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 and Thorson 2019).

Responses to Team and SSC comments on assessments in general

Comments from the November 2019 Joint Groundfish Plan Team meeting

JPT1: "The Teams recommended that authors continue to fill out the risk tables for full assessments." *Response*: This request will be addressed in the final assessment.

JPT2: "The Teams recommended that adjustment of ABC in response to levels of concern should be left to the discretion of the author, the Team(s), and/or the SSC, but should not be mandated by the inclusion of a >1 level in any particular category." *Response*: This request will be addressed in the final assessment.

Comments from the December 2019 SSC meeting

SSC1: "The SSC requests that the GPTs, as time allows, update the risk tables for the 2020 full assessments, as the SSC found this exercise to be very helpful." *Response*: This comment will be addressed in the final assessment.

SSC2: "The SSC recommends dropping the overall risk scores in the tables." *Response*: This comment will be addressed in the final assessment.

SSC3: "The SSC requests that the table explanations be included in all the assessments which include a risk table for completeness." *Response*: This comment will be addressed in the final assessment.

SSC4: "The SSC discussed whether increased risk or uncertainty was relative to previous assessments of the same stock, or relative to other stocks. Both are relevant and elaboration by the authors or GPTs as to what the elevated risk refers to is encouraged." *Response*: This comment will be addressed in the final assessment.

Responses to Team and SSC comments specific to this assessment

Note: Given the time constraints posed by this year's meeting schedule, the SSC co-chairs have suggested that authors not feel obligated to respond to all of last year's SSC and Team comments in this year's assessments.

Comments from the September 2019 BSAI Groundfish Team meeting

BPT1: "The Team recommends continuing investigation of the CCDA model averaging method, realizing it is unlikely to be implemented this year. The Team is very enthusiastic about this approach. The Team will discuss with the author whether additional input would be useful in further testing and developing the method." *Response*: Investigation of the approach is continued in the "Cross-conditional decision analysis" (CCDA) section.

Comments from the October 2019 SSC meeting

SSC5: "The SSC thanks Dr. Thompson for his work on developing the CCDA and supports continued efforts to explore this method. An important feature of this work will be how this method interacts with existing FMP control rules, and specifically how the level of risk aversion chosen ("ra" term in the loss function) maps onto existing control rule policies." *Response*: The level of risk aversion used for calculating ABC in this preliminary assessment is derived from the current harvest control rules in Attachment 2.1.4.

Comments from the November 2019 BSAI Groundfish Team meeting

BPT2: "A major discussion point was whether all three hypotheses should be retained. Hypothesis #2, combining the EBS and NBS surveys, was deemed likely given the observations of Pacific cod in the NBS, no evidence of genetic difference, and the presence of age-1 fish throughout the EBS and NBS. Hypothesis #3 is useful because it admits that dynamics in the NBS may be different than in the EBS. However, the models presented did not capture this possibility and spatial models would be worth investigating. Hypothesis #1 is the most unlikely hypothesis but is worth retaining at this point because it: 1) is the legacy model, 2) is important to understand the dynamics operating at only the EBS level, 3) can help determine the synergy between the NBS and EBS regions, 4) had acceptable retrospective patterns, and 5) may be necessary if NBS surveys are discontinued. It was noted that models under hypothesis #2 may explain the dynamics similarly as models under hypothesis #1, but hypothesis #1 should be retained at least another year, even when given little weight in the ensemble. It was noted that hypothesis #2 carried most of the weight in the ensemble." *Response*: To recap, the hypotheses explored in last year's assessment were as follow: 1) Pacific cod in the NBS are insignificant to the managed stock, so the assessment should include data from the EBS only; 2) Pacific cod in the EBS and NBS comprise a single stock, and the EBS and NBS surveys can be modeled in combination; and 3) Pacific cod in the EBS and NBS comprise a single stock, but the EBS and NBS surveys should be modeled separately. Models consistent with Hypotheses #2 and #3 are included in this preliminary assessment (see this comment and comments BPT5 and SSC7), but models consistent with Hypothesis #1 have been dropped, in part because this hypothesis seems inconsistent with current knowledge regarding stock structure (see comment SSC7) and also in the interest of reducing the number of models (see comments BPT5 and SSC10). Instead, the ensemble included in this preliminary assessment includes models designed to address possible over-parameterization in Model 19.12 (see comment SSC9), use of spatial models (see this comment), and fish movement between areas (see comments BPT5 and SSC11).

BPT3: "The Team supported continued research into the abundance and mortality of Pacific cod outside of U.S. waters for inclusion in the stock assessment." *Response*: Some preliminary results on abundance of Pacific cod in the Western Bering Sea are summarized in the "Data provided for context only" section, courtesy of Cecilia O'Leary (AFSC).

BPT4: "The Team recommended using spatio-temporal models for survey data (i.e., VAST with a cold pool covariate and bias correction) and also recommended that the survey team investigate the efficacy of VAST estimates using methods such as cross-validation." *Response*: As in the ensemble of models included in last year's final assessments, all survey data used in the models presented here are based on the VAST approach, using a cold pool covariate with bias correction, with one exception: Technical issues precluded estimation of the 2019 survey age composition using VAST, so a design-based estimate is used here instead. No new results from cross-validation are available, although efforts are underway to use a "leave-one-out" approach in the next year or two (Jim Thorson, AFSC, *pers. commun*. 8/24/2020).

BPT5: "The Team recommended the 3×3 factorial design for defining models in the ensemble and feels that the current nine models should be used for management advice. Hypothesis #1 is the hypothesis under which the assessment has historically operated, and it is useful to carry forward that legacy and retain the historic EBS only assessment. Hypothesis #3 is useful because it allows for a single stock with different dynamics in the two areas. Although the three models for Hypothesis #3 did not perform particularly well, this hypothesis is useful and the Team supports further development of models under this hypothesis that may incorporate spatial processes such as migration and differences in growth, for example. All three hypotheses and levels of complexity incorporate features that are of interest and useful for explaining structural uncertainty, but it would be useful to investigate reducing the number of models, such as eliminating one of the hypotheses or one of the levels of complexity." *Response*: See comment BPT2.

BPT6: "The Team recommended retaining all models in the ensemble for this assessment, but to simplify and reduce workload, only report models that are above a cutoff of 1% weight to represent the base model in the next assessment. This would include five models for comparison next year." *Response*: In order to address several of the Team and SSC comments, it was necessary to rework the ensemble substantially for this preliminary assessment, and most of the five models referenced in this comment have been dropped. Model 19.12 is included in the new ensemble, as is a minor modification of Model 19.15, but the remaining members of last year's ensemble have been abandoned.

BPT7: "The Team recommended organizing the environmental/ecosystem considerations content of the risk table to those items that are associated with the stock and those that are not (working with ESP and ESR editors may help with this)." *Response*: This comment will be addressed in the final assessment.

BPT8: "The Team recommended a continued investigation into 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." *Response*: All models in this preliminary assessment include time-variability in length at age 1.5, but not in any of the other parameters describing size at age. This issue will likely be among the terms of reference for next year's review of the assessment by the Center of Independent Experts (CIE), and will be addressed in next year's assessment.

BPT9: "The Team recommended continued research into the inclusion of fishery age compositions in the models." *Response*: This will likely be among the terms of reference for next year's review of the assessment by the CIE, and will be addressed in next year's assessment (see comment SSC8).

<u>Comments from the December 2019 SSC meeting</u>

SSC6: "The weighted ensemble was determined using a set of nine criteria with different emphasis factors. These criteria were developed by extracting various comments from the PT and the SSC as to what are important features or hypotheses to include in the model. Factors that were given an emphasis of 3 were deemed to be ones that the PT or SSC has explicitly used for criteria to reject or express strong concern about a model (plausibility). Lower emphasis (factors 2 and 1) was given to criteria that generally were more related to technical model specifications. The SSC thought this part of the weighting scheme was transparent and a reasonable step forward. However, the choice of an exponential average instead of the arithmetic average is a much more influential choice than the ad hoc 3:2:1 choice. For example, Model 19.12 is given over 7 times more weight than the next candidate, despite emphasis-weighted scores

of 15 and 13, respectively. The SSC suggested that it may be more transparent to use a more intuitive arithmetic mean, recognizing that all weighting systems will have subjective decisions and that assessment authors are likely best suited to identify relative model weightings." *Response*: This preliminary assessment explores the use of cross-conditional decision analysis, which involves two sets of model weights. The first set represents the probabilities that each of the models in the ensemble is the true model. The second set represents how well each of the models in the ensemble performs after considering the possibility that *any* of the models in the ensemble *could* be the true model, and is computed conditionally on the first set. The first set of weights was computed as the (rescaled) arithmetic mean of a set of scores, in response to this comment.

SSC7: "A major discussion point was whether all three hypotheses should be retained going forward. Hypothesis #2, combining the EBS and NBS surveys, was considered the most likely given the observations of Pacific cod in the NBS and the lack of genetic differences between these areas. There was general support for removing the models related to Hypothesis #1 (19.7-19.9) altogether, given our understanding of stock structure." *Response*: Two models consistent with Hypothesis #2, including Model 19.12, are included in the new ensemble presented in this preliminary assessment. The new ensemble does not contain any models consistent with Hypothesis #1.

SSC8: "The SSC recommends that the authors focus on continuing to improve Model 19.12 and attempt to resolve problems with using fishery age compositions." *Response*: Although it does not change the structure of Model 19.12, this preliminary assessment presents an improved method for processing the size composition data that go into Model 19.12 (and all of the other models in the ensemble) by excluding sample sizes sufficiently small that they are unlikely to be positively correlated with the stratum-specific catches by which they are weighted. Problems associated with using fishery age compositions will likely be among the terms of reference for next year's review of the assessment by the CIE, and will be addressed in next year's assessment (see comment BPT9).

SSC9: "The authors should consider whether 19.12 could be 'overfitting' as the GPT suggested." *Response*: Half of the models in the new ensemble presented in this preliminary assessment have fewer time-varying parameters than Model 19.12. Also, the use of cross-conditional decision analysis should help to mitigate problems of over-parameterization to the extent that it causes a model to perform poorly.

SSC10: "The SSC recommends that if the authors bring an ensemble model forward in 2021, that it consists of a reduced set of models that still reflect adequate diversity in model structure and hypotheses about stock structure." *Response*: The new ensemble presented in this preliminary assessment is smaller, albeit only slightly, than the ensemble used in last year's assessment, consisting of 8 models rather than 9. Thorough investigation of even a few of the various factors that have been requested for consideration (over-parameterization (see comment SSC9), inter-area movement/migration (see comments BPT2, BPT5, and SSC11), and inclusion of both Hypotheses #2 and #3 (see comments BPT2, BPT5, and SSC7)) proved to be a difficult task with fewer than 8 models. Of course, after reviewing the new ensemble, it is possible that the Team/SSC will determine that one or more of the models in this ensemble can be dropped from the final assessment.

SSC11: "The SSC encourages further investigations into fish movement, both analytically and through tagging studies." *Response*: Two of the models in the new ensemble presented in this preliminary assessment include analytical treatment of fish movement between the EBS and NBS. Recent results from tagging studies are summarized in the "Data provided for context only" section.

SSC12: "The SSC requests that the use of VAST, including its assumptions, are clearly documented in next year's assessment." *Response*: Use of VAST, including its assumptions, are documented in the "Data used in the models" section.

SSC13: "The SSC notes that development of an ESP for EBS Pacific cod would be advantageous. Given the results of the stock assessments and the vital historic economic, social, and community importance of Pacific cod, the SSC recommends that within the recognized constraints of available time and resources, Ecosystem and Socioeconomic Profiles (ESPs) of EBS Pacific cod (as well as AI and GOA Pacific cod) be prioritized as new ESPs are developed." *Response*: Several people have been developing an ESP for GOA and EBS Pacific cod since spring of this year. Draft versions are anticipated to be available in time for review at this year's November Team and December SSC meetings.

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 V3.30.15.09 was used to run all of the models in this preliminary assessment. For the current base model, using last year's data set, this version of SS gave the same value for the objective function as the version used in last year's assessment (Thompson and Thorson 2019).

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 one exception; see "Parameterization issues" section below), with bounds set at values sufficiently extreme that:

- they were non-constraining (with two exceptions; see "Results" section below), 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."

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 a standard deviation (σ) specific to that parameter. For all models in this preliminary assessment, each σ was tuned iteratively as follows:

- Except for the vector associated with log-scale recruitment, σ was tuned to set the variance of the estimates plus the sum of the estimates' variances equal to unity.
- For the vector of annual 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).

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 current base model, 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 going into 2019, Model 16.6i, referred to a model that constituted a minor change from Model 16.6, 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 only data from 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.

Base model

Model 19.12 was adopted by the SSC last year as the new base model. It 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
        - With constrained annual deviations
    - 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 (however, see "Parameterization issues" section below):
        - First size with selectivity=1 freely estimated
        - 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 freely estimated
        - Logit of selectivity at minimum size freely estimated
        - Base value of logit of selectivity at maximum size freely estimated
            - With constrained annual deviations
- Following Thorson et al. (2017), 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 $-\infty$, *Nsamp*=(1+*Ninit*)/2 when $ln\theta$=0, and *Nsamp* approaches *Ninit* as $ln\theta$ approaches $+\infty$), 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)

Primary ensemble

<u>Factorial design</u>

One way to guard against "stacking the deck" in development of a model ensemble is to employ a factorial design. In the "Responses to Team and SSC comments specific to this assessment" section, four topics were identified as being the highest priority for consideration in this preliminary assessment. Each of these is shown below, together with a "binary factor" that interprets the topic in terms of a no/yes question:

Topic	Comment(s)	Binary factor: Does the model...
M19.12 over-parameterization	SSC9	...allow time-varying survey catchability (Q)?
Spatial structure	BPT2	...treat the EBS and NBS as separate areas?
Hypotheses #2 and #3	BPT2, BPT5, SSC7	...use area-specific surveys?
Movement	BPT5, SSC11	...incorporate explicit inter-area movement?

Ordinarily, a factorial design spanning four factors would require 2^4=16 models. However, certain combinations of the above factors are internally inconsistent. Specifically, it would not make sense to entertain the four nominally possible models that *do not* treat the EBS and NBS as separate areas but that *do* incorporate explicit inter-area movement, nor the four nominally possible models that *do* treat the EBS and NBS as separate areas but that *do not* use area-specific surveys, which leaves only eight feasible models, as follows (shading indicates factor/column combinations where the factors are constrained to have the same value, in order to eliminate infeasible combinations):

Time-varying Q?	No				Yes			
Separate areas?	No		Yes		No		Yes	
Separate surveys?	No	Yes	Yes		No	Yes	Yes	
Movement?	No		No	Yes	No		No	Yes
Temporary name	A1	B1	C1	D1	A2	B2	C2	D2

Temporary names have been assigned to all eight models in the above table, because "final" model names are dependent on the average difference in spawning biomass relative to the current base model ("final" model names are assigned near the beginning of the "Results" section below). However, it may be noted that Models A2 and B2 are very similar to Models 19.12 and 19.15, respectively. This is addressed further in the "Parameterization issues" and "Alternative ensemble" sections below.

Models A1 and A2 correspond to Hypothesis #2, Models B1 and B2 correspond to Hypothesis #3, and the remaining models correspond to new hypotheses.

Parameterization issues

As the models in the ensemble were being developed, five parameterization issues were encountered:

1) The various 2-area models require estimation of a parameter (potentially time-varying) describing the inter-area recruitment distribution, and the pair of 2-area models that incorporate explicit inter-area movement require estimation of four parameters (also potentially time-varying) describing the probabilities of staying or moving in or to each of the two areas. The recruitment distribution parameter is simply the logit transform of the proportion of the total number of age 0 recruits that is allocated to the NBS. The interpretation of the movement parameters, on the other hand, is complicated (see Attachment 2.1.1). In developing these models, considerable effort was expended in exploring versions in which the annual values of the parameters describing inter-area recruitment distribution and movement were treated as base parameters modified by constrained annual deviations. Ultimately, these efforts proved unsuccessful, in part because so many years are missing from the NBS survey time series, meaning that little information is available for estimating the deviations in most years. Instead, development of these models was redirected toward use of environmental covariates to provide mechanisms for the time-varying recruitment distribution and movement parameters, where each of these parameters was estimated as a linear function of a single covariate. The following seven potential environmental covariates of inter-area recruitment distribution and movement were explored: sea ice extent, the North Pacific Index (NPI), benthic epifauna, condition factor, and three versions of cold pool extent (temperatures less than 0° C, less than 1° C, and less than 2° C). Sea ice extent proved to have the greatest explanatory power for the proportion of recruitment occurring in the NBS and for the movement of fish from the EBS to the NBS, while the NPI had the greatest explanatory power for the movement of fish from the NBS to the EBS.

2) The pair of 2-area models that incorporate explicit inter-area movement also require specification of three constants governing the ages at which movement is allowed to occur and the range of ages over which movement probabilities are allowed to vary with age (see Attachment 2.1.1). Age 2 was specified as the first age at which movement is allowed to occur. This value was chosen subjectively, albeit informed by the life history of the species. Ages 2 and 7 were specified as the endpoints of the range of ages over which movement probabilities are allowed to vary with age, and were chosen by trial and error, after examining the log-likelihood values associated with alternative combinations of endpoints and also with a view toward keeping the signs of the covariate linkages constant across age.

3) Because no fishery size composition or age composition data are available for the NBS, all NBS fishery selectivity parameters were assumed to "mirror" their base EBS counterparts.

4) As noted in the "Base model" section above, Model 19.12 fixes the logit of the size range with selectivity=1 at -10.0, whereas the logit of selectivity at the minimum size is freely estimated. As other models in the ensemble were being developed, better fits were obtained by flipping the treatments of those two parameters, so that the logit of the size range with selectivity=1 was estimated freely and the logit of selectivity at the minimum size was fixed at -10.0. When these assumptions were applied to the Model 19.12 also (thus transforming Model 19.12 into Model A2), the results were only trivially different (negative log likelihood changed by only 0.01 and 2019 spawning biomass changed by only 0.001%). In the interest of consistency with the other models in the ensemble, the structure of Model 19.12 was changed accordingly without assigning it a new name.

5) At the time the models were being developed, no data on catches in the NBS were available. For the four models that treat the EBS and NBS as separate areas (C1, D1, C2, and D2), this made estimation of ln(Q) for the NBS survey difficult, if not impossible. Therefore, those models included an informative prior distribution for that parameter (or for the base value, in the case of models with time-varying catchability). More specifically, for each such model, a normal prior distribution for the NBS survey ln(Q) was used, with unit variance and a mean equal to the point estimate of the EBS survey ln(Q). This involved tuning the prior mean iteratively for each such model. Although the two models that use area-specific surveys without treating the EBS and NBS as separate areas (Models B1 and B2) appeared to be capable of estimating ln(Q) without imposing an informative prior distribution, the same type of prior distribution was used for those models also, so as to employ a consistent set of assumptions for all six models that use area-specific surveys. The use of an informative prior distribution for NBS survey ln(Q) is the only feature that distinguishes Model B2 from Model 19.15, and the results from Model B2 were very similar to those from Model 19.15. Nevertheless, a new "final" name for Model B2 will be adopted (see "Results" section), for the reason given the "Alternative ensemble" section below.

<u>Parameter counts</u>

The numbers of parameters in the eight models, for data through 2019, are as follow (color gradients in the final three rows proceed from red=low to green=high):

Time-varying Q?	No				Yes			
Separate areas?	No		Yes		No		Yes	
Separate surveys?	No	Yes	Yes		No	Yes	Yes	
Movement?	No		No	Yes	No		No	Yes
Temporary name	A1	B1	C1	D1	A2	B2	C2	D2
True parameters	25	30	37	46	25	30	37	46
Annual deviations	267	267	267	267	305	343	343	343
Total parameters	292	297	304	313	330	373	380	389

In terms of the number of true parameters (i.e., time-invariant parameters and base values of time-varying parameters), the above table proceeds in increasing order from left to right within a given value for the "Time-varying Q?" factor, and the four counts in the "No" column are identical to the four counts in the "Yes" column. So, Models A1 and A2 have the same number of true parameters, as do Models B1 and B2, Models C1 and C2, and Models D1 and D2; with the A1/A2 pair having the fewest and the D1/D2 pair having the most.

In terms of the number of annual deviations, Models A1, B1, C2, and D1 are identical. Model A2 has 38 more than Models A1-D1 because of annually varying catchability in the survey. Models B2, C2, and D2 have 38 more than Model A2 because they include annually varying catchability for two surveys rather than one.

In terms of the total number of parameters (true parameters and annual deviations combined), the above table proceeds in increasing order from left to right. So, Model A1 has the fewest total parameters and Model D2 has the most.

Table 2.1.1 shows the breakdown of parameter counts in further detail.

The five true parameters in Models B1 and B2 that are not included in Models A1 and A2 consist of:

- Base log catchability in the NBS survey
- Two parameters for the NBS survey selectivity (size-based double-normal):
    - Base value of first size with selectivity=1
    - Base value of log standard deviation for 1st normal pdf
- Two Dirichlet-multinomial parameters for the NBS survey:
    - One for size composition
    - One for age composition

The seven true parameters in Models C1 and C2 that are not included in Models B1 and B2 consist of:

- One parameter that governs the distribution of recruits between the EBS and NBS
- Initial fishing mortality rate for the NBS fishery
- Five selectivity parameters for the NBS fishery (size-based double-normal):
    - First size with selectivity=1
    - Logit of size range with selectivity=1
    - Base value of log of standard deviation for 1st normal pdf
    - Log of standard deviation for 2nd normal pdf
    - Base value of logit of selectivity at maximum size

The nine true parameters in Models D1 and D2 that are not included in Models C1 and C2 consist of:

- Four parameters that govern base age-specific movement rates:
    - Slope and intercept terms that govern base movement rates from the EBS to the NBS
    - Slope and intercept terms that govern base movement rates from the NBS to the EBS
- Linkage between an environmental covariate and the distribution of recruits between EBS, NBS
- Linkages between environmental covariates and the four movement parameters

Alternative ensemble

After the models in the primary ensemble had already been largely developed, a small amount of data on catches in the NBS became available (see “NBS catch data” section below), which suggested that it might be appropriate to revisit the question of whether the four models that treat the EBS and NBS as separate areas (C1, D1, C2, and D2) are able to estimate ln(Q) for the NBS survey after all. Moreover, if the prior distribution on NBS ln(Q) is removed from analogues of Models C1, D1, C2, and D2, it seems appropriate to develop prior-less analogues of Models B1 and B2 as well. Thus, in addition to the primary ensemble, a small subset of results will be presented for analogues of Models B1, B2 , C1, C2, D1, and D2 with the prior distribution on NBS ln(Q) removed; which, together with Models A1 and A2 (ie., Model 19.12) from the primary ensemble, can be considered to constitute an alternative ensemble.

Note that, when the prior distribution on NBS ln(Q) is removed from Model B2, it is identical to Model 19.15. Because results from both of these models will be reported (for Model B2 in the primary ensemble and Model 19.15 in the alternative ensemble), it is appropriate to assign a new "final" name to Model B2.

Data

Data used in the models

With the exceptions of a small change in the method used to compile the fishery size composition data (used in all models) and the addition of a time series of NBS catch data (used in the four models that include explicit EBS and NBS areas) and a pair of environmental covariate time series (used in the two models that incorporate explicit movement between areas), the data used in all models presented in this preliminary assessment were all described previously in last year's assessment (Thompson and Thorson 2019). As in last year's ensemble, the survey index and age composition data used for all models in this preliminary assessment are based on the Vector Autoregressive Spatio-Temporal (VAST) approach (Thorson 2019a).

<u>VAST specifications</u>

As noted in last year's assessment, the settings that were used to produce the VAST estimates follow the recommendations given by Thorson (2019a). However, a more detailed description was requested by the SSC (see comment SSC12). In response, the following text was provided by Jim Thorson and Jason Conner (AFSC):

The software versions of dependent programs used to generate VAST estimates were:

- Microsoft Open R (3.5.3)
- INLA (18.7.12)
- TMB (1.7.18)
- TMBhelper (1.2.0)
- VAST (3.2.0)
- FishStatsUtils (2.3.0)

We fitted records of numerical abundance per unit area from all grid cells and corner stations in the 83-112 bottom trawl survey of the EBS, 1982-2019, as well as 83-112 samples available in the NBS in 1982, 1985, 1988, 1991, 2010, and 2017-2019. NBS samples prior to 2010 did not follow the 30 nautical mile sampling grid that was used in 2010, 2017, and 2019; and the 2018 sampling followed a coarsened grid as well. Assimilating these data therefore required extrapolating into unsampled areas. This extrapolation was assisted by including a spatially varying response to cold-pool extent (Thorson 2019). This spatially varying response was estimated for both linear predictors of the delta-model, and detailed comparison of results for EBS pollock has showed that it has a small but notable effect (O'Leary et al. in press). 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 suggests that densities in the NBS increased progressively after 2014 when cold-pool-extent declined prior to 2017.

Specifically, we used a Poisson-link delta-model (Thorson 2018) involving two linear predictors, and a gamma distribution for the distribution of positive catch rates. We extrapolated density to the entire EBS and NBS in each year, using extrapolation-grids that are available within FishStatsUtils are used when integrating densities. 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. We used bilinear interpolation to interpolate densities from 250 "knots" to these extrapolation-grid cells; knots were distributed spatially in proportion to the distribution of extrapolation-grid cells (i.e., having an approximately even distribution across space). We estimated "geometric anisotropy" (the tendency for correlations to decline faster in some cardinal directions than others), and including a spatial and spatio-temporal term for both linear predictors. To improve interpolation of density "hotspots" between unsampled years, we specified that the spatio-temporal term was autocorrelated across years (where the magnitude of autocorrelation was estimated as a fixed effect for each linear predictor). However, we did not include any temporal correlation for intercepts, which we treated as fixed effects for each linear predictor and year. Finally, we used epsilon bias-correction to correct for retransformation bias (Thorson and Kristensen 2016).

Fishery size composition

In last year's assessment, each year's fishery size composition consisted of a catch-weighted average of the respective month-, area-, and gear-specific size compositions, using 1-cm bins. A potential problem with this approach is that, conceivably, a particular month-, area-, and gear-specific size composition could be based on a very small number of measured fish, but be associated with a very large catch, meaning that a very imprecise month-, area-, and gear-specific size composition could have a large impact on that year's catch-weighted average size composition. To avoid this possibility, the number of measured fish by month, area, and gear should be positively correlated with the associated catch. Visual examination of the data suggests that, for the most part, this is true; however, for very small sample sizes, the correlation actually appears to be slightly negative. This suggests that it may be possible to identify an optimal cutoff value for fishery size composition sample size.

Attachment 2.1.2 describes a statistical analysis suggesting that the optimal cutoff value is approximately 30 fish (for any combination of month, area, and gear). Omitting records with sample sizes less than 30 would eliminate 12.1% of all records, but only 0.1% of the total number of fish measured and only 1.8% of the total catch. After eliminating those records, re-running the current base model resulted in less than a 1% change in ending spawning biomass, suggesting that the problem of potential negative correlation between catch and sample size when the latter is small is likely not a major one. However, because a minimum sample size of 30 fish (for any combination of year, month, area, and gear) has a firmer statistical basis than simply accepting any sample size no matter how small, the models presented here all used the recompiled fishery size composition time series with a minimum sample size of 30 fish.

NBS catch data

The NMFS Alaska Region office was able to compile a time series of catches for the NBS, shown below:

Year:	2003	2004	2005	2006	2007	2008	2009	2010	2011
Catch (t):	305	54	57	1	3	19	7	2	2
Year:	2012	2013	2014	2015	2016	2017	2018	2019	
Catch (t):	1	102	101	81	1425	1299	23217	20295	

Environmental covariates

As noted above in the "Parameterization issues" section, of the seven potential environmental covariates that were explored, sea ice extent proved to have the greatest explanatory power for the proportion of recruitment occurring in the NBS and for the movement of fish from the EBS to the NBS, while the NPI had the greatest explanatory power for the movement of fish from the NBS to the EBS (data obtained from https://access.afsc.noaa.gov/REFM/REEM/ecoweb/Index.php?ID=9). More specifically, the sea ice extent for each year *t* is computed as the average of the monthly values from August of year *t*–1 through July of year *t*, while the NPI is computed as the average of the monthly values from November of year *t*–1 through March of year *t*. The time series for these two covariates that were used in the models presented here are shown below (as z-scores):

Year:	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Ice:	-0.113	0.254	0.669	-0.078	-0.217	0.010	0.173	-0.490	0.441	0.643
NPI:	0.812	-2.314	-1.079	0.554	-1.731	-1.215	-0.269	1.311	0.943	1.092

Year:	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Ice:	0.532	0.154	0.479	1.150	-1.075	-0.326	0.636	1.017	1.114	-0.861
NPI:	-1.005	0.002	0.707	-0.081	-0.427	-0.033	-1.429	0.308	-0.129	-0.729

Year:	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Ice:	0.284	-1.171	-0.841	-0.639	0.736	-0.190	0.679	1.037	1.054	-0.581
NPI:	0.199	-1.613	-0.081	-0.261	0.597	0.475	0.243	2.068	-0.987	1.044

Year:	2012	2013	2014	2015	2016	2017	2018
Ice:	2.179	1.227	-0.839	-1.419	-0.926	-1.642	-3.058
NPI:	0.694	0.685	0.466	-0.388	-0.944	0.663	1.854

Preview of data changes in final assessment

Size composition update

Although not included in the data set for any of the models presented here, the fishery size composition time series has been updated through late August of 2020. Broadly speaking, the size composition for 2020 does not appear to include any surprises. Each year in the 1991-2020 time series shows a peak falling somewhere within the 55-75 cm size range. The size associated with the peak has increased in each of the last three years, which might reflect the lack of strong recruitment from the 2014-2016 cohorts, with the peak for 2020 occurring at 75 cm.

The fishery catches very few age 2 fish, making it difficult to draw a strong conclusion from these data regarding the strength of the 2018 year class, which was estimated to be very large in last year's assessment on the basis of the 2019 EBS and NBS surveys. However, it may be noted that the relative frequency of fish within the 30-34 cm range, which may be representative of age 2 fish during the first half of the year, is several times larger in the 2020 size composition than in the size compositions from any of the preceding four years.

It should also be noted that, as with the data files used in last year's assessment, the data file used for the models in this preliminary assessment included a size composition record for 2018 in the NBS survey time series, which could be problematic, given that the sampling design in that year's "rapid response" survey was different from the other years in the time series. It is likely that this record will be dropped from the data used in the final draft of the assessment.

EBS survey age composition update

Last year's assessment used VAST estimates of survey age composition for the entire time series (1994-2018). The otoliths from the 2019 EBS shelf bottom trawl survey have now been processed. However, technical issues have precluded estimation of the 2019 survey age composition using VAST, so a design-based estimate for the 2019 survey age composition will be used in the data file for the final assessment instead. The entire time series, with VAST estimates for the years 1994-2018 and the design-based estimates for 2019, is shown in Table 2.1.2.

Environmental covariates update

The z-scores for sea ice extent in 2019 and 2020 are -2.114 and -0.763, respectively (Rick Thoman, University of Alaska International Arctic Research Center, pers. commun. 8/9/2020); and the z-scores for the NPI in 2019 and 2020 are 0.245 and 1.284, respectively (Adam Phillips, National Center for Atmospheric Research, pers. commun. 8/10/2020). Note that the addition of the new data will result in the z-scores for the rest of each time series changing slightly.

Data provided for context only

Fishery catch per unit effort (CPUE)

Year-to-date CPUE data from the longline fishery suggest that 2020 is on track to have the highest average in the 1991-2020 time series. Monthly averages from January-July of 2020 (except for June, where reporting of data is precluded due to confidentiality restrictions) are all 5-41% higher than their 1991-2019 averages. In particular, the monthly averages for February and May 2020 are the both the second largest in their respective time series and the largest in their respective time series since 1991. Results from a model estimating both “year” and “month” effects for the time series are shown in Figure 2.1.1. The year effect for 2020 is projected to be 46% above the average for the 1991-2020 time series.

The CPUE data from the bottom trawl fishery are harder to interpret than the CPUE data from the longline fishery, because the former tend to be much more variable than the latter. After normalizing each gear-specific year × month time series to a mean of unity, the overall standard deviation for the bottom trawl fishery is 0.71, compared to only 0.34 for the longline fishery. As an example of this variability, the February 2020 average for the bottom trawl fishery was by far the largest in the time series, being 238% higher than the 1991-2019 average for February, whereas the March 2020 was only 12% higher than the 1991-2019 average for March, and the 2020 averages for January, April, May, and June were all 25-48% *lower* than their respective monthly 1991-2019 averages.

Tagging

The following information was provided by Susanne McDermott (AFSC):

Pop-up satellite archival tags were attached to 38 fish near St Lawrence Island during August and September of 2019. In addition, and three stationary tags were deployed in the same area.

To date, 33 fish tags and three stationary tags have popped up and transmitted data. Data from the remaining five fish are expected in August/September of this year.

The number of tags popping up by month is shown below:

Popup year	Popup month	Tags
2019	9	2
2019	10	2
2019	11	7
2019	12	3
2020	1	5
2020	2	3
2020	3	8
2020	6	2
2020	7	1
Total		33
Still in the water		5

The breakdown of recoveries by month is as follows:

- September 2019 to December 2019:
  - 9 fish stayed in the NBS
  - 3 fish moved to Russian waters
- January 2020 to March 2020:
  - 9 fish moved to the NBS slope
  - 1 fish moved to the Gulf of Alaska
  - 3 fish stayed in Russian waters
- June 2020 to July 2020:
  - 1 fish stayed in the EBS and went to Bristol bay
  - 2 fish moved back to the NBS

Western Bering Sea (WBS) abundance

The following was provided by Cecilia O'Leary (AFSC):

Basin-wide Bering Sea biomass indices were 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 using multiple spatially unbalanced survey data products from western (WBS), northern (NBS), and eastern (EBS) Bering Sea and the vector autoregressive spatio-temporal model (VAST; Thorson and Barnett 2017). 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 & spatiotemporal random effects for encounter probability & 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. Agreement was also found between the area-swept (i.e., design-based) index and model-based index of abundance for Pacific cod (Figure 2.1.2), and an overall increase in the proportion of cod in the WBS relative to the EBS + NBS (Figure 2.1.3).

Results

Please note: In tables with color scales, red and green correspond to the minimum and maximum values within the given row or column (whether the scale varies horizontally or vertically depends on the table).

Primary ensemble

Final model names

Based on the time series of spawning biomass estimates (see next section), ADSB values for the models in the primary and alternative ensembles were calculated and final model names were established as shown below:

Time-varying *Q* ?	No				Yes			
Separate areas?	No		Yes		No		Yes	
Separate surveys?	No	Yes	Yes		No	Yes	Yes	
Movement?	No		No	Yes	No		No	Yes
Temporary name	A1	B1	C1	D1	A2	B2	C2	D2
ADSB	0.0755	0.0981	1.2983	0.0732	n/a	0.0775	0.1692	0.3918
Final name	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3

Parameter estimates and derived time series

Table 2.1.3 lists the estimates and standard deviations of all internally estimated parameters except fishing mortality.

Table 2.1.3a shows the values of the main parameters (time-invariant parameters that are common to at least half of the ensemble). A blank cell indicates that the respective parameter (row) is not used in the respective model (column).

Nomenclature pertaining to parameter labels in Table 2.1.3a:

- The terms “fsh” and “srv” refer to the fishery and survey, respectively
- Except for 1-area models with separate EBS and NBS surveys, the term “main” in a parameter label refers to the combined EBS and NBS in a 1-area model and to the EBS in a 2-area model.
- In 1-area models with separate EBS and NBS surveys, the term “main” refers to the combined EBS and NBS in the case of fishery-related parameters, but to the EBS in the case of survey-related parameters.
- Except in the context of log catchability, the term “base” in a parameter label denotes that the parameter is subject to annual random deviations. In the context of log catchability, “base” denotes that the parameter is subject to annual random deviations in at least some of the models (specifically, Models 19.12, 19.12d, 20.2, and 20.3).
- The term “lnDM” refers to the log-scale Dirichlet-multinomial parameter that scales sample size relative to the specified (input) sample size.

The “Parameter estimation” section above noted that there were only two exceptions to the claim that bounds were either non-constraining or bound only by a logical constraint. These exceptions were the estimates of NBS_srv_sel_PeakStart_base in Models 19.12b and 19.12d, where the estimates were just below the upper bound of 80 cm that was specified for that parameter. Other values for the upper bound were explored, but the upper bound of 80 cm was retained because: 1) the corresponding parameter for fishery selectivity was less than 80 cm for all models, and it seems unlikely that the survey would have a lower selectivity for fish of that size than the fishery; 2) setting the upper bound substantially higher than 80 cm still resulted in the estimates being bound; and 3) if the upper bound is set high enough, the becomes confounded with the estimate of catchability.

For many of the parameters in Table 2.1.3a, the estimates do not vary much between models. For example, the estimates of natural mortality range from 0.332 to 0.372 the estimates of mean length at age 1.5 range from 14.594 14.903, and the estimates of the von Bertalanffy (Brody) growth coefficient range from 0.106 to 0.123. Within either of the two specified time blocks (1977-2007 and 2008-2019), the estimates of ageing bias at ages 1 and 20 likewise do not vary by much between models. However, the estimates differ considerably *between* the two time blocks. For the years prior to 2008, the estimates of ageing bias at age 1 range from 0.337 to 0.349, but they are essentially zero after 2007 in all models (range = -0.002 to 0.019). The estimates of ageing bias at age 20 for the years prior to 2008 range from 0.776 to 0.954, but they are strongly negative after 2007 in all models (range = -2.179 to -1.532). Initial fishing mortality ranges from 0.114 to 0.173. Log catchability for the main survey ranges from -0.116 to 0.261, and log catchability for the NBS survey ranges from -1.842 to 0.827. For the size composition components, estimates of the log-scale Dirichlet-multinomial parameter are all near the upper bound set at 10.0; but for the age composition components, values range from -0.006 to 0.541 (for the main survey) and -1.511 to 0.383 (for the NBS survey).

Table 2.1.3b shows the base values of the four movement parameters and the coefficients linking the recruitment distribution parameter and the four movement parameters to their respective environmental covariates (notes that these parameters appear only in Models 19.12c and 20.3). The signs of the parameters lining the proportion of recruitment allocated to the NBS and the base values of the four movement parameters are consistent between the two models that incorporate movement:

- The sign of RecrDist_NBS is negative (i.e., the proportion of recruitment allocated to the NBS varies inversely with sea ice extent).
- The signs of Move_EBS_to_NBS_A_link and Move_EBS_to_NBS_B_link are both negative (i.e., the proportion of fish moving from the EBS to the NBS varies inversely with sea ice extent).
- The signs of Move_NBS_to_EBS_A_link and Move_NBS_to_EBS_B_link are both positive (i.e., the proportion of fish moving from the NBS to the EBS varies directly with the NPI).

The remaining parts of Table 2.1.3 pertain to annual parameter deviations, and generally show very consistent trends across models (i.e., the color scales are similar), with the single exception noted below:

- Table 2.1.3c shows log recruitment deviations for the initial numbers-at-age vector.
- Table 2.1.3d shows log recruitment deviations.
- Table 2.1.3e shows length at age 1.5 deviations.
- Table 2.1.3f shows log catchability deviations (Models 19.12, 19.12d, 20.2, and 20.3 only).
- Table 2.1.3g shows deviations for the fishery selectivity lnSD1 parameter.
- Table 2.1.3h shows deviations for the fishery selectivity logitEnd parameter. This is the only case where the trends are not similar across models. However, for the three models with trends that are noticeably different from the others (Models 19.12c, 20.2, and 20.3), it should be noted that the deviations are all very close to zero.
- Table 2.1.3i shows deviations for the survey selectivity PeakStart parameter.
- Table 2.1.3j shows deviations for the survey selectivity lnSD1 parameter.

The only other internally estimated parameters, which SS treats somewhat differently from those shown in Table 2.1.3, is the time series of fishing mortality rates, which are shown in Table 2.1.4. Separate time series for the EBS and NBS are shown for the 2-area models (20.1, 19.12c, 20.2, and 20.3). The trends are highly similar across models.

Table 2.1.5 shows the iteratively tuned values of the sigma parameters for the various vectors of annual random deviations. For each parameter and model, the columns labeled “var_dev” and “ave_var” represent the variance of the vector of estimated deviations and the average of the variances of the individual estimates in the vector. For parameters other than log recruitment, the deviations pertaining to the other parameters, sigma is tuned so that the square root of the sum of var_dev and ave_var is unity. For the deviations pertaining to log recruitment, sigma is tuned to equal the square root of the sum of var_dev2 and ave_var2 (note that SS treats sigma for log recruitment deviations differently from sigma for other parameter deviations). Note that a few of the parameter/model combinations (shaded gray) have a var_dev value close to zero and an ave_var value close to unity, meaning that the respective vector of deviations had very little effect on model results. Finally, note that the iterative tuning of the sigma parameters was based on a data file that erroneously included the VAST NBS age composition record for 2016, and it was too late to retune them after the error was discovered. However, removal of the extra age composition record tended to have very little impact on estimates of other parameters, so it seems likely that removal of that record would have little effect on the estimates of the sigma parameters.

Schedules of quantities that function like parameters in the state transition and observation processes, but that are actually functions of parameters listed in Table 2.1.3, are shown in Figure 2.1.4 (selectivity, both fishery and survey), Figure 2.1.5 (survey catchability), and Table 2.1.6 (movement probabilities, Models 19.12c and 20.3 only).

- With only a couple of exceptions, fishery and survey selectivity schedules are fairly similar across models (Figure 2.1.4). The first exception is with respect to the “main” fishery (EBS and NBS combined in Models 19.12a and 19.12, EBS by itself in all other models), where the 1-area models (19.12a, 19.12, 19.12b, and 19.12d) all appear fairly similar to each other, but distinct from the 2-area models, which likewise all appear to be fairly similar to each other. Specifically, the 1-area models lack the large decrease in fishery selectivity at the largest sizes that is exhibited by the 2-area models. The second exception is with respect to the NBS survey, where the two models incorporating inter-area movement (19.12c and 20.3) reach maximum selectivity at a much smaller size than in the other models that treat the EBS and NBS surveys separately.
- The catchability time series are displayed on separate panels for the “main” (EBS or combined EBS and NBS) survey and for the NBS survey. For the “main” survey (Figure 2.1.5a), average catchability tended to fall within or very close to the 0.9-1.1 range for all models except those that incorporate inter-area movement, where Model 19.12c gave an average EBS catchability of 1.188 and Model 20.3 gave an average EBS catchability of 1.302. For the NBS survey (Figure 2.1.5b), on the other hand, average catchability fell well outside the 0.9-1.1 range, and, for the models with time-varying catchability, some of the annual values were quite extreme. For example, Model 20.2 resulted in NBS catchability estimates >5 in the final three years of the time series, and Model 20.3 resulted in NBS catchability estimates less than <1/5 in the first 5 years of the time series.
- The movement parameters estimated by Models 19.12c and 20.3 are translated into movement probabilities in Table 2.1.6. For either of the model-specific columns, each row shows the probability of moving from the specified source (“Src.”) area to the destination (“Dst.”) area for ages 2 through 7+. The probability of staying in the source area is simply 1.0 minus the probability of moving, and is not shown in the table, in the interest of efficiency. Estimated movement probabilities vary substantially over time, and can occasionally be quite high. For example, estimates in excess of 0.5 occurred in 5.1% of the possible cases in Model 19.12c and in 2.6% of the cases in Model 20.3.

Time series of biomass and recruitment are shown for all models in Figure 2.1.6 (age 0+ biomass), and Table 2.1.7 (female spawning biomass), Table 2.1.8 (relative spawning biomass), and Table 2.1.9 (age 0 recruitment). Projected values for 2020 and 2021 are included in all of these except for Table 2.1.9.

- The time series of age 0+ biomass is shown for the combined EBS and NBS areas (all models) in Figure 2.1.6a. The 1-area models show very similar values through most years, although the magnitudes diverge a bit in the last few years. Qualitatively, the 2-area models show the same patterns of highs and lows, but the scales are somewhat different, with that of Model 20.1 being much higher than the others. The time series of age 0+ biomass is shown for the separate areas (2-area models only) in Figure 2.1.6b. For the EBS, the two models *without* inter-area movement (yellow) tend to cluster together, with values substantially higher than the two models *with* inter-area movement (green), which tend to form a separate cluster. For the NBS, all of the trajectories are distinct, with Model 20.1 estimating much higher values than the other three models and Model 20.2 tending to estimate the lowest values, particularly in the last few years of the series.
- The time series of female spawning biomass spawning is shown for the combined EBS and NBS areas (all models) in Table 2.1.7a. Qualitatively, the trends are very similar across models, although, in terms of magnitude, Model 20.1 tends to exhibit the highest values. For the last few years of the series, Models 19.12b, 19.12d, and 20.2 exhibit the lowest values. The time series of female spawning biomass is shown for the separate areas (2-area models only) in Table 2.1.7b. As with the time series of NBS age 0+ biomass, Model 20.1 estimates much higher values than the other models. For the last few years of the series, Model 20.2 estimates the lowest values.
- Even though some of the models are spatially structured, Pacific cod in the EBS and NBS are still considered to comprise the same stock, so relative biomass is reported only for the combined EBS and NBS areas in Table 2.1.8. As with female spawning biomass, the relative biomass trends area qualitatively similar across models. Model 19.12c tends to estimate the highest values across all years. For the last few years of the series, Model 19.12d estimates the lowest values.
- The time series of age 0 recruitment is shown for the combined EBS and NBS areas (all models) in Table 2.1.9a. Qualitatively, the time series are extremely similar across models. In absolute terms, Model 20.1 consistently estimates the highest values. For most of the last few years of the series, Model 19.12d estimates the lowest values. The time series of age 0 recruitment is shown for the separate areas (2-area models only) in Table 2.1.9b. Again, the series are qualitatively very similar. In absolute terms, Model 20.1 consistently estimates the highest values and Model 19.12c the lowest values.

<u>Performance measures</u>

Figure 2.1.7 shows the model fits to the surveys. Fits to the "main" survey are shown in Figure 2.1.7a (all models). Qualitatively, the estimated trajectories from all models match their respective observed trajectories, although models *with* time-varying catchability tend to fit the data better than those *without* it, as would be expected. Fits to the NBS survey are shown in Figure 2.1.7b (2-area models only), where the models that lack *both* time-varying catchability and inter-area movement (Models 19.12b and 20.1) clearly fail to fit the data.

Retrospective analyses of all models are shown in Figure 2.1.8, where the value of Mohn's (1999) ρ is listed for each model. As measured by Mohn's ρ, Models 20.1 and 20.3 have the largest retrospective bias, exhibiting values of -0.539 and 0.467, respectively. However, the value for Model 20.3 is influenced heavily by the 10^{th} peel, which will disappear when this year's final assessment is produced. To address the potential sensitivity of Mohn's ρ value to outliers, the 10 bias estimates (one for each peel) that are averaged in order to calculate Mohn's ρ were bootstrapped 100,000 times, enabling estimates of imprecision. The point estimates of Mohn's ρ are shown below, together with bootstrap estimates of the standard deviation and the endpoints of the 95% confidence interval (note that the standard deviation and the width of the 95% confidence interval for Model 20.3 are much larger than for the other models):

Statistic	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
mean	-0.070	-0.079	-0.539	0.100	-0.053	-0.025	-0.109	0.466
st. dev.	0.022	0.034	0.045	0.038	0.014	0.023	0.022	0.339
L95%	-0.116	-0.146	-0.615	0.027	-0.081	-0.074	-0.150	0.028
U95%	-0.031	-0.015	-0.443	0.174	-0.028	0.014	-0.065	1.212

Table 2.1.10 shows objective function values for all components and models. Table 2.1.10a shows aggregated components, and Table 2.1.10b breaks down the survey index, size composition, and age composition components by fleet type (fishery or survey) and area ("main" or NBS). Note the different models use different data sets, so values are difficult to compare across models. Note also that fishery size composition data for the NBS were unavailable at the time that this preliminary assessment was developed, so the objective function values for that sub-component are zero for the 2-area models.

Table 2.1.11 summarizes goodness of fit for the survey index (abundance), size composition, and age composition in terms of ratios, where a value of unity is the goal. For the two columns under the "Area" heading, "Actual" refers to the area associated with the survey data used in the model (EBS, NBS, or "XBS," where the latter refers to the EBS and NBS combined), and "Assumed" refers to the area that the model assumes the data represent (for most models, the Actual and Assumed areas are the same, but for the 1-area models that use separate EBS and NBS surveys, they are different).

- For the abundance data, goodness of fit is measured by the ratio of the log-scale root-mean-squared error to the average of the input log-scale standard errors. The four models exhibiting time-variable catchability do very well by this measure, at least for their respective "main" survey, with ratios ranging from 0.98 to 1.00. However, none of the models that include the NBS survey data as a separate index do a particularly good job of fitting those data, with ratios ranging from 0.70 to 0.78.
- For the compositional data, goodness of fit is measured by the ratio of *Nsamp* to *Ninit* (see "Base model" section). All models fit all of their respective size composition data extremely well, with ratio=1.00 in all cases. Fits to the age composition data were not nearly as good, with ratios for the "main" survey ranging from 0.50 to 0.63, and ratios for the NBS survey ranging from 0.18 to 0.60. The NBS survey age composition data were fit the best by the two models that used those data in a 1-area structure (Models 19.12b and 19.12d).

Table 2.1.12 shows goodness of fit for the size composition on a finer scale, where "N" is the input sample size (same as *Ninit*) and where "DM" and "MI" represent two measures of effective sample size: "DM" (same as *Nsamp*) uses the definition that is consistent with the Dirichlet-multinomial approach of Thorson et al. (2017), and "MI" is the harmonic mean of the quantity as defined by McAllister and Ianelli (1997). Table 2.1.12a shows the results for the fishery data and Table 2.1.12b shows the results for the survey data. In general, DM and MI show similar trends, but MI tends to be larger.

Table 2.1.13 is the age composition analogue to Table 2.1.12 (note that color scales extend across rows in this table, rather than across columns for most tables that show results by year).

- For the "main" survey, the pair of 2-area models that treat the NBS and EBS surveys separately (Models 20.2 and 20.3) show the highest values of DM for all years except 2017, which was one of the years in which an NBS survey took place; while the pair of models that combined the EBS and NBS surveys (Models 19.12a and 19.12) show the lowest values of DM in all years except 2010, 2017, and 2018, which are the years in which an NBS survey took place.

- For the NBS survey, Models 19.12c and 19.12d show the highest values in all three years, and Models 20.1 and 20.2 show the lowest values in all three years.

Alternative ensemble

A small set of results is presented here for the alternative ensemble, so that the performance of the alternative ensemble can be compared easily with that of the primary ensemble, so that the Team and SSC have enough information to determine which (if either) ensemble they would like to see presented in the final draft of this year's assessment.

<u>Final model names</u>

After computing ADSB for the "prior-less" versions of the six models in the primary ensemble that included informative prior distributions for log catchabiltiy in the NBS survey, the models in the alternative ensemble were assigned the names shown below (note that Models 19.12a and 19.12, shaded gray, members of both ensembles; also, new ADSB values are not relevant to Models 19.12 and 19.15, as these models retain the names assigned to them in last year's assessment):

Time-varying *Q* ?	No				Yes			
Separate areas?	No		Yes		No		Yes	
Separate surveys?	No	Yes	Yes		No	Yes	Yes	
Movement?	No		No	Yes	No		No	Yes
ADSB:	0.0755	0.1105	36.5771	0.0724	n/a	n/a	0.1874	0.3642
Model name:	19.12a	20.4	20.5	19.12e	19.12	19.15	20.6	20.7

<u>Parameter estimates and derived time series</u>

Table 2.1.14 compares estimates and standard deviations of the time-invariant parameters that are common to at least half the models in the primary ensemble (estimates for Models 19.12a and 19.12 are not shown, because they are the same in both ensembles).

- Table 2.1.14a compares the point estimates of the parameters between each pair of models. For parameters that are constrained to be positive (top 12 rows in the table), changes (D) are expressed as A/P-1 (where "A" and "B" represent the version of the particular model in the alternative and primary ensembles, respectively), while changes for parameters that are defined on the whole real line are expressed as A-P. To facilitate a focus on the largest changes, let a "substantial" change be defined as one outside the {-0.05, 0.05} range. In the table, changes below a value of -0.05 are highlighted in red, and changes above a value of 0.05 are highlighted in green. There were only 15 cases where changes in parameter estimates were in the "substantial" category (the {19.12c, 19.12e} pair exhibited no substantial changes at all). Not surprisingly, the parameter that most frequently exhibited substantial changes was log catchability for the NBS survey (highlighted by the bold box), which exhibited a substantial change in four out of the six pairs of models. In particular, removing the informative prior distribution on NBS log catchability from Model 20.1 caused the estimate of that parameter to decrease by 3.375 in Model 20.5. Aside from changes in NBS ln(Q), the {20.2, 20.6} and {20.3, 20.7} pairs exhibited no substantial changes in parameter estimates. Note that Model 20.7 exhibited convergence issues unless the value of initial fishing mortality in the NBS fishery was fixed at a very small number rather than estimated, so the value of that parameter is not displayed for Model 20.7.

- Table 2.1.14b is analogous, except that it describes differences in the standard deviations of the parameter estimates rather than the point estimates themselves. Because standard deviations are always constrained to be positive, all changes are expressed as A/P-1. Substantial changes are more common in Table 2.1.14b than in Table 2.1.14a, with 38 occurrences out of a possible 187. For the model pairs {19.12b, 20.4}, {20.2, 20.6}, and {20.3, 20.7}, substantial changes in standard deviations were all negative (i.e., the parameters were more precisely estimated when the prior distribution on NBS ln(*Q*) was removed), while substantial changes in the {19.12d, 19.15} pair were all positive. Substantial changes in the {20.1, 20.5} and {20.2, 20.6} pairs were of mixed direction, while the {19.12c, 19.12e} pair exhibited no substantial changes in standard deviations.

Table 2.1.15 compares estimates of the catchability time series (*not* on the log scale), expressed as A/P-1.

- Table 2.1.15a compares estimates for the EBS survey for the two pairs of 1-area models. The changes are negative and small for all years in both model pairs, staying within the –0.011 to –0.008 range.
- Table 2.1.15b compares estimates for the NBS survey for the two pairs of 1-area models. Changes are slightly larger here than in Table 2.1.15b, still consistently negative, with a value of –0.016 for the {19.12b, 20.4} pair and ranging from -0.056 to -0.017 for the {19.12d, 19.15} pair.
- Table 2.1.15c compares estimates for the EBS survey for the four pairs of 2-area models. Changes are small and positive for the {20.1, 20.5} pair (0.017 in all years) and the {20.2, 20.6} pair (ranging from 0.002 to 0.003}, while changes are small and negative for the {19.12c 19.12e} pair (-0.001 in all years) and the {20.3, 20.7} pair (ranging from -0.012 to 0).
- Table 2.1.15d compares estimates for the NBS survey for the four pairs of 2-area models. Changes here are sometimes quite substantial. In particular, the constant value of NBS Q in Model 20.5 is lower than in its counterpart (Model 20.1) by a factor of 0.966. Changes are uniformly negative in the {19.12c, 19.12e} pair (-0.005 in all years) and the {20.3, 20.7} pair (ranging from -0.107 to -0.054), while changes in the {20.2, 20.6} pair are uniformly positive (ranging from 0.049 to 0.078).

Table 2.1.16 compares estimates of the age 0+ biomass time series, expressed as A/P-1.

- Table 2.1.16a compares combined-area age 0+ biomass. The changes in the {20.2, 20.6} pair are uniformly negative and small, ranging from -0.006 to -0.003. The changes for all other pairs are uniformly positive, with all of the changes in the {20.1, 20.5} pair being truly enormous. For the other pairs with positive changes, the values are all within the 0.001 to 0.047 range.
- Table 2.1.16b compares age 0+ biomass for the individual areas (2-area models only). For the EBS, changes are all small; uniformly negative for the {20.1, 20.5} and {20.2, 20.6} pairs and uniformly positive (with a single exception) for the {19.12c and 19.12e} and {20.3, 20.7} pairs, with values ranging from -0.037 to 0.002. For the NBS, changes are uniformly negative for the {20.2, 20.6} pair, ranging from -0.081 to -0.036, and uniformly positive for the other three model pairs. The changes for the {20.1, 20.5} pair, like their combined-area counterparts, are truly enormous. The changes for the {19.12c, 19.12e} pair range from 0.002 to 0.008, while changes in the {20.3, 20.7} pair range from 0.065 to 0.101.

<u>Performance measures</u>

Table 2.1.17 compares values of the objective function components, expressed as P-A. Cells with negative values (better fit) are shaded red, and cells with positive values (worse fit) are shaded green.

- Table 2.1.17a compares values for the major components. All totals are negative, indicating that removal of the informative prior distribution on log catchability in the NBS survey results in overall better fits to the data, as would be expected. However, a few individual components in each model pair show an improved fit when the prior distribution is removed, although the components associated with such improved fits are not consistent across models, although the survey index is fit better in all but one pair of models {20.2, 20.6}. The age composition component is fit better in half the model pairs.
- Table 2.1.17b compares values for fleet- and area-specific subcomponents. A few individual subcomponents in each model pair show an improved fit when the prior distribution is removed. For each subcomponent of the size composition and age composition components (except for the NBS fishery sizecomp subcomponent, where data do not exist), half the models fit the NBS data better when the prior distribution on log catchability in the NBS survey is removed, and half the models fit the "main" survey data better.

The point estimates of Mohn's ρ for the models in the alternative ensemble are shown below, together with bootstrap estimates of the standard deviation and the endpoints of the 95% confidence interval (values for Models 19.12a and 19.12, shaded gray, are the same as in the primary ensemble):

Statistic	19.12a	20.4	20.5	19.12e	19.12	19.15	20.6	20.7
mean	-0.070	-0.094	-0.012	0.790	-0.053	-0.034	-0.013	0.052
st. dev.	0.022	0.032	0.012	0.329	0.014	0.023	0.038	0.075
L95%	-0.116	-0.158	-0.036	0.231	-0.081	-0.082	-0.078	-0.091
U95%	-0.031	-0.034	0.010	1.509	-0.028	0.006	0.068	0.199

Cross-conditional decision analysis

Introduction

CCDA was introduced during the September 2019 Team meeting (see document posted at https://meetings.npfmc.org/Meeting/Details/843). Briefly, CCDA is a systematic method for answering a question that regularly plagues attempts to choose a single model from a set of alternatives, namely, *"But what if we're wrong?"* CCDA answers this question by considering not only the performance of a given model within the ensemble when the structure of that model is the "true" one, but also the performance of that model when any of the *other* models in the ensemble is the "true" one, repeating this process for each model in the ensemble. Performances are measured by generating a series of bootstrap data sets from each fitted model, then applying each model to each data set and comparing the respective estimates of the quantity of interest to the best estimate from the model that generated the bootstrap data (the "pivot" model). Those performances, together with a set of user-specified values representing the subjective probabilities that each of the models in the ensemble is the "true" one, are then used to estimate a set of model weights that optimize the performance of the overall ensemble. This results in a probability mass function, *pmf*, for the quantity being estimated. Finally, decision theory is then used to obtain an optimal point estimate, given the *pmf* and a specified level of risk aversion, *ra*, where *ra*<0 implies risk proclivity, *ra*=0 implies risk neutrality, and *ra*>0 represents true risk aversion. A full description of the steps involved in CCDA is given in Attachment 2.1.3.

It should be noted that one change has been made to the method since it was introduced in September 2019. This will be addressed in the "Discussion" section.

Application: Estimating OFL and ABC in the primary ensemble

CCDA was applied here to the primary ensemble for the purpose of developing preliminary estimates of the OFL and ABC for 2021. Due to time constraints, a fairly small sample of 10 bootstrap data sets was generated from each of the 8 models in the ensemble. When each of the 8 models was fit to each of the 8×10 bootstrap data sets, the estimates of 2021 OFL shown in Table 2.1.18 resulted. In the event that at least one model failed to converge for a given bootstrap data set, all estimates for that data set were dropped from the analysis (these are represented by blank lines in Table 2.1.18, where cell(s) corresponding to the model(s) that failed to converge are shaded gray).

The probability that any given model in the ensemble is the "true" one was based on scores that were derived from factor-specific formulas that considered the following:

- The extent to which the model structure seems consistent with observed inter-area trends.
- Goodness of fit.
- Retrospective performance (Mohn's ρ).
- The extent to which catchability (combined area or by separate areas) deviates from unity.

The details of the formulas are omitted here in the interest of brevity, given that the choice of functional forms was ultimately subjective, but the resulting scores are shown below:

Model	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
Structure	0.667	0.667	0.333	0.667	1.000	1.000	0.667	1.000
Fit	0.838	0.764	0.712	0.813	1.000	0.972	0.912	0.922
Mohn's ρ	0.956	0.947	0.598	0.927	0.972	1.000	0.920	0.643
Catchability	1.000	0.762	0.673	0.829	0.962	0.824	0.514	0.425
Mean	0.865	0.785	0.579	0.809	0.984	0.949	0.753	0.747
Probability	0.134	0.121	0.089	0.125	0.152	0.147	0.116	0.115

The arithmetic mean of the scores was used as the basis for assigning the probabilities (by rescaling so that the values sum to unity), following the recommendation of the SSC (see comment SSC6).

An important distinction in CCDA is that the probability of a given model being the "true" one is not necessarily equal to, or even related to, how well that model performs when either it or one of the other models in the ensemble is *actually* the true model. The latter concept is represented in CCDA by a vector of model *weights* (as distinguished from probabilities). The model weights are used to form a conditional mean squared error (CMSE) for each pivot model, where the weighted average is computed across models for each bootstrap data set, and then the bootstrap-specific weighted average squared errors are averaged across bootstrap data sets (without weighting, because the bootstrap data sets for a given pivot model are considered to be a random sample). Table 2.1.19 shows example calculations for the case where all of the model weights are equal.

Given the CMSE for each pivot model, an ensemble mean squared error is calculated as the sum of the product of the model CMSEs and the model probabilities. The results for the equal weighting example are shown below:

Model:	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
probability	0.1337	0.1213	0.0895	0.1250	0.1520	0.1467	0.1164	0.1155
CMSE:	0.0207	0.0015	0.0001	0.0005	0.0215	0.0018	0.0014	0.0002
probability×CMSE:	0.0028	0.0002	0.0000	0.0001	0.0033	0.0003	0.0002	0.0000

The sum of the values on the bottom row (=0.0067, or -5.0007 on the log scale) is the ensemble MSE when equal weights are used.

However, a central feature of CCDA is that the model weights are estimated statistically by minimizing the ensemble MSE. The model weights estimated in this application are shown below:

Model	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
Weight	0.000	0.012	0.000	0.244	0.000	0.060	0.000	0.684

Table 2.1.20 shows the results of calculations analogous to those in Table 2.1.19 when the optimized model weights are used instead of equal weighting. The CMSE values from Table 2.1.20 are then multiplied by the model probabilities as shown below:

Model:	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
probability	0.1337	0.1213	0.0895	0.1250	0.1520	0.1467	0.1164	0.1155
CMSE:	0.0004	0.0010	0.0005	0.0002	0.0006	0.0006	0.0003	0.0002
probability×CMSE:	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000

The sum of the values on the bottom row (=0.0005, or -7.6132 on the log scale) is the ensemble MSE when the optimized weights are used.

The above results illustrate the point that a given model's performance across alternative (conditional) truths may be largely unrelated to its probability of being the "true" model. For example, Model 19.12 was subjectively judged to be the most likely to be "true," but its performance weight ended up being essentially zero, while Model 20.3 was subjectively judged to rank next to last in terms of the probability of being "true," but it ended up with the highest performance weight. The two models that incorporate explicit inter-area movement (19.12c and 20.3) ended up with 92.7% of the overall performance weight.

For a given pivot model, the estimates in each column of the corresponding section of Table 2.1.18 can be converted into a scaled histogram, which can then be weighted by the respective performance weight, and then the columns can be summed to generate a conditional weighted average *pmf* for that pivot model. These are shown in Table 2.1.21. Note that the range of OFL values in Table 2.1.9 is truncated at 200,000 t, even though some of the individual *pmf*s or weighted average *pmf*s include some amount of mass outside that range. This is simply for display purposes (i.e., larger values of OFL were not ignored in the analysis).

The model-specific, performance-weighted average *pmf*s are then weighted by the model probabilities, giving the final *pmf* for the overall ensemble shown in Figure 2.1.9 (approximately 2% of the total mass of the final *pmf* occurs at values of OFL larger than 300,000 t; these are not shown in the figure, but were not ignored in the analysis).

Given this *pmf*, the only other quantities that need to be specified in order to estimate OFL and ABC in the CCDA approach are the corresponding values of *ra*.

Because OFL is commonly understood as being a risk-neutral estimate of the fishing mortality rate corresponding to maximum sustainable yield (at least for stocks above the inflection point in the OFL harvest control rule), it seems reasonable to identify *ra*=0 for estimation of OFL. Because ABC is constrained to be less than OFL, it can be viewed as a risk-averse alternative, but this begs the question of *how much* risk aversion is appropriate for estimation of ABC (see comment SSC5). For the present application, *ra*=2 was identified as a reasonable value for estimation of ABC (see Attachment 2.1.4).

Given *ra*=0, the estimate of OFL from CCDA is simply the arithmetic mean of the *pmf*; and given *ra*=2, the estimate of ABC from CCDA is simply the harmonic mean of the *pmf*. The arithmetic and harmonic means of the *pmf* shown in Figure 2.1.9 are 127,084 t (OFL) and 114,288 t (ABC), respectively, representing a buffer of approximately 10%. Of course, the ABC harvest control rule identified in the BSAI Groundfish FMP still applies, so the CCDA estimate of ABC could be used only if it does not exceed the value resulting from application of that control rule.

Discussion

Looking ahead to developing the final draft of this year's assessment, two main issues are important to highlight with at this point: 1) how to structure the ensemble, and 2) whether to use CCDA.

Structure of the ensemble

Two ensembles have been presented here: 1) the primary ensemble, consisting of eight models, one of which is the current base model (19.12); and 2) an alternative ensemble, which is the same as the primary model except that the six models that use an informative prior distribution on NBS survey log catchability in the primary ensemble are replaced by six models that are the same as their primary ensemble counterparts in all respects except for use of that prior distribution.

Fitting and documenting eight models in the brief time available for development of the final draft of this year's assessment will likely prove to be a challenging undertaking, based on last year's experience with a 9-model ensemble. However, both of the 8-model ensembles presented here have the desirable attribute of being based on a factorial design, which helps to regard against "stacking the deck" in selecting models for inclusion in the ensemble, so eliminating models from either ensemble would remove this attribute unless done carefully.

The prior distribution on NBS survey log catchability in the two-survey models from the primary ensemble each have a mean equal to the corresponding point estimate of EBS survey log catchability, which seems reasonable, but it complicates the model fitting process by requiring an iterative process, and these models already involve a complicated iterative process for tuning the sigma terms of the various vectors of annual random deviations. Although the assumption of unit variance in the prior distribution was made with the expectation that it would be only mildly constraining, the effects were, in practice, sometimes substantial, particularly when comparing Models 20.1 (with the prior distribution) and 20.5 (the analogous model without the prior distribution).

Of course, once the Team and SSC have the opportunity to review the results of this preliminary assessment, they may prefer to replace some of the models with new models of their own.

If any of the two-area models presented here are to be included in the final draft, the experience of developing these models for the preliminary draft suggests that fixing the value of initial fishing mortality in the NBS fishery at some very small value would likely be of negligible consequence in terms of parameter estimation but would likely result in improved performance in terms of model convergence.

Use of CCDA

As noted in the "Cross-conditional decision analysis" section, the application of CCDA in this preliminary assessment included some changes relative to the method described in September 2019 (see document posted at https://meetings.npfmc.org/Meeting/Details/843). Here, a single set of model weights and a single ensemble *pmf* were generated, both of which were implicitly based on a risk-neutral loss function, with contrasting attitudes toward risk coming into play only when deriving point estimates from the single ensemble *pmf*. In contrast, the original description of CCDA envisioned estimation of a separate set of model weights and a separate ensemble *pmf* for each value of *ra*. There were two reasons for making this change: First, while risk aversion has a fairly intuitive meaning for something like setting ABC, it is not at all clear that the meaning is similarly clear for many other quantities estimated in the assessment (for example, what does risk aversion mean in the context of estimating a selectivity parameter?). Second, when a separate set of model weights and a separate ensemble *pmf* are estimated for each value of *ra*, it is possible for the estimate of ABC to exceed the estimate of OFL, which might be theoretically valid, but would likely be difficult to explain, and moreover would be precluded by the MSFCMA National Standard Guidelines.

The main advantage of including CCDA in this year's final assessment is that it provides a statistically rigorous answer to the "*But what if we're wrong?*" question that so often plagues the process of selecting a single model.

However, there are several disadvantages as well:

- It is much harder to understand (or explain) than typical approaches to model averaging.
- It is currently very time-consuming, perhaps to such an extent that its use in this year's final assessment is precluded on logistical grounds alone. A major impediment is the fact that some of the models in the ensemble have spatial structures that are nested within those of other models in the ensemble. Even if an analysis similar to the one described here could be conducted in time for this year's final assessment, it would be limited to estimation of OFL and ABC (i.e., there would definitely not be enough time to produce a full set of model-averaged results for parameters or time series of derived quantities).
- As discussed in the document presented in September 2019, use of bootstrap distributions as an approximation of Bayesian posterior distributions is controversial. Even if the approximation is acceptable in principle, the precision of the distributions estimated here is questionable, given the small sample (10 bootstrap data sets per model). As a quick comparison, the averages from the bootstrap distributions presented here were sometimes noticeably (although not drastically) different from the point estimates derived from the actual data.

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Tables

Table 2.1.1. Parameter counts. Gray shading indicates that the parameter/model combination is not applicable. Color scales extend from red=low to green=high.

Time-varying *Q* ?	No				Yes			
Separate areas?	No		Yes		No		Yes	
Separate surveys?	No	Yes	Yes		No	Yes	Yes	
Movement?	No		No	Yes	No		No	Yes
Temporary name	A1	B1	C1	D1	A2	B2	C2	D2
NatMort	1	1	1	1	1	1	1	1
Growth	6	6	6	6	6	6	6	6
Recr_dist			1	1			1	1
Movement				4				4
Recr_dist_cov				1				1
Movement_cov				4				4
Ageing_error	4	4	4	4	4	4	4	4
SR	2	2	2	2	2	2	2	2
InitF(main_srv)	1	1	1	1	1	1	1	1
InitF(NBS_srv)			1	1			1	1
LnQ(main_srv)	1	1	1	1	1	1	1	1
LnQ(NBS_srv)		1	1	1		1	1	1
Sel(main_fsh)	5	5	5	5	5	5	5	5
Sel(NBS_fsh)			5	5			5	5
Sel(main_srv)	2	2	2	2	2	2	2	2
Sel(NBS_srv)		2	2	2		2	2	2
DM(fish&main)	3	3	3	3	3	3	3	3
DM(NBS_srv)		2	2	2		2	2	2
True parameters	25	30	37	46	25	30	37	46
Early_devs	20	20	20	20	20	20	20	20
Rec_devs	42	42	42	42	42	42	42	42
L1_devs	43	43	43	43	43	43	43	43
Main_lnQ_devs					38	38	38	38
NBS_lnQ_devs						38	38	38
Sel(fish)_devs	86	86	86	86	86	86	86	86
Sel(main)_devs	76	76	76	76	76	76	76	76
Annual deviations	267	267	267	267	305	343	343	343
Total parameters	292	297	304	313	330	373	380	389

Table 2.1.2. Age composition time series. Data through 2018 are VAST estimates, and were used in the models presented here. The record for 2019 is a design-based estimate, and will likely be used for this year's final assessment.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1994	0.00014	0.09613	0.40395	0.17319	0.11261	0.10797	0.07225	0.01885	0.00719	0.00419	0.00127	0.00109	0.00116
1995	0.00010	0.05819	0.26053	0.42510	0.10262	0.07361	0.05060	0.01300	0.00666	0.00523	0.00141	0.00155	0.00140
1996	0.00003	0.06610	0.20487	0.19054	0.28907	0.13770	0.06404	0.03050	0.00856	0.00355	0.00183	0.00161	0.00161
1997	0.00022	0.26517	0.17172	0.16133	0.15060	0.11976	0.09091	0.02379	0.01050	0.00246	0.00183	0.00103	0.00069
1998	0.00005	0.07845	0.43779	0.20042	0.11281	0.05824	0.05939	0.03005	0.01704	0.00369	0.00076	0.00085	0.00045
1999	0.00006	0.08528	0.20960	0.31480	0.21893	0.07289	0.05280	0.02580	0.01176	0.00507	0.00103	0.00135	0.00062
2000	0.00000	0.21363	0.11948	0.16697	0.24416	0.15478	0.06074	0.01415	0.01521	0.00502	0.00365	0.00150	0.00072
2001	0.00003	0.29245	0.23927	0.18907	0.08810	0.08647	0.06788	0.02470	0.00733	0.00181	0.00141	0.00105	0.00043
2002	0.00035	0.08038	0.19872	0.30697	0.23702	0.06869	0.05722	0.03609	0.00957	0.00291	0.00095	0.00050	0.00064
2003	0.00001	0.17330	0.16086	0.24003	0.20847	0.12118	0.04409	0.03070	0.01583	0.00370	0.00049	0.00060	0.00076
2004	0.00003	0.14206	0.15181	0.27385	0.13242	0.13298	0.09559	0.03803	0.02036	0.00788	0.00216	0.00203	0.00080
2005	0.00000	0.16085	0.23187	0.20703	0.13136	0.07043	0.09116	0.06183	0.02580	0.01090	0.00382	0.00439	0.00055
2006	0.00000	0.32732	0.14621	0.17330	0.11701	0.08947	0.06074	0.04509	0.02659	0.00932	0.00297	0.00125	0.00074
2007	0.00000	0.66271	0.10804	0.07737	0.04920	0.04994	0.01963	0.01592	0.00825	0.00530	0.00170	0.00102	0.00092
2008	0.00000	0.19811	0.43937	0.15456	0.09171	0.05198	0.03097	0.01097	0.01018	0.00616	0.00254	0.00209	0.00135
2009	0.00000	0.45311	0.18811	0.23141	0.06606	0.02852	0.01488	0.00933	0.00472	0.00181	0.00094	0.00071	0.00041
2010	0.00000	0.04654	0.48121	0.18329	0.19871	0.06219	0.01489	0.00793	0.00257	0.00140	0.00050	0.00060	0.00017
2011	0.00006	0.32372	0.07444	0.36511	0.10766	0.08847	0.02708	0.00687	0.00286	0.00157	0.00107	0.00064	0.00045
2012	0.00000	0.34130	0.26174	0.06302	0.23036	0.06137	0.02983	0.00755	0.00230	0.00165	0.00054	0.00015	0.00020
2013	0.00000	0.09807	0.40589	0.19757	0.11512	0.11578	0.05059	0.01181	0.00341	0.00096	0.00021	0.00031	0.00026
2014	0.00002	0.28151	0.16686	0.24402	0.20263	0.05073	0.03919	0.01039	0.00220	0.00095	0.00084	0.00010	0.00057
2015	0.00002	0.06356	0.43477	0.20238	0.18886	0.07797	0.01825	0.01087	0.00231	0.00047	0.00023	0.00011	0.00020
2016	0.00000	0.10111	0.09245	0.35833	0.22552	0.15171	0.05281	0.01203	0.00365	0.00143	0.00051	0.00030	0.00015
2017	0.00007	0.12941	0.16222	0.16720	0.29456	0.13708	0.07948	0.02114	0.00338	0.00333	0.00065	0.00066	0.00082
2018	0.00004	0.09856	0.11454	0.26881	0.15622	0.23896	0.08099	0.03415	0.00351	0.00254	0.00074	0.00035	0.00059
2019	0.00000	0.69868	0.06224	0.06420	0.05415	0.04050	0.04793	0.02339	0.00620	0.00163	0.00048	0.00043	0.00018

Table 2.1.3a. Estimates of time-invariant parameters common to at least half the models.

Time-varying *Q*?	No								Yes							
Separate areas?	No				Yes				No				Yes			
Separate surveys?	No		Yes		Yes				No		Yes		Yes			
Movement?	No				No		Yes		No				No		Yes	
Model	M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Natural_mortality	0.358	0.011	0.372	0.012	0.372	0.011	0.332	0.011	0.348	0.013	0.358	0.012	0.374	0.011	0.344	0.013
L_at_1.5_base	14.815	0.398	14.799	0.400	14.794	0.404	14.805	0.400	14.894	0.401	14.903	0.418	14.807	0.416	14.594	0.400
L_infinity	113.4	3.123	114.2	3.340	112.9	3.189	118.2	4.594	115.1	3.315	114.6	3.265	116.5	4.188	111.2	3.467
VonBert_K	0.117	0.009	0.117	0.010	0.118	0.010	0.106	0.011	0.114	0.009	0.117	0.009	0.108	0.011	0.123	0.011
Richards_coef	1.444	0.042	1.435	0.045	1.444	0.043	1.480	0.047	1.445	0.042	1.419	0.043	1.479	0.047	1.438	0.046
SD_len_at_1	3.493	0.067	3.483	0.066	3.466	0.066	3.481	0.066	3.510	0.066	3.473	0.065	3.485	0.067	3.490	0.065
SD_len_at_20	9.905	0.383	9.945	0.397	10.136	0.387	10.153	0.446	9.705	0.388	9.882	0.391	10.014	0.430	9.397	0.392
RecrDist_NBS_base					-0.676	0.759	-3.037	0.245					-3.345	0.177	-1.690	0.213
AgeBias_at_1_1977_2007	0.339	0.017	0.349	0.015	0.349	0.015	0.347	0.015	0.337	0.017	0.347	0.015	0.348	0.014	0.346	0.015
AgeBias_at_1_2008_2019	0.014	0.025	-0.002	0.025	0.001	0.024	0.009	0.023	0.019	0.025	0.002	0.026	0.004	0.023	0.008	0.024
AgeBias_at_20_1977_2007	0.859	0.221	0.776	0.205	0.772	0.198	0.843	0.200	0.898	0.221	0.804	0.204	0.825	0.200	0.954	0.205
AgeBias_at_20_2008_2019	-1.532	0.316	-1.697	0.325	-1.646	0.313	-1.698	0.305	-1.708	0.326	-1.930	0.345	-1.790	0.324	-2.179	0.365
ln(Recr_ave_1977_2018)	13.208	0.097	13.271	0.099	13.678	0.271	12.991	0.089	13.121	0.105	13.144	0.103	13.313	0.097	13.185	0.123
ln(Recr_ave_pre1977_offset)	-0.903	0.202	-0.885	0.204	-0.862	0.206	-0.986	0.181	-0.925	0.195	-0.909	0.199	-0.839	0.208	-0.919	0.180
InitF_main_fsh	0.122	0.038	0.127	0.040	0.119	0.037	0.147	0.046	0.127	0.039	0.134	0.043	0.114	0.035	0.173	0.056
InitF_NBS_fsh					0.000	0.000	0.000	0.000					0.000	0.000	0.000	0.000
lnQ_main_srv_base	-0.029	0.063	-0.111	0.066	-0.102	0.057	0.172	0.059	0.019	0.069	-0.037	0.068	-0.116	0.064	0.261	0.065
lnQ_NBS_srv_base			-0.788	0.105	-0.747	0.767	-0.260	0.108			-1.842	0.254	0.827	0.325	-1.466	0.284
Main_fsh_sel_PeakStart	74.984	0.039	75.220	0.598	74.971	0.196	74.982	0.528	74.985	0.035	74.986	0.030	74.931	0.520	75.968	0.590
Main_fsh_sel_logitPeakWidth	-9.765	6.733	-5.712	18.562	-9.439	14.705	0.208	0.465	-9.782	6.361	-9.761	6.755	0.469	0.593	0.097	0.522
Main_fsh_sel_lnSD1_base	5.908	0.029	5.913	0.039	5.898	0.029	5.907	0.039	5.911	0.028	5.905	0.027	5.896	0.037	5.950	0.039
Main_fsh_sel_lnSD2	-9.867	4.111	-1.410	8.489	-9.091	18.173	4.707	1.251	-9.883	3.621	-9.886	3.556	4.345	1.767	4.827	1.357
Main_fsh_sel_logitEnd_base	2.135	0.313	1.987	0.301	3.114	0.786	-3.140	3.513	2.225	0.348	2.084	0.296	-2.647	3.443	-2.855	3.301
Main_srv_sel_PeakStart_base	20.923	0.779	21.036	0.801	20.986	0.794	21.110	0.811	20.817	0.807	20.699	0.831	20.970	0.819	21.827	0.905
Main_srv_sel_lnSD1_base	3.529	0.151	3.532	0.151	3.522	0.151	3.535	0.154	3.503	0.156	3.460	0.161	3.513	0.155	3.613	0.157
NBS_srv_sel_PeakStart			79.998	0.072	74.051	8.817	15.530	1.383			79.997	0.113	68.696	7.855	14.453	1.161
NBS_srv_sel_lnSD1			7.784	0.139	8.881	0.882	2.067	0.640			7.821	0.146	7.925	0.490	1.750	0.675
lnDM_size_main_fish	9.989	0.337	9.989	0.351	9.989	0.358	9.990	0.325	9.989	0.355	9.989	0.358	9.990	0.347	9.989	0.343
lnDM_size_main_sur	9.984	0.520	9.984	0.524	9.985	0.499	9.984	0.496	9.984	0.540	9.984	0.522	9.985	0.470	9.984	0.482
lnDM_size_NBS_sur			9.656	9.374	9.717	7.603	9.923	2.327			9.756	7.420	9.712	8.223	9.935	1.982
lnDM_age_main_srv	-0.006	0.213	0.281	0.252	0.444	0.278	0.478	0.280	0.075	0.225	0.432	0.274	0.522	0.297	0.541	0.282
lnDM_age_NBS_srv			0.213	0.568	-1.511	0.343	0.381	1.052			0.383	0.609	-1.342	0.362	-0.201	0.578

Table 2.1.3b. Estimates of movement parameters and environmental linkages (used by Models 19.12c and 20.3 only).

	M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Move_EBS_to_NBS_A_base							-3.365	0.227							-1.471	0.275
Move_EBS_to_NBS_B_base							-12.77	3.025							-13.82	0.000
Move_NBS_to_EBS_A_base							-6.627	1.796							-7.897	2.424
Move_NBS_to_EBS_B_base							-1.480	0.321							-2.166	0.335
RecrDist_NBS_link							-0.620	0.086							-0.035	0.084
Move_EBS_to_NBS_A_link							-1.740	0.140							-0.870	0.120
Move_EBS_to_NBS_B_link							-7.274	1.963							-3.979	0.280
Move_NBS_to_EBS_A_link							5.615	1.065							6.307	1.380
Move_NBS_to_EBS_B_link							1.209	0.265							0.006	0.184

Table 2.1.3c. Estimates of log-scale recruitment deviations that are used to represent offsets from equilibrium in the initial numbers-at-age vector.

	M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
ln(InitN)_offset_at_01	0.786	0.562	0.751	0.563	0.768	0.577	0.690	0.544	0.803	0.548	0.756	0.570	0.826	0.570	0.748	0.556
ln(InitN)_offset_at_02	-0.081	0.582	-0.077	0.568	-0.059	0.581	-0.112	0.547	-0.089	0.569	-0.086	0.565	-0.048	0.576	-0.081	0.534
ln(InitN)_offset_at_03	0.225	0.499	0.217	0.492	0.246	0.503	0.137	0.479	0.200	0.488	0.204	0.487	0.250	0.497	0.196	0.485
ln(InitN)_offset_at_04	-0.262	0.564	-0.254	0.552	-0.241	0.566	-0.314	0.532	-0.271	0.549	-0.266	0.548	-0.230	0.558	-0.236	0.534
ln(InitN)_offset_at_05	-0.563	0.547	-0.543	0.536	-0.535	0.547	-0.615	0.519	-0.579	0.534	-0.560	0.533	-0.533	0.540	-0.546	0.519
ln(InitN)_offset_at_06	-0.614	0.550	-0.585	0.539	-0.585	0.548	-0.671	0.522	-0.634	0.537	-0.605	0.537	-0.589	0.541	-0.610	0.520
ln(InitN)_offset_at_07	-0.562	0.563	-0.527	0.554	-0.532	0.562	-0.619	0.535	-0.583	0.550	-0.548	0.551	-0.538	0.554	-0.562	0.533
ln(InitN)_offset_at_08	-0.471	0.581	-0.433	0.572	-0.441	0.580	-0.525	0.552	-0.491	0.568	-0.455	0.569	-0.446	0.572	-0.479	0.549
ln(InitN)_offset_at_09	-0.373	0.601	-0.336	0.591	-0.344	0.599	-0.420	0.571	-0.391	0.587	-0.356	0.588	-0.346	0.591	-0.385	0.566
ln(InitN)_offset_at_10	-0.282	0.620	-0.248	0.610	-0.255	0.619	-0.319	0.591	-0.298	0.606	-0.266	0.607	-0.254	0.611	-0.294	0.584
ln(InitN)_offset_at_11	-0.205	0.637	-0.177	0.627	-0.181	0.636	-0.231	0.609	-0.218	0.623	-0.191	0.624	-0.179	0.629	-0.216	0.600
ln(InitN)_offset_at_12	-0.144	0.653	-0.122	0.640	-0.125	0.650	-0.162	0.624	-0.155	0.638	-0.133	0.638	-0.121	0.643	-0.153	0.614
ln(InitN)_offset_at_13	-0.099	0.665	-0.081	0.651	-0.084	0.662	-0.110	0.637	-0.107	0.651	-0.090	0.649	-0.079	0.655	-0.106	0.626
ln(InitN)_offset_at_14	-0.066	0.674	-0.053	0.659	-0.055	0.670	-0.073	0.647	-0.072	0.661	-0.059	0.658	-0.051	0.663	-0.071	0.635
ln(InitN)_offset_at_15	-0.043	0.681	-0.034	0.665	-0.036	0.676	-0.047	0.654	-0.048	0.668	-0.039	0.664	-0.032	0.669	-0.047	0.641
ln(InitN)_offset_at_16	-0.028	0.686	-0.022	0.669	-0.023	0.680	-0.031	0.659	-0.031	0.673	-0.025	0.669	-0.020	0.673	-0.031	0.646
ln(InitN)_offset_at_17	-0.018	0.689	-0.014	0.672	-0.015	0.683	-0.020	0.663	-0.020	0.676	-0.016	0.671	-0.012	0.675	-0.021	0.649
ln(InitN)_offset_at_18	-0.012	0.691	-0.009	0.673	-0.009	0.685	-0.013	0.665	-0.013	0.679	-0.010	0.673	-0.008	0.676	-0.014	0.652
ln(InitN)_offset_at_19	-0.007	0.693	-0.006	0.674	-0.006	0.686	-0.008	0.666	-0.008	0.680	-0.006	0.674	-0.005	0.677	-0.009	0.653
ln(InitN)_offset_at_20	-0.013	0.691	-0.009	0.673	-0.010	0.684	-0.016	0.664	-0.014	0.678	-0.011	0.673	-0.008	0.676	-0.017	0.650

Table 2.1.3d. Estimates of log-scale age 0 recruitment deviations.

	M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	1.008	0.224	1.017	0.222	1.071	0.225	0.857	0.218	0.938	0.227	0.993	0.225	1.061	0.231	0.925	0.225
1978	0.591	0.243	0.622	0.237	0.624	0.252	0.494	0.234	0.578	0.230	0.642	0.231	0.662	0.242	0.566	0.231
1979	0.625	0.129	0.647	0.127	0.663	0.129	0.537	0.128	0.600	0.129	0.652	0.128	0.684	0.130	0.597	0.129
1980	-0.797	0.228	-0.808	0.231	-0.827	0.237	-0.810	0.220	-0.834	0.239	-0.843	0.248	-0.805	0.245	-0.782	0.226
1981	-0.675	0.166	-0.645	0.164	-0.650	0.168	-0.732	0.166	-0.672	0.169	-0.640	0.170	-0.617	0.172	-0.655	0.168
1982	0.881	0.055	0.904	0.054	0.925	0.054	0.825	0.054	0.890	0.059	0.932	0.058	0.959	0.058	0.877	0.061
1983	-0.424	0.152	-0.394	0.151	-0.402	0.155	-0.493	0.150	-0.494	0.159	-0.456	0.160	-0.467	0.163	-0.534	0.156
1984	0.777	0.058	0.798	0.057	0.813	0.058	0.727	0.057	0.778	0.061	0.814	0.062	0.824	0.061	0.800	0.065
1985	-0.015	0.088	0.004	0.088	0.007	0.089	-0.050	0.088	0.013	0.091	0.052	0.092	0.043	0.092	0.045	0.092
1986	-0.610	0.108	-0.585	0.108	-0.588	0.109	-0.632	0.107	-0.553	0.110	-0.529	0.111	-0.528	0.111	-0.597	0.110
1987	-1.790	0.228	-1.767	0.225	-1.793	0.230	-1.808	0.222	-1.636	0.225	-1.625	0.228	-1.639	0.228	-1.705	0.215
1988	-0.248	0.087	-0.244	0.086	-0.227	0.086	-0.263	0.086	-0.230	0.093	-0.213	0.092	-0.204	0.093	-0.273	0.114
1989	0.441	0.061	0.438	0.060	0.457	0.061	0.404	0.061	0.448	0.064	0.469	0.063	0.472	0.063	0.390	0.077
1990	0.420	0.068	0.438	0.067	0.449	0.067	0.386	0.067	0.409	0.070	0.444	0.070	0.431	0.069	0.364	0.076
1991	-0.110	0.091	-0.117	0.091	-0.122	0.093	-0.159	0.093	-0.186	0.097	-0.184	0.100	-0.193	0.098	-0.168	0.094
1992	0.882	0.042	0.893	0.041	0.899	0.041	0.860	0.041	0.804	0.045	0.831	0.044	0.817	0.044	0.845	0.046
1993	-0.105	0.076	-0.071	0.073	-0.069	0.073	-0.088	0.072	-0.101	0.076	-0.047	0.074	-0.068	0.074	-0.053	0.074
1994	-0.276	0.073	-0.256	0.071	-0.262	0.070	-0.270	0.070	-0.294	0.074	-0.257	0.072	-0.278	0.072	-0.312	0.075
1995	-0.428	0.081	-0.424	0.079	-0.426	0.079	-0.317	0.079	-0.406	0.082	-0.379	0.080	-0.393	0.080	-0.126	0.092
1996	0.744	0.043	0.758	0.043	0.771	0.043	0.755	0.043	0.751	0.044	0.788	0.044	0.781	0.044	0.830	0.050
1997	-0.082	0.073	-0.063	0.072	-0.059	0.072	-0.112	0.070	-0.056	0.073	-0.026	0.072	-0.041	0.072	-0.090	0.072
1998	-0.353	0.089	-0.339	0.087	-0.339	0.088	-0.407	0.086	-0.306	0.089	-0.271	0.088	-0.293	0.088	-0.395	0.090
1999	0.542	0.047	0.567	0.046	0.574	0.046	0.528	0.046	0.515	0.049	0.566	0.048	0.547	0.048	0.501	0.053
2000	0.204	0.052	0.213	0.052	0.199	0.051	0.246	0.052	0.214	0.054	0.252	0.054	0.207	0.054	0.410	0.066
2001	-0.680	0.100	-0.617	0.097	-0.623	0.097	-0.595	0.095	-0.662	0.101	-0.567	0.099	-0.612	0.097	-0.556	0.097
2002	-0.201	0.061	-0.181	0.060	-0.202	0.061	-0.096	0.061	-0.169	0.062	-0.122	0.062	-0.173	0.061	0.094	0.074
2003	-0.250	0.065	-0.214	0.064	-0.230	0.063	-0.199	0.062	-0.231	0.067	-0.167	0.066	-0.220	0.065	-0.090	0.070
2004	-0.577	0.082	-0.524	0.081	-0.546	0.081	-0.558	0.080	-0.529	0.084	-0.467	0.083	-0.513	0.083	-0.461	0.079
2005	-0.371	0.076	-0.358	0.075	-0.364	0.075	-0.442	0.074	-0.319	0.075	-0.295	0.073	-0.326	0.075	-0.498	0.081
2006	0.711	0.041	0.681	0.040	0.697	0.040	0.655	0.040	0.772	0.042	0.754	0.041	0.738	0.042	0.583	0.052
2007	-0.218	0.088	-0.245	0.086	-0.223	0.086	-0.240	0.084	-0.171	0.088	-0.183	0.086	-0.197	0.087	-0.374	0.096
2008	1.092	0.039	1.048	0.038	1.058	0.038	1.045	0.039	1.066	0.040	1.037	0.039	1.037	0.040	0.877	0.059
2009	-0.897	0.164	-0.681	0.130	-0.733	0.133	-0.856	0.146	-0.896	0.159	-0.693	0.131	-0.752	0.133	-0.812	0.134
2010	0.623	0.052	0.558	0.051	0.559	0.051	0.650	0.050	0.632	0.053	0.553	0.051	0.558	0.052	0.692	0.071
2011	0.876	0.048	0.794	0.046	0.798	0.046	0.859	0.048	0.883	0.050	0.769	0.045	0.789	0.048	0.682	0.060
2012	0.131	0.089	0.024	0.085	0.023	0.085	0.080	0.088	0.070	0.093	-0.056	0.087	-0.044	0.089	-0.087	0.094
2013	1.120	0.045	0.921	0.044	0.920	0.044	1.187	0.048	1.099	0.052	0.838	0.050	0.893	0.051	1.122	0.060
2014	-0.630	0.115	-0.795	0.108	-0.807	0.109	-0.480	0.109	-0.620	0.116	-0.818	0.110	-0.804	0.112	-0.546	0.120
2015	-0.343	0.076	-0.472	0.073	-0.483	0.074	-0.279	0.077	-0.325	0.083	-0.489	0.077	-0.457	0.080	-0.382	0.084
2016	-0.888	0.116	-1.011	0.105	-1.013	0.107	-0.791	0.110	-0.966	0.124	-1.241	0.093	-1.079	0.119	-0.911	0.118
2017	-1.268	0.267	-1.103	0.238	-1.103	0.240	-0.993	0.225	-1.329	0.274	-1.257	0.236	-1.232	0.229	-1.145	0.230
2018	0.569	0.080	0.590	0.086	0.583	0.085	0.577	0.084	0.525	0.099	0.439	0.104	0.432	0.103	0.350	0.102

Table 2.1.3e. Estimates of log-scale mean length at age 1.5 deviations.

	M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	0.393	0.963	0.301	0.962	0.466	0.964	0.319	0.956	0.335	0.959	0.268	0.953	0.502	0.961	0.264	0.965
1978	-0.111	0.945	-0.110	0.942	-0.102	0.944	-0.132	0.943	-0.116	0.941	-0.114	0.934	-0.101	0.940	-0.136	0.942
1979	0.460	1.011	0.484	1.006	0.479	1.012	0.439	1.000	0.479	1.010	0.516	1.001	0.506	1.021	0.485	1.011
1980	-0.048	0.935	-0.048	0.928	-0.021	0.937	-0.055	0.933	-0.078	0.920	-0.063	0.909	-0.044	0.924	-0.061	0.930
1981	-1.063	0.468	-1.096	0.462	-1.069	0.457	-1.015	0.463	-1.128	0.474	-1.112	0.453	-1.049	0.449	-1.099	0.475
1982	-0.900	0.299	-0.913	0.300	-0.925	0.297	-0.860	0.295	-0.967	0.312	-0.933	0.300	-0.933	0.301	-0.899	0.324
1983	0.762	0.722	0.836	0.725	0.761	0.726	0.843	0.754	1.045	0.768	0.994	0.743	1.051	0.787	0.934	0.750
1984	0.423	0.231	0.410	0.228	0.419	0.226	0.452	0.229	0.360	0.235	0.325	0.226	0.385	0.226	0.364	0.235
1985	-1.501	0.427	-1.468	0.421	-1.458	0.415	-1.453	0.422	-1.598	0.434	-1.543	0.412	-1.492	0.413	-1.553	0.462
1986	0.097	0.271	0.107	0.266	0.118	0.264	0.064	0.270	0.099	0.270	0.111	0.256	0.117	0.260	0.121	0.269
1987	-0.546	0.438	-0.503	0.430	-0.495	0.430	-0.598	0.440	-0.507	0.433	-0.446	0.409	-0.463	0.421	-0.446	0.434
1988	-0.946	0.426	-0.891	0.459	-0.901	0.436	-0.952	0.428	-0.874	0.426	-0.799	0.406	-0.824	0.409	-0.783	0.452
1989	-0.878	0.279	-0.854	0.274	-0.852	0.270	-0.834	0.275	-0.832	0.281	-0.791	0.268	-0.781	0.269	-0.782	0.282
1990	-0.074	0.308	-0.074	0.312	-0.087	0.310	-0.082	0.313	-0.057	0.305	-0.050	0.291	-0.049	0.293	-0.049	0.314
1991	0.450	0.250	0.443	0.246	0.449	0.244	0.456	0.248	0.515	0.256	0.484	0.246	0.513	0.246	0.489	0.248
1992	0.004	0.232	-0.005	0.228	0.001	0.226	-0.004	0.230	-0.035	0.234	-0.040	0.225	-0.021	0.226	-0.014	0.233
1993	0.485	0.351	0.469	0.342	0.445	0.340	0.473	0.346	0.316	0.364	0.296	0.361	0.289	0.365	0.439	0.374
1994	-0.254	0.281	-0.220	0.274	-0.206	0.273	-0.214	0.279	-0.180	0.280	-0.125	0.265	-0.142	0.271	-0.099	0.280
1995	-0.279	0.347	-0.259	0.342	-0.246	0.339	-0.302	0.351	-0.212	0.350	-0.155	0.347	-0.169	0.352	-0.069	0.429
1996	-0.086	0.257	-0.107	0.255	-0.112	0.253	-0.092	0.256	-0.074	0.258	-0.079	0.249	-0.085	0.250	-0.045	0.289
1997	-0.219	0.319	-0.198	0.311	-0.211	0.308	-0.232	0.314	-0.179	0.314	-0.156	0.296	-0.163	0.301	-0.121	0.310
1998	-0.769	0.308	-0.798	0.304	-0.814	0.307	-0.880	0.302	-0.754	0.302	-0.738	0.288	-0.779	0.300	-0.861	0.310
1999	-1.332	0.262	-1.326	0.259	-1.299	0.256	-1.365	0.260	-1.266	0.260	-1.213	0.248	-1.209	0.250	-1.311	0.260
2000	0.899	0.238	0.880	0.234	0.884	0.231	0.812	0.236	0.753	0.241	0.695	0.230	0.736	0.230	0.558	0.236
2001	0.336	0.269	0.312	0.267	0.300	0.267	0.268	0.272	0.316	0.268	0.273	0.259	0.281	0.261	0.268	0.282
2002	0.687	0.235	0.651	0.231	0.665	0.229	0.612	0.235	0.660	0.234	0.609	0.224	0.638	0.226	0.565	0.237
2003	0.146	0.291	0.108	0.289	0.108	0.284	0.123	0.292	0.149	0.291	0.115	0.278	0.129	0.278	0.103	0.310
2004	1.367	0.242	1.277	0.235	1.266	0.234	1.324	0.235	1.311	0.242	1.183	0.230	1.212	0.230	1.246	0.236
2005	-0.196	0.276	-0.189	0.270	-0.183	0.266	-0.127	0.271	-0.194	0.280	-0.175	0.264	-0.176	0.265	-0.162	0.275
2006	-0.284	0.217	-0.232	0.212	-0.243	0.211	-0.276	0.215	-0.295	0.217	-0.242	0.207	-0.231	0.209	-0.202	0.217
2007	-1.164	0.303	-1.088	0.295	-1.097	0.290	-1.164	0.295	-1.056	0.306	-0.971	0.288	-0.978	0.288	-1.079	0.295
2008	-1.330	0.248	-1.304	0.232	-1.281	0.231	-1.358	0.248	-1.263	0.236	-1.184	0.224	-1.212	0.226	-1.299	0.236
2009	-0.657	0.384	-0.567	0.342	-0.576	0.342	-0.745	0.371	-0.774	0.377	-0.615	0.329	-0.614	0.330	-0.680	0.355
2010	0.330	0.211	0.300	0.208	0.324	0.207	0.278	0.209	0.262	0.211	0.256	0.204	0.276	0.205	0.260	0.211
2011	-1.251	0.270	-1.128	0.267	-1.117	0.262	-1.156	0.267	-1.246	0.277	-1.052	0.265	-1.106	0.263	-1.016	0.272
2012	0.145	0.314	0.072	0.324	0.059	0.319	0.151	0.311	0.232	0.307	0.105	0.301	0.113	0.308	0.222	0.318
2013	-0.310	0.229	-0.216	0.222	-0.201	0.220	-0.337	0.226	-0.369	0.230	-0.243	0.217	-0.247	0.219	-0.367	0.228
2014	0.222	0.402	0.236	0.387	0.210	0.384	0.196	0.397	0.141	0.402	0.156	0.374	0.150	0.379	0.096	0.401
2015	1.709	0.218	1.666	0.215	1.656	0.213	1.709	0.217	1.699	0.217	1.607	0.208	1.628	0.210	1.725	0.219
2016	1.831	0.325	2.036	0.292	2.017	0.290	1.884	0.298	1.939	0.320	2.470	0.268	2.127	0.288	1.987	0.294
2017	1.354	0.342	1.647	0.284	1.619	0.282	1.559	0.281	1.369	0.338	1.668	0.273	1.668	0.275	1.628	0.280
2018	2.502	0.190	2.413	0.189	2.383	0.189	2.497	0.188	2.451	0.190	2.215	0.187	2.261	0.188	2.535	0.192
2019	-0.405	1.275	-1.053	1.112	-1.135	1.077	-0.226	1.210	-0.379	1.309	-1.506	0.976	-1.711	0.935	-1.153	1.002

Table 2.1.3f. Estimates of log catchability deviations for each model's "main" survey and NBS survey.

	M19.12		Model 19.12d				Model 20.2				Model 20.3			
	Main		Main		NBS		Main		NBS		Main		NBS	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1982	0.015	0.703	-0.031	0.707	-1.448	0.564	-0.362	0.711	-1.162	0.582	0.235	0.743	-1.311	0.618
1983	0.758	0.742	0.619	0.741	0.000	1.000	0.425	0.745	0.000	1.000	0.607	0.783	0.000	1.000
1984	-0.931	0.672	-0.946	0.672	0.000	1.000	-1.238	0.678	0.000	1.000	-0.944	0.716	0.000	1.000
1985	0.976	0.664	1.009	0.668	-1.053	0.667	0.813	0.674	-0.860	0.685	0.959	0.720	-0.985	0.723
1986	0.329	0.632	0.432	0.636	0.000	1.000	0.292	0.642	0.000	1.000	0.402	0.690	0.000	1.000
1987	0.207	0.621	0.081	0.614	0.000	1.000	0.032	0.621	0.000	1.000	0.189	0.667	0.000	1.000
1988	-0.403	0.603	-0.189	0.607	-2.253	0.665	-0.188	0.613	-2.053	0.684	0.073	0.664	-2.168	0.719
1989	-1.857	0.634	-1.771	0.633	0.000	1.000	-1.718	0.639	0.000	1.000	-1.491	0.697	0.000	1.000
1990	-1.007	0.696	-0.903	0.697	0.000	1.000	-0.901	0.704	0.000	1.000	-1.163	0.743	0.000	1.000
1991	-1.149	0.697	-1.183	0.697	-0.695	0.649	-1.237	0.703	-0.619	0.667	-1.424	0.748	-0.657	0.705
1992	-1.317	0.705	-1.226	0.711	0.000	1.000	-1.225	0.713	0.000	1.000	-1.752	0.762	0.000	1.000
1993	0.669	0.713	0.588	0.712	0.000	1.000	0.623	0.718	0.000	1.000	0.009	0.764	0.000	1.000
1994	4.017	0.634	4.210	0.637	0.000	1.000	4.272	0.643	0.000	1.000	3.844	0.694	0.000	1.000
1995	1.794	0.623	1.958	0.625	0.000	1.000	2.063	0.631	0.000	1.000	1.465	0.689	0.000	1.000
1996	2.073	0.683	1.883	0.647	0.000	1.000	2.015	0.653	0.000	1.000	1.483	0.711	0.000	1.000
1997	-0.133	0.668	-0.314	0.651	0.000	1.000	-0.198	0.656	0.000	1.000	-0.310	0.710	0.000	1.000
1998	-0.027	0.714	-0.496	0.687	0.000	1.000	-0.489	0.693	0.000	1.000	-0.259	0.745	0.000	1.000
1999	-0.481	0.664	-0.326	0.666	0.000	1.000	-0.262	0.672	0.000	1.000	-0.181	0.721	0.000	1.000
2000	-1.556	0.635	-1.620	0.632	0.000	1.000	-1.491	0.638	0.000	1.000	-1.547	0.690	0.000	1.000
2001	1.900	0.642	1.826	0.641	0.000	1.000	1.961	0.646	0.000	1.000	1.591	0.711	0.000	1.000
2002	-0.260	0.663	-0.594	0.652	0.000	1.000	-0.387	0.656	0.000	1.000	-0.438	0.704	0.000	1.000
2003	0.511	0.712	-0.064	0.685	0.000	1.000	0.190	0.690	0.000	1.000	-0.018	0.737	0.000	1.000
2004	-0.891	0.651	-1.305	0.637	0.000	1.000	-0.962	0.643	0.000	1.000	-0.818	0.696	0.000	1.000
2005	-0.003	0.648	-0.508	0.647	0.000	1.000	-0.112	0.651	0.000	1.000	0.440	0.708	0.000	1.000
2006	-0.946	0.646	-1.041	0.641	0.000	1.000	-0.634	0.655	0.000	1.000	0.198	0.731	0.000	1.000
2007	-0.993	0.678	-0.906	0.682	0.000	1.000	-0.768	0.690	0.000	1.000	-0.499	0.750	0.000	1.000
2008	-2.496	0.656	-2.219	0.658	0.000	1.000	-2.051	0.665	0.000	1.000	-0.859	0.749	0.000	1.000
2009	-2.055	0.682	-1.614	0.684	0.000	1.000	-1.359	0.716	0.000	1.000	-0.137	0.795	0.000	1.000
2010	-0.171	0.627	0.403	0.632	-3.310	0.534	0.447	0.637	-3.282	0.549	-0.861	0.699	-2.148	0.604
2011	0.688	0.648	1.001	0.648	0.000	1.000	1.116	0.655	0.000	1.000	-0.172	0.718	0.000	1.000
2012	-0.157	0.714	0.418	0.704	0.000	1.000	0.494	0.724	0.000	1.000	-0.304	0.773	0.000	1.000
2013	-1.679	0.657	-0.821	0.655	0.000	1.000	-0.915	0.664	0.000	1.000	-1.709	0.712	0.000	1.000
2014	1.950	0.718	2.546	0.703	0.000	1.000	2.446	0.712	0.000	1.000	1.675	0.759	0.000	1.000
2015	0.662	0.699	1.943	0.668	0.000	1.000	1.630	0.678	0.000	1.000	1.141	0.723	0.000	1.000
2016	0.807	0.800	1.466	0.665	0.000	1.000	1.158	0.676	0.000	1.000	1.603	0.720	0.000	1.000
2017	-1.340	0.661	-1.746	0.680	1.722	0.408	-1.941	0.697	1.796	0.417	-0.919	0.759	1.213	0.435
2018	1.592	0.763	-0.519	0.744	2.965	0.430	-1.140	0.750	3.222	0.439	0.416	0.818	2.523	0.465
2019	0.905	0.813	-0.042	0.853	2.946	0.413	-0.397	0.847	3.516	0.455	-0.526	0.939	2.616	0.466

Table 2.1.3g. Estimates of fishery selectivity lnSD1 deviations.

	M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	0.127	0.975	0.117	0.979	0.111	0.977	0.178	0.975	0.138	0.977	0.127	0.979	0.114	0.977	0.151	0.975
1978	0.106	0.904	0.105	0.916	0.110	0.911	0.133	0.901	0.105	0.907	0.103	0.917	0.106	0.911	0.108	0.906
1979	0.393	0.804	0.384	0.824	0.402	0.815	0.438	0.798	0.400	0.811	0.377	0.825	0.410	0.817	0.449	0.814
1980	0.332	0.854	0.314	0.869	0.322	0.862	0.339	0.845	0.337	0.857	0.302	0.870	0.350	0.862	0.383	0.854
1981	1.060	0.868	1.014	0.882	1.029	0.875	1.054	0.862	1.044	0.871	1.005	0.882	1.045	0.876	1.055	0.871
1982	-0.078	0.933	-0.083	0.942	-0.085	0.938	-0.093	0.929	-0.080	0.935	-0.080	0.942	-0.071	0.938	-0.064	0.934
1983	0.141	0.826	0.121	0.844	0.143	0.837	0.134	0.818	0.120	0.830	0.119	0.846	0.140	0.836	0.152	0.827
1984	0.906	0.601	0.899	0.627	0.916	0.614	0.909	0.592	0.893	0.608	0.921	0.630	0.921	0.616	0.938	0.606
1985	-0.182	0.536	-0.238	0.561	-0.195	0.547	-0.136	0.525	-0.191	0.544	-0.214	0.567	-0.146	0.551	-0.067	0.539
1986	0.624	0.550	0.592	0.575	0.639	0.560	0.731	0.541	0.625	0.558	0.620	0.581	0.699	0.564	0.772	0.556
1987	-0.134	0.462	-0.192	0.486	-0.150	0.472	0.013	0.455	-0.131	0.469	-0.154	0.490	-0.075	0.475	0.099	0.471
1988	2.329	0.683	2.306	0.702	2.318	0.692	2.449	0.677	2.282	0.685	2.268	0.702	2.299	0.690	2.483	0.689
1989	1.055	0.790	1.013	0.809	1.030	0.801	1.153	0.783	1.027	0.794	0.996	0.810	1.018	0.799	1.241	0.795
1990	0.177	0.598	0.175	0.625	0.156	0.613	0.232	0.591	0.133	0.606	0.160	0.629	0.134	0.614	0.145	0.605
1991	-0.055	0.418	-0.055	0.441	-0.064	0.429	0.066	0.413	-0.031	0.428	-0.025	0.448	-0.026	0.433	0.054	0.429
1992	-0.403	0.385	-0.440	0.406	-0.399	0.390	-0.268	0.376	-0.293	0.398	-0.341	0.417	-0.251	0.398	-0.276	0.396
1993	1.442	0.490	1.476	0.515	1.484	0.503	1.501	0.484	1.637	0.505	1.669	0.525	1.683	0.510	1.604	0.500
1994	0.466	0.418	0.473	0.441	0.482	0.429	0.546	0.412	0.643	0.429	0.663	0.448	0.653	0.434	0.650	0.428
1995	0.749	0.417	0.766	0.439	0.764	0.427	0.834	0.410	0.854	0.423	0.857	0.440	0.851	0.427	0.851	0.420
1996	-0.279	0.423	-0.310	0.446	-0.327	0.434	-0.305	0.412	-0.273	0.427	-0.320	0.446	-0.324	0.431	-0.371	0.422
1997	0.987	0.418	1.039	0.441	0.995	0.429	0.973	0.409	0.871	0.420	0.891	0.439	0.844	0.426	0.772	0.416
1998	-0.043	0.377	-0.024	0.398	-0.056	0.387	-0.093	0.368	-0.197	0.380	-0.209	0.398	-0.220	0.385	-0.306	0.378
1999	0.136	0.333	0.165	0.351	0.114	0.336	-0.055	0.319	-0.047	0.334	-0.065	0.348	-0.060	0.334	-0.240	0.329
2000	-0.157	0.362	-0.156	0.380	-0.209	0.364	-0.392	0.344	-0.349	0.363	-0.368	0.380	-0.375	0.363	-0.597	0.355
2001	-0.273	0.344	-0.284	0.362	-0.270	0.348	-0.437	0.330	-0.349	0.350	-0.364	0.365	-0.361	0.350	-0.567	0.340
2002	0.656	0.326	0.697	0.342	0.750	0.329	0.578	0.313	0.703	0.331	0.693	0.345	0.743	0.330	0.523	0.323
2003	0.489	0.336	0.512	0.352	0.537	0.339	0.394	0.321	0.503	0.340	0.481	0.354	0.522	0.340	0.321	0.332
2004	0.644	0.358	0.681	0.376	0.690	0.365	0.593	0.348	0.618	0.363	0.617	0.378	0.635	0.365	0.554	0.356
2005	0.594	0.354	0.611	0.372	0.609	0.362	0.527	0.345	0.552	0.359	0.549	0.375	0.555	0.362	0.505	0.354
2006	0.001	0.383	-0.027	0.403	-0.052	0.391	-0.214	0.373	-0.060	0.388	-0.080	0.406	-0.091	0.391	-0.168	0.388
2007	-0.196	0.410	-0.214	0.432	-0.266	0.418	-0.404	0.396	-0.269	0.414	-0.247	0.436	-0.301	0.417	-0.464	0.408
2008	-0.239	0.337	-0.145	0.358	-0.222	0.343	-0.352	0.328	-0.296	0.342	-0.166	0.362	-0.255	0.344	-0.332	0.346
2009	-1.121	0.337	-0.957	0.360	-1.075	0.341	-1.267	0.335	-1.147	0.343	-0.967	0.365	-1.059	0.344	-1.094	0.364
2010	-1.576	0.354	-1.481	0.377	-1.558	0.361	-1.361	0.347	-1.524	0.364	-1.414	0.386	-1.493	0.366	-1.735	0.373
2011	-1.427	0.334	-1.413	0.353	-1.460	0.342	-1.356	0.327	-1.257	0.345	-1.217	0.362	-1.323	0.347	-1.296	0.344
2012	-0.500	0.367	-0.525	0.386	-0.552	0.375	-0.499	0.360	-0.394	0.374	-0.362	0.393	-0.483	0.376	-0.387	0.375
2013	-0.219	0.315	-0.209	0.333	-0.215	0.323	-0.168	0.308	-0.174	0.321	-0.108	0.339	-0.176	0.324	-0.021	0.323
2014	-1.236	0.312	-1.236	0.330	-1.204	0.318	-1.175	0.302	-1.209	0.319	-1.179	0.337	-1.145	0.321	-1.031	0.318
2015	-1.631	0.313	-1.568	0.334	-1.541	0.324	-1.554	0.307	-1.609	0.320	-1.521	0.340	-1.512	0.326	-1.421	0.322
2016	-1.677	0.341	-1.539	0.366	-1.506	0.357	-1.434	0.342	-1.659	0.348	-1.539	0.369	-1.525	0.357	-1.249	0.363
2017	-1.612	0.425	-1.547	0.451	-1.501	0.440	-1.604	0.420	-1.644	0.433	-1.643	0.452	-1.613	0.437	-1.296	0.443
2018	-0.309	0.503	-0.447	0.520	-0.421	0.509	-0.478	0.494	-0.298	0.513	-0.493	0.527	-0.581	0.509	-0.165	0.513
2019	-0.069	0.563	-0.370	0.576	-0.272	0.563	-0.128	0.568	-0.002	0.575	-0.342	0.590	-0.255	0.576	-0.663	0.601

Table 2.1.3h. Estimates of fishery selectivity logitEnd deviations.

	M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	-0.061	1.020	-0.065	1.021	-0.003	1.000	-0.001	1.000	-0.065	1.022	-0.074	1.025	0.000	1.000	0.000	1.000
1978	-0.098	1.031	-0.106	1.032	-0.005	1.000	0.000	1.000	-0.096	1.031	-0.111	1.036	0.000	1.000	0.000	1.000
1979	-0.105	1.032	-0.114	1.034	-0.006	1.000	0.000	1.000	-0.101	1.033	-0.118	1.038	0.000	1.000	0.000	1.000
1980	0.006	0.996	0.003	0.996	0.000	1.000	0.000	1.000	0.006	0.996	0.007	0.995	0.000	1.000	0.000	1.000
1981	-0.013	1.003	-0.015	1.004	-0.001	1.000	0.000	1.000	-0.011	1.003	-0.013	1.003	0.000	1.000	0.000	1.000
1982	0.058	0.979	0.060	0.979	0.003	1.000	0.000	1.000	0.055	0.980	0.065	0.976	0.000	1.000	0.000	1.000
1983	0.237	0.922	0.263	0.915	0.014	0.999	0.000	1.000	0.224	0.925	0.260	0.911	0.000	1.000	0.000	1.000
1984	0.398	0.874	0.428	0.865	0.026	0.999	0.000	1.000	0.378	0.878	0.421	0.860	0.000	1.000	0.000	1.000
1985	0.115	0.910	0.125	0.896	0.002	1.000	-0.001	1.000	0.104	0.917	0.113	0.898	-0.001	1.000	-0.001	1.000
1986	-0.065	0.951	-0.026	0.929	-0.007	1.000	0.000	1.000	-0.067	0.959	-0.061	0.936	0.000	1.000	0.000	1.000
1987	0.149	0.886	0.181	0.867	0.007	0.999	-0.001	1.000	0.137	0.895	0.200	0.865	-0.001	1.000	-0.001	1.000
1988	0.061	0.952	0.073	0.943	0.003	1.000	0.000	1.000	0.080	0.950	0.106	0.934	0.000	1.000	0.000	1.000
1989	0.297	0.901	0.332	0.891	0.020	0.999	0.001	1.000	0.279	0.905	0.331	0.886	0.001	1.000	0.001	1.000
1990	0.829	0.794	0.890	0.781	0.081	0.998	0.000	1.000	0.784	0.801	0.860	0.777	0.000	1.000	0.001	1.000
1991	0.446	0.831	0.508	0.813	0.031	0.998	-0.002	1.000	0.420	0.840	0.457	0.816	-0.003	1.000	-0.001	1.000
1992	-0.081	0.897	-0.014	0.866	-0.011	1.000	-0.001	1.000	-0.133	0.917	-0.121	0.877	-0.002	1.000	0.000	1.000
1993	0.053	0.941	0.058	0.930	0.002	1.000	0.000	1.000	-0.027	0.963	0.000	0.942	-0.001	1.000	0.000	1.000
1994	0.079	0.923	0.102	0.908	0.003	1.000	-0.001	1.000	-0.010	0.946	0.043	0.917	-0.001	1.000	0.000	1.000
1995	0.017	0.928	0.046	0.911	-0.003	1.000	-0.002	1.000	-0.040	0.945	-0.013	0.919	-0.002	1.000	-0.002	1.000
1996	0.764	0.802	0.825	0.790	0.071	0.998	-0.001	1.000	0.681	0.815	0.757	0.790	-0.001	1.000	0.000	1.000
1997	0.467	0.841	0.505	0.828	0.033	0.998	-0.001	1.000	0.411	0.852	0.485	0.826	-0.001	1.000	0.000	1.000
1998	0.264	0.861	0.286	0.847	0.013	0.999	0.000	1.000	0.285	0.866	0.338	0.839	0.000	1.000	0.000	1.000
1999	0.042	0.862	0.062	0.838	-0.006	1.000	0.005	1.000	0.180	0.863	0.221	0.833	0.005	1.000	0.005	1.000
2000	-0.020	0.876	-0.018	0.850	-0.006	1.000	0.008	1.000	0.181	0.870	0.245	0.838	0.009	1.000	0.009	1.000
2001	-0.789	0.879	-0.799	0.826	-0.046	1.002	0.000	1.000	-0.381	0.934	-0.349	0.878	0.000	1.000	0.000	1.000
2002	-1.259	0.761	-1.202	0.729	-0.073	1.004	0.000	1.000	-0.900	0.874	-0.929	0.774	0.000	1.000	0.000	1.000
2003	-0.271	0.830	-0.271	0.793	-0.025	1.001	-0.001	1.000	-0.139	0.855	-0.117	0.806	-0.001	1.000	-0.002	1.000
2004	-0.099	0.849	-0.003	0.820	-0.015	1.000	0.000	1.000	-0.107	0.867	-0.019	0.822	0.000	1.000	-0.001	1.000
2005	0.201	0.831	0.269	0.808	0.005	0.999	-0.001	1.000	0.184	0.844	0.258	0.809	-0.001	1.000	-0.002	1.000
2006	0.697	0.795	0.794	0.777	0.062	0.998	0.001	1.000	0.672	0.803	0.757	0.775	0.001	1.000	0.001	1.000
2007	0.535	0.821	0.641	0.800	0.042	0.998	0.000	1.000	0.525	0.827	0.604	0.800	0.001	1.000	0.001	1.000
2008	-0.379	0.888	-0.249	0.852	-0.028	1.001	0.000	1.000	-0.321	0.910	-0.316	0.853	0.000	1.000	0.000	1.000
2009	-0.785	0.932	-0.891	0.856	-0.041	1.002	0.001	1.000	-0.750	0.968	-0.961	0.834	0.001	1.000	0.001	1.000
2010	-0.673	1.030	-1.138	0.931	-0.032	1.002	-0.001	1.000	-0.680	1.060	-1.208	0.898	0.000	1.000	0.000	1.000
2011	-0.005	0.932	-0.151	0.937	-0.004	1.000	0.000	1.000	-0.020	0.942	-0.183	0.942	0.000	1.000	0.000	1.000
2012	0.046	0.922	-0.070	0.927	-0.002	1.000	-0.001	1.000	-0.046	0.944	-0.176	0.937	-0.001	1.000	-0.001	1.000
2013	-0.465	0.954	-0.570	0.921	-0.032	1.001	-0.001	1.000	-0.707	0.979	-0.877	0.872	0.000	1.000	-0.001	1.000
2014	-0.716	0.863	-0.713	0.823	-0.048	1.002	-0.001	1.000	-0.907	0.864	-0.962	0.759	0.000	1.000	-0.002	1.000
2015	-0.348	0.902	-0.347	0.869	-0.025	1.001	-0.001	1.000	-0.446	0.926	-0.426	0.865	0.000	1.000	-0.002	1.000
2016	0.065	0.894	-0.025	0.886	-0.005	1.000	0.000	1.000	0.033	0.908	0.010	0.882	0.000	1.000	-0.001	1.000
2017	0.472	0.839	0.361	0.844	0.023	0.999	0.000	1.000	0.420	0.850	0.409	0.835	0.000	1.000	-0.001	1.000
2018	0.288	0.867	0.258	0.861	0.008	0.999	0.000	1.000	0.261	0.876	0.291	0.855	0.001	1.000	-0.001	1.000
2019	-0.353	0.938	-0.283	0.908	-0.026	1.001	0.000	1.000	-0.348	0.958	-0.203	0.909	0.001	1.000	-0.001	1.000

Table 2.1.3i. Estimates of survey selectivity log-scale PeakStart deviations.

	M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1982	-0.185	0.431	-0.207	0.421	-0.204	0.421	-0.229	0.421	-0.191	0.428	-0.194	0.421	-0.202	0.413	-0.258	0.424
1983	-0.258	0.474	-0.217	0.481	-0.201	0.477	-0.273	0.467	-0.142	0.491	-0.067	0.478	-0.089	0.485	-0.063	0.511
1984	1.187	0.397	1.193	0.396	1.184	0.407	1.101	0.389	1.156	0.388	1.178	0.400	1.155	0.409	0.948	0.390
1985	0.489	0.275	0.463	0.273	0.496	0.277	0.436	0.272	0.532	0.274	0.554	0.270	0.544	0.279	0.399	0.274
1986	-0.409	0.534	-0.418	0.525	-0.422	0.524	-0.450	0.527	-0.381	0.518	-0.374	0.498	-0.400	0.513	-0.357	0.575
1987	0.026	0.353	0.031	0.348	0.043	0.350	-0.020	0.346	0.087	0.348	0.124	0.343	0.085	0.351	-0.034	0.346
1988	0.058	0.539	0.051	0.530	0.036	0.534	-0.015	0.521	0.171	0.530	0.187	0.525	0.144	0.528	0.082	0.505
1989	0.653	0.510	0.658	0.599	0.648	0.554	0.600	0.508	0.601	0.511	0.625	0.505	0.582	0.510	0.558	0.564
1990	-0.237	0.362	-0.251	0.354	-0.227	0.349	-0.286	0.355	-0.279	0.355	-0.225	0.347	-0.258	0.356	-0.332	0.351
1991	1.051	0.469	1.063	0.496	1.071	0.502	0.995	0.486	0.934	0.453	0.997	0.449	0.937	0.453	0.802	0.465
1992	-0.197	0.360	-0.224	0.352	-0.226	0.361	-0.271	0.389	-0.465	0.451	-0.455	0.465	-0.465	0.439	-0.353	0.342
1993	0.206	0.347	0.225	0.318	0.246	0.318	0.198	0.324	0.131	0.331	0.203	0.326	0.161	0.333	0.126	0.312
1994	0.427	0.454	0.467	0.426	0.464	0.424	0.448	0.422	0.642	0.440	0.722	0.472	0.652	0.484	0.650	0.459
1995	0.546	0.431	0.579	0.421	0.584	0.421	0.563	0.418	0.725	0.439	0.816	0.423	0.748	0.431	0.587	0.410
1996	0.285	0.385	0.295	0.380	0.300	0.381	0.373	0.388	0.451	0.384	0.538	0.420	0.484	0.427	0.760	0.560
1997	0.753	0.347	0.759	0.344	0.772	0.345	0.730	0.343	0.778	0.343	0.840	0.341	0.799	0.344	0.816	0.426
1998	2.054	0.361	2.133	0.330	2.172	0.334	2.019	0.322	2.027	0.325	2.098	0.314	2.105	0.336	1.913	0.310
1999	0.347	0.515	0.310	0.503	0.262	0.518	0.172	0.454	0.418	0.492	0.444	0.474	0.326	0.495	0.168	0.477
2000	-0.601	0.303	-0.575	0.299	-0.563	0.300	-0.606	0.294	-0.657	0.290	-0.574	0.285	-0.643	0.292	-0.726	0.285
2001	-0.908	0.361	-0.898	0.350	-0.924	0.351	-0.764	0.345	-0.669	0.333	-0.609	0.323	-0.691	0.327	-0.329	0.298
2002	0.123	0.453	0.253	0.475	0.243	0.481	0.216	0.468	0.131	0.445	0.292	0.477	0.227	0.450	0.303	0.478
2003	0.215	0.338	0.234	0.307	0.231	0.314	0.351	0.315	0.273	0.308	0.323	0.303	0.277	0.309	0.478	0.288
2004	0.279	0.355	0.296	0.352	0.288	0.350	0.320	0.356	0.259	0.347	0.316	0.339	0.261	0.343	0.366	0.372
2005	-0.111	0.415	0.053	0.379	0.037	0.387	0.058	0.380	-0.036	0.397	0.087	0.391	0.082	0.379	0.311	0.295
2006	-1.533	0.322	-1.505	0.314	-1.512	0.313	-1.584	0.316	-1.492	0.325	-1.451	0.291	-1.470	0.313	-1.478	0.298
2007	-2.442	0.253	-2.440	0.245	-2.430	0.247	-2.414	0.246	-2.327	0.240	-2.269	0.232	-2.374	0.242	-2.427	0.248
2008	-1.454	0.302	-1.468	0.297	-1.463	0.296	-1.478	0.293	-1.473	0.297	-1.435	0.289	-1.500	0.295	-1.525	0.289
2009	-0.910	0.565	-1.058	0.438	-1.024	0.451	-0.991	0.568	-1.609	0.411	-1.522	0.384	-1.437	0.524	-1.187	0.440
2010	-0.464	0.444	-0.111	0.471	-0.200	0.478	-0.454	0.427	-0.500	0.386	-0.133	0.472	-0.234	0.429	-0.453	0.411
2011	-0.144	0.258	-0.215	0.249	-0.202	0.250	-0.149	0.253	-0.110	0.251	-0.127	0.243	-0.158	0.251	-0.174	0.244
2012	-1.990	0.351	-2.095	0.372	-2.082	0.369	-2.070	0.363	-1.943	0.368	-2.112	0.286	-2.024	0.374	-2.180	0.376
2013	0.980	0.358	0.814	0.425	0.804	0.414	0.876	0.343	0.867	0.335	0.724	0.396	0.693	0.405	0.572	0.389
2014	-0.050	0.296	-0.192	0.283	-0.179	0.284	-0.028	0.280	-0.005	0.289	-0.115	0.273	-0.125	0.283	-0.116	0.259
2015	0.457	0.469	0.312	0.448	0.281	0.445	0.507	0.450	0.455	0.453	0.392	0.432	0.331	0.438	0.448	0.431
2016	1.169	0.333	1.056	0.316	1.068	0.317	1.231	0.331	1.186	0.328	1.156	0.311	1.159	0.320	1.190	0.335
2017	1.107	0.365	0.985	0.375	0.997	0.378	1.188	0.354	0.915	0.385	-0.638	0.490	0.762	0.466	1.077	0.345
2018	0.780	0.373	0.950	0.305	0.955	0.306	1.038	0.295	0.764	0.366	0.924	0.298	0.873	0.301	0.858	0.287
2019	-1.302	0.297	-1.308	0.314	-1.321	0.354	-1.341	0.343	-1.224	0.307	-1.241	0.328	-1.318	0.348	-1.419	0.331

Table 2.1.3j. Estimates of survey selectivity lnSD1 deviations.

	M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1982	-0.518	0.587	-0.536	0.586	-0.530	0.584	-0.508	0.581	-0.507	0.587	-0.495	0.585	-0.521	0.576	-0.546	0.585
1983	0.392	0.618	0.411	0.632	0.415	0.623	0.409	0.616	0.450	0.623	0.502	0.603	0.484	0.616	0.544	0.642
1984	0.810	0.443	0.847	0.448	0.836	0.455	0.803	0.440	0.891	0.440	0.938	0.448	0.908	0.466	0.729	0.450
1985	0.683	0.369	0.674	0.371	0.698	0.374	0.687	0.369	0.674	0.360	0.702	0.354	0.694	0.371	0.502	0.364
1986	-0.041	0.683	-0.044	0.686	-0.050	0.682	-0.042	0.684	-0.058	0.663	-0.059	0.643	-0.070	0.666	-0.017	0.727
1987	-0.116	0.561	-0.110	0.560	-0.096	0.561	-0.132	0.555	-0.072	0.543	-0.018	0.535	-0.077	0.555	-0.182	0.551
1988	-0.145	0.677	-0.129	0.678	-0.139	0.681	-0.168	0.669	-0.043	0.659	0.000	0.654	-0.058	0.667	-0.079	0.646
1989	0.224	0.582	0.265	0.687	0.245	0.637	0.222	0.584	0.257	0.588	0.313	0.581	0.240	0.596	0.266	0.648
1990	0.156	0.449	0.149	0.446	0.169	0.438	0.146	0.445	0.149	0.441	0.199	0.429	0.169	0.447	0.118	0.442
1991	1.334	0.514	1.367	0.548	1.364	0.552	1.313	0.535	1.301	0.504	1.359	0.497	1.316	0.511	1.187	0.526
1992	-0.125	0.458	-0.140	0.456	-0.136	0.466	-0.157	0.497	-0.363	0.585	-0.343	0.605	-0.352	0.576	-0.204	0.449
1993	0.729	0.447	0.742	0.415	0.763	0.413	0.728	0.419	0.657	0.426	0.714	0.416	0.683	0.432	0.615	0.405
1994	0.385	0.592	0.414	0.565	0.405	0.562	0.406	0.555	0.501	0.551	0.576	0.583	0.492	0.611	0.541	0.577
1995	0.300	0.553	0.341	0.548	0.343	0.548	0.328	0.537	0.471	0.544	0.569	0.520	0.483	0.542	0.355	0.521
1996	-0.264	0.513	-0.237	0.513	-0.235	0.513	-0.146	0.509	-0.081	0.496	0.038	0.531	-0.055	0.550	0.270	0.664
1997	0.751	0.413	0.753	0.413	0.755	0.412	0.746	0.409	0.795	0.405	0.848	0.399	0.794	0.409	0.809	0.497
1998	2.036	0.375	2.112	0.353	2.144	0.355	2.022	0.345	2.001	0.341	2.055	0.329	2.091	0.353	1.934	0.336
1999	0.350	0.578	0.325	0.578	0.273	0.598	0.200	0.529	0.436	0.549	0.469	0.531	0.342	0.567	0.226	0.558
2000	-0.658	0.420	-0.639	0.417	-0.624	0.417	-0.661	0.407	-0.681	0.408	-0.592	0.398	-0.681	0.413	-0.781	0.400
2001	-0.544	0.553	-0.567	0.545	-0.586	0.545	-0.417	0.526	-0.381	0.499	-0.339	0.481	-0.413	0.497	-0.104	0.443
2002	0.083	0.578	0.211	0.605	0.198	0.614	0.158	0.592	0.099	0.567	0.260	0.596	0.183	0.577	0.241	0.594
2003	0.221	0.452	0.235	0.417	0.241	0.426	0.334	0.420	0.279	0.408	0.334	0.400	0.281	0.416	0.382	0.376
2004	0.131	0.472	0.143	0.473	0.135	0.470	0.182	0.470	0.144	0.462	0.206	0.448	0.132	0.462	0.217	0.482
2005	-0.215	0.579	-0.040	0.537	-0.057	0.545	0.000	0.529	-0.140	0.548	0.006	0.537	-0.012	0.528	0.244	0.411
2006	-1.384	0.467	-1.369	0.462	-1.383	0.460	-1.462	0.470	-1.379	0.479	-1.337	0.427	-1.356	0.458	-1.316	0.427
2007	-2.469	0.528	-2.516	0.522	-2.500	0.522	-2.466	0.515	-2.417	0.502	-2.374	0.484	-2.483	0.511	-2.509	0.521
2008	-1.542	0.474	-1.576	0.476	-1.568	0.475	-1.566	0.468	-1.567	0.482	-1.530	0.474	-1.611	0.483	-1.600	0.463
2009	0.144	0.787	-0.087	0.630	-0.033	0.646	0.015	0.808	-0.773	0.639	-0.737	0.591	-0.563	0.800	-0.241	0.637
2010	-0.674	0.601	-0.281	0.610	-0.379	0.629	-0.648	0.591	-0.710	0.538	-0.289	0.615	-0.418	0.575	-0.615	0.570
2011	-0.183	0.355	-0.231	0.348	-0.212	0.348	-0.174	0.350	-0.157	0.341	-0.128	0.330	-0.191	0.347	-0.200	0.336
2012	-1.376	0.560	-1.537	0.630	-1.511	0.620	-1.495	0.602	-1.389	0.599	-1.696	0.501	-1.478	0.626	-1.646	0.654
2013	0.970	0.382	0.892	0.458	0.878	0.446	0.895	0.369	0.943	0.361	0.867	0.427	0.820	0.441	0.699	0.429
2014	-0.097	0.420	-0.149	0.419	-0.131	0.420	-0.078	0.394	-0.062	0.405	-0.068	0.393	-0.114	0.412	-0.195	0.363
2015	0.381	0.560	0.291	0.557	0.263	0.554	0.429	0.540	0.379	0.541	0.347	0.526	0.274	0.543	0.356	0.525
2016	0.756	0.458	0.687	0.448	0.698	0.447	0.795	0.451	0.810	0.447	0.798	0.428	0.774	0.445	0.771	0.458
2017	0.910	0.470	0.843	0.479	0.852	0.479	0.927	0.454	0.871	0.483	-0.762	0.730	0.757	0.544	0.882	0.451
2018	0.079	0.436	-0.151	0.424	-0.150	0.423	-0.075	0.406	0.116	0.427	-0.038	0.403	-0.136	0.417	-0.169	0.403
2019	-1.476	0.558	-1.364	0.581	-1.357	0.637	-1.551	0.632	-1.445	0.576	-1.296	0.602	-1.328	0.628	-1.489	0.608

Table 2.1.4. Estimates of instantaneous full-selection fishing mortality rates.

	19.12a	19.12b	20.1		19.12c		19.12	19.12d	20.2		20.3	
Year	XBS	XBS	EBS	NBS	EBS	NBS	XBS	XBS	EBS	NBS	EBS	NBS
1977	0.186	0.186	0.176	0.000	0.232	0.000	0.195	0.200	0.168	0.000	0.257	0.000
1978	0.225	0.225	0.212	0.000	0.290	0.000	0.237	0.244	0.202	0.000	0.315	0.000
1979	0.162	0.162	0.153	0.000	0.215	0.000	0.172	0.177	0.145	0.000	0.226	0.000
1980	0.167	0.167	0.158	0.000	0.226	0.000	0.178	0.182	0.150	0.000	0.236	0.000
1981	0.124	0.124	0.118	0.000	0.169	0.000	0.134	0.135	0.114	0.000	0.182	0.000
1982	0.095	0.094	0.090	0.000	0.127	0.000	0.102	0.100	0.088	0.000	0.140	0.000
1983	0.114	0.113	0.110	0.000	0.146	0.000	0.122	0.120	0.106	0.000	0.162	0.000
1984	0.157	0.157	0.153	0.000	0.198	0.000	0.166	0.164	0.146	0.000	0.220	0.000
1985	0.173	0.173	0.167	0.000	0.213	0.000	0.182	0.180	0.158	0.000	0.236	0.000
1986	0.164	0.164	0.158	0.000	0.194	0.000	0.171	0.170	0.149	0.000	0.217	0.000
1987	0.190	0.189	0.184	0.000	0.226	0.000	0.196	0.195	0.174	0.000	0.252	0.000
1988	0.224	0.223	0.218	0.000	0.269	0.000	0.231	0.230	0.208	0.000	0.303	0.000
1989	0.211	0.210	0.207	0.000	0.257	0.000	0.216	0.215	0.198	0.000	0.291	0.000
1990	0.240	0.238	0.239	0.000	0.279	0.000	0.243	0.241	0.227	0.000	0.320	0.000
1991	0.409	0.407	0.406	0.000	0.466	0.000	0.407	0.408	0.379	0.000	0.528	0.000
1992	0.452	0.451	0.442	0.000	0.507	0.000	0.442	0.449	0.404	0.000	0.567	0.000
1993	0.305	0.306	0.303	0.000	0.355	0.000	0.300	0.304	0.279	0.000	0.384	0.000
1994	0.402	0.401	0.400	0.000	0.474	0.000	0.400	0.402	0.377	0.000	0.516	0.000
1995	0.498	0.496	0.496	0.000	0.592	0.000	0.510	0.514	0.482	0.000	0.666	0.000
1996	0.469	0.464	0.472	0.000	0.580	0.000	0.498	0.500	0.476	0.000	0.682	0.000
1997	0.514	0.506	0.515	0.000	0.665	0.000	0.566	0.565	0.537	0.000	0.800	0.000
1998	0.410	0.402	0.410	0.000	0.552	0.000	0.458	0.456	0.431	0.000	0.682	0.000
1999	0.390	0.381	0.388	0.000	0.548	0.000	0.435	0.434	0.407	0.000	0.665	0.000
2000	0.379	0.372	0.377	0.000	0.523	0.000	0.418	0.414	0.391	0.000	0.637	0.000
2001	0.343	0.337	0.334	0.000	0.453	0.000	0.363	0.360	0.339	0.000	0.539	0.000
2002	0.372	0.365	0.354	0.000	0.479	0.000	0.384	0.383	0.353	0.000	0.554	0.000
2003	0.376	0.368	0.367	0.001	0.482	0.004	0.391	0.387	0.365	0.007	0.563	0.001
2004	0.388	0.379	0.382	0.000	0.532	0.001	0.406	0.397	0.380	0.001	0.587	0.000
2005	0.408	0.397	0.406	0.000	0.585	0.000	0.425	0.413	0.402	0.001	0.643	0.000
2006	0.447	0.432	0.451	0.000	0.695	0.000	0.464	0.446	0.443	0.000	0.755	0.000
2007	0.430	0.411	0.433	0.000	0.630	0.000	0.442	0.419	0.421	0.000	0.729	0.000
2008	0.526	0.494	0.517	0.000	0.724	0.000	0.532	0.500	0.497	0.001	0.861	0.000
2009	0.657	0.613	0.635	0.000	0.897	0.000	0.652	0.613	0.601	0.000	1.079	0.000
2010	0.619	0.593	0.609	0.000	0.643	0.000	0.600	0.582	0.569	0.000	0.800	0.000
2011	0.721	0.708	0.734	0.000	0.813	0.000	0.690	0.683	0.685	0.000	0.861	0.000
2012	0.616	0.627	0.640	0.000	0.712	0.000	0.608	0.623	0.612	0.000	0.752	0.000
2013	0.557	0.574	0.580	0.000	0.647	0.010	0.563	0.593	0.562	0.003	0.699	0.001
2014	0.608	0.631	0.634	0.000	0.711	0.007	0.618	0.670	0.615	0.002	0.801	0.001
2015	0.571	0.604	0.613	0.000	0.691	0.003	0.585	0.654	0.603	0.002	0.830	0.001
2016	0.510	0.560	0.570	0.002	0.741	0.013	0.528	0.627	0.571	0.031	0.838	0.006
2017	0.403	0.471	0.482	0.002	0.674	0.007	0.423	0.547	0.491	0.027	0.788	0.004
2018	0.295	0.368	0.330	0.031	0.597	0.065	0.309	0.437	0.336	0.582	0.567	0.057
2019	0.288	0.380	0.324	0.029	0.592	0.054	0.300	0.464	0.326	0.934	0.543	0.051

Table 2.1.5. "Sigma" terms for vectors of annual random deviations. Deviations are ~norma(0,σ^2) for ln(Recruits), ~normal(0,1) for others.

	Model 19.12a			Model 19.12b			Model 20.1			Model 19.12c		
Parameter	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma
ln(Recruits)	0.4701	0.0134	0.6954	0.4448	0.0124	0.6762	0.4602	0.0129	0.6877	0.4351	0.0124	0.6690
Length_at_1.5	0.7825	0.2159	0.1494	0.7955	0.2018	0.1524	0.8005	0.2011	0.1548	0.7889	0.2112	0.1508
Sel_fsh_lnSD1	0.7155	0.2879	0.1560	0.6940	0.3081	0.1434	0.7060	0.2961	0.1486	0.7234	0.2807	0.1601
Sel_fsh_logitEnd	0.1803	0.8161	0.7517	0.2183	0.7790	0.7504	0.0000	1.0000	0.1004	0.0000	1.0000	0.1000
Sel_srv_PeakStart	0.8399	0.1572	0.2034	0.8511	0.1502	0.2085	0.8471	0.1505	0.2072	0.8498	0.1490	0.2106
Sel_srv_lnSD1	0.7220	0.2729	0.7641	0.7297	0.2692	0.7640	0.7265	0.2705	0.7631	0.7307	0.2672	0.7824

	Model 19.12			Model 19.12d			Model 20.2			Model 20.3		
Parameter	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma
ln(Recruits)	0.4525	0.0139	0.6830	0.4451	0.0130	0.6766	0.4477	0.0133	0.6791	0.4172	0.0131	0.6559
Length_at_1.5	0.7791	0.2188	0.1502	0.8066	0.1900	0.1603	0.8085	0.1939	0.1601	0.8000	0.2060	0.1512
Sel_fsh_lnSD1	0.7107	0.2936	0.1532	0.6810	0.3104	0.1433	0.7031	0.2975	0.1482	0.7099	0.2921	0.1514
Sel_fsh_logitEnd	0.1557	0.8422	0.7670	0.2134	0.7812	0.7976	0.0000	1.0000	0.1004	0.0000	1.0000	0.1000
Sel_srv_PeakStart	0.8472	0.1485	0.2153	0.8530	0.1486	0.2227	0.8453	0.1557	0.2136	0.8453	0.1542	0.2203
Sel_srv_lnSD1	0.7345	0.2581	0.8064	0.7410	0.2602	0.8318	0.7250	0.2759	0.7829	0.7321	0.2713	0.7850

Table 2.1.6 (page 1 of 2). Movement probabilities (Models 19.12c and 20.3 only).

Year	Src.	Dst.	M19.12c						M20.3					
			2	3	4	5	6	7+	2	3	4	5	6	7+
1981	EBS	NBS	0.033	0.005	0.001	0.000	0.000	0.000	0.187	0.019	0.002	0.000	0.000	0.000
	NBS	EBS	0.001	0.004	0.010	0.028	0.075	0.185	0.000	0.001	0.004	0.011	0.035	0.103
1982	EBS	NBS	0.040	0.007	0.001	0.000	0.000	0.000	0.202	0.023	0.002	0.000	0.000	0.000
	NBS	EBS	0.112	0.148	0.192	0.245	0.307	0.378	0.059	0.066	0.074	0.083	0.092	0.103
1983	EBS	NBS	0.022	0.003	0.000	0.000	0.000	0.000	0.156	0.013	0.001	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.000	0.001	0.014	0.000	0.000	0.000	0.000	0.002	0.102
1984	EBS	NBS	0.011	0.001	0.000	0.000	0.000	0.000	0.114	0.007	0.000	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.001	0.008	0.058	0.000	0.000	0.000	0.001	0.009	0.102
1985	EBS	NBS	0.038	0.007	0.001	0.000	0.000	0.000	0.197	0.021	0.002	0.000	0.000	0.000
	NBS	EBS	0.029	0.048	0.081	0.131	0.206	0.308	0.012	0.019	0.029	0.045	0.068	0.103
1986	EBS	NBS	0.048	0.010	0.002	0.000	0.000	0.000	0.217	0.026	0.003	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.000	0.002	0.027	0.000	0.000	0.000	0.000	0.004	0.102
1987	EBS	NBS	0.033	0.005	0.001	0.000	0.000	0.000	0.186	0.019	0.002	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.001	0.006	0.050	0.000	0.000	0.000	0.001	0.008	0.102
1988	EBS	NBS	0.025	0.003	0.000	0.000	0.000	0.000	0.165	0.015	0.001	0.000	0.000	0.000
	NBS	EBS	0.000	0.001	0.004	0.013	0.044	0.141	0.000	0.000	0.001	0.006	0.025	0.103
1989	EBS	NBS	0.075	0.021	0.006	0.001	0.000	0.000	0.260	0.039	0.005	0.001	0.000	0.000
	NBS	EBS	0.676	0.648	0.618	0.588	0.557	0.526	0.592	0.466	0.345	0.241	0.161	0.104
1990	EBS	NBS	0.016	0.001	0.000	0.000	0.000	0.000	0.135	0.010	0.001	0.000	0.000	0.000
	NBS	EBS	0.209	0.244	0.282	0.324	0.369	0.416	0.125	0.120	0.116	0.111	0.107	0.103
1991	EBS	NBS	0.011	0.001	0.000	0.000	0.000	0.000	0.116	0.007	0.000	0.000	0.000	0.000
	NBS	EBS	0.379	0.395	0.411	0.427	0.444	0.460	0.267	0.224	0.187	0.155	0.127	0.103
1992	EBS	NBS	0.014	0.001	0.000	0.000	0.000	0.000	0.126	0.009	0.001	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.001	0.010	0.063	0.000	0.000	0.000	0.001	0.010	0.102
1993	EBS	NBS	0.026	0.003	0.000	0.000	0.000	0.000	0.167	0.015	0.001	0.000	0.000	0.000
	NBS	EBS	0.001	0.004	0.010	0.028	0.076	0.186	0.000	0.001	0.004	0.012	0.035	0.103
1994	EBS	NBS	0.015	0.001	0.000	0.000	0.000	0.000	0.132	0.009	0.001	0.000	0.000	0.000
	NBS	EBS	0.066	0.095	0.136	0.192	0.263	0.349	0.031	0.040	0.051	0.065	0.082	0.103
1995	EBS	NBS	0.005	0.000	0.000	0.000	0.000	0.000	0.078	0.003	0.000	0.000	0.000	0.000
	NBS	EBS	0.001	0.003	0.008	0.022	0.064	0.171	0.000	0.001	0.003	0.009	0.032	0.103
1996	EBS	NBS	0.183	0.101	0.053	0.027	0.014	0.007	0.369	0.088	0.016	0.003	0.000	0.000
	NBS	EBS	0.000	0.000	0.002	0.008	0.032	0.120	0.000	0.000	0.001	0.004	0.021	0.103
1997	EBS	NBS	0.057	0.013	0.003	0.001	0.000	0.000	0.234	0.031	0.003	0.000	0.000	0.000
	NBS	EBS	0.001	0.003	0.009	0.026	0.071	0.180	0.000	0.001	0.003	0.011	0.034	0.103
1998	EBS	NBS	0.011	0.001	0.000	0.000	0.000	0.000	0.117	0.007	0.000	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.000	0.004	0.039	0.000	0.000	0.000	0.000	0.006	0.102
1999	EBS	NBS	0.006	0.000	0.000	0.000	0.000	0.000	0.087	0.004	0.000	0.000	0.000	0.000
	NBS	EBS	0.007	0.016	0.033	0.068	0.134	0.248	0.003	0.006	0.012	0.025	0.051	0.103
2000	EBS	NBS	0.005	0.000	0.000	0.000	0.000	0.000	0.080	0.004	0.000	0.000	0.000	0.000
	NBS	EBS	0.001	0.002	0.006	0.019	0.058	0.163	0.000	0.001	0.002	0.008	0.030	0.103
2001	EBS	NBS	0.134	0.058	0.024	0.009	0.004	0.001	0.327	0.066	0.010	0.001	0.000	0.000
	NBS	EBS	0.000	0.000	0.001	0.003	0.017	0.086	0.000	0.000	0.000	0.002	0.014	0.102
2002	EBS	NBS	0.021	0.002	0.000	0.000	0.000	0.000	0.152	0.013	0.001	0.000	0.000	0.000
	NBS	EBS	0.004	0.009	0.022	0.050	0.110	0.225	0.001	0.003	0.008	0.019	0.045	0.103

Table 2.1.6 (page 1 of 2). Movement probabilities (Models 19.12c and 20.3 only).

Year	Src.	Dst.	M19.12c						M20.3					
			2	3	4	5	6	7+	2	3	4	5	6	7+
2003	EBS	NBS	0.209	0.129	0.076	0.044	0.025	0.014	0.389	0.100	0.019	0.003	0.001	0.000
	NBS	EBS	0.000	0.000	0.000	0.000	0.003	0.031	0.000	0.000	0.000	0.000	0.005	0.102
2004	EBS	NBS	0.130	0.055	0.022	0.009	0.003	0.001	0.323	0.064	0.010	0.001	0.000	0.000
	NBS	EBS	0.001	0.003	0.008	0.022	0.064	0.171	0.000	0.001	0.003	0.009	0.032	0.103
2005	EBS	NBS	0.095	0.031	0.010	0.003	0.001	0.000	0.286	0.048	0.006	0.001	0.000	0.000
	NBS	EBS	0.000	0.001	0.004	0.013	0.045	0.142	0.000	0.000	0.001	0.006	0.026	0.103
2006	EBS	NBS	0.010	0.001	0.000	0.000	0.000	0.000	0.108	0.006	0.000	0.000	0.000	0.000
	NBS	EBS	0.037	0.059	0.094	0.146	0.221	0.319	0.016	0.023	0.034	0.050	0.072	0.103
2007	EBS	NBS	0.046	0.009	0.002	0.000	0.000	0.000	0.213	0.025	0.002	0.000	0.000	0.000
	NBS	EBS	0.019	0.034	0.061	0.106	0.180	0.288	0.007	0.013	0.022	0.037	0.062	0.103
2008	EBS	NBS	0.010	0.001	0.000	0.000	0.000	0.000	0.113	0.007	0.000	0.000	0.000	0.000
	NBS	EBS	0.005	0.012	0.026	0.056	0.119	0.234	0.002	0.004	0.009	0.021	0.047	0.103
2009	EBS	NBS	0.006	0.000	0.000	0.000	0.000	0.000	0.085	0.004	0.000	0.000	0.000	0.000
	NBS	EBS	0.993	0.985	0.968	0.931	0.860	0.735	0.994	0.976	0.903	0.683	0.333	0.104
2010	EBS	NBS	0.005	0.000	0.000	0.000	0.000	0.000	0.084	0.004	0.000	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.002	0.010	0.065	0.000	0.000	0.000	0.001	0.010	0.102
2011	EBS	NBS	0.087	0.027	0.008	0.002	0.001	0.000	0.276	0.044	0.006	0.001	0.000	0.000
	NBS	EBS	0.318	0.342	0.367	0.393	0.419	0.446	0.212	0.185	0.161	0.139	0.120	0.103
2012	EBS	NBS	0.001	0.000	0.000	0.000	0.000	0.000	0.033	0.001	0.000	0.000	0.000	0.000
	NBS	EBS	0.061	0.090	0.131	0.186	0.257	0.345	0.029	0.037	0.048	0.063	0.081	0.103
2013	EBS	NBS	0.004	0.000	0.000	0.000	0.000	0.000	0.073	0.003	0.000	0.000	0.000	0.000
	NBS	EBS	0.058	0.087	0.127	0.182	0.254	0.343	0.027	0.036	0.047	0.061	0.080	0.103
2014	EBS	NBS	0.129	0.054	0.022	0.008	0.003	0.001	0.323	0.064	0.010	0.001	0.000	0.000
	NBS	EBS	0.018	0.033	0.059	0.104	0.177	0.286	0.007	0.012	0.021	0.036	0.062	0.103
2015	EBS	NBS	0.290	0.230	0.180	0.138	0.105	0.079	0.441	0.139	0.032	0.007	0.001	0.000
	NBS	EBS	0.000	0.001	0.002	0.009	0.035	0.125	0.000	0.000	0.001	0.004	0.022	0.103
2016	EBS	NBS	0.148	0.068	0.030	0.013	0.006	0.002	0.340	0.072	0.012	0.002	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.002	0.011	0.068	0.000	0.000	0.000	0.001	0.011	0.102
2017	EBS	NBS	0.375	0.360	0.346	0.331	0.317	0.304	0.489	0.184	0.050	0.012	0.003	0.001
	NBS	EBS	0.052	0.079	0.118	0.172	0.245	0.337	0.024	0.032	0.043	0.058	0.078	0.103
2018	EBS	NBS	0.876	0.969	0.993	0.998	1.000	1.000	0.767	0.650	0.513	0.374	0.253	0.161
	NBS	EBS	0.978	0.960	0.929	0.878	0.797	0.682	0.978	0.931	0.804	0.556	0.276	0.104
2019	EBS	NBS	0.018	0.020	0.023	0.026	0.029	0.033	0.187	0.019	0.002	0.000	0.000	0.000
	NBS	EBS	0.001	0.004	0.010	0.028	0.075	0.185	0.000	0.001	0.004	0.011	0.035	0.103

Table 2.1.7a (page 1 of 2). Combined-area female spawning biomass (t) time series.

	Model 19.12a		Model 19.12b		Model 20.1		Model 19.12c	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	94746	26527	95697	27309	172363	70968	82214	21943
1978	97838	26384	99000	27195	180714	73440	83066	21527
1979	99646	25063	101067	25900	185245	73202	81785	19846
1980	122635	25509	124562	26402	222456	81577	98551	19695
1981	181260	27479	184845	28554	317690	105210	143606	20543
1982	283156	32653	289321	34085	482882	149770	226329	24207
1983	377388	35776	385013	37367	633260	191108	308192	26919
1984	381020	31085	387458	32414	637205	192295	317517	23827
1985	428286	32392	433815	33651	732850	230541	361716	25297
1986	419983	29514	424656	30617	735310	239610	359235	23438
1987	409327	26056	414239	27103	724275	239376	355079	20912
1988	434265	25341	440144	26480	780705	263394	380714	20434
1989	421399	23286	427929	24488	777195	270628	371474	18761
1990	376820	19748	382515	20831	711235	255168	335121	15943
1991	299868	15601	303580	16421	591000	223434	268668	12669
1992	217791	13055	220039	13686	478111	200478	193058	10644
1993	206812	13476	209029	14166	479881	209894	180701	10843
1994	210956	12695	213567	13457	468504	197480	184857	9950
1995	226093	13385	229476	14313	496414	206983	197319	10229
1996	226615	14216	231075	15326	499209	208182	195457	10635
1997	223121	14366	228396	15575	501300	212400	192222	10699
1998	200084	14336	205792	15518	479281	213397	171251	10750
1999	194495	14841	200343	15965	481264	219634	168179	11390
2000	204284	15752	210431	16876	501325	227580	180775	12462
2001	212671	15376	219033	16494	498632	218810	193037	12593
2002	227165	15138	233871	16284	515745	220713	209382	12799
2003	232430	14673	239634	15865	524300	222786	215331	12804
2004	236152	13975	244027	15214	527095	221676	219575	12645
2005	230334	13274	238612	14502	526605	226183	216878	12455
2006	202967	12013	211179	13125	484713	215616	195171	11655
2007	176443	11134	185018	12150	448344	208463	174913	11082
2008	151021	9877	159842	10752	397704	189263	153880	9936
2009	135434	9501	144649	10276	374266	183178	139434	9446
2010	132435	9434	140479	10109	358535	173411	132154	8867
2011	160157	10205	165318	10802	388740	176276	150089	8843
2012	189655	11557	190513	11983	427561	185309	169486	9356
2013	215368	13263	212904	13510	482726	210560	187918	10466
2014	219956	14547	214677	14540	501765	224392	189933	11462
2015	227123	16069	217215	15719	516640	234233	196343	12855
2016	262823	18876	242699	17924	567875	254709	230409	15438
2017	306482	22120	269155	20339	620065	275465	275175	18743
2018	334399	23967	278519	21505	637390	282649	311780	21221
2019	328197	23785	259843	21076	609165	276701	318790	22129
2020	286189	21240	213933	18807	535980	250900	290688	20706
2021	212502	12223	169717	8128	321877	226453	266319	16187

Table 2.1.7a (page 2 of 2). Combined-area female spawning biomass (t) time series.

	Model 19.12		Model 19.12d		Model 20.2		Model 20.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	90527	25164	88610	25444	106112	29541	108510	27530
1978	92880	25056	91030	25347	110678	29488	112258	27481
1979	93774	23810	92069	24129	114115	28194	113548	26142
1980	114789	24485	113309	24820	140647	28838	136351	26948
1981	168189	27122	168755	27481	205819	31458	194655	30826
1982	262535	33334	266828	33867	317050	37920	299127	40315
1983	352222	37682	359513	38271	417791	42058	399463	48656
1984	358534	33837	365785	34268	419084	37149	407875	46667
1985	405674	36211	412711	36532	470753	39127	466778	53138
1986	400253	33782	406163	33967	462286	35996	466037	52722
1987	392821	30277	397999	30368	450255	31927	460329	50550
1988	419106	29581	424325	29617	476846	30918	495110	53650
1989	409065	27030	413977	27019	463038	28115	490217	53771
1990	369532	22762	373089	22718	415134	23641	449299	49636
1991	297917	17883	299362	17827	333069	18572	370089	42267
1992	219181	14819	219000	14762	247915	15372	284467	36324
1993	209018	14926	208289	14856	238681	15471	274846	35476
1994	211257	13489	210813	13442	238924	14021	268658	30730
1995	222343	13524	222118	13519	250560	14140	279244	30211
1996	215621	13581	215818	13649	244115	14273	273676	29668
1997	206781	13186	207670	13298	234777	13850	270080	30213
1998	181185	12866	182523	13010	208483	13407	249797	30881
1999	174833	13334	176321	13498	202502	13710	252335	33287
2000	184945	14427	186964	14624	214231	14711	275157	37353
2001	196378	14455	199209	14693	225331	14762	291274	38876
2002	213600	14520	216995	14828	242649	14867	311246	40611
2003	220637	14259	224805	14660	250007	14670	317862	41448
2004	225243	13668	230735	14168	254494	14154	322738	42046
2005	220518	12998	227236	13583	249004	13463	325660	44101
2006	195253	11805	202715	12429	221276	12185	305946	44000
2007	170820	11030	179213	11666	195008	11337	290363	44617
2008	147813	9919	156591	10480	169137	10190	266234	42150
2009	134535	9717	143324	10157	154803	9958	251065	40914
2010	133897	9867	140687	10072	152800	9995	233291	36588
2011	163132	10814	166168	10688	180806	10740	241448	32914
2012	190979	12184	188804	11555	207656	11818	242599	28306
2013	213967	13837	207036	12648	230154	13196	250251	26769
2014	216640	15099	204240	13326	230823	14144	244357	25236
2015	221443	16751	200719	14167	231548	15280	246305	25289
2016	253395	19936	217521	16075	254786	17544	277508	28639
2017	292477	23889	233992	18544	278192	20300	320184	35022
2018	318141	26780	236373	20393	285011	22244	353374	41788
2019	312750	27721	214846	21081	264360	22825	355783	45983
2020	272794	25887	169028	19870	217784	21241	321413	44663
2021	206964	16471	146840	11157	165623	9775	243557	26186

Table 2.1.7b. Area-specific female spawning biomass (t) time series.

	Model 20.1			Model 19.12c			Model 20.2			Model 20.3		
Year	EBS	NBS	Sum	EBS	NBS	Sum	EBS	NBS	Sum	EBS	NBS	Sum
1977	96638	75722	172360	75717	6494	82211	100681	5427	106108	69444	39063	108506
1978	100535	80179	180714	76375	6691	83065	104928	5750	110678	71511	40747	112257
1979	103417	81828	185245	74974	6810	81784	108241	5873	114114	72407	41141	113548
1980	127905	94551	222456	90547	8003	98550	133854	6793	140647	89157	47194	136351
1981	189870	127820	317690	131859	11747	143606	196691	9129	205819	128546	66109	194655
1982	295606	187277	482882	207553	18776	226329	303752	13298	317050	197238	101889	299127
1983	390466	242794	633260	288944	19248	308191	400576	17215	417791	270397	129067	399463
1984	390314	246890	637203	295456	22062	317517	401553	17531	419084	276096	131779	407875
1985	434654	298196	732850	333779	27937	361716	449529	21224	470753	311593	155186	466778
1986	423793	311519	735312	335766	23469	359234	440081	22206	462286	309932	156105	466037
1987	411964	312310	724274	328773	26306	355079	427997	22258	450255	305170	155160	460329
1988	436147	344558	780705	349121	31593	380714	452326	24520	476846	322342	172768	495110
1989	422530	354668	777198	338572	32902	371473	437837	25201	463037	309640	180577	490217
1990	376360	334873	711233	318829	16292	335120	391328	23806	415134	287652	161648	449299
1991	297445	293557	591002	259125	9543	268668	312144	20925	333069	235944	134145	370089
1992	214526	263586	478111	187504	5553	193057	229064	18851	247915	172720	111748	284468
1993	203842	276039	479881	173371	7330	180701	218925	19756	238681	165148	109698	274846
1994	208771	259733	468504	176590	8267	184857	220403	18522	238924	169835	98823	268657
1995	224187	272228	496415	188958	8361	197319	231307	19253	250560	178856	100388	279244
1996	225518	273691	499209	184814	10643	195457	225045	19070	244115	169176	104500	273676
1997	222017	279282	501299	175226	16996	192222	215534	19243	234777	158122	111958	270080
1998	198635	280646	479281	150013	21238	171251	189287	19195	208482	131354	118444	249797
1999	192361	288902	481263	139214	28965	168179	182778	19724	202502	123477	128858	252335
2000	201971	299353	501324	147763	33012	180775	193755	20476	214231	130775	144382	275157
2001	210852	287781	498632	156272	36764	193036	205563	19768	225330	140356	150919	291274
2002	225432	290314	515745	167624	41758	209382	222603	20046	242649	153850	157397	311246
2003	231208	293093	524300	177527	37803	215330	229699	20308	250007	161706	156156	317862
2004	235535	291559	527093	172010	47565	219575	234366	20129	254494	164559	158180	322738
2005	229025	297583	526607	163986	52892	216878	228428	20576	249004	156930	168730	325660
2006	200970	283743	484713	137769	57403	195171	201614	19662	221276	133232	172714	305946
2007	173944	274400	448344	124496	50417	174913	175921	19086	195007	114461	175903	290364
2008	148544	249161	397704	110910	42970	153880	151735	17402	169137	99848	166387	266234
2009	133108	241159	374267	100658	38776	139434	137883	16920	154803	90328	160737	251065
2010	130246	228289	358535	122961	9193	132153	136698	16102	152800	106572	126719	233291
2011	156706	232035	388741	142196	7893	150089	164383	16422	180805	139782	101667	241448
2012	183698	243863	427561	165015	4470	169485	190431	17225	207656	164454	78144	242598
2013	205621	277106	482726	183567	4351	187918	210650	19504	230154	179421	70830	250251
2014	206487	295278	501765	183772	6161	189933	210145	20679	230823	173172	71185	244357
2015	208458	308181	516639	184727	11616	196343	210084	21463	231547	165120	81185	246305
2016	232820	335057	567877	182732	47677	230409	231582	23204	254785	170376	107132	277508
2017	258289	361775	620064	190981	84194	275175	253754	24438	278192	172895	147290	320185
2018	266598	370790	637388	156526	155254	311780	260403	24608	285010	166739	186635	353374
2019	255012	354153	609165	146026	172763	318789	249058	15303	264360	162243	193540	355783
2020	216417	319562	535979	134119	156569	290688	210848	6936	217783	144463	176950	321413
2021	34979	286899	321877	124781	141538	266319	158671	6952	165622	83987	159570	243557

Table 2.1.8. Relative spawning biomass time series.

	M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	0.14	0.04	0.15	0.04	0.19	0.05	0.12	0.03	0.14	0.04	0.14	0.04	0.17	0.05	0.15	0.04
1978	0.15	0.04	0.16	0.04	0.19	0.05	0.12	0.03	0.14	0.04	0.14	0.04	0.17	0.05	0.15	0.04
1979	0.15	0.04	0.16	0.04	0.20	0.05	0.12	0.03	0.14	0.04	0.15	0.04	0.18	0.04	0.16	0.03
1980	0.19	0.04	0.20	0.04	0.24	0.05	0.14	0.03	0.17	0.04	0.18	0.04	0.22	0.05	0.19	0.04
1981	0.28	0.04	0.29	0.05	0.34	0.05	0.21	0.03	0.25	0.04	0.27	0.05	0.32	0.05	0.27	0.04
1982	0.43	0.06	0.46	0.06	0.52	0.06	0.33	0.04	0.39	0.06	0.42	0.06	0.50	0.07	0.41	0.05
1983	0.57	0.06	0.61	0.07	0.68	0.07	0.45	0.05	0.53	0.07	0.57	0.07	0.65	0.08	0.55	0.06
1984	0.58	0.06	0.62	0.06	0.69	0.06	0.46	0.05	0.54	0.06	0.58	0.07	0.65	0.07	0.56	0.06
1985	0.65	0.06	0.69	0.06	0.79	0.07	0.52	0.05	0.61	0.07	0.66	0.07	0.74	0.07	0.64	0.07
1986	0.64	0.06	0.68	0.06	0.79	0.08	0.52	0.05	0.60	0.06	0.65	0.07	0.72	0.07	0.64	0.06
1987	0.62	0.05	0.66	0.05	0.78	0.08	0.51	0.04	0.59	0.06	0.63	0.06	0.70	0.06	0.64	0.06
1988	0.66	0.05	0.70	0.05	0.84	0.08	0.55	0.04	0.63	0.06	0.68	0.06	0.75	0.06	0.68	0.06
1989	0.64	0.05	0.68	0.05	0.84	0.09	0.54	0.04	0.61	0.05	0.66	0.06	0.72	0.06	0.68	0.06
1990	0.57	0.04	0.61	0.04	0.76	0.09	0.49	0.04	0.56	0.05	0.59	0.05	0.65	0.05	0.62	0.06
1991	0.46	0.03	0.48	0.03	0.64	0.08	0.39	0.03	0.45	0.04	0.48	0.04	0.52	0.04	0.51	0.05
1992	0.33	0.02	0.35	0.03	0.51	0.09	0.28	0.02	0.33	0.03	0.35	0.03	0.39	0.03	0.39	0.04
1993	0.31	0.03	0.33	0.03	0.52	0.10	0.26	0.02	0.31	0.03	0.33	0.03	0.37	0.03	0.38	0.04
1994	0.32	0.02	0.34	0.03	0.50	0.09	0.27	0.02	0.32	0.03	0.34	0.03	0.37	0.03	0.37	0.03
1995	0.34	0.03	0.37	0.03	0.53	0.09	0.29	0.02	0.33	0.03	0.35	0.03	0.39	0.03	0.39	0.03
1996	0.34	0.03	0.37	0.03	0.54	0.09	0.28	0.02	0.32	0.03	0.34	0.03	0.38	0.03	0.38	0.03
1997	0.34	0.03	0.36	0.03	0.54	0.09	0.28	0.02	0.31	0.03	0.33	0.03	0.37	0.03	0.37	0.03
1998	0.30	0.03	0.33	0.03	0.52	0.10	0.25	0.02	0.27	0.03	0.29	0.03	0.33	0.03	0.34	0.03
1999	0.30	0.03	0.32	0.03	0.52	0.11	0.24	0.02	0.26	0.03	0.28	0.03	0.32	0.03	0.35	0.04
2000	0.31	0.03	0.34	0.03	0.54	0.11	0.26	0.02	0.28	0.03	0.30	0.03	0.33	0.03	0.38	0.04
2001	0.32	0.03	0.35	0.03	0.54	0.10	0.28	0.03	0.30	0.03	0.32	0.03	0.35	0.03	0.40	0.04
2002	0.35	0.03	0.37	0.03	0.55	0.10	0.30	0.03	0.32	0.03	0.35	0.03	0.38	0.03	0.43	0.05
2003	0.35	0.03	0.38	0.03	0.56	0.10	0.31	0.03	0.33	0.03	0.36	0.03	0.39	0.03	0.44	0.05
2004	0.36	0.03	0.39	0.03	0.57	0.10	0.32	0.03	0.34	0.03	0.37	0.03	0.40	0.03	0.45	0.05
2005	0.35	0.03	0.38	0.03	0.57	0.10	0.31	0.03	0.33	0.03	0.36	0.03	0.39	0.03	0.45	0.05
2006	0.31	0.02	0.34	0.03	0.52	0.10	0.28	0.02	0.29	0.02	0.32	0.03	0.35	0.03	0.42	0.05
2007	0.27	0.02	0.30	0.02	0.48	0.10	0.25	0.02	0.26	0.02	0.29	0.02	0.30	0.02	0.40	0.05
2008	0.23	0.02	0.25	0.02	0.43	0.10	0.22	0.02	0.22	0.02	0.25	0.02	0.26	0.02	0.37	0.05
2009	0.21	0.02	0.23	0.02	0.40	0.10	0.20	0.02	0.20	0.02	0.23	0.02	0.24	0.02	0.35	0.05
2010	0.20	0.02	0.22	0.02	0.39	0.09	0.19	0.02	0.20	0.02	0.22	0.02	0.24	0.02	0.32	0.04
2011	0.24	0.02	0.26	0.02	0.42	0.08	0.22	0.02	0.25	0.02	0.26	0.02	0.28	0.02	0.33	0.04
2012	0.29	0.02	0.30	0.02	0.46	0.08	0.25	0.02	0.29	0.02	0.30	0.02	0.32	0.02	0.33	0.03
2013	0.33	0.03	0.34	0.03	0.52	0.10	0.27	0.02	0.32	0.03	0.33	0.03	0.36	0.03	0.35	0.03
2014	0.33	0.03	0.34	0.03	0.54	0.11	0.27	0.02	0.33	0.03	0.33	0.03	0.36	0.03	0.34	0.03
2015	0.35	0.03	0.35	0.03	0.56	0.11	0.28	0.03	0.33	0.03	0.32	0.03	0.36	0.03	0.34	0.03
2016	0.40	0.03	0.39	0.03	0.61	0.12	0.33	0.03	0.38	0.04	0.35	0.03	0.40	0.03	0.38	0.03
2017	0.47	0.04	0.43	0.04	0.67	0.13	0.40	0.04	0.44	0.04	0.37	0.04	0.43	0.04	0.44	0.04
2018	0.51	0.04	0.44	0.04	0.69	0.13	0.45	0.04	0.48	0.05	0.38	0.04	0.45	0.04	0.49	0.05
2019	0.50	0.04	0.41	0.04	0.66	0.13	0.46	0.04	0.47	0.05	0.34	0.04	0.41	0.04	0.49	0.05
2020	0.44	0.04	0.34	0.03	0.58	0.13	0.42	0.04	0.41	0.04	0.27	0.03	0.34	0.04	0.44	0.05
2021	0.32	0.02	0.27	0.02	0.35	0.16	0.39	0.03	0.31	0.03	0.23	0.02	0.26	0.02	0.34	0.03

Table 2.1.9a (page 1 of 2). Combined-area age 0 recuitment (1000s of fish) time series.

	Model 19.12a		Model 19.12b		Model 20.1		Model 19.12c	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	1171540	301539	1275640	328011	2007950	722214	825921	205286
1978	771777	209276	859653	229236	1284300	482769	574372	149297
1979	798850	134127	881015	148098	1336060	404698	599817	97729
1980	192765	48845	205698	52867	301136	109628	155945	37737
1981	217606	43571	241939	48410	359166	116080	168644	33044
1982	1031930	119767	1139800	135029	1735270	482197	800109	87663
1983	279869	52426	311233	58458	460543	145724	214032	38974
1984	930307	106622	1025050	120310	1551380	431017	725260	78376
1985	421194	56221	462971	62762	693345	198749	333349	42743
1986	232290	34034	257001	38112	382303	112123	186257	26132
1987	71396	17850	78790	19600	114543	41038	57495	13904
1988	333710	42570	361405	46873	548662	155570	269549	32214
1989	664484	74421	715204	81999	1086470	300947	524898	54269
1990	650495	74385	715005	83436	1078500	299928	515790	54449
1991	383116	51375	410407	56167	608998	175047	298967	38526
1992	1032920	106293	1126720	119500	1691010	461785	828624	76444
1993	384916	46870	429623	52631	642081	179905	321075	35854
1994	324551	39215	356994	43533	529838	148194	267625	30013
1995	278619	35141	301812	38342	449395	126811	255304	30056
1996	900055	95381	984338	107811	1487840	408678	745454	74258
1997	393715	46777	433331	52535	648809	181751	313472	35723
1998	300298	37921	328531	41841	490274	138805	233283	28104
1999	735255	73494	813543	83563	1222220	333073	594047	57057
2000	524544	53752	570706	60321	839804	229917	448076	44514
2001	216525	28191	248851	32028	369092	104796	193360	23932
2002	349751	37785	385068	42591	562216	155004	318373	33128
2003	332865	35379	372477	40355	547002	150482	287278	29336
2004	240025	29334	273286	33625	398671	112267	200622	23536
2005	294908	34108	322454	37746	478169	133231	225336	24901
2006	870408	81673	911184	87496	1382260	373382	674794	59647
2007	343974	43755	361074	45430	550623	155269	275709	32514
2008	1274290	122854	1315890	128183	1983320	537113	996204	89445
2009	174317	33011	233420	37246	330542	99576	148880	24874
2010	797284	84805	806159	86179	1204150	330048	671114	65100
2011	1026450	109494	1020920	109181	1528220	418625	827330	83561
2012	487197	64431	472440	61296	704234	199579	379778	47813
2013	1309710	142785	1158510	127242	1727170	474522	1148440	119784
2014	227792	34106	208313	30172	307108	89537	216841	30615
2015	303316	35725	287764	33955	424429	118284	265230	29558
2016	175850	26841	167819	24583	249885	72835	158939	22614
2017	120326	33959	153116	39006	228381	82322	129827	31160
2018	755194	83211	831852	99152	1233090	343785	624088	67349

Table 2.1.9a (page 2 of 2). Combined-area age 0 recuitment (1000s of fish) time series.

	Model 19.12		Model 19.12d		Model 20.2		Model 20.3	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	1010390	270800	1097010	291879	1387920	368726	1083210	299314
1978	704913	187756	772350	205170	931863	254053	755881	209711
1979	720034	128941	780313	138383	952343	164775	779849	150871
1980	171641	47076	175025	49213	214766	58981	196421	52789
1981	201953	41920	214326	44457	259261	53213	223142	48553
1982	963079	124882	1032120	132516	1253530	151258	1032200	154258
1983	241238	47828	257597	51009	301117	59347	251676	51749
1984	861012	107262	917546	113503	1094990	128030	955206	144294
1985	400514	56118	428066	59400	501540	67938	448942	72594
1986	227327	34702	239576	36492	283433	41982	236472	38198
1987	76962	19177	80013	20056	93266	23274	78088	19175
1988	314109	42935	328370	44709	391977	51249	326923	45607
1989	618896	73572	649591	76757	770432	86939	634424	76662
1990	595065	70896	633428	74876	739119	83948	618107	75906
1991	328394	46824	338021	48935	395985	54898	363125	55652
1992	883265	93650	933354	98248	1088070	107941	999720	126839
1993	357532	44519	387625	47397	448724	52887	407313	57656
1994	294794	36769	314232	38520	363880	42680	314217	45023
1995	263437	34614	278176	36153	324286	40325	378670	65791
1996	837501	95180	894125	101522	1048940	111876	984248	141207
1997	373702	46856	396092	49403	461161	55287	392616	56254
1998	291211	38176	310084	40231	358509	44871	289358	42978
1999	661484	70614	716089	76401	830057	82382	708825	94232
2000	489803	53604	522868	57288	590979	61548	647059	99876
2001	203959	27358	230553	30310	260467	32566	246280	38922
2002	333755	38078	359744	41235	404247	43846	471560	74971
2003	313826	35486	343996	38562	385420	41253	392274	57874
2004	232928	30139	254781	32843	287726	35572	270852	39221
2005	287267	35008	302766	35619	346961	40039	261024	34292
2006	855756	87534	864124	86496	1004910	93672	769540	82383
2007	333216	43895	338470	42820	394680	48115	295345	36832
2008	1147680	119702	1146620	114878	1354690	130473	1031640	98723
2009	161462	30011	203171	32335	226506	36072	190554	32650
2010	743872	84584	706714	76817	839597	87403	857957	104575
2011	956412	111402	877189	94124	1057560	111464	849672	94950
2012	423840	59225	384390	50771	459923	58990	393499	60619
2013	1186520	143369	939778	108842	1174060	130053	1318470	202370
2014	212677	33131	179325	26805	215069	31531	248745	45170
2015	285657	36801	249342	31804	304177	36868	293038	43448
2016	150501	24687	117529	15869	163353	25511	172748	28993
2017	104641	30414	115607	29380	140203	34400	136658	35448
2018	668202	86356	630652	87428	739984	98406	609473	81087

Table 2.1.9b. Area-specific age 0 recruitment (1000s of fish) time series.

	Model 20.1			Model 19.12c			Model 20.2			Model 20.3		
Year	EBS	NBS	Sum	EBS	NBS	Sum	EBS	NBS	Sum	EBS	NBS	Sum
1977	1330950	676935	2007885	788078	37808	825886	1340600	47264	1387864	914447	168717	1083164
1978	851290	432975	1284265	548054	26293	574347	900089	31733	931822	638118	117734	755852
1979	885596	450423	1336019	572334	27457	599791	919871	32431	952302	658352	121467	779819
1980	199606	101522	301128	148800	7139	155939	207443	7314	214757	165820	30594	196414
1981	238070	121085	359155	160917	7720	168637	250421	8829	259250	188378	34756	223134
1982	1150210	585007	1735217	760908	39166	800074	1210790	42687	1253477	870860	161305	1032165
1983	305267	155262	460529	205600	8423	214023	290849	10254	301103	212756	38910	251666
1984	1028320	523013	1551333	702964	22264	725228	1057650	37288	1094938	809268	145901	955169
1985	459578	233746	693324	317353	15982	333335	484439	17079	501518	378839	70085	448924
1986	253407	128885	382292	176558	9691	186249	273769	9652	283421	199398	37066	236464
1987	75924	38616	114540	54876	2617	57493	90086	3176	93262	65925	12159	78085
1988	363676	184970	548646	258404	11133	269537	378612	13348	391960	276246	50664	326910
1989	720157	366279	1086436	492825	32051	524876	744162	26236	770398	534164	100236	634400
1990	714876	363593	1078469	497614	18154	515768	713917	25170	739087	523041	95043	618084
1991	403669	205310	608979	289630	9324	298954	382483	13485	395968	307603	55508	363111
1992	1120870	570088	1690958	800956	27631	828587	1050970	37053	1088023	846365	153317	999682
1993	425598	216464	642062	307644	13418	321062	433424	15281	448705	344139	63158	407297
1994	351199	178623	529822	258404	9210	267614	351472	12391	363863	265943	48262	314205
1995	297878	151504	449382	249430	5863	255293	313229	11043	324272	321624	57031	378655
1996	986200	501591	1487791	681722	63701	745423	1013170	35720	1048890	826046	158165	984211
1997	430058	218732	648790	296066	17393	313459	445437	15704	461141	330865	61737	392602
1998	324974	165285	490259	225967	7306	233273	346285	12209	358494	245107	44241	289348
1999	810141	412046	1222187	579232	14789	594021	801754	28266	830020	601625	107173	708798
2000	556657	283122	839779	437540	10516	448056	570828	20125	590953	549478	97556	647034
2001	244649	124431	369080	178721	14631	193352	251586	8870	260456	206938	39333	246271
2002	372660	189539	562199	306045	12313	318358	390463	13766	404229	398698	72844	471542
2003	362576	184410	546986	261342	25924	287266	372278	13125	385403	329046	63213	392259
2004	264256	134403	398659	185607	15006	200613	277916	9798	287714	227610	43232	270842
2005	316950	161204	478154	210327	15000	225327	335130	11815	346945	219595	41419	261014
2006	916222	466000	1382222	654859	19905	674764	970644	34221	1004865	652196	117314	769510
2007	364976	185630	550606	261582	14115	275697	381223	13440	394663	249077	46257	295334
2008	1314630	668633	1983263	965761	30399	996160	1308500	46132	1354632	874072	157531	1031603
2009	219097	111435	330532	145212	3661	148873	218782	7713	226495	161753	28795	190548
2010	798159	405952	1204111	654747	16337	671084	810969	28591	839560	728343	129581	857924
2011	1012970	515206	1528176	774029	53266	827295	1021500	36014	1057514	715039	134600	849639
2012	466796	237417	704213	375105	4656	379761	444241	15662	459903	335986	57498	393484
2013	1144840	582279	1727119	1123230	25167	1148397	1134020	39981	1174001	1120300	198125	1318425
2014	203564	103535	307099	200636	16195	216831	207736	7324	215060	209036	39700	248736
2015	281329	143087	424416	237714	27506	265220	293805	10358	304163	245465	47562	293027
2016	165634	84243	249877	146451	12481	158932	157783	5563	163346	145101	27641	172742
2017	151381	76994	228375	114596	15225	129821	135423	4774	140197	114329	22324	136653
2018	817347	415711	1233058	472842	151225	624067	714752	25199	739951	505752	103698	609450

Table 2.1.10a. Objective function values by major component.

Component	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.1	20.2
Catch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Initial_eq_catch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Survey index	-4.39	164.73	145.19	-17.62	-87.66	-95.81	-95.70	-96.60
Size composition	843.93	971.67	974.94	883.72	817.05	941.12	940.86	856.31
Age composition	256.47	270.90	278.82	262.00	251.01	260.10	271.40	250.23
Recruitment	0.24	-1.57	-0.61	-2.00	-0.67	-1.42	-1.29	-3.10
Initial_eq_recr	4.42	4.12	3.76	6.85	5.16	4.75	3.61	5.70
Priors	n/a	0.23	0.21	0.09	n/a	1.64	0.46	1.52
"Softbounds"	0.02	0.03	0.02	0.02	0.02	0.03	0.02	0.02
Deviations	65.76	66.61	62.12	62.55	99.16	122.28	118.52	100.10
Total	1166.45	1476.71	1464.47	1195.61	1084.06	1232.70	1237.87	1114.18

Table 2.1.10b. Objective function values by subcomponent.

Component	Type	Area	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.1	20.2
Index	Survey	Main	-4.39	4.97	3.84	-18.33	-87.66	-88.66	-88.53	-89.56
		NBS		159.77	141.36	0.71		-7.15	-7.16	-7.04
		Total	-4.39	164.73	145.19	-17.62	-87.66	-95.81	-95.70	-96.60
Sizecomp	Fishery	Main	181.89	182.60	186.97	185.96	176.94	175.85	177.63	181.13
		NBS			0.00	0.00			0.00	0.00
	Survey	Main	662.04	664.39	663.65	650.64	640.10	641.90	645.53	623.25
		NBS		124.69	124.33	47.13		123.37	117.70	51.94
	All	Total	843.93	971.67	974.94	883.72	817.05	941.12	940.86	856.31
Agecomp	Survey	Main	256.47	238.80	238.42	234.85	251.01	229.31	233.70	223.48
		NBS		32.10	40.40	27.15		30.79	37.71	26.75
		Total	256.47	270.90	278.82	262.00	251.01	260.10	271.40	250.23

Table 2.1.11. Goodness of fit summary. Ideal value of each ratio is unity.

			Area		Ratio of output to input							
Component	Stat.	Type	Actual	Assumed	M19.12a	M19.12b	M20.1	M19.12c	M19.12	M19.12d	M20.2	M20.3
Abundance	RMSE	Survey	EBS	EBS			0.41	0.47			0.99	1.00
Abundance	RMSE	Survey	EBS	XBS		0.41				0.99		
Abundance	RMSE	Survey	NBS	NBS			0.15	0.45			0.78	0.70
Abundance	RMSE	Survey	NBS	XBS		0.14				0.75		
Abundance	RMSE	Survey	XBS	XBS	0.43				0.98			
Sizecomp	N	Fishery	EBS	EBS			1.00	1.00			1.00	1.00
Sizecomp	N	Fishery	EBS	XBS	1.00	1.00			1.00	1.00		
Sizecomp	N	Survey	EBS	EBS			1.00	1.00			1.00	1.00
Sizecomp	N	Survey	EBS	XBS		1.00				1.00		
Sizecomp	N	Survey	NBS	NBS			1.00	1.00			1.00	1.00
Sizecomp	N	Survey	NBS	XBS		1.00				1.00		
Sizecomp	N	Survey	XBS	XBS	1.00				1.00			
Agecomp	N	Survey	EBS	EBS			0.63	0.59			0.63	0.61
Agecomp	N	Survey	EBS	XBS		0.57				0.62		
Agecomp	N	Survey	NBS	NBS			0.18	0.47			0.20	0.34
Agecomp	N	Survey	NBS	XBS		0.56				0.60		
Agecomp	N	Survey	XBS	XBS	0.50				0.52			

Table 2.1.12a. Two measures of effective sample size for individual fishery size composition records.

		M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Year	N	DM	MI	DM	MI	DM	MI	DM	MI	DM	MI	DM	MI	DM	MI	DM	MI
1977	2	2	159	2	161	2	159	2	138	2	153	2	158	2	155	2	137
1978	9	9	110	9	110	9	109	9	100	9	108	9	109	9	109	9	98
1979	14	14	344	14	337	14	330	14	312	14	346	14	342	14	339	14	303
1980	12	12	392	12	389	12	389	12	396	12	383	12	385	12	382	12	361
1981	9	9	90	9	88	9	88	9	93	9	90	9	88	9	89	9	90
1982	11	11	337	11	344	11	348	11	349	11	337	11	334	11	346	11	400
1983	46	46	1017	46	1035	46	1130	46	1209	46	1016	46	1013	46	1181	46	1299
1984	113	113	1700	113	1795	113	1953	113	2057	113	1679	113	1740	113	2090	113	2438
1985	168	168	2205	168	2334	168	2292	168	2159	168	2092	168	2162	168	2121	168	2232
1986	148	148	1744	148	1712	148	1773	148	1597	148	1547	148	1587	148	1502	148	1490
1987	280	280	1601	280	1536	280	1653	280	1569	280	1435	280	1421	280	1519	280	1709
1988	86	86	426	86	409	86	422	86	464	86	441	86	425	86	459	86	490
1989	57	57	274	57	269	57	277	57	308	57	277	57	274	57	297	57	337
1990	214	214	1026	214	1034	214	994	214	1245	214	989	214	1017	214	1079	214	1112
1991	308	308	3528	308	3442	308	3778	308	4648	308	3540	308	3679	308	4273	308	3660
1992	316	316	2991	316	2855	316	2823	316	2415	316	3087	316	3095	316	2663	316	2767
1993	177	177	2155	177	2131	177	2141	177	2156	177	2284	177	2180	177	2302	177	2370
1994	278	278	1807	278	1812	278	1766	278	1824	278	1932	278	1919	278	1902	278	2050
1995	309	309	3123	309	3199	309	3077	309	3294	309	3927	309	3836	309	3962	309	3900
1996	392	392	1785	392	1805	392	1689	392	1748	392	2412	392	2340	392	2512	392	2260
1997	432	432	2330	432	2421	432	2247	432	2073	432	2436	432	2492	432	2374	432	2120
1998	405	405	5848	405	6145	405	5954	405	6359	405	5793	405	5915	405	6051	405	5818
1999	547	547	9952	547	8684	547	10265	547	12927	547	12262	547	12305	547	12951	547	14078
2000	577	577	5358	577	5321	577	5332	577	4104	577	4229	577	4173	577	4260	577	3320
2001	615	615	8353	615	8149	615	7387	615	7463	615	7981	615	8472	615	7222	615	6742
2002	680	680	4805	680	4072	680	4011	680	4743	680	5820	680	5380	680	5007	680	4685
2003	850	850	11109	850	10447	850	10275	850	8182	850	13760	850	12067	850	11996	850	8777
2004	726	726	8689	726	7838	726	8903	726	9552	726	8792	726	8389	726	9363	726	9445
2005	686	686	10700	686	10430	686	13550	686	16280	686	10302	686	11005	686	14706	686	17369
2006	525	525	2541	525	2552	525	2570	525	3241	525	2589	525	2658	525	2816	525	3178
2007	409	409	3554	409	3463	409	3700	409	4445	409	3660	409	3719	409	3891	409	4053
2008	493	493	5061	493	4711	493	4647	493	4469	493	5443	493	5500	493	4302	493	4719
2009	444	444	3075	444	2814	444	2718	444	2595	444	3036	444	2879	444	2519	444	2332
2010	386	386	2487	386	2776	386	2586	386	1691	386	2110	386	2493	386	2148	386	1627
2011	522	522	3547	522	4113	522	3431	522	3400	522	3705	522	4203	522	3417	522	3428
2012	551	551	2284	551	2674	551	2403	551	2297	551	3138	551	3362	551	3077	551	2976
2013	660	660	3574	660	4160	660	4661	660	3911	660	3198	660	3672	660	4231	660	3501
2014	721	721	5635	721	5447	721	4413	721	3782	721	5312	721	5492	721	4006	721	3950
2015	671	671	6997	671	7110	671	6360	671	5734	671	6910	671	7002	671	5819	671	6234
2016	579	579	4514	579	4964	579	4086	579	5049	579	5302	579	5363	579	4710	579	5665
2017	503	503	3059	503	3886	503	3348	503	3430	503	3434	503	3694	503	3855	503	4632
2018	383	383	10855	383	9258	383	12895	383	10444	383	12436	383	12213	383	17577	383	13061
2019	277	277	9342	277	11078	277	8963	277	10674	277	9273	277	16462	277	8895	277	13186

Table 2.1.12b. Two measures of effective sample size for individual survey size composition records.

		1-area models					2-area models													
			M19.12a		M19.12			M19.12b		M20.1		M19.12c		M19.12d		M20.2		M20.3	
Area	Year	N	DM	MI	DM	MI	N	DM	MI	DM	MI	DM	MI	DM	MI	DM	MI	DM	MI
Main	1982	313	313	543	313	523	313	313	522	313	536	313	531	313	510	313	517	313	523
Main	1983	255	255	892	255	990	255	255	902	255	944	255	907	255	1015	255	1054	255	1034
Main	1984	264	264	324	264	354	264	264	324	264	317	264	309	264	366	264	329	264	348
Main	1985	345	345	486	345	519	345	345	485	345	491	345	478	345	514	345	529	345	498
Main	1986	349	349	1485	349	1575	349	349	1579	349	1545	349	1411	349	1676	349	1618	349	1535
Main	1987	339	339	1495	339	1533	339	339	1545	339	1514	339	1449	339	1563	339	1546	339	1562
Main	1988	339	339	1454	339	1454	339	339	1463	339	1503	339	1432	339	1457	339	1512	339	1438
Main	1989	293	293	1092	293	1005	293	293	1040	293	1051	293	1091	293	995	293	961	293	1061
Main	1990	329	329	1825	329	1991	329	329	1779	329	1758	329	1834	329	1916	329	1894	329	2057
Main	1991	313	313	1007	313	899	313	313	1043	313	1054	313	935	313	940	313	956	313	952
Main	1992	332	332	936	332	919	332	332	991	332	958	332	882	332	962	332	928	332	936
Main	1993	363	363	535	363	515	363	363	541	363	535	363	541	363	511	363	517	363	531
Main	1994	364	364	549	364	675	364	364	548	364	556	364	613	364	678	364	696	364	733
Main	1995	347	347	953	347	903	347	347	970	347	950	347	966	347	899	347	909	347	895
Main	1996	359	359	1258	359	1299	359	359	1272	359	1304	359	1382	359	1299	359	1382	359	1458
Main	1997	369	369	892	369	888	369	369	933	369	928	369	944	369	908	369	918	369	967
Main	1998	362	362	655	362	707	362	362	702	362	710	362	684	362	736	362	781	362	815
Main	1999	336	336	599	336	625	336	336	589	336	586	336	613	336	617	336	618	336	625
Main	2000	355	355	983	355	1109	355	355	963	355	992	355	1038	355	1082	355	1113	355	1162
Main	2001	366	366	745	366	760	366	366	743	366	746	366	771	366	753	366	795	366	828
Main	2002	364	364	727	364	724	364	364	759	364	738	364	757	364	757	364	757	364	828
Main	2003	363	363	496	363	508	363	363	490	363	489	363	501	363	498	363	507	363	502
Main	2004	361	361	1915	361	1972	361	361	2140	361	2088	361	2024	361	2190	361	2286	361	2210
Main	2005	360	360	430	360	429	360	360	418	360	420	360	432	360	418	360	419	360	435
Main	2006	354	354	687	354	693	354	354	674	354	668	354	657	354	688	354	661	354	584
Main	2007	368	368	271	368	269	368	368	248	368	272	368	306	368	245	368	275	368	348
Main	2008	338	338	773	338	819	338	338	788	338	770	338	787	338	829	338	800	338	782
Main	2009	360	360	435	360	475	360	360	427	360	429	360	444	360	461	360	448	360	426
Main	2010	405	405	292	405	337	342	342	304	342	293	342	303	342	344	342	315	342	346
Main	2011	368	368	416	368	426	368	368	370	368	372	368	409	368	382	368	391	368	415
Main	2012	356	356	289	356	301	356	356	290	356	286	356	314	356	327	356	294	356	332
Main	2013	354	354	177	354	186	354	354	172	354	168	354	176	354	180	354	172	354	189
Main	2014	373	373	417	373	427	373	373	407	373	403	373	424	373	421	373	421	373	433
Main	2015	354	354	680	354	723	354	354	707	354	694	354	710	354	747	354	736	354	762
Main	2016	376	376	831	376	854	376	376	762	376	741	376	767	376	760	376	766	376	802
Main	2017	481	481	1755	481	1675	369	369	1055	369	1077	369	871	369	1000	369	999	369	950
Main	2018	413	413	1761	413	1979	364	364	1831	364	1837	364	1985	364	1573	364	1778	364	1275
Main	2019	479	479	665	479	728	365	365	491	365	490	365	407	365	489	365	519	365	489
NBS	2010						63	63	30	63	37	63	99	63	30	63	36	63	94
NBS	2017						112	112	595	112	369	112	313	112	605	112	389	112	294
NBS	2018						49	49	545	49	219	49	610	49	569	49	284	49	466
NBS	2019						114	114	1161	114	525	114	865	114	1103	114	878	114	809

Table 2.1.13. Two measures of effective sample size for individual survey age composition records.

		Combined-survey models					Separate survey models														
			M19.12a		M19.12			M19.12b		M20.1		M19.12c		M19.12d		M20.2		M20.3	
Area	Year	N	DM	MI	DM	MI	N	DM	MI	DM	MI	DM	MI	DM	MI	DM	MI	DM	MI
Main	1994	364	182	448	189	414	364	208	474	222	505	225	480	221	521	229	527	230	377
Main	1995	347	173	33	181	34	347	198	33	212	33	215	31	211	34	218	33	220	30
Main	1996	359	179	511	187	465	359	205	403	219	405	222	363	218	400	226	372	227	327
Main	1997	369	184	337	192	442	369	211	410	225	415	228	398	224	603	232	612	234	694
Main	1998	362	181	575	188	690	362	207	530	221	561	224	530	220	678	228	700	229	615
Main	1999	336	168	348	175	385	336	192	349	205	335	208	403	204	374	211	377	213	390
Main	2000	355	177	187	185	194	355	203	187	217	193	219	197	216	191	223	186	225	181
Main	2001	366	183	177	190	180	366	209	165	223	160	226	165	222	173	230	171	232	172
Main	2002	364	182	71	189	69	364	208	74	222	78	225	87	221	72	229	76	230	89
Main	2003	363	181	384	189	408	363	207	366	222	340	224	353	220	392	228	363	230	425
Main	2004	361	180	37	188	37	361	206	36	220	37	223	37	219	37	227	37	229	39
Main	2005	360	180	277	187	287	360	206	374	220	364	223	250	219	367	226	371	228	285
Main	2006	354	177	68	184	72	354	202	88	216	94	219	109	215	97	223	99	224	116
Main	2007	368	184	33	191	35	368	210	34	225	38	228	47	224	35	231	40	233	61
Main	2008	338	169	95	176	117	338	193	123	206	113	209	107	205	149	213	132	214	179
Main	2009	360	180	92	187	170	360	206	225	220	222	223	204	219	348	226	333	228	523
Main	2010	405	202	166	211	360	342	195	123	209	135	211	195	208	224	215	200	217	250
Main	2011	368	184	105	191	88	368	210	151	225	166	228	133	224	124	231	135	233	133
Main	2012	356	178	164	185	158	356	203	167	217	172	220	219	216	181	224	167	225	262
Main	2013	354	177	111	184	114	354	202	149	216	143	219	124	215	152	223	144	224	137
Main	2014	373	186	172	194	164	373	213	211	228	218	231	214	227	183	234	192	236	190
Main	2015	354	177	280	184	280	354	202	410	216	446	219	304	215	408	223	359	224	357
Main	2016	376	188	75	196	69	376	215	120	229	128	232	127	228	110	236	112	238	138
Main	2017	481	240	276	250	295	369	211	173	225	178	228	160	224	207	232	191	234	174
Main	2018	413	206	72	215	90	364	208	82	222	79	225	68	221	146	229	101	230	83
NBS	2010						63	35	19	12	29	38	20	38	16	14	23	29	22
NBS	2017						49	28	87	10	37	30	55	30	102	11	39	23	50
NBS	2018						114	63	40	21	14	68	74	68	51	24	19	52	58

Table 2.1.14a. Comparison of primary and alternative ensembles: point estimates of main parameters.

Time-varying *Q*?	No									Yes								
Separate areas?	No			Yes						No			Yes					
Separate surveys?	Yes			Yes						Yes			Yes					
Movement?	No			No			Yes			No			No			Yes		
Parameter	19.12b	20.4	Δ	20.1	20.5	Δ	19.12c	19.12e	Δ	19.12d	19.15	Δ	20.2	20.6	Δ	20.3	20.7	Δ
Natural_mortality	0.372	0.373	0.004	0.372	0.369	-0.006	0.332	0.332	0.001	0.358	0.359	0.004	0.374	0.373	-0.001	0.344	0.346	0.006
L_at_1.5_base	14.799	14.798	0.000	14.794	14.796	0.000	14.805	14.804	0.000	14.903	14.900	0.000	14.807	14.808	0.000	14.594	14.577	-0.001
L_infinity	114.2	113.5	-0.006	112.9	115.9	0.027	118.2	118.1	0.000	114.6	114.5	-0.001	116.5	116.5	0.000	111.2	111.1	-0.001
VonBert_K	0.117	0.119	0.019	0.118	0.109	-0.074	0.106	0.106	0.000	0.117	0.117	0.000	0.108	0.108	0.000	0.123	0.123	0.002
Richards_coef	1.435	1.427	-0.006	1.444	1.477	0.023	1.480	1.480	0.000	1.419	1.420	0.001	1.479	1.478	0.000	1.438	1.439	0.001
SD_len_at_1	3.483	3.484	0.000	3.466	3.465	0.000	3.481	3.481	0.000	3.473	3.474	0.000	3.485	3.485	0.000	3.490	3.490	0.000
SD_len_at_20	9.945	9.892	-0.005	10.136	10.393	0.025	10.153	10.150	0.000	9.882	9.869	-0.001	10.014	10.017	0.000	9.397	9.384	-0.001
InitF_main_fsh	0.127	0.124	-0.018	0.119	0.119	0.003	0.147	0.147	-0.001	0.134	0.132	-0.011	0.114	0.115	0.004	0.173	0.172	-0.002
InitF_NBS_fsh				0.000	0.000	-0.965	0.000	0.000	-0.005				0.000	0.000	0.040	0.000		
Main_fsh_sel_PeakStart	75.220	75.012	-0.003	74.971	74.889	-0.001	74.982	74.980	0.000	74.986	74.986	0.000	74.931	74.937	0.000	75.968	75.976	0.000
Main_srv_sel_PeakStart_base	21.036	21.054	0.001	20.986	20.932	-0.003	21.110	21.112	0.000	20.699	20.704	0.000	20.970	20.968	0.000	21.827	21.893	0.003
NBS_srv_sel_PeakStart	79.998	79.998	0.000	74.051	73.453	-0.008	15.530	15.528	0.000	79.997	79.996	0.000	68.696	69.355	0.010	14.453	14.418	-0.002
RecrDist_NBS_base				-0.676	2.691	3.367	-3.037	-3.033	0.004				-3.345	-3.382	-0.037	-1.690	-1.640	0.050
AgeBias_at_1_1977_2007	0.349	0.349	0.000	0.349	0.348	-0.001	0.347	0.347	0.000	0.347	0.347	0.000	0.348	0.348	0.000	0.346	0.347	0.001
AgeBias_at_1_2008_2019	-0.002	-0.002	0.000	0.001	0.001	0.000	0.009	0.009	0.000	0.002	0.002	0.000	0.004	0.004	0.000	0.008	0.007	-0.001
AgeBias_at_20_1977_2007	0.776	0.771	-0.005	0.772	0.782	0.010	0.843	0.842	0.000	0.804	0.802	-0.002	0.825	0.825	0.000	0.954	0.954	0.000
AgeBias_at_20_2008_2019	-1.697	-1.700	-0.003	-1.646	-1.648	-0.002	-1.698	-1.698	0.000	-1.930	-1.932	-0.003	-1.790	-1.790	0.000	-2.179	-2.201	-0.022
ln(Recr_ave_1977_2018)	13.271	13.285	0.014	13.678	16.000	2.321	12.991	12.993	0.002	13.144	13.157	0.013	13.313	13.308	-0.005	13.185	13.220	0.034
ln(Recr_ave_pre1977_offset)	-0.885	-0.877	0.008	-0.862	-0.866	-0.004	-0.986	-0.986	0.001	-0.909	-0.903	0.006	-0.839	-0.841	-0.002	-0.919	-0.912	0.007
lnQ_main_srv_base	-0.111	-0.121	-0.010	-0.102	-0.085	0.017	0.172	0.171	-0.001	-0.037	-0.046	-0.009	-0.116	-0.114	0.002	0.261	0.254	-0.007
lnQ_NBS_srv_base	-0.788	-0.804	-0.016	-0.747	-4.122	-3.375	-0.260	-0.265	-0.005	-1.842	-1.967	-0.125	0.827	0.933	0.106	-1.466	-1.618	-0.151
Main_fsh_sel_logitPeakWidth	-5.712	-9.672	-3.960	-9.439	0.434	9.873	0.208	0.208	0.001	-9.761	-9.772	-0.011	0.469	0.470	0.001	0.097	0.093	-0.004
Main_fsh_sel_lnSD1_base	5.913	5.903	-0.010	5.898	5.892	-0.006	5.907	5.907	0.000	5.905	5.905	0.000	5.896	5.896	0.000	5.950	5.951	0.000
Main_fsh_sel_lnSD2	-1.410	-9.947	-8.537	-9.091	4.406	13.497	4.707	4.707	0.000	-9.886	-9.880	0.006	4.345	4.342	0.00	4.827	4.829	0.00
Main_fsh_sel_logitEnd_base	1.987	2.000	0.013	3.114	-2.759	-5.873	-3.140	-3.137	0.003	2.084	2.079	-0.006	-2.647	-2.643	0.005	-2.855	-2.860	-0.005
Main_srv_sel_lnSD1_base	3.532	3.535	0.003	3.522	3.512	-0.010	3.535	3.535	0.000	3.460	3.460	0.000	3.513	3.513	0.000	3.613	3.620	0.006
NBS_srv_sel_lnSD1	7.784	7.790	0.006	8.881	8.930	0.049	2.067	2.066	-0.001	7.821	7.834	0.014	7.925	7.922	-0.003	1.750	1.738	-0.012
lnDM_size_main_fish	9.989	9.989	0.000	9.989	9.990	0.001	9.990	9.990	0.000	9.989	9.989	0.000	9.990	9.990	0.000	9.989	9.989	0.000
lnDM_size_main_sur	9.984	9.984	0.000	9.985	9.984	-0.001	9.984	9.984	0.000	9.984	9.984	0.000	9.985	9.985	0.000	9.984	9.984	0.000
lnDM_size_NBS_sur	9.656	9.655	0.000	9.717	9.714	-0.003	9.923	9.924	0.002	9.756	9.687	-0.069	9.712	9.712	0.000	9.935	9.936	0.001
lnDM_age_main_srv	0.281	0.252	-0.029	0.444	0.520	0.076	0.478	0.475	-0.002	0.432	0.419	-0.013	0.522	0.527	0.005	0.541	0.540	0.000
lnDM_age_NBS_srv	0.213	0.196	-0.017	-1.511	-1.528	-0.016	0.381	0.377	-0.005	0.383	0.380	-0.003	-1.342	-1.346	-0.004	-0.201	-0.192	0.009

Table 2.1.14b. Comparison of primary and alternative ensembles: standard deviations of main parameters.

Time-varying *Q*?	No									Yes								
Separate areas?	No			Yes						No			Yes					
Separate surveys?	Yes			Yes						Yes			Yes					
Movement?	No			No			Yes			No			No			Yes		
Parameter	19.12b	20.4	Δ	20.1	20.5	Δ	19.12c	19.12e	Δ	19.12d	19.15	Δ	20.2	20.6	Δ	20.3	20.7	Δ
Natural_mortality	0.012	0.012	0.004	0.011	0.011	-0.001	0.011	0.011	0.001	0.012	0.012	0.005	0.011	0.011	0.002	0.013	0.012	-0.066
L_at_1.5_base	0.400	0.400	-0.001	0.404	0.404	-0.001	0.400	0.400	0.000	0.418	0.418	0.000	0.416	0.416	0.000	0.400	0.399	-0.003
L_infinity	3.340	3.088	-0.075	3.189	4.178	0.310	4.594	4.588	-0.001	3.265	3.251	-0.004	4.188	4.193	0.001	3.467	3.440	-0.008
VonBert_K	0.010	0.009	-0.058	0.010	0.011	0.148	0.011	0.011	0.000	0.009	0.009	-0.003	0.011	0.011	0.000	0.011	0.011	0.000
Richards_coef	0.045	0.042	-0.051	0.043	0.047	0.090	0.047	0.047	0.000	0.043	0.043	-0.001	0.047	0.047	0.000	0.046	0.046	0.004
SD_len_at_1	0.066	0.066	0.000	0.066	0.066	-0.004	0.066	0.066	0.000	0.065	0.065	0.001	0.067	0.067	0.000	0.065	0.065	-0.003
SD_len_at_20	0.397	0.382	-0.038	0.387	0.439	0.137	0.446	0.445	-0.001	0.391	0.390	-0.001	0.430	0.430	0.001	0.392	0.391	-0.003
InitF_main_fsh	0.040	0.039	-0.025	0.037	0.037	0.003	0.046	0.046	-0.001	0.043	0.042	-0.013	0.035	0.036	0.004	0.056	0.045	-0.197
InitF_NBS_fsh				0.000	0.000	-0.989	0.000	0.000	-0.003				0.000	0.000	-0.008	0.000		-1.000
Main_fsh_sel_PeakStart	0.598	0.037	-0.938	0.196	0.514	1.619	0.528	0.529	0.000	0.030	0.031	0.013	0.520	0.520	0.000	0.590	0.592	0.002
Main_srv_sel_PeakStart_base	0.801	0.800	-0.001	0.794	0.789	-0.006	0.811	0.811	0.000	0.831	0.831	0.000	0.819	0.819	0.000	0.905	0.903	-0.003
NBS_srv_sel_PeakStart	0.072	0.074	0.031	8.817	8.871	0.006	1.383	1.382	-0.001	0.113	0.124	0.097	7.855	7.947	0.012	1.161	1.144	-0.014
RecrDist_NBS_base				0.759	0.146	-0.807	0.245	0.245	0.001				0.177	0.158	-0.109	0.213	0.179	-0.159
AgeBias_at_1_1977_2007	0.015	0.015	0.002	0.015	0.014	-0.008	0.015	0.015	0.000	0.015	0.015	0.000	0.014	0.014	0.000	0.015	0.015	-0.007
AgeBias_at_1_2008_2019	0.025	0.025	0.001	0.024	0.024	-0.005	0.023	0.023	0.000	0.026	0.026	-0.001	0.023	0.023	0.000	0.024	0.024	0.000
AgeBias_at_20_1977_2007	0.205	0.206	0.005	0.198	0.196	-0.012	0.200	0.200	0.000	0.204	0.205	0.002	0.200	0.200	-0.001	0.205	0.205	
AgeBias_at_20_2008_2019	0.325	0.327	0.007	0.313	0.309	-0.013	0.305	0.305	0.000	0.345	0.347	0.004	0.324	0.324	-0.001	0.365	0.363	-0.003
ln(Recr_ave_1977_2018)	0.099	0.100	0.008	0.271	0.105	-0.612	0.089	0.090	0.002	0.103	0.104	0.010	0.097	0.097	0.000	0.123	0.099	-0.191
ln(Recr_ave_pre1977_offset)	0.204	0.205	0.003	0.206	0.206	-0.002	0.181	0.182	0.001	0.199	0.200	0.004	0.208	0.207	-0.001	0.180	0.136	-0.244
lnQ_main_srv_base	0.066	0.066	0.011	0.057	0.057	-0.012	0.059	0.059	0.002	0.068	0.069	0.013	0.064	0.064	0.000	0.065	0.063	-0.025
lnQ_NBS_srv_base	0.105	0.105	0.007	0.767	0.161	-0.790	0.108	0.109	0.007	0.254	0.263	0.035	0.325	0.325	0.001	0.284	0.250	-0.119
Main_fsh_sel_logitPeakWidth	18.562	9.043	-0.513	14.705	0.533	-0.964	0.465	0.465	0.000	6.755	6.552	-0.030	0.593	0.592	0.000	0.522	0.520	-0.004
Main_fsh_sel_lnSD1_base	0.039	0.027	-0.315	0.029	0.037	0.276	0.039	0.039	0.000	0.027	0.027	0.000	0.037	0.037	0.000	0.039	0.039	0.000
Main_fsh_sel_lnSD2	8.489	1.649	-0.806	18.173	1.598	-0.912	1.251	1.252	0.001	3.556	3.758	0.057	1.767	1.768	0.001	1.357	1.349	-0.006
Main_fsh_sel_logitEnd_base	0.301	0.277	-0.080	0.786	3.537	3.499	3.513	3.513	0.000	0.296	0.295	-0.004	3.443	3.438	-0.002	3.301	3.289	-0.003
Main_srv_sel_lnSD1_base	0.151	0.150	-0.003	0.151	0.150	-0.004	0.154	0.154	0.000	0.161	0.161	0.000	0.155	0.155	0.000	0.157	0.157	0.000
NBS_srv_sel_lnSD1	0.139	0.140	0.007	0.882	0.945	0.071	0.640	0.640	0.000	0.146	0.148	0.017	0.490	0.480	-0.019	0.675	0.673	-0.004
lnDM_size_main_fish	0.351	0.357	0.015	0.358	0.323	-0.099	0.325	0.332	0.022	0.358	0.372	0.041	0.347	0.333	-0.039	0.343	0.349	0.017
lnDM_size_main_sur	0.524	0.515	-0.018	0.499	0.484	-0.030	0.496	0.490	-0.012	0.522	0.510	-0.022	0.470	0.492	0.048	0.482	0.478	-0.010
lnDM_size_NBS_sur	9.374	8.502	-0.093	7.603	8.695	0.144	2.327	2.328	0.000	7.420	10.704	0.443	8.223	9.056	0.101	1.982	1.945	-0.019
lnDM_age_main_srv	0.252	0.246	-0.026	0.278	0.295	0.061	0.280	0.280	-0.001	0.274	0.273	-0.007	0.297	0.298	0.004	0.282	0.282	0.001
lnDM_age_NBS_srv	0.568	0.564	-0.007	0.343	0.342	-0.005	1.052	1.048	-0.004	0.609	0.609	0.001	0.362	0.362	0.000	0.578	0.578	0.000

Table 2.1.15a. Comparison of primary and alternative ensembles: EBS catchability (1-area models).

Q var?	No			Yes		
2 area?	No			No		
2 srv?	Yes			Yes		
Move?	No			No		
Year	19.12b	20.4	Δ	19.12d	19.15	Δ
1982	0.895	0.886	-0.010	0.961	0.951	-0.011
1983	0.895	0.886	-0.010	1.012	1.002	-0.010
1984	0.895	0.886	-0.010	0.893	0.884	-0.010
1985	0.895	0.886	-0.010	1.044	1.034	-0.010
1986	0.895	0.886	-0.010	0.997	0.988	-0.009
1987	0.895	0.886	-0.010	0.969	0.961	-0.009
1988	0.895	0.886	-0.010	0.949	0.941	-0.008
1989	0.895	0.886	-0.010	0.837	0.830	-0.008
1990	0.895	0.886	-0.010	0.896	0.889	-0.008
1991	0.895	0.886	-0.010	0.877	0.869	-0.008
1992	0.895	0.886	-0.010	0.874	0.867	-0.008
1993	0.895	0.886	-0.010	1.009	1.001	-0.008
1994	0.895	0.886	-0.010	1.347	1.336	-0.008
1995	0.895	0.886	-0.010	1.126	1.117	-0.008
1996	0.895	0.886	-0.010	1.119	1.110	-0.008
1997	0.895	0.886	-0.010	0.939	0.932	-0.008
1998	0.895	0.886	-0.010	0.926	0.918	-0.009
1999	0.895	0.886	-0.010	0.939	0.931	-0.009
2000	0.895	0.886	-0.010	0.847	0.840	-0.008
2001	0.895	0.886	-0.010	1.114	1.105	-0.008
2002	0.895	0.886	-0.010	0.919	0.911	-0.008
2003	0.895	0.886	-0.010	0.958	0.951	-0.008
2004	0.895	0.886	-0.010	0.868	0.861	-0.008
2005	0.895	0.886	-0.010	0.925	0.918	-0.008
2006	0.895	0.886	-0.010	0.887	0.880	-0.008
2007	0.895	0.886	-0.010	0.896	0.889	-0.009
2008	0.895	0.886	-0.010	0.807	0.801	-0.008
2009	0.895	0.886	-0.010	0.847	0.840	-0.008
2010	0.895	0.886	-0.010	0.995	0.987	-0.008
2011	0.895	0.886	-0.010	1.043	1.035	-0.008
2012	0.895	0.886	-0.010	0.996	0.987	-0.008
2013	0.895	0.886	-0.010	0.902	0.895	-0.009
2014	0.895	0.886	-0.010	1.180	1.169	-0.009
2015	0.895	0.886	-0.010	1.124	1.114	-0.010
2016	0.895	0.886	-0.010	1.083	1.072	-0.010
2017	0.895	0.886	-0.010	0.838	0.830	-0.010
2018	0.895	0.886	-0.010	0.924	0.915	-0.010
2019	0.895	0.886	-0.010	0.960	0.951	-0.009

Table 2.1.15b. Comparison of primary and alternative ensembles: NBS catchability (1-area models).

Q var?	No			Yes		
2 area?	No			No		
2 srv?	Yes			Yes		
Move?	No			No		
Year	19.12b	20.4	Δ	19.12d	19.15	Δ
1982	0.455	0.448	-0.016	0.065	0.062	-0.040
1985	0.455	0.448	-0.016	0.082	0.078	-0.056
1988	0.455	0.448	-0.016	0.039	0.037	-0.054
1991	0.455	0.448	-0.016	0.103	0.098	-0.053
2010	0.455	0.448	-0.016	0.020	0.020	-0.034
2017	0.455	0.448	-0.016	0.462	0.454	-0.017
2018	0.455	0.448	-0.016	1.000	0.979	-0.021
2019	0.455	0.448	-0.016	0.987	0.968	-0.020

Table 2.1.15c. Comparison of primary and alternative ensembles: EBS catchability (2-area models).

Q var?	No						Yes					
2 area?	Yes						Yes					
2 srv?	Yes						Yes					
Move?	No			Yes			No			Yes		
Year	20.1	20.5	Δ	19.12c	19.12e	Δ	20.2	20.6	Δ	20.3	20.7	Δ
1982	0.903	0.918	0.017	1.188	1.186	-0.001	0.865	0.868	0.003	1.319	1.308	-0.008
1983	0.903	0.918	0.017	1.188	1.186	-0.001	0.920	0.923	0.003	1.353	1.342	-0.009
1984	0.903	0.918	0.017	1.188	1.186	-0.001	0.808	0.810	0.003	1.217	1.207	-0.009
1985	0.903	0.918	0.017	1.188	1.186	-0.001	0.949	0.951	0.003	1.386	1.374	-0.008
1986	0.903	0.918	0.017	1.188	1.186	-0.001	0.911	0.913	0.003	1.334	1.323	-0.008
1987	0.903	0.918	0.017	1.188	1.186	-0.001	0.893	0.895	0.002	1.315	1.306	-0.007
1988	0.903	0.918	0.017	1.188	1.186	-0.001	0.877	0.879	0.002	1.305	1.297	-0.006
1989	0.903	0.918	0.017	1.188	1.186	-0.001	0.778	0.780	0.002	1.173	1.167	-0.005
1990	0.903	0.918	0.017	1.188	1.186	-0.001	0.830	0.832	0.002	1.199	1.192	-0.006
1991	0.903	0.918	0.017	1.188	1.186	-0.001	0.808	0.810	0.002	1.178	1.171	-0.006
1992	0.903	0.918	0.017	1.188	1.186	-0.001	0.809	0.811	0.002	1.152	1.143	-0.008
1993	0.903	0.918	0.017	1.188	1.186	-0.001	0.935	0.937	0.002	1.299	1.290	-0.007
1994	0.903	0.918	0.017	1.188	1.186	-0.001	1.244	1.247	0.002	1.687	1.677	-0.006
1995	0.903	0.918	0.017	1.188	1.186	-0.001	1.046	1.049	0.002	1.435	1.424	-0.007
1996	0.903	0.918	0.017	1.188	1.186	-0.001	1.042	1.045	0.002	1.436	1.426	-0.007
1997	0.903	0.918	0.017	1.188	1.186	-0.001	0.877	0.879	0.002	1.271	1.262	-0.007
1998	0.903	0.918	0.017	1.188	1.186	-0.001	0.857	0.859	0.002	1.275	1.266	-0.007
1999	0.903	0.918	0.017	1.188	1.186	-0.001	0.872	0.874	0.002	1.282	1.273	-0.007
2000	0.903	0.918	0.017	1.188	1.186	-0.001	0.792	0.794	0.002	1.168	1.160	-0.007
2001	0.903	0.918	0.017	1.188	1.186	-0.001	1.038	1.040	0.002	1.447	1.435	-0.008
2002	0.903	0.918	0.017	1.188	1.186	-0.001	0.864	0.866	0.002	1.260	1.251	-0.007
2003	0.903	0.918	0.017	1.188	1.186	-0.001	0.904	0.906	0.002	1.297	1.288	-0.007
2004	0.903	0.918	0.017	1.188	1.186	-0.001	0.826	0.828	0.002	1.228	1.220	-0.006
2005	0.903	0.918	0.017	1.188	1.186	-0.001	0.883	0.884	0.002	1.338	1.330	-0.006
2006	0.903	0.918	0.017	1.188	1.186	-0.001	0.847	0.849	0.002	1.316	1.309	-0.005
2007	0.903	0.918	0.017	1.188	1.186	-0.001	0.838	0.840	0.002	1.255	1.246	-0.007
2008	0.903	0.918	0.017	1.188	1.186	-0.001	0.758	0.760	0.002	1.224	1.222	-0.002
2009	0.903	0.918	0.017	1.188	1.186	-0.001	0.800	0.802	0.002	1.286	1.286	0.000
2010	0.903	0.918	0.017	1.188	1.186	-0.001	0.922	0.924	0.002	1.224	1.216	-0.007
2011	0.903	0.918	0.017	1.188	1.186	-0.001	0.972	0.974	0.002	1.283	1.275	-0.006
2012	0.903	0.918	0.017	1.188	1.186	-0.001	0.925	0.927	0.002	1.272	1.264	-0.006
2013	0.903	0.918	0.017	1.188	1.186	-0.001	0.829	0.831	0.002	1.155	1.148	-0.007
2014	0.903	0.918	0.017	1.188	1.186	-0.001	1.078	1.081	0.002	1.455	1.444	-0.008
2015	0.903	0.918	0.017	1.188	1.186	-0.001	1.011	1.014	0.002	1.403	1.392	-0.008
2016	0.903	0.918	0.017	1.188	1.186	-0.001	0.975	0.977	0.002	1.448	1.439	-0.006
2017	0.903	0.918	0.017	1.188	1.186	-0.001	0.765	0.766	0.002	1.219	1.213	-0.005
2018	0.903	0.918	0.017	1.188	1.186	-0.001	0.814	0.816	0.002	1.335	1.327	-0.006
2019	0.903	0.918	0.017	1.188	1.186	-0.001	0.863	0.866	0.003	1.252	1.237	-0.012

Table 2.1.15c. Comparison of primary and alternative ensembles: EBS catchability (2-area models).

Q var?	No						Yes					
2 area?	Yes						Yes					
2 srv?	Yes						Yes					
Move?	No			Yes			No			Yes		
Year	20.1	20.5	Δ	19.12c	19.12e	Δ	20.2	20.6	Δ	20.3	20.7	Δ
1982	0.474	0.016	-0.966	0.771	0.767	-0.005	1.158	1.235	0.066	0.116	0.105	-0.096
1985	0.474	0.016	-0.966	0.771	0.767	-0.005	1.382	1.489	0.077	0.138	0.123	-0.107
1988	0.474	0.016	-0.966	0.771	0.767	-0.005	0.688	0.739	0.074	0.074	0.066	-0.105
1991	0.474	0.016	-0.966	0.771	0.767	-0.005	1.592	1.711	0.075	0.163	0.147	-0.099
2010	0.474	0.016	-0.966	0.771	0.767	-0.005	0.335	0.357	0.065	0.075	0.067	-0.101
2017	0.474	0.016	-0.966	0.771	0.767	-0.005	6.540	6.858	0.049	0.437	0.408	-0.066
2018	0.474	0.016	-0.966	0.771	0.767	-0.005	15.068	15.949	0.058	0.869	0.813	-0.065
2019	0.474	0.016	-0.966	0.771	0.767	-0.005	17.897	19.296	0.078	0.913	0.864	-0.054

Table 2.1.16a. Comparison of primary and alternative ensembles: age 0+ biomass (combined areas).

Q vary?	No			Yes		
2 area?	No	Yes		No	Yes	
2 srv?	Yes	Yes		Yes	Yes	
Move?	No	No	Yes	No	No	Yes
Pri. model	M19.12b	M20.1	M19.12c	M19.12d	M20.2	M20.3
Alt. model	M20.4	M20.5	M19.12e	M19.5	M20.6	M20.7
1977	0.0184	11.2099	0.0018	0.0154	-0.0061	0.0389
1978	0.0181	11.1805	0.0019	0.0164	-0.0063	0.0399
1979	0.0171	10.6704	0.0021	0.0172	-0.0064	0.0407
1980	0.0161	10.2505	0.0020	0.0161	-0.0061	0.0397
1981	0.0153	10.0626	0.0018	0.0147	-0.0057	0.0383
1982	0.0144	10.0409	0.0017	0.0133	-0.0053	0.0367
1983	0.0134	10.1309	0.0015	0.0119	-0.0049	0.0351
1984	0.0121	10.2756	0.0013	0.0110	-0.0046	0.0340
1985	0.0115	10.7248	0.0013	0.0104	-0.0045	0.0342
1986	0.0109	11.0471	0.0012	0.0098	-0.0044	0.0342
1987	0.0104	11.1514	0.0011	0.0091	-0.0042	0.0338
1988	0.0101	11.4527	0.0010	0.0083	-0.0040	0.0337
1989	0.0099	11.9718	0.0010	0.0078	-0.0040	0.0345
1990	0.0095	12.4605	0.0009	0.0074	-0.0040	0.0346
1991	0.0092	12.9328	0.0009	0.0073	-0.0040	0.0343
1992	0.0097	13.6095	0.0010	0.0078	-0.0043	0.0349
1993	0.0102	13.5437	0.0010	0.0079	-0.0043	0.0330
1994	0.0103	13.1643	0.0010	0.0075	-0.0041	0.0307
1995	0.0108	13.0980	0.0010	0.0073	-0.0041	0.0305
1996	0.0116	13.1391	0.0010	0.0075	-0.0042	0.0315
1997	0.0123	13.7166	0.0011	0.0075	-0.0044	0.0337
1998	0.0135	14.4294	0.0012	0.0084	-0.0048	0.0383
1999	0.0135	14.3758	0.0013	0.0088	-0.0049	0.0402
2000	0.0132	14.1261	0.0013	0.0087	-0.0047	0.0404
2001	0.0124	13.7430	0.0013	0.0083	-0.0045	0.0395
2002	0.0116	13.5157	0.0012	0.0078	-0.0043	0.0388
2003	0.0111	13.5753	0.0012	0.0074	-0.0042	0.0393
2004	0.0108	13.6674	0.0012	0.0071	-0.0042	0.0402
2005	0.0108	14.1880	0.0012	0.0070	-0.0043	0.0425
2006	0.0109	14.6944	0.0013	0.0071	-0.0044	0.0448
2007	0.0111	15.2584	0.0014	0.0073	-0.0047	0.0468
2008	0.0108	15.2350	0.0014	0.0075	-0.0047	0.0458
2009	0.0107	14.9710	0.0013	0.0077	-0.0047	0.0430
2010	0.0104	14.1607	0.0012	0.0077	-0.0044	0.0371
2011	0.0102	13.4183	0.0011	0.0073	-0.0041	0.0310
2012	0.0103	13.2645	0.0010	0.0073	-0.0039	0.0275
2013	0.0106	13.6615	0.0011	0.0077	-0.0041	0.0271
2014	0.0109	13.9092	0.0012	0.0083	-0.0042	0.0270
2015	0.0113	13.8976	0.0014	0.0091	-0.0042	0.0292
2016	0.0118	13.8698	0.0016	0.0098	-0.0041	0.0322
2017	0.0124	14.2303	0.0018	0.0105	-0.0041	0.0354
2018	0.0130	14.7128	0.0019	0.0114	-0.0042	0.0385
2019	0.0136	15.3426	0.0020	0.0125	-0.0044	0.0414
2020	0.0141	15.9889	0.0022	0.0139	-0.0048	0.0443
2021	0.0075	20.7057	0.0018	0.0077	-0.0033	0.0241

Table 2.1.16b. Comparison of primary and alternative ensembles: age 0+ biomass (separate areas).

Area:	Eastern Bering Sea				Northern Bering sea			
Q vary?	No		Yes		No		Yes	
2 area?	Yes		Yes		Yes		Yes	
2 srv?	Yes		Yes		Yes		Yes	
Move?	No	Yes	No	Yes	No	Yes	No	Yes
Pri. mod.	M20.1	M19.12c	M20.2	M20.3	M20.1	M19.12c	M20.2	M20.3
Alt. mod.	M20.5	M19.12e	M20.6	M20.7	M20.5	M19.12e	M20.6	M20.7
1977	-0.0188	0.0015	-0.0046	0.0104	27.7443	0.0056	-0.0391	0.0941
1978	-0.0210	0.0016	-0.0048	0.0127	27.6981	0.0057	-0.0393	0.0944
1979	-0.0257	0.0018	-0.0050	0.0149	27.5130	0.0058	-0.0398	0.0933
1980	-0.0270	0.0017	-0.0047	0.0143	27.4182	0.0057	-0.0398	0.0916
1981	-0.0270	0.0015	-0.0043	0.0128	27.3785	0.0055	-0.0396	0.0893
1982	-0.0261	0.0013	-0.0039	0.0114	27.3885	0.0052	-0.0393	0.0865
1983	-0.0244	0.0012	-0.0035	0.0114	27.4387	0.0050	-0.0389	0.0857
1984	-0.0212	0.0011	-0.0032	0.0104	27.5233	0.0048	-0.0386	0.0843
1985	-0.0194	0.0010	-0.0031	0.0096	27.6095	0.0046	-0.0383	0.0854
1986	-0.0178	0.0009	-0.0029	0.0087	27.6769	0.0049	-0.0380	0.0874
1987	-0.0167	0.0008	-0.0026	0.0078	27.7158	0.0047	-0.0378	0.0864
1988	-0.0160	0.0007	-0.0024	0.0066	27.7671	0.0045	-0.0375	0.0853
1989	-0.0156	0.0007	-0.0023	0.0052	27.8156	0.0044	-0.0372	0.0855
1990	-0.0145	0.0007	-0.0021	0.0051	27.8743	0.0060	-0.0370	0.0913
1991	-0.0133	0.0007	-0.0021	0.0046	27.9366	0.0060	-0.0368	0.0928
1992	-0.0141	0.0009	-0.0022	0.0062	27.9752	0.0053	-0.0367	0.0923
1993	-0.0162	0.0009	-0.0023	0.0073	27.9559	0.0041	-0.0367	0.0867
1994	-0.0171	0.0008	-0.0021	0.0067	27.9396	0.0037	-0.0367	0.0826
1995	-0.0187	0.0008	-0.0021	0.0071	27.9143	0.0037	-0.0366	0.0803
1996	-0.0208	0.0009	-0.0022	0.0074	27.8519	0.0038	-0.0367	0.0779
1997	-0.0224	0.0008	-0.0022	0.0070	27.8745	0.0039	-0.0365	0.0771
1998	-0.0242	0.0008	-0.0024	0.0077	27.8888	0.0038	-0.0365	0.0771
1999	-0.0241	0.0008	-0.0025	0.0077	27.8977	0.0038	-0.0365	0.0784
2000	-0.0238	0.0009	-0.0025	0.0077	27.8993	0.0038	-0.0365	0.0794
2001	-0.0224	0.0009	-0.0024	0.0079	27.8972	0.0038	-0.0365	0.0797
2002	-0.0209	0.0008	-0.0022	0.0070	27.9177	0.0037	-0.0365	0.0799
2003	-0.0204	0.0007	-0.0021	0.0062	27.9339	0.0039	-0.0364	0.0821
2004	-0.0195	0.0005	-0.0020	0.0057	27.9527	0.0038	-0.0365	0.0811
2005	-0.0191	0.0005	-0.0020	0.0053	27.9966	0.0036	-0.0364	0.0801
2006	-0.0187	0.0005	-0.0020	0.0047	28.0302	0.0035	-0.0363	0.0788
2007	-0.0186	0.0006	-0.0021	0.0052	28.0700	0.0036	-0.0362	0.0791
2008	-0.0174	0.0007	-0.0022	0.0044	28.0942	0.0036	-0.0362	0.0788
2009	-0.0173	0.0008	-0.0022	0.0013	28.0950	0.0036	-0.0363	0.0788
2010	-0.0168	0.0010	-0.0022	0.0069	28.0470	0.0083	-0.0364	0.0957
2011	-0.0170	0.0009	-0.0020	0.0067	27.9864	0.0079	-0.0365	0.1008
2012	-0.0180	0.0009	-0.0019	0.0063	27.9258	0.0067	-0.0365	0.0990
2013	-0.0187	0.0010	-0.0019	0.0065	27.9272	0.0048	-0.0364	0.0905
2014	-0.0195	0.0011	-0.0020	0.0078	27.9233	0.0036	-0.0364	0.0808
2015	-0.0199	0.0012	-0.0020	0.0086	27.9117	0.0038	-0.0365	0.0746
2016	-0.0208	0.0010	-0.0019	0.0077	27.8969	0.0036	-0.0365	0.0695
2017	-0.0220	0.0009	-0.0018	0.0061	27.9423	0.0035	-0.0369	0.0684
2018	-0.0228	0.0009	-0.0017	0.0070	27.9927	0.0029	-0.0373	0.0664
2019	-0.0228	0.0017	-0.0016	0.0165	28.6826	0.0024	-0.0555	0.0653
2020	-0.0220	0.0020	-0.0018	0.0179	29.3332	0.0023	-0.0977	0.0687
2021	-0.0191	0.0013	-0.0002	-0.0367	29.1930	0.0023	-0.0810	0.0693

Table 2.1.17a. Comparison of primary and alternative ensembles: objective function components.

Time-varying *Q* ?	No			Yes		
Separate areas?	No	Yes		No	Yes	
Separate surveys?	Yes	Yes		Yes	Yes	
Movement?	No	No	Yes	No	No	Yes
Primary model	M19.12b	M20.1	M19.12c	M19.12d	M20.2	M20.3
Alternative model	M20.4	M20.5	M19.12e	M19.15	M20.6	M20.7
Catch	0.00	0.00	0.00	0.00	0.00	0.00
Initial_eq_catch	0.00	0.00	0.00	0.00	0.00	0.00
Survey index	-0.31	-1.08	-0.02	-0.39	0.20	-0.39
Size composition	-0.74	-1.20	0.00	-0.22	-0.09	0.60
Age composition	0.39	-0.48	0.04	0.34	-0.11	-0.44
Recruitment	-0.01	0.06	0.00	0.02	-0.01	-0.01
Initial_eq_recr	-0.11	0.10	-0.02	-0.11	0.03	-0.17
Priors	-0.23	-0.21	-0.09	-1.64	-0.46	-1.52
"Softbounds"	0.01	0.00	0.00	0.00	0.00	0.00
Deviations	0.17	0.27	-0.01	0.24	-0.06	0.27
Total	-0.84	-2.55	-0.09	-1.76	-0.50	-1.65

Table 2.1.17 b. Comparison of primary and alternative ensembles: objective function subcomponents.

Time-varying *Q* ?			No			Yes		
Separate areas?			No	Yes		No	Yes	
Separate surveys?			Yes	Yes		Yes	Yes	
Movement?			No	No	Yes	No	No	Yes
Primary model			M19.12b	M20.1	M19.12c	M19.12d	M20.2	M20.3
Alternative model			M20.4	M20.5	M19.12e	M19.15	M20.6	M20.7
Index	Survey	Main	-0.14	0.31	-0.06	-0.01	-0.01	-0.09
		NBS	-0.17	-1.39	0.04	-0.38	0.21	-0.30
		Total	-0.31	-1.08	-0.02	-0.39	0.20	-0.39
Sizecomp	Fishery	Main	-0.64	-3.04	0.04	0.01	-0.04	0.32
		NBS		0.00	0.00		0.00	0.00
	Survey	Main	0.19	0.28	-0.05	-0.17	0.07	-0.47
		NBS	-0.30	1.56	0.01	-0.06	-0.13	0.75
	All	Total	-0.74	-1.20	0.00	-0.22	-0.09	0.60
Agecomp	Survey	Main	0.41	-0.72	0.03	0.30	-0.08	-0.20
		NBS	-0.03	0.25	0.01	0.04	-0.03	-0.24
		Total	0.39	-0.48	0.04	0.34	-0.11	-0.44

Table 2.1.18 (page 1 of 2). 2021 OFL (millions of t) from each pivot model, bootstrap set, and model.

Pivot	Bootstrap	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
19.12a	1	0.173737	0.086842	0.205788	0.117112	0.182797	0.347790	0.155245	0.123295
19.12a	2	0.130955	0.612486	0.183632	0.159884	0.137460	0.460267	0.118251	0.084947
19.12a	3	0.144781	0.888500	0.174957	0.175976	0.139972	0.503465	0.128246	0.098897
19.12a	4								
19.12a	5	0.140907	0.813571	0.188078	0.169968	0.149442	0.720794	0.125180	0.091742
19.12a	6	0.123061	0.635104	0.184306	0.081843	0.123493	0.327995	0.114028	0.081357
19.12a	7								
19.12a	8	0.135166	0.696681	0.168117	0.088548	0.141402	0.449962	0.121584	0.098517
19.12a	9	0.156612	1.976270	0.199516	0.109585	0.161574	0.740566	0.142221	0.113775
19.12a	10	0.145384	0.645751	0.162544	0.137253	0.150044	0.330400	0.124064	0.095015
19.12a	Mean:	0.143825	0.794401	0.183367	0.130021	0.148273	0.485155	0.128602	0.098443
19.12b	1								
19.12b	2	0.152494	0.094537	0.155844	0.102819	0.148098	0.102465	0.173651	0.098581
19.12b	3	0.189535	0.129290	0.174717	0.151174	0.170709	0.126970	0.192962	0.160842
19.12b	4	0.170058	0.106575	0.177122	0.123438	0.159576	0.109069	0.175323	0.127174
19.12b	5	0.188338	0.119969	0.175631	0.120163	0.178696	0.125905	0.181572	0.208493
19.12b	6	0.174678	0.113795	0.163867	0.230344	0.158695	0.116166	0.188448	0.120425
19.12b	7	0.138569	0.092467	0.156156	0.096059	0.127208	0.091422	0.147605	0.113901
19.12b	8	0.178934	0.107990	0.149150	0.117374	0.154957	0.109561	0.177806	0.119380
19.12b	9	0.169921	0.110958	0.168141	0.117143	0.154050	0.110399	0.162895	0.118692
19.12b	10	0.214668	0.124157	0.200153	0.131974	0.190791	0.122530	0.203910	0.139028
19.12b	Mean:	0.175244	0.111082	0.168976	0.132276	0.160309	0.112721	0.178241	0.134057
20.1	1	0.171488	0.119874	0.143676	0.160999	0.166624	0.116842	0.149411	0.152360
20.1	2	0.163941	0.109704	0.154499	0.200808	0.148936	0.111515	0.144413	0.119665
20.1	3	0.178794	0.111091	0.136407	0.137927	0.158229	0.112784	0.163071	0.207692
20.1	4	0.147444	0.098269	0.141818	0.154253	0.135775	0.100660	0.135432	0.144199
20.1	5	0.203695	0.101116	0.154951	0.185721	0.167896	0.096316	0.152070	0.162534
20.1	6	0.149695	0.103975	0.147962	0.122669	0.143200	0.103780	0.143738	0.131927
20.1	7	0.172157	0.114134	0.156532	0.166863	0.170647	0.126731	0.159857	0.160075
20.1	8	0.184566	0.120655	0.138388	0.151073	0.175102	0.118568	0.165221	0.178269
20.1	9	0.157238	0.108942	0.114135	0.153186	0.145113	0.101524	0.128932	0.190844
20.1	10	0.174516	0.113434	0.140678	0.193775	0.157878	0.113458	0.160402	0.154601
20.1	Mean:	0.170353	0.110119	0.142905	0.162727	0.156940	0.110218	0.150255	0.160217
19.12c	1	0.154889	0.164829	0.213415	0.124113	0.144934	0.090785	0.108790	0.121162
19.12c	2	0.177546	0.147460	0.293632	0.106440	0.156568	0.096011	0.114062	0.111264
19.12c	3	0.163948	0.105986	0.177798	0.119639	0.169187	0.099943	0.123426	0.120686
19.12c	4	0.147312	0.131403	0.145325	0.107183	0.132959	0.079328	0.104620	0.102163
19.12c	5	0.121456	0.080609	0.121291	0.094740	0.120913	0.078202	0.097958	0.093502
19.12c	6	0.145744	0.097622	0.139275	0.114438	0.137042	0.082926	0.109461	0.108081
19.12c	7	0.119867	0.074426	0.237446	0.076568	0.116404	0.064699	0.086050	0.081446
19.12c	8	0.147224	0.090198	0.144347	0.123496	0.137003	0.077827	0.112138	0.119345
19.12c	9	0.150199	0.109888	0.196776	0.117881	0.153669	0.085152	0.116871	0.107808
19.12c	10	0.149988	0.091762	0.148068	0.092598	0.138250	0.081791	0.103969	0.098379
19.12c	Mean:	0.147817	0.109418	0.181737	0.107710	0.140693	0.083666	0.107734	0.106384

Table 2.1.18 (page 2 of 2). 2021 OFL (millions of t) from each pivot model, bootstrap set, and model.

Bootstrap	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
1	0.130161	0.695315	0.189438	0.130728	0.131280	0.482620	0.115622	0.091581
2	0.113908	0.605577	0.163460	0.081156	0.117364	0.418270	0.108168	0.081145
3	0.114120	1.544130	0.162043	0.102335	0.127082	0.284478	0.107207	0.089666
4	0.116546	0.690755	0.182201	0.083978	0.115425	0.381620	0.103526	0.077039
5	0.165445	0.636654	0.188824	0.156525	0.170032	0.559963	0.147025	0.114110
6	0.158209	1.383390	0.187681	0.115999	0.166263	0.522446	0.146343	0.123167
7	0.117985	0.540450	0.129349	0.126402	0.129405	0.497735	0.109780	0.099661
8	0.141947	0.726739	0.190814	0.137894	0.152606	0.754240	0.126873	0.154281
9	0.134068	1.983360	0.172112	0.134077	0.139347	0.342950	0.118892	0.093320
10	0.141505	0.567170	0.188713	0.136289	0.152741	0.400268	0.136638	0.104825
Mean:	0.133389	0.937354	0.175464	0.120538	0.140155	0.464459	0.122007	0.102879
1	0.134360	0.099397	0.160378	0.085538	0.132194	0.087306	0.110108	0.100950
2	0.156229	0.111846	0.190383	0.102026	0.151006	0.095493	0.160975	0.113748
3	0.144575	0.105431	0.247162	0.161211	0.143636	0.087218	0.134318	0.129116
4	0.135142	0.089562	0.167667	0.206668	0.130972	0.076285	0.108904	0.080150
5	0.135669	0.096272	0.203018	0.146241	0.139299	0.086168	0.140776	0.104634
6	0.119321	0.089728	0.170994	0.107767	0.117051	0.077402	0.117078	0.107009
7	0.128997	0.087731	0.160857	0.113272	0.126928	0.077522	0.111917	0.088440
8	0.126540	0.123602	0.300317	0.108371	0.129016	0.085378	0.121560	0.103326
9	0.131794	0.095597	0.174743	0.091390	0.136382	0.079053	0.109373	0.093168
10	0.136453	0.102672	0.189532	0.103113	0.133495	0.089306	0.129501	0.108363
Mean:	0.134908	0.100184	0.196505	0.122560	0.133998	0.084113	0.124451	0.102890
1	0.180419	0.128213	0.184852	0.119080	0.187737	0.112551	0.148799	0.145497
2								
3	0.189190	0.175585	0.292001	0.108569	0.190152	0.115402	0.119677	0.111899
4	0.115743	0.091239	0.144020	0.099407	0.119432	0.080142	0.088351	0.095886
5	0.145680	0.152242	0.272229	0.089333	0.149135	0.105311	0.103229	0.090767
6	0.173953	0.176171	0.304587	0.147976	0.179385	0.101074	0.104237	0.111539
7	0.178346	0.120074	0.170311	0.106768	0.162765	0.106706	0.112913	0.131326
8	0.150871	0.191392	0.418798	0.080199	0.152017	0.091148	0.099444	0.129059
9	0.155972	0.109936	0.154057	0.095710	0.161048	0.101217	0.109947	0.110924
10	0.173460	0.163544	0.273513	0.149734	0.175735	0.100807	0.137176	0.145647
Mean:	0.162626	0.145377	0.246041	0.110753	0.164156	0.101595	0.113753	0.119172
1	0.137311	0.101591	0.219715	0.120053	0.146247	0.094338	0.127480	0.139565
2	0.160293	0.106903	0.159192	0.120748	0.155310	0.094677	0.119074	0.131841
3	0.154193	0.111519	0.176409	0.131527	0.161344	0.102117	0.124339	0.145360
4	0.179490	0.113337	0.227064	0.124316	0.163615	0.092677	0.122113	0.121110
5	0.172208	0.154254	0.304405	0.118841	0.169247	0.095994	0.118638	0.143999
6	0.170335	0.106354	0.154204	0.127129	0.161648	0.090107	0.104138	0.129489
7	0.140625	0.126107	0.269291	0.100685	0.143895	0.078117	0.099242	0.119518
8								
9	0.162532	0.131650	0.159611	0.110745	0.154016	0.096385	0.110008	0.127280
10	0.197704	0.131018	0.228517	0.150290	0.189955	0.105585	0.136750	0.172422
Mean:	0.163855	0.120304	0.210934	0.122704	0.160586	0.094444	0.117976	0.136732

Table 2.1.19 (page 1 of 2). Calculation of mean squared error for each pivot model (equal weights).

Pivot	Boot.	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	Sum	Best	SqErr
19.12a	1	0.0217	0.0109	0.0257	0.0146	0.0228	0.0435	0.0194	0.0154	0.1741	0.1438	0.0009
19.12a	2	0.0164	0.0766	0.0230	0.0200	0.0172	0.0575	0.0148	0.0106	0.2360	0.1438	0.0085
19.12a	3	0.0181	0.1111	0.0219	0.0220	0.0175	0.0629	0.0160	0.0124	0.2818	0.1438	0.0191
19.12a	4											
19.12a	5	0.0176	0.1017	0.0235	0.0212	0.0187	0.0901	0.0156	0.0115	0.3000	0.1438	0.0244
19.12a	6	0.0154	0.0794	0.0230	0.0102	0.0154	0.0410	0.0143	0.0102	0.2089	0.1438	0.0042
19.12a	7											
19.12a	8	0.0169	0.0871	0.0210	0.0111	0.0177	0.0562	0.0152	0.0123	0.2375	0.1438	0.0088
19.12a	9	0.0196	0.2470	0.0249	0.0137	0.0202	0.0926	0.0178	0.0142	0.4500	0.1438	0.0938
19.12a	10	0.0182	0.0807	0.0203	0.0172	0.0188	0.0413	0.0155	0.0119	0.2238	0.1438	0.0064
19.12a	Mean:											0.0207
19.12b	1											
19.12b	2	0.0191	0.0118	0.0195	0.0129	0.0185	0.0128	0.0217	0.0123	0.1286	0.1111	0.0003
19.12b	3	0.0237	0.0162	0.0218	0.0189	0.0213	0.0159	0.0241	0.0201	0.1620	0.1111	0.0026
19.12b	4	0.0213	0.0133	0.0221	0.0154	0.0199	0.0136	0.0219	0.0159	0.1435	0.1111	0.0011
19.12b	5	0.0235	0.0150	0.0220	0.0150	0.0223	0.0157	0.0227	0.0261	0.1623	0.1111	0.0026
19.12b	6	0.0218	0.0142	0.0205	0.0288	0.0198	0.0145	0.0236	0.0151	0.1583	0.1111	0.0022
19.12b	7	0.0173	0.0116	0.0195	0.0120	0.0159	0.0114	0.0185	0.0142	0.1204	0.1111	0.0001
19.12b	8	0.0224	0.0135	0.0186	0.0147	0.0194	0.0137	0.0222	0.0149	0.1394	0.1111	0.0008
19.12b	9	0.0212	0.0139	0.0210	0.0146	0.0193	0.0138	0.0204	0.0148	0.1390	0.1111	0.0008
19.12b	10	0.0268	0.0155	0.0250	0.0165	0.0238	0.0153	0.0255	0.0174	0.1659	0.1111	0.0030
19.12b	Mean:											0.0015
20.1	1	0.0214	0.0150	0.0180	0.0201	0.0208	0.0146	0.0187	0.0190	0.1477	0.1429	0.0000
20.1	2	0.0205	0.0137	0.0193	0.0251	0.0186	0.0139	0.0181	0.0150	0.1442	0.1429	0.0000
20.1	3	0.0223	0.0139	0.0171	0.0172	0.0198	0.0141	0.0204	0.0260	0.1507	0.1429	0.0001
20.1	4	0.0184	0.0123	0.0177	0.0193	0.0170	0.0126	0.0169	0.0180	0.1322	0.1429	0.0001
20.1	5	0.0255	0.0126	0.0194	0.0232	0.0210	0.0120	0.0190	0.0203	0.1530	0.1429	0.0001
20.1	6	0.0187	0.0130	0.0185	0.0153	0.0179	0.0130	0.0180	0.0165	0.1309	0.1429	0.0001
20.1	7	0.0215	0.0143	0.0196	0.0209	0.0213	0.0158	0.0200	0.0200	0.1534	0.1429	0.0001
20.1	8	0.0231	0.0151	0.0173	0.0189	0.0219	0.0148	0.0207	0.0223	0.1540	0.1429	0.0001
20.1	9	0.0197	0.0136	0.0143	0.0191	0.0181	0.0127	0.0161	0.0239	0.1375	0.1429	0.0000
20.1	10	0.0218	0.0142	0.0176	0.0242	0.0197	0.0142	0.0201	0.0193	0.1511	0.1429	0.0001
20.1	Mean:											0.0001
19.12c	1	0.0194	0.0206	0.0267	0.0155	0.0181	0.0113	0.0136	0.0151	0.1404	0.1077	0.0011
19.12c	2	0.0222	0.0184	0.0367	0.0133	0.0196	0.0120	0.0143	0.0139	0.1504	0.1077	0.0018
19.12c	3	0.0205	0.0132	0.0222	0.0150	0.0211	0.0125	0.0154	0.0151	0.1351	0.1077	0.0007
19.12c	4	0.0184	0.0164	0.0182	0.0134	0.0166	0.0099	0.0131	0.0128	0.1188	0.1077	0.0001
19.12c	5	0.0152	0.0101	0.0152	0.0118	0.0151	0.0098	0.0122	0.0117	0.1011	0.1077	0.0000
19.12c	6	0.0182	0.0122	0.0174	0.0143	0.0171	0.0104	0.0137	0.0135	0.1168	0.1077	0.0001
19.12c	7	0.0150	0.0093	0.0297	0.0096	0.0146	0.0081	0.0108	0.0102	0.1071	0.1077	0.0000
19.12c	8	0.0184	0.0113	0.0180	0.0154	0.0171	0.0097	0.0140	0.0149	0.1189	0.1077	0.0001
19.12c	9	0.0188	0.0137	0.0246	0.0147	0.0192	0.0106	0.0146	0.0135	0.1298	0.1077	0.0005
19.12c	10	0.0187	0.0115	0.0185	0.0116	0.0173	0.0102	0.0130	0.0123	0.1131	0.1077	0.0000
19.12c	Mean:											0.0005

Table 2.1.19 (page 2 of 2). Calculation of mean squared error for each pivot model (equal weights).

Pivot	Boot.	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	Sum	Best	SqErr
19.12	1	0.0163	0.0869	0.0237	0.0163	0.0164	0.0603	0.0145	0.0114	0.2458	0.1402	0.0112
19.12	2	0.0142	0.0757	0.0204	0.0101	0.0147	0.0523	0.0135	0.0101	0.2111	0.1402	0.0050
19.12	3	0.0143	0.1930	0.0203	0.0128	0.0159	0.0356	0.0134	0.0112	0.3164	0.1402	0.0311
19.12	4	0.0146	0.0863	0.0228	0.0105	0.0144	0.0477	0.0129	0.0096	0.2189	0.1402	0.0062
19.12	5	0.0207	0.0796	0.0236	0.0196	0.0213	0.0700	0.0184	0.0143	0.2673	0.1402	0.0162
19.12	6	0.0198	0.1729	0.0235	0.0145	0.0208	0.0653	0.0183	0.0154	0.3504	0.1402	0.0442
19.12	7	0.0147	0.0676	0.0162	0.0158	0.0162	0.0622	0.0137	0.0125	0.2188	0.1402	0.0062
19.12	8	0.0177	0.0908	0.0239	0.0172	0.0191	0.0943	0.0159	0.0193	0.2982	0.1402	0.0250
19.12	9	0.0168	0.2479	0.0215	0.0168	0.0174	0.0429	0.0149	0.0117	0.3898	0.1402	0.0623
19.12	10	0.0177	0.0709	0.0236	0.0170	0.0191	0.0500	0.0171	0.0131	0.2285	0.1402	0.0078
19.12	Mean:											0.0215
19.12d	1	0.0168	0.0124	0.0200	0.0107	0.0165	0.0109	0.0138	0.0126	0.1138	0.0841	0.0009
19.12d	2	0.0195	0.0140	0.0238	0.0128	0.0189	0.0119	0.0201	0.0142	0.1352	0.0841	0.0026
19.12d	3	0.0181	0.0132	0.0309	0.0202	0.0180	0.0109	0.0168	0.0161	0.1441	0.0841	0.0036
19.12d	4	0.0169	0.0112	0.0210	0.0258	0.0164	0.0095	0.0136	0.0100	0.1244	0.0841	0.0016
19.12d	5	0.0170	0.0120	0.0254	0.0183	0.0174	0.0108	0.0176	0.0131	0.1315	0.0841	0.0022
19.12d	6	0.0149	0.0112	0.0214	0.0135	0.0146	0.0097	0.0146	0.0134	0.1133	0.0841	0.0009
19.12d	7	0.0161	0.0110	0.0201	0.0142	0.0159	0.0097	0.0140	0.0111	0.1120	0.0841	0.0008
19.12d	8	0.0158	0.0155	0.0375	0.0135	0.0161	0.0107	0.0152	0.0129	0.1373	0.0841	0.0028
19.12d	9	0.0165	0.0119	0.0218	0.0114	0.0170	0.0099	0.0137	0.0116	0.1139	0.0841	0.0009
19.12d	10	0.0171	0.0128	0.0237	0.0129	0.0167	0.0112	0.0162	0.0135	0.1241	0.0841	0.0016
19.12d	Mean:											0.0018
20.2	1	0.0226	0.0160	0.0231	0.0149	0.0235	0.0141	0.0186	0.0182	0.1509	0.1138	0.0014
20.2	2											
20.2	3	0.0236	0.0219	0.0365	0.0136	0.0238	0.0144	0.0150	0.0140	0.1628	0.1138	0.0024
20.2	4	0.0145	0.0114	0.0180	0.0124	0.0149	0.0100	0.0110	0.0120	0.1043	0.1138	0.0001
20.2	5	0.0182	0.0190	0.0340	0.0112	0.0186	0.0132	0.0129	0.0113	0.1385	0.1138	0.0006
20.2	6	0.0217	0.0220	0.0381	0.0185	0.0224	0.0126	0.0130	0.0139	0.1624	0.1138	0.0024
20.2	7	0.0223	0.0150	0.0213	0.0133	0.0203	0.0133	0.0141	0.0164	0.1362	0.1138	0.0005
20.2	8	0.0189	0.0239	0.0523	0.0100	0.0190	0.0114	0.0124	0.0161	0.1641	0.1138	0.0025
20.2	9	0.0195	0.0137	0.0193	0.0120	0.0201	0.0127	0.0137	0.0139	0.1249	0.1138	0.0001
20.2	10	0.0217	0.0204	0.0342	0.0187	0.0220	0.0126	0.0171	0.0182	0.1650	0.1138	0.0026
20.2	Mean:											0.0014
20.3	1	0.0172	0.0127	0.0275	0.0150	0.0183	0.0118	0.0159	0.0174	0.1358	0.1367	0.0000
20.3	2	0.0200	0.0134	0.0199	0.0151	0.0194	0.0118	0.0149	0.0165	0.1310	0.1367	0.0000
20.3	3	0.0193	0.0139	0.0221	0.0164	0.0202	0.0128	0.0155	0.0182	0.1384	0.1367	0.0000
20.3	4	0.0224	0.0142	0.0284	0.0155	0.0205	0.0116	0.0153	0.0151	0.1430	0.1367	0.0000
20.3	5	0.0215	0.0193	0.0381	0.0149	0.0212	0.0120	0.0148	0.0180	0.1597	0.1367	0.0005
20.3	6	0.0213	0.0133	0.0193	0.0159	0.0202	0.0113	0.0130	0.0162	0.1304	0.1367	0.0000
20.3	7	0.0176	0.0158	0.0337	0.0126	0.0180	0.0098	0.0124	0.0149	0.1347	0.1367	0.0000
20.3	8											
20.3	9	0.0203	0.0165	0.0200	0.0138	0.0193	0.0120	0.0138	0.0159	0.1315	0.1367	0.0000
20.3	10	0.0247	0.0164	0.0286	0.0188	0.0237	0.0132	0.0171	0.0216	0.1640	0.1367	0.0007
20.3	Mean:											0.0002

Table 2.1.20 (page 1 of 2). Calculation of mean squared error for each pivot model (equal weights).

Pivot	Boot.	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	Sum	Best	SqErr
19.12a	1	0.0000	0.0010	0.0000	0.0280	0.0026	0.0209	0.0000	0.0832	0.1357	0.1438	0.0001
19.12a	2	0.0000	0.0072	0.0000	0.0383	0.0020	0.0276	0.0000	0.0573	0.1323	0.1438	0.0001
19.12a	3	0.0000	0.0104	0.0000	0.0421	0.0020	0.0302	0.0000	0.0667	0.1514	0.1438	0.0001
19.12a	4											
19.12a	5	0.0000	0.0095	0.0000	0.0407	0.0021	0.0432	0.0000	0.0619	0.1575	0.1438	0.0002
19.12a	6	0.0000	0.0074	0.0000	0.0196	0.0018	0.0197	0.0000	0.0549	0.1033	0.1438	0.0016
19.12a	7											
19.12a	8	0.0000	0.0081	0.0000	0.0212	0.0020	0.0270	0.0000	0.0665	0.1248	0.1438	0.0004
19.12a	9	0.0000	0.0231	0.0000	0.0262	0.0023	0.0444	0.0000	0.0768	0.1728	0.1438	0.0008
19.12a	10	0.0000	0.0075	0.0000	0.0329	0.0021	0.0198	0.0000	0.0641	0.1265	0.1438	0.0003
19.12a	Mean:											0.0004
19.12b	1											
19.12b	2	0.0000	0.0011	0.0000	0.0246	0.0021	0.0061	0.0000	0.0665	0.1005	0.1111	0.0001
19.12b	3	0.0000	0.0015	0.0000	0.0362	0.0024	0.0076	0.0000	0.1085	0.1563	0.1111	0.0020
19.12b	4	0.0000	0.0012	0.0000	0.0295	0.0023	0.0065	0.0000	0.0858	0.1254	0.1111	0.0002
19.12b	5	0.0000	0.0014	0.0000	0.0288	0.0026	0.0076	0.0000	0.1407	0.1809	0.1111	0.0049
19.12b	6	0.0000	0.0013	0.0000	0.0551	0.0023	0.0070	0.0000	0.0812	0.1470	0.1111	0.0013
19.12b	7	0.0000	0.0011	0.0000	0.0230	0.0018	0.0055	0.0000	0.0768	0.1082	0.1111	0.0000
19.12b	8	0.0000	0.0013	0.0000	0.0281	0.0022	0.0066	0.0000	0.0805	0.1187	0.1111	0.0001
19.12b	9	0.0000	0.0013	0.0000	0.0280	0.0022	0.0066	0.0000	0.0801	0.1182	0.1111	0.0001
19.12b	10	0.0000	0.0015	0.0000	0.0316	0.0027	0.0074	0.0000	0.0938	0.1369	0.1111	0.0007
19.12b	Mean:											0.0010
20.1	1	0.0000	0.0014	0.0000	0.0385	0.0024	0.0070	0.0000	0.1028	0.1521	0.1429	0.0001
20.1	2	0.0000	0.0013	0.0000	0.0481	0.0021	0.0067	0.0000	0.0807	0.1389	0.1429	0.0000
20.1	3	0.0000	0.0013	0.0000	0.0330	0.0023	0.0068	0.0000	0.1401	0.1835	0.1429	0.0016
20.1	4	0.0000	0.0011	0.0000	0.0369	0.0019	0.0060	0.0000	0.0973	0.1433	0.1429	0.0000
20.1	5	0.0000	0.0012	0.0000	0.0445	0.0024	0.0058	0.0000	0.1097	0.1635	0.1429	0.0004
20.1	6	0.0000	0.0012	0.0000	0.0294	0.0020	0.0062	0.0000	0.0890	0.1279	0.1429	0.0002
20.1	7	0.0000	0.0013	0.0000	0.0399	0.0024	0.0076	0.0000	0.1080	0.1593	0.1429	0.0003
20.1	8	0.0000	0.0014	0.0000	0.0362	0.0025	0.0071	0.0000	0.1203	0.1675	0.1429	0.0006
20.1	9	0.0000	0.0013	0.0000	0.0367	0.0021	0.0061	0.0000	0.1288	0.1749	0.1429	0.0010
20.1	10	0.0000	0.0013	0.0000	0.0464	0.0023	0.0068	0.0000	0.1043	0.1611	0.1429	0.0003
20.1	Mean:											0.0005
19.12c	1	0.0000	0.0019	0.0000	0.0297	0.0021	0.0054	0.0000	0.0817	0.1209	0.1077	0.0002
19.12c	2	0.0000	0.0017	0.0000	0.0255	0.0022	0.0058	0.0000	0.0751	0.1103	0.1077	0.0000
19.12c	3	0.0000	0.0012	0.0000	0.0286	0.0024	0.0060	0.0000	0.0814	0.1197	0.1077	0.0001
19.12c	4	0.0000	0.0015	0.0000	0.0257	0.0019	0.0048	0.0000	0.0689	0.1028	0.1077	0.0000
19.12c	5	0.0000	0.0009	0.0000	0.0227	0.0017	0.0047	0.0000	0.0631	0.0931	0.1077	0.0002
19.12c	6	0.0000	0.0011	0.0000	0.0274	0.0020	0.0050	0.0000	0.0729	0.1084	0.1077	0.0000
19.12c	7	0.0000	0.0009	0.0000	0.0183	0.0017	0.0039	0.0000	0.0549	0.0797	0.1077	0.0008
19.12c	8	0.0000	0.0011	0.0000	0.0296	0.0020	0.0047	0.0000	0.0805	0.1178	0.1077	0.0001
19.12c	9	0.0000	0.0013	0.0000	0.0282	0.0022	0.0051	0.0000	0.0727	0.1095	0.1077	0.0000
19.12c	10	0.0000	0.0011	0.0000	0.0222	0.0020	0.0049	0.0000	0.0664	0.0965	0.1077	0.0001
19.12c	Mean:											0.0002

Table 2.1.20 (page 2 of 2). Calculation of mean squared error for each pivot model (equal weights).

Pivot	Boot.	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	Sum	Best	SqErr
19.12	1	0.0000	0.0081	0.0000	0.0313	0.0019	0.0290	0.0000	0.0618	0.1320	0.1402	0.0001
19.12	2	0.0000	0.0071	0.0000	0.0194	0.0017	0.0251	0.0000	0.0547	0.1080	0.1402	0.0010
19.12	3	0.0000	0.0181	0.0000	0.0245	0.0018	0.0171	0.0000	0.0605	0.1219	0.1402	0.0003
19.12	4	0.0000	0.0081	0.0000	0.0201	0.0016	0.0229	0.0000	0.0520	0.1047	0.1402	0.0013
19.12	5	0.0000	0.0074	0.0000	0.0375	0.0024	0.0336	0.0000	0.0770	0.1579	0.1402	0.0003
19.12	6	0.0000	0.0162	0.0000	0.0278	0.0024	0.0313	0.0000	0.0831	0.1608	0.1402	0.0004
19.12	7	0.0000	0.0063	0.0000	0.0303	0.0018	0.0299	0.0000	0.0672	0.1355	0.1402	0.0000
19.12	8	0.0000	0.0085	0.0000	0.0330	0.0022	0.0453	0.0000	0.1041	0.1930	0.1402	0.0028
19.12	9	0.0000	0.0232	0.0000	0.0321	0.0020	0.0206	0.0000	0.0630	0.1408	0.1402	0.0000
19.12	10	0.0000	0.0066	0.0000	0.0326	0.0022	0.0240	0.0000	0.0707	0.1362	0.1402	0.0000
19.12	Mean:											0.0006
19.12d	1	0.0000	0.0012	0.0000	0.0205	0.0019	0.0052	0.0000	0.0681	0.0969	0.0841	0.0002
19.12d	2	0.0000	0.0013	0.0000	0.0244	0.0022	0.0057	0.0000	0.0767	0.1104	0.0841	0.0007
19.12d	3	0.0000	0.0012	0.0000	0.0386	0.0021	0.0052	0.0000	0.0871	0.1342	0.0841	0.0025
19.12d	4	0.0000	0.0010	0.0000	0.0495	0.0019	0.0046	0.0000	0.0541	0.1110	0.0841	0.0007
19.12d	5	0.0000	0.0011	0.0000	0.0350	0.0020	0.0052	0.0000	0.0706	0.1139	0.0841	0.0009
19.12d	6	0.0000	0.0010	0.0000	0.0258	0.0017	0.0046	0.0000	0.0722	0.1054	0.0841	0.0005
19.12d	7	0.0000	0.0010	0.0000	0.0271	0.0018	0.0047	0.0000	0.0597	0.0943	0.0841	0.0001
19.12d	8	0.0000	0.0014	0.0000	0.0259	0.0018	0.0051	0.0000	0.0697	0.1041	0.0841	0.0004
19.12d	9	0.0000	0.0011	0.0000	0.0219	0.0019	0.0047	0.0000	0.0629	0.0925	0.0841	0.0001
19.12d	10	0.0000	0.0012	0.0000	0.0247	0.0019	0.0054	0.0000	0.0731	0.1063	0.0841	0.0005
19.12d	Mean:											0.0006
20.2	1	0.0000	0.0015	0.0000	0.0285	0.0027	0.0068	0.0000	0.0982	0.1376	0.1138	0.0006
20.2	2											
20.2	3	0.0000	0.0021	0.0000	0.0260	0.0027	0.0069	0.0000	0.0755	0.1132	0.1138	0.0000
20.2	4	0.0000	0.0011	0.0000	0.0238	0.0017	0.0048	0.0000	0.0647	0.0961	0.1138	0.0003
20.2	5	0.0000	0.0018	0.0000	0.0214	0.0021	0.0063	0.0000	0.0612	0.0928	0.1138	0.0004
20.2	6	0.0000	0.0021	0.0000	0.0354	0.0026	0.0061	0.0000	0.0753	0.1214	0.1138	0.0001
20.2	7	0.0000	0.0014	0.0000	0.0256	0.0023	0.0064	0.0000	0.0886	0.1243	0.1138	0.0001
20.2	8	0.0000	0.0022	0.0000	0.0192	0.0022	0.0055	0.0000	0.0871	0.1161	0.1138	0.0000
20.2	9	0.0000	0.0013	0.0000	0.0229	0.0023	0.0061	0.0000	0.0748	0.1074	0.1138	0.0000
20.2	10	0.0000	0.0019	0.0000	0.0358	0.0025	0.0060	0.0000	0.0983	0.1446	0.1138	0.0009
20.2	Mean:											0.0003
20.3	1	0.0000	0.0012	0.0000	0.0287	0.0021	0.0057	0.0000	0.0942	0.1318	0.1367	0.0000
20.3	2	0.0000	0.0012	0.0000	0.0289	0.0022	0.0057	0.0000	0.0889	0.1270	0.1367	0.0001
20.3	3	0.0000	0.0013	0.0000	0.0315	0.0023	0.0061	0.0000	0.0981	0.1393	0.1367	0.0000
20.3	4	0.0000	0.0013	0.0000	0.0298	0.0023	0.0056	0.0000	0.0817	0.1207	0.1367	0.0003
20.3	5	0.0000	0.0018	0.0000	0.0284	0.0024	0.0058	0.0000	0.0971	0.1356	0.1367	0.0000
20.3	6	0.0000	0.0012	0.0000	0.0304	0.0023	0.0054	0.0000	0.0874	0.1268	0.1367	0.0001
20.3	7	0.0000	0.0015	0.0000	0.0241	0.0021	0.0047	0.0000	0.0806	0.1130	0.1367	0.0006
20.3	8											
20.3	9	0.0000	0.0015	0.0000	0.0265	0.0022	0.0058	0.0000	0.0859	0.1219	0.1367	0.0002
20.3	10	0.0000	0.0015	0.0000	0.0360	0.0027	0.0063	0.0000	0.1163	0.1629	0.1367	0.0007
20.3	Mean:											0.0002

Table 2.1.21 (page 1 of 4). Model-specific scaled histograms and performance-weighted average *pmf*s for each pivot model.

	Pivot model = 19.12a									Pivot model = 19.12b								
OFL	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	WtAve	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	WtAve
0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.030	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.035	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.050	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.055	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.060	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.065	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.070	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.075	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.080	0	0	0	0.125	0	0	0	0.125	0.116	0	0	0	0	0	0	0	0	0
0.085	0	0.125	0	0	0	0	0	0.125	0.087	0	0	0	0	0	0	0	0	0
0.090	0	0	0	0.125	0	0	0	0.125	0.116	0	0.111	0	0	0	0.111	0	0	0.008
0.095	0	0	0	0	0	0	0	0.125	0.085	0	0.111	0	0.111	0	0	0	0	0.028
0.100	0	0	0	0	0	0	0	0.250	0.171	0	0	0	0	0	0.111	0	0.111	0.083
0.105	0	0	0	0	0	0	0	0	0	0	0.111	0	0.111	0	0	0	0	0.028
0.110	0	0	0	0.125	0	0	0	0	0.030	0	0.222	0	0	0	0.333	0	0	0.023
0.115	0	0	0	0.125	0	0	0.125	0.125	0.116	0	0.111	0	0.222	0	0.111	0	0.111	0.138
0.120	0	0	0	0	0	0	0.250	0	0.000	0	0.111	0	0.111	0	0	0	0.333	0.256
0.125	0.125	0	0	0	0.125	0	0.250	0.125	0.086	0	0.111	0	0.111	0.111	0.333	0	0.111	0.125
0.130	0.125	0	0	0	0	0	0.125	0	0.000	0	0.111	0	0.111	0	0	0	0	0.028
0.135	0.125	0	0	0.125	0.125	0	0	0	0.030	0	0	0	0	0	0	0	0	0
0.140	0.125	0	0	0	0.250	0	0.125	0	0.000	0.111	0	0	0	0	0	0	0.111	0.076
0.145	0.250	0	0	0	0	0	0	0	0.000	0	0	0	0	0	0	0	0	0
0.150	0	0	0	0	0.250	0	0	0	0.000	0.111	0	0.111	0.111	0.111	0	0.111	0	0.027
0.155	0.125	0	0	0	0	0	0.125	0	0.000	0	0	0.222	0	0.222	0	0	0	0.000
0.160	0	0	0	0.125	0.125	0	0	0	0.030	0	0	0	0	0.222	0	0	0.111	0.076
0.165	0	0	0.125	0	0	0	0	0	0.000	0	0	0.111	0	0	0	0.111	0	0.000
0.170	0	0	0.125	0.125	0	0	0	0	0.030	0.222	0	0.111	0	0.111	0	0	0	0.000
0.175	0.125	0	0.125	0.125	0	0	0	0	0.030	0.111	0	0.333	0	0	0	0.222	0	0.000
0.180	0	0	0	0	0	0	0	0	0	0.111	0	0	0	0.111	0	0.222	0	0.000
0.185	0	0	0.250	0	0.125	0	0	0	0.000	0	0	0	0	0	0	0	0	0
0.190	0	0	0.125	0	0	0	0	0	0.000	0.222	0	0	0	0.111	0	0.111	0	0.000
0.195	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.111	0	0.000
0.200	0	0	0.125	0	0	0	0	0	0.000	0	0	0.111	0	0	0	0	0	0.000
> 0.2	0	0.875	0.125	0	0	1.000	0	0	0.071	0.111	0	0	0.111	0	0	0.111	0.111	0.103

Table 2.1.21 (page 2 of 4). Model-specific scaled histograms and performance-weighted average *pmf*s for each pivot model.

	Pivot model = 20.1									Pivot model = 19.12c								
OFL	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	WtAve	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	WtAve
0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.030	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.035	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.050	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.055	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.060	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.065	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.100	0	0	0.006
0.070	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.075	0	0	0	0	0	0	0	0	0	0	0.100	0	0.100	0	0	0	0	0.026
0.080	0	0	0	0	0	0	0	0	0	0	0.100	0	0	0	0.400	0	0.100	0.094
0.085	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.200	0.100	0	0.012
0.090	0	0	0	0	0	0	0	0	0	0	0.200	0	0	0	0.100	0	0	0.008
0.095	0	0	0	0	0	0.100	0	0	0.006	0	0	0	0.200	0	0.100	0	0.100	0.123
0.100	0	0.200	0	0	0	0.200	0	0	0.014	0	0.100	0	0	0	0.100	0.100	0.200	0.144
0.105	0	0.100	0	0	0	0.100	0	0	0.007	0	0.100	0	0.200	0	0	0.200	0	0.050
0.110	0	0.300	0	0	0	0.100	0	0	0.010	0	0.100	0	0	0	0	0.300	0.300	0.206
0.115	0	0.200	0.100	0	0	0.300	0	0	0.021	0	0	0	0.100	0.100	0	0.200	0	0.024
0.120	0	0.200	0	0	0	0.100	0	0.100	0.077	0.200	0	0.100	0.200	0.100	0	0	0.300	0.254
0.125	0	0	0	0.100	0	0.100	0	0	0.030	0	0	0	0.200	0	0	0.100	0	0.049
0.130	0	0	0	0	0	0	0.100	0.100	0.068	0	0.100	0	0	0	0	0	0	0.001
0.135	0	0	0.100	0	0.100	0	0.100	0	0.000	0	0	0	0	0.300	0	0	0	0.000
0.140	0	0	0.300	0.100	0	0	0	0	0.024	0	0	0.100	0	0.100	0	0	0	0.000
0.145	0.100	0	0.100	0	0.200	0	0.200	0.100	0.068	0.300	0.100	0.200	0	0.100	0	0	0	0.001
0.150	0.100	0	0.100	0.100	0.100	0	0.200	0.100	0.093	0.200	0	0.100	0	0	0	0	0	0.000
0.155	0.100	0	0.300	0.200	0	0	0	0.100	0.117	0.100	0	0	0	0.200	0	0	0	0.000
0.160	0	0	0	0.100	0.200	0	0.200	0.100	0.093	0	0	0	0	0	0	0	0	0
0.165	0.100	0	0	0.100	0.100	0	0.200	0.100	0.093	0.100	0.100	0	0	0	0	0	0	0.001
0.170	0.200	0	0	0	0.200	0	0	0	0.000	0	0	0	0	0.100	0	0	0	0.000
0.175	0.100	0	0	0	0.100	0	0	0	0.000	0	0	0	0	0	0	0	0	0
0.180	0.100	0	0	0	0	0	0	0.100	0.068	0.100	0	0.100	0	0	0	0	0	0.000
0.185	0.100	0	0	0.100	0	0	0	0	0.024	0	0	0	0	0	0	0	0	0
0.190	0	0	0	0	0	0	0	0.100	0.068	0	0	0	0	0	0	0	0	0
0.195	0	0	0	0.100	0	0	0	0	0.024	0	0	0.100	0	0	0	0	0	0.000
0.200	0	0	0	0.100	0	0	0	0	0.024	0	0	0	0	0	0	0	0	0
> 0.2	0.100	0	0	0	0	0	0	0.100	0.068	0	0	0.300	0	0	0	0	0	0

Table 2.1.21 (page 3 of 4). Model-specific scaled histograms and performance-weighted average *pmf*s for each pivot model.

	Pivot model = 19.12									Pivot model = 19.12d								
OFL	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	WtAve	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	WtAve
0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.030	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.035	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.050	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.055	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.060	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.065	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.070	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.075	0	0	0	0	0	0	0	0.100	0.068	0	0	0	0	0	0.200	0	0	0.012
0.080	0	0	0	0.100	0	0	0	0.100	0.093	0	0	0	0	0	0.200	0	0.100	0.080
0.085	0	0	0	0.100	0	0	0	0	0.024	0	0	0	0.100	0	0.400	0	0	0.049
0.090	0	0	0	0	0	0	0	0.200	0.137	0	0.300	0	0.100	0	0.100	0	0.100	0.102
0.095	0	0	0	0	0	0	0	0.100	0.068	0	0.200	0	0	0	0.100	0	0.100	0.077
0.100	0	0	0	0.100	0	0	0	0.100	0.093	0	0.100	0	0.100	0	0	0	0.100	0.094
0.105	0	0	0	0	0	0	0.200	0.100	0.068	0	0.200	0	0.100	0	0	0	0.300	0.232
0.110	0	0	0	0	0	0	0.200	0	0.000	0	0.100	0	0.200	0	0	0.400	0.100	0.118
0.115	0.300	0	0	0.100	0.200	0	0.100	0.100	0.093	0	0	0	0.100	0.100	0	0.100	0.100	0.093
0.120	0.100	0	0	0	0	0	0.100	0	0.000	0.100	0	0	0	0	0	0.100	0	0.000
0.125	0	0	0	0.100	0.100	0	0.100	0.100	0.093	0.100	0.100	0	0	0.100	0	0	0	0.001
0.130	0.100	0	0.100	0.100	0.200	0	0	0	0.024	0.200	0	0	0	0.300	0	0.100	0.100	0.068
0.135	0.100	0	0	0.200	0	0	0.100	0	0.049	0.400	0	0	0	0.200	0	0.100	0	0.000
0.140	0.200	0	0	0.100	0.100	0	0	0	0.024	0	0	0	0	0.100	0	0.100	0	0.000
0.145	0	0	0	0	0	0	0.200	0	0.000	0.100	0	0	0.100	0.100	0	0	0	0.024
0.150	0	0	0	0	0	0	0	0	0	0	0	0	0	0.100	0	0	0	0.000
0.155	0	0	0	0.100	0.200	0	0	0.100	0.093	0.100	0	0	0	0	0	0	0	0.000
0.160	0.100	0	0.100	0	0	0	0	0	0.000	0	0	0.200	0.100	0	0	0.100	0	0.024
0.165	0.100	0	0.100	0	0.100	0	0	0	0.000	0	0	0	0	0	0	0	0	0
0.170	0	0	0.100	0	0.100	0	0	0	0.000	0	0	0.200	0	0	0	0	0	0.000
0.175	0	0	0	0	0	0	0	0	0	0	0	0.100	0	0	0	0	0	0.000
0.180	0	0	0.100	0	0	0	0	0	0.000	0	0	0	0	0	0	0	0	0
0.185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.190	0	0	0.500	0	0	0	0	0	0.000	0	0	0.200	0	0	0	0	0	0.000
0.195	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
> 0.2	0	1.000	0	0	0	1.000	0	0	0.072	0	0	0.300	0.100	0	0	0	0	0.024

Table 2.1.21 (page 4 of 4). Model-specific scaled histograms and performance-weighted average *pmf*s for each pivot model.

	Pivot model = 20.2									Pivot model = 20.3								
OFL	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	WtAve	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	WtAve
0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.030	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.035	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.050	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.055	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.060	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.065	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.070	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.075	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.080	0	0	0	0.111	0	0.111	0	0	0.034	0	0	0	0	0	0.111	0	0	0.007
0.085	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.090	0	0.111	0	0.111	0	0.111	0.111	0.111	0.111	0	0	0	0	0	0.111	0	0	0.007
0.095	0	0	0	0.111	0	0	0	0.111	0.103	0	0	0	0	0	0.556	0	0	0.034
0.100	0	0	0	0.111	0	0.333	0.111	0	0.047	0	0.111	0	0.111	0	0.111	0.111	0	0.035
0.105	0	0	0	0.111	0	0.222	0.222	0	0.041	0	0.222	0	0	0	0.111	0.111	0	0.009
0.110	0	0.111	0	0.111	0	0	0.111	0.333	0.256	0	0.111	0	0.111	0	0	0.111	0	0.028
0.115	0.111	0	0	0	0	0.222	0.111	0	0.013	0	0.111	0	0	0	0	0	0	0.001
0.120	0	0.111	0	0.111	0.111	0	0.111	0	0.028	0	0	0	0.333	0	0	0.333	0.222	0.233
0.125	0	0	0	0	0	0	0	0	0	0	0.111	0	0.222	0	0	0.222	0.111	0.131
0.130	0	0.111	0	0	0	0	0	0.222	0.153	0	0.222	0	0.111	0	0	0	0.222	0.182
0.135	0	0	0	0	0	0	0.111	0	0.000	0.111	0	0	0	0	0	0.111	0	0.000
0.140	0	0	0	0	0	0	0	0	0	0.111	0	0	0	0	0	0	0.111	0.076
0.145	0.111	0	0.111	0	0	0	0	0.222	0.152	0	0	0	0	0.222	0	0	0.222	0.152
0.150	0.111	0.111	0	0.222	0.222	0	0.111	0	0.055	0	0	0	0.111	0	0	0	0	0.027
0.155	0.111	0	0.111	0	0	0	0	0	0.000	0.111	0.111	0.111	0	0.222	0	0	0	0.001
0.160	0	0	0	0	0.111	0	0	0	0.000	0.111	0	0.222	0	0.222	0	0	0	0.000
0.165	0	0.111	0	0	0.111	0	0	0	0.001	0.111	0	0	0	0.111	0	0	0	0.000
0.170	0	0	0.111	0	0	0	0	0	0.000	0.222	0	0	0	0.111	0	0	0.111	0.076
0.175	0.222	0.222	0	0	0.111	0	0	0	0.003	0	0	0.111	0	0	0	0	0	0.000
0.180	0.222	0	0	0	0.111	0	0	0	0.000	0.111	0	0	0	0	0	0	0	0.000
0.185	0	0	0.111	0	0	0	0	0	0.000	0	0	0	0	0	0	0	0	0
0.190	0.111	0.111	0	0	0.222	0	0	0	0.001	0	0	0	0	0.111	0	0	0	0.000
0.195	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.200	0	0	0	0	0	0	0	0	0	0.111	0	0	0	0	0	0	0	0.000
> 0.2	0	0	0.556	0	0	0	0	0	0	0	0	0.556	0	0	0	0	0	0

Figures

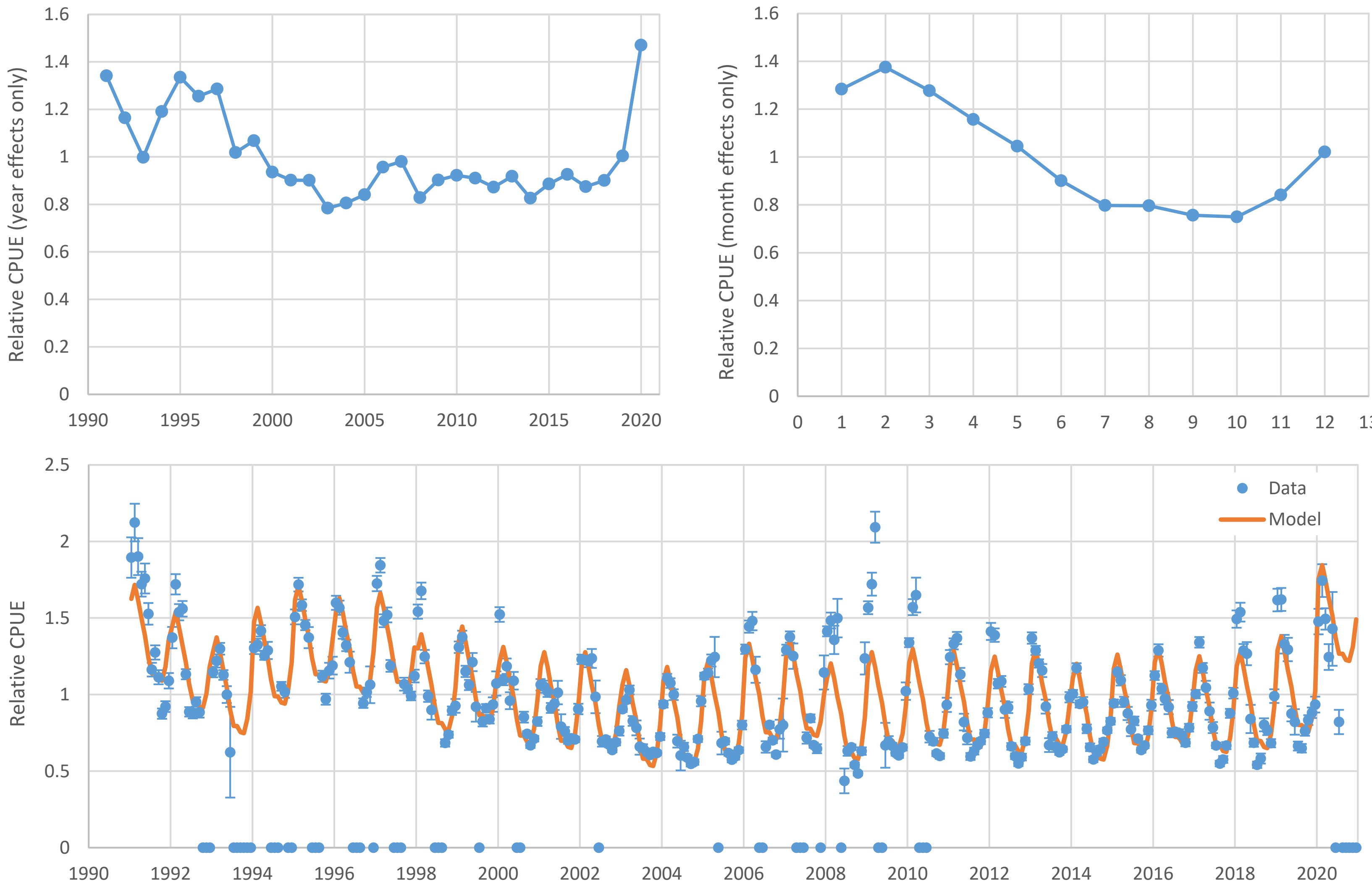

Figure 2.1.1. Estimates of longline fishery CPUE “year effects” and “month effects” (top), and overall model fit to data (bottom).

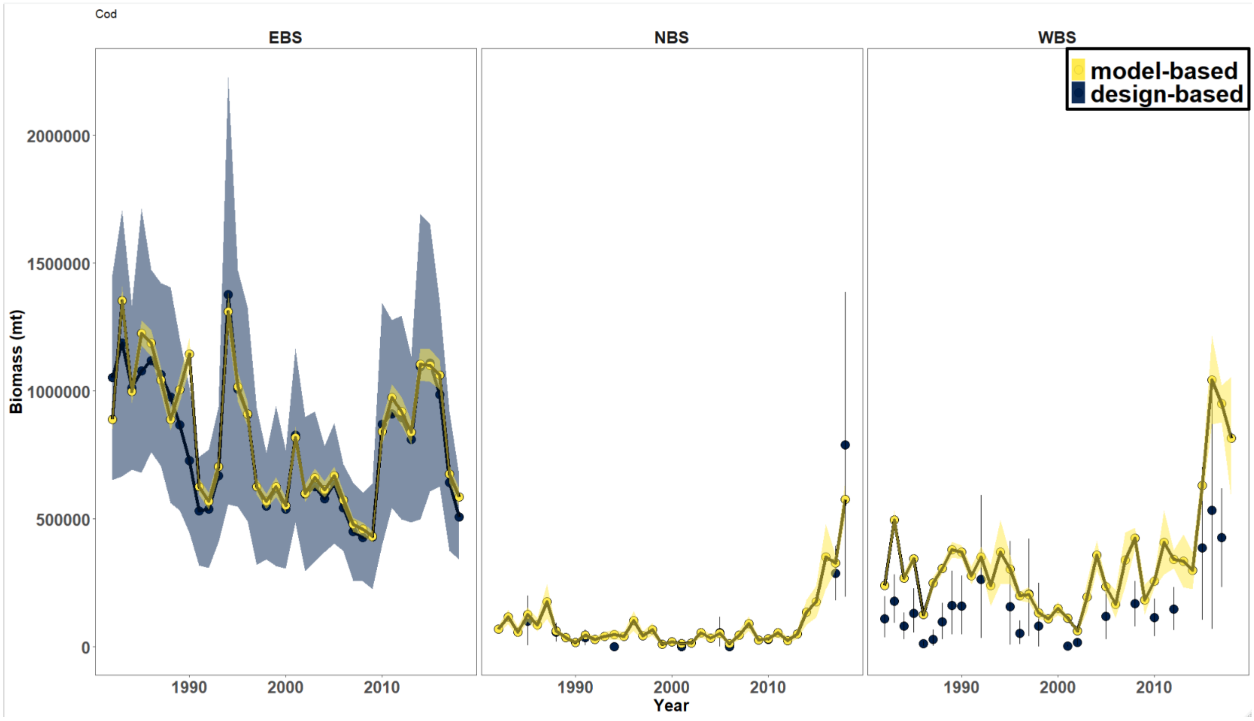

Figure 2.1.2. Comparison of model-based indices (yellow) to area-swept (design-based) biomass indices (blue) for Pacific cod in the EBS, NBS, and WBS.

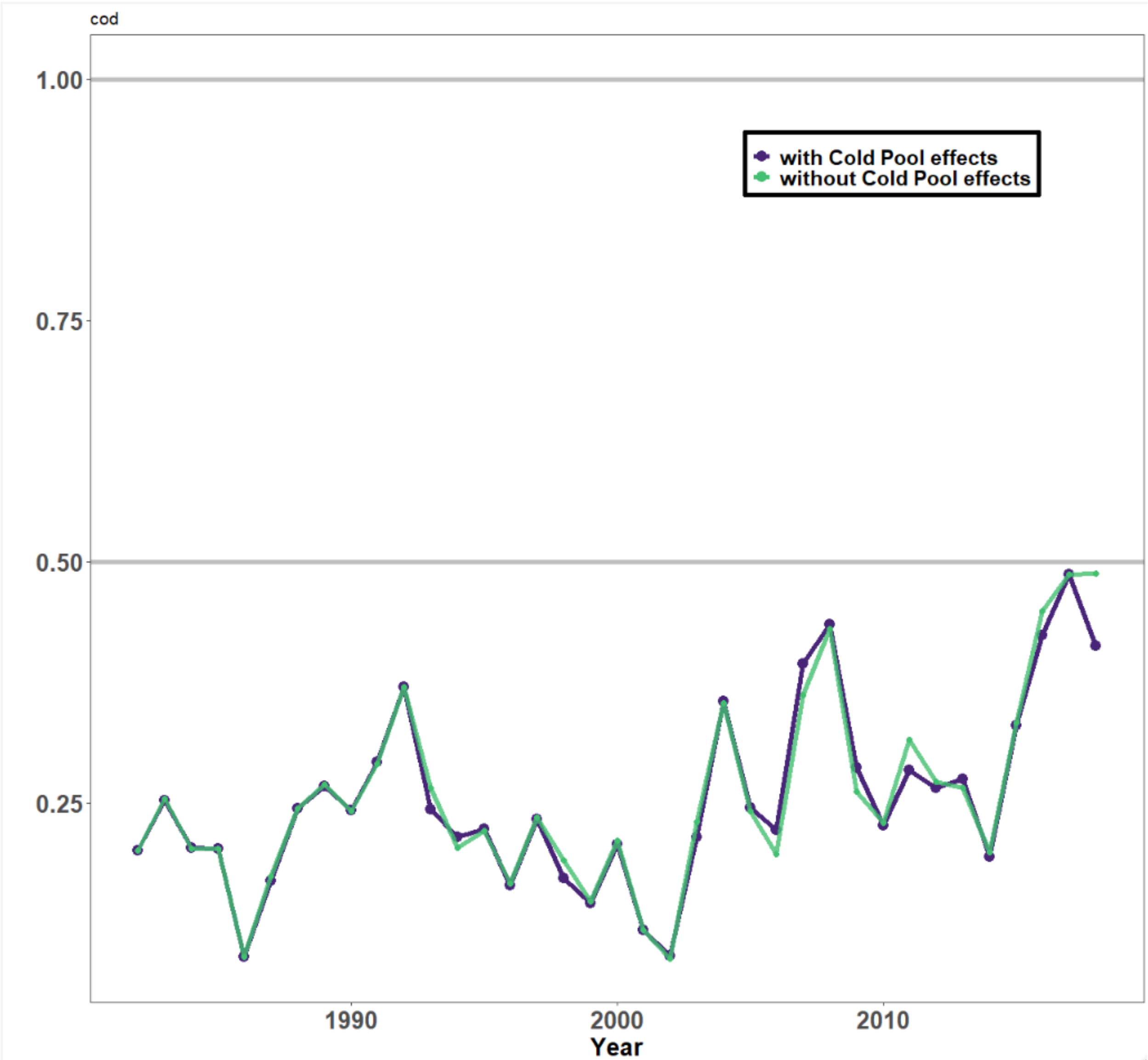

Figure 2.1.3. Proportion of Pacific cod stock in the western Bering Sea (WBS) relative to the entire Bering Sea region (EBS + NBS + WBS) based on explored model-based biomass indices.

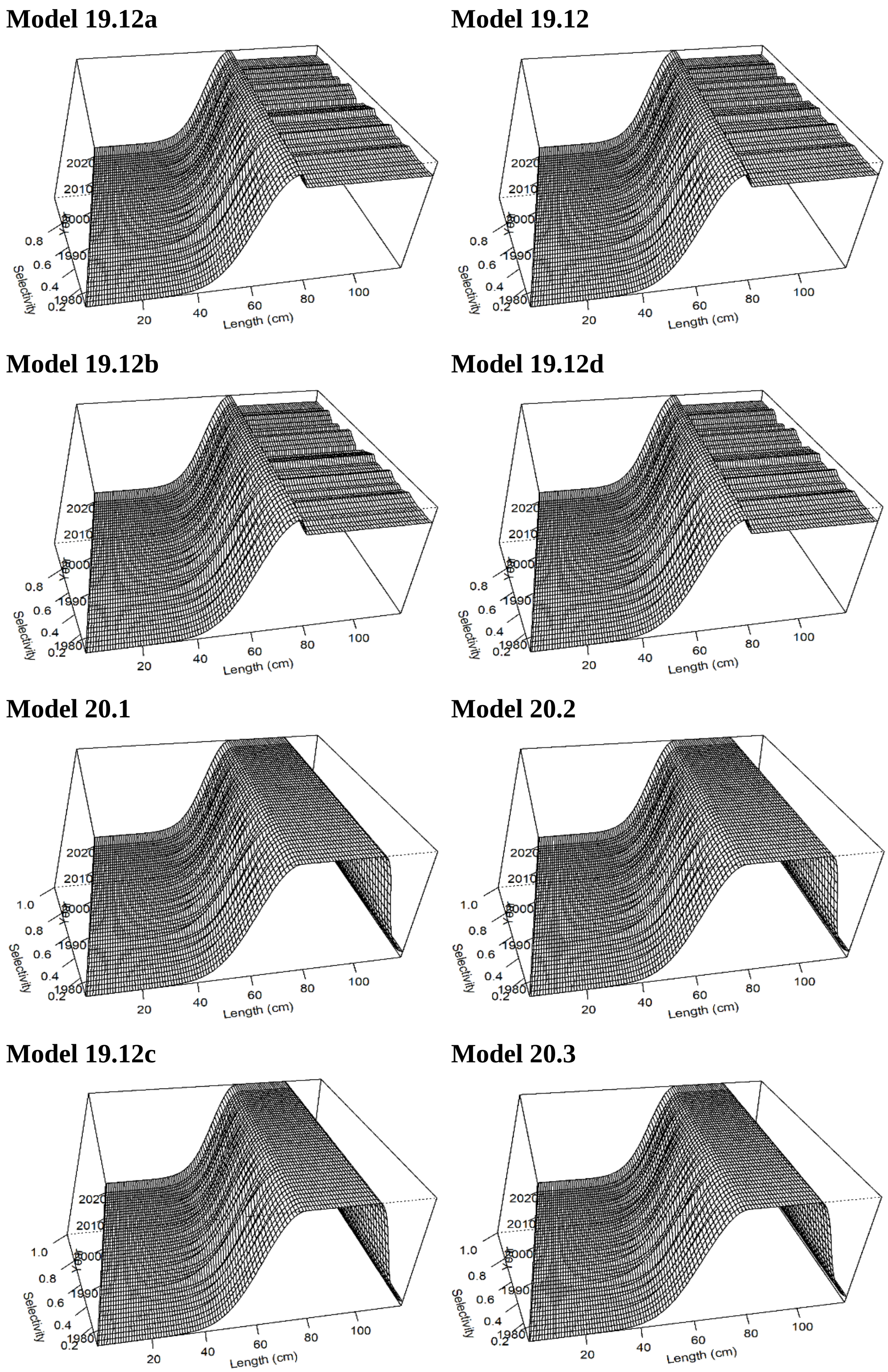

Figure 2.1.4a. Fishery selectivity in the “main” area (EBS or combined EBS and NBS).

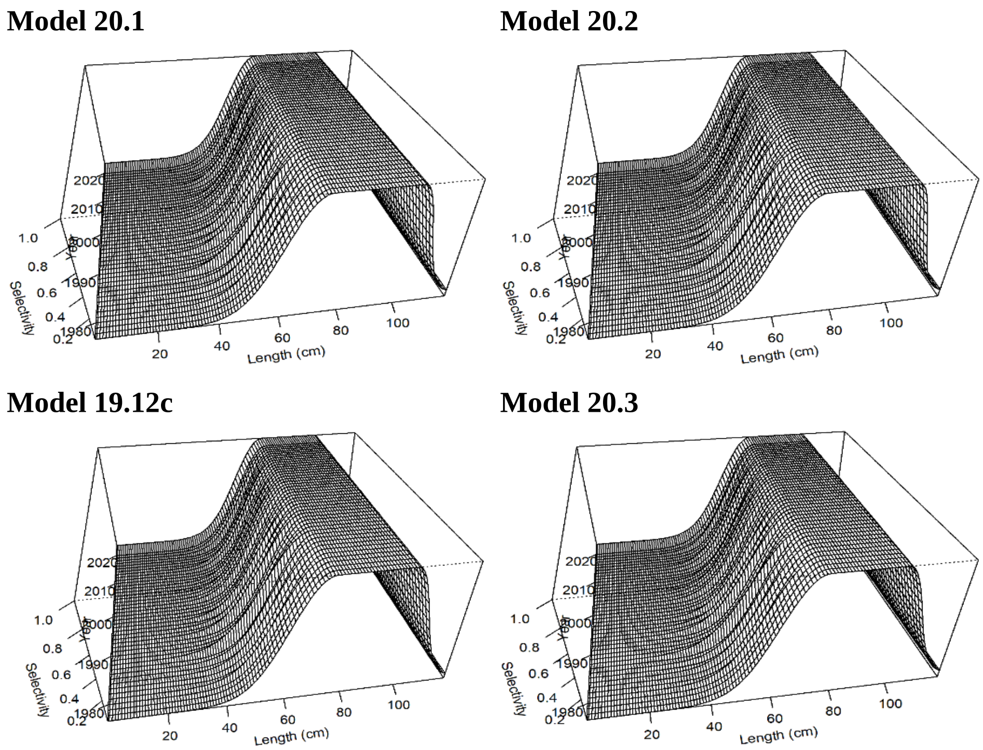

Figure 2.1.4b. Fishery selectivity in the NBS.

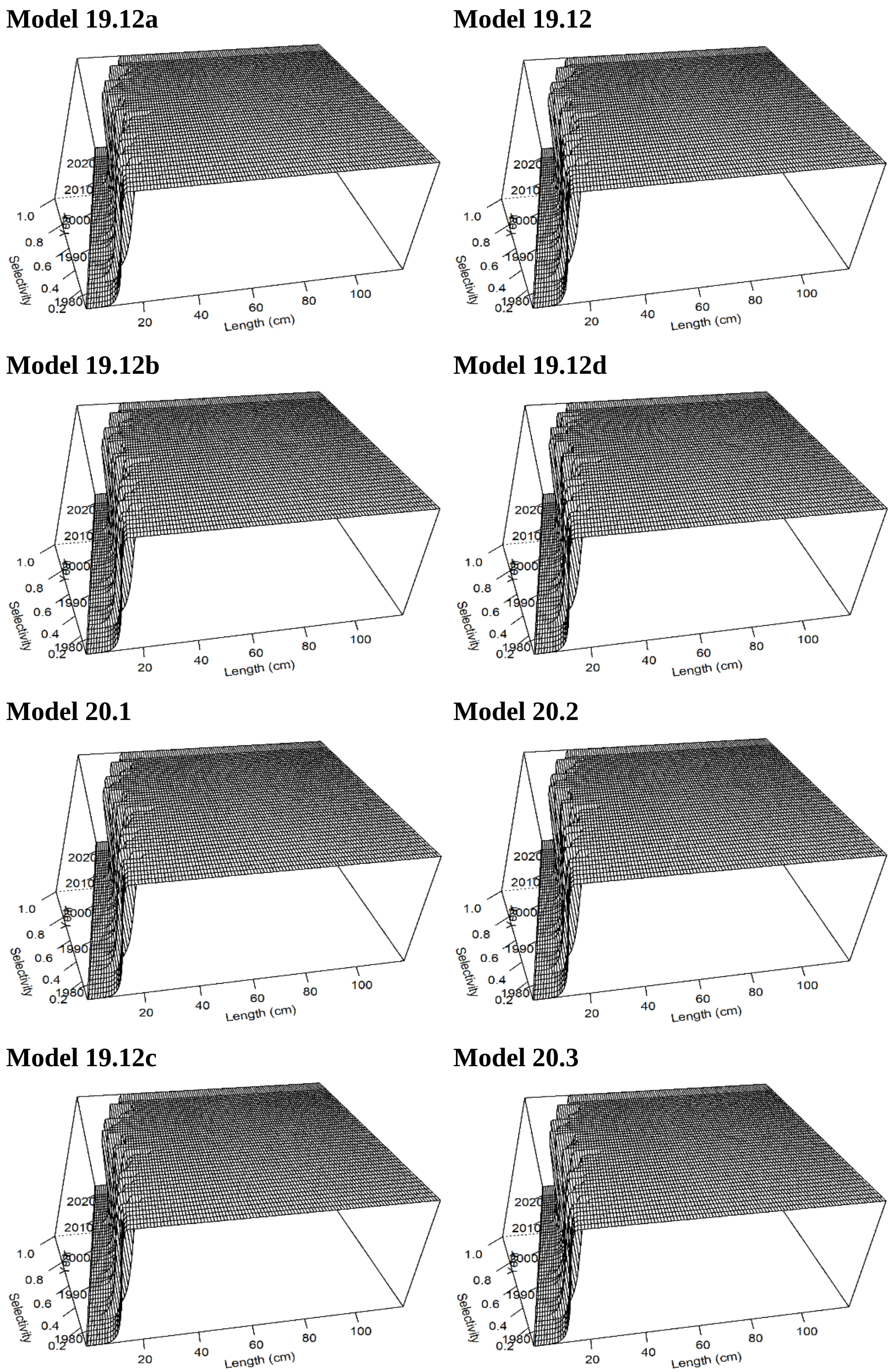

Figure 2.1.4c. Survey selectivity in the “main” area (EBS or combined EBS and NBS).

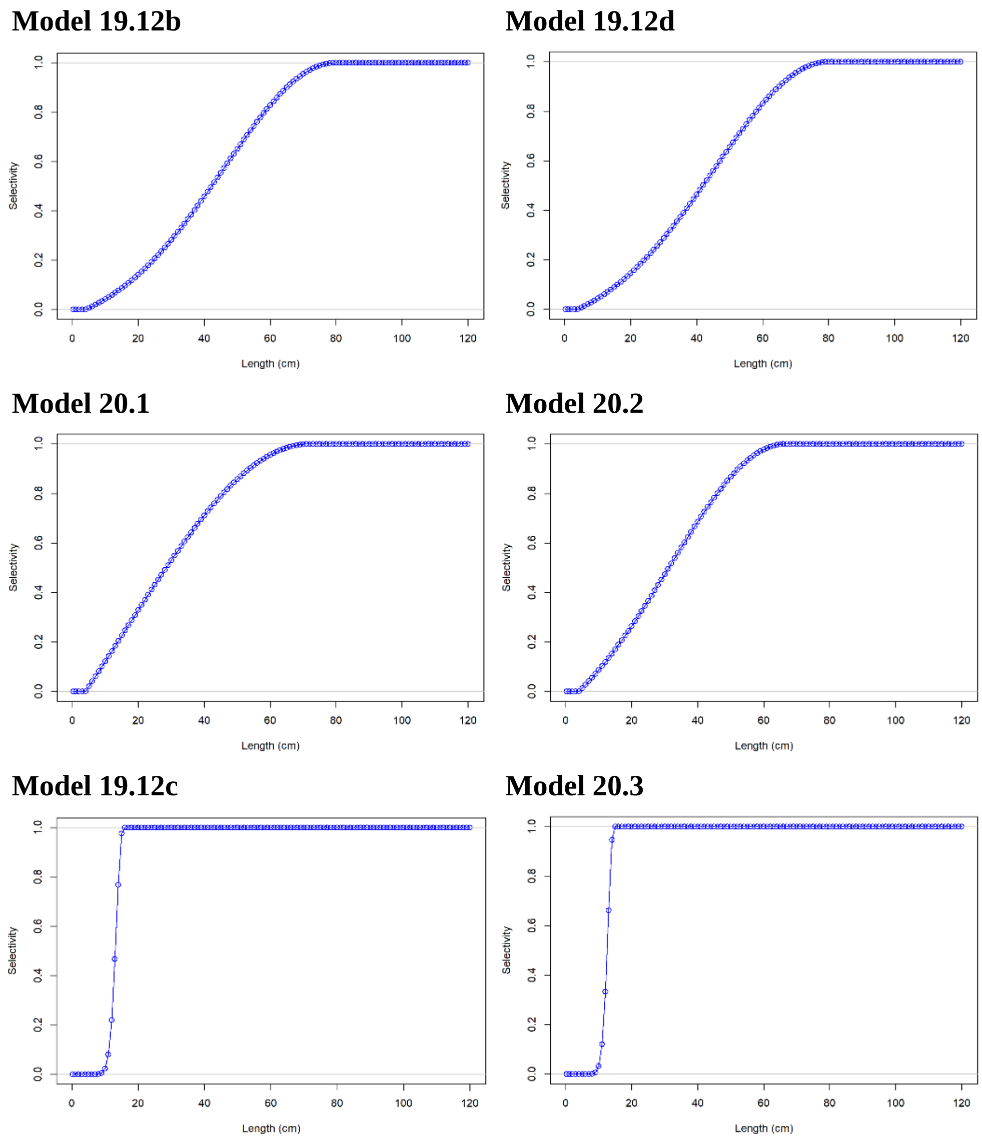

Figure 2.1.4d. Survey selectivity in the NBS.

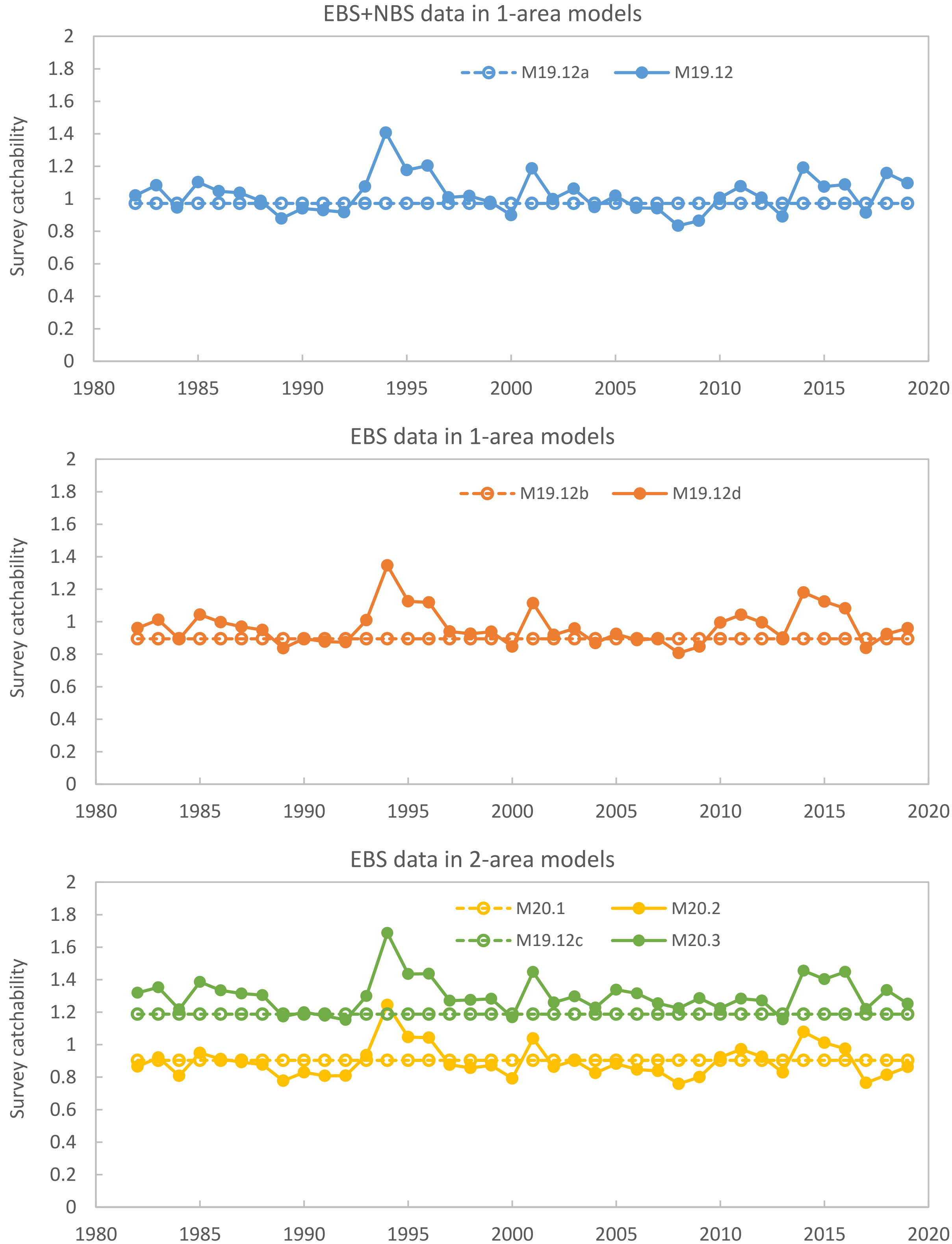

Figure 2.1.5a. Catchability in the “main” survey area (EBS or combined EBS and NBS).

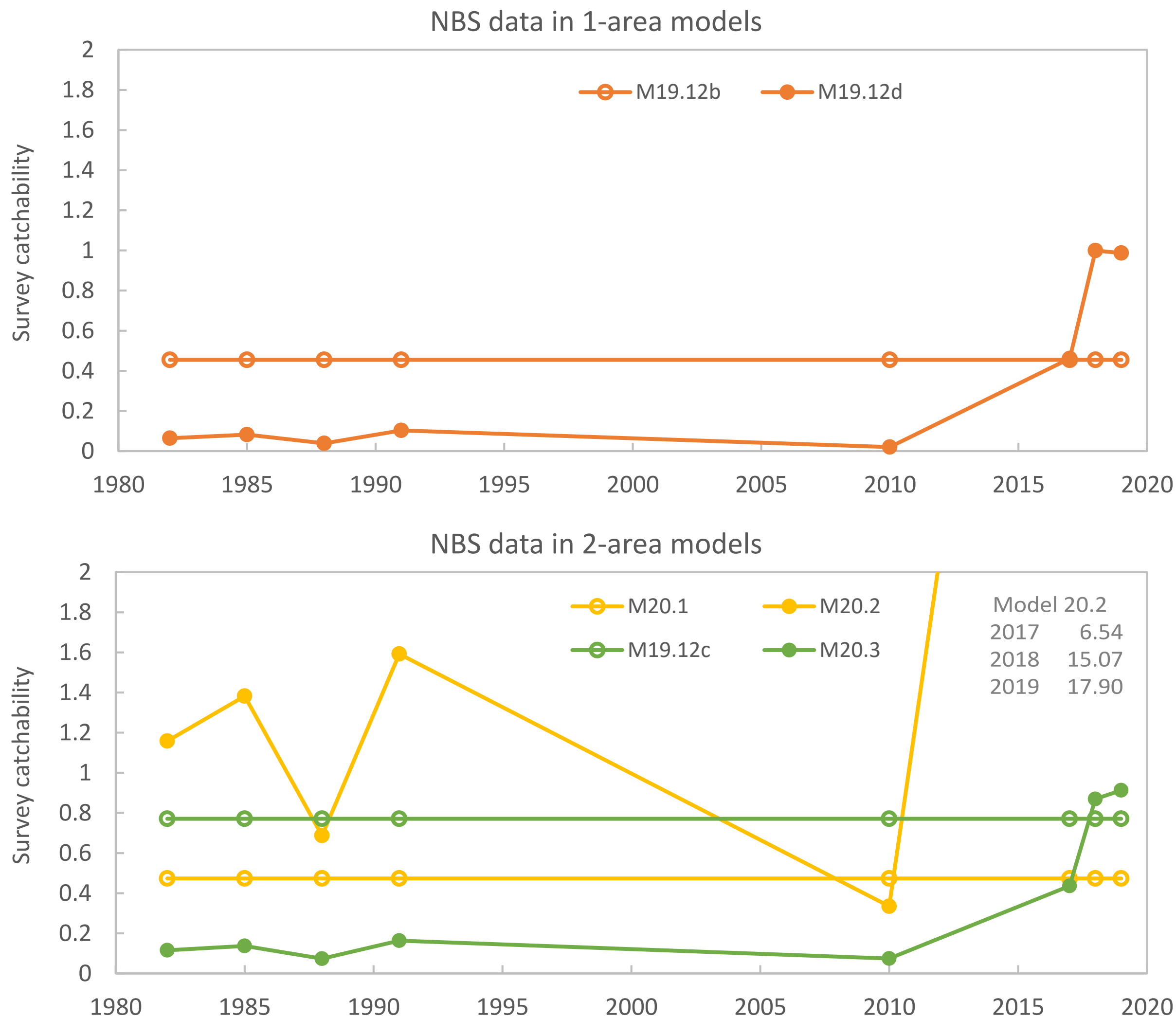

Figure 2.1.5b. Catchability in the NBS survey area.

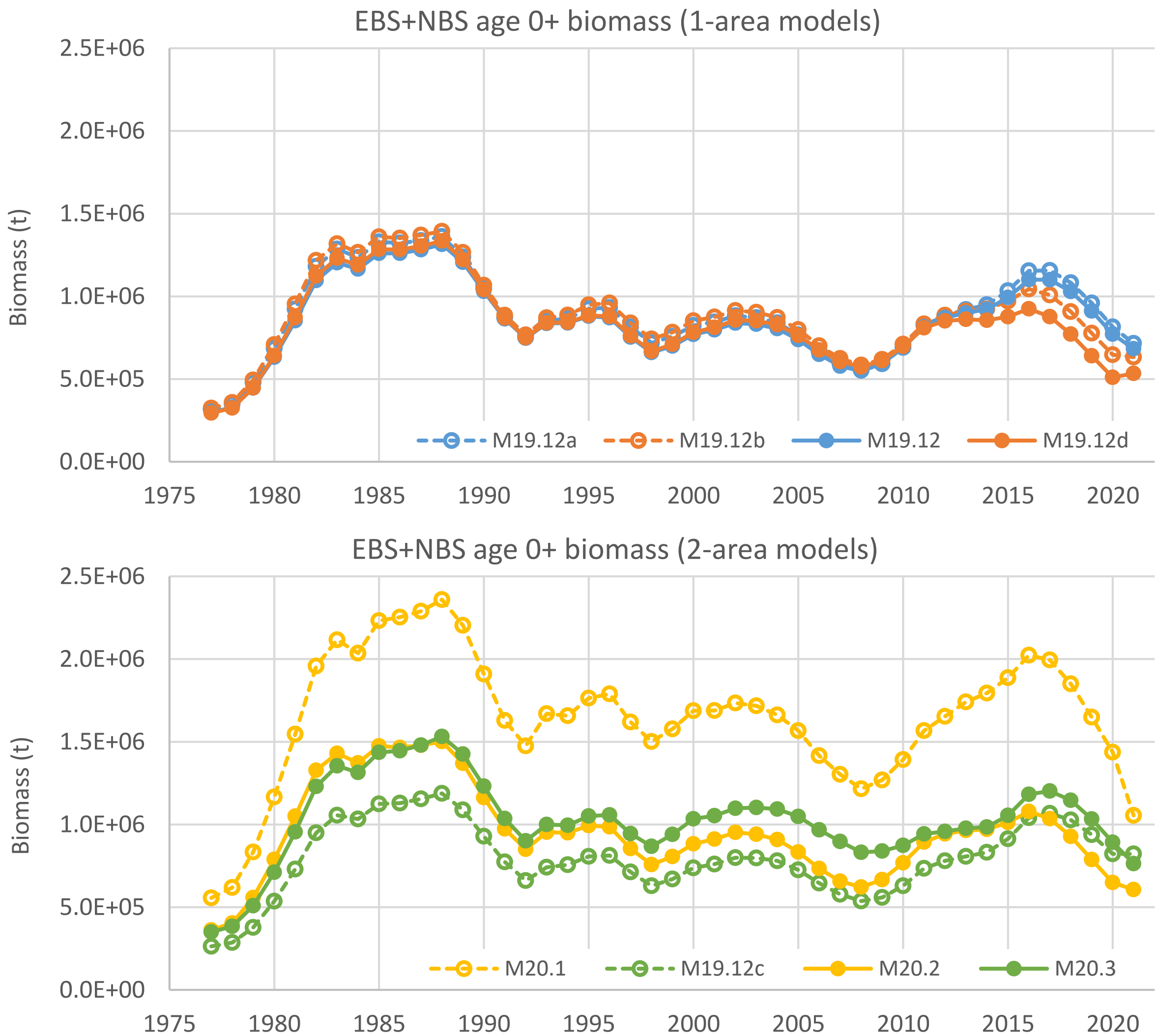

Figure 2.1.6a. Combined area age 0+ biomass (t).

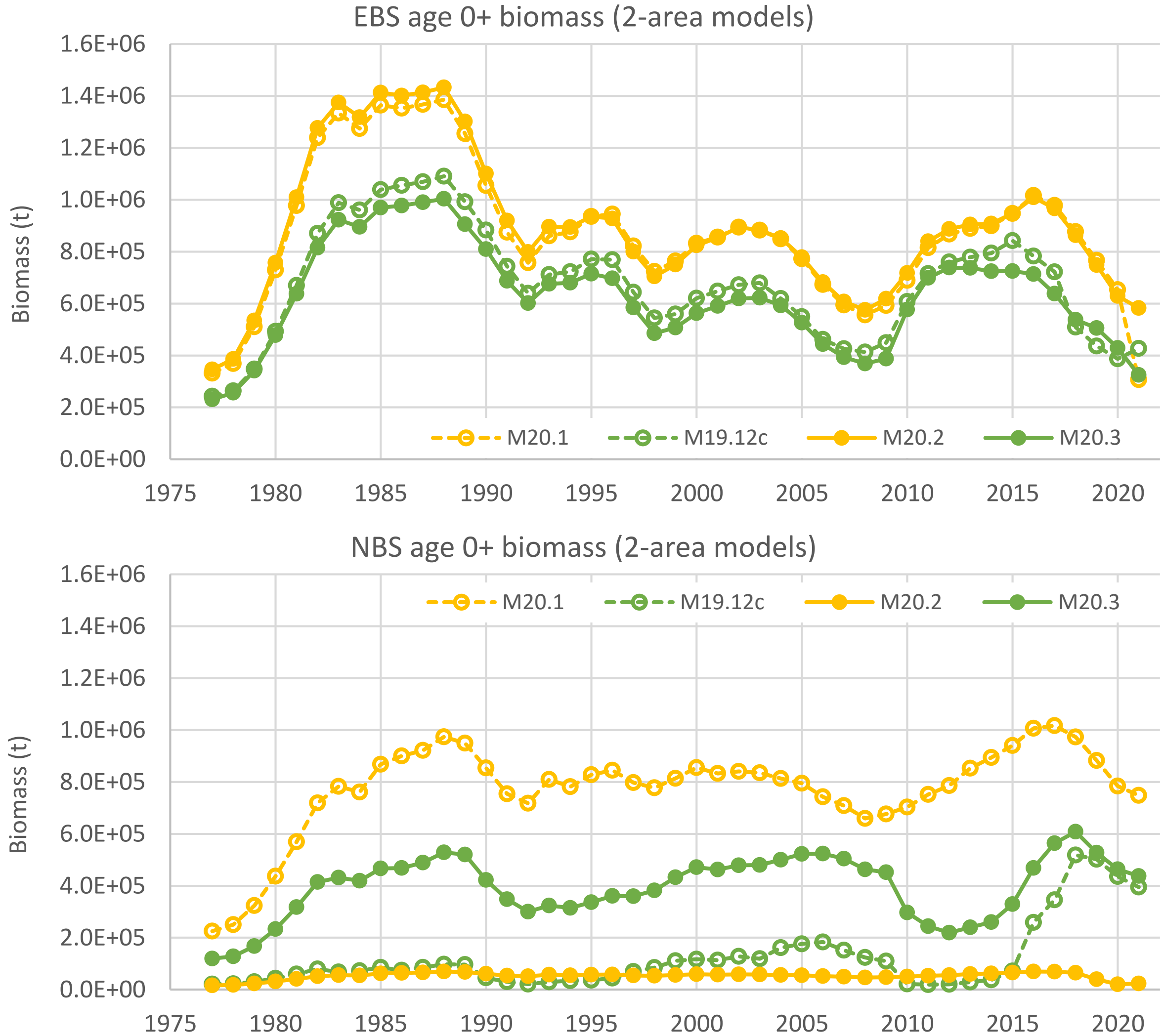

Figure 2.1.6b. Area-specific age 0+ biomass (t), 2-area models only.

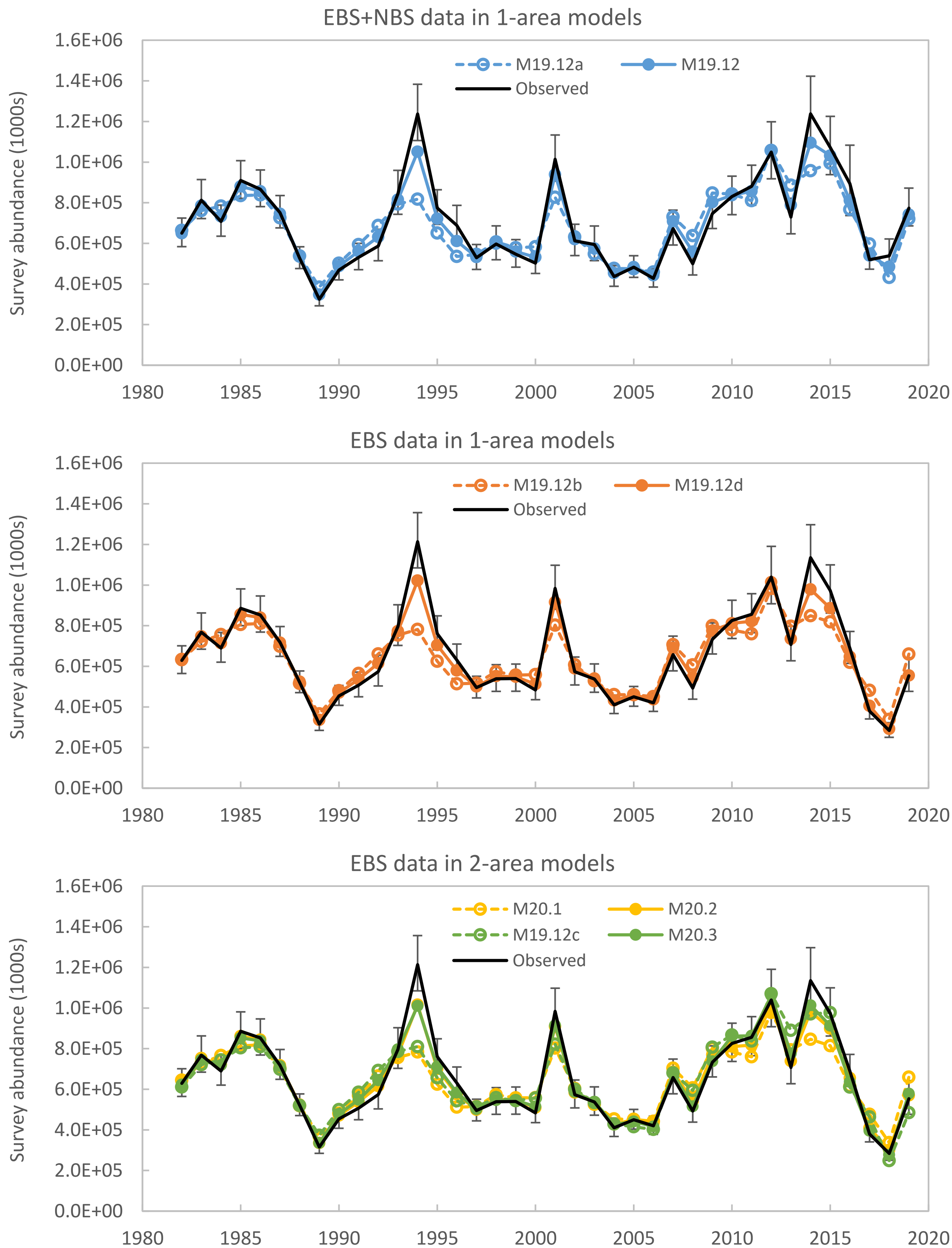

Figure 2.1.7a. Model fits to the “main” survey index time series (EBS or combined EBS and NBS).

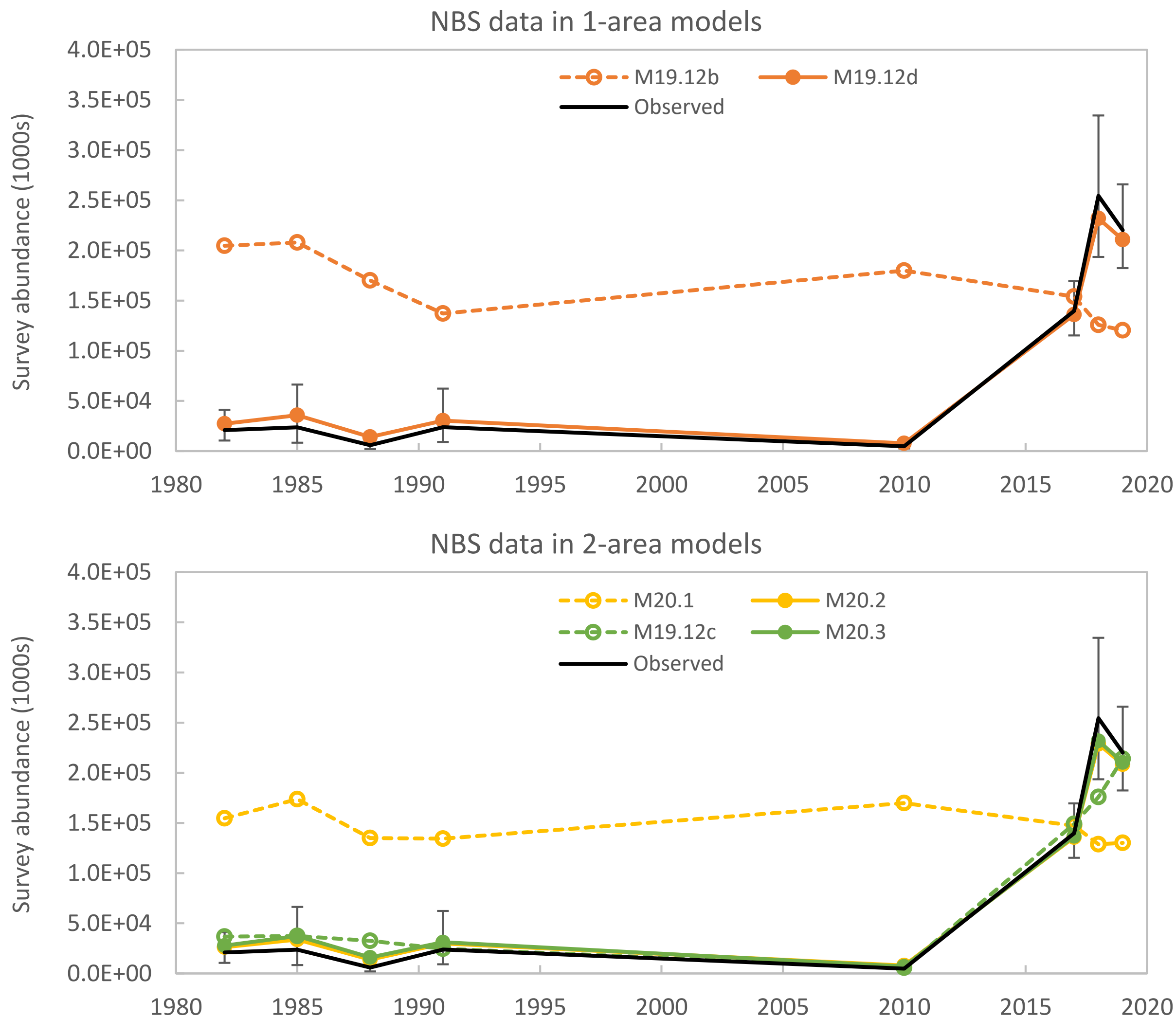

Figure 2.1.7b. Model fits to the NBS survey index time series.

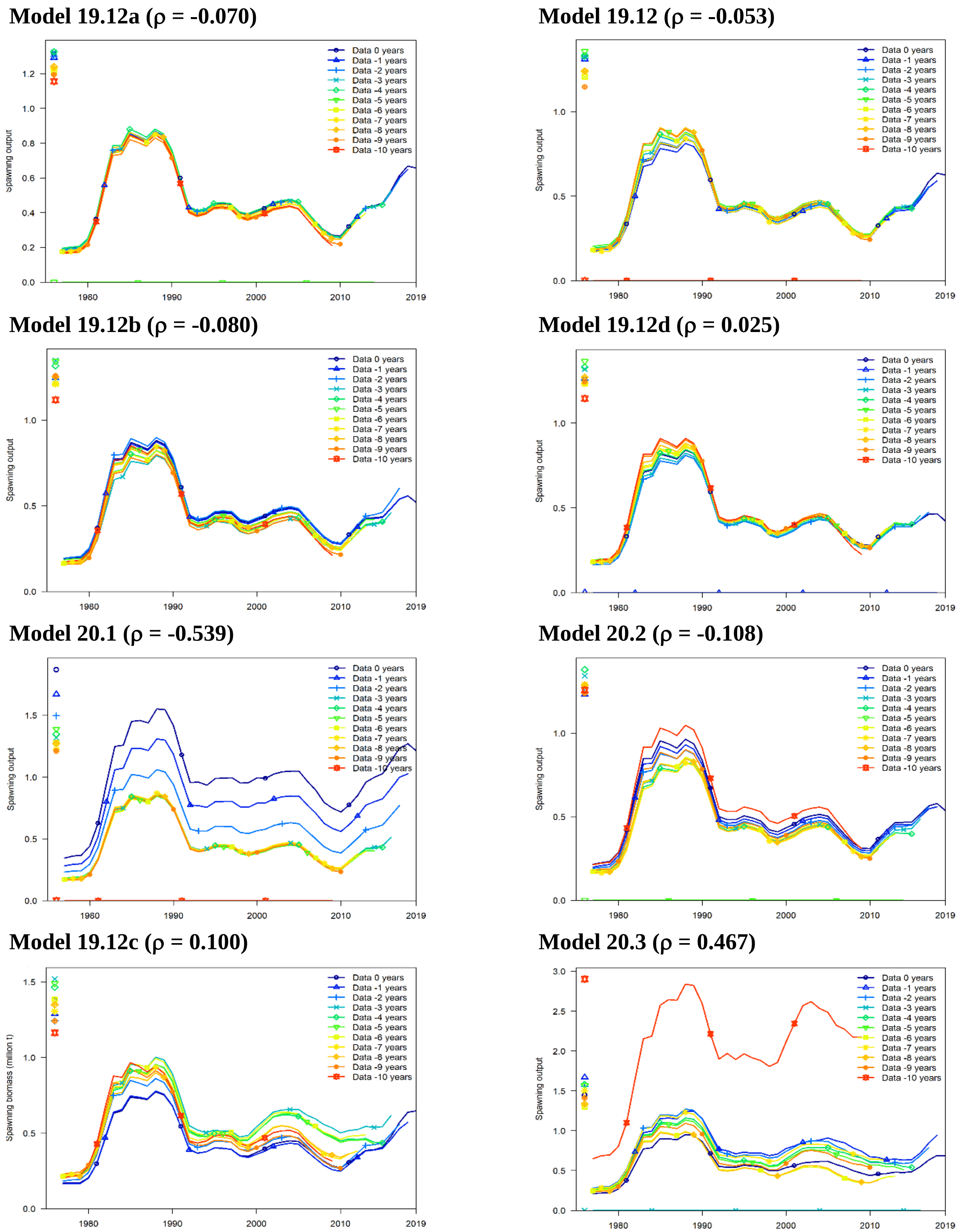

Figure 2.1.8. Retrospective analyses.

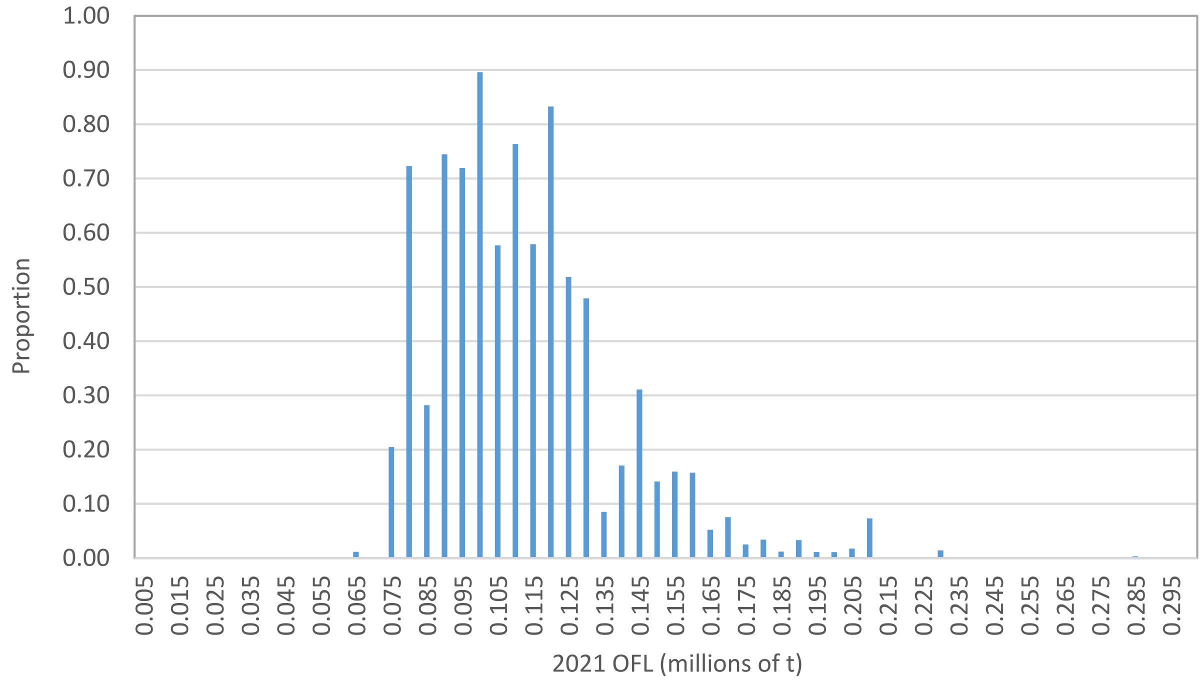

Figure 2.1.9. Probability mass function (pmf) of 2021 OFL (millions of t) from CCDA.

Attachment 2.1.1: Parameterization of two-area movement in Stock Synthesis

Parameterization of movement in SS is somewhat complicated, even for a model with only two areas.

First, three critical ages need to be identified:

- The first age at which movement is allowed, *first_move_age*.
- The ages associated with the endpoints *endp*={1,2} of a linear ramp.
    - Let the age for *endp*=1 be labeled *beg_ramp*, and
    - let the age for *endp*=2 be labeled *end_ramp*.

Second, it is necessary to specify or estimate a vector four parameters, two of which (*move_1to2_A* and *move_1to2_B*) relate to movement from area 1 to area 2 an two of which (*move_2to1_A* and *move_2to1_B*) relate to movement from area 2 to 1.

Third, define a matrix-valued vector **p**, where:

$$p_1 = \begin{bmatrix} 0 & 0 \\ move\_1to2\_A & move\_1to2\_B \end{bmatrix} \text{ and } p_2 = \begin{bmatrix} 0 & 0 \\ move\_2to1\_A & move\_2to1\_B \end{bmatrix}.$$

Fourth, define **Ramp** as a matrix-valued function of age, where, for each combination of source area *sorc*={1,2} and destination area *dest*={1,2}:

$$ramp_{dest,sorc} = q_{dest,1} + \left(\frac{age - beg\_ramp}{end\_ramp - beg\_ramp}\right)\left(q_{dest,2} - q_{dest,1}\right) \text{, where } \mathbf{Q} = p_{sorc}\,.$$

The functions $ramp(age)_{1,sorc}$ return a value of 0 for all values of *age* and each value of *sorc*={1,2}. The functions $ramp(age)_{2,sorc}$ return a line passing through the points {*beg_ramp*, $q_{2,1}$} and {*end_ramp*, $q_{2,2}$} for all values of *age* and each value of *sorc*={1,2}, where **Q** = p_{sorc} in all cases.

Fifth, define a matrix-valued vector **r**, where, for each *sorc*={1,2}, r_{sorc} is equal to a matrix **S**, where, for each combination of *dest*={1,2} and *endp*={1,2}:

$$s_{dest,endp} = exp\left(q_{dest,endp}\right)\left(\sum_{i=1}^{2} exp\left(q_{i,endp}\right)\right)^{-1} \text{, where } \mathbf{Q} = p_{sorc}\,.$$

Finally, define **Prop** as a matrix-valued function of age, where, for each combination of *sorc*={1,2} and *dest*={1,2}:

$$prop_{1,sorc} = 1 \text{ and } prop_{2,sorc} = 0 \text{ if } age < first\_move\_age\,,$$

$$prop_{dest,sorc} = s_{dest,1} \text{ if } first\_move\_age \le age < beg\_ramp \text{, and}$$

$$prop_{dest,sorc} = s_{dest,2} \text{ if } age > end\_ramp \text{; otherwise,}$$

$$prop_{dest,sorc} = exp\left(ramp(age)_{dest,sorc}\right)\left(\sum_{i=1}^{2} exp\left(ramp(age)_{i,sorc}\right)\right)^{-1} \text{, where } \mathbf{S} = r_{sorc}\,.$$

Each column of **Prop** pertains to a particular source area (1 or 2) and defines the proportions of fish:

- that stay in the source area (row 1), and
- that move to the other area (row 2).

Attachment 2.1.2: Estimation of an optimal cutoff sample size for fishery size composition data

The following model was developed for the purpose of estimating an optimal cutoff value for fishery size composition sample size (lnC and lnN represent the logs of catch and sample size, respectively; a_2, b_1, b_2, c_2, d_1, d_2, and m are parameters, where m represents cutoff sample size (for any combination of year, month, area, and gear); and a_1 and c_1 are functions of parameters):

$$lnC \sim normal(a_1(a_2, b_1, b_2) + b_1 lnN, exp(c_1(c_2, d_1, d_2) + d_1 lnN)^2) \; \forall \; lnN \leq ln(m)$$

$$lnC \sim normal(a_2 + b_2 lnN, exp(c_2 + d_2 lnN)^2) \; \forall \; lnN \geq ln(m),$$

where

$$a_1(a_2, b_1, b_2) = a_2 + (b_2 - b_1)ln(m) \; \text{and} \; c_1(c_2, d_1, d_2) = c_2 + (d_2 - d_1)ln(m) \, .$$

The available data from 1991 onward include a total of 4,196 size composition records (with associated catch), with sample sizes ranging from 1 to 47,750 (median = 386, mean = 1,689) measured fish.

Conditional on c_2, d_1, d_2, and m, closed-form solutions for the maximum likelihood estimates of a_2, b_1, and b_2 are available. The maximum likelihood estimate of m was approximated by profiling over values from 5 to 100, in increments of 5. Maximum likelihood estimates of all parameters were as follow:

a_2	b_1	b_2	c_2	d_1	d_2	m
0.265	-0.427	0.893	1.616	0.054	-0.233	30

The increases in negative log likelihood relative to the minimum for the m profile were as follow:

5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
24.7	17.8	11.1	5.8	1.3	0.0	0.9	1.7	2.3	2.8	3.0	3.1	3.1	3.2	3.3	3.2	3.1	2.9	3.0	2.9

Data and results are shown in Figure 2.1.2.1.

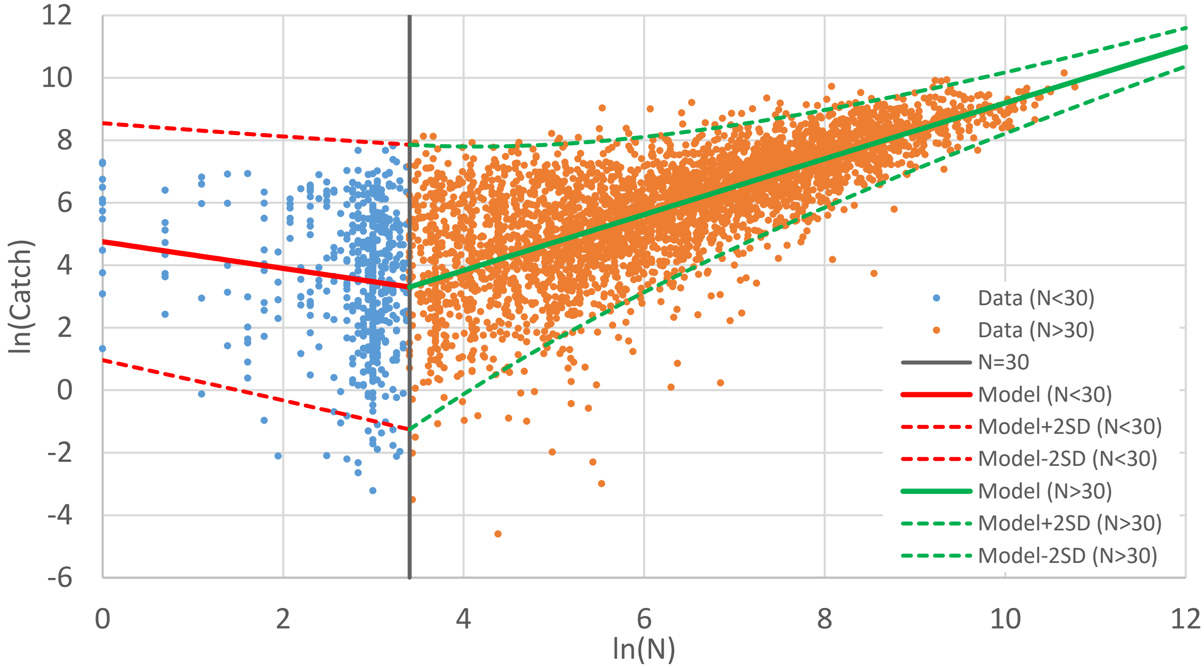

Figure 2.1.2.1. Catch and size composition sample size (*N*) for all available combinations of year, month, area, and gear; and best fit of the model used to estimate an optimal cutoff value of 30 fish.

Attachment 2.1.3: Steps used in cross-conditional decision analysis

The following notational conventions are used:

- Names of matrices consist of, or begin with, an upper-case letter.
- Names of vectors and scalars consist of, or begin with, a lower-case letter.
- Names of matrices and vectors appear in bold font.
- Names of scalars appear in italicized font.

Assume the following loss function:

$$loss(y|\hat{y},ra)=\left(\frac{y^{1-ra}-\hat{y}^{1-ra}}{1-ra}\right)^2,$$

where y is the quantity of interest, $\hat{y}$ is intended to approximate the true-but-unknown value of y, and ra is the level of risk aversion, where any value of $ra > 0$ implies true risk aversion, the special case of $ra = 0$ implies risk neutrality, and any value of $ra < 0$ implies "negative" risk aversion (i.e., risk proclivity). Here, risk aversion means that any underestimate is preferred to an overestimate of the same magnitude.

The following procedure is fairly general, and should be applicable to a wide range of choices as to the quantity of interest, with two constraints: 1) the quantity of interest cannot take negative values; and 2) if any value of ra other than 0 is chosen, the scaling of the quantity has to be consistent with the meaning of risk aversion given above.

The risk-minimizing value of $\hat{y}$ is the y mean of order $1-ra$, defined as the $(1-ra)$th root of the $(1-ra)$th noncentral moment of the probability mass function *pmf*:

$$m(1-ra)=\left(\sum_{i=1}^{\infty}pmf_i y_i{}^{1-ra}\right)^{1/(1-ra)}.$$

For an ensemble containing *nmod* candidate models, compute *pmf* as follows:

1. For each model i = 1,2,...,*nmod* (referred to below as the "pivot" model, indexed i):
   a. Fit pivot model i to the data; this is the "base" run of the pivot model.
   b. Using the parameters estimated from the base run, generate *nsim* sets of conditional parametric bootstrap data.
   c. Fit pivot model i to each bootstrap data set k=1,2,...,*nsim*, resulting in a set of *nsim* estimates of y ($\mathbf{yest}_i$), which will be taken to characterize the distribution of y, conditional on the structure of the pivot model being "true."
   d. Compute the risk-neutral point estimate of $\hat{y}$ ($yopt_i$) conditional on the structure of the pivot model being "true," which will be the $\mathbf{yest}_i$ mean of order 1.
   e. Fit each model $j \neq i$ in the ensemble to each of the *nsim* sets of bootstrap data generated by pivot model i, resulting in a vector $\mathbf{yest}_j$ for each such model, which, together with $\mathbf{yest}_i$, form the columns of the matrix $\mathbf{Yest}_i$ (note: after steps 1a-1e have been completed for all pivot models, a total of *nmod* **Yest** matrices will have been created, one for each pivot model, and each **Yest** matrix will consist of *nsim* rows and *nmod* columns).
   f. For each set of bootstrap data k=1,2,...,*nsim*, if *any* of the *nmod* fitted models fails to produce a positive definite Hessian matrix or if the maximum gradient exceeds a

specified tolerance (e.g., 0.01), delete the corresponding row from $\mathbf{Yest}_i$, resulting in a matrix $\mathbf{Yest\_use}_i$.

g. Determine the probability (p_i) that the structure of pivot model *i* corresponds to the structure of the true model, using either quantitative or qualitative methods.

2. Create a vector of weights **w**, where each element $0 \leq w_i \leq 1$, $i = 1,2,..,nmod$, and the vector is constrained to sum to unity (see note at the end of this list on choice of initial values for **w**).
3. Define a conditional risk for each pivot model *i*=1,2,...,*nmod* as follows:

$$condrisk(\mathbf{w})_i = \left(\frac{1}{nuse_i}\right) \sum_{k=1}^{nuse_i} loss\left(\sum_{j=1}^{nmod} \left(w_j (\mathbf{Yest\_use}_i)_{k,j}\right) \mid yopt_i, 0\right),$$

4. Define the overall risk (i.e., expected loss) associated with **w** as

$$risk(\mathbf{w}) = \sum_{i=1}^{nmod} (p_i condrisk(\mathbf{w})_i) .$$

5. Minimize *risk*(**w**) w.r.t. **w** (the minimization will actually occur w.r.t. only *nmod*–1 elements of **w**, as the remaining element is determined by the constraint that the vector sums to unity; see note at the end of this list regarding a suggested parameterization).
6. For each combination of pivot model *i*=1,2,...,*nmod* and candidate model *j*=1,2,...,*nmod*, form a histogram from the *j*th column of $\mathbf{Yest\_use}_i$, using *nbin* equal-sized bins spanning the range min(**Yest_use**) to max(**Yest_use**) (see note at the end of this list on choice of value for *nbin*).
7. Form an *nmod*×*nmod* matrix of probability mass functions (**Pmf**) by converting each histogram into a probability mass function by normalizing so that the sum of the bar heights equals unity.
8. Form a weighted average probability mass function across models by computing the probability in each *bin*=1,2,...,*nbin* as follows:

$$pmf_{bin} = \sum_{i=1}^{nmod} p_i \sum_{j=1}^{nmod} w_j \left(Pmf_{i,j}\right)_{bin} .$$

Once *pmf* has been calculated, values of $\hat{y}$ can be obtained for as many values of *ra* as desired by computing the corresponding values of *m*(1–*ra*).

Notes:

1. Minimizing risk as a function of **w** can be sensitive to the choice of initial values. Some options to try include the following: A) set each $w_i = 1/nmod$, B) set **w** = **p**, and 3) draw *nmod* random values from a standard normal distribution and convert them via a multivariate logistic transform (this can be done many times as a check on convergence).
2. Problems associated with bounds and tradeoffs between the elements of **w** can be addressed by basing the minimization of *risk*(**w**) on a multivariate logit transform of **w**.
3. Statistics of the distribution can be sensitive to the value of *nbin*. Convergence can be tested by choosing a series of values for *nbin* and computing whatever statistic is of interest for each value. Regardless of the value of *nbin* that is used for computing statistics of the distribution, it may be helpful to use a different value of *nbin* to produce the estimate of *pmf* used for plotting.

Attachment 2.1.4: Deriving the level of risk aversion in the current harvest control rules

Background

Let x denote a positive random variable and let $f(x)$ denote its probability density function (pdf). Then, for real number k, define the "mean of order k" $m(k)$ as the kth root of the kth noncentral moment:

$$m(k) = \left(\int_0^\infty f(x) x^k \, dx \right)^{1/k} .$$

Common special cases include the arithmetic mean (k = 1), the geometric mean (in the limit as k approaches 0), and the harmonic mean (k = –1). For the loss function used in cross-conditional decision analysis, if the level of risk aversion is ra, the optimal estimator is $m(1–ra)$.

Deriving the level of risk aversion implied by the Tier 1 harvest control rules

In Tier 1 of the current harvest control rules:

- F_{OFL} is set at the arithmetic mean of the pdf of F_{MSY},
  - which implies that $m(1-ra_{OFL})=m(1)$,
  - which implies that ra_{OFL} =0.
- $maxF_{ABC}$ is set at the harmonic mean of the pdf of F_{MSY}
  - which implies that $m(1-ra_{ABC})=m(-1)$,
  - which implies that ra_{ABC} =2.

Deriving the level of risk aversion implied by the Tier 3 $maxF_{ABC}$ harvest control rule

By definition, reliable estimates of the F_{MSY} pdf are not available for Tier 3 stocks. However, proxies for the levels of uncertainty that would be implied by those pdfs, if they did exist, can be obtained by assuming that they are similar to those estimated in assessments of Tier 1 stocks.

Assume that the pdfs of F_{MSY} for all Tier 1 and Tier 3 stocks are lognormal. Then, $m(k)$ takes the form

$$m(k) = \exp\left(\mu + \frac{k\sigma^2}{2}\right),$$

where μ and σ are the mean and standard deviation of $\ln(F_{MSY})$.

Let *buffer* be defined as 1– $maxF_{ABC}/F_{OFL}$. Then, given the results from the previous section, σ can be calculated from *buffer* for a Tier 1 stock as

$$\sigma = \sqrt{-\ln(1 - buffer)} .$$

Using the above equation, example values of σ were computed from the values of *buffer* implied by the stock assessment for EBS walleye pollock (a Tier 1 stock) in each year from 2014-2018:

Year:	2014	2015	2016	2017	2018
Sigma:	0.370	0.498	0.394	0.536	0.402

The above were assumed to constitute a random sample of σ values for a Tier 1 stock. Then, the values of *buffer* implied by all "full" stock assessments of Tier 3 BSAI groundfish species over the period 2014-

2018 were calculated. Finally, an estimate of the implicit Tier 3 value of ra_{ABC} was computed for every possible combination of Tier 1 σ (n=5) and Tier 3 *buffer* (n=42), using the following equation:

$$ra_{ABC} = ra_{OFL} - \frac{2\ln(1 - buffer)}{\sigma^2},$$

where it was assumed that ra_{OFL}=0. The resulting set of 210 values had a mean of 1.88 (standard deviation = 0.55, histogram shown in Figure 2.1.3.1), suggesting that the *ra* value of 2 that is identified with the Tier 1 $maxF_{ABC}$ harvest control rule is also a reasonable estimate of the *ra* value that is implied by the Tier 3 $maxF_{ABC}$ harvest control rule.

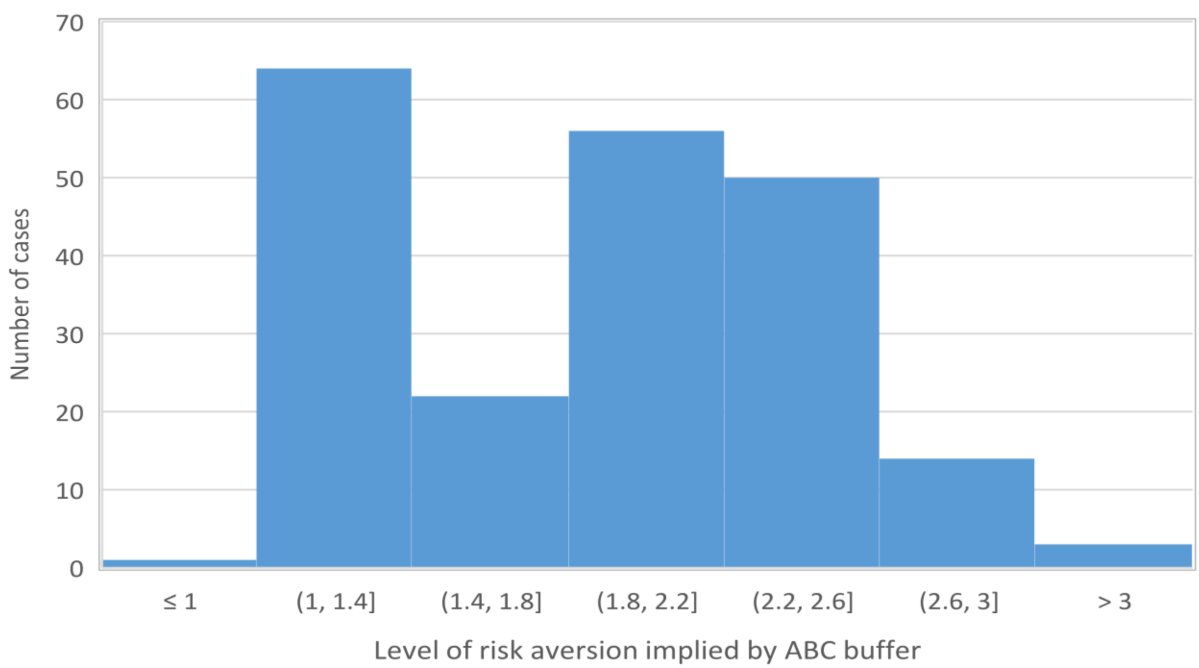

Figure 2.1.3.1. Histogram of risk aversion values implied by the Tier 3 $maxF_{ABC}$ harvest control rule.