Appendix 2.1:
An exploration of alternative assessment models for Pacific cod in the eastern Bering Sea

Grant G. 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

Introduction

This document represents an effort to respond to comments made by the BSAI Plan Team, the Joint BSAI and GOA Plan Teams, and the SSC on last year's assessment of the Pacific cod (*Gadus macrocephalus*) stock in the eastern Bering Sea (EBS, Thompson 2013).

Responses to SSC and Plan Team Comments on Assessments in General

Because last year's SSC and Plan Team comments pertaining to assessments in general all dealt with features of the final SAFE chapters, they will be addressed in this year's final assessment.

Responses to SSC and Plan Team Comments Specific to Eastern Bering Sea Pacific Cod

Note: In previous years, the full Joint Plan Teams have met in the spring to consider recommendations for models to be included in that year's Pacific cod assessments. In 2014, this task was delegated to a Joint Team Subcommittee (JTS) on Pacific Cod Models.

BPT1 (9/13 minutes): *"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."* When any such studies have been completed, their results will be evaluated for possible use in the assessment. See also comments BPT4 and SSC5.

BPT2 (9/13 minutes): *"The Team recommended the following candidate models for the November meeting, intended to provide a number of alternatives to the present standard Model 1:*

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

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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." Because of last year's October government shutdown, this comment was not addressed in last year's final assessment, but was forwarded to the Joint Team Subcommittee on Pacific Cod Models for consideration at its March 2014 meeting. See comments JTS2, JTS3, and SSC7.

SSC1 (10/13 minutes): *"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."* Because of last year's October government shutdown, this comment was not addressed in last year's final assessment, but was forwarded to the Joint Team Subcommittee on Pacific Cod Models for consideration at its March 2014 meeting. See comments JTS2, JTS3, and SSC7.

SSC2 (10/13 minutes): *"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 model 2a (or 2b with mean Q=1) and 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)."* Because of last year's October government shutdown, this comment was not addressed in last year's final assessment, but was forwarded to the Joint Team Subcommittee on Pacific Cod Models for consideration at its March 2014 meeting. See comments JTS2, JTS3, and SSC7.

BPT3 (11/13 minutes): *"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)"*

This comment was forwarded to the Joint Team Subcommittee on Pacific Cod Models for consideration at its March 2014 meeting. See comments JTS2, JTS3, and SSC7.

BPT4 (11/13 minutes): *"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." When any such studies have been completed, their results will be evaluated for possible use in the assessment. See also comments BPT1 and SSC5.

SSC3 (12/13 minutes): *"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 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."* This comment was forwarded to the Joint Team Subcommittee on Pacific Cod Models for consideration at its March 2014 meeting. See comments JTS2, JTS3, and SSC7.

SSC4 (12/13 minutes): *"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.*

1. *The current base model (same as 2011, 2012) for comparison.*
2. *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.*
3. *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.*
4. *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.*
5. *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."*

This comment was forwarded to the Joint Team Subcommittee on Pacific Cod Models for consideration at its March 2014 meeting. See comments JTS2, JTS3, and SSC7.

SSC5 (12/13 minutes): *"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."* When any such studies have been completed, their results will be evaluated for possible use in the assessment. See also comments BPT1 and BPT4.

JTS1 (3/14 minutes): *"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."* The final 2011 model is included in this preliminary assessment as Model 1. However, see also comment SSC10.

JTS2 (3/14 minutes): *"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 above models are included in this preliminary assessment. See also comments JTS3 and SSC7.

JTS3 (3/14 minutes): *"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"*

The first of the above optional models is included in this preliminary assessment as Model 6. See also comments SSC1 and SSC7.

SSC6 (4/14 minutes): *"The process for developing and refining appropriate models for Pacific cod still needs to mature and the SSC recommends that the assessment authors continue to work with the subcommittee to refine this process."* The authors will continue to work with the subcommittee to refine the process of developing appropriate models for Pacific cod. The next meeting of the subcommittee is anticipated to take place in the spring of 2015.

SSC7 (4/14 minutes): *"For 2014, the SSC recommends as an alternative model the use of the time-varying, non-parametric selectivity function described above"* (the reference to "above" in this comment pertains to a recommendation for modeling selectivity as a random walk with respect to age in the GOA Pacific cod assessment). Model 6 in this preliminary assessment includes the time-varying, non-parametric selectivity function.

SSC8 (4/14 minutes): *"Additionally, profiling over the natural mortality rate should be conducted to gain a better understanding of the relationship between global scaling (Q and its associated priors) and natural mortality rate. The mode of the M-profile should not be used as a basis for setting the natural mortality rate in the model as it is conditional on other structural assumptions in the model."* Likelihood profiles with respect to the natural mortality rate are included for all models in this preliminary assessment. The mode is not used for setting the natural mortality rate in Models 1-4, but it is used in Model 5 per request of the Joint Team Subcommittee on Pacific Cod Models (see comment JTS2) and Model 6 ("author's choice," per comment JTS3).

SSC9 (4/14 minutes): *"Lastly, the SSC recommends that as an overarching goal for these three areas, a common model structure be explored and based on the biology of Pacific cod and not devolve over time to address area-specific outliers or retrospective biases"* (the "three areas" referred to in this comment are the EBS, AI, and GOA). The model structures for all three areas already share several features in common. As further steps toward developing a common model structure, Model 6 in this preliminary assessment and all models in the preliminary assessment of the AI stock use the same fleet structure and the same approach to selectivity.

SSC10 (4/14 minutes): *"In light of the presentation, the SSC clarified its intent regarding the use of the base model ('base' being used here to identify the model accepted by the SSC in the previous year) for 'several' years. While the SSC cannot be prescriptive about the exact length of time this would be, the idea is to continue the use of the model until there is general agreement by the stock assessment authors, the Plan Team, and the SSC on discontinuing its use."* The model accepted by the SSC last year is included in this preliminary assessment as Model 1. However, an ambiguity remains: The SSC's request for continued evaluation of the final 2011 model (SSC minutes, December 2011) was not tied to that model being accepted by the SSC as the final model in each subsequent year. The question remains, then, as to how long the final 2011 model needs to be included among the set of candidate models in the event that the SSC chooses some other model as "final."

SSC11 (4/14 minutes): *"The SSC discussed the use of model averaging to ameliorate some of the problems of choosing among competing models with substantially different estimates. Essentially, the SSC agrees with the analyst that this approach should not be used until progress is made regarding issues about the selection of the competing models and averaging over models with nonlinearities in population and fishery processes."* Model averaging is not used in this preliminary assessment.

SSC12 (4/14 minutes): *"The SSC also discussed the nomenclature used to specify models in a historical context (when introduced and the model designator). While the SSC understands that this was useful for the historical presentation, it also notes that the nomenclature is confusing and probably not useful for the assessment in a given year. Furthermore, the use of 'base model' to denote any model that is proposed seems overly inclusive and perhaps should be restricted to the chosen model in a previous assessment year."* Use of the term "base model" will henceforth be restricted to denoting the chosen model in a previous assessment year.

Data

The data used in this preliminary assessment are identical to those used in last year's final assessment, except that estimates of base, seasonal, and annual weight-length parameters were updated using the method described in Thompson and Lauth (2012, Annex 2.1.2).

The following table summarizes the sources, types, and years of data included in the data file for one or more of the stock assessment models:

Source	Type	Years
Fishery	Catch biomass	1977-2013
Fishery	Catch size composition	1977-2013
Fishery	Catch per unit effort	1991-2013
EBS shelf bottom trawl survey	Numerical abundance	1982-2013
EBS shelf bottom trawl survey	Size composition	1982-2013
EBS shelf bottom trawl survey	Age composition	1994-2012
EBS shelf bottom trawl survey	Mean size at age	1994-2012

Model Structures

All of the models presented in this preliminary assessment were developed using Stock Synthesis (SS, Methot and Wetzel 2013). The version used to run all models was SS V3.24s, as compiled on 7/24/2013 (Methot 2013). Stock Synthesis is programmed using the ADMB software package (Fournier et al. 2012).

Six models are presented. As requested by the Joint Team Subcommittee (comment JTS2), Model 1 in this preliminary assessment is the same as last year's final model (which was also the final model in 2011 and 2012). Model 2 is the same as Model 5 in the 2012 preliminary assessment (which is the same as Model 4 in the 2012 final assessment and the 2013 preliminary assessment). Models 3-5 are all based on Model 2, with the following modifications: Model 3 has survey catchability (*Q*) fixed at 1.0; Model 4 estimates *Q* with a uniform prior and adds an internally estimated constant to each year's log-scale survey abundance standard deviation; and Model 5 fixes survey catchability at 1.0 (like Model 3), forces survey selectivity to be asymptotic, and estimates the natural mortality rate (*M*) freely. Model 6 is a new model, which collapses the season-and-gear-specific fisheries of Model 1 into a single fishery (comments SSC1 and JTS3) with time-varying, non-parametric selectivity (comment SSC7). Model 6 is similar in many respects to the models considered in this year's preliminary assessment of the Aleutian Islands (AI) Pacific cod stock.

All of the models in this preliminary assessment except Model 6 used a double-normal curve to model selectivity (SS selectivity-at-length pattern #24 for the fisheries in all models and for the survey in Models 2-4, and SS selectivity-at-age pattern #20 for the survey in Model 1). 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.

Development of the final versions of all models included calculation of the Hessian matrix. All models also passed a "jitter" test of 50 runs with a jitter parameter (equal to half the standard deviation of the logit-scale distribution from which initial values are drawn) of 0.01. In the event that a jitter run produced a better value for the objective function than the base run, then: 1) the model was re-run starting from the final parameter file from the best jitter run, 2) the resulting new control file became the new base run, and 3) the entire process (starting with a new set of jitter runs) was repeated until no jitter run produced a better value for the objective function than the most recent base run.

Except for selectivity parameters in Model 6 and *dev* parameters in all models, all parameters were estimated with uniform prior distributions.

Model 1 used a data file with the same structure used for Model 1 in last year's final assessment. Models 2-5 used a common data file with the same structure used for Model 4 in last year's preliminary assessment. Model 6 used a unique data file structured to accommodate the features of that model.

Differences between Model 2 and Model 1, and between Model 6 and Model 1, are detailed below (separate sections are not presented for Models 3-5, because they each differ from Model 2 in only a few respects, as noted above).

Model 2

Some of the main differences between Model 2 and Model 1 were as follow:

1. An inter- and intra-annually varying weight-length representation based on an explicit phenological process (Thompson and Lauth 2012, Annex 2.1.2) was used. Model 1 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 Model 1, tail compression is turned on.
3. Fishery CPUE data were omitted. In Model 1, 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 Model 1, the lower bound of the first population length bin was 0.5 cm.
5. Mean-size-at-age data were eliminated. In Model 1, 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 Model 1, 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 Model 1, 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 Model 1, 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

(normally distributed random deviations added to the base value of their respective parameter), per Plan Team request.

9. Survey selectivity was modeled as a function of length. In Model 1, 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 Model 1, 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 Model 1, 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 Model 1, 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 Model 1, 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 (Thompson and Lauth 2012, Annex 2.1.1). In Model 1, 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 Model 1, Q was left at the value of 0.77 estimated by a similar procedure in the final 2009 assessment, per Plan Team request.

As recommended in comment BPT2, quantities that were tuned iteratively in Model 2 (in 2012) were not re-tuned in Models 3-5.

Model 6: main features

Some of the main differences between Model 6 and Model 1 were as follow:

1. Each year consisted of a single season instead of five.
2. A single fishery was defined instead of nine season-and-gear-specific fisheries.
3. The survey was assumed to sample age 1 fish at true age 1.5 instead of 1.41667.
4. Initial abundances were estimated for the first ten age groups instead of the first three.
5. The natural mortality rate was estimated internally.
6. The base value of survey catchability was estimated internally.
7. Length at age 1.5 was allowed to vary annually.
8. Survey catchability was allowed to vary annually.
9. Selectivity for both the fishery and the survey were allowed to vary annually.
10. Selectivity for both the fishery and survey was modeled using a random walk with respect to age (SS selectivity-at-age pattern #17) instead of the usual double normal. Selectivity-at-age pattern #17 in SS has one parameter for each age in the model. Except for age 0, the parameter for any given age represents the logarithm of the ratio of selectivity at that age to selectivity at the previous age (i.e., the backward first difference on the log scale). Age 0 fish are often expected to

have a selectivity of zero, which can be achieved in this selectivity pattern by setting the parameter for age 0 equal to -1000, as was done for all six models presented here. As with other parameters in SS, each parameter in this selectivity pattern is associated with a prior distribution (see "Iterative tuning of prior distributions for selectivity parameters" in the next subsection).

Model 6: iterative tuning

Three types of iterative tuning were involved in the development of Model 6. The first of these applied only to the prior distributions for selectivity parameters, and the second applied to all time-varying parameters except catchability, and the third applied only to time-varying catchability.

Iterative tuning of prior distributions for selectivity parameters

Initially, the model was run with recruitment as the only time-varying quantity, with the standard deviation of log-scale recruitment estimated internally (i.e., as a free parameter), and with large standard deviations in the prior distributions for all selectivity parameters.

Once the initial model converged, a pair of transformed logistic curves was fit to the point estimates of the fishery and survey selectivity schedules (a *transformed* logistic curve was used because the selectivity parameters in pattern #17 consist of the backward first differences of selectivity on the log scale, rather than selectivity itself ; Thompson and Palsson 2013). The respective transformed logistic curve (fishery or survey) was then used to specify a new set of means for the selectivity prior distributions (one for each age). A constant (across age) prior standard deviation was then computed such that no age had a prior CV (on the selectivity scale, not the transformed scale) less than 50%.

The model was then run with the new set of prior means and constant prior standard deviations (one for the fishery, one for the survey), then a new pair of transformed logistic curves was fit to the results, and the process was repeated until convergence was achieved. The converged set of prior means (on the transformed scale, not the selectivity scale) was as follows (ages 8+ all had prior means of 0 for both the fishery and the survey):

Age:	1	2	3	4	5	6	7
Fishery:	2.940	2.937	2.887	2.258	0.603	0.045	0.002
Survey:	5.020	0.607	0.003	0.000	0.000	0.000	0.000

The converged prior standard deviations were 0.350 for the fishery and 0.319 for the survey (both constant across age).

Iterative tuning of time-varying parameters other than catchability

Two main loops were involved in the iterative tuning of time-varying parameters other than catchability. These loops were designed to produce the quantities needed to use the method of Thompson and Lauth (2012, Annex 2.1.1) for estimating the standard deviation of a *dev* vector:

1. Estimating "unconstrained" values of the standard deviation(s) of the *dev*s for a particular parameter or parameter vector. The purpose of this loop was to determine the vector of *dev*s for an individual parameter or parameter vector that would be obtained if the *dev*s were completely unconstrained by their respective σs. The following individual parameters and parameter vectors were included in this exercise: *L1* (length at age 1.5), age 0 recruitment, the vector of age-specific fishery selectivity parameters, and the vector of age-specific survey selectivity parameters. For parameter vectors especially, this was not always a straightforward process, as estimating a large

matrix of age×year *dev*s is difficult if the *dev*s are unconstrained. In general, though, the procedure was to begin with a small (constant across age, in the case of a parameter vector) value of σ; calculate the standard deviation of the estimated *dev*s; then increase the value of σ gradually until the standard deviation of the estimated *dev*s reached an asymptote.

2. Estimating "equilibrium" values of the standard deviations for the *dev*s. Again proceeding one parameter or parameter vector fleet at a time, this loop began with σ set at the unconstrained value(s) estimated in the first loop. The standard deviation(s) of the estimated *dev*s then became the age-specific σ(s) for the next run, and the process was repeated until convergence was achieved.

For *L1* and age 0 recruitment, the final values of σ (after application of the algorithm described by Thompson and Lauth (2012, Annex 2.1.1)) were 0.086 and 0.657, respectively (note that the *L1 dev*s are lognormal and multiplicative, while the recruitment *dev*s are normal and additive).

In the case of a vector of age-specific selectivity parameters, it is common for some ages to be "tuned" out during the second loop (i.e., the σs converge on zero). For Model 6, all ages were tuned out except age 4 for the fishery and ages 2 and 3 for the survey. The final values of σ (after application of the algorithm described by Thompson and Lauth (2012, Annex 2.1.1)) were 0.158 for fishery age 4 and 0.106 for survey ages 2 and 3 (note that these *dev*s are all normal and additive).

Unfortunately, the way that selectivity pattern #17 is implemented in SS, large gradients tend to result if significant *dev*s occur at the age of peak selectivity. Because survey selectivity for Model 6 tended to peak at age 3, it turned out to be impossible to include *dev*s for age 3, so Model 6 included survey selectivity *dev*s for age 2 only.

Iterative tuning of time-varying catchability

Unlike the size composition or age composition data sets, the time series of survey abundance includes not only a series of expected values, but a corresponding series of standard errors as well. This formed the basis for the iterative tuning of the σ term for time-varying catchability in Model 6. The procedure involved iteratively adjusting σ until the root-mean-squared-standardized-residual equaled unity. The resulting value of σ was 0.089 (normal and additive, because SS works in terms of ln(Q) rather than Q).

Parameters Estimated Outside the Assessment Model

Parameters estimated outside the assessment model were detailed in last year's final assessment (Thompson 2013). In particular, the natural mortality rate M was fixed at 0.34 in Models 1-4 (M was estimated internally in Models 5 and 6), the standard deviations of the ageing error matrix extended linearly from a value of 0.086 at age 1 to a value of 1.73 at age 20, and the parameters of the logistic maturity-at-age relationship were set at values of 4.88 years (age at 50% maturity) and –0.965 (slope) in all models. As noted in the data section, estimates of base, seasonal, and annual weight-length parameters were updated using the method described in Thompson and Lauth (2012, Annex 2.1.2).

Parameters Estimated Inside the Assessment Model

Parameters estimated inside SS vary to some extent between the six models. Internally estimated parameters common to all models include the von Bertalanffy growth parameters; standard deviation of length at ages 1 and 20; ageing bias at ages 1 and 20; log mean recruitment since the beginning of the time series; offset for log mean recruitment prior to the beginning of the time series; *dev*s for log-scale initial (i.e., 1977) abundance at ages 1 through 3; annual log-scale recruitment *dev*s for 1977-2012; initial

(equilibrium) fishing mortality; and base values for all fishery and survey selectivity parameters (although the nature of these parameters varies between models). A complete list of parameters is presented in the "Parameters, Schedules, and Time Series Estimates" subsection of the "Results" section.

For all parameters estimated within individual SS runs, the estimator used is the mode of the logarithm of the joint posterior distribution, which is in turn calculated as the sum of the logarithms of the parameter-specific prior distributions and the logarithm of the likelihood function.

In addition to the above, the full set of annual fishing mortality rates are also estimated internally, but not in the same sense as the above parameters. The fishing mortality rates are determined (almost) exactly rather than estimated statistically because SS assumes that the input total catch data are true values rather than estimates, so the fishing mortality rates can be computed algebraically given the other parameter values and the input catch data. An option does exist in SS for treating the fishing mortality rates as full parameters, but previous explorations have indicated that adding these parameters has almost no effect on other model output (Methot and Wetzell 2013).

Likelihood Components

All six models include likelihood components for initial (equilibrium) catch, trawl survey relative abundance, fishery and survey size composition, survey age composition, recruitment, prior distributions (Model 6 only), "softbounds" (equivalent to an extremely weak prior distribution used to keep parameters from hitting bounds), and parameter deviations.

In SS, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in previous assessments of this stock, all likelihood components were given an emphasis of 1.0 here.

Results

Overview

The following table summarizes the status of the stock as estimated by the six models ("Value" is the point estimate, "SD" is the standard deviation to the point estimate, "FSB 2014" is female spawning biomass in 2014 (t), and "Bratio 2014" is the ratio of FSB 2014 to $B_{100\%}$:

	Model 1		Model 2		Model 3	
Quantity	Value	SD	Value	SD	Value	SD
FSB 2014	357,617	23,221	439,474	29,313	243,630	18,391
Bratio 2014	0.478	0.026	0.486	0.042	0.325	0.029

	Model 4		Model 5		Model 6	
Quantity	Value	SD	Value	SD	Value	SD
FSB 2014	95,727	18,881	162,445	14,289	245,145	36,050
Bratio 2014	0.151	0.028	0.290	0.026	0.346	0.053

The six models span wide ranges for these quantities. Estimates of FSB 2014 range from 96,000 t (Model 4) to 439,000 t (Model 2), and estimates of Bratio 2014 range from 0.15 (Model 4) to 0.49 (Model 2).

Goodness of Fit

Objective function values are shown for each model below (lower values are better, all else being equal; color scale extends from red (minimum) to green (maximum); note that the parameter counts include constrained deviations):

Component	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Survey index	-6.25	9.22	-12.25	-30.83	-19.78	-57.16
Size composition (fishery)	3813.17	2143.87	2093.76	2065.55	2094.71	204.11
Size composition (survey)	867.17	556.42	552.57	549.72	564.74	439.28
Age composition	138.69	128.56	124.32	121.30	119.69	117.08
Recruitment	21.38	15.58	17.09	15.08	9.31	0.18
Priors	0.00	0.00	0.00	0.00	0.00	15.50
Parameter *devs*	20.65	22.48	23.54	28.01	24.48	26.95
Other	0.03	0.03	0.21	0.41	0.42	0.17
Total	4854.84	2876.15	2799.24	2749.25	2793.56	746.11
Number of parameters	184	144	144	146	142	230
AIC	10077.68	6040.30	5886.48	5790.50	5871.12	1952.22

Models 2-5 have far fewer parameters than Models 1 or 6 (although many of the parameters in Model 6 are constrained deviations). In addition to the problem of counting constrained deviations as full parameters, the AIC values are not comparable across all models due to the fact that different data files are used for Models 1, 2-5, and 6. Although Models 2-5 all used the same data file, the AIC value for Model 4 probably should not be compared to the values for Models 2, 3, and 5, because Model 4 includes an estimated parameter that inflates the log-scale standard errors for the survey abundance time series specified in the data file, which is equivalent to changing the data file. Among Models 2, 3, and 5, Model 5 has the lowest (best) AIC value. Model 5 also has the lowest (best) value for the overall objective function among this subset of models. Evidently, fixing *Q* at a value of 1.0 in Model 3, rather than the fixed value of 0.75 used in Model 2, allows Model 3 to fit the data better than Model 2 overall. Given that the only structural differences between Models 3 and 5 are that survey selectivity is forced to be asymptotic and *M* is estimated internally in Model 5, it is likely that the lower value for the objective function in Model 5 is due to internal estimation of *M*, because forcing survey selectivity to be asymptotic would be expected to result in a worse fit overall.

Figure 2.1.1a shows the fits of the six models to the trawl survey abundance data, and Figure 2.1.1b shows the same thing in terms of standardized residuals (note that the confidence intervals for the observed values do not account for the "extra" measurement error estimated by Model 4). Models 2, 3, and 6 all estimate a 2013 survey biomass within 10% the observed value (the estimates from Models 1, 4, and 5 are 17% high, 35% low, and 11% low, respectively). All models show a mix of positive and negative residuals. Models 1 and 2 tend to overestimate the survey abundance, although usually not by much. Some summary statistics are shown below, where the values for Model 4 incorporate the estimated "extra" measurement error (for comparison to the root mean squared residual, the average log-scale standard error in the data is 0.108, except for Model 4, where the value is 0.234):

Quantity	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Correlation (observed:expected)	0.929	0.909	0.957	0.963	0.974	0.993
Root mean squared residual	0.221	0.251	0.215	0.234	0.192	0.110
Mean standardized residual	0.913	1.032	0.783	0.045	0.225	0.094
Root mean squared stand. residual	2.042	2.266	1.947	1.001	1.822	0.992

Models 4 (given the estimated "extra" measurement error) and 6 do about as well or better than any of the other models by all of the above measures. Model 2 does the worst of all the models by any of the above measures.

Sample size ratios (effective sample size divided by input sample size) for the size composition data are shown in Table 2.1.1. All six models give values (either the mean of the ratios or the ratio of the means) far in excess of unity for both the fishery and the survey.

Figure 2.1.2 shows the models' fits to the survey age composition data. Effective sample sizes and negative log likelihoods are shown in Tables 2.1.2a and 2.1.2b. Models 3-6 give average effective sample sizes in excess of the average input sample size, while Models 1 and 2 do not. However, it should be noted that the values for Models 2-5 in the last two rows of Table 2.1.2a are not strictly comparable to those for Models 1 and 6, because the input sample sizes for Models 2-5 were all multiplied by a factor of 0.85 (a result of the tuning process used for Model 2).

Parameters, Schedules, and Time Series Estimates

Table 2.1.3 (spanning 14 pages) lists the constants and parameters listed in the SS control files for the six models, along with standard deviations for all estimated parameters. Constants are listed in Table 2.1.3a, main parameters (except recruitment and selectivity) common to most or all models are listed in Table 2.1.3b, recruitment *dev*s are listed in Table 2.1.3c, *L1 dev*s and ln(*Q*) *dev*s estimated by Model 6 are listed in Table 2.1.3d (transformed to the raw *L1* and *Q* scales and plotted in Figure 2.1.3), base selectivity parameters estimated by Model 1 are listed in Table 2.1.3e, block selectivity parameters and selectivity *dev*s estimated by Model 1 are listed in Table 2.1.3f (spanning 3 pages), base selectivity parameters estimated by Models 2-5 are listed in Table 2.1.3g, annual *dev*s for selectivity parameter #3 estimated by Models 2-5 are listed in Table 2.1.3h (see third paragraph under "Model Structures" for numbering of selectivity parameters), annual *dev*s for selectivity parameter #5 estimated by Models 2-5 are listed in Table 2.1.3i, base selectivity parameters estimated by Model 6 are listed in Table 2.1.3j, annual *dev*s for the age 4 fishery selectivity parameter estimated by Model 6 are shown in Table 2.1.3k, and annual *dev*s for the age 2 survey selectivity parameter estimated by Model 6 are shown in Table 2.1.3l. Quantities with "n/a" listed under "SD" were fixed rather than estimated.

Figure 2.1.4 (spanning six pages) shows the fishery selectivity schedules estimated by the six models. These schedules are time-varying for Models 1 and 6, but time-invariant for Models 2-5. Figure 2.1.5 shows the survey selectivity schedules estimated by the six models. These are all time-varying. All models except Model 5 (where survey was forced to be asymptotic) estimate that survey selectivity decreases substantially at larger sizes (Models 1-4) or older ages (Model 6).

Time series estimated by the six models are shown for female spawning biomass, relative (to $B_{100\%}$) female spawning biomass, and age 0 recruitment in Figures 2.1.6, 2.1.7, and 2.1.8, respectively. In most cases, Figures 2.1.6 and 2.1.7 are very similar except for scale. Models 1 and 2 tend to estimate the highest values of spawning biomass, while Models 4 and 5 tend to estimate the lowest. Figure 2.1.8 indicates a very high degree of synchrony among the estimates of recruitment, except in the first year of the time series (i.e., the 1977 year class). Model 4 tends to estimate the lowest recruitments of the six models.

Discussion

The models presented here span a wide range of structures, and in many cases the estimates produced by the models are similarly wide ranging. For example, as reported in the "Overview" subsection of the "Results" section, the estimates of female spawning biomass in 2014 range from 96,000 t (Model 4) to

439,000 t (Model 2), and estimates of this quantity relative to $B_{100\%}$ range from 0.15 (Model 4) to 0.49 (Model 2). Estimates of survey catchability range from 0.75 (Model 2) to 1.42 (Model 4). Other results, however, show greater similarity. For example, all models except Model 5, where survey selectivity was forced to be asymptotic, indicate that survey selectivity decreases substantially at larger sizes (Models 2-4) or older ages (Models 1 and 6).

Although the natural mortality rate *M* is estimated internally in only Models 5 and 6, Figure 2A.1.9 shows the likelihood profiles with respect to *M* for each of the models. If *M* were estimated internally in all models, the estimates would range from a low of 0.36 (Model 6) to a high of 0.44 (Model 2). The entire range lies above the estimate of 0.34 that is hard-wired into Models 1-4, although the lower end of the range is close to that value.

All models presented here generally provided good-to-excellent fits to the size composition and age composition data, although Model 1's fit to the age composition data was a bit lacking, and the acceptable fits to the age composition data achieved by Models 2-5 were accomplished by down-weighting those data. However, none of the models except Models 4 and 6 (the only models that estimated *Q* internally) were able to estimate a survey abundance time series that is consistent with the standard errors in the data. Model 4 was able to do so by inflating the raw standard errors, while Model 6 did so by allowing *Q* to have annual *dev*s (note that the estimates of Q from these two models were quite different: 1.42 for Model 4 and 1.03 for Model 6)

Last year's preliminary assessment of the AI Pacific cod stock provided the first exploration of SS selectivity-at-age pattern #17 (random walk with age) for Pacific cod, and use of this pattern has been included here in Model 6. Some advantages of pattern #17 are the following:

1. Pattern #17 allows for use of prior distributions that are consistent with a logistic functional form without actually forcing the resulting selectivity schedule to be logistic.
2. Pattern #17 provides an alternative to the somewhat complicated parameterization of the double normal selectivity curve (which has been used in the EBS Pacific cod models for the last several years), in which the effects of some parameters are conditional on the values of other parameters, thus making it difficult to specify appropriate prior distributions.
3. The iterative tuning procedure used here for the means of the prior distributions provides a way to specify these quantities objectively and uniquely for each age.
4. Estimation of individual selectivities at age avoids the problem of mis-specifying a functional form *a priori*, which can have significant consequences (e.g., Kimura 1990, Clark 1999).

Model 6 also emphasized the potential time variability of both fishery and survey selectivity. Although a scientific consensus on how (or whether) to address this phenomenon has yet to be achieved, some of the presentations at the 2013 CAPAM selectivity workshop (Crone et al., 2013) seemed to favor allowing selectivity to vary over time.

Although Model 6 gives excellent fits to the data, various features of the model may require further evaluation before the model is accepted for use in management. For example, the annual values estimated for the *L1* parameter are only mildly consistent with existing data (not included in the data file) on time variability in that parameter. Figure 2.1.10 compares the time series of *L1* values estimated by Model 6 with three other time-varying measures: 1) the mean length at age 1.5 (i.e., age 1 at the time of the survey) estimated by the age readers, 2) the first mode in the survey size composition data, and 3) the mean of a normal distribution fit to the region around the first mode in the size composition data. The correlation between the Model 6 estimates and these three estimators is only 0.28, 0.07, and 0.05, respectively; and only the comparison with the age reader estimates produces a positive R^2 (=0.23). On the other hand, the

range of Model 6 estimates is quite consistent with the 95% confidence interval for the time series of normal means (dashed lines in Figure 2.1.10).

It should be emphasized that iterative tuning used for various quantities in Model 2 was conducted two years ago, so the tuned values may no longer be optimal now that more data have been added. Moreover, Models 3-5 simply "borrow" the tuned quantities from Model 2. If these iterative tuning procedures were also applied to Models 3-5, the performance of those models would likely change somewhat.

As has been the case for decades now, the models tend to estimate sharply reduced survey selectivity at older ages (larger sizes) unless constrained to do otherwise (as in Model 5): Estimates of selectivity (ignoring Model 5) for the oldest/largest fish range from 0.21 (Model 1) to 0.35 (Model 6). However, except for the study by Nichol et al. (2007), studies by AFSC's RACE Division have failed to verify a mechanism capable of explaining this phenomenon.

In principle, confounding with *Q* might be an issue: Models 1 and 2 were both tuned (during a previous assessment) so that the average product of catchability and selectivity across the 60-81 cm size range equaled the value of 0.47 estimated by Nichol et al. (2007); Models 3-4 were both based on Model 2, so it is not surprising that they exhibit behavior similar to that of Model 2 in this regard; Model 6 was not tuned in this manner, yet it also estimates that survey selectivity decreases substantially once fish are greater than 3 years of age. Although there is a correlation between survey selectivity of oldest/largest fish and *Q* in Models 1-4 and 6, it is not particularly large (0.42); moreover, it is positive, whereas a negative correlation would be easier to explain (as a tradeoff between catchability and selectivity).

Confounding with *M* might also be an issue: Model 5 gave a better fit to the data than Model 3 (its closest relative) even though it forced survey selectivity to be asymptotic, because it also allowed for a higher value of *M* (about 23% higher than the value assumed in Models 1-4. However, Model 6 estimates *M* (at a value about 17% higher than the fixed value assumed in Models 1-4), *Q*, and all selectivity parameters internally; and it still shows substantially lower survey selectivity at older ages, indicating that the fixed value assumed for *M* in Models 1-4 may not be the main cause of declining selectivity at older ages (larger sizes).

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References

Clark, W. G. 1999. Effects of an erroneous natural mortality rate on a simple age-structured stock assessment. *Canadian Journal of Fisheries and Aquatic Sciences* 56:1721-1731.

Crone, P., M. Maunder, J. Valero, J. McDaniel, and B. Semmens (editors). 2013. Selectivity: theory, estimation, and application in fishery stock assessment models. *Workshop Series Report*, available from Center for the Advancement of Population Assessment Methodology (CAPAM), NOAA/NMFS Southwest Fisheries Science Center, 8901 La Jolla Shores Dr., La Jolla, CA 92037, USA. 45 p.

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

Kimura, D. K. 1990. Approaches to age-structured separable sequential population analysis. *Canadian Journal of Fisheries and Aquatic Sciences* 47:2364-2374.

Methot, R. D. 2013. User manual for Stock Synthesis, model version 3.24s. Unpubl. manuscr., available from NOAA Fisheries, Seattle, WA. 152 p.

Methot, R. D., and C. R. Wetzel. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research* 142:86-99.

Nichol, D. G., T. Honkalehto, and G. G. Thompson. 2007. Proximity of Pacific cod to the sea floor: Using archival tags to estimate fish availability to research bottom trawls. *Fisheries Research* 86:129-135.

Thompson, G. G. 2013. Assessment of the Pacific cod stock in the eastern Bering Sea and Aleutian Islands area. *In* Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 239-380. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and R. R. Lauth. 2012. Assessment of the Pacific cod stock in the eastern Bering Sea and Aleutian Islands area. *In* Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 245-544. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and W. A. Palsson. 2013. Assessement of the Pacific cod stock in the Aleutian Islands. In Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions p. 381-507. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Table 2.1.1a—Effective sample size ratioss for size composition fits (Model 1).

	Model 1	
Fleet	Mean(Neff/N)	Mean(Neff)/Mean(N)
Jan-Apr_Trawl_Fishery	5.38	3.21
May-Jul_Trawl_Fishery	9.46	7.47
Aug-Dec_Trawl_Fishery	13.25	6.33
Jan-Apr_Longline_Fishery	8.66	4.06
May-Jul_Longline_Fishery	9.43	5.48
Aug-Dec_Longline_Fishery	6.49	3.21
Jan-Apr_Pot_Fishery	14.35	9.64
May-Jul_Pot_Fishery	18.16	7.63
Aug-Dec_Pot_Fishery	10.87	8.25
Post81_Shelf_Survey	2.03	1.72

Table 2.1.1b—Effective sample size ratios for size composition fits (Models 2-5).

	Mean(Neff/N)				Mean(Neff)/Mean(N)			
Fleet	Model 2	Model 3	Model 4	Model 5	Model 2	Model 3	Model 4	Model 5
Season1_Fishery	8.15	8.01	7.61	7.59	5.20	5.21	4.96	5.01
Season2_Fishery	6.79	6.72	6.62	6.37	4.29	4.24	4.19	4.07
Season3_Fishery	7.91	7.86	7.95	7.88	5.72	5.81	6.06	5.82
Season4_Fishery	9.57	9.78	10.40	9.08	3.50	3.45	3.66	3.06
Season5_Fishery	8.80	8.47	8.49	8.20	3.96	4.04	4.23	4.26
Trawl_Survey	3.12	3.14	3.39	3.17	2.65	2.69	2.88	2.73

Table 2.1.1c—Effective sample size ratiios for size composition fits (Model 6).

	Model 6	
Fleet	Mean(Neff/N)	Mean(Neff)/Mean(N)
Fishery	14.28	9.77
Survey	3.06	2.73

Table 2.1.2a—Effective sample sizes for age composition fits.

		Effective sample size					
Year	N	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
1994	205	468	413	421	356	406	424
1995	172	38	36	35	40	36	67
1996	204	316	350	384	449	388	371
1997	206	150	192	266	998	380	453
1998	182	1029	1010	2656	3024	1416	1625
1999	246	104	70	72	73	81	70
2000	248	110	57	52	59	60	63
2001	272	87	48	48	60	45	101
2002	271	87	86	83	82	85	82
2003	390	276	384	447	842	860	662
2004	298	31	36	36	38	36	52
2005	367	448	600	436	442	336	163
2006	372	148	139	151	133	179	243
2007	413	63	105	97	75	110	571
2008	347	212	257	354	705	695	232
2009	404	88	120	119	129	128	327
2010	370	147	224	221	325	204	218
2011	359	162	131	114	98	105	86
2012	374	82	117	105	97	91	103
Mean	300	213	230	321	422	297	311
Mean (Neff/N)		0.86	1.06	1.65	2.14	1.52	1.24
(Mean Neff)/(Mean N)		0.71	0.90	1.26	1.66	1.24	1.04

Table 2.1.2b—Negative log likelihoods for age composition fits.

	Negative ln(likelihood)					
Year	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
1994	3.15	3.74	3.13	3.08	2.83	3.09
1995	11.01	10.31	9.80	8.33	9.32	6.23
1996	2.07	2.73	1.93	1.45	1.57	1.51
1997	3.92	3.92	2.54	1.13	1.66	1.61
1998	1.05	1.43	0.91	0.90	0.88	0.99
1999	4.99	8.10	7.52	7.59	6.39	7.45
2000	7.27	12.38	12.87	11.89	11.31	12.17
2001	7.09	11.28	11.45	10.36	12.61	8.10
2002	6.75	6.20	6.29	6.96	6.38	6.97
2003	4.65	2.76	1.96	1.76	1.42	1.92
2004	22.40	17.14	17.28	17.07	17.74	13.85
2005	5.73	3.95	4.89	5.74	6.12	8.47
2006	10.50	8.56	7.57	7.36	5.34	6.79
2007	8.89	5.03	5.33	6.84	4.99	3.71
2008	4.52	3.10	2.54	2.05	1.87	3.80
2009	13.80	9.53	9.63	9.11	9.20	5.87
2010	4.07	3.35	3.06	2.67	3.21	3.93
2011	5.10	6.04	6.36	7.40	6.73	9.55
2012	11.74	9.01	9.26	9.61	10.12	11.08
Sum	138.69	128.56	124.32	121.30	119.69	117.08

Table 2.1.3a—Constants listed in the control files for the six models.

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Weight-length a (proportionality)	5.99E-06	6.36E-06	6.36E-06	6.36E-06	6.36E-06	6.36E-06
Weight-length b (exponent)	3.17E+00	3.16E+00	3.16E+00	3.16E+00	3.16E+00	3.16E+00
Age at 50% maturity	4.88E+00	4.88E+00	4.88E+00	4.88E+00	4.88E+00	4.88E+00
Maturity slope	-9.65E-01	-9.65E-01	-9.65E-01	-9.65E-01	-9.65E-01	-9.65E-01
Ageing error st. dev. at age 1	8.50E-02	8.60E-02	8.60E-02	8.60E-02	8.60E-02	8.60E-02
Ageing error st. dev. at age 20	1.71E+00	1.73E+00	1.73E+00	1.73E+00	1.73E+00	1.73E+00
Weight-length a offset--season 1	-2.28E-02	-2.28E-02	-2.28E-02	-2.28E-02	-2.28E-02	n/a
Weight-length a offset--season 2	2.77E-03	2.77E-03	2.77E-03	2.77E-03	2.77E-03	n/a
Weight-length a offset--season 3	1.92E-02	1.92E-02	1.92E-02	1.92E-02	1.92E-02	n/a
Weight-length a offset--season 4	2.30E-03	2.30E-03	2.30E-03	2.30E-03	2.30E-03	n/a
Weight-length a offset--season 5	-1.42E-02	-1.42E-02	-1.42E-02	-1.42E-02	-1.42E-02	n/a
Weight-length b offset--season 1	5.25E-03	5.25E-03	5.25E-03	5.25E-03	5.25E-03	n/a
Weight-length b offset--season 2	-6.47E-04	-6.47E-04	-6.47E-04	-6.47E-04	-6.47E-04	n/a
Weight-length b offset--season 3	-4.54E-03	-4.54E-03	-4.54E-03	-4.54E-03	-4.54E-03	n/a
Weight-length b offset--season 4	-5.39E-04	-5.39E-04	-5.39E-04	-5.39E-04	-5.39E-04	n/a
Weight-length b offset--season 5	3.28E-03	3.28E-03	3.28E-03	3.28E-03	3.28E-03	n/a
Beverton-Holt "steepness"	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00

Table 2.1.3b—Main parameters estimated by the models.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Parameter	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Natural mortality rate	3.40E-01	n/a	3.40E-01	n/a	3.40E-01	n/a	3.40E-01	n/a	4.17E-01	7.54E-03	3.57E-01	3.30E-02
Length at age 1 (cm)	1.41E+01	1.08E-01	1.38E+01	1.47E-01	1.38E+01	1.46E-01	1.41E+01	1.34E-01	1.38E+01	1.44E-01	1.69E+01	2.68E-01
Asymptotic length (cm)	9.22E+01	5.23E-01	9.02E+01	8.43E-01	9.43E+01	1.21E+00	9.45E+01	1.26E+00	1.04E+02	2.18E+00	9.84E+01	2.24E+00
Brody growth coefficient	2.41E-01	2.65E-03	2.83E-01	1.19E-02	2.61E-01	1.29E-02	2.99E-01	1.50E-02	2.25E-01	1.60E-02	2.17E-01	1.47E-02
Richards growth coefficient	n/a	n/a	7.97E-01	5.18E-02	8.16E-01	5.36E-02	5.80E-01	6.00E-02	8.25E-01	6.37E-02	9.38E-01	5.25E-02
SD of length at age 1 (cm)	3.54E+00	7.04E-02	3.44E+00	8.03E-02	3.50E+00	8.31E-02	3.58E+00	8.66E-02	3.55E+00	8.86E-02	3.04E+00	5.12E-02
SD of length at age 20 (cm)	1.01E+01	1.66E-01	1.02E+01	2.13E-01	1.04E+01	2.66E-01	1.02E+01	2.64E-01	1.10E+01	3.91E-01	8.75E+00	3.00E-01
Ageing bias at age 1 (years)	3.40E-01	1.29E-02	3.33E-01	1.48E-02	3.16E-01	1.66E-02	2.61E-01	2.44E-02	2.96E-01	1.87E-02	2.75E-01	2.82E-02
Ageing bias at age 20 (years)	2.80E-01	1.52E-01	3.43E-01	1.73E-01	5.70E-01	1.78E-01	1.01E+00	2.12E-01	7.75E-01	1.91E-01	6.96E-01	2.45E-01
ln(mean post-1976 recruitment)	1.32E+01	1.93E-02	1.34E+01	7.30E-02	1.31E+01	7.04E-02	1.29E+01	6.64E-02	1.34E+01	6.39E-02	1.32E+01	2.26E-01
SD of log recruitment	5.70E-01	n/a	7.97E-01	8.87E-02	8.00E-01	8.49E-02	7.57E-01	8.00E-02	6.97E-01	7.49E-02	6.57E-01	n/a
ln(pre-1977 recruitment offset)	-1.17E+00	1.31E-01	-1.28E+00	2.11E-01	-1.62E+00	1.57E-01	-1.62E+00	1.06E-01	-1.69E+00	1.15E-01	-7.66E-01	2.41E-01
Initial age 10 ln(abundance) dev	n/a	n/a	-4.50E-01	6.71E-01	-2.36E-01	7.39E-01	-5.05E-02	7.48E-01	-3.46E-02	6.88E-01	-2.36E-01	5.95E-01
Initial age 9 ln(abundance) dev	n/a	n/a	-5.58E-01	6.49E-01	-3.41E-01	7.20E-01	-9.76E-02	7.48E-01	-7.48E-02	6.83E-01	-2.92E-01	5.83E-01
Initial age 8 ln(abundance) dev	n/a	n/a	-6.58E-01	6.29E-01	-4.60E-01	6.97E-01	-1.76E-01	7.53E-01	-1.52E-01	6.78E-01	-3.74E-01	5.67E-01
Initial age 7 ln(abundance) dev	n/a	n/a	-7.19E-01	6.12E-01	-5.60E-01	6.70E-01	-2.78E-01	7.55E-01	-2.68E-01	6.67E-01	-4.79E-01	5.47E-01
Initial age 6 ln(abundance) dev	n/a	n/a	-6.82E-01	6.00E-01	-5.66E-01	6.41E-01	-3.32E-01	7.32E-01	-3.53E-01	6.34E-01	-5.64E-01	5.29E-01
Initial age 5 ln(abundance) dev	n/a	n/a	-5.25E-01	5.65E-01	-4.53E-01	5.65E-01	-2.67E-01	6.04E-01	-3.44E-01	5.25E-01	-5.52E-01	5.18E-01
Initial age 4 ln(abundance) dev	n/a	n/a	-5.63E-01	5.59E-01	-6.77E-01	5.42E-01	-6.92E-01	5.02E-01	-7.36E-01	4.62E-01	-1.38E-01	5.09E-01
Initial age 3 ln(abundance) dev	1.29E+00	1.89E-01	1.37E+00	2.48E-01	1.23E+00	2.25E-01	1.07E+00	1.94E-01	9.63E-01	1.97E-01	2.47E-01	4.48E-01
Initial age 2 ln(abundance) dev	-7.31E-01	4.18E-01	-4.70E-01	5.71E-01	-4.31E-01	5.29E-01	-4.24E-01	4.48E-01	-4.41E-01	4.19E-01	-2.31E-01	5.44E-01
Initial age 1 ln(abundance) dev	1.38E+00	2.14E-01	1.67E+00	2.63E-01	1.51E+00	2.38E-01	1.31E+00	2.12E-01	1.20E+00	2.13E-01	7.21E-01	4.52E-01
Initial fishing mortality rate	6.91E-01	1.51E-01	7.83E-01	2.17E-01	2.15E+00	7.99E-01	4.16E+00	2.38E+00	4.36E+00	2.04E+00	1.00E-01	3.32E-02
Survey "extra" SD	n/a	n/a	n/a	n/a	n/a	n/a	1.26E-01	3.35E-02	n/a	n/a	n/a	n/a
Survey ln(catchability)	-2.61E-01	n/a	-2.88E-01	n/a	0.00E+00	n/a	3.50E-01	4.95E-02	0.00E+00	n/a	2.53E-02	1.21E-01

Table 2.1.3c—Recruitment *dev*s estimated by the models.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Year	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
1977	1.36E+00	1.09E-01	1.30E+00	1.46E-01	8.95E-01	1.44E-01	6.44E-01	1.50E-01	5.05E-01	1.39E-01	8.49E-01	2.31E-01
1978	4.95E-01	2.11E-01	1.06E+00	1.81E-01	9.83E-01	1.50E-01	1.02E+00	1.28E-01	9.47E-01	1.19E-01	7.38E-01	1.91E-01
1979	6.86E-01	1.12E-01	4.34E-01	1.83E-01	4.39E-01	1.57E-01	4.14E-01	1.47E-01	4.52E-01	1.33E-01	4.96E-01	1.31E-01
1980	-3.84E-01	1.37E-01	-2.51E-01	1.58E-01	-2.19E-01	1.48E-01	-2.19E-02	1.30E-01	2.80E-02	1.25E-01	-1.93E-01	1.26E-01
1981	-9.20E-01	1.47E-01	-6.97E-01	1.59E-01	-7.26E-01	1.55E-01	-6.85E-01	1.54E-01	-6.60E-01	1.52E-01	-5.25E-01	1.35E-01
1982	9.94E-01	4.16E-02	9.44E-01	4.91E-02	9.16E-01	4.69E-02	9.31E-01	5.04E-02	9.09E-01	4.52E-02	7.93E-01	6.34E-02
1983	-5.36E-01	1.15E-01	-7.54E-01	1.53E-01	-7.18E-01	1.45E-01	-6.06E-01	1.34E-01	-5.94E-01	1.31E-01	-6.47E-01	1.55E-01
1984	7.85E-01	4.63E-02	7.71E-01	5.14E-02	7.90E-01	4.95E-02	8.47E-01	5.09E-02	8.35E-01	4.77E-02	7.07E-01	6.39E-02
1985	-8.09E-02	7.29E-02	8.63E-02	7.69E-02	1.39E-01	7.32E-02	2.40E-01	7.21E-02	2.10E-01	6.84E-02	-2.41E-02	9.39E-02
1986	-8.25E-01	9.68E-02	-8.44E-01	1.20E-01	-7.38E-01	1.15E-01	-6.38E-01	1.12E-01	-6.57E-01	1.06E-01	-6.51E-01	1.25E-01
1987	-1.16E+00	1.11E-01	-1.22E+00	1.43E-01	-1.03E+00	1.27E-01	-6.87E-01	9.78E-02	-7.12E-01	9.46E-02	-1.37E+00	1.99E-01
1988	-2.16E-01	5.72E-02	-2.12E-01	7.13E-02	-1.96E-01	6.91E-02	-1.88E-01	6.91E-02	-2.65E-01	6.84E-02	-1.67E-01	9.56E-02
1989	5.38E-01	4.04E-02	4.26E-01	5.16E-02	4.55E-01	4.90E-02	5.27E-01	4.89E-02	4.56E-01	4.65E-02	4.38E-01	6.99E-02
1990	3.32E-01	4.61E-02	3.35E-01	5.54E-02	4.12E-01	5.18E-02	5.03E-01	5.13E-02	4.46E-01	4.79E-02	3.42E-01	7.30E-02
1991	-3.06E-01	6.26E-02	-3.58E-01	8.17E-02	-2.72E-01	7.80E-02	-1.43E-01	7.29E-02	-2.02E-01	7.12E-02	-3.14E-01	1.01E-01
1992	6.29E-01	3.25E-02	5.18E-01	3.97E-02	5.88E-01	3.78E-02	6.52E-01	3.93E-02	6.00E-01	3.63E-02	6.19E-01	4.98E-02
1993	-4.23E-01	5.88E-02	-5.16E-01	7.09E-02	-4.05E-01	6.64E-02	-2.48E-01	6.36E-02	-3.18E-01	6.05E-02	-1.06E-01	7.26E-02
1994	-3.32E-01	5.14E-02	-5.42E-01	6.36E-02	-4.69E-01	5.98E-02	-3.87E-01	5.92E-02	-4.25E-01	5.47E-02	-3.49E-01	7.51E-02
1995	-2.50E-01	5.44E-02	-5.00E-01	6.72E-02	-4.82E-01	6.33E-02	-3.60E-01	5.95E-02	-4.87E-01	5.78E-02	-3.53E-01	7.95E-02
1996	6.78E-01	3.23E-02	5.10E-01	3.83E-02	4.84E-01	3.69E-02	4.79E-01	3.94E-02	4.01E-01	3.65E-02	5.52E-01	4.79E-02
1997	-2.40E-01	5.20E-02	-1.91E-01	5.81E-02	-1.23E-01	5.35E-02	-1.56E-02	5.15E-02	-9.59E-02	4.90E-02	-4.96E-02	6.55E-02
1998	-2.46E-01	4.98E-02	-1.58E-01	5.86E-02	-9.88E-02	5.48E-02	2.14E-02	5.24E-02	-2.82E-02	4.98E-02	-1.75E-01	7.51E-02
1999	4.37E-01	3.17E-02	5.73E-01	3.61E-02	6.04E-01	3.46E-02	6.67E-01	3.57E-02	5.86E-01	3.43E-02	4.94E-01	4.88E-02
2000	-6.45E-02	3.73E-02	6.72E-02	4.46E-02	1.48E-01	4.17E-02	2.79E-01	4.39E-02	2.34E-01	4.06E-02	4.16E-02	5.76E-02
2001	-8.46E-01	5.78E-02	-7.01E-01	6.68E-02	-6.25E-01	6.26E-02	-5.05E-01	5.92E-02	-5.46E-01	5.70E-02	-4.89E-01	7.06E-02
2002	-3.05E-01	3.88E-02	-3.14E-01	4.98E-02	-2.97E-01	4.71E-02	-2.23E-01	4.65E-02	-2.91E-01	4.42E-02	-3.61E-01	6.46E-02
2003	-5.22E-01	4.65E-02	-4.68E-01	5.71E-02	-4.69E-01	5.34E-02	-4.47E-01	5.19E-02	-4.87E-01	4.97E-02	-4.63E-01	6.82E-02
2004	-6.54E-01	5.16E-02	-5.15E-01	6.15E-02	-5.42E-01	5.75E-02	-5.24E-01	5.36E-02	-5.68E-01	5.30E-02	-5.53E-01	7.55E-02
2005	-5.18E-01	4.87E-02	-4.46E-01	6.07E-02	-4.98E-01	5.65E-02	-4.59E-01	5.20E-02	-5.14E-01	5.40E-02	-2.12E-01	7.07E-02
2006	7.64E-01	3.05E-02	8.51E-01	3.71E-02	7.59E-01	3.33E-02	6.63E-01	2.97E-02	6.36E-01	3.36E-02	5.85E-01	5.13E-02
2007	-4.56E-01	6.36E-02	-1.61E-01	7.74E-02	-2.16E-01	7.21E-02	-2.78E-01	6.50E-02	-2.63E-01	6.59E-02	1.45E-01	7.11E-02
2008	1.15E+00	4.29E-02	1.20E+00	4.71E-02	1.10E+00	4.63E-02	8.25E-01	5.74E-02	9.70E-01	4.87E-02	9.46E-01	6.05E-02
2009	-9.36E-01	1.32E-01	-1.08E+00	1.54E-01	-1.08E+00	1.46E-01	-1.30E+00	1.44E-01	-1.08E+00	1.35E-01	-1.27E+00	1.54E-01
2010	6.35E-01	7.27E-02	4.87E-01	7.12E-02	3.83E-01	7.00E-02	-5.09E-02	1.07E-01	2.29E-01	7.35E-02	2.68E-01	9.48E-02
2011	1.02E+00	8.02E-02	8.87E-01	9.04E-02	7.67E-01	8.76E-02	2.49E-01	1.34E-01	5.83E-01	9.12E-02	7.25E-01	1.17E-01
2012	-2.83E-01	1.81E-01	-5.19E-01	2.11E-01	-6.51E-01	2.06E-01	-1.20E+00	2.33E-01	-8.35E-01	2.03E-01	-4.64E-01	2.28E-01

Table 2.1.3d—Length at age 1.5 (*L1*) *dev*s and ln(*Q*) devs estimated by Model 6.

	L1 dev		ln(*Q*) *dev*	
Year	Value	SD	Value	SD
1982	-1.23E-01	2.18E-02	-1.22E-01	6.60E-02
1983	-9.03E-02	5.64E-02	3.61E-04	7.22E-02
1984	6.12E-02	2.06E-02	-3.08E-02	6.25E-02
1985	-6.71E-02	3.05E-02	5.64E-03	7.52E-02
1986	5.75E-02	3.43E-02	5.36E-02	6.83E-02
1987	9.02E-02	5.75E-02	3.35E-02	5.89E-02
1988	2.00E-02	3.45E-02	1.44E-02	5.97E-02
1989	-4.49E-02	2.62E-02	-1.36E-01	6.07E-02
1990	-6.55E-02	2.91E-02	-6.69E-02	6.94E-02
1991	5.15E-02	2.74E-02	-6.31E-02	7.05E-02
1992	1.15E-02	2.09E-02	-4.85E-02	7.24E-02
1993	4.41E-02	3.19E-02	4.02E-02	7.43E-02
1994	1.82E-02	3.46E-02	2.27E-01	7.26E-02
1995	3.53E-02	3.55E-02	1.30E-01	6.76E-02
1996	-1.06E-02	2.25E-02	7.83E-02	7.57E-02
1997	-1.06E-01	3.23E-02	-2.35E-03	7.61E-02
1998	-5.17E-02	3.45E-02	3.27E-03	6.54E-02
1999	-3.30E-02	2.23E-02	-2.66E-02	6.58E-02
2000	3.59E-02	2.05E-02	-8.28E-02	6.60E-02
2001	-4.11E-03	3.57E-02	1.19E-01	6.71E-02
2002	8.11E-02	2.46E-02	-7.61E-03	6.79E-02
2003	2.70E-02	3.03E-02	-1.95E-02	7.27E-02
2004	1.64E-01	2.34E-02	-9.88E-03	6.39E-02
2005	-6.66E-02	2.34E-02	2.01E-02	7.53E-02
2006	-1.17E-01	1.97E-02	-5.49E-02	5.79E-02
2007	-1.12E-01	2.63E-02	4.87E-03	8.40E-02
2008	-1.45E-01	2.03E-02	-9.82E-02	6.94E-02
2009	-3.06E-02	5.42E-02	-1.34E-01	6.67E-02
2010	8.47E-02	1.96E-02	4.22E-02	7.46E-02
2011	-2.05E-01	2.23E-02	2.52E-02	6.99E-02
2012	-1.22E-01	3.49E-02	9.48E-02	7.27E-02
2013	n/a	n/a	1.09E-02	8.03E-02

Table 2.1.3e—Base selectivity parameters estimated by Model 1 (unlisted parameters were all fixed at 0).

	Model 1	
Parameter	Value	SD
Jan-Apr trawl fishery parameter 5	-999	n/a
Jan-Apr trawl fishery parameter 6	10	n/a
May-Jul trawl fishery parameter 3	5.64E+00	1.04E-01
May-Jul trawl fishery parameter 5	-999	n/a
May-Jul trawl fishery parameter 6	10	n/a
Aug-Dec trawl fishery parameter 5	-999	n/a
Aug-Dec trawl fishery parameter 6	10	n/a
Jan-Apr longline fishery parameter 2	-4.86E+00	2.00E+00
Jan-Apr longline fishery parameter 4	5.08E+00	1.44E-01
Jan-Apr longline fishery parameter 5	-999	n/a
May-Jul longline fishery parameter 3	5.02E+00	4.98E-02
May-Jul longline fishery parameter 5	-999	n/a
May-Jul longline fishery parameter 6	10	n/a
Aug-Dec longline fishery parameter 2	-2.15E+00	2.79E-01
Aug-Dec longline fishery parameter 4	5.13E+00	3.39E-01
Aug-Dec longline fishery parameter 5	-999	n/a
Jan-Apr trawl fishery parameter 2	-9.24E+00	1.82E+01
Jan-Apr trawl fishery parameter 3	5.00E+00	4.92E-02
Jan-Apr trawl fishery parameter 4	4.45E+00	2.88E-01
Jan-Apr trawl fishery parameter 5	-999	n/a
May-Jul trawl fishery parameter 3	4.93E+00	8.12E-02
May-Jul trawl fishery parameter 5	-999	n/a
May-Jul trawl fishery parameter 6	10	n/a
Aug-Dec trawl fishery parameter 5	-999	n/a
Aug-Dec trawl fishery parameter 6	10	n/a
trawl survey parameter 1	1.28E+00	5.58E-02
trawl survey parameter 2	-3.09E+00	5.85E-01
trawl survey parameter 3	-2.11E+00	4.33E-01
trawl survey parameter 4	2.93E+00	3.96E-01
trawl survey parameter 5	-9.99E+00	n/a
trawl survey parameter 6	-1.30E+00	4.47E-01

Table 2.1.3f—Block selectivity parameters and annual selectivity *dev*s estimated by Model 1 (p. 1 of 3).

	Model 1	
Parameter	Value	SD
Jan-Apr trawl fish. par. 1 block 1977	6.92E+01	3.06E+00
Jan-Apr trawl fish. par. 1 block 1985	7.66E+01	1.69E+00
Jan-Apr trawl fish. par. 1 block 1990	6.89E+01	1.11E+00
Jan-Apr trawl fish. par. 1 block 1995	7.41E+01	9.25E-01
Jan-Apr trawl fish. par. 1 block 2000	7.84E+01	1.20E+00
Jan-Apr trawl fish. par. 1 block 2005	7.59E+01	7.55E-01
Jan-Apr trawl fish. par. 3 block 1977	6.18E+00	1.71E-01
Jan-Apr trawl fish. par. 3 block 1985	6.63E+00	7.66E-02
Jan-Apr trawl fish. par. 3 block 1990	6.09E+00	5.88E-02
Jan-Apr trawl fish. par. 3 block 1995	6.30E+00	4.54E-02
Jan-Apr trawl fish. par. 3 block 2000	6.30E+00	6.06E-02
Jan-Apr trawl fish. par. 3 block 2005	5.97E+00	4.52E-02
May-Jul trawl fish. par. 1 block 1977	5.04E+01	1.72E+00
May-Jul trawl fish. par. 1 block 1985	5.15E+01	1.76E+00
May-Jul trawl fish. par. 1 block 1990	6.21E+01	1.57E+00
May-Jul trawl fish. par. 1 block 2000	5.32E+01	1.53E+00
May-Jul trawl fish. par. 1 block 2005	5.91E+01	1.46E+00
Aug-Dec trawl fish. par. 1 block 1977	6.27E+01	4.01E+00
Aug-Dec trawl fish. par. 1 block 1980	8.22E+01	5.64E+00
Aug-Dec trawl fish. par. 1 block 1985	8.70E+01	5.37E+00
Aug-Dec trawl fish. par. 1 block 1990	7.74E+01	3.94E+01
Aug-Dec trawl fish. par. 1 block 1995	1.02E+02	n/a
Aug-Dec trawl fish. par. 1 block 2000	5.74E+01	1.91E+00
Aug-Dec trawl fish. par. 3 block 1977	5.55E+00	3.27E-01
Aug-Dec trawl fish. par. 3 block 1980	6.67E+00	2.27E-01
Aug-Dec trawl fish. par. 3 block 1985	6.62E+00	2.28E-01
Aug-Dec trawl fish. par. 3 block 1990	6.39E+00	2.10E+00
Aug-Dec trawl fish. par. 3 block 1995	7.01E+00	8.80E-02
Aug-Dec trawl fish. par. 3 block 2000	5.25E+00	1.93E-01

Table 2.1.3f—Block selectivity parameters and annual selectivity devs estimated by Model 1 (p. 2 of 3).

	Model 1	
Parameter	Value	SD
Jan-Apr longline fish. par. 1 block 1977	5.91E+01	2.07E+00
Jan-Apr longline fish. par. 1 block 1980	7.25E+01	2.50E+00
Jan-Apr longline fish. par. 1 block 1985	7.52E+01	9.13E-01
Jan-Apr longline fish. par. 1 block 1990	6.61E+01	4.78E-01
Jan-Apr longline fish. par. 1 block 1995	6.58E+01	4.27E-01
Jan-Apr longline fish. par. 1 block 2000	6.35E+01	4.44E-01
Jan-Apr longline fish. par. 1 block 2005	6.71E+01	3.67E-01
Jan-Apr longline fish. par. 3 block 1977	5.15E+00	2.09E-01
Jan-Apr longline fish. par. 3 block 1980	5.91E+00	1.79E-01
Jan-Apr longline fish. par. 3 block 1985	5.86E+00	6.71E-02
Jan-Apr longline fish. par. 3 block 1990	5.23E+00	4.64E-02
Jan-Apr longline fish. par. 3 block 1995	5.30E+00	3.97E-02
Jan-Apr longline fish. par. 3 block 2000	5.36E+00	4.17E-02
Jan-Apr longline fish. par. 3 block 2005	5.32E+00	3.20E-02
Jan-Apr longline fish. par. 6 block 1977	-1.32E+00	8.18E-01
Jan-Apr longline fish. par. 6 block 1980	3.98E-01	1.08E+00
Jan-Apr longline fish. par. 6 block 1985	-1.28E+00	4.67E-01
Jan-Apr longline fish. par. 6 block 1990	-4.78E-01	1.39E-01
Jan-Apr longline fish. par. 6 block 1995	-6.90E-01	1.42E-01
Jan-Apr longline fish. par. 6 block 2000	-1.18E+00	1.48E-01
Jan-Apr longline fish. par. 6 block 2005	-8.83E-01	1.45E-01
May-Jul longline fish. par. 1 block 1977	6.35E+01	2.22E+00
May-Jul longline fish. par. 1 block 1980	6.26E+01	1.36E+00
May-Jul longline fish. par. 1 block 1985	6.35E+01	1.12E+00
May-Jul longline fish. par. 1 block 1990	6.37E+01	5.16E-01
May-Jul longline fish. par. 1 block 2000	5.99E+01	5.59E-01
May-Jul longline fish. par. 1 block 2005	6.46E+01	5.26E-01
Aug-Dec longline fish. par. 1 block 1977	6.07E+01	2.18E+00
Aug-Dec longline fish. par. 1 block 1980	6.98E+01	1.61E+00
Aug-Dec longline fish. par. 1 block 1985	6.45E+01	7.59E-01
Aug-Dec longline fish. par. 1 block 1990	6.71E+01	7.24E-01
Aug-Dec longline fish. par. 1 block 1995	6.96E+01	7.00E-01
Aug-Dec longline fish. par. 1 block 2000	6.37E+01	4.29E-01
Aug-Dec longline fish. par. 1 block 2005	6.34E+01	3.62E-01
Aug-Dec longline fish. par. 3 block 1977	4.54E+00	3.19E-01
Aug-Dec longline fish. par. 3 block 1980	5.42E+00	1.34E-01
Aug-Dec longline fish. par. 3 block 1985	4.88E+00	8.70E-02
Aug-Dec longline fish. par. 3 block 1990	5.04E+00	7.61E-02
Aug-Dec longline fish. par. 3 block 1995	5.51E+00	5.30E-02
Aug-Dec longline fish. par. 3 block 2000	5.18E+00	4.12E-02
Aug-Dec longline fish. par. 3 block 2005	4.97E+00	3.64E-02
Aug-Dec longline fish. par. 6 block 1977	-2.65E+00	2.28E+00
Aug-Dec longline fish. par. 6 block 1980	4.44E-01	7.86E-01
Aug-Dec longline fish. par. 6 block 1985	2.26E-01	2.56E-01
Aug-Dec longline fish. par. 6 block 1990	2.59E+00	1.05E+00
Aug-Dec longline fish. par. 6 block 1995	9.50E+00	1.29E+01
Aug-Dec longline fish. par. 6 block 2000	-3.70E-01	1.96E-01
Aug-Dec longline fish. par. 6 block 2005	9.73E+00	7.55E+00

Table 2.1.3f—Block selectivity parameters and annual selectivity *dev*s estimated by Model 1 (p. 3 of 3).

	Model 1	
Parameter	Value	SD
Jan-Apr pot fish. par. 1 block 1977	6.87E+01	9.22E-01
Jan-Apr pot fish. par. 1 block 1995	6.85E+01	5.48E-01
Jan-Apr pot fish. par. 1 block 2000	6.81E+01	5.18E-01
Jan-Apr pot fish. par. 1 block 2005	6.89E+01	5.12E-01
Jan-Apr pot fish. par. 6 block 1977	2.47E-01	5.67E-01
Jan-Apr pot fish. par. 6 block 1995	-2.27E-01	2.54E-01
Jan-Apr pot fish. par. 6 block 2000	-5.60E-01	2.38E-01
Jan-Apr pot fish. par. 6 block 2005	2.10E-01	2.33E-01
May-Jul pot fish. par. 1 block 1977	6.73E+01	8.59E-01
May-Jul pot fish. par. 1 block 1995	6.60E+01	7.15E-01
Aug-Dec pot fish. par. 1 block 1977	6.86E+01	1.19E+00
Aug-Dec pot fish. par. 1 block 2000	6.20E+01	6.84E-01
Aug-Dec pot fish. par. 1 block 1977	5.19E+00	1.19E-01
Aug-Dec pot fish. par. 1 block 2000	4.45E+00	1.07E-01
Survey par. 3 dev 1982	-5.22E-02	3.35E-02
Survey par. 3 dev 1983	-5.41E-02	1.69E-02
Survey par. 3 dev 1984	-9.10E-02	2.79E-02
Survey par. 3 dev 1985	-1.05E-02	2.07E-02
Survey par. 3 dev 1986	-5.63E-02	2.29E-02
Survey par. 3 dev 1987	2.68E-02	4.22E-02
Survey par. 3 dev 1988	-8.47E-02	3.27E-02
Survey par. 3 dev 1989	-1.29E-01	1.83E-02
Survey par. 3 dev 1990	-4.33E-02	2.04E-02
Survey par. 3 dev 1991	-5.27E-02	2.22E-02
Survey par. 3 dev 1992	7.78E-02	4.16E-02
Survey par. 3 dev 1993	3.80E-02	2.96E-02
Survey par. 3 dev 1994	-5.14E-02	2.16E-02
Survey par. 3 dev 1995	-1.03E-01	1.95E-02
Survey par. 3 dev 1996	-1.25E-01	1.75E-02
Survey par. 3 dev 1997	-7.71E-02	1.48E-02
Survey par. 3 dev 1998	-8.43E-02	1.89E-02
Survey par. 3 dev 1999	-9.02E-02	1.71E-02
Survey par. 3 dev 2000	-5.06E-02	1.53E-02
Survey par. 3 dev 2001	1.52E-01	3.75E-02
Survey par. 3 dev 2002	-2.70E-02	2.36E-02
Survey par. 3 dev 2003	-1.03E-02	1.93E-02
Survey par. 3 dev 2004	-3.07E-02	1.94E-02
Survey par. 3 dev 2005	3.27E-02	2.65E-02
Survey par. 3 dev 2006	1.45E-01	3.76E-02
Survey par. 3 dev 2007	1.90E-01	3.70E-02
Survey par. 3 dev 2008	1.09E-01	3.81E-02
Survey par. 3 dev 2009	-5.12E-03	1.60E-02
Survey par. 3 dev 2010	-2.75E-02	3.13E-02
Survey par. 3 dev 2011	1.11E-02	2.06E-02

Table 2.1.3g—Base selectivity parameters estimated by Models 2-5.

	Model 2		Model 3		Model 4		Model 5	
Parameter	Value	SD	Value	SD	Value	SD	Value	SD
Sea. 1 fish. par. 1	6.90E+01	4.95E-01	7.07E+01	4.79E-01	7.10E+01	4.84E-01	7.25E+01	4.69E-01
Sea. 1 fish. par. 2	-9.44E+00	1.42E+01	-9.48E+00	1.35E+01	-9.46E+00	1.39E+01	-9.56E+00	1.15E+01
Sea. 1 fish. par. 3	5.70E+00	3.27E-02	5.75E+00	3.06E-02	5.75E+00	3.03E-02	5.76E+00	2.85E-02
Sea. 1 fish. par. 4	5.01E+00	2.26E-01	5.10E+00	2.98E-01	5.08E+00	3.12E-01	5.76E+00	4.48E-01
Sea. 1 fish. par. 5	-999	n/a	-999	n/a	-999	n/a	-999	n/a
Sea. 1 fish. par. 6	-2.04E-01	1.60E-01	-9.49E-02	2.11E-01	-4.92E-02	2.17E-01	-5.72E-01	5.37E-01
Sea. 2 fish. par. 1	6.92E+01	5.59E-01	7.10E+01	5.47E-01	7.14E+01	5.53E-01	7.31E+01	5.39E-01
Sea. 2 fish. par. 2	-9.43E+00	1.44E+01	-9.52E+00	1.25E+01	-9.51E+00	1.27E+01	-9.56E+00	1.15E+01
Sea. 2 fish. par. 3	5.89E+00	3.31E-02	5.94E+00	3.11E-02	5.93E+00	3.07E-02	5.94E+00	2.86E-02
Sea. 2 fish. par. 4	4.73E+00	2.89E-01	4.84E+00	4.24E-01	4.80E+00	4.42E-01	6.66E+00	6.70E-01
Sea. 2 fish. par. 5	-999	n/a	-999	n/a	-999	n/a	-999	n/a
Sea. 2 fish. par. 6	2.02E-01	1.59E-01	3.56E-01	2.22E-01	3.96E-01	2.29E-01	-1.30E+00	1.36E+00
Sea. 3 fish. par. 1	6.62E+01	7.20E-01	6.84E+01	7.14E-01	6.89E+01	7.30E-01	7.11E+01	7.21E-01
Sea. 3 fish. par. 2	10	n/a	10	n/a	10	n/a	10	n/a
Sea. 3 fish. par. 3	5.67E+00	5.19E-02	5.74E+00	4.89E-02	5.74E+00	4.86E-02	5.79E+00	4.51E-02
Sea. 3 fish. par. 4	0	n/a	0	n/a	0	n/a	0	n/a
Sea. 3 fish. par. 5	-999	n/a	-999	n/a	-999	n/a	-999	n/a
Sea. 3 fish. par. 6	10	n/a	10	n/a	10	n/a	10	n/a
Sea. 4 fish. par. 1	6.46E+01	4.14E-01	6.62E+01	4.45E-01	6.67E+01	4.61E-01	6.88E+01	4.47E-01
Sea. 4 fish. par. 2	-1.75E+00	3.36E-01	8.14E-01	3.95E-01	8.35E-01	5.01E-01	5.14E-01	3.58E-01
Sea. 4 fish. par. 3	5.09E+00	3.77E-02	5.18E+00	3.68E-02	5.20E+00	3.71E-02	5.30E+00	3.29E-02
Sea. 4 fish. par. 4	1.27E+00	2.54E+00	3.78E+00	2.70E+00	3.69E+00	3.31E+00	4.35E+00	1.53E+00
Sea. 4 fish. par. 5	-999	n/a	-999	n/a	-999	n/a	-999	n/a
Sea. 4 fish. par. 6	2.17E+00	3.49E-01	-2.80E-01	1.70E+00	-1.54E-01	1.81E+00	-1.53E+00	1.55E+00
Sea. 5 fish. par. 1	6.41E+01	5.27E-01	6.59E+01	5.25E-01	6.64E+01	5.33E-01	6.84E+01	5.28E-01
Sea. 5 fish. par. 2	-2.02E+00	4.89E-01	-1.89E+00	5.12E-01	-1.89E+00	5.76E-01	-1.93E+00	5.86E-01
Sea. 5 fish. par. 3	5.20E+00	4.66E-02	5.30E+00	4.30E-02	5.32E+00	4.25E-02	5.40E+00	3.87E-02
Sea. 5 fish. par. 4	5.09E+00	6.67E-01	5.43E+00	9.87E-01	5.46E+00	1.10E+00	7.26E+00	1.02E+00
Sea. 5 fish. par. 5	-999	n/a	-999	n/a	-999	n/a	-999	n/a
Sea. 5 fish. par. 6	2.98E-01	2.77E-01	3.27E-01	5.45E-01	3.22E-01	6.08E-01	-2.72E+00	3.67E+00
Survey par. 1	2.78E+01	6.72E-01	2.87E+01	7.17E-01	3.37E+01	6.93E-01	3.38E+01	5.72E-01
Survey par. 2	-1.36E+00	2.10E-01	-1.45E+00	2.96E-01	-8.93E+00	2.39E+01	1.00E+01	n/a
Survey par. 3	4.83E+00	5.16E-01	5.17E+00	3.91E-01	5.76E+00	3.50E-01	6.01E+00	2.86E-01
Survey par. 4	6.63E+00	3.54E-01	7.10E+00	5.81E-01	7.98E+00	4.99E-01	0.00E+00	n/a
Survey par. 5	-3.98E-01	3.41E-01	-5.57E-01	3.10E-01	-3.43E-01	2.68E-01	-1.01E+00	2.92E-01
Survey par. 6	-1.07E+00	3.50E-01	-7.63E-01	6.16E-01	-9.40E-01	7.53E-01	1.00E+01	n/a

Table 2.1.3h—Annual *dev*s for selectivity parameter #3 estimated by Models 2-5.

	Model 2		Model 3		Model 4		Model 5	
Year	Value	SD	Value	SD	Value	SD	Value	SD
1982	-3.66E+00	1.36E+00	-4.08E+00	1.32E+00	-3.48E+00	7.50E-01	-3.84E+00	6.93E-01
1983	-3.46E+00	1.14E+00	-3.55E+00	1.05E+00	-2.86E+00	7.14E-01	-3.02E+00	6.80E-01
1984	-9.98E-01	6.44E-01	-1.11E+00	5.57E-01	-7.15E-01	4.82E-01	-1.00E+00	4.07E-01
1985	-6.25E-02	4.93E-01	-2.47E-01	3.97E-01	-1.43E-01	3.79E-01	-4.08E-01	3.21E-01
1986	-2.17E+00	6.32E-01	-2.16E+00	5.33E-01	-1.45E+00	4.15E-01	-1.59E+00	3.83E-01
1987	3.46E-01	7.99E-01	-1.52E-02	6.60E-01	-3.20E-01	6.49E-01	-5.30E-01	5.10E-01
1988	-9.13E-01	7.47E-01	-1.20E+00	6.26E-01	-1.18E+00	4.81E-01	-1.41E+00	4.22E-01
1989	-3.25E+00	1.26E+00	-3.70E+00	1.13E+00	-5.26E+00	1.11E+00	-5.93E+00	1.26E+00
1990	-2.33E+00	1.08E+00	-2.53E+00	1.00E+00	-2.11E+00	7.95E-01	-2.40E+00	7.22E-01
1991	-1.53E+00	8.49E-01	-1.76E+00	7.77E-01	-1.47E+00	5.97E-01	-1.67E+00	5.27E-01
1992	1.14E+00	1.10E+00	9.13E-01	1.04E+00	9.27E-01	1.18E+00	5.80E-01	9.10E-01
1993	9.51E-01	9.38E-01	7.34E-01	8.72E-01	4.85E-01	9.46E-01	4.26E-01	7.73E-01
1994	-3.72E-01	6.12E-01	-6.05E-01	5.34E-01	-1.06E+00	5.99E-01	-8.51E-01	4.19E-01
1995	-9.48E-01	6.36E-01	-1.12E+00	5.54E-01	-1.06E+00	4.54E-01	-1.10E+00	3.86E-01
1996	-1.44E+00	7.87E-01	-1.57E+00	7.69E-01	-1.61E+00	6.01E-01	-1.52E+00	4.93E-01
1997	-8.87E-01	5.52E-01	-9.61E-01	4.88E-01	-2.99E+00	7.26E-01	-1.01E+00	4.44E-01
1998	-2.61E+00	7.42E-01	-2.52E+00	6.01E-01	-1.65E+00	4.12E-01	-1.66E+00	3.87E-01
1999	-1.95E+00	6.23E-01	-2.07E+00	5.32E-01	-1.75E+00	4.23E-01	-1.85E+00	3.77E-01
2000	-3.86E+00	1.03E+00	-3.95E+00	9.32E-01	-3.25E+00	6.52E-01	-3.38E+00	5.94E-01
2001	1.94E+00	1.12E+00	1.68E+00	1.05E+00	-3.62E+00	6.88E-01	9.41E-01	7.68E-01
2002	-3.15E+00	1.12E+00	-3.34E+00	9.67E-01	-2.40E+00	5.35E-01	-2.54E+00	4.95E-01
2003	2.37E-01	5.35E-01	1.20E-01	4.67E-01	1.76E-01	4.99E-01	-4.64E-02	4.15E-01
2004	-1.54E-01	5.74E-01	-3.06E-01	5.03E-01	-2.58E+00	7.86E-01	-6.10E-01	4.92E-01
2005	3.34E-01	5.23E-01	2.65E-01	4.66E-01	5.42E-01	5.42E-01	2.95E-01	4.72E-01
2006	1.36E+00	1.59E+00	1.32E+00	1.56E+00	-3.99E+00	1.10E+00	-4.05E+00	1.04E+00
2007	1.77E+00	1.43E+00	1.65E+00	1.44E+00	1.37E+00	1.53E+00	1.34E+00	1.52E+00
2008	-2.22E+00	8.33E-01	-2.18E+00	7.19E-01	-1.37E+00	6.25E-01	-1.60E+00	5.27E-01
2009	-2.91E+00	8.30E-01	-2.84E+00	7.18E-01	-1.83E+00	5.10E-01	-2.10E+00	4.12E-01
2010	-2.23E+00	1.08E+00	-2.19E+00	9.29E-01	-1.28E+00	7.20E-01	-1.47E+00	6.64E-01

Table 2.1.3i—Annual *dev*s for selectivity parameter #5 estimated by Models 2-5.

	Model 2		Model 3		Model 4		Model 5	
Year	Value	SD	Value	SD	Value	SD	Value	SD
1982	-6.95E-01	5.21E-01	-6.02E-01	4.95E-01	-1.00E+00	4.48E-01	-5.97E-01	4.42E-01
1983	-1.28E-01	3.97E-01	-3.09E-02	3.70E-01	-4.80E-01	3.34E-01	1.16E-01	3.42E-01
1984	-7.53E-01	6.24E-01	-7.26E-01	6.20E-01	-1.15E+00	6.85E-01	-8.87E-01	6.94E-01
1985	-1.77E+00	6.95E-01	-1.77E+00	7.13E-01	-2.15E+00	7.09E-01	-1.85E+00	7.50E-01
1986	-5.68E-01	4.37E-01	-5.03E-01	4.12E-01	-9.60E-01	3.92E-01	-3.99E-01	4.07E-01
1987	-6.90E-01	1.02E+00	-8.09E-01	9.71E-01	-9.78E-01	9.22E-01	-8.41E-01	9.42E-01
1988	-1.07E+00	7.57E-01	-1.19E+00	7.19E-01	-1.76E+00	6.67E-01	-1.43E+00	7.01E-01
1989	-1.50E+00	4.38E-01	-1.41E+00	4.15E-01	-1.52E+00	3.79E-01	-1.16E+00	3.82E-01
1990	4.91E-02	4.29E-01	7.43E-02	4.01E-01	-1.57E-01	4.04E-01	1.58E-01	3.70E-01
1991	-3.70E-01	4.57E-01	-3.47E-01	4.32E-01	-6.57E-01	4.20E-01	-2.81E-01	4.24E-01
1992	-3.82E-01	1.08E+00	-4.87E-01	1.05E+00	-5.59E-01	9.97E-01	-6.29E-01	1.01E+00
1993	-5.49E-01	1.01E+00	-6.06E-01	9.98E-01	-6.95E-01	9.48E-01	-6.39E-01	9.83E-01
1994	-1.07E+00	8.00E-01	-1.04E+00	8.05E-01	-1.13E+00	6.34E-01	-1.00E+00	8.12E-01
1995	-1.29E+00	6.47E-01	-1.24E+00	6.54E-01	-1.69E+00	6.14E-01	-1.30E+00	7.18E-01
1996	-1.55E+00	5.88E-01	-1.37E+00	6.12E-01	-1.69E+00	4.83E-01	-1.22E+00	6.33E-01
1997	-1.14E+00	4.87E-01	-1.01E+00	5.31E-01	-7.13E-01	3.14E-01	-8.06E-01	6.70E-01
1998	-9.84E-01	4.17E-01	-9.51E-01	3.92E-01	-1.52E+00	3.73E-01	-9.15E-01	4.13E-01
1999	-1.12E+00	4.11E-01	-1.06E+00	3.87E-01	-1.52E+00	3.56E-01	-9.97E-01	3.80E-01
2000	-5.26E-01	3.70E-01	-4.31E-01	3.41E-01	-8.38E-01	3.03E-01	-2.57E-01	3.19E-01
2001	-5.68E-01	9.48E-01	-7.71E-01	9.29E-01	5.52E-01	3.39E-01	-1.02E+00	9.06E-01
2002	-9.26E-02	4.27E-01	-5.00E-02	3.97E-01	-5.15E-01	3.55E-01	5.89E-03	3.65E-01
2003	-1.33E+00	8.38E-01	-1.25E+00	8.57E-01	-1.40E+00	8.32E-01	-1.17E+00	8.75E-01
2004	-1.13E+00	8.27E-01	-1.04E+00	8.56E-01	-1.55E-01	3.40E-01	-7.48E-01	9.36E-01
2005	-1.57E+00	8.30E-01	-1.45E+00	8.48E-01	-1.62E+00	8.23E-01	-1.36E+00	8.59E-01
2006	1.42E+00	8.66E-01	1.59E+00	8.28E-01	1.19E+00	4.17E-01	1.75E+00	3.91E-01
2007	2.56E+00	7.64E-01	2.76E+00	7.39E-01	2.83E+00	7.12E-01	3.09E+00	6.93E-01
2008	9.81E-01	4.72E-01	1.08E+00	4.42E-01	8.52E-01	4.33E-01	1.10E+00	3.96E-01
2009	4.67E-01	3.76E-01	6.63E-01	3.51E-01	8.73E-01	3.58E-01	8.95E-01	3.28E-01
2010	2.85E-01	5.50E-01	2.67E-01	5.15E-01	-1.26E-01	5.41E-01	1.79E-01	5.50E-01

Table 2.1.3j—Base selectivity parameters estimated by Models 6.

	Model 6	
Parameter	Value	SD
Fishery age 1 selectivity parameter	2.94E+00	3.50E-01
Fishery age 2 selectivity parameter	3.21E+00	3.01E-01
Fishery age 3 selectivity parameter	2.87E+00	1.67E-01
Fishery age 4 selectivity parameter	1.83E+00	2.19E-01
Fishery age 5 selectivity parameter	9.43E-01	9.45E-02
Fishery age 6 selectivity parameter	1.89E-01	1.31E-01
Fishery age 7 selectivity parameter	-2.34E-01	1.83E-01
Fishery age 8 selectivity parameter	-6.25E-02	2.31E-01
Fishery age 9 selectivity parameter	-1.78E-01	2.63E-01
Fishery age 10 selectivity parameter	-1.13E-01	2.79E-01
Fishery age 11 selectivity parameter	2.30E-01	3.00E-01
Fishery age 12 selectivity parameter	1.90E-01	3.25E-01
Fishery age 13 selectivity parameter	-3.03E-02	3.33E-01
Fishery age 14 selectivity parameter	-6.40E-02	3.38E-01
Fishery age 15 selectivity parameter	-8.06E-02	3.36E-01
Fishery age 16 selectivity parameter	-3.61E-02	3.41E-01
Fishery age 17 selectivity parameter	-1.71E-02	3.44E-01
Fishery age 18 selectivity parameter	-6.71E-03	3.47E-01
Fishery age 19 selectivity parameter	-3.54E-03	3.48E-01
Fishery age 20 selectivity parameter	-4.86E-03	3.49E-01
Survey age 1 selectivity parameter	5.02E+00	3.19E-01
Survey age 2 selectivity parameter	8.17E-01	1.62E-01
Survey age 3 selectivity parameter	1.75E-01	4.99E-02
Survey age 4 selectivity parameter	-1.37E-01	5.83E-02
Survey age 5 selectivity parameter	-3.36E-02	8.09E-02
Survey age 6 selectivity parameter	-9.69E-02	1.25E-01
Survey age 7 selectivity parameter	-6.74E-03	1.70E-01
Survey age 8 selectivity parameter	-1.90E-01	2.16E-01
Survey age 9 selectivity parameter	-2.22E-01	2.48E-01
Survey age 10 selectivity parameter	-9.74E-02	2.68E-01
Survey age 11 selectivity parameter	-5.86E-02	2.88E-01
Survey age 12 selectivity parameter	-5.04E-02	3.02E-01
Survey age 13 selectivity parameter	-5.94E-02	3.08E-01
Survey age 14 selectivity parameter	-3.18E-02	3.13E-01
Survey age 15 selectivity parameter	-1.65E-02	3.16E-01
Survey age 16 selectivity parameter	-1.63E-02	3.16E-01
Survey age 17 selectivity parameter	-1.58E-02	3.17E-01
Survey age 18 selectivity parameter	-1.30E-02	3.17E-01
Survey age 19 selectivity parameter	-9.47E-03	3.18E-01
Survey age 20 selectivity parameter	-6.46E-03	3.18E-01

Table 2.1.3k—Annual *dev*s for age 4 fishery selectivity parameter estimated by Model 6.

	Model 6	
Parameter	Value	SD
Fishery age 4 sel. par. dev 1977	-2.20E-02	1.46E-01
Fishery age 4 sel. par. dev 1978	3.80E-04	1.21E-01
Fishery age 4 sel. par. dev 1979	-1.44E-01	6.80E-02
Fishery age 4 sel. par. dev 1980	-1.10E-01	6.78E-02
Fishery age 4 sel. par. dev 1981	-2.08E-01	7.09E-02
Fishery age 4 sel. par. dev 1982	-2.09E-02	1.11E-01
Fishery age 4 sel. par. dev 1983	-6.88E-02	7.75E-02
Fishery age 4 sel. par. dev 1984	-1.48E-01	4.02E-02
Fishery age 4 sel. par. dev 1985	-9.72E-03	3.92E-02
Fishery age 4 sel. par. dev 1986	-1.01E-01	4.40E-02
Fishery age 4 sel. par. dev 1987	-1.58E-02	3.46E-02
Fishery age 4 sel. par. dev 1988	-2.10E-01	3.70E-02
Fishery age 4 sel. par. dev 1989	-1.78E-01	5.28E-02
Fishery age 4 sel. par. dev 1990	-9.69E-02	4.45E-02
Fishery age 4 sel. par. dev 1991	-4.26E-02	3.19E-02
Fishery age 4 sel. par. dev 1992	-3.44E-03	3.09E-02
Fishery age 4 sel. par. dev 1993	-8.80E-02	3.15E-02
Fishery age 4 sel. par. dev 1994	-8.56E-02	3.30E-02
Fishery age 4 sel. par. dev 1995	-6.22E-02	2.84E-02
Fishery age 4 sel. par. dev 1996	6.53E-04	3.90E-02
Fishery age 4 sel. par. dev 1997	-6.02E-02	3.18E-02
Fishery age 4 sel. par. dev 1998	-2.65E-02	3.35E-02
Fishery age 4 sel. par. dev 1999	-3.17E-02	2.82E-02
Fishery age 4 sel. par. dev 2000	1.10E-01	5.71E-02
Fishery age 4 sel. par. dev 2001	4.48E-02	4.75E-02
Fishery age 4 sel. par. dev 2002	-2.64E-02	2.96E-02
Fishery age 4 sel. par. dev 2003	-4.94E-03	3.66E-02
Fishery age 4 sel. par. dev 2004	1.10E-02	4.70E-02
Fishery age 4 sel. par. dev 2005	-2.40E-02	3.71E-02
Fishery age 4 sel. par. dev 2006	3.79E-02	4.73E-02
Fishery age 4 sel. par. dev 2007	6.97E-02	5.69E-02
Fishery age 4 sel. par. dev 2008	4.89E-02	3.75E-02
Fishery age 4 sel. par. dev 2009	1.64E-01	5.41E-02
Fishery age 4 sel. par. dev 2010	2.29E-01	7.96E-02
Fishery age 4 sel. par. dev 2011	1.20E-01	4.67E-02
Fishery age 4 sel. par. dev 2012	1.17E-01	8.35E-02
Fishery age 4 sel. par. dev 2013	-1.54E-02	3.90E-02

Table 2.1.3l—Annual *dev*s for age 2 survey selectivity parameter estimated by Model 6.

	Model 6	
Parameter	Value	SD
Survey age 2 sel. par. dev 1982	5.67E-02	3.41E-02
Survey age 2 sel. par. dev 1983	1.86E-03	2.09E-02
Survey age 2 sel. par. dev 1984	7.75E-02	3.91E-02
Survey age 2 sel. par. dev 1985	-2.19E-02	2.06E-02
Survey age 2 sel. par. dev 1986	3.98E-02	2.60E-02
Survey age 2 sel. par. dev 1987	-1.63E-02	2.95E-02
Survey age 2 sel. par. dev 1988	3.56E-02	4.21E-02
Survey age 2 sel. par. dev 1989	1.17E-01	2.99E-02
Survey age 2 sel. par. dev 1990	3.11E-03	2.38E-02
Survey age 2 sel. par. dev 1991	2.67E-02	2.54E-02
Survey age 2 sel. par. dev 1992	-7.25E-02	2.44E-02
Survey age 2 sel. par. dev 1993	-4.26E-02	2.08E-02
Survey age 2 sel. par. dev 1994	5.12E-02	2.38E-02
Survey age 2 sel. par. dev 1995	7.77E-02	2.80E-02
Survey age 2 sel. par. dev 1996	9.64E-02	2.74E-02
Survey age 2 sel. par. dev 1997	3.27E-02	2.01E-02
Survey age 2 sel. par. dev 1998	8.54E-02	2.52E-02
Survey age 2 sel. par. dev 1999	7.42E-02	2.42E-02
Survey age 2 sel. par. dev 2000	2.20E-02	1.96E-02
Survey age 2 sel. par. dev 2001	-7.54E-02	1.89E-02
Survey age 2 sel. par. dev 2002	2.53E-02	2.30E-02
Survey age 2 sel. par. dev 2003	-3.54E-02	1.99E-02
Survey age 2 sel. par. dev 2004	-2.35E-03	2.10E-02
Survey age 2 sel. par. dev 2005	-5.21E-02	2.02E-02
Survey age 2 sel. par. dev 2006	-5.40E-02	1.94E-02
Survey age 2 sel. par. dev 2007	-1.35E-01	1.88E-02
Survey age 2 sel. par. dev 2008	-3.72E-03	2.01E-02
Survey age 2 sel. par. dev 2009	-4.71E-02	1.84E-02
Survey age 2 sel. par. dev 2010	-2.33E-02	2.95E-02
Survey age 2 sel. par. dev 2011	-6.04E-02	1.96E-02
Survey age 2 sel. par. dev 2012	-3.79E-02	2.05E-02

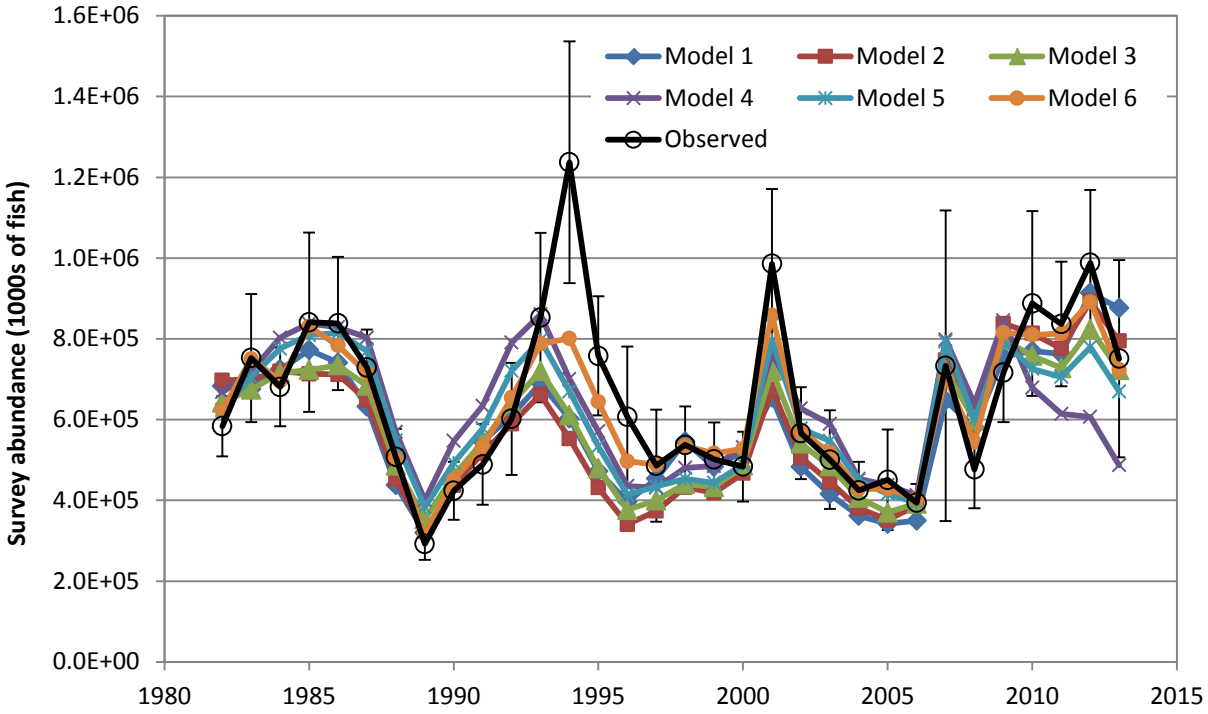


Figure 2.1.1a—Model fits to the survey abundance time series.

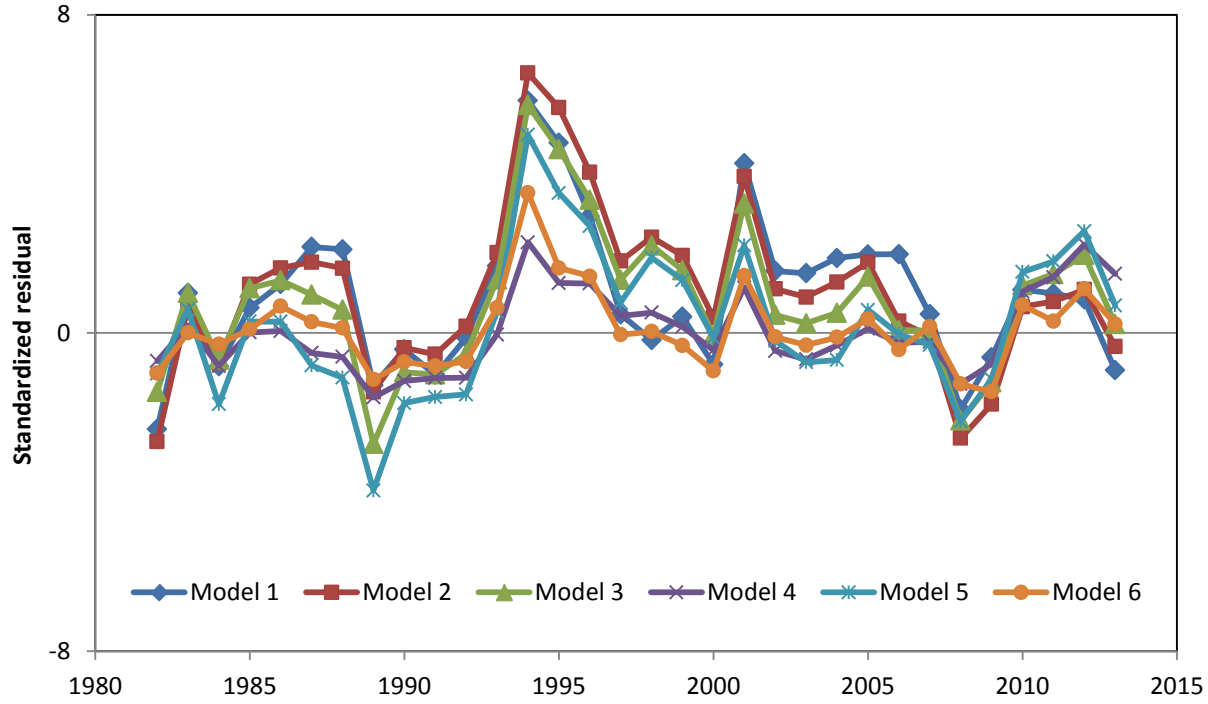


Figure 2.1.1b—Standardized residuals from the model fits to the survey abundance time series.

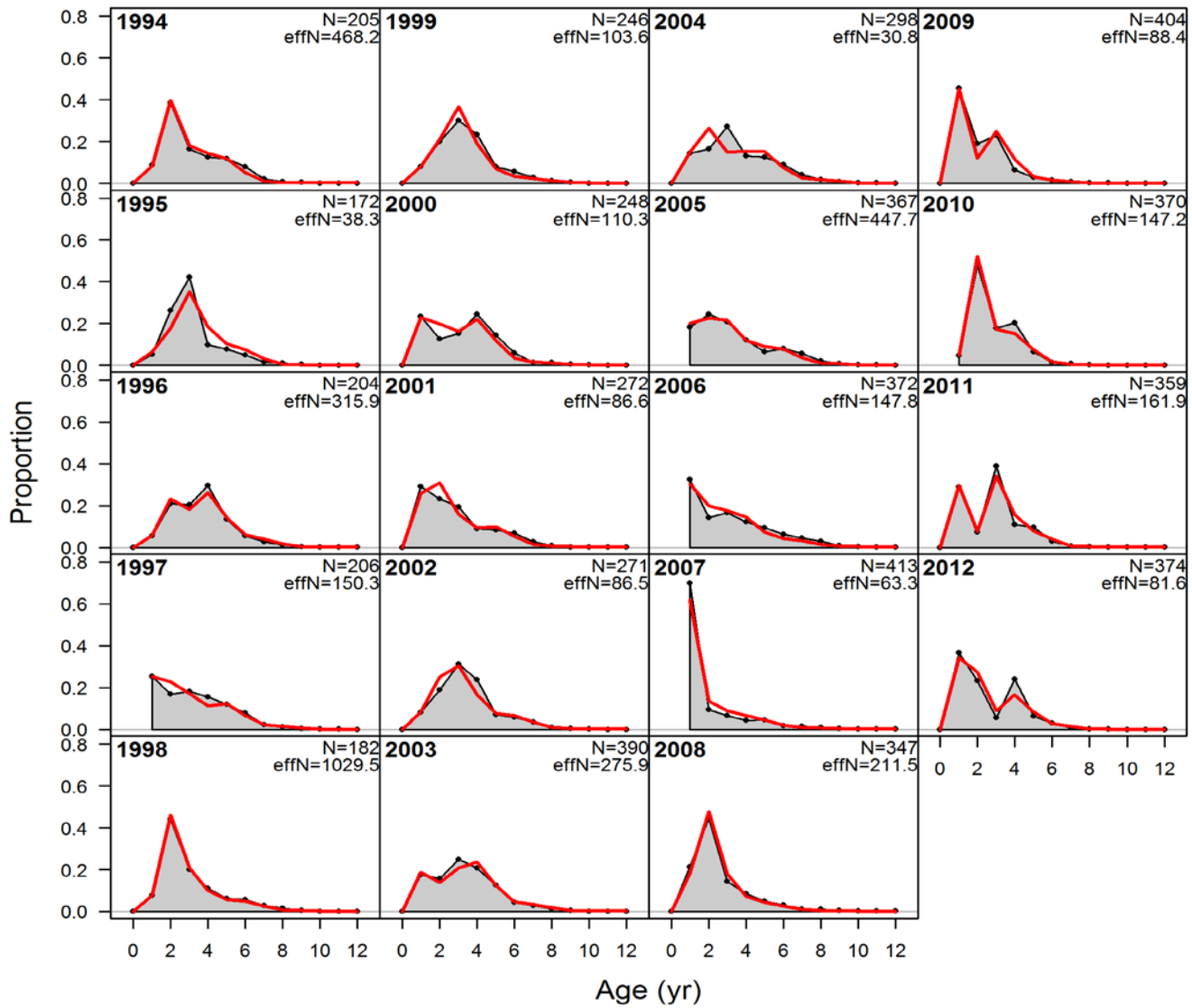


Figure 2.1.2a—Model 1 fits to the fishery age composition data.

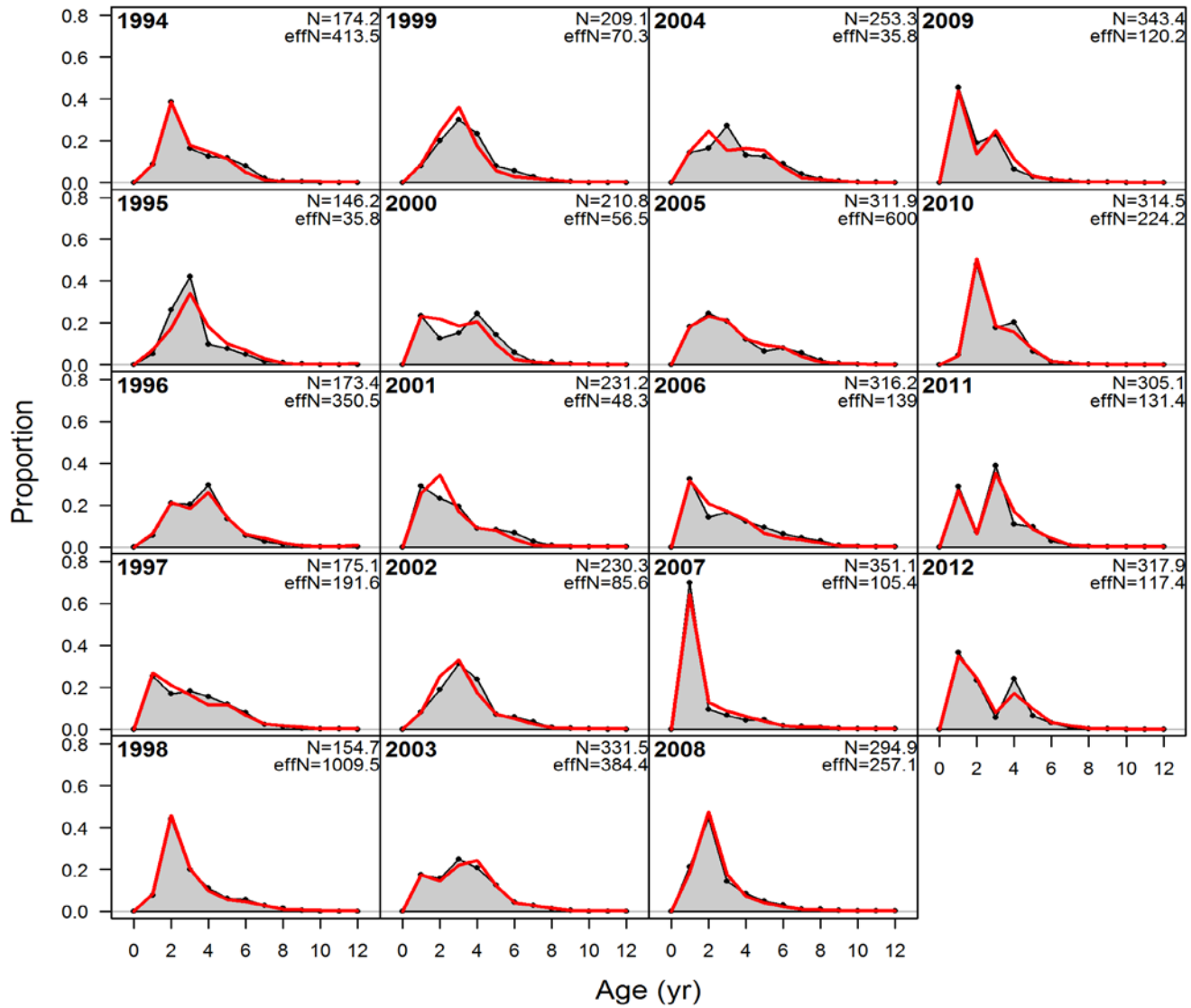


Figure 2.1.2b—Model 2 fits to the fishery age composition data.

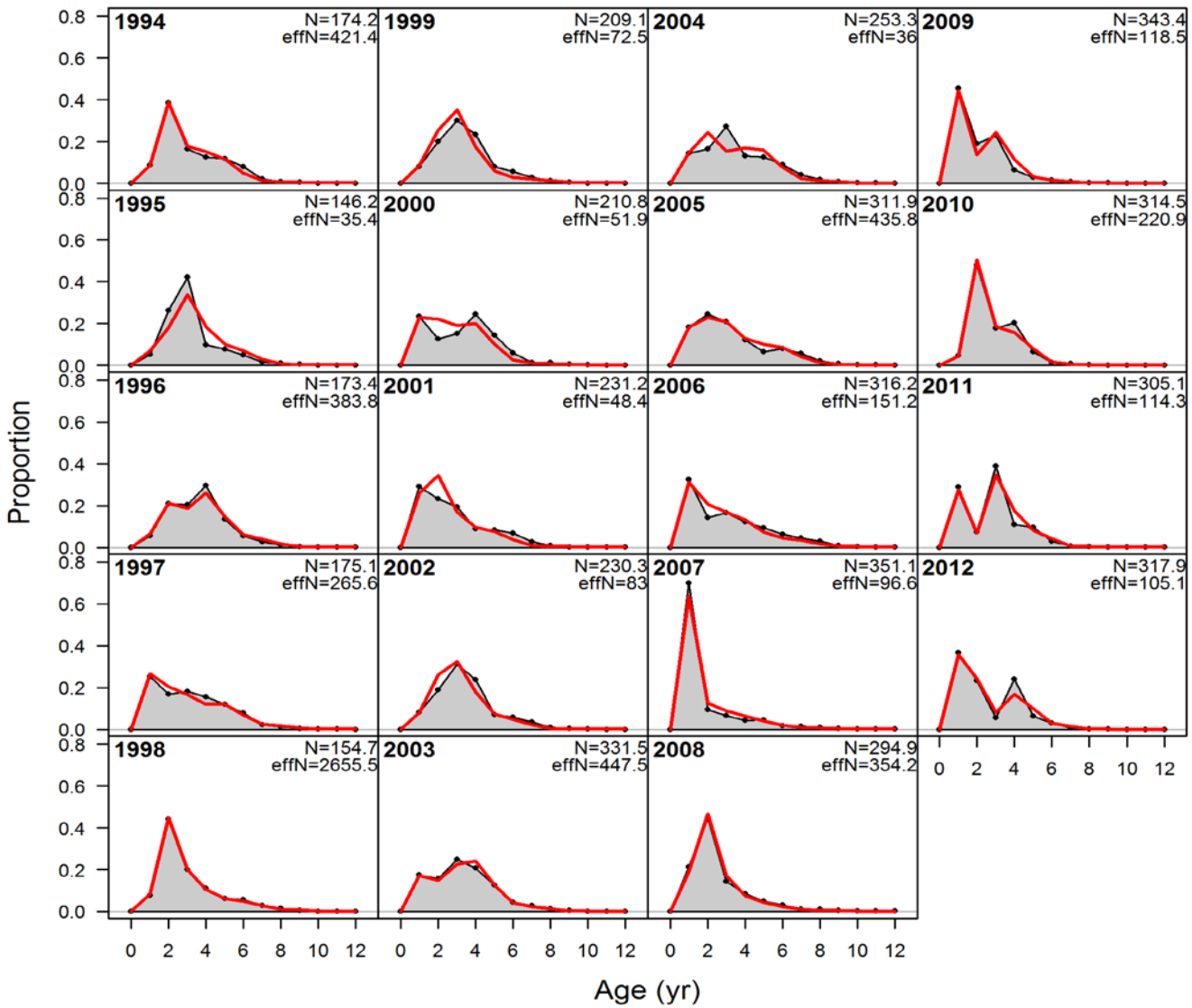


Figure 2.1.2c—Model 3 fits to the fishery age composition data.

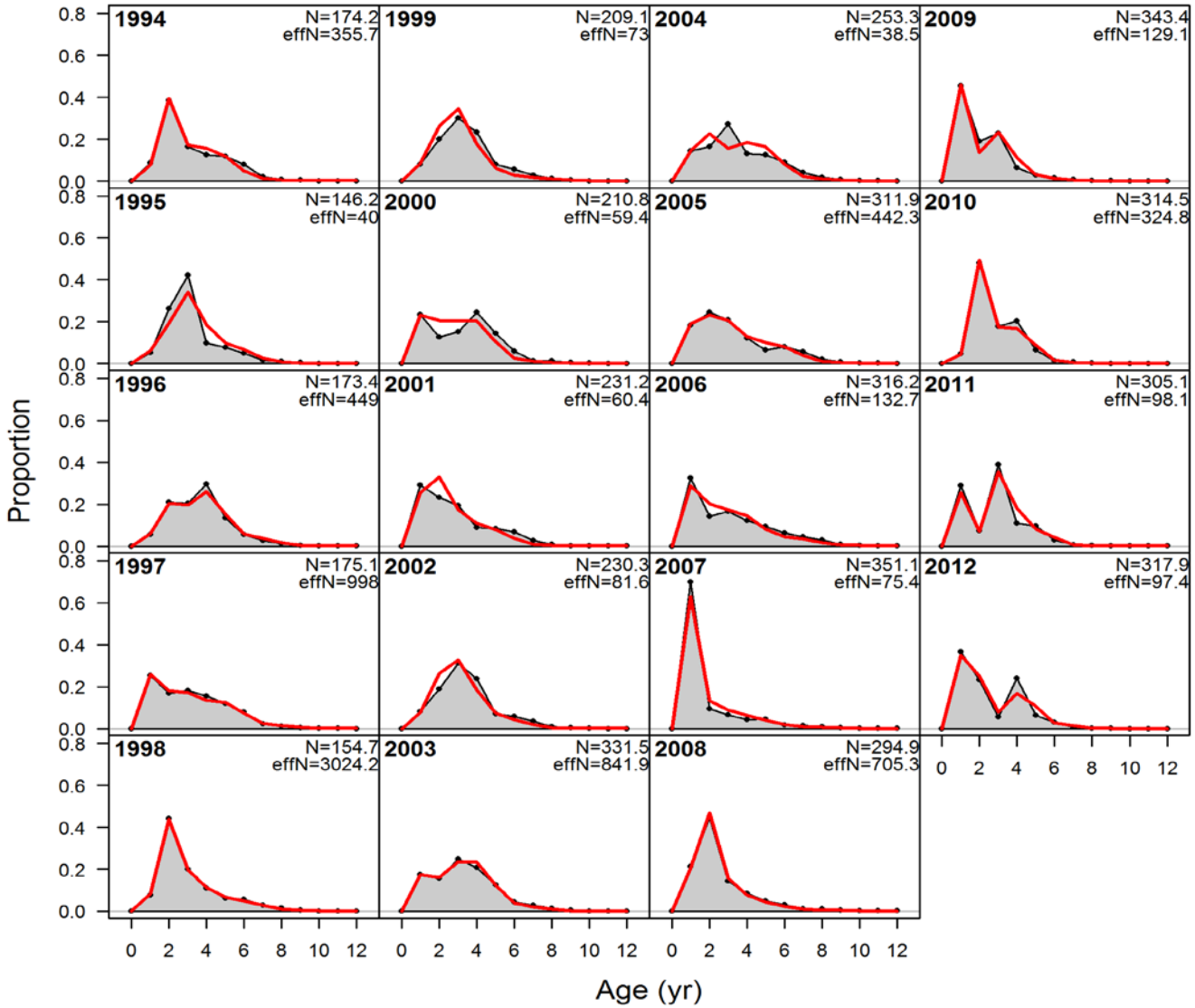


Figure 2.1.2d—Model 4 fits to the fishery age composition data.

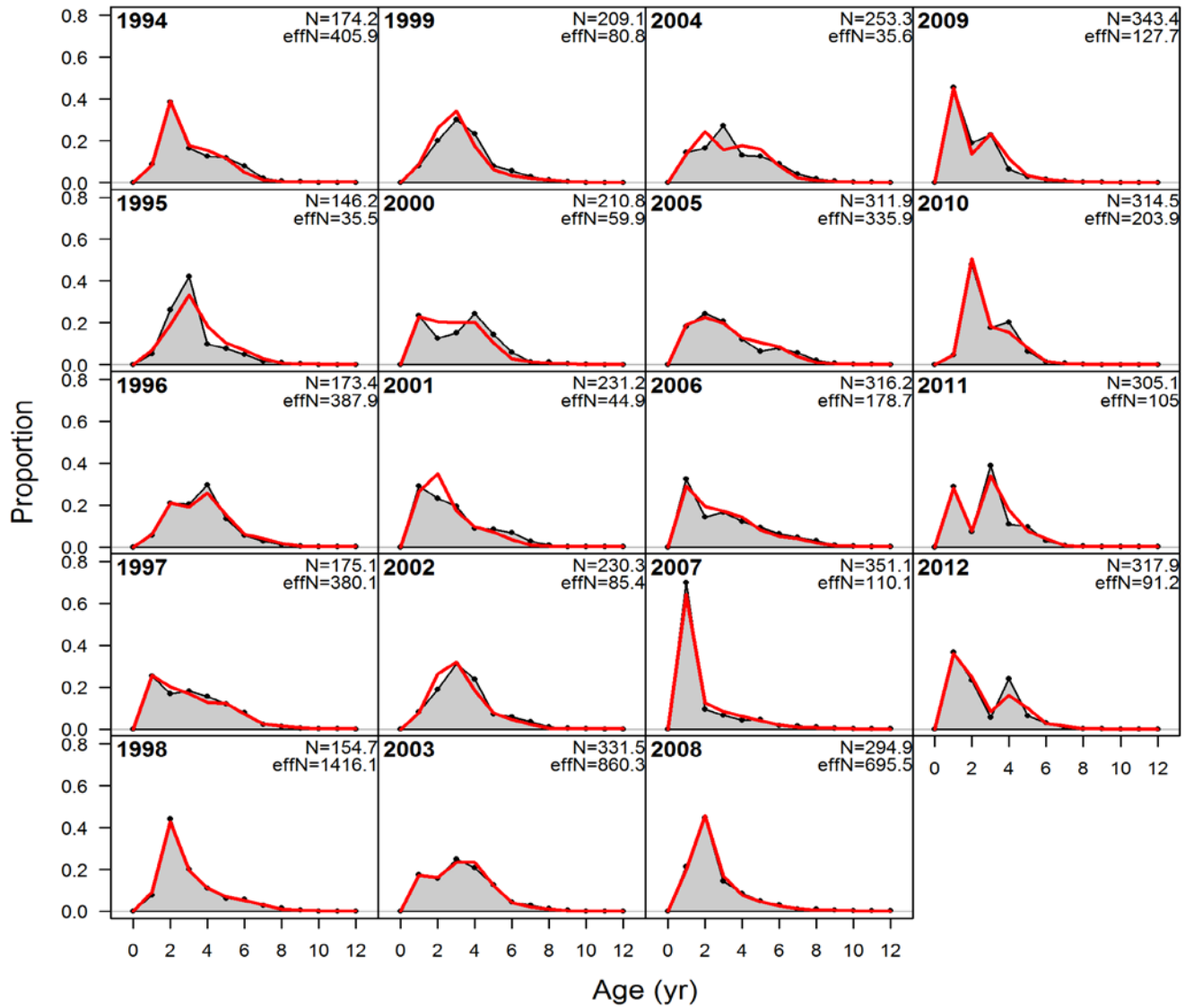


Figure 2.1.2e—Model 5 fits to the fishery age composition data.

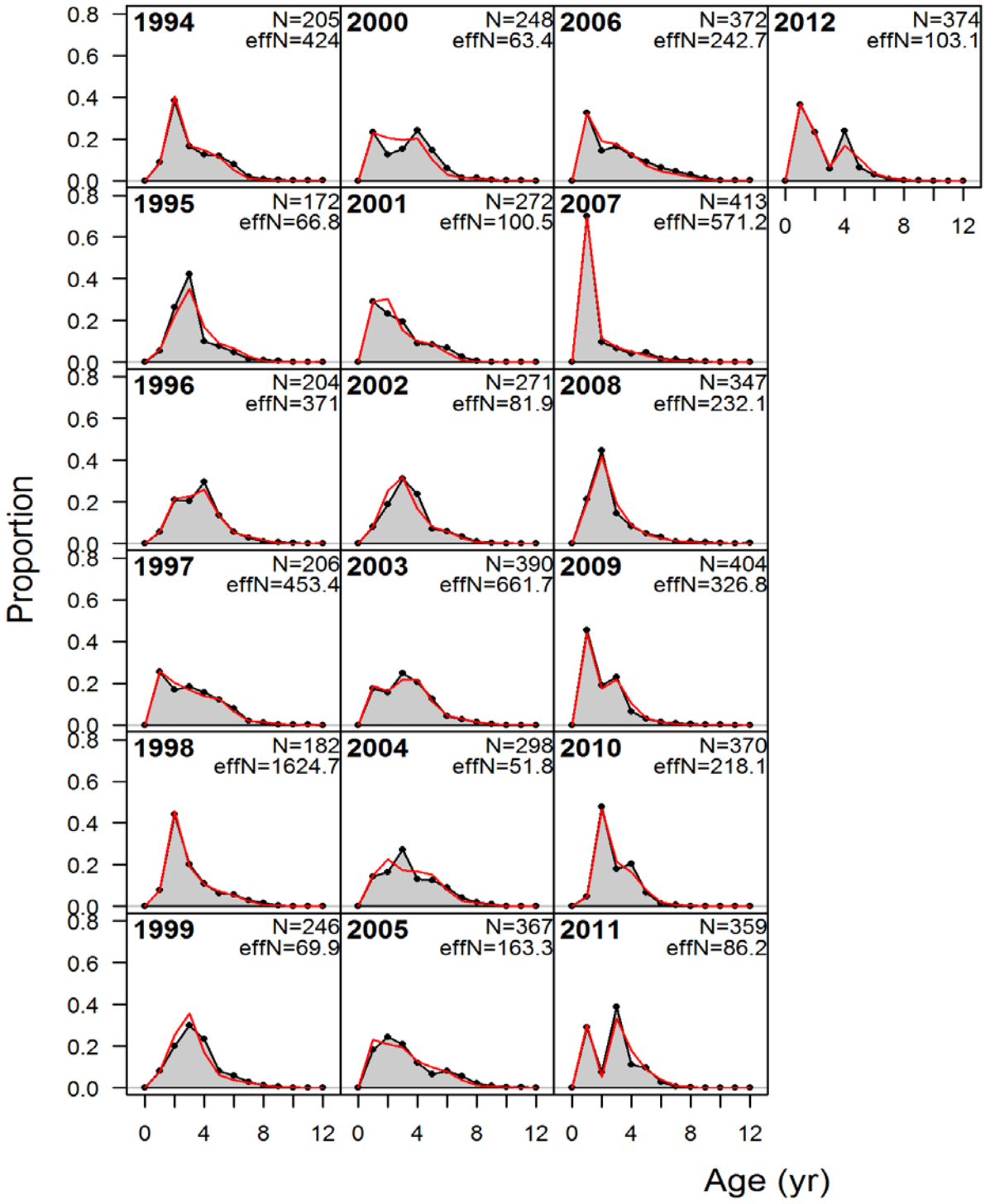
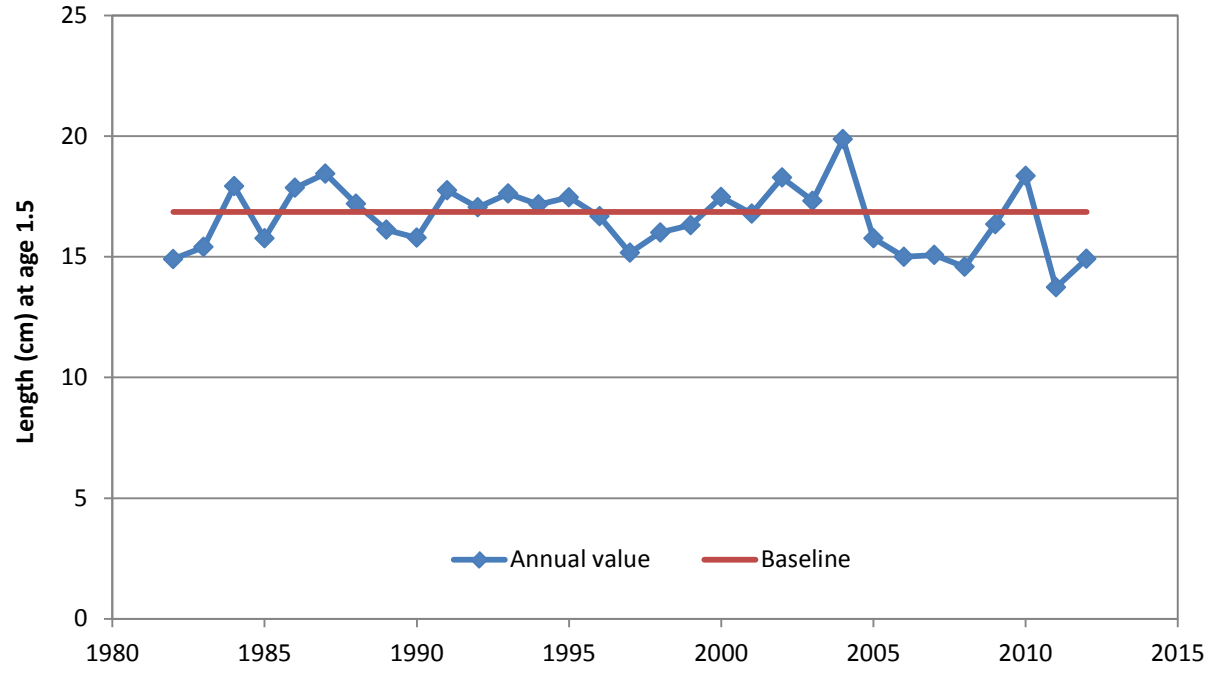


Figure 2.1.2f—Model 6 fits to the fishery age composition data.

Length at age 1.5



Catchability

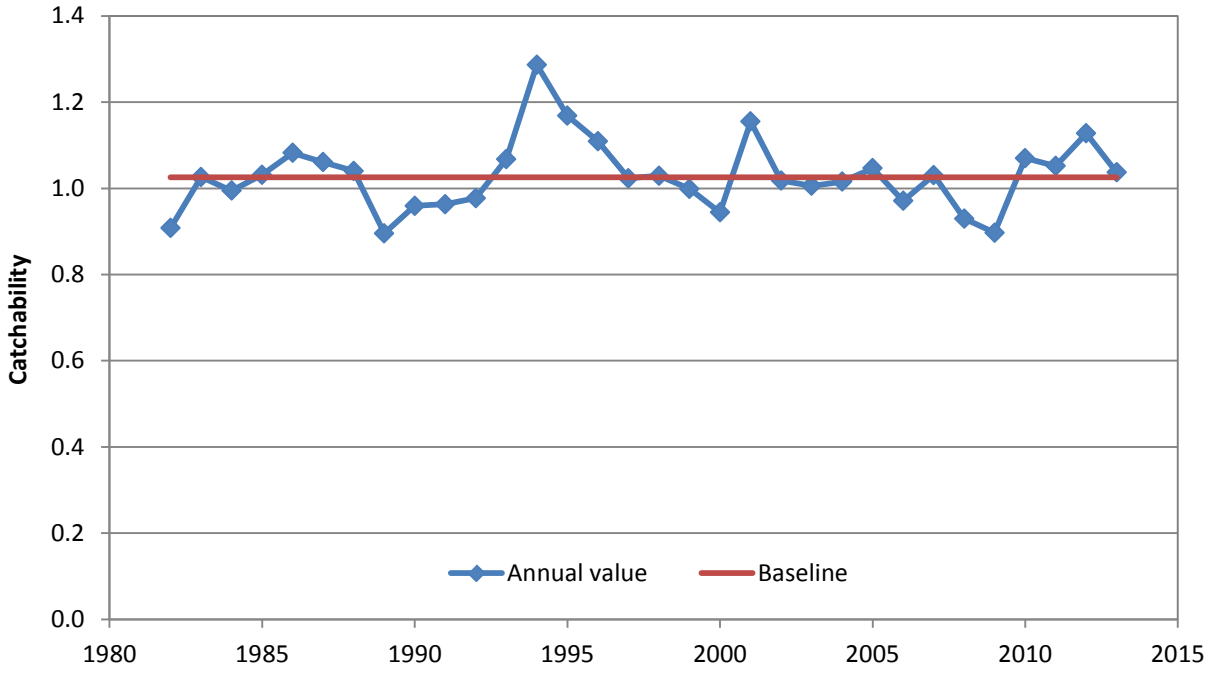


Figure 2.1.3—Time series of length at age 1.5 and survey catchability estimated by Model 6.

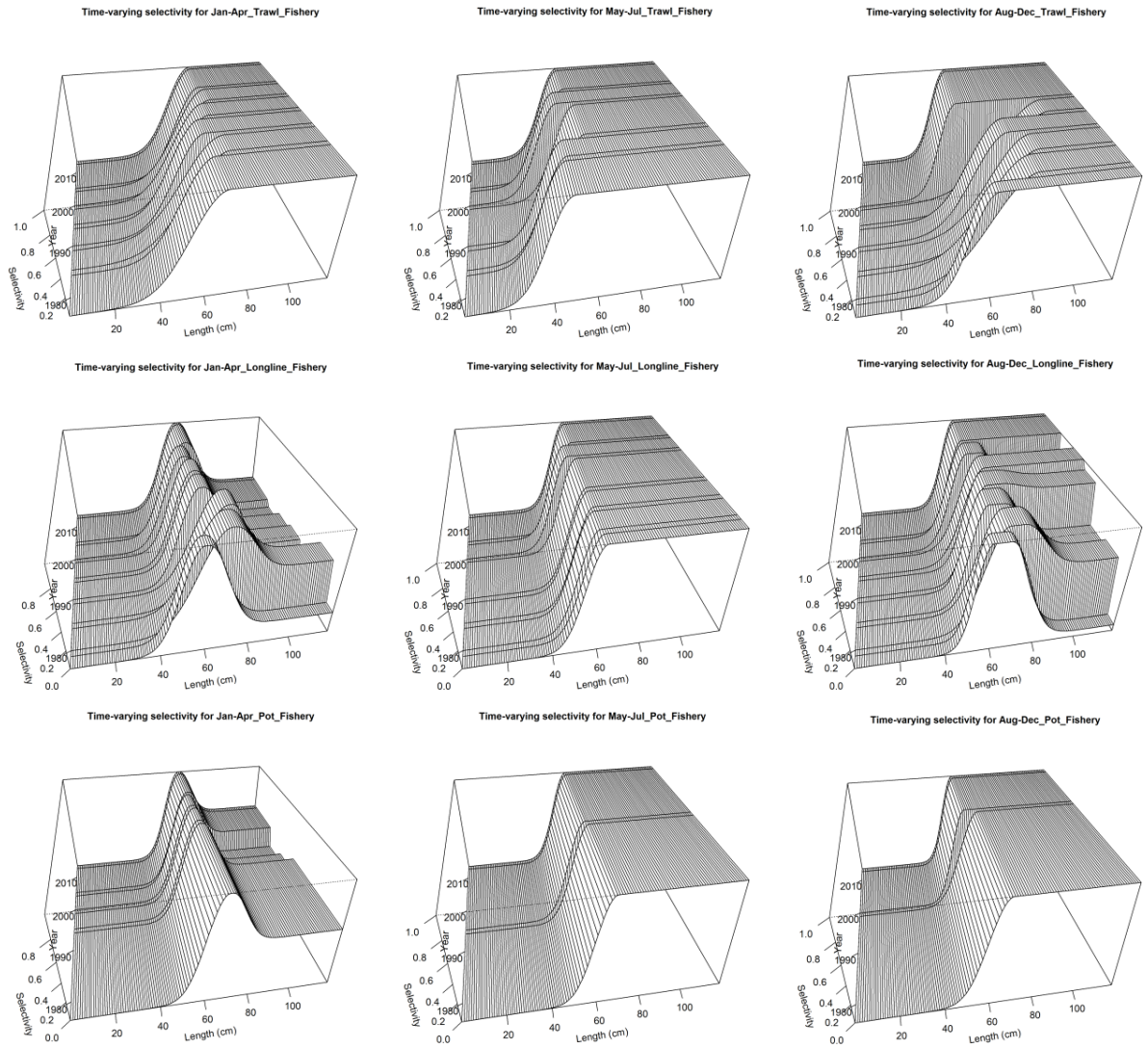


Figure 2.1.4a—Fishery selectivities estimated by Model 1.

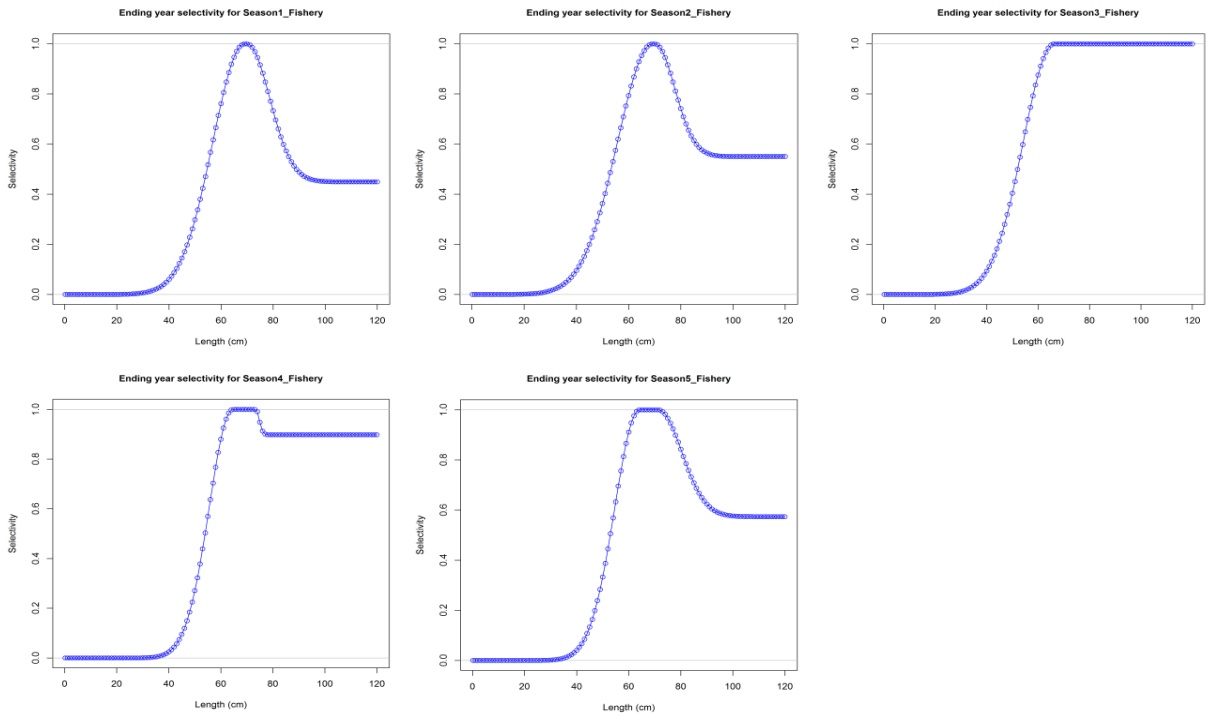


Figure 2.1.4b—Fishery selectivities estimated by Model 2.

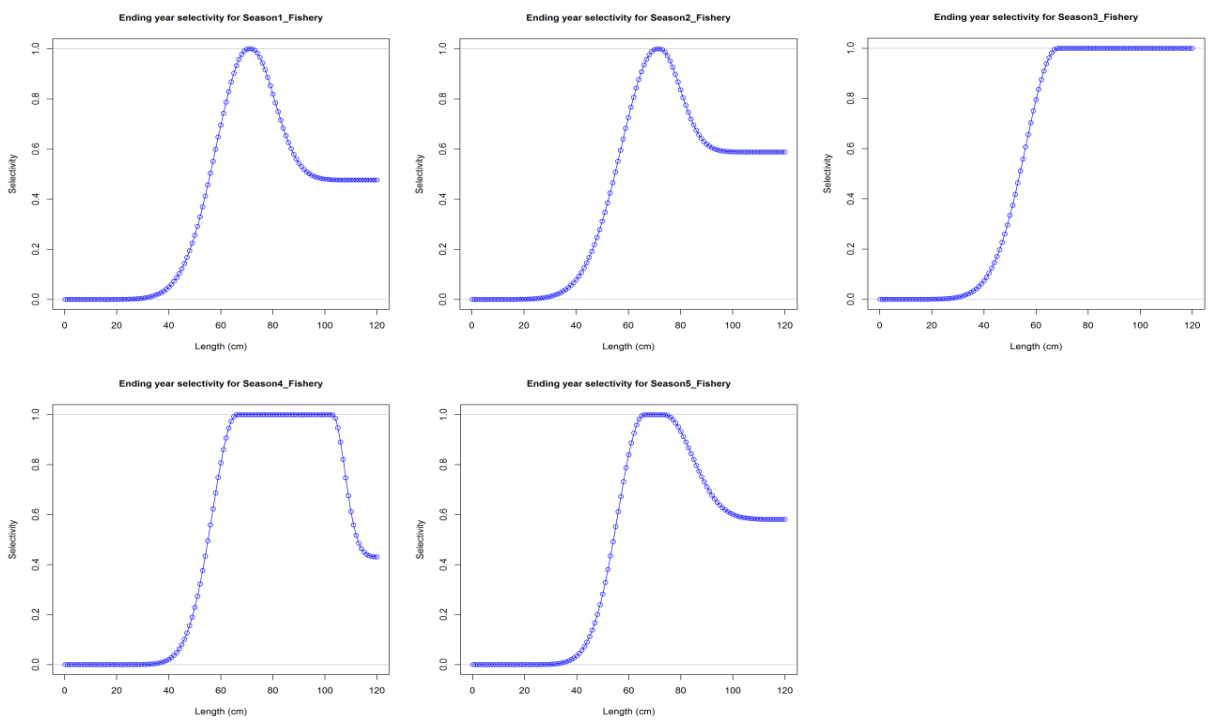


Figure 2.1.4c—Fishery selectivities estimated by Model 3.

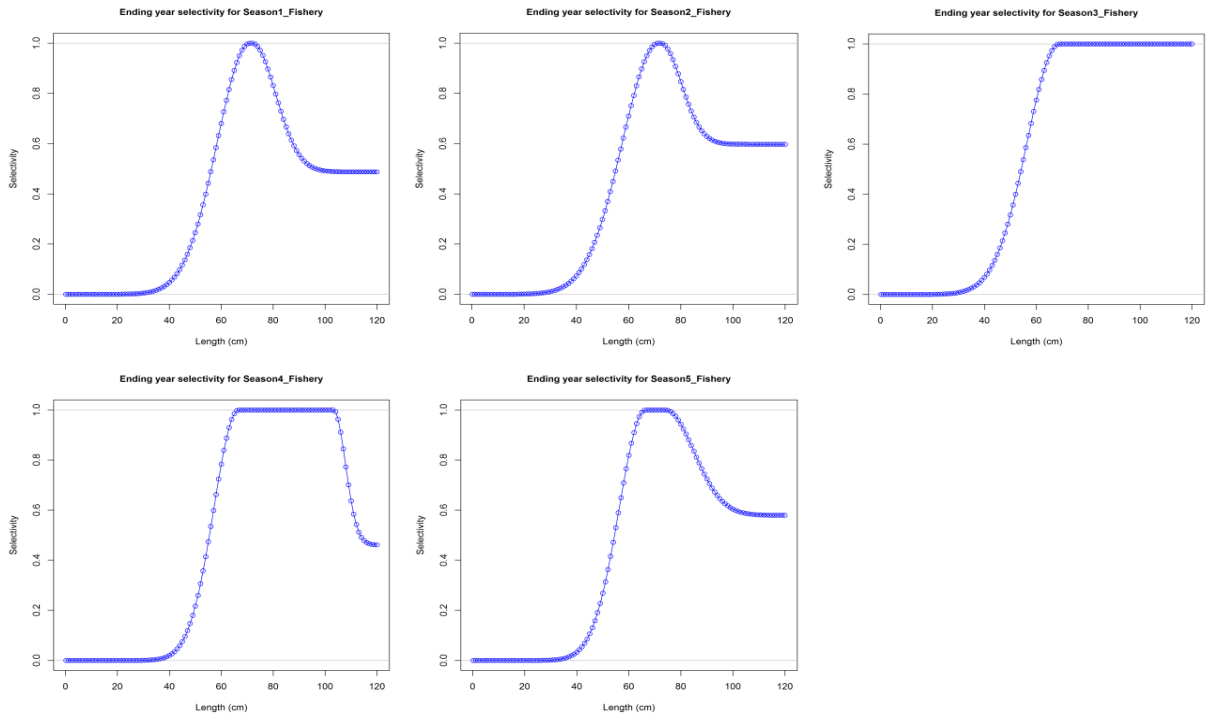


Figure 2.1.4d—Fishery selectivities estimated by Model 4.

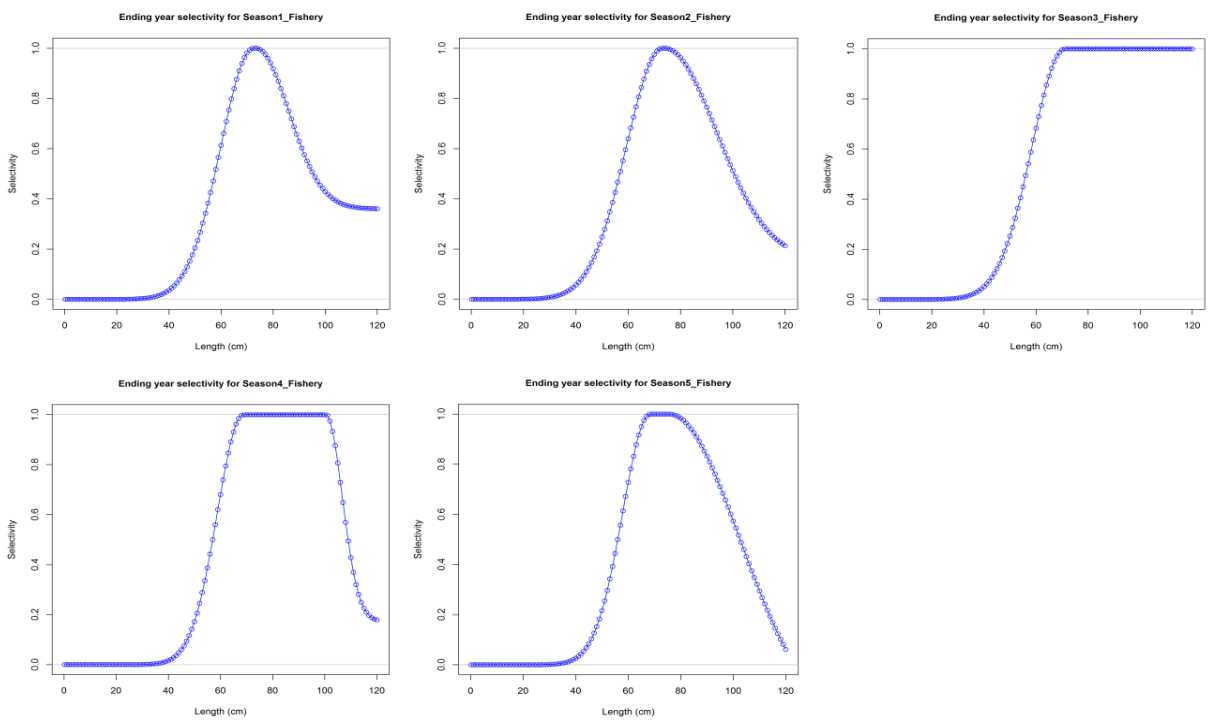


Figure 2.1.4e—Fishery selectivities estimated by Model 5.

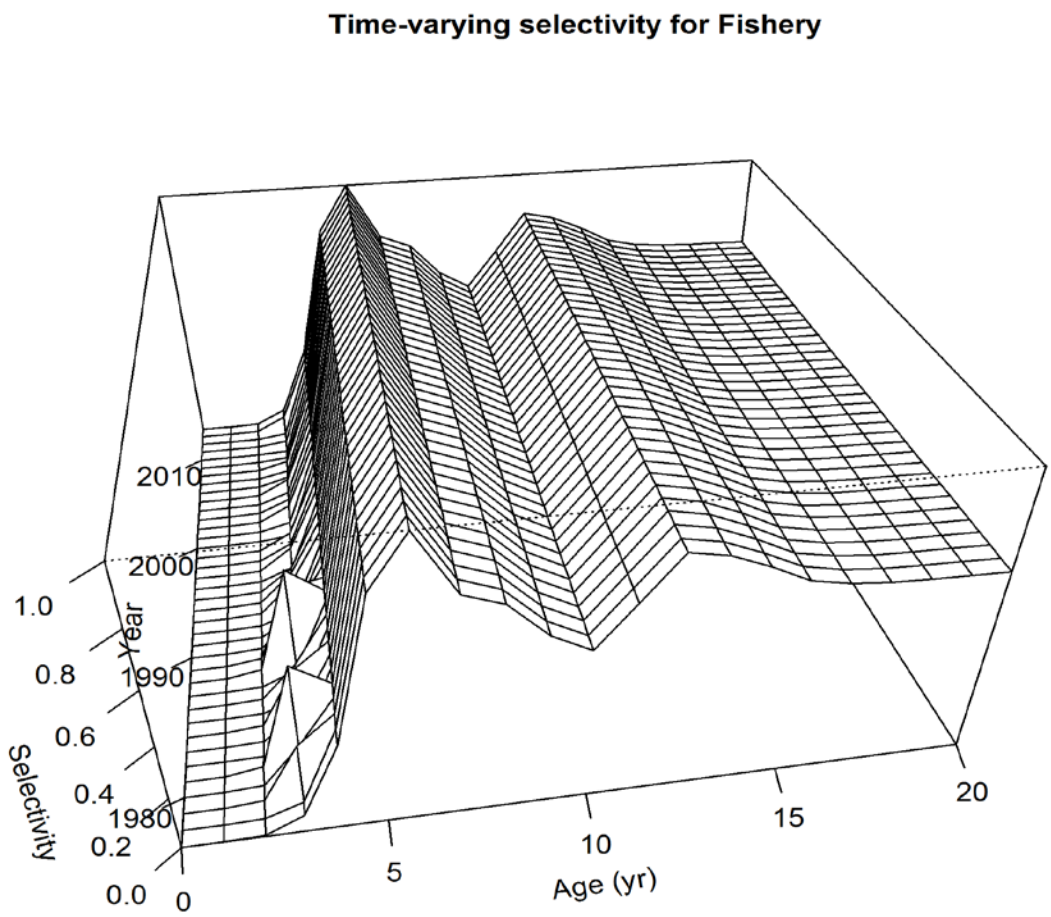
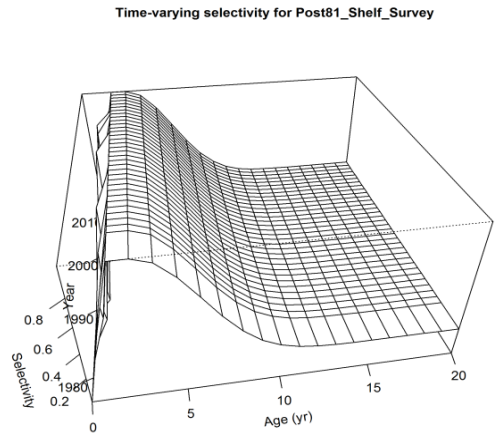
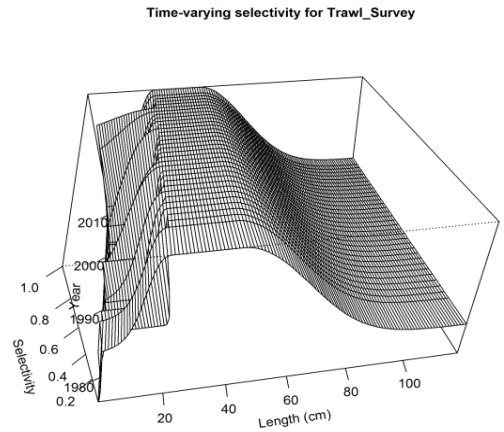


Figure 2.1.4f—Fishery selectivities estimated by Model 6.

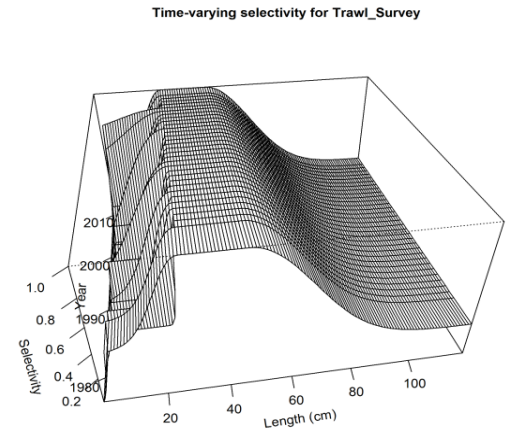
Model 1



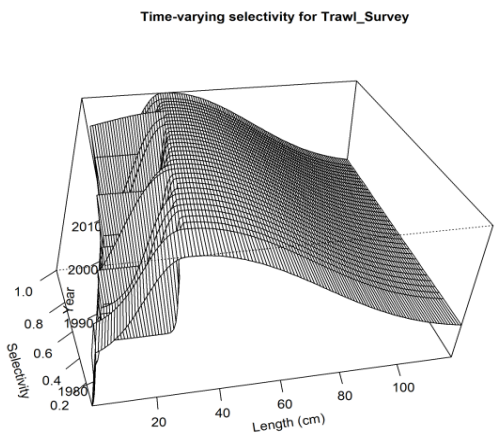
Model 2



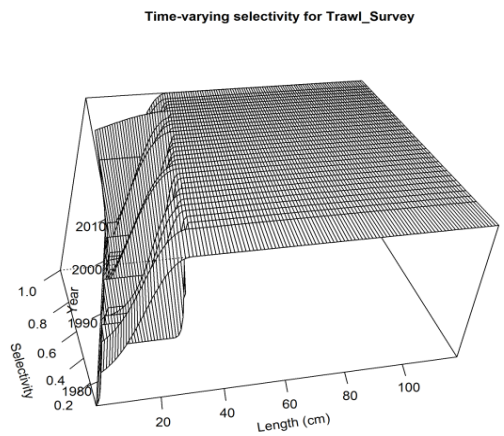
Model 3



Model 4



Model 5



Model 6

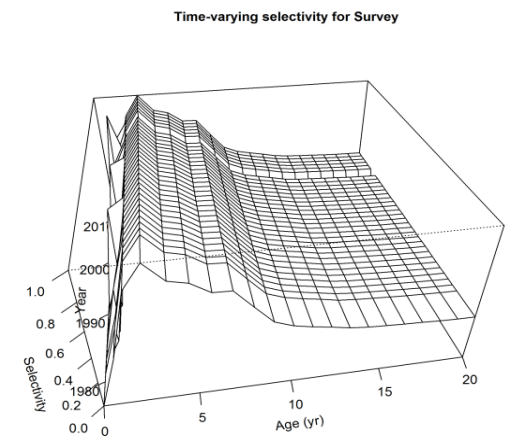


Figure 2.1.5—Survey selectivities estimated by Models 1-6.

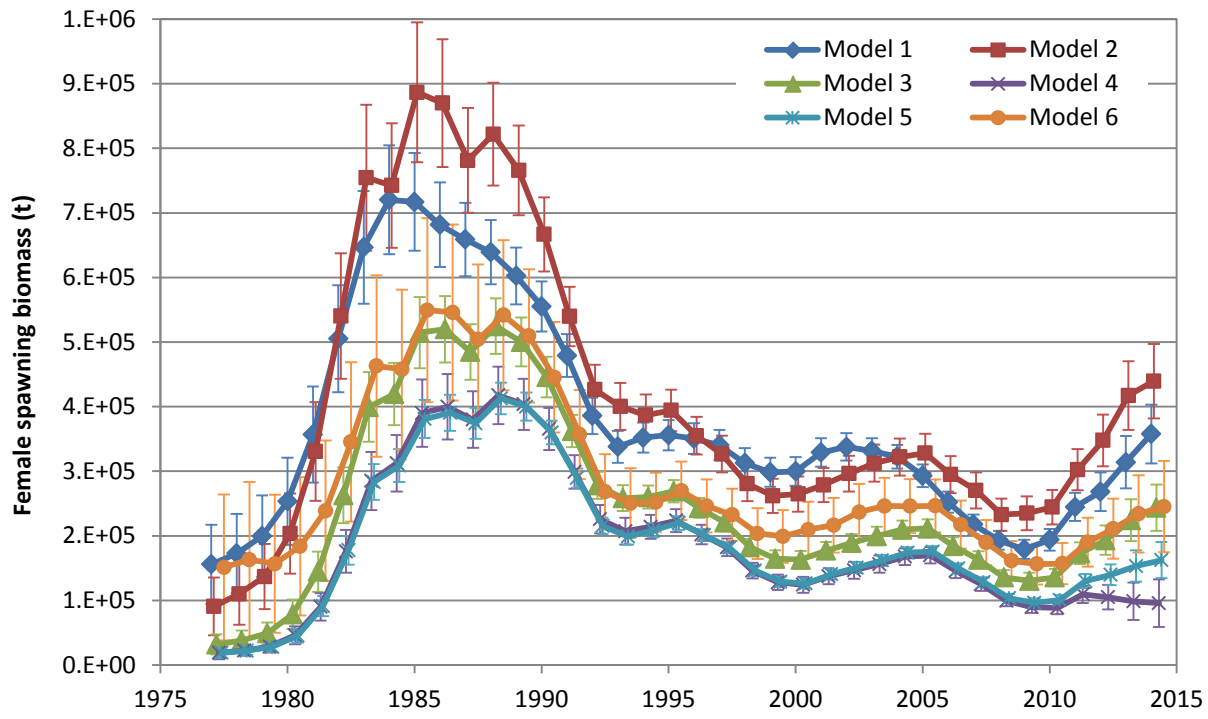


Figure 2.1.6—Model estimates of the female spawning biomass time series.

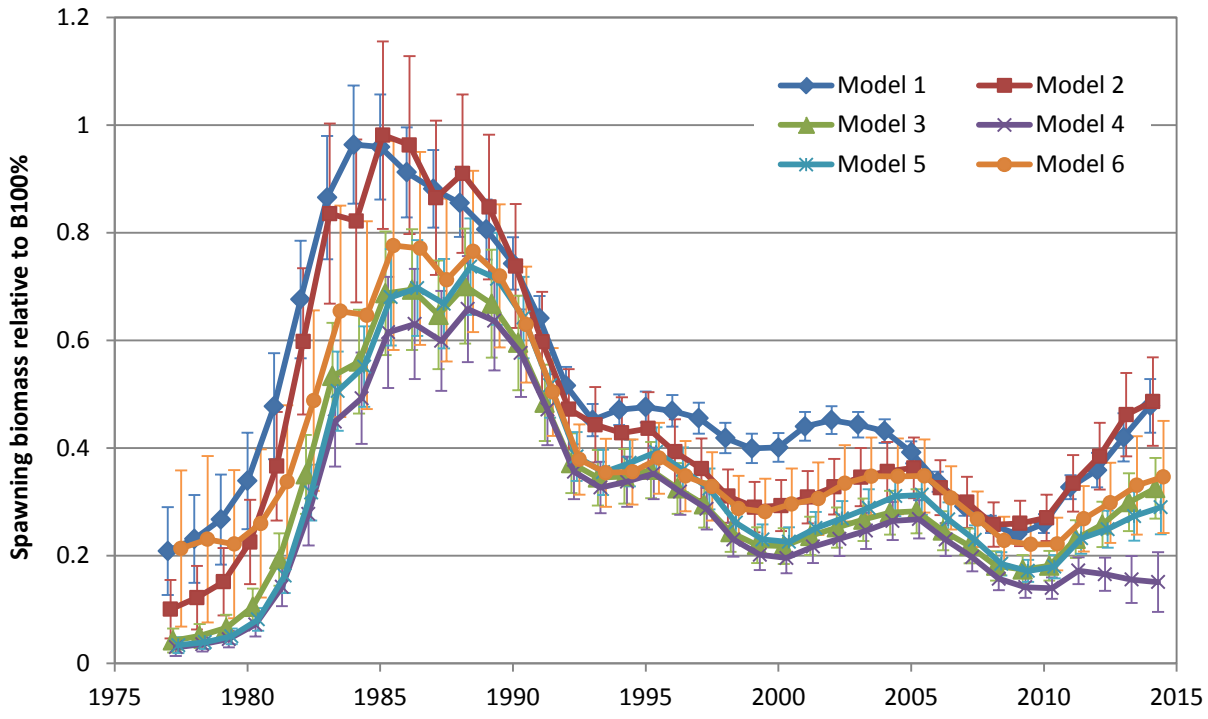


Figure 2.1.7—Model estimates of the relative female spawning biomass time series.

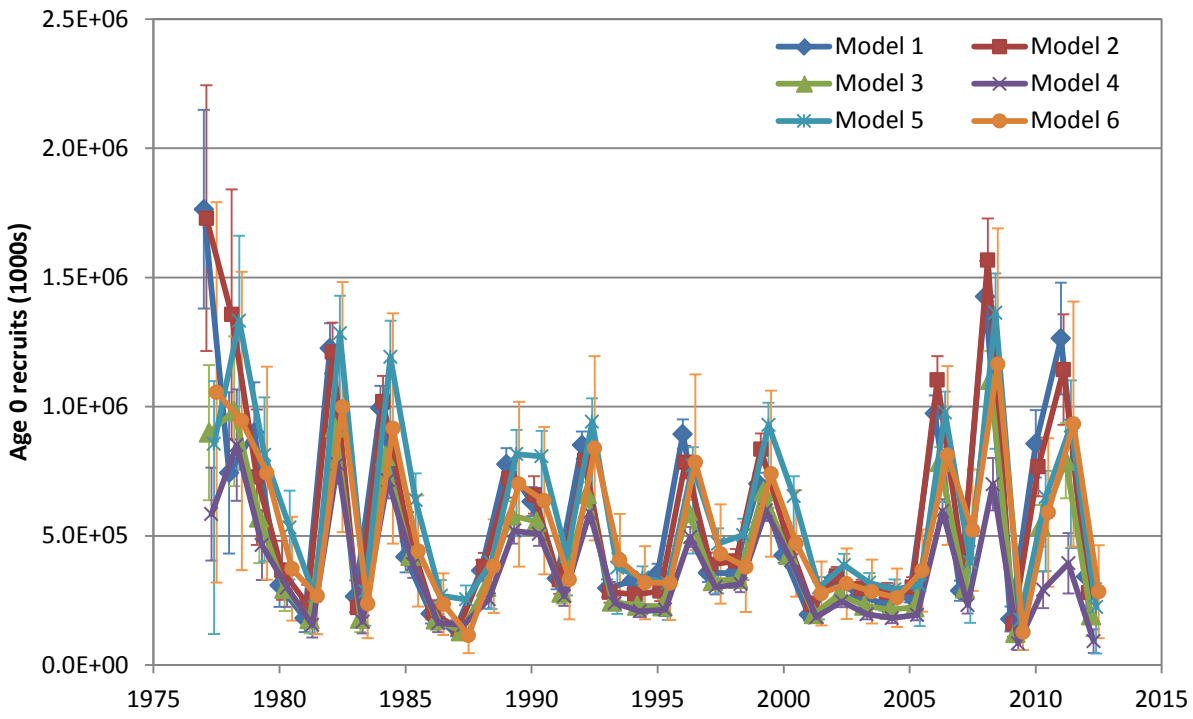


Figure 2.1.8—Model estimates of the age 0 recruitment time series.

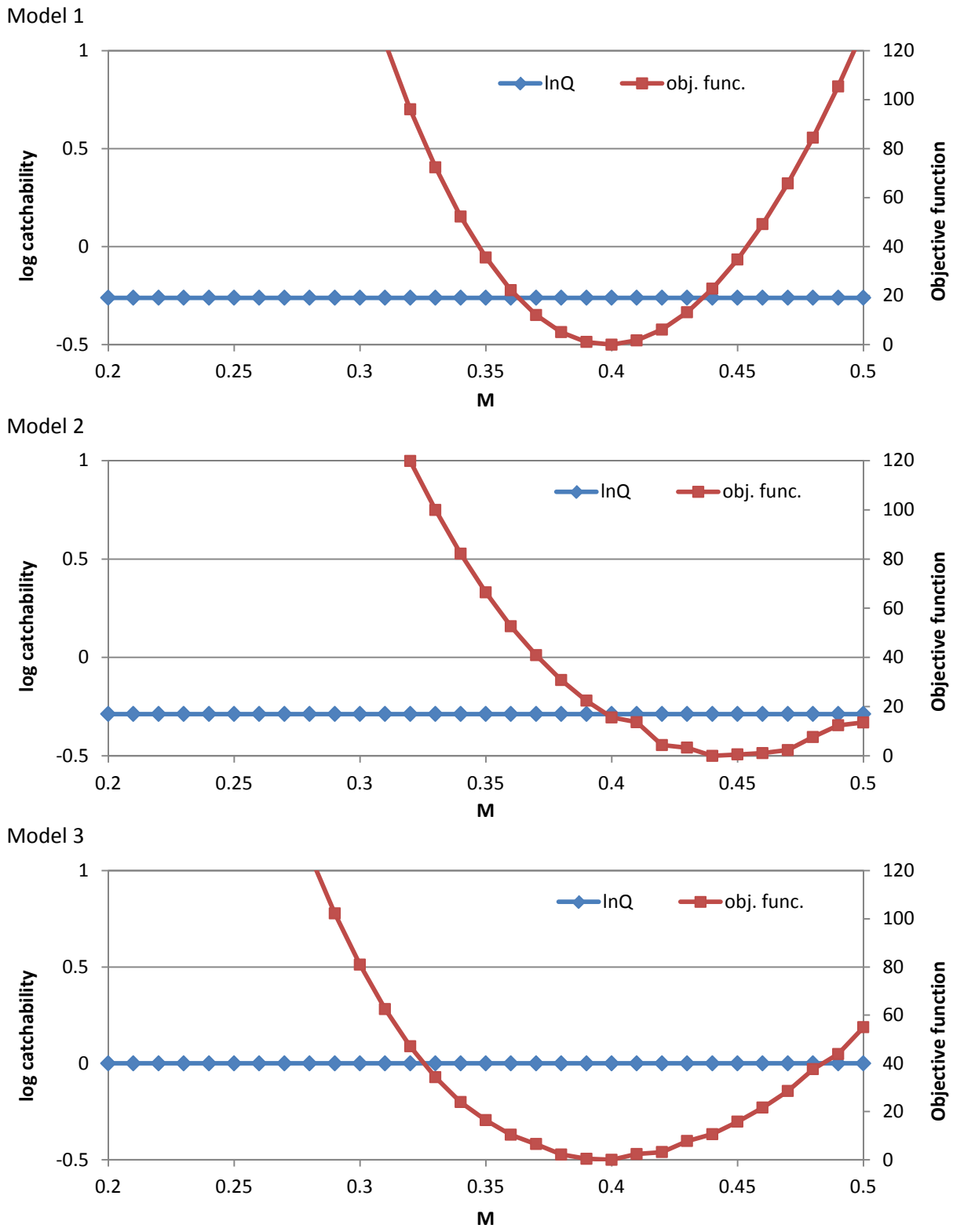


Figure 2.1.9a—Likelihood profiles with respect to the natural mortality rate for Models 1-3. Objective function minima occur at *M*=0.40 (Model 1), *M*=0.44 (Model 2), and *M*=0.40 (Model 3). The relationship between *M* and log *Q* is also shown.

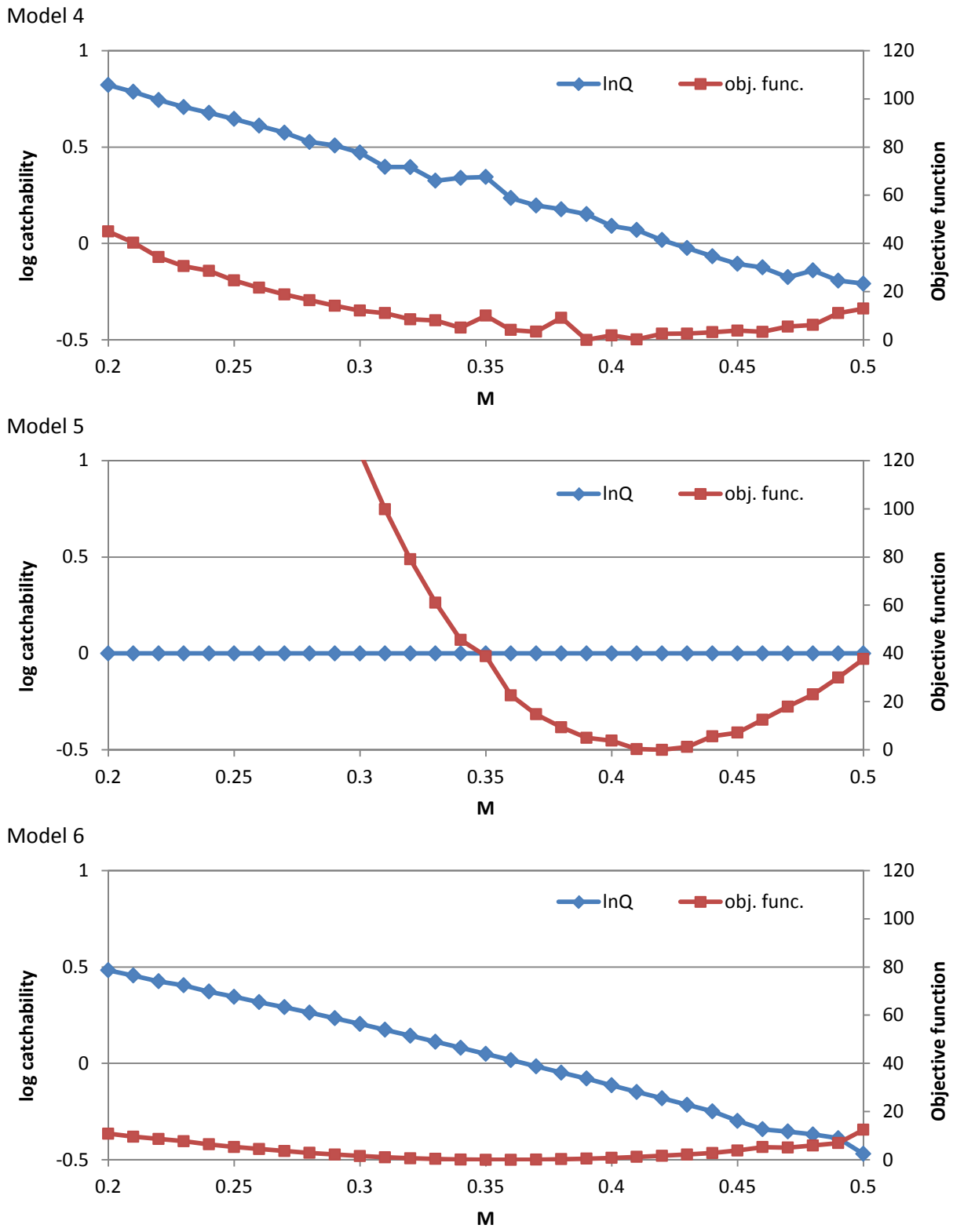


Figure 2.1.9b— Likelihood profiles with respect to the natural mortality rate for Models 4-6. Objective function minima occur at *M*=0.39 (Model 4), *M*=0.42 (Model 5), and *M*=0.36 (Model 3). The relationship between *M* and log *Q* is also shown. Jaggedness indicates lack of convergence in some runs.

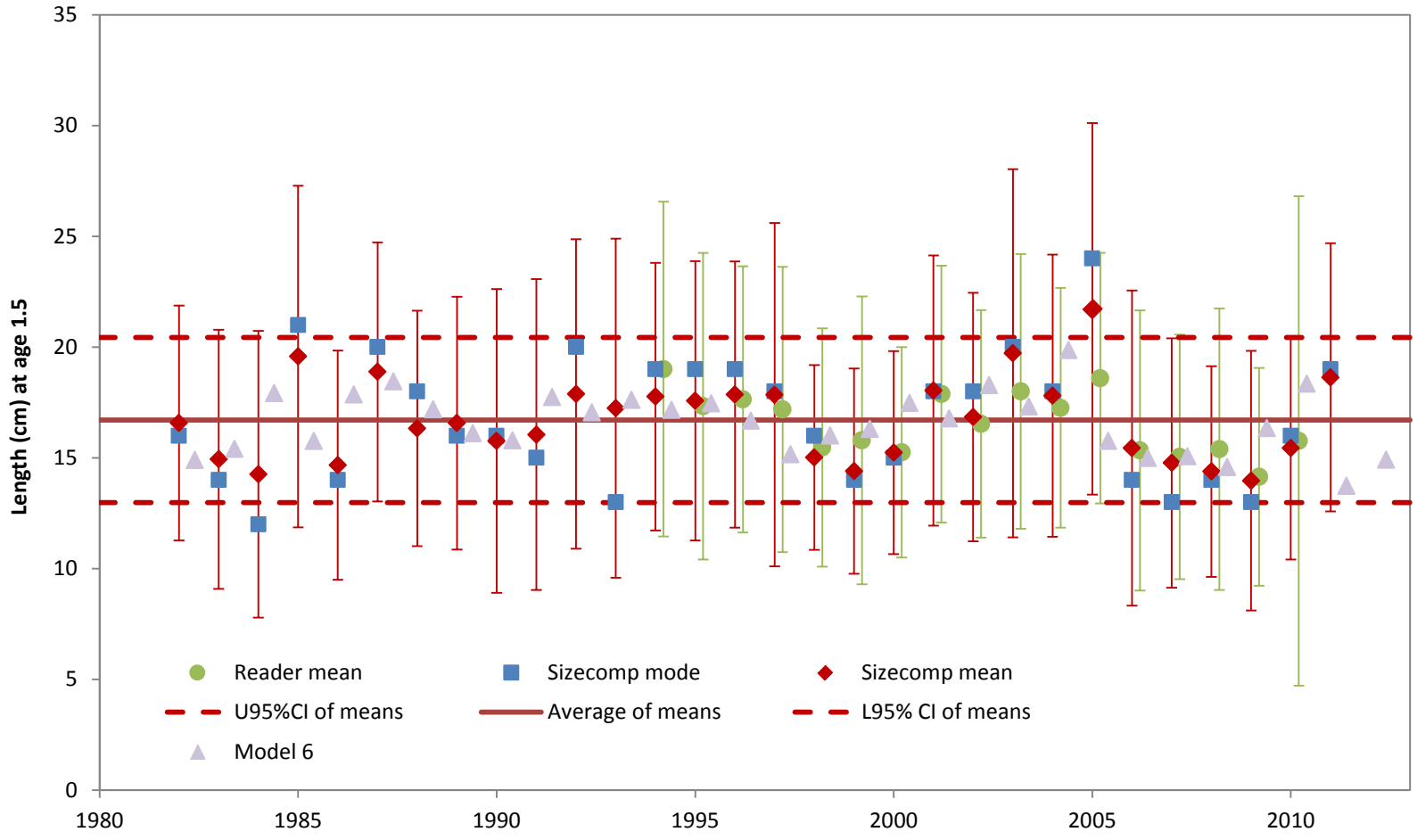


Figure 2.1.10—Various estimators of mean length (cm) at age 1.5.