Bluefish Model Bridge-Building in ASAP

Anthony Wood

October 2022

Introduction

The first step in modeling in ASAP was to conduct a continuity run, which updated the current assessment model with data through 2021. A base model was then constructed by adding new data (CAA, WAA) and indices to the continuity run, keeping the same model settings and weights. A model bridge was then built from the base model to a final ASAP model by changing model data formulation, specifications, and weighting inputs. In total, about 80 variations of ASAP models were explored during this bridge building procedure. The model steps with the most important changes that provide a linear path from the base model to the final ASAP model are presented below. Table 4.1 provides a brief model description and a summary of the important parameters at each bridge steps. Working Paper 16 (Wood 2022c) provides the complete set of diagnostic plots from the major milestone models; individual pdfs of the diagnostics from those runs are linked below in the text.

Model BF01: Continuity run

The continuity run was the first model explored in the model building process for the 2022 research track. This model run was carried out as an update of the SAW60 benchmark final model, and is the model currently used for management advice. Total catch, catch-at-age, weight-at-age, and indices-at-age were updated for 2020 and 2021 using previously established data protocols. The fishery was modeled as two fleets (commercial and recreational) with a single selectivity block per fleet. In addition, 9 indices of abundance were updated for 2020, and 2021:

1. NEFSC Albatross (1985-2008, age-0 – age-6+)
2. NEFSC Bigelow (2009-2021, age-0 – age-6+)
3. MRIP recreational catch-per-angler (1985-2021, age-0 – age-6+)
4. NEAMAP (2009-2021, age-0 – age-6+)
5. SEAMAP (1989-2021, age-0)
6. PSIGNS gillnet (2001-2021, age-0 – age-6+)
7. CT LISTS (1985-2021, age-0 – age-6+)
8. NJ trawl indices (1990-2019, age-0 – age-2)
9. YoY seine (1985-2021, age-0)

Index selectivity was at-age for all indices, with full selectivity (1.0) fixed on a single age. Natural mortality was kept constant at 0.2 for all ages and all years. Maturity was fixed across years at a value of 0 for Age 0, 0.47 for Age 1, 0.97 for Age 2, and full maturity at Age 3+.

A full suite of input, results, diagnostic, retrospective and MCMC plots are available for this run which can be downloaded or viewed from the following link: BF01 plots.

The objective function components for the continuity run show the model is weighted heavily toward the fleet and catch age compositions. Estimates from the model show a decrease in total abundance from a peak in 2006, declining from 158 million to a low of 88 million fish in 2020, and an increase to 103 million fish in 2021 (Figure 4.1). Following a high in recruitment of 95 million fish in 1989, recruitment has remained steady around the time series average of 44 million, with the two lowest values of the time-series occurring in recent years (2019 and 2020: Figure 4.1). Total biomass in 2021 (Jan 1) equaled 97,246 MT, a slight decrease from the 2020 estimate of 83,228 MT. Corresponding spawning stock biomass (SSB) in 2021 was 91,745 MT, an increase from the 2020 estimate of 80,391 MT (Figure 4.1).

The 2021 F value equals 0.159. Fishing mortality fluctuated dramatically from 2015 to 2018, with a peak of 0.584 in 2017. The most recent four estimates are the lowest in the time-series (Figure 4.1).

Retrospective bias for the continuity run was examined for F, SSB, and recruitment using 7-year peels. The analysis showed consistent and significant patternsin the estimates of F and SSB, with Mohn's rho values of -0.277 and 0.294, respectively. Recruitment estimates exhibit lower retrospective patterningthat is inconsistent over the peels, with a Mohn's rho estimate of 0.170.

The variation in the final continuity model estimates for F and SSB was determined using a Monte Carlo Markov Chain with 1000 iterations and a thinning factor of 200. The MCMC calculations for SSB estimated a median value of 84,097 MT, with 90% confidence between 71,327 to 100,588 MT. The point estimates from the assessment model fall above the median values from the MCMC indicating possible issues with model convergence. The MCMC estimates of F were a median estimate of 0.168 in 2021, with 90% confidence from 0.129 to 0.222.

Convergence diagnostics for the continuity run were carried out using a jitter analysis. Initial guesses for starting values were randomly jittered 200 times, with the model being refit to each random set of new guesses. The 200 realizations of the model objective function and gradient were examined to see how robust the model is to the starting values. The continuity run had poor convergence diagnostics, with only 130/200 realizations of the original objective function and 18 non-converged models. Gradient values were also poor for a number of these runs, with the majority of values being greater than 0.0001 (Figure 4.2).

Model BF03: Update all fishery catch and fishery biological sample information

Model BF03 covers the implementation of updated fishery catch data and length information. All of the updates to the fishery data were captured in this modeling step including any additional commercial landings information in the updated data pull as well as new recreational release information from the volunteer angler surveys (eg. new survey: SC VAS). All CAA, WAA total weight vectors were constructed at the season level, consistent with the continuity run methodology, with one exception. A consistent borrowing rule was implemented for commercial lengths which was not used in the past. For group (MEVA, NC, FL)/market/quarter landings without length information, lengths were filled in the following order: within market half, within market annual, unclassified quarter, unclassified half, unclassified annual.

Estimates from model BF03 show similar results to the continuity run with SSB in 2021 was estimated at 85,975 MT, recruitment estimated at 39.2 million, and a fishing mortality estimate of 0.172. Retrospective bias has increased for each of these components (Table 4.1). Convergence diagnostics for this model are still poor, with 142/200 realizations of the original objective function and 21 non-converged models.

Model BF04 to BF07: New L-W parameters, new Rec discard mortality, add commercial discards

Data changes from model BF03 to model BF07 included:

1. New length-weight (LW) parameters that were developed using all of the biological information available to the WG (Working Paper 5; Truesdell et al. 2022). This change had a minimal effect on the model results (Table 4.1). Estimates of recruitment, SSB, and fishing mortality were consistent with the continuity run. In addition, there was very little change in retrospective patterns, with a small decrease in SSB retrospective.

2. Next, a new estimate for recreational discard mortality was applied to the MRIP B2 releases. The previous estimate for discard mortality was 15%, based on analyses from the 2015 benchmark assessment. This value was reduced to a value of 9.4% based on an updated analysis that is detailed in Working Paper 11 (Valenti 2022b). Recreational discards are an important component of the total catch and reducing the amount of catch lowered estimates of F, SSB and recruitment and slightly increased retrospective patternsacross these values (Table 4.1).

3. The final data change from model BF03 to model BF07 was to incorporate commercial discards into the total catch. Commercial discards were a very minor component of the total catch (~0.2%) and the addition of this information did not significantly change any of the model results (Table 4.1).

A full suite of input, results, diagnostic, retrospective and MCMC plots are available for this run which can be downloaded or viewed from the following link: BF07 plots.

Model BF08: New indices (except use MRIP continuity index)

Model BF08 includes a major change to the input data as well as model specification changes associated with this change of data. The 2022RT working group split off a sub-group (fishery independent sub-group: FIG) to develop a consistent set of indices for the assessment. Prior assessments have used state developed indices, with different methods used to develop each index (eg. stratified mean, geometric mean, model standardized). The FIG developed a standard methodology to be applied to each state's raw survey information; see Working Paper 7 (Celestino et al. 2022a) for more details. The exception to this was for SEAMAP age 0 and age 1 indices which were standardized by South Carolina state biologists.

The standardized methodology resulted in minor to no changes in most of the indices. The scale of both the NEAMAP and CT index had the most dramatic changes, however, the trend of these two indices were consistent with previous versions (Figure 4.3).

In addition to developing a standard set of indices, two new indices were incorporated at this step. The ChesMMAP survey and SEAMAP age 1 index. See ASMFC (2021) and Working Paper 7 (Celestino et al. 2022a) for a full description of these indices and how they were developed.

Finally, based on working group discussions and input from State biologists from NJ (who are involved with their Ocean trawl survey) it was decided to remove the NJ Ocean trawl index which captured abundance of ages 0-2. The survey captures predominantly age 0 fish, with very small proportions of ages 1-2 that appeared to reflect periodic availability rather than true trends in abundance. Ultimately, it was decided that this index was not doing a good job of tracking the abundance of these age classes.

Summary of indices at this model step:

Index 1 = NEFSC Inshore trawl (Albatross 1985-2008: FIG methods)
Index 2 = NEFSC Bigelow trawl (Bigelow 2009-2021: FIG methods)
Index 3 = MRIP recreational CPUE (Continuity version)
Index 4 = NEAMAP trawl (2007-2021: FIG methods)
Index 5 = SEAMAP Age 0 (1989-2021: State standardization)
Index 6 = PSIGN gillnet (2001-2021: FIG methods)
Index 7 = CT LISTS trawl (1985-2021: FIG methods
Index 8 = Composite YOY seine (1985-2021: Conn hierarchical model)
Index 9 = ChesMMAP (2002-2018: FIG methods)
Index 10 = SEAMAP Age 1 (1985-2021: State standardization)

At this stage of the model bridge, fleet and index re-weighting was carried out. Iterative adjustments were made to the input CV of each index to account for additional process error. The model was re-run and CVs re-adjusted until the root mean square error of the index was around a value of 1.0. These adjustments were done minimally, and index estimated CVs were used as input CV where possible. Effective sample sizes were also adjusted using an iterative procedure, comparing input ESS with estimated ESS and adjusting as necessary.

The effect of the changes to the indices and model weighting procedures had a minor impact on SSB, increasing SSB from 82,018 MT in model BF07 to 88,424 MT in BF08. Recruitment and fishing mortality were both slightly lower in BF08 than BF07.

Model BF09: Shift from traditional age-length keys to multinomial age length keys

This was an important step in the model bridge. It incorporates a significant change to how the age information was structured for the assessment model. Previous age-length key holes were filled with borrowing rules, which could not always be applied consistently, leading to some subjective decisions by the analyst. The new, multinomial age-length keys are model based and provide consistency and repeatability going forward. Multinomial keys were constructed and applied at a season level, consistent with the level of stratification used previously in the traditional keys. Working Paper 14 (Celestino et al. 2022b) thoroughly covers the development of age data for this assessment, with full analyses, results, and conclusions made by the working group.

The switch to multinomial keys had a significant impact on estimates of SSB and recruitment. Compared to model BF08, SSB declined about 18,000 MT and recruitment declined by 9 million. The multinomial keys had the effect of spreading numbers-at-age in the older ages to younger ages, especially with the plus group (Figure 4.4). This had the result of lowering the SSB as the weight-at-age of these fish was reduced. The number of recruits are very similar for the two models, except in the terminal year. Model BF09 does reduce the retrospective pattern in recruitment from 12% to 4% which could account for the lower estimate.

A very important effect of incorporating the multinomial keys is seen in the convergence diagnostics for this model. All previous models that used the traditional keys did not have very good convergence diagnostics. A jitter analysis of starting parameter values showed that model BF08 did not converge 52 times, and only found the original model solution 129 times out of 200 jitter runs. Conversely, model BF09 is very robust to the original objective function solution and not overly sensitive to the initial starting values. Model BF09 did not converge 6 times, and found the original objective function 193 times, out of 200 jitter runs (Figure 4.5).

Model BF10: Stratify recreational discard lengths by season and region (north and south)

This data step uses recreational discard length information (B2s) that was stratified at a season and region level for the length expansion. There is a significant regional trend in bluefish size that has never been accounted for in the recreational discard lengths. Bluefish encountered in the southern states (NC-FL) tend to be much smaller than those in the northern states (ME-VA), which is reflected in the recreational discard length information (Working Paper 8 Wood 2022a). In previous assessments bluefish release lengths were only stratified by season, and since northern length samples dominate the length information the overall size of recreational releases was biased high. This lead to an inflated estimate of the recreational discard weight. For this assessment the RT2022 working group decided recreational release length information should account for regional differences in size.

This change to the data resulted in a 2,700 MT decrease in SSB, a small decrease in F, and very little change in recruitment.

Model BF11: Shift from MRIP Continuity index to the MRIP Guild index

This was another significant change for the data going into the model. Based on previous comments from assessment peer review panels the RT2022 working group re-evaluated the MRIP catch-per-angler index using a guild approach (Working Paper 13 Drew 2022d).

The MRIP index has historically been the most important index in the assessment model, and effectively scales the model because of the assumed logistic selectivity. Without this flat-top selectivity the model is able to create cryptic biomass in the older ages giving very unrealistic results. Due to the importance of this index small changes in trend have dramatic impacts on the scale of model results. The continuity MRIP index remained fairly flat throughout the time-series. Shifting to the guild approach for the index calculation resulted in a much different trend in the beginning of the index. The guild index starts at a much higher level and experiences a severe decline from 1985 to 1996. From 1997 to 2016 the guild index shows a very gradual increase, but sharply declines over the last 7 years (Figure 4.6).

The overall effect of this new index on the model was a decrease in SSB of 20,000 MT and an increase in F from 0.138 in BF10 to 0.172 in BF11. The switch to the MRIP guild index significantly reduced the retrospective bias in SSB from 40% in model BF10 to 25% in model BF11. The retrospective pattern in fishing mortality was also reduced from 36% in model BF10 to 21% in model BF11. Convergence diagnostics for model BF11 were very good with 191/200 jitter runs finding the original model solution, and 8 non-convergences.

Model BF12: Change M from constant 0.2 to M-at-age using Lorenzen based on empirical WAA

In past stock assessments, a value of 0.2 has been assumed as the instantaneous natural mortality (M) for bluefish over all ages and years. To investigate the validity of this estimate, longevity and life-history based equations were used to estimate different possible values for M (Working Paper 6 Tyrell and Truesdell 2022).

From these analyses, the working group chose an age-based estimate for natural mortality, derived from the Lorenzen approach using empirical weights-at-age. The new M-at-age (constant across years) going into the assessment model was: Age0: 0.850, Age1: 0.575, Age 2: 0.453, Age 3: 0.373, Age 4: 0.324, Age 5: 0.294, Age 6: 0.268.

The change in natural mortality increased SSB by about 18,000 MT, decreased F from 0.172 to 0.110, and greatly increased recruitment from 25.8 million to 97.3 million, when compared to the previous model with constant M = 0.2. Retrospective patterning increased for all model results with the change in natural mortality. Convergence diagnostics were very similar between model BF11 and BF12.

Model BF18 and BF19: Move from single selectivity block per fleet to 5 selectivity blocks

The previous assessment model specified a single selectivity block for each fleet for the entire time-series, assuming that fishery selectivity has not changed over time. The RT2022 working group felt this was a poor assumption, which could be leading to some of the retrospective patterns in results, and decided to change the fleet selectivity block configurations. For model BF18, a selectivity block was added in each fleet beginning in the year 2000, which is the year Amendment 1 to the bluefish fishery management plan was implemented. An additional selectivity block was added in the recreational fleet from 2011-2021. A regional analysis of recreational harvest and discards revealed that the southern component of the catch is increasing (Working Paper 10 Drew 2022b). The last selectivity block was added to account for any selectivity shifts that could occur with these regional shifts in the recreational fishery.

The addition of new selectivity blocks increased the SSB by 14,000 MT over the previous model. Retrospective patterning was reduced in all model estimates. A number of the fleet selectivity parameters were estimated at the bound indicating full selectivity. Model BF19 fixed these parameters at a value of 1.0 and re-estimated the model parameters. In addition, model BF19 shifted from estimating average F at age 1, to average F at ages 1-2. The resulting selectivity input values and estimates for model BF19 are presented in Table 4.2. Fixing bounded selectivity parameters at 1.0 slightly increased SSB and reduced retrospectively bias in SSB and recruitment.

A full suite of input, results, diagnostic, retrospective and MCMC plots are available for this run which can be downloaded or viewed from the following link: BF19 plots.

Model BF20: Use MRIP PSE for total harvest as input CV for fleet 2

The model was using a constant CV of 0.15 as input for fleet 2. This model step changes the input CV for fleet 2 to using the percent standard error for total harvest estimates from MRIP. The time-series of PSE values were scaled to have a mean value of 0.1, to match the input CV used for the commercial catch. This change adds a time-varying uncertainty around the fleet 2 catch (Figure 4.7).

This model change increased the SSB by 9000 MT, slightly increased recruitment, and had a small reduction in fishing mortality. Retrospective patterning in all model results was decreased in response to this change.

Model BF21: Use the MRIP index CV as input CV for the MRIP CPA index (was set at 2xCV)

For this model, the estimated CV for the MRIP catch-per-angler index was used directly as an input CV. Previous models used double the CV values as input. This change forced a tighter fit of the model to the

MRIP CPA index, and was made to explore the effects on retrospective patterns in the model results. The retrospective pattern in SSB decreased from 26% in model BF20, to 19% as a result of this change. Retrospective pattern in F increased slightly, and model BF21 has no retrospective pattern in recruitment.

Model results for this run reduce SBB by around 7,000 MT and recruitment by 15 million fish from model BF20.

Model BF22: Remove CT LIST survey index

Model fit diagnostics to CT LIST trawl survey index indicated a somewhat poor fit early on in the time-series, with a 2 blocks of residuals from 1985-2000 (Figure 4.8). This survey also caused issues with the estimation of retrospective peels, with some peels giving gradient estimates >0.001, indicating poor or no convergence. The RT2022 working group decided to investigate whether removal of this index would improve the retrospective pattern for the model results.

The removal of the CT survey resulted in slight increases in both SSB and recruitment, and little change in fishing mortality. There was small improvement in the retrospective pattern in SSB, and a small increase for the pattern in fishing mortality. Model BF22 did not have the retrospective peel convergence issues that occurred in previous models that included the CT survey.

Model BF23: Re-adjust MRIP CPA input CV to give model more flexibility around this index

The RMSE for the MRIP index from Model BF22 was 1.65. This model step increased the CV by a factor of 1.6, to move the RMSE closer to a value of 1. The increase in CV returned a RMSE estimate for the MRIP index of 1.16.

The results of giving Model BF23 more flexibility to fit the MRIP index led to an increase in both SSB and recruitment, to 94,886 MT and 102 million, respectively. Model BF23 was expected to be the final ASAP model, however, an examination of the age composition diagnostics for both revealed residual blocking in ages 1 and 2 (Figure 4.9).

Model BF24: Re-estimate fleet selectivity blocks – Final ASAP Model

To address poor age composition residual blocking in model BF23, fleet selectivity was re-estimated assuming full selectivity on age 2, instead of age 1 for all selectivity blocks. Selectivity parameters estimated at the bound of 1.0 were fixed and the model was re-run. The age-composition residual diagnostics for model BF24 were much better (Figure 4.10).

This change caused a dramatic decrease in the scale of SSB over the time-series, leading to a 30,000 MT decrease in the terminal year. Recruitment and fishing mortality slightly decreased and increased, respectively, compared to model BF23. Final selectivity block comparisons between model BF23 and BF24 are presented in Figure 4.11.

The working group chose model BF24 as the final bluefish model configuration, prior to migration into the state-space framework of the Woods Hole Assessment Model.

A full suite of input, results, diagnostic, retrospective and MCMC plots are available for this run which can be downloaded or viewed from the following link: BF24 plots. A brief summary of main model results is presented below.

The final ASAP model fleet selectivity at-age estimates for the two catch fleets show a decrease in selectivity at middle ages (ages 3-4), with selectivity increasing at older ages. The final selectivity block in the recreational fleet (2011+) has more of a domed shape, with older fish having much lower selectivity than previous blocks (Figure 4.11). Final model estimates for the index selectivities show a rapid decrease in selectivity after age 0. A few of the indices have higher selectivity towards larger/older fish, the most important being MRIP and PSIGNS, and to a lesser extent the Bigelow survey (Figure 4.12).

Abundance results from model BF24 showed a maximum of 424 million fish in 1985, declining to 166 million in 1995, and then increasing to a peak of 311 million in 2006. Total abundance declined from the peak in 2006 to a low of 147 million in 2016, a small peak to 208 million in 2018, and a terminal year estimate of 169 million fish. Spawning stock biomass started from a high of 208,791 MT in 1985 and declined over the time-series to a low of 44,931 MT in 2018, and increased since to a value of 63,320 MT in 2021. The majority of the spawning stock biomass is ages 5 and 6+ (30-60%) for the entire time-series. Fishing mortality in 2021 was 0.127, compared to an average F from 1985 to 2021 of 0.294. Estimates of F have varied over the time-series from a peak in 1987 of 0.488 to the lowest value of 0.127 in 2021. Estimates of recruitment have remained steady over the time series, fluctuating around an average value of 127 million fish. Recruitment has remained below average for the past 12 years, and was estimated at 95 million fish in 2021.

Retrospective patterns for the final model was examined for F, spawning stock biomass, and recruitment. There is significant retrospective patterning in both SSB (Mohn's rho = 0.326) and fishing mortality (Mohn's rho = -0.277), with very little in recruitment (Mohn's rho = 0.017). Shifting this assessment model into the state-space framework of WHAM and estimating random effects helped to improve the retrospective diagnostics of this model.

The variation in the final ASAP model results for F and SSB was determined using a Monte Carlo Markov chain with 1000 iterations and a thinning factor of 2000 (2,000,000 iterations). Trace plots for both SSB and F show little to no patterning. There is no significant autocorrelation in the SSB or F chains. Terminal year 90% CI from the MCMC ranged from 49,856 to 71,780 MT, with a median estimate of 60,338 MT. The 2021 SSB point estimate from the final model (63,320 MT) is slightly higher than the median estimate from the MCMC distribution. The 90% CI around F ranged from 0.091 and 0.185. The point estimate from the final model (0.127) is nearly identical to the median estimate (0.128) from the MCMC distribution.

Model BF24 had good convergence diagnostics with 192/200 jitter runs finding the original model solution, and 4 non-convergences (Figure 4.13).

Tables

Table 4.1. Model table showing linear steps in the ASAP model bridge building process. Last 3 model bridge steps were very minor changes and were carried out in WHAM.

Model	Description	SSB (MT)	Rec (mil)	F	SSBrho	Rrho	Frho	# at OG OBFunc	Jitter Sol	Not conv
BF00	BLF 2021 MT model	95,742	27.9	0.172	0.226	0.192	-0.221	~	~	~
BF01	BLF RT Continuity Run	91,745	39.4	0.160	0.294	0.170	-0.277	132	51	18
BF03	Update all new data	85,975	39.2	0.172	0.364	0.174	-0.323	142	38	21
BF04	New LW parameters	86,581	39.1	0.172	0.359	0.174	-0.320	~	~	~
BF05	New Rec discard mortality	82,103	35.9	0.159	0.380	0.186	-0.334	~	~	~
BF07	Add commercial discards	82,018	36.2	0.160	0.378	0.185	-0.332	140	28	31
BF08	New Indicies: MRIP Continuity	88,424	35.3	0.158	0.319	0.123	-0.313	129	17	52
BF09	New Indices: MRIP Continuity, MNS Keys	70,336	26.3	0.158	0.352	0.042	-0.321	193	2	6
BF10	New Indices: MRIP Continuity, MNS Keys, Rec discard length by season/region	67,029	26.7	0.138	0.405	0.051	-0.361	197	2	2
BF11	New Indices: MRIP Guild, MNS Keys, Rec discard length by season/region	47,734	25.8	0.172	0.253	0.033	-0.214	191	2	8
BF12	New M: Lorenzen based on empirical WAA	65,946	97.3	0.110	0.346	0.113	-0.266	188	3	9
BF18	5 Sel blocks	79,849	97.9	0.116	0.293	0.035	-0.220	183	2	9
BF19	Fix bounded selectivities F2to3	82,858	98.6	0.113	0.288	0.014	-0.221	194	2	5
BF20	MRIP PSE for fleet 2	91,149	101.7	0.107	0.257	0.023	-0.205	194	4	2
BF21	MRIP index input CV (from 0.3)	84,212	85.3	0.116	0.193	0.000	-0.223	191	3	6
BF22	No CT	88,051	93.1	0.111	0.187	-0.001	-0.229	193	2	6
BF23	Adjust MRIP CV to reduce RMSE (x1.6)	94,886	102.0	0.102	0.225	-0.014	-0.209	199	1	1
BF24	Adjust fixed selectivity at age 2 for some blocks	63,320	94.6	0.127	0.326	0.017	-0.277	192	4	4
WHAM Bridge Models										
BF26W	Reduce fleet 1 CV	63,606	95.7	0.128	0.270	-0.066	-0.215	~	~	~
BF27W	Reduce Fleet 2 CV	68,546	96.4	0.122	0.249	-0.062	-0.198	~	~	~

BF28 W	Reduce both fleets CV	68,63 1	96.4	0.12 2	0.248	-0.063	-0.197	~	~	~

Table 4.2. Input and estimated selectivities for each fleet selectivity block in model BF19. Grey cells indicate a fixed input selectivity value.

Age	Selectvity Block: Input selectivities				
	Com Block 1	Com Block 2	Rec Block 1	Rec Block 2	Rec Block 3
Age 0	0.338	0.338	0.338	0.338	0.338
Age 1	1	1	1	1	1
Age 2	0.942	1	1	1	1
Age 3	0.476	1	0.476	1	0.476
Age 4	0.343	1	0.343	1	0.343
Age 5	0.694	1	0.694	1	0.694
Age 6+	0.914	1	1	1	0.914
	Estimated selectivity model BF19				
Age	Com Block 1	Com Block 2	Rec Block 1	Rec Block 2	Rec Block 3
Age 0	0.063	0.018	0.352	0.338	0.325
Age 1	1	1	1	1	1
Age 2	0.916	1	1	1	1
Age 3	0.400	1	0.838	1	1
Age 4	0.375	1	0.927	1	0.673
Age 5	0.518	1	0.963	1	0.591
Age 6+	0.625	1	1	1	0.545

Table 4.3. Model table for different state-space model variations of BF28W examining different options for treating the yearly transitions (survival) in recruitment and number-at-age.

Model	Description	dAIC	AIC	SSB (MT)	Rec (mil)	F	rho_R	rho_SSB	rho_Fbar	Conv	PD Hess
BF28W	Base model: traditional statistical catch-at-age	~	~	68,631	96.4	0.12	-0.063	0.248	-0.197	TRUE	TRUE
m7	All NAA transitions are random effects correlated by year and age	0	3229	55,344	86.5	0.14	0.010	0.130	-0.096	TRUE	TRUE
m5	All NAA transitions are random effects correlated by year	3	3232	55,070	82.3	0.14	0.019	0.126	-0.097	TRUE	TRUE
m4	All NAA transitions are random effects independent, identically distributed	46.2	3275	58,114	98.6	0.13	-0.008	0.172	-0.144	TRUE	TRUE
m6	All NAA transitions are random effects correlated by age	46.9	3276	58,786	99.9	0.13	-0.004	0.177	-0.148	TRUE	TRUE
m2	Recruitment transitions are random effects independent, identically distributed	111	3340	73,843	104.1	0.12	-0.022	0.236	-0.195	TRUE	TRUE
m3	Recruitment transitions are random effects correlated by year	111	3340	72,329	101.3	0.12	-0.020	0.245	-0.198	TRUE	TRUE

Table 4.4. Results, retrospective, and convergence properties of the final model sensitivity runs

Model	R (mil)	SSB (MT)	F	rho_R	rho_SSB	rho_Fbar	Conv	PDHess
BF28W_m7	**86.5**	**55,344**	**0.141**	**0.010**	**0.130**	**-0.096**	**TRUE**	**TRUE**
rmALB	83.1	53,880	0.146	0.0075	0.127	-0.0924	TRUE	TRUE
rmBIG	86.6	56,327	0.139	0.0281	0.1222	-0.0885	TRUE	TRUE
rmMRIP	101.4	64,964	0.117	-0.0233	0.176	-0.0993	TRUE	TRUE
rmNEA	81.3	57,488	0.137	0.0071	0.1326	-0.0995	TRUE	TRUE
rmSEA0	90.3	55,826	0.140	0.0045	0.1266	-0.0932	TRUE	TRUE
rmPSIGN	75.1	38,725	0.191	0.0635	0.25	-0.1689	TRUE	TRUE
rmYOY	77.4	53,209	0.149	0.0278	0.1473	-0.1118	TRUE	TRUE
rmCHES	86.0	54,749	0.143	0.0048	0.1256	-0.0908	TRUE	TRUE
rmSEA1	86.9	55,633	0.140	0.0116	0.1316	-0.0983	TRUE	TRUE
NEFSC offshore	97.6	59,020	0.131	0.046	0.128	-0.094	TRUE	TRUE
GLM indices	90.5	57,758	0.135	0.0535	0.1513	-0.1155	TRUE	TRUE
MRIP direct	101.4	71,334	0.112	0.004	0.130	-0.096	TRUE	TRUE
MRIP SAA	86.8	60,378	0.139	0.007	0.121	-0.093	TRUE	**FALSE**
Borrow Region	83.4	95,775	0.123	0.090	0.204	-0.132	TRUE	**FALSE**
Borrow AB1	83.6	55,473	0.146	0.0066	0.141	-0.1023	TRUE	TRUE
Use AB1 for B2	80.9	53,674	0.156	0.0071	0.1326	-0.0921	TRUE	TRUE
B2 15% DM	93.9	58,842	0.147	0.0103	0.1244	-0.0935	TRUE	TRUE
M Lorenzen Low	31.4	42,296	0.203	0.0007	0.1316	-0.1003	TRUE	**FALSE**
M Lorenzen High	480.3	205,189	0.037	0.2398	0.4017	-0.2348	TRUE	TRUE

Figures

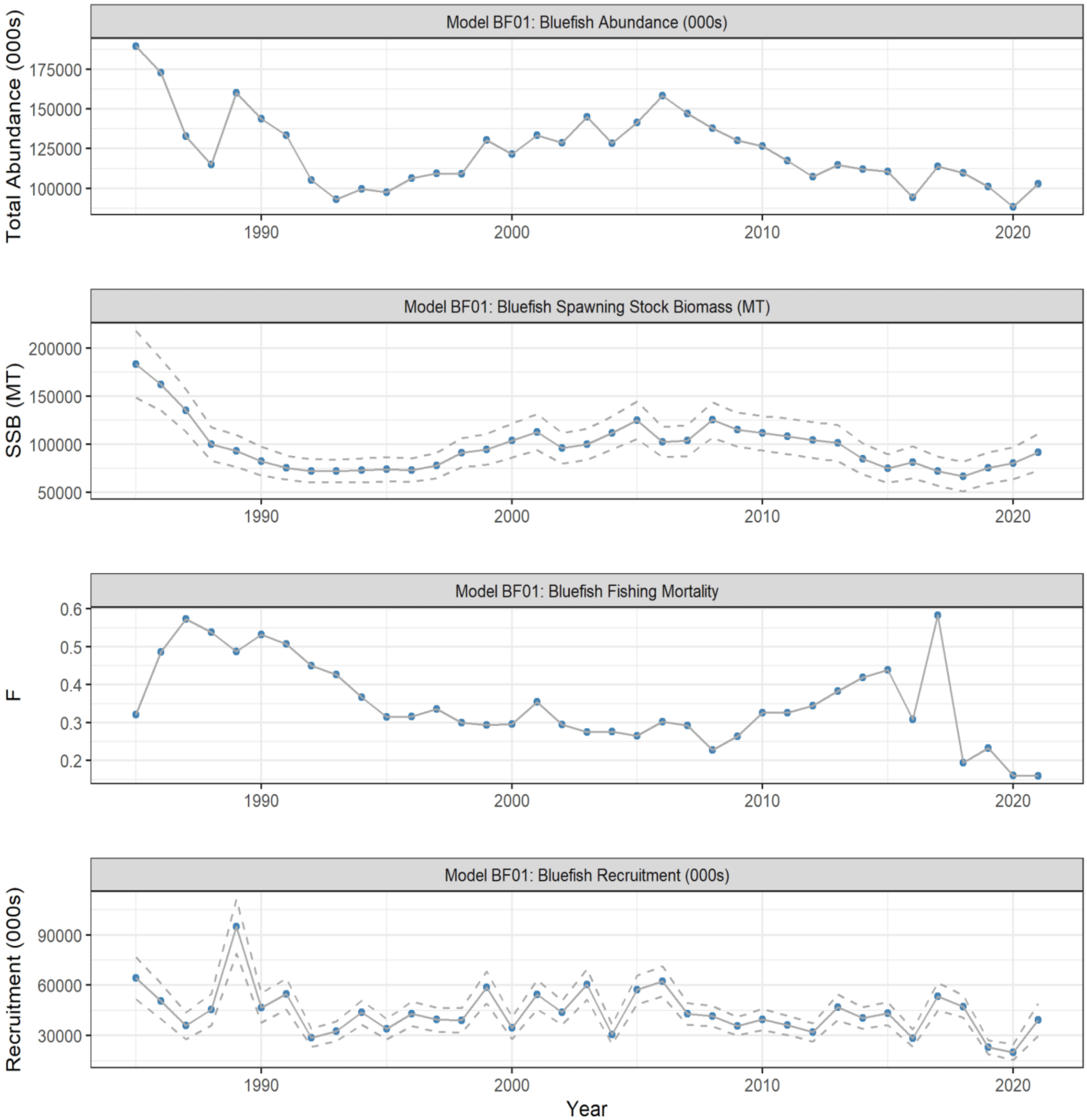


Figure 4.1. Model results of abundance, SSB, fishing mortality, and recruitment for the continuity run, Model BF01.

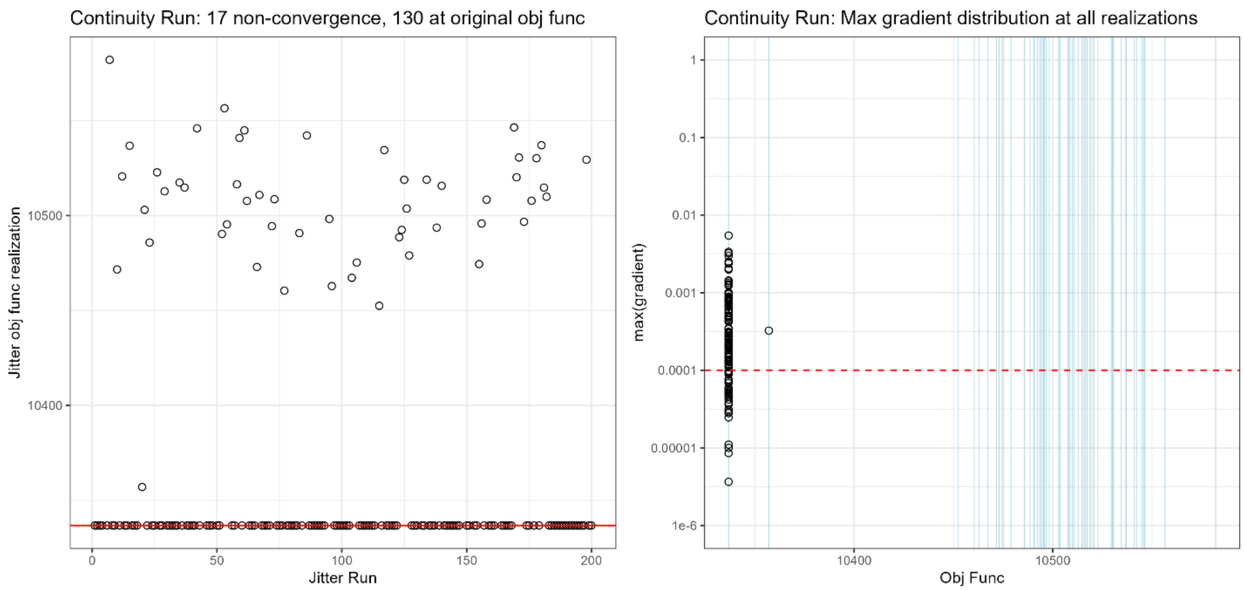


Figure 4.2. Convergence diagnostics for model BF01: the continuity run model.

Figure 4.3. State provided NEAMAP and CT LISTS (Continuity) indices vs RT2022 WG calculated indices scaled to their mean values.

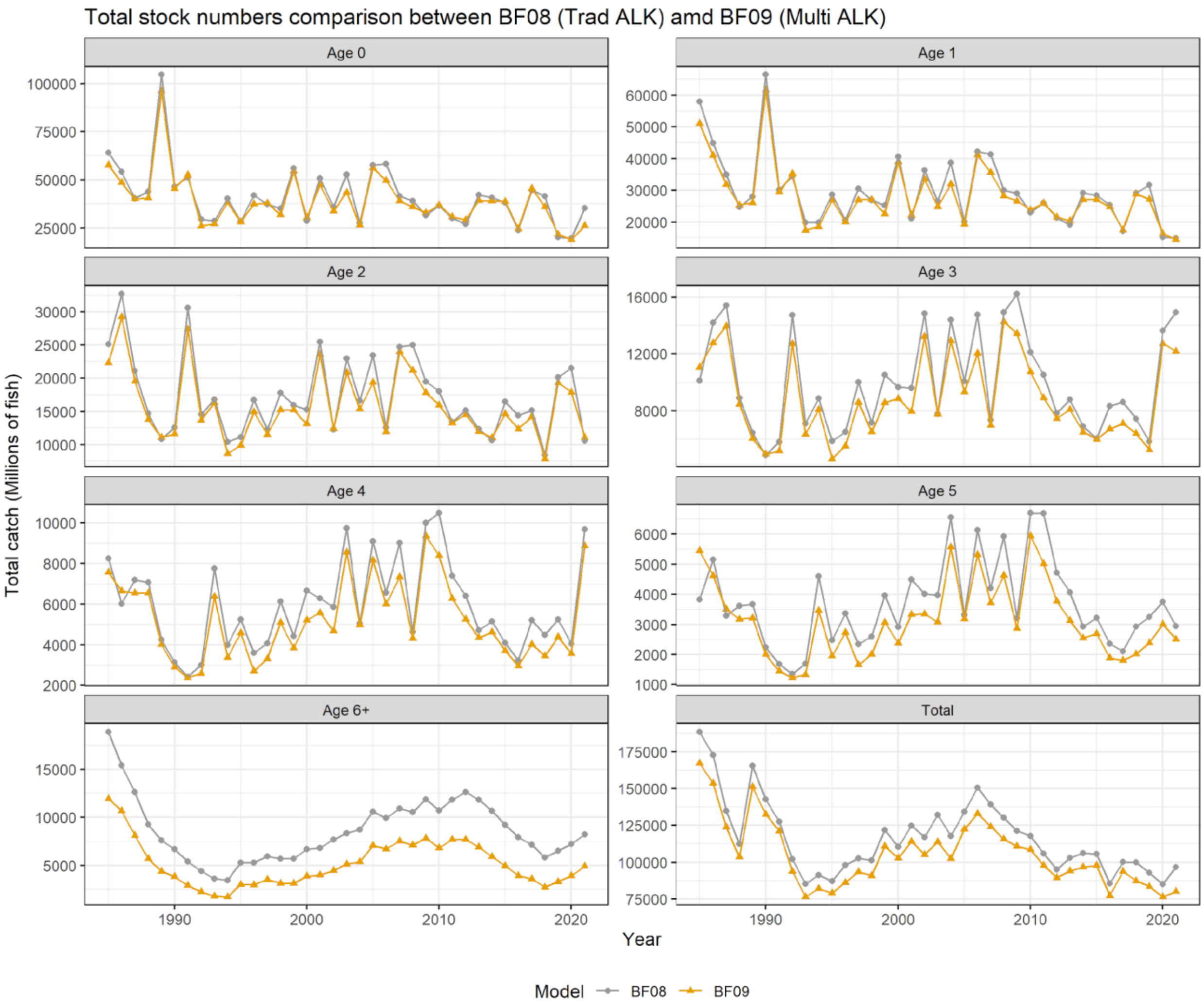


Figure 4.4. Comparison of total stock numbers and numbers at age from model BF08 (Traditional ALK) and model BF09 (Multinomial ALK).

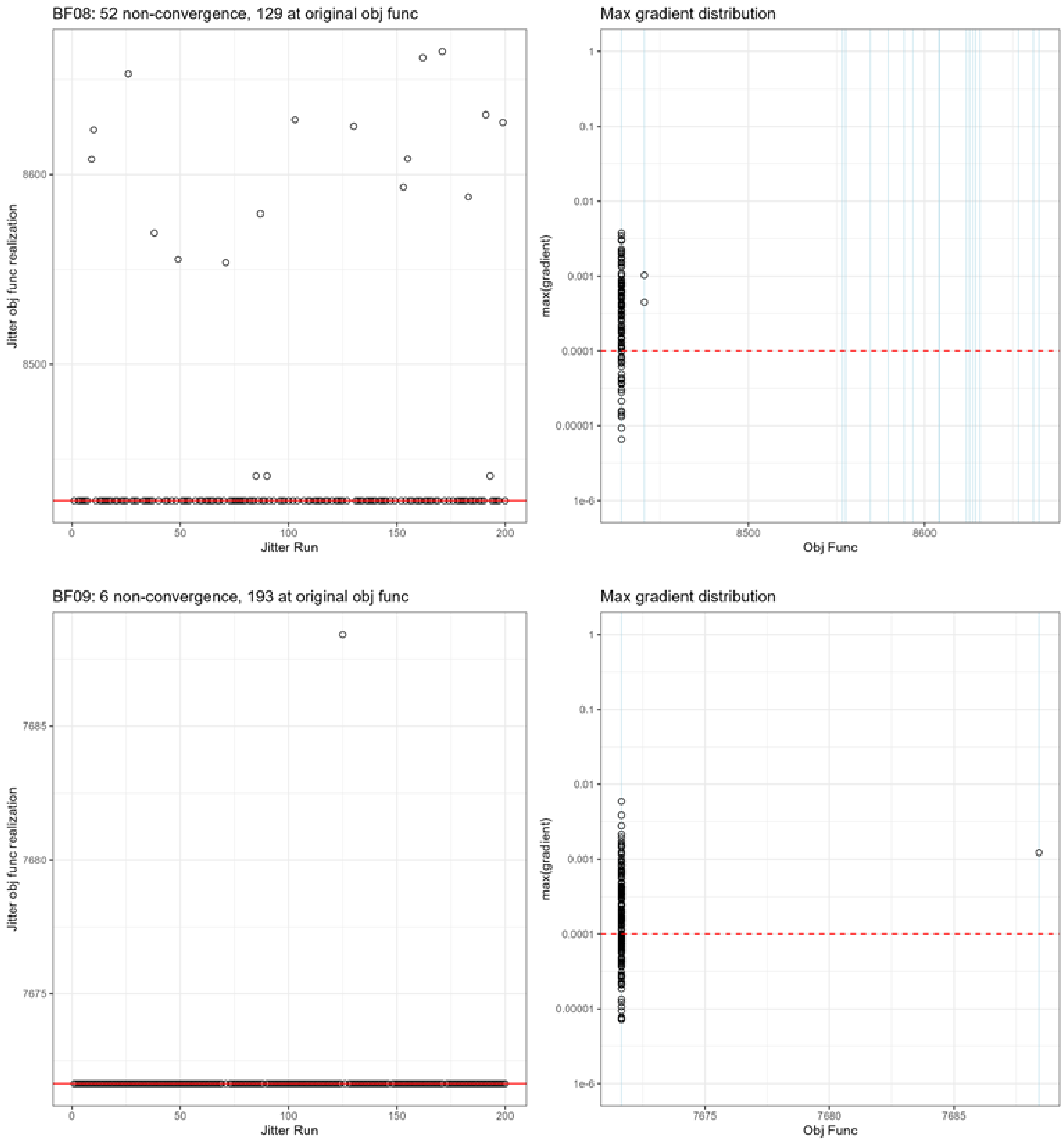
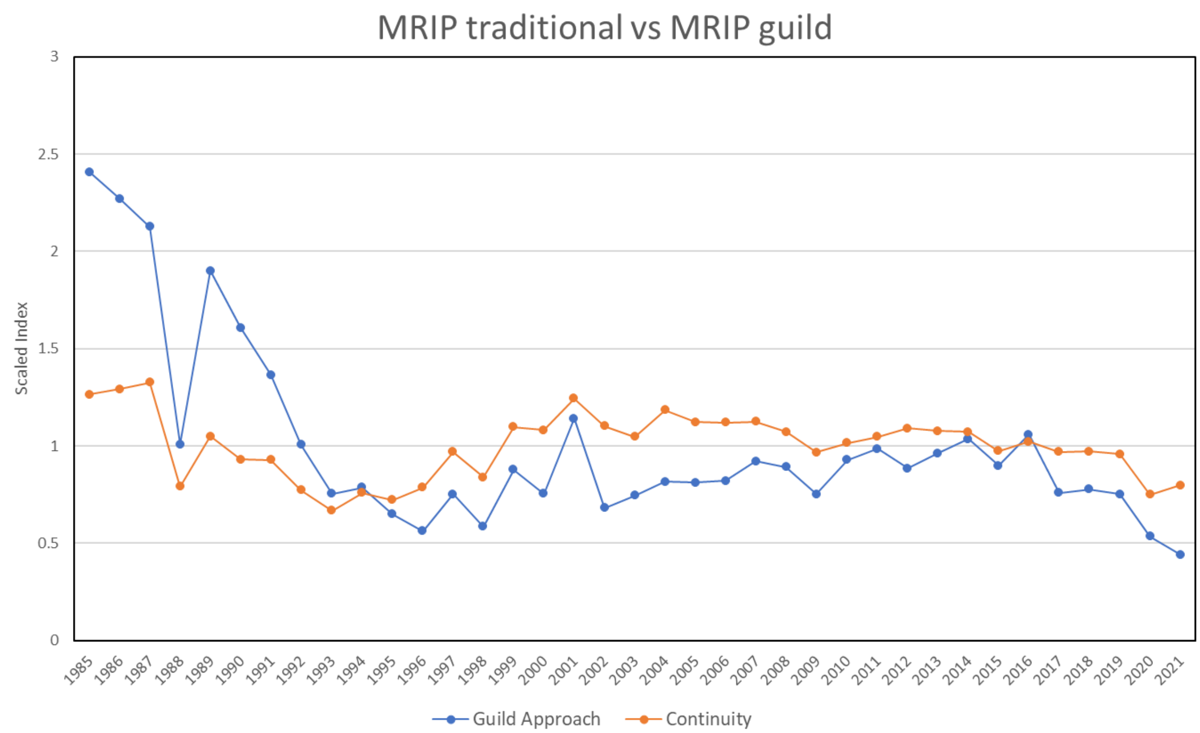


Figure 4.5. Convergence diagnostics comparison between model BF08 (Traditional ALK) and model BF09 (Multinomial ALK).



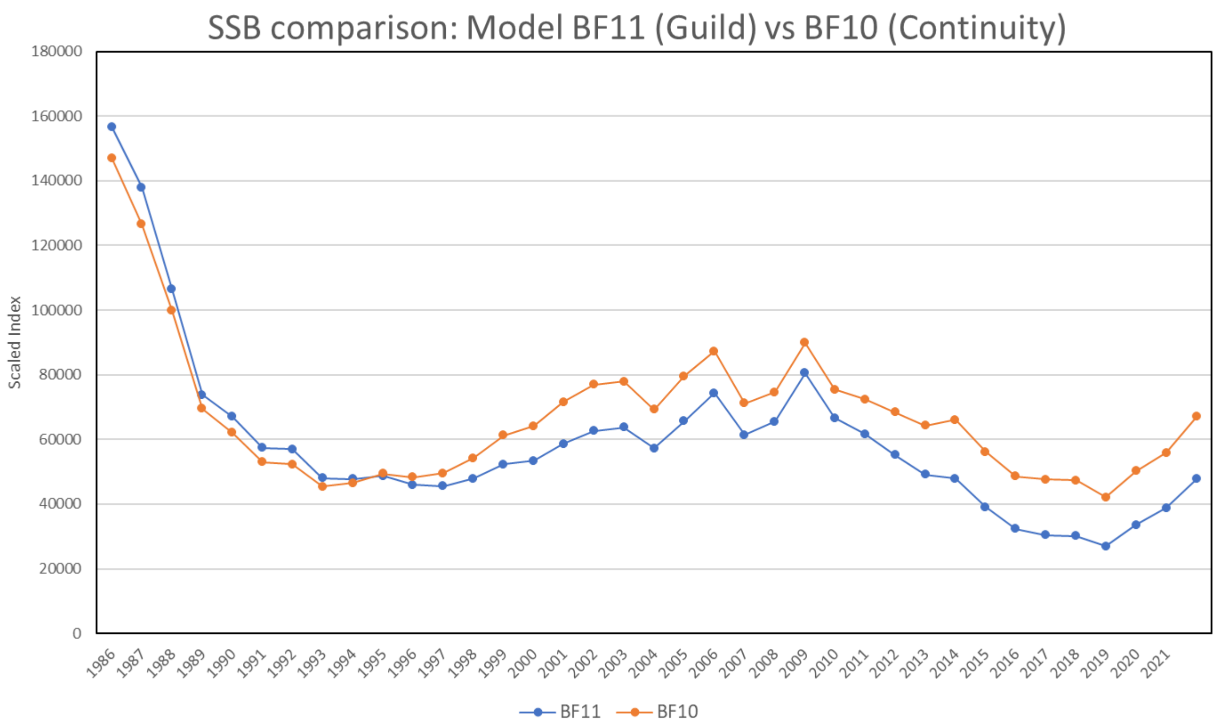


Figure 4.6. MRIP continuity index compared to the new MRIP index developed using the guild approach and resulting model results for SSB for model BF10 and BF11.

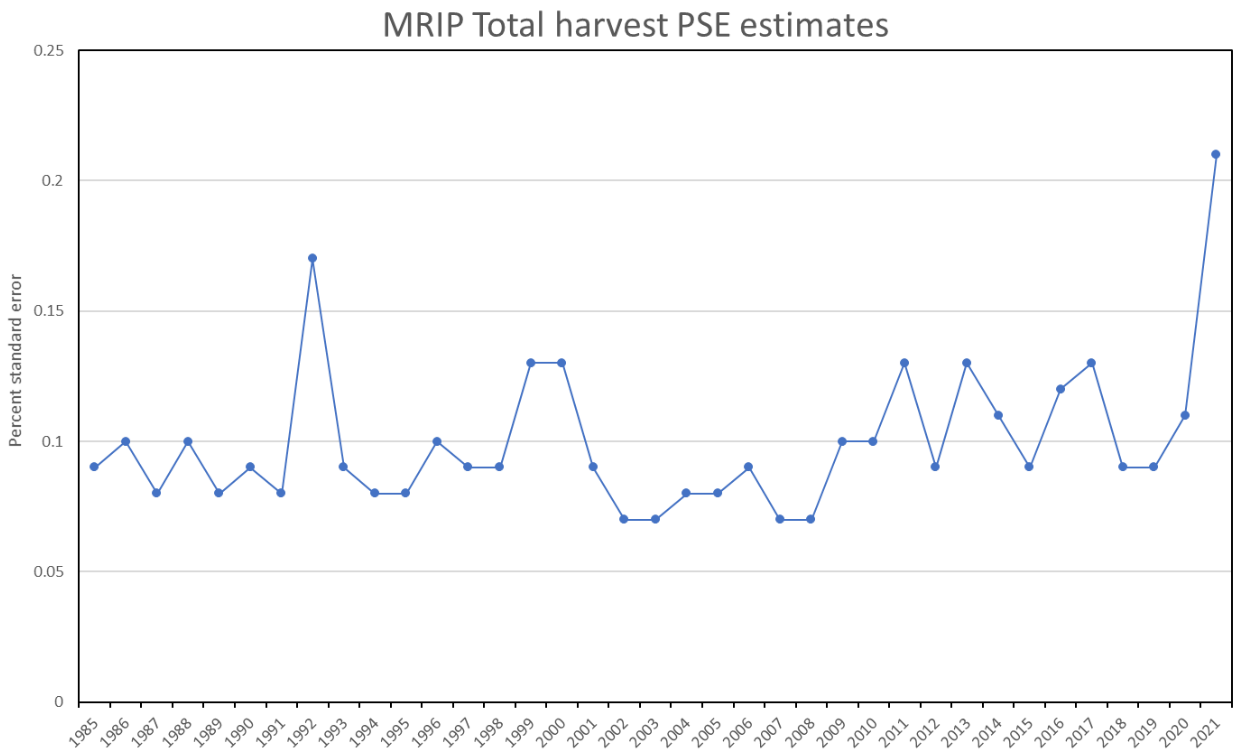


Figure 4.7. MRIP total harvest PSE used as an input CV for fleet 2 catch. These values were scaled to an average of 0.1 to match the input CV of the commercial catch.

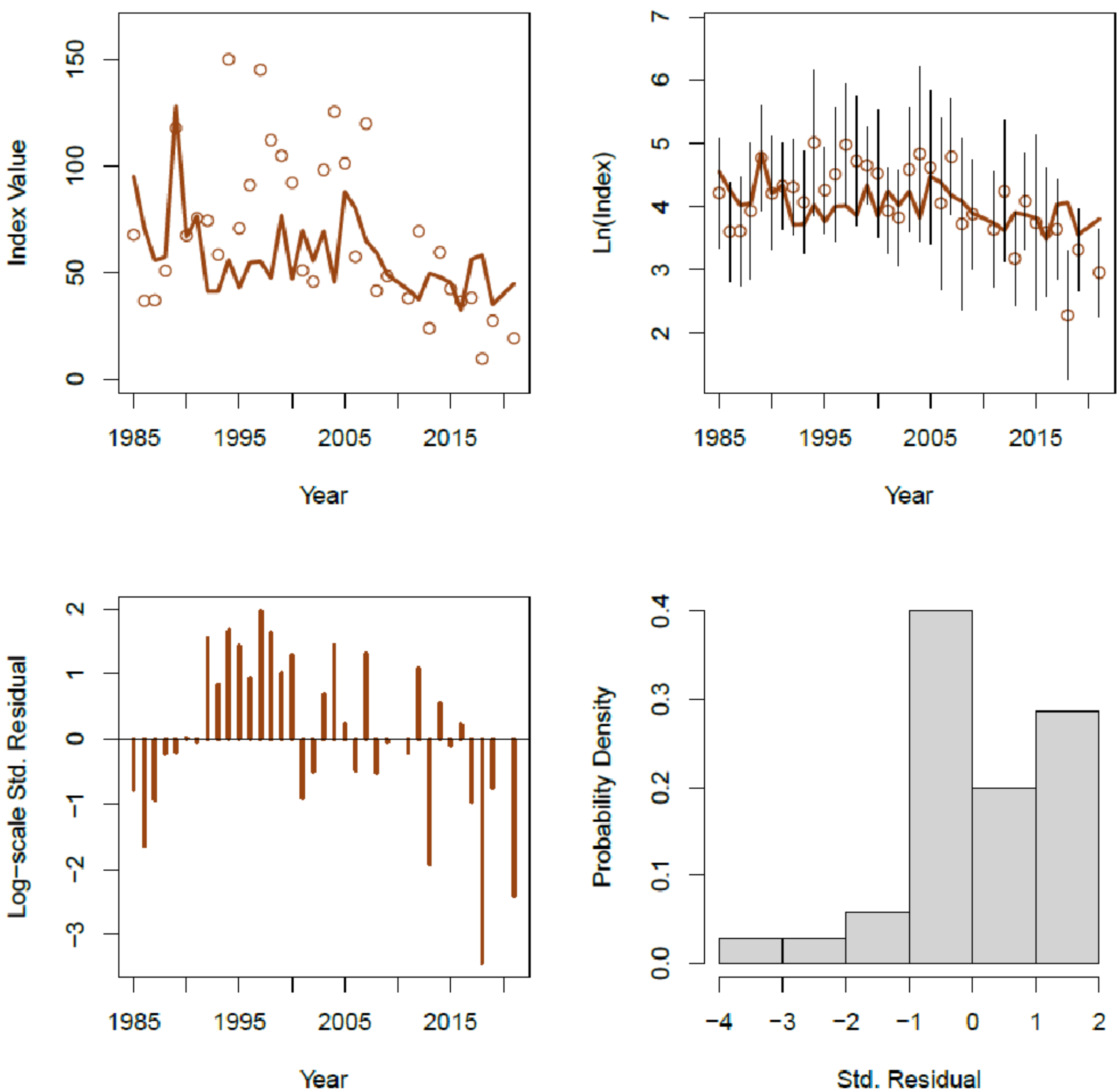


Figure 4.8. Model diagnostics for the CT LISTS survey from model BF21. This survey was removed in model BF22 due to poor diagnostics and causing retrospective convergence issues.

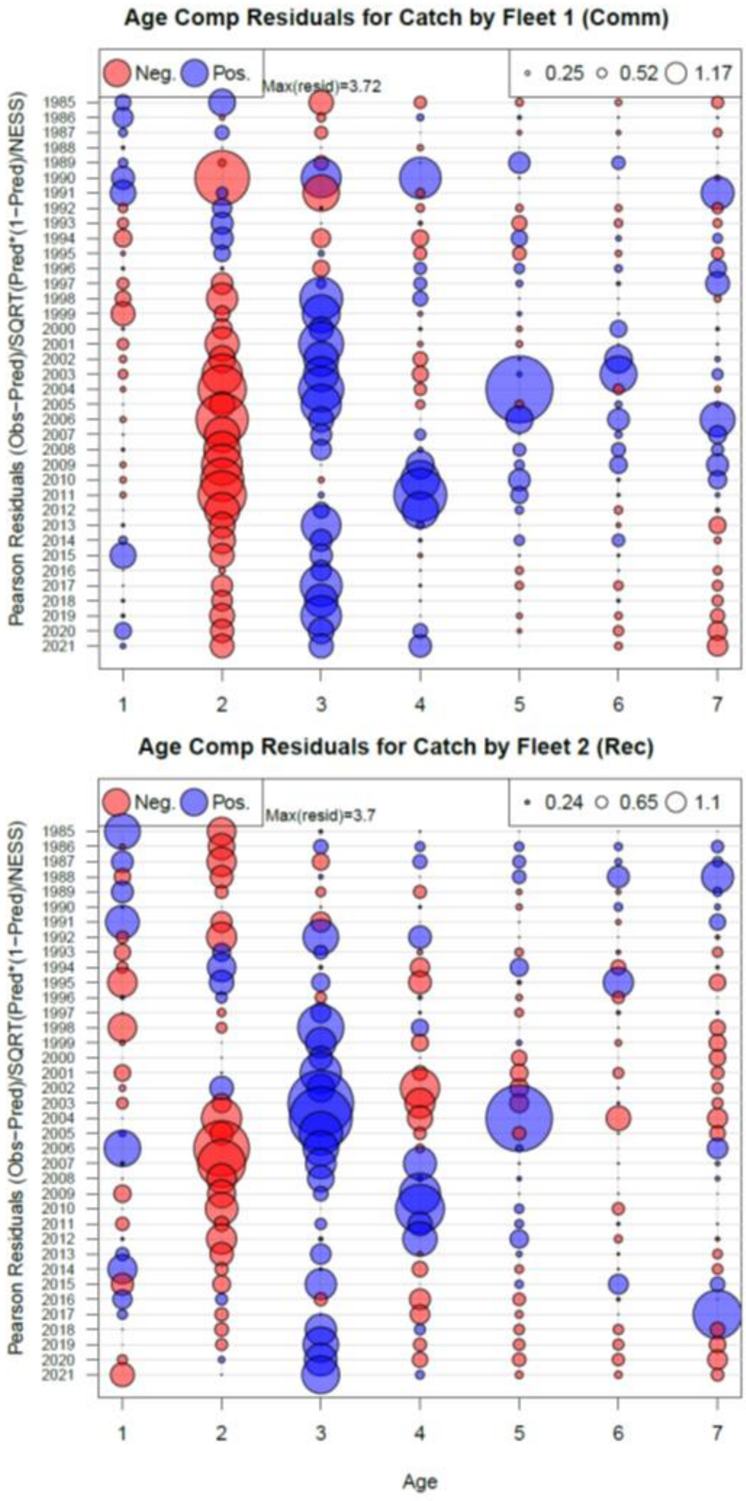


Figure 4.9. Fleet age composition residuals for model BF23 showing blocks in ages 1 and 2 (ASAP ages 2 and 3) for both fleets.

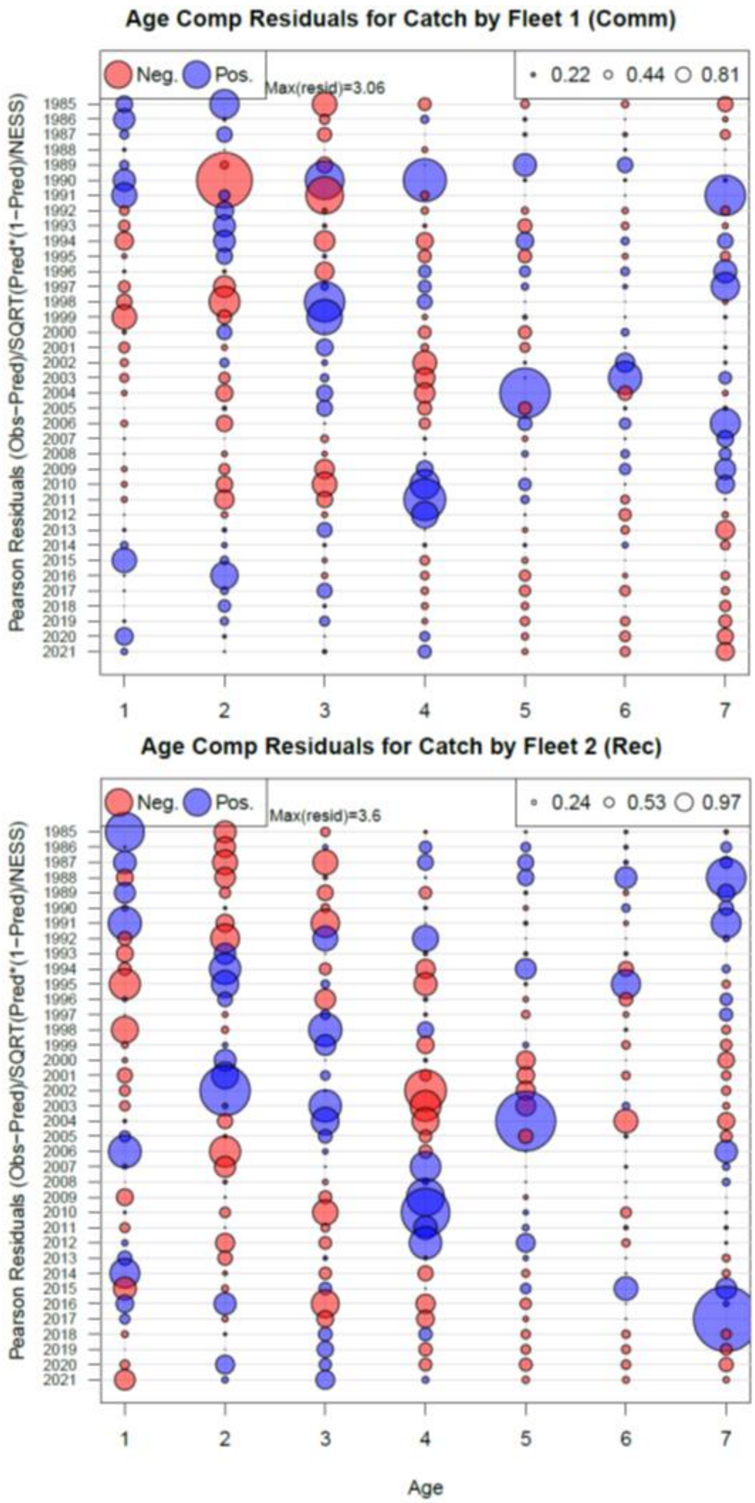


Figure 4.10. Fleet age composition residual for model BF24, after correcting miss-specified full selectivity at ages 1 and 2 (ASAP ages 2 and 3).

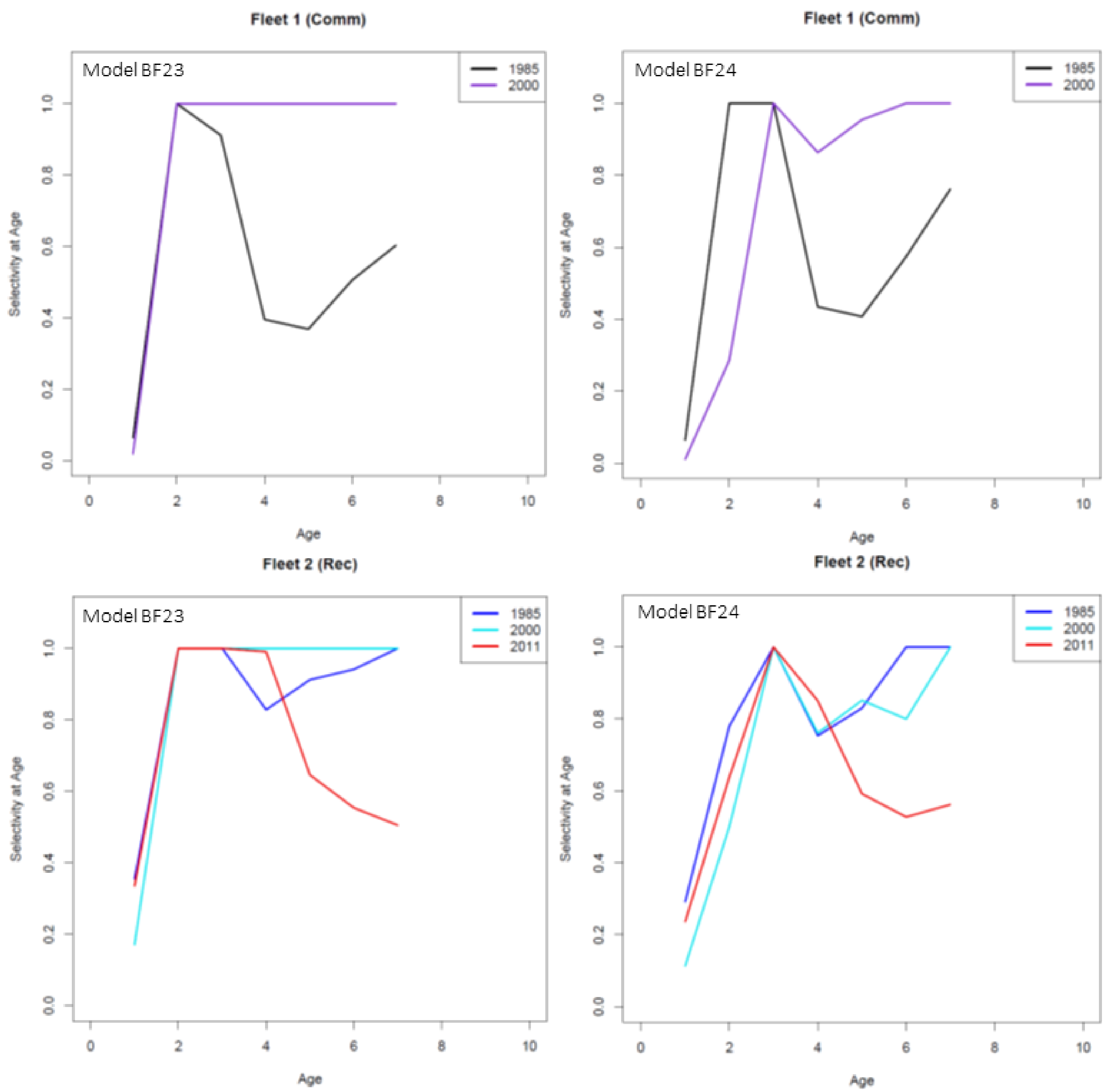


Figure 4.11. Fleet selectivity block comparison between model BF23 (left) and final model BF24 (right) after addressing poor age composition residual blocks in BF23.

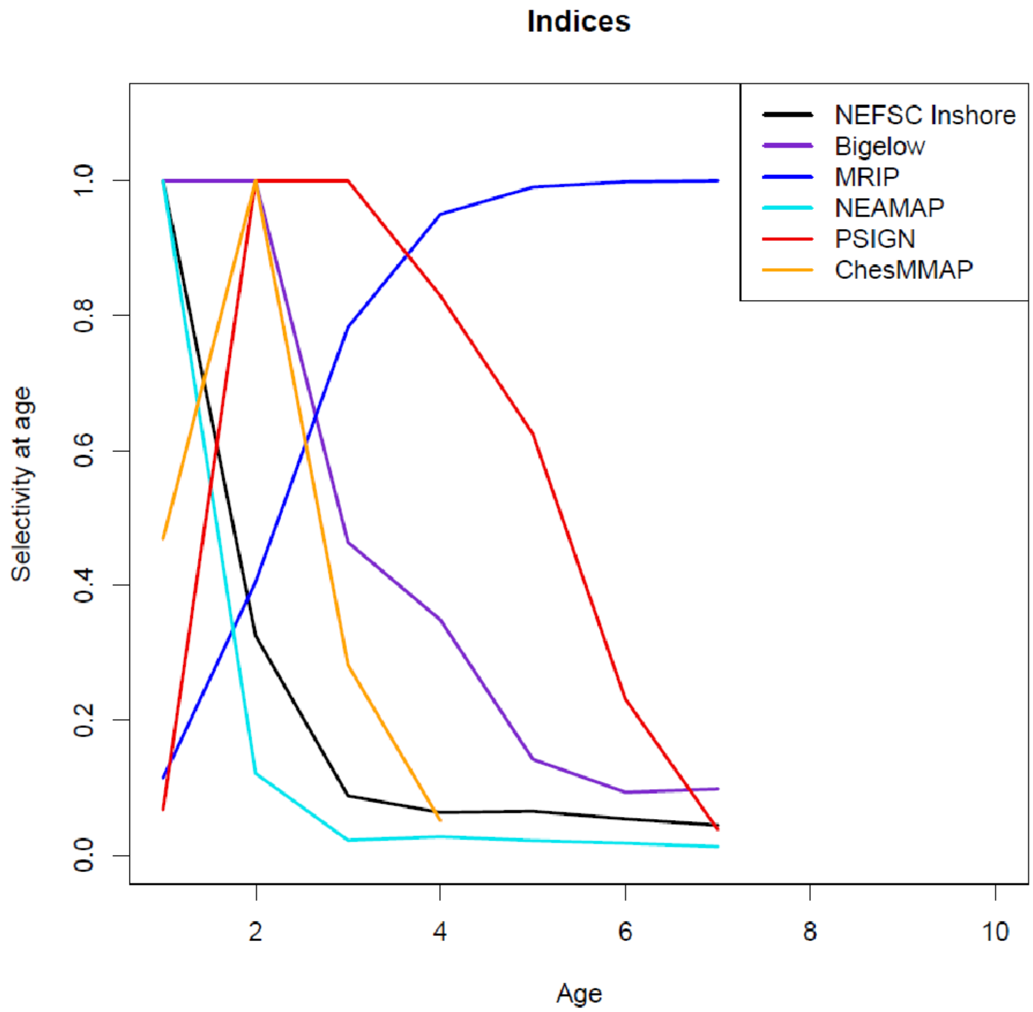


Figure 4.12. Index selectivity at age for model BF24.

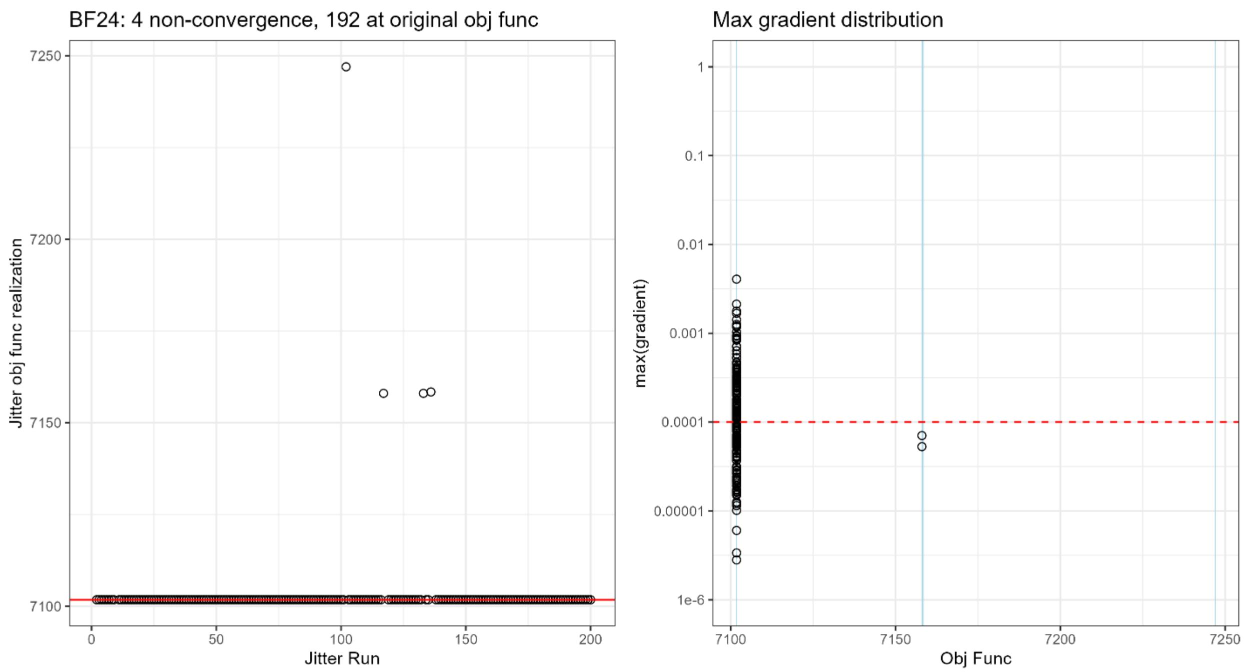


Figure 4.13. Convergence diagnostics for model BF24. The left plot shows objective function results for 200 random sets of starting values, with the original objective function designated by the horizontal red line. The right plot shows gradient values from each model distributed around a 0.0001 criterion for 'good' convergence (blue vertical lines represent other objective function solutions, some where the gradient result is above or below the y-axis range of the plot).