.73	3.75	4.65	3.18	2.51	4.12	1.90	1.82	1.93	1.12	1.21	0.59	0.43	1.30	0.18	0.21	0.07	0.11	0.26	0.03	0.03
2013	10.46	9.89	6.67	5.95	5.94	6.11	3.25	2.41	1.73	1.84	1.35	1.67	0.78	1.11	0.68	0.27	0.41	0.29	0.11	0.42	0.12	0.00	0.00	0.02
2014	18.65	17.69	13.32	11.62	9.93	6.40	5.85	4.50	3.98	3.29	2.92	1.61	1.88	1.15	0.85	0.79	0.33	0.21	0.22	0.12	0.26	0.05	0.03	0.00
2015	24.33	20.68	12.27	9.08	8.90	7.95	5.70	3.76	3.46	3.60	2.58	2.55	1.13	0.91	1.08	0.55	0.04	0.17	0.29	0.26	0.00	0.01	0.01	0.00
2016	19.43	17.52	12.13	11.66	9.13	8.49	6.97	4.10	4.74	2.32	1.76	2.07	1.56	1.01	0.48	1.12	0.32	0.20	0.13	0.57	0.27	0.04	0.00	0.00
2017	15.62	14.38	10.12	6.91	6.61	4.87	3.82	4.32	2.77	2.40	2.31	1.66	0.79	2.00	1.09	0.26	0.37	0.29	0.52	0.19	0.00	0.00	0.00	0.21

Table 2.5b (page 6 of 6)—Fishery survey size composition as used in Models 17.x, by year and cm.

Year	113	114	115	116	117	118	119	120+
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
1985	0.06	0.06	0.06	0.00	0.00	0.03	0.00	0.00
1986	0.00	0.03	0.01	0.01	0.00	0.03	0.03	0.07
1987	0.07	0.10	0.08	0.01	0.04	0.04	0.00	0.00
1988	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
1989	0.07	0.01	0.01	0.00	0.04	0.00	0.03	0.26
1990	0.32	0.25	0.17	0.11	0.07	0.00	0.03	0.00
1991	0.25	0.23	0.13	0.01	0.00	0.00	0.01	0.07
1992	0.37	0.24	0.18	0.04	0.04	0.00	0.01	0.03
1993	0.00	0.09	0.07	0.09	0.11	0.03	0.00	0.05
1994	0.27	0.20	0.16	0.08	0.00	0.15	0.00	0.08
1995	0.14	0.15	0.15	0.14	0.00	0.04	0.02	0.15
1996	0.31	0.33	0.19	0.11	0.05	0.12	0.08	0.42
1997	0.12	0.08	0.09	0.05	0.06	0.02	0.01	0.15
1998	0.42	0.19	0.03	0.07	0.08	0.06	0.05	0.07
1999	0.14	0.10	0.12	0.32	0.08	0.00	0.09	0.30
2000	0.33	0.50	0.29	0.01	0.09	0.00	0.17	0.54
2001	0.27	0.15	0.03	0.06	0.01	0.00	0.08	0.00
2002	0.34	0.00	0.14	0.02	0.09	0.00	0.00	0.07
2003	0.00	0.04	0.07	0.03	0.08	0.00	0.10	0.08
2004	0.11	0.03	0.06	0.00	0.01	0.11	0.00	0.25
2005	0.06	0.02	0.09	0.00	0.01	0.06	0.00	0.01
2006	0.44	0.02	0.22	0.13	0.15	0.07	0.00	0.09
2007	0.24	0.25	0.27	0.10	0.17	0.00	0.01	0.14
2008	0.18	0.00	0.02	0.00	0.00	0.01	0.00	0.08
2009	0.00	0.21	0.00	0.00	0.03	0.00	0.00	0.00
2010	0.01	0.01	0.05	0.00	0.00	0.00	0.09	0.06
2011	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.16
2012	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2013	0.01	0.07	0.08	0.00	0.02	0.00	0.00	0.02
2014	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.16
2015	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.57
2016	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2.6—Total abundance estimates, with standard errors, log-scale standard errors ("Sigma"), and bounds of 95% confidence intervals, as estimated by EBS shelf bottom trawl surveys, 1982-2017.

	Abundance (1000s of fish)				
Year	Estimate	Std. error	Sigma	L95% CI	U95% CI
1982	583,781	38,064	0.065	508,414	659,149
1983	752,456	80,566	0.107	589,632	915,281
1984	651,058	47,126	0.072	557,748	744,369
1985	841,108	113,438	0.134	616,501	1,065,715
1986	838,217	83,855	0.100	672,184	1,004,251
1987	677,054	44,120	0.065	589,697	764,411
1988	507,560	35,581	0.070	437,109	578,011
1989	292,247	19,986	0.068	252,675	331,818
1990	423,835	36,466	0.086	351,632	496,038
1991	488,892	51,108	0.104	387,697	590,087
1992	577,560	68,603	0.118	441,726	713,395
1993	810,608	99,259	0.122	614,075	1,007,141
1994	1,232,175	152,212	0.123	927,751	1,536,598
1995	757,910	75,473	0.099	608,473	907,346
1996	607,198	88,384	0.145	432,198	782,198
1997	485,643	70,802	0.145	344,039	627,247
1998	514,339	46,852	0.091	421,572	607,106
1999	488,337	45,289	0.093	398,665	578,008
2000	483,808	44,188	0.091	396,315	571,301
2001	960,917	91,898	0.095	777,122	1,144,712
2002	536,342	53,802	0.100	428,738	643,946
2003	498,873	62,220	0.124	374,432	623,313
2004	397,948	34,332	0.086	329,970	465,926
2005	450,705	63,363	0.140	325,247	576,164
2006	394,024	23,785	0.060	346,928	441,119
2007	733,402	195,956	0.263	341,489	1,125,315
2008	476,697	49,413	0.103	378,859	574,535
2009	716,637	62,705	0.087	592,481	840,793
2010	887,836	117,022	0.131	656,132	1,119,540
2011	836,822	79,207	0.094	679,992	993,653
2012	987,973	91,589	0.093	804,796	1,171,150
2013	750,889	124,917	0.165	501,055	1,000,723
2014	1,122,144	143,618	0.127	831,892	1,412,397
2015	982,470	113,501	0.115	755,469	1,209,471
2016	640,359	61,639	0.096	413,358	867,361
2017	346,693	31,334	0.090	223,415	469,971

Table 2.7a (page 1 of 4)—Trawl survey size composition as used in Model 16.6, by year and cm (number of fish measured in column 2).

Year	N	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1977	30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	160	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.03	0.08	0.12	0.54
1979	235	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
1980	208	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03
1981	148	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.03	0.03	0.03	0.04	0.03	0.12	0.10
1982	187	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.04	0.01
1983	782	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.11	0.17	0.19	0.06	0.25	0.39
1984	1913	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.00	0.04	0.08	0.11	0.18	0.65	1.06	1.19	1.31	1.55	1.15	1.51	2.47	3.40	5.18
1985	2825	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.01	0.00	0.01	0.03
1986	2496	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.07	0.07	0.17	0.29	0.06	0.08	0.17	0.36	0.34	0.49	0.63	0.82	0.66	1.24	1.80	2.05
1987	4726	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.03	0.11	0.25	0.29	0.21	0.21	0.46	0.19	0.32	0.50	1.07	1.17	1.82	3.08
1988	1458	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.01	0.04	0.01	0.06	0.18	0.15	0.10	0.19	0.37	0.81
1989	966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.06	0.08	0.04	0.04	0.03	0.01	0.01	0.03	0.12	0.30
1990	3601	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.06	0.03	0.01	0.08	0.03	0.21	0.68	0.50	0.91	1.82	2.29	4.73
1991	5188	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.04	0.05	0.01	0.04	0.00	0.15	0.07	0.21	0.38	0.37	0.82	1.46	2.26	3.59
1992	5322	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.10	0.10	0.02	0.20	0.00	0.11	0.07	0.14	0.06	0.21	0.15	0.52	0.84	1.22	2.15
1993	2993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.07	0.02	0.08	0.03	0.13	0.09	0.06	0.11	0.16	0.26	0.53	0.92	1.94
1994	4687	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.01	0.00	0.00	0.04	0.10	0.15	0.36	0.21	0.45	0.88	1.74	3.05	4.95	9.30
1995	5215	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.37	0.43	0.48	0.59	0.69	0.63	0.70	1.13	1.24	2.09	1.83	2.61	2.53
1996	6618	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.08	0.07	0.07	0.13	0.30	0.11	0.40	0.41	0.20	0.54	0.31	0.17	0.26	0.38	1.17	1.97	4.60	6.75
1997	7278	0.00	0.03	0.02	0.00	0.16	0.00	0.03	0.00	0.03	0.07	0.00	0.01	0.13	0.32	0.64	1.16	1.05	1.22	0.97	1.06	0.44	0.84	1.17	1.64	2.99	5.45
1998	6838	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.11	0.07	0.16	0.11	0.00	0.02	0.16	0.21	0.26	0.26	1.45	2.98	5.51	7.70	11.75
1999	9231	0.00	0.00	0.09	0.05	0.13	0.05	0.09	0.07	0.00	0.00	0.00	0.00	0.06	0.00	0.17	0.14	0.09	0.21	0.00	0.15	0.09	0.20	0.34	1.57	2.95	3.88
2000	9731	0.00	0.08	0.12	0.04	0.06	0.04	0.00	0.01	0.00	0.17	0.00	0.00	0.00	0.00	0.06	0.00	0.12	0.02	0.09	0.00	0.10	0.16	0.13	0.36	1.19	2.17
2001	10364	0.00	0.13	0.32	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.10	0.05	0.09	0.20	0.17	0.19	0.07	0.12	0.11	0.32	0.35	0.06	0.12
2002	11472	0.00	0.16	0.24	0.07	0.00	0.15	0.00	0.00	0.00	0.00	0.01	0.08	0.00	0.09	0.21	0.12	0.49	0.53	0.44	0.42	0.79	0.76	0.97	1.35	2.42	2.94
2003	14341	0.00	0.06	0.14	0.49	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.23	0.13	0.00	0.01	0.16	0.26	0.04	0.08	0.00	0.09	0.01	0.19	0.07	0.25	0.61
2004	12242	0.00	0.00	0.17	0.06	0.09	0.04	0.00	0.00	0.00	0.17	0.09	0.01	0.00	0.01	0.00	0.01	0.07	0.00	0.02	0.25	0.03	0.01	0.13	0.26	0.45	0.35
2005	11568	0.00	0.15	0.04	0.29	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.16	0.06	0.00	0.03	0.03	0.10	0.41	0.06	0.32	0.35	0.25	1.02
2006	8849	0.00	0.00	0.08	0.17	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.11	0.00	0.12	0.20	0.15	0.18	0.07	0.01	0.01	0.10	0.26	0.08
2007	6901	0.00	0.00	0.12	0.08	0.01	0.01	0.00	0.00	0.00	0.00	0.10	0.21	0.01	0.00	0.29	0.24	0.17	0.40	0.24	0.41	0.58	0.74	0.98	0.90	1.60	1.50
2008	8320	0.00	0.07	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.14	0.17	0.00	0.26	0.24	0.08	0.14	0.37	0.97	1.65	2.97	2.40	4.71	3.64
2009	7482	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.01	0.06	0.03	0.03	0.10	0.07	0.31	0.42
2010	6514	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.09	0.09	0.15	0.24	0.18	0.42	1.09	1.12
2011	8804	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.03	0.26	0.33	0.16	0.63
2012	9287	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.28	0.32	0.01	0.05	0.44	1.23	2.05	2.53
2013	11126	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.14	0.23	0.12	0.32	0.59	1.14	1.21
2014	12165	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.18	0.05	0.38	0.09	0.02	0.00	0.09	0.00	0.00	0.01	0.49	0.64	2.30	1.95
2015	11309	0.00	0.00	0.00	0.18	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.11	0.00	0.00	0.11	0.42	0.36	1.26
2016	9773	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.02	0.51
2017	5334	0.00	0.00	0.00	0.09	0.00	0.00	0.03	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.09	0.01	0.11	0.45	0.00	0.00	0.00	0.00

Table 2.7a (page 2 of 4)—Trawl survey size composition as used in Model 16.6, by year and cm.

Year	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
1982	240	305	317	237	197	144	146	126	137	180	203	282	302	272	328	329	280	284	270	254	239	278	258	267	225	260	264	261	225	227
1983	165	213	145	127	107	61	62	86	94	143	157	212	269	301	288	298	316	254	248	246	225	298	277	258	262	245	262	245	201	224
1984	345	295	220	155	107	102	88	59	94	75	91	94	96	108	134	106	109	95	109	142	129	156	167	197	198	154	215	169	200	202
1985	300	309	312	288	343	351	389	413	514	500	514	482	470	359	323	244	192	168	128	96	93	103	101	104	85	87	90	85	148	110
1986	557	448	402	349	332	220	194	138	126	136	163	185	216	205	246	218	248	269	258	275	288	299	226	252	251	175	171	120	146	111
1987	280	207	235	201	172	186	221	210	293	327	330	330	322	323	252	251	266	157	159	133	120	146	140	98	123	92	139	136	123	131
1988	190	269	216	195	211	141	184	165	239	222	197	319	277	294	277	247	308	266	229	250	250	260	220	214	227	194	199	166	207	165
1989	70	33	107	109	134	115	125	101	115	115	139	176	165	176	183	176	200	253	236	260	247	234	326	293	219	222	197	290	186	228
1990	124	80	113	96	67	57	67	51	47	38	38	31	35	48	39	41	25	51	31	62	53	66	58	74	72	75	85	89	89	78
1991	308	251	261	195	173	143	118	84	68	64	61	51	61	53	61	74	49	61	42	71	89	58	75	40	34	42	41	34	52	44
1992	304	241	215	176	149	125	180	146	216	188	220	242	186	186	160	143	154	119	107	89	78	57	63	29	42	51	50	66	45	35
1993	315	239	246	227	196	153	161	182	183	221	221	234	270	207	185	193	159	151	129	113	118	108	88	64	66	79	66	57	58	52
1994	673	643	472	362	288	196	115	133	114	221	188	164	233	256	264	299	172	189	230	188	181	175	219	251	252	162	219	153	204	163
1995	198	155	217	249	239	314	378	371	417	421	394	342	335	293	199	189	153	142	115	98	108	95	88	93	86	72	93	99	104	100
1996	251	191	200	168	157	168	154	176	214	238	288	261	292	320	301	297	323	272	282	282	244	254	206	167	152	132	141	99	94	86
1997	222	174	159	155	138	145	136	125	127	135	135	171	194	228	152	172	134	150	180	187	160	167	124	213	164	173	123	130	107	111
1998	537	346	260	228	166	147	134	101	119	117	134	127	169	119	115	133	112	94	89	82	82	72	61	79	89	75	66	77	87	85
1999	227	197	191	240	290	308	382	486	509	584	558	505	395	408	311	233	199	165	142	144	117	117	93	104	92	85	71	117	86	94
2000	197	184	188	174	199	223	256	267	303	306	347	308	355	321	391	342	351	262	315	239	256	194	202	183	159	159	149	112	101	90
2001	921	806	700	512	409	301	218	189	176	152	157	186	229	280	230	266	250	230	262	273	257	235	219	225	189	208	184	149	197	131
2002	520	381	400	312	295	250	289	259	407	359	453	393	389	278	330	188	227	183	166	137	162	129	155	89	109	121	125	101	111	107
2003	316	216	319	240	275	291	318	361	342	389	456	425	461	415	390	277	276	234	246	260	198	185	166	148	124	144	138	116	96	70
2004	317	310	335	313	325	254	242	211	208	188	181	155	148	151	174	170	205	198	162	182	171	186	167	189	143	156	167	148	143	139
2005	197	197	207	231	288	252	204	194	203	207	216	167	205	168	193	131	171	126	144	129	135	111	111	101	98	100	117	84	118	82
2006	264	245	303	263	298	252	244	209	200	161	171	145	151	127	157	147	191	169	175	145	174	137	182	105	128	90	97	105	95	106
2007	124	114	93	93	76	60	73	77	74	68	82	76	85	79	80	60	75	74	82	68	72	59	54	48	52	47	61	50	60	49
2008	341	282	200	161	151	133	130	117	143	129	138	138	139	113	135	121	124	127	134	114	108	101	112	91	113	103	113	91	81	81
2009	306	221	214	215	225	302	304	362	380	379	347	334	280	289	247	181	147	144	117	103	93	82	75	78	85	88	72	85	77	53
2010	269	183	165	106	95	64	75	78	124	132	232	154	165	160	157	124	135	106	147	114	156	151	140	95	140	112	101	71	90	58
2011	164	232	229	272	287	403	457	673	801	859	925	872	790	634	511	347	349	278	265	185	230	225	265	184	276	241	301	228	294	184
2012	279	309	190	158	98	81	61	46	63	59	85	81	130	111	196	188	239	285	379	323	408	309	316	218	198	168	164	97	120	86
2013	310	240	180	174	145	126	184	153	230	292	361	431	519	407	386	349	325	258	259	195	210	136	192	142	214	193	234	192	212	203
2014	460	498	349	311	184	190	145	203	282	444	458	655	675	608	559	492	425	285	216	203	206	182	165	192	249	247	198	191	203	135
2015	1055	1114	987	939	766	575	498	286	267	200	377	373	500	474	469	426	454	320	352	347	318	337	389	337	433	331	300	219	245	158
2016	180	164	230	251	299	283	333	388	471	577	611	812	892	863	883	761	685	538	409	422	295	293	277	267	248	264	247	226	232	228
2017	126	139	145	178	163	174	187	205	184	216	257	214	279	257	267	298	361	335	376	383	440	457	415	418	350	282	264	257	206	248

Table 2.7a (page 3 of 4)—Trawl survey size composition as used in Model 16.6, by year and cm.

Year	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
1982	202	193	190	198	122	172	124	132	73	73	72	64	45	34	37	30	20	27	24	12	8	7	9	3	6	4	1	2	3	0	2	0	1	2	1
1983	196	200	191	166	188	176	145	181	126	122	78	81	79	68	59	39	48	32	29	24	18	12	1	7	8	3	11	1	1	2	4	0	3	0	1
1984	188	161	197	183	181	171	153	145	83	119	98	104	75	82	56	68	46	40	32	33	27	22	28	12	16	19	12	9	4	7	6	0	4	3	2
1985	110	113	171	123	134	146	147	135	135	120	138	107	135	99	95	59	75	59	50	48	21	37	22	22	16	14	10	8	7	8	4	1	3	7	2
1986	81	99	76	84	70	87	105	99	89	70	90	86	69	81	71	62	84	56	53	43	29	26	35	18	21	18	30	10	16	13	5	4	6	3	7
1987	121	132	124	133	132	110	116	94	60	91	53	56	55	23	43	33	33	44	28	29	29	29	9	7	15	9	10	13	6	10	10	2	4	6	3
1988	116	124	99	138	106	106	81	116	84	84	56	79	71	48	41	55	71	62	53	31	30	11	27	15	6	15	2	15	2	6	6	6	5	1	4
1989	242	184	167	241	213	136	201	105	184	198	167	154	143	107	151	107	63	53	85	61	74	88	43	60	41	14	43	30	19	24	28	32	14	10	21
1990	78	54	80	55	60	34	64	43	53	52	53	49	33	38	38	25	37	39	10	24	19	23	19	10	11	18	11	6	5	5	7	11	10	3	1
1991	43	26	45	41	47	46	48	32	31	25	40	32	27	14	16	19	22	33	24	21	12	13	8	13	7	8	6	3	5	4	1	6	8	3	2
1992	25	31	30	47	35	32	24	14	21	22	21	15	24	15	18	24	28	14	17	14	11	13	14	7	10	7	13	5	7	7	4	7	8	3	9
1993	36	66	37	37	61	28	28	14	15	15	14	16	12	12	11	12	12	11	9	5	12	10	4	7	8	8	4	3	4	7	3	7	5	5	4
1994	180	160	126	84	133	62	102	49	67	30	40	20	30	13	21	9	9	10	12	5	9	8	9	7	4	6	35	13	9	3	1	3	6	4	2
1995	87	70	54	60	72	71	69	50	54	45	36	28	22	37	20	25	21	20	18	12	13	10	7	8	7	7	4	11	3	4	4	10	1	3	2
1996	79	57	60	60	56	56	45	56	62	32	44	36	28	29	35	22	21	24	25	15	25	10	13	22	17	9	3	3	7	10	3	5	5	3	2
1997	115	101	99	92	80	69	56	61	53	29	18	31	20	28	16	11	10	9	12	17	12	10	8	9	9	4	3	8	7	2	6	3	2	4	0
1998	74	65	97	58	63	47	46	52	55	37	52	29	36	21	21	25	13	16	9	15	11	8	10	7	4	3	5	5	10	3	6	3	1	2	2
1999	80	95	63	70	49	62	70	49	45	51	37	28	28	23	26	27	24	19	13	17	15	12	11	17	16	6	16	6	5	5	5	2	5	6	6
2000	85	54	65	58	52	36	50	33	38	31	34	29	22	12	14	22	22	12	18	19	8	9	5	9	26	7	7	7	4	4	10	2	8	5	3
2001	155	151	107	83	106	67	78	57	51	33	38	26	20	27	20	31	17	17	12	11	13	5	10	6	6	5	7	5	4	2	4	6	1	2	0
2002	99	56	106	72	64	66	58	47	35	35	32	24	31	24	13	10	20	14	6	6	2	7	2	4	5	2	2	4	5	5	1	3	2	3	6
2003	95	64	72	69	66	67	76	47	56	40	40	36	35	26	28	16	18	21	22	11	14	7	9	6	7	5	4	4	3	2	1	0	1	1	0
2004	120	103	101	86	105	82	64	73	59	58	34	50	45	43	46	32	27	24	23	16	22	11	26	12	19	15	13	6	4	8	4	3	4	4	2
2005	127	104	112	101	101	77	83	74	70	59	72	51	72	54	65	49	44	40	40	32	25	17	28	20	23	14	10	14	10	8	4	9	5	3	4
2006	90	88	98	61	96	51	71	60	58	64	67	57	59	42	57	44	58	50	51	37	42	39	34	20	35	16	23	15	18	10	10	6	11	9	1
2007	49	45	46	32	43	40	31	24	32	23	38	21	19	14	12	17	17	18	10	10	9	25	11	8	9	15	10	13	8	3	8	4	6	2	3
2008	88	62	71	64	71	44	53	35	39	23	43	19	23	21	23	13	16	12	16	14	12	8	20	11	10	8	12	5	10	10	10	9	3	8	9
2009	65	71	52	38	48	30	40	29	21	24	13	17	14	15	14	4	13	6	8	4	4	7	6	6	3	4	5	1	1	1	2	3	5	2	3
2010	67	40	42	29	22	16	19	17	9	6	7	8	10	3	7	2	2	4	2	2	1	3	4	0	2	1	2	1	1	2	0	0	2	1	0
2011	249	172	205	152	159	115	126	61	78	51	50	27	25	21	15	14	18	7	14	10	7	3	4	4	4	4	1	5	3	4	7	2	1	0	1
2012	104	78	79	63	66	46	72	37	47	24	29	21	20	19	18	6	10	4	7	6	6	4	4	4	1	1	2	2	1	3	3	2	0	0	1
2013	234	213	193	163	141	136	109	104	92	51	63	44	31	44	29	31	8	29	12	24	12	10	7	7	4	3	5	4	4	5	1	2	0	1	0
2014	140	110	106	62	62	52	66	56	53	66	49	43	40	29	28	20	15	16	8	8	8	4	4	6	3	1	6	2	3	2	0	0	3	1	2
2015	168	113	107	111	98	81	65	61	62	57	45	55	43	35	24	24	20	23	14	7	12	7	17	9	6	3	4	1	2	2	0	2	1	1	1
2016	212	225	245	190	172	158	168	135	95	85	69	51	46	47	36	24	24	35	16	19	21	16	10	9	8	8	5	6	5	3	2	3	2	2	2
2017	182	176	155	144	119	152	128	105	89	112	84	95	90	81	66	71	70	21	40	35	22	13	10	16	11	16	4	8	9	1	7	6	1	4	1

Table 2.7a (page 4 of 4)—Trawl survey size composition as used in Model 16.6, by year and cm.

Year	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120+
1982	0	0	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	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	4	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	2	4	3	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	1	1	3	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	8	3	1	3	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
1989	11	10	22	1	22	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	1	5	0	6	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	3	0	1	0	6	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	1	4	3	3	3	3	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0
1993	4	1	2	2	1	8	2	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
1994	1	2	9	6	3	1	7	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
1995	3	5	1	3	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
1996	2	4	1	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
1997	1	2	0	0	1	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1998	1	1	1	8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	3	2	1	0	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	5	1	1	0	2	1	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2002	1	1	0	0	1	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
2003	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	2	0	1	0	5	0	1	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0
2005	0	4	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	7	5	3	2	3	2	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
2007	3	3	2	8	1	2	1	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0
2008	2	4	3	7	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2009	1	2	1	1	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2010	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	2	2	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	2	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	1	3	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2.7b (page 1 of 6)—Trawl survey size composition as used in Models 17.x, by year and cm (number of sampled hauls in column 2).

Year	N	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1982	313	0	0	0	0	0	0.02	0.23	0.27	0.57	0.77	1.55	1.76	3.24	1.97	1.5	1.54	1.36	0.58	0.25	0.26	0.06
1983	255	0	0	0	0	0	0.14	1.86	5.63	8.82	8.88	9.38	8.95	8.41	7.65	4.89	4.84	2.32	1.43	0.86	0.55	0.17
1984	264	0	0	0	0	0	0.14	0.54	0.78	1.19	0.95	0.59	0.55	0.56	0.65	1	0.69	1.39	1.56	1.96	2.71	5.01
1985	345	0	0	0	0	0	0.09	1.14	2.08	3.67	2.96	4.41	5.87	6.22	7.6	10.28	10.36	10.75	13.21	11.43	11.34	6.57
1986	349	0	0	0	0	0.01	0.51	0.86	2.11	3.03	2.95	4.57	3.96	4.01	3.4	2.1	0.78	0.6	0.46	0.5	1.63	2.59
1987	338	0	0	0	0	0	0	0.43	0.12	0.23	0.77	1.21	1.92	2.58	3.45	3.85	3.84	4.89	3.95	2.56	1.95	1.51
1988	334	0	0	0	0	0	0	0.02	0.26	0.25	0.94	0.45	0.9	0.88	0.76	1.4	0.91	0.6	0.88	1.16	1.59	2.28
1989	316	0	0	0	0	0	0.08	0.08	0.6	1.49	1.16	2.2	2.72	3.41	3.32	3.19	2.07	1.24	0.61	0.68	0.95	0.11
1990	328	0	0	0	0	0	1.5	4.16	6.06	8.95	8.74	10.76	13.74	15.08	11.92	8.68	6.81	5.2	3.32	2.01	2.41	2.46
1991	324	0	0	0	0	0	0.29	1.39	4.21	5.04	6.29	6.13	7.33	5.96	6.11	5.74	4.8	6.06	3.85	3.21	3.24	3.52
1992	322	0	0	0	0	0	0	0.02	0.56	2.72	6.15	6.39	5.86	5.04	6.65	7.42	7.82	8.3	7.22	7.6	3.73	3.98
1993	351	0	0	0	0	0.02	0.08	0.98	2.72	6.43	14.28	9.88	13.61	11.94	10.82	10.74	11.57	10.5	10.84	7.27	4.53	3.27
1994	346	0	0	0	0	0	0.08	0.25	0.14	0.66	1.04	1.9	2.27	2.47	2.48	2.87	3.38	2.76	2.56	2.26	3.27	2.99
1995	335	0	0	0	0	0.01	0.12	0.42	0.54	0.48	0.69	1.5	1.35	1.53	2.03	2.15	2.93	2.48	1.25	0.87	0.69	1.34
1996	341	0	0	0	0	0	0.04	0.06	0.41	0.34	0.83	1.21	1.75	2.33	1.93	2.42	2.51	2.32	1.98	1.31	0.73	0.8
1997	351	0	0	0	0	0	0.32	0.67	2.49	4.37	6.4	7.38	7.36	7.51	8.12	10.85	8.65	8.35	8.64	6.79	4	2.2
1998	344	0	0	0	0	0	0.05	0.16	0.84	1.91	3.02	4.2	3.75	4.89	3.27	1.63	0.8	0.22	0.15	0.62	0.88	2.06
1999	320	0	0	0	0	0	0.02	0.41	1.46	2.74	2.99	3.33	2.56	3.1	2.14	1.15	0.81	1.13	1.34	1.06	1.45	2.99
2000	343	0	0	0	0.11	0.28	0.63	1.4	2.7	3.73	8.14	13.06	15.9	12.08	7.6	7.48	3.87	2.38	0.89	0.25	0.33	0.67
2001	348	0	0	0	0	0.08	0.11	0.47	1.11	2.24	3.6	5.49	7.92	11.6	12.51	13.49	11.95	11.67	7.76	6.16	3.86	2.4
2002	344	0	0	0	0	0.02	0.08	0.16	0.59	1.22	1.77	2.24	2.85	4.46	3.14	4.65	3.11	2	1.45	0.98	0.49	1.18
2003	345	0	0	0.03	0	0.02	0.08	0.15	0.32	1.56	2.58	3.84	5.73	6.48	5.74	6.96	7.09	7.86	7.04	6.62	5.56	6.1
2004	345	0	0.05	0	0	0	0.02	0.12	0.62	1.43	2.75	4.86	3.37	6.18	5.96	6.86	6.72	4.3	4.58	3.54	2.07	1.78
2005	344	0	0	0	0	0	0	0.03	0.12	0.68	1.31	2.65	4.2	6.12	7.57	9.27	8.66	9.18	8.82	11.02	11.02	11.8
2006	344	0	0.02	0	0.12	0.21	1.14	2.86	9.53	11.48	12.1	12.84	11.38	9.72	9.35	10.17	7.95	6.9	4.15	2.98	1.85	1.52
2007	348	0	0	0	0	0.2	0.2	3.51	13.06	31.59	38.7	37.96	30.98	19.84	19.42	13.89	8.85	10.87	6.24	3.29	3.31	1.14
2008	330	0	0	0.02	0	0	0.14	1.38	4.3	8.89	9.65	9.91	8.91	7.93	5.77	3.83	1.91	1.02	0.53	1.01	1.78	4.12
2009	347	0.01	0	0.01	0.15	0.75	2.2	8.34	20.21	22.01	22.61	18.27	15.48	13.53	10.1	9.57	6.61	4.56	2.38	0.72	0.58	0.69
2010	328	0	0	0	0	0	0.03	0.21	0.76	1.04	1.26	2.17	2.17	2.44	2.01	1.33	0.65	0.72	0.4	0.58	1.36	2.61
2011	350	0	0	0	0	0	0.13	0.33	1.28	2.4	4.34	5.16	6.5	6.96	10.07	10.57	15.26	14.95	14.36	9.04	4.83	1.85
2012	343	0	0	0.15	0	0.01	1.93	9.94	18	19.2	14.76	11.11	10.94	8.13	10.75	10.38	5.45	3.37	1.25	0.82	0.27	0.74
2013	343	0	0	0	0	0.01	0.17	0.91	2.13	2.69	3.8	4.07	5.19	4.39	3.25	2.32	0.64	0.39	1.16	1.58	4.91	7.31
2014	355	0	0	0	0.03	0	0.01	0.19	1.77	2.31	4.72	6.73	9.22	10.27	13	9.85	12.02	9.69	10.3	6.09	4.32	2.19
2015	341	0	0	0	0	0	0	0.19	0.74	0.74	1.51	1.36	0.92	0.84	1.01	1.01	1.06	1.3	1.5	1.22	1.37	1.33
2016	356	0	0	0	0	0.02	0	0.11	0.35	0.55	1.12	1.26	0.83	0.46	1.08	1.37	2.06	3.15	4.73	5.73	5.41	4.75
2017	353	0	0	0	0	0	0	0.06	0.06	0.41	1.11	1.45	1.45	1.93	1.78	2.2	2.66	3.02	3.89	4.17	4.9	5.44

Table 2.7b (page 2 of 6)—Trawl survey size composition as used in Models 17.x, by year and cm.

Year	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
1982	0.24	0.53	0.74	1.18	1.99	2.57	3.65	5.73	6.55	7.12	9.06	9.4	7.03	5.83	4.28	4.33	3.73	4.07	5.35	6.01
1983	0.1	0.35	0.66	0.89	1.08	1.95	2.43	2.83	3.36	3.21	4.13	2.82	2.46	2.08	1.18	1.2	1.67	1.83	2.76	3.05
1984	6.78	8.24	10.01	12.49	13.04	14.06	12.38	10.37	8.56	7.5	6.42	4.79	3.36	2.32	2.21	1.91	1.27	2.04	1.63	1.99
1985	4.34	2.66	1.86	2.05	2.18	3.25	4.49	4.41	5.56	6.12	6.31	6.37	5.88	7	7.18	7.95	8.45	10.51	10.22	10.5
1986	4.95	8.17	10.19	15.82	14.27	13.99	14.49	14.83	13.16	12.64	10.17	9.12	7.92	7.54	5	4.41	3.13	2.85	3.09	3.7
1987	2.01	2.42	3.73	3.95	6.39	8.74	9.62	10.37	9.29	8.92	6.61	7.49	6.4	5.48	5.94	7.06	6.7	9.35	10.41	10.52
1988	2.58	2.93	2.89	3.66	2.79	4.13	4.08	4.57	5.99	6.36	8.99	7.21	6.53	7.05	4.71	6.14	5.51	7.97	7.41	6.58
1989	0.48	0.49	1.12	0.42	1.06	0.96	0.76	1.04	1.17	2.2	1.04	3.37	3.45	4.25	3.63	3.96	3.2	3.63	3.62	4.4
1990	1.91	2.73	4.45	4.48	5.57	5.98	5.66	5.37	6.87	7.23	4.64	6.58	5.59	3.92	3.33	3.89	2.98	2.72	2.22	2.2
1991	4.49	4.34	7.44	8.63	11.89	12.78	14.59	12.95	16.7	13.8	11.26	11.72	8.77	7.76	6.4	5.3	3.77	3.04	2.85	2.71
1992	4.54	6.11	8.85	9.65	10.11	11.72	12.52	11.66	10.38	10.21	8.07	7.21	5.9	5	4.18	6.04	4.89	7.24	6.31	7.37
1993	2.07	1.84	2.24	2.88	3.18	5.83	6.96	7.78	9.78	10.61	8.07	8.29	7.66	6.6	5.15	5.43	6.15	6.19	7.45	7.45
1994	4.24	3.83	5.1	7.97	10.7	13.73	15.88	18.19	19.06	16.71	15.99	11.72	9.01	7.15	4.87	2.87	3.29	2.83	5.49	4.68
1995	1.7	3.24	3.91	5.75	7.04	8.3	7.92	8.9	8.2	7.21	5.65	7.89	9.05	8.7	11.43	13.75	13.51	15.17	15.33	14.33
1996	0.86	2.11	2.35	4.72	5.95	7.08	8.35	10.05	8.65	9.14	6.97	7.3	6.12	5.73	6.11	5.6	6.42	7.8	8.68	10.51
1997	1.57	1.56	1.3	2.69	4.17	3.94	5.88	8.52	8.84	8.5	6.67	6.07	5.94	5.27	5.54	5.2	4.77	4.86	5.18	5.17
1998	2.6	6.55	9.91	13.67	17.75	21.53	22.55	22.07	18.42	19.31	12.43	9.35	8.2	5.96	5.27	4.82	3.63	4.27	4.2	4.82
1999	3.01	5.37	6.24	6.07	8.49	7.34	8.07	8.42	6.57	6.22	5.39	5.23	6.56	7.94	8.42	10.45	13.29	13.92	15.98	15.25
2000	1.06	2.12	3.25	4.65	5.39	6.02	7.07	8.34	6.06	5.39	5.04	5.15	4.76	5.45	6.09	7.01	7.29	8.27	8.37	9.49
2001	1.98	2.82	3.98	5.53	6.44	8.93	11.57	14.66	14.55	16.23	14.21	12.33	9.02	7.21	5.3	3.84	3.33	3.11	2.67	2.76
2002	1.78	2.98	4.51	6.76	7.52	12.2	13.32	15.59	15.53	14.61	10.71	11.25	8.77	8.29	7.03	8.13	7.27	11.44	10.08	12.72
2003	4.31	3.35	1.85	1.6	1.63	2.2	1.6	3.2	4.03	8.82	6.03	8.91	6.71	7.66	8.12	8.89	10.07	9.56	10.87	12.73
2004	2.31	2.94	3.31	6.01	6.25	6.99	7.59	8.73	9.61	10.12	9.91	10.7	9.99	10.38	8.12	7.73	6.75	6.63	6.01	5.77
2005	11.46	8.8	6.39	4.16	4.12	4.31	3.5	4.83	5.43	6	5.99	6.31	7.03	8.79	7.68	6.21	5.92	6.19	6.3	6.58
2006	1.6	1.56	1.83	2.43	3.26	4.76	5.37	6.99	6.88	7.47	6.95	8.59	7.47	8.46	7.16	6.91	5.91	5.67	4.55	4.85
2007	1.19	1.77	2.34	3.36	3.17	4.19	3.32	3.8	4	3.36	3.09	2.51	2.53	2.07	1.64	1.99	2.1	2.02	1.86	2.23
2008	7.8	12.18	13.98	17.97	18.93	18.28	17.33	14.21	11.73	8.67	7.16	5.09	4.09	3.84	3.38	3.31	2.97	3.63	3.27	3.5
2009	1.71	1.95	3.6	5.27	7	8.25	9.73	9.08	7.06	6.36	4.59	4.45	4.47	4.69	6.28	6.32	7.53	7.91	7.89	7.22
2010	5.48	8.37	10.46	15.38	18.66	18.07	17.06	17.08	14	11.64	7.94	7.15	4.59	4.13	2.79	3.26	3.39	5.37	5.72	10.04
2011	0.58	0.62	0.92	0.82	0.95	1.22	2.05	2.3	3.17	2.77	3.92	3.86	4.59	4.85	6.8	7.72	11.35	13.51	14.5	15.61
2012	0.98	1.54	2.21	4.67	6.79	7.06	9.38	9.24	10.23	7.33	8.11	4.98	4.14	2.56	2.12	1.6	1.2	1.66	1.55	2.24
2013	11.99	14.41	18.02	19.77	15.41	16.66	11.95	12.08	7.62	5.69	4.41	3.31	3.19	2.67	2.3	3.37	2.8	4.22	5.35	6.63
2014	2.03	1.8	1.42	1.9	4.38	4.88	8.29	6.54	9.57	9.1	9.85	6.9	6.15	3.64	3.77	2.88	4.01	5.58	8.78	9.06
2015	1.38	1.43	2.15	3.12	4.88	6.8	9.25	12.74	15.98	18.62	19.67	17.42	16.57	13.53	10.16	8.79	5.05	4.72	3.53	6.65
2016	3.2	2.27	1.2	0.73	0.83	1.41	1.81	2.18	2.72	3.73	3.39	4.77	5.21	6.2	5.86	6.9	8.03	9.76	11.96	12.66
2017	5.62	5.03	4.21	3	2.88	2.8	3.52	2.72	3.4	3.52	3.88	4.04	4.98	4.55	4.85	5.22	5.71	5.13	6.02	7.19

Table 2.7b (page 3 of 6)—Trawl survey size composition as used in Models 17.x, by year and cm.

Year	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
1982	8.36	8.97	8.07	9.74	9.75	8.32	8.44	8.01	7.54	7.09	8.25	7.66	7.93	6.67	7.72	7.84	7.75	6.67	6.74	6	5.74	5.63
1983	4.11	5.22	5.84	5.58	5.78	6.13	4.92	4.81	4.78	4.36	5.79	5.36	5	5.09	4.76	5.08	4.76	3.89	4.34	3.8	3.88	3.7
1984	2.04	2.1	2.35	2.91	2.3	2.38	2.06	2.37	3.08	2.8	3.4	3.62	4.28	4.31	3.35	4.68	3.67	4.34	4.4	4.1	3.51	4.29
1985	9.86	9.61	7.34	6.6	4.98	3.93	3.43	2.63	1.97	1.91	2.1	2.07	2.12	1.74	1.78	1.85	1.73	3.03	2.24	2.24	2.3	3.49
1986	4.2	4.9	4.65	5.57	4.94	5.63	6.1	5.86	6.25	6.54	6.8	5.13	5.71	5.69	3.98	3.87	2.71	3.31	2.52	1.83	2.24	1.72
1987	10.52	10.27	10.29	8.04	7.99	8.47	5	5.06	4.24	3.82	4.66	4.46	3.14	3.93	2.92	4.42	4.33	3.93	4.18	3.86	4.22	3.96
1988	10.65	9.26	9.83	9.26	8.24	10.3	8.89	7.67	8.37	8.36	8.69	7.35	7.14	7.57	6.47	6.64	5.54	6.91	5.5	3.89	4.13	3.32
1989	5.56	5.23	5.56	5.78	5.55	6.31	8.01	7.45	8.23	7.81	7.4	10.29	9.25	6.92	7.03	6.22	9.15	5.86	7.2	7.66	5.81	5.29
1990	1.81	2.03	2.82	2.25	2.36	1.47	2.99	1.8	3.63	3.12	3.87	3.4	4.31	4.22	4.39	4.95	5.19	5.18	4.52	4.56	3.12	4.66
1991	2.3	2.74	2.36	2.73	3.32	2.19	2.76	1.87	3.2	4.01	2.58	3.35	1.8	1.51	1.88	1.84	1.53	2.32	1.97	1.92	1.18	2.01
1992	8.11	6.25	6.23	5.38	4.78	5.17	4.01	3.59	2.98	2.63	1.91	2.12	0.96	1.42	1.71	1.69	2.23	1.51	1.18	0.85	1.05	1.01
1993	7.9	9.12	6.98	6.24	6.51	5.36	5.09	4.37	3.82	3.98	3.64	2.98	2.16	2.22	2.65	2.22	1.91	1.95	1.77	1.21	2.23	1.24
1994	4.08	5.78	6.36	6.56	7.44	4.29	4.7	5.72	4.68	4.51	4.35	5.45	6.23	6.27	4.02	5.44	3.8	5.06	4.06	4.46	3.97	3.14
1995	12.46	12.18	10.67	7.22	6.88	5.57	5.15	4.16	3.57	3.94	3.47	3.18	3.37	3.14	2.63	3.36	3.62	3.79	3.64	3.17	2.55	1.95
1996	9.52	10.67	11.69	10.99	10.83	11.77	9.94	10.29	10.28	8.91	9.26	7.52	6.08	5.55	4.82	5.14	3.6	3.44	3.12	2.86	2.09	2.19
1997	6.53	7.43	8.74	5.81	6.57	5.14	5.73	6.88	7.15	6.12	6.38	4.74	8.17	6.29	6.61	4.69	4.96	4.09	4.24	4.39	3.85	3.79
1998	4.57	6.08	4.28	4.12	4.78	4.03	3.37	3.18	2.95	2.95	2.59	2.19	2.82	3.21	2.71	2.36	2.78	3.12	3.05	2.65	2.32	3.49
1999	13.82	10.8	11.16	8.52	6.38	5.43	4.51	3.87	3.94	3.19	3.19	2.54	2.85	2.51	2.34	1.95	3.2	2.35	2.56	2.19	2.61	1.71
2000	8.42	9.71	8.78	10.7	9.35	9.6	7.15	8.61	6.54	6.99	5.29	5.51	5.01	4.35	4.35	4.06	3.06	2.77	2.46	2.33	1.48	1.78
2001	3.28	4.03	4.94	4.05	4.68	4.41	4.05	4.63	4.82	4.52	4.14	3.85	3.96	3.33	3.67	3.25	2.63	3.48	2.32	2.73	2.65	1.88
2002	11.05	10.93	7.82	9.29	5.28	6.38	5.14	4.68	3.85	4.56	3.62	4.37	2.51	3.07	3.4	3.5	2.84	3.13	3.01	2.79	1.59	2.97
2003	11.87	12.87	11.58	10.89	7.74	7.7	6.54	6.87	7.25	5.53	5.16	4.65	4.14	3.47	4.02	3.84	3.24	2.68	1.97	2.64	1.78	2.01
2004	4.94	4.71	4.83	5.55	5.44	6.54	6.33	5.17	5.8	5.45	5.94	5.34	6.04	4.56	4.99	5.33	4.74	4.56	4.44	3.84	3.29	3.21
2005	5.09	6.25	5.13	5.88	4	5.2	3.85	4.4	3.93	4.1	3.38	3.38	3.07	3	3.04	3.57	2.55	3.6	2.51	3.86	3.17	3.41
2006	4.11	4.29	3.6	4.45	4.16	5.41	4.79	4.96	4.12	4.94	3.88	5.16	2.99	3.63	2.56	2.75	2.96	2.7	3.02	2.55	2.5	2.79
2007	2.06	2.31	2.15	2.17	1.64	2.04	2.01	2.21	1.84	1.95	1.61	1.47	1.31	1.41	1.27	1.65	1.35	1.64	1.33	1.34	1.23	1.25
2008	3.51	3.53	2.86	3.43	3.07	3.16	3.23	3.42	2.89	2.74	2.56	2.84	2.3	2.88	2.62	2.87	2.32	2.06	2.05	2.24	1.57	1.8
2009	6.96	5.83	6.02	5.15	3.76	3.05	3	2.43	2.13	1.94	1.71	1.56	1.63	1.77	1.83	1.49	1.76	1.6	1.1	1.34	1.47	1.09
2010	6.68	7.17	6.91	6.8	5.37	5.83	4.61	6.37	4.96	6.74	6.54	6.05	4.12	6.06	4.86	4.37	3.09	3.91	2.53	2.91	1.75	1.81
2011	14.72	13.33	10.7	8.62	5.86	5.89	4.69	4.47	3.12	3.88	3.8	4.48	3.11	4.66	4.07	5.08	3.84	4.96	3.1	4.2	2.9	3.46
2012	2.12	3.42	2.91	5.14	4.92	6.28	7.48	9.94	8.46	10.7	8.11	8.29	5.72	5.18	4.41	4.3	2.54	3.15	2.26	2.72	2.03	2.07
2013	7.91	9.53	7.46	7.08	6.4	5.97	4.73	4.75	3.57	3.85	2.49	3.53	2.6	3.93	3.54	4.29	3.53	3.89	3.72	4.29	3.91	3.55
2014	12.97	13.36	12.03	11.06	9.73	8.41	5.64	4.27	4.01	4.08	3.61	3.27	3.79	4.92	4.89	3.93	3.78	4.01	2.67	2.76	2.18	2.1
2015	6.59	8.83	8.36	8.28	7.52	8.01	5.66	6.22	6.13	5.61	5.94	6.86	5.95	7.65	5.84	5.29	3.86	4.32	2.8	2.96	2	1.89
2016	16.83	18.5	17.89	18.3	15.78	14.2	11.15	8.48	8.75	6.12	6.08	5.75	5.54	5.14	5.47	5.12	4.68	4.81	4.73	4.39	4.67	5.08
2017	5.96	7.79	7.18	7.44	8.31	10.07	9.36	10.5	10.68	12.28	12.75	11.59	11.7	9.77	7.87	7.36	7.16	5.75	6.91	5.07	4.91	4.31

Table 2.7b (page 4 of 6)—Trawl survey size composition as used in Models 17.x, by year and cm.

Year	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
1982	5.87	3.62	5.11	3.69	3.91	2.17	2.16	2.14	1.91	1.32	1.02	1.09	0.88	0.59	0.79	0.71	0.37	0.22	0.19	0.27	0.08	0.18	0.12	0.02
1983	3.22	3.65	3.42	2.81	3.5	2.44	2.36	1.51	1.56	1.53	1.31	1.14	0.76	0.94	0.62	0.56	0.46	0.34	0.23	0.02	0.13	0.16	0.06	0.22
1984	3.97	3.93	3.71	3.32	3.14	1.81	2.6	2.12	2.27	1.63	1.79	1.22	1.48	1	0.87	0.69	0.71	0.59	0.47	0.61	0.26	0.35	0.41	0.27
1985	2.51	2.75	2.99	3	2.76	2.75	2.44	2.81	2.19	2.76	2.03	1.95	1.2	1.54	1.21	1.02	0.98	0.43	0.76	0.45	0.45	0.33	0.28	0.21
1986	1.92	1.6	1.97	2.38	2.24	2.03	1.6	2.04	1.95	1.57	1.84	1.61	1.41	1.9	1.26	1.21	0.97	0.65	0.6	0.79	0.42	0.48	0.41	0.68
1987	4.25	4.2	3.52	3.7	3	1.9	2.89	1.68	1.79	1.76	0.75	1.38	1.06	1.05	1.41	0.9	0.94	0.93	0.94	0.27	0.23	0.48	0.3	0.32
1988	4.62	3.54	3.53	2.72	3.89	2.82	2.81	1.87	2.64	2.37	1.61	1.38	1.85	2.37	2.09	1.78	1.02	0.99	0.37	0.9	0.5	0.2	0.51	0.08
1989	7.6	6.72	4.3	6.34	3.31	5.81	6.26	5.27	4.86	4.52	3.38	4.77	3.4	2	1.67	2.69	1.93	2.35	2.79	1.35	1.89	1.31	0.45	1.35
1990	3.19	3.52	1.98	3.71	2.52	3.12	3.04	3.1	2.84	1.92	2.19	2.21	1.44	2.16	2.27	0.59	1.37	1.08	1.36	1.13	0.57	0.63	1.08	0.67
1991	1.84	2.13	2.05	2.15	1.46	1.38	1.14	1.8	1.45	1.23	0.63	0.72	0.84	0.96	1.49	1.07	0.96	0.54	0.57	0.38	0.56	0.33	0.35	0.27
1992	1.58	1.17	1.07	0.8	0.47	0.72	0.75	0.69	0.51	0.81	0.5	0.6	0.82	0.95	0.48	0.56	0.49	0.38	0.42	0.47	0.22	0.32	0.25	0.42
1993	1.23	2.06	0.95	0.94	0.48	0.5	0.52	0.48	0.55	0.41	0.39	0.36	0.4	0.42	0.37	0.31	0.16	0.39	0.35	0.15	0.24	0.26	0.25	0.14
1994	2.08	3.3	1.54	2.53	1.21	1.66	0.74	1.01	0.49	0.73	0.33	0.53	0.22	0.22	0.26	0.31	0.13	0.22	0.2	0.23	0.16	0.1	0.15	0.86
1995	2.18	2.6	2.57	2.5	1.83	1.97	1.63	1.3	1.03	0.81	1.34	0.73	0.89	0.78	0.72	0.65	0.43	0.47	0.37	0.27	0.28	0.27	0.27	0.16
1996	2.18	2.05	2.04	1.65	2.06	2.26	1.16	1.61	1.31	1.01	1.06	1.26	0.8	0.78	0.88	0.9	0.54	0.9	0.36	0.49	0.81	0.63	0.33	0.12
1997	3.51	3.04	2.63	2.13	2.35	2.04	1.11	0.69	1.17	0.78	1.06	0.61	0.42	0.38	0.33	0.47	0.65	0.47	0.37	0.31	0.35	0.36	0.16	0.11
1998	2.08	2.27	1.7	1.64	1.87	1.97	1.35	1.86	1.04	1.3	0.76	0.74	0.89	0.45	0.58	0.33	0.54	0.38	0.3	0.35	0.26	0.14	0.11	0.18
1999	1.91	1.33	1.69	1.91	1.35	1.24	1.39	1.01	0.76	0.77	0.63	0.7	0.74	0.67	0.53	0.35	0.47	0.41	0.33	0.31	0.46	0.43	0.17	0.44
2000	1.59	1.43	0.97	1.35	0.91	1.04	0.84	0.93	0.79	0.6	0.33	0.37	0.59	0.61	0.33	0.49	0.52	0.23	0.26	0.14	0.24	0.72	0.18	0.2
2001	1.46	1.86	1.19	1.37	1.01	0.9	0.58	0.67	0.45	0.34	0.47	0.35	0.55	0.31	0.3	0.22	0.2	0.22	0.1	0.18	0.11	0.11	0.1	0.12
2002	2.03	1.8	1.85	1.62	1.33	0.99	1	0.89	0.69	0.87	0.67	0.37	0.29	0.56	0.4	0.17	0.18	0.07	0.2	0.05	0.1	0.14	0.04	0.06
2003	1.93	1.84	1.88	2.13	1.32	1.57	1.11	1.12	1	0.97	0.74	0.78	0.45	0.5	0.58	0.6	0.32	0.39	0.21	0.26	0.16	0.19	0.15	0.11
2004	2.76	3.35	2.6	2.04	2.32	1.87	1.84	1.08	1.6	1.44	1.36	1.46	1.01	0.88	0.76	0.75	0.5	0.71	0.35	0.82	0.39	0.62	0.48	0.41
2005	3.07	3.06	2.35	2.54	2.26	2.13	1.78	2.2	1.57	2.19	1.64	1.97	1.49	1.35	1.23	1.23	0.98	0.75	0.53	0.85	0.62	0.71	0.43	0.31
2006	1.72	2.72	1.45	2.02	1.7	1.65	1.8	1.9	1.6	1.67	1.2	1.61	1.25	1.63	1.42	1.46	1.04	1.19	1.11	0.96	0.56	1	0.44	0.65
2007	0.88	1.17	1.08	0.85	0.64	0.87	0.63	1.03	0.58	0.51	0.37	0.33	0.47	0.45	0.49	0.27	0.28	0.24	0.68	0.29	0.22	0.24	0.4	0.28
2008	1.62	1.81	1.13	1.34	0.88	0.99	0.58	1.1	0.47	0.59	0.55	0.57	0.32	0.4	0.3	0.41	0.35	0.31	0.21	0.5	0.29	0.26	0.21	0.3
2009	0.79	0.99	0.63	0.83	0.6	0.44	0.5	0.26	0.35	0.28	0.31	0.29	0.09	0.28	0.13	0.16	0.09	0.08	0.15	0.12	0.12	0.07	0.08	0.1
2010	1.26	0.94	0.71	0.83	0.72	0.4	0.27	0.29	0.36	0.43	0.11	0.32	0.1	0.07	0.18	0.1	0.1	0.03	0.13	0.19	0.01	0.1	0.02	0.09
2011	2.57	2.69	1.94	2.13	1.03	1.31	0.86	0.85	0.45	0.42	0.35	0.26	0.24	0.3	0.11	0.24	0.17	0.12	0.05	0.06	0.07	0.07	0.06	0.02
2012	1.65	1.72	1.2	1.9	0.97	1.24	0.62	0.75	0.56	0.52	0.5	0.46	0.16	0.27	0.11	0.19	0.16	0.17	0.1	0.11	0.11	0.02	0.03	0.07
2013	3	2.59	2.49	2	1.91	1.69	0.94	1.15	0.8	0.57	0.8	0.54	0.56	0.15	0.54	0.23	0.44	0.21	0.19	0.13	0.14	0.08	0.06	0.09
2014	1.23	1.23	1.02	1.3	1.1	1.05	1.3	0.98	0.84	0.79	0.57	0.56	0.4	0.3	0.32	0.16	0.15	0.16	0.07	0.08	0.11	0.07	0.02	0.12
2015	1.96	1.72	1.44	1.16	1.08	1.09	1	0.8	0.97	0.77	0.63	0.42	0.43	0.35	0.4	0.25	0.13	0.21	0.13	0.31	0.17	0.1	0.05	0.08
2016	3.94	3.56	3.28	3.48	2.8	1.97	1.77	1.43	1.06	0.95	0.98	0.75	0.5	0.5	0.73	0.33	0.39	0.44	0.34	0.2	0.19	0.16	0.16	0.11
2017	4.03	3.31	4.24	3.57	2.92	2.49	3.11	2.34	2.64	2.52	2.27	1.85	1.97	1.94	0.57	1.11	0.97	0.63	0.35	0.29	0.44	0.3	0.44	0.11

Table 2.7b (page 5 of 6)—Trawl survey size composition as used in Models 17.x, by year and cm.

Year	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114
1982	0.07	0.1	0	0.07	0	0.03	0.06	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0.01	0.01	0.04	0.08	0	0.05	0	0.02	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0
1984	0.2	0.09	0.16	0.13	0	0.08	0.06	0.05	0.01	0.01	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0
1985	0.16	0.15	0.17	0.09	0.02	0.07	0.14	0.04	0.07	0.04	0	0.07	0	0	0	0	0	0	0	0	0	0	0	0
1986	0.22	0.37	0.3	0.1	0.09	0.13	0.06	0.16	0.04	0.09	0.06	0	0.09	0.05	0	0	0	0	0	0	0	0	0	0
1987	0.41	0.19	0.33	0.32	0.05	0.13	0.19	0.1	0.04	0.02	0.08	0.09	0	0.03	0	0	0	0	0	0.01	0	0	0	0
1988	0.52	0.08	0.19	0.22	0.22	0.17	0.03	0.14	0.26	0.11	0.02	0.09	0	0	0.01	0	0	0	0	0.13	0	0	0	0
1989	0.96	0.59	0.75	0.9	1.02	0.45	0.33	0.65	0.36	0.31	0.7	0.02	0.71	0.21	0	0	0	0	0	0	0	0	0	0
1990	0.32	0.27	0.27	0.39	0.63	0.58	0.15	0.09	0.07	0.27	0	0.34	0.02	0	0.06	0.07	0.03	0	0	0	0	0	0	0
1991	0.13	0.24	0.18	0.07	0.26	0.34	0.14	0.09	0.12	0	0.02	0.01	0.25	0.04	0.02	0.06	0	0	0	0	0	0	0	0
1992	0.18	0.23	0.23	0.15	0.23	0.27	0.09	0.3	0.05	0.14	0.1	0.09	0.09	0.09	0.04	0.02	0.02	0	0.02	0	0.02	0	0	0
1993	0.11	0.12	0.25	0.09	0.24	0.17	0.16	0.12	0.12	0.04	0.07	0.06	0.02	0.29	0.08	0	0.03	0.01	0	0.01	0	0.01	0	0
1994	0.33	0.23	0.07	0.01	0.08	0.16	0.09	0.04	0.02	0.06	0.24	0.15	0.08	0.02	0.17	0	0	0.02	0	0.02	0	0	0	0
1995	0.41	0.12	0.15	0.13	0.36	0.04	0.12	0.07	0.1	0.18	0.03	0.12	0.01	0	0.05	0	0.02	0	0.01	0	0.03	0	0	0
1996	0.09	0.24	0.36	0.11	0.17	0.17	0.1	0.08	0.07	0.14	0.05	0.06	0	0.02	0	0	0	0.11	0	0	0	0	0	0
1997	0.31	0.28	0.07	0.21	0.13	0.09	0.14	0	0.04	0.07	0	0	0.03	0.06	0	0	0.01	0	0	0	0	0.01	0	0.02
1998	0.19	0.35	0.11	0.22	0.09	0.05	0.07	0.07	0.02	0.02	0.03	0.3	0	0	0	0.02	0	0.02	0	0.02	0	0	0	0
1999	0.17	0.14	0.14	0.15	0.06	0.15	0.17	0.18	0.09	0.07	0.04	0	0.06	0.02	0	0.02	0.04	0	0	0	0	0	0	0
2000	0.2	0.1	0.12	0.27	0.07	0.21	0.13	0.09	0.03	0.01	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0.08	0.07	0.04	0.07	0.1	0.01	0.04	0.01	0.08	0.01	0.02	0	0.03	0.02	0.05	0.01	0	0.02	0	0	0	0	0	0
2002	0.1	0.14	0.14	0.03	0.1	0.05	0.09	0.17	0.03	0.04	0	0	0.03	0	0.05	0	0	0	0	0	0	0	0.02	0
2003	0.12	0.08	0.05	0.03	0	0.03	0.02	0.01	0	0	0.02	0	0.01	0	0	0	0	0	0	0	0	0	0	0
2004	0.19	0.12	0.24	0.12	0.09	0.14	0.13	0.07	0.05	0	0.02	0	0.16	0	0.04	0	0	0.05	0	0.03	0	0	0	0
2005	0.44	0.3	0.23	0.11	0.28	0.16	0.09	0.11	0.01	0.11	0.06	0.01	0.02	0.01	0	0	0	0	0	0	0	0	0	0
2006	0.43	0.51	0.29	0.27	0.18	0.31	0.25	0.04	0.21	0.14	0.07	0.07	0.07	0.04	0	0.03	0	0	0.06	0	0	0	0	0
2007	0.36	0.23	0.09	0.21	0.1	0.15	0.06	0.08	0.07	0.08	0.05	0.21	0.04	0.06	0.03	0.05	0	0.01	0.01	0	0	0.01	0	0
2008	0.13	0.25	0.26	0.25	0.23	0.08	0.22	0.22	0.06	0.11	0.08	0.18	0.03	0.03	0	0	0.01	0	0	0.02	0	0	0	0
2009	0.01	0.02	0.02	0.04	0.07	0.1	0.05	0.06	0.01	0.04	0.03	0.02	0	0.01	0.04	0	0	0.01	0	0	0	0	0	0
2010	0.04	0.03	0.08	0.02	0	0.08	0.04	0.02	0.06	0.05	0	0	0	0	0.02	0	0	0.02	0	0.01	0	0	0	0
2011	0.09	0.06	0.08	0.12	0.03	0.01	0	0.02	0	0.04	0.03	0.02	0	0.03	0.01	0	0	0	0	0	0	0	0	0
2012	0.05	0.03	0.08	0.07	0.04	0.01	0	0.04	0.04	0.03	0.01	0	0.01	0.02	0	0.01	0	0.01	0	0.01	0	0	0	0
2013	0.07	0.08	0.09	0.03	0.03	0.01	0.03	0.01	0.02	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0.04	0.06	0.04	0.01	0	0.06	0.02	0.04	0	0.03	0	0	0.03	0	0	0	0.01	0	0	0	0	0	0	0
2015	0.02	0.03	0.03	0.01	0.03	0.01	0.02	0.02	0.03	0.02	0	0	0.01	0.01	0.02	0	0	0	0	0	0	0	0	0
2016	0.13	0.1	0.07	0.03	0.06	0.03	0.05	0.04	0	0.03	0.06	0.03	0.02	0.04	0	0	0	0	0	0	0	0	0	0
2017	0.23	0.25	0.04	0.18	0.16	0.02	0.12	0.02	0	0.02	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0

Table 2.7b (page 6 of 6)—Trawl survey size composition as used in Models 17.x, by year and cm.

Year	115	116	117	118	119	120+
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0
1989	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1992	0	0	0	0	0	0
1993	0.1	0	0	0	0	0
1994	0	0	0	0	0	0
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
1997	0	0	0	0	0	0
1998	0	0	0	0	0	0
1999	0	0	0	0	0	0
2000	0	0	0	0	0	0
2001	0	0	0	0	0	0
2002	0	0	0	0	0	0
2003	0	0	0	0	0	0
2004	0	0	0	0	0	0
2005	0	0	0	0	0	0
2006	0	0	0	0	0	0
2007	0	0	0	0	0	0
2008	0	0	0	0	0	0
2009	0	0	0	0	0	0
2010	0	0	0	0	0	0
2011	0	0	0	0	0	0
2012	0	0	0	0	0	0
2013	0	0	0	0	0	0
2014	0	0	0	0	0	0
2015	0	0	0	0	0	0
2016	0	0	0	0	0	0
2017	0	0	0	0	0	0

Table 2.8—Trawl survey age compositions, as within-year proportions by age (Nage = number of otoliths, Nhaul = number of sampled hauls).

Year	Nage	Nhaul	0	1	2	3	4	5	6	7	8	9	10	11	12+
1994	715	346	0.00000	0.08906	0.38238	0.17148	0.12309	0.11848	0.08011	0.02056	0.00707	0.00462	0.00136	0.00098	0.00081
1995	571	335	0.00001	0.05279	0.26401	0.42067	0.09969	0.07898	0.04932	0.01601	0.00894	0.00593	0.00158	0.00087	0.00120
1996	711	341	0.00001	0.05640	0.20763	0.20268	0.29306	0.13575	0.05768	0.02868	0.01003	0.00433	0.00180	0.00106	0.00088
1997	719	351	0.00000	0.25632	0.16894	0.18349	0.15669	0.12022	0.07696	0.02179	0.01005	0.00309	0.00128	0.00082	0.00036
1998	635	344	0.00000	0.07696	0.44068	0.20395	0.11228	0.05666	0.05960	0.02830	0.01593	0.00403	0.00080	0.00060	0.00021
1999	860	320	0.00000	0.07942	0.19952	0.30277	0.23182	0.08061	0.05778	0.02725	0.01208	0.00532	0.00131	0.00152	0.00059
2000	860	343	0.00002	0.23424	0.12709	0.14999	0.24191	0.14755	0.06156	0.01389	0.01374	0.00546	0.00288	0.00126	0.00043
2001	920	348	0.00001	0.28936	0.23550	0.19364	0.09085	0.08354	0.06818	0.02635	0.00779	0.00217	0.00150	0.00082	0.00029
2002	870	344	0.00006	0.08001	0.18794	0.31779	0.23342	0.07199	0.05884	0.03382	0.01028	0.00379	0.00106	0.00054	0.00047
2003	1263	345	0.00001	0.17500	0.15625	0.25057	0.20941	0.11888	0.04105	0.03010	0.01359	0.00363	0.00052	0.00052	0.00046
2004	995	345	0.00002	0.14384	0.16568	0.27088	0.12814	0.12790	0.09067	0.04002	0.01897	0.00853	0.00218	0.00256	0.00062
2005	1279	344	0.00000	0.18328	0.24443	0.20926	0.12113	0.06528	0.07945	0.05496	0.02383	0.01045	0.00363	0.00365	0.00064
2006	1300	344	0.00000	0.32441	0.14277	0.16496	0.12141	0.09299	0.06330	0.04644	0.02848	0.00988	0.00303	0.00144	0.00087
2007	1441	348	0.00000	0.70042	0.09556	0.06713	0.04138	0.04597	0.01760	0.01430	0.00839	0.00504	0.00174	0.00151	0.00097
2008	1213	330	0.00014	0.21331	0.44525	0.14489	0.08267	0.04860	0.03297	0.01026	0.01026	0.00574	0.00275	0.00141	0.00175
2009	1412	347	0.00068	0.45428	0.18941	0.23091	0.06415	0.02879	0.01464	0.00945	0.00393	0.00204	0.00083	0.00057	0.00033
2010	1292	328	0.00000	0.04651	0.47939	0.17932	0.20324	0.06443	0.01457	0.00770	0.00255	0.00126	0.00038	0.00053	0.00013
2011	1253	350	0.00003	0.29047	0.07300	0.38813	0.11109	0.09557	0.02785	0.00693	0.00334	0.00162	0.00097	0.00056	0.00044
2012	1301	343	0.00005	0.36601	0.23426	0.05829	0.23722	0.06172	0.03065	0.00743	0.00205	0.00154	0.00047	0.00016	0.00016
2013	1418	343	0.00000	0.10724	0.42699	0.17804	0.10837	0.11291	0.05040	0.01093	0.00360	0.00081	0.00019	0.00029	0.00022
2014	1223	355	0.00005	0.27877	0.18778	0.23806	0.19721	0.04780	0.03584	0.01019	0.00225	0.00090	0.00072	0.00014	0.00028
2015	856	341	0.00000	0.06386	0.42549	0.20207	0.19335	0.08190	0.01858	0.01123	0.00242	0.00055	0.00025	0.00016	0.00014
2016	854	356	0.00000	0.11203	0.09418	0.36104	0.22136	0.14502	0.04871	0.01150	0.00406	0.00128	0.00043	0.00030	0.00011

Table 2.9—Total biomass estimates, with standard errors, log-scale standard errors ("Sigma"), and bounds of 95% confidence intervals, as estimated by EBS shelf bottom trawl surveys, 1982-2017.

	Biomass (t)				
Year	Estimate	Std. error	Sigma	L95% CI	U95% CI
1982	1,013,061	73,621	0.073	867,292	1,158,831
1983	1,187,096	120,958	0.102	942,640	1,431,553
1984	1,013,558	62,513	0.062	889,782	1,137,334
1985	1,001,112	55,845	0.056	890,540	1,111,684
1986	1,118,006	69,626	0.062	980,146	1,255,866
1987	1,027,518	63,670	0.062	734,927	1,320,109
1988	960,962	76,961	0.080	610,794	1,311,129
1989	833,473	62,713	0.075	566,551	1,100,394
1990	691,256	51,455	0.074	479,036	903,477
1991	514,407	38,039	0.074	343,890	684,925
1992	529,049	44,616	0.084	325,394	732,704
1993	663,308	53,143	0.080	447,603	879,013
1994	1,360,790	247,737	0.181	605,977	2,134,392
1995	1,002,961	91,622	0.091	603,798	1,403,635
1996	889,366	87,521	0.098	533,064	1,245,669
1997	604,439	68,120	0.112	356,002	852,876
1998	534,150	42,937	0.080	362,747	705,554
1999	569,765	49,471	0.087	372,590	766,939
2000	531,171	43,160	0.081	356,851	705,491
2001	811,816	73,211	0.090	536,531	1,087,102
2002	584,565	63,820	0.109	358,740	810,391
2003	590,973	62,121	0.105	379,743	802,203
2004	562,309	33,739	0.060	420,139	704,479
2005	606,050	43,056	0.071	435,833	776,267
2006	517,698	28,341	0.055	399,142	636,254
2007	423,704	34,811	0.082	282,682	564,725
2008	403,125	26,822	0.066	281,887	524,364
2009	421,291	34,969	0.083	261,797	582,541
2010	860,210	102,307	0.119	451,575	1,268,846
2011	896,039	66,843	0.074	594,847	1,197,231
2012	890,665	100,473	0.112	530,407	1,250,924
2013	791,958	73,952	0.093	512,056	1,071,860
2014	1,079,712	153,299	0.141	537,183	1,622,240
2015	1,102,261	150,981	0.136	605,174	1,599,347
2016	944,621	76,948	0.081	649,624	1,239,617
2017	598,260	46,278	0.077	409,985	786,535

Table 2.10—Fulton's condition factor (as z-score) by year and age with negative values highlighted (upper panel), and with recent strong cohorts highlighted (lower panel).

Year	1	2	3	4	5	6	7	8	9	10	Mean
2000	-1.64	-0.90	0.34	0.08	0.01	0.12	-1.39	-1.49	-0.13	-0.60	-0.44
2001	0.28	0.46	-0.40	-0.48	-0.72	-0.28	-0.62	-0.49	-1.03	-1.26	-0.94
2002	0.24	-0.51	-1.70	-1.49	-0.28	0.33	1.00	0.46	1.27	-0.12	-0.40
2003	0.71	1.40	1.79	0.55	2.30	2.61	2.08	2.15	0.57	0.54	2.47
2004	0.92	-0.03	-0.04	-1.11	0.40	1.51	1.23	0.47	1.43	2.56	0.84
2005	0.51	-1.27	0.01	-1.06	-0.68	-0.13	1.19	1.09	1.30	1.85	0.72
2006	-0.58	-0.13	-1.22	-0.90	-1.02	-0.84	0.51	0.79	0.66	0.59	0.10
2007	-0.33	0.13	-0.24	0.41	0.78	1.10	0.26	0.53	1.55	-0.03	0.52
2008	-0.61	-0.56	0.08	0.93	0.74	0.01	-0.32	-0.78	-0.61	-0.28	-0.54
2009	-0.95	-1.13	-0.50	0.42	0.76	-0.69	-0.75	-1.59	-1.45	-0.46	-1.59
2010	-1.10	0.04	0.79	1.47	-0.39	-1.14	-0.16	0.70	-0.32	-1.40	-0.43
2011	0.11	0.15	1.18	1.98	1.43	0.20	-0.45	0.66	-0.34	-0.16	0.42
2012	-0.26	-0.91	-1.68	0.44	-1.38	-1.30	-1.64	-0.60	-0.95	0.17	-1.21
2013	-0.88	-0.83	0.02	-0.38	0.07	-0.12	0.25	0.31	-0.29	-0.18	-0.24
2014	0.24	0.67	0.41	0.83	-0.13	-0.19	-1.00	-1.01	-1.57	-0.35	-0.20
2015	0.64	0.78	-0.45	-1.25	-1.58	-1.11	-0.54	-0.85	0.35	-0.97	-0.54
2016	2.70	2.63	1.62	-0.45	-0.33	-0.06	0.37	-0.34	-0.43	0.08	1.45

Year	1	2	3	4	5	6	7	8	9	10
2006	-0.58	-0.13	-1.22	-0.90	-1.02	-0.84	0.51	0.79	0.66	0.59
2007	-0.33	0.13	-0.24	0.41	0.78	1.10	0.26	0.53	1.55	-0.03
2008	-0.61	-0.56	0.08	0.93	0.74	0.01	-0.32	-0.78	-0.61	-0.28
2009	-0.95	-1.13	-0.50	0.42	0.76	-0.69	-0.75	-1.59	-1.45	-0.46
2010	-1.10	0.04	0.79	1.47	-0.39	-1.14	-0.16	0.70	-0.32	-1.40
2011	0.11	0.15	1.18	1.98	1.43	0.20	-0.45	0.66	-0.34	-0.16
2012	-0.26	-0.91	-1.68	0.44	-1.38	-1.30	-1.64	-0.60	-0.95	0.17
2013	-0.88	-0.83	0.02	-0.38	0.07	-0.12	0.25	0.31	-0.29	-0.18
2014	0.24	0.67	0.41	0.83	-0.13	-0.19	-1.00	-1.01	-1.57	-0.35
2015	0.64	0.78	-0.45	-1.25	-1.58	-1.11	-0.54	-0.85	0.35	-0.97
2016	2.70	2.63	1.62	-0.45	-0.33	-0.06	0.37	-0.34	-0.43	0.08

Table 2.11—Initial steps toward a bridging analysis between Models 16.6 and 17.6. See text for details.

Sorted in order of increasing average difference in spawning biomass ("ADSB")	
Feature	ADSB
Prior distribution for natural mortality	0.0067
Flat-topped, time-invariant, double normal selectivity	0.0146
Random time variability in length at age 1.5	0.0178
Random time variability in survey catchability	0.0444
New fishery agecomps	0.0474
Gear/week/area-catch-weighted sizecomp data	0.0605
Double normal selectivity with variability in survey selparm P1	0.0699
Double normal selectivity with variability in survey selparm P3	0.1080
Double normal selectivity with variability in fishery selparm P3	0.1091
Double normal selectivity with variability in fishery selparm P1	0.1818
Haul-based sample sizes with harmonic mean reweighting	0.2420
Haul-based sample sizes without reweighting	0.3705

Sorted in order of increasing change in 2016 spawning biomass ("ΔSB16")	
Feature	ΔSB16
Random time variability in survey catchability	0.0101
Prior distribution for natural mortality	0.0114
Flat-topped, time-invariant, double normal selectivity	0.0126
Random time variability in length at age 1.5	0.0272
Double normal selectivity with variability in survey selparm P3	0.0379
Gear/week/area-catch-weighted sizecomp data	0.0414
New fishery agecomps	0.0587
Double normal selectivity with variability in fishery selparm P3	0.0967
Double normal selectivity with variability in fishery selparm P1	0.1142
Haul-based sample sizes with harmonic mean reweighting	0.2016
Double normal selectivity with variability in survey selparm P1	0.2116
Haul-based sample sizes without reweighting	0.5197

Table 2.12—Annual offsets to the base values of the α and β weight-at-length parameters.

Year:	1977	1978	1979	1980	1981	1982	1983	1984
α offset:	2.17E-06	-2.43E-06	1.42E-06	-2.04E-07	7.55E-07	2.78E-06	3.91E-07	1.16E-05
β offset:	-7.41E-02	1.38E-01	-5.06E-02	4.89E-03	-3.52E-02	-8.81E-02	-6.32E-03	-2.80E-01

Year:	1985	1986	1987	1988	1989	1990	1991	1992
α offset:	-9.74E-07	-2.21E-06	-1.59E-07	-2.14E-06	-1.22E-06	1.25E-06	1.73E-06	2.80E-07
β offset:	5.51E-02	1.28E-01	1.36E-02	1.31E-01	7.83E-02	-3.29E-02	-6.44E-02	-2.05E-02

Year:	1993	1994	1995	1996	1997	1998	1999	2000
α offset:	2.72E-06	5.41E-07	-9.26E-07	7.68E-06	1.18E-06	1.66E-06	1.92E-06	2.17E-06
β offset:	-7.58E-02	-2.03E-02	4.58E-02	-2.03E-01	-5.60E-02	-7.37E-02	-7.18E-02	-6.71E-02

Year:	2001	2002	2003	2004	2005	2006	2007	2008
α offset:	4.05E-06	1.44E-06	-2.81E-07	2.12E-06	5.44E-08	9.98E-07	5.26E-07	4.28E-06
β offset:	-1.25E-01	-5.18E-02	1.26E-02	-7.52E-02	1.58E-03	-3.65E-02	-1.52E-02	-1.33E-01

Year:	2009	2010	2011	2012	2013	2014	2015	2016
α offset:	-6.64E-07	1.18E-06	6.51E-07	2.96E-06	-7.01E-07	-1.89E-06	-2.12E-06	-1.85E-06
β offset:	3.45E-02	-4.61E-02	-3.13E-02	-1.08E-01	2.71E-02	8.88E-02	9.87E-02	8.63E-02

Table 2.13—Input multinomial sample sizes for length composition data as specified in Model 16.6 and Models 17.x.

	Model 16.6		Models 17.x	
Year	Fishery	Survey	Fishery	Survey
1977	2		30	
1978	11		160	
1979	17		235	
1980	15		208	
1981	11		148	
1982	13	251	187	313
1983	56	312	782	255
1984	137	289	1913	264
1985	203	401	2825	345
1986	177	366	2496	349
1987	337	252	4726	338
1988	105	238	1458	334
1989	69	238	966	316
1990	259	134	3601	328
1991	355	172	5188	324
1992	368	228	5322	322
1993	231	247	2993	351
1994	371	331	4687	346
1995	367	219	5215	335
1996	461	222	6618	341
1997	500	218	7278	351
1998	444	228	6838	344
1999	402	278	9231	320
2000	423	298	9731	343
2001	446	469	10364	348
2002	489	291	11472	344
2003	610	294	14341	345
2004	495	257	12242	345
2005	485	268	11568	344
2006	383	288	8849	344
2007	298	305	6901	348
2008	354	309	8320	330
2009	313	396	7482	347
2010	276	180	6514	328
2011	361	493	8804	350
2012	398	311	9287	343
2013	501	444	11126	343
2014	494	426	12165	355
2015	454	459	11309	341
2016	395	408	9773	356
2017	213	280	5334	353

Table 2.14—Objective function components and parameter counts.

Component	M16.6	M17.1	M17.2	M17.3	M17.6	M17.7
Catch	0.00	0.00	0.00	0.00	0.00	0.00
Equilibrium catch	0.00	0.12	0.02	0.07	0.05	0.06
Survey abundance index	-23.31	-9.30	-11.44	-40.39	-64.68	-64.61
Recruitment	5.14	12.34	3.93	-2.95	2.44	-0.82
Priors	0.00	0.44	0.17	0.41	0.45	0.48
"Softbounds"	0.01	0.00	0.00	0.00	0.00	0.00
Deviations	0.00	-240.88	-94.79	-267.46	-398.01	-401.84
Size composition (fishery)	376.60	1586.83	491.42	323.16	365.70	325.80
Size composition (survey)	1030.55	1119.77	1015.71	984.28	1017.45	670.06
Age composition (fishery)	0.00	440.15	40.17	31.75	37.78	37.78
Age composition (survey)	293.08	275.90	54.33	62.24	61.48	61.07
Total	1682.06	3185.37	1499.53	1091.11	1022.66	627.97

Parameter type	M16.6	M17.1	M17.2	M17.3	M17.6	M17.7
Free parameters	18	16	16	17	17	17
Parameters with priors	0	1	1	1	1	1
Constrained deviations	60	214	142	214	286	286
Total	78	231	159	232	304	304

Table 2.15—Input and output effective sample sizes. See text for details.

				Model 16.6				
Type	Fleet	Yrs	N	Mult	N×Mult	Har	ΣNeff1	ΣNeff2
Size	Fish.	41	300	1.0000	300	582	12299	23850
Size	Surv.	36	300	1.0000	300	308	10798	11086
Age	Fish.	–	–	–	–	–	–	–
Age	Surv.	23	300	1.0000	300	61	6898	1395
				SEave	SEextra	RMSE		
Index	Surv.	36	336	0.1074	0	0.1886	12083	3921
						Ave:	10519	10063
								0.96

				Model 17.1					Model 17.2				
Type	Fleet	Yrs	N	Mult	N×Mult	Har	ΣNeff1	ΣNeff2	Mult	N×Mult	Har	ΣNeff1	ΣNeff2
Size	Fish.	41	5522	1.0000	5522	1826	226402	74884	0.2425	1339	1365	54902	55964
Size	Surv.	36	336	1.0000	336	290	12083	10438	0.8480	285	284	10246	10217
Age	Fish.	4	11093	1.0000	11093	839	44373	3357	0.0836	927	844	3710	3375
Age	Surv.	23	343	1.0000	343	73	7891	1670	0.1155	40	40	911	915
				SEave	SEextra	RMSE			SEave	SEextra	RMSE		
Index	Surv.	36	336	0.1074	0	0.1968	12083	3601	0.1074	0	0.2072	12083	3247
						Ave:	60566	18790			Ave:	16371	14744

				Model 17.3				
Type	Fleet	Yrs	N	Mult	N×Mult	Har	ΣNeff1	ΣNeff2
Size	Fish.	41	5522	0.1525	842	827	34526	33901
Size	Surv.	36	336	1.0237	344	345	12369	12428
Age	Fish.	4	11093	0.0599	664	662	2658	2646
Age	Surv.	23	343	0.2561	88	89	2021	2054
				SEave	SEextra	RMSE		
Index	Surv.	36	336	0.1074	0.0944	0.1959	12083	12832
						Ave:	12732	12772

				Model 17.6					Model 17.7				
Type	Fleet	Yrs	N	Mult	N×Mult	Har	ΣNeff1	ΣNeff2	Mult	N×Mult	Har	ΣNeff1	ΣNeff2
Size	Fish.	41	5522	0.1611	890	846	36473	34686	0.1554	858	840	35183	34425
Size	Surv.	36	336	1.5903	534	536	19216	19290	1.0000	336	507	12083	18242
Age	Fish.	4	11093	0.0690	765	765	3062	3060	0.0736	816	841	3266	3363
Age	Surv.	23	343	0.2502	86	86	1974	1988	0.2499	86	86	1972	1972
				SEave	SEextra	RMSE			SEave	SEextra	RMSE		
Index	Surv.	36	336	0.1074	0	0.1075	12083	12062	0.1074	0	0.1071	12083	12145
						Ave:	14562	14217			Ave:	12917	14029

Table 2.16—Input and output effective sample sizes for each age composition. Last two rows for each fleet show arithmetic and harmonic means.

		Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.6		Model 17.7	
Fleet	Year	Ninp	Neff	Ninp	Neff	Ninp	Neff	Ninp	Neff	Ninp	Neff	Ninp	Neff
Fishery	2013			11126	536	930	625	666	363	768	725	819	642
Fishery	2014			12165	663	1017	648	729	452	839	470	895	540
Fishery	2015			11309	888	945	979	677	1412	780	963	832	1132
Fishery	2016			9773	3773	817	1736	585	2730	674	1466	719	2152
Fishery	Arith.			11093		927		664		765		816	
Fishery	Harm.				839		844		662		765		841
Survey	1994	346	205	346	145	40	131	89	139	87	166	86	175
Survey	1995	335	33	335	111	39	63	86	98	84	90	84	91
Survey	1996	341	94	341	690	39	118	87	1115	85	1363	85	1312
Survey	1997	351	64	351	144	41	115	90	233	88	214	88	192
Survey	1998	344	108	344	1048	40	40	88	459	86	362	86	517
Survey	1999	320	61	320	25	37	22	82	29	80	39	80	39
Survey	2000	343	58	343	20	40	24	88	28	86	44	86	39
Survey	2001	348	38	348	67	40	23	89	60	87	66	87	72
Survey	2002	344	40	344	75	40	44	88	57	86	47	86	54
Survey	2003	345	804	345	326	40	272	88	410	86	276	86	292
Survey	2004	345	36	345	30	40	26	88	31	86	23	86	24
Survey	2005	344	164	344	255	40	151	88	288	86	174	86	184
Survey	2006	344	47	344	93	40	25	88	132	86	110	86	107
Survey	2007	348	10	348	14	40	5	89	23	87	19	87	17
Survey	2008	330	123	330	235	38	340	85	623	83	235	82	209
Survey	2009	347	104	347	331	40	47	89	771	87	193	87	208
Survey	2010	328	310	328	214	38	271	84	406	82	2460	82	1502
Survey	2011	350	105	350	177	40	152	90	157	88	264	87	253
Survey	2012	343	73	343	103	40	54	88	143	86	153	86	147
Survey	2013	343	113	343	73	40	70	88	100	86	82	86	81
Survey	2014	355	397	355	200	41	132	91	207	89	272	89	304
Survey	2015	341	252	341	387	39	752	87	388	85	499	85	563
Survey	2016	356	309	356	1243	41	211	91	399	89	337	89	374
Survey	Arith.	343		343		40		88		86		86	
Survey	Harm.		61		73		40		89		86		86

Table 2.17a—Scalar parameters estimated by the models (a blank under "Est." means that the parameter was not used in the respective model, and a blank under "SD" means that the parameter was not estimated internally in the respective model).

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.6		Model 17.7	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Natural mortality	0.359	0.012	0.324	0.009	0.385	0.017	0.328	0.015	0.322	0.012	0.317	0.014
Length at age 1.5 (cm)	16.418	0.088	16.601	0.084	16.451	0.093	16.411	0.084	16.909	0.286	16.872	0.293
Asymptotic length (cm)	99.636	1.921	113.727	1.290	108.676	1.845	109.146	2.134	106.534	1.866	107.172	2.096
Brody growth coefficient	0.198	0.012	0.148	0.005	0.176	0.009	0.173	0.010	0.181	0.009	0.180	0.010
Richards growth coefficient	1.038	0.048	1.195	0.023	1.056	0.038	1.055	0.039	0.983	0.037	0.988	0.043
SD of length at age 1 (cm)	3.438	0.058	3.526	0.050	3.488	0.059	3.488	0.055	3.119	0.039	3.133	0.049
SD of length at age 20 (cm)	9.789	0.277	8.060	0.135	8.753	0.223	8.662	0.254	9.556	0.217	9.311	0.239
Ageing bias at age 1	0.332	0.012	0.351	0.010	0.360	0.025	0.345	0.019	0.365	0.017	0.358	0.018
Ageing bias at age 20	0.281	0.142	-0.804	0.060	-0.803	0.175	-0.441	0.150	-0.578	0.140	-0.553	0.142
SD of ageing error at age 1	0.085		0.082		0.082		0.082		0.082		0.082	
SD of ageing error at age 20	1.695	_	1.632	_	1.632	_	1.632	_	1.632	_	1.632	_
SD of L at age 1.5 devs									0.097		0.098	
ln(mean post-1976 recruitment)	13.123	0.100	12.760	0.065	13.170	0.122	12.782	0.101	12.782	0.087	12.744	0.098
SD of ln(recruitment) devs	0.644	0.066	0.492		0.569		0.515		0.579		0.554	
ln(pre-1977 recruitment offset)	-1.122	0.212	-1.459	0.034	-1.449	0.136	-0.986	0.193	-1.024	0.210	-0.950	0.197
Initial fishing mortality rate	0.180	0.069	1.029	0.358	0.470	0.302	1.632	0.779	1.674	0.903	1.697	0.842
ln(trawl survey catchability)	-0.074	0.061	0.177	0.039	0.023	0.059	0.196	0.064	0.169	0.057	0.193	0.061
"Extra" survey index std. error							0.094	0.024				
SD of lnQ devs									0.089	_	0.088	_
Autocorrelation of lnQ devs									0.482	0.126	0.472	0.127
Fishery selectivity A50%	4.349	0.045										
Fishery selectivity A95%-A50%	1.164	0.032										
Survey selecivity A50%	1.009	0.006										
Survey selectivity A95%-A50%	0.287	0.052										
Fishery selectivity P1			5.796	0.123	5.721	0.119	5.722	0.123	5.850	0.130	5.842	0.131
Fishery selectivity P3			0.996	0.075	0.886	0.072	0.927	0.072	0.952	0.080	0.971	0.079
Survey selectivity P1			1.037	0.011	2.563	0.147	1.056	0.015	1.041	0.013	1.042	0.014
Survey selectivity P3			-8.179	1.202	1.243	0.210	-6.394	0.699	-7.182	0.941	-7.081	0.966
SD of fishery selectivity P1 devs			0.129		0.112		0.113		0.119		0.118	
SD of fishery selectivity P3 devs			0.454	_	0.391	_	0.367	_	0.430	_	0.412	_
SD of survey selectivity P1 devs			0.057				0.055		0.055		0.057	
SD of survey selectivity P3 devs			0.159				0.159		0.159		0.159	

Table 2.17b—Initial age composition deviations estimated by the stock assessment models.

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.6		Model 17.7	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Initial age 20 ln(abundance) dev	-0.004	0.643	0.000	0.492	0.000	0.569	0.000	0.515	0.000	0.579	0.000	0.554
Initial age 19 ln(abundance) dev	-0.003	0.644	0.000	0.492	0.000	0.569	0.000	0.515	0.000	0.579	0.000	0.554
Initial age 18 ln(abundance) dev	-0.004	0.643	0.000	0.492	0.000	0.569	0.000	0.515	0.000	0.579	0.000	0.554
Initial age 17 ln(abundance) dev	-0.008	0.642	0.000	0.492	0.000	0.569	0.000	0.515	0.000	0.579	0.000	0.554
Initial age 16 ln(abundance) dev	-0.013	0.641	0.000	0.492	0.000	0.569	0.000	0.515	0.000	0.579	0.000	0.554
Initial age 15 ln(abundance) dev	-0.021	0.638	0.000	0.492	-0.001	0.568	0.000	0.515	0.000	0.579	0.000	0.554
Initial age 14 ln(abundance) dev	-0.035	0.634	0.000	0.492	-0.002	0.568	0.000	0.515	0.000	0.579	0.000	0.554
Initial age 13 ln(abundance) dev	-0.057	0.628	0.000	0.492	-0.005	0.568	0.000	0.515	0.000	0.579	0.000	0.554
Initial age 12 ln(abundance) dev	-0.091	0.620	0.000	0.492	-0.010	0.566	0.000	0.515	0.000	0.579	0.000	0.554
Initial age 11 ln(abundance) dev	-0.142	0.608	0.000	0.492	-0.023	0.565	0.000	0.515	0.000	0.579	0.000	0.554
Initial age 10 ln(abundance) dev	-0.214	0.593	0.001	0.492	-0.049	0.564	0.000	0.515	0.000	0.579	0.000	0.554
Initial age 9 ln(abundance) dev	-0.309	0.575	0.002	0.492	-0.098	0.566	0.001	0.515	0.001	0.579	0.001	0.555
Initial age 8 ln(abundance) dev	-0.423	0.555	0.006	0.494	-0.180	0.573	0.005	0.516	0.006	0.581	0.005	0.556
Initial age 7 ln(abundance) dev	-0.544	0.533	0.015	0.502	-0.294	0.576	0.025	0.521	0.029	0.588	0.027	0.562
Initial age 6 ln(abundance) dev	-0.639	0.513	0.017	0.516	-0.408	0.556	0.103	0.539	0.126	0.613	0.115	0.584
Initial age 5 ln(abundance) dev	-0.624	0.501	-0.140	0.394	-0.435	0.497	0.324	0.582	0.415	0.668	0.372	0.635
Initial age 4 ln(abundance) dev	-0.262	0.484	0.184	0.212	-0.016	0.402	1.211	0.483	1.309	0.509	1.357	0.473
Initial age 3 ln(abundance) dev	-0.096	0.469	0.779	0.125	0.596	0.276	0.574	0.330	0.411	0.370	0.455	0.363
Initial age 2 ln(abundance) dev	-0.139	0.520	-0.801	0.280	-0.397	0.409	-0.379	0.377	-0.416	0.418	-0.419	0.400
Initial age 1 ln(abundance) dev	0.755	0.519	1.150	0.119	1.165	0.259	0.683	0.302	0.879	0.313	0.758	0.306

Table 2.17c—Annual log-scale recruitment deviations estimated by the stock assessment models.

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.6		Model 17.7	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	0.959	0.210	0.242	0.085	0.464	0.151	0.416	0.163	0.521	0.159	0.448	0.171
1978	0.503	0.252	0.278	0.080	0.505	0.138	0.373	0.145	0.483	0.136	0.428	0.154
1979	0.515	0.143	0.434	0.060	0.502	0.101	0.372	0.104	0.454	0.090	0.412	0.104
1980	-0.256	0.138	-0.678	0.100	-0.270	0.119	-0.463	0.122	-0.760	0.157	-0.700	0.172
1981	-0.851	0.142	0.150	0.050	-0.377	0.103	-0.444	0.114	-0.596	0.117	-0.463	0.126
1982	0.819	0.051	0.410	0.042	0.722	0.053	0.638	0.061	0.764	0.051	0.707	0.058
1983	-0.545	0.126	-0.039	0.054	-0.322	0.102	-0.265	0.104	-0.356	0.103	-0.316	0.116
1984	0.808	0.050	0.360	0.040	0.663	0.049	0.585	0.057	0.657	0.053	0.598	0.062
1985	-0.159	0.090	0.166	0.042	0.095	0.064	0.126	0.070	0.115	0.066	0.102	0.076
1986	-0.563	0.102	-0.433	0.055	-0.388	0.076	-0.421	0.087	-0.437	0.081	-0.433	0.093
1987	-1.436	0.180	-0.641	0.053	-0.957	0.101	-1.029	0.122	-1.242	0.134	-1.082	0.138
1988	-0.414	0.095	-0.127	0.041	-0.354	0.067	-0.188	0.074	-0.207	0.073	-0.212	0.083
1989	0.578	0.057	0.348	0.031	0.440	0.044	0.409	0.054	0.482	0.048	0.455	0.054
1990	0.378	0.063	0.365	0.030	0.343	0.046	0.401	0.053	0.402	0.052	0.377	0.058
1991	-0.069	0.076	-0.271	0.043	-0.172	0.062	-0.238	0.076	-0.252	0.075	-0.271	0.085
1992	0.783	0.038	0.645	0.023	0.686	0.034	0.666	0.039	0.708	0.038	0.689	0.041
1993	-0.099	0.057	-0.241	0.035	-0.219	0.059	-0.160	0.062	-0.165	0.062	-0.189	0.068
1994	-0.302	0.062	-0.421	0.031	-0.427	0.054	-0.405	0.060	-0.355	0.058	-0.370	0.063
1995	-0.391	0.069	-0.360	0.031	-0.498	0.057	-0.432	0.062	-0.384	0.062	-0.361	0.067
1996	0.627	0.037	0.381	0.023	0.429	0.036	0.461	0.041	0.595	0.039	0.542	0.042
1997	-0.177	0.059	0.110	0.026	0.082	0.045	0.080	0.052	0.010	0.058	0.009	0.063
1998	-0.212	0.063	0.079	0.027	-0.016	0.048	-0.021	0.057	-0.145	0.068	-0.100	0.071
1999	0.523	0.039	0.536	0.022	0.536	0.035	0.568	0.040	0.569	0.040	0.549	0.044
2000	0.255	0.043	0.016	0.030	0.175	0.045	0.111	0.052	0.181	0.049	0.133	0.054
2001	-0.542	0.066	-0.639	0.037	-0.747	0.067	-0.579	0.068	-0.732	0.078	-0.715	0.083
2002	-0.263	0.052	-0.237	0.029	-0.222	0.047	-0.217	0.053	-0.048	0.047	-0.091	0.051
2003	-0.431	0.056	-0.190	0.029	-0.303	0.050	-0.226	0.056	-0.085	0.051	-0.089	0.055
2004	-0.604	0.061	-0.524	0.037	-0.511	0.058	-0.521	0.070	-0.568	0.073	-0.566	0.082
2005	-0.306	0.055	-0.247	0.032	-0.305	0.052	-0.361	0.063	-0.171	0.060	-0.148	0.064
2006	0.827	0.034	0.455	0.023	0.563	0.038	0.582	0.040	0.715	0.038	0.656	0.042
2007	-0.003	0.056	0.149	0.031	0.123	0.054	0.095	0.063	-0.147	0.077	-0.127	0.083
2008	1.138	0.031	0.921	0.019	0.954	0.032	0.943	0.035	1.006	0.032	0.981	0.034
2009	-0.927	0.114	-0.923	0.044	-0.989	0.107	-0.908	0.116	-1.033	0.121	-0.965	0.121
2010	0.607	0.044	0.585	0.025	0.572	0.044	0.497	0.048	0.556	0.044	0.557	0.046
2011	0.986	0.043	0.782	0.033	0.885	0.047	0.782	0.050	0.826	0.045	0.806	0.049
2012	0.132	0.066	0.280	0.045	0.262	0.067	0.210	0.078	0.056	0.076	0.102	0.081
2013	0.933	0.051	0.712	0.053	0.855	0.059	0.691	0.085	0.743	0.074	0.741	0.080
2014	-0.943	0.107	-0.997	0.109	-0.894	0.137	-0.949	0.151	-0.785	0.129	-0.763	0.144
2015	-0.662	0.105	-0.862	0.140	-0.751	0.127	-0.844	0.163	-1.058	0.147	-1.036	0.168
2016	-1.220	0.225	-0.573	0.390	-1.133	0.206	-0.338	0.438	-0.319	0.465	-0.297	0.460

Table 2.17d—Annual deviations in fishery selectivity parameter P1 as estimated by the models.

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.6		Model 17.7	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977			-0.249	0.614	-0.247	0.762	-1.452	0.972	-1.137	0.997	-1.277	0.995
1978			-0.358	0.502	-0.341	0.693	0.178	0.772	0.155	0.788	0.179	0.787
1979			-1.998	0.461	-1.013	0.695	-0.464	0.735	-0.516	0.737	-0.476	0.741
1980			-0.562	0.543	-0.241	0.716	-0.055	0.733	0.051	0.733	0.007	0.740
1981			-2.072	0.687	-1.239	0.788	-1.129	0.826	-1.000	0.858	-1.026	0.851
1982			1.065	0.490	0.664	0.632	0.552	0.653	0.629	0.675	0.589	0.673
1983			1.705	0.358	1.153	0.559	0.926	0.575	1.129	0.606	1.043	0.601
1984			2.401	0.308	1.795	0.465	1.499	0.540	1.761	0.500	1.670	0.490
1985			0.342	0.264	-0.308	0.466	-0.256	0.480	-0.557	0.500	-0.359	0.481
1986			0.481	0.226	0.358	0.332	0.368	0.373	0.298	0.346	0.288	0.359
1987			0.291	0.234	0.413	0.352	0.565	0.372	0.565	0.344	0.513	0.363
1988			-0.251	0.386	-0.139	0.525	-0.411	0.577	-0.257	0.563	-0.335	0.573
1989			1.952	0.326	1.400	0.530	0.855	0.580	1.024	0.571	0.967	0.578
1990			1.798	0.209	1.956	0.341	1.849	0.379	2.003	0.372	1.888	0.377
1991			0.405	0.223	-0.023	0.338	0.078	0.386	0.063	0.376	0.130	0.377
1992			-0.337	0.201	-0.822	0.281	-0.579	0.314	-0.720	0.305	-0.617	0.316
1993			-0.728	0.241	-0.324	0.350	-0.372	0.416	-0.271	0.391	-0.314	0.406
1994			-0.424	0.207	-0.093	0.332	-0.132	0.375	0.029	0.366	-0.072	0.373
1995			-0.695	0.224	-0.464	0.351	-0.560	0.404	-0.422	0.398	-0.476	0.403
1996			0.717	0.196	1.038	0.301	0.782	0.330	0.809	0.331	0.765	0.333
1997			0.644	0.191	0.904	0.295	0.822	0.322	0.845	0.311	0.768	0.319
1998			0.127	0.186	0.176	0.269	0.336	0.305	0.369	0.300	0.299	0.299
1999			-0.140	0.186	-0.385	0.272	-0.156	0.305	-0.161	0.299	-0.133	0.300
2000			-0.097	0.179	-0.176	0.242	-0.038	0.272	-0.164	0.277	-0.095	0.277
2001			-0.438	0.189	-0.402	0.279	-0.207	0.313	0.117	0.301	0.039	0.309
2002			-0.530	0.185	-0.766	0.258	-0.691	0.294	-0.555	0.295	-0.498	0.298
2003			-0.545	0.179	-0.690	0.235	-0.613	0.258	-0.720	0.258	-0.653	0.264
2004			-1.562	0.183	-1.157	0.232	-1.148	0.256	-1.147	0.248	-1.225	0.253
2005			-1.428	0.189	-1.325	0.291	-1.038	0.288	-1.165	0.299	-1.240	0.292
2006			-1.047	0.183	-1.006	0.252	-0.843	0.286	-0.998	0.267	-1.021	0.269
2007			0.410	0.183	0.469	0.259	0.525	0.293	0.392	0.286	0.384	0.289
2008			0.182	0.186	0.148	0.259	0.225	0.292	0.307	0.284	0.335	0.293
2009			-0.325	0.192	-0.279	0.283	-0.366	0.322	-0.443	0.310	-0.357	0.316
2010			-0.121	0.185	0.003	0.278	-0.046	0.305	-0.357	0.319	-0.194	0.332
2011			0.576	0.195	0.882	0.330	0.885	0.356	1.280	0.321	1.225	0.332
2012			0.291	0.184	0.230	0.271	0.360	0.313	0.407	0.342	0.422	0.334
2013			-0.883	0.219	-0.985	0.432	-1.019	0.443	-1.304	0.396	-1.203	0.432
2014			0.072	0.179	0.038	0.283	-0.111	0.309	-0.261	0.292	-0.208	0.292
2015			0.401	0.188	0.436	0.322	0.218	0.352	0.018	0.338	0.056	0.340
2016			0.441	0.212	0.397	0.407	0.164	0.431	-0.490	0.452	-0.329	0.440
2017			0.488	0.293	-0.037	0.378	0.497	0.407	0.392	0.403	0.539	0.428

Table 2.17e—Annual deviations in fishery selectivity parameter P3 as estimated by the models.

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.6		Model 17.7	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977			-0.241	0.734	0.005	0.859	1.963	0.874	1.752	0.860	1.916	0.835
1978			-0.405	0.471	-0.304	0.667	-0.234	0.728	-0.182	0.676	-0.210	0.691
1979			-1.627	0.564	-0.472	0.704	-0.166	0.721	-0.218	0.673	-0.192	0.686
1980			-0.079	0.508	0.130	0.662	0.171	0.713	0.178	0.655	0.170	0.673
1981			0.193	0.702	0.889	0.749	0.864	0.813	0.832	0.777	0.830	0.790
1982			0.679	0.473	0.207	0.689	0.063	0.758	0.043	0.713	0.036	0.728
1983			1.427	0.320	0.998	0.573	0.722	0.666	0.756	0.633	0.726	0.639
1984			2.303	0.249	2.168	0.390	1.985	0.484	2.054	0.398	1.996	0.410
1985			0.316	0.288	-0.260	0.575	-0.320	0.634	-0.515	0.619	-0.346	0.595
1986			0.909	0.224	0.849	0.357	0.769	0.437	0.636	0.384	0.633	0.403
1987			0.519	0.236	0.609	0.367	0.677	0.412	0.591	0.353	0.566	0.380
1988			1.290	0.386	1.502	0.551	1.222	0.662	1.227	0.599	1.187	0.620
1989			2.425	0.299	2.093	0.517	1.584	0.625	1.575	0.568	1.550	0.585
1990			1.629	0.205	1.960	0.330	1.869	0.397	1.834	0.353	1.752	0.369
1991			0.512	0.222	0.251	0.354	0.276	0.433	0.308	0.382	0.327	0.393
1992			-0.306	0.212	-0.957	0.346	-0.796	0.408	-0.824	0.373	-0.729	0.386
1993			0.069	0.246	0.381	0.364	0.341	0.465	0.392	0.399	0.388	0.421
1994			0.374	0.203	0.695	0.314	0.700	0.380	0.793	0.333	0.733	0.349
1995			-0.206	0.244	0.029	0.394	-0.080	0.494	0.142	0.425	0.087	0.445
1996			0.963	0.200	1.237	0.314	1.001	0.385	0.976	0.345	0.964	0.356
1997			0.975	0.187	1.298	0.278	1.202	0.329	1.083	0.291	1.048	0.305
1998			0.184	0.189	0.318	0.281	0.393	0.338	0.389	0.301	0.305	0.312
1999			-0.083	0.190	-0.319	0.299	-0.167	0.354	-0.178	0.323	-0.179	0.330
2000			-0.666	0.192	-0.949	0.308	-0.931	0.373	-1.104	0.381	-1.021	0.376
2001			-0.945	0.203	-0.971	0.329	-0.878	0.387	-0.448	0.336	-0.558	0.352
2002			-0.535	0.195	-0.848	0.306	-0.884	0.377	-0.455	0.333	-0.438	0.342
2003			-0.591	0.194	-1.015	0.302	-1.056	0.365	-0.935	0.338	-0.838	0.346
2004			-1.938	0.226	-1.476	0.329	-1.667	0.401	-1.331	0.346	-1.431	0.358
2005			-1.754	0.226	-1.583	0.404	-1.400	0.412	-1.269	0.385	-1.429	0.389
2006			-1.882	0.223	-1.887	0.382	-1.813	0.463	-1.836	0.395	-1.948	0.407
2007			-0.203	0.198	-0.202	0.316	-0.219	0.392	-0.449	0.369	-0.510	0.380
2008			-0.319	0.191	-0.475	0.288	-0.423	0.345	-0.419	0.319	-0.439	0.332
2009			-1.090	0.211	-1.265	0.349	-1.471	0.438	-1.630	0.419	-1.585	0.429
2010			-1.176	0.208	-1.406	0.391	-1.656	0.483	-2.292	0.532	-2.032	0.550
2011			0.032	0.193	0.282	0.313	0.198	0.361	0.487	0.293	0.452	0.309
2012			-0.458	0.202	-0.568	0.348	-0.670	0.453	-0.515	0.444	-0.542	0.436
2013			-0.510	0.225	-0.460	0.475	-0.489	0.526	-0.605	0.449	-0.579	0.489
2014			0.039	0.181	0.084	0.311	-0.034	0.366	0.004	0.319	-0.012	0.324
2015			0.226	0.186	0.346	0.323	0.153	0.385	0.190	0.335	0.149	0.343
2016			0.378	0.207	0.456	0.410	0.186	0.480	-0.275	0.489	-0.201	0.476
2017			-0.428	0.350	-1.369	0.630	-0.987	0.642	-0.760	0.575	-0.595	0.586

Table 2.17f—Annual deviations in survey selectivity parameter P1 as estimated by the models.

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.6		Model 17.7	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1982			1.254	0.320			0.533	0.301	0.523	0.329	0.607	0.366
1983			-0.333	0.198			-0.079	0.205	0.007	0.209	-0.035	0.211
1984			0.933	0.370			0.686	0.370	0.499	0.357	0.494	0.386
1985			-0.933	0.336			-0.220	0.198	-0.142	0.200	-0.170	0.200
1986			0.394	0.292			0.286	0.230	0.333	0.237	0.305	0.249
1987			-0.137	0.236			0.001	0.228	-0.029	0.221	-0.015	0.230
1988			1.076	0.389			0.560	0.362	0.472	0.377	0.563	0.424
1989			1.136	0.292			0.675	0.289	0.883	0.304	0.834	0.332
1990			-0.275	0.207			-0.208	0.197	-0.122	0.201	-0.127	0.202
1991			-0.087	0.217			0.027	0.208	0.010	0.210	0.004	0.214
1992			-0.775	0.255			-0.596	0.250	-0.554	0.239	-0.544	0.259
1993			-1.053	0.437			-0.320	0.193	-0.252	0.187	-0.250	0.190
1994			0.028	0.231			0.243	0.228	0.193	0.223	0.137	0.230
1995			0.555	0.272			0.437	0.253	0.548	0.290	0.481	0.297
1996			0.853	0.263			0.574	0.270	0.731	0.303	0.696	0.322
1997			-0.090	0.203			0.073	0.201	0.155	0.199	0.113	0.206
1998			0.959	0.243			0.676	0.267	0.719	0.285	0.682	0.302
1999			0.866	0.247			0.549	0.250	0.582	0.285	0.589	0.302
2000			-0.055	0.198			0.052	0.201	0.082	0.204	0.073	0.208
2001			-0.631	0.205			-0.651	0.240	-0.515	0.203	-0.580	0.252
2002			-0.136	0.221			-0.007	0.218	-0.118	0.211	-0.091	0.217
2003			-0.294	0.203			-0.254	0.198	-0.182	0.196	-0.184	0.197
2004			-0.030	0.203			0.010	0.207	0.036	0.210	0.054	0.213
2005			-0.400	0.184			-0.465	0.213	-0.627	0.288	-0.553	0.257
2006			-0.448	0.177			-0.760	0.290	-0.433	0.189	-0.394	0.191
2007			-0.637	0.186			-0.991	0.267	-0.734	0.227	-0.727	0.235
2008			-0.212	0.214			-0.167	0.200	-0.291	0.192	-0.257	0.196
2009			-0.373	0.186			-0.402	0.191	-0.287	0.183	-0.279	0.185
2010			-0.152	0.232			-0.029	0.243	-0.103	0.229	-0.059	0.240
2011			-0.305	0.200			-0.323	0.192	-0.241	0.189	-0.231	0.190
2012			-0.399	0.183			-0.403	0.194	-0.315	0.183	-0.320	0.185
2013			0.166	0.242			0.169	0.218	0.069	0.218	0.095	0.224
2014			-0.309	0.200			-0.232	0.196	-0.162	0.197	-0.168	0.198
2015			-0.238	0.224			0.063	0.255	0.094	0.244	0.071	0.253
2016			-0.318	0.207			-0.092	0.230	-1.189	0.438	-1.166	0.445
2017			0.402	0.545			0.585	0.474	0.360	0.520	0.353	0.490

Table 2.17g—Annual deviations in survey selectivity parameter P3 as estimated by the models.

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.6		Model 17.7	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1982			0.000	1.000			-0.017	0.997	-0.003	0.999	-0.002	0.999
1983			0.007	1.000			0.004	0.999	0.000	0.999	0.001	0.999
1984			0.000	1.000			-0.014	0.997	-0.004	0.999	-0.004	0.999
1985			-0.027	0.999			0.011	0.999	0.005	0.999	0.006	1.000
1986			0.000	1.000			-0.015	0.998	-0.007	0.999	-0.007	0.999
1987			0.003	1.000			0.000	0.999	0.001	0.999	0.001	0.999
1988			0.000	1.000			-0.017	0.997	-0.004	0.999	-0.003	0.999
1989			0.000	1.000			-0.014	0.997	0.000	1.000	0.000	1.000
1990			0.007	1.000			0.011	0.999	0.005	0.999	0.005	0.999
1991			0.002	1.000			-0.001	0.998	0.000	0.999	0.000	0.999
1992			-0.009	1.000			0.017	1.000	0.008	1.000	0.008	1.000
1993			-0.061	0.999			0.014	0.999	0.008	1.000	0.008	1.000
1994			0.000	1.000			-0.013	0.998	-0.006	0.999	-0.005	0.999
1995			0.000	1.000			-0.018	0.997	-0.003	0.999	-0.005	0.999
1996			0.000	1.000			-0.017	0.997	-0.001	1.000	-0.001	0.999
1997			0.002	1.000			-0.004	0.998	-0.005	0.999	-0.004	0.999
1998			0.000	1.000			-0.014	0.997	-0.001	1.000	-0.001	0.999
1999			0.000	1.000			-0.017	0.997	-0.002	0.999	-0.002	0.999
2000			0.001	1.000			-0.003	0.998	-0.003	0.999	-0.003	0.999
2001			0.000	1.000			0.017	1.000	0.009	1.000	0.007	1.000
2002			0.003	1.000			0.000	0.999	0.005	0.999	0.004	0.999
2003			0.007	1.000			0.012	0.999	0.007	1.000	0.007	1.000
2004			0.001	1.000			0.000	0.998	-0.002	0.999	-0.002	0.999
2005			0.007	1.000			0.017	1.000	0.005	1.000	0.007	1.000
2006			0.006	1.000			0.014	1.000	0.010	1.000	0.010	1.000
2007			0.000	1.000			0.001	1.000	0.000	1.000	0.000	1.000
2008			0.005	1.000			0.009	0.999	0.009	1.000	0.008	1.000
2009			0.007	1.000			0.016	1.000	0.009	1.000	0.008	1.000
2010			0.004	1.000			0.002	0.999	0.004	0.999	0.002	0.999
2011			0.007	1.000			0.015	0.999	0.008	1.000	0.008	1.000
2012			0.007	1.000			0.016	1.000	0.009	1.000	0.009	1.000
2013			0.000	1.000			-0.009	0.998	-0.003	0.999	-0.004	0.999
2014			0.007	1.000			0.011	0.999	0.006	1.000	0.006	1.000
2015			0.006	1.000			-0.004	0.998	-0.004	0.999	-0.003	0.999
2016			0.007	1.000			0.005	0.999	-0.055	0.998	-0.052	0.998
2017			0.000	1.000			-0.016	0.997	-0.006	0.999	-0.007	0.999

Table 2.17h—Annual deviations in length at age 1.5 and ln(Q) as estimated by Models 17.6 and 17.7.

	Length at age 1.5					ln(survey catchability)			
	Model 17.6		Model 17.7			Model 17.6		Model 17.7	
Year	Est.	SD	Est.	SD	Year	Est.	SD	Est.	SD
1981	-0.697	0.410	-0.454	0.465	1982	0.919	0.665	1.026	0.683
1982	-0.822	0.254	-0.721	0.286	1983	1.084	0.787	1.059	0.800
1983	0.894	0.410	0.869	0.466	1984	0.331	0.709	0.401	0.724
1984	0.360	0.217	0.381	0.237	1985	0.629	0.815	0.669	0.826
1985	-1.287	0.359	-1.154	0.414	1986	0.723	0.763	0.829	0.772
1986	0.189	0.239	0.168	0.268	1987	-0.012	0.657	0.090	0.670
1987	-0.043	0.325	-0.029	0.369	1988	-0.591	0.678	-0.565	0.688
1988	-0.168	0.305	-0.101	0.350	1989	-2.241	0.660	-2.368	0.670
1989	-0.840	0.236	-0.780	0.264	1990	-1.907	0.735	-2.004	0.750
1990	-0.024	0.246	0.004	0.276	1991	-1.473	0.766	-1.502	0.777
1991	0.498	0.220	0.511	0.241	1992	-0.800	0.789	-0.794	0.797
1992	-0.029	0.211	0.002	0.229	1993	0.704	0.800	0.707	0.810
1993	0.641	0.297	0.673	0.339	1994	2.517	0.800	2.523	0.805
1994	0.380	0.230	0.451	0.248	1995	2.214	0.751	2.229	0.758
1995	0.431	0.290	0.422	0.329	1996	1.473	0.828	1.479	0.835
1996	0.272	0.223	0.283	0.246	1997	0.481	0.830	0.488	0.839
1997	-0.294	0.292	-0.301	0.331	1998	-0.110	0.729	-0.023	0.737
1998	-0.175	0.228	-0.160	0.248	1999	-0.392	0.729	-0.350	0.737
1999	-0.912	0.234	-0.859	0.259	2000	-0.683	0.730	-0.726	0.740
2000	0.616	0.219	0.636	0.241	2001	0.457	0.773	0.433	0.780
2001	0.738	0.233	0.697	0.255	2002	-0.476	0.750	-0.438	0.758
2002	0.980	0.217	0.978	0.236	2003	-0.709	0.802	-0.655	0.809
2003	0.541	0.261	0.513	0.298	2004	-1.269	0.727	-1.180	0.737
2004	1.349	0.221	1.260	0.243	2005	-1.209	0.832	-1.137	0.841
2005	-1.062	0.234	-0.972	0.259	2006	-1.705	0.664	-1.673	0.681
2006	-1.210	0.206	-1.155	0.223	2007	-1.364	0.918	-1.279	0.926
2007	-1.365	0.259	-1.290	0.290	2008	-1.888	0.770	-1.776	0.779
2008	-1.614	0.210	-1.552	0.228	2009	-1.354	0.740	-1.277	0.755
2009	-0.624	0.323	-0.641	0.369	2010	0.040	0.816	0.086	0.823
2010	0.346	0.205	0.376	0.220	2011	0.454	0.747	0.441	0.758
2011	-1.864	0.236	-1.784	0.264	2012	0.435	0.749	0.379	0.761
2012	0.190	0.263	0.194	0.299	2013	0.492	0.864	0.423	0.869
2013	-0.246	0.215	-0.238	0.235	2014	1.363	0.830	1.241	0.839
2014	0.307	0.340	0.325	0.393	2015	1.589	0.837	1.442	0.848
2015	1.953	0.211	1.878	0.231	2016	0.959	0.858	0.768	0.872
2016	1.857	0.267	1.791	0.321	2017	-0.173	0.904	-0.372	0.917

Table 2.18—Annual fishing mortality rates as estimated by the models.

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.6		Model 17.7	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	0.284	0.109	0.813	0.209	0.575	0.273	0.494	0.137	0.501	0.160	0.491	0.143
1978	0.370	0.148	0.708	0.168	0.620	0.296	1.266	0.708	1.197	0.673	1.261	0.724
1979	0.290	0.113	0.320	0.041	0.328	0.108	0.522	0.180	0.527	0.180	0.534	0.189
1980	0.321	0.106	0.367	0.066	0.368	0.133	0.509	0.183	0.552	0.207	0.541	0.205
1981	0.201	0.039	0.151	0.015	0.140	0.027	0.179	0.037	0.173	0.039	0.182	0.041
1982	0.104	0.013	0.275	0.050	0.192	0.050	0.222	0.060	0.231	0.071	0.235	0.071
1983	0.118	0.011	0.314	0.039	0.200	0.037	0.229	0.041	0.237	0.049	0.241	0.049
1984	0.160	0.013	0.407	0.043	0.251	0.035	0.286	0.042	0.286	0.041	0.296	0.042
1985	0.177	0.014	0.272	0.016	0.209	0.019	0.254	0.025	0.241	0.020	0.252	0.023
1986	0.180	0.013	0.239	0.014	0.204	0.017	0.247	0.025	0.242	0.021	0.247	0.024
1987	0.191	0.012	0.249	0.013	0.224	0.019	0.272	0.028	0.272	0.026	0.272	0.027
1988	0.255	0.016	0.267	0.013	0.240	0.018	0.273	0.023	0.271	0.021	0.274	0.022
1989	0.214	0.012	0.326	0.020	0.265	0.024	0.283	0.029	0.287	0.028	0.290	0.030
1990	0.239	0.012	0.369	0.017	0.321	0.024	0.352	0.031	0.363	0.032	0.363	0.033
1991	0.421	0.023	0.473	0.018	0.425	0.024	0.467	0.031	0.456	0.027	0.467	0.030
1992	0.513	0.035	0.463	0.018	0.460	0.028	0.502	0.037	0.503	0.033	0.505	0.036
1993	0.393	0.027	0.283	0.013	0.324	0.026	0.336	0.031	0.353	0.032	0.346	0.032
1994	0.420	0.025	0.361	0.013	0.390	0.028	0.404	0.032	0.426	0.035	0.417	0.034
1995	0.532	0.031	0.487	0.015	0.507	0.029	0.524	0.032	0.540	0.033	0.538	0.034
1996	0.497	0.031	0.621	0.021	0.654	0.045	0.662	0.047	0.690	0.050	0.683	0.050
1997	0.540	0.033	0.770	0.028	0.752	0.058	0.814	0.066	0.859	0.071	0.844	0.071
1998	0.429	0.028	0.606	0.018	0.560	0.033	0.631	0.039	0.638	0.041	0.642	0.041
1999	0.438	0.030	0.620	0.020	0.567	0.036	0.637	0.043	0.636	0.042	0.649	0.044
2000	0.424	0.030	0.702	0.028	0.681	0.053	0.756	0.063	0.766	0.062	0.776	0.065
2001	0.338	0.021	0.485	0.022	0.459	0.041	0.515	0.051	0.559	0.058	0.558	0.059
2002	0.409	0.024	0.465	0.017	0.439	0.028	0.475	0.033	0.479	0.032	0.492	0.035
2003	0.445	0.026	0.445	0.015	0.445	0.027	0.483	0.032	0.491	0.031	0.493	0.033
2004	0.422	0.023	0.383	0.010	0.384	0.018	0.414	0.020	0.418	0.020	0.417	0.020
2005	0.430	0.022	0.445	0.010	0.423	0.017	0.459	0.020	0.454	0.019	0.461	0.019
2006	0.494	0.026	0.560	0.013	0.545	0.023	0.571	0.027	0.568	0.026	0.579	0.028
2007	0.483	0.028	0.675	0.020	0.662	0.039	0.676	0.044	0.669	0.045	0.687	0.048
2008	0.599	0.038	0.713	0.025	0.726	0.048	0.725	0.054	0.704	0.052	0.730	0.057
2009	0.747	0.056	0.793	0.026	0.858	0.062	0.844	0.064	0.804	0.056	0.830	0.060
2010	0.580	0.043	0.856	0.031	0.963	0.082	1.015	0.092	0.980	0.086	0.995	0.091
2011	0.594	0.040	1.116	0.054	1.100	0.146	1.233	0.175	1.507	0.218	1.465	0.211
2012	0.567	0.041	1.051	0.036	0.875	0.082	1.084	0.099	1.149	0.105	1.186	0.112
2013	0.468	0.033	0.564	0.014	0.486	0.031	0.559	0.030	0.535	0.022	0.553	0.027
2014	0.546	0.045	0.818	0.023	0.691	0.055	0.804	0.056	0.766	0.049	0.793	0.053
2015	0.483	0.042	0.863	0.046	0.702	0.089	0.853	0.100	0.798	0.087	0.822	0.094
2016	0.430	0.039	0.755	0.064	0.582	0.082	0.773	0.105	0.684	0.079	0.712	0.091
2017	0.365	0.036	0.745	0.100	0.528	0.076	0.940	0.177	0.968	0.159	0.973	0.189

Table 2.19—Summary of key management reference points from the standard projection model, except that the last six rows are from SS). All biomass figures are in t. Color scale: red = row minimum, green = row maximum.

Quantity	M16.6	M17.1	M17.2	M17.3	M17.6	M17.7
B100%	593,000	644,000	548,000	622,000	633,000	644,000
B40%	237,000	258,000	219,000	249,000	253,000	258,000
B35%	207,000	226,000	192,000	218,000	221,000	225,000
B(2018)	264,000	173,000	217,000	146,000	142,000	145,000
B(2019)	248,000	200,000	211,000	179,000	177,000	181,000
B(2018)/B100%	0.45	0.27	0.40	0.24	0.22	0.23
B(2019)/B100%	0.42	0.31	0.39	0.29	0.28	0.28
F40%	0.31	0.25	0.32	0.26	0.26	0.26
F35%	0.38	0.31	0.38	0.31	0.32	0.31
maxFABC(2018)	0.31	0.16	0.31	0.15	0.14	0.14
maxFABC(2019)	0.31	0.19	0.30	0.18	0.18	0.18
maxABC(2018)	201,000	75,500	172,000	59,100	57,300	57,600
maxABC(2019)	170,000	92,400	148,000	79,900	79,200	80,300
FOFL(2018)	0.38	0.20	0.38	0.18	0.17	0.17
FOFL(2019)	0.38	0.23	0.37	0.22	0.22	0.21
OFL(2018)	238,000	89,600	202,000	70,300	68,400	68,700
OFL(2019)	201,000	109,000	173,000	94,500	93,900	95,100
Pr(maxABC(2018)>truOFL(2018))	0.03	0.11	0.05	0.21	0.14	0.17
Pr(maxABC(2019)>truOFL(2019))	0.09	0.12	0.23	0.22	0.13	0.15
Pr(B(2018)<B20%)	0.00	0.00	0.00	0.13	0.09	0.11
Pr(B(2019)<B20%)	0.00	0.00	0.00	0.00	0.00	0.00
Pr(B(2020)<B20%)	0.00	0.00	0.00	0.00	0.00	0.00
Pr(B(2021)<B20%)	0.00	0.00	0.00	0.00	0.00	0.00

Legend:

B100% = equilibrium unfished spawning biomass
B40% = 40% of B100% (the inflection point of the harvest control rules in Tier 3)
B35% = 35% of B100% (the BMSY proxy for Tier 3)
B(year) = projected spawning biomass for year
B(year)/B100% = ratio of spawning biomass to B100%
F40% = fishing mortality that reduces equilibrium spawning per recruit to 40% of unfished
F35% = fishing mortality that reduces equilibrium spawning per recruit to 35% of unfished
maxFABC(year) = maximum permissible ABC fishing mortality rate under Tier 3
maxABC(year) = maximum permissible ABC under Tier 3
FOFL(year) = OFL fishing mortality rate under Tier 3
OFL(year) = OFL under Tier 3
Pr(maxABC(year)>truOFL(year)) = probability that maxABC is greater than the "true" OFL
Pr(B(year)<B20%) = probability that spawning biomass is less than 20% of unfished

Table 2.20—Schedules of length (cm) at age as defined by parameter estimates from Model 17.2.

	Begin-year length		Mid-year length	
Age	Mean	SD	Mean	SD
0	0.001	3.488	5.484	3.488
1	10.968	3.488	16.451	3.488
2	24.660	3.956	32.043	4.378
3	38.721	4.759	44.780	5.105
4	50.290	5.420	55.307	5.706
5	59.880	5.967	64.051	6.205
6	67.859	6.423	71.335	6.621
7	74.511	6.802	77.413	6.968
8	80.066	7.120	82.491	7.258
9	84.709	7.385	86.738	7.500
10	88.593	7.606	90.291	7.703
11	91.845	7.792	93.266	7.873
12	94.567	7.947	95.758	8.015
13	96.848	8.078	97.845	8.135
14	98.758	8.187	99.594	8.234
15	100.360	8.278	101.060	8.318
16	101.702	8.355	102.289	8.388
17	102.827	8.419	103.320	8.447
18	103.771	8.473	104.183	8.496
19	104.562	8.518	104.908	8.538
20	105.949	8.753	106.179	8.753

Table 2.21—Schedules of selectivity by fleet, year, and age as estimated by Model 17.2.

Fleet	Year	0	1	2	3	4	5	6	7	8	9	10	11	12
Fish.	1977	0.000	0.000	0.005	0.067	0.365	0.877	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1978	0.000	0.000	0.003	0.054	0.349	0.888	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1979	0.000	0.000	0.008	0.111	0.545	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1980	0.000	0.000	0.007	0.075	0.381	0.881	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1981	0.000	0.009	0.075	0.319	0.756	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1982	0.000	0.000	0.001	0.022	0.169	0.598	0.991	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1983	0.000	0.000	0.003	0.032	0.172	0.529	0.930	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1984	0.000	0.002	0.012	0.059	0.205	0.494	0.839	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1985	0.000	0.000	0.003	0.054	0.345	0.881	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1986	0.000	0.001	0.010	0.076	0.323	0.764	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1987	0.000	0.000	0.006	0.055	0.275	0.726	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1988	0.000	0.007	0.048	0.204	0.543	0.912	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1989	0.000	0.003	0.018	0.083	0.267	0.594	0.916	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1990	0.000	0.001	0.007	0.038	0.154	0.421	0.785	0.997	1.000	1.000	1.000	1.000	1.000
Fish.	1991	0.000	0.000	0.006	0.065	0.337	0.830	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1992	0.000	0.000	0.002	0.053	0.412	0.973	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1993	0.000	0.001	0.012	0.105	0.442	0.910	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1994	0.000	0.001	0.015	0.108	0.420	0.872	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1995	0.000	0.000	0.008	0.090	0.434	0.927	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1996	0.000	0.001	0.007	0.051	0.224	0.596	0.955	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1997	0.000	0.001	0.009	0.064	0.260	0.644	0.973	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1998	0.000	0.000	0.005	0.054	0.294	0.776	0.999	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	1999	0.000	0.000	0.004	0.057	0.360	0.899	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2000	0.000	0.000	0.000	0.017	0.213	0.801	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2001	0.000	0.000	0.001	0.025	0.273	0.876	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2002	0.000	0.000	0.002	0.055	0.408	0.965	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2003	0.000	0.000	0.001	0.040	0.358	0.949	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2004	0.000	0.000	0.001	0.049	0.463	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2005	0.000	0.000	0.001	0.058	0.515	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2006	0.000	0.000	0.000	0.022	0.345	0.991	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2007	0.000	0.000	0.001	0.017	0.159	0.623	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2008	0.000	0.000	0.001	0.020	0.194	0.718	0.999	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2009	0.000	0.000	0.000	0.013	0.199	0.819	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2010	0.000	0.000	0.000	0.005	0.120	0.689	0.999	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2011	0.000	0.000	0.001	0.017	0.138	0.528	0.964	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2012	0.000	0.000	0.000	0.014	0.165	0.678	0.999	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2013	0.000	0.000	0.008	0.108	0.537	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2014	0.000	0.000	0.004	0.049	0.297	0.801	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2015	0.000	0.000	0.003	0.039	0.234	0.694	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2016	0.000	0.000	0.004	0.047	0.258	0.717	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fish.	2017	0.000	0.000	0.000	0.006	0.132	0.711	0.999	1.000	1.000	1.000	1.000	1.000	1.000
Surv.	All	0.000	0.405	0.897	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 2.22—Mid-year weight (kg) at age as defined by input weight-at-length parameters and length-at-age parameters estimated by Model 17.2.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	0.05	0.38	1.08	2.09	3.33	4.67	6.05	7.40	8.68	9.86	10.92	11.87	12.71	13.44	14.07	14.61	15.06	15.45	15.77	16.35
1978	0.04	0.35	1.04	2.09	3.38	4.83	6.32	7.79	9.20	10.51	11.69	12.76	13.70	14.52	15.22	15.83	16.35	16.79	17.15	17.81
1979	0.05	0.40	1.11	2.13	3.37	4.71	6.07	7.40	8.65	9.81	10.85	11.78	12.60	13.31	13.92	14.45	14.89	15.27	15.58	16.14
1980	0.05	0.37	1.06	2.06	3.27	4.60	5.96	7.29	8.55	9.72	10.77	11.71	12.53	13.25	13.87	14.40	14.85	15.24	15.56	16.13
1981	0.05	0.38	1.07	2.06	3.25	4.56	5.88	7.18	8.40	9.53	10.55	11.45	12.25	12.95	13.55	14.06	14.49	14.86	15.17	15.72
1982	0.06	0.41	1.14	2.18	3.43	4.77	6.14	7.47	8.72	9.86	10.90	11.82	12.63	13.33	13.94	14.46	14.90	15.27	15.58	16.14
1983	0.05	0.39	1.12	2.18	3.46	4.86	6.30	7.70	9.02	10.24	11.35	12.33	13.20	13.95	14.61	15.16	15.64	16.04	16.37	16.97
1984	0.07	0.43	1.13	2.07	3.15	4.30	5.45	6.55	7.57	8.50	9.34	10.08	10.73	11.29	11.77	12.18	12.52	12.82	13.07	13.50
1985	0.05	0.38	1.10	2.16	3.47	4.90	6.38	7.83	9.20	10.47	11.62	12.65	13.56	14.35	15.03	15.62	16.12	16.54	16.89	17.52
1986	0.04	0.36	1.07	2.14	3.46	4.93	6.45	7.95	9.38	10.70	11.91	12.99	13.94	14.77	15.49	16.11	16.63	17.08	17.45	18.11
1987	0.05	0.38	1.10	2.15	3.42	4.82	6.24	7.64	8.97	10.19	11.29	12.28	13.15	13.91	14.56	15.12	15.59	16.00	16.33	16.93
1988	0.04	0.37	1.10	2.21	3.57	5.09	6.66	8.21	9.69	11.06	12.31	13.43	14.42	15.28	16.02	16.66	17.20	17.66	18.05	18.73
1989	0.05	0.39	1.14	2.25	3.62	5.13	6.69	8.22	9.68	11.02	12.25	13.34	14.30	15.14	15.87	16.49	17.02	17.46	17.84	18.51
1990	0.05	0.41	1.16	2.24	3.54	4.95	6.40	7.81	9.14	10.37	11.48	12.47	13.34	14.09	14.74	15.30	15.78	16.18	16.51	17.11
1991	0.05	0.39	1.10	2.11	3.32	4.63	5.97	7.27	8.49	9.62	10.64	11.55	12.35	13.04	13.64	14.15	14.58	14.95	15.25	15.80
1992	0.05	0.37	1.04	2.02	3.20	4.49	5.81	7.10	8.31	9.43	10.44	11.35	12.14	12.83	13.43	13.94	14.37	14.74	15.05	15.59
1993	0.06	0.43	1.19	2.28	3.59	5.00	6.44	7.83	9.15	10.36	11.45	12.43	13.28	14.02	14.66	15.21	15.67	16.07	16.40	16.98
1994	0.05	0.39	1.09	2.11	3.35	4.69	6.07	7.41	8.68	9.85	10.91	11.86	12.69	13.41	14.03	14.56	15.02	15.40	15.72	16.29
1995	0.05	0.37	1.07	2.11	3.37	4.76	6.19	7.59	8.91	10.14	11.25	12.25	13.12	13.89	14.55	15.11	15.59	15.99	16.34	16.94
1996	0.06	0.44	1.17	2.18	3.36	4.62	5.89	7.11	8.25	9.30	10.24	11.07	11.80	12.43	12.97	13.44	13.83	14.16	14.44	14.94
1997	0.05	0.37	1.05	2.02	3.18	4.44	5.73	6.98	8.16	9.25	10.23	11.11	11.88	12.55	13.12	13.61	14.03	14.39	14.68	15.21
1998	0.05	0.38	1.05	2.01	3.16	4.41	5.68	6.91	8.07	9.14	10.10	10.96	11.72	12.37	12.94	13.42	13.83	14.18	14.47	14.98
1999	0.05	0.39	1.09	2.10	3.30	4.60	5.93	7.21	8.43	9.54	10.55	11.45	12.24	12.92	13.51	14.02	14.45	14.81	15.11	15.65
2000	0.06	0.41	1.15	2.21	3.47	4.85	6.24	7.60	8.88	10.06	11.12	12.07	12.90	13.63	14.25	14.78	15.24	15.62	15.94	16.51
2001	0.06	0.42	1.14	2.16	3.38	4.68	6.01	7.29	8.49	9.59	10.59	11.47	12.25	12.92	13.50	14.00	14.42	14.77	15.07	15.60
2002	0.05	0.39	1.11	2.13	3.36	4.69	6.06	7.38	8.63	9.78	10.82	11.75	12.56	13.27	13.88	14.40	14.85	15.22	15.54	16.09
2003	0.05	0.38	1.07	2.09	3.33	4.69	6.08	7.44	8.73	9.92	10.99	11.95	12.80	13.54	14.17	14.71	15.18	15.57	15.90	16.48
2004	0.05	0.40	1.11	2.12	3.34	4.65	5.99	7.29	8.51	9.64	10.66	11.56	12.36	13.05	13.64	14.15	14.58	14.95	15.26	15.80
2005	0.05	0.38	1.09	2.13	3.38	4.75	6.16	7.53	8.83	10.02	11.11	12.08	12.93	13.67	14.31	14.85	15.32	15.71	16.04	16.63
2006	0.05	0.39	1.10	2.12	3.36	4.70	6.07	7.41	8.67	9.83	10.88	11.82	12.64	13.36	13.98	14.50	14.95	15.33	15.65	16.21
2007	0.05	0.39	1.11	2.15	3.41	4.79	6.19	7.56	8.86	10.06	11.14	12.10	12.95	13.69	14.33	14.87	15.34	15.73	16.06	16.64
2008	0.06	0.42	1.14	2.15	3.35	4.65	5.96	7.22	8.41	9.51	10.49	11.36	12.13	12.80	13.37	13.86	14.27	14.63	14.92	15.44
2009	0.05	0.38	1.08	2.12	3.39	4.78	6.21	7.62	8.94	10.17	11.28	12.28	13.15	13.91	14.57	15.13	15.61	16.02	16.36	16.96
2010	0.05	0.39	1.09	2.10	3.31	4.63	5.98	7.29	8.53	9.67	10.70	11.62	12.42	13.12	13.73	14.25	14.68	15.06	15.37	15.92
2011	0.05	0.38	1.06	2.06	3.25	4.56	5.89	7.18	8.41	9.54	10.56	11.47	12.27	12.97	13.57	14.08	14.52	14.89	15.20	15.74
2012	0.05	0.39	1.08	2.06	3.22	4.47	5.74	6.97	8.13	9.20	10.16	11.01	11.76	12.41	12.97	13.45	13.85	14.20	14.49	15.00
2013	0.05	0.36	1.05	2.04	3.26	4.60	5.97	7.31	8.59	9.76	10.83	11.78	12.61	13.34	13.97	14.51	14.97	15.35	15.68	16.26
2014	0.04	0.34	1.01	2.00	3.22	4.56	5.95	7.32	8.62	9.82	10.92	11.89	12.76	13.51	14.16	14.71	15.19	15.59	15.92	16.52
2015	0.04	0.33	0.98	1.95	3.14	4.47	5.83	7.18	8.45	9.64	10.71	11.68	12.53	13.27	13.91	14.45	14.92	15.31	15.65	16.24
2016	0.04	0.34	1.01	1.99	3.21	4.55	5.94	7.30	8.59	9.79	10.88	11.85	12.71	13.46	14.11	14.66	15.13	15.53	15.87	16.46
2017	0.05	0.38	1.08	2.09	3.33	4.67	6.05	7.40	8.68	9.86	10.92	11.87	12.71	13.44	14.07	14.61	15.06	15.45	15.77	16.35

Table 2.23—Sample, age-length key integrated, and model weights (kg) at age for the fishery, 2013-2016. See text for details.

	2013				2014				2015				2016			
Age	N	Sample	ALK-int.	M17.2	N	Sample	ALK-int.	M17.2	N	Sample	ALK-int.	M17.2	N	Sample	ALK-int.	M17.2
2	14	0.69	0.81	0.36	11	0.55	0.59	0.34	3	0.62	0.59	0.33	3	0.83	0.84	0.34
3	157	1.50	1.51	1.05	139	1.35	1.38	1.01	69	1.42	1.40	0.98	90	1.41	1.34	1.01
4	115	2.21	2.20	2.04	306	2.32	2.39	2.00	323	2.25	2.23	1.95	196	2.03	2.14	1.99
5	487	3.23	3.27	3.26	186	3.28	3.24	3.22	347	3.19	3.22	3.14	397	3.19	3.21	3.21
6	161	4.40	4.42	4.60	251	4.45	4.40	4.56	128	4.31	4.36	4.47	199	4.46	4.42	4.55
7	42	5.19	5.37	5.97	70	5.39	5.52	5.95	88	5.32	5.41	5.83	52	5.62	5.85	5.94
8	8	6.97	6.57	7.31	21	6.77	6.41	7.32	24	6.11	5.97	7.18	27	6.59	6.37	7.30
9	3	7.60	10.03	8.59	1	6.62		8.62	9	8.71	7.21	8.45				8.59
10				9.76	1	11.00	9.28	9.82				9.64	1	12.06	9.75	9.79
11				10.83				10.92	2	7.82	7.87	10.71				10.88
12	1	10.06	12.78	11.78	1	14.82	12.43	11.89	1	7.76	7.97	11.68				11.85

Table 2.24—Time series of EBS Pacific cod age 0+ biomass, age 3+ biomass, female spawning biomass (t), and standard deviation of spawning biomass ("SB SD") as estimated by the final models in last year's and this year's assessments. Spawning biomasses listed for 2017 under last year's assessment and for 2018 under this year's assessment represent output from the standard projection model.

	Last year's assessment				This year's assessment			
Year	Age 0+	Age 3+	Spawn.	SB SD	Age 0+	Age 3+	Spawn.	SB SD
1977	238,614	223,326	70,865	24,355	141,375	132,096	29,341	11,232
1978	256,462	223,849	69,420	24,426	168,018	138,198	32,826	10,402
1979	370,312	265,037	70,557	23,663	256,991	189,601	39,601	10,596
1980	570,378	505,965	92,073	24,019	402,847	338,764	58,551	11,810
1981	827,796	765,577	145,981	25,966	606,904	545,185	98,042	14,413
1982	1,106,220	1,073,460	247,693	31,990	842,699	808,946	172,778	19,847
1983	1,237,100	1,210,540	350,393	36,843	976,294	940,915	250,527	24,792
1984	1,190,670	1,090,430	371,180	33,482	985,062	892,040	276,388	24,278
1985	1,276,680	1,246,900	420,649	35,009	1,077,610	1,043,670	323,008	26,773
1986	1,269,260	1,194,720	406,577	31,529	1,098,950	1,032,120	326,245	25,131
1987	1,291,840	1,259,500	395,026	27,811	1,145,050	1,102,990	330,965	22,809
1988	1,315,560	1,296,100	417,063	26,771	1,190,340	1,166,230	358,690	22,310
1989	1,200,380	1,189,160	402,900	24,351	1,108,230	1,091,340	355,509	20,446
1990	1,016,270	982,785	365,345	20,398	962,763	927,552	325,846	17,126
1991	833,926	762,154	292,052	15,778	807,681	743,141	266,739	13,030
1992	719,402	665,888	207,754	12,834	697,177	644,971	197,288	10,337
1993	830,487	780,122	192,784	12,988	790,695	745,228	187,507	10,186
1994	859,959	780,070	200,617	12,101	801,243	726,559	192,052	9,083
1995	913,253	881,497	222,817	12,672	830,061	799,990	205,390	8,795
1996	912,478	876,930	223,066	13,106	800,727	768,872	195,193	8,439
1997	785,469	753,258	214,083	12,595	668,675	639,633	176,697	7,662
1998	685,519	616,558	188,334	12,288	558,275	498,456	146,132	7,059
1999	717,289	681,281	182,377	12,549	576,823	531,473	134,749	7,098
2000	777,932	737,965	189,306	13,136	642,192	594,614	136,950	7,837
2001	792,518	719,162	196,919	12,876	688,964	614,335	144,505	8,494
2002	826,840	777,016	210,966	12,865	747,388	701,027	165,986	9,198
2003	825,474	802,516	211,567	12,515	756,937	736,814	180,102	9,381
2004	801,338	769,480	215,587	11,985	732,691	698,749	191,654	8,985
2005	727,157	701,947	213,810	11,370	660,547	631,542	190,519	7,944
2006	629,130	605,741	189,101	10,217	572,235	546,501	164,038	6,468
2007	556,424	518,554	160,504	9,330	509,888	474,325	135,900	5,501
2008	566,147	466,989	137,495	8,453	514,677	438,183	117,192	4,785
2009	635,332	585,479	127,669	8,726	557,345	506,521	110,754	4,748
2010	785,604	665,880	139,011	9,933	666,310	570,634	116,703	5,430
2011	949,486	925,047	185,652	12,560	784,432	762,403	146,886	6,966
2012	1,033,000	944,495	224,467	15,964	828,447	749,234	170,669	8,773
2013	1,080,380	978,122	258,446	19,443	842,213	755,706	186,310	10,468
2014	1,136,650	1,088,360	273,303	22,390	869,052	819,349	191,217	11,903
2015	1,185,890	1,101,870	284,191	25,368	898,681	826,612	191,663	14,245
2016	1,324,040	1,308,360	337,455	31,215	949,989	935,410	217,782	18,300
2017	1,255,550	1,233,720	326,592	35,425	927,325	909,280	240,537	22,752
2018					806,562	789,609	217,174	25,229

Table 2.25—Time series of age 0 recruitment (1000s of fish), with standard deviations, as estimated by the final models in last year's and this year's assessments.

	Last year's values		This year's values	
Year	Recruits	Std. dev.	Recruits	Std. dev.
1977	1,144,750	291,512	709,009	151,161
1978	728,494	206,031	738,647	151,564
1979	727,199	136,045	736,481	128,330
1980	338,565	59,776	340,380	62,839
1981	185,901	34,070	305,836	52,610
1982	982,656	119,243	917,716	133,642
1983	251,708	42,442	323,258	55,644
1984	966,891	112,849	865,802	120,769
1985	367,518	50,174	490,326	69,675
1986	243,353	34,115	302,598	43,117
1987	101,666	20,766	171,289	26,816
1988	277,455	37,886	313,127	41,811
1989	763,595	86,361	692,334	84,659
1990	625,925	71,589	628,247	76,276
1991	415,703	51,114	375,651	47,980
1992	928,333	95,226	885,614	102,624
1993	368,560	43,036	358,291	45,439
1994	319,622	37,706	290,895	36,100
1995	289,947	35,339	270,908	34,219
1996	798,434	85,113	684,958	82,954
1997	375,721	43,067	483,957	60,553
1998	348,699	38,932	438,919	54,715
1999	727,777	72,993	762,005	89,577
2000	556,135	56,753	531,465	63,638
2001	246,470	27,034	211,212	26,847
2002	332,437	34,816	357,273	41,552
2003	279,904	29,449	329,435	38,619
2004	234,562	25,592	267,521	31,910
2005	317,928	34,223	328,612	39,058
2006	1,023,420	106,295	782,694	92,272
2007	447,919	51,147	504,369	64,781
2008	1,420,070	153,244	1,157,520	137,463
2009	183,956	27,608	165,891	26,195
2010	856,424	96,804	790,473	100,603
2011	1,269,710	147,292	1,080,040	143,033
2012	528,928	66,385	579,628	82,919
2013	1,200,650	141,608	1,048,440	143,827
2014	168,227	29,891	182,381	34,259
2015	197,947	44,945	210,383	37,817
2016			143,660	35,239
Average	552,389		518,931	

Table 2.26—Numbers (1000s) at age as estimated by Model 17.2.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	709009	228662	32617	59826	21390	8069	3734	1779	848	392	175	76	33	14	6	3	1	0	0	0	0
1978	738647	482657	155644	22136	39191	11802	3317	1431	682	325	150	67	29	13	5	2	1	0	0	0	0
1979	736481	502832	328550	105736	14571	21491	4633	1215	524	250	119	55	25	11	5	2	1	0	0	0	0
1980	340380	501364	342279	223049	69408	8294	10552	2271	595	257	122	58	27	12	5	2	1	0	0	0	0
1981	305836	231715	341271	232426	147692	41068	4084	4974	1071	281	121	58	27	13	6	2	1	0	0	0	0
1982	917716	208201	157540	229914	151335	90471	24316	2418	2945	634	166	72	34	16	8	3	1	1	0	0	0
1983	323258	624744	141734	107219	155849	99742	54918	13690	1359	1655	356	93	40	19	9	4	2	1	0	0	0
1984	865802	220061	425283	96421	72523	102500	61078	31037	7629	757	922	199	52	22	11	5	2	1	0	0	0
1985	490326	589401	149749	288646	64669	46898	61625	33674	16433	4040	401	488	105	28	12	6	3	1	1	0	0
1986	302598	333794	401233	101870	194281	40958	26555	34040	18600	9077	2231	221	270	58	15	7	3	1	1	0	0
1987	171289	205996	227202	272600	68288	123819	23856	14738	18891	10322	5038	1238	123	150	32	8	4	2	1	0	0
1988	313127	116606	140224	154475	183320	43702	71611	12975	8016	10275	5614	2740	674	67	81	18	5	2	1	0	0
1989	692334	213164	79255	94369	100149	109576	23906	38362	6950	4294	5504	3007	1468	361	36	44	9	2	1	1	0
1990	628247	471311	145019	53699	62841	63526	63754	12771	20046	3632	2244	2876	1571	767	189	19	23	5	1	1	0
1991	375651	427683	320776	98518	36108	40715	37775	33732	6312	9899	1793	1108	1420	776	379	93	9	11	2	1	1
1992	885614	255726	291115	217823	65244	21301	19479	16817	15015	2810	4406	798	493	632	345	169	41	4	5	1	1
1993	358291	602883	174084	197993	144740	36752	9266	8369	7225	6451	1207	1893	343	212	272	148	72	18	2	2	1
1994	290895	243909	410324	118036	130260	85392	18631	4562	4120	3557	3176	594	932	169	104	134	73	36	9	1	1
1995	270908	198028	165974	277723	77036	75263	41367	8585	2102	1898	1639	1463	274	429	78	48	62	34	16	4	1
1996	684958	184421	134785	112516	180628	42077	32008	16957	3519	862	778	672	600	112	176	32	20	25	14	7	2
1997	483957	466282	125500	91345	74106	106218	19395	11667	6001	1245	305	275	238	212	40	62	11	7	9	5	3
1998	438919	329450	317223	84828	59279	41505	44548	6351	3745	1926	400	98	88	76	68	13	20	4	2	3	3
1999	762005	298793	224248	215379	56040	34238	18297	17328	2469	1456	749	155	38	34	30	26	5	8	1	1	2
2000	531465	518733	203393	152353	141977	31099	13998	7063	6688	953	562	289	60	15	13	11	10	2	3	1	1
2001	211212	361792	353124	138420	102510	83606	12268	4824	2434	2305	328	194	100	21	5	5	4	4	1	1	1
2002	357273	143783	246290	240311	93134	61564	38050	5275	2074	1046	991	141	83	43	9	2	2	2	2	0	1
2003	329435	243215	97879	167492	159719	53020	27444	16707	2316	911	459	435	62	37	19	4	1	1	1	1	0
2004	267521	224263	165568	66593	112027	92719	23659	11970	7287	1010	397	200	190	27	16	8	2	0	0	0	0
2005	328612	182116	152668	112659	44484	63862	43018	10976	5553	3380	469	184	93	88	13	7	4	1	0	0	0
2006	782694	223704	123976	103868	74847	24357	28493	19187	4896	2477	1508	209	82	41	39	6	3	2	0	0	0
2007	504369	532818	152286	84385	69884	42217	9668	11253	7578	1933	978	595	83	32	16	16	2	1	1	0	0
2008	1157520	343347	362710	103619	56814	42809	19016	3394	3950	2660	679	343	209	29	11	6	5	1	0	0	0
2009	165891	787974	233729	246783	69546	33584	17298	6265	1118	1301	876	223	113	69	10	4	2	2	0	0	0
2010	790473	112929	536404	159081	166190	39893	11323	4992	1808	322	375	253	64	33	20	3	1	1	1	0	0
2011	1080040	538103	76875	365132	107769	100773	13992	2945	1298	470	84	98	66	17	8	5	1	0	0	0	0
2012	579628	735219	366292	52272	243882	63025	38389	3298	668	294	106	19	22	15	4	2	1	0	0	0	0
2013	1048440	394575	500490	249251	35138	143668	23723	10906	936	190	83	30	5	6	4	1	1	0	0	0	0
2014	182381	713723	268578	339365	160980	18424	60337	9931	4566	392	79	35	13	2	3	2	0	0	0	0	0
2015	210383	124154	485821	182365	223261	89269	7207	20578	3386	1557	134	27	12	4	1	1	1	0	0	0	0
2016	143660	143217	84510	330006	120830	128909	37321	2431	6940	1142	525	45	9	4	1	0	0	0	0	0	0
2017	524218	97796	97484	57390	218645	70786	57817	14202	925	2641	435	200	17	3	2	1	0	0	0	0	0

Table 2.27—Model 17.2 estimates of “effective” fishing mortality (= $-\ln(N_{a+1,t+1}/N_{a,t})-M$) at age and year.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.000	0.003	0.038	0.210	0.505	0.575	0.575	0.575	0.575	0.575	0.575	0.575	0.575	0.575	0.575	0.575	0.575	0.575	0.575
1978	0.000	0.002	0.034	0.216	0.551	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620
1979	0.000	0.003	0.036	0.179	0.327	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328
1980	0.000	0.003	0.028	0.140	0.324	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368
1981	0.001	0.010	0.045	0.106	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
1982	0.000	0.000	0.004	0.032	0.115	0.190	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192
1983	0.000	0.001	0.006	0.034	0.106	0.186	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
1984	0.000	0.003	0.015	0.051	0.124	0.211	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251
1985	0.000	0.001	0.011	0.072	0.184	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209
1986	0.000	0.002	0.015	0.066	0.156	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204
1987	0.000	0.001	0.012	0.062	0.163	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224	0.224
1988	0.002	0.011	0.049	0.130	0.219	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240
1989	0.001	0.005	0.022	0.071	0.157	0.242	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265
1990	0.000	0.002	0.012	0.049	0.135	0.252	0.320	0.321	0.321	0.321	0.321	0.321	0.321	0.321	0.321	0.321	0.321	0.321	0.321
1991	0.000	0.003	0.028	0.143	0.353	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425
1992	0.000	0.001	0.024	0.189	0.448	0.460	0.460	0.460	0.460	0.460	0.460	0.460	0.460	0.460	0.460	0.460	0.460	0.460	0.460
1993	0.000	0.004	0.034	0.143	0.295	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324	0.324
1994	0.000	0.006	0.042	0.164	0.340	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390
1995	0.000	0.004	0.046	0.220	0.470	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507
1996	0.000	0.004	0.033	0.146	0.390	0.625	0.654	0.654	0.654	0.654	0.654	0.654	0.654	0.654	0.654	0.654	0.654	0.654	0.654
1997	0.001	0.007	0.048	0.195	0.484	0.732	0.752	0.752	0.752	0.752	0.752	0.752	0.752	0.752	0.752	0.752	0.752	0.752	0.752
1998	0.000	0.003	0.030	0.164	0.435	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560
1999	0.000	0.002	0.032	0.204	0.510	0.567	0.567	0.567	0.567	0.567	0.567	0.567	0.567	0.567	0.567	0.567	0.567	0.567	0.567
2000	0.000	0.000	0.012	0.145	0.546	0.681	0.681	0.681	0.681	0.681	0.681	0.681	0.681	0.681	0.681	0.681	0.681	0.681	0.681
2001	0.000	0.000	0.012	0.125	0.403	0.459	0.459	0.459	0.459	0.459	0.459	0.459	0.459	0.459	0.459	0.459	0.459	0.459	0.459
2002	0.000	0.001	0.024	0.179	0.423	0.439	0.439	0.439	0.439	0.439	0.439	0.439	0.439	0.439	0.439	0.439	0.439	0.439	0.439
2003	0.000	0.001	0.018	0.159	0.422	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445	0.445
2004	0.000	0.000	0.019	0.177	0.383	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384
2005	0.000	0.001	0.024	0.218	0.423	0.423	0.423	0.423	0.423	0.423	0.423	0.423	0.423	0.423	0.423	0.423	0.423	0.423	0.423
2006	0.000	0.000	0.012	0.188	0.539	0.545	0.545	0.545	0.545	0.545	0.545	0.545	0.545	0.545	0.545	0.545	0.545	0.545	0.545
2007	0.000	0.001	0.011	0.106	0.413	0.662	0.662	0.662	0.662	0.662	0.662	0.662	0.662	0.662	0.662	0.662	0.662	0.662	0.662
2008	0.000	0.001	0.014	0.141	0.522	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.726
2009	0.000	0.000	0.011	0.171	0.703	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858	0.858
2010	0.000	0.000	0.005	0.116	0.663	0.962	0.963	0.963	0.963	0.963	0.963	0.963	0.963	0.963	0.963	0.963	0.963	0.963	0.963
2011	0.000	0.001	0.019	0.152	0.581	1.060	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100
2012	0.000	0.000	0.013	0.145	0.593	0.874	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875
2013	0.000	0.004	0.053	0.261	0.483	0.486	0.486	0.486	0.486	0.486	0.486	0.486	0.486	0.486	0.486	0.486	0.486	0.486	0.486
2014	0.000	0.003	0.034	0.205	0.554	0.691	0.691	0.691	0.691	0.691	0.691	0.691	0.691	0.691	0.691	0.691	0.691	0.691	0.691
2015	0.000	0.002	0.027	0.165	0.488	0.702	0.702	0.702	0.702	0.702	0.702	0.702	0.702	0.702	0.702	0.702	0.702	0.702	0.702
2016	0.000	0.002	0.027	0.150	0.417	0.582	0.582	0.582	0.582	0.582	0.582	0.582	0.582	0.582	0.582	0.582	0.582	0.582	0.582
2017	0.000	0.000	0.003	0.070	0.375	0.528	0.528	0.528	0.528	0.528	0.528	0.528	0.528	0.528	0.528	0.528	0.528	0.528	0.528

Table 2.28—Model 17.2 projections for catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2018-2030 (Scenario 1), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	172,000	172,000	172,000	172,000	0
2019	144,000	144,000	144,000	144,000	0
2020	101,000	101,000	101,000	101,000	19
2021	85,100	85,400	85,500	86,200	380
2022	97,500	101,000	101,000	108,000	3,541
2023	108,000	123,000	127,000	161,000	16,301
2024	100,000	136,000	142,000	198,000	32,024
2025	93,400	145,000	148,000	218,000	39,548
2026	86,600	149,000	151,000	222,000	43,235
2027	87,100	151,000	154,000	233,000	44,959
2028	88,300	152,000	154,000	230,000	44,882
2029	87,300	152,000	153,000	226,000	43,616
2030	89,400	153,000	152,000	225,000	42,570

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	217,000	217,000	217,000	217,000	0
2019	208,000	208,000	208,000	208,000	0
2020	183,000	183,000	183,000	183,000	34
2021	169,000	169,000	169,000	170,000	618
2022	172,000	176,000	177,000	184,000	4,054
2023	179,000	191,000	194,000	218,000	13,083
2024	177,000	202,000	208,000	259,000	25,775
2025	172,000	210,000	216,000	287,000	35,750
2026	166,000	213,000	221,000	296,000	41,692
2027	168,000	215,000	224,000	310,000	44,813
2028	167,000	215,000	225,000	312,000	45,553
2029	167,000	216,000	224,000	308,000	44,328
2030	168,000	216,000	224,000	304,000	42,746

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.31	0.31	0.31	0.31	0.00
2019	0.30	0.30	0.30	0.30	0.00
2020	0.26	0.26	0.26	0.26	0.00
2021	0.24	0.24	0.24	0.24	0.00
2022	0.24	0.25	0.25	0.26	0.01
2023	0.25	0.27	0.28	0.31	0.02
2024	0.25	0.29	0.29	0.32	0.02
2025	0.24	0.30	0.29	0.32	0.03
2026	0.24	0.31	0.29	0.32	0.03
2027	0.24	0.31	0.29	0.32	0.03
2028	0.24	0.31	0.29	0.32	0.03
2029	0.24	0.31	0.29	0.32	0.03
2030	0.24	0.31	0.29	0.32	0.03

Table 2.29—Model 17.2 projections for catch (t), spawning biomass (t), and fishing mortality under the assumption that catches in 2018-2019 are less than ABC by amounts predicted from past performance, but that $F = max\ F_{ABC}$ in 2020-2030 (Scenario 2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	162,000	162,000	162,000	162,000	0
2019	148,000	148,000	148,000	148,000	0
2020	103,000	103,000	103,000	103,000	20
2021	85,900	86,200	86,300	87,000	381
2022	97,800	101,000	102,000	108,000	3,545
2023	108,000	123,000	127,000	161,000	16,294
2024	100,000	136,000	142,000	198,000	32,020
2025	93,400	145,000	148,000	218,000	39,551
2026	86,600	149,000	151,000	222,000	43,237
2027	87,100	151,000	154,000	233,000	44,960
2028	88,300	152,000	154,000	230,000	44,883
2029	87,300	152,000	153,000	226,000	43,616
2030	89,400	153,000	152,000	225,000	42,570

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	217,000	217,000	217,000	217,000	0
2019	211,000	211,000	211,000	211,000	0
2020	184,000	184,000	184,000	184,000	34
2021	169,000	170,000	170,000	171,000	618
2022	172,000	176,000	177,000	185,000	4,053
2023	179,000	191,000	194,000	218,000	13,082
2024	177,000	202,000	208,000	259,000	25,776
2025	172,000	210,000	216,000	287,000	35,751
2026	166,000	213,000	221,000	296,000	41,692
2027	168,000	215,000	224,000	310,000	44,813
2028	167,000	215,000	225,000	312,000	45,552
2029	167,000	216,000	224,000	308,000	44,327
2030	168,000	216,000	224,000	304,000	42,745

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.29	0.29	0.29	0.29	0.00
2019	0.30	0.30	0.30	0.30	0.00
2020	0.26	0.26	0.26	0.26	0.00
2021	0.24	0.24	0.24	0.24	0.00
2022	0.25	0.25	0.25	0.26	0.01
2023	0.25	0.27	0.28	0.31	0.02
2024	0.25	0.29	0.29	0.32	0.02
2025	0.24	0.30	0.29	0.32	0.03
2026	0.24	0.31	0.29	0.32	0.03
2027	0.24	0.31	0.29	0.32	0.03
2028	0.24	0.31	0.29	0.32	0.03
2029	0.24	0.31	0.29	0.32	0.03
2030	0.24	0.31	0.29	0.32	0.03

Table 2.30—Model 17.2 projections for 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 2018-2030 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	304,000	304,000	304,000	304,000	0
2019	207,000	207,000	207,000	207,000	0
2020	136,000	136,000	136,000	136,000	4
2021	118,000	118,000	118,000	118,000	204
2022	141,000	144,000	145,000	150,000	3,175
2023	145,000	163,000	167,000	205,000	19,830
2024	125,000	168,000	177,000	256,000	42,804
2025	116,000	173,000	181,000	276,000	50,571
2026	114,000	176,000	185,000	280,000	53,691
2027	114,000	177,000	187,000	292,000	55,056
2028	114,000	178,000	186,000	282,000	53,865
2029	115,000	179,000	185,000	277,000	51,387
2030	115,000	177,000	184,000	277,000	50,613

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	207,000	207,000	207,000	207,000	0
2019	156,000	156,000	156,000	156,000	0
2020	110,000	110,000	110,000	111,000	35
2021	92,800	93,300	93,500	94,700	646
2022	97,000	101,000	102,000	110,000	4,281
2023	99,000	112,000	115,000	141,000	13,794
2024	92,300	118,000	124,000	174,000	25,454
2025	86,000	123,000	128,000	188,000	31,717
2026	83,200	126,000	131,000	191,000	34,376
2027	84,900	127,000	132,000	198,000	35,323
2028	84,000	127,000	132,000	197,000	34,728
2029	84,500	127,000	131,000	192,000	33,278
2030	86,000	127,000	131,000	191,000	32,550

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.62	0.62	0.62	0.62	0.00
2019	0.62	0.62	0.62	0.62	0.00
2020	0.62	0.62	0.62	0.62	0.00
2021	0.62	0.62	0.62	0.62	0.00
2022	0.62	0.62	0.62	0.62	0.00
2023	0.62	0.62	0.62	0.62	0.00
2024	0.62	0.62	0.62	0.62	0.00
2025	0.62	0.62	0.62	0.62	0.00
2026	0.62	0.62	0.62	0.62	0.00
2027	0.62	0.62	0.62	0.62	0.00
2028	0.62	0.62	0.62	0.62	0.00
2029	0.62	0.62	0.62	0.62	0.00
2030	0.62	0.62	0.62	0.62	0.00

Table 2.31—Model 17.2 projections for catch (t), spawning biomass (t), and fishing mortality under the assumption that the upper bound on F_{ABC} is set at $F_{60\%}$ in 2018-2030 (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	50,600	50,600	50,600	50,600	0
2019	56,800	56,800	56,800	56,800	0
2020	57,000	57,000	57,000	57,000	1
2021	60,800	60,800	60,800	60,900	46
2022	68,500	69,000	69,100	70,100	557
2023	73,700	77,000	77,700	84,200	3,456
2024	72,800	82,700	84,500	103,000	9,495
2025	71,800	87,500	89,600	117,000	13,848
2026	70,700	91,900	93,700	123,000	16,456
2027	70,900	94,400	96,900	130,000	18,177
2028	71,900	96,300	99,000	134,000	19,180
2029	72,600	97,800	100,000	136,000	19,469
2030	73,100	98,600	101,000	136,000	19,188

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	147,000	147,000	147,000	147,000	0
2019	184,000	184,000	184,000	184,000	0
2020	203,000	203,000	203,000	203,000	23
2021	217,000	218,000	218,000	218,000	439
2022	235,000	238,000	239,000	245,000	3,082
2023	252,000	263,000	266,000	286,000	10,955
2024	260,000	287,000	291,000	338,000	24,650
2025	262,000	306,000	313,000	387,000	39,108
2026	260,000	323,000	329,000	424,000	50,399
2027	258,000	335,000	342,000	445,000	58,164
2028	262,000	344,000	352,000	470,000	62,989
2029	264,000	350,000	358,000	477,000	65,207
2030	265,000	354,000	361,000	481,000	65,269

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
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
2027	0.12	0.12	0.12	0.12	0.00
2028	0.12	0.12	0.12	0.12	0.00
2029	0.12	0.12	0.12	0.12	0.00
2030	0.12	0.12	0.12	0.12	0.00

Table 2.32—Model 17.2 projections for catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = 0$ in 2018-2030 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	0	0	0	0	0
2022	0	0	0	0	0
2023	0	0	0	0	0
2024	0	0	0	0	0
2025	0	0	0	0	0
2026	0	0	0	0	0
2027	0	0	0	0	0
2028	0	0	0	0	0
2029	0	0	0	0	0
2030	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	149,000	149,000	149,000	149,000	0
2019	206,000	206,000	206,000	206,000	0
2020	249,000	249,000	249,000	249,000	23
2021	285,000	285,000	286,000	286,000	439
2022	322,000	325,000	325,000	331,000	3,092
2023	357,000	368,000	370,000	391,000	11,136
2024	383,000	411,000	415,000	465,000	26,116
2025	399,000	449,000	456,000	543,000	44,401
2026	408,000	483,000	491,000	609,000	61,186
2027	417,000	511,000	521,000	655,000	74,566
2028	424,000	536,000	544,000	698,000	84,382
2029	430,000	552,000	562,000	734,000	90,689
2030	437,000	566,000	576,000	751,000	93,708

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.00	0.00	0.00	0.00	0.00
2019	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00
2021	0.00	0.00	0.00	0.00	0.00
2022	0.00	0.00	0.00	0.00	0.00
2023	0.00	0.00	0.00	0.00	0.00
2024	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00
2026	0.00	0.00	0.00	0.00	0.00
2027	0.00	0.00	0.00	0.00	0.00
2028	0.00	0.00	0.00	0.00	0.00
2029	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00

Table 2.33—Model 17.2 projections for catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2018-2030 (Scenario 6), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	70,300	70,300	70,300	70,300	0
2019	90,500	90,500	90,500	90,500	0
2020	87,800	87,800	87,800	87,800	13
2021	91,600	91,800	91,900	92,400	289
2022	106,000	108,000	109,000	114,000	2,620
2023	114,000	125,000	128,000	153,000	12,671
2024	106,000	135,000	141,000	195,000	27,791
2025	98,400	141,000	146,000	209,000	35,038
2026	93,100	144,000	148,000	211,000	38,226
2027	92,700	145,000	150,000	219,000	39,829
2028	91,700	145,000	150,000	222,000	40,378
2029	90,400	145,000	150,000	215,000	40,056
2030	93,200	145,000	149,000	218,000	39,251

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	146,000	146,000	146,000	146,000	0
2019	174,000	174,000	174,000	174,000	0
2020	179,000	179,000	179,000	180,000	22
2021	183,000	183,000	183,000	184,000	420
2022	192,000	194,000	195,000	200,000	2,890
2023	198,000	208,000	210,000	228,000	9,771
2024	195,000	217,000	220,000	259,000	19,930
2025	190,000	223,000	226,000	280,000	27,837
2026	185,000	225,000	229,000	286,000	32,518
2027	183,000	226,000	231,000	296,000	35,175
2028	183,000	226,000	232,000	303,000	36,437
2029	182,000	227,000	232,000	296,000	36,326
2030	183,000	226,000	231,000	297,000	35,274

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.18	0.18	0.18	0.18	0.00
2019	0.21	0.21	0.21	0.21	0.00
2020	0.22	0.22	0.22	0.22	0.00
2021	0.22	0.22	0.22	0.23	0.00
2022	0.24	0.24	0.24	0.25	0.00
2023	0.24	0.26	0.26	0.28	0.01
2024	0.24	0.27	0.27	0.31	0.02
2025	0.23	0.28	0.28	0.31	0.03
2026	0.23	0.28	0.28	0.31	0.03
2027	0.22	0.28	0.28	0.31	0.03
2028	0.22	0.28	0.28	0.31	0.03
2029	0.22	0.28	0.28	0.31	0.03
2030	0.22	0.28	0.28	0.31	0.03

Table 2.34—Model 17.2 projections for catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2018-2019 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	59,100	59,100	59,100	59,100	0
2019	79,900	79,900	79,900	79,900	0
2020	95,600	95,600	95,600	95,600	13
2021	96,100	96,400	96,400	97,000	294
2022	108,000	111,000	111,000	116,000	2,643
2023	115,000	126,000	129,000	154,000	12,690
2024	106,000	136,000	141,000	195,000	27,754
2025	98,400	141,000	146,000	209,000	35,027
2026	93,000	143,000	148,000	211,000	38,230
2027	92,700	145,000	150,000	219,000	39,835
2028	91,700	144,000	150,000	222,000	40,381
2029	90,400	145,000	150,000	215,000	40,057
2030	93,200	145,000	149,000	218,000	39,251

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	146,000	146,000	146,000	146,000	0
2019	179,000	179,000	179,000	179,000	0
2020	187,000	187,000	187,000	187,000	22
2021	188,000	188,000	188,000	189,000	420
2022	194,000	197,000	198,000	203,000	2,886
2023	199,000	209,000	211,000	229,000	9,762
2024	196,000	217,000	221,000	259,000	19,917
2025	190,000	223,000	226,000	280,000	27,835
2026	185,000	225,000	229,000	286,000	32,518
2027	183,000	226,000	231,000	296,000	35,173
2028	183,000	226,000	232,000	303,000	36,434
2029	182,000	227,000	232,000	296,000	36,322
2030	183,000	226,000	231,000	297,000	35,272

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.15	0.15	0.15	0.15	0.00
2019	0.18	0.18	0.18	0.18	0.00
2020	0.23	0.23	0.23	0.23	0.00
2021	0.23	0.23	0.23	0.23	0.00
2022	0.24	0.24	0.24	0.25	0.00
2023	0.25	0.26	0.26	0.28	0.01
2024	0.24	0.27	0.27	0.31	0.02
2025	0.23	0.28	0.28	0.31	0.03
2026	0.23	0.28	0.28	0.31	0.03
2027	0.22	0.28	0.28	0.31	0.03
2028	0.22	0.28	0.28	0.31	0.03
2029	0.22	0.28	0.28	0.31	0.03
2030	0.22	0.28	0.28	0.31	0.03

Table 2.35a (page 1 of 2)—Incidental catch (t) of FMP species taken in the EBS trawl fishery for Pacific cod, expressed as a proportion of the incidental catch of that species taken in all FMP EBS fisheries, 1991-2017 (2017 data current through October 8). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both pages of the table).

Species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Alaska Plaice												0.03	0.03	0.05
Arrowtooth Flounder	0.06	0.24	0.21	0.16	0.20	0.26	0.24	0.11	0.12	0.11	0.19	0.38	0.43	0.52
Atka Mackerel	0.12	0.20	0.01	0.02	0.01	0.11	0.22	0.82	0.11	0.19	0.27	0.35	0.75	0.76
Flathead Sole					0.32	0.30	0.29	0.16	0.21	0.19	0.11	0.22	0.23	0.33
Flounder	0.02	0.07	0.13	0.14										
Greenland Turbot	0.02	0.03	0.04	0.02	0.06	0.06	0.02	0.09	0.01	0.05	0.03	0.04	0.11	0.17
Kamchatka Flounder														
Northern Rockfish												0.40	0.24	0.59
Octopus														
Other Flatfish					0.06	0.07	0.06	0.04	0.03	0.05	0.05	0.14	0.33	0.49
Other Rockfish	0.04	0.28	0.23	0.05	0.14	0.11	0.07	0.35	0.14	0.19	0.02	0.11	0.28	0.33
Other Species													0.12	0.12
Pacific Cod	0.08	0.14	0.17	0.16	0.20	0.12	0.17	0.03	0.12	0.06	0.06	0.16	0.09	0.07
Pacific Ocean Perch	0.21	0.24	0.27	0.23	0.29	0.19	0.39	0.27	0.14	0.53	0.04	0.02	0.04	0.26
Pollock	0.05	0.12	0.24	0.20	0.21	0.25	0.30	0.23	0.45	0.30	0.18	0.27	0.38	0.39
Rock Sole	0.04	0.08	0.12	0.18	0.34	0.31	0.30	0.22	0.31	0.19	0.27	0.22	0.27	0.30
Rougheye Rockfish														0.12
Sablefish	0.01	0.01	conf	0.01	0.00	0.04	0.00	0.03	0.06	0.08	0.04	0.10	0.19	0.32
Sculpin														
Shark														
Sharpchin/Northern Rockfish		0.29	0.30								0.12			
Shortraker Rockfish														conf
Shortraker/Rougheye Rockfish		0.02	conf								conf	0.05	0.05	
Short/Rough/Sharp/North Rockfish	0.26	0.58	0.18	0.12	0.17	0.13	0.45	0.27	0.16	0.28	0.46			
Skate														
Squid	0.01	0.03	0.00	0.28	0.00	conf	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.01
Yellowfin Sole	0.00	0.01	0.03	0.04	0.01	0.05	0.02	0.02	0.03	0.07	0.05	0.09	0.06	0.11

Table 2.35a (page 2 of 2)—Incidental catch (t) of FMP species taken in the EBS trawl fishery for Pacific cod, expressed as a proportion of the incidental catch of that species taken in all FMP EBS fisheries, 1991-2017 (2017 data current through October 8). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both pages of the table).

Species/group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Alaska Plaice	0.04	0.02	0.03	0.00	0.01	0.00	0.01	0.01	0.05	0.02	0.00	0.00	0.00
Arrowtooth Flounder	0.41	0.45	0.23	0.08	0.08	0.07	0.06	0.07	0.07	0.08	0.08	0.08	0.07
Atka Mackerel	0.36	0.24	0.17	0.10	0.40	0.39	0.35	0.27	0.06	0.09	0.03	0.84	0.00
Flathead Sole	0.23	0.41	0.39	0.11	0.07	0.06	0.09	0.08	0.08	0.08	0.08	0.08	0.08
Flounder													
Greenland Turbot	0.05	0.11	0.21	0.01	0.00	0.03	0.00	0.02	0.01	0.01	0.02	0.00	conf
Kamchatka Flounder							0.01	0.01	0.02	0.04	0.02	0.02	0.01
Northern Rockfish	0.31	0.28	0.08	0.05	0.03	0.20	0.06	0.11	0.01	0.01	0.00	conf	0.24
Octopus							0.03	0.01	0.02	0.02	0.01	0.00	0.10
Other Flatfish	0.35	0.20	0.07	0.03	0.03	0.04	0.03	0.03	0.03	0.01	0.07	0.12	0.04
Other Rockfish	0.32	0.24	0.06	0.06	0.02	0.03	0.03	0.32	0.03	0.03	0.07	0.04	0.01
Other Species	0.07	0.11	0.17	0.04	0.03	0.03							
Pacific Cod	0.03	0.08	0.12	0.01	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.10
Pacific Ocean Perch	0.22	0.08	0.04	0.01	0.01	0.00	0.01	0.07	0.00	conf	0.00	0.00	0.00
Pollock	0.36	0.53	0.75	0.43	0.37	0.32	0.42	0.29	0.22	0.17	0.05	0.10	0.05
Rock Sole	0.37	0.35	0.27	0.14	0.07	0.12	0.18	0.16	0.07	0.21	0.30	0.25	0.14
Rougheye Rockfish	0.05			conf		conf						conf	conf
Sablefish	0.09	0.00	0.00	0.00	conf	conf	conf	conf	0.02		0.01	0.00	0.01
Sculpin							0.07	0.07	0.07	0.07	0.07	0.12	0.06
Shark									0.00	0.00	0.01	conf	0.01
Sharpchin/Northern Rockfish													
Shortraker Rockfish		conf	conf		conf				conf			conf	conf
Shortraker/Rougheye Rockfish													
Short/Rough/Sharp/North Rockfish													
Skate							0.01	0.01	0.01	0.01	0.01	0.01	0.01
Squid	0.00	conf	0.00	conf		0.00	0.00	0.00	0.00	0.00	0.00	conf	conf
Yellowfin Sole	0.11	0.08	0.03	0.01	0.00	0.01	0.01	0.01	0.06	0.02	0.00	0.00	0.01

Table 2.35b (page 1 of 2)—Incidental catch (t) of FMP species taken in the EBS longline fishery for Pacific cod, expressed as a proportion of the incidental catch of that species taken in all FMP EBS fisheries, 1991-2017 (2017 data current through October 8). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both pages of the table).

Species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Alaska Plaice												0.00	0.00	0.00
Arrowtooth Flounder	0.11	0.15	0.08	0.10	0.20	0.15	0.23	0.11	0.08	0.14	0.14	0.11	0.11	0.09
Atka Mackerel	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01
Flathead Sole		conf			0.03	0.03	0.03	0.05	0.06	0.06	0.08	0.09	0.09	0.11
Flounder	0.01	0.01	0.01	0.01										
Greenland Turbot	0.10	0.20	0.05	0.09	0.14	0.19	0.19	0.07	0.04	0.12	0.05	0.08	0.17	0.11
Kamchatka Flounder														
Northern Rockfish												0.08	0.09	0.05
Octopus														
Other Flatfish					0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.06	0.04	0.06
Other Rockfish	0.03	0.12	0.14	0.08	0.06	0.20	0.11	0.08	0.20	0.12	0.35	0.25	0.11	0.23
Other Species													0.56	0.65
Pacific Cod	0.09	0.08	0.07	0.10	0.09	0.11	0.16	0.70	0.42	0.69	0.62	0.58	0.65	0.75
Pacific Ocean Perch	0.00	0.01	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Pollock	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.02	0.05	0.06	0.04	0.05	0.03
Rock Sole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rougheye Rockfish														0.14
Sablefish	0.05	0.73	0.07	0.08	0.12	0.13	0.12	0.08	0.08	0.39	0.32	0.20	0.30	0.16
Sculpin														
Shark														
Sharpchin/Northern Rockfish		0.01	0.01								0.05			
Shortraker Rockfish														0.12
Shortraker/Rougheye Rockfish		0.10	0.19								0.74	0.19	0.20	
Short/Rough/Sharp/North Rockfish	0.03	0.05	0.04	0.11	0.18	0.18	0.05	0.14	0.03	0.19	0.05			
Skate														
Squid										0.00		conf	conf	conf
Yellowfin Sole	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.07	0.05	0.05	0.04

Table 2.35b (page 2 of 2)—Incidental catch (t) of FMP species taken in the EBS longline fishery for Pacific cod, expressed as a proportion of the incidental catch of that species taken in all FMP EBS fisheries, 1991-2017 (2017 data current through October 8). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both pages of the table).

Species/group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Alaska Plaice	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arrowtooth Flounder	0.14	0.12	0.16	0.18	0.20	0.16	0.22	0.28	0.14	0.21	0.33	0.25	0.37
Atka Mackerel	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.01	0.13	0.17	0.02	0.04	0.08
Flathead Sole	0.14	0.11	0.06	0.14	0.12	0.14	0.18	0.17	0.24	0.39	0.39	0.35	0.49
Flounder													
Greenland Turbot	0.12	0.13	0.15	0.11	0.15	0.15	0.15	0.11	0.01	0.02	0.13	0.43	0.31
Kamchatka Flounder							0.13	0.11	0.07	0.09	0.13	0.19	0.10
Northern Rockfish	0.08	0.04	0.11	0.30	0.56	0.68	0.39	0.16	0.39	0.43	0.48	0.34	0.45
Octopus							0.05	0.12	0.11	0.06	0.08	0.08	0.15
Other Flatfish	0.09	0.07	0.01	0.01	0.06	0.07	0.02	0.03	0.01	0.01	0.04	0.02	0.01
Other Rockfish	0.26	0.24	0.24	0.19	0.16	0.58	0.38	0.21	0.38	0.49	0.51	0.23	0.37
Other Species	0.68	0.56	0.44	0.51	0.51	0.53							
Pacific Cod	0.82	0.63	0.68	0.63	0.73	0.51	0.78	0.66	0.63	0.78	0.79	0.81	0.59
Pacific Ocean Perch	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Pollock	0.03	0.03	0.03	0.11	0.10	0.22	0.17	0.09	0.11	0.04	0.06	0.08	0.07
Rock Sole	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.03	0.05	0.02	0.02
Rougheye Rockfish	0.33	0.68	0.48	0.39	0.31	0.18	0.27	0.19	0.18	0.25	0.45	0.38	0.09
Sablefish	0.22	0.21	0.16	0.03	0.04	0.04	0.16	0.02	0.10	0.06	0.24	0.71	0.17
Sculpin							0.25	0.25	0.17	0.31	0.38	0.35	0.35
Shark							0.31	0.33	0.40	0.42	0.44	0.38	0.15
Sharpchin/Northern Rockfish													
Shortraker Rockfish	0.31	0.20	0.63	0.12	0.64	0.31	0.28	0.22	0.09	0.22	0.23	0.14	0.16
Shortraker/Rougheye Rockfish													
Short/Rough/Sharp/North Rockfish													
Skate							0.76	0.76	0.78	0.84	0.89	0.91	0.89
Squid	conf			conf	conf	conf	0.00		0.00	0.00	0.00		conf
Yellowfin Sole	0.07	0.05	0.02	0.06	0.09	0.03	0.14	0.20	0.23	0.39	0.47	0.36	0.35

Table 2.35c (page 1 of 2)—Incidental catch (t) of FMP species taken in the EBS pot fishery for Pacific cod, expressed as a proportion of the incidental catch of that species taken in all FMP EBS fisheries, 1991-2017 (2017 data current through October 8). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both pages of the table).

Species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Alaska Plaice												conf	conf	conf
Arrowtooth Flounder	0.00	0.00	conf	conf	0.00	0.00	0.00	0.00	conf	conf	conf	0.02	0.00	0.00
Atka Mackerel	0.00	0.03	conf	0.05	0.23	0.11	0.29	0.03	conf	conf	conf	conf	0.06	0.03
Flathead Sole					conf	0.00	conf	conf	0.00	conf	conf	conf	0.00	0.00
Flounder	conf	0.00	conf	conf										
Greenland Turbot	conf	conf		conf	0.00	0.00	conf	conf	conf		conf	conf	0.00	
Kamchatka Flounder														
Northern Rockfish												conf	0.02	0.01
Octopus														
Other Flatfish					conf	0.00	0.00	conf	conf	conf	conf	conf	0.00	0.00
Other Rockfish	0.00	0.00	conf	0.01	0.02	0.04	0.06	0.03	conf	conf	conf	conf	0.07	0.04
Other Species													0.02	0.01
Pacific Cod	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.01	0.02	0.02	0.02	0.03	0.06	0.02
Pacific Ocean Perch	conf	conf	conf	conf	0.00	0.00	conf	conf	conf	conf	conf	conf	0.00	0.00
Pollock	0.00	0.00	conf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	conf	0.00	0.00	0.00
Rock Sole	0.00	0.00	conf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	conf	conf	0.00	0.00
Rougheye Rockfish														0.00
Sablefish	conf	conf		conf	conf	conf	conf	conf	conf		conf	conf	0.00	0.01
Sculpin														
Shark														
Sharpchin/Northern Rockfish		conf	conf								conf			
Shortraker Rockfish														
Shortraker/Rougheye Rockfish		conf	conf								conf	conf	0.00	
Short/Rough/Sharp/North Rockfish	0.00			conf	0.01	0.00	0.00	conf	conf	conf	conf			
Skate														
Squid					conf	conf			conf		conf	conf		
Yellowfin Sole	0.00	0.00	conf	conf	0.00	0.01	0.00	0.00	0.00	0.00	conf	0.00	0.01	0.01

Table 2.35c (page 2 of 2)—Incidental catch (t) of FMP species taken in the EBS pot fishery for Pacific cod, expressed as a proportion of the incidental catch of that species taken in all FMP EBS fisheries, 1991-2017 (2017 data current through October 8). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both pages of the table).

Species/group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Alaska Plaice	conf	conf	conf					0.00	conf	conf	conf	conf	conf
Arrowtooth Flounder	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atka Mackerel	0.17	0.29	0.11	0.68	0.03	0.56	0.11	0.05	0.19	0.35	0.07	0.08	0.01
Flathead Sole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Flounder													
Greenland Turbot	conf	0.00	conf	conf	conf		0.00			conf	conf	conf	conf
Kamchatka Flounder							0.00	0.00	0.00	conf	0.00	0.00	conf
Northern Rockfish	0.02	0.01	0.02	0.11	0.06	0.02	0.02	0.01	0.00	0.01	0.01	0.00	conf
Octopus							0.88	0.81	0.85	0.91	0.86	0.87	0.67
Other Flatfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Other Rockfish	0.10	0.12	0.01	0.02	0.00	0.02	0.04	0.02	0.12	0.06	0.05	0.04	0.02
Other Species	0.01	0.02	0.01	0.02	0.01	0.01							
Pacific Cod	0.02	0.03	0.02	0.08	0.01	0.01	0.01	0.01	0.02	0.04	0.03	0.03	0.02
Pacific Ocean Perch	0.00	0.00	conf	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
Pollock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rock Sole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rougheye Rockfish	0.01												
Sablefish	0.00	0.08					conf		0.00			0.01	0.01
Sculpin							0.03	0.02	0.06	0.07	0.06	0.07	0.02
Shark							conf	0.00					
Sharpchin/Northern Rockfish													
Shortraker Rockfish						0.00				conf			
Shortraker/Rougheye Rockfish													
Short/Rough/Sharp/North Rockfish													
Skate							0.00	conf		0.00	conf	conf	conf
Squid	conf		conf			conf				conf		0.00	
Yellowfin Sole	0.01	0.01	0.02	0.02	0.01	0.00	0.01	0.01	0.05	0.08	0.08	0.03	0.03

Table 2.36—Incidental catch (t) of selected members of the former "Other Species" complex taken in the EBS fisheries for Pacific cod (all gears), expressed as a proportion of the incidental catch of that species taken in all FMP EBS fisheries, 1991-2017 (2017 data current through October 8). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both panels of the table).

Species Common Name	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
octopus, North Pacific									conf	conf	conf	0.73	0.81	0.82
shark, other									conf	conf	0.05	0.09	0.50	0.56
shark, Pacific sleeper												conf	0.66	0.35
shark, salmon									conf				conf	conf
shark, spiny dogfish										0.91	0.42	0.92	0.99	0.97
skate, Alaska														
skate, big														0.84
skate, longnose												conf	0.71	0.55
skate, other									0.16	0.04	conf	0.43	0.81	0.85
squid, majestic	0.01	0.03	0.00	0.28	0.00	conf	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.01

Species Common Name	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
octopus, North Pacific	0.88	0.94	0.89	0.90	0.66	0.84	0.97	0.94	0.98	0.98	0.95	0.95	0.92
shark, other	0.60	0.41	0.20	0.17	0.30	0.59	0.50	0.22	0.39	0.61	0.61	0.57	0.46
shark, Pacific sleeper	0.52	0.01	0.16	0.42	0.72	0.48	0.75	0.41	0.79	0.79	0.61	0.43	0.64
shark, salmon	0.07	0.02							0.01		conf		conf
shark, spiny dogfish	0.98	0.97	0.83	0.63	0.95	0.93	0.93	0.98	0.82	0.90	0.89	0.87	0.91
skate, Alaska						0.26							
skate, big	0.72	0.92	0.73	0.71	0.51	0.73							
skate, longnose	0.97	0.67	0.37	1.00	0.67	0.49							
skate, other	0.85	0.78	0.75	0.70	0.67	0.93	0.77	0.77	0.80	0.85	0.90	0.93	0.91
squid, majestic	0.00	conf	0.00	conf	conf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2.37—Incidental catch (herring and halibut in t, salmon and crab in number of individuals) of prohibited species taken in the EBS fisheries for Pacific cod (all gears), expressed as a proportion of the incidental catch of that species taken in all FMP EBS fisheries, 1991-2017 (2017 data current through October 8). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both panels of the table). Note that all entries for 2003 are marked "n/a", due to problems in the database for that year, which are under investigation.

Species Group Name	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Bairdi Tanner Crab	0.20	0.10	0.07	0.13	0.14	0.22	0.15	0.10	0.17	0.16	0.14	0.29	n/a	0.30
Blue King Crab													n/a	0.94
Chinook Salmon	0.09	0.12	0.13	0.18	0.34	0.09	0.09	0.04	0.14	0.20	0.08	0.04	n/a	0.08
Golden (Brown) King Crab													n/a	0.00
Halibut	0.52	0.64	0.49	0.67	0.71	0.74	0.71	0.68	0.66	0.69	0.63	0.67	n/a	0.73
Herring	conf	0.01	0.03	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.02	n/a	0.01
Non-Chinook Salmon	0.00	0.00	0.00	0.01	0.04	0.00	0.01	0.01	0.00	0.00	0.03	0.01	n/a	0.01
Opilio Tanner (Snow) Crab	0.02	0.02	0.02	0.04	0.05	0.10	0.17	0.17	0.33	0.12	0.12	0.34	n/a	0.14
Other King Crab	0.02	0.12	0.01	0.08	0.16	0.66	0.54	0.73	0.35	0.33	0.58	0.69	n/a	
Red King Crab	0.31	0.07	0.01	0.01	0.17	0.78	0.36	0.23	0.18	0.38	0.26	0.32	n/a	0.14

Species Group Name	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Bairdi Tanner Crab	0.19	0.40	0.57	0.66	0.53	0.45	0.27	0.22	0.26	0.50	0.61	0.61	0.51
Blue King Crab	0.95	0.70	1.00	0.87	0.89	1.00	0.60	0.80	0.37	0.73	0.84	0.83	0.99
Chinook Salmon	0.04	0.03	0.04	0.03	0.01	0.04	0.00	0.05	0.04	0.05	0.05	0.08	0.05
Golden (Brown) King Crab	0.21	0.01	0.00	0.00	0.01	0.03	0.00	0.02	0.03	0.03	0.02	0.02	0.78
Halibut	0.72	0.68	0.63	0.65	0.63	0.65	0.68	0.69	0.67	0.63	0.66	0.56	0.55
Herring	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Non-Chinook Salmon	0.00	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Opilio Tanner (Snow) Crab	0.08	0.34	0.53	0.47	0.52	0.31	0.20	0.08	0.06	0.19	0.23	0.21	0.43
Other King Crab													
Red King Crab	0.16	0.14	0.32	0.29	0.10	0.06	0.35	0.26	0.76	0.82	0.90	0.40	0.43

Table 2.38a (page 1 of 2)—Incidental catch (t) of non-target species groups—other than birds—taken in the EBS fisheries for Pacific cod (all gears), expressed as a proportion of the incidental catch of that species group taken in all FMP EBS fisheries, 2003-2017 (2017 data are current through October 8). Color shading: red = row minimum, green = row maximum.

Species Group Name	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Benthic urochordata	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.04	0.20	0.28	0.20	0.29	0.27	0.05	0.08
Bivalves	0.42	0.85	0.74	0.77	0.62	0.85	0.85	0.47	0.82	0.92	0.88	0.79	0.81	0.79	0.87
Brittle star unidentified	0.02	0.02	0.01	0.02	0.04	0.01	0.05	0.01	0.07	0.06	0.09	0.04	0.08	0.05	0.46
Capelin		0.02			0.00	0.00		0.00	0.00	0.00	0.10	0.02	0.00		0.00
Corals Bryozoans - Corals Bryozoans Unidentified	0.51	0.48	0.40	0.10	0.88	0.15	0.85	0.24	0.50	0.92	0.25	0.50	0.61	0.39	0.83
Corals Bryozoans - Red Tree Coral	0.90	0.66	0.46	0.01	0.99	0.02	0.09								conf
Dark Rockfish						0.98	0.96			0.79					
Eelpouts	0.23	0.37	0.47	0.30	0.11	0.09	0.04	0.05	0.05	0.14	0.16	0.28	0.58	0.49	0.43
Eulachon		0.00	0.00	0.00	0.00	0.00		conf	0.00	0.00					conf
Giant Grenadier	0.03	0.08	0.12	0.06	0.07	0.08	0.07	0.12	0.28	0.21	0.13	0.20	0.04	0.16	0.10
Greenlings	0.75	0.66	0.58	0.65	0.20	0.73	0.74	0.78	0.64	0.77	1.00	0.85	0.69	0.62	0.45
Grenadier - Pacific Grenadier		0.70	0.00					0.05							
Grenadier - Ratail Grenadier Unidentified	0.09	0.11	0.14	0.10	0.23	0.40	0.08								
Grenadier - Rattail Grenadier Unidentified								0.19	0.04	0.04	0.78	0.07	0.61	0.10	0.00
Gunnels		1.00	1.00		0.03									conf	
Hermit crab unidentified	0.05	0.05	0.02	0.04	0.03	0.03	0.06	0.02	0.03	0.06	0.08	0.06	0.15	0.17	0.19
Invertebrate unidentified	0.03	0.01	0.01	0.08	0.22	0.02	0.24	0.41	0.38	0.21	0.25	0.30	0.27	0.42	0.41
Lanternfishes (myctophidae)		conf													
Large Sculpins	0.62	0.60	0.50	0.45	0.37										
Large Sculpins - Bigmouth Sculpin						0.35	0.46			0.58					
Large Sculpins - Brown Irish Lord						1.00	1.00								
Large Sculpins - Great Sculpin						0.19	0.16			0.23					
Large Sculpins - Hemilepidotus Unidentified						0.90	0.99			0.99					
Large Sculpins - Myoxocephalus Unidentified						0.24	0.62			0.96					
Large Sculpins - Plain Sculpin						0.01	0.01			0.03					
Large Sculpins - Red Irish Lord						0.11	0.64			1.00					
Large Sculpins - Warty Sculpin						0.22	0.15			0.09					
Large Sculpins - Yellow Irish Lord						0.52	0.33			0.64					
Misc crabs	0.15	0.12	0.16	0.46	0.38	0.18	0.12	0.19	0.12	0.16	0.20	0.22	0.20	0.16	0.38
Misc crustaceans	0.26	0.21	0.51	0.17	0.21	0.03	0.02	0.05	0.04	0.03	0.10	0.08	0.05	0.14	0.02
Misc fish	0.48	0.43	0.40	0.28	0.19	0.15	0.19	0.20	0.24	0.33	0.24	0.61	0.45	0.52	0.27
Misc inverts (worms etc)	0.07	0.02	0.01	0.06	0.33	0.01	0.02	0.00	0.01	0.00	0.00	conf	0.03		conf
Other Sculpins	0.49	0.65	0.56	0.57	0.41	0.70	0.59			0.75					

Table 2.38a (page 2 of 2)—Incidental catch (t) of non-target species groups—other than birds—taken in the EBS fisheries for Pacific cod (all gears), expressed as a proportion of the incidental catch of that species group taken in all FMP EBS fisheries, 2003-2017 (2017 data are current through October 8). Color shading: red = row minimum, green = row maximum.

Species Group Name	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Other osmerids	0.01	0.06	0.00	0.01	0.00		0.00	0.00	0.00	0.00	conf		0.00		conf
Pacific Sand lance	0.45	0.34	0.60	0.04	0.12	0.21		0.01	0.01	0.00		0.02	conf	0.09	0.21
Pacific Sandfish								0.28				0.07	0.19	0.32	0.84
Pandalid shrimp	0.09	0.17	0.01	0.02	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polychaete unidentified	0.13	0.02	0.73	0.00	0.01	0.00	0.10	0.04	0.08	0.37	0.04	0.28	0.43	0.47	0.01
Scypho jellies	0.10	0.09	0.07	0.02	0.04	0.01	0.01	0.01	0.02	0.02	0.05	0.01	0.02	0.01	0.01
Sea anemone unidentified	0.68	0.62	0.86	0.79	0.35	0.51	0.74	0.62	0.76	0.86	0.76	0.81	0.86	0.88	0.78
Sea pens whips	0.87	0.90	0.93	0.87	0.63	0.86	0.92	0.87	0.90	0.91	0.96	0.96	0.96	0.96	0.95
Sea star	0.11	0.14	0.16	0.12	0.09	0.07	0.15	0.11	0.09	0.20	0.15	0.22	0.20	0.19	0.28
Snails	0.13	0.07	0.10	0.08	0.10	0.09	0.25	0.17	0.17	0.25	0.31	0.43	0.46	0.69	0.54
Sponge unidentified	0.03	0.10	0.07	0.15	0.08	0.08	0.07	0.03	0.06	0.15	0.09	0.09	0.17	0.15	0.27
State-managed Rockfish								0.96	0.98		0.98	0.37	0.77	0.25	0.51
Stichaeidae	0.17	0.06	0.14	0.07	0.01	0.04	0.00	conf					0.03		
urchins dollars cucumbers	0.37	0.49	0.50	0.43	0.26	0.17	0.08	0.15	0.35	0.41	0.26	0.40	0.49	0.60	0.19

Table 2.38b—Incidental catch (t) of bird species groups taken in the EBS fisheries for Pacific cod (all gears), expressed as a proportion of the incidental catch of that species group taken in all FMP EBS fisheries, 2003-2017 (2017 data are current through October 8).

Species Group Name	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Auklets									1.00		0.33	1.00	1.00
Black-footed Albatross	1.00	1.00	0.95	1.00	1.00	1.00	1.00						
Cormorant			1.00										
Gull	1.00	1.00	0.97	0.60	0.99	0.90	0.89	1.00	1.00	0.96	1.00	1.00	0.96
Kittiwake	0.31	0.44				0.34		1.00	1.00	1.00	1.00	1.00	1.00
Laysan Albatross	0.76	0.37	0.01	0.00	0.68	0.00	0.31	0.94	0.71	0.20	0.75	0.17	0.67
Murre	0.41	0.01	0.65	0.73	1.00	1.00			1.00				0.22
Northern Fulmar	0.91	0.86	0.57	0.74	0.75	0.86	0.85	0.86	0.79	0.87	0.82	0.84	0.93
Other Alcid	1.00												
Other													
Puffin							1.00						
Shearwaters	0.99	0.37	0.95	0.94	0.99	0.87	0.85	0.72	0.90	0.69	0.36	0.66	0.93
Short-tailed Albatross							1.00	1.00			0.32		
Storm Petrels			0.33										
Unidentified Albatross			1.00								0.92		
Unidentified	0.96	0.98	0.97	0.96	1.00	0.92	0.94	1.00	0.95	0.94	1.00	0.94	0.99

FIGURES

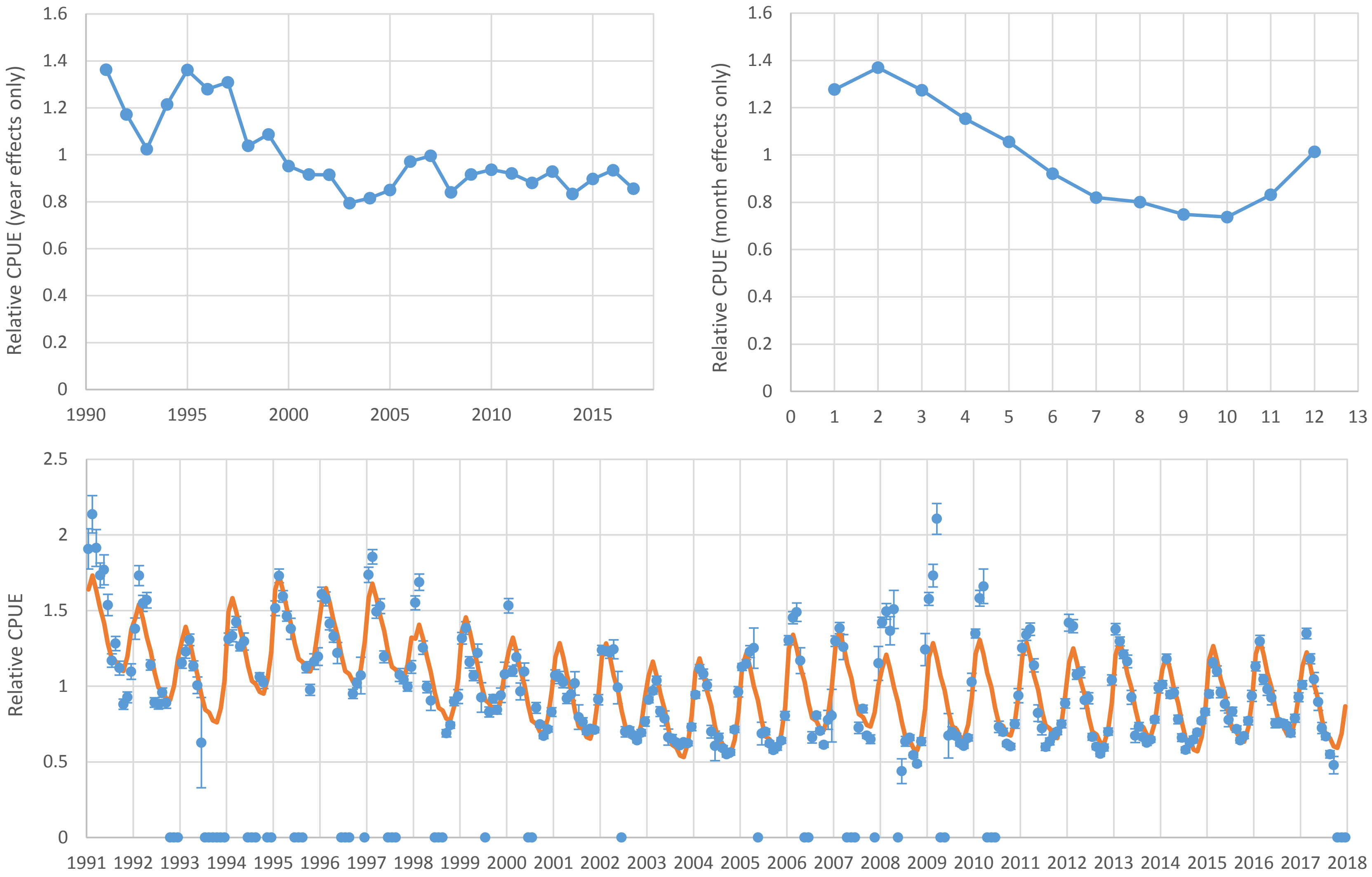


Figure 2.1—Longline fishery CPUE. Upper left panel: year effects, upper right panel: month effects: lower panel: monthly data and model fit.

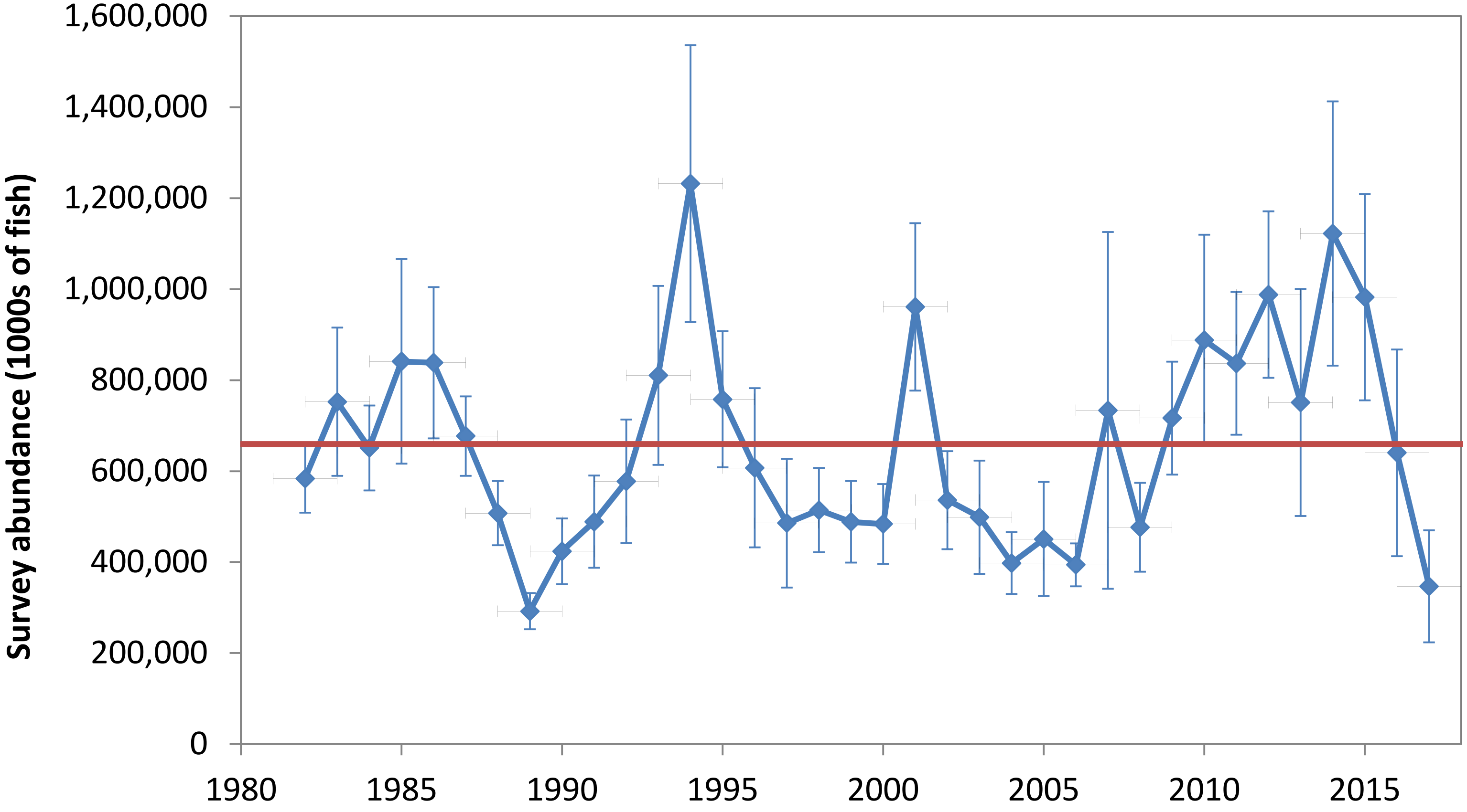


Figure 2.2—EBS trawl survey numerical abundance estimates with 95% confidence intervals (standard area). Red line = long-term average.

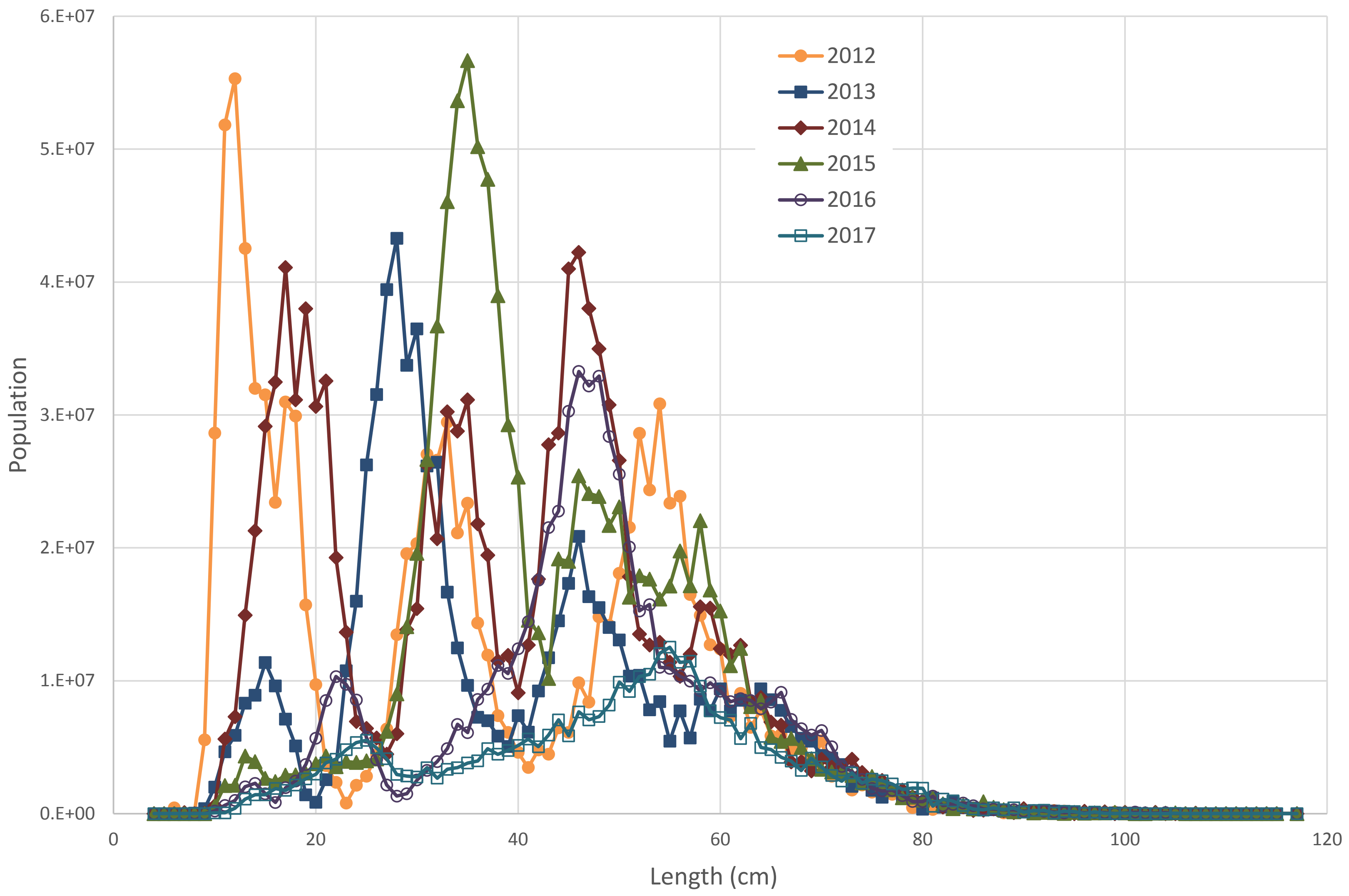


Figure 2.3—Comparison of recent size compositions from the EBS shelf bottom trawl survey.

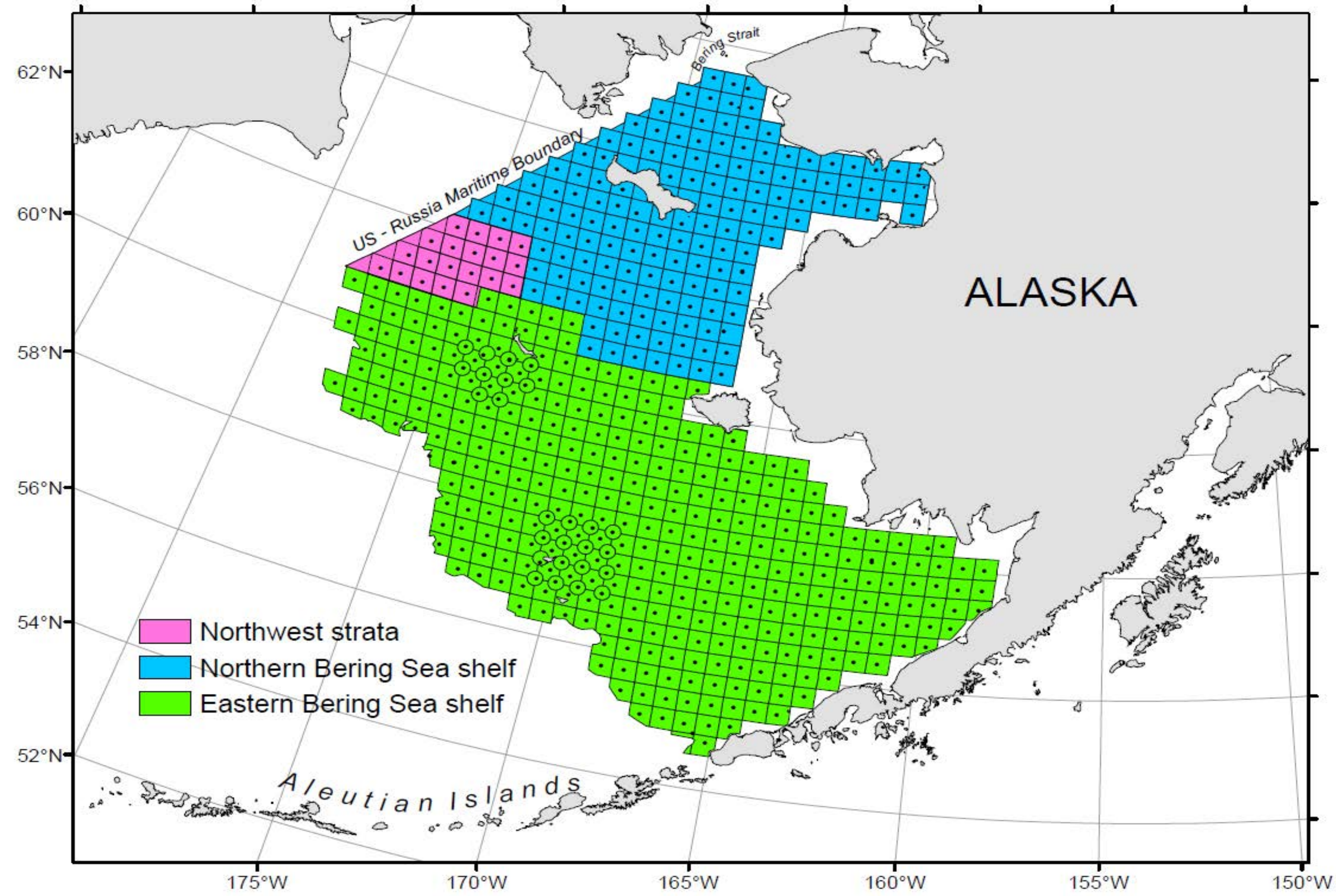


Figure 2.4a—Map of EBS shelf trawl survey standard area, EBS shelf trawl survey northwest strata, and NBS trawl survey area.

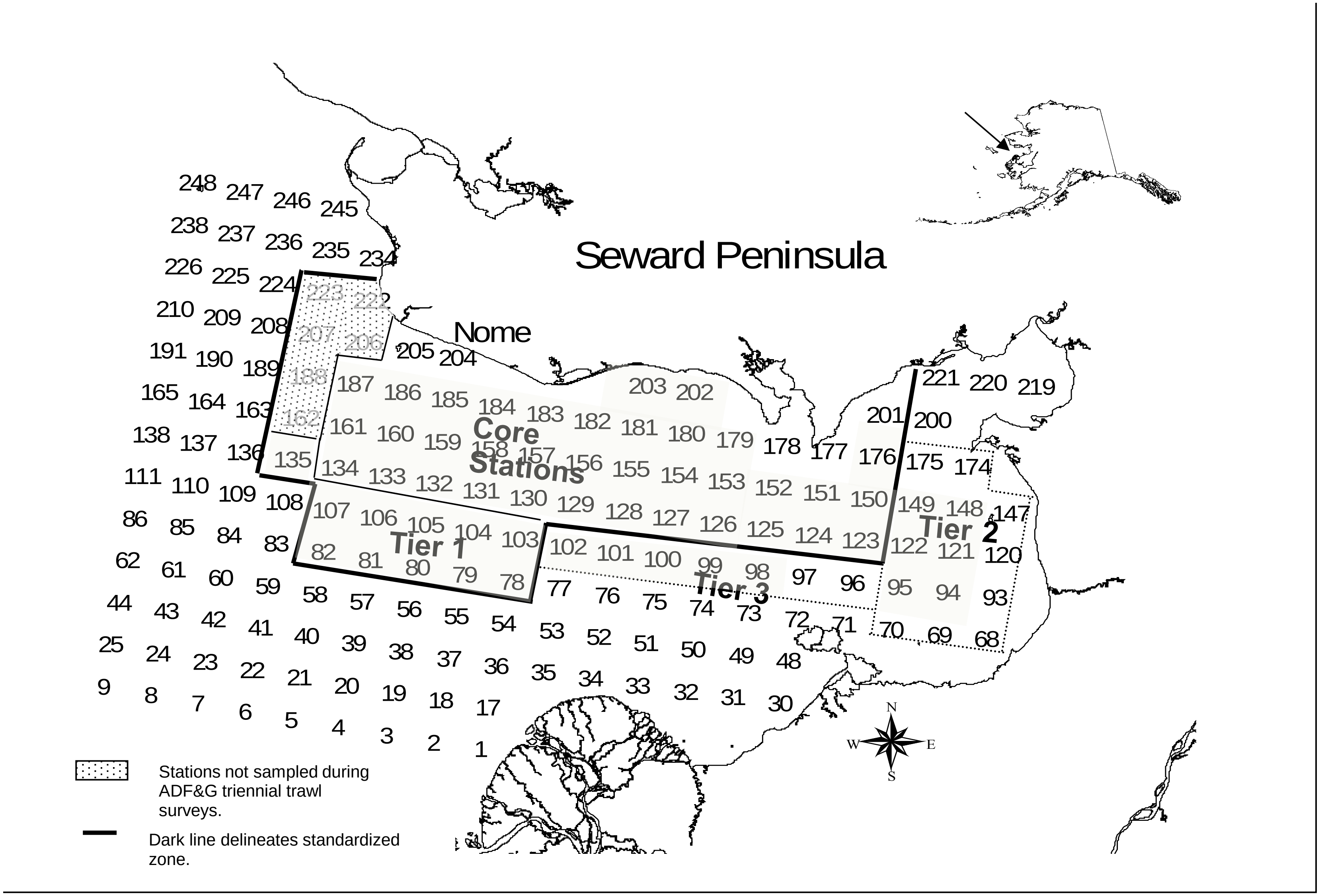


Figure 2.4b—Map of Norton Sound trawl survey area.

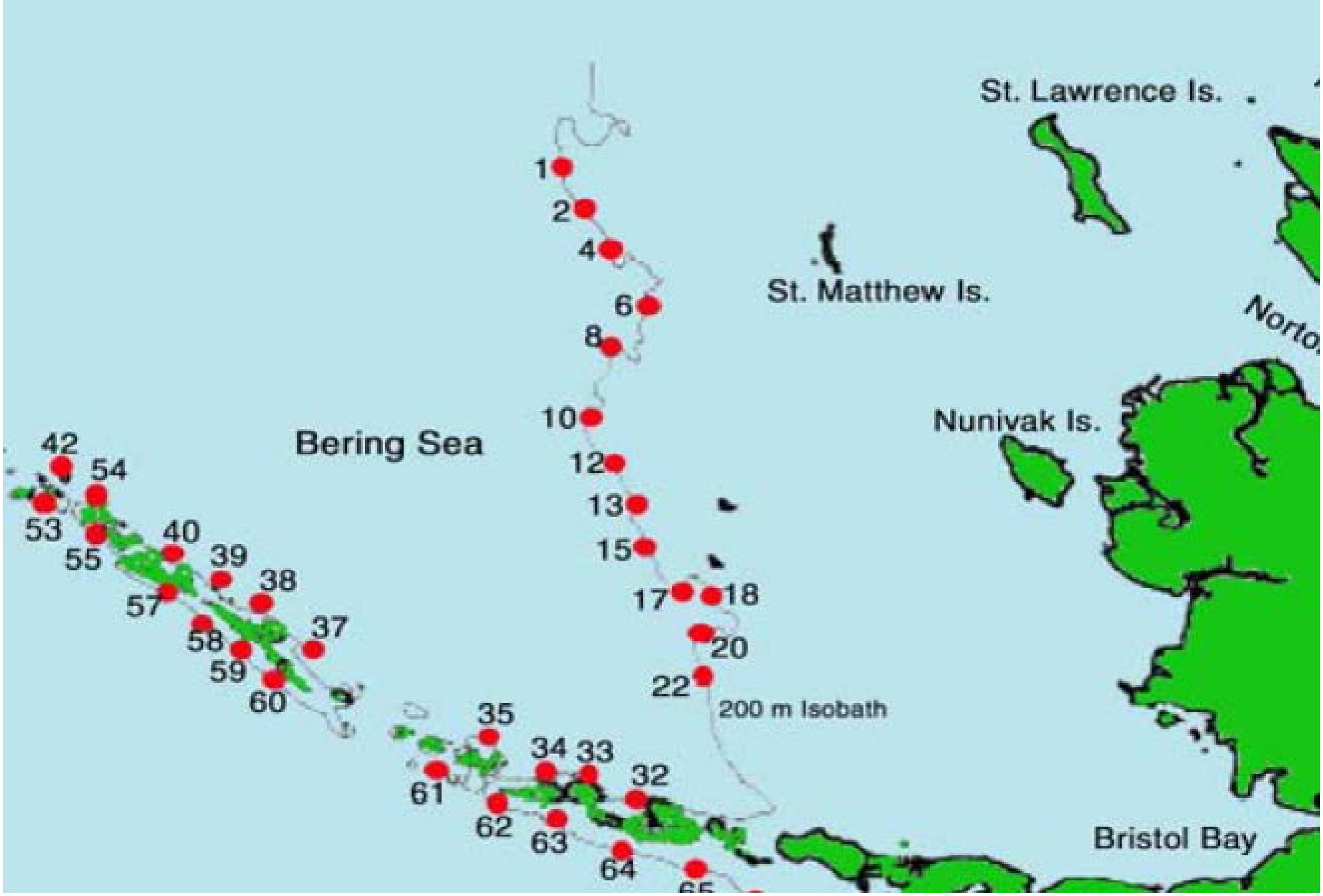


Figure 2.4c—Map of NMFS longline survey area in the EBS and AI.

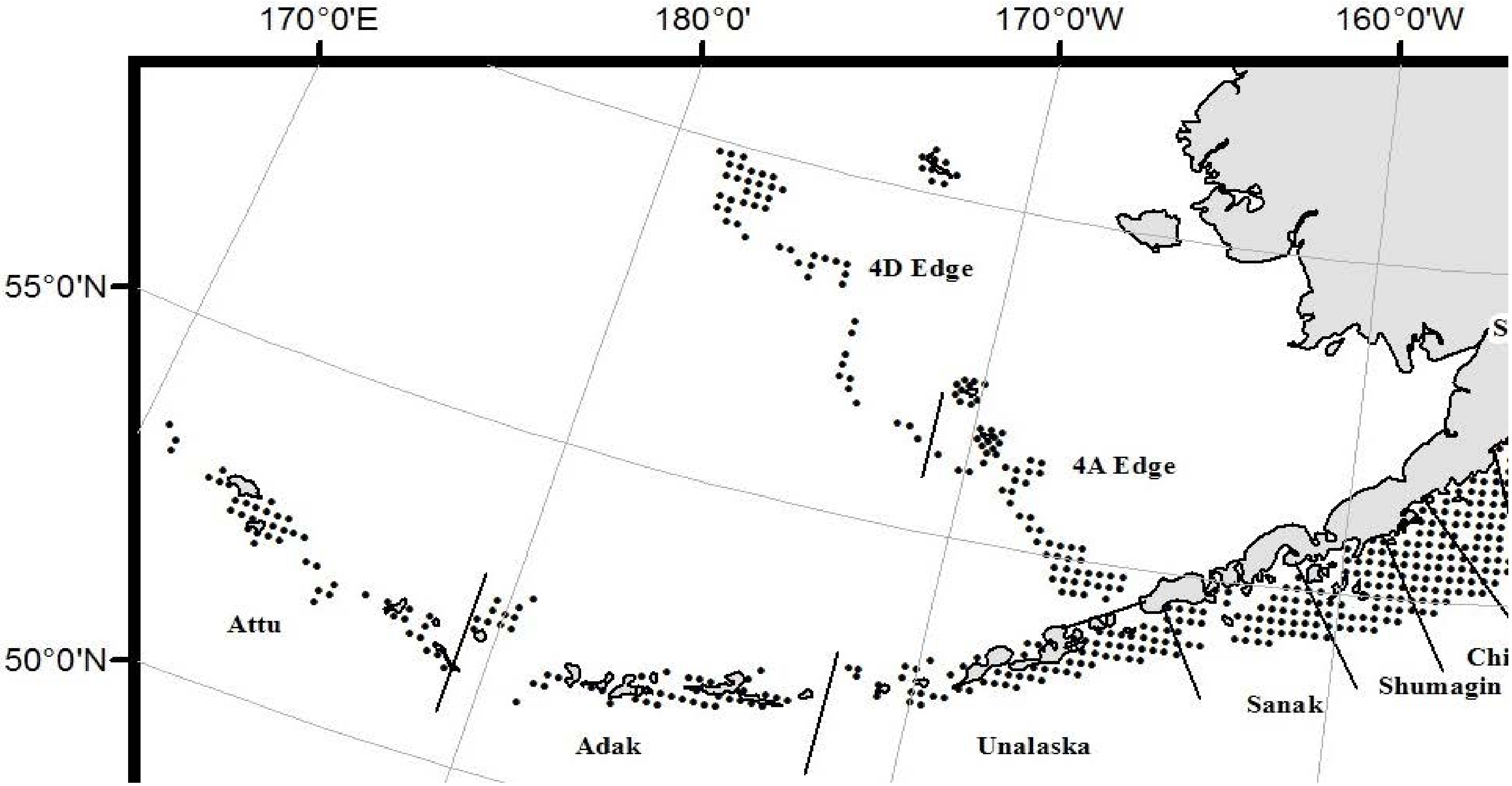


Figure 2.4d—Map of IPHC longline survey area in the EBS and AI.

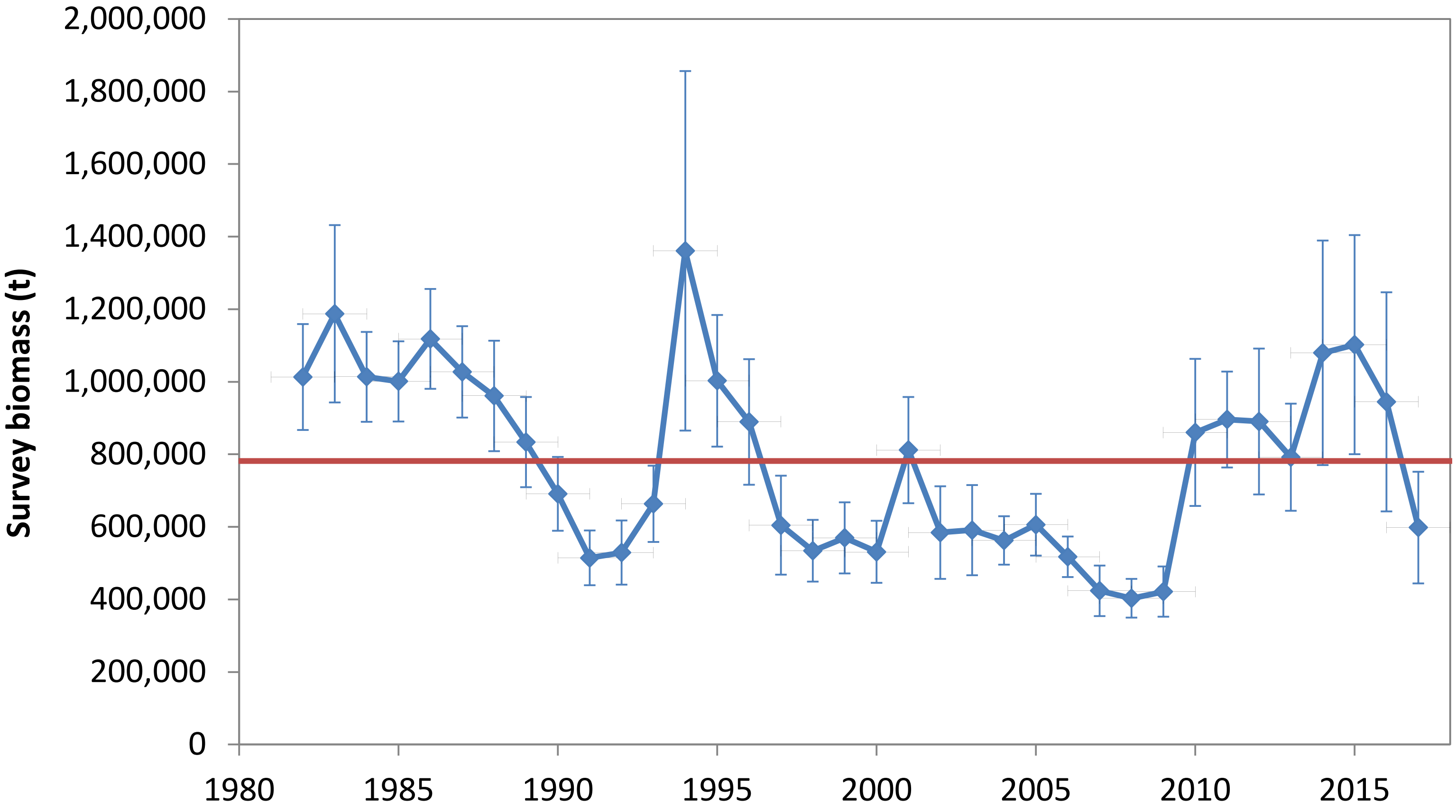


Figure 2.5—EBS trawl survey biomass estimates with 95% confidence intervals (standard area). Red line = long-term average.

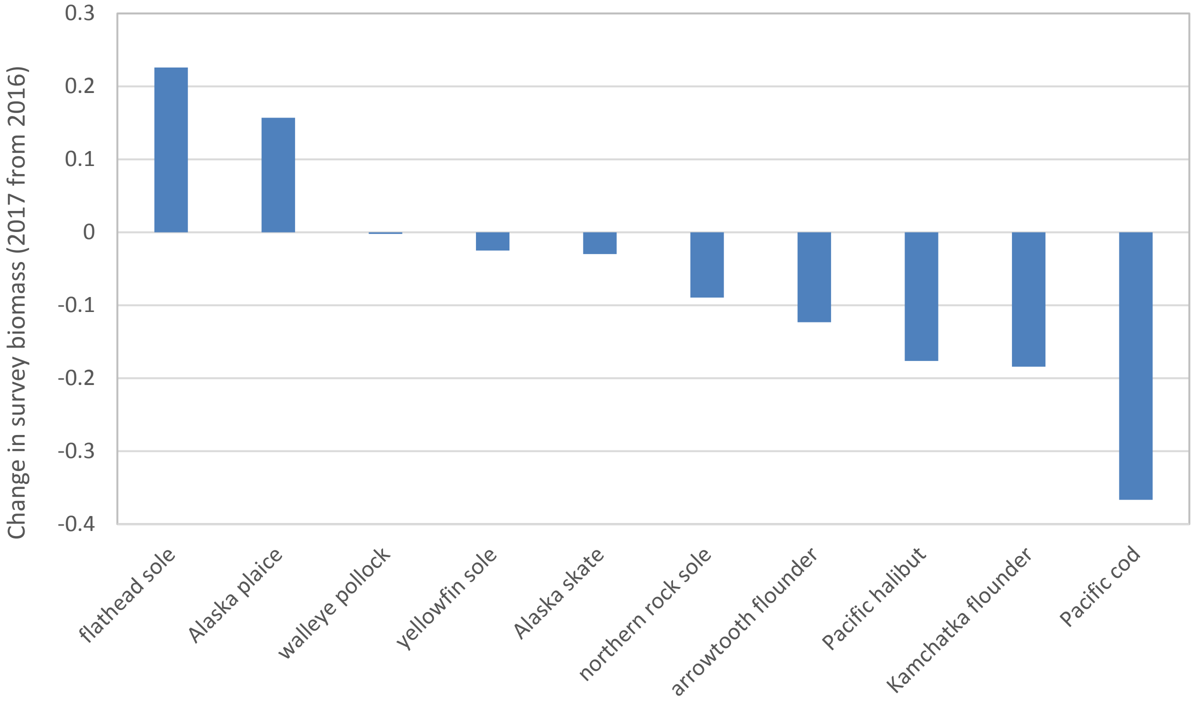


Figure 2.6—Changes in EBS shelf bottom trawl survey biomass estimates from 2016-2017, looking only at species that were present in at least 50% of the stations in both years.

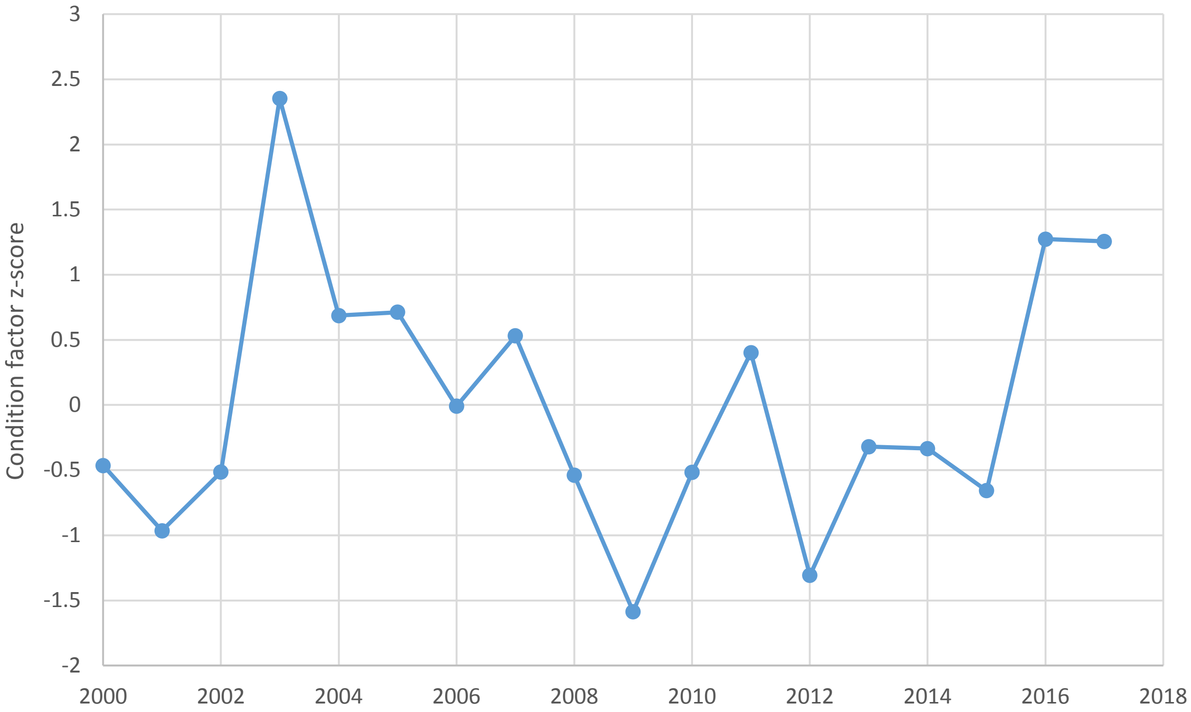


Figure 2.7—Fulton's condition factor by year, 2000-2017, expressed as z-scores.

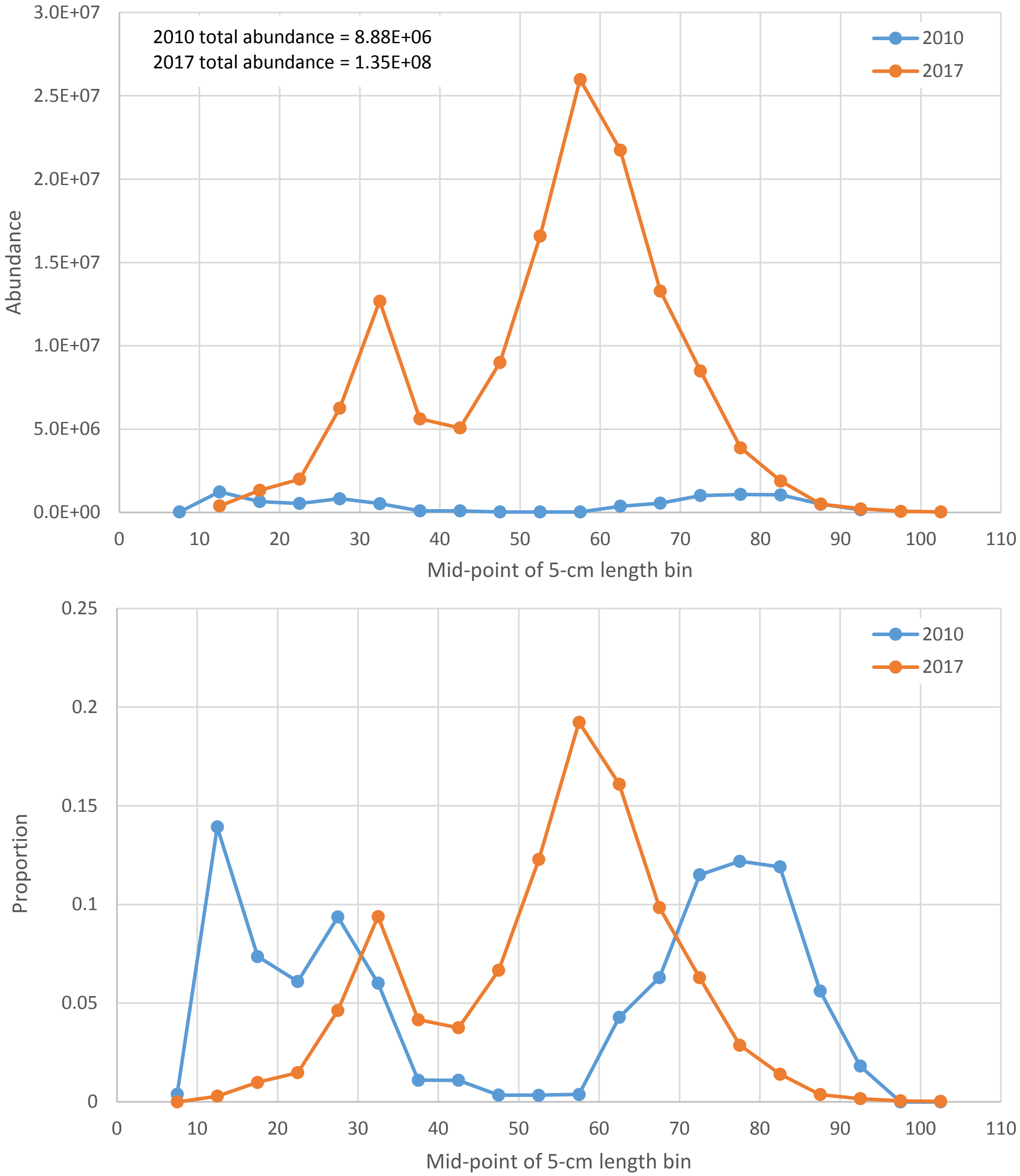


Figure 2.8—Size compositions from the NBS survey by 5-cm bins, 2010 and 2017. Upper panel: population size at length; lower panel: proportion at length.

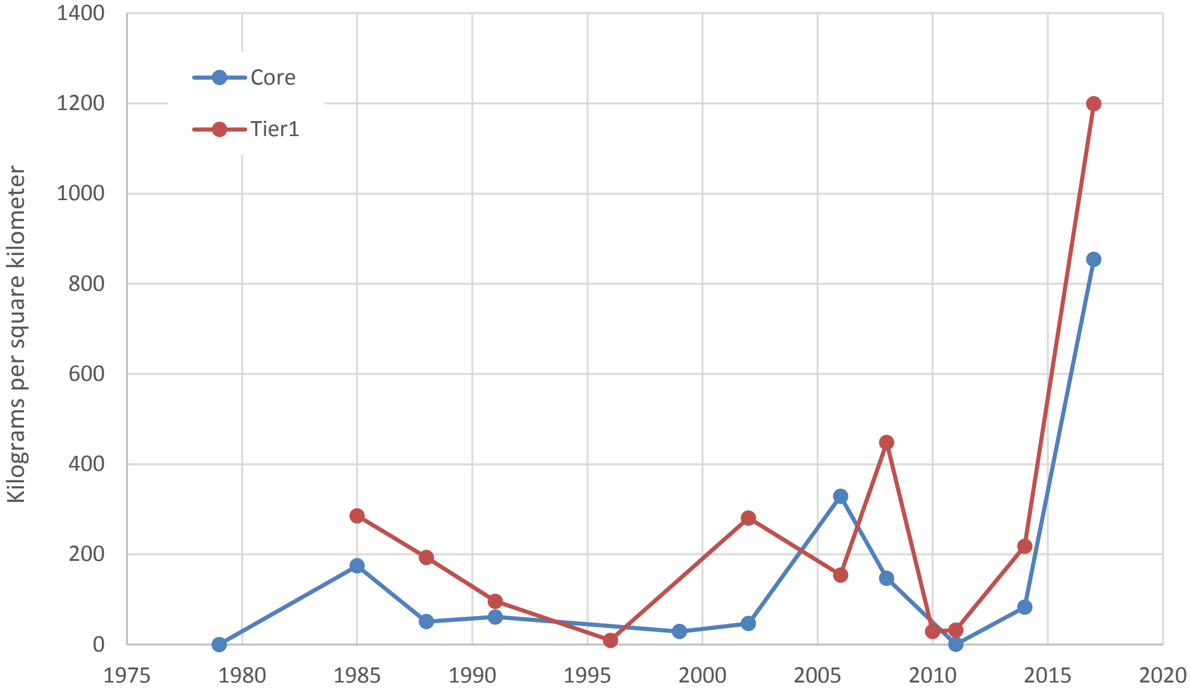


Figure 2.9—Norton Sound survey CPUE time series (see Figure 2.4b for “Core” and “Tier1” areas).

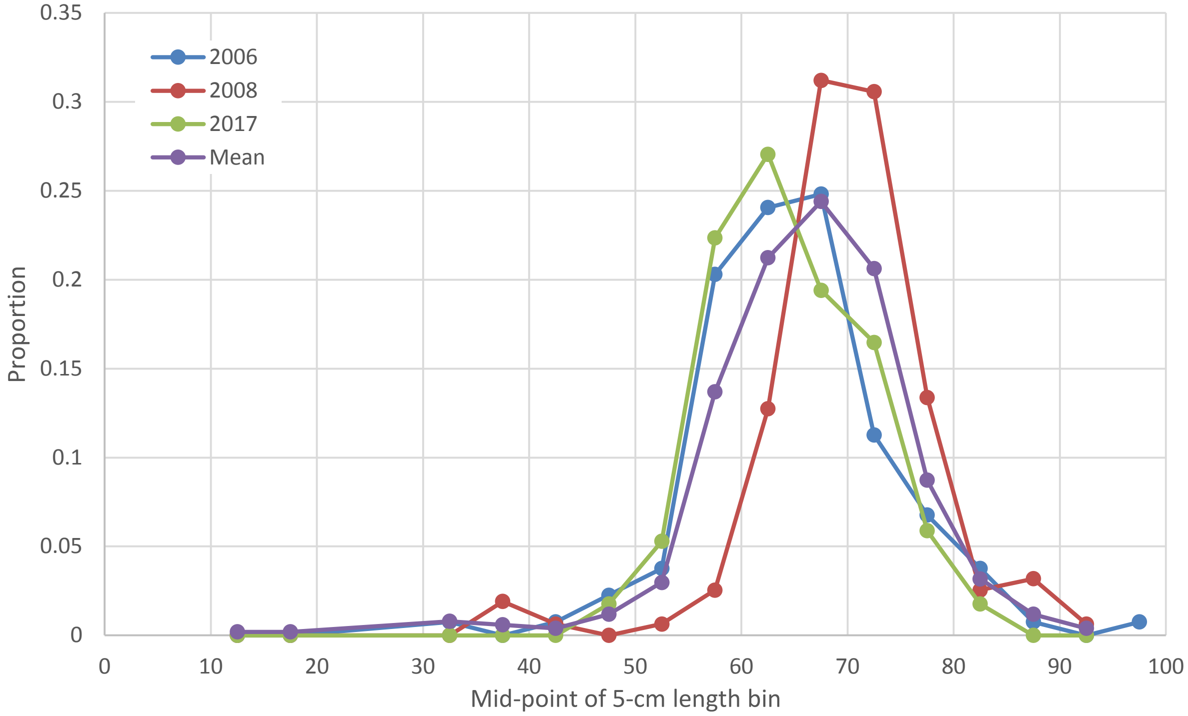


Figure 2.10—Norton Sound survey size compositions (all years with n>100; plus long-term average).

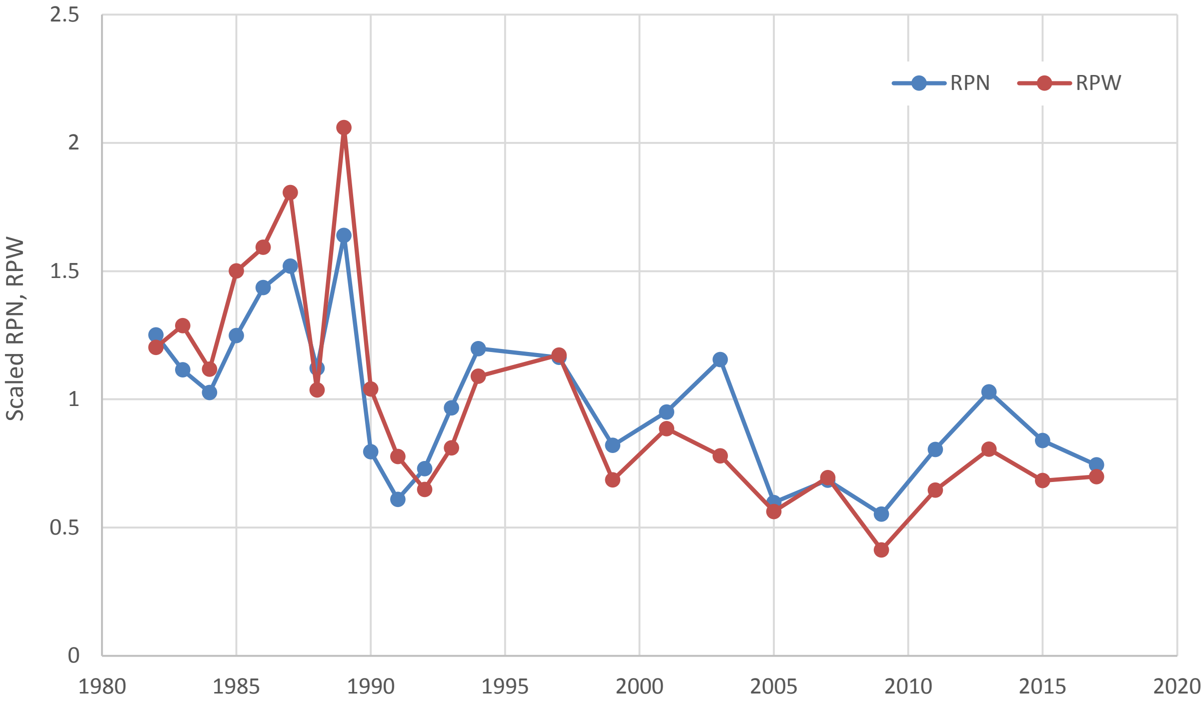


Figure 2.11—NMFS longline survey RPN and RPW, rescaled so that the average of each is 1.0.

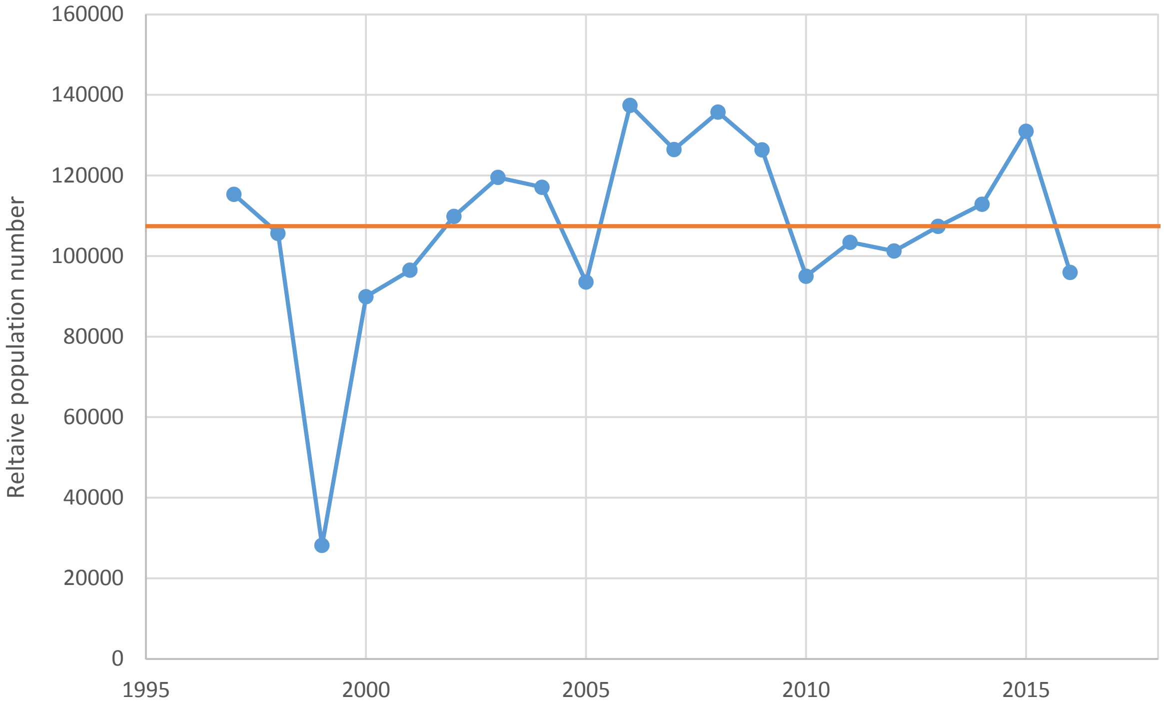


Figure 2.12—IPHC longline survey RPN. Orange line = long-term average.

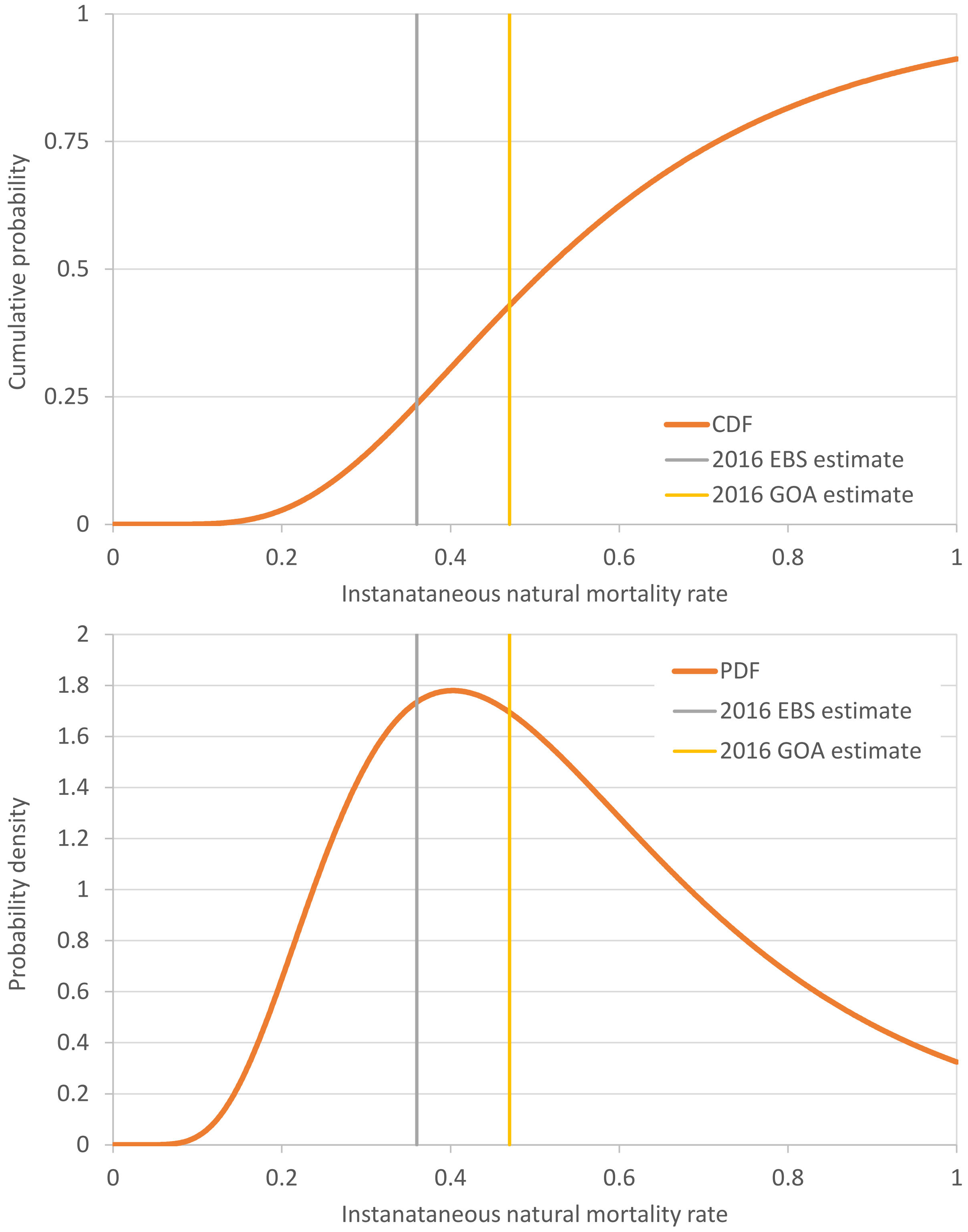


Figure 2.13—Prior distribution for the natural mortality rate. Upper panel: cumulative distribution function; lower panel: probability density function.

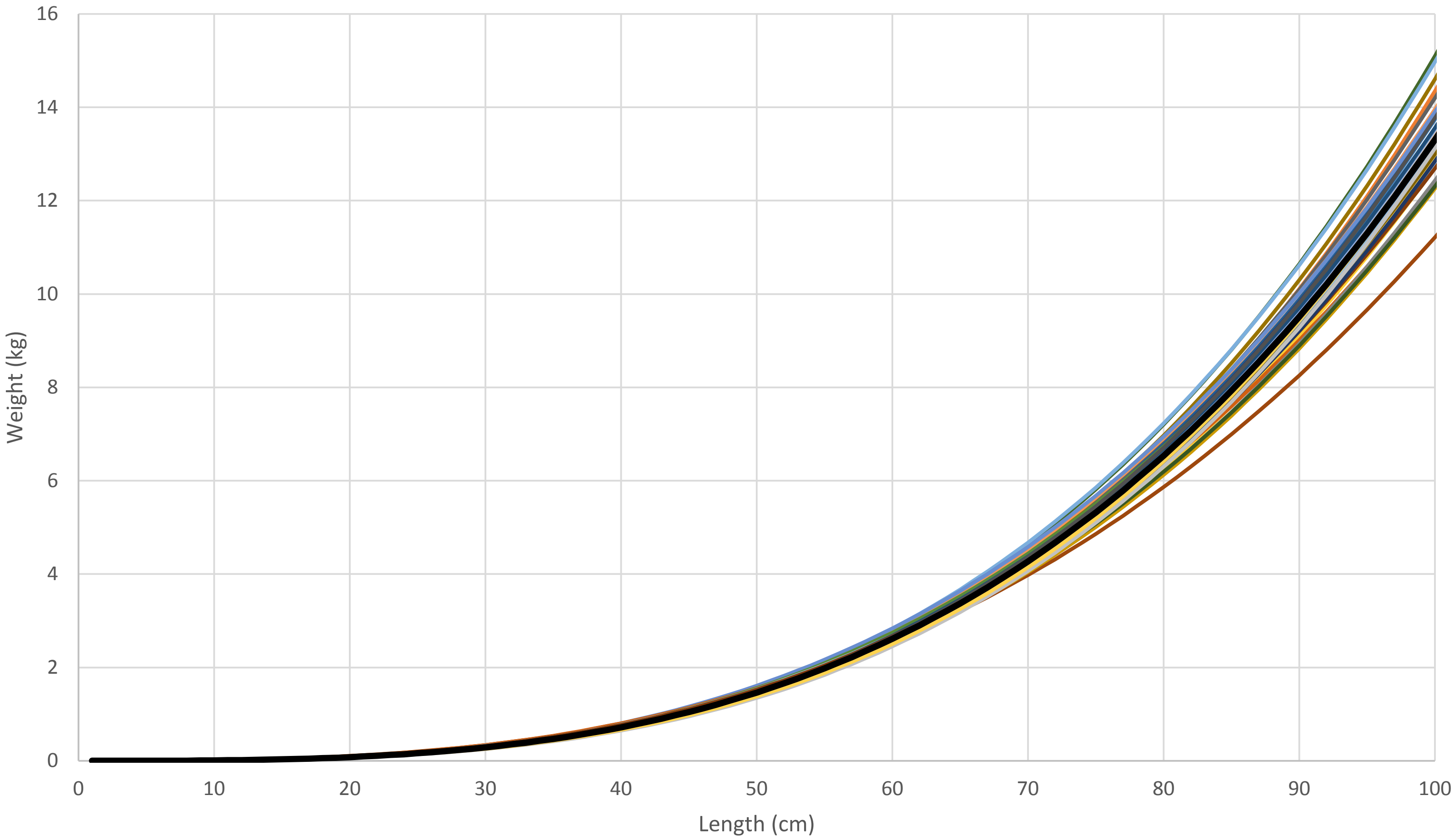


Figure 2.14—Weight-at-length relationships for each year from 1978-2016. Solid black curve represents base parameter values. The curve that is noticeably lower than the others at lengths greater than about 70 cm represents the 1984 relationship.

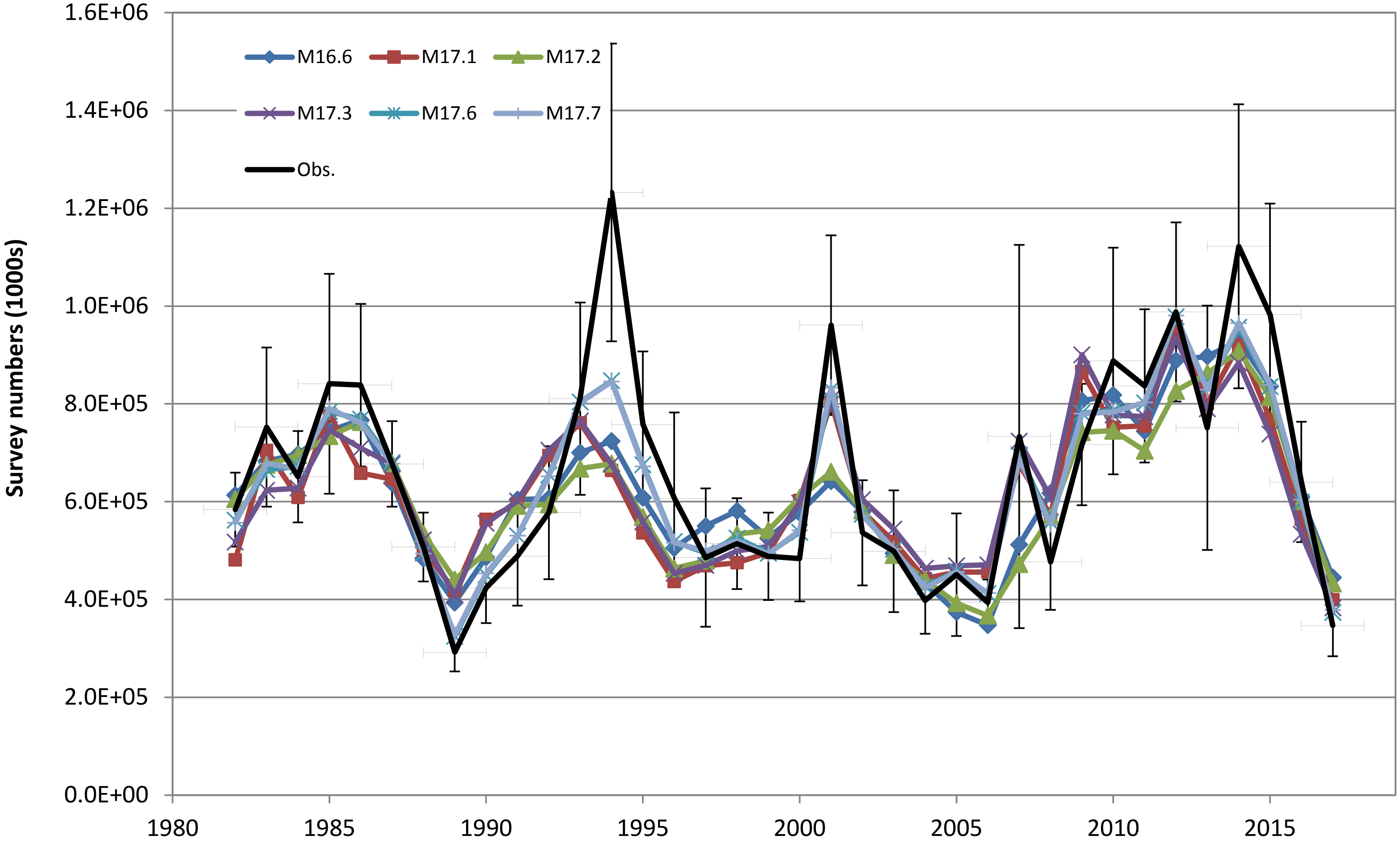


Figure 2.15—Model fits to the EBS shelf bottom trawl survey abundance time series.

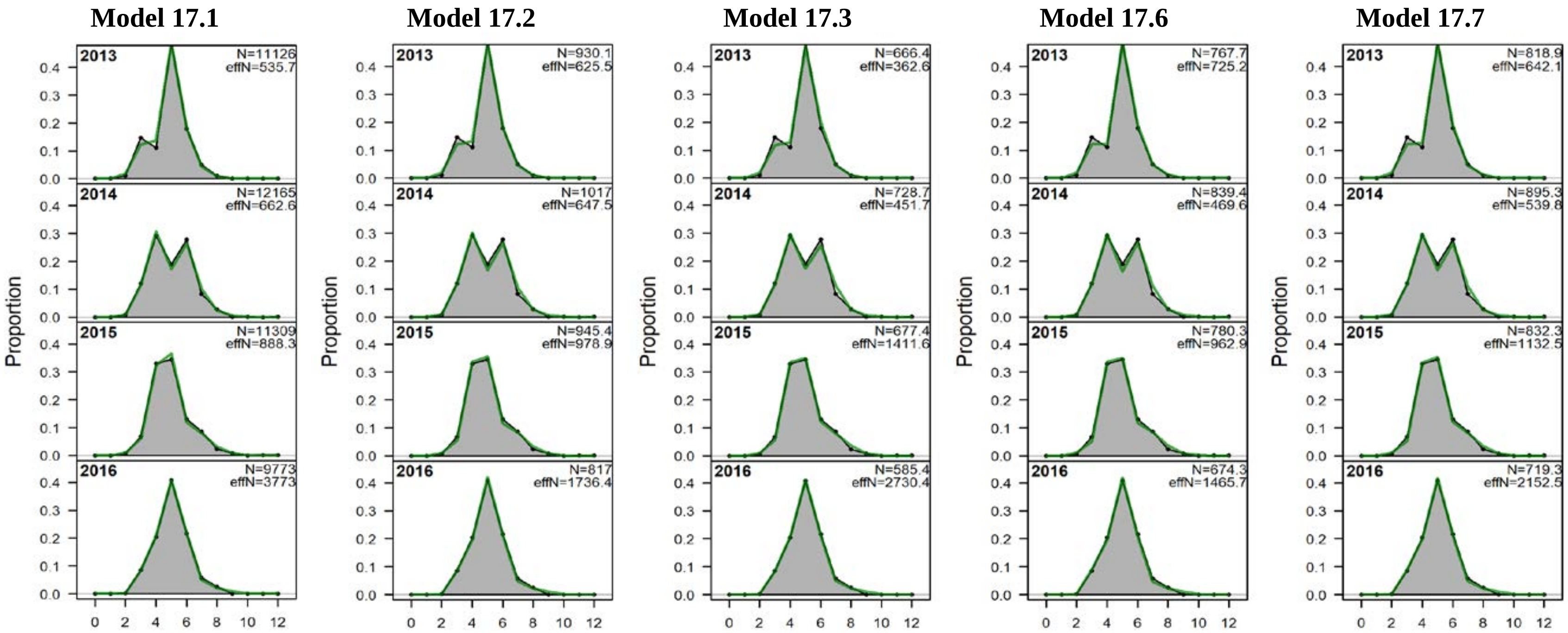


Figure 2.16—Model fits to the fishery age composition data.

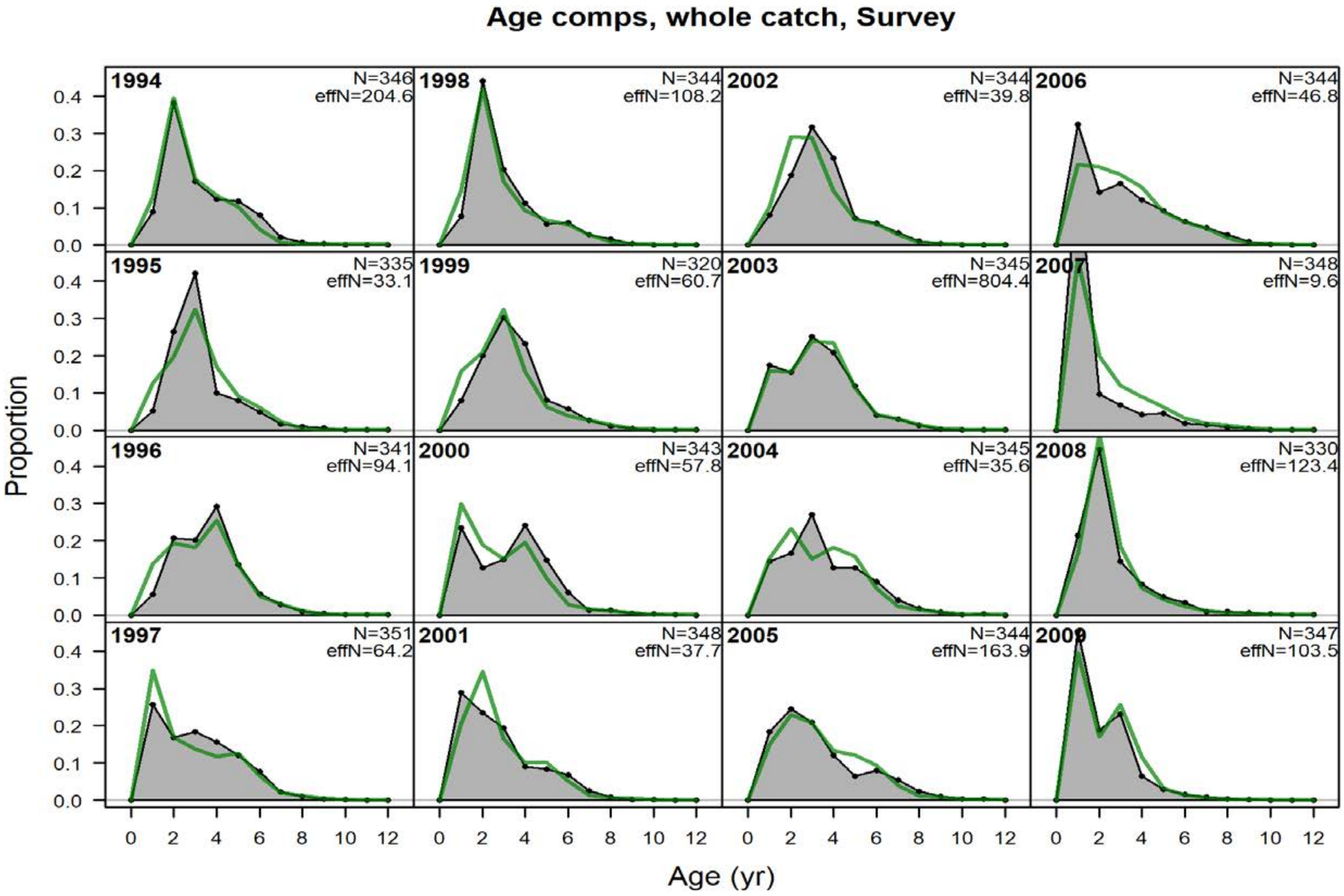


Figure 2.17a (page 1 of 2)—Model 16.6 fits to the survey age composition data.

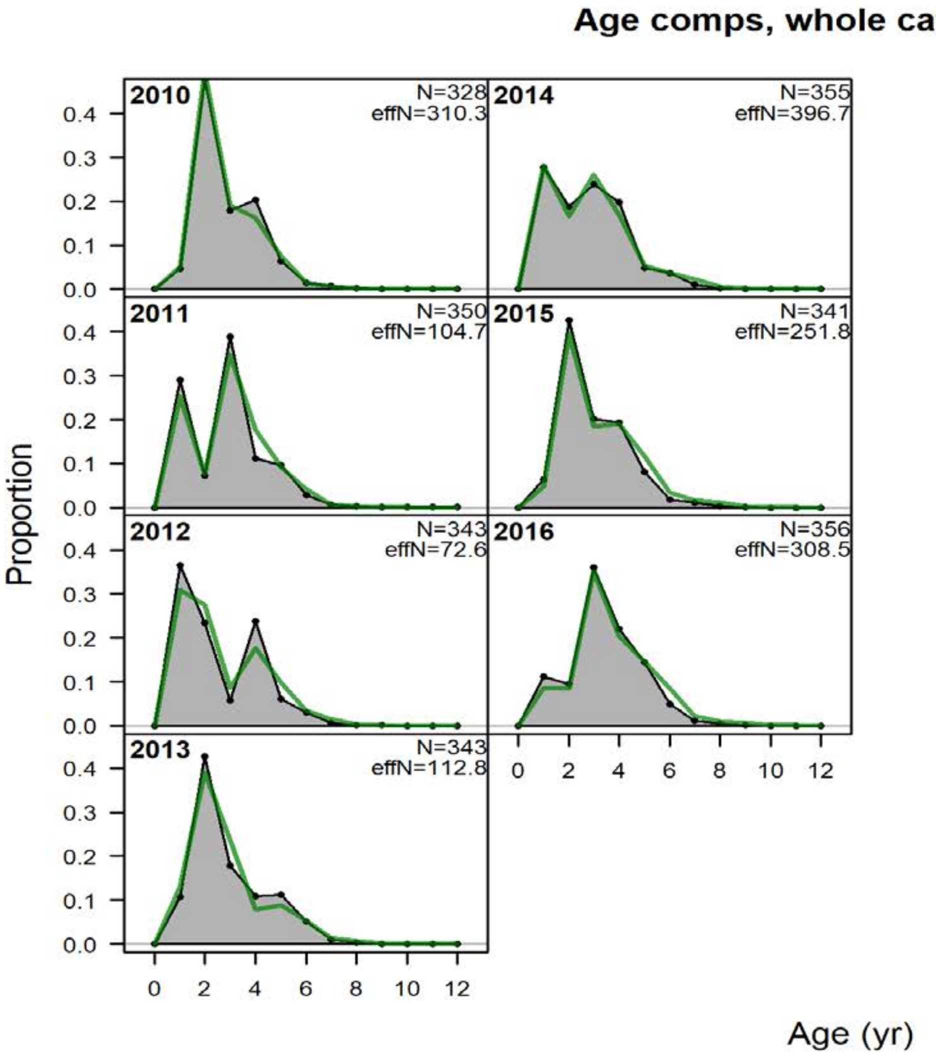


Figure 2.17a (page 2 of 2)—Model 16.6 fits to the survey age composition data.

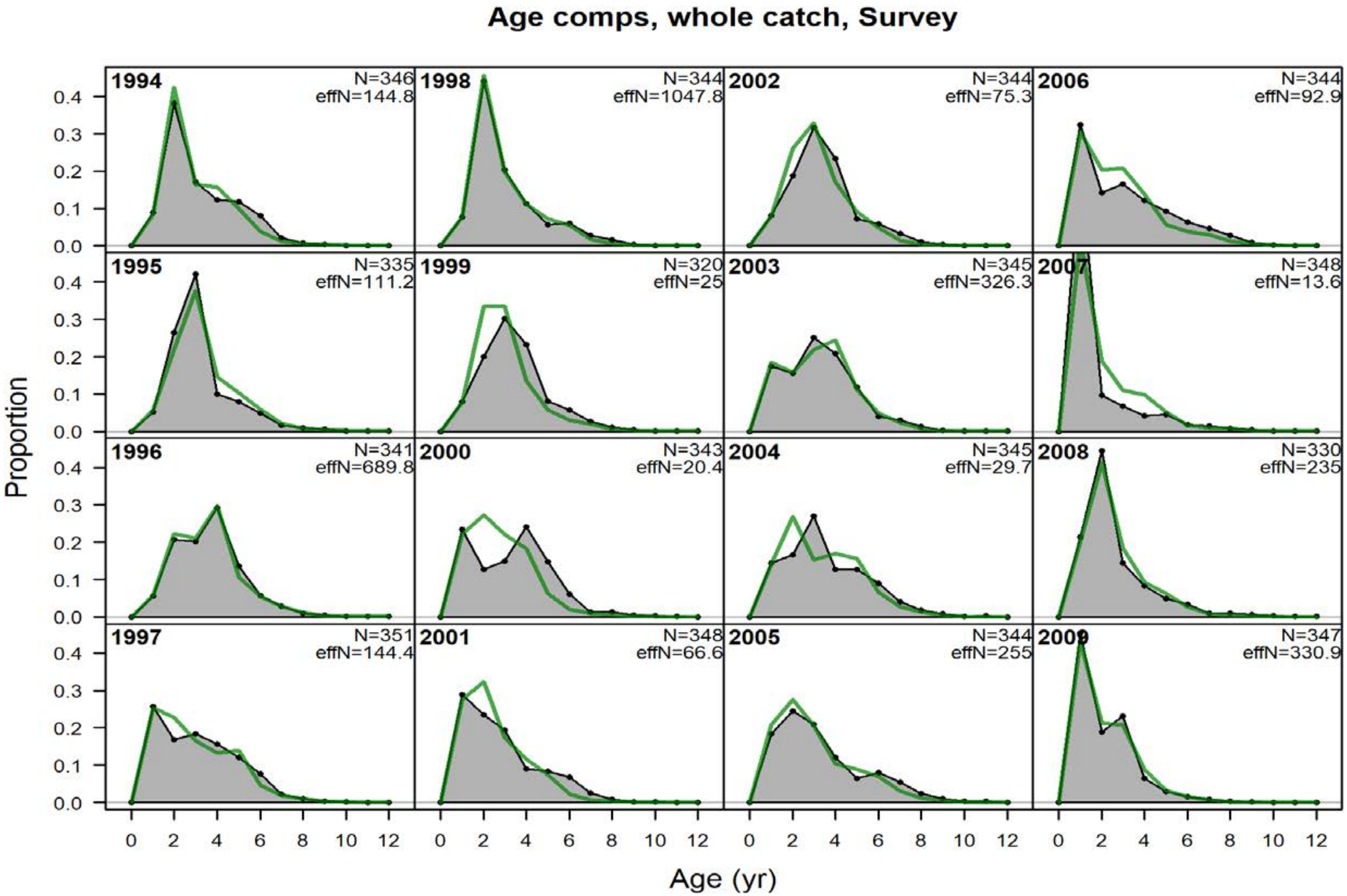


Figure 2.17b (page 1 of 2)—Model 17.1 fits to the survey age composition data.

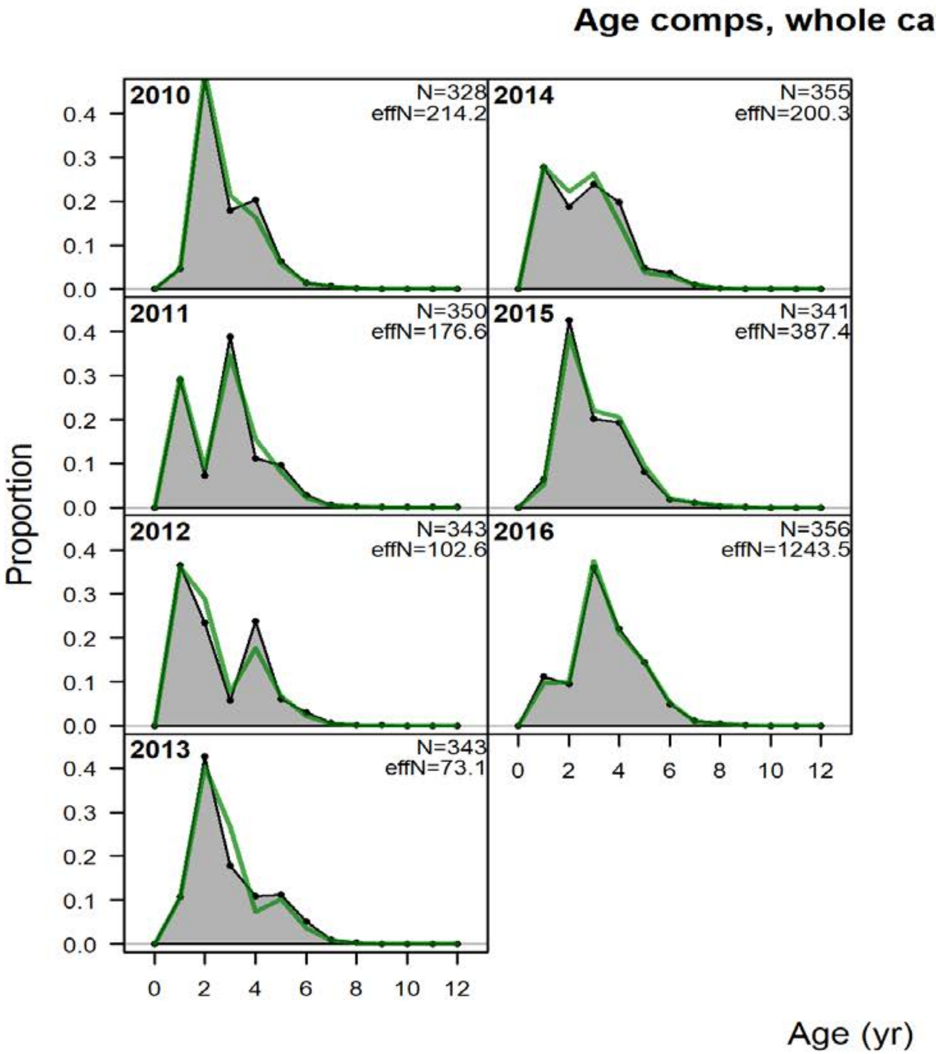


Figure 2.17b (page 2 of 2)—Model 17.1 fits to the survey age composition data.

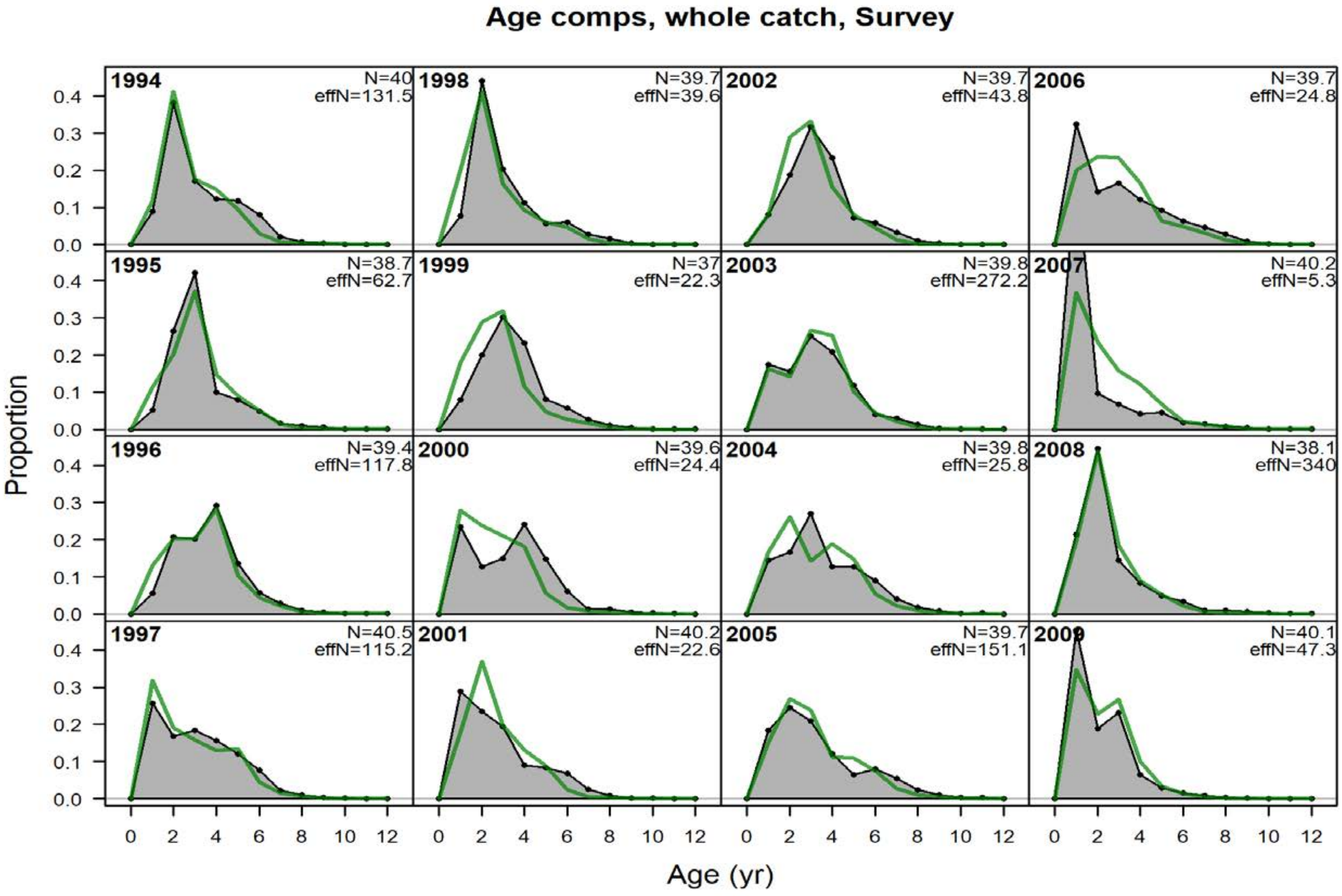


Figure 2.17c (page 1 of 2)—Model 17.2 fits to the survey age composition data.

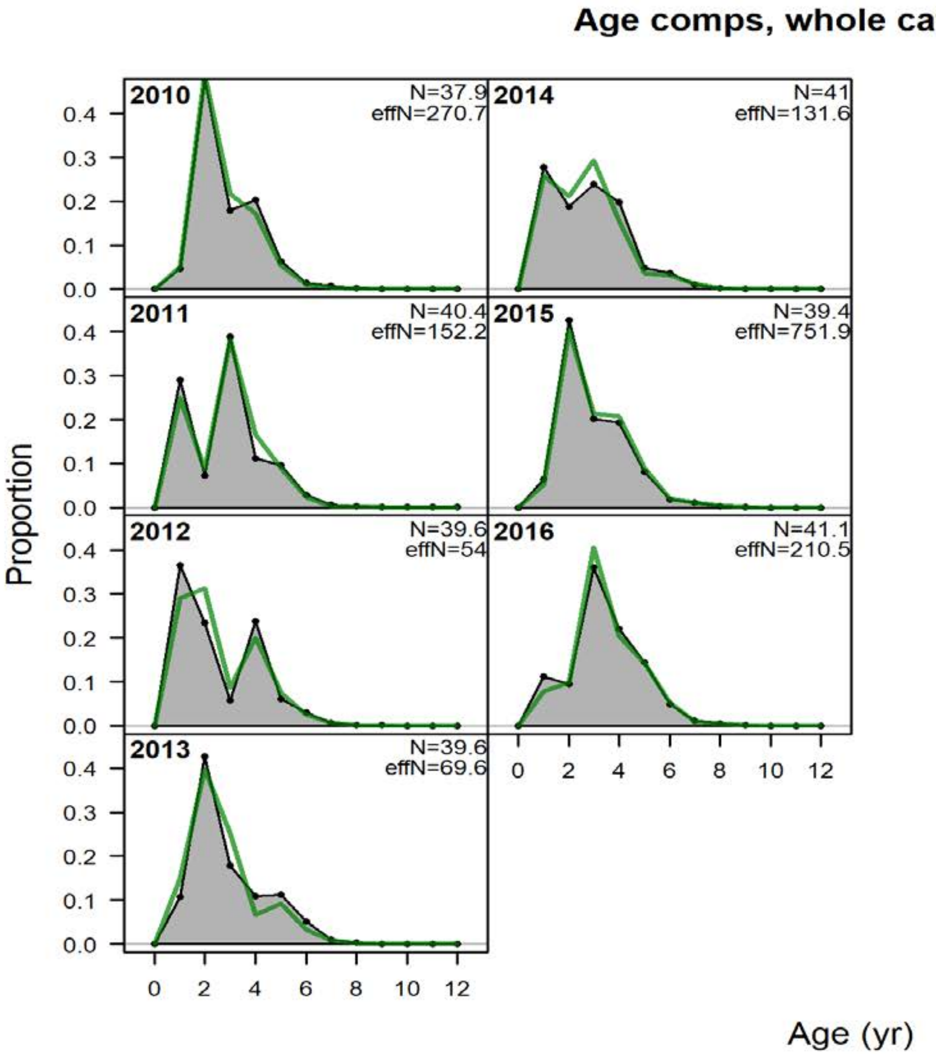


Figure 2.17c (page 2 of 2)—Model 17.2 fits to the survey age composition data.

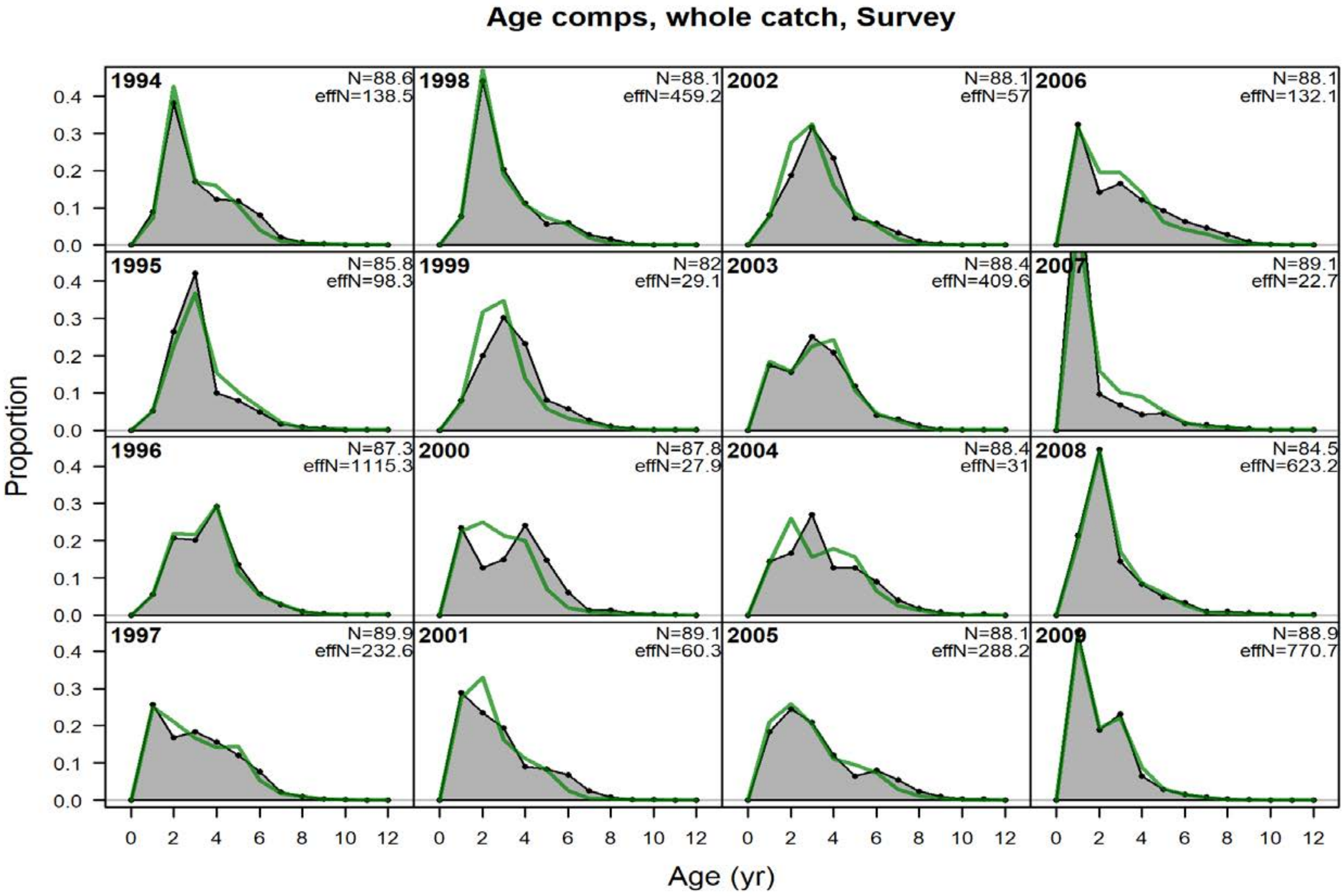


Figure 2.17d (page 1 of 2)—Model 17.3 fits to the survey age composition data.

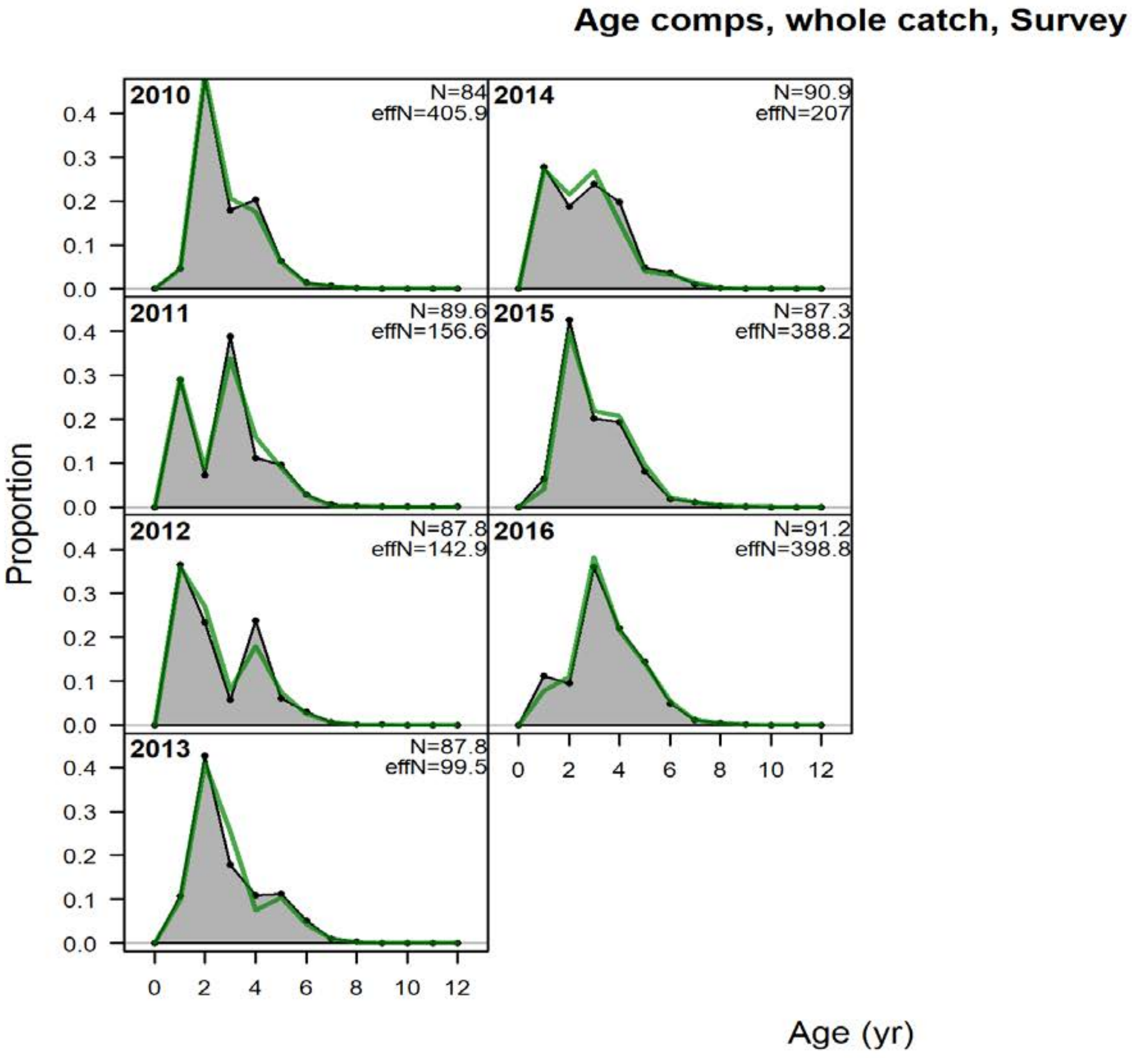


Figure 2.17d (page 2 of 2)—Model 17.3 fits to the survey age composition data.

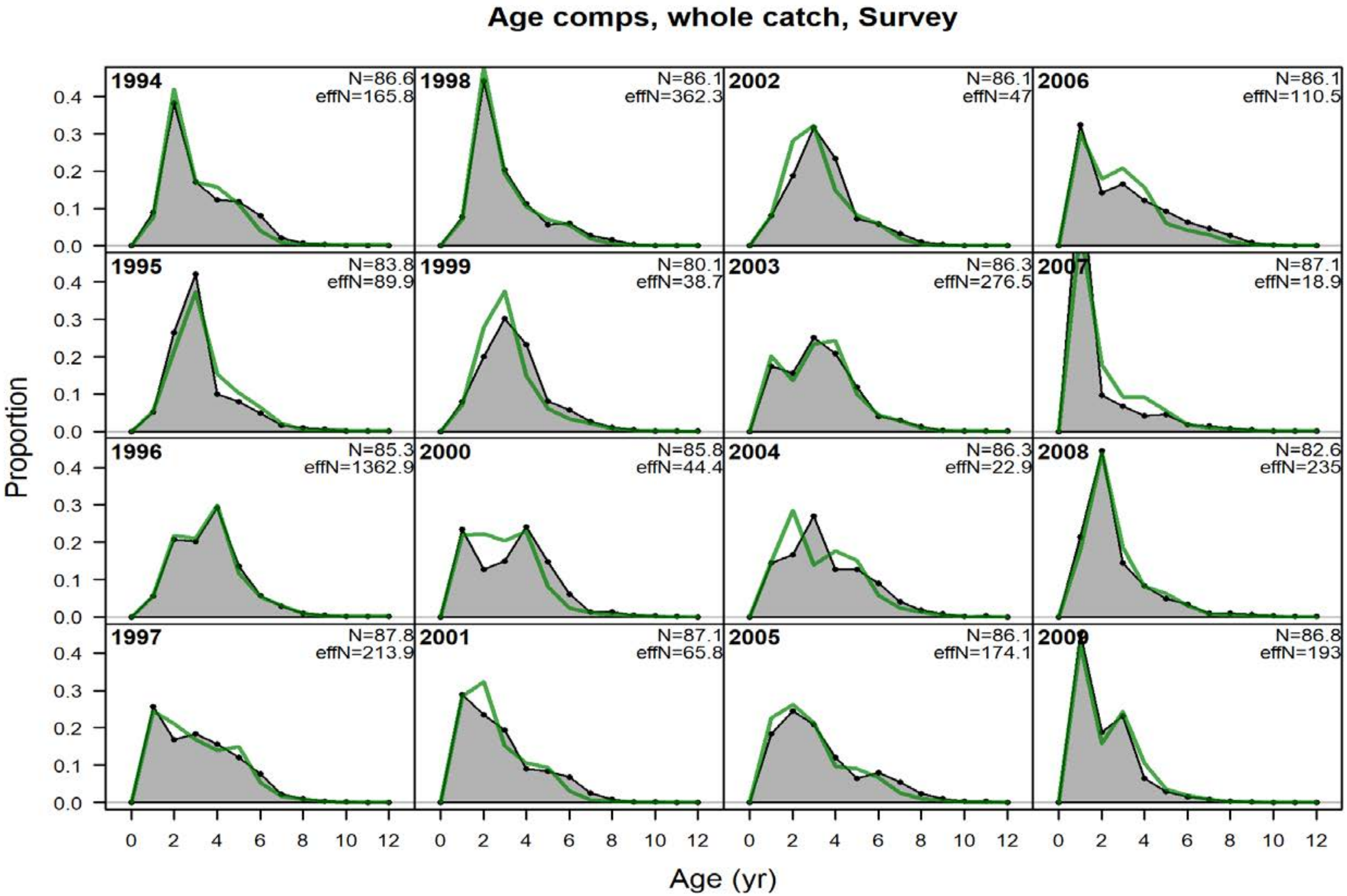


Figure 2.17e (page 1 of 2)—Model 17.6 fits to the survey age composition data.

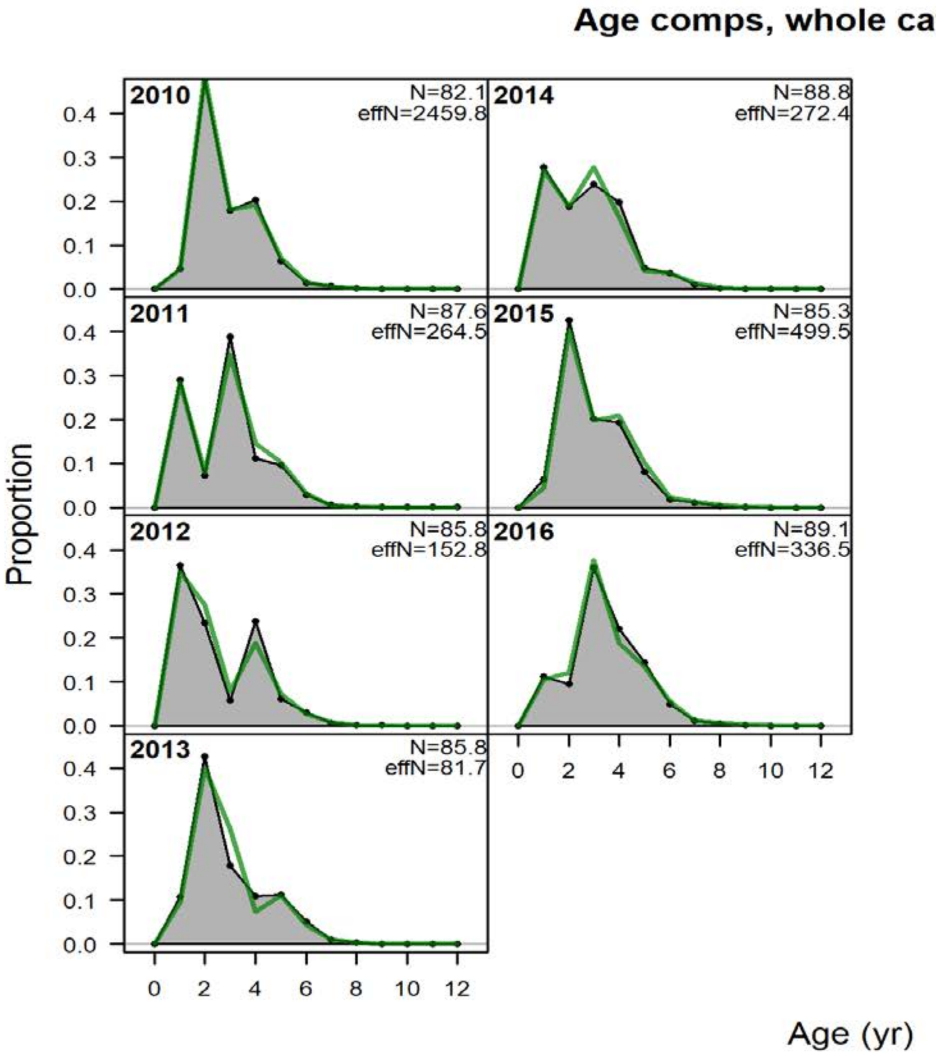


Figure 2.17e (page 2 of 2)—Model 17.6 fits to the survey age composition data.

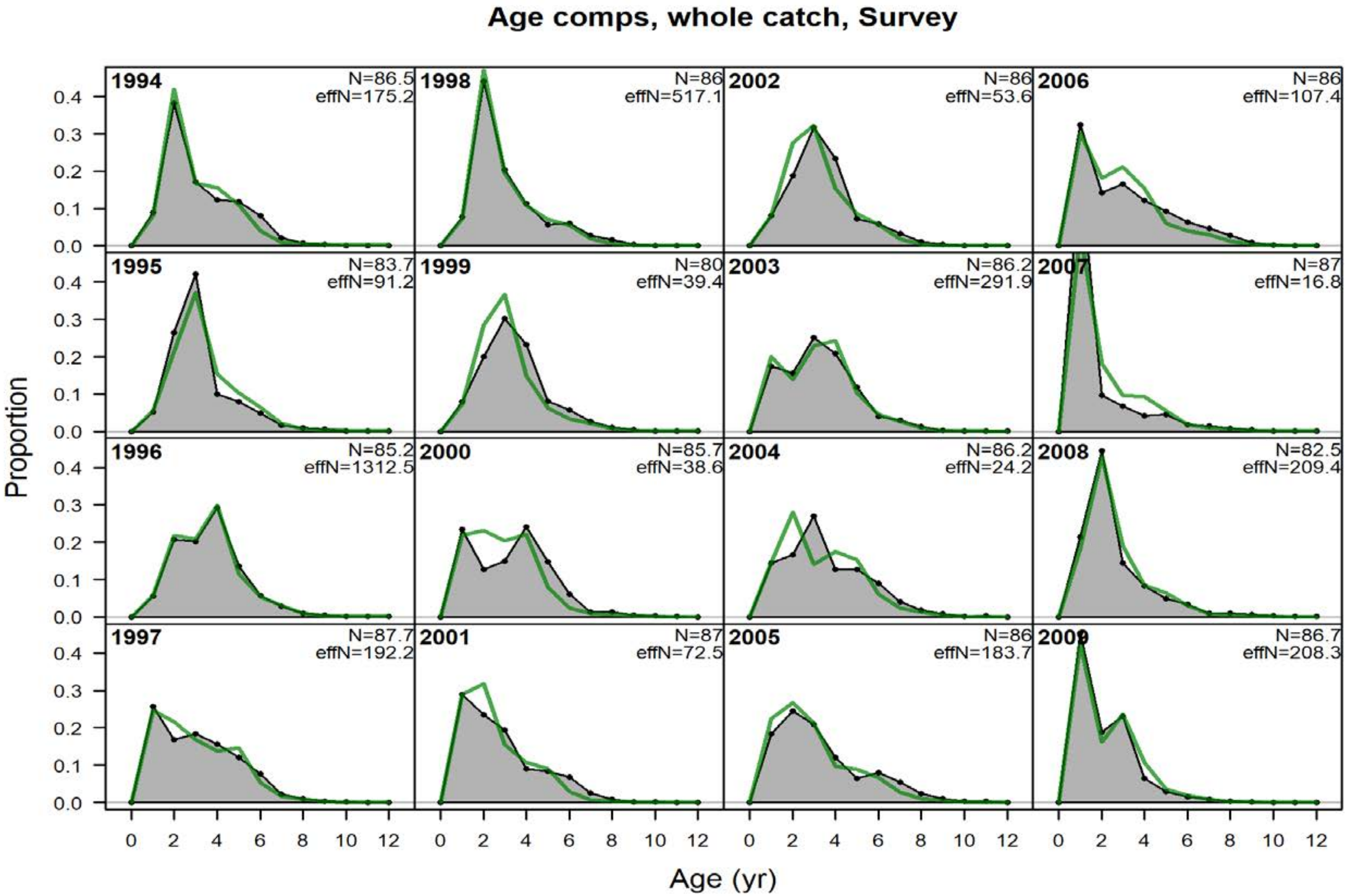


Figure 2.17f (page 1 of 2)—Model 17.7 fits to the survey age composition data.

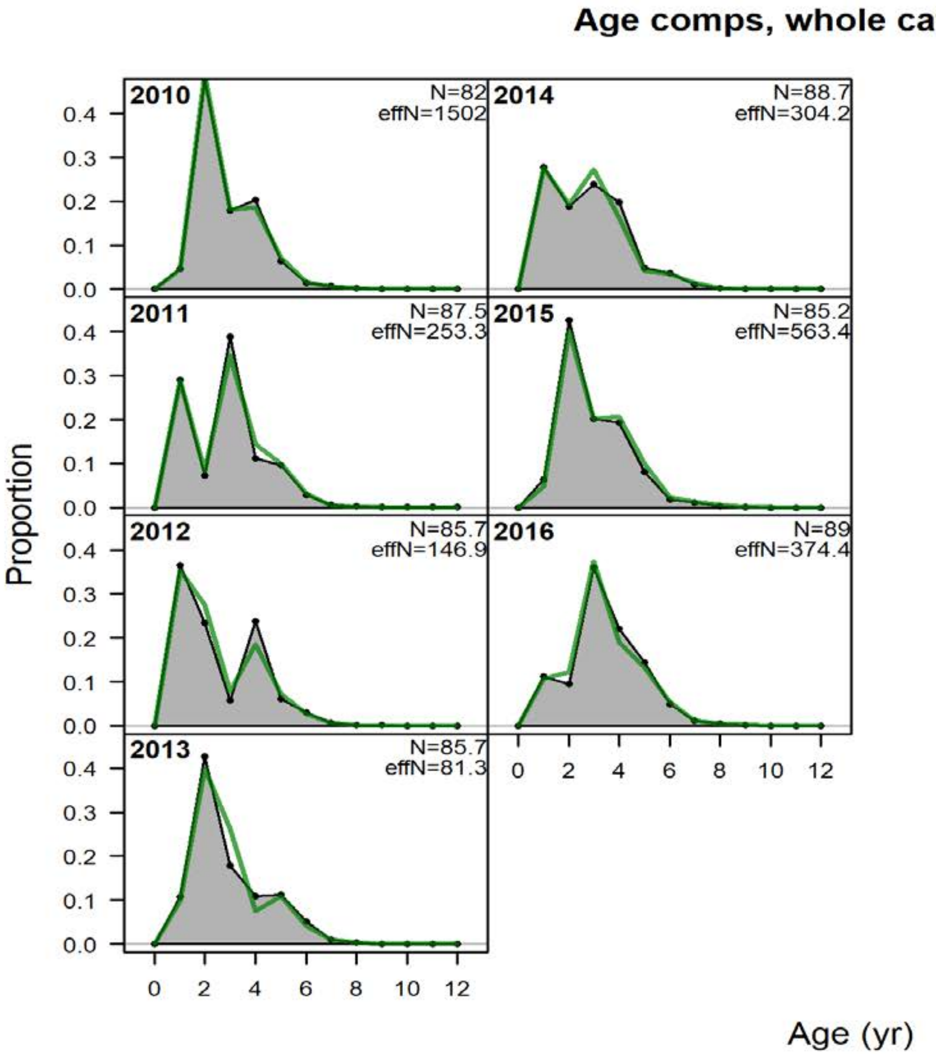
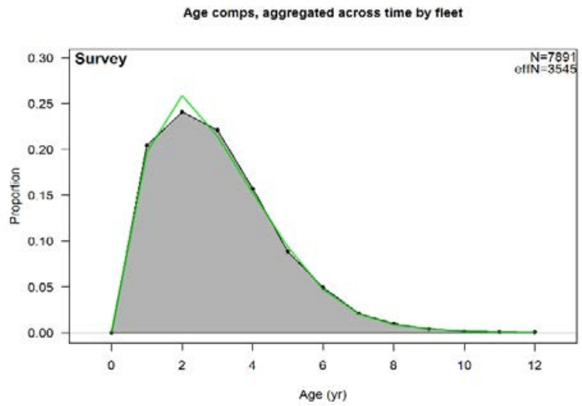
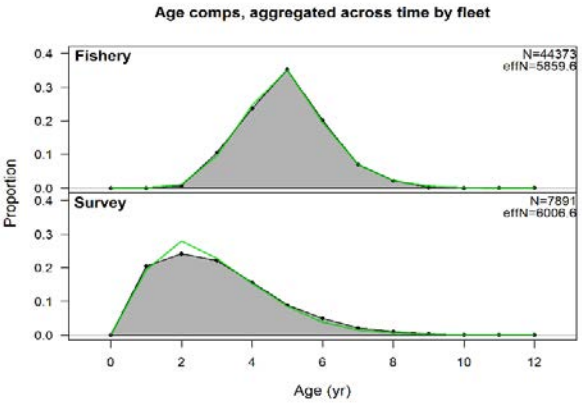


Figure 2.17f (page 2 of 2)—Model 17.7 fits to the survey age composition data.

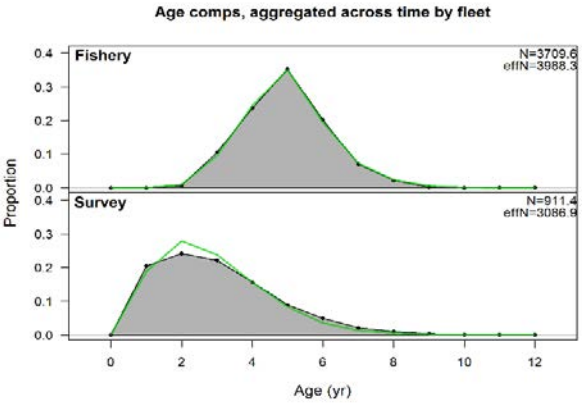
Model 16.6



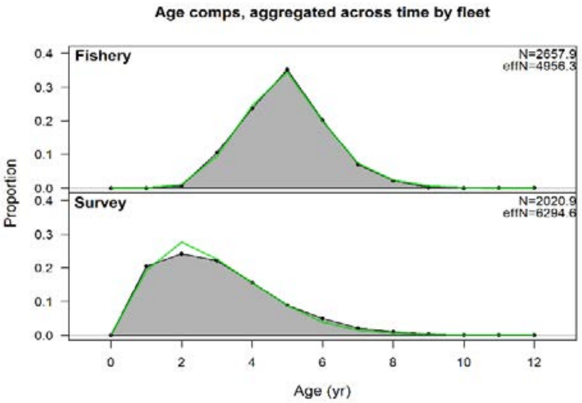
Model 17.1



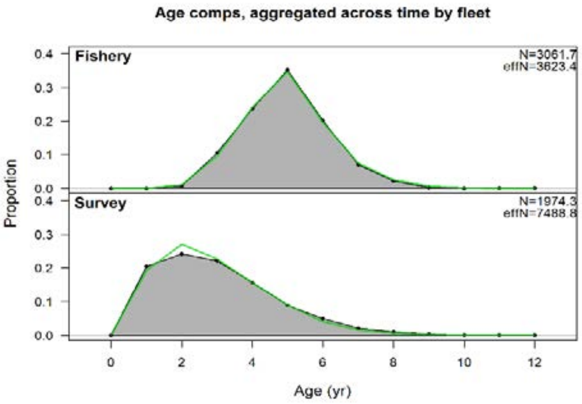
Model 17.2



Model 17.3



Model 17.6



Model 17.7

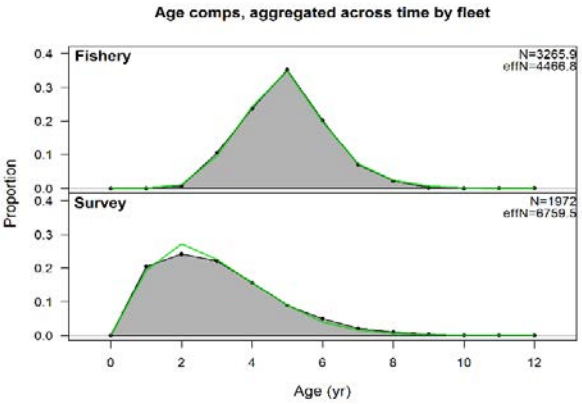


Figure 2.18—Time-aggregated age composition fits.

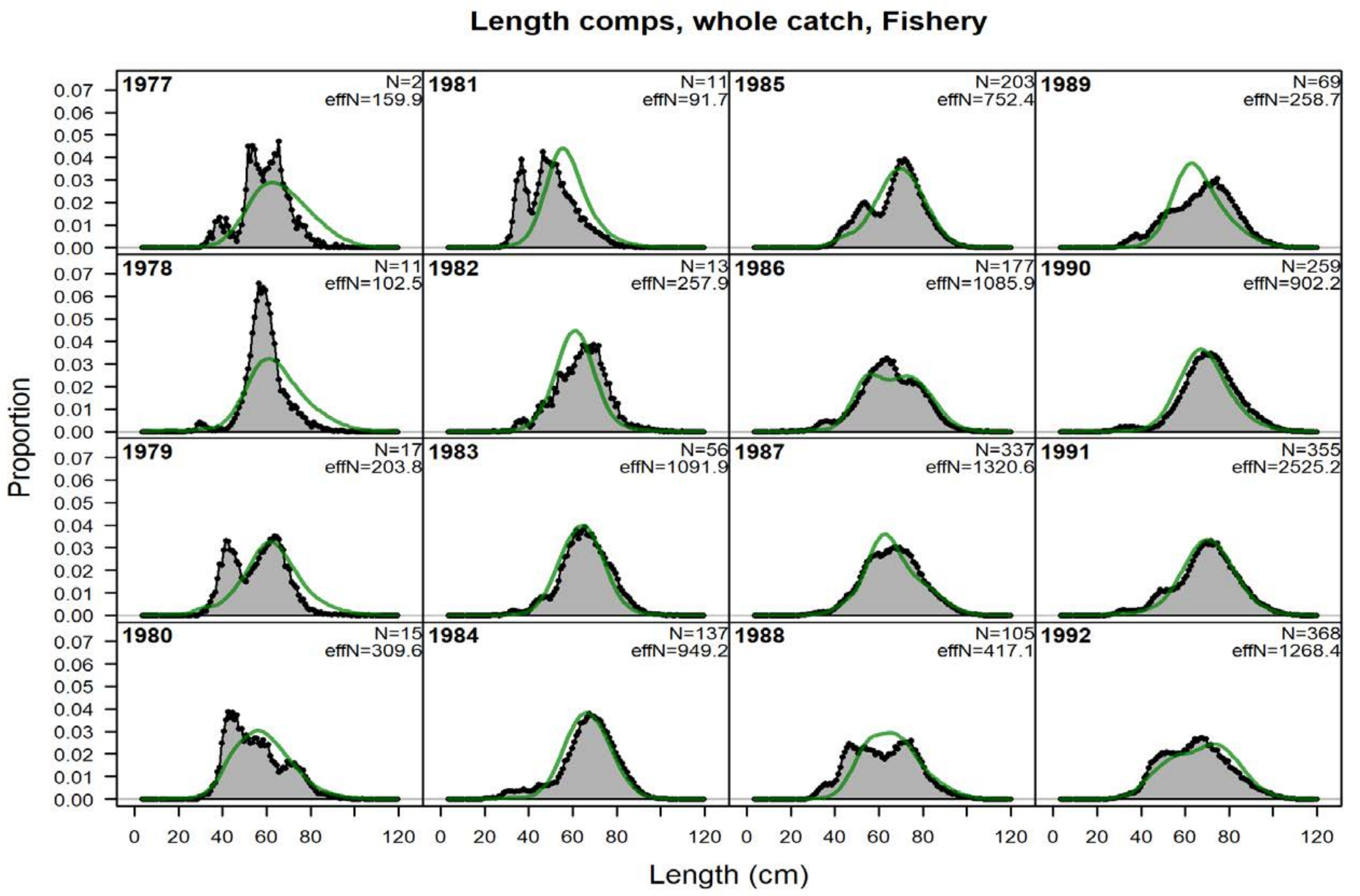


Figure 2.19a (page 1 of 3)—Model 16.6 fits to the fishery size composition data.

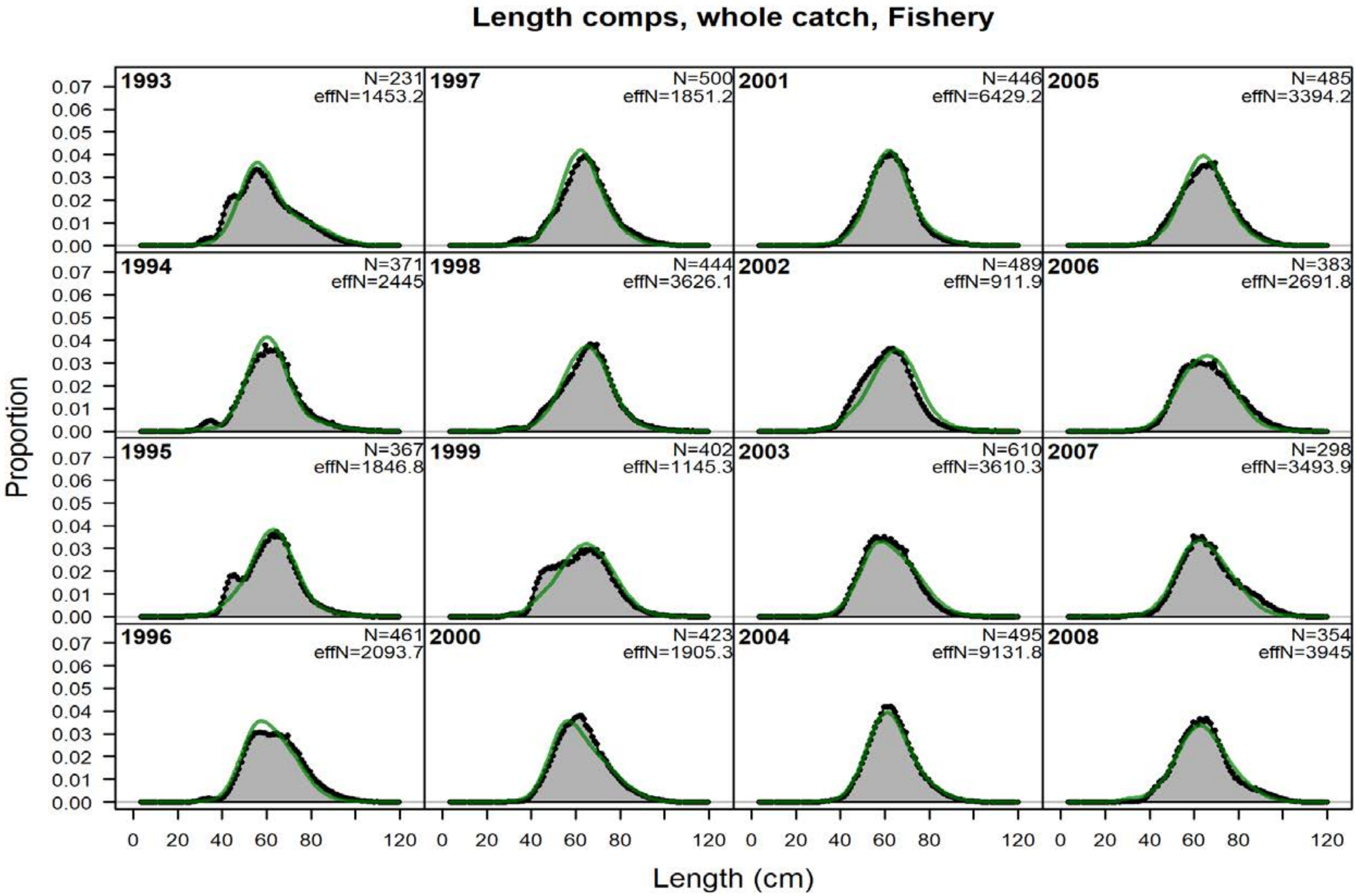


Figure 2.19a (page 2 of 3)—Model 16.6 fits to the fishery size composition data.

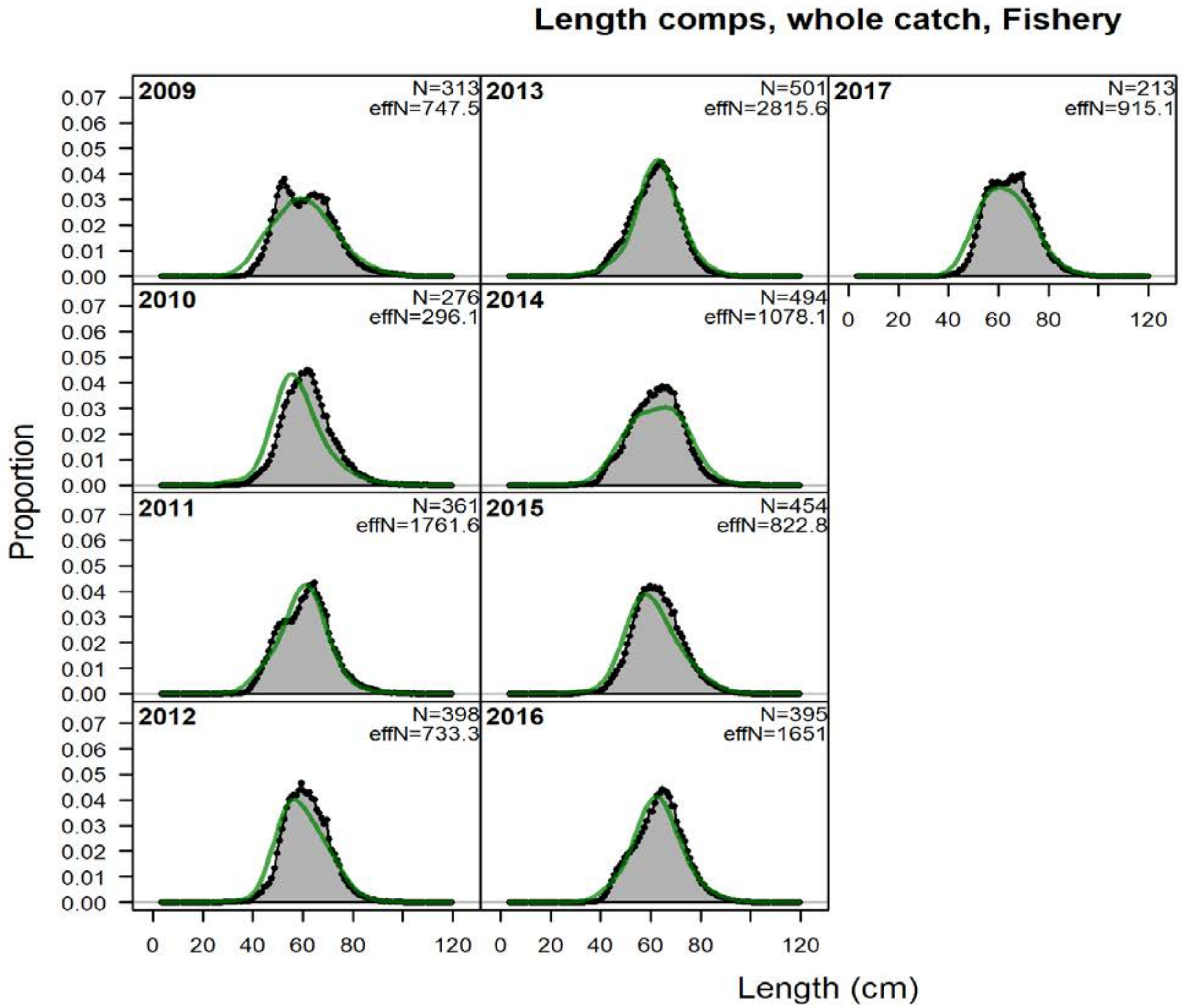


Figure 2.19a (page 3 of 3)—Model 16.6 fits to the fishery size composition data.

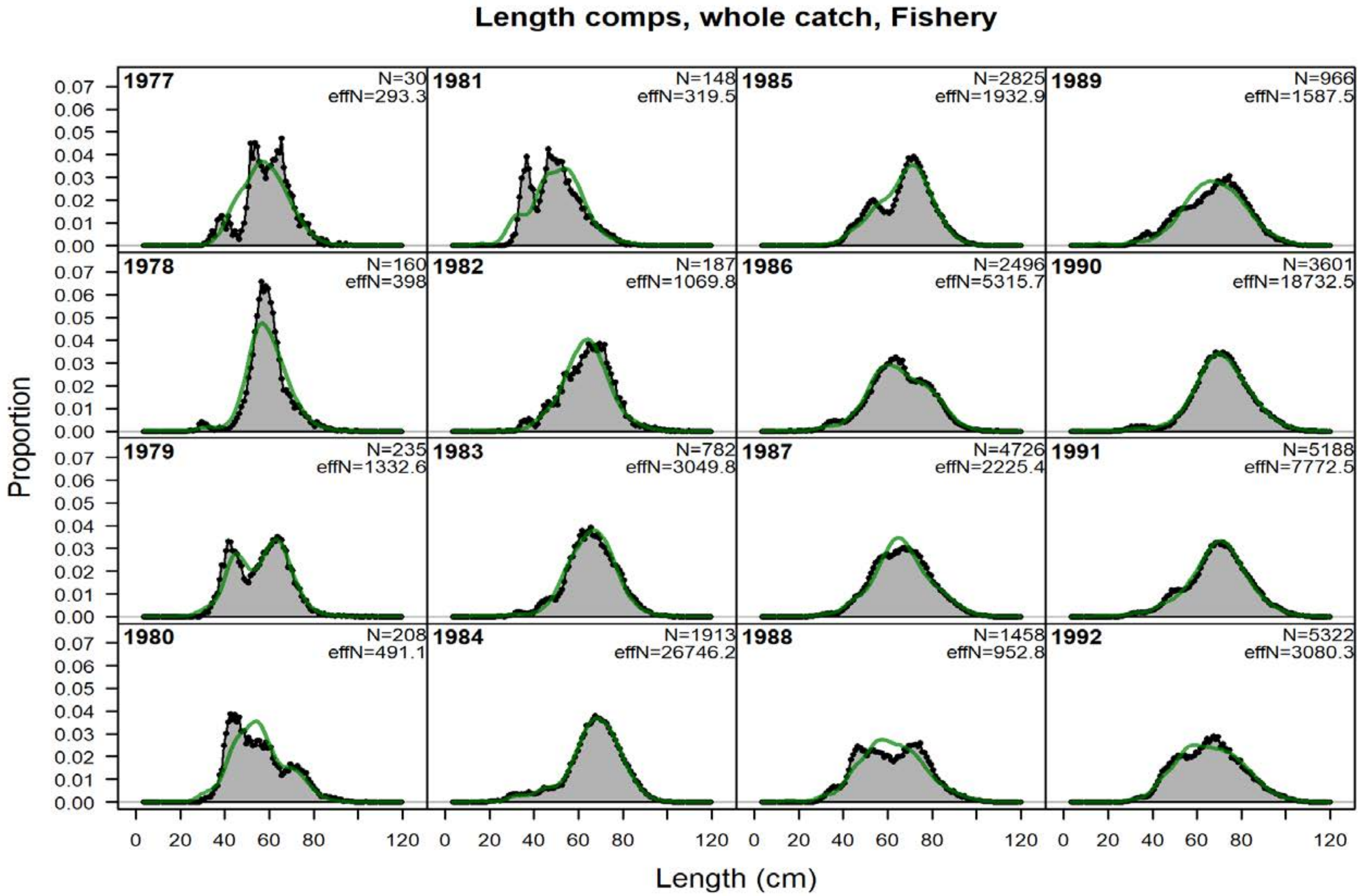


Figure 2.19b (page 1 of 3)—Model 17.1 fits to the fishery size composition data.

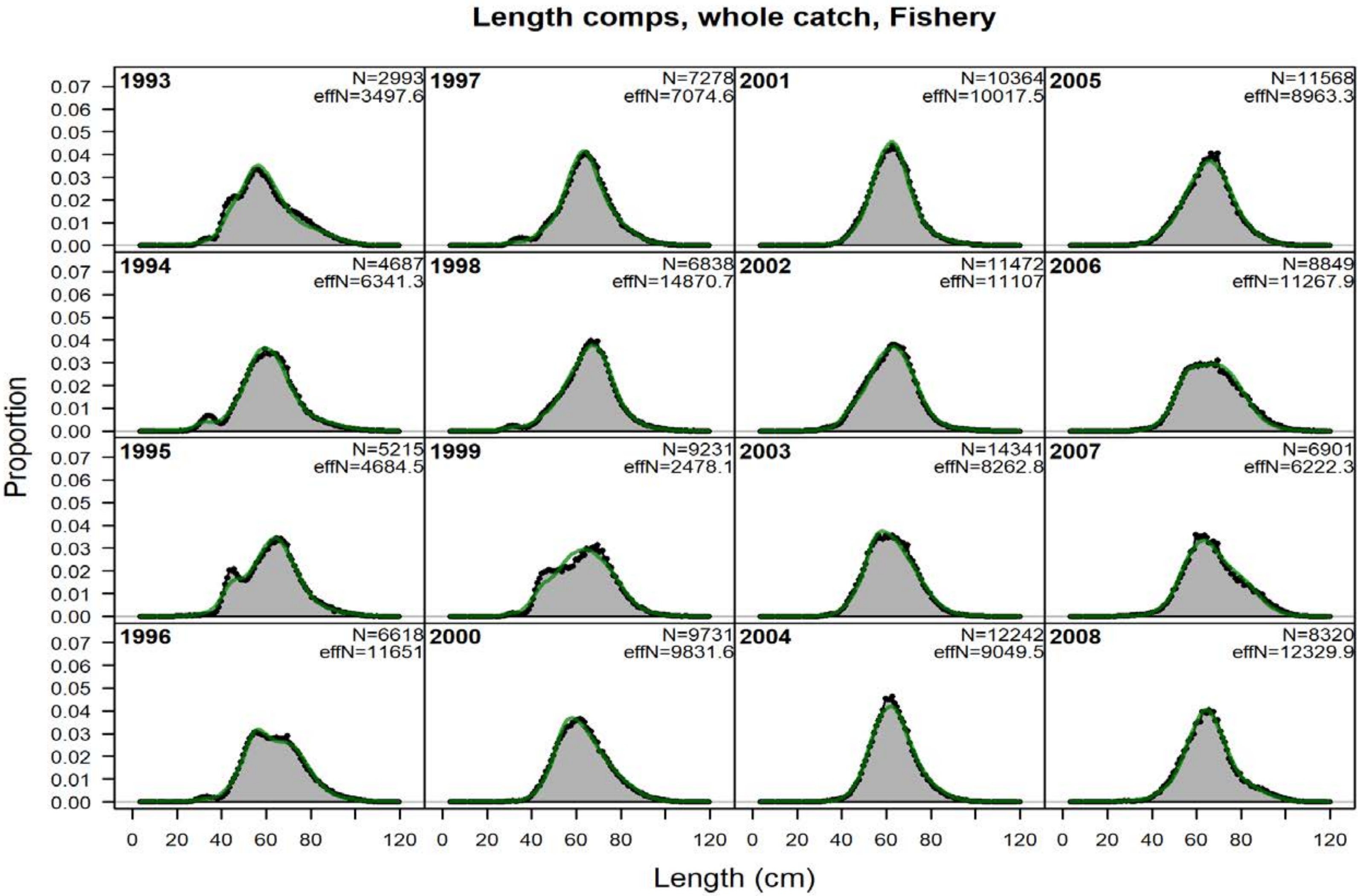


Figure 2.19b (page 2 of 3)—Model 17.1 fits to the fishery size composition data.

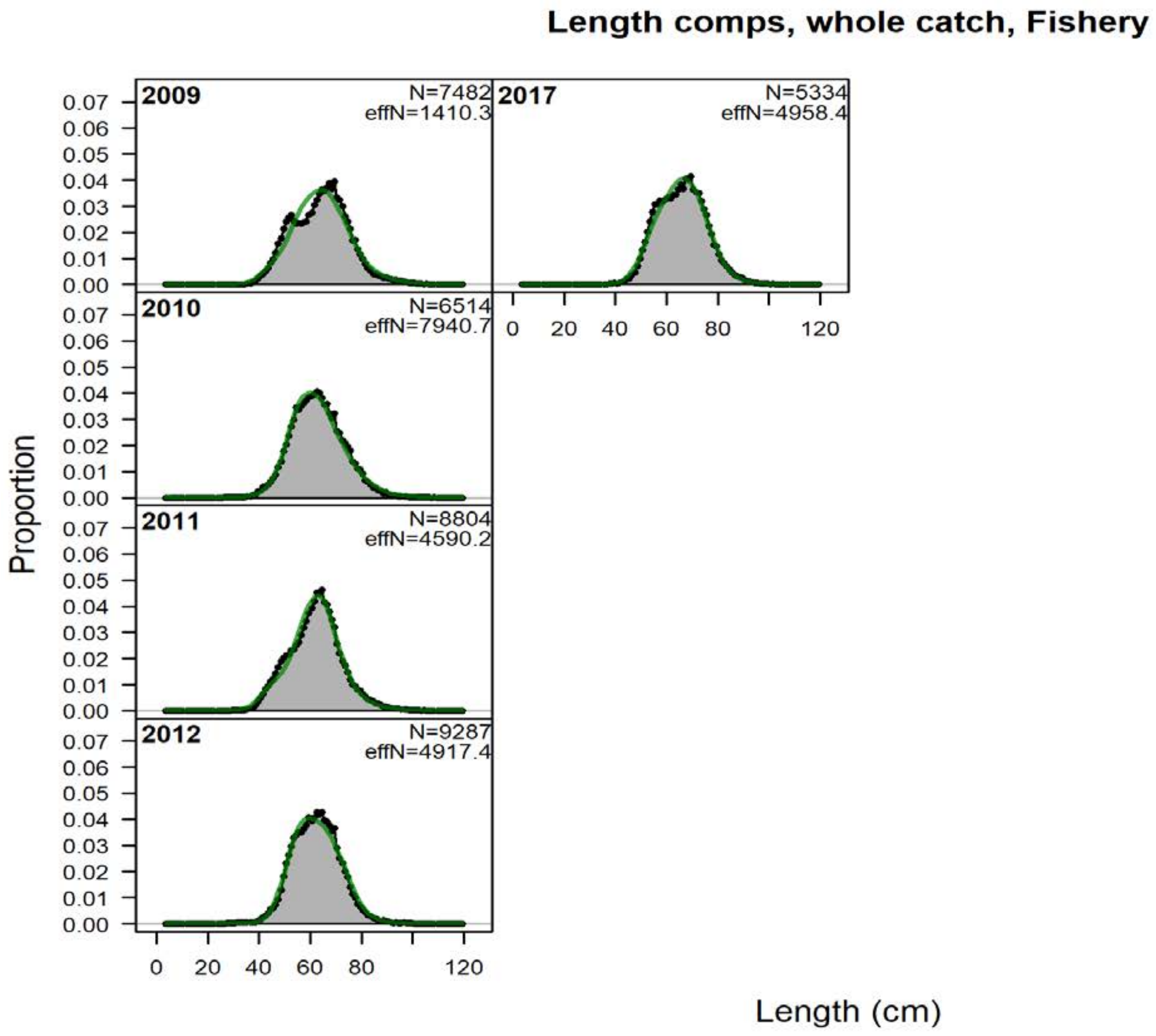


Figure 2.19b (page 3 of 3)—Model 17.1 fits to the fishery size composition data.

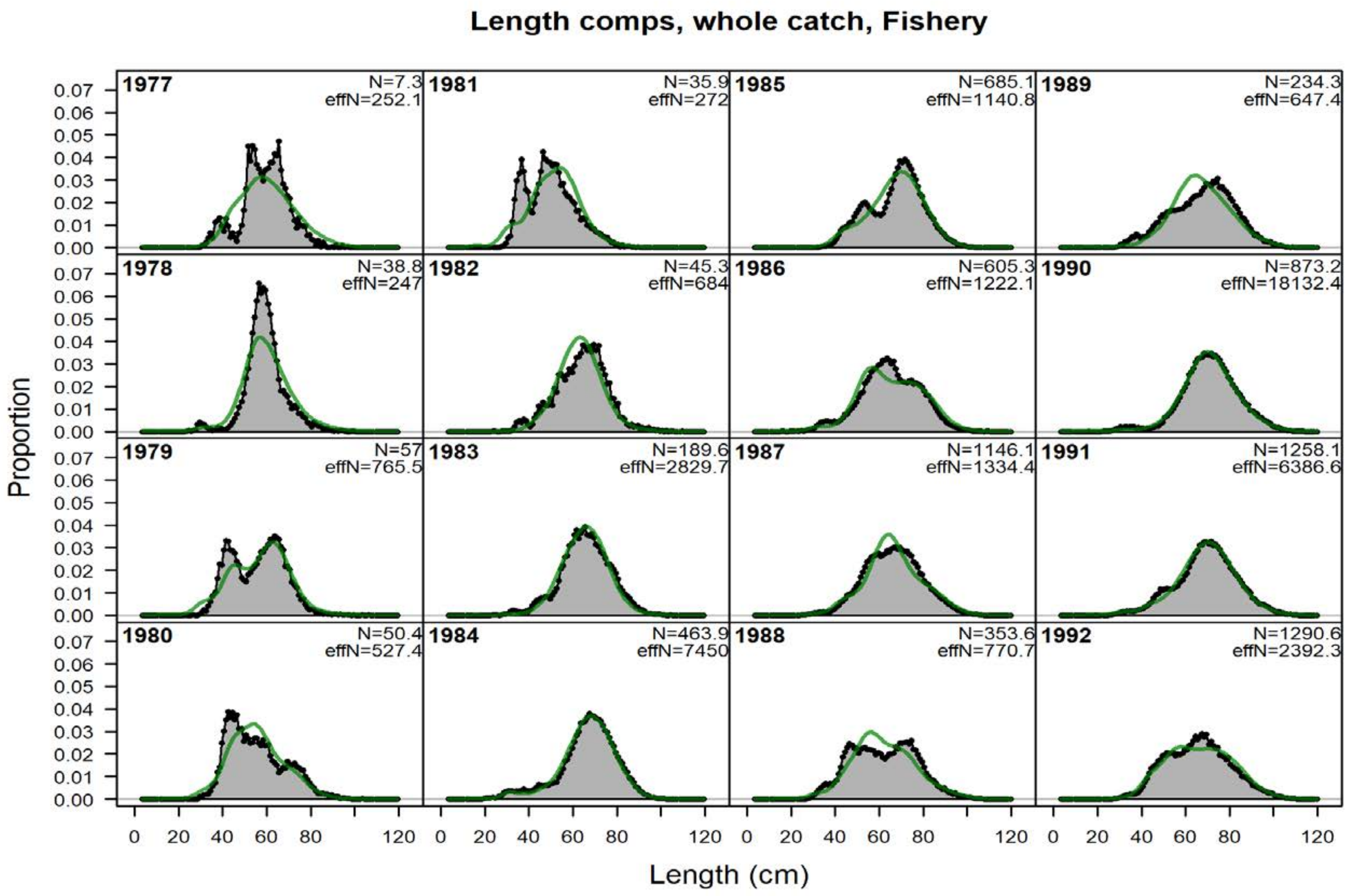


Figure 2.19c (page 1 of 3)—Model 17.2 fits to the fishery size composition data.

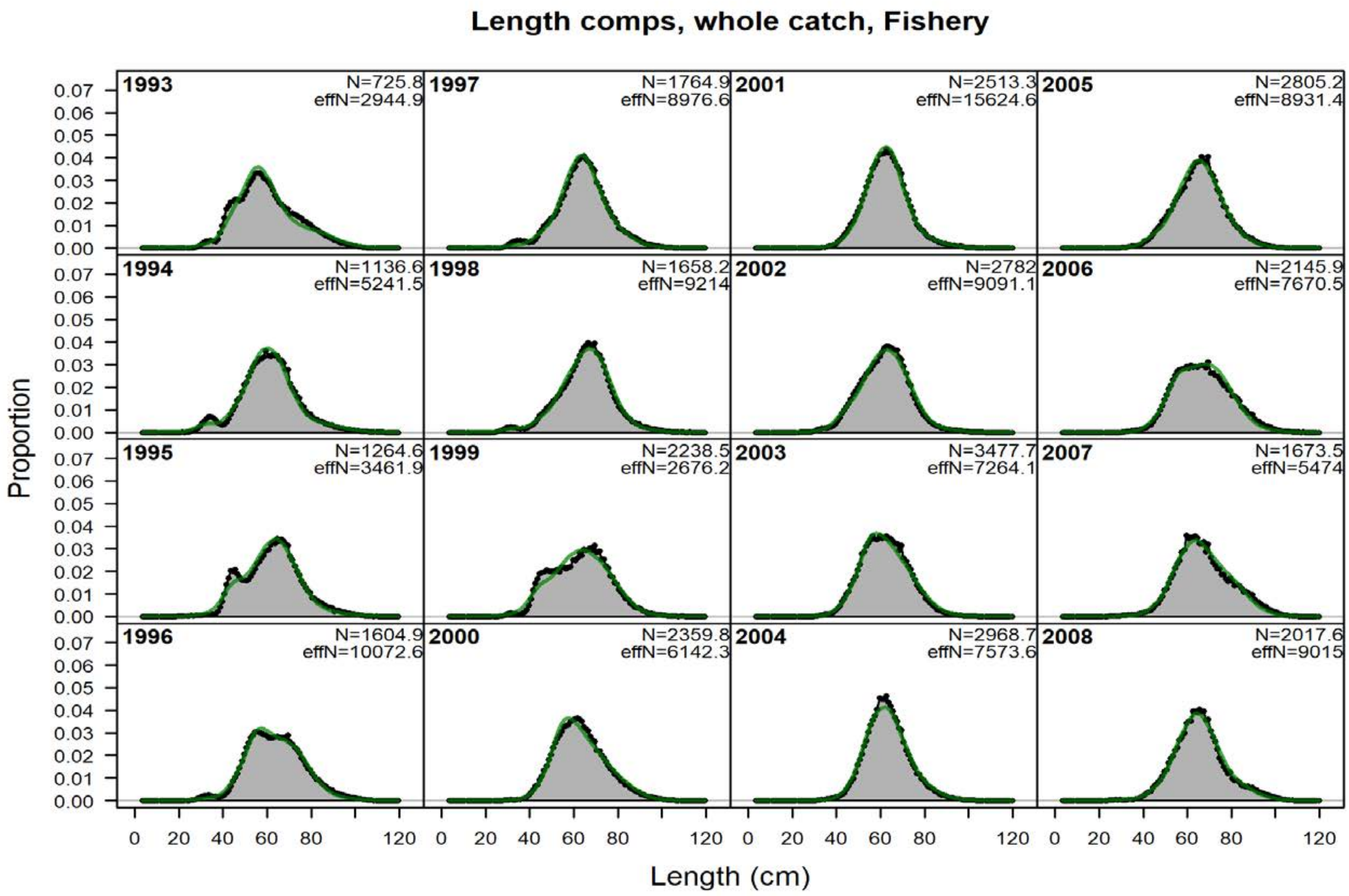


Figure 2.19c (page 2 of 3)—Model 17.2 fits to the fishery size composition data.

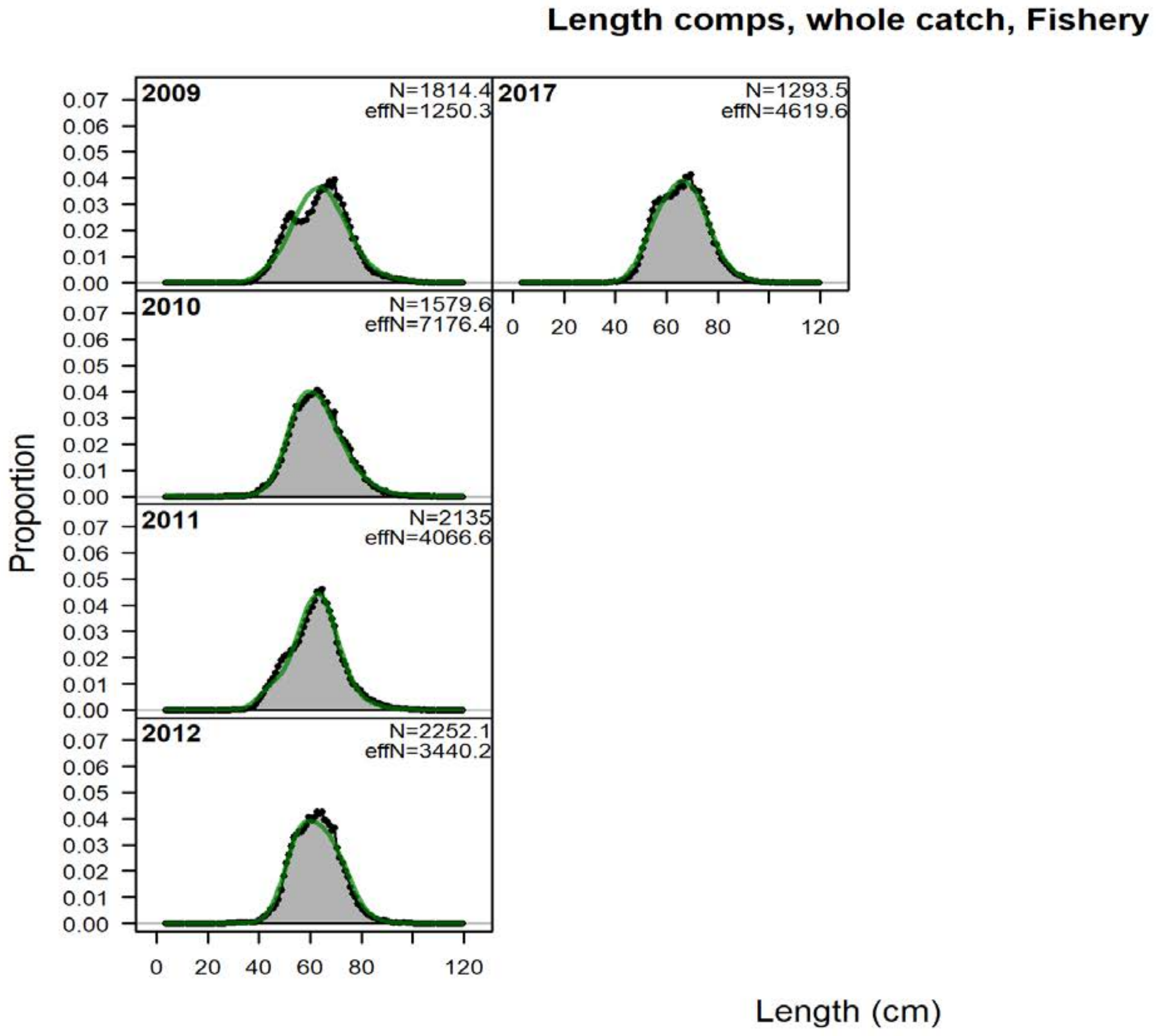


Figure 2.19c (page 3 of 3)—Model 17.2 fits to the fishery size composition data.

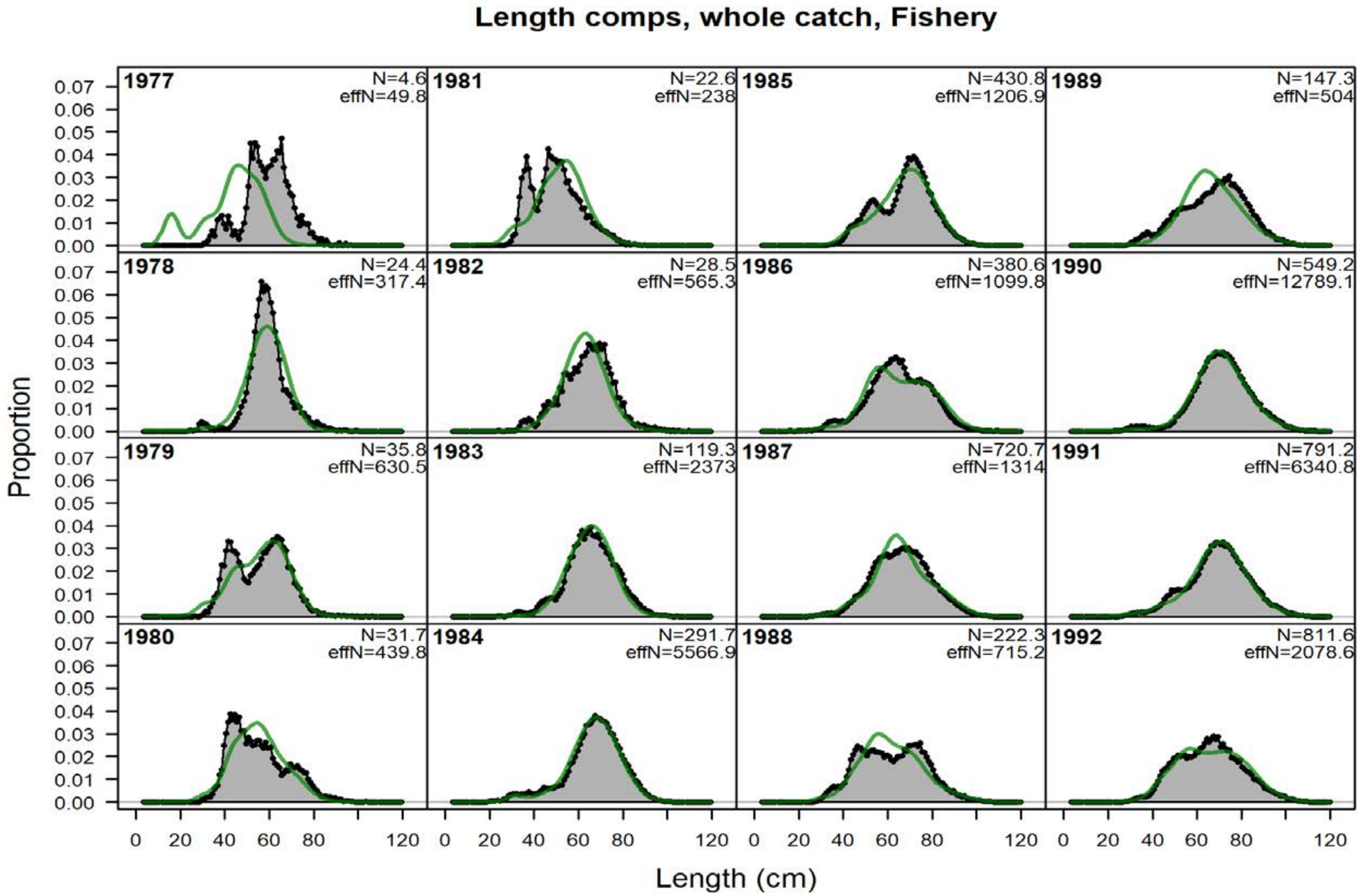


Figure 2.19d (page 1 of 3)—Model 17.3 fits to the fishery size composition data.

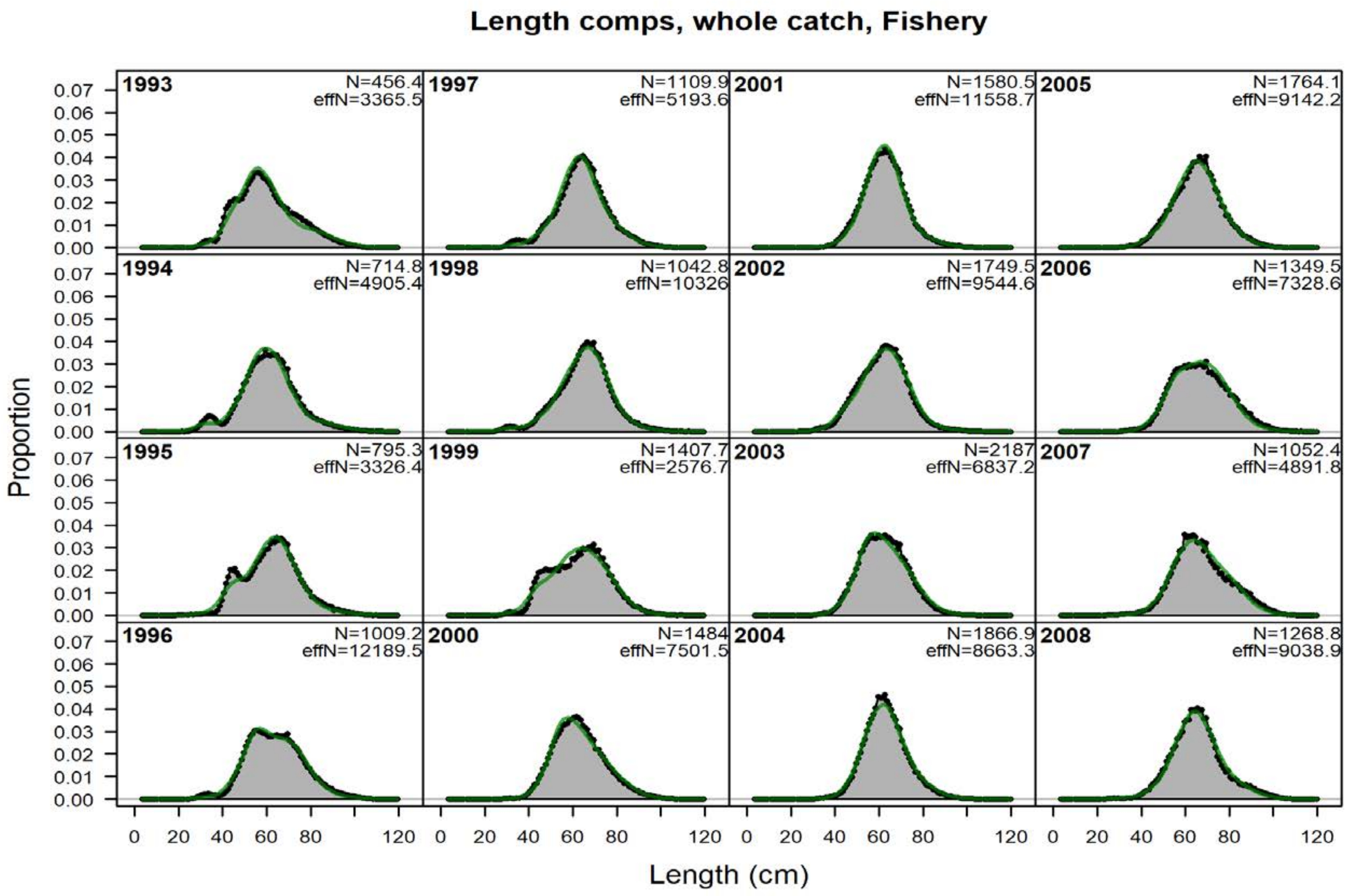


Figure 2.19d (page 2 of 3)—Model 17.3 fits to the fishery size composition data.

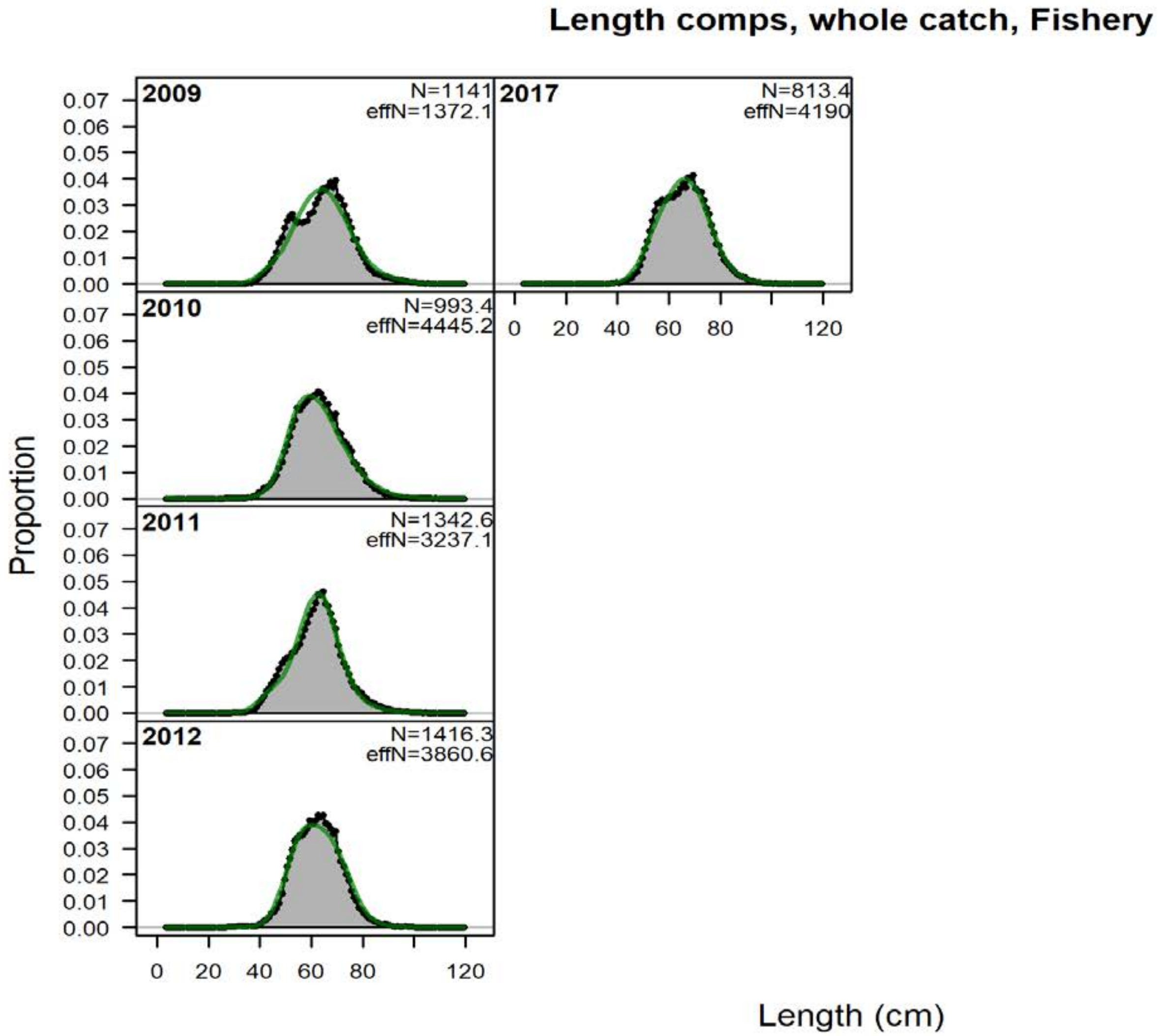


Figure 2.19d (page 3 of 3)—Model 17.3 fits to the fishery size composition data.

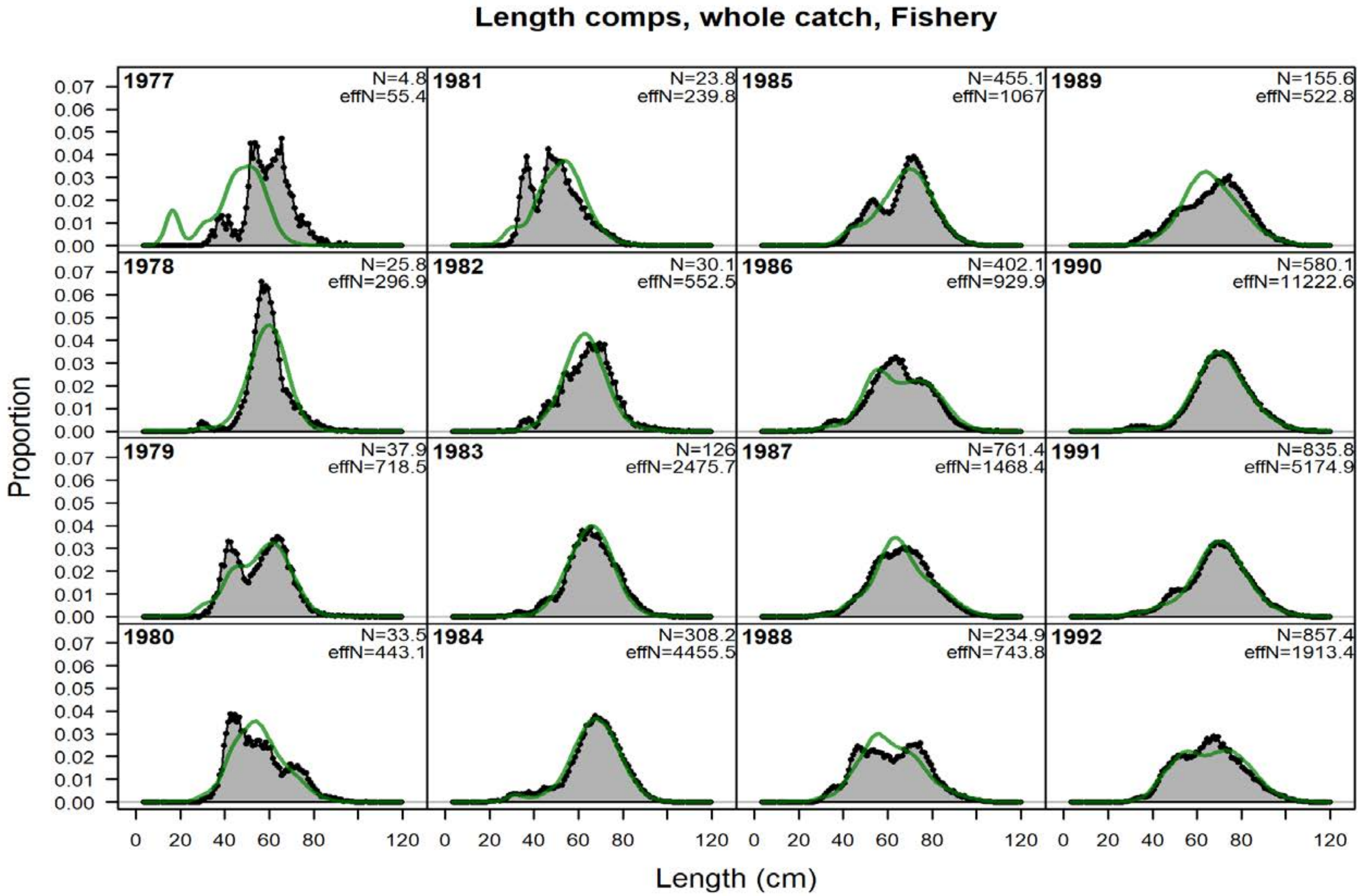


Figure 2.19e (page 1 of 3)—Model 17.6 fits to the fishery size composition data.

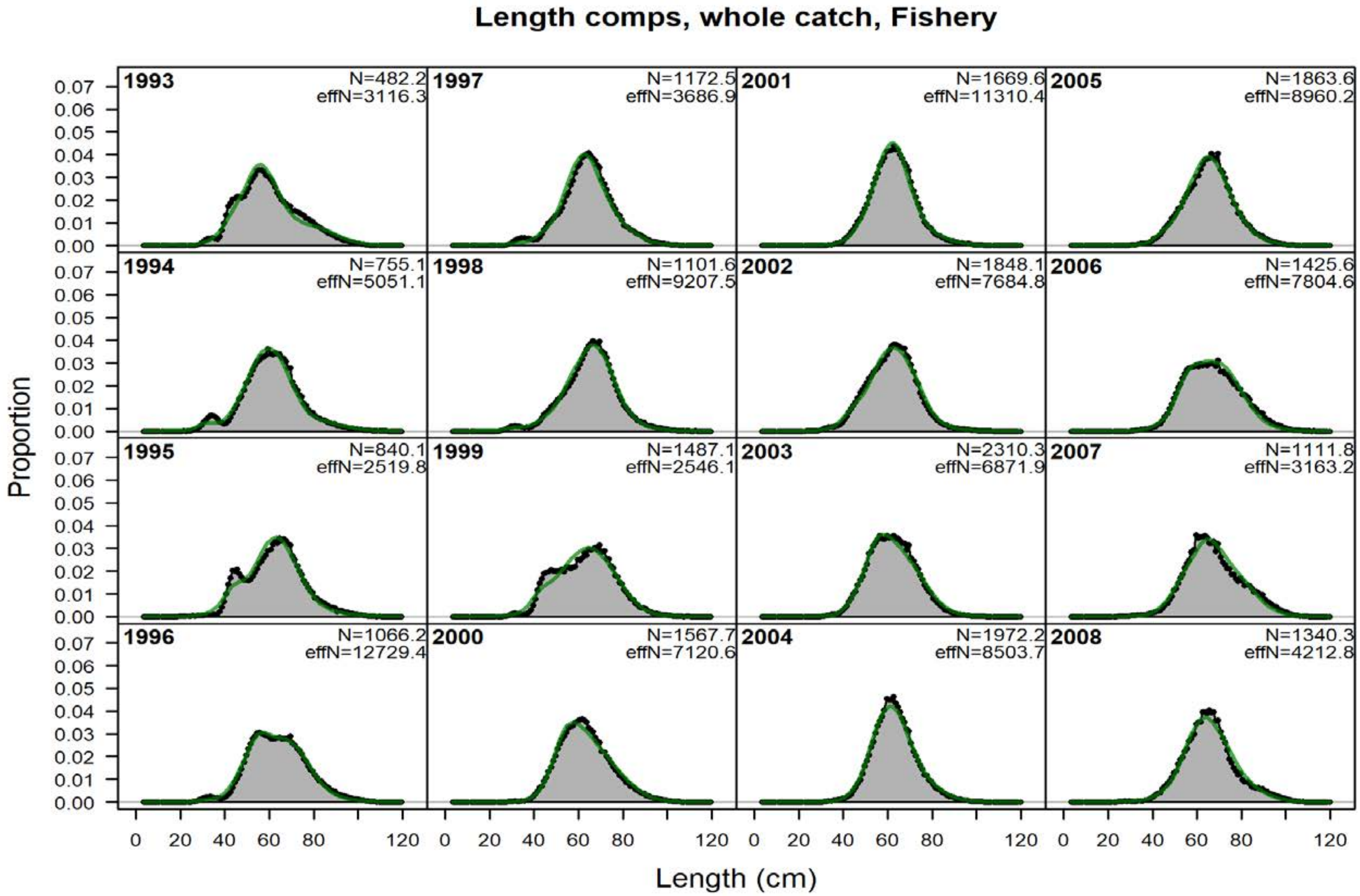


Figure 2.19e (page 2 of 3)—Model 17.6 fits to the fishery size composition data.

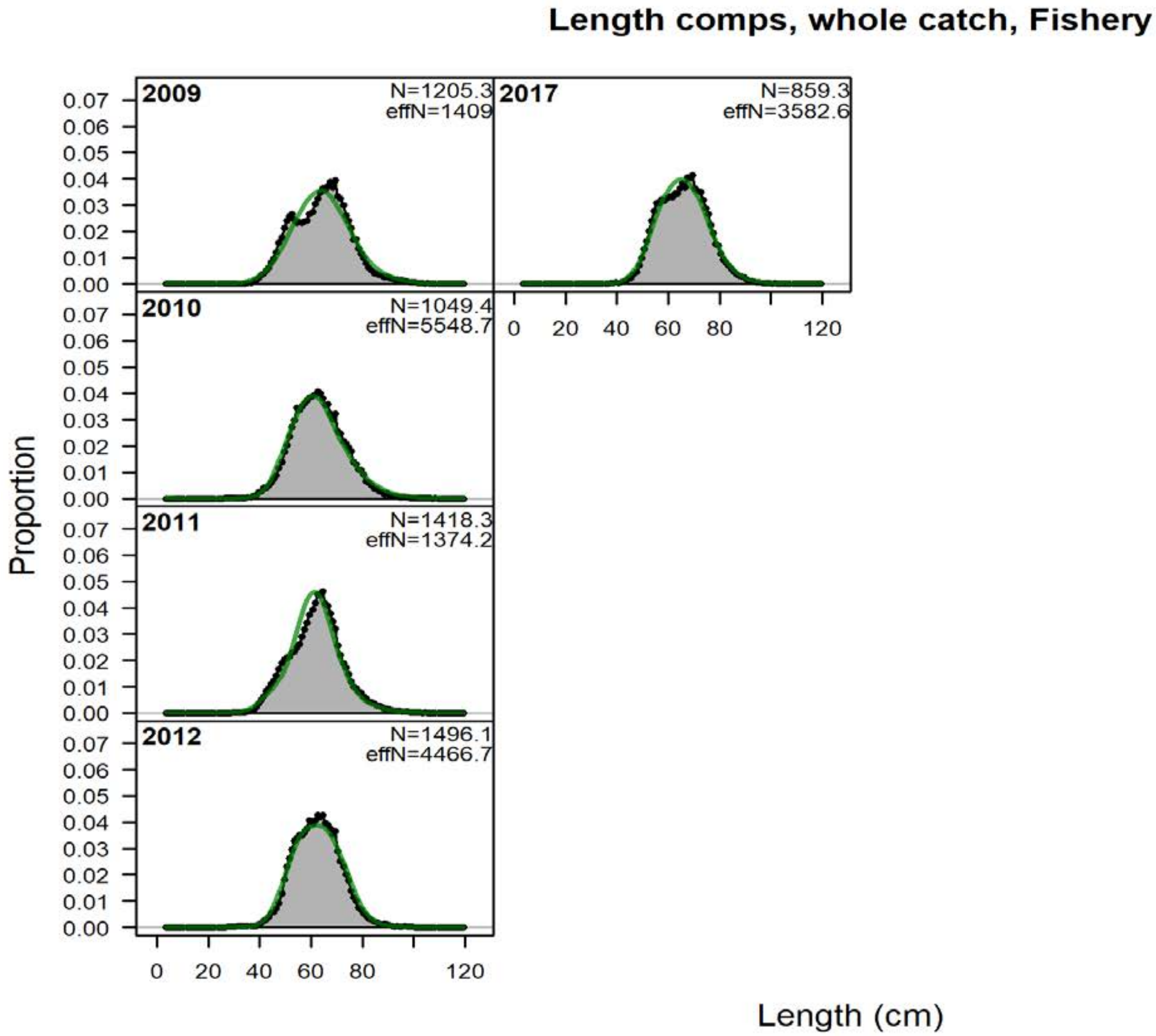


Figure 2.19e (page 3 of 3)—Model 17.6 fits to the fishery size composition data.

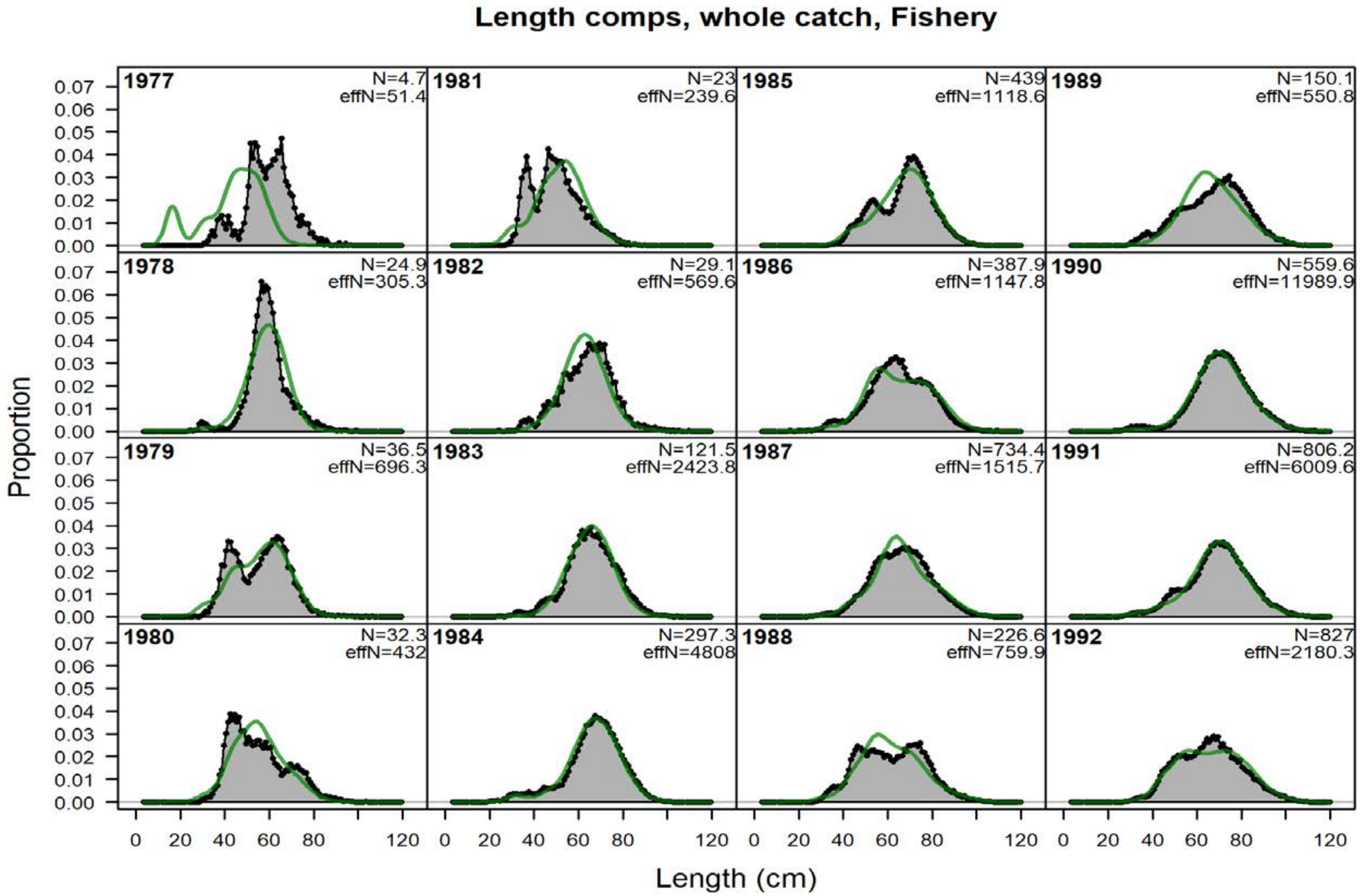


Figure 2.19f (page 1 of 3)—Model 17.7 fits to the fishery size composition data.

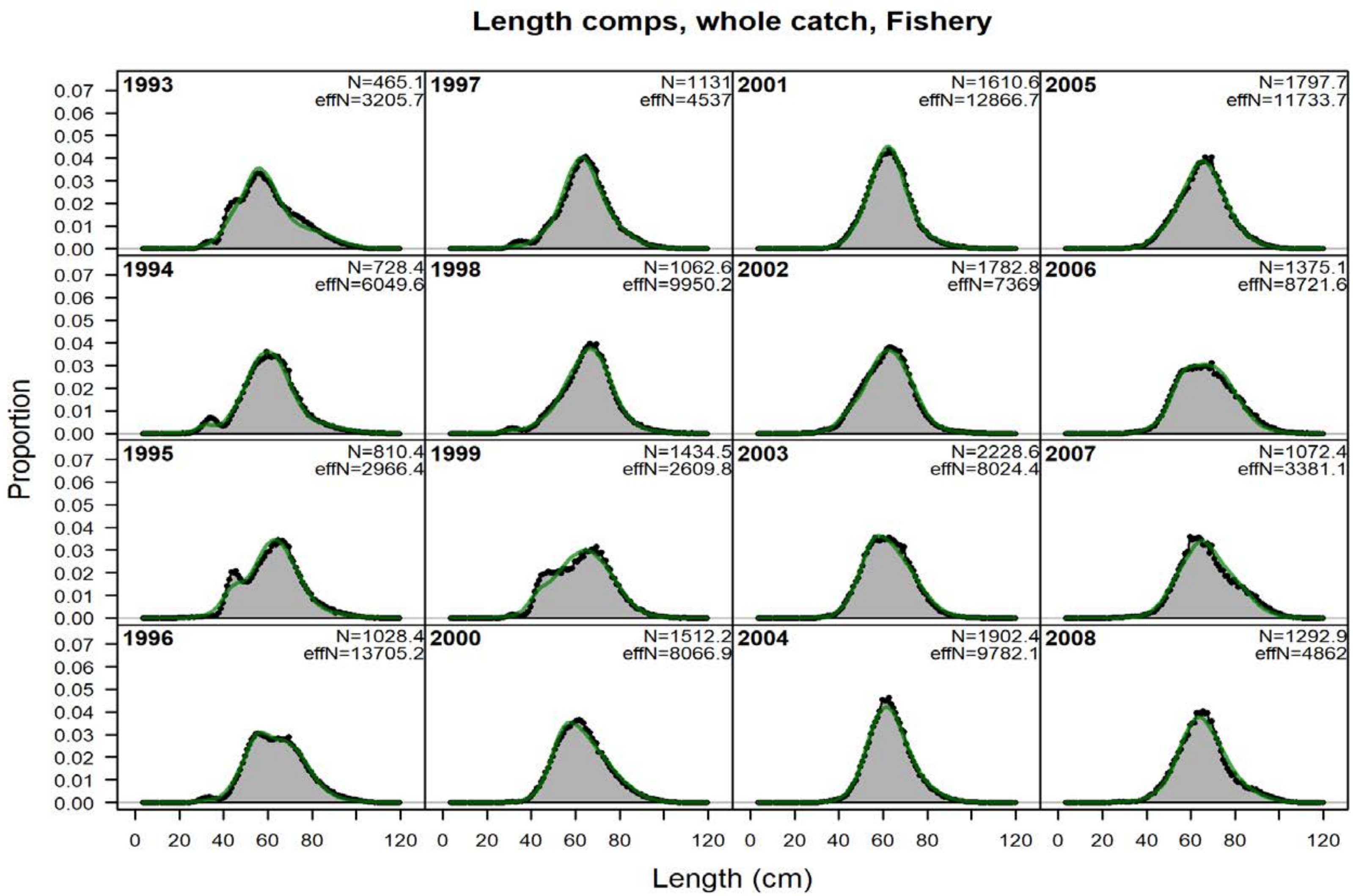


Figure 2.19f (page 2 of 3)—Model 17.7 fits to the fishery size composition data.

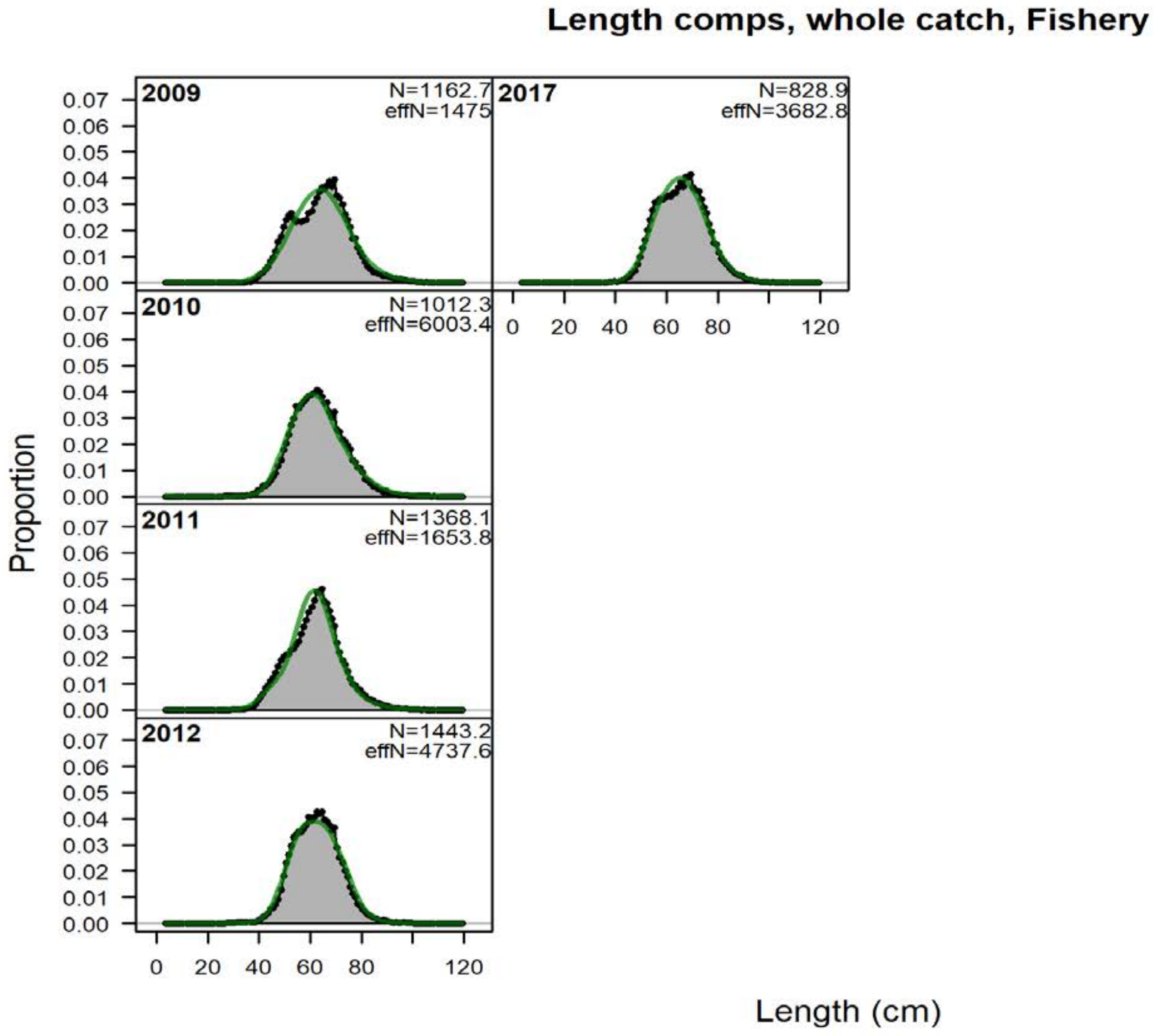


Figure 2.19f (page 3 of 3)—Model 17.7 fits to the fishery size composition data.

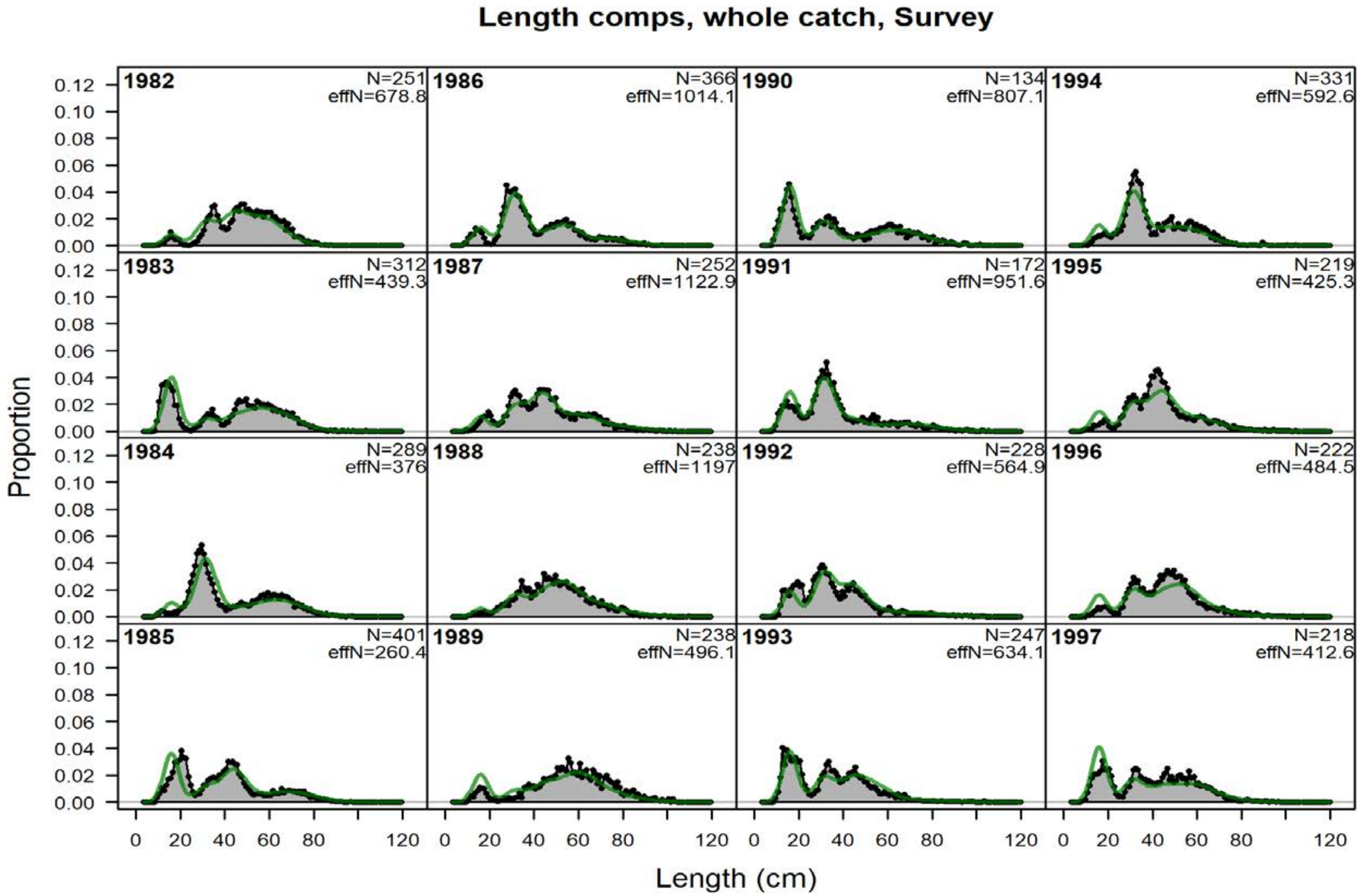


Figure 2.20a (page 1 of 3)—Model 16.6 fits to the survey size composition data.

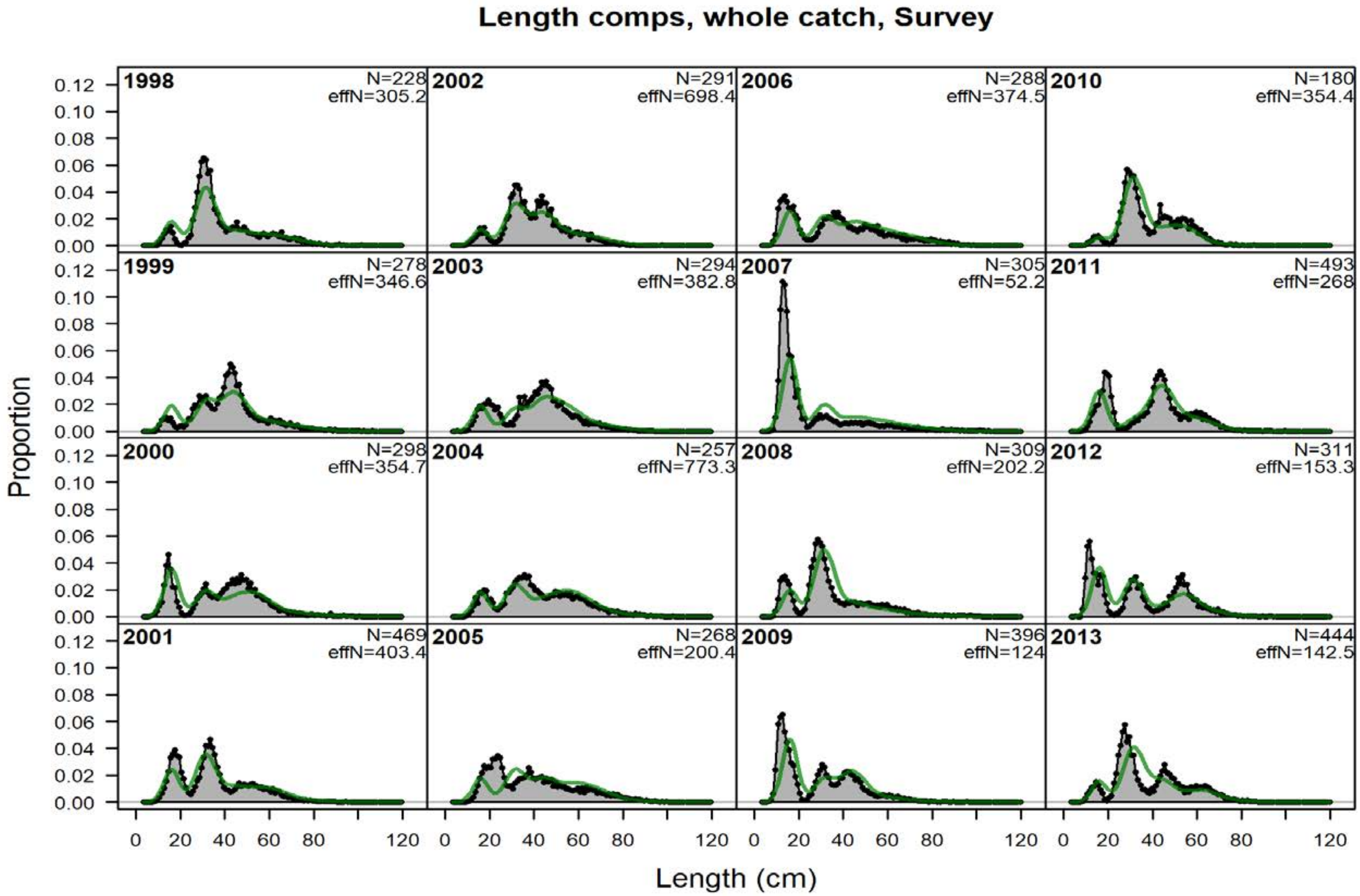


Figure 2.20a (page 2 of 3)—Model 16.6 fits to the survey size composition data.

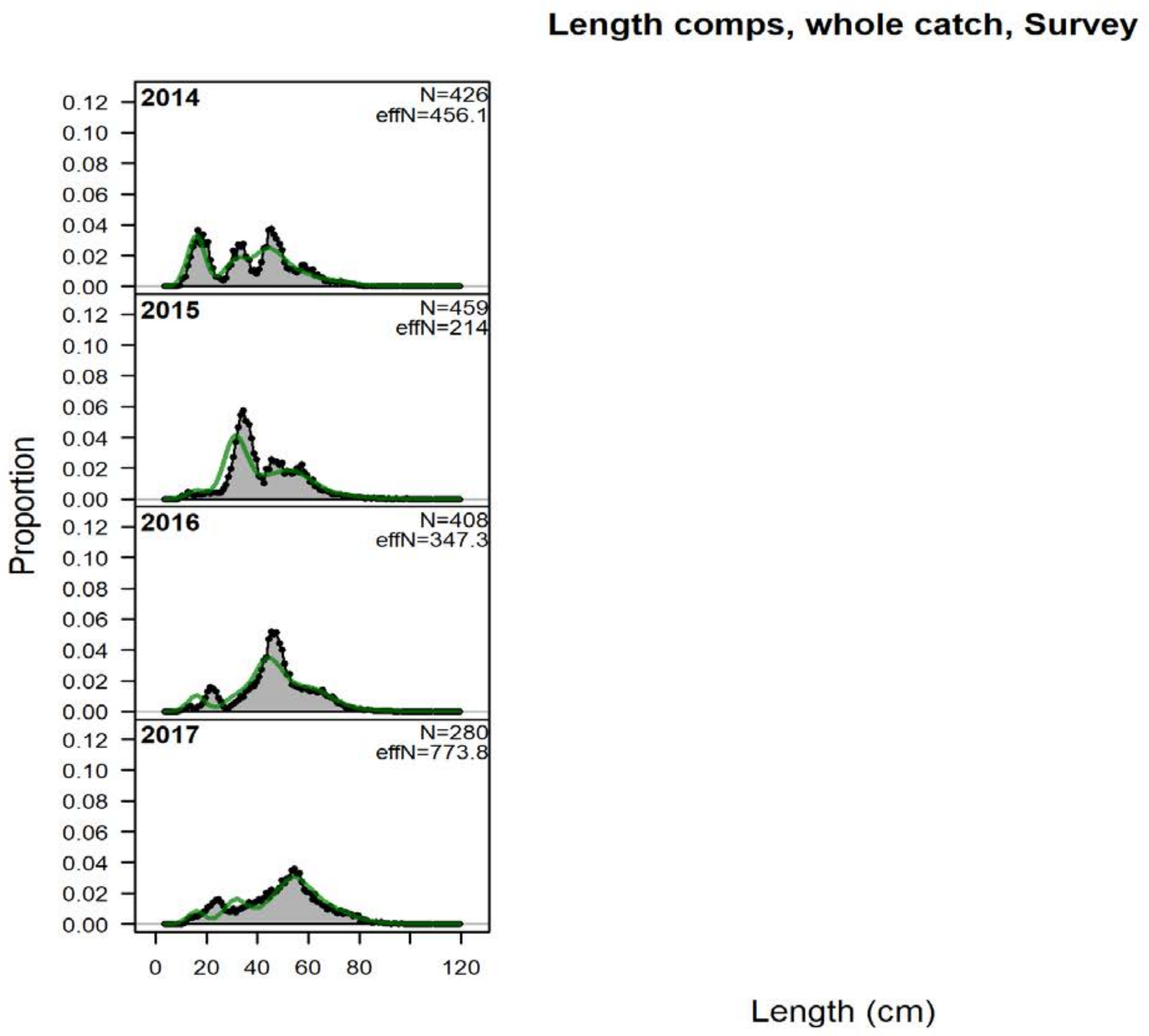


Figure 2.20a (page 3 of 3)—Model 16.6 fits to the survey size composition data.

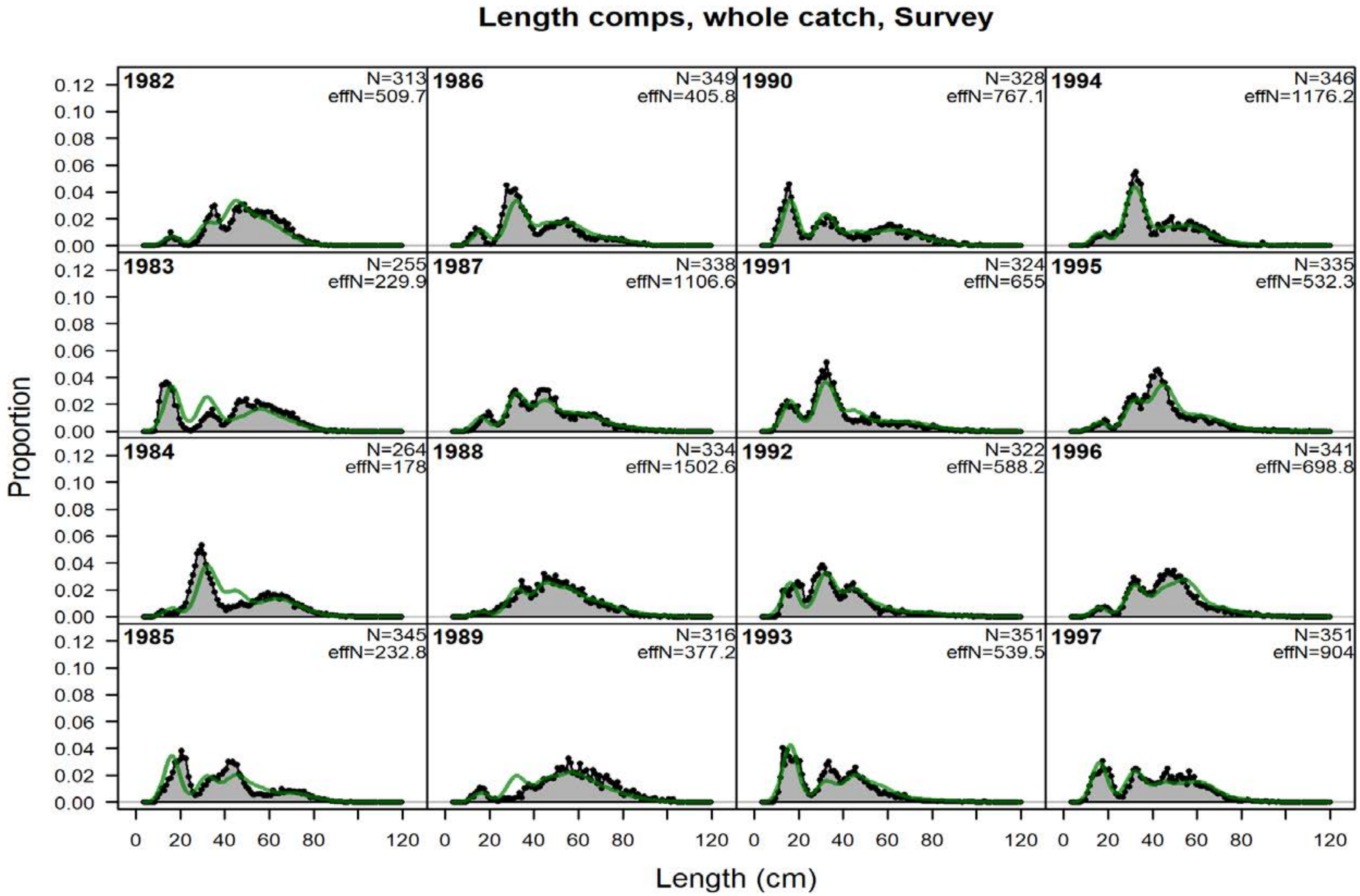


Figure 2.20b (page 1 of 3)—Model 17.1 fits to the survey size composition data.

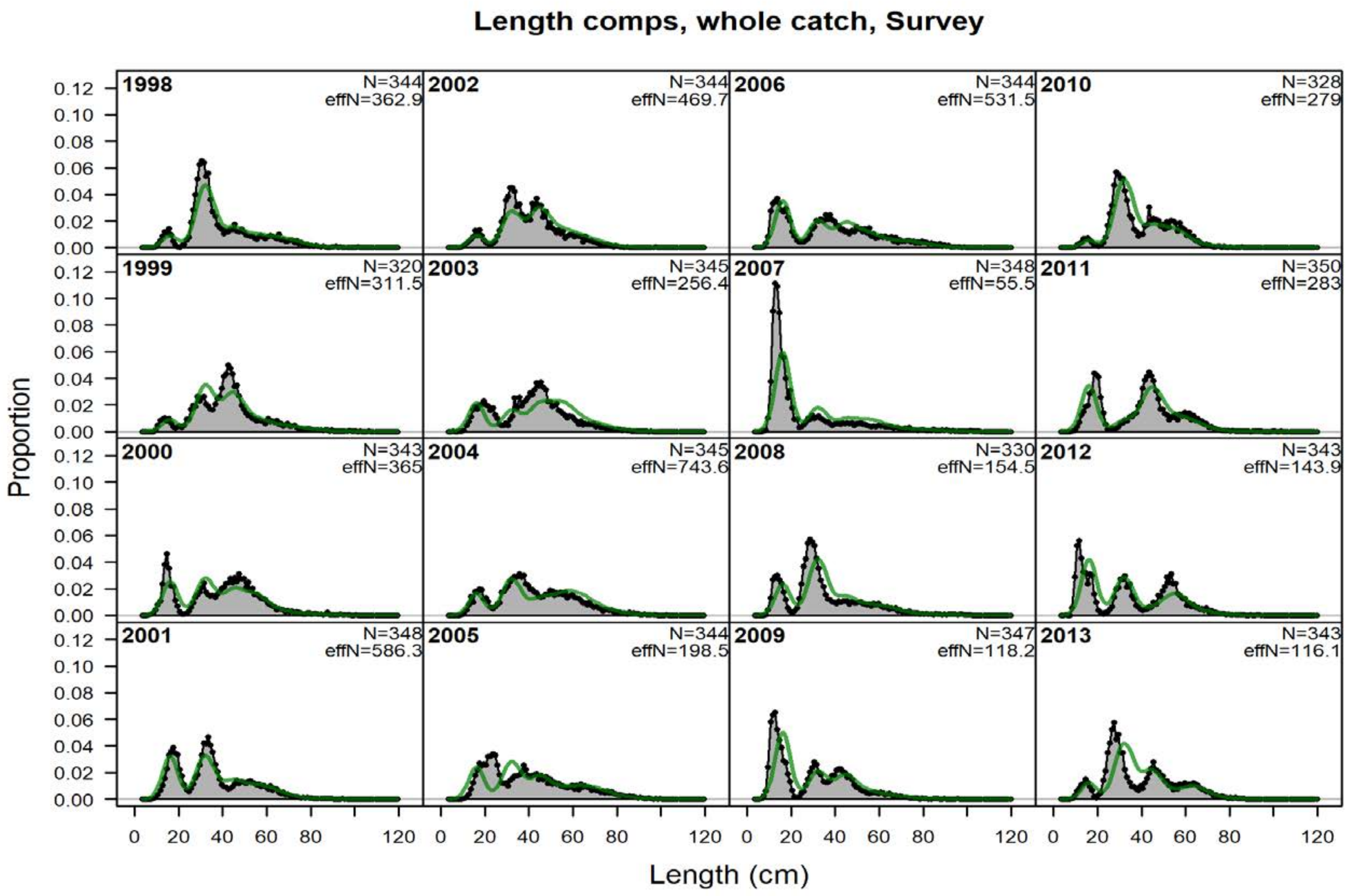


Figure 2.20b (page 2 of 3)—Model 17.1 fits to the survey size composition data.

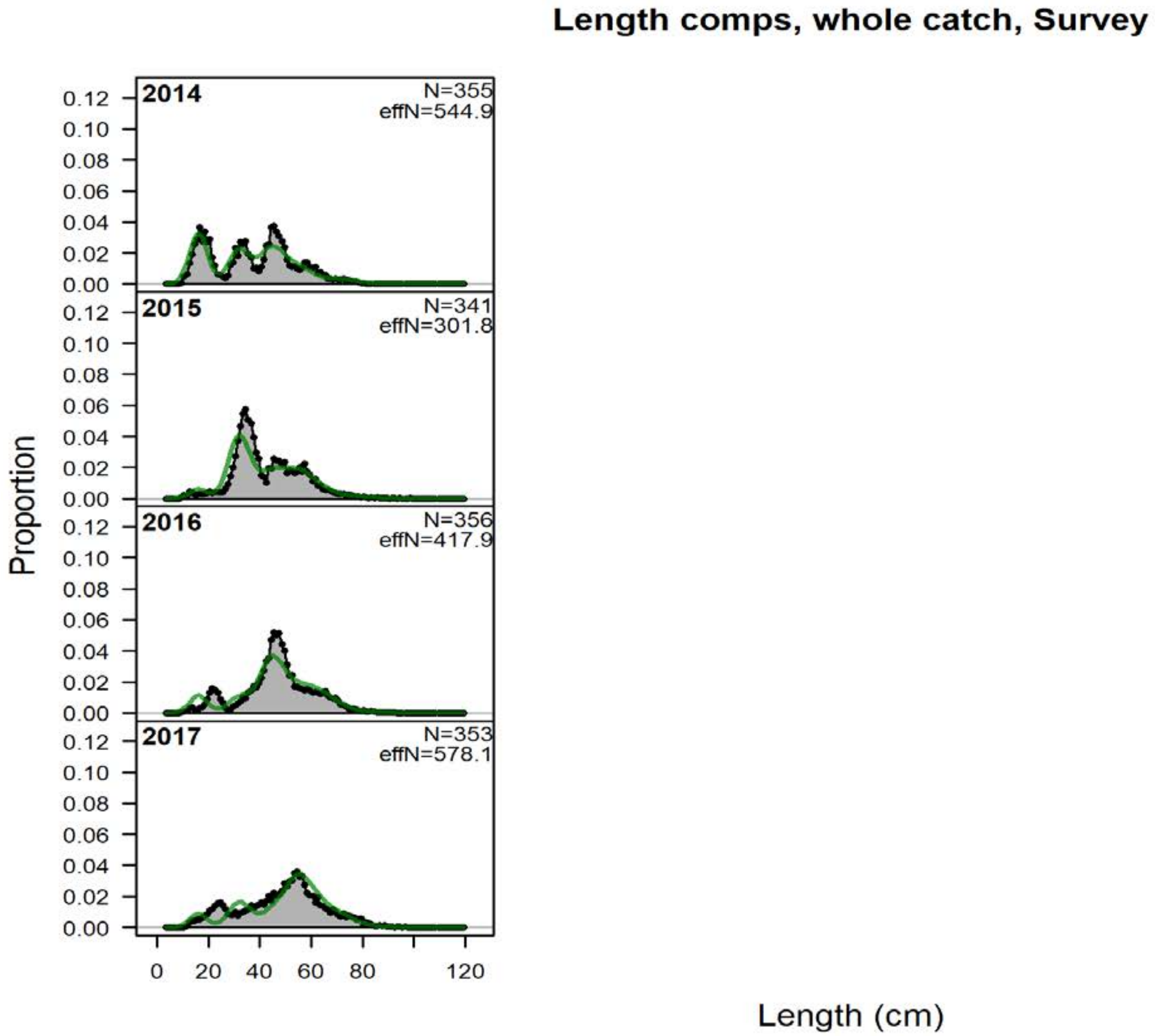


Figure 2.20b (page 3 of 3)—Model 17.1 fits to the survey size composition data.

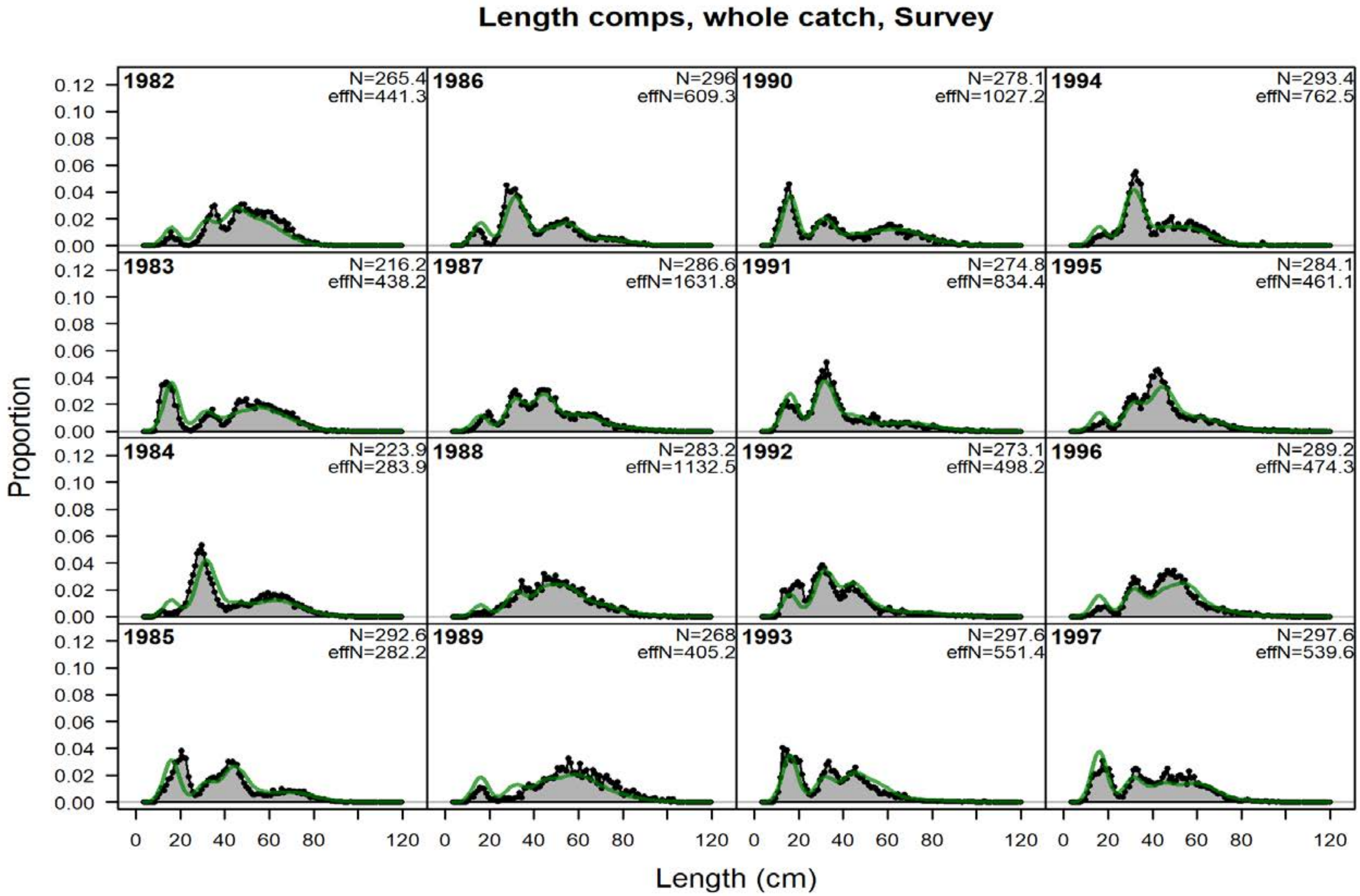


Figure 2.20c (page 1 of 3)—Model 17.2 fits to the survey size composition data.

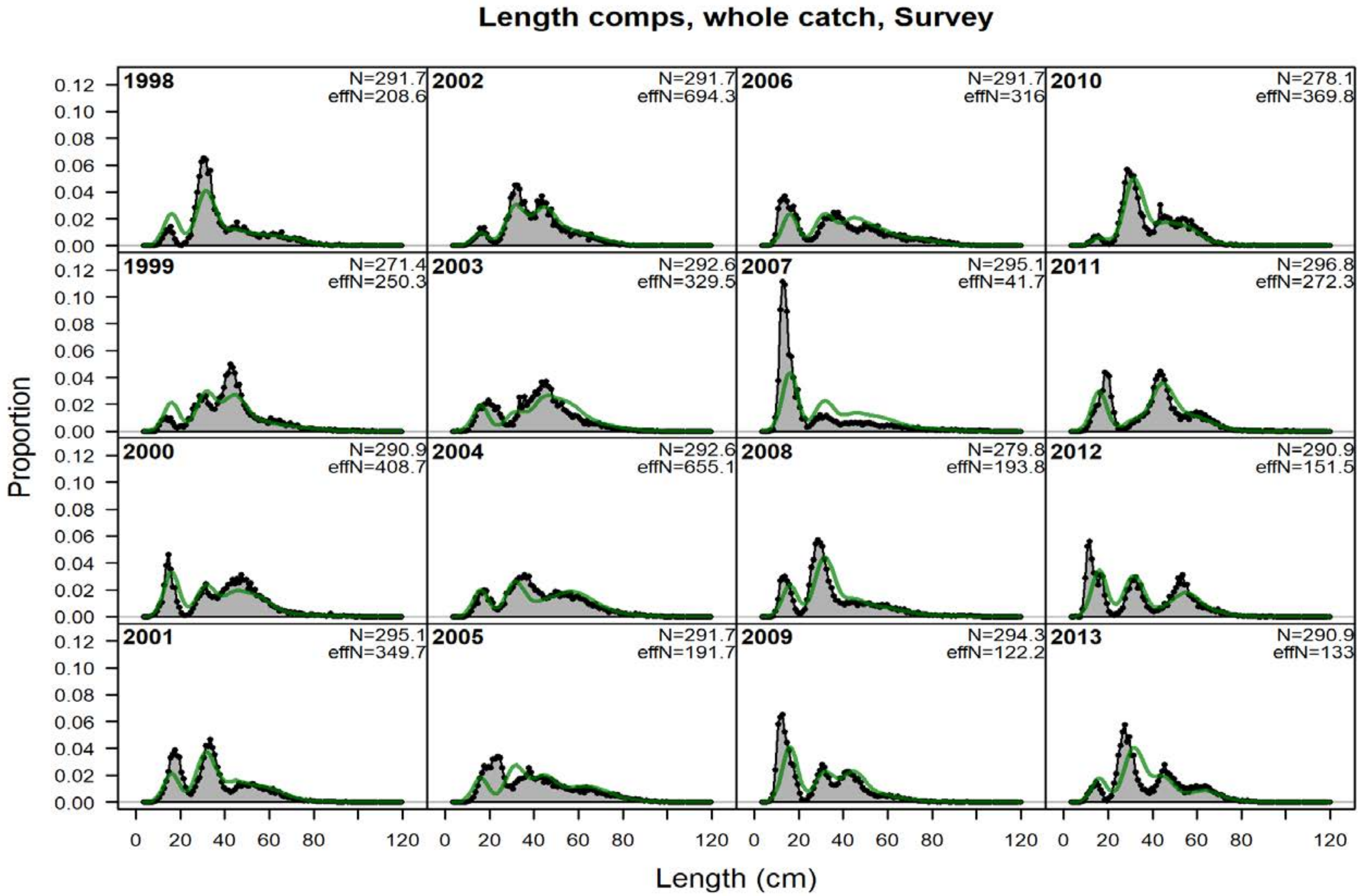


Figure 2.20c (page 2 of 3)—Model 17.2 fits to the survey size composition data.

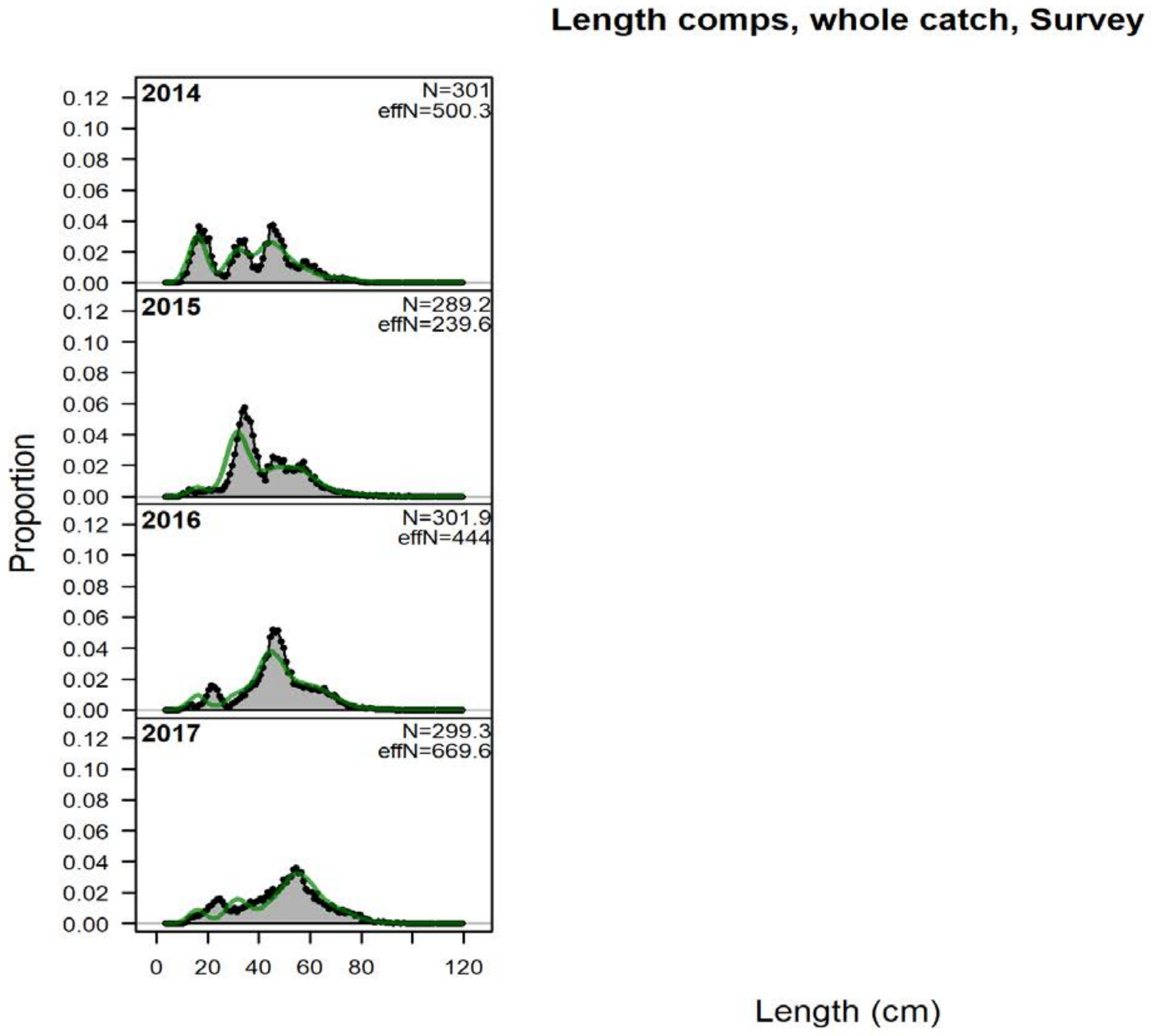


Figure 2.20c (page 3 of 3)—Model 17.2 fits to the survey size composition data.

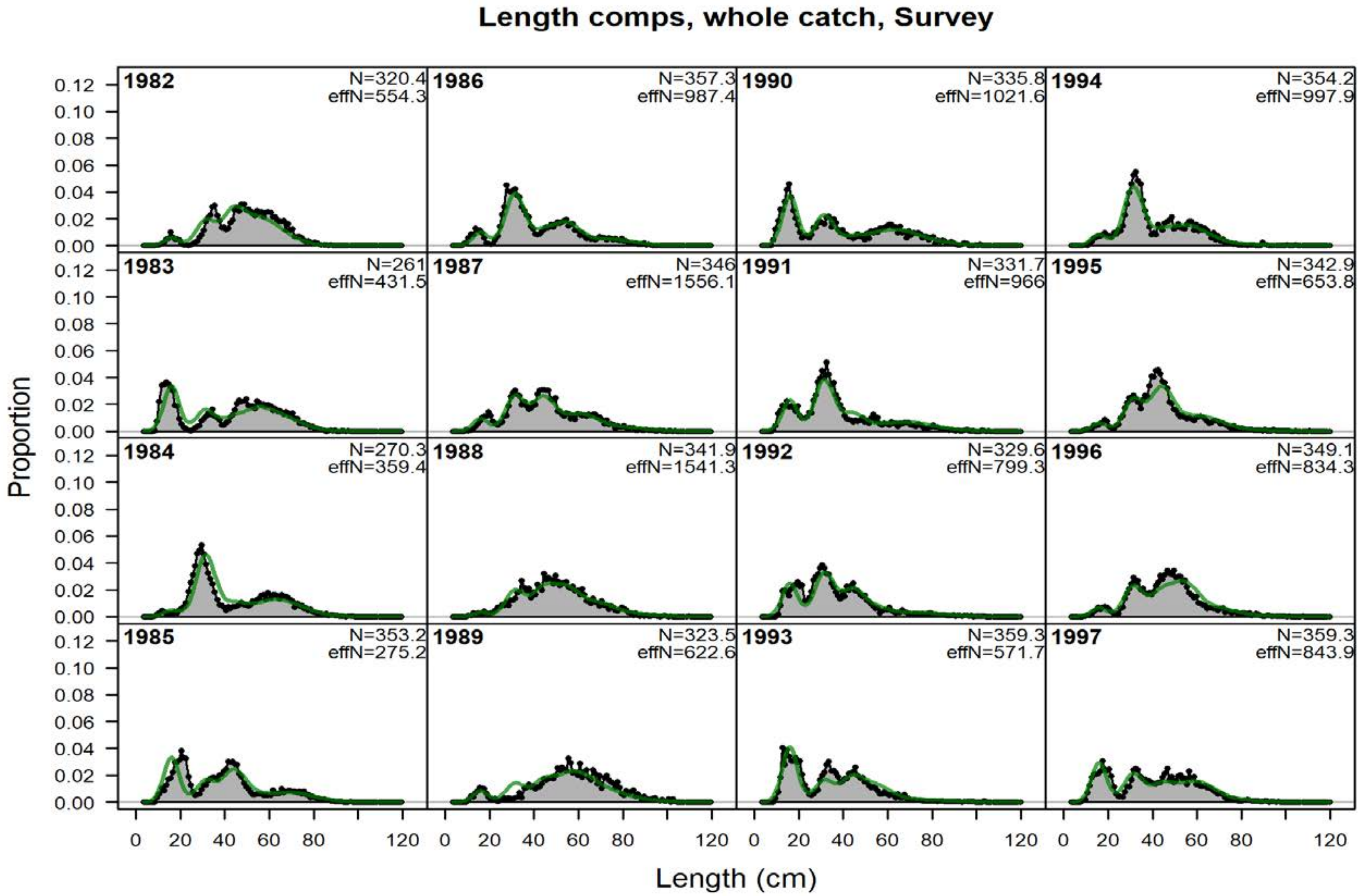


Figure 2.20d (page 1 of 3)—Model 17.3 fits to the survey size composition data.

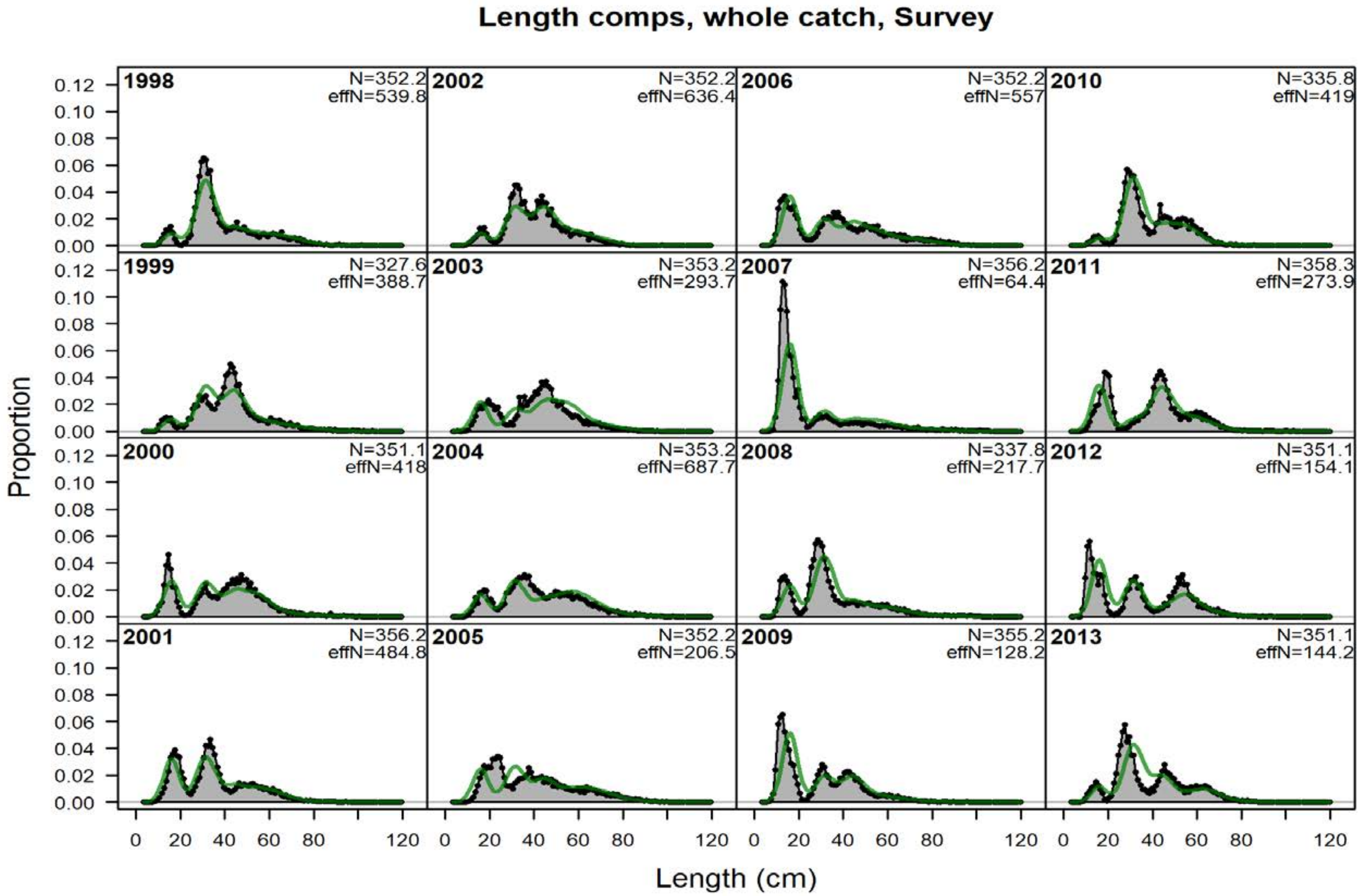


Figure 2.20d (page 2 of 3)—Model 17.3 fits to the survey size composition data.

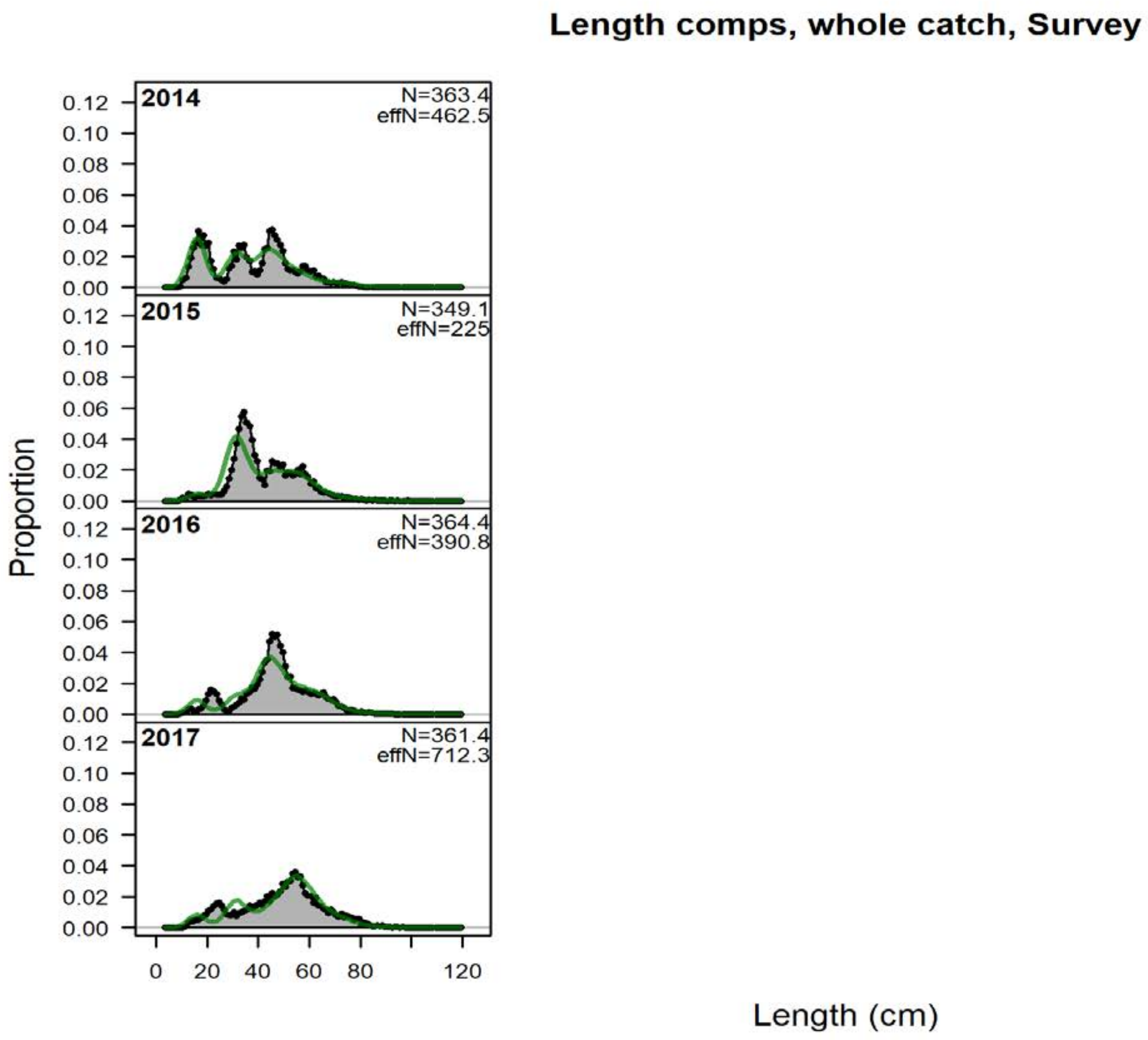


Figure 2.20d (page 3 of 3)—Model 17.3 fits to the survey size composition data.

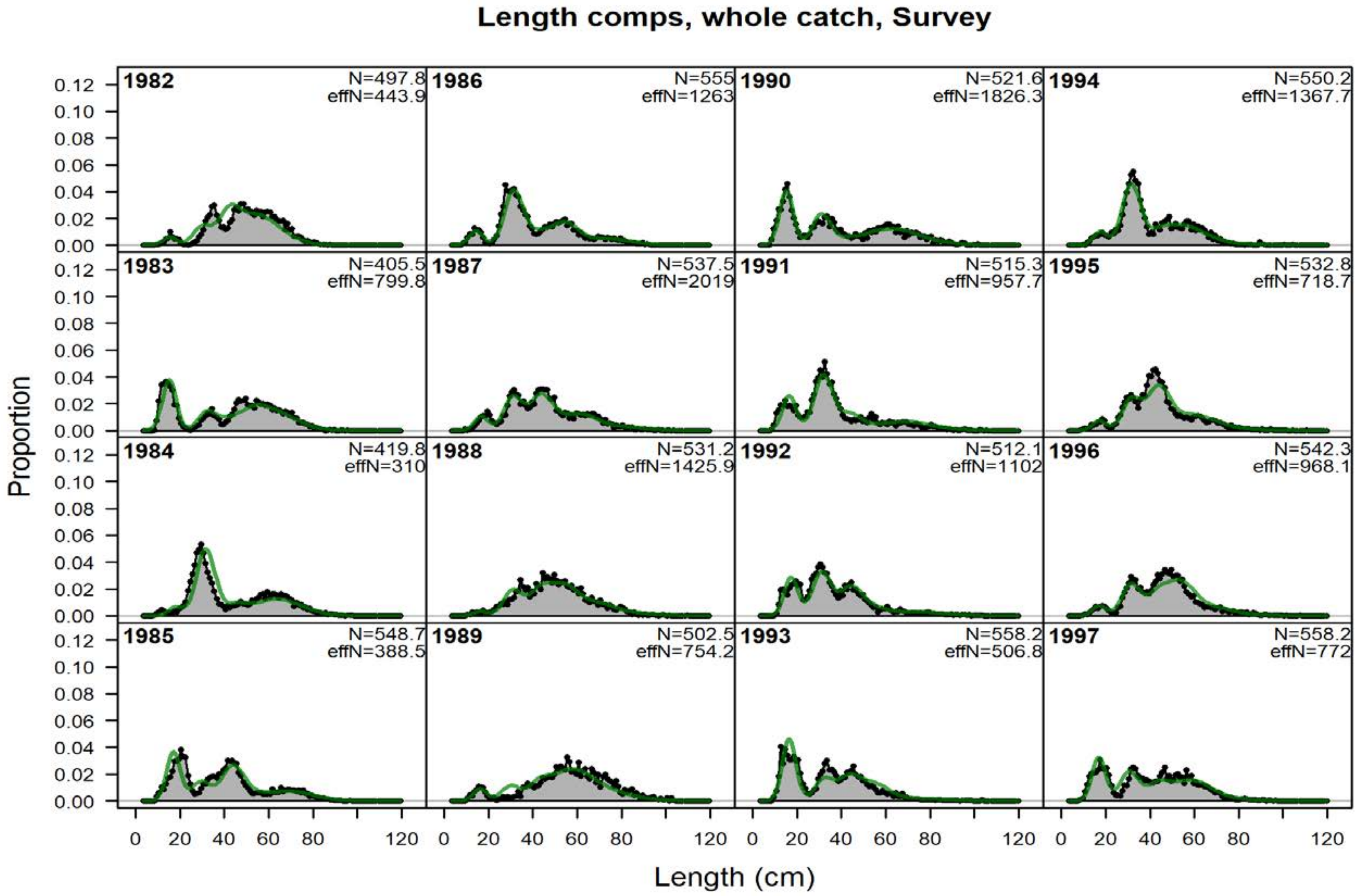


Figure 2.20e (page 1 of 3)—Model 17.6 fits to the survey size composition data.

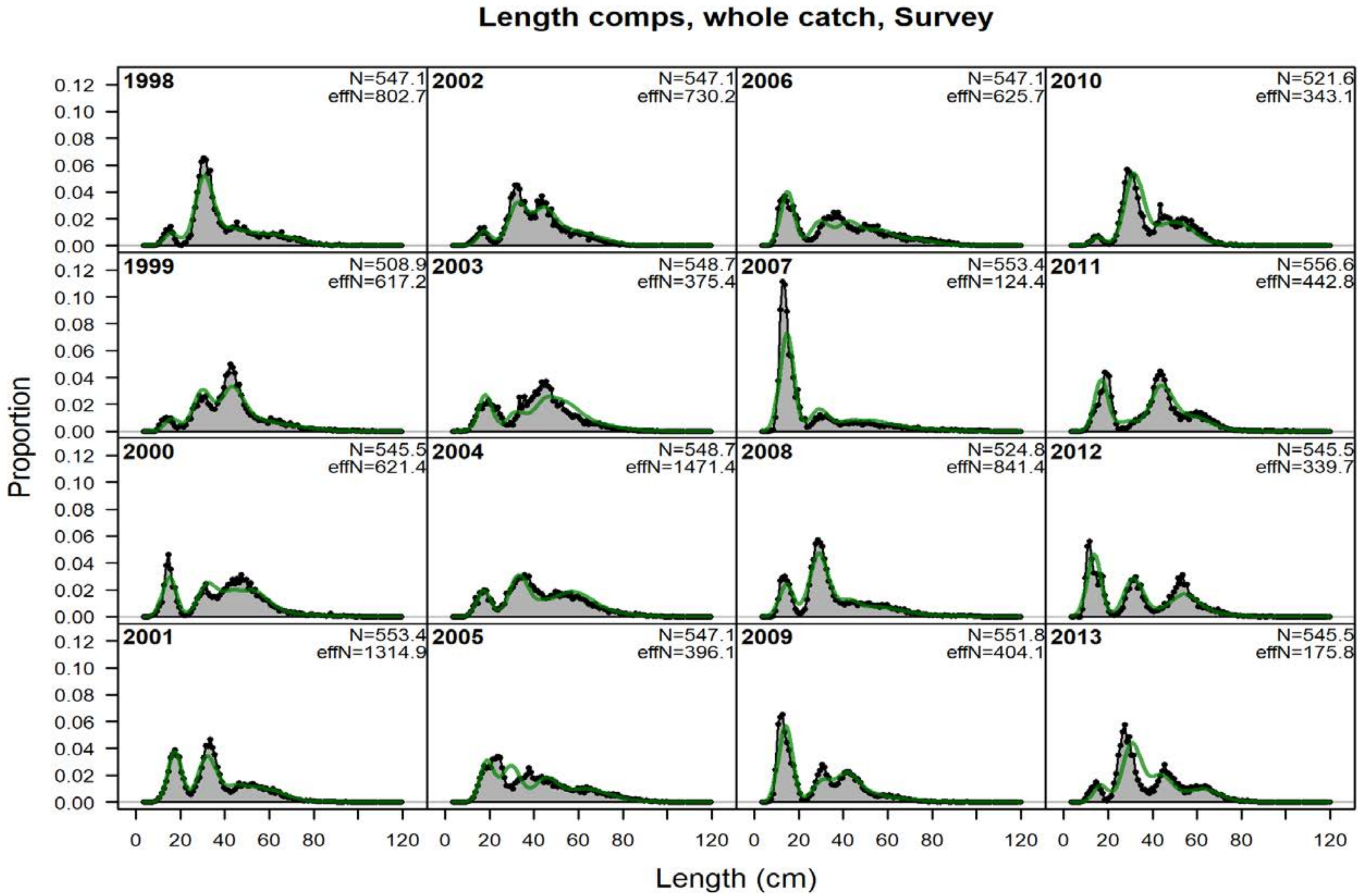


Figure 2.20e (page 2 of 3)—Model 17.6 fits to the survey size composition data.

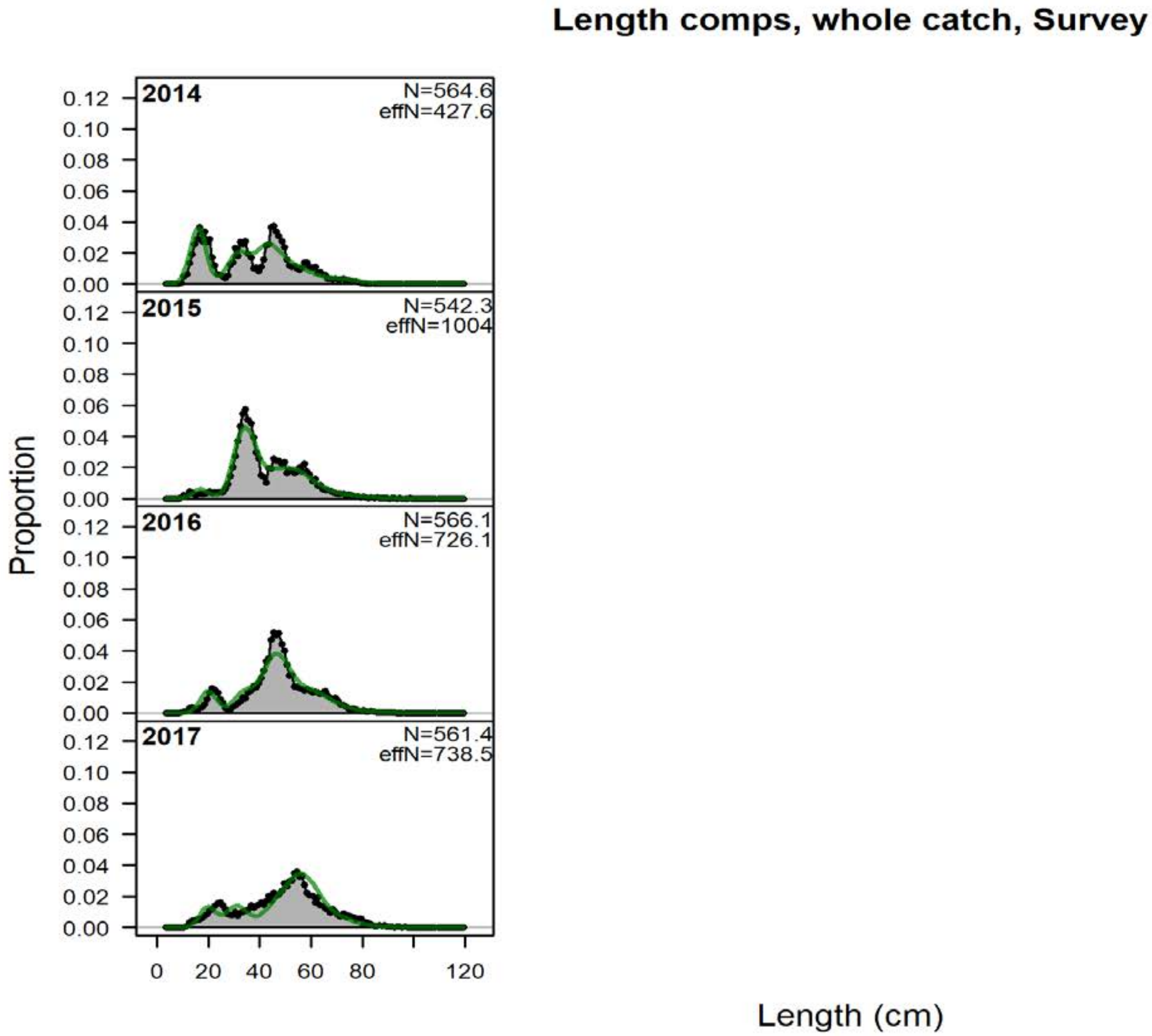


Figure 2.20e (page 3 of 3)—Model 17.6 fits to the survey size composition data.

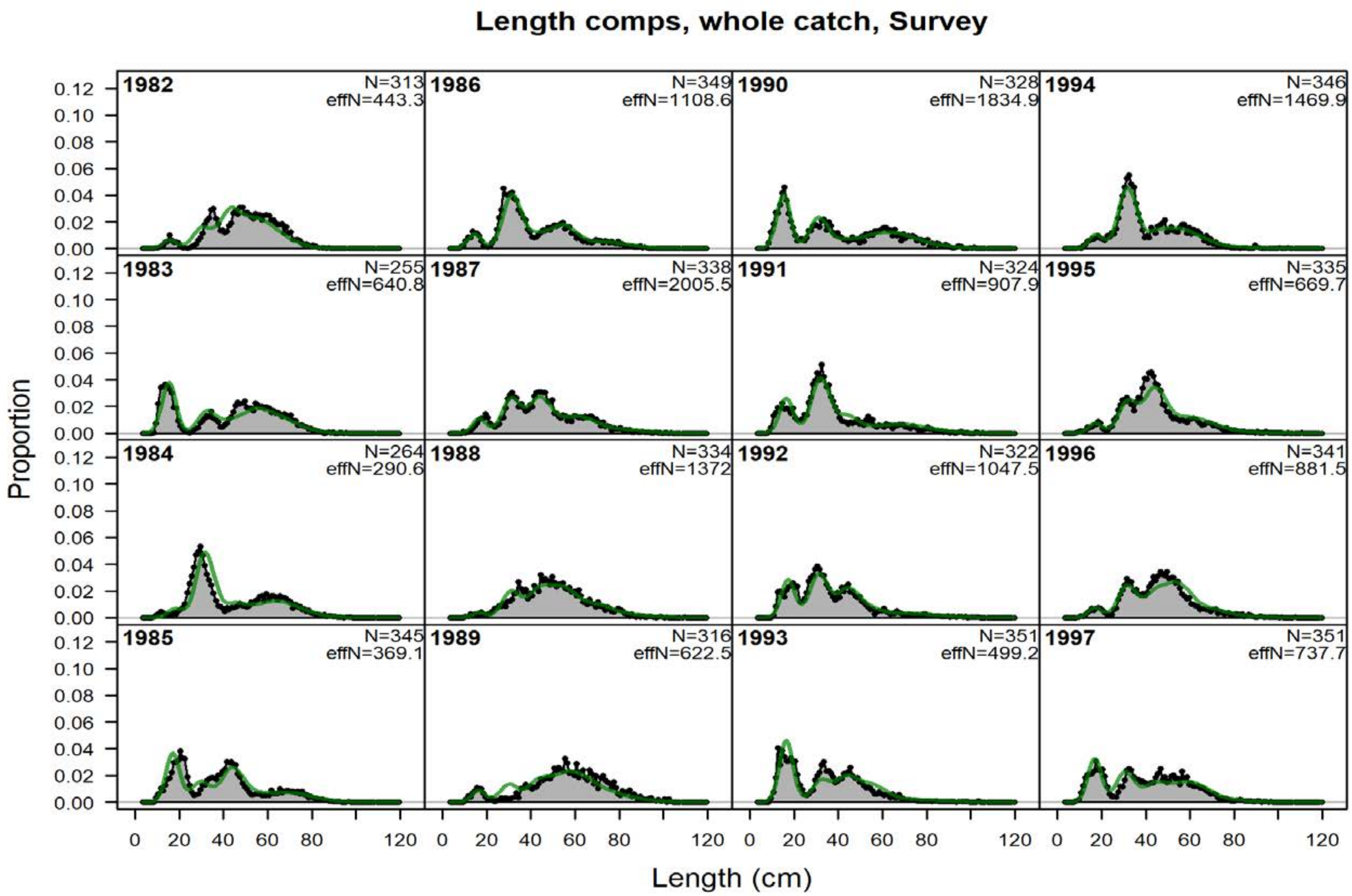


Figure 2.20f (page 1 of 3)—Model 17.7 fits to the survey size composition data.

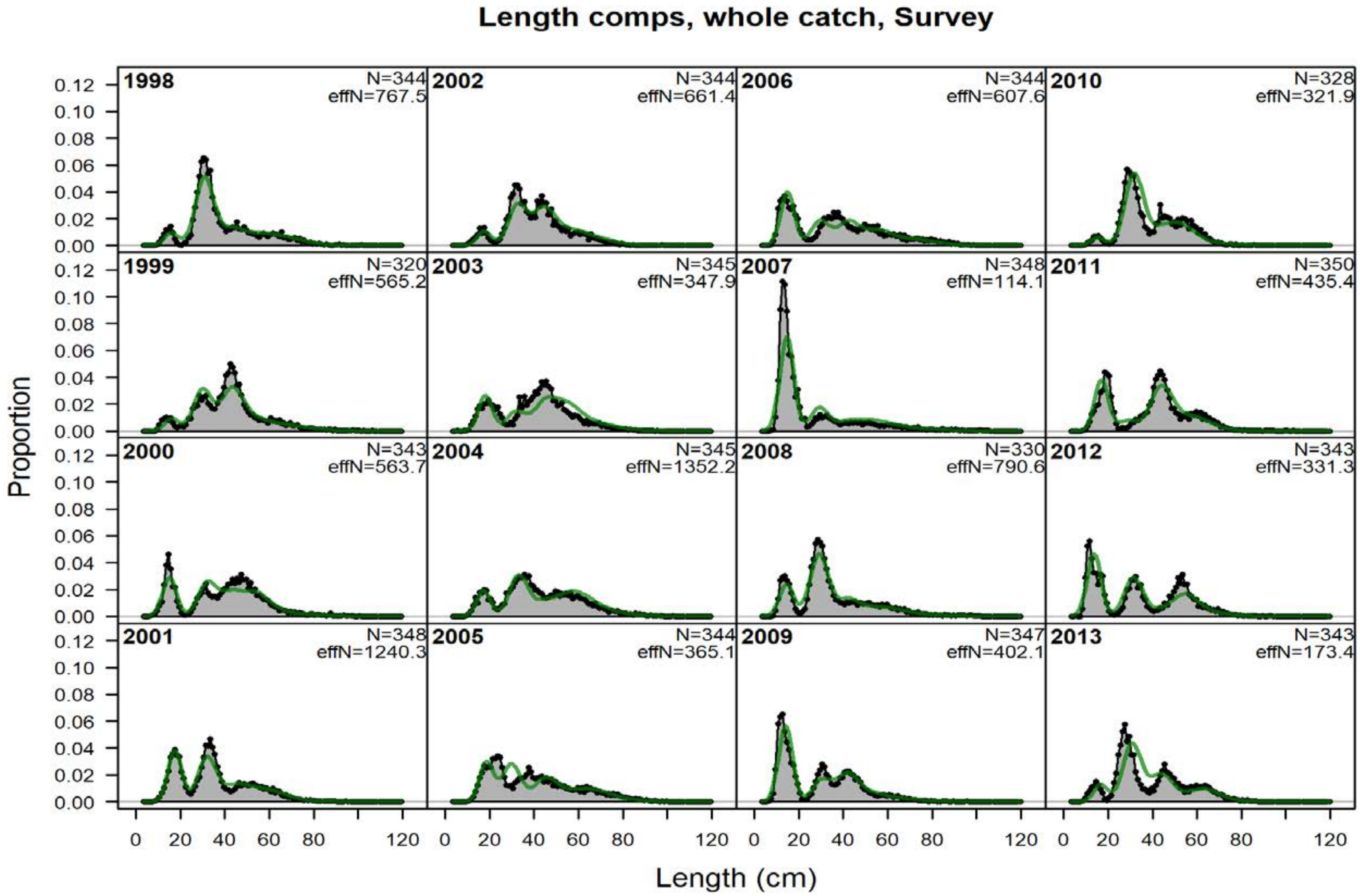


Figure 2.20f (page 2 of 3)—Model 17.7 fits to the survey size composition data.

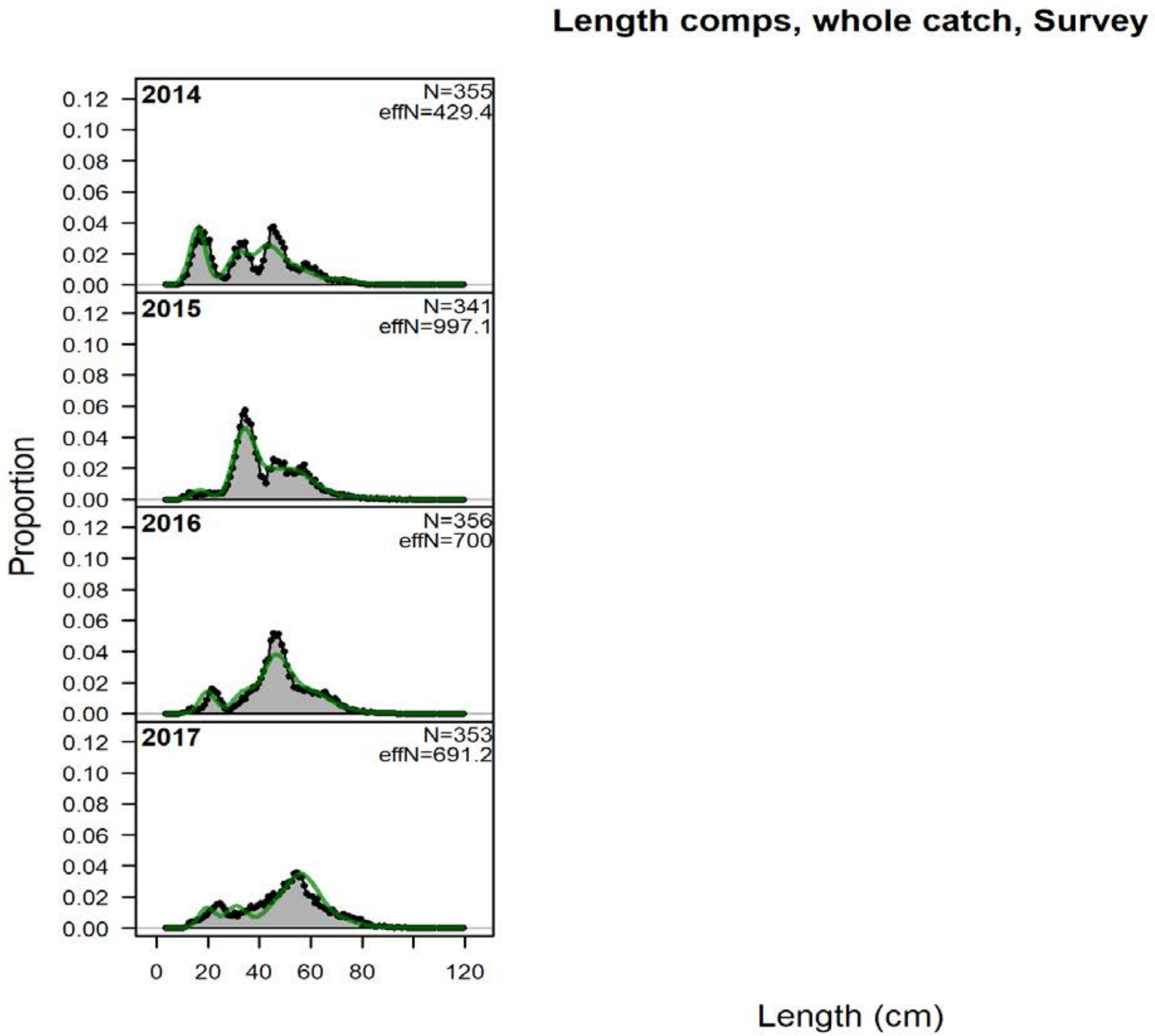
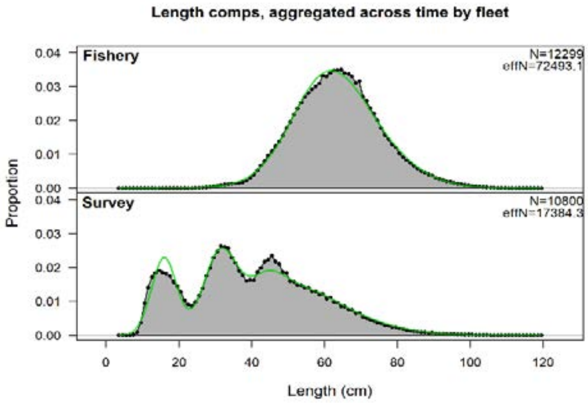
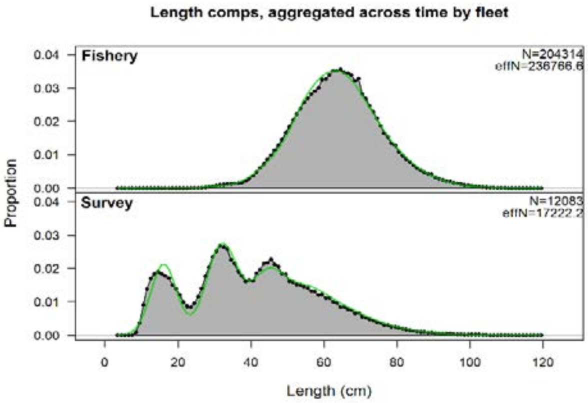


Figure 2.20f (page 3 of 3)—Model 17.7 fits to the survey size composition data.

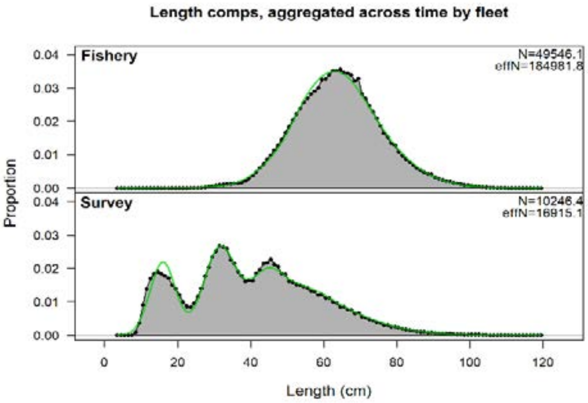
Model 16.6



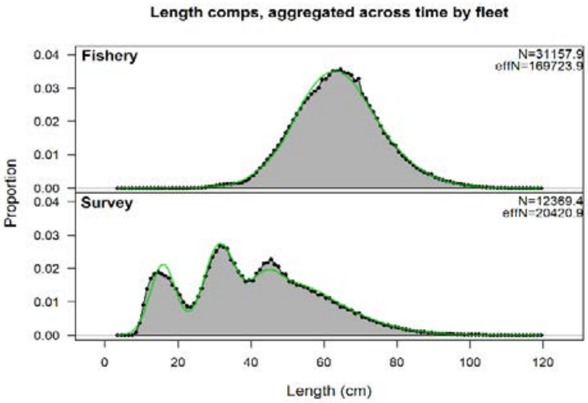
Model 17.1



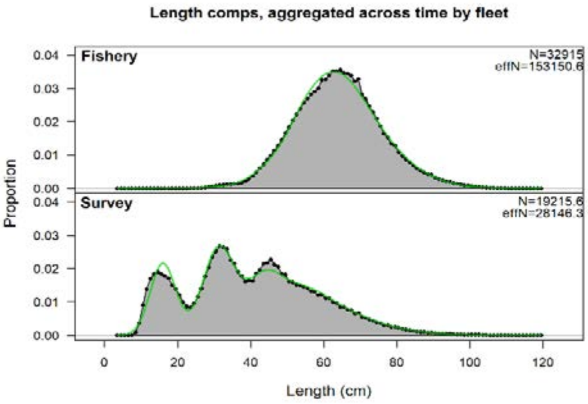
Model 17.2



Model 17.3



Model 17.6



Model 17.7

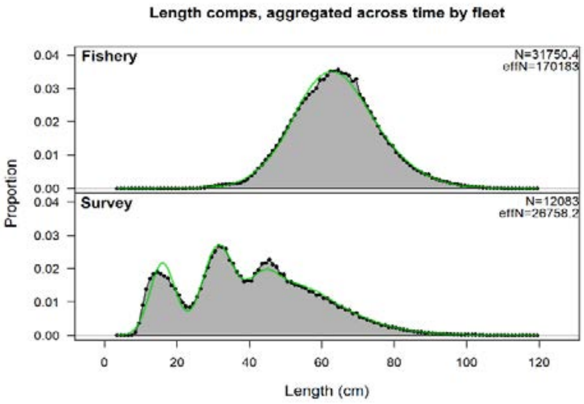


Figure 2.21—Time-aggregated fits to the size composition data.

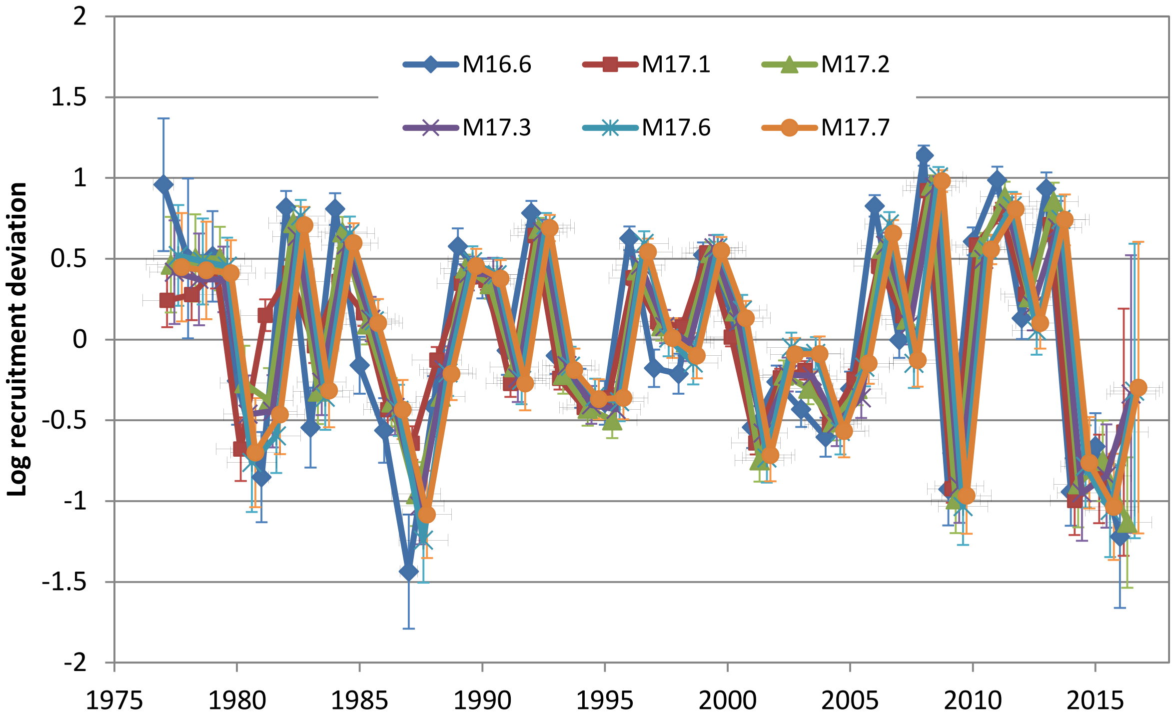


Figure 2.22—Recruitment deviations as estimated by the models. Series have been offset along the vertical axis by small amounts to prevent over-plotting.

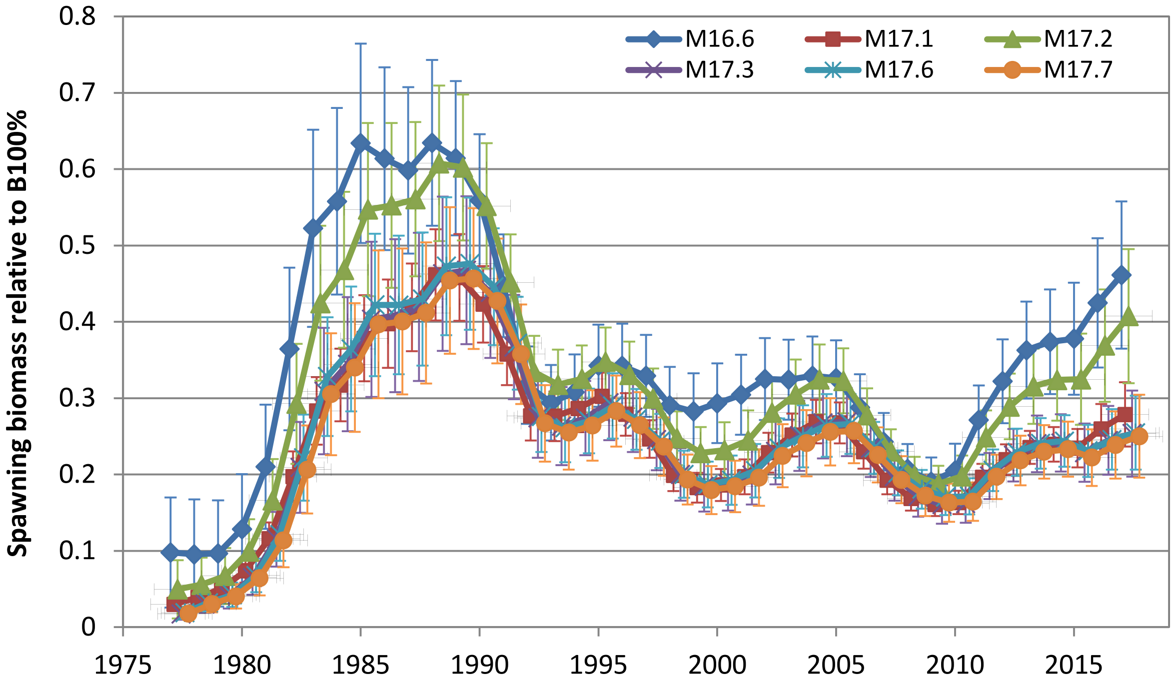


Figure 2.23—Spawning biomass relative to $B_{100\%}$ as estimated by the models.

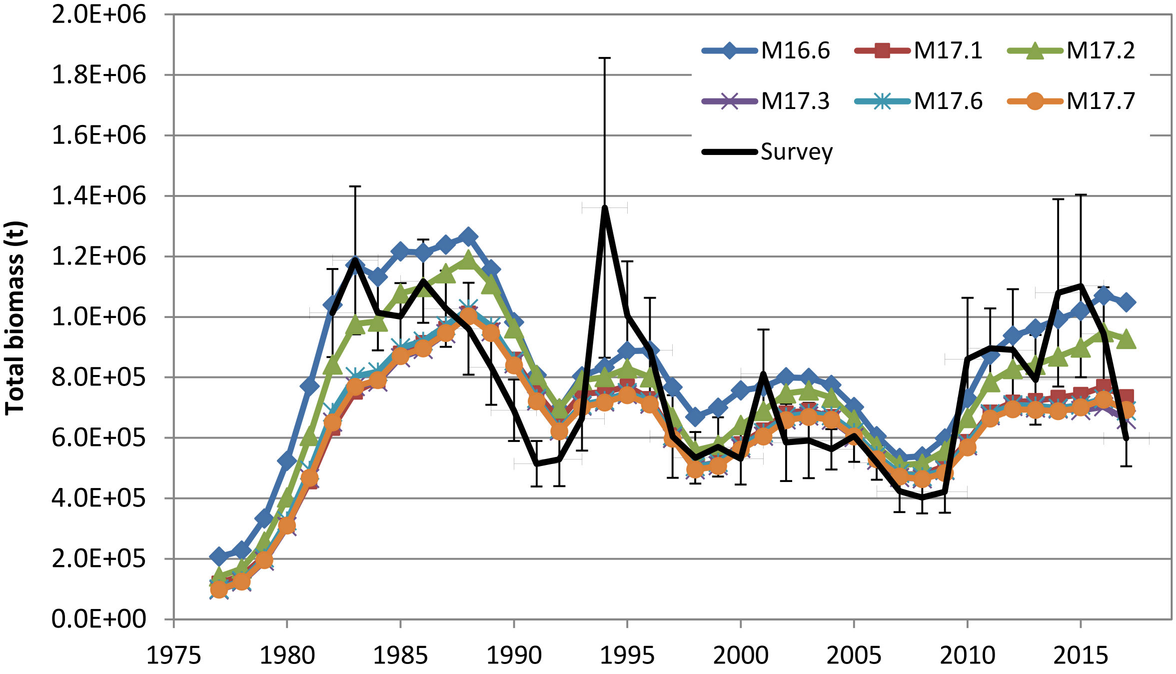
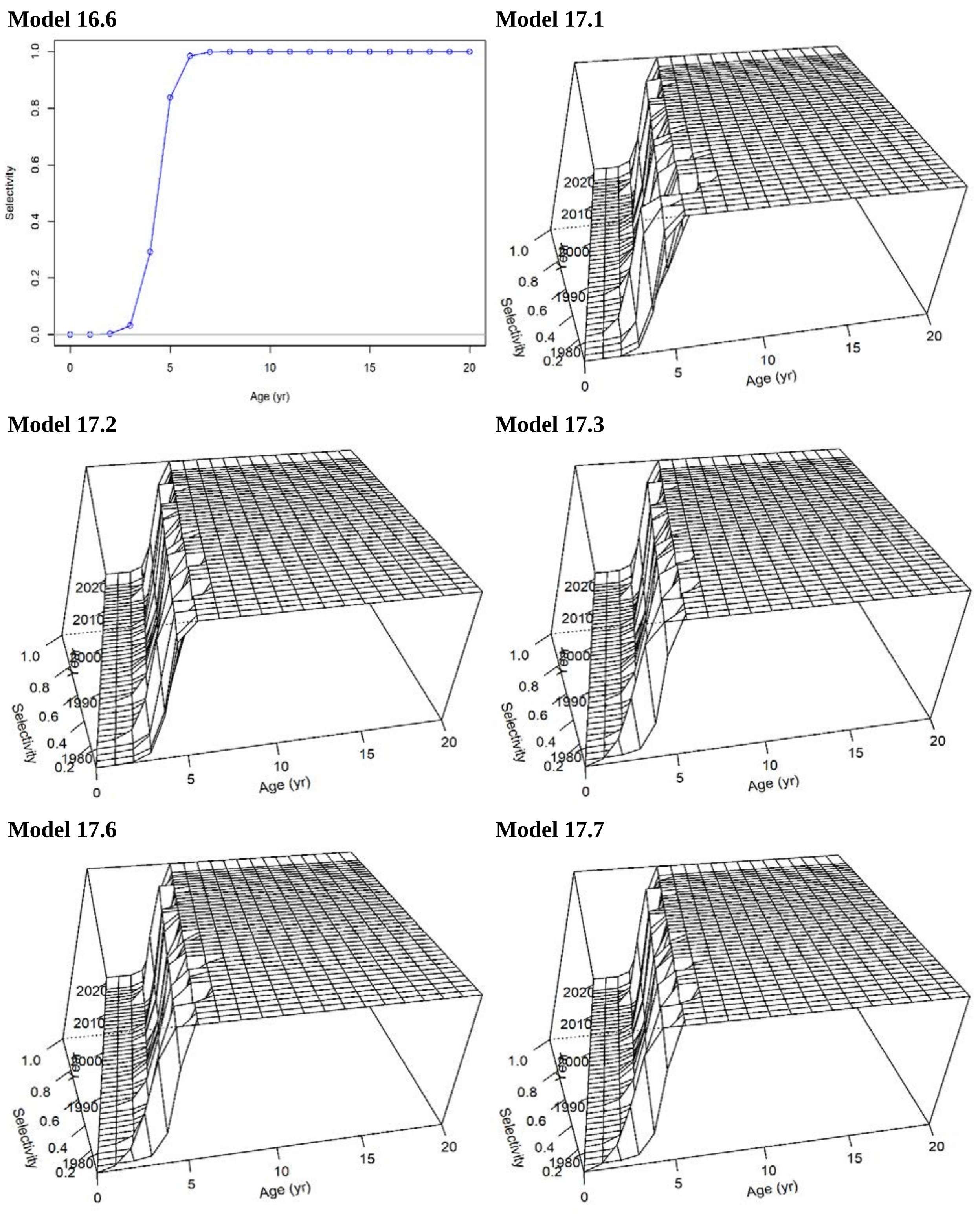


Figure 2.24—Total biomass as estimated by the models. Survey biomass shown for comparison.



Model 16.6

Model 17.1

Model 17.2

Model 17.3

Model 17.6

Model 17.7

Figure 2.25—Fishery selectivity as estimated by the models.

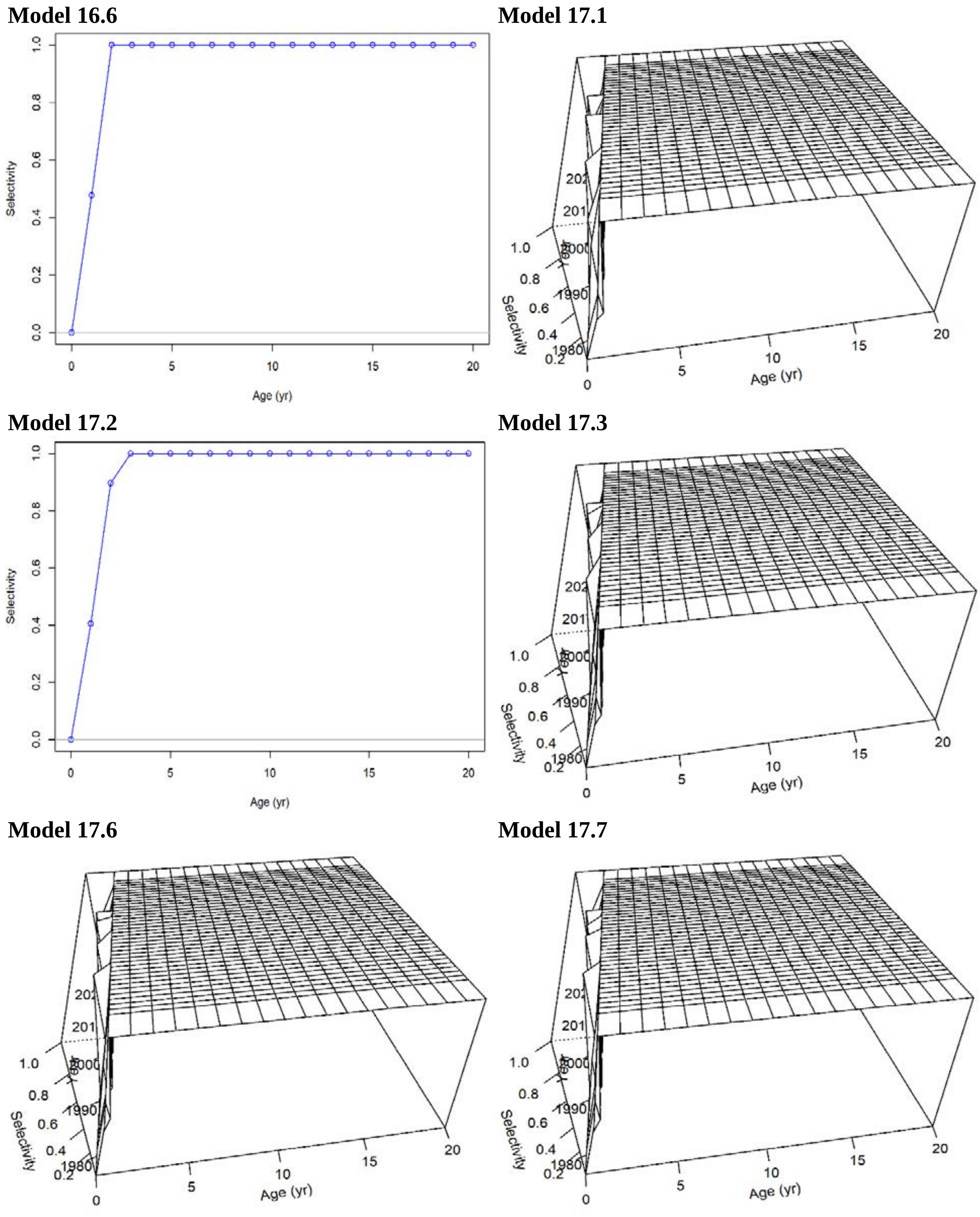


Figure 2.26—Survey selectivity as estimated by the models.

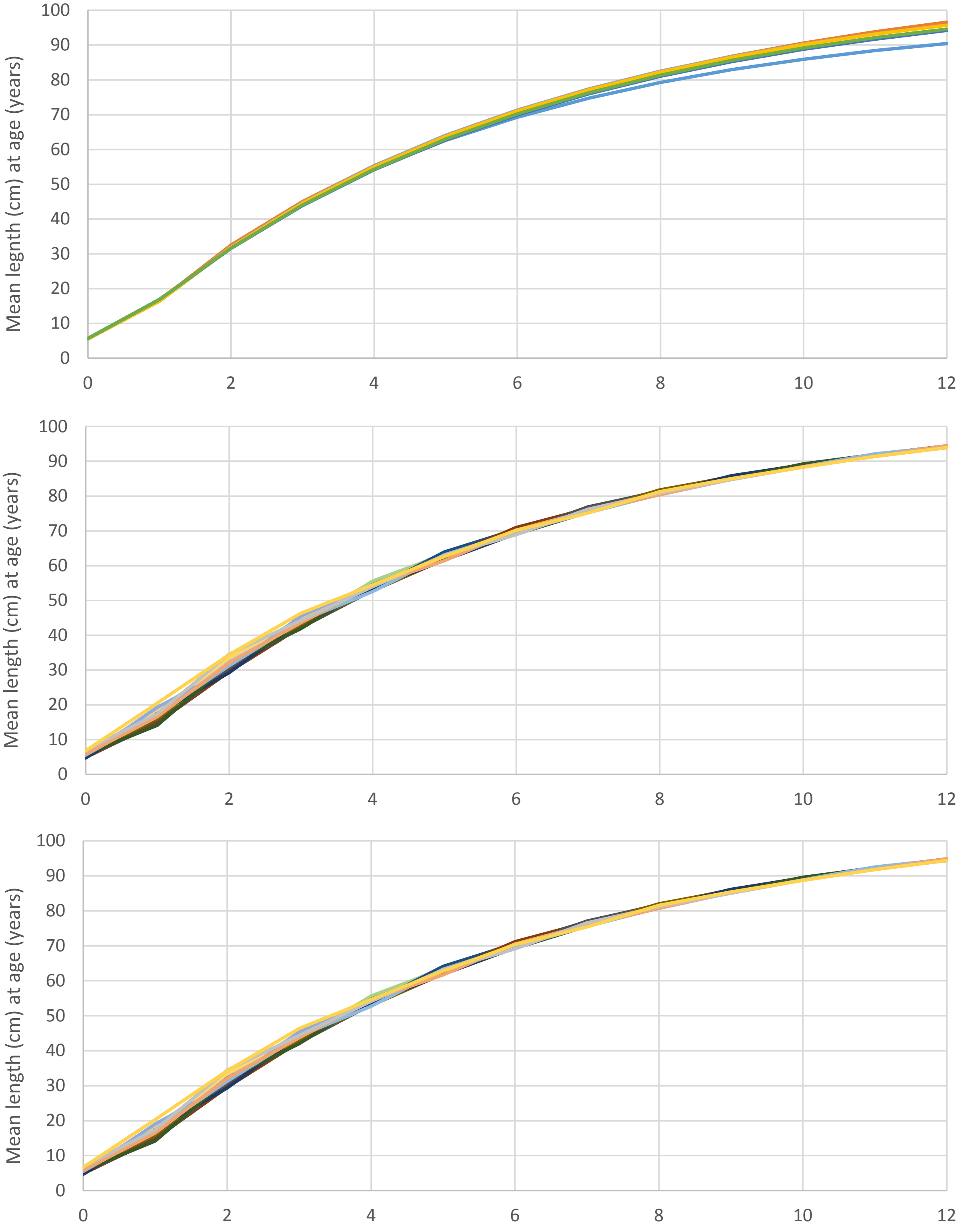


Figure 2.27—Mean length at age as estimated by the models. Top panel: base values for all six models (the curve for Model 16.6 is noticeably lower than the others at ages greater than about 6 years). Middle panel and bottom panels: annual curves (1977-2016) for Models 17.6 and 17.7, respectively.

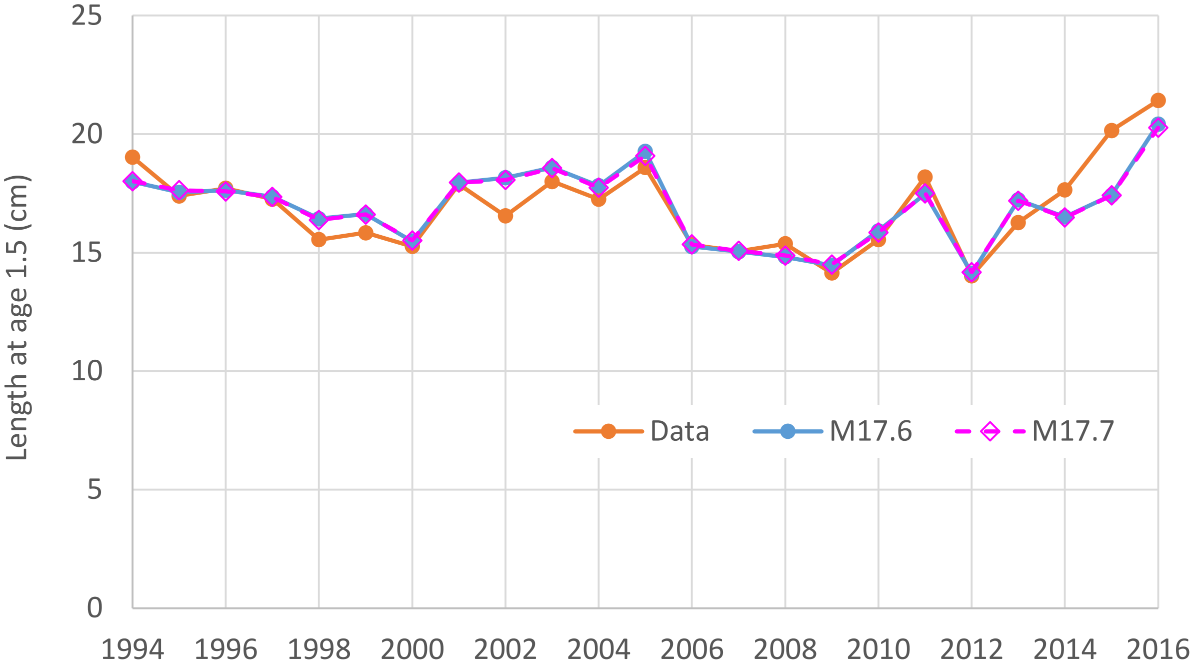


Figure 2.28—Length at age 1.5 as estimated by the ageing data (filtered through the survey age-length keys and the survey size compositions) and Models 17.6 and 17.7.

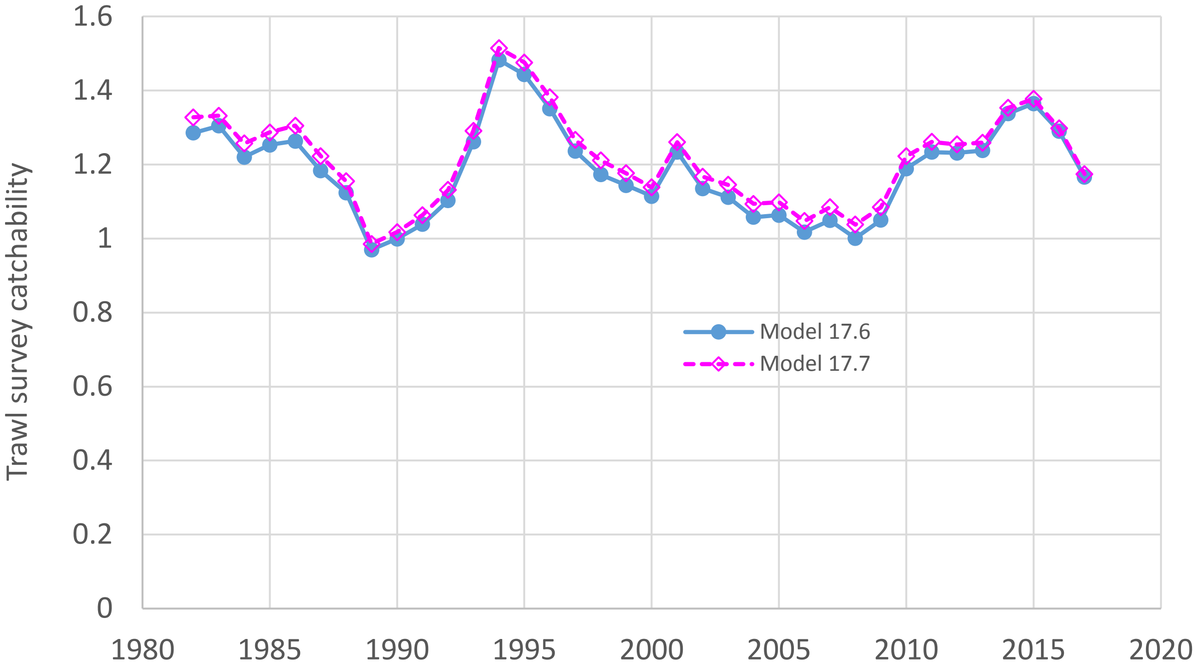


Figure 2.29—EBS shelf bottom trawl survey catchability as estimated by Models 17.6 and 17.7.

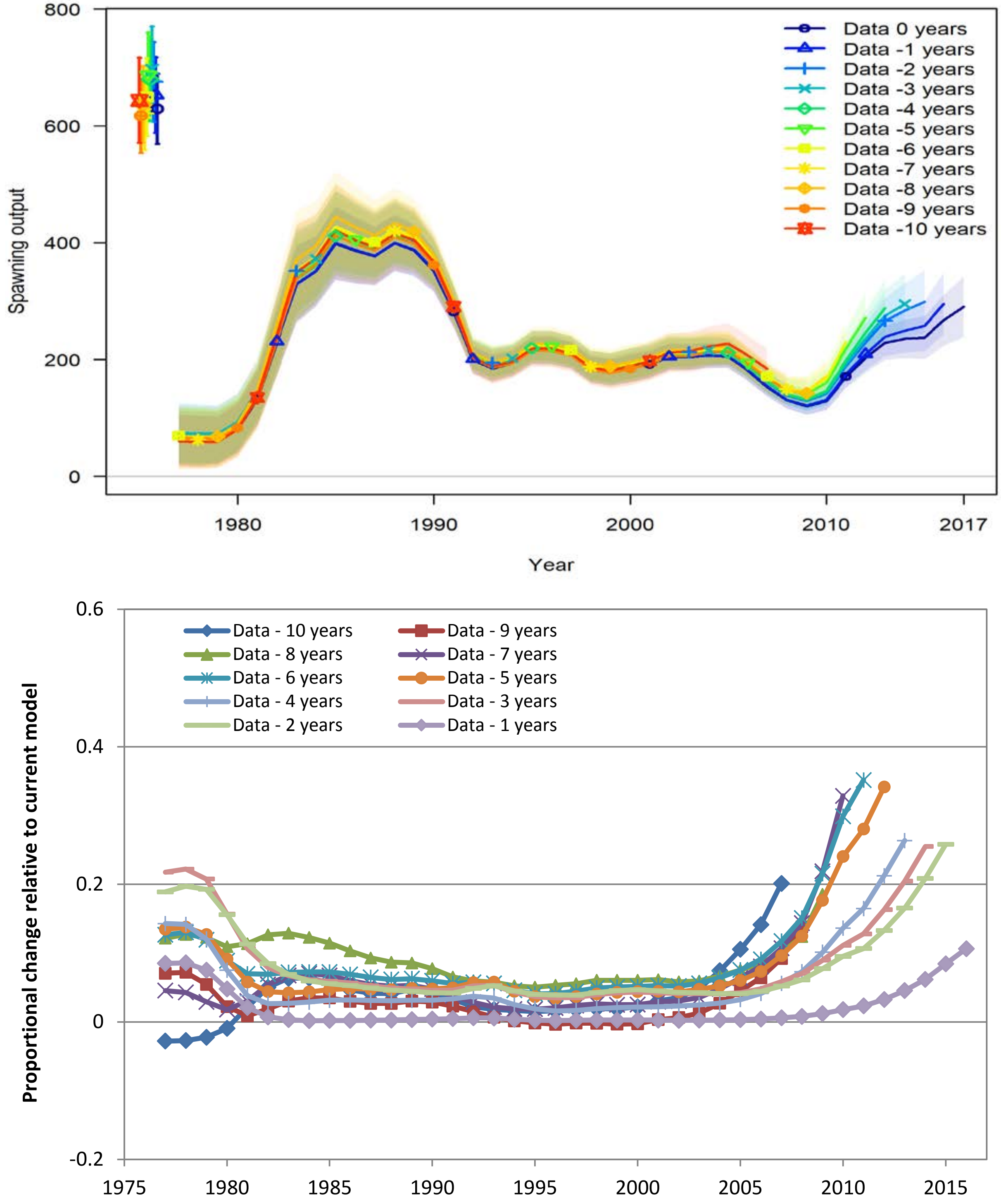


Figure 2.30a—Retrospective analysis of spawning biomass estimates from Model 16.6. Top panel: spawning biomass time series with 95% confidence intervals from the current version of Model 16.6 (2017) and 10 retrospective runs (2007-2016) obtained by dropping one year of data at a time. Bottom panel: change in spawning biomass relative to the current version of Model 16.6 for each of 10 retrospective runs. Mohn's $\rho = 0.243$.

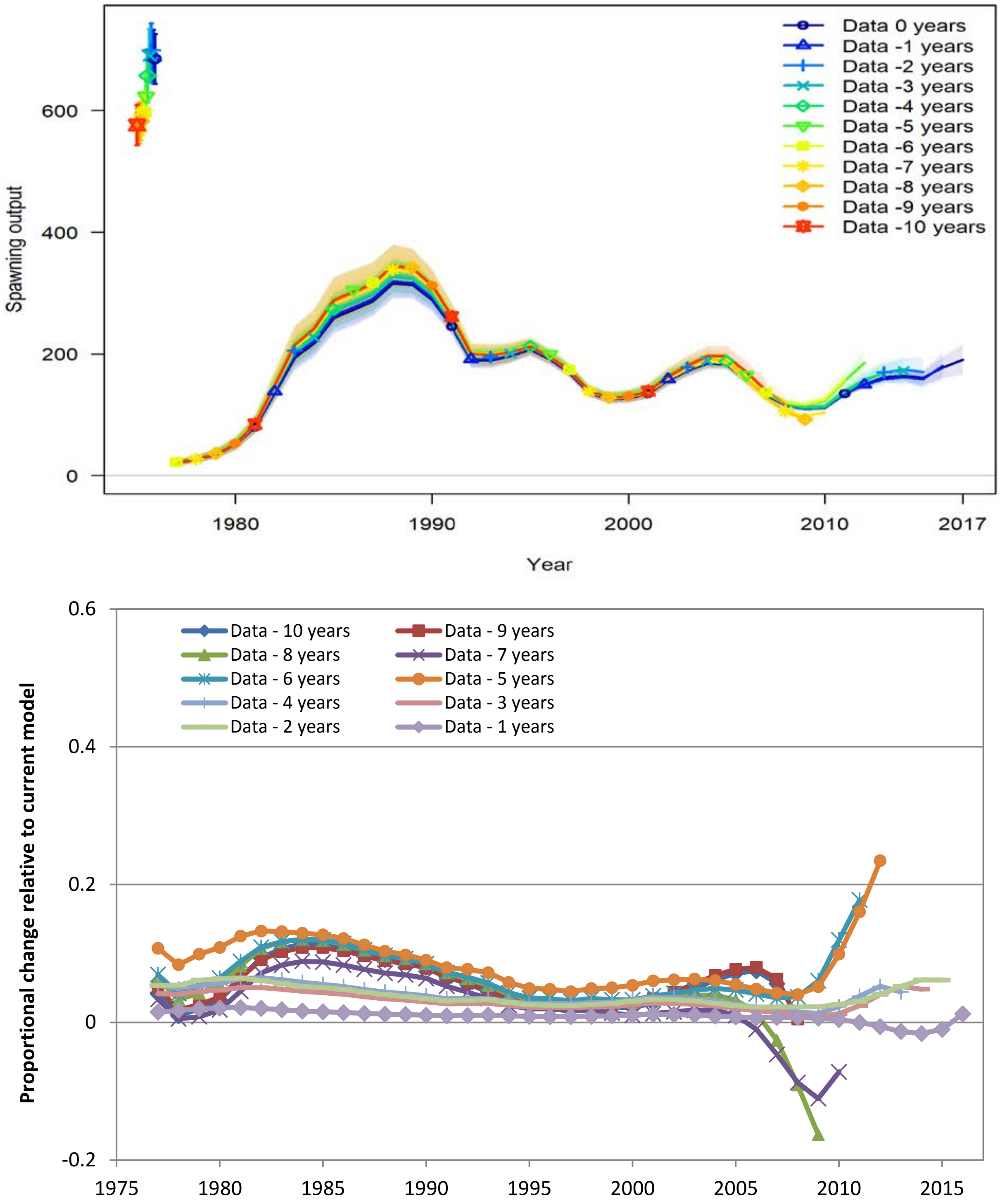


Figure 2.30b—Retrospective analysis of spawning biomass estimates from Model 17.1. Top panel: spawning biomass time series with 95% confidence intervals from the current version of Model 17.1 (2017) and 10 retrospective runs (2007-2016) obtained by dropping one year of data at a time. Bottom panel: change in spawning biomass relative to the current version of Model 17.1 for each of 10 retrospective runs. Mohn's $\rho = 0.040$.

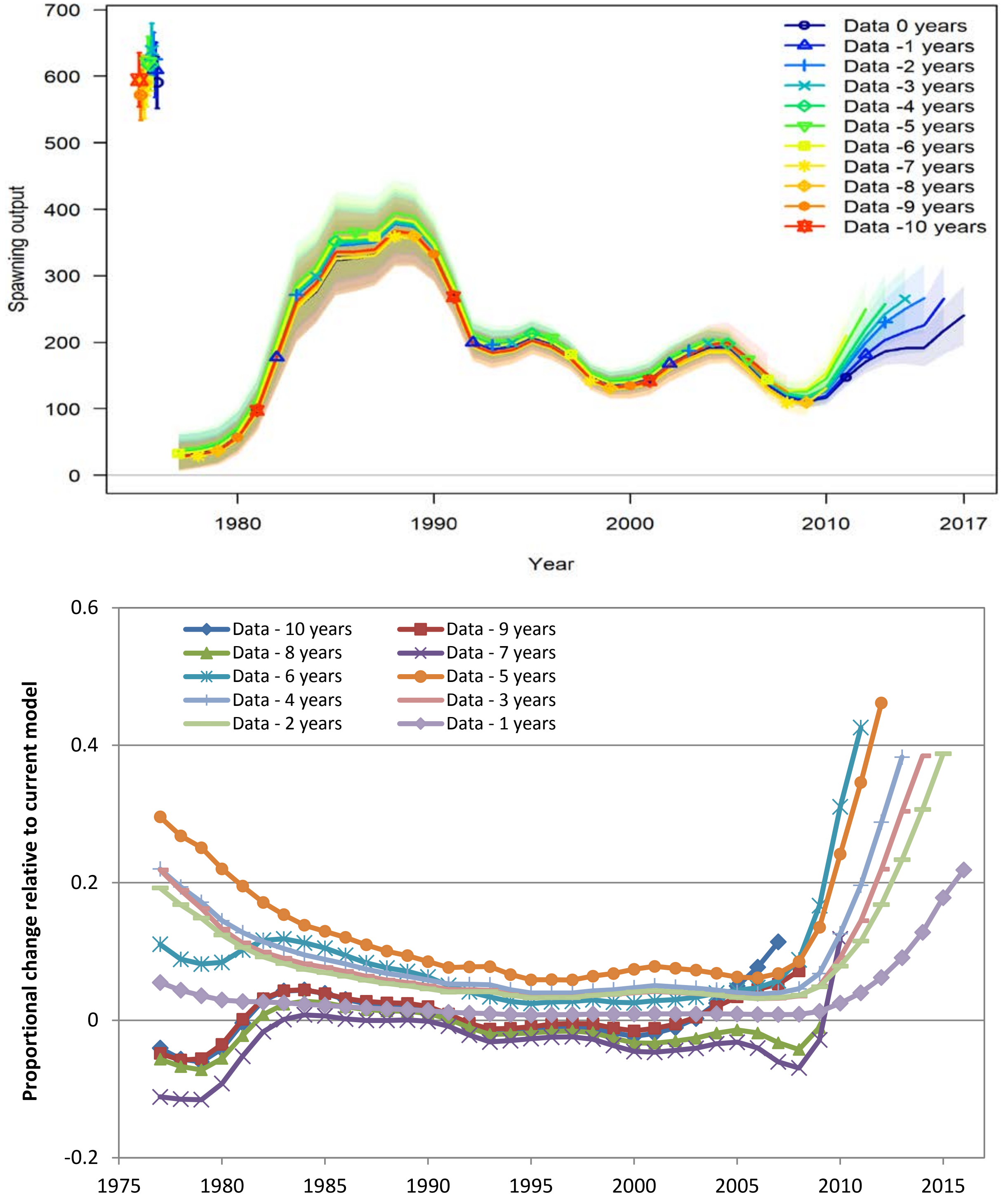


Figure 2.30c—Retrospective analysis of spawning biomass estimates from Model 17.2. Top panel: spawning biomass time series with 95% confidence intervals from the current version of Model 17.2 (2017) and 10 retrospective runs (2007-2016) obtained by dropping one year of data at a time. Bottom panel: change in spawning biomass relative to the current version of Model 17.2 for each of 10 retrospective runs. Mohn's $\rho = 0.255$.

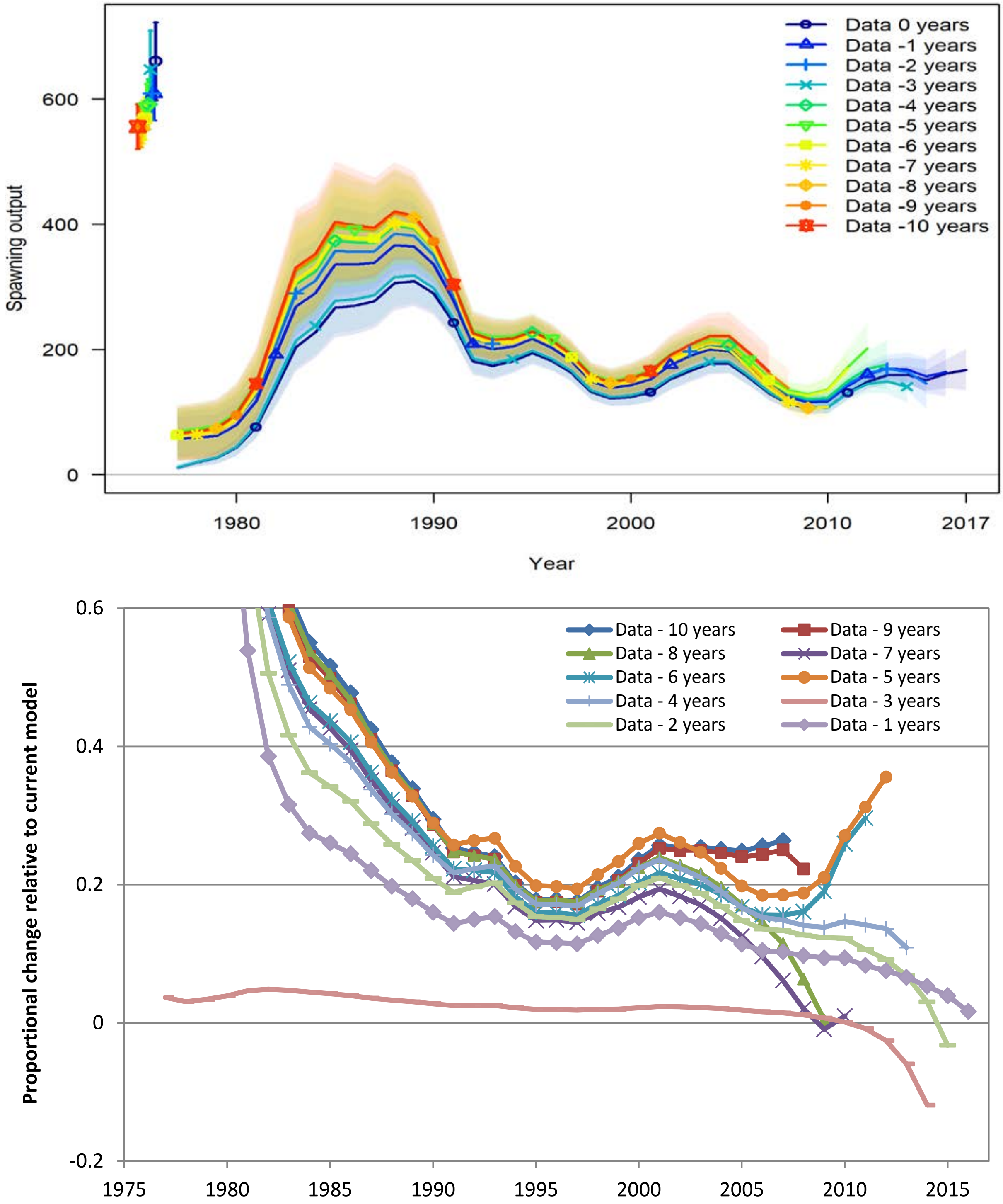


Figure 2.30d—Retrospective analysis of spawning biomass estimates from Model 17.3. Top panel: spawning biomass time series with 95% confidence intervals from the current version of Model 17.3 (2017) and 10 retrospective runs (2007-2016) obtained by dropping one year of data at a time. Bottom panel: change in spawning biomass relative to the current version of Model 17.3 for each of 10 retrospective runs. Mohn's $\rho = 0.113$.

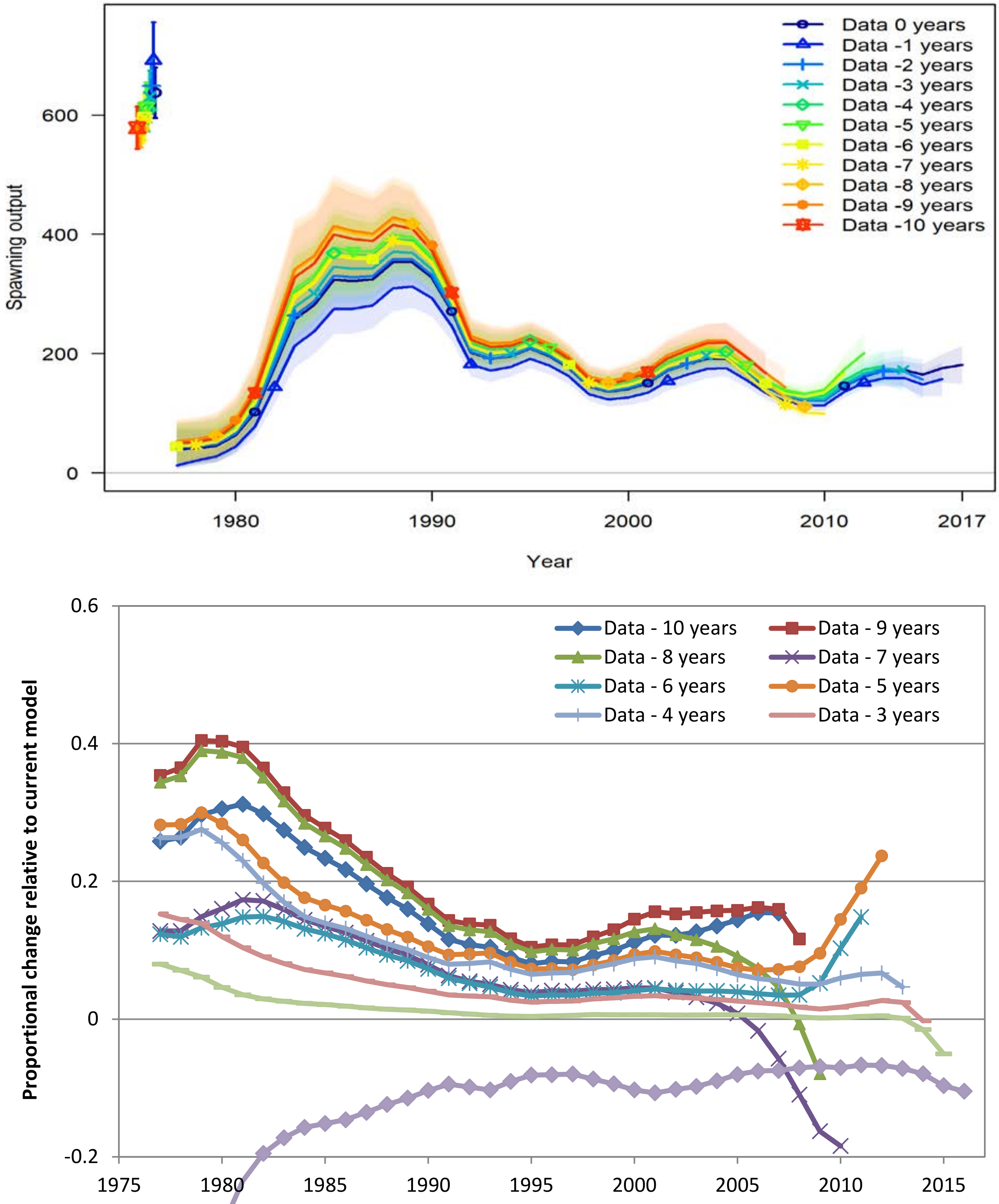


Figure 2.30e—Retrospective analysis of spawning biomass estimates from Model 17.6. Top panel: spawning biomass time series with 95% confidence intervals from the current version of Model 17.6 (2017) and 10 retrospective runs (2007-2016) obtained by dropping one year of data at a time. Bottom panel: change in spawning biomass relative to the current version of Model 17.6 for each of 10 retrospective runs. Mohn's $\rho = 0.028$.

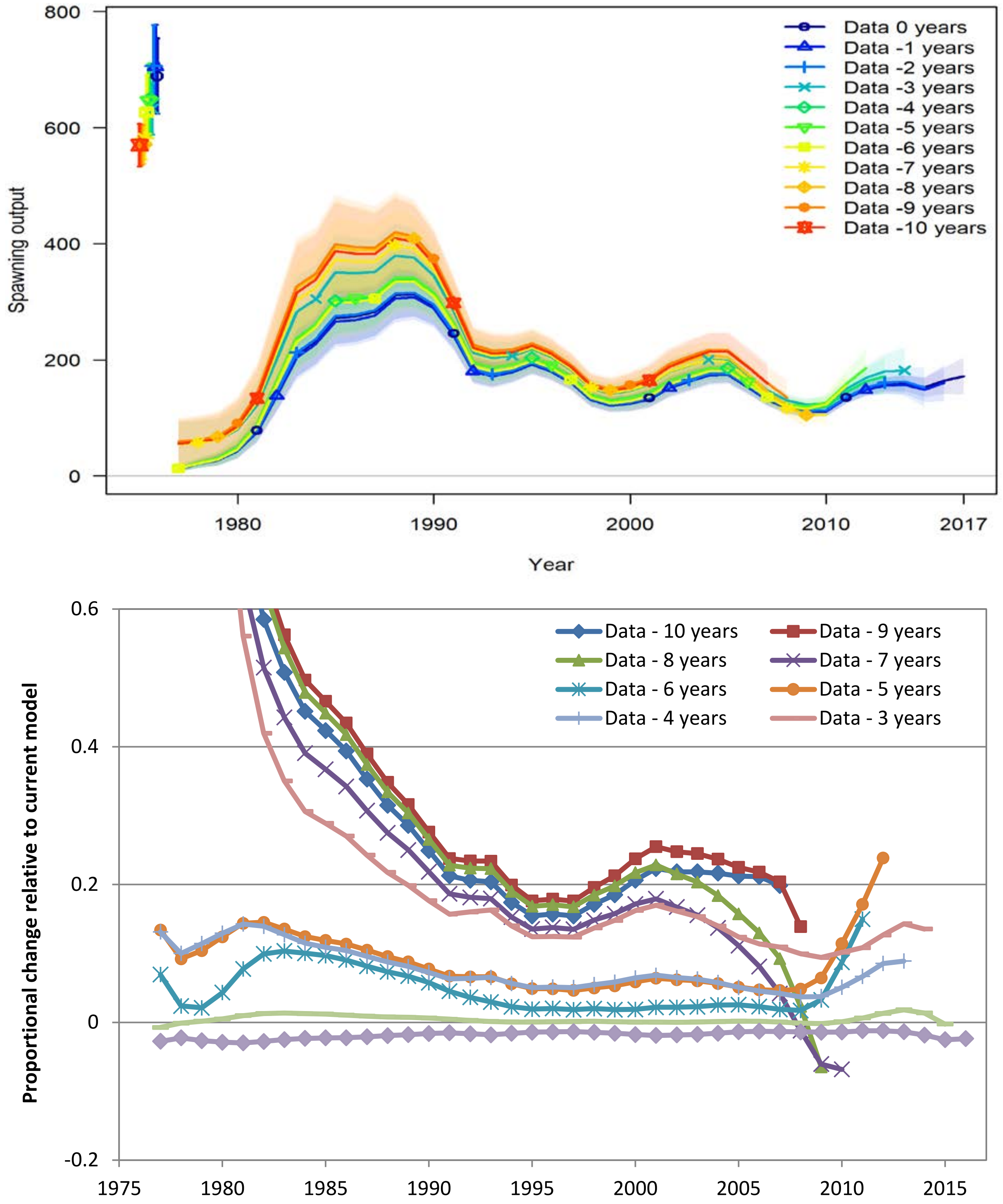


Figure 2.30f—Retrospective analysis of spawning biomass estimates from Model 17.7. Top panel: spawning biomass time series with 95% confidence intervals from the current version of Model 17.7 (2017) and 10 retrospective runs (2007-2016) obtained by dropping one year of data at a time. Bottom panel: change in spawning biomass relative to the current version of Model 17.7 for each of 10 retrospective runs. Mohn's $\rho = 0.079$.

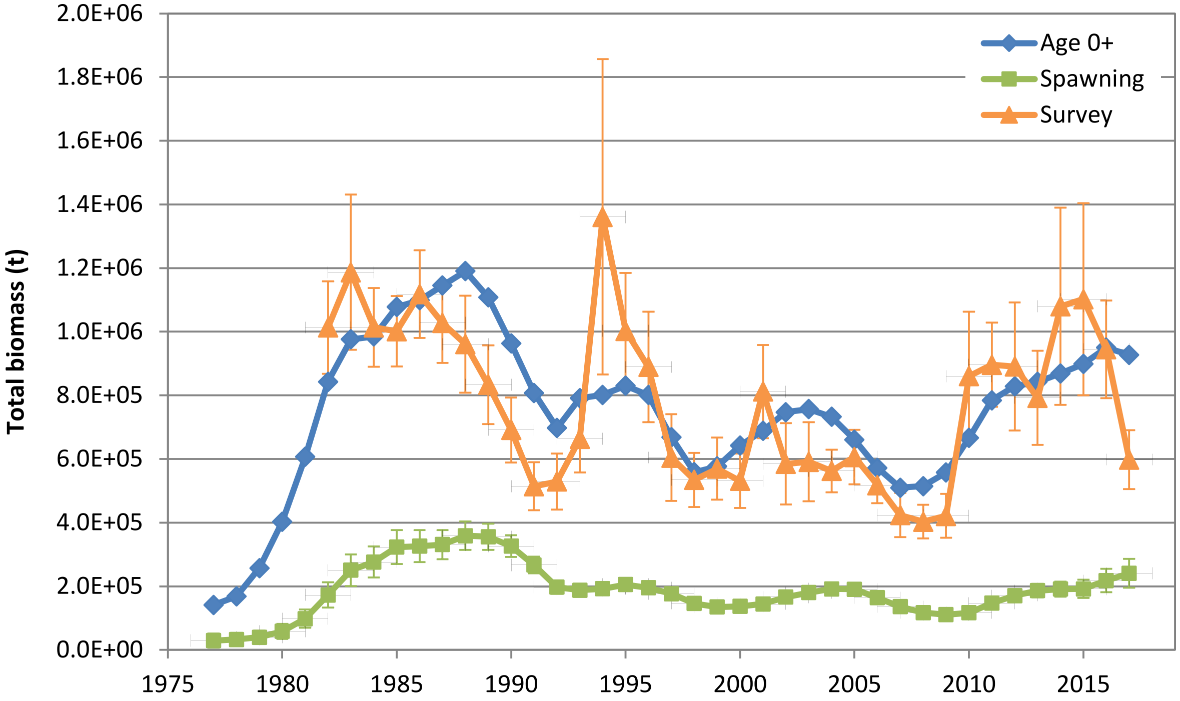


Figure 2.31—Time series of age 0+ and female spawning biomass as estimated by Model 17.2. Survey biomass is shown for comparison.

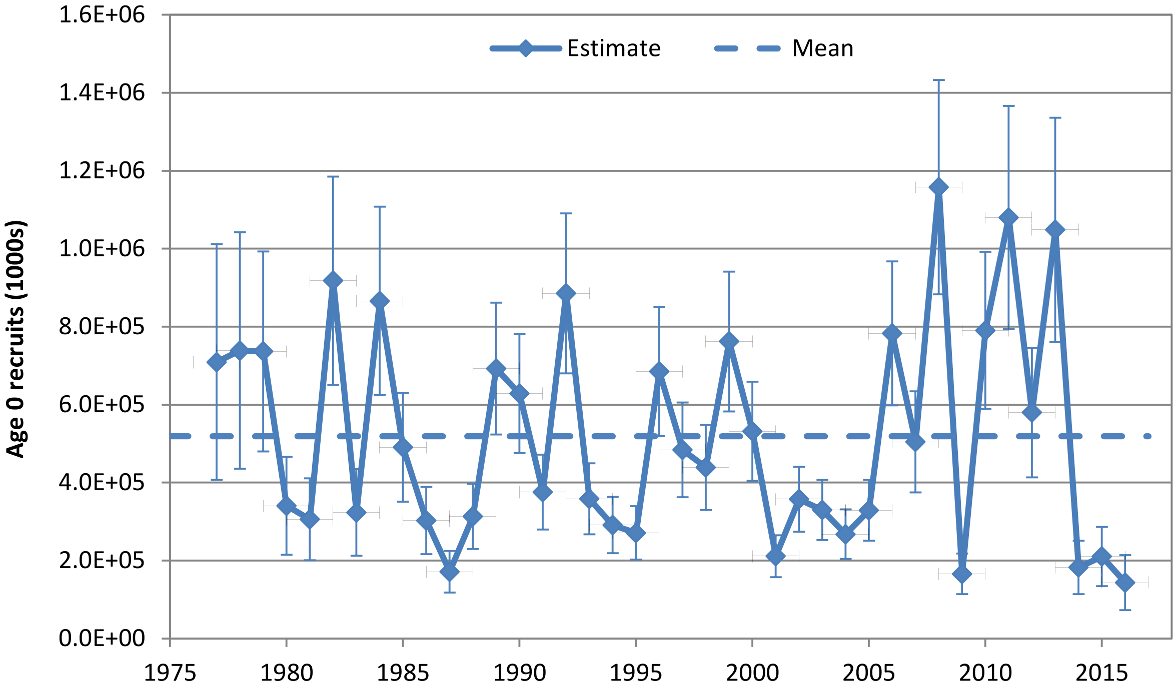


Figure 2.32—Time series of recruitment at age 0 as estimated Model 17.2.

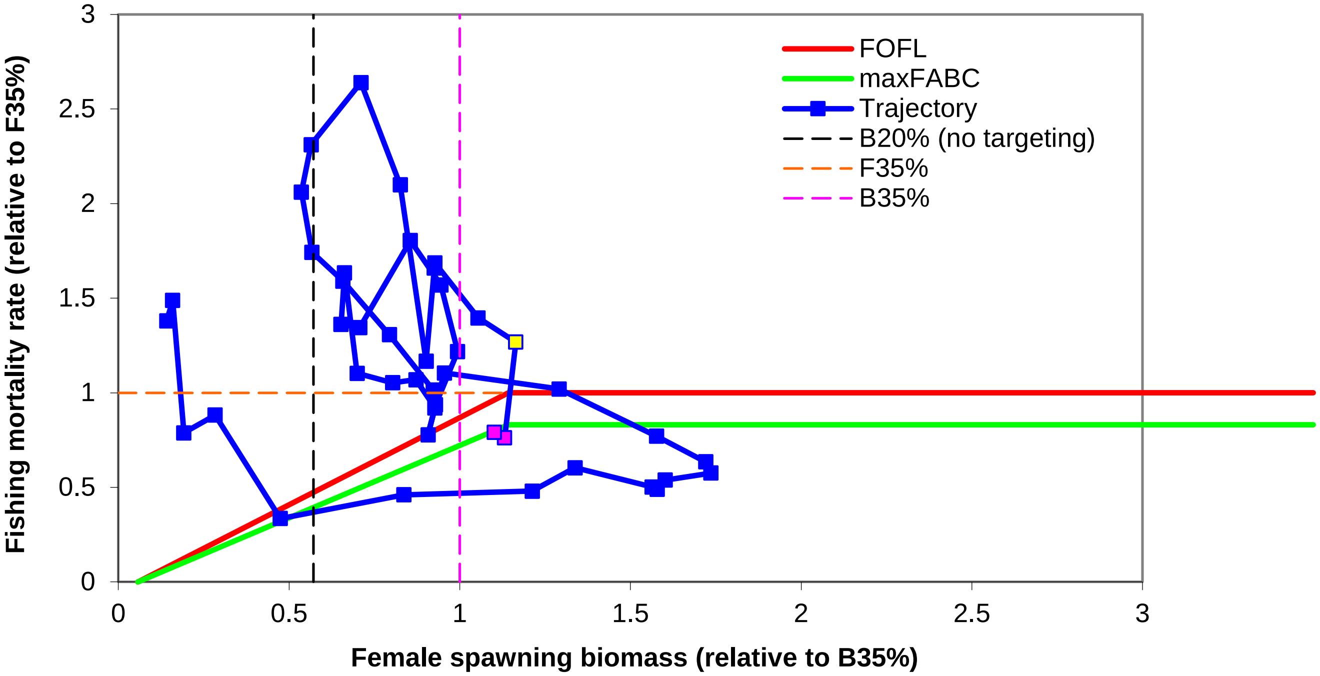


Figure 2.33—Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model 17.2, 1977-2019 (yellow square = current year, magenta squares = first two projection years).

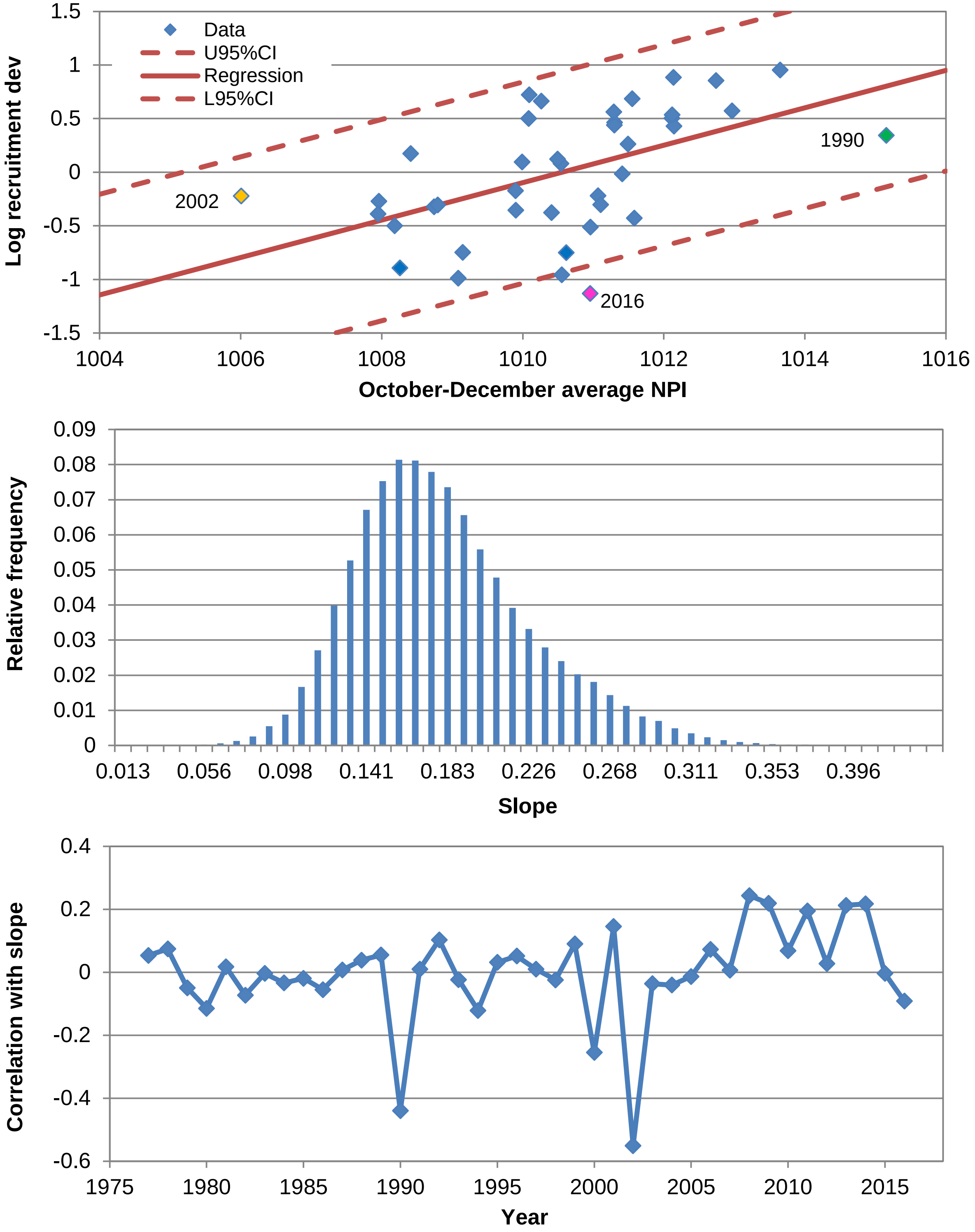


Figure 2.34—Environmental effects on recruitment. Upper panel: Estimated log recruitment deviations (age 0) versus same-year October-December average of the NPI, with regression line and 95% confidence interval. Middle panel: Distribution of the regression slope, as generated by a cross-validation analysis. Lower panel: Correlation between individual data points and regression slope. See text for details.

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

Grant G. Thompson

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

Introduction

This document represents an effort to respond to comments made by the BSAI Plan Team ("Team"), the Scientific and Statistical Committee ("SSC"), and the Subcommittee on Pacific Cod Models ("Subcommittee," which was a subcommittee of the Joint Teams in 2016 but a subcommittee of just the BSAI Team in 2017) on last year's assessment of the Pacific cod (*Gadus macrocephalus*) stock in the eastern Bering Sea (EBS, Thompson 2016a). The comments listed below from the May 2016 Subcommittee meeting, the September and November 2016 Team meetings, and the October and December 2016 SSC meetings were all considered by the Subcommittee during its June 2017 meeting (https://www.npfmc.org/wp-content/PDFdocuments/membership/PlanTeam/Groundfish/BSAIPcod_subcommittee617minutes.pdf), and so are not responded to here. Responses are provided here only for the comments from the June 2017 Subcommittee meeting.

Comments from the May 2016 Subcommittee meeting

During its May 2016 meeting, in addition to making several recommendations for the 2016 assessment, the Subcommittee listed some recommendations that it designated as having "medium" priority, defined as recommendations that the Subcommittee felt should be considered in either the 2017 or 2018 assessments.

Sub1 (originally from the 2016 review by CIE member Jean-Jacques Maguire, labeled as comment 2e.06 in the minutes of the May 2016 Subcommittee meeting): "Only those parameters where there is external information suggesting that changes are occurring should be allowed to vary, probably one at a time to avoid incorrect interpretation."

Sub2 (originally from the December 2015 SSC minutes, labeled as comment SSC2 in the minutes of the May 2016 Subcommittee meeting): "The SSC was encouraged by the author's explanation that dome-shaped selectivity may, in part, be explained by the possibility that some of older fish may be residing in the northern Bering Sea (NBS) at the time of the survey. This is supported by the size composition of the fish in the 2010 NBS trawl survey, which suggested that up to 40% of the fish in some larger size classes reside in this area, although the overall proportion in the NBS was small. The SSC encourages the author to further examine Pacific cod catches from trawl surveys conducted triennially by the National Marine Fisheries Service (NMFS) (1976-1991) and by the Alaska Department of Fish & Game (1996 to the present) to monitor the distribution and abundance of red king crab and demersal fish (see: Hamazaki, T., Fair, L., Watson, L., Brennan, E., 2005. Analyses of Bering Sea bottom-trawl surveys in Norton Sound: absence of regime shift effect on epifauna and demersal fish. ICES Journal of Marine Science 62, 1597-1602). While the 2010 bottom trawl survey in the NBS found relatively few Pacific cod (3% of total biomass), it is possible that the proportion of Pacific cod that are outside the standard survey area was higher in other years. A second possibility is that older Pacific cod migrate to nearshore areas to feed in the summer, making them unavailable to the survey."

Sub3 (developed by the Subcommittee during its May 2016 meeting, where it was labeled JTS5): "Use reasonably time-varying, double normal selectivity (Bering Sea only). CIE comments 2e.01 and 2e.09 suggested that some amount of time-variability in fishery selectivity is appropriate, CIE comment 2e.12 cautioned against allowing 'too much' time-variability in selectivity, and CIE comment 2b.07 suggested use of the double normal selectivity function."

Comments from the September 2016 Team meeting
BPT1: "The Team recommends that the mid-year meetings cease unless exceptional circumstances necessitate such a meeting."

Comments from the October 2016 SSC meeting
SSC1: "The observed discrepancies among different models in these assessments are a good—if perhaps extreme—example of the model uncertainty that pervades most assessments. This uncertainty is largely ignored once a model is approved for specifications. We encourage the authors and Plan Teams to consider approaches such as multi-model inference to account for at least some of the structural uncertainty. We recommend that a working group be formed to address such approaches."

SSC2: "Regarding the mid-year model vetting process, the SSC re-iterates its recommendation from June to continue for now. The process has proven useful for the industry as an avenue to provide formal input and for the author to prioritize the range of model options to consider."

SSC3: "With regard to data weighting, the SSC recommends that the authors consider computing effective sample sizes based on the number of hauls that were sampled for lengths and weights, rather than the number of individual fish."

SSC4: "Although there is genetic evidence for stock structuring within the Pacific cod population among regions, the uncertainty in model scale for all three regions seems to suggest that some sharing of information among the three assessments might be helpful. Over the long term, authors could consider whether a joint assessment recognizing the population structuring, but simultaneously estimating key population parameters (e.g., natural mortality, catchability or others) might lend more stability and consistency of assumptions for this species."

SSC5: "The SSC notes that, in spite of the concerns over dome-shaped survey selectivity in the survey, there are many potential mechanisms relating to the availability of larger fish to the survey gear that could result in these patterns, regardless of the efficiency of the trawl gear to capture large fish in its path. For example, in the Bering Sea the patterns could be due to larger Pacific cod being distributed in deeper waters or in the northern Bering Sea at the time of the survey. The northern Bering Sea survey planned for 2017 should provide additional information on the latter possibility."

Comments from the November 2016 Team meeting
BPT3: "The Team recommends comparing model predicted weight-at-age in Models 16.6 and 16.7 to the empirical weight-at-age used in Model 16.1."

BPT4: "The Team recommends weighting (tuning) composition data using the Francis method or the harmonic mean of the effective sample size (McAllister & Ianelli approach)."

BPT5: "The Team believes that time-varying selectivity is important and recommends continued investigation of time-varying fishery selectivity for use in future models. In addition, the Team recommends investigating methods to determine the variance of the penalty function applied to the deviations (i.e., tuning the deviates)."

BPT6: "The Team recommends comparing the estimated recruitment variability (σ_R) to the root mean squared error (RMSE) of the estimated recruitment deviations over a period of years that is well informed (i.e., when the variance of the estimated recruitment deviation is small)."

Comments from the December 2016 SSC meeting
SSC7: "The SSC supports the author's observation that ageing bias needs to be further investigated for cod, with results potentially applicable to all three assessments." Summary: *Investigate ageing bias further*.

SSC8: "The SSC continues to support the spring Pacific cod workshop to review and plan for model development each year, and also supports all of the technical PT recommendations for future model development."

SSC9: "The SSC recommended discarding Model 11.5 for future analyses after one or more 16.x models incorporating time-varying selectivity in some reasonable manner (for the survey and/or fishery) are developed to take its place in this set of models. Depending on staff availability, this could be presented at the spring meeting; however, if that is not possible, it should be brought forward for the September 2017 PT meeting."

SSC10: "The SSC recommends that including existing fishery ages in the assessment and ageing additional fishery otoliths for this assessment should be priorities…."

SSC11: "The SSC recommends continued exploration of the treatment of weight-at-age using both internally and externally estimated values."

SSC12: "The SSC [recommended] further considering model averaging based on the outcome of the SSC workshop during the February 2017 meeting" (term in square brackets added).

Comments from the June 2017 Subcommittee meeting
The comments shown below pertain to this preliminary assessment. The minutes of the June 2017 Subcommittee meeting also reached some conclusions pertaining to this year's final assessment, which will be addressed when the final assessment is produced.

Sub4: "The Subcommittee recommends that the following models be included in this year's preliminary EBS Pacific cod assessment (note that model labels shown here are temporary placeholders; actual model labels for September will be established during the analysis, except for Model A, which corresponds to Model 16.6):

- Model A: Model 16.6 (last year's final model), after translating from SS V3.24u to V3.30.
- Model B: Same as Model A, but with the following features added:
    1. Adjust timing of the fishery and survey in SS.
    2. Do not use currently available fishery agecomp data, but do add new fishery agecomps.
    3. Switch to haul-based input sample size and catch-weighted sizecomp data.
    4. Develop a prior distribution for natural mortality based on previous estimates.
    5. Switch to age-based, flat-topped, double normal selectivity.
    6. Allow random time variability in selectivity, with σs fixed at the restricted MLEs.
- Model C: Same as Model B, but with the following features added:
    1. Use harmonic mean weighting of composition data.
    2. Allow time-varying selectivity for the fishery but not the survey.
- Model D: Same as Model B, but with the following features added:
    1. Use harmonic mean weighting of composition data.

    2. Estimate survey index standard error internally (‘extra SD’ option in SS).
- Model E: Same as Model B, but with the following feature added:
    1. Use Francis weighting.
- Model F: Same as Model B, but with the following feature added:
    1. Give less weight to fishery comps than survey comps, less to sizecomps than agecomps.”

Response: All six of the recommended models are included in this preliminary assessment. As noted above, Model A corresponds to Model 16.6, which was last year’s final model. Once the parameters of Models B-F had been estimated, these models were all found to exhibit an average difference in spawning biomass (relative to Model 16.6) in excess of 10%, meaning that they all constitute major changes from Model 16.6 under Option “A” of the convention form model numbering described in the SAFE chapter guidelines, and so are designated Models 17.1-17.5 respectively. In addition to the above six models, a seventh model is also included in this preliminary assessment. Like Models 17.1-17.5, the seventh model also constitutes a major change from Model 16.6, and so is designated Model 17.6. It is similar to Model 17.2 (formerly “C”), except that it includes annually time-varying length at age 1.5, trawl survey catchability, and survey selectivity.

Sub5: “The Subcommittee recommends that the following non-model analyses be conducted for the preliminary 2017 EBS assessment:

- Compare σ_R to the RMSE of estimated recruitment deviations.
- Report Francis weights from the terminal run if harmonic mean is used and vice-versa.”

Response: The above quantities are reported for all models.

Sub6: “With respect to implementation of the above recommendations, the Subcommittee reached the following conclusions:

- For feature GT5 (‘Switch to haul-based input sample size and catch-weighted sizecomp data’), the Subcommittee understands that the author will likely set initial input sample sizes equal to the number of hauls (or sets), rather than a more complicated haul-based approach such as that described by Stewart and Hamel (2014).
- For feature SSC6 (‘Develop a prior distribution for natural mortality based on previous estimates’), if faced with a choice between the lognormal and normal examples given in the background document..., the Subcommittee prefers the lognormal.
- For feature New4 (‘Give less weight to fishery comps than survey comps, less to sizecomps than agecomps’), which is used in Model F, if the Francis weightings obtained in Model E accomplish the same thing, then Model F does not need to be included. Also, the Subcommittee’s preferred method for implementing feature New4 is to begin with the weightings obtained in Model E and then adjust them as little as possible subject to the constraints described by this feature.
- For feature New6 (‘Report Francis weights from the terminal run if harmonic mean is used and vice-versa’), the confidence intervals surrounding the Francis weights should also be reported.”

Response: All of the above conclusions were implemented.

Sub7: “The Subcommittee concluded that the EBS Pacific cod assessment is not a good candidate for model averaging at this time.”

Response: Given the SSC’s repeated interest in seeing model averaging explored, this preliminary assessment offers an initial attempt at model averaging.

Data

For Model 16.6, the data file used in this preliminary assessment was identical to the one used in last year's assessment (Thompson 2016a). For Models 17.1-17.6, the following changes were made to the data file:

Size composition sample size measured as number of hauls

For the years 1991-2016, the numbers of hauls sampled for fishery lengths were taken from the domestic observer database. For years prior to 1990, the numbers of sampled hauls in the fishery sizecomp data were approximated by using the regression shown in Figure 2.1.13 of the 2015 EBS assessment to convert last year's Model 11.5 input fishery sample sizes into haul equivalents. Table 2.1.1 compares input sample sizes used in Model 16.6 with those used in Models 17.1-17.6.

The 1991-2016 fishery size composition data from each year/week/gear/area cell were weighted proportionally to the official estimate of catch taken in that cell.

Figure 2.1.1 compares the 1991-2016 fishery size composition data used in Model 16.6 with those used in Models 17.1-17.6. In general, there is little difference between the two sets of sizecomp data. The effective sample sizes (treating the catch-weighted data as "true") range from 1,732 to 37,958, with a mean of 12,357.

Inclusion of fishery age composition for 2015 and 2016

Selection of otoliths for the fishery age composition data proceeded as follows: Given a desired total annual sample size of 1000 otoliths, the objectives were, first, to distribute the sample so as to reflect the proportion of the total catch in each gear/area/week combination as closely as possible, and second, conditional on achieving the first objective, to maximize the number of hauls sampled.

Totals of 999 and 995 otoliths were aged from the 2015 and 2016 fisheries, respectively. These otoliths were chosen randomly and in proportion to the catch taken in each 3-digit area, in each week, by each gear type. The resulting age compositions were as follow (rows sum to unity; note that ages 0 and 1 were both unrepresented in the otolith collections for both years):

Year	2	3	4	5	6	7	8	9	10	11	12+
2015	0.0092	0.0764	0.3354	0.3349	0.1266	0.0838	0.0222	0.0081	0	0.0018	0.0016
2016	0.0037	0.1026	0.2147	0.3992	0.2034	0.0522	0.0237	0	0.0004	0	0

When expressing input sample sizes in terms of the number of sampled hauls, age composition data pose a question, because it is necessary to choose between the number of hauls sampled for age (to construct the age-length key) and the number of hauls sampled for length (by which the age-length key is pre-multiplied in order to obtain an estimate of the age composition). For this preliminary assessment, input sample sizes for age composition data were set equal to the number of hauls sampled for *length*, per comment SSC3.

Fishery age composition data for 2013 and 2014 are also scheduled to be available in time for use in this year's final assessment.

Model structures

Software

As with all assessments of the EBS Pacific cod stock since 1992, the Stock Synthesis (SS) software package (Methot and Wetzel 2013) was used to develop and run the models. Since 2005, new versions of SS have been programmed in ADMB (Fournier et al. 2012). SS V3.30.05.03 was used to run all of the models in this preliminary assessment. SS V3.30 is a major upgrade from V3.24, which had been used for the 2013-2016 assessments.

Base model

Model 16.6 was adopted by the SSC last year as the new base model. In contrast to the previous base model (Model 11.5, which had been in use since 2011), Model 16.6 is a very simple model. Its main structural features are as follow:

- One fishery, one gear type, one season per year.
- Logistic age-based selectivity for both the fishery and survey.
- External estimation of time-varying weight-at-length parameters and the standard deviations of ageing error at ages 1 and 20.
- All parameters constant over time except for recruitment and fishing mortality.
- Internal estimation of all natural mortality, fishing mortality, length-at-age (including ageing bias), recruitment (conditional on Beverton-Holt recruitment fixed at 1.0), catchability, and selectivity parameters.

Alternative models

The five alternative models suggested by the Subcommittee (Models 17.1-17.5) and one additional alternative model (17.6) are presented. These were described in the Introduction, under “Comments from the June 2017 Subcommittee meeting,” comment Sub4. Most of the features of the alternative models are fairly self-explanatory, but the following merit some further elaboration:

Prior distribution for natural mortality

Comment SSC6 requests that a prior distribution for the natural mortality rate (*M*) be developed on the basis of the previous studies referenced with respect to estimation of *M* in the Pacific cod assessments for the EBS, AI, and Gulf of Alaska (GOA); and comment Sub4 likewise requests that Models 17.1-17.5 include a prior distribution for *M*. The list of previous studies in the 2016 GOA assessment (https://www.afsc.noaa.gov/REFM/Docs/2016/GOApcod.pdf) is the longest of the three, providing 15 point estimates of *M* from the EBS, GOA, British Columbia, Korea, and Japan. The lists in the 2016 EBS and AI assessments are subsets of the list in the GOA assessment. If the estimates of *M* obtained in the 2016 EBS and GOA assessments (0.36 and 0.47) are added to the list in the GOA assessment, a total of 17 estimates are available. If a lognormal distribution is assumed (see comment Sub6), the log-scale sample mean and standard deviation are –0.811 and 0.410, respectively (coefficient of variation = 0.435, 95% confidence interval spans 0.199-0.993). Figure 2.1.2 shows the cumulative distribution function and probability density function for both the normal and lognormal cases, along with the point estimate from the 2016 EBS assessment, which comes very close to matching the mode of the distribution.

Selectivity

All of the alternative models feature “age-based, flat-topped, double normal selectivity.” There are multiple ways to configure double normal selectivity so as to achieve a flat-topped functional form. The one adopted here is the one presented for consideration at the June 2017 Subcommittee meeting. The parameter governing the point at which the flat-topped portion of the function begins and the “ascending width” parameter are the only two parameters estimated internally. The others are fixed as follows:

- The parameter defining the length of the flat-topped portion of the curve (as a logit transform between the beginning of the flat-topped portion and the maximum age) was fixed at a value of 10.0, thereby eliminating any descending limb.
- Given the above, the parameters defining the “descending width” and selectivity at the maximum age are rendered essentially superfluous, and were both fixed at a value of 10.0.

- The parameter defining the selectivity at age 0 was fixed at a value of -10.0, corresponding to a selectivity indistinguishable from 0.0.

All of the alternative models also feature random annual time variability in selectivity (fishery only in the case of Model 17.2; both fishery and survey in all of the other alternative models). In all cases, development of the model began with both parameters of the relevant selectivity curve(s) being allowed to vary over time. However, in the case of Model 17.4, the process of tuning the input standard deviations of the time-varying parameters (see subsection below) began converging on a configuration that did not result in a positive definite Hessian matrix. This configuration included extremely small estimated deviations for the "ascending width" survey selectivity parameter. However, when this parameter was forced to remain constant, the tuning process converged on a model with a positive definite Hessian. This was therefore accepted as the final version of Model 17.4 (two time-varying fishery selectivity parameters, but only one time-varying survey selectivity parameter). Because Model 17.5 was requested to be based on Model 17.4 (comment Sub6), Model 17.5 also features time-invariant "ascending width" for the survey selectivity. The configurations of the models with respect to time-varying selectivity is therefore as follows (an "x" indicates that the parameter is time-varying; note that no selectivity parameters are time-varying in Model 16.6):

Fleet	Parameter	M17.1	M17.2	M17.3	M17.4	M17.5	M17.6
Fishery	Beginning of flat top	x	x	x	x	x	x
Fishery	Ascending width	x	x	x	x	x	x
Survey	Beginning of flat top	x		x	x	x	x
Survey	Ascending width	x		x			x

The *dev*s pertaining to the parameter defining the beginning of the flat top were of the multiplicative type, because this parameter is logically constrained to be positive; while the *dev*s pertaining to the "ascending width" parameter were of the additive type, because this parameter is expressed on a log scale and so can take either positive or negative values.

The ranges of years for which selectivity *dev*s were estimated were 1977-2016 for the fishery and 1982-2016 for the survey, corresponding to the full ranges of years spanned by the fishery data and survey data used in the model, respectively. However, it should be noted that including survey selectivity *dev*s for 2015 or 2016 may result in confounding with the recruitment *dev* for 2015.

Tuning the input standard deviations of annually time-varying parameters

Deriving statistically valid estimates of the standard deviations that are used to constrain annually time-varying parameters ("*dev*" vectors) is a perennial problem in stock assessments that use a penalized likelihood approach. SS V3.30 includes, as a new feature, the ability treat these standard deviations as additional parameters to be estimated internally. Unfortunately, the maximum likelihood estimates based on the penalized likelihood tend to be biased (Thompson 2016b). An alternative procedure was introduced in the 2015 assessment (Thompson 2015), which constituted a multivariate generalization of one of the methods mentioned by Methot and Taylor (2011), viz., the third method listed on p. 1749), and proceeded as follows:

1. Set initial guesses for the *σdev*s.
2. Run SS.
3. Compute the covariance matrix (**V1**) of the set of *dev* vectors (e.g., element {*i*,*j*} is equal to the covariance between the subsets of the *i*th *dev* vector and the *j*th *dev* vector consisting of years that those two vectors have in common).
4. Compute the covariance matrix of the parameters (the negative inverse of the Hessian matrix).

5. Extract the part of the covariance matrix of the parameters corresponding to the *dev* vectors, using only those years common to all *dev* vectors.
6. Average the values in the matrix obtained in step 5 across years to obtain an "average" covariance matrix (**V2**).
7. Compute the vector of σdevs corresponding to **V1**+**V2**.
8. Return to step 2 and repeat until the σdevs converge.

However, this method will not work in SS V3.30, because the functional form of the penalty term has been changed. In previous versions of SS, the penalty term was

$$-n\cdot\ln(\sigma dev)-\left(\frac{1}{2}\right)\cdot\sum_{i=1}^{n}\left(\frac{dev_i}{\sigma dev}\right)^2,$$

and the *dev*-adjusted parameter for year *i* (for the case of additive devs) took the form $parameter_i = base\_value + dev_i$.

In SS V3.30, on the other hand, σdev is removed from the denominator in the summation, so the penalty term is now

$$-n\cdot\ln(\sigma dev)-\left(\frac{1}{2}\right)\cdot\sum_{i=1}^{n}\left(dev_i\right)^2,$$

and the *dev*-adjusted parameter for year *i* takes the form $parameter_i = base\_value + \sigma dev\cdot dev_i$.

Note that, once the appropriate constant was added, the old form of the penalty term took the form of a sum of logged $N(0,\sigma dev)$ probability density functions. However, the new form of the penalty term takes the form of a sum of logged $N(0,1)$ probability density functions *minus* the quantity $n\cdot\ln(\sigma dev)$, meaning that the exponentiated penalty term no longer integrates to unity.

Further complicating matters is the fact that the new form of the penalty term in V3.30 does not apply to recruitment *dev*s, which still use the old form of the penalty term.

However, the most significant problem posed by the new form of the penalty term with respect to the above algorithm for estimating the σdevs is that, with the exception of σ_R, none of the σdevs appears in either **V1** or **V2**. To remedy this situation, the following changes were made to the algorithm (note that these changes assume implicitly that the *dev* vectors are all independent, which is not the case in the original algorithm):

- To obtain a covariance matrix analogous to the one in step #3 above:
  - Form a diagonal matrix consisting of the variances of the *dev* vectors.
- To obtain a covariance matrix analogous to the one in step #4 above:
  - Let *ndev* represent the number of non-recruitment *dev* vectors in the model, indexed k=1,...,*ndev*.
  - Read the Hessian matrix **H** returned by ADMB.
  - For each row *i* in **H**, set $dvec_i=k$ if the parameter represented by row *i* is an element of the *k*th *dev* vector; otherwise, set $dvec_i=0$.
  - For each row *i* and column *j* in **H**, if $dvec_i>0$, then multiply $\mathbf{H}_{i,j}$ by $dvec_i$, and if $dvec_j>0$, then multiply $\mathbf{H}_{i,j}$ by $dvec_j$.
  - Invert **H**.

- Because (given the above changes) it is now assumed implicitly that the *dev* vectors are all independent, it is no longer necessary to use only those years common to all *dev* vectors.

The above changes to the algorithm for estimating the *σdev*s should be considered experimental at this point.

Another new feature of randomly time-varying parameters in SS V3.30 is the requirement either to specify or to estimate the degree of autocorrelation among the *dev*s in the log likelihood. Except as specified otherwise in the next subsection, all autocorrelation terms in all models were fixed at zero. Initial explorations allowing the recruitment autocorrelation term to be estimated internally resulted in values close to zero.

Data weighting in Model 17.5

Model 17.5 is supposed to "give less weight to fishery comps than survey comps, less to sizecomps than agecomps" (comment Sub4). This begs two questions:

1. How should "weight" be measured? Lacking explicit guidance from the Subcommittee, the weight assigned to a component or data type is defined here as the sum (across years) of the nominal sample sizes specified in the data file and the multiplier ("Francis weight") derived during the process of tuning Model 17.4.
2. How much less is "less?" Lacking explicit guidance from the Subcommittee, Model 17.5 was developed so as to give half as much weight to fishery comps as to survey comps and half as much weight to sizecomps as to agecomps.

Comment Sub6 requests that the Subcommittee's preferred method for implementing Model 17.5 is to begin with the weightings obtained in Model 17.4 and then "adjust them as little as possible subject to the constraints described by this feature." It turns out that there is a closed-form solution for the multipliers needed in order to achieve the criteria listed above, conditional on the sum of the multipliers in the two models being equal:

- For composition type *i* (letting size=1 and age=2) and fleet *j* (letting fishery=1 and survey=2), let $A_{i,j}$ represent the sum (across years) of the nominal sample sizes specified in the data, let $B_{i,j}$ represent the multiplier ("Francis weight") derived during the process of tuning Model 17.4, and let $C_{i,j}$ represent the multiplier needed for Model 17.5.
- Let Δ represent a single proportion by which both:
  - the weight given to fishery comps is less than the weight given to survey comps and
  - the weight given to sizecomps is less than the weight the weight given to agecomps.
- Let:
  - $\Sigma mult = B_{1,1} + B_{1,2} + B_{2,1} + B_{2,2}$.
  - $$\begin{aligned} denom = {} & B_{2,2} \cdot A_{1,1} \cdot A_{1,2} \cdot A_{2,1} + (1-\Delta) \cdot \left(B_{1,2} \cdot A_{2,1} + B_{2,1} \cdot A_{1,2}\right) \cdot A_{1,1} \cdot A_{2,2} + \\ & (1-\Delta)^2 \cdot B_{2,2} \cdot A_{1,1} \cdot A_{1,2} \cdot A_{2,1} \end{aligned} .$$
- Then:

$$\begin{bmatrix} C_{1,1} & C_{1,2} \\ C_{2,1} & C_{2,2} \end{bmatrix} = \left(\frac{\Sigma mult}{denom}\right) \cdot \begin{bmatrix} (1-\Delta)^2 \cdot B_{1,1} \cdot A_{1,2} \cdot A_{2,1} \cdot A_{2,2} & (1-\Delta) \cdot B_{1,2} \cdot A_{1,1} \cdot A_{2,1} \cdot A_{2,2} \\ (1-\Delta) \cdot B_{2,1} \cdot A_{1,1} \cdot A_{1,2} \cdot A_{2,2} & B_{2,2} \cdot A_{1,1} \cdot A_{1,2} \cdot A_{2,1} \end{bmatrix}.$$

Additional time variability in Model 17.6

In addition to random annual variability in recruitment and the fishery and survey selectivity parameters, Model 17.6 includes also includes random annual variability in two other parameters: the mean length at age 1.5 (i.e., age 1 measured at mid-year, to coincide with the timing of the EBS shelf bottom trawl survey) and the catchability coefficient (*Q*) for the EBS shelf bottom trawl survey.

For the mean length at age 1.5, multiplicative *dev*s were estimated for the years 1981-2015. Care needs to be taken when interpreting the years for which these *dev*s were estimated. Each *dev* becomes "active" in the year for which it is estimated, meaning that it governs the parameters of the mean-length-at-age relationship for fish recruiting at age 0 in that year. However, its impact on the mean length of age 1.5 fish does not occur until the *following* year. Thus, the impacts of the *dev*s estimated for the years 1981-2015 are manifested at age 1.5 in the years 1982-2016, which are the years spanned by the survey data.

Catchability is expressed on a log scale in SS, so additive *dev*s were estimated for this parameter. Devs were estimated for the years 1982-2016.

Tuning of the σdev parameter for the *Q dev*s followed a different procedure than the one described in the previous subsection. The procedure for tuning the σdev parameter for the *Q dev*s was analogous to a procedure that was often used historically (in assessment models for other stocks developed under certain older versions of SS) to estimate the amount of survey index measurement error, which was to inflate the standard errors specified in the data file by adding a constant chosen so as to equate the root-mean-squared-error (model estimates versus data) with the mean (across years) standard error specified in the data file. Here, however, the equivalence was achieved by tuning σdev rather than the standard errors. The reasons for using this procedure rather than the one described in the previous section were twofold: 1) it maintains consistency with historical precedents for dealing with survey index data; and 2) *Q* has a direct (proportional) relationship to the survey index data, for which estimates of the amount of observation error are available due to the statistical design of the survey.

Unlike the other parameters for which random annual variability was allowed, the autocorrelation coefficient for *Q* was allowed to be estimated freely rather than fixed at zero, because early explorations indicated that the amount of autocorrelation was likely to be substantial and because internal estimation of the autocorrelation coefficient would not complicate the estimation of σdev.

Results

Note: In all tables with color scales, red and green correspond to the minimum and maximum values across models, respectively.

Overview

Some highlights from the set of models are shown below (*FSB*(2017) represents female spawning biomass in 2017 (in units of t), and *Bratio*(2017) represents the ratio of *FSB*(2017) to $B_{100\%}$,:

Model:	16.6	17.1	17.2	17.3	17.4	17.5	17.6
FSB (2017):	359,766	187,677	298,746	161,672	430,949	131,546	174,282
Bratio (2017):	0.546	0.279	0.465	0.267	0.510	0.187	0.268
M :	0.363	0.333	0.369	0.372	0.320	0.313	0.345
Q :	0.876	1.113	0.948	0.982	1.153	1.106	1.012

The results for *FSB*(2017) and *Bratio*(2017) span fairly wide ranges, with the ratio of the maximum to minimum value for these two quantities equaling 3.28 and 2.92, respectively. The ranges spanned by the estimates of M and Q are not so broad, with maximum/minimum ratios of 1.19 and 1.32, respectively.

Note that Model 17.5 suggests that *Bratio*(2017) is less than 0.2, which is the cutoff for allowing a directed fishery.

Goodness of fit

Table 2.1.2 shows objective function values and numbers of nominal parameters for all models. The upper part of the table shows objective function values by component and overall. The middle part of the table breaks down the size composition and age composition values by fleet. Blank cells under Model 16.6 in the first two parts of the table indicate that certain components are not included in that model. The bottom part of the table shows the numbers of nominal parameters for all models, with the numbers of *dev*s and scalar parameters indicated separately. Note that the numbers of effective parameters are smaller than the totals shown, because the *dev*s are constrained and thus do not represent completely free parameters. In general, it is difficult to compare objective function values across models, because either the data sets, σdev values, multipliers, or number of parameters differ.

Table 2.1.3 shows effective sample sizes and input and output weights.

- Cells shaded gray represent data (Note that the data file used for Models 17.1-17.6 differs from Model 16.6's data file). The quantities in this category consist of:
    - The number of years represented in the particular data type ("Yrs").
    - The average sample size for the particular data type as specified in the data file ("N"), which, in the case of survey index data, consists of the average number of stations (hauls) sampled over the time series.
    - The average standard error of the survey abundance index ("SEave").
- Cells shaded tan represent values that are specified by the modeler, or that show results computed by SS. The quantities in this category consist of:
    - The multiplier ("Mult") that is used to modify sample sizes for the particular data type that are specified in the data file.
    - The product of the multiplier and the average specified sample size ("N×Mult").
    - The harmonic mean of the effective sample size ("Har").
    - The "extra" standard error (if any) estimated by SS for the survey index data ("SEextra").
    - The root-mean-squared-error of the model's survey index estimates ("RMSE").
- Cells shaded green represent a pair of aggregate sample sizes computed outside of SS.
    - For composition data, the quantities in this category consist of:
        - The aggregate effective sample size *assigned* to the particular data type ("ΣNeff1"), computed as Yrs×N×Mult.
        - The aggregate effective sample size *achieved* for the particular data type ("ΣNeff2"), computed as Yrs×Har.
    - For survey index data, this category consists of the same two quantities (ΣNeff1 and ΣNeff2), and ΣNeff1 is computed just as in the case of composition data, but ΣNeff2 is computed as:
        - $\text{Yrs}\times\text{N}\times((\text{SEave}+\text{SEextra})/\text{RMSE})^2$.

By expressing ΣNeff1 and ΣNeff2 in units of hauls for both composition data and index data, the values for the two data types are comparable, and the average across data types is a meaningful statistic (see last row under each model).

The ratio ΣNeff2/ΣNeff1 for a given data component provides a measure of how well the model is tuned with respect to that component (specifically, the ratio should equal unity), except in the cases of Model 17.4, where the Francis approach rather than the harmonic mean approach is used to tune the input sample sizes for composition data, and Model 17.5, where an *ad hoc* modification of the Francis approach is used. Of the remaining models, only Models 17.3 and 17.6 achieve ratios equal (approximately) to unity for all components. Note that these two models achieve a ratio of unity for the survey index by two different methods: Model 17.3 achieves this result by inflating the standard error of the observations, while Model 17.6 achieves the same result by allowing time variability in survey catchability. However, in the process of setting all of the component-specific ratios equal to unity, Model 17.6 also achieves a higher average (across components) aggregate effective sample size than Model 17.3 (ΣNeff2=16,265 versus ΣNeff2=14,465).

Figure 2.1.3 shows the fit of each model to the survey abundance data. Most of the models show qualitatively similar trends, except that Model 17.4 shows an immense spike in 2012-2014 that is not reflected in either the data or by any of the other models. This is likely due to the extremely low weight that Model 17.4 places on the survey sizecomp and agecomp data (multipliers of 0.0448 and 0.0406, respectively).

Figure 2.1.4 shows the fit of Model 17.6 to the length at age 1.5 time series (none of the other models allows time variability in this parameter). The correlation between the data and the model estimates is 0.809. In the past, it has been suggested that variability in survey start date might account for most of the observed variability in length at age 1.5. However, this does not appear to be the case, as the correlation between the length at age data and survey start date (1994-2015) is only –0.008, and the correlation between the SS estimates (lagged appropriately) and survey start date (1982-2016) is only –0.021.

Parameter estimates, derived time series, and retrospective analysis

The *σdev* values for all *dev* vectors in all models are shown below (all of which were estimated iteratively by the procedures described previously, except that σ_R in Model 16.6 was estimated internally):

Dev vector	M16.6	M17.1	M17.2	M17.3	M17.4	M17.5	M17.6
Recruitment	0.6377	0.4693	0.5602	0.4958	0.9708	0.6551	0.5730
Selectivity begin peak (fishery)		0.1222	0.1078	0.0993	0.2595	0.1261	0.1037
Selectivity ascend width (fishery)		0.3619	0.2564	0.2287	0.9773	0.4366	0.2573
Selectivity begin peak (survey)		0.0524		0.0545	0.1703	0.0554	0.0535
Selectivity ascend width (survey)		0.1597		0.1593			0.1595
Length at age 1.5							0.0936
ln(Catchability)							0.0898

Note that Model 17.4 has the highest *σdev* value of any model for every *dev* vector that it includes.

As requested by the Subcommittee (see comment Sub5), *σdev* for recruitment is compared with the standard deviation of the estimated recruitment *dev*s for each model below:

Model:	16.6	17.1	17.2	17.3	17.4	17.5	17.6
σ_R:	0.6377	0.4693	0.5602	0.4958	0.9708	0.6551	0.5730
SD(Rdevs):	0.6631	0.4758	0.5672	0.5036	0.9836	0.6670	0.5807

Also as requested by the Subcommittee (see comment Sub5), Table 2.1.4 shows various multipliers and related quantities for each model (column 1), composition data type (column 2) and fleet (column 3):

- Column 4, labeled “Model Multiplier,” shows the multiplier that is actually used in the final version of the respective model.
- Columns 5 and 6, labeled “Multiplier” and “Adjust” under the heading “Harmonic mean,” show:

    - The multiplier that would be suggested by the harmonic mean approach (column 5).
    - The amount by which the amount in column 4 would need to be adjusted (multiplicatively) in order to match the suggested value in column 5 (column 6). Note that the adjustments for Models 17.2, 17.3, and 17.6 (cells shaded gray in column 6) are all close to unity, because those models were tuned by the harmonic mean approach.
- Columns 7-10, labeled "Multiplier, "Adjust," "Adj.(L95%)," and "Adj.(U95%)" under the heading "Francis (2011, Equation TA1.8)" show:
    - The multiplier that would be suggested by the Francis approach (column 7).
    - The amount by which the amount in column 4 would need to be adjusted (multiplicatively) in order to match the suggested value in column 7 (column 8). Note that the adjustments for Model 17.4 (cells shaded gray in column 8) are all close to unity, because that model was tuned by the Francis approach.
    - The lower limit of the 95% confidence interval for the quantity shown in column 8 (column 9).
    - The upper limit of the 95% confidence interval for the quantity shown in column 8 (column 10).

Table 2.1.5 shows the values of some selected constants as well as all estimated parameters (with standard deviations) for all models (note that fishing mortality is a derived quantity in SS rather than a parameter):

- Table 2.1.5a shows selected constants and all scalar parameters except for base values of selectivity parameters.
- Table 2.1.5b shows base values of selectivity parameters.
- Table 2.1.5c shows "early" recruitment *dev*s, which determine the numbers at age in the initial year of the model.
- Table 2.1.5d shows recruitment *dev*s.
- Table 2.1.5e shows selectivity *dev*s.
- Table 2.1.5f shows *dev*s for mean length at age 1.5 and log catchability (Model 17.6 only).

Table 2.1.6 shows the time series of instantaneous fishing mortality rates, with standard deviations, for all models.

Figure 2.1.5 shows selectivity for all models. Fisher selectivity is shown in Figure 2.1.5a and survey selectivity is shown in Figure 2.1.5b. Solid blue lines indicate median values, dashed green lines show the 80% concentration (determined empirically by sorting the time series at each age), and dotted red lines show the full range of estimated values. The age range is truncated at age 9 because all curves in all models for both the fishery and survey reached a value of 0.95 by that age.

Figure 2.1.6 shows the time series of EBS bottom trawl survey catchability as estimated by Model 17.6.

Figure 2.1.7 shows the time series of estimated recruitment deviations for all models. The time series estimated by the various models are all highly correlated with each other, with the exception of the time series estimated by Model 17.4. Correlations between the time series estimated by Model 17.4 and those estimated by the other models range from 0.24 to 0.39, whereas all other between-model correlations range from 0.86 to 0.98.

Figure 2.1.8 shows the time series of estimated total (age 0+) biomass for all models, along with the survey biomass time series for comparison (note that the models attempt to fit survey abundance rather than survey biomass). The estimates from Model 17.4 are higher than those from the other models for the last four years, while the estimates from Model 17.5 are lower than those from the other models for the last four years. The estimates from Models 17.1, 17.3, and 17.6 tend to be very similar from about 1990 onward.

Figure 2.1.9 shows the time series of estimated relative spawning biomass (female spawning boimass divided by $B_{100\%}$) for all models. The estimates from Model 16.6 are higher than those from the other models from 2007 onward. The estimates from Model 17.4 are lower than those from the other models prior to 2015, but increased sharply in recent years, such that the 2016 estimate is higher than the estimates from all other models except Model 16.6 and 17.2.

Mohn's rho, along with boundaries on acceptable values thereof as suggested by regressions against M based on the results of Hurtado-Ferro et al. (2015), are shown below:

Model:	16.6	17.1	17.2	17.3	17.4	17.5	17.6
Rho:	0.148	0.101	0.287	0.094	0.122	0.313	0.074
M:	0.363	0.333	0.369	0.372	0.320	0.313	0.345
Min:	-0.207	-0.197	-0.209	-0.210	-0.192	-0.190	-0.201
Max:	0.281	0.267	0.284	0.286	0.260	0.256	0.272

Note that only Model 17.2 and Model 17.5 have rho values that fall outside the acceptable range, with Model 17.2's value being with 0.003 of the acceptable range.

Model averaging

As noted in the Introduction, the SSC has expressed repeated interest in use of a model averaging approach. Stewart and Martell (2015) discuss various issues related to model averaging in the context of stock assessment. Two problems to be addressed when moving toward a model averaging approach are deciding: 1) which models to average, and 2) how to weight the models. These problems are related, because once the set of models is determined, this decision automatically assigns as weight of zero to all models not included in the set. For the purposes of this preliminary assessment, Models 16.6 and 17.1-17.6 will be considered to constitute the set of models needing to be averaged.

The simplest weighting system is to weight all models equally. An alternative is to weight better-performing models more heavily than poorer-performing models, but this obviously begs the question of how to measure performance. As an initial step toward a model averaging approach, the measure that will be adopted here begins with the average (across components) of the aggregate effective sample sizes represented by ΣNeff2 in Table 2.1.3. For convenience, these are summarized below:

Type	Fleet	M16.6	M17.1	M17.2	M17.3	M17.4	M17.5	M17.6
Sizecomp	Fishery	22,747	67,315	42,558	42,295	85,151	29,746	41,911
Sizecomp	Survey	10,587	10,014	10,033	11,737	3,646	12,377	18,213
Agecomp	Fishery		3,459	7,752	3,472	13,552	4,775	7,136
Agecomp	Survey	1,298	1,654	893	1,955	141	3,617	1,753
Index	Survey	4,137	3,870	3,549	12,868	2,248	3,057	12,312
	Average:	9,692	17,263	12,957	14,465	20,948	10,715	16,265

Model 17.4 gives the highest average value in the above table. However, this is due almost entirely to the value for the fishery sizecomp component. It may be advisable to consider alternatives to the arithmetic mean, for example the geometric and harmonic means, so as to penalize models that achieve nearly all their success by focusing on a single component while essentially ignoring the others. The table below

shows the arithmetic, geometric, and harmonic means of the ΣNeff2 values, both in raw form (“Mean”) and normalized so as to sum to unity (“Weight”).

	Arithmetic		Geometric		Harmonic	
Model	Mean	Weight	Mean	Weight	Mean	Weight
16.6	9692	0.0947	5997	0.1213	3477	0.1274
17.1	17262	0.1687	6836	0.1383	3947	0.1447
17.2	12957	0.1267	6370	0.1289	3023	0.1108
17.3	14465	0.1414	8461	0.1712	5071	0.1858
17.4	20948	0.2048	4217	0.0853	633	0.0232
17.5	10715	0.1047	7208	0.1459	5392	0.1976
17.6	16265	0.1590	10329	0.2090	5743	0.2105
Sum:	102304	1	49417	1	27286	1

Note that when either the geometric or harmonic mean is used, Model 17.6 is given the highest weight and Model 17.4 is given the lowest.

By themselves, however, the averages in the final row of the above table are insufficient as measures of model performance, because they ignore the fact that the models tend to have different numbers of parameters. Unfortunately, determining the effective number of parameters in a model with constrained *dev*s is not entirely straightforward. The method adopted here, for each *dev* vector, was to estimate the effective number of parameters as the minimum number of truly free parameters that would give the same fit to the data as that given by the *dev* vector. A linear-normal approximation was involved, similar in some ways to what was done in order to develop the algorithm for tuning the *σdev* parameters described above in the “Model structures” section. Table 2.1.7 shows the effective number of parameters for all models. The cells shaded gray indicate the two cases where the algorithm failed to result in a positive value for the observation error variance. In these two cases, the effective number of parameters was simply set to the nominal number of parameters (i.e., the length of the *dev* vector). The method should be considered experimental at this point.

Given the average aggregate effective sample size and the effective number of parameters for each model, model performance was defined as the ratio of the two (effective sample size divided by effective number of parameters). The table below shows the arithmetic, geometric, and harmonic means of the performance measures, both in raw form (“Mean”) and normalized so as to sum to unity (“Weight”).

	Arithmetic		Geometric		Harmonic	
Model	Mean	Weight	Mean	Weight	Mean	Weight
16.6	162	0.0920	100	0.1278	58	0.1405
17.1	308	0.1756	122	0.1560	70	0.1709
17.2	216	0.1230	106	0.1357	50	0.1222
17.3	268	0.1526	157	0.2003	94	0.2277
17.4	499	0.2841	100	0.1283	15	0.0366
17.5	116	0.0663	78	0.1001	59	0.1421
17.6	187	0.1065	119	0.1518	66	0.1601
Sum:	1756	1	782	1	412	1

The projected 2018 ABC was chosen as an example of a quantity to be averaged across models. The means and standard deviations of this quantity (using the normal approximation obtained by inverting the

Hessian matrix) were as follow (values are in units of t; note that this is the 2018 ABC as computed by SS, not the standard projection model):

	2018 ABC	
Model	Mean	SD
16.6	258031	23900
17.1	150324	18403
17.2	236527	23211
17.3	121543	28344
17.4	236901	26178
17.5	73343	5545
17.6	130064	22732

The four weighting systems were indexed as follows:

1. Arithmetic
2. Geometric
3. Harmonic
4. Equal

The model-averaged mean for a given weighting system is given by

$$m_j = \sum_{i=1}^{nmod} \left(W_{i,j} \cdot \mu_i \right) \quad ,$$

where *nmod* represents the number of models (in this case, seven), *i* indexes model, *j* indexes weighting system, *W* represents the matrix of weights, and μ represents the vector of 2018 ABC means.

The model-averaged standard deviation for a given weighting system is given by

$$s_j = \sqrt{\sum_{i=1}^{nmod} \left(W_{i,j} \cdot \left(\left(\mu_i - m_j \right)^2 + \sigma_i{}^2 \right) \right)} \quad ,$$

where σ represents the vector of 2018 ABC standard deviations.

Some statistics relating to the distribution of the 2018 ABC, depending on which weighting scheme is used, are shown below:

Weight	Mean	Sdev	L90%	U90%	L95%	U95%	L99%	U99%
Arithmetic	183,794	64,088	78,378	289,210	58,183	309,405	18,714	348,875
Geometric	170,348	66,351	61,212	279,485	40,304	300,393	-559	341,256
Harmonic	158,439	65,896	50,050	266,827	29,286	287,591	-11,297	328,174
Equal	172,390	69,456	58,146	286,635	36,260	308,521	-6,515	351,296

Figure 2.1.10 shows a pair of probability density functions (PDFs) and cumulative distribution functions (CDFs) for each weighting scheme. The blue curves represent the weighted averages of the model-

specific functions, and the tan curves represent normal distributions with the same means and standard deviations as the blue curves.

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Tables

Table 2.1.1—Comparison of input sample sizes in Model 16.6 (“old”) and Models 17.1-17.6 (“new”).

	Fishery sizecomp		Survey sizecomp		Survey agecomp	
Year	N(old)	N(new)	N(old)	N(new)	N(old)	N(new)
1977	2	30	n/a	n/a	n/a	n/a
1978	12	160	n/a	n/a	n/a	n/a
1979	17	235	n/a	n/a	n/a	n/a
1980	15	208	n/a	n/a	n/a	n/a
1981	11	148	n/a	n/a	n/a	n/a
1982	13	187	250	313	n/a	n/a
1983	56	782	312	255	n/a	n/a
1984	138	1913	288	264	n/a	n/a
1985	204	2825	400	345	n/a	n/a
1986	178	2496	365	349	n/a	n/a
1987	339	4726	251	339	n/a	n/a
1988	105	1458	237	339	n/a	n/a
1989	70	966	237	293	n/a	n/a
1990	260	3601	134	329	n/a	n/a
1991	357	5188	171	313	n/a	n/a
1992	369	5322	228	332	n/a	n/a
1993	232	2993	247	363	n/a	n/a
1994	372	4687	330	364	204	364
1995	368	5215	218	347	163	347
1996	463	6618	222	359	203	359
1997	502	7278	218	369	205	369
1998	446	6838	227	362	181	362
1999	404	9231	277	336	246	336
2000	425	9731	298	355	246	355
2001	448	10364	469	366	263	366
2002	491	11472	290	364	248	364
2003	612	14341	293	363	361	363
2004	497	12242	257	361	284	361
2005	487	11568	268	360	365	360
2006	384	8849	288	354	371	354
2007	299	6901	304	368	412	368
2008	355	8320	308	338	346	338
2009	315	7482	396	360	403	360
2010	277	6514	179	342	369	342
2011	363	8804	492	368	358	368
2012	400	9287	310	356	372	356
2013	503	11126	443	354	405	354
2014	497	12165	426	373	349	373
2015	456	11309	458	354	244	354
2016	257	9553	407	376	n/a	n/a

Table 2.1.2—Objective function values and counts of nominal parameters.

Component	M16.6	M17.1	M17.2	M17.3	M17.4	M17.5	M17.6
Equilibrium catch	0.00	0.14	0.01	0.01	0.01	0.05	0.02
Survey index	-25.21	-14.65	-15.76	-36.31	6.20	-1.69	-62.35
Size composition	1372.94	2947.78	1454.99	1393.99	3729.21	7437.48	1453.89
Age composition	241.40	456.28	120.43	94.29	3434.03	3505.39	125.06
Recruitment	4.25	14.29	1.13	-5.09	32.25	12.76	5.07
Priors		0.25	0.11	0.09	0.33	0.37	0.19
"Softbounds"	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Non-recruit devs		-245.56	-115.84	-286.45	-72.94	-178.40	-417.90
Total	1593.39	3158.53	1445.07	1160.54	7129.10	10776.00	1103.97

Sub-component	M16.6	M17.1	M17.2	M17.3	M17.4	M17.5	M17.6
Sizecomp (fishery)	364.60	1819.35	470.08	437.71	3531.12	767.73	469.32
Sizecomp (survey)	1008.34	1128.43	984.91	956.28	198.10	6669.75	984.57
Sizecomp (total)	1372.94	2947.78	1454.99	1393.99	3729.21	7437.48	1453.89
Agecomp (fishery)		205.72	68.86	38.75	2923.14	855.24	69.67
Agecomp (survey)	241.40	250.57	51.57	55.54	510.89	2650.15	55.38
Agecomp (total)	241.40	456.28	120.43	94.29	3434.03	3505.39	125.06

Parameter type	M16.6	M17.1	M17.2	M17.3	M17.4	M17.5	M17.6
Devs	39	189	119	189	154	154	259
Scalars	38	37	37	38	36	36	38
Total	77	226	156	227	190	190	297

Table 2.1.3—Input and output sample sizes. See text for details.

				Model 16.6				
Type	Fleet	Yrs	N	Mult	N×Mult	Har	ΣNeff1	ΣNeff2
Size	Fish.	40	300	1.0000	300	569	11999	22747
Size	Surv.	35	300	1.0000	300	302	10498	10587
Age	Fish.	–	–	–	–	–	–	–
Age	Surv.	22	300	1.0000	300	59	6598	1298
				SEave	SEextra	RMSE		
Index	Surv.	35	353	0.1079	0	0.1865	12355	4137
						Ave:	10363	9692
								0.94

				Model 17.1					Model 17.2				
Type	Fleet	Yrs	N	Mult	N×Mult	Har	ΣNeff1	ΣNeff2	Mult	N×Mult	Har	ΣNeff1	ΣNeff2
Size	Fish.	38	5849	1.0000	5849	1771	222271	67315	0.1910	1117	1120	42454	42558
Size	Surv.	35	345	1.0000	345	286	12083	10014	0.8303	287	287	10033	10033
Age	Fish.	2	10410	1.0000	10410	1730	20820	3459	0.3718	3870	3876	7741	7752
Age	Surv.	22	358	1.0000	358	75	7873	1654	0.1135	41	41	894	893
				SEave	SEextra	RMSE			SEave	SEextra	RMSE		
Index	Surv.	35	353	0.1079	0	0.1928	12355	3870	0.1079	0	0.2013	12355	3549
						Ave:	55080	17263			Ave:	14695	12957

				Model 17.3					Model 17.4				
Type	Fleet	Yrs	N	Mult	N×Mult	Har	ΣNeff1	ΣNeff2	Mult	N×Mult	Har	ΣNeff1	ΣNeff2
Size	Fish.	38	5849	0.1910	1117	1113	42454	42295	2.3684	13853	2241	526425	85151
Size	Surv.	35	345	0.9716	335	335	11740	11737	0.0448	15	104	541	3646
Age	Fish.	2	10410	0.1660	1728	1736	3456	3472	30.5489	318014	6776	636027	13552
Age	Surv.	22	358	0.2474	89	89	1948	1955	0.0406	15	6	320	141
				SEave	SEextra	RMSE			SEave	SEextra	RMSE		
Index	Surv.	35	353	0.1079	0.1105	0.2140	12355	12868	0.1079	0	0.2530	12355	2248
						Ave:	14390	14465			Ave:	235134	20948

				Model 17.5					Model 17.6				
Type	Fleet	Yrs	N	Mult	N×Mult	Har	ΣNeff1	ΣNeff2	Mult	N×Mult	Har	ΣNeff1	ΣNeff2
Size	Fish.	38	5849	0.1919	1122	783	42654	29746	0.1881	1100	1103	41809	41911
Size	Surv.	35	345	7.0648	2439	354	85364	12377	1.5068	520	520	18207	18213
Age	Fish.	2	10410	4.0977	42657	2388	85314	4775	0.3425	3565	3568	7131	7136
Age	Surv.	22	358	21.6483	7747	164	170437	3617	0.2225	80	80	1752	1753
				SEave	SEextra	RMSE			SEave	SEextra	RMSE		
Index	Surv.	35	353	0.1079	0	0.2169	12355	3057	0.1079	0	0.1081	12355	12312
						Ave:	79225	10715			Ave:	16251	16265

Table 2.1.4—Multipliers for sizecomp and agecomp data. See text for details.

			Model	Harmonic mean		Francis (2011, Equation TA1.8)			
Model	Type	Fleet	Multiplier	Multiplier	Adjust	Multiplier	Adjust	Adj.(L95%)	Adj.(U95%)
M16.6	Length	Fishery	1.0000	1.8958	1.8958	0.2105	0.2105	0.1429	0.3615
M16.6	Length	Survey	1.0000	1.0084	1.0084	0.2217	0.2217	0.1412	0.4569
M16.6	Age	Survey	1.0000	0.1967	0.1967	0.2040	0.2040	0.1198	0.4664
M17.1	Length	Fishery	1.0000	0.3029	0.3029	1.5692	1.5692	1.0823	2.7426
M17.1	Length	Survey	1.0000	0.8288	0.8288	0.2311	0.2311	0.1560	0.4466
M17.1	Age	Fishery	1.0000	0.1661	0.1661	0.8157	0.8157	0.8157	infinity
M17.1	Age	Survey	1.0000	0.2101	0.2101	0.2522	0.2522	0.1470	0.6707
M17.2	Length	Fishery	0.1910	0.1915	1.0025	0.2639	1.3815	1.0132	2.0883
M17.2	Length	Survey	0.8303	0.8303	1.0001	0.1190	0.1434	0.0859	0.2897
M17.2	Age	Fishery	0.3718	0.3724	1.0015	0.5203	1.3994	1.3994	infinity
M17.2	Age	Survey	0.1135	0.1135	0.9997	0.1079	0.9509	0.5252	2.4545
M17.3	Length	Fishery	0.1910	0.1903	0.9963	0.3823	2.0017	1.5552	2.9672
M17.3	Length	Survey	0.9716	0.9714	0.9997	0.3761	0.3871	0.2533	0.7052
M17.3	Age	Fishery	0.1660	0.1667	1.0045	0.7397	4.4560	4.4560	infinity
M17.3	Age	Survey	0.2474	0.2483	1.0036	0.2992	1.2095	0.7393	2.9756
M17.4	Length	Fishery	2.3684	0.3831	0.1618	2.3701	1.0007	0.6725	1.9112
M17.4	Length	Survey	0.0448	0.3018	6.7358	0.0448	1.0003	0.6530	2.1189
M17.4	Age	Fishery	30.5489	0.6509	0.0213	30.5448	0.9999	0.9999	infinity
M17.4	Age	Survey	0.0406	0.0179	0.4398	0.0406	0.9995	0.5590	3.5087
M17.5	Length	Fishery	0.1919	0.1338	0.6974	0.0317	0.1654	0.1063	0.3409
M17.5	Length	Survey	7.0648	1.0244	0.1450	0.4062	0.0575	0.0411	0.1013
M17.5	Age	Fishery	4.0977	0.2294	0.0560	1.0813	0.2639	0.2639	infinity
M17.5	Age	Survey	21.6483	0.4595	0.0212	0.6903	0.0319	0.0181	0.0850
M17.6	Length	Fishery	0.1881	0.1886	1.0024	0.2636	1.4016	1.0417	2.1257
M17.6	Length	Survey	1.5068	1.5073	1.0004	0.4446	0.2951	0.2017	0.5300
M17.6	Age	Fishery	0.3425	0.3427	1.0007	0.6991	2.0413	2.0413	infinity
M17.6	Age	Survey	0.2225	0.2226	1.0006	0.2857	1.2840	0.8316	2.8291

Table 2.1.5a—Selected constants and base values of non-selectivity parameters.

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.4		Model 17.5		Model 17.6	
Parameter/constant	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Weight-length multiplier	5.6E-06	_	5.6E-06	_	5.6E-06	_	5.6E-06	_	5.6E-06	_	5.6E-06	_	5.6E-06	_
Weight-length exponent	3.18315	_	3.18315	_	3.18315	_	3.18315	_	3.18315	_	3.18315	_	3.18315	_
Age at 50% maturity	4.8832	_	4.8832	_	4.8832	_	4.8832	_	4.8832	_	4.8832	_	4.8832	_
Logistic maturity slope	-0.9654	_	-0.9654	_	-0.9654	_	-0.9654	_	-0.9654	_	-0.9654	_	-0.9654	_
Ageing error SD at a=1	0.085	_	0.085	_	0.085	_	0.085	_	0.085	_	0.085	_	0.085	_
Ageing error SD at a=20	1.705	_	1.705	_	1.705	_	1.705	_	1.705	_	1.705	_	1.705	_
Proportion female	0.5	_	0.5	_	0.5	_	0.5	_	0.5	_	0.5	_	0.5	_
Beverton-Holt steepness	1	_	1	_	1	_	1	_	1	_	1	_	1	_
Natural mortality	0.3625	0.013	0.3331	0.009	0.3686	0.016	0.3723	0.013	0.3196	0.021	0.3128	0.004	0.3449	0.011
Initial fishing mortality	0.1554	0.056	0.8505	0.310	0.1942	0.074	0.1751	0.058	0.5725	0.183	1.3134	0.842	0.2339	0.099
Length at a=1.5 mean	16.4011	0.088	16.5445	0.082	16.3720	0.091	16.3727	0.084	35.4975	0.156	16.3104	0.031	16.7850	0.277
Length at a=1.5 dev SD													0.0936	_
Asymptotic length	99.3869	1.901	109.9040	1.058	104.9930	1.727	106.1030	1.742	120.5450	1.174	107.1690	1.135	104.5350	1.636
Brody growth coefficient	0.1974	0.012	0.1563	0.005	0.1761	0.009	0.1739	0.009	0.0995	0.003	0.1576	0.005	0.1770	0.008
Richards growth coef.	1.0499	0.048	1.1975	0.023	1.1075	0.040	1.1057	0.037	1.5910	0.037	1.1600	0.019	1.0432	0.035
Length at a=1 SD	3.4251	0.058	3.4983	0.050	3.4223	0.058	3.4554	0.055	4.8030	0.078	3.3943	0.021	3.0796	0.039
Length at a=20 SD	9.7171	0.282	8.3603	0.136	9.2442	0.225	8.8043	0.236	7.4946	0.184	9.6703	0.137	9.6923	0.205
Ageing bias at a=1	0.3210	0.013	0.3365	0.011	0.3370	0.034	0.3419	0.019	0.7846	0.005	0.3383	0.003	0.3520	0.020
Ageing bias at a=20	0.3513	0.154	-0.3884	0.113	-1.1456	0.251	-0.2301	0.190	0.9732	0.066	-0.2466	0.031	-0.8161	0.187
ln(mean post-76 recruits)	13.2195	0.104	12.8790	0.067	13.1953	0.110	13.1578	0.095	12.7959	0.132	12.8103	0.031	13.0273	0.083
σ(recruitment)	0.6377	0.066	0.4693	_	0.5602	_	0.4958	_	0.9708	_	0.6551	_	0.5730	_
ln(pre-77 recruits offset)	-1.0990	0.216	-1.5149	0.030	-1.2066	0.177	-1.1067	0.164	-1.8085	0.046	-1.2602	0.235	-1.2416	0.168
ln(catchability)	-0.1328	0.065	0.1068	0.040	-0.0537	0.055	-0.0181	0.066	0.1425	0.081	0.1006	0.025	0.0122	0.057
ln(catchability) dev SD													0.0898	_
ln(catchability) dev corr.													0.4959	0.126
Survey index "extra SE"							0.1105	0.031						

Table 2.1.5b—Base values of selectivity parameters.

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.4		Model 17.5		Model 17.6	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
A50% (fishery)	4.3240	0.046												
A95%-A50% (fishery)	1.1583	0.032												
A50% (survey)	1.0055	0.006												
A95%-A50% (survey)	0.2892	0.050												
Begin peak (fishery)			5.7421	0.119	5.7698	0.122	5.6960	0.113	5.1712	0.204	5.9552	0.132	5.9545	0.119
Plateau width (fishery)			10.0000	_	10.0000	_	10.0000	_	10.0000	_	10.0000	_	10.0000	_
Ascend. width (fishery)			1.0418	0.063	0.9991	0.057	0.9768	0.053	1.5322	0.160	1.0741	0.078	1.0700	0.055
Descend. width (fishery)			10.0000	_	10.0000	_	10.0000	_	10.0000	_	10.0000	_	10.0000	_
Select. at a=0 (fishery)			-10.0000	_	-10.0000	_	-10.0000	_	-10.0000	_	-10.0000	_	-10.0000	_
Select. at a=20 (fishery)			10.0000	_	10.0000	_	10.0000	_	10.0000	_	10.0000	_	10.0000	_
Begin peak (survey)			1.0414	0.012	2.4144	0.161	1.0550	0.013	0.0615	0.008	1.0259	0.010	1.0472	0.014
Plateau width (survey)			10.0000	_	10.0000	_	10.0000	_	10.0000	_	10.0000	_	10.0000	_
Ascend. width (survey)			-7.5611	1.105	1.0855	0.254	-6.5731	0.705	-10.0000	_	-10.0000	_	-6.7770	0.864
Descend. width (survey)			10.0000	_	10.0000	_	10.0000	_	10.0000	_	10.0000	_	10.0000	_
Select. at a=0 (survey)			-10.0000	_	-10.0000	_	-10.0000	_	-10.0000	_	-10.0000	_	-10.0000	_
Select. at a=20 (survey)			10.0000	_	10.0000	_	10.0000	_	10.0000	_	10.0000	_	10.0000	_
P1 dev SD (fishery)			0.1225	_	0.1078	_	0.0993	_	0.2595	_	0.1261	_	0.1037	_
P3 dev SD (fishery)			0.3634	_	0.2564	_	0.2287	_	0.9773	_	0.4366	_	0.2573	_
P1 dev SD (survey)			0.0568	_			0.0545	_	0.1703	_	0.0554	_	0.0535	_
P3 dev SD (survey)			0.1588	_			0.1593	_					0.1595	_

Table 2.1.5c—“Early” recruitment *dev*s (used to define the numbers at age in the initial year of the model).

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.4		Model 17.5		Model 17.6	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Recruit dev for age=20	-0.0051	0.636	0.0000	0.469	-0.0030	0.559	-0.0032	0.495	0.0000	0.971	0.0000	0.655	-0.0026	0.572
Recruit dev for age=19	-0.0034	0.637	0.0000	0.469	-0.0023	0.560	-0.0023	0.495	0.0000	0.971	0.0000	0.655	-0.0020	0.572
Recruit dev for age=18	-0.0057	0.636	0.0000	0.469	-0.0039	0.559	-0.0040	0.495	-0.0001	0.971	0.0000	0.655	-0.0036	0.572
Recruit dev for age=17	-0.0094	0.635	0.0000	0.469	-0.0068	0.558	-0.0069	0.494	-0.0003	0.971	0.0000	0.655	-0.0063	0.571
Recruit dev for age=16	-0.0156	0.633	0.0000	0.469	-0.0117	0.557	-0.0116	0.493	-0.0006	0.971	0.0000	0.655	-0.0110	0.570
Recruit dev for age=15	-0.0255	0.630	0.0000	0.469	-0.0200	0.555	-0.0197	0.491	-0.0013	0.970	0.0000	0.655	-0.0191	0.568
Recruit dev for age=14	-0.0413	0.626	-0.0001	0.469	-0.0338	0.552	-0.0329	0.488	-0.0030	0.969	0.0000	0.655	-0.0328	0.565
Recruit dev for age=13	-0.0659	0.619	-0.0002	0.469	-0.0565	0.547	-0.0543	0.484	-0.0064	0.968	0.0000	0.655	-0.0556	0.560
Recruit dev for age=12	-0.1032	0.610	-0.0006	0.469	-0.0923	0.539	-0.0877	0.477	-0.0134	0.965	0.0000	0.655	-0.0919	0.554
Recruit dev for age=11	-0.1574	0.597	-0.0018	0.469	-0.1465	0.529	-0.1380	0.469	-0.0269	0.959	0.0002	0.655	-0.1473	0.545
Recruit dev for age=10	-0.2322	0.582	-0.0053	0.468	-0.2237	0.517	-0.2094	0.457	-0.0548	0.950	0.0011	0.655	-0.2264	0.534
Recruit dev for age=9	-0.3284	0.563	-0.0149	0.468	-0.3247	0.501	-0.3033	0.444	-0.0999	0.939	0.0048	0.657	-0.3301	0.521
Recruit dev for age=8	-0.4421	0.543	-0.0379	0.470	-0.4434	0.484	-0.4146	0.429	-0.1594	0.928	0.0194	0.661	-0.4511	0.505
Recruit dev for age=7	-0.5599	0.523	-0.0822	0.481	-0.5612	0.466	-0.5268	0.413	-0.2039	0.910	0.0705	0.677	-0.5692	0.485
Recruit dev for age=6	-0.6497	0.505	-0.1449	0.481	-0.6370	0.448	-0.6027	0.399	-0.1726	0.871	0.2226	0.713	-0.6411	0.464
Recruit dev for age=5	-0.6281	0.495	-0.2426	0.383	-0.5810	0.435	-0.5601	0.388	-0.0262	0.723	0.4901	0.799	-0.5717	0.450
Recruit dev for age=4	-0.2461	0.478	0.2250	0.223	-0.0372	0.402	-0.0899	0.365	0.0337	0.446	1.1736	0.644	0.1081	0.392
Recruit dev for age=3	-0.0920	0.463	0.8426	0.134	0.3756	0.327	0.3132	0.302	0.4695	0.236	0.3478	0.408	0.2785	0.353
Recruit dev for age=2	-0.1529	0.516	-0.7300	0.290	-0.3781	0.430	-0.3459	0.381	1.5464	0.105	-0.3301	0.488	-0.3362	0.446
Recruit dev for age=1	0.7444	0.513	1.2691	0.124	1.0392	0.305	0.9186	0.284	-1.4057	0.555	1.4168	0.292	1.2446	0.297

Table 2.1.5d—Recruitment *dev*s (page 1 of 2).

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.4		Model 17.5		Model 17.6	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Recruit dev for 1977	0.9345	0.212	0.3023	0.091	0.5613	0.178	0.5772	0.169	-0.1046	0.105	0.6748	0.112	0.6608	0.164
Recruit dev for 1978	0.4826	0.253	0.3410	0.088	0.5623	0.162	0.5502	0.155	0.4268	0.083	0.4441	0.094	0.5566	0.150
Recruit dev for 1979	0.4808	0.144	0.4549	0.066	0.4070	0.124	0.4613	0.113	0.2409	0.090	0.4161	0.055	0.4822	0.098
Recruit dev for 1980	-0.2837	0.137	-0.7048	0.109	-0.2923	0.130	-0.3828	0.129	0.6875	0.065	-0.5355	0.063	-0.6862	0.158
Recruit dev for 1981	-0.8832	0.142	0.1523	0.054	-0.5380	0.121	-0.2929	0.115	-1.3449	0.250	-0.9306	0.073	-0.5088	0.121
Recruit dev for 1982	0.7818	0.051	0.4421	0.044	0.7461	0.054	0.7097	0.065	0.4590	0.050	0.8080	0.027	0.8141	0.052
Recruit dev for 1983	-0.5802	0.125	-0.0936	0.060	-0.4909	0.121	-0.2352	0.109	0.3910	0.045	-0.3938	0.056	-0.3651	0.109
Recruit dev for 1984	0.7657	0.050	0.3466	0.042	0.6601	0.052	0.5918	0.060	0.0162	0.056	0.7428	0.026	0.6653	0.055
Recruit dev for 1985	-0.2017	0.090	0.1359	0.044	-0.0295	0.074	0.1101	0.074	0.2443	0.039	0.0794	0.036	0.0745	0.069
Recruit dev for 1986	-0.6139	0.102	-0.5440	0.061	-0.5106	0.086	-0.4745	0.091	0.1999	0.037	-0.4351	0.043	-0.5038	0.086
Recruit dev for 1987	-1.4867	0.179	-0.6779	0.057	-1.1286	0.124	-0.9911	0.122	-0.4387	0.055	-1.5581	0.093	-1.1982	0.137
Recruit dev for 1988	-0.4828	0.097	-0.1047	0.043	-0.3565	0.073	-0.1486	0.075	-0.5239	0.048	0.0349	0.034	-0.1606	0.074
Recruit dev for 1989	0.5296	0.058	0.3002	0.032	0.4268	0.048	0.3797	0.055	0.0418	0.033	0.5663	0.024	0.4717	0.050
Recruit dev for 1990	0.3308	0.065	0.3775	0.030	0.3109	0.051	0.3982	0.053	0.3332	0.026	0.4136	0.024	0.4006	0.055
Recruit dev for 1991	-0.0785	0.078	-0.2867	0.044	-0.1569	0.067	-0.2894	0.078	0.4474	0.027	-0.1936	0.030	-0.2787	0.092
Recruit dev for 1992	0.7250	0.041	0.6233	0.023	0.6827	0.037	0.6388	0.040	-0.3824	0.044	0.8152	0.015	0.6968	0.039
Recruit dev for 1993	-0.1988	0.067	-0.2224	0.037	-0.2608	0.067	-0.1836	0.063	0.7406	0.025	0.0648	0.018	-0.1977	0.063
Recruit dev for 1994	-0.3413	0.069	-0.3627	0.032	-0.3902	0.061	-0.3692	0.061	-0.2615	0.036	-0.1633	0.019	-0.3198	0.059
Recruit dev for 1995	-0.4387	0.077	-0.3529	0.035	-0.4627	0.066	-0.3899	0.065	-0.2432	0.028	-0.1265	0.021	-0.3169	0.065
Recruit dev for 1996	0.5742	0.040	0.4469	0.025	0.5329	0.040	0.5353	0.044	-0.3311	0.030	0.7173	0.016	0.6672	0.039
Recruit dev for 1997	-0.1796	0.063	0.1476	0.027	0.0336	0.054	0.1151	0.053	0.5393	0.020	-0.1432	0.020	0.0083	0.059
Recruit dev for 1998	-0.2542	0.067	-0.0625	0.029	-0.1787	0.058	-0.1252	0.059	0.2538	0.022	-0.0122	0.021	-0.2211	0.070
Recruit dev for 1999	0.4816	0.041	0.3623	0.024	0.3796	0.040	0.4202	0.042	-0.0123	0.024	0.6034	0.016	0.4486	0.043
Recruit dev for 2000	0.2126	0.044	0.0300	0.030	0.1128	0.046	0.0597	0.051	0.3417	0.023	0.0643	0.015	0.1134	0.048
Recruit dev for 2001	-0.6012	0.067	-0.6360	0.036	-0.7778	0.073	-0.6297	0.068	0.1272	0.029	-0.1989	0.019	-0.7777	0.079
Recruit dev for 2002	-0.3020	0.052	-0.3397	0.030	-0.2988	0.051	-0.3198	0.054	-0.7013	0.036	-0.2935	0.019	-0.1208	0.047
Recruit dev for 2003	-0.4740	0.055	-0.3011	0.030	-0.4451	0.056	-0.3543	0.057	-0.2059	0.030	-0.2406	0.019	-0.2078	0.052
Recruit dev for 2004	-0.6507	0.060	-0.6606	0.039	-0.6384	0.064	-0.6725	0.073	-0.1542	0.029	-0.6949	0.023	-0.6426	0.074

Table 2.1.5d—Recruittment *dev*s (page 2 of 2).

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.4		Model 17.5		Model 17.6	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Recruit dev for 2005	-0.3466	0.054	-0.2166	0.034	-0.2997	0.056	-0.3258	0.062	-0.4484	0.035	-0.4482	0.019	-0.0683	0.056
Recruit dev for 2006	0.8225	0.034	0.3819	0.024	0.5128	0.038	0.4656	0.040	-0.2252	0.041	0.8349	0.014	0.6183	0.039
Recruit dev for 2007	-0.0038	0.056	0.0587	0.033	-0.0774	0.059	-0.0019	0.060	0.4019	0.033	-0.0614	0.023	-0.1670	0.075
Recruit dev for 2008	1.1500	0.033	0.8045	0.023	0.9342	0.033	0.8273	0.038	0.0173	0.035	1.0425	0.013	0.9393	0.033
Recruit dev for 2009	-0.8937	0.111	-0.2201	0.045	-0.5159	0.089	-0.4425	0.098	0.9612	0.023	-0.8555	0.032	-0.6749	0.099
Recruit dev for 2010	0.6443	0.048	0.2752	0.039	0.5579	0.053	0.2233	0.065	0.3281	0.025	0.2836	0.019	0.3517	0.053
Recruit dev for 2011	1.0381	0.049	0.7546	0.045	0.9180	0.051	0.6468	0.075	1.3840	0.039	0.7571	0.021	0.6978	0.057
Recruit dev for 2012	0.1624	0.073	0.3057	0.055	0.3776	0.066	0.0954	0.103	1.5733	0.044	0.2148	0.028	0.1289	0.077
Recruit dev for 2013	0.9822	0.061	0.7317	0.063	0.8996	0.067	0.5250	0.120	0.3933	0.052	0.6222	0.033	0.6757	0.087
Recruit dev for 2014	-0.9831	0.143	-0.9719	0.144	-0.9685	0.159	-1.2450	0.202	-0.1730	0.063	-1.2617	0.075	-1.3641	0.176
Recruit dev for 2015	-0.8204	0.198	-1.0170	0.351	-0.7994	0.210	-0.4568	0.404	-4.9990	0.011	-1.6538	0.168	-0.6916	0.451

Table 2.1.5e—Selectivity parameter *dev*s (page 1 of 5).

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.4		Model 17.5		Model 17.6	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
P1 dev. for 1977 (fishery)			-0.0725	0.594	-0.2904	0.769	-0.3550	0.784	-0.4860	0.459	-0.8887	1.001	-0.3081	0.800
P1 dev. for 1978 (fishery)			-0.2799	0.506	-0.4363	0.610	-0.4707	0.609	-0.5684	0.323	0.1591	0.778	-0.3503	0.637
P1 dev. for 1979 (fishery)			-1.8104	0.466	-0.8390	0.604	-0.8718	0.598	-1.7472	0.322	-0.4978	0.681	-0.7254	0.633
P1 dev. for 1980 (fishery)			-0.5189	0.541	-0.3998	0.634	-0.4591	0.630	-0.2987	0.434	0.2145	0.660	-0.2227	0.647
P1 dev. for 1981 (fishery)			-2.0296	0.653	-1.3845	0.716	-1.4406	0.714	-2.2838	0.653	-1.0794	0.861	-1.3123	0.778
P1 dev. for 1982 (fishery)			1.1306	0.489	0.6559	0.613	0.6796	0.613	0.7526	0.300	0.7442	0.667	0.7278	0.647
P1 dev. for 1983 (fishery)			1.7866	0.363	0.8516	0.524	0.8638	0.512	1.1526	0.245	1.3979	0.524	0.9868	0.551
P1 dev. for 1984 (fishery)			2.4849	0.321	1.2895	0.508	1.2167	0.511	1.5831	0.209	2.1484	0.500	1.4994	0.526
P1 dev. for 1985 (fishery)			0.3072	0.258	-0.2222	0.436	-0.1569	0.422	0.5044	0.204	-0.5062	0.488	-0.4399	0.440
P1 dev. for 1986 (fishery)			0.5030	0.233	0.2877	0.352	0.3353	0.365	0.2942	0.176	0.3696	0.322	0.1931	0.348
P1 dev. for 1987 (fishery)			0.2789	0.249	0.4372	0.350	0.5411	0.369	-0.1511	0.183	0.7347	0.287	0.5078	0.344
P1 dev. for 1988 (fishery)			-0.5187	0.412	-0.6357	0.502	-0.7814	0.521	0.8001	0.281	-0.7485	0.540	-0.7011	0.513
P1 dev. for 1989 (fishery)			1.8586	0.328	0.6777	0.545	0.5809	0.545	1.7456	0.241	0.4612	0.523	0.6661	0.543
P1 dev. for 1990 (fishery)			1.8542	0.215	1.8652	0.366	1.9249	0.376	0.8650	0.162	2.1399	0.321	2.0372	0.370
P1 dev. for 1991 (fishery)			0.0968	0.224	-0.5077	0.400	-0.2768	0.393	0.3805	0.172	0.5055	0.403	-0.4212	0.398
P1 dev. for 1992 (fishery)			-0.2333	0.208	-0.7322	0.303	-0.4352	0.315	-0.0885	0.162	-0.1321	0.282	-0.6914	0.314
P1 dev. for 1993 (fishery)			-1.4130	0.246	-0.7493	0.399	-0.9804	0.427	0.3679	0.252	-0.1162	0.456	-0.8651	0.423
P1 dev. for 1994 (fishery)			-0.1572	0.209	0.2121	0.344	0.1260	0.353	-0.5188	0.164	-0.3707	0.299	0.1724	0.336
P1 dev. for 1995 (fishery)			-1.1341	0.220	-0.6948	0.362	-0.9335	0.371	-0.8705	0.168	-0.2839	0.338	-0.8971	0.392
P1 dev. for 1996 (fishery)			0.3556	0.196	0.6557	0.316	0.4930	0.308	0.0337	0.160	0.9786	0.313	0.3807	0.326
P1 dev. for 1997 (fishery)			0.5175	0.201	0.7692	0.333	0.7297	0.328	0.2544	0.162	-0.1933	0.257	0.7151	0.324
P1 dev. for 1998 (fishery)			-0.0346	0.193	0.0550	0.299	0.2039	0.306	-0.3862	0.158	0.2112	0.242	0.1677	0.306
P1 dev. for 1999 (fishery)			-0.3974	0.195	-0.5402	0.300	-0.3251	0.305	-0.4784	0.160	0.6539	0.257	-0.3870	0.305
P1 dev. for 2000 (fishery)			-0.1430	0.184	-0.1353	0.264	0.0451	0.272	-0.3409	0.155	0.1961	0.269	-0.0920	0.278
P1 dev. for 2001 (fishery)			-0.0541	0.193	0.0515	0.298	0.2032	0.307	-0.3584	0.158	-0.3164	0.251	0.4146	0.298
P1 dev. for 2002 (fishery)			-0.8078	0.187	-0.9522	0.271	-0.8630	0.282	-0.8137	0.157	-0.3749	0.245	-0.8494	0.295
P1 dev. for 2003 (fishery)			-0.7231	0.185	-0.7154	0.258	-0.6175	0.266	-0.7961	0.158	-0.3604	0.236	-0.7573	0.270
P1 dev. for 2004 (fishery)			-1.0672	0.185	-0.6069	0.267	-0.7494	0.278	-1.1410	0.156	-1.6163	0.274	-0.7730	0.278
P1 dev. for 2005 (fishery)			-1.1549	0.192	-0.7939	0.303	-0.8443	0.295	-1.1489	0.158	-0.9150	0.239	-1.0250	0.308
P1 dev. for 2006 (fishery)			-0.6248	0.191	-0.3796	0.280	-0.3531	0.288	-0.6104	0.156	-0.4704	0.261	-0.6433	0.282

Table 2.1.5e—Selectivity parameter *dev*s (page 2 of 5).

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.4		Model 17.5		Model 17.6	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
P1 dev. for 2007 (fishery)			0.4869	0.187	0.5733	0.279	0.6674	0.287	0.1548	0.156	0.3600	0.252	0.4769	0.284
P1 dev. for 2008 (fishery)			0.3396	0.192	0.3831	0.285	0.4300	0.294	0.1036	0.159	0.2801	0.245	0.4419	0.297
P1 dev. for 2009 (fishery)			-0.1553	0.196	-0.1014	0.303	-0.1376	0.310	-0.4157	0.163	-1.5077	0.254	-0.3144	0.307
P1 dev. for 2010 (fishery)			0.1647	0.189	0.4033	0.271	0.4920	0.283	-0.5525	0.155	-0.4600	0.233	0.4373	0.286
P1 dev. for 2011 (fishery)			0.2594	0.210	0.3811	0.335	0.6474	0.345	-0.5578	0.157	-1.6938	0.299	0.8929	0.340
P1 dev. for 2012 (fishery)			0.3852	0.186	0.4936	0.263	0.6857	0.286	-0.3010	0.153	-0.2759	0.314	0.5580	0.289
P1 dev. for 2013 (fishery)			-0.3008	0.217	-0.1360	0.353	-0.0621	0.380	-0.0622	0.154	0.5530	0.219	0.3127	0.319
P1 dev. for 2014 (fishery)			-0.0646	0.183	0.0049	0.251	-0.0054	0.266	0.8007	0.157	0.6362	0.238	-0.0377	0.263
P1 dev. for 2015 (fishery)			0.3760	0.204	0.6926	0.274	0.2518	0.317	2.3912	0.172	0.0152	0.183	0.1380	0.276
P1 dev. for 2016 (fishery)			0.5096	0.293	0.5126	0.357	0.0012	0.433	2.7917	0.391	0.0483	0.209	0.0869	0.386
P3 dev. for 1977 (fishery)			-0.3464	0.784	0.0457	0.939	0.0743	0.950	-0.8005	0.447	1.1429	1.034	0.0721	0.940
P3 dev. for 1978 (fishery)			-0.5997	0.544	-0.3830	0.811	-0.3551	0.834	-0.6379	0.261	-0.2835	0.660	-0.4013	0.798
P3 dev. for 1979 (fishery)			-1.8265	0.636	-0.3816	0.809	-0.3226	0.825	-1.2781	0.309	-0.4121	0.670	-0.3736	0.793
P3 dev. for 1980 (fishery)			-0.2160	0.590	0.0009	0.819	0.0163	0.839	0.0240	0.356	0.1499	0.638	0.0448	0.801
P3 dev. for 1981 (fishery)			0.2447	0.769	0.7729	0.879	0.8052	0.888	-0.3893	0.704	0.8533	0.791	0.8190	0.884
P3 dev. for 1982 (fishery)			0.6571	0.557	0.0264	0.848	0.0154	0.862	0.2655	0.250	0.0441	0.706	-0.0267	0.840
P3 dev. for 1983 (fishery)			1.6078	0.376	0.7051	0.777	0.6846	0.794	0.6018	0.206	0.8588	0.557	0.6728	0.789
P3 dev. for 1984 (fishery)			2.7116	0.291	2.3411	0.601	2.3179	0.636	0.9697	0.183	2.2084	0.396	2.5605	0.586
P3 dev. for 1985 (fishery)			0.1366	0.326	-0.4573	0.742	-0.5187	0.747	0.2351	0.195	-0.5871	0.611	-0.6724	0.728
P3 dev. for 1986 (fishery)			0.9767	0.257	0.8545	0.535	0.8901	0.572	0.3642	0.178	0.5554	0.368	0.6553	0.528
P3 dev. for 1987 (fishery)			0.4438	0.283	0.5636	0.514	0.7025	0.558	-0.1078	0.183	0.5436	0.311	0.5636	0.488
P3 dev. for 1988 (fishery)			1.1764	0.489	1.2648	0.757	1.1947	0.802	1.7275	0.286	0.7331	0.628	1.1988	0.761
P3 dev. for 1989 (fishery)			2.7020	0.350	1.7609	0.746	1.6431	0.778	1.5441	0.216	1.0452	0.569	1.6126	0.742
P3 dev. for 1990 (fishery)			1.8268	0.230	2.3645	0.490	2.4000	0.528	0.4096	0.170	1.7660	0.318	2.3826	0.483
P3 dev. for 1991 (fishery)			0.3525	0.245	-0.2225	0.579	0.0301	0.588	0.2539	0.173	0.7397	0.387	-0.0230	0.550
P3 dev. for 1992 (fishery)			-0.2575	0.236	-1.2902	0.502	-0.8282	0.518	-0.1389	0.169	-0.2665	0.332	-1.0306	0.495
P3 dev. for 1993 (fishery)			-0.4121	0.283	0.2906	0.547	0.2308	0.621	1.1227	0.241	0.8210	0.413	0.3698	0.559
P3 dev. for 1994 (fishery)			0.3601	0.222	0.7729	0.449	0.8512	0.481	-0.2394	0.170	0.1126	0.304	0.8891	0.424
P3 dev. for 1995 (fishery)			-0.7704	0.279	-0.2636	0.574	-0.5152	0.628	-0.4874	0.178	0.1602	0.366	-0.2461	0.587
P3 dev. for 1996 (fishery)			0.3177	0.227	0.6069	0.502	0.3603	0.528	-0.0485	0.169	0.8338	0.334	0.3094	0.510

Table 2.1.5e—Selectivity parameter *dev*s (page 3 of 5).

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.4		Model 17.5		Model 17.6	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
P3 dev. for 1997 (fishery)			0.9210	0.208	1.4725	0.419	1.4305	0.440	0.3113	0.169	0.0090	0.280	1.2712	0.401
P3 dev. for 1998 (fishery)			-0.2269	0.212	-0.1261	0.432	-0.0465	0.456	-0.4710	0.167	-0.0703	0.269	-0.0500	0.424
P3 dev. for 1999 (fishery)			-0.6039	0.218	-0.9952	0.472	-0.7961	0.483	-0.5061	0.169	0.6131	0.267	-0.8013	0.455
P3 dev. for 2000 (fishery)			-0.6351	0.208	-0.9690	0.438	-0.8240	0.455	-0.4830	0.166	-0.0200	0.314	-1.0421	0.466
P3 dev. for 2001 (fishery)			-0.3749	0.211	-0.3571	0.422	-0.2428	0.449	-0.4492	0.167	-0.5807	0.283	0.1055	0.396
P3 dev. for 2002 (fishery)			-0.6798	0.211	-1.1442	0.432	-1.0307	0.465	-0.5398	0.167	-0.2460	0.280	-0.6605	0.440
P3 dev. for 2003 (fishery)			-0.7179	0.213	-1.2063	0.442	-0.9921	0.460	-0.5363	0.169	-0.3551	0.286	-0.9093	0.439
P3 dev. for 2004 (fishery)			-1.2388	0.220	-0.9336	0.438	-1.1631	0.480	-0.9175	0.168	-2.0561	0.435	-0.8576	0.426
P3 dev. for 2005 (fishery)			-1.5032	0.236	-1.2023	0.505	-1.3949	0.511	-1.0479	0.170	-1.0393	0.309	-1.3416	0.485
P3 dev. for 2006 (fishery)			-1.3189	0.238	-1.2209	0.502	-1.3157	0.532	-0.7848	0.168	-0.7227	0.339	-1.6568	0.492
P3 dev. for 2007 (fishery)			0.1188	0.205	0.1972	0.414	0.2802	0.447	-0.1666	0.166	0.1349	0.290	-0.1592	0.425
P3 dev. for 2008 (fishery)			-0.0164	0.203	-0.0831	0.388	-0.0221	0.413	-0.1726	0.167	0.0878	0.252	-0.1601	0.394
P3 dev. for 2009 (fishery)			-0.8238	0.220	-1.1907	0.469	-1.3516	0.500	-0.5529	0.170	-2.4241	0.363	-1.7701	0.501
P3 dev. for 2010 (fishery)			-0.6524	0.207	-0.8068	0.406	-0.8236	0.439	-0.7770	0.165	-1.2762	0.316	-1.0479	0.456
P3 dev. for 2011 (fishery)			-0.2553	0.227	-0.2837	0.458	-0.0120	0.478	-0.7677	0.167	-2.6260	0.462	0.3280	0.421
P3 dev. for 2012 (fishery)			-0.1758	0.203	-0.2596	0.395	-0.0162	0.440	-0.7062	0.165	-1.1704	0.525	-0.1380	0.422
P3 dev. for 2013 (fishery)			-0.5406	0.235	-0.5443	0.472	-0.3436	0.526	-0.5226	0.164	0.3094	0.221	0.1356	0.388
P3 dev. for 2014 (fishery)			-0.9180	0.203	-1.2247	0.398	-1.3271	0.434	-0.0054	0.165	0.0824	0.251	-1.1369	0.412
P3 dev. for 2015 (fishery)			0.0823	0.207	0.6343	0.319	0.2055	0.420	1.1556	0.168	0.0673	0.183	0.1880	0.323
P3 dev. for 2016 (fishery)			0.4743	0.289	0.8710	0.426	0.1091	0.594	4.5494	0.471	0.2641	0.203	0.3264	0.467
P1 dev. for 1982 (survey)			1.2210	0.326			0.6272	0.344	0.0315	0.963	0.2329	0.239	0.5194	0.306
P1 dev. for 1983 (survey)			-0.2959	0.210			-0.0941	0.212	-0.4158	0.953	0.0104	0.191	0.0196	0.206
P1 dev. for 1984 (survey)			0.8641	0.377			0.6900	0.400	0.1564	0.991	1.0437	0.239	0.4211	0.314
P1 dev. for 1985 (survey)			-1.1390	0.428			-0.2498	0.203	-0.4961	0.954	-0.2675	0.171	-0.1590	0.197
P1 dev. for 1986 (survey)			0.3194	0.283			0.2623	0.240	-0.2812	0.972	0.4085	0.201	0.2781	0.223
P1 dev. for 1987 (survey)			-0.1405	0.240			-0.0389	0.235	-0.1711	0.979	-0.1273	0.215	-0.0472	0.218
P1 dev. for 1988 (survey)			1.0153	0.392			0.6458	0.408	0.1183	0.993	0.3563	0.276	0.5155	0.357
P1 dev. for 1989 (survey)			1.1435	0.303			0.7954	0.330	1.7426	0.963	1.3620	0.199	0.9031	0.328
P1 dev. for 1990 (survey)			-0.2536	0.213			-0.2224	0.202	0.1015	0.942	-0.2772	0.171	-0.1163	0.198
P1 dev. for 1991 (survey)			-0.0233	0.226			0.0295	0.216	0.1779	0.965	-0.1066	0.192	0.0314	0.208

Table 2.1.5e—Selectivity parameter *dev*s (page 4 of 5).

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.4		Model 17.5		Model 17.6	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
P1 dev. for 1992 (survey)			-0.9238	0.305			-1.3847	0.426	-0.2528	0.969	-0.5165	0.171	-1.0450	0.523
P1 dev. for 1993 (survey)			-0.3335	0.200			-0.3013	0.196	-0.7884	0.926	-0.3155	0.171	-0.2493	0.188
P1 dev. for 1994 (survey)			0.0758	0.220			0.2617	0.237	-0.2166	0.983	0.4422	0.178	0.2037	0.221
P1 dev. for 1995 (survey)			0.5923	0.275			0.5426	0.289	-0.1169	0.984	0.9321	0.180	0.5789	0.280
P1 dev. for 1996 (survey)			0.8061	0.268			0.7002	0.310	0.0929	0.992	1.1075	0.179	0.7755	0.312
P1 dev. for 1997 (survey)			-0.0178	0.214			0.1192	0.206	0.2006	0.959	0.1208	0.175	0.2112	0.198
P1 dev. for 1998 (survey)			0.9070	0.250			0.7271	0.289	0.5312	0.984	0.4941	0.178	0.6127	0.270
P1 dev. for 1999 (survey)			0.6051	0.256			0.4537	0.254	0.4442	0.991	0.7556	0.178	0.4268	0.240
P1 dev. for 2000 (survey)			-0.1245	0.223			-0.0410	0.206	0.3684	0.957	-0.0522	0.175	0.0229	0.202
P1 dev. for 2001 (survey)			-0.5915	0.200			-0.5761	0.210	-0.7809	0.940	-0.4612	0.171	-0.5719	0.220
P1 dev. for 2002 (survey)			-0.0594	0.229			0.0028	0.224	0.0467	0.988	0.3930	0.178	-0.0938	0.211
P1 dev. for 2003 (survey)			-0.2851	0.207			-0.2591	0.202	-0.0879	0.970	-0.3437	0.170	-0.1775	0.195
P1 dev. for 2004 (survey)			-0.0451	0.222			-0.0198	0.213	0.2474	0.972	-0.1891	0.174	0.0207	0.206
P1 dev. for 2005 (survey)			-1.0933	0.396			-0.4726	0.208	-0.1495	0.970	-0.5321	0.171	-0.6852	0.297
P1 dev. for 2006 (survey)			-0.3977	0.188			-0.5176	0.203	-0.4826	0.929	-0.4612	0.171	-0.3208	0.189
P1 dev. for 2007 (survey)			-0.7135	0.199			-0.9735	0.246	-0.7847	0.916	-0.4613	0.170	-0.8573	0.261
P1 dev. for 2008 (survey)			-0.1818	0.221			-0.1686	0.205	0.0640	0.967	-0.3578	0.171	-0.2715	0.196
P1 dev. for 2009 (survey)			-0.3820	0.189			-0.3912	0.191	-0.7131	0.897	-0.3558	0.170	-0.2961	0.185
P1 dev. for 2010 (survey)			0.6507	0.284			0.3657	0.276	0.1726	0.993	-0.1453	0.188	0.1777	0.240
P1 dev. for 2011 (survey)			-0.4213	0.186			-0.4503	0.198	0.4895	0.925	-0.3864	0.170	-0.3389	0.188
P1 dev. for 2012 (survey)			-0.3544	0.194			-0.3784	0.194	0.7889	0.932	-0.3528	0.170	-0.3470	0.187
P1 dev. for 2013 (survey)			0.2616	0.230			0.1952	0.225	0.1892	0.990	0.3472	0.177	0.2229	0.214
P1 dev. for 2014 (survey)			-0.2468	0.213			-0.2407	0.201	-0.3694	0.959	-0.3157	0.170	-0.1518	0.195
P1 dev. for 2015 (survey)			-0.1961	0.238			-0.0387	0.263	-0.0474	0.996	-0.5875	0.172	-0.1852	0.237
P1 dev. for 2016 (survey)			-0.2419	0.279			0.3999	0.438	0.1905	0.977	-1.3939	0.601	-0.0274	0.337
P3 dev. for 1982 (survey)			0.0000	1.000			-0.0083	0.998					-0.0102	0.998
P3 dev. for 1983 (survey)			0.0084	1.000			0.0049	0.999					-0.0009	0.999
P3 dev. for 1984 (survey)			0.0000	1.000			-0.0066	0.998					-0.0121	0.998
P3 dev. for 1985 (survey)			-0.0522	0.998			0.0117	0.999					0.0072	0.999
P3 dev. for 1986 (survey)			-0.0012	1.000			-0.0113	0.998					-0.0113	0.998

Table 2.1.5e—Selectivity parameter *dev*s (page 5 of 5).

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.4		Model 17.5		Model 17.6	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
P3 dev. for 1987 (survey)			0.0046	1.000			0.0021	0.999					0.0023	0.999
P3 dev. for 1988 (survey)			0.0000	1.000			-0.0078	0.998					-0.0104	0.998
P3 dev. for 1989 (survey)			0.0000	1.000			-0.0040	0.998					-0.0016	0.999
P3 dev. for 1990 (survey)			0.0077	1.000			0.0107	0.999					0.0055	0.999
P3 dev. for 1991 (survey)			0.0007	1.000			-0.0015	0.999					-0.0015	0.999
P3 dev. for 1992 (survey)			-0.0168	0.999			-0.0530	0.999					-0.0163	1.001
P3 dev. for 1993 (survey)			0.0088	1.000			0.0134	0.999					0.0102	1.000
P3 dev. for 1994 (survey)			-0.0017	1.000			-0.0113	0.998					-0.0091	0.999
P3 dev. for 1995 (survey)			-0.0001	1.000			-0.0106	0.997					-0.0087	0.998
P3 dev. for 1996 (survey)			0.0000	1.000			-0.0063	0.998					-0.0036	0.998
P3 dev. for 1997 (survey)			0.0007	1.000			-0.0058	0.999					-0.0092	0.999
P3 dev. for 1998 (survey)			0.0000	1.000			-0.0056	0.998					-0.0078	0.998
P3 dev. for 1999 (survey)			0.0000	1.000			-0.0122	0.998					-0.0119	0.998
P3 dev. for 2000 (survey)			0.0042	1.000			0.0023	0.999					-0.0010	0.999
P3 dev. for 2001 (survey)			0.0056	1.000			0.0168	1.000					0.0122	1.000
P3 dev. for 2002 (survey)			0.0019	1.000			-0.0001	0.999					0.0044	0.999
P3 dev. for 2003 (survey)			0.0083	1.000			0.0121	0.999					0.0078	0.999
P3 dev. for 2004 (survey)			0.0015	1.000			0.0011	0.999					-0.0012	0.999
P3 dev. for 2005 (survey)			-0.0416	0.998			0.0168	1.000					0.0093	1.000
P3 dev. for 2006 (survey)			0.0092	1.000			0.0171	1.000					0.0121	1.000
P3 dev. for 2007 (survey)			0.0001	1.000			0.0007	1.000					0.0003	1.000
P3 dev. for 2008 (survey)			0.0059	1.000			0.0085	0.999					0.0110	1.000
P3 dev. for 2009 (survey)			0.0083	1.000			0.0154	1.000					0.0111	1.000
P3 dev. for 2010 (survey)			0.0000	1.000			-0.0127	0.998					-0.0080	0.999
P3 dev. for 2011 (survey)			0.0091	1.000			0.0167	1.000					0.0124	1.000
P3 dev. for 2012 (survey)			0.0089	1.000			0.0154	1.000					0.0124	1.000
P3 dev. for 2013 (survey)			-0.0017	0.999			-0.0091	0.998					-0.0097	0.999
P3 dev. for 2014 (survey)			0.0075	1.000			0.0113	0.999					0.0068	0.999
P3 dev. for 2015 (survey)			0.0063	1.000			0.0021	0.999					0.0081	0.999
P3 dev. for 2016 (survey)			0.0075	1.000			-0.0127	0.998					0.0013	0.999

Table 2.1.5f—Length at age 1.5 *dev*s and log catchability *dev*s (Model 17.6 only).

	Model 17.6			Model 17.6	
Parameter	Est.	SD	Parameter	Est.	SD
Length at a=1.5 dev 1981	-0.5359	0.427	ln(catchability) dev 1982	0.1614	0.666
Length at a=1.5 dev 1982	-0.7982	0.261	ln(catchability) dev 1983	0.3407	0.795
Length at a=1.5 dev 1983	0.9574	0.439	ln(catchability) dev 1984	-0.4004	0.707
Length at a=1.5 dev 1984	0.5102	0.221	ln(catchability) dev 1985	0.0997	0.819
Length at a=1.5 dev 1985	-1.2744	0.369	ln(catchability) dev 1986	0.3132	0.771
Length at a=1.5 dev 1986	0.2554	0.248	ln(catchability) dev 1987	-0.2777	0.664
Length at a=1.5 dev 1987	-0.0492	0.350	ln(catchability) dev 1988	-0.7361	0.689
Length at a=1.5 dev 1988	-0.1767	0.327	ln(catchability) dev 1989	-2.3785	0.662
Length at a=1.5 dev 1989	-0.8144	0.242	ln(catchability) dev 1990	-2.1423	0.737
Length at a=1.5 dev 1990	0.0477	0.255	ln(catchability) dev 1991	-1.6903	0.767
Length at a=1.5 dev 1991	0.6069	0.226	ln(catchability) dev 1992	-0.9912	0.792
Length at a=1.5 dev 1992	0.0186	0.215	ln(catchability) dev 1993	0.5942	0.797
Length at a=1.5 dev 1993	0.6623	0.308	ln(catchability) dev 1994	2.3997	0.806
Length at a=1.5 dev 1994	0.4413	0.239	ln(catchability) dev 1995	2.1028	0.749
Length at a=1.5 dev 1995	0.3926	0.305	ln(catchability) dev 1996	1.2757	0.820
Length at a=1.5 dev 1996	0.3147	0.228	ln(catchability) dev 1997	0.1150	0.822
Length at a=1.5 dev 1997	-0.2994	0.302	ln(catchability) dev 1998	-0.7125	0.728
Length at a=1.5 dev 1998	-0.0665	0.234	ln(catchability) dev 1999	-0.9142	0.728
Length at a=1.5 dev 1999	-0.8790	0.239	ln(catchability) dev 2000	-0.9479	0.728
Length at a=1.5 dev 2000	0.6728	0.223	ln(catchability) dev 2001	0.5164	0.783
Length at a=1.5 dev 2001	0.7261	0.240	ln(catchability) dev 2002	-0.2599	0.750
Length at a=1.5 dev 2002	1.0125	0.221	ln(catchability) dev 2003	-0.4486	0.797
Length at a=1.5 dev 2003	0.6251	0.266	ln(catchability) dev 2004	-0.9435	0.725
Length at a=1.5 dev 2004	1.5300	0.224	ln(catchability) dev 2005	-0.8328	0.821
Length at a=1.5 dev 2005	-1.0112	0.238	ln(catchability) dev 2006	-1.1889	0.668
Length at a=1.5 dev 2006	-1.2023	0.208	ln(catchability) dev 2007	-1.0712	0.894
Length at a=1.5 dev 2007	-1.3981	0.264	ln(catchability) dev 2008	-1.5917	0.765
Length at a=1.5 dev 2008	-1.5726	0.214	ln(catchability) dev 2009	-1.0510	0.738
Length at a=1.5 dev 2009	-0.7864	0.338	ln(catchability) dev 2010	0.3033	0.806
Length at a=1.5 dev 2010	0.4275	0.208	ln(catchability) dev 2011	0.6953	0.747
Length at a=1.5 dev 2011	-1.8848	0.240	ln(catchability) dev 2012	0.9390	0.762
Length at a=1.5 dev 2012	0.2161	0.270	ln(catchability) dev 2013	0.9669	0.900
Length at a=1.5 dev 2013	-0.1111	0.217	ln(catchability) dev 2014	1.7532	0.878
Length at a=1.5 dev 2014	0.3076	0.353	ln(catchability) dev 2015	2.0610	0.897
Length at a=1.5 dev 2015	2.0145	0.213	ln(catchability) dev 2016	1.8283	0.907

Table 2.1.6—Instantaneous fishing mortality rates (page 1 of 2).

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.4		Model 17.5		Model 17.6	
Year	Est	SD	Est	SD	Est	SD	Est	SD	Est	SD	Est	SD	Est	SD
1977	0.2443	0.090	0.7355	0.195	0.2734	0.098	0.2324	0.074	0.6410	0.134	0.4674	0.184	0.3312	0.123
1978	0.3135	0.120	0.6202	0.150	0.3108	0.110	0.2689	0.085	0.4392	0.088	0.9461	0.468	0.3939	0.150
1979	0.2447	0.091	0.2801	0.039	0.1975	0.060	0.1768	0.049	0.1927	0.023	0.4499	0.116	0.2512	0.081
1980	0.2739	0.087	0.3099	0.055	0.2209	0.067	0.1997	0.056	0.2179	0.031	0.4832	0.141	0.2794	0.089
1981	0.1781	0.034	0.1294	0.013	0.1087	0.020	0.1071	0.020	0.0967	0.010	0.1372	0.024	0.1220	0.025
1982	0.0958	0.012	0.2276	0.040	0.1439	0.037	0.1358	0.033	0.2117	0.032	0.2041	0.061	0.1642	0.046
1983	0.1107	0.011	0.2584	0.031	0.1499	0.024	0.1447	0.023	0.2601	0.033	0.2305	0.038	0.1683	0.029
1984	0.1509	0.013	0.3326	0.034	0.1906	0.023	0.1843	0.024	0.3575	0.041	0.2914	0.038	0.2077	0.026
1985	0.1677	0.014	0.2330	0.013	0.1807	0.015	0.1811	0.018	0.2321	0.020	0.2230	0.009	0.1918	0.016
1986	0.1696	0.013	0.2065	0.012	0.1775	0.014	0.1752	0.017	0.1891	0.014	0.2336	0.010	0.1916	0.016
1987	0.1814	0.012	0.2172	0.012	0.2001	0.016	0.1965	0.019	0.1928	0.013	0.2804	0.015	0.2186	0.019
1988	0.2421	0.016	0.2357	0.011	0.2105	0.014	0.2057	0.017	0.2384	0.016	0.2519	0.012	0.2217	0.016
1989	0.2046	0.012	0.2821	0.016	0.2207	0.019	0.2136	0.019	0.3044	0.023	0.2613	0.018	0.2328	0.021
1990	0.2293	0.013	0.3300	0.015	0.2843	0.021	0.2746	0.023	0.3184	0.018	0.3791	0.023	0.3033	0.024
1991	0.4036	0.023	0.4219	0.016	0.3788	0.021	0.3702	0.025	0.4298	0.025	0.4621	0.019	0.3837	0.022
1992	0.4874	0.035	0.4259	0.018	0.4222	0.026	0.3990	0.030	0.3973	0.023	0.5137	0.017	0.4235	0.028
1993	0.3732	0.028	0.2340	0.010	0.2679	0.021	0.2382	0.019	0.2349	0.015	0.3183	0.026	0.2650	0.022
1994	0.4021	0.026	0.3559	0.014	0.3933	0.030	0.3524	0.027	0.3022	0.015	0.3835	0.018	0.3921	0.029
1995	0.5087	0.032	0.4293	0.012	0.4434	0.025	0.4128	0.023	0.3862	0.017	0.5183	0.021	0.4415	0.025
1996	0.4701	0.031	0.5465	0.018	0.5613	0.038	0.5233	0.034	0.4801	0.021	0.6999	0.038	0.5637	0.036
1997	0.5183	0.034	0.6619	0.026	0.6302	0.052	0.6231	0.048	0.6034	0.030	0.6135	0.026	0.6952	0.054
1998	0.4160	0.029	0.5181	0.018	0.4638	0.030	0.4824	0.033	0.4525	0.023	0.5164	0.017	0.5119	0.033
1999	0.4245	0.031	0.4969	0.018	0.4444	0.031	0.4623	0.033	0.4349	0.024	0.5184	0.020	0.4885	0.033
2000	0.4082	0.031	0.5093	0.022	0.4758	0.038	0.4852	0.040	0.4296	0.025	0.4709	0.020	0.5240	0.041
2001	0.3265	0.022	0.3943	0.018	0.3677	0.032	0.3699	0.033	0.3342	0.020	0.3391	0.015	0.4210	0.039
2002	0.3917	0.025	0.3546	0.012	0.3383	0.019	0.3320	0.020	0.3072	0.017	0.3733	0.010	0.3537	0.020
2003	0.4225	0.027	0.3705	0.012	0.3737	0.021	0.3603	0.021	0.3213	0.016	0.4021	0.011	0.3880	0.021
2004	0.4008	0.023	0.3718	0.010	0.3795	0.020	0.3600	0.019	0.3347	0.015	0.3496	0.007	0.3876	0.020

Table 2.1.6—Instantaneous fishing mortality rates (page 2 of 2).

	Model 16.6		Model 17.1		Model 17.2		Model 17.3		Model 17.4		Model 17.5		Model 17.6	
Year	Est	SD	Est	SD	Est	SD	Est	SD	Est	SD	Est	SD	Est	SD
2005	0.4099	0.022	0.4241	0.010	0.4089	0.018	0.4005	0.018	0.3931	0.016	0.4026	0.008	0.4153	0.018
2006	0.4686	0.027	0.5403	0.013	0.5246	0.024	0.5088	0.025	0.5028	0.019	0.4761	0.012	0.5251	0.024
2007	0.4547	0.028	0.6167	0.019	0.5918	0.036	0.5669	0.035	0.5658	0.022	0.5159	0.017	0.5827	0.037
2008	0.5608	0.038	0.7083	0.024	0.6979	0.047	0.6575	0.044	0.6161	0.026	0.6220	0.023	0.6583	0.047
2009	0.6879	0.056	0.8032	0.029	0.8246	0.064	0.7813	0.058	0.5891	0.023	0.6761	0.018	0.7586	0.052
2010	0.5254	0.043	0.8195	0.035	0.8866	0.083	0.8799	0.080	0.5359	0.017	0.7789	0.035	0.9112	0.081
2011	0.5332	0.041	0.9522	0.046	0.8791	0.091	0.9592	0.100	0.6899	0.022	0.6013	0.015	1.0693	0.121
2012	0.4964	0.040	1.0083	0.038	0.8987	0.072	0.9694	0.080	0.8225	0.024	0.9295	0.032	1.0030	0.077
2013	0.4044	0.033	0.6811	0.028	0.5780	0.054	0.6568	0.058	0.6997	0.024	0.9000	0.044	0.7597	0.063
2014	0.4534	0.042	0.9242	0.034	0.7112	0.054	0.8946	0.064	0.9311	0.043	1.1662	0.044	0.9126	0.048
2015	0.3915	0.038	0.9133	0.072	0.6444	0.073	0.8397	0.109	1.4220	0.096	1.0274	0.035	0.8692	0.086
2016	0.3433	0.034	0.7756	0.106	0.4695	0.061	0.7358	0.144	0.2555	0.028	0.9690	0.064	0.7815	0.119

Table 2.1.7—Effective number of parameters (nyrs = length of *dev* vector, npar = effective parameters).

	M16.6		M17.1		M17.2		M17.3		M17.4		M17.5		M17.6	
Vector	nyrs	npar	nyrs	npar	nyrs	npar	nyrs	npar	nyrs	npar	nyrs	npar	nyrs	npar
Recruitment	39	22	39	11	39	20	39	11	39	1	39	17	39	8
Length at a=1.5													35	35
ln(Catchability)													35	1
Sel_fish_P1			40	3	40	2	40	2	40	3	40	1	40	2
Sel_fish_P3			40	3	40	1	40	1	40	1	40	3	40	1
Sel_surv_P1			35	1			35	1	35	1	35	35	35	1
Sel_surv_P3			35	1			35	1					35	1
Sum	39	22	189	19	119	23	189	16	154	6	154	56	259	49
Nominal parms		77		226		156		227		190		190		297
Effective parms		60		56		60		54		42		92		87

Figures

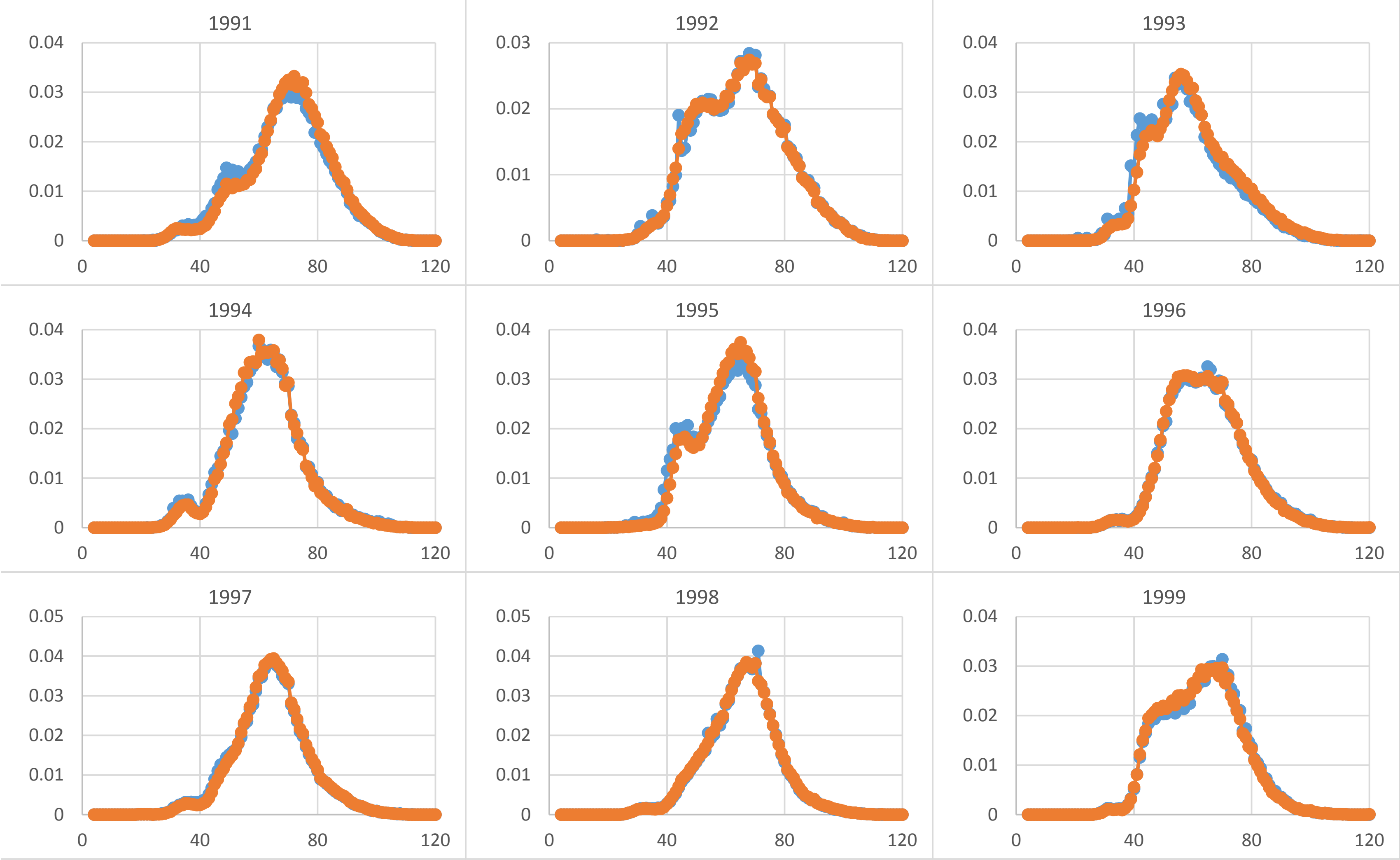

Figure 2.1.1 (page 1 of 3). Comparison of sizecomp data used in last year's assessment (orange) with catch-weighted sizecomp data (blue).

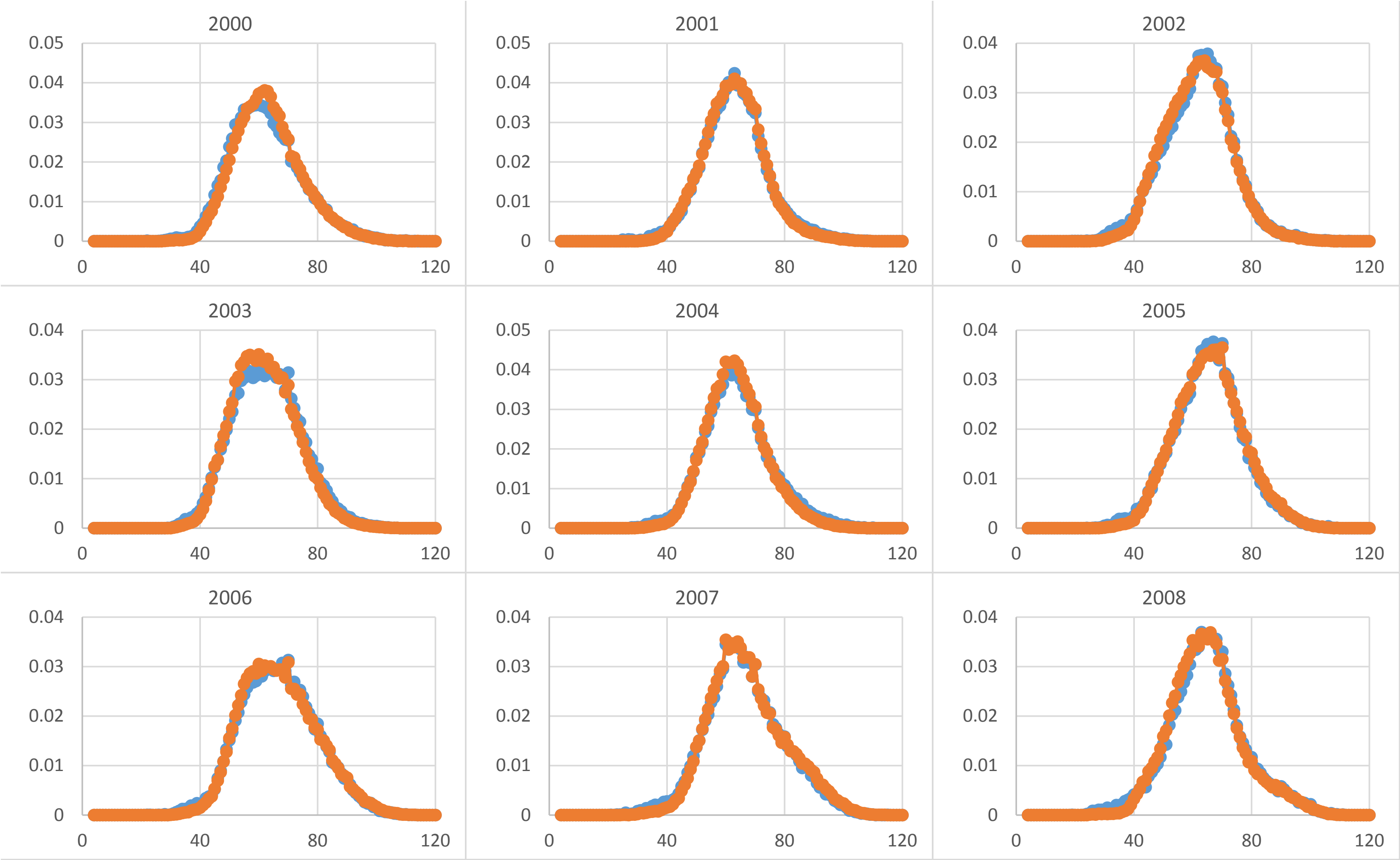

Figure 2.1.1 (page 2 of 3). Comparison of sizecomp data used in last year’s assessment (orange) with catch-weighted sizecomp data (blue).

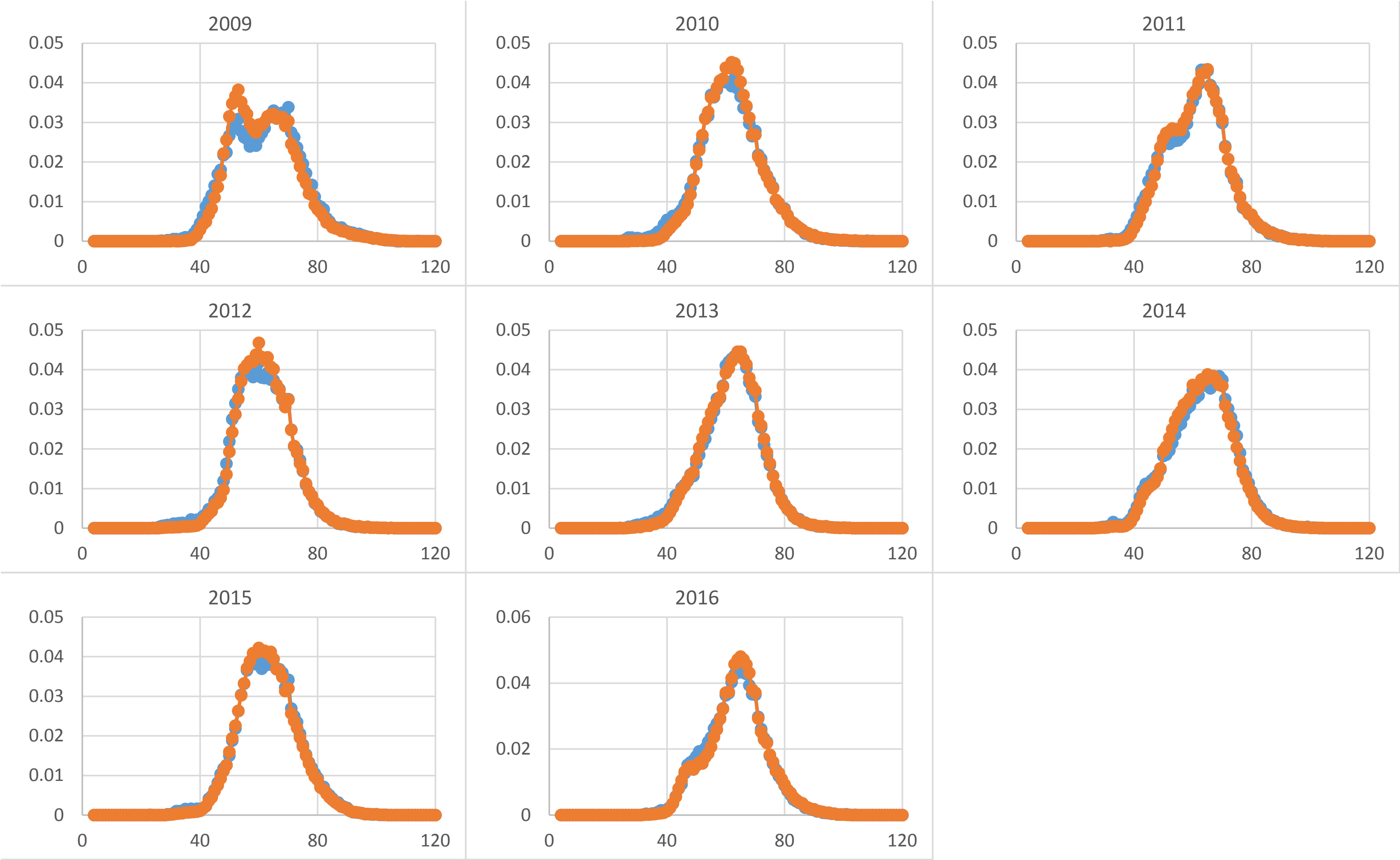

Figure 2.1.1 (page 3 of 3). Comparison of sizecomp data used in last year's assessment (orange) with catch-weighted sizecomp data (blue).

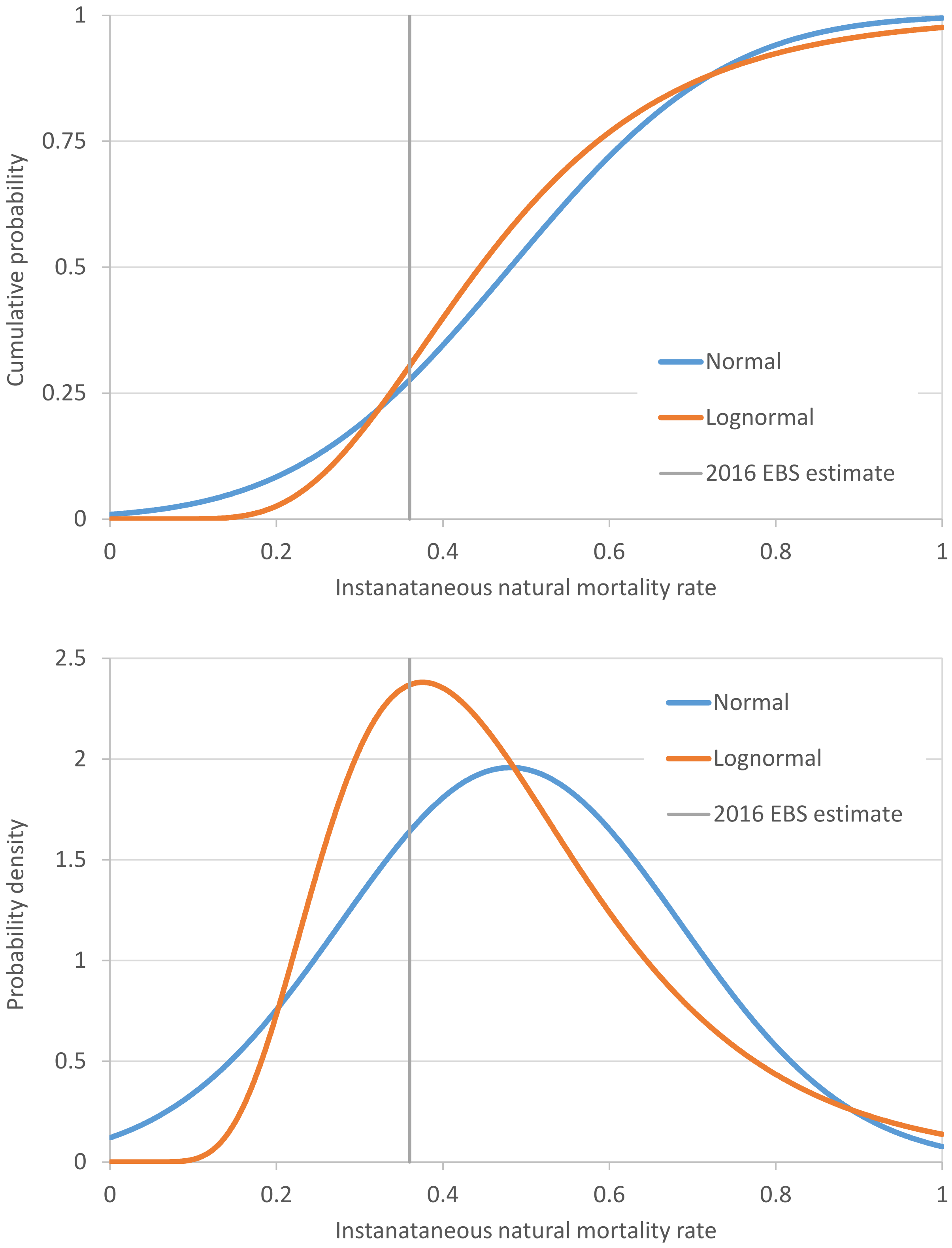

Figure 2.1.2. Prior distribution of the instantaneous natural mortality rate.

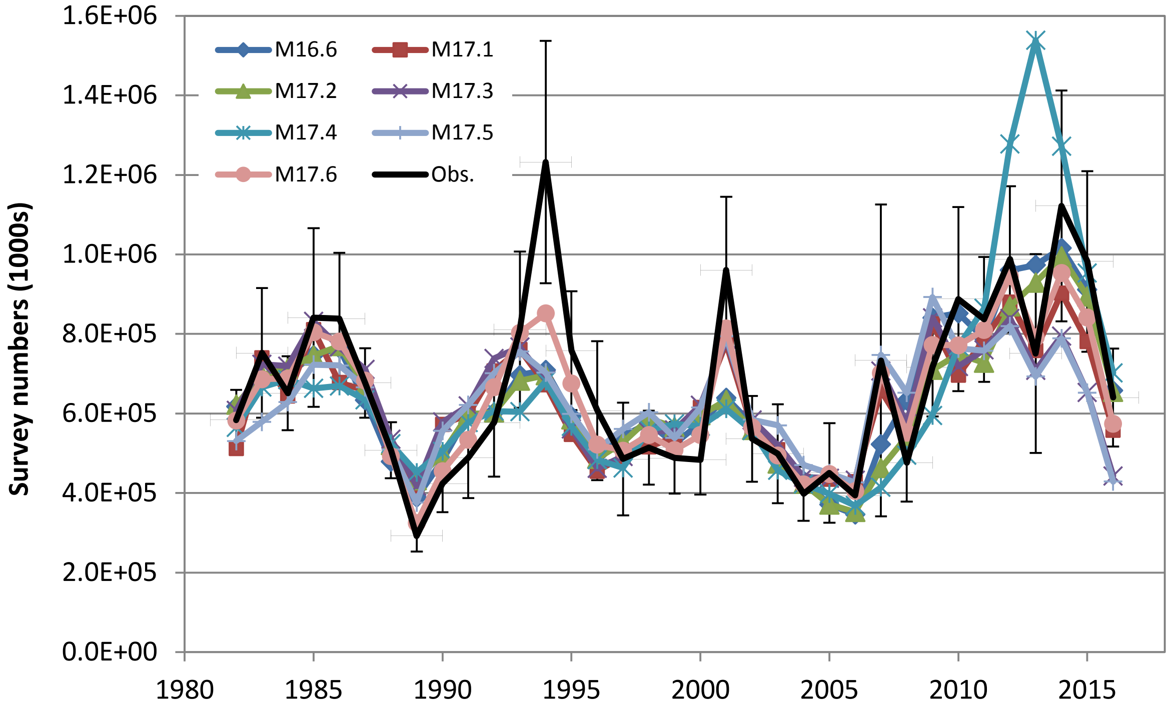

Figure 2.1.3. Model fits to survey abundance.

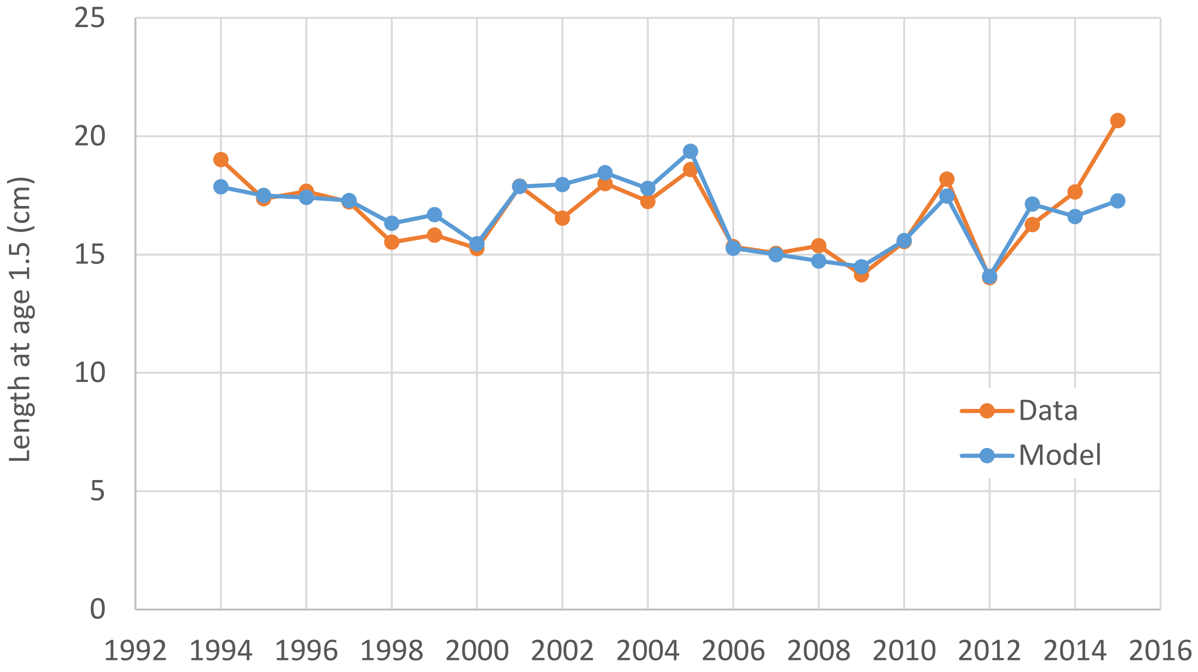

Figure 2.1.4. Model 17.6 fit to mean length at age 1.5 data.

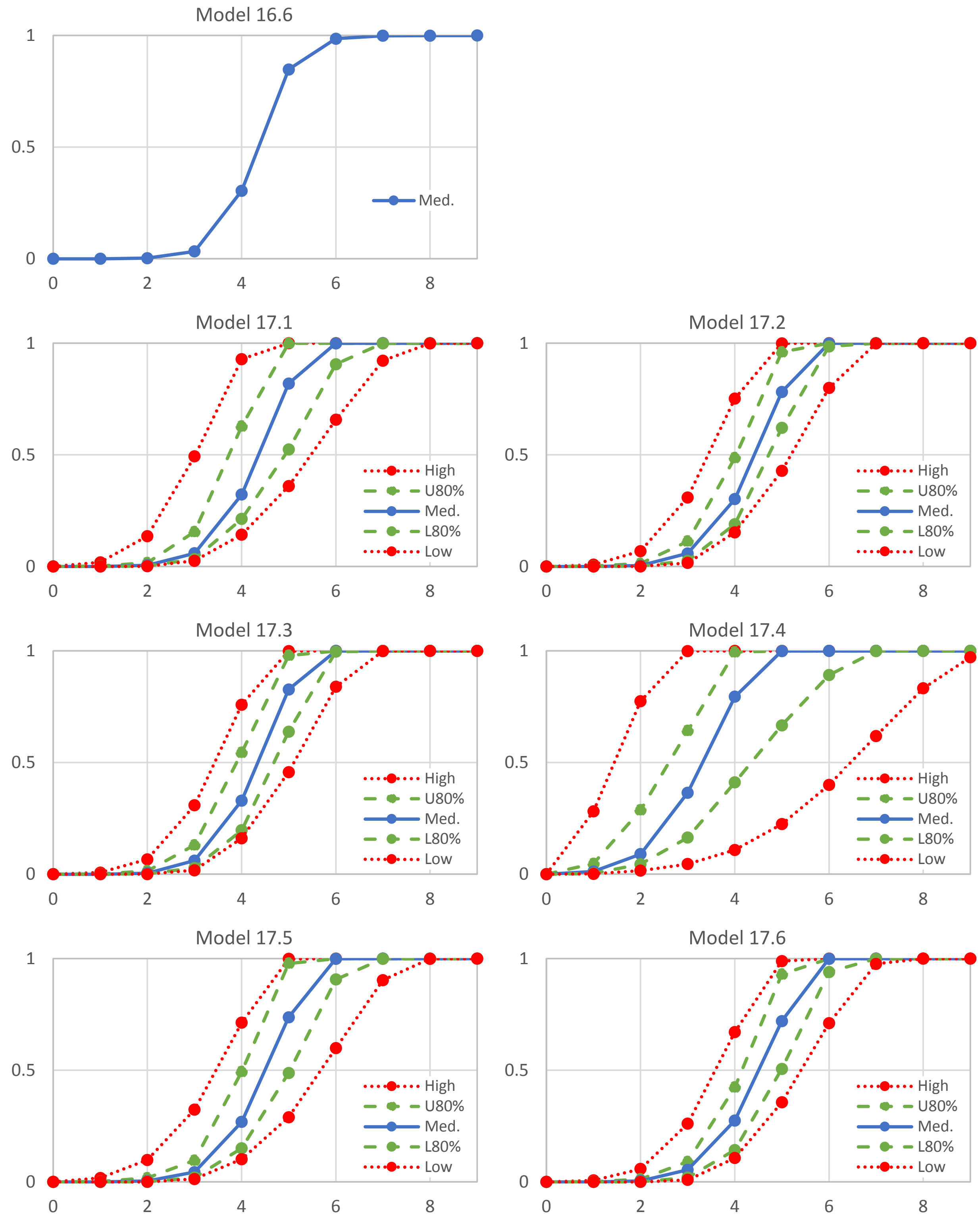

Figure 2.1.5a—Model estimates of fishery selectivity.

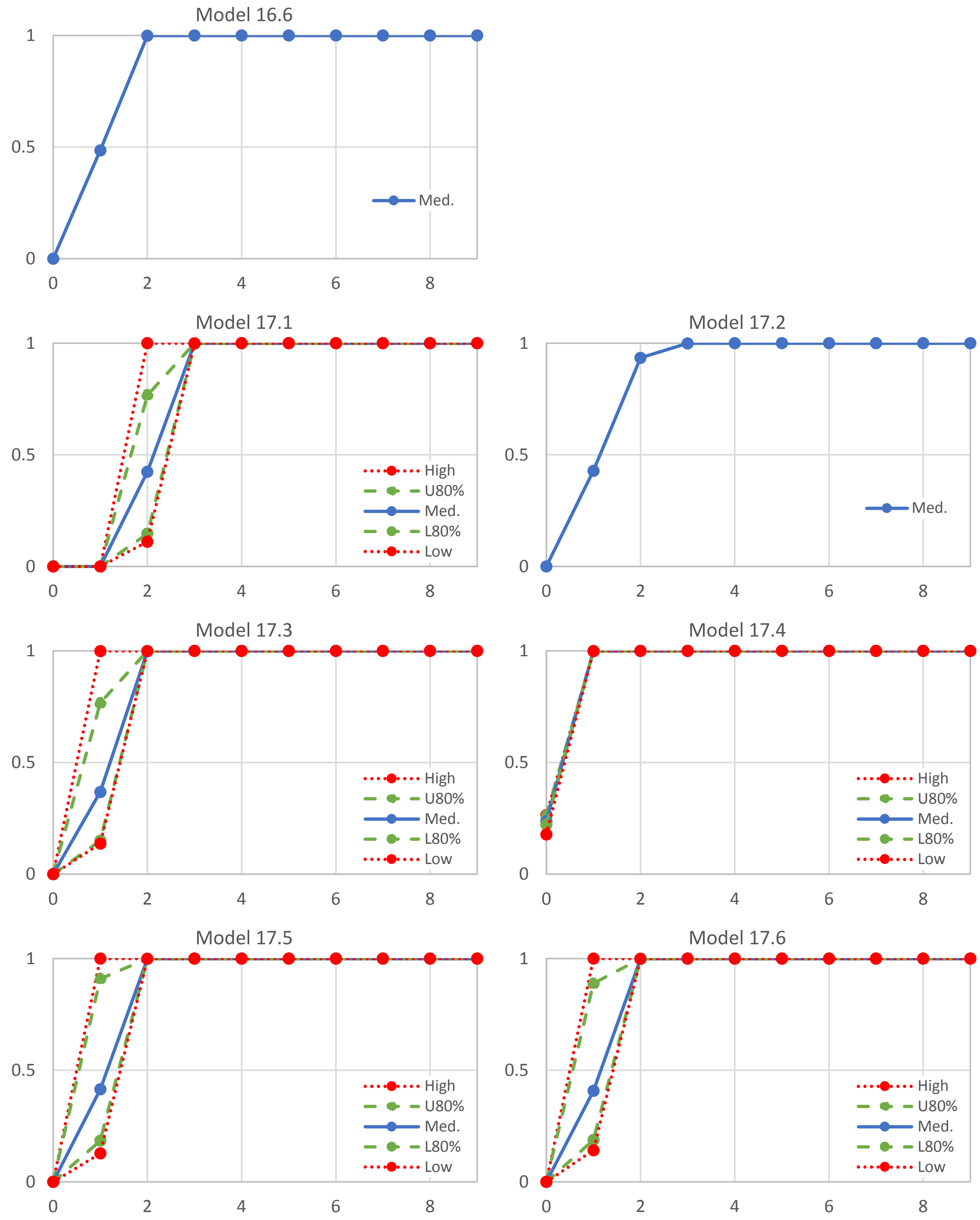

Figure 2.1.5b—Model estimates of survey selectivity.

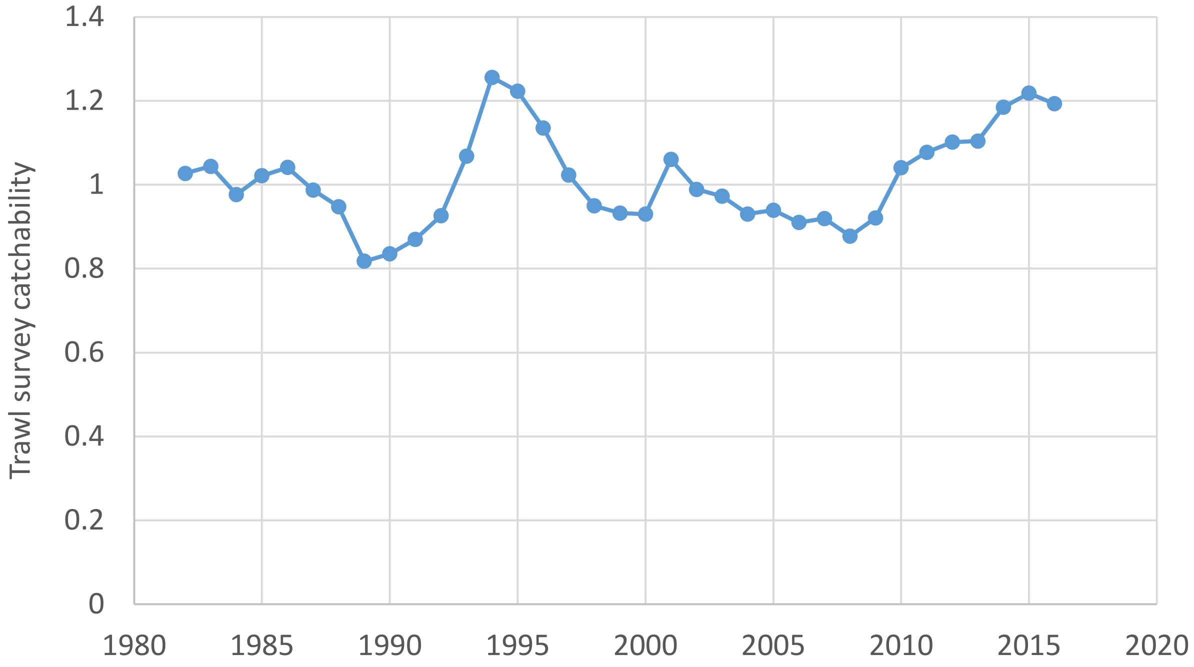

Figure 2.1.6. Trawl survey catchability time series as estimated by Model 17.6.

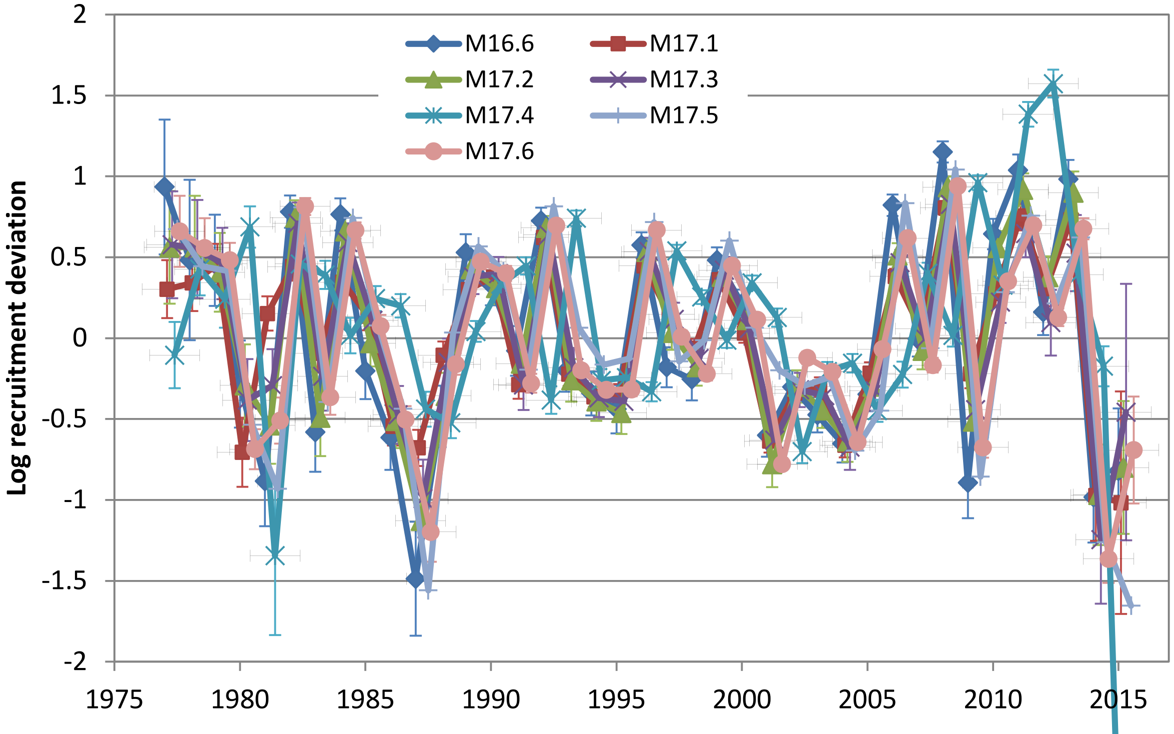

Figure 2.1.7. Recruitment *devs* estimated by the models.

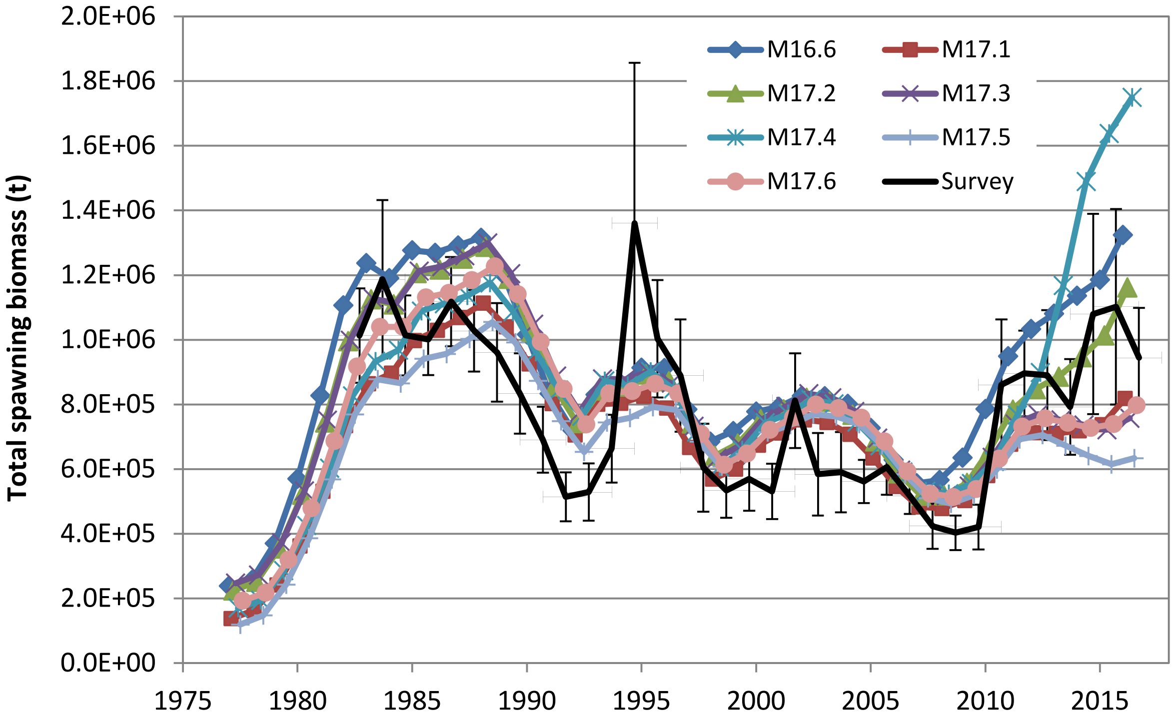

Figure 2.1.8. Model estimates of total (age 0+) biomass, with survey biomass for comparison.

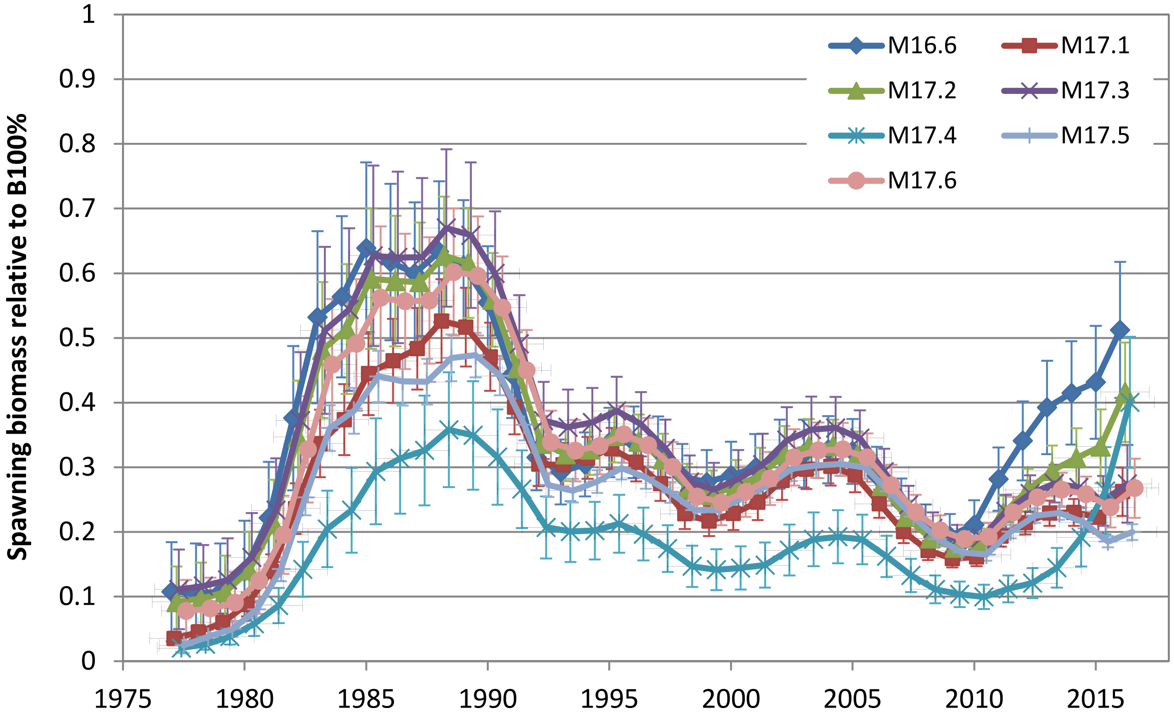

Figure 2.1.9. Model estimates of female spawning biomass relative to $B_{100\%}$.

Figure 2.1.10. Distributions of the 2018 ABC based on model averaging.

APPENDIX 2.2: BSAI PACIFIC COD ECONOMIC PERFORMANCE REPORT FOR 2016

Ben Fissel

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

Pacific cod is the second largest species in terms of catch in the Bering Sea & Aleutian Island (BSAI) region. Pacific cod accounted for 13% of the BSAI's FMP groundfish harvest and 80% of the total Pacific cod harvest in Alaska. Retained catch of Pacific cod increased 8% to 257.5 thousand t in 2016 and was 43% higher than the 2007-2011 average (Table 2.2.1). The products made from BSAI Pacific cod had a first-wholesale value of $387 million in 2016, which was up from $365 million in 2015 and above the 2007-2011 average of $307 million (Table 2.2.2). The higher revenue is the result of increased catch and production levels and strong first-wholesale fillet price for Pacific cod products.

Cod is an iconic fishery with a long history of production across much of the globe. Global catch was consistently over 2 million t through the 1980s, but began to taper off in the 1990s as cod stocks began to collapse in the northwest Atlantic Ocean. Over roughly the same period, the U.S. catch of Pacific cod (caught in Alaska) grew to approximately 250 thousand tons where it remained throughout the early to mid-2000s. European catch of Atlantic cod in the Barents Sea (conducted mostly by Russia, Norway, and Iceland) slowed and global catch hit a low in 2007 at 1.13 million t. U.S. Pacific cod's share of global catch was at a high at just over 20% in the early 2000s. Since 2007 global catch has grown to 1.85 million t in 2014 as catch in the Barents Sea has rebounded and U.S. catch has remained strong at over 300 thousand t since 2011. European Atlantic cod and U.S. Pacific cod remain the two major sources supplying the cod market over the past decade accounting for roughly 75% and 20%, respectively. Atlantic cod and Pacific cod are substitutes in the global market. Because of cod's long history global demand is present in a number of geographical regions, but Europe, China, Japan, and the U.S. are the primary markets for many Pacific cod products. The market for cod is also indirectly affected by activity in the pollock fisheries which experienced a similar period of decline in 2008-2010 before rebounding. Cod and pollock are commonly used to produce breaded fish portions. Alaska caught Pacific cod in the BSAI became certified by the Marine Stewardship Council (MSC) in 2010, a NGO based third-party sustainability certification, which some buyers seek.

The Pacific cod total allowable catch (TAC) is allocated to multiple sectors (fleets). CDQ entities receive 10% of the total BSAI quota. The largest sectoral allocation goes to the Freezer longline CPs which receive roughly 44% of the total BSAI cod quota (48.7% non-CDQ quota). While not an official catch share program, the Freezer longline CPs have formed a voluntary cooperative that allows them to form private contracts among members to distribute the sectoral allocation. The remaining large sectors are the trawl CPs, trawl CVs, the pot gear CVs and some smaller sideboard limits to cover the catch of Pacific cod while targeting other species. The CVs (collectively referred to as the inshore sector) make deliveries to shore-based processors, and catcher/processors process catch at-sea before going directly to the wholesale markets. Among the at-sea CPs, catch is distributed approximately three-quarters to the hook-and-line and one quarter to trawl. The inshore sector accounts for 25%-30% of the total BSAI Pacific cod catch of which approximately two-thirds is caught by the trawl and one-third by the pot gear sectors. The retained catch of the inshore sector increased 26% increase to 86 thousand t. The value of these deliveries (shoreside ex-vessel value) totaled $44.6 million in 2016, which was up 31% from 2015, as ex-vessel prices also increased 6% to $0.26 per pound. Changes in ex-vessel prices over time generally reflect changes in the corresponding wholesale prices. Catch from the fixed gear vessels (which includes hook-and-line and pot gear) typically receive a slightly higher price from processors because they incur less damage when caught. The fixed gear price premium has varied over time but recently has been about $0.03 per pound.

The first-wholesale value of Pacific cod products was up 6% to $386.8 million in 2016, and revenues in recent years remain high as result of strong catch levels (Table 2.2.2). The average price of Pacific cod products in 2016 increased 1% to $1.39. Head and gut (H&G) production is the focus of the BSAI processors but a significant amount of fillets are produced as well. H&G typically constitutes approximately 80% of value and fillets approximately 10% of value. Shoreside processors produce the majority of the fillets. Almost all of the at-sea sector's catch is processed into H&G. Other product types are not produced in significant quantities. At-sea head and gut prices tend to be about 20%-30% higher, in part because of the shorter period of time between catch and freezing, and in part because the at-sea sector is disproportionately caught by hook-and-line which yields a better price. Head & gut prices bottomed out at $1.05 per pound in 2013, a year in which Barents Sea cod catch increased roughly 240 thousand t (an increase that is approximately the size of Alaska's cod total catch) but rebounded to $1.37 in 2015. The H&G price was down 5% at $1.30 per pound in 2016. Fillet prices steady declined from over $3 in 2011 to $2.67 in 2015, but prices increased 23% in 2016 to $3.29. Changes in global catch and production account for much the trends in the cod markets. In particular, the average first-wholesale prices peaked at over $1.80 per pound in 2007-2008 and subsequent declined precipitously in 2009 to $1.20 per pound as markets priced in consecutive years of approximately 100 thousand t increases in the Barents Sea cod catch in 2009-2011; coupled with reduced demand from the recession. Average first-wholesale prices since have fluctuated between approximately $1.20 and $1.55 per pound. Media reports indicate that Pacific cod prices were soft in early 2016 with weak demand from Japan, an important consumer market for Pacific cod. By the middle of the year prices had begun to rise with strong demand from the U.S., Japan, and other markets. High prices of common fish protein substitutes such as salmon were also cited as contributing to the strong cod demand. Strong demand globally coupled with tight supply have resulted in high prices continuing throughout 2017. The market for H&G products was comparatively weaker than the market for fillets which is reflected in decreased H&G price and increased fillet price which affected the BSAI Pacific cod fisheries which produce a higher proportion of H&G.

U.S. exports of cod are roughly proportional to U.S. cod production. More than 90% of the exports are H&G, much of which goes to China for secondary processing and re-export (Table 2.2.3). China's rise as re-processor is fairly recent. Between 2001 and 2011 exports to China have increased nearly 10 fold. Japan and Europe (mostly Germany and the Netherlands) are also important export destinations. Approximately 30% of Alaska's cod production is estimated to remain in the U.S.. Because U.S. cod production is approximately 20% of global production and the BSAI is approximately 75-80% of U.S. production, the BSAI Pacific cod is a significant component of the broader global cod market. However, strong demand and tight supply in 2017 from the U.S. and globally have contributed to high prices. With the Barents Sea quota reduced by 13% 2018 the global cod supply is expected to remain constrained relative to recent levels which could result in continued high price levels through 2018.

Table 2.2.1. Bering Sea & Aleutian Islands Pacific cod catch and ex-vessel data. Total and retained catch (thousand metric tons), number of vessel, catcher/processor (CP) hook-and-line (H&L) share of catch, CP trawl share of catch, Shoreside retained catch (thousand metric tons), shoreside number of vessel, shoreside pot gear share of catch, shoreside trawl share of catch, shoreside ex-vessel value and price (million US$), and fixed gear to trawl price premium (US$ per pound); 2007-2011 average and 2012-2016.

	Avg 07-11	2012	2013	2014	2015	2016
Total catch K mt	182.7	251	250.2	249.3	242	260.8
Retained catch K mt	179.8	246.5	243.5	244.4	238.9	257.5
Vessels #	189	175	175	156	149	162
CP H&L share of BSAI catch	53%	52%	50%	50%	54%	49%
CP trawl share of BSAI catch	17%	15%	18%	14%	15%	14%
Shoreside retained catch K mt	51.0	75.2	71.1	79.0	68.3	85.9
Shoreside catcher vessels #	131	121	125	109	100	110
CV pot gear share of BSAI catch	9%	11%	11%	14%	12%	15%
CV trawl share of BSAI catch	18%	20%	18%	17%	16%	18%
Shoreside ex-vessel value M $	$36.6	$49.0	$37.0	$44.7	$34.1	$44.6
Shoreside ex-vessel price lb $	$0.326	$0.323	$0.244	$0.274	$0.248	$0.264
Shoreside fixed gear ex-vessel price premium	$0.06	$0.03	$0.01	$0.03	$0.03	$0.03

Source: NMFS Alaska Region Blend and Catch-accounting System estimates; NMFS Alaska Region At-sea Production Reports; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

Table 2.2.2. Bering Sea & Aleutian Islands Pacific cod first-wholesale market data. First-wholesale production (thousand metric tons), value (million US$), price (US$ per pound); fillet and head and gut volume (thousand metric tons), value share, and price (US$ per pound); At-sea share of value and at-sea shoreside price difference (US$ per pound); 2007-2011 average and 2012-2016.

		Avg 07-11	2012	2013	2014	2015	2016
All products	**volume K mt**	88.96	122.67	121.70	123.51	120.47	126.36
All products	**Value M $**	$ 306.6	$ 380.9	$ 303.7	$ 353.8	$ 365.1	$ 386.8
All products	**price lb $**	$ 1.56	$ 1.41	$ 1.13	$ 1.30	$ 1.37	$ 1.39
Fillets	**volume K mt**	4.72	6.76	8.79	8.42	6.28	10.03
Fillets	**value share**	11%	12%	18%	14%	10%	19%
Fillets	**price lb $**	$ 3.14	$ 3.10	$ 2.84	$ 2.68	$ 2.67	$ 3.29
Head & Gut	**volume K mt**	73.29	104.24	97.76	100.56	100.82	98.65
Head & Gut	**value share**	82%	82%	74%	79%	83%	73%
Head & Gut	**price lb $**	$ 1.56	$ 1.37	$ 1.05	$ 1.26	$ 1.36	$ 1.30
At-sea	**value share**	74%	71%	69%	69%	76%	70%
At-sea	**price premium ($/lb)**	-$0.03	-$0.13	-$0.28	-$0.01	$0.07	-$0.29

Source: NMFS Alaska Region Blend and Catch-accounting System estimates; NMFS Alaska Region At-sea Production Reports; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

Table 2.2.3. Cod U.S. trade and global market data. Global production (thousand metric tons), U.S. share of global production, and Europe's share of global production; U.S. export volume (thousand metric tons), value (million US$), and price (US$ per pound); U.S. cod consumption (estimated), and share of domestic production remaining in the U.S. (estimated); and the share of U.S. export volume and value for head and gut (H&G), fillets, China, Japan, and Germany and Netherlands; 2007-2011 average and 2012-2017.

		Avg 07-11	2012	2013	2014	2015	2016	2017 (thru July)
Global cod catch K mt		1,272	1,600	1,831	1,853	1,764	-	-
U.S. P. cod share of global catch		19.7%	20.7%	17.0%	17.7%	18.1%	-	-
Europe share of global catch		72.3%	73.2%	76.7%	75.9%	74.8%	-	-
Pacific cod share of U.S. catch		96.7%	98.6%	99.3%	99.3%	99.5%	-	-
U.S. cod consumption K mt (est.)		80	97	104	114	107	113	-
Share of U.S. cod not exported		25%	30%	31%	31%	26%	29%	-
Export volume K mt		90.3	111.1	101.8	107.3	113.2	105.2	67.7
Export value M US$		$286.3	$363.6	$308.0	$314.2	$335.0	$311.7	$208.0
Export price lb US$		$1.439	$1.485	$1.373	$1.328	$1.342	$1.344	$1.393
Frozen (H&G)	**volume Share**	68%	80%	91%	92%	91%	94%	94%
	value share	68%	80%	89%	91%	90%	92%	92%
Fillets	**volume Share**	13%	9%	4%	2%	3%	3%	5%
	value share	16%	11%	5%	4%	4%	4%	6%
China	**volume Share**	27%	46%	51%	54%	53%	55%	59%
	value share	25%	43%	48%	51%	51%	52%	57%
Japan	**volume Share**	18%	16%	13%	16%	13%	14%	12%
	value share	18%	16%	13%	16%	14%	15%	13%
Netherlands & Germany	**volume Share**	11%	8%	8%	9%	8%	5%	3%
	value share	12%	9%	9%	10%	8%	5%	3%

Notes: Pacific cod in this table is for all U.S. Unless noted, `cod' in this table refers to Atlantic and Pacific cod. Russia, Norway, and Iceland account for the majority of Europe's cod catch which is largely focused in the Barents Sea.

Source: FAO Fisheries & Aquaculture Dept. Statistics http://www.fao.org/fishery/statistics/en. NOAA Fisheries, Fisheries Statistics Division, Foreign Trade Division of the U.S. Census Bureau, http://www.st.nmfs.noaa.gov/commercial-fisheries/foreign-trade/index. U.S. Department of Agriculture http://www.ers.usda.gov/data-products/agricultural-exchange-rate-data-set.aspx.

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

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

Pre-2005

Timeline

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

Main features of the early Stock Synthesis EBS Pacific cod models

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

2005

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

Three models were included:

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

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

2006

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

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

2007

Technical workshop

SS introduced a six-parameter form of the double normal selectivity curve (the previous version used only four parameters). This functional form is constructed from two underlying and linearly rescaled normal distributions, with a horizontal line segment joining the two peaks. As configured in SS, the equation uses the following six parameters:

1. *beginning_of_peak_region* (where the curve first reaches a value of 1.0)
2. *width_of_peak_region* (where the curve first departs from a value of 1.0)

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

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

Model 0 was prepared ahead of workshop:

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

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

- Two models to examine inside/outside growth estimation:
  - Model 1 was identical to Model 0 except length-at-age parameters estimated outside the model
  - Model 2 was identical to Model 0 except standard deviation of length at age 12 estimated internally
- Two models to examine *M* conditional on *Q,* vice-versa:
  - Model 3 was identical to Model 0 except *M* fixed at 0.37 and *Q* free
  - Model 4 was identical to Model 0 except *Q* fixed at 0.75 and *M* free
- Six models to examine effects of prior distributions:
  - Model 5 was identical to Model 0 except 30% CV instead of 50%
  - Model 6 was identical to Model 0 except 40% CV instead of 50%
  - Model 7 was identical to Model 0 except emphasis = 0.2 instead of 1.0
  - Model 8 was identical to Model 0 except emphasis = 0.4 instead of 1.0
  - Model 9 was identical to Model 0 except emphasis = 0.6 instead of 1.0
  - Model 10 was identical to Model 0 except emphasis = 0.8 instead of 1.0
- Four models to examine effects of asymptotic selectivity:
  - Model 11 was identical to Model 0 except Jan-May trawl fishery selectivity forced asymptotic
  - Model 12 was identical to Model 0 except longline fishery selectivity forced asymptotic
  - Model 13 was identical to Model 0 except pot fishery selectivity forced asymptotic
  - Model 14 was identical to Model 0 except shelf trawl survey selectivity forced asymptotic
- One model to examine estimation of stock-recruit relationship:
  - Model 15 was identical to Model 0 except parameters of a Ricker stock-recruitment relationship estimated internally
- Six models to address EBS-specific comments from the public:
  - Model 16 was identical to Model 0 except input *N* determined by iterative re-weighting
  - Model 17 was identical to Model 0 except input *N* for mean-size-at-age data decreased by an order of magnitude
  - Model 18 was identical to Model 0 except standard error from the shelf trawl survey doubled
  - Model 19 was identical to Model 0 except all age data removed
  - Model 20 was identical to Model 0 except slope survey data removed

    - Model 21 was identical to Model 0 except start year changed to 1982

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

Eight models were developed during the workshop itself:

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

Preliminary assessment
In general:

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

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

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

Also attempted but not included:

- Simplified model with only a single fishery and no seasons

Final assessment
Four models were included:

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

2008

Preliminary assessment
Five models were included:

- Model 1 was identical to the 2007 final model
- Model 2 was identical to Model 1 except growth parameter *L2* estimated externally
- Model 3 was identical to Model 1 except exponential-logistic selectivity used instead of double normal
- Model 4 was identical to 2007 Model 4
- Model 5 was identical to Model 1 except:
    - Fishery selectivity blocks (5 yr, 10 yr, 20 yr, or no blocks) chosen by AIC
    - Lower bound of descending "width" = 5.0
    - Regime-specific recruitment "dev" vectors

  - "SigmaR" set equal (iteratively) to stdev(dev) from current regime
  - Seasonal weight-length, based on fishery data
  - Number of free initial ages chosen by AIC
  - Size-at-age data used if modes ambiguous

Final assessment
Eight models were included:

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

2009

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

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

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

Other features explored but not included in the above models:

- Fixing trawl survey catchability at the mean of the above normal prior distribution
- Allowing trawl survey catchability to vary as a random walk
- Fixing trawl survey catchability at a value of 1.00 for the pre-1982 portion of the time series, but allowing it to be estimated freely for the post-1981 portion of the time series
- Reducing the number of survey selectivity parameters subject to annual deviations
- Use of additive, rather than multiplicative, deviations for certain survey selectivity parameters
- Decreasing the value of the σ parameter used to constrain annual survey selectivity deviations

- Turning off annual deviations in survey selectivity parameters for the three most recent years
- Turning off all annual deviations in survey selectivity parameters
- Forcing trawl survey selectivity to peak at age 6.5, the approximate mid-point of the size range of 60-81 cm spanned by the results of Nichol et al. (2007)
- Imposing a beta prior distribution on the shape parameter of the exponential-logistic selectivity function in the trawl survey.

Final assessment

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

- Models without mean-size-at-age data:
    - Model A1 was identical to the 2008 final model, with the addition of new data, including the first available fishery agecomp data (from the 2008 Jan-May longline fishery)
    - Model A2 was identical to Model A1, except all agecomp data omitted
    - Model A3 was identical to Model A1, except 2008 Jan-May longline fishery agecomp data omitted
    - Model F2 was identical to Model F2 from the final assessment for 2008
- Models with mean-size-at-age data and agecomp data:
    - **Model B1** was identical to Model A1 except:
        - Survey selectivity held constant for most recent two years
        - Cohort-specific growth included
        - Input standard deviations of all “dev” vectors were set iteratively by matching the standard deviations of the set of estimated *dev*s
        - Standard deviation of length at age was estimated outside the model as a linear function of mean length at age
        - Selectivity at maximum size or age was treated as a controllable parameter
        - Q for the post-1981 trawl survey was fixed at the value that sets the average (weighted by numbers at length) of the product of Q and selectivity for the 60-81 cm size range equal to the point estimate of 0.47 obtained by Nichol et al. (2007)
        - Potential ageing bias was accounted for in the ageing error matrix by examining alternative bias values in increments of 0.1 for ages 2 and above (age-specific bias values were also examined, but did not improve the fit significantly).
    - Model C1 was identical to Model B1 except:
        - Input standard deviations for all “dev” vectors and the amount of ageing bias fixed at the values obtained iteratively in Model B1
        - *Catchability itself* (rather than the average product of catchability and selectivity for the 60-81 cm size range) set equal to 0.47
    - Model D1 was identical to Model B1 except:
        - Input standard deviations for all “dev” vectors and the amount of ageing bias fixed at the values obtained iteratively in Model B1
        - Selectivity at maximum size or age was removed from the set of controllable parameters (instead, selectivity at maximum size or age becomes a function of other selectivity parameters)
    - Model E1 was identical to Model B1 except:
        - Input standard deviations for all “dev” vectors and the amount of ageing bias fixed at the values obtained iteratively in Model B1
        - Selectivity at maximum size or age for all non-asymptotic fleets was set equal to a single value that was constant across fleets
    - Model G1 was identical to Model B1 except:

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

2010

Preliminary assessment
Six models were included:

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

Final assessment
Three models were included:

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

2011

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

    - All sizecomp data turned on
    - Nine season × gear fisheries consolidated into five seasonal fisheries
    - Pre-1982 trawl survey data omitted
    - Mean-size-at-age data omitted
    - Fishery CPUE data omitted

  - Average input *N* set to 100 for all fisheries and the survey
  - First reference age for length-at-age relationship set at 0.833333
  - Richards growth implemented
  - Ageing bias estimated internally
  - Selectivities modeled as random walks with age (constant for ages 8+)

Twelve new models were developed during the review itself:

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

Preliminary assessment
Seven models were included:

- Model 1 was identical to the 2010 final model
- Model 2a was identical to Model 1 except for use of spline-based selectivity
- Model 2b was identical to Model 1 except for omission of pre-1982 survey data
- Model 3 was identical to Model 2b except:
  - Ageing bias estimated internally rather than by trial and error
  - First reference age for length-at-age relationship (*amin*) set at 1.0
  - Standard deviation of length at age *amin* tuned iteratively to match the value predicted externally by regression
- Model 4 was identical to Model 2b except:
  - All agecomp data turned off
  - All sizecomp data turned on
  - First reference age for length-at-age relationship (*amin*) set at 1.0

    - Parameters governing standard deviation of length at age estimated internally
- Model A was identical to Model 2b except:
    - First reference age in the mean length-at-age relationship was set at 1.41667, to coincide with age 1 at the time of year when the survey takes place (in Models 1-2b, first reference age was set at 0; in Models 3-4, it was set at 1)
    - Richards growth equation was used (in Models 1-4, von Bertalanffy was used)
    - Ageing bias was estimated internally (as in Model 3; in Models 1-2 and 4, ageing bias was left at the values specified in the 2009 and 2010 assessments—although this was irrelevant for Model 4, which did not attempt to fit the age data)
    - σ_R was estimated internally (in Models 1-4, this parameter was left at the value used in the 2009 and 2010 assessments)
    - Fishery selectivity curves were defined for each of the five seasons, but were not stratified by gear type (in Models 1-4, seasons 1-2 and 4-5 were lumped into a pair of "super" seasons, and fisheries were also *gear*-specific)
    - Selectivity curve for the fishery that came closest to being asymptotic on its own (in this case, the season 4 fishery) was forced to be asymptotic by fixing both *width_of_peak_region* and *final_selectivity* at a value of 10.0 and *descending_width* at a value of 0.0 (in Models 1-4, the Jan-Apr trawl fishery was forced to exhibit asymptotic selectivity)
    - Survey selectivity was modeled as a function of length (in Models 1-4, survey selectivity was modeled as a function of age)
    - Number of estimated year class strengths in the initial numbers-at-age vector was set at 10 (in Models 1-4, only 3 elements were estimated)
    - The following parameters were tuned iteratively:
        - Standard deviation of length at the first reference age was tuned iteratively to match the value from the regression of standard deviation against length at age presented in the final assessment for 2010 (as in Model 3; in Models 1-2, this parameter was set at 0.01 because the first reference age was 0; in Model 4, it was estimated internally)
        - Base value for *Q* was tuned iteratively to set the average of the product of *Q* and survey selectivity across the 60-81 cm range equal to 0.47, corresponding to the Nichol et al. (2007) estimate (in Models 1-4, the base value was left at the value used in the 2009 and 2010 assessments)
        - *Q* was given annual (but not random walk) *dev*s, with σdev tuned iteratively to set the root-mean-squared-standardized-residual of the survey abundance estimates equal to 1.0 (in Models 1-4, *Q* was constant)
        - All estimated selectivity parameters were given annual random walk *dev*s with *σdev* tuned iteratively to match the standard deviation of the estimated *dev*s, except that the *dev*s for any selectivity parameter with a tuned σdev less than 0.005 were removed (in Models 1-4, certain fishery selectivity parameters were estimated independently in pre-specified blocks of years; the only time-varying selectivity parameter for the survey was *ascending_width*, which had annual—but not random walk—*dev*s with *σdev* set at the value used in the 2009 and 2010 assessments)
        - Age composition "variance adjustment" multiplier was tuned iteratively to set the mean effective sample size equal to the mean input sample size (in Models 1-4, this multiplier was fixed at 1.0)
- Model 5 was identical to Model A except that it used the time series of selectivity parameters estimated (using random walk *dev*s) in Model A to identify appropriate breakpoints for defining block-specific selectivity parameters

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

- Annually varying Brody growth parameter

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

Final assessment
Five models were included:

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

2012

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

- Model 1 was identical to the 2011 final model
    - Model 1.1: Same as Model 1, except survey catchability estimated internally
    - Model 1.2: Same as Model 1, except ageing bias parameters fixed at GOA values
    - Model 1.3 Same as Model 1, except with revised weight-length representation
- Model 2 was identical to Model 1, except survey catchability re-tuned to match archival tag data
- Model 3 was identical to Model 1, except new fishery selectivity period beginning in 2008
- Model 4 was identical to Model 4 from the final assessment for 2011
    - Model Pre5.1: Same as Model 1.3, except for three minor changes to the data file
    - Model Pre5.2: Same as Model Pre5.1, except ages 1-10 in the initial vector estimated individually
    - Model Pre5.3: Same as Model Pre5.2, except Richards growth curve used
    - Model Pre5.4: Same as Model Pre5.3, except σ for recruitment *dev*s estimated internally as a free parameter
    - Model Pre5.5: Same as Model Pre5.4, except survey selectivity modeled as a function of length
    - Model Pre5.6: Same as Model Pre5.5, except fisheries defined by season only (not season-and-gear)

- Model 5: Same as Model Pre5.6, except four quantities estimated iteratively:
    - Survey catchability tuned to match archival tag data
    - Agecomp *N* tuned to set the mean ratio of effective *N* to input *N* equal to 1
    - Selectivity *dev* sigmas tuned according to the new method described in Annex 2.1.1 of the SAFE chapter

Final assessment
Four models were included:

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

2013

Preliminary assessment
Four models were included:

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

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

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

2014

Preliminary assessment
Six models were included:

- Model 1 was identical to the 2011-2013 final models
- Model 2 was the identical to Model 5 from the 2012 preliminary assessment (also identical to Model 4 in the 2012 final assessment and the 2013 preliminary assessment)
- Model 3 was identical to Model 2, except that survey catchability *Q* was fixed at 1.0
- Model 4 was identical to Model 2, except that *Q* was estimated with a uniform prior and with an internally estimated constant added to each year's log-scale survey abundance standard deviation
- Model 5 was identical to Model 2, except that Q was fixed at 1.0, survey selectivity was forced to be asymptotic, and the natural mortality rate *M* was estimated freely
- Model 6 was a substantially new model, with the following differences from Model 1:
    - Each year consisted of a single season instead of five
    - A single fishery was defined instead of nine season-and-gear-specific fisheries
    - The survey was assumed to sample age 1 fish at true age 1.5 instead of 1.41667

  - Initial abundances were estimated for the first ten age groups instead of the first three
  - The natural mortality rate was estimated internally
  - The base value of survey catchability was estimated internally
  - Length at age 1.5 was allowed to vary annually
  - Survey catchability was allowed to vary annually
  - Selectivity for both the fishery and the survey were allowed to vary annually
  - Selectivity for both the fishery and survey was modeled using a random walk with respect to age (SS selectivity-at-age pattern #17) instead of the usual double normal
  - Several quantities were tuned iteratively: prior distributions for selectivity parameters, catchability, and time-varying parameters other than catchability

Final assessment
Two models were included:

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

2015

Preliminary assessment
Eight models were included.

Group A:

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

Subgroup B1:

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

For all models in Subgroup B1, selectivity prior distributions and the parameters governing time-variability in recruitment, selectivity, and survey catchability were *not* re-tuned. That is, they were left at the values estimated for Model 2 during the 2014 assessment, except that time variability in survey catchability was turned off in Model 3. Note that the tuning for Model 2 was performed during the 2014 *preliminary* assessment (where it was labeled Model 6), and was not updated during the final 2014 assessment.

Subgroup B2:

- Model 5 was based on Model 2, but had a number of differences (described below), one of which was that SS runs were accepted even if the gradient was large, so long as the estimated covariance matrix of the parameters appeared reasonable.
- Model 6 was the same as Model 5, except that SS runs were accepted only if the gradient was small. In the event that a large gradient was obtained, age-specific selectivity *dev* vectors were removed, one at a time, until the large gradient disappeared.

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

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

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

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

7. Compute the vector of σs corresponding to **V1**+**V2**.
8. Return to step 2 and repeat until the σs converge.

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

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

Final assessment
The final assessment included the same two models that were featured in the 2014 final assessment:

- **Model 11.5** was identical to the 2011-2014 final models
- Model 14.2 was identical to Model 2 from the 2014 final assessment

2016

Preliminary assessment
Six models were presented in this preliminary assessment, including Model 11.5 and five variants of Model 15.6, which was introduced in the 2015 preliminary assessment (where it was labeled "Model 6"). As described by the Joint Team Subcommittee (with subsequent re-numbering to adhere to the established model numbering convention), the full set of models consisted of the following:

- Model 11.5: BS Model 11.5, the final model from 2015
- Model 16.1: Like BS Model 15.6, but simplified as follows:
    - Weight abundance indices more heavily than sizecomps.
    - Use the simplest selectivity form that gives a reasonable fit.
    - Do not allow survey selectivity to vary with time.
    - Do not allow survey catchability to vary with time.
    - Force trawl survey selectivity to be asymptotic.
    - Do not allow strange selectivity patterns.
    - Use empirical weight at age.
- Model 16.2: Like Model 15.6, but including the IPHC longline survey data and other features, specifically:
    - Do not allow strange selectivity patterns.
    - Estimate catchability of new surveys internally with non-restrictive priors.
    - Include additional data sets to increase confidence in model results.
    - Include IPHC longline survey, with 'extra SD.'
- Model 16.3: Like Model 16.2 above, but including the NMFS longline survey instead of the IPHC longline survey.
- Model 16.4: Like Models 16.2 and 16.3 above, but including both the IPHC and NMFS longline survey data and two features not included in either Model 16.2 or 16.3, specifically:
    - Start including fishery agecomp data.
    - Use empirical weight at age.
- Model 16.5: Like Model 16.4 above, but including two features not included in Model 16.4, specifically:
    - Use either Francis or harmonic mean weighting.
    - Explore age-specific M (e.g., using Lorenzen function)."

Note that some points in the above lists of features may be somewhat duplicative, but were included by the JTS in order to address specific comments made by CIE reviewers. For Model 6, harmonic mean weighting (Punt in press) and the age-specific natural mortality function proposed by Lorenzen (1996, 2011) were used.

In the minutes of its May 2016 meeting, the JTS recognized that some of the terms used in the descriptions of its requested models were somewhat subjective and that, in making those requests, the assessment author would need to determine:

1. How to measure the "weight" assigned to abundance indices and size composition data in the same units (Model 16.1).
2. What constitutes a "reasonable fit" to the size/age composition data (Model 16.1).
3. What constitutes a "strange" selectivity pattern (Models 16.1-16.5).

These issues were addressed as follows:

1. The relative "weight" assigned to abundance indices and size composition data was determined by comparing the average spawning biomasses from three models:
    A. a model with a specified set of likelihood "emphasis" (λ) values, with each $\lambda \geq 1.0$;
    B. a model in which λ for the abundance data was set equal to 0.01 while each λ for the size composition data (fishery and survey) was left at the value specified in model A; and

C. a model in which each λ for the size composition data (fishery and survey) was set equal to 0.01 while each λ for the abundance data was left at the value specified in model B.

Model B was taken to represent model A with the *abundance* data "turned off," while model C was taken to represent model A with the *size composition* data "turned off" (a λ value of 0.01 rather than 0 was used for to represent "turning off" a data component because some parameters might prove inestimable if that data component were removed entirely). The abundance data in model A were determined to receive greater weight than the size composition data in that model if the absolute value of the proportional change in spawning biomass between models B and A exceeded the analogous value between models C and A. The JTS requested that this criterion (giving greater weight to abundance data than size composition data) be included in Model 16.1 only. As it turned out, the default λ value of 1.0 for all data components was sufficient to satisfy this criterion, so no adjustments to any of the λ values were necessary.

2. To focus on the ability of a particular functional form to fit the data, independent of the absolute values of the sample sizes specified for the associated multinomial distribution or λ values, weighted coefficients of determination (R^2), computed on both the raw and logit scales, were used to measure goodness of fit (the equations below are written in terms of age composition; the equations for size compositions are analogous):

$$R^2 = \sum_{y=ymin}^{ymax}\left(w_y \cdot \left(1 - \frac{\sum_{a=0}^{amax}\left(Pobs_{a,y} - Pest_{a,y}\right)^2}{\sum_{a=0}^{amax}\left(Pobs_{a,y} - Pobs_{ave,y}\right)^2}\right)\right) \quad ,$$

and

$$R^2 = \sum_{y=ymin}^{ymax}\left(w_y \cdot \left(1 - \frac{\sum_{a=0}^{amax}\left(logit\left(Pobs_{a,y}\right) - logit\left(Pest_{a,y}\right)\right)^2}{\sum_{a=0}^{amax}\left(logit\left(Pobs_{a,y}\right) - logit\left(Pobs_{ave,y}\right)\right)^2}\right)\right) \quad ,$$

where

$$w_y = \frac{n_y}{\sum_{i=ymin}^{ymax} n_i} \quad ,$$

$Pobs_{a,y}$ represents the observed proportion at age a in year y, $Pobs_{ave,y}$ represents the average (across ages) observed proportion in year y, $Pest_{a,y}$ represents the estimated proportion at age a in year y, and n_y represents the specified multinomial sample size in year y. To guard against the possibility of achieving misleadingly high R^2 values by extending the size or age range beyond the sizes or ages actually observed, the data were filtered by removing all records with $Pobs_{a,y} < 0.001$ prior to computing the R^2 values. A fit was determined to be "reasonable" if it yielded *both* an R^2 value of at least 0.99 on the raw scale *and* an R^2 value of at least 0.70 on the logit scale. As with #1 above, the JTS requested that this criterion (simplest selectivity function that gives a reasonable fit) be included in Model 16.1 only. Because the "random walk with respect to age" selectivity function gave a reasonable fit, the function was simplified in successive steps first by removing all time-variability, then by switching to a double-normal function, and finally by switching to a logistic function. The logistic function (for both the fishery and the survey) gave a reasonable fit to the fishery size composition data, the survey size composition data, and the survey age composition data, so it was retained as the final functional form.

3. In general, a "strange" selectivity pattern was defined here as one which was non-monotonic (i.e., where the signs of adjacent first differences changed), particularly if the first differences associated with sign changes were large (in absolute value), and particularly if sign changes in first differences occurred at relatively early ages. Specifically, an index of "strangeness" was defined as follows:
    - A. Age-specific weighting factors P_a were calculated as the equilibrium unfished numbers at age expressed as a proportion of equilibrium unfished numbers.
    - B. For each year, age-specific first differences in selectivity $\Delta_{a,y}$ were calculated.
    - C. "Strangeness" was then calculated as:

$$\left(\frac{1}{ymax-ymin+1}\right)\cdot\sum_{y=ymin}^{ymax}\sqrt{\sum_{a=2}^{amax}\left(P_a\cdot\left(\left(sign\left(\Delta_{a,y}\right)\neq sign\left(\Delta_{a-1,y}\right)\right)\cdot\left(\Delta_a\right)^2\right)\right)}\quad,$$

where the expression $sign\left(\Delta_{a,y}\right)\neq sign\left(\Delta_{a-1,y}\right)$ returned a value of 1 if the sign of $\Delta_{a,y}$ differed from the sign of $\Delta_{a-1,y}$ and a value of 0 otherwise. This index attains a minimum of 0 when selectivity is constant across age (or varies monotonically) and a maximum of 1 if selectivity alternates between values of 0 and 1 at all pairs of adjacent ages.

A time series of selectivity at age (for a given fleet) was determined to be "strange" if the index described above exceeded a value of 0.05. If a model produced a "strange" selectivity pattern, the standard deviations of the prior distributions for the selectivity parameters and the standard deviations of any selectivity *dev* vectors were decreased proportionally relative to the values estimated for Model 15.6 in last year's assessment until the threshold value of 0.05 was satisfied.

Final assessment

The final assessment included Models 11.5 and Model 16.1 from the preliminary assessment, and four variants of Model 16.1:

- **Model 16.6**: Model 16.1 without empirical weight at age
- Model 16.7: Model 16.1 without empirical weight at age and including the NMFS LL survey
- Model 16.8: Model 16.1 with time-varying survey selectivity
- Model 16.9: Model 16.1 with time-varying fishery selectivity

Empirical weight at age was first explored for the EBS Pacific cod stock in this year's preliminary assessment. Some key similarities and differences between the models *without* empirical weight at age (Models 11.5, 16.6, and 16.7) and those *with* empirical weight at age (Models 16.1, 16.8, and 16.9) are as follow: All six models estimate (internally) a time-invariant relationship between mean length and age, which is used for fitting the size composition data, among other things. Models *without* empirical weight at age use externally estimated parameters describing a weight-at-length relationship (seasonally varying but constant across years in the case of Model 11.5, annually varying in the cases of Models 16.6 and 16.7) in combination with the internally estimated length-at-age relationship to compute weight at age. Models *with* empirical weight at age bypass the link between weight at age and length at age, and instead use externally estimated, time-varying schedules of weight at age directly.

In Model 16.7, logistic selectivity was assumed for the NMFS longline survey, just as for fishery and trawl survey selectivity.

Time-varying selectivity in Models 16.8 and 16.9 was implemented in the form of annual deviations from a base selectivity function. The “sigma” parameters governing the extent to which selectivity *dev*s can vary from zero (specified as inputs to the model, not estimated internally) in Models 16.8 and 16.9 were set at large values to maximize those models’ ability to fit the data, essentially treating each *dev* as an unconstrained parameter. Values of the sigma parameters were increased across several trial runs of each model until the resulting estimate of 2016 spawning biomass did not change (to 3 significant digits) with further increases.

APPENDIX 2.4: SUPPLEMENTAL CATCH DATA

NMFS Alaska Region has made substantial progress in developing a database documenting many of the removals of FMP species that have resulted from activities outside of fisheries prosecuted under the BSAI Groundfish FMP, including removals resulting from scientific research, subsistence fishing, personal use, recreational fishing, exempted fishing permit activities, and commercial fisheries other than those managed under the BSAI groundfish FMP. Estimates for EBS Pacific cod from this dataset are shown in Table 2.4.1.

Although many sources of removal are documented in Table 2.4.1, the time series is highly incomplete for many of these. Cells shaded gray represent data contained in the NMFS database. Other entries represent extrapolations for years in which the respective activity was known or presumed to have taken place, where each extrapolated value consists of the time series average of the official data for the corresponding activity. In the case of surveys, years with missing values were identified from the literature or by contacting individuals knowledgeable about the survey (the NMFS database contains names of contact persons for most activities); in the case of fisheries, it was assumed that the activity occurred every year.

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

The average of the total removals in Table 2.4.1 for the last three complete years (2014-2016) is 9,497 t.

It should be emphasized that these calculations are provided purely for purposes of comparison and discussion, as NMFS and the Council continue to refine policy pertaining to treatment of removals from sources other than the directed groundfish fishery.

Reference

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

Table 2.4.1—Total removals of Pacific cod (t) from activities not related to directed fishing. Cells shaded gray represent data contained in the NMFS database. Other entries represent extrapolations for years in which the respective activity was known or presumed to have taken place.

Activity	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Aleutian Island Trawl Survey				2			2			2					2			2		
Annual Longline Survey						28	28	28	28	28	28	28	28	28	28	28	28	28		
Bait for Crab Fishery	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823
Bering Sea Acoustic Survey			0			0			0			0			0			0		0
Bering Sea Slope Survey			1		1	1			1			1			1					
Eastern Bering Sea Trawl Survey	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Gulf of Alaska Trawl Survey								0			0			0			0			0
IPHC Annual Longline Survey																				
Large-Mesh Trawl Survey														1	1			1	1	
Northern Bering Sea Trawl Survey			1		1	1			1			1			1					
Pollock EFP 11-01																				
Pribilof Islands Crab Survey																				
Sport fishery	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
St. Mathews Crab Survey																			9	
Subsistence Fishery	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	0	2	5	2	2
Summer EBS Survey with Russia																		0		

Activity	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Aleutian Island Trawl Survey	2			2		2		2		2				2		1		2		2
Annual Longline Survey	38		30		36		30		23		25		20		24		27		32	
Bait for Crab Fishery	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	6823	1737	4544	6697	6618	9452	10233	8481
Bering Sea Acoustic Survey	0		0	0		0		0		0	0	0	0	0		0		0		0
Bering Sea Slope Survey				1		1		1				1		2		1	1	1		1
Eastern Bering Sea Trawl Survey	40	40	40	40	40	40	40	40	40	40	40	40	40	38	42	52	33	39	39	36
Gulf of Alaska Trawl Survey			0		0		0		0		0		0		0		0		0	
IPHC Annual Longline Survey		37	37	37	37	37	37	37	37	37	37	37	37	32	20	17	29	52	59	47
Large-Mesh Trawl Survey			1	1			1	1	1	1	1	1	1	1	1	2	1	1	1	1
Northern Bering Sea Trawl Survey														1						
Pollock EFP 11-01															11	307				
Pribilof Islands Crab Survey							5		5			5			5					5
Sport fishery	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
St. Mathews Crab Survey		9			9			9			9			9			9			
Subsistence Fishery	2	1	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Summer EBS Survey with Russia						0		0			0	0	0	0		0				

APPENDIX 2.5: MODEL AVERAGING

This appendix develops responses to various suggestions by the SSC that encourage exploration of model averaging in the EBS Pacific cod assessment, including comments SSC17, SSC19, SSC20, SSC21, SSC22, and SSC25 from the October 2017 meeting. For all tables in this appendix, color shading extends from red = lowest value across models to green = highest value across models).

Model Weighting Method Used in the Preliminary Assessment

In the preliminary assessment (Appendix 2.1), development of model weights (for approaches other than equal weighting) began by considering the vector of ΣNeff2 values for each model, such as are shown for this final assessment in Table 2.15 and reproduced for convenience below:

Type	Fleet	M16.6	M17.1	M17.2	M17.3	M17.6	M17.7
Sizecomp	Fishery	23,850	74,884	55,964	33,901	34,686	34,425
Sizecomp	Survey	11,086	10,438	10,217	12,428	19,290	18,242
Agecomp	Fishery		3,357	3,375	2,646	3,060	3,363
Agecomp	Survey	1,395	1,670	915	2,054	1,988	1,972
Index	Survey	3,921	3,601	3,247	12,832	12,062	12,145

One way to combine the scores from each column into a single value for the respective model would be to compute the arithmetic mean. However, the preliminary assessment suggested that it may be advisable to consider alternatives to the arithmetic mean as well, for example the geometric and harmonic means, so as to allow for the possibility of penalizing models that achieve nearly all their success by focusing on a single component while essentially ignoring the others. The arithmetic, geometric, and harmonic means of the columns in the above table are as follow:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
Arithmetic:	10,063	18,790	14,744	12,772	14,217	14,029
Geometric:	6,166	6,912	5,645	7,828	8,673	8,726
Harmonic:	3,622	3,895	2,757	4,750	5,033	5,151

In the preliminary assessment, it was suggested that the quantities shown in the above table are insufficient as measures of model performance, because they ignore the fact that the models tend to have different numbers of parameters. Unfortunately, determining the effective number of parameters in a model with constrained deviations is not entirely straightforward. The method adopted in the preliminary assessment was to estimate the effective number of parameters corresponding to a vector of deviations as the minimum number of truly free parameters that would give the same fit to the data as that given by the vector of constrained deviations. A linear-normal approximation was involved, similar in some ways to what was done in order to develop the algorithm for tuning the input "sigma" values for vectors of deviations described in the "Model structures" section of Appendix 2.1. Table 2.5.1 shows the effective number of parameters for all models in this final assessment. The cells shaded gray indicate the three cases (out of 28) where the algorithm failed to result in a positive value for the observation error variance. In those three cases, the effective number of parameters was set equal to the average value from all other models that include deviations for that same base parameter and where the algorithm was successful.

Estimates of the effective number of parameters ("P_effective") for each model and each vector of deviations from the last row of Table 2.5.1 are reproduced below for ease of reference:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
P_effective:	59	56	64	51	83	86

In the preliminary assessment, the effective number of parameters was used to adjust the goodness of fit (measured by an order mean of ΣNeff2) by forming a ratio of the two, with P_effective as the denominator. Applying this method to the models in this final assessment gives the following results:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
Arithmetic:	170.56	335.53	230.37	250.44	171.29	163.13
Geometric:	104.51	123.43	88.20	153.49	104.50	101.46
Harmonic:	61.40	69.56	43.08	93.14	60.63	59.89

Additional Weighting Factors Requested by the SSC

The SSC has recommended use of model weighting that includes: 1) model fit, 2) retrospective performance, 3) model convergence behavior, and 4) general plausibility" (comment SSC21). Although the effective number of parameters was not included in the SSC's recommendation, neither was it explicitly excluded. Because penalizing model fit by the number of parameters is a common practice, for example in the Akaike Information Criterion (Akaike 1974), use of the effective number of parameters to scale ΣNeff2 (as above) shall be retained here.

Retrospective Performance

Retrospective analyses for all of the models are shown in Figure 2.28. In an attempt to address the SSC's recommendation, Mohn's ρ was used to form the basis of a multiplicative adjustment factor for model weighting, defined as exp(−|ρ|), giving the following values:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
ρ:	0.243	0.040	0.255	0.113	0.028	0.079
Adjustment:	0.784	0.960	0.775	0.893	0.972	0.924

Model Convergence Behavior

Model convergence behavior was measured on the basis of the RMSE from each model's "jitter" test (see "Description of Alternative Models" section), where the squared error for each jitter run was defined as the squared proportional difference between the 2017 spawning biomass estimated in that run and the 2017 spawning biomass estimated in the final (converged) run). In an attempt to address the SSC's recommendation, the RMSE was used to create a multiplicative adjustment factor for model weighting, defined as exp(–RMSE), giving the following values:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
RMSE:	0.000	0.110	0.044	0.067	0.128	0.196
Adjustment:	1.000	0.895	0.957	0.935	0.880	0.822

General Plausibility

Two quantities were used to measure "general plausibility:" First, because conventional wisdom is that the EBS Pacific cod stock was not heavily exploited prior to the rapid increase in biomass resulting from the 1977 regime shift (Wespestad et al. 1982), estimates of the initial (pre-1977) fishing mortality rate *Finit* that exceed the natural mortality rate were penalized. Second, because field studies to date provide little, if any, evidence that catchability in the EBS bottom trawl survey exceeds unity (Weinberg et al.

2016), estimates of catchability that exceed unity were penalized. In an attempt to address the SSC's recommendation, two multiplicative adjustments were defined as exp(−max(0,*Finit*–*M*)) and exp(−max(0,ln(*Q*))), giving the following values (the final row gives the total adjustment for "general plausibility," equal to the product of the two quantity-specific adjustments):

Model:	16.6	17.1	17.2	17.3	17.6	17.7
Finit:	0.180	1.029	0.470	1.632	1.674	1.697
M:	0.359	0.324	0.385	0.328	0.322	0.317
Adjustment:	1.000	0.494	0.918	0.271	0.259	0.252
ln(*Q*):	-0.074	0.177	0.023	0.196	0.169	0.193
Adjustment:	1.000	0.838	0.978	0.822	0.844	0.824
Total adj.:	1.000	0.414	0.897	0.223	0.218	0.207

Final Model Weights

Multiplying the ratio of ΣNeff2 to the effective number of parameters by the product of the adjustment factors for retrospective performance, model convergence behavior, and general plausibility gives the following values:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
Arithmetic:	133.77	119.40	153.28	46.67	31.99	25.69
Geometric:	81.97	43.92	58.69	28.60	19.52	15.98
Harmonic:	48.15	24.75	28.67	17.36	11.32	9.43

Rescaling the above so that each row sums to unity gives the final model weights shown below:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
Arithmetic:	0.2619	0.2337	0.3001	0.0914	0.0626	0.0503
Geometric:	0.3296	0.1766	0.2360	0.1150	0.0785	0.0642
Harmonic:	0.3447	0.1772	0.2052	0.1243	0.0811	0.0675

Model-Specific Distributions of 2018 and 2019 ABC and OFL

Based on the Hessian approximations from the SS projections, the 2018 ABC, 2018 OFL, 2019 ABC, and 2019 OFL are normally distributed with the following means and standard deviations (in t):

Quantity	Statistic	16.6	17.1	17.2	17.3	17.6	17.7
2018 ABC	Mean	214,025	82,395	185,835	64,324	65,464	65,379
2018 ABC	SD	24,473	15,640	24,532	19,096	16,848	18,520
2018 OFL	Mean	255,042	98,618	221,189	77,116	78,848	78,659
2018 OFL	SD	29,266	18,592	29,228	22,762	20,184	22,170
2019 ABC	Mean	172,137	98,163	151,408	84,652	89,824	90,593
2019 ABC	SD	15,614	12,146	25,754	17,255	15,303	16,887
2019 OFL	Mean	204,853	117,028	180,040	101,027	107,588	108,404
2019 OFL	SD	25,833	20,728	43,394	27,967	24,754	27,223

Results

A full factorial design of alternative model-averaged values for the 2018 ABC, 2018 OFL, 2019 ABC, and 2019 OFL are provided in this appendix, based on the following factors:

1. Weighting approach: Results using an equal weighting approach, along with results using each of the three sets of final weights listed above, are included.
2. Models to include: Comment SSC19 suggests that the diagnostics and evaluation provided in this final assessment are needed "in order to determine" which models "may be candidates for inclusion in a model averaged result in December." For *nmod* models, the number of possible subsets is equal to $2^{nmod}-1$ (the "−1" is necessary because the empty set is not a logical option for averaging). Given that six models are presented here, this yields a total of 63 possible subsets.
3. Measure of central tendency: Comment SSC25 requested the author to "clarify, with the Joint Plan Teams, the preferred measure of central tendency (e.g., median or mean) for assessments reporting probabilistic results either via Bayesian posteriors or model-averaged distributions." This item is on the agenda for the November meeting of the Joint Plan Teams. Because this final assessment was prepared prior to the November meeting, there was no way to know which measure of central tendency would be preferred by the Teams. Therefore, results using both the mean and median are included.

Therefore, a total of 504 alternative values (= 4 weighting approaches × 63 possible subsets of models to include, × 2 measures of central tendency) are provided for each harvest quantity to be specified. The alternative values for the 2018 ABC, 2018 OFL, 2019 ABC, and 2019 OFL are shown in Tables 2.5.2, 2.5.3, 2.5.4, and 2.5.5, respectively. Note that these are based on SS projections, not the AFSC's standard projection model.

Population Distributions versus Sample Distributions

Advocates of model averaging have noted, correctly, that choosing a single model to the exclusion of the other models in a sample implicitly assigns a weight of unity to the chosen model and a weight of zero to each of the others in the sample (e.g., Stewart and Martell 2015). A generalization of this criticism was explored to a very limited extent in the preliminary assessment, *viz*., that choosing a single sample of models implicitly assigns a weight of zero to each model not included in the sample. If the chosen ensemble of models represents a random sample of the universe of all possible models, then it would be appropriate to attempt to infer the population distribution of a particular result (e.g., a harvest specification) based on the statistics of the sample. For example, if the population distribution is normal, then the model-averaged mean and standard deviation could be used to parameterize the population distribution.

On the other hand, to the extent that the chosen ensemble of models does not represent a random sample of all possible models, inferring the population distribution of a particular model-averaged result will be problematic. However, this also implies that drawing other inferences from the model-averaged sample distribution will also be problematic; for example, the model-averaged ABC for a particular year will be biased.

As described in the preliminary assessment, the model-averaged mean for a given harvest quantity and a given weighting approach is given by

$$m_j = \sum_{i=1}^{nmod} \left(W_{i,j} \cdot \mu_i \right) \quad ,$$

where *nmod* represents the number of models, *i* indexes model, *j* indexes weighting approach, *W* represents the matrix of weights, and μ represents the vector of model-specific means for the given harvest quantity. There is no closed-form solution for the model-averaged median, which must be computed numerically instead.

The corresponding model-averaged standard deviation for the given harvest quantity and weighting approach is given by

$$s_j = \sqrt{\sum_{i=1}^{nmod} \left(W_{i,j} \cdot \left(\left(\mu_i - m_j \right)^2 + \sigma_i^{\ 2} \right) \right)} \quad ,$$

where σ represents the vector of model-specific standard deviations for the given harvest quantity.

Model-averaged standard deviations are provided along with model-averaged means and medians for each alternative in Tables 2.5.2, 2.5.3, 2.5.4, and 2.5.5 so that readers can use them to fit any two-parameter parametric population distribution desired (assuming that the standard deviation and either the mean or median exist in the desired distribution).

Figure 2.5.1 provides examples of sample distributions and (assumed normal) population distributions, expressed as both probability density functions (PDFs) and cumulative distribution functions (CDFs), for the case where all six models are included in the ensemble. Examples are shown for all four weighting approaches (equal, adjusted arithmetic mean, adjusted geometric mean, and adjusted harmonic mean), and both measures of central tendency (mean and median). Note that, for the CDFs, the population distributions parametrized by the mean tend to run approximately through the middle of the respective sample distributions, whereas the populations parameterized by the median tend to lie almost entirely above or almost entirely below the respective sample distributions.

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Tables

Table 2.5.1—Effective number of parameters.

	M16.6		M17.1		M17.2		M17.3		M17.6		M17.7	
Vector	nyrs	npar	nyrs	npar	nyrs	npar	nyrs	npar	nyrs	npar	nyrs	npar
Recruitment	40	21	40	9	40	21	40	7	40	13	40	15
Length at a=1.5									36	26	36	26
ln(Catchability)									36	1	36	1
Sel_fish_P1			41	3	41	3	41	1	41	1	41	1
Sel_fish_P3			41	5	41	3	41	3	41	2	41	3
Sel_surv_P1			36	1			36	1	36	1	36	1
Sel_surv_P3			36	1			36	1	36	1	36	1
Sum	40	21	194	19	122	27	194	13	266	45	266	48
Nominal parms		78		231		159		232		304		304
Effective parms		59		56		64		51		83		86

Table 2.5.2—Model averaging results (2018 ABC). Mean, median, and standard deviation in 1000s of t.

Include in ensemble (1=yes, 0=no)?						Mean				Median				Standard deviation			
16.6	17.1	17.2	17.3	17.6	17.7	Equ.	Ari.	Geo.	Har.	Equ.	Ari.	Geo.	Har.	Equ.	Ari.	Geo.	Har.
1	0	0	0	0	0	214	214	214	214	214	214	214	214	24.5	24.5	24.5	24.5
0	1	0	0	0	0	82	82	82	82	82	82	82	82	15.6	15.6	15.6	15.6
0	0	1	0	0	0	186	186	186	186	186	186	186	186	24.5	24.5	24.5	24.5
0	0	0	1	0	0	64	64	64	64	64	64	64	64	19.1	19.1	19.1	19.1
0	0	0	0	1	0	65	65	65	65	65	65	65	65	16.8	16.8	16.8	16.8
0	0	0	0	0	1	65	65	65	65	65	65	65	65	18.5	18.5	18.5	18.5
1	1	0	0	0	0	148	152	168	169	134	175	196	197	68.9	68.9	66.4	66.1
1	0	1	0	0	0	200	199	202	204	200	199	203	204	28.3	28.3	28.2	28.0
1	0	0	1	0	0	139	175	175	174	130	203	203	203	78.0	69.5	69.5	70.0
1	0	0	0	1	0	140	185	185	186	126	207	207	207	77.2	63.1	63.0	62.8
1	0	0	0	0	1	140	190	190	190	129	208	208	208	77.4	59.5	59.8	59.9
0	1	1	0	0	0	134	141	142	138	123	156	158	149	55.7	55.5	55.4	55.6
0	1	0	1	0	0	73	77	75	75	74	78	76	76	19.7	18.6	19.2	19.3
0	1	0	0	1	0	74	79	77	77	74	79	78	78	18.3	17.3	17.8	17.9
0	1	0	0	0	1	74	79	78	78	75	80	79	78	19.1	17.4	18.1	18.2
0	0	1	1	0	0	125	157	146	140	118	176	170	165	64.6	56.5	61.5	63.1
0	0	1	0	1	0	126	165	156	152	114	179	175	173	63.8	51.2	56.9	58.8
0	0	1	0	0	1	126	169	160	156	117	181	177	175	64.0	48.5	54.7	56.9
0	0	0	1	1	0	65	65	65	65	65	65	65	65	18.0	18.2	18.2	18.2
0	0	0	1	0	1	65	65	65	65	65	65	65	65	18.8	18.9	18.9	18.9
0	0	0	0	1	1	65	65	65	65	65	65	65	65	17.7	17.6	17.6	17.6
1	1	1	0	0	0	161	165	174	174	181	183	191	192	60.7	58.8	57.2	57.9
1	1	0	1	0	0	120	138	149	149	87	100	175	177	69.7	71.2	72.7	72.9
1	1	0	0	1	0	121	142	154	155	87	105	184	186	69.2	70.7	71.3	71.2
1	1	0	0	0	1	121	144	157	157	87	109	187	188	69.3	70.5	70.8	70.7
1	0	1	1	0	0	155	180	179	178	181	193	195	196	68.9	54.0	58.2	60.2
1	0	1	0	1	0	155	186	186	186	181	195	198	199	68.2	48.5	52.3	53.4
1	0	1	0	0	1	155	188	188	188	181	196	198	199	68.3	45.9	49.6	50.9
1	0	0	1	1	0	115	159	159	158	77	194	194	194	73.2	75.5	75.4	75.6
1	0	0	1	0	1	115	162	161	161	78	196	196	195	73.4	74.8	74.8	75.1
1	0	0	0	1	1	115	169	169	169	77	200	200	200	72.9	71.8	71.9	71.8
0	1	1	1	0	0	111	129	125	120	87	108	100	94	57.2	58.4	59.1	58.6
0	1	1	0	1	0	111	133	129	125	87	127	108	99	56.6	57.6	58.3	58.0
0	1	1	0	0	1	111	134	131	127	87	139	116	102	56.8	57.3	58.1	57.9
0	1	0	1	1	0	71	75	73	73	71	76	74	74	19.1	18.8	19.2	19.2
0	1	0	1	0	1	71	76	73	73	71	77	74	74	19.6	19.0	19.5	19.5
0	1	0	0	1	1	71	77	75	75	71	78	75	75	18.8	18.1	18.6	18.6
0	0	1	1	1	0	105	145	131	125	77	169	153	116	60.6	61.6	64.1	64.3
0	0	1	1	0	1	105	147	134	127	78	170	157	141	60.7	61.0	64.0	64.4
0	0	1	0	1	1	106	153	140	135	77	174	165	159	60.3	58.3	62.4	63.3
0	0	0	1	1	1	65	65	65	65	65	65	65	65	18.2	18.3	18.3	18.3
1	1	1	1	0	0	137	154	159	158	123	176	182	182	67.8	63.8	65.3	66.5
1	1	1	0	1	0	137	157	163	163	123	178	185	186	67.4	62.4	63.2	64.1
1	1	1	0	0	1	137	159	165	165	123	179	186	187	67.5	61.8	62.4	63.4
1	1	0	1	1	0	107	131	140	140	79	94	103	104	65.4	71.2	73.6	73.8
1	1	0	1	0	1	107	133	141	141	80	95	107	107	65.5	71.3	73.6	73.7
1	1	0	0	1	1	107	136	146	146	79	98	161	167	65.2	71.1	72.9	73.0
1	0	1	1	1	0	132	170	167	166	119	189	190	190	71.6	61.1	65.3	66.9
1	0	1	1	0	1	132	172	169	168	120	190	191	191	71.7	60.1	64.4	66.1
1	0	1	0	1	1	133	177	175	174	118	192	193	194	71.3	56.6	60.9	62.3
1	0	0	1	1	1	102	149	149	148	73	184	184	183	67.5	77.2	77.2	77.2
0	1	1	1	1	0	100	124	117	112	79	98	91	87	53.9	58.8	59.0	57.9
0	1	1	1	0	1	99	125	118	113	80	99	92	88	54.1	58.8	59.1	58.1
0	1	1	0	1	1	100	127	122	118	79	103	96	91	53.7	58.4	58.9	58.1
0	1	0	1	1	1	69	74	72	72	70	75	73	72	19.1	19.0	19.3	19.3
0	0	1	1	1	1	95	137	123	117	73	161	96	86	56.0	63.4	64.1	63.5
1	1	1	1	1	0	122	149	151	150	89	170	175	174	67.4	65.6	67.9	68.8
1	1	1	1	0	1	122	150	153	151	90	171	177	176	67.5	65.3	67.6	68.6
1	1	1	0	1	1	123	152	156	156	89	174	180	180	67.2	64.3	66.2	67.1
1	1	0	1	1	1	98	127	133	133	76	90	94	95	61.3	70.9	73.6	73.7
1	0	1	1	1	1	119	163	159	158	83	185	185	185	69.9	64.7	68.6	70.0
0	1	1	1	1	1	93	120	112	108	76	93	87	84	50.8	58.9	58.4	56.9
1	1	1	1	1	1	113	144	146	144	83	164	168	166	65.6	66.6	69.1	70.0

Table 2.5.3—Model averaging results (2018 OFL). Mean, median, and standard deviation in 1000s of t.

Include in ensemble (1=yes, 0=no)?						Mean				Median				Standard deviation			
16.6	17.1	17.2	17.3	17.6	17.7	Equ.	Ari.	Geo.	Har.	Equ.	Ari.	Geo.	Har.	Equ.	Ari.	Geo.	Har.
1	0	0	0	0	0	255	255	255	255	255	255	255	255	29.3	29.3	29.3	29.3
0	1	0	0	0	0	99	99	99	99	99	99	99	99	18.6	18.6	18.6	18.6
0	0	1	0	0	0	221	221	221	221	221	221	221	221	29.2	29.2	29.2	29.2
0	0	0	1	0	0	77	77	77	77	77	77	77	77	22.8	22.8	22.8	22.8
0	0	0	0	1	0	79	79	79	79	79	79	79	79	20.2	20.2	20.2	20.2
0	0	0	0	0	1	79	79	79	79	79	79	79	79	22.2	22.2	22.2	22.2
1	1	0	0	0	0	177	181	200	202	159	208	234	235	82.0	81.9	79.0	78.5
1	0	1	0	0	0	238	237	241	242	238	237	241	243	33.8	33.8	33.7	33.5
1	0	0	1	0	0	166	209	209	208	155	242	242	241	92.7	82.7	82.7	83.3
1	0	0	0	1	0	167	221	221	221	151	246	246	246	91.6	74.9	74.8	74.5
1	0	0	0	0	1	167	227	226	226	155	248	248	248	91.9	70.7	71.0	71.1
0	1	1	0	0	0	160	168	169	164	146	185	188	178	66.0	65.8	65.7	66.0
0	1	0	1	0	0	88	93	90	90	89	94	91	91	23.4	22.1	22.9	23.0
0	1	0	0	1	0	89	94	93	92	89	95	93	93	21.8	20.6	21.2	21.2
0	1	0	0	0	1	89	95	93	93	90	96	94	94	22.8	20.7	21.5	21.6
0	0	1	1	0	0	149	188	174	167	140	210	202	196	76.7	67.0	72.9	74.9
0	0	1	0	1	0	150	197	186	181	137	213	209	206	75.5	60.6	67.4	69.6
0	0	1	0	0	1	150	201	191	186	140	215	211	209	75.8	57.4	64.8	67.4
0	0	0	1	1	0	78	78	78	78	78	78	78	78	21.5	21.8	21.8	21.8
0	0	0	1	0	1	78	78	78	78	78	78	78	78	22.5	22.6	22.6	22.6
0	0	0	0	1	1	79	79	79	79	79	79	79	79	21.2	21.1	21.1	21.1
1	1	1	0	0	0	192	196	207	207	215	218	227	229	72.1	69.8	68.0	68.9
1	1	0	1	0	0	144	165	178	178	104	120	209	210	82.8	84.7	86.4	86.6
1	1	0	0	1	0	144	170	184	185	104	126	220	221	82.1	84.0	84.7	84.6
1	1	0	0	0	1	144	172	187	188	104	130	223	224	82.4	83.8	84.1	84.0
1	0	1	1	0	0	184	215	213	212	215	230	232	233	81.8	64.2	69.3	71.6
1	0	1	0	1	0	185	221	221	221	215	232	235	237	80.8	57.6	62.1	63.5
1	0	1	0	0	1	185	224	224	225	215	233	236	238	81.1	54.6	59.0	60.5
1	0	0	1	1	0	137	189	189	189	92	231	231	231	87.0	89.7	89.6	89.8
1	0	0	1	0	1	137	193	193	192	93	233	233	233	87.2	88.9	89.0	89.2
1	0	0	0	1	1	138	202	202	202	93	238	238	238	86.6	85.3	85.3	85.3
0	1	1	1	0	0	132	154	149	143	104	129	119	112	67.8	69.2	70.1	69.5
0	1	1	0	1	0	133	158	154	149	104	151	129	119	67.1	68.2	69.1	68.7
0	1	1	0	0	1	133	160	157	152	104	165	139	122	67.3	68.0	68.9	68.6
0	1	0	1	1	0	85	90	88	87	85	91	89	88	22.8	22.4	22.8	22.9
0	1	0	1	0	1	85	91	88	88	85	92	89	89	23.4	22.6	23.2	23.2
0	1	0	0	1	1	85	92	90	90	86	93	90	90	22.4	21.6	22.1	22.1
0	0	1	1	1	0	126	173	157	149	92	201	182	139	71.8	73.0	76.0	76.2
0	0	1	1	0	1	126	175	159	152	93	203	187	167	72.0	72.3	75.9	76.4
0	0	1	0	1	1	126	182	168	161	93	207	196	189	71.4	69.1	73.9	75.0
0	0	0	1	1	1	78	78	78	78	78	78	78	78	21.7	21.9	21.9	21.9
1	1	1	1	0	0	163	184	190	188	147	209	217	217	80.6	75.8	77.7	79.0
1	1	1	0	1	0	163	188	195	194	146	212	221	221	79.9	74.1	75.1	76.2
1	1	1	0	0	1	163	189	197	196	147	213	222	223	80.1	73.4	74.2	75.3
1	1	0	1	1	0	127	157	167	167	95	112	123	124	77.7	84.7	87.5	87.7
1	1	0	1	0	1	127	158	168	169	95	114	127	128	77.8	84.8	87.5	87.7
1	1	0	0	1	1	128	162	174	175	95	117	192	199	77.4	84.5	86.6	86.7
1	0	1	1	1	0	158	203	199	198	142	225	226	226	84.9	72.6	77.6	79.4
1	0	1	1	0	1	158	205	202	200	143	226	227	227	85.1	71.4	76.5	78.5
1	0	1	0	1	1	158	210	208	208	141	228	230	231	84.5	67.2	72.3	73.9
1	0	0	1	1	1	122	177	177	177	88	219	219	218	80.2	91.7	91.7	91.8
0	1	1	1	1	0	119	147	140	134	95	117	109	105	63.9	69.7	69.9	68.6
0	1	1	1	0	1	119	149	141	135	95	119	110	106	64.1	69.8	70.1	68.9
0	1	1	0	1	1	119	152	146	140	95	123	114	109	63.6	69.2	69.8	68.8
0	1	0	1	1	1	83	89	86	86	84	90	87	87	22.8	22.7	23.0	23.0
0	0	1	1	1	1	114	163	146	139	88	192	116	103	66.3	75.1	76.0	75.3
1	1	1	1	1	0	146	177	180	179	107	202	209	208	80.0	77.9	80.6	81.8
1	1	1	1	0	1	146	178	182	180	108	204	210	209	80.2	77.6	80.3	81.5
1	1	1	0	1	1	146	182	186	186	107	207	214	214	79.7	76.4	78.6	79.7
1	1	0	1	1	1	118	151	159	159	91	108	113	113	72.8	84.2	87.4	87.6
1	0	1	1	1	1	142	195	190	188	99	221	220	220	82.9	76.8	81.5	83.1
0	1	1	1	1	1	111	143	134	128	91	112	104	101	60.2	69.8	69.2	67.5
1	1	1	1	1	1	135	172	174	172	99	195	200	197	77.8	79.1	82.1	83.1

Table 2.5.4—Model averaging results (2019 ABC). Mean, median, and standard deviation in 1000s of t.

Include in ensemble (1=yes, 0=no)?						Mean				Median				Standard deviation			
16.6	17.1	17.2	17.3	17.6	17.7	Equ.	Ari.	Geo.	Har.	Equ.	Ari.	Geo.	Har.	Equ.	Ari.	Geo.	Har.
1	0	0	0	0	0	172	172	172	172	172	172	172	172	15.6	15.6	15.6	15.6
0	1	0	0	0	0	98	98	98	98	98	98	98	98	12.1	12.1	12.1	12.1
0	0	1	0	0	0	151	151	151	151	151	151	151	151	25.8	25.8	25.8	25.8
0	0	0	1	0	0	85	85	85	85	85	85	85	85	17.3	17.3	17.3	17.3
0	0	0	0	1	0	90	90	90	90	90	90	90	90	15.3	15.3	15.3	15.3
0	0	0	0	0	1	91	91	91	91	91	91	91	91	16.9	16.9	16.9	16.9
1	1	0	0	0	0	135	137	146	147	131	147	161	161	39.5	39.5	38.1	37.9
1	0	1	0	0	0	162	161	163	164	164	164	166	167	23.7	24.0	22.9	22.4
1	0	0	1	0	0	128	150	150	149	131	165	165	165	46.7	41.5	41.5	41.8
1	0	0	0	1	0	131	156	156	156	131	167	167	167	44.0	36.0	36.0	35.9
1	0	0	0	0	1	131	159	159	159	133	168	168	168	43.9	33.9	34.0	34.1
0	1	1	0	0	0	125	128	129	127	115	122	124	119	33.4	33.7	33.7	33.6
0	1	0	1	0	0	91	94	93	93	93	95	94	94	16.4	15.1	15.8	15.9
0	1	0	0	1	0	94	96	96	96	94	97	96	96	14.4	13.3	13.7	13.8
0	1	0	0	0	1	94	97	96	96	95	97	97	97	15.2	13.4	14.0	14.0
0	0	1	1	0	0	118	136	130	126	111	141	135	130	39.9	37.1	39.1	39.7
0	0	1	0	1	0	121	141	136	134	113	145	140	138	37.4	33.6	35.6	36.2
0	0	1	0	0	1	121	143	138	136	115	146	142	141	37.4	32.6	34.7	35.5
0	0	0	1	1	0	87	87	87	87	87	87	87	87	16.5	16.7	16.7	16.7
0	0	0	1	0	1	88	87	87	87	88	87	87	87	17.3	17.4	17.4	17.4
0	0	0	0	1	1	90	90	90	90	90	90	90	90	16.1	16.0	16.0	16.0
1	1	1	0	0	0	141	143	148	148	148	150	157	158	36.4	35.6	34.8	35.0
1	1	0	1	0	0	118	129	135	135	103	113	148	148	41.3	41.6	42.6	42.7
1	1	0	0	1	0	120	132	139	139	104	117	153	154	39.7	40.5	40.8	40.7
1	1	0	0	0	1	120	133	140	141	105	120	155	156	39.7	40.3	40.4	40.4
1	0	1	1	0	0	136	150	150	150	148	159	160	161	42.4	35.2	36.9	37.7
1	0	1	0	1	0	138	154	155	155	148	160	162	163	40.0	31.6	32.7	33.0
1	0	1	0	0	1	138	155	156	156	148	161	163	164	39.9	30.4	31.4	31.7
1	0	0	1	1	0	116	141	141	140	98	159	159	159	43.2	44.2	44.2	44.3
1	0	0	1	0	1	116	142	142	142	99	161	161	160	43.2	43.9	43.9	44.0
1	0	0	0	1	1	118	147	147	147	101	163	163	163	41.8	40.8	40.8	40.8
0	1	1	1	0	0	111	122	119	116	102	113	109	106	34.6	35.3	35.8	35.4
0	1	1	0	1	0	113	124	122	120	103	115	113	110	33.1	34.3	34.6	34.2
0	1	1	0	0	1	113	125	123	121	104	117	115	111	33.1	34.2	34.5	34.2
0	1	0	1	1	0	91	94	92	92	92	95	93	93	16.0	15.2	15.8	15.8
0	1	0	1	0	1	91	94	92	92	92	95	93	93	16.6	15.4	16.0	16.1
0	1	0	0	1	1	93	96	95	95	93	96	95	95	15.4	14.0	14.6	14.6
0	0	1	1	1	0	109	129	122	119	98	134	120	112	36.3	38.3	39.0	39.0
0	0	1	1	0	1	109	131	124	120	99	135	123	115	36.4	38.2	39.1	39.1
0	0	1	0	1	1	111	135	128	126	100	139	130	125	35.0	36.0	37.3	37.5
0	0	0	1	1	1	88	88	88	88	88	88	88	88	16.7	16.8	16.8	16.8
1	1	1	1	0	0	127	137	139	139	117	143	150	150	40.7	38.5	39.4	39.9
1	1	1	0	1	0	128	139	142	142	117	145	152	153	39.2	37.2	37.5	37.8
1	1	1	0	0	1	128	139	143	143	118	146	153	154	39.1	36.9	37.1	37.4
1	1	0	1	1	0	111	125	130	130	98	108	116	116	38.6	41.5	42.9	43.0
1	1	0	1	0	1	111	126	131	131	99	109	119	120	38.7	41.5	42.9	43.0
1	1	0	0	1	1	113	129	134	134	100	111	139	142	37.6	40.7	41.6	41.6
1	0	1	1	1	0	125	145	144	143	116	155	156	156	42.5	38.0	39.7	40.4
1	0	1	1	0	1	125	146	145	144	117	156	157	157	42.5	37.5	39.3	40.1
1	0	1	0	1	1	126	149	149	149	117	158	159	160	41.1	35.0	36.5	37.0
1	0	0	1	1	1	109	135	135	135	96	153	153	153	39.8	44.9	44.9	45.0
0	1	1	1	1	0	106	119	115	113	98	109	105	103	32.3	35.2	35.3	34.6
0	1	1	1	0	1	106	119	116	113	98	110	106	104	32.4	35.3	35.4	34.8
0	1	1	0	1	1	107	121	119	117	99	112	108	106	31.4	34.5	34.5	34.0
0	1	0	1	1	1	91	93	92	92	91	94	93	93	16.3	15.4	15.9	16.0
0	0	1	1	1	1	104	126	118	115	95	126	110	105	33.5	38.6	38.4	38.0
1	1	1	1	1	0	119	134	135	135	106	137	143	142	39.8	39.2	40.4	40.8
1	1	1	1	0	1	119	134	136	135	106	138	144	144	39.8	39.0	40.2	40.7
1	1	1	0	1	1	120	136	139	138	107	141	148	148	38.8	38.0	38.8	39.2
1	1	0	1	1	1	107	123	127	127	96	106	110	110	36.3	41.2	42.7	42.9
1	0	1	1	1	1	118	142	140	139	104	152	152	152	41.1	39.4	41.0	41.6
0	1	1	1	1	1	103	117	113	110	96	107	103	101	30.5	35.0	34.7	33.9
1	1	1	1	1	1	114	131	132	132	102	131	135	133	38.5	39.5	40.8	41.2

Table 2.5.5—Model averaging results (2019 OFL). Mean, median, and standard deviation in 1000s of t.

Include in ensemble (1=yes, 0=no)?						Mean				Median				Standard deviation			
16.6	17.1	17.2	17.3	17.6	17.7	Equ.	Ari.	Geo.	Har.	Equ.	Ari.	Geo.	Har.	Equ.	Ari.	Geo.	Har.
1	0	0	0	0	0	205	205	205	205	205	205	205	205	25.8	25.8	25.8	25.8
0	1	0	0	0	0	117	117	117	117	117	117	117	117	20.7	20.7	20.7	20.7
0	0	1	0	0	0	180	180	180	180	180	180	180	180	43.4	43.4	43.4	43.4
0	0	0	1	0	0	101	101	101	101	101	101	101	101	28.0	28.0	28.0	28.0
0	0	0	0	1	0	108	108	108	108	108	108	108	108	24.8	24.8	24.8	24.8
0	0	0	0	0	1	108	108	108	108	108	108	108	108	27.2	27.2	27.2	27.2
1	1	0	0	0	0	161	163	174	175	156	165	186	187	49.8	49.8	48.3	48.1
1	0	1	0	0	0	192	192	195	196	196	195	198	198	37.8	38.3	36.4	35.6
1	0	0	1	0	0	153	178	178	177	155	193	193	193	58.5	52.6	52.6	52.9
1	0	0	0	1	0	156	186	186	186	155	197	197	197	54.8	46.2	46.1	46.0
1	0	0	0	0	1	157	189	189	189	158	199	198	198	55.0	44.0	44.1	44.2
0	1	1	0	0	0	149	152	153	151	137	143	144	140	46.4	47.2	47.3	46.9
0	1	0	1	0	0	109	113	111	110	110	114	112	112	25.9	24.1	25.1	25.2
0	1	0	0	1	0	112	115	114	114	113	115	114	114	23.3	22.0	22.5	22.5
0	1	0	0	0	1	113	116	115	115	113	116	115	115	24.6	22.3	23.0	23.0
0	0	1	1	0	0	141	162	154	150	132	164	154	147	53.8	52.4	53.8	54.2
0	0	1	0	1	0	144	168	162	160	134	169	162	159	50.6	49.1	50.5	50.9
0	0	1	0	0	1	144	170	165	162	136	171	166	163	50.9	48.5	50.0	50.6
0	0	0	1	1	0	104	104	104	104	105	104	104	104	26.6	26.9	26.9	26.9
0	0	0	1	0	1	105	104	104	104	105	104	104	104	27.8	27.9	27.9	27.9
0	0	0	0	1	1	108	108	108	108	108	108	108	108	26.0	25.9	25.9	25.9
1	1	1	0	0	0	167	170	176	176	171	174	184	185	48.6	48.1	46.9	46.9
1	1	0	1	0	0	141	154	161	161	127	142	166	167	52.1	52.2	53.4	53.6
1	1	0	0	1	0	143	157	165	166	128	147	174	175	49.9	50.8	51.2	51.2
1	1	0	0	0	1	143	158	167	167	129	150	177	178	50.1	50.7	50.9	50.9
1	0	1	1	0	0	162	179	179	178	171	187	189	189	55.4	48.6	49.6	50.2
1	0	1	0	1	0	164	183	184	184	171	190	192	192	52.5	45.0	45.2	45.3
1	0	1	0	0	1	164	185	186	186	171	191	193	193	52.6	44.0	44.1	44.1
1	0	0	1	1	0	138	167	167	167	122	184	184	183	54.2	55.4	55.4	55.6
1	0	0	1	0	1	138	169	169	169	123	186	186	185	54.5	55.1	55.2	55.3
1	0	0	0	1	1	140	176	176	176	125	190	190	190	52.5	51.4	51.5	51.4
0	1	1	1	0	0	133	145	142	139	123	135	131	128	46.8	48.4	48.8	48.1
0	1	1	0	1	0	135	148	146	143	125	137	135	132	44.8	47.4	47.5	46.8
0	1	1	0	0	1	135	149	147	144	126	138	137	134	45.1	47.4	47.6	47.0
0	1	0	1	1	0	109	112	110	110	109	113	111	111	25.5	24.3	25.1	25.2
0	1	0	1	0	1	109	112	110	110	110	113	111	111	26.3	24.6	25.5	25.6
0	1	0	0	1	1	111	114	113	113	111	115	113	113	24.8	22.9	23.6	23.7
0	0	1	1	1	0	130	154	146	142	119	152	138	133	48.7	52.9	53.0	52.6
0	0	1	1	0	1	130	156	147	143	120	155	141	135	49.0	52.9	53.3	53.0
0	0	1	0	1	1	132	160	153	150	122	160	148	143	47.2	50.8	51.4	51.4
0	0	0	1	1	1	106	105	105	105	106	105	105	105	26.9	27.1	27.1	27.1
1	1	1	1	0	0	151	163	166	165	141	164	173	173	52.8	50.9	51.6	52.0
1	1	1	0	1	0	152	165	170	170	142	167	177	177	50.9	49.5	49.5	49.7
1	1	1	0	0	1	153	166	171	171	143	169	178	179	51.0	49.3	49.2	49.3
1	1	0	1	1	0	133	149	155	155	120	135	147	147	48.9	52.0	53.7	53.9
1	1	0	1	0	1	133	150	156	156	121	136	150	151	49.2	52.1	53.8	53.9
1	1	0	0	1	1	134	153	160	160	122	140	159	161	47.7	51.1	52.2	52.2
1	0	1	1	1	0	148	173	171	171	140	182	182	182	54.9	51.1	52.3	52.8
1	0	1	1	0	1	149	174	173	172	141	183	184	183	55.0	50.7	52.0	52.5
1	0	1	0	1	1	150	178	177	177	142	186	187	187	53.3	48.1	49.0	49.2
1	0	0	1	1	1	130	161	161	161	117	174	174	173	50.5	56.2	56.2	56.3
0	1	1	1	1	0	126	142	137	134	118	131	127	124	43.8	48.0	47.8	46.8
0	1	1	1	0	1	127	142	138	135	119	132	128	125	44.1	48.1	48.0	47.1
0	1	1	0	1	1	128	145	141	139	120	134	131	128	42.7	47.3	47.1	46.3
0	1	0	1	1	1	109	111	110	110	109	112	111	110	26.0	24.6	25.4	25.5
0	0	1	1	1	1	124	150	141	137	116	145	131	127	45.3	52.7	51.9	51.1
1	1	1	1	1	0	142	159	161	160	129	157	164	163	51.5	51.5	52.5	52.8
1	1	1	1	0	1	142	160	162	161	130	158	166	165	51.6	51.4	52.4	52.7
1	1	1	0	1	1	144	162	165	165	131	162	170	170	50.3	50.3	50.8	51.0
1	1	0	1	1	1	128	146	151	151	117	132	138	139	46.4	51.7	53.6	53.7
1	0	1	1	1	1	140	168	166	165	128	177	176	176	53.0	52.4	53.5	54.0
0	1	1	1	1	1	123	139	135	132	116	129	125	122	41.6	47.6	47.0	45.9
1	1	1	1	1	1	136	156	158	157	124	151	156	154	49.9	51.7	52.8	53.1

Figure

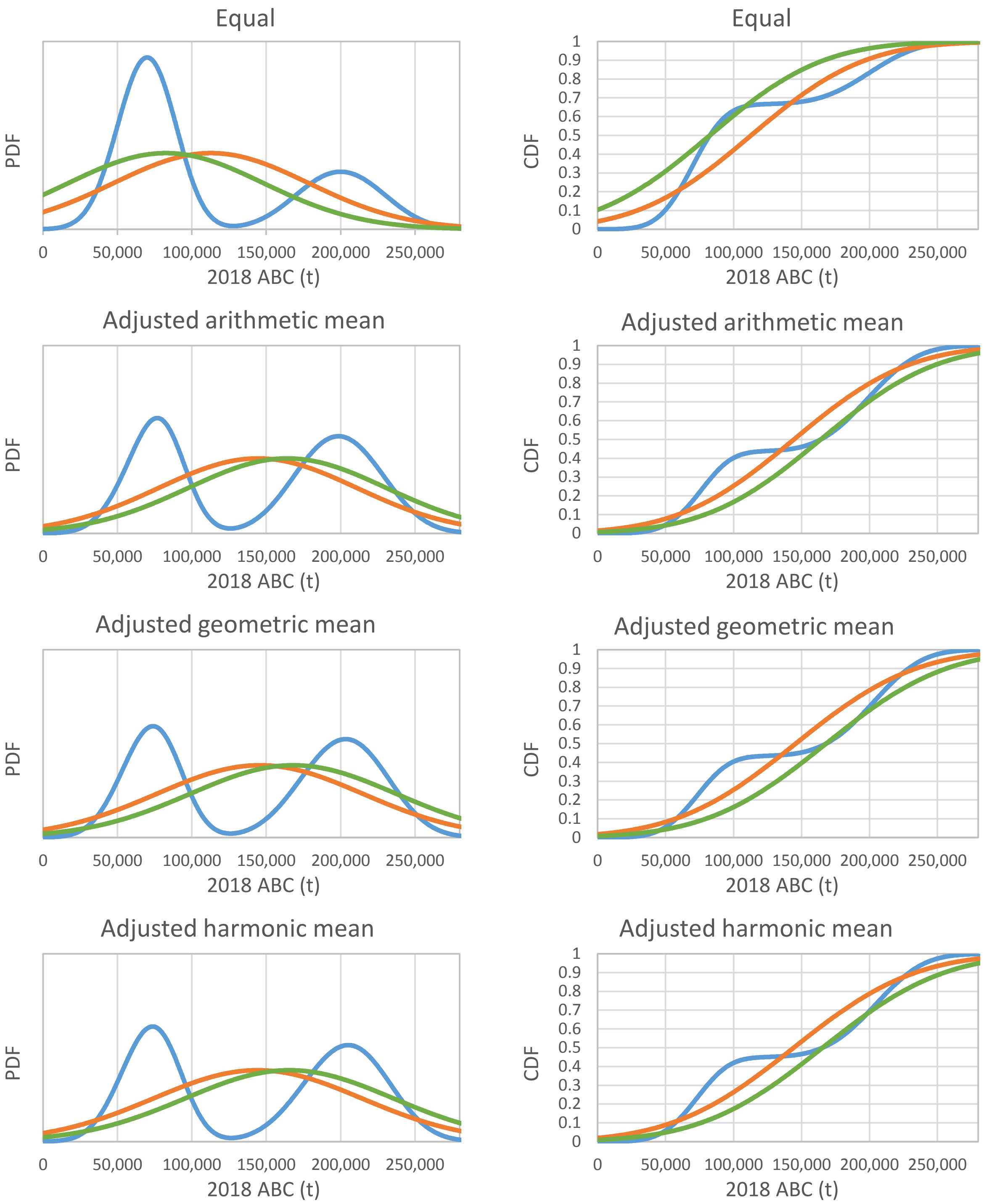

Figure 2.5.1. PDFs and CDFs for distributions of the 2018 ABC based on all six models. Blue = sample distribution, orange = normal distribution with the same mean and standard deviation (SD) as the sample distribution; green = normal distribution with the same median and SD as the sample distribution.

APPENDIX 2.6: PARALLEL RESULTS FOR THE "HARVEST RECOMMENDATIONS" SECTION, BASED ON MODEL 16.6

The results presented in the "Harvest Recommendations" section of the main text are based on Model 17.2. Because the structure of this model differs substantively from Model 16.6 (the current base model), a set of parallel results for the items in that section, based on Model 16.6, is provided here.

Amendment 56 Reference Points
Model 16.6's estimates of $B_{100\%}$, $B_{40\%}$, and $B_{35\%}$ are 593,000 t, 237,000 t, and 207,000 t, respectively.

Specification of OFL and Maximum Permissible ABC
Given the assumptions of Scenario 2 (below), female spawning biomass for 2018 and 2019 is estimated by Model 16.6 to be above the $B_{40\%}$ value of 237,000 t, thereby placing Pacific cod in sub-tier "a" of Tier 3 for both 2018 and 2019. Given this, Model 16.6 estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2018 and 2098 as follows:

Year	Overfishing Level	Maximum Permissible ABC
2018	OFL = 238,000 t	maxABC = 201,000 t
2019	OFL = 201,000 t	maxABC = 170,000 t
2018	*FOFL* = 0.38	*maxFABC* = 0.31
2019	*FOFL* = 0.38	*maxFABC* = 0.31

The age 0+ biomass projections for 2018 and 2019 from Model 16.6 (using SS rather than the standard projection model) are 918,000 t and 762,000 t. For comparison, the age 3+ biomass projections for 2018 and 2019 from Model 16.6 (again using SS) are 903,000 t and 716,000 t.

Standard Harvest Scenarios, Projection Methodology, and Projection Results
The standard harvest scenarios and projection methodology were the same as described for Model 17.2 in the main text. Projections corresponding to the standard scenarios are shown for Model 16.6 in Tables 2.6.28-2.6.34 (table numbering is kept the same as in the main text, so as to facilitate comparisons).

Status Determination
Methodology for status determination is as described in the main text. The status with respect to overfishing is independent of model choice for next year's specifications, as it depends entirely on the previous year's catch and OFL.

Based on the criteria described in the main text and Tables 2.6.28 and 2.6.34, the stock is not overfished and is not approaching an overfished condition.

Table 2.6.28—Model 16.6 projections for catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2018-2030 (Scenario 1), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	201,000	201,000	201,000	201,000	0
2019	165,000	165,000	165,000	165,000	0
2020	110,000	110,000	110,000	110,000	21
2021	87,400	87,700	87,800	88,500	384
2022	100,000	103,000	104,000	110,000	3,489
2023	109,000	124,000	129,000	168,000	18,500
2024	97,400	137,000	146,000	219,000	40,567
2025	87,900	147,000	153,000	246,000	49,951
2026	81,700	152,000	157,000	245,000	53,868
2027	80,000	156,000	160,000	257,000	56,349
2028	80,500	157,000	161,000	258,000	56,469
2029	80,300	156,000	160,000	255,000	55,256
2030	82,300	155,000	159,000	254,000	54,198

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	263,000	263,000	263,000	263,000	0
2019	240,000	240,000	240,000	240,000	0
2020	202,000	202,000	202,000	202,000	40
2021	183,000	183,000	183,000	185,000	762
2022	184,000	188,000	189,000	199,000	5,093
2023	189,000	203,000	207,000	239,000	16,801
2024	185,000	215,000	223,000	286,000	33,739
2025	178,000	224,000	233,000	328,000	46,742
2026	172,000	228,000	239,000	338,000	53,990
2027	170,000	230,000	243,000	345,000	57,911
2028	171,000	232,000	244,000	352,000	59,172
2029	170,000	231,000	244,000	357,000	58,152
2030	171,000	231,000	243,000	355,000	56,680

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.31	0.31	0.31	0.31	0.00
2019	0.31	0.31	0.31	0.31	0.00
2020	0.26	0.26	0.26	0.26	0.00
2021	0.23	0.23	0.23	0.24	0.00
2022	0.24	0.24	0.24	0.26	0.01
2023	0.24	0.26	0.27	0.31	0.02
2024	0.24	0.28	0.28	0.31	0.03
2025	0.23	0.29	0.28	0.31	0.03
2026	0.22	0.30	0.28	0.31	0.03
2027	0.22	0.30	0.28	0.31	0.03
2028	0.22	0.30	0.28	0.31	0.03
2029	0.22	0.30	0.28	0.31	0.03
2030	0.22	0.30	0.28	0.31	0.03

Table 2.6.29—Model 16.6 projections for catch (t), spawning biomass (t), and fishing mortality under the assumption that 2018-19 catches are less than ABC by amounts predicted from past performance, but $F = max\ F_{ABC}$ in 2020-2030 (Scenario 2), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	180,000	180,000	180,000	180,000	0
2019	161,000	161,000	161,000	161,000	0
2020	119,000	119,000	119,000	119,000	22
2021	91,200	91,500	91,600	92,300	390
2022	102,000	105,000	105,000	112,000	3,509
2023	110,000	125,000	130,000	168,000	18,451
2024	97,500	137,000	146,000	219,000	40,539
2025	87,800	147,000	153,000	246,000	49,960
2026	81,700	152,000	157,000	245,000	53,879
2027	80,000	156,000	160,000	257,000	56,355
2028	80,500	156,000	161,000	258,000	56,472
2029	80,300	156,000	160,000	255,000	55,257
2030	82,300	155,000	159,000	254,000	54,198

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	264,000	264,000	264,000	264,000	0
2019	248,000	248,000	248,000	248,000	0
2020	211,000	211,000	211,000	211,000	40
2021	187,000	187,000	187,000	189,000	761
2022	186,000	190,000	191,000	201,000	5,089
2023	190,000	204,000	208,000	240,000	16,796
2024	185,000	215,000	223,000	286,000	33,753
2025	178,000	224,000	233,000	328,000	46,761
2026	172,000	228,000	239,000	338,000	54,001
2027	170,000	230,000	243,000	345,000	57,915
2028	171,000	232,000	244,000	352,000	59,172
2029	170,000	231,000	244,000	357,000	58,150
2030	171,000	231,000	243,000	355,000	56,679

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.27	0.27	0.27	0.27	0.00
2019	0.29	0.29	0.29	0.29	0.00
2020	0.27	0.27	0.27	0.27	0.00
2021	0.24	0.24	0.24	0.24	0.00
2022	0.24	0.24	0.25	0.26	0.01
2023	0.24	0.26	0.27	0.31	0.02
2024	0.24	0.28	0.28	0.31	0.03
2025	0.23	0.29	0.28	0.31	0.03
2026	0.22	0.30	0.28	0.31	0.03
2027	0.22	0.30	0.28	0.31	0.03
2028	0.22	0.30	0.28	0.31	0.03
2029	0.22	0.30	0.28	0.31	0.03
2030	0.22	0.30	0.28	0.31	0.03

Table 2.6.30—Model 16.6 projections for 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 2018-2030 (Scenario 3), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	284,000	284,000	284,000	284,000	0
2019	205,000	205,000	205,000	205,000	0
2020	143,000	143,000	143,000	143,000	1
2021	118,000	118,000	118,000	118,000	66
2022	137,000	138,000	139,000	142,000	1,573
2023	141,000	155,000	160,000	193,000	17,979
2024	120,000	160,000	172,000	261,000	47,142
2025	110,000	167,000	178,000	289,000	57,254
2026	105,000	171,000	182,000	287,000	60,483
2027	103,000	173,000	186,000	303,000	63,281
2028	104,000	174,000	186,000	302,000	62,673
2029	104,000	175,000	185,000	301,000	60,589
2030	106,000	173,000	183,000	296,000	59,445

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	257,000	257,000	257,000	257,000	0
2019	206,000	206,000	206,000	206,000	0
2020	155,000	155,000	155,000	155,000	42
2021	129,000	129,000	129,000	131,000	797
2022	127,000	132,000	133,000	143,000	5,396
2023	128,000	143,000	148,000	182,000	18,047
2024	120,000	152,000	160,000	227,000	35,309
2025	111,000	160,000	168,000	259,000	45,994
2026	105,000	164,000	173,000	263,000	50,742
2027	104,000	167,000	175,000	270,000	53,003
2028	105,000	168,000	176,000	274,000	53,044
2029	106,000	167,000	176,000	275,000	51,608
2030	107,000	167,000	175,000	274,000	50,486

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.46	0.46	0.46	0.46	0.00
2019	0.46	0.46	0.46	0.46	0.00
2020	0.46	0.46	0.46	0.46	0.00
2021	0.46	0.46	0.46	0.46	0.00
2022	0.46	0.46	0.46	0.46	0.00
2023	0.46	0.46	0.46	0.46	0.00
2024	0.46	0.46	0.46	0.46	0.00
2025	0.46	0.46	0.46	0.46	0.00
2026	0.46	0.46	0.46	0.46	0.00
2027	0.46	0.46	0.46	0.46	0.00
2028	0.46	0.46	0.46	0.46	0.00
2029	0.46	0.46	0.46	0.46	0.00
2030	0.46	0.46	0.46	0.46	0.00

Table 2.6.31—Model 16.6 projections for catch (t), spawning biomass (t), and fishing mortality under the assumption that the upper bound on F_{ABC} is set at $F_{60\%}$ in 2018-2030 (Scenario 4), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	101,000	101,000	101,000	101,000	0
2019	95,200	95,200	95,200	95,200	0
2020	82,700	82,700	82,700	82,700	0
2021	74,600	74,700	74,700	74,700	21
2022	80,300	80,600	80,800	81,700	495
2023	83,700	88,200	89,800	101,000	5,940
2024	77,400	92,800	97,200	132,000	18,079
2025	73,400	97,500	103,000	151,000	24,805
2026	70,800	102,000	107,000	157,000	28,274
2027	69,300	106,000	110,000	162,000	30,651
2028	70,100	107,000	112,000	169,000	31,509
2029	70,200	108,000	113,000	168,000	31,123
2030	71,500	109,000	113,000	168,000	30,517

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	269,000	269,000	269,000	269,000	0
2019	282,000	282,000	282,000	282,000	0
2020	267,000	267,000	267,000	267,000	42
2021	249,000	250,000	250,000	252,000	797
2022	245,000	249,000	250,000	261,000	5,409
2023	247,000	262,000	267,000	302,000	18,494
2024	243,000	278,000	288,000	364,000	39,775
2025	234,000	296,000	307,000	429,000	60,022
2026	227,000	310,000	322,000	461,000	74,106
2027	221,000	320,000	333,000	476,000	82,722
2028	223,000	328,000	341,000	498,000	87,055
2029	224,000	332,000	345,000	502,000	87,772
2030	223,000	335,000	347,000	507,000	86,635

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.15	0.15	0.15	0.15	0.00
2019	0.15	0.15	0.15	0.15	0.00
2020	0.15	0.15	0.15	0.15	0.00
2021	0.15	0.15	0.15	0.15	0.00
2022	0.15	0.15	0.15	0.15	0.00
2023	0.15	0.15	0.15	0.15	0.00
2024	0.15	0.15	0.15	0.15	0.00
2025	0.15	0.15	0.15	0.15	0.00
2026	0.15	0.15	0.15	0.15	0.00
2027	0.15	0.15	0.15	0.15	0.00
2028	0.15	0.15	0.15	0.15	0.00
2029	0.15	0.15	0.15	0.15	0.00
2030	0.15	0.15	0.15	0.15	0.00

Table 2.6.32—Model 16.6 projections for catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = 0 in 2018-2030 (Scenario 5), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	0	0	0	0	0
2022	0	0	0	0	0
2023	0	0	0	0	0
2024	0	0	0	0	0
2025	0	0	0	0	0
2026	0	0	0	0	0
2027	0	0	0	0	0
2028	0	0	0	0	0
2029	0	0	0	0	0
2030	0	0	0	0	0

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	275,000	275,000	275,000	275,000	0
2019	326,000	326,000	326,000	326,000	0
2020	347,000	347,000	347,000	347,000	42
2021	353,000	354,000	354,000	355,000	797
2022	362,000	366,000	367,000	378,000	5,416
2023	374,000	390,000	394,000	430,000	18,702
2024	381,000	418,000	429,000	509,000	42,069
2025	381,000	449,000	462,000	601,000	68,830
2026	377,000	477,000	492,000	670,000	91,584
2027	372,000	500,000	516,000	713,000	108,239
2028	375,000	518,000	536,000	745,000	119,186
2029	378,000	533,000	550,000	771,000	124,828
2030	383,000	545,000	559,000	786,000	126,515

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.00	0.00	0.00	0.00	0.00
2019	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00
2021	0.00	0.00	0.00	0.00	0.00
2022	0.00	0.00	0.00	0.00	0.00
2023	0.00	0.00	0.00	0.00	0.00
2024	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00
2026	0.00	0.00	0.00	0.00	0.00
2027	0.00	0.00	0.00	0.00	0.00
2028	0.00	0.00	0.00	0.00	0.00
2029	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00

Table 2.6.33—Model 16.6 projections for catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2018-2030 (Scenario 6), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	238,000	238,000	238,000	238,000	0
2019	176,000	176,000	176,000	176,000	0
2020	110,000	110,000	110,000	110,000	23
2021	88,300	88,600	88,700	89,500	422
2022	105,000	108,000	109,000	116,000	3,896
2023	115,000	132,000	138,000	183,000	22,149
2024	102,000	145,000	158,000	248,000	48,642
2025	90,800	155,000	165,000	273,000	58,311
2026	84,600	158,000	168,000	268,000	61,851
2027	83,400	160,000	170,000	281,000	64,174
2028	83,800	160,000	170,000	282,000	63,984
2029	83,000	160,000	169,000	280,000	62,500
2030	85,800	159,000	168,000	279,000	61,407

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	260,000	260,000	260,000	260,000	0
2019	225,000	225,000	225,000	225,000	0
2020	185,000	185,000	185,000	185,000	40
2021	167,000	167,000	168,000	169,000	759
2022	170,000	174,000	176,000	185,000	5,062
2023	176,000	190,000	194,000	225,000	16,514
2024	172,000	201,000	208,000	270,000	32,115
2025	165,000	209,000	216,000	301,000	42,608
2026	159,000	211,000	220,000	304,000	47,846
2027	158,000	212,000	222,000	314,000	50,626
2028	158,000	213,000	222,000	317,000	51,176
2029	157,000	212,000	221,000	317,000	49,817
2030	159,000	212,000	220,000	317,000	48,465

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.38	0.38	0.38	0.38	0.00
2019	0.36	0.36	0.36	0.36	0.00
2020	0.29	0.29	0.29	0.29	0.00
2021	0.26	0.26	0.26	0.26	0.00
2022	0.26	0.27	0.27	0.29	0.01
2023	0.27	0.30	0.30	0.36	0.02
2024	0.27	0.32	0.32	0.38	0.04
2025	0.26	0.33	0.33	0.38	0.04
2026	0.25	0.33	0.33	0.38	0.05
2027	0.24	0.33	0.33	0.38	0.05
2028	0.24	0.33	0.33	0.38	0.05
2029	0.24	0.33	0.33	0.38	0.05
2030	0.25	0.33	0.33	0.38	0.05

Table 2.6.34—Model 16.6 projections for catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2018-2019 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment.

Catch projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	201,000	201,000	201,000	201,000	0
2019	165,000	165,000	165,000	165,000	0
2020	130,000	130,000	130,000	130,000	25
2021	95,900	96,200	96,400	97,100	434
2022	108,000	111,000	112,000	119,000	3,933
2023	117,000	133,000	139,000	184,000	22,116
2024	102,000	145,000	158,000	248,000	48,608
2025	90,700	155,000	164,000	273,000	58,321
2026	84,500	158,000	168,000	268,000	61,866
2027	83,400	160,000	170,000	281,000	64,181
2028	83,800	160,000	170,000	282,000	63,986
2029	82,900	160,000	169,000	280,000	62,500
2030	85,800	159,000	168,000	279,000	61,406

Biomass projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	263,000	263,000	263,000	263,000	0
2019	240,000	240,000	240,000	240,000	0
2020	201,000	201,000	201,000	201,000	40
2021	174,000	175,000	175,000	176,000	757
2022	174,000	178,000	179,000	188,000	5,053
2023	177,000	191,000	195,000	227,000	16,499
2024	172,000	201,000	209,000	270,000	32,117
2025	165,000	209,000	216,000	301,000	42,618
2026	159,000	211,000	220,000	304,000	47,850
2027	158,000	212,000	222,000	314,000	50,625
2028	158,000	213,000	222,000	317,000	51,172
2029	157,000	212,000	221,000	317,000	49,814
2030	159,000	212,000	220,000	317,000	48,463

Fishing mortality projections:

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2018	0.31	0.31	0.31	0.31	0.00
2019	0.31	0.31	0.31	0.31	0.00
2020	0.32	0.32	0.32	0.32	0.00
2021	0.27	0.27	0.27	0.27	0.00
2022	0.27	0.28	0.28	0.29	0.01
2023	0.28	0.30	0.30	0.36	0.02
2024	0.27	0.32	0.32	0.38	0.04
2025	0.26	0.33	0.33	0.38	0.04
2026	0.24	0.33	0.33	0.38	0.05
2027	0.24	0.33	0.33	0.38	0.05
2028	0.24	0.33	0.33	0.38	0.05
2029	0.24	0.33	0.33	0.38	0.05
2030	0.25	0.33	0.33	0.38	0.05