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," Thompson 2018).

Responses to Team and SSC comments on assessments in general

Comments from the December 2018 SSC meeting

SSC1: "The SSC requests that all authors fill out the risk table in 2019, and that the PTs provide comment on the author's results in any cases where a reduction to the ABC may be warranted (concern levels 2-4)." *Response*: This request will be addressed in the final assessment.

SSC2: "In response to the PT's request for guidance on model averaging and the development of ensembles, the SSC offers the following general recommendations:

- "Progress on this effort will require an example to work through both expected and unanticipated details of how this process may work. The SSC requests again for 2019 that one or more assessments bring forward an ensemble of models.
- "The combining of model output should occur on the basic estimates from the assessment (biomass, F, etc.) and not the reference points themselves.
- "Where variance estimates among models differ appreciably, it may be more appropriate to combine the posterior distribution functions from each model than to average the expectations.
- "It will be difficult for the PTs to combine model results without the author's assistance. Such an approach should only be attempted in unique cases, and it is preferable for the author to identify the intention to bring forward an ensemble in September and perform the analysis before the November PT meetings."

Response: A document describing a new method for model weighting that may be useful in developing an example will be discussed at the September Team meeting. Although it does not satisfy the recommendation to operate on the "basic estimates from the assessment (biomass, F, etc.)," it does satisfy the recommendation to average posterior distribution functions.

Responses to Team and SSC comments specific to this assessment

Comments from the November 2018 Team meeting

"For next year's assessment, the Team recommended that...

BPT1: "...the EBS Pacific cod ages be examined for potential biases and reader effects as seen with GOA Pacific cod (i.e., Barbeaux et al 2018/GOA cod assessment and Kastelle et al., 2017/Age validation of Pacific cod (*Gadus macrocephalus*) using high-resolution stable oxygen isotope (δ18O) chronologies in otoliths)." *Response*: All assessments of the EBS Pacific cod stock since 2009 have included estimates of ageing bias, and this practice is continued in all models presented here. In response to a recent concern that ageing criteria may have shifted after 2007, three of the models presented here include separate estimates of ageing bias for the pre-2008 and post-2007 portions of the time series.

BPT2: "...fisheries data be examined to determine if there are within-year patterns that may indicate seasonal movement, and if the survey timing may intersect with that seasonal migration." *Response*: The requested analysis is presented in the Discussion section.

BPT3: "...a model-based survey time-series be developed that can predict combined abundance of the expanded EBS survey area and the Northern Bering Sea survey area for all years. Length and age compositions should also be created that account for and are appropriately weighted by these model-based estimates. Validate the predictions using various methods as well as consistency with observations from other external surveys (e.g., BASIS)." *Response*: A model-based survey time series for the combined EBS and Northern Bering Sea (NBS) areas, based on the vector autoregressive spatio-temporal (VAST) method developed by Thorson (2019), has been developed and is used in two of the models presented here, as are corresponding VAST estimates of survey age composition. However, when attempts were made to estimate corresponding VAST estimates of survey size composition, the 1-cm bin size currently used in the models caused computational problems that have not yet been resolved. Validation of the estimates using various methods and comparison for consistency with other surveys has not yet been attempted.

BPT4: "...the NBS survey be conducted again in 2019 to provide data for the Pacific cod assessment." *Reponse*: The NBS survey was conducted again in 2019 and will provide data for the Pacific cod assessment.

BPT5: "...Pacific cod fishery catches and Pacific cod survey data in Russia be researched and summarized." *Response*: A small amount of data on Russian catches of Pacific cod has been obtained and efforts to obtain further estimates, perhaps using Automatic Identification System data, are being discussed. The available data will be reported in the final assessment.

BPT6: "...the significance of retrospective patterns when using a time-series with data mainly in recent years (for example, removing 2017 and 2018 leaves only one observation for the Northern Bering Sea survey time-series) be investigated and explained. For example, are the Mohn's ρ estimates useful to compare across models?" *Response*: Some results pertaining to this issue are presented in the Discussion section.

BPT7: "...the author considers an ensemble of models using the three hypotheses discussed above to address the structural uncertainty resulting from these hypotheses, as well as additional uncertainties captured by various models. The three hypotheses are 1) P. cod in the NBS are insignificant to the managed stock, 2) P. cod in the NBS are simply the same stock as in the EBS and should be managed as one stock, and 3) P. cod in the NBS and EBS are from the same stock and should be managed as one stock, but P. cod in the NBS should be modeled separately within one model with separate catchability and selectivity to capture differences observed in the fish in that area. *Response*: In addition to the base model, six new models are presented here, spread across the Team's three hypotheses (specifically, two new models per hypothesis).

BPT8: "...the author considers bringing forward an ensemble of models to capture structural uncertainty with a justifiable weighting as well as a "null" approach with equal weights. The Plan Team may also consider an ensemble even if not recommended by the author. If an ensemble is used, all model outputs in the ensemble that are management related should be averaged, and the ABC should be determined from those averaged outputs (i.e., the application of the control rule to averaged biological reference values). The Team would appreciate feedback from the SSC on appropriate methods to average model outputs to determine an ABC." *Response*: See Comment SSC2. The document describing a new model averaging approach includes a focus on justifiable model weights.

BPT9: "...the authors coordinate with Council staff to augment the fishery information section of the assessment for next year. Council staff will be providing a cod allocation review in 2019 and will work with the author to provide pertinent summary sections over the summer." *Response*: The requested augmentation will occur in the final assessment.

BPT10: "...the authors coordinate with Alaska Department of Fish and Game on assessment data needs from the state managed Area O Pacific cod fishery as the fishery GHL is expanded under new allocation rules from 6.4% to a maximum 15% of the Bering Sea Pacific cod ABC." *Response*: Representatives from the Alaska Department of Fish and Game have been contacted regarding the need for data from the State-managed Pacific cod fishery in the EBS. They indicate a willingness to begin collecting these data. Specifics of the collection process will be developed soon.

<u>Comments from the December 2018 SSC meeting</u>

SSC3: "The SSC recommends that future efforts focus on treatment of the Northern Bering Sea data prior to adding to the assessment – via summation of the components (as in model 16.6i) or through model-based approaches that can estimate contributions of unsampled areas (such as developed for EBS walleye pollock). However, the SSC noted that many requested changes made in development of the 17.x and 18.x series of models represent improvements over the 16.x models. These improvements include inclusion of fishery age composition data, the prior on natural mortality, composition data weighted by the number of hauls, and harmonic mean composition weights. Other changes continue to be worthy of evaluation, but may not be clear improvements, such as time-varying selectivity and catchability. The SSC recommends bringing these branched model series back together either in the form of one model, or an ensemble of models for 2019." *Response*: Results from Model 16.6i, which uses simple summation of the design-based survey estimates, are again reported here, along with results from six new models, two of which use VAST estimates of survey abundance and age composition (see Comment BPT3). All of the new models include fishery age composition data and initial weighting of compositional data by the number of hauls (in either absolute or relative terms), and three of the new models include reweighting of compositional data and time-varying selectivity and catchability.

SSC4: "The greatest concern identified by the SSC was the future survival and contribution to the greater cod stock of the fish observed in the Northern Bering Sea (over half of the total biomass) in 2018. The SSC reiterated its recommendation from October that in-season reporting of fishery performance be used to track the presence and/or success of these fish into next spring." *Response*: This request could not be accommodated due to lack of the necessary data.

"The SSC agreed with PT recommendations for additional work on...

SSC5: "...resolving issues with ageing methods and historical age data, following the issues raised in the GOA Pacific cod assessment which may be applicable in the Bering Sea." Response: See Comment BPT1.

SSC6: "...use of a model-based method for developing a survey abundance estimate for the entire Bering Sea." See Comment BPT3.

SSC7: "...the critical importance of a Northern Bering Sea survey in 2019." See Comment BPT4.

SSC8: "The SSC strongly supported the PT approach of organizing alternative models around explicit hypotheses regarding the assessment structure or population dynamics. This approach was very helpful to make clear where the need for additional research was most important, and also provided a logical framework for developing an ensemble of models corresponding to each hypothesis. Moving forward, weighting of models for an ensemble may be developed based on the relative plausibility of each model hypothesis. The SSC recommends further efforts in developing this approach." *Response*: See Comment BPT7 regarding the Team's three hypotheses. See Comments SSC2 and BPT8 regarding model averaging. In addition to including a focus on justifiable model weights, the document describing a new model averaging approach also provides an explicit role for the relative plausibility of each model in the ensemble.

SSC9: "The SSC supports tagging, which may be helpful for understanding connectivity among areas of the greater Bering Sea." *Response*: This year's NBS survey included plans to fit 32 fish with satellite archival tags. Genetic samples were to be taken prior to release, to determine spawning site fidelity.

SSC10: "The SSC supported the use of projections integrated with the assessment analysis and the use of fixed catches (rather than fishing mortality rates) in these projections. This approach provided for more realistic projections that included uncertainty in the fishing mortality rate, parameter uncertainty, and allowed for the explicit calculation of the probability of exceeding the overfishing limit. The SSC suggest that this method be explored in other assessments and considered for routine use." *Response*: Projections are again integrated with the assessment analysis here.

SSC11: "The SSC also encouraged additional work to investigate recent and historical fishery catch in the Northern Bering Sea as there were a number questions regarding reports of fishery activity, but only a small amount of fishing identified by the author." *Response*: Additional investigation revealed that the absence of fishery data from the NBS survey area last year was due to the timing of last year's analysis. Last year's data query was run in July, and resulted in very few records. However, when the same query was run *this* July, 620 records (hauls) were retrieved for 2018, all but 12 of which were for the months August-December. No records were retrieved for 2019 as a result of this year's query, however.

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 V3.30.14.00 was used to run all of the models in this preliminary assessment. For the current base model, this version of SS gave the same value for the objective function as the version used in last year's assessment (Thompson 2018).

Base model

Model 16.6i was adopted by the SSC last year as the new base model. Like its predecessor (Model 16.6, adopted in 2016), Model 16.6i is a very simple model. Its main structural features are as follow:

- One fishery, one gear type, one season per year.
- Logistic age-based selectivity for both the fishery and survey.
- External estimation of time-varying weight-at-length parameters and the standard deviations of ageing error at ages 1 and 20.
- All parameters constant over time except for recruitment and fishing mortality.

- Internal estimation of all natural mortality, fishing mortality, length-at-age (including ageing bias), recruitment (conditional on Beverton-Holt recruitment steepness fixed at 1.0), catchability, and selectivity parameters.

The only difference between Model 16.6i and Model 16.6 is the inclusion in Model 16.6i of data from the NBS survey, which were incorporated by simple summation with the EBS survey data.

Alternative models

A total of six alternative models are presented here in addition to the base model. These constitute a factorial design involving the Team's three hypotheses regarding treatment of the NBS (Comments BPT7 and SSC8) and the SSC's desire to explore multiple ranges of possible enhancements to the structure of the base model (Comment SSC3).

The Team's three hypotheses are:

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.
3. Pacific cod in the EBS and NBS comprise a single stock, but the EBS and NBS surveys should be modeled separately.

Relative to the base model, two ranges of structural modifications are featured among the alternative models. More specifically, two models are presented for each hypothesis, one of which contains a certain set of structural modifications, and the other of which contains a second, larger, set of structural modifications. The two sets of structural modifications are the same across hypotheses, except that an additional set of survey parameters is required for Hypothesis 3. In addition to structural differences, the models for the various hypotheses also involve different data.

The first (smaller) set of structural modifications is as follows:

- Set input sample size for compositional data equal to the number of hauls, rescaled to an average of 300 for each component (Model 16.6i sets input sample size equal to the number of *observations*, rescaled to an average of 300 for each component).
- Include the available fishery age composition data (Model 16.6i ignores those data).
- Use age-based, double-normal selectivity, potentially dome-shaped for the fishery but forced asymptotic for the survey (Model 16.6i uses age-based, logistic survey for both fleets).
- Tune the input standard deviation of log-scale recruitment deviations (σ_R) to match the square root of the variance of the estimates plus the sum of the estimates' variances (Methot and Taylor 2011; Model 16.6i estimates σ_R internally).
- Use size-based maturity (Model 16.6i uses age-based maturity).

The second (larger) set of structural modifications is as follows:

- Set input sample size for compositional data equal to raw number of hauls rather (than rescaled to an average of 300 for each component).
- Reweight compositional data internally using the Dirichlet-multinomial distribution (Thorson et al. 2017; see also Discussion section here).
- Use size-based double-normal selectivity rather than age-based (but keeping the assumption of asymptotic survey selectivity).

- Allow mean ageing bias at ages 1 and 20 to differ between the pre-2008 and post-2007 periods in order to compensate for an apparent change in ageing criteria (Beth Matta, AFSC Age and Growth Program, pers. commun., 6/27/2019) .
- Allow yearly random variation in survey selectivity (two parameters), with the input standard deviation of the deviations tuned to set the variance of the estimates plus the sum of the estimates' variances equal to unity.
- Allow yearly random variation in survey catchability, with the input standard deviation of the deviations tuned to set the variance of the estimates plus the sum of the estimates' variances equal to unity.
- Allow yearly random variation in mean length at age 1.5, with the input standard deviation of the deviations tuned to set the variance of the estimates plus the sum of the estimates' variances equal to unity, in order to address the significant amount of time-variability in growth documented by Puerta et al. (2019).
- Allow yearly random variation in fishery selectivity (three parameters), with the input standard deviation of the deviations tuned to set the variance of the estimates plus the sum of the estimates' variances equal to unity.

(Note that the method for tuning the input standard deviations of log-scale recruitment deviations is slightly different than the method for tuning the input standard deviations of all other deviation vectors. This is because SS treats log-scale recruitment deviations differently from all other deviation vectors.)

Referring to models conforming to the first set of structural modifications as "simple" and models conforming to the second (larger) set of structural modifications as "complex," the set of alternative models can be summarized as follows:

Hypothesis:	1: EBS only		2: Combine EBS and NBS		3: Separate EBS and NBS	
Structure:	Simple	Complex	Simple	Complex	Simple	Complex
Name:	M19.1	M19.2	M19.3	M19.4	M19.5	M19.6

Features explored but not included in the models presented here

A total of 256 one-at-a-time model runs (plus 862 "jitter" runs—see "Convergence behavior" below—and over 60 retrospective runs) were made in developing the models presented here. Many of these explored various features, sometimes in multiple combinations, that ultimately were not included in the models presented here. Among those features were the following:

- Use of VAST estimates of survey abundance without the cold pool as a covariate
- Use of VAST estimates of survey abundance without bias correction
- Internal estimation of a time-invariant increment to the log-scale survey index standard error
- Allowing yearly random variation in the Brody growth coefficient (*K*)
- Internal estimation of a parameter expressing cohort-specific growth
- External re-weighting of compositional data components
- Survey catchability fixed (not estimated statistically) at 1.0
- Exponential-logistic fishery selectivity
- Exponential-logistic survey selectivity
- Different combinations of selectivity parameters that are subject to yearly random variation
- Allowing survey selectivity to be dome-shaped

Data

The data used in the base model were described in last year's assessment (Thompson 2018). Various modifications were used in the alternative models.

The data files for all of the alternative models involve changes to the input sample size for compositional data, substituting either rescaled number of hauls (Models 19.1, 19.3, 19.5) or raw number of hauls (Models 19.2, 19.4, 19.6) for the rescaled number of observations used in Model 16.6i. The time series of raw and rescaled numbers of hauls for the fishery, EBS survey, NBS survey, and combined EBS and NBS surveys are shown in Table 2.1.1.

In addition, the design-based EBS+NBS survey estimates used in Model 16.6i were replaced by design-based EBS-only survey estimates in Models 19.1 and 19.2 (Hypothesis 1), VAST estimates for the combined surveys in Models 19.3 and 19.4 (Hypothesis 2), and area-specific design-based estimates for the EBS and NBS surveys in Models 19.5 and 19.6 (Hypothesis 3). The various time series of survey index estimates are shown in Table 2.1.2, and the time series for the design-based estimates and VAST estimates of the combined EBS and NBS surveys are also shown in Figure 2.1.1. This figure suggests that few Pacific cod were present in the NBS during years when that region was not surveyed. The VAST estimates incorporated a cold pool effect and were bias corrected. In addition, all settings used to generate the VAST estimates followed the recommendations given by Thorson (2019).

Finally, the VAST estimates of age composition were substituted for their design-based counterparts in all models. The differences between the two sets of estimates (VAST minus design-based) are shown in Table 2.1.3, where the color scale extends from red=low to green=high. In general the differences between the two sets of estimates are small, with 84% of the cells in Table 2.1.3 falling within the range (-0.01,0.01), 95% falling within the range (-0.02,0.02), and 99% falling within the range (-0.04,0.04). Age 1 had the largest positive changes (4% increases in 1997 and 2009, 5% increase in 2011) and ages 2 and 3 had the largest negative changes (4% decreases at age 2 in 2013 and age 3 in 1997).

Convergence behavior

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

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

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

Results

Note: In all 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 varies by table).

Bridging analysis, part 1: Model 16.6i to Model 19.3

The differences between Model 16.6i and Model 19.3 serve as a convenient bridge from the current base model to the set of alternative models, as both have a relatively simple structure and both use data from the combined EBS and NBS surveys (design-based estimates in the former case, VAST estimates in the latter). The steps can be outlined as shown in the following table, where Steps 1-4 all involve changes in data and Steps 5-8 all involve changes in model structure:

Step	Description
0	Model 16.6i (base model)
1	Same as Step 0, but using VAST survey index
2	Same as Step 1, but using VAST agecomps
3	Same as Step 2, but with sizecomp N = rescaled number of hauls
4	Same as Step 3, but with fishery agecomp data included (N = rescaled no. hauls)
5	Same as Step 4, but with asymptotic double-normal selectivity (fishery and survey)
6	Same as Step 5, but with potentially domed fishery selectivity
7	Same as Step 6, but with SD(ln(recruits)) tuned iteratively
8	Same as Step 7, but with size-based maturity

The results of the above are shown in Table 2.1.4.

The first 8 rows show management-related quantities for 2019 and 2020: female spawning biomass (B), maximum permissible acceptable biological catch (maxABC), the ratio of B to equilibrium unexploited female spawning biomass (B100%), and fishing mortality at maxABC (maxFABC). Most of these quantities reach a minimum in Step 4 and a maximum somewhere between Steps 5 and 8.

The value of the overall objective function is shown in row 9, and the next 8 rows show the individual components of that overall value. These rows are not color shaded, as they are not truly comparable, given differences in data and number of parameters across steps.

The next 16 rows show the values of some key parameters. Estimates of the natural mortality rate ranged between 0.31 and 0.37 and estimates of log catchability ranged between 0.03 (catchability=1.03) to 0.22 (catchability=1.24).

The next row shows the root-mean-squared-error (RMSE) of the survey index, which shows very little difference across steps.

The final four rows show effective sample size, as calculated by the method of McAllister and Ianelli (1997). Again, there is very little difference in any of these measures of goodness of fit across steps.

Bridging analysis, part 2: Model 19.3 to Model 19.4

Having created a bridge from the current base model to the closest analogue within the set of alternative models, it may be helpful to create a bridge from the “simple” Model 19.3 to its “complex” counterpart, Model 19.4. The steps can be outlined as shown in the following table, where Steps 1 involves a change in data and Steps 2-9 all involve changes in model structure:

Step	Description
0	Model 19.3
1	Same as Step 0, but with composition input N = number of hauls (no rescaling)
2	Same as Step 1, but with Dirichlet composition data weights
3	Same as Step 2, but with size-based selectivity
4	Same as Step 3, but with block-specific ageing bias (pre-2008, post-2007)
5	Same as Step 4, but with yearly random variation in survey selectivity (2 parameters)
6	Same as Step 5, but with re-tuned SD(ln(recruits))
7	Same as Step 6, but with yearly random variation in survey catchability
8	Same as Step 7, but with yearly random variation in mean length at age 1.5
9	Same as Step 8, but with yearly random variation in fishery selectivity (3 parameters)

The results of the above are shown in Table 2.1.5, which has the same structure as Table 2.1.4. In general, differences across steps in Table 2.1.5 are greater than those in Table 2.1.4. For the management-related quantities in the first 8 rows, Step 1 consistently resulted in the lowest values and Step 8 the highest, with the ratio between the two (high to low) ranging between 1.8 and 4.7. Natural mortality ranged between 0.28 to 0.37, and log catchability ranged between 0.01 (catchability=1.01) and 0.40 (catchability=1.49). Survey RMSE ranged between 0.06 and 0.20, and effective sample sizes all showed fairly wide ranges as well.

One thing to keep in mind when examining the results of a bridging analysis such as this is that the results can be highly dependent on the order in which the steps are taken. That is, a step that shows a big increase (or decrease) in some quantity might show a smaller (or even opposite) change if the steps were rearranged.

Main results

Table 2.1.6 presents the main results for the base model and the six alternative models, and contains most of the same rows as Tables 2.1.4 and 2.1.5 (parameter estimates are not shown, as they appear in a separate table), plus two new rows near the top of the table. The first of the new rows shows the "average difference in spawning biomass" (ADSB) that is used to distinguish models that are "minor" changes relative to the original form of the base model (ADSB<0.1) from those that are "major" (ADSB>0.1). All of the alternative models qualify as major changes, although two of them (Models 19.3 and 19.5) do so just barely. The second of the new rows shows Mohn's ρ, a measure of retrospective bias. All models except Models 16.6i and 19.1 show large positive retrospective biases.

Many of the rows in Table 2.1.6 show wide ranges of values. For the 8 management-related quantities, Model 19.1 is a clear outlier, with values far below those of any other model. Although Model 19.1 passed the standard convergence test, it should be remembered that this is a test of local stability only, and it is possible that Model 19.1 converged at a local minimum other than the global minimum. Model 19.4 has the highest values for all of the management-related quantities. The "complex" models tend to have lower survey RMSEs and higher effective sample sizes than the "simple" models, as would be expected.

The models' fits to the survey index data are shown in Figure 2.1.2.

Parameter estimates and derived time series

Table 2.1.7 lists the estimates and standard deviations of all parameters except fishing mortality (constants estimated outside the model are not shown, and have the same values reported in last year's assessment).

Table 2.1.7a shows the values of the main parameters. A blank cell indicates that the respective parameter (row) is not used in the respective model (column), and a parameter with an estimate (Est.) but no standard deviation (SD) means that the respective parameter was estimated iteratively rather than internally. Natural mortality ranges between 0.265 and 0.380. The Brody growth coefficient ranges between 0.083 and 0.197. When ageing bias is permitted to vary between the pre-2008 and post-2007 eras, the sign of the bias flips from mostly positive (pre-2008) to mostly negative (post-2007). Initial fishing mortality ranges between 0.142 and 1.827. Log catchability for the EBS survey (or the combined EBS and NBS surveys in the case of Models 16.6i, 19.3, or 19.4) ranges from -0.058 (catchability=0.943) to 0.356 (catchability=1.428).

Table 2.1.7b shows log recruitment deviations for the initial numbers-at-age vector, and Table 2.1.7c shows log recruitment deviations for the time series. Table 2.1.7d shows selectivity parameters (not counting deviations).

Tables 2.1.7e-l apply to the "complex" models only (Models 19.2, 19.4, and 19.6).

Table 2.1.7e shows input standard deviations for deviation vectors other than log recruitment (all estimated iteratively) and the coefficients governing compositional data weighting in the Dirichlet-multinomial approach (Thorson et al. 2017). The Dirichlet coefficients for the fishery size composition data and the EBS survey size composition data (EBS+NBS in the case of Model 19.4) were all bound high (upper bound = 10.0), and so estimation of those parameters was disabled. The input sample sizes and the effective sample sizes using the definitions of both Thorson et al. 2017 and McAllister and Ianelli (1997, harmonic mean) are as follow:

	Average no. hauls			Thorson N			McAllister-Ianelli N		
Component	M19.2	M19.4	M19.6	M19.2	M19.4	M19.6	M19.2	M19.4	M19.6
Fishery sizecomps	5225	5225	5225	5225	5225	5225	2012	2013	2007
EBS survey sizecomps	346	352	346	346	352	346	578	561	576
NBS survey sizecomps	n/a	n/a	68	n/a	n/a	68	n/a	n/a	81
Fishery agecomps	9517	9517	9517	173	155	172	215	212	218
EBS survey agecomps	359	359	359	184	167	182	107	100	106
NBS survey agecomps	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 2.1.7f shows deviations for mean length at age 1.5, The corresponding time series of mean length at age 1.5 is shown in Figure 2.1.3, and the time series of the full length-at-age relationship is shown in Figure 2.1.4.

Table 2.1.7g shows deviations for log catchability. The catchability time series is shown in Figure 2.1.5.

Tables 2.1.7h-l show deviations for the time-varying selectivity parameters. The selectivity schedules corresponding to the parameters listed in Tables 2.1.7d and 2.1.7h-l are displayed in Figure 2.1.6, with fishery selectivity shown in Figure 2.1.6a, EBS survey selectivity (EBS+NBS in the case of Model 19.3 or Model 19.4) shown in Figure 2.1.6b, and NBS survey selectivity shown in Figure 2.1.6c.

The time series of full-selection fishing mortality rates are shown in Table 2.1.8.

The time series of age 0 recruitment, total (age 0+) biomass, and relative spawning biomass are shown in Figures 2.1.7, 2.1.8, and 2.1.9, respectively.

Discussion

Spatio-temporal trends in fishery CPUE during summer

Comment BPT2 raises the question of whether fishery CPUE data might suggest that Pacific cod are migrating in space and time in a manner similar to the survey vessels, which could support estimates of catchability greater than unity. This might be especially important for 2017 and 2018, when the NBS survey found unprecedented biomasses of Pacific cod.

The observer database was queried for CPUE data (longline vessels only, measured in kg per 1000 hooks), binned into half-by-one latitude-longitude blocks for the months of June, July, and August. When the data are screened for confidentiality, the patterns shown in Figure 2.1.10 result (the polygon at the top of each panel is a rough approximation of the standard NBS survey area). Figures 2.1.10a-c show June-August CPUE for all years combined, Figures 2.1.10d-f show June-August CPUE for 2017, and Figures 2.1.10g-i show June-August CPUE for 2018. These results do not suggest a strong pattern of movement along the same spatio-temporal lines as the survey vessels.

To see if the confidentiality screening might be obscuring such a pattern, a set of linear regressions using all data was conducted: one for 2017 only, one for 2018 only, and one for 2017 and 2018 combined. Fishery CPUE was the dependent variable, and the independent variables were:

- Day of year
- Latitude
- Longitude
- Day × latitude
- Day × longitude
- Latitude × longitude
- Day × latitude × longitude

The resulting parameter estimates, and the ratios of the estimates to their respective standard deviations, were as follow:

	2017 model		2018 model		2017-2018 model	
Parameter	Est.	Est./SD	Est.	Est./SD	Est.	Est./SD
Intercept	-4.85E+05	8.03E+00	-4.34E+04	6.88E-01	-3.53E+05	8.74E+00
Day	2.39E+03	8.45E+00	3.01E+02	9.81E-01	1.75E+03	9.00E+00
Latitude	8.32E+03	7.98E+00	6.63E+02	6.17E-01	6.08E+03	8.83E+00
Longitude	-2.81E+03	7.94E+00	-2.46E+02	6.68E-01	-2.05E+03	8.65E+00
Day x latitude	-4.10E+01	8.38E+00	-4.71E+00	9.01E-01	-3.00E+01	9.05E+00
Day x longitude	1.39E+01	8.38E+00	1.74E+00	9.69E-01	1.02E+01	8.93E+00
Latitude x longitude	4.81E+01	7.90E+00	3.71E+00	5.91E-01	3.52E+01	8.73E+00
Day x latitude x longitude	-2.38E-01	8.32E+00	-2.72E-02	8.89E-01	-1.74E-01	8.98E+00

None of the models fit the data very well (the coefficients of determination for the 2017, 2018, and 2017-2018 models were 0.20, 0.05, and 0.10, respectively), and the coefficients of the 2018 model were estimated very imprecisely (see Est./SD column), although the coefficients of the other two models were fairly well estimated. Regardless, the estimated coefficient for Day × latitude was negative in all three models, suggesting that Pacific cod overall are not migrating northward during the summer months.

Calculating retrospective bias with short time series

Comment BPT6 raises the question of whether estimates of retrospective bias are meaningful when one or more parameters are associated with a data set that does not span the full number of “peels” in the retrospective analysis. For example, the catchability and selectivity parameters for the NBS survey have no meaning apart from the NBS survey, but after the first two peels (stripping away the 2018 and 2017 data), the only remaining year in the NBS survey time series is 2010, and even that disappears after the eighth peel.

Retrospective analysis of Models 19.5 and 19.6 provides an opportunity to address this issue, as these models treat the NBS survey separately from the EBS survey. The table below shows the models estimates of log catchability for the NBS survey for each peel of the analysis, along with the standard deviations of those estimates and the retrospective bias associated with each peel (these are the quantities that are averaged to compute Mohn’s ρ). Rows shaded gray correspond to years with NBS surveys. The last two rows correspond to peels for which no NBS survey data remain in the data file.

		Model 19.5			Model 19.6		
Peel	Last_yr	Est.	SD	Bias	Est.	SD	Bias
0	2018	-1.686	1.17E-01	n/a	-1.564	3.52E-01	n/a
1	2017	-2.184	1.63E-01	0.146	-2.359	4.46E-01	0.083
2	2016	-4.527	3.92E-01	0.206	-2.258	9.47E-01	0.236
3	2015	-4.604	3.83E-01	0.428	-2.359	9.41E-01	0.345
4	2014	-4.661	3.82E-01	0.537	-2.448	9.43E-01	0.448
5	2013	-4.793	4.54E-01	0.695	-2.547	9.48E-01	0.553
6	2012	-4.948	5.79E-01	0.875	-2.777	9.45E-01	0.775
7	2011	-5.028	5.70E-01	0.823	-2.937	9.25E-01	0.961
8	2010	-5.143	5.58E-01	0.833	-3.089	9.40E-01	1.231
9	2009	-1.684	1.25E+04	0.596	-1.478	1.21E+04	1.811
10	2008	-1.684	1.25E+04	0.436	-1.484	1.21E+04	0.916

Note that the standard deviations of the estimates become immense once the NBS survey data have been peeled away. Other than that, it is not obvious that the removal of the entire NBS survey time series has a particular effect on the retrospective bias. For example, in Model 19.5, the retrospective bias is lower in peels 9 and 10 (where no NBS survey data exist) than in peels 4 through 8, and in Model 19.6, the retrospective bias in peel 10 is lower than in peels 8 and 9.

Internal estimation of compositional sample size

Comment SSC3 lists “harmonic mean composition weights” as a possible candidate for further investigation. While harmonic mean weighting has advantages over simply assuming a sample size a priori, a different approach was taken in the present investigation, viz., the Dirichlet-multinomial approach of Thorson et al. (2017). The authors list the following as reasons to prefer their approach:

1. The approach is faster than alternatives based on iteration, as the weighting is done internally by estimation of a single additional parameter.

2. Because the single additional parameter is estimated, uncertainty in that estimate is propagated appropriately, unlike iterative approaches that result in a fixed constant.
3. The same standard for convergence that is used for all other parameters applies to the weighting, unlike iterative approaches.
4. The resulting estimates of effective sample size can never exceed the input sample size, which is a desirable property so long as the input sample size is appropriate.

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Tables

Table 2.1.1. Compositional sample sizes.

	Fishery		EBS only		NBS only		EBS and NBS	
Year	Raw	Rescaled	Raw	Rescaled	Raw	Rescaled	Raw	Rescaled
1977	30	1						
1978	160	8						
1979	235	12						
1980	208	10						
1981	148	7						
1982	187	9	308	267			308	263
1983	782	39	255	221			255	218
1984	1913	95	264	229			264	225
1985	2825	140	342	296			342	292
1986	2496	124	349	302			349	298
1987	4726	235	339	294			339	289
1988	1458	72	339	294			339	289
1989	966	48	293	254			293	250
1990	3601	179	329	285			329	281
1991	5188	258	313	271			313	267
1992	5322	264	332	288			332	283
1993	2993	149	363	315			363	310
1994	4687	233	364	315			364	311
1995	5215	259	347	301			347	296
1996	6618	329	359	311			359	306
1997	7278	361	369	320			369	315
1998	6838	340	362	314			362	309
1999	9231	458	336	291			336	287
2000	9731	483	355	308			355	303
2001	10364	515	366	317			366	312
2002	11472	570	364	315			364	311
2003	14341	712	363	315			363	310
2004	12242	608	361	313			361	308
2005	11568	574	360	312			360	307
2006	8849	439	354	307			354	302
2007	6901	343	368	319			368	314
2008	8320	413	338	293			338	288
2009	7482	371	360	312			360	307
2010	6514	323	342	296	6	26	348	297
2011	8804	437	368	319			368	314
2012	9287	461	356	309			356	304
2013	11126	552	354	307			354	302
2014	12165	604	373	323			373	318
2015	11309	561	354	307			354	302
2016	9773	485	376	326			376	321
2017	7154	355	369	320	119	525	488	416
2018	3267	162	364	315	79	349	443	378

Table 2.1.2. Comparison of design-based and VAST survey indices.

	Design-based EBS		Design-based NBS		Design-based E+N		VAST E+N	
Year	Est.	Sigma	Est.	Sigma	Est.	Sigma	Est.	Sigma
1982	583781	0.065			583781	0.065	649671	0.055
1983	752456	0.107			752456	0.107	814129	0.060
1984	651058	0.072			651058	0.072	708088	0.055
1985	841108	0.134			841108	0.134	909961	0.053
1986	838217	0.1			838217	0.100	867470	0.054
1987	697075	0.064			697075	0.064	752342	0.055
1988	512095	0.069			512095	0.069	526940	0.053
1989	301748	0.066			301748	0.066	325492	0.054
1990	438107	0.084			438107	0.084	468569	0.056
1991	496765	0.103			496765	0.103	532064	0.063
1992	585436	0.117			585436	0.117	587264	0.067
1993	814187	0.121			814187	0.121	847643	0.066
1994	1255544	0.121			1255544	0.121	1236873	0.057
1995	761681	0.099			761681	0.099	773905	0.056
1996	614493	0.143			614493	0.143	694181	0.069
1997	493660	0.143			493660	0.143	530345	0.059
1998	522586	0.09			522586	0.090	602707	0.072
1999	542229	0.1			542229	0.100	547447	0.063
2000	488605	0.09			488605	0.090	503574	0.055
2001	974016	0.094			974016	0.094	1016424	0.057
2002	544602	0.099			544602	0.099	617107	0.065
2003	516468	0.12			516468	0.120	601214	0.075
2004	404687	0.085			404687	0.085	438444	0.059
2005	464647	0.136			464647	0.136	485142	0.057
2006	407584	0.059			407584	0.059	427740	0.054
2007	753821	0.256			753821	0.256	673575	0.066
2008	492643	0.101			492643	0.101	500108	0.060
2009	721812	0.087			721812	0.087	747307	0.053
2010	896301	0.13	6671	0.184	902971	0.129	832106	0.059
2011	844482	0.094			844482	0.094	880293	0.057
2012	991342	0.092			991342	0.092	1050007	0.069
2013	760225	0.163			760225	0.163	727888	0.061
2014	1129255	0.127			1129255	0.127	1235189	0.071
2015	985698	0.115			985698	0.115	1069240	0.068
2016	660996	0.093			660996	0.093	890248	0.097
2017	364129	0.088	137182	0.123	501310	0.073	519020	0.049
2018	248542	0.071	243638	0.18	492180	0.097	552584	0.077

Table 2.1.3. Comparison of design-based and VAST survey age compositions.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
1994	0.00024	0.01528	0.01794	-0.00408	-0.01527	-0.00916	-0.00426	-0.00120	0.00045	-0.00043	-0.00002	0.00014	0.00038
1995	0.00016	0.00959	-0.00607	-0.00518	0.00325	-0.00250	0.00420	-0.00239	-0.00163	-0.00045	-0.00005	0.00079	0.00029
1996	0.00003	0.01601	-0.01188	-0.02337	-0.00894	0.01058	0.01321	0.00430	-0.00090	-0.00063	0.00014	0.00062	0.00081
1997	0.00032	0.04365	-0.00851	-0.03707	-0.01698	-0.00266	0.01743	0.00273	0.00071	-0.00069	0.00054	0.00020	0.00032
1998	0.00008	0.01032	-0.00432	-0.00957	-0.00389	0.00147	0.00212	0.00294	0.00103	-0.00052	-0.00005	0.00022	0.00021
1999	0.00009	0.01432	0.01333	0.00788	-0.02138	-0.00920	-0.00411	-0.00056	-0.00005	-0.00011	-0.00020	-0.00007	0.00006
2000	-0.00002	-0.01059	-0.01025	0.01305	-0.00573	0.00897	0.00098	0.00053	0.00206	-0.00046	0.00086	0.00029	0.00029
2001	0.00003	0.00701	0.00095	-0.00892	-0.00634	0.00413	0.00295	0.00018	-0.00014	-0.00033	0.00001	0.00029	0.00016
2002	0.00045	0.00381	0.00500	-0.02090	0.00564	0.00039	0.00253	0.00425	-0.00032	-0.00091	-0.00010	-0.00002	0.00017
2003	0.00000	-0.00014	0.00095	-0.01812	-0.00179	0.00882	0.00526	0.00241	0.00242	-0.00009	-0.00003	0.00006	0.00026
2004	0.00002	0.00338	-0.01270	-0.00666	0.00151	0.00660	0.00849	-0.00091	0.00157	-0.00089	-0.00003	-0.00057	0.00016
2005	0.00001	-0.02183	-0.00631	-0.00766	0.00557	0.00493	0.01396	0.00847	0.00203	0.00014	0.00017	0.00061	-0.00009
2006	0.00000	0.02470	-0.00110	-0.00096	-0.01076	-0.00640	-0.00249	-0.00076	-0.00167	-0.00045	0.00011	-0.00012	-0.00008
2007	0.00000	-0.02258	0.00829	0.00461	0.00453	0.00218	0.00195	0.00155	-0.00019	0.00023	-0.00003	-0.00049	-0.00006
2008	-0.00014	-0.00843	-0.01302	0.00676	0.00860	0.00442	-0.00089	0.00095	0.00052	0.00075	0.00006	0.00077	-0.00033
2009	-0.00068	0.04061	-0.01629	-0.01866	-0.00354	-0.00213	-0.00026	-0.00014	0.00089	-0.00020	0.00014	0.00014	0.00010
2010	0.00000	0.00171	0.00217	0.00201	-0.00589	-0.00194	0.00061	0.00053	0.00019	0.00025	0.00019	0.00012	0.00005
2011	0.00006	0.04794	-0.00215	-0.03108	-0.00716	-0.00764	-0.00025	0.00029	-0.00028	-0.00001	0.00017	0.00011	0.00002
2012	-0.00005	-0.01793	0.01913	0.00251	-0.00917	0.00241	0.00116	0.00096	0.00050	0.00027	0.00013	-0.00001	0.00006
2013	0.00000	-0.00272	-0.04109	0.01808	0.00820	0.01153	0.00387	0.00182	0.00003	0.00017	0.00003	0.00002	0.00005
2014	-0.00002	-0.00291	-0.02199	-0.00204	0.01135	0.00830	0.00619	0.00091	-0.00008	0.00000	0.00009	-0.00004	0.00025
2015	0.00002	-0.00202	0.00452	-0.00249	-0.00004	0.00058	-0.00029	-0.00007	-0.00011	-0.00009	-0.00002	-0.00005	0.00005
2016	0.00000	-0.02911	-0.00511	-0.01275	0.01747	0.02287	0.00684	0.00037	-0.00061	0.00001	0.00004	-0.00003	0.00001
2017	0.00007	-0.02334	0.00862	-0.03243	0.01693	0.01940	0.01070	0.00096	-0.00148	0.00010	0.00008	0.00008	0.00032
Ave:	0.00003	0.00403	-0.00333	-0.00779	-0.00141	0.00316	0.00375	0.00117	0.00021	-0.00018	0.00009	0.00013	0.00014

Table 2.1.4. Results of bridging analysis, part 1 (Model 16.6i to Model 19.3).

Step	0	1	2	3	4	5	6	7	8
B(2019)	290205	276542	281489	296803	260110	296340	299878	297312	303532
B(2020)	246467	235633	237954	252229	241528	243672	246114	245173	244208
maxABC(2019)	181431	176213	178281	184627	135539	196561	199539	196689	200978
maxABC(2020)	137364	130401	131135	140557	108726	148361	149111	141119	142515
B(2019)/B100%	0.44	0.43	0.44	0.45	0.37	0.48	0.48	0.46	0.47
B(2020)/B100%	0.38	0.37	0.37	0.38	0.34	0.40	0.40	0.38	0.38
maxFABC(2019)	0.31	0.31	0.31	0.30	0.24	0.32	0.33	0.33	0.34
maxFABC(2020)	0.29	0.28	0.28	0.29	0.22	0.32	0.33	0.31	0.31
Objective function	1679.54	1762.47	1737.49	1659.54	1773.34	1744.61	1743.21	1743.68	1743.68
Equilibrium catch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Survey index	-26.54	45.77	45.63	37.54	41.20	37.95	37.69	37.78	37.78
Size compostion	1427.42	1437.81	1434.17	1349.17	1367.17	1357.60	1355.58	1354.36	1354.36
Age composition	271.94	272.60	250.74	266.17	357.12	346.41	347.52	347.41	347.41
Recruitment	-2.57	-2.84	-2.04	-0.22	-0.67	-3.11	-3.18	-1.18	-1.18
Initial regime	9.27	9.13	8.98	6.87	8.51	5.77	5.59	5.31	5.31
"Softbounds"	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Deviations	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural mortality	0.34	0.34	0.34	0.34	0.31	0.37	0.37	0.36	0.36
Length at age 1.5	16.38	16.38	16.38	16.38	16.42	16.42	16.43	16.42	16.42
Asymptotic length	100.62	99.57	99.56	100.53	101.39	102.26	102.39	102.43	102.43
Brody growth (K)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Richards growth	1.04	1.01	1.02	1.02	1.02	0.99	0.99	0.99	0.99
SD(length at *a* =1)	3.46	3.45	3.45	3.44	3.48	3.48	3.48	3.48	3.48
SD(length at *a* =20)	9.53	9.54	9.57	9.19	8.60	8.48	8.48	8.50	8.50
Ageing bias (*a* =1)	0.33	0.33	0.33	0.33	0.34	0.32	0.33	0.33	0.33
Ageing bias (*a* =20)	0.16	0.22	0.41	0.38	-0.30	-0.25	-0.27	-0.27	-0.27
Bias (*a* =1, 2008+)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Bias (*a* =20, 2008+)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ln(mean recruits)	12.98	12.99	12.99	12.96	12.76	13.12	13.12	13.14	13.14
SD(ln(recruits))	0.66	0.65	0.66	0.66	0.67	0.62	0.62	0.69	0.69
ln(regime offset)	-1.16	-1.15	-1.15	-0.99	-1.01	-0.95	-0.93	-0.99	-0.99
Initial fishing mort.	0.19	0.19	0.19	0.14	0.13	0.13	0.14	0.14	0.14
ln(catchability)	0.03	0.11	0.10	0.10	0.22	0.10	0.09	0.10	0.10
Survey RMSE	0.18	0.17	0.17	0.17	0.17	0.17	0.16	0.17	0.17
Neff(fishery,size)	583	585	586	495	495	519	520	533	533
Neff(survey,size)	321	321	320	311	308	310	310	310	310
Neff(fishery,age)	n/a	n/a	n/a	n/a	116	133	134	134	134
Neff(survey,age)	61	60	66	63	60	61	61	61	61

For all runs in this table, "survey" means the combined EBS and NBS surveys
Step 0 uses design-based survey estimates; all other steps used VAST survey estimates

Table 2.1.5. Results of bridging analysis, part 2 (Model 19.3 to Model 19.4).

Step	0	1	2	3	4	5	6	7	8	9
B(2019)	303532	173690	230190	201686	205506	261955	262341	229335	248724	322998
B(2020)	244208	191242	225249	210212	211002	223558	223457	199915	211349	266750
maxABC(2019)	200978	46439	100880	72697	77731	176911	177884	149193	167945	218243
maxABC(2020)	142515	52740	89744	73762	76683	124003	134001	108160	120215	169733
B(2019)/B100%	0.47	0.20	0.30	0.27	0.28	0.40	0.44	0.39	0.42	0.50
B(2020)/B100%	0.38	0.23	0.29	0.28	0.29	0.34	0.37	0.34	0.36	0.42
maxFABC(2019)	0.34	0.12	0.20	0.16	0.17	0.34	0.34	0.33	0.34	0.37
maxFABC(2020)	0.31	0.13	0.20	0.17	0.18	0.29	0.32	0.28	0.30	0.37
Objective function	1743.68	7027.31	5571.25	5328.35	5315.12	4725.28	4726.94	4609.49	4376.22	2094.11
Equilibrium catch	0.00	0.06	0.04	0.06	0.06	0.02	0.04	0.04	0.04	0.01
Survey index	37.78	105.08	77.41	82.96	82.77	32.32	32.42	-84.15	-84.73	-85.07
Size compostion	1354.36	5149.60	4950.84	4660.78	4662.90	4133.31	4134.33	4083.91	3861.44	1602.93
Age composition	347.41	1756.49	530.01	563.74	549.22	509.09	509.01	512.15	499.47	436.92
Recruitment	-1.18	-5.25	-5.84	-1.63	-1.58	-4.46	-8.87	-8.80	-11.33	-10.05
Initial regime	5.31	21.32	18.76	22.44	21.75	14.57	19.62	19.69	19.32	9.67
"Softbounds"	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deviations	0.00	0.00	0.00	0.00	0.00	40.43	40.38	86.65	92.01	139.70
Natural mortality	0.36	0.28	0.31	0.28	0.29	0.36	0.36	0.36	0.36	0.37
Length at age 1.5	16.42	16.61	16.58	13.84	13.83	14.72	14.71	14.71	15.56	15.13
Asymptotic length	102.43	116.52	107.72	105.56	106.05	104.85	104.99	104.98	104.57	104.07
Brody growth (K)	0.20	0.13	0.17	0.16	0.16	0.17	0.17	0.18	0.17	0.18
Richards growth	0.99	1.29	1.13	1.23	1.23	1.12	1.12	1.11	1.15	1.12
SD(length at *a* =1)	3.48	3.45	3.51	3.58	3.57	3.46	3.46	3.46	3.36	3.46
SD(length at *a* =20)	8.50	9.23	8.65	10.05	10.10	9.83	9.81	9.78	9.94	9.09
Ageing bias (*a* =1)	0.33	0.25	0.33	0.33	0.31	0.31	0.31	0.30	0.31	0.33
Ageing bias (*a* =20)	-0.27	-0.70	0.28	0.48	1.62	1.55	1.57	1.66	1.50	0.89
Bias (*a* =1, 2008+)	n/a	n/a	n/a	n/a	0.03	0.03	0.03	0.04	0.04	0.02
Bias (*a* =20, 2008+)	n/a	n/a	n/a	n/a	-1.73	-1.53	-1.54	-1.84	-1.60	-2.22
ln(mean recruits)	13.14	12.59	12.76	12.54	12.57	13.15	13.08	13.05	13.04	13.22
SD(ln(recruits))	0.69	0.69	0.69	0.69	0.69	0.69	0.56	0.56	0.56	0.56
ln(regime offset)	-0.99	-1.48	-1.55	-1.50	-1.51	-1.63	-1.56	-1.55	-1.53	-1.13
Initial fishing mort.	0.14	1.37	1.07	1.13	1.10	0.69	0.70	0.74	0.70	0.23
ln(catchability)	0.10	0.39	0.30	0.40	0.38	0.16	0.15	0.19	0.16	0.01
Survey RMSE	0.17	0.20	0.19	0.19	0.19	0.16	0.16	0.07	0.06	0.06
Neff(fishery,size)	533	750	762	727	726	723	726	728	739	2013
Neff(survey,size)	310	258	255	261	262	396	396	412	502	561
Neff(fishery,age)	134	259	75	51	47	40	40	38	30	212
Neff(survey,age)	61	45	42	38	38	64	64	63	71	100

For all runs in this table, "survey" means the combined EBS and NBS surveys, using VAST estimates.
For Steps 4-9, the two rows labeled "Ageing bias..." apply to 1977-2007 only.

Table 2.1.6. Main results.

EBS/NBS hypothesis:	Combine	EBS only		Combine		Separate	
Model structure:	Base	Simple	Complex	Simple	Complex	Simple	Complex
Model	M16.6i	M19.1	M19.2	M19.3	M19.4	M19.5	M19.6
ADSB	0.090	0.323	0.255	0.106	0.573	0.100	0.351
Mohn's ρ	0.207	0.093	0.679	0.337	0.741	0.558	0.736
B(2019)	290205	96355	190394	303532	322998	221920	201524
B(2020)	246467	118012	169236	244208	266750	194879	176107
maxABC(2019)	181431	12191	108116	200978	218243	135217	120504
maxABC(2020)	137364	17707	81106	142515	169733	98986	87074
B(2019)/B100%	0.44	0.11	0.32	0.47	0.50	0.35	0.34
B(2020)/B100%	0.38	0.13	0.28	0.38	0.42	0.31	0.29
maxFABC(2019)	0.31	0.05	0.30	0.34	0.37	0.30	0.32
maxFABC(2020)	0.29	0.07	0.27	0.31	0.37	0.26	0.28
Objective function	1679.54	6582.42	2046.81	1743.68	2094.11	1796.06	2091.54
Equilibrium catch	0.00	0.11	0.01	0.00	0.01	0.00	0.01
Survey index	-26.54	4.63	-66.47	37.78	-85.07	140.42	-70.16
Size compostion	1427.42	4938.20	1566.20	1354.36	1602.93	1327.04	1599.77
Age composition	271.94	1619.83	426.08	347.41	436.92	324.75	427.56
Recruitment	-2.57	-5.32	-7.25	-1.18	-10.05	-1.29	-7.32
Initial regime	9.27	24.97	9.02	5.31	9.67	5.13	9.15
"Softbounds"	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Deviations	0.00	0.00	119.22	0.00	139.70	0.00	132.53
Main survey RMSE	0.18	0.21	0.11	0.17	0.06	0.20	0.11
NBS survey RMSE	n/a	n/a	n/a	n/a	n/a	1.85	0.18
Neff(fishery,size)	583	748	2012	533	2013	533	2007
Neff(main survey,size)	321	248	578	310	561	319	576
Neff(NBS survey, size)	n/a	n/a	n/a	n/a	n/a	667	81
Neff(fishery,age)	n/a	278	215	134	212	125	218
Neff(main survey,age)	61	43	107	61	100	65	106

For Models 16.6i, 19.3, and 19.4, "Main survey" means the combined EBS and NBS surveys.
For all other models, "Main survey" means the EBS survey only.
Models 19.3 and 19.4 use VAST survey index and agecomp estimates.
All other models use design-based survey index and agecomp estimates.

Table 2.1.7a. Main parameters.

Treatment of EBS and NBS surveys:[a]	Combined		EBS only				Combined				Separated			
Model:	Model 16.6i		Model 19.1		Model 19.2		Model 19.3		Model 19.4		Model 19.5		Model 19.6	
Reweighted, size select., time-varying:	No		No		Yes		No		Yes		No		Yes	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Natural mortality rate	0.340	0.012	0.265	0.013	0.382	0.012	0.363	0.017	0.372	0.013	0.366	0.017	0.380	0.012
Length at age 1.5	16.377	0.088	16.673	0.090	15.205	0.406	16.425	0.091	15.128	0.408	16.530	0.093	15.177	0.395
Asymptotic length	100.619	1.955	139.565	5.677	104.772	1.203	102.426	1.898	104.071	1.138	104.061	2.149	104.797	1.194
Brody growth coefficient (K)	0.195	0.012	0.083	0.008	0.178	0.007	0.197	0.011	0.180	0.007	0.185	0.011	0.178	0.007
Richards growth coefficient	1.039	0.047	1.449	0.033	1.118	0.034	0.992	0.045	1.120	0.034	1.019	0.046	1.121	0.034
SD(length at age 1)	3.456	0.058	3.501	0.053	3.430	0.061	3.478	0.060	3.456	0.061	3.529	0.061	3.447	0.061
SD(length at age 20)	9.532	0.272	9.877	0.250	9.150	0.205	8.497	0.271	9.087	0.203	8.907	0.282	9.119	0.205
Mean ageing bias at age 1[b]	0.335	0.012	0.188	0.024	0.343	0.016	0.325	0.014	0.332	0.017	0.320	0.015	0.343	0.016
Mean ageing bias at age 20[b]	0.157	0.145	-0.520	0.095	0.754	0.221	-0.267	0.130	0.888	0.233	-0.256	0.132	0.743	0.222
Mean ageing bias at age 1 (post-2007)					0.011	0.026			0.024	0.026			0.012	0.026
Mean ageing bias at age 20 (post-2007)					-2.163	0.341			-2.223	0.362			-2.149	0.342
ln(mean post-1976 recruitment)	12.984	0.097	12.377	0.089	13.233	0.104	13.142	0.124	13.218	0.110	13.161	0.125	13.219	0.102
SD(log-scale recruitment)	0.656	0.067	0.618	_	0.592	_	0.687	_	0.563	_	0.685	_	0.586	_
ln(pre-1977 mean recruitment offset)	-1.158	0.201	-1.336	0.050	-1.187	0.190	-0.993	0.204	-1.130	0.182	-0.985	0.205	-1.179	0.188
Pre-1977 mean fishing mortality rate	0.190	0.075	1.827	0.657	0.261	0.094	0.142	0.047	0.226	0.076	0.147	0.050	0.259	0.092
ln(catchability) for EBS survey[c]	0.030	0.059	0.356	0.041	-0.054	0.069	0.101	0.059	0.007	0.072	-0.016	0.061	-0.058	0.068
ln(catchability) for NBS survey											-1.686	0.117	-1.564	0.352

a. Survey abundance data are design-based estimates in all cases except for Models 19.3 and 19.4, which use VAST estimates.

b. For Models 19.2, 19.4, and 19.6, this parameter applies to 1977-2007 only.

c. For Models 16.6i, 19.3, and 19.4, this parameter applies to the combined EBS and NBS surveys.

d. For Model 19.4, this parameter applies to the combined EBS and NBS surveys.

Table 2.1.7b. Log recruitment deviations for the initial (1977) numbers-at-age vector.

Treatment of EBS and NBS surveys:	Combined		EBS only				Combined				Separated			
Model:	Model 16.6i		Model 19.1		Model 19.2		Model 19.3		Model 19.4		Model 19.5		Model 19.6	
Reweighted, size select., time-varying:	No		No		Yes		No		Yes		No		Yes	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Initial age 20 ln(recruits) dev	-0.005	0.655	0.000	0.618	-0.009	0.589	-0.007	0.685	-0.018	0.558	-0.006	0.683	-0.011	0.583
Initial age 19 ln(recruits) dev	-0.003	0.655	0.000	0.618	-0.009	0.590	-0.004	0.686	-0.010	0.560	-0.004	0.684	-0.006	0.585
Initial age 18 ln(recruits) dev	-0.005	0.654	0.000	0.618	-0.009	0.589	-0.007	0.685	-0.015	0.558	-0.006	0.683	-0.010	0.583
Initial age 17 ln(recruits) dev	-0.009	0.653	0.000	0.618	-0.014	0.587	-0.011	0.684	-0.023	0.556	-0.010	0.682	-0.017	0.582
Initial age 16 ln(recruits) dev	-0.015	0.651	0.000	0.618	-0.026	0.585	-0.017	0.682	-0.035	0.553	-0.016	0.680	-0.026	0.579
Initial age 15 ln(recruits) dev	-0.025	0.649	0.000	0.618	-0.039	0.581	-0.027	0.679	-0.051	0.549	-0.026	0.677	-0.040	0.576
Initial age 14 ln(recruits) dev	-0.041	0.644	0.000	0.618	-0.057	0.576	-0.042	0.674	-0.076	0.544	-0.041	0.672	-0.059	0.571
Initial age 13 ln(recruits) dev	-0.066	0.638	0.000	0.618	-0.089	0.569	-0.066	0.667	-0.109	0.536	-0.063	0.666	-0.089	0.564
Initial age 12 ln(recruits) dev	-0.105	0.628	0.000	0.618	-0.131	0.560	-0.100	0.658	-0.153	0.527	-0.097	0.656	-0.132	0.555
Initial age 11 ln(recruits) dev	-0.161	0.616	0.000	0.618	-0.182	0.549	-0.148	0.645	-0.208	0.517	-0.145	0.644	-0.184	0.545
Initial age 10 ln(recruits) dev	-0.238	0.601	0.001	0.618	-0.253	0.538	-0.213	0.630	-0.272	0.506	-0.210	0.629	-0.253	0.533
Initial age 9 ln(recruits) dev	-0.338	0.583	0.005	0.620	-0.327	0.526	-0.297	0.612	-0.342	0.496	-0.294	0.611	-0.327	0.521
Initial age 8 ln(recruits) dev	-0.457	0.562	0.027	0.625	-0.399	0.514	-0.400	0.591	-0.407	0.486	-0.401	0.589	-0.398	0.510
Initial age 7 ln(recruits) dev	-0.580	0.540	0.118	0.647	-0.452	0.501	-0.520	0.568	-0.455	0.475	-0.524	0.565	-0.451	0.497
Initial age 6 ln(recruits) dev	-0.674	0.519	0.570	0.690	-0.444	0.485	-0.628	0.545	-0.458	0.460	-0.625	0.544	-0.445	0.481
Initial age 5 ln(recruits) dev	-0.656	0.505	-0.054	0.467	-0.343	0.455	-0.637	0.532	-0.393	0.437	-0.616	0.533	-0.345	0.452
Initial age 4 ln(recruits) dev	-0.273	0.486	0.261	0.186	-0.075	0.444	-0.306	0.518	-0.131	0.430	-0.256	0.517	-0.077	0.441
Initial age 3 ln(recruits) dev	-0.083	0.467	0.502	0.123	0.843	0.267	-0.057	0.481	0.706	0.263	-0.069	0.495	0.837	0.265
Initial age 2 ln(recruits) dev	-0.170	0.522	-0.966	0.343	-0.742	0.396	-0.249	0.543	-0.788	0.375	-0.204	0.555	-0.741	0.392
Initial age 1 ln(recruits) dev	0.803	0.494	1.292	0.102	1.355	0.235	0.746	0.461	1.247	0.231	0.819	0.474	1.341	0.234

Table 2.1.7c. Log recruitment deviations for the time series.

Treatment of EBS and NBS surveys:	Combined		EBS only				Combined				Separated			
Model:	Model 16.6i		Model 19.1		Model 19.2		Model 19.3		Model 19.4		Model 19.5		Model 19.6	
Reweighted, size select., time-varying:	No		No		Yes		No		Yes		No		Yes	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
ln(recruits) dev 1977	0.855	0.209	0.293	0.084	0.752	0.154	0.762	0.211	0.686	0.152	0.842	0.217	0.748	0.152
ln(recruits) dev 1978	0.456	0.238	0.284	0.079	0.397	0.195	0.560	0.197	0.331	0.195	0.575	0.210	0.403	0.193
ln(recruits) dev 1979	0.467	0.138	0.253	0.063	0.739	0.105	0.456	0.128	0.672	0.104	0.476	0.135	0.741	0.103
ln(recruits) dev 1980	-0.273	0.134	-0.581	0.095	-0.353	0.153	-0.173	0.126	-0.425	0.150	-0.189	0.136	-0.357	0.153
ln(recruits) dev 1981	-0.860	0.141	0.149	0.047	-0.304	0.108	-0.797	0.145	-0.366	0.106	-0.795	0.151	-0.300	0.108
ln(recruits) dev 1982	0.788	0.051	0.453	0.039	0.811	0.053	0.823	0.052	0.747	0.050	0.863	0.055	0.811	0.052
ln(recruits) dev 1983	-0.554	0.125	-0.096	0.060	0.037	0.084	-0.482	0.129	-0.032	0.083	-0.510	0.139	0.036	0.083
ln(recruits) dev 1984	0.797	0.051	0.593	0.035	0.524	0.058	0.802	0.050	0.463	0.056	0.847	0.052	0.526	0.057
ln(recruits) dev 1985	-0.202	0.095	-0.030	0.047	0.316	0.057	-0.055	0.079	0.250	0.056	-0.024	0.083	0.316	0.056
ln(recruits) dev 1986	-0.614	0.118	-0.475	0.054	-0.354	0.079	-0.497	0.090	-0.436	0.079	-0.446	0.093	-0.355	0.078
ln(recruits) dev 1987	-1.193	0.181	-0.562	0.051	-0.814	0.109	-1.355	0.153	-0.902	0.109	-1.303	0.159	-0.813	0.108
ln(recruits) dev 1988	-0.331	0.100	-0.123	0.038	-0.274	0.058	-0.473	0.084	-0.341	0.057	-0.382	0.085	-0.271	0.057
ln(recruits) dev 1989	0.549	0.058	0.496	0.027	0.365	0.044	0.494	0.050	0.304	0.043	0.557	0.051	0.366	0.042
ln(recruits) dev 1990	0.388	0.062	0.439	0.028	0.394	0.047	0.384	0.055	0.341	0.046	0.391	0.057	0.395	0.045
ln(recruits) dev 1991	-0.055	0.076	0.019	0.037	-0.343	0.064	0.019	0.067	-0.367	0.063	0.012	0.069	-0.342	0.063
ln(recruits) dev 1992	0.785	0.038	0.753	0.021	0.767	0.040	0.871	0.035	0.746	0.036	0.858	0.036	0.770	0.037
ln(recruits) dev 1993	-0.099	0.059	-0.184	0.034	-0.257	0.060	-0.029	0.054	-0.330	0.058	-0.055	0.055	-0.258	0.058
ln(recruits) dev 1994	-0.298	0.062	-0.293	0.029	-0.367	0.058	-0.310	0.057	-0.439	0.052	-0.291	0.058	-0.364	0.055
ln(recruits) dev 1995	-0.379	0.070	-0.161	0.027	-0.328	0.053	-0.380	0.062	-0.379	0.051	-0.344	0.063	-0.323	0.051
ln(recruits) dev 1996	0.626	0.038	0.469	0.020	0.738	0.042	0.630	0.035	0.685	0.039	0.679	0.035	0.741	0.040
ln(recruits) dev 1997	-0.159	0.061	0.055	0.025	0.363	0.049	-0.116	0.054	0.300	0.048	-0.110	0.056	0.364	0.048
ln(recruits) dev 1998	-0.180	0.064	0.180	0.023	0.023	0.053	-0.114	0.057	-0.048	0.053	-0.078	0.058	0.025	0.052
ln(recruits) dev 1999	0.537	0.040	0.661	0.018	0.501	0.042	0.547	0.038	0.451	0.041	0.556	0.038	0.502	0.040
ln(recruits) dev 2000	0.265	0.044	0.199	0.025	0.233	0.046	0.297	0.041	0.188	0.044	0.256	0.043	0.233	0.044
ln(recruits) dev 2001	-0.530	0.067	-0.384	0.033	-0.655	0.064	-0.466	0.060	-0.697	0.063	-0.480	0.062	-0.654	0.063
ln(recruits) dev 2002	-0.238	0.053	0.013	0.024	-0.151	0.049	-0.173	0.049	-0.180	0.047	-0.210	0.050	-0.146	0.048
ln(recruits) dev 2003	-0.402	0.057	-0.142	0.026	-0.231	0.053	-0.314	0.052	-0.246	0.051	-0.367	0.053	-0.226	0.052
ln(recruits) dev 2004	-0.564	0.062	-0.405	0.030	-0.688	0.060	-0.558	0.059	-0.702	0.060	-0.643	0.061	-0.683	0.059
ln(recruits) dev 2005	-0.282	0.055	-0.439	0.030	-0.544	0.061	-0.398	0.054	-0.553	0.060	-0.439	0.056	-0.539	0.060
ln(recruits) dev 2006	0.842	0.034	0.634	0.018	0.705	0.046	0.692	0.034	0.638	0.044	0.705	0.036	0.705	0.044
ln(recruits) dev 2007	0.018	0.056	0.222	0.022	-0.134	0.076	-0.106	0.055	-0.199	0.078	-0.056	0.056	-0.140	0.075
ln(recruits) dev 2008	1.150	0.031	1.059	0.017	0.843	0.044	1.050	0.031	0.820	0.043	1.051	0.033	0.845	0.042
ln(recruits) dev 2009	-0.877	0.111	-0.659	0.037	-1.217	0.159	-0.850	0.096	-1.155	0.159	-0.936	0.100	-1.208	0.159
ln(recruits) dev 2010	0.648	0.043	0.728	0.018	0.416	0.055	0.648	0.040	0.494	0.056	0.631	0.041	0.426	0.053
ln(recruits) dev 2011	1.042	0.039	0.778	0.018	0.627	0.054	1.001	0.036	0.743	0.057	0.952	0.036	0.642	0.052
ln(recruits) dev 2012	0.234	0.063	0.257	0.024	-0.081	0.082	0.358	0.056	0.106	0.082	0.239	0.057	-0.059	0.081
ln(recruits) dev 2013	1.029	0.045	0.696	0.028	0.663	0.065	1.127	0.039	0.935	0.060	0.937	0.043	0.702	0.063
ln(recruits) dev 2014	-0.695	0.094	-0.937	0.070	-0.838	0.118	-0.710	0.092	-0.626	0.119	-0.719	0.085	-0.785	0.114
ln(recruits) dev 2015	-0.362	0.079	-1.016	0.075	-0.990	0.109	-0.363	0.071	-0.647	0.101	-0.394	0.068	-0.848	0.104
ln(recruits) dev 2016	-0.803	0.113	-1.233	0.104	-0.920	0.149	-1.286	0.123	-0.526	0.138	-0.891	0.095	-0.912	0.147
ln(recruits) dev 2017	-1.528	0.269	-1.962	0.227	-0.368	0.597	-1.516	0.218	-0.304	0.457	-1.767	0.205	-0.713	0.381

Table 2.1.7d. Selectivity parameters (other than parameter deviations).

Treatment of EBS and NBS surveys:	Combined		EBS only				Combined				Separated			
Model:	Model 16.6i		Model 19.1		Model 19.2		Model 19.3		Model 19.4		Model 19.5		Model 19.6	
Reweighted, size select., time-varying:	No		No		Yes		No		Yes		No		Yes	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Age inflection Fishery(1)	4.346	0.044												
Age 95%width Fishery(1)	1.180	0.031												
Age inflection Survey(2)	1.006	0.006												
Age 95%width Survey(2)	0.285	0.055												
Age DblN peak Fishery(4)	5.780	0.073	6.044	0.023			5.651	0.075			5.771	0.073		
Age DblN top logit Fishery(4)	-1.927	3.415	-1.895	0.263			-2.476	4.460			-1.937	3.326		
Age DblN ascend se Fishery(4)	0.929	0.047	1.134	0.013			0.886	0.050			0.930	0.047		
Age DblN descend se Fishery(4)	-3.464	35.553	2.364	0.215			-1.705	25.353			-3.417	34.680		
Age DblN start logit Fishery(4)	-10.000		-10.000				-10.000				-10.000			
Age DblN end logit Fishery(4)	2.169	1.118	-9.410	14.197			1.700	0.782			1.869	0.873		
Age DblN peak EBS survey(5)	2.896	0.170	2.233	0.217			2.889	0.157			2.912	0.166		
Age DblN top logit EBS survey(5)	10.000		10.000				10.000				10.000			
Age DblN ascend se EBS survey(5)	2.043	0.257	1.420	0.516			2.014	0.238			2.055	0.252		
Age DblN descend se EBS survey(5)	10.000		10.000				10.000				10.000			
Age DblN start logit EBS survey(5)	-10.000		-10.000				-10.000				-10.000			
Age DblN end logit EBS survey(5)	10.000		10.000				10.000				10.000			
Age DblN peak NBS survey(6)	5.534	1.177									3.728	0.439		
Age DblN top logit NBS survey(6)	10.000										10.000			
Age DblN ascend se NBS survey(6)	-3.833	30.059									2.013	0.574		
Age DblN descend se NBS survey(6)	10.000										10.000			
Age DblN start logit NBS survey(6)	-10.000										-10.000			
Age DblN end logit NBS survey(6)	10.000										10.000			
Size DblN peak Fishery(1)					74.220	1.108			73.868	1.098			74.198	1.104
Size DblN top logit Fishery(1)					-10.000				-10.000				-10.000	
Size DblN ascend se Fishery(1)					5.843	0.074			5.835	0.076			5.843	0.075
Size DblN descend se Fishery(1)					4.381	0.118			4.419	0.114			4.385	0.117
Size DblN start logit Fishery(1)					-10.000				-10.000				-10.000	
Size DblN end logit Fishery(1)					0.699	0.298			0.556	0.294			0.695	0.297
Size DblN peak EBS survey(2)					23.636	1.467			23.500	1.405			23.518	1.429
Size DblN top logit EBS survey(2)					10.000				10.000				10.000	
Size DblN ascend se EBS survey(2)					3.899	0.223			3.901	0.216			3.884	0.220
Size DblN descend se EBS survey(2)					10.000				10.000				10.000	
Size DblN start logit EBS survey(2)					-10.000				-10.000				-10.000	
Size DblN end logit EBS survey(2)					10.000				10.000				10.000	
Size DblN peak NBS survey(3)													66.701	8.978
Size DblN top logit NBS survey(3)													10.000	
Size DblN ascend se NBS survey(3)													6.999	0.445
Size DblN descend se NBS survey(3)													10.000	
Size DblN start logit NBS survey(3)													-10.000	
Size DblN end logit NBS survey(3)													10.000	

Table 2.1.7e. Input standard deviations for deviation vectors (except recruitment); Dirichlet coefficients.

Treatment of EBS and NBS surveys:	EBS only		Combined		Separated	
Model:	Model 19.2		Model 19.4		Model 19.6	
Reweighted, size select., time-varying:	Yes		Yes		Yes	
Parameter	Est.	SD	Est.	SD	Est.	SD
SD(L at age 1.5 deviations)	0.155	_	0.156	_	0.150	_
SD(EBS catchability deviations)[a]	0.110	_	0.090	_	0.108	_
SD(NBS catchability deviations)					0.531	_
SD(fishery peak deviations)	0.089	_	0.088	_	0.088	_
SD(fishery ascending_se deviations)	0.455	_	0.461	_	0.457	_
SD(fishery end_logit deviations)	1.446	_	1.457	_	1.439	_
SD(survey peak deviations)	0.360	_	0.348	_	0.353	_
SD(survey ascending_se deviations)	1.257	_	1.218	_	1.244	_
Dirichlet coef. (fishery sizecomps)	9.990	_	10.000	_	9.967	_
Dirichlet coef. (EBS survey sizecomps)[a]	9.983	_	10.000	_	9.978	_
Dirichlet coef. (NBS survey sizecomps)					9.976	_
Dirichlet coef. (fishery agecomps)	-3.998	0.197	-4.109	0.206	-4.002	0.197
Dirichlet coef. (EBS survey agecomps)[a]	0.049	0.201	-0.144	0.183	0.022	0.198
Dirichlet coef. (NBS survey agecomps)					0.000	_

Table 2.1.7f. Deviations in mean length at age 1.5.

Treatment of EBS and NBS surveys: Model: Reweighted, size select., time-varying:	EBS only Model 19.2 Yes		Combined Model 19.4 Yes		Separated Model 19.6 Yes	
Parameter	Est.	SD	Est.	SD	Est.	SD
L at age 1.5 dev 1977	-0.065	0.826	-0.035	0.845	-0.045	0.836
L at age 1.5 dev 1978	-1.883	0.622	-1.881	0.624	-1.875	0.633
L at age 1.5 dev 1979	-0.975	0.749	-0.954	0.751	-0.936	0.760
L at age 1.5 dev 1980	-0.317	1.057	-0.313	1.061	-0.289	1.059
L at age 1.5 dev 1981	0.345	0.374	0.356	0.372	0.358	0.384
L at age 1.5 dev 1982	-0.709	0.342	-0.703	0.338	-0.738	0.355
L at age 1.5 dev 1983	0.179	0.452	0.187	0.450	0.200	0.464
L at age 1.5 dev 1984	0.273	0.225	0.294	0.224	0.295	0.229
L at age 1.5 dev 1985	-1.267	0.446	-1.277	0.452	-1.293	0.458
L at age 1.5 dev 1986	0.094	0.237	0.100	0.237	0.105	0.242
L at age 1.5 dev 1987	-0.195	0.277	-0.203	0.278	-0.198	0.284
L at age 1.5 dev 1988	0.190	0.282	0.191	0.283	0.201	0.289
L at age 1.5 dev 1989	-0.695	0.266	-0.685	0.265	-0.711	0.272
L at age 1.5 dev 1990	0.162	0.236	0.181	0.236	0.177	0.241
L at age 1.5 dev 1991	0.001	0.213	0.009	0.213	0.012	0.217
L at age 1.5 dev 1992	-0.361	0.214	-0.320	0.214	-0.368	0.218
L at age 1.5 dev 1993	0.699	0.256	0.743	0.258	0.731	0.263
L at age 1.5 dev 1994	-0.535	0.217	-0.557	0.215	-0.547	0.220
L at age 1.5 dev 1995	-0.063	0.384	-0.306	0.326	-0.077	0.364
L at age 1.5 dev 1996	-0.078	0.231	-0.063	0.223	-0.078	0.235
L at age 1.5 dev 1997	0.053	0.224	0.111	0.221	0.064	0.227
L at age 1.5 dev 1998	-0.897	0.213	-0.854	0.213	-0.914	0.216
L at age 1.5 dev 1999	-1.245	0.226	-1.251	0.228	-1.279	0.230
L at age 1.5 dev 2000	0.431	0.216	0.472	0.216	0.457	0.220
L at age 1.5 dev 2001	0.323	0.212	0.353	0.212	0.342	0.215
L at age 1.5 dev 2002	0.587	0.204	0.593	0.204	0.610	0.207
L at age 1.5 dev 2003	0.517	0.269	0.500	0.271	0.535	0.275
L at age 1.5 dev 2004	0.833	0.215	0.841	0.215	0.872	0.218
L at age 1.5 dev 2005	0.409	0.239	0.439	0.238	0.436	0.244
L at age 1.5 dev 2006	-0.364	0.206	-0.333	0.206	-0.362	0.209
L at age 1.5 dev 2007	-1.217	0.260	-1.200	0.261	-1.236	0.266
L at age 1.5 dev 2008	-0.993	0.212	-0.944	0.212	-1.014	0.216
L at age 1.5 dev 2009	-0.401	0.328	-0.407	0.335	-0.420	0.338
L at age 1.5 dev 2010	0.108	0.202	0.081	0.203	0.104	0.205
L at age 1.5 dev 2011	-1.230	0.281	-1.363	0.277	-1.273	0.288
L at age 1.5 dev 2012	0.079	0.268	0.058	0.274	0.091	0.274
L at age 1.5 dev 2013	-0.371	0.217	-0.401	0.220	-0.390	0.221
L at age 1.5 dev 2014	0.278	0.370	0.353	0.371	0.292	0.383
L at age 1.5 dev 2015	1.503	0.206	1.488	0.207	1.546	0.209
L at age 1.5 dev 2016	1.985	0.265	1.935	0.285	2.081	0.283
L at age 1.5 dev 2017	1.844	0.311	1.755	0.299	1.598	0.320
L at age 1.5 dev 2018	2.966	0.292	3.009	0.270	2.930	0.294

Table 2.1.7g. Deviations in log catchability.

Treatment of EBS and NBS surveys: Model: Reweighted, size select., time-varying:	EBS only Model 19.2 Yes		Combined Model 19.4 Yes		Separated Model 19.6 Yes	
Parameter	Est.	SD	Est.	SD	Est.	SD
ln(EBS Q) dev 1982	-0.283	0.624	0.164	0.653	-0.238	0.629
ln(EBS Q) dev 1983	-0.078	0.754	0.098	0.703	-0.055	0.759
ln(EBS Q) dev 1984	-1.036	0.617	-0.945	0.611	-0.994	0.622
ln(EBS Q) dev 1985	-0.024	0.792	0.263	0.609	0.001	0.796
ln(EBS Q) dev 1986	0.435	0.703	0.653	0.588	0.468	0.707
ln(EBS Q) dev 1987	-0.460	0.565	-0.254	0.585	-0.413	0.570
ln(EBS Q) dev 1988	-0.683	0.577	-0.964	0.561	-0.642	0.582
ln(EBS Q) dev 1989	-1.240	0.673	-1.383	0.693	-1.235	0.677
ln(EBS Q) dev 1990	-1.443	0.670	-1.732	0.637	-1.417	0.675
ln(EBS Q) dev 1991	-0.884	0.721	-1.105	0.656	-0.855	0.725
ln(EBS Q) dev 1992	-0.535	0.749	-1.136	0.651	-0.504	0.753
ln(EBS Q) dev 1993	0.658	0.764	1.002	0.666	0.680	0.769
ln(EBS Q) dev 1994	2.805	0.763	4.485	0.622	2.820	0.767
ln(EBS Q) dev 1995	1.587	0.691	2.138	0.578	1.621	0.696
ln(EBS Q) dev 1996	1.067	0.805	2.504	0.646	1.081	0.808
ln(EBS Q) dev 1997	0.026	0.806	0.015	0.629	0.041	0.810
ln(EBS Q) dev 1998	0.001	0.692	0.485	0.700	0.018	0.697
ln(EBS Q) dev 1999	0.315	0.724	-0.005	0.680	0.327	0.728
ln(EBS Q) dev 2000	-2.054	0.667	-3.058	0.587	-2.024	0.672
ln(EBS Q) dev 2001	0.703	0.681	1.020	0.599	0.739	0.686
ln(EBS Q) dev 2002	-0.983	0.693	-0.914	0.628	-0.956	0.698
ln(EBS Q) dev 2003	-0.370	0.755	0.029	0.681	-0.344	0.760
ln(EBS Q) dev 2004	-1.142	0.654	-1.434	0.618	-1.120	0.659
ln(EBS Q) dev 2005	-0.033	0.791	-0.271	0.602	-0.018	0.795
ln(EBS Q) dev 2006	-0.950	0.552	-1.371	0.590	-0.926	0.557
ln(EBS Q) dev 2007	0.040	0.921	-0.879	0.644	0.059	0.923
ln(EBS Q) dev 2008	-1.271	0.709	-2.177	0.627	-1.232	0.714
ln(EBS Q) dev 2009	-1.393	0.665	-2.194	0.599	-1.342	0.670
ln(EBS Q) dev 2010	0.832	0.776	0.643	0.600	0.862	0.780
ln(EBS Q) dev 2011	1.435	0.687	1.707	0.620	1.480	0.692
ln(EBS Q) dev 2012	0.598	0.687	0.396	0.703	0.616	0.692
ln(EBS Q) dev 2013	0.245	0.837	-0.993	0.637	0.240	0.841
ln(EBS Q) dev 2014	1.771	0.778	2.130	0.692	1.740	0.783
ln(EBS Q) dev 2015	1.640	0.754	1.036	0.682	1.555	0.758
ln(EBS Q) dev 2016	1.376	0.709	1.110	0.777	1.224	0.714
ln(EBS Q) dev 2017	-0.139	0.726	-0.506	0.677	-0.431	0.729
ln(EBS Q) dev 2018	-0.520	0.773	1.443	0.789	-0.823	0.764
ln(NBS Q) dev 2010					-4.134	0.639
ln(NBS Q) dev 2017					1.421	0.618
ln(NBS Q) dev 2018					2.715	0.634

Table 2.1.7h. Deviations in the size at peak fishery selectivity.

Treatment of EBS and NBS surveys:	EBS only		Combined		Separated	
Model:	Model 19.2		Model 19.4		Model 19.6	
Reweighted, size select., time-varying:	Yes		Yes		Yes	
Parameter	Est.	SD	Est.	SD	Est.	SD
DblN_peak_Fishery_dev_1977	-0.467	0.572	-0.558	0.556	-0.473	0.571
DblN_peak_Fishery_dev_1978	-1.130	0.502	-1.213	0.471	-1.137	0.499
DblN_peak_Fishery_dev_1979	-1.361	0.421	-1.314	0.394	-1.357	0.421
DblN_peak_Fishery_dev_1980	0.000	0.534	-0.008	0.509	-0.006	0.536
DblN_peak_Fishery_dev_1981	-2.118	0.995	-2.137	1.013	-2.126	0.997
DblN_peak_Fishery_dev_1982	1.240	0.502	1.223	0.490	1.237	0.501
DblN_peak_Fishery_dev_1983	1.722	0.386	1.727	0.376	1.726	0.386
DblN_peak_Fishery_dev_1984	1.606	0.302	1.654	0.297	1.619	0.302
DblN_peak_Fishery_dev_1985	0.128	0.227	0.167	0.229	0.132	0.228
DblN_peak_Fishery_dev_1986	0.494	0.225	0.504	0.227	0.491	0.226
DblN_peak_Fishery_dev_1987	0.485	0.211	0.485	0.211	0.482	0.211
DblN_peak_Fishery_dev_1988	0.838	0.286	0.838	0.286	0.835	0.286
DblN_peak_Fishery_dev_1989	2.144	0.332	2.152	0.331	2.143	0.332
DblN_peak_Fishery_dev_1990	1.721	0.253	1.720	0.251	1.723	0.253
DblN_peak_Fishery_dev_1991	-0.075	0.266	-0.112	0.264	-0.076	0.266
DblN_peak_Fishery_dev_1992	-0.400	0.202	-0.405	0.201	-0.403	0.202
DblN_peak_Fishery_dev_1993	-0.187	0.255	-0.174	0.248	-0.191	0.254
DblN_peak_Fishery_dev_1994	-0.093	0.209	-0.041	0.206	-0.092	0.208
DblN_peak_Fishery_dev_1995	-0.048	0.229	0.068	0.231	-0.039	0.229
DblN_peak_Fishery_dev_1996	1.249	0.237	1.351	0.243	1.253	0.237
DblN_peak_Fishery_dev_1997	0.411	0.218	0.403	0.219	0.415	0.218
DblN_peak_Fishery_dev_1998	-0.124	0.197	-0.138	0.197	-0.119	0.197
DblN_peak_Fishery_dev_1999	-0.123	0.192	-0.141	0.191	-0.119	0.192
DblN_peak_Fishery_dev_2000	0.055	0.192	0.027	0.192	0.055	0.193
DblN_peak_Fishery_dev_2001	-0.355	0.191	-0.353	0.189	-0.355	0.191
DblN_peak_Fishery_dev_2002	-0.581	0.192	-0.559	0.190	-0.583	0.192
DblN_peak_Fishery_dev_2003	-0.761	0.195	-0.723	0.195	-0.768	0.195
DblN_peak_Fishery_dev_2004	-1.436	0.180	-1.398	0.180	-1.438	0.180
DblN_peak_Fishery_dev_2005	-0.893	0.181	-0.853	0.182	-0.891	0.181
DblN_peak_Fishery_dev_2006	-0.925	0.202	-0.893	0.203	-0.921	0.203
DblN_peak_Fishery_dev_2007	-0.436	0.218	-0.400	0.218	-0.432	0.218
DblN_peak_Fishery_dev_2008	-1.122	0.186	-1.094	0.185	-1.122	0.186
DblN_peak_Fishery_dev_2009	-0.572	0.179	-0.562	0.179	-0.575	0.179
DblN_peak_Fishery_dev_2010	0.370	0.522	0.131	0.551	0.336	0.527
DblN_peak_Fishery_dev_2011	0.232	0.585	0.240	0.581	0.230	0.585
DblN_peak_Fishery_dev_2012	0.785	0.416	0.745	0.407	0.780	0.416
DblN_peak_Fishery_dev_2013	-0.080	0.453	-0.074	0.448	-0.079	0.453
DblN_peak_Fishery_dev_2014	0.428	0.430	0.414	0.426	0.427	0.430
DblN_peak_Fishery_dev_2015	0.570	0.458	0.546	0.461	0.567	0.457
DblN_peak_Fishery_dev_2016	0.292	0.427	0.243	0.427	0.292	0.426
DblN_peak_Fishery_dev_2017	-0.121	0.418	-0.083	0.428	-0.079	0.422
DblN_peak_Fishery_dev_2018	-1.362	0.210	-1.398	0.207	-1.368	0.210

Table 2.1.7i. Deviations in fishery selectivity log-scale ascending width.

Treatment of EBS and NBS surveys: Model: Reweighted, size select., time-varying:	EBS only Model 19.2 Yes		Combined Model 19.4 Yes		Separated Model 19.6 Yes	
Parameter	Est.	SD	Est.	SD	Est.	SD
DblN_ascend_se_Fishery_dev_1977	-0.212	0.638	-0.187	0.638	-0.209	0.636
DblN_ascend_se_Fishery_dev_1978	-0.723	0.453	-0.776	0.438	-0.725	0.450
DblN_ascend_se_Fishery_dev_1979	-0.631	0.380	-0.585	0.362	-0.619	0.378
DblN_ascend_se_Fishery_dev_1980	0.539	0.396	0.548	0.381	0.538	0.394
DblN_ascend_se_Fishery_dev_1981	0.525	0.780	0.522	0.789	0.523	0.778
DblN_ascend_se_Fishery_dev_1982	0.729	0.396	0.717	0.389	0.725	0.394
DblN_ascend_se_Fishery_dev_1983	1.415	0.285	1.406	0.279	1.408	0.284
DblN_ascend_se_Fishery_dev_1984	1.570	0.223	1.581	0.220	1.568	0.222
DblN_ascend_se_Fishery_dev_1985	0.069	0.218	0.100	0.218	0.074	0.218
DblN_ascend_se_Fishery_dev_1986	0.800	0.204	0.803	0.204	0.796	0.203
DblN_ascend_se_Fishery_dev_1987	0.515	0.196	0.509	0.196	0.511	0.196
DblN_ascend_se_Fishery_dev_1988	2.005	0.242	2.007	0.241	1.998	0.241
DblN_ascend_se_Fishery_dev_1989	2.222	0.259	2.223	0.258	2.212	0.258
DblN_ascend_se_Fishery_dev_1990	1.401	0.211	1.395	0.210	1.394	0.211
DblN_ascend_se_Fishery_dev_1991	0.125	0.224	0.098	0.223	0.125	0.224
DblN_ascend_se_Fishery_dev_1992	-0.269	0.196	-0.282	0.194	-0.267	0.195
DblN_ascend_se_Fishery_dev_1993	0.632	0.215	0.611	0.211	0.628	0.214
DblN_ascend_se_Fishery_dev_1994	0.551	0.187	0.556	0.185	0.549	0.186
DblN_ascend_se_Fishery_dev_1995	0.301	0.204	0.371	0.204	0.307	0.204
DblN_ascend_se_Fishery_dev_1996	1.202	0.199	1.263	0.200	1.199	0.198
DblN_ascend_se_Fishery_dev_1997	0.738	0.188	0.742	0.188	0.736	0.188
DblN_ascend_se_Fishery_dev_1998	-0.051	0.182	-0.051	0.182	-0.048	0.181
DblN_ascend_se_Fishery_dev_1999	-0.149	0.182	-0.148	0.181	-0.143	0.182
DblN_ascend_se_Fishery_dev_2000	-0.338	0.183	-0.346	0.182	-0.334	0.183
DblN_ascend_se_Fishery_dev_2001	-0.563	0.183	-0.558	0.182	-0.558	0.183
DblN_ascend_se_Fishery_dev_2002	-0.234	0.183	-0.223	0.182	-0.231	0.183
DblN_ascend_se_Fishery_dev_2003	-0.331	0.190	-0.308	0.189	-0.333	0.190
DblN_ascend_se_Fishery_dev_2004	-1.197	0.183	-1.167	0.183	-1.193	0.183
DblN_ascend_se_Fishery_dev_2005	-0.771	0.183	-0.747	0.182	-0.766	0.182
DblN_ascend_se_Fishery_dev_2006	-0.915	0.205	-0.897	0.205	-0.906	0.205
DblN_ascend_se_Fishery_dev_2007	-0.396	0.207	-0.371	0.206	-0.390	0.207
DblN_ascend_se_Fishery_dev_2008	-1.276	0.183	-1.230	0.183	-1.266	0.183
DblN_ascend_se_Fishery_dev_2009	-1.404	0.180	-1.338	0.180	-1.392	0.180
DblN_ascend_se_Fishery_dev_2010	-0.027	0.452	-0.100	0.471	-0.034	0.453
DblN_ascend_se_Fishery_dev_2011	-0.161	0.554	-0.160	0.554	-0.159	0.551
DblN_ascend_se_Fishery_dev_2012	-0.220	0.539	-0.254	0.537	-0.225	0.536
DblN_ascend_se_Fishery_dev_2013	-0.210	0.425	-0.273	0.428	-0.215	0.423
DblN_ascend_se_Fishery_dev_2014	-0.263	0.454	-0.345	0.454	-0.270	0.452
DblN_ascend_se_Fishery_dev_2015	-0.520	0.456	-0.587	0.458	-0.530	0.453
DblN_ascend_se_Fishery_dev_2016	-1.070	0.510	-1.152	0.522	-1.085	0.506
DblN_ascend_se_Fishery_dev_2017	-1.592	0.680	-1.508	0.690	-1.575	0.683
DblN_ascend_se_Fishery_dev_2018	-1.828	0.249	-1.857	0.245	-1.823	0.247

Table 2.1.7j. Deviations in fishery logit-scale selectivity at maximum length.

Treatment of EBS and NBS surveys: Model: Reweighted, size select., time-varying:	EBS only Model 19.2 Yes		Combined Model 19.4 Yes		Separated Model 19.6 Yes	
Parameter	Est.	SD	Est.	SD	Est.	SD
DblN_end_logit_Fishery_dev_1977	-0.878	0.867	-0.990	0.789	-0.886	0.864
DblN_end_logit_Fishery_dev_1978	-0.934	0.652	-1.068	0.575	-0.948	0.649
DblN_end_logit_Fishery_dev_1979	-0.970	0.619	-1.122	0.559	-0.984	0.618
DblN_end_logit_Fishery_dev_1980	-0.058	0.873	-0.208	0.824	-0.062	0.874
DblN_end_logit_Fishery_dev_1981	0.308	0.840	0.303	0.831	0.300	0.841
DblN_end_logit_Fishery_dev_1982	0.030	0.902	-0.019	0.883	0.025	0.902
DblN_end_logit_Fishery_dev_1983	-0.094	0.870	-0.177	0.831	-0.102	0.870
DblN_end_logit_Fishery_dev_1984	-0.344	0.687	-0.397	0.657	-0.357	0.688
DblN_end_logit_Fishery_dev_1985	0.382	0.380	0.453	0.372	0.396	0.384
DblN_end_logit_Fishery_dev_1986	-0.334	0.307	-0.221	0.304	-0.324	0.308
DblN_end_logit_Fishery_dev_1987	-0.105	0.272	-0.001	0.267	-0.099	0.273
DblN_end_logit_Fishery_dev_1988	-0.276	0.389	-0.196	0.377	-0.275	0.389
DblN_end_logit_Fishery_dev_1989	-0.153	0.636	-0.065	0.616	-0.145	0.636
DblN_end_logit_Fishery_dev_1990	0.735	0.587	0.852	0.566	0.739	0.585
DblN_end_logit_Fishery_dev_1991	1.874	0.524	1.907	0.516	1.878	0.525
DblN_end_logit_Fishery_dev_1992	0.370	0.293	0.391	0.274	0.370	0.293
DblN_end_logit_Fishery_dev_1993	0.044	0.343	0.066	0.318	0.040	0.342
DblN_end_logit_Fishery_dev_1994	-0.258	0.262	-0.233	0.253	-0.268	0.262
DblN_end_logit_Fishery_dev_1995	0.462	0.374	0.417	0.349	0.443	0.371
DblN_end_logit_Fishery_dev_1996	1.116	0.603	1.062	0.597	1.099	0.604
DblN_end_logit_Fishery_dev_1997	1.233	0.521	1.316	0.510	1.225	0.519
DblN_end_logit_Fishery_dev_1998	0.663	0.365	0.676	0.340	0.670	0.366
DblN_end_logit_Fishery_dev_1999	0.319	0.288	0.333	0.273	0.329	0.290
DblN_end_logit_Fishery_dev_2000	0.525	0.333	0.468	0.297	0.535	0.335
DblN_end_logit_Fishery_dev_2001	0.007	0.266	-0.044	0.249	0.003	0.266
DblN_end_logit_Fishery_dev_2002	0.060	0.266	0.023	0.253	0.059	0.267
DblN_end_logit_Fishery_dev_2003	-0.180	0.240	-0.160	0.233	-0.179	0.240
DblN_end_logit_Fishery_dev_2004	-0.400	0.218	-0.339	0.213	-0.407	0.218
DblN_end_logit_Fishery_dev_2005	-0.176	0.220	-0.105	0.215	-0.181	0.221
DblN_end_logit_Fishery_dev_2006	1.856	0.500	1.906	0.491	1.855	0.500
DblN_end_logit_Fishery_dev_2007	2.137	0.506	2.196	0.498	2.146	0.506
DblN_end_logit_Fishery_dev_2008	-0.128	0.238	-0.047	0.232	-0.125	0.239
DblN_end_logit_Fishery_dev_2009	-1.214	0.220	-1.113	0.214	-1.216	0.220
DblN_end_logit_Fishery_dev_2010	-0.412	0.903	-0.292	0.856	-0.396	0.902
DblN_end_logit_Fishery_dev_2011	-0.143	0.865	-0.194	0.845	-0.141	0.866
DblN_end_logit_Fishery_dev_2012	-1.290	0.738	-1.305	0.716	-1.298	0.737
DblN_end_logit_Fishery_dev_2013	-0.918	0.732	-0.975	0.701	-0.927	0.731
DblN_end_logit_Fishery_dev_2014	-0.842	0.785	-0.893	0.753	-0.849	0.784
DblN_end_logit_Fishery_dev_2015	-0.030	0.914	-0.084	0.904	-0.032	0.915
DblN_end_logit_Fishery_dev_2016	-1.023	0.796	-1.074	0.764	-1.023	0.798
DblN_end_logit_Fishery_dev_2017	-1.085	0.778	-1.059	0.774	-1.065	0.788
DblN_end_logit_Fishery_dev_2018	0.118	0.324	0.011	0.276	0.175	0.330

Table 2.1.7k. Deviations in the size at peak survey selectivity.

Treatment of EBS and NBS surveys: Model: Reweighted, size select., time-varying:	EBS only Model 19.2 Yes		Combined Model 19.4 Yes		Separated Model 19.6 Yes	
Parameter	Est.	SD	Est.	SD	Est.	SD
DblN_peak_EBS_survey_dev_1982	1.321	0.252	1.351	0.254	1.352	0.255
DblN_peak_EBS_survey_dev_1983	-0.085	0.523	-0.187	0.529	-0.110	0.540
DblN_peak_EBS_survey_dev_1984	0.425	0.237	0.446	0.240	0.446	0.238
DblN_peak_EBS_survey_dev_1985	-0.097	0.228	-0.108	0.228	-0.089	0.228
DblN_peak_EBS_survey_dev_1986	0.246	0.478	0.203	0.493	0.266	0.486
DblN_peak_EBS_survey_dev_1987	-0.093	0.283	-0.118	0.286	-0.087	0.286
DblN_peak_EBS_survey_dev_1988	0.305	0.305	0.305	0.309	0.321	0.308
DblN_peak_EBS_survey_dev_1989	2.523	0.339	2.563	0.337	2.564	0.348
DblN_peak_EBS_survey_dev_1990	-0.487	0.270	-0.499	0.273	-0.492	0.272
DblN_peak_EBS_survey_dev_1991	0.772	0.304	0.811	0.308	0.792	0.304
DblN_peak_EBS_survey_dev_1992	-0.766	0.294	-0.727	0.289	-0.774	0.299
DblN_peak_EBS_survey_dev_1993	-0.222	0.239	-0.224	0.242	-0.219	0.240
DblN_peak_EBS_survey_dev_1994	1.119	0.233	1.034	0.257	1.147	0.234
DblN_peak_EBS_survey_dev_1995	0.111	0.297	0.034	0.303	0.125	0.301
DblN_peak_EBS_survey_dev_1996	0.571	0.562	0.124	0.333	0.576	0.485
DblN_peak_EBS_survey_dev_1997	0.332	0.277	0.255	0.256	0.345	0.280
DblN_peak_EBS_survey_dev_1998	1.159	0.207	1.178	0.208	1.190	0.207
DblN_peak_EBS_survey_dev_1999	1.774	0.232	1.782	0.243	1.811	0.234
DblN_peak_EBS_survey_dev_2000	-0.850	0.220	-0.837	0.223	-0.856	0.221
DblN_peak_EBS_survey_dev_2001	-0.700	0.238	-0.734	0.240	-0.706	0.239
DblN_peak_EBS_survey_dev_2002	-0.099	0.315	-0.114	0.334	-0.097	0.323
DblN_peak_EBS_survey_dev_2003	-0.083	0.235	-0.090	0.237	-0.077	0.237
DblN_peak_EBS_survey_dev_2004	0.263	0.333	0.258	0.342	0.268	0.336
DblN_peak_EBS_survey_dev_2005	-0.542	0.249	-0.495	0.251	-0.544	0.252
DblN_peak_EBS_survey_dev_2006	-1.470	0.217	-1.525	0.221	-1.480	0.218
DblN_peak_EBS_survey_dev_2007	-1.819	0.191	-1.861	0.193	-1.839	0.192
DblN_peak_EBS_survey_dev_2008	-1.240	0.239	-1.246	0.239	-1.253	0.241
DblN_peak_EBS_survey_dev_2009	-1.676	0.240	-1.720	0.241	-1.696	0.242
DblN_peak_EBS_survey_dev_2010	-0.599	0.368	-0.371	0.387	-0.595	0.373
DblN_peak_EBS_survey_dev_2011	-0.328	0.201	-0.349	0.209	-0.324	0.206
DblN_peak_EBS_survey_dev_2012	-1.717	0.230	-1.568	0.287	-1.728	0.231
DblN_peak_EBS_survey_dev_2013	0.294	0.234	0.387	0.248	0.318	0.236
DblN_peak_EBS_survey_dev_2014	-0.384	0.223	-0.330	0.230	-0.371	0.224
DblN_peak_EBS_survey_dev_2015	0.295	0.423	0.372	0.453	0.324	0.431
DblN_peak_EBS_survey_dev_2016	0.166	0.235	0.299	0.242	0.250	0.242
DblN_peak_EBS_survey_dev_2017	0.527	0.264	0.780	0.280	0.582	0.294
DblN_peak_EBS_survey_dev_2018	1.045	0.483	0.918	0.357	0.651	0.288

Table 2.1.7l. Deviations in survey selectivity log-scale ascending width.

Treatment of EBS and NBS surveys: Model: Reweighted, size select., time-varying:	EBS only Model 19.2 Yes		Combined Model 19.4 Yes		Separated Model 19.6 Yes	
Parameter	Est.	SD	Est.	SD	Est.	SD
DblN_ascend_se_survey_dev_1982	1.146	0.264	1.167	0.268	1.164	0.266
DblN_ascend_se_survey_dev_1983	0.427	0.652	0.322	0.676	0.402	0.672
DblN_ascend_se_survey_dev_1984	0.241	0.283	0.245	0.288	0.256	0.285
DblN_ascend_se_survey_dev_1985	0.128	0.290	0.119	0.293	0.138	0.291
DblN_ascend_se_survey_dev_1986	0.472	0.523	0.432	0.544	0.493	0.528
DblN_ascend_se_survey_dev_1987	-0.176	0.412	-0.216	0.423	-0.172	0.416
DblN_ascend_se_survey_dev_1988	0.092	0.385	0.075	0.392	0.102	0.387
DblN_ascend_se_survey_dev_1989	2.203	0.318	2.230	0.319	2.222	0.323
DblN_ascend_se_survey_dev_1990	-0.145	0.339	-0.169	0.344	-0.146	0.341
DblN_ascend_se_survey_dev_1991	1.173	0.344	1.198	0.350	1.191	0.343
DblN_ascend_se_survey_dev_1992	-0.762	0.426	-0.729	0.412	-0.769	0.434
DblN_ascend_se_survey_dev_1993	0.090	0.299	0.094	0.306	0.095	0.300
DblN_ascend_se_survey_dev_1994	1.187	0.265	1.183	0.296	1.208	0.265
DblN_ascend_se_survey_dev_1995	-0.010	0.381	-0.072	0.397	0.002	0.385
DblN_ascend_se_survey_dev_1996	0.341	0.619	-0.174	0.422	0.336	0.533
DblN_ascend_se_survey_dev_1997	0.365	0.319	0.291	0.298	0.375	0.321
DblN_ascend_se_survey_dev_1998	1.002	0.222	1.030	0.226	1.023	0.223
DblN_ascend_se_survey_dev_1999	1.723	0.241	1.755	0.253	1.746	0.242
DblN_ascend_se_survey_dev_2000	-0.862	0.305	-0.863	0.310	-0.863	0.307
DblN_ascend_se_survey_dev_2001	-0.537	0.350	-0.575	0.358	-0.540	0.352
DblN_ascend_se_survey_dev_2002	-0.038	0.401	-0.055	0.427	-0.038	0.410
DblN_ascend_se_survey_dev_2003	-0.024	0.301	-0.045	0.306	-0.020	0.303
DblN_ascend_se_survey_dev_2004	0.402	0.411	0.376	0.425	0.403	0.413
DblN_ascend_se_survey_dev_2005	-0.678	0.383	-0.635	0.383	-0.683	0.387
DblN_ascend_se_survey_dev_2006	-1.583	0.328	-1.645	0.341	-1.580	0.331
DblN_ascend_se_survey_dev_2007	-2.139	0.348	-2.185	0.359	-2.146	0.351
DblN_ascend_se_survey_dev_2008	-1.365	0.380	-1.376	0.376	-1.373	0.384
DblN_ascend_se_survey_dev_2009	-1.345	0.407	-1.399	0.411	-1.351	0.409
DblN_ascend_se_survey_dev_2010	-0.697	0.520	-0.323	0.470	-0.693	0.523
DblN_ascend_se_survey_dev_2011	-0.338	0.251	-0.385	0.266	-0.338	0.260
DblN_ascend_se_survey_dev_2012	-1.626	0.390	-1.352	0.467	-1.621	0.388
DblN_ascend_se_survey_dev_2013	0.438	0.260	0.465	0.272	0.453	0.261
DblN_ascend_se_survey_dev_2014	-0.348	0.301	-0.335	0.309	-0.341	0.302
DblN_ascend_se_survey_dev_2015	0.365	0.500	0.419	0.525	0.371	0.503
DblN_ascend_se_survey_dev_2016	0.065	0.308	0.131	0.316	0.128	0.318
DblN_ascend_se_survey_dev_2017	0.359	0.334	0.571	0.339	0.495	0.356
DblN_ascend_se_survey_dev_2018	0.483	0.485	0.431	0.372	0.067	0.348

Table 2.1.8. Full-selection fishing mortality.

	Model 16.6i		Model 19.1		Model 19.2		Model 19.3		Model 19.4		Model 19.5		Model 19.6	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
1977	0.312	0.117	1.226	0.131	0.306	0.097	0.226	0.071	0.271	0.082	0.231	0.075	0.304	0.096
1978	0.411	0.162	1.208	0.100	0.290	0.068	0.290	0.092	0.277	0.063	0.297	0.097	0.288	0.068
1979	0.325	0.125	0.762	0.066	0.194	0.039	0.226	0.068	0.192	0.039	0.231	0.072	0.193	0.039
1980	0.359	0.114	0.730	0.060	0.184	0.041	0.254	0.064	0.178	0.039	0.260	0.067	0.183	0.041
1981	0.227	0.042	0.444	0.032	0.086	0.014	0.185	0.031	0.086	0.014	0.188	0.033	0.086	0.014
1982	0.119	0.014	0.244	0.015	0.136	0.027	0.109	0.013	0.132	0.025	0.109	0.013	0.136	0.026
1983	0.134	0.012	0.254	0.014	0.155	0.023	0.124	0.012	0.152	0.022	0.123	0.012	0.155	0.023
1984	0.179	0.014	0.323	0.017	0.190	0.022	0.169	0.013	0.189	0.022	0.167	0.014	0.191	0.022
1985	0.196	0.015	0.327	0.017	0.172	0.016	0.187	0.014	0.171	0.016	0.183	0.014	0.172	0.016
1986	0.197	0.014	0.297	0.014	0.168	0.015	0.190	0.013	0.166	0.015	0.189	0.014	0.167	0.015
1987	0.208	0.013	0.306	0.014	0.190	0.015	0.202	0.013	0.187	0.015	0.202	0.014	0.190	0.015
1988	0.276	0.017	0.387	0.016	0.218	0.017	0.264	0.016	0.216	0.017	0.264	0.017	0.218	0.017
1989	0.231	0.013	0.334	0.012	0.235	0.020	0.221	0.012	0.230	0.020	0.222	0.014	0.235	0.020
1990	0.257	0.013	0.346	0.011	0.256	0.021	0.244	0.013	0.250	0.020	0.238	0.013	0.256	0.020
1991	0.453	0.024	0.573	0.017	0.330	0.022	0.428	0.023	0.325	0.022	0.414	0.024	0.330	0.022
1992	0.543	0.036	0.634	0.021	0.357	0.024	0.514	0.035	0.356	0.025	0.484	0.032	0.356	0.024
1993	0.412	0.028	0.485	0.016	0.253	0.019	0.403	0.027	0.254	0.020	0.387	0.027	0.253	0.019
1994	0.446	0.026	0.565	0.016	0.344	0.020	0.445	0.028	0.345	0.021	0.434	0.027	0.344	0.020
1995	0.566	0.032	0.711	0.019	0.453	0.027	0.551	0.034	0.453	0.029	0.542	0.033	0.453	0.027
1996	0.530	0.031	0.691	0.018	0.513	0.036	0.487	0.032	0.503	0.039	0.494	0.031	0.513	0.036
1997	0.580	0.034	0.833	0.023	0.543	0.038	0.517	0.035	0.520	0.040	0.536	0.035	0.543	0.038
1998	0.464	0.029	0.683	0.019	0.427	0.031	0.403	0.028	0.409	0.034	0.415	0.028	0.426	0.031
1999	0.475	0.032	0.720	0.022	0.427	0.037	0.408	0.029	0.408	0.039	0.423	0.030	0.425	0.037
2000	0.458	0.031	0.716	0.024	0.411	0.040	0.399	0.030	0.393	0.041	0.412	0.029	0.410	0.040
2001	0.364	0.022	0.588	0.020	0.300	0.025	0.328	0.022	0.294	0.026	0.336	0.022	0.299	0.025
2002	0.435	0.025	0.625	0.020	0.279	0.020	0.386	0.024	0.277	0.021	0.390	0.024	0.278	0.020
2003	0.470	0.027	0.610	0.020	0.278	0.018	0.410	0.025	0.277	0.019	0.419	0.025	0.278	0.018
2004	0.444	0.023	0.561	0.017	0.307	0.018	0.395	0.024	0.305	0.019	0.408	0.023	0.308	0.018
2005	0.452	0.022	0.550	0.016	0.343	0.021	0.401	0.022	0.336	0.022	0.420	0.022	0.343	0.021
2006	0.517	0.027	0.595	0.017	0.327	0.022	0.446	0.025	0.316	0.023	0.474	0.025	0.326	0.022
2007	0.502	0.028	0.537	0.015	0.318	0.024	0.423	0.025	0.302	0.024	0.461	0.025	0.317	0.024
2008	0.619	0.038	0.594	0.015	0.443	0.030	0.506	0.031	0.415	0.030	0.572	0.032	0.440	0.030
2009	0.768	0.056	0.718	0.018	0.736	0.060	0.617	0.041	0.669	0.056	0.737	0.047	0.730	0.059
2010	0.600	0.043	0.729	0.018	0.578	0.102	0.543	0.038	0.499	0.087	0.654	0.043	0.569	0.100
2011	0.618	0.040	0.918	0.022	0.660	0.103	0.631	0.044	0.630	0.097	0.733	0.047	0.660	0.102
2012	0.595	0.041	0.930	0.022	0.846	0.116	0.637	0.046	0.798	0.111	0.731	0.047	0.849	0.116
2013	0.490	0.033	0.841	0.019	0.621	0.058	0.556	0.041	0.595	0.059	0.635	0.042	0.624	0.058
2014	0.566	0.043	0.969	0.023	0.823	0.088	0.636	0.052	0.745	0.087	0.742	0.054	0.824	0.088
2015	0.492	0.039	0.946	0.026	0.901	0.138	0.535	0.046	0.741	0.121	0.646	0.052	0.897	0.136
2016	0.427	0.034	0.924	0.029	0.881	0.123	0.454	0.038	0.660	0.094	0.557	0.046	0.871	0.121
2017	0.384	0.032	0.941	0.042	0.694	0.102	0.384	0.032	0.473	0.068	0.501	0.044	0.683	0.100
2018	0.292	0.025	0.869	0.059	0.441	0.048	0.283	0.023	0.285	0.028	0.388	0.037	0.418	0.045

Figures

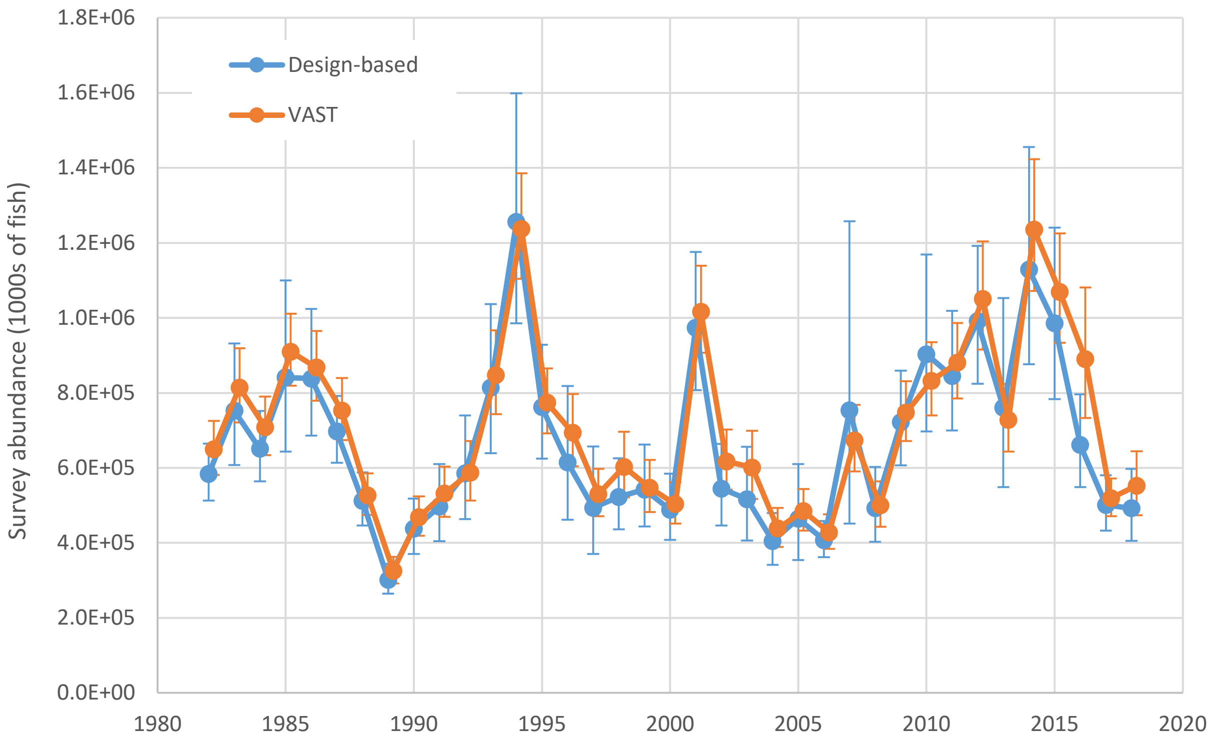


Figure 2.1.1. Comparison of design-based and VAST survey indices (EBS and NBS combined).

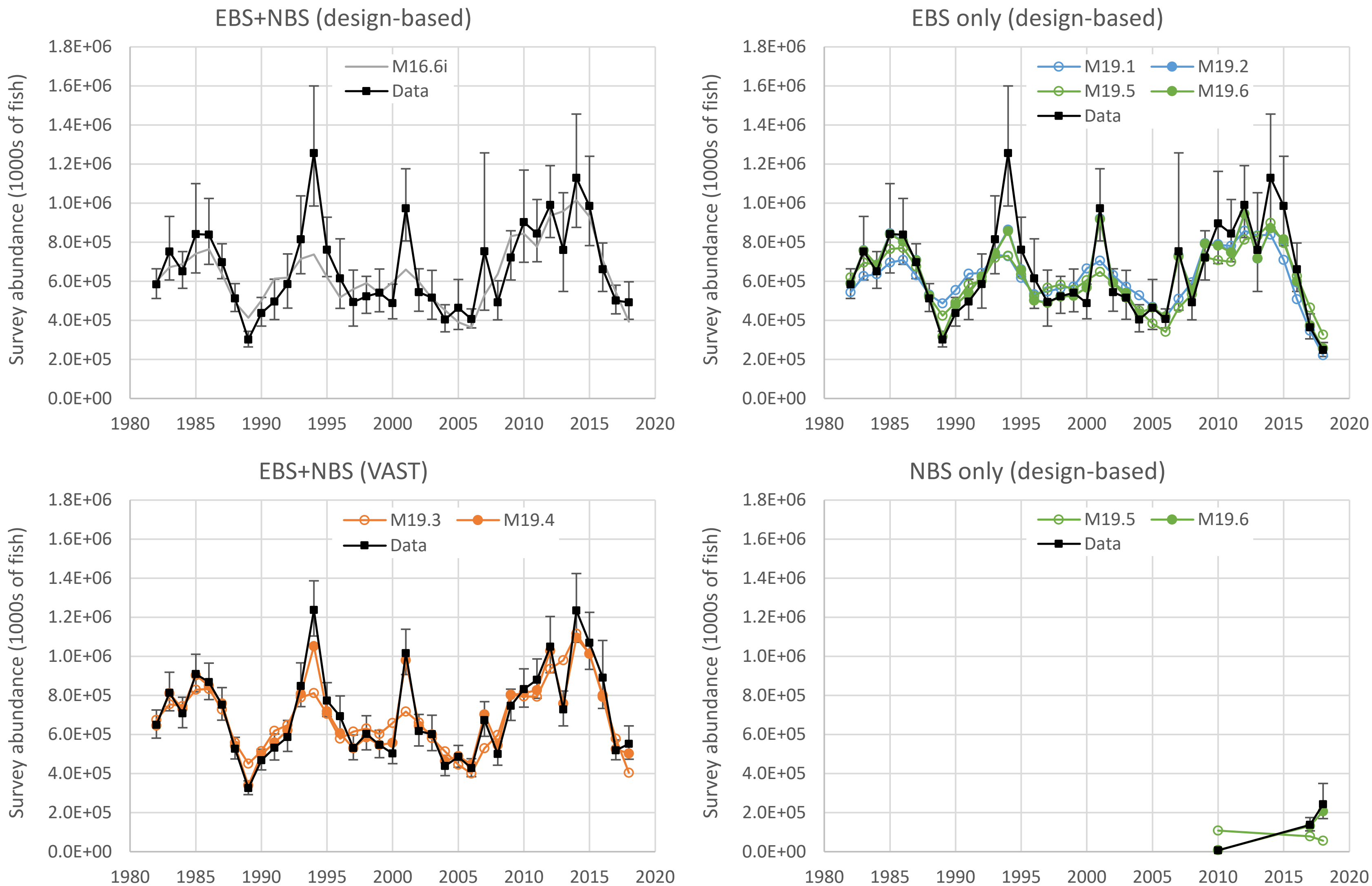


Figure 2.1.2. Fits to survey indices.

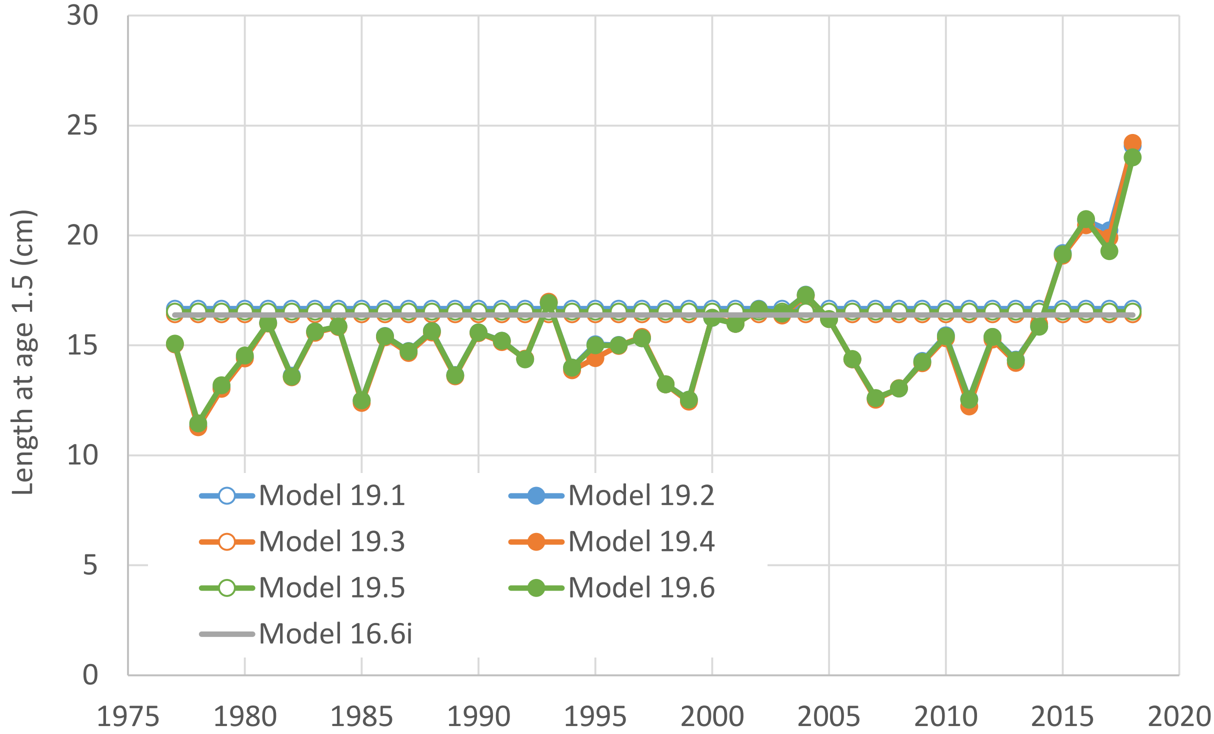
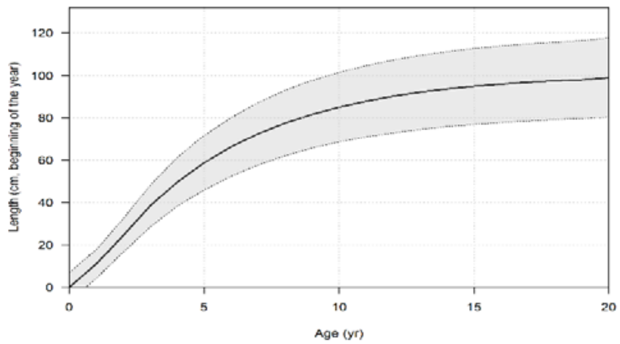
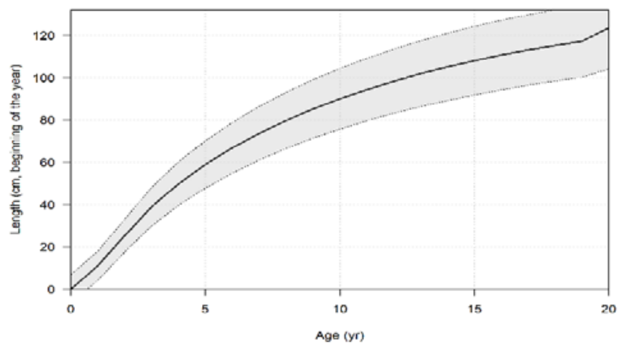


Figure 2.1.3. Mean length at age 1.5.

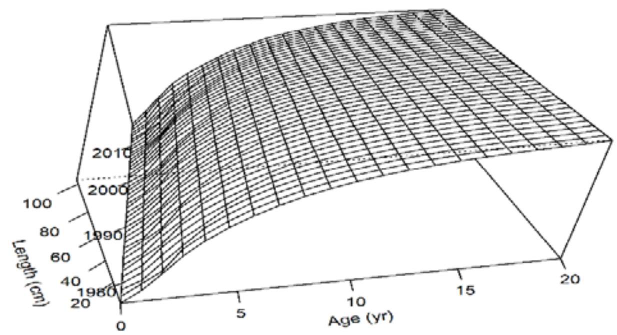
Model 16.6i



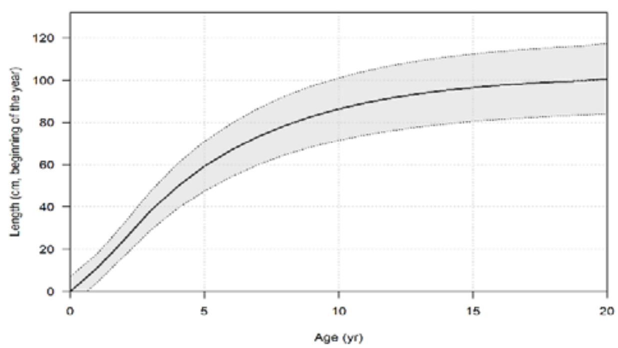
Model 19.1



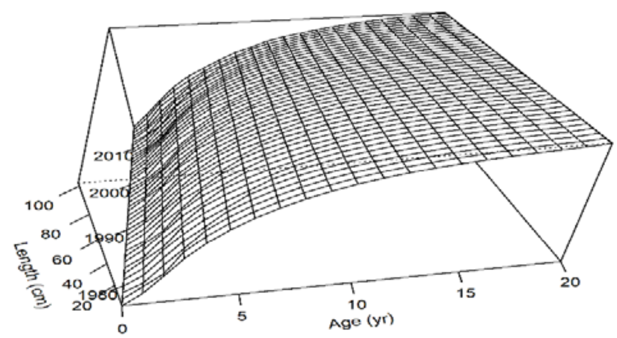
Model 19.2



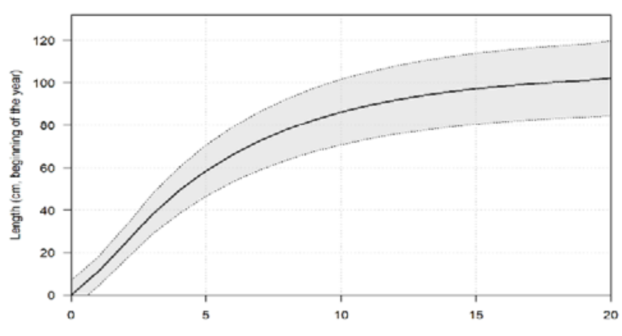
Model 19.3



Model 19.4



Model 19.5



Model 19.6

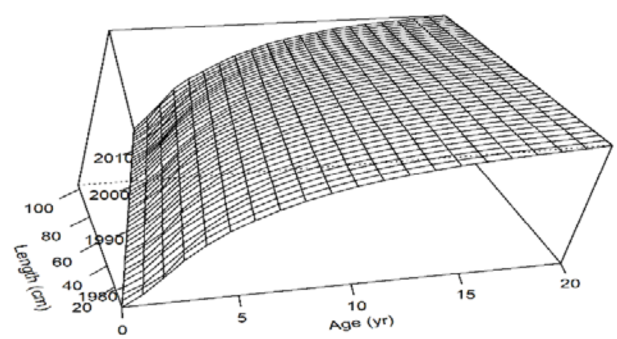


Figure 2.1.4. Length at age.

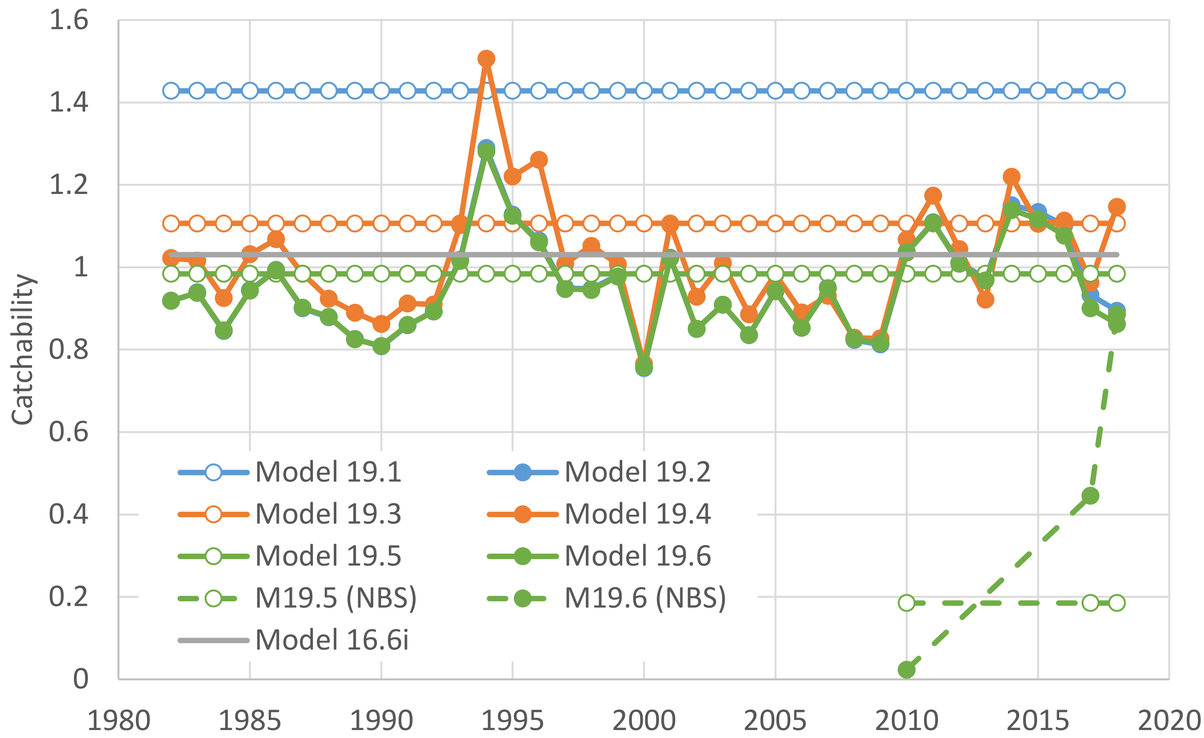


Figure 2.1.5. Survey catchability.

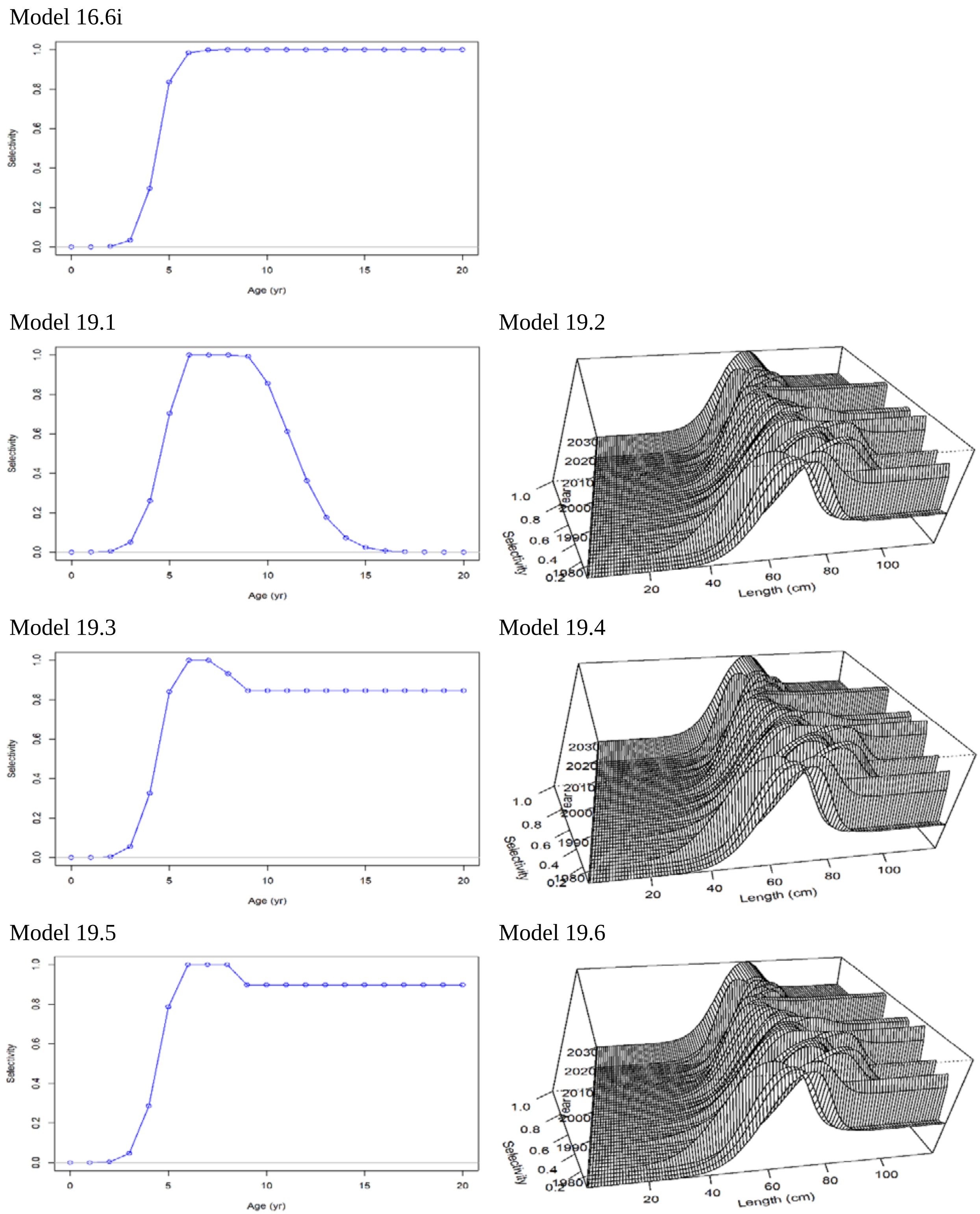
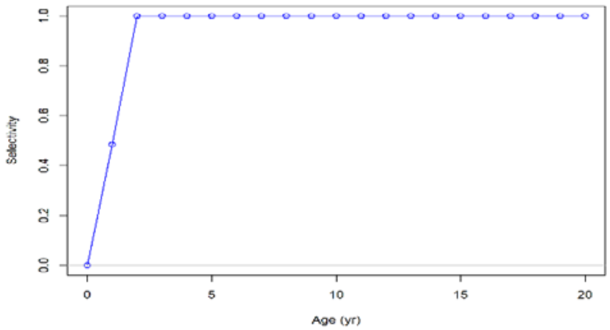
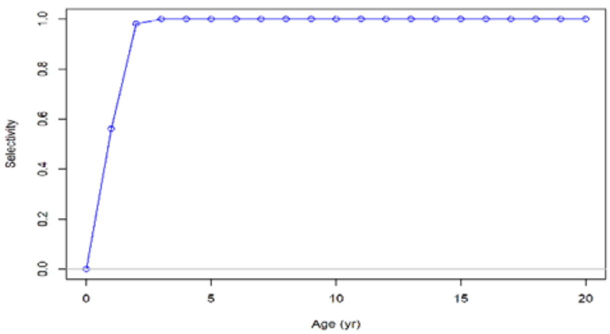


Figure 2.1.6a. Fishery selectivity.

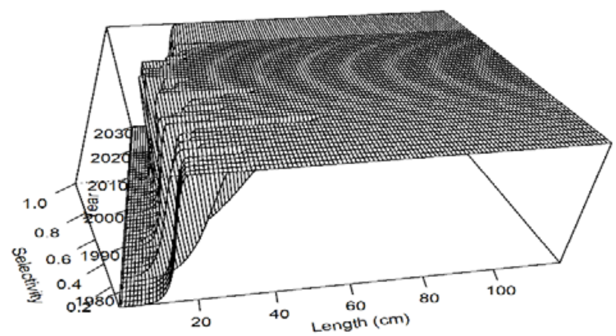
Model 16.6i



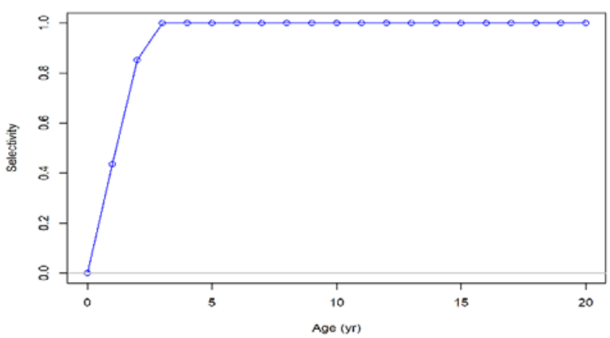
Model 19.1



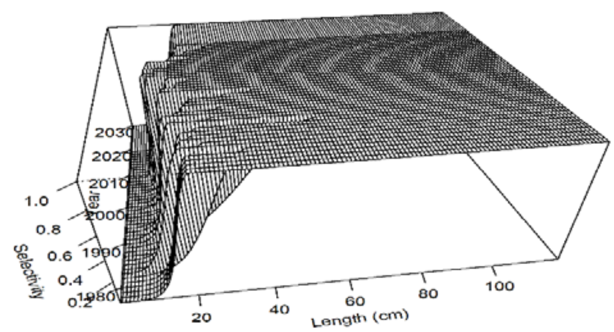
Model 19.2



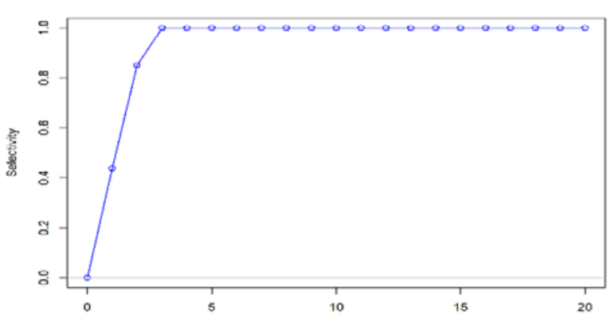
Model 19.3



Model 19.4



Model 19.5



Model 19.6

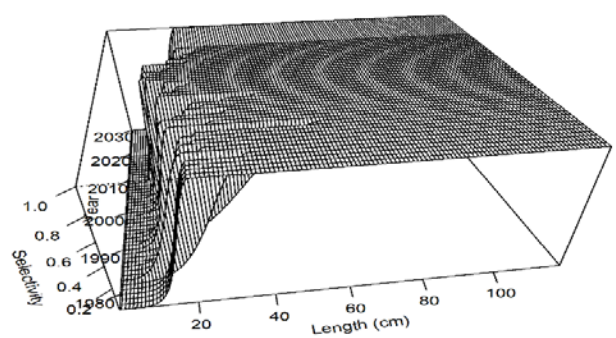


Figure 2.1.6b. EBS survey selectivity (EBS+NBS for Models 16.6i, 19.3, and 19.4).

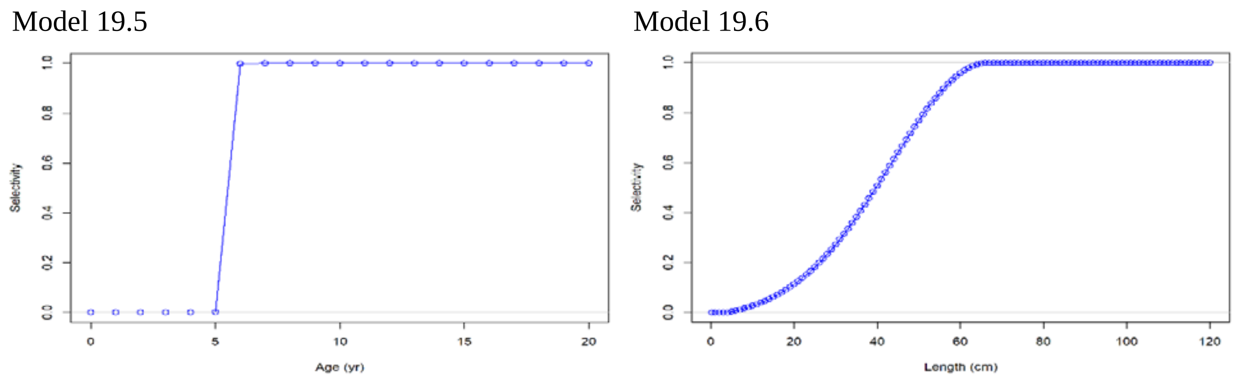


Figure 2.1.6c. NBS survey selectivity.

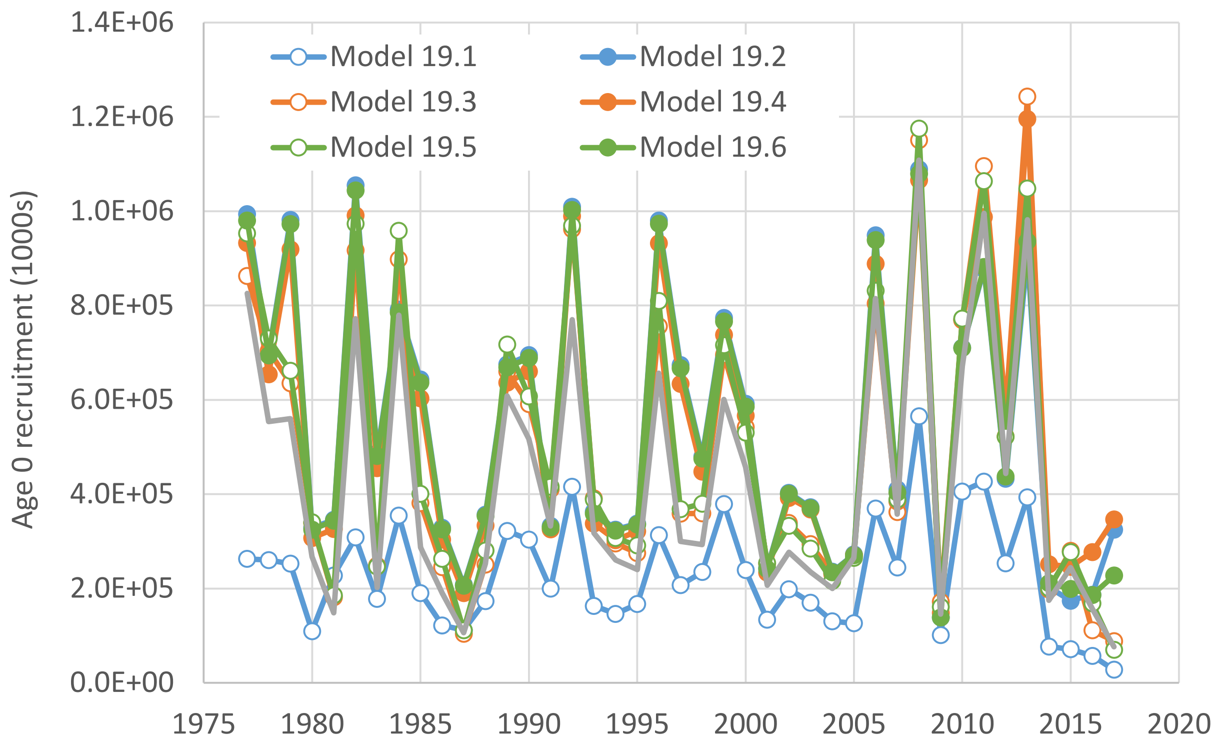


Figure 2.1.7. Age 0 recruitment.

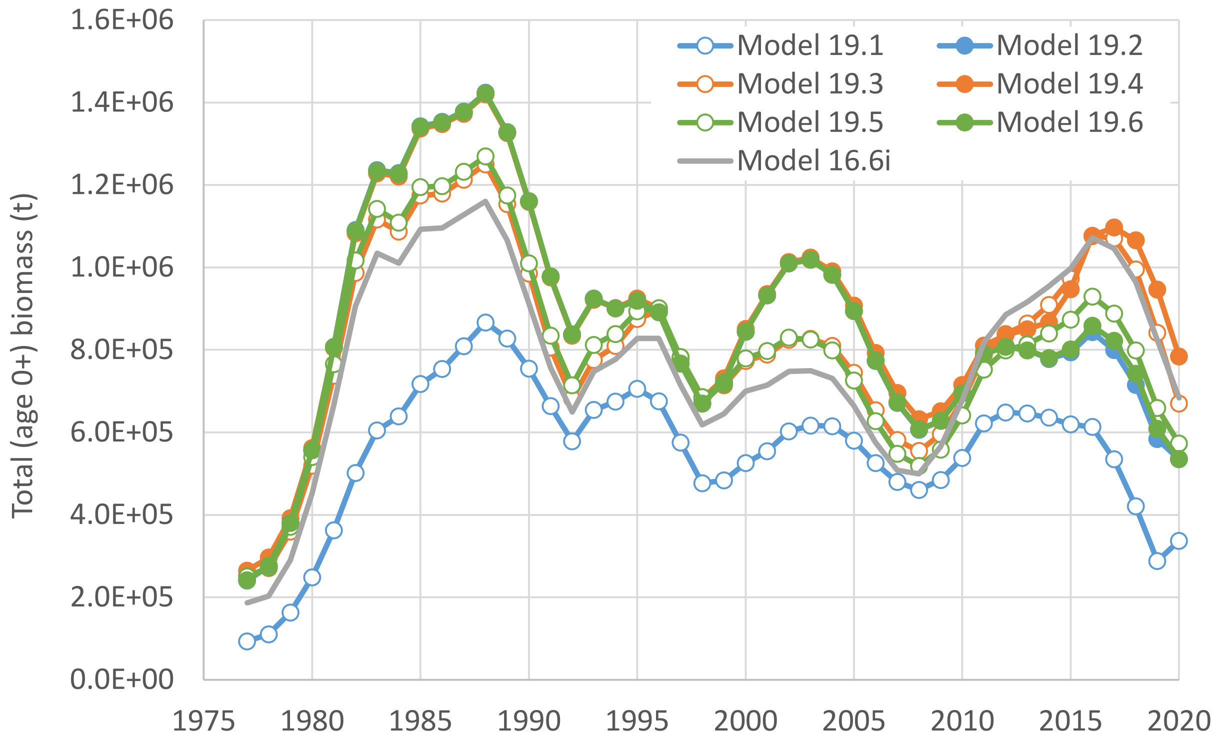


Figure 2.1.8. Total (age 0+) biomass.

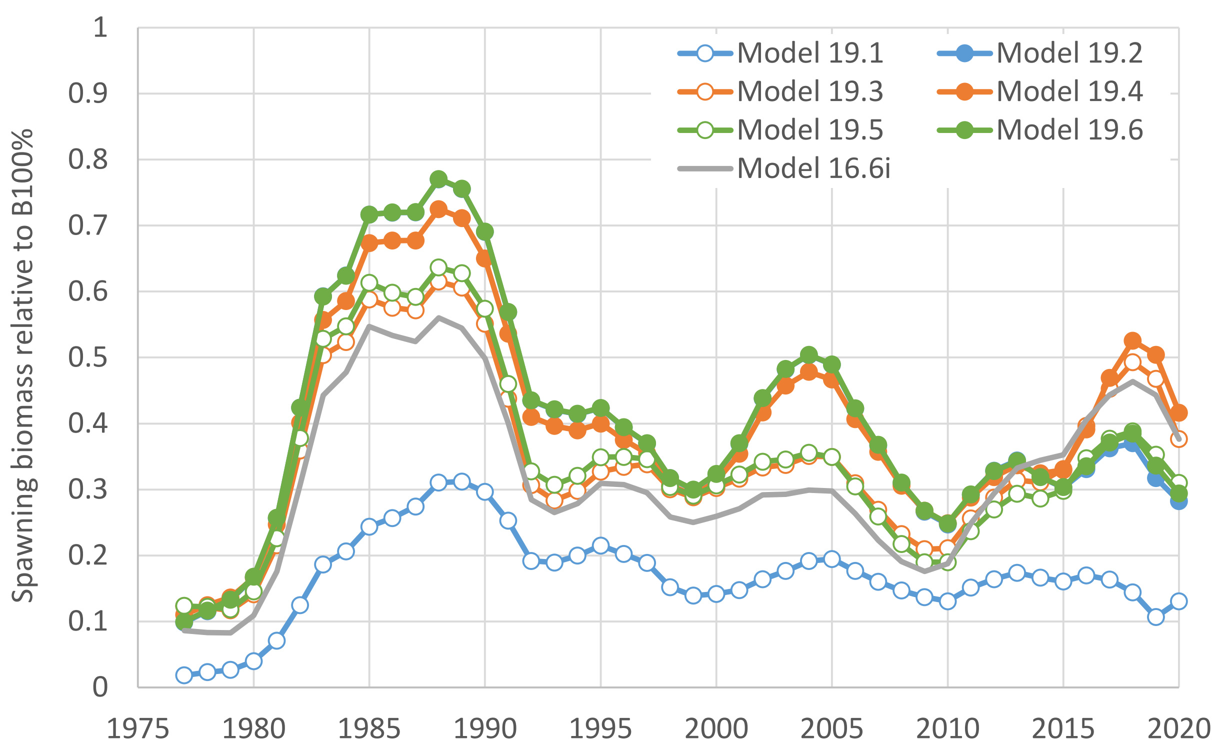


Figure 2.1.9. Relative spawning biomass.

	-178	-177	-176	-175	-174	-173	-172	-171	-170	-169	-168	-167	-166	-165	-164	-163	-162	-161	All
-62.5																			
-62																			
-61.5																			
-61			437	455															446
-60.5			377	405															391
-60	354			333															344
-59.5	579	490	546		572	412	250												481
-59	967	630	488	698	675	423	402	539	473										555
-58.5		775	643	727	663	486	430	437	446										570
-58				198	979	356	387	427	403										485
-57.5					754	538	173	310	396		450								437
-57						738	561	363	340	343	440								468
-56.5						767	646	471		405									624
-56								653	499	310								557	460
-55.5											533								533
-55															824				824
-54.5														655					655
-54													308						308
-53.5												610							610
-53																			
All	620	632	528	552	731	551	455	419	431	337	460	610	308	655	824			557	510

Figure 2.1.10a. Longline fishery CPUE, June, all years combined.

	-178	-177	-176	-175	-174	-173	-172	-171	-170	-169	-168	-167	-166	-165	-164	-163	-162	-161	All
-62.5																			
-62																			
-61.5																			
-61																			
-60.5			188	428															308
-60	949	331		270		426	357	488											537
-59.5	635	426	336	415	335	379	292	541	511										392
-59	700	704	501	519	380	338	322	484	345	669									475
-58.5		683	388	454	492	488	353	395	437	500	465								460
-58				1166	625	510	287	419	415	369	380		250						477
-57.5					408	407	416	357	396	258	250								386
-57						381	402	262	339		481	478							374
-56.5						318	236	376	252	359	384	334	223				310		328
-56								443	464	447	506	282	298	392		131	386	592	419
-55.5											444	255	330	356			309		378
-55												481	522	241	478				458
-54.5														329					329
-54													229	874					551
-53.5												415							415
-53																			
All	803	585	405	487	463	409	334	407	386	439	436	387	305	416	478	131	348	592	425

Figure 2.1.10b. Longline fishery CPUE, July, all years combined.

	-178	-177	-176	-175	-174	-173	-172	-171	-170	-169	-168	-167	-166	-165	-164	-163	-162	-161	All
-62.5								386											386
-62									326										326
-61.5																			
-61			356																356
-60.5	225	294	349	310		729													360
-60	372	329	312	388	262	428		736											372
-59.5	322	418	330	313	290	329	341	524	432										345
-59	459	410	393	359	324	268	329	331	322										357
-58.5		417	382	366	501	472	316	279	401			368							404
-58				544	544	386	240	234	385	431		393	354						408
-57.5					446	435	352	252	461	446	364	474	322	427					400
-57						335	395	326	411	393	336	328	312			276	223		358
-56.5						189	375	362	292	348	417	384	365		358	422			367
-56								348	429	368	482	394	392	370	323	388			398
-55.5											401	239		372	385	440			388
-55												364	351	378	355	252			353
-54.5													393	576					531
-54																			
-53.5												443							443
-53																			
All	346	392	361	367	422	387	352	344	389	369	434	371	369	407	357	402	223		380

Figure 2.1.10c. Longline fishery CPUE, August, all years combined.

	-178	-177	-176	-175	-174	-173	-172	-171	-170	-169	-168	-167	-166	-165	-164	-163	-162	-161	All
-62.5																			
-62																			
-61.5																			
-61																			
-60.5																			
-60																			
-59.5																			
-59							511	572	365										482
-58.5							608	453	544										535
-58								540	357										448
-57.5								275	305										290
-57									314	420	313								349
-56.5																			
-56																			
-55.5																			
-55																			
-54.5																			
-54																			
-53.5																			
-53																			
All							559	460	377	420	313								429

Figure 2.1.10d. Longline fishery CPUE, June, 2017.

	-178	-177	-176	-175	-174	-173	-172	-171	-170	-169	-168	-167	-166	-165	-164	-163	-162	-161	All
-62.5																			
-62																			
-61.5																			
-61																			
-60.5																			
-60																			
-59.5					312	417	380												370
-59				311	455	360	394												380
-58.5						335	411	393											379
-58						327	304	366											332
-57.5						294													294
-57									278										278
-56.5									251								310		280
-56										238							317		277
-55.5																			
-55																			
-54.5																			
-54																			
-53.5																			
-53																			
All				311	384	347	372	379	264	238							313		340

Figure 2.1.10e. Longline fishery CPUE, July, 2017.

	-178	-177	-176	-175	-174	-173	-172	-171	-170	-169	-168	-167	-166	-165	-164	-163	-162	-161	All
-62.5																			
-62																			
-61.5																			
-61																			
-60.5																			
-60	392																		392
-59.5	210																		210
-59		173	175		154		297												200
-58.5			220	267			246												244
-58						264	230												247
-57.5																			
-57						193					250								221
-56.5												307	253						280
-56													294	256	258				269
-55.5															262				262
-55												244			313				278
-54.5																			
-54																			
-53.5																			
-53																			
All	301	173	198	267	154	228	258				250	275	273	256	278				250

Figure 2.1.10f. Longline fishery CPUE, August, 2017.

	-178	-177	-176	-175	-174	-173	-172	-171	-170	-169	-168	-167	-166	-165	-164	-163	-162	-161	All
-62.5																			
-62																			
-61.5																			
-61			437	455															446
-60.5			377	405															391
-60	354			333															344
-59.5							250												250
-59							405												405
-58.5								422	322										372
-58								298											298
-57.5								233											233
-57																			
-56.5																			
-56																			
-55.5																			
-55																			
-54.5																			
-54																			
-53.5																			
-53																			
All	354		407	398			328	318	322										358

Figure 2.1.10g. Longline fishery CPUE, June, 2018.

	-178	-177	-176	-175	-174	-173	-172	-171	-170	-169	-168	-167	-166	-165	-164	-163	-162	-161	All
-62.5																			
-62																			
-61.5																			
-61																			
-60.5			188																188
-60				255															255
-59.5					247	284													265
-59						297	251												274
-58.5					450														450
-58																			
-57.5																			
-57								223	230										227
-56.5																			
-56																			
-55.5																			
-55																			
-54.5																			
-54																			
-53.5																			
-53																			
All			188	255	349	290	251	223	230										269

Figure 2.1.10h. Longline fishery CPUE, July, 2018.

	-178	-177	-176	-175	-174	-173	-172	-171	-170	-169	-168	-167	-166	-165	-164	-163	-162	-161	All
-62.5								386											386
-62									326										326
-61.5																			
-61																			
-60.5																			
-60																			
-59.5						229													229
-59					297														297
-58.5				242	212														227
-58																			
-57.5						228													228
-57																			
-56.5																			
-56																			
-55.5															283				283
-55																			
-54.5																			
-54																			
-53.5																			
-53																			
All				242	254	229		386	326						283				275

Figure 2.1.10i. Longline fishery CPUE, August, 2018.