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Redfish (*Centroberyx affinis*) stock assessment based on data up to 2019 – development of a preliminary base case

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Australian Fisheries Management Authority

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Acknowledgments

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Executive summary

This document presents a suggested base case for an updated quantitative Tier 1 Eastern Redfish (*Centroberyx affinis*) assessment for presentation at the first SERAG meeting in 2020. The last full assessment was presented in 2017 (Tuck et. al., 2017). The preliminary base case has been updated with the inclusion of data up to the end of 2019, which entails an additional 3 years of catch, discard, CPUE, length and age data and ageing error updates since the 2017 assessment. This document describes the process used to develop a preliminary base case for Redfish through the sequential updating of recent data to the stock assessment, using the stock assessment package Stock Synthesis (SS-V3.30).

The base case specifications agreed by the SERAG in 2017 were maintained into the preliminary base case presented here.

Results show reasonably good fits to the length data and conditional age-at-length data. Fits to the catch rate data are reasonable but recent years over-estimate observed catch rates. The 2020 preliminary assessment estimates that the projected 2021 spawning stock biomass will be 7.30% of virgin stock biomass (projected assuming 2019 catches in 2020), compared to 7.72% at the start of 2018 from the last assessment (Tuck et. al., 2017). The 2020 base case assessment estimates relative spawning stock biomass was as low as 3.02% in 2015. The reduction in estimated stock status since the 2017 assessment is likely due to continued flat or reduced catch rates since 2017 and no evidence of strong recruitment.

Further development should include models that separate port and onboard lengths by zone. As noted in Tuck et. al. (2017), there are distinct differences between Eastern Bass (EBass) and NSW port lengths. EBass port lengths are considerably larger than NSW port lengths, with ascending limbs beginning at ~10cm for NSW and ~15-20cm for EBass. This appears to be driven by different discard practices, as the distribution of retained fish lengths from the onboard length data are similar for EBass and NSW.

1 Introduction

1.1 2020 Redfish assessment base case

The 2020 preliminary base case assessment of Eastern Redfish uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Version 3.30.16.00, Methot et. al. 2020). The methods utilised in SS are based on the integrated analysis paradigm. SS can allow for multiple seasons, areas and fleets, but most applications are based on a single season and area. Recruitment is governed by a stochastic Beverton-Holt stock-recruitment relationship, parameterized in terms of the steepness of the stock-recruitment function (*h*), the expected average recruitment in an unfished population (R_0), and the degree of variability about the stock-recruitment relationship (σ_r). SS allows the user to choose among a large number of age- and length-specific selectivity patterns. The values for the parameters of SS are estimated by fitting to data on catches, catch-rates, discard rates, discard and retained catch length-frequencies, and conditional age-at-length data. The population dynamics model and the statistical approach used in fitting the model to the various data types are given in the SS technical documentation (Methot, 2005).

The base–case model includes the following key features:

A single region, single stock model is considered, aggregated across zones 10, 20 and 30 (RAG agreed base-case since 2014).

The selectivity pattern for the trawl fleet was assumed to be length-specific and logistic. The parameters of the selectivity function for each fleet were estimated within the assessment. A selectivity pattern is estimated separately from port and onboard length frequency distributions due to large differences between port and onboard length compositions. The length at 50% selectivity for the port fleet was fixed at the value estimated in the 2017 assessment (23.81 cm) in order to ensure convergence and a sensible selectivity function.

The model accounts for males and females separately.

The initial and final years are 1975 and 2019. Previous models (Thomson, 2002; Klaer, 2005; Tuck 2014; Tuck et. al. 2017) used 1975 as the initial year due to the generally perceived poorer quality of data prior to this year. An initial fishing mortality is estimated to account for catches prior to the starting year.

The CVs of the CPUE indices were initially set at a value equal to the standard error from a loess fit (0.26; Sporcic, 2020), before being re-tuned to the model-estimated standard errors within SS.

Discard tonnage was estimated through the assignment of a retention function. This was defined as a logistic function of length, and the inflection and slope of this function were estimated where discard information was available. A retention function was estimated for each ‘block’ period: namely 1975 – 1985 and 1986 – 2019.

Over the period 1975-1985 a logistic retention function is used with a cap less than 1.0 (i.e. larger fish do not reach full retention and can be discarded; fixed at 0.8; Tuck and Day, 2014).

The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The value for M is assumed to be 0.1 y^{-1}.

Recruitment to the stock is assumed to follow a Beverton-Holt stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, *h*. Steepness for the base-case analysis is set to 0.75.

The initial value of the parameter determining the magnitude of the process error in annual recruitment, σ_r, is set to 0.7.

The population plus-group is modelled at age 40 years, as is the maximum age for observations.

Growth is assumed to follow a von Bertalanffy length-at-age relationship, with the parameters of the growth function estimated separately for females and males inside the assessment model.

Retained and discarded onboard length sample sizes were capped at 200, with greater than 100 fish sampled annually required for inclusion in the model. For Sydney Fish Market samples (1975 to 1991) numbers of fish were divided by 10 and capped at 200. For port samples, numbers of trips were used as the sampling unit, with a cap of 100 (which was not reached). The sample size is reduced because the appropriate sample size for length frequency data is probably more closely related to the number of shots (onboard) or trips (port) sampled, rather than the number of fish measured.

The values assumed for some of the (non-estimated) parameters of the base case models are shown in Table 1.

Table 1. Parameter values assumed for some of the non-estimated parameters of the base-case model.

Parameter	Description	Value
M	Natural mortality	0.1
h	"steepness" of the Beverton-Holt stock-recruit curve	0.75
x	age observation plus group	40 years
a	allometric length-weight equations	0.0577 g^{-1}.cm
b	allometric length-weight equations	2.77
l_m	Female length at 50% maturity	19cm

1.2 Bridging from 2017 to 2020 assessments

The previous full quantitative assessment for Redfish was performed in 2017 (Tuck et. al., 2017) using Stock Synthesis (version SS-V3.30.08.04, Methot, 2017). The 2020 assessment uses the current version of Stock Synthesis (version SS-V3.30.16.00, Methot, 2020).

As a first step in the process of bridging to a new model, the data used in the 2017 assessment was used in the new software (SS-V3.30.16.00) using the same data and model structure used in the 2017 assessment. Once this translation was complete, improved features unavailable in SS-V3.30.08 were incorporated into the SS-V3.30.16 assessment. Following this step, the model was re-tuned using the most recent tuning protocols (Pacific Fishery Management Council, 2018), 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 may 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 2017 simply through changes to software and assessment practices. In addition, any catches up to 2017 that were amended since the 2017 assessment are updated.

The subsequent bridging exercise (Bridge 2) then sequentially updates the model with new data through to 2019. These additional data included new catch, discard estimates, CPUE, length composition data, conditional age-at-length data and an updated ageing error matrix. The last year of recruitment estimation was extended to 2015 (from 2012 in Tuck et. al. (2017)). The final step is to re-tune the model.

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.

1.2.1 Bridge 1 results - update to Stock Synthesis SSV-3.30.16.00

The 2017 Redfish assessment was converted to the most recent version of the software, Stock Synthesis version SS-V3.30.16.00. There was a change in the spawning biomass between the start of the timeseries in 1968 (when recruitment deviations are first estimated) and 1974 (when catch data is introduced into the model) (Figure 1). The recruitment over this period also differed with higher recruitment in the new model between 1972 and 1976 before lower recruitment between 1997 and 1981 (Figure 2). These differences can be attributed to incorrect implementation of the retention function in the previous version of Stock Synthesis, which has been subsequently fixed by NOAA staff in recent versions of Stock Synthesis. This change has resulted in improved fits to the length data and the aforementioned changes in spawning biomass and recruitment (Figure 1, Figure 2). These changes have not influenced the estimates of stock status at the end of the time series (Figure 1).

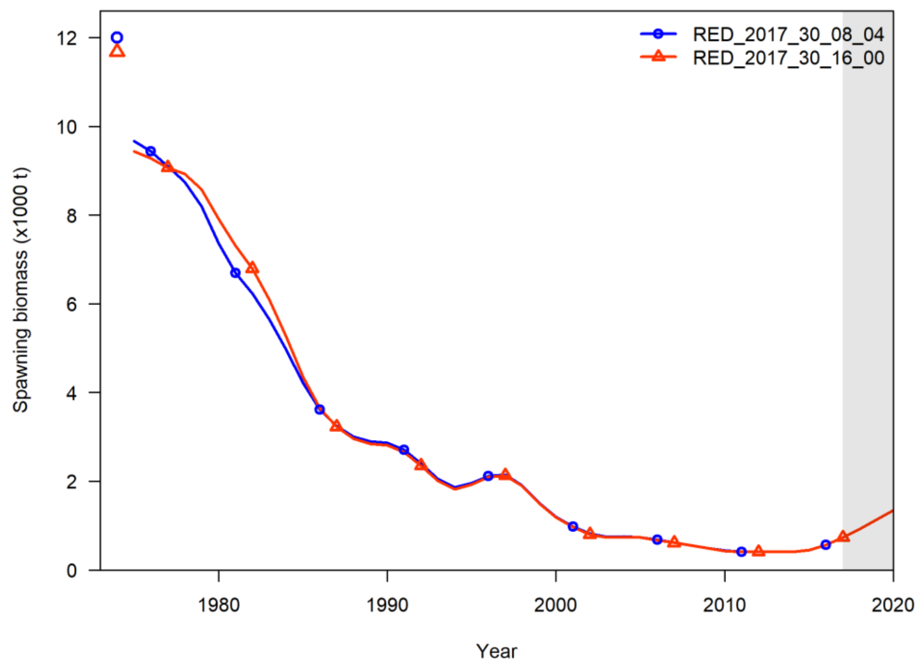


Figure 1. Comparison of the spawning biomass time series for the 2017 assessment (SS3-30.08) and a model converted to SS-V3.30.16. Note that the section shaded in grey indicates a few years of future projections, beyond the period covering data used in the assessment, which stops in 2016.

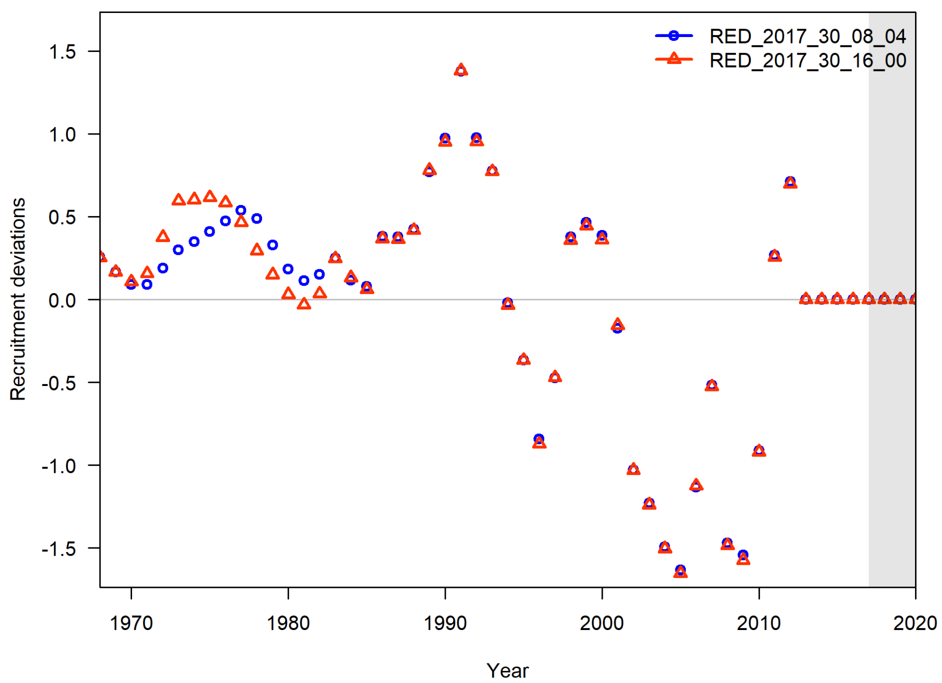


Figure 2. Comparison of the recruitment time series for the 2017 assessment (SS3-30.08) and a model converted to SS-V3.30.16. Note that the section shaded in grey indicates a few years of future projections, beyond the period covering data used in the assessment, which stops in 2016.

New features available in the newer versions of Stock Synthesis, such as allowing smaller lower bounds on minimum sample sizes and estimating additional standard deviation to abundance indices were then incorporated (labelled New2), followed by retuning using the latest tuning protocol (labelled Tuned) (Figure 3). Details of the tuning procedure used are listed in Section 1.2.1. 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 2017. This initial bridging step, Bridge 1, does not incorporate any data after 2016 or any structural changes to the assessment.

When these time series are plotted together, there are some changes resulting from incorporating new features in Stock Synthesis (Figure 3, Figure 4, blue and red lines). These differences are apparent between 1974 and 2000, where biomass is higher in the updated model (Figure 3, Figure 4). The new tuning procedures result in no change to the biomass series (Figure 3, Figure 4, red and green lines).

Fits to the standardised CPUE are not affected by the update in model settings or the tuning procedure (Figure 5). There have been minor changes in some years of recruitment estimates with the new model settings after 1990, however no further changes were observed after tuning (Figure 6).

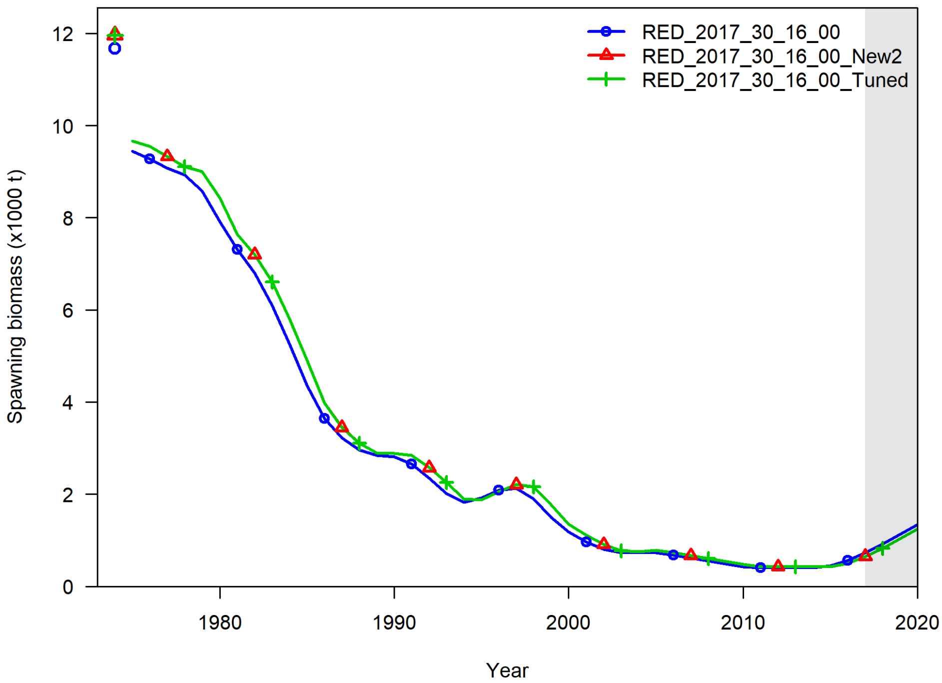


Figure 3. Comparison of the spawning biomass time series for the 2017 assessment updated to the latest Stock Synthesis version (SS-V3.30.16), with new settings applied to the model (New2) and final tuning of the model (Tuned). Note that the section shaded in grey indicates a few years of future projections, beyond the period covering data used in the assessment, which stops in 2016.

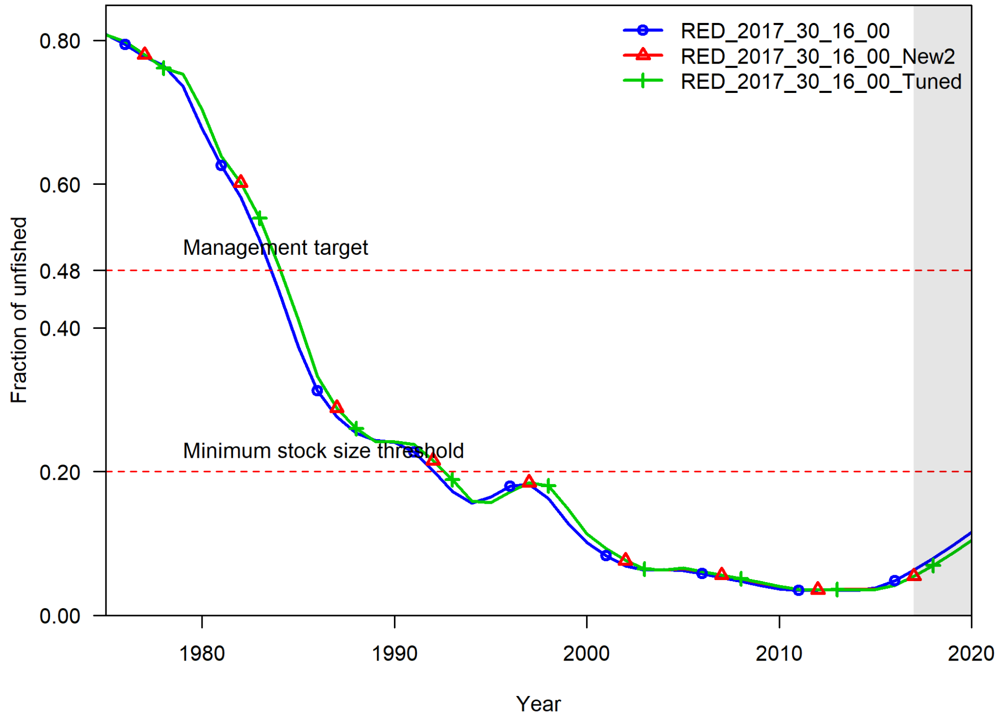


Figure 4. Comparison of the time-series of relative spawning biomass from the 2016 assessment (V3_30.16 – in blue), incorporating new features (New2 – in red), and retuning the model using the latest tuning protocols (Tuned – in green). Note that the section shaded in grey indicates a few years of future projections, beyond the period covering data used in the assessment, which stops in 2016.

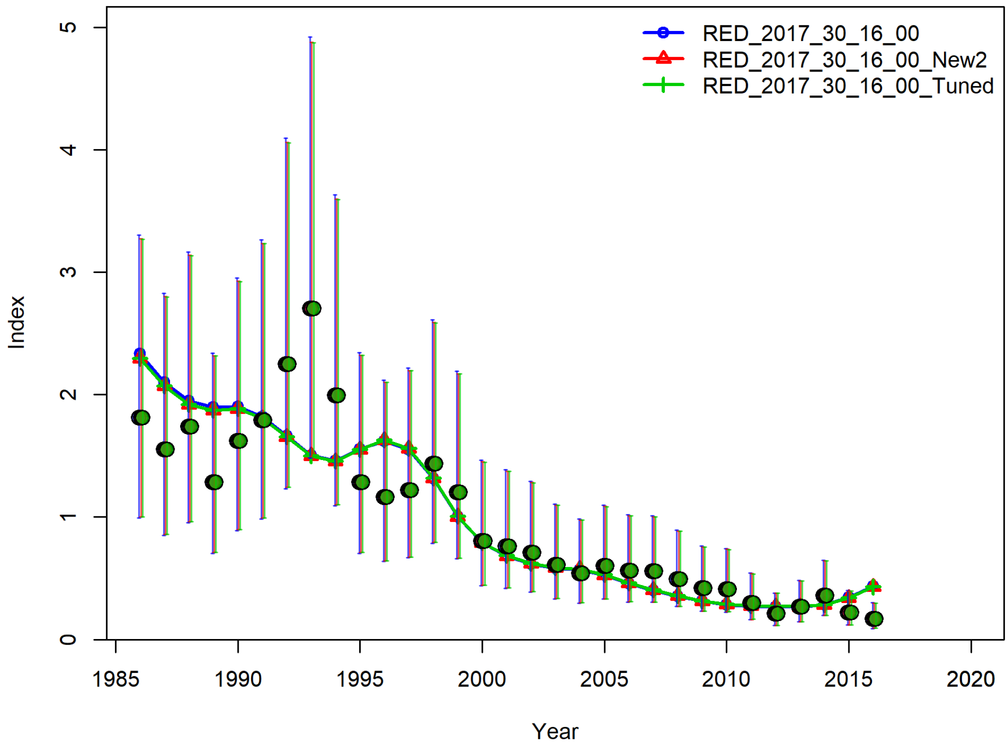


Figure 5. Comparison of the fit to the trawl CPUE index for the 2016 assessment (V3_30.16 – in blue), incorporating new features (New2 – in red), and retuning the model using the latest tuning protocols (Tuned – in green).

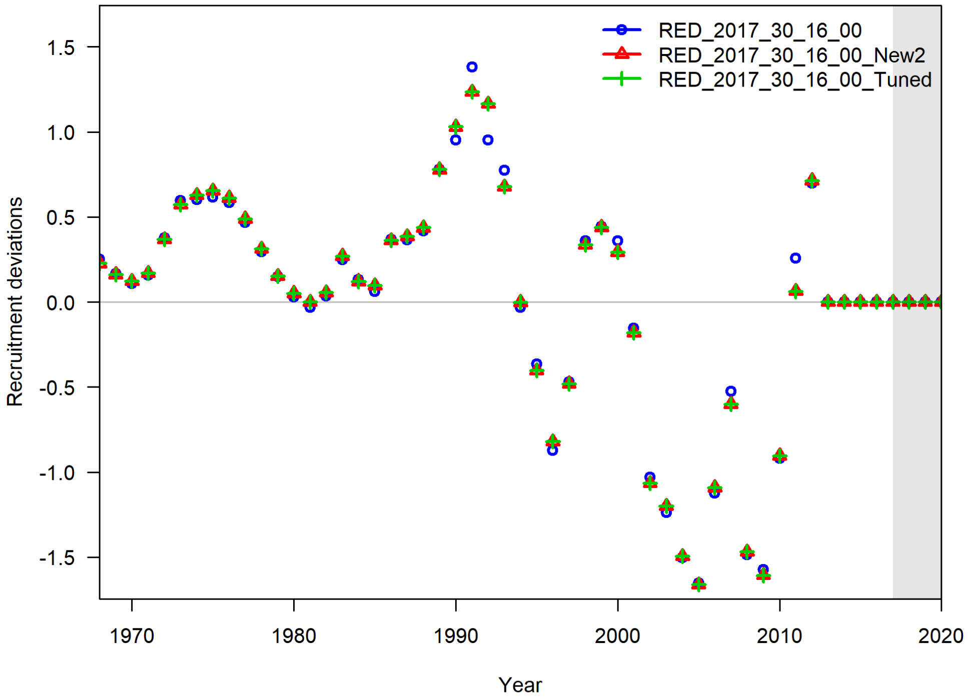


Figure 6. Comparison of the recruitment time series for the 2017 assessment updated to the latest Stock Synthesis version (SS-V3.30.16), with new settings applied to the model (New2) and final tuning of the model (Tuned). Note that the section shaded in grey indicates a few years of future projections, beyond the period covering data used in the assessment, which stops in 2016.

1.2.2 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 underestimate 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.

1.3 Inclusion of new data

The data inputs to the assessment come from multiple sources: length and conditional age-at-length data from the trawl fishery, updated standardized CPUE series (Sporcic, 2020), the annual total mass landed and discard rates, and age-reading error. Data were formulated by calendar year (i.e. 1 Jan to 31 Dec) and were aggregated across all eastern zones (Zones 10, 20 and 30).

Starting from the converted 2017 base case model (labelled RED_2020_Updated), additional and updated data to 2019 were added sequentially to develop a preliminary base case for the 2020 assessment:

1. Change final assessment year to 2019, add catch to 2019 (addCatch2019).
2. Add CPUE to 2019 (from Sporcic (2020)) (addCPUE2019).
3. Add updated discard fraction estimates to 2019 (add_Discards2019).
4. Update length frequency data, including both port and onboard length frequencies (addLengths2019).
5. Add updated age error matrix and age-at-length data to 2019 (addAge2019).
6. Change the final year for which recruitments are estimated from 2012 to 2015 (extendRec2015).
7. Retune using latest tuning protocols, including Francis weighting on length-compositions and conditional age-at-length data (Tuned).

New data included in the model are summarised below.

1.3.1 Catch data

Total annual catches (t) for Redfish have been estimated based on a combination of sources, including Sydney Fish Market (SFM) data (to 1986), NSW and Victorian landings and the SEF logbook data (Table 28 of Rowling (1994); Appendix 1 of Rowling (1999); Table 1 of Thomson (2002); Table 1 of Klaer (2005)). The estimated annual tonnages of landings, discard rates and CPUE are provided in Table 2. Where available, previously agreed catch tonnages from RAGs were used (Rowling, 1999; Klaer, 2005). CDR records and NSW state catch data are used from 2005 for the base-case model. Figure 7 shows a comparison of the agreed total catch (Commonwealth and NSW combined) from the 2017 assessment and the updated catch estimates for the 2020 assessment. Table 2 shows the annual catch values used in the assessment.

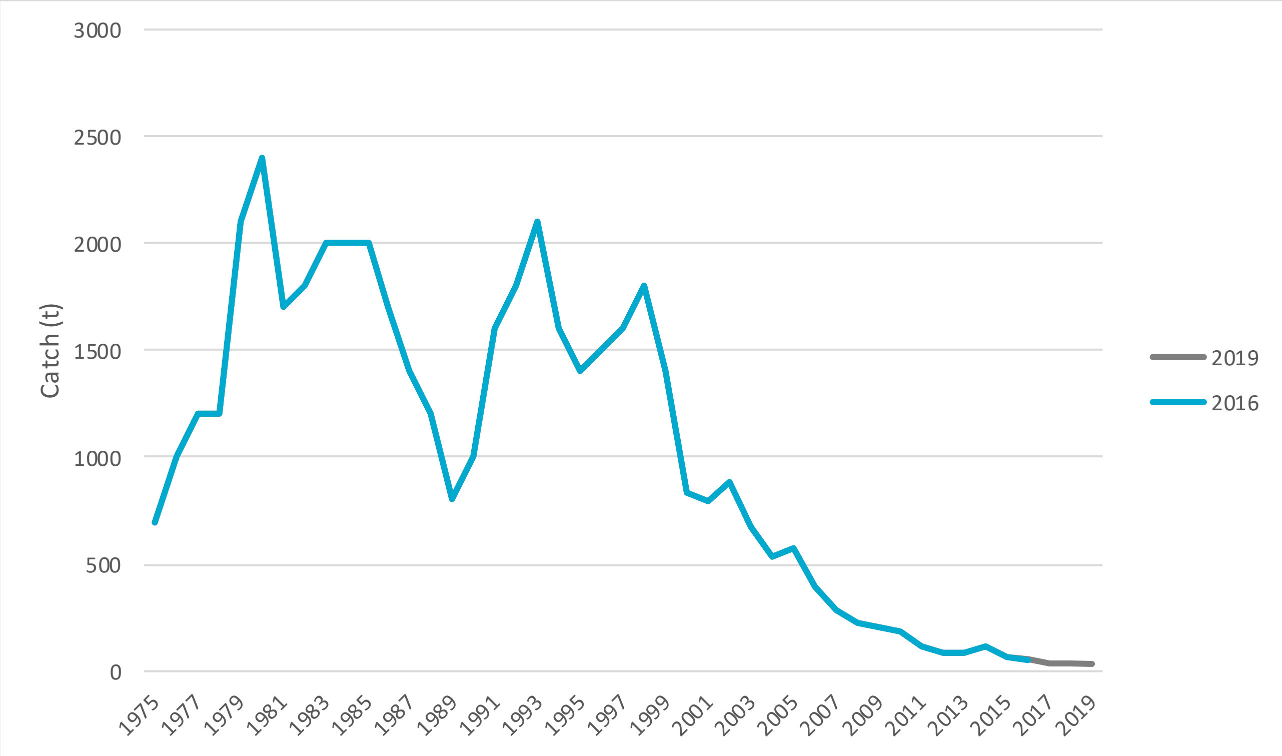


Figure 7. A comparison of total annual catches from the 2017 base case assessment (2016) and the updated catch used in the 2020 assessment (2019).

Table 2. Estimated landings (t), discard rates and standardized CPUE (Sporcic 2020) for Redfish by calendar year. Total catch (Commonwealth and state) for years 1975 to 2004 were taken from previously agreed catch estimates from Redfish assessment group meetings (Rowling, 1999, Appendix 1; Klaer, 2005) and from CDR records for 2005 onwards. Also shown are the NSW state catches from 2005 onwards. State catches exist prior to 2005 but are included in the Redfish assessment group agreed catches (Landings column) until 2004.

Year	Landings (t)	NSW Landings (t)	Total Landings (t)	Discard Rates	CPUE
1975	700		700	0.40	
1976	1000		1000	0.40	
1977	1200		1200	0.40	
1978	1200		1200	0.40	
1979	2100		2100	0.40	
1980	2400		2400	0.30	
1981	1700		1700	0.20	
1982	1800		1800	0.20	
1983	2000		2000	0.20	
1984	2000		2000	0.20	
1985	2000		2000	0.20	
1986	1700		1700	0.20	1.95
1987	1400		1400	0.15	1.67
1988	1200		1200	0.15	1.87
1989	800		800	0.15	1.38
1990	1000		1000	0.10	1.75
1991	1600		1600	0.10	1.93
1992	1800		1800	0.25	2.42
1993	2100		2100	0.588	2.91
1994	1600		1600	0.568	2.15
1995	1400		1400	0.767	1.32
1996	1500		1500	0.265	1.26
1997	1600		1600	0.067	1.32
1998	1800		1800	0.213	1.55
1999	1406		1406	0.046	1.29
2000	835		835	0.131	0.86
2001	794		794	0.375	0.82
2002	880		880	0.580	0.77
2003	677		677	0.327	0.66
2004	538		538	0.398	0.58
2005	533	47	579	0.231	0.65
2006	322	76	398	0.038	0.60
2007	230	54	284	0.124	0.59
2008	201	29	231	0.018	0.52
2009	182	27	210	0.357	0.44
2010	166	22	188	0.120	0.44
2011	99	17	115	0.143	0.32
2012	73	16	89	0.021	0.22
2013	66	17	83	0.261	0.28
2014	96	16	112	0.336	0.38
2015	59	11	70	0.433	0.23
2016	42	10	53	0.362	0.19
2017	26	9	35	0.308	0.19
2018	33	5	37	0.547	0.18
2019	27	7	34	0.472	0.21

1.3.2 Discard rates

Discard rates prior to 1992 are those estimated by the Redfish RAG (Rowling, 1999; Thomson, 2002). Discard rates after 1992 were estimated from on-board data which gives the weight of the retained and discarded component of those shots that were monitored (Thomson and Klaer, 2011). Rowling (1999) provides considerable detail on how the historical discard rates were estimated and the factors that influenced discard practices. Redfish discarding was discussed at a Redfish workshop held in Cronulla in April 1997 and at various open Redfish assessment group meetings during late 1997 and early 1998. The resulting discard rates are documented in Rowling (1999) and also listed in the last Redfish assessment group (Thomson, 2002) and Shelf RAG (Klaer, 2005) assessments of Redfish. Here we update the discard estimates by the addition of on-board estimates through to 2019 (Table 2).

The assessment model allows an estimation of the probability of retention (which is 1 – P(discard)) as a function of length in order to estimate the annual discard rate and any information on discard length composition. It is apparent that the Redfish fishery has undergone numerous changes that may have influenced the behaviour of discarding; these changes are documented in Rowling (1999; Appendix 2). In consultation with K. Rowling (pers. comm.), the following discarding periods have been identified:

1975 – 1985. Market driven discarding

1975 – 1985. Discards largely across all size ranges, but with more small fish discarded

1986 – 2000. Surimi markets period

1986 – 1992. Surimi market. Discarding rates lower, mainly small fish.

1993 – 1995. Quantity of fish sent to surimi market declined, Geelong surimi market closes; consequent increase in discarding.

1996 – 2000. Discarding declined 'as Redfish became less available'. Close of Hacker surimi processor in 2000.

2001 – 2019. Size based discarding period

2001 – 2019. Assume mostly small fish discarded

These changes in discarding behaviour have influenced the large variations in discard rates observed (Table 2), as well as the catches, catch rates and discard length composition. The RAG agreed (2014) base case model allows the retention function to vary according to the identified discard period from 1975 to 1985 (market driven), and from 1986 to 2019 (size driven).

1.3.3 Catch rates

Sporcic (2020) provides the updated catch rate series for Redfish (Table 2; Figure 8). After substantial increases in catch rate in the early and late 1990s, the catch rate has continued to decline since then, and is now less than 10% of levels in 1986. A short-lived increasing trend in catch rate occurred in 2014 but subsequent estimates have either declined or remained stable (Figure 8).

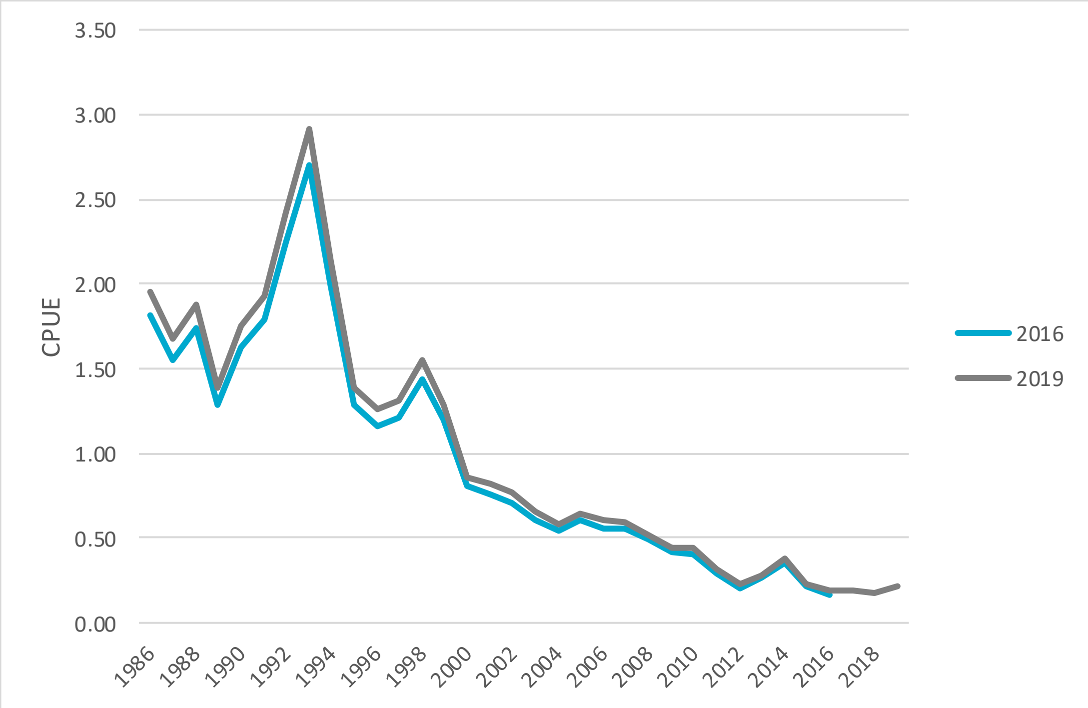


Figure 8. A comparison of the annual catch rates series for redfish between 2016 and 2019.

1.3.4 Length frequencies and age data

Length and age data have been included in the model as length frequency data and conditional age-at-length data by year and sex (when available). Age composition data is included in diagnostic plots but is not used directly within the fitting procedure. Length frequency data were obtained from NSW records of fish measured at the Sydney Fish Markets to 1991. After 1991 length frequencies were obtained from ISMP on-board and port measurements. The observed length and age data are shown in later figures with the corresponding model predicted values. The Kapala length frequencies and Fishery Independent Survey (FIS) abundance indices are not included in the RAG agreed base-case model (Tuck and Day, 2014; Tuck et. al., 2017).

1.3.5 Biological parameters and stock structure assumptions

The assessment assumes that length at 50% maturity is 19cm for females (Thomson, 2002). Natural mortality is assumed to be 0.10y^{-1}. Redfish natural mortality is generally assumed to be in the 0.05 and 0.15y^{-1} range (SEFAG, 2000). Morison and Rowling (2001) calculated natural mortality values between 0.07 and 0.11y^{-1}. Steepness is assumed to be 0.75. Parameters for the length weight relationship were taken from Klaer (2005; also used by Thomson, 2002). Growth parameters, including the von Bertalanffy growth parameter *k*, are estimated (Thomson, 2002). Data were formulated by calendar year (i.e. 1 Jan to 31 Dec) and were aggregated across all eastern zones

(Zones 10, 20 and 30), as sufficiently strong evidence to suggest a north-south split did not exist (Shelf RAG agreement, September 2014; Haddon, 2014). The 2019 base case model structure follows the RAG agreed base case from 2017 (Tuck et. al., 2017).

1.3.6 Age-reading error

Standard deviations for aging error by reader have been estimated, producing the age-reading error matrix of Table 3 (P. Burch, pers. comm.).

Table 3. The standard deviation of age reading error.

Age	Expected Age	SD	Age	Expected Age	SD
0	0.5	0.244577	21	21.5	0.979434
1	1.5	0.244577	22	22.5	1.0126
2	2.5	0.284775	23	23.5	1.04544
3	3.5	0.324588	24	24.5	1.07797
4	4.5	0.364019	25	25.5	1.11019
5	5.5	0.403073	26	26.5	1.1421
6	6.5	0.441753	27	27.5	1.1737
7	7.5	0.480063	28	28.5	1.205
8	8.5	0.518006	29	29.5	1.236
9	9.5	0.555585	30	30.5	1.26671
10	10.5	0.592805	31	31.5	1.29712
11	11.5	0.629668	32	32.5	1.32724
12	12.5	0.666178	33	33.5	1.35707
13	13.5	0.702339	34	34.5	1.38661
14	14.5	0.738154	35	35.5	1.41587
15	15.5	0.773625	36	36.5	1.44486
16	16.5	0.808757	37	37.5	1.47356
17	17.5	0.843552	38	38.5	1.50199
18	18.5	0.878015	39	39.5	1.53015
19	19.5	0.912147	40	40.5	1.55804
20	20.5	0.945953			

1.3.7 Bridge 2 results – inclusion of new data

Inclusion of the new data resulted in a series of changes to the estimates of recruitment and the time-series of absolute and relative spawning biomass (Figure 9 to Figure 11). The inclusion of new catch data makes little difference to the time series of abundance. The most important changes are the inclusion of updated CPUE data, with this having the largest impact on the spawning and relative biomass in recent years (Figure 9, Figure 10). The addition of length data, age data, extending recruitment deviations and tuning had small, incremental effects on population size estimates between 1974 and 2000 (Figure 9, Figure 10). Extending the recruitment to 2015 led to a peak of above average recruitment in 2012, which was also observed in the last year of recruitment estimation in the previous assessment. This late recruitment spike in the 2017 assessment has subsequently been revised to below average with the inclusion of additional data (Tuck et. al. 2017, Figure 11). While the most recent recruitment (2015) is well estimated, it should be treated with some caution as it is possible for future data to result in modifications to estimates of recent recruitment events.

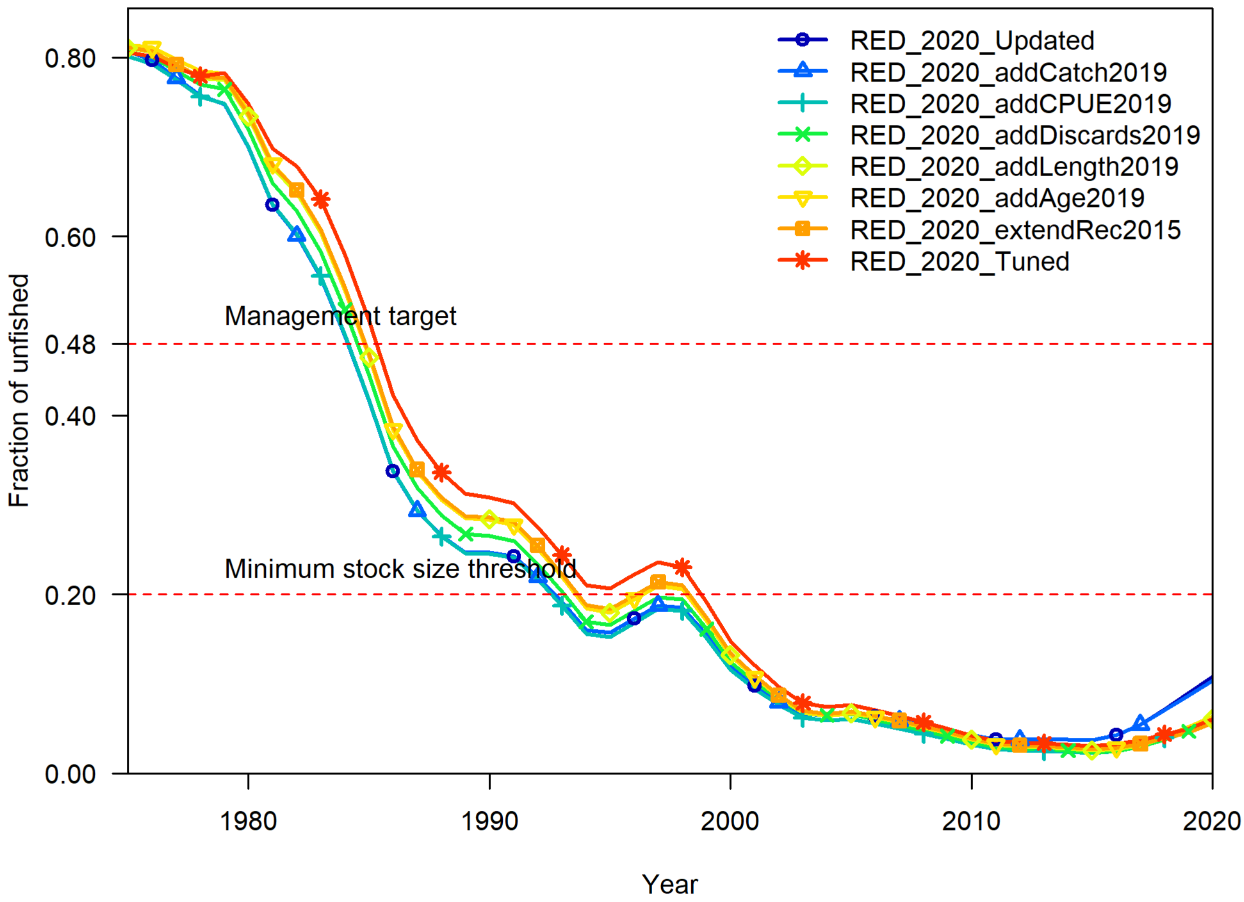


Figure 9. Comparison of the time series of relative spawning biomass for the updated 2020 assessment model converted to SS-V3.30.16 (RED_2020_Updated - blue) with various bridging models leading to a proposed 2020 base case model (RED_2020_Tuned - red).

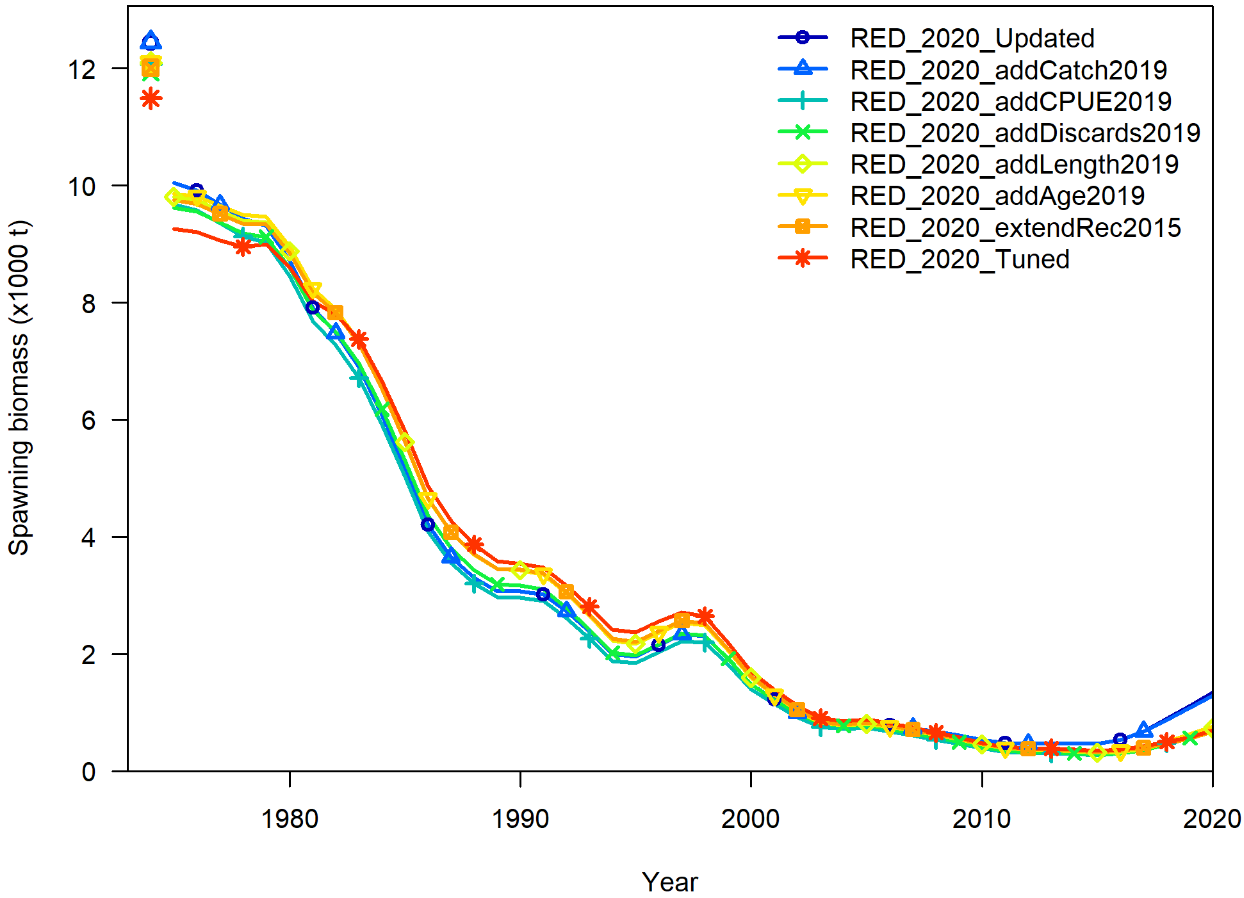


Figure 10. Comparison of the time series of spawning biomass for the updated 2020 assessment model converted to SS-V3.30.16 (RED_2020_Updated - blue) with various bridging models leading to a proposed 2020 base case model (RED_2020_Tuned - red).

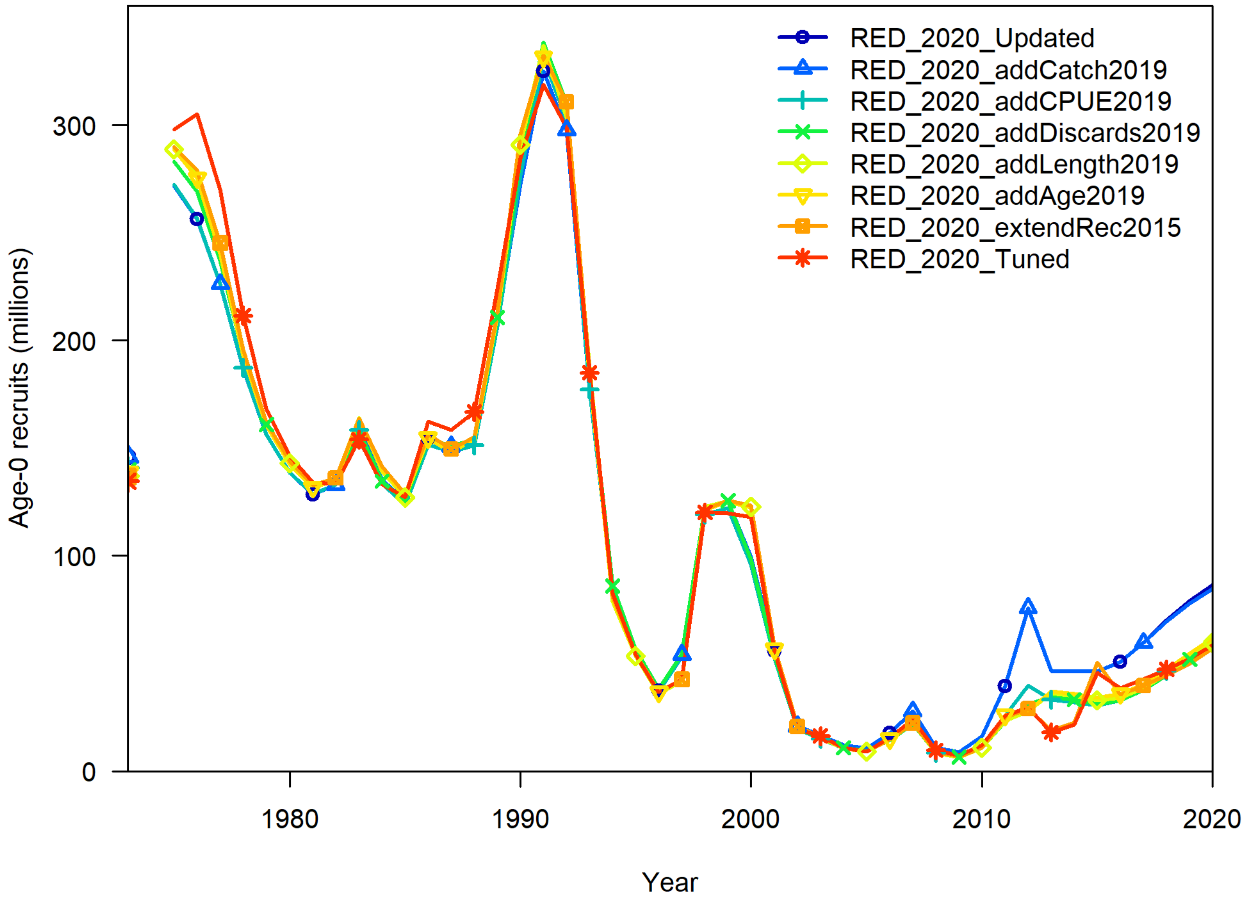


Figure 11. Comparison of the time series of recruitment from the updated 2020 assessment model converted to SS-SS-V3.30.16 (RED_2020_Updated - blue) with various bridging models leading to a proposed 2020 base case model (RED_2020_Tuned - red).

Fits to the trawl CPUE (Figure 12) change with the inclusion of the new CPUE data (RED_2020_addCPUE2019, light blue). In all cases the model is not able to fit the low CPUE values at the end of the timeseries (Figure 12).

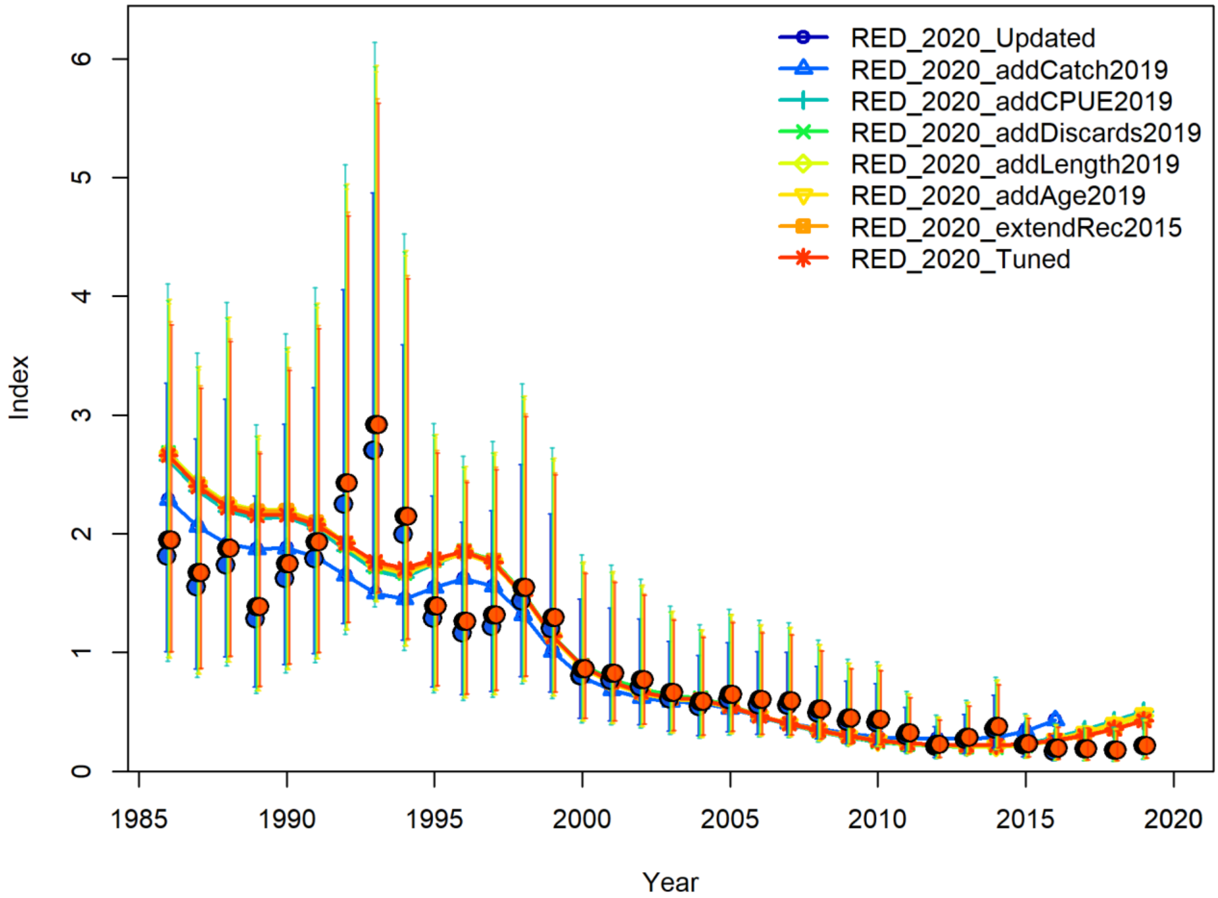


Figure 12. Comparison of the fit to the trawl CPUE index for the updated 2020 assessment model converted to SS-V3.30.16 (RED_2020_Updated - blue) with various bridging models leading to a proposed 2020 base case model (RED_2020_Tuned - red).

1.4 Likelihood profiles

Likelihood profiles are a standard component of the toolbox of applied statisticians and they are most often used to obtain a 95% confidence interval for a parameter of interest (Punt 2018). Many stock assessments "fix" key parameters such as *M* and *h* 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).

The likelihood profile for stock recruitment steepness (*h*) suggests there is little information in the model that can would inform estimation of this parameter (fixed at 0.75 in the model, Figure 13). There is conflict in the data inputs, with this driven by recruitment and to a lesser extent CPUE and length data, which suggest a lower value of *h* is preferable, while discard and age data suggest higher values are more appropriate (Figure 13).

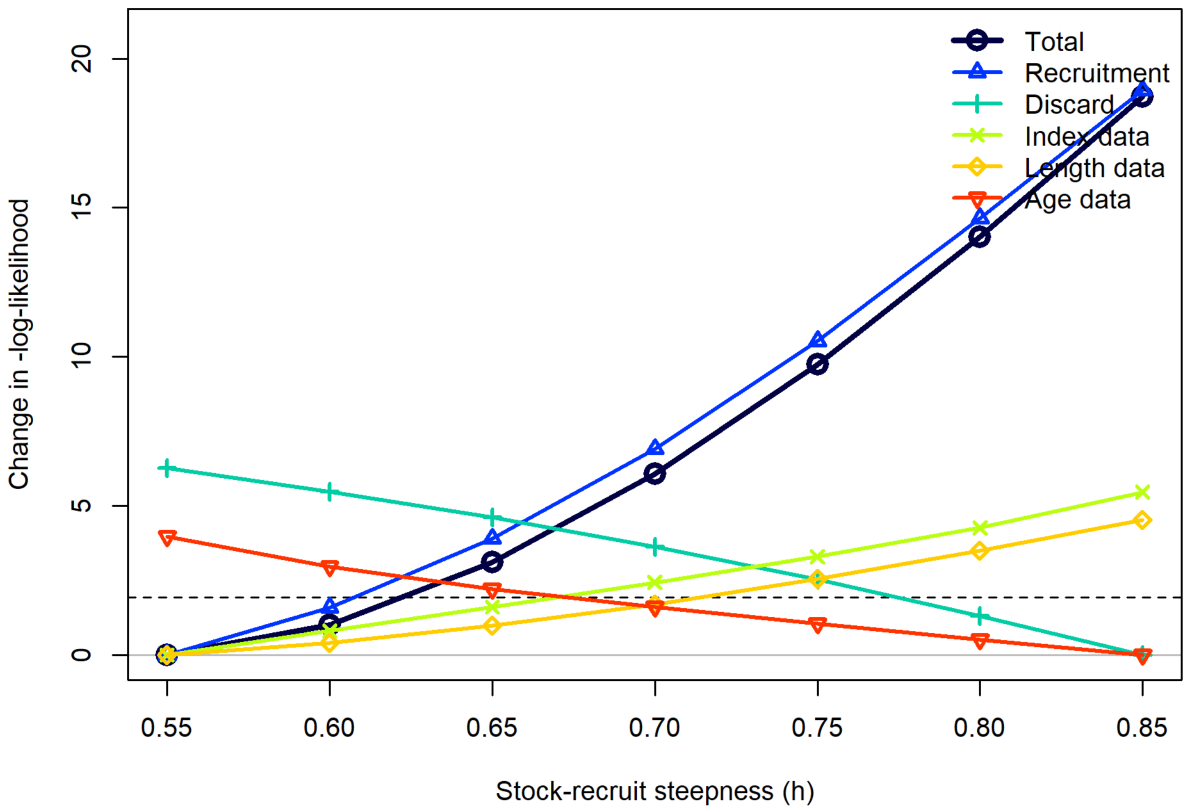


Figure 13. The likelihood profile for stock recruitment steepness (h), with *h* ranging from 0.55 to 0.90. The fixed value for *h* is 0.75.

A likelihood profile for 1974 spawning biomass (SSB_{1974}) at the start of the assessment timeseries is shown in Figure 14. This profile is not the virgin SSB as an initial depletion is estimated at the start of the assessment. Figure 14 displays the total likelihood shown in black and components of the total likelihood from different data sources shown in a range of colours. SSB_{1974} is a derived parameter which is linked to the estimated parameters R_0, which is the average equilibrium recruitment. To construct a likelihood profile on SSB_{1974} requires setting up an additional "fleet" with a single data point (in 1975) 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 7,500 and 11,500t with the most likely value at around 9,250t (Figure 14). The index, discard and age data suggest higher SSB_{1974} while length and recruitment data suggest lower SSB_{1974} (Figure 14).

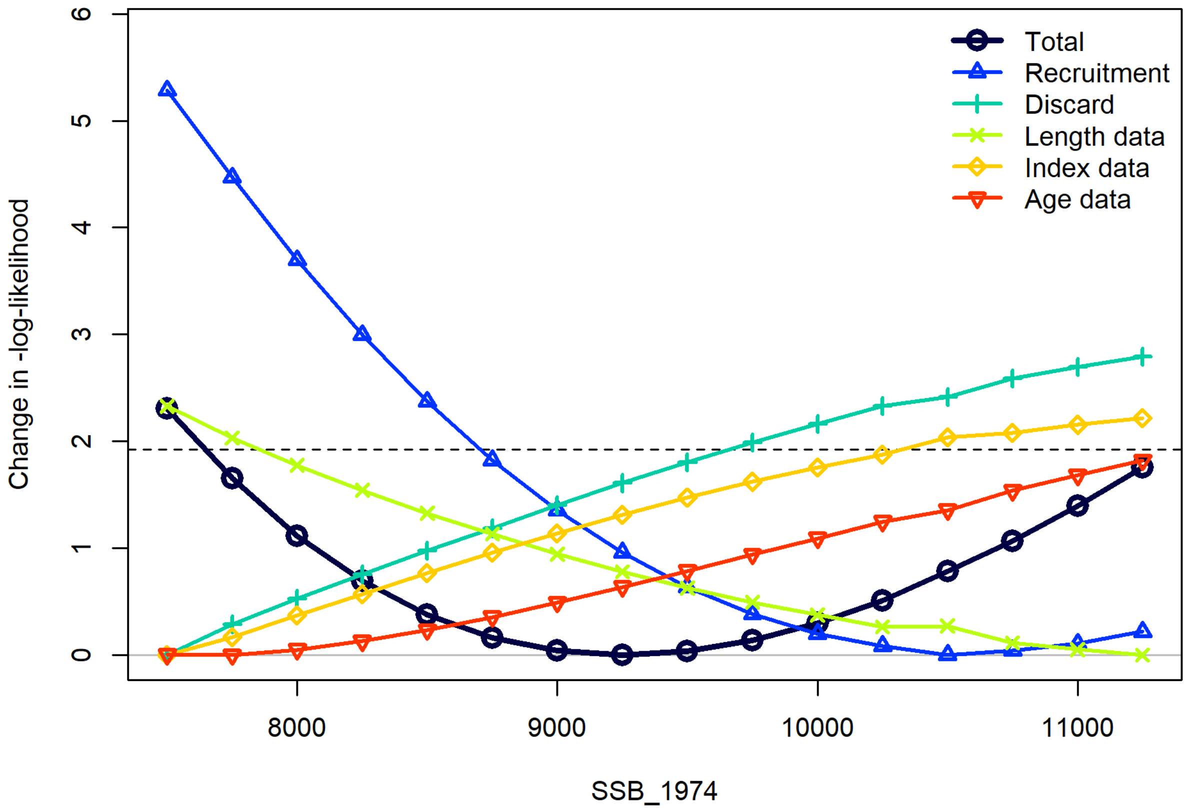


Figure 14. The likelihood profile for virgin spawning biomass in 1974, with SSB_{1974} ranging from 7,500 to 11,500t. The estimated value for SSB_{1974} is 8,781t.

Likelihood profiles for natural mortality (M), current spawning stock biomass (SSB_{2019}) and depletion would provide further insight of the confidence intervals surrounding these parameters and current depletion levels.

1.5 Retrospectives

A retrospective analysis was completed, starting from the most recent year of data, working backward in time and removing 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 15, with the data after 2019 removed initially (shown in light blue), then successive years of data removed back to 2015 (shown in red). The same analysis is plotted in terms of relative spawning biomass in Figure 16. In both cases the changes are minor with a slightly larger population estimated with each successive year of data removed (Figure 15, Figure 16).

When this retrospective analysis is applied to the recruitment time series (Figure 17), the more recent data results in a downward revision to the recruitment estimate in 2013. This recruitment is first estimated in the retrospective to 2015 (which corresponds to the data used in the 2016 assessment, shown in yellow), and this revision downwards is supported by data in 2016, 2017 and 2018. The first estimate of the 2013 recruitment is made in the 2016 retrospective (green) and is well below average. This estimate of 2013 recruitment is revised further downwards when data from 2017 and 2018 is added.

These retrospective analyses reveal that there is a systematic revision of recruitment deviations downward at the end of the time series as new data is incorporated. This down weighting suggests that the 2015 recruitment deviation that is the first above the average level of recruitment since 2000 will likely be down weighted to below average with the inclusion of more data in the future. This trend warrants further investigation.

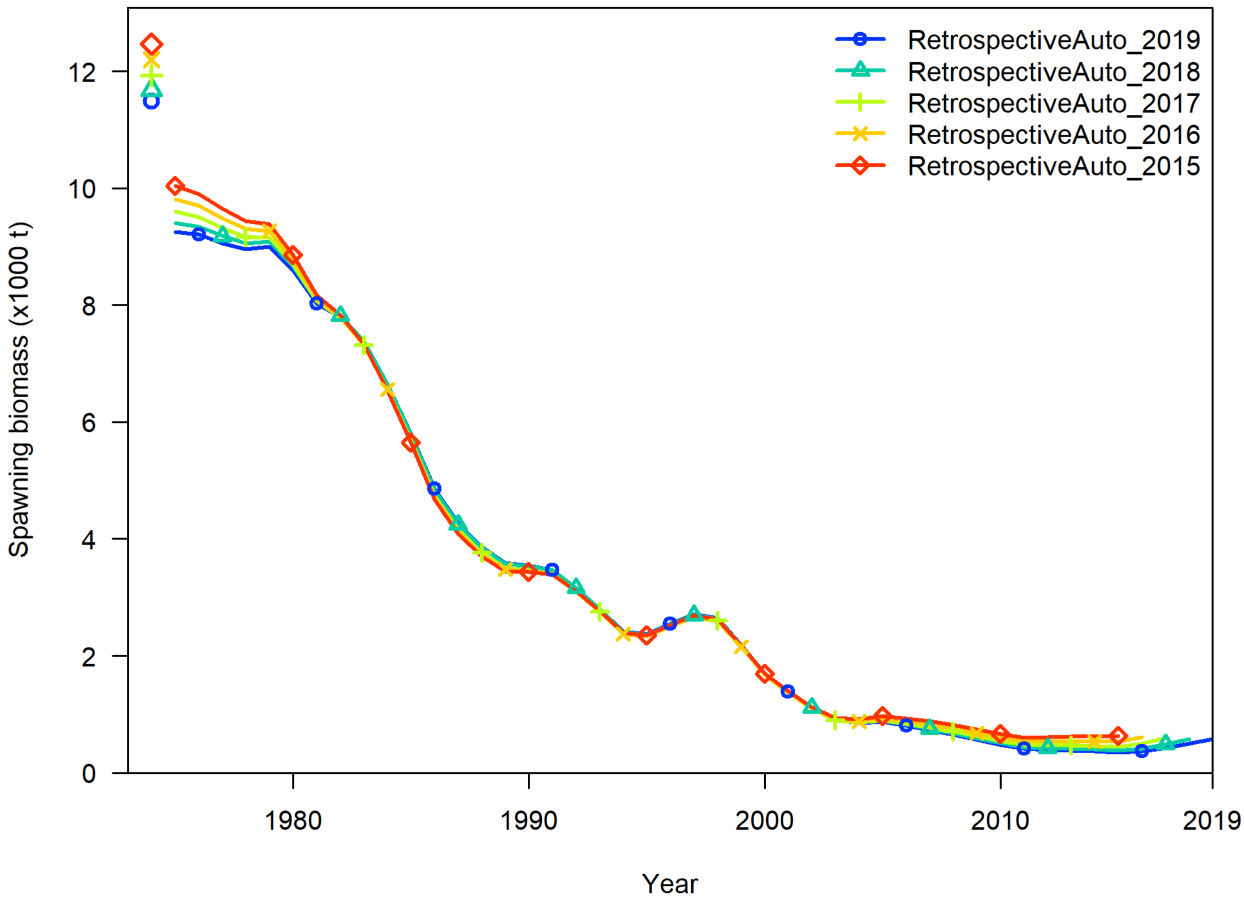


Figure 15. Retrospectives for absolute spawning biomass for Redfish, with data included to 2019 (blue) and then successive years removed back to 2015 (red).

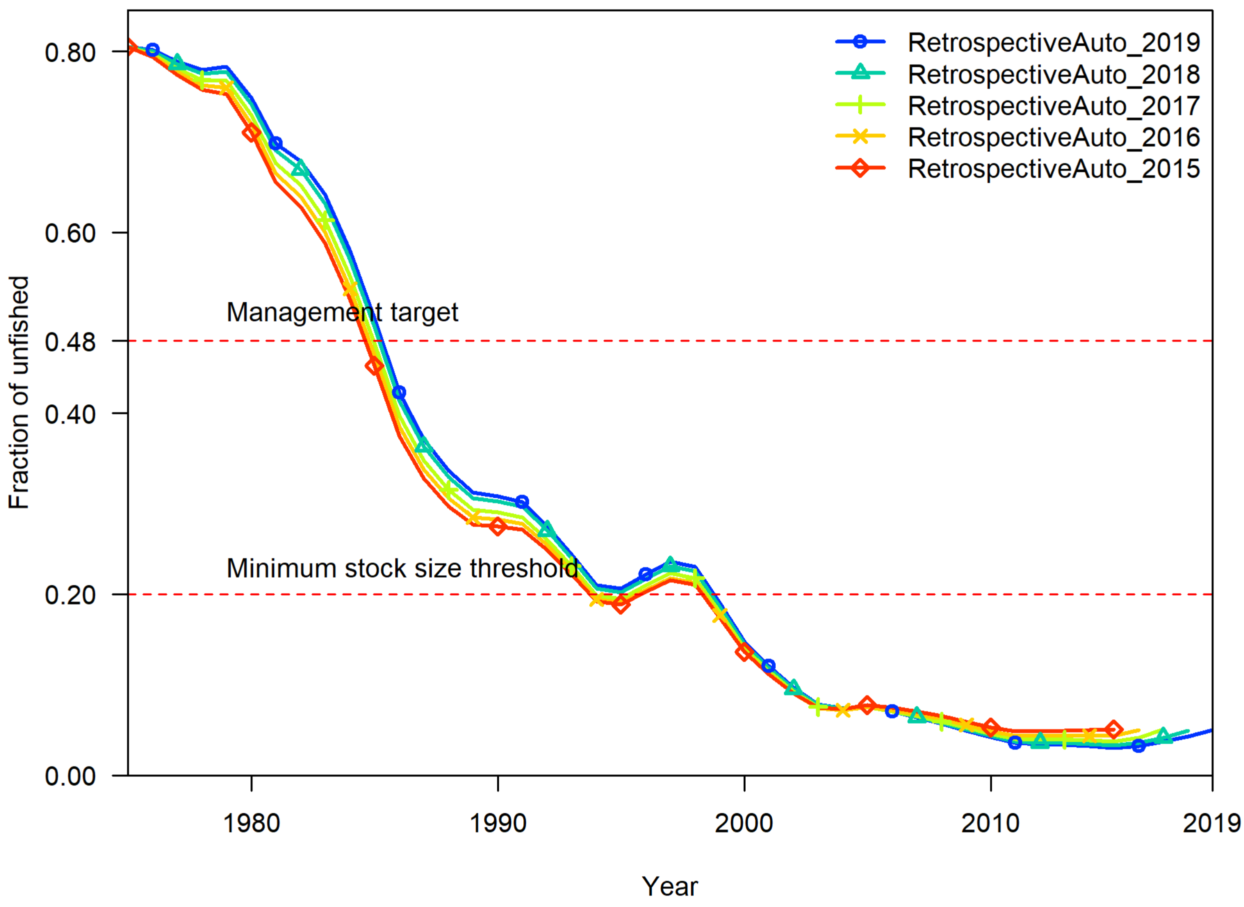


Figure 16. Retrospectives for relative spawning biomass for Redfish, with data included to 2020 (blue) and then successive years removed back to 2015 (red).

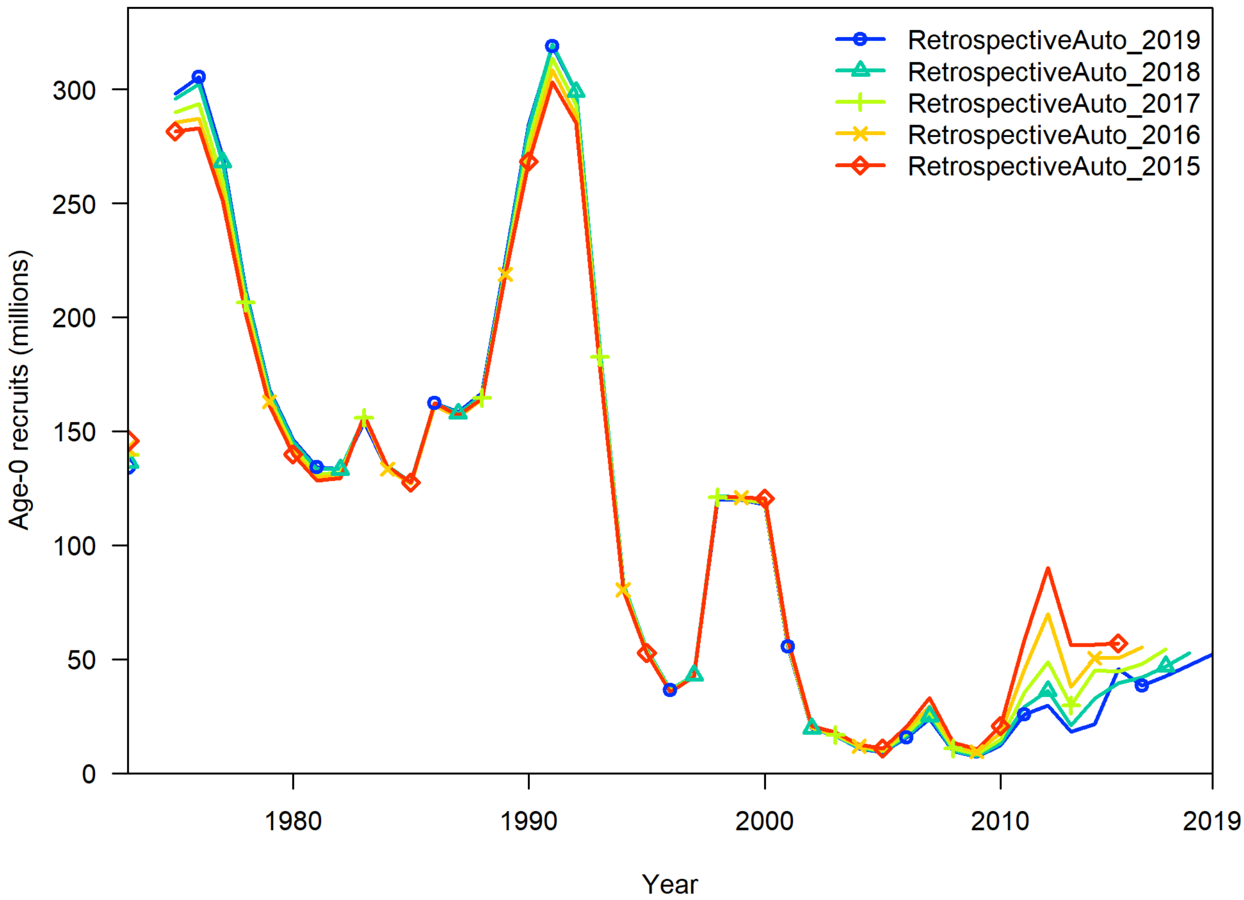


Figure 17. Retrospectives for recruitment for Redfish, with data included to 2019 (blue) and then successive years removed back to 2015 (red).

1.6 Future sensitivities

Standard sensitivities to the base-case will be conducted for the next SERAG meeting. These include alternative values for natural mortality, steepness, and varying the weights on age, length and index data. In addition, models that attempt to account for the differences in port and onboard data should be explored. Initially, a model with a single selectivity will be considered. Given the observed differences in port and onboard data, this is unlikely to provide a good fit to the length data (Figure 18, Figure 19). However, having a single selectivity associated with a single gear-type is generally the accepted model structure for selectivities. The base case for the Redfish model has two selectivities, one for port and one for onboard due to the issues identified with models trying to fit to the two length data sources. A more appropriate model structure to explore would include a single selectivity for trawl, with alternative retention functions for Eastern Bass and NSW to account for the difference in port data observed between the zones.

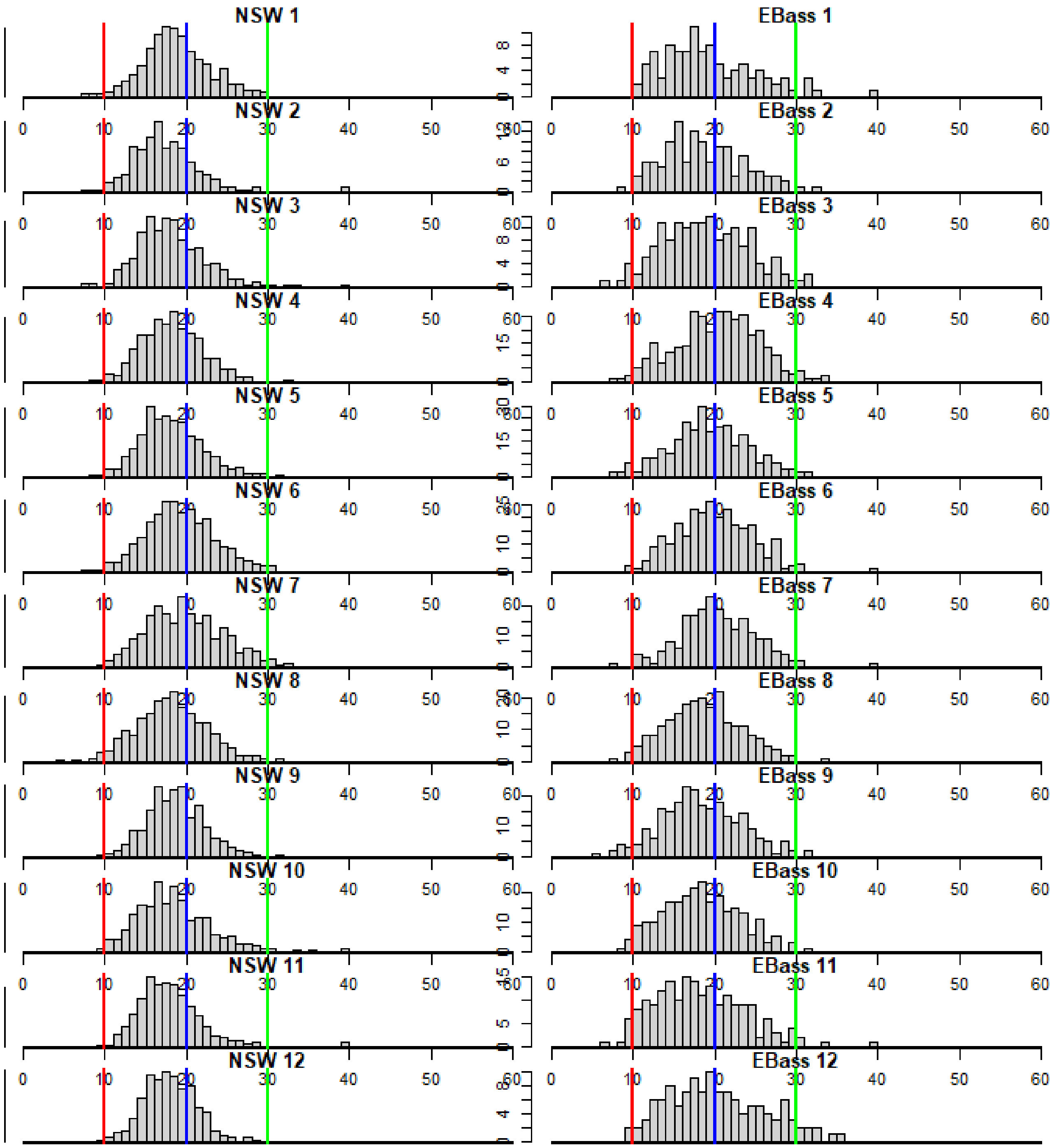


Figure 18. Onboard (retained and discard) length distributions of redfish by month and zone (NSW and Eastern Bass). Red (10cm), Blue (20cm) and Green (30cm).

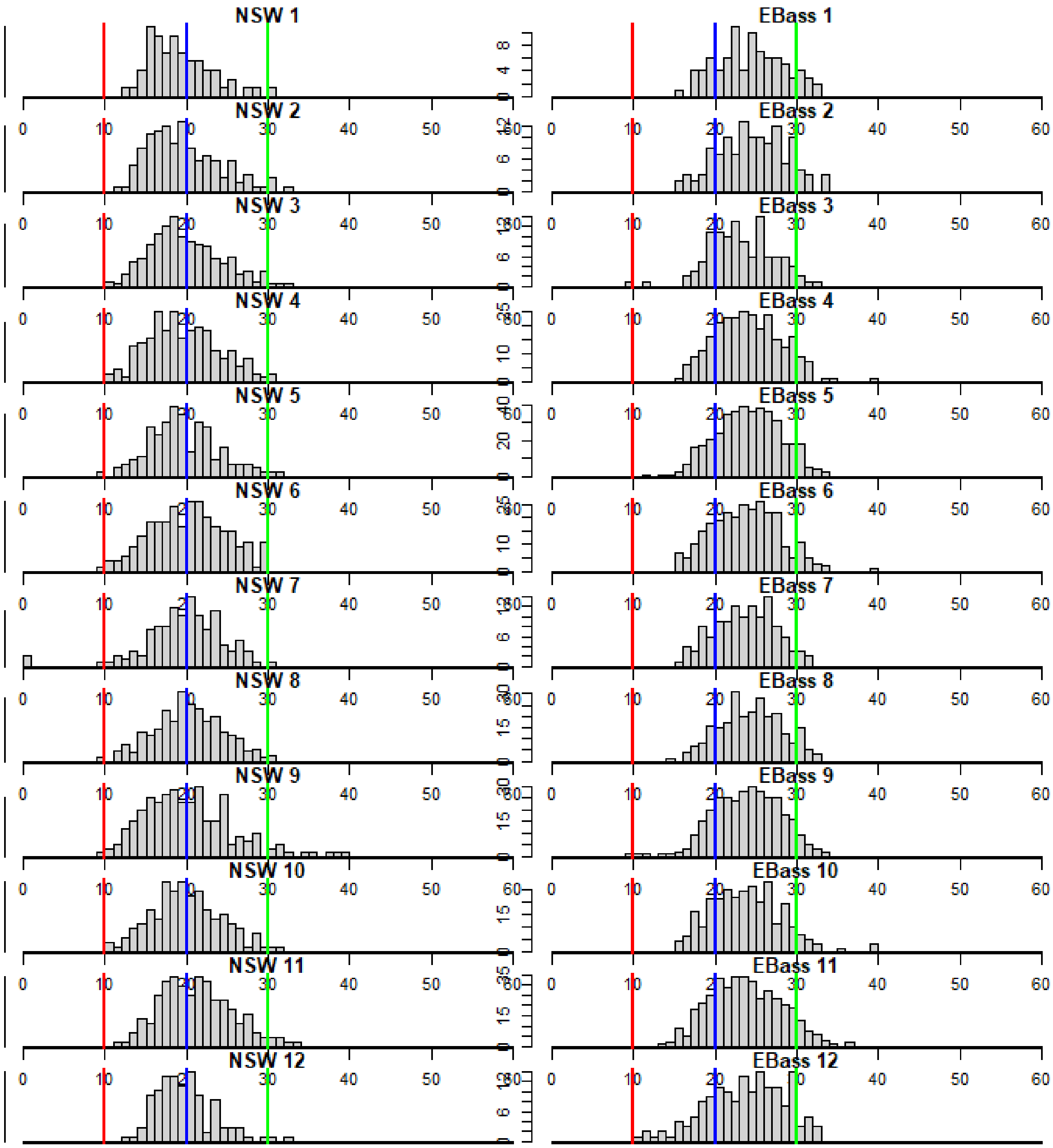


Figure 19. Port length distributions of redfish by month and zone (NSW and Eastern Bass). Red (10cm), Blue (20cm) and Green (30cm).

1.7 The 2020 preliminary base case

The base case specifications agreed by SERAG in 2017 are maintained into the 2020 preliminary base case presented here.

Results show reasonably good fits to the length data and conditional age-at-length data (Appendix). Recent fits to the catch rate data show on over-estimation compared to observed catch rates. Issues to note include that there is considerable difference between the port and onboard retained length frequencies, with the mode of port lengths generally larger than onboard lengths (Appendix, Figure A.5). The 2020 preliminary assessment estimates that the projected 2021 spawning stock biomass will be 7.30% of virgin stock biomass (projected assuming 2019 catches in 2020; Figure 21), compared to 7.72% at the start of 2017 from the last assessment (Tuck et. al., 2017).

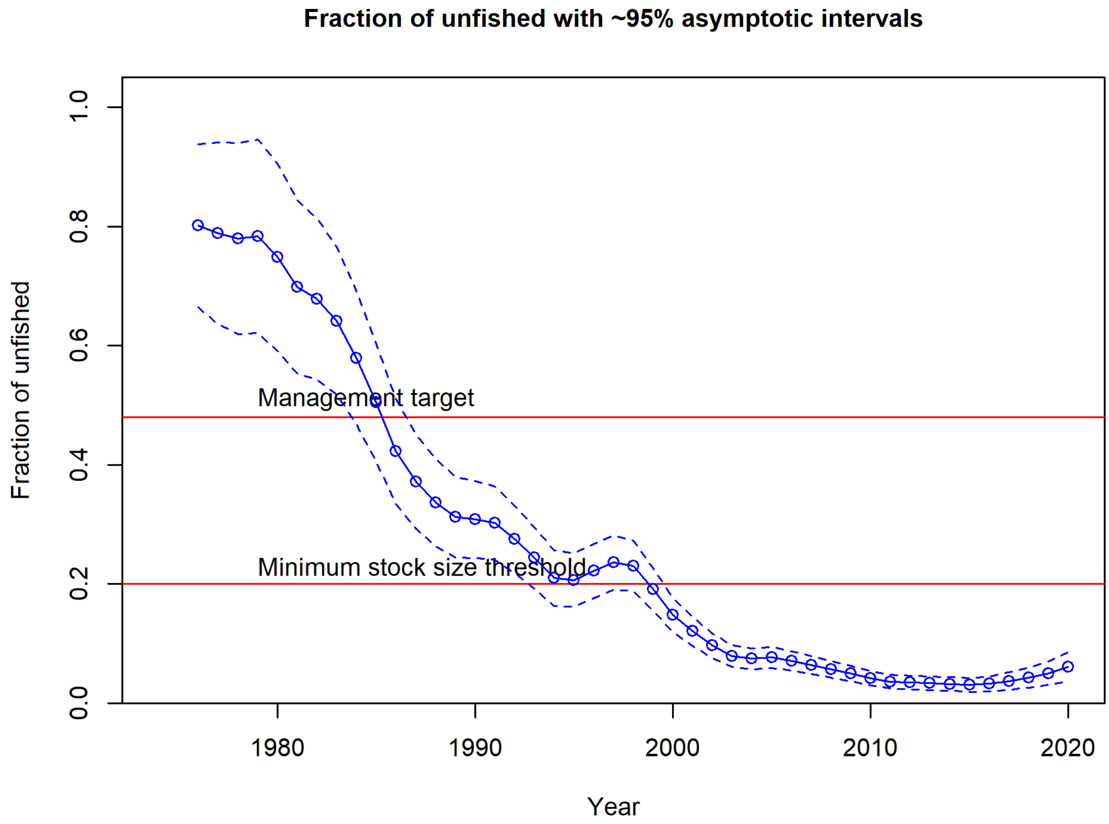


Figure 20. The estimated time-series of relative spawning biomass for the 2020 preliminary base case assessment for Redfish.

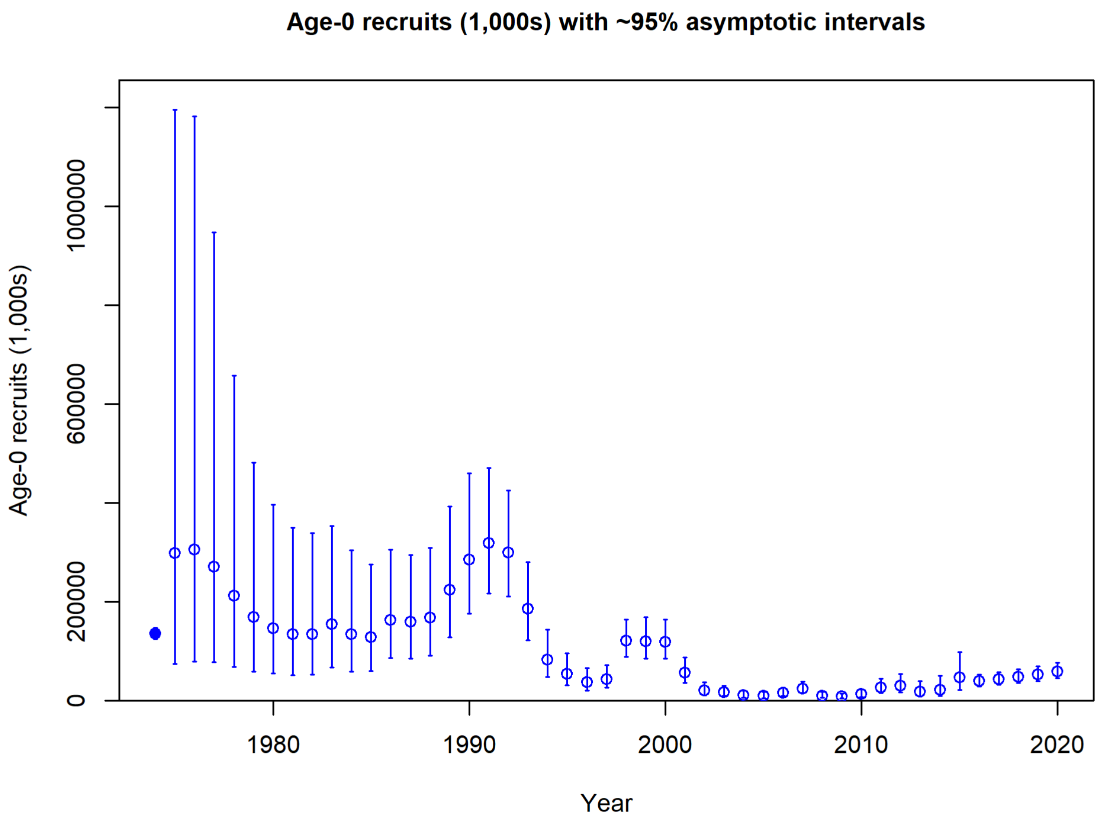
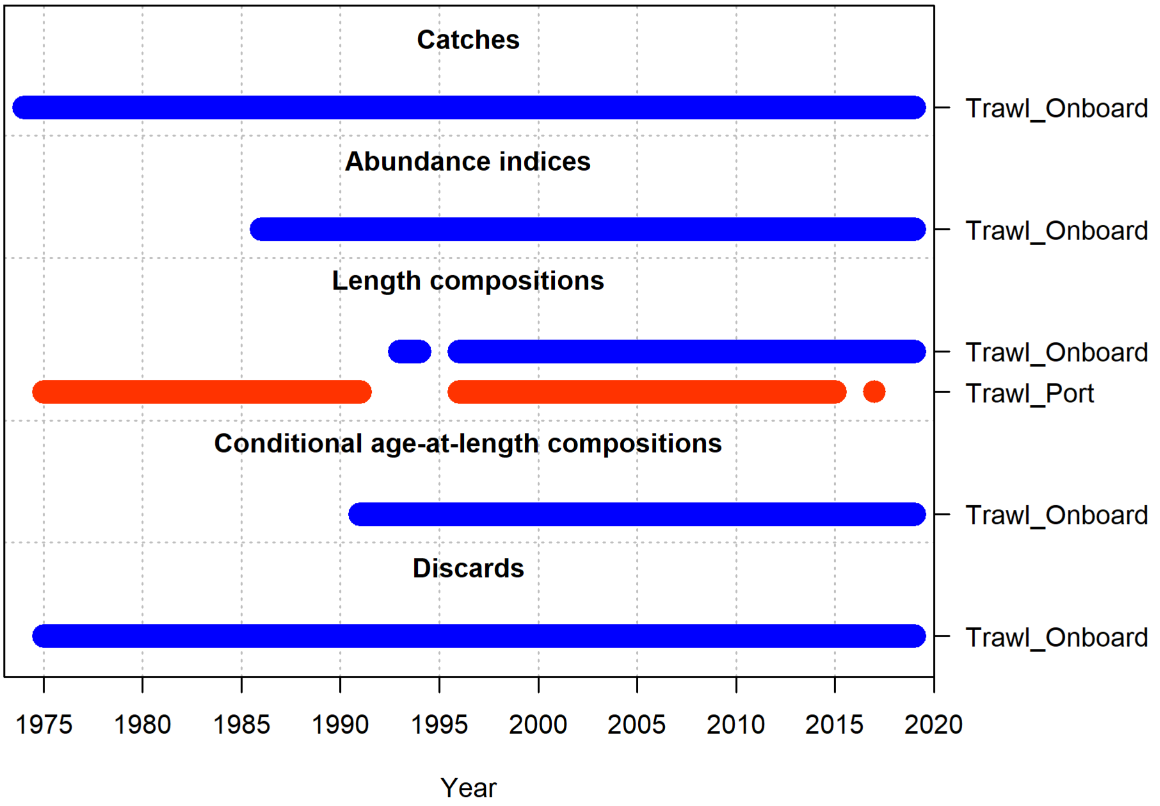


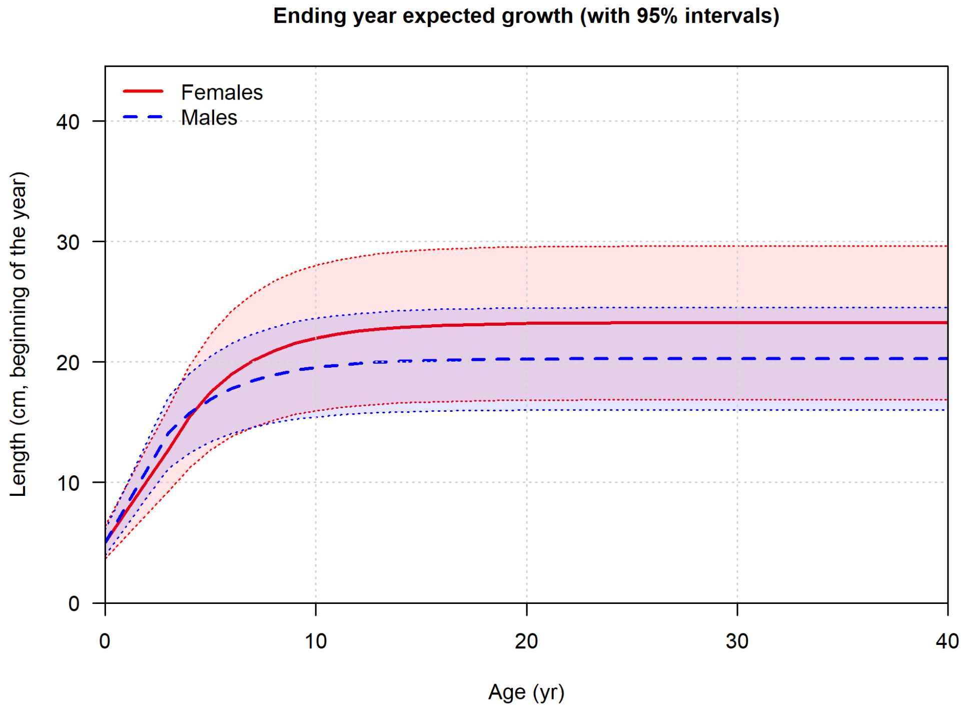
Figure 21. The estimated time-series of annual recruitment for the 2020 preliminary base case assessment for Redfish.

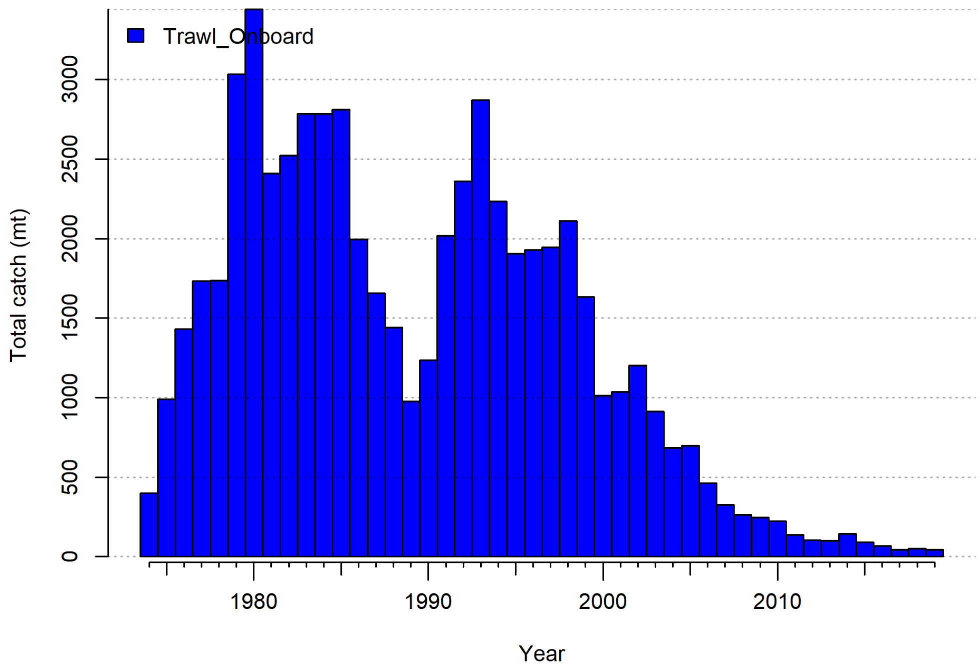
Appendix A

1.8 Preliminary base case diagnostics

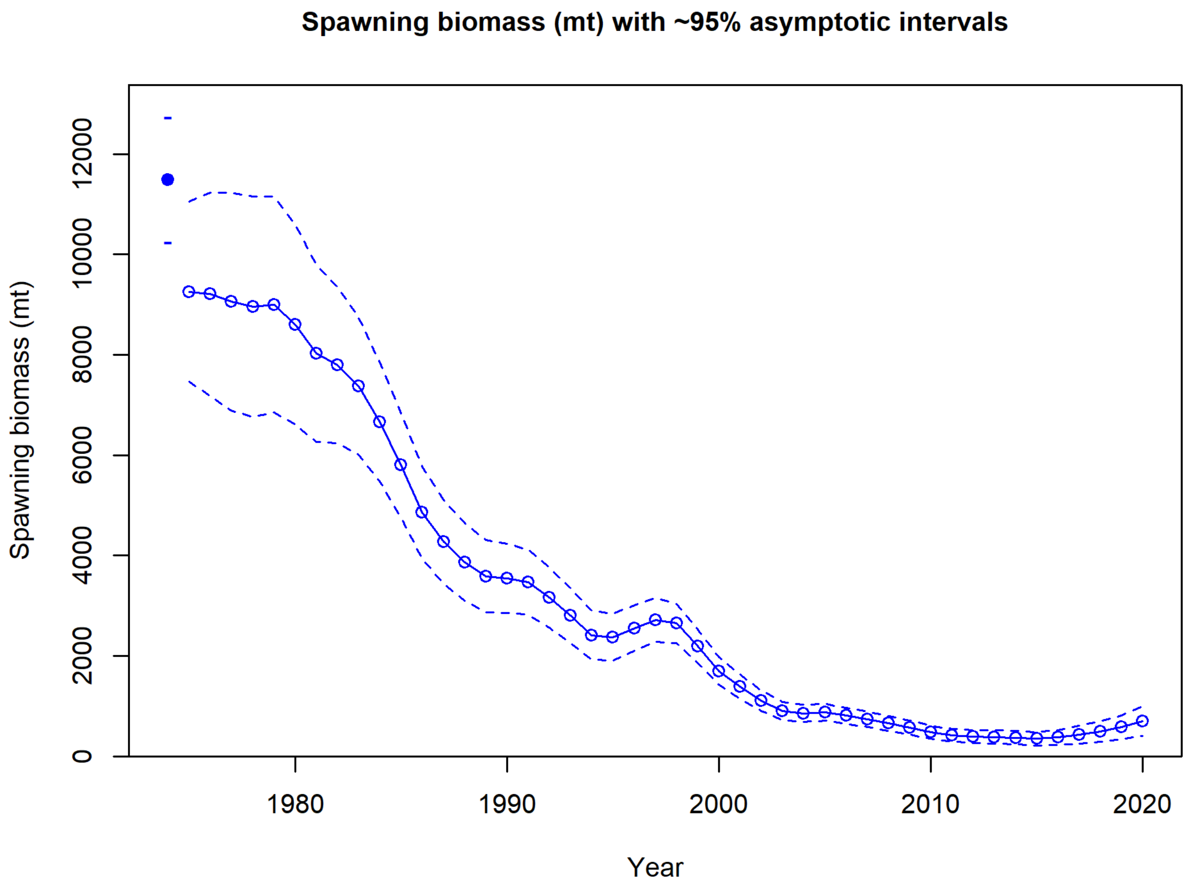


Apx Figure A.1 Summary of data sources for the preliminary base case assessment.

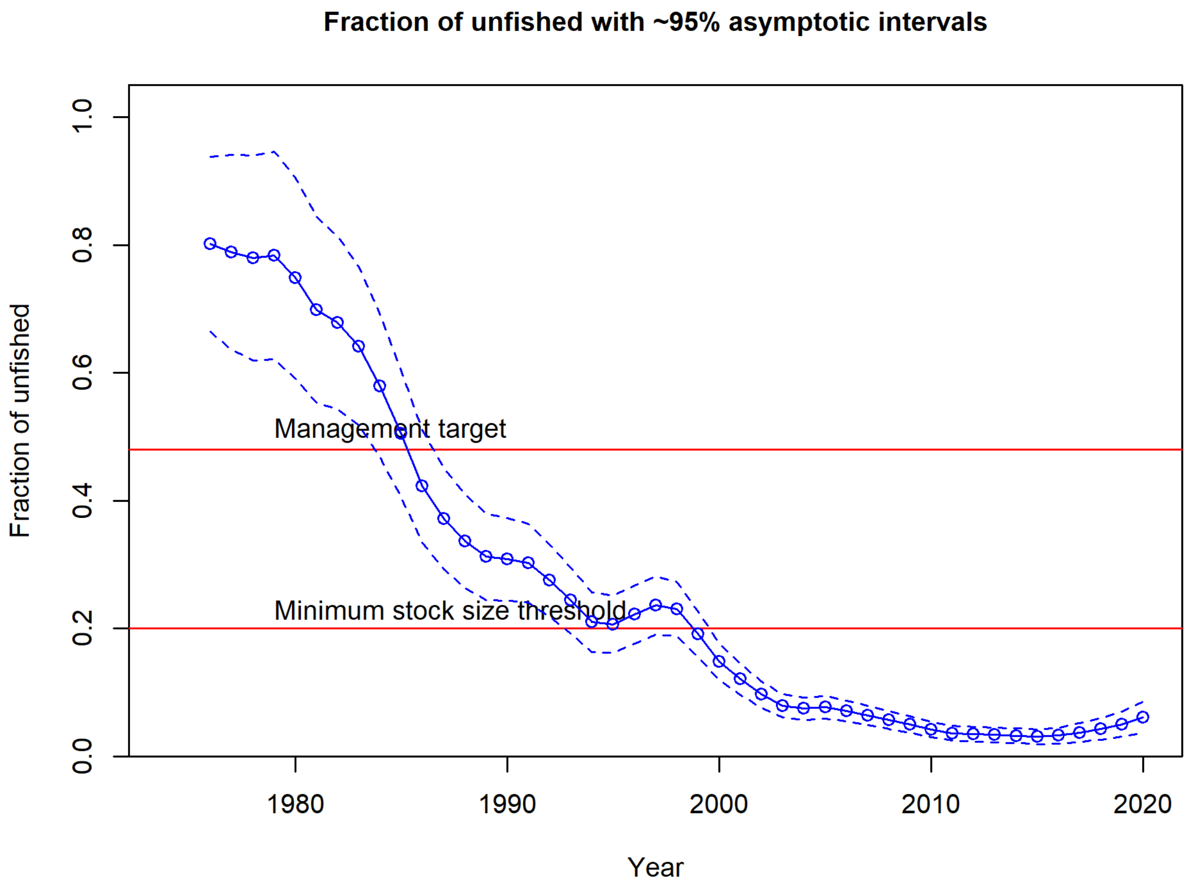




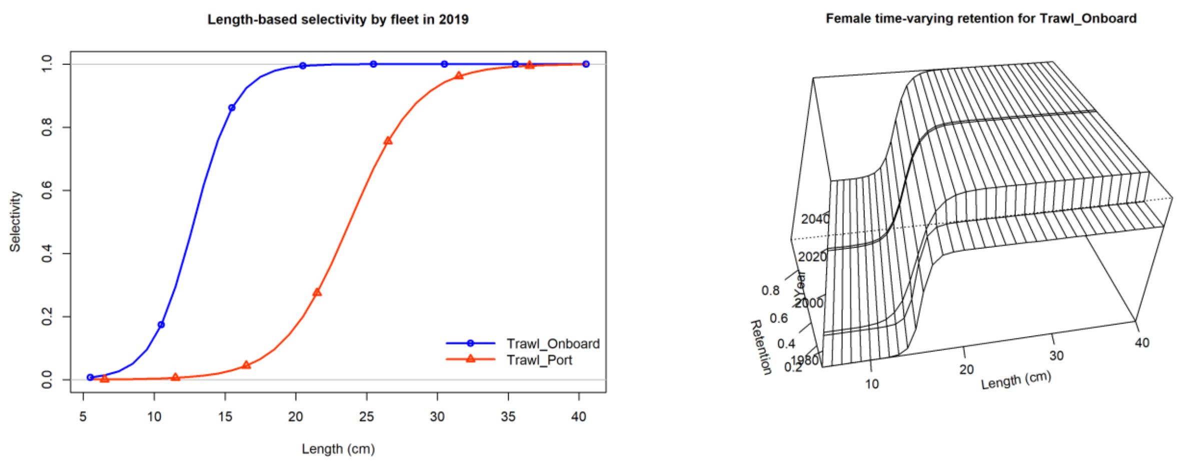
Apx Figure A.2 Growth and landings for Redfish.



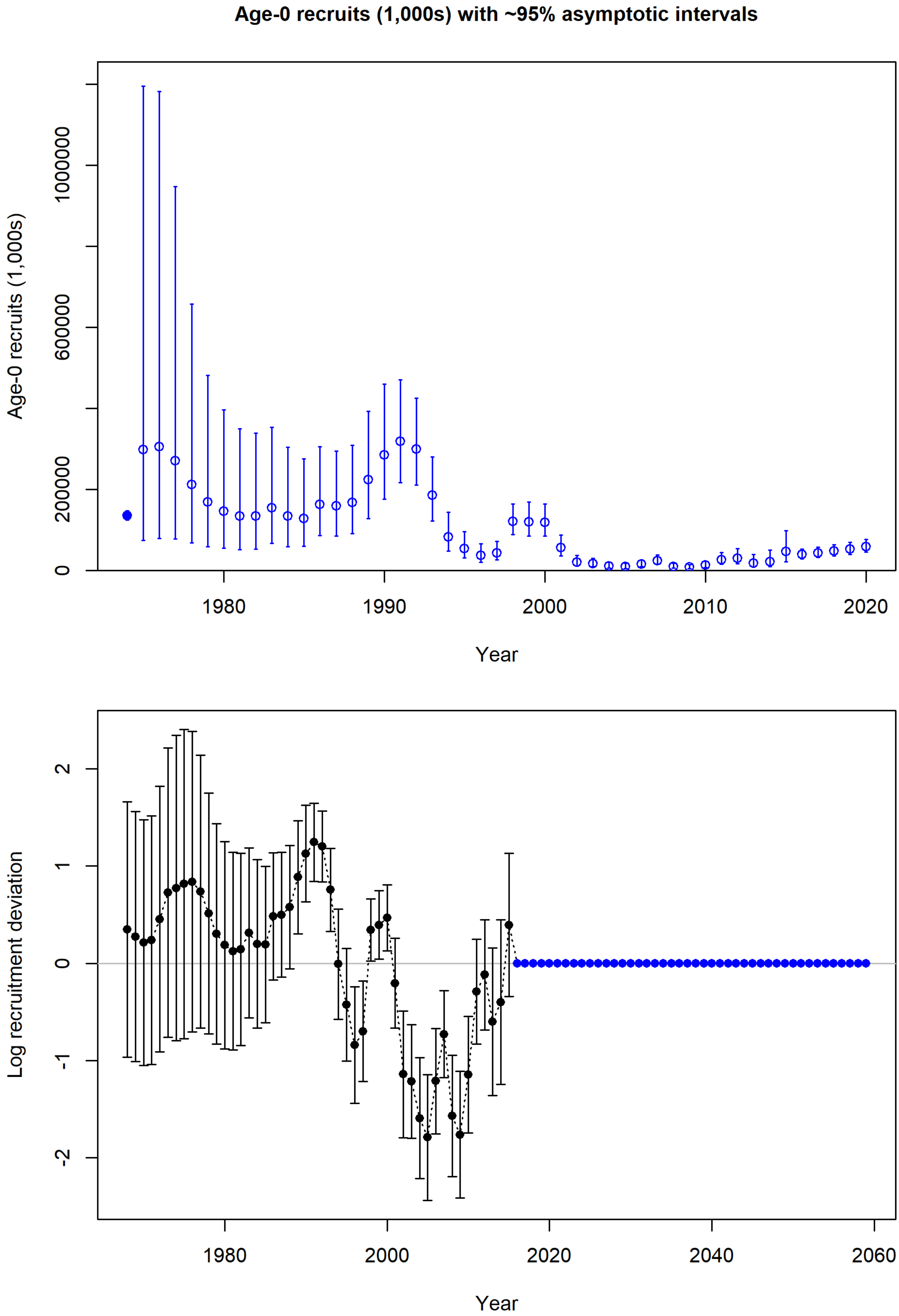
Apx Figure A.3 Time series showing absolute spawning biomass with confidence intervals.



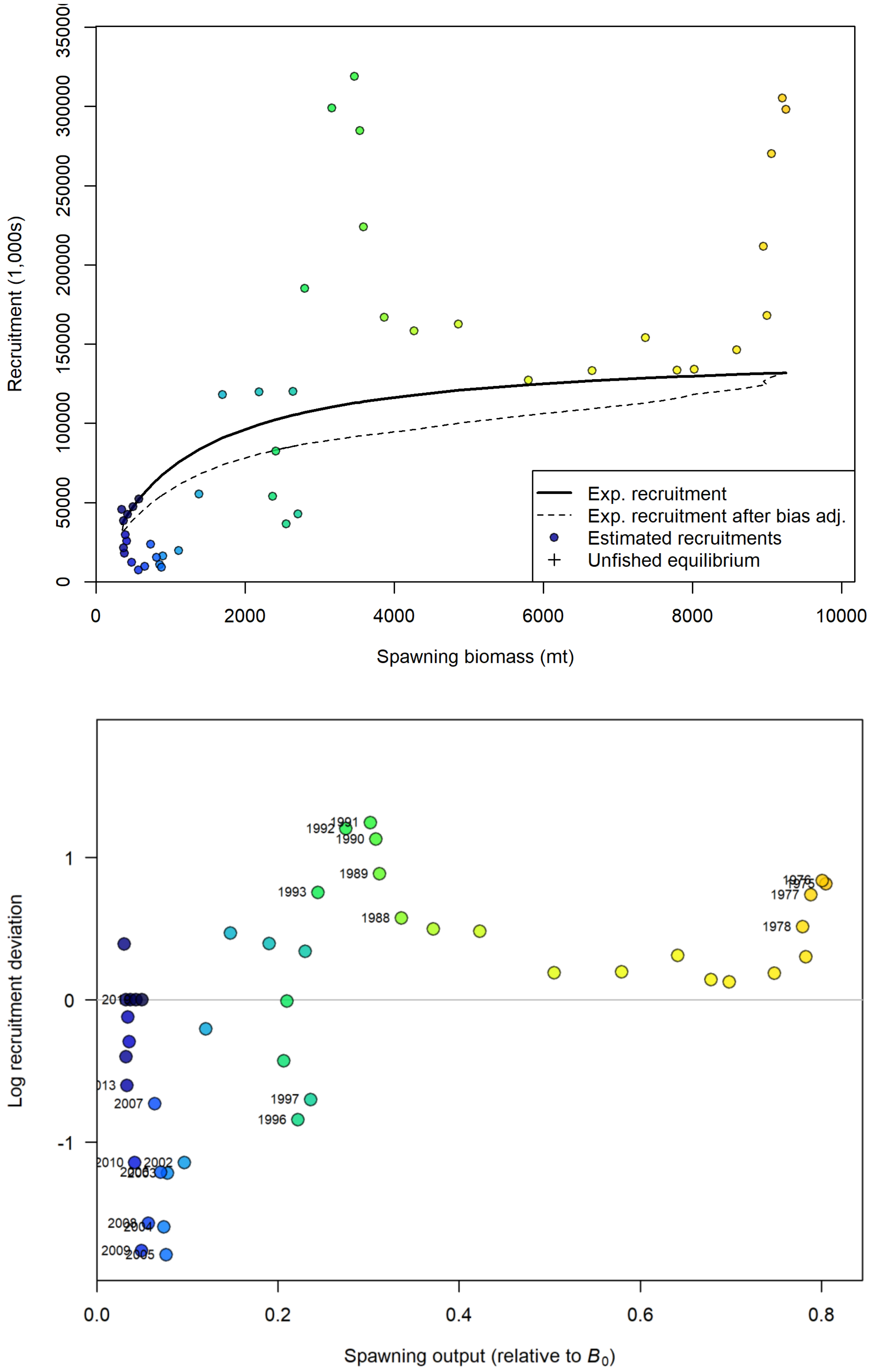
Apx Figure A.4 Time series showing relative spawning biomass with confidence intervals.



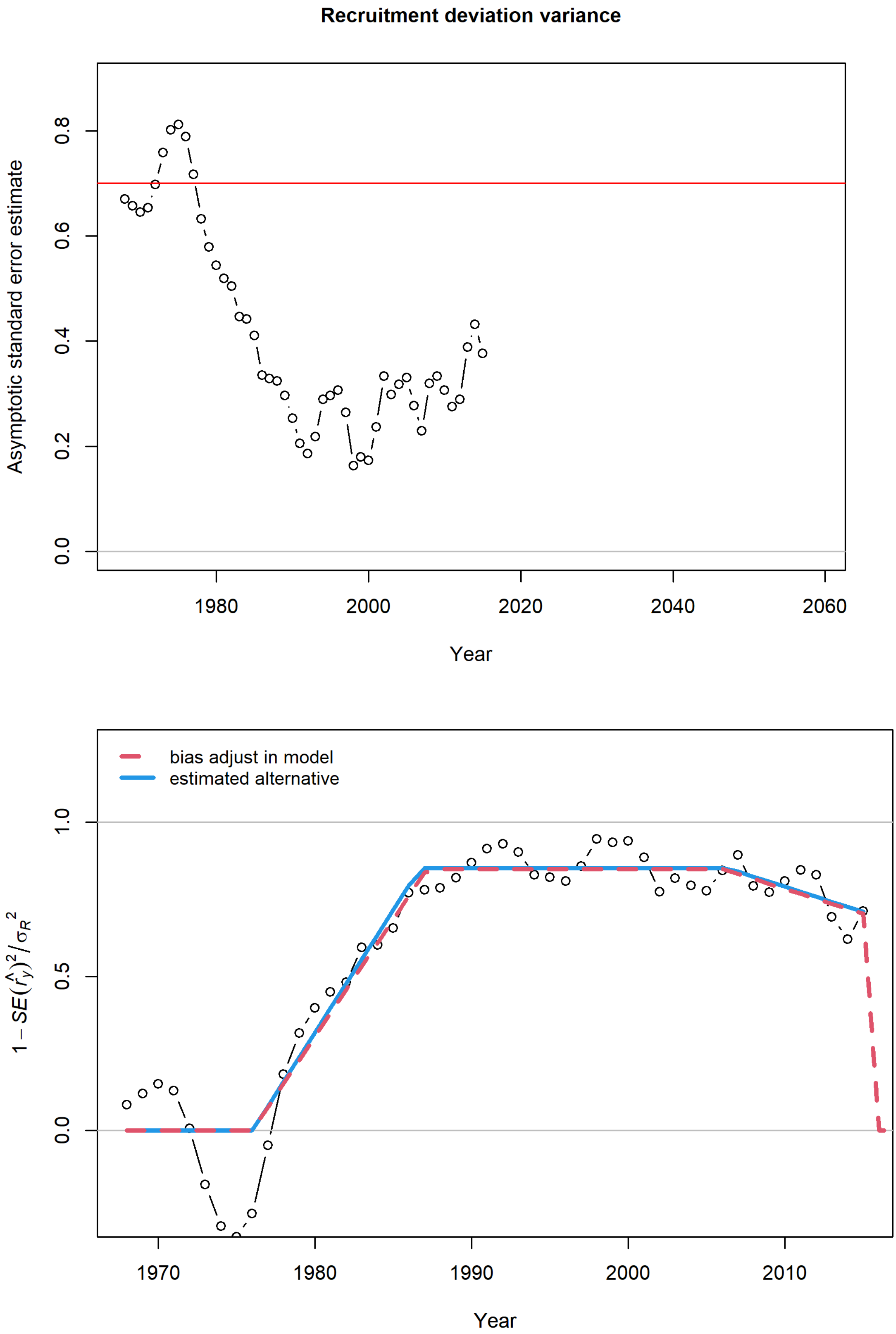
Apx Figure A.5 Estimated trawl selectivity for port (P) and onboard (O) and the retention function for Redfish.



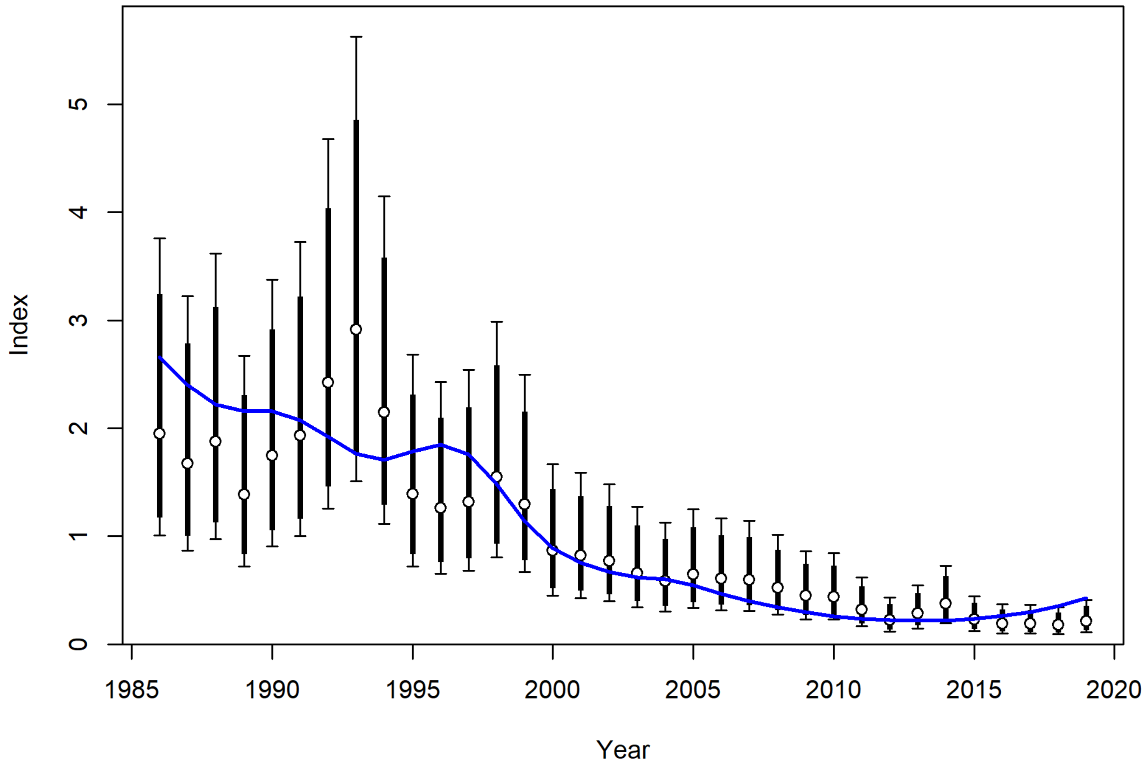
Apx Figure A.6 Time series showing absolute recruitment estimates with confidence intervals (top) and recruitment deviations with confidence intervals (bottom) for Redfish.



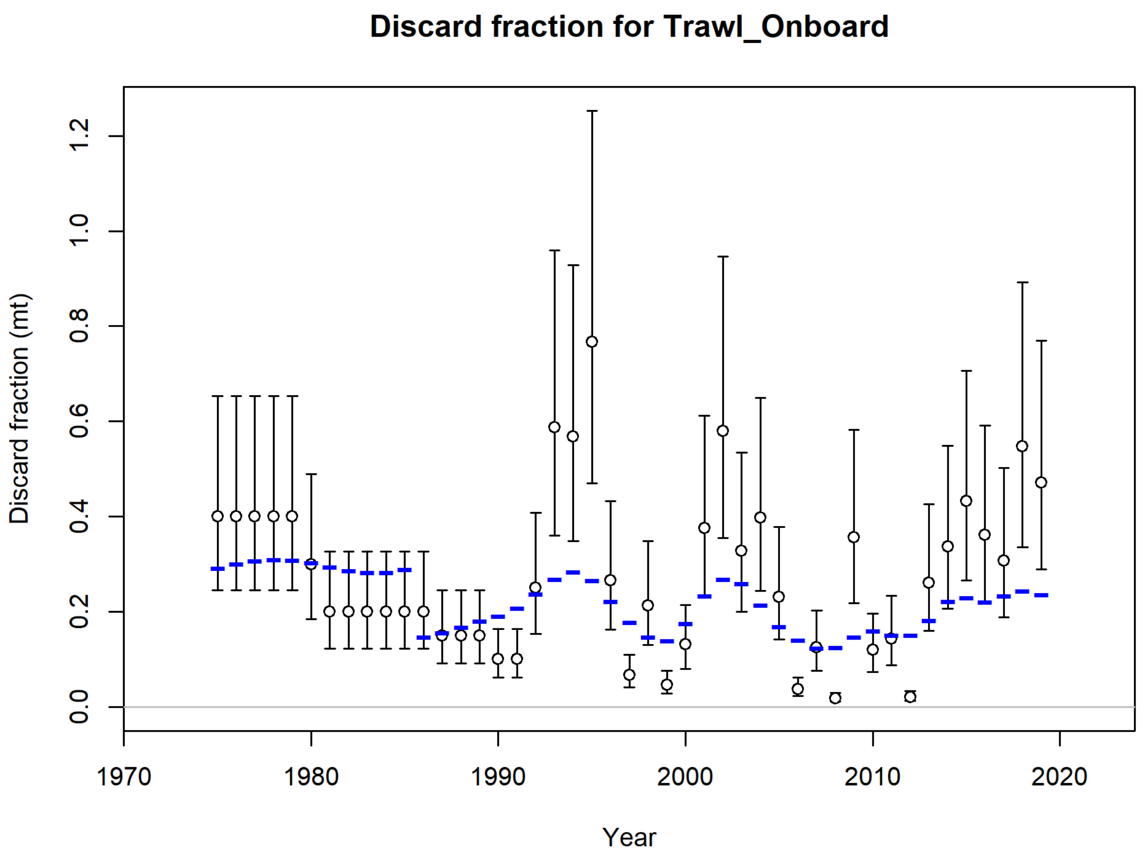
Apx Figure A.7 Time series showing , stock recruitment curve (top) and stock recruitment deviations (bottom) for Redfish.



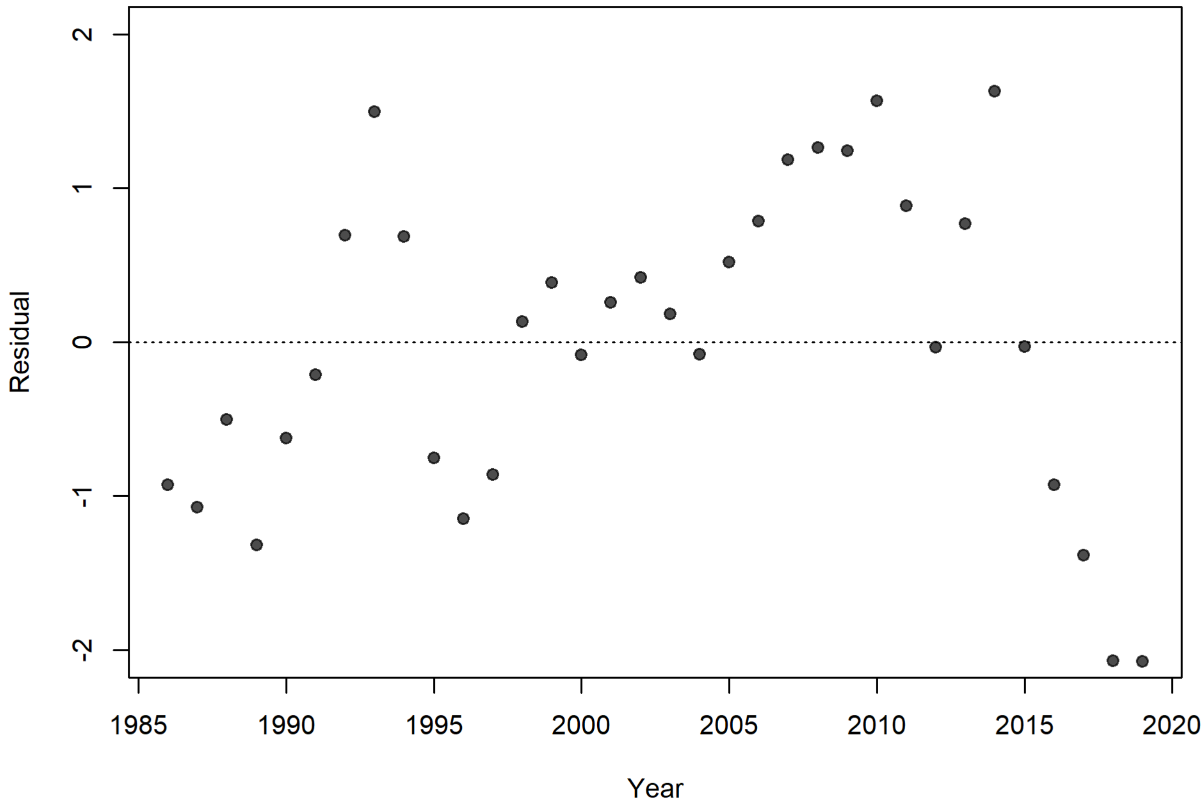
Apx Figure A.8 Recruitment deviation variance check and bias ramp adjustment for Redfish.



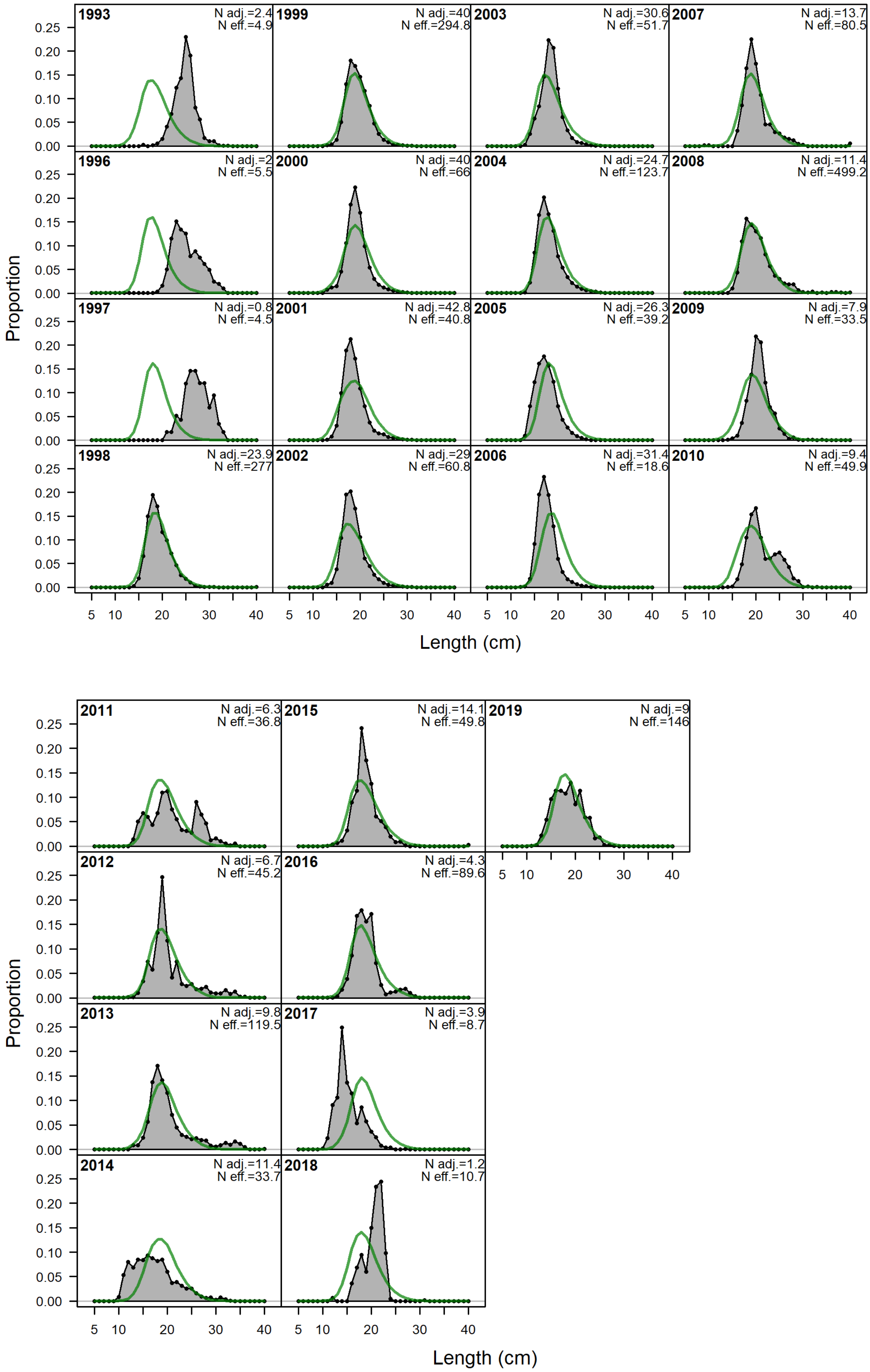
Apx Figure A.9 Fits to trawl CPUE for Redfish.



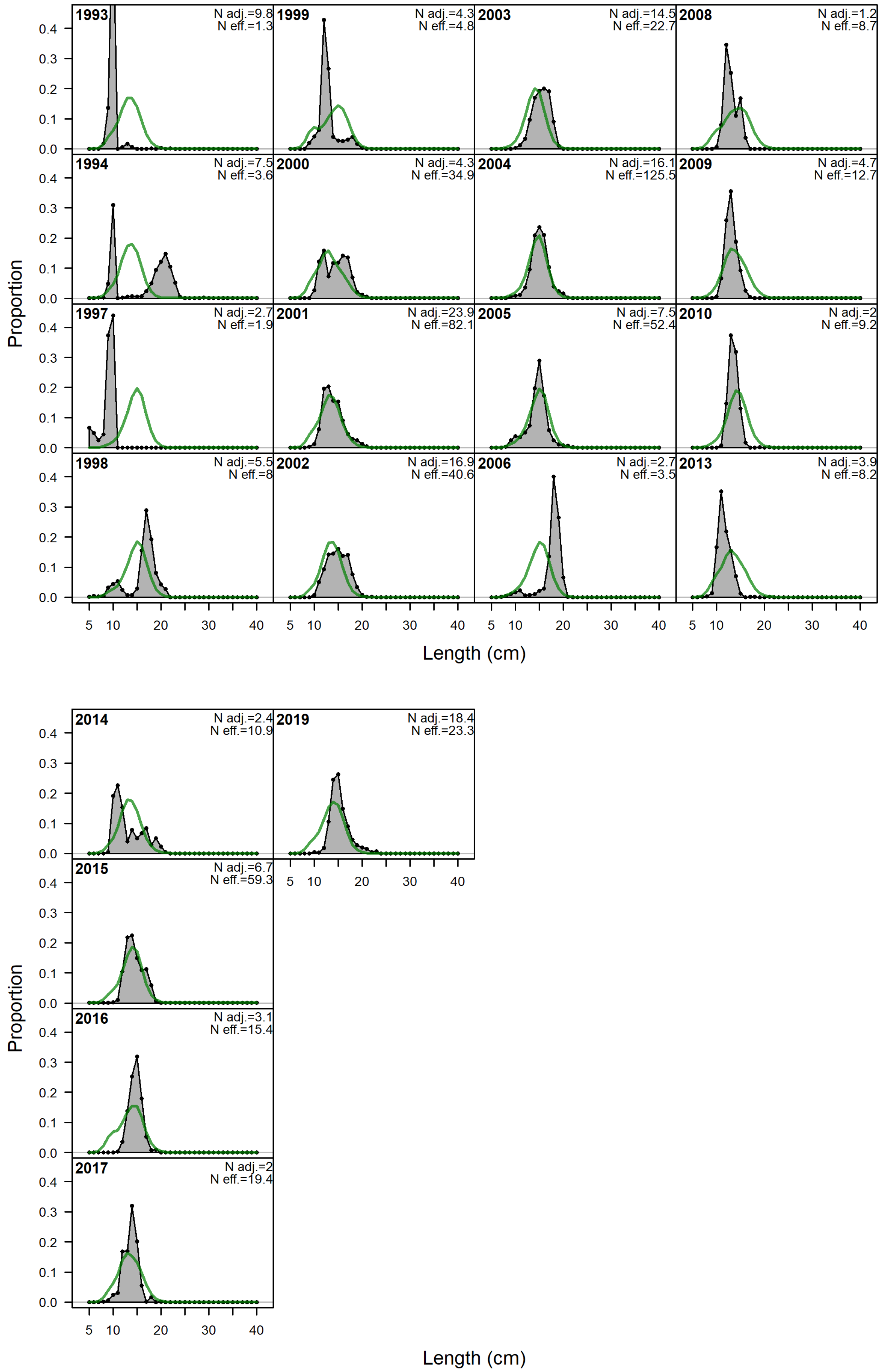
Apx Figure A.10 Fits to trawl discards for Redfish.



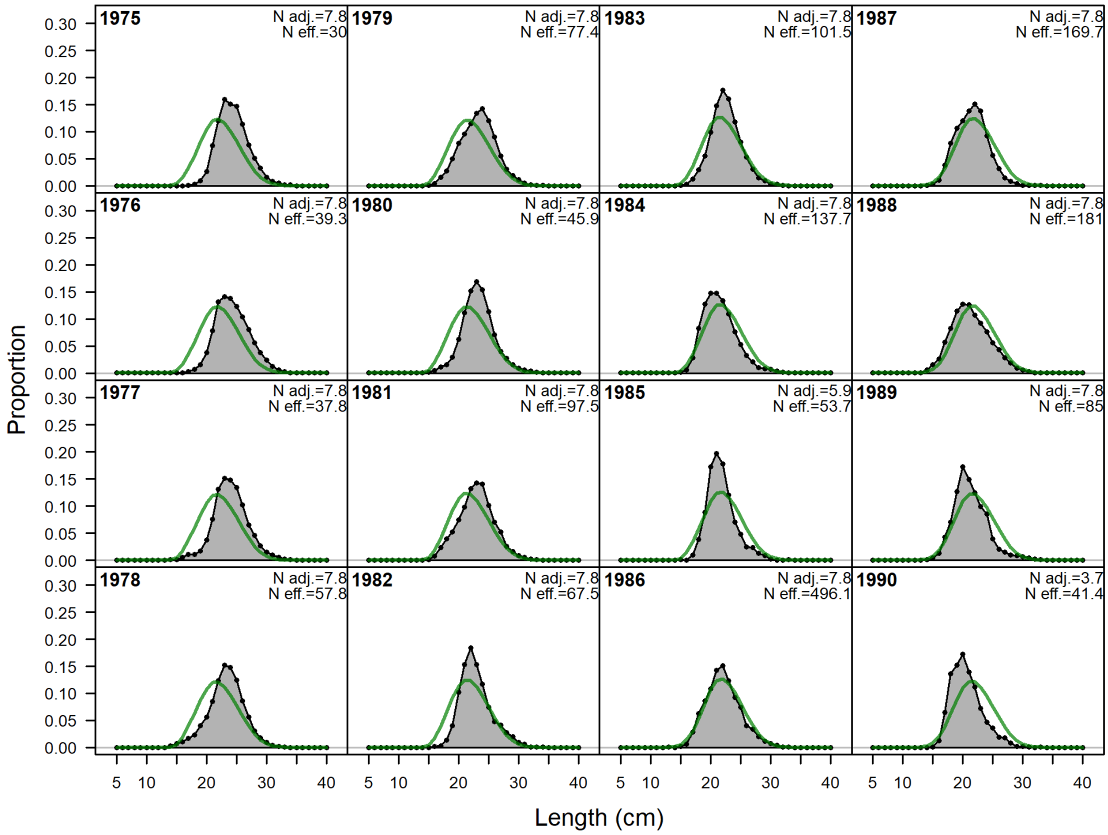
Apx Figure A.11 Residuals for fits to CPUE for Redfish.

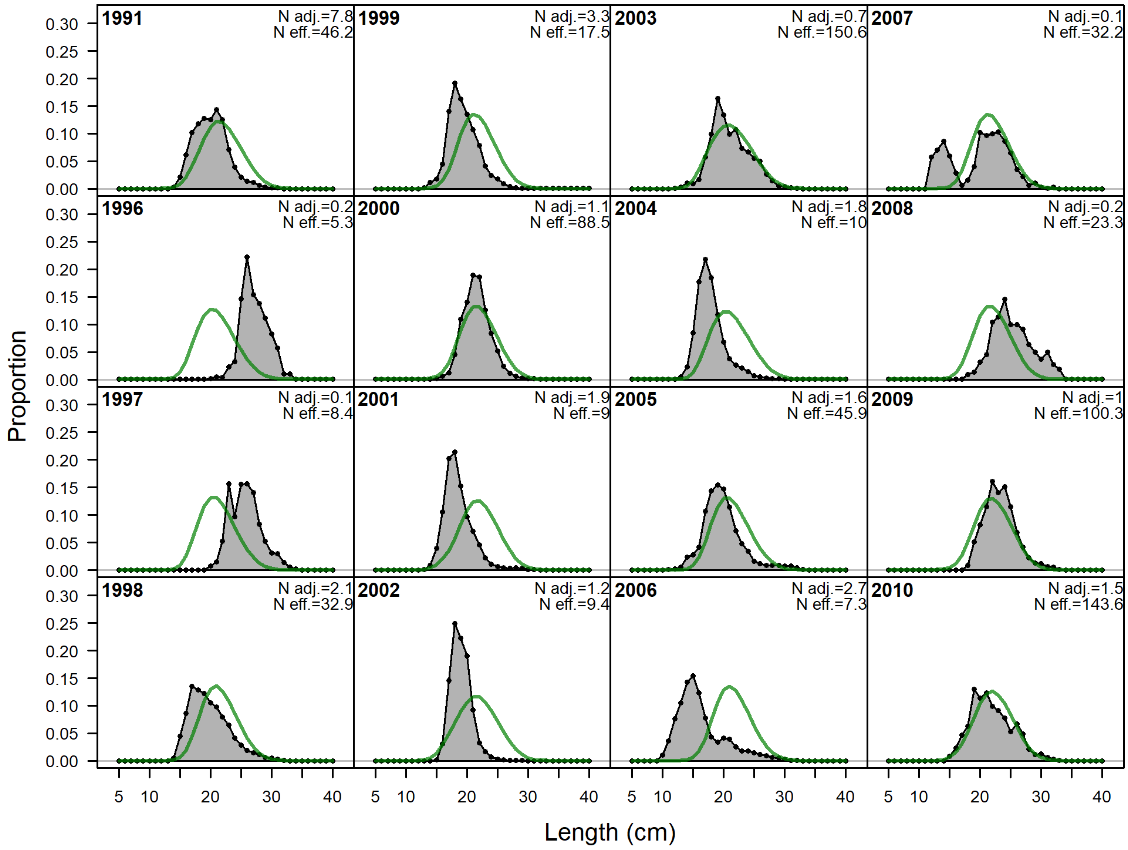


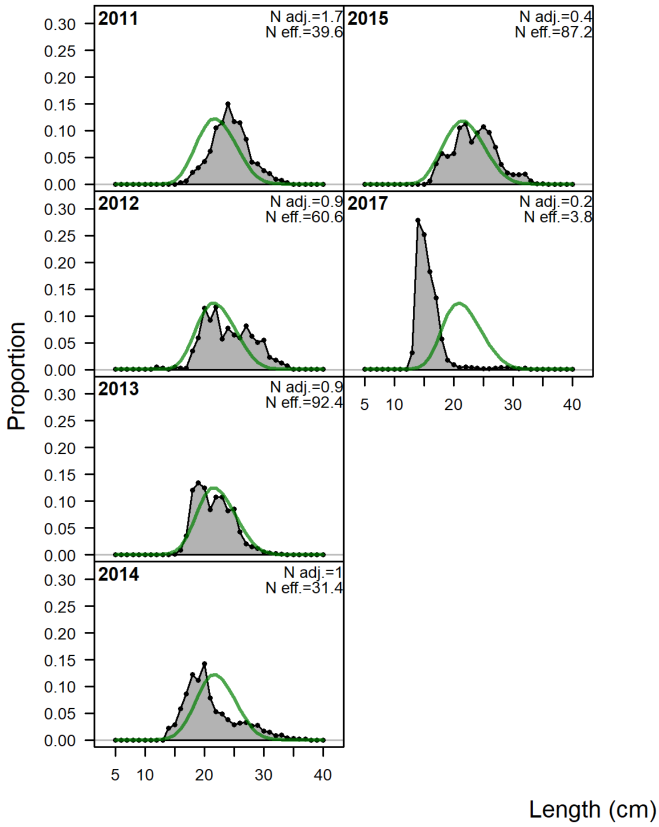
Apx Figure A.12 Redfish length composition fits: onboard trawl retained.



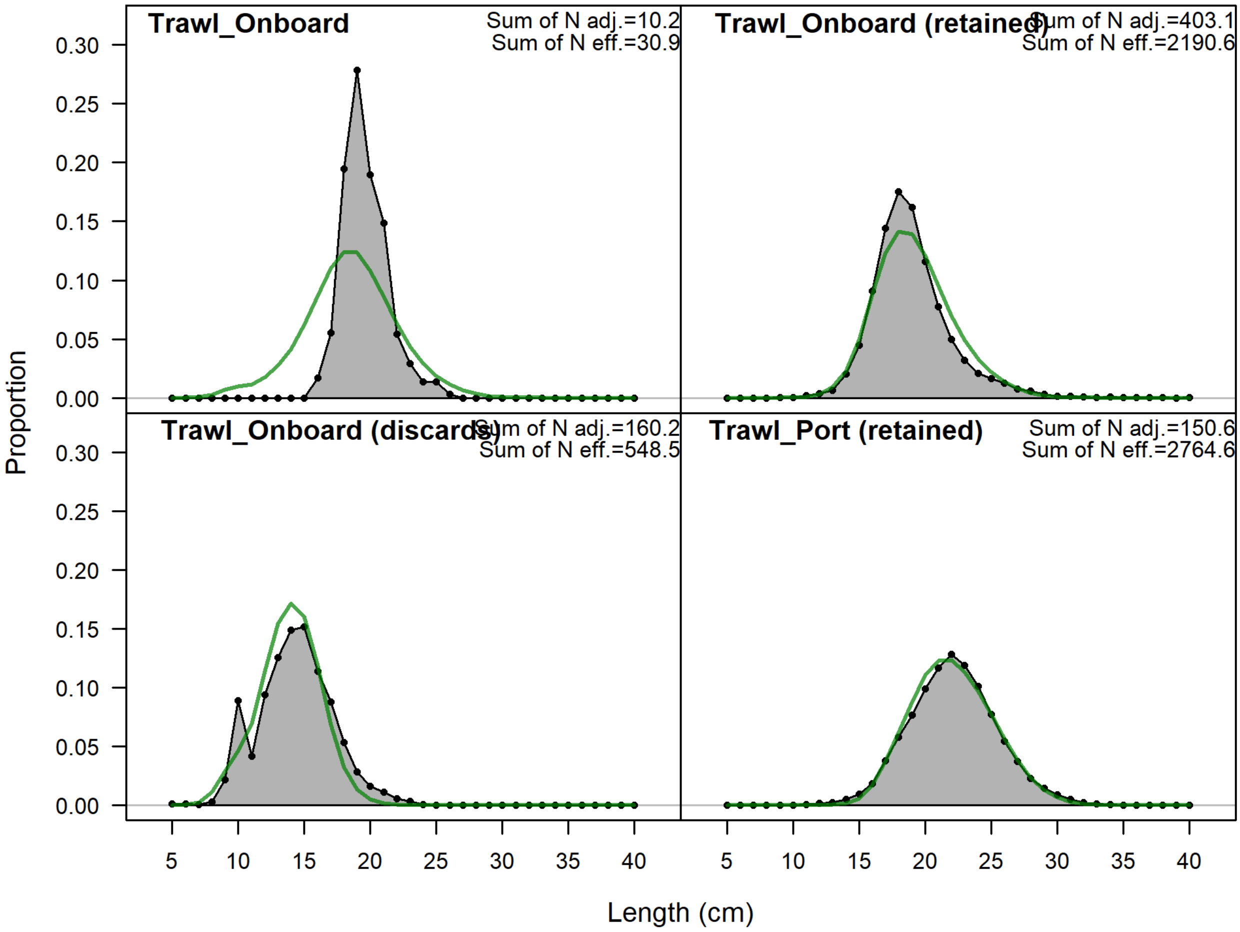
Apx Figure A.13 Redfish length composition fits: onboard trawl discard.


1975
N adj.=7.8
N eff.=30
1979
N adj.=7.8
N eff.=77.4
1983
N adj.=7.8
N eff.=101.5
1987
N adj.=7.8
N eff.=169.7
1976
N adj.=7.8
N eff.=39.3
1980
N adj.=7.8
N eff.=45.9
1984
N adj.=7.8
N eff.=137.7
1988
N adj.=7.8
N eff.=181
1977
N adj.=7.8
N eff.=37.8
1981
N adj.=7.8
N eff.=97.5
1985
N adj.=5.9
N eff.=53.7
1989
N adj.=7.8
N eff.=85
1978
N adj.=7.8
N eff.=57.8
1982
N adj.=7.8
N eff.=67.5
1986
N adj.=7.8
N eff.=496.1
1990
N adj.=3.7
N eff.=41.4
Proportion
Length (cm)

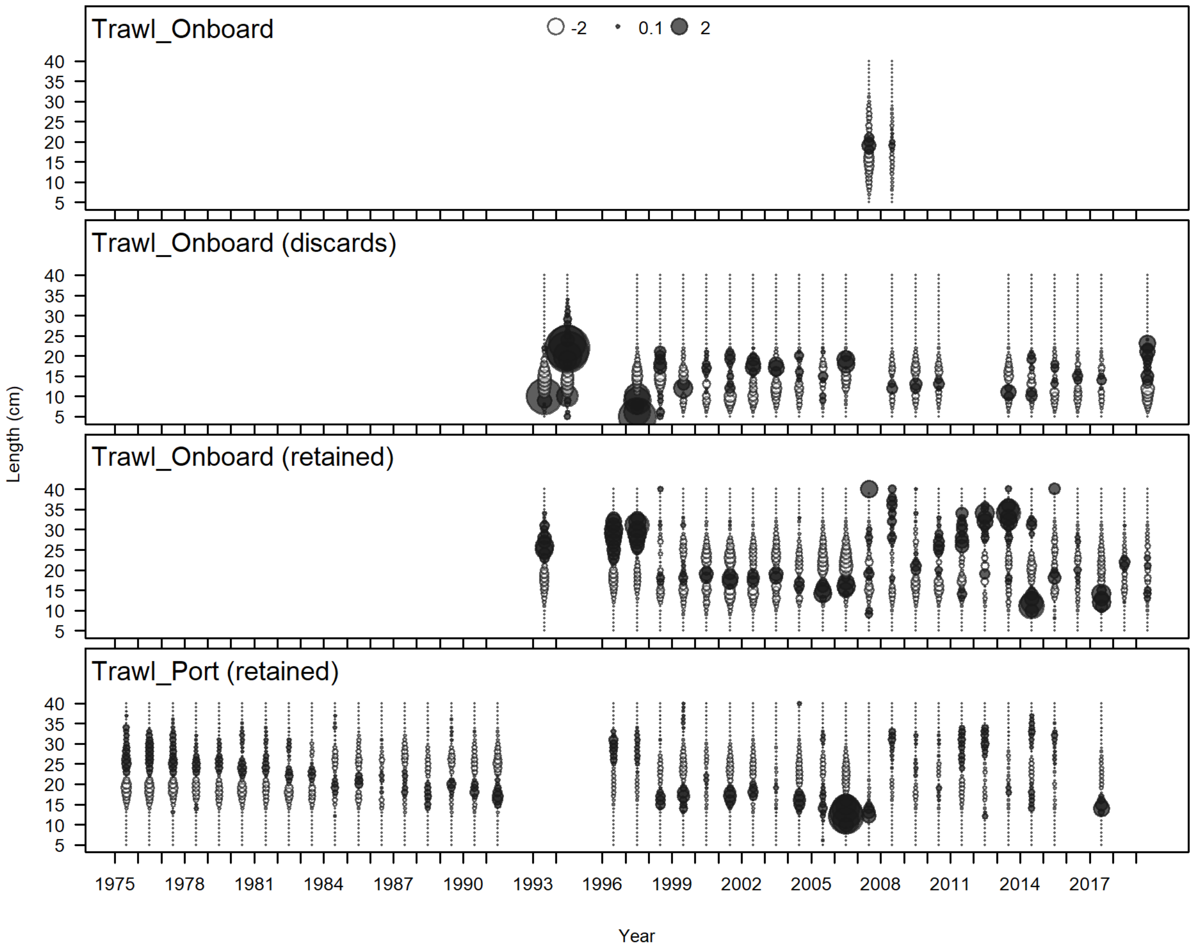

1991
N adj.=7.8
N eff.=46.2
1999
N adj.=3.3
N eff.=17.5
2003
N adj.=0.7
N eff.=150.6
2007
N adj.=0.1
N eff.=32.2
1996
N adj.=0.2
N eff.=5.3
2000
N adj.=1.1
N eff.=88.5
2004
N adj.=1.8
N eff.=10
2008
N adj.=0.2
N eff.=23.3
1997
N adj.=0.1
N eff.=8.4
2001
N adj.=1.9
N eff.=9
2005
N adj.=1.6
N eff.=45.9
2009
N adj.=1
N eff.=100.3
1998
N adj.=2.1
N eff.=32.9
2002
N adj.=1.2
N eff.=9.4
2006
N adj.=2.7
N eff.=7.3
2010
N adj.=1.5
N eff.=143.6
Proportion
Length (cm)



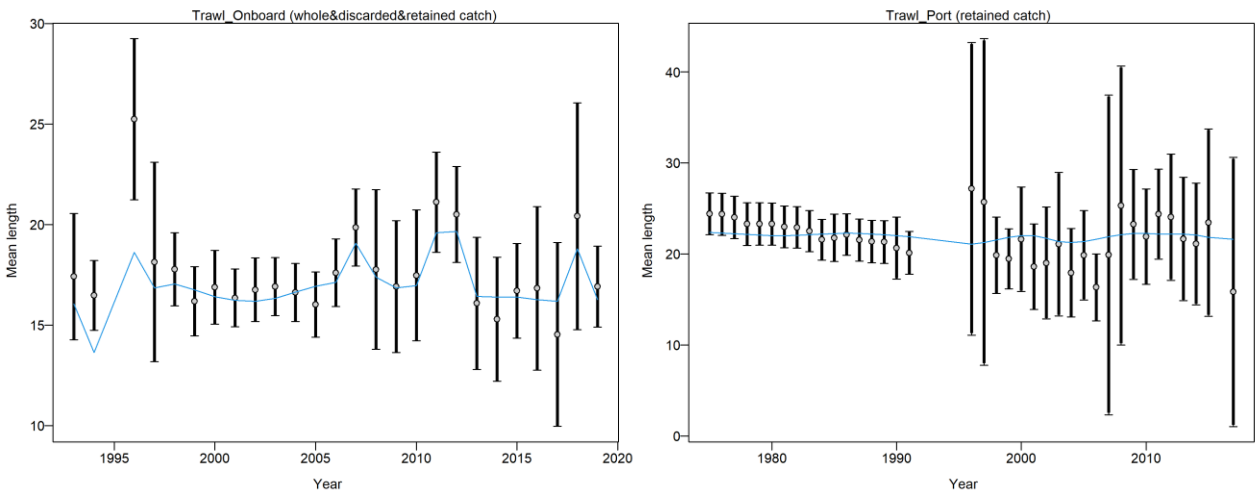
Apx Figure A.14 Redfish length composition fits: Port trawl.



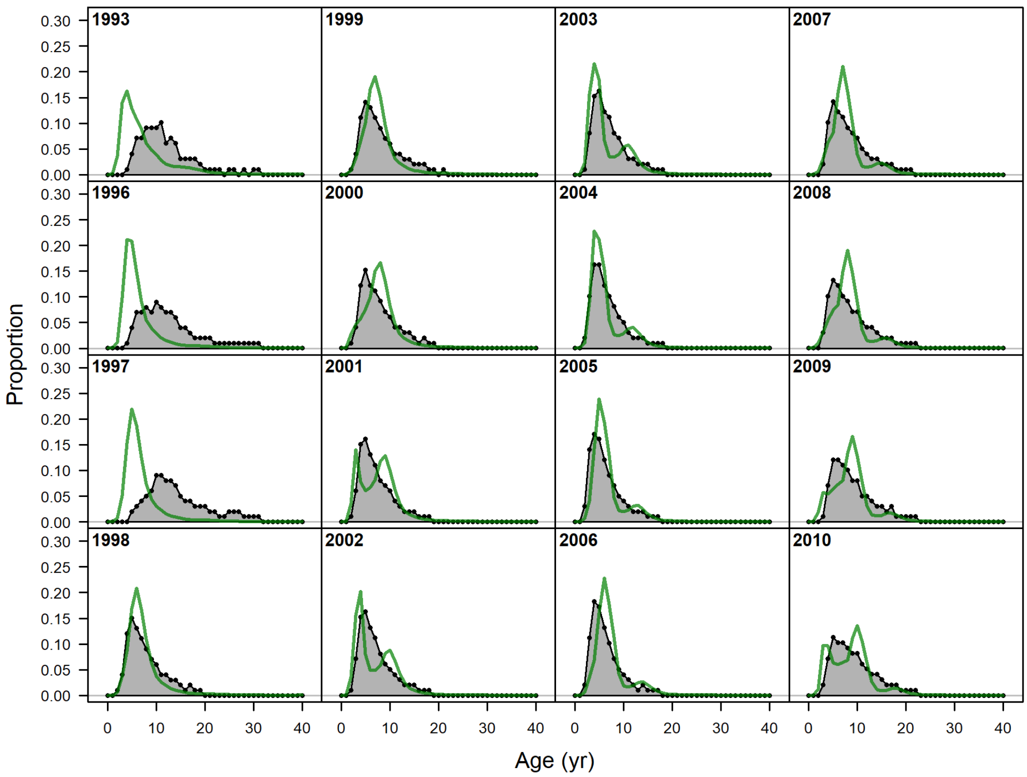
Apx Figure A.15 Redfish length composition fits aggregated across years.

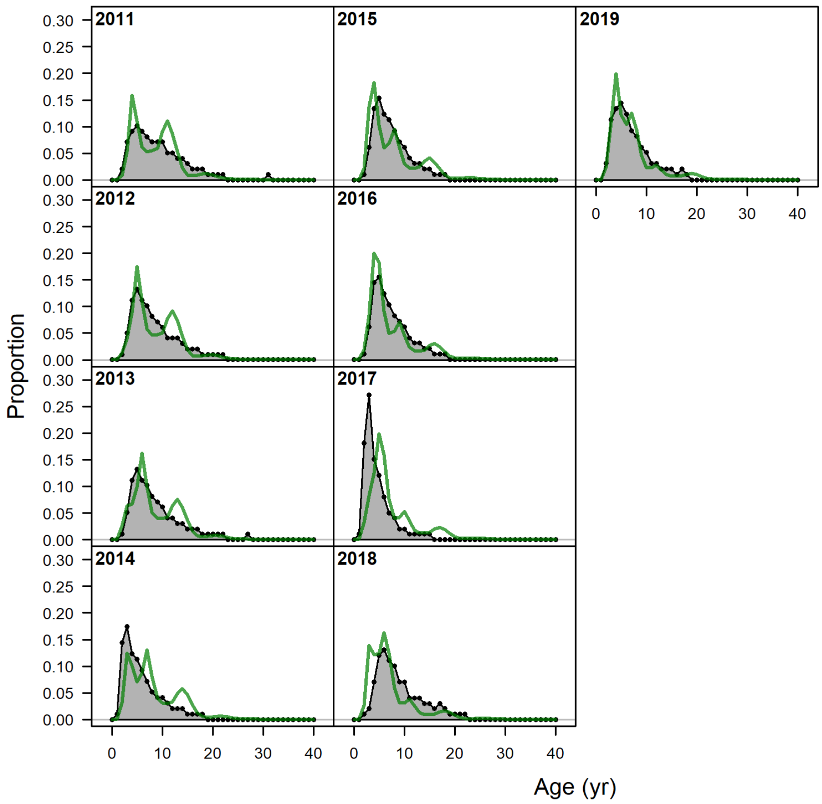


Apx Figure A.16 Residuals from the annual length compositions (retained) for redfish displayed by year.

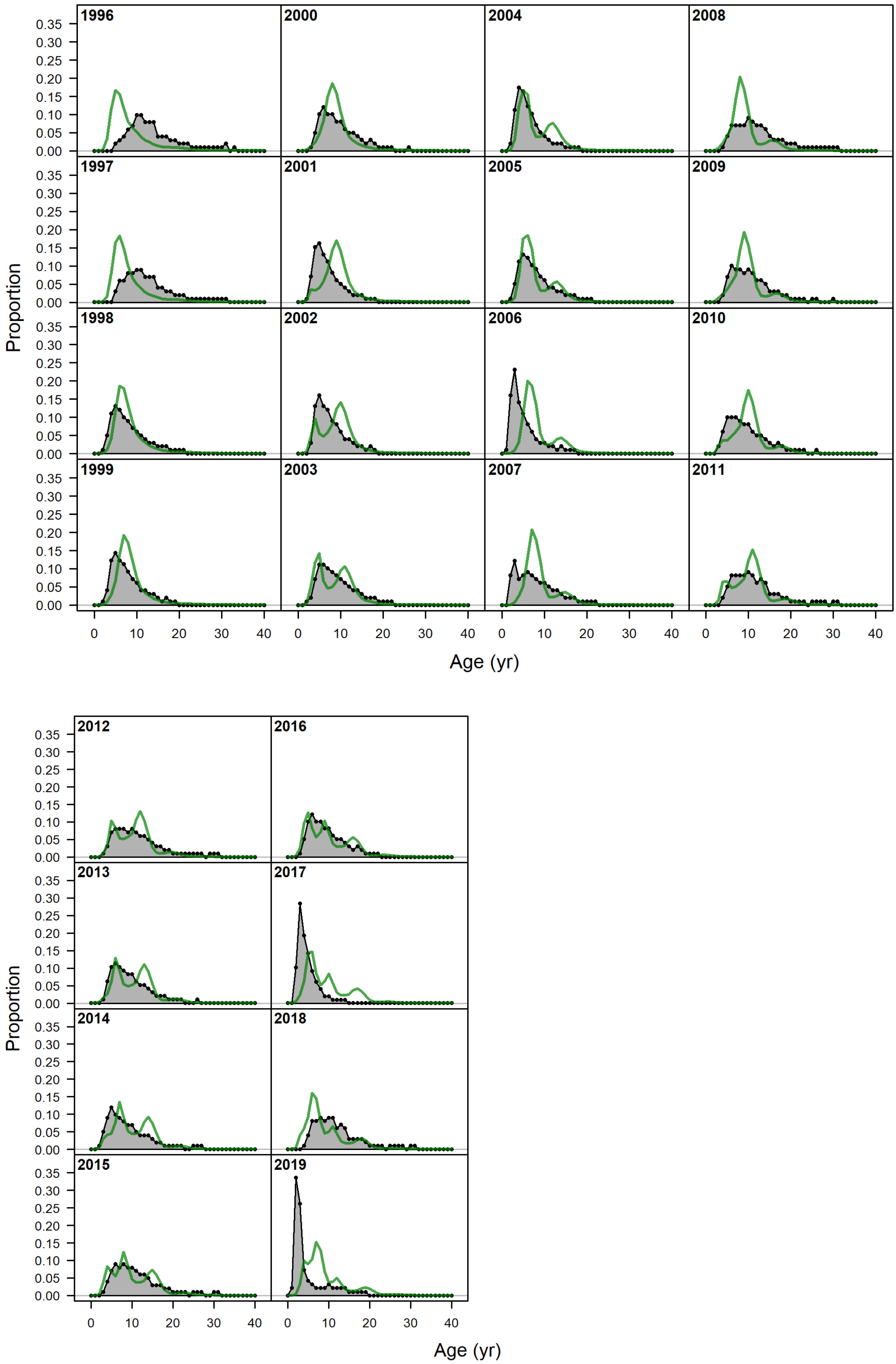


Apx Figure A.17 Redfish length composition fit diagnostics from tuning. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for length data.

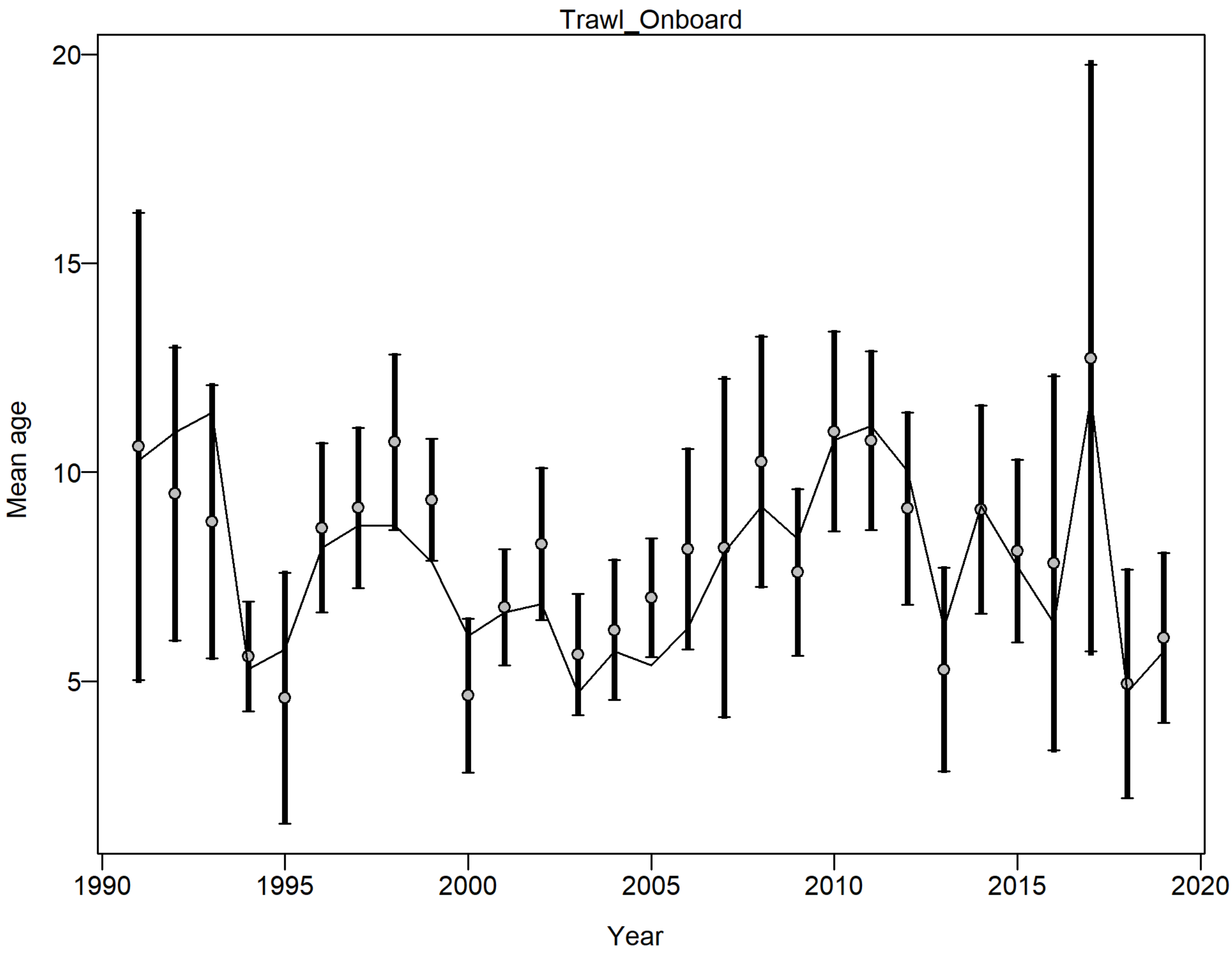




Apx Figure A.18 Redfish onboard age composition fits.



Apx Figure A.19 Redfish port age composition fits.



Apx Figure A.20 Redfish conditional age at length fit diagnostics from tuning. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for conditional age-at-length data.

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