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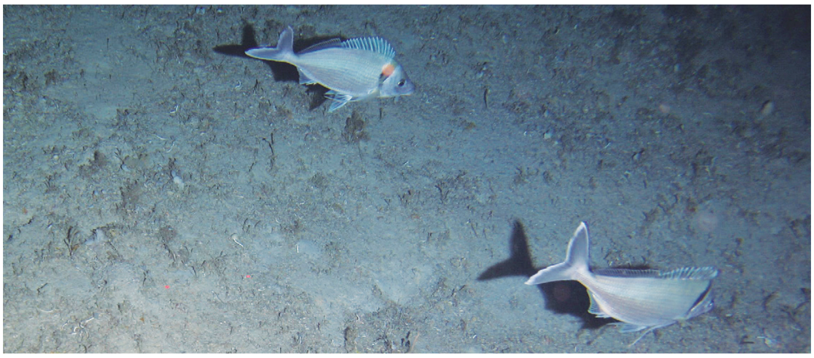
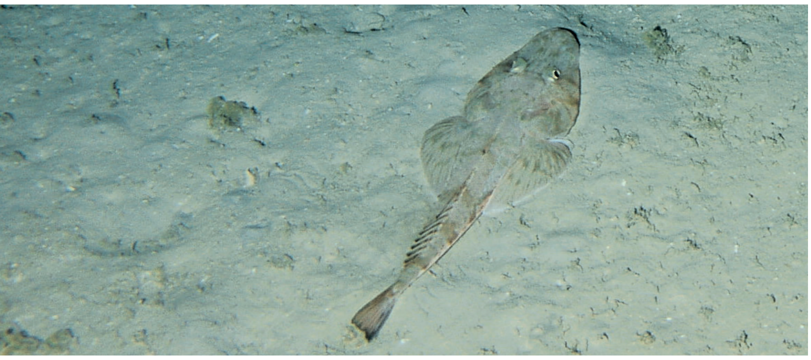
2017/0824 June 2020

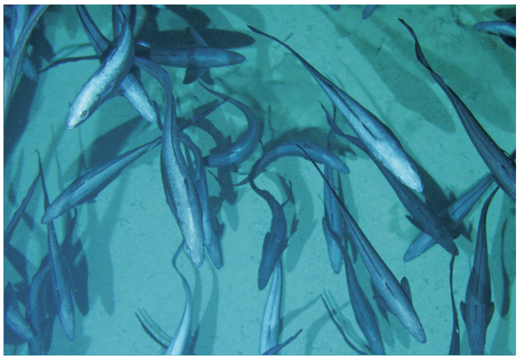
Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2018 and 2019



PART 1

2019





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Cover photographs

Front cover, jackass morwong, orange roughy, blue grenadier, and flathead.

Report structure

Part 1 of this report describes the Tier 1 assessments of 2019. Part 2 describes the Tier 3 and Tier 4 assessments, catch rate standardisations and other work contributing to the assessment and management of SESSF stocks in 2019.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2018 and 2019

Part 1: 2019

G.N. Tuck
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Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2019

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9. Bight Redfish (*Centroberyx gerrardi*) stock assessment based on data to 2018-19: development of a preliminary base case

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9.1 Executive Summary

This document presents a suggested base case for an updated quantitative Tier 1 Bight Redfish (*Centroberyx gerradi*) assessment for presentation at the first GAB RAG meeting in 2019. The last full assessment was presented in Haddon (2015). The preliminary base case has been updated by the inclusion of data up to the end of financial year 2018-19, which entails an additional four years of catch, CPUE, length and/or age data and ageing error updates since the 2015 assessment and incorporation of survey results from the 2017-18 GAB Fishery Independent Survey (FIS). This document describes the process used to develop a preliminary base case for Bight Redfish through the sequential updating of recent data used by the stock assessment, using the stock assessment package Stock Synthesis (SS-V3.30.14).

Changes to the last stock assessment include: incorporation of conditional age-at-length data for 2005 from the GAB FIS; improvement to the method of estimating the bias ramp and using an updated tuning method.

Results show poor fits to the CPUE and FIS abundance series, but reasonable fits to length and conditional age-at-length data. This assessment estimates that the projected 2020-21 spawning stock biomass will be 70% of virgin stock biomass (projected assuming 2018-19 catches in 2019-2020), compared to 62% at the start of 2016-17 from the 2015 assessment (Haddon 2015) and 90% at the start of 2012-13 from the 2011 assessment (Klaer 2011). This change in stock status is mostly due to revisions to the estimates of recent large recruitment events towards the end of the time series, particularly in 1995, 1996 and 1999.

9.2 Introduction

9.2.1 *Bridging from 2014-15 to 2018-19 assessment*

The previous full quantitative assessment for Bight Redfish was conducted in 2015 (Haddon, 2015) using Stock Synthesis (version SS-V3.24U; Methot and Wetzel 2013, Methot 2015). The 2019 assessment uses the current version of Stock Synthesis (version SS-V3.30.14.05; Methot 2019), which includes some changes from SS-V3.24U.

As a first step in the process of bridging to a new model, the model was translated from version SS-V3.24U (Methot 2015) to version SS-V3.30.14.05 (Methot et. al. 2019) using the same data and model structure used in the 2015 assessment. Once this translation was complete, improved features unavailable in SS-V3.24U were incorporated into the SS-V3.30 assessment. These included allowing smaller lower bounds on minimum sample sizes and estimating a parameter that tunes the standard deviation to abundance indices. Following this step, the model was re-tuned using the most recent tuning protocols, thus allowing the examination of changes to both assessment practices and the tuning procedure on the previous model structure. These changes to software and tuning practices are likely to lead to changes to key model outputs, such as the estimates of depletion and the trajectory of spawning biomass. This initial bridging phase (Bridge 1) highlights changes that have occurred since 2015 simply through changes to software and assessment practices. The subsequent bridging exercise (Bridge 2) then sequentially updates the model with new data through to 2018.

The second part of the bridging analysis includes updating historical data (up to 2014-15), followed by including the data from financial years 2015-16 to 2018-19 into the model. These additional data included new catch, CPUE, FIS abundance indices, length composition data, conditional age-at-length data and an updated ageing error matrix. Additional FIS data were also included: 2017 GAB-FIS abundance index and 2017 GAB-FIS length frequencies. The last year of recruitment estimation was changed to 2003 (from 2005 in the 2015 assessment).

The use of updated software and the inclusion of additional data resulted in some differences in the fits to CPUE, conditional age-at-length data and length composition data. The usual process of bridging to a new model by adding new data piecewise and analysing which components of the data could be attributed to changes in the assessment outcome was conducted with the details outlined below.

9.2.2 *Update to Stock Synthesis SSV-3.30 and updated catch history (Bridge 1)*

The 2015 Bight Redfish assessment (BightRedfishV2015_3.24U) was initially converted to the most recent version of the software, Stock Synthesis version SS-V3.30.14.05 (BightRedfish2015_3.30.14). There are no discernible differences in the estimated annual spawning biomass between the two Stock Synthesis version updates (i.e., 3.24U and 3.30.14; Figure 9.1).

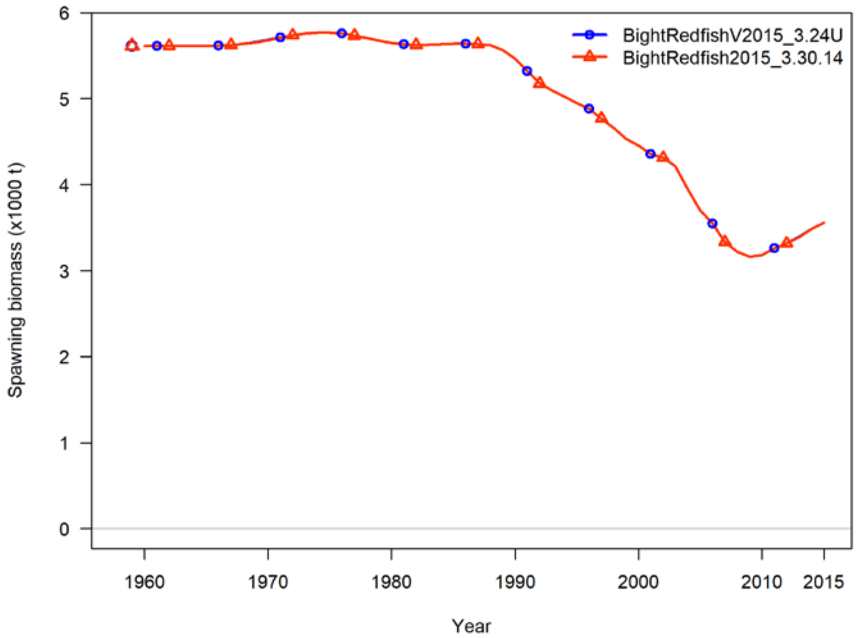

Figure 9.1. Comparison of the time-series of absolute spawning biomass from the 2015 assessment (BightRedfishV2015_3.24U – dark blue) and a model converted to SS-V3.30 (BightRedfish2015_3.30.14 – red).

New features available in the new version of Stock Synthesis, such as allowing smaller lower bounds on minimum sample sizes and estimating additional standard deviation to abundance indices were then incorporated (BightRedfish2015_3.30New), followed by retuning using the latest tuning protocol (BightRedfish_3.30Tuned). Details of the tuning procedure used are listed in Section 9.2.2.1. Revisions to the historical catches, which involved only updating the estimated 2014-15 catch with the actual 2014-15 catch, were then added to this tuned version of the 2015 model (BightRedfish2015_3.30ReviseCatch). This process demonstrates the outcomes that could theoretically have been achieved with the last assessment if we had the latest software, tuning protocols and corrected data available in 2015. This initial bridging step, Bridge 1, does not incorporate any data after 2014-15 or any structural changes to the assessment.

There was an overall increase in spawning biomass time series accounting for new features, tuning and revised catch (i.e., 2014-15 landed catch updated) (Figure 9.2, Figure 9.3).

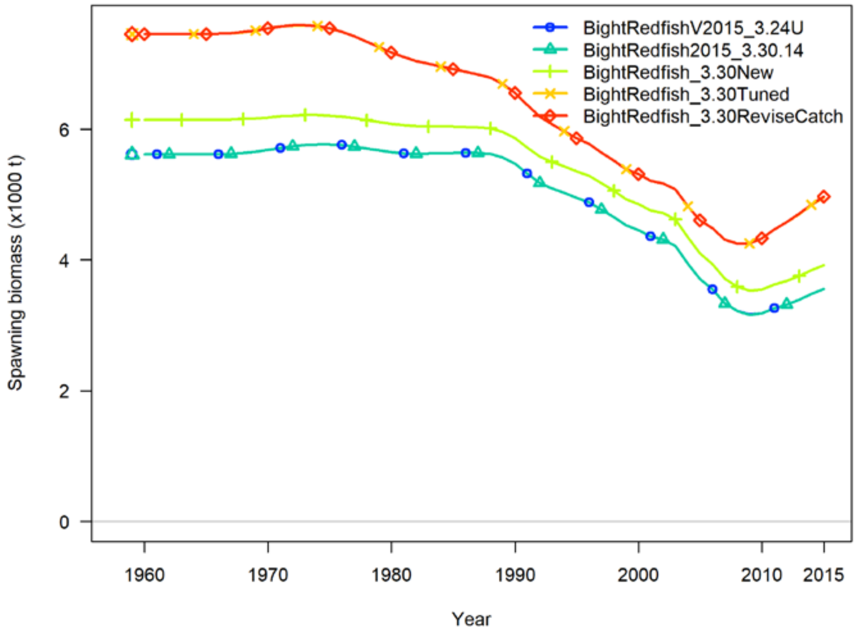

Figure 9.2. Comparison of the time-series of absolute spawning biomass from the 2015 assessment (BightRedfishV2015_3.30.14 – dark blue), a model converted to SS-V3.30 (BightRedfish2015_3.30.14 – light blue), incorporating new features (BightRedfish2015_3.30New – green), retuning the model using the latest tuning protocols (BightRedfish2015_3.30Tuned – yellow) and revising the historical catch to 2015 and the projected catch in 2016 (BightRedfish2015_3.30ReviseCatch – red).

The results of Bridge 1 suggest that the stock was marginally less depleted in 2015 than the previous assessment indicated (63% of SSB_0). These changes are small enough to be within the confidence bounds of the 2016 assessment results and the fits are generally improved through these revisions (Figure 9.3). Fits to the abundance indices (Figure 9.4 and Figure 9.5) show minor changes through this process. The estimated recruitment series shows little change in broad trends during Bridge 1 (Figure 9.6), although there are several minor changes resulting from the new tuning procedures. In particular, the new tuning procedures allow for greater variation in recruitment and higher base level recruitment (R_0) and increases to the peak recruitment events towards the end of the time series (1995, 1996 and 1999).

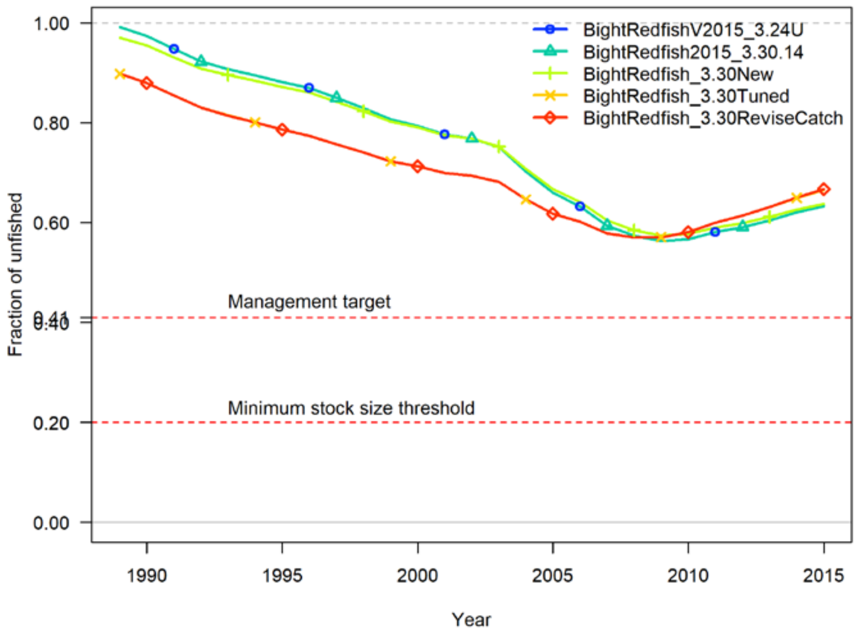

Figure 9.3. Comparison of the time-series of relative spawning biomass from the 2015 assessment (BightRedfishV2015_3.24U – dark blue), a model converted to SS-V3.30 (BightRedfish2015_3.30.14 – light blue), incorporating new features (BightRedfish2015_3.30New – green), retuning the model using the latest tuning protocols (BightRedfish2015_3.30Tuned – yellow) and revising the historical catch to 2015 and the projected catch in 2016 (BightRedfish2015_3.30ReviseCatch – red).

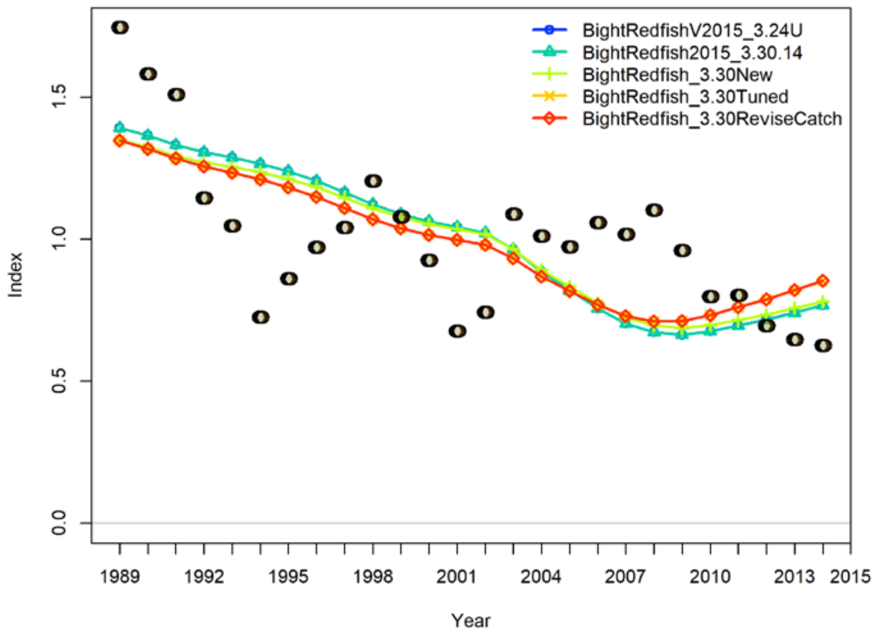

Figure 9.4. Comparison of the fit to the trawl CPUE index for the 2015 assessment (BightRedfishV2015_3.24U – dark blue), a model converted to SS-V3.30 (BightRedfish2015_3.30.14 – light blue), incorporating new features (BightRedfish2015_3.30New – green), retuning the model using the latest tuning protocols (BightRedfish2015_3.30Tuned – yellow) and revising the historical catch to 2014-15 (BightRedfish2015_3.30ReviseCatch – red).

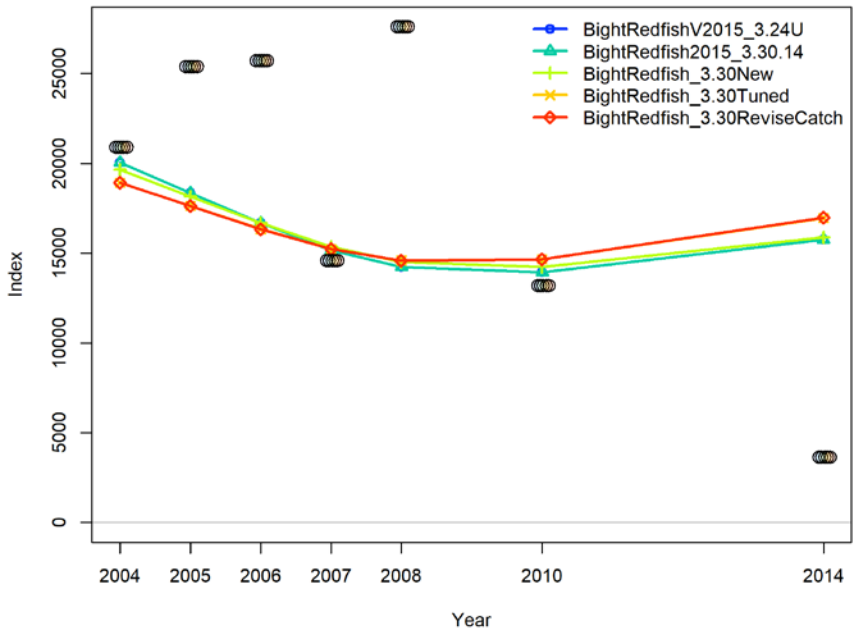

Figure 9.5. Comparison of the fit to the GAB-FIS abundance index for the 2015 assessment (BightRedfishV2015_3.24U – dark blue), a model converted to SS-V3.30 (BightRedfish2015_3.30.14 – light blue), incorporating new features (BightRedfish2015_3.30New – green), retuning the model using the latest tuning protocols (BightRedfish2015_3.30Tuned – yellow) and revising the historical catch to 2014-15 (BightRedfish2015_3.30ReviseCatch – red).

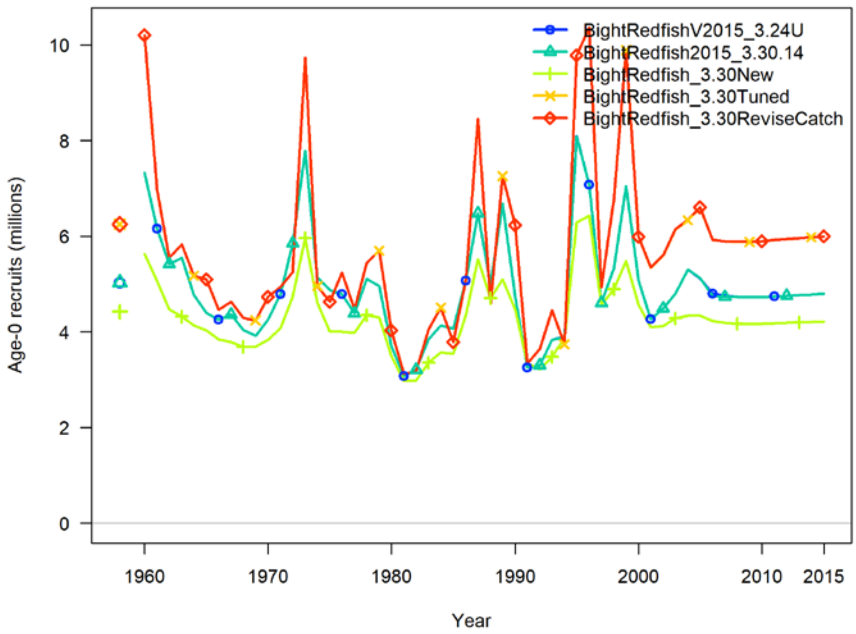

Figure 9.6. Comparison of the time series of recruitment from the 2015 assessment (BightRedfishV2015_3.24U – dark blue), a model converted to SS-V3.30 (BightRedfish2015_3.30.14 – light blue), incorporating new features (Flathead2015_3.30New – green), retuning the model using the latest tuning protocols (Flathead2015_3.30Tuned – yellow) and revising the historical catch to 2015 and the projected catch in 2016 (Flathead2015_3.30ReviseCatch – red).

9.2.2.1 Tuning method

Iterative rescaling (reweighting) of input and output CVs or input and effective sample sizes is a repeatable method for ensuring that the expected variation of the different data streams is comparable to what is input (Pacific Fishery Management Council, 2018). Most of the indices (CPUE, surveys and composition data) used in fisheries under-estimate their true variance by only reporting measurement or estimation error and not including process error.

In iterative reweighting, the effective annual sample sizes are tuned/adjusted so that the input sample size is equal to the effective sample size calculated by the model. In SS-V3.30 it is possible to estimate an additional standard deviation parameter to add to the input CVs for the abundance indices (CPUE).

1. Set the standard error for the log of relative abundance indices (CPUE or FIS) to the standard deviation of a loess curve fitted to the original data - which will provide a more realistic estimate to that obtained from the original statistical analysis. SS-V3.30 then allows an estimate to be made for an additional adjustment to the relative abundance variances appropriately.

An automated iterative tuning procedure was used for the remaining adjustments. For the recruitment bias adjustment ramps:

2. Adjust the maximum bias adjustment and the start and finish bias adjustment ramps as predicted by SS-V3.30 at each step.

For the age and length composition data:

3. Multiply the stage-1 (initial) sample sizes for the conditional age-at-length data by the sample size multipliers using the approach of Punt (2017).
4. Similarly multiply the initial samples sizes by the sample size multipliers for the length composition data using the 'Francis method' (Francis, 2011).
5. Repeat steps 2 - 4, until all are converged and stable (with proposed changes < 1 – 2%).

This procedure constitutes current best practice for tuning assessments.

9.2.3 *Inclusion of new data: 2015-26 to 2018-19 (Bridge 2)*

Starting from the translated, retuned 2016 base case model with updated data to 2014-15 (previously referred to as "BightRedfish_3.30ReviseCatch" but simplified to "BightRedfish2015_3.30Updated" from here on), additional data from 2015-16 to 2018-19 were added sequentially to build a preliminary base case for the 2019 assessment:

1. Change final assessment year to 2018 and add catch to 2018 (BightRedfish2019_addCatch2018).
2. Add GAB-FIS abundance index for 2017 (Knuckey et al. 2018) (BightRedfish2019_addFIS2017) and CPUE to 2018 (from Sporcic 2019a; 2019b) (BightRedfish2019_addCPUE2018).
3. Add updated length frequency data to 2018 (BightRedfish2019_addLength2018).
4. Add updated age error matrix and conditional age-at-length data to 2018 and GAB-FIS conditional age-at-length data from 2008 (BightRedfish2019_addAge2018FIS).
5. Change the final year for which recruitments are estimated from 2005 to 2003 (BightRedfish2019_Rec2003).

6. Retune using current tuning protocols, including Francis weighting on length-compositions and conditional age-at-length data (BightRedfish2019_Tuned).

Inclusion of the new data resulted in a series of changes to estimated recruitment and the time-series of relative spawning biomass (Figure 9.7 and Figure 9.8). Changes to stock status are largest between 2005 to 2015. Adding each data source reduces the stock status slightly in this period, with a small increase at the final step (re-tuning the model).

Peaks in estimated recruitment are generally revised downwards between 1980 and 2000, as more data is added (Figure 9.9). By contrast, as more data is added, there is an increase to the 2003 estimated recruitment, with a slight decrease at the final step (re-tuning the model). Note that the last year of estimated recruitment is changed from 2005 to 2003 at the step when length is added, as it became apparent that too many recruitment years were estimated in earlier models.

Fits to both CPUE and GAB-FIS indices are largely unchanged with the addition of new data (Figure 9.9, Figure 9.10). In both series, estimated fits are poor. This is due to the biology and life span of this species, which make it difficult to follow the short-term variability evident in the abundance series. This suggests that CPUE may be showing short term changes that do not just reflect changes in population abundance.

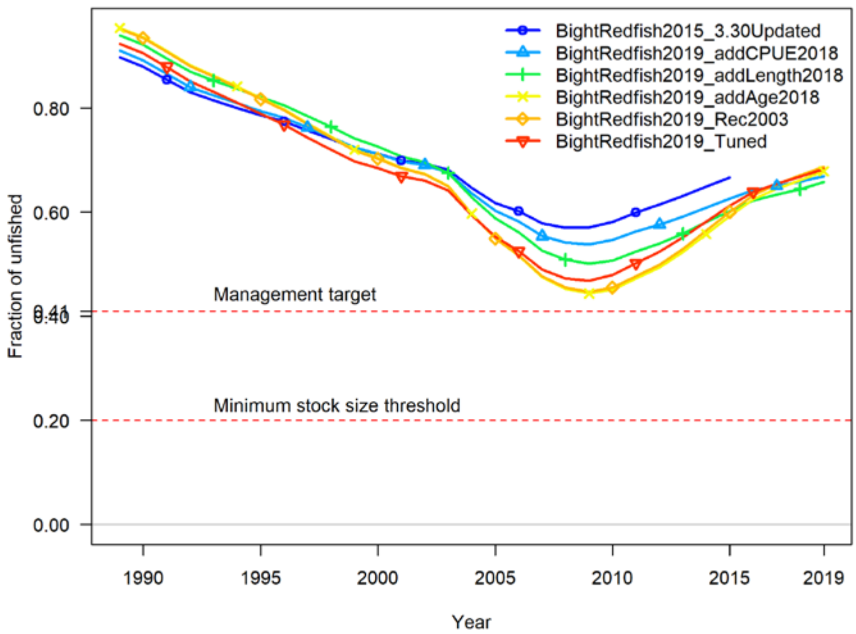

Figure 9.7. Comparison of the time series of relative spawning biomass for the updated 2015 assessment model converted to SS-V3.30.14 (BightRedfish2015_3.30Updated - blue) with various bridging models leading to a proposed 2019 base case model (BightRedfish2019_Tuned - red).

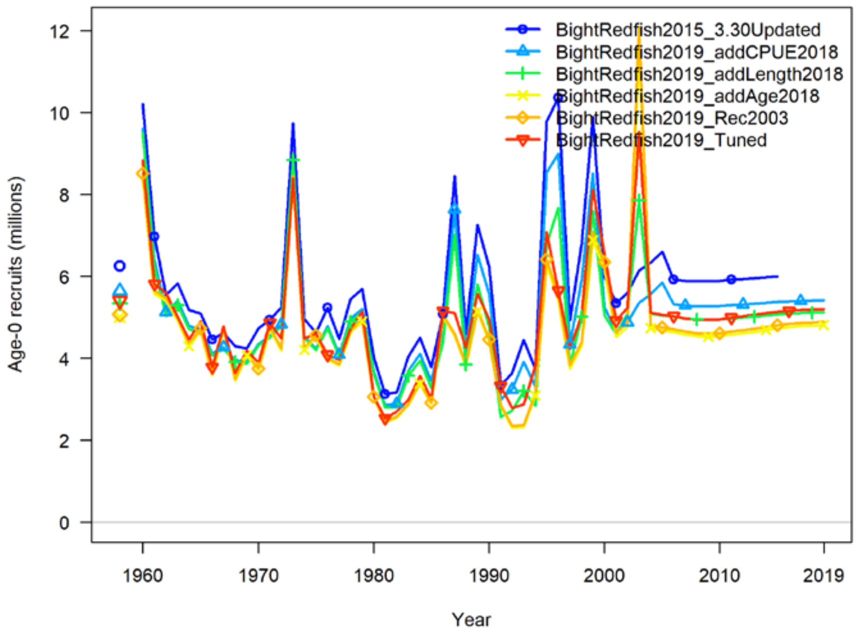

Figure 9.8. Comparison of the time series of recruitment from the updated 2015 assessment model converted to SS-V3.30.14 (BightRedfish2015_3.30Updated – dark blue) with various bridging models leading to a proposed 2019 base case model (BightRedfish2019_Tuned – red).

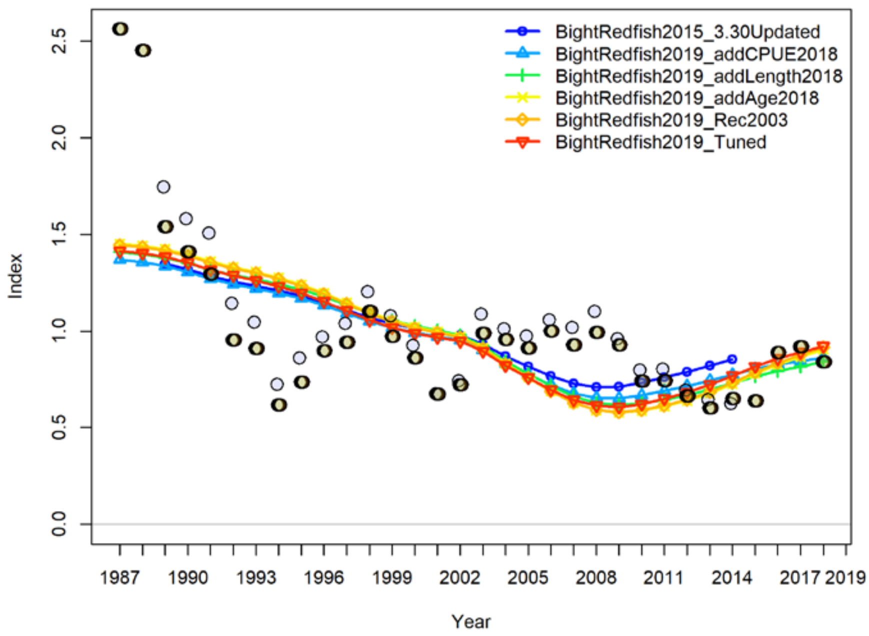

Figure 9.9. Comparison of the fit to the trawl CPUE index for the updated 2015 assessment model converted to SS-V3.30.14 (BightRedfish2015_3.30Updated – dark blue) with various bridging models leading to a proposed 2019 base case model (BightRedfish2019_Tuned – red).

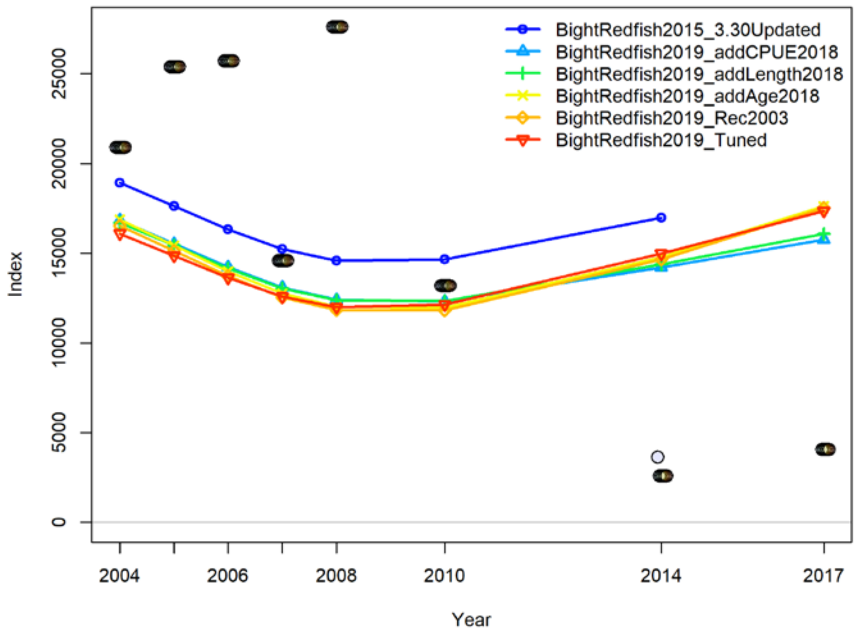

Figure 9.10. Comparison of the fit to the FIS abundance index for the updated 2015 assessment model converted to SS-V3.30.14 (BightRedfish2015_3.30Updated – dark blue) with various bridging models leading to a proposed 2019 base case model (BightRedfish2015_Tuned – red).

9.3 Assessment outcomes of the 2019 base case model

9.3.1 *Results*

Results show poor fits to the CPUE and GAB-FIS abundance series, but reasonable fits to length and conditional age-at-length data (Appendix A). Selected fixed and/or estimated parameters are tabulated in Table 9.1 and landed catch and standardized CPUE tabulated in Table 9.2.

This assessment estimates that the projected 2020-21 spawning stock biomass will be 70% of virgin stock biomass (projected assuming 2018-19 catches in 2019-2020), compared to 62% at the start of 2016-17 from the 2015 assessment (Haddon 2015) and 90% at the start of 2012-13 from the 2011 assessment (Klaer 2011). This change in stock status is mostly due to revisions to the estimates of recent large recruitment events towards the end of the time series, particularly in 1995, 1996 and 1999.

Table 9.1. Bight Redfish: Summary of selected parameters from the 2019 base case model. Years represent the first year of each financial year e.g., 2015 refers to 2015-16.

Description	Parameter	Combined Male/Female	Comment(s)
Years	y	1988-2018	
Recruitment Deviates	r	estimated 1980 - 2003	
Fleets		1 Trawl only	
Discards		none significant, not Fitted	
Age classes	a	0 – 64 years	
Sex ratio	p_s	0.5 (1:1)	
Natural mortality	M	estimated (0.1017) per year	
Steepness	h	0.75	
Recruitment variation	σ_r	0.7	
Female maturity		25 cm (TL)	
Growth	L_{max}	37.939 cm (TL)	fixed
	K	0.110936	fitted
	L_{min}	16.7648	fitted
	CV	0.131095	fitted
		Female	Male
Length-weight (based	f_1	0.0001 cm (TL)/gm	0.002
on standard length)	f_2	2.559	2.552

Table 9.2. Bight Redfish: Financial year values of catch and estimated standardized CPUE (Trawl) from 1988-89 to 2018-19. Catch is taken from logbook estimates until 2005-06. Subsequently, CDR catches are used to 2014-15 (Haddon, 2015) and catches from 2015-16 to 2018-19 from CDR landings database. Discards are assumed to be trivial. Standardized CPUE is from Sporcic (2019).

Season	Catch (t)	CPUE
1987-88		2.5623
1988-89	85.65	2.4517
1989-90	170.83	1.5382
1990-91	281.81	1.4084
1991-92	265.61	1.2932
1992-93	120.70	0.9523
1993-94	107.47	0.9084
1994-95	157.80	0.6177
1995-96	173.92	0.7349
1996-97	327.18	0.8966
1997-98	372.62	0.9406
1998-99	437.79	1.1019
1999-00	323.64	0.9718
2000-01	387.88	0.8591
2001-02	262.61	0.673
2002-03	424.67	0.7201
2003-04	946.48	0.9862
2004-05	937.46	0.954
2005-06	789.70	0.9101
2006-07	1023.91	0.9977
2007-08	808.02	0.9275
2008-09	681.89	0.9927
2009-10	469.70	0.9282
2010-11	297.60	0.7396
2011-12	341.48	0.742
2012-13	273.45	0.6629
2013-14	207.05	0.5994
2014-15	196.56	0.6496
2015-16	176.95	0.6367
2016-17	317.09	0.8866
2017-18	288.49	0.918
2018-19	214.50	0.8385

9.3.2 *Likelihood profiles*

As stated by Punt (2018), likelihood profiles are a standard component of the toolbox of applied statisticians. They are most often used to obtain a 95% confidence interval for a parameter of interest. Many stock assessments “fix” key parameters such as M and steepness based on *a priori* considerations. Likelihood profiles can be used to evaluate whether there is evidence in the data to support fixing a parameter at a chosen value. If the parameter is within the entire range of the 95% confidence interval, this provides no support in the data to change the fixed value. If the fixed value is outside the 95% confidence interval, it would be reasonable for a review panel to ask why the parameter was fixed and not estimated, and if the value is to be fixed, on what basis and why should what amounts to inconsistency with the data be ignored. Integrated stock assessments include multiple data sources (e.g., commonly catch-rates, length-compositions, and age-compositions) that may be in conflict, due for example to inconsistencies in sampling, but more commonly owing to incorrect assumptions (e.g., assuming that catch-rates are linearly related to abundance), i.e. model-misspecification. Likelihood profiles can be used as a diagnostic to identify these data conflicts (Punt, 2018).

Standard parameters to consider are natural mortality (*M*), steepness (*h*) and the logarithm of the unfished recruitment ($\ln R_0$).

9.3.2.1 Natural mortality (M)

For Bight Redfish, the likelihood profile for natural mortality, *M*, is shown in Figure 9.11 with the total likelihood shown in black and components of the total likelihood from different data sources shown in a range of colours. This parameter is estimated in the model (M=0.1017 y^{-1}) and the likelihood profile suggests that it is well estimated. The index (suggest higher mortality) and length data (suggest lower mortality) show some conflict. The age data are most influential on the total likelihood, with similar minimum values. The confidence intervals on *M* are narrow ranging between approximately 0.093 and 0.11.

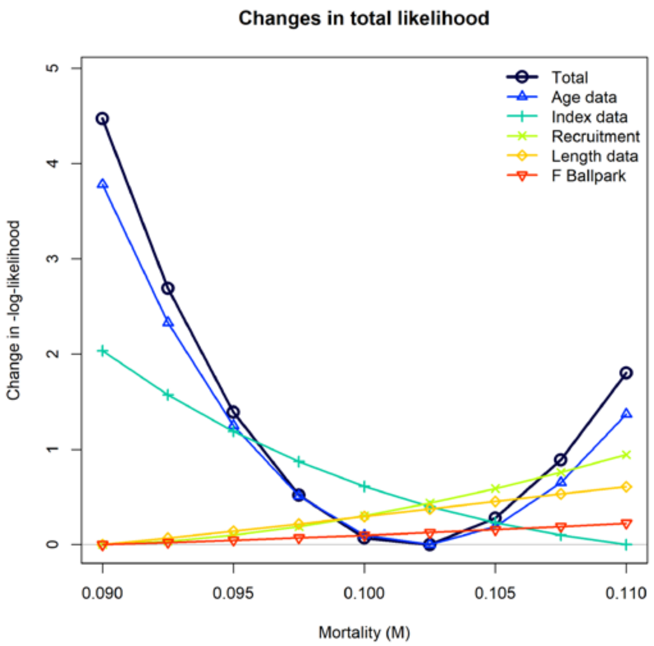

Figure 9.11. Bight Redfish: The likelihood profile for natural mortality (*M*), ranging from 0.09 to 0.11. The estimated value for *M* is 0.1017 yr^{-1}.

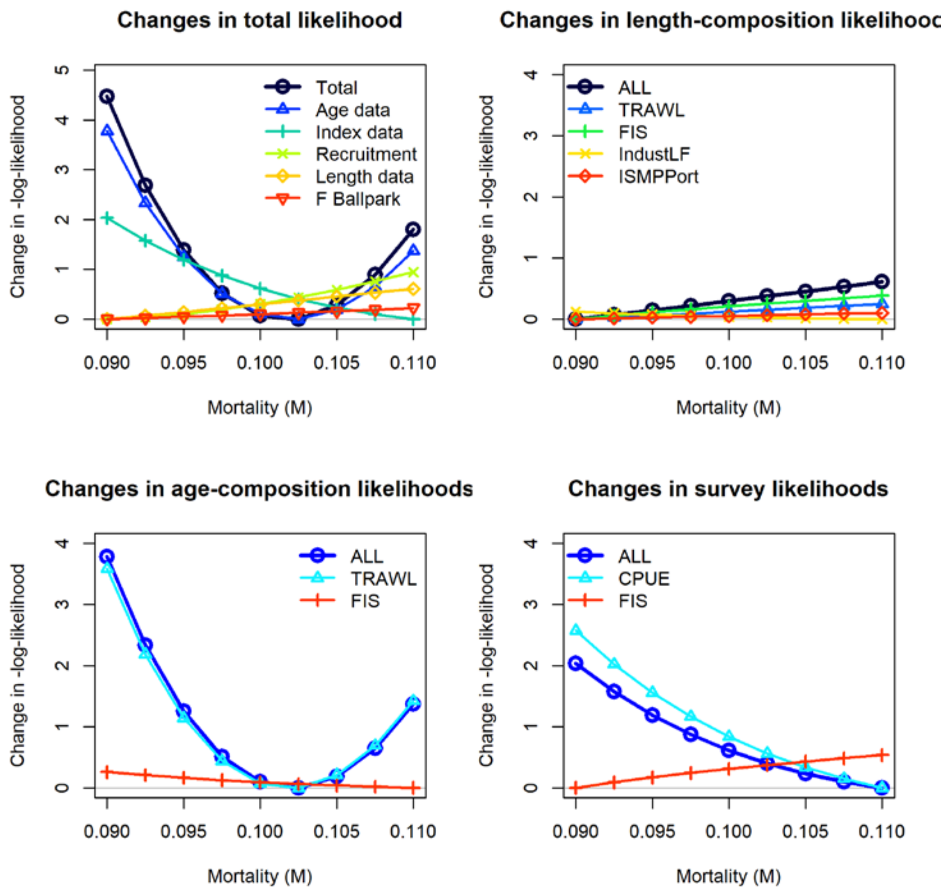

Figure 9.12. Bight Redfish: The likelihood profile for natural mortality (*M*), ranging from 0.09 to 0.11. The estimated value for *M* is 0.1017 yr^{-1}. Bight Redfish: Piner plot for the likelihood profile for natural mortality (*M*), showing components of the change in likelihood for length, age and indices (CPUE; GAB-FIS) in addition to the changes in the total likelihood.

9.3.2.2 Steepness (h)

A likelihood profile on steepness, *h*, shows the total likelihood shown in black and components of the total likelihood from different data sources shown in a range of colours (Figure 9.13). This figure shows that steepness is not well defined as the 95% confidence limits are not crossed (log-likelihood of 1.92 on the y-axis) by the total likelihood within the range considered (*h* = 0.6 to 0.8). This is not surprising given the stock in the base case model has not been depleted to levels that would define steepness. It is therefore reasonable to fix steepness at 0.75.

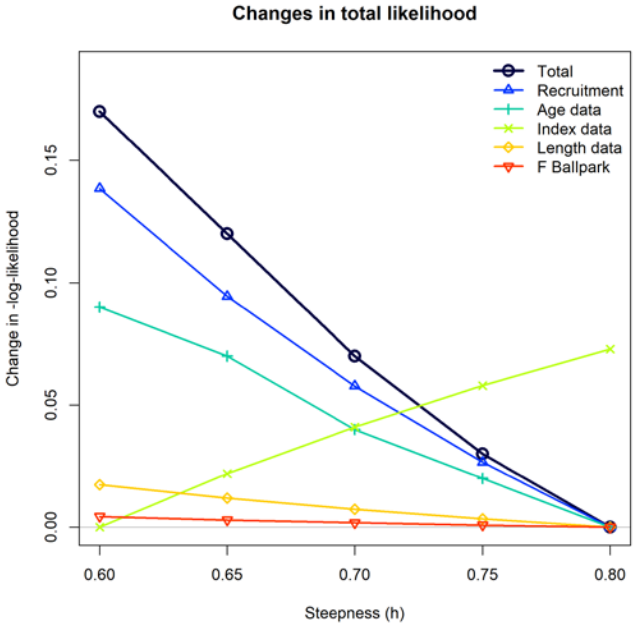

Figure 9.13. Bight Redfish: The likelihood profile for steepness (*h*), ranging from 0.6 to 0.8. The fixed value for *h* is 0.75.

9.3.2.3 *Virgin spawning biomass (SSB_0)*

A likelihood profile for virgin spawning biomass (SSB_0) is shown in Figure 9.14 and Figure 9.15 with the total likelihood shown in black and components of the total likelihood from different data sources shown in a range of colours. SSB_0 is a derived parameter which is linked to the estimated parameters R_0, which is the average equilibrium recruitment and constructing this likelihood profile. To construct a likelihood profile on SSB_0 requires setting up an additional "fleet" with a single data point (in 1960) with very low standard error, essentially adding a "highly precise survey" of spawning biomass, setting the selectivity type to 30 (an index of *SSB*) and then allowing this spawning biomass value to vary between runs. This likelihood profile suggests a broad range of plausible values for SSB_0 ranging between around 6000 and 9500 t with the most likely value at around 7300 t. The important data sources in providing information on SSB_0 are the index data and age data (Trawl). SSB_0 needs to be sufficiently high to enable the historical catches to be sustained, so this results in the recruitment component of the likelihood providing a lower bound on SSB_0 and the fits to the age data deteriorate with larger values of SSB_0.

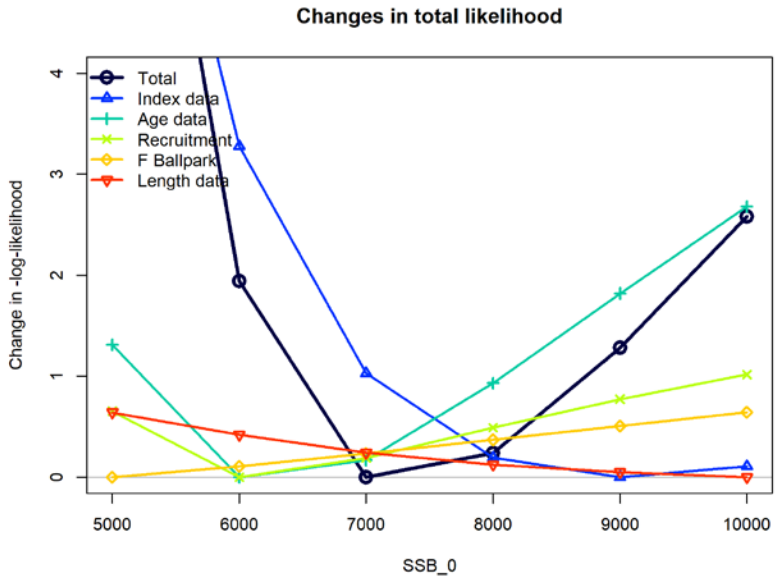

Figure 9.14. Bight Redfish: The likelihood profile for virgin spawning biomass, with SSB_0 ranging from 2000 to 800 t. The estimated value for SSB_0 is 7295 t.

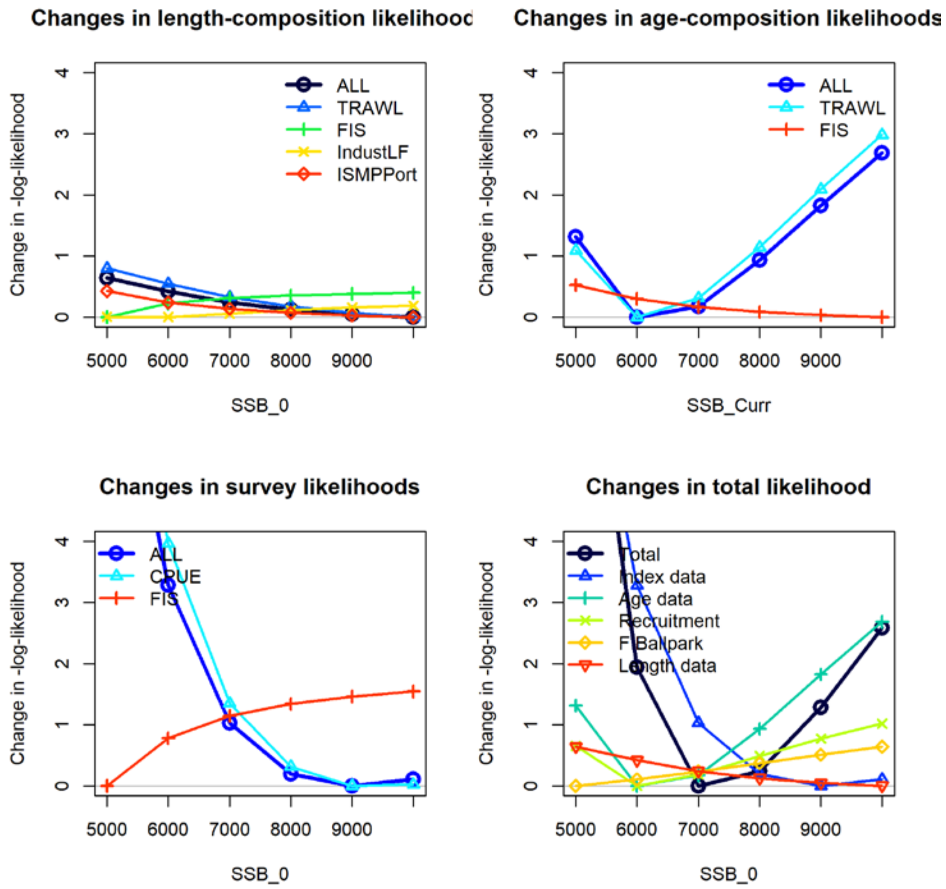

Figure 9.15. Bight Redfish: Piner plot for the likelihood profile for 2018 spawning biomass (SSB_Curr), showing components of the change in likelihood for length, age and indices (CPUE, GAB-FIS) in addition to the changes in the total likelihood.

9.3.2.4 Current (2018) spawning biomass (SSB_{2018})

A likelihood profile for current (2018) spawning biomass (SSB_{2018}), using the same techniques as for SSB_0, is shown in Figure 9.16 and Figure 9.17 with the total likelihood shown in black and components of the total likelihood from different data sources shown in a range of colours.

This likelihood profile suggests a broad range of plausible values for SSB_{2018} ranging between around 3500 and 7500 t with the most likely value at around 4900 t. The important data sources in providing information on SSB_{2018} are the index data and estimated recruitments. SSB_{2018} needs to be sufficiently high to enable the historical catches to be sustained, so this results in the recruitment component of the likelihood providing a higher bound on SSB_{2018} and the fits to the index data deteriorate with smaller values of SSB_{2018}. A likelihood profile for depletion would be a useful addition to this analysis.

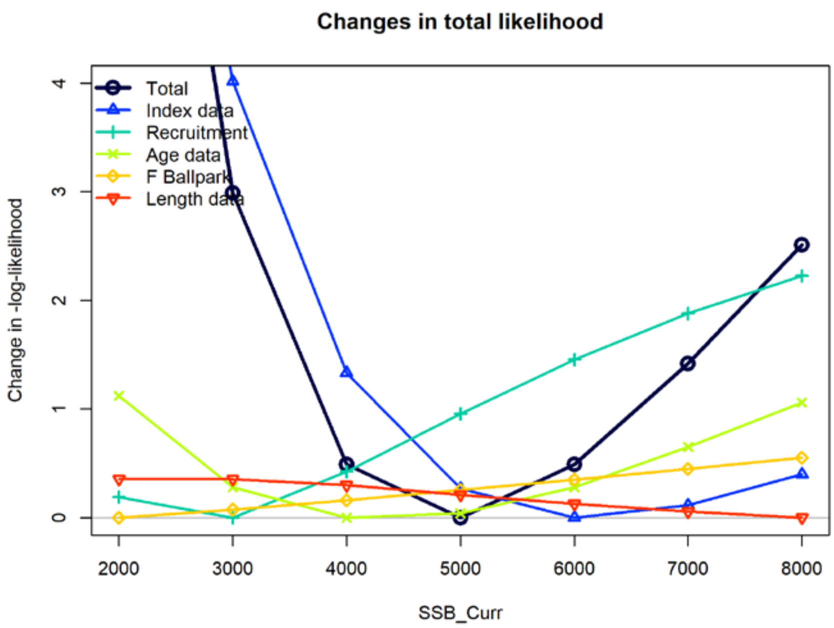

Figure 9.16. Bight Redfish: The likelihood profile for current (2018) spawning biomass, with SSB_{2018} ranging from 2000 to 800 t. The estimated value for SSB_{2018} is 4879 t.

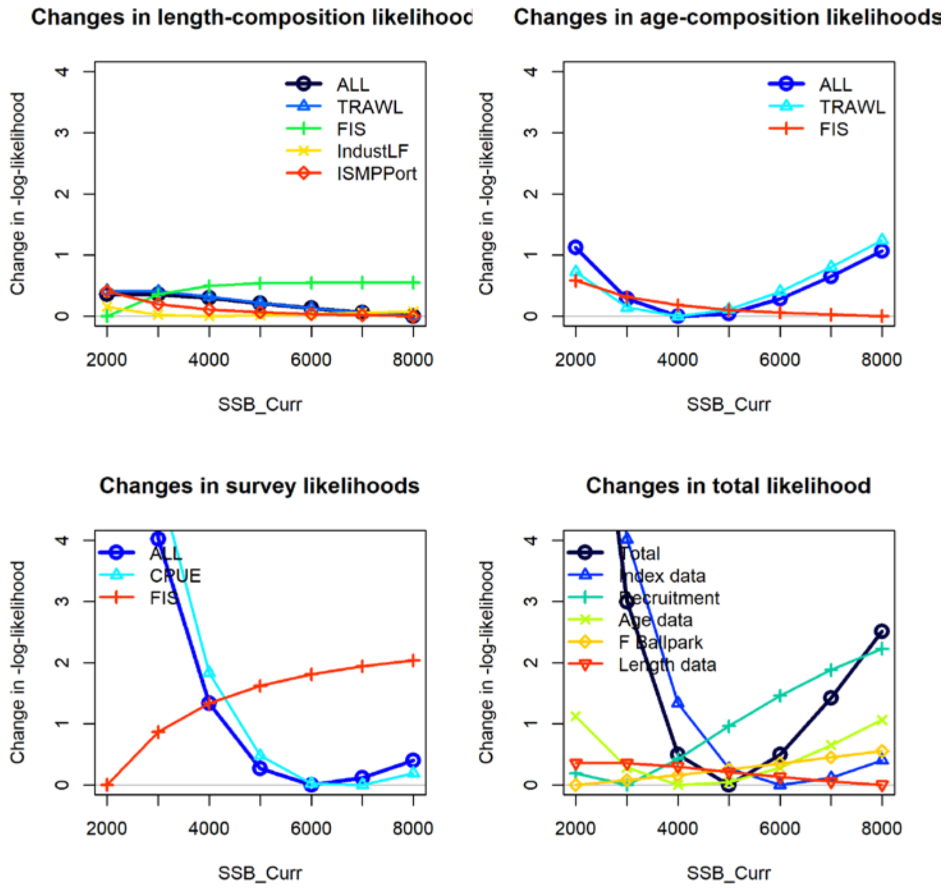

Figure 9.17. Bight Redfish: Piner plot for the likelihood profile for current (2018) spawning biomass (SSB_Curr), showing components of the change in likelihood for length, age and indices (CPUE, GAB-FIS) in addition to the changes in the total likelihood.

9.3.3 *Retrospectives*

A retrospective analysis was completed, starting from the most recent year of data, working backward in time and removing five successive years of data from the assessment. This analysis can highlight potential problems and instability in an assessment, or some features that appear from the data.

A retrospective analysis for absolute spawning biomass is shown in Figure 9.18, with the base case model in dark blue, and then successive years data removed back to 2013 (shown in red). The same analysis is plotted in terms of relative spawning biomass in Figure 9.19. In both cases the changes are minor with the largest change with the last retrospective in the series, which deletes all data from 2014 onwards (Retrospective_2013, red). This retrospective shifts the whole absolute spawning biomass series upwards. The relative series is mostly unchanged until 2005 (Figure 9.19). The most recent data results in lower estimates of relative biomass from 2005 onwards, with the largest change occurring with the addition of the 2014 data. This pattern in biomass spawning change is explained by the changes in recruitment in the 2013 retrospective analysis, with recruitment generally being revised downwards with the addition of the 2014 data (red to orange; Figure 9.20) from about the late 1980s onwards. The large spikes in recruitment at the end of the last two retrospective analyses (light and dark blue) may be revised when extra years of data are included in a future assessment.

These retrospective analyses do not reveal any pathological patterns or apparent biases in the estimates at the end of the time series due to the addition of new data, which provides additional confidence in the stability of this assessment.

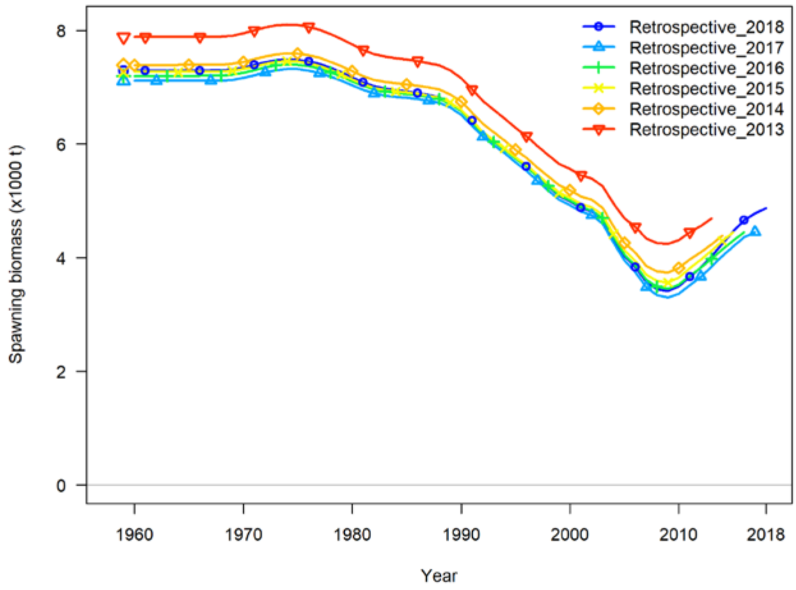

Figure 9.18. Bight Redfish: Retrospectives for absolute spawning biomass, with the most recent base case assessment shown (blue) and then successive years removed back to 2013 (red).

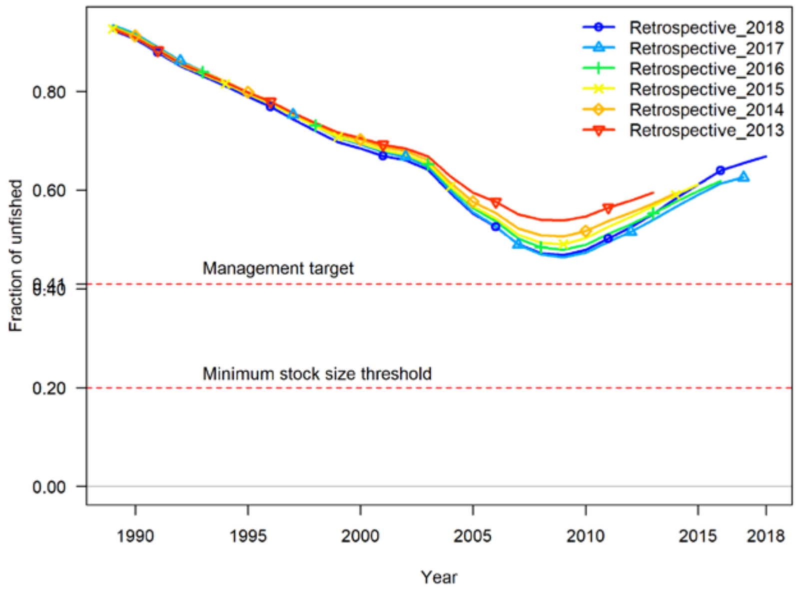

Figure 9.19. Bight Redfish: Retrospectives for relative spawning biomass, with the most recent base case assessment shown (blue) and then successive years removed back to 2013 (red).

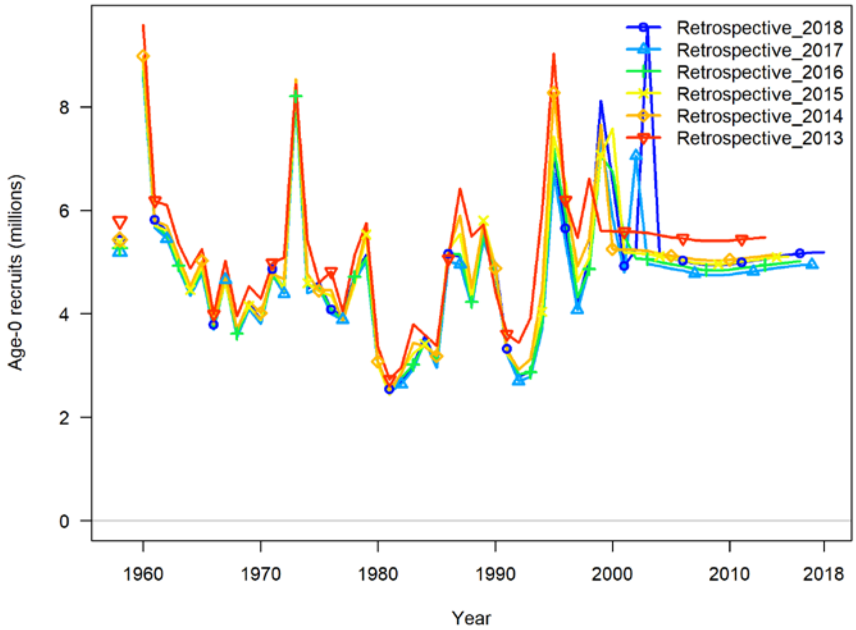

Figure 9.20. Bight Redfish: Retrospectives for recruitment, with the most recent base case assessment shown (blue) and then successive years removed back to 2013 (red).

9.3.4 *Future sensitivities*

Sensitivities to this potential base case have not yet been explored. In addition to the usual set of sensitivities (Haddon, 2015), (which includes sensitivities on mortality, maturity, fixing steepness and estimating mortality, σ_R and halving and doubling the weighting on length, age and CPUE data), there is an additional sensitivity that may be useful to explore:

1. Incorporating CPUE abundance indices to end FY 2019.

Given the relatively small changes to the input data and the quantity of other data used in the assessment, it is unlikely that this additional sensitivity will produce results that are noticeably different to the preliminary base case.

9.4 Acknowledgements

Age data was provided by Kyne Krusic-Golub (Fish Ageing Services), Integrated Scientific Monitoring Program (ISMP) and Commonwealth logbook and Catch Disposal Record (CDR) data were provided by John Garvey (AFMA). Thanks also goes to the CSIRO contributors: Mike Fuller, Roy Deng, Franzis Althaus and Robin Thomson for pre-processing the data. Geoff Tuck (CSIRO), Robin Thomson, Malcolm Haddon (CSIRO) and Ian Taylor (NOAA) are thanked for helpful discussions on this work. André Punt (CSIRO) updated the ageing error matrix. Malcolm Haddon provided code for auto-tuning and Athol Whitten provided R code for organising plots.

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9.6 Appendix A

A.1 Preliminary base case diagnostics

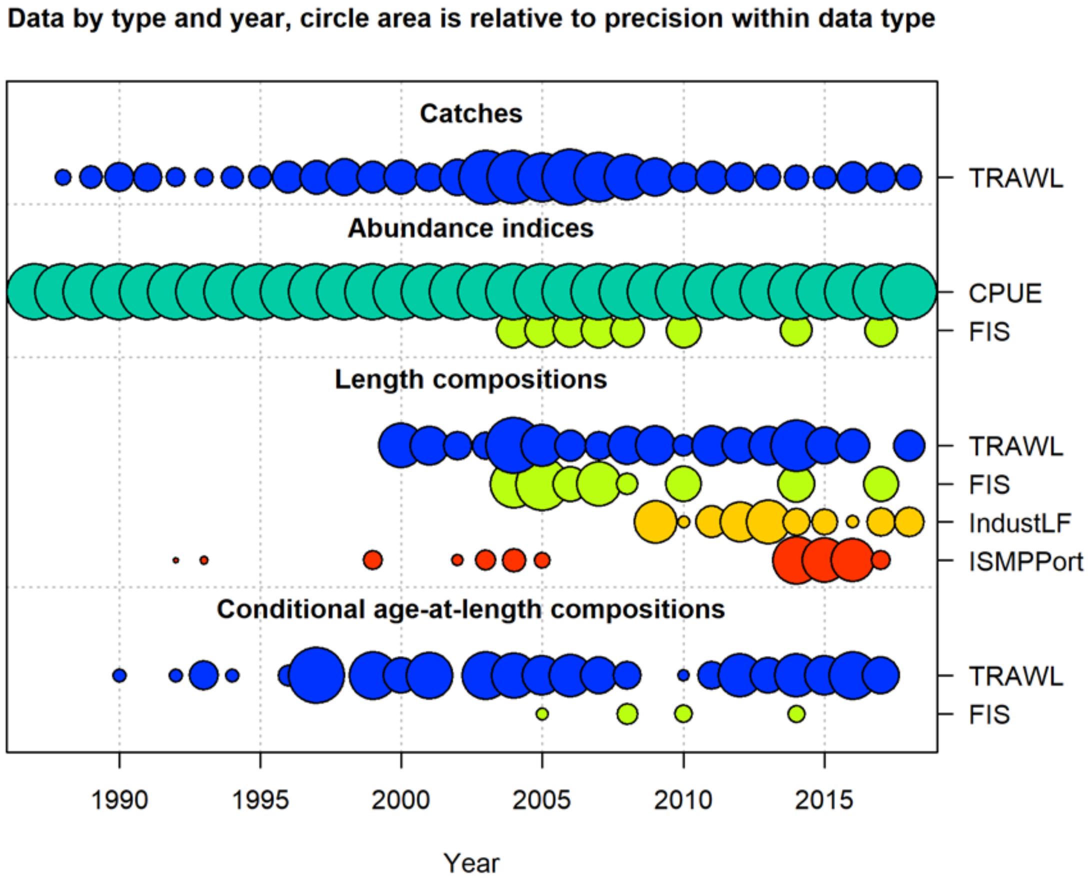

Figure A 9.1. Summary of data sources for Bight Redfish stock assessment.

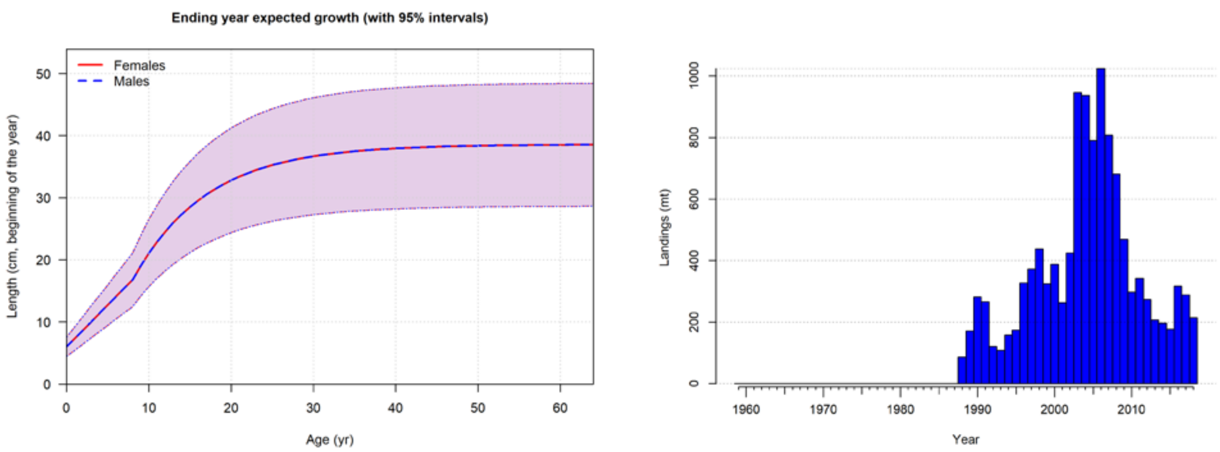

Figure A 9.2. Bight Redfish: Estimated growth curve and landings frequency distribution.

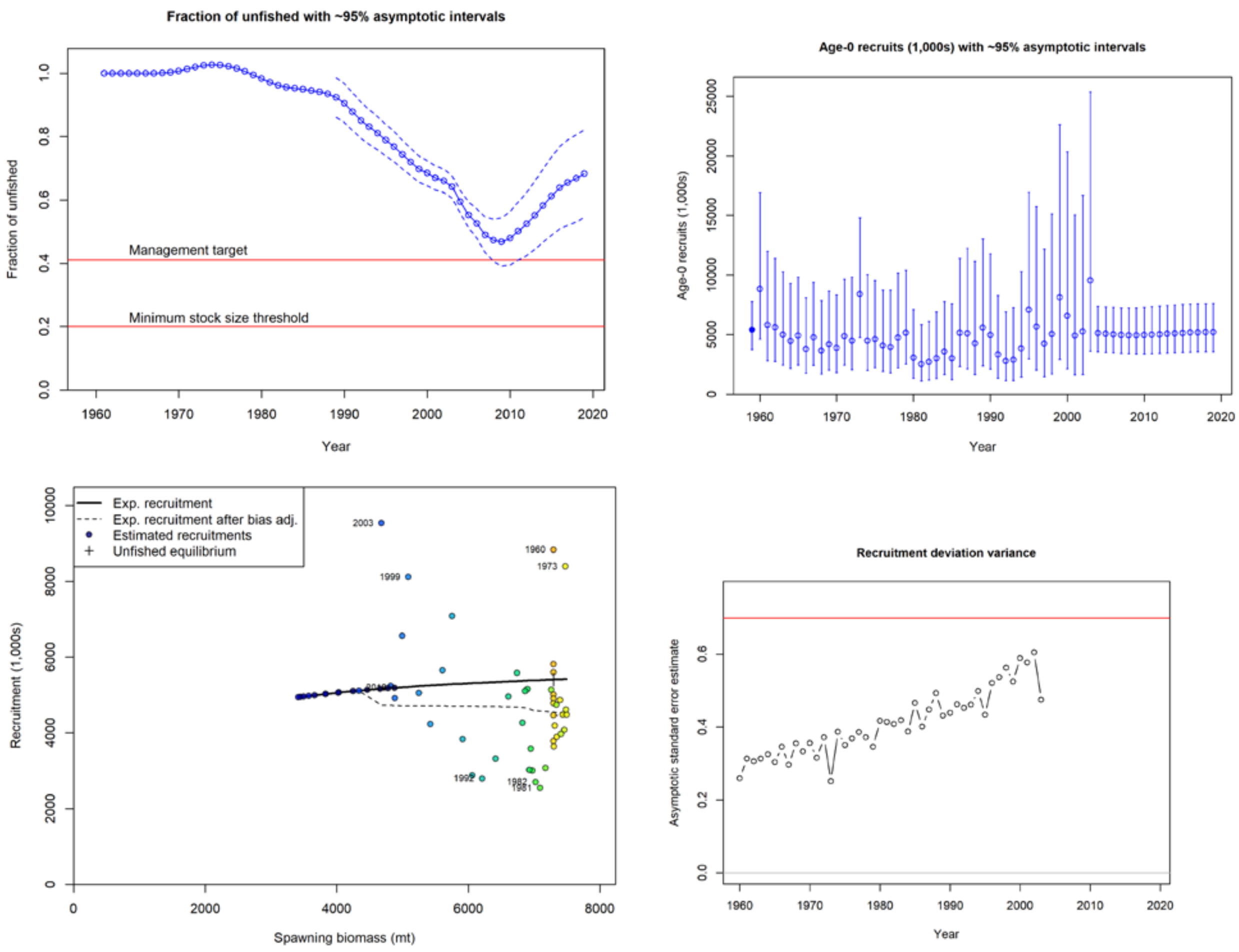

Figure A 9.3. Bight Redfish: Time series showing depletion of spawning biomass with confidence intervals (top left), recruitment estimates with confidence intervals (top right), stock recruitment curve (bottom left) and recruitment deviation variance check (bottom right).

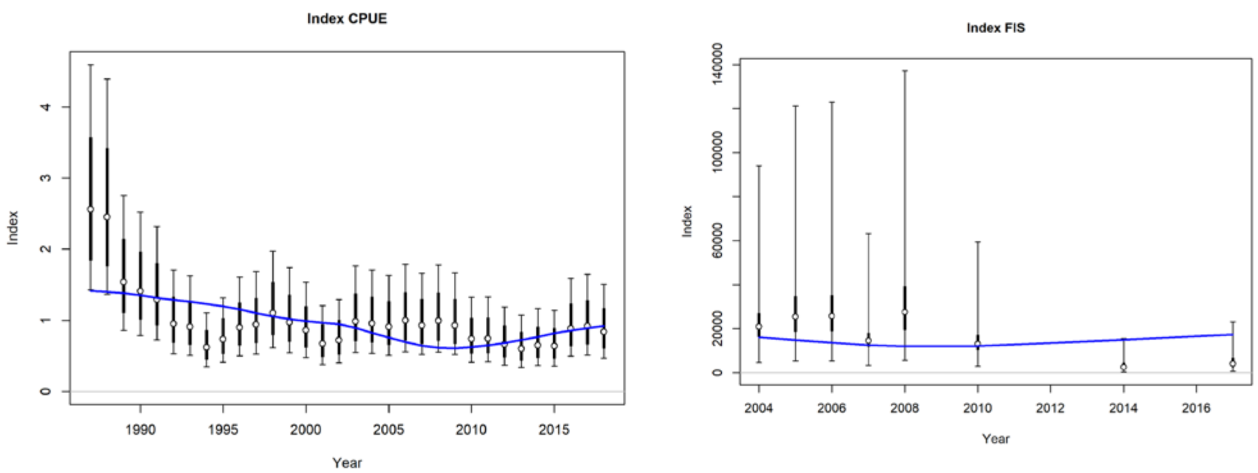

Figure A 9.4. Bight Redfish: Fits to CPUE and GAB Fishery Independent Survey (FIS).

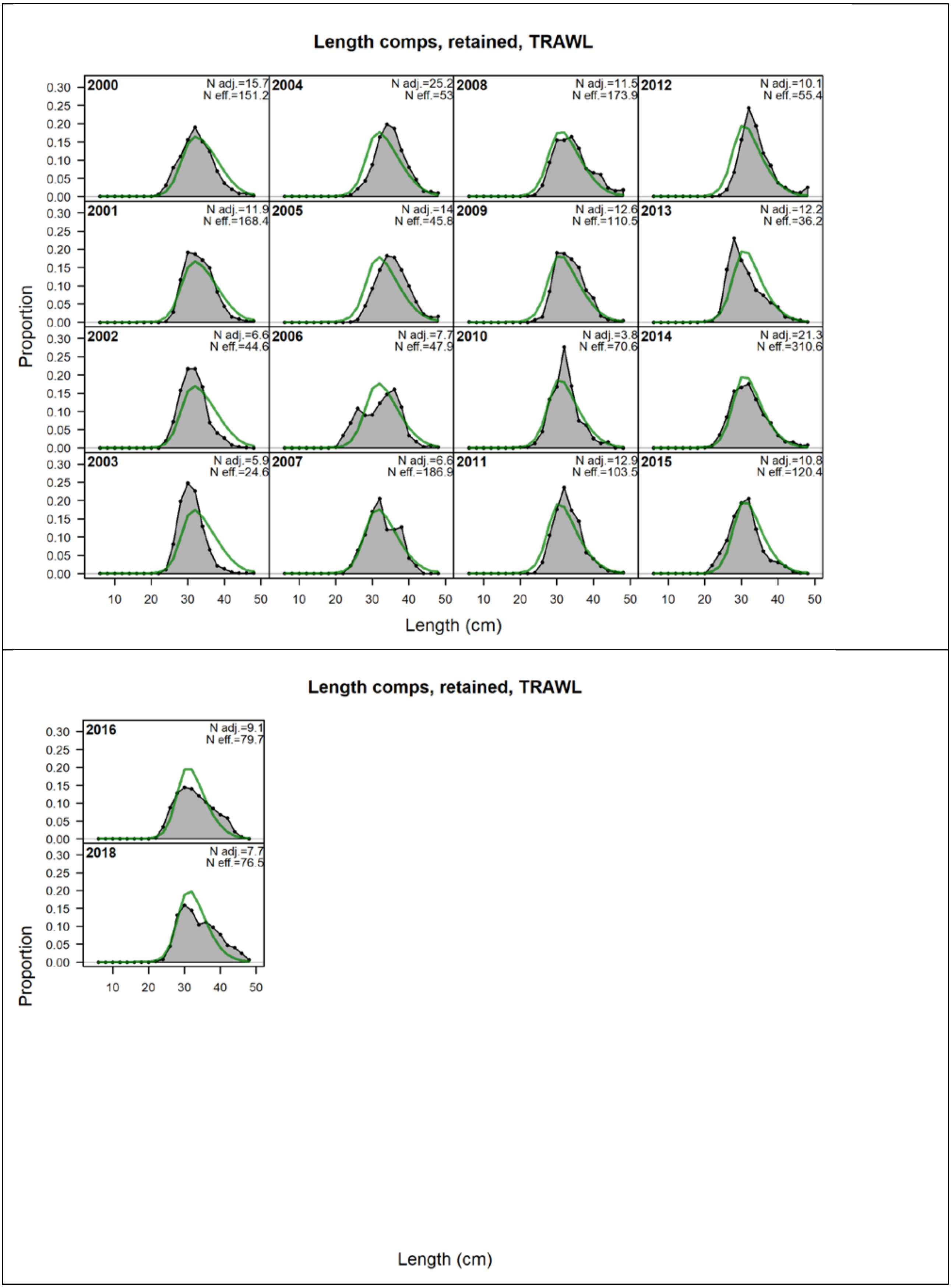

Figure A 9.5. Bight Redfish: Length composition fits - trawl retained.

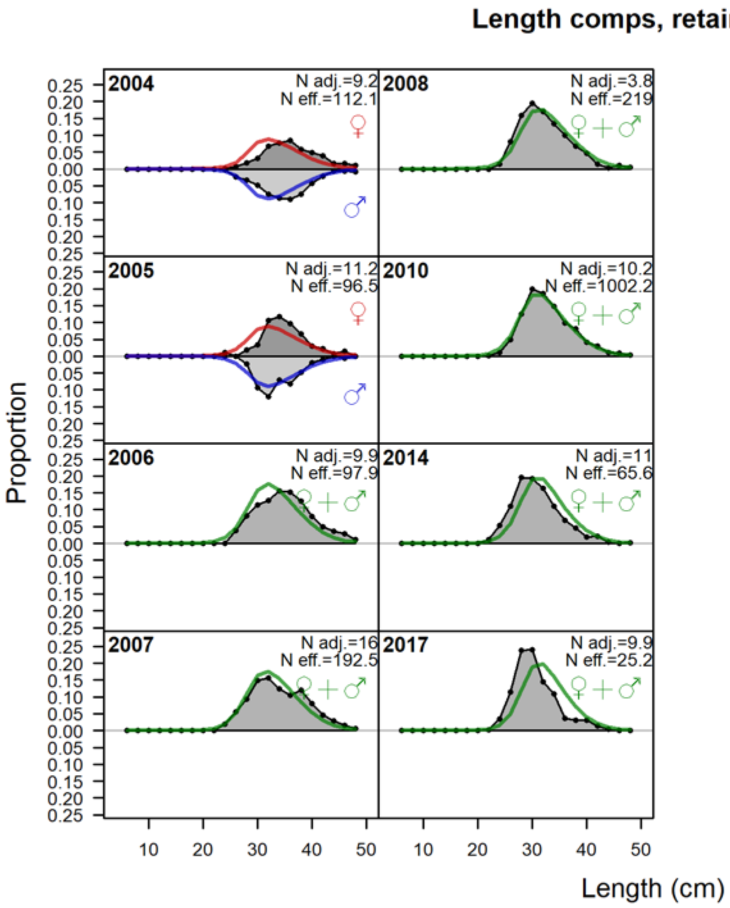

Figure A 9.6. Bight Redfish: Length composition fits - FIS retained.

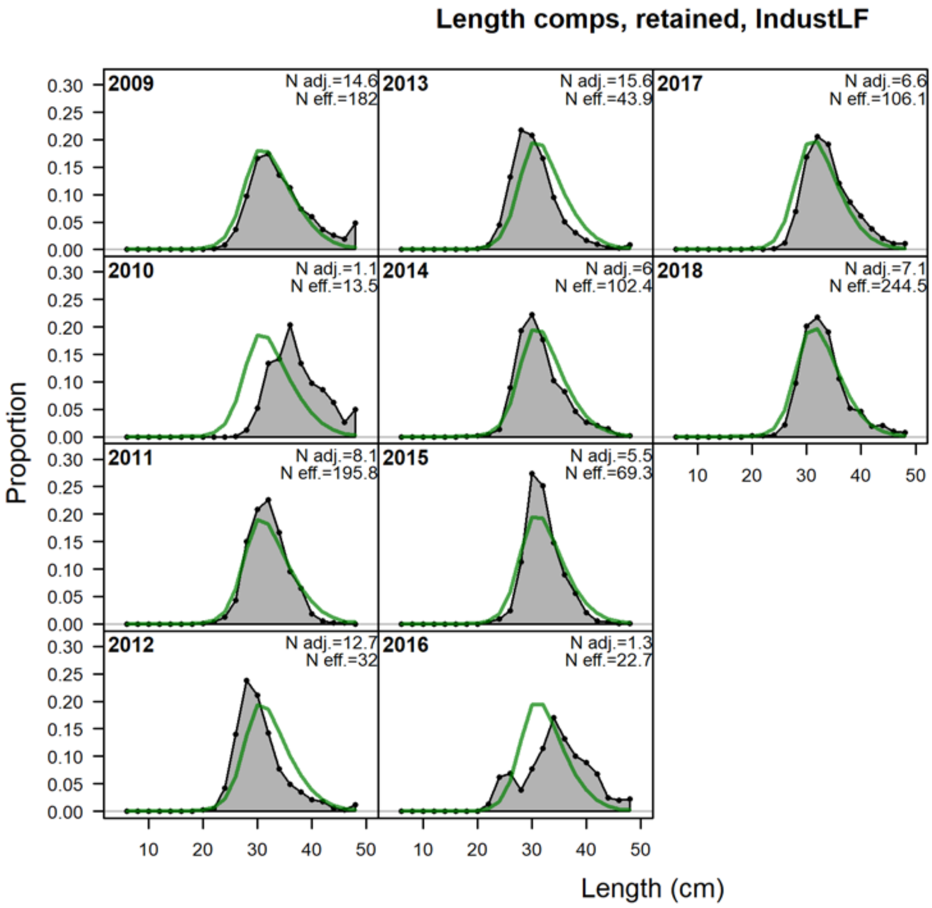

Figure A 9.7. Bight Redfish: Port length composition fits - Trawl.

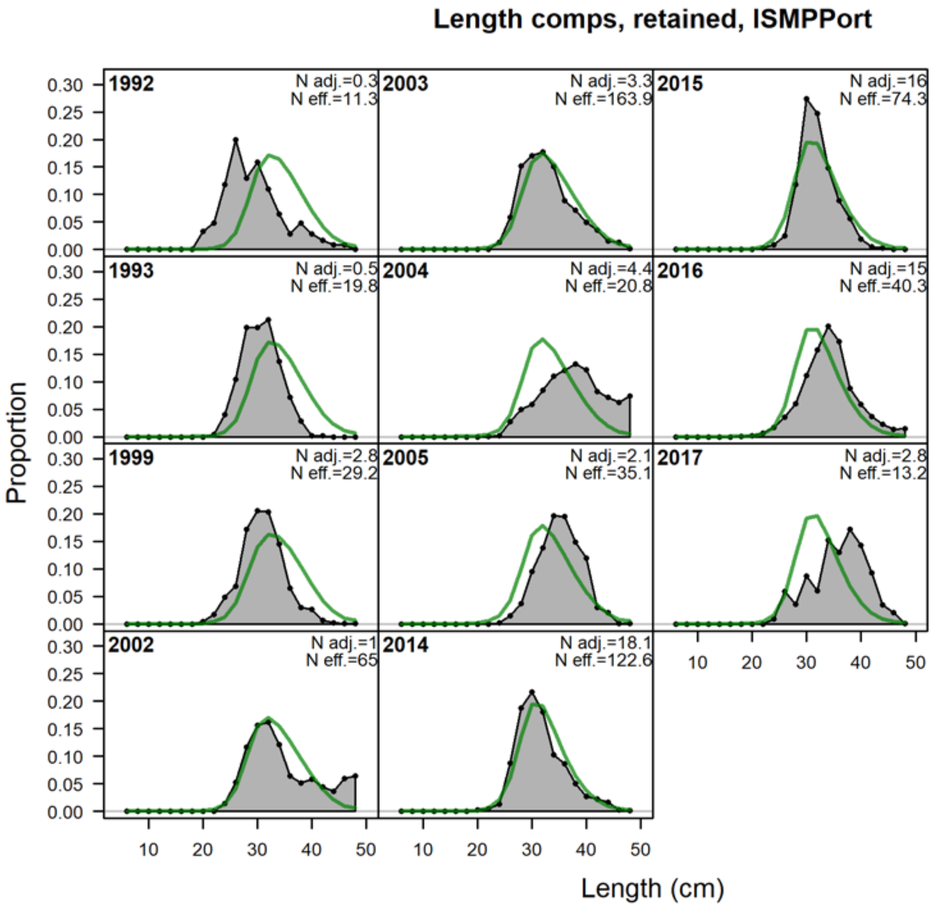

Figure A 9.8. Bight Redfish: Port length composition fits - ISMP Port.

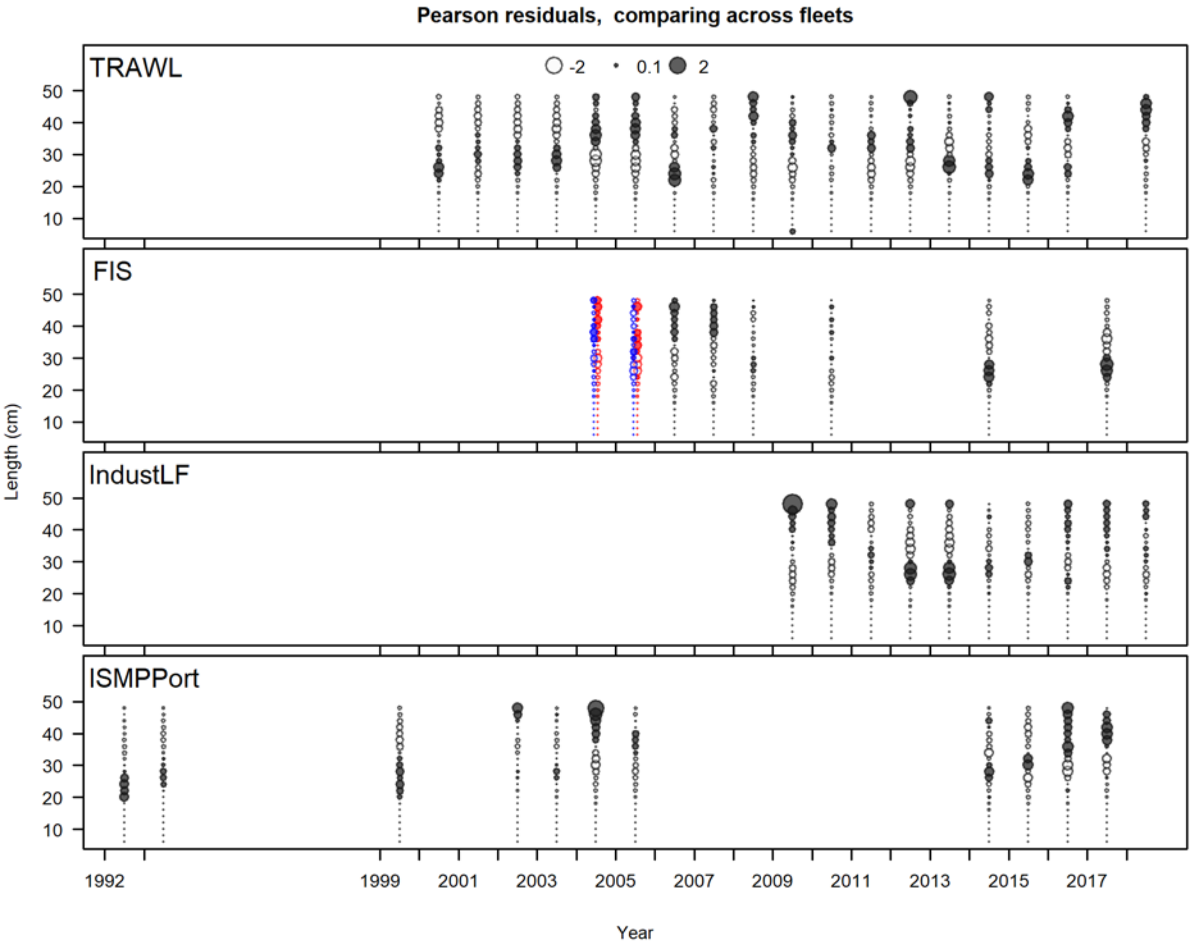

Figure A 9.9. Bight Redfish: Residuals from the annual length compositions (retained) displayed by year and fleet.

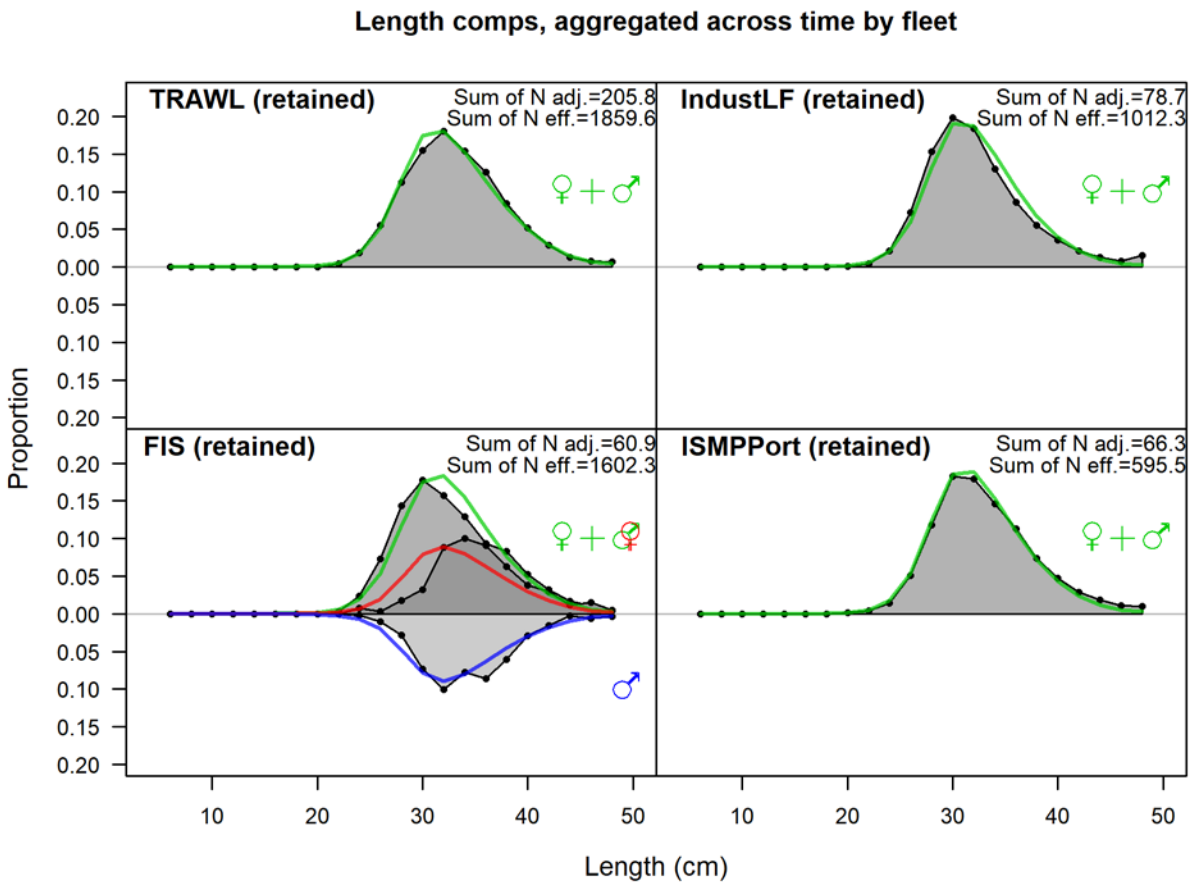

Figure A 9.10. Bight Redfish: Aggregated fits (across all years) to the length compositions displayed by fleet.

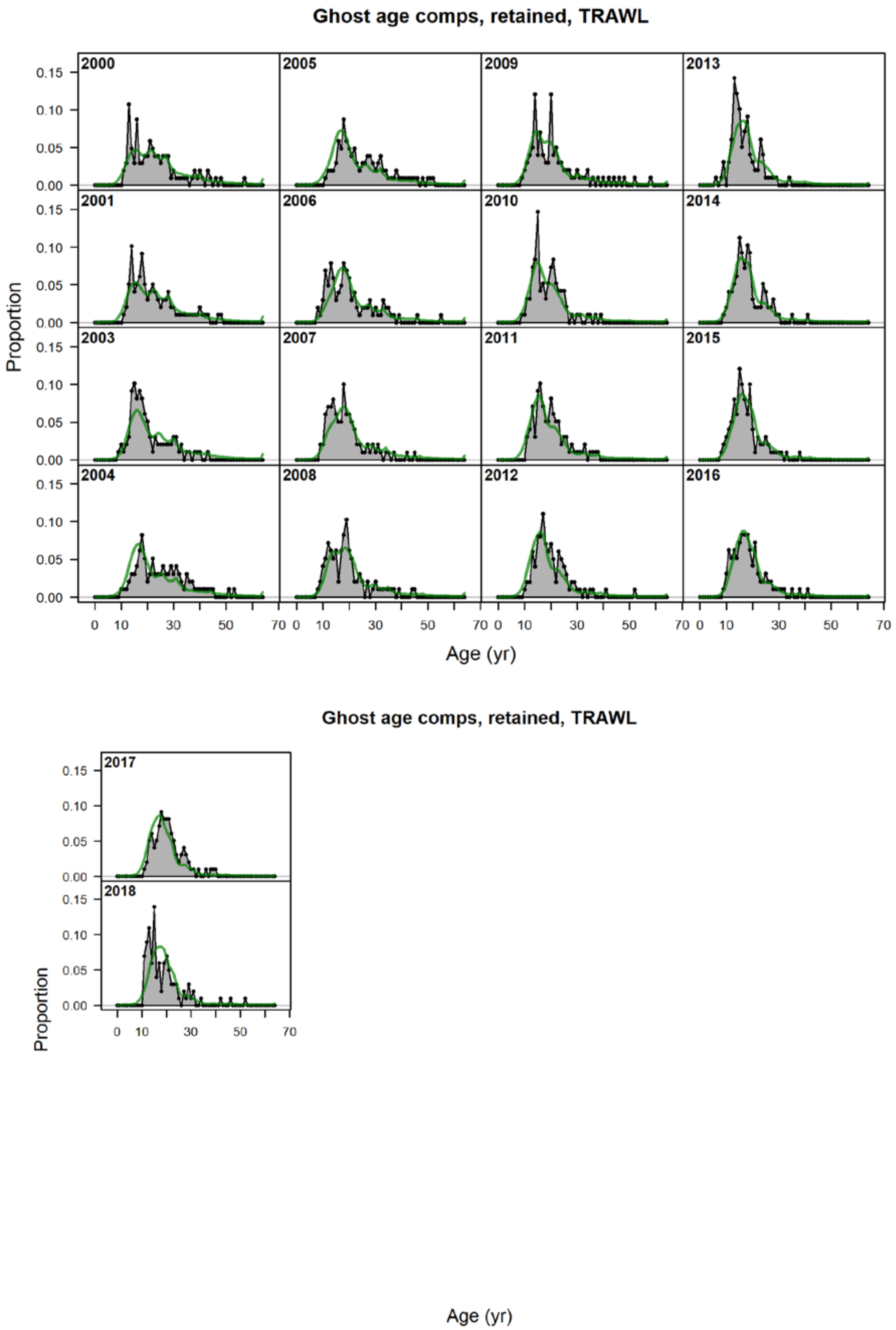

Figure A 9.11. Bight Redfish: Implied fits to age - Trawl onboard (retained).

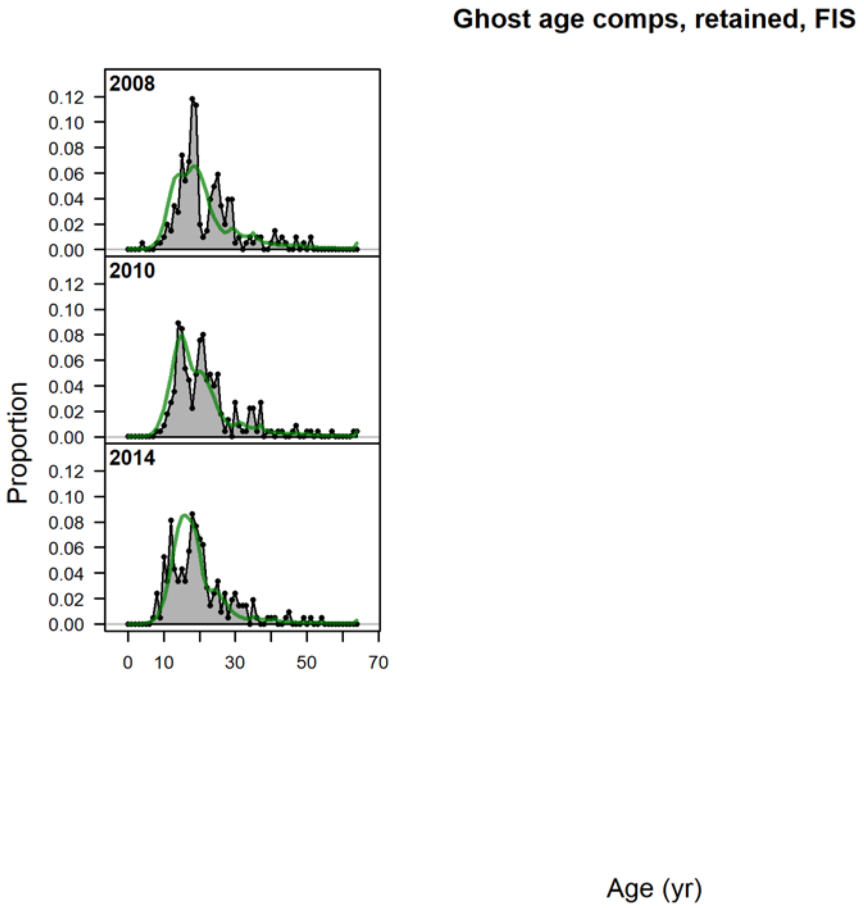

Figure A 9.12. Bight Redfish: Implied fits to age: GAB FIS (retained).

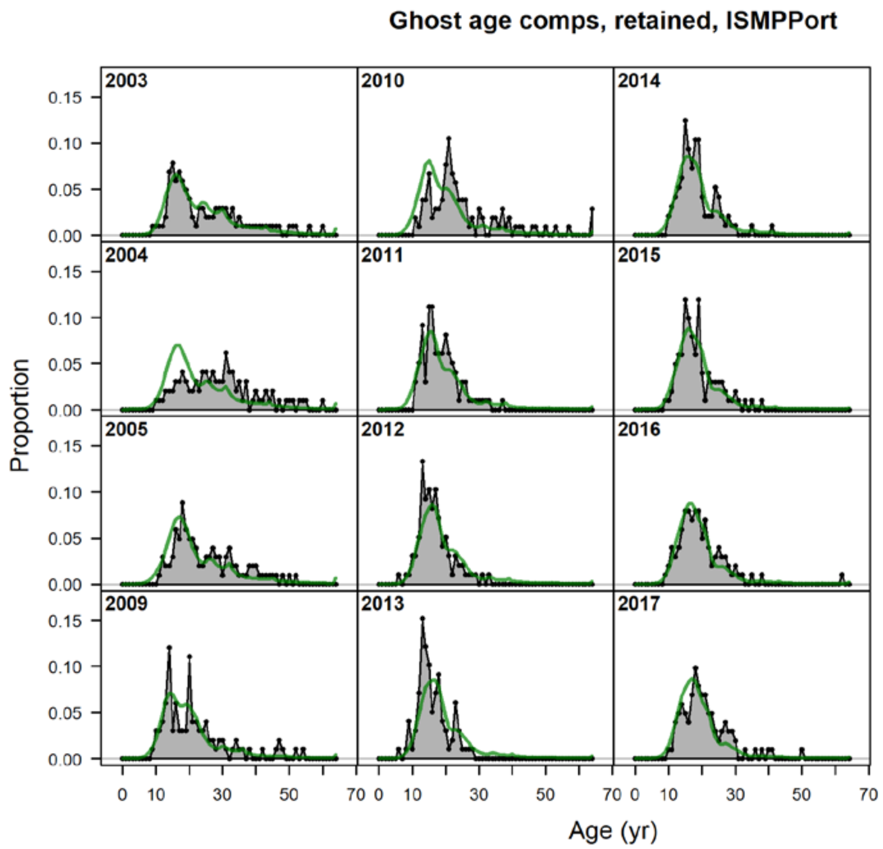

Figure A 9.13. Bight Redfish: Implied fits to age - ISMP Port.

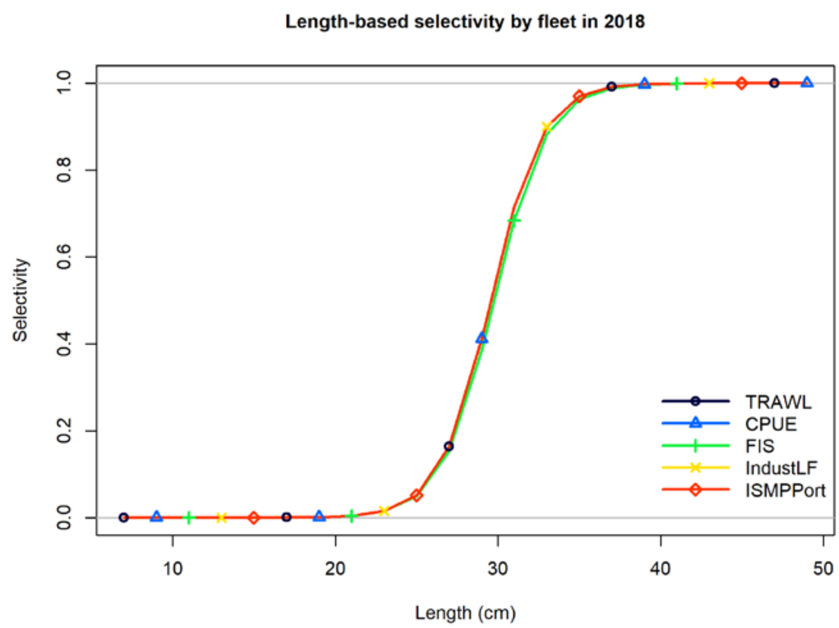

Figure A 9.14. Bight Redfish: Estimated selectivity curves. There are five different selectivity curves, all having the same selectivity.

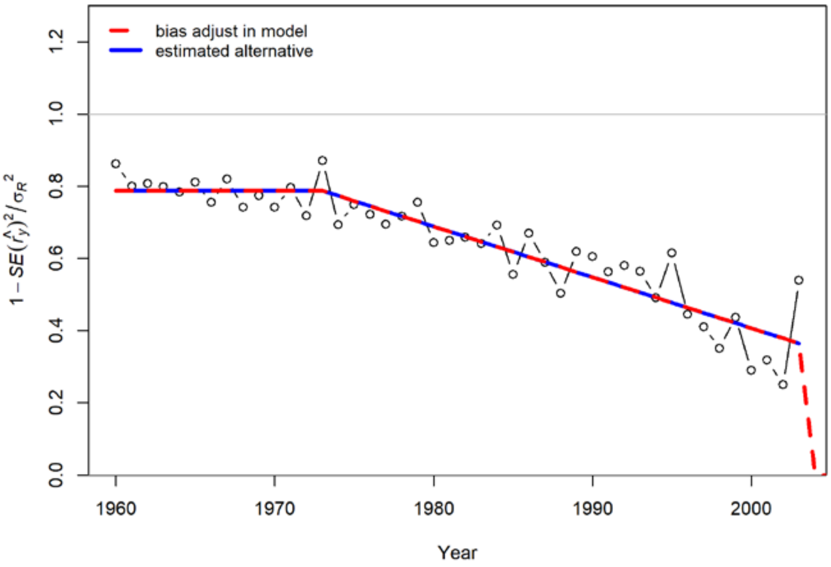

Figure A 9.15. Bight Redfish: Bias ramp adjustment.

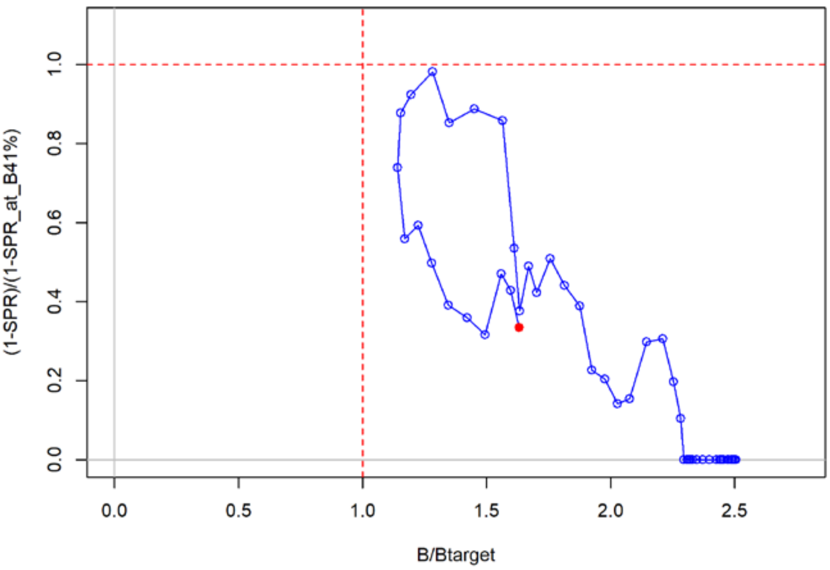

Figure A 9.16. Bight Redfish: Phase plot of biomass vs SPR ratio.