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

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Introduction

This document represents an effort to respond to comments made by the BSAI Plan Team ("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

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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

SSC6: “All three cod assessments could benefit from a formal prior on *M* based on the variety of studies referenced in each. The SSC recommends that a prior for use in all cod assessments be developed for 2017.”

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-multplied 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:

<u>Prior distribution for natural mortality</u>

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 *σdev*s corresponding to **V1**+**V2**.
8. Return to step 2 and repeat until the *σdev*s 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

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

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 σ*dev*s is that, with the exception of σ_R, none of the σ*dev*s 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 kth *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 σ*dev*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.

<u>Data weighting in Model 17.5</u>

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:
  - $\Sigma mult = B_{1,1} + B_{1,2} + B_{2,1} + B_{2,2}$.
  - $denom = B_{2,2} \cdot A_{1,1} \cdot A_{1,2} \cdot A_{2,1} + (1-\Delta) \cdot \left(B_{1,2} \cdot A_{2,1} + B_{2,1} \cdot A_{1,2}\right) \cdot A_{1,1} \cdot A_{2,2} + (1-\Delta)^2 \cdot B_{2,2} \cdot A_{1,1} \cdot A_{1,2} \cdot A_{2,1}$.
- Then:

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

<u>Additional time variability in Model 17.6</u>

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:
    - $Yrs \times N \times ((SEave+SEextra)/RMSE)^2$.

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), 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 σ*dev* value of any model for every *dev* vector that it includes.

As requested by the Subcommittee (see comment Sub5), σ*dev* 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 straightfoward. 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 projecton 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 *devs* (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

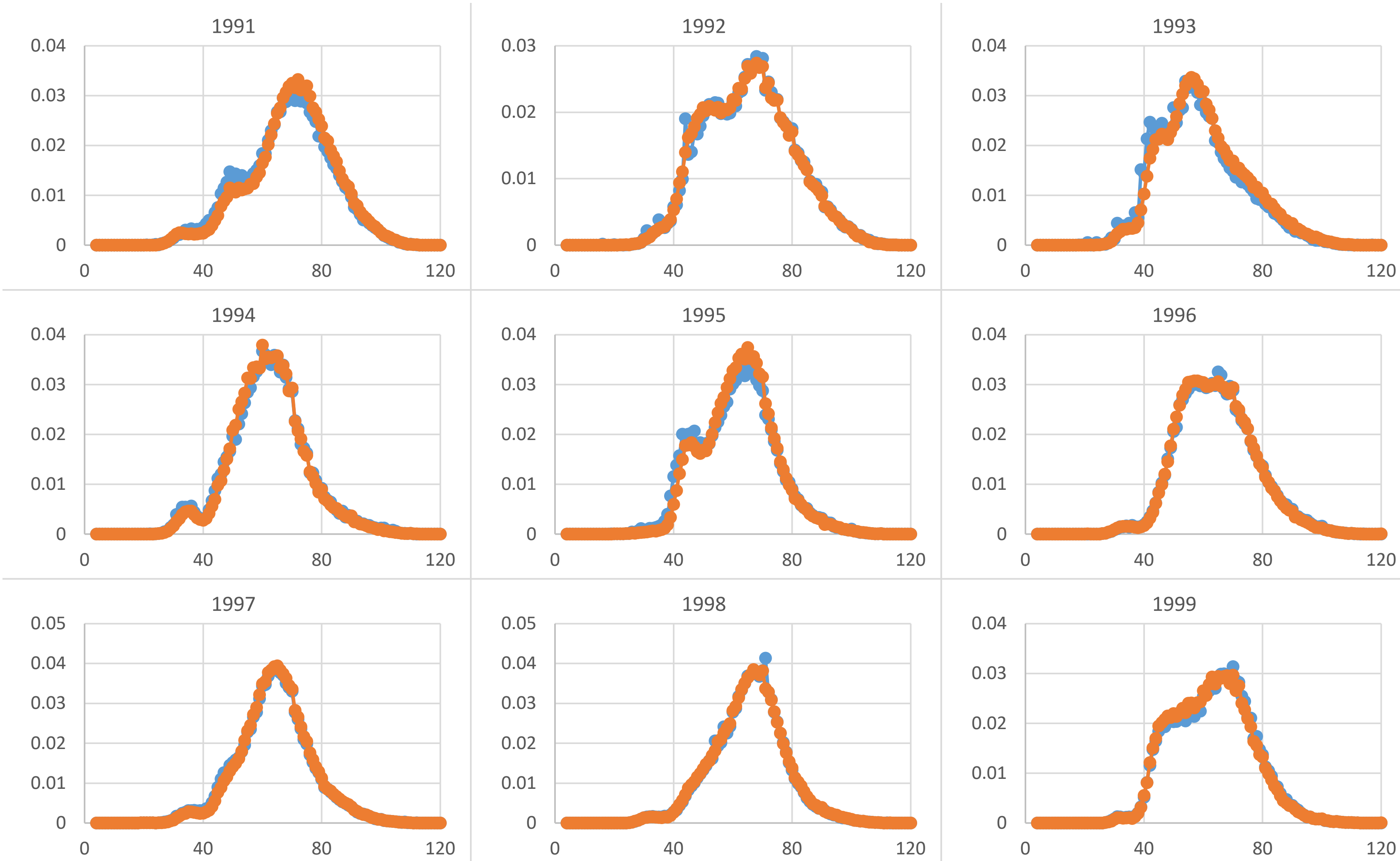

Figure 2.1.1 (page 1 of 3). Comparison of sizecomp data used in last year's assessment (orange) with catch-weighted sizecomp data (blue).

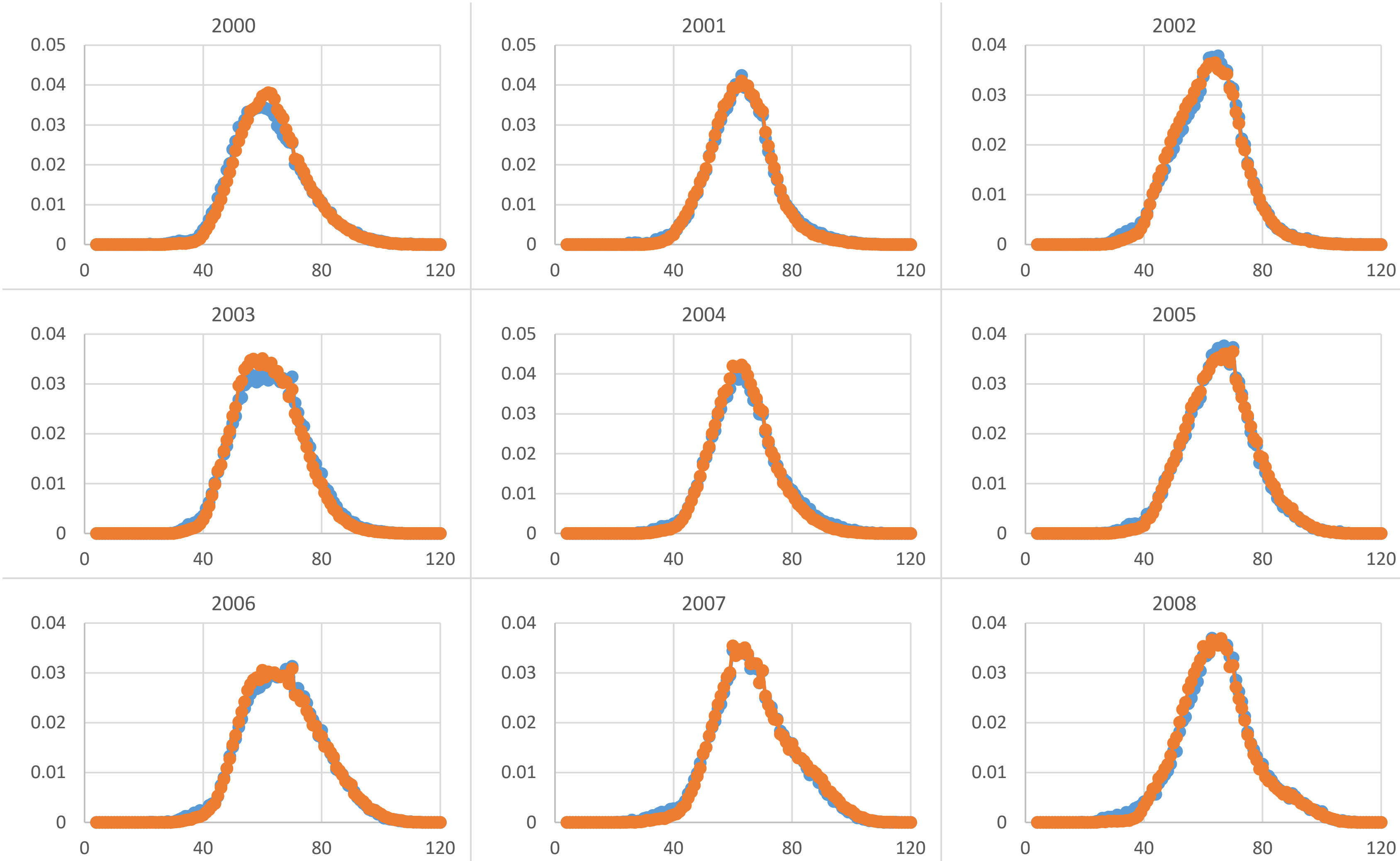

Figure 2.1.1 (page 2 of 3). Comparison of sizecomp data used in last year's assessment (orange) with catch-weighted sizecomp data (blue).

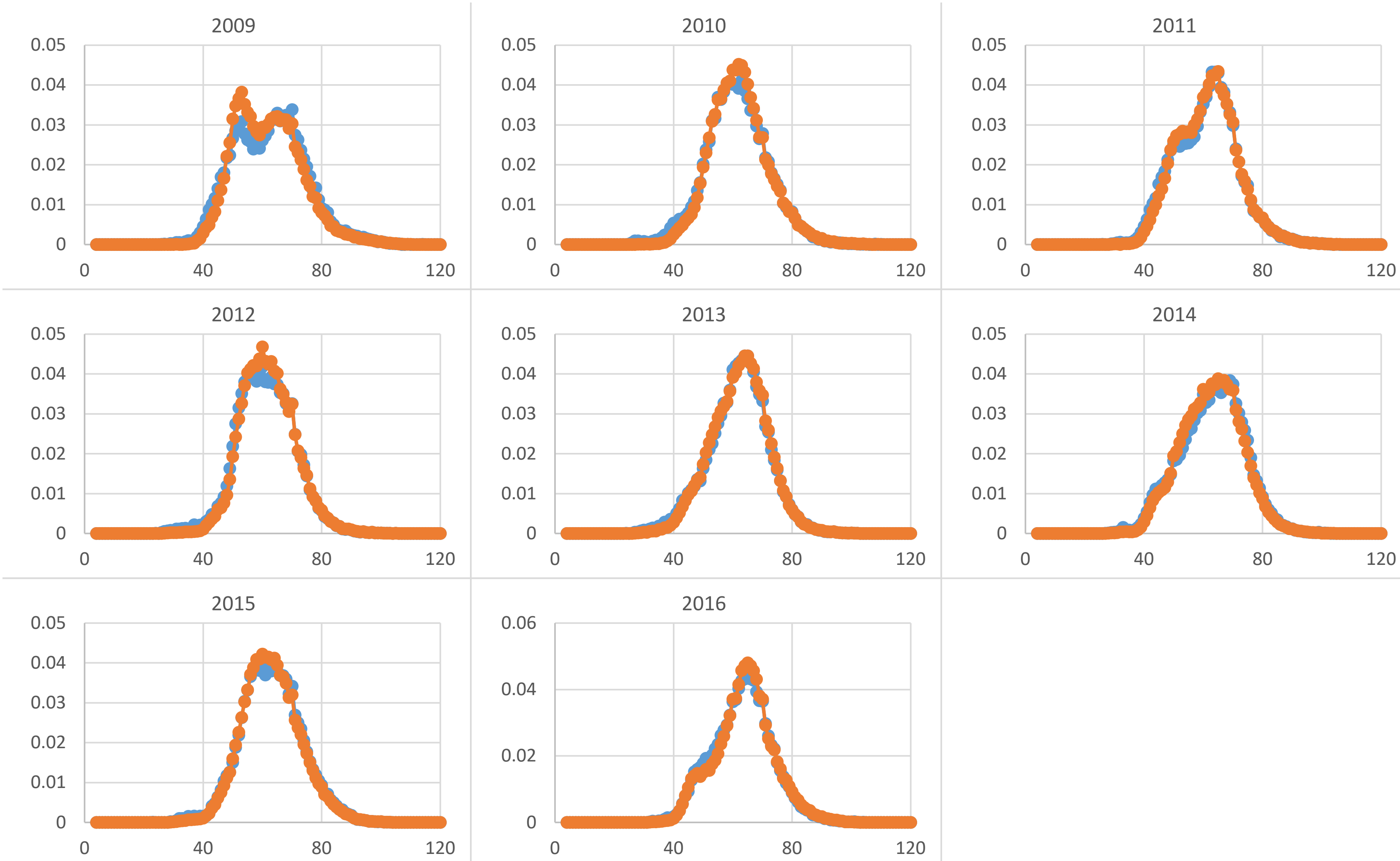

Figure 2.1.1 (page 3 of 3). Comparison of sizecomp data used in last year's assessment (orange) with catch-weighted sizecomp data (blue).

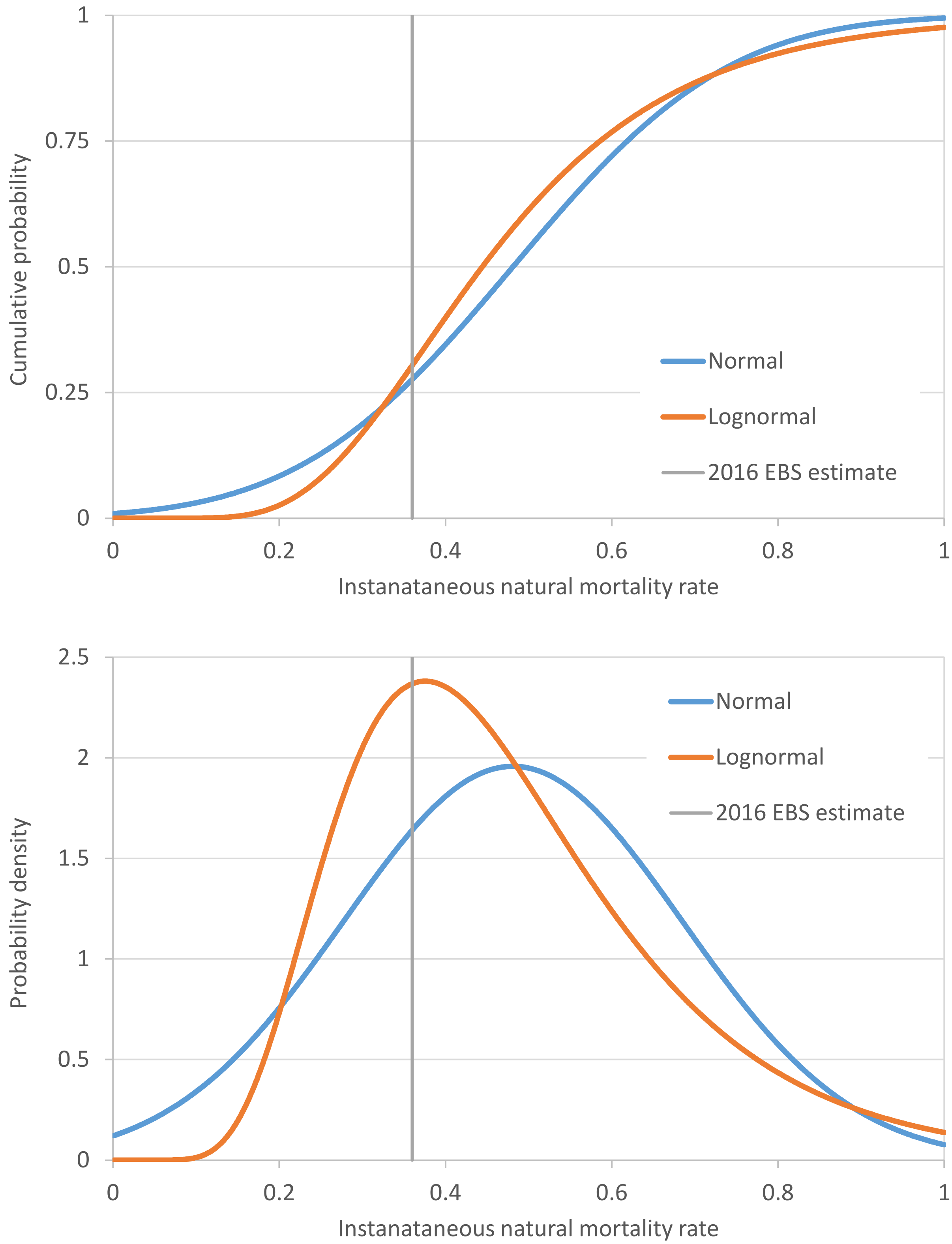

Figure 2.1.2. Prior distribution of the instantaneous natural mortality rate.

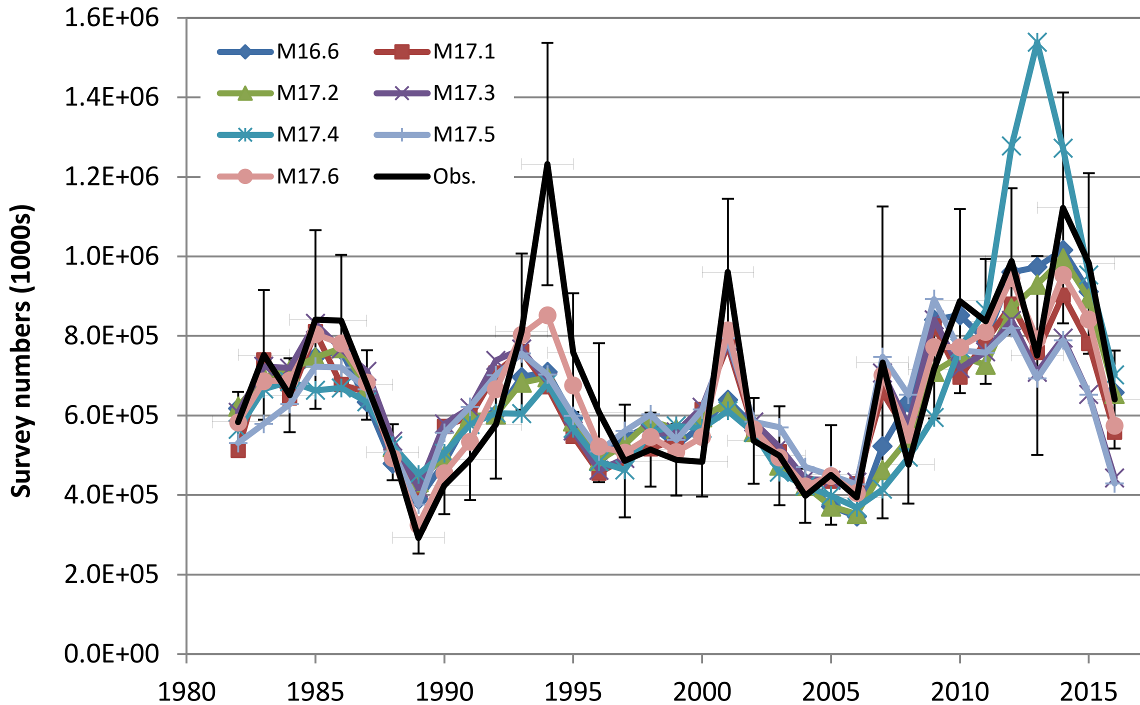

Figure 2.1.3. Model fits to survey abundance.

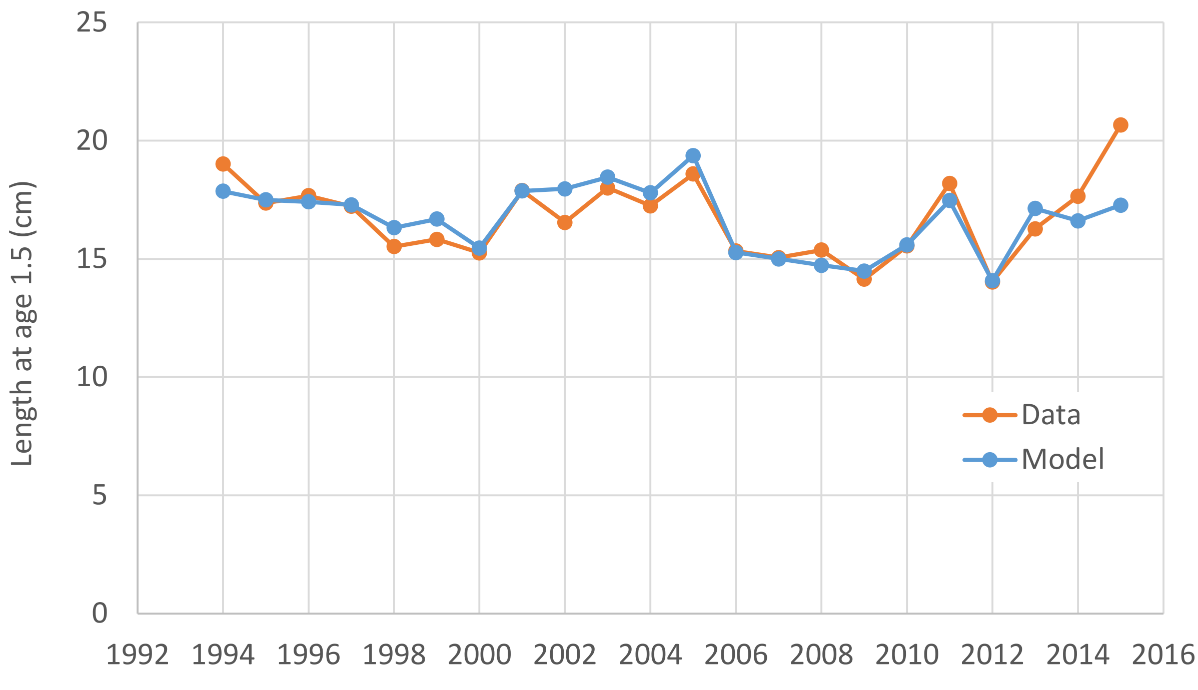

Figure 2.1.4. Model 17.6 fit to mean length at age 1.5 data.

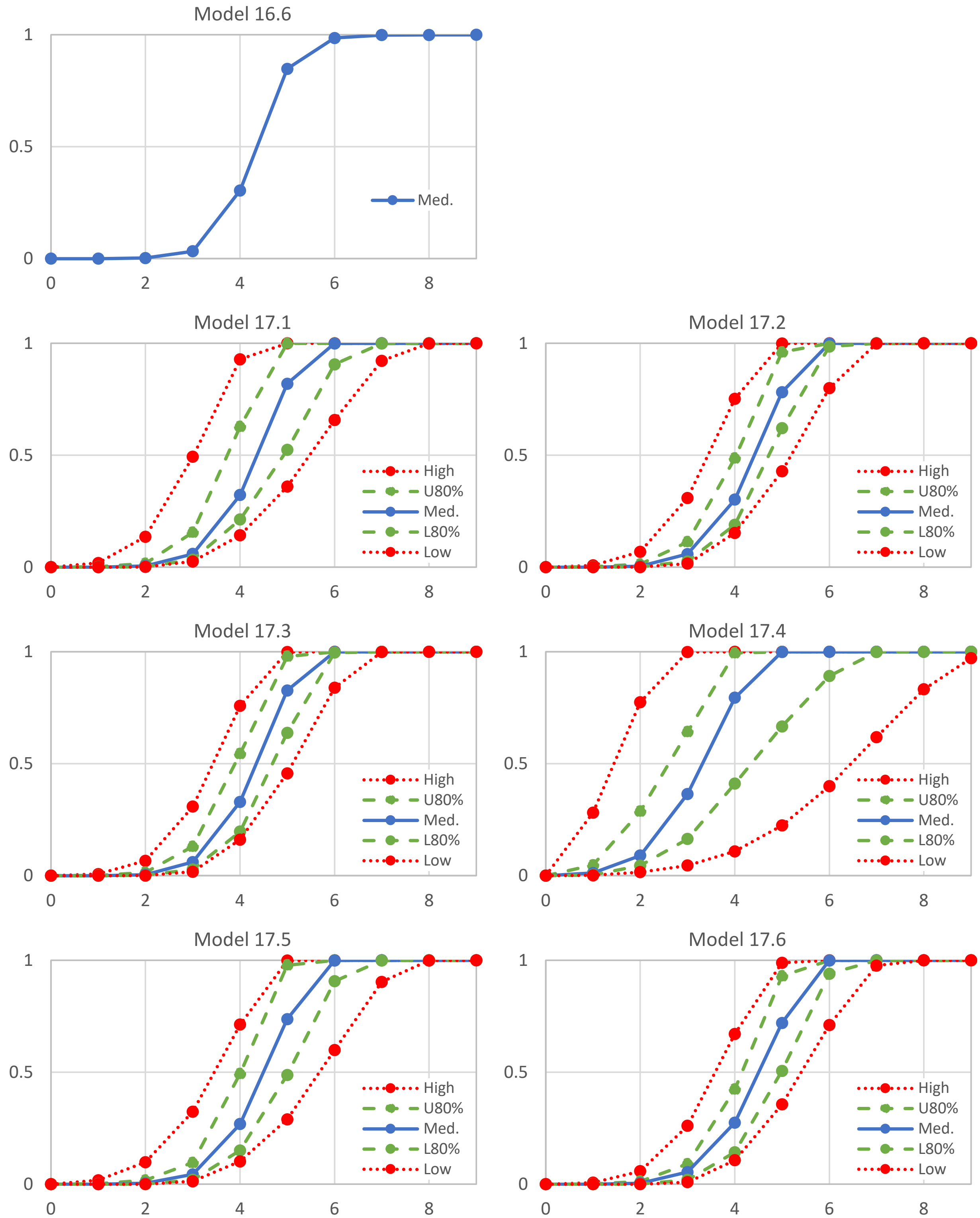

Figure 2.1.5a—Model estimates of fishery selectivity.

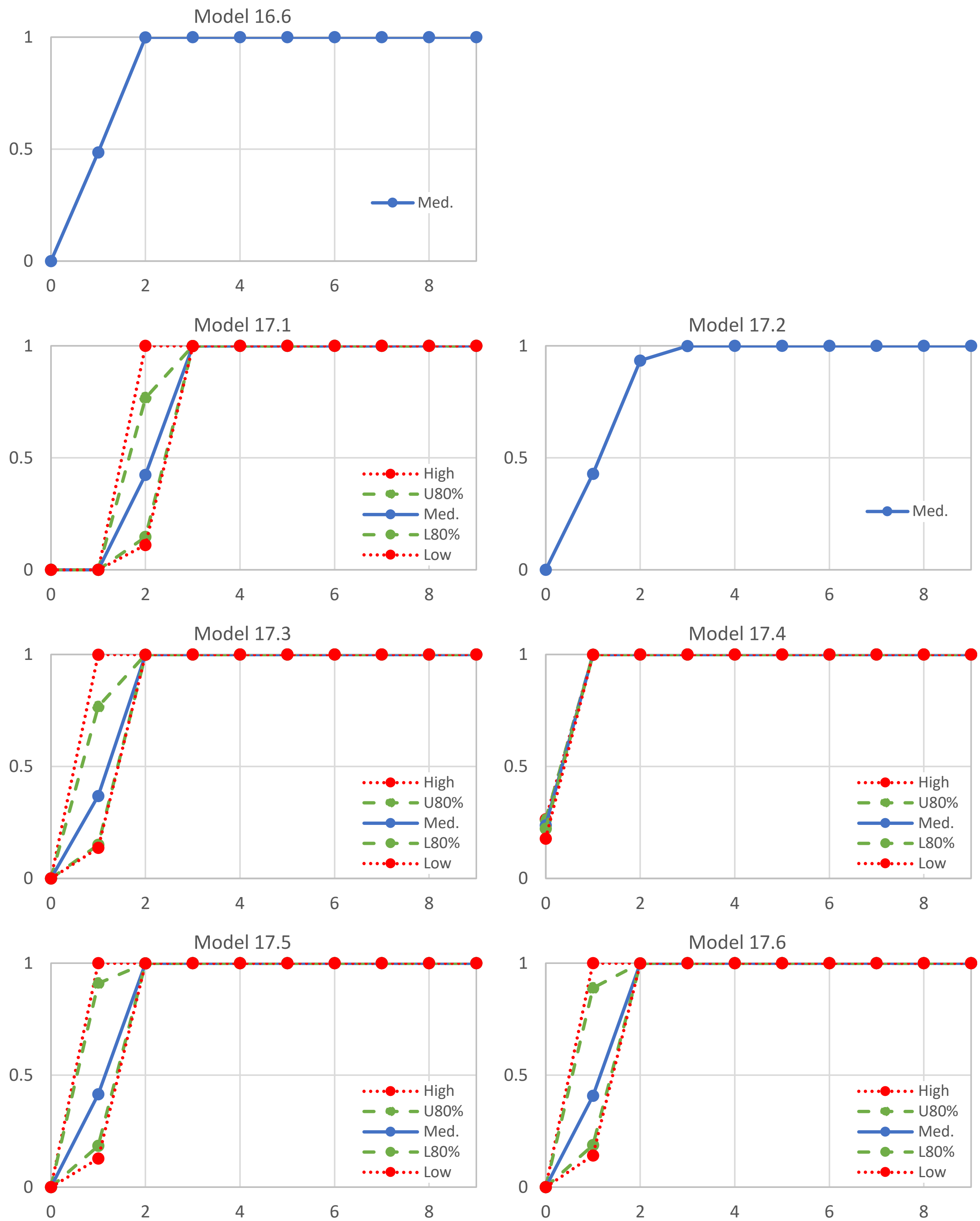

Figure 2.1.5b—Model estimates of survey selectivity.

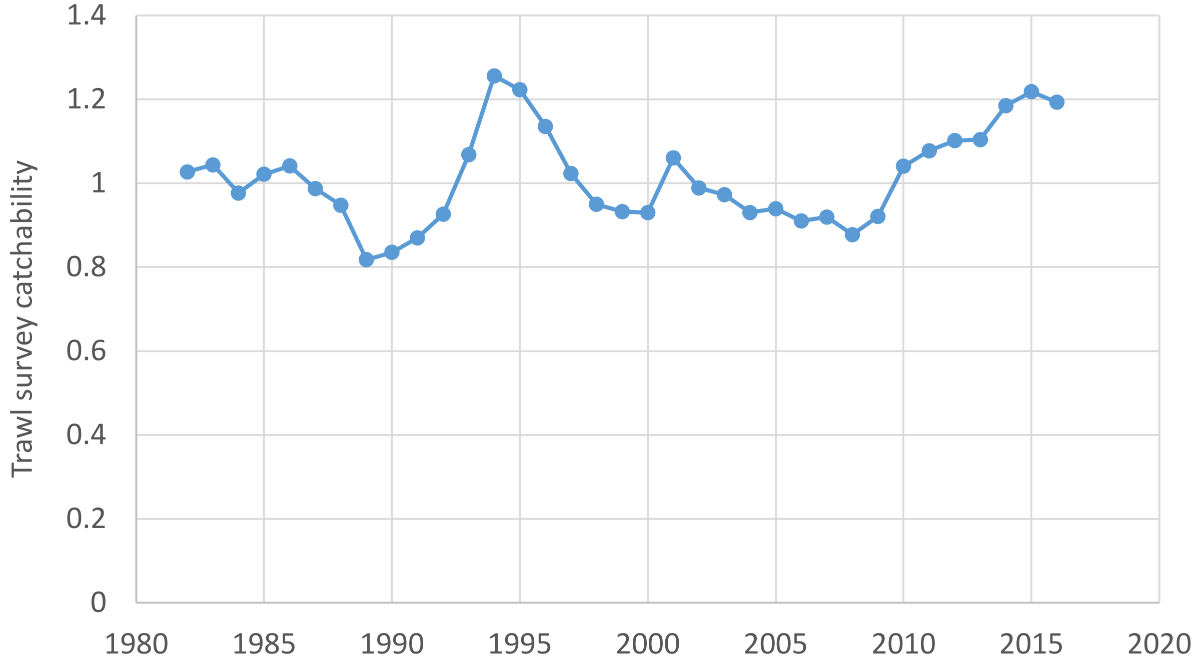

Figure 2.1.6. Trawl survey catchability time series as estimated by Model 17.6.

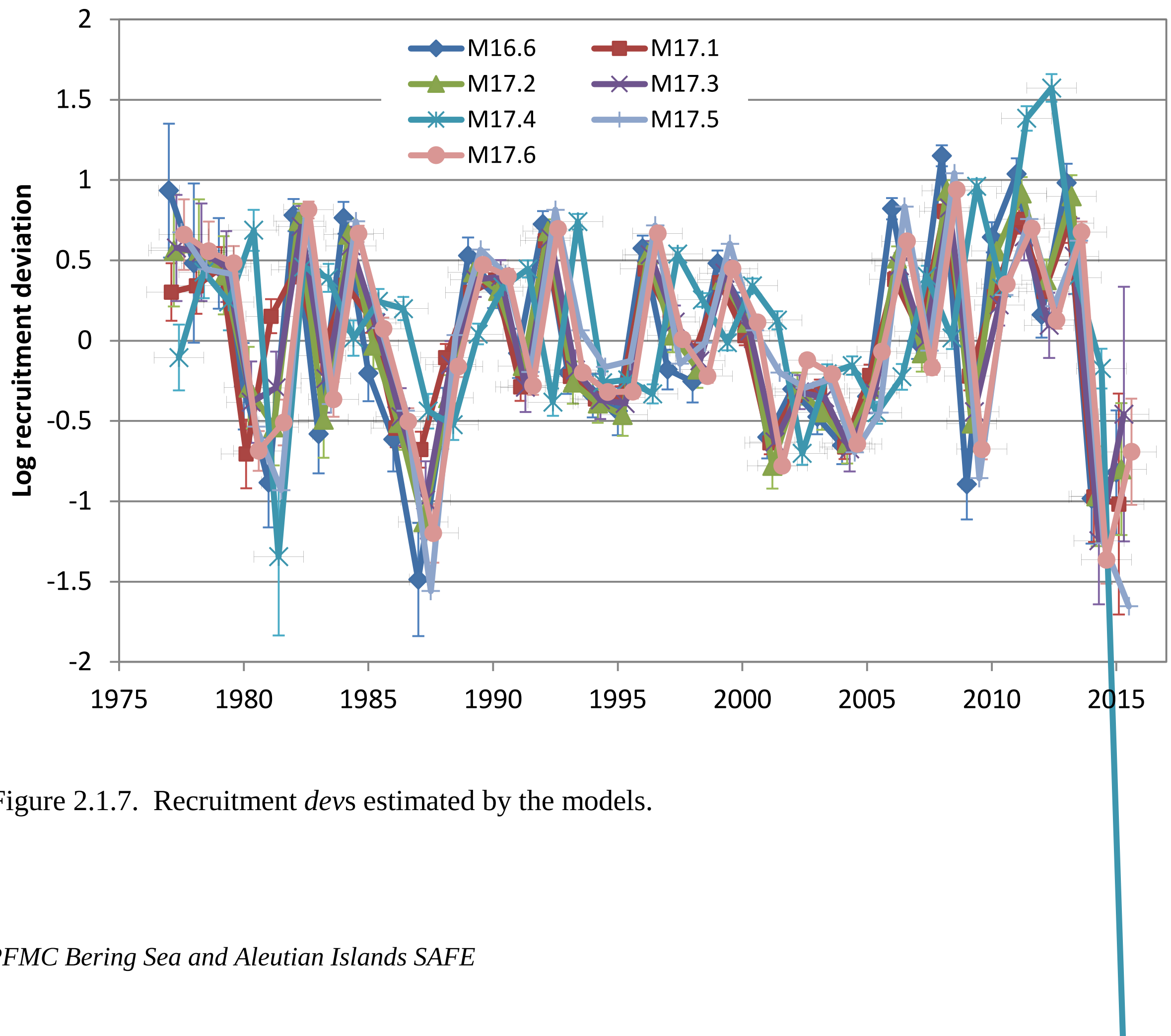

Figure 2.1.7. Recruitment *dev*s estimated by the models.

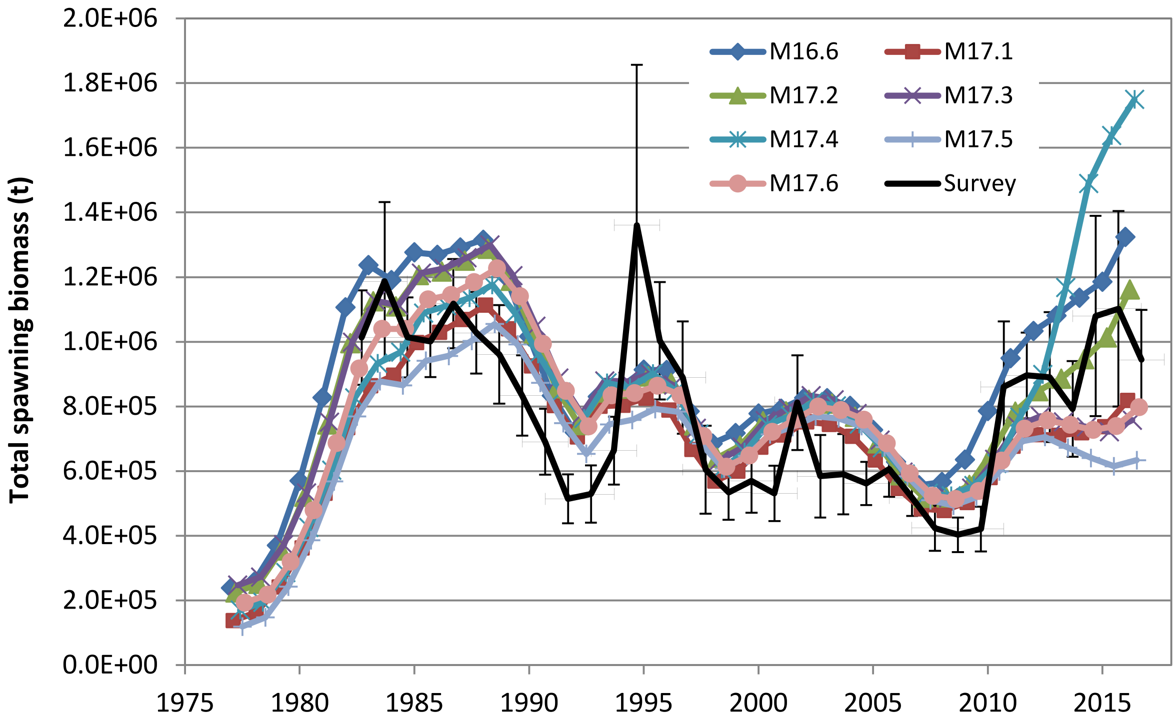

Figure 2.1.8. Model estimates of total (age 0+) biomass, with survey biomass for comparison.

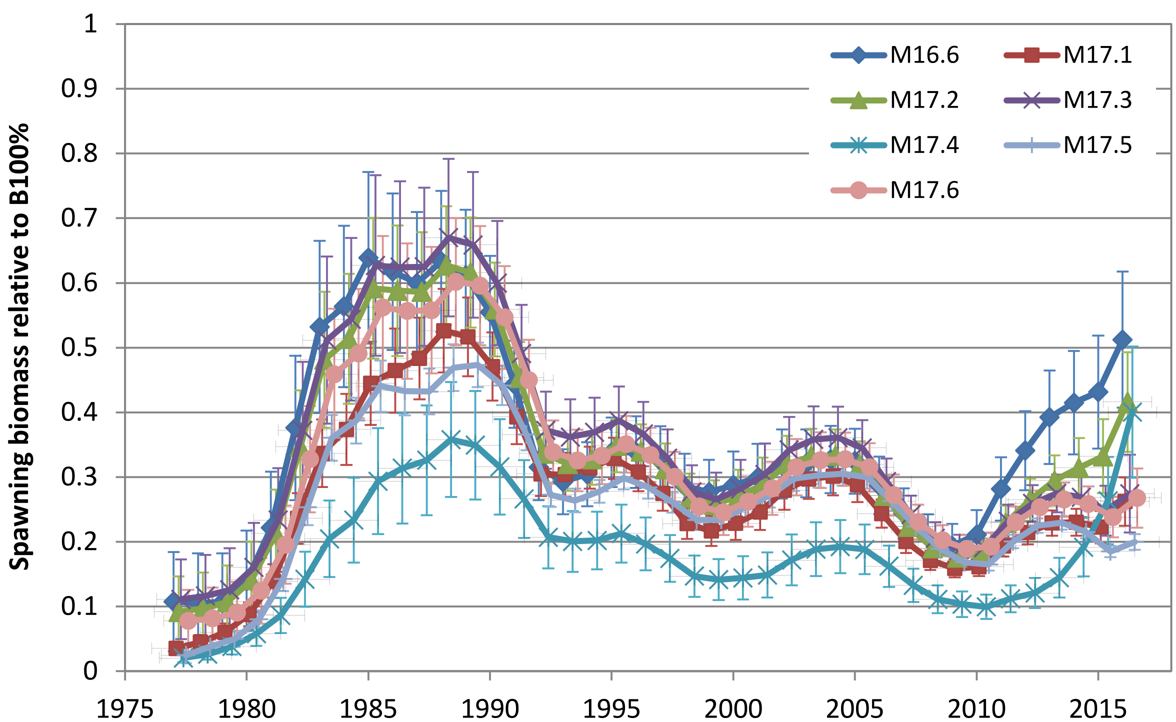

Figure 2.1.9. Model estimates of female spawning biomass relative to $B_{100\%}$.

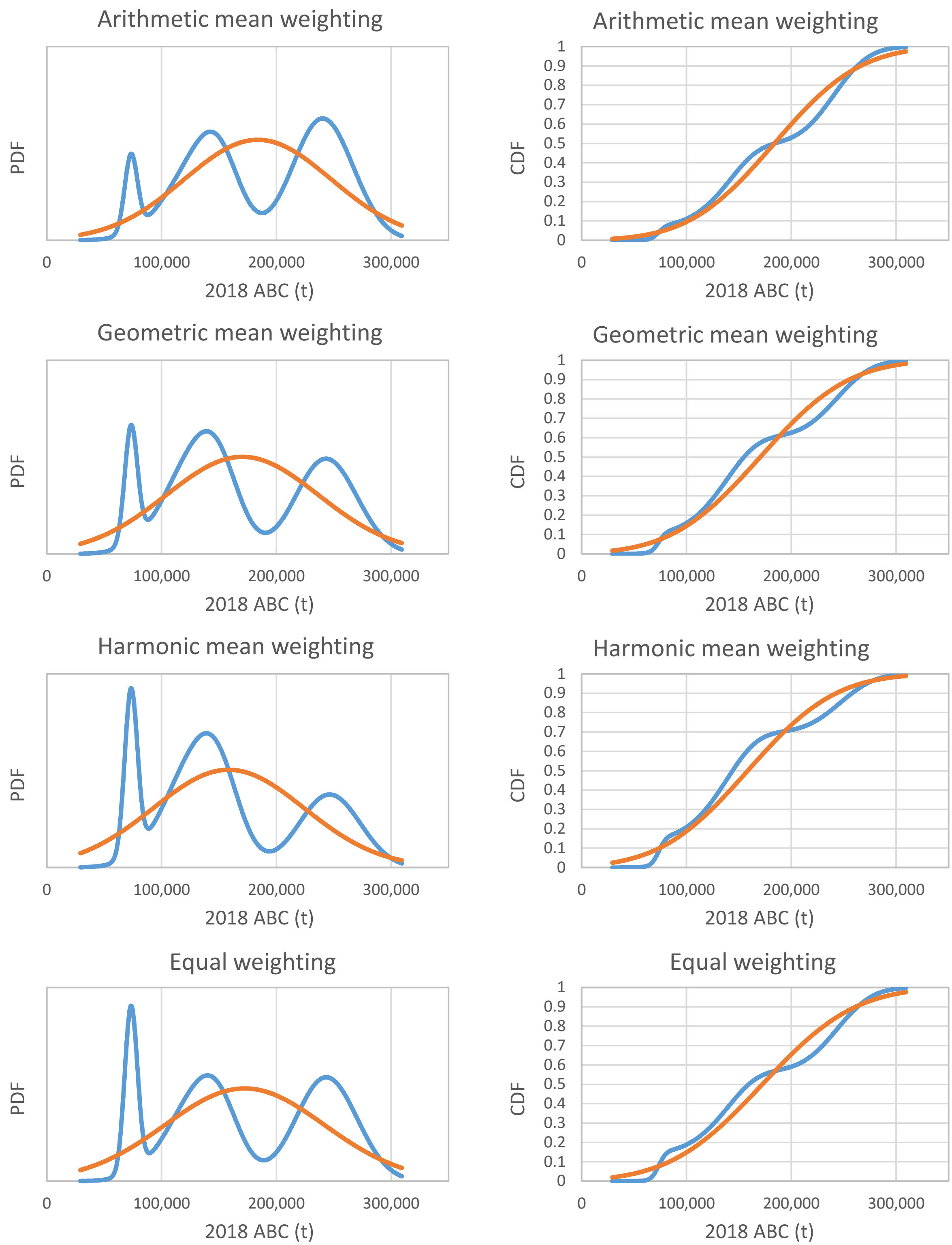

Figure 2.1.10. Distributions of the 2018 ABC based on model averaging.