Minutes of the Joint Team Subcommittee on Pacific Cod Models

March 12, 2014

Following a suggestion made at the May 2013 meeting of the joint BSAI and GOA Groundfish Plan Teams and reviewed by the SSC at its June 2013 meeting, 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, Dana Hanselman, and Mike Sigler; and GOA Team members Jim Ianelli, Paul Spencer, and Ian Stewart. The subcommittee met via WebEx on March 12, 2014. All members were present, as were Grant Thompson (EBS and AI assessment author), Teresa A'mar (GOA assessment author), and Sandra Lowe (guest).

A total of 28 unique model proposals were received prior to the meeting (not counting a few that were already addressed in the 2013 assessments): 11 for the EBS, 3 for the AI, and 14 for the GOA. In addition, 2 proposals were not received explicitly but were taken as "given" (*viz*., inclusion of the final 2011 EBS model and the final 2013 GOA model), and the subcommittee developed and advanced 5 new proposals (2 for the EBS and 3 for the GOA) during the meeting itself, for a total of 35 unique model proposals: 14 for the EBS, 3 for the AI, and 18 for the GOA. For the first time since 2006, no proposals were submitted by members of the public.

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

- Appendix 1: "Pacific cod model proposals and other comments submitted by the Teams and SSC in 2013." This file excerpts the full text of relevant minutes from the September 2013 BSAI and GOA Team minutes, the October 2013 SSC minutes, the November 2013 BSAI and GOA Team minutes, and the December 2013 SSC minutes; and parses them into individual model proposals and non-model-related comments.
- Appendix 2: "History of final models used to assess the EBS stock of Pacific cod." This file documents, in narrative form, the evolution of final EBS models.
- Appendix 3: "History of final models used to assess the GOA stock of Pacific cod." This file documents, in narrative form, the evolution of final GOA models.
- Appendix 4: "History of alternative models developed for assessing Pacific cod in the EBS, AI, and GOA." This file documents, in bullet form, every model that has been presented for the EBS, AI, and GOA stocks since 2005.
- Appendix 5: "Base models referenced in the proposals." This file compares the features of the base models referenced in the various proposals.

The meeting began with overviews of the base models referenced in the various proposals. Grant provided the overview of the base models for the EBS. Because no base models were referenced in any of the AI proposals, Grant provided an overview of all models developed in last year's preliminary and final AI assessments instead. Teresa provided the overview of the base models for the GOA.

Following these overviews, the subcommittee discussed the model proposals (including those developed during the meeting itself) and used those proposals to recommended sets of models to be developed for this year's preliminary assessments. The subcommittee used Table 1 to structure its discussion and summarize its recommendations. Grant led the discussions on the EBS and AI model proposals, and Teresa led the discussion on the GOA model proposals.

The subcommittee discussed the SSC's minute from December 2011 requesting that the final 2011 model for each stock be evaluated over "several amendment cycles," noting that the definition of "several" is unclear. For the EBS, the 2011 model was re-evaluated in 2012 and 2013. For the GOA, the 2011 model was re-evaluated in 2012, but not in 2013 due to the government shutdown in October of that year. **For this year, the subcommittee proceeded under the assumption that the SSC wishes to continue re-evaluating the 2011 models. However, the subcommittee recommended that 2014 be the final year for re-evaluation of the 2011 models, unless the 2011 model in one or more regions is chosen as the final model in 2014.**

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

- Model 1: Final model from 2011 (same as the final models from 2012 and 2013)
- Model 2: Model 5 from the 2012 preliminary assessment (same as Model 4 from the 2012 final and 2013 preliminary assessments)
- Model 3: Same as Model 2 in this list, but with:
    - survey catchability fixed at 1.0
- Model 4: Model 2 from the 2013 preliminary assessment, but with:
    - an internally estimated constant added to each year's survey abundance sigma
- Model 5: Model 3 from the 2013 preliminary assessment, but with:
    - survey catchability fixed at 1.0
    - natural mortality estimated freely

The subcommittee noted that the above list includes all of the model proposals contained in the SSC's December 2013 minutes except for SSC3c (equivalent to BPT1c and BPT2b), which called for a model based on Model 2 from the 2013 preliminary assessment, but using annually varying survey catchability with unconstrained mean. The subcommittee felt that Model 4 in the above list would accomplish basically the same thing as SSC3c. However, the subcommittee noted that the SSC could add SSC3c to the above list and still stay within the traditional limit of six requested models.

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

- Model 1: A new model (author's choice) with the regime change recruitment offset fixed at 0.0
- Model 2: A new model (author's choice) with alternative selectivity specification(s)
- Model 3: A new model (author's choice) with forced asymptotic selectivity

The subcommittee noted that the above list includes both of the model proposals contained in the SSC's December 2013 minutes. The subcommittee also suggested that obtaining a much larger supply of age data from the AI is more important than development of additional models at this point.

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

- Model 0: Final model from 2011
- Model 1: Final model from 2013
- Model 2: Model 6 from the 2013 preliminary assessment, but with:
    - empirical weight at age
    - all agecomp data omitted
    - use of the SS "multiplier" on σ_R instead of setting recent recruitments equal to the mean

    - retuned input sample sizes and survey abundance standard deviations
- Model 3: Final model from 2013, but with:
    - use of the SS "multiplier" on σ_R instead of setting recent recruitments equal to the mean
    - retuned input sample sizes and survey abundance standard deviations
    - empirical weight at age
- Model 4: Final model from 2013, but with:
    - use of the SS "multiplier" on σ_R instead of setting recent recruitments equal to the mean
    - retuned input sample sizes and survey abundance standard deviations
    - age 1 abundance split out as a separate index

The subcommittee noted that the above list does not contain several of the model proposals contained in the GOA Team's November 2013 minutes (the SSC's December 2013 minutes simply endorsed the Team's November 2013 model proposals). However, the subcommittee also noted that the SSC could add another model to the above list and still stay within the traditional limit of six requested models.

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

For the EBS, the discretionary models were as follow:

- A new model (author's choice) with no seasonal structure
- A new model (author's choice) with gear-specific fisheries and no seasonal structure

For the GOA, the discretionary models were as follow:

- Final model from 2013, but with:
    - fewer selectivity blocks
    - alternative functional forms for selectivity
- Final model from 2013, but with:
    - ADFG, IPHC, or NMFS longline survey indices included

Four other new proposals were developed and discussed by the subcommittee during its meeting, but not advanced:

- For the EBS, three new proposals (in addition to the one incorporated in Model 4) were developed as an alternative to completely free time-varying survey catchability:
    - constraining catchability *dev*s significantly
    - keeping catchability constant but estimated freely
    - splitting the survey time series into two parts, with mean catchability in the two parts constrained to be equal (to eliminate the possibility of long-term trends in catchability)
- For the GOA, the subcommittee discussed the possibility of modifying the final model from 2013 by omitting all age 1 data and excluding age 1 fish from model predictions

Table 1. Paraphrased model proposals (see Appendix 1) and assignment thereof to candidate models, as recommended by the subcommittee. A base model's date corresponds to the year and month of its initial presentation in an assessment. Labels of base models are constructed in "yy.mm.#" format (e.g., Model 2 from the September 2013 assessment is labeled 13.09.2). Symbols: *D* = author's discretion, *M* = natural mortality rate, *N* = sample size, *Q* = catchability, *R* = recruitment, *S* = selectivity.

				September model							
Region	Base model	Proposal number(s)	Brief description of proposal(s)	0	1	2	3	4	5	6	*D*
EBS	11.11.3b	none	Final model from 2011		x						
EBS	11.11.3b	BPT1a, BPT2a, SSC3a	Final model from last year		x						
EBS	12.09.5	BPT1f, SSC3b	Base model			x					
EBS	12.09.5	SSC2a, SSC3d	Base model with Q=1				x				
EBS	13.09.2	BPT1b	Base model								
EBS	13.09.2	BPT1c, BPT2b, SSC3c	Base model with annually varying Q where mean is free								
EBS	13.09.2	new	Base model with additive survey sigma (estimated internally)					x			
EBS	13.09.2	SSC2b	Base model with annually varying Q where mean is fixed at 1								
EBS	13.09.3	BPT1d	Base model								
EBS	13.09.3	SSC2c, BPT2c, SSC3e	Base model with Q=1								
EBS	13.09.3	BPT1e	Base model with free M								
EBS	13.09.3	BPT2d	Base model with Q=1 and free M						x		
EBS	n/a	SSC1	New model (author's choice) with no seasonal structure								x
EBS	n/a	new	New model (author's choice) with gears and no seasonal structure								x
AI	n/a	BPT1a	New model (author's choice) with regime change R offset fixed at 0		x						
AI	n/a	SSC1a	New model (author's choice) with alternative S specification(s)			x					
AI	n/a	SSC1b	New model (author's choice) with asymptotic S				x				
GOA	11.11.3	GPT3a, SSC1	Final model from 2011	x							
GOA	13.11.2	none	Final model from last year		x						
GOA	11.11.3	GPT1, SSC1	Base model with reduced first reference age for growth								
GOA	11.11.3	GPT2, SSC1	Base model with tuned sample sizes and variances								
GOA	11.11.3	GPT3b, SSC1	Base model with sub-27 survey split into 3 periods								
GOA	13.09.6	GPT4a, SSC1	Base model with empirical weight at age			x					
GOA	13.09.6	GPT4b, SSC1	Base model with agecomps removed			x					
GOA	13.11.2	GPT5, SSC2	Base model using σR multiplier instead of setting recent R=mean			x	x	x			
GOA	13.11.2	new	Base model with tuned sample sizes and variances			x	x	x			
GOA	13.11.2	GPT6a, SSC2	Base model with empirical weight at age				x				
GOA	13.11.2	GPT6b, SSC2	Base model with fewer S blocks and alternative S curves								x
GOA	13.11.2	GPT7a, SSC2	Base model with age 1 bin replacing sub-27 survey length data								
GOA	13.11.2	new	Base model with age 1 abundance split out as separate index					x			
GOA	13.11.2	GPT7b, SSC2	Base model with sub-27 data smoothed outside the model								
GOA	13.11.2	GPT7d, SSC2	Base model with lower N for age 1 and higher N for other ages								
GOA	13.11.2	SSC3a	Base model with ADFG survey index								
GOA	13.11.2	SSC3b	Base model with ADFG survey index and IPHC survey index								
GOA	13.11.2	new	Base model with ADFG, IPHC, or NMFS longline survey indices								x

1 Pacific cod model proposals and other comments submitted by the Teams and SSC in 2013

Compiled by Grant Thompson and Teresa A'mar

Resource Ecology and Fisheries Management Division
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7600 Sand Point Way NE., Seattle, WA 98115-6349

Last year, the BSAI and GOA Plan Teams (BPT and GPT, respectively) and the Scientific and Statistical Committee (SSC) made several recommendations relevant to this year's Pacific cod stock assessments. This document compiles, in the order of their occurrence, the recommendations from the September and November 2013 meetings of the BPT and GPT and the October and December 2013 meetings of the SSC.

Ordinarily, recommendations from the September Team meetings and the October SSC meeting would have been addressed in last year's final assessments. However, because of last year's October government shut-down, this did not occur, except in the case of the Aleutian Islands assessment.

Proposal numbering starts (or re-starts) at 1 for each stock (Bering Sea, Aleutian Islands, or Gulf of Alaska). For example, proposal SSC1 for the Aleutian Islands stock is not the same as proposal SSC1 for the Bering Sea stock. Recommendations that do not relate directly to development of a new model are labeled "comment" and are not numbered.

Although not listed here, it may also be important to note the SSC's recommendation from December 2011 suggesting that the performance of the 2011 model for each stock be evaluated over "several assessment cycles." The definition of "several" has not been determined.

Bering Sea

BPT minutes (September 2013)

BPT comment: "The Plan Team recommended that studies of the vertical distribution of Pacific cod continue in order to test the previous finding that the average product of survey catchability and selectivity across the 60-81 cm size range is 0.47 (based on vertical distribution from archival tags). These studies should include: 1) analysis of existing fish acoustic data (as recommended by Bob Lauth); and 2) depending on the results of that analysis, repeat the 2012 experiment in an area where Pacific cod are distributed farther off bottom and using an acoustic buoy to measure vertical response to the passing vessel."

BPT1: "The Team recommended the following candidate models for the November meeting, intended to provide a number of alternatives to the present standard Model 1:

a. Model 1: the standard for the last two years.
b. Model 2a: Model 2 from the September meeting, with fixed *M* and freely estimated survey *Q*.
c. Model 2b: Model 2 from the September meeting, with fixed *M* but annually varying survey *Q* (mean value and *dev* vector estimated freely).
d. Model 3a: Model 3 from the September meeting, with asymptotic survey selectivity and a prior on survey *Q*.
e. Model 3b: Like Model 3a but with *M* estimated.
f. Model 4: Same as last year's Model 4.

The Team recommended that the author feel free to apply the iterative tuning procedures to Model 4 only, and use the values of the iteratively tuned quantities from Model 4 for the remaining models (other than Model 1) because all of the models other than Model 1 involve labor-intensive iterative tuning, and given that all of these iteratively tuned models are based to some extent on Model 4."

SSC minutes (October 2013)

SSC1: "The SSC notes that all of the Pacific cod models are characterized by a large number of parameters and dome-shaped selectivities, features that were found to be associated with retrospective patterns and a higher risk of overfishing in the meta-analysis by Hanselman et al. (see separate section). The SSC has previously encouraged the authors to simplify the models when possible and appreciates the suggestion by Grant Thompson (AFSC) to consider omitting seasonal structure in one or more of these models in the future."

SSC2: "The SSC agrees with Plan Team recommendations regarding models to bring forward in December. In addition to the recommended model configurations, the SSC would like to see a model or models that fix survey catchability at Q=1. We suggest presenting variants of:

a. model 2a with Q=1 or
b. 2b with mean Q=1 and
c. model 3a with Q=1.

Our rationale for this request is based on the increasing evidence that catchability is higher and quite possibly much higher than the current standard assumption that selectivity in the 60-81 cm size range is 0.47, which is based on a limited study by Nichol (2007). Evidence from an unpublished study conducted in 2012 (Lauth) suggests that there is no difference in catchability between the low-opening (2.5 m) trawl used in the Bering Sea survey and the high opening (7 m) trawl used in the Gulf of Alaska survey. Moreover, observations of acoustic backscatter showed that Pacific cod tended to be near the bottom in the study area, consistent with a dive response to passing vessels commonly observed in other gadids. We note that the default assumption in most assessments is that survey catchability is 1, unless there is strong evidence to the contrary. The evidence to date consists of the vertical distribution of 11 tagged fish under undisturbed conditions over a period of one month (Nichol et al 2007)."

BPT minutes (November 2013)

BPT2: "The Team recommended … the following candidate models for next year's September meeting:

a. Model 1: 2011-2012 standard (rationale: standard practice)
b. Model 2b: Model 4 from the 2012 assessment with fixed M, free survey selectivity, and annually varying survey Q (freely estimated mean and *dev* vector; rationale: … survey data simply cannot be fitted with a constant survey Q)
c. Model 3a: Model 4 from the 2012 assessment with fixed M, asymptotic survey selectivity, and Q=1 (rationale: an asymptotic candidate, one of the models requested by the SSC)
d. Model 3b: Like Model 3a but with M estimated (rationale: a check on the effect of freeing M)"

BPT comment: "The Team also repeated its previous recommendation that studies of the vertical distribution of Pacific cod continue in order to test the previous finding that the average product of survey catchability and selectivity across the 60-81 cm size range is 0.47 (based on vertical distribution from archival tags). These studies should include: 1) analysis of existing fish acoustic data (as recommended by Bob Lauth); and 2) depending on the results of that analysis, repeat the 2012 experiment in an area where

Pacific cod are distributed farther off bottom and using an acoustic buoy to measure vertical response to the passing vessel."

SSC minutes (December 2013)

SSC comment: "The SSC re-iterates its concerns over the best value for the catchability coefficient (see December 2012 and October 2013 minutes), which prompted an SSC request for additional model runs in October with catchability fixed at 1. In addition to the models already requested by the Plan Team in September 2013, this resulted in a large number of requested models. The Plan Team reduced the suite of models to three models in addition to the current base model, implementing changes to both *Q* and survey selectivity simultaneously and, secondly, exploring the effect of estimating *M* freely. The SSC discussed the need for a more incremental approach to implementing changes to the model. The two main issues of concern at this time are the shape of the selectivity function and the appropriate value for catchability (Q). Therefore, the SSC suggests a modeling approach that evaluates changes to selectivity and Q separately and in combination. To limit the number of requested model configurations, the SSC suggests that the Plan Team request for a model that freely estimates *M* be deferred to a future assessment."

SSC3: "Therefore, the SSC requests the following models to be brought forward in the 2014 assessment cycle. These recommendations pertain to the overall model structure only and would not preclude updating any of the models with new information. For example, if new estimates of catchability from the proposed analysis of acoustic data become available in time, they should be included in any of the models that are tuned to an empirical estimate of catchability.

a. The current base model (same as 2011, 2012) for comparison.
b. Model 4 from the 2012 assessment. Rationale: This model implemented a large number of changes relative to the base model and produced a good fit to the data in the 2012 assessment. However, the model was not accepted in 2012 because it had not been fully vetted. Re-fitting the model with 2 years of new data would allow further vetting of the model as a potential new base model and can serve as a basis for exploring the effects of modifying the shape of the survey selectivity function and changing *Q*.
c. Model 4 with annually varying survey *Q* (freely estimated mean and *dev* vector). Rationale: This follows a Plan Team recommendation reflecting the senior author's conviction that the survey data cannot be fitted with a constant survey *Q*. The SSC also notes that time-varying catchability was recognized at a recent international meeting as a possible avenue for improving stock assessments.
d. Model 4 with survey catchability fixed at Q=1. Rationale: The default assumption in most assessments is that survey catchability is 1, unless there is strong evidence to the contrary. The evidence for a lower *Q* has been put into question based on recent work and is more fully detailed in our October 2013 minutes. This model will allow an evaluation of the effect of fixing *Q* without also changing the way selectivity is parameterized to help untangle effects of changing *Q* and changing selectivity.
e. Model 4 with fixed Q=1 and asymptotic survey selectivity. Rationale: This model was previously recommended by the SSC and recommended by the Plan Team in November 2013 to help understand the consequences of using dome-shaped versus asymptotic selectivity in the model."

SSC comment: "To improve our understanding of survey catchability and provide better empirical estimates of selectivity, the SSC endorses the Plan Team recommendations with regard to survey catchability, specifically studies of the vertical distribution of Pacific cod, including an analysis of existing acoustic data."

Aleutian Islands

BPT minutes (September 2013)

All of these recommendations were addressed in the final 2013 assessment.

SSC minutes (October 2013)

All of these recommendations were addressed in the final 2013 assessment.

BPT minutes (November 2013)

BPT1: "For continued development of a Tier 3 assessment, the Team recommended:

a. forcing the regime change recruitment offset to zero
b. examining the usefulness of IPHC longline survey data, and
c. continuing to monitor commercial CPUE."

(Note: subsequent conversation with Team members clarified that only item (a) in the above list was a model proposal; the other two items were comments not directly related to development of a new model.)

SSC minutes (December 2013)

SSC comment: "The SSC encourages further work on the age-structured models. Some of the issues are very similar to those in the Bering Sea, in particular the appropriate shape of the selectivity function. The SSC notes that selectivity was modeled differently in the AI model using an empirical and more flexible approach, although the model with asymptotic selectivity (and estimated *Q*) produced a better fit."

SSC1: "At this still early stage of model development, the SSC does not want to be overly prescriptive, but suggests bringing forward models that:

a. focus on exploring the effects of different shapes of selectivity-at-age,
b. including a model with asymptotic selectivity."

Gulf of Alaska

GPT minutes (September 2013)

GPT comment: "The Team recommended that the effects of parameter bounds continue to be explored for convergence-related issues. This should include which phases the parameters are estimated in."

GPT1: "A downward adjustment of the first reference age in the growth model (amin) was suggested for exploration to avoid the linear extrapolation of length-at-age below this value."

GPT comment: "The Team recommended including confidence intervals for plotted data points."

GPT2: "The Team recommended tuning input sample sizes by fleet to harmonic mean effective sample sizes, and checking that input variances are consistent with model results."

GPT3: "The Team recommended going forward with:

a. 2011 Model 3,

b. possibly with the 27- split into three groups…."

(Note: subsequent conversation with Team members clarified that the above reference to Model 3 from the final 2011 assessment is correct, even though that model was not the preferred model in 2012; also, "three groups" refers to three *periods*.)

GPT4: "The Team recommended two additional variations of Model 6:

a. Model 6b would use the growth parameters assumed in model 6 and include empirical weights-at-age.
b. Model 6c would resemble model 7 by excluding age composition data, and fit to length data only, but unlike model 7, model 6c would not estimate growth parameters."

(Note: subsequent conversation with Team members clarified that, although the full text of the above minute references Model 6 from the final 2012 assessment, the Team actually meant to refer to Model 6 from the preliminary 2013 assessment.)

GPT comment: "The Team recommended (but not necessarily by November) coordinating with ADFG to examine (age, length, maturity) data from the GHL fishery. Otoliths from Prince William Sound and Cook Inlet cod fisheries have been collected but not aged. The Team recommended determining how much catch occurred in these areas and coordinating with ADFG to analyze these data."

GPT comment: "The Team recommended that explorations of sex-specific models be postponed unless time permits."

SSC minutes (October 2013)

SSC1: "We agree with the Plan Team recommendations regarding the suite of models to bring forward in December."

SSC comment: "We note the large and increasing number of models and model variants being considered. While most of these models have a similar overall structure, the SSC cautions the analyst and Plan Team to carefully explore incremental changes to the model to evaluate their effects on model fits and reference points."

GPT minutes (November 2013)

GPT5: "The Team does not recommend setting recruitment to its average level as a general procedure for avoiding anomalous recruitment deviations at the end of a time series. A better approach is to use the optional multiplier for σ_r in Stock Synthesis, which provides a rough diagnostic for recruitment strength, and allows some uncertainty in recruitment to be projected forward."

GPT6: "The Team recommends continuing work on the September 2013 recommendations:

a. Using empirical weight-at-age without estimating growth parameters,
b. Exploring fewer fishery/survey selectivity blocks; different fishery and survey selectivity curves,
c. Working with ADFG to examine (age, length, maturity) data from the GHL fishery."

(Note: subsequent conversation with Team members clarified that only items (a) and (b) in the above list were model proposals; item (c) was a comment not directly related to development of a new model.)

GPT comment: "In addition, the Team recommends including plots of likelihood profiles over a population scale parameter."

GPT comment: "In an effort to incorporate all of the survey data, the Team recommends analyzing the spatial distribution of smaller cod."

GPT7: "Additionally, the Team recommends trying alternatives to the current truncation threshold being set at 27cm. This includes:

a. omitting length data and constructing a bin for age-1 fish,
b. smoothing data in the <27cm group outside the model,
c. examining correlations between age-1 and recruitment, and
d. investigating a smaller value for effective sample size for age-1 (with a larger effective sample size for the remaining age classes) so that additional uncertainty in the survey estimates for age-1 can be accounted for within the same likelihood for the entire survey age composition time series."

(Note: subsequent conversation with Team members clarified that only items (a), (b), and (d) in the above list were model proposals, while item (c) was a comment not directly related to development of a new model; also, item (a) is supposed to pertain only to survey length data in the sub-27 group; finally, the correlation referenced in item (c) is supposed to be between *survey* estimates of age 1 abundance and *model* estimates of recruitment.)

SSC minutes (December 2013)

SSC2: "With respect to further development of the model, the SSC endorses the Plan Team recommendations in the GOA PT minutes and also refers to last year's SSC recommendations (December 2012 SSC minutes) with regards to down-weighting size-at-age data and parameterizing fishery selectivity."

(Note: All of the SSC's recommendations from December 2012 were addressed in the preliminary 2013 assessment.)

SSC3: "In addition, the SSC recommends exploring the use of both:

a. the ADF&G bottom trawl survey time series and
b. possibly the IPHC survey data as additional survey indices.

For example, a GLM approach could be used to develop an index suitable for inclusion in the assessment model. This approach was previously proposed in the December 2005 and December 2006 minutes but was not fully explored at the time because the focus shifted to other aspects of model development."

2 History of final models used to assess the EBS stock of Pacific cod

Grant Thompson

Resource Ecology and Fisheries Management Division
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7600 Sand Point Way NE., Seattle, WA 98115-6349

Stock Synthesis 1 (SS1, Methot 1986, 1990, 1998, 2000) was first applied to the EBS Pacific cod stock in the 1992 assessment (Thompson 1992). This first application used age-structured data. Beginning with the 1993 SAFE report (Thompson and Methot 1993) and continuing through the 2004 SAFE report (Thompson and Dorn 2004), SS1 continued to be used, but based largely on length-structured data.

SS1 was a program that used the parameters of a set of equations governing the assumed dynamics of the stock (the "model parameters") as surrogates for the parameters of statistical distributions from which the data were assumed to be drawn (the "distribution parameters"), and varies the model parameters systematically in the direction of increasing likelihood until a maximum is reached. The overall likelihood was the product of the likelihoods for each of the model components. In part because the overall likelihood could be a very small number, SS1 used the logarithm of the likelihood as the objective function. Each likelihood component was associated with a set of data assumed to be drawn from statistical distributions of the same general form (e.g., multinomial, lognormal, etc.). Typically, likelihood components were associated with data sets such as catch size (or age) composition, survey size (or age) composition, and survey abundance (either biomass or numbers, either relative or absolute).

SS1 permitted each data time series to be divided into multiple segments, resulting in a separate set of parameter estimates for each segment. The EBS Pacific cod assessments, for example, usually divided the shelf bottom trawl survey size composition time series into pre-1982 and post-1981 segments to account for the effects of a change in the trawl survey gear instituted in 1982. Also, to account for possible differences in selectivity between the mostly foreign (also joint venture) and mostly domestic fisheries, the fishery size composition time series was split into pre-1989 and post-1988 segments during the era of SS1-based assessments.

Until 2010, each year was partitioned into three seasons defined as January-May, June-August, and September-December (these seasonal boundaries were suggested by industry participants). Four fisheries were defined during the era of SS1-based assessments: The January-May trawl fishery, the June-December trawl fishery, the longline fishery, and the pot fishery.

Following a series of modifications from 1993 through 1997, the base model for EBS Pacific cod remained completely unchanged from 1997 through 2001. During the late 1990s, a number of attempts were made to estimate the natural mortality rate M and the shelf bottom trawl survey catchability coefficient Q, but these were not particularly successful and the Plan Team and SSC always opted to retain the base model in which M and Q were fixed at traditional values of 0.37 and 1.0, respectively.

A minor modification of the base model was suggested by the SSC in 2001, namely, that consideration be given to dividing the domestic era into pre-2000 and post-1999 segments. This modification was tested in the 2002 assessment (Thompson and Dorn 2002), where it was found to result in a statistically significant improvement in the model's ability to fit the data. In the 2004 assessment (Thompson and Dorn 2004), further modifications were made to the base model. The 2004 model included a set of selectivity parameters for the EBS slope bottom trawl survey and added new likelihood components for the age

compositions and length-at-age data from the 1998-2003 EBS shelf bottom trawl surveys and the size composition and biomass data from the 2002 and 2004 EBS slope bottom trawl surveys. Incorporation of age data and slope survey data had been suggested by the SSC (SSC minutes, December 2003).

A major change took place in the 2005 assessment (Thompson and Dorn 2005), as the model was migrated to the newly developed Stock Synthesis 2 program, which made use of the ADMB modeling architecture (Fournier et al. 2012) currently used in most age-structured assessments of BSAI and GOA groundfish. The move to Stock Synthesis 2 facilitated improved estimation of model parameters as well as statistical characterization of the uncertainty associated with parameter estimates and derived quantities such as spawning biomass. Technical details of Stock Synthesis 2 were described by Methot (2005).

The 2006 assessment (Thompson et al. 2006) explored alternative functional forms for selectivity, use of Pacific cod incidental catch data from the NMFS sablefish longline survey, and the influence of prior distributions.

In 2007, SS introduced a six-parameter double-normal selectivity curve. This functional form is constructed from two underlying and linearly rescaled normal distributions, with a horizontal line segment joining the two peaks. As configured in SS, the equation uses the following six parameters:

1. *beginning_of_peak_region* (where the curve first reaches a value of 1.0)
2. *width_of_peak_region* (where the curve first departs from a value of 1.0)
3. *ascending_width* (equal to twice the variance of the underlying normal distribution)
4. *descending_width* (equal to twice the variance of the underlying normal distribution)
5. *initial_selectivity* (at minimum length/age)
6. *final_selectivity* (at maximum length/age)

All but *beginning_of_peak_region* are transformed: The *ascending_width* and *descending_width* are log-transformed and the other three parameters are logit-transformed.

A technical workshop was held in April of 2007 to address possible improvements to the assessment model (Thompson and Conners 2007). Based on suggestions received at the workshop, several alternative models were considered in a preliminary 2007 assessment (Thompson et al. 2007a), and four models were advanced during the final 2007 assessment (Thompson et al. 2007b). The recommended model from the final 2007 assessment (Model 1) included a number of features that distinguished it from the model used in the 2006 assessment, including:

1. A fixed value of 0.34 was adopted for the natural mortality rate, based on life history theory.
2. The six parameter double-normal function was used for all selectivities.
3. The maturity schedule modeled as a function of age rather than length.
4. Trawl survey selectivity modeled as a function of age rather than length.
5. Fishery selectivity was assumed to be constant across all years.
6. Annual *dev*s were estimated in the *ascending_width* parameter of the trawl survey selectivity schedule, with an assumed standard deviation of 0.2.
7. The standard deviation of length at age modeled as a linear function of length at age.
8. Survey abundance was measured in numbers of fish (rather than biomass).
9. The input sample sizes for multinomial distributions were set on the basis of a scaled bootstrap harmonic mean.

Relative to the 2007 assessment, the model accepted by the Plan Team and SSC from the 2008 assessment (Thompson et al. 2008) featured two main changes:

1. An explicit algorithm was used to determine which fleets (including surveys as well as fisheries) would be forced to exhibit asymptotic selectivity.
2. An explicit algorithm was used to determine which selectivity parameters would be allowed to vary periodically in "blocks" of years, and to determine the appropriate block length for each such time-varying parameter.

The 2009 assessment (Thompson et al. 2009) featured a total of 14 models reflecting many alternative assumptions and use or non-use of certain data, particularly age composition data. Relative to the 2008 assessment, the main changes in the model accepted by the Plan Team and SSC were as follow:

1. Input standard deviations of all *dev* vectors were set iteratively by matching the standard deviations of the set of estimated *dev*s.
2. The standard deviation of length at age was estimated outside the model as a linear function of mean length at age.
3. Catchability for the post-1981 trawl survey was fixed at the value that sets the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.47 obtained by Nichol et al. (2007).
4. 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, resulting in a positive bias of 0.4 years for these ages (age-specific bias values were also examined, but did not improve the fit significantly).
5. Cohort-specific growth *dev*s were estimated for all years through 2008.

Many changes were made or considered in the 2010 stock assessment (Thompson et al. 2010). Six models were presented in the preliminary assessment, as requested by the Plan Teams in May, with subsequent concurrence (given two minor modifications) by the SSC in June. Following review in September and October, three of these models, or modifications thereof, were requested by the Plan Teams or SSC to be included in the final assessment. Relative to the 2009 assessment, the main changes in the model that was ultimately accepted by the Plan Team and SSC in 2010 were as follow:

1. Relative abundance data and the two records of size composition data from the IPHC longline survey were excluded.
2. The single available record (each) of fishery age composition and mean length-at-age data was excluded.
3. A new length structure consisting of 1-cm bins was adopted, replacing the combination of 3-cm and 5-cm bins used in previous assessments.
4. A new seasonal structure was adopted, consisting of five catch seasons defined as January-February, March-April, May-July, August-October, and November-December; and three selectivity seasons defined as January-April, May-July, and August-December; with spawning identified as occurring at the beginning of the second catch season (March).
5. Cohort-specific growth rates were removed (these were introduced for the first time in the 2009 assessment).

Per request from the Plan Teams, quantities that were estimated iteratively in the 2009 assessment were not re-estimated in the 2010 assessment.

Following a review by the Center for Independent Experts earlier in the year that resulted in a total of 128 unique recommendations from the three reviewers, the 2011 stock assessment (Thompson and Lauth 2011) again considered several possible model changes. A set of seven models was requested for inclusion in the preliminary by the Plan Teams in May, with subsequent concurrence by the SSC in June. Following review in August and September, four of these models were requested by the Plan Teams or

SSC to be included in the final assessment. In addition, the SSC requested one new model, which was ultimately accepted by both the BSAI Plan Team and the SSC. Relative to the 2010 assessment, the main changes in the accepted model were as follow:

1. The pre-1982 portion of the bottom trawl time series was omitted.
2. The 1977-1979 and 1980-1984 time blocks for the January-April trawl fishery selectivity parameters were combined. This change was made because the selectivity curve for the 1977-1979 time block tended to have a very difficult-to-rationalize shape (almost constant across length, even at very small sizes), which led to very high and also difficult-to-rationalize initial fishing mortality rates.
3. The age corresponding to the *L1* parameter in the length-at-age equation was increased from 0 to 1.4167, to correspond to the age of a 1-year-old fish at the time of the survey, which is when the age data are collected. This change was adopted to prevent mean size at age from going negative (as sometimes happened for age 0 fish in previous assessments, and as happened even for age 1 fish in one of the models from the 2010 assessment), and to facilitate comparison of estimated and observed length at age and variability in length at age.
4. A column for age 0 fish was added to the age composition and mean-size-at-age portions of the data file. Even though there are virtually no age 0 fish represented in these two portions of the data file, unless a column for age 0 is included, SS will interpret age 1 fish as being ages 0 and 1 combined, which can bias the estimates of year class strength.
5. Ageing bias was estimated internally.
6. The parameters governing variability in length were estimated internally.
7. All size composition records were included in the log-likelihood function.
8. The fit to the mean-size-at-age data was not included in the log-likelihood function.

It should also be noted that, consistent with the Plan Team request made in 2010, quantities that were estimated iteratively in the 2009 assessment were not re-estimated in the 2011 assessment.

Many model changes in the 2012 stock assessment (Thompson and Lauth 2012). Five primary models and nine secondary models were presented in the preliminary assessment. Of these, four of the primary models and three of the secondary models were requested by the Plan Teams, with subsequent concurrence by the SSC. Following review in September and October, four of the models from the preliminary assessment were requested by the Plan Teams or SSC to be included in the final assessment:

Model 1 was identical to the model accepted for use by the BSAI Plan Team and SSC last year, except for inclusion of new data.

Model 2 was identical to Model 1, except that the survey catchability coefficient was estimated as a free parameter.

Model 3 was also identical to Model 1, except that ageing bias was not estimated internally and the fit to the age composition data was not included in the log-likelihood function.

Model 4 was an exploratory model that differed from Model 1 in several respects:

1. A new, inter- and intra-annually varying weight-length representation developed in the preliminary assessment was used.
2. "Tail compression" was turned off. This feature aggregates size composition bins with few or zero data on a record-by-record basis, which improves computational speed, but which also makes some of the graphs in the R4SS package difficult to interpret. In Models 1-3, tail compression was turned on.

3. Fishery CPUE data were omitted. In Models 1-3, fishery CPUE data were included for purposes of comparison, but were not used in estimation.
4. A new population length bin was added for fish in the 0-0.5 cm range, which was used for extrapolating the length-at age curve below the first reference age. In Models 1-3, the lower bound of the first population length bin was 0.5 cm.
5. Mean-size-at-age data were eliminated. In Models 1-3, mean-size-at-age data were included, but not used in estimation.
6. The number of estimated year class strengths in the initial numbers-at-age vector was set at 10. In Models 1-3, only 3 elements of the initial numbers-at-age vector were estimated, which causes an automatic warning in SS.
7. The Richards growth equation (Richards 1959, Schnute 1981, Schnute and Richards 1990) was used, which adds one more parameter. In Models 1-3, the von Bertalanffy equation—a special case of the Richards equation—was used.
8. The log-scale standard deviation of recruitment was estimated internally (i.e., as a free parameter estimated by ADMB). In Models 1-3, this parameter was held constant at the value of 0.57 that was estimated in the final 2009 assessment by matching the standard deviation of the recruitment *dev*s, per Plan Team request.
9. Survey selectivity was modeled as a function of length. In Models 1-3, survey selectivity was modeled as a function of age.
10. Fisheries were defined with respect to each of the five seasons, but not with respect to gear. In Models 1-3, fisheries were defined with respect to both season and gear.
11. Fishery selectivity curves were defined for each of the five seasons, but were not stratified by gear type. In Models 1-3, seasons 1-2 and 4-5 were lumped into a pair of "super" seasons for the purpose of defining fishery selectivity curves, and fishery selectivities were also *gear*-specific (3 super-seasons × 3 gears = 9 selectivity curves).
12. The selectivity curve for the fishery that came closest to being asymptotic on its own (in this case, the season 3 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 1-3, six of the nine super-season × gear fisheries were forced to exhibit asymptotic selectivity.
13. Survey catchability was tuned iteratively to set the average of the product of catchability and survey selectivity across the 60-81 cm range equal to 0.47, corresponding to the Nichol et al. (2007) estimate. In Models 1-3, Q was left at the value of 0.77 estimated by a similar procedure in the final 2009 assessment, per Plan Team request.
14. The age composition sample size multiplier was tuned iteratively to set the mean of the ratio of effective sample size to input sample size equal to 1.0. In Models 1-3, the variance adjustment was fixed at 1.0.
15. The two parameters governing the ascending limb of the survey selectivity schedule were given annual additive *dev*s with each σ_{dev} tuned to match the estimate that would be appropriate for a univariate linear-normal model with random effects integrated out. In Models 1-3, no *dev* vector corresponding to the *initial_selectivity* parameter was used, because it was "tuned out" in the 2009 final assessment; and σ_{dev} for the *ascending_width* parameter was left at the value of 0.07 estimated iteratively in the final 2009 assessment, per Plan Team request.

Following review of the 2012 final assessment, Model 1 (the same model used in 2011) was accepted by both the BSAI Plan Team and the SSC.

An updated description of the SS framework has been published by Methot and Wetzel (2013).

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3 History of final models used to assess the GOA stock of Pacific cod

Teresa A'mar

Resource Ecology and Fisheries Management Division
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7600 Sand Point Way NE., Seattle, WA 98115-6349

Beginning with the 1994 SAFE report (Thompson and Zenger 1994), a model using the Stock Synthesis 1 (SS1) assessment program (Methot 1986, 1990, 1998, 2000) and based largely on length-structured data formed the primary analytical tool used to assess the GOA Pacific cod stock.

SS1 was a program that used the parameters of a set of equations governing the assumed dynamics of the stock (the "model parameters") as surrogates for the parameters of statistical distributions from which the data were assumed to be drawn (the "distribution parameters"), and varies the model parameters systematically in the direction of increasing likelihood until a maximum is reached. The overall likelihood was the product of the likelihoods for each of the model components. In part because the overall likelihood could be a very small number, SS1 used the logarithm of the likelihood as the objective function. Each likelihood component was associated with a set of data assumed to be drawn from statistical distributions of the same general form (e.g., multinomial, lognormal, etc.). Typically, likelihood components were associated with data sets such as catch size (or age) composition, survey size (or age) composition, and survey abundance (either biomass or numbers, either relative or absolute).

SS1 permitted each data time series to be divided into multiple segments, resulting in a separate set of parameter estimates for each segment. In the base model for the GOA Pacific cod assessment, for example, possible differences in selectivity between the mostly foreign (also joint venture) and mostly domestic fisheries were accommodated by splitting the fishery size composition time series into pre-1987 and post-1986 segments during the era of SS1-based assessments.

Until 2010, each year was been partitioned into three seasons defined as January-May, June-August, and September-December (these seasonal boundaries were suggested by industry participants in the EBS fishery). Four fisheries were defined during the era of SS1-based assessments: The January-May trawl fishery, the June-December trawl fishery, the longline fishery, and the pot fishery.

Following a series of modifications from 1993 through 1997, the base model for GOA Pacific cod remained completely unchanged from 1997 through 2001. During the late 1990s, a number of attempts were made to estimate the natural mortality rate M and the shelf bottom trawl survey catchability coefficient Q, but these were not particularly successful and the Plan Team and SSC always opted to retain the base model in which M and Q were fixed at traditional values of 0.37 and 1.0, respectively.

A minor modification of the base model was suggested by the SSC in 2001, namely, that consideration be given to dividing the domestic era into pre-2000 and post-1999 segments. This modification was tested in the 2002 assessment (Thompson et al. 2002), where it was found to result in a statistically significant improvement in the model's ability to fit the data.

A major change took place in the 2005 assessment (Thompson and Dorn 2005), as the model was migrated to the newly developed Stock Synthesis 2 (SS2) program, which made use of the ADMB modeling architecture (Fournier et al. 2012) currently used in most age-structured assessments of BSAI and GOA groundfish. The move to SS2 facilitated improved estimation of model parameters as well as

statistical characterization of the uncertainty associated with parameter estimates and derived quantities such as spawning biomass. Technical details of SS2 were described by Methot (2005a, 2007).

The 2006 assessment model (Thompson et al. 2006) was structured similarly to the 2005 assessment model; the primary change being external estimation of growth parameters.

A technical workshop was convened in April, 2007 to consider a wide range of issues pertaining to both the BSAI and GOA Pacific cod assessments (Thompson and Conners 2007).

The 2007 assessment model (Thompson et al. 2007b) for Pacific cod in the GOA was patterned after the model used in that year's assessment of the BSAI Pacific cod stock (Thompson et al. 2007a), with several changes as described in the assessment document. However, the 2007 assessment model was not accepted by the Plan Team or the SSC.

For the 2008 assessment, the recommended model for the GOA was based largely on the recommended model from the 2008 BSAI Pacific cod assessment. Among other things, this model used an explicit algorithm to determine which fleets (including surveys as well as fisheries) would be forced to exhibit asymptotic selectivity, and another explicit algorithm to determine which selectivity parameters would be allowed to vary periodically in "blocks" of years and to determine the appropriate block length for each such time-varying parameter. One other significant change in the recommended model from the 2008 GOA assessment, which was not shared by the BSAI assessment, was a substantial downweighting of the age composition data. This downweighting was instituted as a means of keeping the root mean squared error of the fit to the survey abundance data close to the sampling variability of those data.

The 2009 assessment (Thompson et al. 2009) featured a total of ten models reflecting a great many alternative assumptions and use or non-use of certain data, particularly age composition data. Relative to the 2008 assessment, the main changes in the model accepted by the Plan Team and SSC were as follow: 1) input standard deviations of all "dev" vectors were set iteratively by matching the standard deviations of the set of estimated "devs;" 2) the standard deviation of length at age was estimated outside the model as a linear function of mean length at age; 3) catchability for the pre-1996 trawl survey was estimated freely while catchability for the post-1993 trawl survey was fixed at the value that sets the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.916 obtained by Nichol et al. (2007); 4) 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, resulting in a positive bias of 0.4 years for these ages (age-specific bias values were also examined, but did not improve the fit significantly); 5) weighting of the age composition data was returned to its traditional level; 6) except for the parameter governing selectivity at age 0, all parameters of the selectivity function for the post-1993 years of the 27-plus trawl survey were allowed to vary in each survey year except for the most recent; and 7) cohort-specific growth devs were estimated for all years through 2008.

Many changes were made or considered in the 2010 stock assessment model (Thompson et al. 2010). Five models were presented preliminary assessment, as requested by the Plan Teams in May, with subsequent concurrence (given two minor modifications) by the SSC in June. Following review in September and October, three of these models, or modifications thereof, were requested by the Plan Teams or SSC to be included in the final assessment. Relative to the 2009 assessment, the main changes in the model that was ultimately accepted by the Plan Team and SSC in 2010 were as follow: 1) exclude the single record (each) of fishery age composition and mean length-at-age data, 2) use a finer length bin structure than previous models, and 3) re-evaluate the existing seasonal structure used in the model and revise it as appropriate, and 4) remove cohort-specific growth rates (these were introduced for the first time in the 2009 assessment). The new length bin structure consisted of 1-cm bins, replacing the

combination of 3-cm and 5-cm bins used in previous assessments. The new seasonal structure consisted of five catch seasons defined as January-February, March-April, May-August, September-October, and November-December; and three selectivity seasons defined as January-April, May-August, and September-December; with spawning identified as occurring at the beginning of the second catch season (March).

Following a review by the Center for Independent Experts in 2011 that resulted in a total of 128 unique recommendations from the three reviewers, the 2011 stock assessment (Thompson et al. 2011) again considered several possible model changes. Three models were requested by the Plan Teams to be included in the final GOA assessment. The SSC concurred, and added one more model. The model that was ultimately accepted by the Team and SSC differed from the 2010 model in the following respects:

- The age corresponding to the *L1* parameter in the length-at-age equation was increased from 0 to 1.3333, to correspond to the age of a 1-year-old fish at the time of the survey, which is when the age data are collected. This change was adopted to prevent mean size at age from going negative (as sometimes happened in previous EBS Pacific cod models), and to facilitate comparison of estimated and observed length at age and variability in length at age.
- The parameters governing variability in length at age were re-tuned. This was necessitated by the change in the age corresponding to the *L1* parameter (above).
- A column for age 0 fish was added to the age composition and mean-size-at-age portions of the data file. Even though there are virtually no age 0 fish represented in these two portions of the data file, unless a column for age 0 is included, SS will interpret age 1 fish as being ages 0 and 1 combined, which can bias the estimates of year class strength.
- Ageing bias was estimated internally. To preserve a large value for the strength of the 1977 year class and to keep the mean recruitment from the pre-1977 environmental regime lower than the mean recruitment from the post-1976 environmental regime, ageing bias was constrained to be positive (this constraint ultimately proved to be binding only at the maximum age).

It should also be noted that, consistent with Plan Team policy adopted in 2010, quantities that were estimated iteratively in the 2009 assessment were not re-estimated in the 2010 assessment (with the exception of the parameters governing variability in length at age, for the reason listed above).

4 History of alternative models developed for assessing Pacific cod in the EBS, AI, and GOA

Grant Thompson and Teresa A'mar

Resource Ecology and Fisheries Management Division
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7600 Sand Point Way NE., Seattle, WA 98115-6349

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 *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 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)

o 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:

o 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

o 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
- Two models for the AI:
    - Model 1 was identical to Model 1 from September, except that *Q* was fixed at 1.0
    - Model 2 was identical to Model 1 except:
        - *Q* was estimated with the same prior as in Model 2 from September
        - Survey selectivity was forced asymptotic
    - Neither of the models was accepted by the Team or SSC
- 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)

5 Base models referenced in the proposals

EBS

Four base models for the EBS are listed in the spreadsheet. Base model 12.09.5 is a modification of base model 11.11.3b, and base models 13.09.2 and 13.09.3 are both modifications of base model 12.09.5.

Base model 12.09.5 is identical to base model 11.11.3b except:

1. An inter- and intra-annually varying weight-length representation based on an explicit phenological process (Attachment 2.1, Annex 2.1.2 in Thompson and Lauth 2012) was used. Base model 11.11.3b also used an intra-annually varying weight-length representation, but each set of seasonal parameters was estimated independently of the other seasons, without being constrained by any phenological process.
2. "Tail compression" was turned off. This feature aggregates size composition bins with few or zero data on a record-by-record basis, which improves computational speed, but which also makes some of the graphs in the R4SS package difficult to interpret. In base model 11.11.3b, tail compression is turned on.
3. Fishery CPUE data were omitted. In base model 11.11.3b, fishery CPUE data were included for purposes of comparison, but are not used in estimation.
4. A new population length bin was added for fish in the 0-0.5 cm range, which was used for extrapolating the length-at age curve below the first reference age. In base model 11.11.3b, the lower bound of the first population length bin was 0.5 cm.
5. Mean-size-at-age data were eliminated. In base model 11.11.3b, mean-size-at-age data were included, but not used in estimation.
6. The number of estimated year class strengths in the initial numbers-at-age vector was set at 10. In base model 11.11.3b, only 3 elements of the initial numbers-at-age vector were estimated, which causes an automatic warning in SS.
7. The Richards growth equation (Richards 1959, Schnute 1981, Schnute and Richards 1990) was used, which adds one more parameter. In base model 11.11.3b, the von Bertalanffy equation—a special case of the Richards equation—was used.
8. The log-scale standard deviation of recruitment was estimated internally (i.e., as a free parameter estimated by ADMB). In base model 11.11.3b, this parameter was held constant at the value of 0.57 that was estimated in the final 2009 assessment by matching the standard deviation of the recruitment *dev*s, per Plan Team request.
9. Survey selectivity was modeled as a function of length. In base model 11.11.3b, survey selectivity was modeled as a function of age.
10. Fisheries were defined with respect to each of the five seasons, but not with respect to gear. In base model 11.11.3b, fisheries were defined with respect to both season and gear.
11. Fishery selectivity curves were defined for each of the five seasons, but were not stratified by gear type. In base model 11.11.3b, seasons 1-2 and 4-5 were lumped into a pair of "super" seasons for the purpose of defining fishery selectivity curves, and fishery selectivities were also *gear*-specific (3 super-seasons × 3 gears = 9 selectivity curves).
12. The selectivity curve for the fishery that came closest to being asymptotic on its own (in this case, the season 3 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 base model 11.11.3b, six of the nine super-season × gear fisheries were forced to exhibit asymptotic selectivity.

13. The age composition sample size multiplier was tuned iteratively to set the mean of the ratio of effective sample size to input sample size equal to 1.0. In base model 11.11.3b, the variance adjustment was fixed at 1.0.
14. The two parameters governing the ascending limb of the survey selectivity schedule were given annual additive *dev*s with each σ_{dev} tuned to match the estimate that would be appropriate for a univariate linear-normal model with random effects integrated out (see Attachment 2.1, Annex 2.1.1 in Thompson and Lauth 2012). In base model 11.11.3b, no *dev* vector corresponding to the *initial_selectivity* parameter was used, because it was "tuned out" in the 2009 final assessment; and σ_{dev} for the *ascending_width* parameter was left at the value of 0.07 estimated iteratively in the final 2009 assessment, per Plan Team request.
15. The logarithm of survey catchability (ln(*Q*)) was re-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 base model 11.11.3b, *Q* was left at the value of 0.77 estimated by a similar procedure in the final 2009 assessment, per Plan Team request.

Base model 13.09.2 is identical to base model 12.09.5 except that ln(*Q*) is estimated internally, using a non-constraining uniform prior distribution.

Base model 13.09.3 is identical to base model 12.09.5, except that ln(*Q*) is estimated internally, using a normal prior distribution derived from the archival tagging data used by Nichol et al. (2007), and with asymptotic trawl survey selectivity.

GOA

Three base models for the GOA are listed in the spreadsheet. Base model 13.11.2 is a modification of base model 11.11.3, and base model 13.09.6 is a modification of base model 13.11.2.

Base model 13.11.2 is identical to base model 11.11.3 except:

- *Q* is fixed at 1.0
- All sub-27 survey data are omitted
- Age 0 recruitment for the four most recent years fixed at time series average

Base model 13.09.6 is identical to base model 13.11.2 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