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) and the Scientific and Statistical Committee (SSC) on last year's assessment of the Pacific cod stock in the Eastern Bering Sea (EBS), which also includes Pacific cod in the Northern Bering Sea (NBS, Thompson et al. 2020). In addition, comments from this year's review of the assessment by members of the Center for Independent Experts (CIE) are addressed (Attachment 2.1.1).

A note on table formatting: All tables presented in this preliminary assessment that include "color scales" follow the convention red=low and green=high. Depending on the context, color scales may extend across a row, a column, or the entire table.

Responses to Team and SSC comments on assessments in general

Note that, although the SSC made a number of generic recommendations regarding the "risk table" during its June 2021 meeting, those recommendations are not addressed here, because: 1) they will not be finalized until the SSC's October meeting and therefore may undergo changes, and 2) the risk table is typically not updated until the final draft of the assessment. The final draft of this year's assessment will address any final recommendations on the risk table adopted by the SSC at its October meeting.

Comments from the December 2020 SSC meeting

SSC1: "The SSC cautions against standardized model fitting (e.g., a single error distribution, set of covariates, number of knots), other than as a starting point. The species-specific biological distribution, and interaction of this distribution with covariates, may require differing error distributions to fit the data adequately. It is more important for each species to have a statistically rigorous model selection process resulting in good model fit and diagnostics than the simplicity of fitting the same approach to all species: unlike design-based estimators, the SSC suggests that one size does not fit all for VAST models. For each species, assessment documents should describe why the particular error distributions, covariates, and number of knots were chosen for that individual species." *Response:* An evaluation of alternative configurations for the VAST model of trawl survey index data is presented under "VAST estimates of survey abundance" in the "Data" section.

SSC2: "In general, …the SSC recommends the continued inclusion of community engagement and dependency indices at varying scales in ESPs, ESRs, and SAFEs. For ESPs specifically, changes in patterns of community engagement and dependency at the stock level have the potential to inform not only stock assessments and analyses that support fishery management, but they may also function as early indicators of larger ecosystem changes." *Response:* See response listed in the revised ESP (https://apps-afsc.fisheries.noaa.gov/Plan_Team/2021/EBSPcod_esp.pdf).

Responses to Team and SSC comments specific to this assessment

Comments from the November 2020 BSAI Groundfish Plan Team meeting

GPT1: “The Team recommended that the fishery CPUE be standardized using alternative statistical methods and that it be discussed at the CIE review in 2021. This should also include a discussion of historical changes in the fishery that may affect the relationship of the index to abundance.” *Response:* A first attempt at standardizing fishery CPUE using alternative statistical methods has been completed (see “VAST estimates of fishery catch per unit effort” in the “Data” section). This comment was forwarded to the CIE reviewers for their consideration (Attachment 2.1.1). In response, one result of the CIE review was the inclusion in this preliminary assessment of a model incorporating the new index of fishery CPUE (see “Alternative models” in the “Models” section).

GPT2: “The Team recommended collating fishery information in the ESP. Although the CPUE index was of concern to the Team, the Team recognizes that fishery performance has been improving and that these observations should not be ignored. Inclusion of fishery performance in the ESP and evaluation of the CPUE index with those performance metrics may help provide important insights.” *Response:* Collating *all* fishery information in the ESP could prove awkward, because some of it is routinely used by the assessment models (e.g., catch and fishery size composition), and it seems more appropriate to collate such data in the main text of the assessment. Moreover, because fishery CPUE data are used in one of the assessment models, it seems more efficient to collate all fishery CPUE information in the main text than to split this information into two parts, with one part placed in the main text and the other in the ESP. The revised ESP (https://apps-afsc.fisheries.noaa.gov/Plan_Team/2021/EBSPcod_esp.pdf) continues to include aspects of fishery performance other than fishery CPUE.

GPT3: “The Team recommended the following topics could be considered for the 2021 CIE review: development of a fishery CPUE index, incorporation of dome-shaped survey selectivity, models to include in an ensemble, whether to apply the sloping HCR before or after ensemble averaging of SSB and other reference points, and development of movement models.” *Response:* These topics were considered during the CIE review (Attachment 2.1.1). In response, some results of the CIE review were the inclusion in this preliminary assessment of: 1) a model incorporating a new index of fishery CPUE (see response to comment GPT1), 2) a model incorporating dome-shaped survey selectivity, 3) a set of models to include in an ensemble, 4) a simple conceptual model (*not* part of the ensemble) addressing movement of Pacific cod between American and Russian jurisdictions (Attachment 2.1.2), and 5) further analysis of whether to apply the harvest control rule before or after model averaging (Attachment 2.1.3)

Comments from the December 2020 SSC meeting

SSC3: “The SSC supports items proposed by the BSAI GPT for inclusion in the CIE review of this assessment planned for 2021. Proposed topics include: development of a standardized fishery CPUE index using alternative statistical methods, incorporation of dome-shaped survey selectivity, discussion of models to include in an ensemble, whether to apply the sloping harvest control rule before or after ensemble averaging of SSB and other reference points, and development of movement models.” *Response:* See response to comment GPT3.

SSC4: “The SSC also recommends consideration of suggestions offered by Alistair Dunn (public comment) about other factors that could be included in the CIE review if time is available including: inclusion of other survey information (e.g., the IPHC and sablefish surveys), and considerations about how best to include the fishery age and size composition data. Additionally, Mr. Dunn suggested that the analysis of fishery CPUE data suggested by the GPT could include development of spatiotemporal analyses of fleet-specific CPUE indices that may help inform the assessment. *Response:* These topics were considered during the CIE review (Attachment 2.1.1). Although most of them did not result in very many specific recommendations from the reviewers, it may be noted that the new fishery CPUE index mentioned in response to comment GPT1 does involve a spatiotemporal, fleet-specific analysis.

SSC5: "The SSC also encourages review of further efforts to include fishery age data in future analyses." *Response:* This comment was forwarded for consideration during the CIE review. Although some specific recommendations were received (Attachment 2.1.1), time was insufficient to implement them in this preliminary assessment.

SSC6: "If time allows, the CIE could comment on avenues for incorporating spatial dynamics and movement." *Response:* This comment was forwarded for consideration during the CIE review. In response, one result of the CIE review was the inclusion in this preliminary assessment of a conceptual model (*not* part of the ensemble) addressing movement of Pacific cod between American and Russian jurisdictions (Attachment 2.1.2).

SSC7: "In addition, the SSC would like the CIE review to include an evaluation of the use of ensemble modeling in the NPFMC management system, and specifically whether the structural uncertainty and historical challenges in identifying a robust base model make Pacific cod a good application for ensemble modeling. The SSC acknowledges the trade-off between review capacity and the addition of models comprising an ensemble, but also recognizes that the goals of developing an ensemble that describes a range of structural uncertainties differs from those of refining a single best model." *Response:* This comment was forwarded for consideration during the CIE review. The reviewers were unanimous in their conclusion that the EBS Pacific cod assessment is a good candidate for ensemble modeling, in part *because* of the structural uncertainty associated with it.

SSC8: "For community harvest revenue indicators, the SSC recommends that the analysts consider aggregating small communities that cannot be individually disclosed into a single indicator that can be displayed along with the limited number of larger community indicators that can be disclosed, for consistency with other ESPs and for the sake of a more comprehensive portrayal of EBS Pacific cod community engagement trends." *Response:* See response listed in the revised ESP (https://apps-afsc.fisheries.noaa.gov/Plan_Team/2021/EBSPcod_esp.pdf).

Data

This section is divided into two parts. The first part provides updates of certain data that were presented in last year's assessment, and that here incorporate year-to-date results for informational purposes only (i.e., either last year's data continue to be used in the assessment models presented in this preliminary assessment, or the data are not used in the assessment models at all). The second part provides methodological updates of data that *are* included in at least one of the assessment models presented here, but that do not include any current-year data.

Data updates provided for informational purposes only

Catch

Table 2.1.1 and Figure 2.1.1 update the time series of catch through August of 2021, both by gear and overall. These data correspond to catches taken throughout the portion of the Bering Sea covered by the Fishery Management Plan, which includes the areas covered by the EBS and NBS bottom trawl surveys (Figure 2.1.2). Figure 2.1.3 partitions the catches since 2003 into those taken in the Northern Bering Sea Research Area, which approximates the NBS survey area, and those taken in the remainder of the FMP area. Note that the catch data used in the assessment models presented here *do not* include these updates.

Fishery catch per unit effort (CPUE)

The methods used to summarize the information presented *in this subsection* are similar to those that have been used in the last several assessments, as distinguished from both the method used to devise the all-gear CPUE index that was used in Model 20.9 from last year's assessment (and which is *not* used in this preliminary assessment) and the method described below under "Data updates used in the models."

Table 2.1.2 shows simple year-and-month averages of catch (in weight) per unit effort for four gear types: longline, bottom trawl, pot, and pelagic trawl. The values have been normalized so that the average across all non-empty cells is unity (empty cells indicate either that there are no data, or that presentation of the data is precluded due to confidentiality restrictions). For the first three gear types, the data represent hauls/sets/lifts that satisfy the Regional Office's definition of a Pacific cod target, whereas the data for pelagic trawl gear include all hauls (because the majority of the Pacific cod taken by pelagic trawl gear consists of incidental catch). For all three of the gear types that target Pacific cod, Table 2.1.2 indicates that 2021 is shaping up to be an above-average year with respect to fishery CPUE. Relative to the 1996-2020 monthly averages, the 2021 monthly averages for the various gear types may be summarized as follows (reporting only those months where data are available and can be presented):

- Longline CPUE was above average for every month from January-August except for May.
- Bottom trawl CPUE was above average for every month from February-April; in particular, CPUE for February was extremely high (more than triple the 1996-2020 average), repeating the performance observed in 2020.
- Pot CPUE was above average for January.
- Pelagic trawl CPUE (including incidental catches) was mixed from January-March, with January being below average and February-March being above average; in particular, CPUE for March was more than double the 1996-2020 average.

Figure 2.1.4 shows the results of the conventional model that estimates "year" and "month" effects for each gear. For n years of data, where year "n" is the current year, the model initially estimates the year and month effects (with each vector normalized to a mean of zero) for the first $n-1$ years of the time series, after which the year effect for the current year is estimated freely, conditional on the month effects that were estimated for the first $n-1$ years (which means that the full set of year effects, through year n, will no longer have a mean of zero). Because the estimated year effect for the current year is conditional on the vector of month effects, the fact that the data for the current year do not span the entire year should not cause the estimate of the current year effect to be biased. The year and month effects shown in Figure 2.1.4 have been incremented by 1.0 in order to represent values relative to the respective average. The estimated year effects for 2021 (shown in the top left panel of each page of Figure 2.1.4) for all four gear types confirm that this is shaping up to be an above-average year with respect to fishery CPUE. The fits to the data are shown in the bottom panel of each page of Figure 2.1.4. The inverse-variance-weighted R^2 values were as follow:

- Longline: 0.902
- Bottom trawl: 0.949
- Pot: 0.853
- Pelagic trawl (includes incidental catch): 0.918

Tagging

During the summers of 2017–2019, the distribution of Pacific cod appeared to shift northward into the NBS in conjunction with unprecedented increases in seawater temperature and decreases in sea ice extent

(Stevenson and Lauth 2019). To determine whether this northward shift in distribution was seasonal or year-round, and to assess seasonal movement between management areas, a tagging study was initiated in the NBS during the summer of 2019 (Principal investigators: S. McDermott, D. Nichol, S. Kotwicki, and L. Dawson). Thirty-eight Pacific cod were tagged with Pop-up Satellite Archival Tags (PSATs) and 86 with conventional tags near St. Lawrence Island in a collaboration between NOAA, the Norton Sound Economic Development Corporation, and the village of Savoonga. PSATs were programmed to pop up throughout the year (range 90 - 360 days) to provide information on seasonal movement. Movement pathways were reconstructed with a hidden Markov model based on maximum daily depth and light-based longitude. The model output provides gridded probability estimates of individual fish locations for each day; location probabilities for individual fish were summarized for each month and the peak spawning period (February 15 - March 31). Monthly and peak spawning period location probabilities from all tagged fish were then combined to provide overall tagged fish location probability distributions and the proportion of the overall probability in each management region. Recovery locations were obtained for 33 PSATs and 2 conventional tags (Figure 2.1.5a), and movement pathways were reconstructed for 31 fish tagged with PSATs. Overall location probability in the NBS declined beginning in November as tagged fish moved south and west ahead of the oncoming winter sea ice (Figure 2.1.5a, Figure 2.1.5b). Most (77%) of the overall location probability during the spawning period was in the EBS, where tagged fish occupied traditional spawning grounds (Neidetcher et al. 2014). However, the finding of some probability in the Gulf of Alaska (GOA, 7%) and in Russian waters (16%) indicated greater movement between management areas than expected. Tagged animals traveled 400 - 1000 km from their release locations to reach areas occupied during the spawning period. Four (3 PSAT and 1 conventional tag) of 5 recovery locations obtained the following summer were in the NBS. No evidence from geolocation or temperature records was found to suggest that any tagged fish lived in the NBS during the winter. These movement results, combined with a recent genetics study (Spies et al. 2020), suggest that the northward shift in distribution observed during the summers of 2017–2019 is related to an expansion of summer foraging habitat and does not currently represent a separate spawning population. This research provides important insights into mechanisms that may underlie the spatial dynamics of Pacific cod in a changing climate. Additional tags were deployed in the GOA in the winter and in the EBS and NBS the summer of 2021 to increase sample size, characterize activity patterns during summer, and assess seasonal movement patterns in years with differing environmental conditions.

Western Bering Sea (WBS) catch and survey biomass

Table 2.1.3 shows catches (t) taken in the WBS, obtained by summing the values in Tables 6-12 of Lajus et al. (2019).

Recently, basin-wide Bering Sea biomass indices have been explored for Pacific cod. Biomass indices were estimated using a spatio-temporal index model with and without cold pool extent effects incorporated. Models were fit by applying VAST (Thorson and Barnett 2017) to multiple spatially unbalanced survey data products from the WBS, NBS, and EBS. Epsilon bias-corrected biomass indices were used to correct for retransformation bias (Thorson and Kristensen 2016), and a temporally-invariant catchability parameter between WBS and EBS/NBS surveys was estimated within the models. Data were analyzed from multiple surveys using a Poisson link delta-model, while using a gamma distribution for the observation error distribution of the positive catch rates (Thorson 2018). Model specification included spatial and spatiotemporal random effects for encounter probability and positive catch rate with no autocorrelation across time. Spatial smoothing at every location for models estimating biomass indices is interpolated using bilinear interpolation in a triangulated mesh (Lindgren 2012; Lindgren and Rue 2015). AIC indicated that including the cold pool extent in the spatio-temporal model was more parsimonious than excluding this effect.

Figure 2.1.6 shows results for a representative subset of years from the overall time series. Pacific cod expanded across the Bering Sea from 2016 – 2019. Pacific cod density exhibited estimated hotspots emerging in the NBS, north of St. Lawrence Island, that span the Convention Line, particularly in warmer years when the cold pool extent is lower than the long-term average.

Data updates used in the models

The data used in the assessment models described in this preliminary assessment include some updates due to methodological improvements, and one model includes an entirely new data set. These are described below. As in last year's assessment, survey index and age composition data do not extend beyond 2019.

VAST estimates of survey abundance

The software versions of dependent programs used to generate VAST (Thorson and Barnett 2017) estimates were:

- Microsoft Open R (4.0.2)
- INLA (21.02.23)
- TMB (1.7.18)
- TMBhelper (1.3.0)
- VAST (3.6.1)
- FishStatsUtils (2.8.0)

The data consisted of observations of numerical abundance per unit area from all grid cells and corner stations in the 83-112 bottom trawl survey of the EBS, 1982-2021, including 83-112 samples available in the NBS in 1982, 1985, 1988, 1991, 2010, and 2017-2021. NBS samples collected prior to 2010 and in 2018 did not follow the 20 nautical mile sampling grid that was used in 2010, 2017, 2019, and 2021 surveys. Assimilating these data therefore required extrapolating into unsampled areas. In the 2019 and 2020 assessments, this extrapolation was facilitated by including a spatially varying response to cold-pool extent (Thorson 2019b). This spatially varying response was estimated for both linear predictors of the delta-model, and detailed comparison of results for EBS pollock has shown that it has a small but notable effect (O'Leary et al. 2020). For example, the NBS was not sampled between 2010 and 2017, and the cold-pool extent started to decrease substantially around 2014; therefore, including this covariate results in estimates that depart somewhat from a "Brownian bridge" between 2010 and 2017, and instead indicates that population densities in the NBS increased progressively after 2014 when cold-pool-extent declined prior to 2017.

Population density was extrapolated to the entire EBS and NBS in each year, using extrapolation grids available within FishStatsUtils. These extrapolation grids are defined using 3705 m (2 nmi) × 3705 m (2 nmi) cells; this results in 36,690 extrapolation-grid cells for the eastern Bering Sea and 15,079 in the northern Bering Sea. Bilinear interpolation was used to interpolate densities from a specified number of "knots" to these extrapolation grid cells; knots were approximately evenly distributed over space, in proportion to the dimensions of the extrapolation grid. Geometric anisotropy (how spatial autocorrelation declines with differing rates over distance in some cardinal directions than others) was estimated, and included a spatial and spatio-temporal term for both linear predictors. To facilitate interpolation of density between unsampled years, the spatio-temporal fields were structured over time as an AR(1) process (where the magnitude of autocorrelation was estimated as a fixed effect for each linear predictor). However, temporal correlation for intercepts was not included, which were treated as fixed effects for each linear predictor and year. Finally, epsilon bias-correction was used to correct for retransformation bias (Thorson and Kristensen 2016). In general, VAST settings conformed to the recommendations of Thorson (2019a).

In response to a request from the SSC (see comment SSC1), alternative configurations for the use of covariates, number of knots, and error distribution were explored. Specifically, VAST estimates were obtained for each of the following configurations (differences in configurations #2-4 with respect to configuration #1 are shown in italics):

1. Cold pool used as a covariate, 750 knots, Poisson-linked delta-gamma distribution.
2. Cold pool *not* used as a covariate, 750 knots, Poisson-linked delta-gamma distribution.
3. Cold pool used as a covariate, *100* knots, Poisson-linked delta-gamma distribution.
4. Cold pool used as a covariate, 750 knots, *Tweedie* distribution.

Comparisons of the Poisson-linked delta-gamma and Tweedie distributions within VAST have previously been provided by Thorson (2018) and Thorson et al. (2021). Use of the Poisson-linked delta-gamma distribution has become something of a standard in applications of VAST to EBS and GOA survey index data, whereas use of the Tweedie distribution has been far less common, suggesting that a brief description of the latter may be useful here: In its unconstrained form, the Tweedie distribution is extremely flexible, and incorporates several better-known distributions as special cases, including the normal, Poisson, gamma, and inverse Gaussian distributions (Jørgensen 1987). In particular, VAST uses the subset of special cases corresponding to the compound Poisson-gamma distributions. Use of the Tweedie distribution has the advantage of needing to estimate only half as many parameters as alternative distributions, because the Tweedie distribution does not treat zeros as a special case (Foster and Bravington 2013), and so does not need to estimate parameters for the first linear predictor in VAST.

The point estimates from the four VAST configurations, together with the associated lognormal “sigma” terms, are shown for the combined EBS and NBS survey areas, the EBS survey area, and the NBS survey area in Table 2.1.4 and Figure 2.1.7. For all areas and VAST configurations, the point estimates are very similar, with correlations ranging from 0.968-0.998 in the combined EBS and NBS, 0.988-0.993 in the EBS, and 0.898-0.992 in the NBS (Table 2.1.5). In all three areas, the estimates from configuration #4 (Tweedie distribution) were the least similar to the others. For all three areas, the lognormal sigmas were very similar for configurations #1-3 (Poisson-linked delta-gamma distribution), but substantially lower for configuration #4, particularly in the NBS. In the NBS, the lognormal sigmas from all four configurations were nearly identical in all *survey* years except 1982, and the plots of the lognormal sigmas against time for configurations #1-3 tended to be dome-shaped within multi-year gaps in the time series, whereas the plot tended to be essentially flat within multi-year gaps for configuration #4.

Model fits were checked for evidence of non-convergence by confirming that: 1) the derivative of the marginal likelihood with respect to each fixed effect was sufficiently small (approximately <0.0001), and 2) the Hessian matrix was positive definite.

Normally, model fit would be evaluated further by: 1) computing Dunn-Smyth “Probability-Integral Transform” (PIT) residuals (Dunn and Smyth 1996) and visualizing these using a quantile-quantile plot within the DHARMa R package, and 2) inspected the residuals for evidence of spatio-temporal patterns. In preparing this preliminary assessment, however, technical difficulties precluded taking these additional steps. Therefore, the choice of a final configuration was based primarily on comparison of AIC values, which were as follow:

Configuration	Cold pool?	Knots	Distribution	AIC	ΔAIC
1	Yes	750	P-link Δ-gamma	220372.7	0
2	No	750	P-link Δ-gamma	220480.6	107.9
3	Yes	100	P-link Δ-gamma	222030.2	1657.5
4	Yes	750	Tweedie	222268.2	1895.5

Given the above, configuration #1 was used to derive the survey abundance data used in this preliminary assessment.

VAST estimates of survey age composition

The software versions of dependent programs used to generate VAST (Thorson and Barnett 2017) estimates of survey age composition were the same as those listed above for survey abundance.

The data consisted of observations of numerical abundance-at-age at each sampling location. This was made possible by applying year-specific and region-specific (EBS and NBS) unstratified age-length keys to records of numerical abundance and length composition. The VAST configuration included a conventional delta-model with logit-link for encounter probability and log-link for positive catch rates, following a gamma distribution. A cold-pool covariate was not included. The same extrapolation grid as implemented for abundance indices was used here, but with only 50 knots for the spatial and spatiotemporal fields. This reduction in the spatial resolution of the model, relative to that used for abundance indices, was necessary due to the increased computational load of fitting multiple age categories and using epsilon bias-correction. The diagnostics used for checking convergence and model fit were the same as those used for the survey abundance index.

The resulting age compositions, expressed as within-year proportions at age, are shown in Table 2.1.6a. The differences relative to the age compositions used in last year’s assessment, which are due to refinements in the data set, are shown in Table 2.1.6b. These are generally very small, the largest (in absolute value) being a decrease of 4.4% in the proportion at age 1 in 2011 and an increase of 2.3% in the proportion at age 1 in 2012.

VAST estimates of fishery catch per unit effort

Developing an index from fishery catch-and-effort (CPUE) data has been a goal in fisheries for at least sixty years (Beverton and Holt 1957). Analysts have identified many overlapping concerns that will cause an abundance index from fishery CPUE data to be uninformative about abundance changes, including:

1. Spatial targeting causing sampled CPUE not to represent changes in population density for the average fish (Walters 2003).
2. Spatial or interannual variation in fishing gear performance, either via changes in mechanical configuration, time-of-day deployment, or unmeasured fine-scale variation (Abbott et al. 2015).
3. Improvements in technology and associated changes over time in fishing gear and power (Robins et al. 1998, Hannesson 2007).

These mechanisms may in turn change due to a variety of institutional and structural incentives, including:

A. Changing costs for labor and fuel.
B. Changing access to capital markets and buy-back programs.

C. Changing co-production and limits on (or incentives to avoid) incidental catch.

Because of the above concerns, past EBS Pacific cod assessment models have, for the most part, not included use of fishery CPUE data. The main exception occurred in last year's assessment, when a composite (all-gear) fishery CPUE index was developed and used in Model 20.9. The index was developed in a fairly simplistic way, and proved to be "of concern" to the Team (comment GPT2), who recommended pursuing "alternative statistical methods" for developing a fishery CPUE index (comment GPT1). The SSC similarly recommended "development of spatiotemporal analyses of fleet-specific CPUE indices" (comment SSC4).

During recent decades, researchers have developed methods to use high-resolution spatial and timing information to account for challenge #1 above (spatial targeting), where these methods implicitly impute or predict the CPUE that would have arisen in unsampled locations. This imputation occurs either structurally (Carruthers et al. 2011), via post-stratification and area-weighting (Campbell 2016), or using area-weighting within spatio-temporal statistical models (Thorson 2019a). Spatio-temporal models for fishery CPUE data have been tested successfully using operating models mimicking fishery-dependent CPUE data that were developed independently and that do not match the estimation model (Grüss et al. 2019, Thorson et al. 2017a).

For this preliminary assessment, a univariate spatio-temporal model was developed for fishery longline CPUE data measured in cod biomass, restricting data to sets that target and catch Pacific cod (i.e., no observations of zero catch) during January and February and using log-hooks as offset (the January-February period was chosen because no fishing occurs in the NBS during those months, meaning that the "footprint" of the EBS bottom trawl survey could be used to conduct the analysis). This was implemented using VAST (Thorson and Barnett 2017), specifying a gamma distribution for positive catches and "turning off" the first linear predictor; that is, specifying intercepts to attain 100% encounter probabilities within the delta-gamma modelling framework. Both a spatial term ("omega") and spatio-temporal components ("epsilon") were estimated for the single log-linked linear predictor used in the gamma distribution, and geometric anisotropy was included when estimating those spatial and spatio-temporal components (Thorson et al. 2015). Densities were predicted across the entire EBS bottom trawl survey area, distributing 100 knots across this spatial domain and using bilinear interpolation between knots. No catchability or density covariates were included, although future exploration could account for challenge #2 (changes in gear configuration/deployment) and #3 (changes in fishing power), using auxiliary variables as catchability covariates. The model converged successfully, with no evidence of poor fit based on standard Dunn-Smyth PIT residuals (Dunn and Smyth 1996). Epsilon bias correction was used to account for retransformation bias (Thorson and Kristensen 2016) when calculating the index of biomass.

The resulting fishery CPUE index is listed in Table 2.1.7 and shown (on the original scale) in Figure 2.1.8a and compared with the final VAST survey index (both on normalized scales) in Figure 2.1.8b. Maps of log density, log density standard error, and model residuals are shown in Figures 2.1.9a, 2.1.9b, and 2.9c, respectively; and a residual quantile-quantile plot is shown in Figure 2.1.9d.

Models

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 V3.30.17.01 was used to run all of the models in this preliminary assessment. Using this version to run the current base model (Model 19.12a) with last year’s data set gave a 2020 spawning biomass that was within 0.0002% of the value obtained in last year’s assessment (using SS V3.30.16.02). The objective function values, however, were not close. This is because SS V3.30.17.01 adds a large constant to the objective function for models that use the Dirichlet-Multinomial option for compositional data, in order to make the objective function values for such models similar to those for models that do not use the Dirichlet-multinomial option. Because all of the models in both last year’s assessment and this preliminary assessment use the Dirichlet-multinomial option, objective function values for the models in this preliminary assessment will appear very different from those in last year’s assessment.

Parameter estimation

SS requires that prior distributions be associated with all internally estimated time-invariant parameters and the base values of all internally estimated time-varying parameters. For the models presented in this preliminary assessment, uniform prior distributions were used for estimation of all such parameters, with bounds set at values sufficiently extreme that:

- they were non-constraining, or
- extending the bounds to even more extreme values would have no practical impact (because, when the parameter is back-transformed to the natural scale, the resulting quantity is indistinguishable from a logical constraint; e.g., selectivity cannot fall outside the (0,1) range).

To simplify terminology, such parameters will be referred to here as being “freely estimated.” In any instances where parameter estimates are pinned against either bound, those parameters are fixed in the final run of that model (typically at the bound, but perhaps at their final estimated value).

On the other hand, for each parameter that varies randomly on an annual basis, SS estimates a vector of annual deviations that is constrained by a standard normal probability density function, and then multiplies that vector by an input standard deviation (σ) specific to that parameter. For all models in this preliminary assessment, each σ was tuned iteratively as follows:

- For a vector of deviations associated with log catchability, σ was tuned to set the root-mean-squared-standardized-residual (RMSSR) equal to unity.
- For the vector of deviations associated with log-scale recruitment, σ was tuned to match the square root of the variance of the estimates plus the sum of the estimates’ variances (Methot and Taylor 2011).
- For all other vectors of deviations, σ was tuned to set the variance of the estimates plus the sum of the estimates’ variances equal to unity.

All models were run using the “-hess_step” option in ADMB, with 2 steps specified. This resulted in all model gradients equaling 0 in the final pass. As an additional check on convergence, the final versions of all models successfully passed a “jitter” test of 50 runs with the jitter rate set at 0.1.

Base model

At the conclusion of last year’s assessment cycle, Model 19.12a was adopted by the SSC as the new base model, supplanting Model 19.12, which had been adopted as the base model at the conclusion of the 2019 assessment cycle. Model 19.12a contains the following features:

- Sexes combined
- One season per year
- Natural mortality (constant across age and time) freely estimated

- Mean length at age follows a Richards growth function, with parameters as follow:
    - Base value of length at age 1.5 freely estimated
        - With constrained annual deviations on the log scale, in order to begin addressing the significant amount of time-variability in size at age documented by Puerta et al. (2019) and Ciannelli et al. (2019)
    - Von Bertalanffy (Brody) growth coefficient freely estimated
    - Asymptotic length freely estimated
    - Richards growth coefficient freely estimated
- Standard deviation of length at age varies linearly with length at age, parameters freely estimated
- Weight at length varies annually ($W = \exp(\ln(\alpha_t)+\beta_t\ln(L))$), estimated outside the model
- Maturity at length (constant across time) estimated outside the model
- Mean ageing error varies linearly with age, freely estimated within each of 2 time blocks in order to compensate for an apparent change in ageing criteria (Beth Matta, AFSC Age and Growth Program, *pers. commun.*, 6/27/2019):
    - 1977-2007
    - 2008-present
- Recruitment is independent of stock size:
    - Mean freely estimated within each of 2 time blocks:
        - Pre-1977
        - 1977-present
    - With constrained annual deviations on the log scale
- One survey, covering the EBS and NBS combined
    - Base value of log catchability freely estimated
    - Size-based, double-normal selectivity, with parameters as follow:
        - Base value of first size with selectivity=1 freely estimated
            - With constrained annual deviations on the log scale
        - Logit of size range with selectivity=1 fixed at 10.0
        - Base value of log of standard deviation for 1st normal pdf freely estimated
            - With constrained annual deviations
        - Log of standard deviation for 2nd normal pdf fixed at 10.0
        - Logit of selectivity at minimum size fixed at -10.0
        - Logit of selectivity at maximum size fixed at 10.0
- One fishery, covering the EBS and NBS combined
    - Size-based, double-normal selectivity, with parameters as follow:
        - First size with selectivity=1 freely estimated
        - Logit of size range with selectivity=1 freely estimated
        - Base value of log of standard deviation for 1st normal pdf freely estimated
            - With constrained annual deviations
        - Log of standard deviation for 2nd normal pdf freely estimated
        - Logit of selectivity at minimum size fixed at -10.0
        - Base value of logit of selectivity at maximum size freely estimated
            - With constrained annual deviations
- Following Thorson et al. (2017b), input sample sizes (*Nsamp*) for compositional data range between zero and an initial number of (*Ninit*) according to the formula $Nsamp = (1+\exp(ln\theta)\,Ninit)/(1+\exp(ln\theta))$, where $ln\theta$ is a time-invariant parameter (the "Dirichlet-multinomial" parameter, estimated in natural log space, so that *Nsamp* approaches 0 as $ln\theta$ approaches –∞, *Nsamp*=(1+*Ninit*)/2 when $ln\theta$=0, and *Nsamp* approaches *Ninit* as $ln\theta$ approaches +∞), freely estimated for each of the compositional data types (fishery size composition data, survey size composition data, and survey age composition data), where:
    - For survey compositional data, *Ninit* is the number of sampled hauls

- For fishery compositional data, *Ninit* is equal to the number of sampled hauls rescaled so that the average *Ninit* for the fishery is equal to the average *Ninit* for the survey (so that, on average, fishery data are emphasized equally with survey data)

Alternative models recommended by the CIE reviewers

The CIE reviewers recommended that this year's assessment be based on an ensemble of five models, consisting of the current base model and four alternative models (Attachment 2.1.1). Although this preliminary assessment is structured accordingly, the authors recognize that the Team, the SSC, or the authors themselves may recommend use of a different ensemble, or no ensemble at all, in the final assessment.

The CIE reviewers developed their set of alternative models by adding features, one at a time, to the base model as follows:

Feature 1: Allow catchability to vary?	no	yes	no	no	no
Feature 2: Allow domed survey selectivity?	no	no	yes	no	no
Feature 3: Use fishery CPUE?	no	no	no	yes	no
Feature 4: Estimate survey CV internally?	no	no	no	no	yes
Model (quotes indicate CIE review name):	19.12a	19.12	"20.8a"	"20.9a"	"21.cie"

Models "20.8a," "20.9a," and "21.cie" were developed during the meeting; model numbering for this group is provisional only, and follows the convention adopted during the meeting. Final model names will be assigned in the "Results" section, following the protocol described therein.

The parameter sets for the five models are compared in Table 2.1.8. Except for the fact that Model 19.12 includes a vector of deviations for log catchability, overall parameter counts for the models differ by only a few. (Note that parameter counts in Table 2.1.8 may differ slightly from those of the final model runs, due to the possibility that a few parameters may end up fixed at a bound.)

Results

Model naming

Beginning with the final 2015 assessment (Thompson 2015), model naming has followed the protocol given by Option A in the SAFE chapter guidelines. Names of all final models adopted between the 2005 assessment (when an ADMB-based version of SS was first used) and the 2015 assessment were translated according to that protocol in Table 2.11 of the 2015 assessment. The goal of the protocol is to make it easy to distinguish between major and minor changes in models and to identify the years in which major model changes were introduced. Names of models constituting *major* changes get linked to the year that they are introduced (e.g., the base model that emerged from the 2019 assessment, Model 19.12, was one of several models introduced in 2019 that constituted a major change from the then-current base model, Model 16.6i), while names of models constituting *minor* changes from the original form of the current base model get linked to the name of that model (e.g., the name of the base model that emerged from the 2020 assessment, Model 19.12a, referred to a model that constituted a minor change from Model 19.12, regardless of the year in which it was introduced).

The distinction between major and minor changes, in turn, is based on the average difference in spawning biomass ("ADSB"), defined as the root-mean-squared relative difference in spawning biomass between the new model and the original version of the current base model over the time series from 1977 through the year in which the original version of the current base model was first adopted, using data from only that set of years. A value of ADSB<0.1 means that the new model constitutes only a minor change, while a value of ADSB≥0.1 means that the new model constitutes a major change.

Implications of data updates for names of the existing models

The updated survey abundance and age composition data described in the "Data" section are used by all of the models in the ensemble, including Models 19.12a and 19.12, which raises the question of whether use of these updated data sets should result in new names for those two models.

The SSC has stressed that model names should not change simply as a result of routine incrementing of existing time series (e.g., adding the most recent catch or survey index datum). In keeping with the spirit of that policy, it seems that *any* sufficiently minor adjustments to existing time series should likewise not result in a new model name. Of course, this begs the question of how to determine which adjustments are "sufficiently minor." Building upon the existing protocol for model naming, the criterion adopted in this preliminary assessment is that, *based on revisions to existing data alone*, a value of ADSB<0.05 does not merit a new model name.

Figure 2.1.10 shows the results of a simple "bridging" analysis for Models 19.12a and 19.12, in which estimated spawning biomass time series are compared for model runs with last year's ("original") data, last year's data with updated survey index values, and last year's data with both updated survey index and age composition values. Visually, the differences between the time series are almost imperceptible. The ADSB values are all below the 5% cutoff, as shown below:

Update type	M19.12a	M19.12
Updated index data only	0.0243	0.0072
Updated index and agecomp data	0.0228	0.0095

On the basis of the above results, Models 19.12a and 19.12 are *not* assigned new names in this preliminary assessment.

Names of the new models

Per the model numbering protocol given by Option A in the SAFE chapter guidelines, ADSB values were computed for the three new models. All values exceeded the cutoff of 0.1 distinguishing "major" from "minor" changes, thus resulting in the following set of final model names:

Feature 1: Allow catchability to vary?	no	yes	no	no	no
Feature 2: Allow domed survey selectivty?	no	no	yes	no	no
Feature 3: Use fishery CPUE?	no	no	no	yes	no
Feature 4: Estimate survey CV internally?	no	no	no	no	yes
CIE review model name:	19.12a	19.12	"20.8a"	"20.9a"	"21.cie"
Average difference in spawning biomass:	n/a	n/a	0.4047	0.1299	0.1175
Final model name:	19.12a	19.12	21.1	21.2	21.3

Results of the individual models

Goodness of fit

Table 2.1.9 shows the objective function value for each data component in each model, along with the number of parameters in each model, where the latter is broken down into "true" (unconstrained) parameters and constrained deviations. With few exceptions, objective function values are not truly comparable across models, and attempts to apply information-theoretic statistics such as the AIC may be misleading, because:

- The total parameter counts overestimate the number of "effective" parameters, as these counts include parameters with constrained deviations.
- Models sometimes use different data files (specifically, Model 21.2 uses a different data file than the other models).
- The data are weighted differently between models, due to tuning of the σ terms for deviations.

The root-mean-squared-standardized-residual for the survey abundance data (and fishery CPUE where applicable) is shown for all models below, where values within the range of 0.99-1.01 are shaded green:

Index:	Survey					Fishery
Model:	M19.12a	M19.12	M21.1	M21.2	M21.3	M21.2
RMSSR:	2.301	1.002	2.298	2.425	1.002	2.561

Ideally, RMSSR values should equal unity, and this was the standard that was used to tune the σ term for the log catchability devs in Model 19.12. Model 21.3 also achieved a value near unity, but this was accomplished by adding an estimated constant to the log-scale survey standard errors rather than tuning variability in log catchability. The other models under-fit the survey index data substantially, and Model 21.2 likewise under-fit the fishery CPUE data substantially.

Fits to the trawl survey abundance data are shown for all models in Figure 2.1.11a, where the 95% confidence intervals for the survey are based on the lognormal sigmas estimated by VAST. Fits for the two models with RMSSR values near unity (Models 19.12 and 21.3) are shown in Figure 2.1.11b, where 95% confidence errors for the survey are shown both for the lognormal sigmas estimated by VAST and also for the additional standard error estimated by Model 21.3. Figure 2.1.11c shows Model 21.2's fit to the fishery CPUE index.

Effective sample sizes implied by the models' fits to the size composition and age composition data are compared with the corresponding input sample sizes in Table 2.1.10. Input sample sizes are expressed as arithmetic means. Two formulations of effective sample size are shown:

- The formulation popularized by McAllister and Ianelli (1997), which has been used in many previous assessments, is expressed as a harmonic mean. Ideally, the harmonic mean of this formulation of effective sample size should equal the arithmetic mean of the input sample size, which typically requires iterative tuning.
- The formulation of Thorson et al. (2017b), which uses the Dirichlet-multinomial distribution to model compositional data, is expressed a function of an internally estimated parameter ($\ln(\theta)$), so iterative tuning is not required.

Size composition: By the McAllister-Ianelli measure, both the fishery and survey size composition data were *over*fit by all of the models. The Dirichlet-multinomial parameter was constrained by the upper bound for both the fishery and survey size composition data in all models, meaning that, by the Thorson et al. measure, the effective sample size was equal to the average input sample size.

Age composition: By the McAllister-Ianelli measure, the age composition data were *under*fit by all of the models. The effective sample sizes for the Thorson et al. formulation were of the same magnitude as, but larger than, the effective sample sizes for the McAllister-Ianelli formulation. By both measures, Models 19.12 and 21.3 exhibited slightly better fits than the other models.

Residual plots for the size and age composition data are shown in Figures 2.1.12 and 2.1.13, respectively.

Retrospective behavior

Retrospective analyses of all models are shown in Figure 2.1.14. Values of ρ (Mohn 1999, Hurtado-Ferro et al. 2015) for spawning biomass are shown below:

Model:	M19.12a	M19.12	M21.1	M21.2	M21.3
Mohn's ρ	-0.0500	-0.0352	0.0326	0.0875	-0.0535

Parameter estimates

Table 2.1.11 displays the values of all estimated parameters (except fishing mortality rates, because these are functions of other parameters and are therefore shown separately) estimated internally in any of the models, along with their standard deviations. Standard deviations are based on the inverse of the Hessian matrix, and assume a normal distribution.

Table 2.1.11a shows all time-invariant estimated parameters (color scales are row-specific). A blank cell in Table 2.1.11a indicates that the respective parameter (row) is not used in the respective model (column). As noted under "Goodness of fit" above, the Dirichlet-multinomial parameters for size composition ended up being pinned at the upper bound for all models, so those were fixed at the bound and omitted from the table. The two other cases where a parameter was pinned at a bound are indicated in Table 2.1.11a by the presence of a "_" symbol in the SD column. Natural mortality ranges from 0.309 (Model 21.1) to 0.348 (Model 19.12a). The Brody growth coefficient (K) ranges from 0.097 (Model 21.3) to 0.158 (Model 21.1). Similar to last year's assessment, the sign of the ageing bias flips from all positive (pre-2008) to very near zero at age 1 but negative at older ages (post-2007) in all models. Initial fishing mortality ranges from 0.074 (Model 21.1) to 0.137 (Model 21.3). Log survey catchability (base value in the case of Model 19.12) ranges from -0.030 (Model 21.2) to 0.146 (Model 21.3).

Tables 2.1.11b-2.1.11f show time series of annual parameter deviations. Color scales are column-specific in all these portions of Table 2.1.11, and show that, in general, time trends between models are very similar. Table 2.1.11b shows log deviations for the initial numbers-at-age vector, Table 2.1.11c shows log recruitment (at age 0) deviations, Table 2.1.11d shows deviations for mean length at age 1.5, Table 2.1.11e shows deviations for the time-varying selectivity parameters, and Table 2.1.11f shows deviations for log survey catchability (Model 19.12 only).

Tuning of annually varying parameters

As noted in the "Parameter estimation" subsection of the "Models" section, except for the sigmas associated with annual deviations of log catchability, tuning of the sigmas involved two quantities: 1) the variance of the estimated deviations, and 2) the sum of the variances of the individual estimated deviations. For parameters other than log-scale recruitment, deviations are modeled in SS as being normal(0,1), and sigma was tuned so that the sum of those two quantities equaled unity, with a tolerance of +/- 0.01. For recruitment, deviations are modeled in SS as being normal($0,\sigma^2$), and sigma was tuned so that it matched the square root of the sum, again with a tolerance of +/- 0.01.

Table 2.1.12 shows the values of the iteratively tuned "sigma" quantities for parameters with annual deviations (other than log catchabilities). Model 21.3 had the highest sigma values for four of the six parameters common to all models, while sigma values for Model 19.12a tended to be in the middle of the range for all parameters. Sigmas for log recruitment, the logit of fishery selectivity at maximum size, and the log of the standard deviation of the 1st normal pdf for survey selectivity tended to have larger values than those associated with other parameters.

For Model 19.12 (the only model that includes annual deviations for log survey catchability), sigma was tuned so as to set RMSSR=1.0 (tolerance = +/- 0.01), resulting in a value of 0.0839.

Derived quantities

Figure 2.1.15 shows selectivity for all models. Figure 2.1.15a shows selectivity for the fishery, and Figure 2.1.15b shows selectivity for the survey. Note that the shapes of the fishery selectivity schedules cluster into two groups: one for the two models that give RMSSR=1.0 for the survey index (Models 19.12 and 21.3), and another for the remaining models.

Table 2.1.13 shows back-transformed survey catchability for Model 19.12. Estimates tended to be lower than average during the period 2004-2013 (except for 2005 and 2011), and higher than average for the period 2014-2019 (except for 2017).

Results of the CIE ensemble

Model weights

For the last few years, the Team and SSC have expressed interest in using a model averaging approach for the EBS Pacific cod assessment. However, the question of how to weight the models has proved to be difficult. The last two assessments have computed model weights as an emphasis-weighted average of a set of ranking criteria, and this general approach was also adopted, with some modifications, by the CIE reviewers (Attachment 2.1.1). Table 2.1.14 shows the ranking criteria, other aspects of thee system, and final model weights recommended by the CIE reviewers. Each reviewer assigned a score of 0, 1, or 2 for each criterion/model combination, after which the reviewer scores for each criterion/model combination were averaged (shown in the columns associated with the five models). Each criterion was then assigned an emphasis ("Emph."). Criteria for which all models exhibited the same score were assigned an emphasis of 0 and the scores ignored, to avoid skewing the weights toward equality. The reviewers nevertheless recommended keeping the criteria with emphasis=0 in the table in the event that, for some future set of models, at least one of the models were to exhibit a score different from the others.

The criteria to which the CIE reviewers assigned an emphasis greater than zero, along with the reviewers' rationales for any cases where a score less than the maximum of 2 was assigned, were as follow:

- General plausibility: The CIE reviewers judged all of the alternative models to be less plausible than the base model for the following reasons: 1) the amount of time-variability in survey catchability estimated by Model 19.12 (σ = 0.0839), 2) the low survey selectivity at larger sizes estimated by Model 21.1 (base selectivity = 0.3096 at 120 cm), 3) the use of fishery CPUE data in Model 21.2 (which may not be reflective of population size), and 4) the large extra standard deviation for the survey index estimated by Model 21.3 ("extra" SD = 0.1518).

- Acceptable retrospective bias: The values of ρ for spawning biomass shown above under "Retrospective performance" are repeated below, together with bounds on acceptable levels defined as a function of *M*, based on results reported by Hurtado-Ferro et al. (2015):

Model:	M19.12a	M19.12	M21.1	M21.2	M21.3
Time-vary *Q* ?	no	yes	no	no	no
Survey dome?	no	no	yes	no	no
Fishery CPUE?	no	no	no	yes	no
Extra SE?	no	no	no	no	yes
M	0.3479	0.3313	0.3088	0.3433	0.3277
Mohn's ρ	-0.0500	-0.0352	0.0326	0.0875	-0.0535
ρmin	-0.2018	-0.1959	-0.1881	-0.2001	-0.1947
ρmax	0.2740	0.2656	0.2544	0.2716	0.2639

  By the above criterion, all models exhibited values of ρ well within the acceptable range. Nevertheless, the CIE reviewers noted that Model 21.2 had the highest (absolute value) of ρ, and that, while Model 21.1 had a low value of ρ, the degree to which survey selectivity at large sizes varied with retrospective peel was concerning.
- Uses properly vetted data: The CIE reviewers felt that the fishery CPUE data used by Model 21.2 had been less fully vetted than the other data components, as the Powerpoint file describing the development of this data set was less detailed than the reviewers would have liked.
- Acceptable residual patterns: The CIE reviewers were concerned by the recent string of several positive residuals in Model 21.3's fit to the survey index.
- Comparable complexity: The CIE reviewers assigned Models 19.12 and 21.1 a lower score than the others because: 1) Model 19.12 estimates 38 annual log catchability deviations that the other models do not, and 2) Model 21.1 estimates three survey selectivity parameters that the other models do not.
- Fits consistent with variances: The CIE reviewers assigned lower scores to Models 19.12a, 21.1, and 21.2 because all three exhibited a survey index RMSSR much greater than unity and Model 21.2 also exhibited a fishery CPUE RMSSR much greater than unity.

The criteria to which the CIE reviewers assigned an emphasis of zero (because all models scored the same) were as follow:

- Deviation sigmas estimated appropriately: All models tune the σ terms for the respective deviation vectors in a statistically reasonable manner.
- Incremental changes: Each of the alternative models involves only a single changes relative to the base model, and were deemed to exhibit suitably incremental changes from the base model.
- Objective criterion for sample sizes: All models use the Dirichlet-multinomial approach to scale the input sample sizes.
- Change in ageing criteria addressed: All models estimate ageing bias separately for pre-2008 and post-2007 time blocks.
- Density dependence (other than recruitment) addressed: None of the models address density dependence in quantities other than recruitment (steepness is fixed at 1.0 in all models, implying density dependent survival of age 0 fish).
- Regime shifts addressed: All models estimate an offset in mean recruitment for year classes spawned prior to the 1976-1977 regime shift (Hare and Mantua 2000).

Multiplying the average score for each criterion/model combination by the emphasis for that criterion and then computing the weighted average across criteria gives the row of values labeled "Average emphasis" in Table 2.1.14, and rescaling those so that they sum to unity gives the last row of values, which are the CIE reviewers' recommended model weights. The weights span the range 0.1311 – 0.2459, with Model 21.2 receiving the lowest weight and Model 19.12a the highest.

The CIE reviewers anticipated that the Team or SSC would provide their own scores for the criteria listed in Table 2.1.14 after reviewing this preliminary assessment, thus resulting a revised set of model weights.

Derived quantities

Mohn's (1999) ρ for the ensemble was 0.0037 (based on the weighted average of the individual models' retrospective "peels," as distinguished from the weighted average of the individual models' ρ values).

In the following tables and figures, results are shown for all models and the ensemble (point estimates and standard deviations in the case of tables, point estimates in the case of figures).

Table	Figure	Quantity
2.1.15	2.1.16	female spawning biomass (millions of t)
2.1.16	2.1.17	female spawning biomass relative to $B_{100\%}$
2.1.17	2.1.18	age 0 recruitment (billions of fish)
2.1.18	2.1.19	full-selection instantaneous fishing mortality

Some caveats for the above sets of tables and figures:

- For individual models, the Hessian approximation to the distribution was used, implying that each distribution is normal, and the distribution for the ensemble was computed as the weighted average of the individual model distributions.
- The 2021-2022 fishing mortality rates shown in Table 2.1.18 and Figure 2.1.19 are those resulting from application of the *maxABC* harvest control rule to each model (i.e., they were *not* conditioned on the 2021 ABC that was actually specified).

In the following tables, point estimates for each age and year are shown for all models and the ensemble.

Table	Quantity
2.1.19	mid-year population length (cm)
2.1.20	mid-year fishery weight (kg)
2.1.21	mid-year survey weight (kg)
2.1.22	fishery selectivity
2.1.23	survey selectivity
2.1.24	population numbers (billions of fish)

The following figures show point estimates and error bars corresponding to +/– two standard deviations, for the ensemble only:

Figure	Quantity
2.1.20	female spawning biomass (millions of t)
2.1.21	female spawning biomass relative to $B_{100\%}$
2.1.22	age 0 recruitment (billions of fish)
2.1.23	full-selection instantaneous fishing mortality

Some caveats for the above set of figures:

- The distributions for the ensemble, being averages of normal distributions, are themselves *not* normal, meaning that, while the standard deviations are correct (given the Hessian approximations of the distributions for the individual models), the ensemble error bars shown in the figures may or may not approximate the 95% confidence intervals.
- As in Table 2.1.18 and Figure 2.1.19, the 2021-2022 fishing mortality rates shown in Figure 2.1.23 are those resulting from application of the *maxABC* harvest control rule to each model (i.e., they were *not* conditioned on the 2021 ABC that was actually specified).

Table 2.1.24 lists the means and standard deviations of the 2021 ABC, 2021 OFL, 2022 ABC, and 2022 OFL distributions for all models and the ensemble, and Figure 2.1.24 shows the distributions of those quantities (again, these values result from application of the *maxABC* harvest control rule to each model; i.e., they were *not* conditioned on the 2021 ABC that was actually specified).

Discussion

Ensemble evaluation

As noted in the "Models" section, although this preliminary assessment is based on the ensemble (both the set of models and their respective weights) recommended by the CIE reviewers (Attachment 2.1.1), the authors recognize that the Team, the SSC, or the authors themselves may recommend use of a different ensemble, or no ensemble at all, in the final assessment. As noted under "Model weights" in the "Results" section, it should be emphasized that the CIE reviewers anticipated that the Team or SSC would provide their own scores for the criteria listed in Table 2.1.14 after reviewing this preliminary assessment, thus resulting a revised set of model weights.

Model 19.12a

This is the base model for the current assessment, having been adopted by the SSC at the conclusion of the 2020 assessment cycle. In many respects, it performs very well. The CIE reviewers gave it (unanimously) the highest possible score for all but one of the ranking criteria, and it was explicitly endorsed as the single best model in the ensemble by at least two of the CIE reviewers. It is also the most parsimonious of all the models in the ensemble. However, while this model clearly tracks the survey index to an appreciable degree (correlation = 0.853), the fit to those data is less than fully satisfactory, statistically speaking (RMSSR = 2.301).

Model 19.12

Although Model 19.12 was adopted by the SSC as the base model at the conclusion of the 2019 assessment cycle, it was supplanted by Model 19.12a at the conclusion of the 2020 cycle. The only difference with respect to Model 19.12a is that Model 19.12 includes randomly varying survey catchability. A key consideration for the SSC last year was that the only justification that was provided for including randomly varying survey catchability was that it provided a statistically satisfactory fit to the survey index (RMSSR = 0.999 in last year's assessment, RMSSR = 1.002 here). The question of time-varying survey catchability has been addressed several times in recent assessments, but has always been controversial, with 2019 being the only assessment year in which a model with this feature was adopted by the SSC.

Arguments against use of time-varying catchability have typically centered on: 1) the danger of over-parameterization, 2) the decreased impact of the survey index on model results, and 3) the lack of an identified mechanism contributing to the time variability.

- With respect to the issue of over-parameterization, it has been suggested that the pattern of time-varying catchability estimated by Model 19.12 simply matches the time trend of the survey index. While they clearly covary (correlation = 0.622), the relationship is far from perfect, and the relative variability in the catchability time series is much less than in the survey index time series (Figure 2.1.25a).
- With respect to the issue of survey impact, it is true that allowing for time-varying catchability decreases the impact of the survey on the results. For example, Figure 2.1.25b compares the fits to the survey index achieved by Model 19.12a and by an "adjusted" version of Model 19.12 in which the effect of time-varying catchability has been removed (this was achieved by multiplying the model's estimate of the survey index in each year *t* by the ratio $Q_t/\bar{Q}$, *not* by re-running the model with constant Q, which would just give the same results as Model 19.12). The "adjusted" version of Model 19.12 gives RMSSR=2.892, compared to 2.303 in Model 19.12; and a correlation (with respect to the data) of 0.772, compared to 0.853 in Model 19.12a. However, the really important question is not whether the survey data have *less* impact in Model 19.12 than in Model 19.12a, but whether those data have the *appropriate* impact.
- With respect to the issue of an identified mechanism, although some amount of temperature dependence seems like a plausible hypothesis, it has not been proven, and even if it were, it would likely not explain all of the time-variability estimated by Model 19.12a.

The main argument in favor of time-varying catchability is that it is one of the few ways to achieve a fit to the survey index data that is consistent with the uncertainty in those data (as estimated outside the assessment model). In fact, Wilberg et al. (2010) concluded that time-varying catchability should be the "default assumption" for stock assessments, particularly if the survey does not cover the whole range of the stock. It should also be noted that recent analyses of stock-wide (EBS, NBS, and WBS) survey data, outside the context of assessment modeling, have begun to demonstrate the existence of regionally time-varying catchability. For example, O'Leary et al. (2021) estimated that "availability" (which is related to catchability) in the 2017 EBS survey was 27% lower than in 2010.

Model 21.1

This model differs with respect to Model 19.12a by allowing for the possibility of dome-shaped survey selectivity. This was a regular feature of EBS Pacific cod assessments prior to 2016, and as recently as September 2015 the Team stated, "Dome-shaped survey selectivity seems inescapable." However, Weinberg et al. (2016) concluded, "The results of our experiment do not support the use of a dome-shaped survey selectivity function." Following recommendations from the 2016 CIE review, the Joint Team Subcommittee on Pacific cod models (meeting in May 2016) suggested simplifying the existing base model (Model 11.5) in various ways, including use of "the simplest selectivity form that gives a reasonable fit." A "reasonable fit" to the size and age composition data was defined as one that achieved both $R^2 \geq 0.99$ on the raw scale and $R^2 \geq 0.70$ on the logit scale, where each year's contribution to the score was weighted by that year's proportion of the aggregate (across years) sample size (Thompson 2016). All functional forms considered in the 2016 assessment were found to achieve a reasonable fit, of which a logistic equation was the simplest. Although both the Team and the SSC recommended adopting a model with asymptotic selectivity at the conclusion of the 2016 assessment cycle, the SSC noted, "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" (October, 2016). In this preliminary assessment, allowing for dome-shaped survey selectivity resulted in a pronounced decrease in survey selectivity at larger sizes (Figure 2.1.15), consistent with pre-2016 assessments. While this had a substantial effect on estimates of quantities such as spawning biomass (Figure 2.1.16), fishing mortality (Figure 2.1.19), and ABC and OFL (Figure 2.1.24), it resulted in little improvement in goodness of fit relative to Model 19.12a.

Model 21.2

This model differs with respect to Model 19.12a by including a new fishery CPUE index as a measure of abundance (see "VAST estimates of fishery catch per unit effort" in the "Data" section). As noted previously, use of fishery CPUE data in this manner has long been associated with a number of concerns. Because of these, most previous EBS Pacific cod assessment models have not included use of fishery CPUE data, the main exception being the development and use of a composite (all-gear) fishery CPUE index in last year's assessment (Model 20.9). The new index described in the "Data" section was provided in response to Team and SSC recommendations, and was originally intended simply as the first step in what was anticipated to be a multi-year process of index development. As suggested by the spatial pattern of standard errors for the log density in Figure 2.1.9b, fishery CPUE data are lacking in much of the area, which results in a large variance in the overall index from integrating over that imprecision. Although the CIE reviewers assigned Model 21.2 a score of 0 under the "Uses properly vetted data" criterion (Table 2.1.14), they nevertheless recommended including Model 21.2 in this year's ensemble, rather than waiting for the index to be developed further. In the context of the assessment models, one factor complicating the interpretation of the new index is that it is specific to the longline fishery, whereas the assessment models combine all gear types into a single fishery. In terms of its impacts on the quantities of greatest significance to management, Model 21.2 is, generally speaking, the closest of the alternative models in the ensemble to the base model. In terms of goodness of fit, Model 21.2 generally performs slightly less well than the base model, because it has the added task of fitting the fishery CPUE index. The fit of Model 21.2 to the fishery CPUE index (RMSSR = 2.561, Figure 2.1.11c) is roughly similar to its fit to the survey index (RMSSR = 2.425, Figure 2.1.11a).

Model 21.3

This model differs with respect to Model 19.12a by including a parameter ("extra SD") that is added to the log-scale standard errors of the survey index. Another model incorporating the "extra SD" feature was considered, but not accepted, during the 2017 assessment cycle (Model 17.3, Thompson 2017). The "extra SD" parameter was estimated at a value of 0.1518. Summing the "extra SD" term with the log-scale standard errors (average = 0.0665) gives values that are higher than the original by a factor of 3.2822, on average. Relative to the base model, the impacts on spawning biomass (Figure 2.1.16), spawning biomass relative to $B_{100\%}$ (Figure 2.1.17), and ABC and OFL (Figure 2.1.24) are quite substantial, and all in the negative (lower) direction. In particular, Model 21.3 estimates that spawning biomass is currently below the $B_{20\%}$ threshold that results in closure of the directed fishery. As with Model 19.12, the resulting fit to the survey index is very good (RMSSR = 1.002, Figure 2.1.11b), but the mechanisms by which those two models achieve that result are different. Similar to Model 19.12, one argument against use of Model 21.3 might be the decreased impact of the survey index on model results. The CIE reviewers noted the recent string of positive residuals in the fit to the survey index (six years, Figure 2.1.11) when assigning it a score of 1 under the "Acceptable residual patterns" criterion (Table 2.1.14). Wilberg et al. (2010) noted that inflating the standard deviations of the index data will often produce trends in residuals if catchability is actually time-varying.

ABC and OFL

As noted previously, the 2021-2022 fishing mortality rates, ABCs, and OFLs shown in Tables 2.1.18 and 2.1.24 and Figures 2.1.19, 2.1.23, and 2.1.24 were based on application of the respective harvest control rule to each model rather than conditioning them on the 2021 ABC that was actually specified. This was done in order to enable comparison of these results with those derived in last year's assessment, as distinguished from making the best current prediction of 2022 values (the latter will occur in the final assessment).

One of the take-home messages from Figure 2.1.24 is that the configuration of the ensemble (both the set of models and their associated weights) can have a significant impact on ABC and OFL. In each panel of Figure 2.1.24, the black vertical dashed line represents the value that is currently specified and the gray vertical dashed line represents the mean of the ensemble distribution, and there is a substantial decrease (gray relative to black) in every case, ranging from 18% to 25%. A small part of each difference is due to use of the updates described in the "Data" section (recall that "updates" in this context refers to use of updated methodology; in no case are 2021 data included in any of the models), but most of each difference is due to the choice of models and weights in the CIE reviewers' recommended ensemble.

It should also be emphasized that the plots in Figure 2.1.24 are based on the Hessian approximation, which results in normal distributions. The fact that non-negligible portions of the normal distributions for Model 21.3 consist of negative ABC and OFL values suggests that the Hessian approximation may not be appropriate for that model.

Preliminary exploration of interjurisdictional issues

Previous attempts at incorporating movement into assessment models of the EBS Pacific cod stock (Thompson 2018, Thompson et al. 2020) have failed to move beyond the "preliminary assessment" stage, as both the Team and SSC have been skeptical of the possibility of estimating movement rates given present data limitations. Likewise, for the near term at least, none of the CIE reviewers recommended development of an assessment model incorporating movement.

The CIE reviewers did make many other recommendations related to movement, however. Unlike most previous discussions of this topic by the Team or SSC, which focused primarily on movement between the EBS and NBS, the CIE reviewers' interest in movement focused primarily on movement between American and Russian jurisdictions. Development of a "simulation study" and "analytical models," rather than an assessment model, were recommended as ways to increase understanding of the interjurisdictional issues involved, including the possibility of disproportionate harvesting. Attachment 2.1.2 was developed in response to these recommendations.

Attachment 2.1.2 develops a very simple, deterministic, age-structured, two-area model, with results focused primarily on age-aggregated (but area-specific) equilibrium outcomes. The primary goals are to understand which variables determine both relative and absolute biomasses and yields in the two areas, how various outcomes may be independent of specific parameters, and how various parameters covary in order to result in particular outcomes.

In general, the results shown in Attachment 2.1.2 illustrate the intuitive principle that, the more the stock is concentrated in the EBS (where, in context of Attachment 2.1.2, this term is taken to include the NBS)—either due to recruitment being concentrated in that area, fish tending not to stray from that area once they arrive, or both—the smaller the impacts of fishing in the WBS.

Another pair of intuitive results is that, if the exploitation rate in the EBS is left constant, increased fishing in the WBS will result in reduced equilibrium yield in the EBS and, if the exploitation rate in the EBS is adjusted in order to achieve a target level of overall (i.e., across areas) relative spawning per recruit, the reduction in EBS yield will be even greater. However, reported WBS catches in recent years (Lajus et al. 2019) do not appear to be particularly high relative to estimates of WBS survey biomass (O'Leary et al. 2021).

One more result that may have some generality is that, for some quantities, certain parameters may have very little impact; perhaps unintuitively so. For example, under the right conditions, the equilibrium biomass *proportions* (as distinguished from the biomasses themselves) are entirely independent of the exploitation rate in either area.

Use of harvest control rules in model averaging

For the last three years, the senior author of the assessment and various members of the Team and SSC have spent considerable time and effort debating the issue of whether, in the context of ensemble modeling, the harvest control rules should be applied *before* or *after* model averaging. At the request of the Team and SSC, this issue was considered yet again during the CIE review, but the responses of the reviewers were, generally speaking, somewhat nuanced. None of the reviewers gave an unqualified endorsement of either approach, and one of them suggested that a conclusion would have to await "further investigations and examples."

Attachment 2.1.3 was developed in response to this suggestion. The bulk of that attachment evaluates the properties of the two procedures in the context of a highly simplified system. A central focus of the analysis is the relative uncertainty in ABC or OFL resulting from the two procedures. In brief, the uncertainty associated with the "before" approach is very likely to be greater, and perhaps substantially so, than the uncertainty associated with the "after" approach. This is because the "before" approach incorporates both the *within*-model and *between*-model uncertainty in F_{ABC} or F_{OFL}, whereas the "after" approach ignores both of these. In addition, the attachment summarizes various theoretical arguments for and against each procedure, ultimately concluding that the "before" approach is superior. Similarly, Burnham and Anderson (2002) concluded that *parameters* in nonlinear models "should not be averaged" and that, instead, "model averaging the *expected response variable*" is the appropriate course of action.

Acknowledgments

Julie Nielsen and Susanne McDermott provided the text and figures for the subsection on tagging. Rick Methot, Ian Taylor, and Chantel Wetzel provided technical advice on SS. In addition to presentations by the authors of this preliminary assessment, Giancarlo Correa, Mary Furuness, Joel Kraski, Julie Nielsen (with several coauthors), Kalei Shotwell (with several coathors), and Kali Stone (with Delsa Anderl) provided presentations for the CIE review. Anne Hollowed and the BSAI Groundfish Plan Team provided reviews of this document.

References

Abbott, J. K., A. C. Haynie, and M. N. Reimer. 2015. Hidden flexibility: Institutions, incentives, and the margins of selectivity in fishing. *Land Economics* 91:169–195. https://doi.org/10.3368/le.91.1.169

Beverton, R. J. H., and S. J. Holt. 1957. *On the Dynamics of Exploited Fish Populations*. Chapman & Hall, London.

Burnham, K. P. , and D. R. Anderson. 2002. *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach*. Springer-Verlag, New York.

Campbell, R. A. 2014. A new spatial framework incorporating uncertain stock and fleet dynamics for estimating fish abundance. *Fish and Fisheries* 17:56–77. https://doi.org/10.1111/faf.12091

Carruthers, T. R., R. N. Ahrens, M. K. McAllister, and C. J. Walters, C.J. 2011. Integrating imputation and standardization of catch rate data in the calculation of relative abundance indices. *Fisheries Research* 109:157–167. http://dx.doi.org/10.1016/j.fishres.2011.01.033

Ciannelli, L., I. Tolkova, R. Lauth, P. Puerta, T. Helser, A. Gitelman, G. Thompson. 2019. Spatial, interannual, and generational sources of trait variability in a marine population. *Ecology* 0:000-000. https://doi.org/10.1002/ecy.2907

Dunn, P. K., and G. K. Smyth. 1996. Randomized quantile residuals. *Journal of Computational and Graphical Statistics* 5:236–244. https://doi.org/10.2307/1390802

Foster, S. D., and M. V. Bravington. 2013. A Poisson-gamma model for analysis of ecological non-negative continuous data. *Environmental and Ecological Statistics* 20:533-552. https://doi.org/10.1007/s10651-012-0233-0

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optimization Methods and Software* 27:233-249. https://doi.org/10.1080/10556788.2011.597854

Grüss, A., J. F. Walter, E. A. Babcock, F. C. Forrestal, J. T. Thorson, M. V. Lauretta, M.V., and M. J. Schirripa. 2019. Evaluation of the impacts of different treatments of spatio-temporal variation in catch-per-unit-effort standardization models. *Fisheries Research* 213:75–93. https://doi.org/10.1016/j.fishres.2019.01.008

Hannesson, R. 2007. Growth accounting in a fishery. *Journal of Environmental Economics and Management* 53:364–376. https://doi.org/10.1016/j.jeem.2006.11.001

Hare, S., and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. *Progress in Oceanography* 47:103-145. http://dx.doi.org/10.1016/S0079-6611(00)00033-1

Hurtado-Ferro, F., C. S. Szuwalski, J. L. Valero, S. C. Anderson, C. J. Cunningham, K. F. Johnson, R. Licandeo, C. R. McGilliard, C. C. Monnahan, M. L. Muradian, K. Ono, K. A. Vert-Pre, A. R. Whitten, and A. E. Punt. 2015. Looking in the rear-view mirror: bias and retrospective patterns in integrated, age-structured stock assessment models. *ICES Journal of Marine Science* 72:99-110. http://dx.doi.org/10.1093/icesjms/fsu198

Jørgensen, B. 1987. Exponential dispersion models. *Journal of the Royal Statistical Society. Series B (Methodological)* 49:127-162. https://doi.org/10.1111/j.2517-6161.1987.tb01685.x

Lajus, D., D. Safronova, A. Orlov, and R. Blyth-Skyrme. 2019. MSC Sustainable Fisheries Certification: Western Bering Sea Pacific cod and Pacific halibut longline. Marine Stewardship Council. Marine House, 1 Snow Hill, London, UK, EC1A 2DH. 327 p. https://fisheries.msc.org/en/fisheries/western-bering-sea-pacific-cod-and-pacific-halibut-longline/@@assessments

Lindgren, F. 2012. Continuous domain spatial models in R-INLA. *The ISBA Bulletin* 19(4):14–20. https://bayesian.org/wp-content/uploads/2016/09/1212.pdf

Lindgren, F., and H. Rue. 2015. Bayesian spatial modelling with R-INLA. *Journal of Statistical Software* 63:1–25. http://dx.doi.org/10.18637/jss.v063.i19

McAllister, M. K., and J. N. Ianelli. 1997. Bayesian stock assessment using catch-age data and the sampling - importance resampling algorithm. *Canadian Journal of Fisheries and Aquatic Sciences* 54:284–300. https://doi.org/10.1139/f96-285

Methot, R. D., and I. G. Taylor. 2011. Adjusting for bias due to variability of estimated recruitments in fishery assessment models. *Canadian Journal of Fisheries and Aquatic Sciences* 68:1744-1760. http://dx.doi.org/10.1139/f2011-092

Methot, R. D., and C. R. Wetzel. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research* 142:86-99. https://doi.org/10.1016/j.fishres.2012.10.012

Mohn, R. 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. *ICES Journal of Marine Science* 56: 473-488. https://doi.org/10.1006/jmsc.1999.0481

Neidetcher, S. K., T. P. Hurst, L. Ciannelli, and E. A. Logerwell. 2014. Spawning phenology and geography of Aleutian Islands and eastern Bering Sea Pacific cod (Gadus macrocephalus). *Deep Sea Research Part II: Topical Studies in Oceanography* 109:204-214. https://doi.org/10.1016/j.dsr2.2013.12.006

O'Leary, C. A., J. T. Thorson, J. N. Ianelli, S. Kotwicki, S. 2020. Adapting to climate-driven distribution shifts using model-based indices and age composition from multiple surveys in the walleye pollock (*Gadus chalcogrammus*) stock assessment. *Fisheries Oceanography* 29:541-557. https://doi.org/10.1111/fog.12494

O'Leary, C. A., S. Kotwicki, G. R. Hoff, J. T. Thorson, V. V. Kulik, J. N. Ianelli, R. R. Lauth, D. G. Nichol, J. Conner, and A. E. Punt. 2021. Estimating spatiotemporal availability of transboundary fishes to fishery-independent surveys. *Journal of Applied Ecology*. https://doi.org/10.1111/1365-2664.13914

Puerta, P., B. Johnson, L. Ciannelli, T. Helser, and R. Lauth. 2019. Subsampling populations with spatially structured traits: a field comparison of stratified and random strategies. *Canadian Journal of Fisheries and Aquatic Sciences* 76:511-522. https://doi.org/10.1139/cjfas-2017-0248

Robins, C. M., Y. G. Wang, and D. Die. 1998. The impact of global positioning systems and plotters on fishing power in the northern prawn fishery, Australia. *Canadian Journal of Fisheries and Aquatic Sciences* 55:1645–1651. https://doi.org/10.1139/f98-037

Spies, I., K. M. Gruenthal, D. P. Drinan, A. B. Hollowed, D. E. Stevenson, C. M. Tarpey, and L. Hauser. 2020. Genetic evidence of a northward range expansion in the eastern Bering Sea stock of Pacific cod. *Evolutionary Applications* 13:362-375. https://doi.org/10.1111/eva.12874

Stevenson, D. E., and R. R. Lauth. 2019. Bottom trawl surveys in the northern Bering Sea indicate recent shifts in the distribution of marine species. *Polar Biology* 42:407–421. https://doi.org/10.1007/s00300-018-2431-1

Thompson, G. G. 2015. Assessment of the Pacific cod stock in the Eastern Bering Sea. *In* Plan Team for the Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 251-470. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501. https://apps-afsc.fisheries.noaa.gov/refm/docs/2015/EBSpcod.pdf

Thompson, G. G. 2016. Assessment of the Pacific cod stock in the Eastern Bering Sea. *In* Plan Team for the Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 311-544. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501. https://apps-afsc.fisheries.noaa.gov/refm/docs/2016/EBSpcod.pdf

Thompson, G. G. 2017. Assessment of the Pacific cod stock in the Eastern Bering Sea. *In* Plan Team for the Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 229-516. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501. https://apps-afsc.fisheries.noaa.gov/refm/docs/2017/EBSpcod.pdf

Thompson, G. G. 2018. Assessment of the Pacific cod stock in the Eastern Bering Sea. *In* Plan Team for the Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 1-386. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501. https://apps-afsc.fisheries.noaa.gov/refm/docs/2018/BSAI/EBSpcod.pdf

Thompson, G. G., J. Conner, S. K. Shotwell, B. Fissel, T. Hurst, B. Laurel, L. Rogers, and E. Siddon. 2020. Assessment of the Pacific cod stock in the Eastern Bering Sea. *In* Plan Team for the Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 1-

344. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501. https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/EBSpcod.pdf

Thorson, J.T. 2018. Three problems with the conventional delta-model for biomass sampling data, and a computationally efficient alternative. *Canadian Journal of Fisheries and Aquatic Sciences* 75:1369–1382. https://doi.org/10.1139/cjfas-2017-0266

Thorson, J. T. 2019a. Guidance for decisions using the Vector Autoregressive Spatio-Temporal (VAST) package in stock, ecosystem, habitat and climate assessments. *Fisheries Research* 210:143-161. https://doi.org/10.1016/j.fishres.2018.10.013

Thorson, J. T. 2019b. Measuring the impact of oceanographic indices on species distribution shifts: The spatially varying effect of cold-pool extent in the eastern Bering Sea. *Limnology and Oceanography* 64:2632–2645. https://doi.org/10.1002/lno.11238

Thorson, J.T., and L.A.K. Barnett. 2017. Comparing estimates of abundance trends and distribution shifts using single- and multispecies models of fishes and biogenic habitat. *ICES Journal of Marine Science* 74:1311-1321. https://doi.org/10.1093/icesjms/fsw193

Thorson, J. T., C. J. Cunningham, E. Jorgensen, A. Havron, P.-J. F. Hulson, C. C. Monnahan, and P. von Szalay. 2021. The surprising sensitivity of index scale to delta-model assumptions: Recommendations for model-based index standardization. *Fisheries Research*. https://doi.org/10.1016/j.fishres.2020.105745

Thorson, J. T., R. Fonner, M. A. Haltuch, K. Ono, K., and H. Winker. 2017a. Accounting for spatiotemporal variation and fisher targeting when estimating abundance from multispecies fishery data. *Canadian Journal of Fisheries and Aquatic Sciences* 74:1794–1807. https://doi.org/10.1139/cjfas-2015-0598

Thorson, J. T., K. F. Johnson, R. D. Methot, and I. G. Taylor. 2017b. Model-based estimates of effective sample size in stock assessment models using the Dirichlet-multinomial distribution. *Fisheries Research* 192:84-93. http://dx.doi.org/10.1016/j.fishres.2016.06.005

Thorson, J.T., and K. Kristensen. 2016. Implementing a generic method for bias correction in statistical models using random effects, with spatial and population dynamics examples. *Fisheries Research* 175:66–74. https://doi.org/10.1016/j.fishres.2015.11.016

Thorson, J. T., A. O. Shelton, E. J. Ward, E.J., and H. J. Skaug. 2015. Geostatistical delta-generalized linear mixed models improve precision for estimated abundance indices for West Coast groundfishes. *ICES Journal of Marine Science* 72:1297–1310. https://doi.org/10.1093/icesjms/fsu243

Walters, C. 2003. Folly and fantasy in the analysis of spatial catch rate data. *Canadian Journal of Fisheries and Aquatic Sciences* 60:1433–1436. http://dx.doi.org/10.1139/f03-152

Weinberg, K. L., C. Yeung, D. A. Somerton, G. G. Thompson, and P. H. Ressler. 2016. Is the survey selectivity curve for Pacific cod (*Gadus macrocephalus*) dome-shaped? Direct evidence from field studies. *Fishery Bulletin* 114:360-369. https://doi.org/10.7755/FB.114.3.8

Wilberg, M. J., J. T. Thorson, B. C. Linton, and J. Berkson. 2010. Incorportating time-varying catchability into population dynamic stock assessment models. Reviews in Fisheries Science 18:7-24. https://doi.org/10.1080/10641260903294647

Tables

Table 2.1.1. Catch (t) time series, by gear.

Year	Longline	Trawl	Pot	Other	Total
1991	77,505	129,393	3,343	0	210,241
1992	79,404	77,261	7,512	33	164,210
1993	49,295	81,791	2,098	2	133,186
1994	78,564	84,932	8,037	730	172,263
1995	97,666	110,958	19,275	599	228,498
1996	88,883	91,912	28,006	267	209,067
1997	117,010	93,925	21,493	173	232,601
1998	84,324	60,781	13,233	192	158,529
1999	81,464	51,903	12,400	100	145,867
2000	81,642	53,817	15,849	68	151,376
2001	90,361	35,657	16,472	52	142,542
2002	100,271	51,067	15,052	166	166,555
2003	108,673	46,675	19,940	155	175,443
2004	108,481	57,793	17,242	231	183,748
2005	113,125	52,608	17,102	104	182,940
2006	96,565	53,209	18,960	84	168,818
2007	77,136	45,673	17,238	82	140,129
2008	88,924	33,493	17,366	19	139,802
2009	96,598	36,956	13,608	13	147,174
2010	81,618	41,205	19,678	344	142,845
2011	116,794	63,929	27,996	505	209,224
2012	128,460	75,508	28,727	85	232,781
2013	124,820	81,614	30,251	15	236,699
2014	127,270	72,262	39,194	2	238,728
2015	128,201	66,672	37,937	28	232,838
2016	127,918	72,577	47,077	47	247,619
2017	122,762	68,881	46,181	13	237,838
2018	100,213	59,967	39,686	0	199,866
2019	88,778	49,023	41,053	50	178,904
2020	72,061	50,566	32,971	38	155,637
2021	43,360	33,434	21,702	20	98,517

Table 2.1.2a. Longline fishery mean CPUE by year and month, Pacific cod target hauls only (catch is in weight; values have been normalized to an overall mean of 1.0).

Year	1	2	3	4	5	6	7	8	9	10	11	12
1996	1.646	1.665	1.480	1.366	1.263				0.986	1.040	1.086	
1997	1.807	1.908	1.597	1.576	1.242				1.081	1.085	1.033	1.142
1998	1.605	1.740	1.300	1.031	0.959				0.691	0.751	0.907	0.973
1999	1.361	1.431	1.202	1.090	1.232			0.817	0.960	0.863	0.974	1.086
2000	1.588	1.156	1.202	1.059	1.142			0.865	0.769	0.688	0.715	0.846
2001	1.118	1.073	1.065	0.949	0.943	1.052	0.865	0.782	0.729	0.734	0.724	0.878
2002	1.290	1.249	1.267	1.310			0.666	0.727	0.685	0.659	0.705	0.784
2003	0.933	0.984	1.071	0.864	0.838		0.651	0.643	0.632	0.629	0.651	0.750
2004	0.999	1.186	1.136	1.098	0.780		0.657	0.605	0.576	0.565	0.715	0.966
2005	1.168	1.193	1.272	1.261			0.711	0.640	0.580	0.620	0.641	0.815
2006	1.308	1.530	1.521	1.453			0.686	0.811	0.747	0.630	0.790	0.835
2007	1.356	1.406	1.339				0.711	0.873	0.729	0.649	0.807	1.185
2008	1.455	1.556	1.463	1.525			0.646	0.682	0.578	0.488	0.619	1.262
2009	1.632	1.795	2.194				0.650	0.713	0.646	0.625	0.685	1.034
2010	1.395	1.616	1.734				0.752	0.728	0.652	0.617	0.779	0.934
2011	1.287	1.393	1.390	1.248	0.851	0.821	0.611	0.652	0.683	0.725	0.767	0.909
2012	1.413	1.534	1.119	1.137	0.935	0.950	0.693	0.623	0.585	0.620	0.671	1.044
2013	1.424	1.377	1.257	1.234	0.994	0.688	0.766	0.689	0.652	0.647	0.800	1.023
2014	1.012	1.210	1.020	1.018	0.797	0.684	0.575	0.649	0.663	0.719	0.790	0.853
2015	0.983	1.197	1.125	1.017	0.952	0.804	0.847	0.772	0.655	0.699	0.788	0.961
2016	1.172	1.353	1.096	1.008	0.971	0.773	0.795	0.775	0.774	0.728	0.794	0.947
2017	1.022	1.399	1.220	1.130	0.977	0.856	0.713	0.574	0.595	0.668	0.898	1.044
2018	1.532	1.639	1.351	1.342	0.866	0.708	0.570	0.571	0.798	0.794	0.711	0.986
2019	1.626	1.792	1.383	1.369	0.907	0.905	0.678	0.679	0.791	0.844	0.930	0.974
2020	1.481	1.784	1.598	1.293	1.467	1.020	0.802	0.741	0.785	0.924	0.922	0.986
2021	1.364	1.569	1.532	1.247	0.735	1.043	0.941	0.823				

Table 2.1.2b. Bottom trawl fishery mean CPUE by year and month, Pacific cod target hauls only (catch is in weight; values have been normalized to an overall mean of 1.0).

Year	1	2	3	4	5	6	7	8	9	10	11	12
1996	0.520	0.789	0.967	1.024		0.357					0.724	
1997	1.123	1.644	1.219	0.834	0.409	0.168	0.480	0.490				
1998	1.045	1.516	0.818	0.488	0.355			0.401	0.365	0.158	0.173	
1999	0.563	1.121	0.775	0.821	0.471				0.365	0.324		
2000	0.790	0.781	0.843	0.550	0.617	0.253	0.247					
2001	0.271	0.592	0.702	0.361	0.332	1.012	1.354	0.333	0.342	0.161		
2002	0.755	0.910	0.806	0.403	0.485	0.943	0.689	0.281	0.317	0.304	0.630	
2003	0.418	0.555	0.766	0.459	0.288	0.893	0.958	0.412	0.435			
2004	1.098	1.286	1.290	0.640	0.548	0.532	0.637	0.384	0.403	0.217		
2005	0.700	0.866	1.609	0.566	0.418	0.335	0.208	0.146				
2006	0.668	0.831	0.956	1.061	0.573		0.179	0.344	0.173			
2007	0.458	0.632	1.033	0.809	0.674	0.821	0.449		0.008			
2008	0.392	0.553	0.644	0.714	0.934	0.176		1.817	0.280			
2009	0.438	0.871	1.323	1.811	0.788	0.600		0.507		1.079		
2010	0.544	1.004	1.236		0.400		1.034	0.629		0.949		
2011	1.089	1.213	2.047	0.867	0.892		1.123	0.924	1.243	1.056		
2012	2.120	2.500	1.703	1.033	1.333	0.964		0.798	0.677			
2013	1.447	1.710	1.106	2.027	0.568	0.493		1.244	1.533			
2014	1.306	1.302	1.513	1.296	1.519			0.763	1.270			
2015	0.438	1.376	1.777	1.180	1.464		1.288	2.590				
2016	0.923	1.543	2.133	1.140		0.588	0.961	0.618	0.558	0.735		
2017	0.982	2.124	2.146	1.899		0.386			0.132			
2018	1.394	1.646	6.402	5.496								
2019	1.351	1.763	3.977	6.247	0.187				0.364			
2020	0.687	4.678	1.575	0.710	0.440							
2021		4.616	2.813	1.962								

Table 2.1.2c. Pot fishery mean CPUE by year and month, Pacific cod target hauls only (catch is in weight; values have been normalized to an overall mean of 1.0).

Year	1	2	3	4	5	6	7	8	9	10	11	12
1996			0.929				0.593	0.614	0.516	0.576		
1997			1.066	1.245	0.682	0.636	0.524	0.689	0.379	0.700	0.493	0.545
1998				1.005	0.682	0.584	0.689	0.473	0.406	0.370		0.658
1999				0.880	0.621	0.486			0.427	0.512		
2000		0.743	0.593									
2001			0.839						0.574	0.675	0.419	
2002		1.110	0.853						0.559	0.538	0.635	
2003		0.970	0.904						0.742	0.809	0.777	
2004	0.805	1.035	0.936						0.632	0.522	0.873	
2005	1.439	1.062							0.675	0.521		
2006	1.103	0.945							0.632	0.869	0.454	0.492
2007	0.816								0.815	1.203		
2008	1.056								0.828	0.548		
2009	1.189											
2010	1.114								1.111	0.953	1.358	
2011	1.704								1.086	0.988		
2012	1.866								0.742	1.055		
2013	1.635	1.728							1.253	1.043	1.150	
2014	1.244	1.565	2.079						1.132	0.942	0.707	1.334
2015	1.193	1.751	1.796	1.699					1.207	1.035	0.853	1.122
2016	1.152	1.421	1.505	1.443					1.302	1.035	0.843	1.054
2017	1.205	2.048							0.918	0.929	0.911	0.839
2018	1.162		2.356						1.156	1.324	0.720	1.146
2019	1.232		2.788						1.764		1.718	
2020	1.224								1.742			
2021	1.446											

Table 2.1.2d. Pelagic trawl fishery mean Pacific cod CPUE by year and month, all hauls—regardless of target (catch is in weight; values have been normalized to an overall mean of 1.0).

Year	1	2	3	4	5	6	7	8	9	10	11	12
1996	2.432	1.167	0.842					0.263	0.530	0.436	0.603	
1997	4.976	1.911	2.422	2.522				0.381	0.514	0.464		
1998	2.558	1.384	4.247					0.130	0.430	0.677	0.459	
1999	1.570	0.964	0.623				0.389	0.441	0.412	0.395	0.228	
2000	4.365	0.736	0.654	0.336			0.283	0.248	0.379	0.298	0.629	
2001	1.272	0.595	0.456	0.621		0.225	0.294	0.481	0.286	0.335	0.116	
2002	2.036	1.682	0.982	1.691		0.280	0.250	0.366	0.465	0.416		
2003	3.236	1.493	0.772	1.301		0.272	0.278	0.357	0.432	0.306		
2004	1.978	1.884	0.968			0.495	0.254	0.231	0.376	0.202		
2005	2.619	1.522	1.541			0.296	0.244	0.279	0.449	0.309		
2006	2.649	1.673	1.428			0.304	0.354	0.459	0.349	0.295	0.443	
2007	1.003	1.054	1.272			0.307	0.407	0.405	0.269	0.288	0.339	
2008	1.204	1.002	1.674			0.604	0.424	0.378	0.206	0.141	0.078	
2009	1.080	1.467	1.648	3.581		0.298	0.451	0.383	0.211	0.290		
2010	1.241	1.828	1.523	2.103		0.481	0.531	0.326	0.361	0.323		
2011	1.379	1.735	1.472	1.164		0.417	0.378	0.249	0.253	0.332	0.411	
2012	3.047	2.766	1.681	0.830		0.327	0.617	0.264	0.331	0.409	0.411	
2013	1.099	1.275	1.765	1.479		0.682	0.512	0.454	0.349	0.427		
2014	0.731	0.600	0.739	2.210		0.354	0.345	0.371	0.421			
2015	0.613	1.519	1.729	1.962		0.485	0.839	0.812	0.964	1.260		
2016	0.651	1.142	1.218	2.102		0.644	0.437	0.330	0.253	0.225		
2017	1.050	1.487	1.973	4.658		0.659	0.387	0.367	0.311	1.940		
2018	0.596	2.026	1.758	2.362		0.360	0.133	0.162	0.199			
2019	1.810	2.870	3.096	4.441		0.390	0.204	0.196	0.127	0.064		
2020	0.995	3.646	3.290	2.955	2.764	0.200	0.196	0.292	0.216	0.141		
2021	1.333	1.827	3.571	2.240	2.196	0.664						

Table 2.1.3. Western Bering Sea catch (t).

Year	Catch
2001	42,000
2002	31,600
2003	36,300
2004	46,300
2005	34,800
2006	28,700
2007	34,504
2008	43,154
2009	34,301
2010	46,020
2011	47,038
2012	54,560
2013	53,163
2014	53,130
2015	55,930
2016	58,340
2017	70,320
2018	61,450

Table 2.1.4. Comparison of configurations for VAST estimates of the survey index.

Cold pool?		Yes		No		Yes		Yes	
Knots:		750		750		100		750	
Distribution:		P-link Δ-gamma		P-link Δ-gamma		P-link Δ-gamma		Tweedie	
Area	Year	Est.	Sigma	Est.	Sigma	Est.	Sigma	Est.	Sigma
EBS+NBS	1982	638301	0.054	647144	0.056	670574	0.062	736081	0.068
EBS+NBS	1983	896361	0.082	891402	0.081	910960	0.088	942060	0.077
EBS+NBS	1984	680494	0.053	681124	0.053	706241	0.059	746312	0.058
EBS+NBS	1985	880950	0.048	883642	0.049	997611	0.056	929340	0.051
EBS+NBS	1986	870246	0.050	874564	0.052	901021	0.056	937501	0.048
EBS+NBS	1987	817756	0.067	791661	0.059	828025	0.071	811543	0.064
EBS+NBS	1988	539668	0.046	541439	0.046	562918	0.052	548239	0.048
EBS+NBS	1989	353903	0.060	346850	0.057	336870	0.058	344278	0.057
EBS+NBS	1990	472346	0.055	473651	0.055	486150	0.059	507147	0.060
EBS+NBS	1991	518984	0.054	522790	0.055	532537	0.060	549861	0.055
EBS+NBS	1992	546007	0.062	554494	0.063	587472	0.068	587560	0.056
EBS+NBS	1993	823858	0.063	814274	0.061	816977	0.068	871939	0.059
EBS+NBS	1994	1143009	0.051	1148294	0.052	1238136	0.056	1243283	0.048
EBS+NBS	1995	703347	0.050	707505	0.050	739381	0.055	751058	0.049
EBS+NBS	1996	646006	0.075	632858	0.070	709021	0.079	644801	0.062
EBS+NBS	1997	544664	0.068	553649	0.074	554297	0.073	532938	0.053
EBS+NBS	1998	660275	0.096	628229	0.086	626609	0.097	637767	0.069
EBS+NBS	1999	532079	0.058	528878	0.059	557655	0.067	548843	0.053
EBS+NBS	2000	516305	0.060	518065	0.061	517236	0.061	522535	0.051
EBS+NBS	2001	1035971	0.059	1042461	0.060	1047952	0.061	1016133	0.049
EBS+NBS	2002	667313	0.084	654892	0.082	649547	0.082	627537	0.060
EBS+NBS	2003	661229	0.103	626216	0.090	622994	0.103	623623	0.065
EBS+NBS	2004	500962	0.086	492343	0.082	451537	0.071	468784	0.058
EBS+NBS	2005	523294	0.081	509431	0.075	505118	0.075	512824	0.059
EBS+NBS	2006	446364	0.051	448638	0.052	445457	0.056	436770	0.043
EBS+NBS	2007	614865	0.061	627277	0.068	707535	0.070	700702	0.058
EBS+NBS	2008	487941	0.056	489708	0.057	518148	0.062	511925	0.055
EBS+NBS	2009	718208	0.050	725837	0.053	775986	0.056	767992	0.050
EBS+NBS	2010	740143	0.051	743297	0.051	773959	0.055	804113	0.048
EBS+NBS	2011	861528	0.054	852899	0.052	904648	0.057	865958	0.047
EBS+NBS	2012	1051115	0.064	1050167	0.064	1068602	0.069	1038860	0.049
EBS+NBS	2013	741318	0.061	749649	0.064	741633	0.063	797384	0.054
EBS+NBS	2014	1316205	0.096	1302307	0.096	1305998	0.089	1316338	0.062
EBS+NBS	2015	1142591	0.093	1144105	0.095	1118469	0.084	1050099	0.058
EBS+NBS	2016	1042775	0.156	988717	0.149	947856	0.131	831053	0.074
EBS+NBS	2017	523384	0.046	525384	0.046	519894	0.048	500158	0.037
EBS+NBS	2018	544275	0.068	529139	0.065	526869	0.071	488939	0.049
EBS+NBS	2019	773120	0.056	767441	0.056	770276	0.061	729799	0.041

Table 2.1.5. Correlations between survey index estimates resulting from alternative VAST configurations.

	Cold pool?			Yes	No	Yes	Yes
		Knots		750	750	100	750
Area			Distribution	P-link Δ-gamma	P-link Δ-gamma	P-link Δ-gamma	Tweedie
EBS+NBS	Yes	750	P-link Δ-gamma	1.000	0.998	0.985	0.968
EBS+NBS	No	750	P-link Δ-gamma	0.998	1.000	0.990	0.977
EBS+NBS	Yes	100	P-link Δ-gamma	0.985	0.990	1.000	0.987
EBS+NBS	Yes	750	Tweedie	0.968	0.977	0.987	1.000
EBS	Yes	750	P-link Δ-gamma	1.000	1.000	0.991	0.988
EBS	No	750	P-link Δ-gamma	1.000	1.000	0.992	0.989
EBS	Yes	100	P-link Δ-gamma	0.991	0.992	1.000	0.993
EBS	Yes	750	Tweedie	0.988	0.989	0.993	1.000
NBS	Yes	750	P-link Δ-gamma	1.000	0.992	0.982	0.898
NBS	No	750	P-link Δ-gamma	0.992	1.000	0.983	0.901
NBS	Yes	100	P-link Δ-gamma	0.982	0.983	1.000	0.946
NBS	Yes	750	Tweedie	0.898	0.901	0.946	1.000

Table 2.1.6a. Updated VAST estimates of survey age composition.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1994	0.00025	0.10960	0.36178	0.16724	0.11357	0.11841	0.08868	0.02324	0.00894	0.00437	0.00148	0.00115	0.00128
1995	0.00016	0.06394	0.24421	0.41964	0.10467	0.07786	0.05798	0.01463	0.00731	0.00548	0.00141	0.00142	0.00128
1996	0.00003	0.06777	0.18147	0.17359	0.28545	0.15581	0.08064	0.03683	0.00964	0.00364	0.00189	0.00163	0.00160
1997	0.00029	0.27106	0.16713	0.14830	0.14075	0.12328	0.10537	0.02746	0.01106	0.00218	0.00172	0.00081	0.00058
1998	0.00007	0.07735	0.42642	0.19449	0.11092	0.06057	0.06975	0.03585	0.01884	0.00370	0.00078	0.00082	0.00043
1999	0.00010	0.10650	0.18680	0.29143	0.21182	0.07817	0.06794	0.03386	0.01407	0.00600	0.00119	0.00144	0.00067
2000	0.00000	0.20120	0.10995	0.15719	0.23899	0.17274	0.07443	0.01709	0.01716	0.00498	0.00393	0.00167	0.00068
2001	0.00004	0.27894	0.22734	0.17678	0.08903	0.09894	0.08474	0.03119	0.00801	0.00185	0.00160	0.00110	0.00045
2002	0.00023	0.07471	0.17881	0.29519	0.24556	0.07753	0.06866	0.04348	0.01062	0.00309	0.00103	0.00049	0.00060
2003	0.00001	0.16659	0.14230	0.23106	0.21247	0.13663	0.05220	0.03584	0.01724	0.00374	0.00051	0.00063	0.00079
2004	0.00005	0.13003	0.15148	0.26514	0.12787	0.13909	0.10903	0.04254	0.02159	0.00817	0.00225	0.00196	0.00080
2005	0.00000	0.14653	0.22804	0.20325	0.12604	0.07255	0.10355	0.07164	0.02821	0.01106	0.00411	0.00445	0.00057
2006	0.00000	0.33628	0.13637	0.15493	0.10952	0.09310	0.06940	0.05420	0.02987	0.01053	0.00353	0.00137	0.00090
2007	0.00000	0.66394	0.09784	0.07039	0.04857	0.05437	0.02432	0.02031	0.00992	0.00602	0.00207	0.00120	0.00105
2008	0.00000	0.21988	0.41153	0.14618	0.08927	0.05506	0.03663	0.01380	0.01322	0.00739	0.00320	0.00231	0.00154
2009	0.00000	0.48663	0.17650	0.21229	0.05935	0.02726	0.01581	0.01123	0.00611	0.00222	0.00127	0.00082	0.00052
2010	0.00000	0.05070	0.49801	0.17026	0.18543	0.06049	0.01713	0.01047	0.00416	0.00185	0.00070	0.00064	0.00016
2011	0.00008	0.30585	0.06959	0.36466	0.11080	0.09755	0.03340	0.00929	0.00408	0.00197	0.00139	0.00077	0.00056
2012	0.00000	0.36834	0.24105	0.05898	0.21603	0.06419	0.03542	0.00961	0.00306	0.00213	0.00073	0.00018	0.00027
2013	0.00000	0.10458	0.35269	0.19492	0.12110	0.13941	0.06485	0.01571	0.00449	0.00124	0.00029	0.00037	0.00035
2014	0.00004	0.28420	0.17128	0.22332	0.19972	0.05718	0.04679	0.01231	0.00252	0.00099	0.00093	0.00010	0.00061
2015	0.00002	0.05978	0.41467	0.20764	0.19774	0.08474	0.01977	0.01199	0.00257	0.00049	0.00027	0.00011	0.00020
2016	0.00000	0.08644	0.09400	0.35140	0.22860	0.16502	0.05655	0.01214	0.00359	0.00136	0.00049	0.00027	0.00014
2017	0.00007	0.10561	0.17242	0.15945	0.29978	0.15092	0.08353	0.02037	0.00305	0.00299	0.00061	0.00053	0.00067
2018	0.00003	0.07259	0.09656	0.25352	0.16826	0.28695	0.08715	0.02951	0.00258	0.00174	0.00051	0.00022	0.00038
2019	0.00001	0.58946	0.07873	0.08517	0.07615	0.05909	0.07176	0.03172	0.00630	0.00082	0.00032	0.00023	0.00025

Table 2.1.6b. Differences between updated VAST estimates of survey age composition and last year's estimates.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1994	0.00002	0.00273	-0.02990	0.00037	0.00364	0.00825	0.01082	0.00278	0.00098	0.00008	0.00009	0.00003	0.00009
1995	0.00000	-0.00205	-0.00946	0.00579	0.00184	0.00087	0.00267	0.00057	0.00005	0.00012	-0.00007	-0.00019	-0.00015
1996	-0.00001	-0.00701	-0.01105	-0.00435	0.00436	0.00862	0.00676	0.00228	0.00031	0.00006	0.00002	0.00003	-0.00004
1997	-0.00002	-0.01809	0.00829	0.00150	0.00055	0.00246	0.00520	0.00094	-0.00019	-0.00021	-0.00016	-0.00019	-0.00009
1998	0.00000	-0.01096	0.00026	0.00054	0.00125	0.00103	0.00411	0.00230	0.00118	0.00019	0.00006	0.00002	0.00002
1999	0.00002	0.01209	-0.02326	-0.01498	0.00325	0.00463	0.01029	0.00517	0.00162	0.00088	0.00014	0.00009	0.00006
2000	0.00000	-0.02159	-0.00443	-0.00323	0.00433	0.01389	0.00811	0.00145	0.00112	0.00001	0.00019	0.00016	-0.00001
2001	0.00000	-0.01097	-0.00518	-0.00096	0.00344	0.00503	0.00599	0.00206	0.00031	0.00008	0.00013	0.00005	0.00003
2002	-0.00027	-0.00961	-0.01234	0.00306	0.00818	0.00405	0.00347	0.00299	0.00028	0.00017	0.00005	0.00000	-0.00003
2003	0.00000	-0.00797	-0.01017	0.00171	0.00372	0.00695	0.00329	0.00155	0.00069	0.00010	0.00002	0.00006	0.00005
2004	0.00001	-0.01518	0.00266	0.00311	-0.00254	0.00305	0.00631	0.00159	0.00051	0.00035	0.00008	0.00003	0.00003
2005	0.00000	-0.01026	-0.00128	0.00026	-0.00211	0.00160	0.00548	0.00444	0.00128	0.00020	0.00017	0.00021	0.00003
2006	0.00000	-0.00863	-0.00421	-0.00636	-0.00049	0.00530	0.00579	0.00509	0.00202	0.00092	0.00030	0.00012	0.00015
2007	0.00000	-0.00765	-0.00482	-0.00134	0.00190	0.00389	0.00329	0.00270	0.00104	0.00046	0.00026	0.00017	0.00011
2008	0.00000	0.01516	-0.01594	-0.00353	-0.00204	0.00051	0.00222	0.00128	0.00141	0.00050	0.00023	0.00013	0.00009
2009	0.00000	-0.00320	0.00315	-0.00030	-0.00174	-0.00003	0.00034	0.00069	0.00051	0.00021	0.00019	0.00009	0.00008
2010	0.00000	0.00162	0.02010	-0.01069	-0.01115	-0.00225	0.00086	0.00090	0.00042	0.00012	0.00006	0.00002	-0.00002
2011	-0.00001	-0.04395	-0.00093	0.02246	0.00859	0.00822	0.00358	0.00099	0.00052	0.00021	0.00013	0.00008	0.00009
2012	0.00000	0.02335	-0.01121	-0.00197	-0.01191	-0.00093	0.00166	0.00035	0.00026	0.00021	0.00010	0.00002	0.00005
2013	0.00000	-0.00027	-0.02689	-0.00066	0.00488	0.01274	0.00743	0.00182	0.00056	0.00020	0.00006	0.00005	0.00008
2014	0.00001	0.01249	0.00945	-0.01408	-0.01014	-0.00042	0.00211	0.00030	0.00014	0.00004	0.00004	0.00001	0.00005
2015	0.00000	-0.00162	-0.01068	0.00643	0.00374	0.00113	0.00061	0.00019	0.00015	0.00001	0.00002	0.00001	0.00001
2016	0.00000	0.00363	0.00589	0.00292	-0.00852	-0.00351	-0.00036	-0.00012	0.00003	0.00003	0.00000	0.00001	0.00001
2017	0.00000	-0.00154	0.00684	0.00507	-0.00604	-0.00227	-0.00104	-0.00092	-0.00012	0.00004	0.00001	-0.00002	-0.00001
2018	-0.00001	-0.00305	0.00346	0.01128	0.00171	-0.01095	-0.00242	-0.00003	0.00002	-0.00003	0.00000	0.00001	0.00001
2019	0.00000	0.00141	-0.00067	-0.00041	-0.00087	-0.00019	0.00107	-0.00006	-0.00025	-0.00001	-0.00001	0.00001	0.00001

Table 2.1.7. VAST fishery CPUE index (units are proportional to kg/hook).

Year	Estimate	SD	Sigma
1996	367	25.1	0.071
1997	434	32.9	0.079
1998	341	24.3	0.074
1999	315	21.2	0.070
2000	278	19.9	0.074
2001	235	15.7	0.070
2002	304	22.6	0.077
2003	213	11.8	0.057
2004	234	13.4	0.059
2005	259	15.3	0.061
2006	313	21.0	0.070
2007	329	20.8	0.065
2008	325	20.4	0.065
2009	356	23.9	0.070
2010	340	22.4	0.068
2011	315	23.0	0.076
2012	279	19.3	0.072
2013	304	20.7	0.071
2014	241	15.6	0.067
2015	226	14.9	0.069
2016	321	21.0	0.068
2017	264	14.7	0.058
2018	362	22.3	0.064
2019	356	24.9	0.073
2020	334	25.0	0.078

Table 2.1.8. Potential parameter counts in the models ("potential" because any parameters that ended up bounded in the estimation will be turned off for the final run).

Model	19.12a	19.12	"20.8a"	"20.9a"	"21.cie"
Feature 1: Allow catchability to vary?	no	yes	no	no	no
Feature 2: Allow domed survey selectivty?	no	no	yes	no	no
Feature 3: Use fishery CPUE?	no	no	no	yes	no
Feature 4: Estimate survey CV internally?	no	no	no	no	yes
"Early" recruitment deviations	20	20	20	20	20
"Main" recruitment deviations	43	43	43	43	43
Length at age 1.5 deviations	43	43	43	43	43
Selectivity (fishery) deviations	88	88	88	88	88
Selectivity (survey) deviations	76	76	76	76	76
Log catchability (survey) deviations		38			
Annual deviations	270	308	270	270	270
Natural mortality	1	1	1	1	1
Growth	6	6	6	6	6
Ageing error	4	4	4	4	4
Stock-recruitment	2	2	2	2	2
Initial fishing mortality	1	1	1	1	1
Dirichlet-multinomial coefficients	3	3	3	3	3
Log catchability (survey)	1	1	1	1	1
Selectivity (fishery)	5	5	5	5	5
Selectivity (survey, ascending)	2	2	2	2	2
Selectivity (survey, top and descending)			3		
Log catchability (fishery)				1	
"Extra" survey standard deviation					1
True parameters	25	25	28	26	26
Total parameters	295	333	298	296	296

Table 2.1.9. Objective function values and final parameter counts.

Model:	M19.12a	M19.12	M21.1	M21.2	M21.3
Allow catchability to vary?	no	yes	no	no	no
Allow domed survey selectivty?	no	no	yes	no	no
Use fishery CPUE?	no	no	no	yes	no
Estimate survey CV internally?	no	no	no	no	yes
Objective function components					
Equilibrium catch:	0.00	0.00	0.00	0.00	0.00
Indices:	-3.87	-85.40	-4.15	21.64	-38.90
Sizecomps:	9335.21	9305.66	9321.96	9397.42	9291.17
Agecomps:	781.34	775.10	781.33	779.74	770.37
Recruitment:	-1.37	-1.75	-1.52	-1.83	-0.07
Initial recruitment:	5.08	6.38	3.25	5.05	6.35
Softbounds:	0.01	0.00	0.01	0.00	0.00
Parameter devs:	66.98	96.85	70.77	71.28	63.39
Total:	10183.38	10096.84	10171.64	10273.31	10092.32
Subcomponents					
Index(fishery)	n/a	n/a	n/a	14.42	n/a
Index(survey)	-3.87	-85.40	-4.15	7.22	-38.90
Sizecomp(fishery)	4209.07	4205.60	4200.23	4251.67	4203.97
Sizecomp(survey)	5126.13	5100.05	5121.73	5145.75	5087.20
Parameter counts					
True parameters	22	23	26	23	24
Parameter devs	269	307	269	269	269
Total	291	330	295	292	293

Table 2.1.10. Fits to compositional data. Note that Nave for the size composition data does not equal Nave for the age composition data because the time series are of different lengths.

Size composition data

	Fleet:	Fishery				
	Model:	M19.12a	M19.12	M21.1	M21.2	M21.3
	Nave:	356	356	356	356	356
McAllister-Ianelli	Neff:	815	813	809	809	820
	Ratio:	2.292	2.286	2.275	2.275	2.305
Thorson et al.	ln(θ):	10.000	10.000	10.000	9.989	10.000
	Neff:	356	356	356	356	356
	Ratio:	1.000	1.000	1.000	1.000	1.000

	Fleet:	EBS+NBS survey				
	Model:	M19.12a	M19.12	M21.1	M21.2	M21.3
	Nave:	356	356	356	356	356
McAllister-Ianelli	Neff:	596	621	603	570	636
	Ratio:	1.676	1.744	1.695	1.603	1.787
Thorson et al.	ln(θ):	10.000	10.000	10.000	9.982	10.000
	Neff:	356	356	356	356	356
	Ratio:	1.000	1.000	1.000	1.000	1.000

Age composition data

	Fleet:	EBS+NBS survey				
	Model:	M19.12a	M19.12	M21.1	M21.2	M21.3
	Nave:	373	373	373	373	373
McAllister-Ianelli	Neff:	101	111	100	93	118
	Ratio:	0.272	0.299	0.268	0.250	0.316
Thorson et al.	ln(θ):	-0.133	0.091	-0.291	-0.331	0.191
	Neff:	174	195	160	156	204
	Ratio:	0.468	0.524	0.429	0.419	0.549

Table 2.1.11a. Time-invariant parameters.

Feature	Model 19.12a		Model 19.12		Model 21.1		Model 21.2		Model 21.3	
Allow catchability to vary?	no		yes		no		no		no	
Allow domed survey selectivty?	no		no		yes		no		no	
Use fishery CPUE?	no		no		no		yes		no	
Estimate survey CV internally?	no		no		no		no		yes	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Natural mortality	0.348	0.011	0.331	0.012	0.309	0.015	0.343	0.011	0.328	0.013
Mean length at age 1.5	14.777	0.387	14.877	0.392	14.819	0.374	14.645	0.391	15.004	0.399
Asymptotic length	112.948	3.052	120.718	5.047	103.223	2.670	116.248	3.482	122.377	5.471
Brody growth coefficient	0.118	0.009	0.099	0.011	0.158	0.013	0.104	0.009	0.097	0.011
Richards growth coefficient	1.439	0.042	1.498	0.047	1.287	0.052	1.517	0.042	1.491	0.048
SD(length at age 1)	3.485	0.067	3.501	0.066	3.507	0.069	3.506	0.069	3.476	0.065
SD(length at age 20)	9.905	0.380	10.071	0.463	9.062	0.365	10.167	0.432	10.182	0.485
Mean ageing bias at age 1	0.343	0.017	0.338	0.016	0.338	0.018	0.344	0.018	0.338	0.016
Mean ageing bias at age 20	1.116	0.226	1.195	0.221	1.214	0.241	1.100	0.236	1.205	0.218
Mean bias at age 1 (2008+)	0.002	0.025	0.007	0.024	0.004	0.026	0.005	0.026	0.005	0.025
Mean bias at age 20 (2008+)	-1.708	0.317	-1.924	0.317	-1.820	0.339	-1.882	0.343	-2.066	0.329
ln(mean post-1976 recruits)	13.129	0.096	12.979	0.099	12.940	0.117	13.130	0.098	12.921	0.106
ln(pre-1977 recruits offset)	-0.908	0.192	-0.945	0.182	-0.627	0.189	-0.880	0.188	-0.957	0.185
Pre-1977 fishing mortality	0.122	0.037	0.127	0.037	0.074	0.020	0.117	0.035	0.137	0.042
ln(Dirichlet-multinomial coef. for agecomps)	-0.133	0.192	0.091	0.221	-0.291	0.186	-0.331	0.176	0.191	0.240
ln(survey catchability)	0.003	0.062	0.099	0.064	0.094	0.078	-0.030	0.064	0.146	0.075
Fishery selectivity: begin flattop	74.984	0.039	74.867	0.515	72.179	0.718	75.949	0.061	74.990	0.519
Fishery selectivity: logit(flatop width)	-9.739	7.362	0.280	0.516	-9.669	9.085	-9.833	_	0.249	0.499
Fishery selectivity: ln(ascending SD)	5.914	0.028	5.909	0.038	5.853	0.042	5.968	0.031	5.911	0.037
Fishery selectivity: ln(descending SD)	-10.000	_	4.575	1.418	3.988	0.511	-8.275	14.966	4.595	1.341
Fishery selectivity: logit(ending value)	2.101	0.301	-2.828	3.088	0.765	0.333	1.856	0.271	-2.940	3.042
Survey selectivity: begin flattop	20.875	0.780	20.672	0.820	20.800	0.770	20.291	0.733	20.602	0.871
Survey selectivity: ln(ascending SD)	3.522	0.153	3.475	0.161	3.536	0.150	3.412	0.149	3.451	0.174
Survey selectivity: logit(flattop width)					-1.239	0.217				
Survey selectivity: ln(descending SD)					7.421	0.551				
Survey selectivity: logit(ending value)					-0.802	0.668				
ln(fishery catchability)							-5.952	0.064		
"Extra" survey standard deviation									0.152	0.030

Table 2.1.11b. Initial numbers-at-age deviations (“early” recruitment deviations).

	Model 19.12a		Model 19.12		Model 21.1		Model 21.2		Model 21.3	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
ln(InitN)_offset_at_20	-0.016	0.671	-0.018	0.661	-0.050	0.658	-0.020	0.662	-0.018	0.679
ln(InitN)_offset_at_19	-0.009	0.674	-0.009	0.663	-0.022	0.666	-0.011	0.665	-0.009	0.682
ln(InitN)_offset_at_18	-0.014	0.672	-0.014	0.662	-0.031	0.663	-0.017	0.663	-0.014	0.681
ln(InitN)_offset_at_17	-0.021	0.670	-0.022	0.659	-0.043	0.659	-0.025	0.660	-0.021	0.678
ln(InitN)_offset_at_16	-0.032	0.666	-0.033	0.656	-0.060	0.654	-0.038	0.656	-0.033	0.674
ln(InitN)_offset_at_15	-0.049	0.661	-0.051	0.651	-0.082	0.648	-0.057	0.651	-0.051	0.669
ln(InitN)_offset_at_14	-0.073	0.654	-0.078	0.643	-0.112	0.640	-0.083	0.643	-0.077	0.661
ln(InitN)_offset_at_13	-0.107	0.644	-0.116	0.633	-0.150	0.629	-0.121	0.633	-0.117	0.651
ln(InitN)_offset_at_12	-0.155	0.632	-0.170	0.620	-0.199	0.617	-0.171	0.620	-0.172	0.637
ln(InitN)_offset_at_11	-0.217	0.617	-0.242	0.603	-0.258	0.603	-0.235	0.605	-0.245	0.620
ln(InitN)_offset_at_10	-0.295	0.600	-0.330	0.585	-0.328	0.588	-0.314	0.588	-0.335	0.602
ln(InitN)_offset_at_09	-0.387	0.582	-0.432	0.566	-0.406	0.573	-0.405	0.571	-0.440	0.581
ln(InitN)_offset_at_08	-0.485	0.563	-0.539	0.547	-0.489	0.557	-0.501	0.553	-0.548	0.562
ln(InitN)_offset_at_07	-0.575	0.546	-0.632	0.530	-0.564	0.542	-0.587	0.537	-0.642	0.544
ln(InitN)_offset_at_06	-0.626	0.533	-0.679	0.517	-0.603	0.532	-0.632	0.525	-0.689	0.531
ln(InitN)_offset_at_05	-0.575	0.531	-0.615	0.516	-0.543	0.532	-0.572	0.525	-0.620	0.529
ln(InitN)_offset_at_04	-0.280	0.546	-0.299	0.529	-0.243	0.547	-0.269	0.542	-0.289	0.543
ln(InitN)_offset_at_03	0.179	0.489	0.139	0.477	0.190	0.487	0.173	0.493	0.168	0.484
ln(InitN)_offset_at_02	-0.095	0.564	-0.110	0.551	-0.123	0.560	-0.066	0.564	-0.108	0.567
ln(InitN)_offset_at_01	0.752	0.551	0.793	0.527	0.767	0.522	0.825	0.546	0.857	0.531

Table 2.1.11c. Log recruitment deviations.

	Model 19.12a		Model 19.12		Model 21.1		Model 21.2		Model 21.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	0.970	0.223	0.864	0.227	1.032	0.242	0.987	0.230	0.872	0.233
1978	0.557	0.243	0.522	0.229	0.579	0.249	0.513	0.260	0.553	0.226
1979	0.591	0.130	0.549	0.129	0.566	0.132	0.571	0.134	0.571	0.131
1980	-0.796	0.224	-0.858	0.239	-0.784	0.222	-0.785	0.222	-0.927	0.259
1981	-0.682	0.167	-0.668	0.169	-0.694	0.166	-0.695	0.171	-0.633	0.172
1982	0.855	0.055	0.869	0.058	0.841	0.056	0.859	0.056	0.922	0.063
1983	-0.423	0.151	-0.531	0.161	-0.418	0.148	-0.453	0.156	-0.531	0.165
1984	0.788	0.057	0.775	0.061	0.765	0.058	0.788	0.057	0.815	0.065
1985	0.003	0.089	0.008	0.092	-0.011	0.088	-0.026	0.091	0.055	0.096
1986	-0.604	0.109	-0.550	0.111	-0.627	0.109	-0.617	0.110	-0.491	0.114
1987	-1.696	0.221	-1.583	0.222	-1.719	0.216	-1.700	0.222	-1.511	0.229
1988	-0.272	0.088	-0.217	0.093	-0.317	0.089	-0.253	0.089	-0.161	0.098
1989	0.405	0.060	0.446	0.063	0.373	0.061	0.415	0.061	0.504	0.066
1990	0.390	0.068	0.405	0.070	0.357	0.070	0.392	0.069	0.470	0.068
1991	-0.100	0.091	-0.186	0.099	-0.087	0.089	-0.087	0.092	-0.230	0.089
1992	0.866	0.043	0.789	0.045	0.860	0.043	0.899	0.042	0.808	0.047
1993	-0.126	0.078	-0.100	0.077	-0.093	0.077	-0.138	0.082	-0.050	0.079
1994	-0.296	0.075	-0.310	0.075	-0.295	0.076	-0.255	0.075	-0.278	0.077
1995	-0.404	0.081	-0.388	0.081	-0.391	0.082	-0.425	0.086	-0.342	0.083
1996	0.748	0.043	0.752	0.043	0.744	0.044	0.682	0.043	0.798	0.047
1997	-0.100	0.075	-0.064	0.075	-0.102	0.075	-0.205	0.083	-0.013	0.076
1998	-0.330	0.089	-0.297	0.090	-0.358	0.092	-0.390	0.091	-0.247	0.092
1999	0.548	0.048	0.532	0.049	0.524	0.049	0.539	0.048	0.565	0.052
2000	0.232	0.054	0.229	0.054	0.258	0.054	0.284	0.054	0.269	0.057
2001	-0.712	0.104	-0.681	0.106	-0.726	0.106	-0.601	0.106	-0.632	0.108
2002	-0.152	0.061	-0.134	0.061	-0.143	0.062	0.019	0.060	-0.088	0.063
2003	-0.255	0.068	-0.219	0.067	-0.256	0.066	-0.080	0.066	-0.166	0.069
2004	-0.580	0.084	-0.522	0.084	-0.581	0.079	-0.463	0.081	-0.467	0.087
2005	-0.399	0.074	-0.315	0.072	-0.406	0.073	-0.308	0.076	-0.250	0.074
2006	0.675	0.041	0.764	0.041	0.665	0.043	0.694	0.040	0.834	0.043
2007	-0.233	0.087	-0.170	0.086	-0.225	0.087	-0.321	0.091	-0.111	0.085
2008	1.075	0.039	1.067	0.039	1.067	0.040	0.993	0.039	1.082	0.039
2009	-0.884	0.164	-0.883	0.156	-0.850	0.161	-0.928	0.162	-0.882	0.155
2010	0.608	0.053	0.630	0.051	0.597	0.054	0.544	0.052	0.627	0.050
2011	0.845	0.049	0.845	0.047	0.857	0.049	0.793	0.047	0.812	0.048
2012	0.102	0.091	0.066	0.092	0.105	0.091	0.052	0.097	-0.013	0.096
2013	1.098	0.046	1.062	0.051	1.099	0.046	1.076	0.043	0.941	0.068
2014	-0.614	0.113	-0.618	0.112	-0.588	0.112	-0.655	0.118	-0.748	0.122
2015	-0.333	0.074	-0.326	0.080	-0.333	0.074	-0.331	0.075	-0.488	0.108
2016	-0.809	0.106	-0.914	0.115	-0.803	0.106	-0.807	0.108	-1.150	0.152
2017	-1.166	0.200	-1.226	0.202	-1.102	0.192	-1.197	0.204	-1.440	0.223
2018	0.608	0.069	0.581	0.089	0.622	0.071	0.623	0.070	0.350	0.145

Table 2.1.11d. Length at age 1.5 deviations.

	Model 19.12a		Model 19.12		Model 21.1		Model 21.2		Model 21.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	0.389	0.963	0.421	0.957	0.096	0.973	0.655	0.965	0.398	0.954
1978	-0.114	0.945	-0.118	0.942	-0.171	0.940	-0.097	0.950	-0.119	0.938
1979	0.453	1.008	0.465	1.014	0.377	0.998	0.460	1.027	0.477	1.016
1980	-0.050	0.937	-0.077	0.924	-0.085	0.933	-0.037	0.950	-0.089	0.911
1981	-1.042	0.470	-1.113	0.475	-1.105	0.485	-0.960	0.470	-1.202	0.473
1982	-0.837	0.300	-0.931	0.307	-0.774	0.307	-0.821	0.296	-1.018	0.320
1983	0.677	0.700	1.134	0.805	0.612	0.642	0.601	0.741	1.381	0.777
1984	0.431	0.230	0.419	0.234	0.375	0.235	0.531	0.230	0.399	0.235
1985	-1.491	0.429	-1.585	0.433	-1.500	0.438	-1.439	0.411	-1.627	0.435
1986	0.143	0.271	0.135	0.271	0.154	0.269	0.178	0.277	0.145	0.266
1987	-0.546	0.441	-0.536	0.444	-0.502	0.426	-0.608	0.459	-0.484	0.435
1988	-0.906	0.425	-0.892	0.429	-0.807	0.418	-0.992	0.423	-0.845	0.430
1989	-0.827	0.277	-0.794	0.279	-0.840	0.280	-0.796	0.276	-0.784	0.279
1990	-0.126	0.313	-0.068	0.307	-0.180	0.309	-0.176	0.314	-0.010	0.301
1991	0.429	0.248	0.549	0.259	0.412	0.250	0.480	0.253	0.694	0.259
1992	0.040	0.231	-0.002	0.233	0.049	0.231	0.060	0.232	-0.047	0.231
1993	0.563	0.350	0.320	0.371	0.783	0.343	0.546	0.352	0.230	0.394
1994	-0.233	0.281	-0.134	0.283	-0.188	0.275	-0.207	0.288	-0.039	0.276
1995	-0.307	0.355	-0.232	0.368	-0.249	0.354	-0.295	0.359	-0.182	0.374
1996	-0.055	0.257	-0.073	0.259	-0.071	0.258	-0.080	0.258	-0.081	0.258
1997	-0.202	0.321	-0.205	0.319	-0.184	0.327	-0.969	0.450	-0.192	0.313
1998	-0.757	0.307	-0.772	0.312	-0.685	0.294	-0.586	0.296	-0.737	0.305
1999	-1.325	0.262	-1.303	0.260	-1.334	0.265	-1.313	0.263	-1.292	0.258
2000	0.908	0.239	0.762	0.241	0.907	0.241	0.879	0.242	0.661	0.240
2001	0.364	0.269	0.347	0.271	0.411	0.268	0.200	0.279	0.332	0.267
2002	0.703	0.234	0.678	0.234	0.680	0.237	0.629	0.240	0.640	0.232
2003	0.209	0.294	0.145	0.294	0.198	0.300	0.161	0.296	0.095	0.293
2004	1.444	0.248	1.361	0.245	1.461	0.248	1.543	0.251	1.284	0.242
2005	-0.135	0.275	-0.166	0.277	-0.132	0.280	-0.098	0.281	-0.201	0.276
2006	-0.293	0.216	-0.286	0.215	-0.295	0.219	-0.190	0.217	-0.304	0.213
2007	-1.164	0.303	-0.995	0.306	-1.197	0.309	-0.899	0.310	-0.926	0.303
2008	-1.316	0.245	-1.249	0.235	-1.337	0.238	-1.202	0.239	-1.116	0.239
2009	-0.647	0.388	-0.794	0.381	-0.549	0.387	-0.725	0.394	-0.835	0.372
2010	0.359	0.209	0.285	0.209	0.343	0.210	0.442	0.211	0.259	0.207
2011	-1.132	0.272	-1.088	0.279	-1.160	0.276	-1.017	0.274	-1.030	0.277
2012	0.193	0.315	0.264	0.314	0.289	0.310	0.017	0.355	0.305	0.315
2013	-0.276	0.228	-0.294	0.228	-0.276	0.230	-0.287	0.230	-0.282	0.226
2014	0.265	0.404	0.169	0.405	0.342	0.401	0.070	0.420	0.123	0.402
2015	1.767	0.217	1.770	0.216	1.770	0.218	1.780	0.221	1.754	0.213
2016	1.801	0.333	1.905	0.323	1.799	0.350	1.779	0.338	1.936	0.319
2017	1.308	0.335	1.303	0.329	1.311	0.339	1.343	0.343	1.266	0.322
2018	2.527	0.190	2.459	0.190	2.574	0.193	2.584	0.193	2.371	0.189
2019	-1.016	0.942	-1.015	0.935	-1.123	0.942	-0.963	0.947	-1.121	0.908

Table 2.1.11e (page 1 of 4). Deviations for the log standard deviation of the first normal pdf in the double-normal fishery selectivity curve.

	Model 19.12a		Model 19.12		Model 21.1		Model 21.2		Model 21.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	0.137	0.976	0.162	0.977	0.122	0.976	0.152	0.970	0.157	0.979
1978	0.119	0.904	0.119	0.905	0.114	0.904	0.112	0.881	0.099	0.911
1979	0.408	0.805	0.424	0.810	0.496	0.803	0.394	0.777	0.394	0.821
1980	0.335	0.854	0.348	0.854	0.480	0.849	0.352	0.830	0.328	0.862
1981	1.050	0.869	1.037	0.870	1.136	0.860	1.087	0.850	1.016	0.877
1982	-0.083	0.934	-0.092	0.935	-0.001	0.933	-0.098	0.920	-0.092	0.939
1983	0.133	0.827	0.093	0.828	0.274	0.830	0.123	0.797	0.078	0.836
1984	0.901	0.603	0.866	0.607	1.028	0.598	0.806	0.565	0.854	0.619
1985	-0.187	0.538	-0.171	0.541	-0.177	0.544	-0.170	0.501	-0.200	0.553
1986	0.596	0.550	0.659	0.555	0.610	0.550	0.536	0.516	0.638	0.569
1987	-0.185	0.462	-0.094	0.466	-0.218	0.466	-0.191	0.431	-0.115	0.479
1988	2.319	0.685	2.315	0.684	2.320	0.685	2.269	0.658	2.281	0.692
1989	1.079	0.792	1.053	0.792	1.156	0.792	1.081	0.764	1.013	0.800
1990	0.192	0.604	0.109	0.605	0.384	0.605	0.119	0.561	0.074	0.618
1991	0.033	0.424	0.003	0.428	0.042	0.423	0.023	0.393	-0.026	0.439
1992	-0.283	0.389	-0.192	0.392	-0.259	0.389	-0.237	0.364	-0.193	0.406
1993	1.463	0.490	1.674	0.502	1.405	0.484	1.321	0.458	1.791	0.519
1994	0.460	0.419	0.669	0.428	0.369	0.412	0.314	0.388	0.781	0.442
1995	0.744	0.419	0.889	0.421	0.600	0.415	0.594	0.389	0.966	0.431
1996	-0.297	0.424	-0.298	0.424	-0.284	0.425	-0.330	0.390	-0.288	0.434
1997	0.944	0.418	0.808	0.418	0.943	0.415	1.184	0.362	0.792	0.428
1998	-0.101	0.377	-0.264	0.377	-0.122	0.374	0.275	0.329	-0.308	0.387
1999	0.073	0.333	-0.115	0.327	0.059	0.333	0.461	0.288	-0.168	0.335
2000	-0.199	0.362	-0.455	0.355	-0.110	0.364	-0.001	0.303	-0.532	0.364
2001	-0.291	0.345	-0.419	0.344	-0.299	0.341	-0.537	0.288	-0.461	0.354
2002	0.640	0.327	0.703	0.324	0.537	0.320	0.368	0.275	0.732	0.333
2003	0.471	0.337	0.480	0.334	0.357	0.335	-0.636	0.262	0.493	0.343
2004	0.634	0.359	0.610	0.359	0.515	0.357	-0.522	0.285	0.618	0.368
2005	0.605	0.357	0.553	0.356	0.492	0.356	-0.207	0.293	0.554	0.366
2006	0.068	0.389	-0.067	0.386	0.047	0.391	-0.046	0.327	-0.098	0.395
2007	-0.070	0.416	-0.265	0.411	-0.013	0.418	0.426	0.349	-0.313	0.421
2008	-0.111	0.341	-0.226	0.337	-0.073	0.335	0.613	0.295	-0.274	0.346
2009	-1.004	0.342	-1.017	0.337	-1.025	0.335	0.449	0.298	-1.064	0.347
2010	-1.535	0.356	-1.461	0.359	-1.527	0.349	-0.126	0.293	-1.456	0.372
2011	-1.450	0.333	-1.284	0.340	-1.468	0.331	-0.684	0.287	-1.192	0.353
2012	-0.560	0.367	-0.502	0.368	-0.525	0.364	-0.545	0.301	-0.406	0.380
2013	-0.253	0.315	-0.191	0.318	-0.336	0.311	-0.269	0.271	-0.072	0.330
2014	-1.255	0.312	-1.151	0.313	-1.297	0.309	-1.344	0.259	-1.051	0.325
2015	-1.658	0.313	-1.594	0.316	-1.648	0.310	-1.927	0.259	-1.520	0.329
2016	-1.730	0.340	-1.681	0.344	-1.743	0.341	-1.753	0.275	-1.601	0.360
2017	-1.706	0.424	-1.765	0.425	-1.645	0.432	-2.671	0.304	-1.761	0.440
2018	-0.476	0.497	-0.494	0.503	-0.526	0.500	-1.018	0.394	-0.496	0.518
2019	-0.222	0.559	-0.108	0.563	-0.347	0.564	-0.314	0.469	-0.162	0.580
2020	0.248	0.566	0.329	0.573	0.157	0.557	0.569	0.488	0.193	0.591

Table 2.1.11e (page 2 of 4). Deviations for the logit of fishery selectivity at maximum length.

	Model 19.12a		Model 19.12		Model 21.1		Model 21.2		Model 21.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	-0.068	1.022	-0.005	0.998	-0.128	1.020	-0.132	1.063	-0.005	0.998
1978	-0.108	1.034	-0.004	0.999	-0.223	1.026	-0.216	1.096	-0.003	0.999
1979	-0.115	1.035	-0.003	0.999	-0.246	1.027	-0.224	1.098	-0.002	0.999
1980	0.004	0.996	-0.001	1.000	-0.046	0.999	0.004	0.990	0.000	1.000
1981	-0.013	1.003	0.001	1.000	-0.044	1.003	-0.018	1.005	0.001	1.000
1982	0.060	0.979	0.000	1.000	0.057	0.984	0.092	0.953	0.000	1.000
1983	0.243	0.920	-0.001	1.000	0.312	0.919	0.349	0.848	0.000	1.000
1984	0.408	0.870	-0.003	0.999	0.550	0.846	0.541	0.781	-0.003	0.999
1985	0.130	0.904	-0.006	0.998	0.131	0.818	0.201	0.803	-0.005	0.998
1986	-0.058	0.946	-0.003	0.999	-0.134	0.827	-0.042	0.827	-0.003	0.999
1987	0.150	0.882	-0.009	0.997	-0.092	0.739	0.067	0.758	-0.008	0.997
1988	0.054	0.952	-0.002	0.999	-0.225	0.912	0.075	0.886	-0.001	1.000
1989	0.286	0.902	0.011	1.000	0.380	0.875	0.395	0.822	0.011	1.000
1990	0.836	0.791	-0.002	0.998	1.214	0.745	0.940	0.699	-0.001	0.999
1991	0.448	0.828	-0.024	0.993	0.630	0.721	0.598	0.724	-0.023	0.994
1992	-0.133	0.893	-0.018	0.994	-0.030	0.698	-0.057	0.710	-0.018	0.995
1993	0.016	0.945	-0.006	0.998	-0.228	0.839	-0.039	0.857	-0.007	0.998
1994	0.022	0.929	-0.010	0.997	-0.339	0.798	-0.090	0.819	-0.011	0.997
1995	-0.015	0.930	-0.020	0.995	-0.242	0.808	0.018	0.813	-0.018	0.995
1996	0.779	0.798	-0.012	0.996	1.179	0.751	0.908	0.704	-0.011	0.996
1997	0.494	0.835	-0.008	0.997	0.728	0.767	0.762	0.721	-0.007	0.997
1998	0.289	0.855	-0.001	0.999	0.414	0.763	0.598	0.733	-0.001	0.999
1999	0.098	0.853	0.044	1.004	0.281	0.718	0.269	0.705	0.042	1.003
2000	0.075	0.864	0.075	1.021	0.205	0.716	-0.392	0.569	0.071	1.019
2001	-0.671	0.881	0.001	1.000	-0.819	0.654	-1.327	0.377	0.001	1.000
2002	-1.206	0.758	0.000	1.000	-1.347	0.612	-1.305	0.382	0.000	1.000
2003	-0.252	0.822	-0.012	0.996	-0.449	0.626	-1.158	0.347	-0.010	0.997
2004	-0.093	0.841	-0.002	0.999	0.072	0.669	-0.647	0.456	-0.002	0.999
2005	0.192	0.826	-0.008	0.997	0.298	0.678	0.363	0.685	-0.007	0.998
2006	0.693	0.792	0.013	1.004	1.227	0.710	1.232	0.654	0.013	1.004
2007	0.509	0.820	0.009	1.003	1.054	0.728	1.219	0.659	0.008	1.002
2008	-0.561	0.864	0.003	1.001	-0.233	0.683	0.721	0.710	0.003	1.001
2009	-1.052	0.872	0.012	1.003	-1.241	0.650	0.335	0.751	0.010	1.003
2010	-0.925	1.009	-0.003	0.999	-1.365	0.744	-0.525	0.695	-0.004	0.999
2011	-0.103	0.943	-0.002	0.999	-0.566	0.821	-0.853	0.578	-0.002	0.999
2012	0.028	0.921	-0.006	0.998	-0.249	0.861	-1.060	0.527	-0.006	0.998
2013	-0.402	0.942	-0.005	0.998	-0.721	0.797	-1.156	0.465	-0.005	0.998
2014	-0.602	0.865	-0.004	0.999	-0.570	0.734	-1.075	0.418	-0.005	0.999
2015	-0.257	0.892	-0.004	0.999	-0.209	0.746	-0.852	0.475	-0.004	0.999
2016	0.102	0.885	-0.003	0.999	-0.063	0.790	0.068	0.752	-0.003	0.999
2017	0.509	0.832	-0.001	1.000	0.495	0.802	-0.002	0.721	-0.001	1.000
2018	0.382	0.851	-0.002	0.999	0.473	0.798	0.508	0.748	-0.002	0.999
2019	-0.313	0.929	-0.002	0.999	-0.270	0.786	0.178	0.754	-0.002	0.999
2020	0.136	0.907	0.021	1.004	0.378	0.820	0.728	0.731	0.020	1.004

Table 2.1.11e (page 3 of 4). Deviations for the first size at which survey selectivity reaches 1.0.

	Model 19.12a		Model 19.12		Model 21.1		Model 21.2		Model 21.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1982	-0.173	0.432	-0.158	0.427	-0.176	0.427	-0.078	0.451	-0.163	0.412
1983	-0.335	0.483	-0.180	0.467	-0.234	0.501	-0.352	0.486	-0.012	0.481
1984	1.185	0.392	1.157	0.385	1.129	0.367	1.289	0.449	1.145	0.331
1985	0.504	0.275	0.568	0.274	0.428	0.295	0.668	0.302	0.595	0.272
1986	-0.404	0.534	-0.373	0.507	-0.374	0.534	-0.409	0.488	-0.330	0.495
1987	-0.001	0.383	0.091	0.339	0.026	0.387	0.076	0.384	0.141	0.338
1988	0.101	0.537	0.180	0.525	0.024	0.504	0.117	0.538	0.232	0.518
1989	0.546	0.515	0.539	0.504	0.683	0.512	0.557	0.514	0.559	0.499
1990	-0.286	0.361	-0.289	0.351	-0.366	0.356	-0.230	0.371	-0.274	0.342
1991	0.994	0.473	0.899	0.444	0.762	0.437	0.988	0.472	0.919	0.430
1992	-0.094	0.359	-0.453	0.473	-0.179	0.353	0.000	0.375	-1.108	0.384
1993	0.208	0.347	0.124	0.327	0.132	0.338	0.317	0.354	0.145	0.317
1994	0.382	0.457	0.618	0.443	0.907	0.504	0.389	0.453	0.677	0.484
1995	0.584	0.436	0.751	0.440	0.608	0.434	0.714	0.451	0.879	0.448
1996	0.352	0.392	0.486	0.409	0.424	0.390	0.430	0.402	0.576	0.417
1997	0.777	0.351	0.782	0.340	0.714	0.334	0.784	0.349	0.800	0.332
1998	2.009	0.359	1.984	0.327	1.905	0.396	0.041	0.736	1.945	0.314
1999	0.344	0.523	0.303	0.528	0.289	0.520	0.465	0.529	0.353	0.497
2000	-0.606	0.304	-0.619	0.285	-0.659	0.299	-0.558	0.313	-0.593	0.277
2001	-0.839	0.369	-0.611	0.330	-0.771	0.371	-0.680	0.378	-0.501	0.321
2002	0.017	0.422	0.094	0.467	-0.126	0.429	0.130	0.424	0.155	0.441
2003	0.269	0.319	0.305	0.306	0.120	0.325	0.521	0.334	0.339	0.300
2004	0.231	0.369	0.248	0.350	0.143	0.352	0.425	0.380	0.261	0.338
2005	-0.194	0.494	-0.060	0.426	-0.248	0.405	-0.100	0.439	-0.006	0.404
2006	-1.652	0.298	-1.507	0.287	-1.693	0.303	-1.541	0.355	-1.425	0.279
2007	-2.414	0.255	-2.262	0.235	-2.463	0.250	-2.452	0.275	-2.135	0.221
2008	-1.459	0.302	-1.472	0.288	-1.454	0.306	-1.496	0.323	-1.442	0.279
2009	-0.809	0.531	-1.616	0.451	-1.009	0.494	-1.193	0.628	-1.844	0.353
2010	-0.377	0.450	-0.499	0.379	-0.140	0.516	-0.392	0.418	-0.534	0.358
2011	-0.085	0.262	-0.038	0.251	-0.096	0.263	-0.026	0.272	-0.037	0.242
2012	-2.124	0.388	-2.145	0.289	-2.012	0.363	-2.260	0.425	-2.099	0.289
2013	0.962	0.358	0.863	0.364	1.071	0.367	0.883	0.535	0.768	0.399
2014	-0.031	0.298	-0.008	0.285	-0.009	0.301	0.049	0.305	-0.013	0.275
2015	0.510	0.461	0.484	0.441	0.649	0.463	0.464	0.471	0.440	0.434
2016	1.185	0.335	1.198	0.326	1.156	0.331	1.368	0.345	1.134	0.323
2017	1.183	0.365	0.976	0.368	1.078	0.370	1.336	0.367	0.796	0.406
2018	0.826	0.354	0.820	0.339	0.948	0.335	0.973	0.367	0.781	0.328
2019	-1.286	0.291	-1.178	0.320	-1.188	0.322	-1.219	0.313	-1.125	0.290

Table 2.1.11e (page 4 of 4). Deviations for the log standard deviation of the first normal pdf in the double-normal survey selectivity curve.

	Model 19.12a		Model 19.12		Model 21.1		Model 21.2		Model 21.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1982	-0.503	0.586	-0.464	0.581	-0.529	0.588	-0.444	0.632	-0.442	0.549
1983	0.358	0.633	0.428	0.595	0.537	0.667	0.388	0.664	0.502	0.575
1984	0.787	0.435	0.905	0.433	0.722	0.420	0.899	0.500	0.941	0.376
1985	0.678	0.367	0.716	0.357	0.604	0.399	0.898	0.416	0.716	0.340
1986	-0.033	0.682	-0.049	0.647	0.017	0.689	0.000	0.657	-0.034	0.613
1987	-0.113	0.600	-0.043	0.527	-0.062	0.615	-0.059	0.625	0.019	0.503
1988	-0.110	0.672	-0.029	0.650	-0.208	0.651	-0.122	0.705	0.043	0.617
1989	0.166	0.598	0.222	0.583	0.314	0.593	0.128	0.633	0.284	0.555
1990	0.139	0.450	0.155	0.434	0.069	0.455	0.238	0.480	0.161	0.407
1991	1.259	0.518	1.261	0.492	1.038	0.496	1.305	0.541	1.281	0.465
1992	-0.041	0.451	-0.344	0.608	-0.170	0.455	0.048	0.488	-1.204	0.631
1993	0.739	0.446	0.660	0.418	0.660	0.443	0.892	0.471	0.640	0.391
1994	0.374	0.598	0.489	0.551	1.006	0.630	0.367	0.623	0.523	0.570
1995	0.328	0.553	0.509	0.537	0.331	0.557	0.424	0.593	0.649	0.514
1996	-0.215	0.515	-0.036	0.519	-0.156	0.515	-0.171	0.552	0.104	0.498
1997	0.778	0.415	0.797	0.397	0.712	0.407	0.878	0.437	0.803	0.374
1998	2.001	0.371	1.957	0.340	1.933	0.408	0.066	0.947	1.849	0.316
1999	0.350	0.585	0.338	0.592	0.279	0.595	0.490	0.612	0.396	0.537
2000	-0.654	0.420	-0.637	0.398	-0.743	0.424	-0.638	0.450	-0.576	0.376
2001	-0.453	0.558	-0.315	0.488	-0.368	0.571	-0.306	0.585	-0.235	0.455
2002	-0.028	0.545	0.059	0.592	-0.205	0.572	0.003	0.571	0.138	0.536
2003	0.273	0.424	0.319	0.402	0.071	0.448	0.439	0.455	0.354	0.378
2004	0.120	0.493	0.146	0.464	-0.003	0.489	0.251	0.519	0.173	0.434
2005	-0.284	0.676	-0.151	0.579	-0.369	0.586	-0.199	0.622	-0.076	0.528
2006	-1.504	0.441	-1.389	0.422	-1.572	0.458	-1.344	0.533	-1.294	0.401
2007	-2.433	0.529	-2.352	0.487	-2.553	0.528	-2.408	0.587	-2.211	0.442
2008	-1.542	0.475	-1.565	0.469	-1.558	0.485	-1.575	0.528	-1.512	0.456
2009	0.255	0.729	-0.815	0.707	0.005	0.702	-0.083	0.946	-1.166	0.580
2010	-0.585	0.596	-0.700	0.528	-0.301	0.651	-0.633	0.588	-0.699	0.498
2011	-0.130	0.358	-0.084	0.337	-0.140	0.365	-0.042	0.387	-0.049	0.314
2012	-1.532	0.644	-1.727	0.503	-1.340	0.592	-1.644	0.752	-1.718	0.512
2013	0.970	0.381	0.947	0.385	1.088	0.394	0.953	0.572	0.891	0.407
2014	-0.076	0.420	-0.025	0.397	-0.043	0.432	-0.019	0.447	0.015	0.373
2015	0.420	0.546	0.407	0.523	0.571	0.553	0.372	0.586	0.393	0.502
2016	0.768	0.457	0.843	0.438	0.768	0.464	0.897	0.487	0.843	0.419
2017	0.920	0.468	0.885	0.462	0.784	0.484	1.052	0.491	0.798	0.472
2018	0.123	0.421	0.177	0.399	0.241	0.403	0.211	0.453	0.204	0.374
2019	-1.569	0.531	-1.499	0.582	-1.427	0.575	-1.512	0.578	-1.502	0.529

Table 2.1.11f. Deviations for log survey catchability (Model 19.12 only).

	Model 19.12	
Year	Est.	SD
1982	0.159	0.682
1983	1.241	0.781
1984	-1.094	0.647
1985	0.832	0.631
1986	0.435	0.600
1987	0.779	0.665
1988	-0.283	0.552
1989	-1.221	0.643
1990	-1.110	0.675
1991	-1.474	0.646
1992	-1.953	0.671
1993	0.459	0.688
1994	3.558	0.585
1995	1.043	0.573
1996	1.495	0.695
1997	0.109	0.686
1998	0.500	0.778
1999	-0.759	0.624
2000	-1.223	0.645
2001	1.961	0.634
2002	0.217	0.729
2003	0.786	0.792
2004	0.028	0.741
2005	0.356	0.731
2006	-0.739	0.604
2007	-1.649	0.640
2008	-2.798	0.617
2009	-2.441	0.665
2010	-1.202	0.570
2011	0.539	0.614
2012	-0.264	0.664
2013	-1.408	0.637
2014	1.789	0.780
2015	0.976	0.767
2016	0.894	0.887
2017	-1.103	0.638
2018	1.793	0.740
2019	0.773	0.787

Table 2.1.12. Sigmas for time-varying parameters.

	Model 19.12a			Model 19.12			Model 21.1			Model 21.2			Model 21.3		
Parameter	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma
ln(Recruits)	0.4434	0.0125	0.6765	0.4312	0.0129	0.6664	0.4407	0.0126	0.6733	0.4334	0.0131	0.6682	0.4547	0.0144	0.6852
Length_at_1.5	0.7944	0.1985	0.1474	0.7991	0.2019	0.1486	0.8040	0.1967	0.1422	0.7951	0.2060	0.1480	0.7950	0.1985	0.1504
Sel_fsh_lnSD1	0.7089	0.2897	0.1559	0.7097	0.2913	0.1542	0.7112	0.2883	0.1734	0.7466	0.2496	0.1721	0.6994	0.3017	0.1482
Sel_fsh_logitEnd	0.1913	0.8072	0.7525	0.0002	0.9989	0.7640	0.3612	0.6457	0.6288	0.4351	0.5581	1.1255	0.0002	0.9989	0.7350
Sel_srv_PeakStart	0.8508	0.1589	0.2035	0.8552	0.1480	0.2204	0.8466	0.1569	0.2011	0.8208	0.1815	0.1875	0.8582	0.1395	0.2380
Sel_srv_lnSD1	0.7332	0.2752	0.7691	0.7521	0.2539	0.8365	0.7267	0.2789	0.7519	0.6631	0.3410	0.6889	0.7683	0.2272	0.9320

Table 2.1.13. Catchability time series (Model 19.12 only).

Year	19.12
1982	1.118
1983	1.225
1984	1.007
1985	1.183
1986	1.145
1987	1.178
1988	1.078
1989	0.996
1990	1.005
1991	0.975
1992	0.937
1993	1.147
1994	1.487
1995	1.204
1996	1.251
1997	1.114
1998	1.151
1999	1.035
2000	0.996
2001	1.301
2002	1.124
2003	1.179
2004	1.106
2005	1.137
2006	1.037
2007	0.961
2008	0.873
2009	0.899
2010	0.998
2011	1.155
2012	1.079
2013	0.981
2014	1.282
2015	1.198
2016	1.189
2017	1.006
2018	1.283
2019	1.177

Table 2.1.14. Ranking criteria and model weights as adopted by the CIE reviewers.

Feature	19.12a	19.12	21.1	21.2	21.3
Feature 1: Allow catchability to vary?	no	yes	no	no	no
Feature 2: Allow domed survey selectivity?	no	no	yes	no	no
Feature 3: Use fishery CPUE?	no	no	no	yes	no
Feature 4: Estimate survey CV internally?	no	no	no	no	yes

Criterion	Emph.	19.12a	19.12	21.1	21.2	21.3
General plausibility of the model	3	2	1	0.6667	1	1.3333
Acceptable retrospective bias	3	2	2	1.3333	1	2
Uses properly vetted data	3	2	2	2	0	2
Acceptable residual patterns	3	2	2	2	2	1
Comparable complexity	2	2	1	1	2	2
Fits consistent with variances	2	1	2	1	0	2
Dev sigmas estimated appropriately	0					
Incremental changes	0					
Objective criterion for sample sizes	0					
Change in ageing criteria addressed	0					
Density dependence (other than R) addressed	0					
Regime shifts addressed	0					

Quantity	19.12a	19.12	21.1	21.2	21.3
Average emphasis:	0.9375	0.8438	0.6875	0.5000	0.8438
Model weight:	0.2459	0.2213	0.1803	0.1311	0.2213

Table 2.1.15. Female spawning biomass (millions of t) time series for all models and the ensemble.

	no		yes		no		no		no		Time-vary *Q* ?	
	no		no		yes		no		no		Survey dome?	
	no		no		no		yes		no		Fishery CPUE?	
	no		no		no		no		yes		Extra SD?	
	Model 19.12a		Model 19.12		Model 21.1		Model 21.2		Model 21.3		Ensemble	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	0.186	0.051	0.201	0.054	0.110	0.030	0.177	0.049	0.221	0.061	0.182	0.063
1978	0.229	0.061	0.252	0.067	0.132	0.035	0.219	0.059	0.278	0.077	0.226	0.079
1979	0.166	0.041	0.186	0.046	0.096	0.024	0.158	0.039	0.204	0.053	0.165	0.056
1980	0.173	0.036	0.196	0.042	0.102	0.022	0.165	0.035	0.213	0.047	0.173	0.053
1981	0.130	0.019	0.150	0.024	0.085	0.014	0.126	0.020	0.161	0.027	0.133	0.034
1982	0.099	0.012	0.113	0.015	0.068	0.010	0.099	0.013	0.120	0.017	0.101	0.022
1983	0.119	0.011	0.134	0.014	0.088	0.011	0.119	0.012	0.141	0.016	0.122	0.023
1984	0.163	0.013	0.180	0.017	0.126	0.013	0.161	0.014	0.189	0.019	0.166	0.027
1985	0.180	0.015	0.193	0.017	0.142	0.015	0.178	0.016	0.202	0.020	0.180	0.026
1986	0.171	0.014	0.179	0.015	0.139	0.015	0.170	0.016	0.187	0.018	0.170	0.022
1987	0.196	0.014	0.205	0.016	0.161	0.016	0.196	0.016	0.213	0.019	0.195	0.024
1988	0.229	0.015	0.242	0.017	0.194	0.019	0.227	0.018	0.251	0.020	0.230	0.026
1989	0.214	0.013	0.226	0.016	0.176	0.016	0.211	0.015	0.233	0.018	0.214	0.025
1990	0.240	0.013	0.254	0.016	0.192	0.016	0.236	0.014	0.261	0.018	0.239	0.028
1991	0.405	0.025	0.418	0.027	0.327	0.030	0.392	0.026	0.427	0.031	0.397	0.044
1992	0.446	0.035	0.445	0.033	0.355	0.037	0.433	0.039	0.451	0.037	0.429	0.051
1993	0.307	0.023	0.308	0.023	0.250	0.025	0.301	0.026	0.310	0.025	0.297	0.033
1994	0.410	0.027	0.416	0.028	0.336	0.031	0.409	0.031	0.417	0.030	0.399	0.042
1995	0.513	0.034	0.536	0.036	0.419	0.039	0.505	0.037	0.542	0.038	0.506	0.056
1996	0.483	0.033	0.534	0.038	0.374	0.038	0.470	0.034	0.548	0.040	0.487	0.070
1997	0.534	0.037	0.613	0.042	0.422	0.042	0.499	0.034	0.638	0.045	0.550	0.087
1998	0.428	0.032	0.499	0.037	0.335	0.036	0.392	0.029	0.523	0.039	0.443	0.076
1999	0.405	0.033	0.473	0.037	0.315	0.035	0.370	0.029	0.498	0.040	0.420	0.075
2000	0.389	0.032	0.454	0.038	0.300	0.033	0.383	0.031	0.478	0.041	0.406	0.071
2001	0.348	0.025	0.387	0.029	0.279	0.027	0.387	0.028	0.403	0.032	0.362	0.052
2002	0.377	0.027	0.398	0.028	0.312	0.028	0.417	0.030	0.411	0.029	0.383	0.046
2003	0.379	0.025	0.410	0.027	0.313	0.028	0.463	0.033	0.423	0.029	0.395	0.054
2004	0.388	0.024	0.421	0.026	0.317	0.028	0.449	0.031	0.434	0.028	0.401	0.052
2005	0.404	0.025	0.440	0.026	0.330	0.030	0.421	0.028	0.455	0.028	0.412	0.051
2006	0.436	0.028	0.481	0.030	0.341	0.034	0.411	0.027	0.497	0.032	0.439	0.062
2007	0.415	0.029	0.454	0.031	0.318	0.034	0.352	0.024	0.469	0.032	0.410	0.064
2008	0.510	0.038	0.533	0.038	0.393	0.041	0.389	0.027	0.548	0.040	0.487	0.075
2009	0.645	0.056	0.647	0.052	0.503	0.056	0.438	0.033	0.661	0.055	0.596	0.098
2010	0.623	0.051	0.615	0.051	0.480	0.053	0.450	0.035	0.619	0.053	0.572	0.087
2011	0.744	0.053	0.737	0.057	0.569	0.059	0.634	0.047	0.733	0.058	0.694	0.088
2012	0.643	0.043	0.656	0.048	0.499	0.049	0.644	0.045	0.662	0.049	0.624	0.076
2013	0.584	0.038	0.597	0.042	0.468	0.043	0.616	0.042	0.612	0.043	0.576	0.067
2014	0.640	0.049	0.649	0.051	0.502	0.052	0.712	0.054	0.679	0.053	0.635	0.084
2015	0.606	0.046	0.632	0.053	0.467	0.050	0.714	0.055	0.685	0.060	0.618	0.096
2016	0.545	0.042	0.585	0.051	0.424	0.045	0.620	0.047	0.665	0.064	0.568	0.095
2017	0.432	0.034	0.478	0.044	0.336	0.036	0.534	0.040	0.577	0.065	0.470	0.094
2018	0.314	0.024	0.346	0.032	0.255	0.025	0.351	0.025	0.441	0.057	0.344	0.071
2019	0.299	0.025	0.319	0.031	0.249	0.025	0.315	0.024	0.435	0.070	0.327	0.074
2020	0.320	0.028	0.345	0.038	0.263	0.029	0.324	0.025	0.518	0.114	0.360	0.107
2021	0.290	0.039	0.215	0.037	0.262	0.036	0.280	0.037	0.130	0.039	0.232	0.071
2022	0.265	0.024	0.210	0.026	0.238	0.023	0.263	0.024	0.144	0.032	0.221	0.053

Table 2.1.16. Spawning biomass relative to B100% time series for all models and the ensemble.

	no		yes		no		no		no		Time-vary *Q* ?	
	no		no		yes		no		no		Survey dome?	
	no		no		no		yes		no		Fishery CPUE?	
	no		no		no		no		yes		Extra SD?	
	Model 19.12a		Model 19.12		Model 21.1		Model 21.2		Model 21.3		Ensemble	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	0.186	0.051	0.201	0.054	0.110	0.030	0.177	0.049	0.221	0.061	0.182	0.000
1978	0.229	0.061	0.252	0.067	0.132	0.035	0.219	0.059	0.278	0.077	0.226	0.000
1979	0.166	0.041	0.186	0.046	0.096	0.024	0.158	0.039	0.204	0.053	0.165	0.000
1980	0.173	0.036	0.196	0.042	0.102	0.022	0.165	0.035	0.213	0.047	0.173	0.000
1981	0.130	0.019	0.150	0.024	0.085	0.014	0.126	0.020	0.161	0.027	0.133	0.000
1982	0.099	0.012	0.113	0.015	0.068	0.010	0.099	0.013	0.120	0.017	0.101	0.000
1983	0.119	0.011	0.134	0.014	0.088	0.011	0.119	0.012	0.141	0.016	0.122	0.000
1984	0.163	0.013	0.180	0.017	0.126	0.013	0.161	0.014	0.189	0.019	0.166	0.000
1985	0.180	0.015	0.193	0.017	0.142	0.015	0.178	0.016	0.202	0.020	0.180	0.000
1986	0.171	0.014	0.179	0.015	0.139	0.015	0.170	0.016	0.187	0.018	0.170	0.000
1987	0.196	0.014	0.205	0.016	0.161	0.016	0.196	0.016	0.213	0.019	0.195	0.000
1988	0.229	0.015	0.242	0.017	0.194	0.019	0.227	0.018	0.251	0.020	0.230	0.000
1989	0.214	0.013	0.226	0.016	0.176	0.016	0.211	0.015	0.233	0.018	0.214	0.000
1990	0.240	0.013	0.254	0.016	0.192	0.016	0.236	0.014	0.261	0.018	0.239	0.000
1991	0.405	0.025	0.418	0.027	0.327	0.030	0.392	0.026	0.427	0.031	0.397	0.000
1992	0.446	0.035	0.445	0.033	0.355	0.037	0.433	0.039	0.451	0.037	0.429	0.000
1993	0.307	0.023	0.308	0.023	0.250	0.025	0.301	0.026	0.310	0.025	0.297	0.000
1994	0.410	0.027	0.416	0.028	0.336	0.031	0.409	0.031	0.417	0.030	0.399	0.000
1995	0.513	0.034	0.536	0.036	0.419	0.039	0.505	0.037	0.542	0.038	0.506	0.000
1996	0.483	0.033	0.534	0.038	0.374	0.038	0.470	0.034	0.548	0.040	0.487	0.000
1997	0.534	0.037	0.613	0.042	0.422	0.042	0.499	0.034	0.638	0.045	0.550	0.000
1998	0.428	0.032	0.499	0.037	0.335	0.036	0.392	0.029	0.523	0.039	0.443	0.000
1999	0.405	0.033	0.473	0.037	0.315	0.035	0.370	0.029	0.498	0.040	0.420	0.000
2000	0.389	0.032	0.454	0.038	0.300	0.033	0.383	0.031	0.478	0.041	0.406	0.000
2001	0.348	0.025	0.387	0.029	0.279	0.027	0.387	0.028	0.403	0.032	0.362	0.000
2002	0.377	0.027	0.398	0.028	0.312	0.028	0.417	0.030	0.411	0.029	0.383	0.000
2003	0.379	0.025	0.410	0.027	0.313	0.028	0.463	0.033	0.423	0.029	0.395	0.000
2004	0.388	0.024	0.421	0.026	0.317	0.028	0.449	0.031	0.434	0.028	0.401	0.000
2005	0.404	0.025	0.440	0.026	0.330	0.030	0.421	0.028	0.455	0.028	0.412	0.000
2006	0.436	0.028	0.481	0.030	0.341	0.034	0.411	0.027	0.497	0.032	0.439	0.000
2007	0.415	0.029	0.454	0.031	0.318	0.034	0.352	0.024	0.469	0.032	0.410	0.000
2008	0.510	0.038	0.533	0.038	0.393	0.041	0.389	0.027	0.548	0.040	0.487	0.000
2009	0.645	0.056	0.647	0.052	0.503	0.056	0.438	0.033	0.661	0.055	0.596	0.000
2010	0.623	0.051	0.615	0.051	0.480	0.053	0.450	0.035	0.619	0.053	0.572	0.000
2011	0.744	0.053	0.737	0.057	0.569	0.059	0.634	0.047	0.733	0.058	0.694	0.000
2012	0.643	0.043	0.656	0.048	0.499	0.049	0.644	0.045	0.662	0.049	0.624	0.000
2013	0.584	0.038	0.597	0.042	0.468	0.043	0.616	0.042	0.612	0.043	0.576	0.000
2014	0.640	0.049	0.649	0.051	0.502	0.052	0.712	0.054	0.679	0.053	0.635	0.000
2015	0.606	0.046	0.632	0.053	0.467	0.050	0.714	0.055	0.685	0.060	0.618	0.000
2016	0.545	0.042	0.585	0.051	0.424	0.045	0.620	0.047	0.665	0.064	0.568	0.000
2017	0.432	0.034	0.478	0.044	0.336	0.036	0.534	0.040	0.577	0.065	0.470	0.000
2018	0.314	0.024	0.346	0.032	0.255	0.025	0.351	0.025	0.441	0.057	0.344	0.000
2019	0.299	0.025	0.319	0.031	0.249	0.025	0.315	0.024	0.435	0.070	0.327	0.000
2020	0.320	0.028	0.345	0.038	0.263	0.029	0.324	0.025	0.518	0.114	0.360	0.000
2021	0.290	0.039	0.215	0.037	0.262	0.036	0.280	0.037	0.130	0.039	0.232	0.000
2022	0.265	0.024	0.210	0.026	0.238	0.023	0.263	0.024	0.144	0.032	0.221	0.000

Table 2.1.17. Age 0 recruitment (billions of fish) time series for all models and the ensemble.

	no		yes		no		no		no		Time-vary *Q*?	
	no		no		yes		no		no		Survey dome?	
	no		no		no		yes		no		Fishery CPUE?	
	no		no		no		no		yes		Extra SD?	
	Model 19.12a		Model 19.12		Model 21.1		Model 21.2		Model 21.3		Ensemble	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	1.056	0.269	0.823	0.218	0.933	0.262	1.082	0.283	0.773	0.213	0.923	0.276
1978	0.699	0.189	0.585	0.153	0.593	0.169	0.674	0.193	0.562	0.149	0.621	0.179
1979	0.723	0.121	0.601	0.105	0.585	0.110	0.713	0.123	0.572	0.106	0.637	0.130
1980	0.181	0.045	0.147	0.040	0.152	0.039	0.184	0.046	0.128	0.038	0.157	0.047
1981	0.202	0.041	0.178	0.036	0.166	0.036	0.201	0.042	0.172	0.036	0.183	0.041
1982	0.941	0.108	0.827	0.103	0.770	0.104	0.952	0.111	0.813	0.110	0.858	0.128
1983	0.262	0.049	0.204	0.040	0.219	0.043	0.256	0.049	0.190	0.039	0.225	0.053
1984	0.880	0.100	0.753	0.090	0.714	0.096	0.887	0.102	0.730	0.093	0.790	0.121
1985	0.402	0.054	0.350	0.048	0.329	0.050	0.393	0.054	0.342	0.049	0.362	0.058
1986	0.219	0.032	0.200	0.030	0.177	0.029	0.217	0.033	0.198	0.031	0.202	0.034
1987	0.073	0.018	0.071	0.017	0.060	0.015	0.074	0.018	0.071	0.018	0.070	0.018
1988	0.305	0.039	0.279	0.037	0.242	0.036	0.313	0.041	0.275	0.039	0.282	0.045
1989	0.600	0.066	0.542	0.061	0.482	0.064	0.610	0.068	0.535	0.064	0.553	0.078
1990	0.591	0.066	0.520	0.059	0.475	0.064	0.597	0.068	0.517	0.061	0.539	0.078
1991	0.362	0.048	0.288	0.040	0.305	0.044	0.370	0.050	0.257	0.034	0.313	0.061
1992	0.951	0.096	0.764	0.076	0.785	0.096	0.990	0.102	0.725	0.076	0.835	0.136
1993	0.353	0.043	0.314	0.038	0.303	0.041	0.351	0.044	0.308	0.038	0.325	0.046
1994	0.298	0.036	0.254	0.030	0.247	0.035	0.313	0.038	0.245	0.030	0.269	0.043
1995	0.267	0.034	0.235	0.030	0.225	0.032	0.264	0.034	0.230	0.030	0.244	0.036
1996	0.846	0.089	0.736	0.080	0.699	0.088	0.797	0.084	0.718	0.084	0.760	0.102
1997	0.362	0.043	0.325	0.040	0.300	0.041	0.329	0.042	0.319	0.041	0.329	0.047
1998	0.288	0.037	0.258	0.033	0.232	0.034	0.273	0.035	0.253	0.034	0.261	0.040
1999	0.692	0.069	0.591	0.060	0.561	0.069	0.691	0.071	0.569	0.061	0.619	0.088
2000	0.505	0.052	0.436	0.046	0.430	0.052	0.536	0.057	0.423	0.047	0.462	0.066
2001	0.196	0.026	0.175	0.024	0.161	0.025	0.221	0.031	0.172	0.024	0.183	0.032
2002	0.344	0.037	0.303	0.033	0.288	0.036	0.411	0.046	0.296	0.034	0.323	0.054
2003	0.310	0.033	0.279	0.030	0.257	0.032	0.372	0.042	0.274	0.031	0.294	0.049
2004	0.224	0.028	0.206	0.026	0.186	0.025	0.254	0.032	0.203	0.027	0.212	0.034
2005	0.269	0.030	0.253	0.029	0.221	0.029	0.296	0.036	0.252	0.030	0.257	0.037
2006	0.786	0.072	0.745	0.072	0.646	0.073	0.807	0.077	0.744	0.077	0.745	0.090
2007	0.317	0.040	0.293	0.037	0.265	0.037	0.293	0.038	0.289	0.037	0.293	0.041
2008	1.172	0.109	1.009	0.100	0.966	0.110	1.088	0.102	0.954	0.097	1.039	0.135
2009	0.165	0.031	0.143	0.026	0.142	0.028	0.159	0.030	0.134	0.024	0.149	0.030
2010	0.735	0.077	0.651	0.071	0.603	0.075	0.695	0.072	0.605	0.067	0.659	0.090
2011	0.931	0.098	0.808	0.087	0.783	0.096	0.891	0.091	0.728	0.081	0.827	0.119
2012	0.443	0.059	0.371	0.050	0.369	0.055	0.425	0.058	0.319	0.044	0.384	0.070
2013	1.200	0.130	1.003	0.116	0.998	0.125	1.182	0.126	0.829	0.107	1.035	0.185
2014	0.217	0.032	0.187	0.028	0.185	0.030	0.209	0.032	0.153	0.025	0.189	0.037
2015	0.287	0.033	0.250	0.031	0.238	0.032	0.289	0.034	0.198	0.030	0.251	0.047
2016	0.178	0.026	0.139	0.021	0.149	0.024	0.180	0.026	0.102	0.020	0.148	0.037
2017	0.125	0.027	0.102	0.023	0.110	0.024	0.122	0.027	0.077	0.019	0.106	0.030
2018	0.735	0.074	0.620	0.073	0.619	0.075	0.751	0.077	0.459	0.079	0.630	0.130

Table 2.1.18. Full-selection instantaneous fishing mortality time series for all models and the ensemble.

	no		yes		no		no		no		Time-vary *Q* ?	
	no		no		yes		no		no		Survey dome?	
	no		no		no		yes		no		Fishery CPUE?	
	no		no		no		no		yes		Extra SD?	
	Model 19.12a		Model 19.12		Model 21.1		Model 21.2		Model 21.3		Ensemble	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	0.186	0.051	0.201	0.054	0.110	0.030	0.177	0.049	0.221	0.061	0.182	0.063
1978	0.229	0.061	0.252	0.067	0.132	0.035	0.219	0.059	0.278	0.077	0.226	0.079
1979	0.166	0.041	0.186	0.046	0.096	0.024	0.158	0.039	0.204	0.053	0.165	0.056
1980	0.173	0.036	0.196	0.042	0.102	0.022	0.165	0.035	0.213	0.047	0.173	0.053
1981	0.130	0.019	0.150	0.024	0.085	0.014	0.126	0.020	0.161	0.027	0.133	0.034
1982	0.099	0.012	0.113	0.015	0.068	0.010	0.099	0.013	0.120	0.017	0.101	0.022
1983	0.119	0.011	0.134	0.014	0.088	0.011	0.119	0.012	0.141	0.016	0.122	0.023
1984	0.163	0.013	0.180	0.017	0.126	0.013	0.161	0.014	0.189	0.019	0.166	0.027
1985	0.180	0.015	0.193	0.017	0.142	0.015	0.178	0.016	0.202	0.020	0.180	0.026
1986	0.171	0.014	0.179	0.015	0.139	0.015	0.170	0.016	0.187	0.018	0.170	0.022
1987	0.196	0.014	0.205	0.016	0.161	0.016	0.196	0.016	0.213	0.019	0.195	0.024
1988	0.229	0.015	0.242	0.017	0.194	0.019	0.227	0.018	0.251	0.020	0.230	0.026
1989	0.214	0.013	0.226	0.016	0.176	0.016	0.211	0.015	0.233	0.018	0.214	0.025
1990	0.240	0.013	0.254	0.016	0.192	0.016	0.236	0.014	0.261	0.018	0.239	0.028
1991	0.405	0.025	0.418	0.027	0.327	0.030	0.392	0.026	0.427	0.031	0.397	0.044
1992	0.446	0.035	0.445	0.033	0.355	0.037	0.433	0.039	0.451	0.037	0.429	0.051
1993	0.307	0.023	0.308	0.023	0.250	0.025	0.301	0.026	0.310	0.025	0.297	0.033
1994	0.410	0.027	0.416	0.028	0.336	0.031	0.409	0.031	0.417	0.030	0.399	0.042
1995	0.513	0.034	0.536	0.036	0.419	0.039	0.505	0.037	0.542	0.038	0.506	0.056
1996	0.483	0.033	0.534	0.038	0.374	0.038	0.470	0.034	0.548	0.040	0.487	0.070
1997	0.534	0.037	0.613	0.042	0.422	0.042	0.499	0.034	0.638	0.045	0.550	0.087
1998	0.428	0.032	0.499	0.037	0.335	0.036	0.392	0.029	0.523	0.039	0.443	0.076
1999	0.405	0.033	0.473	0.037	0.315	0.035	0.370	0.029	0.498	0.040	0.420	0.075
2000	0.389	0.032	0.454	0.038	0.300	0.033	0.383	0.031	0.478	0.041	0.406	0.071
2001	0.348	0.025	0.387	0.029	0.279	0.027	0.387	0.028	0.403	0.032	0.362	0.052
2002	0.377	0.027	0.398	0.028	0.312	0.028	0.417	0.030	0.411	0.029	0.383	0.046
2003	0.379	0.025	0.410	0.027	0.313	0.028	0.463	0.033	0.423	0.029	0.395	0.054
2004	0.388	0.024	0.421	0.026	0.317	0.028	0.449	0.031	0.434	0.028	0.401	0.052
2005	0.404	0.025	0.440	0.026	0.330	0.030	0.421	0.028	0.455	0.028	0.412	0.051
2006	0.436	0.028	0.481	0.030	0.341	0.034	0.411	0.027	0.497	0.032	0.439	0.062
2007	0.415	0.029	0.454	0.031	0.318	0.034	0.352	0.024	0.469	0.032	0.410	0.064
2008	0.510	0.038	0.533	0.038	0.393	0.041	0.389	0.027	0.548	0.040	0.487	0.075
2009	0.645	0.056	0.647	0.052	0.503	0.056	0.438	0.033	0.661	0.055	0.596	0.098
2010	0.623	0.051	0.615	0.051	0.480	0.053	0.450	0.035	0.619	0.053	0.572	0.087
2011	0.744	0.053	0.737	0.057	0.569	0.059	0.634	0.047	0.733	0.058	0.694	0.088
2012	0.643	0.043	0.656	0.048	0.499	0.049	0.644	0.045	0.662	0.049	0.624	0.076
2013	0.584	0.038	0.597	0.042	0.468	0.043	0.616	0.042	0.612	0.043	0.576	0.067
2014	0.640	0.049	0.649	0.051	0.502	0.052	0.712	0.054	0.679	0.053	0.635	0.084
2015	0.606	0.046	0.632	0.053	0.467	0.050	0.714	0.055	0.685	0.060	0.618	0.096
2016	0.545	0.042	0.585	0.051	0.424	0.045	0.620	0.047	0.665	0.064	0.568	0.095
2017	0.432	0.034	0.478	0.044	0.336	0.036	0.534	0.040	0.577	0.065	0.470	0.094
2018	0.314	0.024	0.346	0.032	0.255	0.025	0.351	0.025	0.441	0.057	0.344	0.071
2019	0.299	0.025	0.319	0.031	0.249	0.025	0.315	0.024	0.435	0.070	0.327	0.074
2020	0.320	0.028	0.345	0.038	0.263	0.029	0.324	0.025	0.518	0.114	0.360	0.107
2021	0.290	0.039	0.215	0.037	0.262	0.036	0.280	0.037	0.130	0.039	0.232	0.071
2022	0.265	0.024	0.210	0.026	0.238	0.023	0.263	0.024	0.144	0.032	0.221	0.053

Table 2.1.19a. Mid-year length (cm) at age (Model 19.12a).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	5.2	15.6	32.0	43.9	53.3	61.1	67.7	73.3	78.1	82.3	86.0	89.1	91.9	94.4	96.5	98.4	100.1	101.6	102.9	104.0	106.7
1978	4.8	15.6	31.3	43.9	53.3	61.1	67.7	73.3	78.1	82.3	86.0	89.1	91.9	94.4	96.5	98.4	100.1	101.6	102.9	104.0	106.7
1979	5.3	14.5	32.1	43.3	53.3	61.1	67.7	73.3	78.1	82.3	86.0	89.1	91.9	94.4	96.5	98.4	100.1	101.6	102.9	104.0	106.5
1980	4.9	15.8	31.4	44.0	52.9	61.1	67.7	73.3	78.1	82.3	86.0	89.1	91.9	94.4	96.5	98.4	100.1	101.6	102.9	104.0	106.4
1981	4.2	14.7	30.2	43.4	53.4	60.7	67.7	73.3	78.1	82.3	86.0	89.1	91.9	94.4	96.5	98.4	100.1	101.6	102.9	104.0	106.4
1982	4.4	12.7	30.4	42.4	52.9	61.2	67.4	73.3	78.1	82.3	86.0	89.1	91.9	94.4	96.5	98.4	100.1	101.6	102.9	104.0	106.4
1983	5.4	13.1	32.5	42.6	52.1	60.8	67.7	73.0	78.1	82.3	86.0	89.1	91.9	94.4	96.5	98.4	100.1	101.6	102.9	104.0	106.4
1984	5.2	16.3	32.1	44.2	52.3	60.1	67.4	73.3	77.9	82.3	86.0	89.1	91.9	94.4	96.5	98.4	100.1	101.6	102.9	104.0	106.4
1985	4.0	15.7	29.7	43.9	53.6	60.3	66.9	73.1	78.2	82.1	86.0	89.1	91.9	94.4	96.5	98.4	100.1	101.6	102.9	104.0	106.4
1986	5.0	11.9	31.7	42.1	53.4	61.3	67.0	72.6	77.9	82.4	85.8	89.1	91.9	94.4	96.5	98.4	100.1	101.6	102.9	104.0	106.4
1987	4.5	15.1	30.8	43.6	51.8	61.1	67.9	72.7	77.5	82.1	86.0	89.0	91.9	94.4	96.5	98.4	100.1	101.6	102.9	104.0	106.4
1988	4.3	13.6	30.3	42.9	53.1	59.9	67.7	73.5	77.6	81.8	85.8	89.2	91.8	94.4	96.5	98.4	100.1	101.6	102.9	104.0	106.5
1989	4.4	12.9	30.4	42.6	52.5	60.9	66.6	73.3	78.3	81.9	85.5	89.0	92.0	94.3	96.5	98.4	100.1	101.6	102.9	104.0	106.5
1990	4.8	13.1	31.3	42.6	52.2	60.4	67.5	72.4	78.2	82.5	85.6	88.7	91.8	94.4	96.4	98.4	100.1	101.6	102.9	104.0	106.5
1991	5.2	14.5	32.1	43.3	52.3	60.2	67.1	73.2	77.4	82.3	86.1	88.8	91.6	94.3	96.5	98.3	100.1	101.6	102.9	104.0	106.5
1992	5.0	15.7	31.5	43.9	52.9	60.3	66.9	72.8	78.0	81.7	86.0	89.2	91.6	94.1	96.4	98.4	100.0	101.6	102.9	104.0	106.5
1993	5.4	14.9	32.3	43.5	53.4	60.7	67.0	72.6	77.7	82.2	85.4	89.2	92.0	94.1	96.2	98.3	100.1	101.5	102.9	104.0	106.2
1994	4.8	16.1	31.2	44.1	53.0	61.1	67.4	72.7	77.6	82.0	85.9	88.6	91.9	94.5	96.3	98.2	100.0	101.6	102.8	104.0	105.9
1995	4.7	14.3	31.1	43.2	53.5	60.8	67.7	73.0	77.6	81.8	85.6	89.1	91.5	94.4	96.6	98.2	99.9	101.5	102.9	103.9	106.0
1996	4.9	14.1	31.4	43.1	52.8	61.3	67.5	73.3	77.9	81.9	85.5	88.9	91.9	94.0	96.5	98.5	99.9	101.4	102.8	104.0	105.7
1997	4.8	14.7	31.2	43.4	52.7	60.6	67.8	73.1	78.2	82.1	85.6	88.8	91.7	94.3	96.2	98.4	100.1	101.4	102.7	103.9	105.4
1998	4.4	14.3	30.5	43.2	52.9	60.6	67.3	73.4	78.0	82.3	85.8	88.8	91.6	94.2	96.5	98.1	100.1	101.6	102.7	103.9	105.7
1999	4.1	13.2	29.9	42.7	52.8	60.8	67.3	73.0	78.2	82.2	86.0	89.0	91.6	94.1	96.3	98.4	99.8	101.6	102.9	103.9	105.8
2000	5.6	12.2	32.9	42.2	52.3	60.7	67.4	72.9	77.8	82.4	85.8	89.2	91.8	94.1	96.3	98.2	100.0	101.3	102.9	104.0	106.4
2001	5.2	16.9	32.0	44.5	51.9	60.3	67.3	73.1	77.8	82.1	86.0	89.0	91.9	94.3	96.3	98.2	99.9	101.5	102.6	104.0	106.7
2002	5.5	15.6	32.5	43.9	53.8	60.0	67.0	73.0	77.9	82.0	85.7	89.2	91.8	94.4	96.4	98.2	99.9	101.4	102.8	103.8	105.9
2003	5.1	16.4	31.8	44.3	53.3	61.5	66.7	72.7	77.9	82.1	85.7	89.0	92.0	94.3	96.5	98.3	99.9	101.4	102.7	104.0	106.3
2004	6.1	15.2	33.8	43.7	53.6	61.1	68.1	72.5	77.6	82.1	85.8	88.9	91.8	94.4	96.4	98.4	100.0	101.4	102.7	103.9	105.9
2005	4.8	18.3	31.3	45.2	53.1	61.4	67.7	73.6	77.4	81.9	85.8	89.0	91.7	94.2	96.6	98.3	100.1	101.5	102.7	103.9	106.1
2006	4.7	14.5	31.1	43.3	54.4	61.0	67.9	73.3	78.4	81.7	85.6	89.0	91.8	94.2	96.4	98.4	100.0	101.6	102.8	103.9	106.4
2007	4.2	14.2	30.0	43.1	52.8	62.0	67.6	73.5	78.1	82.6	85.4	88.8	91.8	94.3	96.4	98.3	100.1	101.5	102.9	103.9	106.8
2008	4.1	12.4	29.9	42.3	52.7	60.7	68.5	73.2	78.3	82.3	86.2	88.7	91.6	94.2	96.4	98.3	100.0	101.6	102.8	104.0	106.2
2009	4.5	12.2	30.6	42.2	52.1	60.6	67.4	74.0	78.0	82.5	86.0	89.3	91.5	94.1	96.4	98.3	100.0	101.5	102.9	104.0	105.6
2010	5.2	13.4	32.0	42.8	52.0	60.1	67.3	73.0	78.7	82.2	86.1	89.1	92.1	94.0	96.3	98.3	100.0	101.5	102.8	104.0	105.6
2011	4.2	15.6	30.1	43.8	52.4	60.0	66.8	72.9	77.9	82.8	85.9	89.3	91.9	94.5	96.2	98.2	100.0	101.5	102.8	103.9	105.8
2012	5.1	12.5	31.8	42.4	53.3	60.4	66.7	72.5	77.8	82.1	86.4	89.1	92.0	94.4	96.6	98.1	99.9	101.5	102.8	103.9	105.4
2013	4.7	15.2	31.1	43.7	52.1	61.1	67.1	72.5	77.5	82.0	85.8	89.5	91.9	94.5	96.5	98.5	99.8	101.4	102.8	103.9	105.8
2014	5.1	14.2	31.9	43.2	53.1	60.1	67.7	72.8	77.4	81.8	85.7	89.0	92.3	94.3	96.6	98.4	100.2	101.3	102.7	103.9	106.0
2015	6.4	15.4	34.4	43.7	52.7	61.0	66.8	73.3	77.7	81.7	85.5	88.9	91.8	94.7	96.5	98.5	100.1	101.6	102.7	103.9	106.0
2016	6.4	19.2	34.5	45.7	53.2	60.6	67.6	72.6	78.1	81.9	85.4	88.7	91.7	94.3	96.8	98.4	100.1	101.5	102.9	103.8	105.4
2017	6.0	19.3	33.6	45.8	54.8	61.0	67.3	73.2	77.5	82.3	85.6	88.7	91.6	94.2	96.4	98.6	100.1	101.6	102.8	104.1	105.7
2018	7.1	17.9	36.0	45.1	54.9	62.4	67.6	72.9	78.0	81.8	86.0	88.8	91.5	94.0	96.4	98.3	100.3	101.5	102.9	104.0	106.0
2019	4.2	21.4	30.2	47.0	54.3	62.4	68.8	73.2	77.8	82.2	85.5	89.1	91.7	94.0	96.2	98.3	100.0	101.7	102.8	104.0	105.7
2020	5.2	15.6	31.5	42.5	55.8	61.9	68.8	74.2	78.1	82.1	85.9	88.7	91.9	94.1	96.2	98.2	100.0	101.5	103.0	104.0	105.8

Table 2.1.19b. Mid-year length (cm) at age (Model 19.12).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	5.3	15.8	32.1	43.8	53.2	61.0	67.6	73.4	78.4	82.9	86.8	90.2	93.3	96.1	98.5	100.7	102.7	104.4	106.0	107.5	111.3
1978	4.9	15.8	31.3	43.8	53.2	61.0	67.6	73.4	78.4	82.9	86.8	90.2	93.3	96.1	98.5	100.7	102.7	104.4	106.0	107.5	111.3
1979	5.3	14.6	32.2	43.2	53.2	61.0	67.6	73.4	78.4	82.9	86.8	90.2	93.3	96.1	98.5	100.7	102.7	104.4	106.0	107.5	111.1
1980	4.9	15.9	31.4	43.8	52.7	61.0	67.6	73.4	78.4	82.9	86.8	90.2	93.3	96.1	98.5	100.7	102.7	104.4	106.0	107.5	111.0
1981	4.2	14.7	30.1	43.2	53.2	60.6	67.6	73.4	78.4	82.9	86.8	90.2	93.3	96.1	98.5	100.7	102.7	104.4	106.0	107.5	110.9
1982	4.3	12.6	30.3	42.3	52.7	61.0	67.3	73.4	78.4	82.9	86.8	90.2	93.3	96.1	98.5	100.7	102.7	104.4	106.0	107.5	110.9
1983	5.9	13.0	33.3	42.4	51.9	60.6	67.7	73.1	78.4	82.9	86.8	90.2	93.3	96.1	98.5	100.7	102.7	104.4	106.0	107.5	110.9
1984	5.3	17.6	32.1	44.7	52.0	59.9	67.3	73.4	78.2	82.9	86.8	90.2	93.3	96.1	98.5	100.7	102.7	104.4	106.0	107.5	110.9
1985	3.9	15.8	29.6	43.8	53.9	60.0	66.7	73.1	78.5	82.6	86.8	90.2	93.3	96.1	98.5	100.7	102.7	104.4	106.0	107.5	111.0
1986	5.1	11.8	31.7	41.9	53.1	61.6	66.8	72.6	78.2	82.9	86.6	90.2	93.3	96.1	98.5	100.7	102.7	104.4	106.0	107.5	111.0
1987	4.6	15.2	30.8	43.5	51.6	61.0	68.2	72.7	77.7	82.6	86.8	90.0	93.3	96.1	98.5	100.7	102.7	104.4	106.0	107.5	111.1
1988	4.3	13.7	30.4	42.8	52.9	59.6	67.6	73.9	77.8	82.2	86.6	90.2	93.1	96.1	98.5	100.7	102.7	104.4	106.0	107.5	111.1
1989	4.4	13.0	30.5	42.5	52.3	60.7	66.5	73.4	78.8	82.3	86.2	90.1	93.3	95.9	98.5	100.7	102.7	104.4	106.0	107.5	111.2
1990	4.9	13.2	31.4	42.5	52.1	60.3	67.4	72.4	78.4	83.2	86.3	89.7	93.2	96.1	98.4	100.7	102.7	104.4	106.0	107.5	111.3
1991	5.4	14.7	32.3	43.3	52.1	60.0	67.0	73.2	77.6	82.9	87.1	89.8	92.9	95.9	98.5	100.6	102.7	104.4	106.0	107.5	111.3
1992	5.0	16.1	31.5	43.9	52.7	60.1	66.8	72.9	78.3	82.1	86.8	90.5	92.9	95.7	98.4	100.7	102.6	104.4	106.0	107.5	111.2
1993	5.2	14.9	32.0	43.3	53.3	60.6	66.9	72.7	78.0	82.7	86.1	90.2	93.6	95.7	98.2	100.6	102.7	104.3	106.0	107.5	110.9
1994	4.9	15.6	31.3	43.7	52.8	61.1	67.3	72.8	77.8	82.5	86.6	89.6	93.3	96.3	98.2	100.4	102.6	104.5	105.9	107.5	110.4
1995	4.8	14.6	31.2	43.2	53.1	60.6	67.7	73.1	77.9	82.3	86.4	90.1	92.8	96.1	98.7	100.4	102.4	104.4	106.0	107.4	110.5
1996	4.9	14.4	31.4	43.1	52.7	60.9	67.4	73.5	78.2	82.4	86.3	89.9	93.2	95.6	98.5	100.9	102.4	104.2	106.0	107.5	110.0
1997	4.8	14.7	31.2	43.2	52.6	60.5	67.6	73.2	78.5	82.6	86.3	89.8	93.0	96.0	98.1	100.7	102.8	104.2	105.8	107.4	109.5
1998	4.4	14.4	30.5	43.1	52.7	60.5	67.3	73.3	78.2	82.9	86.6	89.8	92.9	95.8	98.4	100.3	102.7	104.6	105.8	107.3	109.8
1999	4.1	13.3	29.9	42.6	52.6	60.6	67.2	73.1	78.4	82.7	86.8	90.1	93.0	95.7	98.3	100.6	102.3	104.4	106.2	107.3	110.1
2000	5.6	12.3	32.6	42.1	52.1	60.5	67.3	73.0	78.2	82.8	86.6	90.3	93.2	95.7	98.2	100.5	102.6	104.1	106.0	107.6	110.9
2001	5.2	16.7	32.0	44.2	51.8	60.1	67.2	73.1	78.1	82.6	86.7	90.1	93.4	95.9	98.2	100.4	102.5	104.4	105.8	107.5	111.4
2002	5.5	15.7	32.5	43.7	53.5	59.8	66.9	73.0	78.2	82.6	86.5	90.2	93.2	96.1	98.4	100.5	102.4	104.3	106.0	107.2	110.7
2003	5.1	16.5	31.7	44.1	53.1	61.3	66.6	72.8	78.1	82.6	86.5	90.0	93.3	95.9	98.5	100.6	102.5	104.2	105.9	107.4	111.2
2004	6.1	15.2	33.7	43.5	53.4	60.9	67.9	72.5	77.9	82.6	86.6	90.0	93.1	96.0	98.4	100.7	102.6	104.2	105.8	107.3	110.8
2005	4.8	18.2	31.3	45.0	52.9	61.2	67.6	73.6	77.7	82.4	86.5	90.1	93.1	95.9	98.5	100.6	102.7	104.4	105.9	107.3	111.1
2006	4.8	14.5	31.1	43.1	54.1	60.7	67.8	73.4	78.6	82.2	86.3	90.0	93.2	95.9	98.4	100.7	102.6	104.5	106.0	107.3	111.4
2007	4.3	14.3	30.3	43.0	52.6	61.8	67.4	73.6	78.4	83.0	86.2	89.8	93.1	95.9	98.4	100.6	102.7	104.4	106.1	107.4	112.0
2008	4.1	12.8	30.0	42.4	52.5	60.5	68.4	73.2	78.6	82.8	86.9	89.7	93.0	95.9	98.4	100.6	102.6	104.4	106.0	107.5	111.4
2009	4.4	12.4	30.5	42.2	52.0	60.4	67.2	74.0	78.3	83.0	86.7	90.4	92.8	95.7	98.4	100.6	102.5	104.3	106.0	107.4	110.5
2010	5.2	13.2	31.9	42.5	51.8	60.0	67.2	73.1	79.0	82.7	86.9	90.2	93.4	95.6	98.2	100.6	102.6	104.3	105.9	107.4	110.2
2011	4.2	15.5	30.2	43.6	52.1	59.8	66.8	73.0	78.1	83.3	86.7	90.3	93.3	96.2	98.1	100.5	102.6	104.4	105.9	107.4	110.4
2012	5.2	12.7	31.9	42.3	53.0	60.1	66.7	72.7	78.1	82.6	87.2	90.1	93.4	96.0	98.6	100.4	102.5	104.3	106.0	107.4	109.7
2013	4.7	15.5	31.1	43.6	51.9	60.9	66.9	72.6	77.8	82.6	86.5	90.6	93.2	96.1	98.5	100.8	102.4	104.2	105.9	107.4	110.1
2014	5.1	14.2	31.7	43.0	53.0	59.9	67.5	72.8	77.7	82.3	86.5	90.0	93.7	96.0	98.6	100.7	102.8	104.2	105.9	107.4	110.4
2015	6.5	15.3	34.4	43.5	52.5	60.8	66.7	73.3	77.9	82.2	86.3	90.0	93.1	96.4	98.4	100.8	102.7	104.5	105.8	107.3	110.5
2016	6.6	19.4	34.7	45.6	52.9	60.4	67.5	72.6	78.4	82.4	86.2	89.8	93.1	95.9	98.8	100.6	102.7	104.4	106.1	107.2	109.7
2017	6.0	19.7	33.6	45.8	54.6	60.8	67.2	73.3	77.8	82.8	86.3	89.7	92.9	95.9	98.4	101.0	102.6	104.5	106.0	107.5	110.1
2018	7.1	18.1	35.9	44.9	54.8	62.2	67.5	73.0	78.4	82.3	86.7	89.8	92.9	95.7	98.3	100.6	102.9	104.4	106.1	107.4	110.5
2019	4.3	21.4	30.2	46.7	54.1	62.4	68.7	73.3	78.1	82.8	86.2	90.2	93.0	95.6	98.2	100.6	102.6	104.6	106.0	107.5	110.2
2020	5.3	15.8	31.5	42.3	55.6	61.8	68.9	74.3	78.3	82.5	86.7	89.8	93.3	95.7	98.1	100.4	102.5	104.3	106.2	107.4	110.3

Table 2.1.19c. Mid-year length (cm) at age (Model 21.1).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	5.0	15.0	31.5	43.8	53.5	61.4	67.9	73.4	77.9	81.7	85.0	87.7	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.3
1978	4.8	15.0	31.2	43.8	53.5	61.4	67.9	73.4	77.9	81.7	85.0	87.7	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.3
1979	5.2	14.5	32.0	43.5	53.5	61.4	67.9	73.4	77.9	81.7	85.0	87.7	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.4
1980	4.9	15.6	31.3	44.1	53.3	61.4	67.9	73.4	77.9	81.7	85.0	87.7	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.4
1981	4.2	14.6	29.9	43.6	53.8	61.2	67.9	73.4	77.9	81.7	85.0	87.7	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.4
1982	4.4	12.7	30.4	42.5	53.3	61.6	67.8	73.4	77.9	81.7	85.0	87.7	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.5
1983	5.4	13.3	32.3	42.9	52.5	61.3	68.1	73.2	77.9	81.7	85.0	87.7	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.5
1984	5.2	16.2	32.0	44.4	52.8	60.6	67.8	73.5	77.8	81.7	85.0	87.7	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.5
1985	4.0	15.6	29.5	44.1	54.0	60.8	67.2	73.3	78.0	81.6	85.0	87.7	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.5
1986	5.0	12.0	31.6	42.2	53.8	61.8	67.4	72.8	77.8	81.8	84.9	87.7	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.5
1987	4.6	15.1	30.7	43.9	52.2	61.6	68.3	72.9	77.4	81.7	85.1	87.6	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.6
1988	4.4	13.8	30.3	43.1	53.6	60.4	68.1	73.6	77.6	81.3	84.9	87.8	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.6
1989	4.4	13.2	30.3	42.8	53.0	61.4	67.1	73.5	78.2	81.4	84.6	87.6	90.1	91.9	93.6	95.1	96.3	97.3	98.2	98.9	100.6
1990	4.8	13.2	31.1	42.8	52.7	61.0	68.0	72.6	78.0	81.9	84.7	87.4	90.0	92.0	93.6	95.1	96.3	97.3	98.2	98.9	100.6
1991	5.2	14.4	32.0	43.5	52.7	60.8	67.6	73.4	77.3	81.8	85.1	87.5	89.8	91.9	93.7	95.0	96.3	97.3	98.2	98.9	100.6
1992	5.0	15.7	31.5	44.2	53.2	60.8	67.4	73.1	77.9	81.2	85.1	87.8	89.8	91.8	93.6	95.1	96.2	97.3	98.2	98.9	100.6
1993	5.5	14.9	32.6	43.7	53.8	61.2	67.4	72.9	77.7	81.8	84.5	87.8	90.1	91.8	93.5	95.0	96.3	97.3	98.2	98.9	100.5
1994	4.8	16.6	31.1	44.6	53.5	61.7	67.8	72.9	77.5	81.5	85.0	87.3	90.1	92.1	93.5	94.9	96.2	97.3	98.1	98.9	100.3
1995	4.8	14.4	31.0	43.5	54.2	61.4	68.1	73.2	77.5	81.4	84.8	87.7	89.7	92.0	93.7	94.9	96.1	97.3	98.2	98.9	100.3
1996	4.9	14.3	31.3	43.4	53.2	62.0	67.9	73.5	77.8	81.4	84.7	87.5	90.0	91.7	93.7	95.1	96.2	97.2	98.1	98.9	100.1
1997	4.8	14.7	31.1	43.6	53.2	61.2	68.4	73.3	78.1	81.6	84.7	87.5	89.9	92.0	93.4	95.1	96.3	97.2	98.1	98.9	99.9
1998	4.5	14.4	30.5	43.5	53.3	61.2	67.8	73.7	77.9	81.9	84.9	87.5	89.8	91.9	93.6	94.9	96.3	97.3	98.1	98.8	100.1
1999	4.1	13.4	29.7	43.0	53.2	61.3	67.7	73.2	78.2	81.7	85.1	87.6	89.8	91.8	93.5	95.1	96.1	97.3	98.2	98.8	100.2
2000	5.6	12.3	32.8	42.3	52.8	61.2	67.8	73.2	77.8	82.0	85.0	87.8	89.9	91.8	93.5	95.0	96.3	97.1	98.2	98.9	100.5
2001	5.2	16.9	32.0	44.8	52.3	60.9	67.8	73.3	77.8	81.6	85.2	87.7	90.1	91.9	93.5	94.9	96.2	97.3	98.0	98.9	100.7
2002	5.4	15.7	32.4	44.2	54.3	60.4	67.5	73.2	77.8	81.6	84.9	87.9	90.0	92.0	93.6	94.9	96.2	97.2	98.2	98.8	100.3
2003	5.1	16.3	31.7	44.5	53.8	62.1	67.1	73.0	77.8	81.7	84.9	87.6	90.2	92.0	93.7	95.0	96.2	97.2	98.1	98.9	100.5
2004	6.1	15.2	33.8	43.9	54.1	61.6	68.5	72.7	77.6	81.6	84.9	87.6	89.9	92.1	93.6	95.1	96.2	97.2	98.1	98.9	100.3
2005	4.8	18.2	31.2	45.6	53.6	61.9	68.1	73.8	77.4	81.5	84.9	87.7	89.9	91.9	93.8	95.0	96.3	97.3	98.1	98.8	100.4
2006	4.7	14.5	31.0	43.5	54.9	61.5	68.3	73.5	78.3	81.3	84.7	87.6	90.0	91.9	93.6	95.2	96.3	97.3	98.1	98.8	100.6
2007	4.2	14.2	29.8	43.4	53.3	62.6	68.0	73.7	78.1	82.1	84.6	87.5	89.9	91.9	93.6	95.0	96.3	97.3	98.2	98.9	100.8
2008	4.1	12.5	29.7	42.5	53.1	61.2	68.9	73.4	78.2	81.9	85.2	87.4	89.8	91.9	93.6	95.0	96.2	97.4	98.2	98.9	100.6
2009	4.6	12.3	30.6	42.3	52.4	61.1	67.8	74.2	78.0	82.0	85.1	87.9	89.7	91.8	93.6	95.0	96.2	97.3	98.2	98.9	100.2
2010	5.2	13.7	31.9	43.1	52.3	60.5	67.7	73.2	78.6	81.8	85.2	87.8	90.2	91.7	93.5	95.0	96.2	97.2	98.1	99.0	100.1
2011	4.2	15.6	29.9	44.1	52.9	60.4	67.2	73.2	77.8	82.3	85.0	87.9	90.1	92.1	93.4	95.0	96.2	97.3	98.1	98.9	100.2
2012	5.1	12.6	31.8	42.5	53.7	60.9	67.1	72.8	77.7	81.7	85.5	87.7	90.1	92.0	93.8	94.9	96.2	97.3	98.1	98.9	99.9
2013	4.8	15.4	31.0	44.0	52.5	61.6	67.5	72.7	77.4	81.6	84.9	88.1	90.0	92.1	93.7	95.2	96.1	97.2	98.1	98.9	100.1
2014	5.2	14.2	31.9	43.4	53.7	60.6	68.1	73.0	77.4	81.3	84.8	87.6	90.4	92.0	93.7	95.1	96.4	97.2	98.1	98.9	100.3
2015	6.4	15.6	34.4	44.1	53.2	61.6	67.2	73.5	77.6	81.3	84.6	87.6	90.0	92.3	93.7	95.1	96.3	97.4	98.0	98.8	100.3
2016	6.4	19.1	34.5	46.0	53.7	61.1	68.1	72.8	78.0	81.5	84.6	87.4	89.9	91.9	93.9	95.1	96.3	97.3	98.2	98.8	100.0
2017	6.0	19.1	33.5	46.1	55.3	61.6	67.7	73.5	77.4	81.8	84.8	87.4	89.7	91.9	93.6	95.3	96.3	97.3	98.2	99.0	100.1
2018	7.1	17.9	36.1	45.3	55.3	62.9	68.1	73.2	78.0	81.3	85.0	87.5	89.7	91.8	93.6	95.0	96.4	97.3	98.2	98.9	100.3
2019	4.2	21.4	29.9	47.3	54.8	62.9	69.2	73.5	77.8	81.8	84.6	87.8	89.9	91.7	93.4	95.0	96.2	97.4	98.2	98.9	100.1
2020	5.0	15.0	31.4	42.5	56.4	62.4	69.2	74.4	78.0	81.6	85.0	87.4	90.1	91.9	93.4	94.9	96.2	97.3	98.3	98.9	100.2

Table 2.1.19d. Mid-year length (cm) at age (Model 21.2).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	5.4	16.1	32.4	44.0	53.2	60.8	67.2	72.8	77.6	81.9	85.6	88.8	91.7	94.3	96.6	98.6	100.4	102.1	103.5	104.8	108.1
1978	4.8	16.1	31.4	44.0	53.2	60.8	67.2	72.8	77.6	81.9	85.6	88.8	91.7	94.3	96.6	98.6	100.4	102.1	103.5	104.8	108.1
1979	5.2	14.4	32.1	43.2	53.2	60.8	67.2	72.8	77.6	81.9	85.6	88.8	91.7	94.3	96.6	98.6	100.4	102.1	103.5	104.8	107.9
1980	4.9	15.7	31.4	43.7	52.5	60.8	67.2	72.8	77.6	81.9	85.6	88.8	91.7	94.3	96.6	98.6	100.4	102.1	103.5	104.8	107.7
1981	4.2	14.6	30.3	43.2	53.0	60.2	67.2	72.8	77.6	81.9	85.6	88.8	91.7	94.3	96.6	98.6	100.4	102.1	103.5	104.8	107.7
1982	4.3	12.7	30.5	42.4	52.5	60.6	66.8	72.8	77.6	81.9	85.6	88.8	91.7	94.3	96.6	98.6	100.4	102.1	103.5	104.8	107.6
1983	5.3	13.0	32.3	42.5	51.9	60.3	67.1	72.4	77.6	81.9	85.6	88.8	91.7	94.3	96.6	98.6	100.4	102.1	103.5	104.8	107.6
1984	5.3	16.0	32.2	43.9	52.0	59.7	66.8	72.7	77.3	81.9	85.6	88.8	91.7	94.3	96.6	98.6	100.4	102.1	103.5	104.8	107.6
1985	3.9	15.8	29.8	43.8	53.1	59.8	66.3	72.4	77.5	81.5	85.6	88.8	91.7	94.3	96.6	98.6	100.4	102.1	103.5	104.8	107.6
1986	5.0	11.8	31.7	42.0	53.0	60.7	66.4	72.0	77.3	81.8	85.3	88.8	91.7	94.3	96.6	98.6	100.4	102.1	103.5	104.8	107.7
1987	4.5	15.0	30.7	43.4	51.6	60.7	67.2	72.1	76.9	81.6	85.5	88.6	91.7	94.3	96.6	98.6	100.4	102.1	103.5	104.8	107.7
1988	4.2	13.4	30.3	42.7	52.7	59.4	67.2	72.8	77.0	81.3	85.3	88.8	91.5	94.3	96.6	98.6	100.4	102.1	103.5	104.8	107.8
1989	4.3	12.6	30.5	42.4	52.1	60.4	66.1	72.7	77.6	81.3	85.0	88.6	91.7	94.1	96.6	98.6	100.4	102.1	103.5	104.8	107.8
1990	4.8	13.0	31.3	42.5	51.8	59.9	66.9	71.8	77.6	81.8	85.1	88.4	91.5	94.3	96.4	98.6	100.4	102.1	103.5	104.8	107.8
1991	5.2	14.3	32.2	43.1	52.0	59.7	66.5	72.5	76.8	81.8	85.5	88.4	91.3	94.1	96.5	98.5	100.4	102.1	103.5	104.8	107.8
1992	4.9	15.7	31.6	43.8	52.4	59.8	66.3	72.2	77.4	81.1	85.5	88.8	91.3	93.9	96.4	98.6	100.3	102.1	103.5	104.8	107.7
1993	5.3	14.8	32.2	43.3	53.0	60.2	66.4	72.0	77.1	81.7	84.9	88.8	91.7	94.0	96.3	98.5	100.4	101.9	103.5	104.8	107.5
1994	4.7	15.9	31.2	43.8	52.6	60.6	66.7	72.1	76.9	81.4	85.4	88.3	91.7	94.3	96.3	98.3	100.3	102.0	103.4	104.8	107.1
1995	4.7	14.2	31.1	43.1	53.1	60.3	67.1	72.4	77.0	81.2	85.1	88.7	91.2	94.3	96.6	98.4	100.2	101.9	103.5	104.7	107.2
1996	4.8	14.0	31.4	43.0	52.4	60.7	66.9	72.7	77.2	81.3	85.0	88.5	91.6	93.8	96.6	98.6	100.2	101.8	103.4	104.8	106.7
1997	4.2	14.5	30.3	43.2	52.3	60.2	67.2	72.5	77.5	81.5	85.1	88.4	91.4	94.2	96.2	98.6	100.4	101.8	103.3	104.7	106.4
1998	4.5	12.7	30.8	42.4	52.5	60.1	66.7	72.7	77.4	81.8	85.3	88.4	91.3	94.0	96.5	98.3	100.4	102.1	103.3	104.6	106.8
1999	4.0	13.4	30.0	42.7	51.9	60.2	66.7	72.3	77.6	81.6	85.5	88.6	91.4	93.9	96.3	98.5	100.1	102.0	103.5	104.6	106.9
2000	5.6	12.1	32.8	42.1	52.1	59.7	66.8	72.3	77.2	81.8	85.3	88.8	91.5	94.0	96.3	98.4	100.4	101.8	103.5	104.8	107.6
2001	5.0	16.7	31.8	44.2	51.6	59.9	66.3	72.4	77.2	81.5	85.5	88.6	91.7	94.1	96.3	98.3	100.2	102.0	103.2	104.8	107.9
2002	5.4	15.1	32.4	43.5	53.4	59.5	66.5	72.0	77.3	81.5	85.3	88.8	91.6	94.3	96.4	98.4	100.2	101.9	103.4	104.6	107.0
2003	5.0	16.1	31.7	43.9	52.7	61.0	66.2	72.2	76.9	81.6	85.2	88.6	91.7	94.2	96.5	98.5	100.2	101.8	103.3	104.7	107.5
2004	6.1	15.0	33.9	43.4	53.1	60.4	67.4	71.9	77.1	81.2	85.3	88.5	91.5	94.3	96.5	98.6	100.3	101.8	103.3	104.7	107.0
2005	4.8	18.4	31.4	45.1	52.7	60.8	67.0	72.9	76.8	81.4	85.0	88.6	91.5	94.1	96.6	98.5	100.4	101.9	103.3	104.6	107.3
2006	4.7	14.4	31.2	43.2	54.1	60.4	67.2	72.6	77.8	81.1	85.1	88.4	91.5	94.1	96.4	98.6	100.3	102.0	103.4	104.6	107.6
2007	4.3	14.2	30.4	43.1	52.5	61.6	66.9	72.8	77.4	82.0	84.9	88.5	91.3	94.1	96.4	98.5	100.4	102.0	103.5	104.7	108.1
2008	4.1	12.8	30.1	42.4	52.4	60.2	67.9	72.5	77.6	81.7	85.7	88.3	91.4	93.9	96.4	98.4	100.3	102.0	103.4	104.8	107.3
2009	4.4	12.3	30.6	42.2	51.9	60.2	66.8	73.4	77.4	81.8	85.4	88.9	91.2	94.0	96.3	98.5	100.3	101.9	103.5	104.7	106.7
2010	5.2	13.2	32.1	42.6	51.7	59.7	66.7	72.4	78.1	81.6	85.6	88.7	91.8	93.9	96.3	98.3	100.3	101.9	103.4	104.8	106.7
2011	4.2	15.6	30.3	43.7	52.0	59.6	66.4	72.4	77.3	82.3	85.4	88.8	91.6	94.4	96.2	98.4	100.2	101.9	103.4	104.7	106.9
2012	4.9	12.6	31.5	42.3	53.0	59.8	66.2	72.0	77.2	81.5	86.0	88.7	91.7	94.2	96.6	98.3	100.2	101.8	103.4	104.7	106.5
2013	4.7	14.7	31.1	43.3	51.8	60.6	66.4	71.9	77.0	81.5	85.3	89.2	91.6	94.3	96.5	98.7	100.1	101.9	103.3	104.7	106.9
2014	4.9	14.0	31.6	43.0	52.6	59.7	67.1	72.1	76.9	81.3	85.3	88.6	92.0	94.2	96.6	98.5	100.5	101.8	103.3	104.6	107.1
2015	6.4	14.8	34.3	43.3	52.4	60.3	66.3	72.7	77.0	81.2	85.1	88.6	91.5	94.6	96.5	98.6	100.4	102.1	103.3	104.7	107.2
2016	6.4	19.1	34.3	45.4	52.6	60.1	66.8	72.0	77.5	81.3	85.0	88.4	91.5	94.1	96.8	98.5	100.4	102.0	103.5	104.6	106.6
2017	6.0	19.1	33.5	45.4	54.4	60.3	66.7	72.5	76.9	81.8	85.1	88.3	91.3	94.1	96.4	98.8	100.3	102.1	103.4	104.8	106.9
2018	7.2	17.9	35.9	44.8	54.4	61.8	66.9	72.3	77.3	81.2	85.5	88.4	91.3	93.9	96.4	98.5	100.6	102.0	103.5	104.7	107.2
2019	4.2	21.5	30.3	46.7	53.9	61.8	68.1	72.5	77.2	81.6	85.0	88.8	91.4	93.9	96.3	98.5	100.3	102.2	103.4	104.8	106.7
2020	5.4	16.1	31.5	42.4	55.4	61.4	68.1	73.6	77.4	81.5	85.3	88.4	91.7	94.0	96.2	98.3	100.3	101.9	103.7	104.7	106.8

Table 2.1.19e. Mid-year length (cm) at age (Model 21.3).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	5.3	15.9	32.0	43.7	53.1	60.9	67.6	73.4	78.5	83.0	87.0	90.5	93.7	96.5	99.0	101.3	103.3	105.1	106.8	108.3	112.3
1978	4.9	15.9	31.3	43.7	53.1	60.9	67.6	73.4	78.5	83.0	87.0	90.5	93.7	96.5	99.0	101.3	103.3	105.1	106.8	108.3	112.3
1979	5.4	14.7	32.2	43.1	53.1	60.9	67.6	73.4	78.5	83.0	87.0	90.5	93.7	96.5	99.0	101.3	103.3	105.1	106.8	108.3	112.1
1980	4.9	16.1	31.3	43.8	52.6	60.9	67.6	73.4	78.5	83.0	87.0	90.5	93.7	96.5	99.0	101.3	103.3	105.1	106.8	108.3	112.0
1981	4.2	14.8	29.9	43.1	53.1	60.5	67.6	73.4	78.5	83.0	87.0	90.5	93.7	96.5	99.0	101.3	103.3	105.1	106.8	108.3	111.9
1982	4.3	12.5	30.1	42.1	52.6	61.0	67.3	73.4	78.5	83.0	87.0	90.5	93.7	96.5	99.0	101.3	103.3	105.1	106.8	108.3	111.9
1983	6.2	12.9	33.7	42.2	51.7	60.5	67.7	73.1	78.5	83.0	87.0	90.5	93.7	96.5	99.0	101.3	103.3	105.1	106.8	108.3	111.9
1984	5.3	18.5	32.0	45.0	51.8	59.8	67.3	73.5	78.3	83.0	87.0	90.5	93.7	96.5	99.0	101.3	103.3	105.1	106.8	108.3	111.9
1985	3.9	15.9	29.5	43.7	54.1	59.9	66.6	73.1	78.6	82.8	87.0	90.5	93.7	96.5	99.0	101.3	103.3	105.1	106.8	108.3	112.0
1986	5.1	11.7	31.7	41.7	53.1	61.8	66.7	72.6	78.3	83.1	86.8	90.5	93.7	96.5	99.0	101.3	103.3	105.1	106.8	108.3	112.0
1987	4.7	15.3	30.8	43.4	51.4	60.9	68.4	72.7	77.8	82.8	87.0	90.3	93.7	96.5	99.0	101.3	103.3	105.1	106.8	108.3	112.1
1988	4.4	13.9	30.3	42.7	52.8	59.5	67.6	74.1	77.9	82.4	86.8	90.6	93.5	96.5	99.0	101.3	103.3	105.1	106.8	108.3	112.2
1989	4.4	13.2	30.4	42.4	52.3	60.7	66.4	73.4	79.1	82.4	86.4	90.3	93.7	96.3	99.0	101.3	103.3	105.1	106.8	108.3	112.3
1990	5.0	13.3	31.4	42.4	52.0	60.2	67.4	72.4	78.5	83.6	86.5	90.0	93.5	96.5	98.9	101.3	103.3	105.1	106.8	108.3	112.3
1991	5.6	15.0	32.5	43.2	52.0	60.0	67.0	73.3	77.6	83.0	87.5	90.1	93.2	96.3	99.0	101.2	103.3	105.1	106.8	108.3	112.3
1992	5.0	16.7	31.4	44.1	52.7	60.0	66.8	72.9	78.4	82.2	87.0	91.0	93.3	96.1	98.9	101.3	103.2	105.1	106.8	108.3	112.2
1993	5.2	14.9	31.8	43.2	53.4	60.6	66.9	72.7	78.1	82.9	86.3	90.5	94.1	96.1	98.6	101.2	103.3	105.0	106.8	108.3	111.9
1994	5.0	15.5	31.4	43.5	52.6	61.2	67.3	72.8	77.9	82.6	86.9	89.9	93.7	96.8	98.7	100.9	103.2	105.1	106.7	108.3	111.4
1995	4.9	14.9	31.2	43.2	52.9	60.5	67.8	73.2	78.0	82.5	86.6	90.4	93.1	96.5	99.3	101.0	103.0	105.0	106.8	108.2	111.5
1996	4.9	14.6	31.3	43.0	52.6	60.8	67.3	73.6	78.3	82.5	86.5	90.2	93.6	96.0	99.0	101.5	103.0	104.9	106.7	108.3	110.9
1997	4.9	14.8	31.2	43.1	52.5	60.6	67.5	73.2	78.7	82.8	86.5	90.1	93.4	96.4	98.6	101.3	103.6	104.9	106.5	108.2	110.4
1998	4.5	14.6	30.5	43.0	52.6	60.4	67.3	73.3	78.3	83.2	86.8	90.1	93.3	96.2	98.9	100.9	103.3	105.4	106.6	108.0	110.7
1999	4.1	13.4	29.8	42.5	52.5	60.5	67.2	73.2	78.4	82.8	87.1	90.4	93.3	96.2	98.8	101.2	102.9	105.1	107.0	108.1	111.0
2000	5.5	12.4	32.5	42.0	52.1	60.4	67.3	73.1	78.3	82.9	86.8	90.6	93.5	96.2	98.7	101.1	103.2	104.8	106.8	108.4	111.9
2001	5.3	16.6	31.9	44.0	51.6	60.1	67.2	73.1	78.2	82.8	86.9	90.4	93.8	96.4	98.7	101.0	103.1	105.1	106.5	108.3	112.4
2002	5.5	15.8	32.4	43.6	53.3	59.7	66.9	73.1	78.3	82.8	86.8	90.5	93.5	96.6	98.9	101.0	103.1	105.0	106.7	108.0	111.7
2003	5.1	16.5	31.6	44.0	53.0	61.1	66.6	72.8	78.2	82.8	86.8	90.4	93.6	96.4	99.1	101.2	103.1	104.9	106.6	108.2	112.3
2004	6.1	15.2	33.5	43.3	53.3	60.8	67.8	72.5	78.0	82.8	86.8	90.3	93.5	96.4	98.9	101.3	103.2	104.9	106.6	108.1	111.8
2005	4.9	18.2	31.2	44.9	52.8	61.1	67.6	73.6	77.7	82.5	86.8	90.4	93.5	96.4	99.0	101.2	103.4	105.1	106.6	108.1	112.1
2006	4.8	14.6	31.0	43.0	54.0	60.7	67.8	73.4	78.7	82.3	86.6	90.3	93.5	96.3	98.9	101.2	103.2	105.2	106.7	108.1	112.5
2007	4.4	14.3	30.2	42.9	52.5	61.7	67.4	73.6	78.5	83.2	86.4	90.1	93.5	96.4	98.9	101.2	103.3	105.0	106.8	108.2	113.1
2008	4.2	13.1	30.0	42.3	52.4	60.4	68.3	73.3	78.7	83.0	87.1	90.0	93.3	96.3	98.9	101.1	103.2	105.1	106.7	108.3	112.6
2009	4.4	12.7	30.4	42.1	51.9	60.4	67.2	74.1	78.4	83.1	87.0	90.6	93.2	96.2	98.9	101.2	103.2	105.0	106.7	108.2	111.6
2010	5.2	13.2	31.8	42.4	51.8	59.9	67.1	73.1	79.1	82.9	87.1	90.5	93.8	96.1	98.7	101.1	103.2	105.0	106.7	108.2	111.2
2011	4.3	15.6	30.1	43.5	52.0	59.8	66.8	73.0	78.2	83.5	86.9	90.6	93.7	96.6	98.6	101.0	103.2	105.0	106.7	108.2	111.5
2012	5.2	12.9	31.9	42.2	52.9	60.0	66.7	72.7	78.2	82.7	87.4	90.4	93.8	96.5	99.1	100.9	103.1	105.0	106.7	108.2	110.7
2013	4.8	15.7	31.1	43.6	51.8	60.8	66.8	72.6	77.9	82.7	86.8	90.9	93.6	96.6	99.0	101.3	103.0	104.9	106.7	108.2	111.1
2014	5.1	14.4	31.6	42.9	53.0	59.9	67.5	72.8	77.8	82.5	86.7	90.3	94.0	96.4	99.1	101.3	103.4	104.8	106.6	108.2	111.4
2015	6.5	15.3	34.4	43.4	52.4	60.8	66.7	73.4	77.9	82.4	86.5	90.3	93.5	96.8	98.9	101.3	103.3	105.2	106.5	108.1	111.5
2016	6.7	19.5	34.8	45.6	52.8	60.4	67.5	72.7	78.5	82.5	86.4	90.1	93.5	96.3	99.3	101.2	103.4	105.1	106.8	108.0	110.6
2017	6.1	20.1	33.5	45.9	54.6	60.7	67.2	73.4	77.9	83.0	86.5	90.0	93.3	96.3	98.9	101.5	103.2	105.2	106.8	108.3	111.0
2018	7.1	18.2	35.8	44.8	54.9	62.2	67.4	73.0	78.5	82.4	86.9	90.1	93.2	96.1	98.8	101.1	103.5	105.1	106.8	108.3	111.5
2019	4.2	21.4	30.0	46.6	54.0	62.4	68.8	73.3	78.2	83.0	86.5	90.5	93.3	96.1	98.7	101.1	103.2	105.3	106.7	108.3	111.2
2020	5.3	15.9	31.5	42.1	55.5	61.7	68.9	74.4	78.4	82.7	87.0	90.1	93.6	96.2	98.7	101.0	103.2	105.0	107.0	108.2	111.3

Table 2.1.19f. Mid-year length (cm) at age (ensemble).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	5.2	15.7	32.0	43.8	53.2	61.0	67.6	73.3	78.2	82.4	86.1	89.4	92.3	94.8	97.0	99.0	100.7	102.3	103.7	104.9	108.0
1978	4.9	15.7	31.3	43.8	53.2	61.0	67.6	73.3	78.2	82.4	86.1	89.4	92.3	94.8	97.0	99.0	100.7	102.3	103.7	104.9	108.0
1979	5.3	14.6	32.1	43.3	53.2	61.0	67.6	73.3	78.2	82.4	86.1	89.4	92.3	94.8	97.0	99.0	100.7	102.3	103.7	104.9	107.8
1980	4.9	15.9	31.4	43.9	52.8	61.0	67.6	73.3	78.2	82.4	86.1	89.4	92.3	94.8	97.0	99.0	100.7	102.3	103.7	104.9	107.7
1981	4.2	14.7	30.1	43.3	53.3	60.7	67.6	73.3	78.2	82.4	86.1	89.4	92.3	94.8	97.0	99.0	100.7	102.3	103.7	104.9	107.7
1982	4.3	12.6	30.3	42.3	52.8	61.1	67.3	73.3	78.2	82.4	86.1	89.4	92.3	94.8	97.0	99.0	100.7	102.3	103.7	104.9	107.7
1983	5.7	13.0	32.9	42.5	52.0	60.7	67.7	73.0	78.2	82.4	86.1	89.4	92.3	94.8	97.0	99.0	100.7	102.3	103.7	104.9	107.7
1984	5.3	17.0	32.1	44.5	52.2	60.0	67.4	73.3	77.9	82.4	86.1	89.4	92.3	94.8	97.0	99.0	100.7	102.3	103.7	104.9	107.7
1985	3.9	15.8	29.6	43.9	53.8	60.2	66.8	73.0	78.2	82.2	86.1	89.4	92.3	94.8	97.0	99.0	100.7	102.3	103.7	104.9	107.7
1986	5.1	11.8	31.7	42.0	53.3	61.5	66.9	72.6	78.0	82.5	86.0	89.4	92.3	94.8	97.0	99.0	100.7	102.3	103.7	104.9	107.8
1987	4.6	15.2	30.8	43.6	51.7	61.1	68.0	72.6	77.5	82.2	86.2	89.2	92.3	94.8	97.0	99.0	100.7	102.3	103.7	104.9	107.8
1988	4.3	13.7	30.3	42.8	53.0	59.8	67.7	73.6	77.6	81.9	86.0	89.4	92.1	94.8	97.0	99.0	100.7	102.3	103.7	104.9	107.9
1989	4.4	13.0	30.4	42.5	52.4	60.9	66.6	73.3	78.5	81.9	85.6	89.2	92.3	94.6	97.0	99.0	100.7	102.3	103.7	104.9	107.9
1990	4.9	13.2	31.3	42.6	52.2	60.4	67.5	72.4	78.2	82.7	85.7	89.0	92.1	94.8	96.9	99.0	100.7	102.3	103.7	104.9	108.0
1991	5.3	14.6	32.2	43.3	52.2	60.2	67.1	73.2	77.4	82.4	86.4	89.0	91.9	94.7	97.0	98.9	100.7	102.3	103.7	104.9	108.0
1992	5.0	16.0	31.5	44.0	52.8	60.2	66.9	72.8	78.1	81.7	86.2	89.6	91.9	94.4	96.9	99.0	100.6	102.3	103.7	104.9	107.9
1993	5.3	14.9	32.2	43.4	53.4	60.7	66.9	72.6	77.8	82.3	85.5	89.4	92.4	94.5	96.7	98.9	100.7	102.2	103.7	104.9	107.6
1994	4.8	15.9	31.3	43.9	52.9	61.2	67.3	72.7	77.6	82.1	86.0	88.8	92.3	94.9	96.7	98.7	100.6	102.3	103.6	104.9	107.3
1995	4.8	14.5	31.1	43.2	53.3	60.8	67.7	73.0	77.6	81.9	85.8	89.3	91.8	94.8	97.1	98.7	100.5	102.2	103.7	104.8	107.4
1996	4.9	14.3	31.4	43.1	52.8	61.1	67.4	73.4	77.9	82.0	85.7	89.1	92.2	94.4	97.0	99.1	100.5	102.1	103.6	104.9	106.9
1997	4.7	14.7	31.1	43.3	52.7	60.6	67.7	73.1	78.3	82.2	85.7	89.0	92.0	94.7	96.6	99.0	100.8	102.1	103.5	104.8	106.6
1998	4.4	14.2	30.5	43.1	52.8	60.6	67.3	73.3	78.0	82.5	86.0	89.0	91.9	94.6	96.9	98.6	100.7	102.4	103.5	104.7	106.9
1999	4.1	13.3	29.9	42.7	52.6	60.7	67.2	73.0	78.2	82.3	86.2	89.2	91.9	94.5	96.8	98.9	100.4	102.3	103.8	104.7	107.0
2000	5.6	12.2	32.7	42.1	52.3	60.5	67.4	73.0	77.9	82.5	86.0	89.4	92.1	94.5	96.7	98.8	100.7	102.0	103.7	105.0	107.7
2001	5.2	16.7	32.0	44.3	51.9	60.3	67.2	73.0	77.9	82.2	86.2	89.3	92.3	94.6	96.8	98.7	100.6	102.2	103.4	104.9	108.1
2002	5.5	15.6	32.5	43.8	53.7	59.9	67.0	72.9	78.0	82.2	85.9	89.4	92.1	94.8	96.9	98.8	100.5	102.1	103.6	104.7	107.4
2003	5.1	16.4	31.7	44.2	53.2	61.4	66.7	72.7	77.9	82.2	85.9	89.2	92.3	94.7	97.0	98.9	100.5	102.1	103.5	104.9	107.8
2004	6.1	15.2	33.7	43.6	53.5	61.0	68.0	72.5	77.7	82.2	86.0	89.2	92.1	94.8	96.9	99.0	100.6	102.1	103.5	104.8	107.4
2005	4.8	18.3	31.3	45.1	53.0	61.3	67.6	73.6	77.5	82.0	85.9	89.2	92.1	94.6	97.0	98.9	100.8	102.2	103.5	104.7	107.7
2006	4.7	14.5	31.1	43.2	54.3	60.9	67.8	73.3	78.4	81.8	85.8	89.2	92.1	94.6	96.9	99.0	100.7	102.3	103.6	104.8	108.0
2007	4.2	14.2	30.1	43.1	52.8	62.0	67.5	73.5	78.2	82.6	85.6	89.1	92.1	94.7	96.9	98.9	100.7	102.2	103.7	104.8	108.5
2008	4.1	12.7	29.9	42.4	52.6	60.6	68.4	73.2	78.3	82.4	86.3	88.9	92.0	94.6	96.9	98.8	100.6	102.3	103.6	104.9	107.9
2009	4.5	12.4	30.5	42.2	52.1	60.5	67.3	74.0	78.1	82.6	86.1	89.5	91.8	94.5	96.9	98.9	100.6	102.2	103.7	104.8	107.2
2010	5.2	13.4	31.9	42.7	51.9	60.1	67.2	73.0	78.8	82.3	86.3	89.4	92.4	94.4	96.8	98.8	100.6	102.2	103.6	104.9	107.0
2011	4.2	15.6	30.1	43.8	52.3	59.9	66.8	72.9	77.9	82.9	86.1	89.5	92.2	94.9	96.7	98.8	100.6	102.2	103.6	104.8	107.2
2012	5.1	12.6	31.8	42.3	53.2	60.3	66.7	72.6	77.9	82.2	86.6	89.3	92.3	94.8	97.1	98.7	100.5	102.2	103.6	104.8	106.7
2013	4.7	15.3	31.1	43.6	52.0	61.0	67.0	72.5	77.6	82.2	85.9	89.8	92.2	94.8	97.0	99.1	100.5	102.1	103.6	104.8	107.1
2014	5.1	14.2	31.8	43.1	53.1	60.0	67.6	72.7	77.5	81.9	85.9	89.2	92.6	94.7	97.1	99.0	100.8	102.0	103.5	104.8	107.3
2015	6.4	15.3	34.4	43.6	52.6	60.9	66.8	73.3	77.7	81.8	85.7	89.2	92.1	95.1	96.9	99.0	100.7	102.3	103.5	104.8	107.3
2016	6.5	19.3	34.6	45.7	53.1	60.5	67.5	72.6	78.2	82.0	85.6	89.0	92.1	94.6	97.3	98.9	100.8	102.3	103.7	104.7	106.7
2017	6.0	19.5	33.5	45.8	54.8	60.9	67.2	73.2	77.5	82.4	85.8	88.9	91.9	94.6	96.9	99.2	100.7	102.3	103.7	104.9	107.0
2018	7.1	18.0	35.9	45.0	54.9	62.3	67.5	72.9	78.1	81.9	86.1	89.1	91.8	94.4	96.9	98.9	100.9	102.2	103.7	104.9	107.3
2019	4.2	21.4	30.1	46.9	54.2	62.4	68.7	73.2	77.9	82.4	85.6	89.4	92.0	94.4	96.7	98.8	100.6	102.5	103.6	104.9	107.0

Table 2.1.20a. Mid-year weight (kg) at age in the fishery (Model 19.12a).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.01	0.08	0.59	1.38	2.31	3.29	4.26	5.24	6.27	7.34	8.39	9.39	10.34	11.22	12.03	12.77	13.44	14.04	14.58	15.06	16.18
1978	0.00	0.06	0.49	1.30	2.26	3.30	4.33	5.41	6.56	7.76	8.95	10.10	11.19	12.21	13.15	14.01	14.80	15.51	16.15	16.72	18.05
1979	0.01	0.06	0.57	1.31	2.29	3.27	4.24	5.24	6.28	7.36	8.43	9.45	10.40	11.30	12.12	12.87	13.55	14.16	14.71	15.20	16.28
1980	0.00	0.07	0.51	1.30	2.17	3.18	4.15	5.14	6.18	7.26	8.33	9.35	10.32	11.22	12.05	12.81	13.50	14.12	14.68	15.17	16.23
1981	0.00	0.06	0.46	1.24	2.18	3.08	4.09	5.06	6.09	7.14	8.18	9.17	10.11	10.98	11.78	12.52	13.18	13.78	14.32	14.80	15.79
1982	0.00	0.04	0.54	1.31	2.33	3.36	4.28	5.32	6.37	7.44	8.49	9.51	10.46	11.34	12.15	12.90	13.57	14.18	14.72	15.21	16.20
1983	0.01	0.04	0.60	1.29	2.23	3.33	4.40	5.39	6.54	7.67	8.79	9.87	10.88	11.82	12.69	13.49	14.21	14.86	15.45	15.97	17.04
1984	0.01	0.10	0.60	1.36	2.09	2.94	3.87	4.77	5.60	6.53	7.39	8.22	8.98	9.69	10.34	10.93	11.47	11.95	12.38	12.76	13.55
1985	0.00	0.07	0.47	1.39	2.39	3.28	4.30	5.45	6.64	7.74	8.96	10.08	11.13	12.12	13.03	13.86	14.62	15.31	15.92	16.47	17.61
1986	0.00	0.03	0.51	1.18	2.29	3.38	4.29	5.36	6.63	7.92	9.06	10.29	11.40	12.43	13.39	14.26	15.06	15.78	16.43	17.01	18.22
1987	0.00	0.06	0.52	1.36	2.19	3.36	4.39	5.27	6.34	7.57	8.74	9.76	10.82	11.77	12.64	13.44	14.17	14.82	15.41	15.93	17.04
1988	0.01	0.04	0.43	1.21	2.25	3.19	4.51	5.70	6.75	8.00	9.37	10.64	11.72	12.85	13.84	14.75	15.57	16.32	16.99	17.59	18.88
1989	0.00	0.04	0.48	1.27	2.29	3.45	4.41	5.75	6.99	8.05	9.26	10.56	11.74	12.72	13.74	14.63	15.43	16.16	16.81	17.39	18.67
1990	0.00	0.05	0.57	1.33	2.29	3.36	4.47	5.38	6.68	7.84	8.80	9.86	10.97	11.96	12.78	13.63	14.35	15.00	15.59	16.11	17.27
1991	0.01	0.06	0.58	1.31	2.18	3.13	4.12	5.16	6.03	7.26	8.32	9.16	10.09	11.04	11.88	12.57	13.27	13.87	14.41	14.88	15.94
1992	0.00	0.07	0.53	1.31	2.16	3.04	3.96	4.93	6.00	6.89	8.10	9.11	9.90	10.76	11.64	12.41	13.03	13.66	14.20	14.68	15.70
1993	0.01	0.07	0.60	1.37	2.39	3.38	4.36	5.41	6.55	7.76	8.73	9.98	11.02	11.81	12.67	13.53	14.28	14.88	15.49	16.00	17.00
1994	0.00	0.08	0.52	1.35	2.23	3.25	4.18	5.12	6.16	7.28	8.43	9.32	10.46	11.39	12.10	12.86	13.62	14.28	14.81	15.34	16.18
1995	0.00	0.05	0.49	1.25	2.26	3.22	4.27	5.25	6.28	7.41	8.57	9.73	10.61	11.73	12.64	13.32	14.05	14.78	15.40	15.90	16.87
1996	0.01	0.06	0.61	1.39	2.31	3.32	4.20	5.17	6.08	6.99	7.95	8.90	9.82	10.51	11.37	12.06	12.57	13.12	13.65	14.11	14.74
1997	0.01	0.06	0.49	1.23	2.08	3.01	4.02	4.92	5.96	6.92	7.85	8.81	9.74	10.63	11.30	12.13	12.79	13.28	13.80	14.31	14.89
1998	0.00	0.06	0.49	1.26	2.14	3.03	3.94	4.93	5.85	6.88	7.80	8.67	9.55	10.40	11.21	11.81	12.54	13.12	13.55	14.00	14.72
1999	0.00	0.05	0.48	1.26	2.21	3.18	4.10	5.07	6.17	7.15	8.22	9.15	10.02	10.88	11.70	12.48	13.05	13.75	14.29	14.69	15.50
2000	0.01	0.04	0.65	1.31	2.30	3.35	4.35	5.34	6.41	7.60	8.62	9.70	10.62	11.47	12.31	13.11	13.85	14.40	15.06	15.57	16.58
2001	0.01	0.10	0.61	1.47	2.22	3.21	4.19	5.14	6.11	7.15	8.27	9.19	10.15	10.96	11.70	12.41	13.09	13.71	14.16	14.71	15.79
2002	0.01	0.07	0.58	1.34	2.33	3.10	4.09	5.08	6.12	7.18	8.27	9.40	10.31	11.25	12.03	12.74	13.42	14.06	14.65	15.08	15.97
2003	0.00	0.08	0.53	1.34	2.24	3.29	4.06	5.11	6.22	7.34	8.41	9.47	10.55	11.42	12.30	13.04	13.71	14.35	14.94	15.49	16.52
2004	0.01	0.07	0.65	1.33	2.29	3.23	4.25	5.01	6.08	7.19	8.24	9.22	10.16	11.10	11.86	12.62	13.25	13.81	14.35	14.84	15.67
2005	0.00	0.11	0.52	1.44	2.25	3.31	4.27	5.37	6.22	7.38	8.53	9.61	10.58	11.52	12.44	13.18	13.92	14.53	15.07	15.59	16.60
2006	0.00	0.06	0.53	1.32	2.42	3.26	4.30	5.27	6.39	7.24	8.35	9.42	10.40	11.27	12.11	12.93	13.58	14.22	14.75	15.21	16.30
2007	0.00	0.05	0.49	1.32	2.28	3.46	4.32	5.41	6.45	7.63	8.49	9.59	10.64	11.58	12.41	13.21	13.98	14.58	15.18	15.66	16.94
2008	0.00	0.04	0.49	1.25	2.23	3.22	4.34	5.17	6.25	7.29	8.42	9.22	10.23	11.17	12.01	12.75	13.43	14.10	14.62	15.13	16.05
2009	0.00	0.03	0.53	1.28	2.23	3.30	4.27	5.44	6.36	7.56	8.65	9.82	10.63	11.64	12.58	13.40	14.12	14.79	15.43	15.93	16.71
2010	0.00	0.03	0.60	1.33	2.22	3.19	4.19	5.15	6.37	7.31	8.46	9.48	10.53	11.26	12.15	12.98	13.69	14.32	14.89	15.45	16.15
2011	0.00	0.05	0.50	1.38	2.22	3.12	4.07	5.09	6.13	7.40	8.30	9.38	10.31	11.26	11.92	12.72	13.45	14.09	14.64	15.14	15.97
2012	0.00	0.04	0.58	1.25	2.24	3.07	3.92	4.84	5.86	6.86	8.01	8.80	9.72	10.50	11.30	11.83	12.49	13.08	13.59	14.03	14.61
2013	0.00	0.06	0.51	1.30	2.11	3.20	4.06	4.98	6.02	7.18	8.28	9.50	10.33	11.29	12.10	12.91	13.46	14.13	14.72	15.24	16.05
2014	0.00	0.03	0.54	1.27	2.23	3.08	4.14	5.01	5.99	7.10	8.29	9.38	10.57	11.36	12.28	13.04	13.81	14.32	14.94	15.49	16.42
2015	0.00	0.04	0.65	1.30	2.16	3.14	3.96	5.03	5.96	6.98	8.07	9.20	10.20	11.29	12.01	12.84	13.52	14.20	14.65	15.20	16.15
2016	0.00	0.09	0.67	1.49	2.26	3.17	4.15	5.01	6.19	7.18	8.21	9.28	10.35	11.30	12.32	12.99	13.74	14.37	14.98	15.39	16.12
2017	0.00	0.10	0.63	1.50	2.45	3.25	4.17	5.22	6.16	7.43	8.43	9.45	10.50	11.53	12.43	13.39	14.01	14.72	15.29	15.86	16.64
2018	0.01	0.09	0.74	1.42	2.42	3.40	4.19	5.14	6.24	7.20	8.43	9.37	10.31	11.25	12.17	12.96	13.79	14.33	14.93	15.42	16.32
2019	0.00	0.16	0.47	1.58	2.38	3.46	4.45	5.29	6.32	7.51	8.51	9.76	10.70	11.61	12.52	13.41	14.16	14.95	15.46	16.02	16.79
2020	0.00	0.03	0.49	1.15	2.42	3.22	4.26	5.27	6.13	7.16	8.30	9.22	10.35	11.18	11.99	12.79	13.56	14.22	14.89	15.33	16.15

Table 2.1.20b. Mid-year weight (kg) at age in the fishery (Model 19.12).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.01	0.08	0.58	1.36	2.28	3.26	4.26	5.31	6.40	7.52	8.61	9.62	10.52	11.30	11.96	12.52	13.00	13.42	13.79	14.11	14.77
1978	0.00	0.06	0.49	1.28	2.23	3.26	4.34	5.49	6.71	7.96	9.20	10.36	11.39	12.29	13.06	13.71	14.28	14.77	15.20	15.58	16.36
1979	0.01	0.06	0.57	1.29	2.25	3.24	4.25	5.31	6.42	7.55	8.65	9.68	10.59	11.37	12.05	12.62	13.11	13.53	13.90	14.23	14.86
1980	0.00	0.07	0.51	1.28	2.13	3.15	4.15	5.20	6.31	7.44	8.55	9.58	10.50	11.29	11.97	12.55	13.05	13.48	13.85	14.19	14.79
1981	0.00	0.06	0.45	1.22	2.15	3.05	4.09	5.13	6.21	7.32	8.40	9.40	10.29	11.06	11.71	12.27	12.75	13.16	13.53	13.85	14.42
1982	0.00	0.04	0.53	1.28	2.28	3.33	4.28	5.39	6.49	7.62	8.72	9.73	10.64	11.42	12.08	12.65	13.14	13.56	13.92	14.25	14.83
1983	0.01	0.04	0.63	1.27	2.19	3.29	4.40	5.44	6.66	7.85	9.02	10.10	11.07	11.90	12.61	13.22	13.74	14.19	14.59	14.94	15.56
1984	0.01	0.12	0.59	1.38	2.05	2.90	3.86	4.81	5.68	6.67	7.57	8.40	9.13	9.76	10.29	10.75	11.13	11.47	11.76	12.02	12.48
1985	0.00	0.07	0.47	1.36	2.40	3.23	4.28	5.50	6.77	7.92	9.20	10.33	11.33	12.20	12.94	13.58	14.12	14.60	15.01	15.38	16.05
1986	0.00	0.03	0.50	1.15	2.25	3.39	4.27	5.42	6.77	8.12	9.31	10.55	11.60	12.51	13.29	13.96	14.53	15.03	15.46	15.85	16.57
1987	0.00	0.06	0.52	1.33	2.13	3.31	4.45	5.31	6.45	7.74	8.97	9.99	11.01	11.85	12.56	13.17	13.69	14.14	14.54	14.89	15.56
1988	0.01	0.05	0.43	1.19	2.21	3.15	4.51	5.85	6.88	8.19	9.62	10.91	11.93	12.94	13.74	14.43	15.02	15.54	15.99	16.39	17.18
1989	0.00	0.04	0.48	1.25	2.26	3.41	4.39	5.80	7.19	8.22	9.49	10.81	11.94	12.81	13.65	14.32	14.90	15.40	15.84	16.23	17.02
1990	0.00	0.05	0.57	1.31	2.26	3.32	4.45	5.40	6.77	8.07	8.99	10.08	11.15	12.04	12.71	13.35	13.88	14.33	14.72	15.08	15.80
1991	0.01	0.06	0.58	1.30	2.14	3.09	4.11	5.20	6.12	7.42	8.58	9.37	10.26	11.11	11.81	12.33	12.84	13.25	13.62	13.94	14.60
1992	0.00	0.07	0.52	1.30	2.12	3.00	3.95	4.99	6.12	7.05	8.31	9.39	10.08	10.84	11.57	12.16	12.61	13.05	13.41	13.73	14.37
1993	0.01	0.07	0.58	1.34	2.36	3.34	4.35	5.47	6.68	7.95	8.94	10.22	11.25	11.90	12.60	13.27	13.82	14.23	14.65	14.99	15.60
1994	0.01	0.07	0.52	1.30	2.18	3.22	4.18	5.17	6.28	7.45	8.65	9.54	10.64	11.51	12.04	12.62	13.18	13.64	13.99	14.35	14.83
1995	0.00	0.06	0.49	1.23	2.19	3.17	4.28	5.32	6.41	7.59	8.80	9.97	10.80	11.81	12.59	13.06	13.59	14.10	14.52	14.85	15.40
1996	0.01	0.07	0.61	1.37	2.28	3.26	4.18	5.21	6.16	7.13	8.13	9.09	9.97	10.58	11.31	11.86	12.20	12.58	12.94	13.26	13.57
1997	0.01	0.06	0.50	1.21	2.06	2.99	4.00	4.96	6.07	7.07	8.04	9.01	9.91	10.70	11.25	11.89	12.39	12.70	13.05	13.40	13.64
1998	0.00	0.06	0.50	1.24	2.11	3.01	3.95	4.96	5.94	7.04	7.99	8.88	9.72	10.48	11.14	11.59	12.14	12.56	12.82	13.12	13.47
1999	0.00	0.05	0.49	1.25	2.18	3.15	4.11	5.14	6.25	7.31	8.44	9.37	10.20	10.96	11.65	12.24	12.65	13.14	13.53	13.78	14.20
2000	0.01	0.04	0.64	1.30	2.27	3.32	4.36	5.41	6.54	7.74	8.83	9.94	10.81	11.57	12.26	12.87	13.41	13.79	14.25	14.61	15.18
2001	0.01	0.09	0.61	1.44	2.19	3.18	4.21	5.23	6.28	7.37	8.48	9.43	10.35	11.05	11.65	12.20	12.69	13.12	13.42	13.80	14.47
2002	0.01	0.08	0.58	1.31	2.27	3.07	4.12	5.22	6.34	7.45	8.57	9.64	10.52	11.35	11.98	12.51	13.01	13.45	13.85	14.13	14.72
2003	0.00	0.08	0.52	1.32	2.20	3.23	4.06	5.17	6.36	7.53	8.65	9.72	10.71	11.49	12.23	12.79	13.26	13.71	14.11	14.48	15.18
2004	0.01	0.07	0.64	1.30	2.26	3.19	4.24	5.07	6.20	7.36	8.46	9.45	10.35	11.16	11.79	12.38	12.83	13.22	13.58	13.91	14.48
2005	0.00	0.11	0.52	1.41	2.21	3.27	4.27	5.41	6.33	7.55	8.75	9.83	10.77	11.60	12.34	12.92	13.46	13.88	14.24	14.59	15.28
2006	0.00	0.06	0.53	1.30	2.37	3.22	4.29	5.31	6.47	7.38	8.54	9.64	10.57	11.36	12.05	12.65	13.13	13.59	13.94	14.25	15.01
2007	0.00	0.05	0.51	1.31	2.25	3.43	4.31	5.46	6.55	7.77	8.69	9.81	10.82	11.65	12.35	12.95	13.49	13.92	14.34	14.66	15.57
2008	0.00	0.04	0.49	1.25	2.20	3.18	4.36	5.25	6.41	7.49	8.64	9.46	10.43	11.26	11.94	12.51	13.01	13.46	13.81	14.16	14.87
2009	0.00	0.03	0.52	1.26	2.20	3.26	4.30	5.57	6.56	7.82	8.94	10.07	10.85	11.75	12.51	13.14	13.66	14.13	14.55	14.89	15.43
2010	0.00	0.03	0.59	1.29	2.17	3.16	4.21	5.26	6.56	7.54	8.73	9.74	10.71	11.36	12.10	12.73	13.24	13.68	14.07	14.43	14.85
2011	0.00	0.05	0.50	1.34	2.15	3.07	4.07	5.15	6.25	7.57	8.51	9.60	10.48	11.32	11.86	12.48	13.01	13.45	13.82	14.16	14.66
2012	0.00	0.04	0.58	1.23	2.20	3.02	3.92	4.90	5.97	7.02	8.21	9.00	9.88	10.57	11.21	11.63	12.11	12.52	12.86	13.16	13.45
2013	0.00	0.06	0.50	1.28	2.07	3.15	4.05	5.05	6.17	7.38	8.51	9.73	10.51	11.36	12.02	12.63	13.03	13.49	13.90	14.24	14.66
2014	0.00	0.04	0.53	1.24	2.18	3.03	4.14	5.08	6.15	7.33	8.54	9.62	10.74	11.44	12.19	12.77	13.31	13.67	14.09	14.46	14.97
2015	0.00	0.04	0.64	1.27	2.11	3.10	3.95	5.10	6.07	7.16	8.31	9.43	10.39	11.34	11.93	12.56	13.05	13.51	13.82	14.18	14.73
2016	0.00	0.10	0.68	1.46	2.20	3.12	4.15	5.06	6.30	7.33	8.43	9.52	10.54	11.38	12.21	12.71	13.26	13.69	14.10	14.37	14.74
2017	0.00	0.10	0.63	1.49	2.41	3.20	4.16	5.27	6.26	7.58	8.63	9.69	10.69	11.61	12.34	13.07	13.52	14.01	14.40	14.77	15.18
2018	0.01	0.10	0.73	1.40	2.40	3.36	4.17	5.18	6.35	7.36	8.63	9.58	10.50	11.34	12.09	12.70	13.30	13.67	14.08	14.41	14.92
2019	0.00	0.16	0.47	1.54	2.34	3.44	4.47	5.35	6.46	7.73	8.76	10.00	10.88	11.72	12.47	13.14	13.68	14.23	14.57	14.95	15.38
2020	0.00	0.04	0.48	1.13	2.37	3.18	4.28	5.33	6.23	7.33	8.52	9.45	10.52	11.25	11.93	12.55	13.11	13.56	14.02	14.31	14.78

Model 2.1.20c. Mid-year weight (kg) at age in the fishery (Model 21.1).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.01	0.07	0.56	1.35	2.29	3.26	4.19	5.09	6.00	6.92	7.83	8.69	9.48	10.18	10.80	11.34	11.82	12.23	12.58	12.88	13.47
1978	0.00	0.06	0.48	1.28	2.24	3.26	4.27	5.24	6.24	7.27	8.30	9.28	10.18	10.99	11.71	12.35	12.90	13.37	13.79	14.14	14.84
1979	0.01	0.06	0.56	1.30	2.26	3.24	4.18	5.08	5.99	6.92	7.84	8.72	9.52	10.23	10.86	11.41	11.90	12.31	12.67	12.98	13.61
1980	0.01	0.07	0.50	1.29	2.16	3.15	4.08	4.99	5.91	6.85	7.77	8.65	9.45	10.16	10.80	11.35	11.84	12.26	12.62	12.93	13.58
1981	0.01	0.06	0.44	1.23	2.18	3.08	4.03	4.93	5.83	6.74	7.64	8.49	9.27	9.96	10.57	11.11	11.58	11.98	12.33	12.64	13.27
1982	0.00	0.05	0.53	1.29	2.32	3.35	4.24	5.18	6.10	7.04	7.96	8.82	9.61	10.31	10.93	11.48	11.95	12.36	12.72	13.02	13.68
1983	0.01	0.05	0.58	1.28	2.22	3.32	4.36	5.28	6.29	7.28	8.25	9.17	10.00	10.75	11.41	11.98	12.49	12.93	13.30	13.63	14.34
1984	0.01	0.10	0.58	1.35	2.09	2.93	3.84	4.69	5.43	6.24	7.00	7.70	8.33	8.90	9.39	9.82	10.20	10.52	10.81	11.05	11.58
1985	0.00	0.07	0.46	1.38	2.39	3.28	4.26	5.33	6.38	7.34	8.38	9.33	10.20	10.98	11.67	12.28	12.81	13.27	13.66	14.01	14.77
1986	0.00	0.03	0.50	1.17	2.29	3.37	4.26	5.24	6.36	7.46	8.45	9.47	10.39	11.21	11.94	12.58	13.14	13.62	14.04	14.40	15.22
1987	0.00	0.07	0.52	1.36	2.18	3.35	4.34	5.15	6.08	7.15	8.17	9.03	9.90	10.65	11.32	11.91	12.41	12.86	13.24	13.57	14.32
1988	0.01	0.05	0.42	1.20	2.26	3.20	4.47	5.56	6.47	7.53	8.72	9.80	10.70	11.58	12.33	13.00	13.57	14.08	14.51	14.89	15.75
1989	0.01	0.05	0.47	1.26	2.30	3.46	4.38	5.63	6.74	7.68	8.72	9.83	10.79	11.57	12.32	12.96	13.52	14.00	14.42	14.79	15.64
1990	0.01	0.05	0.55	1.31	2.29	3.35	4.44	5.30	6.50	7.55	8.39	9.28	10.19	10.96	11.57	12.16	12.66	13.09	13.47	13.79	14.56
1991	0.01	0.06	0.57	1.31	2.18	3.13	4.09	5.07	5.86	6.95	7.87	8.59	9.35	10.10	10.73	11.23	11.70	12.10	12.45	12.75	13.46
1992	0.00	0.07	0.52	1.31	2.16	3.03	3.94	4.83	5.77	6.54	7.59	8.45	9.11	9.79	10.46	11.02	11.46	11.87	12.22	12.52	13.22
1993	0.01	0.07	0.61	1.37	2.40	3.38	4.33	5.30	6.29	7.34	8.16	9.24	10.10	10.74	11.39	12.03	12.56	12.97	13.36	13.68	14.38
1994	0.01	0.09	0.51	1.37	2.24	3.25	4.14	4.99	5.90	6.86	7.85	8.61	9.57	10.31	10.86	11.42	11.96	12.40	12.75	13.07	13.67
1995	0.00	0.06	0.49	1.26	2.30	3.23	4.24	5.12	6.02	7.00	8.00	8.99	9.71	10.61	11.30	11.81	12.32	12.81	13.22	13.53	14.19
1996	0.01	0.07	0.60	1.39	2.31	3.34	4.17	5.09	5.93	6.75	7.60	8.40	9.15	9.69	10.34	10.83	11.19	11.55	11.90	12.18	12.62
1997	0.01	0.06	0.49	1.22	2.09	3.02	4.03	4.85	5.79	6.63	7.45	8.27	9.03	9.73	10.23	10.83	11.29	11.62	11.95	12.26	12.67
1998	0.00	0.06	0.49	1.26	2.14	3.03	3.92	4.86	5.66	6.57	7.36	8.11	8.85	9.52	10.13	10.55	11.07	11.46	11.74	12.01	12.50
1999	0.00	0.05	0.47	1.27	2.22	3.18	4.08	4.98	5.99	6.82	7.75	8.53	9.25	9.95	10.57	11.13	11.53	12.00	12.35	12.60	13.14
2000	0.01	0.04	0.64	1.29	2.30	3.34	4.32	5.24	6.20	7.26	8.12	9.04	9.79	10.47	11.12	11.70	12.22	12.58	13.01	13.33	13.99
2001	0.01	0.10	0.61	1.47	2.21	3.21	4.15	5.00	5.83	6.70	7.67	8.44	9.25	9.90	10.48	11.02	11.51	11.94	12.23	12.59	13.30
2002	0.01	0.08	0.58	1.35	2.34	3.10	4.07	4.96	5.80	6.65	7.56	8.53	9.28	10.05	10.67	11.21	11.71	12.16	12.55	12.83	13.47
2003	0.01	0.08	0.53	1.34	2.26	3.29	4.03	4.99	5.95	6.90	7.82	8.73	9.64	10.32	11.00	11.54	12.01	12.45	12.84	13.19	13.89
2004	0.01	0.07	0.64	1.33	2.30	3.24	4.22	4.93	5.88	6.84	7.75	8.59	9.37	10.13	10.69	11.24	11.68	12.06	12.41	12.72	13.30
2005	0.01	0.11	0.51	1.44	2.26	3.31	4.26	5.27	6.02	7.04	8.04	8.95	9.76	10.50	11.21	11.73	12.24	12.65	13.00	13.32	14.02
2006	0.00	0.06	0.52	1.32	2.43	3.26	4.28	5.21	6.23	6.98	7.96	8.87	9.66	10.35	10.97	11.57	12.00	12.42	12.76	13.05	13.79
2007	0.00	0.06	0.48	1.32	2.29	3.46	4.30	5.33	6.29	7.34	8.08	9.02	9.87	10.60	11.23	11.80	12.34	12.73	13.11	13.40	14.27
2008	0.00	0.04	0.48	1.24	2.23	3.21	4.31	5.07	6.02	6.91	7.88	8.55	9.40	10.15	10.79	11.33	11.82	12.28	12.60	12.92	13.62
2009	0.00	0.03	0.53	1.27	2.23	3.29	4.23	5.26	6.00	6.98	7.90	8.88	9.56	10.40	11.14	11.76	12.28	12.75	13.18	13.49	14.09
2010	0.00	0.03	0.60	1.34	2.21	3.17	4.13	4.97	5.97	6.72	7.68	8.55	9.44	10.03	10.76	11.38	11.90	12.34	12.73	13.09	13.60
2011	0.00	0.05	0.50	1.38	2.23	3.11	4.01	4.94	5.83	6.91	7.68	8.61	9.39	10.16	10.66	11.26	11.78	12.21	12.57	12.89	13.47
2012	0.00	0.04	0.58	1.24	2.24	3.07	3.88	4.72	5.62	6.48	7.48	8.16	8.92	9.55	10.16	10.55	11.02	11.42	11.75	12.03	12.44
2013	0.00	0.07	0.51	1.31	2.11	3.19	4.03	4.84	5.72	6.71	7.64	8.70	9.38	10.16	10.79	11.39	11.77	12.24	12.63	12.95	13.50
2014	0.00	0.04	0.55	1.27	2.24	3.06	4.10	4.89	5.73	6.67	7.69	8.61	9.60	10.23	10.94	11.50	12.04	12.38	12.79	13.14	13.77
2015	0.00	0.04	0.65	1.31	2.16	3.13	3.91	4.90	5.72	6.59	7.53	8.50	9.33	10.20	10.74	11.34	11.82	12.27	12.56	12.91	13.57
2016	0.00	0.10	0.67	1.49	2.27	3.15	4.11	4.88	5.93	6.79	7.67	8.59	9.48	10.24	11.01	11.49	12.02	12.44	12.84	13.09	13.61
2017	0.00	0.10	0.63	1.50	2.45	3.24	4.12	5.11	5.95	7.07	7.95	8.81	9.67	10.49	11.17	11.86	12.28	12.75	13.12	13.47	14.01
2018	0.01	0.10	0.74	1.42	2.43	3.39	4.17	5.04	6.04	6.88	7.95	8.76	9.52	10.26	10.96	11.53	12.11	12.46	12.85	13.15	13.77
2019	0.00	0.16	0.46	1.60	2.40	3.46	4.41	5.17	6.06	7.10	7.94	9.01	9.79	10.52	11.21	11.87	12.40	12.93	13.25	13.61	14.15
2020	0.00	0.04	0.48	1.14	2.44	3.22	4.23	5.16	5.94	6.83	7.83	8.59	9.52	10.19	10.79	11.37	11.91	12.34	12.78	13.05	13.61

Model 2.1.20d. Mid-year weight (kg) at age in the fishery (Model 21.2).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.01	0.08	0.60	1.38	2.30	3.26	4.20	5.14	6.14	7.19	8.25	9.28	10.26	11.18	12.05	12.85	13.58	14.25	14.86	15.40	16.77
1978	0.00	0.07	0.49	1.30	2.24	3.26	4.27	5.30	6.40	7.58	8.78	9.96	11.09	12.17	13.17	14.11	14.97	15.76	16.47	17.12	18.74
1979	0.01	0.06	0.57	1.29	2.27	3.23	4.18	5.13	6.14	7.20	8.27	9.32	10.32	11.26	12.14	12.95	13.70	14.38	14.99	15.55	16.84
1980	0.00	0.07	0.51	1.28	2.13	3.14	4.09	5.05	6.06	7.12	8.19	9.24	10.24	11.19	12.07	12.89	13.65	14.34	14.96	15.52	16.78
1981	0.01	0.06	0.46	1.22	2.13	3.02	4.03	4.97	5.96	7.00	8.05	9.06	10.03	10.95	11.80	12.60	13.33	13.99	14.59	15.14	16.31
1982	0.00	0.04	0.54	1.30	2.29	3.30	4.21	5.24	6.25	7.31	8.37	9.40	10.38	11.31	12.18	12.98	13.72	14.39	15.00	15.55	16.72
1983	0.01	0.04	0.59	1.28	2.20	3.27	4.33	5.29	6.43	7.55	8.67	9.76	10.80	11.79	12.72	13.58	14.37	15.09	15.75	16.34	17.60
1984	0.01	0.10	0.60	1.33	2.06	2.90	3.81	4.68	5.49	6.43	7.30	8.14	8.93	9.67	10.36	11.00	11.59	12.12	12.60	13.03	13.95
1985	0.00	0.07	0.47	1.37	2.34	3.23	4.23	5.34	6.49	7.57	8.82	9.96	11.06	12.09	13.06	13.96	14.79	15.55	16.24	16.86	18.19
1986	0.00	0.03	0.51	1.17	2.26	3.30	4.21	5.25	6.46	7.72	8.87	10.16	11.31	12.39	13.41	14.36	15.24	16.03	16.76	17.42	18.84
1987	0.00	0.06	0.52	1.34	2.16	3.31	4.30	5.16	6.20	7.39	8.57	9.61	10.74	11.74	12.67	13.53	14.32	15.05	15.71	16.30	17.61
1988	0.01	0.04	0.43	1.18	2.20	3.13	4.41	5.55	6.58	7.81	9.18	10.48	11.60	12.81	13.87	14.85	15.75	16.58	17.33	18.01	19.53
1989	0.01	0.04	0.48	1.24	2.24	3.38	4.33	5.63	6.82	7.88	9.10	10.41	11.62	12.66	13.77	14.73	15.61	16.41	17.15	17.81	19.31
1990	0.00	0.05	0.56	1.32	2.25	3.30	4.39	5.30	6.56	7.68	8.65	9.74	10.87	11.91	12.79	13.72	14.51	15.23	15.89	16.48	17.83
1991	0.01	0.06	0.58	1.29	2.14	3.07	4.05	5.07	5.93	7.13	8.17	9.04	10.00	10.99	11.89	12.63	13.42	14.08	14.68	15.22	16.46
1992	0.00	0.07	0.53	1.29	2.12	2.99	3.89	4.82	5.86	6.74	7.95	8.96	9.80	10.71	11.64	12.47	13.16	13.87	14.47	15.01	16.21
1993	0.01	0.07	0.59	1.36	2.35	3.31	4.28	5.28	6.38	7.58	8.56	9.84	10.90	11.75	12.67	13.59	14.41	15.09	15.78	16.36	17.53
1994	0.00	0.08	0.52	1.33	2.20	3.20	4.10	5.01	6.00	7.10	8.26	9.18	10.36	11.32	12.10	12.92	13.75	14.48	15.08	15.69	16.67
1995	0.00	0.05	0.49	1.24	2.22	3.16	4.19	5.13	6.13	7.23	8.40	9.58	10.51	11.69	12.63	13.39	14.19	14.99	15.69	16.26	17.39
1996	0.01	0.06	0.61	1.38	2.28	3.27	4.13	5.08	5.96	6.88	7.82	8.78	9.74	10.46	11.38	12.11	12.69	13.29	13.88	14.40	15.13
1997	0.01	0.06	0.45	1.19	2.03	2.95	3.94	4.83	5.84	6.78	7.72	8.68	9.65	10.59	11.31	12.20	12.91	13.47	14.05	14.62	15.29
1998	0.00	0.04	0.49	1.18	2.08	2.96	3.86	4.84	5.73	6.75	7.66	8.56	9.46	10.35	11.22	11.86	12.67	13.30	13.79	14.30	15.13
1999	0.00	0.05	0.48	1.24	2.10	3.10	4.02	4.97	6.03	7.00	8.08	9.01	9.92	10.82	11.70	12.54	13.17	13.94	14.54	15.01	15.94
2000	0.01	0.04	0.63	1.28	2.26	3.22	4.25	5.18	6.20	7.36	8.41	9.53	10.49	11.40	12.30	13.16	13.98	14.59	15.33	15.90	17.08
2001	0.01	0.09	0.61	1.46	2.20	3.19	4.03	4.90	5.76	6.77	7.92	8.92	9.97	10.84	11.65	12.44	13.18	13.89	14.40	15.02	16.27
2002	0.01	0.07	0.58	1.32	2.29	3.06	4.01	4.83	5.81	6.84	7.96	9.14	10.13	11.15	11.99	12.77	13.53	14.24	14.91	15.39	16.43
2003	0.00	0.07	0.56	1.37	2.25	3.27	4.00	4.91	5.82	6.97	8.08	9.21	10.36	11.31	12.27	13.07	13.82	14.53	15.20	15.83	17.02
2004	0.01	0.06	0.68	1.36	2.31	3.21	4.18	4.89	5.89	6.88	8.02	9.03	10.03	11.03	11.84	12.68	13.36	13.99	14.59	15.16	16.11
2005	0.00	0.11	0.54	1.46	2.25	3.28	4.21	5.28	6.11	7.25	8.32	9.47	10.48	11.46	12.45	13.25	14.06	14.73	15.35	15.92	17.10
2006	0.00	0.06	0.54	1.31	2.38	3.21	4.23	5.17	6.28	7.12	8.24	9.24	10.31	11.23	12.12	13.00	13.71	14.43	15.01	15.54	16.80
2007	0.00	0.06	0.49	1.29	2.22	3.38	4.23	5.30	6.32	7.49	8.36	9.49	10.48	11.53	12.42	13.27	14.11	14.79	15.46	16.00	17.50
2008	0.00	0.05	0.47	1.22	2.16	3.13	4.27	5.10	6.17	7.18	8.31	9.13	10.17	11.08	12.02	12.81	13.57	14.30	14.88	15.46	16.53
2009	0.00	0.04	0.48	1.20	2.13	3.17	4.18	5.39	6.29	7.46	8.53	9.71	10.56	11.62	12.53	13.47	14.26	15.00	15.72	16.29	17.19
2010	0.00	0.04	0.56	1.24	2.10	3.08	4.07	5.01	6.20	7.11	8.27	9.30	10.41	11.19	12.16	12.98	13.82	14.52	15.17	15.79	16.60
2011	0.00	0.06	0.49	1.33	2.13	3.04	3.96	4.89	5.85	7.10	8.02	9.15	10.13	11.17	11.89	12.78	13.52	14.28	14.90	15.47	16.43
2012	0.00	0.04	0.56	1.25	2.21	3.02	3.83	4.65	5.56	6.54	7.74	8.57	9.56	10.39	11.27	11.87	12.60	13.21	13.82	14.32	14.99
2013	0.00	0.05	0.51	1.27	2.09	3.14	3.94	4.76	5.71	6.83	7.95	9.26	10.14	11.17	12.05	12.95	13.57	14.32	14.94	15.57	16.52
2014	0.00	0.03	0.53	1.27	2.19	3.05	4.05	4.81	5.72	6.80	8.00	9.14	10.41	11.26	12.24	13.07	13.93	14.51	15.22	15.80	16.94
2015	0.00	0.03	0.66	1.30	2.15	3.10	3.90	4.86	5.71	6.71	7.84	8.99	10.05	11.22	11.99	12.88	13.63	14.40	14.92	15.54	16.69
2016	0.00	0.09	0.67	1.47	2.22	3.13	4.08	4.93	6.06	7.01	8.06	9.16	10.26	11.25	12.34	13.05	13.87	14.56	15.26	15.73	16.64
2017	0.00	0.07	0.67	1.55	2.49	3.26	4.16	5.12	6.04	7.26	8.25	9.31	10.40	11.47	12.43	13.47	14.15	14.92	15.57	16.22	17.18
2018	0.01	0.09	0.75	1.43	2.41	3.37	4.13	5.06	6.11	7.08	8.30	9.24	10.22	11.21	12.18	13.03	13.94	14.53	15.20	15.76	16.83
2019	0.00	0.16	0.48	1.56	2.35	3.39	4.38	5.18	6.21	7.35	8.38	9.64	10.59	11.57	12.55	13.48	14.30	15.18	15.74	16.38	17.23
2020	0.00	0.04	0.48	1.13	2.36	3.14	4.17	5.17	6.00	7.03	8.14	9.11	10.26	11.12	12.00	12.87	13.70	14.42	15.19	15.67	16.57

Model 2.1.20e. Mid-year weight (kg) at age in the fishery (Model 21.3).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.01	0.08	0.58	1.35	2.27	3.25	4.26	5.32	6.43	7.57	8.68	9.70	10.61	11.39	12.06	12.63	13.11	13.53	13.91	14.23	14.90
1978	0.00	0.06	0.49	1.27	2.21	3.25	4.34	5.50	6.73	8.01	9.27	10.45	11.50	12.40	13.18	13.84	14.41	14.90	15.33	15.72	16.52
1979	0.01	0.06	0.57	1.28	2.24	3.23	4.25	5.32	6.44	7.59	8.72	9.76	10.68	11.48	12.15	12.73	13.22	13.65	14.02	14.36	14.99
1980	0.00	0.07	0.50	1.28	2.12	3.14	4.15	5.21	6.33	7.49	8.62	9.67	10.59	11.40	12.08	12.66	13.16	13.59	13.97	14.31	14.93
1981	0.00	0.06	0.44	1.21	2.14	3.04	4.09	5.14	6.24	7.36	8.46	9.48	10.38	11.15	11.81	12.38	12.86	13.28	13.65	13.97	14.55
1982	0.00	0.04	0.52	1.27	2.27	3.32	4.28	5.40	6.52	7.66	8.78	9.81	10.73	11.52	12.19	12.76	13.25	13.67	14.04	14.38	14.96
1983	0.01	0.04	0.65	1.25	2.17	3.28	4.41	5.45	6.69	7.90	9.09	10.19	11.16	12.01	12.72	13.33	13.86	14.31	14.71	15.07	15.70
1984	0.01	0.14	0.59	1.41	2.03	2.89	3.86	4.82	5.70	6.70	7.62	8.46	9.20	9.84	10.38	10.83	11.22	11.56	11.85	12.12	12.58
1985	0.00	0.07	0.46	1.35	2.43	3.21	4.27	5.51	6.80	7.97	9.27	10.42	11.43	12.31	13.06	13.70	14.25	14.72	15.14	15.52	16.20
1986	0.00	0.03	0.50	1.14	2.24	3.43	4.26	5.42	6.80	8.18	9.38	10.65	11.71	12.63	13.41	14.08	14.66	15.16	15.61	16.00	16.73
1987	0.00	0.07	0.51	1.32	2.12	3.30	4.49	5.31	6.46	7.78	9.05	10.08	11.11	11.95	12.67	13.28	13.81	14.27	14.67	15.02	15.70
1988	0.01	0.05	0.43	1.18	2.21	3.13	4.51	5.92	6.89	8.23	9.70	11.01	12.05	13.06	13.87	14.56	15.16	15.68	16.14	16.54	17.35
1989	0.00	0.05	0.48	1.24	2.25	3.41	4.38	5.82	7.28	8.26	9.55	10.90	12.05	12.92	13.77	14.45	15.03	15.54	15.99	16.38	17.19
1990	0.00	0.05	0.57	1.30	2.25	3.32	4.45	5.40	6.80	8.17	9.05	10.15	11.25	12.15	12.82	13.47	14.00	14.45	14.85	15.21	15.95
1991	0.01	0.07	0.59	1.30	2.13	3.09	4.11	5.21	6.13	7.46	8.69	9.44	10.34	11.21	11.91	12.44	12.95	13.37	13.73	14.06	14.73
1992	0.00	0.08	0.52	1.30	2.12	2.99	3.95	5.00	6.14	7.08	8.37	9.51	10.16	10.93	11.67	12.27	12.71	13.16	13.52	13.85	14.50
1993	0.01	0.07	0.56	1.33	2.36	3.34	4.35	5.48	6.70	8.00	9.00	10.31	11.39	11.99	12.71	13.38	13.93	14.35	14.77	15.12	15.73
1994	0.01	0.07	0.52	1.28	2.16	3.23	4.18	5.18	6.30	7.50	8.72	9.61	10.74	11.64	12.14	12.72	13.29	13.75	14.11	14.47	14.95
1995	0.01	0.06	0.49	1.23	2.17	3.15	4.30	5.34	6.43	7.64	8.87	10.06	10.89	11.92	12.73	13.17	13.70	14.22	14.65	14.99	15.53
1996	0.01	0.07	0.60	1.36	2.27	3.24	4.17	5.24	6.19	7.16	8.19	9.17	10.06	10.67	11.40	11.98	12.29	12.68	13.05	13.37	13.67
1997	0.01	0.06	0.49	1.20	2.05	2.99	3.99	4.97	6.12	7.12	8.10	9.09	10.00	10.80	11.34	12.00	12.52	12.81	13.16	13.51	13.75
1998	0.00	0.06	0.49	1.24	2.10	3.00	3.95	4.96	5.96	7.11	8.06	8.95	9.81	10.57	11.24	11.69	12.24	12.68	12.93	13.24	13.57
1999	0.00	0.05	0.48	1.24	2.18	3.14	4.12	5.16	6.27	7.35	8.53	9.45	10.29	11.06	11.75	12.35	12.75	13.25	13.67	13.90	14.31
2000	0.01	0.04	0.63	1.29	2.26	3.31	4.36	5.42	6.58	7.78	8.89	10.05	10.91	11.67	12.37	12.98	13.53	13.90	14.37	14.76	15.31
2001	0.01	0.09	0.61	1.42	2.17	3.18	4.21	5.24	6.30	7.42	8.53	9.50	10.46	11.15	11.75	12.30	12.80	13.23	13.53	13.92	14.60
2002	0.01	0.08	0.57	1.30	2.25	3.05	4.11	5.23	6.36	7.50	8.64	9.71	10.61	11.47	12.09	12.62	13.12	13.57	13.97	14.25	14.86
2003	0.00	0.08	0.52	1.31	2.19	3.22	4.06	5.18	6.38	7.58	8.72	9.81	10.80	11.60	12.36	12.90	13.38	13.83	14.24	14.61	15.33
2004	0.01	0.07	0.63	1.29	2.24	3.19	4.23	5.08	6.22	7.41	8.52	9.53	10.45	11.25	11.89	12.50	12.94	13.33	13.70	14.04	14.62
2005	0.00	0.11	0.51	1.39	2.20	3.26	4.27	5.41	6.35	7.59	8.82	9.92	10.87	11.72	12.44	13.03	13.59	14.00	14.36	14.72	15.44
2006	0.00	0.06	0.53	1.29	2.36	3.21	4.29	5.32	6.49	7.42	8.61	9.72	10.66	11.46	12.16	12.76	13.24	13.72	14.06	14.38	15.17
2007	0.00	0.05	0.50	1.30	2.24	3.42	4.31	5.47	6.58	7.81	8.75	9.90	10.92	11.76	12.46	13.07	13.61	14.04	14.47	14.79	15.74
2008	0.00	0.04	0.49	1.24	2.19	3.17	4.35	5.26	6.44	7.54	8.70	9.54	10.52	11.36	12.05	12.62	13.13	13.57	13.93	14.30	15.04
2009	0.00	0.03	0.51	1.26	2.20	3.25	4.30	5.58	6.58	7.86	9.01	10.15	10.95	11.85	12.63	13.25	13.78	14.25	14.67	15.02	15.60
2010	0.00	0.03	0.58	1.27	2.16	3.15	4.20	5.26	6.58	7.58	8.79	9.82	10.80	11.46	12.20	12.84	13.36	13.80	14.20	14.55	15.01
2011	0.00	0.06	0.49	1.32	2.13	3.07	4.06	5.15	6.27	7.61	8.57	9.69	10.58	11.41	11.96	12.59	13.12	13.57	13.95	14.29	14.82
2012	0.00	0.04	0.57	1.22	2.18	3.00	3.92	4.91	5.99	7.05	8.26	9.07	9.97	10.66	11.30	11.73	12.21	12.62	12.97	13.27	13.58
2013	0.00	0.07	0.50	1.27	2.05	3.13	4.04	5.06	6.20	7.42	8.57	9.81	10.60	11.46	12.13	12.74	13.14	13.61	14.02	14.37	14.80
2014	0.00	0.04	0.52	1.22	2.17	3.02	4.14	5.08	6.18	7.37	8.60	9.71	10.84	11.54	12.30	12.88	13.42	13.79	14.21	14.59	15.11
2015	0.00	0.04	0.64	1.25	2.09	3.09	3.95	5.10	6.09	7.21	8.38	9.51	10.48	11.45	12.03	12.67	13.16	13.63	13.94	14.32	14.87
2016	0.00	0.10	0.67	1.45	2.18	3.10	4.15	5.07	6.32	7.36	8.50	9.61	10.63	11.48	12.32	12.82	13.38	13.81	14.22	14.51	14.87
2017	0.00	0.11	0.62	1.49	2.40	3.19	4.15	5.28	6.28	7.62	8.69	9.78	10.80	11.71	12.45	13.19	13.64	14.13	14.53	14.91	15.32
2018	0.01	0.10	0.72	1.39	2.40	3.36	4.17	5.19	6.39	7.41	8.70	9.66	10.60	11.45	12.20	12.81	13.41	13.79	14.20	14.54	15.05
2019	0.00	0.15	0.46	1.53	2.33	3.45	4.48	5.36	6.49	7.78	8.83	10.09	10.98	11.83	12.59	13.26	13.80	14.35	14.70	15.09	15.53
2020	0.00	0.03	0.48	1.12	2.37	3.18	4.31	5.36	6.25	7.38	8.60	9.53	10.61	11.35	12.05	12.67	13.22	13.68	14.14	14.44	14.92

Table 2.1.20f. Mid-year weight (kg) at age in the fishery (ensemble).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.01	0.08	0.58	1.36	2.29	3.26	4.24	5.23	6.27	7.33	8.38	9.37	10.27	11.08	11.80	12.43	13.00	13.49	13.93	14.32	15.18
1978	0.00	0.06	0.49	1.29	2.24	3.27	4.32	5.40	6.55	7.75	8.94	10.07	11.11	12.04	12.88	13.62	14.28	14.86	15.37	15.83	16.85
1979	0.01	0.06	0.57	1.30	2.26	3.24	4.23	5.23	6.28	7.35	8.42	9.42	10.34	11.16	11.88	12.53	13.10	13.60	14.05	14.45	15.27
1980	0.00	0.07	0.51	1.29	2.14	3.15	4.13	5.13	6.18	7.26	8.32	9.33	10.25	11.08	11.81	12.47	13.04	13.55	14.00	14.41	15.22
1981	0.01	0.06	0.45	1.22	2.16	3.06	4.07	5.06	6.09	7.14	8.18	9.15	10.05	10.85	11.56	12.19	12.74	13.24	13.67	14.06	14.83
1982	0.00	0.04	0.53	1.29	2.30	3.34	4.26	5.32	6.36	7.44	8.49	9.49	10.39	11.21	11.93	12.57	13.13	13.63	14.07	14.46	15.24
1983	0.01	0.04	0.61	1.27	2.20	3.30	4.39	5.38	6.54	7.68	8.79	9.85	10.82	11.68	12.45	13.13	13.74	14.27	14.75	15.17	16.00
1984	0.01	0.11	0.59	1.37	2.06	2.91	3.85	4.76	5.60	6.53	7.40	8.21	8.94	9.59	10.17	10.68	11.13	11.52	11.87	12.18	12.80
1985	0.00	0.07	0.47	1.37	2.39	3.25	4.27	5.44	6.64	7.74	8.96	10.06	11.07	11.97	12.78	13.49	14.12	14.68	15.18	15.62	16.51
1986	0.00	0.03	0.51	1.16	2.27	3.38	4.26	5.35	6.63	7.91	9.05	10.26	11.32	12.27	13.11	13.87	14.53	15.12	15.65	16.11	17.07
1987	0.00	0.06	0.52	1.34	2.16	3.33	4.41	5.26	6.33	7.56	8.73	9.73	10.75	11.62	12.39	13.08	13.69	14.22	14.70	15.12	16.00
1988	0.01	0.04	0.43	1.19	2.23	3.16	4.49	5.74	6.74	7.98	9.35	10.61	11.64	12.68	13.56	14.33	15.02	15.64	16.18	16.66	17.69
1989	0.00	0.04	0.48	1.25	2.27	3.43	4.38	5.74	7.03	8.04	9.26	10.54	11.67	12.57	13.47	14.23	14.90	15.50	16.03	16.50	17.52
1990	0.00	0.05	0.56	1.32	2.27	3.33	4.45	5.36	6.68	7.89	8.80	9.85	10.92	11.83	12.56	13.28	13.88	14.42	14.89	15.31	16.24
1991	0.01	0.06	0.58	1.30	2.15	3.11	4.10	5.15	6.03	7.27	8.36	9.15	10.04	10.92	11.67	12.25	12.84	13.33	13.77	14.15	15.00
1992	0.00	0.07	0.52	1.30	2.14	3.01	3.94	4.93	6.00	6.88	8.09	9.12	9.84	10.64	11.42	12.08	12.60	13.12	13.55	13.94	14.76
1993	0.01	0.07	0.59	1.35	2.38	3.35	4.34	5.40	6.54	7.75	8.71	9.96	10.97	11.67	12.43	13.18	13.81	14.30	14.80	15.21	16.00
1994	0.01	0.08	0.52	1.32	2.20	3.23	4.16	5.10	6.15	7.27	8.41	9.29	10.39	11.27	11.87	12.53	13.17	13.71	14.14	14.56	15.22
1995	0.00	0.06	0.49	1.24	2.23	3.19	4.27	5.25	6.27	7.40	8.56	9.70	10.54	11.58	12.40	12.97	13.58	14.18	14.69	15.09	15.84
1996	0.01	0.07	0.61	1.38	2.29	3.29	4.17	5.17	6.08	7.00	7.96	8.90	9.78	10.41	11.18	11.78	12.19	12.64	13.08	13.45	13.91
1997	0.01	0.06	0.49	1.21	2.06	3.00	4.00	4.92	5.97	6.92	7.86	8.80	9.69	10.52	11.10	11.83	12.39	12.77	13.19	13.60	14.01
1998	0.00	0.05	0.49	1.24	2.12	3.01	3.93	4.92	5.84	6.89	7.80	8.67	9.51	10.29	11.01	11.51	12.14	12.62	12.96	13.32	13.84
1999	0.00	0.05	0.48	1.25	2.18	3.15	4.09	5.08	6.16	7.15	8.23	9.14	9.97	10.76	11.49	12.16	12.63	13.21	13.67	13.98	14.58
2000	0.01	0.04	0.64	1.29	2.28	3.32	4.34	5.34	6.41	7.58	8.61	9.69	10.56	11.35	12.10	12.78	13.41	13.85	14.39	14.82	15.59
2001	0.01	0.10	0.61	1.45	2.20	3.19	4.17	5.13	6.09	7.13	8.22	9.14	10.08	10.81	11.47	12.09	12.66	13.18	13.54	13.99	14.85
2002	0.01	0.08	0.58	1.32	2.29	3.08	4.09	5.09	6.12	7.17	8.25	9.33	10.21	11.09	11.78	12.39	12.97	13.50	13.98	14.32	15.06
2003	0.00	0.08	0.53	1.33	2.22	3.26	4.05	5.09	6.19	7.31	8.38	9.43	10.45	11.26	12.06	12.69	13.24	13.77	14.26	14.70	15.55
2004	0.01	0.07	0.64	1.32	2.28	3.21	4.23	5.01	6.08	7.17	8.23	9.20	10.11	10.96	11.64	12.30	12.82	13.28	13.72	14.12	14.81
2005	0.00	0.11	0.52	1.43	2.23	3.29	4.26	5.36	6.22	7.39	8.53	9.59	10.53	11.39	12.20	12.84	13.46	13.95	14.39	14.81	15.65
2006	0.00	0.06	0.53	1.31	2.39	3.23	4.28	5.27	6.39	7.25	8.37	9.41	10.35	11.16	11.90	12.59	13.14	13.67	14.09	14.47	15.38
2007	0.00	0.05	0.50	1.31	2.26	3.43	4.30	5.40	6.46	7.63	8.50	9.59	10.58	11.45	12.20	12.88	13.51	14.01	14.50	14.88	15.96
2008	0.00	0.04	0.49	1.24	2.21	3.19	4.33	5.18	6.28	7.31	8.42	9.21	10.18	11.04	11.79	12.42	13.00	13.54	13.96	14.38	15.19
2009	0.00	0.03	0.52	1.26	2.20	3.26	4.26	5.46	6.38	7.56	8.64	9.77	10.55	11.49	12.31	13.02	13.63	14.18	14.70	15.11	15.77
2010	0.00	0.03	0.59	1.30	2.18	3.16	4.17	5.15	6.37	7.29	8.43	9.42	10.42	11.09	11.90	12.60	13.21	13.73	14.20	14.64	15.21
2011	0.00	0.05	0.50	1.35	2.18	3.09	4.04	5.06	6.09	7.36	8.26	9.33	10.22	11.10	11.68	12.38	12.99	13.52	13.97	14.38	15.03
2012	0.00	0.04	0.57	1.24	2.21	3.04	3.90	4.82	5.83	6.83	7.98	8.76	9.65	10.37	11.07	11.54	12.09	12.57	12.99	13.35	13.79
2013	0.00	0.06	0.50	1.29	2.09	3.16	4.03	4.96	6.00	7.15	8.24	9.45	10.24	11.13	11.84	12.54	13.00	13.56	14.04	14.46	15.07
2014	0.00	0.04	0.53	1.25	2.20	3.05	4.12	5.00	5.99	7.09	8.27	9.34	10.47	11.20	12.02	12.67	13.31	13.73	14.24	14.68	15.40
2015	0.00	0.04	0.65	1.28	2.13	3.11	3.94	5.02	5.94	6.97	8.06	9.17	10.13	11.13	11.77	12.47	13.04	13.60	13.97	14.41	15.16
2016	0.00	0.10	0.67	1.47	2.23	3.13	4.14	5.00	6.18	7.16	8.20	9.26	10.29	11.16	12.06	12.63	13.26	13.77	14.27	14.60	15.15
2017	0.00	0.10	0.63	1.50	2.43	3.23	4.15	5.21	6.16	7.42	8.42	9.44	10.44	11.39	12.19	13.01	13.53	14.10	14.57	15.02	15.62
2018	0.01	0.10	0.73	1.41	2.41	3.38	4.17	5.13	6.25	7.21	8.43	9.35	10.26	11.13	11.94	12.62	13.32	13.75	14.24	14.64	15.34
2019	0.00	0.16	0.47	1.56	2.36	3.44	4.44	5.29	6.33	7.52	8.52	9.74	10.62	11.48	12.29	13.05	13.68	14.33	14.73	15.19	15.78

Table 2.1.21a. Mid-year weight (kg) at age in the survey (Model 19.12a).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.02	0.07	0.40	1.06	1.92	2.93	4.02	5.14	6.26	7.36	8.41	9.41	10.35	11.23	12.03	12.77	13.44	14.04	14.58	15.06	16.19
1978	0.01	0.05	0.33	0.98	1.86	2.91	4.08	5.30	6.55	7.78	8.98	10.12	11.20	12.22	13.16	14.02	14.80	15.51	16.15	16.72	18.05
1979	0.02	0.06	0.40	1.01	1.91	2.92	4.01	5.14	6.28	7.39	8.45	9.47	10.42	11.31	12.12	12.87	13.55	14.17	14.71	15.20	16.28
1980	0.02	0.06	0.35	1.00	1.79	2.83	3.91	5.04	6.17	7.28	8.35	9.37	10.33	11.23	12.05	12.81	13.50	14.12	14.68	15.17	16.23
1981	0.02	0.06	0.32	0.97	1.85	2.77	3.88	4.98	6.08	7.16	8.20	9.19	10.12	10.99	11.79	12.52	13.18	13.78	14.32	14.80	15.79
1982	0.02	0.05	0.36	0.98	1.92	2.99	4.02	5.21	6.34	7.45	8.51	9.52	10.47	11.35	12.16	12.90	13.57	14.18	14.72	15.21	16.20
1983	0.01	0.04	0.41	0.97	1.82	2.95	4.15	5.26	6.51	7.68	8.81	9.88	10.89	11.83	12.70	13.49	14.21	14.87	15.45	15.97	17.04
1984	0.02	0.10	0.44	1.09	1.77	2.64	3.67	4.68	5.57	6.53	7.40	8.22	8.99	9.70	10.35	10.94	11.47	11.95	12.38	12.77	13.55
1985	0.01	0.06	0.30	1.04	1.97	2.86	4.00	5.32	6.61	7.75	8.98	10.09	11.15	12.13	13.04	13.87	14.63	15.31	15.92	16.47	17.61
1986	0.01	0.03	0.35	0.88	1.91	3.02	4.02	5.25	6.62	7.94	9.09	10.31	11.41	12.44	13.39	14.27	15.06	15.79	16.43	17.01	18.23
1987	0.02	0.06	0.34	1.02	1.76	2.97	4.13	5.13	6.30	7.57	8.76	9.77	10.83	11.78	12.65	13.44	14.17	14.82	15.41	15.93	17.04
1988	0.02	0.05	0.32	0.97	1.94	2.88	4.31	5.64	6.75	8.03	9.40	10.67	11.74	12.86	13.85	14.75	15.58	16.32	16.99	17.59	18.88
1989	0.02	0.05	0.34	0.98	1.92	3.10	4.14	5.64	6.97	8.06	9.28	10.57	11.75	12.73	13.74	14.63	15.43	16.16	16.81	17.39	18.67
1990	0.02	0.05	0.39	1.00	1.88	2.96	4.19	5.22	6.62	7.83	8.80	9.86	10.97	11.97	12.79	13.63	14.35	15.00	15.59	16.11	17.27
1991	0.01	0.06	0.40	1.00	1.78	2.75	3.85	5.03	5.98	7.26	8.33	9.17	10.10	11.04	11.89	12.57	13.27	13.87	14.41	14.88	15.94
1992	0.02	0.06	0.35	0.99	1.76	2.66	3.69	4.81	5.98	6.90	8.12	9.13	9.92	10.77	11.64	12.41	13.04	13.67	14.20	14.68	15.70
1993	0.02	0.06	0.44	1.10	2.05	3.06	4.13	5.31	6.54	7.79	8.75	10.01	11.03	11.82	12.67	13.53	14.28	14.89	15.49	16.00	17.00
1994	0.02	0.07	0.36	1.04	1.86	2.91	3.94	5.00	6.14	7.30	8.45	9.34	10.48	11.40	12.11	12.87	13.63	14.28	14.81	15.34	16.18
1995	0.02	0.05	0.34	0.96	1.90	2.87	4.04	5.15	6.26	7.43	8.60	9.75	10.63	11.74	12.64	13.33	14.06	14.78	15.41	15.90	16.87
1996	0.03	0.08	0.42	1.05	1.90	2.95	3.93	5.03	6.02	6.98	7.95	8.90	9.82	10.51	11.37	12.06	12.57	13.12	13.65	14.11	14.74
1997	0.01	0.06	0.35	0.96	1.75	2.70	3.81	4.82	5.93	6.92	7.86	8.82	9.75	10.64	11.31	12.14	12.79	13.28	13.80	14.31	14.89
1998	0.01	0.05	0.34	0.95	1.76	2.67	3.69	4.82	5.81	6.88	7.81	8.68	9.56	10.41	11.21	11.81	12.55	13.12	13.55	14.00	14.72
1999	0.01	0.05	0.32	0.95	1.83	2.82	3.85	4.96	6.15	7.16	8.24	9.16	10.03	10.89	11.71	12.48	13.05	13.75	14.29	14.70	15.50
2000	0.02	0.05	0.45	0.97	1.87	2.95	4.08	5.21	6.38	7.61	8.64	9.71	10.63	11.48	12.32	13.11	13.86	14.40	15.06	15.57	16.58
2001	0.02	0.07	0.42	1.13	1.80	2.83	3.94	5.06	6.13	7.20	8.31	9.23	10.18	10.97	11.71	12.42	13.09	13.72	14.17	14.72	15.79
2002	0.02	0.07	0.42	1.04	1.97	2.75	3.88	5.06	6.21	7.29	8.36	9.46	10.36	11.28	12.05	12.75	13.43	14.07	14.66	15.08	15.98
2003	0.02	0.07	0.37	1.04	1.87	2.95	3.81	5.01	6.22	7.37	8.44	9.50	10.56	11.43	12.31	13.04	13.71	14.35	14.94	15.49	16.52
2004	0.02	0.07	0.47	1.03	1.94	2.90	4.04	4.91	6.07	7.21	8.27	9.24	10.18	11.11	11.86	12.62	13.25	13.81	14.35	14.85	15.67
2005	0.02	0.08	0.36	1.13	1.88	2.97	4.04	5.27	6.19	7.39	8.55	9.62	10.59	11.52	12.45	13.19	13.93	14.53	15.07	15.59	16.60
2006	0.02	0.04	0.36	1.00	2.03	2.89	4.05	5.14	6.35	7.22	8.35	9.43	10.40	11.28	12.11	12.93	13.58	14.22	14.75	15.21	16.30
2007	0.01	0.04	0.32	0.99	1.87	3.10	4.06	5.28	6.41	7.62	8.49	9.60	10.64	11.58	12.42	13.21	13.98	14.58	15.18	15.66	16.94
2008	0.02	0.04	0.32	0.93	1.83	2.84	4.13	5.09	6.27	7.33	8.46	9.26	10.26	11.19	12.02	12.75	13.44	14.10	14.62	15.13	16.05
2009	0.01	0.03	0.33	0.91	1.76	2.86	4.00	5.40	6.41	7.64	8.73	9.87	10.67	11.67	12.59	13.41	14.13	14.80	15.44	15.94	16.72
2010	0.02	0.05	0.37	0.93	1.72	2.72	3.89	5.05	6.41	7.37	8.52	9.52	10.56	11.28	12.17	12.99	13.70	14.32	14.90	15.45	16.15
2011	0.02	0.06	0.30	0.99	1.74	2.66	3.74	4.95	6.09	7.41	8.32	9.40	10.32	11.27	11.92	12.73	13.46	14.09	14.64	15.15	15.97
2012	0.02	0.03	0.38	0.92	1.84	2.69	3.65	4.71	5.83	6.87	8.03	8.82	9.73	10.51	11.30	11.84	12.49	13.08	13.59	14.03	14.61
2013	0.01	0.06	0.34	0.97	1.70	2.82	3.80	4.86	6.01	7.22	8.31	9.53	10.35	11.30	12.11	12.92	13.46	14.13	14.73	15.24	16.05
2014	0.01	0.04	0.34	0.90	1.76	2.63	3.86	4.89	5.99	7.14	8.34	9.41	10.59	11.38	12.29	13.05	13.81	14.32	14.94	15.49	16.42
2015	0.02	0.05	0.42	0.92	1.68	2.69	3.63	4.90	5.93	6.99	8.10	9.22	10.22	11.30	12.02	12.84	13.52	14.20	14.65	15.20	16.15
2016	0.02	0.09	0.44	1.08	1.77	2.70	3.83	4.83	6.14	7.17	8.22	9.29	10.36	11.31	12.32	12.99	13.75	14.37	14.98	15.39	16.12
2017	0.01	0.09	0.40	1.09	1.96	2.78	3.83	5.05	6.08	7.41	8.43	9.46	10.50	11.53	12.43	13.39	14.01	14.72	15.29	15.86	16.64
2018	0.03	0.09	0.53	1.07	2.01	3.03	3.92	4.99	6.20	7.19	8.44	9.38	10.32	11.25	12.17	12.96	13.79	14.33	14.93	15.42	16.33
2019	0.02	0.10	0.30	1.24	1.97	3.09	4.23	5.19	6.31	7.55	8.55	9.79	10.72	11.63	12.53	13.41	14.17	14.95	15.46	16.02	16.79
2020	0.01	0.04	0.33	0.86	2.06	2.88	4.05	5.18	6.11	7.17	8.32	9.24	10.36	11.19	12.00	12.80	13.56	14.22	14.90	15.33	16.15

Table 2.1.21b. Mid-year weight (kg) at age in the survey (Model 19.12).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.02	0.07	0.41	1.05	1.90	2.90	4.00	5.15	6.32	7.49	8.64	9.75	10.82	11.84	12.79	13.68	14.50	15.25	15.92	16.52	18.02
1978	0.01	0.05	0.33	0.97	1.84	2.88	4.06	5.32	6.62	7.93	9.24	10.51	11.75	12.93	14.04	15.08	16.05	16.93	17.73	18.45	20.24
1979	0.02	0.06	0.40	1.00	1.89	2.90	4.00	5.16	6.34	7.52	8.69	9.81	10.90	11.92	12.89	13.80	14.63	15.39	16.07	16.69	18.14
1980	0.02	0.06	0.35	0.99	1.77	2.81	3.90	5.05	6.23	7.42	8.58	9.72	10.81	11.85	12.83	13.75	14.59	15.36	16.06	16.68	18.12
1981	0.02	0.06	0.32	0.96	1.83	2.74	3.87	4.99	6.15	7.30	8.43	9.53	10.59	11.59	12.54	13.42	14.24	14.98	15.65	16.25	17.61
1982	0.02	0.05	0.35	0.96	1.89	2.96	4.00	5.23	6.41	7.59	8.75	9.87	10.94	11.96	12.92	13.82	14.64	15.39	16.07	16.67	18.04
1983	0.01	0.04	0.44	0.95	1.79	2.91	4.13	5.27	6.58	7.83	9.05	10.25	11.39	12.48	13.51	14.47	15.36	16.17	16.90	17.55	19.03
1984	0.02	0.11	0.44	1.12	1.74	2.61	3.65	4.69	5.62	6.65	7.59	8.50	9.37	10.19	10.96	11.67	12.32	12.91	13.44	13.92	15.00
1985	0.01	0.06	0.30	1.03	2.00	2.82	3.97	5.32	6.68	7.89	9.23	10.48	11.67	12.81	13.89	14.90	15.83	16.68	17.44	18.13	19.71
1986	0.01	0.03	0.35	0.87	1.88	3.05	3.99	5.24	6.68	8.10	9.34	10.71	11.96	13.16	14.29	15.35	16.33	17.22	18.04	18.76	20.46
1987	0.02	0.06	0.34	1.01	1.73	2.93	4.18	5.13	6.35	7.71	9.00	10.13	11.34	12.43	13.47	14.43	15.32	16.13	16.86	17.52	19.08
1988	0.02	0.05	0.32	0.96	1.91	2.84	4.28	5.73	6.80	8.16	9.66	11.08	12.30	13.61	14.78	15.87	16.89	17.81	18.65	19.40	21.23
1989	0.02	0.05	0.34	0.97	1.89	3.06	4.10	5.65	7.12	8.19	9.52	10.96	12.30	13.44	14.65	15.72	16.71	17.61	18.43	19.16	20.97
1990	0.02	0.05	0.39	0.99	1.86	2.93	4.17	5.21	6.69	8.05	9.02	10.20	11.46	12.62	13.59	14.61	15.50	16.31	17.04	17.69	19.33
1991	0.01	0.06	0.41	0.99	1.76	2.73	3.83	5.04	6.02	7.39	8.62	9.49	10.53	11.64	12.64	13.47	14.32	15.06	15.73	16.33	17.84
1992	0.02	0.06	0.35	0.99	1.74	2.63	3.67	4.82	6.04	7.01	8.34	9.53	10.35	11.34	12.38	13.31	14.07	14.86	15.52	16.12	17.60
1993	0.02	0.06	0.43	1.08	2.04	3.03	4.11	5.32	6.60	7.92	8.97	10.36	11.59	12.44	13.45	14.48	15.41	16.15	16.91	17.55	19.00
1994	0.02	0.07	0.36	1.01	1.83	2.89	3.92	5.01	6.19	7.42	8.68	9.66	10.96	12.09	12.86	13.78	14.71	15.53	16.19	16.85	18.08
1995	0.02	0.06	0.34	0.96	1.85	2.84	4.04	5.17	6.32	7.56	8.83	10.11	11.10	12.40	13.53	14.29	15.19	16.09	16.87	17.50	18.87
1996	0.03	0.08	0.42	1.04	1.89	2.90	3.91	5.06	6.08	7.09	8.15	9.20	10.24	11.03	12.06	12.93	13.51	14.18	14.84	15.42	16.31
1997	0.01	0.06	0.35	0.95	1.73	2.68	3.77	4.82	6.00	7.04	8.07	9.12	10.18	11.21	12.00	13.00	13.85	14.41	15.06	15.69	16.49
1998	0.01	0.05	0.34	0.94	1.74	2.65	3.68	4.80	5.86	7.02	8.02	8.99	9.98	10.96	11.91	12.62	13.53	14.28	14.78	15.34	16.30
1999	0.02	0.05	0.32	0.94	1.80	2.79	3.84	4.97	6.17	7.28	8.47	9.49	10.47	11.46	12.43	13.37	14.06	14.93	15.64	16.10	17.20
2000	0.02	0.05	0.44	0.96	1.85	2.92	4.06	5.23	6.45	7.71	8.86	10.08	11.11	12.10	13.08	14.04	14.95	15.61	16.44	17.12	18.46
2001	0.02	0.07	0.42	1.10	1.78	2.79	3.92	5.06	6.19	7.34	8.50	9.55	10.64	11.56	12.42	13.28	14.10	14.87	15.42	16.12	17.61
2002	0.02	0.07	0.41	1.03	1.92	2.72	3.86	5.07	6.26	7.42	8.59	9.77	10.82	11.90	12.81	13.65	14.49	15.27	16.01	16.53	17.93
2003	0.02	0.07	0.37	1.03	1.84	2.90	3.79	5.01	6.28	7.50	8.68	9.85	11.02	12.05	13.12	14.00	14.81	15.60	16.34	17.03	18.63
2004	0.02	0.07	0.46	1.02	1.91	2.86	4.00	4.91	6.12	7.33	8.48	9.57	10.64	11.69	12.60	13.53	14.29	14.98	15.65	16.28	17.62
2005	0.02	0.08	0.36	1.11	1.85	2.93	4.02	5.26	6.24	7.51	8.78	9.97	11.08	12.16	13.22	14.14	15.06	15.80	16.48	17.12	18.72
2006	0.02	0.04	0.36	0.98	1.99	2.85	4.02	5.14	6.39	7.34	8.57	9.76	10.87	11.89	12.88	13.84	14.65	15.46	16.11	16.69	18.38
2007	0.02	0.04	0.33	0.98	1.85	3.06	4.03	5.29	6.46	7.75	8.71	9.94	11.13	12.21	13.21	14.17	15.08	15.84	16.60	17.20	19.14
2008	0.02	0.04	0.32	0.93	1.81	2.81	4.10	5.08	6.33	7.46	8.68	9.58	10.71	11.79	12.78	13.67	14.51	15.30	15.96	16.61	18.20
2009	0.01	0.03	0.32	0.90	1.75	2.83	3.98	5.40	6.46	7.78	8.97	10.22	11.15	12.31	13.40	14.39	15.28	16.11	16.88	17.52	18.87
2010	0.02	0.04	0.37	0.92	1.70	2.71	3.87	5.06	6.47	7.50	8.76	9.87	11.04	11.89	12.94	13.93	14.80	15.58	16.30	16.97	18.11
2011	0.02	0.06	0.31	0.97	1.70	2.64	3.73	4.95	6.15	7.54	8.54	9.74	10.79	11.88	12.68	13.64	14.54	15.32	16.02	16.65	17.90
2012	0.02	0.03	0.39	0.91	1.81	2.65	3.63	4.72	5.88	6.99	8.24	9.12	10.17	11.07	11.99	12.66	13.45	14.18	14.82	15.37	16.23
2013	0.01	0.06	0.34	0.97	1.68	2.78	3.76	4.87	6.08	7.34	8.54	9.88	10.82	11.93	12.89	13.85	14.54	15.36	16.11	16.75	17.89
2014	0.01	0.04	0.34	0.89	1.75	2.60	3.83	4.88	6.04	7.28	8.57	9.76	11.09	12.02	13.10	14.02	14.94	15.60	16.37	17.06	18.36
2015	0.02	0.05	0.42	0.90	1.66	2.67	3.61	4.90	5.96	7.12	8.33	9.56	10.69	11.95	12.81	13.81	14.64	15.48	16.06	16.74	18.10
2016	0.02	0.09	0.44	1.07	1.73	2.67	3.82	4.84	6.19	7.28	8.44	9.64	10.85	11.94	13.14	13.95	14.88	15.66	16.42	16.94	18.00
2017	0.01	0.09	0.40	1.09	1.94	2.74	3.80	5.06	6.14	7.54	8.64	9.81	11.00	12.18	13.25	14.40	15.17	16.05	16.77	17.48	18.62
2018	0.03	0.09	0.52	1.06	2.00	3.00	3.88	5.00	6.27	7.32	8.66	9.71	10.79	11.88	12.95	13.90	14.92	15.59	16.35	16.96	18.25
2019	0.02	0.10	0.31	1.22	1.95	3.08	4.22	5.18	6.37	7.69	8.78	10.15	11.19	12.27	13.35	14.40	15.32	16.30	16.93	17.64	18.81
2020	0.01	0.04	0.33	0.85	2.03	2.85	4.06	5.20	6.15	7.30	8.55	9.57	10.83	11.79	12.77	13.74	14.67	15.48	16.33	16.87	18.09

Table 2.1.21c. Mid-year weight (kg) at age in the survey (Model 21.1).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.02	0.06	0.39	1.05	1.91	2.89	3.91	4.93	5.91	6.84	7.71	8.50	9.22	9.86	10.43	10.94	11.38	11.77	12.11	12.40	12.95
1978	0.01	0.05	0.32	0.97	1.85	2.87	3.96	5.07	6.16	7.20	8.18	9.08	9.90	10.64	11.30	11.88	12.40	12.85	13.24	13.58	14.24
1979	0.02	0.06	0.39	1.01	1.90	2.88	3.90	4.93	5.93	6.87	7.74	8.54	9.27	9.92	10.50	11.01	11.46	11.86	12.20	12.50	13.09
1980	0.02	0.06	0.35	1.01	1.80	2.79	3.81	4.83	5.82	6.76	7.64	8.44	9.17	9.83	10.41	10.93	11.39	11.78	12.13	12.43	13.04
1981	0.02	0.06	0.31	0.98	1.86	2.75	3.78	4.77	5.74	6.66	7.51	8.29	9.00	9.64	10.20	10.70	11.14	11.53	11.86	12.15	12.76
1982	0.02	0.05	0.35	0.98	1.93	2.96	3.94	5.00	5.99	6.93	7.81	8.61	9.33	9.98	10.56	11.07	11.51	11.90	12.24	12.54	13.16
1983	0.01	0.04	0.41	0.98	1.83	2.93	4.05	5.07	6.14	7.13	8.06	8.91	9.68	10.37	10.98	11.53	12.01	12.43	12.79	13.11	13.78
1984	0.02	0.10	0.43	1.10	1.79	2.64	3.62	4.53	5.31	6.11	6.82	7.47	8.05	8.56	9.02	9.42	9.78	10.09	10.35	10.58	11.08
1985	0.01	0.06	0.30	1.05	1.98	2.86	3.92	5.13	6.26	7.22	8.20	9.07	9.87	10.58	11.22	11.78	12.28	12.71	13.09	13.42	14.14
1986	0.01	0.03	0.35	0.88	1.92	2.99	3.95	5.05	6.26	7.38	8.31	9.26	10.10	10.85	11.52	12.12	12.64	13.10	13.51	13.85	14.63
1987	0.02	0.06	0.34	1.03	1.77	2.95	4.04	4.96	5.98	7.06	8.03	8.82	9.62	10.31	10.92	11.46	11.94	12.36	12.73	13.04	13.75
1988	0.02	0.05	0.31	0.98	1.96	2.87	4.22	5.42	6.40	7.47	8.60	9.59	10.40	11.20	11.89	12.51	13.05	13.52	13.94	14.30	15.12
1989	0.02	0.05	0.33	0.99	1.94	3.09	4.07	5.43	6.59	7.52	8.50	9.52	10.40	11.11	11.81	12.40	12.93	13.39	13.79	14.14	14.94
1990	0.02	0.05	0.38	1.01	1.90	2.95	4.11	5.03	6.28	7.30	8.10	8.94	9.79	10.52	11.10	11.67	12.15	12.57	12.93	13.25	13.99
1991	0.01	0.06	0.40	1.01	1.80	2.76	3.80	4.87	5.69	6.77	7.64	8.31	9.00	9.70	10.29	10.75	11.20	11.58	11.91	12.20	12.87
1992	0.02	0.06	0.35	1.00	1.77	2.64	3.63	4.65	5.67	6.45	7.45	8.25	8.85	9.47	10.10	10.62	11.03	11.43	11.76	12.05	12.72
1993	0.02	0.06	0.45	1.11	2.07	3.04	4.06	5.14	6.22	7.28	8.06	9.05	9.83	10.42	11.01	11.61	12.10	12.49	12.85	13.16	13.82
1994	0.01	0.07	0.36	1.08	1.88	2.90	3.87	4.84	5.85	6.82	7.76	8.44	9.31	9.98	10.47	10.98	11.48	11.89	12.22	12.53	13.08
1995	0.02	0.06	0.34	0.98	1.95	2.87	3.97	4.97	5.95	6.94	7.89	8.79	9.45	10.26	10.89	11.36	11.83	12.29	12.67	12.97	13.59
1996	0.03	0.08	0.41	1.07	1.92	2.97	3.87	4.87	5.73	6.54	7.35	8.10	8.80	9.30	9.92	10.38	10.73	11.07	11.41	11.69	12.10
1997	0.01	0.06	0.35	0.97	1.77	2.70	3.78	4.66	5.63	6.46	7.23	7.99	8.69	9.34	9.80	10.37	10.80	11.11	11.43	11.73	12.11
1998	0.01	0.05	0.34	0.96	1.79	2.70	3.66	4.71	5.54	6.43	7.18	7.86	8.52	9.13	9.68	10.07	10.55	10.91	11.17	11.43	11.87
1999	0.02	0.05	0.32	0.97	1.84	2.81	3.79	4.79	5.86	6.69	7.57	8.29	8.95	9.59	10.17	10.70	11.07	11.52	11.85	12.10	12.60
2000	0.02	0.05	0.45	0.97	1.89	2.93	4.00	5.03	6.06	7.13	7.95	8.81	9.50	10.14	10.74	11.29	11.78	12.12	12.54	12.85	13.49
2001	0.02	0.07	0.42	1.14	1.80	2.81	3.86	4.88	5.83	6.75	7.68	8.39	9.12	9.70	10.23	10.73	11.18	11.58	11.86	12.20	12.88
2002	0.02	0.07	0.41	1.06	1.98	2.74	3.81	4.89	5.89	6.82	7.70	8.58	9.24	9.92	10.46	10.94	11.40	11.81	12.17	12.43	13.02
2003	0.02	0.07	0.36	1.05	1.89	2.94	3.74	4.84	5.90	6.88	7.76	8.59	9.41	10.02	10.64	11.14	11.58	11.99	12.36	12.69	13.35
2004	0.02	0.07	0.47	1.04	1.95	2.89	3.96	4.74	5.77	6.74	7.60	8.37	9.09	9.79	10.30	10.82	11.23	11.59	11.93	12.23	12.78
2005	0.02	0.08	0.36	1.15	1.90	2.95	3.96	5.08	5.87	6.90	7.86	8.70	9.44	10.13	10.80	11.28	11.77	12.16	12.50	12.81	13.47
2006	0.02	0.04	0.35	1.00	2.03	2.86	3.95	4.95	6.01	6.75	7.70	8.56	9.32	9.97	10.57	11.15	11.57	11.99	12.31	12.60	13.32
2007	0.01	0.04	0.32	1.00	1.87	3.06	3.96	5.08	6.08	7.12	7.83	8.74	9.55	10.25	10.85	11.40	11.93	12.31	12.68	12.98	13.82
2008	0.02	0.04	0.31	0.93	1.83	2.82	4.03	4.90	5.94	6.86	7.79	8.41	9.19	9.89	10.48	10.99	11.45	11.89	12.20	12.51	13.19
2009	0.01	0.03	0.33	0.91	1.76	2.84	3.91	5.19	6.07	7.12	8.02	8.92	9.52	10.27	10.93	11.49	11.97	12.40	12.81	13.10	13.66
2010	0.02	0.05	0.37	0.95	1.73	2.71	3.82	4.87	6.07	6.88	7.82	8.61	9.39	9.91	10.55	11.11	11.58	11.98	12.33	12.67	13.14
2011	0.02	0.06	0.30	1.00	1.76	2.65	3.67	4.77	5.78	6.90	7.63	8.48	9.19	9.88	10.33	10.89	11.37	11.78	12.12	12.42	12.96
2012	0.02	0.03	0.39	0.92	1.84	2.67	3.56	4.53	5.54	6.43	7.40	8.03	8.74	9.32	9.89	10.26	10.70	11.09	11.41	11.68	12.07
2013	0.01	0.06	0.33	1.00	1.72	2.82	3.75	4.70	5.71	6.73	7.63	8.58	9.18	9.87	10.43	10.97	11.32	11.75	12.11	12.42	12.92
2014	0.01	0.04	0.34	0.91	1.79	2.61	3.78	4.73	5.67	6.66	7.64	8.49	9.38	9.95	10.59	11.11	11.60	11.93	12.31	12.64	13.23
2015	0.02	0.05	0.42	0.94	1.70	2.70	3.56	4.73	5.63	6.51	7.42	8.30	9.05	9.84	10.34	10.89	11.33	11.76	12.03	12.36	12.97
2016	0.02	0.09	0.43	1.10	1.80	2.70	3.79	4.67	5.83	6.69	7.53	8.37	9.18	9.86	10.56	11.00	11.49	11.88	12.26	12.49	12.97
2017	0.01	0.09	0.40	1.11	1.99	2.80	3.77	4.89	5.77	6.89	7.73	8.51	9.30	10.05	10.67	11.31	11.71	12.15	12.50	12.84	13.34
2018	0.03	0.09	0.53	1.09	2.03	3.02	3.86	4.83	5.89	6.71	7.73	8.47	9.17	9.85	10.49	11.02	11.57	11.90	12.27	12.56	13.13
2019	0.02	0.10	0.30	1.25	1.98	3.06	4.12	5.00	5.98	7.04	7.85	8.85	9.56	10.23	10.88	11.49	11.99	12.50	12.81	13.15	13.66
2020	0.01	0.04	0.33	0.86	2.08	2.87	3.96	4.98	5.79	6.68	7.63	8.34	9.19	9.80	10.37	10.91	11.42	11.84	12.26	12.52	13.04

Table 2.1.21d. Mid-year weight (kg) at age in the survey (Model 21.2).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.02	0.07	0.42	1.06	1.91	2.88	3.94	5.03	6.14	7.23	8.29	9.31	10.29	11.20	12.06	12.86	13.59	14.26	14.86	15.41	16.77
1978	0.01	0.05	0.33	0.99	1.84	2.86	3.99	5.19	6.41	7.64	8.84	10.01	11.13	12.19	13.19	14.12	14.98	15.76	16.48	17.12	18.75
1979	0.02	0.06	0.40	1.00	1.90	2.87	3.93	5.04	6.15	7.26	8.33	9.37	10.35	11.28	12.15	12.96	13.70	14.38	15.00	15.55	16.84
1980	0.02	0.06	0.35	0.99	1.76	2.79	3.84	4.93	6.05	7.15	8.23	9.27	10.26	11.20	12.08	12.90	13.65	14.34	14.96	15.53	16.78
1981	0.02	0.05	0.32	0.96	1.81	2.70	3.80	4.88	5.96	7.04	8.09	9.10	10.06	10.97	11.82	12.60	13.33	13.99	14.60	15.14	16.31
1982	0.02	0.05	0.36	0.97	1.88	2.91	3.91	5.11	6.22	7.32	8.39	9.42	10.40	11.32	12.19	12.99	13.72	14.39	15.00	15.55	16.72
1983	0.01	0.04	0.41	0.96	1.79	2.87	4.03	5.12	6.38	7.55	8.68	9.77	10.82	11.80	12.73	13.58	14.37	15.10	15.75	16.34	17.60
1984	0.03	0.10	0.44	1.07	1.73	2.59	3.58	4.56	5.44	6.43	7.31	8.14	8.94	9.68	10.37	11.01	11.59	12.12	12.60	13.03	13.95
1985	0.01	0.06	0.31	1.03	1.91	2.79	3.90	5.18	6.44	7.58	8.85	9.99	11.07	12.10	13.07	13.97	14.79	15.55	16.24	16.86	18.20
1986	0.01	0.03	0.35	0.88	1.87	2.92	3.91	5.11	6.45	7.76	8.92	10.20	11.33	12.41	13.43	14.37	15.24	16.04	16.76	17.42	18.85
1987	0.02	0.06	0.34	1.01	1.73	2.90	4.00	5.00	6.16	7.41	8.60	9.64	10.76	11.75	12.68	13.54	14.33	15.05	15.71	16.30	17.61
1988	0.02	0.05	0.31	0.95	1.90	2.81	4.20	5.47	6.58	7.86	9.23	10.52	11.63	12.83	13.88	14.86	15.76	16.59	17.34	18.01	19.53
1989	0.02	0.05	0.34	0.96	1.87	3.01	4.04	5.49	6.78	7.88	9.12	10.42	11.64	12.67	13.78	14.73	15.61	16.42	17.15	17.81	19.31
1990	0.02	0.04	0.38	0.99	1.84	2.88	4.08	5.09	6.47	7.65	8.64	9.74	10.87	11.91	12.79	13.72	14.51	15.23	15.89	16.48	17.83
1991	0.01	0.05	0.40	0.98	1.75	2.68	3.74	4.90	5.85	7.11	8.17	9.05	10.01	11.00	11.89	12.64	13.42	14.08	14.68	15.22	16.46
1992	0.02	0.06	0.35	0.98	1.72	2.60	3.59	4.68	5.84	6.76	7.98	9.00	9.83	10.73	11.65	12.48	13.16	13.88	14.47	15.01	16.22
1993	0.02	0.06	0.44	1.08	2.01	2.97	4.03	5.17	6.38	7.63	8.61	9.88	10.92	11.77	12.68	13.60	14.42	15.09	15.78	16.36	17.53
1994	0.02	0.07	0.36	1.03	1.82	2.83	3.83	4.88	5.98	7.13	8.30	9.22	10.39	11.34	12.11	12.93	13.76	14.49	15.08	15.69	16.67
1995	0.02	0.05	0.34	0.95	1.85	2.80	3.94	5.01	6.11	7.26	8.44	9.62	10.53	11.70	12.64	13.40	14.20	14.99	15.69	16.26	17.39
1996	0.03	0.08	0.41	1.04	1.87	2.88	3.83	4.91	5.88	6.84	7.81	8.78	9.74	10.47	11.38	12.11	12.69	13.29	13.88	14.40	15.13
1997	0.01	0.06	0.32	0.94	1.71	2.63	3.71	4.69	5.79	6.76	7.73	8.69	9.65	10.59	11.31	12.21	12.91	13.47	14.05	14.62	15.29
1998	0.02	0.05	0.34	0.89	1.72	2.61	3.60	4.69	5.67	6.74	7.66	8.57	9.47	10.36	11.22	11.87	12.67	13.30	13.79	14.30	15.13
1999	0.02	0.05	0.33	0.95	1.73	2.74	3.75	4.83	5.99	7.01	8.10	9.03	9.94	10.83	11.71	12.55	13.17	13.95	14.54	15.01	15.94
2000	0.02	0.04	0.44	0.96	1.85	2.81	3.97	5.08	6.23	7.44	8.49	9.59	10.53	11.43	12.32	13.17	13.99	14.59	15.34	15.91	17.09
2001	0.02	0.07	0.41	1.10	1.77	2.77	3.77	4.92	5.98	7.06	8.17	9.11	10.09	10.92	11.71	12.47	13.21	13.90	14.41	15.03	16.28
2002	0.02	0.06	0.41	1.01	1.91	2.69	3.79	4.86	6.05	7.13	8.22	9.33	10.26	11.23	12.05	12.81	13.55	14.26	14.92	15.40	16.44
2003	0.02	0.07	0.37	1.02	1.81	2.86	3.71	4.89	5.99	7.21	8.29	9.37	10.46	11.38	12.32	13.11	13.84	14.55	15.21	15.84	17.03
2004	0.02	0.07	0.47	1.01	1.88	2.80	3.92	4.78	5.94	6.99	8.12	9.11	10.09	11.06	11.87	12.69	13.37	14.00	14.60	15.16	16.12
2005	0.02	0.08	0.36	1.12	1.84	2.87	3.91	5.12	6.04	7.24	8.33	9.49	10.49	11.47	12.45	13.25	14.07	14.73	15.35	15.93	17.10
2006	0.02	0.04	0.36	0.99	1.99	2.81	3.92	4.98	6.18	7.07	8.22	9.23	10.31	11.23	12.12	13.00	13.71	14.43	15.01	15.54	16.80
2007	0.01	0.04	0.34	0.99	1.84	3.02	3.94	5.13	6.23	7.45	8.34	9.48	10.48	11.53	12.42	13.28	14.11	14.79	15.46	16.00	17.50
2008	0.02	0.04	0.32	0.94	1.80	2.77	4.02	4.94	6.11	7.16	8.31	9.13	10.18	11.08	12.02	12.82	13.57	14.30	14.88	15.46	16.53
2009	0.01	0.03	0.33	0.90	1.75	2.79	3.89	5.26	6.24	7.46	8.55	9.73	10.57	11.63	12.54	13.48	14.27	15.01	15.72	16.29	17.20
2010	0.02	0.05	0.38	0.92	1.70	2.68	3.80	4.92	6.27	7.21	8.36	9.37	10.46	11.23	12.18	13.00	13.83	14.52	15.17	15.79	16.61
2011	0.02	0.06	0.31	0.98	1.70	2.60	3.67	4.82	5.95	7.26	8.16	9.26	10.21	11.22	11.92	12.80	13.54	14.29	14.91	15.48	16.44
2012	0.02	0.03	0.38	0.92	1.80	2.62	3.56	4.61	5.70	6.73	7.90	8.69	9.64	10.45	11.30	11.89	12.62	13.22	13.83	14.33	15.00
2013	0.01	0.05	0.34	0.95	1.68	2.75	3.69	4.74	5.89	7.07	8.17	9.41	10.25	11.25	12.09	12.98	13.59	14.34	14.96	15.58	16.53
2014	0.02	0.04	0.33	0.89	1.71	2.57	3.76	4.75	5.85	7.01	8.19	9.28	10.50	11.32	12.28	13.10	13.95	14.53	15.23	15.81	16.95
2015	0.02	0.05	0.42	0.89	1.64	2.60	3.54	4.77	5.77	6.85	7.97	9.10	10.12	11.27	12.02	12.90	13.65	14.41	14.93	15.55	16.69
2016	0.02	0.09	0.43	1.06	1.71	2.63	3.70	4.71	6.00	7.00	8.08	9.18	10.27	11.26	12.34	13.05	13.88	14.56	15.27	15.74	16.64
2017	0.01	0.09	0.40	1.06	1.91	2.69	3.72	4.88	5.94	7.25	8.27	9.33	10.42	11.49	12.44	13.48	14.15	14.93	15.57	16.22	17.18
2018	0.03	0.09	0.52	1.06	1.95	2.94	3.79	4.86	6.02	7.05	8.30	9.25	10.23	11.22	12.18	13.03	13.94	14.53	15.21	15.76	16.83
2019	0.02	0.10	0.31	1.22	1.93	3.00	4.10	5.02	6.15	7.36	8.40	9.66	10.61	11.58	12.55	13.49	14.31	15.19	15.74	16.38	17.24
2020	0.01	0.04	0.33	0.85	2.01	2.80	3.93	5.03	5.93	7.01	8.14	9.11	10.27	11.13	12.01	12.88	13.70	14.42	15.19	15.67	16.57

Table 2.1.21e. Mid-year weight (kg) at age in the survey (Model 21.3).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.02	0.07	0.40	1.04	1.89	2.89	4.00	5.16	6.35	7.54	8.71	9.86	10.96	12.00	12.99	13.91	14.76	15.54	16.24	16.86	18.40
1978	0.01	0.05	0.33	0.97	1.83	2.87	4.06	5.33	6.65	7.99	9.32	10.63	11.90	13.12	14.28	15.36	16.36	17.28	18.11	18.85	20.69
1979	0.02	0.06	0.40	0.99	1.88	2.89	3.99	5.17	6.37	7.57	8.76	9.91	11.03	12.09	13.10	14.03	14.90	15.69	16.40	17.03	18.52
1980	0.02	0.06	0.35	0.99	1.76	2.80	3.89	5.06	6.26	7.46	8.66	9.82	10.95	12.02	13.04	13.99	14.86	15.66	16.38	17.03	18.51
1981	0.02	0.06	0.31	0.95	1.82	2.73	3.86	5.00	6.17	7.34	8.50	9.63	10.72	11.76	12.74	13.66	14.50	15.27	15.96	16.58	17.99
1982	0.02	0.05	0.35	0.95	1.88	2.95	3.99	5.23	6.43	7.63	8.82	9.97	11.07	12.13	13.12	14.05	14.91	15.68	16.39	17.01	18.42
1983	0.02	0.04	0.46	0.94	1.77	2.90	4.13	5.27	6.61	7.87	9.13	10.35	11.53	12.66	13.73	14.73	15.65	16.48	17.24	17.92	19.44
1984	0.02	0.12	0.44	1.14	1.72	2.59	3.64	4.70	5.64	6.69	7.65	8.59	9.48	10.32	11.12	11.85	12.53	13.14	13.69	14.19	15.30
1985	0.01	0.06	0.30	1.02	2.03	2.80	3.95	5.33	6.71	7.94	9.31	10.59	11.82	13.00	14.12	15.16	16.13	17.01	17.80	18.51	20.15
1986	0.01	0.03	0.35	0.85	1.87	3.09	3.97	5.23	6.71	8.15	9.42	10.83	12.12	13.36	14.53	15.63	16.65	17.58	18.42	19.17	20.92
1987	0.02	0.06	0.34	1.00	1.71	2.92	4.23	5.12	6.36	7.75	9.09	10.23	11.48	12.61	13.68	14.68	15.60	16.45	17.20	17.88	19.49
1988	0.02	0.05	0.31	0.95	1.90	2.82	4.28	5.79	6.81	8.20	9.74	11.21	12.45	13.81	15.02	16.16	17.21	18.18	19.04	19.82	21.71
1989	0.02	0.05	0.33	0.96	1.88	3.05	4.09	5.66	7.21	8.23	9.59	11.08	12.47	13.64	14.89	16.00	17.03	17.97	18.81	19.57	21.44
1990	0.02	0.05	0.39	0.98	1.85	2.93	4.17	5.21	6.71	8.15	9.08	10.29	11.60	12.81	13.81	14.86	15.78	16.62	17.38	18.05	19.75
1991	0.01	0.06	0.41	0.99	1.75	2.72	3.83	5.05	6.04	7.43	8.74	9.57	10.65	11.80	12.84	13.69	14.59	15.35	16.05	16.66	18.22
1992	0.02	0.06	0.35	0.99	1.74	2.62	3.67	4.83	6.06	7.04	8.41	9.67	10.47	11.49	12.58	13.55	14.33	15.15	15.84	16.46	17.98
1993	0.02	0.06	0.42	1.07	2.05	3.03	4.11	5.33	6.63	7.98	9.03	10.47	11.78	12.60	13.64	14.73	15.69	16.46	17.25	17.91	19.39
1994	0.02	0.07	0.36	1.00	1.81	2.90	3.93	5.01	6.22	7.47	8.75	9.75	11.09	12.31	13.06	14.00	14.98	15.83	16.51	17.20	18.44
1995	0.01	0.06	0.35	0.96	1.83	2.82	4.06	5.18	6.35	7.61	8.91	10.22	11.23	12.58	13.79	14.53	15.46	16.41	17.22	17.86	19.27
1996	0.03	0.08	0.41	1.04	1.89	2.88	3.90	5.09	6.11	7.13	8.21	9.30	10.36	11.17	12.24	13.17	13.73	14.43	15.13	15.72	16.61
1997	0.01	0.06	0.35	0.94	1.73	2.68	3.75	4.82	6.05	7.09	8.13	9.22	10.31	11.37	12.17	13.23	14.14	14.68	15.35	16.01	16.83
1998	0.01	0.05	0.34	0.93	1.73	2.65	3.69	4.80	5.88	7.08	8.09	9.08	10.10	11.12	12.10	12.83	13.78	14.59	15.06	15.64	16.62
1999	0.01	0.05	0.32	0.93	1.79	2.78	3.84	4.99	6.19	7.32	8.57	9.60	10.60	11.62	12.63	13.60	14.30	15.21	15.98	16.42	17.55
2000	0.02	0.04	0.43	0.95	1.84	2.91	4.05	5.24	6.48	7.75	8.93	10.21	11.25	12.26	13.29	14.28	15.22	15.90	16.77	17.49	18.85
2001	0.02	0.07	0.41	1.09	1.76	2.79	3.92	5.07	6.22	7.39	8.57	9.64	10.79	11.72	12.61	13.50	14.35	15.15	15.72	16.44	17.97
2002	0.02	0.07	0.41	1.02	1.91	2.71	3.85	5.08	6.29	7.47	8.68	9.87	10.95	12.09	13.02	13.89	14.75	15.57	16.33	16.86	18.32
2003	0.02	0.07	0.36	1.02	1.83	2.88	3.78	5.02	6.30	7.55	8.76	9.97	11.15	12.22	13.35	14.25	15.08	15.91	16.68	17.38	19.05
2004	0.02	0.07	0.46	1.01	1.90	2.85	3.99	4.91	6.14	7.38	8.55	9.67	10.78	11.84	12.79	13.78	14.56	15.27	15.96	16.61	18.02
2005	0.02	0.08	0.35	1.10	1.84	2.92	4.01	5.26	6.26	7.56	8.86	10.07	11.22	12.35	13.43	14.38	15.36	16.12	16.81	17.48	19.15
2006	0.02	0.04	0.36	0.97	1.98	2.84	4.02	5.15	6.41	7.38	8.64	9.87	11.00	12.07	13.10	14.07	14.92	15.78	16.44	17.04	18.79
2007	0.02	0.04	0.33	0.97	1.83	3.04	4.02	5.30	6.49	7.78	8.78	10.04	11.26	12.39	13.43	14.42	15.35	16.15	16.96	17.56	19.58
2008	0.02	0.04	0.32	0.92	1.79	2.79	4.09	5.09	6.36	7.51	8.74	9.67	10.84	11.96	12.98	13.90	14.78	15.59	16.28	16.97	18.63
2009	0.01	0.03	0.32	0.90	1.74	2.81	3.97	5.41	6.48	7.83	9.04	10.32	11.29	12.48	13.62	14.64	15.57	16.43	17.22	17.89	19.34
2010	0.02	0.04	0.37	0.90	1.70	2.70	3.87	5.06	6.49	7.54	8.83	9.98	11.17	12.05	13.15	14.17	15.08	15.89	16.64	17.32	18.54
2011	0.02	0.06	0.31	0.96	1.69	2.63	3.73	4.96	6.17	7.59	8.61	9.84	10.93	12.05	12.87	13.88	14.81	15.62	16.34	17.00	18.34
2012	0.02	0.03	0.39	0.91	1.80	2.63	3.63	4.73	5.90	7.02	8.31	9.21	10.29	11.22	12.17	12.86	13.69	14.45	15.11	15.68	16.59
2013	0.01	0.06	0.33	0.96	1.67	2.77	3.75	4.88	6.10	7.39	8.60	9.99	10.95	12.11	13.09	14.09	14.81	15.67	16.44	17.10	18.29
2014	0.01	0.04	0.33	0.88	1.74	2.59	3.83	4.88	6.07	7.33	8.64	9.86	11.23	12.19	13.32	14.27	15.22	15.91	16.71	17.43	18.77
2015	0.02	0.05	0.42	0.89	1.65	2.67	3.61	4.91	5.98	7.17	8.40	9.66	10.83	12.12	13.01	14.05	14.92	15.78	16.39	17.10	18.50
2016	0.02	0.09	0.45	1.07	1.72	2.66	3.82	4.85	6.22	7.32	8.52	9.75	10.98	12.11	13.36	14.20	15.17	15.97	16.76	17.30	18.40
2017	0.01	0.09	0.40	1.09	1.93	2.73	3.80	5.08	6.16	7.59	8.71	9.92	11.14	12.36	13.46	14.66	15.46	16.38	17.12	17.85	19.03
2018	0.03	0.09	0.51	1.06	2.01	3.00	3.88	5.01	6.30	7.37	8.74	9.80	10.93	12.05	13.16	14.15	15.20	15.90	16.68	17.32	18.65
2019	0.02	0.10	0.30	1.21	1.94	3.09	4.22	5.19	6.40	7.75	8.86	10.25	11.33	12.46	13.57	14.66	15.61	16.62	17.28	18.01	19.25
2020	0.01	0.04	0.33	0.84	2.02	2.85	4.07	5.22	6.17	7.35	8.64	9.67	10.97	11.96	12.99	13.99	14.95	15.79	16.66	17.23	18.51

Table 2.1.21f. Mid-year weight (kg) at age in the survey (ensemble).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.02	0.07	0.40	1.05	1.91	2.90	3.98	5.09	6.22	7.32	8.39	9.41	10.38	11.28	12.13	12.91	13.62	14.26	14.83	15.35	16.58
1978	0.01	0.05	0.33	0.98	1.84	2.88	4.04	5.26	6.50	7.74	8.95	10.12	11.23	12.28	13.27	14.18	15.01	15.77	16.45	17.06	18.52
1979	0.02	0.06	0.40	1.00	1.90	2.89	3.98	5.10	6.23	7.35	8.43	9.46	10.44	11.36	12.22	13.01	13.73	14.38	14.97	15.49	16.68
1980	0.02	0.06	0.35	1.00	1.78	2.81	3.88	4.99	6.12	7.24	8.33	9.37	10.36	11.29	12.15	12.95	13.68	14.34	14.94	15.47	16.65
1981	0.02	0.06	0.31	0.96	1.83	2.74	3.85	4.94	6.04	7.13	8.18	9.19	10.15	11.05	11.88	12.65	13.36	14.00	14.57	15.08	16.20
1982	0.02	0.05	0.35	0.97	1.90	2.96	3.98	5.17	6.30	7.41	8.49	9.52	10.49	11.41	12.26	13.04	13.75	14.40	14.98	15.49	16.62
1983	0.01	0.04	0.43	0.96	1.80	2.92	4.11	5.21	6.46	7.64	8.78	9.88	10.91	11.89	12.80	13.64	14.41	15.10	15.73	16.28	17.50
1984	0.02	0.11	0.44	1.11	1.75	2.61	3.64	4.64	5.53	6.50	7.38	8.22	9.00	9.74	10.42	11.04	11.60	12.11	12.57	12.98	13.86
1985	0.01	0.06	0.30	1.03	1.98	2.83	3.96	5.27	6.56	7.70	8.95	10.09	11.17	12.19	13.14	14.02	14.82	15.55	16.21	16.79	18.09
1986	0.01	0.03	0.35	0.87	1.89	3.02	3.98	5.19	6.57	7.90	9.06	10.31	11.44	12.51	13.51	14.43	15.28	16.05	16.74	17.36	18.75
1987	0.02	0.06	0.34	1.01	1.74	2.94	4.13	5.08	6.25	7.53	8.73	9.76	10.86	11.84	12.75	13.59	14.36	15.06	15.68	16.24	17.52
1988	0.02	0.05	0.31	0.96	1.92	2.85	4.27	5.63	6.69	7.97	9.37	10.66	11.77	12.93	13.97	14.92	15.80	16.59	17.31	17.95	19.43
1989	0.02	0.05	0.34	0.97	1.90	3.07	4.09	5.59	6.96	8.00	9.24	10.56	11.77	12.79	13.85	14.79	15.64	16.42	17.11	17.73	19.20
1990	0.02	0.05	0.39	0.99	1.87	2.94	4.15	5.16	6.57	7.83	8.76	9.85	10.99	12.03	12.89	13.78	14.55	15.24	15.87	16.42	17.76
1991	0.01	0.06	0.40	0.99	1.77	2.73	3.82	4.99	5.93	7.22	8.34	9.16	10.11	11.09	11.98	12.70	13.44	14.08	14.65	15.16	16.38
1992	0.02	0.06	0.35	0.99	1.75	2.63	3.66	4.77	5.94	6.86	8.09	9.16	9.93	10.82	11.73	12.55	13.21	13.88	14.45	14.96	16.15
1993	0.02	0.06	0.44	1.09	2.04	3.03	4.10	5.27	6.50	7.75	8.72	10.00	11.09	11.87	12.76	13.67	14.47	15.11	15.76	16.30	17.47
1994	0.02	0.07	0.36	1.03	1.84	2.89	3.91	4.96	6.09	7.26	8.42	9.32	10.50	11.49	12.19	12.99	13.80	14.50	15.06	15.62	16.61
1995	0.02	0.06	0.34	0.96	1.88	2.84	4.02	5.11	6.22	7.39	8.57	9.74	10.64	11.80	12.78	13.46	14.23	15.01	15.68	16.21	17.32
1996	0.03	0.08	0.41	1.05	1.89	2.92	3.89	5.00	5.98	6.94	7.92	8.89	9.84	10.55	11.46	12.20	12.72	13.30	13.87	14.36	15.08
1997	0.01	0.06	0.35	0.95	1.74	2.68	3.77	4.78	5.90	6.88	7.83	8.81	9.76	10.69	11.38	12.26	12.98	13.48	14.02	14.57	15.22
1998	0.01	0.05	0.34	0.94	1.75	2.66	3.67	4.78	5.77	6.86	7.78	8.68	9.57	10.45	11.29	11.91	12.69	13.33	13.76	14.24	15.03
1999	0.02	0.05	0.32	0.95	1.80	2.79	3.82	4.92	6.09	7.12	8.22	9.16	10.05	10.94	11.80	12.61	13.21	13.96	14.56	14.96	15.86
2000	0.02	0.05	0.44	0.96	1.86	2.91	4.04	5.17	6.34	7.55	8.61	9.72	10.66	11.54	12.42	13.25	14.04	14.62	15.33	15.89	17.01
2001	0.02	0.07	0.42	1.11	1.78	2.80	3.90	5.01	6.09	7.17	8.28	9.22	10.21	11.03	11.80	12.55	13.26	13.93	14.40	14.99	16.21
2002	0.02	0.07	0.41	1.03	1.94	2.72	3.85	5.01	6.16	7.25	8.34	9.44	10.38	11.35	12.14	12.88	13.61	14.28	14.91	15.36	16.46
2003	0.02	0.07	0.36	1.03	1.85	2.91	3.77	4.96	6.16	7.33	8.42	9.50	10.58	11.48	12.42	13.19	13.89	14.57	15.21	15.79	17.04
2004	0.02	0.07	0.47	1.02	1.92	2.87	3.99	4.86	6.02	7.16	8.24	9.23	10.20	11.16	11.95	12.77	13.42	14.02	14.59	15.12	16.16
2005	0.02	0.08	0.36	1.12	1.86	2.93	4.00	5.21	6.14	7.35	8.51	9.61	10.62	11.59	12.54	13.33	14.12	14.76	15.34	15.89	17.13
2006	0.02	0.04	0.36	0.99	2.00	2.86	4.00	5.09	6.29	7.18	8.33	9.42	10.43	11.35	12.22	13.07	13.77	14.47	15.02	15.52	16.84
2007	0.02	0.04	0.33	0.99	1.85	3.06	4.01	5.23	6.36	7.57	8.47	9.60	10.67	11.65	12.53	13.37	14.17	14.82	15.47	15.98	17.52
2008	0.02	0.04	0.32	0.93	1.81	2.81	4.08	5.03	6.22	7.29	8.43	9.25	10.28	11.25	12.12	12.90	13.63	14.32	14.88	15.44	16.64
2009	0.01	0.03	0.33	0.90	1.75	2.83	3.96	5.34	6.35	7.60	8.70	9.86	10.69	11.73	12.69	13.56	14.33	15.04	15.72	16.25	17.29
2010	0.02	0.05	0.37	0.92	1.71	2.70	3.86	5.01	6.36	7.33	8.50	9.52	10.58	11.33	12.27	13.12	13.88	14.55	15.17	15.74	16.63
2011	0.02	0.06	0.30	0.98	1.72	2.64	3.72	4.90	6.05	7.37	8.29	9.39	10.34	11.32	12.01	12.86	13.63	14.31	14.90	15.44	16.44
2012	0.02	0.03	0.38	0.91	1.82	2.65	3.61	4.67	5.79	6.83	8.01	8.81	9.76	10.57	11.39	11.97	12.66	13.29	13.84	14.30	15.00
2013	0.01	0.06	0.34	0.97	1.69	2.79	3.75	4.82	5.98	7.18	8.28	9.52	10.36	11.35	12.19	13.04	13.63	14.34	14.97	15.52	16.45
2014	0.01	0.04	0.34	0.90	1.75	2.60	3.82	4.84	5.94	7.11	8.31	9.40	10.61	11.43	12.39	13.19	13.99	14.55	15.21	15.80	16.87
2015	0.02	0.05	0.42	0.91	1.67	2.67	3.60	4.85	5.87	6.95	8.08	9.21	10.24	11.36	12.11	12.98	13.70	14.42	14.91	15.49	16.60
2016	0.02	0.09	0.44	1.08	1.75	2.67	3.80	4.79	6.09	7.12	8.19	9.29	10.38	11.36	12.42	13.12	13.92	14.59	15.24	15.68	16.54
2017	0.01	0.09	0.40	1.09	1.95	2.75	3.79	5.01	6.04	7.36	8.39	9.45	10.53	11.59	12.53	13.53	14.19	14.94	15.56	16.16	17.08
2018	0.03	0.09	0.52	1.07	2.00	3.00	3.87	4.95	6.16	7.16	8.41	9.36	10.34	11.31	12.26	13.09	13.97	14.55	15.19	15.71	16.76
2019	0.02	0.10	0.30	1.23	1.95	3.07	4.19	5.13	6.26	7.51	8.52	9.78	10.73	11.70	12.65	13.57	14.37	15.21	15.75	16.35	17.28

Table 2.1.22a. Selectivity at age in the fishery (Model 19.12a).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.000	0.000	0.012	0.101	0.323	0.596	0.793	0.878	0.898	0.897	0.893	0.890	0.888	0.887	0.887	0.887	0.886	0.886	0.886	0.886	0.886
1978	0.000	0.000	0.010	0.101	0.322	0.595	0.792	0.877	0.896	0.895	0.890	0.887	0.885	0.884	0.884	0.883	0.883	0.883	0.883	0.883	0.883
1979	0.000	0.000	0.014	0.102	0.336	0.606	0.798	0.879	0.897	0.895	0.890	0.887	0.885	0.884	0.883	0.883	0.883	0.883	0.882	0.882	0.882
1980	0.000	0.000	0.012	0.109	0.318	0.604	0.798	0.882	0.902	0.902	0.898	0.895	0.894	0.893	0.892	0.892	0.892	0.892	0.891	0.891	0.891
1981	0.000	0.000	0.014	0.125	0.369	0.619	0.813	0.888	0.904	0.902	0.898	0.894	0.893	0.892	0.891	0.891	0.890	0.890	0.890	0.890	0.890
1982	0.000	0.000	0.007	0.076	0.300	0.589	0.781	0.879	0.903	0.904	0.901	0.899	0.897	0.897	0.896	0.896	0.896	0.896	0.895	0.895	0.895
1983	0.000	0.000	0.013	0.084	0.287	0.584	0.796	0.883	0.911	0.914	0.912	0.911	0.909	0.909	0.908	0.908	0.908	0.908	0.908	0.908	0.908
1984	0.000	0.001	0.019	0.133	0.329	0.593	0.807	0.897	0.920	0.923	0.922	0.920	0.919	0.918	0.918	0.918	0.918	0.918	0.918	0.918	0.918
1985	0.000	0.000	0.006	0.092	0.316	0.552	0.765	0.877	0.906	0.908	0.906	0.904	0.902	0.901	0.901	0.901	0.900	0.900	0.900	0.900	0.900
1986	0.000	0.000	0.015	0.091	0.346	0.622	0.786	0.876	0.900	0.899	0.894	0.891	0.889	0.888	0.888	0.887	0.887	0.887	0.887	0.887	0.887
1987	0.000	0.000	0.007	0.088	0.264	0.584	0.792	0.873	0.904	0.909	0.907	0.905	0.903	0.903	0.902	0.902	0.902	0.902	0.902	0.902	0.902
1988	0.000	0.001	0.030	0.165	0.424	0.641	0.839	0.902	0.912	0.908	0.903	0.899	0.897	0.896	0.896	0.895	0.895	0.895	0.895	0.895	0.895
1989	0.000	0.000	0.015	0.113	0.344	0.627	0.792	0.896	0.917	0.918	0.916	0.913	0.912	0.911	0.911	0.911	0.911	0.910	0.910	0.910	0.910
1990	0.000	0.000	0.011	0.086	0.293	0.574	0.796	0.886	0.931	0.939	0.940	0.940	0.940	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939
1991	0.000	0.000	0.011	0.090	0.287	0.560	0.780	0.887	0.915	0.924	0.923	0.922	0.921	0.921	0.920	0.920	0.920	0.920	0.920	0.920	0.920
1992	0.000	0.000	0.008	0.089	0.289	0.548	0.763	0.867	0.893	0.893	0.888	0.885	0.884	0.883	0.882	0.881	0.881	0.881	0.881	0.881	0.881
1993	0.000	0.001	0.026	0.141	0.389	0.635	0.806	0.888	0.907	0.904	0.900	0.896	0.895	0.894	0.893	0.893	0.893	0.892	0.892	0.892	0.892
1994	0.000	0.000	0.012	0.115	0.329	0.610	0.793	0.877	0.902	0.903	0.899	0.897	0.895	0.894	0.893	0.893	0.893	0.893	0.893	0.893	0.893
1995	0.000	0.000	0.014	0.111	0.358	0.611	0.807	0.883	0.902	0.902	0.898	0.894	0.893	0.891	0.891	0.890	0.890	0.890	0.890	0.890	0.890
1996	0.000	0.000	0.008	0.079	0.285	0.584	0.782	0.892	0.926	0.936	0.938	0.938	0.937	0.937	0.937	0.936	0.936	0.936	0.936	0.936	0.936
1997	0.000	0.000	0.016	0.121	0.343	0.612	0.817	0.897	0.924	0.927	0.926	0.925	0.924	0.923	0.923	0.923	0.922	0.922	0.922	0.922	0.922
1998	0.000	0.000	0.007	0.085	0.299	0.568	0.780	0.885	0.912	0.916	0.915	0.913	0.912	0.911	0.911	0.911	0.911	0.911	0.911	0.910	0.910
1999	0.000	0.000	0.007	0.083	0.304	0.581	0.782	0.878	0.905	0.907	0.904	0.902	0.900	0.899	0.899	0.898	0.898	0.898	0.898	0.898	0.898
2000	0.000	0.000	0.011	0.070	0.278	0.566	0.779	0.874	0.902	0.905	0.902	0.900	0.899	0.898	0.897	0.897	0.897	0.897	0.897	0.897	0.896
2001	0.000	0.000	0.009	0.097	0.262	0.548	0.767	0.852	0.863	0.854	0.844	0.839	0.836	0.834	0.833	0.832	0.832	0.832	0.832	0.832	0.832
2002	0.000	0.000	0.018	0.117	0.364	0.575	0.776	0.839	0.828	0.806	0.789	0.778	0.774	0.771	0.769	0.769	0.768	0.768	0.768	0.768	0.768
2003	0.000	0.000	0.014	0.118	0.338	0.624	0.775	0.871	0.890	0.886	0.881	0.877	0.874	0.873	0.872	0.872	0.872	0.871	0.871	0.871	0.871
2004	0.000	0.000	0.022	0.114	0.357	0.615	0.812	0.874	0.898	0.897	0.892	0.889	0.887	0.886	0.885	0.885	0.884	0.884	0.884	0.884	0.884
2005	0.000	0.001	0.014	0.139	0.340	0.623	0.805	0.892	0.909	0.913	0.910	0.908	0.906	0.905	0.905	0.905	0.905	0.904	0.904	0.904	0.904
2006	0.000	0.000	0.009	0.091	0.355	0.588	0.802	0.894	0.927	0.933	0.934	0.934	0.933	0.933	0.933	0.933	0.932	0.932	0.932	0.932	0.932
2007	0.000	0.000	0.007	0.085	0.299	0.621	0.789	0.891	0.920	0.926	0.926	0.925	0.924	0.924	0.924	0.923	0.923	0.923	0.923	0.923	0.923
2008	0.000	0.000	0.006	0.074	0.293	0.571	0.799	0.859	0.870	0.863	0.854	0.850	0.847	0.845	0.844	0.844	0.843	0.843	0.843	0.843	0.843
2009	0.000	0.000	0.004	0.052	0.233	0.529	0.746	0.834	0.833	0.817	0.805	0.797	0.793	0.791	0.789	0.789	0.788	0.788	0.788	0.788	0.788
2010	0.000	0.000	0.004	0.047	0.208	0.486	0.731	0.827	0.839	0.829	0.818	0.811	0.807	0.806	0.805	0.804	0.804	0.803	0.803	0.803	0.803
2011	0.000	0.000	0.002	0.059	0.224	0.487	0.728	0.855	0.888	0.892	0.890	0.887	0.886	0.885	0.884	0.884	0.884	0.883	0.883	0.883	0.883
2012	0.000	0.000	0.007	0.063	0.289	0.540	0.751	0.864	0.898	0.902	0.899	0.897	0.895	0.894	0.894	0.894	0.893	0.893	0.893	0.893	0.893
2013	0.000	0.000	0.008	0.086	0.267	0.579	0.765	0.856	0.879	0.875	0.868	0.863	0.861	0.860	0.859	0.859	0.858	0.858	0.858	0.858	0.858
2014	0.000	0.000	0.004	0.056	0.253	0.499	0.753	0.840	0.862	0.858	0.850	0.845	0.842	0.841	0.840	0.839	0.839	0.839	0.839	0.839	0.839
2015	0.000	0.000	0.006	0.053	0.224	0.516	0.722	0.852	0.879	0.882	0.879	0.875	0.873	0.872	0.872	0.871	0.871	0.871	0.871	0.871	0.871
2016	0.000	0.000	0.006	0.074	0.234	0.500	0.745	0.850	0.897	0.903	0.903	0.901	0.900	0.899	0.899	0.899	0.898	0.898	0.898	0.898	0.898
2017	0.000	0.000	0.005	0.075	0.284	0.516	0.740	0.869	0.908	0.923	0.925	0.925	0.924	0.924	0.923	0.923	0.923	0.923	0.923	0.923	0.923
2018	0.000	0.000	0.018	0.099	0.343	0.617	0.780	0.878	0.913	0.919	0.920	0.918	0.918	0.917	0.917	0.916	0.916	0.916	0.916	0.916	0.916
2019	0.000	0.001	0.006	0.140	0.336	0.627	0.806	0.866	0.884	0.881	0.876	0.871	0.869	0.868	0.867	0.867	0.866	0.866	0.866	0.866	0.866
2020	0.000	0.000	0.011	0.085	0.411	0.628	0.822	0.893	0.907	0.909	0.906	0.904	0.903	0.902	0.901	0.901	0.901	0.901	0.901	0.901	0.901

Table 2.1.22b. Selectivity at age in the fishery (Model 19.12).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.000	0.000	0.012	0.100	0.320	0.596	0.810	0.925	0.973	0.989	0.990	0.979	0.954	0.915	0.864	0.806	0.746	0.685	0.628	0.575	0.443
1978	0.000	0.000	0.010	0.099	0.318	0.594	0.809	0.924	0.972	0.989	0.990	0.979	0.954	0.915	0.864	0.806	0.746	0.685	0.628	0.575	0.443
1979	0.000	0.000	0.014	0.100	0.332	0.606	0.815	0.927	0.974	0.990	0.991	0.979	0.954	0.915	0.864	0.806	0.746	0.685	0.628	0.575	0.449
1980	0.000	0.000	0.012	0.107	0.313	0.603	0.814	0.926	0.973	0.989	0.991	0.979	0.954	0.915	0.864	0.806	0.746	0.685	0.628	0.575	0.453
1981	0.000	0.000	0.014	0.121	0.364	0.616	0.828	0.933	0.976	0.990	0.991	0.979	0.954	0.915	0.864	0.807	0.746	0.685	0.628	0.575	0.454
1982	0.000	0.000	0.007	0.073	0.294	0.587	0.794	0.922	0.972	0.989	0.990	0.979	0.954	0.915	0.864	0.806	0.746	0.685	0.628	0.575	0.455
1983	0.000	0.000	0.015	0.080	0.279	0.579	0.809	0.919	0.972	0.989	0.990	0.979	0.954	0.915	0.864	0.806	0.746	0.685	0.628	0.575	0.454
1984	0.000	0.001	0.018	0.139	0.319	0.587	0.816	0.931	0.973	0.990	0.991	0.979	0.954	0.915	0.864	0.806	0.746	0.685	0.628	0.575	0.454
1985	0.000	0.000	0.006	0.090	0.327	0.547	0.776	0.917	0.972	0.988	0.990	0.979	0.954	0.915	0.864	0.806	0.745	0.685	0.628	0.575	0.453
1986	0.000	0.000	0.015	0.090	0.344	0.637	0.799	0.918	0.973	0.990	0.991	0.979	0.954	0.915	0.864	0.806	0.746	0.685	0.628	0.575	0.451
1987	0.000	0.000	0.008	0.088	0.261	0.585	0.819	0.911	0.967	0.988	0.990	0.980	0.954	0.915	0.864	0.806	0.745	0.685	0.628	0.575	0.449
1988	0.000	0.001	0.029	0.162	0.417	0.636	0.853	0.948	0.976	0.991	0.992	0.980	0.956	0.915	0.864	0.806	0.746	0.685	0.628	0.575	0.446
1989	0.000	0.000	0.015	0.110	0.337	0.623	0.800	0.933	0.978	0.989	0.991	0.980	0.954	0.918	0.865	0.807	0.746	0.685	0.628	0.576	0.444
1990	0.000	0.000	0.010	0.082	0.284	0.568	0.803	0.909	0.972	0.990	0.991	0.981	0.956	0.915	0.867	0.806	0.746	0.685	0.628	0.575	0.442
1991	0.000	0.000	0.011	0.088	0.281	0.555	0.789	0.920	0.966	0.989	0.990	0.981	0.958	0.917	0.864	0.810	0.745	0.685	0.628	0.575	0.440
1992	0.000	0.000	0.009	0.092	0.289	0.549	0.779	0.913	0.970	0.987	0.990	0.978	0.958	0.921	0.867	0.806	0.749	0.685	0.628	0.575	0.444
1993	0.000	0.001	0.027	0.146	0.398	0.642	0.824	0.929	0.975	0.991	0.992	0.980	0.952	0.921	0.872	0.809	0.745	0.688	0.628	0.575	0.455
1994	0.000	0.000	0.014	0.115	0.332	0.619	0.812	0.920	0.970	0.989	0.991	0.982	0.954	0.911	0.871	0.815	0.749	0.685	0.631	0.575	0.470
1995	0.000	0.000	0.016	0.115	0.352	0.613	0.828	0.927	0.972	0.989	0.991	0.980	0.959	0.915	0.860	0.814	0.754	0.688	0.627	0.578	0.467
1996	0.000	0.000	0.008	0.078	0.283	0.574	0.791	0.921	0.969	0.987	0.991	0.981	0.955	0.922	0.864	0.801	0.753	0.694	0.631	0.575	0.486
1997	0.000	0.000	0.015	0.113	0.333	0.606	0.822	0.927	0.975	0.990	0.991	0.981	0.957	0.916	0.874	0.806	0.740	0.693	0.636	0.578	0.502
1998	0.000	0.000	0.007	0.079	0.286	0.560	0.790	0.919	0.970	0.989	0.990	0.981	0.958	0.919	0.866	0.817	0.746	0.680	0.635	0.583	0.491
1999	0.000	0.000	0.006	0.076	0.289	0.571	0.792	0.917	0.971	0.988	0.990	0.980	0.958	0.921	0.870	0.809	0.757	0.686	0.624	0.583	0.483
2000	0.000	0.000	0.009	0.063	0.261	0.553	0.786	0.913	0.968	0.988	0.990	0.979	0.956	0.920	0.871	0.813	0.748	0.697	0.629	0.573	0.458
2001	0.000	0.000	0.008	0.089	0.252	0.540	0.785	0.914	0.968	0.988	0.990	0.980	0.954	0.917	0.871	0.814	0.751	0.687	0.638	0.575	0.438
2002	0.000	0.000	0.018	0.117	0.356	0.576	0.802	0.925	0.973	0.989	0.991	0.980	0.956	0.914	0.867	0.813	0.753	0.691	0.630	0.585	0.462
2003	0.000	0.000	0.014	0.115	0.333	0.619	0.789	0.918	0.972	0.989	0.991	0.980	0.955	0.917	0.864	0.809	0.752	0.692	0.633	0.577	0.443
2004	0.000	0.000	0.021	0.110	0.349	0.611	0.826	0.916	0.971	0.989	0.991	0.980	0.956	0.916	0.867	0.806	0.749	0.692	0.635	0.580	0.459
2005	0.000	0.001	0.013	0.133	0.330	0.619	0.817	0.931	0.969	0.989	0.991	0.980	0.956	0.918	0.865	0.809	0.745	0.688	0.634	0.582	0.449
2006	0.000	0.000	0.009	0.085	0.340	0.579	0.810	0.922	0.973	0.987	0.991	0.980	0.956	0.918	0.868	0.807	0.748	0.685	0.631	0.582	0.437
2007	0.000	0.000	0.006	0.078	0.283	0.610	0.795	0.923	0.971	0.989	0.991	0.981	0.956	0.917	0.868	0.810	0.746	0.688	0.627	0.578	0.418
2008	0.000	0.000	0.006	0.071	0.282	0.564	0.821	0.918	0.972	0.989	0.990	0.982	0.958	0.918	0.867	0.810	0.749	0.686	0.631	0.575	0.437
2009	0.000	0.000	0.004	0.051	0.231	0.527	0.771	0.923	0.967	0.988	0.990	0.978	0.959	0.920	0.868	0.810	0.750	0.689	0.629	0.578	0.469
2010	0.000	0.000	0.004	0.046	0.208	0.490	0.757	0.902	0.970	0.986	0.990	0.979	0.953	0.922	0.870	0.810	0.749	0.689	0.631	0.576	0.479
2011	0.000	0.000	0.003	0.060	0.224	0.492	0.749	0.903	0.965	0.988	0.990	0.979	0.954	0.913	0.873	0.813	0.749	0.688	0.632	0.578	0.471
2012	0.000	0.000	0.008	0.064	0.284	0.536	0.766	0.906	0.968	0.988	0.990	0.980	0.953	0.915	0.862	0.816	0.752	0.689	0.631	0.579	0.494
2013	0.000	0.000	0.008	0.087	0.266	0.578	0.780	0.907	0.967	0.988	0.990	0.977	0.955	0.914	0.865	0.804	0.755	0.692	0.632	0.578	0.481
2014	0.000	0.000	0.005	0.057	0.254	0.502	0.776	0.900	0.961	0.986	0.990	0.980	0.951	0.916	0.863	0.807	0.743	0.694	0.634	0.579	0.473
2015	0.000	0.000	0.007	0.052	0.221	0.519	0.739	0.905	0.961	0.985	0.990	0.980	0.956	0.910	0.866	0.805	0.746	0.683	0.637	0.581	0.469
2016	0.000	0.000	0.007	0.073	0.229	0.499	0.762	0.890	0.965	0.985	0.990	0.981	0.956	0.918	0.858	0.808	0.744	0.686	0.626	0.583	0.496
2017	0.000	0.000	0.005	0.074	0.278	0.509	0.749	0.903	0.959	0.986	0.990	0.981	0.958	0.918	0.868	0.800	0.747	0.684	0.629	0.573	0.482
2018	0.000	0.000	0.018	0.097	0.342	0.617	0.790	0.912	0.970	0.987	0.990	0.981	0.959	0.921	0.868	0.810	0.739	0.687	0.626	0.576	0.468
2019	0.000	0.001	0.007	0.140	0.336	0.637	0.833	0.920	0.969	0.989	0.991	0.979	0.958	0.922	0.871	0.811	0.749	0.678	0.630	0.574	0.480
2020	0.000	0.000	0.012	0.086	0.408	0.631	0.844	0.939	0.972	0.989	0.991	0.981	0.955	0.920	0.873	0.814	0.750	0.689	0.622	0.577	0.476

Table 2.1.22c. Selectivity at age in the fishery (Model 21.1).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.000	0.000	0.015	0.132	0.403	0.691	0.854	0.882	0.843	0.793	0.752	0.724	0.706	0.694	0.686	0.681	0.677	0.675	0.673	0.672	0.671
1978	0.000	0.000	0.014	0.131	0.403	0.691	0.853	0.879	0.838	0.785	0.742	0.713	0.694	0.681	0.673	0.668	0.664	0.662	0.660	0.659	0.657
1979	0.000	0.000	0.020	0.141	0.423	0.705	0.859	0.881	0.837	0.783	0.740	0.710	0.691	0.679	0.670	0.665	0.661	0.659	0.657	0.656	0.654
1980	0.000	0.000	0.018	0.153	0.414	0.704	0.860	0.887	0.849	0.800	0.761	0.733	0.716	0.704	0.697	0.692	0.688	0.686	0.684	0.683	0.682
1981	0.000	0.001	0.021	0.171	0.467	0.721	0.871	0.891	0.851	0.801	0.761	0.734	0.716	0.704	0.697	0.692	0.689	0.686	0.685	0.683	0.682
1982	0.000	0.000	0.011	0.106	0.391	0.694	0.850	0.887	0.854	0.808	0.771	0.745	0.728	0.717	0.710	0.705	0.702	0.700	0.698	0.697	0.695
1983	0.000	0.000	0.019	0.121	0.376	0.692	0.863	0.896	0.868	0.828	0.795	0.772	0.757	0.747	0.741	0.737	0.734	0.732	0.730	0.729	0.728
1984	0.000	0.001	0.028	0.184	0.426	0.698	0.872	0.906	0.883	0.846	0.817	0.796	0.782	0.774	0.768	0.764	0.762	0.760	0.759	0.758	0.756
1985	0.000	0.000	0.008	0.126	0.405	0.659	0.838	0.887	0.856	0.815	0.778	0.753	0.736	0.726	0.719	0.714	0.711	0.709	0.708	0.706	0.705
1986	0.000	0.000	0.021	0.123	0.438	0.722	0.854	0.886	0.845	0.791	0.753	0.723	0.705	0.693	0.685	0.680	0.677	0.674	0.672	0.671	0.669
1987	0.000	0.000	0.010	0.120	0.341	0.686	0.854	0.881	0.850	0.796	0.755	0.729	0.710	0.698	0.691	0.686	0.682	0.680	0.678	0.677	0.675
1988	0.000	0.002	0.043	0.220	0.522	0.736	0.888	0.890	0.847	0.792	0.744	0.712	0.694	0.681	0.673	0.668	0.664	0.662	0.660	0.659	0.657
1989	0.000	0.000	0.022	0.158	0.440	0.729	0.861	0.903	0.872	0.837	0.805	0.780	0.764	0.755	0.749	0.745	0.742	0.740	0.739	0.738	0.736
1990	0.000	0.000	0.016	0.125	0.390	0.687	0.868	0.914	0.909	0.886	0.869	0.854	0.843	0.837	0.833	0.830	0.828	0.827	0.826	0.826	0.825
1991	0.000	0.000	0.016	0.123	0.371	0.667	0.852	0.902	0.887	0.850	0.821	0.805	0.792	0.782	0.776	0.773	0.770	0.769	0.768	0.767	0.765
1992	0.000	0.000	0.011	0.123	0.374	0.654	0.838	0.882	0.848	0.807	0.761	0.734	0.719	0.707	0.699	0.694	0.691	0.688	0.687	0.685	0.684
1993	0.000	0.001	0.038	0.187	0.482	0.730	0.866	0.889	0.844	0.785	0.748	0.712	0.692	0.682	0.674	0.667	0.664	0.661	0.659	0.658	0.656
1994	0.000	0.000	0.016	0.158	0.415	0.708	0.853	0.878	0.836	0.778	0.730	0.703	0.679	0.666	0.658	0.653	0.648	0.646	0.644	0.642	0.641
1995	0.000	0.000	0.018	0.145	0.452	0.707	0.864	0.882	0.842	0.788	0.743	0.711	0.694	0.679	0.670	0.666	0.662	0.659	0.657	0.656	0.655
1996	0.000	0.000	0.011	0.110	0.372	0.696	0.855	0.913	0.907	0.886	0.866	0.851	0.840	0.835	0.830	0.827	0.825	0.824	0.823	0.822	0.822
1997	0.000	0.001	0.023	0.163	0.436	0.714	0.881	0.910	0.889	0.859	0.833	0.814	0.801	0.792	0.788	0.783	0.781	0.780	0.778	0.777	0.777
1998	0.000	0.000	0.010	0.117	0.384	0.673	0.850	0.896	0.873	0.834	0.805	0.784	0.769	0.759	0.753	0.749	0.746	0.744	0.743	0.742	0.741
1999	0.000	0.000	0.010	0.115	0.391	0.685	0.852	0.893	0.863	0.826	0.791	0.769	0.755	0.744	0.738	0.733	0.730	0.728	0.726	0.726	0.724
2000	0.000	0.000	0.017	0.099	0.367	0.675	0.850	0.890	0.863	0.816	0.785	0.760	0.745	0.736	0.729	0.724	0.721	0.719	0.717	0.716	0.714
2001	0.000	0.000	0.012	0.133	0.340	0.655	0.837	0.858	0.802	0.733	0.673	0.640	0.615	0.601	0.591	0.584	0.579	0.576	0.574	0.572	0.569
2002	0.000	0.000	0.023	0.156	0.454	0.674	0.844	0.846	0.769	0.685	0.619	0.569	0.544	0.524	0.513	0.505	0.500	0.496	0.493	0.491	0.489
2003	0.000	0.000	0.018	0.155	0.426	0.721	0.842	0.875	0.826	0.766	0.720	0.687	0.664	0.652	0.642	0.637	0.633	0.630	0.628	0.627	0.625
2004	0.000	0.000	0.029	0.150	0.444	0.713	0.870	0.891	0.859	0.811	0.773	0.747	0.730	0.718	0.712	0.707	0.704	0.702	0.700	0.699	0.697
2005	0.000	0.001	0.018	0.184	0.426	0.720	0.867	0.896	0.873	0.830	0.795	0.771	0.756	0.746	0.739	0.735	0.732	0.730	0.729	0.728	0.726
2006	0.000	0.000	0.013	0.124	0.451	0.692	0.869	0.916	0.908	0.890	0.869	0.854	0.844	0.838	0.834	0.831	0.830	0.828	0.827	0.827	0.826
2007	0.000	0.000	0.009	0.119	0.388	0.726	0.861	0.912	0.901	0.875	0.858	0.841	0.830	0.823	0.819	0.816	0.814	0.812	0.811	0.811	0.809
2008	0.000	0.000	0.009	0.102	0.380	0.678	0.864	0.877	0.833	0.782	0.738	0.715	0.694	0.681	0.672	0.667	0.663	0.660	0.659	0.657	0.656
2009	0.000	0.000	0.005	0.071	0.306	0.636	0.820	0.831	0.769	0.686	0.627	0.582	0.561	0.541	0.529	0.521	0.515	0.512	0.509	0.507	0.505
2010	0.000	0.000	0.005	0.067	0.277	0.593	0.807	0.830	0.747	0.678	0.610	0.568	0.538	0.524	0.511	0.502	0.497	0.493	0.490	0.488	0.486
2011	0.000	0.000	0.003	0.081	0.300	0.592	0.805	0.857	0.814	0.744	0.704	0.670	0.649	0.634	0.627	0.621	0.616	0.613	0.611	0.610	0.608
2012	0.000	0.000	0.010	0.088	0.377	0.650	0.826	0.874	0.836	0.783	0.733	0.710	0.689	0.678	0.669	0.665	0.661	0.658	0.657	0.655	0.654
2013	0.000	0.000	0.010	0.118	0.342	0.680	0.834	0.862	0.813	0.742	0.689	0.647	0.629	0.613	0.604	0.597	0.594	0.590	0.588	0.586	0.585
2014	0.000	0.000	0.006	0.077	0.335	0.604	0.827	0.858	0.820	0.760	0.706	0.672	0.646	0.635	0.625	0.619	0.615	0.613	0.611	0.609	0.607
2015	0.000	0.000	0.008	0.076	0.299	0.628	0.804	0.866	0.836	0.790	0.747	0.715	0.696	0.682	0.675	0.670	0.666	0.664	0.662	0.661	0.659
2016	0.000	0.000	0.008	0.103	0.314	0.608	0.822	0.869	0.841	0.799	0.762	0.734	0.714	0.702	0.693	0.689	0.686	0.684	0.682	0.681	0.680
2017	0.000	0.000	0.007	0.107	0.377	0.631	0.820	0.886	0.875	0.839	0.812	0.792	0.778	0.768	0.762	0.757	0.755	0.753	0.752	0.751	0.750
2018	0.000	0.000	0.025	0.135	0.436	0.719	0.850	0.894	0.874	0.843	0.809	0.789	0.776	0.766	0.760	0.756	0.752	0.751	0.750	0.749	0.748
2019	0.000	0.001	0.008	0.186	0.423	0.725	0.862	0.874	0.836	0.779	0.742	0.707	0.689	0.677	0.668	0.662	0.658	0.655	0.654	0.652	0.651
2020	0.000	0.000	0.015	0.112	0.510	0.727	0.877	0.895	0.870	0.834	0.800	0.781	0.764	0.755	0.749	0.745	0.742	0.740	0.738	0.737	0.736

Table 2.1.22d. Selectivity at age in the fishery (Model 21.2).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.000	0.000	0.013	0.101	0.307	0.565	0.763	0.855	0.874	0.869	0.861	0.855	0.851	0.849	0.848	0.848	0.847	0.847	0.847	0.847	0.847
1978	0.000	0.000	0.010	0.099	0.305	0.563	0.761	0.850	0.867	0.860	0.850	0.843	0.839	0.837	0.836	0.835	0.835	0.834	0.834	0.834	0.834
1979	0.000	0.000	0.015	0.098	0.320	0.576	0.769	0.854	0.868	0.859	0.849	0.842	0.838	0.836	0.834	0.834	0.833	0.833	0.833	0.833	0.833
1980	0.000	0.000	0.013	0.105	0.298	0.574	0.770	0.863	0.886	0.884	0.877	0.872	0.869	0.868	0.867	0.866	0.866	0.866	0.866	0.866	0.866
1981	0.000	0.001	0.017	0.125	0.352	0.590	0.790	0.872	0.889	0.883	0.876	0.870	0.867	0.865	0.864	0.863	0.863	0.863	0.863	0.863	0.863
1982	0.000	0.000	0.008	0.073	0.276	0.548	0.746	0.860	0.889	0.891	0.886	0.882	0.880	0.878	0.878	0.877	0.877	0.877	0.877	0.877	0.877
1983	0.000	0.000	0.013	0.081	0.269	0.546	0.764	0.866	0.906	0.912	0.911	0.909	0.907	0.906	0.905	0.905	0.905	0.905	0.905	0.905	0.905
1984	0.000	0.001	0.020	0.124	0.308	0.559	0.777	0.884	0.918	0.926	0.926	0.925	0.923	0.923	0.922	0.922	0.922	0.922	0.922	0.922	0.922
1985	0.000	0.000	0.006	0.088	0.288	0.514	0.732	0.857	0.895	0.900	0.897	0.894	0.892	0.891	0.890	0.890	0.890	0.889	0.889	0.889	0.889
1986	0.000	0.000	0.015	0.088	0.324	0.581	0.753	0.855	0.883	0.880	0.873	0.867	0.864	0.862	0.861	0.860	0.860	0.860	0.860	0.859	0.859
1987	0.000	0.000	0.007	0.082	0.244	0.546	0.755	0.848	0.885	0.888	0.884	0.880	0.877	0.876	0.875	0.874	0.874	0.874	0.874	0.874	0.874
1988	0.000	0.001	0.033	0.167	0.411	0.619	0.819	0.889	0.901	0.896	0.887	0.882	0.879	0.877	0.876	0.875	0.875	0.875	0.875	0.875	0.875
1989	0.000	0.000	0.017	0.112	0.327	0.596	0.765	0.884	0.914	0.918	0.916	0.913	0.911	0.910	0.910	0.910	0.909	0.909	0.909	0.909	0.909
1990	0.000	0.000	0.010	0.081	0.268	0.533	0.762	0.868	0.929	0.945	0.948	0.949	0.949	0.949	0.949	0.949	0.949	0.949	0.949	0.949	0.949
1991	0.000	0.000	0.012	0.085	0.267	0.521	0.745	0.872	0.912	0.928	0.929	0.929	0.928	0.927	0.927	0.927	0.926	0.926	0.926	0.926	0.926
1992	0.000	0.000	0.009	0.085	0.266	0.512	0.727	0.844	0.877	0.877	0.870	0.864	0.862	0.860	0.859	0.858	0.858	0.858	0.857	0.857	0.857
1993	0.000	0.001	0.027	0.136	0.366	0.599	0.777	0.866	0.888	0.882	0.875	0.868	0.864	0.862	0.861	0.861	0.860	0.860	0.860	0.860	0.860
1994	0.000	0.000	0.012	0.105	0.300	0.568	0.755	0.850	0.878	0.875	0.867	0.861	0.857	0.855	0.854	0.854	0.853	0.853	0.853	0.853	0.853
1995	0.000	0.000	0.014	0.104	0.328	0.570	0.774	0.862	0.887	0.886	0.880	0.874	0.872	0.870	0.869	0.868	0.868	0.868	0.867	0.867	0.867
1996	0.000	0.000	0.008	0.073	0.260	0.540	0.747	0.875	0.923	0.941	0.946	0.947	0.947	0.947	0.947	0.947	0.947	0.947	0.947	0.947	0.947
1997	0.000	0.001	0.018	0.128	0.339	0.592	0.797	0.891	0.930	0.939	0.940	0.940	0.939	0.939	0.938	0.938	0.938	0.938	0.938	0.938	0.938
1998	0.000	0.000	0.010	0.084	0.295	0.547	0.759	0.879	0.917	0.928	0.929	0.929	0.928	0.927	0.927	0.927	0.926	0.926	0.926	0.926	0.926
1999	0.000	0.000	0.010	0.094	0.286	0.561	0.761	0.868	0.903	0.907	0.904	0.901	0.899	0.898	0.898	0.897	0.897	0.897	0.897	0.897	0.897
2000	0.000	0.000	0.013	0.073	0.269	0.519	0.744	0.835	0.851	0.838	0.825	0.816	0.811	0.808	0.807	0.806	0.805	0.805	0.805	0.805	0.805
2001	0.000	0.000	0.007	0.082	0.229	0.500	0.700	0.769	0.735	0.682	0.640	0.618	0.605	0.599	0.595	0.593	0.592	0.591	0.591	0.590	0.590
2002	0.000	0.000	0.015	0.101	0.325	0.530	0.733	0.785	0.743	0.689	0.648	0.623	0.611	0.604	0.601	0.599	0.598	0.597	0.597	0.596	0.596
2003	0.000	0.000	0.006	0.075	0.254	0.533	0.696	0.779	0.760	0.713	0.680	0.660	0.648	0.642	0.639	0.637	0.636	0.636	0.636	0.635	0.635
2004	0.000	0.000	0.011	0.072	0.271	0.520	0.740	0.810	0.822	0.803	0.783	0.771	0.764	0.760	0.758	0.757	0.757	0.756	0.756	0.756	0.756
2005	0.000	0.000	0.008	0.104	0.275	0.548	0.750	0.869	0.900	0.912	0.912	0.910	0.908	0.907	0.907	0.906	0.906	0.906	0.906	0.906	0.906
2006	0.000	0.000	0.009	0.084	0.324	0.543	0.767	0.882	0.937	0.952	0.960	0.962	0.962	0.963	0.963	0.963	0.962	0.962	0.962	0.962	0.962
2007	0.000	0.000	0.011	0.098	0.302	0.605	0.772	0.892	0.937	0.956	0.960	0.962	0.962	0.962	0.962	0.962	0.962	0.962	0.962	0.962	0.962
2008	0.000	0.000	0.012	0.096	0.310	0.568	0.800	0.883	0.925	0.936	0.937	0.937	0.936	0.936	0.936	0.935	0.935	0.935	0.935	0.935	0.935
2009	0.000	0.000	0.011	0.087	0.287	0.558	0.764	0.882	0.906	0.912	0.910	0.907	0.906	0.905	0.904	0.904	0.904	0.903	0.903	0.903	0.903
2010	0.000	0.000	0.010	0.074	0.252	0.515	0.736	0.828	0.835	0.820	0.803	0.794	0.787	0.785	0.783	0.782	0.781	0.781	0.780	0.780	0.780
2011	0.000	0.000	0.005	0.071	0.232	0.481	0.704	0.800	0.796	0.763	0.744	0.728	0.721	0.716	0.714	0.712	0.712	0.711	0.711	0.711	0.711
2012	0.000	0.000	0.007	0.060	0.265	0.497	0.702	0.787	0.771	0.732	0.697	0.683	0.672	0.667	0.664	0.663	0.662	0.661	0.661	0.661	0.661
2013	0.000	0.000	0.008	0.078	0.248	0.538	0.715	0.784	0.763	0.715	0.681	0.658	0.649	0.643	0.640	0.638	0.637	0.637	0.636	0.636	0.636
2014	0.000	0.000	0.004	0.048	0.216	0.452	0.699	0.772	0.766	0.729	0.698	0.679	0.667	0.663	0.660	0.659	0.658	0.657	0.657	0.657	0.657
2015	0.000	0.000	0.004	0.039	0.184	0.447	0.660	0.781	0.788	0.767	0.744	0.729	0.721	0.716	0.714	0.712	0.712	0.711	0.711	0.711	0.711
2016	0.000	0.000	0.005	0.062	0.198	0.449	0.695	0.819	0.876	0.883	0.882	0.879	0.877	0.875	0.875	0.874	0.874	0.874	0.874	0.874	0.874
2017	0.000	0.000	0.002	0.042	0.203	0.413	0.656	0.808	0.859	0.874	0.873	0.870	0.868	0.867	0.866	0.865	0.865	0.865	0.865	0.865	0.865
2018	0.000	0.000	0.013	0.075	0.282	0.548	0.723	0.850	0.904	0.918	0.922	0.921	0.921	0.920	0.920	0.919	0.919	0.919	0.919	0.919	0.919
2019	0.000	0.001	0.006	0.126	0.303	0.580	0.776	0.855	0.892	0.898	0.895	0.892	0.890	0.889	0.888	0.887	0.887	0.887	0.887	0.887	0.887
2020	0.000	0.000	0.015	0.094	0.400	0.605	0.804	0.896	0.924	0.936	0.938	0.937	0.937	0.936	0.936	0.936	0.936	0.936	0.936	0.936	0.936

Table 2.1.22e. Selectivity at age in the fishery (Model 21.3).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.000	0.000	0.012	0.097	0.313	0.589	0.806	0.923	0.972	0.989	0.990	0.976	0.947	0.903	0.847	0.783	0.717	0.652	0.591	0.536	0.401
1978	0.000	0.000	0.010	0.095	0.310	0.587	0.805	0.923	0.972	0.989	0.990	0.976	0.947	0.903	0.847	0.783	0.717	0.652	0.591	0.536	0.401
1979	0.000	0.000	0.014	0.096	0.324	0.598	0.811	0.926	0.973	0.989	0.990	0.976	0.947	0.903	0.847	0.783	0.717	0.652	0.591	0.536	0.408
1980	0.000	0.000	0.011	0.104	0.306	0.596	0.810	0.925	0.973	0.989	0.990	0.976	0.947	0.903	0.847	0.783	0.717	0.652	0.591	0.536	0.411
1981	0.000	0.000	0.013	0.116	0.355	0.608	0.824	0.931	0.975	0.990	0.990	0.976	0.947	0.903	0.847	0.783	0.717	0.652	0.591	0.536	0.413
1982	0.000	0.000	0.007	0.070	0.288	0.582	0.791	0.921	0.972	0.989	0.989	0.976	0.947	0.903	0.847	0.783	0.717	0.652	0.591	0.536	0.413
1983	0.000	0.000	0.016	0.076	0.270	0.572	0.806	0.918	0.972	0.989	0.990	0.976	0.947	0.903	0.847	0.783	0.717	0.652	0.591	0.536	0.413
1984	0.000	0.001	0.017	0.141	0.309	0.576	0.812	0.930	0.973	0.990	0.990	0.976	0.947	0.903	0.847	0.783	0.717	0.652	0.591	0.536	0.412
1985	0.000	0.000	0.005	0.087	0.331	0.537	0.770	0.915	0.972	0.988	0.989	0.976	0.947	0.903	0.847	0.783	0.717	0.652	0.591	0.536	0.411
1986	0.000	0.000	0.014	0.085	0.335	0.640	0.793	0.915	0.972	0.990	0.990	0.976	0.947	0.903	0.847	0.783	0.717	0.652	0.591	0.536	0.409
1987	0.000	0.000	0.008	0.085	0.253	0.579	0.822	0.908	0.966	0.988	0.989	0.977	0.947	0.903	0.847	0.783	0.717	0.652	0.591	0.536	0.407
1988	0.000	0.001	0.027	0.154	0.406	0.624	0.849	0.949	0.975	0.990	0.991	0.976	0.949	0.903	0.847	0.783	0.717	0.652	0.591	0.536	0.404
1989	0.000	0.000	0.014	0.104	0.328	0.615	0.793	0.931	0.979	0.989	0.991	0.977	0.947	0.906	0.847	0.783	0.717	0.652	0.592	0.537	0.402
1990	0.000	0.000	0.010	0.078	0.277	0.561	0.799	0.906	0.972	0.990	0.990	0.979	0.949	0.903	0.850	0.783	0.717	0.652	0.591	0.536	0.399
1991	0.000	0.000	0.011	0.086	0.274	0.548	0.786	0.919	0.965	0.989	0.989	0.979	0.952	0.905	0.846	0.786	0.716	0.652	0.591	0.536	0.398
1992	0.000	0.000	0.008	0.092	0.285	0.543	0.776	0.912	0.970	0.987	0.989	0.974	0.952	0.910	0.850	0.782	0.720	0.652	0.591	0.536	0.402
1993	0.000	0.001	0.027	0.144	0.399	0.640	0.821	0.929	0.975	0.991	0.991	0.976	0.943	0.910	0.855	0.786	0.716	0.655	0.591	0.536	0.413
1994	0.000	0.000	0.015	0.113	0.329	0.622	0.812	0.920	0.971	0.989	0.990	0.980	0.947	0.897	0.855	0.792	0.720	0.651	0.595	0.536	0.430
1995	0.000	0.000	0.016	0.115	0.346	0.608	0.829	0.927	0.972	0.989	0.990	0.977	0.953	0.903	0.839	0.791	0.726	0.655	0.591	0.539	0.427
1996	0.000	0.000	0.008	0.076	0.280	0.567	0.788	0.922	0.969	0.987	0.990	0.978	0.948	0.912	0.846	0.775	0.726	0.662	0.594	0.536	0.447
1997	0.000	0.000	0.014	0.109	0.326	0.601	0.817	0.925	0.976	0.989	0.990	0.979	0.950	0.904	0.857	0.783	0.708	0.661	0.600	0.539	0.463
1998	0.000	0.000	0.006	0.076	0.278	0.554	0.787	0.917	0.969	0.989	0.990	0.978	0.951	0.907	0.848	0.795	0.717	0.644	0.600	0.545	0.451
1999	0.000	0.000	0.006	0.073	0.282	0.562	0.788	0.916	0.971	0.988	0.989	0.977	0.951	0.909	0.852	0.785	0.729	0.653	0.585	0.544	0.443
2000	0.000	0.000	0.008	0.059	0.253	0.545	0.781	0.911	0.968	0.988	0.989	0.975	0.949	0.909	0.854	0.789	0.719	0.665	0.593	0.531	0.416
2001	0.000	0.000	0.008	0.084	0.244	0.533	0.781	0.913	0.968	0.988	0.989	0.977	0.946	0.905	0.853	0.791	0.723	0.654	0.602	0.536	0.396
2002	0.000	0.000	0.017	0.114	0.348	0.569	0.799	0.924	0.973	0.989	0.990	0.977	0.949	0.901	0.849	0.790	0.725	0.658	0.593	0.546	0.420
2003	0.000	0.000	0.013	0.112	0.326	0.610	0.785	0.917	0.972	0.989	0.990	0.977	0.948	0.905	0.844	0.786	0.724	0.660	0.597	0.538	0.400
2004	0.000	0.000	0.020	0.106	0.342	0.605	0.821	0.914	0.970	0.989	0.990	0.977	0.949	0.904	0.849	0.781	0.720	0.659	0.599	0.541	0.415
2005	0.000	0.001	0.012	0.128	0.322	0.612	0.813	0.930	0.969	0.988	0.990	0.977	0.949	0.905	0.848	0.786	0.714	0.655	0.598	0.543	0.405
2006	0.000	0.000	0.008	0.081	0.332	0.570	0.806	0.920	0.973	0.987	0.990	0.977	0.949	0.906	0.849	0.784	0.720	0.650	0.594	0.543	0.393
2007	0.000	0.000	0.006	0.074	0.275	0.601	0.790	0.921	0.971	0.989	0.990	0.978	0.949	0.906	0.850	0.786	0.718	0.655	0.590	0.539	0.374
2008	0.000	0.000	0.006	0.068	0.274	0.555	0.816	0.916	0.972	0.988	0.989	0.979	0.951	0.906	0.850	0.787	0.720	0.653	0.594	0.535	0.391
2009	0.000	0.000	0.004	0.050	0.226	0.520	0.766	0.922	0.967	0.988	0.989	0.975	0.953	0.908	0.850	0.786	0.721	0.655	0.593	0.539	0.423
2010	0.000	0.000	0.004	0.045	0.206	0.487	0.754	0.901	0.970	0.986	0.989	0.976	0.946	0.911	0.853	0.787	0.720	0.656	0.594	0.537	0.435
2011	0.000	0.000	0.003	0.061	0.223	0.494	0.749	0.903	0.965	0.988	0.989	0.975	0.947	0.901	0.856	0.790	0.721	0.655	0.595	0.539	0.426
2012	0.000	0.000	0.008	0.064	0.283	0.533	0.766	0.906	0.968	0.988	0.989	0.977	0.946	0.903	0.845	0.793	0.724	0.656	0.594	0.540	0.451
2013	0.000	0.000	0.008	0.089	0.266	0.576	0.779	0.908	0.967	0.988	0.990	0.974	0.948	0.902	0.847	0.781	0.727	0.659	0.595	0.539	0.439
2014	0.000	0.000	0.005	0.058	0.256	0.502	0.776	0.899	0.962	0.986	0.989	0.977	0.943	0.905	0.845	0.783	0.715	0.662	0.598	0.540	0.431
2015	0.000	0.000	0.007	0.053	0.221	0.520	0.739	0.905	0.961	0.985	0.989	0.977	0.949	0.897	0.848	0.781	0.717	0.650	0.601	0.542	0.427
2016	0.000	0.000	0.007	0.075	0.228	0.498	0.764	0.891	0.965	0.985	0.989	0.978	0.950	0.906	0.840	0.785	0.715	0.652	0.590	0.545	0.455
2017	0.000	0.000	0.005	0.075	0.277	0.504	0.747	0.903	0.959	0.986	0.989	0.978	0.951	0.907	0.850	0.776	0.719	0.650	0.592	0.535	0.441
2018	0.000	0.000	0.017	0.094	0.341	0.613	0.786	0.911	0.970	0.987	0.989	0.978	0.952	0.909	0.851	0.787	0.709	0.654	0.590	0.537	0.427
2019	0.000	0.001	0.006	0.134	0.328	0.633	0.830	0.918	0.969	0.989	0.990	0.976	0.951	0.910	0.854	0.788	0.721	0.645	0.593	0.535	0.437
2020	0.000	0.000	0.011	0.078	0.394	0.620	0.841	0.938	0.972	0.988	0.990	0.979	0.948	0.909	0.855	0.791	0.722	0.656	0.585	0.539	0.433

Table 2.1.22f. Selectivity at age in the fishery (ensemble).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.000	0.000	0.013	0.106	0.332	0.607	0.807	0.896	0.918	0.915	0.906	0.894	0.878	0.857	0.832	0.804	0.775	0.747	0.720	0.696	0.636
1978	0.000	0.000	0.011	0.104	0.331	0.606	0.805	0.894	0.916	0.912	0.902	0.890	0.874	0.852	0.827	0.799	0.770	0.742	0.715	0.691	0.632
1979	0.000	0.000	0.015	0.107	0.346	0.618	0.812	0.897	0.916	0.912	0.902	0.889	0.873	0.852	0.826	0.798	0.769	0.741	0.715	0.690	0.634
1980	0.000	0.000	0.013	0.115	0.329	0.616	0.812	0.900	0.922	0.920	0.911	0.900	0.884	0.863	0.837	0.809	0.781	0.752	0.726	0.702	0.647
1981	0.000	0.000	0.015	0.130	0.380	0.630	0.826	0.906	0.924	0.920	0.911	0.899	0.883	0.862	0.837	0.809	0.780	0.752	0.725	0.701	0.647
1982	0.000	0.000	0.008	0.079	0.309	0.601	0.794	0.897	0.923	0.923	0.915	0.904	0.888	0.867	0.842	0.814	0.785	0.757	0.731	0.707	0.653
1983	0.000	0.000	0.015	0.088	0.295	0.595	0.809	0.899	0.930	0.932	0.925	0.915	0.900	0.879	0.854	0.827	0.798	0.770	0.743	0.719	0.665
1984	0.000	0.001	0.020	0.144	0.337	0.602	0.818	0.912	0.937	0.939	0.934	0.924	0.909	0.889	0.864	0.836	0.808	0.779	0.753	0.729	0.674
1985	0.000	0.000	0.006	0.096	0.334	0.562	0.777	0.894	0.924	0.926	0.919	0.908	0.892	0.872	0.847	0.819	0.790	0.762	0.735	0.711	0.656
1986	0.000	0.000	0.016	0.095	0.357	0.642	0.798	0.893	0.920	0.917	0.909	0.896	0.880	0.859	0.833	0.805	0.776	0.748	0.722	0.698	0.642
1987	0.000	0.000	0.008	0.092	0.272	0.597	0.811	0.887	0.919	0.921	0.913	0.902	0.886	0.865	0.840	0.812	0.783	0.755	0.728	0.704	0.647
1988	0.000	0.001	0.032	0.172	0.434	0.650	0.851	0.919	0.927	0.922	0.911	0.898	0.883	0.861	0.835	0.807	0.778	0.750	0.724	0.700	0.641
1989	0.000	0.000	0.016	0.118	0.354	0.638	0.803	0.912	0.936	0.935	0.929	0.918	0.902	0.883	0.857	0.829	0.801	0.773	0.746	0.722	0.663
1990	0.000	0.000	0.011	0.090	0.302	0.585	0.807	0.898	0.945	0.953	0.951	0.944	0.929	0.909	0.886	0.857	0.828	0.800	0.774	0.750	0.690
1991	0.000	0.000	0.012	0.094	0.295	0.570	0.792	0.902	0.932	0.940	0.935	0.927	0.914	0.892	0.866	0.840	0.810	0.782	0.756	0.732	0.671
1992	0.000	0.000	0.009	0.096	0.300	0.561	0.778	0.887	0.917	0.917	0.908	0.895	0.883	0.863	0.835	0.806	0.779	0.749	0.723	0.699	0.639
1993	0.000	0.001	0.029	0.150	0.407	0.650	0.820	0.903	0.923	0.918	0.910	0.895	0.877	0.861	0.836	0.806	0.775	0.749	0.721	0.697	0.643
1994	0.000	0.000	0.014	0.121	0.341	0.627	0.807	0.893	0.917	0.915	0.905	0.894	0.876	0.852	0.832	0.805	0.773	0.744	0.719	0.693	0.646
1995	0.000	0.000	0.016	0.118	0.367	0.623	0.822	0.900	0.920	0.918	0.909	0.896	0.882	0.858	0.830	0.808	0.780	0.749	0.721	0.698	0.648
1996	0.000	0.000	0.008	0.083	0.296	0.592	0.794	0.907	0.941	0.950	0.949	0.942	0.927	0.911	0.883	0.852	0.831	0.803	0.774	0.749	0.709
1997	0.000	0.000	0.017	0.125	0.353	0.624	0.827	0.912	0.941	0.944	0.940	0.931	0.917	0.896	0.875	0.843	0.811	0.790	0.764	0.737	0.703
1998	0.000	0.000	0.008	0.087	0.306	0.579	0.794	0.901	0.931	0.935	0.930	0.921	0.907	0.887	0.861	0.837	0.804	0.773	0.753	0.729	0.687
1999	0.000	0.000	0.008	0.087	0.309	0.591	0.795	0.896	0.927	0.928	0.922	0.912	0.898	0.878	0.853	0.823	0.799	0.766	0.737	0.719	0.674
2000	0.000	0.000	0.011	0.072	0.283	0.572	0.789	0.889	0.918	0.917	0.910	0.898	0.883	0.864	0.840	0.811	0.781	0.757	0.726	0.699	0.648
2001	0.000	0.000	0.009	0.097	0.266	0.556	0.778	0.869	0.882	0.869	0.851	0.836	0.816	0.795	0.771	0.743	0.713	0.683	0.660	0.631	0.569
2002	0.000	0.000	0.018	0.121	0.370	0.586	0.793	0.871	0.870	0.850	0.829	0.809	0.790	0.765	0.740	0.714	0.684	0.655	0.627	0.606	0.550
2003	0.000	0.000	0.013	0.117	0.339	0.625	0.782	0.880	0.898	0.888	0.874	0.859	0.841	0.820	0.792	0.766	0.739	0.711	0.683	0.657	0.597
2004	0.000	0.000	0.021	0.113	0.356	0.617	0.818	0.887	0.913	0.910	0.900	0.888	0.872	0.850	0.825	0.795	0.769	0.742	0.716	0.691	0.636
2005	0.000	0.001	0.013	0.139	0.341	0.627	0.813	0.907	0.928	0.931	0.925	0.915	0.900	0.880	0.854	0.827	0.796	0.770	0.745	0.721	0.661
2006	0.000	0.000	0.009	0.092	0.360	0.595	0.812	0.908	0.945	0.952	0.951	0.943	0.930	0.910	0.886	0.858	0.830	0.800	0.776	0.753	0.688
2007	0.000	0.000	0.007	0.089	0.307	0.631	0.801	0.909	0.941	0.949	0.947	0.939	0.925	0.905	0.881	0.854	0.824	0.797	0.769	0.747	0.674
2008	0.000	0.000	0.007	0.080	0.304	0.585	0.820	0.891	0.916	0.913	0.904	0.895	0.879	0.857	0.831	0.804	0.775	0.745	0.720	0.694	0.631
2009	0.000	0.000	0.005	0.059	0.251	0.550	0.772	0.879	0.890	0.881	0.868	0.852	0.838	0.815	0.788	0.759	0.731	0.702	0.674	0.651	0.601
2010	0.000	0.000	0.005	0.053	0.226	0.510	0.756	0.861	0.880	0.870	0.854	0.839	0.819	0.801	0.774	0.744	0.715	0.686	0.659	0.634	0.590
2011	0.000	0.000	0.003	0.065	0.239	0.508	0.748	0.869	0.897	0.891	0.881	0.867	0.850	0.827	0.807	0.777	0.747	0.718	0.692	0.668	0.619
2012	0.000	0.000	0.008	0.068	0.299	0.552	0.765	0.874	0.901	0.896	0.882	0.871	0.853	0.832	0.805	0.783	0.752	0.723	0.696	0.672	0.633
2013	0.000	0.000	0.008	0.092	0.278	0.591	0.777	0.871	0.891	0.880	0.865	0.847	0.832	0.808	0.783	0.753	0.730	0.700	0.672	0.647	0.604
2014	0.000	0.000	0.005	0.059	0.264	0.513	0.769	0.861	0.886	0.880	0.866	0.851	0.830	0.811	0.784	0.756	0.726	0.703	0.675	0.650	0.602
2015	0.000	0.000	0.007	0.055	0.231	0.529	0.736	0.869	0.896	0.896	0.886	0.873	0.856	0.831	0.809	0.779	0.751	0.722	0.701	0.675	0.625
2016	0.000	0.000	0.007	0.078	0.241	0.512	0.760	0.867	0.914	0.918	0.913	0.903	0.887	0.866	0.837	0.813	0.782	0.755	0.727	0.708	0.669
2017	0.000	0.000	0.005	0.076	0.287	0.519	0.747	0.879	0.918	0.929	0.926	0.918	0.904	0.883	0.858	0.826	0.801	0.771	0.746	0.721	0.680
2018	0.000	0.000	0.018	0.101	0.351	0.626	0.789	0.892	0.930	0.935	0.931	0.923	0.909	0.889	0.863	0.836	0.802	0.778	0.750	0.727	0.679
2019	0.000	0.001	0.007	0.145	0.346	0.642	0.824	0.889	0.914	0.912	0.905	0.891	0.877	0.857	0.832	0.803	0.773	0.740	0.718	0.692	0.650

Table 2.1.23a. Selectivity at age in the survey (Model 19.12a).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.011	0.484	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1978	0.009	0.484	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1979	0.012	0.385	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1980	0.009	0.497	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1981	0.006	0.397	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1982	0.004	0.216	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1983	0.043	0.441	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1984	0.004	0.252	0.988	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1985	0.008	0.429	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1986	0.022	0.295	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1987	0.006	0.415	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1988	0.004	0.260	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1989	0.003	0.140	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1990	0.021	0.386	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1991	0.019	0.299	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1992	0.011	0.521	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1993	0.030	0.476	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1994	0.008	0.440	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1995	0.004	0.229	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1996	0.002	0.202	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1997	0.009	0.277	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1998	0.011	0.181	0.925	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1999	0.006	0.236	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	0.017	0.284	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2001	0.029	0.807	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2002	0.012	0.467	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2003	0.010	0.494	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2004	0.013	0.381	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2005	0.008	0.745	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2006	0.029	0.740	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2007	0.036	0.824	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2008	0.013	0.475	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2009	0.048	0.496	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2010	0.009	0.328	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2011	0.006	0.488	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2012	0.071	0.682	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2013	0.009	0.292	0.990	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2014	0.010	0.354	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2015	0.015	0.346	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2016	0.007	0.447	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2017	0.009	0.486	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2018	0.005	0.371	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2019	0.010	0.986	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2020	0.010	0.244	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 2.1.23b. Selectivity at age in the survey (Model 19.12).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.012	0.509	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1978	0.009	0.509	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1979	0.012	0.400	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1980	0.009	0.518	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1981	0.006	0.407	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1982	0.004	0.217	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1983	0.048	0.410	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1984	0.006	0.356	0.988	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1985	0.008	0.420	0.991	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1986	0.022	0.289	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1987	0.006	0.404	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1988	0.004	0.257	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1989	0.003	0.150	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1990	0.024	0.418	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1991	0.025	0.344	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1992	0.015	0.661	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1993	0.031	0.504	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1994	0.006	0.334	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1995	0.004	0.223	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1996	0.002	0.198	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1997	0.009	0.280	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1998	0.011	0.177	0.916	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1999	0.006	0.251	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	0.019	0.314	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2001	0.025	0.761	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2002	0.012	0.465	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2003	0.010	0.497	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2004	0.013	0.378	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2005	0.008	0.719	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2006	0.029	0.743	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2007	0.040	0.837	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2008	0.015	0.551	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2009	0.053	0.639	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2010	0.010	0.347	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2011	0.006	0.480	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2012	0.080	0.722	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2013	0.011	0.334	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2014	0.010	0.366	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2015	0.016	0.343	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2016	0.008	0.452	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2017	0.013	0.590	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2018	0.005	0.378	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2019	0.009	0.985	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2020	0.010	0.254	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 2.1.23c. Selectivity at age in the survey (Model 21.1).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.011	0.438	0.999	0.994	0.947	0.868	0.783	0.707	0.644	0.593	0.553	0.521	0.496	0.476	0.460	0.447	0.437	0.428	0.421	0.415	0.406
1978	0.010	0.438	0.999	0.994	0.947	0.868	0.783	0.707	0.644	0.593	0.553	0.521	0.496	0.476	0.460	0.447	0.437	0.428	0.421	0.415	0.406
1979	0.012	0.389	0.999	0.994	0.947	0.868	0.783	0.707	0.644	0.593	0.553	0.521	0.496	0.476	0.460	0.447	0.437	0.428	0.421	0.415	0.405
1980	0.010	0.492	0.999	0.993	0.949	0.868	0.783	0.707	0.644	0.593	0.553	0.521	0.496	0.476	0.460	0.447	0.437	0.428	0.421	0.415	0.405
1981	0.007	0.404	0.997	0.994	0.945	0.870	0.783	0.707	0.644	0.593	0.553	0.521	0.496	0.476	0.460	0.447	0.437	0.428	0.421	0.415	0.405
1982	0.004	0.222	0.998	0.995	0.944	0.859	0.778	0.700	0.637	0.586	0.547	0.515	0.491	0.471	0.455	0.443	0.433	0.424	0.418	0.412	0.402
1983	0.047	0.464	1.000	0.994	0.949	0.861	0.771	0.699	0.635	0.584	0.545	0.513	0.489	0.469	0.454	0.442	0.431	0.423	0.417	0.411	0.400
1984	0.004	0.259	0.989	0.998	0.976	0.919	0.837	0.759	0.698	0.643	0.599	0.564	0.536	0.513	0.494	0.480	0.467	0.457	0.449	0.442	0.429
1985	0.009	0.442	0.993	0.996	0.954	0.891	0.811	0.728	0.661	0.612	0.569	0.536	0.509	0.488	0.472	0.458	0.447	0.438	0.431	0.425	0.412
1986	0.024	0.311	1.000	0.995	0.936	0.849	0.775	0.700	0.630	0.578	0.541	0.509	0.485	0.466	0.451	0.438	0.429	0.421	0.414	0.409	0.398
1987	0.007	0.429	0.998	0.994	0.957	0.866	0.780	0.714	0.652	0.595	0.552	0.522	0.496	0.476	0.460	0.448	0.437	0.429	0.422	0.416	0.404
1988	0.005	0.292	0.997	0.995	0.948	0.881	0.782	0.704	0.650	0.599	0.554	0.521	0.497	0.476	0.460	0.448	0.437	0.429	0.422	0.416	0.404
1989	0.003	0.151	0.990	0.998	0.967	0.893	0.825	0.736	0.671	0.626	0.584	0.546	0.518	0.497	0.479	0.465	0.454	0.445	0.437	0.431	0.417
1990	0.023	0.415	1.000	0.993	0.945	0.860	0.768	0.702	0.628	0.577	0.543	0.513	0.486	0.466	0.451	0.439	0.429	0.421	0.414	0.409	0.397
1991	0.020	0.328	0.997	0.998	0.970	0.904	0.822	0.742	0.687	0.624	0.580	0.551	0.524	0.500	0.481	0.468	0.456	0.447	0.439	0.433	0.419
1992	0.012	0.539	0.999	0.992	0.945	0.869	0.783	0.704	0.636	0.593	0.545	0.514	0.492	0.473	0.456	0.442	0.433	0.424	0.418	0.412	0.401
1993	0.034	0.499	1.000	0.995	0.948	0.875	0.796	0.719	0.653	0.598	0.563	0.524	0.498	0.481	0.465	0.450	0.439	0.431	0.424	0.418	0.407
1994	0.012	0.419	0.992	0.997	0.969	0.900	0.827	0.756	0.691	0.635	0.589	0.559	0.526	0.503	0.488	0.474	0.461	0.450	0.443	0.436	0.425
1995	0.005	0.241	0.994	0.997	0.957	0.891	0.807	0.737	0.676	0.622	0.578	0.542	0.519	0.494	0.476	0.464	0.453	0.443	0.435	0.429	0.418
1996	0.002	0.211	0.996	0.996	0.959	0.878	0.802	0.724	0.664	0.614	0.572	0.537	0.509	0.491	0.471	0.457	0.448	0.439	0.431	0.424	0.416
1997	0.009	0.294	0.994	0.997	0.966	0.897	0.809	0.740	0.674	0.624	0.584	0.549	0.521	0.498	0.483	0.466	0.454	0.446	0.438	0.431	0.424
1998	0.012	0.198	0.940	0.999	0.987	0.943	0.877	0.800	0.742	0.685	0.642	0.606	0.574	0.548	0.526	0.512	0.496	0.484	0.476	0.468	0.456
1999	0.006	0.264	0.995	0.996	0.956	0.880	0.799	0.722	0.652	0.605	0.562	0.531	0.507	0.486	0.468	0.454	0.445	0.434	0.427	0.422	0.412
2000	0.019	0.305	1.000	0.993	0.937	0.847	0.758	0.683	0.620	0.566	0.531	0.500	0.478	0.461	0.446	0.433	0.423	0.416	0.409	0.404	0.394
2001	0.031	0.799	1.000	0.985	0.939	0.847	0.755	0.678	0.617	0.567	0.525	0.498	0.474	0.457	0.443	0.431	0.422	0.413	0.408	0.402	0.391
2002	0.013	0.513	1.000	0.992	0.938	0.875	0.784	0.704	0.640	0.590	0.549	0.515	0.492	0.472	0.457	0.445	0.435	0.426	0.419	0.414	0.404
2003	0.010	0.520	0.999	0.993	0.948	0.865	0.799	0.718	0.651	0.598	0.558	0.526	0.498	0.479	0.462	0.450	0.440	0.431	0.424	0.418	0.407
2004	0.014	0.404	1.000	0.994	0.947	0.870	0.782	0.723	0.654	0.600	0.558	0.527	0.501	0.478	0.464	0.450	0.440	0.432	0.425	0.419	0.409
2005	0.009	0.756	0.999	0.988	0.941	0.853	0.770	0.690	0.642	0.587	0.545	0.514	0.489	0.470	0.453	0.441	0.431	0.423	0.417	0.411	0.401
2006	0.031	0.752	1.000	0.981	0.891	0.810	0.716	0.644	0.582	0.546	0.507	0.478	0.456	0.439	0.426	0.414	0.407	0.400	0.395	0.390	0.381
2007	0.038	0.831	1.000	0.974	0.892	0.774	0.698	0.621	0.565	0.519	0.493	0.465	0.443	0.427	0.415	0.405	0.397	0.391	0.386	0.382	0.372
2008	0.014	0.483	1.000	0.987	0.916	0.821	0.715	0.653	0.590	0.545	0.507	0.485	0.462	0.443	0.430	0.419	0.410	0.403	0.397	0.393	0.383
2009	0.052	0.529	1.000	0.991	0.932	0.836	0.746	0.657	0.606	0.556	0.520	0.490	0.472	0.453	0.438	0.426	0.417	0.410	0.403	0.399	0.391
2010	0.009	0.324	0.999	0.994	0.953	0.873	0.781	0.703	0.629	0.587	0.545	0.515	0.490	0.474	0.457	0.444	0.434	0.425	0.419	0.412	0.405
2011	0.007	0.499	0.998	0.993	0.949	0.876	0.789	0.706	0.641	0.582	0.549	0.516	0.492	0.471	0.459	0.446	0.435	0.426	0.419	0.414	0.405
2012	0.076	0.678	1.000	0.982	0.897	0.808	0.723	0.645	0.580	0.534	0.493	0.471	0.449	0.433	0.420	0.412	0.403	0.396	0.391	0.386	0.381
2013	0.010	0.304	0.988	0.998	0.977	0.907	0.837	0.768	0.701	0.642	0.597	0.556	0.533	0.509	0.492	0.476	0.467	0.456	0.448	0.441	0.430
2014	0.011	0.367	0.999	0.994	0.946	0.877	0.781	0.711	0.651	0.598	0.554	0.521	0.492	0.475	0.459	0.446	0.435	0.429	0.421	0.415	0.406
2015	0.017	0.351	0.999	0.997	0.965	0.891	0.821	0.735	0.676	0.626	0.582	0.545	0.518	0.492	0.478	0.463	0.453	0.443	0.437	0.430	0.419
2016	0.008	0.464	0.997	0.997	0.972	0.915	0.835	0.771	0.697	0.648	0.606	0.569	0.538	0.514	0.493	0.480	0.467	0.458	0.449	0.444	0.434
2017	0.008	0.505	0.996	0.996	0.961	0.907	0.835	0.757	0.701	0.639	0.599	0.566	0.537	0.512	0.493	0.476	0.466	0.455	0.447	0.440	0.431
2018	0.006	0.352	0.999	0.996	0.958	0.888	0.824	0.755	0.686	0.640	0.590	0.558	0.532	0.509	0.489	0.474	0.460	0.452	0.443	0.437	0.426
2019	0.010	0.982	1.000	0.968	0.906	0.807	0.721	0.660	0.603	0.553	0.521	0.487	0.467	0.450	0.436	0.423	0.414	0.406	0.401	0.396	0.389
2020	0.011	0.247	0.999	0.996	0.923	0.856	0.766	0.693	0.642	0.595	0.552	0.524	0.495	0.477	0.462	0.448	0.437	0.428	0.420	0.415	0.407

Table 2.1.23d. Selectivity at age in the survey (Model 21.2).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.013	0.558	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1978	0.009	0.558	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1979	0.012	0.403	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1980	0.010	0.515	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1981	0.007	0.414	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1982	0.004	0.225	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1983	0.041	0.448	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1984	0.004	0.253	0.991	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1985	0.008	0.443	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1986	0.023	0.310	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1987	0.006	0.421	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1988	0.004	0.262	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1989	0.003	0.140	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1990	0.021	0.391	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1991	0.019	0.304	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1992	0.011	0.527	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1993	0.029	0.473	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1994	0.008	0.453	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1995	0.004	0.229	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1996	0.002	0.212	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1997	0.007	0.300	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1998	0.008	0.259	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1999	0.006	0.257	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	0.017	0.283	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2001	0.025	0.776	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2002	0.010	0.416	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2003	0.008	0.435	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2004	0.012	0.348	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2005	0.008	0.761	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2006	0.029	0.723	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2007	0.042	0.832	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2008	0.015	0.532	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2009	0.050	0.561	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2010	0.010	0.327	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2011	0.007	0.515	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2012	0.071	0.707	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2013	0.009	0.298	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2014	0.009	0.349	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2015	0.016	0.338	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2016	0.006	0.443	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2017	0.008	0.483	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2018	0.005	0.382	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2019	0.010	0.985	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2020	0.010	0.262	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 2.1.23e. Selectivity at age in the survey (Model 21.3).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.011	0.519	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1978	0.009	0.519	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1979	0.012	0.410	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1980	0.009	0.536	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1981	0.006	0.416	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1982	0.003	0.211	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1983	0.048	0.371	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1984	0.007	0.416	0.987	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1985	0.008	0.416	0.989	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1986	0.021	0.284	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1987	0.005	0.405	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1988	0.004	0.261	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1989	0.003	0.156	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1990	0.026	0.435	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1991	0.030	0.365	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1992	0.018	0.833	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1993	0.030	0.504	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1994	0.006	0.305	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1995	0.005	0.220	0.989	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1996	0.002	0.193	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1997	0.009	0.278	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1998	0.011	0.174	0.901	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1999	0.006	0.255	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	0.018	0.329	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2001	0.023	0.741	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2002	0.012	0.463	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2003	0.010	0.492	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2004	0.013	0.376	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2005	0.007	0.709	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2006	0.029	0.754	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2007	0.042	0.849	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2008	0.017	0.593	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2009	0.059	0.726	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2010	0.010	0.366	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2011	0.006	0.495	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2012	0.086	0.758	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2013	0.012	0.371	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2014	0.011	0.388	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2015	0.017	0.354	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2016	0.010	0.475	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2017	0.016	0.666	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2018	0.005	0.386	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2019	0.008	0.986	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2020	0.010	0.245	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 2.1.23f. Selectivity at age in the survey (ensemble).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	0.012	0.498	0.999	0.999	0.991	0.976	0.961	0.947	0.936	0.927	0.919	0.914	0.909	0.905	0.903	0.900	0.898	0.897	0.896	0.895	0.893
1978	0.009	0.498	0.999	0.999	0.991	0.976	0.961	0.947	0.936	0.927	0.919	0.914	0.909	0.905	0.903	0.900	0.898	0.897	0.896	0.895	0.893
1979	0.012	0.397	0.999	0.999	0.991	0.976	0.961	0.947	0.936	0.927	0.919	0.914	0.909	0.905	0.903	0.900	0.898	0.897	0.896	0.895	0.893
1980	0.010	0.512	0.999	0.999	0.991	0.976	0.961	0.947	0.936	0.927	0.919	0.914	0.909	0.905	0.903	0.900	0.898	0.897	0.896	0.895	0.893
1981	0.006	0.407	0.998	0.999	0.990	0.977	0.961	0.947	0.936	0.927	0.919	0.914	0.909	0.905	0.903	0.900	0.898	0.897	0.896	0.895	0.893
1982	0.004	0.217	0.998	0.999	0.990	0.975	0.960	0.946	0.935	0.925	0.918	0.913	0.908	0.905	0.902	0.900	0.898	0.896	0.895	0.894	0.892
1983	0.046	0.424	1.000	0.999	0.991	0.975	0.959	0.946	0.934	0.925	0.918	0.912	0.908	0.904	0.902	0.899	0.897	0.896	0.895	0.894	0.892
1984	0.005	0.313	0.988	1.000	0.996	0.985	0.971	0.957	0.946	0.936	0.928	0.921	0.916	0.912	0.909	0.906	0.904	0.902	0.901	0.899	0.897
1985	0.008	0.428	0.992	0.999	0.992	0.980	0.966	0.951	0.939	0.930	0.922	0.916	0.912	0.908	0.905	0.902	0.900	0.899	0.897	0.896	0.894
1986	0.022	0.296	1.000	0.999	0.988	0.973	0.959	0.946	0.933	0.924	0.917	0.912	0.907	0.904	0.901	0.899	0.897	0.896	0.894	0.893	0.891
1987	0.006	0.413	0.998	0.999	0.992	0.976	0.960	0.948	0.937	0.927	0.919	0.914	0.909	0.906	0.903	0.900	0.898	0.897	0.896	0.895	0.893
1988	0.004	0.265	0.997	0.999	0.991	0.979	0.961	0.947	0.937	0.928	0.920	0.914	0.909	0.906	0.903	0.900	0.898	0.897	0.896	0.895	0.893
1989	0.003	0.148	0.992	1.000	0.994	0.981	0.968	0.952	0.941	0.933	0.925	0.918	0.913	0.909	0.906	0.904	0.902	0.900	0.898	0.897	0.895
1990	0.023	0.410	1.000	0.999	0.990	0.975	0.958	0.946	0.933	0.924	0.918	0.912	0.907	0.904	0.901	0.899	0.897	0.896	0.894	0.893	0.891
1991	0.023	0.329	0.996	1.000	0.995	0.983	0.968	0.953	0.944	0.932	0.924	0.919	0.914	0.910	0.906	0.904	0.902	0.900	0.899	0.898	0.895
1992	0.014	0.625	1.000	0.999	0.990	0.976	0.961	0.947	0.934	0.927	0.918	0.912	0.908	0.905	0.902	0.899	0.898	0.896	0.895	0.894	0.892
1993	0.031	0.492	0.999	0.999	0.991	0.978	0.963	0.949	0.937	0.927	0.921	0.914	0.910	0.906	0.904	0.901	0.899	0.897	0.896	0.895	0.893
1994	0.008	0.385	0.995	0.999	0.994	0.982	0.969	0.956	0.944	0.934	0.926	0.920	0.915	0.910	0.908	0.905	0.903	0.901	0.900	0.898	0.896
1995	0.004	0.228	0.993	0.999	0.992	0.980	0.965	0.953	0.942	0.932	0.924	0.917	0.913	0.909	0.906	0.903	0.901	0.900	0.898	0.897	0.895
1996	0.002	0.202	0.996	0.999	0.993	0.978	0.964	0.950	0.939	0.930	0.923	0.917	0.911	0.908	0.905	0.902	0.900	0.899	0.897	0.896	0.895
1997	0.009	0.284	0.993	1.000	0.994	0.981	0.966	0.953	0.941	0.932	0.925	0.919	0.914	0.909	0.907	0.904	0.902	0.900	0.899	0.897	0.896
1998	0.010	0.192	0.930	0.999	0.998	0.990	0.978	0.964	0.953	0.943	0.935	0.929	0.923	0.919	0.915	0.912	0.909	0.907	0.906	0.904	0.902
1999	0.006	0.251	0.995	0.999	0.992	0.978	0.964	0.950	0.937	0.929	0.921	0.916	0.911	0.907	0.904	0.902	0.900	0.898	0.897	0.896	0.894
2000	0.018	0.304	1.000	0.999	0.989	0.972	0.956	0.943	0.932	0.922	0.916	0.910	0.906	0.903	0.900	0.898	0.896	0.895	0.893	0.892	0.891
2001	0.027	0.776	1.000	0.997	0.989	0.972	0.956	0.942	0.931	0.922	0.914	0.910	0.905	0.902	0.900	0.897	0.896	0.894	0.893	0.892	0.890
2002	0.012	0.467	0.999	0.999	0.989	0.977	0.961	0.947	0.935	0.926	0.919	0.912	0.908	0.905	0.902	0.900	0.898	0.896	0.895	0.894	0.892
2003	0.010	0.491	0.998	0.999	0.991	0.976	0.964	0.949	0.937	0.928	0.920	0.914	0.909	0.906	0.903	0.901	0.899	0.897	0.896	0.895	0.893
2004	0.013	0.379	1.000	0.999	0.990	0.977	0.961	0.950	0.938	0.928	0.920	0.915	0.910	0.906	0.903	0.901	0.899	0.898	0.896	0.895	0.893
2005	0.008	0.735	0.999	0.998	0.989	0.974	0.959	0.944	0.935	0.926	0.918	0.912	0.908	0.904	0.901	0.899	0.897	0.896	0.895	0.894	0.892
2006	0.030	0.744	1.000	0.997	0.980	0.966	0.949	0.936	0.925	0.918	0.911	0.906	0.902	0.899	0.896	0.894	0.893	0.892	0.891	0.890	0.888
2007	0.039	0.835	1.000	0.995	0.980	0.959	0.946	0.932	0.922	0.913	0.909	0.903	0.900	0.897	0.895	0.893	0.891	0.890	0.889	0.889	0.887
2008	0.015	0.527	1.000	0.998	0.985	0.968	0.949	0.937	0.926	0.918	0.911	0.907	0.903	0.900	0.897	0.895	0.894	0.892	0.891	0.890	0.889
2009	0.052	0.593	1.000	0.998	0.988	0.970	0.954	0.938	0.929	0.920	0.913	0.908	0.905	0.901	0.899	0.897	0.895	0.894	0.892	0.892	0.890
2010	0.010	0.340	1.000	0.999	0.991	0.977	0.960	0.946	0.933	0.926	0.918	0.913	0.908	0.905	0.902	0.900	0.898	0.896	0.895	0.894	0.893
2011	0.006	0.493	0.998	0.999	0.991	0.978	0.962	0.947	0.935	0.925	0.919	0.913	0.908	0.905	0.902	0.900	0.898	0.897	0.895	0.894	0.893
2012	0.077	0.710	1.000	0.997	0.981	0.965	0.950	0.936	0.924	0.916	0.909	0.905	0.901	0.898	0.895	0.894	0.892	0.891	0.890	0.889	0.888
2013	0.010	0.322	0.991	1.000	0.996	0.983	0.971	0.958	0.946	0.935	0.927	0.920	0.916	0.912	0.908	0.906	0.904	0.902	0.900	0.899	0.897
2014	0.010	0.366	0.999	0.999	0.990	0.978	0.960	0.948	0.937	0.928	0.920	0.914	0.908	0.905	0.902	0.900	0.898	0.897	0.896	0.895	0.893
2015	0.016	0.347	1.000	0.999	0.994	0.980	0.968	0.952	0.942	0.933	0.925	0.918	0.913	0.908	0.906	0.903	0.901	0.900	0.898	0.897	0.895
2016	0.008	0.457	0.997	0.999	0.995	0.985	0.970	0.959	0.945	0.936	0.929	0.922	0.917	0.912	0.909	0.906	0.904	0.902	0.901	0.900	0.898
2017	0.011	0.552	0.996	0.999	0.993	0.983	0.970	0.956	0.946	0.935	0.928	0.922	0.916	0.912	0.909	0.905	0.904	0.902	0.900	0.899	0.897
2018	0.005	0.374	0.999	0.999	0.992	0.980	0.968	0.956	0.943	0.935	0.926	0.920	0.916	0.911	0.908	0.905	0.903	0.901	0.900	0.898	0.896
2019	0.009	0.985	1.000	0.994	0.983	0.965	0.950	0.939	0.928	0.919	0.914	0.908	0.904	0.901	0.898	0.896	0.894	0.893	0.892	0.891	0.890

Table 2.1.24a. Begin-year numbers at age (1000s of fish, Model 19.12a).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	1055860	241691	73168	67905	29929	15121	9429	6361	4414	3081	2136	1462	985	654	429	278	179	115	73	47	80
1978	698615	745589	170663	51554	47055	19901	9556	5744	3814	2637	1841	1277	875	590	392	257	167	107	69	44	76
1979	722893	493320	526471	120234	35574	30863	12261	5628	3318	2193	1517	1060	736	504	340	226	148	96	62	40	69
1980	180521	510465	348345	370885	83476	23754	19701	7581	3433	2018	1334	924	646	448	307	207	138	90	59	38	66
1981	202423	127473	360447	245480	257008	55779	15107	12115	4594	2073	1219	806	558	390	271	186	125	83	55	35	63
1982	940997	142939	90010	254052	170552	172949	36334	9594	7619	2883	1301	765	507	351	245	171	117	79	52	34	62
1983	262195	664480	100935	63515	178050	116903	115202	23746	6210	4919	1861	840	494	327	227	159	110	76	51	34	62
1984	880029	185147	469213	71165	44402	121489	76992	73973	15091	3933	3115	1179	532	313	207	144	100	70	48	32	61
1985	401581	621424	130730	330316	49176	29716	77878	47660	45120	9171	2389	1892	716	324	190	126	87	61	42	29	57
1986	218832	283573	438805	92219	229421	32806	19001	47921	28743	27072	5500	1433	1136	430	194	114	76	52	37	25	51
1987	73430	154526	200240	309090	64121	152706	20833	11734	29140	17407	16399	3334	869	689	261	118	69	46	32	22	47
1988	304805	51852	109115	141196	214549	43001	96187	12599	6985	17240	10289	9697	1972	514	408	154	70	41	27	19	41
1989	599916	215232	36606	76527	95993	137462	26213	56025	7233	4002	9884	5906	5571	1134	296	234	89	40	24	16	34
1990	591325	423624	151977	25765	52750	62967	84875	15622	32652	4197	2321	5736	3429	3236	658	172	136	52	23	14	29
1991	362056	417559	299132	107046	17822	34720	38737	49511	8919	18440	2365	1308	3232	1933	1824	371	97	77	29	13	24
1992	951195	255661	294841	210273	72881	11205	19550	19954	24415	4349	8960	1150	636	1572	940	887	181	47	37	14	18
1993	352693	671673	180523	207448	142697	45250	6198	9826	9576	11580	2062	4258	547	303	749	448	423	86	22	18	15
1994	297828	249047	474207	126445	140264	89417	26296	3417	5284	5119	6195	1105	2284	294	163	402	241	227	46	12	18
1995	267213	210307	175842	333198	85181	86561	49175	13415	1684	2577	2496	3025	540	1117	144	80	197	118	111	23	15
1996	845833	188688	148487	123272	222267	50070	44691	22956	6024	749	1146	1112	1351	241	500	64	36	88	53	50	17
1997	362002	597271	133235	104459	83807	136751	26672	21630	10540	2720	337	515	500	607	108	224	29	16	40	24	30
1998	287697	255620	421681	93265	69159	49266	69636	12173	9460	4544	1171	145	222	215	262	47	97	12	7	17	23
1999	692380	203153	180496	296836	63500	42974	27291	35229	5887	4524	2169	559	69	106	103	125	22	46	6	3	19
2000	504684	488915	143449	127086	202655	39656	23986	14045	17438	2882	2214	1062	274	34	52	51	61	11	23	3	11
2001	196393	356376	345235	100849	87316	128435	22462	12507	7057	8666	1431	1100	528	136	17	26	25	31	5	11	7
2002	343943	138680	251638	243028	68844	56279	74918	12140	6563	3689	4544	753	580	279	72	9	14	13	16	3	10
2003	310233	242870	97917	176522	164192	42391	32000	39494	6249	3392	1923	2384	397	306	147	38	5	7	7	9	7
2004	224096	219067	171480	68783	119201	101990	23632	16842	20048	3149	1712	973	1208	201	155	75	19	2	4	4	8
2005	268577	158241	154675	120055	46462	73299	56744	12182	8472	9992	1570	855	487	605	101	78	37	10	1	2	6
2006	785800	189652	111714	108624	80133	28591	40233	28942	5998	4142	4879	768	418	238	296	49	38	18	5	1	4
2007	317096	554881	133913	78567	73713	48463	15617	20020	13836	2826	1946	2291	361	197	112	139	23	18	9	2	2
2008	1172310	223913	391808	94298	53558	45993	26453	7951	9770	6673	1359	936	1103	174	95	54	67	11	9	4	2
2009	165411	827807	158108	275782	64120	32581	24277	12430	3624	4428	3036	621	429	506	80	43	25	31	5	4	3
2010	735035	116802	584533	111364	188302	38956	16354	10596	5126	1496	1846	1276	262	181	214	34	18	11	13	2	3
2011	931428	519031	82477	411811	76369	116807	20320	7320	4468	2146	630	783	543	112	78	92	14	8	5	6	2
2012	443334	657710	366495	58136	278377	45636	57415	8345	2736	1629	780	229	286	198	41	28	34	5	3	2	3
2013	1200130	313052	464420	257625	39413	163236	22766	25007	3381	1084	644	309	91	113	79	16	11	13	2	1	2
2014	216689	847449	221044	326507	172968	23809	82229	10288	10717	1430	459	274	132	39	49	34	7	5	6	1	1
2015	286940	153011	598401	155649	222461	103912	12220	35866	4245	4361	583	188	113	54	16	20	14	3	2	2	1
2016	178257	202617	108044	420974	106425	137183	53688	5573	15115	1760	1805	242	78	47	23	7	8	6	1	1	1
2017	124742	125873	143071	76046	285578	66151	73766	25256	2475	6545	760	779	104	34	20	10	3	4	3	1	1
2018	735401	88084	88881	100818	51990	178315	37363	37830	12248	1180	3101	360	369	49	16	10	5	1	2	1	1
2019	503144	519293	62197	62402	69005	32959	103713	20649	20274	6491	624	1640	190	195	26	8	5	2	1	1	1
2020	503144	355290	366633	43837	42255	44069	19292	57537	11252	10989	3521	339	892	104	106	14	5	3	1	0	1

Table 2.1.24b. Begin-year numbers at age (1000s of fish, Model 19.12).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	823249	214026	62270	57282	26196	13168	8223	5583	3913	2761	1935	1339	912	612	407	269	177	117	78	52	106
1978	584543	591102	153668	44602	40308	17638	8387	5017	3329	2310	1624	1139	789	540	366	245	164	110	73	49	103
1979	600751	419708	424400	110057	31235	26713	10901	4911	2853	1870	1292	908	639	445	308	211	144	98	66	45	97
1980	147013	431346	301346	303916	77568	21086	17140	6728	2969	1710	1117	772	544	384	270	188	130	90	62	42	93
1981	177794	105557	309698	215874	213683	52374	13451	10491	4028	1761	1011	661	457	324	230	164	115	81	56	39	88
1982	827405	127658	75787	221904	152214	145288	34287	8530	6549	2499	1090	626	410	285	203	145	104	74	52	37	85
1983	204043	594089	91660	54373	158009	105715	97607	22500	5517	4212	1604	700	402	264	184	132	95	69	49	35	83
1984	752943	146505	426560	65684	38622	109284	70225	62867	14279	3476	2648	1008	440	254	168	118	85	62	45	32	79
1985	349755	540621	105181	305271	45997	26181	70599	43526	38167	8604	2088	1591	607	266	155	103	73	53	39	29	73
1986	200206	251129	388164	75439	215411	31012	16919	43657	26195	22729	5107	1239	946	363	160	94	63	45	34	25	67
1987	71211	143750	180310	277963	53306	145465	19872	10533	26608	15809	13676	3072	747	573	221	99	58	40	29	22	60
1988	279200	51130	103212	129259	196004	36280	92639	12065	6275	15672	9270	8016	1805	441	341	133	60	36	25	18	53
1989	541701	200466	36703	73584	89248	127235	22339	54124	6889	3559	8858	5238	4543	1029	254	199	79	36	22	15	46
1990	520225	388946	143929	26264	51540	59374	79351	13386	31471	3965	2043	5082	3013	2628	600	150	119	48	22	14	39
1991	287980	373527	279262	103078	18468	34430	36902	46458	7631	17650	2214	1141	2844	1697	1496	346	88	71	29	14	34
1992	763617	206771	268183	199561	71334	11790	19600	19051	22704	3659	8382	1051	543	1368	830	748	177	46	38	16	28
1993	313785	548281	148455	191833	137557	45038	6631	9954	9116	10590	1694	3875	489	255	652	406	376	91	24	21	25
1994	254449	225298	393583	105695	131684	87374	26532	3694	5367	4846	5602	896	2057	262	138	358	227	214	53	14	28
1995	235301	182696	161745	280950	72340	82343	48476	13585	1808	2573	2305	2663	428	993	129	69	183	119	116	29	25
1996	735994	168946	131156	115169	189668	43013	42565	22335	5933	771	1087	973	1131	184	436	58	32	88	59	59	29
1997	325382	528446	121299	93783	79333	117116	22732	20034	9807	2540	327	460	414	488	81	198	27	15	44	30	48
1998	257591	233624	379362	86299	62825	46454	57993	9864	8150	3874	994	128	181	165	200	34	87	12	7	21	40
1999	590668	184952	167737	271503	59572	39119	25225	28085	4478	3609	1699	436	56	81	75	93	16	43	6	4	34
2000	436197	424103	132792	120077	188031	37305	21446	12457	13071	2031	1624	764	197	26	37	36	46	8	22	3	22
2001	175461	313191	304504	94951	83788	119936	20834	10773	5909	6045	931	743	351	92	12	18	18	23	4	12	14
2002	303317	125983	224864	217949	65871	54574	69853	11038	5428	2916	2960	455	365	174	46	6	9	10	13	2	16
2003	278732	217782	90445	160307	149389	41044	31160	36452	5486	2647	1412	1433	221	179	87	23	3	5	5	7	11
2004	205850	200131	156350	64582	109790	93591	22871	16189	17965	2645	1267	676	689	108	88	44	12	2	3	3	10
2005	253224	147800	143680	111268	44271	68058	51957	11602	7907	8575	1253	600	321	331	53	44	22	6	1	1	8
2006	744513	181816	106097	102576	75355	27482	37211	26035	5528	3706	3984	581	280	151	159	26	22	12	3	0	5
2007	292652	534564	130539	75869	70707	45939	14941	18103	12002	2486	1655	1777	261	127	70	75	13	11	6	2	3
2008	1008590	210126	383808	93467	52580	44636	25001	7476	8546	5544	1139	758	817	121	60	34	37	6	6	3	3
2009	143433	724175	150867	274709	64612	32482	23734	11590	3290	3655	2350	482	322	352	53	27	16	18	3	3	3
2010	651437	102985	519952	108062	190817	39952	16584	10353	4582	1264	1385	890	184	125	139	22	12	7	8	2	3
2011	807781	467733	73943	372453	75419	120575	21213	7474	4268	1811	495	541	350	73	51	59	10	5	3	4	3
2012	370599	579987	335824	52982	255844	45920	60220	8769	2758	1505	627	171	189	124	27	19	23	4	2	1	3
2013	1003000	266090	416422	239940	36485	152425	23190	26163	3475	1050	565	235	65	73	49	11	8	10	2	1	2
2014	187036	720153	191042	297605	163517	22347	77511	10447	10925	1401	418	225	94	26	30	21	5	4	5	1	2
2015	250308	134292	517061	136759	205967	99535	11586	33624	4183	4203	530	158	85	36	10	12	9	2	2	2	1
2016	138984	179721	96420	369728	95009	128598	51504	5217	13634	1637	1620	204	61	34	15	4	5	4	1	1	2
2017	101802	99791	129036	68965	254301	59668	68969	23672	2225	5567	661	652	82	25	14	6	2	2	2	1	1
2018	620133	73094	71648	92443	47796	159891	33597	34624	11041	1010	2495	296	293	37	12	7	3	1	1	1	1
2019	433073	445259	52480	51130	64190	30482	92723	18350	18130	5666	515	1271	151	151	20	6	4	2	1	1	1
2020	433073	310950	319637	37599	35105	41396	17859	51025	9822	9551	2967	270	668	80	81	11	3	2	1	0	1

Table 2.1.24c. Begin-year numbers at age (1000s of fish, Model 21.1).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	932875	280606	84628	84869	40057	21145	13889	9953	7380	5531	4143	3086	2278	1667	1208	869	620	440	311	219	495
1978	592716	685042	206054	62044	61430	28144	14395	9288	6635	4941	3723	2802	2093	1549	1134	823	592	423	300	212	487
1979	585250	435251	503038	151040	44777	42772	18863	9443	6072	4362	3271	2479	1872	1402	1039	762	553	398	284	202	471
1980	151644	429770	319613	368679	109426	31579	29365	12761	6375	4116	2972	2238	1701	1287	965	716	525	381	275	196	464
1981	165969	111358	315584	234279	266546	77034	21582	19751	8560	4293	2786	2020	1525	1161	880	660	490	359	261	188	452
1982	770222	121877	81770	231339	169559	188152	53218	14722	13450	5849	2946	1918	1394	1054	803	609	457	339	249	181	444
1983	218832	565602	89498	60003	168651	121228	131753	36869	10174	9316	4064	2052	1338	974	737	562	426	320	238	174	438
1984	713886	160696	415337	65611	43596	119826	83780	89704	25030	6923	6362	2783	1408	920	670	507	387	293	220	164	422
1985	328508	524230	117993	303931	47082	30347	80614	55143	58788	16452	4572	4217	1850	937	613	447	338	258	196	147	391
1986	177428	241235	384951	86551	219231	32639	20291	52544	35689	38219	10759	3005	2782	1223	621	406	296	224	171	130	357
1987	59549	130291	177143	281878	62479	151476	21681	13234	34115	23304	25143	7116	1996	1852	816	414	271	198	150	115	326
1988	241894	43729	95675	129876	203036	43426	99571	13871	8429	21840	15048	16345	4645	1307	1215	536	272	179	130	99	290
1989	482476	177627	32101	69680	91375	134718	27638	61526	8568	5250	13749	9563	10451	2981	841	783	346	176	115	84	251
1990	475057	354297	130428	23481	49769	62093	87005	17442	38542	5396	3327	8763	6122	6709	1916	541	504	223	113	74	216
1991	304671	348849	260164	95479	16834	33905	39954	54065	10743	23763	3342	2067	5460	3822	4194	1199	339	316	139	71	182
1992	784910	223729	256158	190080	67353	10952	20026	22216	29569	5904	13221	1877	1167	3096	2174	2390	684	193	180	80	145
1993	302780	576382	164282	187352	133610	43321	6379	10925	11932	16077	3257	7413	1062	664	1769	1246	1372	393	111	104	129
1994	247472	222338	423162	119491	131275	86961	26499	3771	6423	7094	9699	1983	4555	656	411	1098	774	854	245	69	145
1995	224790	181726	163248	309072	83211	83874	50349	14611	2062	3562	4012	5575	1150	2663	385	242	647	457	505	145	127
1996	699081	165069	133430	118963	213538	50551	45795	25745	7414	1064	1880	2158	3039	631	1472	214	135	360	255	281	152
1997	300006	513355	121211	97589	83848	136414	28606	24417	13435	3877	561	998	1152	1629	339	792	115	73	194	137	234
1998	232296	220301	376894	88152	66896	51209	74080	14481	12206	6776	1981	289	520	603	856	179	418	61	38	103	196
1999	561133	170582	161767	275837	62249	43180	30001	40897	7874	6689	3761	1110	163	295	343	488	102	239	35	22	171
2000	430007	412057	125259	118432	195361	40415	25553	16841	22662	4405	3786	2152	640	95	171	200	285	59	139	20	113
2001	160742	315767	302580	91525	84423	128517	24239	14542	9471	12851	2533	2197	1259	376	56	101	118	168	35	83	79
2002	287873	118037	231865	221427	64757	56380	78602	14091	8406	5561	7691	1541	1350	778	233	35	63	74	105	22	101
2003	257197	211393	86668	169053	154877	41279	33558	44370	7947	4857	3298	4657	948	837	485	146	22	40	46	66	78
2004	185934	188867	155214	63290	118264	99522	24185	18929	24772	4505	2806	1933	2758	565	501	291	88	13	24	28	87
2005	221382	136536	138676	112932	44315	75437	58284	13478	10479	13853	2558	1612	1120	1607	331	294	171	52	8	14	68
2006	646288	162567	100238	101245	78061	28278	43693	32166	7366	5771	7737	1446	918	641	923	190	169	99	30	4	47
2007	265203	474588	119371	73293	71265	49155	16399	23852	17280	3969	3128	4223	793	506	354	510	105	94	55	16	29
2008	965942	194747	348490	87396	51830	46259	28661	9161	13110	9531	2207	1749	2374	447	286	200	289	60	53	31	26
2009	141958	709319	143004	255032	61647	32773	26019	14984	4764	6936	5145	1212	969	1327	251	161	113	163	34	30	32
2010	603348	104243	520865	104733	180707	38815	17476	12645	7243	2376	3607	2756	664	537	742	142	91	64	93	19	35
2011	782957	443054	76548	381587	74486	116177	21449	8712	6235	3717	1260	1976	1541	377	306	427	82	53	37	54	32
2012	368933	574945	325340	56115	267575	46112	60915	9964	3929	2882	1788	620	992	782	193	158	220	42	27	19	44
2013	997664	270917	422188	237698	39443	162838	24490	29633	4732	1902	1432	911	320	516	410	101	83	116	22	14	34
2014	184626	732611	198930	308623	165187	24677	86985	12174	14536	2375	987	762	494	175	285	227	56	46	65	12	27
2015	238153	135576	537968	145651	218094	102553	13387	42196	5812	7075	1192	508	400	262	93	153	122	30	25	35	21
2016	148877	174881	99556	393499	103231	139288	56162	6754	20679	2888	3592	617	267	212	140	50	82	66	16	13	30
2017	110400	109325	128417	72860	276679	66368	79057	29119	3433	10636	1512	1910	332	145	116	77	27	45	36	9	24
2018	618776	81070	80279	94086	51622	179022	39432	44071	15876	1879	5893	845	1075	188	82	66	44	16	26	21	19
2019	416806	454386	59529	58577	66762	33927	109481	23323	25777	9334	1113	3522	508	648	113	50	40	26	9	16	24
2020	416806	306074	333616	43633	41069	44115	20795	64843	13774	15369	5644	679	2169	314	402	71	31	25	17	6	25

Table 2.1.24d. Begin-year numbers at age (1000s of fish, Model 21.2).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	1081730	270900	78832	70914	31972	16162	10098	6854	4795	3379	2372	1646	1127	761	507	335	219	142	92	60	106
1978	673708	767438	192183	55797	49420	21480	10372	6257	4178	2913	2055	1444	1004	687	464	310	204	134	87	56	101
1979	713380	477963	544435	136033	38734	32796	13470	6228	3684	2451	1711	1210	852	592	406	274	183	121	79	51	93
1980	183906	506109	339082	385353	95025	26124	21239	8462	3860	2278	1518	1062	751	529	368	252	171	114	75	49	90
1981	201225	130473	359046	240067	268729	64185	16862	13274	5208	2367	1398	932	652	462	325	226	155	105	70	46	86
1982	951982	142760	92559	254192	167665	182372	42275	10829	8438	3304	1502	888	593	415	294	207	144	99	67	45	84
1983	256214	675388	101281	65618	179042	115744	122554	27859	7056	5482	2146	976	577	385	270	191	135	94	64	43	83
1984	886642	181772	479152	71745	46108	123027	76950	79395	17831	4495	3489	1366	622	368	245	172	122	86	60	41	81
1985	392819	629030	128949	338867	49891	31127	79748	48158	48834	10908	2746	2132	835	380	225	150	105	74	52	37	74
1986	217471	278687	446256	91383	236676	33623	20150	49665	29327	29539	6593	1660	1290	505	230	136	91	64	45	32	67
1987	73688	154285	197711	315791	63869	158897	21606	12575	30463	17902	18042	4031	1016	790	310	141	83	56	39	28	61
1988	313081	52278	109456	140065	220442	43188	101276	13218	7553	18166	10668	10761	2406	607	472	185	84	50	33	23	53
1989	610357	222111	37078	77068	95679	142481	26630	59678	7666	4369	10519	6189	6251	1399	353	274	108	49	29	19	44
1990	596545	433018	157568	26210	53402	63350	89119	16071	35121	4484	2553	6150	3620	3658	819	207	161	63	29	17	37
1991	369659	423219	307199	111515	18243	35565	39628	52813	9289	20008	2545	1448	3487	2053	2074	464	117	91	36	16	31
1992	990273	262253	300239	216960	76531	11658	20573	20991	26617	4609	9867	1254	714	1720	1013	1023	229	58	45	18	23
1993	351082	702546	186045	212222	148353	48388	6627	10653	10332	12914	2237	4803	612	349	841	495	501	112	28	22	20
1994	312525	249072	498321	130936	144536	94269	28665	3721	5822	5610	7024	1219	2624	335	191	460	271	274	61	15	23
1995	263635	221720	176685	351841	89002	90688	53008	14929	1864	2884	2782	3495	608	1311	167	95	230	136	137	31	19
1996	797287	187034	157279	124473	236912	53519	48244	25441	6856	845	1308	1266	1595	278	600	77	44	105	62	63	23
1997	328524	565632	132686	111183	85339	148723	29463	24103	11965	3153	385	595	576	725	126	273	35	20	48	28	39
1998	273115	233068	401179	93306	74008	51120	78523	14043	10965	5338	1400	171	264	256	322	56	121	15	9	21	30
1999	691365	193760	165343	283456	64050	46770	29256	41360	7057	5428	2631	690	84	130	126	159	28	60	8	4	25
2000	535652	490488	137455	116862	194217	40877	26964	15665	21289	3585	2754	1336	351	43	66	64	81	14	30	4	15
2001	220976	380016	347967	97041	80636	124286	23772	14391	8072	10905	1846	1424	694	182	22	35	33	42	7	16	10
2002	410999	156771	269591	246192	66706	52352	72673	12865	7583	4310	5944	1022	796	389	103	13	19	19	24	4	15
2003	372135	291581	111210	190055	167450	41330	29777	37978	6581	3946	2294	3218	559	438	215	57	7	11	10	13	10
2004	253692	264010	206854	78662	130221	105591	22904	15303	18778	3283	2011	1187	1682	294	231	113	30	4	6	6	12
2005	296362	179981	187295	146012	54019	81793	59293	11653	7545	9208	1623	1004	596	846	148	116	57	15	2	3	9
2006	806782	210253	127672	132413	99138	34129	46069	30674	5734	3663	4449	784	485	288	410	72	56	28	7	1	6
2007	292501	572369	149157	90238	90770	61553	19365	23845	15145	2767	1757	2127	375	232	138	196	34	27	13	3	3
2008	1087940	207514	406039	105418	61854	57896	35289	10470	12360	7725	1402	889	1076	189	117	70	99	17	14	7	3
2009	159327	771836	147211	286770	72052	38891	32929	18337	5268	6117	3808	691	438	530	93	58	34	49	9	7	5
2010	694916	113034	547548	103918	195815	45078	21606	16714	8839	2513	2910	1813	329	209	253	45	28	16	23	4	6
2011	891288	493005	80189	386667	71302	124049	25371	11005	8170	4306	1232	1438	900	164	104	126	22	14	8	12	5
2012	424813	632319	349744	56728	262192	43656	64885	11519	4703	3498	1884	546	643	404	74	47	57	10	6	4	7
2013	1182410	301380	448583	247065	38712	156857	22493	29305	4926	2031	1549	853	249	296	187	34	22	26	5	3	5
2014	209388	838850	213800	316772	167046	23577	79880	10273	12823	2184	927	722	404	119	141	89	16	10	13	2	4
2015	289488	148548	595105	151298	217214	101625	12127	34456	4205	5273	922	400	316	178	52	63	40	7	5	6	3
2016	179844	205374	105385	420887	104377	135175	52396	5371	13991	1700	2164	384	169	134	76	22	27	17	3	2	4
2017	121752	127588	145697	74534	287313	65489	72628	24174	2294	5770	698	889	158	70	55	31	9	11	7	1	2
2018	751418	86376	90516	103263	51699	182846	37261	36293	11138	1028	2567	311	396	71	31	25	14	4	5	3	2
2019	504043	533091	61278	63936	71361	33217	106994	20503	19099	5751	528	1317	159	203	36	16	13	7	2	3	2
2020	504043	357594	378137	43390	43591	46011	19628	59432	11107	10229	3074	283	706	85	109	19	9	7	4	1	3

Table 2.1.24e. Begin-year numbers at age (1000s of fish, Model 21.3).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	773124	210752	57827	54849	24706	12242	7603	5141	3589	2523	1763	1215	824	552	365	241	159	105	70	47	97
1978	561998	557091	151856	41562	38684	16614	7745	4585	3021	2086	1461	1021	706	482	326	218	146	98	65	44	94
1979	572491	404960	401405	109133	29165	25571	10169	4462	2556	1661	1142	800	561	391	270	185	127	86	59	40	88
1980	127910	412521	291793	288439	77118	19674	16312	6212	2663	1511	979	673	472	333	234	164	114	79	54	38	84
1981	171617	92168	297237	209763	203314	52069	12490	9895	3677	1560	882	571	394	278	198	141	100	70	49	35	80
1982	812864	123663	66411	213745	148367	138369	34028	7883	6139	2265	959	542	352	244	173	125	90	64	46	32	77
1983	190084	585729	89108	47816	152731	103285	92985	22302	5086	3937	1450	614	347	226	158	113	82	59	43	31	74
1984	730098	136970	422058	64068	34087	105941	68645	59787	14115	3195	2467	908	385	219	144	101	73	53	39	28	71
1985	341520	526088	98683	303133	44952	23170	68467	42427	36136	8463	1909	1474	544	232	133	88	63	46	34	25	66
1986	197889	246090	379076	71033	214633	30302	14983	42246	25421	21409	4997	1127	873	324	139	81	54	39	29	22	60
1987	71330	142593	177323	272428	50382	145286	19378	9313	25665	15279	12826	2994	677	527	197	86	50	34	25	19	54
1988	275197	51399	102746	127570	192767	34400	92553	11721	5530	15055	8921	7487	1752	399	313	119	52	31	21	16	48
1989	535152	198297	37027	73536	88438	125464	21199	53912	6658	3120	8463	5014	4223	995	229	183	70	31	19	13	41
1990	517483	385615	142880	26594	51711	59022	78317	12694	31257	3817	1785	4839	2876	2440	580	135	110	43	19	12	35
1991	256943	372884	277857	102695	18775	34669	36743	45820	7223	17482	2125	994	2702	1618	1389	335	80	66	26	12	30
1992	725274	185144	268675	199240	71346	12038	19771	18936	22305	3448	8261	1004	472	1297	792	698	173	42	36	15	25
1993	307618	522608	133400	192890	137722	45201	6789	10040	9041	10374	1592	3809	466	221	620	389	353	90	23	20	24
1994	244711	221657	376488	95327	132945	87685	26713	3793	5425	4816	5499	844	2028	251	120	343	220	204	53	14	27
1995	229760	176330	159698	269631	65516	83517	48745	13720	1863	2608	2297	2622	404	985	124	61	177	117	112	30	24
1996	718346	165556	127035	114099	182563	39147	43294	22417	5981	793	1100	968	1113	174	435	57	28	86	59	59	30
1997	319156	517615	119289	91159	78848	112838	20684	20269	9749	2535	333	461	408	477	76	197	27	14	43	31	48
1998	252584	229971	372911	85182	61292	46158	55415	8855	8095	3771	972	128	178	161	193	32	86	12	7	21	42
1999	568847	182003	165703	267844	58997	38190	24901	26463	3950	3515	1621	418	55	78	72	89	15	43	6	3	35
2000	422930	409892	131141	119052	186122	36952	20799	12122	12084	1756	1549	714	185	25	36	34	44	8	22	3	22
2001	171786	304749	295350	94122	83388	118856	20520	10314	5649	5479	789	695	322	85	12	17	17	22	4	12	15
2002	296186	123784	219583	212158	65557	54450	69068	10791	5142	2754	2650	381	338	159	42	6	9	9	12	2	16
2003	273784	213421	89183	157101	145897	40944	31053	35840	5320	2484	1322	1271	184	165	79	22	3	5	5	7	11
2004	202601	197280	153765	63913	107972	91566	22788	16050	17519	2541	1178	626	606	89	81	40	11	2	3	3	11
2005	251862	145987	142138	109835	43981	67060	50729	11493	7774	8281	1191	552	295	289	43	40	20	6	1	1	8
2006	744414	181483	105169	101849	74675	27373	36588	25256	5428	3607	3808	547	255	138	138	21	20	11	3	0	6
2007	289440	536399	130765	75481	70493	45634	14859	17669	11521	2413	1592	1678	243	115	63	65	10	10	6	2	4
2008	953836	208561	386499	93968	52527	44650	24797	7392	8262	5265	1093	721	764	112	54	31	33	5	5	3	3
2009	133847	687302	150277	277630	65219	32570	23735	11420	3222	3494	2206	458	304	327	49	24	14	16	3	3	3
2010	605272	96446	495236	108034	193559	40477	16648	10311	4476	1226	1311	827	173	117	129	20	10	6	7	1	3
2011	728169	436136	69494	356009	75710	122754	21578	7525	4256	1770	480	513	326	70	48	55	9	5	3	4	2
2012	319187	524691	314254	49965	245352	46347	61611	8982	2799	1512	618	168	181	117	26	18	22	4	2	1	3
2013	828613	229994	378062	225253	34502	146560	23465	26735	3552	1062	567	231	63	70	46	11	8	10	2	1	2
2014	152945	597067	165712	271057	153702	21121	74228	10498	11050	1416	418	223	92	26	29	20	5	4	5	1	2
2015	198371	110206	430215	119014	187808	93051	10824	31574	4106	4141	522	154	83	35	10	12	8	2	2	2	1
2016	102415	142938	79409	308519	82724	116270	46964	4702	12236	1531	1519	191	57	31	14	4	5	4	1	1	2
2017	76607	73796	102991	56944	211457	51214	60152	20368	1873	4641	573	567	72	22	12	6	2	2	2	0	1
2018	458579	55200	53173	74011	39292	129910	27600	28181	8720	776	1894	234	232	30	9	5	3	1	1	1	1
2019	408829	330436	39773	38026	51153	24358	71410	14059	13587	4096	362	882	109	110	14	5	3	1	0	1	1
2020	408829	294589	238042	28583	25847	31960	13327	35865	6797	6424	1920	170	416	52	53	7	2	1	1	0	1

Table 2.1.24f. Begin-year numbers at age (1000s of fish, ensemble).

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	923023	239569	70170	66118	30041	15275	9650	6631	4705	3367	2402	1697	1185	819	561	382	259	175	119	81	168
1978	620772	661630	171944	50252	46612	20366	9876	6033	4088	2894	2076	1487	1055	741	515	355	243	166	113	77	163
1979	636507	444988	474333	123152	35269	31174	12846	5978	3591	2429	1726	1244	896	640	452	317	220	152	105	72	155
1980	156698	456156	319032	339317	86956	23982	20329	8139	3746	2250	1527	1090	789	571	409	291	205	143	99	69	151
1981	183424	112297	326953	228294	238794	59140	15559	12793	5061	2329	1404	957	686	499	363	262	187	133	93	65	145
1982	858146	131470	80488	233939	161026	163152	39194	10066	8214	3251	1502	909	622	448	327	239	173	124	88	62	142
1983	224762	615073	94248	57660	166447	112041	110340	26057	6634	5412	2148	995	605	415	300	220	161	117	84	60	140
1984	789629	161081	440926	67456	40918	115249	74865	71923	16847	4281	3503	1395	649	396	273	198	145	107	78	56	135
1985	362493	565913	115453	315121	47254	27784	74923	47002	44545	10429	2657	2184	874	409	250	174	126	93	69	50	125
1986	202430	259822	405645	82685	222162	31932	18034	46784	28773	27191	6393	1636	1352	544	256	158	110	80	60	44	114
1987	70005	145098	186261	290059	58358	150051	20553	11313	28881	17711	16798	3974	1022	850	344	163	101	71	52	39	104
1988	282327	50183	104020	133349	204321	39711	95875	12597	6841	17360	10668	10174	2425	628	526	215	102	64	45	33	92
1989	552891	202337	35970	74050	91954	132707	24558	56608	7327	3982	10123	6258	6014	1448	377	319	131	63	39	28	79
1990	538966	396268	145030	25705	51800	61191	83142	14866	33468	4315	2353	5993	3725	3607	876	230	196	81	39	25	68
1991	313048	386279	284057	103705	18053	34608	38226	49273	8636	19219	2478	1357	3464	2167	2115	519	137	118	49	24	57
1992	834822	224341	276883	202696	71680	11533	19830	20073	24788	4311	9565	1240	685	1760	1115	1103	275	74	64	27	45
1993	324895	598240	160793	197773	139562	45256	6514	10208	9880	12080	2115	4714	618	345	895	576	578	147	40	35	41
1994	269319	232916	428695	114301	135685	88775	26788	3665	5610	5412	6650	1174	2631	348	196	512	333	338	87	24	46
1995	243742	193020	166989	305661	78133	85010	49640	13934	1843	2801	2721	3377	604	1365	183	104	275	182	187	49	40
1996	760480	174723	138342	118829	206612	46630	44576	23528	6354	833	1276	1258	1586	289	660	90	52	139	93	97	48
1997	328845	545129	125267	98796	81928	128623	25189	21802	10911	2905	380	588	588	752	139	321	44	26	70	48	76
1998	261361	235749	390757	89018	66244	48549	65879	11589	9561	4731	1264	167	262	267	348	66	153	22	13	35	63
1999	618730	187339	169034	279272	61480	41597	27051	33534	5658	4607	2291	617	82	131	136	180	34	81	12	7	54
2000	462029	443429	134300	120855	193338	38834	23392	13985	16734	2811	2290	1152	313	42	69	72	97	19	45	6	35
2001	183110	331170	317847	95874	84268	123905	22164	12252	7060	8429	1431	1172	597	164	22	37	40	54	10	25	24
2002	323066	131223	237407	227166	66441	55000	72872	12044	6464	3730	4526	782	646	334	93	13	21	23	32	6	30
2003	293749	231512	94045	169063	155615	41433	31594	38693	6224	3363	1974	2447	431	360	189	53	7	13	14	19	22
2004	212301	210503	165917	67080	115909	97851	23281	16697	19713	3165	1732	1032	1301	233	196	104	30	4	7	8	24
2005	256613	152155	150860	117968	46032	72258	54965	12065	8433	9893	1601	888	536	687	125	106	57	16	2	4	18
2006	745097	183928	109046	107575	79986	28746	40147	28291	5980	4158	4903	802	451	276	359	66	57	31	9	1	13
2007	292982	534109	131846	77866	74131	49120	15932	20268	13710	2858	1992	2369	392	223	139	183	34	30	16	5	8
2008	1039447	210054	382917	94255	53890	47004	27322	8271	10107	6765	1410	989	1190	200	115	73	97	18	16	9	7
2009	148534	745070	150620	273653	65066	33419	25486	13256	3883	4724	3182	670	476	583	100	59	38	51	10	9	9
2010	658807	106480	534146	107724	189638	40290	17361	11651	5730	1677	2083	1429	307	222	279	49	29	19	26	5	9
2011	827042	472219	76346	382003	75009	119793	21662	8134	5181	2555	759	971	679	149	110	141	25	15	10	14	8
2012	383916	592816	338527	54638	262011	45682	60575	9288	3228	2047	1037	315	415	296	66	50	65	12	7	5	11
2013	1035448	275148	424993	241569	37592	156244	23290	27043	3886	1343	870	455	141	191	139	32	24	32	6	4	8
2014	189280	742028	197221	303337	164433	23017	79964	10708	11801	1690	597	399	216	68	95	70	16	12	17	3	6
2015	250768	135666	531848	140987	209666	99995	11969	35377	4478	4886	712	259	178	100	32	46	34	8	6	9	5
2016	147691	179702	97255	379779	97809	130771	51993	5488	15006	1878	2070	309	116	82	47	15	23	17	4	3	7
2017	106034	105816	128797	69479	260875	61363	70496	24378	2435	6543	824	922	140	54	39	23	8	11	9	2	6
2018	629697	76000	75828	92139	48147	164247	34728	35909	11709	1159	3133	399	453	70	27	20	12	4	6	5	4
2019	451312	451217	54482	54024	63893	30716	95602	19145	19158	6194	618	1688	217	249	39	16	12	7	2	4	5
2020	451312	323470	323328	38985	37003	41061	17970	52866	10385	10351	3368	340	943	122	143	23	9	7	4	1	6

Table 2.1.25. Means and standard deviations of the ABC and OFL pdfs for all models and the ensemble.

Feature	19.12a	19.12	21.1	21.2	21.3
Allow catchability to vary?	no	yes	no	no	no
Allow domed survey selectivity?	no	no	yes	no	no
Use fishery CPUE?	no	no	no	yes	no
Estimate survey CV internally?	no	no	no	no	yes
Model weight:	0.2459	0.2213	0.1803	0.1311	0.2213

Year	Quantity	Statistic	19.12a	19.12	21.1	21.2	21.3	Ensemble
2021	ABC	mean	118044	83930	128897	110619	33599	92789
2021	ABC	sdev	22316	21641	26245	20106	17347	41186
2021	OFL	mean	141089	100683	152279	132399	40597	110785
2021	OFL	sdev	26414	25811	30727	23883	20857	48690
2022	ABC	mean	105613	82924	115920	102594	41566	87880
2022	ABC	sdev	12059	14233	15254	11607	15769	30379
2022	OFL	mean	117275	93561	128750	114476	48335	98472
2022	OFL	sdev	12304	15085	15880	11993	17699	32692

Figures

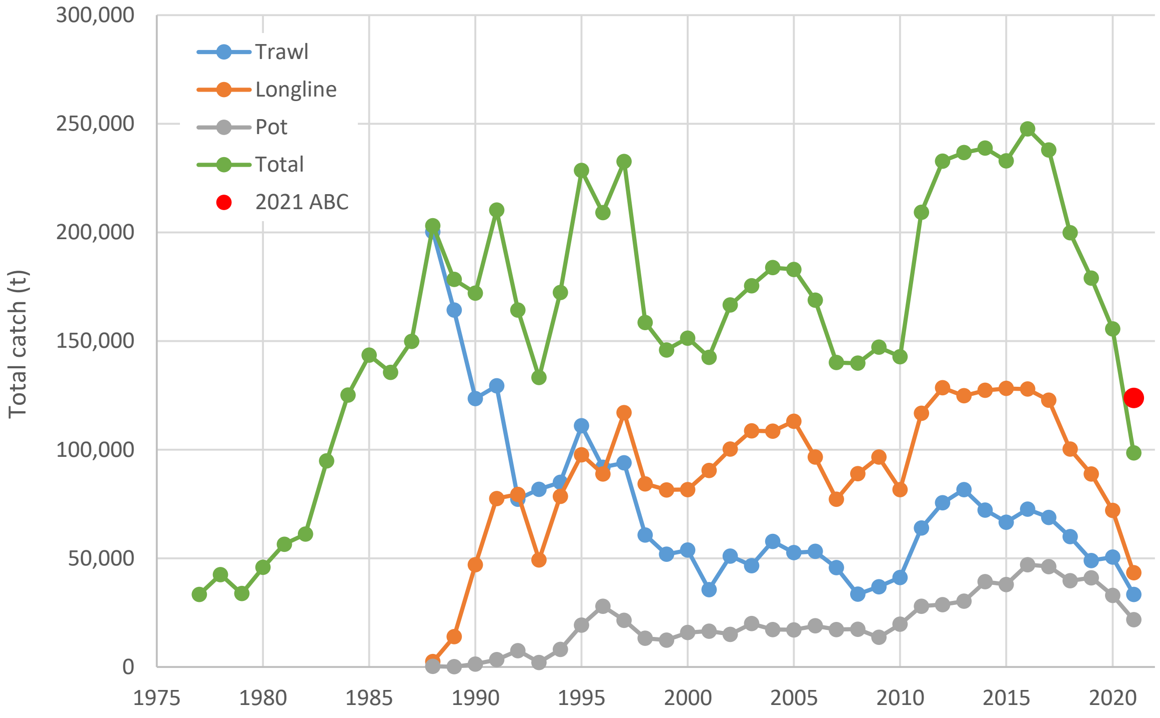


Figure 2.1.1. Catch (t) by gear. Data for 2021 are current through August.

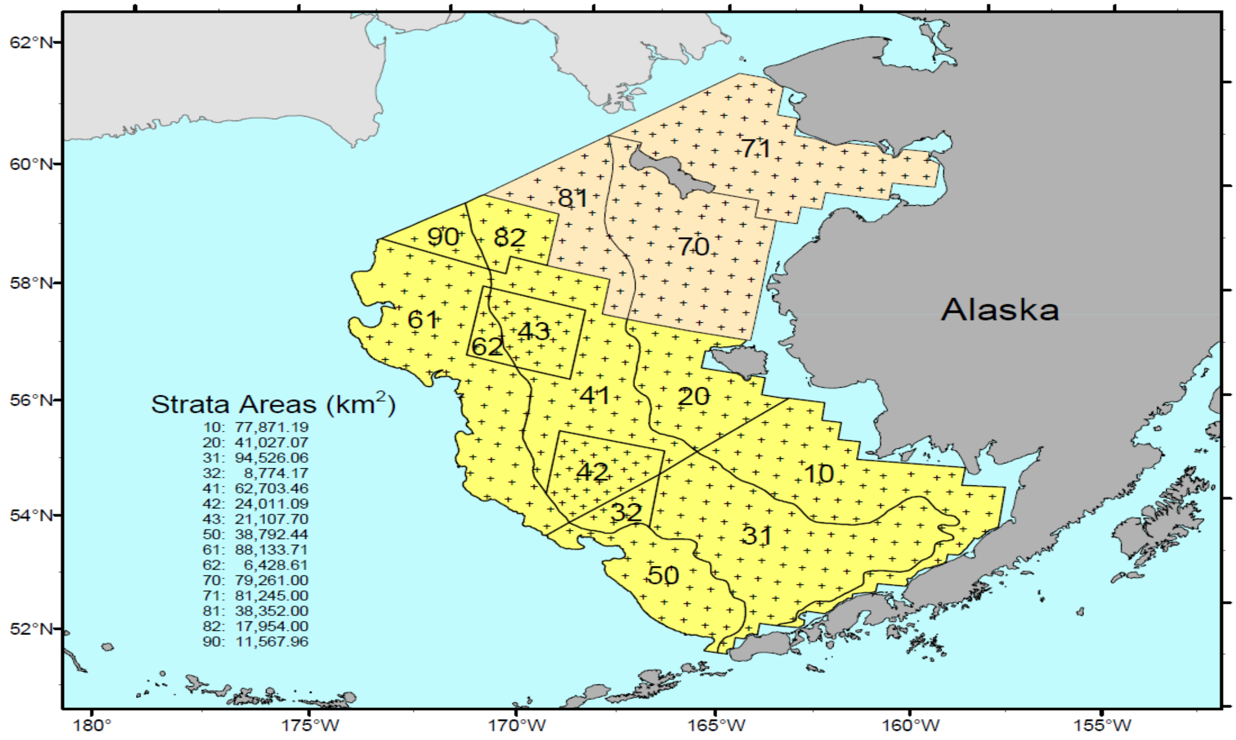


Figure 2.1.2. Map of the EBS (yellow) and NBS (tan) bottom trawl survey areas.

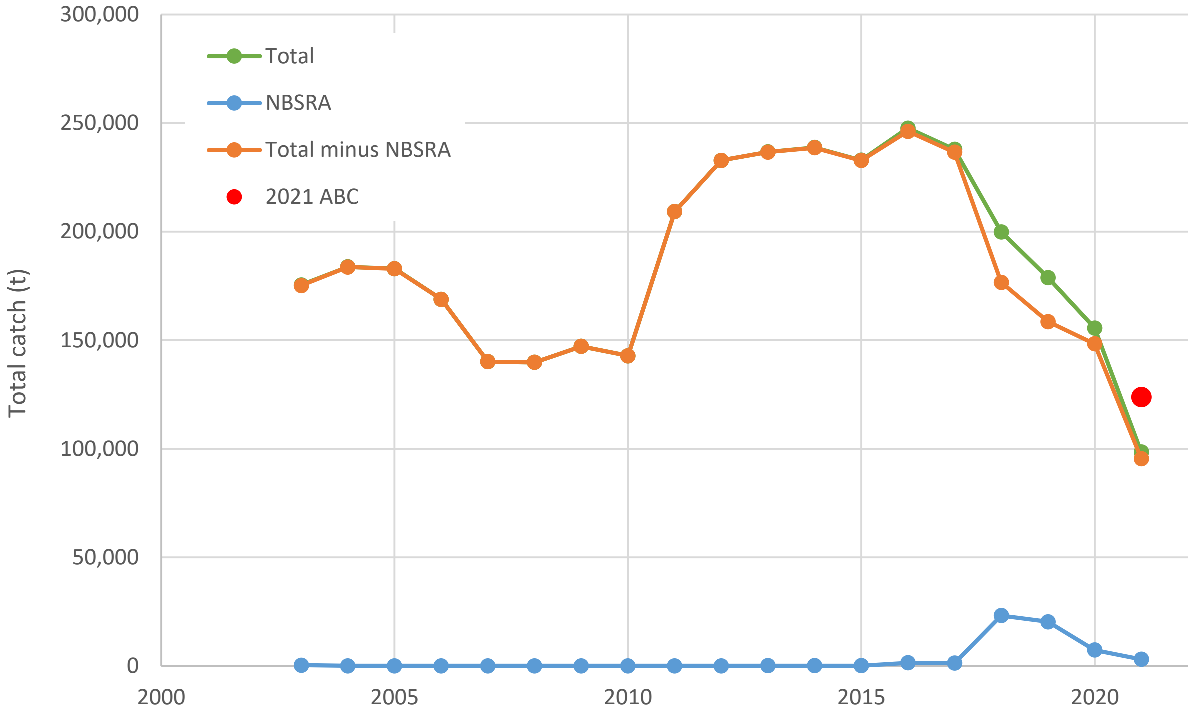


Figure 2.1.3. Catch by area (the Northern Bering Sea Research Area approximates the NBS survey area).

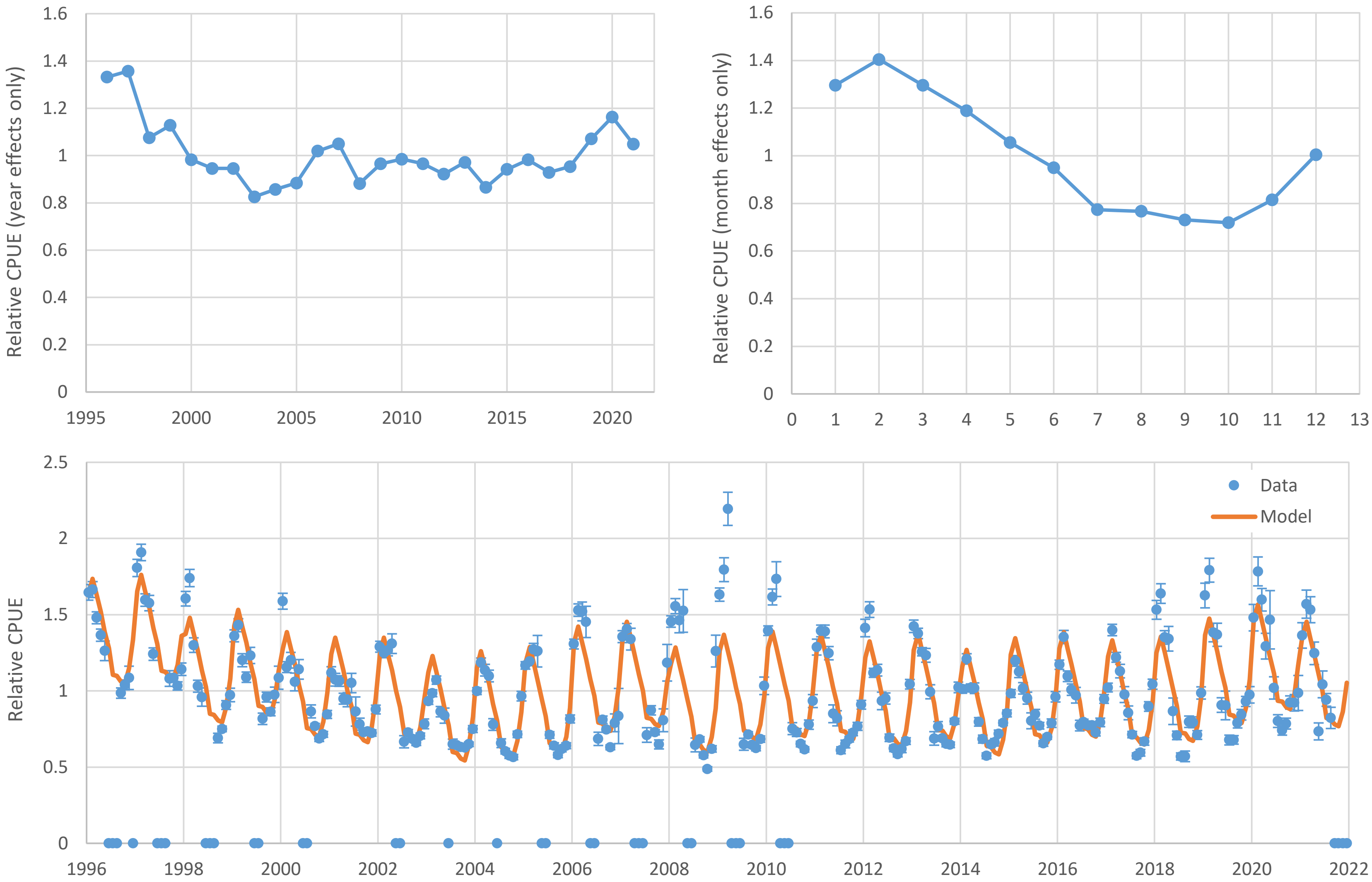


Figure 2.1.4a. Longline fishery CPUE (target only). Top left: year effects, top right: month effects, bottom: monthly data and model fit.

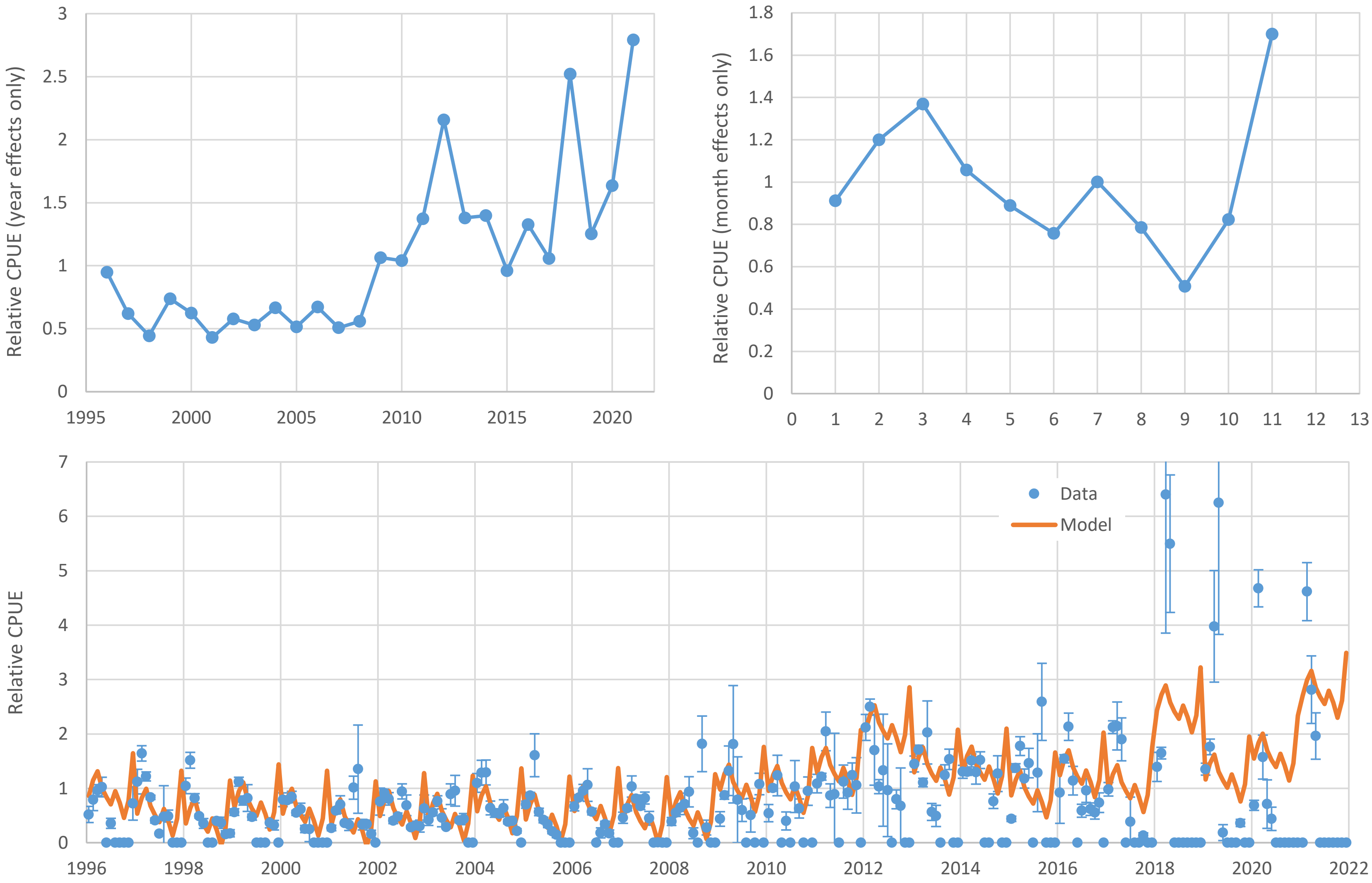


Figure 2.1.4b. Bottom trawl fishery CPUE (target only). Top left: year effects, top right: month effects, bottom: monthly data and model fit.

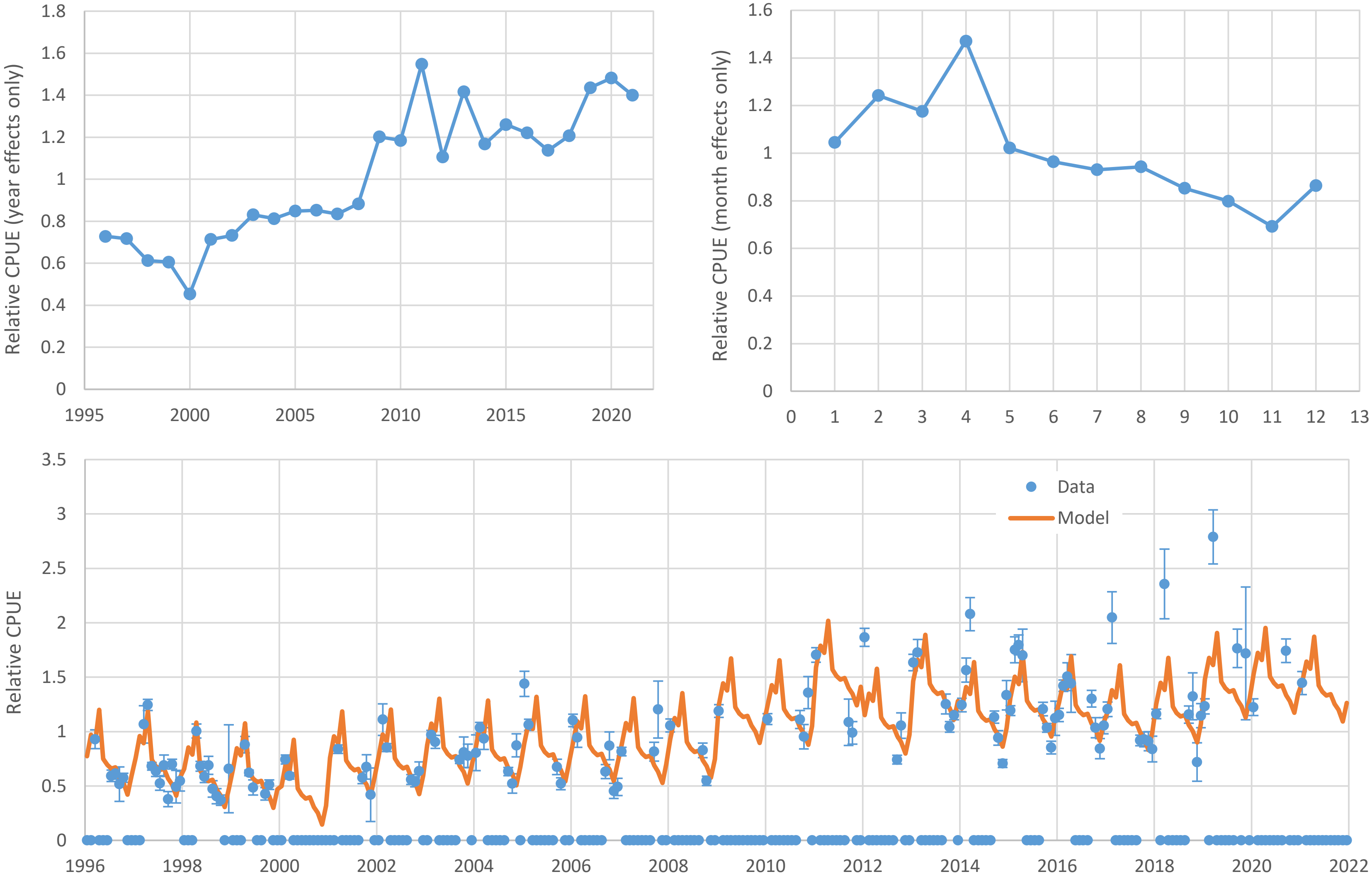


Figure 2.1.4c. Pot fishery CPUE (target only). Top left: year effects, top right: month effects, bottom: monthly data and model fit.

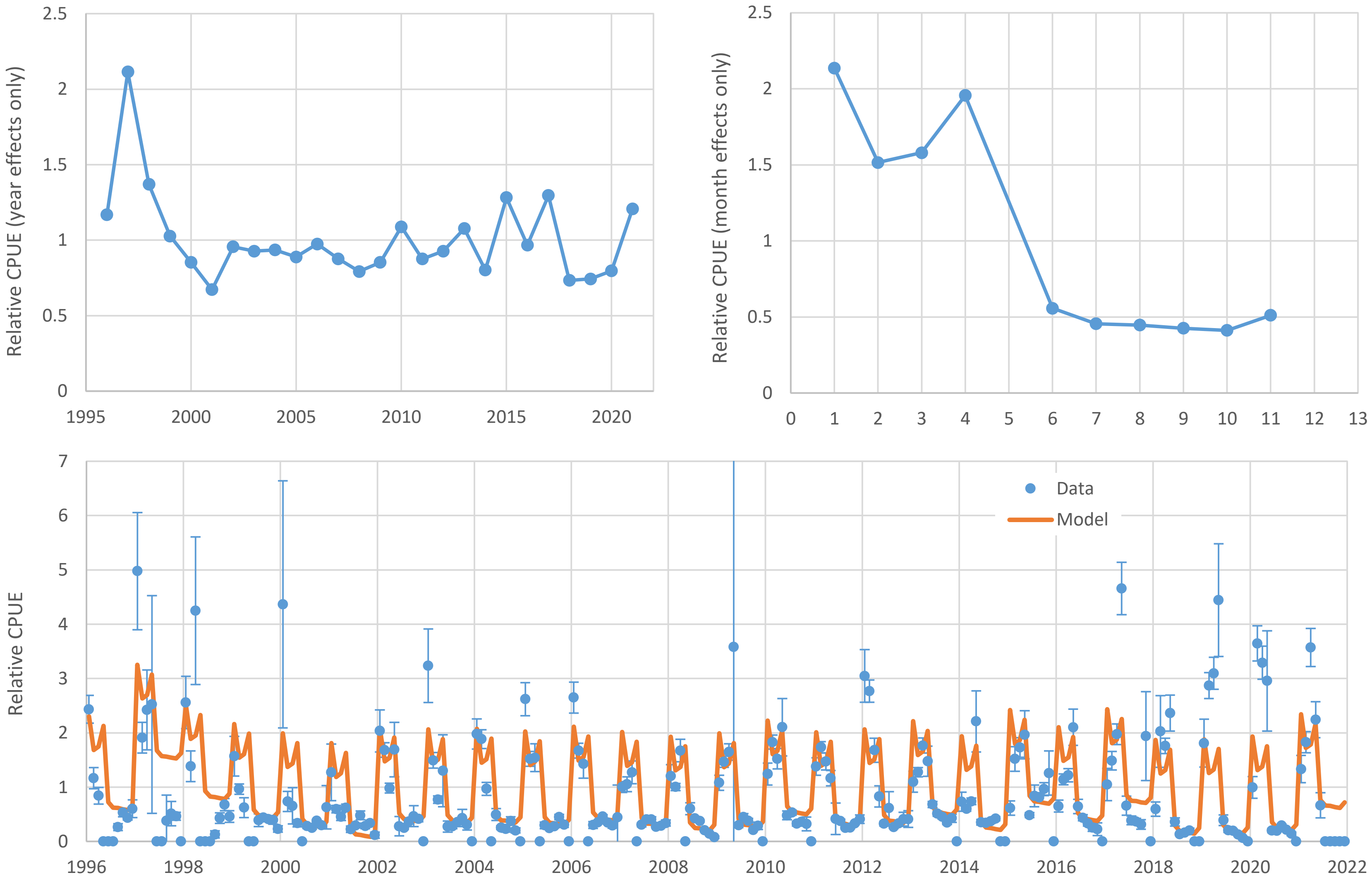


Figure 2.1.4d. Pelagic trawl fishery CPUE (includes bycatch). Top left: year effects, top right: month effects, bottom: monthly data and model fit.

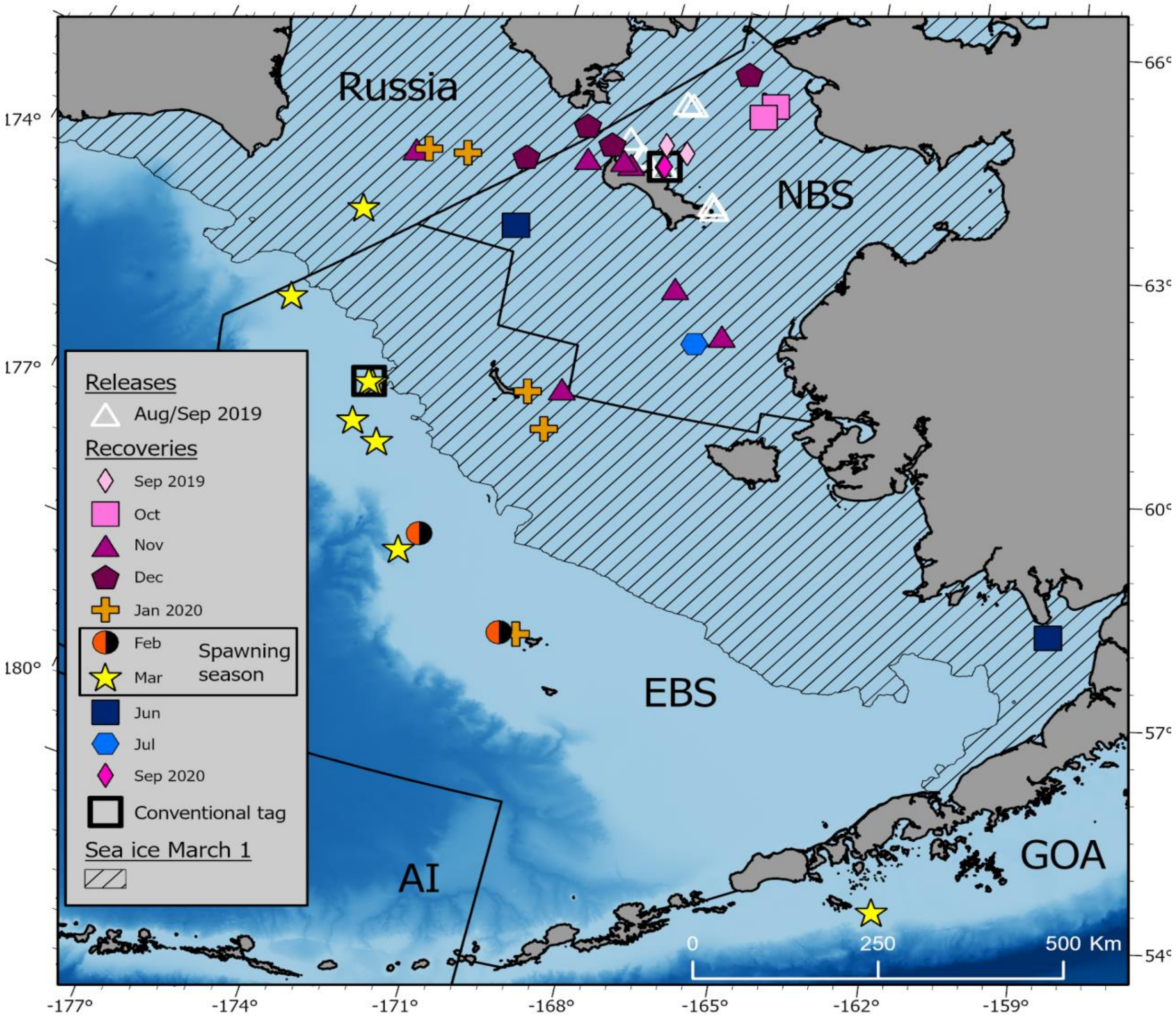


Figure 2.1.5a. Pacific cod tag release and monthly recovery locations by region (AI = Aleutian Islands, GOA = Gulf of Alaska). Conventional tag recoveries are indicated by black boxes around symbols. Tagged fish moved from the NBS to the EBS, Russia, and the GOA during the spawning period (February/March). Locations during spawning were largely beyond the edge of the sea ice extent (diagonal hatched lines indicate sea ice extent on March 1, 2020).

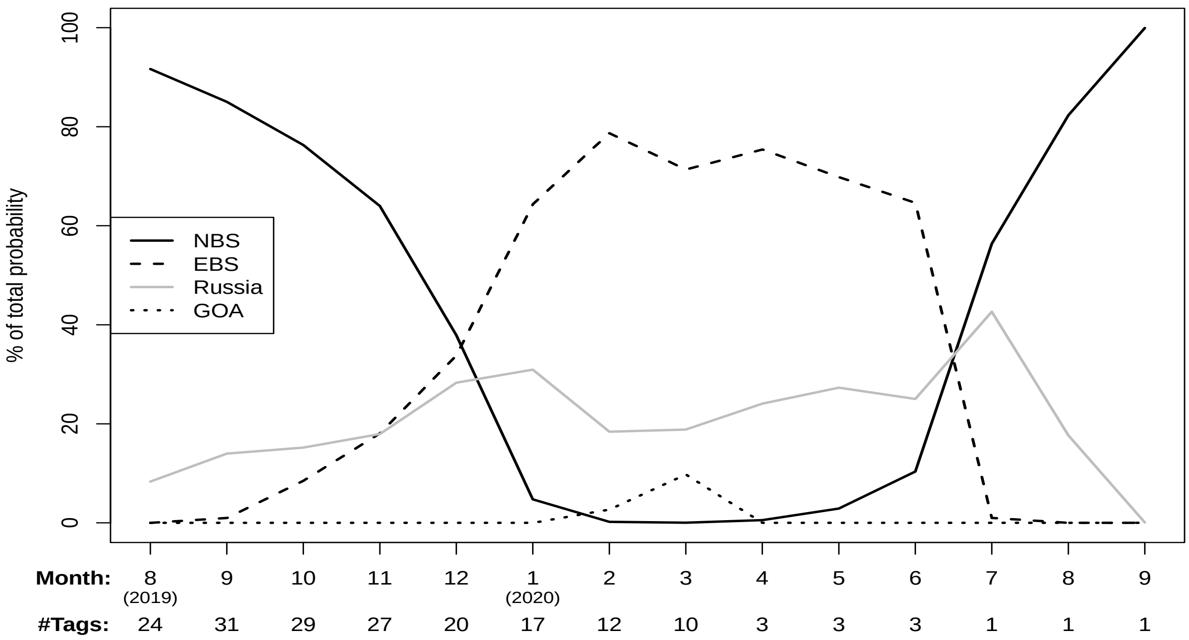


Figure 2.1.5b. Proportion of overall monthly location probability (all geolocated fish combined) by management area. Note that sample size declines over time due to the staggered pop-up schedule and early pop-ups.

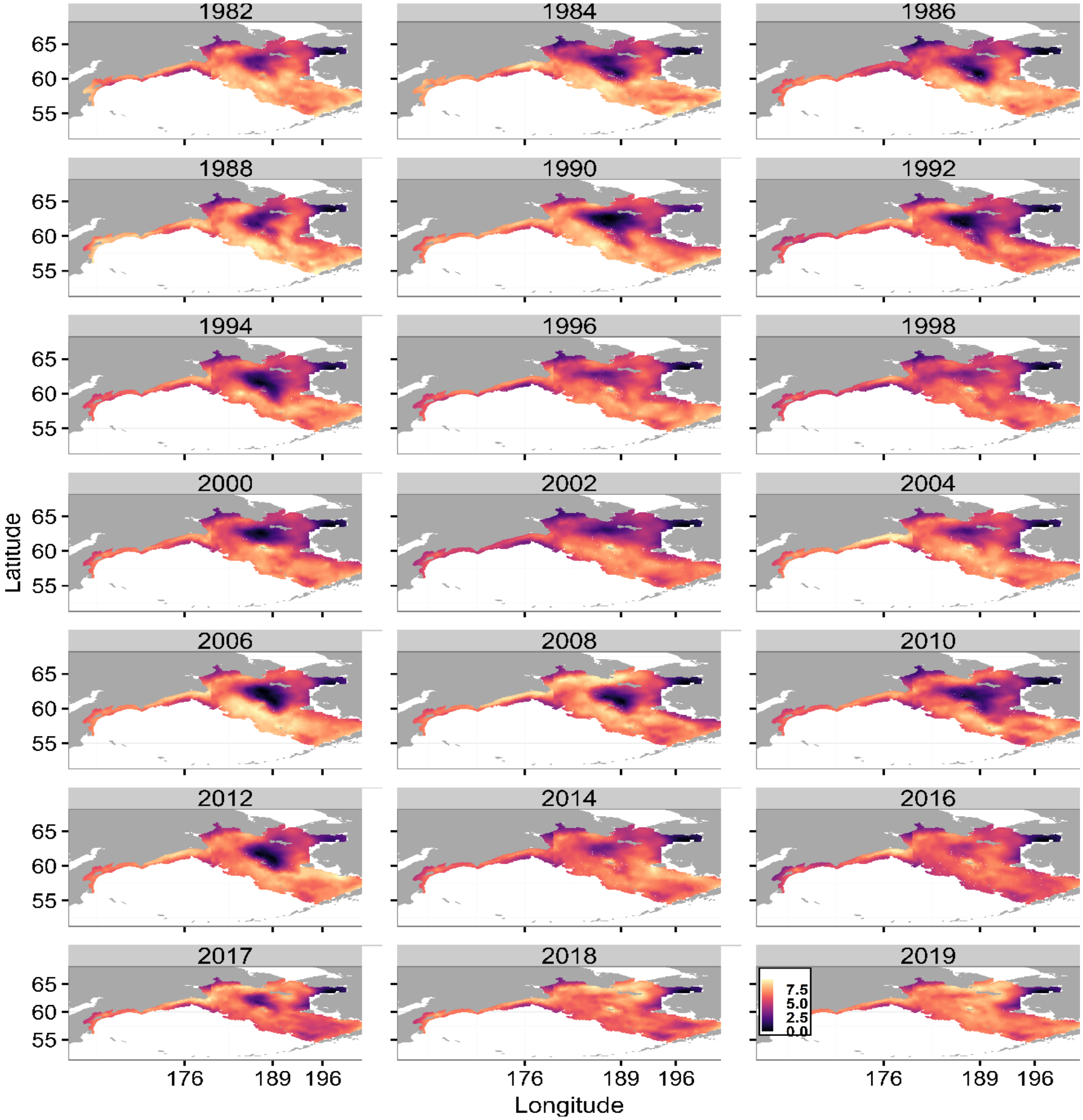
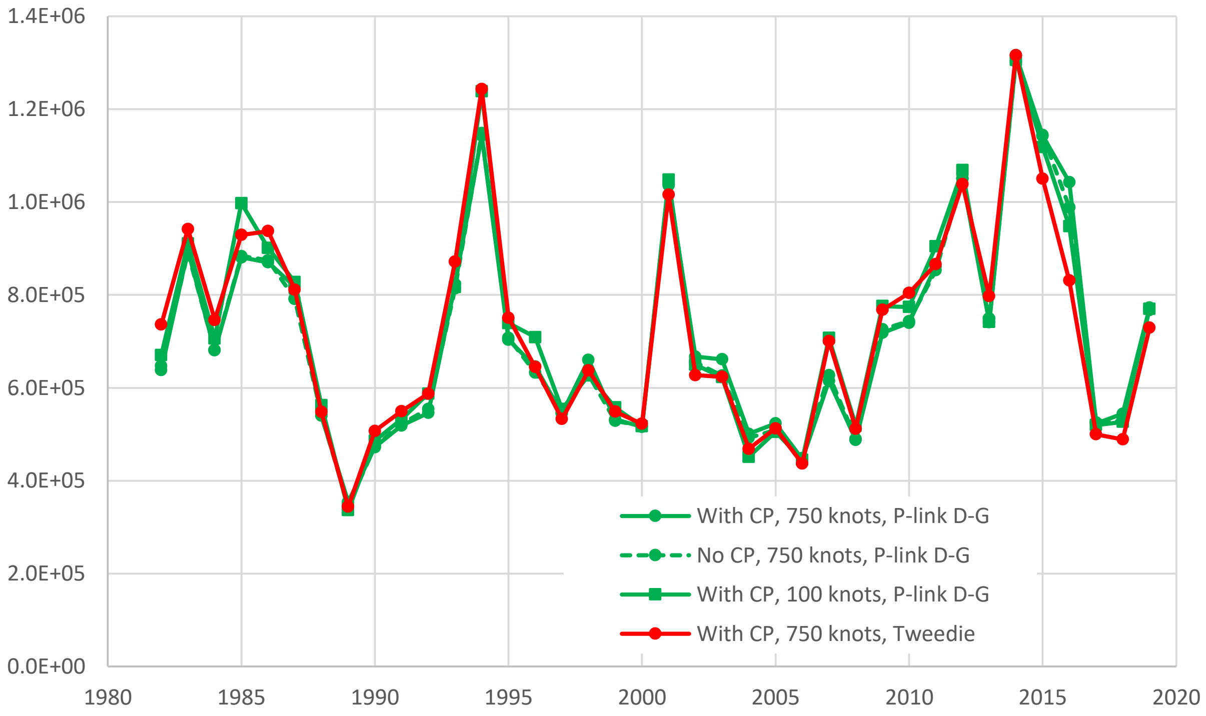


Figure 2.1.6. VAST estimates of survey density for U.S. and Russian data combined for selected years.



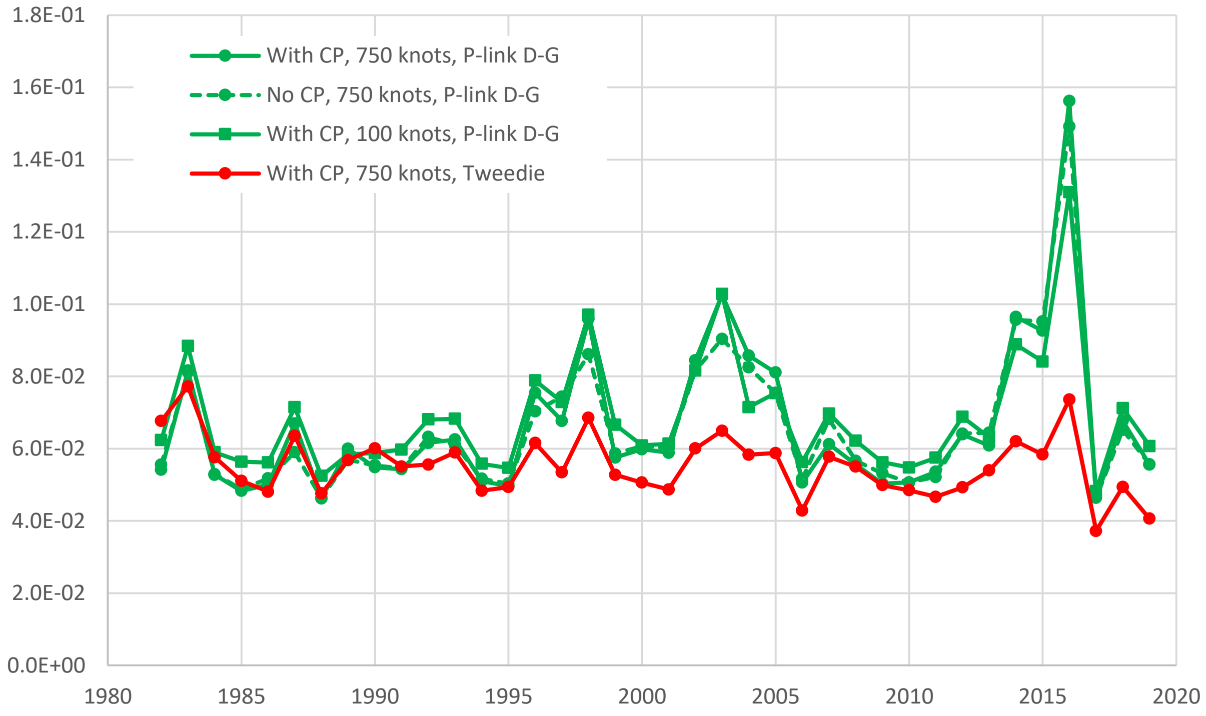


Figure 2.1.7a. VAST configuration comparison (survey index, EBS and NBS combined). Top: estimated abundance (1000s of fish), bottom: lognormal sigma. Solid = with cold pool, dashed = no cold pool; circles = 750 knots, squares = 100 knots; green = Poisson-linked delta-gamma, red = Tweedie.

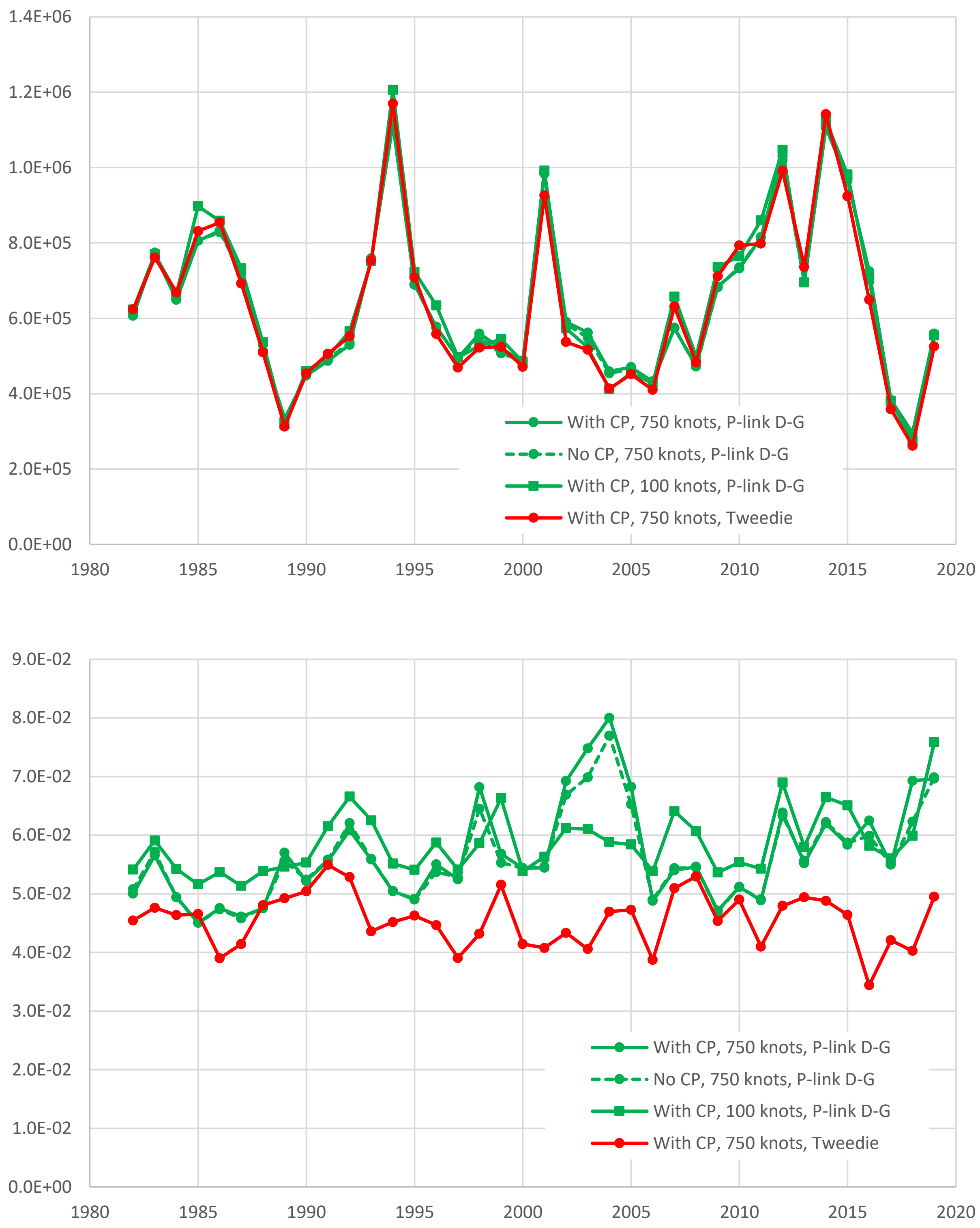


Figure 2.1.7b. VAST configuration comparison (survey index, EBS only). Top: estimated abundance (1000s of fish), bottom: lognormal sigma. Solid = with cold pool, dashed = no cold pool; circles = 750 knots, squares = 100 knots; green = Poisson-linked delta-gamma, red = Tweedie.

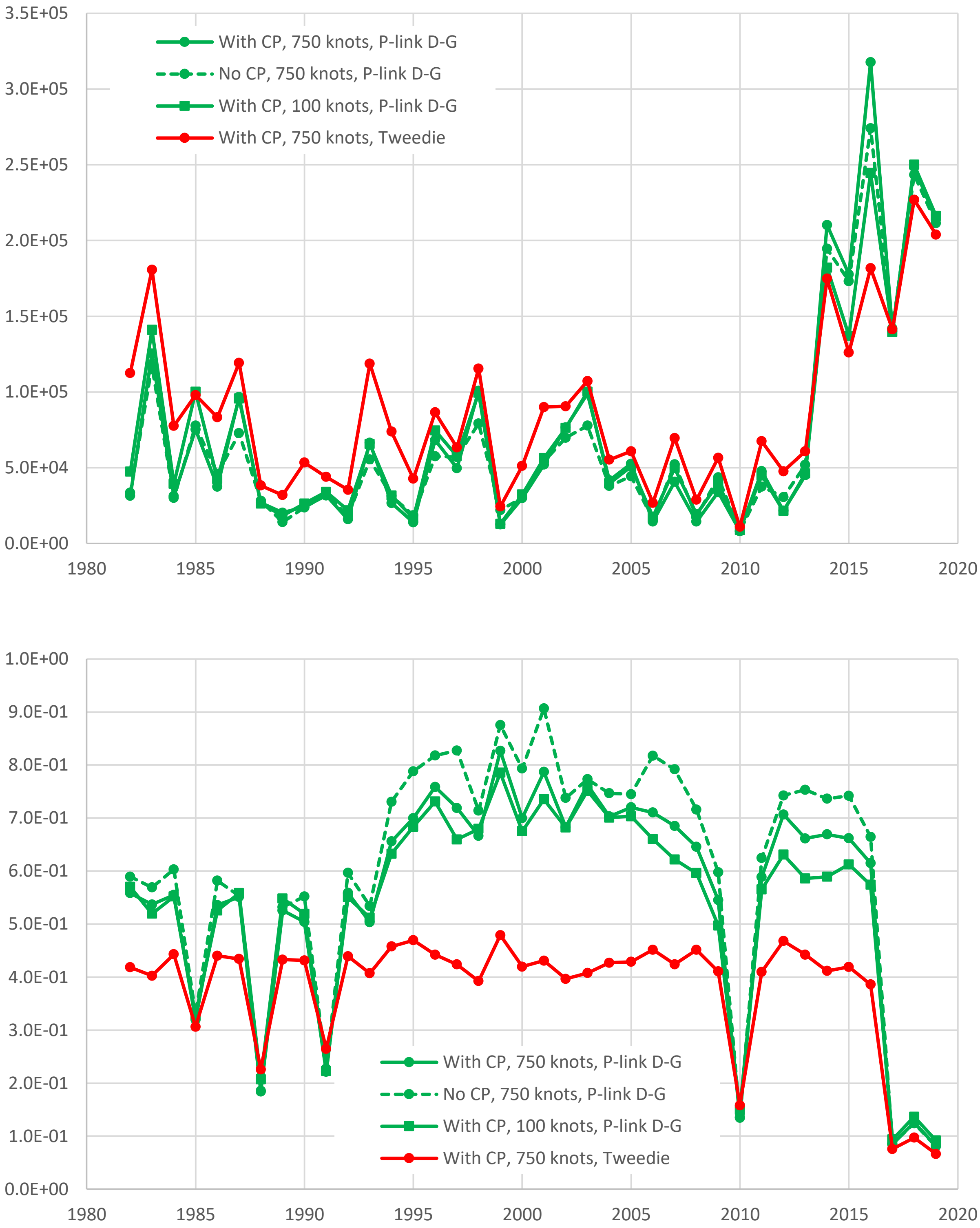


Figure 2.1.7c. VAST configuration comparison (survey index, NBS only). Top: estimated abundance (1000s of fish), bottom: lognormal sigma. Solid = with cold pool, dashed = no cold pool; circles = 750 knots, squares = 100 knots; green = Poisson-linked delta-gamma, red = Tweedie.

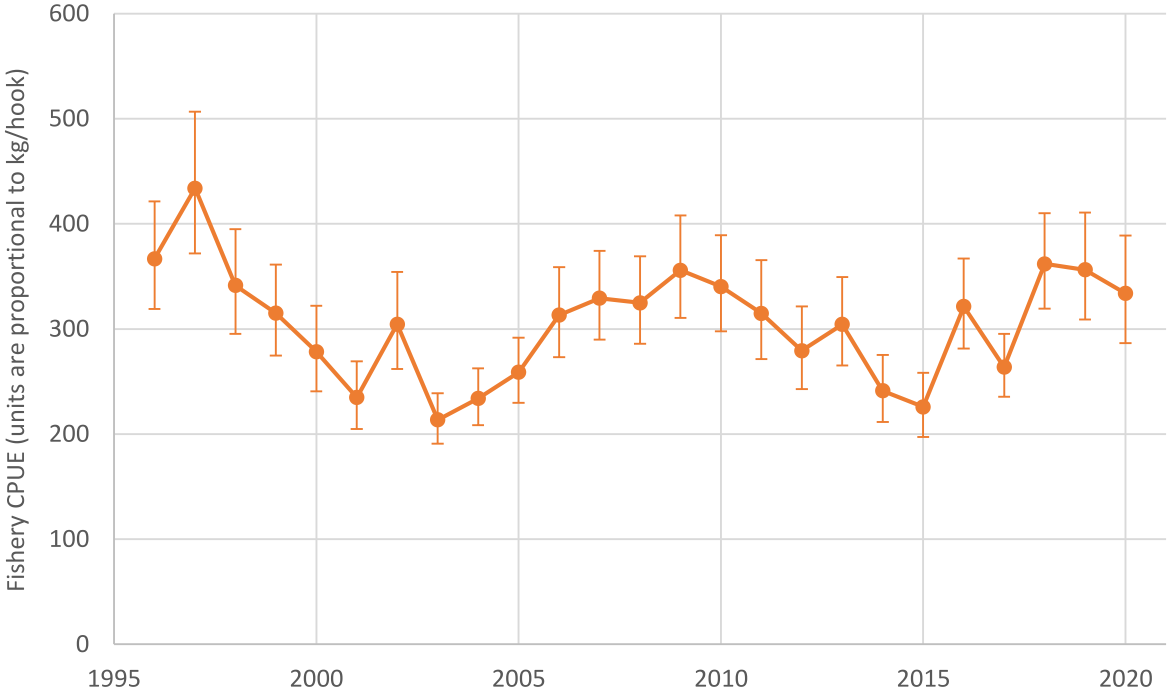


Figure 2.1.8a. VAST winter longline fishery CPUE index.

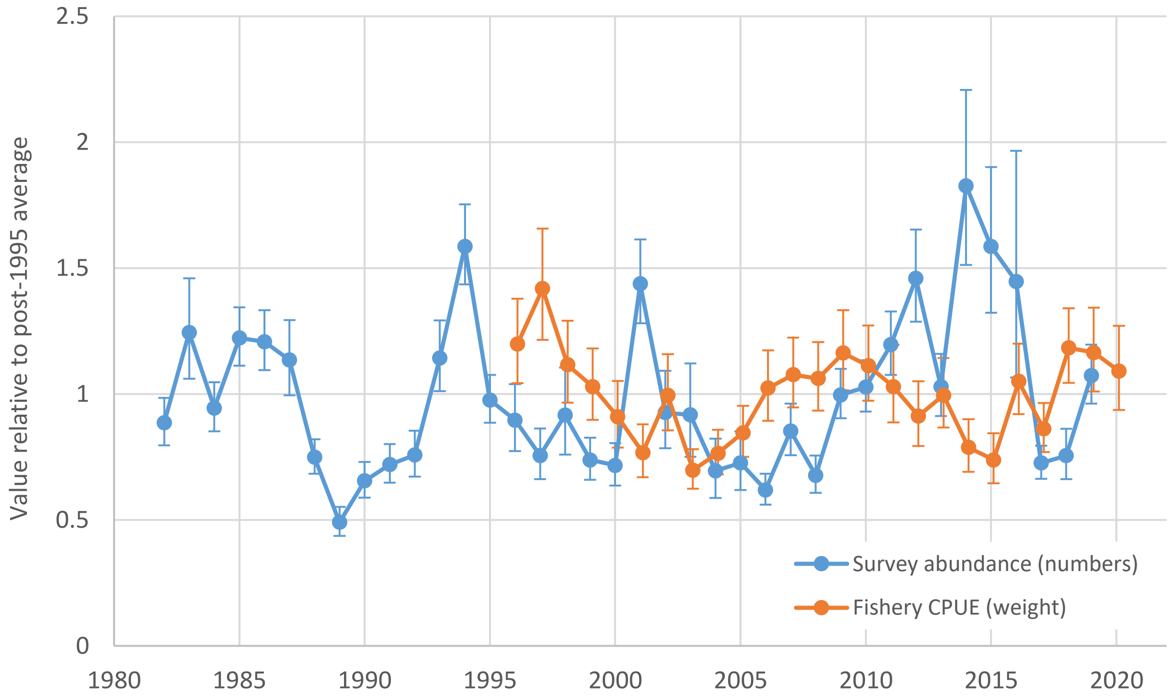


Figure 2.1.8b. Comparison of the VAST survey index (in numbers of fish) and VAST winter longline fishery CPUE index (proportional to weight per hook), both normalized to unity.

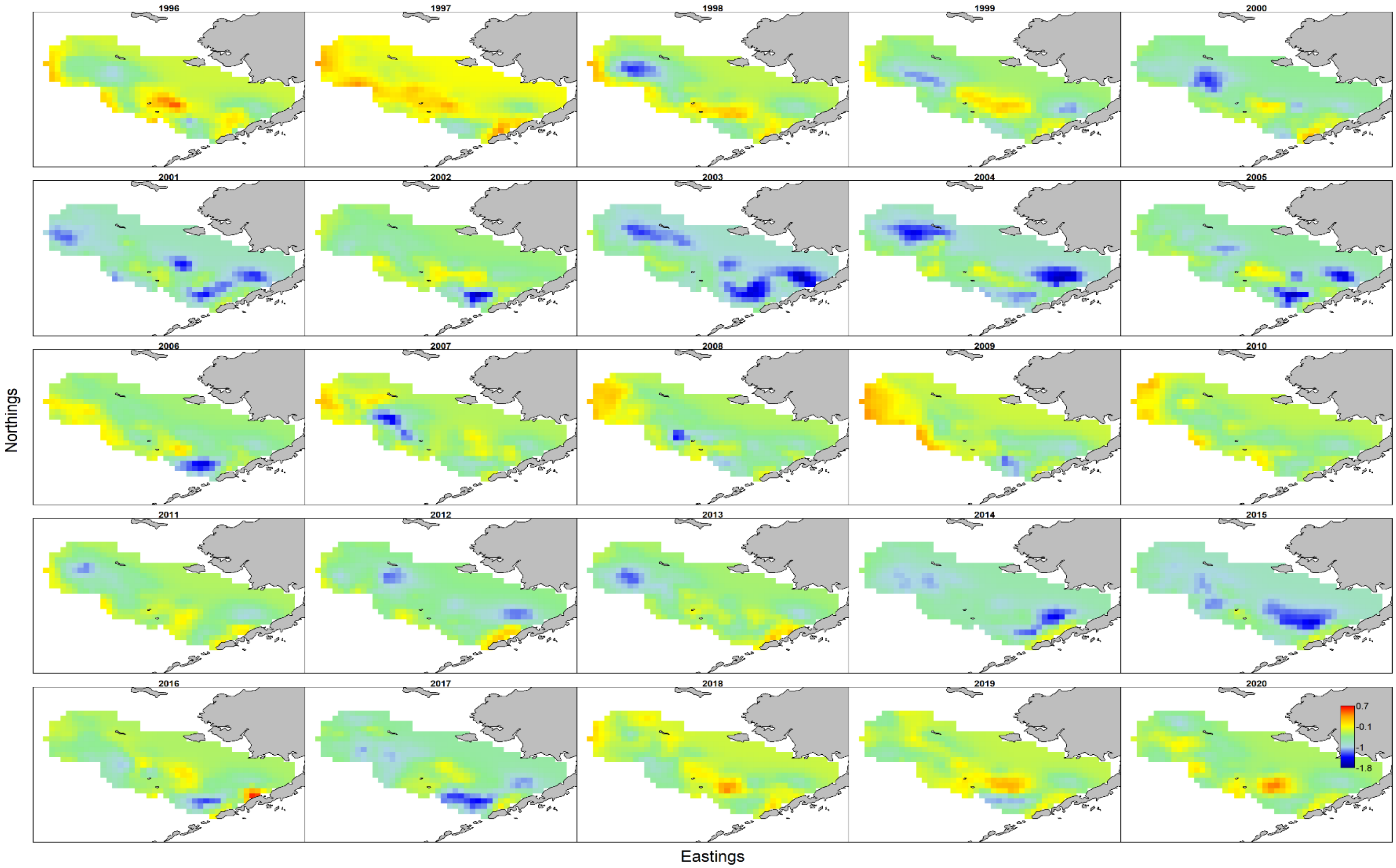


Figure 2.1.9a. VAST winter longline fishery CPUE log density maps, by year.

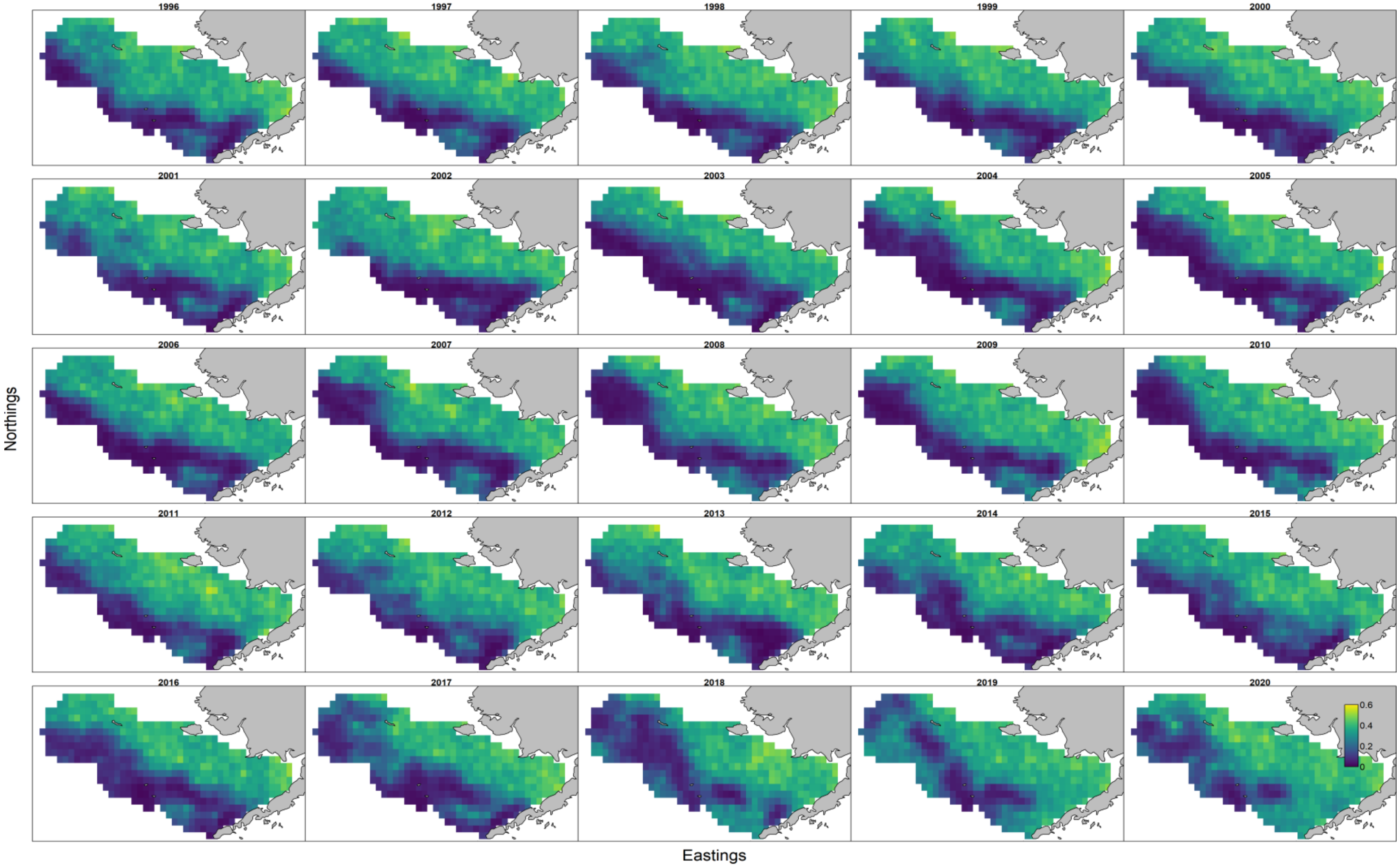


Figure 2.1.9b. VAST winter longline fishery CPUE log density standard error maps.

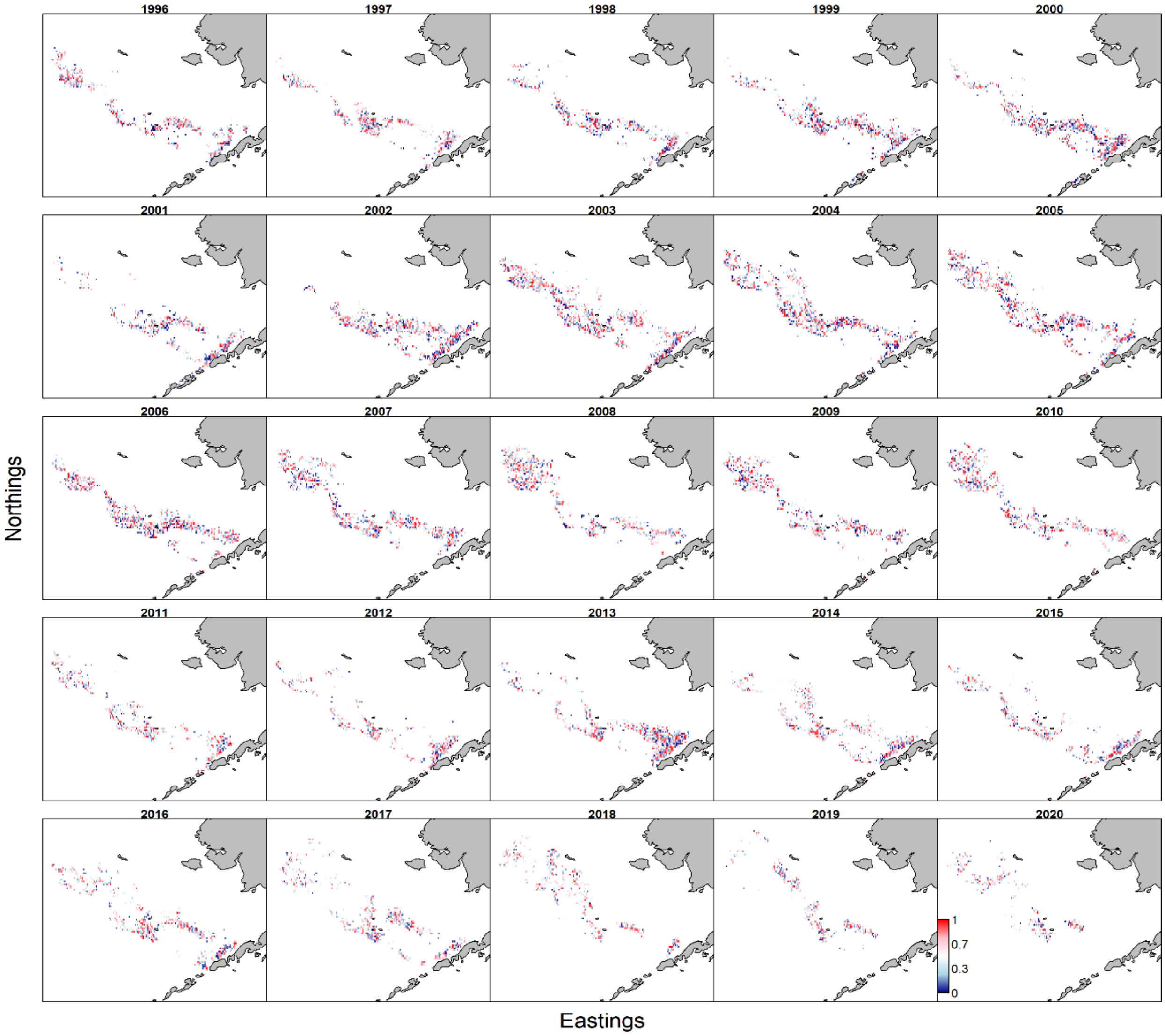


Figure 2.1.9c. VAST winter longline fishery CPUE residual maps, by year.

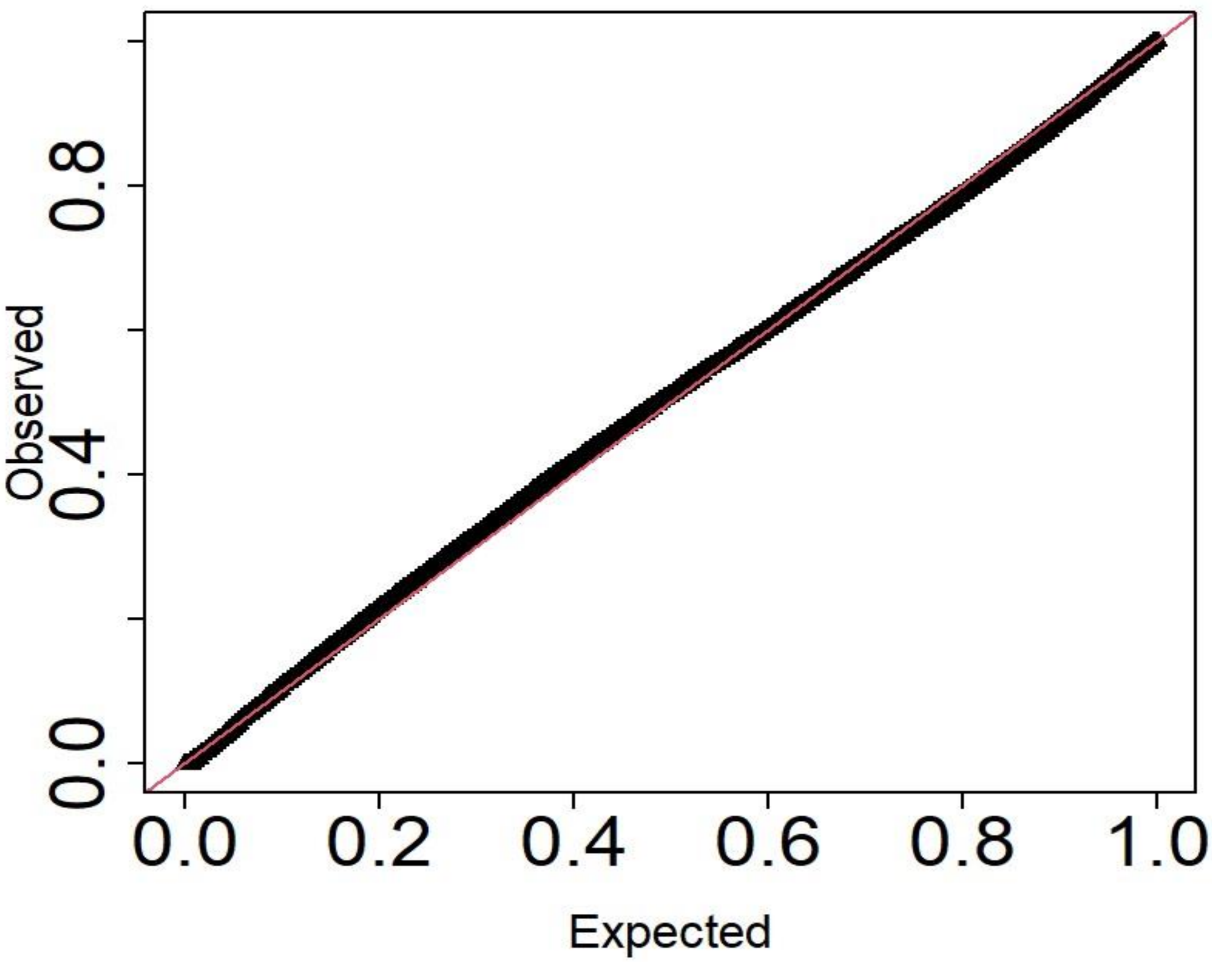


Figure 2.1.9d. VAST winter longline fishery CPUE residuals quantile-quantile plot.

Figure 2.1.10. Data update bridging analysis, showing the effects of updating the survey index by itself and updating both the survey index and the agecomps. Top: Model 19.12a, bottom: Model 19.12.

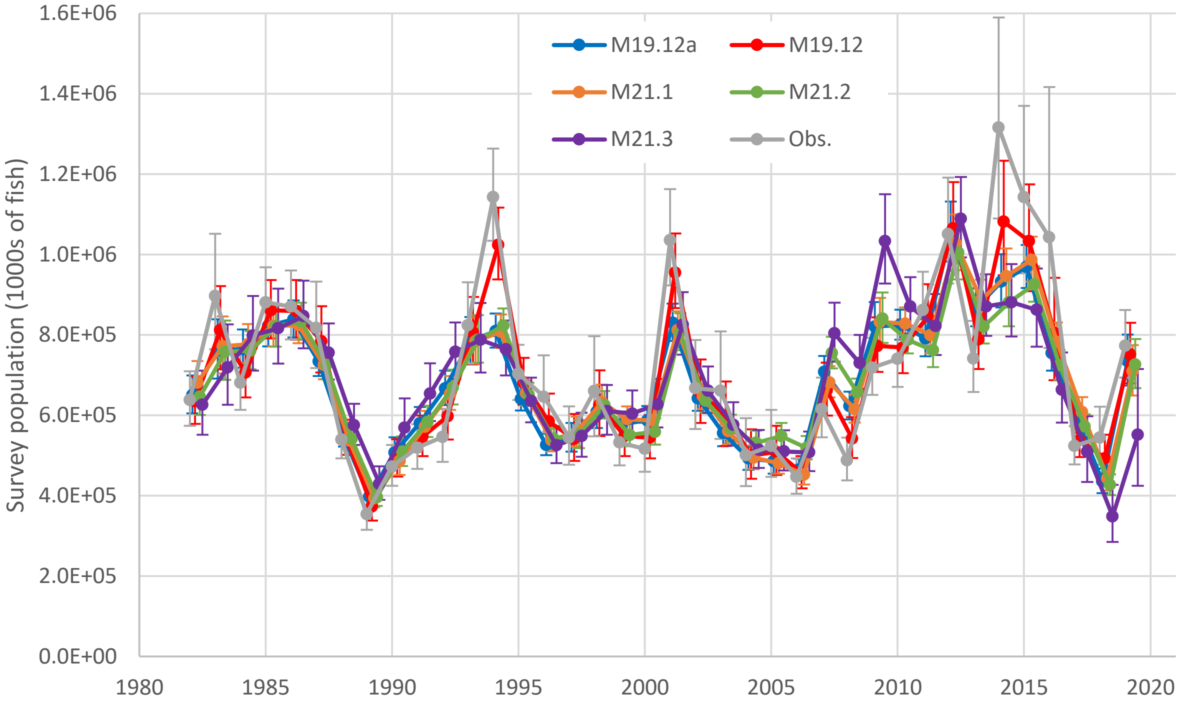


Figure 2.1.11a. Fits to "original" survey index data for all models and the ensemble.

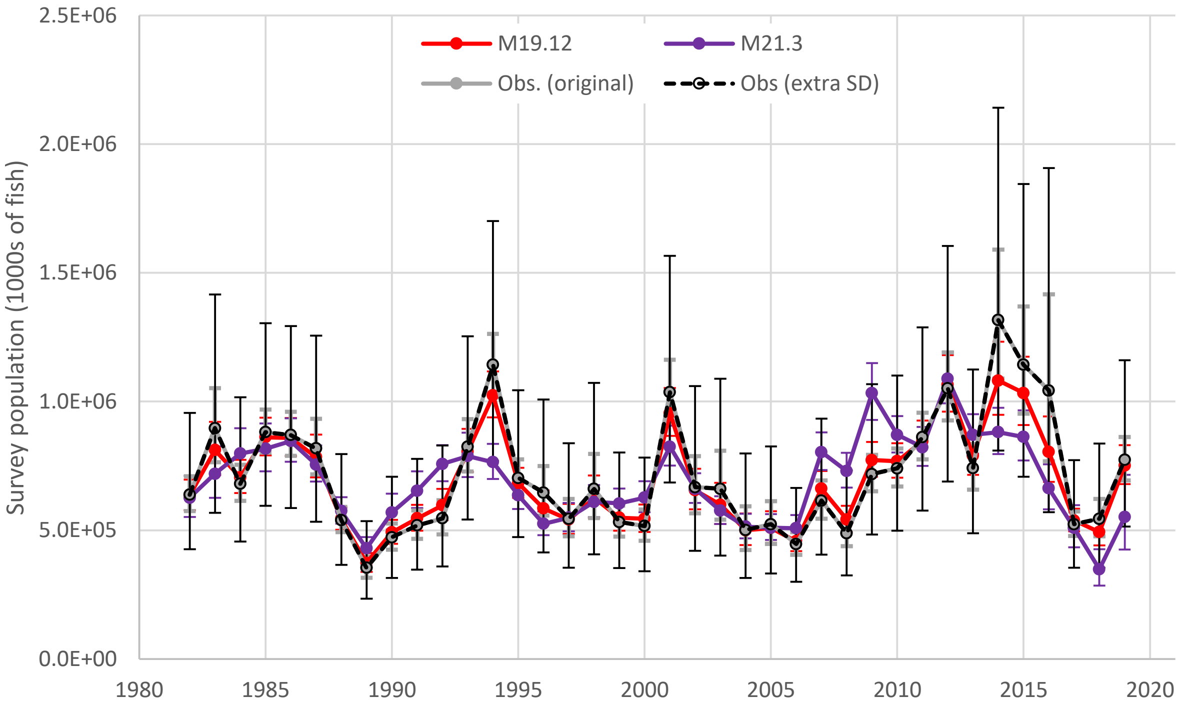


Figure 2.1.11b. Fits to survey index data, including "extra SD" adjustments, for Models 19.12 and 21.3.

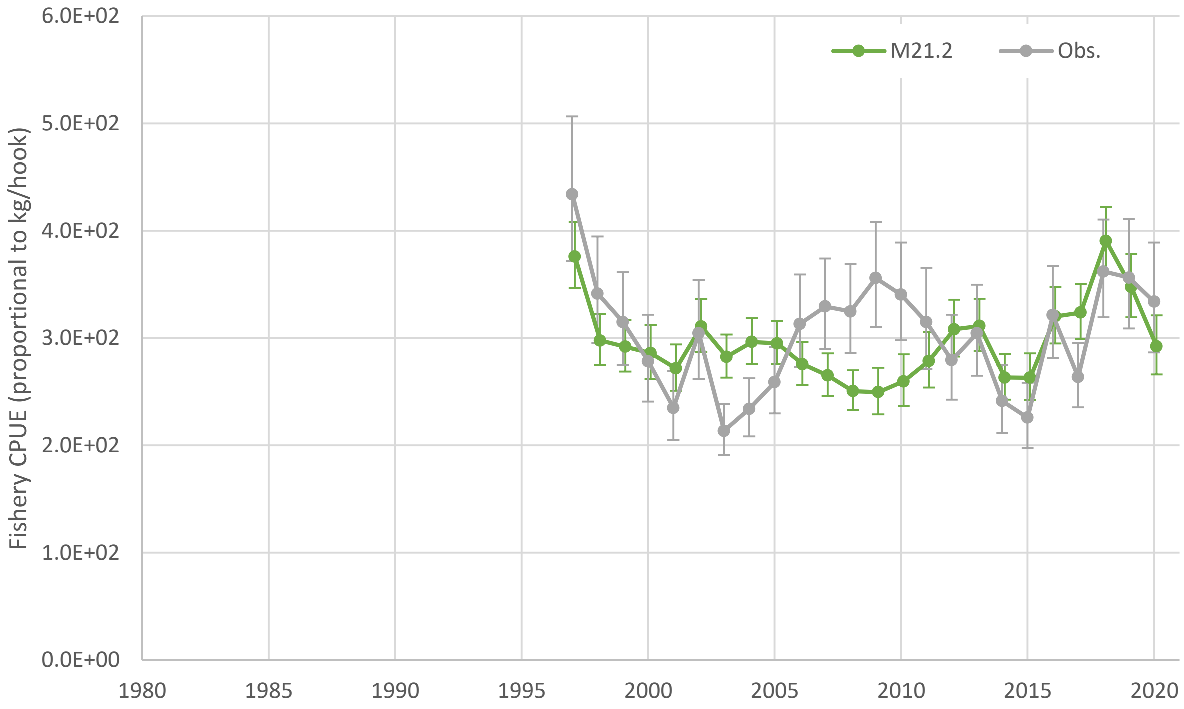


Figure 2.1.11c. Fit to VAST winter longline fishery CPUE index for Model 21.2.

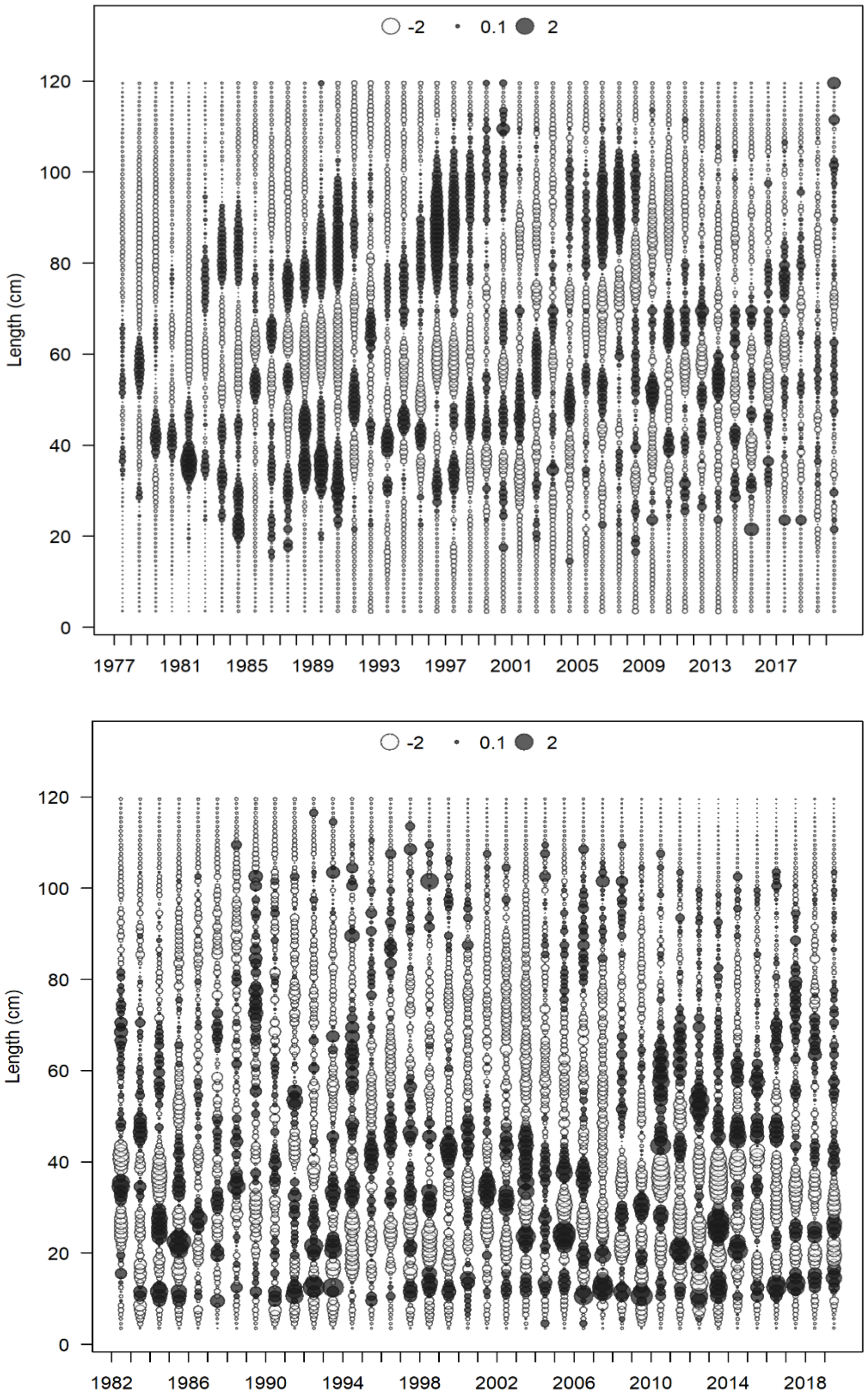


Figure 2.1.12a. Residuals from fit to sizecomp data (Model 19.12a). Top: fishery, bottom: survey.

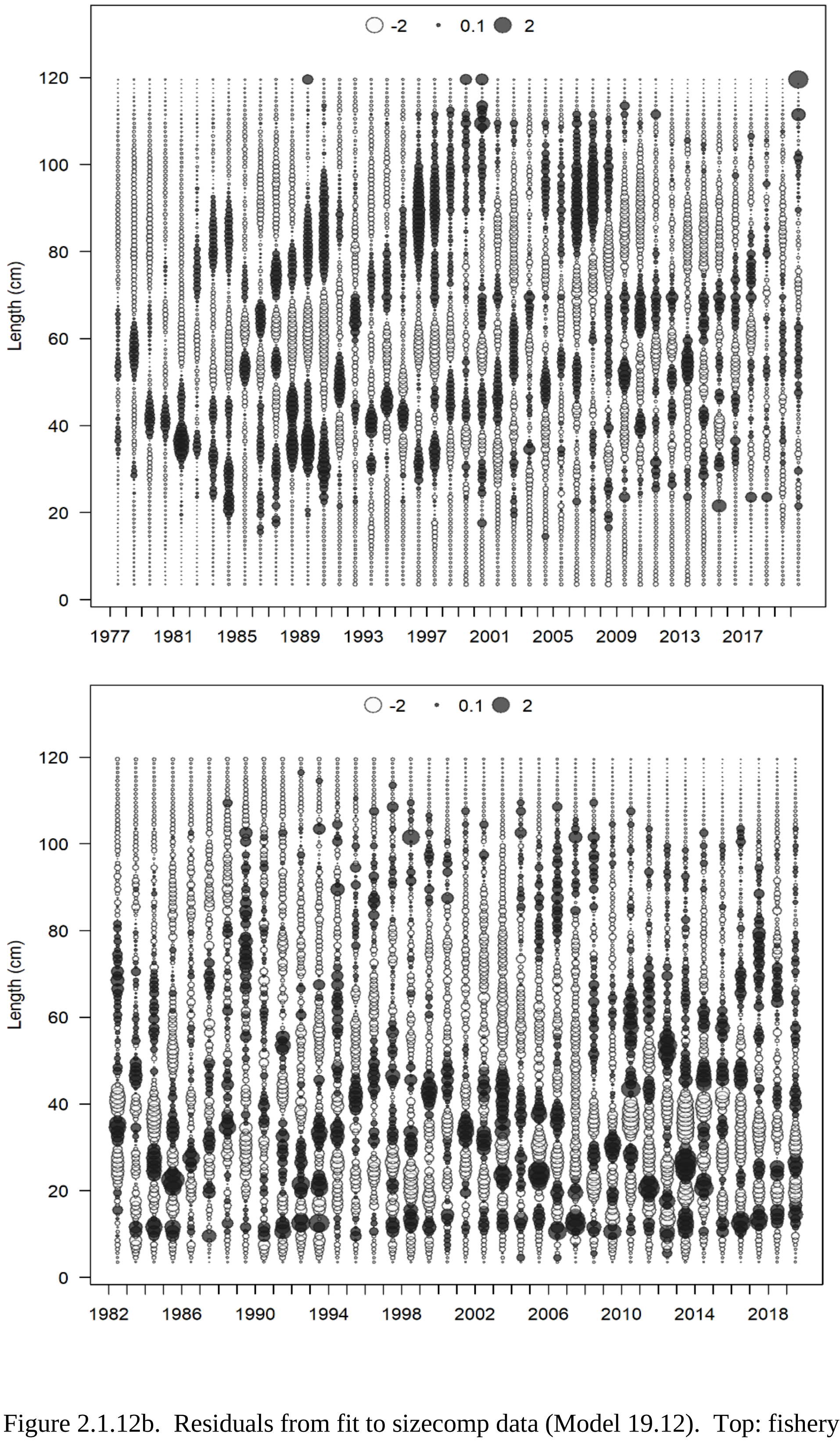
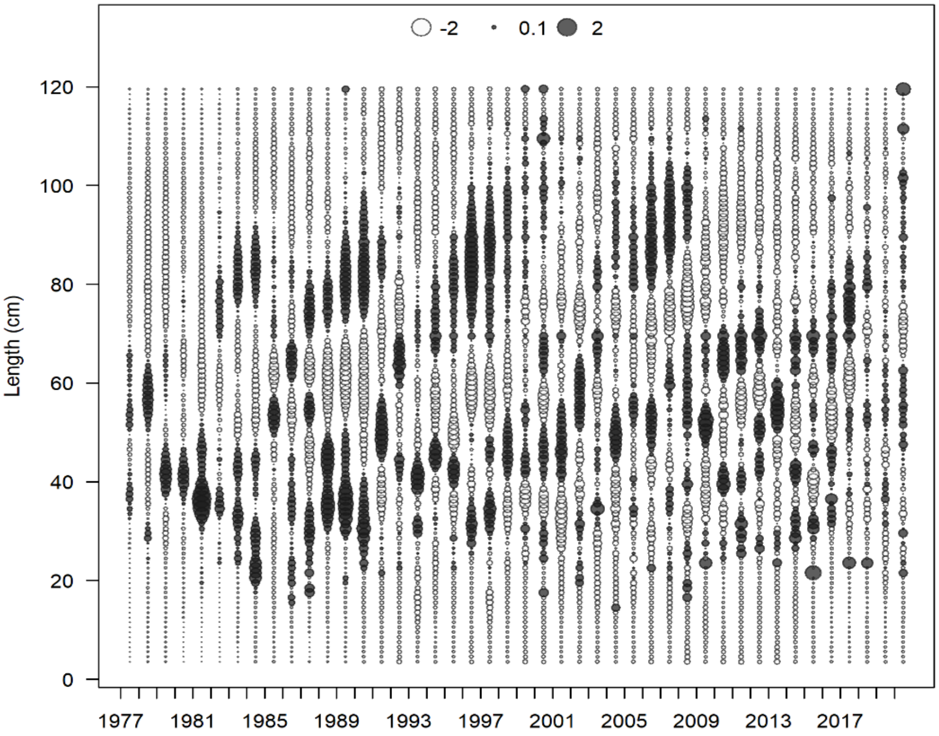


Figure 2.1.12b. Residuals from fit to sizecomp data (Model 19.12). Top: fishery, bottom: survey.



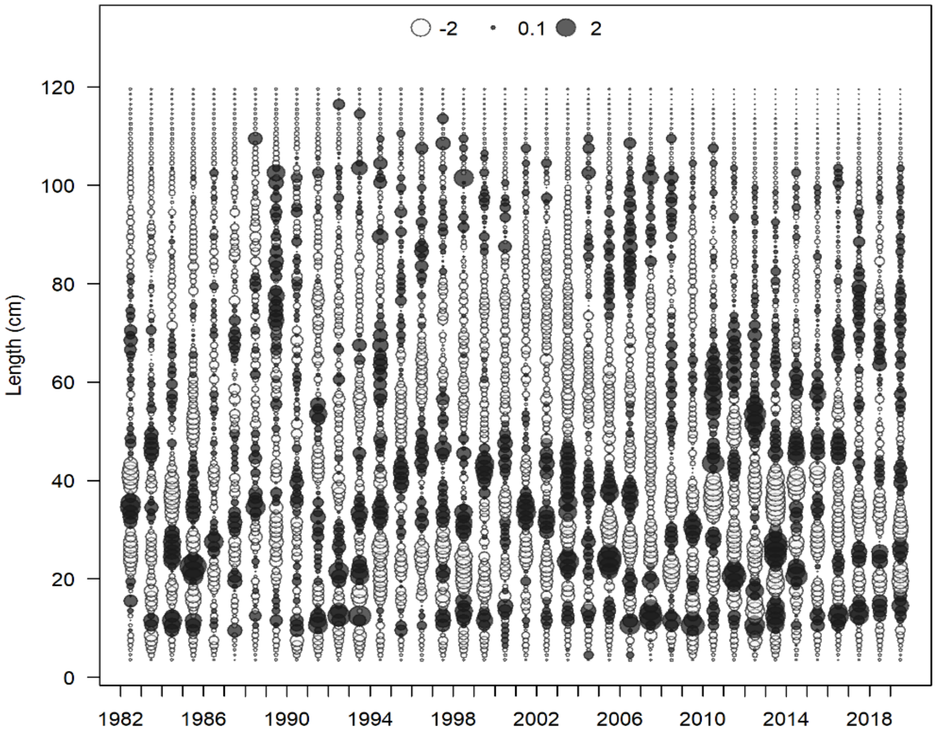


Figure 2.1.12c. Residuals from fit to sizecomp data (Model 21.1). Top: fishery, bottom: survey.

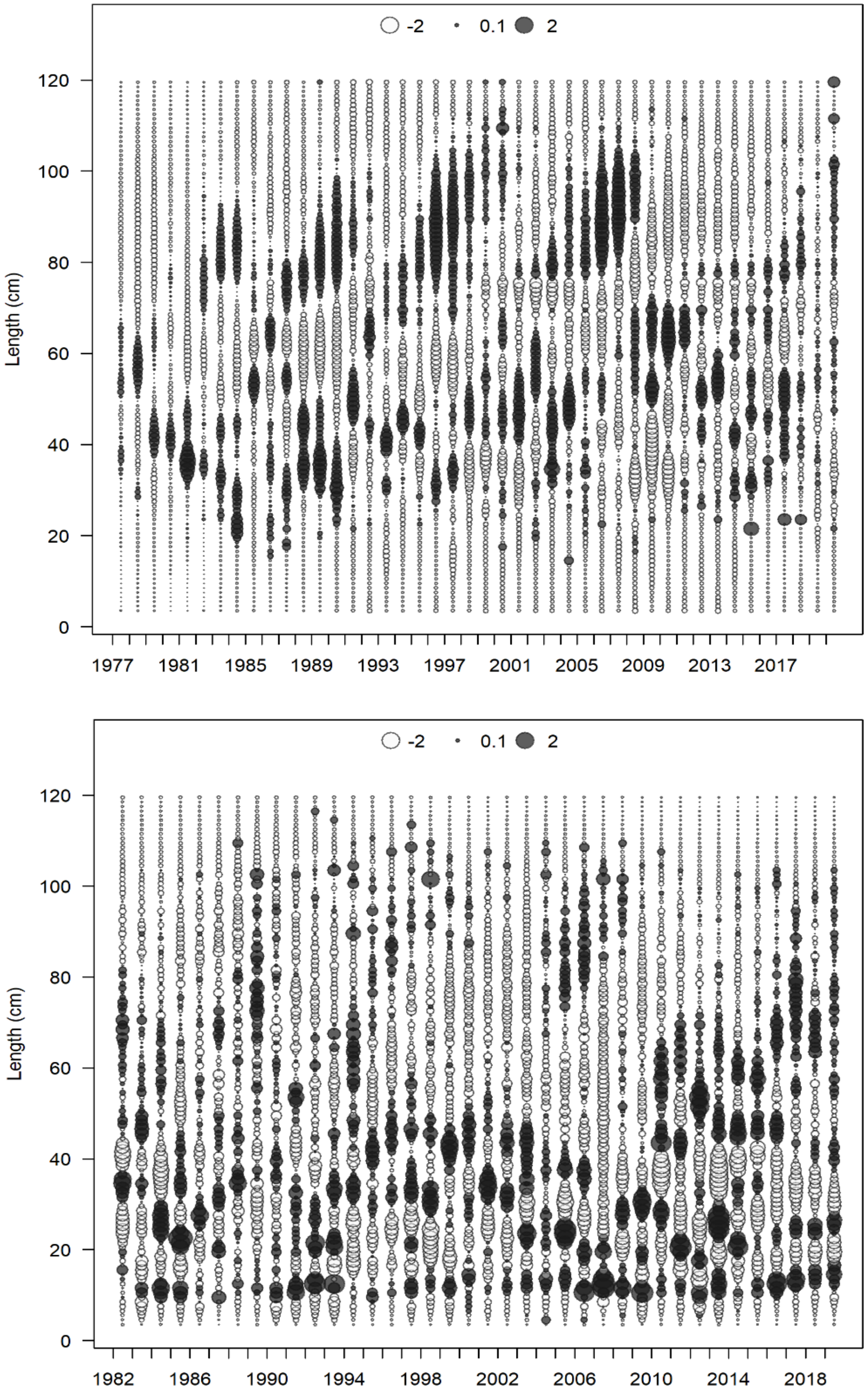


Figure 2.1.12d. Residuals from fit to sizecomp data (Model 21.2). Top: fishery, bottom: survey.

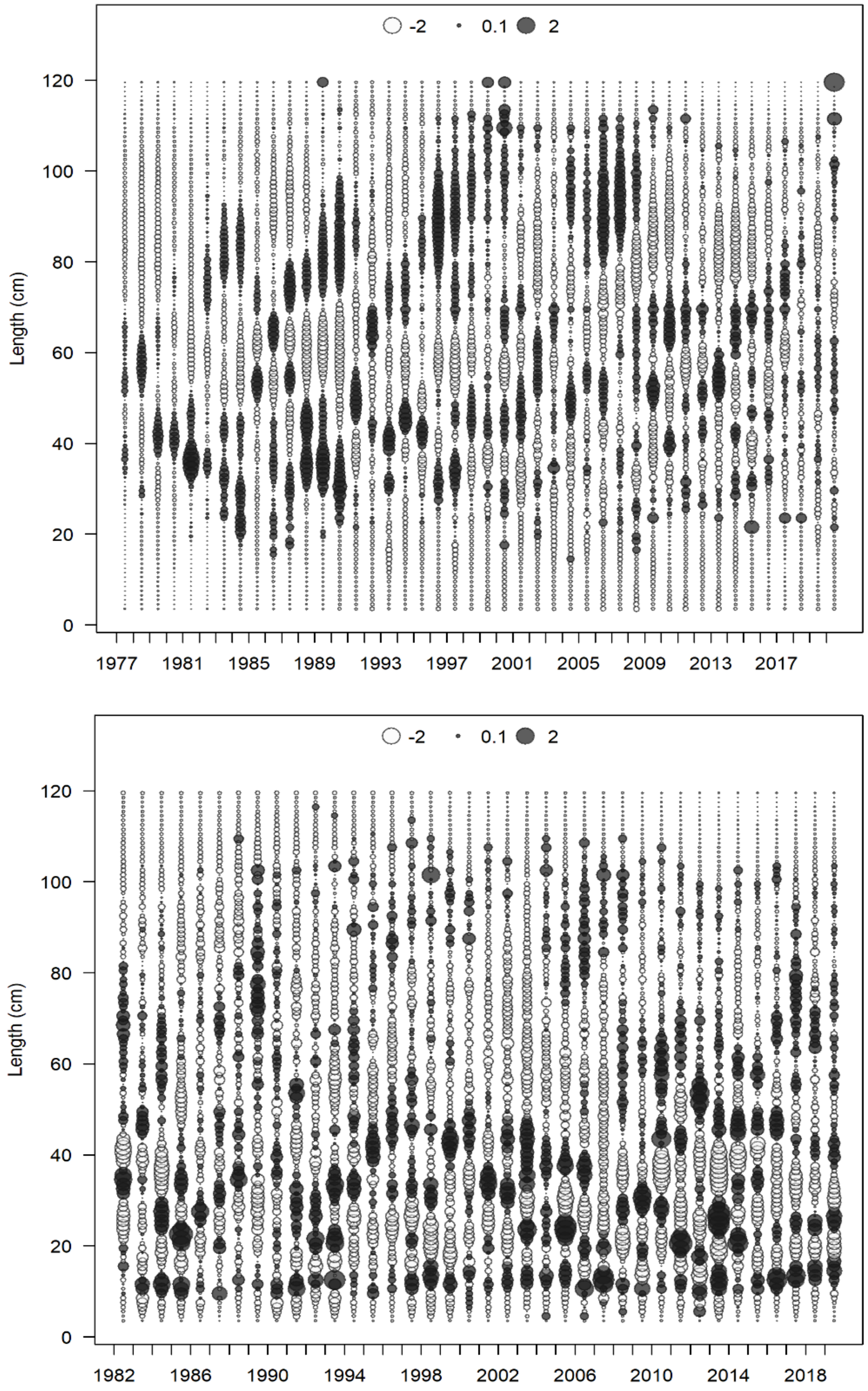


Figure 2.1.12. Residuals from fit to sizecomp data (Model 21.3). Top: fishery, bottom: survey.

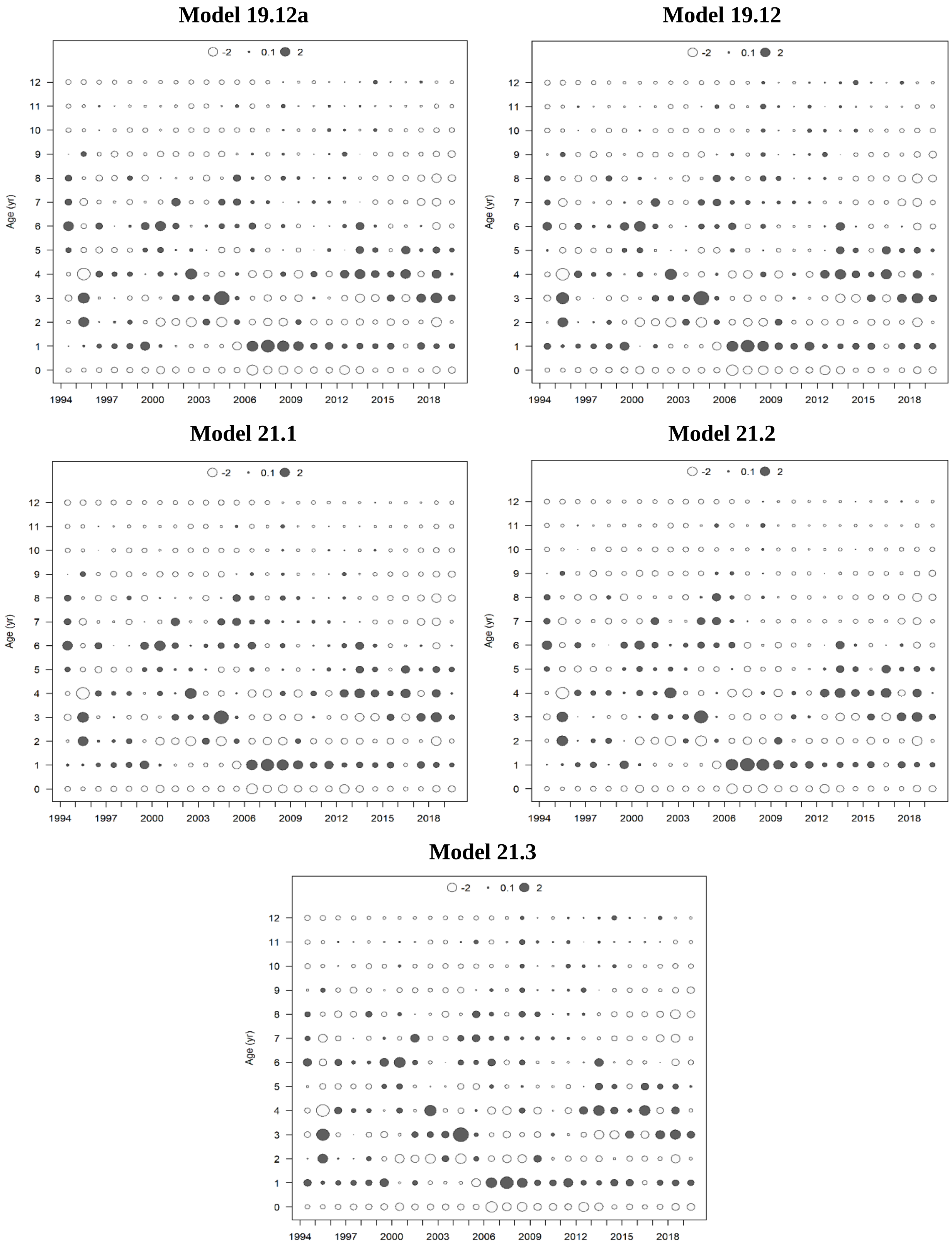


Figure 2.1.13. Residuals from fits to survey agecomp data (all models).

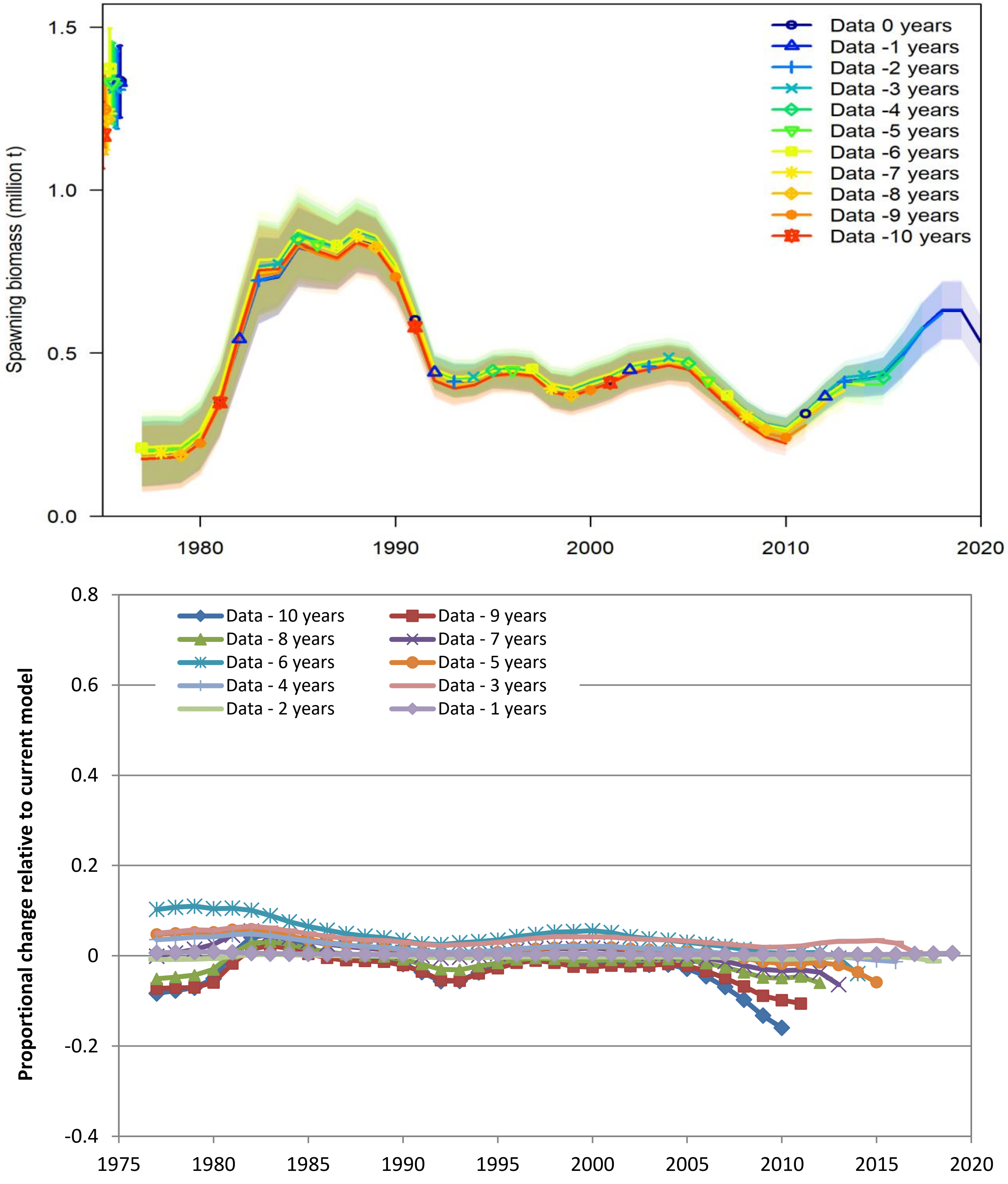


Figure 2.1.14a. Retrospective analysis of combined-sex spawning biomass (Model 19.12a).

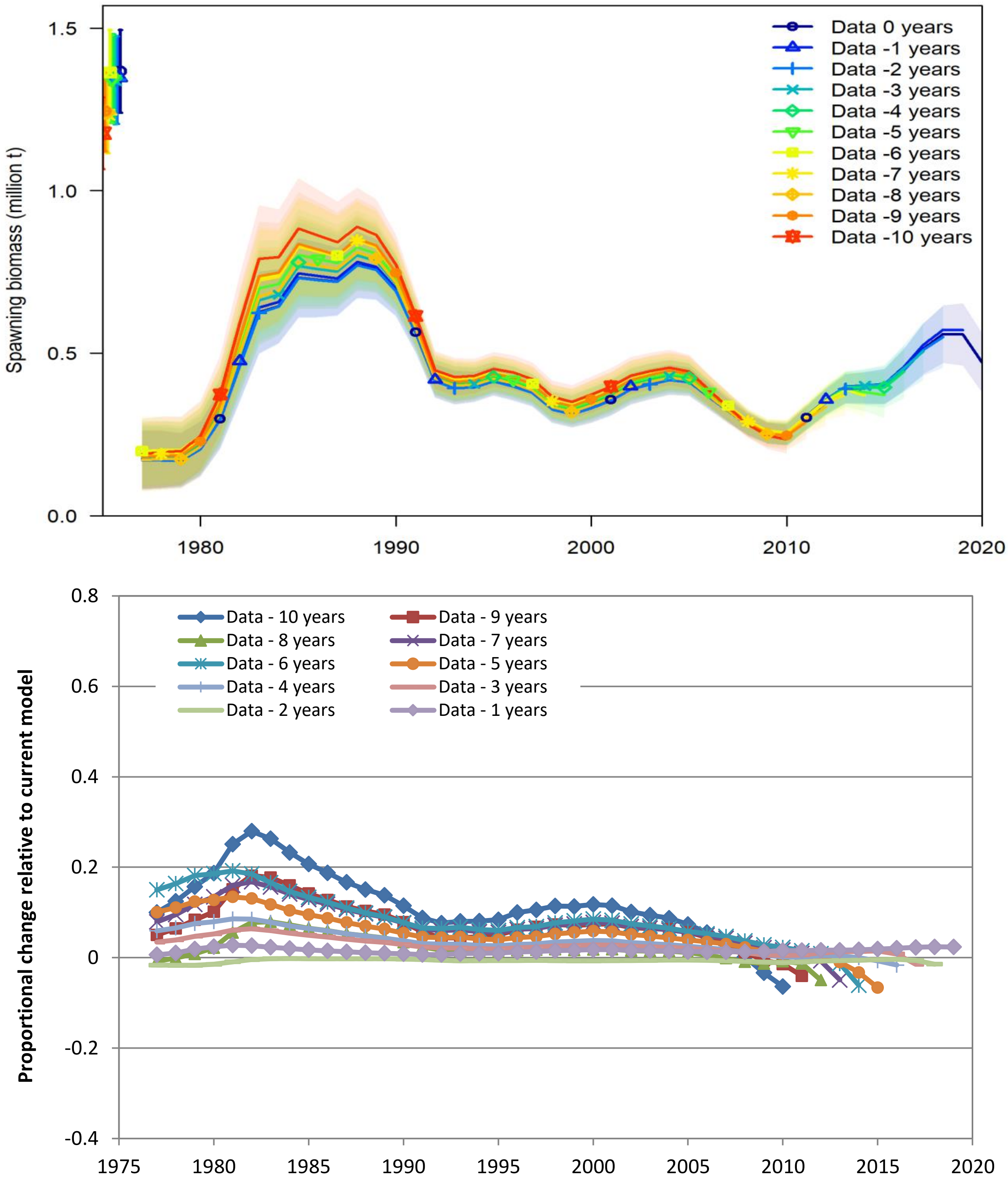


Figure 2.1.14b. Retrospective analysis of combined-sex spawning biomass (Model 19.12).

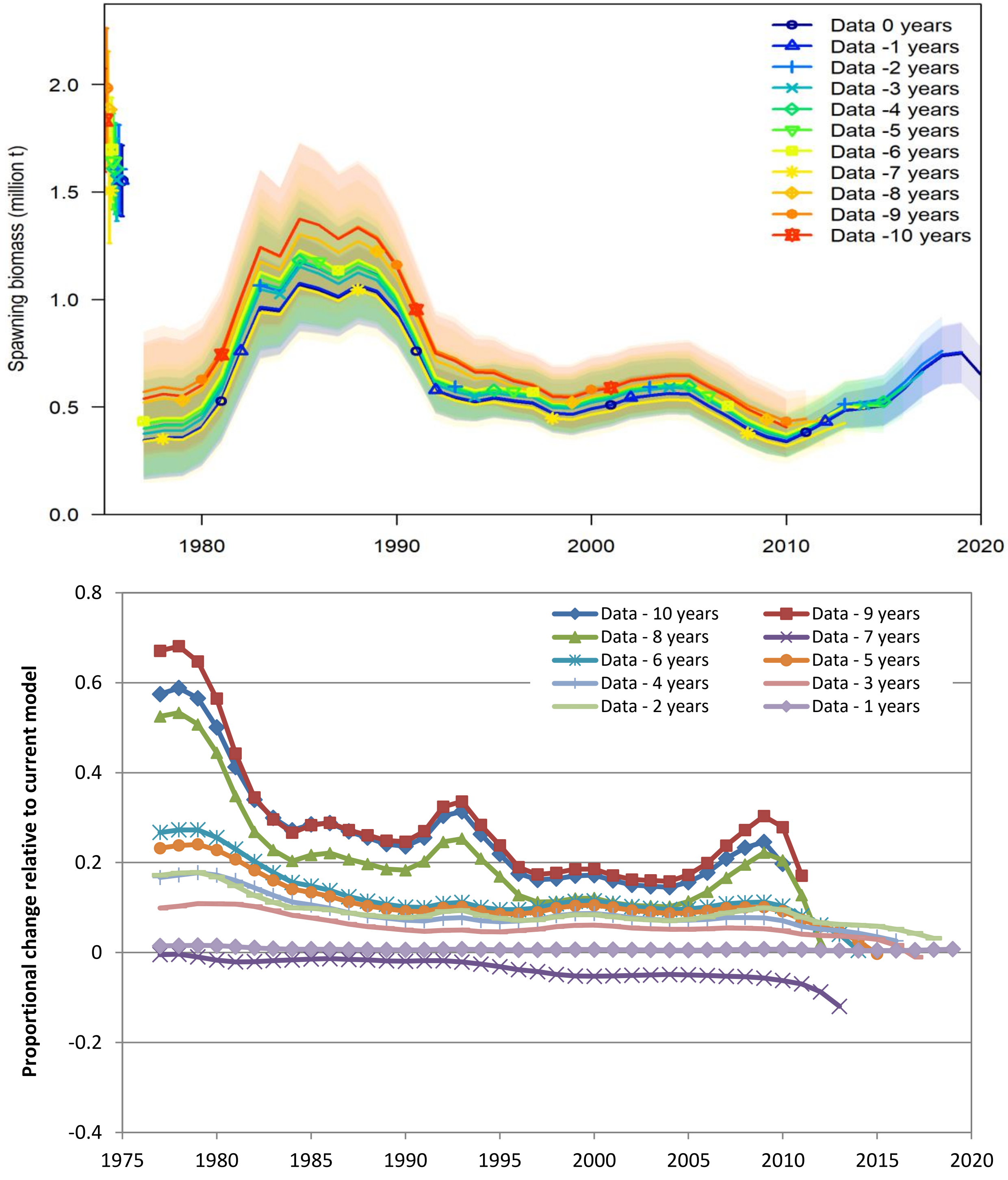


Figure 2.1.14c. Retrospective analysis of combined-sex spawning biomass (Model 21.1).

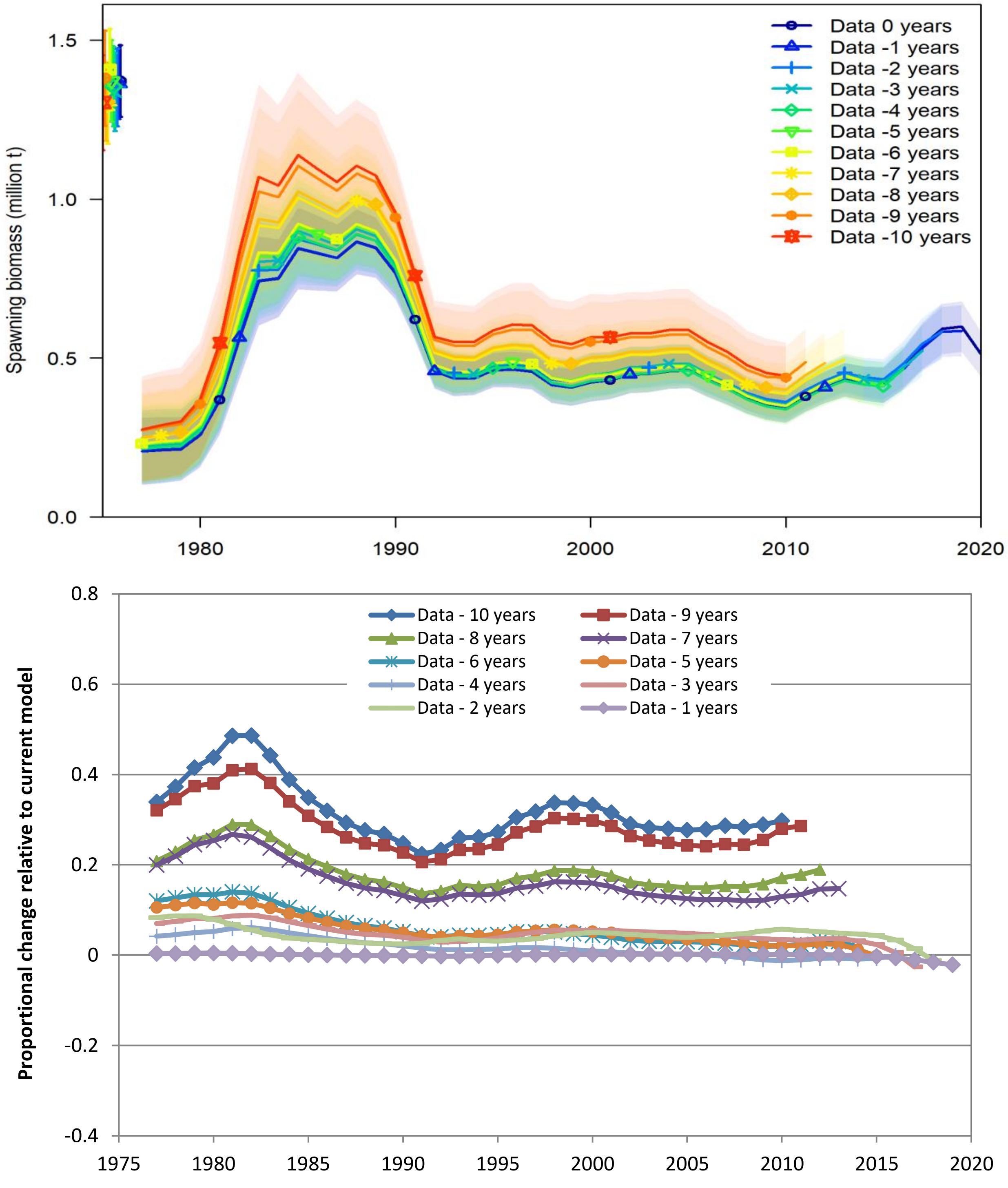


Figure 2.1.14d. Retrospective analysis of combined-sex spawning biomass (Model 21.2).

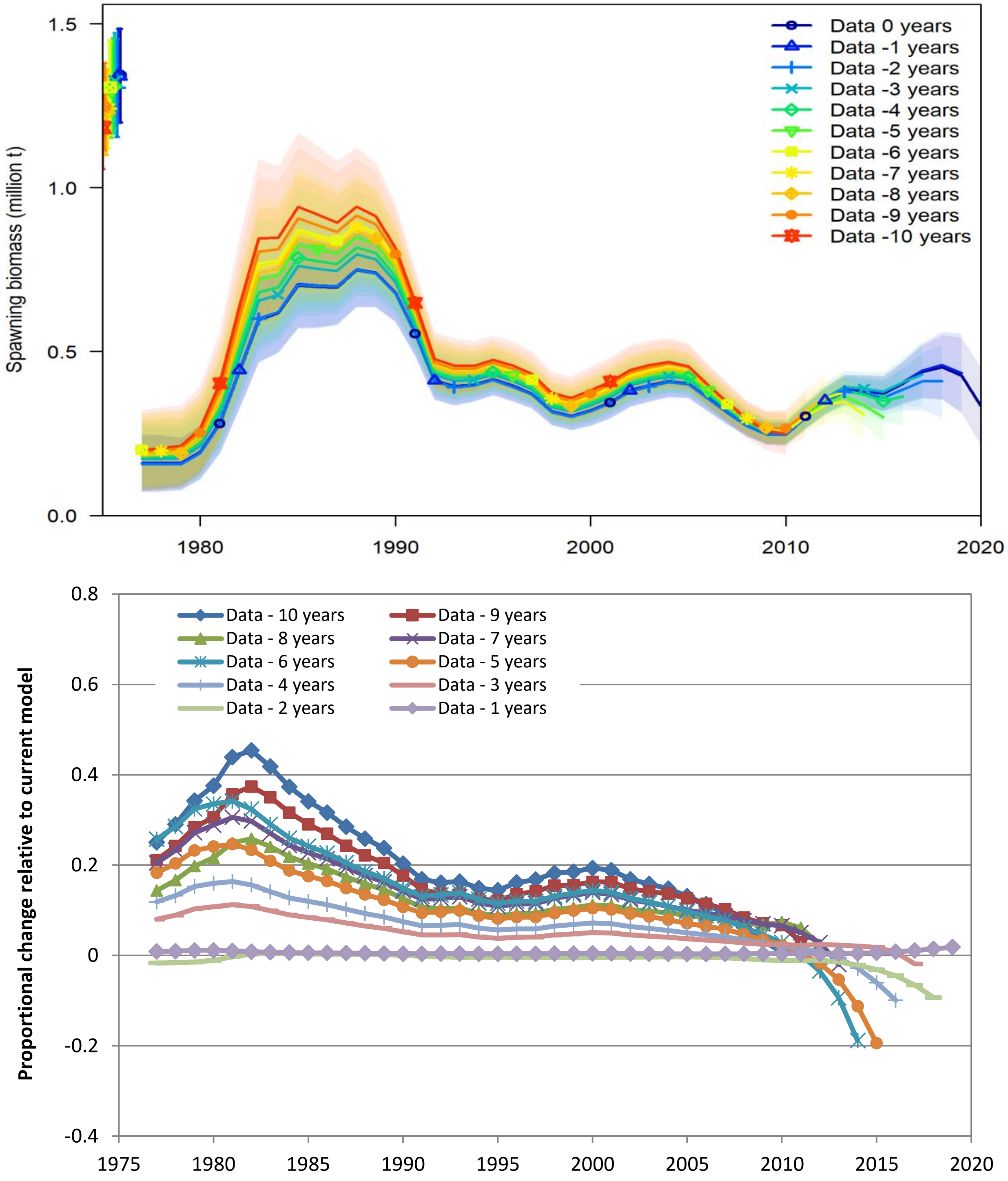
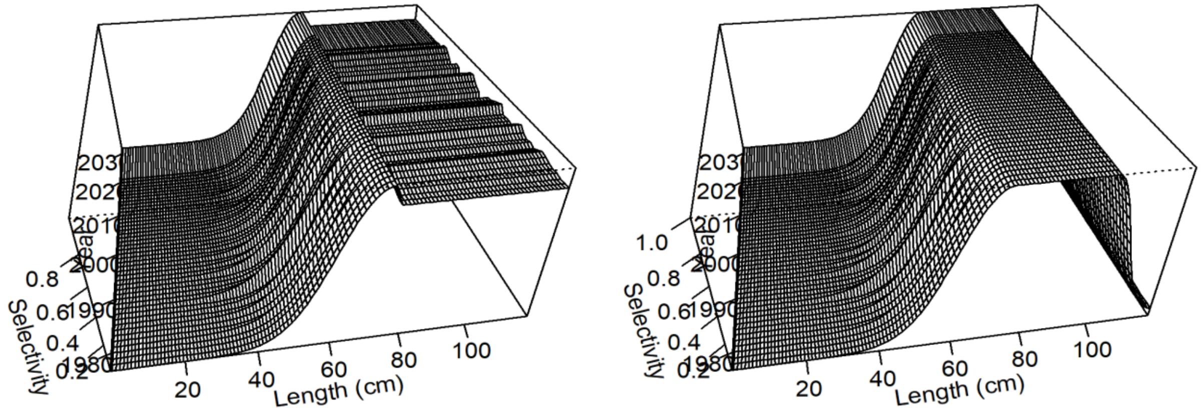
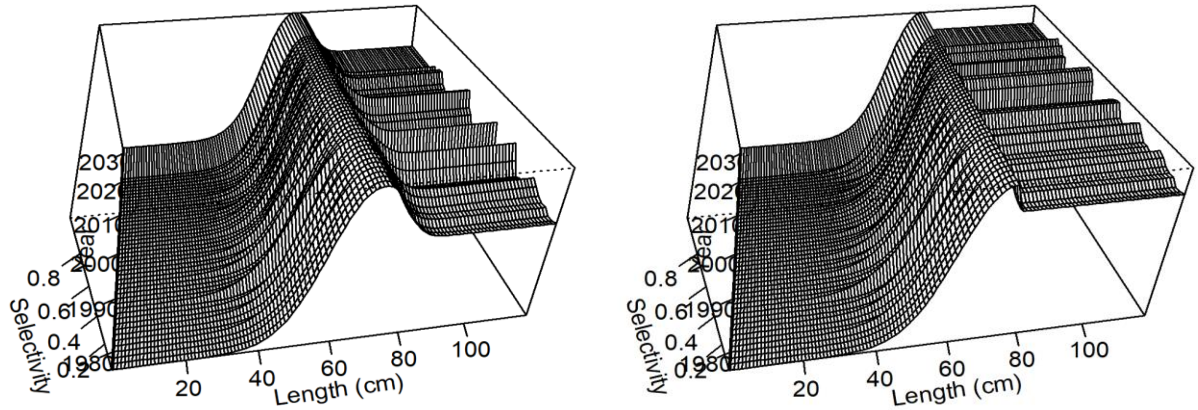


Figure 2.1.14e. Retrospective analysis of combined-sex spawning biomass (Model 21.3).


Model 19.12a

Model 19.12


Model 21.1

Model 21.2

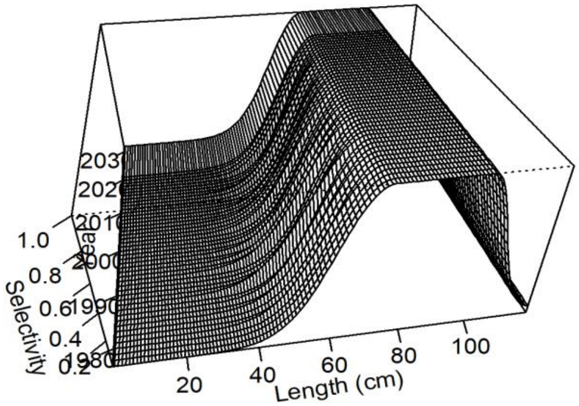
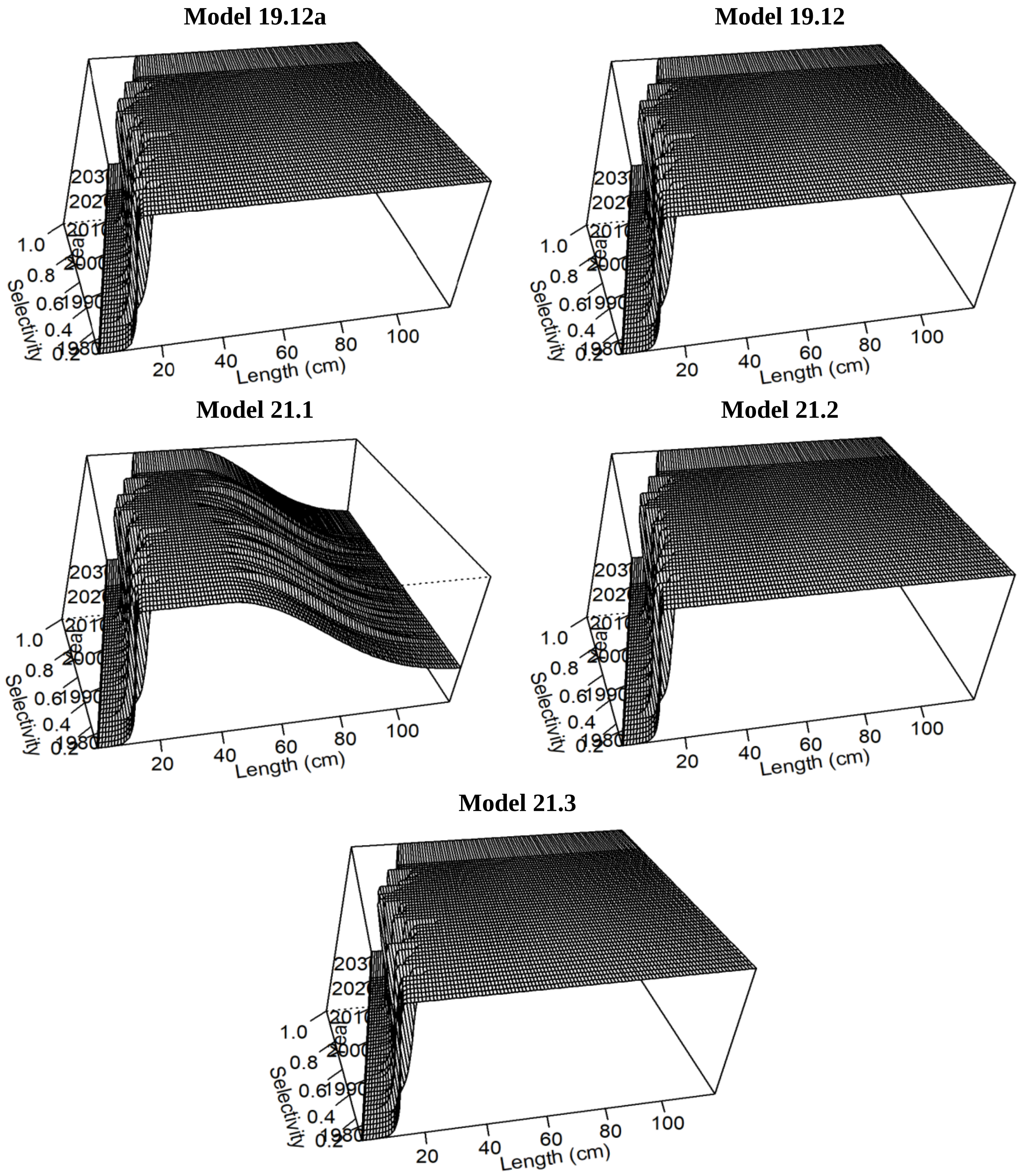

Model 21.3

Figure 2.1.15a. Fishery selectivity as estimated by the models.



Model 19.12a

Model 19.12

Model 21.1

Model 21.2

Model 21.3

Figure 2.1.15b. Survey selectivity as estimated by the models.

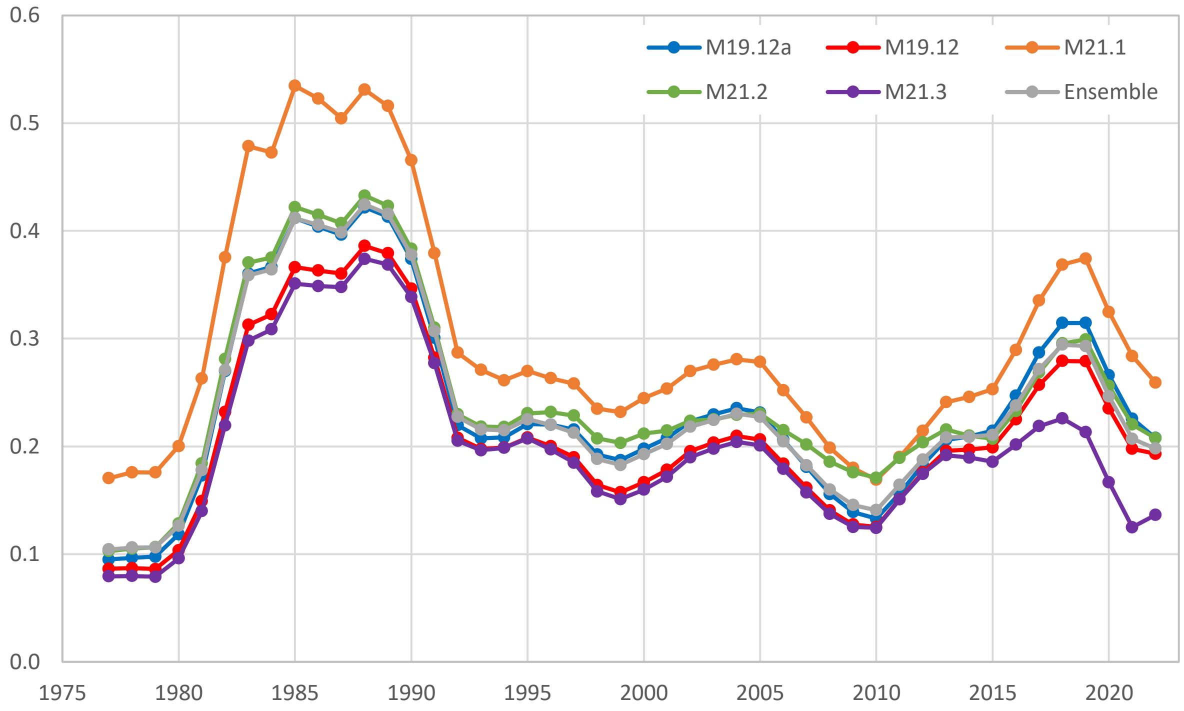


Figure 2.1.16. Female spawning biomass (millions of t) as estimated by the models and ensemble.

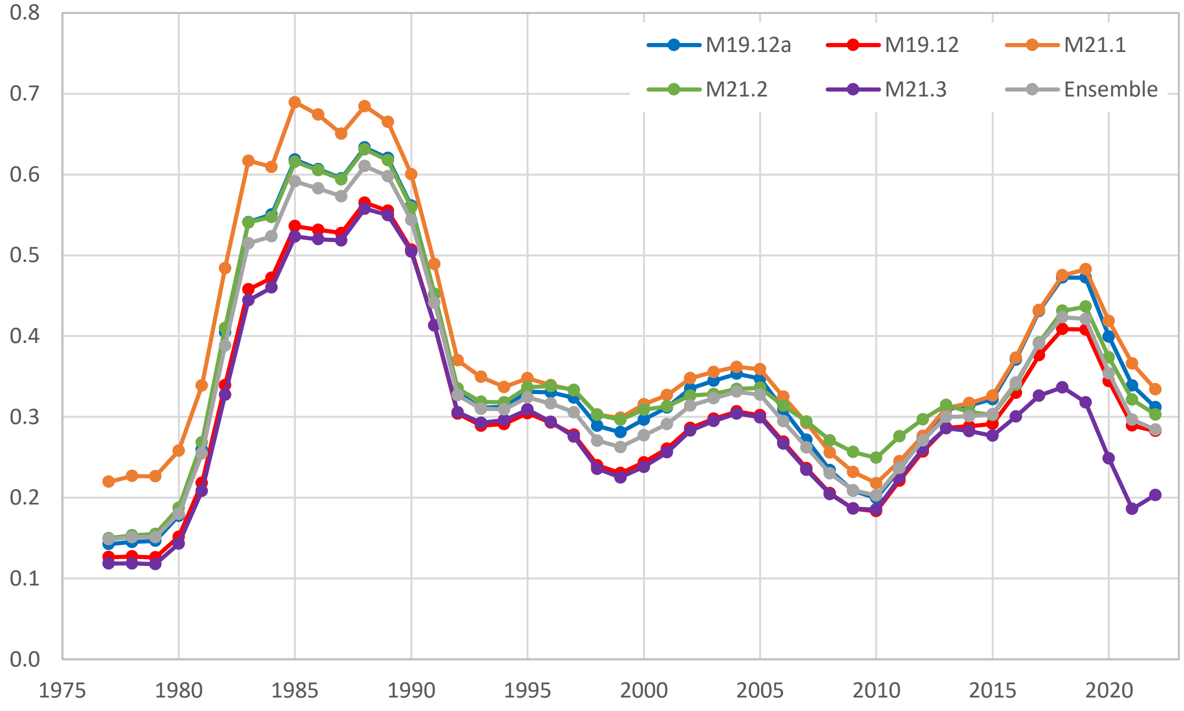


Figure 2.1.17. Relative (to $B_{100\%}$) spawning biomass as estimated by the models and ensemble.

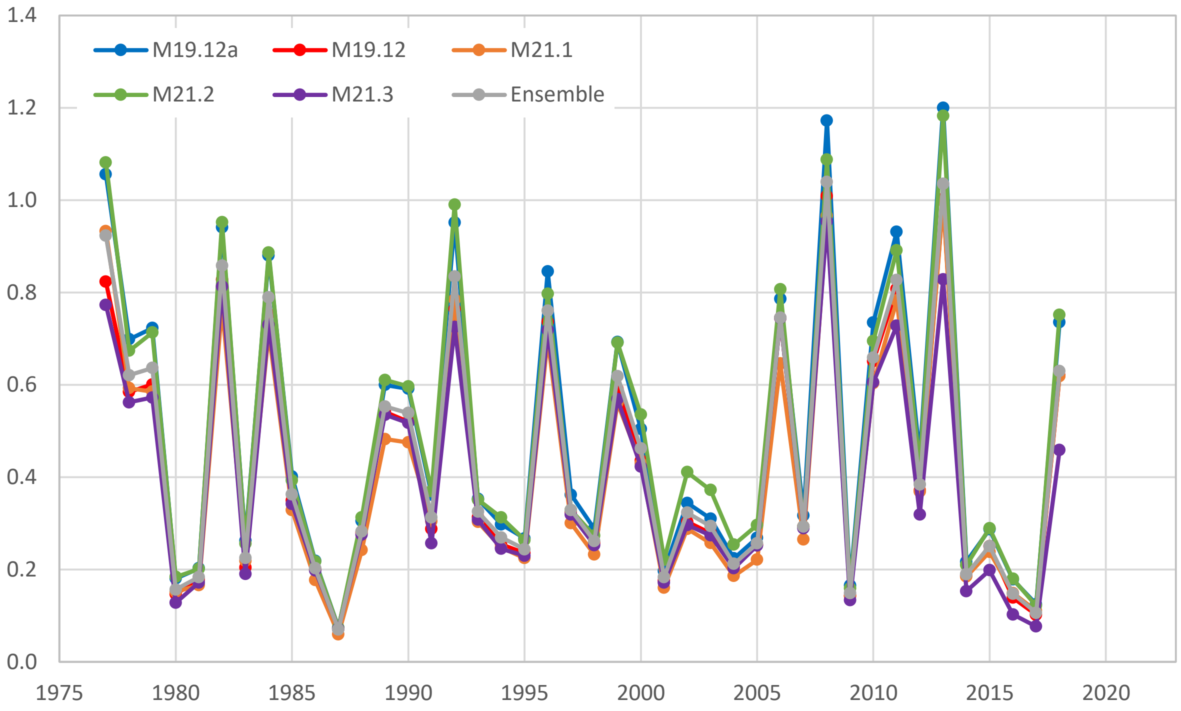


Figure 2.1.18. Age 0 recruitment (billions of fish) as estimated by the models and ensemble.

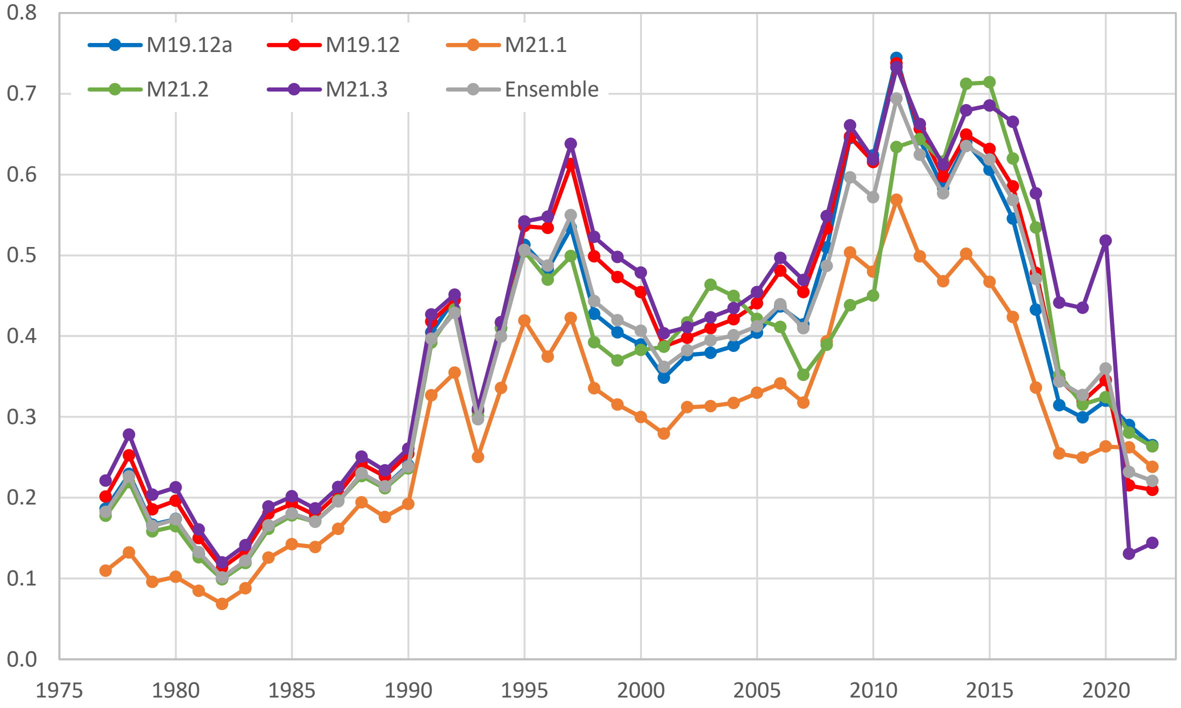


Figure 2.1.19. Full-selection instantaneous fishing mortality as estimated by the models and ensemble.

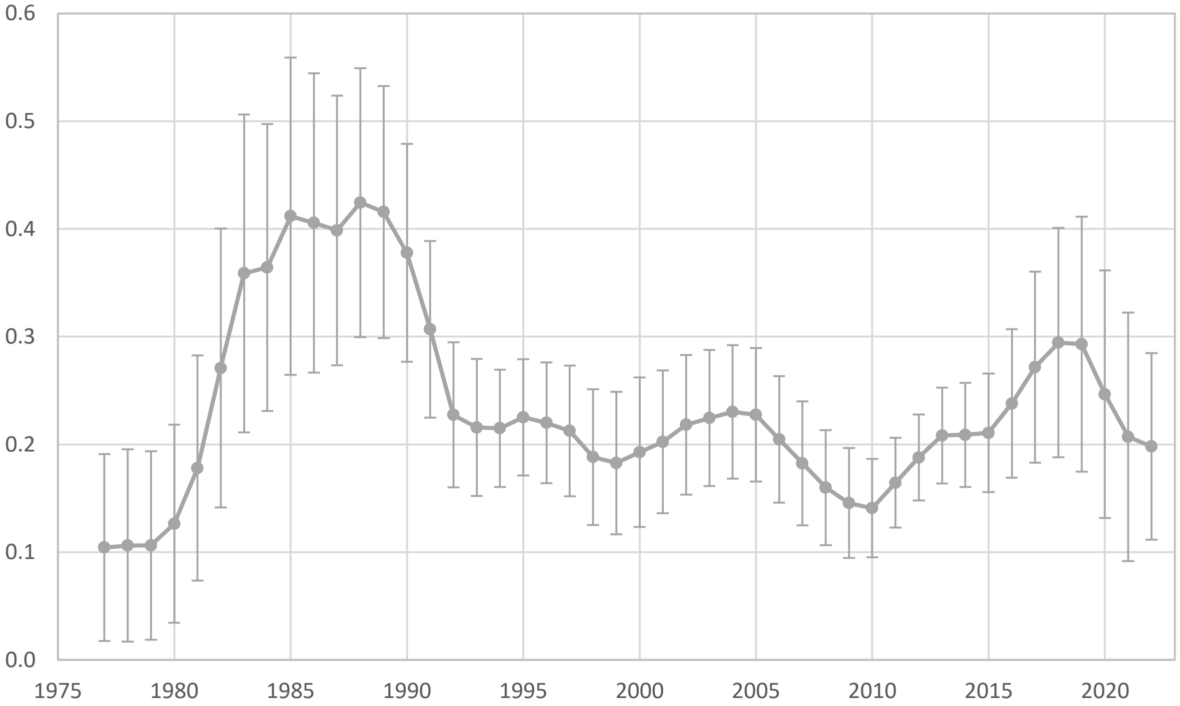


Figure 2.1.20. Female spawning biomass (millions of t), with error bars, as estimated by the ensemble.

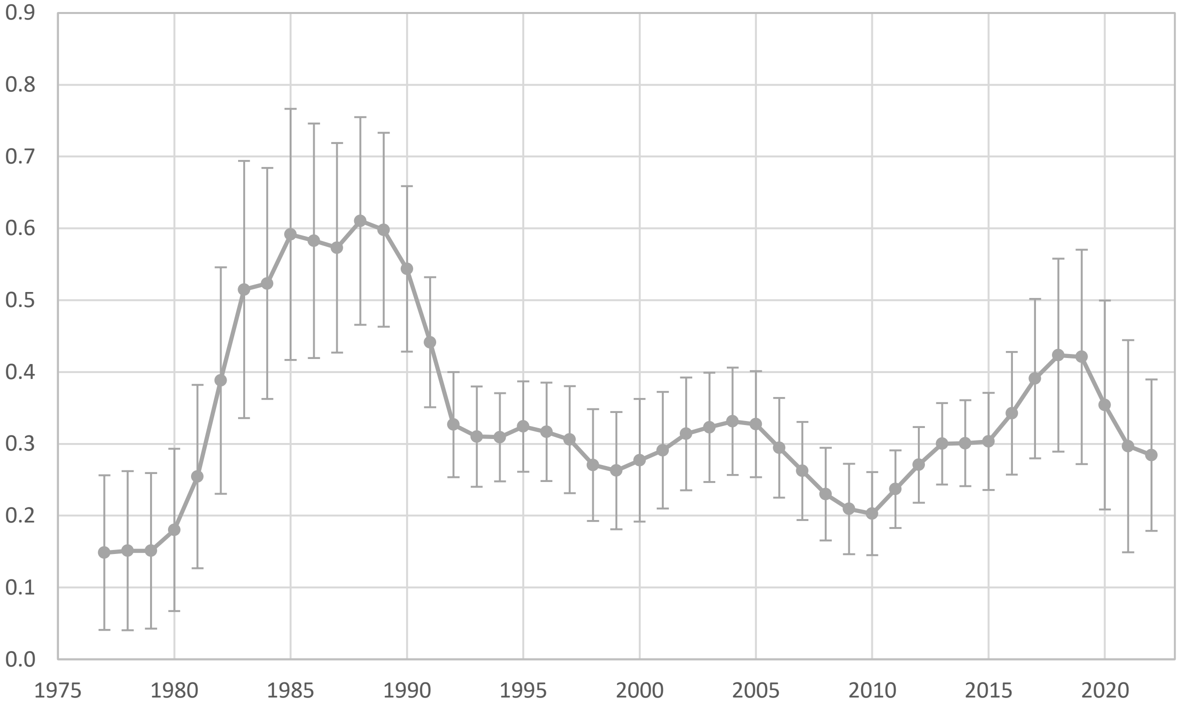


Figure 2.1.21. Relative (to $B_{100\%}$) spawning biomass, with error bars, as estimated by the ensemble.

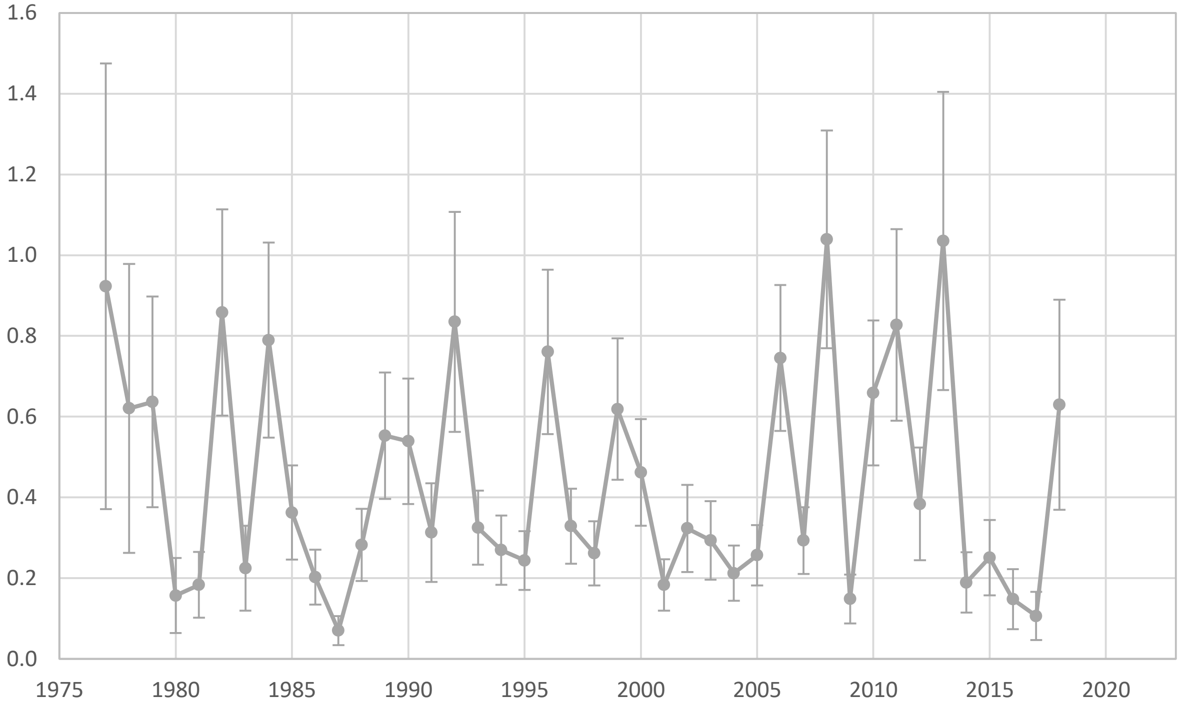


Figure 2.1.22. Age 0 recruitment (billions of fish), with error bars, as estimated by the ensemble.

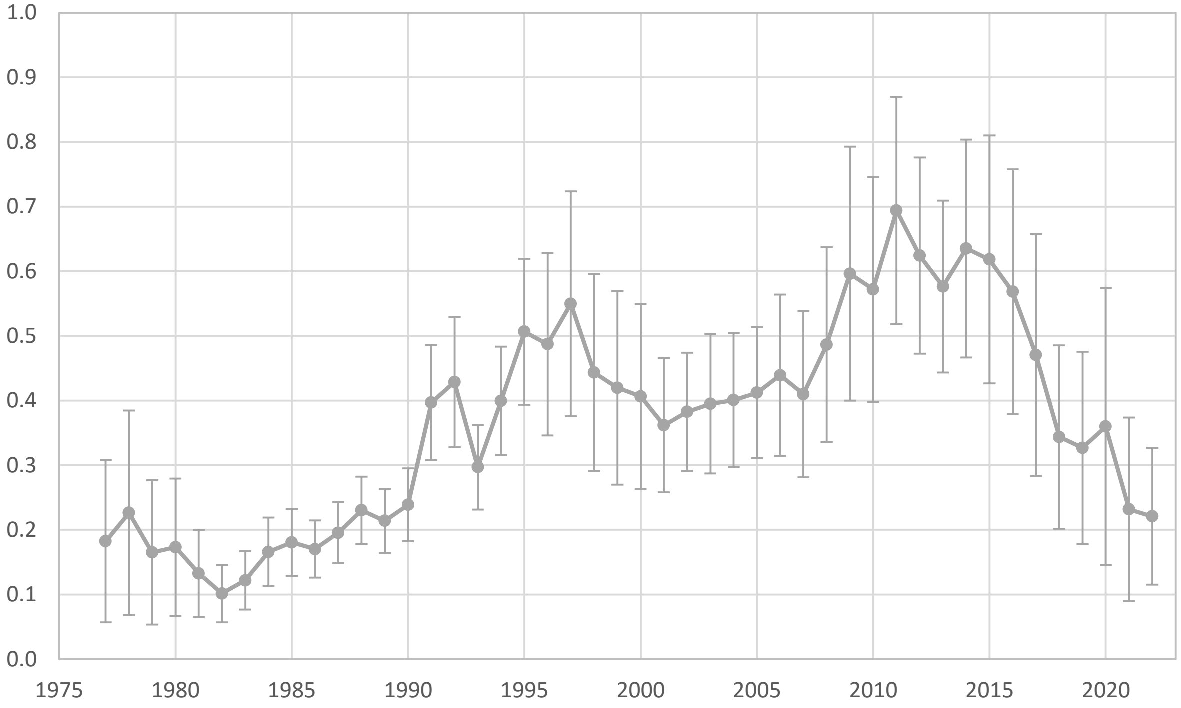


Figure 2.1.23. Full-selection fishing mortality, with error bars, as estimated by the ensemble.

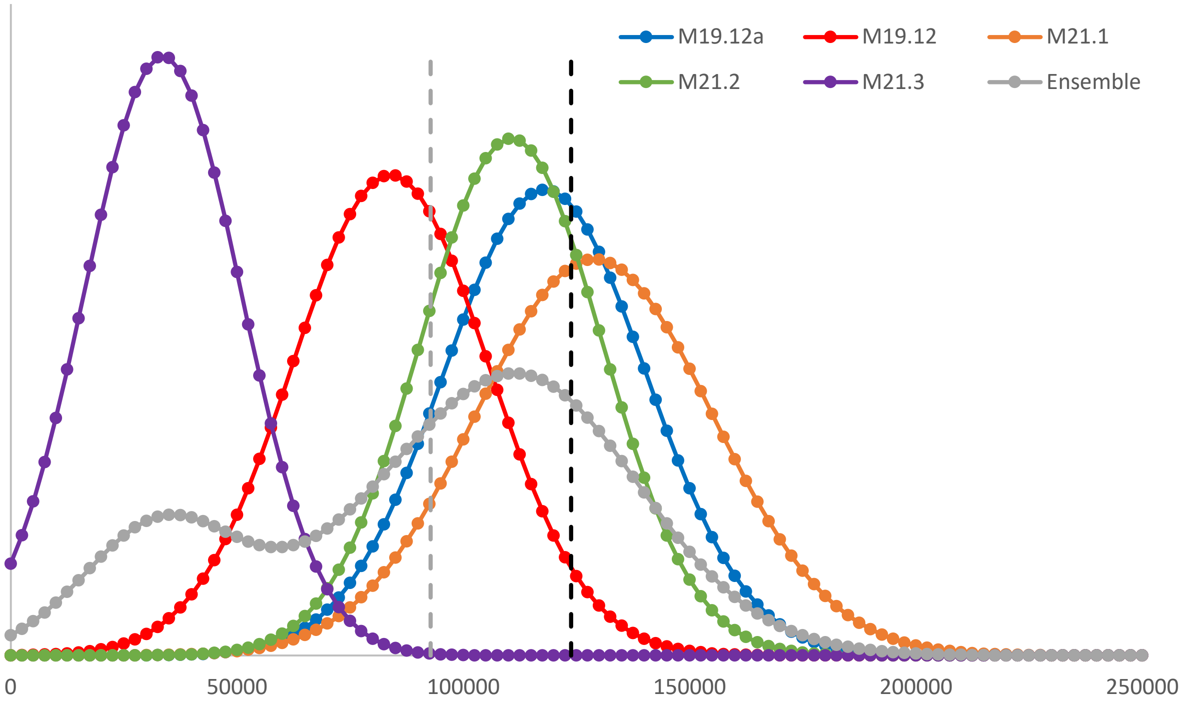


Figure 2.1.24a. Distributions of 2021 ABC as estimated by the models and ensemble. Vertical dashed lines: black = value as currently specified, gray = ensemble mean.

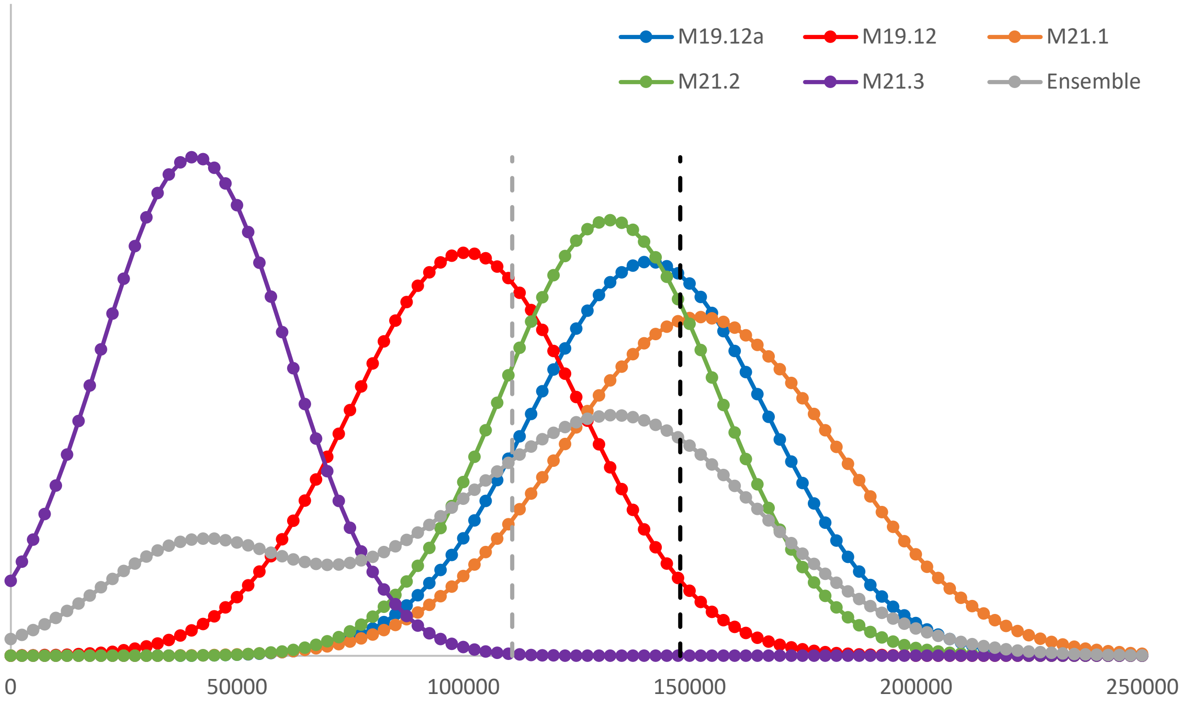


Figure 2.1.24b. Distributions of 2021 OFL as estimated by the models and ensemble. Vertical dashed lines: black = value as currently specified, gray = ensemble mean.

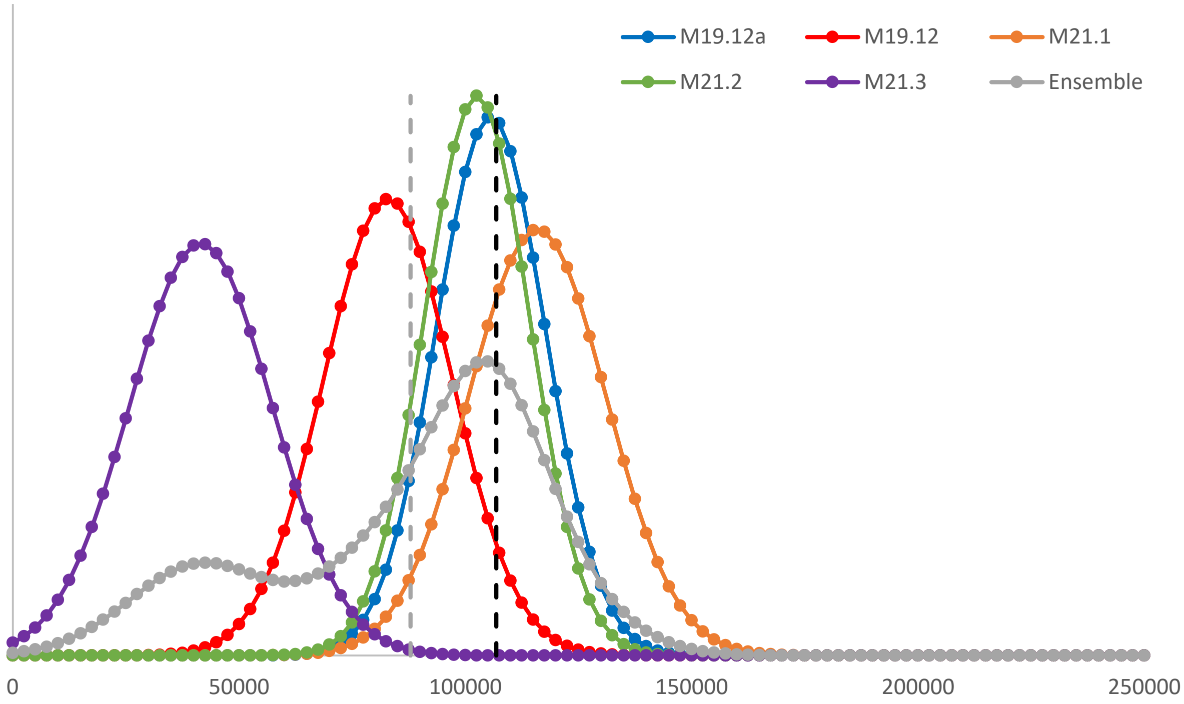


Figure 2.1.24c. Distributions of 2022 ABC as estimated by the models and ensemble. Vertical dashed lines: black = value as currently specified, gray = ensemble mean.

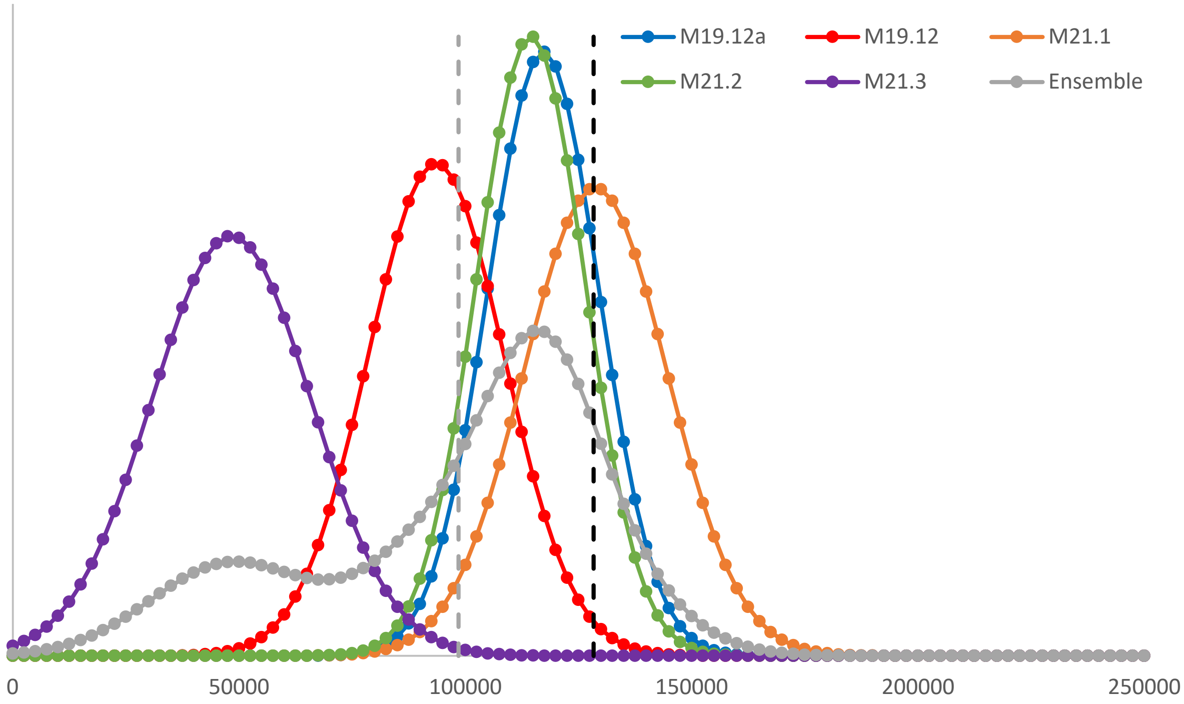


Figure 2.1.24d. Distributions of 2022 OFL as estimated by the models and ensemble. Vertical dashed lines: black = value as currently specified, gray = ensemble mean.

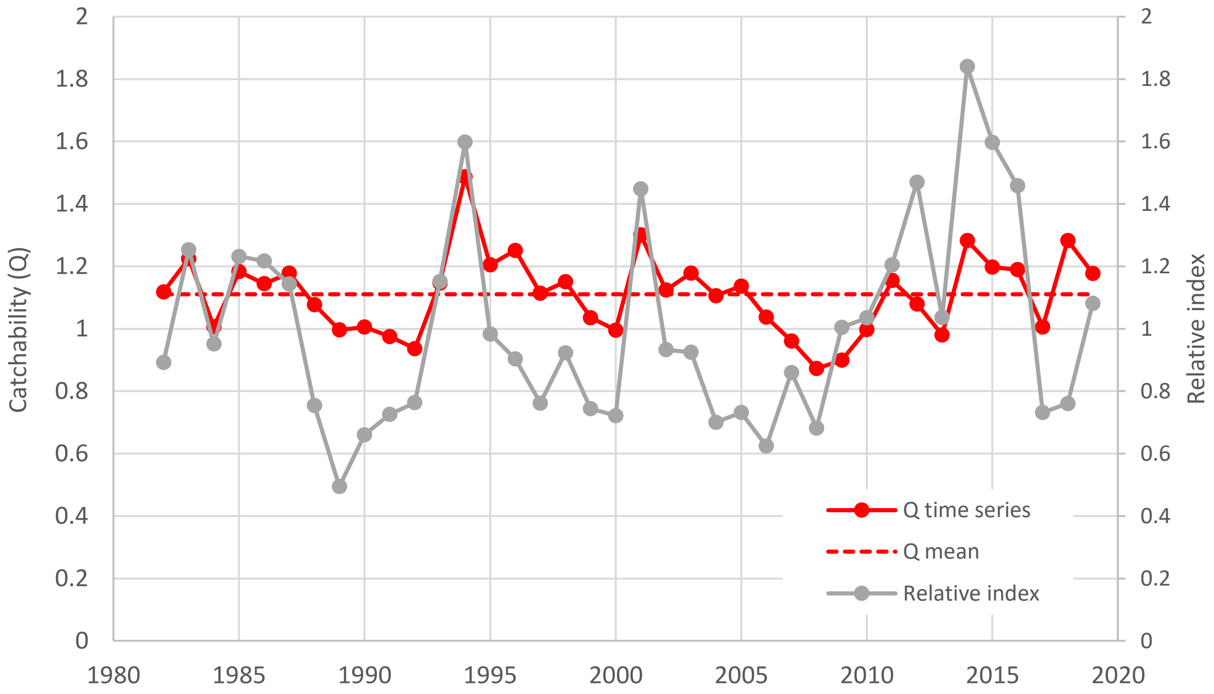


Figure 2.1.25a. Time-varying survey catchability estimated by Model 19.12, compared to survey index.

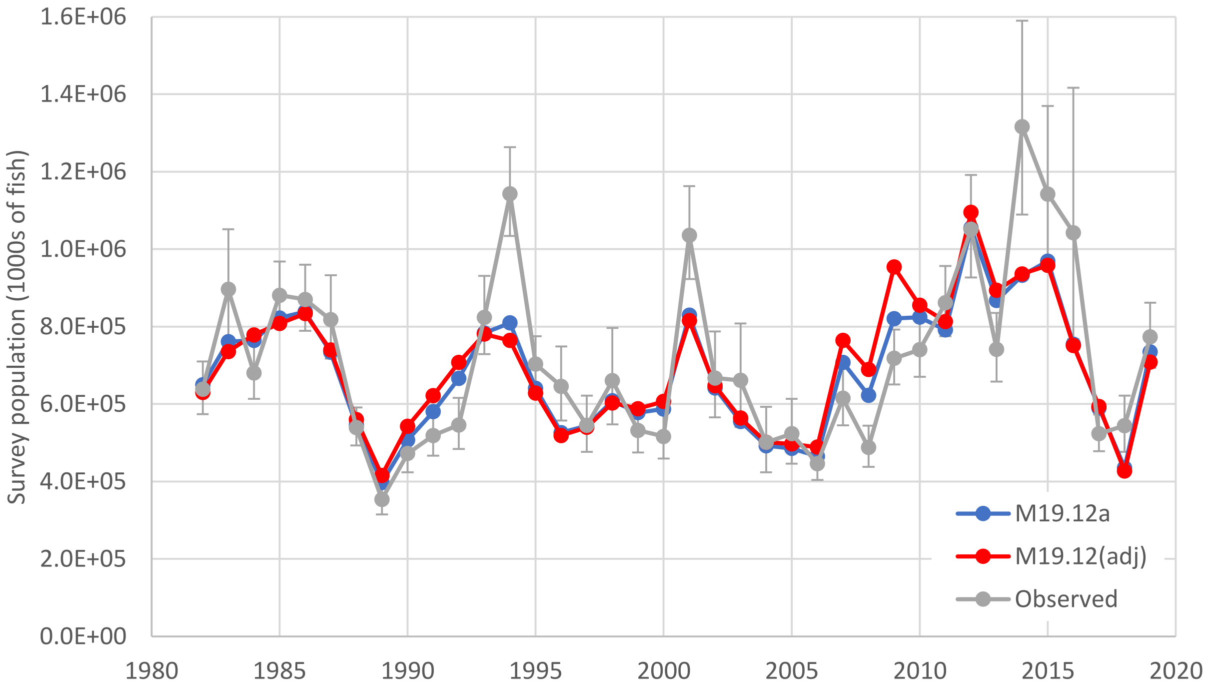


Figure 2.1.25b. Fits to survey index achieved by Model 19.12a and an "adjusted" Model 19.12 (see text).

Attachment 2.1.1: Summary of recommendations from the 2021 CIE review

Compiled by Grant Thompson, Steven Barbeaux, and Ingrid Spies

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National Oceanic and Atmospheric Administration
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Introduction

A review of the stock assessment for Pacific cod in the Eastern Bering Sea was conducted by three reviewers contracted by the Center for Independent Experts (CIE) during the dates of April 26-30, 2021. The reviewers were Yan Jiao (Virginia Polytechnic Institute and State University), Arni Magnusson (General Fisheries Commission of the Mediterranean, FAO), and Henrik Sparholt (University of Copenhagen). The meeting was chaired by Ingrid Spies, and the assessment team consisted of Grant Thompson and Steven Barbeaux. The original terms of reference, plan for conduct of the meeting, background documents, and full reports of the reviewers can be found at https://apps-afsc.fisheries.noaa.gov/Plan_Team/2021_pcod_cie/ (note that the address previously used for this website is no longer valid).

The terms of reference consisted of six main topics, each of which included three subtopics recommended by either the Groundfish Plan Team, the Scientific and Statistical Committee, or Alistair Dunn (a consultant contracted by the Freezer Longline Coalition). In addition, the reviewers added a fourth subtopic of their own to the "Other" topic. As was understood going into the review, there was insufficient time to address all topics and subtopics, so the reviewers were asked to prioritize them. This resulted in some subtopics receiving no recommendations from the reviewers, as expected.

Most of the discussion during the meeting focused on the "Ensemble Modeling" topic, especially the development of specific models to include in the ensemble and the specification of model weights. The reviewers recommended adopting the following set of five models, where Model 19.12a is the current base model (Models "20.8a," "20.9a," and "21.cie" were developed during the meeting; model numbering for this group is provisional only, and follows the convention adopted during the meeting):

Feature 1: Allow catchability to vary?	no	yes	no	no	no
Feature 2: Allow domed survey selectivity?	no	no	yes	no	no
Feature 3: Use fishery CPUE?	no	no	no	yes	no
Feature 4: Estimate survey CV internally?	no	no	no	no	yes
Model (quotes indicate CIE review name):	19.12a	19.12	"20.8a"	"20.9a"	"21.cie"

The criteria in the table below were used to develop the model weights. Each reviewer assigned a score of 0, 1, or 2 for each criterion/model combination, after which the reviewer scores for each criterion/model combination were averaged (shown in the columns associated with the five models). Each criterion was then assigned an emphasis ("Emph.," with color scale extending from red=low to green=high). Criteria for which all models exhibited the same score were assigned an emphasis of 0 and the scores ignored, to avoid skewing the weights toward equality. The reviewers nevertheless recommended keeping the criteria with emphasis=0 in the table in the event that, for some future set of models, at least one of the models were to exhibit a score different from the others.

Criterion	Emph.	19.12a	19.12	20.8a	20.9a	21.cie
General plausibility of the model	3	2	1	0.6667	1	1.3333
Acceptable retrospective bias	3	2	2	1.3333	1	2
Uses properly vetted data	3	2	2	2	0	2
Acceptable residual patterns	3	2	2	2	2	1
Comparable complexity	2	2	1	1	2	2
Fits consistent with variances	2	1	2	1	0	2
Dev sigmas estimated appropriately	0					
Incremental changes	0					
Objective criterion for sample sizes	0					
Change in ageing criteria addressed	0					
Density dependence (other than R) addressed	0					
Regime shifts addressed	0					

Multiplying the average score for each criterion/model combination by the emphasis for that criterion and then computing the weighted average across criteria gives the first row of values in the table below, and rescaling those so that they sum to unity gives the second row of values, which are the reviewers' recommended model weights:

Quantity	19.12a	19.12	20.8a	20.9a	21.cie
Average emphasis:	0.9375	0.8438	0.6875	0.5000	0.8438
Model weight (Ensemble CIE):	0.2459	0.2213	0.1803	0.1311	0.2213

The remainder of this document is organized in order of the terms of reference as prioritized by the reviewers during the meeting, and consists primarily of excerpted recommendations from each reviewer for each topic and subtopic. To reduce duplication, the excerpts were taken primarily from the main body of each reviewer's report, ignoring essentially redundant recommendations in the Executive Summary or Conclusions sections. It should also be noted that substantial portions of the reviewers' reports were devoted to descriptions of the review process, the assessment background, and the structures and results of the models in the reviewers' consensus ensemble, which, while valuable, are not included in the list of recommendations presented here. A total of 50 recommendations were excerpted, distributed across topics, subtopics, and reviewers as shown in Table 2.1.1.1. For ease of reference here and elsewhere, each recommendation in the text is assigned an alphanumeric label containing the first letter of the reviewer's last name. Each recommendation is accompanied by a response from the compilers of this summary.

1. Ensemble modeling

<u>1a. Develop the models to include in an ensemble.</u>

Yan Jiao:

1a.J1: "Given the data available and the stock assessment developed by the assessment team, I support the recommended model ensemble as the best available science and its projected biomass for management consideration."

> *Response*: The CIE reviewers' consensus ensemble is included in the current preliminary assessment.

Arni Magnusson:

1a.M1: “This subtopic was an overarching question during the review workshop: given everything we know about the stock, which model(s) should be used as the basis of scientific advice. The model run that was presented as the base model (19.12a) was thoroughly scrutinized during the workshop and this reviewer agrees this model is the best model for advisory purposes.”

> *Response*: As the current base model, Model 19.12a is included in the current preliminary assessment, and will also be included in this year’s final assessment.

Henrik Sparholt:

1a.S1: “Model selection related to ensemble modeling involved a broad discussion of all the models considered. In relation to this, density dependence in growth, maturity and natural mortality, was considered important to include in assessment models in the future, because it can cause bias especially in the biological reference points estimations missing them. The extremely high level of complexity in the current SS models (in terms of data and mathematics, not so much in biology where maybe it is too simple) was a concern because it decreases transparency, increases the risk of coding and input errors, increases the risk of selecting a local instead of global maximum in the goal function and make high demands on expertise in statistics, mathematics, and computer skills. A simpler biomass dynamic model (Surplus Production Model) approach, which by design includes all density dependent factors (although not disentangled), was briefly discussed. This was based on a rough analysis by me at the meeting, using the female SSB and the catch time series as input data and various assumptions on the shape of the production curve and its height (Fmsy) from recent meta-analysis. Such an analysis could in the future be an important supplement to the current approach or might even be an alternative given the good quality of the time series of survey and catch data available for this stock.”

> *Response*: Because the CIE reviewers’ consensus ensemble did not include a biomass dynamic model, such a model is not included in the current preliminary assessment.

<u>1b. Evaluate the use of ensemble modeling in the NPFMC management system, and specifically whether the structural uncertainty and historical challenges in identifying a robust base model make Pacific cod a good application for ensemble modeling.</u>

Yan Jiao:

1b.J1: “The ensemble approach can be used to deal with situations with structural uncertainty, alternative hypothesis on key parameters, and the application of alternative datasets. The review panel suggested to investigate and compare the model goodness of fit (negative loglikelihood and # of parameters used) and retrospective error for each model considered in the ensemble.”

> *Response*: Agreed. Objective function values, parameter counts, and retrospective errors are always reported for all models.

1b.J2: “The current weighting is based on the rank of the three reviewers. For future usage of this approach, it should be reasonable for AFSC and SSC members to participate in the weighting surveys.”

> *Response*: Agreed. The model weights recommended by the Plan Team during last year’s November meeting were based on such an exercise.

1b.J3: "The review panel and the assessment team also discussed the cross-conditional model averaging approach developed by Thompson (2021). Reviewers generally demonstrated interest in this approach. However, it is not possible to try this approach based on the EBS Pacific cod case in a short time."

> *Response*: The reviewers' interest in the cross-conditional model averaging approach is appreciated. A manuscript describing the approach has been submitted to *Fisheries Research*.

Arni Magnusson:

1b.M1: "Overall, the model ensemble approach proved to be efficient and balanced, fueling constructive and insightful discussions."

> *Response*: Agreed.

Henrik Sparholt:

1b.S1: "Precisely, because it is difficult to get good data on whether a selection curve is dome-shaped or not, the ensemble approach is especially suitable for this situation because several realistic levels of dome shapes can be included, and the ensemble results might reflect this uncertainty appropriately."

> *Response*: Agreed.

1b.S2: "The panel also discussed a suggestion by Grant Thompson on a more objective approach to determine model weights in the ensemble approach. It is called "Cross-conditional model averaging" (CCMA)…. The method has an appealing objectivity aspect, which the above approach does not have. Time did not allow the panel to go into a deep analysis of the approach, but noted two other major issues, one is that of increased complexity, and the other that of a challenge of incorporating models structured differently from the SS models like e.g., biomass dynamic models."

> *Response*: The reviewer's interest is appreciated. He is correct that the CCMA approach is more complicated than conventional model averaging. However, incorporation of biomass dynamic models, particularly if they use a subset of the data used by the age-structured models, should not pose a problem for the CCMA approach. See also response to recommendation 1b.J3.

<u>1c. Consider whether to apply the sloping harvest control rule before or after ensemble averaging of SSB and other reference points.</u>

Yan Jiao:

1c.J1: "The 'before' approach averages SSB and reference points from each model in the ensemble, so easy to perform."

> *Response:* Averaging of SSB and reference points from each model is common to both the "before" and "after" approaches. The distinction is whether to average the harvest specifications (or their distributions): 1) as freely estimated in each model (the "before" approach), or 2) after re-running the models with the ABC or OFL fishing mortality rate fixed at the ensemble average (the "after" approach). The reviewer is correct that the "before" approach is simpler.

1c.J2: "The 'after' approach requires generating a 'new' model with averaged parameters, so computationally can be more complicated. I generally support the "after" approach. When Bayesian approaches are used, the computation of the "after" approach can be done by resampling the posterior runs of the parameters including the estimated F, and project into the next year etc., so not impossible. Bootstrap algorithm can be used to reach the goal also. After discussion with the assessment team, such an approach is currently not available in the SS3 existing functions but may be considered outside of the SS3 computation."

> *Response:* This is just one interpretation of the "after" approach, and would likely require an immense amount of work. One aspect of this approach that appears intractable is how to "average" parameter values in models with fundamentally different structures.

1c.J3: "In the 'after' approach, unlike in the 'before' approach, F2021 is assumed as a constant rather than a function of internally estimated parameters, and so has zero standard deviation. The estimated standard deviation of the ensemble ABC in the 'after' approach is smaller because of this. If computation outside of SS3 is not available in a short time, the average uncertainty of F2021 from each model may be considered as an approximate measurement of F2021 in the 'after' approach when computing ABC in the future."

> *Response:* Except in the case of a simple biomass dynamic model, it is unclear how an after-the-fact approximation of the uncertainty in F_{ABC} or F_{OFL} would be used to adjust a distribution of ABC or OFL that has been computed on the basis of a fixed value for F_{ABC} or F_{OFL}.

Arni Magnusson:

1c.M1: "Without going very deep into the statistical intricacies, the conclusion for this reviewer was that it did not make a big difference and would require further investigations and examples to produce convincing arguments for selecting one approach over the other."

> *Response:* Attachment 2.1.3 describes further investigations and examples.

Henrik Sparholt:

1c.S1: "The panel discussed whether model averaging should be applied before or after application of the Harvest Control Rule and tended to the slight preference for calculating the goal parameter, e.g., the ABC, by each model, before averaging. However, based on a presentation by Grant Thompson at the meeting where all the pros and cons were listed, it was not easy to judge. It was not even easy to say which approach was the simplest one as at least the one where the averaging is done before the HCR is applied, can be conducted in many alternative ways. In terms of the often-suggested strategy, that of a module build approach where each element in the scientific advice is done separately, the philosophy of having the averaging done to reflect the best estimate of the current stock size and reference points estimates, even though they might not be completely consistent (understood as could be derived by one model), the averaging done before would be better. The panel did not reach a conclusion. I am inclined to favor the option of averaging the ABCs after the HCR has been applied to each model, because it seems simpler and because it can accommodate different model structures like cohort-based models mixed with biomass dynamic models."

> *Response:* To be consistent with the terms of reference and the rest of the discussion on this subtopic, it should be noted that:
>
> - The reviewer's reference to "the one where the averaging is done *before* the HCR is applied" actually corresponds to the "*after*" approach.
> - The reviewer's reference to "averaging the ABCs *after* the HCR has been applied to each model" actually corresponds to the "*before*" approach.

> The reviewer is correct that the "before" approach is simpler and, unlike the "after" approach, can accommodate models with fundamentally different structures. The current preliminary assessment uses the "before" approach to compute the ensemble ABC and OFL.

2. Movement

2a. Comment on avenues for incorporating spatial dynamics and movement.

Yan Jiao:

2a.J1: "The review panel found the satellite tag experiment and model developed very informative and may be further continued if possible. The satellite tagging study and the genetic study suggested that the EBS and NBS Pacific cod is appropriate to be managed as one stock but there is a seasonal movement of the individuals and how the movement rate may change given environmental factors or age groups needs further studies (Rand et al. 2014; Spies et al. 2020; Nielsen et al. 2021 presentation). The studies also suggest that the EBS cod may move to the Russian water and further communication or data exchange with the Russian fisheries management agency should help future studies on movement or changes in the spatial distribution of Pacific cod."

> *Response*: Agreed.

2a.J2: "Because the satellite tagging study was only for about one year, and years with NBS survey are limited also, the data available for the potential to incorporate movement is limited, a simulation study to look into the influence of movement on the stock assessment, how the model ensemble or base model without considering movement may perform should help in a short time before further tagging data available."

> *Response:* Attachment 2.1.2 describes, and reports results from, a simulation study with some of the reviewer's suggested features.

2a.J3: "I would also recommend an approach developed in Jiao et al. (2016), in which the spatial asynchrony was considered, and the area-specific population abundance indices were used to calibrate it."

> *Response*: The paper by Jiao et al. (2016) describes a method for incorporating surveys with little or no spatial overlap by accounting for spatial autocorrelation. Because this is precisely what the VAST model already does, and because the VAST estimates of the combined EBS and NBS surveys have already been accepted for use by the Plan Team and SSC, the approach of Jiao et al. (2016) is not used in the current preliminary assessment.

Arni Magnusson:

2a.M1: "There is clear evidence from the trawl surveys that the distribution of the EBS Pacific cod has shifted north and northwest. The northward shift poses a problem for the stock assessment if a substantial part of the population is outside the defined geographic range of the assessment, in Russian waters. This would cause a negative bias in the observed survey index and total catches, which have in fact both been declining in recent years. A bias could also affect the age and length composition data if, for example, older and larger fish are the ones making long-distance feeding migrations into Russian waters. A solution to these problems could be to combine US and Russian data from trawl surveys and the commercial fisheries."

> *Response*: Although movement into Russian waters does pose a problem for the assessment, whether this phenomenon causes a negative bias in the observed survey index and total catches is less clear, as the existence of such bias may depend on whether those time series are viewed as representative of the overall stock or just the portion residing in the U.S. EEZ. Attachment 2.1.2 is intended to begin the process of understanding potential implications of movement to and from Russian waters. Some of the input values used in that study were based on combining data from U.S. and Russian trawl surveys.

2a.M2: "In addition to biased estimates, the northward shift can also pose a problem for the management of the stock, if the fishing mortality rates (F) are higher on one side of the boundary. In a hypothetical scenario where F increases to high levels on the Russian side in the path of the feeding migrations, the population could decline on the US side even if a sustainable level of F is applied. A solution to this problem could be if the two countries agree on a similar target F for the shared stock."

> *Response*: Attachment 2.1.2 includes an examination of the impacts of, and potential management responses to, unequal harvest rates in the two national jurisdictions. In order for an international agreement on a target fishing mortality rate to be meaningful, it seems that it would have to be accompanied by international agreement on assessments of the portions of the overall stock residing within each nation's jurisdiction, both of which sound like difficult undertakings, unlikely to be achieved in the short term.

2a.M3: "Rather than adding spatial dynamics and movement into the stock assessment model, it is recommended that a variety of spatial analyses should be conducted to monitor and understand shifts in the geographic distribution of the stock. This applies both to shifts within US waters and the stock range extending into Russian waters. The approaches can include sophisticated analytical models, but also basic plots of densities in surveys, catches in the Western Bering Sea, and locations of tag recoveries."

> *Response*: Neither spatial dynamics nor movement have been added to any of the models in the current preliminary assessment. Attachment 2.1.2 is an example of a spatial analysis of the type recommended here. A table of catches in the WBS and plots of survey densities and tag recovery locations are also included in the current preliminary assessment.

Henrik Sparholt:

2a.S1: "The movement discussion mostly focused on whether cod in the Eastern Bering Sea may move into Russian waters, and there was a large emphasis placed on preliminary work by Cecilia O'Leary on this topic using data from Russian surveys in Russian waters and pop-up tags which showed that several fish moved from U.S. waters to Russian waters. Internal movements within the Eastern Bering Sea, including the Northern Bering Sea, were not regarded as one of the most important issues, because the survey now covers the area EBS + NBS and the VAST method can fill in the missing years in the past time series. Whether the entire EBS + NBS + WBS (Russian part of the Bering Sea) area has one stock only seems plausible, but it is an exceptionally large area and there might by sub-populations or even genetically distinct population. This seems to be an important future research topic to try to find out."

> *Response*: Agreed. Further work is merited to examine the relationship between cod from these regions, particularly incorporating the WBS that has not been done to date. Recent satellite tagging work combined with genetics will help determine whether there is a genetic predisposition for cod tagged in the EBS in summer to move into Russian waters versus move southward into the EBS. In addition, if samples were available from across the WBS, more genomics work could be done to explore this question.

2a.S2: “Even if biologically distinct, P.cod is one stock spanning the entire U.S. and Russian area, in terms of management it might be practical to keep the US part separate from the Russian part. Because the area is so huge and both countries are now running a sensible management of the fisheries (Russia got its fishery MSC certified a few years ago) it is unlikely that one part could severely impact the total stock and that way damage the fishery for the other part by its management or lack of management.”

> *Response:* Attachment 2.1.2 addresses the issue of unequal harvest rates in the two national jurisdictions. See also the response to recommendation 2a.M2.

2a.S3: “Furthermore, it is not unlikely that there are in fact genetically separate sub-stocks (which then would be real stocks) in this huge area. In the North Sea, a similar sized area in the eastern Atlantic, it has recently been discovered by use of the now easily available genetics techniques that Atlantic cod (a remarkably similar species) is in fact made up of at least two genetically separate stocks (that mix outside spawning time) (ICES 2020).”

> *Response*: It is unlikely that Pacific cod in the Bering Sea consist of two groups that are as differentiated as the two ecotypes of Atlantic cod (Northeast Arctic cod, NEAC, and Norwegian Coastal Cod, NCC). Whole genome research indicates that there are large differences between cod found in the Aleutian Islands and Eastern Bering Sea that are likely due to local adaptation (Tarpey et al., *in prep*.), but differences within the Bering Sea are not as large as those found between NCC and NEAC. There is some indication of genetic differences among cod spawning along the Bering Sea shelf (Spies 2012; Spies et al. 2019); however, more work is needed to understand whether these differences are significant or whether cod that spawn along the eastern Bering Sea shelf represent a single stock. Similarly, cod that are fished on the Russian side of the Bering Sea shelf are likely genetically similar to cod on the U.S. side of the Bering Sea shelf, but more work remains to understand that relationship. Few studies have looked for large-scale differentiation among Pacific cod from the U.S. and Russia. Smirnova et al. (2018) found a break between Japan and Korean cod. Similarly, spatially distinct patterns have been found at a putative zona pellucida gene between spawning samples adjacent to the Bering Sea and samples further southward (Spies et al., *in prep*.).

<u>2b. Consider how to inform the dynamics of movement or abundance between the Northern Bering Sea and the Eastern Bering Sea, specifically from additional experiments and analyses, data analyses that include these assumptions (i.e., VAST), and how these can best be used within the different models as indices of abundance.</u>

Yan Jiao:

2b.J1: “The review panel was not able to evaluate the VAST or the ADT modeling approach because of lacking details on the model developed, data used, and results.”

> *Response*: The current preliminary assessment provides details on the model developed, data used, and results.

Arni Magnusson:

2b.M1: “The reviewers agreed that it would be useful to gain better understanding of fish movement between the NBS and EBS areas, as well as identification of spawning areas within NBS. Overall, fish movement within the geographic range of the stock assessment may in many cases not pose any significant problems. Local depletion is one factor to consider, though, when an increase in stock abundance is mainly in the north, but most of the fishing takes place further south.”

> *Response*: Agreed. Additional tagging work was conducted during this summer's bottom trawl surveys, with 16 pop-up satellite archival tags (PSATs) being deployed during the EBS survey, and up to 30 in the NBS (with 3 stationary tags). All tags were deployed using hook and line gear. The NBS locations were similar to those of the previous PSAT project, with one additional location in the northeast corner of the survey area, toward the Bering Strait.

Henrik Sparholt:

No recommendations.

2c. Develop movement models.

Yan Jiao:

2c.J1: "The review panel questioned whether we really need movement models for a stock whose distribution is covered almost entirely by the EBS and NBS bottom trawl surveys. The panel felt understanding the degree to which the stock ranges into Russian waters is of great concern also. Overall, the panel recommends further tagging studies."

> *Response*: Agreed for the most part, although movement between the EBS and the NBS could be important if fishery characteristics (e.g., selectivity) or life history characteristics (e.g., growth) differ between the two areas. With respect to movement between either the EBS and the NBS or the combined EBS and NBS and the WBS, the need for movement models may be of less immediate relevance than the lack of data sufficient to parameterize such models.

Arni Magnusson:

No recommendations.

Henrik Sparholt:

No recommendations.

3. Fishery CPUE

3a. Discuss standardization of fishery CPUE using alternative statistical methods, including a discussion of historical changes in the fishery that may affect the relationship of the index to abundance.

Yan Jiao:

No recommendations.

Arni Magnusson:

No recommendations.

Henrik Sparholt:

No recommendations.

<u>3b. Develop a fishery CPUE index.</u>

Yan Jiao:

3b.J1: "CIE review panel all agreed that the development of an appropriate index is important, but it cannot be accomplished during this meeting. I agree with this recommendation."

> *Response*: Agreed. Curry Cunningham (University of Alaska) will be supervising a graduate student with this as his or her thesis topic.

Arni Magnusson:

No recommendations.

Henrik Sparholt:

No recommendations.

<u>3c. Consider how best to further analyze CPUE, including development of spatio-temporal analyses of fleet specific CPUE indices that may help inform the model or supplement the trawl survey biomass indices.</u>

Yan Jiao:

3c.J1: "The VAST model did not provide enough details and it only uses one type of fishery data (hook-and-line) and only used two months of data (January and February). I feel that a model-based approach is necessary but the rationale of only using two-month data and only use one fishery need to be addressed. The fishery has a clear monthly pattern and likely important to be considered. Also, the first two months (January and February) of hook-and-line fishery may face gear saturation and it is unclear whether such factors were considered or not. The review panel feels that the model and approach are promising but further details are needed."

> *Response*: The current preliminary assessment provides details of the VAST fishery CPUE index, including a rationale for focusing on the January-February longline fishery. The reviewer is correct that the longline fishery CPUE data exhibit a clear monthly pattern. However, it is unclear that this renders selection of the January-February interval problematic, because: 1) the existing assessment models all use an annual time step, 2) the index is relative only, and 3) the monthly pattern appears to remain approximately constant across years (see Figure 2.4 in last year's stock assessment). The reviewer is correct that, at least in principle, gear saturation poses a potential problem.

3c.J2: "I would recommend a hierarchical Bayesian model or a mixed effect model to be considered. In such approaches, the fishery fleet can be considered as random effect when considering multiple fisheries in the fishery CPUE standardization."

> *Response*: This recommendation has been forwarded to Curry Cunningham for consideration in his graduate student's research (see response to recommendation 3b.J1).

3c.J3: "I feel fleet-specific fishery CPUE analysis for the fishery with better quality data, such as with larger spatial coverage, credible logbook records with spatial-temporal information, etc., is reasonable.

The specific gear selectivity needs to be further considered since the current stock assessment models used one fleet that combines all the fishery types."

> *Response*: The first part of this recommendation has been forwarded to Curry Cunningham for consideration in his graduate student's research (see response to recommendation 3b.J1). Regarding the second part, given that the reviewers' consensus ensemble retains the combined-fishery format of the current base model, models with gear-specific selectivity are not included in the current preliminary assessment. Nevertheless, the reviewer is correct that this aspect of the reviewers' proposed model incorporating the fishery CPUE index is problematic.

Arni Magnusson:

3c.M1: "The VAST approach seems promising as method to analyze CPUE, calibrating the annual catch rate index from the commercial fishery in a way that gives appropriate weighting to data points based on their spatial location. However, it is not apparent that commercial CPUE will add useful information to the stock assessment, given that a high-quality survey is already in place."

> *Response*: Agreed.

Henrik Sparholt:

3c.S1: "Fishery CPUE has been given up in most data rich assessments in the northern hemisphere due to problems getting proper fleet definition…. For the fishery on P.cod in the EBS+NBS sufficient detailed data seems to be available and the issue with targeting seems to be less of a problem than usually, at least for the most important fleet component, the hook and line procession vessels…. Thus, it seems to be a potential option to try to develop a fishery CPUE index for this H&L PV fleet component…. Developing a quality CPUE index is, however, not something which is done 'overnight' and would rather be suitable for say, a PhD project."

> *Response*: Agreed. See the response to recommendation 3a.J1.

3c.S2: "Hyper-stability is an issue that needs special attention and the panel speculated that this might be tackled by somehow including 'other data' (maybe from the survey or from other fleets and where the focus should be on the special distribution of the stock by season) in the approach."

> *Response*: Agreed. Hyper-stability of fishery CPUE data is an issue, and the VAST modeling framework does, at least in principle, allow inclusion of survey CPUE data along with fishery CPUE data in a deriving an index of abundance. However, in keeping with the reviewers' consensus ensemble, the models presented in the current preliminary do not include a VAST index based on both fishery CPUE and survey CPUE data. This recommendation has been forwarded to Curry Cunningham for consideration in his graduate student's research (see response to recommendation 3b.J1).

3c.S3: "Variation in market conditions from year to year might also influence when a vessel decides to stop fishing at low catch rates, and this influences what to assume for not-fished space-time cells in the analysis (if it is cell based), and this is an important further complication."

> *Response*: This recommendation has been forwarded to Curry Cunningham for consideration in his graduate student's research (see response to recommendation 3b.J1).

3c.S4: "Technological development and improvements in fishing gears and thus in catchability are extra challenges. Usually, many aspects of the fishing operation are changing just in a single year, and of course even more so over a long time series and often these cannot be easily revealed and quantified. The panel speculated that the ambition could be to aim for a quite short CPUE timeseries – say 10 years – so that not too much technological creeping is going on in the time window considered. This could mean that for each future year the time series should be truncated by discarding data more than 11 years old."

> *Response*: This recommendation has been forwarded to Curry Cunningham for consideration in his graduate student's research (see response to recommendation 3b.J1).

4. Age data

4a. Attempt to resolve problems with using fishery age compositions.

Yan Jiao:

4a.J1: "I am wondering whether the number differences of age bin and size bin matters when using age composition and size compositions. For example, there are only 12 age groups but the size bin used in the model is 1cm, which implied that there are lots more size composition data to be fitted than that of age composition."

> *Response*: This concern seems misplaced. First, note that the average input sample sizes for length data and age data are the same (per fleet), and that use of the Dirichlet-multinomial approach automatically adjusts the average sample sizes appropriately. Second, for a given sample size, an increase in the number of bins for a given multinomial data set would likely decrease, rather than increase, the leverage of that data set relative to the other data. For example:
>
> - Let m and n represent the number of bins and the sample size, respectively.
> - Let n be a power of 2; specifically, $n = 2^{jmax}$, for some positive integer $jmax$.
> - Then, consider a range of values for m. Specifically, for j=1,2,…,$jmax$, set $m_j = 2^j$.
> - For each m_j, let the samples be distributed evenly among the bins.
> - This implies that the MLE of the proportions will always be $1/m_j$.
> - Then, the log of the determinant of the Hessian matrix **H**, evaluated at the MLE, is:
>
> $$\ln(|\mathbf{H}|) = -ln(m_j) - (m_j - 1)\cdot\left(ln(m_j) + ln(n)\right),$$
>
> which is a monotone decreasing function of the number of bins.

4a.J2: "The future diagnostics may include checking the fitting to age and size compositions to see which year and age groups that the model did not fit well and where the retrospective error mainly caused by; checking the model performance when using larger size bins to match the number of age groups in the age composition data."

> *Response*: See response to recommendation 4a.J1. Moreover, use of a coarser bin structure for size data is likely to degrade the model's ability to estimate growth parameters, so even if this suggestion were to eliminate the retrospective bias associated with use of the fishery age composition data, it is not clear that biased estimates of growth parameters is an acceptable cost.

Arni Magnusson:

4a.M1: "A good tool to examine discrepancies in the age data would be to fit a simple statistical catch-at-age model. Residual patterns and other diagnostics from that model can be used to guide the examination of possible errors in the age data, or at least pinpoint where exactly discrepancies occur in the age data.

Findings from this examination can then be used to make informed choices to update the data preparation or consider making specific changes in the base model."

> *Response*: Agreed.

Henrik Sparholt:

4a.S1: "The panel suggested that growth estimates from tagging studies could also be included in verification of the age readings. This has proven useful for other fish stocks."

> *Response*: Agreed.

<u>4b. Consider how best to include the fisheries age and size composition data, including consideration of fleet specific age composition data in the model.</u>

Yan Jiao:

No recommendations.

Arni Magnusson:

No recommendations.

Henrik Sparholt:

4b.S1: "The hope is that age data from the fishery can be included in the assessment models at some point in time. The panel speculated that maybe the used growth curve lacking seasonal variations in growth might contribute to the problem, and now the assessment model is based on years and not quarters of the year. Of course, this means that the model should go back to how it was some years ago, to be based on quarterly time steps or other changes to accommodate this seasonal growth pattern."

> *Response*: Agreed. However, since all of the CIE reviewers' recommended models were based on an annual time step, models with seasonal structure are not included in the current preliminary assessment.

4b.S2: "In order not to go against the aim for reducing model complexity one could think of stop including length data and use only age data. These should then be worked up by fleet and season before merged into annual data and entering the assessment model. This would also avoid the complexity of having to estimate growth. Maturity by age could then also be given by year, which is an unfortunate lack of biological complexity at the moment of the SS models. In that way density dependence in both growth and maturity would automatically be included in the part of the model assessing the historical stock development."

> *Response*: Because estimates of fishery weight at age are currently lacking for many years, eliminating the model's ability to estimate length-at-age parameters would likely prove problematic, because calculation of weight at age is currently based on applying weight at length parameters to length at age estimates.

<u>4c. Investigate whether a change in growth contributed to the ageing bias fit for 2008 and onward in the complex models as ageing bias and growth may be confounded.</u>

Yan Jiao:

4c.J1: "Some review panel members suggested that this may be diagnosed step by step. For example, one model scenario can be to turn off ageing bias and see what happens; another scenario can use the externally estimated growth with ageing uncertainty and see what happens."

> *Response*: Agreed, although external estimates of fishery length at age are currently lacking for many years.

Arni Magnusson:

No recommendations.

Henrik Sparholt:

No recommendations.

5. Compositional data

<u>5a. Consider methods (e.g., bootstrapping) to estimate uncertainty and variance in the composition data, with the results then used to estimate initial sample sizes for each season, fleet, combination for input into the assessment model.</u>

Yan Jiao:

No recommendations.

Arni Magnusson:

No recommendations.

Henrik Sparholt:

No recommendations.

<u>5b. Review methods to scale the composition data and include consideration of methods that scale observer samples to the catch by vessel, location, and time of event.</u>

Yan Jiao:

No recommendations.

Arni Magnusson:

No recommendations.

Henrik Sparholt:

5b.S1: "The ad hoc approach used in the current models of scaling the hauls numbers from the fishery to the hauls numbers from the survey seems quite sensible although it would not reflect large persistent changes in sampling intensity in either of the two entities."

> *Response*: The current approach scales all of the fishery input sample sizes so that the average equals the average of the survey input sample sizes, meaning that inter-annual proportional changes in sampling intensity are still reflected in the time series of input sample sizes.

<u>5c. Consider analyses of the size- and age- composition data to identify if there are specific locations or time periods when a recruitment signal may be apparent to assist in informing the assessment model of the strength of recent recruitment.</u>

Yan Jiao:

5c.J1: "The review panel felt that this topic is meaningful and very useful for the assessment. The study may start from the age composition or size composition data to look into the overlap cross cohorts in the earlier age groups. The analysis may also look into the age or size groups with low or zero selectivity by the fishing gears but selected by the survey gears. Because the assessment models all used time-varying selectivity, it may confound with the cohort signals to be estimated. An external analysis with plots such as bubble plots, etc., is encouraged for future external analysis."

> *Response*: Although the analyses described in this recommendation may provide additional insights, it is worth noting that the existing survey time series has historically provided a remarkably reliable early indication of year class strengths.

Arni Magnusson:

No recommendations.

Henrik Sparholt:

No recommendations.

6. Other

<u>6a. Consider incorporation of dome-shaped survey selectivity.</u>

Yan Jiao:

6a.J1: "The CIE review panel found that existing studies based on field data do not suggest that a dome-shaped survey selectivity is largely possible (Weinberg et al. 2016). To address this hypothesis, a model (M20.8a) with dome-shaped survey selectivity was suggested to be included in this year's models of the ensemble or simply as a sensitivity run."

> *Response*: The CIE reviewers' recommended model with dome-shaped survey selectivity (or, more accurately, unconstrained survey selectivity parameters) is included in the current preliminary assessment.

Arni Magnusson:

6a.M1: "All in all, there is no convincing evidence that the survey is dome-shaped, but to take this possibility into account, one such model is included in the model ensemble. The commercial fleet selectivity is already estimated as dome-shaped and having the survey selectivity also dome-shaped can give the model more flexibility than is warranted by the data. The base model is therefore a more robust and useful basis for management purposes."

> *Response*: See response to recommendation 6a.J1. In keeping with the CIE reviewers' consensus regarding model weights, the base model is given more weight than the model with dome-shaped selectivity in the current preliminary assessment.

Henrik Sparholt:

6a.S1: "It is in general difficult to determine whether a selection is dome-shaped or not, but a study referred to from 2016 looking at underwater videos of the behavior of cod in front of the trawl gear during fishing operation indicated that large cod did not avoid the trawl more than young cod pointing towards a flat selection curve. Without going into the study in details it was noted that such studies are notoriously difficult to conduct. For instance, the potential spatial distribution of large cod in attractive habitat like rough areas and around shipwrecks, where fishing is difficult, might still result in a dome-shaped selection. The possibly hidden large fish probably come forward at spawning time and if it would be somehow possible to get absolute stock estimates of spawners at that time, maybe this could be used to obtain information about the amount of 'hiding' of large fish and then of extent of the dome-shape selection curve."

> *Response*: It is not clear how estimates of the total number of spawners could be obtained, except from the stock assessment model, but then the argument would be circular.

6a.S2: "Another possibility might be by the use of pop-up satellite tags and catch rates of these by size of cod, but many tags would probably be needed, and they are expensive. This type of study is probably best conducted separately from the annual stock assessment modelling."

> *Response*: The overall number of PSAT tags deployed, while increasing over time, is still far too small for this recommendation to be implemented, which will likely be the case for many years.

<u>6b. Consider the diagnostic plots of fits and residuals (including normalised or Pearson residuals) for the age and size composition data and make recommendations on how the model fits may be improved.</u>

Yan Jiao:

No recommendations.

Arni Magnusson:

No recommendations.

Henrik Sparholt:

No recommendations.

<u>6c. Consider inclusion of other survey information (e.g., the IPHC and sablefish surveys).</u>

Yan Jiao:

No recommendations.

Arni Magnusson:

No recommendations.

Henrik Sparholt:

No recommendations.

<u>6d. Although not listed in the original set of recommendations for the 'other' category, the review panel suggested that consideration of density dependence in a variety of life history processes may be important in assessment models."</u>

Yan Jiao:

No recommendations.

Arni Magnusson:

6d.M1: "The base model allows recruitment to be estimated freely, according to the information in the data about cohort sizes, and those recruitment fluctuations may or may not turn out be related to density dependence. The base model also incorporates time-varying length-weight coefficients estimated from the data, so changes in growth may or may not be related to density dependence. The review workshop did not identify a simple setting in the SS3 model settings that would allow specific examination of possible density-dependent effects. Overall, it seems that the base model has the flexibility to take density dependence into account, if the data suggest that is the case."

> *Response*: Because the time-varying weight-at-length parameters are estimated freely outside of the assessment model, the reviewer is correct that there is some potential for those estimates to reflect density dependence. Although the reviewer is correct that the consensus understanding during the meeting was that SS does not allow density-dependent effects, after the review meeting it was discovered that SS does now feature such an option, so inclusion of density-dependent effects in a future assessment is not outside the realm of possibility.

Henrik Sparholt:

6d.S1: "I presented a rough run using biomass dynamic models (Surplus Production Models - SPM). The SPMs by design includes all density dependent mechanisms, although not in a disentangled way. Such a disentangling is not needed for ABC advise, but of course it would be useful to = understand the population dynamics of the stock. The runs were based on the software SPiCT (Pedersen et al. 2016 and GitHub - DTUAqua/spict: Surplus Production model in Continuous Time), a software used extensively by ICES expert groups in recent years and on an ad hoc Excel software…. As expected, (due to the inclusion of all density dependent factors and not just that in egg survival to the recruitment stage), the B100% (and thus B40% and B35%) was generally estimated to be lower than by SS and Fmsy higher. MSY was generally estimated to be about the same. If this model is closer to the true population dynamic of the stock, it has of course implications for the annual advice. Therefore, it might be fruitful to analyse this approach in much more detail than done here for the current assessment."

> *Response*: Because models based on the SPiCT approach were not included in the CIE reviewers' consensus ensemble, neither are they included in the current preliminary assessment (see also response to recommendation 1a.S1).

References

Jiao, Y., O'Reilly, R., Smith, E., and Orth, D. 2016. Integrating spatial synchrony/asynchrony of population distribution into stock assessment models: a spatial hierarchical Bayesian statistical catch-at-age approach. *ICES Journal of Marine Science* 73:1725-1738. https://doi:10.1093/icesjms/fsw036

Pedersen, M. W., and C. W. Berg. 2017. A stochastic surplus production model in continuous time. *Fish and Fisheries* 18:226–243. https://doi.org/10.1111/faf.12174.

Smirnova, M. A., S. Y. Olova, P. V. Kalchugin, M. I. Bojko, J. H. Park, and A. M. Orlov. 2018. Population structure of Pacific cod Gadus microcephalus in the southern part of the range based on the microsatellite analyses. *Russian Journal of Genetics* 54:670-679. https://doi.org/10.1134/S1022795418060108

Spies, I. 2012. Landscape genetics reveals population subdivision in Bering Sea and Aleutian Islands Pacific cod. *Transactions of the American Fisheries Society* 141:1557-1573. https://doi.org/10.1080/00028487.2012.711265

Spies, I., D. Drinan, E. Petrou, R. Spurr, C. Tarpey, T. Hartinger, and L. Hauser. *In prep.* Evidence for divergent selection and spatial differentiation in a putative zona pellucida gene is indicative of local adaptation in Pacific cod. Submitted to *Molecular Ecology*.

Spies, I., K. M. Gruenthal, D. P. Drinan, A. B. Hollowed, D. E. Stevenson, C. M. Tarpey, and L. Hauser. 2020. Genetic evidence of a northward range expansion in the eastern Bering Sea stock of Pacific cod. *Evolutionary applications* 13:362-375. https://doi.org/10.1111/eva.12874

Tarpey, C., I. Spies, L. Hauser, and T. Kristiansen. *In prep.* A closer look at the genome of Pacific cod using PoolSeq reveals visual adaptation in the eastern Bering Sea and Aleutian Islands.

Weinberg, K. L., C. Yeung, D. A. Somerton, G. G. Thompson, and P. H. Ressler. 2016. Is the survey selectivity curve for Pacific cod (*Gadus macrocephalus*) dome-shaped? Direct evidence from field studies. *Fishery Bulletin* 114:360-369. https://doi.org/10.7755/FB.114.3.8

Table 2.1.1.1.

Counts of reviewer recommendations.

Topic	Subtopic	Reviewer			Total
		Jiao	Magnusson	Sparholt	
1	a	1	1	1	3
	b	3	1	2	6
	c	3	1	1	5
2	a	3	3	3	9
	b	1	1	0	2
	c	1	0	0	1
3	a	0	0	0	0
	b	1	0	0	1
	c	3	1	4	8
4	a	2	1	1	4
	b	0	0	2	2
	c	1	0	0	1
5	a	0	0	0	0
	b	0	0	1	1
	c	1	0	0	1
6	a	1	1	2	4
	b	0	0	0	0
	c	0	0	0	0
	d	0	1	1	2
Grand total:		21	11	18	50

Attachment 2.1.2: A simple, two-area model of the Pacific cod stock in the Bering Sea

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Introduction

A key concern identified by the 2021 CIE review of the stock assessment for Pacific cod (see Attachment 2.1.1) was the lack of understanding regarding the relationship between the fisheries for Pacific cod in the American and Russian portions of the Bering Sea, because the few data available to date suggest that Pacific cod move back and forth between the two areas (see, for example, Figure 2.1.5 in the main text). Because the amount of data available to describe this relationship is fairly small, the reviewers did not suggest attempting to create a full, statistical assessment model incorporating movement between the two areas. However, one reviewer did suggest development of "a simulation study to look into the influence of movement on the stock assessment," and another suggested development of "analytical models" to "understand shifts in the geographic distribution of the stock … extending into Russian waters." This attachment represents a first attempt at responding to these requests.

The study described here consists of developing a very simple, deterministic, age-structured, two-area model, with results focused primarily on age-aggregated (but area-specific) equilibrium outcomes. The primary goals are to understand which variables determine both relative and absolute biomasses and yields in the two areas, how various outcomes may be independent of specific parameters, and how various parameters covary in order to result in particular outcomes.

Area 1 will be defined here as the portion of the Bering Sea under the jurisdiction of the U.S.A., comprised of the Eastern Bering Sea (EBS) and Northern Bering Sea (NBS) survey areas; and area 2 will be defined as the Western Bering Sea (WBS), under the jurisdiction of Russia. From the perspective of managing the American fishery, exploitation by the Russian fishery represents an externality. In principle, harvest rates in the American fishery can be set independently of this externality, or they can be adjusted in light of this externality to achieve an overall (i.e., across areas) harvest objective, and this is among the outcomes explored here.

Methods

Assumptions

The model reflects the following assumptions:

- The stock occupies two areas, indexed 1 and 2.
- Fishery management is designed to achieve a target level of relative spawning per recruit (*rspr*).
- The harvest control rule consists of a single exploitation rate (i.e., no inflection points).
- All parameters are both age- and time-invariant.
- Individual body weight varies linearly with age.
- Time (t) is measured in discrete units of years.
- Population dynamics are entirely deterministic.

- Annual population dynamic processes occur as discrete steps, in the following order:
    - Recruitment
    - Growth
    - Exploitation
    - Natural mortality
    - Movement

Constants

The model makes use of the following constants:

- *amax* is the maximum (terminal) age in the population.
- *arec* is the age of recruitment (to both the exploited and spawning stock).
- *nage* is the number of ages in the model, equal to *amax*–*arec*+1.
- *ntim* is the number of time periods (years) over which population dynamics are simulated by the model, equal to *nage*+2 to assurance convergence to the equilibrium state.
- $rspr_{targ}$ is the target level of *rspr*.

Parameters

The parameters used in the model are as follow:

- *v* is the area-invariant discrete annual natural mortality rate.
- w_{arec} is the area-invariant individual body weight at the age of recruitment (in kg).
- *k* is the area-invariant relative slope of the linear weight-at-age relationship.
- u_1 and u_2 are the area-specific discrete annual exploitation rates.
- $pstay_1$ and $pstay_2$ are the area-specific "staying" probabilities (i.e., the probability that a fish residing in area *i* in year *t* will stay in area *i* in year *t*+1).
- $prect_1$ is the proportion of each year's recruitment that resides in area 1.
- $rect_1$ is the number of individuals (in 1000s) recruiting to area 1 at the start of each year.

System dynamics

Define the following quantities:

- **I** is the identity matrix of order 2.
- **Pmove** is a 2×2 area transition matrix, defined as $\begin{bmatrix} pstay_1 & 1-pstay_2 \\ 1-pstay_1 & pstay_2 \end{bmatrix}$.
- *rtot* is the overall (i.e., across areas) number of individual fish (in 1000s) recruiting to the population each year, computed as $rect_1/prect_1$.
- **Rec** is a 2×*nage* recruitment matrix, the first column of which consists of *rtot*×**prect**, and the remaining elements of which are all zero.
- **w** is a *nage*×1 vector of individual body weights (in kg), with each element defined as $w_{a-arec+1} = w_{arec}\big(1 + k\cdot(a - arec)\big),\ \forall\, arec \le a \le amax$.
- **Inc** is a *nage*×*nage* age transition matrix that increments each age group by 1 each year, consisting of a lower shift matrix (i.e., a matrix comprised entirely of 0s except for the subdiagonal, which is comprised entirely of 1s).
- $\mathbf{Pop}_t$ is the 2×*nage* matrix of population size (in 1000s of fish) in each area and age at time *t*.
- $\mathbf{Cat}_t$ is the 2×*nage* matrix of catch (in 1000s of individuals) in each area and age at time *t*.
- $\mathbf{Bio}_t$ is the 2×*nage* matrix of stock biomass (in tons) in each area and age at time *t*.

- $\mathbf{Yld}_t$ is the 2×*nage* matrix of yield (in tons) in each area and age at time *t*.

Then, starting from an initial condition of $\mathbf{Pop}_1$, for each year *t* from 2 to *ntim*, the system dynamics are given as follows:

$$\mathbf{Pop}_t = \mathbf{Pmove} \cdot \left(\mathbf{I} - diag(\mathbf{u})\right) \cdot (1-v) \cdot \mathbf{Pop}_{t-1} \cdot \mathbf{Inc} + \mathbf{Rec}\,,$$

$$\mathbf{Cat}_t = diag(\mathbf{u}) \cdot \mathbf{Pop}_t\,,$$

$$\mathbf{Bio}_t = \mathbf{Pop}_t \cdot diag(\mathbf{w})\,, \text{and}$$

$$\mathbf{Yld}_t = \mathbf{Cat}_t \cdot diag(\mathbf{w})\,.$$

Verification that the system reached had equilibrium by time *t*=*ntim* was accomplished by confirming that each of the above four matrices had the same value at times *t*=*ntim* and *t*=*ntim*–1.

Age-aggregated system equilibria

The first part of this subsection deals with the general case, in which the values of $pstay_1$, $pstay_2$, and $prect_1$ are independent.

For notational convenience, define the following pair of matrices:

$$\mathbf{G} = \mathbf{Pmove} \cdot \left(\mathbf{I} - diag(\mathbf{u})\right) \text{ and}$$

$$\mathbf{H} = \mathbf{I} - \mathbf{G} \cdot (1-v)\,.$$

Then, the age-aggregated (but area-specific) 2×1 system equilibrium vectors can be written as follows:

$$\mathbf{pop} = \mathbf{H}^{-1} \cdot \mathbf{prect} \cdot rtot\,,$$

$$\mathbf{cat} = diag(\mathbf{u}) \cdot \mathbf{pop}\,,$$

$$\mathbf{bio} = \left(\mathbf{H}^{-1} + k \cdot \mathbf{G} \cdot \mathbf{H}^{-2} \cdot (1-v)\right) \cdot \mathbf{prect} \cdot rtot \cdot w_{arec}\,, \text{and}$$

$$\mathbf{yld} = diag(\mathbf{u}) \cdot \mathbf{bio}\,.$$

Verification of the above equations was accomplished by confirming that each vector was equal to the vector obtained by summing the corresponding matrix at time *t*=*ntim* across age; for example,

$$pop_i = \sum_{j=1}^{nage} (\mathbf{Pop}_{ntim})_{i,j}\,, \text{for areas } i = 1{,}2\,.$$

Equilibrium *rspr* in this model can be written as a quadratic function of u_1 and u_2, meaning that a closed-form solution for u_1 as a function of u_2 (or vice-versa), conditional on $rspr=rspr_{targ}$, is available. The value of u_1 that satisfies $rspr=rspr_{targ}$ for the special case where $u_2=u_1$ (denoted $\bar{u}$) is independent of **prect** and **pstay**.

Likewise, equilibrium bio_1 and bio_2 in this model can be written as quadratic functions of $pstay_1$ and $pstay_2$, meaning that, with $pbio_i$ defined as $bio_i/(bio_1+bio_2)$ for i=1 or i=2, a closed-form solution for $pstay_1$ as a function of $pstay_2$ (or vice-versa), conditional a specified value of $pbio_1$ (or $pbio_2$), is available.

The remainder of this subsection deals with a particular special case. For a generic probability (or proportion) parameter p, consider the special case where $pstay_1=prect_1=p$ and $pstay_2=1-p$, hereafter referred to as the “balanced” special case.

For notational convenience, let a composite parameter m be defined as follows:

$$m = \big(p \cdot (1-u_1) + (1-p) \cdot (1-u_2)\big) \cdot (1-v)\,.$$

Then, the age-aggregated system equilibria in this special case can be written quite simply as follows:

$$\mathbf{pop} = \begin{bmatrix} p \\ 1-p \end{bmatrix} \cdot \left(\frac{1}{1-m}\right) \cdot rtot\,,$$

$$\mathbf{cat} = \begin{bmatrix} p \cdot u_1 \\ (1-p) \cdot u_2 \end{bmatrix} \cdot \left(\frac{1}{1-m}\right) \cdot rtot\,,$$

$$\mathbf{bio} = \begin{bmatrix} p \\ 1-p \end{bmatrix} \cdot \left(\frac{1-(1-k)\cdot m}{(1-m)^2}\right) \cdot rtot \cdot w_{arec}\,, \text{and}$$

$$\mathbf{yld} = \begin{bmatrix} p \cdot u_1 \\ (1-p) \cdot u_2 \end{bmatrix} \cdot \left(\frac{1-(1-k)\cdot m}{(1-m)^2}\right) \cdot rtot \cdot w_{arec}\,.$$

Note that the area proportions of the system equilibria take very simple forms in this special case. For population and biomass, the proportions in areas 1 and 2 are simply p and $1-p$, respectively, which is the reason for referring to this as the “balanced” special case. For catch and yield, the area proportions are only slightly more complicated, being given by

$$\frac{p \cdot u_1}{p \cdot u_1 + (1-p) \cdot u_2} \text{ and } \frac{(1-p) \cdot u_2}{p \cdot u_1 + (1-p) \cdot u_2}\,, \text{respectively.}$$

<u>Input values</u>

Values of constants and parameters that do not vary by area were estimated as follows:

- The discrete annual natural mortality rate (v) was estimated as $1 - \exp(-M)$, where M was set at the value of 0.354 estimated in last year’s stock assessment by Model 19.12a (Thompson et al. 2020), giving v=0.30.
- The maximum age, *amax*, was set at 50 years, corresponding to the age at which only 1 out of a million recruits is still alive in the equilibrium unfished stock, given the estimated value of v. A relatively high value of *amax* seems appropriate, given the model’s lack of an “age-plus” group.
- The age at recruitment, *arec*, was set as follows:
    1. Candidate values of *arec*=2, *arec*=3, and *arec*=4 were considered.
    2. Values of $rect_1$, w_{arec}, and k for each candidate value of *arec* were calculated on the basis of the results from Model 19.12a in last year’s assessment (Thompson et al. 2020; see below for further details regarding calculation of w_{arec} and k).

3. After setting $prect_1$=$pstay_1$=1.0, $pstay_2$=0.0, u_2=0, and u_1 at the value that satisfies $rspr$=$rspr_{targ}$, equilibrium yield and equilibrium biomass for area 1 were computed.
4. The relative differences between the equilibrium yield and biomass values for area 1 computed in step 3 and the corresponding values from Model 19.12a in last year's assessment (Thompson et al. 2021) were computed.
5. The relative differences computed in step 4 were used to compute a root-mean-squared-relative-error (*rmsre*) for each of the three candidate values of *arec*, giving: *rmsre*(*arec*=2) = 0.190, *rmsre*(*arec*=3) = 0.131, and *rmsre*(*arec*=4) = 0.186.
6. Because an *arec* value of 3 years exhibited the lowest *rmsre* of the three candidate *arec* values, it was adopted for use here.

- The number of individuals (in 1000s) recruiting to area 1 at the start of each year, $rect_1$, was set at the estimate of equilibrium *unexploited* numbers at age 3 estimated in last year's stock assessment by Model 19.12a (Thompson et al. 2020), giving a value of $rect_1$=182,351 (note that this value differs from Model 19.12a's corresponding estimate of equilibrium numbers at age 3 under F=$F_{40\%}$ by less than 0.4%).
- The parameters of the linear weight-at-age relationship (w_{arec} and k) were estimated from the begin-year base weights at ages 3-20 estimated in last year's stock assessment by Model 19.12a (Thompson et al. 2020) via ordinary least squares, giving w_{arec}=0.91 and k=1.04 (R^2=0.99).
- The target value of *rspr*, $rspr_{targ}$, was set at 40%, corresponding to the ABC harvest control rule.

Values of parameters that varied by area were estimated on the basis of the following data:

- Biomass proportions for areas 1 and 2 as estimated by O'Leary et al. (2021).
- Absolute biomass (in tons) for area 1 as estimated in Model 19.12a by Thompson et al. (2020).
- Catch (in tons) for area 2 as reported by Lajus et al. (2019).

Estimated biomass proportions are available only for those six years in which surveys were conducted in both parts of area 1 (i.e., EBS and NBS) and also in area 2 (WBS): 1985, 1988, 2001, 2005, 2010, and 2017. These were inflated to units of absolute biomass for the combined areas 1 and 2 by dividing the corresponding absolute biomass estimate for area 1 by the area 1 biomass proportion. These, in turn, were multiplied by the area 2 biomass proportions to obtain estimates of absolute biomass for area 2.

Area 2 exploitation rates were calculated by dividing each year's overall area 2 catch (obtained by summing the values for the various zones and subzones in Tables 6-12 of Lajus et al. (2019)) by the corresponding area 2 absolute biomass computed above. However, because the catch time series goes back only to 2001, the first two years of absolute biomass estimates (1985 and 1988) had to be dropped. Moreover, the exploitation rate calculated for 2001 was so high (=13.31) as to be obviously untenable (note that the catch for this year was not particularly high, being about 9% below the time series average, but the biomass estimate was extremely low, being about 98% below the time series average), so 2001 was also dropped from the time series.

This left the following time series of estimated biomass proportions and exploitation rates for area 2:

Quantity	2005	2010	2017
Biomass proportion	0.15	0.11	0.31
Exploitation rate	0.28	0.61	0.15

Because the "balanced" special case requires specification of fewer probabilities/proportions than the general case (1 rather than 3), most of the examples described here conform to the former. Example values of *p* were chosen by taking the complement of the minimum and maximum biomass proportion values in the table above (i.e., so as to correspond to area 1 rather than area 2), rounding slightly, and including one intermediate value, giving $p = \{0.70, 0.80, 0.90\}$.

In addition, some examples of "unbalanced" models were also developed, in which:

- $pstay_2 = \{0.0, 0.2, 0.4\}$, for the special case $prect_1$=$pstay_1$=0.8 ($pstay_2$=0.2 actually corresponds to the "balanced" special case, but is included in the set here for completeness).
- $pstay_2$ varied continuously within the range (0,1), with $pstay_1$ adjusted so as to achieve $pbio_1$=p.

In general, u_1 was held constant at $\bar{u} = 0.247$, except when adjusted so to achieve $rspr$=$rspr_{targ}$, conditional on u_2.

Most examples allowed u_2 to vary continuously within the range (0,1). However, examples were also developed by identifying the minimum and maximum exploitation rates in the table above, rounding the latter slightly, and including two intermediate values, giving $u_2 = \{0.15, 0.30, 0.45, 0.60\}$.

Results

Results are displayed in Figures 2.1.2.1-7, which employ consistent formatting conventions to the extent possible. Gray dashed lines represent quantities that do not vary between models (in particular, the gray vertical dashed line in Figures 2.1.2.1-6 represents $\bar{u}$). Results for area 1 and for the combined areas are represented by blue, orange, and green curves for p values of 0.7, 0.8, and 0.9, respectively; while the corresponding results for area 2 are represented by brown, red, and purple curves, respectively. In Figures 2.1.2.1-4, results for the case where u_1 is not adjusted in order to compensate for u_2 departures from $\bar{u}$ are represented by solid curves, while the corresponding results for the case where u_1 is adjusted in order to achieve $rspr$=$rspr_{targ}$ are represented by colored dashed curves. In Figures 2.1.2.5 and 2.1.2.6, the colored dashed and dotted curves correspond to unbalanced models, regardless of whether u_1 is adjusted. The color coding also remains the same in Figure 2.1.2.7, but symbols are used to distinguish between alternative values of u_2, with values of 0.15, 0.30, 0.45, and 0.60 being represented by squares, diamonds, triangles, and circles, respectively. Also, in Figure 2.1.2.7 only, labels of the form "p=0.x" mean that $prect_1$=$pstay_1$=$pbio_1$=0.x, but $pstay_2$ is actually variable (unlike the balanced case where p=0.x means that $prect_1$=$pstay_1$=0.x and $pstay_2$=1–0.x); and the horizontal dashed lines show how all curves intersect at the corresponding balanced value of $pstay_2$.

The upper panel of Figure 2.1.2.1 illustrates how $rspr$ varies with u_2 for each of the three balanced models when u_1 is not adjusted, while the lower panel illustrates how u_1 would need to be adjusted in order to achieve $rspr$=$rspr_{targ}$ for each of the three balanced models. Note that, in both the upper and lower panels, the slope of the relationship varies inversely with p, which would be expected, because higher values of p imply that the stock is concentrated primarily in area 1, meaning that the impact of an increase in u_2 is smaller. In the lower panel, for p=0.7, the area 1 fishery with u_1 adjusted would shut down entirely if u_2 were to exceed a value of about 0.82.

Figure 2.1.2.2 shows how absolute biomass, both by area (upper panel) and overall (lower panel) varies with u_2, both when u_1 is not adjusted and when it is adjusted in order to achieve $rspr$=$rspr_{targ}$, for each of the three balanced models. Note that, by definition, all three models result in the same area 1 absolute biomass in the case where u_1 is adjusted in order to achieve $rspr$=$rspr_{targ}$ (horizontal gray dashed line in upper panel). Both the area 2 absolute biomass and the overall absolute biomass are also independent of u_2 when u_1 is adjusted, but the amounts differ between models (colored dashed lines in both panels).

Figure 2.1.2.3 is the absolute yield analogue of Figure 2.1.2.2. Here, however, the area-specific values vary with u_2 even in the case where u_1 is adjusted (colored dashed curves in the upper panel; the gray dashed line in the upper panel now represents the absolute yield at which the curves intersect, corresponding to $u_1 = u_2 = \bar{u}$). Absolute yield in area 1 decreases with increasing u_2 regardless of whether u_1 is adjusted, but the decreases are larger when u_1 is adjusted, with the differences between the unadjusted and adjusted yields varying inversely with p.

The upper panel of Figure 2.1.2.4 shows the *proportions* of the overall biomass present in each area, and illustrates the principle that, for balanced models, the biomass proportions are independent of the exploitation rate in either area, being equal simply to p and $1-p$ for areas 1 and 2, respectively. The lower panel of Figure 2.1.2.4 is the yield proportion analogue of the upper panel. In contrast to the biomass proportions, the yield proportions do depend on the exploitation rates in the two areas, with the qualitative shapes of the curves being roughly similar to the absolute yield curves in Figure 2.1.2.3, except that the intersection of the area 1 curves occurs at $u_2=0$ rather than at $u_2=\bar{u}$.

Figure 2.1.2.5 shows how two of the curves from the upper panel of Figure 2.1.2.4, specifically those for $p=0.8$ (implying $pstay_2=0.2$), change when the corresponding balanced model from Figure 2.1.2.4 is replaced by either of two unbalanced models; specifically, where $pstay_2=0.0$ or $pstay_2=0.4$. The upper panel represents the case where u_1 is unadjusted and the lower panel represents the case where u_1 is adjusted. The impacts of changing $pstay_2$ from a value of 0.2 to a value of 0.0 or 0.4 on the biomass proportions are small, regardless of whether u_1 is adjusted.

Figure 2.1.2.6 is the yield proportion analogue of Figure 2.1.2.5. Similar to the impacts on biomass proportions shown in Figure 2.1.2.5, the impacts of changing $pstay_2$ from a value of 0.2 to a value of 0.0 or 0.4 on the yield proportions are small, regardless of whether u_1 is adjusted.

Like Figures 2.1.2.5 and 2.1.2.6, Figure 2.1.2.7 explores some of the impacts of unbalanced models. Here, $prect_1=pbio_1=p$, but $pstay_1$ is allowed to vary and $pstay_2$ is adjusted so as to set the area 2 biomass proportion equal to $pbio_2=1-pbio_1$, for the usual values of p and various values of u_2. The necessary adjustments to $pstay_2$ are large relative to the associated changes in $pstay_1$, and become increasingly steep both with increasing p and increasing u_2. Looking at the problem from the opposite perspective, only a fairly narrow range of $pstay_1$ values is compatible with any of the p values examined, whereas all or nearly all of the feasible range of $pstay_2$ values is compatible (conditional on $pstay_1$).

Discussion

Given that the previous attempts at incorporating movement between the EBS and NBS survey areas into the stock assessment model have proven unsuccessful (Thompson 2018, Thompson et al. 2020), and given that the data limitations for statistical estimation of parameters governing movement between the combined EBS and NBS survey areas and the WBS are even more serious than those pertaining to movement between the EBS and NBS survey areas, it is reasonable to consider a simpler, less statistical, model, if only for heuristic purposes.

Although the input values used for the parameters and constants required by the model developed here were not estimated with the same statistical rigor as those in a modern, integrated stock assessment model, neither are they arbitrary, and for those parameters where it was necessary to resort to ranges of values rather than best point estimates (e.g., WBS biomass proportions ranging from 0.10-0.30 and WBS exploitation rates ranging from 0.15-0.60), those ranges seem reasonably likely to bracket the point estimates that would result from an integrated stock assessment model if it were possible to create one.

In general, the results shown here illustrate the intuitive principle that, the more the stock is concentrated in one area (either due to recruitment being concentrated in that area, fish tending not to stray from that area once they arrive, or both), the smaller the impacts of fishing in the other area.

Another pair of intuitive results is that, if the exploitation rate in area 1 is left constant, increased fishing in area 2 will result in reduced equilibrium yield in area 1 and, if the exploitation rate in area 1 is adjusted in order to achieve a target level of overall (i.e., across areas) relative spawning per recruit, the reduction in area 1 yield will be even greater.

One more result that may have some generality is that, for some quantities such as the inter-area biomass proportions, some parameters may have very little impact. For example, in a balanced model, the equilibrium biomass proportions are entirely independent of the exploitation rate in either area (upper panel of Figure 2.1.2.4). Although perfectly balanced models (in the sense used here) are almost certain not to occur in nature, modest departures therefrom may result in outcomes that are only slightly different from the balanced case (Figure 2.1.2.5).

References

Lajus, D., D. Safronova, A. Orlov, and R. Blyth-Skyrme. 2019. MSC Sustainable Fisheries Certification: Western Bering Sea Pacific cod and Pacific halibut longline. Marine Stewardship Council. Marine House, 1 Snow Hill, London, UK, EC1A 2DH. 327 p. https://fisheries.msc.org/en/fisheries/western-bering-sea-pacific-cod-and-pacific-halibut-longline/@@assessments

O'Leary, C., S. Kotwicki, G. R. Hoff, J. T. Thorson, V. V. Kulik, J. N. Ianelli, R. R. Lauth, D. G. Nichol, J. Conner, and A. E. Punt. 2021. Estimating spatiotemporal availability of transboundary fishes to fishery-independent surveys. *Journal of Applied Ecology*. https://doi.org/10.1111/1365-2664.13914

Thompson, G. G. 2018. Assessment of the Pacific cod stock in the Eastern Bering Sea. *In* Plan Team for the Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 1-386. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501. https://apps-afsc.fisheries.noaa.gov/refm/docs/2018/EBSpcod.pdf

Thompson, G. G., J. Conner, S. K. Shotwell, B. Fissel, T. Hurst, B. Laurel, L. Rogers, and E. Siddon. 2020. Assessment of the Pacific cod stock in the Eastern Bering Sea. *In* Plan Team for the Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 1-344. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501. https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/EBSpcod.pdf

Figures

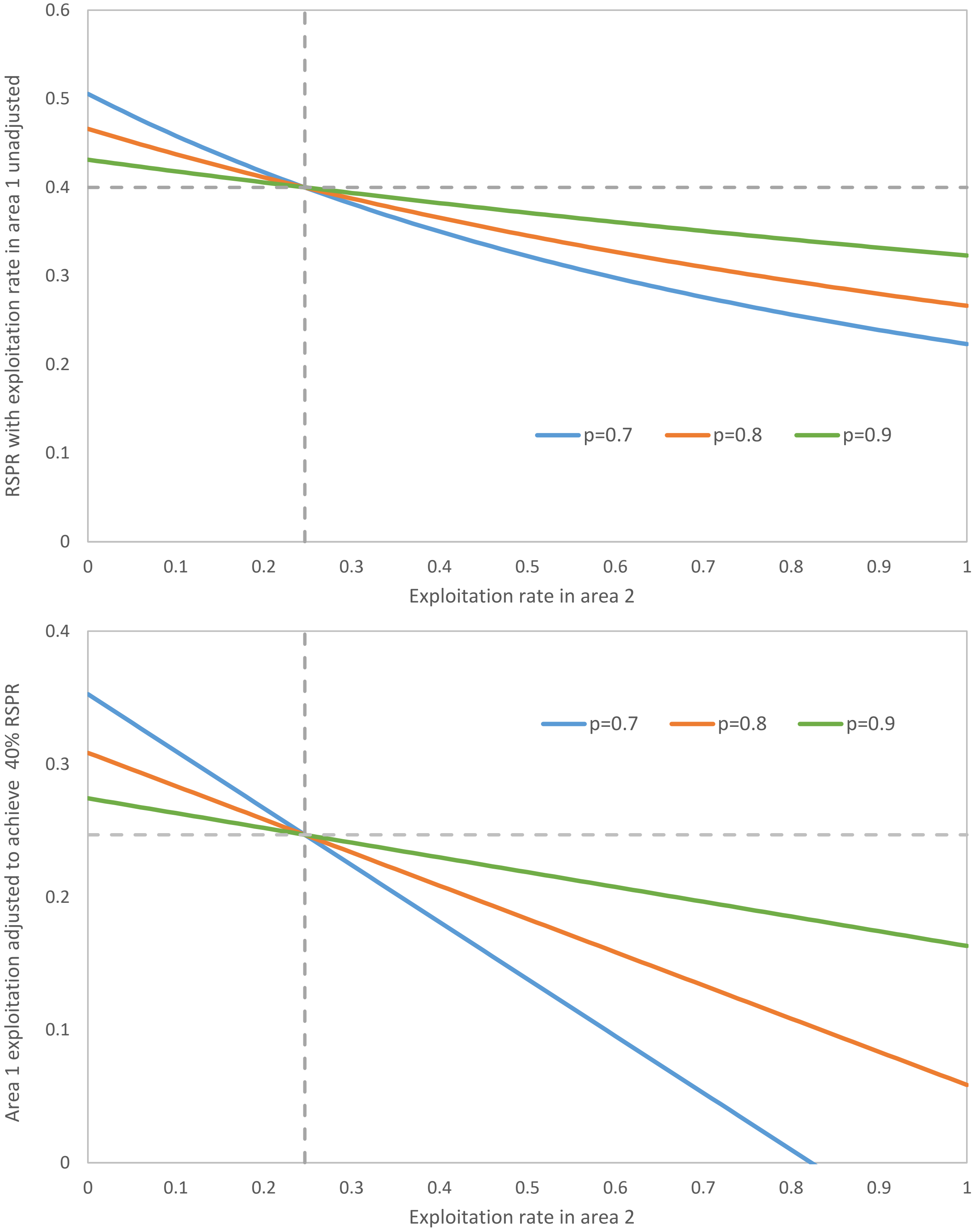

Figure 2.1.2.1. Equilibrium *rspr* with u_1 unadjusted (upper panel) and adjustments to u_1 necessary to achieve *rspr*=0.4 (lower panel) as functions of the exploitation rate in area 2 for three balanced models.

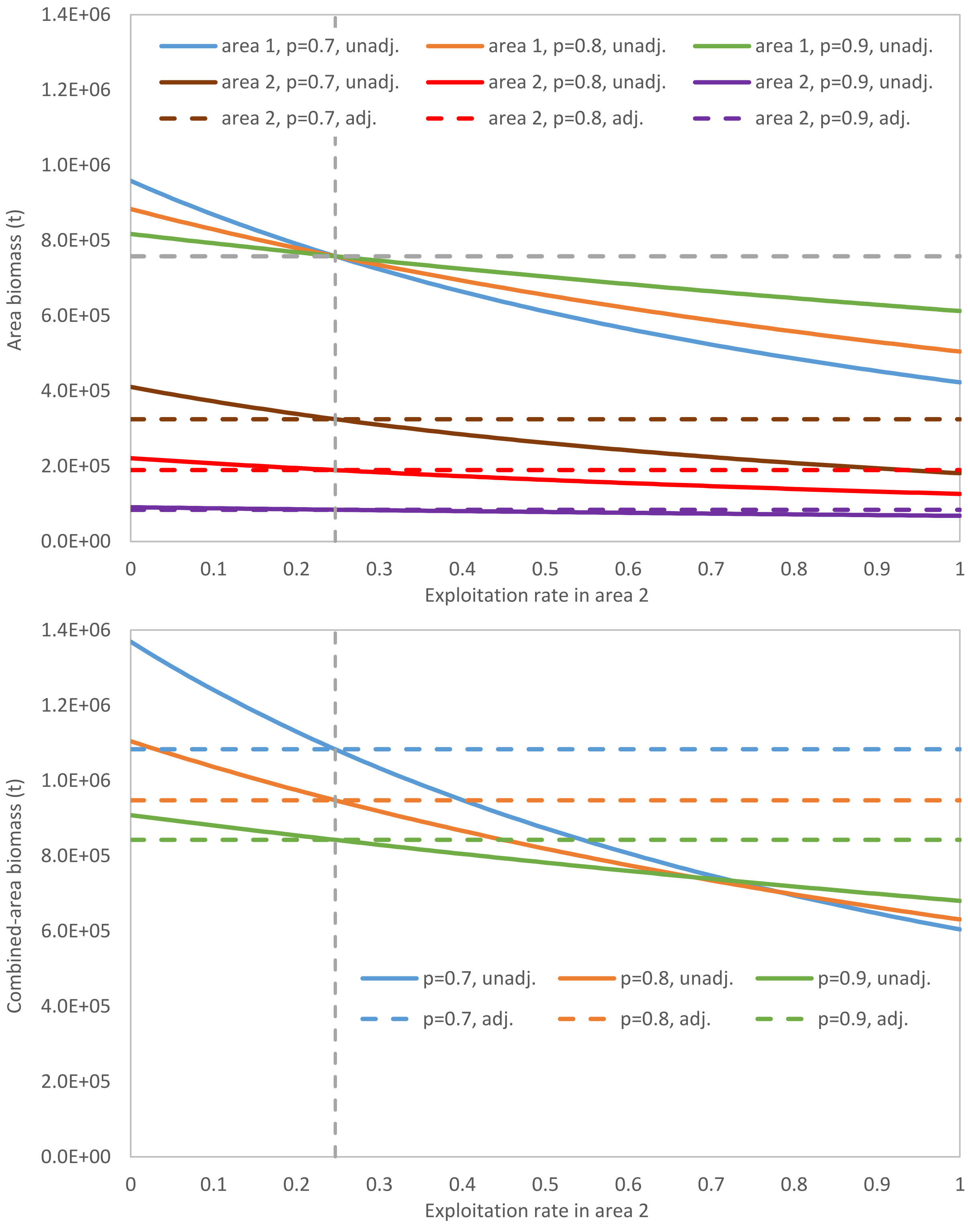

Figure 2.1.2.2. Equilibrium biomasses as functions of the area 2 exploitation rate for three balanced models.

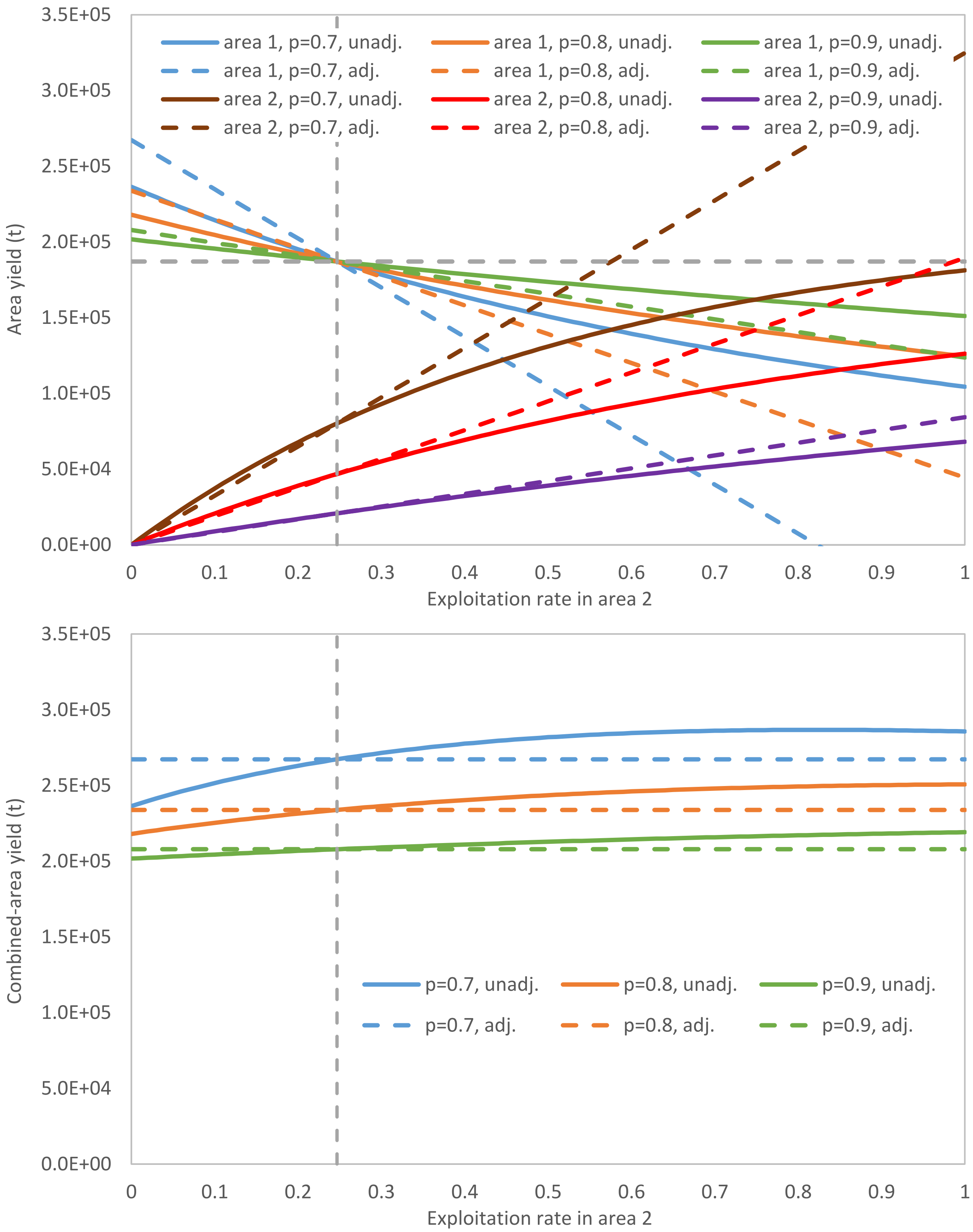

Figure 2.1.2.3. Equilibrium yields as functions of the area 2 exploitation rate for three balanced models.

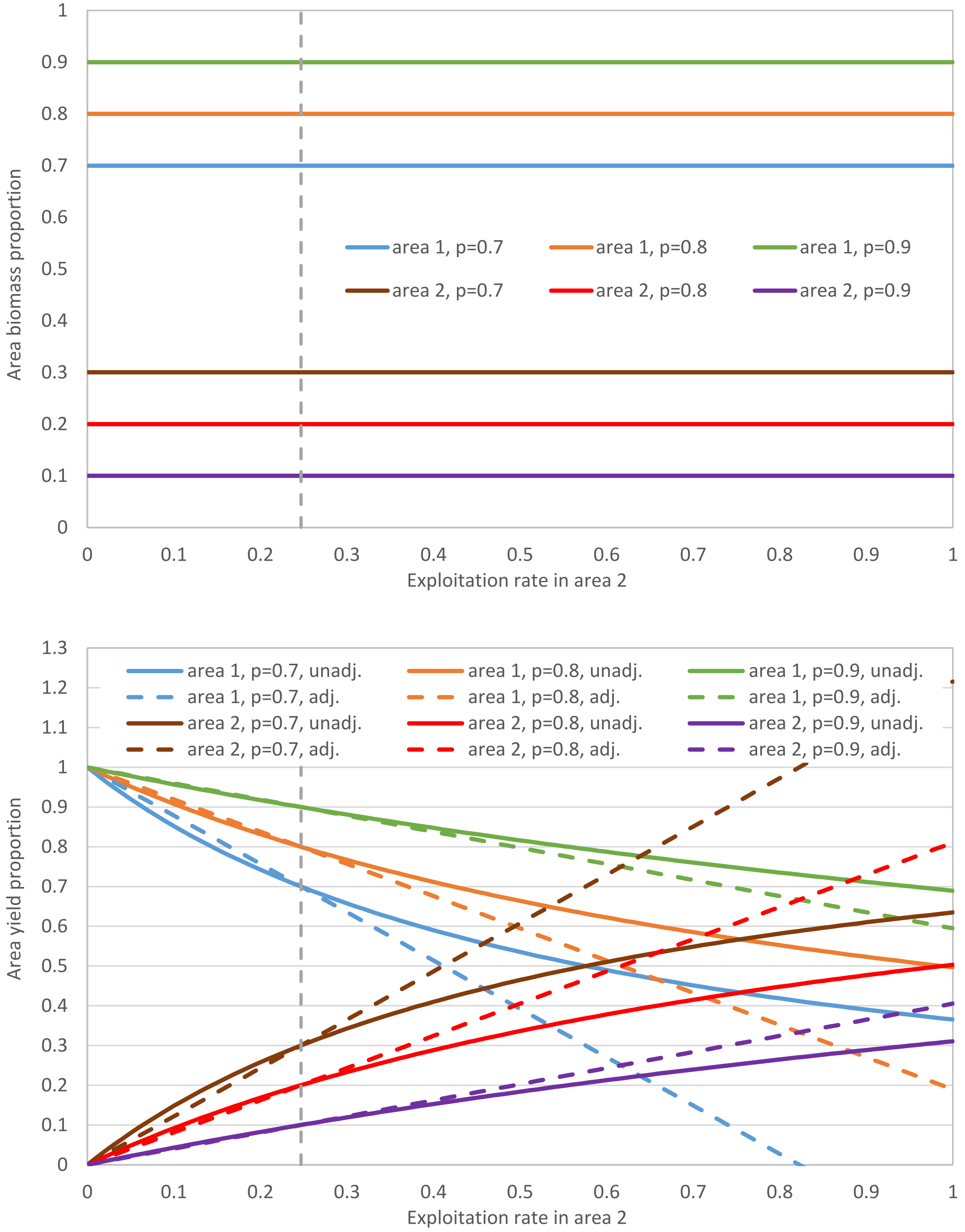

Figure 2.1.2.4. Equilibrium biomass proportions (upper panel) and yield proportions (lower panel) as functions of the exploitation rate in area 2 for three balanced models.

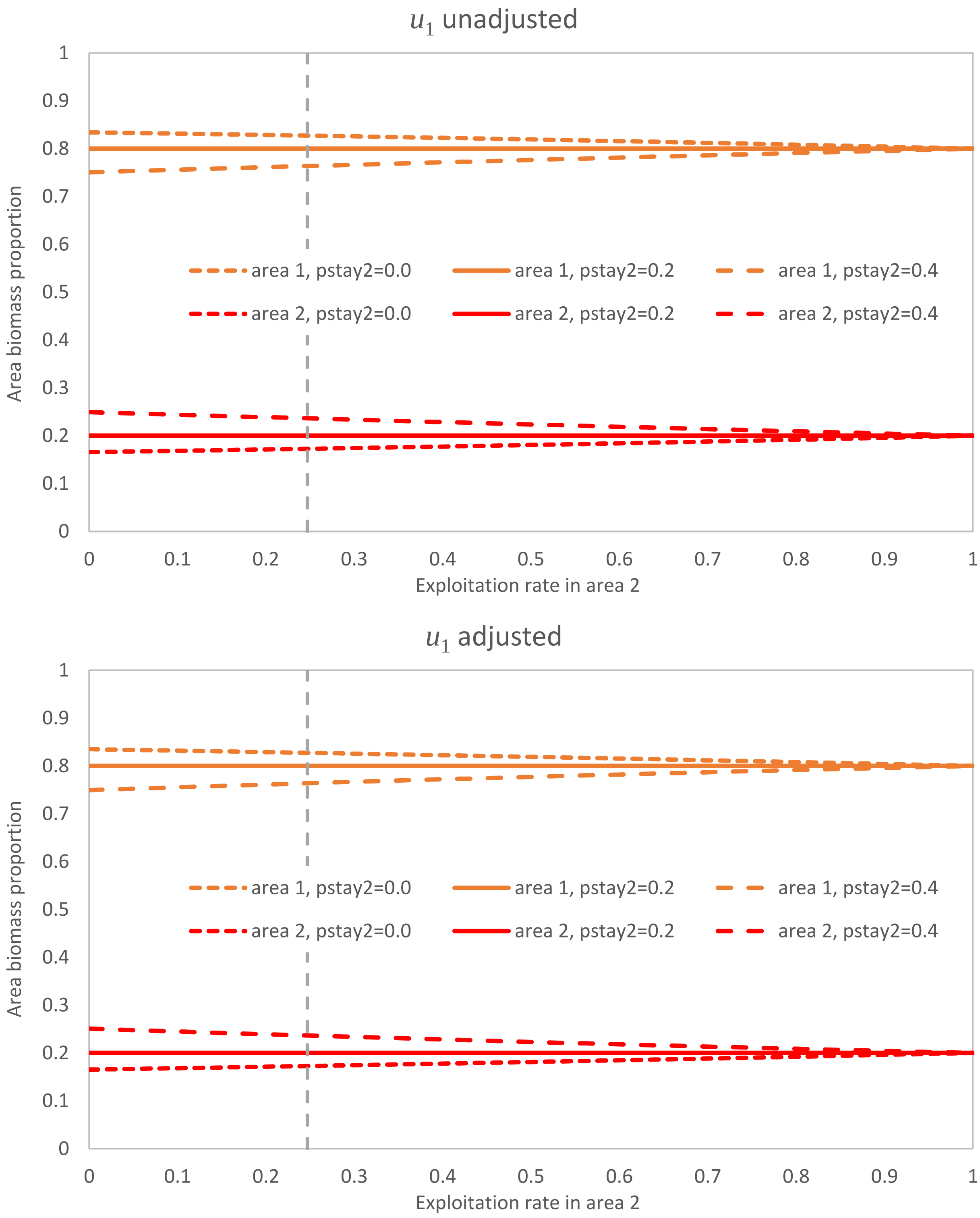

Figure 2.1.2.5. Equilibrium biomass proportions with u_1 unadjusted (upper panel) and with u_1 adjusted (lower panel) as functions of the exploitation rate in area 2 for one balanced and two unbalanced models.

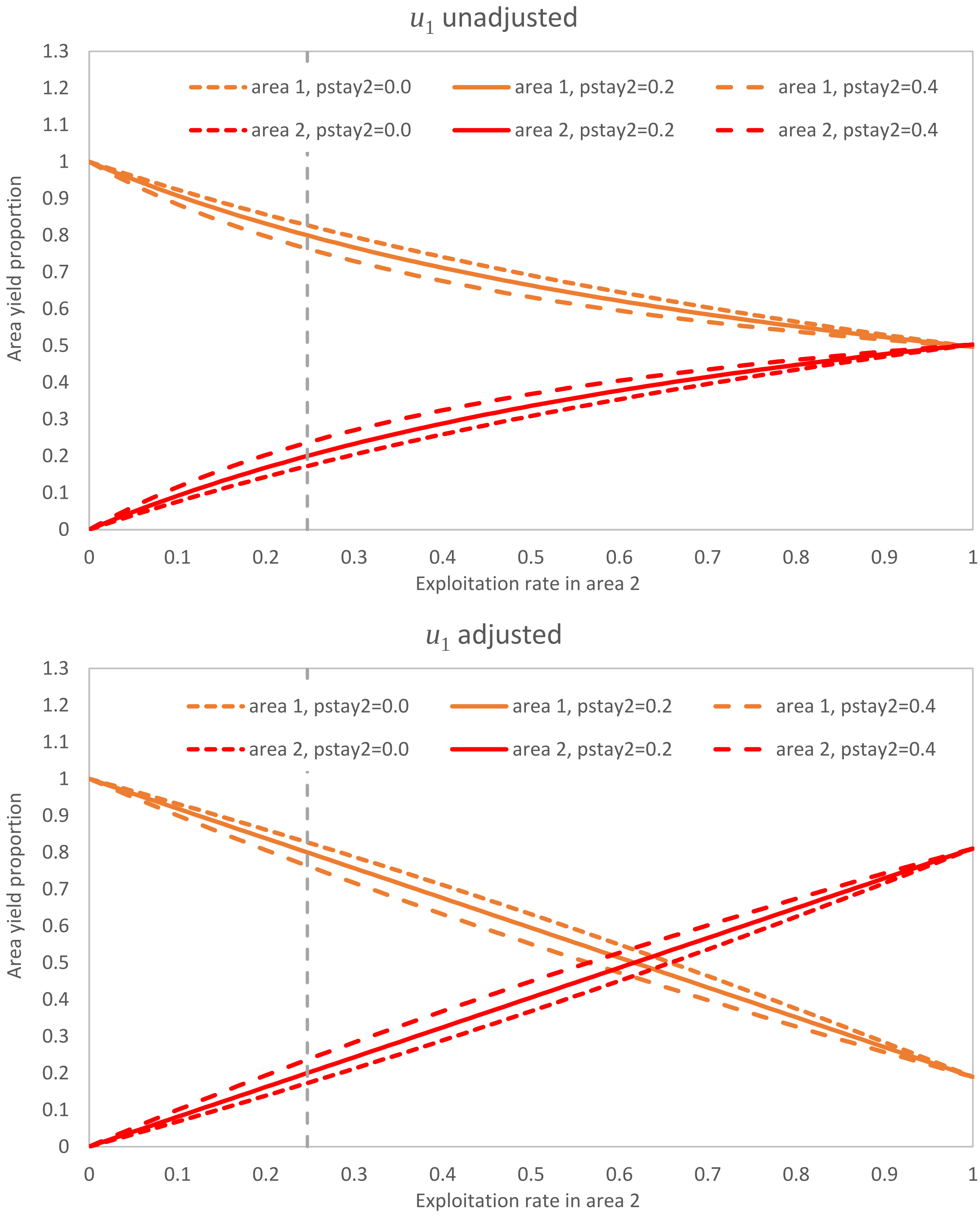

Figure 2.1.2.6. Equilibrium yield proportions with u_1 unadjusted (upper panel) and with u_1 adjusted (lower panel) as functions of the exploitation rate in area 2 for one balanced and two unbalanced models.

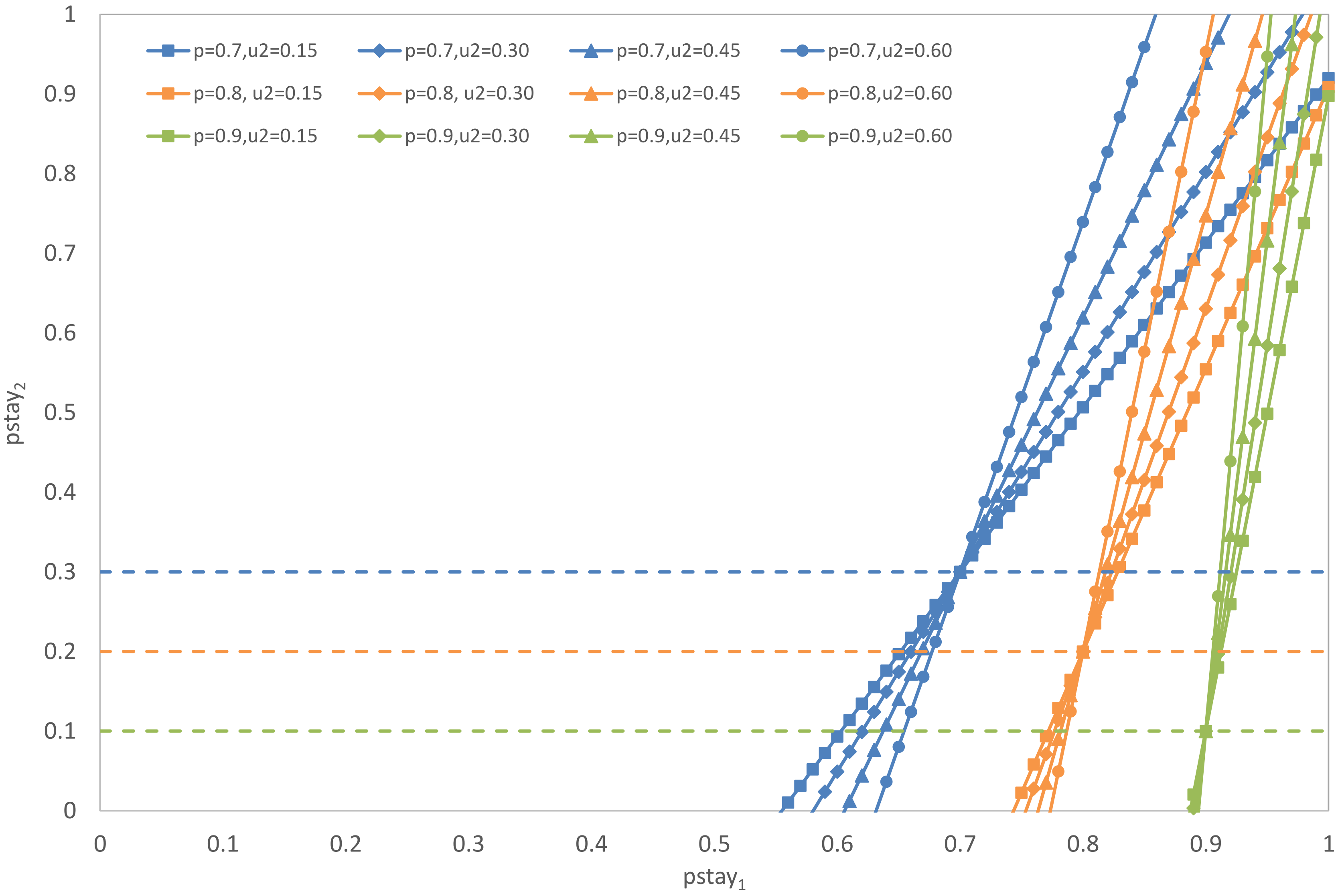

Figure 2.1.2.7. Adjustments to *pstay*$_2$ needed in order to set the proportion of biomass in area 2 equal to 1−*pbio*$_1$, as functions of *pstay*$_1$, for twelve unbalanced models (factorial design of three values of *prect*$_1$=*pbio*$_1$=*p* and four values of *u*$_2$).

Attachment 2.1.3: Application of the harvest control rule: Before or after model averaging?

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Introduction

For the last three years, members of the North Pacific Fishery Management Council's BSAI Groundfish Plan Team ("Team") and Scientific and Statistical Committee (SSC) have debated with assessment authors regarding the issue of whether, in the context of ensemble modeling, the harvest control rules that are used to set the overfishing level (*OFL*) and the upper limit on acceptable biological catch (*ABC*, used here in place of *maxABC* in the interest of brevity) should be applied *before* or *after* model averaging. The two approaches may be summarized as follows (for simplicity, the Tier 3 harvest control rules are assumed here):

- In the "before" approach:
    1. Compute the model-specific values of $F_{35\%}$ (for *OFL*) or $F_{40\%}$ (for *ABC*) and $B_{40\%}$.
    2. Use the values obtained in Step 1 to parameterize *model-specific* harvest control rules.
    3. Compute the model-specific projected female spawning biomass values.
    4. Evaluate each *model-specific* harvest control rule at the respective *model-specific* projected female spawning biomass.
    5. Apply the resulting *model-specific* F_{OFL} or F_{ABC} values to their respective models.
    6. Average the resulting model-specific *OFL*s or *ABC*s.
- In the "after" approach:
    1. Proceed as in Step 1 of the "before" approach, *but then average* the model-specific values of $F_{35\%}$ (for *OFL*) or $F_{40\%}$ (for *ABC*) and $B_{40\%}$.
    2. Use the values obtained in Step 1 to parameterize an *average* harvest control rule.
    3. Proceed as in Step 3 of the "before" approach, *but then average* the model-specific projected female spawning biomass values.
    4. Evaluate the *average* harvest control rule at the *average* projected female spawning biomass.
    5. Apply the resulting *average* F_{OFL} or F_{ABC} to each model in the ensemble.
    6. Proceed as in Step 6 of the "before" approach.

Methods

To investigate the properties of the two procedures, a highly simplified system was evaluated, focusing just on ABC, in the interest of simplicity.

Assumptions

- The harvest control rule used to set the upper limit on the fishing mortality limit corresponding to ABC consists of a simple linear relationship, viz., $F_{ABC} = F_{40\%} \times (B/B_{40\%})$, where B represents the projected level of female spawning biomass for the coming year, $F_{40\%}$ is the fishing mortality rate that sets equilibrium spawning biomass per recruit equal to 40% of the unfished equilibrium

spawning biomass per recruit, and $B_{40\%}$ is the equilibrium spawning biomass when the stock is fished at a rate of $F_{40\%}$.
- Male spawning biomass is equal to female spawning biomass.
- Exploitable biomass for the stock is equal to the sum of female and male spawning biomass.
- The nature of the assessment models is such that catch is equal to the product of F and exploitable biomass.
- The set of models in the ensemble is immense.
- The set of $F_{40\%}$, $B_{40\%}$, and B estimates jointly follow a trivariate lognormal distribution.
- All models are weighted equally.
- The mean is used as the point estimate of any quantity.

Notation

- $[\mu_1 \quad \sigma_1]$, $[\mu_2 \quad \sigma_2]$, and $[\mu_3 \quad \sigma_3]$ represent the log-scale means and standard deviations of $F_{40\%}$, $B_{40\%}$, and B, respectively.
- ρ_{12}, ρ_{13}, and ρ_{23} represent the log-scale correlations between $F_{40\%}$ and $B_{40\%}$, $F_{40\%}$ and B, and $B_{40\%}$ and B, respectively.
- m_X and CV_X represent the mean and coefficient of variation of quantity X, respectively.
- Names of statistics pertaining to the special case where all correlations are zero have suffixes that begin with “0.”
- Names of statistics pertaining to the “before” and “after” approaches have suffixes that end with “*bef*” and “*aft*,” respectively.

Results

Special case: all correlations = 0

“Before” approach:

- $m_{0.FABC.bef} = \exp\left(\mu_1 - \mu_2 + \mu_3 + \frac{{\sigma_1}^2+{\sigma_2}^2+{\sigma_3}^2}{2}\right)$
- $CV_{0.FABC.bef} = \sqrt{\exp({\sigma_1}^2 + {\sigma_2}^2 + {\sigma_3}^2) - 1}$
- $m_{0.ABC.bef} = 2\exp\left(\mu_1 - \mu_2 + 2\mu_3 + \frac{{\sigma_1}^2+{\sigma_2}^2}{2} + 2{\sigma_3}^2\right)$
- $CV_{0.ABC.bef} = \sqrt{\exp\left({\sigma_1}^2 + {\sigma_2}^2 + 4{\sigma_3}^2\right) - 1}$

“After” approach:

- $m_{0.FABC.aft} = m_{0.FABC.bef}$
- $CV_{0.FABC.aft} = 0$
- $m_{0.ABC.aft} = m_{0.ABC.bef}\exp(-{\sigma_3}^2)$
- $CV_{0.ABC.aft} = \sqrt{\exp({\sigma_3}^2) - 1}$

Ratios (“after” relative to “before”):

- $\frac{m_{0.FABC.aft}}{m_{0.FABC.bef}} = 1$
- $\frac{CV_{0.FABC.aft}}{CV_{0.FABC.bef}} = 0$

- $\frac{m_{ABC.aft}}{m_{ABC.bef}} = \exp(-{\sigma_3}^2)$
- $\frac{CV_{ABC.aft}}{CV_{ABC.bef}} = \sqrt{\frac{\exp({\sigma_3}^2)-1}{\exp({\sigma_1}^2+{\sigma_2}^2+4{\sigma_3}^2)-1}}$

The ratio of the ABC means is monotone decreasing w.r.t. σ_3 (Figure 2.1.3.1), and the ratio of the ABC CVs is monotone decreasing w.r.t. both σ_1 and σ_2. However, the latter ratio is non-monotone w.r.t. σ_3.

Let:

$$y = {\sigma_1}^2 + {\sigma_2}^2 \,,$$

$$u(y) = \left(\exp(-y)\left(\sqrt{1-\exp(-y)}+1\right)\right)^{1/3} \,,$$

and

$$v(y) = \frac{3}{2}\left(u(y) + \frac{\exp(-y)}{u(y)}\right) + 1 \,.$$

Then, the ratio of the ABC CVs reaches a maximum at

$$\sigma_3 = \sigma_{3.max}(y) = \sqrt{\ln\left(\frac{1}{3}\left(\sqrt{v(y)} + \sqrt{\frac{2}{\sqrt{\sqrt{v(y)}}} - v(y) + 3} + 1\right)\right)} \,.$$

Figure 2.1.3.2 shows an example with *y* set at a value of 0.5. Here, the ratio of the ABC CVs increases w.r.t. σ_3 from a value of 0 at $\sigma_3 = 0$ to a value of about 0.288 at $\sigma_3 = \sigma_{3.max}(0.5) \approx 0.488$, then decreases w.r.t. σ_3 thereafter.

As *y* becomes large, $\sigma_{3.max}$ reaches an upper asymptote of $\sqrt{\ln(4/3)} \approx 0.536$ (Figure 2.1.3.3). Figure 2.1.3.4 shows the ratio of the ABC CVs as a function of *y* for various fixed values of σ_3 and also with σ_3 set according to the above formula. Note that the ratio of the ABC CVs can never exceed 0.5.

General case: correlations potentially ≠ 0

"Before" approach:

- $m_{FABC.bef} = m_{0,FABC.bef}\exp(-\rho_{12}\sigma_1\sigma_2 + \rho_{13}\sigma_1\sigma_3 - \rho_{23}\sigma_2\sigma_3)$
- $CV_{FABC.bef} = \sqrt{\exp\left({\sigma_1}^2 + {\sigma_2}^2 + 4{\sigma_3}^2 - 2\rho_{12}\sigma_1\sigma_2 + 2\rho_{13}\sigma_1\sigma_3 - 2\rho_{23}\sigma_2\sigma_3\right) - 1}$
- $m_{ABC.bef} = m_{0.ABC.bef}\exp({\sigma_3}^2 - \rho_{12}\sigma_1\sigma_2 + 2\rho_{13}\sigma_1\sigma_3 - 2\rho_{23}\sigma_2\sigma_3)$
- $CV_{ABC.bef} = \sqrt{\exp\left({\sigma_1}^2 + {\sigma_2}^2 + 4{\sigma_3}^2 - 2\rho_{12}\sigma_1\sigma_2 + 2\rho_{13}\sigma_1\sigma_3 - 2\rho_{23}\sigma_2\sigma_3\right) - 1}$

"After" approach:

- $m_{FABC.aft} = m_{0.FABC.bef}$

- $CV_{FABC.aft} = 0$
- $m_{ABC.aft} = m_{0.ABC.aft}$
- $CV_{ABC.aft} = CV_{0.ABC.aft}$

Ratios ("after" relative to "before"):

- $\frac{m_{FABC.aft}}{m_{FABC.bef}} = \exp(\rho_{12}\sigma_1\sigma_2 - \rho_{13}\sigma_1\sigma_3 + \rho_{23}\sigma_2\sigma_3)$
- $\frac{CV_{FABC.aft}}{CV_{FABC.bef}} = 0$
- $\frac{m_{ABC.aft}}{m_{ABC.bef}} = \exp(-{\sigma_3}^2+\rho_{12}\sigma_1\sigma_2 - 2\rho_{13}\sigma_1\sigma_3 + 2\rho_{23}\sigma_2\sigma_3)$
- $\frac{CV_{ABC.aft}}{CV_{ABC.bef}} = \sqrt{\frac{\exp({\sigma_3}^2)-1}{\exp({\sigma_1}^2+{\sigma_2}^2+4{\sigma_3}^2-2\rho_{12}\sigma_1\sigma_2+4\rho_{13}\sigma_1\sigma_3-4\rho_{23}\sigma_2\sigma_3)-1}}$

Except for the ratio of the F_{ABC} CVs, which is still identically zero, the results for the general case are more ambiguous than in the special case where all correlations are zero, because they admit the possibility of being either less than or greater than unity, depending on the values of the σ and ρ terms.

As a first step toward getting some idea of likely values for the three non-zero ratios, distributions of the σ and ρ terms were simulated by assuming that:

- The three σ terms are i.i.d. lognormal random variables with mean *σmean* and standard deviation *σsdev*.
- For the three ρ terms, the quantities $(\rho + 1)/2$ are i.i.d. symmetric beta random variables with standard deviation *ρsdev*.

The hyperparameters *σmean*, *σsdev*, and *ρsdev* were set at values of either 0.2 or 0.4 in a factorial design. Values of each of the three σ terms and each of the three ρ terms were drawn from their respective hyperdistributions repeatedly, retaining only those combinations that resulted in a positive definite covariance matrix, until a sample of 100,000 parameter sets was obtained. These were then used to generate distributions of the three non-zero ratios. Table 2.1.3.1 shows some summary statistics from the distributions, and Figure 2.1.3.5 shows the 99% concentrations of the distributions (i.e., the distributions with the lower and upper 0.5% tails omitted). The results may be summarized as follows:

F_{ABC} ratio: Consistent with the zero-correlation special case, the distributions for the F_{ABC} ratio tended to be concentrated at values near unity across a broad range of hyperparameter values. For example, both the median and the mean were within the 1.00-1.08 range for all combinations of hyperparameter values, although in some cases there were outliers that resulted in the standard deviations being substantial. Specifically, for all cases in which *σsdev* was equal to 0.2, the standard deviation of the F_{ABC} ratio never exceeded 0.14, but for the two cases in which both *σsdev* and *ρsdev* were equal to 0.4, the standard deviation was in excess of 4.77. Given that the median is so close to unity for all combinations of hyperparameter values, it is not surprising that the proportion of simulations in which the F_{ABC} ratio exceeded unity ranged from 0.50-0.51.

ABC ratio: Also consistent with the zero-correlation special case, the distributions for the *ABC* ratio tended to be concentrated at values slightly less than unity across a broad range of hyperparameter values. In the zero-correlation special case, if σ_3 were set equal to 0.2 or 0.4, the *ABC* ratio would be about 0.96 or 0.85, respectively. In comparison, for the *σmean* =0.2 case, the median ratio ranges between 0.98 and 0.99 and the mean ratio ranges between 0.93 and 0.94, and for the *σmean* =0.4 case, the median ratio ranges between 0.88 and 0.92 and the mean ratio ranges between 0.84 and 0.88. The standard deviation of the ABC ratio ranges between 0.12 and 0.27 in all cases except where both $\sigma sdev$ and $\rho sdev$ were equal to 0.4, in which case the standard deviations were 0.89 (when $\sigma mean$=0.2) and 1.83 (when $\sigma mean$=0.4). The proportion of simulations in which the *ABC* ratio exceeded unity was invariably smaller than for the F_{ABC} ratio, ranging from 0.10-0.26.

CV_{ABC} ratio: Also consistent with the zero-correlation special case, the distributions for the CV_{ABC} ratio tended to be concentrated at values considerably less than unity across a broad range of hyperparameter values. In the zero-correlation special case, if σ_1, σ_2, and σ_3 were all set equal to 0.2 or all set equal to 0.4, the CV_{ABC} ratio would be about 0.39 or 0.33, respectively. In comparison, for the $\sigma mean$ =0.2 case, the median ratio ranges between 0.28 and 0.34 and the mean ratio ranges between 0.27 and 0.33, and for the $\sigma mean$ =0.4 case, the median ratio ranges between 0.26 and 0.30 and the mean ratio ranges between 0.25 and 0.32. The standard deviations were all within the 0.09-0.18 range. The coefficients of variation were uniformly larger for the CV_{ABC} ratio than their respective F_{ABC} ratio and *ABC* ratio counterparts, with the exception of the cases in which both $\sigma sdev$ and $\rho sdev$ were equal to 0.4. The proportion of simulations in which the CV_{ABC} ratio exceeded unity was invariably tiny, never reaching a value of 0.01 (recall that, in the zero-correlation special case, the CV_{ABC} ratio can never exceed 0.5).

Because the proportion of simulations in which the CV_{ABC} ratio exceeded unity was so small—but not necessarily zero—in all of these examples, it seemed appropriate to consider further the conditions under which a CV_{ABC} ratio in excess of unity can be obtained. Additional explorations involving alternative values for the parameters of the hyperdistributions tended to confirm the trends evident in Table 2.1.3.1, such that the proportion of simulations in which the CV_{ABC} ratio exceeded unity tended to be associated with high values of $\sigma mean$ and $\rho sdev$ and low values of $\sigma sdev$. For example, with $\sigma mean$ = 1.0, $\sigma sdev$ = 0.1, and $\rho sdev$ = 0.9 (note that the symmetric beta distribution is U-shaped for $\sqrt{1/3} < \rho sdev < 1$), about 13% of the simulations resulted in the CV_{ABC} ratio exceeding unity. For these hyperparameter values, the subset of simulations in which the CV_{ABC} ratio exceeded unity tended to be associated with fairly extreme values of the correlation coefficients, with ρ_{12} and ρ_{13} tending to be close to –1 and ρ_{23} tending to be close to +1; and with ρ_{12} and ρ_{13} strongly and positively correlated, and ρ_{12} and ρ_{23} strongly and negatively correlated. Specifically, the median values of ρ_{12}, ρ_{13}, and ρ_{23} were –0.97, –0.97, and 0.98, respectively, and the correlations between ρ_{12} and ρ_{13} and between ρ_{12} and ρ_{23} were 0.71 and –0.74, respectively (the only other correlation with an absolute value greater than about 0.05 was the correlation between ρ_{13} and ρ_{23}, with a value of –0.21).

The final analysis of the CV_{ABC} ratio consisted of exploring the proportion of the 3-dimensional potential correlation volume (i.e., the cube in $\{\rho_{12}, \rho_{13}, \rho_{23}\}$-space with sides spanning [–1,1] in all three dimensions) under which a ratio greater than unity is possible. The math is somewhat complicated and so is not presented here, but the results are shown in Figure 2.1.3.6, where the two axes represent the ratios σ_1/σ_3 and σ_2/σ_3. The main conclusion to be drawn from this figure is that no combination of σ parameters can result in a CV_{ABC} ratio greater than unity outside of a small subset of the potential correlation volume. Specifically, in no case does the size of this subset reach even 7% of the potential correlation volume.

In conclusion, while there are indeed parameter combinations for which the CV_{ABC} ratio exceeds unity, they are comparatively rare and typically involve extreme values of the ρ terms.

Discussion and conclusions

Point estimates

It will be assumed here that point estimation follows a decision-theoretic approach, such that the optimal estimator is that which minimizes the expected loss. This implies that the estimator will depend on both the form of the loss function and the weights assigned to the individual models in the ensemble. In the interest of simplicity, risk neutrality (i.e., squared error loss) and equal weighting will also be assumed, meaning that the optimal estimator of any quantity is simply the arithmetic mean of the individual model estimates. However, the conclusions are readily generalizable to alternative assumptions regarding the loss function and model weighting.

When nonlinearities are involved, two inevitable consequences of ensemble modeling, except in special cases are as follow:

- For given parameters values, a function evaluated at the average of the model-specific values of the argument will not equal the average of the function evaluated at the model-specific values of the argument. For example, considering the function $f(x) = x^{\beta}$ with β fixed at a value of 2 and model-specific values of x={10,20}, $((10 + 20)/2)^2 = 225 \neq (10^2 + 20^2)/2 = 250$.
- When evaluated at a given value of the argument, a function whose parameter values consist of the averages of their respective model-specific values will not equal the average of the functions with model-specific parameter values. For example, considering the same function as above but with x fixed at a value of 10 and model-specific values of β={2,4}, $10^{(2+4)/2} = 1000 \neq (10^2 + 10^4)/2 = 5050$.

It has been suggested that the "after" approach is preferable to the "before" approach because the ensemble ABC or OFL resulting from the "after" approach is generated by the ensemble fishing mortality rate prescribed by the ensemble harvest control rule, and is therefore internally consistent. However, as shown above, complete internal consistency is typically impossible in ensemble modeling when nonlinearities are involved. The alleged internal consistency of the "after" approach is ephemeral, because it relies on picking the "right" values to compare. As a counter-example, the individual model *ABC* or *OFL* values computed under the "after" approach, which form the basis of the ensemble ABC or OFL, will typically be *inconsistent* with respect to the harvest control rule as applied to those models.

Rather than chasing the unachievable goal of internal consistency of *results*, a better strategy is to focus on achieving internal consistency of *methods*. When it comes to *ABC* or *OFL*, the "before" approach uses the *same estimator* that is used for all other quantities (viz., the mean of the individual models' actual estimates of *ABC* or *OFL*), whereas the "after" approach *switches the estimator* to the mean of what the individual estimates *would have been* if they had all been generated by applying the F_{ABC} or F_{OFL} from the ensemble control rule. Note that there is no disagreement between the two approaches with respect to the estimates of the ensemble harvest control rule parameters (both estimate them as the averages of the model-specific values); the disagreement is entirely with respect to how those values should be used.

Treatment of uncertainty

The "before" approach treats the parameters of the respective harvest control rule, and the fishing mortality rate resulting therefrom, as random variables, just as any other quantity estimated by the assessment models, such that the set of values generated by the individual assessment models is treated as a distribution and the full uncertainty associated with them is retained when computing the distribution of *ABC* or *OFL*. The "after" approach, on the other hand, treats the parameters of the harvest control rule, and the fishing mortality rate resulting therefrom, as constants, meaning that both the *within*-model and *between*-model uncertainty in F_{ABC} or F_{OFL} is ignored when computing the distribution of *ABC* or *OFL*.

Extensions of the "after" approach can easily be imagined, wherein the point estimates of additional parameters or vectors of age- or size-specific rates (e.g., natural mortality, weight at age, selectivity at age, etc.) are averaged and then treated as constants when computing the distribution of *ABC* or *OFL*. In the extreme, the point estimates of all parameters could be averaged and then treated as constants, in which case the distribution of *ABC* or *OFL* would be reduced to a single point.

The results shown here demonstrate that the uncertainty in *ABC* or *OFL*, when measured by the coefficient of variation, will typically be substantially less under the "after" approach than under the "before" approach (although exceptions are possible). Because this reduction in uncertainty is a direct consequence of ignoring both the *within*-model and *between*-model uncertainty in F_{ABC} or F_{OFL}, when there is no logical reason why those uncertainties should be ignored while the analogous uncertainties associated with other quantities are not, the treatment of uncertainty afforded by the "before" approach seems altogether preferable.

Table 2.1.3.1.

Summary statistics from a factorial design of simulation studies.

Hyperparameter			FABC_ratio				ABC_ratio				ABC_CV_ratio			
σmean	σsdev	ρsdev	prop>1	median	mean	sdev	prop>1	median	mean	sdev	prop>1	median	mean	sdev
0.2	0.2	0.2	0.499	1.000	1.000	0.028	0.150	0.979	0.940	0.118	0.000	0.337	0.313	0.128
0.2	0.2	0.4	0.506	1.000	1.002	0.073	0.242	0.979	0.942	0.131	0.001	0.335	0.327	0.153
0.2	0.4	0.2	0.500	1.000	1.003	0.303	0.192	0.991	0.933	0.270	0.000	0.286	0.270	0.161
0.2	0.4	0.4	0.502	1.000	1.030	4.778	0.262	0.991	0.944	0.891	0.001	0.284	0.278	0.178
0.4	0.2	0.2	0.500	1.000	1.003	0.070	0.102	0.878	0.842	0.164	0.000	0.297	0.293	0.089
0.4	0.2	0.4	0.507	1.002	1.009	0.137	0.222	0.878	0.855	0.221	0.003	0.299	0.315	0.143
0.4	0.4	0.2	0.497	1.000	1.007	0.232	0.150	0.918	0.836	0.274	0.000	0.257	0.248	0.130
0.4	0.4	0.4	0.504	1.001	1.076	13.940	0.242	0.918	0.878	1.832	0.001	0.260	0.266	0.161

Figures

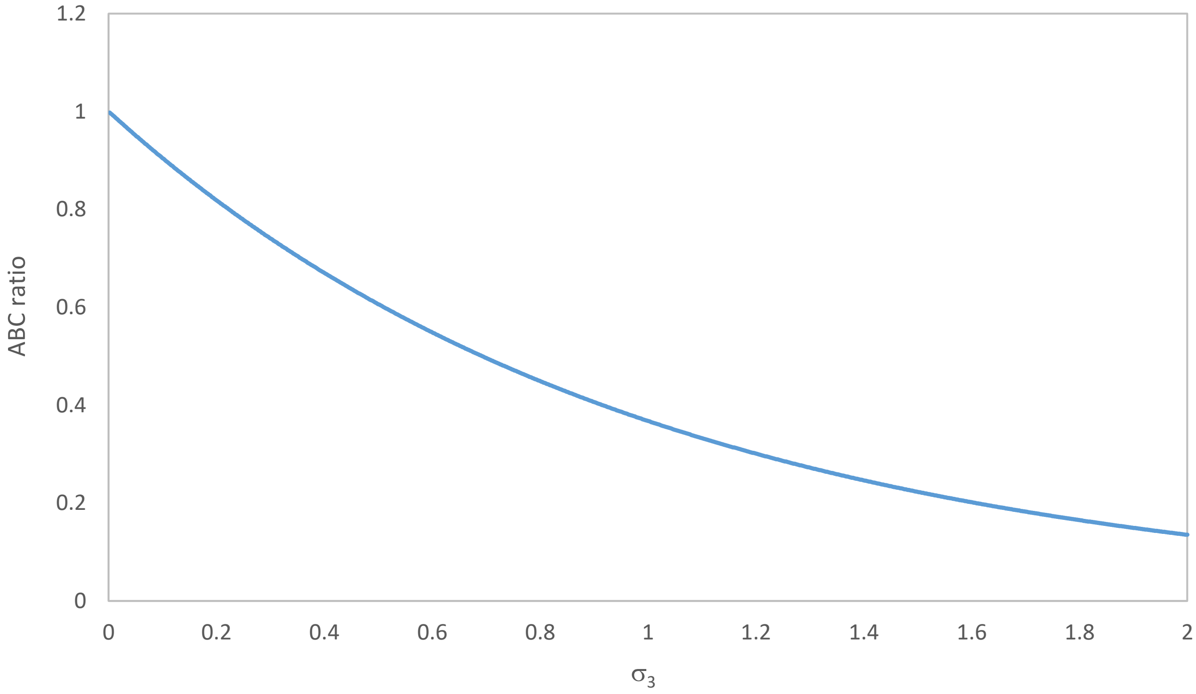

Figure 2.1.3.1. *ABC* ratio as a function of the log-scale standard deviation of female spawning biomass.

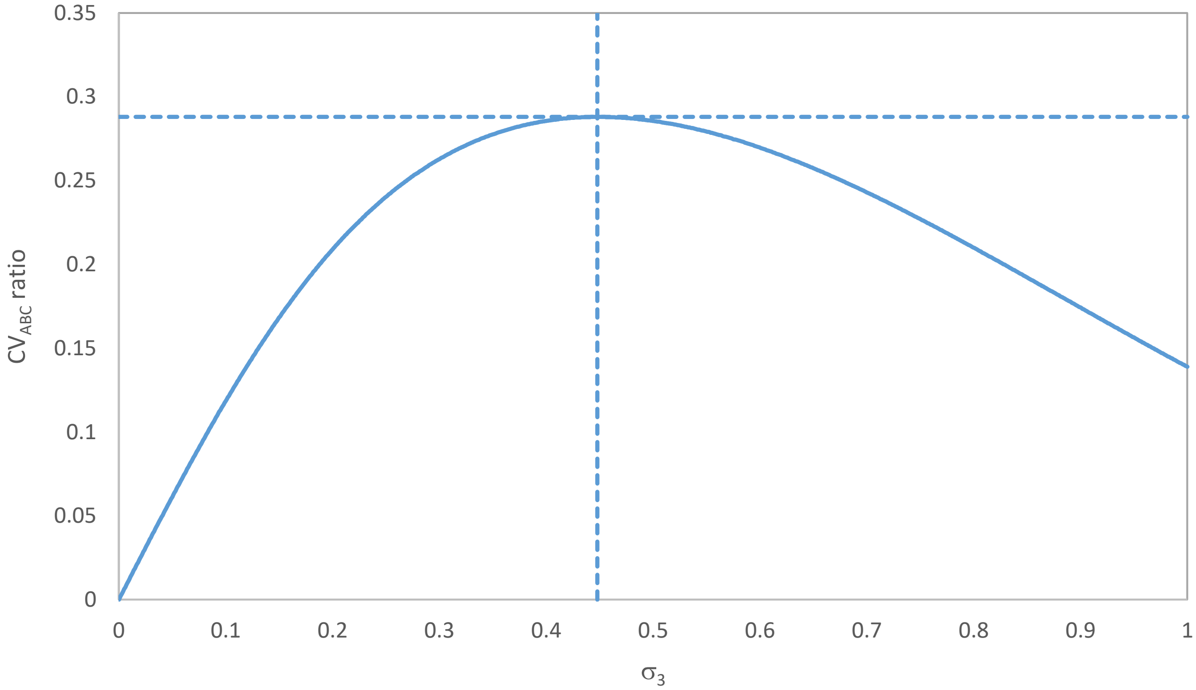

Figure 2.1.3.2. CV_{ABC} ratio as a function of the log-scale standard deviation of female spawning biomass for the special case where the sum of the log-scale variances of $F_{40\%}$ and $B_{40\%}$ equals 0.5.

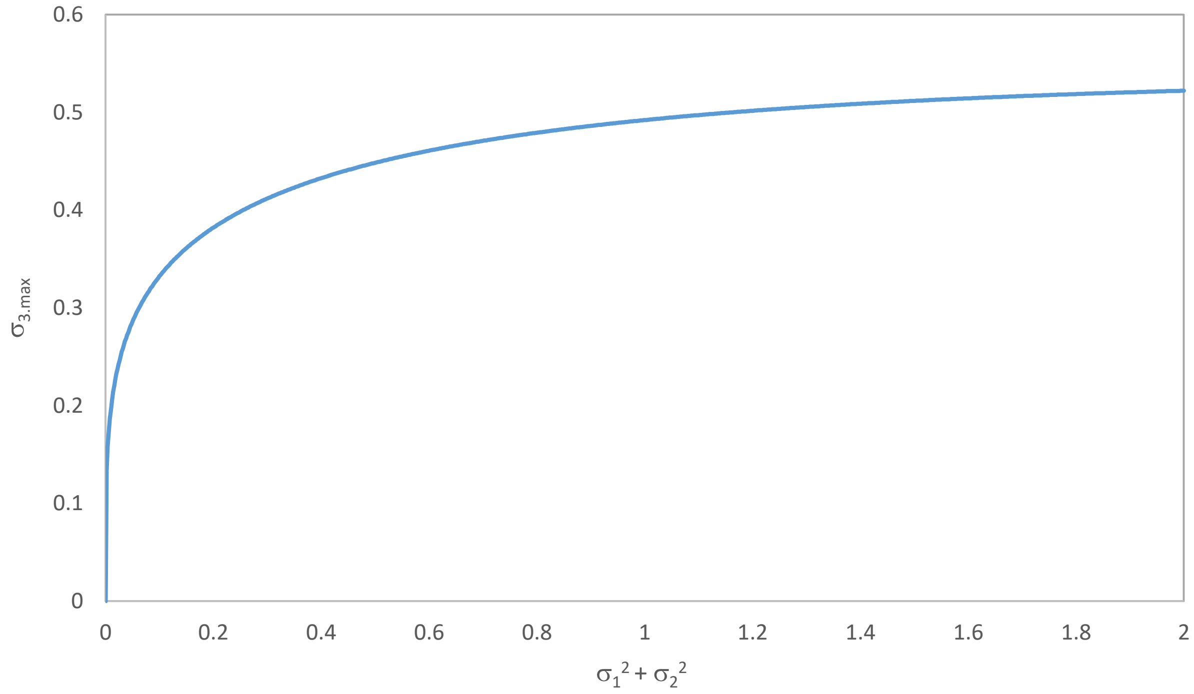

Figure 2.1.3.3. Log-scale standard deviation of female spawning biomass that maximizes the CV_{ABC} ratio as a function of the sum of the log-scale variances of $F_{40\%}$ and $B_{40\%}$.

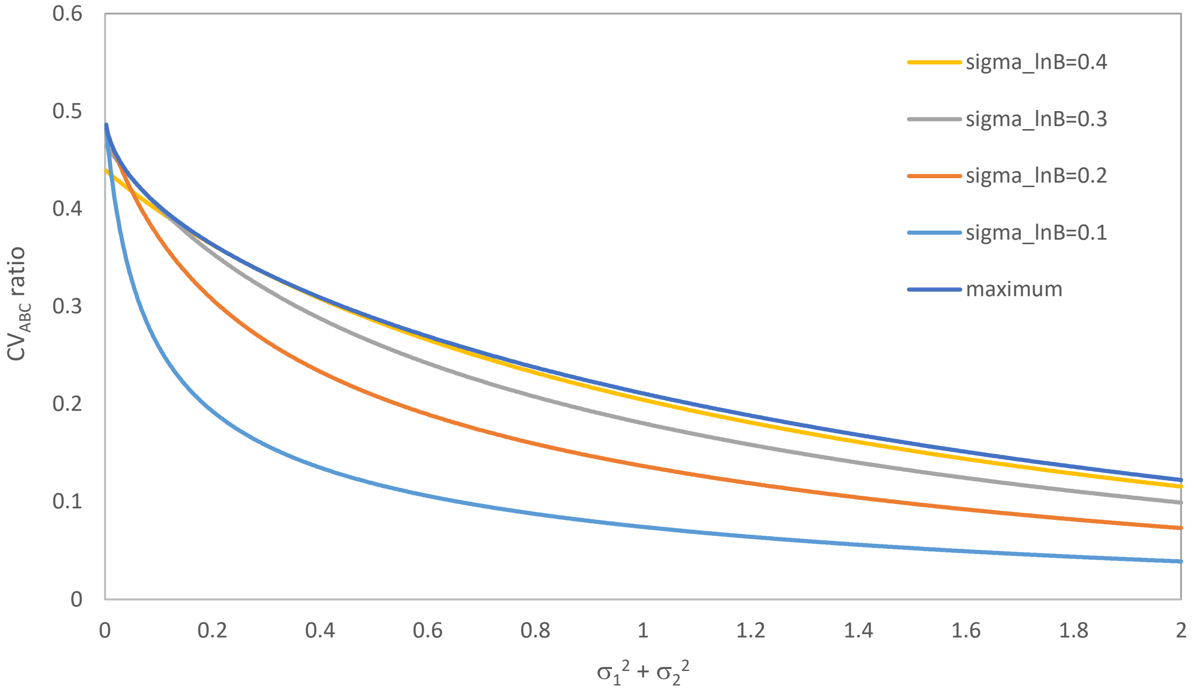

Figure 2.1.3.4. CV_{ABC} ratio as a function of the sum of the log-scale variances of $F_{40\%}$ and $B_{40\%}$.

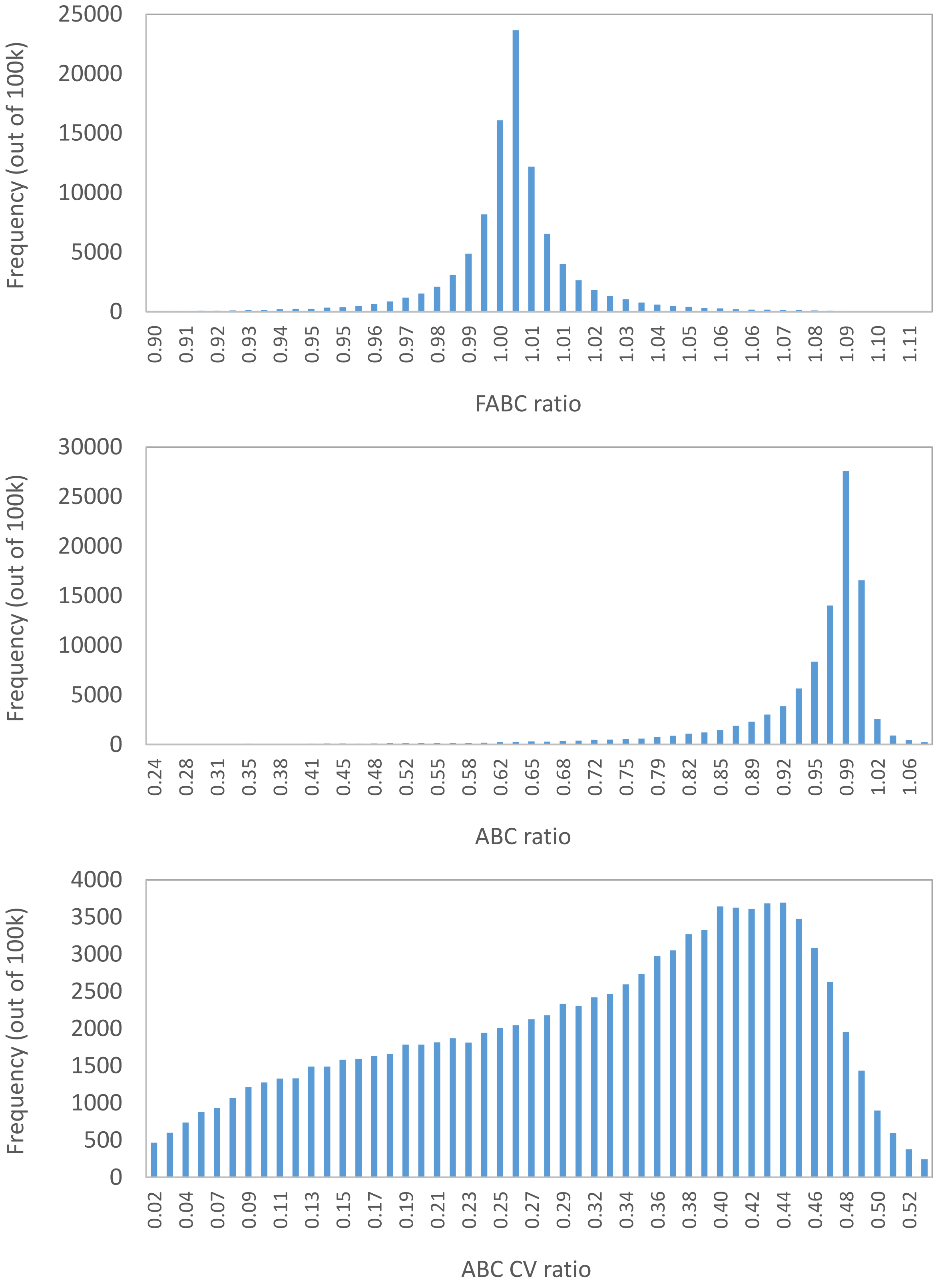

Figure 2.1.3.5a. Results of simulations for hyperparameter values σmean = 0.2, σsdev = 0.2, ρsdev = 0.2.

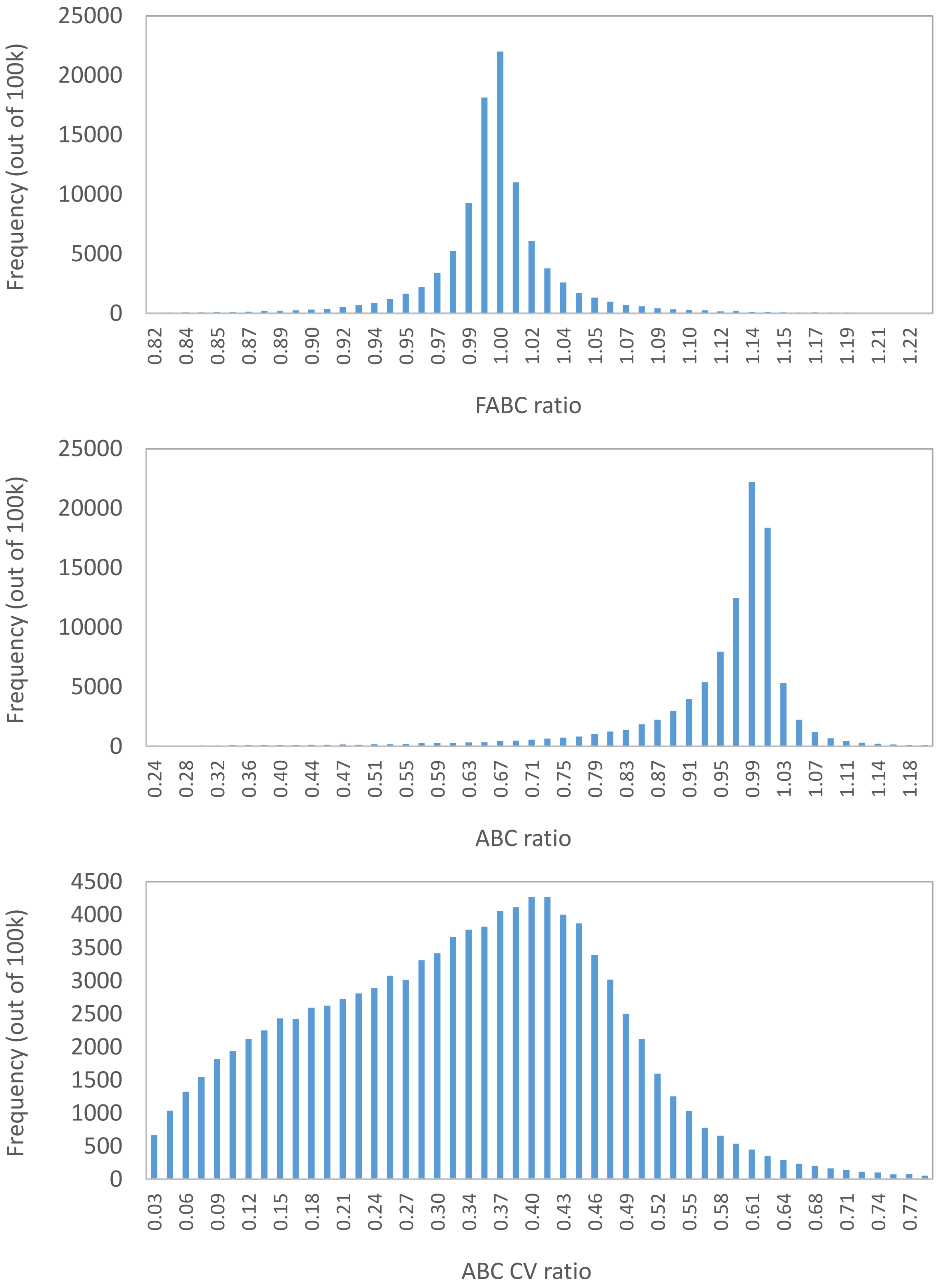

Figure 2.1.3.5b. Results of simulations for hyperparameter values σmean = 0.2, σsdev = 0.2, ρsdev = 0.4.

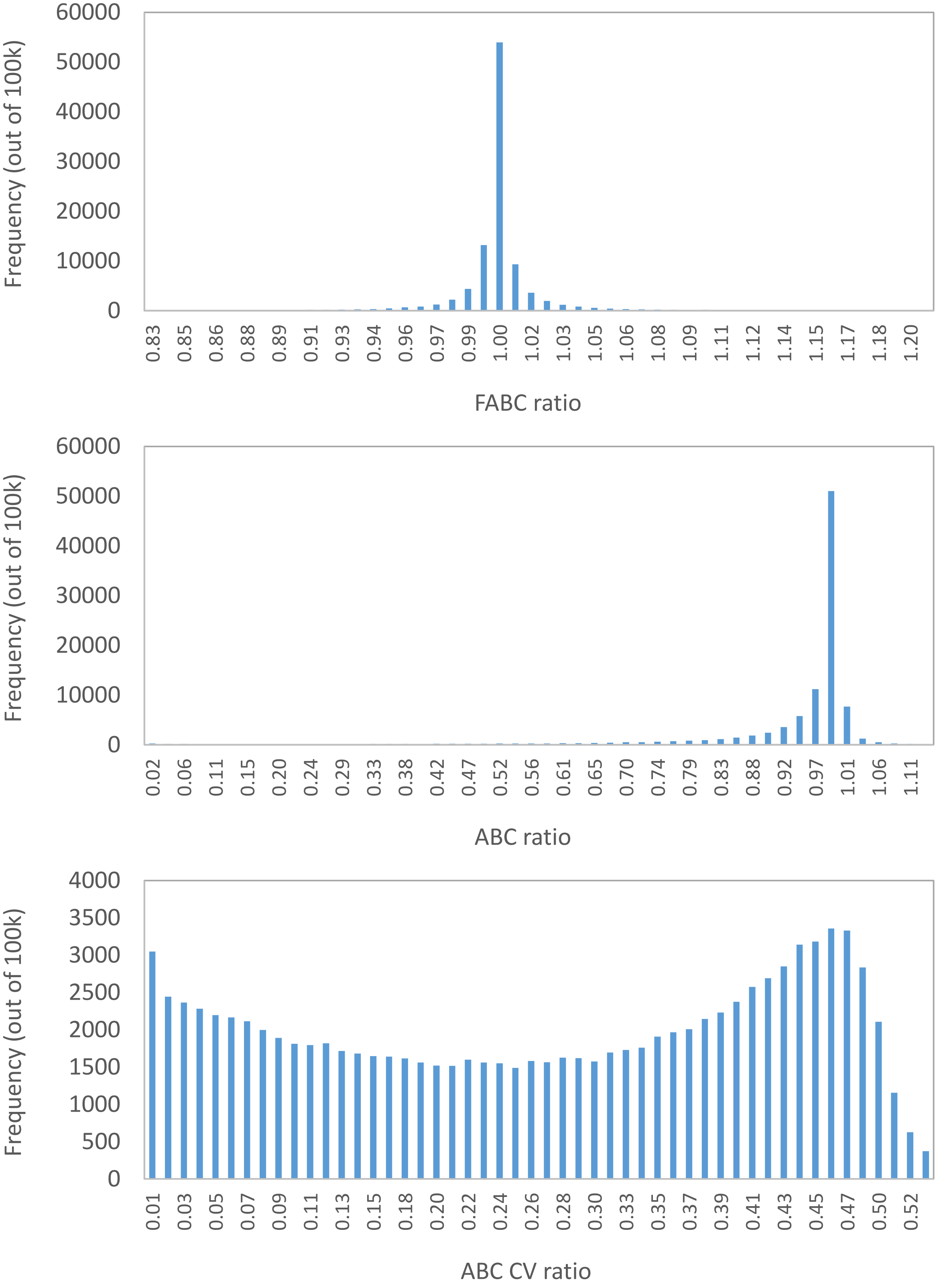

Figure 2.1.3.5c. Results of simulations for hyperparameter values σmean = 0.2, σsdev = 0.4, ρsdev = 0.2.

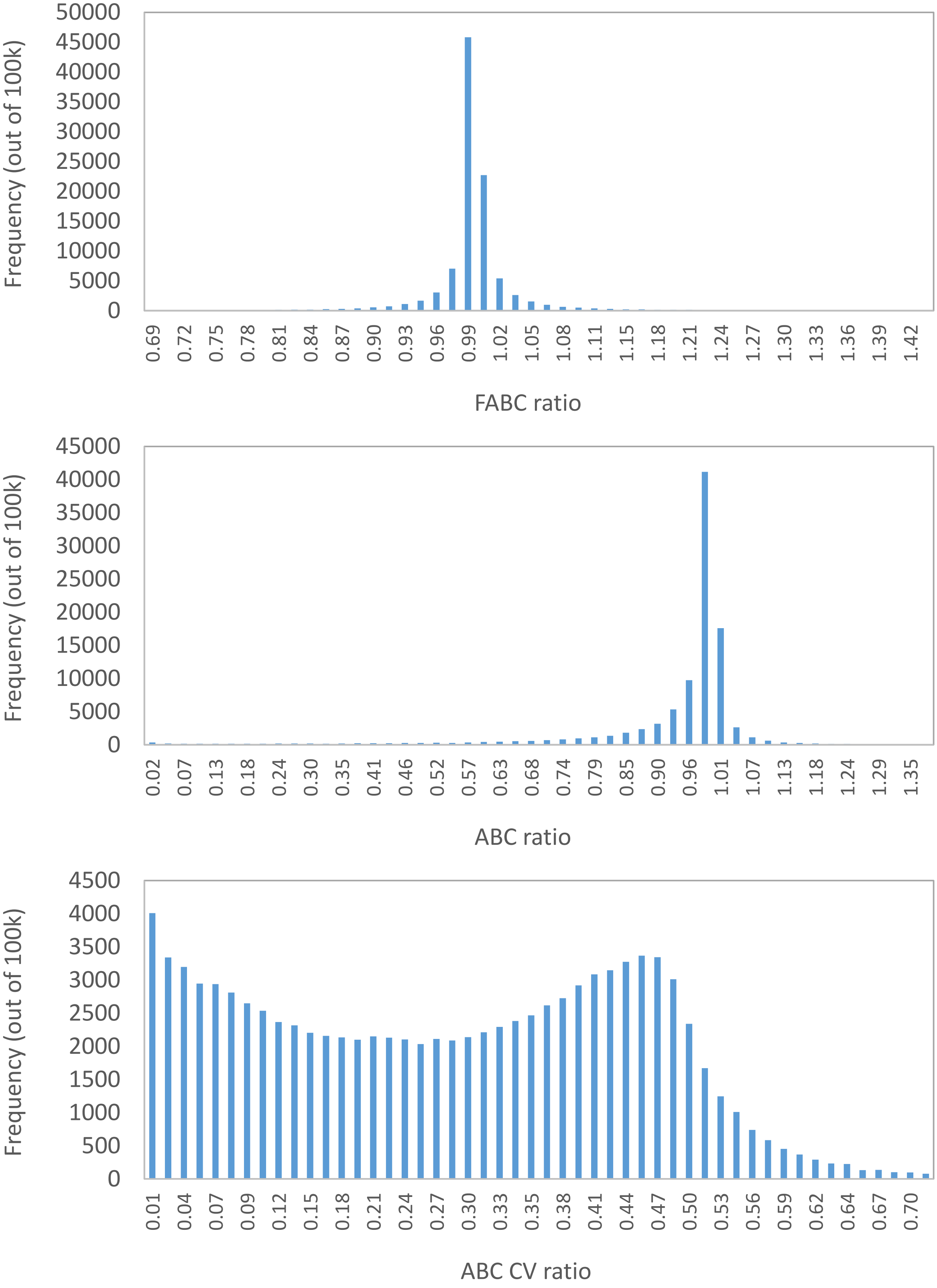

Figure 2.1.3.5d. Results of simulations for hyperparameter values σmean = 0.2, σsdev = 0.4, ρsdev = 0.4.

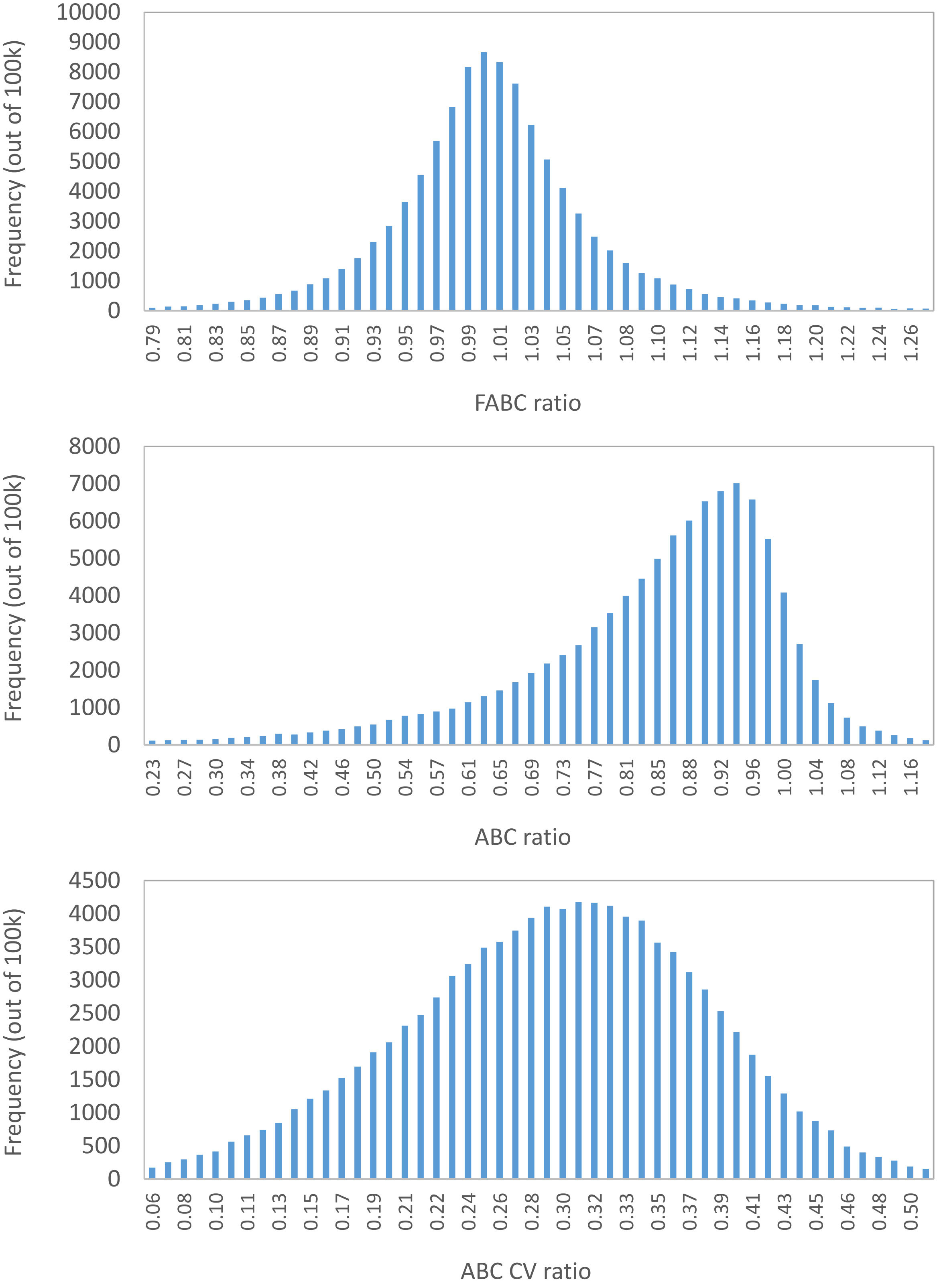

Figure 2.1.3.5e. Results of simulations for hyperparameter values σmean = 0.4, σsdev = 0.2, ρsdev = 0.2.

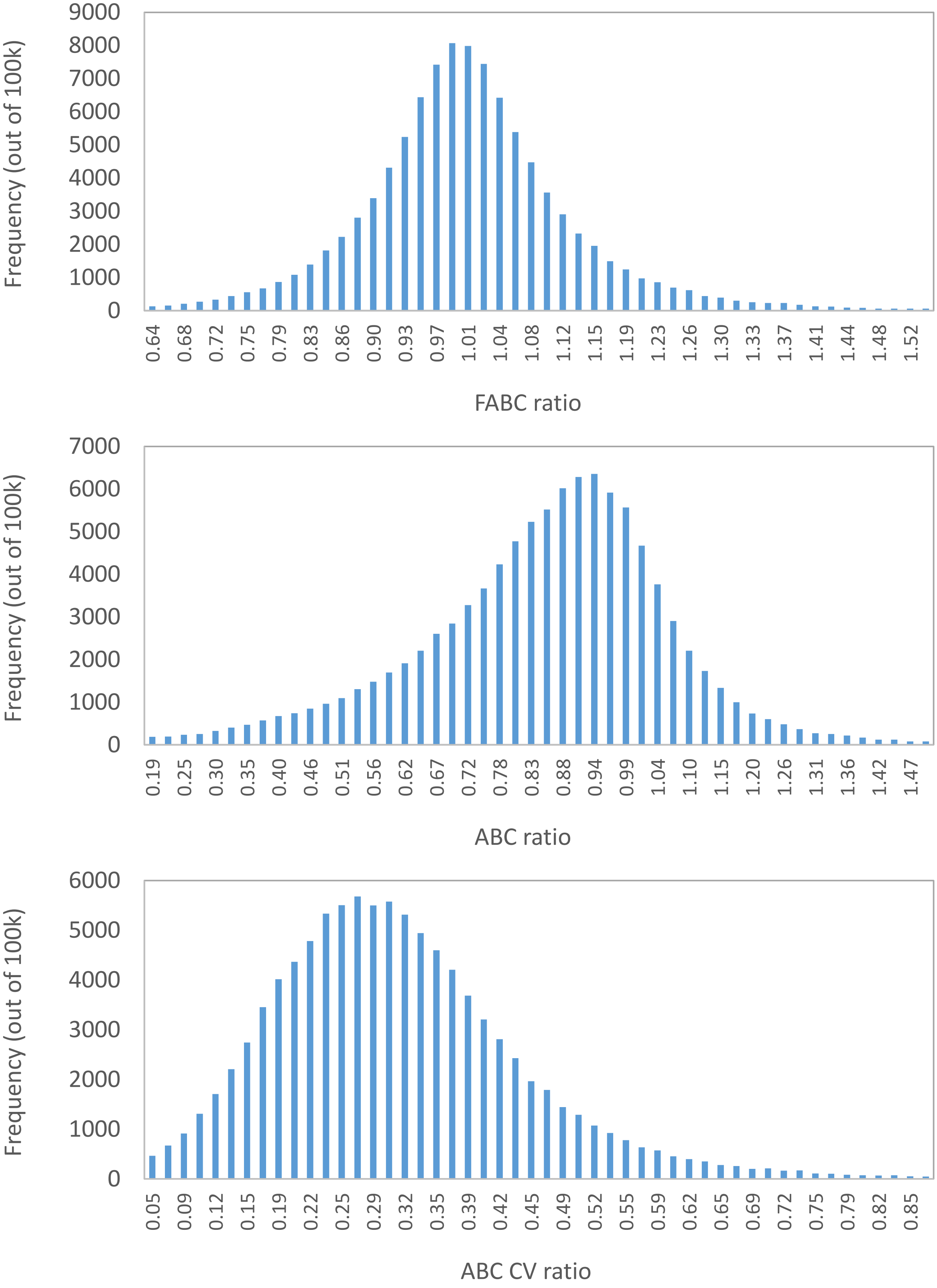

Figure 2.1.3.5f. Results of simulations for hyperparameter values σmean = 0.4, σsdev = 0.2, ρsdev = 0.4.

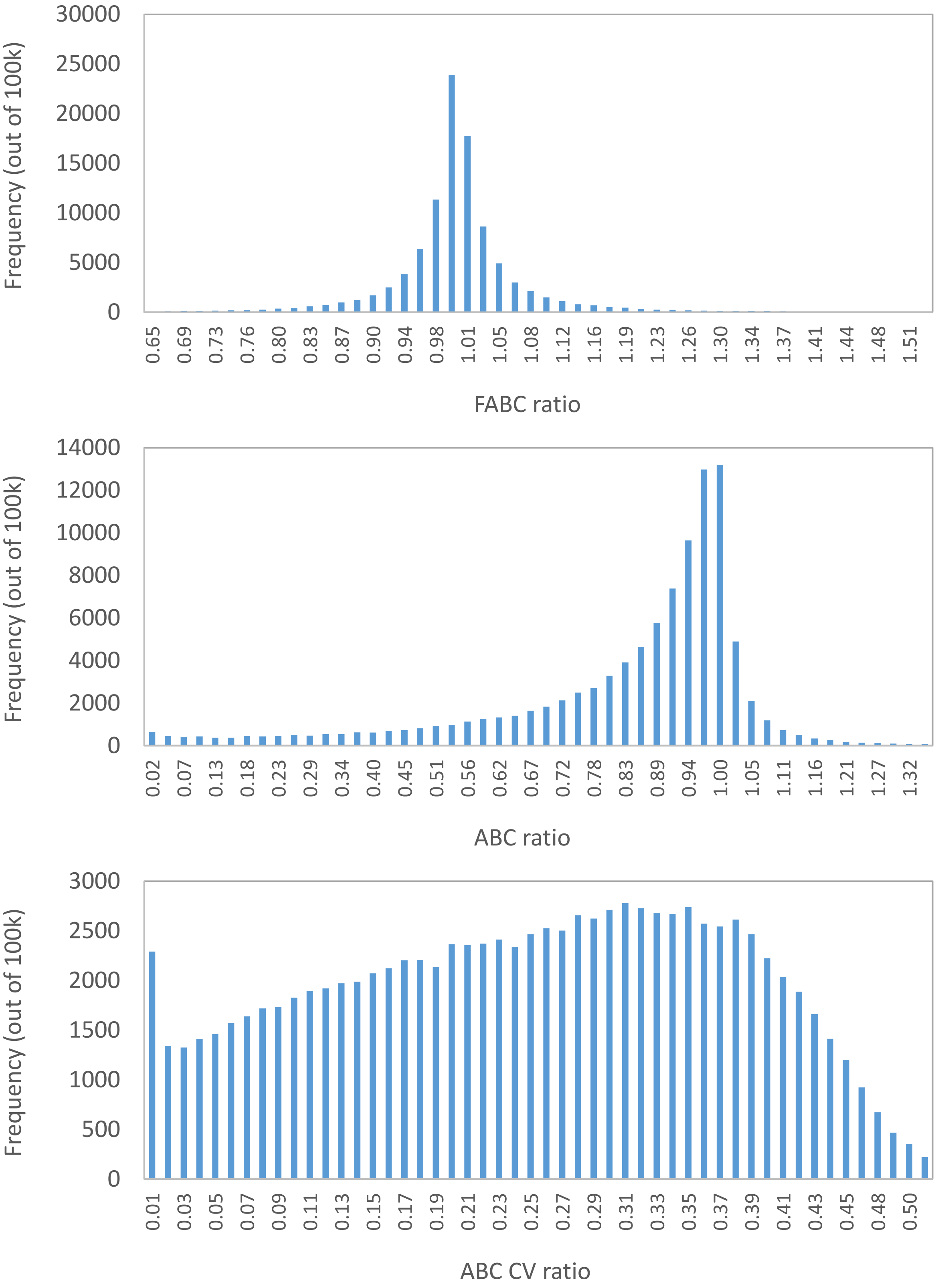

Figure 2.1.3.5g. Results of simulations for hyperparameter values σmean = 0.4, σsdev = 0.4, ρsdev = 0.2.

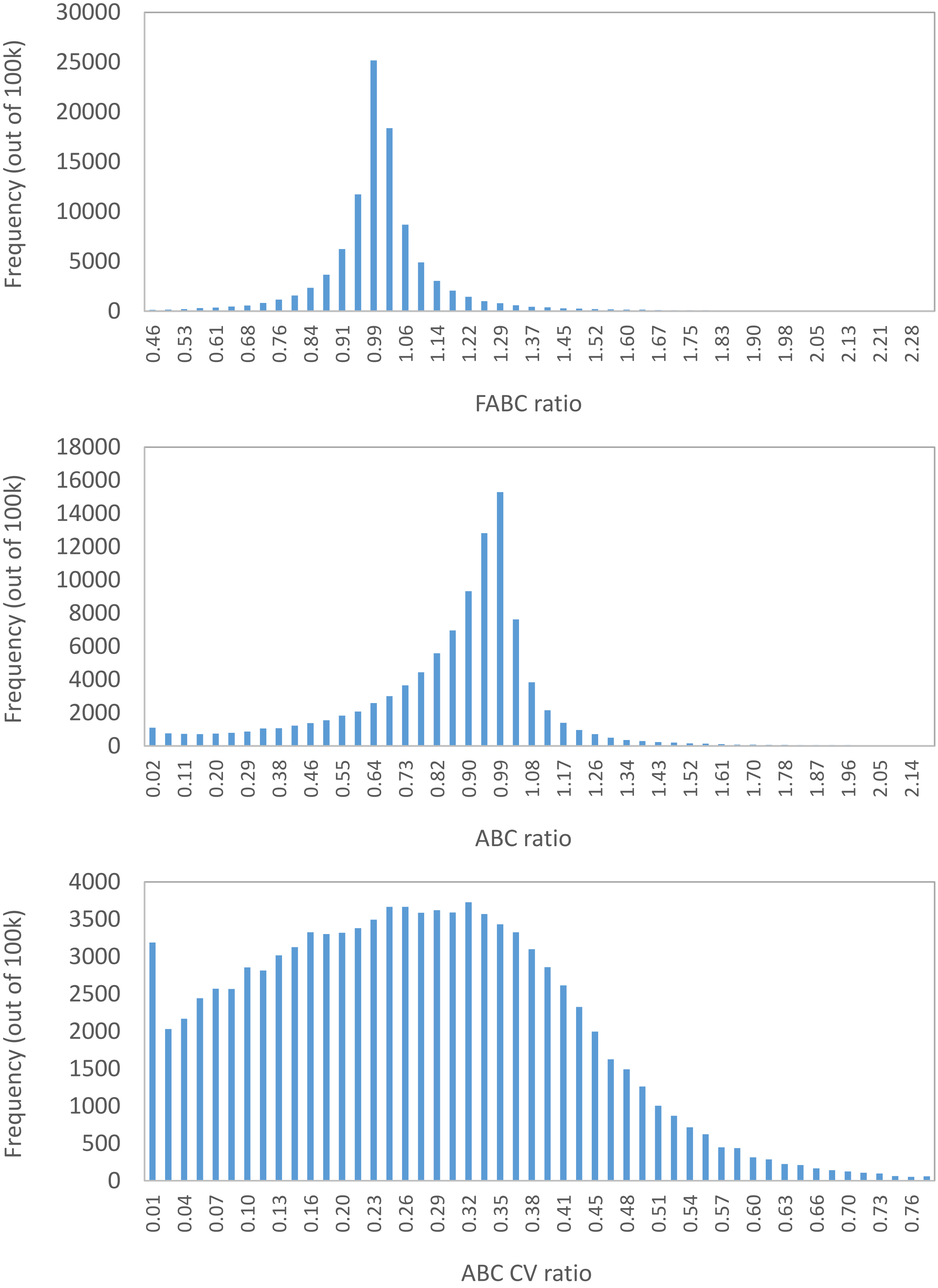

Figure 2.1.3.5h. Results of simulations for hyperparameter values σmean = 0.4, σsdev = 0.4, ρsdev = 0.4.

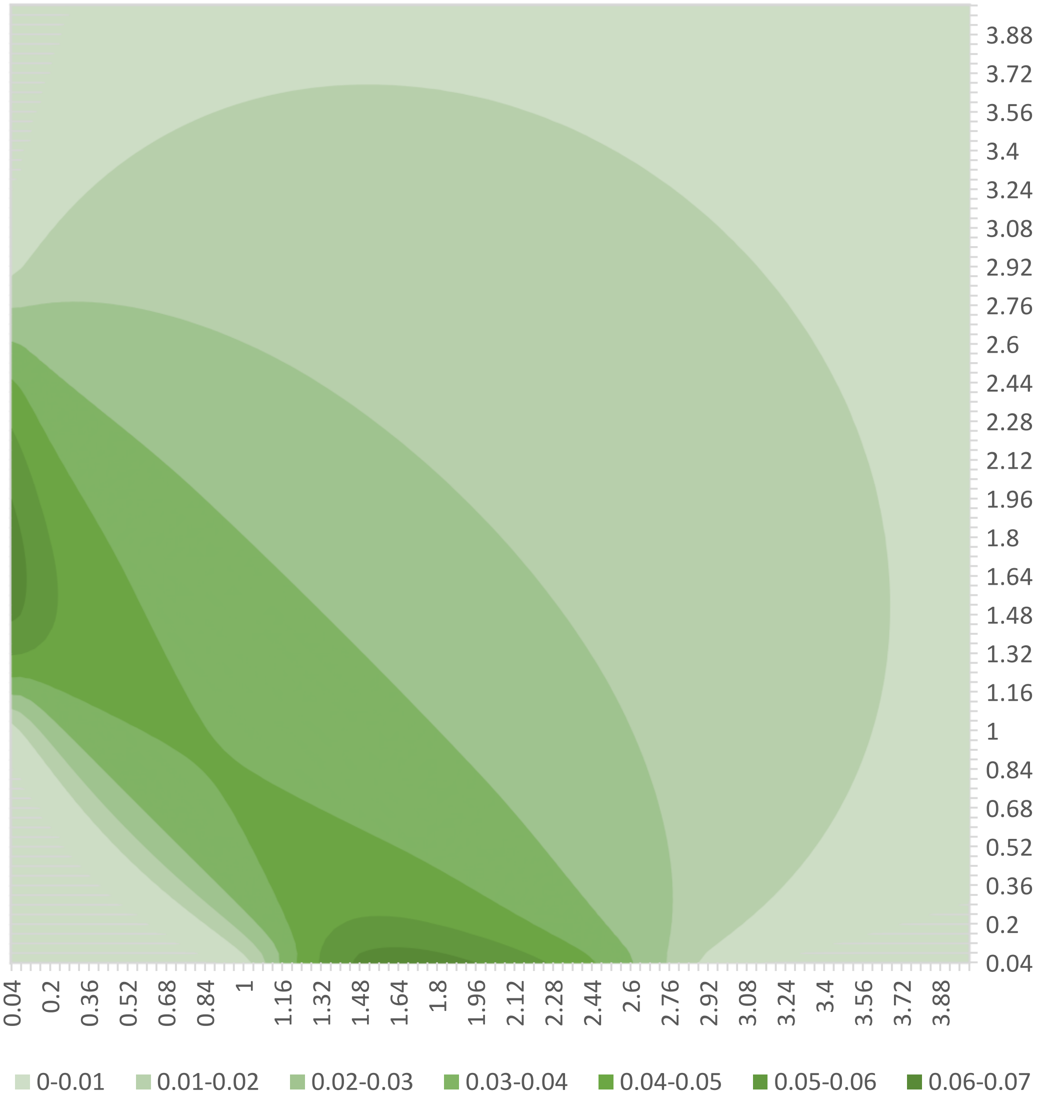

Figure 2.1.3.6. Contour plot showing the proportion of the 3-dimensional correlation volume under which the CV_{ABC} ratio exceeds unity, as a function of the ratios σ_1/σ_3 and σ_2/σ_3 (axes are interchangeable), where σ_1 is the log-scale standard deviation of $F_{40\%}$, σ_2 is the log-scale standard deviation of $B_{40\%}$, and σ_3 is the log-scale standard deviation of female spawning biomass.