Agenda Item D.8
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The 2015 stock assessment of arrowtooth flounder (*Atheresthes stomias*) in California, Oregon, and Washington waters

by

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Executive Summary

Stock, data and assessment

A catch and index only stock assessment (i.e., “data-moderate”) was applied to arrowtooth flounder treated as one coastwide stock. Three fleets and four surveys were used. Updates to both input types were made since the last assessment (Kaplan and Helser 2007). Stock Synthesis was used for all models and model treatments included maximum likelihood estimation (MLE), Markov-chain Monte Carlo (MCMC), and extended Simple Stock Synthesis (XSSS).

Derived outputs

The MLE model showed low sensitivity in derived quantities to abundance index use, steepness values and selectivity assumptions. The largest relative sensitivity was in spawning stock biomass when the old catch stream was used, but it was not a large discrepancy. The new assessment demonstrated higher biomasses in all models relative to the 2007 model (Table ES-1). Bayesian models had the highest estimated biomass (Figure ES-1), stock status (Figure ES-2) and uncertainty (Table ES-1). The differences in spawning biomass between the MLE and Bayesian models are large. No models had any significant stock status density below the target biomass reference point of $SB_{30\%}$, thus there seems to be no evidence that this is an overfished stock or that it is near the target biomass. OFL values are much higher for the Bayesian models versus the MLE. The MCMC run using a lnR_0 prior of N(11.3,0.78) is the recommended base case (Table ES-1).

Table ES-1. Derived quantity and parameter estimates for each arrowtooth flounder assessment treatment compared to the 2007 assessment. Values provided are medians with the coefficient of variation in parentheses. Proposed base case indicated in gray.

Output		MLE	MCMC			XSSS		2007 base case
			lnR_0: 3-18	lnR_0: 3-14	lnR_0: N(11.3,0.78)	$2007_{06\ depletion}$	$2015_{14\ depletion}$	
Derived quantitiy	SB0	106733 (0.12)	289431 (2.38)	169651 (1.36)	158178 (0.91)	259118 (0.69)	193673 (0.56)	80313 (0.08)
	SB2015	66085 (0.21)	257529 (2.39)	133817 (1.48)	120938 (1.1)	213227 (0.82)	141227 (0.74)	38125
	SB2015/SB0	0.62 (0.12)	0.89 (0.18)	0.79 (0.17)	0.77 (0.15)	0.83 (0.13)	0.73 (0.16)	0.47
	OFL2015	8223 (0.21)	70291 (2.39)	16610 (1.47)	15019 (1.1)	45180 (0.93)	28092 (0.84)	6523
	OFL2016	8082 (0.2)	58973 (2.39)	15762 (1.46)	14304 (1.07)	40015 (0.88)	25107 (0.79)	6207
Parameter	Mfemale	0.17	0.17	0.17	0.17	0.12 (0.34)	0.12 (0.3)	0.17
	Mmale	0.27	0.27	0.27	0.27	0.26 (0.32)	0.27 (0.31)	0.27
	h	0.82 (0.11)	0.8 (0.11)	0.81 (0.11)	0.81 (0.11)	0.85 (0.09)	0.85 (0.09)	0.9
	lnR0	10.54 (0.01)	11.54 (0.18)	11.01 (0.09)	10.95 (0.05)	10.89 (0.07)	10.48 (0.06)	10.26 (0.01)
	Tri xSD	0.18 (0.49)	0.28 (0.49)	0.25 (0.5)	0.25 (0.5)	0.21 (0.03)	0.21 (0.04)	0
	AFSC slope xSD	0.42 (0.50)	0.62 (0.70)	0.62 (0.68)	0.61 (0.66)	0.43 (0.01)	0.43 (0.01	0.07
	NWFSC slope xSD	0.08 (1.29)	0.18 (1.13)	0.17 (1.12)	0.17 (1.15)	0.06 (0.04)	0.07 (0.07)	0.36
	NWFSC xSD	0.03 (1.00)	0.08 (0.64)	0.06 (0.67)	0.06 (0.64)	0.05 (0.154)	0.04 (0.21)	0

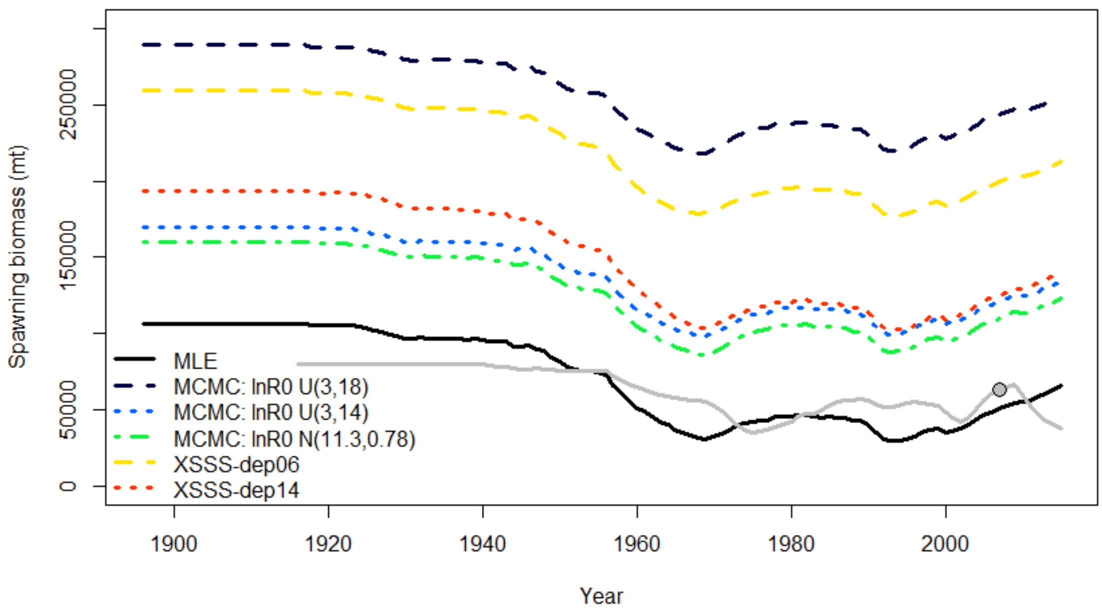

Figure ES-1. Spawning biomass time series across all potential base case models and treatments compared to the 2007 assessment. The point indicates where the 2007 assessment ended. Time series beyond that point are projected values. Proposed base case is "MCMC lnR_0 N(11.3,0.78)"

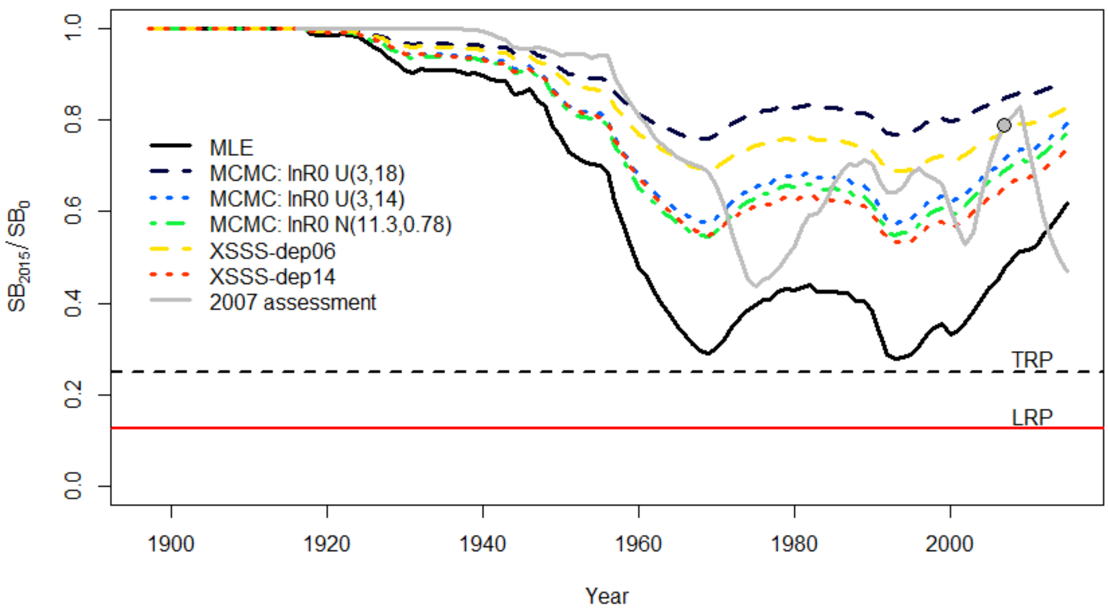

Figure ES-2. Stock status time series across all potential base case models and treatments compared to the 2007 assessment. The point indicates where the 2007 assessment ended. Time series beyond that point projected values. Proposed base case is "MCMC lnR_0 N(11.3,0.78)"

Decision table

To be determined after SSC review.

1 Introduction

This document provides details to the data, inputs, and model runs that comprise the 2015 data-moderate stock assessment for the arrowtooth flounder (*Atheresthes stomias*). The data-moderate assessment approach is strictly limited to using only catch and abundance indices to provide information on population dynamics, therefore no compositional data is used in this analysis.

1.1 Basic biology and ecology

Arrowtooth flounder (*Atheresthes stomias*), member of the right-eyed *Pleuronectidae* family of flatfishes, commonly occurs from the Bering Sea down to northern California. They have a wide depth of occurrence (9-1,145 m; Love 2011), but are most typically encountered in depths of 50-550m (Figure 1-Figure 14). Arrowtooth flounders are medium sized flatfishes, reaching sizes near 90 cm. While the previous assessment (Kaplan and Helser 2007) notes arrowtooth flounder have been aged to almost 30 years, Love (2011) registers longevity of at least 56 years old. Spies and Turnock (2013), who conducted a stock assessment in the Gulf of Alaska, record the oldest aged individual at 23 years old. Age and size at maturity indicate area- and sex-specific differences, but males generally mature at smaller size and younger ages (Kaplan and Helser 2007; Love 2011). Arrowtooth flounder are batch-spawners of eggs with extended spawning periods. Eggs can be extruded from September to March off Washington or Oregon waters. Pelagic egg and larval periods can last several months (Love 2011). Diets consist mainly of crustaceans and fish, while they are preyed on by a variety of fishes both as juveniles and adults (Field 2004, Field et al. 2006).

Most famously, arrowtooth flounder have proven a challenge to store and market to human consumers. The flesh can quickly turn to mush ("flatfish pudding"[1]), a noticeably undesirable trait to unsuspecting diners hoping to eat tasty "flounder"[2]. This mix of a lack of a substantial targeted fishery, predatory habits and the great abundance in Alaskan waters have prompted concern that arrowtooth flounder could negatively affect the population of important commercial stocks, such as walleye pollock (Mueter et al. 2011, Zador et al. 2011).

1.2 Stock Structure

There are no studies on the genetics, movement, microchemistry or spatially varying biological characteristics (other than maturity) that could indicate important stock structure relevant to a stock assessment of arrowtooth flounder populations off the Pacific Coast waters. Alaska waters also lack this basic information. Other flatfishes found with arrowtooth flounder, such as Dover (*Microstomus pacificus*), English (*Parophrys vetulus*) and petrale (*Eopsetta jordani*) soles, have typically been treated as one stock on the west coast. Furthermore, it is expected that these fish do not recognize political borders, thus it could be one continuous stock from the Pacific coast, up through Canada, and into Alaska. Despite this possibility, the current stock assessment assumes,

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[1] http://www.adn.com/article/alaska-flatfish-pudding-now-wal-mart-near-you
[2] http://reviews.walmart.com/1336/11980622/arrowtooth-flounder-fillets-2-lbs-reviews/reviews.htm

as did the previous assessment (Kaplan and Helser 2007), that U.S. west coast is one continuous stock that ends at the Canadian border.

2 Assessment

2.1 Data and Inputs

2.1.1 Removal histories

The previous assessment identified three primary removal sources: the mink fishery (1928-1980), the fillet fishery (1981-2006), and the discard fishery (1956-2006). The mink fishery was, in essence, an historical fishery that gave way to PacFIN reporting of the fillet fishery starting in 1981. The previous assessment reported the bycatch/dead discard fishery as beginning abruptly in 1956, much of which was not officially recorded. This lack of historically recorded discards required a reconstruction of possible dead discards, of which the former assessment approach chose to apply a 13% bycatch rate to the catches of Dover, English and petrale soles (Kaplan and Helser 2007). All bycatch was assumed to be discarded, with a discard mortality of 100%.

The approach in this assessment to removal histories retains the three primary removal sectors, but combines new data and new and previous estimation methods to construct the full removal time series.

2.1.1.1 Historical removals (1896-1981)

Formal historical catch (landings only) reconstructions for arrowtooth flounder are available for California (Ralston et al. 2010) and Oregon (V. Gertseva, pers. comm.; Table 1). The Oregon time series moves the model back from 1916 to 1896. Washington does not have a historical catch reconstruction for arrowtooth flounder, so the reconstruction made in the 2007 assessment was retained for this area. Notable differences in the occurrence of peak landings are apparent for the two states with new catch reconstructions (Figure 15).

2.1.1.2 Fillet fishery

PacFIN remains the sole (no pun intended, arrowtooth is a flounder) source of arrowtooth flounder landings from 1981-present. The differences between the current and former PacFIN estimates for years in common are small and likely due to changes in updates in fish ticket processing or changes in species compositions used to allocate catches to arrowtooth flounder.

2.1.1.3 Bycatch/ Dead Discards

Coastwide discards have been directly measured for arrowtooth flounder by the West Coast Groundfish Observer program starting in 2002 and provided through 2013 (Somers et al. 2014; K. Somers pers. comm.; Table 2). Discards in 2014 are not yet available, so were estimated as the harmonic mean of the discard ratio of discarded (with 100% discard mortality) to landed arrowtooth flounder from years 2011-2013, the years individual fishing quotas were established for the trawl fishery (the primary removal sector of arrowtooth flounder; Table 2). The resultant discard rate was 15.5% and multiplied by the landing of arrowtooth in 2014.

Historical discard removals provide the bulk of discard removal years, but have no primary source. The former approach of applying a 13% discard ratio to the total landings of Dover, English and petrale soles was reconsidered in this assessment. Instead of a constant ratio, a generalized linear model (GLM) framework predicting arrowtooth flounder discards from flatfish landings was explored (e.g., $ATF_{discards}=Dover_{landings}+English_{landings}+Petrale_{landings}$). And instead of just the three flatfished considered before, it was reasoned that the amount of arrowtooth flounder could also provide a reasonable predictive variable (i.e., the more arrowtooth landed may be associated with how much was discarded), as well as the potential inclusion of rex sole, another flatfish associated with arrowtooth catches (Cope and Haltuch 2012). Flatfish removal time series were taken from the most recent stock assessments of each stock. Each possible combination of flatfish landings was considered and Akaike Information Criteria (AIC; Burnham and Anderson 2002) was used to choose between models within two different assumed error structures (Gaussian and gamma). Data under both error structures supported the same model (Table 3). This model was then used to predict the amount of arrowtooth flounder discards back to the beginning of the catch time series (Table 2), assuming 100% discard mortality as was previously done. Difference between the former and current assessment discard removal time series is substantial, as is the subsequent total removal history (Figure 15).

Total removals for the current assessment are provided in Table 2 and Figure 16. Sensitivity to the removal differences in the current and former assessments was explored through model sensitivity.

2.1.2 Abundance indices

Four abundance indices, all based on fishery-independent trawl surveys, were retained from the last assessment for consideration in the base model: The Alaska Fisheries Science Center Triennial (1980-2004) and slope surveys (1997, 1999-2001) and the Northwest Fisheries Science Center slope (1999-2002) and shelf-slope (2003-2014) surveys. No other indices were considered, though it has been routine to consider the Triennial shelf survey as two separate time series (1980-1992 and 1995-2004), something that may decrease the influence of the index in the assessment. This proposed break in the survey is due to a major change in the depths covered and survey timing, with the years before 1995 infrequently sampling depths beyond 366m and starting in July rather than in June. Given arrowtooth flounder is present at depths greater than 350m, but more typically inhabit shallower depths, the magnitude of the survey change in not obvious (Figure 2). Both treatments of the Triennial survey (continuous and split) are considered when developing and exploring model sensitivities to the abundance indices.

Approaches to standardizing the data sets have changed substantially since 2007. Since the mid-2000s, trawl survey indices have typically been generated using a delta generalized linear mixed model (delta-GLMM) framework (Helser et al. 2004). This GLMM framework allows the exploration of non-normal error distributions while retaining the statistical approach and theory of linear modeling. The “delta” portion of the framework allows separate modelling of the presence-absence (via logistic mixed regression) and the magnitude of non-zero catches (via generalized linear mixed modelling). The “mixed” portion of the model refers to the fact that not all model effects are fixed. Specifically, the vessel component, which can change over the time series, is considered a random effect. The strata (i.e., depth-latitude combination)-year level interaction was also explored as either a fixed or random effect, as well as not included in the model ("no effect"). Subsequent work has developed the delta-GLMM approach (Thorson and Ward 2014) to be quicker and more efficient, and thus differs from the tool used in the previous assessment.

The delta-GLMM was applied to each of the four indices using version 1.0.0 of the Bayesian stratified delta-GLMM (R package *BayesDeltaGLM* available at https://github.com/nwfsc-assess/nwfscDeltaGLM). Six candidate models for each survey (Table 4) were considered that included two possible distributions for positive catch rates (lognormal and gamma) and three possible strata-year interaction configurations (fixed, random, or no effect). Stratification for each survey was determined by considering first the survey design-based strata, then any additional strata that give at least 5 positive occurrences for each stratum. Survey design-based depth strata for each survey relevant for arrowtooth flounder were 55-183, 184-366 and 367-500m (AFSC Triennial shelf); 55-183, 184-300 and 301-500m (AFSC slope); 183-549m (NWFSC slope), 55-183 m and 184-549m (NWFSC shelf-slope). Strata used in the delta-GLMM models are given in Figure 1 to Figure 14. All strata are similar to what was used in the 2007 assessment except for the NWFSC shelf-slope survey. Indices based on both the old and newly proposed (i.e., an alternative based on positive samples) strata are developed and considered in model sensitivity runs. All models used three independent Markov chain Monte Carlo simulations of 100,000 samples as burn-in, followed by 100,000 monitored samples and a thinning rate of 100 (i.e., retaining 3,000 samples across all three simulations). Non-convergence was assessed by visual inspection of mixing in sampling chains for all estimated and derived parameters. Model fit was examined through a Bayesian quantile-quantile (Q-Q) plot. Final model selection for each survey used DIC (Table 4). The comparison of the indices and associated variability are provided in Figure 17 to Figure 23. Q-Q plots for each selected model are provided in Figure 24, with no apparent misfits to the underlying assumption of positive catch distribution in the selected model. All GLMM treatments of the triennial slope data failed to produce useable indices (highly variable point index values with unusably large uncertainty; Figure 20), so the design-based index was used instead.

In addition to the delta-GLMM framework, a newly developed geostatistical approach (Shelton et al. 2014; Thorson et al. 2015) was applied to the NWFSC shelf-slope data (the method has yet to be developed for the other index data). This approach was reviewed by the PFMC SSC and recently applied in the canary rockfish assessment (Thorson and Wetzel, in review). The geostatistical approach treats spatial variation in encounter rates of positive catch rates as a random function (i.e., the value of this random function at 1000 pre-defined locations (i.e., "knots") is treated as a random effect). The annual variation and the magnitude of residual variation and variation among vessels can therefore be treated as fixed effects, and estimated via maximum marginal likelihood. Two benefits to this approach is that one avoids having to determine sampling strata (see above GLMM sensitivities) and the geostatistical approach generally decreases abundance estimation imprecision (Thorson et al *In press*). Two distributions for positive catches (gamma and lognormal) were considered and AIC was used to select among models. Version 3.2.0 of the geostatistical model software (available at https://github.com/nwfsc-assess/geostatistical_delta-GLMM) was used. AIC did not demonstrate significant differences between the gamma and lognormal models (Table 4), so each was retained for base case consideration. Q-Q plots for each model showed similar behavior and no indication of a misspecification in dispersion of positive catch rates (Figure 25). The resultant predicted spatial distribution of arrowtooth flounder are very similar in each model, indicating arrowtooth flounder is unsurprisingly most common from Northern California to Washington in intermediate survey depths (Figure 26). Abundance indices are given in Figure 21 and Figure 22 as compared to delta-GLMM models using the new and old strata. The reduction in index variance from the geostatistical models is noticeable.

2.1.3 Biological parameters

The major biological inputs to the model are age and growth parameters, natural mortality, weight-length, maturity and stock-recruitment parameters (Table 5). No major works on life history of arrowtooth flounder have been completed since the last assessment, so all fixed values are taken from the prior 2007 assessment, which are in line with arrowtooth assessments from other regions (e.g., Spies and Turnock 2013).

2.1.4 Available data not used

The data-moderate approach has been defined to use catch, life history, and abundance data only to provide stock status and derived quantities. This leaves out length, weight and age compositions that would otherwise be used. Table 6 reports the collections of those biological samples not being used in the assessment.

2.2 History of Modeling Approaches Used for this Stock

Two previous stock assessments have been conducted for arrowtooth resources off the U.S. west coast. Rickey (1993) provided the first look at arrowtooth flounder resources off Oregon and Washington using an equilibrium yield per recruit model. Kaplan and Helser (2007) used a statistical catch-at-age model (Stock Synthesis 2) to incorporate catches and life history information with indices of abundance and biological compositions (both age and length compositions) to estimate derived management quantities. Given the limitations of the data-moderate approach, the later assessment estimated values provides the basis for many parameter values in the current model configuration.

2.3 Model Description

Stock Synthesis (SS; Methot and Wetzel 2013) has continued to develop, and is currently in its third version (SS3 v. 3.24o). Extensions of Stock Synthesis have proved it to be a flexible means to explore simplified models (Cope 2013; Cope et al. 2013; Cope et al. 2015; Dick et al. 2007) as well as complex data-driven models. The data-limited stock assessment are conveniently captured in the Stock Synthesis framework, thus it is used in this assessment. Explicitly, the model being used is sex- and age-structured with a Beverton-Holt stock-recruitment relationship, though recruitment is assumed deterministic. Selectivity values for each fishery and survey are assumed the same as was estimated from the last assessment, which includes offsets for males (Table 7; Figure 27). In other applications of data-limited or –moderate models, it has been common to assume selectivity equals maturity when nothing else is known; this assumption was explored via model sensitivity, with male offsets removed.

There are three applications of the SS3 model, all varying in how uncertainty is estimated.

2.3.1 Maximum likelihood estimation (MLE) with asymptotic variation

There are six estimated parameters in the MLE model (Table 5): the log-value of initial recruitment (lnR_0), steepness (h) and extra variability on each of the four surveys. Attempts were made to estimate natural mortality for females and/or males, but no converged model was found. While most of the estimated parameters assumed uniform priors (Table 5), the steepness prior is based on the Myers et al. (1999) developed a normally distributed steepness meta-analysis for flatfishes ($\mu = 0.8$; $\sigma = 0.093$). This is the typical steepness prior currently used for west coast flatfishes, but different than what was used in the past assessment (fixed at $h = 0.9$). The major likelihood components therefore include fits to the abundance indices and any penalties on priors. Sensitivities of derived quantities to the inclusion of indices of abundance were also explored. Stock Synthesis is coded in AD Model Builder, thus converged models that produce Hessians provide the calculation of asymptotic variance for all estimated parameters and derived quantities.

2.3.2 Markov Chain Monte Carlo (MCMC)

In addition to the asymptotic variance of the base case, a MCMC chain of 10,200,000 was run (-mcmc 10200000) with the first 200,000 iterations (-mcscale 200000) undergoing a rescaling of the covariance matrix until a desirable acceptance rate is achieved, and every 10,000th iteration being retained (-mcsave 10000). The first 99 iterations are then removed to leave 1000 draws for the posterior. The application of MCMC in these data-moderate models has not always converged, so a third way of estimating uncertainty was explored using XSSS with Adaptive Importance Sampling. Subsequent evaluation of the XSSS models also led to two additional MCMC runs: 1) The lnR_0 prior truncated to an upper value of 14 based on the post-model, pre-data (i.e., not fit to the index data) distributions of lnR_0 from the XSSS models (details of those models given in the next section); 2) prior on lnR_0 set to the distribution found via the XSSS post-model, pre-data (N(11.3,0.78)) based on the stock status prior from the 2007 assessment (Figure 28).

2.3.3 XSSS with Adaptive Importance Sampling (AIS)

Sampling importance resampling (SIR) (Ruben 1988) and the AIS extension that updates the initial sampling distributions based on a completion (convergence) criterion (e.g., entropy) has become a standard application in data-moderate models using extended Simple Stock Synthesis (XSSS; Cope et al. 2015). This approach allows for additional parameter uncertainty to be explored, in this case the estimation of female and male natural mortality (assuming a lognormal prior using the mean values from the base case, and standard deviation = 0.3), but also requires a prior on stock status (SB_y/SB_0, where y is year) that can be set for any given year. Two stock status priors were explored as potential base case models: 1) using stock status in 2006 from the previous assessment (0.6 in 2006); 2) using stock status in 2014 from the current base case MLE (0.58 in 2014). The last option comes from the idea that the prior can be informed by the MLE because the XSSS method is being used in a manner subsequent to establishing the MLE to get the variance. Each of the priors assumed a beta distribution with a beta standard deviation of 0.2, a value that is a midpoint of stock status prior variance for west coast groundfishes (Cope et al. 2014). Sensitivity to these priors is explored with two additional models: 1) using the stock status (0.45) from the MLE in 2006, 2) assuming natural mortality is fixed using the 2006 stock status prior from the 2007 assessment, so only steepness and stock status have sampling distributions.

Details of the XSSS using the AIS approach are outlined in Cope et al. 2015, but the basic approach is as follows: 2000 initial and subsequent parameter draws are taken until the entropy criterion (the summed ratio of sampling weights to sample size) of 0.92 is met (otherwise re-reweighted samples are iteratively drawn until it is) and a final sampling of 5000 draws is made. Each final draw results in parameter estimates and derived quantities that are summarized as posterior distributions.

2.3.4 Pros and cons of each approach

- MLE: approach offers the quickest way to obtain results, allowing for expedited sensitivity tests and is often what is used in west coast stock assessments using Stock Synthesis (e.g., what was used in the last assessment), but the MLE traditional estimates less variance than Bayesian methods.
- MCMC: works from the MLE results (i.e., requires a converged MLE model) and explores uncertainty more thoroughly than the MLE, but it takes a much longer time (e.g., 60 seconds versus 48 hours) and convergence does not always occur, mostly due to likelihood values lacking sufficient contrast and wide priors assumed on lnR_0. Because of long run times, model exploration is limited to the MLE. In both the MLE and MCMC, the estimation process may also limit what parameters are estimable. In this case, natural mortality is not estimated.
- XSSS with AIS: Much quicker than MCMC (e.g., runs in this model took 9 hours) while also exploring uncertainty typically better than the MLE. Also effective at exploring parameters not estimable in the MLE and MCMC models (e.g., natural mortality) as long as the overall number of parameters are low (e.g., < 10 parameters). This approach does require a prior on stock status and relies on an entropy criterion (used as a convergence indicator) that is not well understood. Post-processing of results is much more time intensive than either MLE or MCMC approaches.

2.4 Base-Models, Uncertainty and Sensitivity Analyses

2.4.1 Base case abundance index selection

The first step in selecting a data-moderate base case was choosing which formulation of the Triennial and NWFSC shelf-slope abundance indices to use (there are only one version of each slope survey considered, so further model selection is not needed). All combinations of the two possible Triennial surveys (continuous or split) and four possible NWFSC shelf-slope (new or old strata and the gamma or lognormal geospatial delta GLMM) indices were examined via MLE models (Table 8, scenarios 1-8). Given no formal model selection is available to make these decisions, all surveys were included in the SS3 data file and their contribution to the likelihood was controlled via the lambda parameter in the control file (a value of 0 removes the likelihood contribution; 1 maintains full likelihood contribution). The usefulness of this set-up allows one to evaluate consistency and measure how the use of one survey affects the likelihood component of all other surveys, whether they are contributing to the likelihood component or not. The sensitivity of each survey to the inclusion or exclusion of other surveys was also considered based on changes in the likelihood components, parameter estimates and derived quantities.

In general, any survey configuration produced similar productivity parameters and relatively similar derived quantities (Table 8), so the decision between them is not a choice among extremes. Splitting the triennial survey showed the largest sensitivity to the inclusion of the NWFSC survey and generally indicated a more depleted stock (Table 8). The fits to the split series remained good when implementing the continuous series (because extra variance was estimated for the continuous series; scenarios 1-4 in Table 8), while the continuous series was poorly fit when using the split series (scenarios 5-8 in Table 8). While the absolute biomass differences were not large between the two index treatments or from the design-based index, the continuous survey had less variability (Figure 29). Given the above results, the change in survey depths had little influence on arrowtooth CPUE, and it is not apparent timing changes in the survey would affect arrowtooth abundance, the continuous time series (1980-2004) was chosen for the base case.

The NWFSC shelf-slope based on the new strata showed the highest catchability value (>1; Table 8) and the biggest difference in index value, though the trends matched the geostatistical indices better than the old strata index (Figure 30). The GLMM based on the old strata also had catchability >1 in scenarios when not contributing to the overall likelihood, and the largest absolute biomass. The geostatistical indices had substantially lower uncertainty and did not require explicit strata definitions, while also showing more similarity to the design-based values (Figure 30). The index based on the lognormal geostatistical delta GLMM model was ultimately chosen for the base case for the following reasons: a) general lack of model output sensitivity to the choice of these indices in general (i.e., little penalty for choosing any particular one), b) the lower uncertainty of the geostatistical indices, c) the lognormal geostatistical index retained the general trend of the geostatistical gamma and new strata indices, but was not the extreme in the estimation of scale as those two models were (high and low, respectively; Figure 30), and d) had slightly better fits (i.e., more consistency) to the other indices than the other indices.

Using all design-based indices instead of GLMM-derived indices demonstrated little sensitivity, with lower absolute biomass and a more depleted stock (scenario 19 in Table 8), though this was not seriously considered for base case treatment given the many benefits of the GLMM treatment in the other indices.

The final indices used in the base case arrowtooth flounder model showed mostly scale differences compared to the indices used in the 2007 assessment (Figure 31 to Figure 34). Uncertainty tended to be lower in the current estimations. One notable difference comes in the NWFSC shelf-slope survey (Figure 34). The 2007 assessment only had three years available, while the current has an additional eight years. The trends are very different, with the former short time series showing a slight downward trend, whereas the current index indicates a strong upward trend in the population over the whole time series.

Model input files for the MLE (and from which the other model treatments are generated) are provided in Appendices A-D.

2.4.2 Model fits and diagnostics

2.4.2.1 MLE

A converged model was found with appropriate gradient, covariance and Hessian properties. Jittering the starting value of estimated parameters helped confirm the model did not settle on a local likelihood minimum. A jitter value of 0.5 was applied 100 times and confirmed the model likelihood minimum over a large exploration of initial parameter values. The converged model demonstrated good fits to each index of abundance (Figure 36 to Figure 39). Analytical estimates of catchability for each parameter seemed reasonable (Table 8) and are in line with Dover sole.

2.4.2.2 MCMC

Trace and other diagnostic plots for all parameters and select derived parameters of each considered MCMC run are given in Appendix E. There are no indications in any of the model treatments of non-convergence as the objective function and parameter trace plots appear acceptable, as do the autocorrelation plots (Figure E.1 1 to Figure E.1 7; Figure E.2 1 to Figure E.2 7;Figure E.3 1 to Figure E.3 7). Derived quantities show greater variability in the trace plots and longer density tails particularly in the broader $\ln R_0$ priors (Figure E.1 8 to Figure E.1 10; Figure E.2 8 to Figure E.2 10; Figure E.3 8 to Figure E.3 10). Additional MCMC diagnostic do not indicate any substantial convergence issues (Table 9). Posterior values for all estimated parameters relative to the prior and MLE values are given in Figure 40 to Figure 42. Median values are most different for $\ln R_0$, with the MCMC results indicating a larger overall biomass, but with the posterior mode at each MLE. The MCMC run using the $\ln R_0$ prior implied from the stock status prior from the 2007 assessment is most closely matched to the MLE. Pairs plots indicate the expected strong correlation between $\ln R_0$ and stock status in the current year for each MCMC model treatment (Figure 43 to Figure 45).

2.4.2.3 XSSS

Two main models based on different stock status priors are considered as potential base case models: 1) stock status developed from the 2007 assessment for year 2006; 2) stock status prior developed from the current assessment MLE for year 2015. Pair plots indicated both models show correlations between female mortality and the stock status prior (Figure 46 and Figure 47). Comparisons of the prior, post-model (catch-only; no fits to the abundance indices), and posterior distributions (complete model fitting) for the four input parameters show departures from the prior for three of the four parameters with a notable portion of the difference occurring before the introduction of the abundance indices, though their inclusion also caused further deviations from the prior (Figure 48 and Figure 49). Fits to the indices are not inconsistent with the indices of abundance, but very rigid in both models (Figure 50 and Figure 51). Analytical estimates of catchability for each survey for both models are all below 1 (Figure 52), consistent with the MCMC runs.

2.4.3 MLE sensitivities

The MLE from the initial base case model (using a lnR_0 prior of Unif(3,18)) was generally insensitive to several alternative data and parameter scenarios (Table 8). Removal of different indices (scenarios 9-14) from the base case did not show any significant sensitivity. Assuming selectivity is equal to maturity (rather than assuming the more complex values from the 2007 assessment) made little difference in model outputs. The largest sensitivity observed was when using the catch stream from the 2007 assessment (scenarios 16 and 17). While this had small influence on the final stock status, it did change the absolute abundance of the stock, making the scale more similar to the 2007 assessment. In general, spawning biomass was more sensitive (and thus less certain) than stock status or any parameter value estimate. Estimates of parameters values were generally stable across all sensitivity runs.

2.4.4 Results and comparisons among MLE, MCMC and XSSS models

2.4.4.1 Spawning biomass

Spawning biomass estimates are similar among the MLE estimates between the 2007 and current assessments, but greatly differ from the Bayesian models (Table 10; Figure 53). Uncertainty is also much higher (as anticipated) in the Bayesian models (Table 10; Figure 54 and Figure 55) despite starting with different stock status priors. The median MLE is on the low end of the uncertainty estimates of the MCMC runs (Figure 54), but not contained in the uncertainty envelope of either XSSS model. The two sensitivity runs of the XSSS model (using a 2006 stock status prior from the current assessment and no estimation of natural mortality) also differed greatly from the MLEs, thus relatively high spawning biomass estimates were insensitive to the choice of stock status prior (Table 10). Limiting the possible values of natural mortality values made the spawning biomass estimates even higher.

The main scaling parameter in these models is the initial recruitment parameter (lnR_0). The posterior values for each proposed base case (Figure 56) indicates the low uncertainty in the MLE estimate and the longer tail of values in the Bayesian model, consistent with the differences is scale seen in biomass (Table 10; Figure 53). The XSSS models are able to express lower values of lnR_0 because of the added uncertainty in the natural mortality parameters being explored. The MCMC models do capture the mode found in the MLE, despite the differences in median values (Figure 40 to Figure 42). Considering the post-model, pre-data distribution of lnR_0 for the XSSS models versus the assumed lnR_0 prior in the MLE and MCMC model (Figure 28), it is clear that the stock status priors used in the XSSS models were more restrictive than the initial MCMC model using the broadest $\ln R_0$ prior, thus explaining the shorter tails in those models. The MCMC using the normally distributed $\ln R_0$ prior to match the XSSS model using the 2006 stock status prior from the last assessment still produced a smaller biomass estimates (Table 10). Regardless, all the Bayesian models support greater biomass and greater uncertainty relative to the MLE, and the MCMC runs all had higher uncertainty than the XSSS models (Table 10). A likelihood profile demonstrates how high $\ln R_0$ values are not far removed in likelihood space from the MLE, but result in much higher spawning biomass (Figure 57). Stock status also rapidly rises as $\ln R_0$ increases, with values of $\ln R_0$ above 14 leading to huge biomass with no reduction in stock size (i.e., biomass is essentially at unfished conditions).

2.4.4.2 Stock status

Stock status is also different between the current MLE and the Bayesian models, with the latter estimating substantially higher status (Table 10; Figure 59 and Figure 60). The 2007 assessment MLE (before the projection period) is closer to the Bayesian estimates of stock status. Uncertainty is much larger in the Bayesian models (again, largest in the MCMC results) relative to the asymptotic MLE results (Figure 59). The MLE stock status time series is on the low end of the uncertainty estimates of the MCMC models (Figure 59) and the very low end of the uncertainty envelopes of the XSSS models (Figure 60). Despite this mismatch in stock status estimation, none of the models propose any significant posterior density below the target reference point of $SB_{30\%}$ (Figure 61). The most restricted MCMC run (N(11.3,0.78)) and the two XSSS runs all show one mode, whereas the MCMC runs using the uniform priors on $\ln R_0$ are bimodal. All Bayesian models show how the stock status quickly approaches a virgin state once $\ln R_0$ is larger than 12 and essentially reach that point at $\ln R_0 \geq 14$ (Figure 62), which explains the bimodality in the least restrictive $\ln R_0$ priors used in the MCMC runs.

2.4.5 Proposed base case for management

Several possible base case models have been proposed. While there are benefits and drawbacks to each, the MCMC run using a prior on $\ln R_0$ of N(11.3,0.78) that is equivalent to using the stock status prior in 2006 from the last assessment is put forward as the base case for status determination and management use. Secondarily, one of the XSSS models would be recommended. The main reasons for choosing that particular MCMC model over the other candidates are: 1) Better estimation of uncertainty than the MLE, an important consideration when conducting a data-moderate assessment, and especially important considering the $\ln R_0$ likelihood profile, 2) avoids bimodality of the other MCMC treatments, thus excluding highly unlikely “unfished conditions” scenarios, 3) uses information from the last assessment, just as the XSSS models do, 4) but uses less arbitrary convergence criteria and does a better job of integrating out nuisance parameters (e.g., extra abundance index variance), 5) has broader uncertainty bands than the AIS models, 6) includes the last assessment in its uncertainty envelops of both abundance and stock status, and 7) is the least extreme of all the Bayesian model treatments considered in the change of absolute abundance (and thus resulting catch recommendations) from the 2007 assessment. The only drawback compared to the XSSS models (besides the run time) is the lack of exploring uncertainty in natural mortality. But despite that, the MCMC model still reports larger overall uncertain than any of the XSSS models considered.

3 Harvest Projections and Decision Tables

To be determined following SSC discussion of the stock assessment.

4 Research Needs

The following list contains research recommendations to further improve the application of catch and index only stock assessments for arrowtooth flounder:

- Historical estimates of discards are a large contributor to total removals. The current modelling exercise of using co-occurring flatfish species as predictors of discard could use further exploration.
- Such large difference in biomass between MLE and Bayesian results was unexpected. Further investigation into these large differences is warranted.
- Further exploration in the upper limits of $\ln R_0$ priors to exclude the unlikely scenario of the current state being at unfished conditions.
- Greater understanding of the differences between the MCMC and XSSS models could help inform a better convergence criterion when using AIS.

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7 Tables

Table 1. Reconstructed landed catch history (1896-1980) of arrowtooth flounder by state. Landings are prior to those recorded in PacFIN. Data sources indicated below the table.

	Landings (mt)				Landings (mt)		
Year	CA[1]	OR[2]	WA[3]	Year	CA[1]	OR[2]	WA[3]
1896	0.00	1.64	0.00	1939	0.00	6.90	0.00
1897	0.00	1.35	0.00	1940	0.00	12.76	0.00
1898	0.00	1.05	0.00	1941	0.00	11.26	0.00
1899	0.00	1.02	0.00	1942	0.00	40.15	0.00
1900	0.00	0.99	0.00	1943	2.35	240.19	0.00
1901	0.00	0.96	0.00	1944	2.06	47.83	0.00
1902	0.00	0.94	0.00	1945	0.53	10.13	0.00
1903	0.00	0.91	0.00	1946	0.00	25.17	0.00
1904	0.00	0.88	0.00	1947	0.00	57.84	0.00
1905	0.00	0.85	0.00	1948	0.00	245.81	0.00
1906	0.00	0.82	0.00	1949	0.00	244.29	0.00
1907	0.00	0.79	0.00	1950	39.71	97.96	0.00
1908	0.00	0.77	0.00	1951	27.13	182.95	0.00
1909	0.00	0.74	0.00	1952	51.17	200.40	0.00
1910	0.00	0.71	0.00	1953	40.08	440.64	0.00
1911	0.00	0.68	0.00	1954	254.53	676.50	0.00
1912	0.00	0.65	0.00	1955	339.40	1484.92	0.00
1913	0.00	0.62	0.00	1956	483.58	1450.38	1911.00
1914	0.00	0.60	0.00	1957	422.90	1110.87	770.00
1915	0.00	0.57	0.00	1958	261.16	1208.73	456.00
1916	0.00	0.54	0.00	1959	338.56	1265.53	599.00
1917	0.00	0.51	0.00	1960	456.55	542.84	404.00
1918	0.00	0.48	0.00	1961	27.42	695.77	1523.00
1919	0.00	0.45	0.00	1962	24.04	1311.77	937.00
1920	0.00	0.43	0.00	1963	7.87	1067.03	974.00
1921	0.00	0.40	0.00	1964	4.42	1140.69	1044.00
1922	0.00	0.37	0.00	1965	5.26	1235.50	603.00
1923	0.00	0.34	0.00	1966	1.59	659.86	602.00
1924	0.00	0.31	0.00	1967	2.74	794.58	758.00
1925	0.00	0.28	0.00	1968	6.08	545.96	360.00
1926	0.00	0.26	0.00	1969	4.53	530.27	342.00
1927	0.00	0.24	0.00	1970	2.78	404.80	160.00
1928	0.00	0.00	0.00	1971	1.21	360.76	242.00
1929	0.00	10.34	0.00	1972	74.37	170.95	33.00
1930	0.00	7.37	0.00	1973	107.16	153.91	180.00
1931	0.00	4.60	0.00	1974	95.49	89.55	108.00
1932	0.00	4.97	0.00	1975	32.08	145.43	23.00
1933	0.00	10.47	0.00	1976	84.02	95.30	156.00
1934	0.00	13.42	0.00	1977	100.83	143.48	116.00
1935	0.00	7.28	0.00	1978	93.71	184.83	244.00
1936	0.00	10.43	0.00	1979	108.05	347.59	410.00
1937	0.00	12.66	0.00	1980	55.71	221.08	345.00
1938	0.00	7.60	0.00				

[1]CalCOM (http://calcomfish.ucsc.edu/qry_all_home.asp)

[2]Oregon Historical Catch reconsutruction (V. Gertseva, pers. Comm.)

[3]Kaplan and Helser 2007

Table 2. Complete removal history and sectors used in the arrowtooth flounder stock assessment. Data sources indicated below table.

	Removal sectors				Removal sectors				Removal sectors		
Year	Historical	Fillet	Discard	Year	Historical	Fillet	Discard	Year	Historical	Fillet	Discard
1896	2	0	0	1936	10	0	1344	1976	335	0	5405
1897	1	0	0	1937	13	0	1498	1977	360	0	2745
1898	1	0	0	1938	8	0	786	1978	523	0	4366
1899	1	0	0	1939	7	0	2024	1979	866	0	5159
1900	1	0	0	1940	13	0	2210	1980	622	0	3741
1901	1	0	0	1941	11	0	1294	1981	0	1074	3461
1902	1	0	0	1942	40	0	1255	1982	0	2351	4834
1903	1	0	0	1943	243	0	4650	1983	0	2077	3522
1904	1	0	0	1944	50	0	1026	1984	0	2379	2786
1905	1	0	0	1945	11	0	306	1985	0	2679	3631
1906	1	0	0	1946	25	0	4727	1986	0	2230	3565
1907	1	0	0	1947	58	0	2703	1987	0	2830	5316
1908	1	0	0	1948	246	0	7300	1988	0	1946	3693
1909	1	0	0	1949	244	0	4555	1989	0	3552	5679
1910	1	0	0	1950	138	0	6111	1990	0	5824	6733
1911	1	0	0	1951	210	0	3711	1991	0	4945	6459
1912	1	0	0	1952	252	0	3225	1992	0	3573	3987
1913	1	0	0	1953	481	0	3060	1993	0	2713	3093
1914	1	0	0	1954	931	0	2230	1994	0	3249	2713
1915	1	0	0	1955	1824	0	3433	1995	0	2321	1817
1916	1	0	102	1956	3845	0	7781	1996	0	2192	1579
1917	1	0	1394	1957	2304	0	6982	1997	0	2344	2224
1918	0	0	480	1958	1926	0	7620	1998	0	3168	2308
1919	0	0	0	1959	2203	0	7698	1999	0	5285	4109
1920	0	0	0	1960	1403	0	5448	2000	0	3276	2078
1921	0	0	0	1961	2246	0	5966	2001	0	2465	1657
1922	0	0	512	1962	2273	0	6415	2002	0	2085	1188
1923	0	0	545	1963	2049	0	5910	2003	0	2327	531
1924	0	0	1683	1964	2189	0	6388	2004	0	2327	566
1925	0	0	1573	1965	1844	0	6205	2005	0	2240	2179
1926	0	0	1391	1966	1263	0	6226	2006	0	1922	802
1927	0	0	2416	1967	1555	0	5979	2007	0	2262	820
1928	0	0	1771	1968	912	0	5417	2008	0	2668	741
1929	10	0	2616	1969	877	0	3340	2009	0	3844	1585
1930	7	0	1323	1970	568	0	2535	2010	0	3228	868
1931	5	0	0	1971	604	0	2323	2011	0	2292	350
1932	5	0	1191	1972	278	0	2774	2012	0	2243	256
1933	10	0	986	1973	441	0	3556	2013	0	1991	502
1934	13	0	837	1974	293	0	3898	2014	0	1248	194
1935	7	0	1271	1975	201	0	4262				

Sources:

(orange)	See Table 1 for sources
(green)	GLM prediction based on flatfish landings
(light blue)	WCGOP discarde estimates
(purple)	PacFIN
(olive)	Landings times the harmonic mean of 2011-2013 (ITQ years) discard ratio

Table 3. Model selection for terms to predict the historical (1876-1980) amount of arrowtooth flounder discard from the landings of five possible flatfishes, including retained arrowtooth flounder (ATF) for two possible error distributions. Bold value indicated model most supported by the data. Coefficients of the selected model are provided below the table.

	Error distribution			
	Gaussian		Gamma	
Models	AIC	ΔAIC	AIC	ΔAIC
ATF+Dover+English+Petrale+Rex	186.88	2.86	176.08	3.75
ATF+English+Petrale+Rex	185.11	1.09	174.25	1.92
ATF+Dover+English+Petrale	185.2	1.18	174.09	1.76
ATF+Dover+Petrale+Rex	185.59	1.57	175.38	3.05
ATF+Dover+English+Rex	188.21	4.19	176.29	3.96
Dover+English+Petrale+Rex	190.24	6.22	177.28	4.95
ATF+English+Petrale	**184.02**	**0**	**172.33**	0
ATF+Petrale+Rex	186.05	2.03	175.63	3.30
ATF+English+Rex	186.37	2.35	176.31	3.98
English+Petrale+Rex	189.59	5.57	180.86	8.53
ATF+Petrale	184.68	0.66	177.06	4.73
ATF+English	184.96	0.94	176.37	4.04
English+Petrale	189.43	5.41	185.45	13.12

Final coefficients
Intercept: 5.91e-03
AFT: -9.54e-07
English: -1.44e-06
Petrale: -6.64e-07

Table 4. Model configurations and selection for each survey prepared for the arrowtooth flounder stock assessment. MSC= Model selection criteria. MSC_{GLMM}= DIC; $MSC_{GeoSpatial}$ =AIC Selected models in bold.

Survey	Version	Strata-year	Positives	MSC	ΔMSC
Triennial	1980-2004	Fixed	gamma	19052	26
		Fixed	lognormal	19038	12
		Random	gamma	19045	19
		Random	**lognormal**	**19025**	**0**
		None	gamma	19146	121
		None	lognormal	19046	21
	1980-1992	Fixed	gamma	10464	4
		Fixed	lognormal	10507	47
		Random	**gamma**	**10460**	**0**
		Random	lognormal	10488	28
		None	gamma	10484	24
		None	lognormal	10484	25
	1995-2004	Fixed	gamma	8575	54
		Fixed	lognormal	8526	5
		Random	gamma	8573	52
		Random	**lognormal**	**8521**	**0**
		None	gamma	8647	126
		None	lognormal	8539	18
AFSC slope	1997, 1999-2001	Fixed	gamma	1182	22
		Fixed	lognormal	1168	8
		Random	gamma	1178	18
		Random	**lognormal**	**1163**	**2**
		None	gamma	1174	14
		None	**lognormal**	**1160**	**0**
NWFSC shelf-slope	New strata	Fixed	gamma	25182	286
		Fixed	lognormal	24917	21
		Random	gamma	25171	275
		Random	**lognormal**	**24896**	**0**
		None	gamma	25383	487
		None	lognormal	25034	138
	Old strata	Fixed	gamma	25661	273
		Fixed	lognormal	25388	0
		Random	gamma	25660	272
		Random	**lognormal**	**25388**	**0**
		None	lognormal	25431	43
	Geospatial	**None**	**gamma**	**1**	**1**
		None	**lognormal**	**0**	**0**
NWFSC slope	1999-2002	Fixed	gamma	2374	44
		Fixed	lognormal	2330	1
		Random	gamma	2371	41
		Random	**lognormal**	**2330**	**0**
		None	gamma	2387	58
		None	lognormal	2347	18

Table 5. Life history and productivity parameter values for the arrowtooth flounder assessment. Prior values refer to those used in the MLE and MCMC applications.

Parameter	Bounds	Fixed value	Prior Type	Prior Mean	Prior SD	Estimated value
Female						
Natural mortality (M)	-2 to 0.01	0.166	No prior			
Length at age=1	-2 to 5	8.00	No prior			
Length at age=40	-2 to 40	72.26	No prior			
VBGF K	-2 to 0.05	0.17	No prior			
Length CV at age=1	-3 to 0.05	0.14	No prior			
Length CV at age=40	-3 to 0.05	0.08	No prior			
Weight-Length a	-3 to 0	0.000004	No prior			
Weight-Length b	-3 to 0	3.25	No prior			
Length at 50% maturity	-3 to 0	37.30	No prior			
Maturity slope	-3 to 0	-0.50	No prior			
Eggs/kg	-3 to 0	1.00	No prior			
Eggs/kg slope	-3 to -3	0.00	No prior			
Male						
Natural mortality (M)	-2 to 0.01	0.274	No prior			
Length at age=1	-2 to 5	8.00	No prior			
Length at age=40	-2 to 30	45.58	No prior			
VBGF K	-2 to 0.5	0.39	No prior			
Length CV at age=1	-3 to 0.5	0.21	No prior			
Length CV at age=40	-3 to 0.5	0.08	No prior			
Weight-Length a	-3 to -3	0.000003	No prior			
Weight-Length b	-3 to -1	3.26	No prior			
Stock-recruit						
$\ln(R_0)$	3 to 18		No prior			10.54
steepness (h)	0.25 to 0.99		normal	0.80	0.09	0.82
s_R	0 to 2	0.01	No prior			
Extra index variance						
Triennial (1980-2004)	0 to 5		No prior			0.18
Triennial slope	0 to 5		No prior			0.00
NWFSC slope	0 to 5		No prior			0.03
NWFSC shelf-slope	0 to 5		No prior			0.08

Table 6. Length, weight and age compositions not used in the data-moderate arrowtooth flounder assessment. Reported available ages are not structures, not necessarily aged structures.

	Sample source																	
	Commercial catch			WCGOP			NWFSC Survey			NWFSC slope			AFSC slope			AFSC triennial		
Year	Lengths	Weights	Ages	Lengths	Weights	Ages	Lengths	Weights	Ages	Lengths	Weights	Ages	Lengths	Weights	Ages	Lengths	Weights	Ages
1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	827	0	0
1981	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1982	1	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1983	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	163	0	0
1984	0	0	0	-	-	-	-	-	-	-	-	-	465	-	-	-	-	-
1985	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1986	950	0	847	-	-	-	-	-	-	-	-	-	-	-	-	6457	614	423
1987	1200	0	995	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1988	800	0	729	-	-	-	-	-	-	-	-	-	492	-	-	-	-	-
1989	850	0	778	-	-	-	-	-	-	-	-	-	-	-	-	9348	409	0
1990	974	0	973	-	-	-	-	-	-	-	-	-	423	-	-	-	-	-
1991	1917	0	899	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1992	1500	0	0	-	-	-	-	-	-	-	-	-	783	-	-	5081	175	0
1993	900	0	0	-	-	-	-	-	-	-	-	-	515	-	-	-	-	-
1994	1000	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1995	1098	0	0	-	-	-	-	-	-	-	-	-	283	-	-	5258	48	0
1996	900	0	0	-	-	-	-	-	-	-	-	-	755	320	320	-	-	-
1997	900	0	0	-	-	-	-	-	-	-	-	-	537	219	219	-	-	-
1998	1001	0	300	-	-	-	-	-	-	-	-	-	443	247	247	5585	0	0
1999	1099	0	0	-	-	-	-	-	-	0	0	0	315	144	168	-	-	-
2000	1050	0	0	-	-	-	-	-	-	0	0	0	722	235	235	-	-	-
2001	800	0	0	-	-	-	-	-	-	158	0	0	-	-	-	11068	0	0
2002	500	0	500	-	-	-	-	-	-	0	0	0	-	-	-	-	-	-
2003	453	0	300	0	0	0	4502	903	1369	-	-	-	-	-	-	-	-	-
2004	300	0	300	0	0	0	2713	556	687	-	-	-	-	-	-	8674	0	0
2005	361	0	200	2	2	0	3935	860	857	-	-	-	-	-	-	-	-	-
2006	1688	42	540	1607	10	0	3036	729	735	-	-	-	-	-	-	-	-	-
2007	2979	3	1231	1722	8	0	3553	892	895	-	-	-	-	-	-	-	-	-
2008	2710	9	1189	2285	9	0	3227	875	874	-	-	-	-	-	-	-	-	-
2009	3089	11	1269	3386	5	0	3476	965	963	-	-	-	-	-	-	-	-	-
2010	3402	125	1412	2625	2	0	3703	1133	1134	-	-	-	-	-	-	-	-	-
2011	3543	36	1947	4817	0	0	3060	1047	1043	-	-	-	-	-	-	-	-	-
2012	3301			-	-	-	3045	1026	1026	-	-	-	-	-	-	-	-	-
2013	2391			-	-	-				-	-	-	-	-	-	-	-	-
2014	1860			-	-	-				-	-	-	-	-	-	-	-	-

Table 7. Selectivity parameters fixed in the arrowtooth flounder stock assessment. Values are the estimates from the 2007 stock assessment.

Fishery			Survey		
Parameter	Bounds	Fixed value	Parameter	Bounds	Fixed value
Historical fleet			Triennial survey		
double-normal parameter 1	20 to 46	30.43	double-normal parameter 1	20 to 70	31.1509
double-normal parameter 2	-6 to 6	6	double-normal parameter 2	-6 to 4	-5
double-normal parameter 3	-1 to 10	4.63	double-normal parameter 3	-1 to 9	4.70292
double-normal parameter 4	-5 to 9	1	double-normal parameter 4	-1 to 9	5
double-normal parameter 5	-10 to 10	-10	double-normal parameter 5	-5 to 9	-5
double-normal parameter 6	0 to 50	50	double-normal parameter 6	-5 to 9	9
Fillet			Male offset parameter 1	20 to 70	30
double-normal parameter 1	20 to 70	60	Male offset parameter 2	-3 to 0	0
double-normal parameter 2	-6 to 6	6	Male offset parameter 3	-3 to 0	-6.61E-10
double-normal parameter 3	-1 to 10	5.1294	Male offset parameter 4	-3 to 0	-0.096472
double-normal parameter 4	-5 to 9	1	AFSC slope		
double-normal parameter 5	-10 to 10	-10	double-normal parameter 1	20 to 70	31.8236
double-normal parameter 6	0 to 50	50	double-normal parameter 2	-6 to 4	-5
Male offset parameter 1	20 to 70	30	double-normal parameter 3	-1 to 9	3.58867
Male offset parameter 2	-3 to 0	0	double-normal parameter 4	-1 to 9	5
Male offset parameter 3	-3 to 0	-0.000000002	double-normal parameter 5	-5 to 9	-5
Male offset parameter 4	-3 to 0	-0.000000107	double-normal parameter 6	-5 to 9	9
Discard			Male offset parameter 1	20 to 70	30
double-normal parameter 1	20 to 70	35.4119	Male offset parameter 2	-3 to 0	0
double-normal parameter 2	-6 to 4	-5	Male offset parameter 3	-3 to 0	-5.66E-09
double-normal parameter 3	-1 to 9	4.46779	Male offset parameter 4	-3 to 0	-0.615001
double-normal parameter 4	-1 to 9	5	NWFSC slope (Mirrored to AFSC slope)		
double-normal parameter 5	-5 to 9	-5	NWFSC slope & shelf-slope		
double-normal parameter 6	-5 to 9	9	double-normal parameter 1	20 to 70	38.0017
			double-normal parameter 2	-6 to 6	6
			double-normal parameter 3	-1 to 10	4.40027
			double-normal parameter 4	-5 to 9	1
			double-normal parameter 5	-10 to 10	-10
			double-normal parameter 6	0 to 50	50
			Male offset parameter 1	20 to 70	30
			Male offset parameter 2	-3 to 0	0
			Male offset parameter 3	-3 to 0	-5.63E-08
			Male offset parameter 4	-3 to 0	-0.883314

Table 8. Likelihood and parameter values (based on the MLE) of the sensitivity models runs for the arrowtooth flounder stock assessment. Bolded values indicate which surveys are included in the model scenario. Grayed scenario is the base case model. "Index removal" scenarios use the base case model to evaluate the sensitivity of removing indices from it.

	Sensitivity scenario																		
	Triennial 1980-2004				Triennial split				Index removal						old h	old h, old catch	old catch	Sel= Maturity	design-based indices
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Survey Likelihood Components																			
Triennial 1980-2004	**-4.04**	**-4.11**	**-3.85**	**-4.16**	9.21	3.97	8.52	4.53	4.41	**-4.15**	**-4.15**	**-4.16**	**-4.17**	4.46	**-4.40**	**-3.04**	**-3.03**	**-3.52**	**-0.68**
Triennial 1980-1992	-2.61	-2.46	-2.62	-2.56	**-2.68**	**-2.65**	**-2.68**	**-2.70**	-2.56	-2.56	-2.50	-2.57	-2.53	-2.57	-2.60	-1.84	-1.89	-2.35	-2.60
Triennial 1995-2004	-0.96	-0.42	-1.05	-0.74	**-1.21**	**-0.94**	**-1.19**	**-1.09**	-0.74	-0.74	-0.55	-0.78	-0.64	-0.77	-0.99	0.19	0.33	-0.51	-0.96
Triennial slope	**-0.15**	**-0.12**	**-0.15**	**-0.14**	**-0.13**	**-0.13**	**-0.13**	**-0.14**	**-0.14**	14.48	**-0.13**	**-0.14**	14.51	14.49	**-0.15**	**-0.09**	**-0.08**	**-0.11**	**-0.05**
NWFSC GLMM: new strata	**-15.22**	-14.06	-15.01	-14.56	**-15.58**	-14.40	-15.18	-14.81	-14.67	-14.55	-14.25	-14.60	-14.39	-14.72	-14.62	-13.17	-13.00	-14.23	-14.95
NWFSC GLMM: old strata	-15.12	**-15.90**	-14.89	-15.36	-14.30	**-15.82**	-14.46	-15.19	-15.30	-15.37	-15.47	-15.33	-15.43	-15.27	-15.28	-15.34	-15.33	-15.44	-15.02
NWFSC geostat: gamma	-16.87	-14.55	**-17.26**	-16.03	-17.51	-15.58	**-17.53**	-16.73	-16.37	-16.01	-15.14	-16.16	-15.56	-16.48	-16.20	-11.55	-11.03	-15.03	-17.08
NWFSC geostat: lognormal	-15.52	-15.14	-15.29	**-15.86**	-14.32	-15.47	-14.60	**-15.87**	**-15.89**	**-15.86**	-15.35	**-15.87**	-15.46	**-15.89**	**-15.85**	**-14.42**	**-14.27**	**-15.61**	**-15.30**
NWFSC slope	**-2.83**	**-2.96**	**-2.81**	**-2.88**	**-2.81**	**-2.91**	**-2.82**	**-2.86**	**-2.88**	**-2.89**	**-2.93**	-2.50	-2.56	-2.50	**-2.83**	**-3.09**	**-3.12**	**-2.97**	**-3.43**
Parameters																			
R_0	10.49	10.65	10.47	10.54	10.45	10.58	10.46	10.51	10.55	10.55	10.61	10.53	10.57	10.54	10.47	10.25	10.36	10.54	10.49
h	0.83	0.81	0.84	0.82	0.83	0.81	0.82	0.81	0.80	0.82	0.82	0.83	0.82	0.80	0.90	0.90	0.81	0.81	0.82
Extra SD Triennial 1980-2004	**0.20**	**0.19**	**0.21**	**0.19**						**0.19**	**0.19**	**0.19**	**0.19**		**0.18**	**0.24**	**0.24**	**0.22**	**0.37**
Extra SD Triennial 1980-1992					**0.06**	**0.06**	**0.06**	**0.06**											
Extra SD Triennial 1995-2004					**0.09**	**0.12**	**0.09**	**0.10**											
Extra SD Triennial slope	**0.43**	**0.43**	**0.42**	**0.43**	**0.43**	**0.43**	**0.43**	**0.43**	**0.43**		**0.43**	**0.43**			**0.42**	**0.44**	**0.44**	**0.43**	**0.42**
Extra SD NWFSC slope	**0.08**	**0.08**	**0.09**	**0.08**	**0.09**	**0.08**	**0.09**	**0.08**	**0.08**	**0.08**	**0.08**				**0.09**	**0.07**	**0.06**	**0.07**	**0.03**
Extra SD NWFSC GLMM: new strata	**0.00**				**0.00**														
Extra SD NWFSC GLMM: old strata		**0.00**				**0.00**													
Extra SD NWFSC geostat: gamma			**0.02**				**0.01**												
Extra SD NWFSC geostat: lognormal				**0.03**				**0.03**	**0.03**	**0.03**		**0.03**		**0.03**	**0.03**	**0.05**	**0.05**	**0.04**	**0.02**
Catchability (analytic solution)																			
Triennial 1980-2004	**0.32**	**0.20**	**0.35**	**0.26**	0.39	0.23	0.37	0.29	0.26	**0.26**	**0.22**	**0.27**	**0.24**	0.27	**0.29**	**0.26**	**0.22**	**0.27**	**0.27**
Triennial 1980-1992	0.21	0.14	0.23	0.18	**0.27**	**0.16**	**0.26**	**0.20**	0.19	0.18	0.15	0.18	0.16	0.19	0.20	0.18	0.15	0.18	2.20
Triennial 1995-2004	0.44	0.26	0.49	0.36	**0.61**	**0.32**	**0.58**	**0.41**	0.38	0.35	0.30	0.37	0.32	0.39	0.39	0.37	0.31	0.37	0.46
Triennial slope	**0.19**	**0.11**	**0.21**	**0.15**	**0.27**	**0.13**	**0.26**	**0.18**	**0.16**	0.16	**0.12**	**0.15**	0.15	0.18	**0.16**	**0.15**	**0.13**	**0.15**	**0.17**
NWFSC slope	**0.15**	**0.09**	**0.17**	**0.12**	**0.21**	**0.11**	**0.20**	**0.14**	**0.13**	**0.12**	**0.10**	0.12	0.11	0.13	**0.13**	**0.12**	**0.10**	**0.12**	**0.16**
NWFSC GLMM: new strata	**1.48**	1.00	1.62	1.28	**1.94**	1.18	1.87	1.44	1.34	1.27	1.11	1.30	1.18	1.37	1.36	1.56	1.33	1.30	1.55
NWFSC GLMM: old strata	1.04	**0.70**	1.14	0.89	1.36	**0.83**	1.32	1.01	0.94	0.89	0.77	0.91	0.83	0.96	0.95	1.09	0.92	0.91	1.09
NWFSC geostat: gamma	0.70	0.47	**0.76**	0.60	0.91	0.55	**0.88**	0.67	0.63	0.60	0.52	0.61	0.55	0.64	0.64	0.73	0.62	0.61	0.73
NWFSC geostat: lognormal	0.89	0.60	0.97	**0.76**	1.16	0.70	1.12	**0.86**	**0.80**	**0.76**	0.66	**0.78**	0.71	**0.82**	**0.81**	**0.93**	**0.79**	**0.77**	**0.70**
Dervied quantities																			
SB_0	101051	119177	98720	106760	96759	110943	97805	103360	106825	106999	113537	105555	109981	105898	99527	79283	89054	106586	100810
SB_{2015}	58436	80888	54580	66024	47802	70441	49037	60039	63539	66244	74416	64796	70300	62450	62404	49506	57717	67579	56503.6
SB_{2015}/SB_0	57.83%	67.87%	55.29%	61.84%	49.40%	63.49%	50.14%	58.09%	59.48%	61.91%	65.54%	61.39%	63.92%	58.97%	62.70%	62.44%	64.81%	63.40%	56.05%

Table 9. Four additional MCMC diagnostics for each stock and model. AC Lag 1 is the autocorrelation lag 1 value, with a value >0.1 undesirable; Neff/N is the effective sample size to true posterior sample size. The closer to 1, the better the convergence; Geweke-Z statistic, where values outside of the range -1.96 to 1.96 are considered a sign of poor convergence; Heidelberger-Welch test. Failed or NA or signs of poor convergence.

		MCMC diagnostics			
lnR0 prior	Parameter	AC Lag 1	N_{eff}/N	Geweke-Z	Heidelberger-Welch
Unif (3,18)	h	0.04	0.98	0.32	Passed
	lnR_0	-0.01	0.98	1.33	Passed
	xSD: Tri	-0.048	0.98	0.421	Passed
	xSD: Tri slope	-0.07	0.98	-0.999	Passed
	xSD: NWFSC slope	0.02	0.98	-0.477	Passed
	xSD: NWFSC shelf-slope	0.01	0.98	-0.07	Passed
	SB_0	0.00	0.98	0.95	Passed
	SB_{2015}	0.00	0.98	0.95	Passed
	SB_{2015}/SB_0	0.02	0.98	0.42	Passed
Unif (3,14)	h	0.02	0.80	-0.16	Passed
	lnR_0	-0.02	0.80	-1.70	Passed
	xSD: Tri	-0.04	0.80	-1.83	Passed
	xSD: Tri slope	-0.06	0.80	-1.11	Passed
	xSD: NWFSC slope	0.03	0.80	-1.59	Passed
	xSD: NWFSC shelf-slope	0	0.80	0.74	Passed
	SB_0	-0.01	0.80	-1.14	Passed
	SB_{2015}	-0.01	0.80	-1.15	Passed
	SB_{2015}/SB_0	-0.03	0.80	-1.68	Passed
Norm (11.3,0.78)	h	0.04	0.80	-0.26	Passed
	lnR_0	-0.01	0.80	-0.256	Passed
	xSD: Tri	-0.01	0.80	-0.59	Passed
	xSD: Tri slope	-0.05	0.80	-0.14	Passed
	xSD: NWFSC slope	0.02	0.80	-1.64	Passed
	xSD: NWFSC shelf-slope	-0.03	0.80	-0.3	Passed
	SB_0	-0.02	0.80	-1.68	Passed
	SB_{2015}	-0.02	0.80	-1.68	Passed
	SB_{2015}/SB_0	-0.02	0.80	-0.52	Passed

Table 10. Derived quantity and parameter estimates for each arrowtooth flounder assessment treatment compared to the 2007 assessment. Values provided are medians with the coefficient of variation in parentheses.

Output		MLE	MCMC			XSSS				
			lnR_0: 3-18	lnR_0: 3-14	lnR_0: N(11.3,0.78)	$2007_{06\ depletion}$	$2015_{14\ depletion}$	$2015_{'06\ depletion}$	$2015_{'06\ depletion,\ M\ est.}$	2007 base case
Derived quantitiy	SB0	106733 (0.12)	289431 (2.38)	169651 (1.36)	158178 (0.91)	259118 (0.69)	193673 (0.56)	244413 (0.43)	300232 (0.64)	80313 (0.08)
	SB2015	66085 (0.21)	257529 (2.39)	133817 (1.48)	120938 (1.1)	213227 (0.82)	141227 (0.74)	187979 (0.56)	267897.5 (0.7)	38125
	SB2015/SB0	0.62 (0.12)	0.89 (0.18)	0.79 (0.17)	0.77 (0.15)	0.83 (0.13)	0.73 (0.16)	0.78 (0.15)	0.89 (0.04)	0.47
	OFL2015	8223 (0.21)	70291 (2.39)	16610 (1.47)	15019 (1.1)	45180 (0.93)	28092 (0.84)	35280 (0.71)	73083 (0.7)	6523
	OFL2016	8082 (0.2)	58973 (2.39)	15762 (1.46)	14304 (1.07)	40015 (0.88)	25107 (0.79)	31481 (0.67)	61296 (0.69)	6207
Parameter	Mfemale	0.17	0.17	0.17	0.17	0.12 (0.34)	0.12 (0.3)	0.11 (0.35)	0.17	0.17
	Mmale	0.27	0.27	0.27	0.27	0.26 (0.32)	0.27 (0.31)	0.26 (0.28)	0.27	0.27
	h	0.82 (0.11)	0.8 (0.11)	0.81 (0.11)	0.81 (0.11)	0.85 (0.09)	0.85 (0.09)	0.85 (0.1)	0.83 (0.1)	0.9
	lnR0	10.54 (0.01)	11.54 (0.18)	11.01 (0.09)	10.95 (0.05)	10.89 (0.07)	10.48 (0.06)	10.56 (0.06)	11.58 (0.04)	10.26 (0.01)
	Tri xSD	0.18 (0.49)	0.28 (0.49)	0.25 (0.5)	0.25 (0.5)	0.21 (0.03)	0.21 (0.04)	0.22 (0.05)	0.22 (0.02)	0
	AFSC slope xSD	0.42 (0.50)	0.62 (0.70)	0.62 (0.68)	0.61 (0.66)	0.43 (0.01)	0.43 (0.01	0.43 (0.004)	0.43 (0.002)	0.07
	NWFSC slope xSD	0.08 (1.29)	0.18 (1.13)	0.17 (1.12)	0.17 (1.15)	0.06 (0.04)	0.07 (0.07)	0.07 (0.04)	0.06 (0.02)	0.36
	NWFSC xSD	0.03 (1.00)	0.08 (0.64)	0.06 (0.67)	0.06 (0.64)	0.05 (0.154)	0.04 (0.21)	0.05 (0.17)	0.06 (0.05)	0

8 Figures

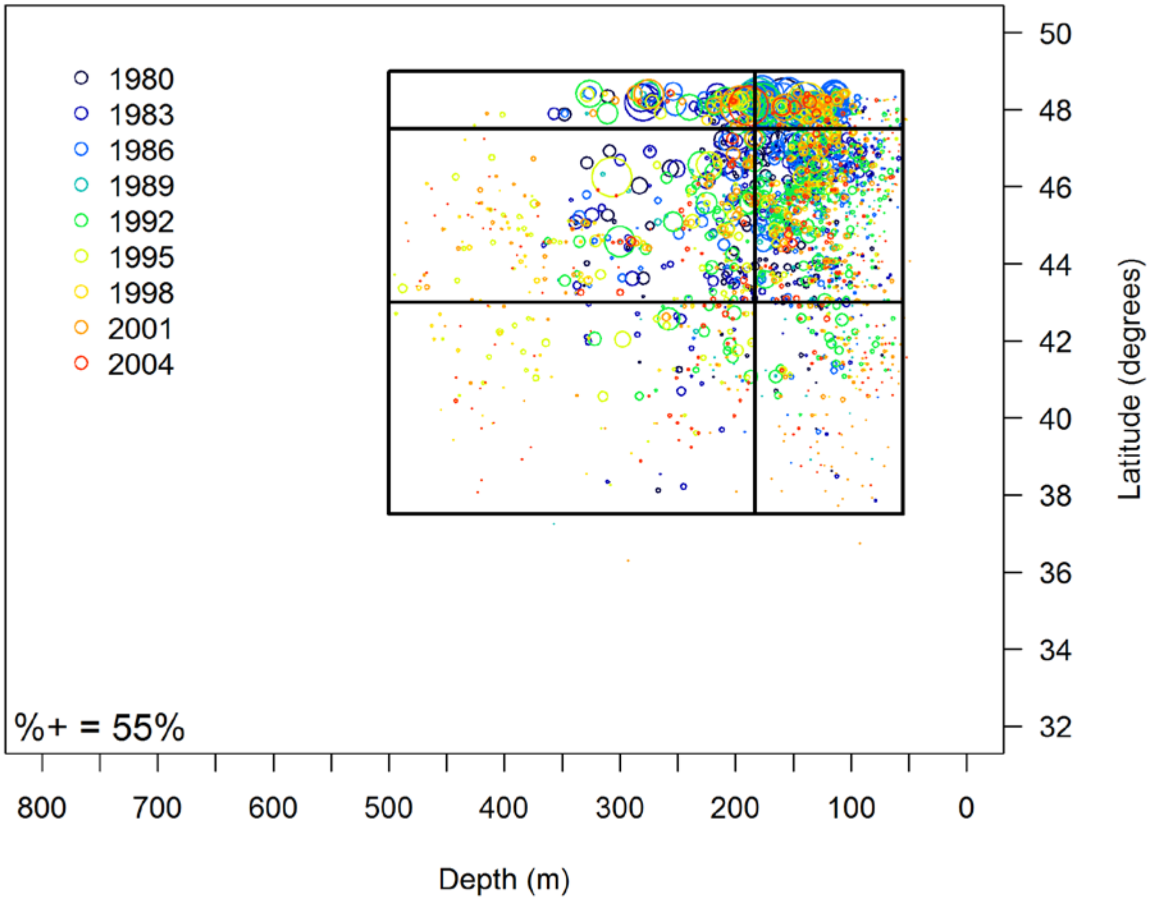

Figure 1. Distribution of arrowtooth flounder for each year in the Alaska Fisheries Science Center Triennial survey. The diameter of each circle indicates the relative biomass density. The depth and area strata used in the survey GLMM are indicated by the black squares.

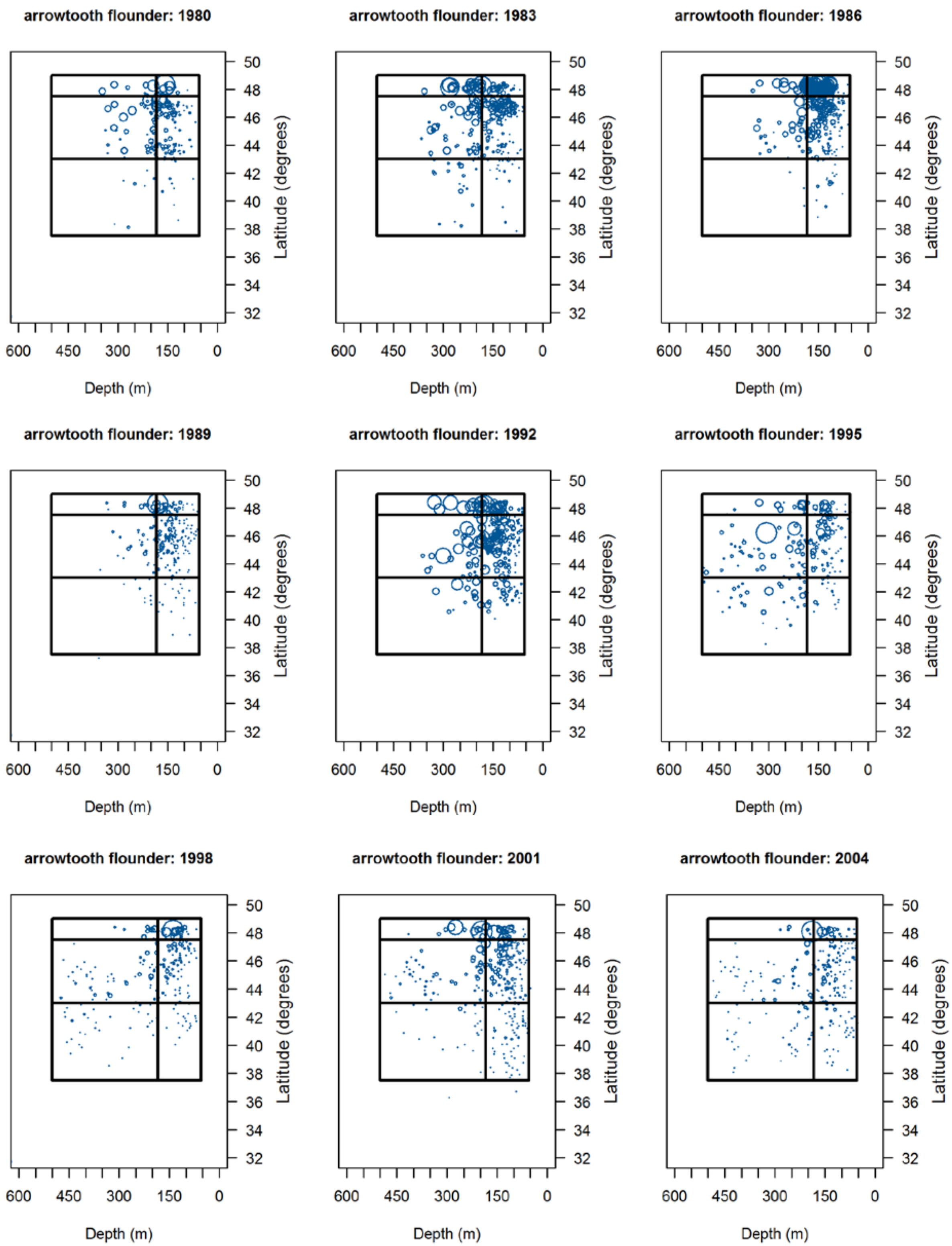

Figure 2. Yearly arrowtooth flounder distribution and depth by area strata for the AFSC triennial survey.

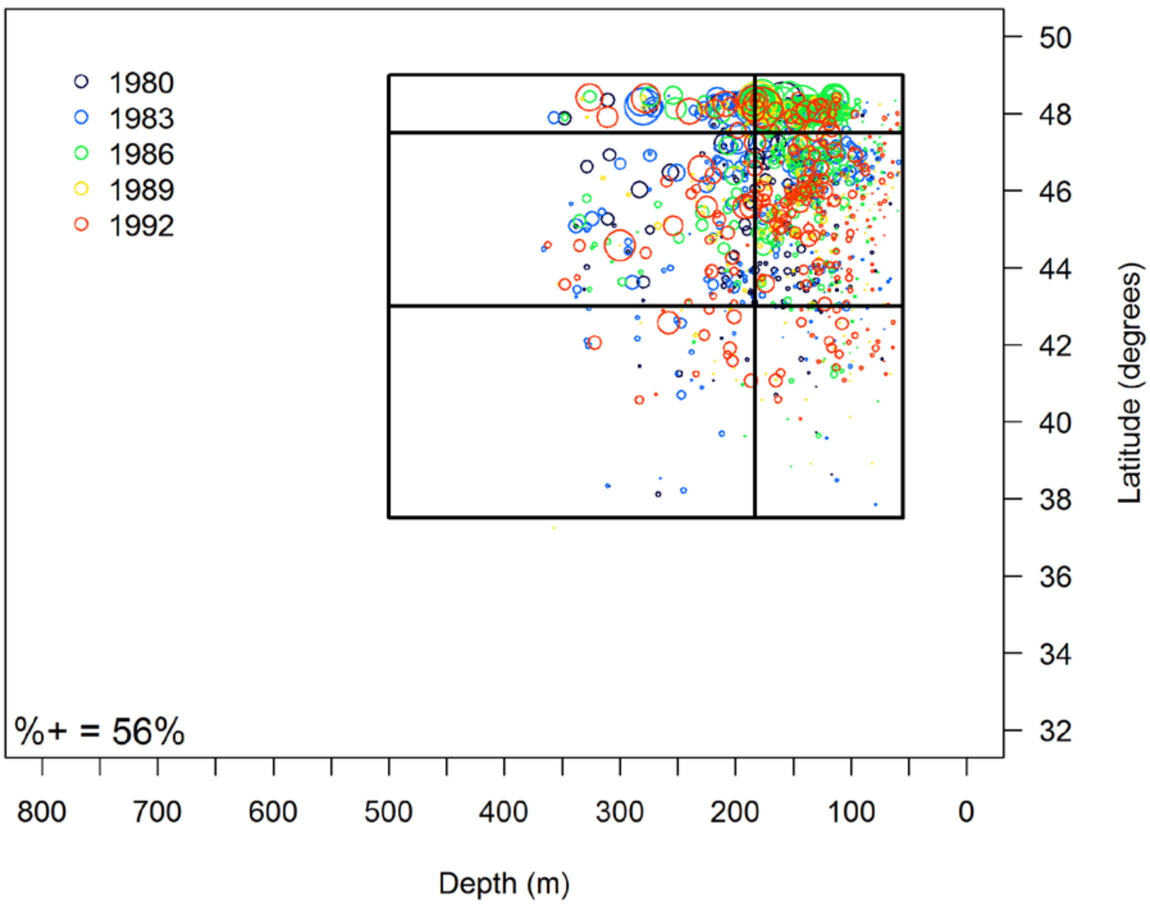

Figure 3. Distribution of arrowtooth flounder for each year in the Alaska Fisheries Science Center Triennial survey for years prior to 1995. The depth and area strata used in the survey GLMM are indicated by the black squares.

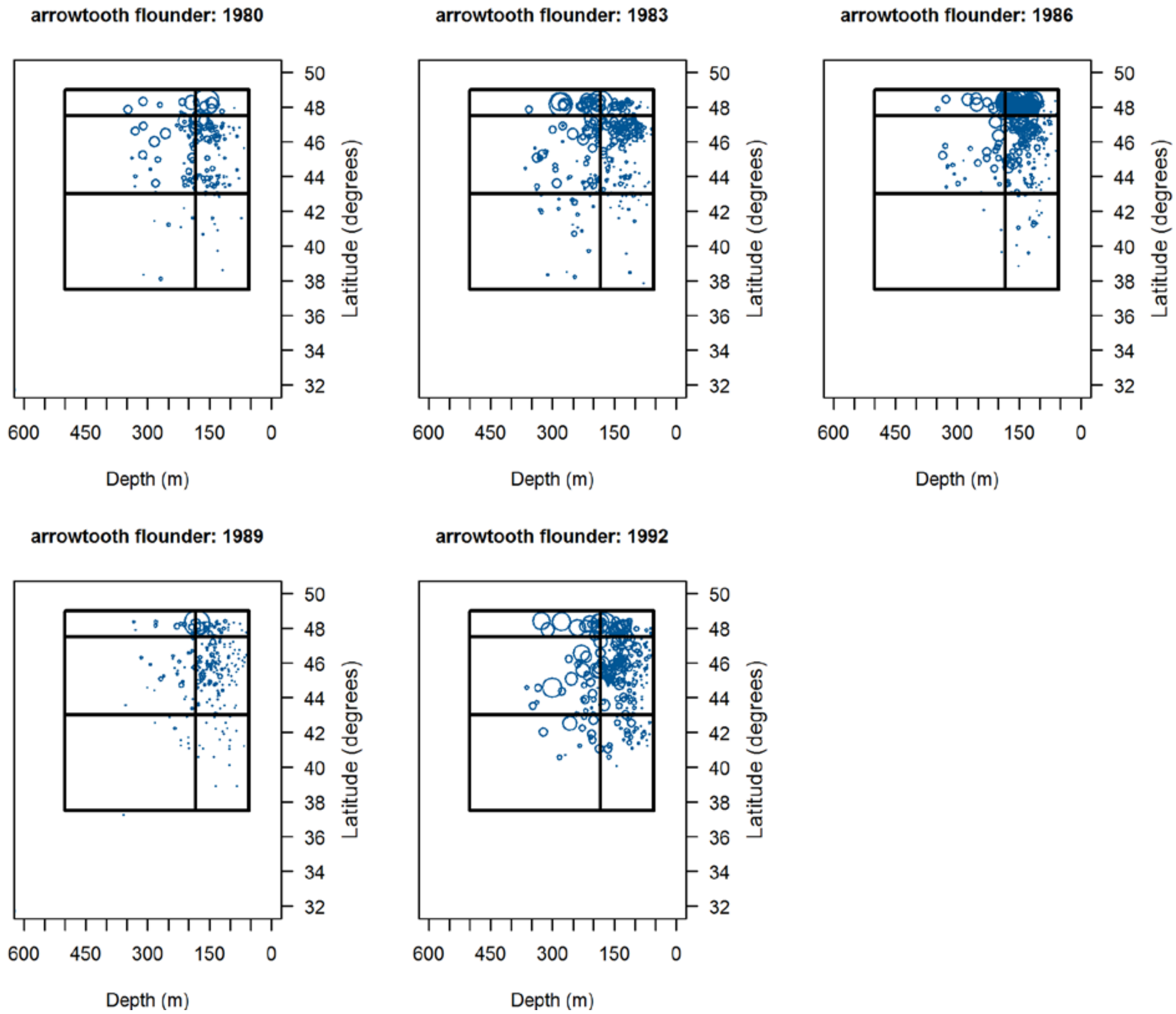

Figure 4. Yearly arrowtooth flounder distribution and depth by area strata for the AFSC triennial survey for years prior to 1995.

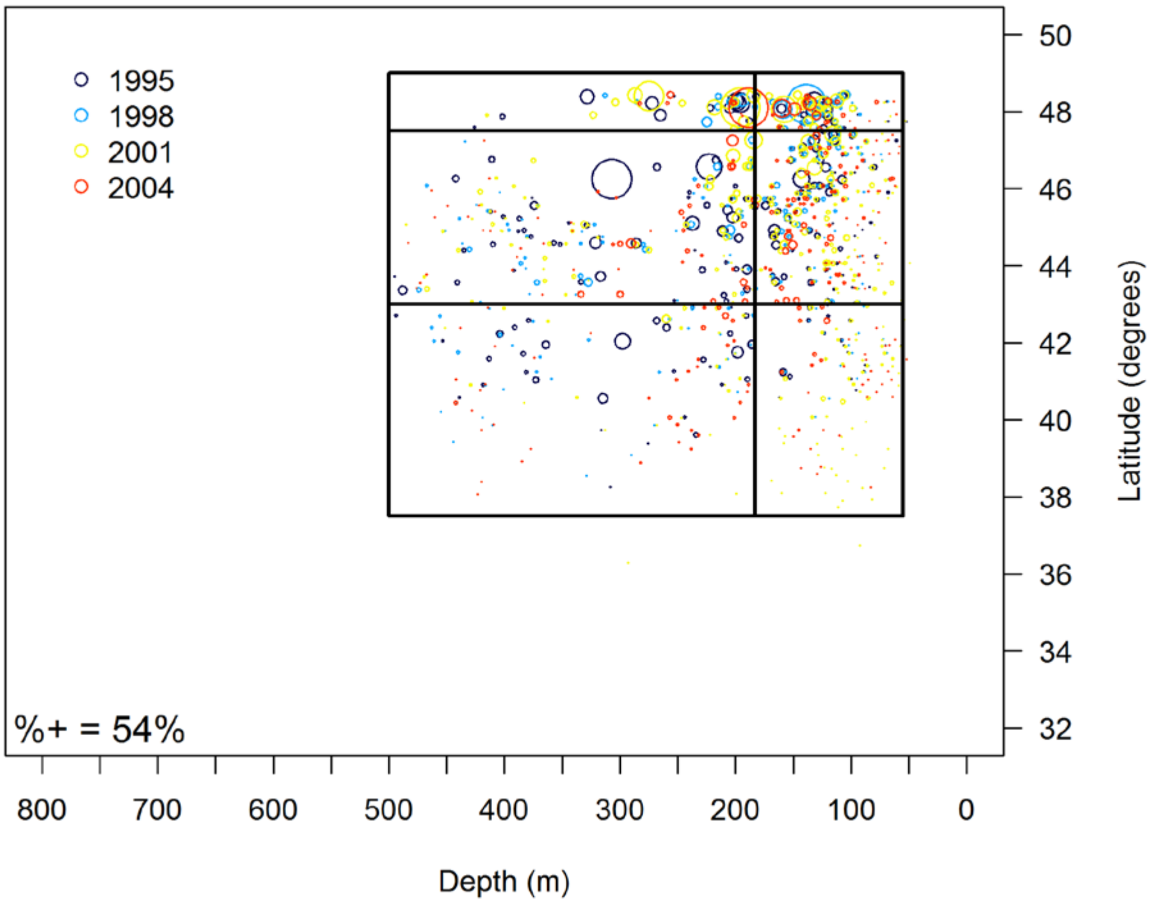

Figure 5. Distribution of arrowtooth flounder for each year in the Alaska Fisheries Science Center Triennial survey for years after 1992. The depth and area strata used in the survey GLMM are indicated by the black squares.

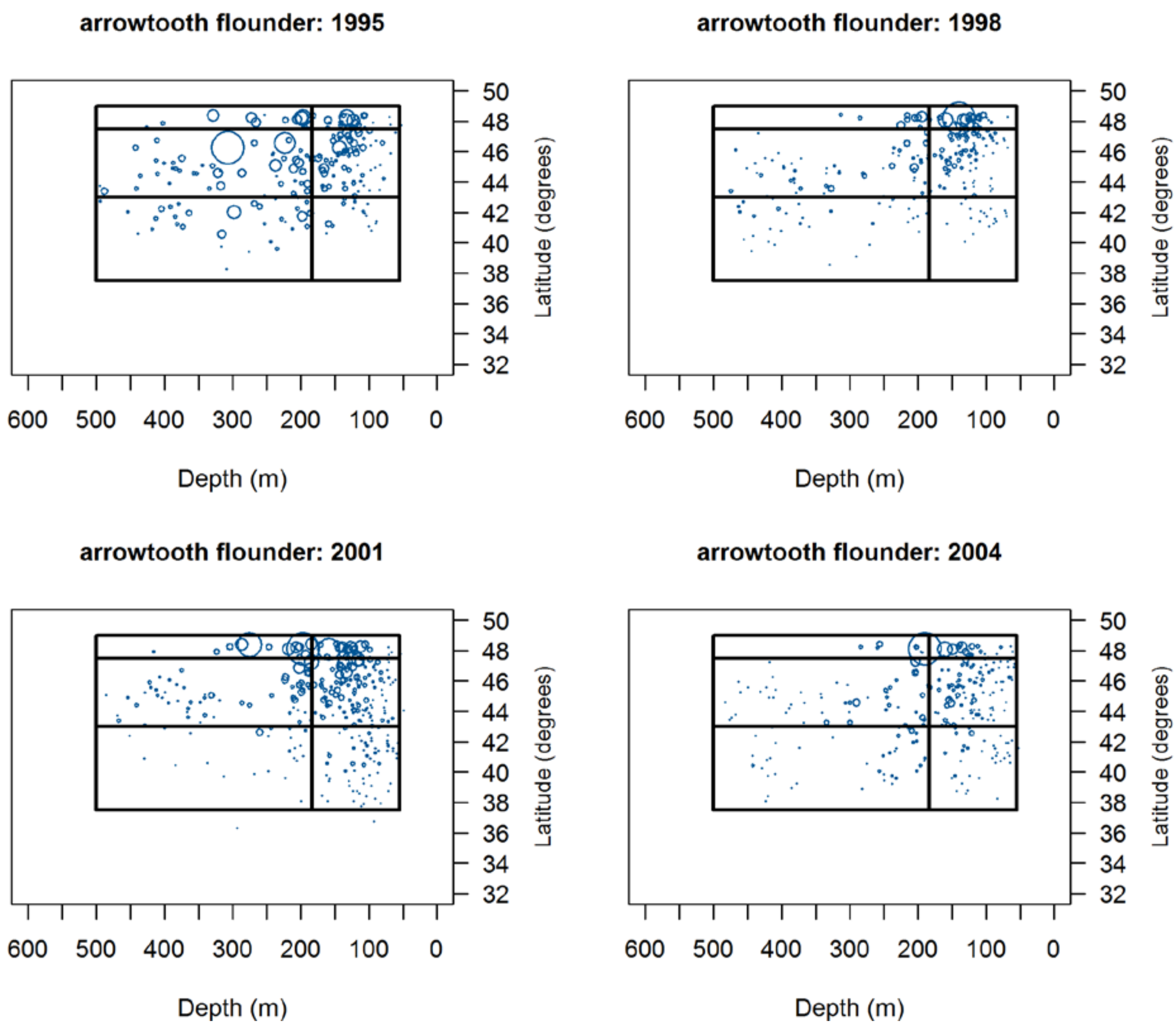

Figure 6. Yearly arrowtooth flounder distribution and depth by area strata for the AFSC triennial survey for years after 1992.

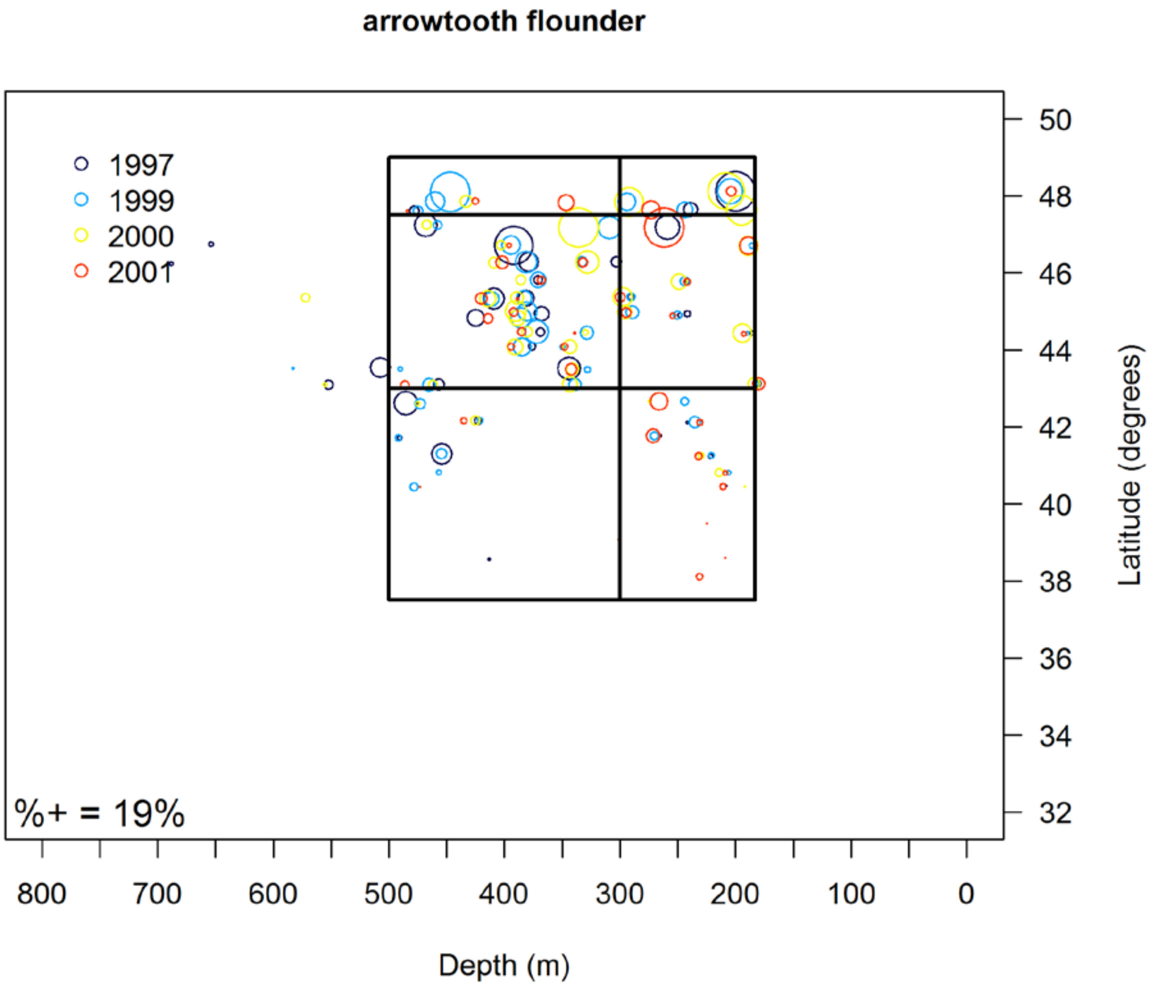

Figure 7. Distribution of arrowtooth flounder for each year in the Alaska Fisheries Science Center slope survey. The depth and area strata used in the survey GLMM are indicated by the black squares.

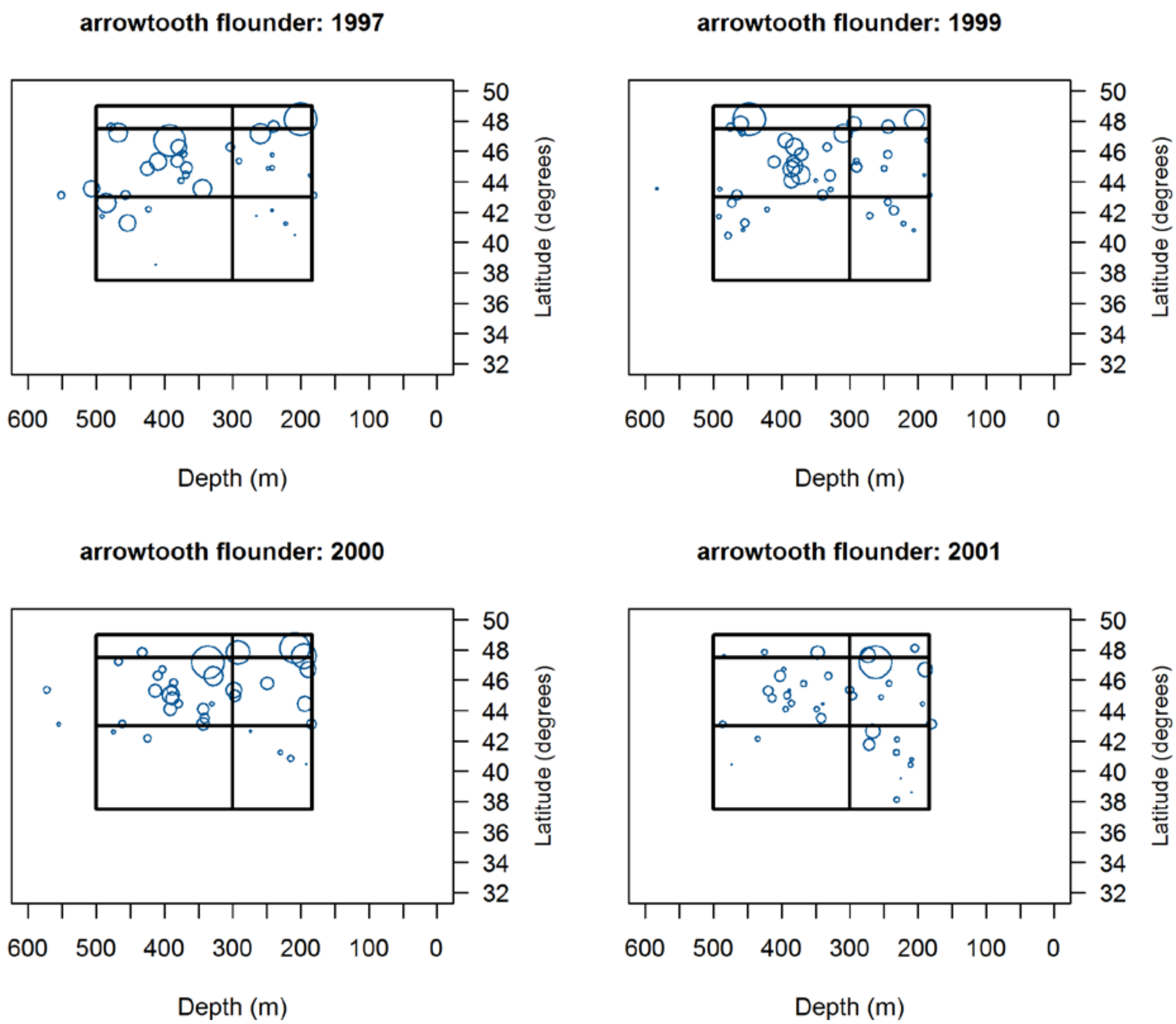

Figure 8. Yearly arrowtooth flounder distribution and depth by area strata for the AFSC slope survey.

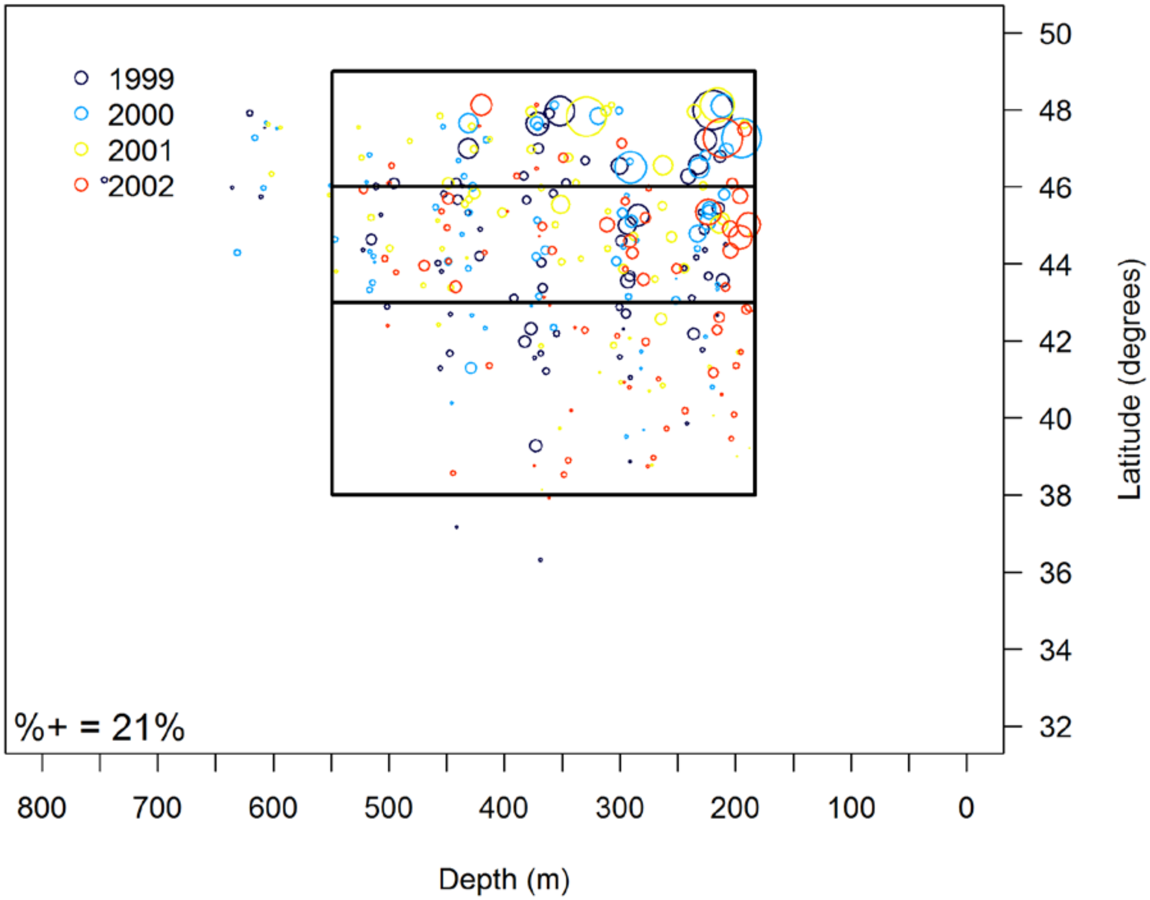

Figure 9. Distribution of arrowtooth flounder for each year in the Norwest Fisheries Science Center (NWFSC) slope survey. The depth and area strata used in the GLMM are indicated by the black squares.

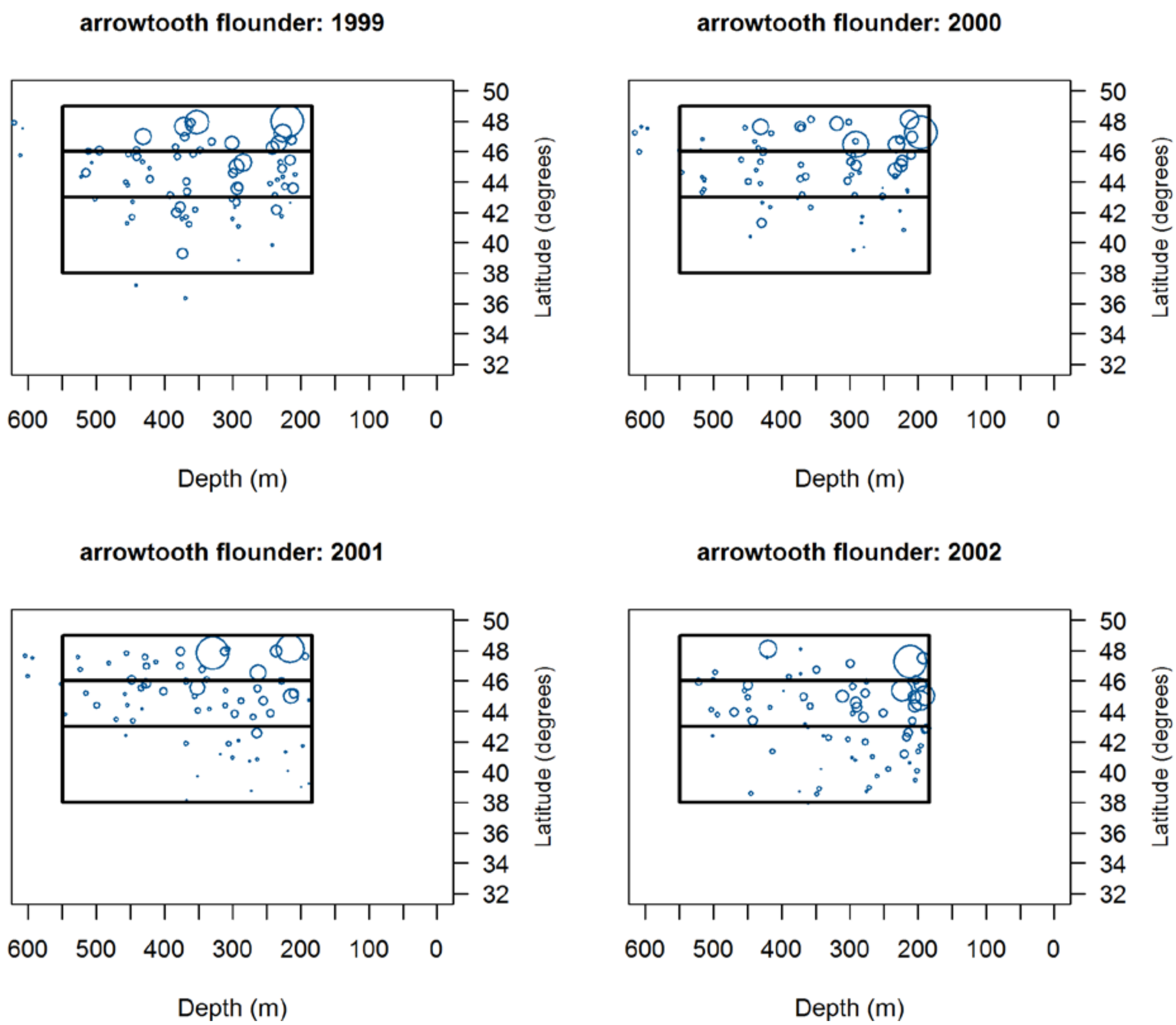

Figure 10. Yearly arrowtooth flounder distribution and depth by area strata for the NWFSC slope survey.

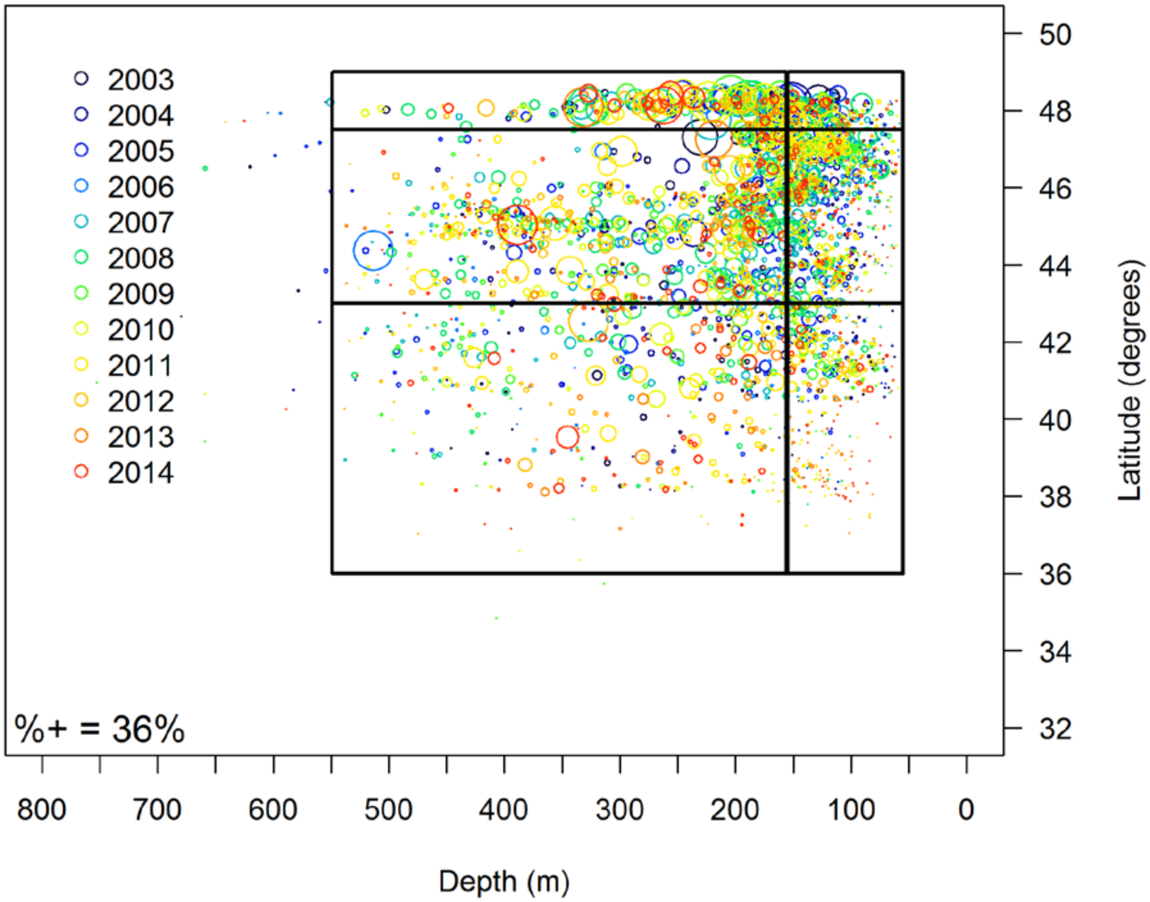

Figure 11. Distribution of arrowtooth flounder for each year in the NWFSC shelf-slope survey. The depth and area strata from the 2007 assessment are indicated by the black squares.

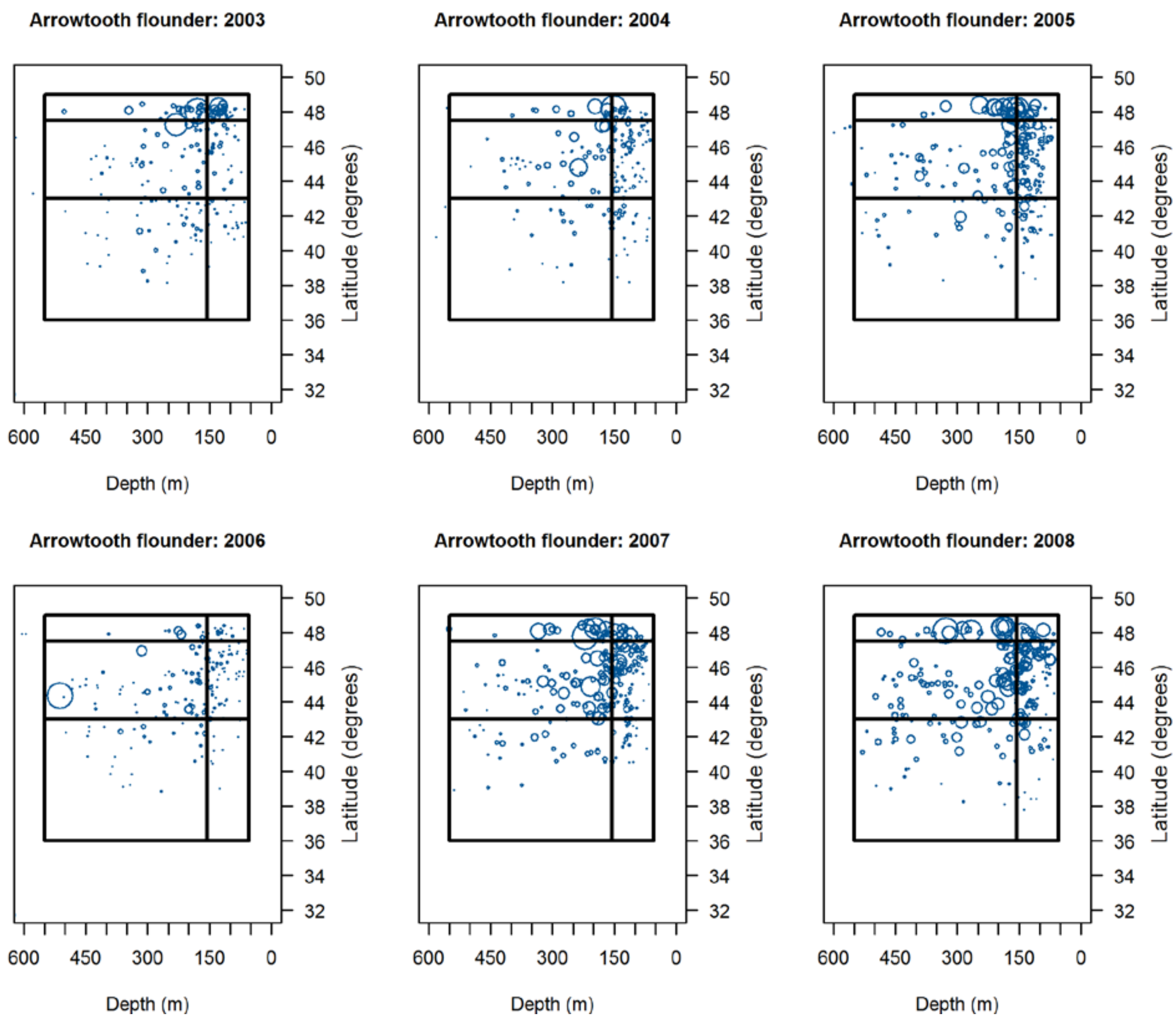

Figure 12. Yearly arrowtooth flounder distribution and depth by area strata from the 2007 assessment for the NWFSC shelf-slope survey. Figure continues onto next page.

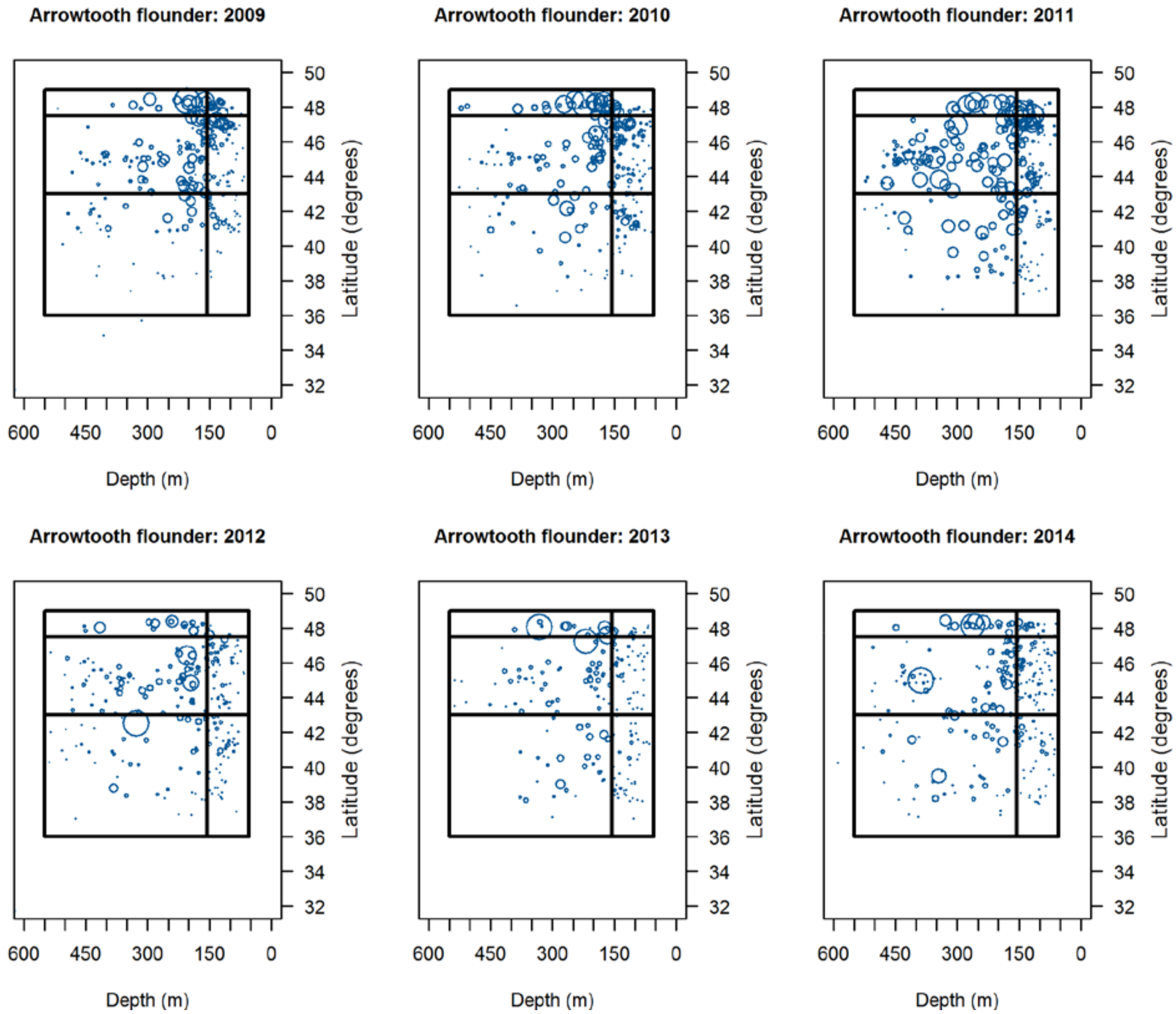

Figure 12 (continued).

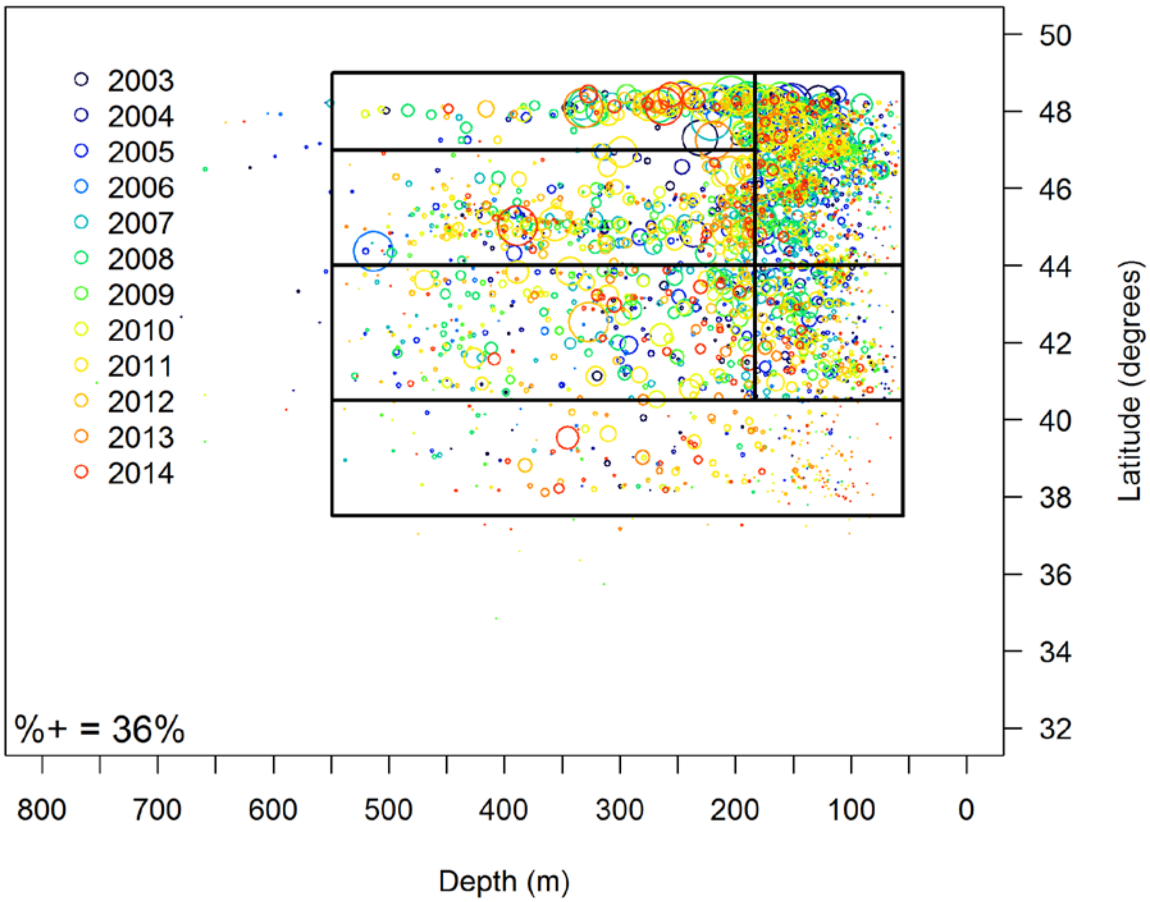

Figure 13. Distribution of arrowtooth flounder for each year in the Norwest Fisheries Science Center shelf-slope survey. The depth and area strata updated for the current assessment are indicated by the black squares.

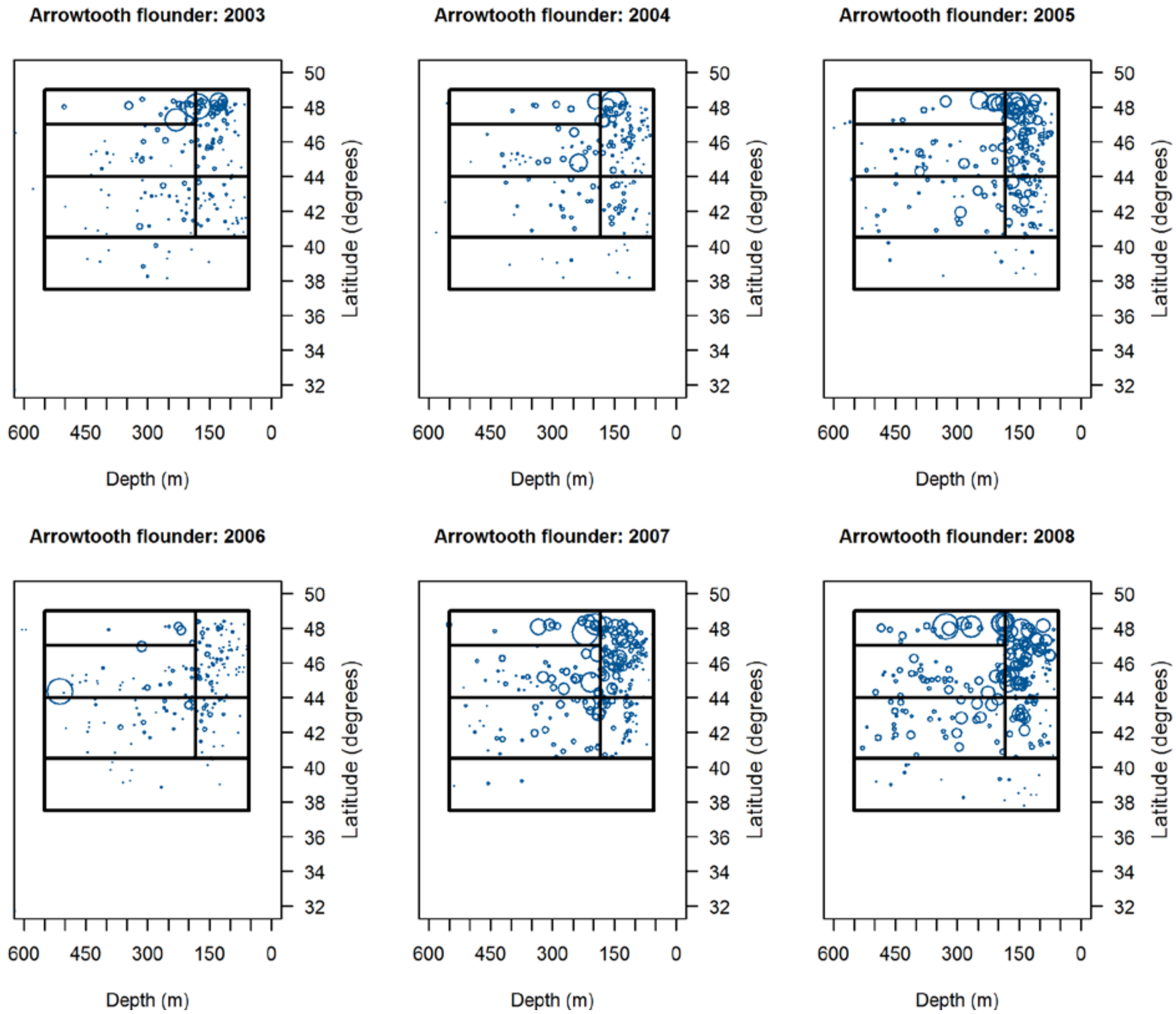

Figure 14. Yearly arrowtooth flounder distribution and depth by area strata updated for the current assessment for the NWFSC shelf-slope survey. Figure continues onto next page.

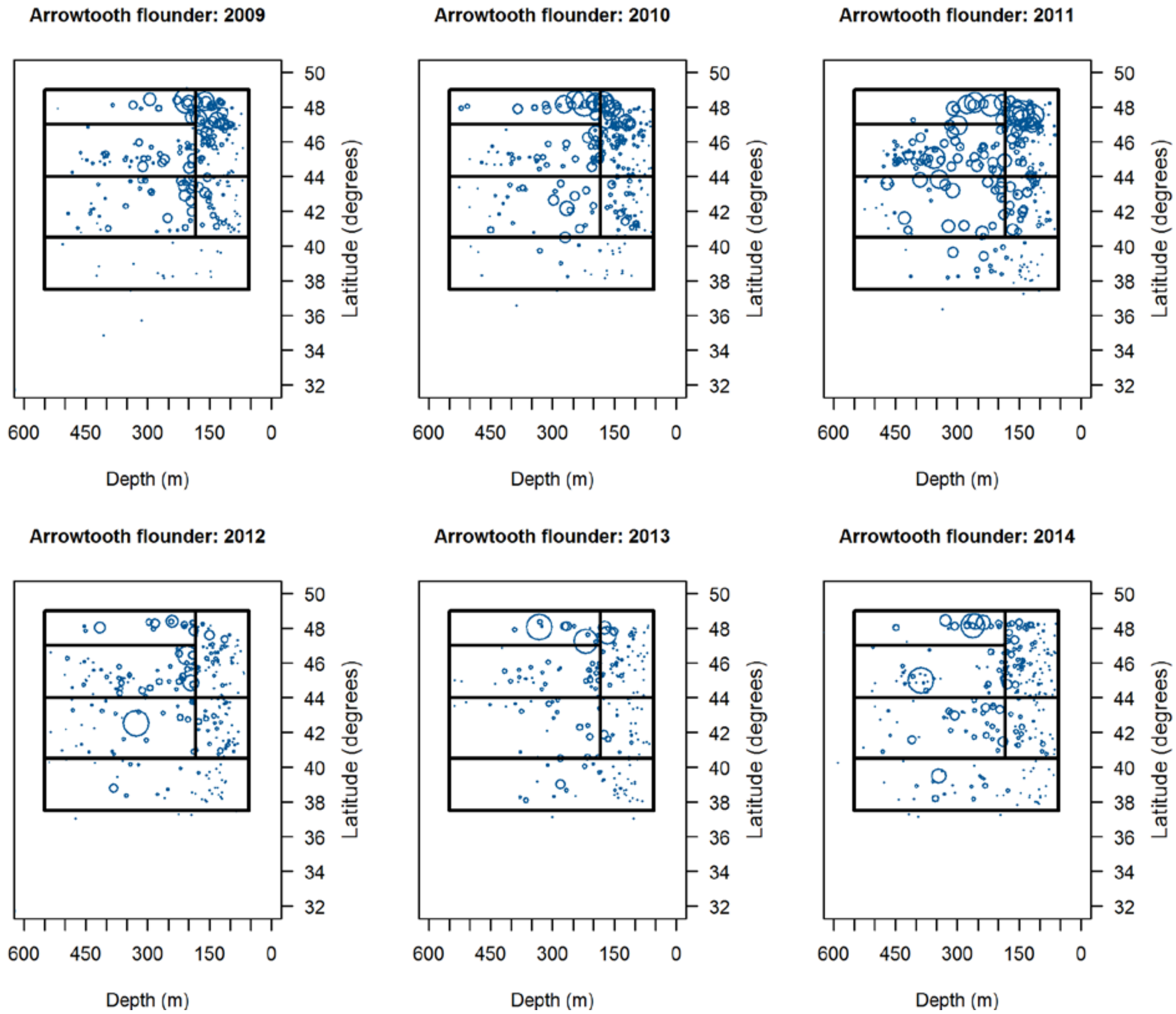

Figure 14 (continued).

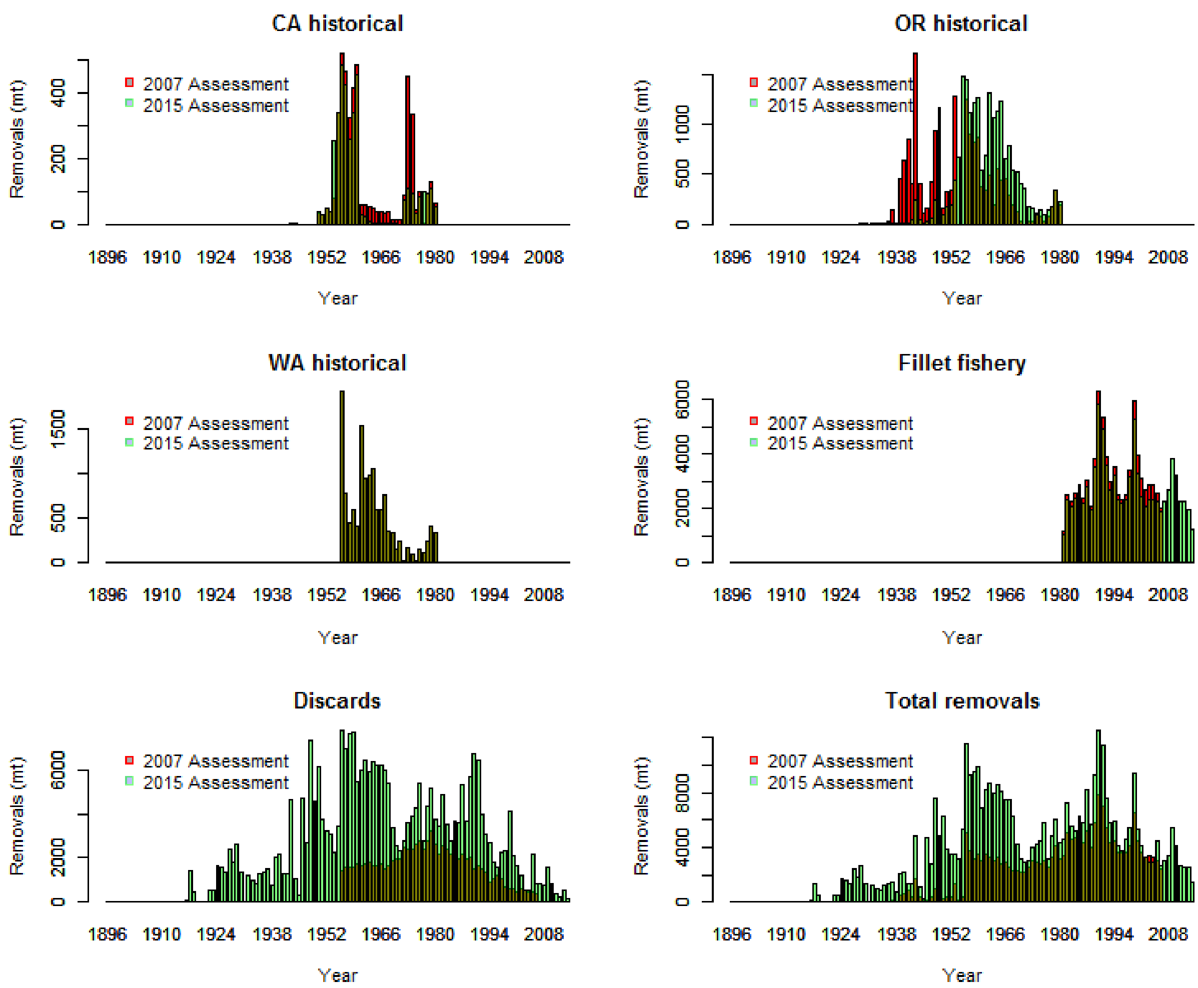

Figure 15. Comparison of removals by sector and overall all sectors between the 2007 and current (2015) assessment.

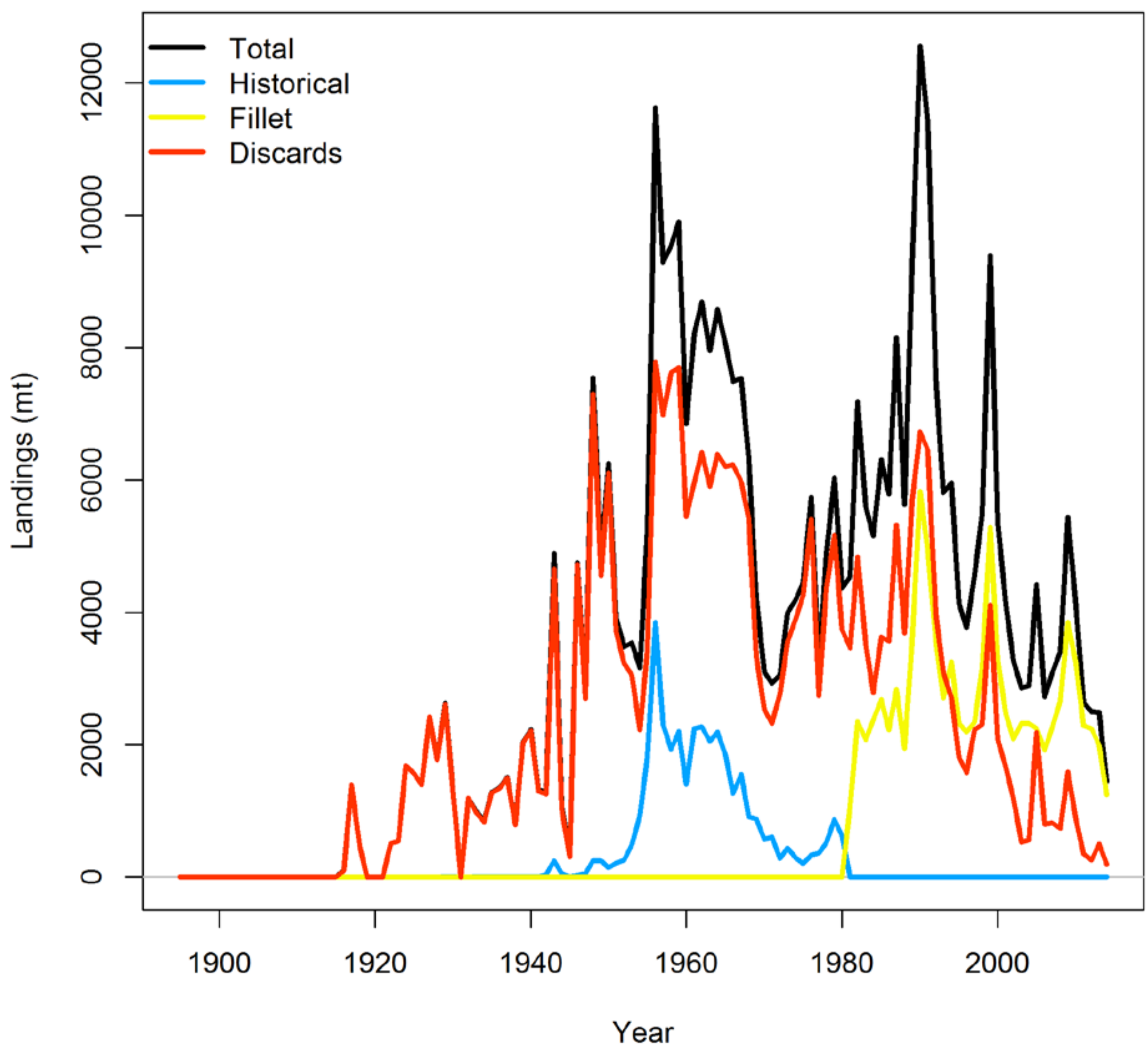

Figure 16. Complete removal history (1896-2014) by sector for arrowtooth flounder used in the stock assessment. A description of each sector can be found in Section 2.1.1.1 to 2.1.1.3.

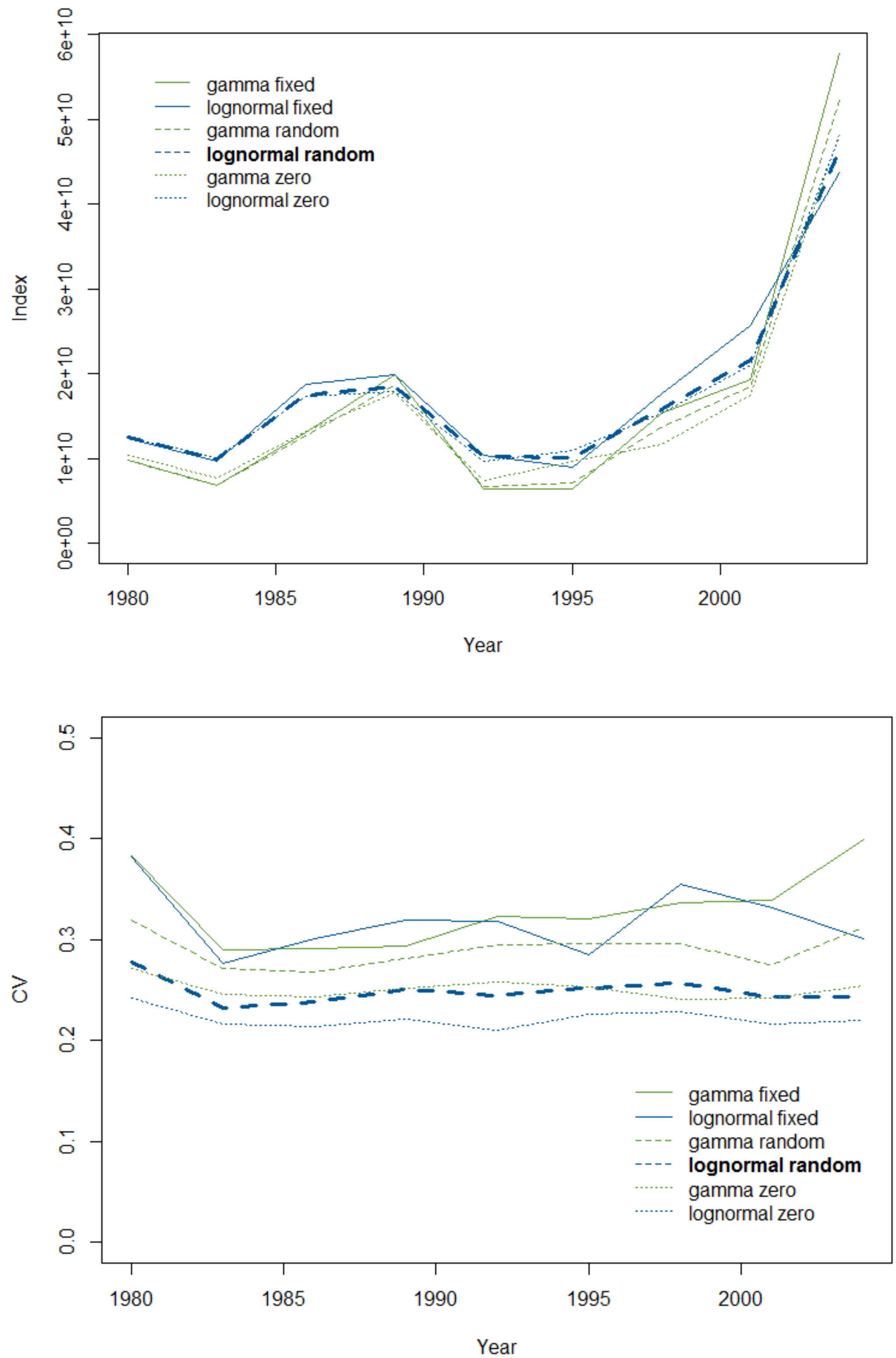

Figure 17. Abundance index (top panel) and associated variability (bottom panel) for the Triennial shelf survey 1980-2005 delta-GLMM models. Selected model (via DIC) in bold and thickest line.

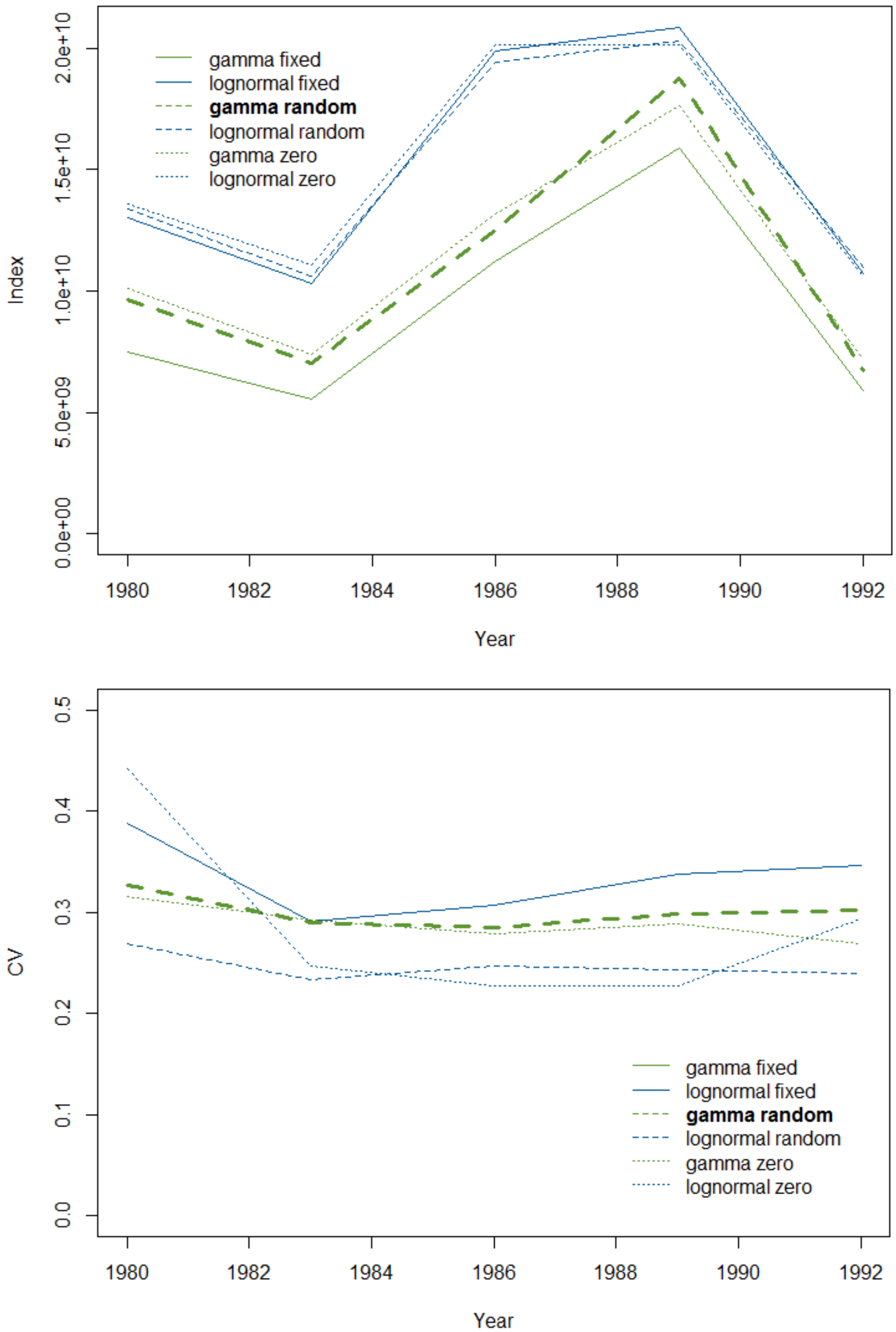

Figure 18. Abundance index (top panel) and associated variability (bottom panel) for the Triennial shelf survey 1980-1992 delta-GLMM models. Selected model (via DIC) in bold and thickest line.

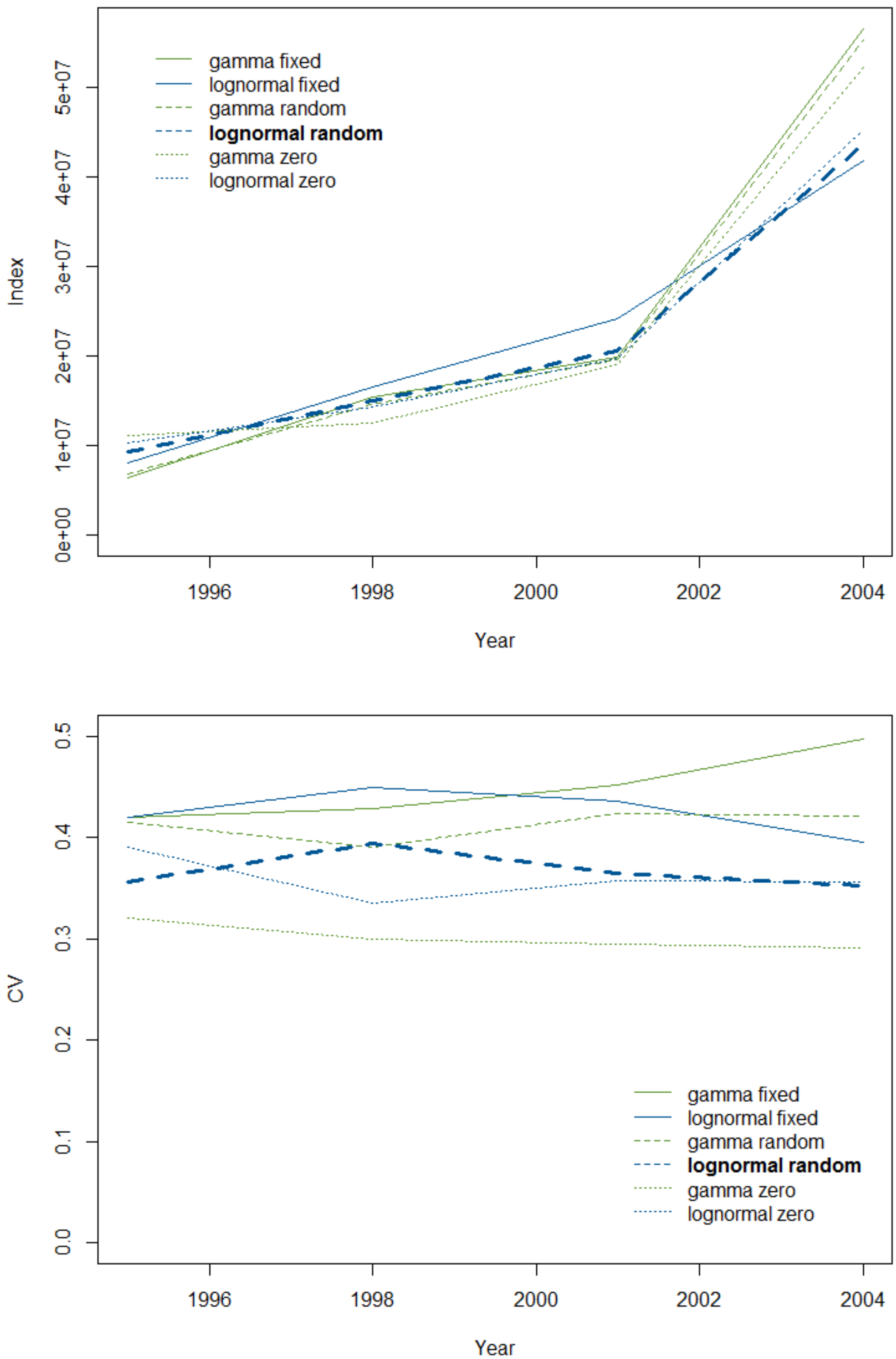

Figure 19. Abundance index (top panel) and associated variability (bottom panel) for the Triennial shelf survey 1995-2004 delta-GLMM models. Selected model (via DIC) in bold and thickest line.

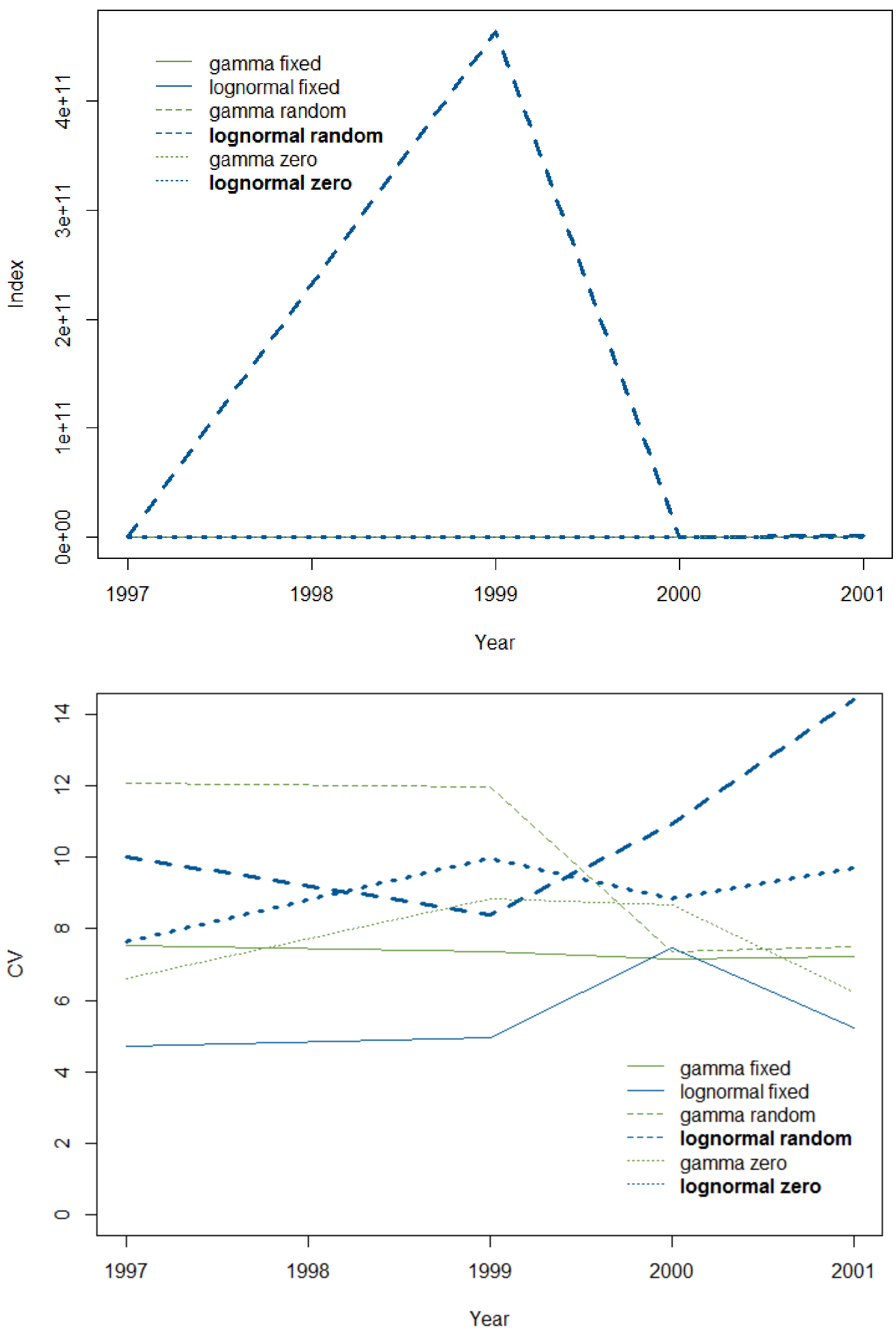

Figure 20. Abundance index (top panel) and associated variability (bottom panel) for the AFSC slope survey delta-GLMM models. Selected model (via DIC) in bold and thickest line.

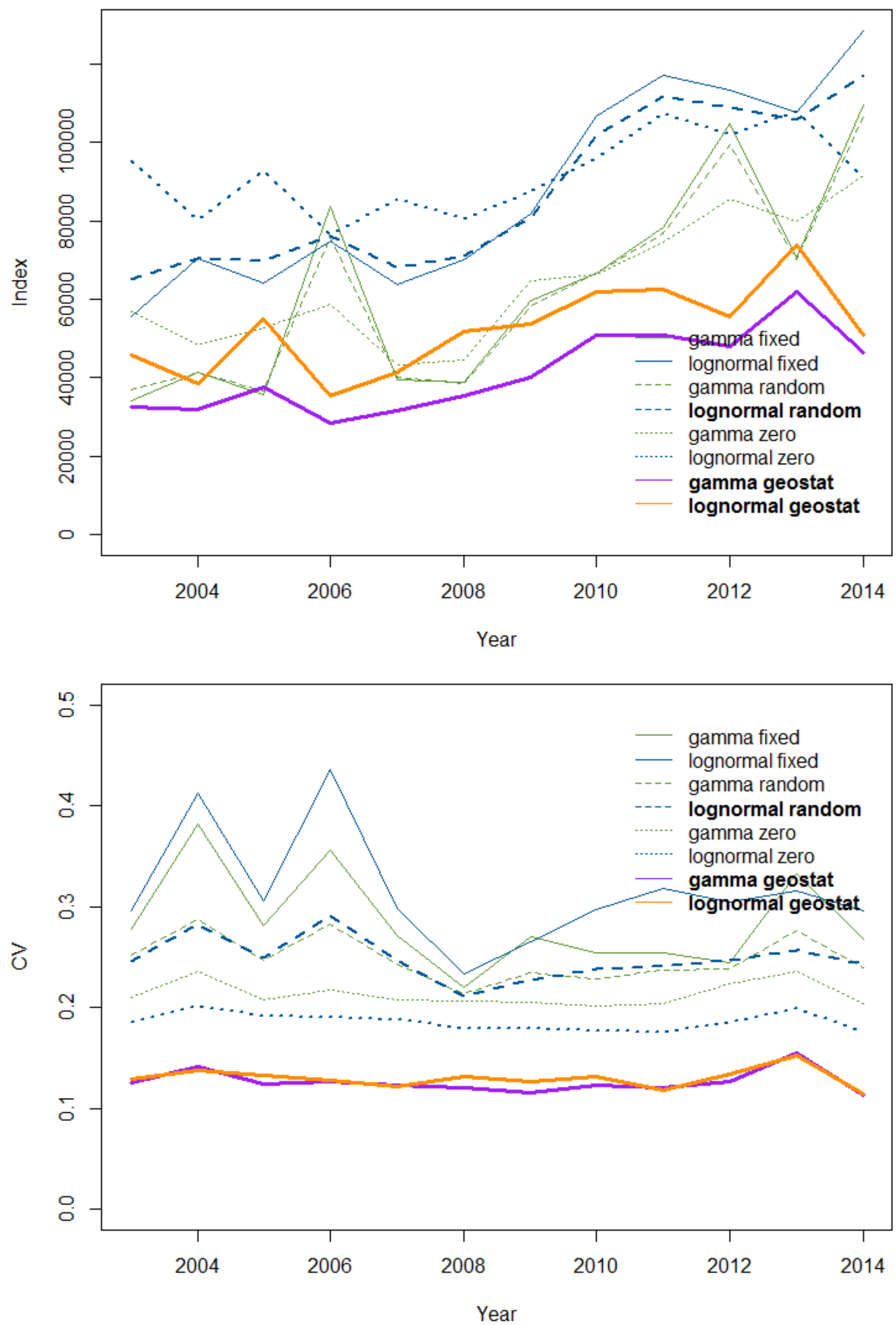

Figure 21. Abundance index (top panel) and associated variability (bottom panel) for the NWFSC shelf-slope survey (using the new strata) delta-GLMM models. Selected model (via DIC) in bold and thickest line.

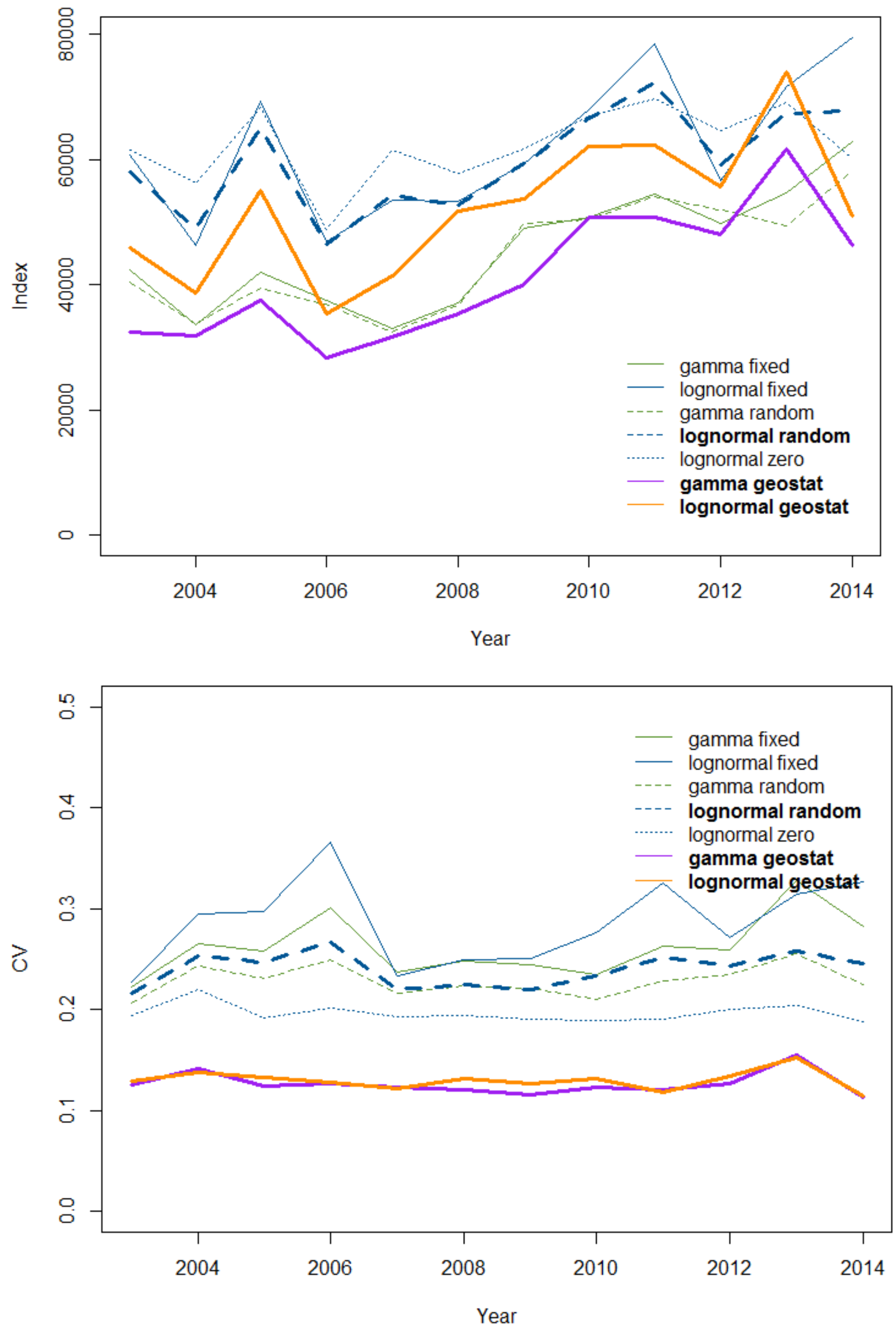

Figure 22. Abundance index (top panel) and associated variability (bottom panel) for the NWFSC shelf-slope survey (using the 2007 assessment strata) delta-GLMM models. Selected model (via DIC) in bold and thickest line.

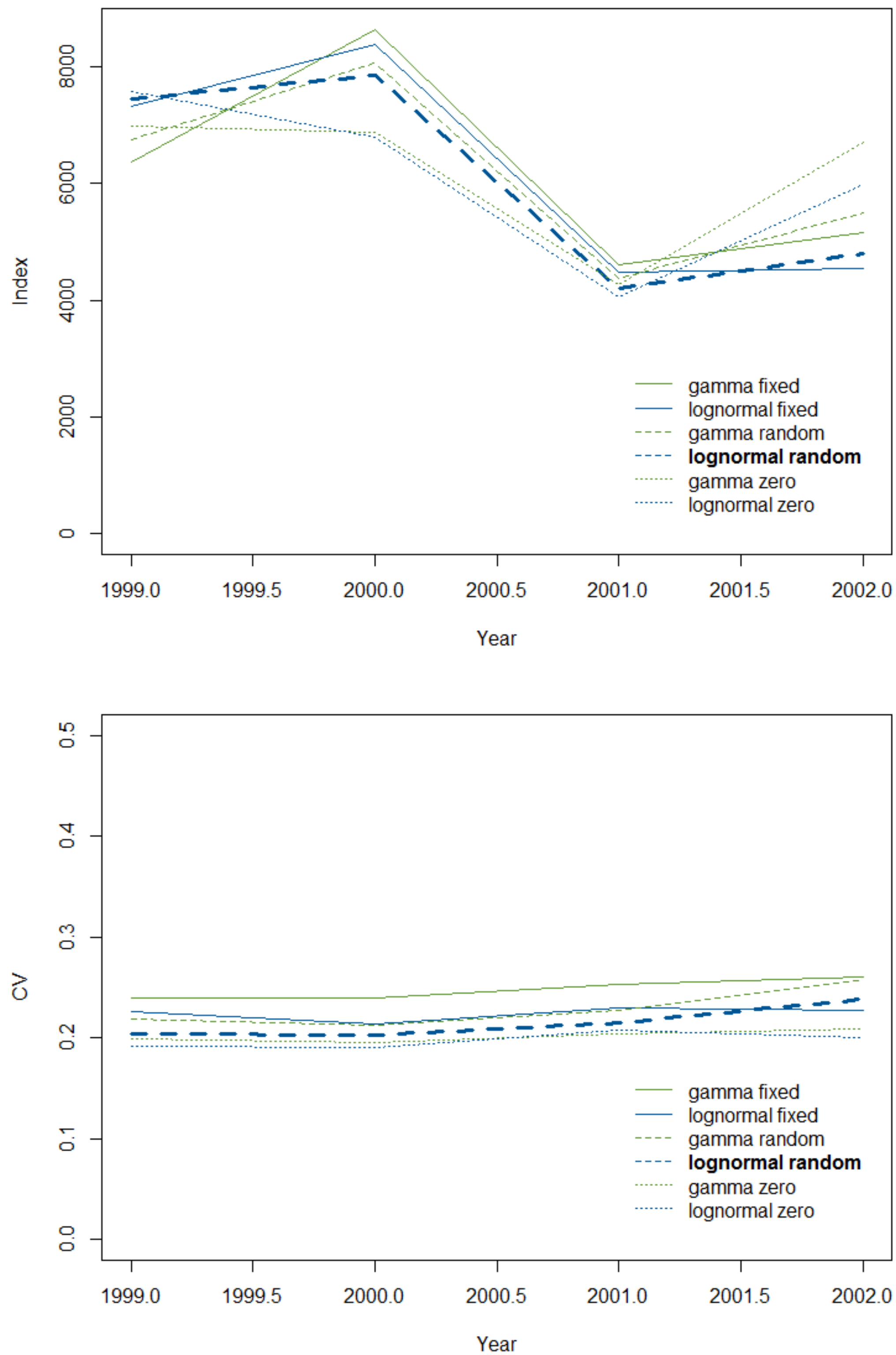

Figure 23. Abundance index (top panel) and associated variability (bottom panel) for the NWFSC slope survey delta-GLMM models. Selected model (via DIC) in bold and thickest line.

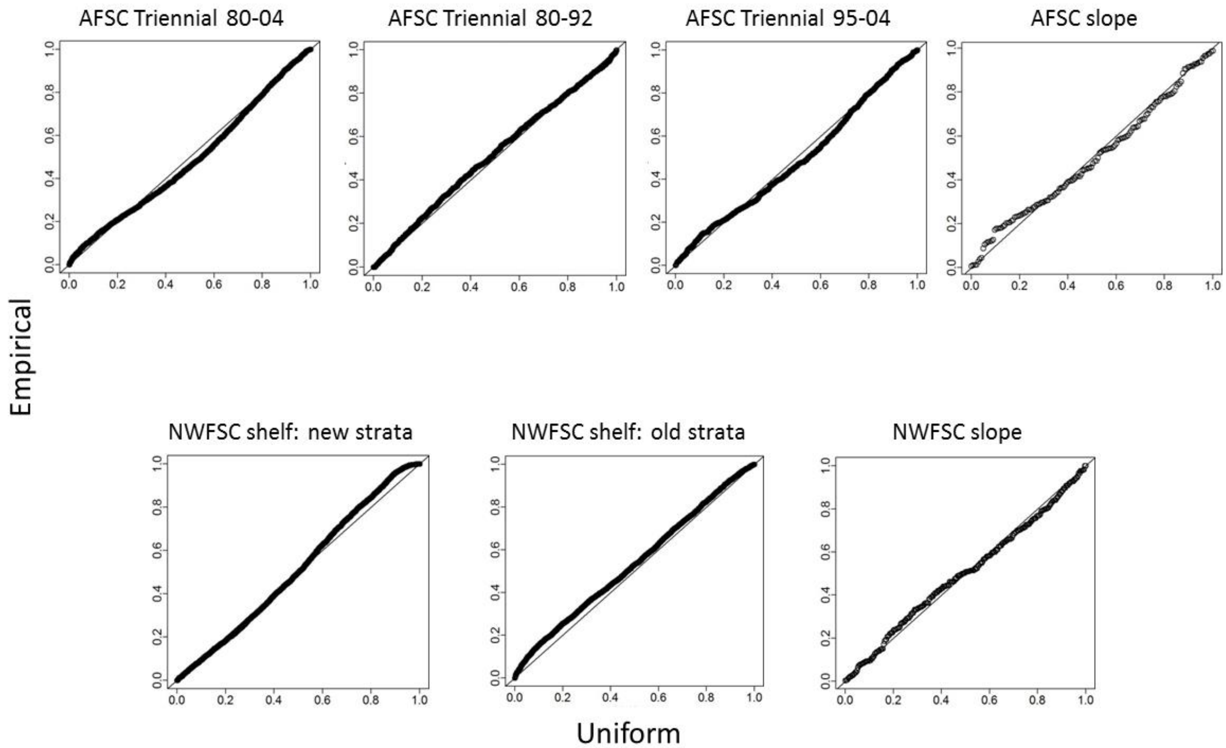

Figure 24. Q-Q plots of the selected model fit to the positive catch rates in each index based on the delta-GLMM framework.

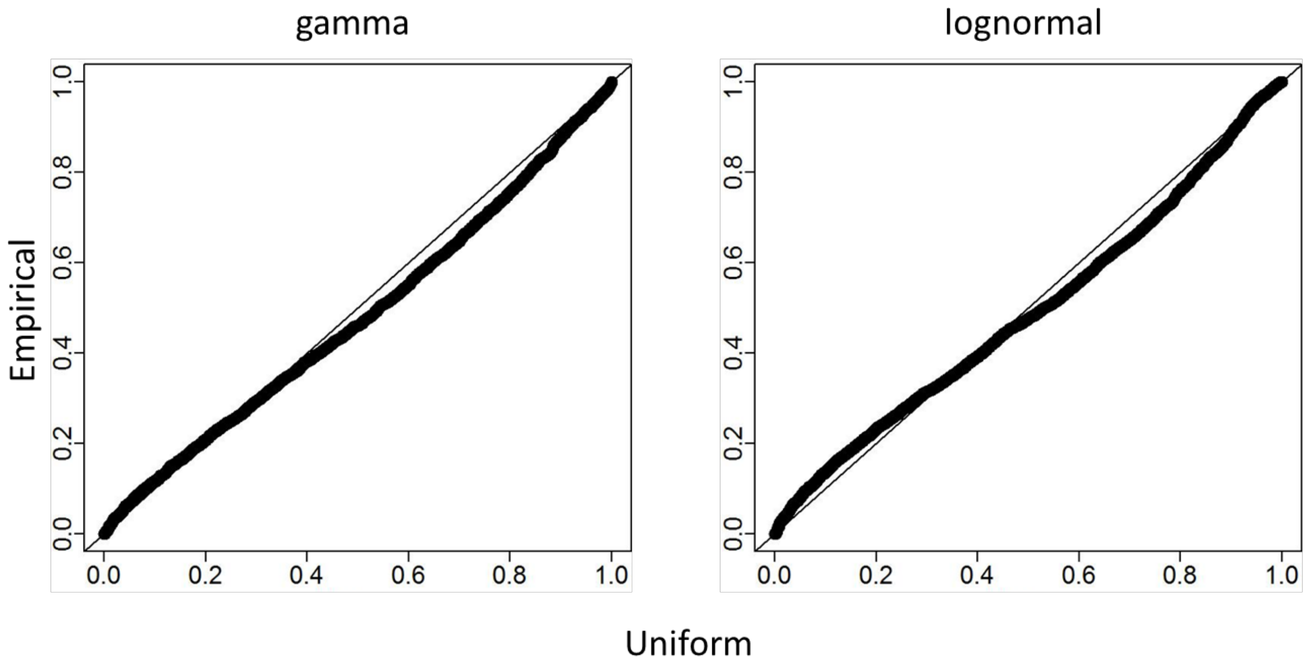

Figure 25. Q-Q plots of the selected model fit to the positive catch rates in each index based on the geostatistical framework.

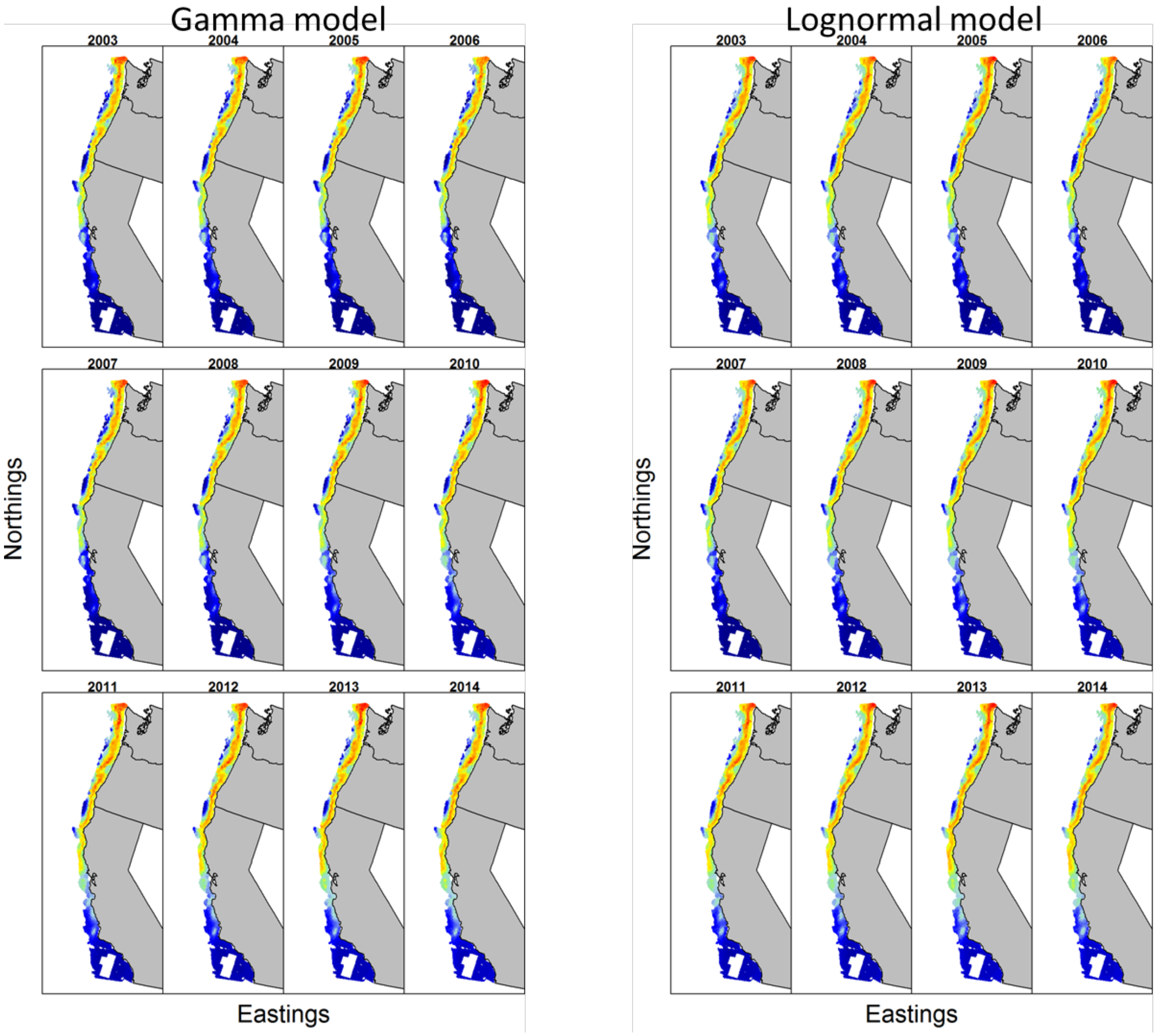

Figure 26. Spatial variation in density of arrowtooth flounder estimated from the geostatistical model.

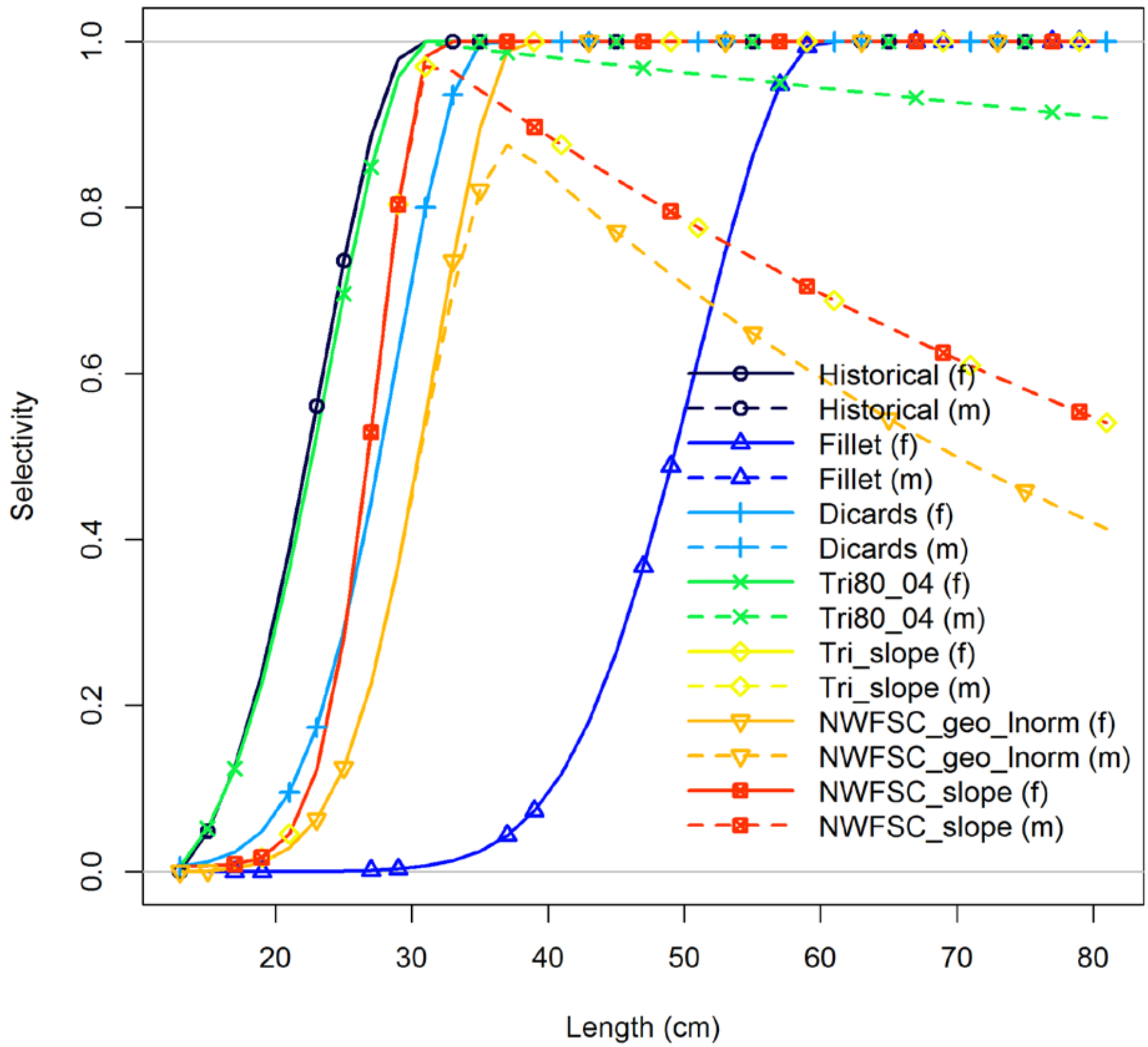

Figure 27. Selectivities for each fishery and survey used in the arrowtooth flounder stock assessment. Selectivity values taken from the 2007 stock assessment.

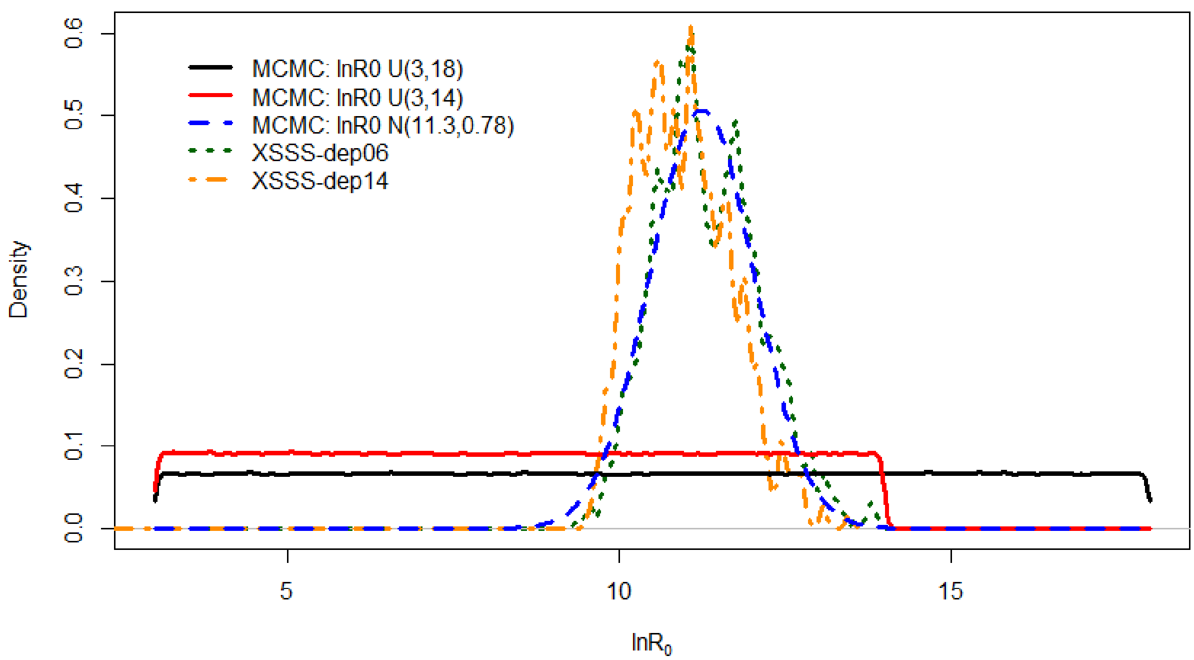

Figure 28. MCMC priors and implied priors from XSSS models on lnR_0 for different model treatments.

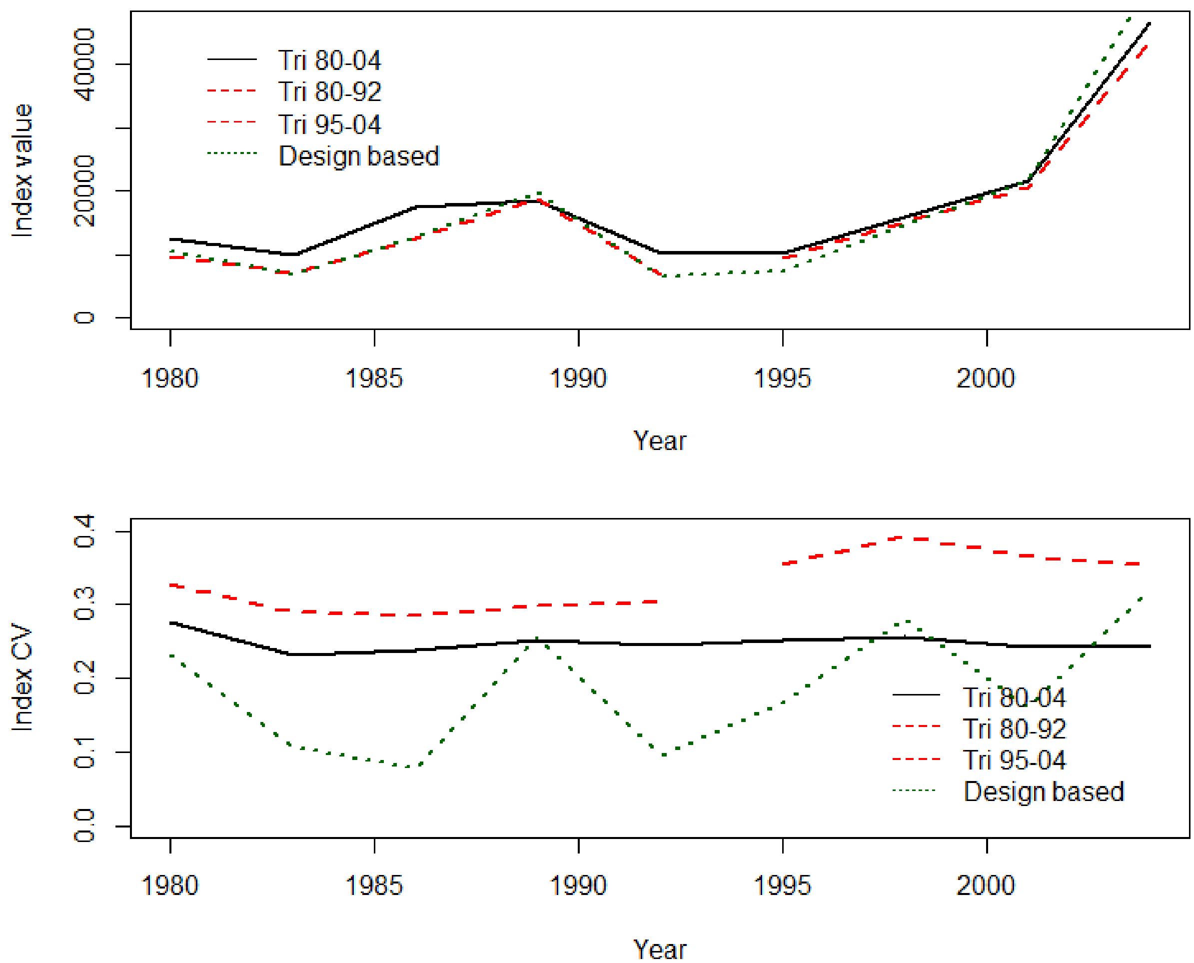

Figure 29. Comparison of abundance index value (top panel) and variability (bottom panel) for the two different formulations of the Triennial survey.

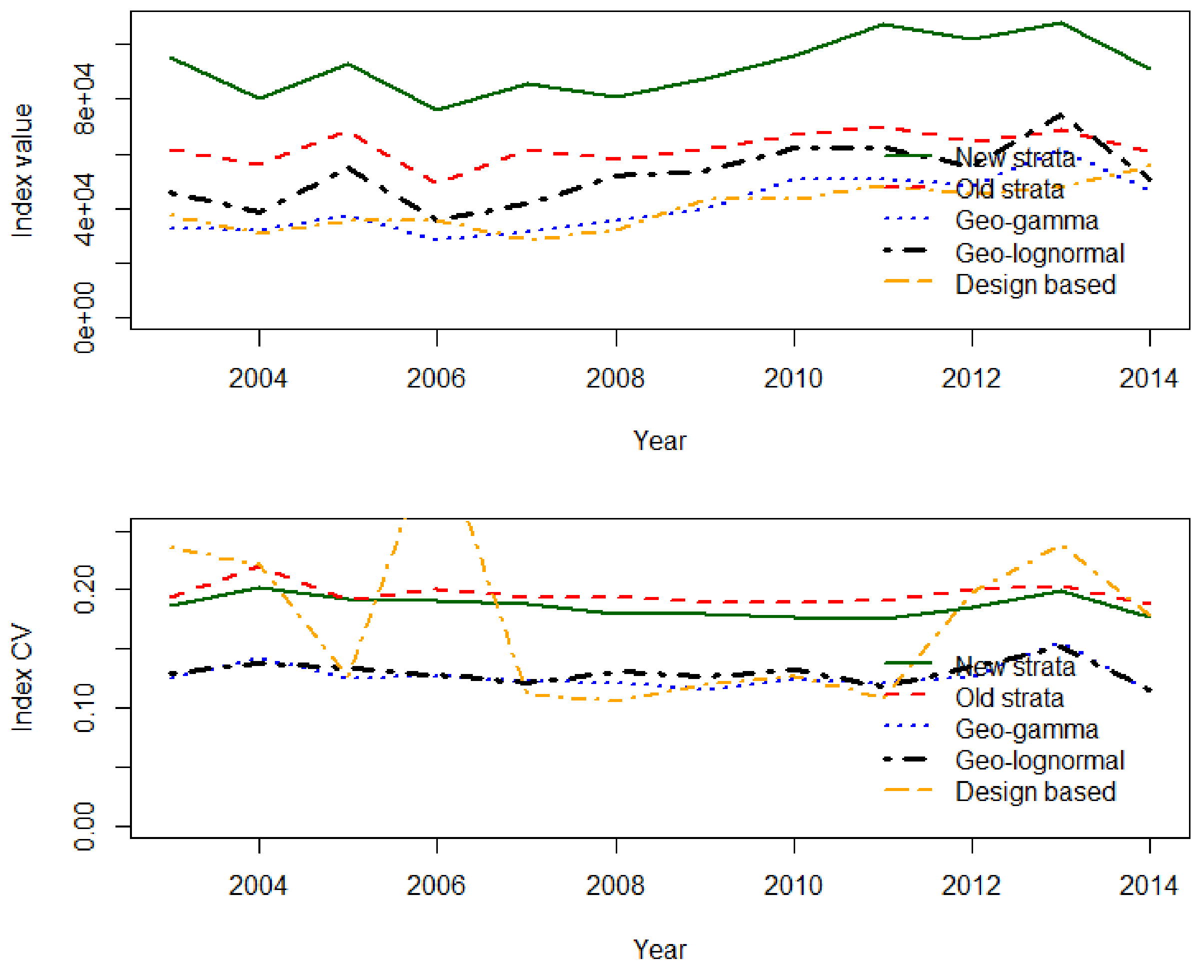

Figure 30. Comparison of abundance index values (top panel) and variability (bottom panel) for the four different formulations of the NWFSC shelf-slope survey. "Old strata" is the stratification used in the last assessment. "New strata" is an alternative stratification explored in the new assessment.

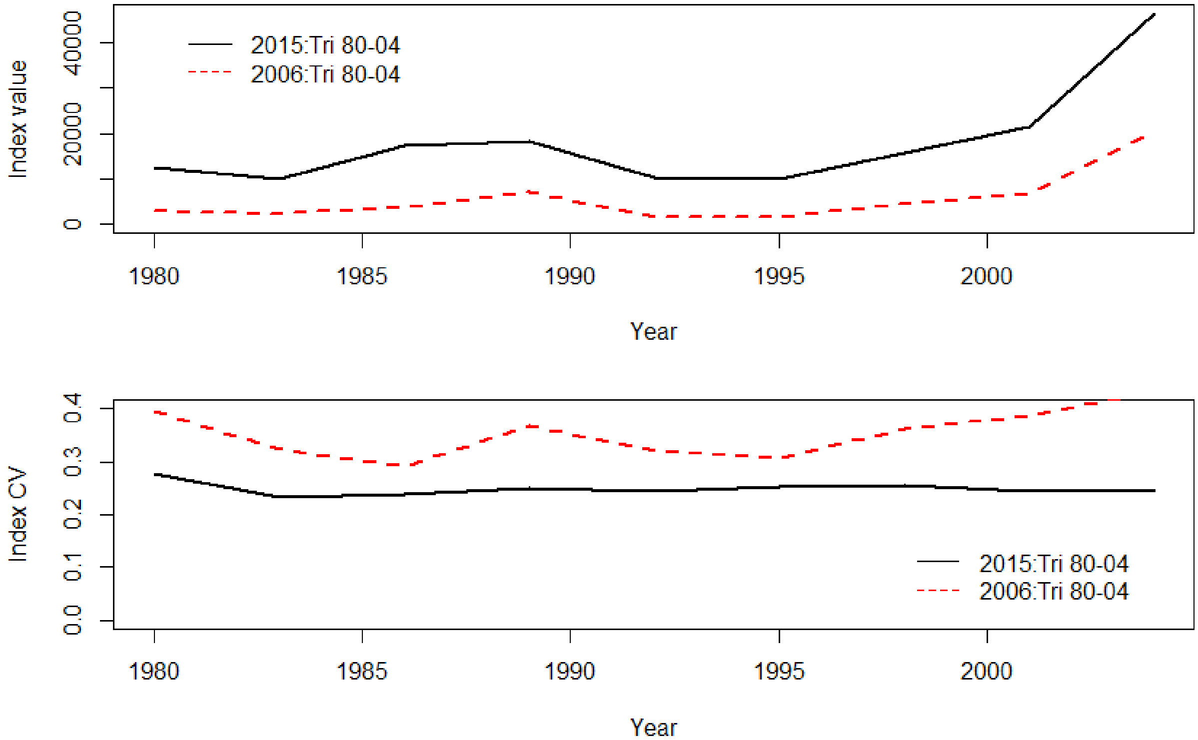

Figure 31. Comparison of the triennial survey (1980-2004) indices (top panel) and associated uncertainty (bottom panel) used in the current assessment versus the 2007 assessment.

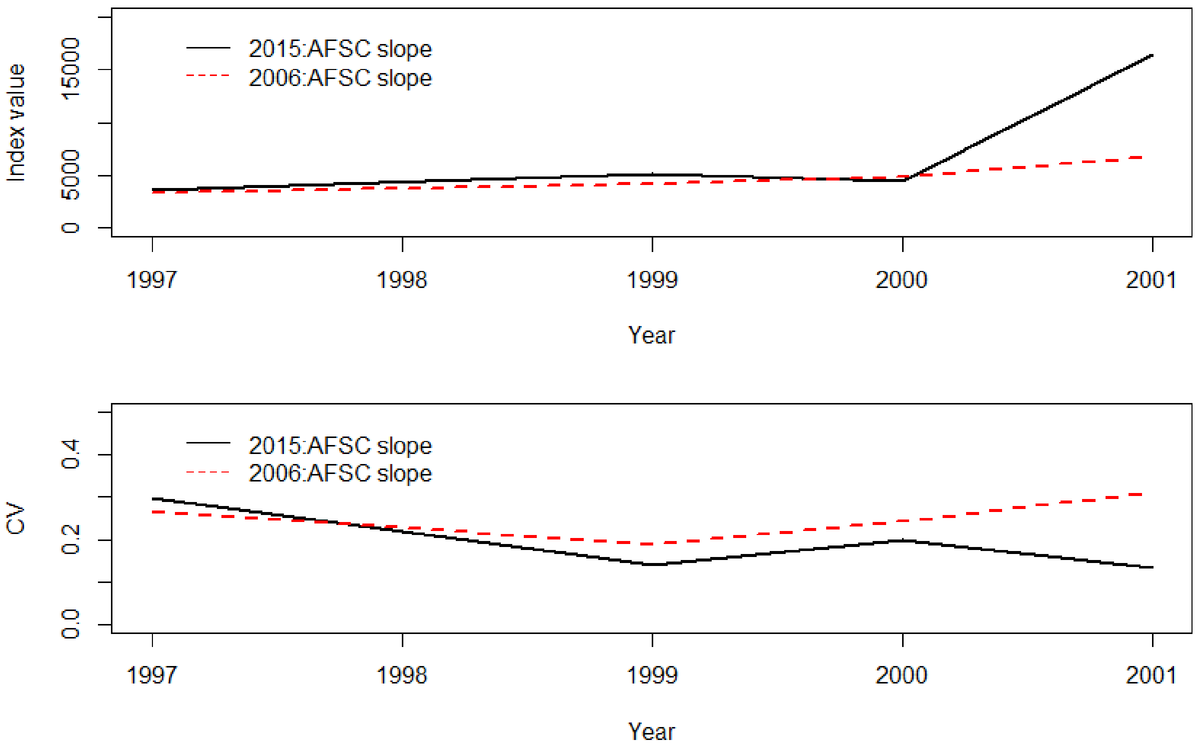

Figure 32. Comparison of the AFSC slope survey indices (top panel) and associated uncertainty (bottom panel) used in the current assessment versus the 2007 assessment.

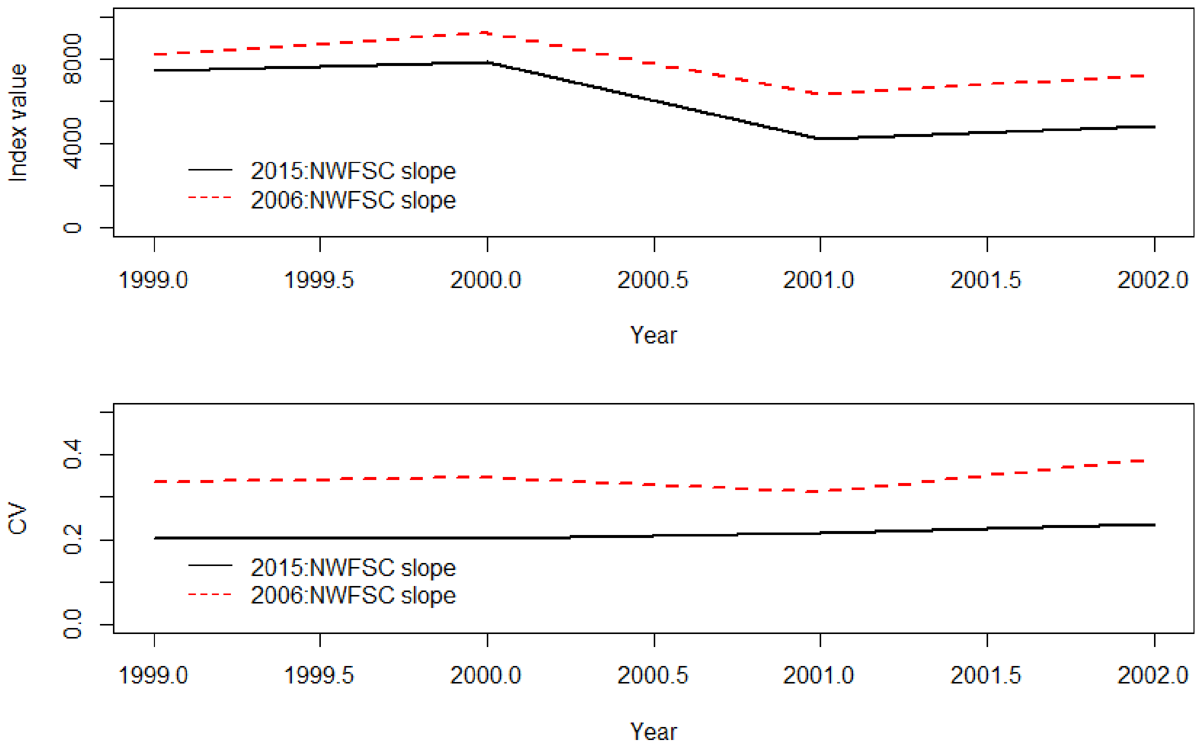

Figure 33. Comparison of the NWFSC slope survey indices (top panel) and associated uncertainty (bottom panel) used in the current assessment versus the 2007 assessment.

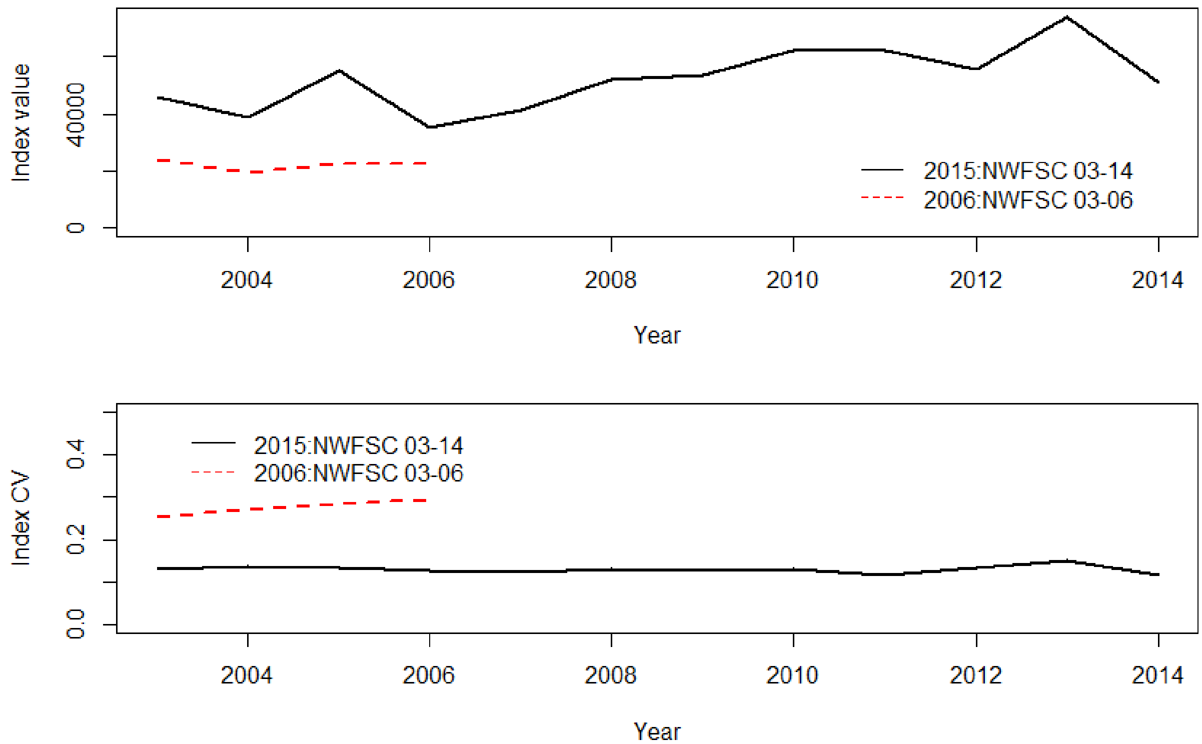

Figure 34. Comparison of the NWFSC survey indices (top panel) and associated uncertainty (bottom panel) used in the current assessment versus the 2007 assessment.

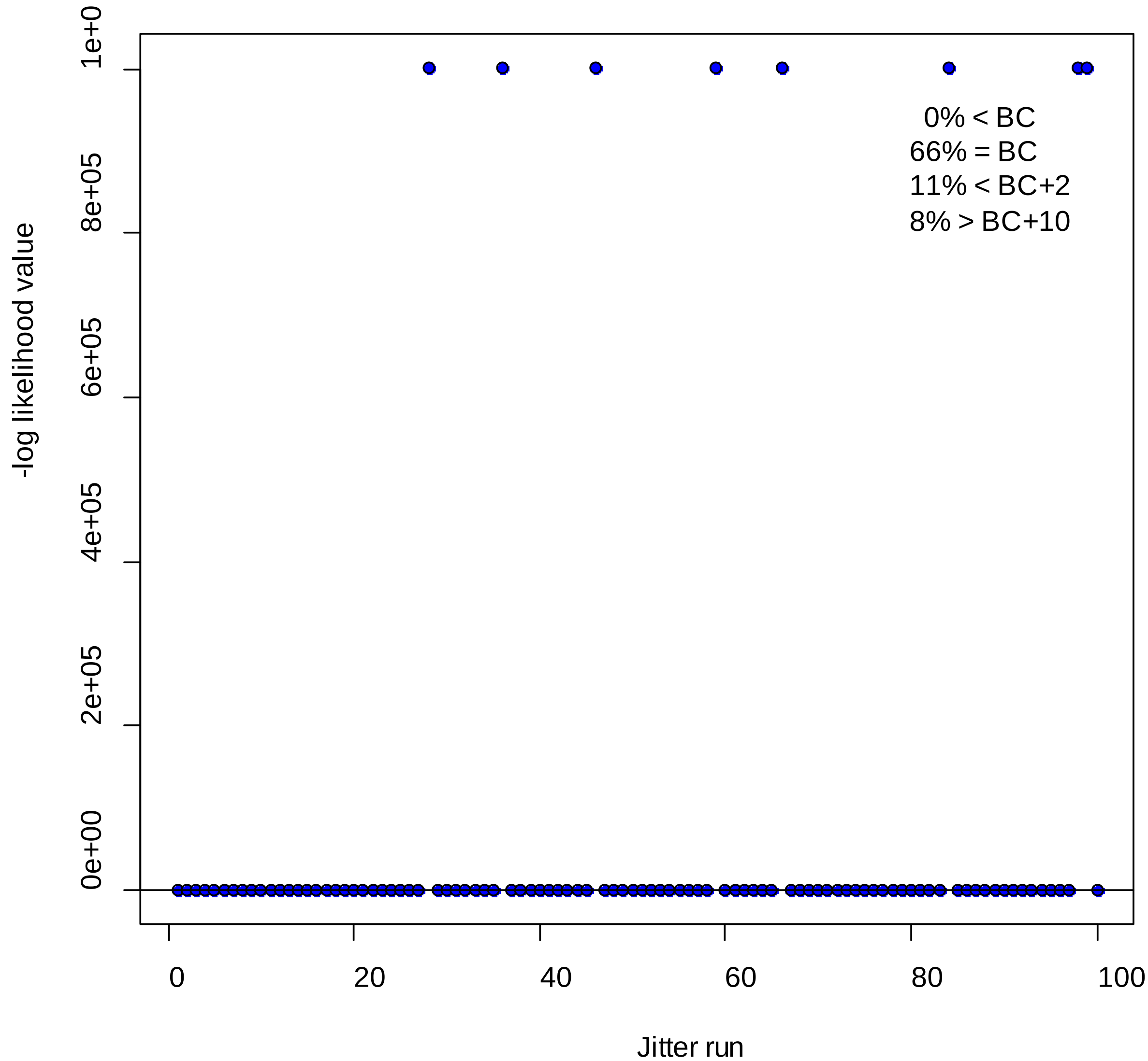

Figure 35. Results from 100 jitter runs using jitter values of 0.5. Results relative to the assumed base case MLE are plotted. <2 indicates runs within, but not equal to, the base case MLE. +10 indicates runs with likelihoods 10 or more units from the base case.

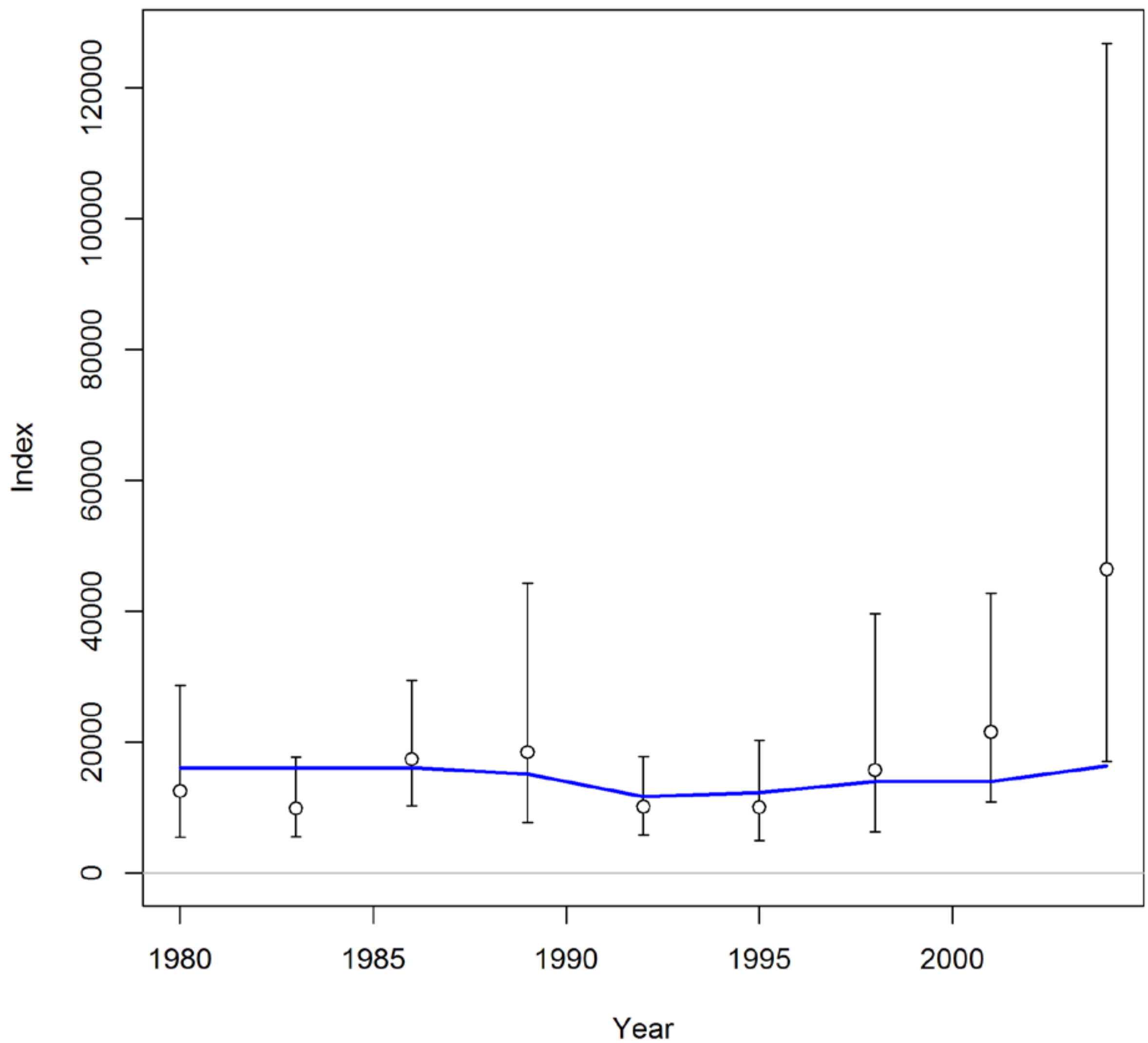

Figure 36. Base case MLE fit to the Triennial survey.

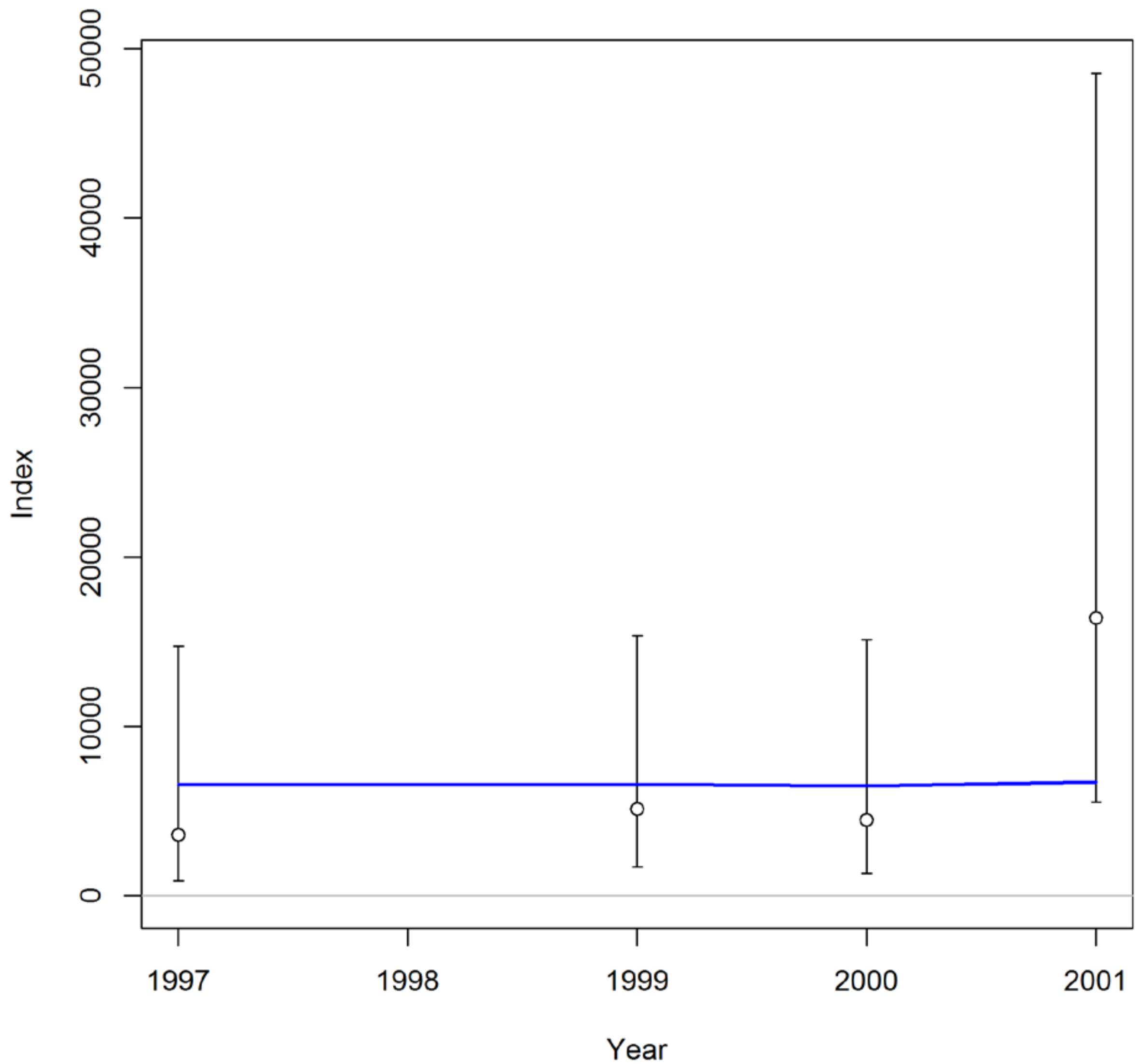

Figure 37. Base case MLE fit to the Triennial slope survey.

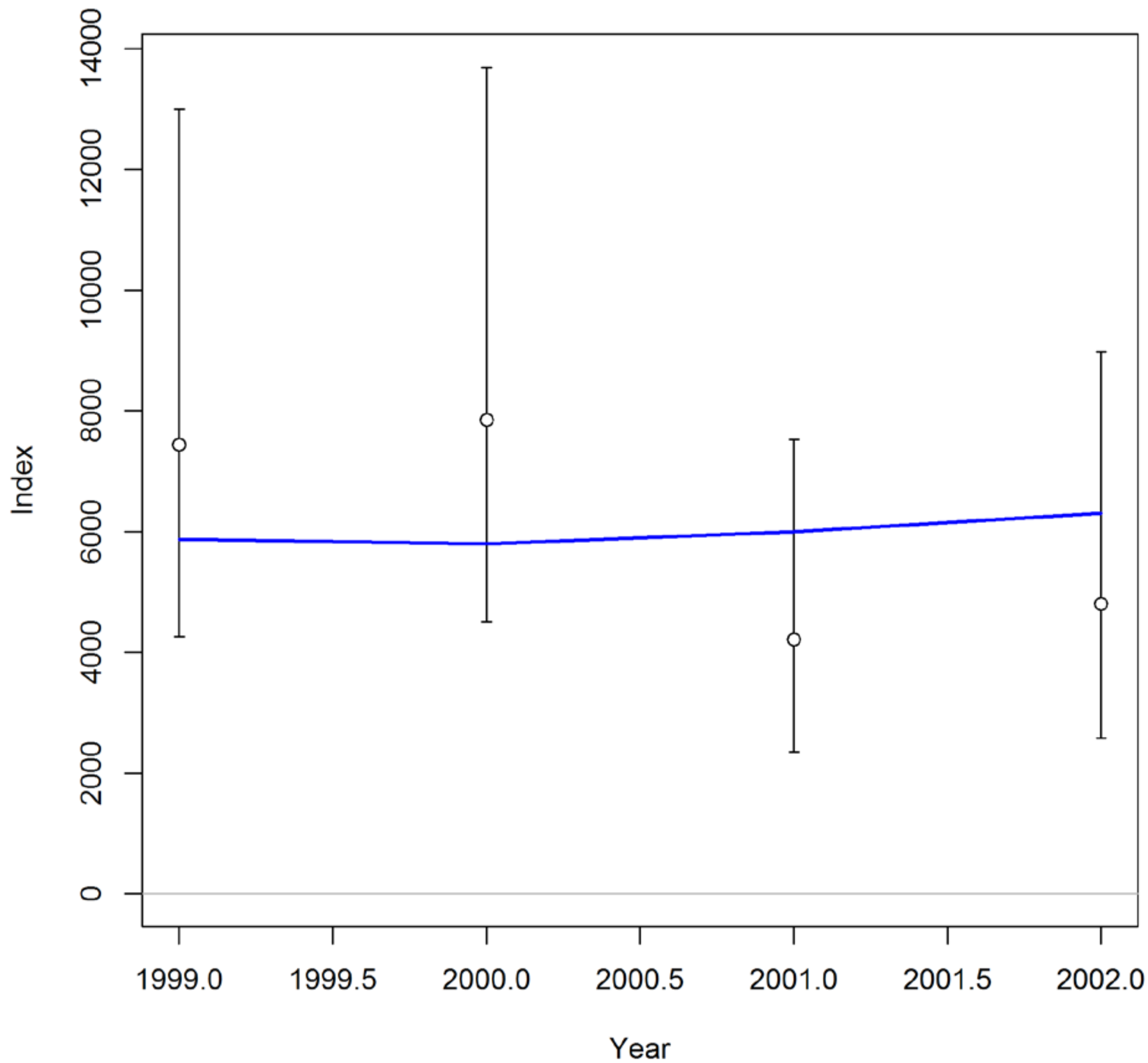

Figure 38. Base case MLE fit to the NWFSC slope survey.

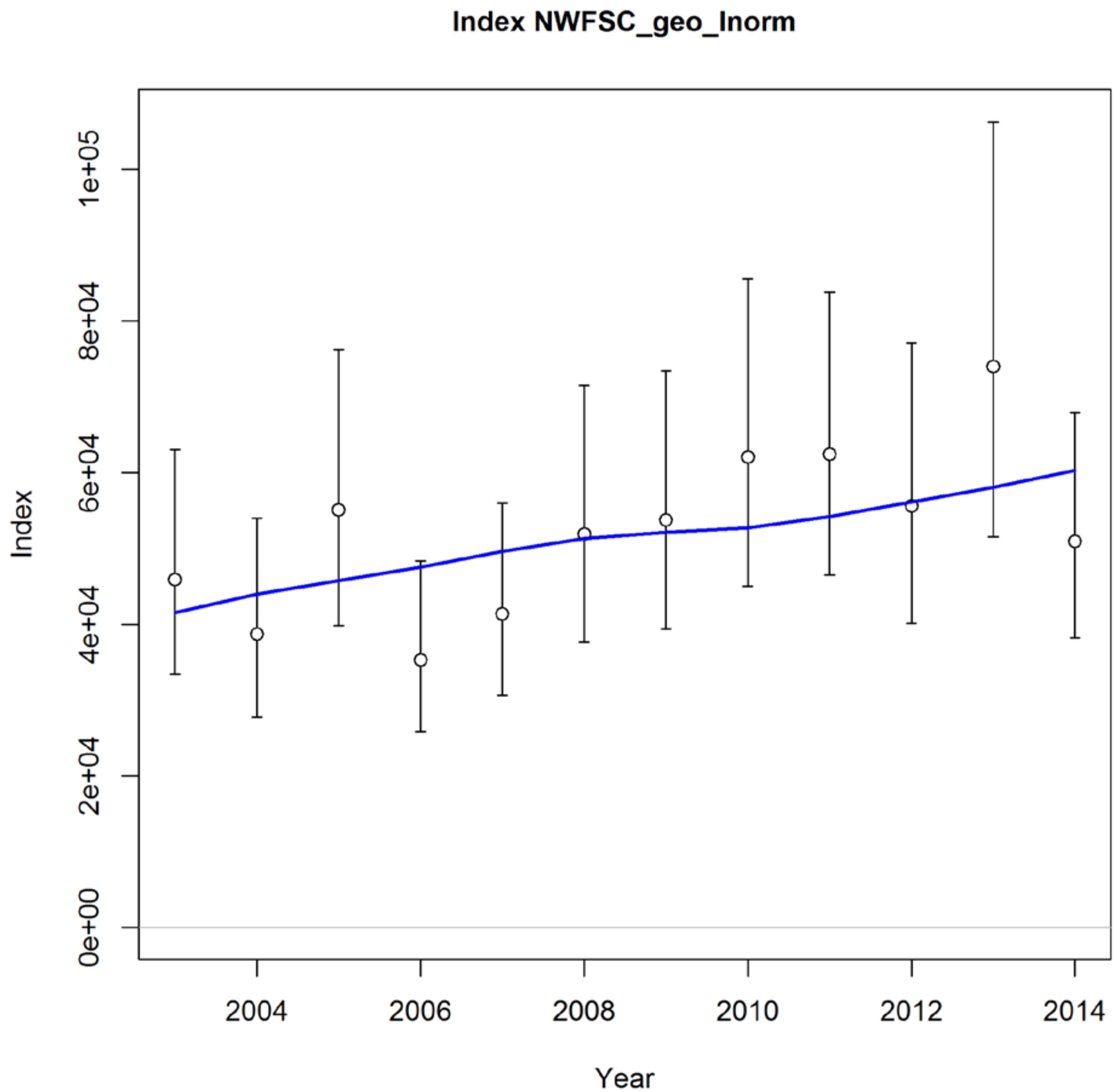

Figure 39. Base case MLE fit to the NWFSC shelf-slope survey.

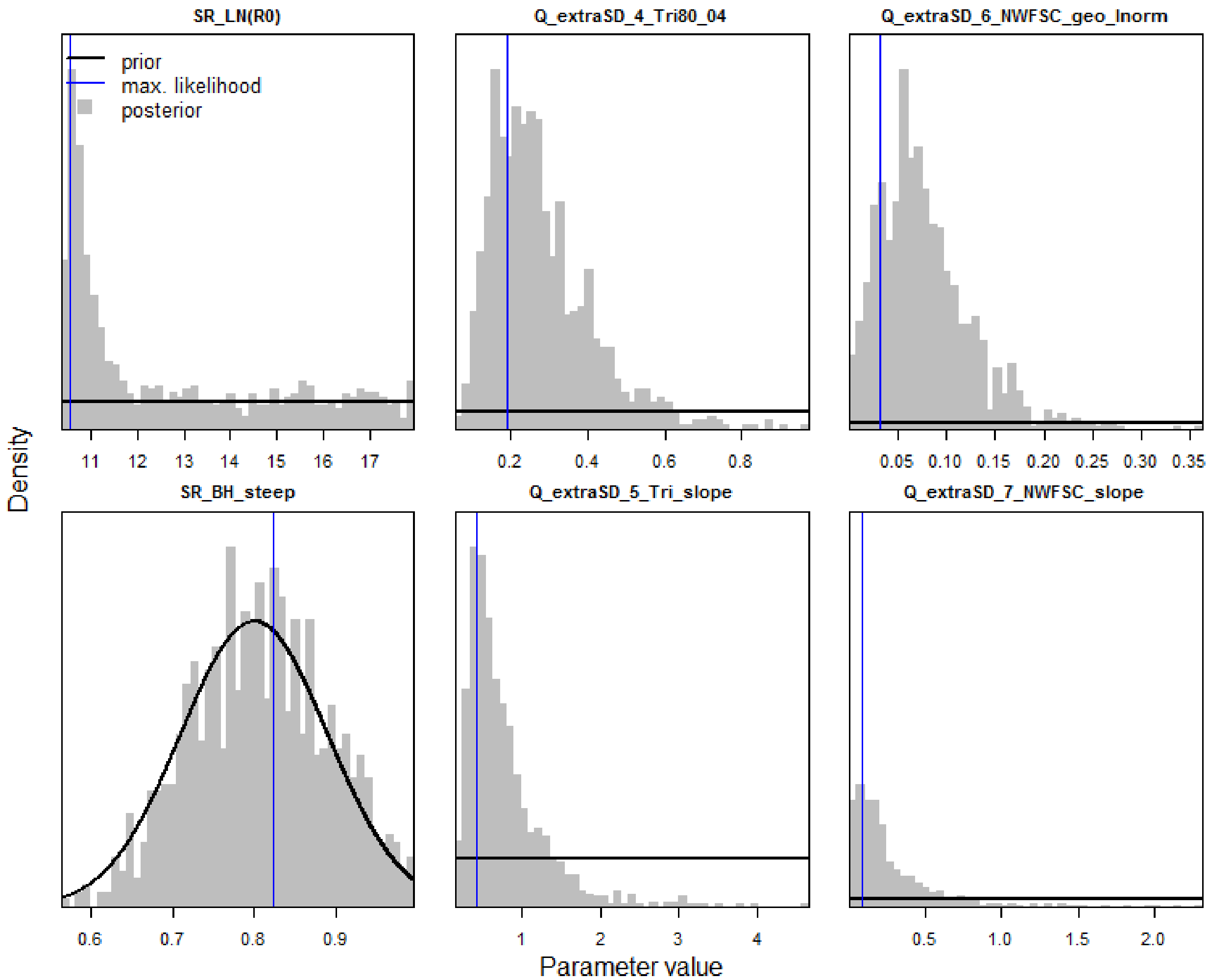

Figure 40. Prior and posterior comparisons from the MCMC run for arrowtooth flounder using a lnR_0 prior U(3,18).

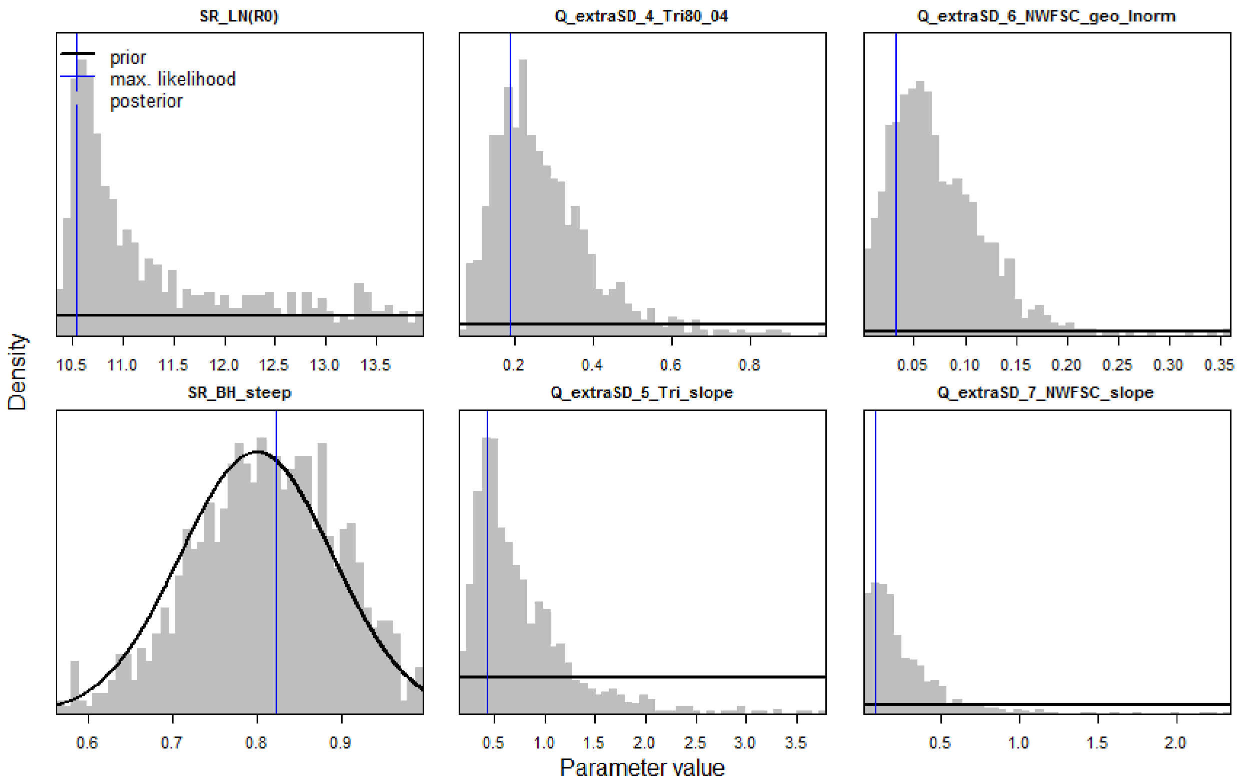

Figure 41. Prior and posterior comparisons from the MCMC run for arrowtooth flounder using a lnR_0 prior U(3,14).

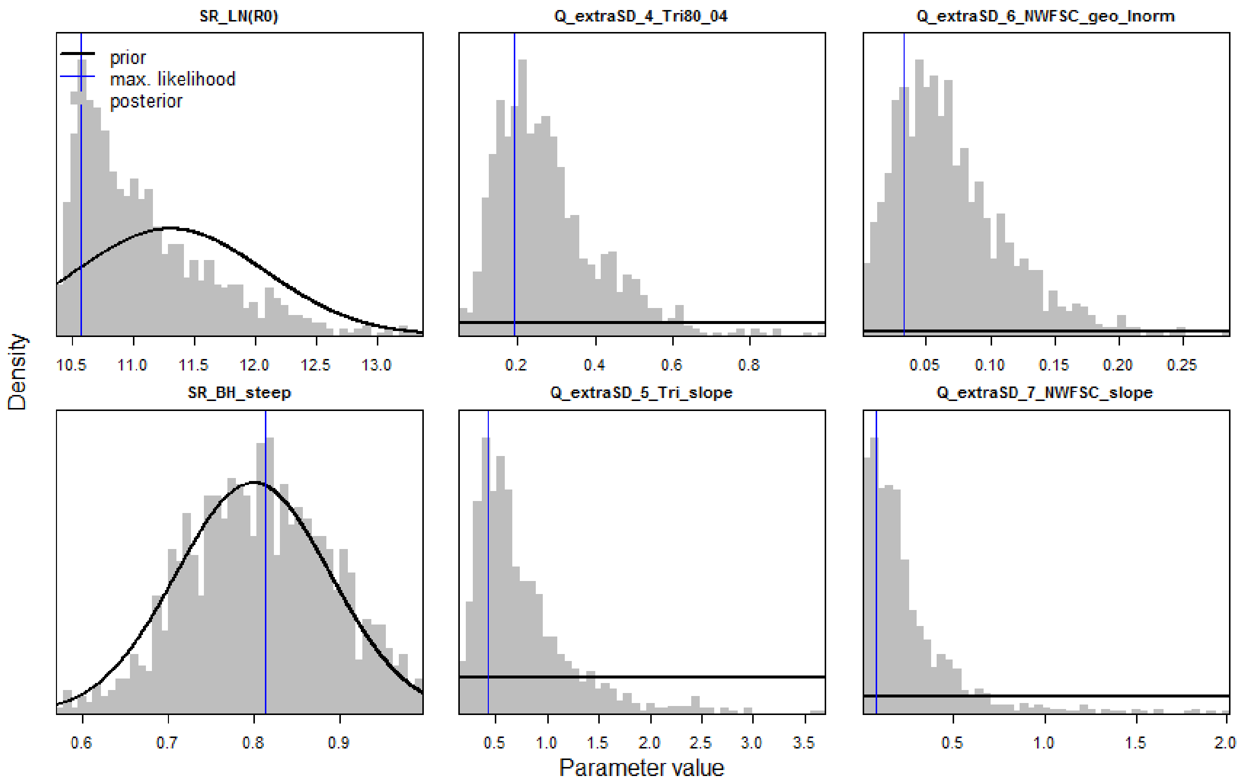

Figure 42. Prior and posterior comparisons from the MCMC run for arrowtooth flounder using a lnR_0 prior N(11.3,0.78).

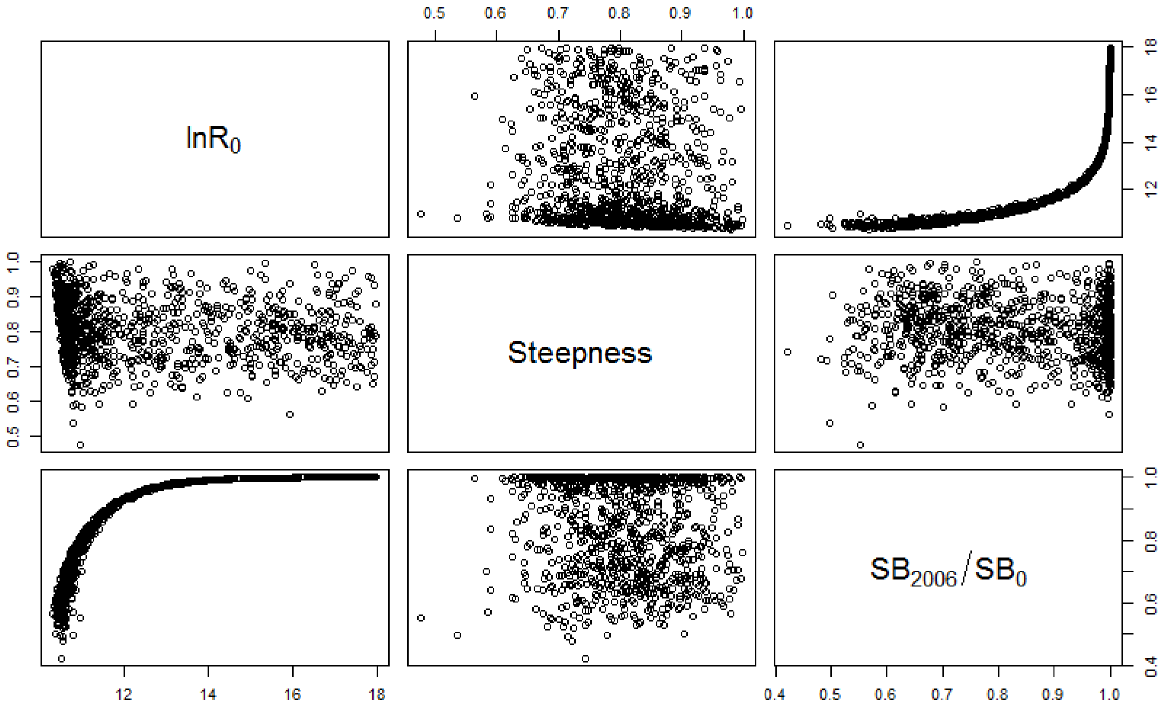

Figure 43. Pairs plots for initial recruitment, steepness and stock status in the MCMC treatment of uncertainty using a ln*R₀* prior of U(3,18).

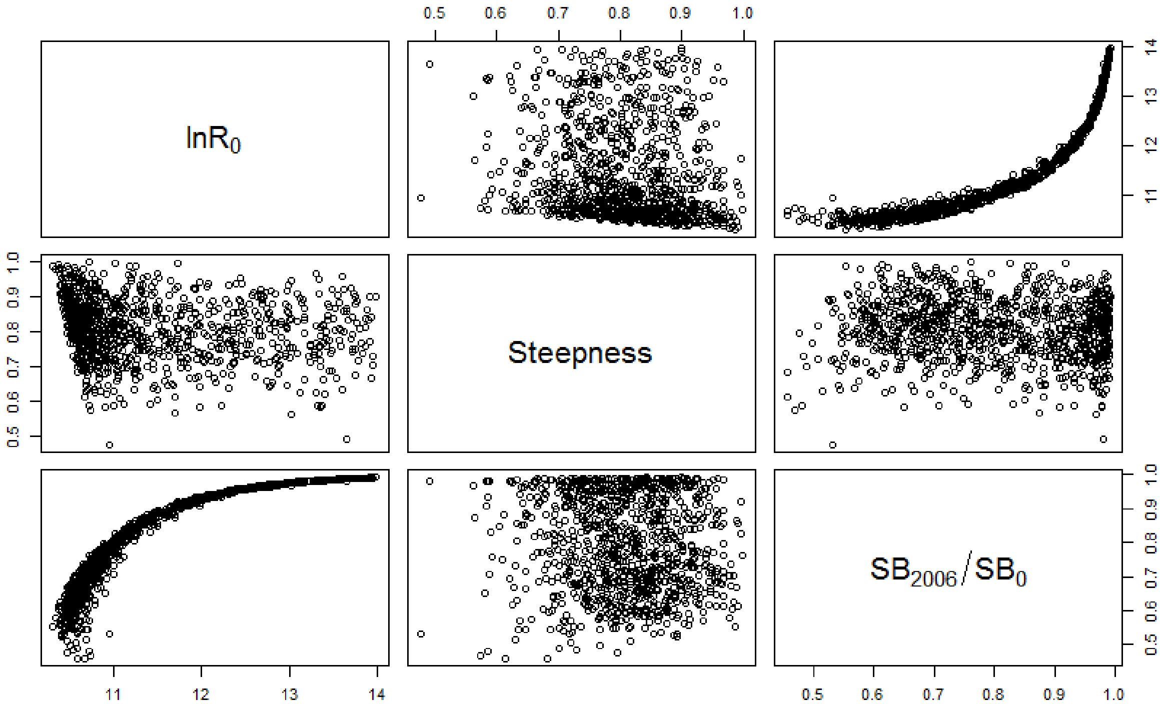

Figure 44. Pairs plots for initial recruitment, steepness and stock status in the MCMC treatment of uncertainty using a ln*R_0* prior of U(3,14).

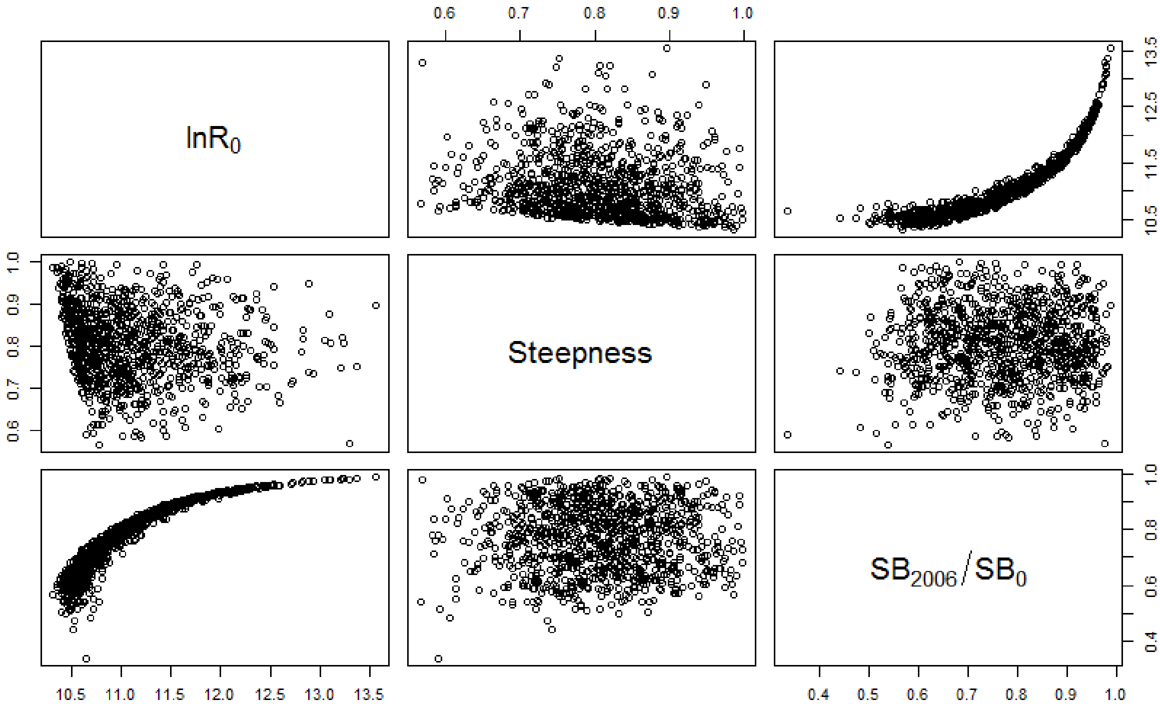

Figure 45. Pairs plots for initial recruitment, steepness and stock status in the MCMC treatment of uncertainty using a ln*R₀* prior of N(11.3,0.78).

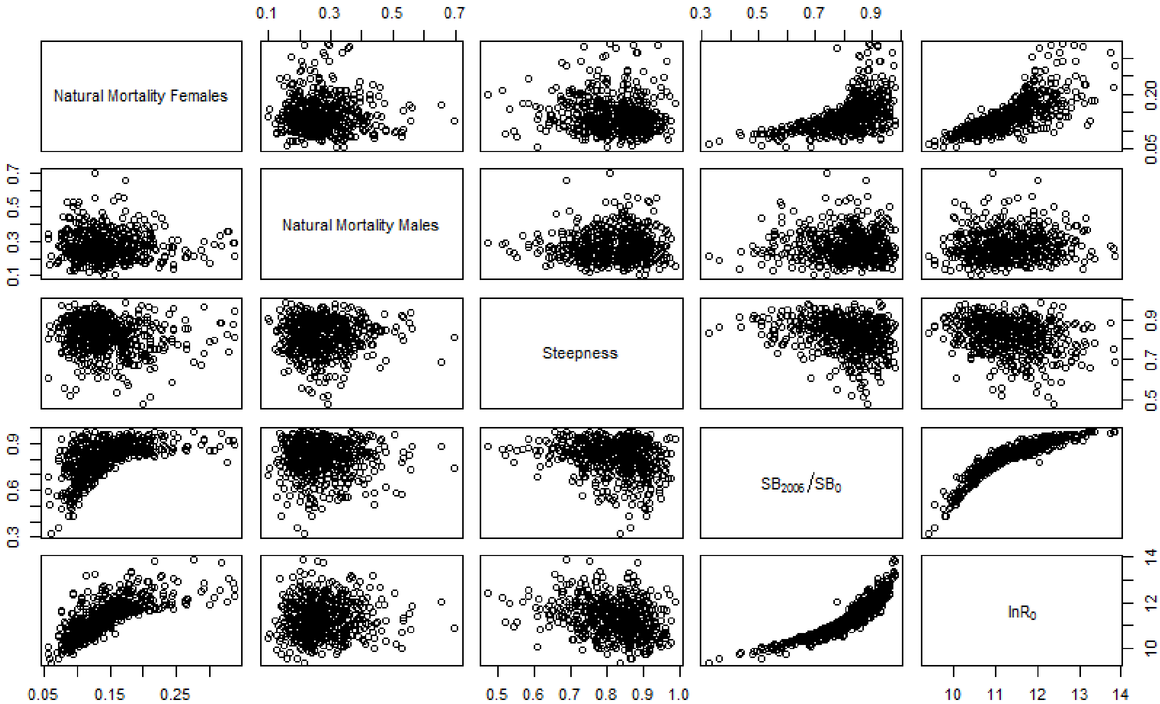

Figure 46. Pairs plots for each parameter in the XSSS AIS treatment of uncertainty using the 2006 stock status (i.e. depletion) prior from the 2007 assessment.

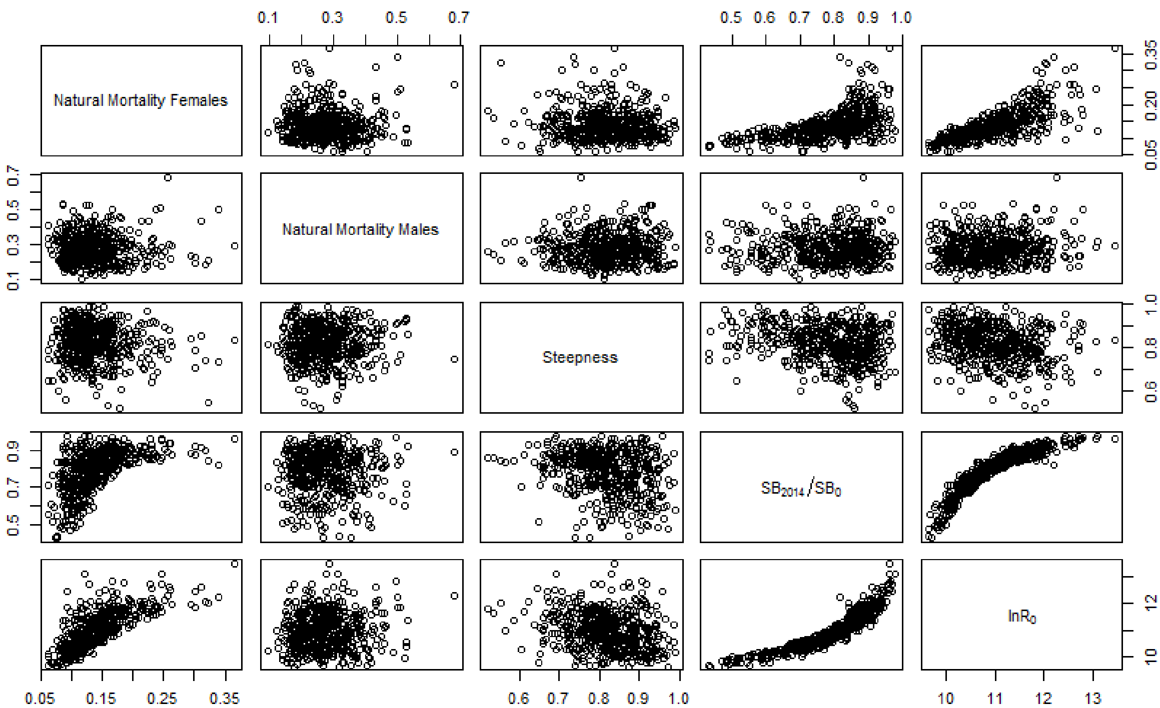

Figure 47. Pairs plots for each parameter in the XSSS AIS treatment of uncertainty using the 2014 stock status (i.e. depletion) prior from the current assessment MLE.

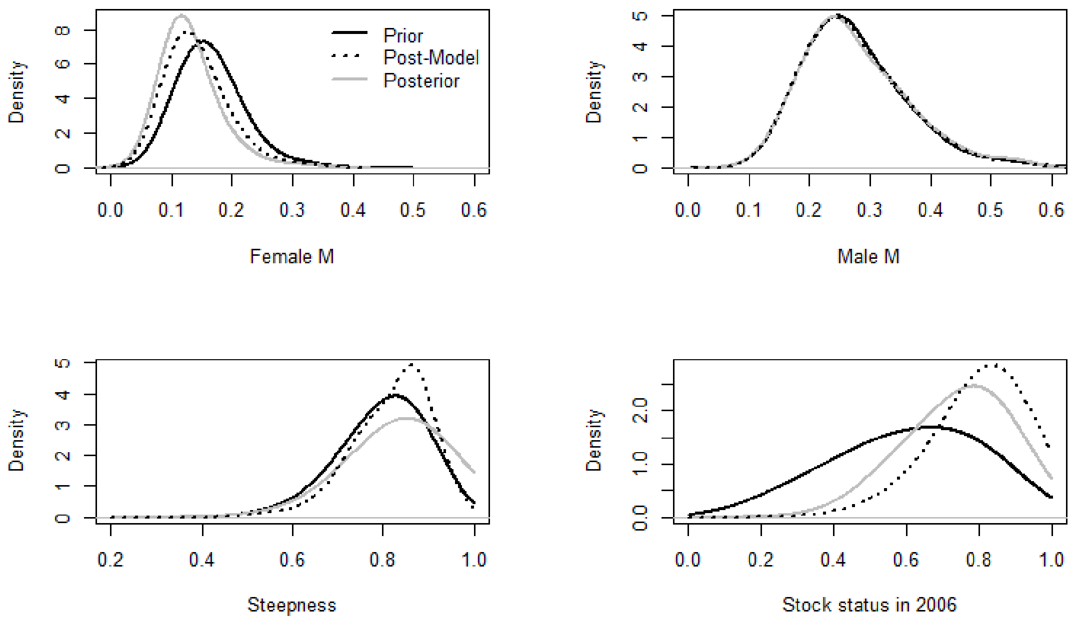

Figure 48. Prior, post-model (catch-only) and posterior distributions for each input parameter of the XSSS AIS uncertainty estimation using the 2006 stock status prior from the 2007 assessment.

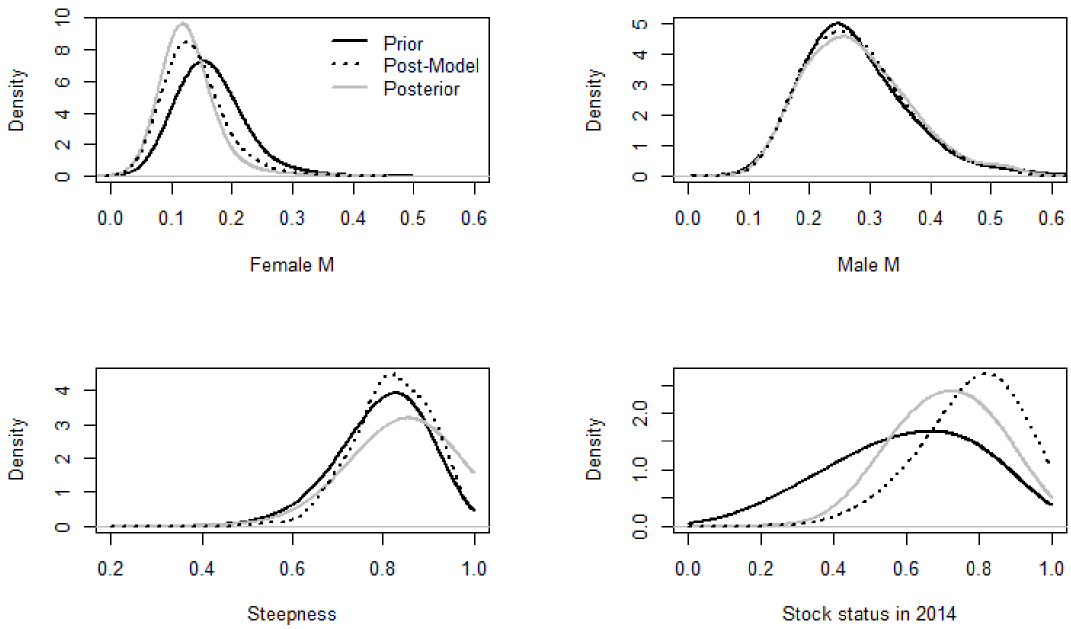

Figure 49. Prior, post-model (catch-only) and posterior distributions for each input parameter of the XSSS AIS uncertainty estimation using the 2014 stock status prior from the current assessment MLE.

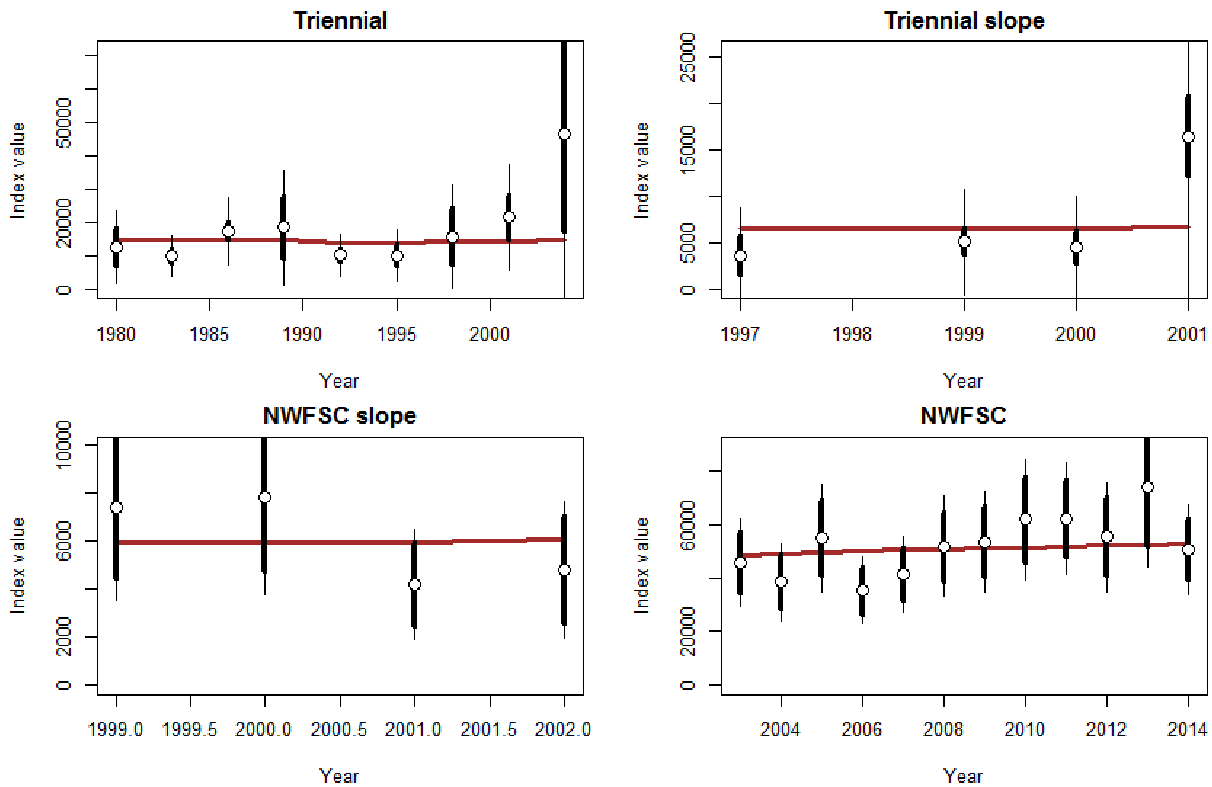

Figure 50. Fits to the surveys from the XSSS AIS model using the 2006 stock status prior from the 2007 assessment. Thick lines are inputted variance; thin lines are estimated added variance. Both lines show the 95% confidence intervals.

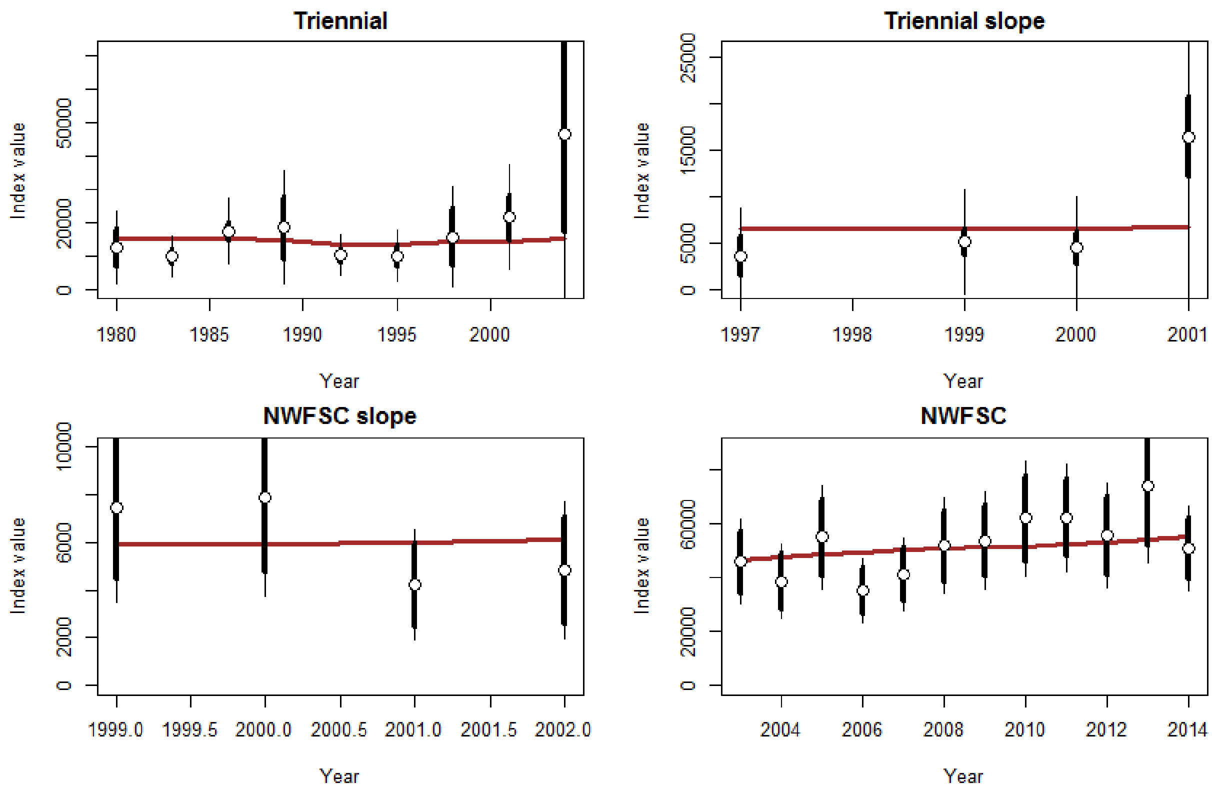

Figure 51. Fits to the surveys from the XSSS AIS model using the 2014 stock status prior from the MLE of the current assessment. Thick lines are inputted variance; thin lines are estimated added variance. Both lines show the 95% confidence intervals.

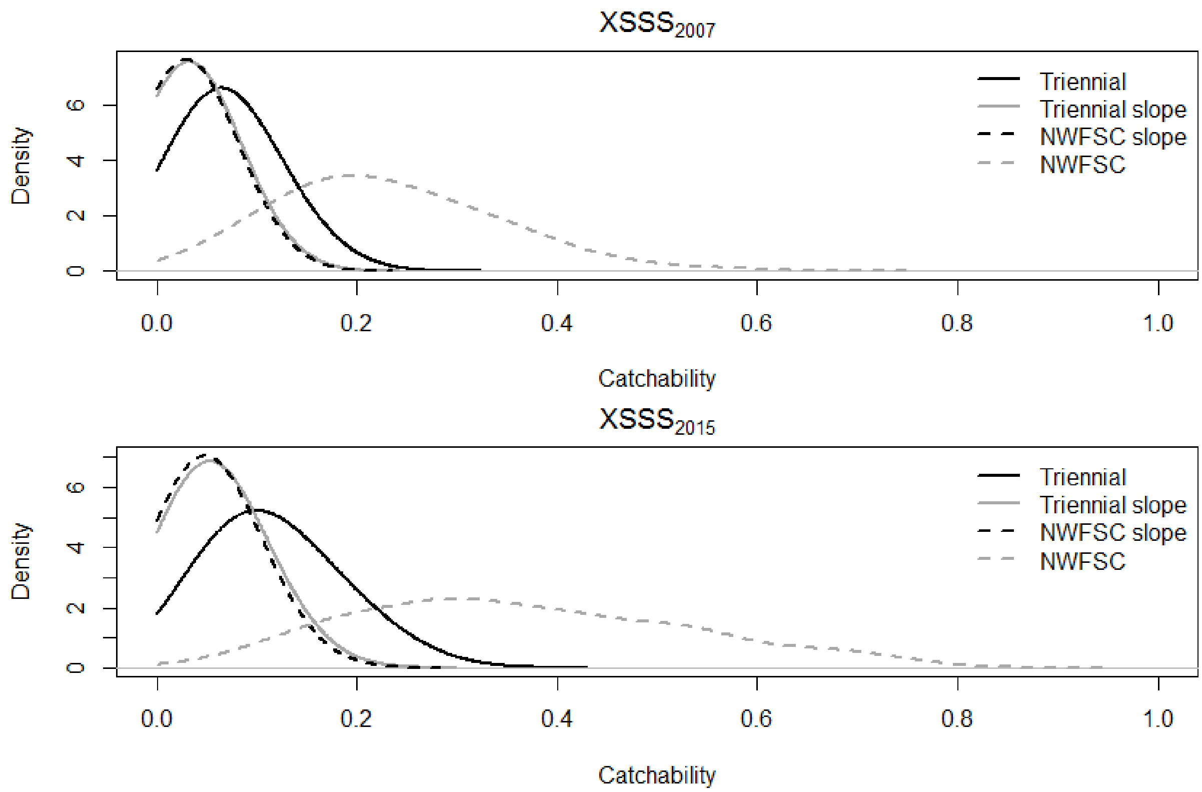

Figure 52. Posterior distributions of the catchability coefficients (*q*) for each survey from the XSSS model using the 2006 stock status prior from the 2007 assessment (top panel) and the 2014 stock status prior based on the MLE from the current model.

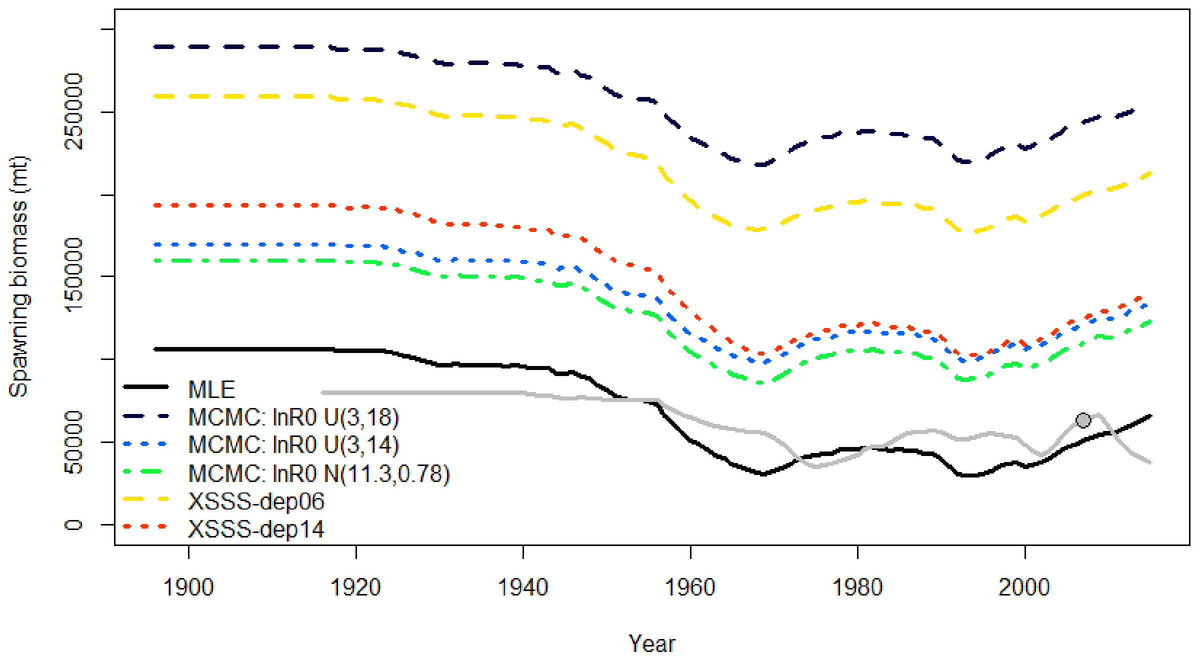

Figure 53. Spawning biomass time series across all potential base case models and treatments compared to the 2007 assessment. The point indicates where the 2007 assessment ended. Time series beyond that point are projected values.

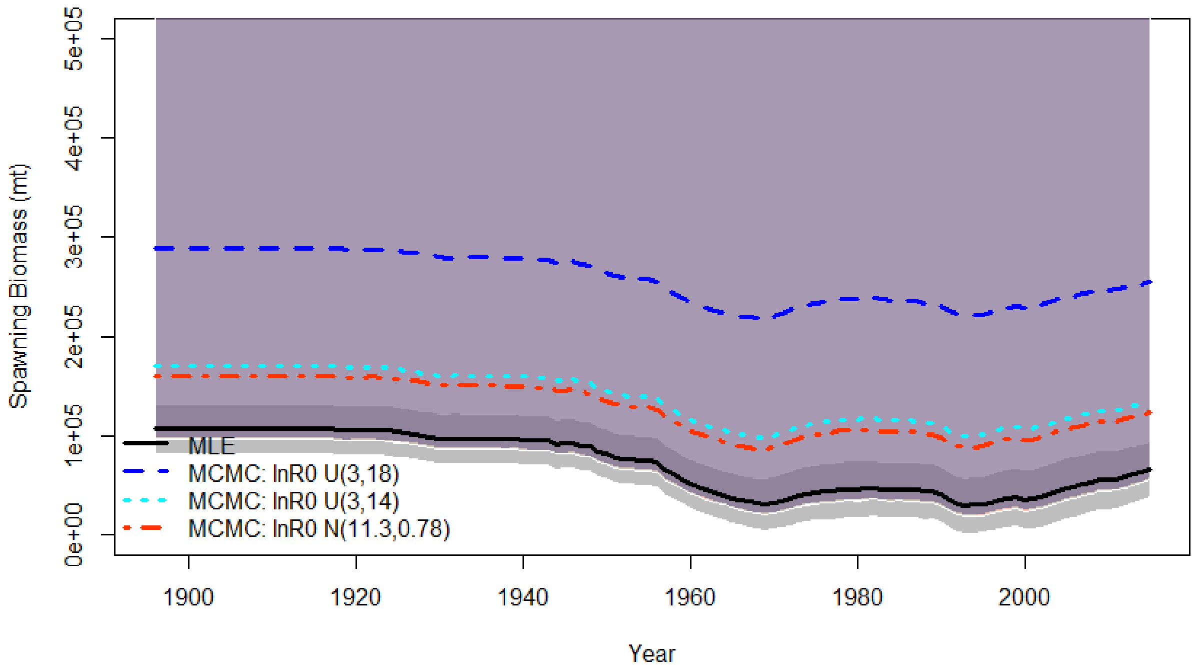

Figure 54. Comparison of spawning biomass among the MLE and MCMC treatments with accompanying uncertainty. Lines are median values. Uncertainty envelopes are shaded values.

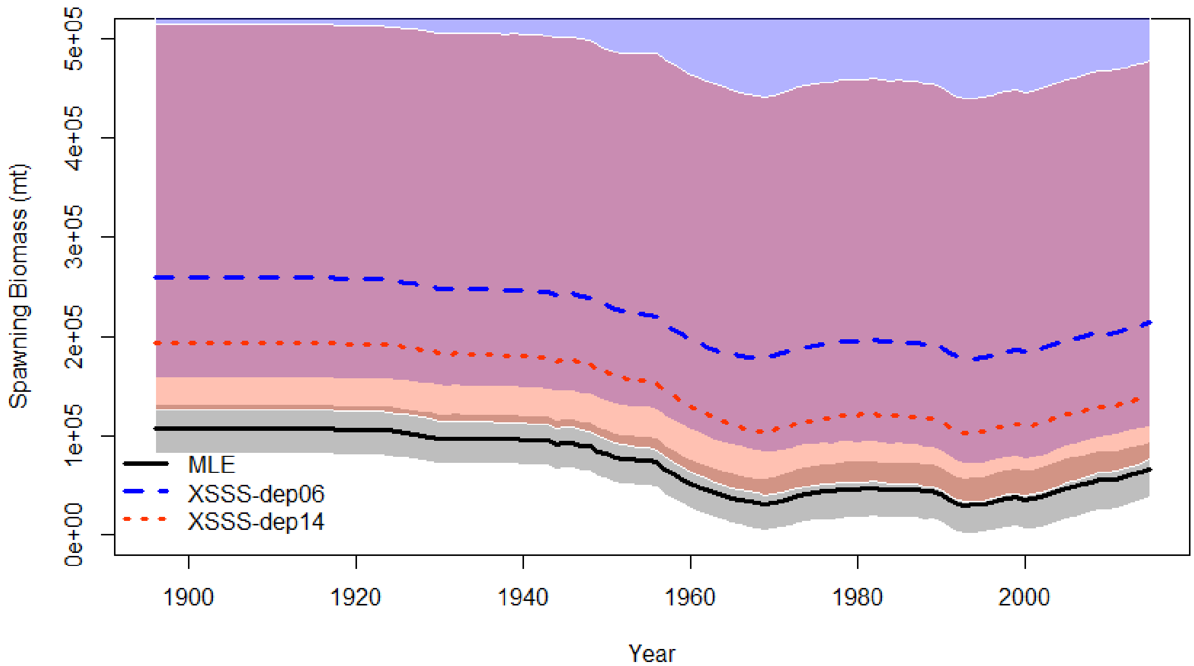

Figure 55. Comparison of spawning biomass among the MLE and XSSS treatments with accompanying uncertainty. Lines are median values. Uncertainty envelopes are shaded values.

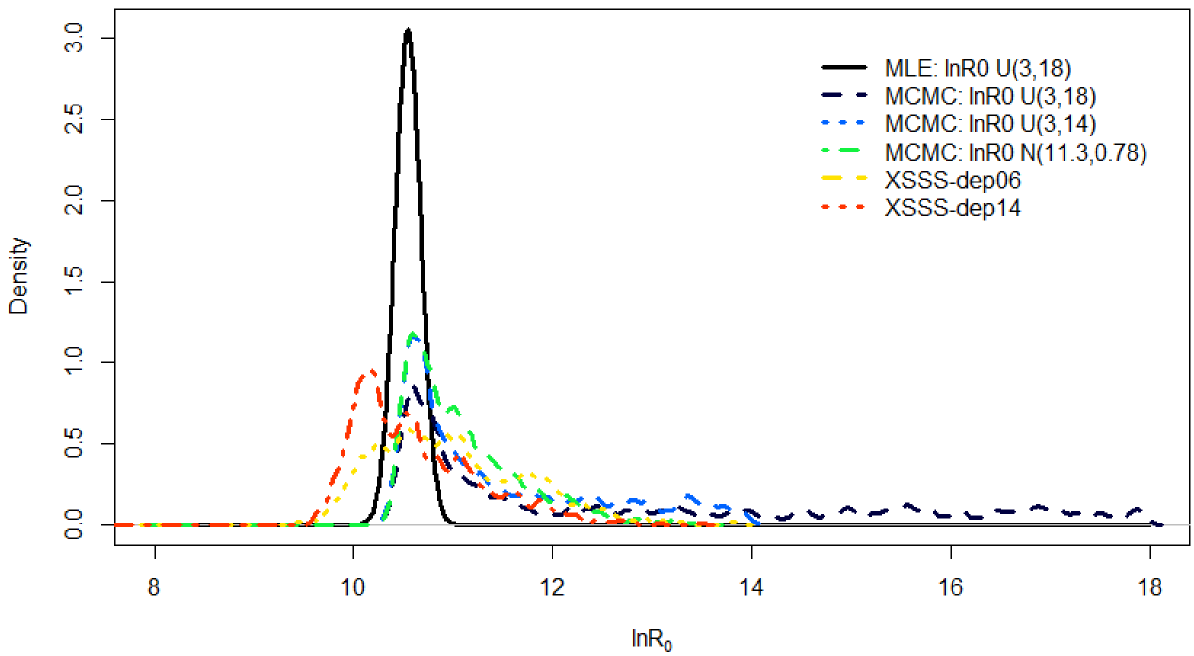

Figure 56. Asymptotic variance of the MLE and posterior densities from the Bayesian models of log initial recruitment (ln*R_0*).

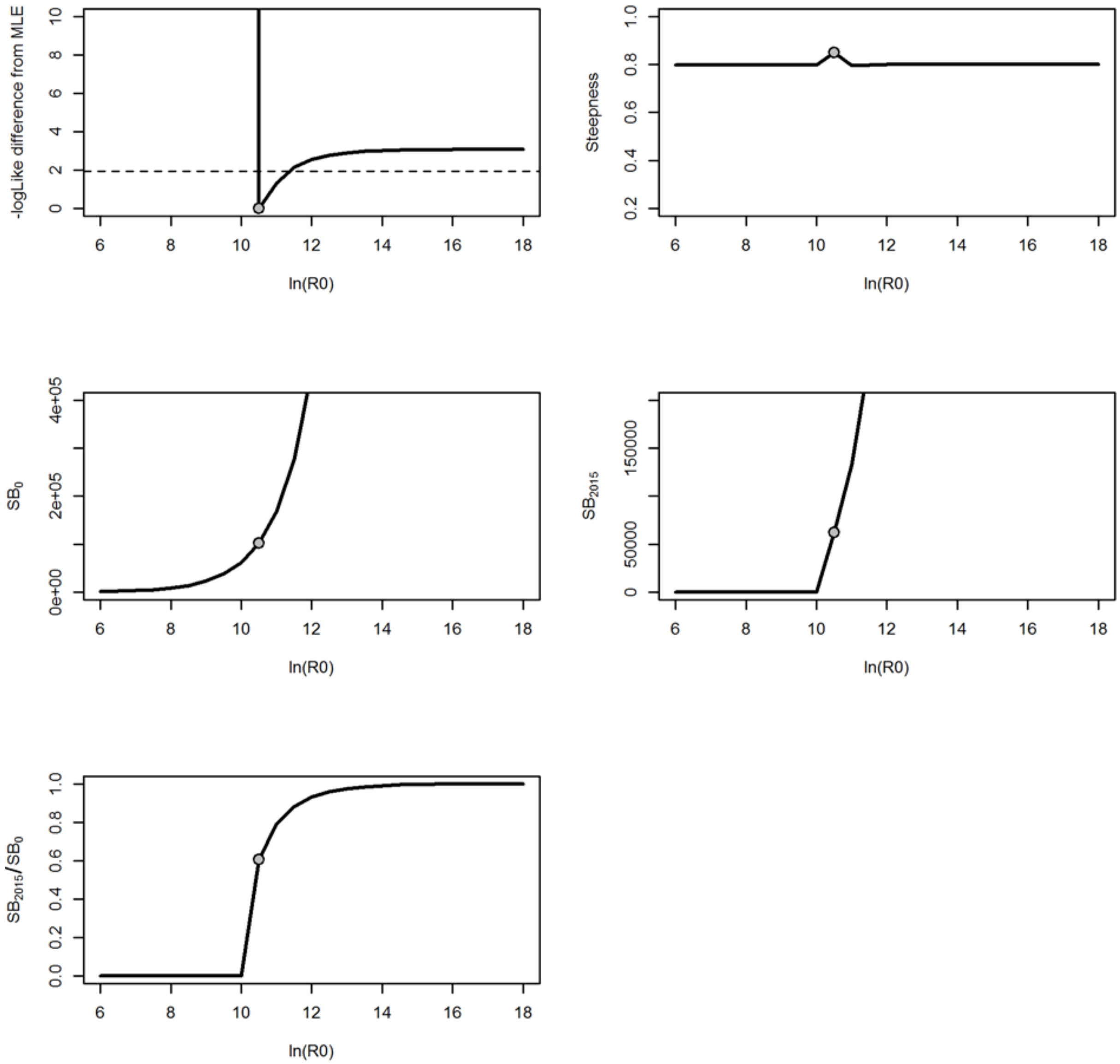

Figure 57. Likelihood profile for log initial recruitment (top left panel) and the resultant values for steepness (top right panel), initial spawning biomass (middle left panel), terminal biomass (middle right panel) and stock status (bottom left panel).

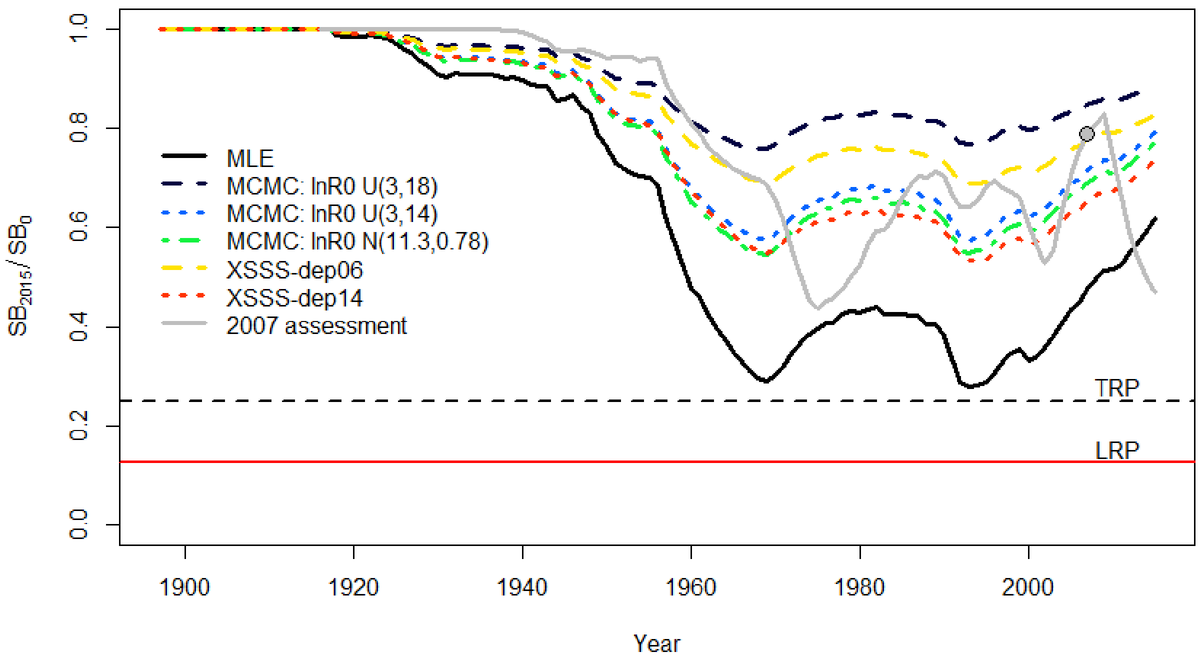

Figure 58. Stock status time series across all potential base case models and treatments compared to the 2007 assessment. The point indicates where the 2007 assessment ended. Time series beyond that point projected values. Target (TRP) and limit (LRP) reference points are indicated by the horizontal lines.

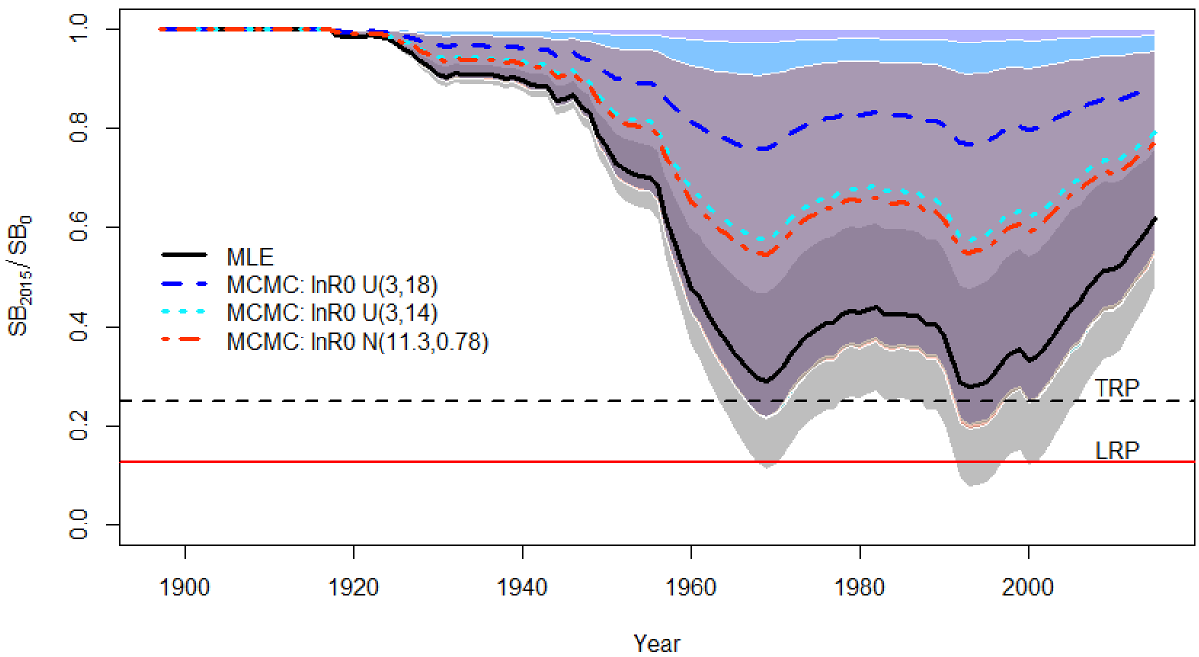

Figure 59. Comparison of stock status among the MLE and MCMC treatments with accompanying uncertainty. Lines are median values. Uncertainty envelopes are shaded values. Horizontal lines indicate the target (TRP) and limit (LRP) reference points.

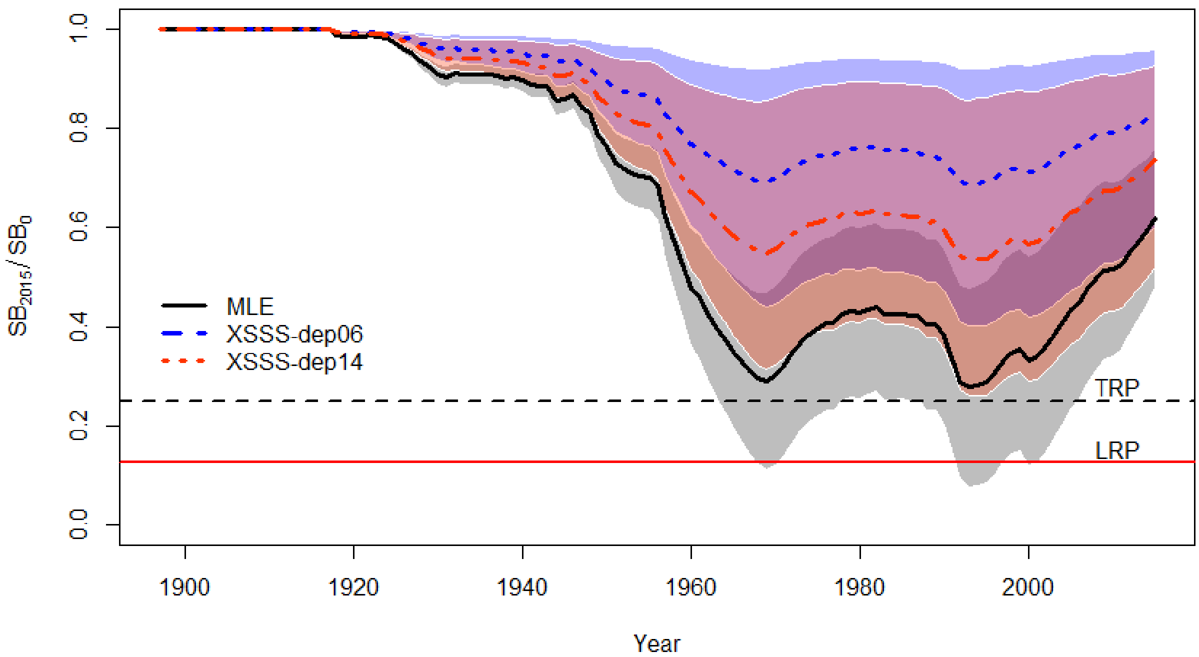

Figure 60. Comparison of stock status among the MLE and XSSS treatments with accompanying uncertainty. Lines are median values. Uncertainty envelopes are shaded values. Horizontal lines indicate the target (TRP) and limit (LRP) reference points.

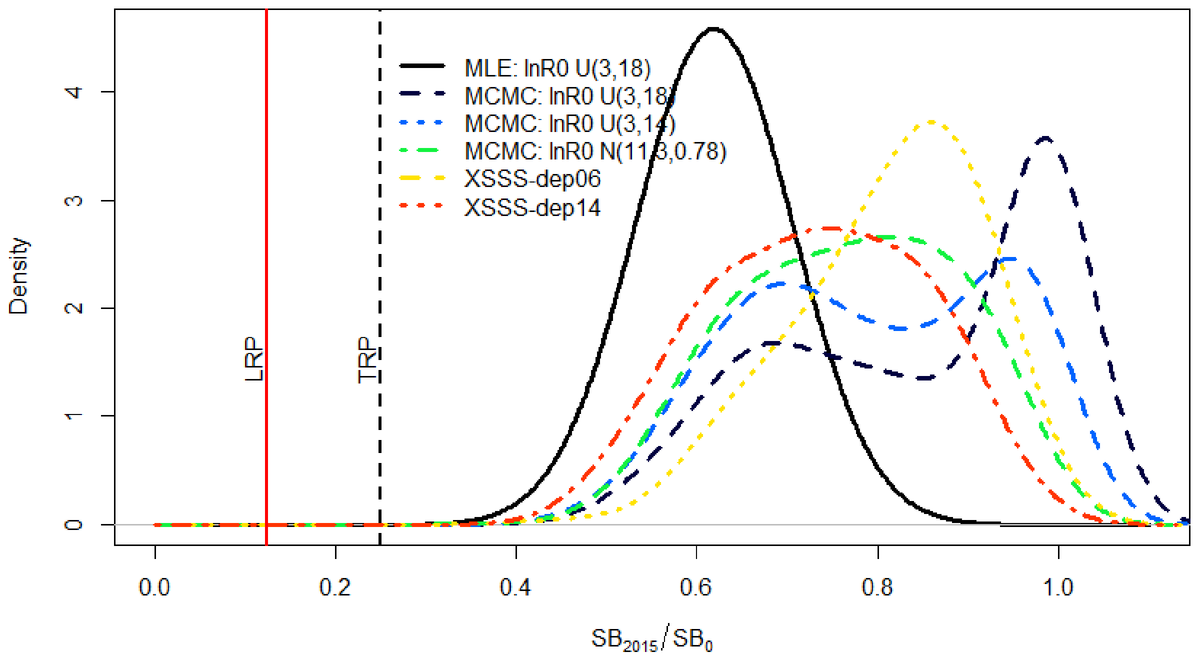

Figure 61. Comparison of the MLE asymptotic variance and Bayesian posterior densities of stock status for each of the model treatments. TRP is the stock status target reference point. LRP is the stock status limit reference point.

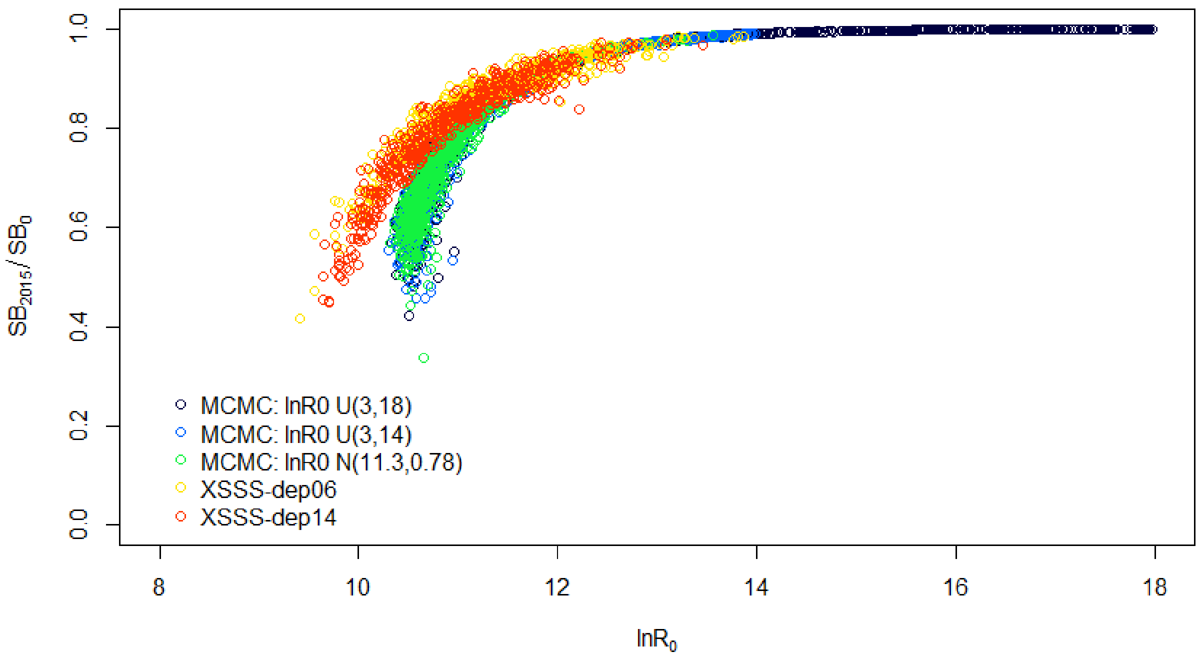

Figure 62. Relationship between log initial recruitment and stock status for the Bayesian models.

Appendix A. SS data file

```
#ARROWTOOTH FLOUNDER
### Global model specifications ###
1896 # Start year
2014 # End year
1 # Number of seasons/year
12 # Number of months/season
1 # Spawning occurs at beginning of season
3 # Number of fishing fleets
4 # Number of surveys
1 # Number of areas
Historical%Fillet%Dicards%Tri80_04%Tri_slope%NWFSC_geo_lnorm%NWFSC_slope # Fleet names separated by %
0.5417 0.5417 0.5417 0.5417 0.5417 0.5417 0.5417 #Timing of each fishery/survey
1 1 1 1 1 1 1 #Area of each fleet
1 1 1 #_units of catch: 1=bio; 2=num
0.05 0.05 0.05 #_se of log(catch) only used for init_eq_catch and for Fmethod2 and 3; use -1 for discard only fleets
2 # Number of genders
35 # Number of ages in population dynamics
### Catch section ###
0 0 0 # Initial equilibrium catch (landings + discard) by fishing fleet
119 # Number of lines catch data
#_catch_biomass(mtons):_columns_are_fisheries,year,season
#Historical Fillet Dicard Year Season
1.643190252 0 0 1896 1
1.346069418 0 0 1897 1
1.048948585 0 0 1898 1
1.020365548 0 0 1899 1
0.992157583 0 0 1900 1
0.963949618 0 0 1901 1
0.935741653 0 0 1902 1
0.907158616 0 0 1903 1
0.878950651 0 0 1904 1
0.850742686 0 0 1905 1
0.822159649 0 0 1906 1
0.793951684 0 0 1907 1
0.765743719 0 0 1908 1
0.737160682 0 0 1909 1
0.708952717 0 0 1910 1
0.680744752 0 0 1911 1
0.652536787 0 0 1912 1
0.62395375 0 0 1913 1
0.595745785 0 0 1914 1
0.56753782 0 0 1915 1
0.538954783 0 102.0047016 1916 1
0.510746818 0 1393.600293 1917 1
0.482538853 0 480.1944304 1918 1
```

0.454330888	0	0	1919	1
0.425747851	0	0	1920	1
0.397539886	0	0	1921	1
0.369331921	0	512.1042403	1922	1
0.340748885	0	545.0394526	1923	1
0.312540919	0	1682.91379	1924	1
0.284332954	0	1573.049287	1925	1
0.255749918	0	1390.643063	1926	1
0.240658928	0	2415.773944	1927	1
8.04574E-05	0	1770.515597	1928	1
10.34048344	0	2615.598827	1929	1
7.374305722	0	1322.808802	1930	1
4.603715449	0	0	1931	1
4.973128374	0	1190.736856	1932	1
10.4732108	0	986.1648337	1933	1
13.41953894	0	836.8542854	1934	1
7.278931311	0	1270.59795	1935	1
10.43478267	0	1344.313136	1936	1
12.65843272	0	1498.172603	1937	1
7.600043763	0	785.8292804	1938	1
6.89763884	0	2023.528602	1939	1
12.75698355	0	2209.754435	1940	1
11.26418513	0	1294.321799	1941	1
40.14888511	0	1254.635594	1942	1
242.5386404	0	4650.125521	1943	1
49.88874353	0	1025.965282	1944	1
10.65529453	0	306.169153	1945	1
25.16913663	0	4727.205409	1946	1
57.83662766	0	2703.406192	1947	1
245.8050917	0	7300.37478	1948	1
244.2895859	0	4555.20903	1949	1
137.6667834	0	6111.367751	1950	1
210.0797214	0	3710.775499	1951	1
251.5704029	0	3225.47764	1952	1
480.7245845	0	3060.111486	1953	1
931.0277556	0	2230.457829	1954	1
1824.325657	0	3432.785756	1955	1
3844.957626	0	7780.688369	1956	1
2303.777964	0	6981.524215	1957	1
1925.888642	0	7619.706811	1958	1
2203.087656	0	7698.359869	1959	1
1403.394561	0	5447.603443	1960	1
2246.192007	0	5965.605213	1961	1
2272.813992	0	6415.341029	1962	1
2048.899477	0	5910.081896	1963	1
2189.108833	0	6388.459158	1964	1
1843.76124	0	6204.766893	1965	1
1263.445201	0	6226.076659	1966	1
1555.321634	0	5979.04171	1967	1

912.0408634	0	5416.604342	1968	1
876.8020117	0	3340.426091	1969	1
567.5733197	0	2534.998949	1970	1
603.969734	0	2322.80394	1971	1
278.3196098	0	2773.748623	1972	1
441.0647741	0	3556.065977	1973	1
293.0357747	0	3897.84693	1974	1
200.5099974	0	4262.46504	1975	1
335.3203587	0	5405.375807	1976	1
360.3134345	0	2744.74368	1977	1
522.5425514	0	4366.381818	1978	1
865.6398537	0	5159.475149	1979	1
621.7949161	0	3740.580581	1980	1
0	1074.106414	3461.135116	1981	1
0	2351.004264	4833.679712	1982	1
0	2076.553116	3521.736055	1983	1
0	2379.340016	2786.02425	1984	1
0	2679.396262	3630.996537	1985	1
0	2229.95464	3564.669464	1986	1
0	2829.70743	5316.37065	1987	1
0	1945.79697	3693.025314	1988	1
0	3552.480722	5679.024525	1989	1
0	5824.141341	6733.07658	1990	1
0	4945.277601	6458.945739	1991	1
0	3573.19423	3986.965849	1992	1
0	2712.885784	3092.975197	1993	1
0	3249.403066	2712.874881	1994	1
0	2321.189331	1817.284709	1995	1
0	2191.572621	1579.108439	1996	1
0	2343.513563	2224.273482	1997	1
0	3168.477275	2307.561177	1998	1
0	5284.974145	4108.566363	1999	1
0	3276.410233	2078.224979	2000	1
0	2464.843963	1656.878514	2001	1
0	2084.589041	1187.866471	2002	1
0	2327.043001	531.4745324	2003	1
0	2327.012156	565.6153162	2004	1
0	2240.237231	2179.112119	2005	1
0	1922.445795	802.203682	2006	1
0	2261.738637	820.392174	2007	1
0	2667.641295	740.641459	2008	1
0	3843.983035	1585.448425	2009	1
0	3227.787807	867.9916552	2010	1
0	2292.072485	350.4923222	2011	1
0	2243.375669	255.6049931	2012	1
0	1990.932595	501.6913254	2013	1
0	1248.477275	194.2172897	2014	1

29 #Number of index observations

#Units: 0=numbers,1=biomass,2=F; Errortype: -1=normal,0=lognormal,>0=T

#Fleet	Units	Errortype		
1	1	0	#	Catch pre-1980
2	1	0	#	Fillet fishery
3	1	0	#	Discard
4	1	0	#	Triennial 1980-2004
5	1	0	#	Triennial slope
6	1	0	#	NWFSC geo lognormal
7	1	0	#	NWFSC Slope

#_year	seas	index	obs	se(log)	
#year	seas	index	obs	se(log)	
1980	1	4	12571.54312	0.230855857	#Triennial 1980-2004
1983	1	4	9904.954791	0.105309645	
1986	1	4	17407.4197	0.078052707	
1989	1	4	18461.85435	0.256261072	
1992	1	4	10187.1739	0.094235568	
1995	1	4	10072.49963	0.165702976	
1998	1	4	15754.1515	0.28044218	
2001	1	4	21573.59503	0.158919147	
2004	1	4	46496.77171	0.321411222	
1997	1	5	3.61E+03	0.297659263	#Triennial slope
1999	1	5	5.11E+03	0.141053353	
2000	1	5	4.48E+03	0.199792867	
2001	1	5	1.64E+04	0.13351539	
2003	1	6	45910.64992	0.128847981	#NWFSC geo lognormal
2004	1	6	38691.64303	0.137099637	
2005	1	6	55099.23238	0.132916065	
2006	1	6	35317.62947	0.127487655	
2007	1	6	41394.60531	0.121451537	
2008	1	6	51876.91593	0.131034727	
2009	1	6	53746.27499	0.126279634	
2010	1	6	62060.27882	0.131429678	
2011	1	6	62408.77222	0.117828226	
2012	1	6	55588.87647	0.134326486	
2013	1	6	73976.46772	0.152191402	
2014	1	6	50914.29101	0.114630474	
1999	1	7	7442.38	0.2035525	#NWFSC Slope
2000	1	7	7852.168	0.2024455	
2001	1	7	4207.238	0.2154356	
2002	1	7	4808.54	0.2376217	

0 #_N_fleets_with_discard
0 #_N_discard_obs

0 #_N_meanbodywt_obs
30 #_DF_meanwt

Population size structure

1 # length bin method: 1=use databins; 2=generate from binwidth,min,max below; 3=read vector
binwidth for population size comp
minimum size in the population (lower edge of first bin and size at age 0.00)
maximum size in the population (lower edge of last bin)

-1 #_comp_tail_compression
1e-007 #_add_to_comp
0 #_combine males into females at or below this bin number
#

35	#_N_LengthBins											
#	Data	length	bins									
12	14	16	18	20	22	24	26	28	30	32	34	36
38	40	42	44	46	48	50	52	54	56	58	60	62
64	66	68	70	72	74	76	78	80				
#												
0	#_N_Length_obs											
#Year	Seas	Fleet	Gender	Part	Nsamp	F-8	F-10	F-12	F-14	F-16	F-18	F-20
F-22	F-24	F-26	F-28	F-30	F-32	F-34	F-36	F-38	M-8	M-10	M-12	M-14
M-16	M-18	M-20	M-22	M-24	M-26	M-28	M-30	M-32	M-34	M-36	M-38	

#Age	composition	set-up										
31	#_N_age_bins											
0 1	2	3	4	5	6	7	8	9	10	11	12	13
14	15	16	17	18	19	20	21	22	23	24	25	26
27	28	29	30									

0 #_N_ageerror_definitions
0 #_N_Agecomp_obs
1 #_Lbin_method: 1=poplenbins; 2=datalenbins; 3=lengths
0 #_combine males into females at or below this bin number
0 #_N_MeanSize-at-Age_obs
0 #_N_environ_variables
0 #_N_environ_obs
0 # N sizefreq methods to read
0 # no tag data
0 # no morphcomp data

999 # End data file

Appendix B. SS control file

1 #_N_Growth_Patterns
1 #_N_Morphs_Within_GrowthPattern
0 #_Nblock_Patterns
#_Cond 0 #_blocks_per_pattern
begin and end years of blocks
#
0.5 #_fracfemale
0 #_natM_type:_0=1Parm; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
#_no additional input for selected M option; read 1P per morph
1 # GrowthModel: 1=vonBert with L1&L2; 2=Richards with L1&L2; 3=not implemented; 4=not implemented
1 #_Growth_Age_for_L1
30 #_Growth_Age_for_L2 (999 to use as Linf)
0 #_SD_add_to_LAA (set to 0.1 for SS2 V1.x compatibility)
0 #_CV_Growth_Pattern: 0 CV=f(LAA); 1 CV=F(A); 2 SD=F(LAA); 3 SD=F(A)
1 #_maturity_option: 1=lengthlogistic; 2=age logistic; 3=read age-maturity matrix by growth_pattern; 4=read age-fecundity; 5=read fec and wt from wtatage.ss
#_placeholder for empirical age-maturity by growth pattern
0 #_First_Mature_Age
1 #_fecundity option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b
0 #_hermaphroditism option: 0=none; 1=age-specific fxn
1 #_parameter_offset_approach (1=none, 2= M, G, CV_G as offset from female-GP1, 3=like SS2 V1.x)
2 #_env/block/dev_adjust_method (1=standard; 2=logistic transform keeps in base parm bounds; 3=standard w/ no bound check)
#
#_growth_parms
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn
0.01 0.8 0.166 0.166 3 0.541 -2 0 0 0 0 0 0 0 # NatM_p_1_Fem_GP_1
5 25 8 10 -1 99 -2 0 0 0 0 0.5 0 0 # L_at_Amin_Fem_GP_1
40 90 72.2566 76.82 -1 99 -2 0 0 0 0 0.5 0 0 # L_at_Amax_Fem_GP_1
0.05 0.25 0.170895 0.1402 -1 99 -2 0 0 0 0 0.5 0 0 # VonBert_K_Fem_GP_1
0.05 0.25 0.14 0.1 -1 99 -3 0 0 0 0 0.5 0 0 # CV_young_Fem_GP_1
0.05 0.25 0.08 0.1 -1 99 -3 0 0 0 0 0.5 0 0 # CV_old_Fem_GP_1
0.01 0.8 0.274 0.274 3 0.540 -2 0 0 0 0 0 0 0 # NatM_p_1_Mal_GP_1
5 25 8 10 -1 99 -2 0 0 0 0 0.5 0 0 # L_at_Amin_Mal_GP_1
30 70 45.5847 45.5847 -1 99 -2 0 0 0 0 0.5 0 0 # L_at_Amax_Mal_GP_1
0.05 0.50 0.387262 0.387262 -1 99 -2 0 0 0 0 0.5 0 0 # VonBert_K_Mal_GP_1

0.05 0.25 0.21 0.1 -1 99 -3 0 0 0 0 0.5 0
0 # CV_young_Mal_GP_1
0.05 0.25 0.08 0.1 -1 99 -3 0 0 0 0 0.5 0
0 # CV_old_Mal_GP_1
0 0.5 3.78538E-06 3.78538E-06 -1 99 -3 0 0 0 0
0.5 0 0 # Wtlen_1_Fem
0 5 3.24547 3.24547 -1 99 -3 0 0 0 0 0.5 0
0 # Wtlen_2_Fem
0 50 37.3 37.3 -1 99 -3 0 0 0 0 0.5 0
0 # Mat50%_Fem
-1 1 -0.5 -0.5 -1 99 -3 0 0 0 0 0.5 0
0 # Mat_slope_Fem
0 1 1 1 -1 99 -3 0 0 0 0 0.5 0
0 # Eggs/kg_inter_Fem
0 1 0 0 -1 99 -3 0 0 0 0 0.5 0
0 # Eggs/kg_slope_wt_Fem
0 0.5 3.48474E-06 3.48474E-06 -1 99 -3 0 0 0 0
0.5 0 0 # Wtlen_1_Mal
0 5 3.25607 3.25607 -1 99 -3 0 0 0 0 0.5 0
0 # Wtlen_2_Mal
0 0 0 0 -1 0 -4 0 0 0 0 0 0
0 # RecrDist_GP_1
0 0 0 0 -1 0 -4 0 0 0 0 0 0
0 # RecrDist_Area_1
0 0 0 0 -1 0 -4 0 0 0 0 0 0
0 # RecrDist_Seas_1
0 0 0 0 -1 0 -4 0 0 0 0 0 0
0 # CohortGrowDev
#
#_Cond 0 #custom_MG-env_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no MG-environ parameters
#
#_Cond 0 #custom_MG-block_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no MG-block parameters
#_Cond No MG parm trends
#
#_seasonal_effects_on_biology_parms
0 0 0 0 0 0 0 0 0 0
#_femwtlen1,femwtlen2,mat1,mat2,fec1,fec2,Malewtlen1,malewtlen2,L1,K
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no seasonal MG parameters
#
#_Cond -4 #_MGparm_Dev_Phase
#
#_Spawner-Recruitment
3 #_SR_function
#_LO HI INIT PRIOR PR_type SD PHASE

3 18 12 7.5 -1 10 1 # SR_R0
0.2 1 0.9 0.8 0 0.09 2 # SR_steep
0 2 0.01 0.8 -1 0.8 -4 # SR_sigmaR
-5 5 0.1 0 -1 1 -3 # SR_envlink
-5 5 0 0 -1 1 -4 # SR_R1_offset
0 0 0 0 -1 0 -99 # SR_autocorr
0 #_SR_env_link
0 #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness
0 #do_recdev: 0=none; 1=devvector; 2=simple deviations
2010 # first year of main recr_devs; early devs can preceed this era
2010 # last year of main recr_devs; forecast devs start in following year
-2 #_recdev phase
1 # (0/1) to read 13 advanced options
0 #_recdev_early_start (0=none; neg value makes relative to recdev_start)
-4 #_recdev_early_phase
-1 #_forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)
1 #_lambda for fore_recr_like occurring before endyr+1
1990 #_last_early_yr_nobias_adj_in_MPD
1999 #_first_yr_fullbias_adj_in_MPD
2000 #_last_yr_fullbias_adj_in_MPD
2010 #_first_recent_yr_nobias_adj_in_MPD
1.0 #_max_bias_adj_in_MPD (-1 to override ramp and set biasadj=1.0 for all estimated recdevs)
0 #_periodof cycles in recruitment (N parms read below)
-5 #min rec_dev
5 #max rec_dev
0 #_read_recdevs
#_end of advanced SR options
#
#_placeholder for full parameter lines for recruitment cycles
read specified recr devs
#_Yr Input_value
#
all recruitment deviations
#
#Fishing Mortality info
0.3 # F ballpark for tuning early phases
-2001 # F ballpark year (neg value to disable)
1 # F_Method: 1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)
0.9 # max F or harvest rate, depends on F_Method
no additional F input needed for Fmethod 1
if Fmethod=2; read overall start F value; overall phase; N detailed inputs to read
if Fmethod=3; read N iterations for tuning for Fmethod 3
#
#_initial_F_parms

```
#_LO HI INIT PRIOR PR_type SD PHASE
 0 1 0 0.01 -1 99 -1 # InitF_1FISHERY1
 0 1 0 0.01 -1 99 -1 # InitF_1FISHERY1
 0 1 0 0.01 -1 99 -1 # InitF_1FISHERY1
#
#_Q_setup
 # Q_type options: <0=mirror, 0=median_float, 1=mean_float, 2=parameter, 3=parm_w_random_dev, 4=parm_w_randwalk, 5=mean_unbiased_float_assign_to_parm
 #_Den-dep  env-var  extra_se  Q_type
 0 0 0 0 # 1 pre-1980
 0 0 0 0 # 2 Fillet
 0 0 0 0 # 3 Discards
 0 0 1 0 # 4 Tiennial 1980-2004
 0 0 1 0 # 7 Triennial slope
 0 0 1 0 # 11 NWFSC geo lognormal
 0 0 1 0 # 12 NWFSC Slope

#
#_Cond 0 #_If q has random component, then 0=read one parm for each fleet with random q; 1=read a parm for each year of index
#_Q_parms(if_any)
# LO HI INIT PRIOR PR_type SD PHASE
 0 5 0.01 0.01 -1 99 1 # 4 Tiennial 1980-2004
 0 5 0.01 0.01 -1 99 1 # 7 Triennial slope
 0 5 0.01 0.01 -1 99 1 # 11 NWFSC geo lognormal
 0 5 0.01 0.01 -1 99 1 # 12 NWFSC Slope
#_SELEX_&_RETENTION_PARAMETERS
# Size-based setup
# A=Selex option: 1-24
# B=Do_retention: 0=no, 1=yes
# C=Male offset to female: 0=no, 1=yes
# D=Mirror selex (#)
# A B C D
# Size selectivity
 24	0	0	0 # 1 pre-1980
 24	0	1	0 # 2 Fillet
 24	0	0	0 # 3 Discards
 24	0	1	0  # 4 Tiennial 1980-2004
 24	0	1	0  # 7 Triennial slope
 24	0	1	0 # 11 NWFSC geo lognormal
 5	0	0	5 # 12 NWFSC Slope
# Age selectivity
 10	0	0	0 # 1 pre-1980
 10	0	0	0 # 2 Fillet
 10	0	0	0 # 3 Discards
 10	0	0	0  # 4 Tiennial 1980-2004
 10	0	0	0  # 7 Triennial slope
 10	0	0	0 # 11 NWFSC geo lognormal
 10	0	0	0 # 12 NWFSC Slope
```

Selectivity parameters

```
# Lo	Hi	Init	Prior	Prior	Prior	Param	Env	Use	Dev	Dev	Dev	Block	block
# bnd	bnd	value	mean	type	SD	phase	var	dev	minyr	maxyr	SD	design	switch
# Block design 1 means that parm’ = baseparm + blockparm, 2 means that parm’ = blockparm
# Fleet 1 historical landings size based selectivity (using option 24)
	20	46	30.43	29.5	-1	50	-2	0	0	0	0	0	0	0	#	peak
	-6	6	6	6	-1	50	-50	0	0	0	0	0	0	0	#	width
	-1	10	4.63	4	-1	50	-2	0	0	0	0	0	0	0	#	var-ascending
	-5	9	1	1	-1	50	-50	0	0	0	0	0	0	0	#	var-descending
	-10	10	-10	-10	-1	50	-50	0	0	0	0	0	0	0	#	initial
	0	50	50	50	-1	50	-50	0	0	0	0	0	0	0	#	final
#	Fleet	2	(Fillet	fishery)	size	based	selectivity	(using	option	24)

	20	70	60	60	-1	50	-4	0	0	0	0	0	0	0	#	peak
	-6	6	6	6	-1	50	-50	0	0	0	0	0	0	0	#	width
	-1	10	5.1294	4	-1	50	-4	0	0	0	0	0	0	0	#	var-ascending
	-5	9	1	1	-1	50	-50	0	0	0	0	0	0	0	#	var-descending
	-10	10	-10	-10	-1	50	-50	0	0	0	0	0	0	0	#	initial
	0	50	50	50	-1	50	-4	0	0	0	0	0	0	0	#	final
#	Fleet	2	sex	offset	(Fillet	fishery)	size	based	selectivity	(using	option	24)
	20	70	30	29.5	-1	50	-4	0	0	0	0	0	0	0	#	peak
	-3	0	0	6	-1	50	-50	0	0	0	0	0	0	0	#	width
	-3	0	-2.00E-09	4	-1	50	-4	0	0	0	0	0	0	0	0	#	var-ascending
	-3	0	-1.07E-07	1	-1	50	-4	0	0	0	0	0	0	0	0	#	var-descending
#	Fleet	3	(discard	fishery)	size	based	selectivity	(using	option	24)

	20	70	35.4119	30	-1	50	-4	0	0	0	0	0	0	0	#	peak
```

```
-6	4	-5	-5	-1	50	-50	0	0	0	0	0
0	0	#	width
-1	9	4.46779	4	-1	50	-4	0	0	0	0	0
0	0	#	var-ascending
-1	9	5	1	-1	50	-3	0	0	0	0	0
0	0	#	var-descending
-5	9	-5	-10	-1	50	-50	0	0	0	0	0
0	0	#	initial
-5	9	9	50	-1	50	-2	0	0	0	0	0
0	0	#	final
#	Fleet	4	Triennial	size	based	selectivity	(using	option	24)

20	70	31.1509	30	-1	50	-4	0	0	0	0	0
0	0	#	peak
-6	4	-5	-5	-1	50	-50	0	0	0	0	0
0	0	#	width
-1	9	4.70292	4	-1	50	-4	0	0	0	0	0
0	0	#	var-ascending
-1	9	5	1	-1	50	-3	0	0	0	0	0
0	0	#	var-descending
-5	9	-5	-10	-1	50	-50	0	0	0	0	0
0	0	#	initial
-5	9	9	50	-1	50	-2	0	0	0	0	0
0	0	#	final
#	Fleet	4	sex	offset	(Triennial)	size	based	selectivity	(using	option
24)
20	70	30	29.5	-1	50	-4	0	0	0	0	0
0	0	#	peak
-3	0	0	6	-1	50	-50	0	0	0	0	0
0	0	#	width
-3	0	-6.61E-10	4	-1	50	-4	0	0	0	0
0	0	0	#	var-ascending
-3	0	-0.0964715	1	-1	50	-4	0	0	0	0
0	0	0	#	var-descending
#	Survey	7	AKC	slope,	size	based	selectivity	(using	option	24)

20	70	31.8236	30	-1	50	-4	0	0	0	0	0
0	0	#	peak
-6	4	-5	-5	-1	50	-50	0	0	0	0	0
0	0	#	width
-1	9	3.58867	4	-1	50	-4	0	0	0	0	0
0	0	#	var-ascending
-1	9	5	1	-1	50	-3	0	0	0	0	0
0	0	#	var-descending
-5	9	-5	-10	-1	50	-50	0	0	0	0	0
0	0	#	initial
-5	9	9	50	-1	50	-2	0	0	0	0	0
0	0	#	final
```

```
# Fleet 7 sex offset (AKC Slope) size based selectivity (using option 24)
20 70 30 29.5 -1 50 -4 0 0 0 0 0 0 0 # peak
-3 0 0 6 -1 50 -50 0 0 0 0 0 0 0 # width
-3 0 -5.66E-09 4 -1 50 -4 0 0 0 0 0 0 0 # var-ascending
-3 0 -0.615001 1 -1 50 -4 0 0 0 0 0 0 0 # var-descending
# Fleet 11 (FRAM Slope Shelf 2003-2006) size based selectivity (using option 24)
20 70 38.0017 29.5 -1 50 -4 0 0 0 0 0 0 0 # peak
-6 6 6 6 -1 50 -50 0 0 0 0 0 0 0 # width
-1 10 4.40027 4 -1 50 -4 0 0 0 0 0 0 0 # var-ascending
-5 9 1 1 -1 50 -50 0 0 0 0 0 0 0 # var-descending
-10 10 -10 -10 -1 50 -50 0 0 0 0 0 0 0 # initial
0 50 50 50 -1 50 -4 0 0 0 0 0 0 0 # final
# Fleet 11 sex offset (FRAM Slope Shelf 2003-2006) size based selectivity (using option 24)
20 70 30 29.5 -1 50 -4 0 0 0 0 0 0 0 # peak
-3 0 0 6 -1 50 -50 0 0 0 0 0 0 0 # width
-3 0 -5.63E-08 4 -1 50 -4 0 0 0 0 0 0 0 # var-ascending
-3 0 -0.883314 1 -1 50 -4 0 0 0 0 0 0 0 # var-descending
# Fleet 12 (FRAM Slope mirrored to AKC slope)

-2 0 -1 44 -1 50 -50 0 0 0 0 0 0 0 # min bin mirror
-2 0 -1 18 -1 50 -50 0 0 0 0 0 0 0 # max bin mirror

0  # TG_custom:  0=no read; 1=read if tags exist
#_Cond -6 6 1 1 2 0.01 -4 0 0 0 0 0 0 0  #_placeholder if no parameters
#
0 #_Variance_adjustments_to_input_values
#_fleet: 1 2 3
#  0 0 #_add_to_survey_CV
#  0 0 #_add_to_discard_stddev
#  0 0 #_add_to_bodywt_CV
```

1 1 #_mult_by_lencomp_N
1 1 #_mult_by_agecomp_N
1 1 #_mult_by_size-at-age_N
#
1 #_maxlambdaphase
1 #_sd_offset
#
0 # number of changes to make to default Lambdas (default value is 1.0)
# Like_comp codes: 1=surv; 2=disc; 3=mnwt; 4=length; 5=age; 6=SizeFreq; 7=sizeage; 8=catch;
# 9=init_equ_catch; 10=recrdev; 11=parm_prior; 12=parm_dev; 13=CrashPen; 14=Morphcomp; 15=Tag-comp;
16=Tag-negbin
#like_comp fleet/survey phase value sizefreq_method
#
lambdas (for info only; columns are phases)

0 # (0/1) read specs for more stddev reporting

999

Appendix C. SS starter file

ATF_2015_dat.ss #_datfile
ATF_2015_ctl.ss #_ctlfile
0 #_init_values_src
0 #_run_display_detail
0 #_detailed_age_structure
0 #_checkup
0 #_parmtrace
0 #_cumreport
0 #_prior_like
1 #_soft_bounds
0 #_N_bootstraps
10 #_last_estimation_phase
1 #_MCMCburn
1 #_MCMCthin
0 #_jitter_fraction
-1 #_minyr_sdreport
-2 #_maxyr_sdreport
0 #_N_STD_yrs
0.001 #_converge_criterion
0 #_retro_yr
0 #_min_age_summary_bio
1 #_depl_basis
1 #_depl_denom_frac
1 #_SPR_basis
3 #_F_report_units
0 #_F_report_basis
#
999

Appendix D. SS forecast file

```
#V3.24o
# for all year entries except rebuilder; enter either: actual year, -999 for styr, 0 for endyr, neg number for rel. endyr
1 # Benchmarks: 0=skip; 1=calc F_spr,F_btgt,F_msy
2 # MSY: 1= set to F(SPR); 2=calc F(MSY); 3=set to F(Btgt); 4=set to F(endyr)
0.3 # SPR target (e.g. 0.40)
0.25 # Biomass target (e.g. 0.40)
#_Bmark_years: beg_bio, end_bio, beg_selex, end_selex, beg_relF, end_relF (enter actual year, or values of 0 or -integer to be rel. endyr)
 0 0 0 0 0 0
#  2010 2010 2010 2010 2010 2010 # after processing
1 #Bmark_relF_Basis: 1 = use year range; 2 = set relF same as forecast below
#
1 # Forecast: 0=none; 1=F(SPR); 2=F(MSY) 3=F(Btgt); 4=Ave F (uses first-last relF yrs); 5=input annual F scalar
12 # N forecast years
0.2 # F scalar (only used for Do_Forecast==5)
#_Fcast_years:  beg_selex, end_selex, beg_relF, end_relF  (enter actual year, or values of 0 or -integer to be rel. endyr)
 0 0 -10 0
#  2010 2010 2000 2010 # after processing
1 # Control rule method (1=catch=f(SSB) west coast; 2=F=f(SSB) )
0.25 # Control rule Biomass level for constant F (as frac of Bzero, e.g. 0.40)
0.05 # Control rule Biomass level for no F (as frac of Bzero, e.g. 0.10)
0.75 # Control rule target as fraction of Flimit (e.g. 0.75)
3 #_N forecast loops (1-3) (fixed at 3 for now)
3 #_First forecast loop with stochastic recruitment
0 #_Forecast loop control #3 (reserved for future bells&whistles)
0 #_Forecast loop control #4 (reserved for future bells&whistles)
0 #_Forecast loop control #5 (reserved for future bells&whistles)
2010  #FirstYear for caps and allocations (should be after years with fixed inputs)
0 # stddev of log(realized catch/target catch) in forecast (set value>0.0 to cause active impl_error)
0 # Do West Coast gfish rebuilder output (0/1)
1999 # Rebuilder:  first year catch could have been set to zero (Ydecl)(-1 to set to 1999)
2002 # Rebuilder:  year for current age structure (Yinit) (-1 to set to endyear+1)
1 # fleet relative F:  1=use first-last alloc year; 2=read seas(row) x fleet(col) below
# Note that fleet allocation is used directly as average F if Do_Forecast=4
2 # basis for fcast catch tuning and for fcast catch caps and allocation  (2=deadbio; 3=retainbio; 5=deadnum; 6=retainnum)
# Conditional input if relative F choice = 2
# Fleet relative F:  rows are seasons, columns are fleets
#_Fleet:  South.fixed Central.fixed Central.trawl
#  0.190524 0.315408 0.494067
# max totalcatch by fleet (-1 to have no max) must enter value for each fleet
 -1 -1 -1
# max totalcatch by area (-1 to have no max); must enter value for each fleet
 -1
# fleet assignment to allocation group (enter group ID# for each fleet, 0 for not included in an alloc group)
 0 0 0
#_Conditional on >1 allocation group
```

allocation fraction for each of: 0 allocation groups
no allocation groups
0 # Number of forecast catch levels to input (else calc catch from forecast F)
2 # basis for input Fcast catch: 2=dead catch; 3=retained catch; 99=input Hrate(F) (units are from fleetunits; note new codes in SSV3.20)
Input fixed catch values
#
999 # verify end of input

Appendix E. MCMC Diagnostics

Appendix E.1. lnR_0 prior Unif(3,18)

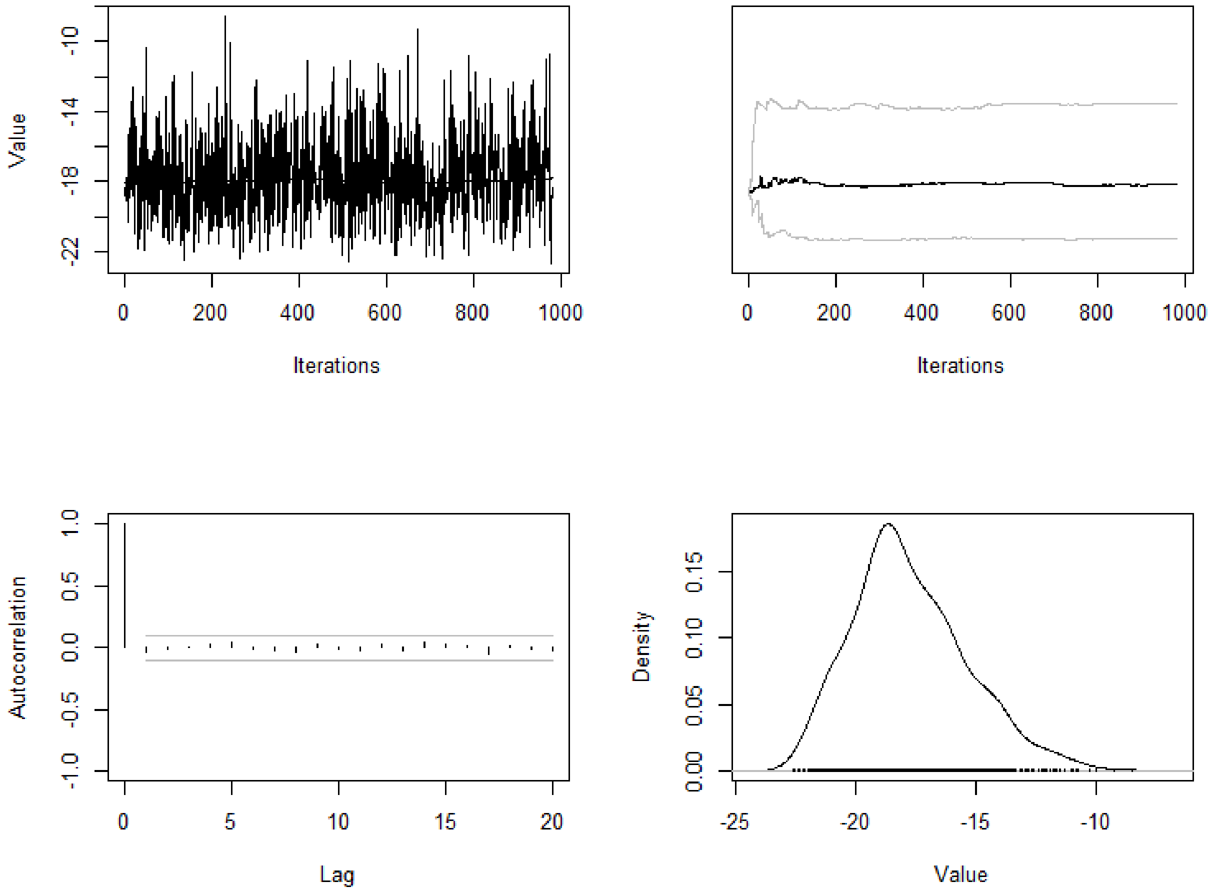

Figure E.1 1. MCMC diagnostics for the objective function. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

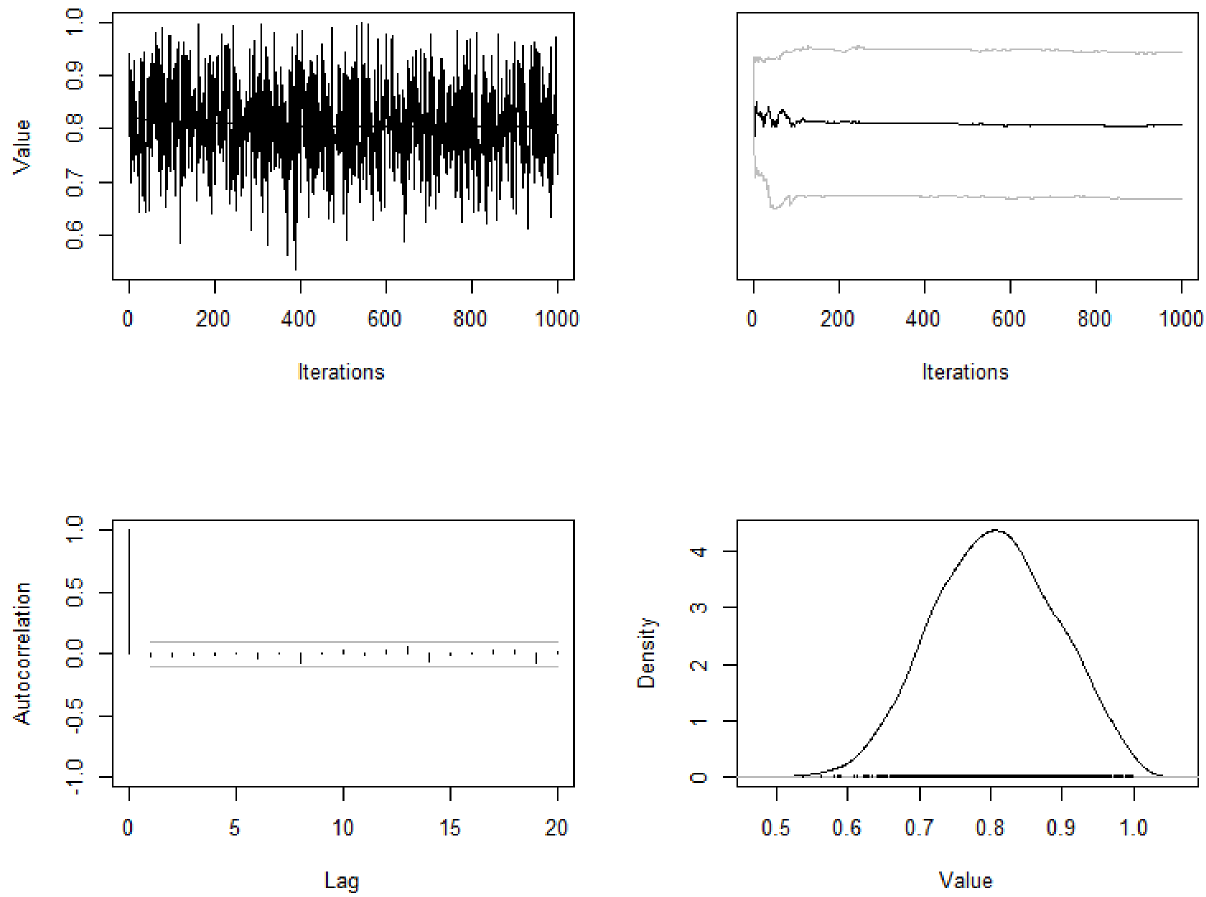

Figure E.1 2. MCMC diagnostics for steepness. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

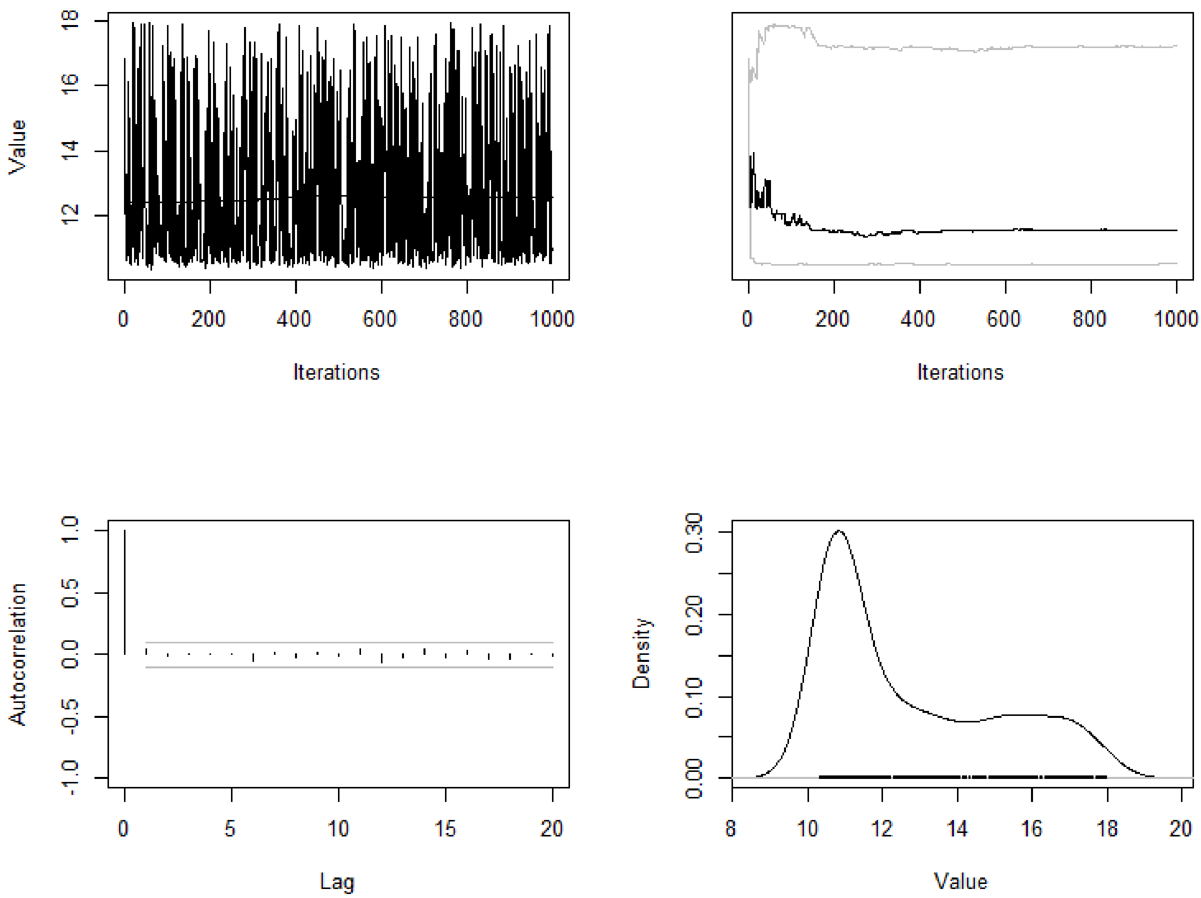

Figure E.1 3. MCMC diagnostics for log of the initial recruitment (lnR_0). Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

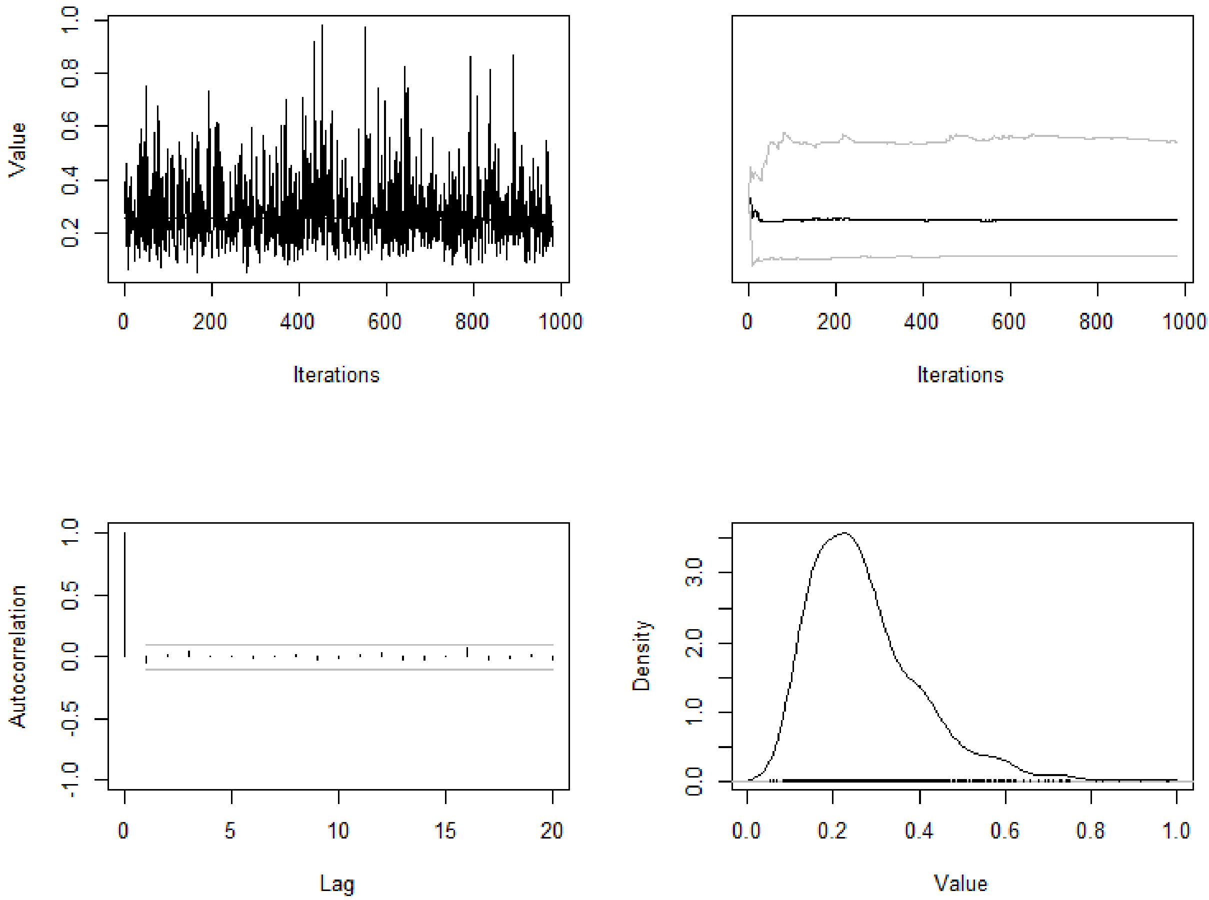

Figure E.1 4. MCMC diagnostics of extra variance estimated for the Triennial survey. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

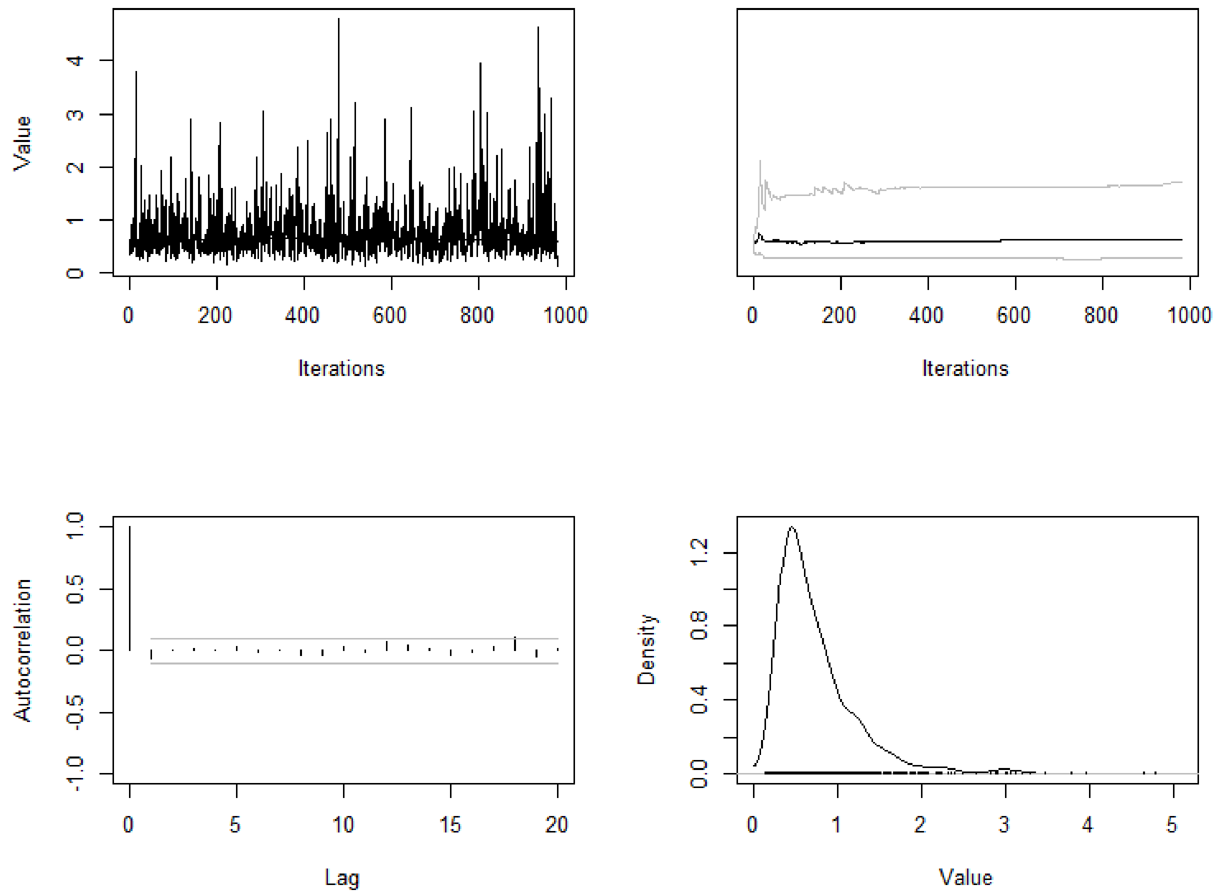

Figure E.1 5. MCMC diagnostics of extra variance estimated for the AFSC slope survey. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

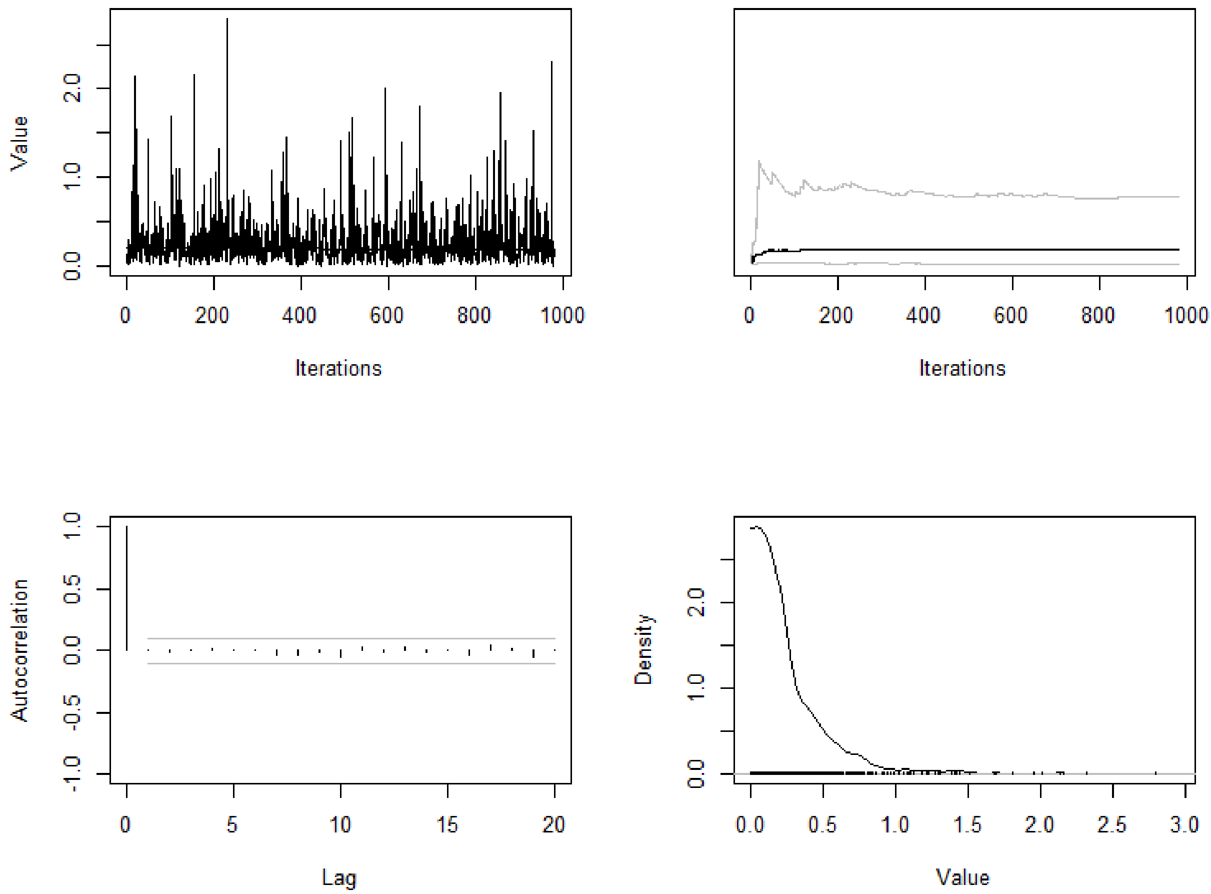

Figure E.1 6. MCMC diagnostics of extra variance estimated for the NWFSC slope survey. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

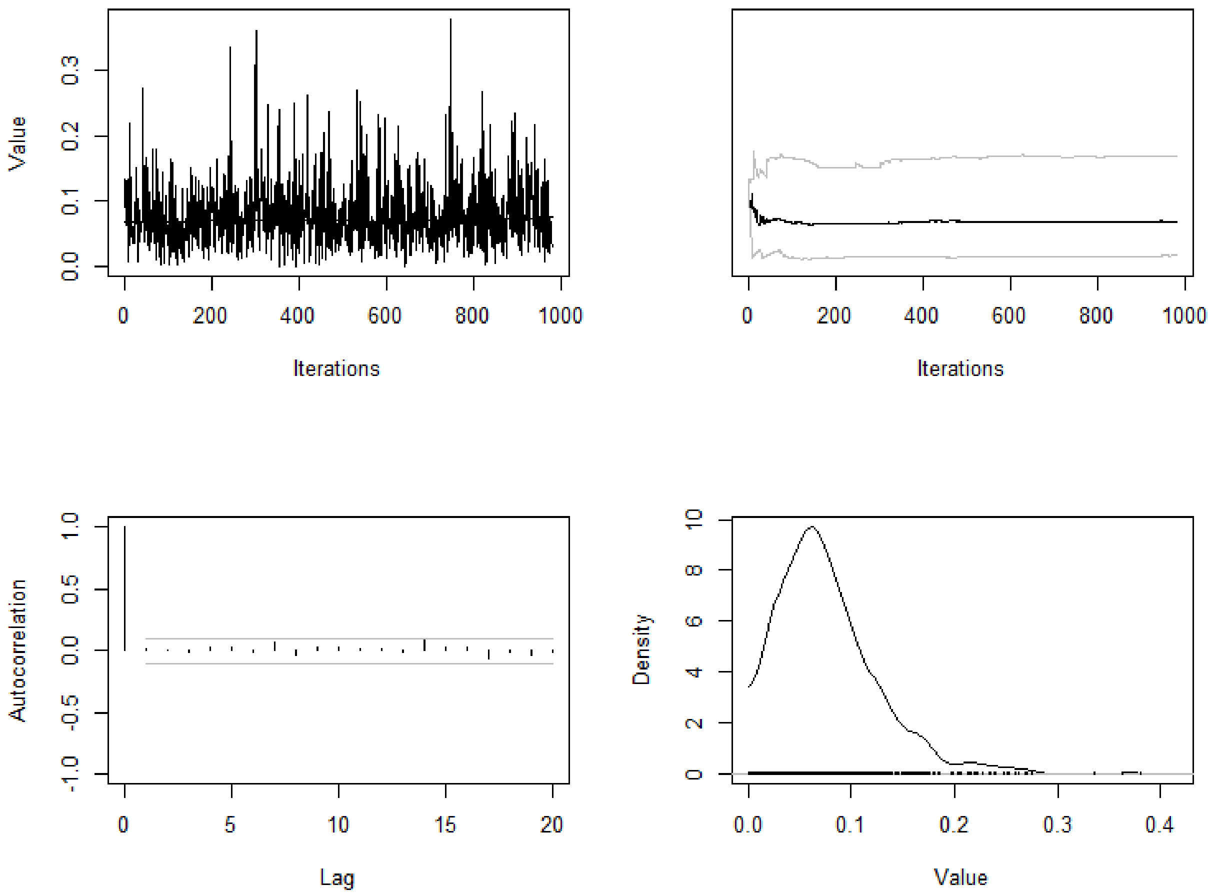

Figure E.1 7. MCMC diagnostics of extra variance estimated for the NWFSC shelf-slope survey. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

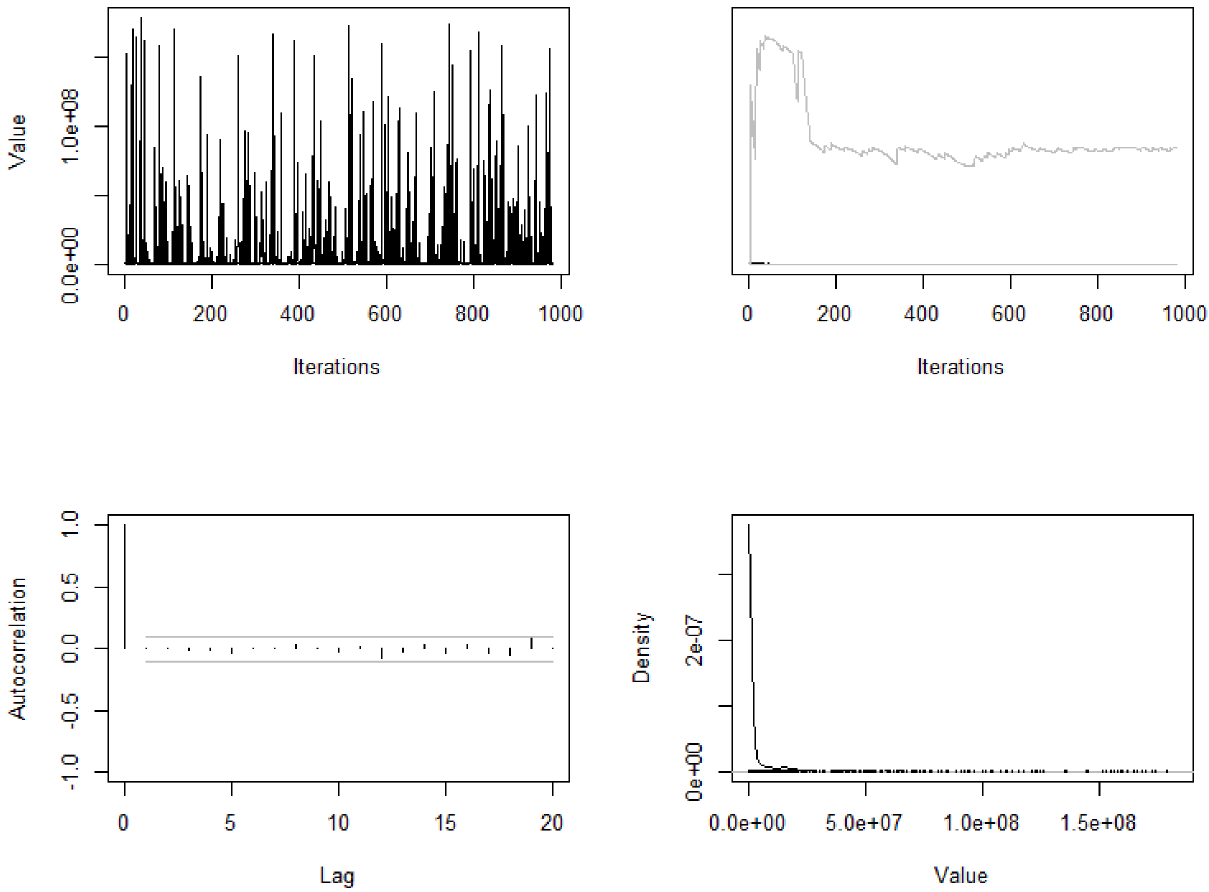

Figure E.1 8. MCMC diagnostics of initial spawning biomass. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

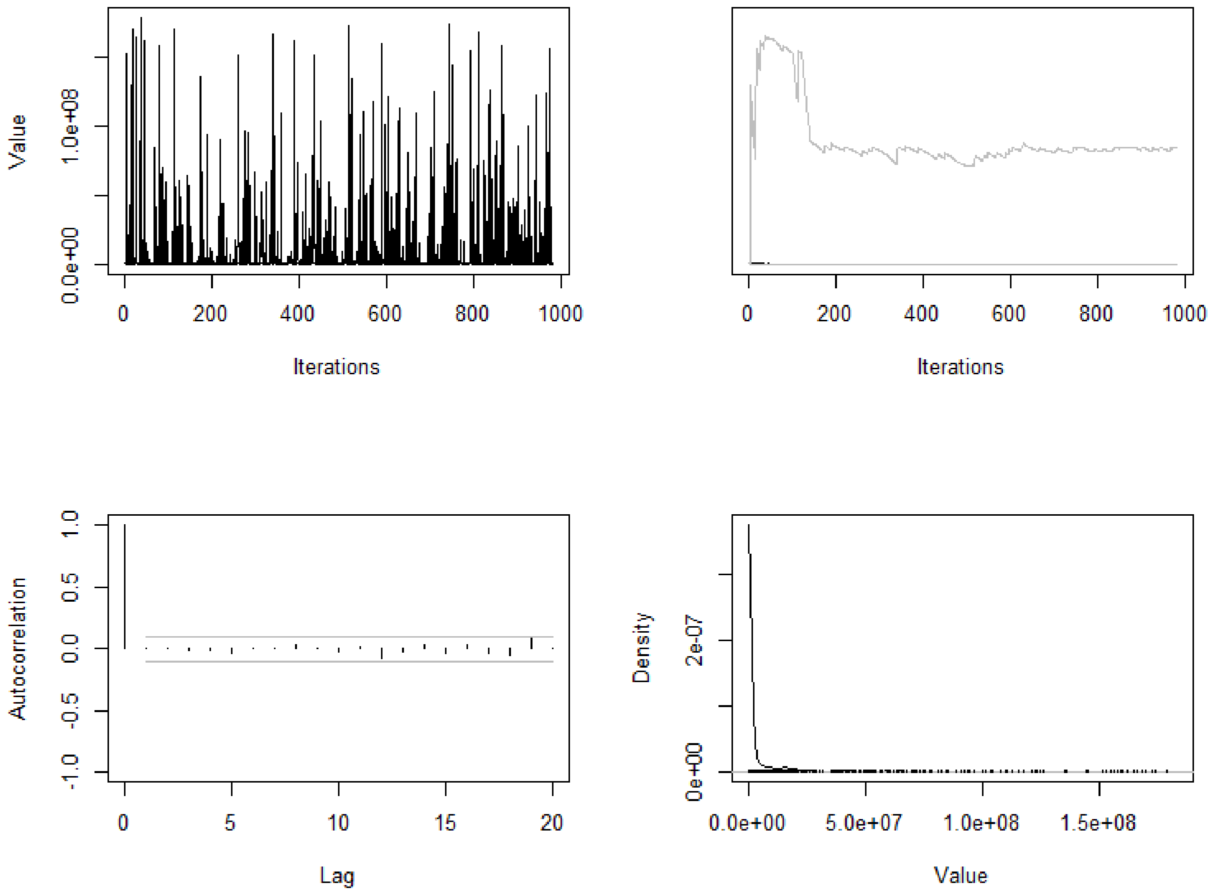

Figure E.1 9. MCMC diagnostics of spawning biomass in year 2015. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

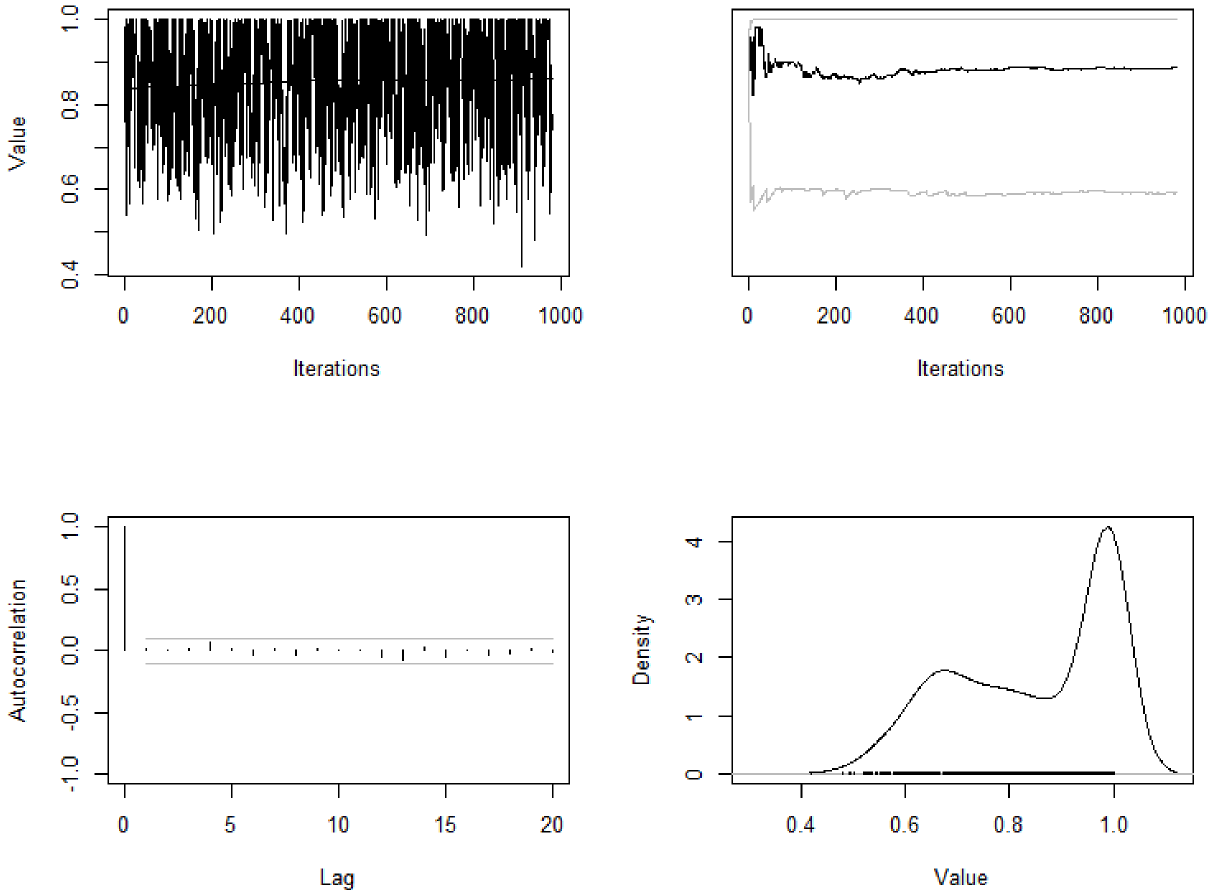

Figure E.1 10. MCMC diagnostics of stock status in year 2015. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

Appendix E.2. lnR_0 prior Unif(3,14)

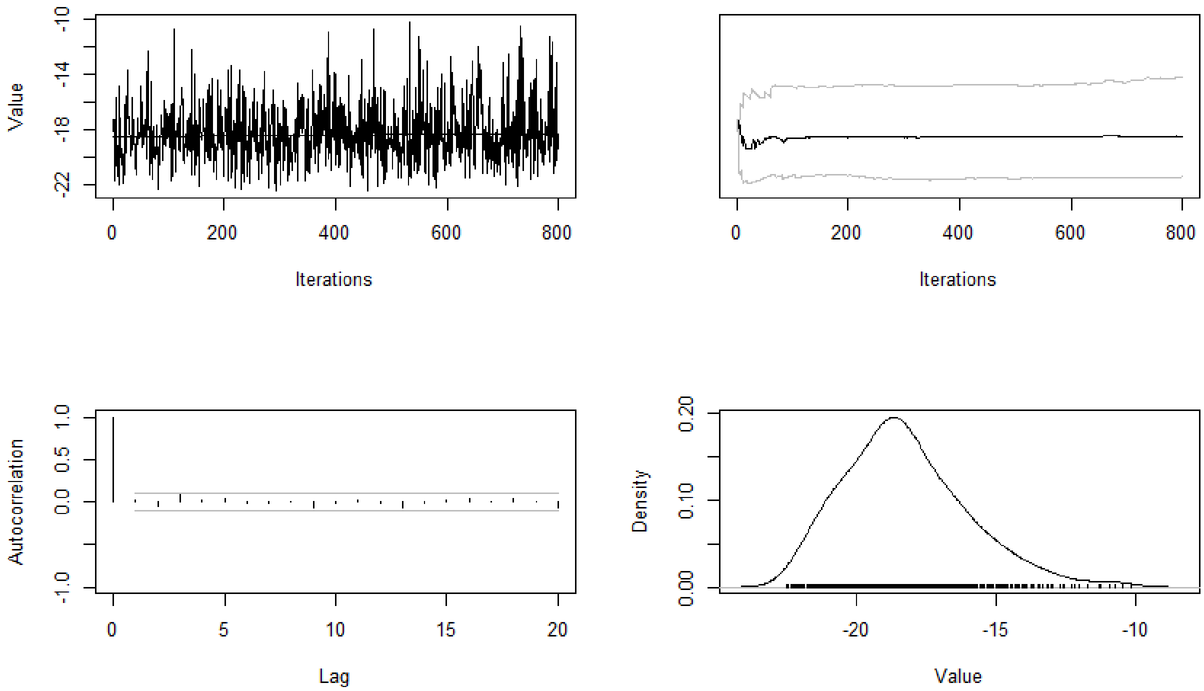

Figure E.2 1. MCMC diagnostics for the objective function. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

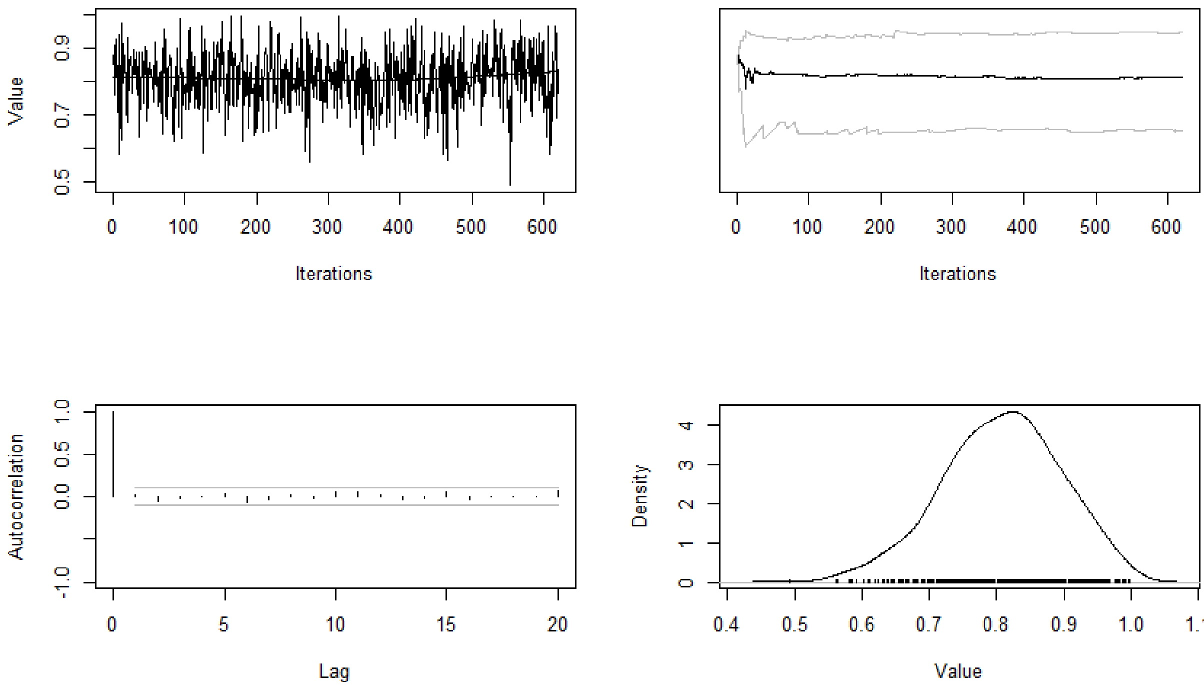

Figure E.2 2. MCMC diagnostics for steepness. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

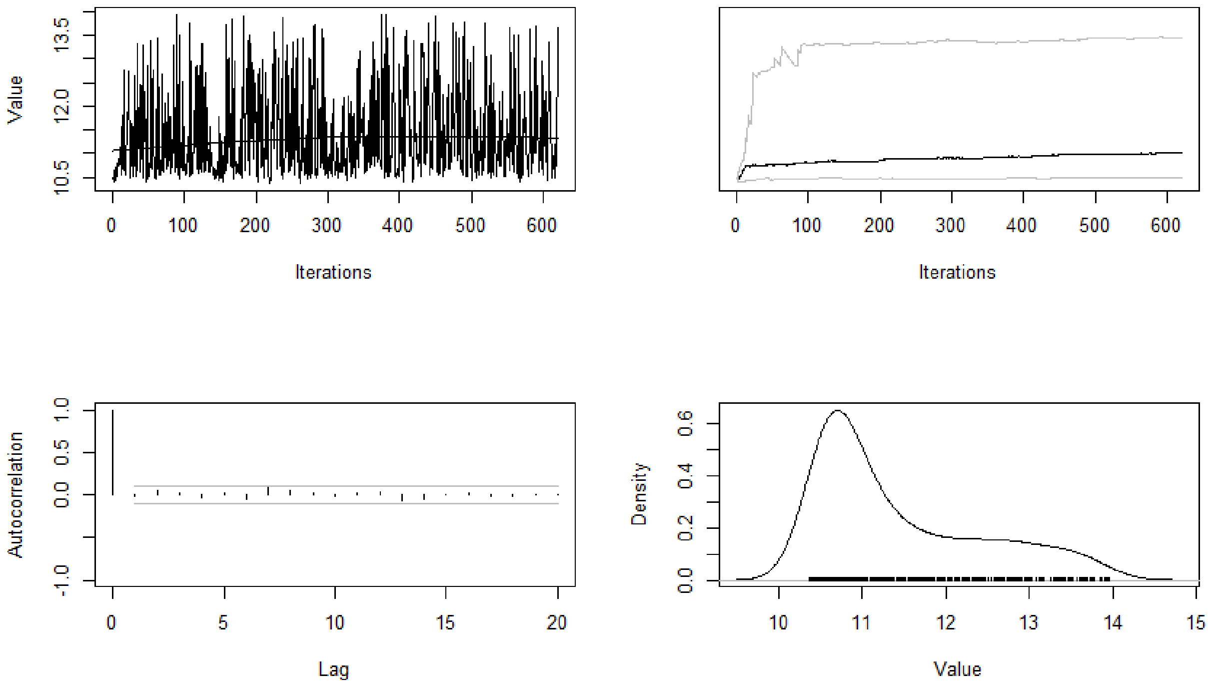

Figure E.2 3. MCMC diagnostics for log of the initial recruitment (ln*R_0*). Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

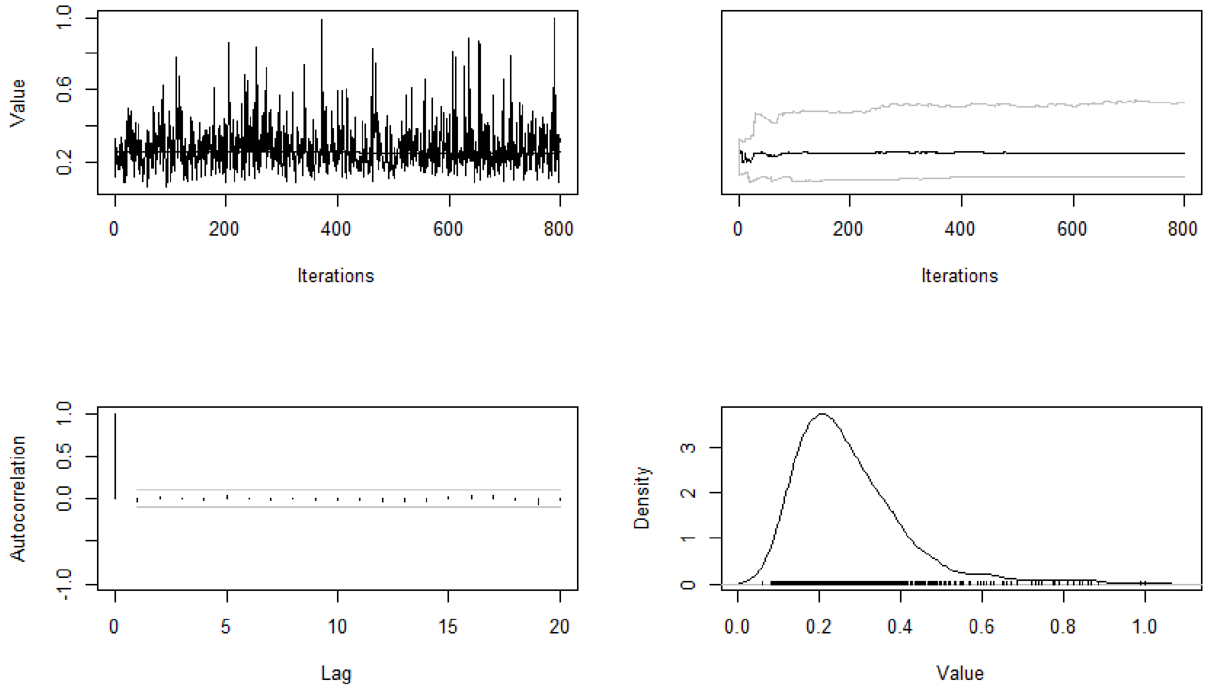

Figure E.2 4. MCMC diagnostics of extra variance estimated for the Triennial survey. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

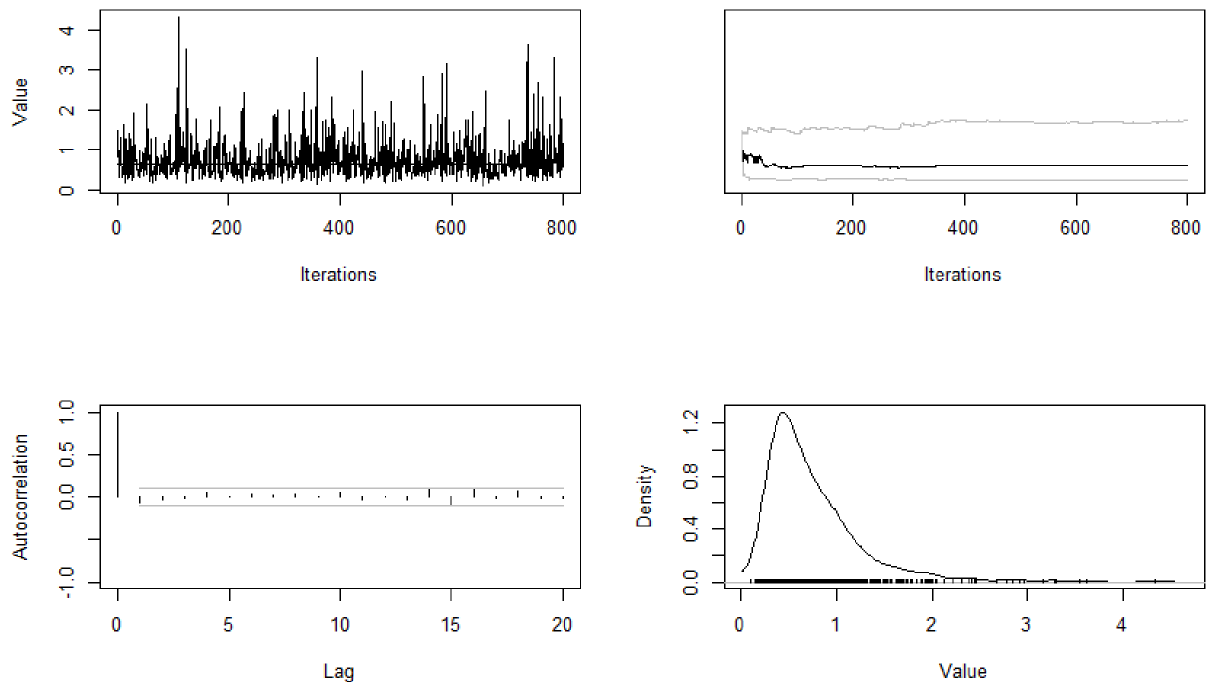

Figure E.2 5. MCMC diagnostics of extra variance estimated for the AFSC slope survey. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

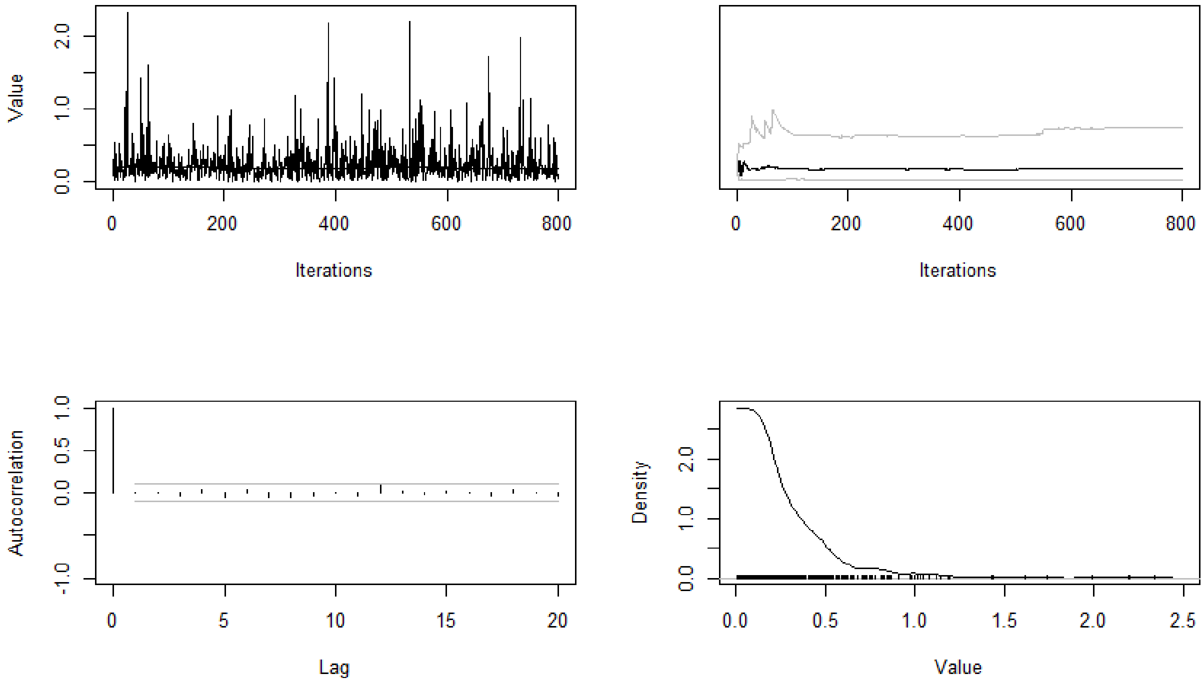

Figure E.2 6. MCMC diagnostics of extra variance estimated for the NWFSC slope survey. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

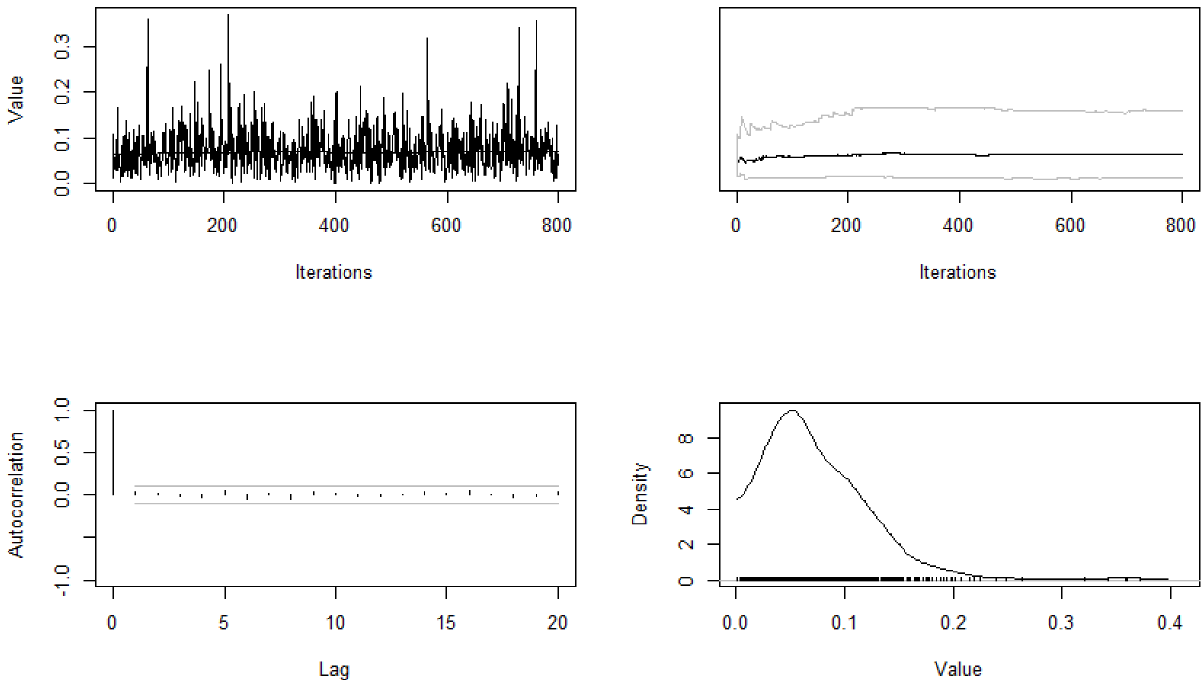

Figure E.2 7. MCMC diagnostics of extra variance estimated for the NWFSC shelf-slope survey. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

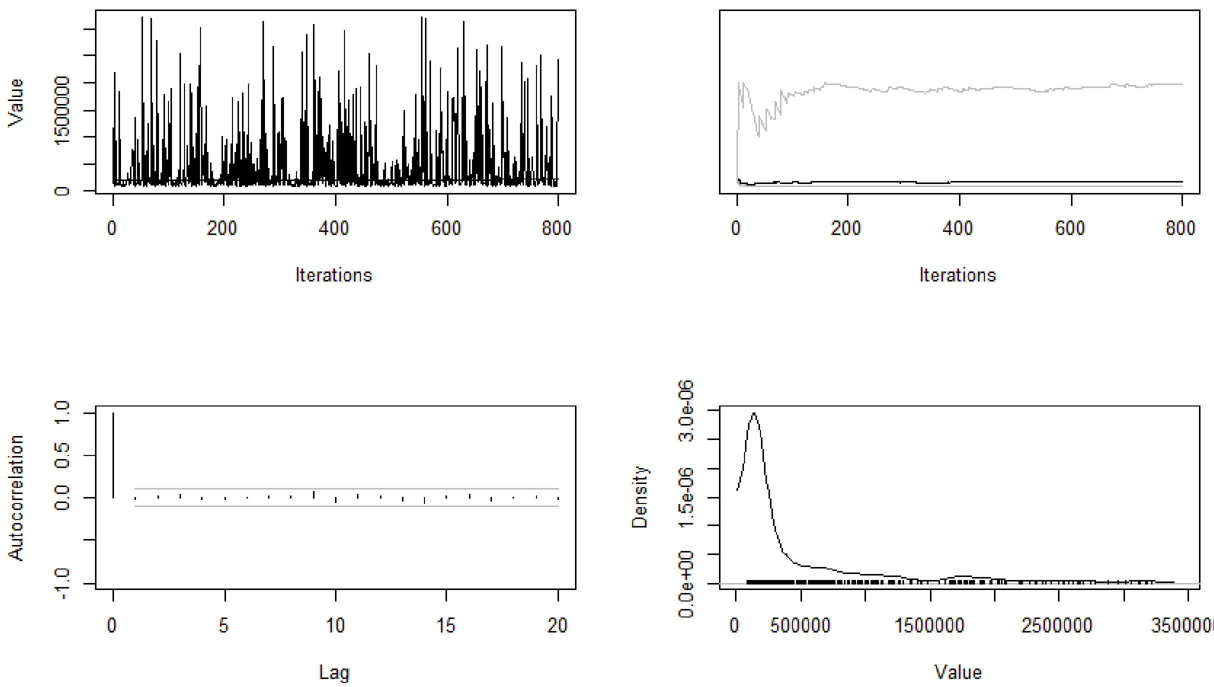

Figure E.2 8. MCMC diagnostics of initial spawning biomass. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

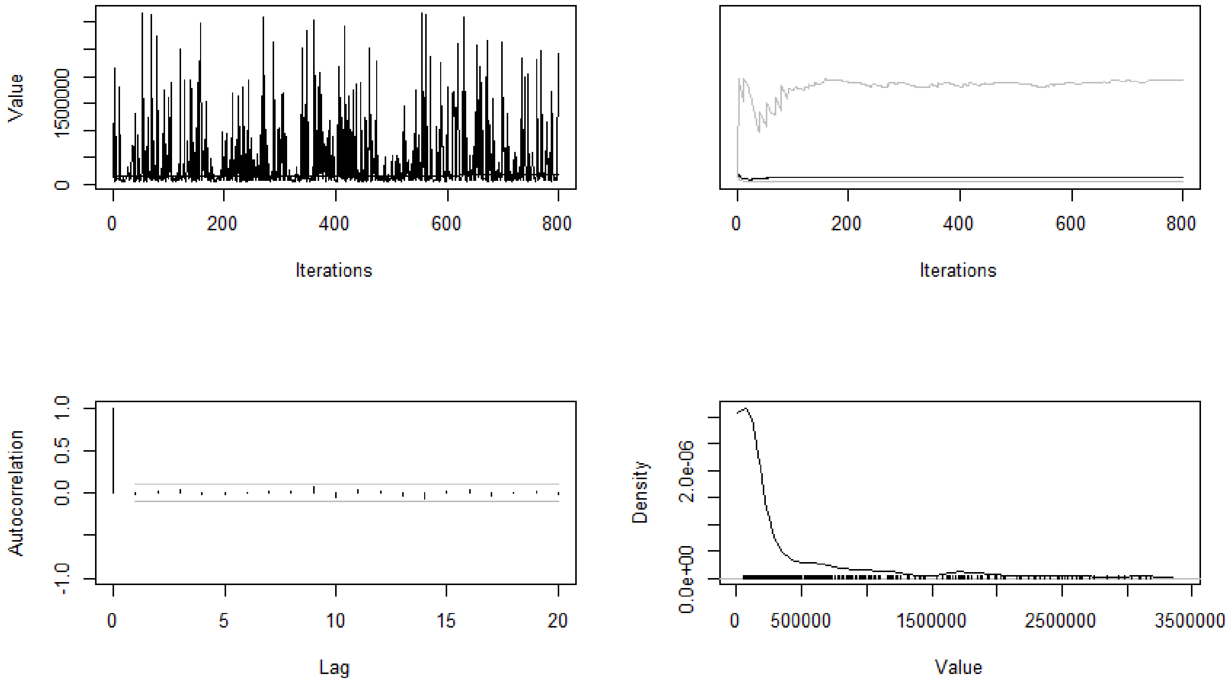

Figure E.2 9. MCMC diagnostics of spawning biomass in year 2015. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

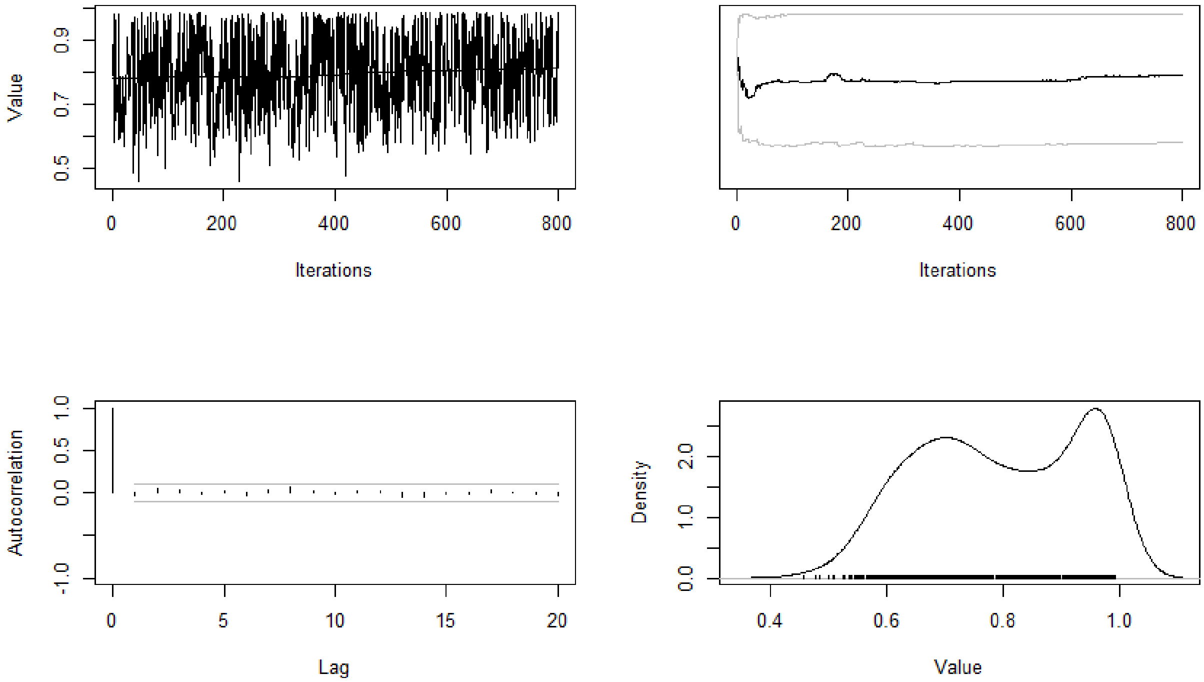

Figure E.2 10. MCMC diagnostics of stock status in year 2015. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

Appendix E.3. lnR_0 prior N(11.3,0.78)

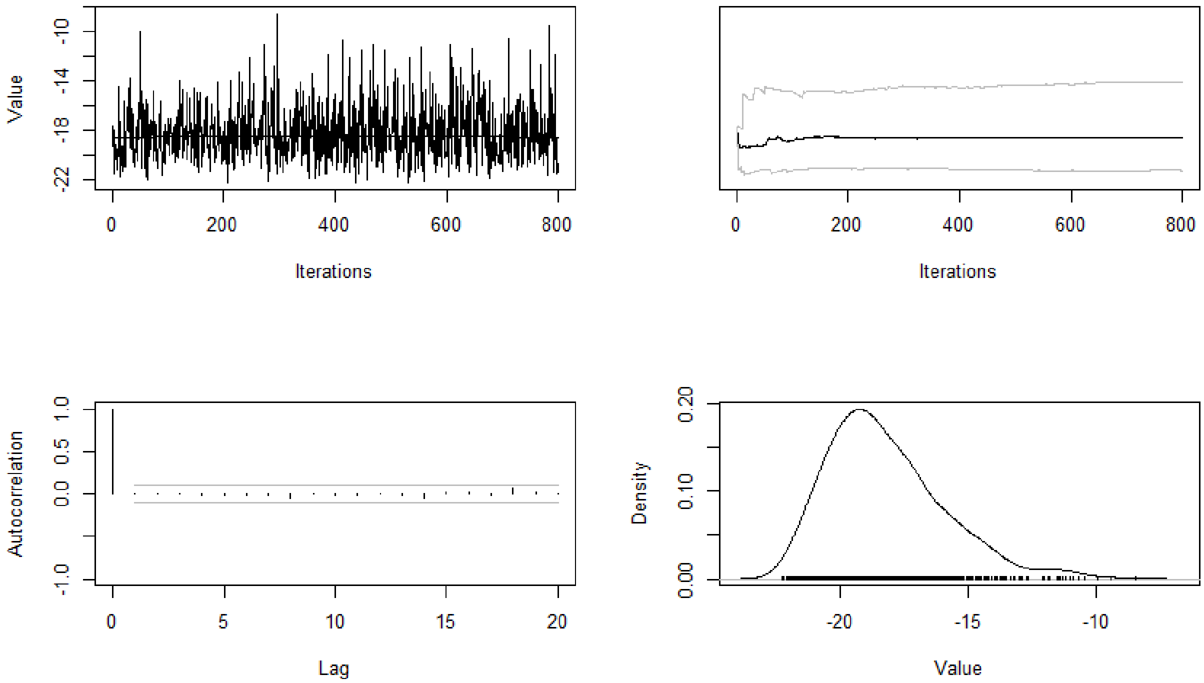

Figure E.3 1. MCMC diagnostics for the objective function. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

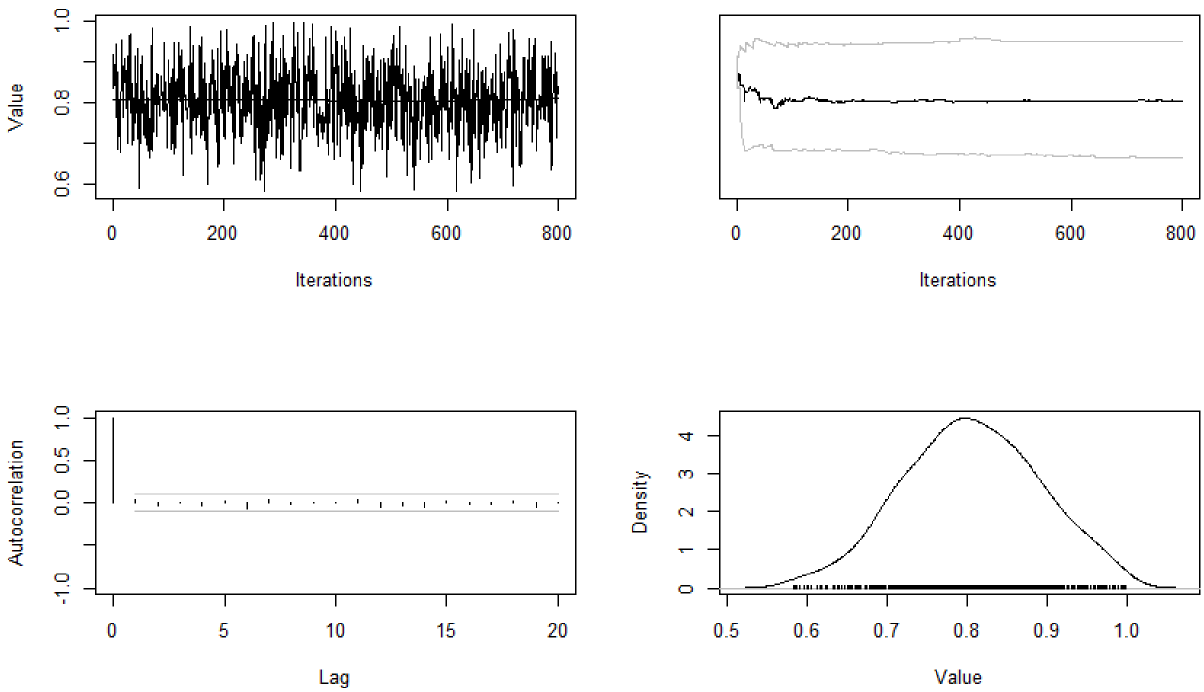

Figure E.3 2. MCMC diagnostics for steepness. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

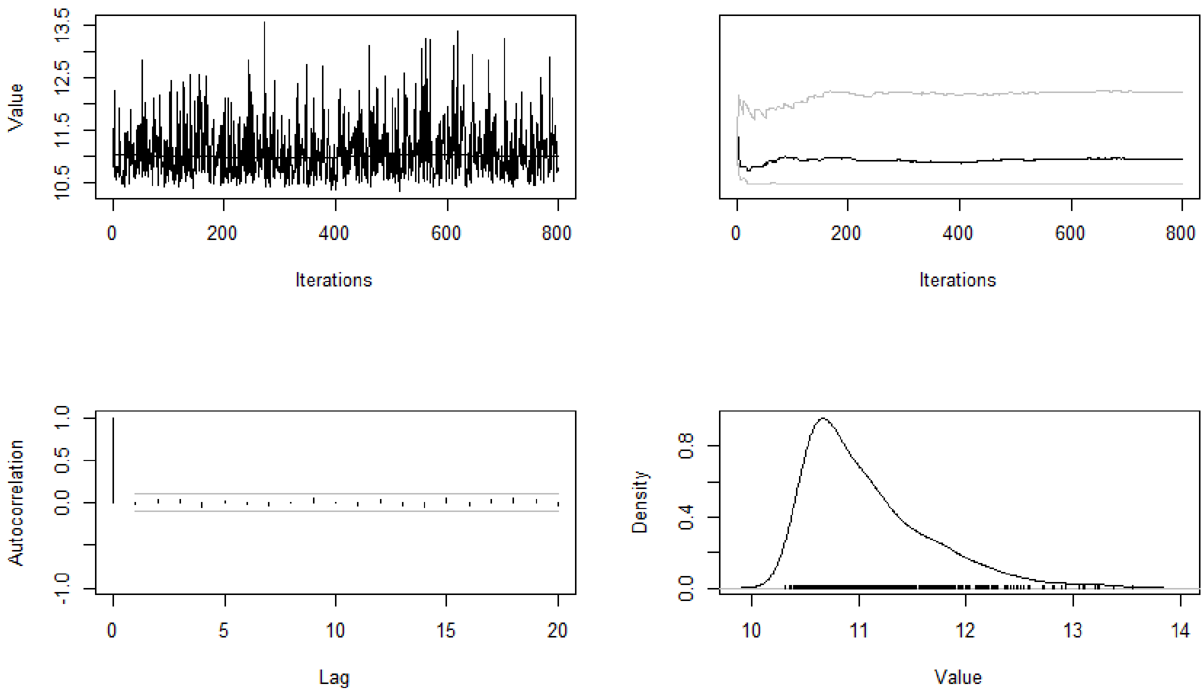

Figure E.3 3. MCMC diagnostics for log of the initial recruitment (ln*R_0*). Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

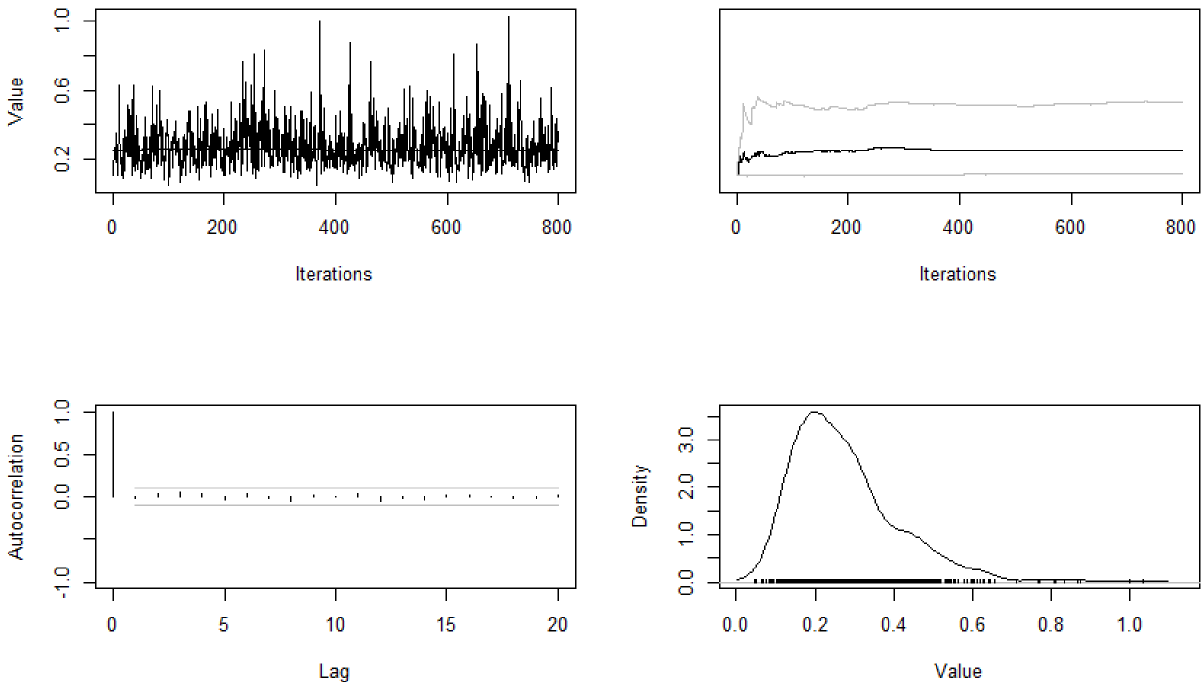

Figure E.3 4. MCMC diagnostics of extra variance estimated for the Triennial survey. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

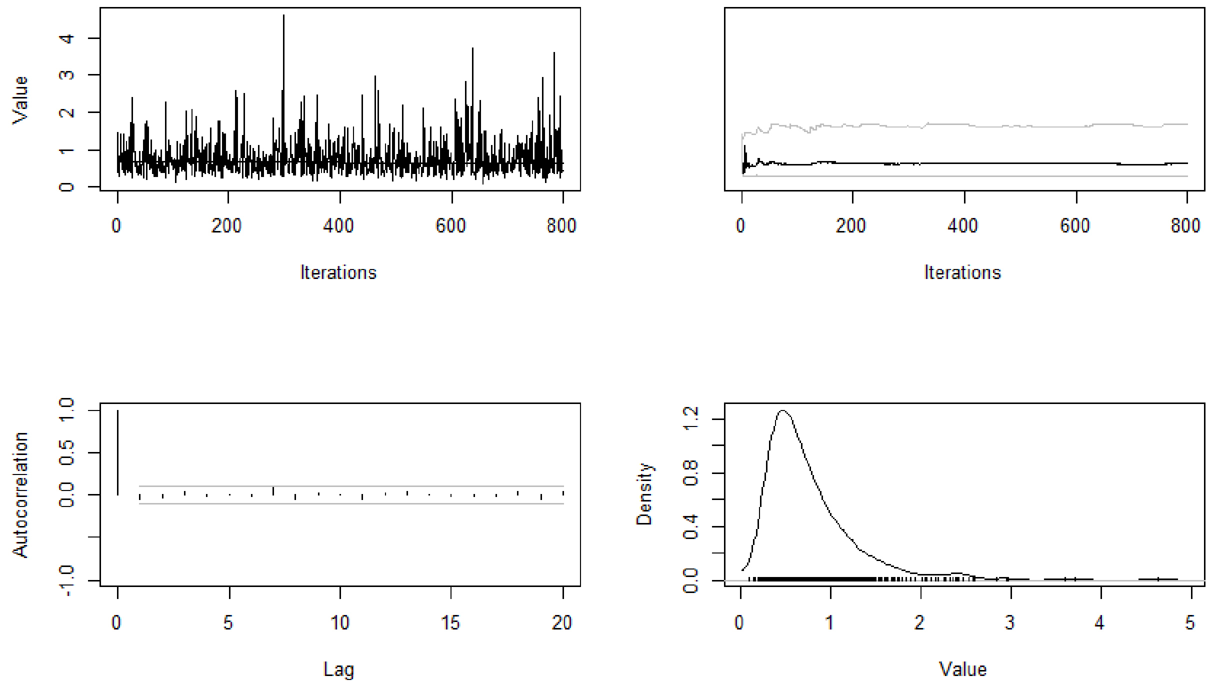

Figure E.3 5. MCMC diagnostics of extra variance estimated for the AFSC slope survey. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

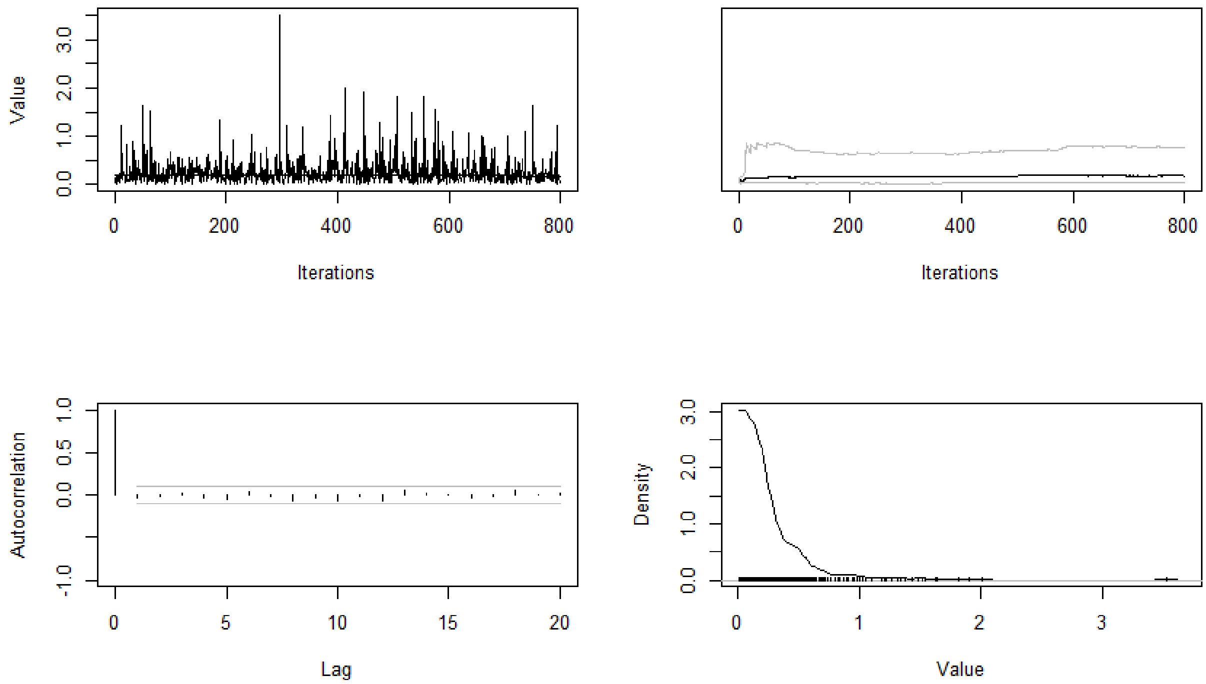

Figure E.3 6. MCMC diagnostics of extra variance estimated for the NWFSC slope survey. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

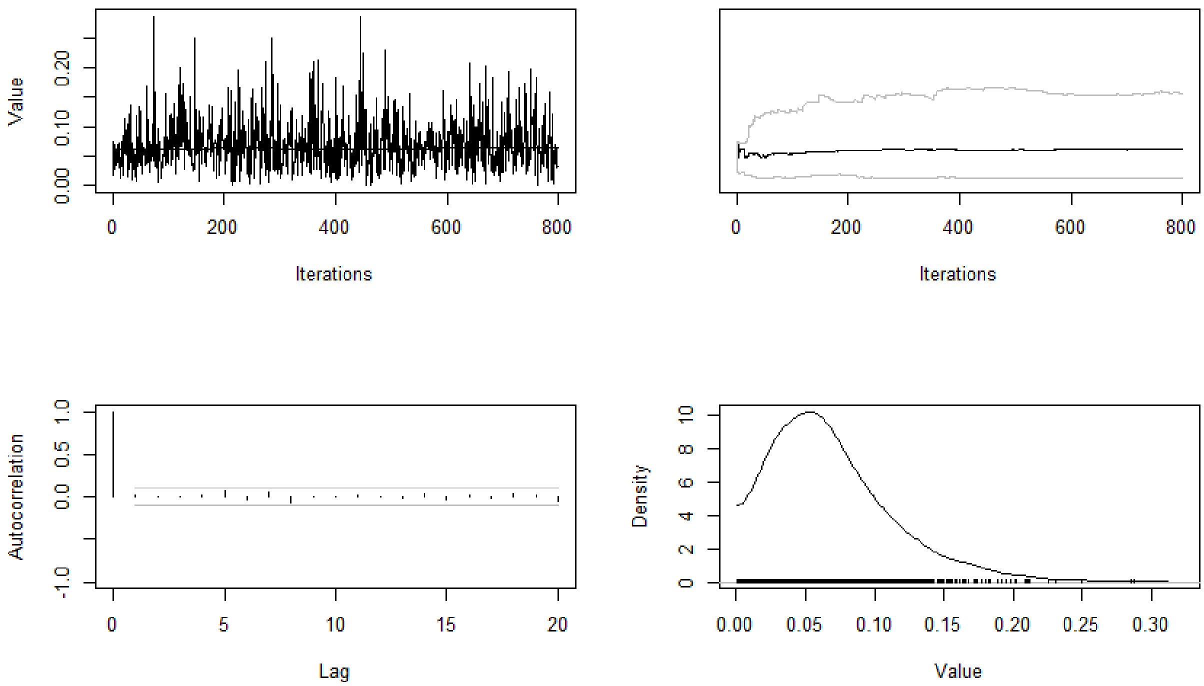

Figure E.3 7. MCMC diagnostics of extra variance estimated for the NWFSC shelf-slope survey. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

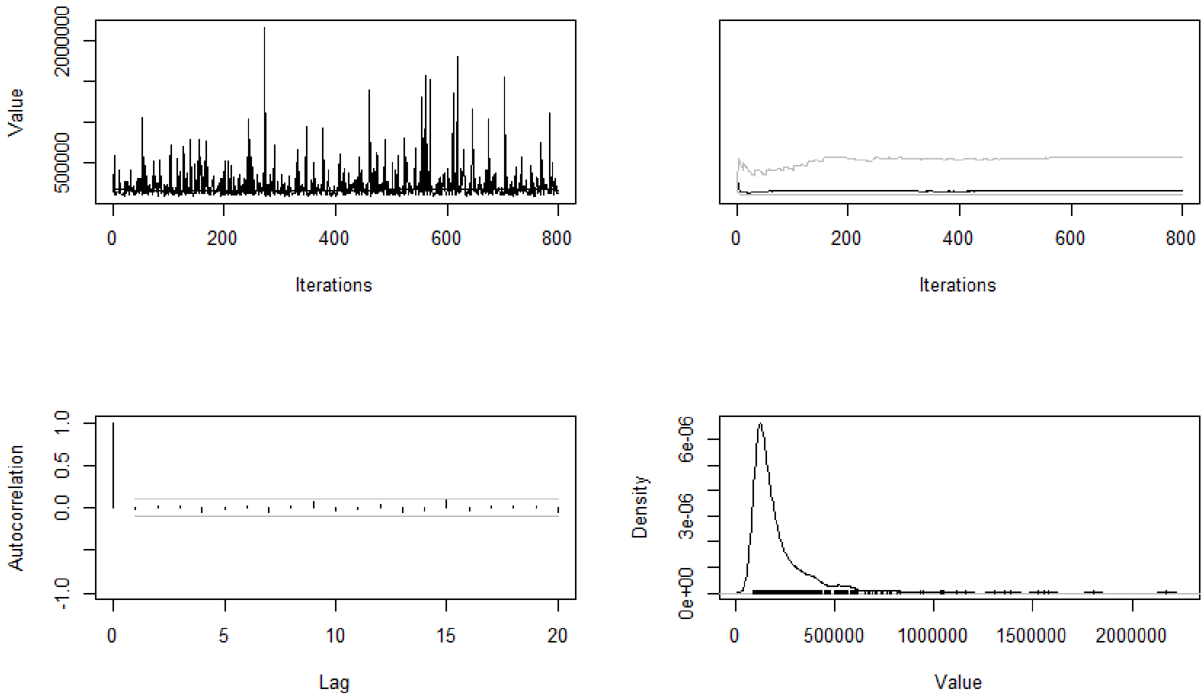

Figure E.3 8. MCMC diagnostics of initial spawning biomass. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

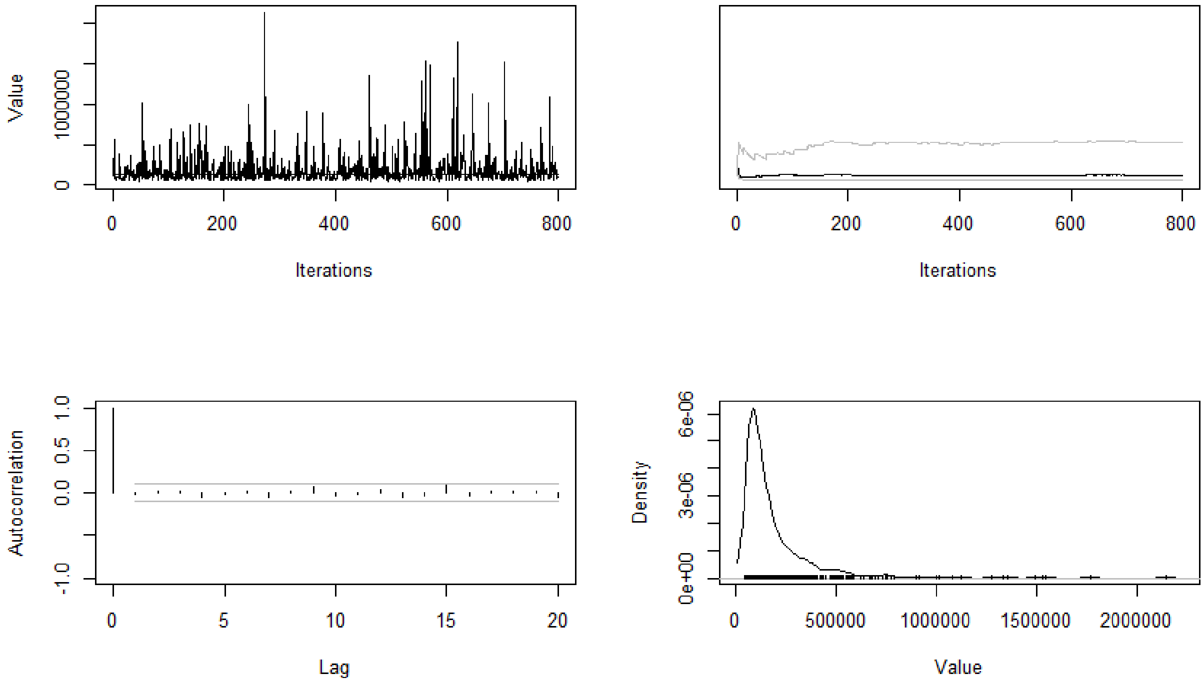

Figure E.3 9. MCMC diagnostics of spawning biomass in year 2015. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).

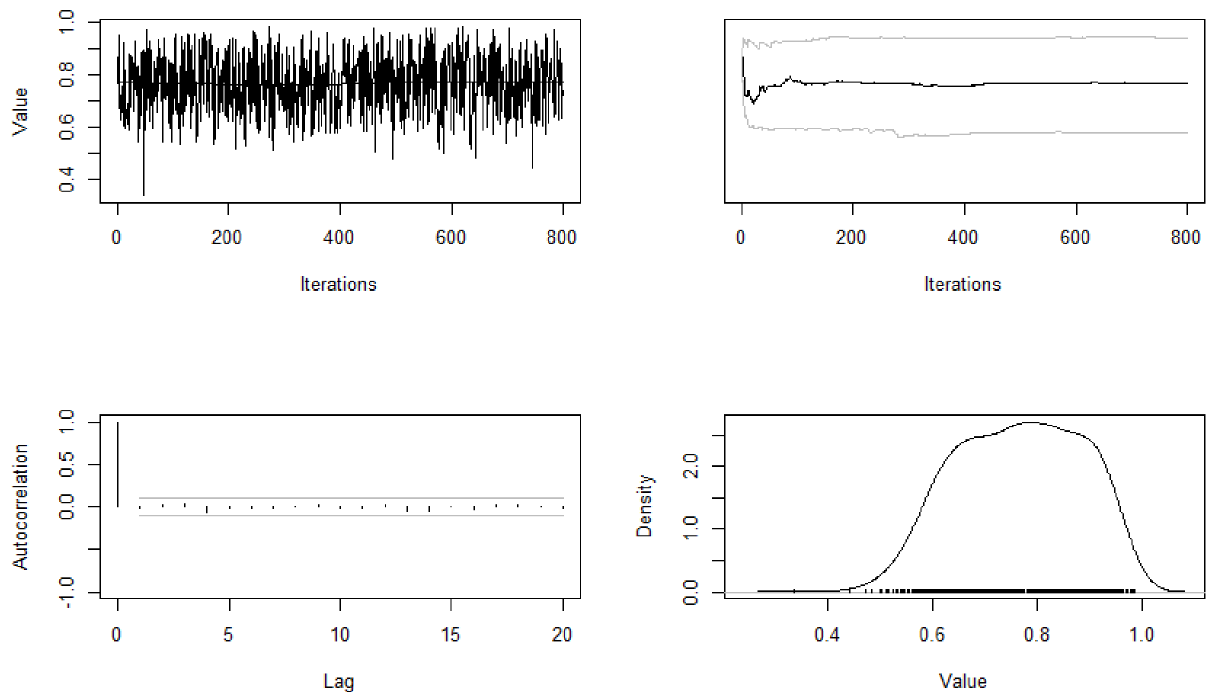

Figure E.3 10. MCMC diagnostics of stock status in year 2015. Trace plot (top left panel); trace quantile plots (top right panel); autocorrelation (bottom left panel); density plot (bottom right panel).