Minutes of the Joint Team Subcommittee on Pacific Cod Models

May 11, 2015

As with the 2014 Pacific cod assessments, initial Team review of proposals for models to be considered in this year's preliminary assessments of Pacific cod in the EBS, AI, and GOA was conducted by a subcommittee rather than the full joint Teams. The subcommittee consisted of BSAI Team members Bill Clark and Dana Hanselman, and GOA Team members Jim Ianelli, Paul Spencer, and Ian Stewart. The subcommittee met via WebEx on May 11, 2015. All members except Bill and Jim were present, as were Teresa A'mar (GOA assessment author), Jim Armstrong (GOA plan coordinator), Steve Barbeaux (AFSC), Kenny Down (Freezer Longline Coalition), Sandra Lowe (GOA Team member), and Grant Thompson (BSAI Team chair and EBS and AI assessment author),. Grant chaired the meeting, which began with presentations by Grant and Teresa of last year's assessments (both preliminary and final) in the three regions.

Two weeks prior to the meeting, subcommittee members were provided with the following documents (included as appendices to these minutes):

- Appendix 1: "Pacific cod model and non-model analysis proposals (May, 2015)." This file contains just the proposals (no context).
- Appendix 2: "Full text of the November 2014 BSAI Team Pacific cod minutes." This file provides the context for the BSAI Team proposals.
- Appendix 3: "Full text of the November 2014 GOA Team Pacific cod minutes." This file provides the context for the GOA Team proposals.
- Appendix 4: "Full text of the December 2014 SSC Pacific cod minutes." This file provides the context for the SSC proposals.
- Appendix 5: "Mark Maunder's review of the EBS Pacific cod assessment." This file provides the context for Mark's proposals.
- Appendix 6: "History of alternative Pacific cod models (all regions)." This file summarizes every Pacific cod model that has been substantially vetted in the SAFE reports since 2005.

For this year's subcommittee meeting, proposals were separated into "proposed models," which pertained to inclusion of particular models in this year's preliminary assessments, and "proposed non-model analyses," which pertained to assessment activities that might not necessarily result in an included model.

A total of 11 proposed models were received prior to the meeting: 10 for the EBS, 1 for the AI, and 0 for the GOA. In addition, 5 proposed models were not received explicitly but were taken as "given," *viz*., inclusion of the final 2011 EBS model (the same as the 2014 EBS model), the final 2014 AI model (Tier 5 random effects), the final 2011 GOA model, and the final 2014 GOA model. Also, the subcommittee developed and advanced 9 new proposed models (5 for the EBS, 3 for the AI, and 1 for the GOA) during the meeting itself, for a total of 25 proposed models: 17 for the EBS, 5 for the AI, and 3 for the GOA.

A total of 5 proposed non-model analyses were received prior to the meeting: 3 for the EBS, 1 for the AI, and 1 for the GOA. In addition, the subcommittee developed and advanced 1 new proposed non-model analysis for the EBS stock.

The subcommittee used Table 1 to structure its discussion and summarize its recommendations. The purpose of the recommendations was to winnow the lists of proposals into smaller sets of models and non-model analyses to be included in this year's preliminary assessments, with the understanding that the assessment authors can bring forward additional models and non-model analyses at any time. Model numbering was guided by the SSC's minutes from April 2014 (clarifying that the term "base model" is to be used only when referencing a model approved in a previous year, and clarifying that the final 2011 model from each region is to be re-evaluated each year until such time as there is general agreement by the stock assessment authors, the Plan Team, and the SSC to discontinue this practice) and December 2014 (clarifying that model numbers 0 and 1 are reserved for last year's model without and with new data; thus, there are no models numbered "1" for the September assessment).

For the EBS, the subcommittee recommended that the following models be developed for this year's preliminary assessment:

- Model 0: Final model from 2014 (same as the final models from 2011, 2012, and 2013)
- Model 2: Model 2 from the 2014 final assessment
- Model 3: Model 2 from the 2014 final assessment, but with:
    - composition data weighted either: 1) iteratively, 2) by the method of Francis (2011), or 3) by tuning the harmonic mean of the effective sample sizes to the mean input sample size
    - time-varying catchability turned off
- Model 4: Model 2 from the 2014 final assessment, but with:
    - internal estimation of σ_R replaced by something that attempts to account for the downward bias in the MLE
    - estimation of a larger number of age groups in the initial vector

For the EBS, the subcommittee recommended that the following non-model analyses be conducted for this year's preliminary assessment:

- Analysis 1: R_0 profile using the observed data and using simulated data without error
- Analysis 2: Plot the time series of the ratio of catch to survey biomass (or exploitable biomass, time permitting) to determine whether current values are within historic range
- Analysis 3: Initialize the composition weighting process by setting sample sizes equal to number of sampled hauls

For the AI, the subcommittee recommended that the following models be developed for this year's preliminary assessment:

- Model 0: Final model from 2014
- Model 2: Model 2 from the final 2014 assessment, but with:
    - continued work on the problems with the model so as to make progress toward an age-structured AI assessment
- Model 3: Model 2 from the final 2014 assessment, but with:
    - inclusion of the pre-1991 fishery data

For the AI, the subcommittee recommended that the following non-model analyses be conducted for this year's preliminary assessment:

- Analysis 1: Examine NMFS trawl survey data, IPHC longline survey data, AFSC longline survey data, and commercial data to investigate the distribution of AI Pacific cod relative to the NMFS trawl survey stations

For the GOA, the subcommittee recommended that the following models be developed for this year's preliminary assessment:

- Model 0: Final model from 2014

- Model 2: Final model from 2011

For the GOA, the subcommittee recommended that the following non-model analyses be conducted for this year's preliminary assessment:

- Analysis 1: Examine the longline survey RPN and length frequency data for use within the model

In addition to the models contained in the above lists, the subcommittee expressed special interest in certain other models and non-model analyses, but left development of those up to the respective author's discretion rather than including them in the lists of requested models and non-model analyses.

For the EBS, the discretionary models were as follow:

- Final model from 2014, but with iterative re-weighting or the approach of Francis (2011) for composition data
- Final model from 2014, but with estimation of a larger number of age groups in the initial vector
- Final model from 2014, but with survey abundance CVs estimated from the residuals of a smooth curve fit to the survey abundance point estimates
- Final model from 2014, but with empirical standard deviations for the composition data and time-varying fishery selectivity
- Final model from 2014, but with time-varying growth
- Final model from 2014, but with Richards growth
- Model 2 from the final 2014 assessment, but with the composition weighting process initialized by setting sample sizes equal to the number of sampled hauls
- Model 2 from the final 2014 assessment, but with alternative weightings of process error and measurement error

For the EBS, the discretionary non-model analysis was as follows:

- Simulation study of selectivity type 17 parameters and annual deviations

For the AI, the discretionary models were as follow:

- Model 2 from the final 2014 assessment, but with catch data extended back to 1977
- Model 2 from the final 2014 assessment, but with estimation of a larger number of age groups in the initial vector

For the AI, there were no discretionary non-model analyses.

For the GOA, the discretionary model was as follows:

- Final model from 2014, but with an exploration of initial conditions

For the GOA, there were no discretionary non-model analyses.

Table 1. Paraphrased proposals (see Appendix 1) and assignment thereof to candidate models and non-model analyses, as recommended by the subcommittee. M = model, SPM = starting point model (i.e., the model addressed by the respective proposal), D = author's discretion.

List of proposed models				September model							
Region	Proposal	SPM	Brief description of proposal	0	1	2	3	4	5	6	D
EBS	none	2011 M3b	No changes	x	n/a						
EBS	none	2014 M1	No changes (note that 2014 M1 is identical to 2011 M3b)	x	n/a						
EBS	BPT1	2014 M2	No changes		n/a	x					
EBS	SSC2	2014 M1	Use iterative re-weighting or the approach of Francis (2011) for composition data (see also MM5)		n/a						x
EBS	MM2	2014 M1	Age-specific natural mortality (estimated and fixed)		n/a						
EBS	MM3	2014 M1	Include more initial age devs		n/a						x
EBS	MM4	2014 M1	Fit a smooth curve to the survey abundance index data to estimate the CV		n/a						x
EBS	MM5	2014 M1	Run the model with Francis weighting for composition data		n/a						x
EBS	MM6	2014 M1	Run the model with empirical sd's for composition data and time varying commercial selectivity		n/a						x
EBS	MM7	2014 M1	Split out age 1 and 2 based on length and model as separate surveys		n/a						
EBS	MM8	2014 M1	Time varying growth		n/a						x
EBS	MM9	2014 M1	Richards growth curve		n/a						x
EBS	new	2014 M2	Iterative re-weighting, Francis (2011), or harmonic mean for comp. data; turn off time-varying *Q*				x				
EBS	new	2014 M2	Do not use internal estimate of σ_R					x			
EBS	new	2014 M2	Include more initial age devs					x			
EBS	new	2014 M2	Initialize the composition weighting process by setting sample sizes equal to number of sampled hauls								x
EBS	new	2014 M2	Compare process error versus observation error weightings								x
AI	none	2014 M1	No changes	x	n/a						
AI	BPT1	2014 M2	Work on the problems with the model so as to make progress toward an age-structured assessment		n/a	x					
AI	new	2014 M2	Include pre-1991 data				x				
AI	new	2014 M2	Extend catch data back to 1977								x
AI	new	2014 M2	Include more initial age devs								x
GOA	none	2014 MS1a	No changes	x	n/a						
GOA	none	2011 M3	No changes		n/a	x					
GOA	new	2014 MS1a	Explore initial conditions								x

List of proposed non-model analyses				September analysis							
Region	Proposal	SPM	Brief description of proposal	0	1	2	3	4	5	6	D
EBS	SSC1	n/a	Simulation study on estimability of selectivity type 17 parameters and annual deviations								x
EBS	MM1	2014 M1	R_0 profile using the observed data and using simulated data without error		x						
EBS	MM10	2014 M1	Plot the time series of catch/survey to determine whether current values are within historic range*			x					
EBS	new	2014 M2	Initialize the composition weighting process by setting sample sizes equal to number of sampled hauls				x				
AI	BPT2	n/a	Spatial comparison of NMFS trawl survey, IPHC survey, AFSC longline survey, and fishery data		x						
GOA	GPT1	n/a	Examine longline survey RPN and length frequency data for use in the model		x						

1 Pacific cod model and non-model analysis proposals for September 2015

Compiled by Grant Thompson and Teresa A'mar

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This document compiles proposals for models and non-model analyses of the three Pacific cod stocks that have been submitted since last year's assessments were submitted to their respective Plan Teams. These include proposals from the BSAI and GOA Plan Teams (BPT and GPT, respectively), the Scientific and Statistical Committee (SSC), and Mark Maunder (MM), who has been retained by the Freezer Longline Coalition to comment on the Bering Sea assessment.

Proposal numbering starts (or re-starts) at 1 for each stock (Bering Sea, Aleutian Islands, or Gulf of Alaska). For example, proposal BPT1 for the Aleutian Islands stock is not the same as proposal BPT1 for the Bering Sea stock.

Although not listed here, the SSC's recommendation from December 2011 suggesting that the performance of the 2011 model for each stock be evaluated over "several assessment cycles" should also be noted. Last year, the Teams suggested that further evaluation of the 2011 models was no longer warranted, except in the case of the Bering Sea, where the current base model was identical to the 2011 model. The SSC disagreed, stating that the criterion for discontinuing evaluation of the 2011 model would be "general agreement by the stock assessment authors, the Plan Team, and the SSC."

The SSC has also issued clarifications of various aspects of model nomenclature. In April 2014, the SSC determined that the term *base model* "should be restricted to the chosen model in a previous assessment year." In December 2014, the SSC requested that stock assessment authors use the following model naming conventions in SAFE chapters:

- Model 0: last year's model with no new data,
- Model 1: last year's model with updated data, and
- Model numbers higher than 1 are for proposed new models.

Subsequent communication with the SSC chair clarified that inclusion of Model 0 in final assessments is optional. However, because preliminary assessments typically do not update the data file(s), inclusion of Model 0 in preliminary assessments would normally be expected.

Bering Sea

BPT1: "The Team … recommends … bring[ing] Model 2 back next year as the presumptive reference model for 2016."

SSC1: "The SSC recommends that the author conduct a simulation study to better understand the estimability of the selectivity type 17 in Stock Synthesis and the estimation of annual deviations."

SSC2: "The SSC recommends that a statistical approach be used to weight the composition data (i.e., iterative re-weighting, or other methods outlined in Francis 2011)."

MM1: "R0 profile using the observed data and using simulated data without error."

MM2: "Age-specific natural mortality. Estimated and fixed."

MM3: "Include more initial age devs to potentially remove the retrospective bias."

MM4: "Fit a smooth curve to the survey abundance index data to estimate the appropriate CV."

MM5: "Run the model with Francis weighting for composition data."

MM6: "Run the model with empirical sd's for composition data and time varying commercial selectivity."

MM7: "Split out age 0 and 1 based on length and model as separate surveys."

MM8: "Time varying growth"

MM9: "Richards growth curve"

MM10: "Plot the time series of catch/survey to determine whether the current values are within the historic values. The survey data should be restricted to lengths in the catch data."

Aleutian Islands

BPT1: "The Team … recommend[s] … continue[d] work on the problems with Model 2 so as to make progress toward an age-structured AI assessment."

BPT2: "Specifically, the Team recommends examining NMFS trawl survey data, IPHC longline survey data, AFSC longline survey data, and commercial data to investigate the distribution of AI Pacific cod relative to the NMFS trawl survey stations."

Gulf of Alaska

GPT1: "The Team recommended examining the longline survey RPN and length frequency data for use within the model."

(The GOA Team minutes also included a minor recommendation that was satisfied in the final draft of last year's GOA assessment.)

2 Full text of the November 2014 BSAI Plan Team minutes on Pacific cod

EBS Pacific cod

Grant Thompson reported that survey biomass was higher again in 2014, continuing an upward trend that began around 2006 and has been sustained by several good year-classes. Spawning stock biomass is now estimated to be in the vicinity of B40%.

As requested by the Team/SSC at their September/October meetings, Grant had fitted two candidate models for this meeting. Model 1 was the base model, used for specifications in 2011-2013, with these main features:

(i) M fixed at 0.34.

(ii) Length-specific commercial selectivities for all fisheries/seasons, some forced to be asymptotic, estimated for blocks of years.

(iii) Age-specific survey selectivity with annually varying left limb.

(iv) Survey catchability fixed at the value obtained in the 2009 assessment (0.77), where it resulted in the product of catchability and selectivity equal (on average, over the 60-81 cm size range) to the desired value of 0.47 in the EBS. The desired value was based on a small number (11) of archival tags.

(v) A single von Bertalanffy growth schedule estimated for all years.

(vi) Intercept and slope of age reading bias estimated internally.

(vii) Standard deviation of length at age estimated internally.

(viii) Mean length at age data left out of the fit.

(ix) All age and length composition data included in the fit.

Model 2 had been presented as an exploratory model in September. It differed from the base model in many respects, all of them regarded as desirable features of a succession of alternative models that had been developed and discussed over the last few years:

(i) Annually varying length-weight relationship.

(ii) 10 (rather than 3) initial abundances at age estimated.

(iii) Richards (4-parameter) growth curve.

(iv) R estimated freely.

(v) Length-specific survey selectivity.

(vi) 2 (rather than 1) survey selectivity parameters have annual devs.

(vii) Input catch composition sample sizes tuned to be no less than the output effective sample sizes.

(viii) A single fishery and fishing season instead of nine season-and-gear-specific fisheries.

(ix) Natural mortality M estimated internally.

(x) The mean value of survey catchability Q estimated internally.

(xi) Survey catchability allowed to vary annually (penalized devs estimated).

(xii) Selectivity for both the fishery and the survey potentially allowed to vary annually (penalized devs estimated).

(xiii) Selectivities for both the fishery and survey modeled as random walks with respect to age instead of the usual double normal (SS selectivity-at-age pattern 17). Priors are set on the age-specific parameters such that the form tends to a logistic if the data are uninformative, but the priors have large standard deviations (minimum CV of 0.5).

Both models achieved satisfactory fits. Model 2 naturally fitted the survey times series better because Q was allowed to vary annually. Both models fitted the survey age and size composition data well, matched the first three modes in the average survey length compositions, and estimated similar survey selectivities. The time series of recruitments and spawning biomass were also similar except for the last few years, where the Model 1 estimates rose above the Model 2 estimates, which was somewhat puzzling. The freely estimated value of M in Model 2 was 0.34, equal to the fixed value in Model 1. A likelihood profile showed that the best value of M in Model 1 would be 0.40. The freely estimated value of survey Q in Model 2 was close to 1, consistent with recently reported field work on survey trawl catchability.

The retrospective behavior of Model 1 was poor. It persistently produced biomass estimates that subsequently were revised downward by 50% or more when fitted to later data. The retrospective behavior of Model 2 was good.

Grant recommended sticking with Model 1 this year because it avoids changes in methods and because he feels there are some properties of SS selectivity pattern 17 that need further investigation. The Team is willing to go along for this year, but we feel that the assessment should advance to Model 2 or something similar next year. Model 2 implements many technical improvements on Model 1, fits the data better, has good retrospective performance, and does not rely on the fixed value of survey Q based on archival tags, which is no longer very credible. We suspect that the divergence between Model 1 and Model 2 biomass estimates in the last few years is associated with the poor retrospective behavior of Model 1 rather than with any problem in Model 2. Moving from Model 1 to Model 2 would be a wholesale change, but we think it would be a change for the better in many ways.

The Team therefore recommends Model 1 for this year but urge Grant to resolve his remaining questions about selectivity and bring Model 2 back next year as the presumptive reference model for 2016.

While recommending that Model 1 be chosen again as the reference model, Grant regarded the model point estimates of ABC and OFL as risky because of the model's retrospective record of persistent downward revisions of current biomass estimates. As a way of accounting for that, Grant proposed holding the 2015 ABC at the 2014 level of 255,000 mt rather than adopting the Model 1 estimate of 295,000 mt.

The Team endorses this downward adjustment as a reasonable measure in the circumstances. We also recommend a provisional ABC of 255,000 mt for 2016.

AI Pacific cod

Grant Thompson reported that the survey biomass index has been flat and below the long-term average for the last ten years.

The Team and SSC at their September/October meetings had asked Grant to fit three models for November, all of them excluding data before 1991 as recommended by an advisory committee last spring. (Grant had also done some research to recall the exact reasons for excluding the pre-1991 data.) Model 1 was Tier 5, specifically a random effects model that filters the survey biomass estimates. Model 2 was nearly identical to Model 2 in the EBS assessment (which see) except that a constant rather than annually varying value of survey Q was estimated, the standard von Bertalanffy growth equation was used (i.e., the fourth ("Richards growth") parameter was not included), and sigmaR was estimated internally rather than by the method of Thompson and Lauth (2012). Model 3 was the same as Model 2 except that the priors on survey selectivity were tightened until estimated selectivity at the oldest age was midway between one and the value estimated by Model 2.

In the fits, Model 1 naturally tracked the survey biomass estimates closely. (That's all it does.) Models 2 and 3 both fitted the age and size compositions well, but Model 2 achieved a better overall fit. Models 2 and 3 produced similar estimates of present biomass, but the estimates are on the order of three times the swept-area estimates from the survey, which seems suspiciously high. Models 2 and 3 both displayed poor retrospective performance; historical estimates of abundance were revised upward by 100% or more when the models were fitted to later data.

Grant recommended sticking with Model 1 (ABC=17,600 mt) for this year because of the very high Model 2&3 biomass estimates relative to the swept-area estimates, the poor retrospective patterns, and the same concerns about SS selectivity pattern 17 as in the EBS assessment.

The Team concurred, but at the same time **we recommend that Grant continue work on the problems with Model 2 so as to make progress toward an age-structured AI assessment.** Specifically, **the Team recommends examining NMFS trawl survey data, IPHC longline survey data, AFSC longline survey data, and commercial data to investigate the distribution of AI Pacific cod relative to the NMFS trawl survey stations.**

3 Full text of the November 2014 GOA Plan Team minutes on Pacific cod

Teresa A'mar presented three sets of models: Model 1 was identical to the final model configuration from 2013. Model 2 identical to Model 1 but used the recruitment variability multiplier. The two new models (S1a and S1b) also used the recruitment variability multiplier and:

1. treat the bottom trawl survey as a single source of data instead of splitting the sub 27 and 27-plus data for lengths and ages,
2. include survey age data as conditional age-at-length data;
3. instead of incorporating 12 blocks of logistic survey selectivity (Models 1 and 2), Model S1a uses 3 blocks of non-parametric survey selectivity and Model S1b uses cubic spline based survey selectivity.

The Team agreed with the Teresa's proposal to use S1a as the preferred model primarily because it fit the data better than S1b.

Teresa presented results from additional age-composition data (2013 GOA bottom trawl survey) that was provided after the assessment was completed. She noted that when incorporated, these data reduced the estimated abundance at age (~ 8% of biomass) relative to the selected model in the assessment without the 2013 survey age data.

The Team discussed how this could affect accepting the maximum permissible ABC level. After much deliberation considering a number of alternatives (including rolling over last year's ABC) they concluded that although the model configuration was acceptable, recommending an ABC less than the maximum permissible would be prudent. Therefore, an ABC for 2015 set halfway between the maximum permissible ABC in the assessment and the 2014 ABC would be reasonable for the following reasons:

- Model runs including the 2013 survey age composition resulted in an ABC that was about 10,000 t lower (the data were made available only one day before the Team meetings and hence were unavailable for the assessment).
- Concern over retrospective pattern
- New survey information in 2015 will be available and the 2016 recommendation will be updated

Other comments and discussions led to the following recommendations:

The Team recommended cross checking length composition figures for inconsistency (e.g., data presented in Fig. 2.6 appeared inconsistent with that shown in Fig. 2.17).

The Team recommended examining the longline survey RPN and length frequency data for use within the model.

4 Full text of the December 2014 SSC minutes on Pacific cod

BSAI Pacific Cod

Public testimony was presented by Chad See and Gerry Merrigan (Freezer Longline Coalition) and Jason Anderson (Alaska Seafood Cooperative). Mr. See and Mr. Merrigan support the scientific approach and support the ABC recommendation of 255,000 mt. They expressed concerns about survey catchability and positive retrospective bias in the assessment model. Mr. Anderson expressed that Pacific cod is now the new "prohibited species cap" ("choke species"). In the Amendment 80 fisheries, they are actively avoiding Pacific cod and Pacific halibut species in pursuit of yellowfin sole and rock sole. He commented that the Pacific cod tend to separate from yellowfin sole in mid-September.

Bering Sea:

Two alternative assessment models were put forward this year for Bering Sea Pacific cod. Model 1 is the same Stock Synthesis model that has been in use since 2011. Model 2 differed significantly from Model 1 in that a single season was used instead of five seasons, a single fishery was defined where the composition data were catch weighted, Richards growth model, natural mortality, and survey catchability were all estimated internally. Survey catchability and selectivity were allowed to vary annually (based on a random walk), and an iterative method was used to tune the standard deviations for penalized deviation vectors.

The author and Plan Team recommended the use of Model 1 for specifying stock status and determining ABC and OFL levels. The 2015 maxABC for Model 1 is 295,000 mt; however, the author and Plan Team recommend rolling over the 2014 ABC due to the strong retrospective pattern in the estimated spawning biomass – the retrospective analysis suggest the biomass is over-estimated by as much as 50%. In contrast, Model 2, which has good statistical fits to the observed data, results in a 2015 max ABC of 112,000 mt. The author was not comfortable using this model due to difficulty in resolving questions about selectivity type 17 (random walk in selectivity with respect to age) in Stock Synthesis. Specifically, the use of the max function (not differentiable), difficulty including dev vectors at age of peak selectivity, and the tendency of the model to estimate extremely low selectivity values for ages with exception of age classes close to the plus group. The author attempted to identify the source of the retrospective bias, but no obvious solution was found. The SSC notes that Model 2 does not have the same retrospective bias problem and the solution to this bias must lie in the differences between Models 1 and 2.

Both the Plan Team and the SSC note that Model 2 has desirable properties with respect to improved fits to the data and improved retrospective performance. The SSC recommends that the author conduct a simulation study to better understand the estimability of the selectivity type 17 in Stock Synthesis and the estimation of annual deviations.

The vector of effective sample sizes for the composition data set was assumed to have a mean of 300 in Model 1. The author noted that in combining the fisheries data the effective sample size in Model 2 has a mean of 2700 (9 fleets times 300). The SSC recommends that a statistical approach be used to weight the composition data (i.e., iterative re-weighting, or other methods outlined in Francis 2011).

The SSC had a long discussion regarding major differences in the estimated reference points and ABC recommendations between the two models. Model 2 is preferable due to its better performance overall with respect to fitting data and minimal retrospective bias. However, trends in the trawl survey indicate a relatively stable (even slightly increasing) population since 2009, with commercial catches exceeding 200,000 mt since 2011. Since 2006, Model 1 does estimate above average recruitment, but these estimates are likely biased high due to the retrospective behavior in the model. The SSC agrees with the author and Plan Team recommendation of rolling over the 2014 ABC based on trends in the trawl biomass survey and using Model 1 for stock status determination. **The SSC recommends the rollover of the 2014 ABC/OFL for 2015, and the following ABC/OFL for 2016 (in mt).**

Stock/ Assemblage	**Area**	**2015 OFL**	**ABC**	**2016 OFL**	**ABC**
Pacific cod	BS	346,000	255,000	389,000	255,000

Aleutian Islands:

The assessment author presented three models for the AI Pacific cod, one Tier 5 assessment based on the random effects model (Model 1), and two Tier 3 age-structured models. The author and Plan Team both recommend the Tier 5 assessment. The survey index for 2014 has increased by 8% from 2012 and biomass increased by 25%.

Model 2 and Model 3 are both age-structured models similar to the models used for the Bering Sea Pacific cod assessments, except the model starts in 1991. Model 3 differs from Model 2 by using a more logistic-like selectivity. The author and Plan Team were concerned about using these models at this stage due to the random walk in selectivity (same issue in the Bering Sea Model 2 assessment), and estimated biomass was on average 3.3 times larger than the survey biomass estimates.

The SSC recommends adopting Model 1 (Tier 5) for the purposes of setting ABC and OFL. The 2015 and 2016 ABC/OFL recommendations (in mt) below.

Stock/ Assemblage	**Area**	**2015 OFL**	**ABC**	**2016 OFL**	**ABC**
Pacific cod	AI	23,400	17,900	23,400	17,900

GOA Pacific cod

There were four alternative assessment models. Model 1 is an update of the 2013 assessment, Model 2 is the same as Model 1 with an additional recruitment variability multiplier added. The other two models represent a change in methodology, where 3 blocks of non-parametric or cubic spline-based selectivity parameters are used instead of the double normal. Survey at age data were substituted for conditional age-at-length data, and the GOA NMFS trawl survey data are treated as a single index rather than split into sub-27 and 27-plus for the abundance indices.

The author and Plan Team recommend Model S1a, which uses non-parametric selectivity with 3 time blocks. The SSC noted that the spawning biomass for this stock has been increasing since 2009, and the length composition data indicate a new cohort starting to recruit. Model S1a does have retrospective bias on the order of 20%-40%, and therefore the Plan Team recommends adjusting the ABC downward from 117,200 mt to 102,850 mt (split the difference).

The SSC recommends adopting the author and Plan Team recommendations of OFL and ABC for 2015 and 2016 (in mt).

Stock/ Assemblage	Area	2015 OFL	ABC	2016 OFL	ABC
Pacific cod	W		38,702		38,702
	C		61,320		61,320
	E		2,828		2,828
	Total	140,300	102,850	133,100	102,850

5 Mark Maunder's review of the EBS Pacific cod assessment

Introduction

The Base model used in 2014 was simply a data update of the same model that was used in 2011 through 2013. The only alternative model fully presented in December 2015 was vastly different from the base model. There has been several stock assessment advancements since the based model was developed in 2011 and some of these have been implemented in the alternative model. The base case model still shows poor diagnostics (e.g. retrospective patterns) and improvements are necessary. Unfortunately, the alternative model is not yet ready for use as a management tool. Some of the main concerns with the base case model are specification of survey catchability, choice of asymptotic selectivity, time varying growth, composition data weighting, and the level of natural mortality.

Survey catchability

Survey catchability has been a serious issue in the EBS Pcod assessment for a long time. The base case model fixed catchability based on an estimate made back in 2009 using an iterative approach to match the tag data inside the stock assessment model. This is not satisfactory because some model assumptions have changed since 2009 and there are several years of new data used in the current stock assessment.

Recent information external to the assessment has not supported a catchability substantially less than one. No difference in catchabilty was found between GOA (7m head rope height) and BS (2.5m head rope height) survey nets (Lauth unpublished), and acoustic back scatter showed cod near bottom in the survey area. Unless abundance in untrawlable areas is higher or there are fish outside the survey area, these new results suggest catchability may be higher than assumed. However, the models consistently estimate the survey selectivity to be highly dome shaped, which is inconsistent with this new data unless natural mortality for older fish is higher than assumed.

The assessment author has suggested that the model cannot fit the survey index of abundance with a constant catchability. The alternative model allowed for catchability to change over time. Obviously, a model with time varying catchability is going to fit the survey better. This approach essentially down weights the influence of the survey while making it appear that the model fits it better. If the catchability is really time varying, this may be an appropriate approach. It is possible that with the low head rope height, small changes is the vertical distribution of the cod (e.g. due to the position in the water column of the prey) could change catchability over time. However, this conflicts with the lack of difference found between the BS and GOA survey nets. Some of the changes, particularly increases, in the survey abundance do appear to be unrealistically large. However, modelling time varying catchability may just be hiding some other form of model misspecification (e.g. age specific or time varying natural mortality).

Catchability could be estimated inside the stock assessment model. However, other model misspecifications need to be dealt with first otherwise the catchability will be estimated to compensate for the model misspecifications. The alternative model estimates catchability with reasonable precision (e.g. the base case assumption is outside the confidence interval of the alternative models estimate) despite the flexibility provided by estimation of several additional parameters (e.g. natural mortality) and temporal variation. Pcod is short lived, has large fluctuations in recruitment, and the fishery mortality rates are relatively low. Therefore, information contained in a relative index of abundance due to the effect of catch could be minimal and any information on absolute abundance (i.e. catchability) is coming from the composition data, which is arbitrarily weighted (see below). Diagnostics such as the R0 profile (see Figures and the section on composition sample size below) and the age-structured production model diagnostic should be applied to determine where the information on absolute abundance is coming from and which data sets are in conflict.

Natural mortality

The value of natural mortality used in the base case model (0.34) has been used since 2007. Many of the recent models support a value higher than this. However, given that the model is probably misspecified and estimates of natural mortality often compensate for the misspecification, it may be premature to conclude that natural mortality is higher. It is also worth noting that an increased value for natural mortality did not appear to reduce the decline in survey selectivity for old individuals.

Age specific natural mortality should be considered and may improve some of the fits to the data. For example, it is unlikely that the smallest fish vulnerable to the survey (e.g. age 1) have the same natural mortality as adults. Increased natural mortality for the old individuals may reduce the estimated decline in survey selectivity for old individuals.

Retrospective bias

The base case model shows substantial retrospective bias. This is a clear indication that the model is misspecified. However, care needs to be taken when interpreting this bias in terms of management advice. This is not statistical bias that can be adjusted for in the traditional sense. Due to model misspecification, there is no guarantee that the model with more years of data is less biased for a historic biomass estimate. Retrospective bias also tends to change sign over time, although the change in sign generally tends to be a slow process.

There are a variety of model misspecifications that can cause retrospective bias including incorrect fixed parameters, not accounting for time varying process, and incorrect model structure. The alternative model did not show any retrospective bias and this may provide some insight into the cause of the retrospective bias. For example, the alternative model estimated natural mortality, catchability, allowed time varying selectivity, and allowed both survey and fishery selectivities to be dome shape.

The retrospective pattern was correlated with a lot of parameters related to the start of the time series. Also, the base case model estimates of survey abundance were similar to the alternative model for the first few years, but not for the rest of the time series. This suggests that the retrospective pattern may be related to the initial conditions (e.g. the number of years of initial recruitment deviates estimated and fitting to the equilibrium catch) or the selectivities in the early period.

One surprising fact about the retrospective analysis is that despite the large over estimates of biomass, the resulting management actions did not cause the population to collapse. This indicates that either the stock is more productive than assumed (e.g. higher natural mortality), or the retrospective bias is not that large. It would be interesting to conduct an alternative retrospective analysis plotting the estimated biomass from the assessment in the given year (which may differ from the current assessment model) against the estimated biomass using the current model with all the data.

Composition sample size

The sample sizes for the composition data, which weight their influence on the results, use a convoluted procedure that ends up making the average sample size equal to 300 for all composition data combined (length and age done separately; the alternative model does it by fishery). This is essentially an arbitrary decision and can have a huge impact on the results. Recent research (Francis 2012) suggests that standard approaches to weight composition data (e.g. the McAllister and Ianelli (1997) iterative approach) give too much weight to composition data. There are essentially two alternative approaches that are starting to get support: 1) use the Francis (2012) approach, which is based on choosing a sample size so that the coverage of the confidence intervals of mean length (or mean age) are correct, and explains process error as observation error or 2) use the empirical sample size (e.g. from bootstrapping) and model the process error. There has not been enough research to determine which of these approaches are best and in what circumstances.

A R0 profile was conducted to investigate the influence of the composition data on the estimates of absolute abundance (as represented by R0; Figures 1 and 2) and make comparisons with the survey data. For the model used in 2014, the survey data was the dominated the information on absolute abundance However, the length composition data for fisheries 5 (May-Jul_Longline_Fishery) and 6 (Aug-Dec_Longline_Fishery) also had an influence, pushing the absolute abundance lower. Note that fishey 5 has an asymptotic selectivity (although many fisheries do) and may need to be dome shape. A quick analysis using a sigle dome shape selectivity for fishery 5 over the whole time period did not inflinece the estimate of R0.

When the catchability parameter was freely estimated, the survey data was no longer dominant. The length composition data for fisheries 5 and 6 continued to push the abundance lower, while length composition data for several other fisheries pushed the abundance higher. This suggests that under the current sample size assumptions for the composition data, the composition data will control the estimate of absolute abundance unless the catchability is fixed in the assessment model. This is expected as discussed in the section on survey catchability above.

The survey index is weighted by the estimated CVs. However, given the inability of the assessment model to fit the survey index, possibly because of changes in selectivity as discussed above, the CVs might be an under estimation of the combined sampling and process error in the survey index. Francis (2012) suggests fitting a smooth curve to the abundance data to estimate the appropriate CV. This type of analysis would be interesting to conduct to see how different the CV would be from that currently used in the assessment. Note that modelling time varying catchability is similar to increasing the survey observation error CV.

Survey selectivity

Specification of the survey selectivity is important because it underlies the index of abundance. A study has indicated that age 2 cod may congregate in untrawlable areas relative to age 1 cod. This suggests a more flexible selectivity curve. It may be worthwhile separating out the age 1 and 2 year olds based on the length compositions and including them as two separate indices of abundance. The survey has annual deviates for the ascending width (young ages) of the selectivity curve. It is not clear if the inclusion of this variation is to deal with variation in selectivity, growth, or both. If it is for variation in growth, then separating out the age 1 and 2 year olds might address this issue. If it is for variation in selectivity, it suggests that the survey data for ages 1 and 2 might not be informative.

In ideal circumstances the survey selectivity would be asymptotic to help stabilize the model. Having at least one selectivity curve asymptotic avoids the issue of cryptic biomass. The survey is currently estimated to be dome shape, which is supported by the tag data, despite the fact that there is no known mechanism for survey selectivity being dome shape. The method of Clark (2015) should be considered to compare length composition data in an attempt to determine if the survey selectivity is dome shape and which fisheries/survey should have asymptotic selectivity. Waterhouse et al. (2015) illustrated that fishery selectivity could be monotonically increasing rather than dome shape due to spatial variation. Based on this, it is conceptually possible that the survey selectivity is asymptotic, natural mortality increases with age, and/or some fisheries have high selectivity for large fish.

Recent research (summarized in Crone et al. 2014 and Maunder et al. 2014) suggests that fishery selectivity is often dome-shape and changes over time due to the spatial characteristics of the stock and fleet. Therefore, it may not be wise to rely on the assumption that fishery selectivity is asymptotic. It is also important to get the growth curve correct, particularly the asymptotic size, when fitting to length composition data. Improvements to the survey and aging would go along way in improving the assessment.

Fishery selectivity

Recent research suggests that fishery selectivity as defined in contemporary statistical stock assessments can take on a variety of shapes and vary over time due to the spatial dynamics of the fishery and the population. There is temporal variation in the spatial distribution of the fishery and Pcod's migrations and may vary over time. This suggests that fishery selectivity for Pcod may change over time. A recommendation of the CAPAM workshop on selectivity was to model time varying selectivity using flexible selectivity curves for fisheries. The base case assessment complies somewhat with this recommendation because it uses time blocks for selectivity. However, it is not clear if the selectivity curves are flexible enough over age/length or time. The pot fisheries have a large time block for the early period and it might be necessary to add more time blocks for this period. Although, they are not that influential in the R0 plot (Figure 1). Perhaps, the approach used in the alternative model (see below) could be used for each of the fisheries in the base case model.

The alternative model uses a more flexible approach to selectivity, but the flexibility is reduced by combining all the fisheries into a single fishery and only one age ended up varying over time. In addition, the variability for this age was relatively low. It is not clear if the variation in selectivity was taken up by another time varying process. The alternative model also puts a prior on the selectivity based on a logistic functional form. One problem with combining all the fisheries into a single fishery is that any fishery with logistic selectivity is lost, which might be necessary for model stability. In fact, the selectivity is bimodal, which is not a surprise when combining fisheries. One approach may be to identify a fishery with consistent asymptotic selectivity and model that fishery as a separate fishery.

Growth

Specification of growth, particularly the asymptotic length, is important when fitting to length composition data as shown by the influence of the length composition data on the absolute abundance shown in the R0 profiles (Figures 1 and 2). There is substantial error in the aging data and estimation of aging error inside the model emphasizes the length composition data in the estimation of growth. The recent CAPAM workshop, as summarized by Maunder et al. (2015), suggests that an assumption of time varying growth should be the default assumption and that time varying growth should be estimated if adequate data is available. Time varying growth parameters, particularly the asymptotic length, appear to be a better option than cohort related deviations. In addition, more flexible functional forms should be considered. Substantial age-length data is available for Pcod, but due to the aging error it is unclear if it is sufficient to estimate time varying growth. The Richards growth curve available in Stock Synthesis should also be considered.

The survey data shows substantial variation in growth for age 1 ranging from a mode of approximately 11cm to 22cm (Figure 3). The variation for age 2 is about the same at approximately 28cm to 36cm (Figure 4). The variation for age 3 is also about the same at approximately 43cm to 54cm (Figure 5), but the modes are more difficult to identify because they potentially merge with the older ages. This variation in the empirical data suggests that growth variation should be modelled and the empirical data could be used to help define the variation used in the model. An analysis of the modes (e.g. fitting normal distributions to the truncated length compositions) from the empirical data could be used to determine if the growth is cohort specific, year specific and consistent across all ages, or some other complex relationship, and how it should be modelled in Stock Synthesis.

Management

The retrospective analysis and the ABC estimated by the alternative model suggest that the estimates of ABC might have been too high in the past. However, the stock does not appear to have been adversely impacted. One way to double check the current ABC is to compare the ratio of ABC to survey abundance and ensure that the current level is within that seen historically. Figure 6 shows the catch divided by the survey abundance and that the current estimates are within the range of the historical estimates. The analysis should be improved by calculating the survey biomass restricted to the sizes caught in the fishery.

Model Runs

The following is a list of recommended analyzes and model runs.

R0 profile using the observed data and using simulated data without error

Age-specific natural mortality. Estimated and fixed.

Include more initial age devs to potentially remove the retrospective bias

Fit a smooth curve to the survey abundance index data to estimate the appropriate CV.

Run the model with Francis weighting for composition data

Run the model with empirical sd's for composition data and time varying commercial selectivity

Split out age 0 and 1 based on length and model as a separate surveys.

Time varying growth

Richards growth curve

Plot the time series of catch/survey to determine whether the current values are within the historic values. The survey data should be restricted to lengths in the catch data.

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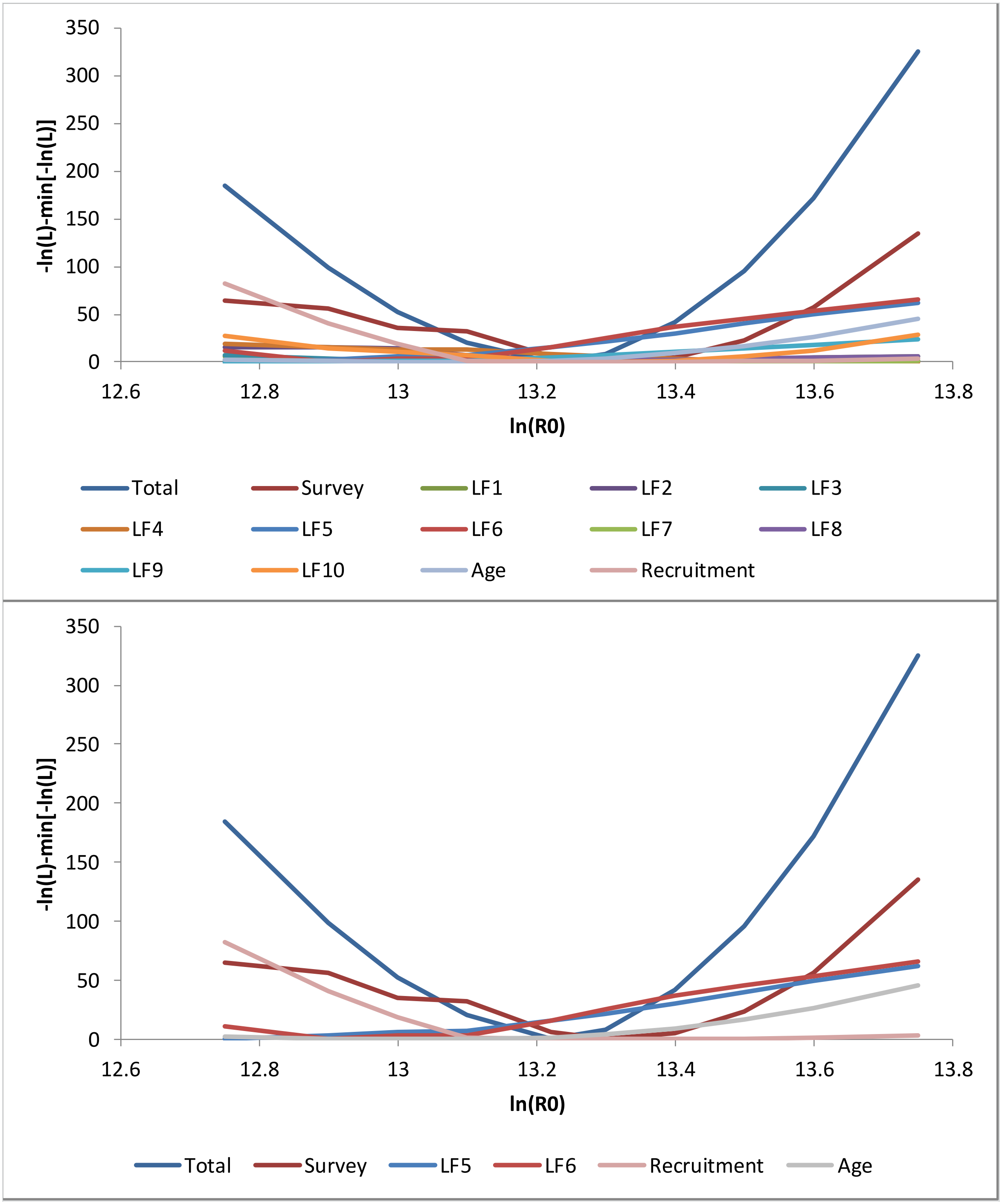

Figure 1. The negative log likelihood for each data component minus the minimum for that component plotted against the logarithm of virgin recruitment for the 2014 model.

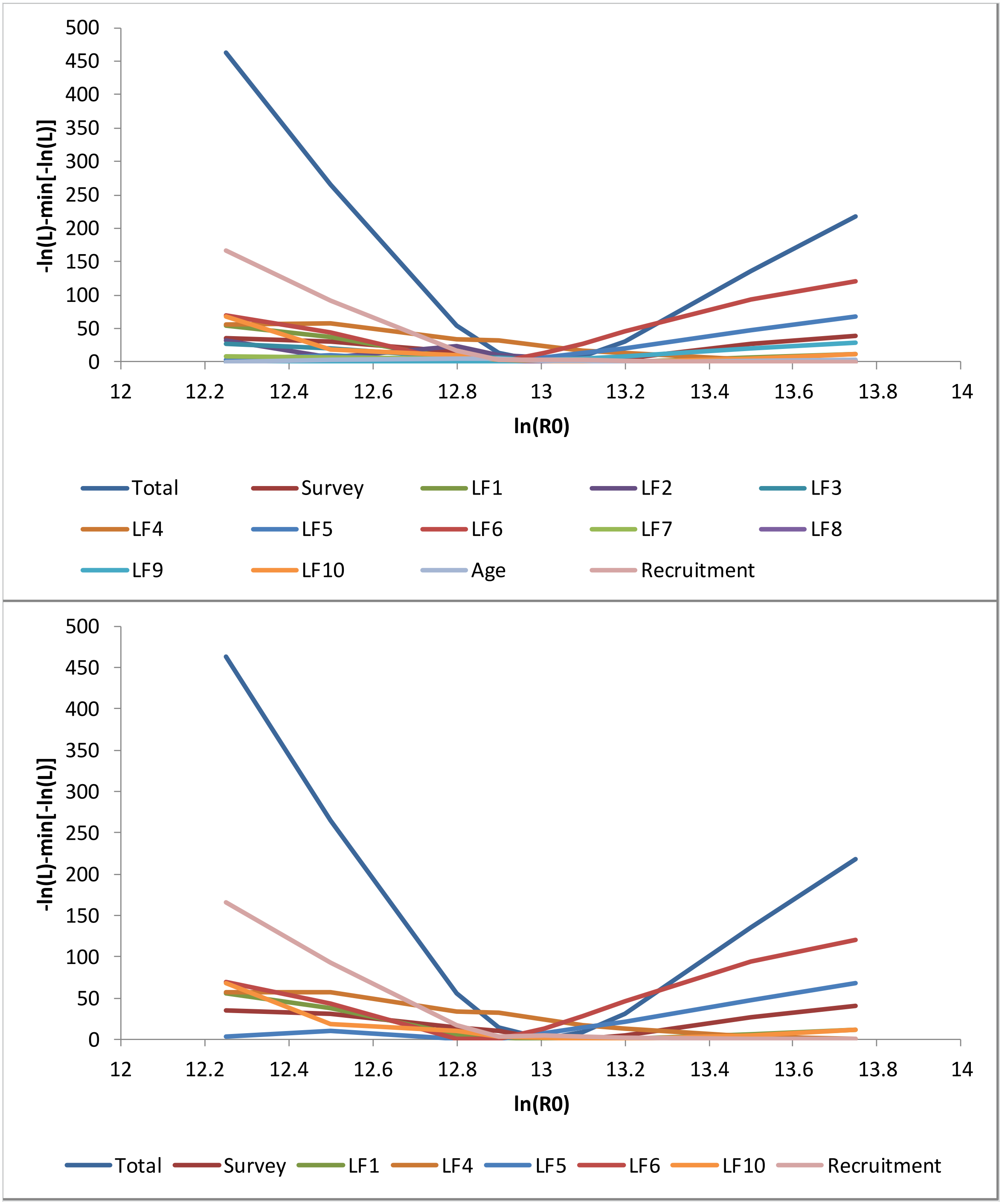

Figure 2. The negative log likelihood for each data component minus the minimum for that component plotted against the logarithm of virgin recruitment for the 2014 model with survey catchability estimated.

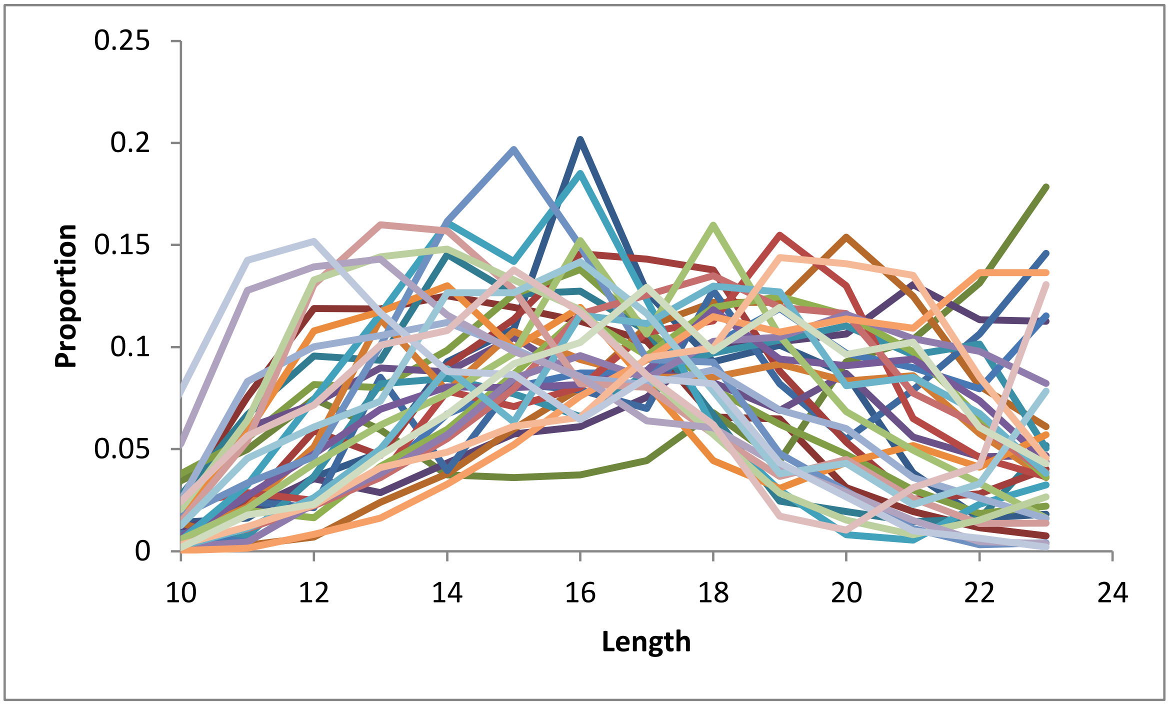

Figure 3. Survey length compositions for age 1 showing the annual variation in growth.

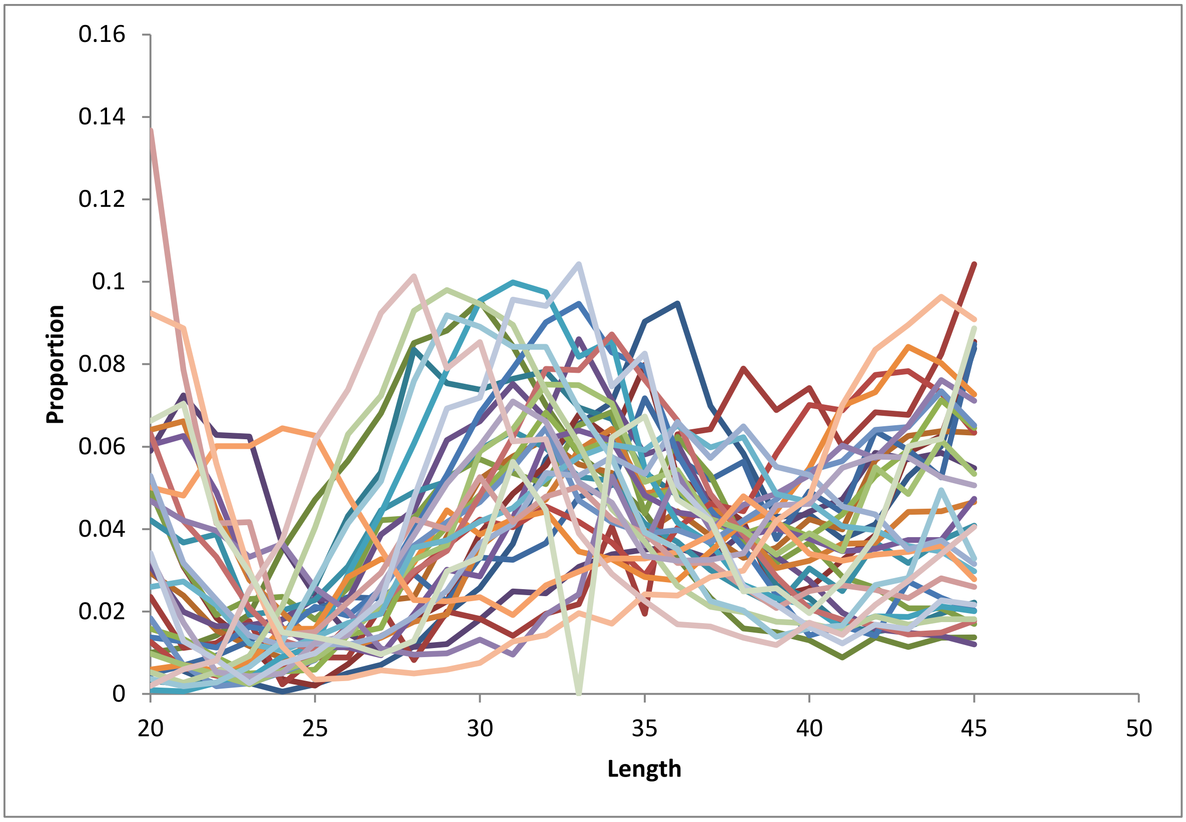

Figure 4. Survey length compositions for age 2 showing the annual variation in growth.

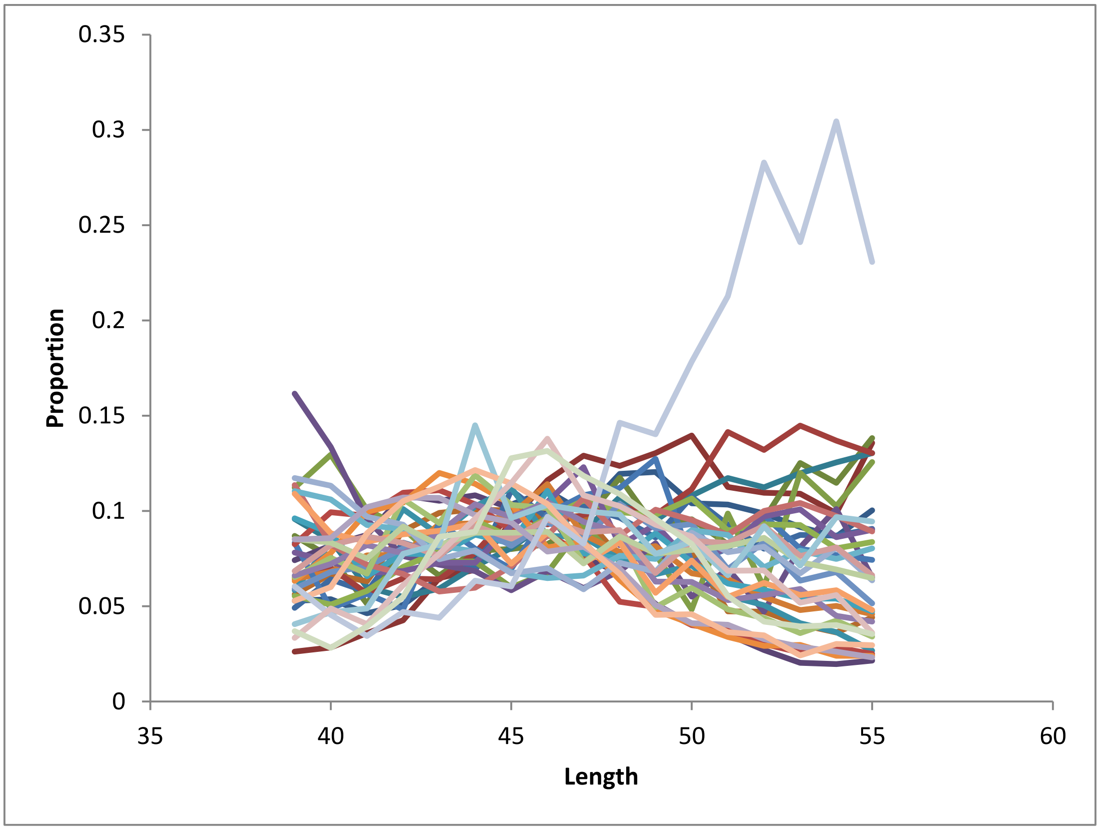

Figure 5. Survey length compositions for age 2 showing the annual variation in growth.

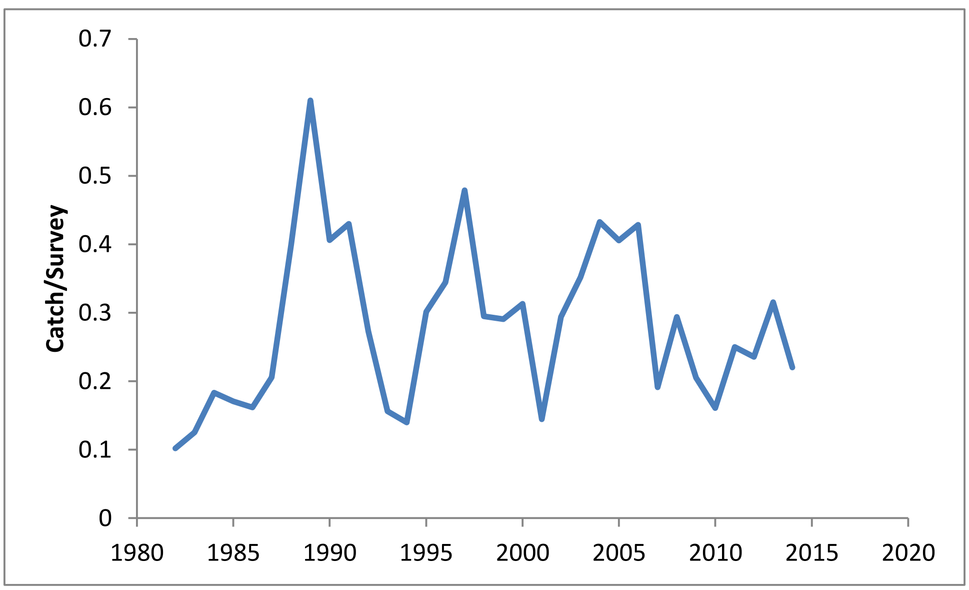

Figure 6. Time series of catch divided by survey abundance.

6 History of alternative Pacific cod models (all regions)

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

Pre-2005

- EBS:
  - Pre-1985: Simple projections of current survey nos. at age
  - 1985: Projections based on 1979-1985 survey nos. at age
  - 1986-1991: *ad hoc* separable age-structured model
  - 1992: Stock Synthesis 1 (SS1), with age-based data
    - Strong 1989 cohort "disappears;" production ageing ceased
  - 1993-2003: SS1, with length-based data only
  - 2001: CIE review of code for proposed "ALASKA" (Age-, Length-, and Area-Structured Kalman Assessment) model and methodology for decision-theoretic estimation of OFL and ABC
    - Although review was favorable, use of ALASKA was postponed "temporarily"
  - 2004: SS1, with length- *and* age-based data
    - New age data, based on revised ageing protocol
    - Agecomp data used in "marginal" form
- GOA:
  - Pre-1988: MSY = 0.5 × *M* × current survey biomass
  - 1988-1993: Stock reduction analysis (Kimura et al. 1984)
  - 1994-2004: SS1, with length-based data
- Main features of SS1 models (EBS and GOA):
  - Start year = 1977
  - Three seasons (Jan-May, Jun-Aug, Sep-Dec)
  - Four fisheries (Jan-May trawl, Jun-Dec trawl, longline, pot)
  - *M* constant at 0.37 in both BS and GOA
  - *Q* constant at 1.00 in both BS and GOA
  - Efforts at internal estimation of *M*, *Q* unsuccessful
  - Double-logistic selectivity for all fleets (fisheries and survey)
  - No fleets constrained to exhibit asymptotic selectivity
  - Sizecomp input sample size = square root of true sample size
  - Survey index standard deviations set to values reported by RACE Division

2005

- Three models for both EBS and GOA:
  - Model 1 was identical to last year's final model (configured under SS1), except for use of new maturity schedule developed by Stark

- **Model 2** was configured under SS2, and was designed to be as close as possible to Model 1 given the limitations of the respective software packages, except:
  - Nonuniform priors used throughout
  - *M* fixed at 0.37, *Q* fixed at 1.00
- Model 3 was identical to Model 2 except that *M* and *Q* were estimated internally

- Weight-length and length-age data examined for evidence of sexual dimorphism in both areas; none found

2006

- Nine models for the EBS, consisting of last year's final model and a 3-way factorial design of alternative models (the factorial models all differed from last year's final model in that they estimated trawl survey *Q* internally—in last year's final model, it was fixed at 1.0; and they estimated all selectivity parameters except for selectivity at the minimum size bin internally—in last year's final model, a few selectivity parameters were fixed externally):
  - Model 0 was identical to last year's final model
  - Model A1 was identical to Model 0 except as noted above, with:
    - NMFS longline survey data omitted
    - Double logistic selectivity
    - Prior emphasis = 1.0
  - Model A2 was identical to Model 0 except as noted above, with:
    - NMFS longline survey data omitted
    - Double logistic selectivity
    - Prior emphasis = 0.5
  - **Model B1** was identical to Model 0 except as noted above, with:
    - NMFS longline survey data omitted
    - Double normal (four parameter) selectivity
    - Prior emphasis = 1.0
  - Model B2 was identical to Model 0 except as noted above, with:
    - NMFS longline survey data omitted
    - Double normal (four parameter) selectivity
    - Prior emphasis = 0.5
  - Model C1 was identical to Model 0 except as noted above, with:
    - NMFS longline survey data included
    - Double logistic selectivity
    - Prior emphasis = 1.0
  - Model C2 was identical to Model 0 except as noted above, with:
    - NMFS longline survey data included
    - Double logistic selectivity
    - Prior emphasis = 0.5
  - Model D1 was identical to Model 0 except as noted above, with:
    - NMFS longline survey data included
    - Double normal (four parameter) selectivity
    - Prior emphasis = 1.0
  - Model D2 was identical to Model 0 except as noted above, with:
    - NMFS longline survey data included

        - Double normal (four parameter) selectivity
        - Prior emphasis = 0.5
- Only one model for the GOA, due to the fact that the assessments were conducted simultaneously with an external review:
    - **Model 1** was identical to last year's final model

April 2007 (technical workshop)

- Model 0 prepared ahead of workshop for both EBS and GOA:
    - *M* estimated internally
    - Length-at-age parameters estimated internally
    - Disequilibrium initial age structure
    - Regime shift recruitment offset estimated internally
    - Start year changed from 1964 to 1976
    - New six-parameter double normal selectivity function used
        - Previous double normal had only four parameters
    - Prior distributions reflect 50% CV for most parameters
- Twenty-one other models prepared ahead of workshop for both EBS and GOA, each of which was based on Model 0:
    - Two models to examine inside/outside growth estimation:
        - Model 1 was identical to Model 0 except length-at-age parameters estimated outside the model
        - Model 2 was identical to Model 0 except standard deviation of length at age 12 estimated internally
    - Two models to examine *M* conditional on *Q*, vice-versa:
        - Model 3 was identical to Model 0 except *M* fixed at 0.37 and *Q* free
        - Model 4 was identical to Model 0 except *Q* fixed at 0.75 and *M* free
    - Six models to examine effects of prior distributions:
        - Model 5 was identical to Model 0 except 30% CV instead of 50%
        - Model 6 was identical to Model 0 except 40% CV instead of 50%
        - Model 7 was identical to Model 0 except emphasis = 0.2 instead of 1.0
        - Model 8 was identical to Model 0 except emphasis = 0.4 instead of 1.0
        - Model 9 was identical to Model 0 except emphasis = 0.6 instead of 1.0
        - Model 10 was identical to Model 0 except emphasis = 0.8 instead of 1.0
    - Four models to examine effects of asymptotic selectivity:
        - Model 11 was identical to Model 0 except Jan-May trawl fishery selectivity forced asymptotic
        - Model 12 was identical to Model 0 except longline fishery selectivity forced asymptotic
        - Model 13 was identical to Model 0 except pot fishery selectivity forced asymptotic
        - Model 14 was identical to Model 0 except shelf trawl survey selectivity forced asymptotic
    - One model to examine estimation of stock-recruit relationship:
        - Model 15 was identical to Model 0 except parameters of a Ricker stock-recruitment relationship estimated internally
    - Six models to address EBS-specific comments from the public:

    - Model 16 was identical to Model 0 except input *N* determined by iterative re-weighting
    - Model 17 was identical to Model 0 except input *N* for mean-size-at-age data decreased by an order of magnitude
    - Model 18 was identical to Model 0 except standard error from the shelf trawl survey doubled
    - Model 19 was identical to Model 0 except all age data removed
    - Model 20 was identical to Model 0 except slope survey data removed
    - Model 21 was identical to Model 0 except start year changed to 1982
- Immense factorial grid of fixed *M*×*Q* models also prepared ahead of workshop, for which only partial results were presented
- Eight models developed during workshop (EBS only):
  - Model 22 was identical to Model 0 except "old" (pre-Stark) maturity schedule used
  - Model 23 was identical to Model 0 except priors turned off and separate *M* estimated for ages 1-2
  - Model 24 was identical to Model 0 except priors turned off and longline fishery CPUE included as an index of abundance
  - Model 25 was identical to Model 0 except priors turned off and Pcod bycatch from IPHC survey included as an index of abundance
  - Model 26 was identical to Model 0 except priors turned off and either *Q* (=0.75) or *M* (=0.37) fixed
  - Model 27 was identical to Model 0 except all priors turned off other than that for Jan-May trawl selectivity in largest size bin
  - Model 28 was identical to Model 0 except survey selectivity forced asymptotic and *Q* fixed at 0.5
  - Model 29 was identical to Model 0 except separate *M* estimated for ages 9+

September 2007 (EBS only)

- In general:
  - Agecomp data presented as "age conditioned on length" (i.e., not marginals)
  - Length-at-age SD a linear function of age
  - Annual *dev*s for length at age 1, sigma=0.11
  - Annual *dev*s for recruitment, sigma=0.6, 1973-2005
  - Annual *dev*s for ascending selectivity, sigma=0.4
  - All parameters estimated internally
  - Except selectivity parameters pinned against bounds
  - Uniform priors used exclusively
  - Monotone selectivity for Jan-May trawl fishery
  - All other selectivities new "double normal" (see next 4 slides)
- Four models considered, all of which were identical to last year's final model except as specified above:
  - Model 1:
    - Estimated effect of 1976 regime shift on median recruitment
    - Addeda large constant to fishery CPUE sigmas
  - Model 2 was identical to Model 1 except age-dependent *M* estimated for ages 8+

  - Model 3 was identical to Model 1 except that it did not add the large constant to longline CPUE sigmas
  - Model 4 was identical to Model 1 except:
    - Effect of regime shift assumed to be zero
    - Did not add large constant to longline CPUE sigmas
    - Zero emphasis placed on initial catch and age composition
    - Iteratively re-weighted input sigmas and input *N*
- Also attempted but not included:
  - Simplified model with only a single fishery and no seasons

November 2007

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

  - Large number of changes undertaken in the EBS assessment resulted in little time being left for development of the GOA assessment
  - Making things even worse, a very small error in EBS data file, with very large implications, was discovered very late in the cycle
  - As a consequence, GOA SAFE chapter was incomplete and was delivered late to Plan Team
  - Although both Teams participated fully in the development and evaluation of EBS Model 1 (which was accepted by the BSAI Team and accepted "in principle" by the SSC), the GOA Team and SSC rejected the GOA assessment due to insufficient time for review

September 2008

- Five models included for the EBS:
  - Model 1 was identical to last year's final model
  - Model 2 was identical to Model 1 except growth parameter *L2* estimated externally
  - Model 3 was identical to Model 1 except exponential-logistic selectivity used instead of double normal
  - Model 4 was identical to last year's Model 4
  - Model 5 was identical to Model 1 except:
    - Fishery selectivity blocks (5 yr, 10 yr, 20 yr, or no blocks) chosen by AIC
    - Lower bound of descending "width" = 5.0
    - Regime-specific recruitment "dev" vectors
    - "SigmaR" set equal (iteratively) to stdev(dev) from current regime
    - Seasonal weight-length, based on fishery data
    - Number of free initial ages chosen by AIC
    - Size-at-age data used if modes ambiguous
- Three models included for the GOA:
  - Model 1 was identical to the 2006 final model
  - Model 2 was identical to the 2007 model
  - Model 3 was similar to EBS Model 5, except:
    - Size at age data included
    - Survey sizecomp, agecomp data downweighted
    - Time series of survey abundance, sizecomps split into separate "sub-27" and "27-plus" time series:
    - 27-plus survey split into pre-1996, post-1993 eras, to coincide with switch from 30-min. to 15-min. tows
    - 27-plus *Q* fixed for post-1993, free for pre-1996
    - Sub-27 *Q* free, estimated as random walk

November 2008

- Eight models for the EBS:
  - Model A1 was identical to Model 5 from September except lower bound on selectivity descending "width" parameter relaxed so as not to be constraining
  - Model A2 was identical to Model A1, except without age data
  - **Model B1** was identical to Model A1, except:
    - "Asymptotic algorithm" used to determine which fisheries will be forced to exhibit asymptotic selectivity
    - "Constant-parameters-across-blocks algorithm" used to determine which selectivity parameters can be held constant across blocks
  - Model B2 was identical to Model B1, except without age data

- Model C1 was identical to Model B1, except with M estimated internally
- Model D2 was identical to Model B1, except:
  - No age data
  - Maturity modeled as function of length rather than age
  - M estimated iteratively, based on mat. at len and len. at age
- Model E2 was identical to Model B1, except:
  - No age data
  - Post-1981 trawl survey selectivity forced to be asymptotic
  - M estimated internally
- Model F2 was identical to last year's Model 4, except start year = 1977

- Two models for the GOA:
  - Model A was identical to Model 3 from September except:
    - Lower bound on selectivity descending "width" parameter relaxed so as not to be constraining
  - **Model B** was identical to Model A, except:
    - "Constant-parameters-across-blocks algorithm" used
    - Constant *Q* for 27-plus survey assumed (needed to keep pre-1996 *Q* from going too high)
    - Input sample sizes for age data decreased from 100 to 12 (needed to achieve good fit to survey nos. given constant *Q*)

September 2009

- Eight models for the EBS, based on factorial design of the following:
  - Selectivity functional form: double normal or exponential-logistic?
  - Catchability: free or fixed at 1.0?
  - Survey selectivity estimation: free or forced asymptotic?
- Partial results presented for a model with prior distribution for *Q* based on archival tags
  - Prior had virtually no impact, which was why only partial results were presented
- Other features explored but not included in the above models:
  - Fixing trawl survey catchability at the mean of the above normal prior distribution
  - Allowing trawl survey catchability to vary as a random walk
  - Fixing trawl survey catchability at a value of 1.00 for the pre-1982 portion of the time series, but allowing it to be estimated freely for the post-1981 portion of the time series
  - Reducing the number of survey selectivity parameters subject to annual deviations
  - Use of additive, rather than multiplicative, deviations for certain survey selectivity parameters
  - Decreasing the value of the σ parameter used to constrain annual survey selectivity deviations
  - Turning off annual deviations in survey selectivity parameters for the three most recent years
  - Turning off all annual deviations in survey selectivity parameters
  - Forcing trawl survey selectivity to peak at age 6.5, the approximate mid-point of the size range of 60-81 cm spanned by the results of Nichol et al. (2007)
  - Imposing a beta prior distribution on the shape parameter of the exponential-logistic selectivity function in the trawl survey.
- Eleven models for the GOA, based on a not-quite-factorial design of the following:
  - Include recently discovered sizecomp data from early years?
  - Agecomp emphasis : 0.12 or 1.00?
  - Pre-1996 Q: 0.92 or 1.00?
  - 27-plus selectivity: age-based or length-based?

  - Selectivity functional form: double normal or exponential-logistic?
  - Jan-May trawl fishery selectivity estimation: free or forced asymptotic?
  - 27-plus selectivity estimation: free or forced asymptotic?
- Other features explored but not included in the above models:
  - Decreasing size composition emphasis
  - Decreasing age composition emphasis (including zero emphasis)
  - Decreasing size-at-age emphasis (including zero emphasis)
  - Adding a constant to the 27-plus trawl survey "sigma"
  - Decreasing the 27-plus trawl survey "sigma"
  - Turning off size composition data for various blocks of years
  - Turning off size composition data one year at a time
  - Turning off size composition data one fleet at a time
  - Freeing catchability for the 27-plus trawl survey
  - Freeing pre-1996 catchability for the 27-plus trawl survey
  - Imposing an informative normal prior on pre-1996 Q for the 27-plus trawl survey
  - Allowing catchability in the 27-plus trawl survey to follow a random walk
  - Allowing all double normal selectivity parameters to change in each survey year
  - Introducing cohort-specific length at age, with varying amounts of freedom
  - Changing the age range from 0-20+ to 1-12+ or 1-13+
  - Doubling the amount ageing error
  - Setting the natural mortality rate equal to 0.40
  - Freeing M
  - Freeing M at ages 0 and 1
  - Forcing M at ages 0 and 1 to be higher than at ages 2 and above
  - Imposing symmetric beta priors on exponential-logistic selectivity parameters
  - Relaxing the assumption that at least one fleet must exhibit asymptotic selectivity
  - Changing from size-based to age-based selectivity for fisheries
  - Estimating a separate, *time-invariant*, selectivity for each age in the 27-plus survey
  - Estimating a separate, *time-variant*, selectivity for each age in the 27-plus survey

November 2009

- Fourteen models for the EBS (all new since September except for Model A1):
  - Models without mean-size-at-age data:
    - Model A1 was identical to last year's final model, with the addition of new data, including the first available fishery agecomp data (from the 2008 Jan-May longline fishery)
    - Model A2 was identical to Model A1, except all agecomp data omitted
    - Model A3 was identical to Model A1, except 2008 Jan-May longline fishery agecomp data omitted
    - Model F2 was identical to last year's Model F2
  - Models with mean-size-at-age data and agecomp data:
    - **Model B1** was identical to Model A1 except:
      - Survey selectivity held constant for most recent two years
      - Cohort-specific growth included
      - Input standard deviations of all "dev" vectors were set iteratively by matching the standard deviations of the set of estimated *devs*
      - Standard deviation of length at age was estimated outside the model as a linear function of mean length at age

            - Selectivity at maximum size or age was treated as a controllable parameter
            - *Q* for the post-1981 trawl survey was fixed at the value that sets the average (weighted by numbers at length) of the product of *Q* and selectivity for the 60-81 cm size range equal to the point estimate of 0.47 obtained by Nichol et al. (2007)
            - Potential ageing bias was accounted for in the ageing error matrix by examining alternative bias values in increments of 0.1 for ages 2 and above (age-specific bias values were also examined, but did not improve the fit significantly).
        - Model C1 was identical to Model B1 except:
            - Input standard deviations for all "dev" vectors and the amount of ageing bias fixed at the values obtained iteratively in Model B1
            - *Catchability itself* (rather than the average product of catchability and selectivity for the 60-81 cm size range) set equal to 0.47
        - Model D1 was identical to Model B1 except:
            - Input standard deviations for all "dev" vectors and the amount of ageing bias fixed at the values obtained iteratively in Model B1
            - Selectivity at maximum size or age was removed from the set of controllable parameters (instead, selectivity at maximum size or age becomes a function of other selectivity parameters)
        - Model E1 was identical to Model B1 except:
            - Input standard deviations for all "dev" vectors and the amount of ageing bias fixed at the values obtained iteratively in Model B1
            - Selectivity at maximum size or age for all non-asymptotic fleets was set equal to a single value that was constant across fleets
        - Model G1 was identical to Model B1 except:
            - Input standard deviations for all "dev" vectors and the amount of ageing bias fixed at the values obtained iteratively in Model B1
            - Survey selectivity was held constant across all years (i.e., no selectivity *dev*s are estimated for any years)
    - Models with mean-size-at-age data and without agecomp data:
        - Models B2, C2, D2, E2, and G2 were identical to their B1, C1, D1, E1, and G1 counterparts except that agecomp data were ignored and the corresponding sizecomp data were active.
- Ten models for the GOA:
    - Models based on last year's final model, with different uses of agecomp data:
        - Model A1 was identical to last year's final model, with the addition of new data, including the first available fishery agecomp data (from the 2008 Jan-May longline fishery)
        - Model A2 was identical to Model A1, except all agecomp data omitted
        - Model A3 was identical to Model A1, except 2008 Jan-May longline fishery agecomp data omitted
        - Model A4 was identical to Model A1, except standard deviations in the ageing error matrix were doubled for ages 2-4
    - Substantially revised models with age composition data:

        - **Model B1** was identical to Model A1 except:
            - Survey selectivity held constant for most recent two years
            - Cohort-specific growth included
            - Input standard deviations of all "dev" vectors were set iteratively by matching the standard deviations of the set of estimated *dev*s
            - Standard deviation of length at age was estimated outside the model as a linear function of mean length at age
            - Selectivity at maximum size or age was treated as a controllable parameter
            - *Q* for the pre-1996 years of the 27-plus survey was estimated freely
            - *Q* for the post-1993 years was fixed at the value that sets the average (weighted by numbers at length) of the product of *Q* and selectivity for the 60-81 cm size range equal to the point estimate of 0.92 obtained by Nichol et al. (2007)
            - Potential ageing bias was accounted for in the ageing error matrix by examining alternative bias values in increments of 0.1 for ages 2 and above (age-specific bias values were also examined, but did not improve the fit significantly).
        - Model D1 was identical to Model B1 except:
            - Input standard deviations for all "dev" vectors and the amount of ageing bias were fixed at the values obtained iteratively in Model B1
            - Selectivity at maximum size or age was removed from the set of controllable parameters (instead, selectivity at maximum size or age becomes a function of other selectivity parameters)
        - Model E1 was identical to Model B1 except:
            - Input standard deviations for all "dev" vectors and the amount of ageing bias were fixed at the values obtained iteratively in Model B1
            - Selectivity at maximum size or age for all non-asymptotic fleets was set equal to a single value that was constant across fleets
    - Substantially revised models without age composition data:
        - Models B2, D2, and E2 were identical to their B1, D1, and E1 counterparts except that agecomp data were ignored and the corresponding sizecomp data were active

September 2010

- Six models for the EBS and five models for the GOA:
    - Model 1 (EBS and GOA) was identical to last year's final model
    - Model 2 (EBS and GOA) was identical to Model 1 except:
        - Input standard deviations for all "dev" vectors fixed at the values obtained iteratively in Model 1
        - IPHC survey data omitted
        - fishery age data omitted

        - Traditional 3-or-5 cm size bins replaced with 1 cm size bins
        - Traditional 3-season structure replaced with new, 5-season structure
        - Spawn time changed from beginning of season 1 to beginning of season 2
    - Model 3 (EBS and GOA) was identical to Model 2 except:
        - Non-uniform prior distributions used for selectivity parameters and *Q*
    - Model 4 (EBS and GOA) was identical to Model 2 except:
        - All age data omitted
        - Maturity schedule was length-based rather than age-based
    - Model 5 (EBS and GOA) was identical to Model 4 except:
        - Parameters governing spread of lengths at age around mean length at age estimated internally
    - Model 6 (EBS only) was identical to Model 5 except:
        - Cohort-specific growth replaced by annual variability in each of the three von Bertalanffy parameters

November 2010

- Three models for both the EBS and GOA:
    - Model A was identical to Model 1 from September
    - **Model B** was identical Model 2 from September, except cohort-specific growth replaced by constant growth
    - Model C: same as Model 4 from September, except cohort-specific growth replaced by constant growth

March 2011 (CIE review)

- Exploratory EBS model developed prior to review:
    - Same as last year's final model, except:
        - All sizecomp data turned on
        - Nine season × gear fisheries consolidated into five seasonal fisheries
        - Pre-1982 trawl survey data omitted
        - Mean-size-at-age data omitted
        - Fishery CPUE data omitted
        - Average input *N* set to 100 for all fisheries and the survey
        - First reference age for length-at-age relationship set at 0.833333
        - Richards growth implemented
        - Ageing bias estimated internally
        - Selectivities modeled as random walks with age (constant for ages 8+)
- Twelve new models for the EBS developed during the review:
    - Model 1 was identical to last year's final model except:
        - Length at age 0 constrained to be positive
        - Richards growth implemented
    - Model 2 was identical to last year's final model except length at age 0 constrained to be positive
    - Model 3 was identical to last year's final model except:
        - All time blocks removed
        - All selectivity parameters freed except fishery selectivity at initial age

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

September 2011 (EBS only)

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

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

were estimated independently in pre-specified blocks of years; the only time-varying selectivity parameter for the survey was *ascending_width*, which had annual—but not random walk—*dev*s with *σdev* set at the value used in the 2009 and 2010 assessments)

        - Age composition "variance adjustment" multiplier was tuned iteratively to set the mean effective sample size equal to the mean input sample size (in Models 1-4, this multiplier was fixed at 1.0)
    - Model 5 was identical to Model A except that it used the time series of selectivity parameters estimated (using random walk *dev*s) in Model A to identify appropriate breakpoints for defining block-specific selectivity parameters
- Other model features explored but not included in any of the above:
    - Annually varying Brody growth parameter
    - Annually varying length at the first reference age
    - Internal estimation of standard deviation of length at age
    - Ordinary (not random walk) *dev*s for annually varying selectivity parameters
    - One selectivity parameter for each age (up to some age-plus group) and fleet, either with ordinary or random walk *dev*s or constant
    - Not forcing any fleet to exhibit asymptotic selectivity
    - Internal estimation of survey catchability
    - Iterative re-weighting of size composition likelihood components
    - Internal estimation of the natural mortality rate
    - Changing the SS parameter *comp_tail_compression* (the tails of each age or size composition record are compressed until the specified amount was reached; sometimes referred to as "dynamic binning")
    - Changing the SS parameter *add_to_comp* (this amount was added to each element of each age or size composition vector—both observed and expected, which avoids taking the logarithm of zero and may also have robustness-related attributes)
    - Internal estimation of ageing error variances

November 2011

- Five models for the EBS:
    - Model 1 was identical to last year's final model (and Model 1 from September)
    - Model 2b was identical to Model 2b from September
    - Model 3 was identical to Model 3 from September
    - **Model 3b** was identical to Model 3 from September except:
        - Parameters governing variability in length at age estimated internally
        - All sizecomp data turned on
        - Mean-size-at-age data turned off
    - Model 4 was identical to Model 4 from September
- Four models for the GOA:
    - Model 1 was identical to last year's final model
    - **Model 3** was identical to Model 1 except:
        - First reference age for length-at-age relationship set at 1.3333
        - Parameters governing variability in length at age estimated by trial and error

        - Column for age 0 fish added to the agecomp and mean-size-at-age portions of the data file
        - Ageing bias estimated internally
    - Model 3b was identical to Model 3 except:
        - Parameters governing variability in length at age estimated internally
        - All sizecomp data turned on
        - Mean-size-at-age data turned off
        - Selectivity and catchability for 27-plus survey forced to be constant
        - Catchability *dev*s in the sub-27 survey were given normal priors with mean = 0 and standard deviation = 0.46
    - Model 4 was identical to Model 3b except:
        - Variability in survey catchability and selectivity was configured as in Models 1 and 3
        - All agecomp data turned off
        - Ageing bias was not estimated internally
        - Mean recruitment in the pre-1977 environmental regime was constrained to be less than mean recruitment in the post-1976 environmental regime.

September 2012

- Five primary and nine secondary models for the EBS (names of secondary models have decimal points; full results presented for primary models only):
    - Model 1 was identical to last year's final model
        - Model 1.1: Same as Model 1, except survey catchability estimated internally
        - Model 1.2: Same as Model 1, except ageing bias parameters fixed at GOA values
        - Model 1.3 Same as Model 1, except with revised weight-length representation
    - Model 2 was identical to Model 1, except survey catchability re-tuned to match archival tag data
    - Model 3 was identical to Model 1, except new fishery selectivity period beginning in 2008
    - Model 4 was identical to last year's Model 4 (also identical to Model 1 except that age data ignored)
        - Model Pre5.1: Same as Model 1.3, except for three minor changes to the data file
        - Model Pre5.2: Same as Model Pre5.1, except ages 1-10 in the initial vector estimated individually
        - Model Pre5.3: Same as Model Pre5.2, except Richards growth curve used
        - Model Pre5.4: Same as Model Pre5.3, except σ for recruitment *dev*s estimated internally as a free parameter
        - Model Pre5.5: Same as Model Pre5.4, except survey selectivity modeled as a function of length
        - Model Pre5.6: Same as Model Pre5.5, except fisheries defined by season only (not season-and-gear)
    - Model 5: Same as Model Pre5.6, except four quantities estimated iteratively:

        - Survey catchability tuned to match archival tag data
        - Agecomp *N* tuned to set the mean ratio of effective *N* to input *N* equal to 1
        - Selectivity *dev* sigmas tuned according to the new method described in Annex 2.1.1 of the SAFE chapter
- Two models for the AI:
    - Model 1 was similar to last year's final EBS model except:
        - Only one season
        - Only one fishery
        - AI-specific weight-length parameters used
        - Length bins (1 cm each) extended out to 150 cm instead of 120 cm
        - Fishery selectivity forced asymptotic
        - Fishery selectivity constant over time
        - Survey samples age 1 fish at true age 1.5
        - Ageing bias not estimated (no age data available)
        - *Q* tuned to match the value from the archival tagging data relevant to the GOA/AI survey net
    - Model 2 was identical to Model 1 except with time-varying *L1* and *Linf*
    - Six other models considered in a factorial design in order to determine which growth parameters would be time-varying in Model 2, but only partial results presented
- Twelve models for the GOA:
    - Model 1 was identical to last year's final model
    - Model 1Q was identical to Model 1 except mean *Q* for the 27-plus survey tuned iteratively to match archival tagging results
    - Model A was identical to Model 1 except tail compression turned off
    - Model AQ was identical to Model A except mean *Q* for the 27-plus survey tuned iteratively to match archival tagging results
    - Model B was identical to Model A except:
        - Sub-27 survey changed from time-varying *Q* and constant selectivity to two blocks for both *Q* and selectivity (split at 1996)
        - Initial value for the pre-1996 *Q* deviation for both the 27-plus and sub-27 surveys set to 0.0
    - Model BQ was identical to Model B except mean *Q* for the 27-plus survey tuned iteratively to match archival tagging results
    - Model C was identical to Model B except:
        - Initial value for pre-1977 recruitment offset changed to 0.0
        - Upper bound on pre-1977 recruitment offset increased to allow positive values
    - Model CQ was identical to Model C except mean *Q* for the 27-plus survey tuned iteratively to match archival tagging results
    - Model D was identical to Model C except 27-plus survey selectivity changed from 11 blocks to 2 (split at 1996)
    - Model E was identical to Model A except:
        - *Q* for the 27plus survey estimated
        - Initial value for the pre-1996 *Q* deviation for both the 27-plus and sub-27 surveys set to 0.0

  - Model 1B was identical to Model B except tail compression set to the value used in Model 1
  - Model 1C was identical to Model C except tail compression set to the value used in Model 1

November 2012

- Four models for the EBS:
  - **Model 1** was identical to last year's final model
  - Model 2 was identical to Model 1 except *Q* was estimated freely
  - Model 3 was identical to Model 1 except:
    - Ageing bias was not estimated internally
    - All agecomp data are ignored
  - Model 4 was identical to Model 5 from the September assessment
- Four models for the AI:
  - Model 1 was identical to Model 1 from September
  - Model 2 was identical to Model 2 from September
  - Model 3 was identical to Model 1 except that input *N* values were multiplied by 1/3
  - Model 4 was identical to Model 1 except:
    - Survey data from years prior to 1991 were omitted
    - Q was allowed to vary randomly around a base value
    - Survey selectivity was forced asymptotic
    - Fishery selectivity was allowed to be domed
    - Input N values for sizecomp data were estimated iteratively by setting the root-mean-squared-standardized-residual of the survey abundance time series equal to unity
    - All fishery selectivitiy parameters except *initial_selectivity* and the *ascending_width* survey selectivity parameters were allowed (initially) to vary randomly, with the input standard deviations estimated iteratively by matching the respective standard deviations of the estimated *dev*s
    - Input standard deviation for log-scale recruitment *dev*s was estimated internally (i.e., as a free parameter)
  - None of the models was accepted by the Team or SSC
- Ten models for the GOA:
  - Model A was identical to last year's final model
  - Model B was identical to last year's final model except tail compression turned off
  - Model 1 was identical to Model C from September
  - Model 1Q was identical to Model 1 except *Q* fixed at 1.04 (the value used in 2011)
  - **Model 2** was identical to Model A except:
    - *Q* fixed at 1.0
    - All sub-27 survey data omitted
  - Model 2Q was identical to Model 2 except *Q* fixed at 1.04 (the value used in 2011)
  - Model 3 was identical to Model A except:

    - *Q* fixed at 1.0
    - 2 periods of catchability and selectivity for the sub-27 survey
    - All sub-27 and 27-plus survey mean-length-at-age data omitted
  - Model 3Q was identical to Model 3 except *Q* fixed at 1.04 (the value used in 2011)
  - Model 4 was identical to Model 2 except all 27-plus mean-length-at-age data omitted
  - Model 5 was identical to Model 1 except all sub-27 mean-length-at-age data omitted

September 2013

- Four models for the EBS:
  - Model 1 was identical to last year's final model
  - Model 2 was identical to last November's Model 4 except *Q* estimated internally using a non-constraining uniform prior distribution
  - Model 3 was identical to last November's Model 4 except:
    - *Q* estimated internally using a prior distribution based on archival tagging data
    - Survey selectivity forced asymptotic
  - Model 4 was identical to last November's Model 4
- Three models for the AI:
  - Model 1 was identical to Model 1 from last year's assessment except:
    - Fishery selectivity was not forced asymptotic
    - Selectivity was estimated as a random walk with respect to age instead of the double normal, with normal priors tuned so that the prior mean is consistent with logistic selectivity and the prior standard deviation is consistent with apparent departures from logistic selectivity
    - Potentially, length and age composition input sample sizes could be tuned so that the harmonic mean effective sample size is at least as large as the arithmetic mean input sample size (if it turned out that the initial average *N* of 300 already satisfied this criterion, no tuning was done)
    - Potentially, each selectivity parameter could be time-varying with annual additive *dev*s, where the sigma term is tuned to match the standard deviation of the estimated *dev*s (if this tuning resulted in a sigma that was essentially equal to zero, time variability was turned off)
  - Model 2 was identical to Model 1 except that *Q* was estimated with an informative prior developed from a meta-analysis of other AI assessments
  - Model 3 was identical to Model 1 except that both *M* and *Q* were estimated freely
- Eighteen models for the GOA (the "N" series represents runs with alternative initial values):
  - Models 1 and 1N are identical to the 2011 (not 2012) final model
  - Models 2 and 2N are identical to Models 1 and 1N except tail compression turned off
  - Models 3 and 3N are identical to Models 1 and 1N except:
    - Tail compression turned off
    - Number of periods for *Q* in the sub-27 survey changed from 11 to 2

        - Number of periods for selectivity in the sub-27 survey changed from 1 to 2
    - Models 4 and 4N are identical to the 2012 (not 2011) final model
    - Models 5 and 5N are identical to Models 4 and 4N except 27-plus mean-length-at-age data omitted
    - Models 6 and 6N are identical to Models 5 and 5N except:
        - All selectivity curves forced to equal zero at age 0
        - Growth parameters fixed at the values estimated in last year's final model
        - Number of blocks for selectivity in the 27-plus survey changed from 11 to 2
    - Models 7 and 7N are identical to Models 4 and 4N except:
        - Survey agecomps turned off
        - Corresponding survey sizecomps turned on
    - Models 8 and 8N are identical to Models 4 and 4N except Richards growth model used instead of von Bertalanffy
    - Models 9 and 9N are identical to Models 4 and 4N except 27-plus mean-length-at-age emphasis decreased from 1.0 to 0.25
    - In addition, preliminary work was presented on two sex-specific GOA models, featuring:
        - Three gear types
        - One fishery selectivity "season"
        - Three periods for the trawl and longline fishery selectivity curves
        - Two periods for the pot and survey selectivity curves
        - Two periods for survey *Q*

November 2013

- One model for the EBS:
    - **Model 1** was identical to last year's final model
- Four models for the AI:
    - Tier 3 Model 1 was identical to Model 1 from September, except that *Q* was fixed at 1.0
    - Tier 3 Model 2 was identical to Tier 3 Model 1 except:
        - *Q* was estimated with the same prior as in Model 2 from September
        - Survey selectivity was forced asymptotic
    - Tier 5 Model 1 was the Kalman filter model that had been used since 2004 to estimate the expansion factor for converting results from the EBS Pacific cod model into BSAI equivalents
    - **Tier 5 Model 2** was the random effects model recommended by the Survey Averaging Working Group
- Two models for the GOA:
    - Model 1 was identical to last year's final model
    - **Model 2** was identical to Model 1 except age 0 recruitment for the four most recent years fixed at time series average (Model 1 estimated age 0 recruitment in 2010 and 2011)

September 2014

- Six models for the EBS:
  - Model 1 was identical to the 2011-2013 final models
  - Model 2 was the identical to Model 5 from the 2012 preliminary assessment (also identical to Model 4 in the 2012 final assessment and the 2013 preliminary assessment)
  - Model 3 was identical to Model 2, except that survey catchability *Q* was fixed at 1.0
  - Model 4 was identical to Model 2, except that *Q* was estimated with a uniform prior and with an internally estimated constant added to each year's log-scale survey abundance standard deviation
  - Model 5 was identical to Model 2, except that Q was fixed at 1.0, survey selectivity was forced to be asymptotic, and the natural mortality rate *M* was estimated freely
  - Model 6 was a substantially new model, with the following differences from Model 1:
    1. Each year consisted of a single season instead of five
    2. A single fishery was defined instead of nine season-and-gear-specific fisheries
    3. The survey was assumed to sample age 1 fish at true age 1.5 instead of 1.41667
    4. Initial abundances were estimated for the first ten age groups instead of the first three
    5. The natural mortality rate was estimated internally
    6. The base value of survey catchability was estimated internally
    7. Length at age 1.5 was allowed to vary annually
    8. Survey catchability was allowed to vary annually
    9. Selectivity for both the fishery and the survey were allowed to vary annually
    10. Selectivity for both the fishery and survey was modeled using a random walk with respect to age (SS selectivity-at-age pattern #17) instead of the usual double normal
    11. Several quantities were tuned iteratively: prior distributions for selectivity parameters, catchability, and time-varying parameters other than catchability
- Three models for the AI:
  - Model 1 was identical to Model 2 from the final 2013 assessment, except that survey selectivity was not forced to be asymptotic, each selectivity was allowed (potentially) to very with time, a normal prior distribution for each selectivity parameter was tuned using the same method as Model 6 from the September 2014 EBS assessment, prior distributions and standard deviations for the annual selectivity deviations were estimated iteratively, and the 1976-1977 "recruitment offset" parameter was fixed at zero
  - Model 2 was identical to Model 1, except that the recruitment offset was estimated freely
  - Model 3 was identical to Model 2, except that survey selectivity first-differences were forced to equal zero after the age at which survey selectivity peaked in Model 2, and the lower bound on survey selectivity first-differences at all earlier ages was set at 0 (the combination of these two changes forced survey selectivity

to increase monotonically until the age at which it peaked in Model 2, after which survey selectivity was constant at unity)

- Seven models for the GOA:
  - Model 1 was the 2011 final model with tail compression turned off
  - Model 2 was the 2013 final model
  - Model 3 was Model 6 from September 2013
  - Model 4 was Model 2 with empirical weight-at-age; the use of the SS "multiplier" on σR instead of setting recent recruitments equal to the mean; and retuned input sample sizes and survey abundance standard deviations
  - Model 5 was Model 1 with age-1 abundance split out as a separate index; the use of the SS "multiplier" on σR instead of setting recent recruitments equal to the mean; and retuned input sample sizes and survey abundance standard deviations
  - Model 6 was Model 2 with the bottom trawl survey treated as one data source, not two (sub-27 and 27-plus); two blocks for catchability for the survey, 1984 – 1993 and 1996 – 2013; two blocks for selectivity-at-age for the survey, 1984 – 1993 and 1996 – 2013; the use of conditional age-at-length survey data; non-parametric survey selectivity-at-age curves; and the use of the SS "multiplier" on σR instead of setting recent recruitments equal to the mean
  - Model 7 was Model 6 with three blocks for selectivity-at-age for the survey, 1984 – 1993, 1996 – 2003, and 2005 – 2013; and cubic spline-based survey selectivity-at-age curves

November 2014

- Two models for the EBS:
  - **Model 1** was identical to the 2011-2013 final models
  - Model 2 was identical to Model 2 from September, except that the *L1* growth parameter was not allowed to vary with time.
- Three models for the AI:
  - **Model 1** was identical to Tier 5 Model 2 from the final 2013 assessment
  - Model 2 was identical to Model 1 from September
  - Model 3 was identical to Model 1 from September, except that the prior distributions for survey selectivity parameters were tightened so that the resulting selectivity curve was less dome-shaped
- Four models for the GOA:
  - Model 1 was the 2013 model with the sample sizes for the fishery and survey length and age composition data a function of the number of hauls, not the number of samples
  - Model 2 was Model 1 with age-0 recruits estimated through 2011 instead of 2009 and the SS "multiplier" on σR used for age-0 recruits in 2012, 2013, and 2014
  - **Model 3** was Model 2 with the bottom trawl survey used as one source of data instead of two, 3 time blocks for survey selectivity instead of 12, non-parametric survey selectivity-at-age curves, and the use of the survey age and length data as conditional age-at-length data instead of age composition and mean size-at-age data
  - Model 4 was Model 3 with cubic spline-based survey selectivity-at-age curves