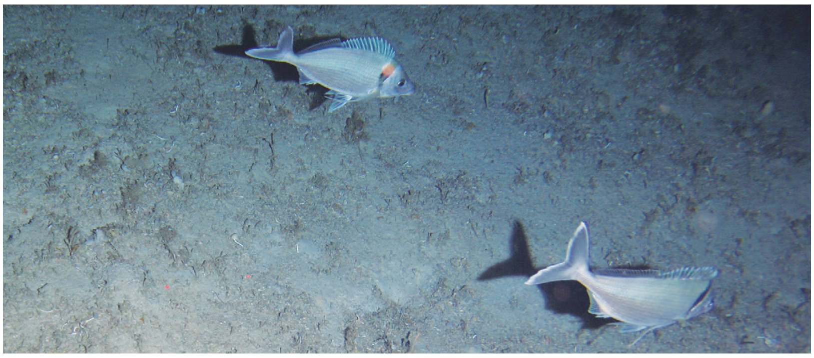
Cite as:
Tuck, G., Day, J., Haddon M. and Castillo-Jordán, C. (2017) Redfish (*Centroberyx affinis*) stock assessment based on data to 2016. pp 691 - 729 *in* Tuck, G.N. (ed.) 2018. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2016 and 2017*. Part 2, 2017. Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere, Hobart. 837p.

Australian Government
Australian Fisheries Management Authority

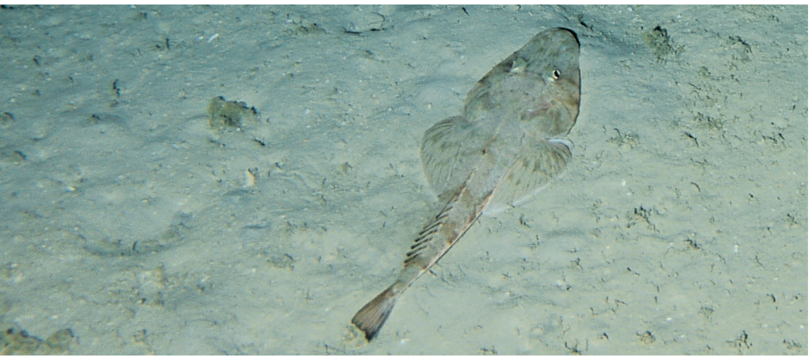
2015/0817 June 2018

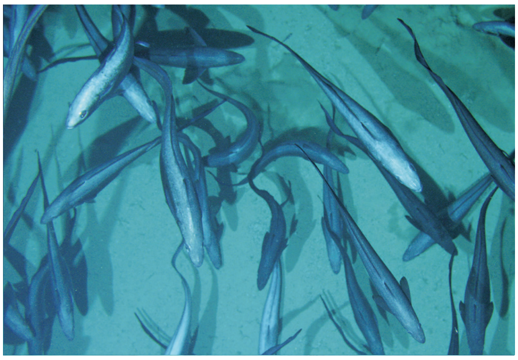
Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2016 and 2017

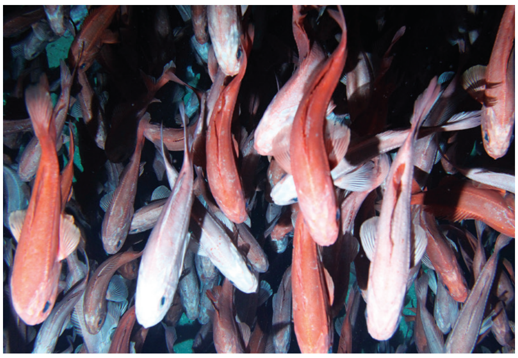


PART 2

2017







Principal investigator **G.N. Tuck**

CSIRO

www.afma.gov.au

Protecting our fishing future

Box 7051, Canberra Business Centre, ACT 2610 Tel **(02) 6225 5555** Fax (02) 6225 5500 **AFMA Direct 1300 723 621**

Stock Assessment for the Southern and Eastern scalefish and shark fishery 2016 and 2017.
Report Ref # 2015/0817.
By PI: Tuck, G.N.
June 2018 - ONLINE

ISBN 978-1-4863-1012-8

Preferred way to cite this report

Tuck, G.N. (ed.) 2018. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2016 and 2017. Part 2, 2017. Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere, Hobart. 837p.

Acknowledgements

All authors wish to thank the science, management and industry members of the south east, GAB and shark resource assessment groups for their contributions to the work presented in this report. Authors also acknowledge support from Fish Ageing Services (for fish ageing data) and AFMA (for the on-board and port length-frequencies, and in particular John Garvey, for the log book data). Toni Cracknell is greatly thanked for her assistance with the production of this report.

Cover photographs

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

Report structure

Parts 1 and 2 of this report describe the assessments of 2016 and 2017 respectively

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2016 and 2017

Part 2: 2017

G.N. Tuck
June 2018
Report 2015/0817

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2017

TABLE OF CONTENTS

1. NON-TECHNICAL SUMMARY 1

1.1 OUTCOMES ACHIEVED 1
1.2 GENERAL 1
1.3 SLOPE, SHELF AND DEEPWATER SPECIES 3
1.4 SHARK SPECIES 5
1.5 GAB SPECIES 6

2. BACKGROUND 8

3. NEED 9

4. OBJECTIVES 9

5. EXECUTIVE SUMMARY: CATCH RATE STANDARDIZATIONS FOR SELECTED SESSF SPECIES (DATA TO 2016) 10

5.1 SUMMARY 10
5.2 INTRODUCTION 10
5.3 METHODS 10
5.4 ACTION ITEMS AND ISSUES BY FISHERY 11
5.5 ACKNOWLEDGEMENTS 20
5.6 REFERENCES 20

6. BLUE-EYE AUTO-LINE AND DROP-LINE CATCH-PER-HOOK (DATA 1997 - 2016) 21

6.1 INTRODUCTION 21
6.2 INTRODUCTION 22
6.3 OBJECTIVES 27
6.4 RESULTS 30
6.5 DISCUSSION 39
6.6 CONCLUSIONS 41
6.7 REFERENCES 41

7. CATCH RATE STANDARDIZATIONS FOR SELECTED SESSF SPECIES (DATA TO 2016) 43

7.1 INTRODUCTION 43
7.2 THE LIMITS OF STANDARDIZATION 43
7.3 METHODS 44
7.4 JOHN DORY 10 – 20 45
7.5 SCHOOL WHITING 60 55
7.6 SCHOOL WHITING TW 10 20 91 63
7.7 SCHOOL WHITING TW 10 20 72
7.8 MIRROR DORY 10 – 30 81
7.9 MIRROR DORY 40 – 50 90
7.10 JACKASS MORWONG 30 99
7.11 JACKASS MORWONG 10 – 20 108
7.12 JACKASS MORWONG 40 – 50 117
7.13 SILVER WAREHOU 40 – 50 126
7.14 SILVER WAREHOU 10 – 30 135
7.15 FLATHEAD TW 30 144

7.16 FLATHEAD TW 10 – 20 153
7.17 FLATHEADDS2060 162
7.18 REDFISH 10 – 20 170
7.19 BLUE-EYE TREVALLA TW 2030 179
7.20 BLUE-EYE TREVALLA TW 4050 188
7.21 BLUE-GRENADIER NON-SPAWNING 197
7.22 PINK LING 10 – 30 206
7.23 PINK LING 40 – 50 215
7.24 OCEAN PERCH OFFSHORE 1020 224
7.25 OCEAN PERCH OFFSHORE 1050 233
7.26 OCEAN PERCH INSHORE 1020 245
7.27 OCEAN JACKETS 1050 254
7.28 OCEAN JACKETS GAB 263
7.29 WESTERN GEMFISH 4050 272
7.30 WESTERN GEMFISH 4050GAB 281
7.31 WESTERN GEMFISH GAB 290
7.32 BLUE WAREHOUSE 10 – 30 299
7.33 BLUE WAREHOU 40 – 50 308
7.34 DEEPWATER FLATHEAD 317
7.35 BIGHT REDFISH 326
7.36 RIBALDO 10-50 335
7.37 RIBALDOAL 344
7.38 SILVER TREVALLY 1020 352
7.39 SILVER TREVALLY 1020 - NO MPA 361
7.40 ROYAL RED PRAWN 10 370
7.41 EASTERN GEMFISH NONSPAWNING 10-40 379
7.42 EASTERN GEMFISH SP 388
7.43 ALFONSINO 397
7.44 ACKNOWLEDGEMENTS 406
7.45 REFERENCES 406

8. CPUE STANDARDIZATIONS FOR SELECTED SHARK SESSF SPECIES (DATA TO 2016) 407

8.1 EXECUTIVE SUMMARY 407
8.2 INTRODUCTION 408
8.3 METHODS 409
8.4 GUMMY SHARK: SOUTH AUSTRALIA GILLNET 411
8.5 GUMMY SHARK: BASS STRAIT GILLNET 420
8.6 GUMMY SHARK: TASMANIA GILLNET 429
8.7 GUMMY SHARK: TRAWL 438
8.8 GUMMY SHARK BOTTOM LINE 447
8.9 SCHOOL SHARK TRAWL 456
8.10 SAWSHARK GILLNET 465
8.11 SAWSHARK TRAWL 474
8.12 SAWSHARK DANISH SEINE 484
8.13 ELEPHANT FISH: GILLNET 494
8.14 ACKNOWLEDGEMENTS 503
8.15 REFERENCES 503

9. YIELD, TOTAL MORTALITY VALUES AND TIER 3 ESTIMATES FOR SELECTED SHELF AND SLOPE SPECIES IN THE SESSF 2017 504

9.1 SUMMARY 504
9.2 METHODS 505
9.3 RESULTS 513
9.4 ACKNOWLEDGEMENTS 517
9.5 REFERENCES 517
9.6 APPENDIX 1 – DATA SUMMARY FOR JOHN DORY 520
9.7 APPENDIX 2 – DETAILS OF VALUES THAT WERE USED AS ESTIMATES OF TOTAL Z (SHOWN HIGHLIGHTED) 521

10. TIER 4 ASSESSMENTS FOR BLUE EYE 522

10.1 Introduction 522
10.2 Blue Eye Non-Trawl 524

11. TIER 4 ANALYSIS FOR ELEPHANT FISH AND SAWSHARK 526

11.1 Executive Summary 526
11.2 Introduction 527
11.3 Elephant Fish (Callorhinchus milii) discards 529
11.4 Elephant Fish (Callorhinchus milii) - no discards 531
11.5 Sawshark 533
11.6 Appendix: Methods 535
11.7 References 541

12. SCHOOL WHITING (*SILLAGO FLINDERSI*): ADDITIONAL DATA AND 2017 ASSESSMENT OPTIONS 542

12.1 School whiting 542
12.2 Acknowledgements 545
12.3 References 545

13. DISCUSSION PAPER: OPTIONS FOR USE OF NSW DATA IN A SCHOOL WHITING ASSESSMENT IN 2017 546

13.1 Current Assessment 546
13.2 Issue 546
13.3 Acknowledgements 547
13.4 References 547

14. SCHOOL WHITING (*SILLAGO FLINDERSI*) STOCK ASSESSMENT BASED ON DATA UP TO 2016 – DEVELOPMENT OF A PRELIMINARY BASE CASE 548

14.1 Executive Summary 548
14.2 Introduction 548
14.3 Acknowledgements 557
14.4 References 557
14.5 Appendix A 558

15. SCHOOL WHITING (*SILLAGO FLINDERSI*) STOCK ASSESSMENT BASED ON DATA UP TO 2016 588

15.1 Executive Summary 588
15.2 Introduction 589
15.3 Methods 592
15.4 Results and Discussion 615
15.5 Acknowledgements 635
15.6 References 635
15.7 Appendix A 637

16. REDFISH (*CENTROBERYX AFFINIS*) STOCK ASSESSMENT BASED ON DATA UP TO 2016 – DEVELOPMENT OF A PRELIMINARY BASE CASE 664

16.1 Executive Summary 664
16.2 Introduction 664
16.3 Results 674
16.4 Acknowledgements 677
16.5 References 677
16.6 Appendix A 678

17. REDFISH (*CENTROBERYX AFFINIS*) STOCK ASSESSMENT BASED ON DATA UP TO 2016 691

17.1 Executive Summary 691
17.2 Introduction 691
17.3 Results 699
17.4 Future directions 707
17.5 Acknowledgements 711
17.6 References 711

17.7 APPENDIX A 713
17.8 APPENDIX B 724

18. ORANGE ROUGHY EAST (*HOPLOSTETHUS ATLANTICUS*) STOCK ASSESSMENT USING DATA TO 2016 - DEVELOPMENT OF A PRELIMINARY BASE CASE 730

18.1 SUMMARY 730
18.2 INTRODUCTION 731
18.3 METHODS 733
18.4 RESULTS 743
18.5 DISCUSSION 752
18.6 ACKNOWLEDGEMENTS 753
18.7 REFERENCES 753
18.8 APPENDIX A 758

19. ORANGE ROUGHY EAST (*HOPLOSTETHUS ATLANTICUS*) STOCK ASSESSMENT USING DATA TO 2016 760

19.1 SUMMARY 760
19.2 INTRODUCTION 762
19.3 METHODS 765
19.4 RESULTS 774
19.5 DISCUSSION 796
19.6 ACKNOWLEDGEMENTS 798
19.7 REFERENCES 798
19.8 APPENDIX A 804

20. WESTERN ORANGE ROUGHY 806

20.1 SUMMARY 806
20.2 INTRODUCTION 806
20.3 OBJECTIVES 807
20.4 RESULTS 808
20.5 THE STATISTICAL ANALYSIS 810
20.6 ACKNOWLEDGEMENTS 818
20.7 REFERENCES 818
20.8 APPENDIX 1: ORANGE ROUGHY DATA 821

21. ON THE POTENTIAL EFFECTS OF A SEISMIC SURVEY ON COMMERCIAL FISHERY CATCH RATES IN THE GREAT AUSTRALIAN BIGHT 822

21.1 INTRODUCTION 822
21.2 RESULTS 827
21.3 DISCUSSION AND SUMMARY 827
21.4 RECOMMENDATIONS 828
21.5 ACKNOWLEDGEMENTS 829
21.6 REFERENCES 829
21.7 APPENDIX – SURVEY COORDINATES 830
21.8 APPENDIX – STANDARDIZATION RESULTS 831

22. BENEFITS 833

23. CONCLUSION 834

24. APPENDIX: INTELLECTUAL PROPERTY 836

25. APPENDIX: PROJECT STAFF 837

17. Redfish (*Centroberyx affinis*) stock assessment based on data up to 2016

Geoff Tuck, Jemery Day, Malcolm Haddon and Claudio Castillo-Jordan

CSIRO Oceans and Atmosphere, GPO Box 1538, Hobart, TAS 7001, Australia

17.1 Executive Summary

This document describes the base case assessment and some of the issues encountered during the development of the quantitative Tier 1 eastern redfish (*Centroberyx affinis*) assessment in 2017. The last full assessment was presented in 2014 (Tuck and Day, 2014; Tuck, 2014). A preliminary base case was presented at the September RAG and was updated from the 2014 assessment by the inclusion of data up to the end of 2016, which entails an additional 3 years of catch, discard, CPUE, length and age data and ageing error updates since the 2014 assessment.

A base case assessment was achieved according to the RAG-agreed model structure that did not separate length data by zone. The model fits to the catch rate data, length data and conditional age-at-length data reasonably well. The magnitude of the estimated recruitment in 2011 in the 2014 assessment has been greatly reduced in the 2017 assessment (although estimates of recent recruitment have increased compared to the period of poor recruitment during 2002-2010). The assessment estimates that the projected 2018 spawning stock biomass will be 8% of virgin stock biomass (projected assuming 2016 catches in 2017). Estimates of recruitment since the early 2000s have been lower than average (except for 2011, 2012), potentially as a consequence of directional environmental change influencing productivity. Low recruitment scenarios using average historical recruitment residuals from 2001 to 2010 for future projections of constant annual catches showed a markedly slow increase in spawning biomass for annual catches of 50t. Catches of 150t were not sustainable under this low recruitment assumption.

Initial difficulties in reaching a tuned base case according to the RAG-agreed model structure led to several attempts at alternative models (such as single and two selectivity models to fit to port and onboard length data, fixing parameters, and removing EBass and Sydney Fish Market length data). As part of the investigation into this issue, a breakdown of the length data by year, month, zone, onboard/port, discarded and retained was conducted. This revealed that 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 caught fish lengths from the onboard length data are similar for EBass and NSW. As such, future models should consider data separated by zone, with a different discard function estimated for each zone.

17.2 Introduction

17.2.1 *Data*

Tuck (2017) described the process of moving to the new version of Stock Synthesis (version SS-V3.30.06.02, Methot, 2017) and this is not repeated here. Further minor changes to the Stock Synthesis platform occurred since September 2017 (such as corrections to projection code) and the version used here is V3.30.08.04. For completeness, the data inputs to the model are described. 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 (Haddon and Sporcic, 2017), the annual total mass landed and annual 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).

17.2.1.1 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 17.1. 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 development (referred to as BC4 in Tuck (2014)). Figure 17.1 shows a comparison of the agreed total catch (Commonwealth and NSW combined) from the 2014 assessment and the updated catch estimates for the 2017 assessment. Table 17.1 shows the annual catch values used in the assessment.

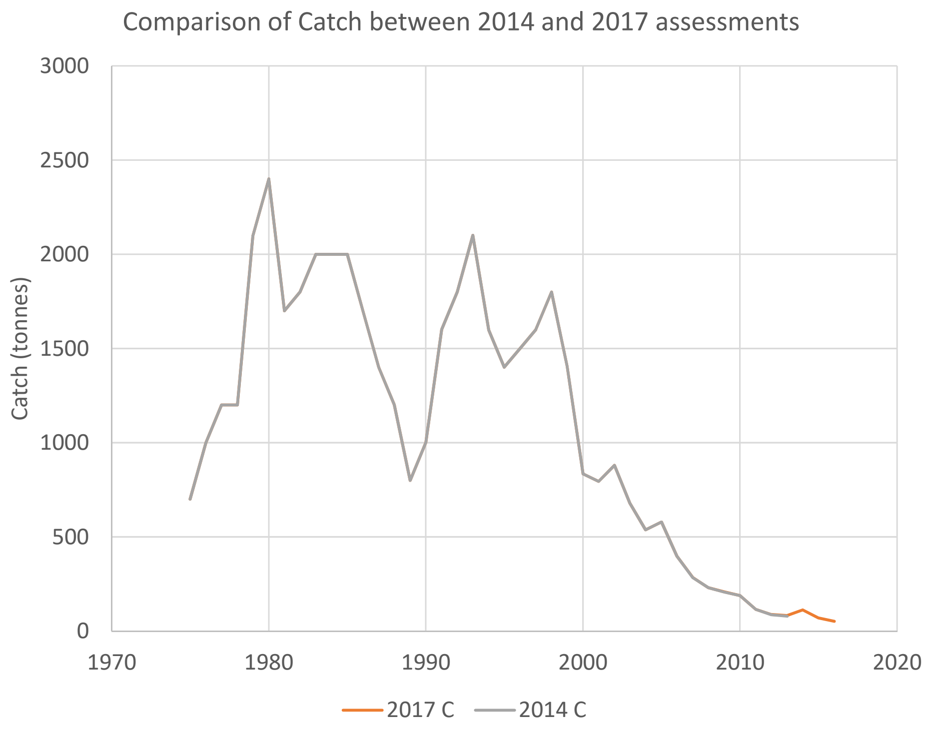


Figure 17.1. Comparison of total annual catches from the 2014 base case assessment (2014 C) and the updated catch used in the 2017 assessment (2017 C).

Table 17.1. Estimated landings (t), discard rates and standardized CPUE (Sporcic and Haddon, 2017) 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	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	1.81
1987	1400		1400	0.15	1.55
1988	1200		1200	0.15	1.74
1989	800		800	0.15	1.28
1990	1000		1000	0.10	1.62
1991	1600		1600	0.10	1.79
1992	1800		1800	0.25	2.25
1993	2100		2100	0.588	2.70
1994	1600		1600	0.569	1.99
1995	1400		1400	0.767	1.29
1996	1500		1500	0.265	1.16
1997	1600		1600	0.067	1.22
1998	1800		1800	0.213	1.43
1999	1406		1406	0.046	1.20
2000	835		835	0.131	0.80
2001	794		794	0.375	0.76
2002	880		880	0.580	0.71
2003	677		677	0.327	0.61
2004	538		538	0.398	0.54
2005	532	47	579	0.231	0.60
2006	321	76	397	0.038	0.56
2007	230	54	284	0.124	0.55
2008	201	29	231	0.018	0.49
2009	182	26	208	0.357	0.42
2010	166	23	188	0.120	0.41
2011	99	17	115	0.143	0.30
2012	72	16	88	0.021	0.21
2013	66	17	83	0.261	0.27
2014	96	16	112	0.333	0.36
2015	59	11	70	0.429	0.22
2016	43	9	52	0.404	0.17

17.2.1.2 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 2016 (Table 17.1).

The assessment model estimates the probably of retention (which is 1 – P(discard)) as a function of length in order to estimate the annual discard rate and to fit to 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 – 2013. Size based discarding period

2001 – 2013. Assume mostly small fish discarded

These changes in discarding behaviour have influenced the large variations in discard rates observed (Table 17.1), 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 onwards (size-driven).

17.2.1.3 Catch rates

Haddon and Sporcic (2017) provides the updated catch rate series for redfish (Table 17.1; Figure 17.2). After substantial increases in catch rate during the early and late 1990s, the catch rates have continued to decline since then, and the catch rate is now less than 10% of the levels in 1986. A small increase in catch rate occurred during 2013-14 but has since declined.

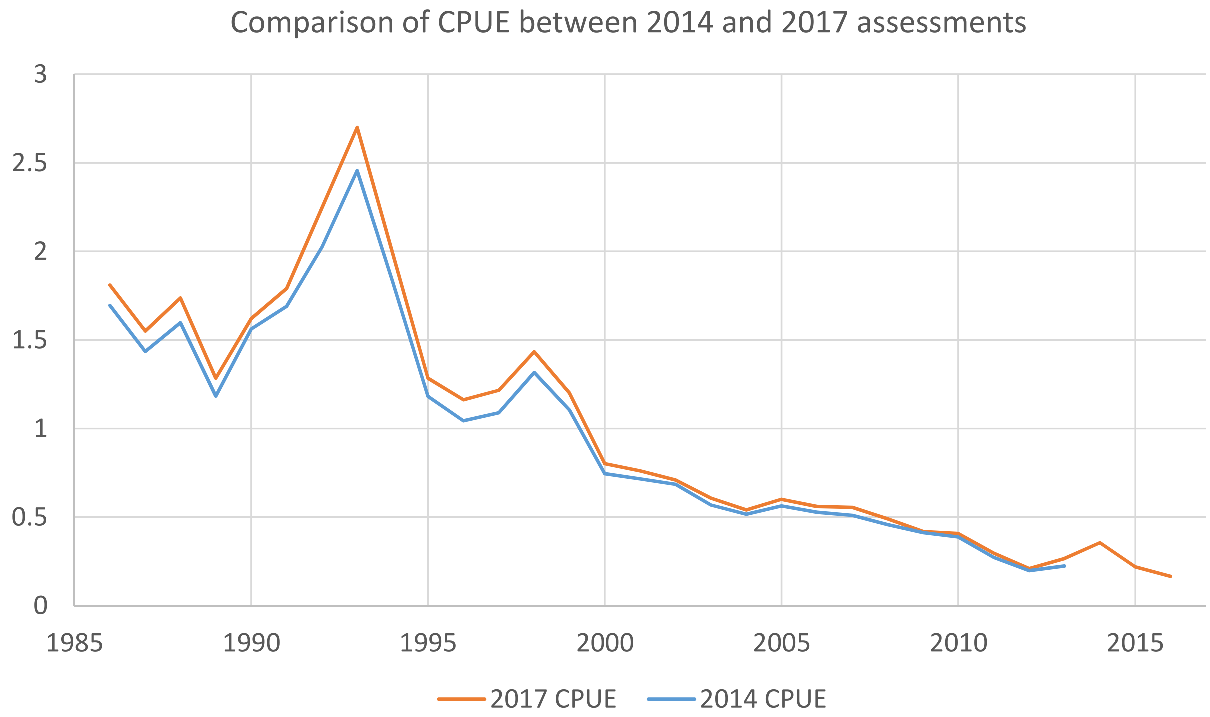


Figure 17.2. Comparison of the annual catch rates series for redfish between 2014 (2014 CPUE) and 2017 (2017 CPUE).

17.2.1.4 Length frequencies and age data

Length and age composition data have been included in the model as length frequency data and conditional age-at-length data by year and sex (when available). Marginal age composition data are included in diagnostic plots but are not used directly within the fitting procedure. Catch 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).

17.2.1.5 Biological parameters and stock structure assumptions

The assessment assumes that the 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 0.15 y^{-1} range (SEFAG, 2000). Morison and Rowling (2001) calculated natural mortality values between 0.07 and 0.11 y^{-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 there is sufficiently strong evidence to suggest a north-south split did not exist (Shelf RAG agreement, September 2014; Haddon, 2014). The 2017 base case model structure follows the RAG agreed base case from 2014 (Tuck and Day, 2014; Tuck, 2014) except that the length data are now separated into port and onboard, and updated tuning methods are applied. A new feature of SS3.30

allows specification of spawning and settlement month. Here we assume redfish spawn in July and settle in January. Previous versions of SS3 had assumed these events occurred in January.

17.2.1.6 Age-reading error

Standard deviations for aging error by reader have been estimated, producing the age-reading error matrix of Table 17.2 (A.E. Punt, pers. comm.).

17.2.1.7 Analytic approach

The 2017 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 3.30.08.04, NOAA 2017). 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).

Table 17.2. The standard deviation of age reading error.

Age	St Dev	Age	St Dev
0	0.214	20	0.922
1	0.214	21	0.946
2	0.267	22	0.969
3	0.317	23	0.992
4	0.365	24	1.013
5	0.412	25	1.034
6	0.456	26	1.053
7	0.499	27	1.072
8	0.540	28	1.090
9	0.579	29	1.108
10	0.617	30	1.125
11	0.654	31	1.141
12	0.688	32	1.156
13	0.722	33	1.171
14	0.754	34	1.185
15	0.785	35	1.199
16	0.815	36	1.212
17	0.843	37	1.225
18	0.870	38	1.237
19	0.897	39	1.249
		40	1.260

The base–case model includes the following key features:

a) A single region, single stock model is considered, with data aggregated across zones 10, 20 and 30 (RAG agreed base-case, 2014).
b) 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 for each of port and onboard lengths due to large differences in length compositions.
c) The model accounts for males and females separately.
d) The initial and final years are 1975 and 2016. Previous models (Thomson, 2002; Klaer, 2005) 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.
e) The CVs of the CPUE indices were initially set at a value equal to the standard error from a loess fit (0.247; Sporcic and Haddon, 2017), before being re-tuned to the model-estimated standard errors within SS.
f) 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 – 2013.
g) Over the period 1975-1985 the logistic retention function has an asymptotic value 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).
h) The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The value for M is 0.1 y^{-1}.
i) Recruitment to the stock is assumed to follow a Beverton-Holt type 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.
j) The initial value of the parameter determining the magnitude of the process error in annual recruitment, σ_r, is set to 0.6. This was tuned to an upper bound of 0.7.
k) The population plus-group is modelled at age 40 years, as is the maximum age for observations.
l) Growth is assumed to follow a von Bertalanffy type length-at-age relationship, with the parameters of the growth function being estimated separately for females and males during the model-fitting process.
m) Retained and discard onboard length sample sizes were capped at 200 and required to have a minimum of 100 fish sampled to be included. 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 17.3.

Table 17.3. 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

17.2.1.8 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. Most of the data sets (CPUE, surveys, 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 SS3.30 there is an automatic adjustment made to survey CVs (CPUE).

1. set the standard error for the relative abundance indices (CPUE, acoustic abundance survey, or FIS) to their estimated standard errors for each survey or for CPUE (and FIS values) 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. SS3.30 then re-balances the relative abundance variances appropriately.

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

2. adjust the recruitment variance (σ_R) by replacing it with the RMSE or a defined minimum (0.3) or maximum (0.7) and iterate to convergence (keep altering the recruitment bias adjustment ramps as predicted by SS3.30 at the same time).

Finally for the conditional age-at-length and length composition data:

3. multiply the initial sample sizes by the sample size multipliers for the age composition data using Francis weights (Francis, 2011).
4. similarly multiply the initial samples sizes by the sample size multipliers for the length composition data.
5. repeat steps 2 to 4, until all are converged and stable (proposed changes are < 1 – 2%).

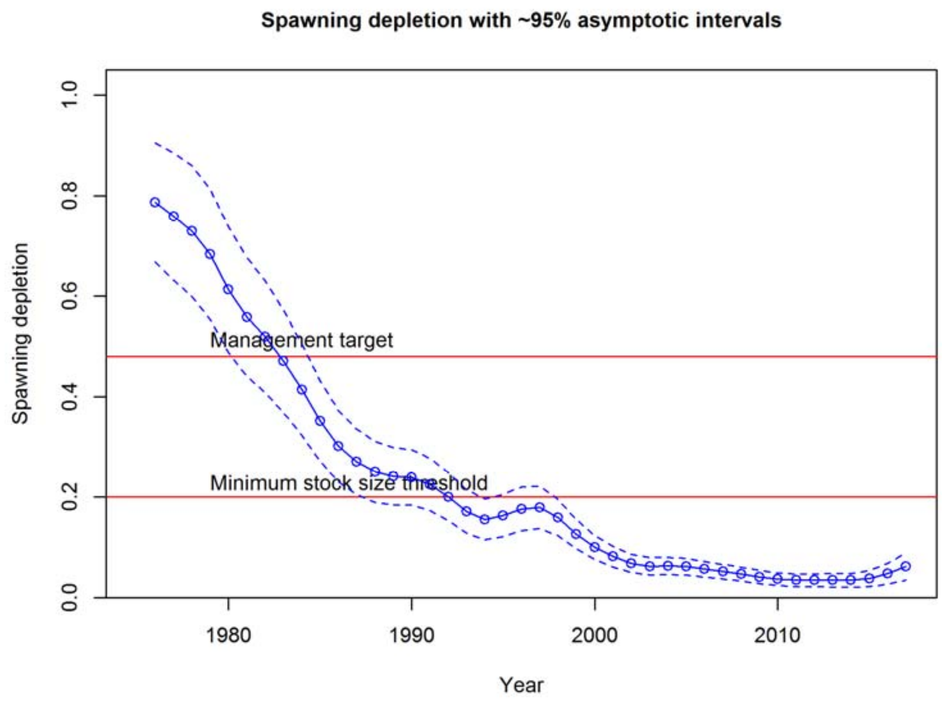
This procedure may change in the future after further investigations but constitutes current best practice.

17.3 Results

17.3.1 *The base case assessment model*

While the SERAG accepted the model structure of the preliminary base case assessment for redfish presented in September 2017, it also recommended that the 1993, 1996 and 1997 length composition data be included (which had been removed as anomalously large) and that the model estimate recruitment to 2012, rather than 2015. The large length compositions of 1993, 1996 and 1997 were from EBass (Zone 20) and were evident in both onboard and port measurements. While sample sizes are small, they are not sufficiently small to be removed according to current rules that determine acceptable annual length samples. Diagnostics presented at the September 2017 SERAG revealed that recruitments after 2012 were not sufficiently well estimated to be included in the base case assessment model. Investigations by project staff (J Day pers. comm) since the September 2017 SERAG discovered that the model had not been properly tuned to ages. The minimum sample size for ages was not sufficiently small to allow appropriate re-weighting of the age at length data. As a consequence, the model's age-at-length variance adjustment parameters were not balancing. This particular aspect was not identified until 2 November 2017. This paper has corrected this issue and provides the base case assessment results.

Diagnostic figures for the base-case model tuned according to the now agreed tuning methods are provided in Figures 3 to 6 and in Appendix A. Plots of the time-series of the spawning biomass and recruitment residuals (Figure 17.3) are similar to those shown at the September RAG (Tuck, 2017). The 2017 base case model estimates that the female spawning biomass depletion in 2018 is 8% of original biomass levels. The initial (1973) female spawning biomass is estimated to be 12,003 tonnes.



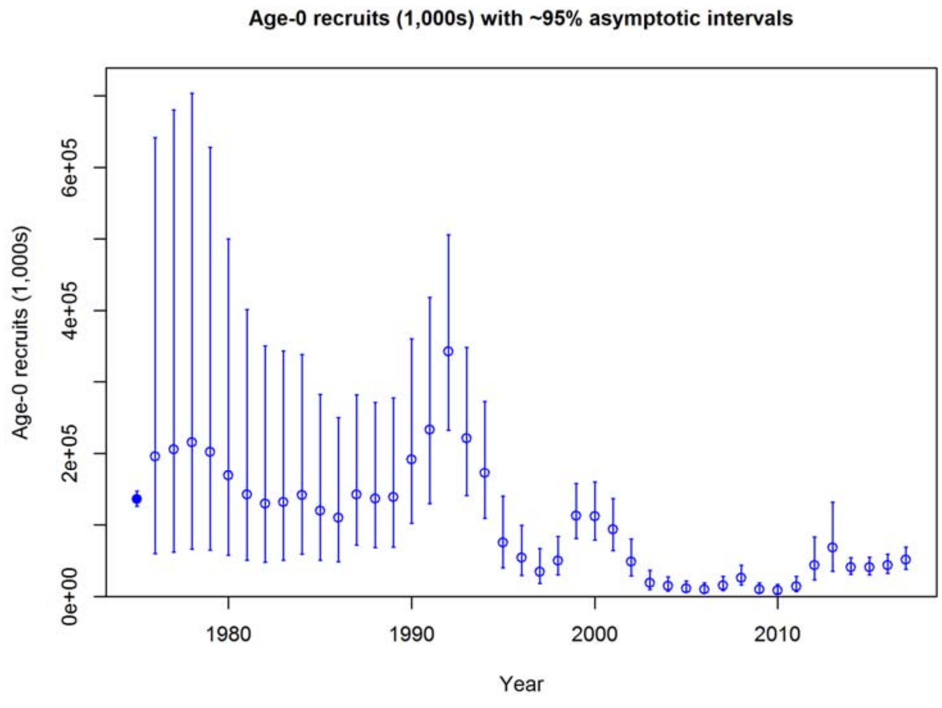


Figure 17.3. The estimated time-series of relative spawning biomass and annual recruitment for the 2017 base case assessment for redfish.

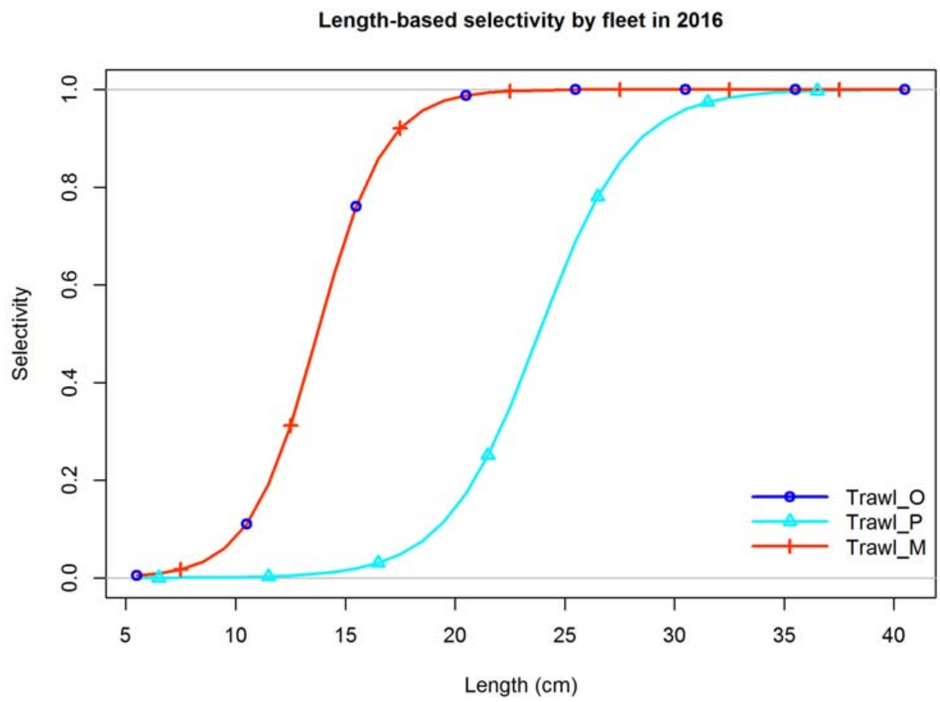


Figure 17.4. The estimated selectivity for onboard (O) and port (P) lengths for the 2 selectivity base case model.

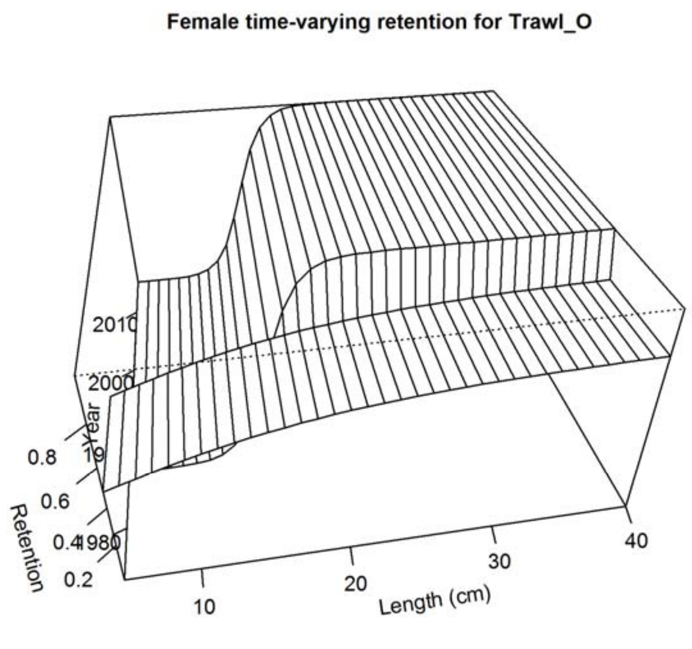


Figure 17.5. The base case estimated retention function for the 2 selectivity base case model.

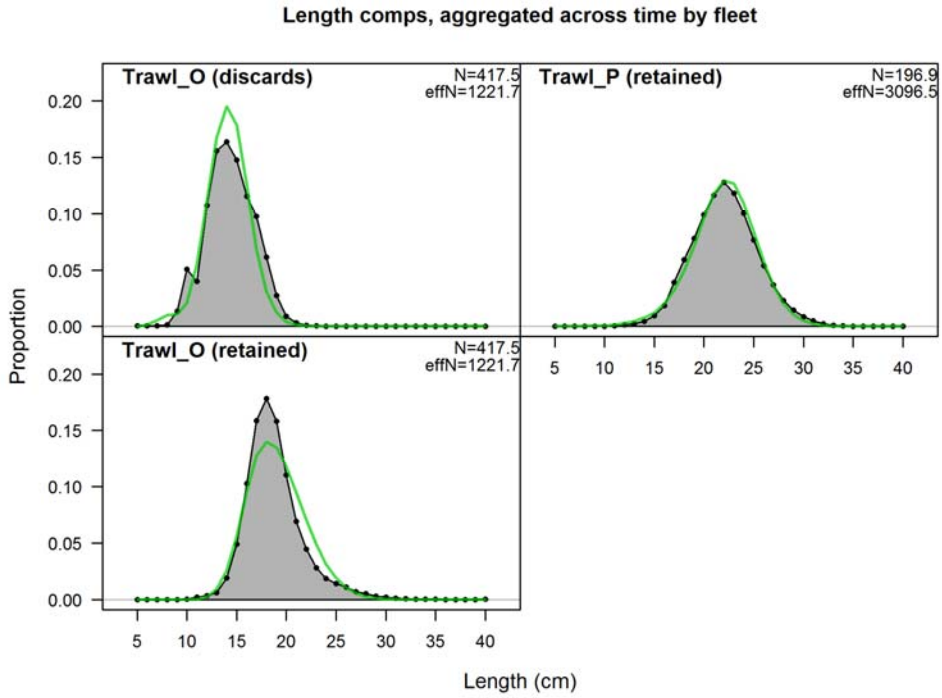


Figure 17.6. Redfish length composition data and fits (green line) aggregated across years for the 2 selectivity base case model.

17.3.2 *Standard and low recruitment projections*

Estimates of recruitment strength for eastern redfish show considerably lower values than average since at least the early 2000s (Figure 17.3 and Figure A 17.3). This could be a consequence of directional environmental change. The base case model assumes that recruitment values are taken from the stock recruitment curve for historical years that are not estimated and for future projections (in our case from 2013 onwards). If there has been an environmental driven change in productivity, this may be an overly optimistic recruitment scenario. The following scenario projects all future recruitments with the average recruitment deviations taken from the 10 year period 2001 to 2010 (average = -1.11; Figure A.3). Constant annual catches are then projected with low recruitments to explore future potential trajectories of biomass. As the low recruitment scenario markedly reduces stock productivity, annual catches of 50t take a considerably long time (beyond the 40 year projection horizon) to recover to the limit reference point (current catch is estimated to be 52t). An annual catch of 150t is unsustainable for the stock (Figure 17.7). Under the standard harvest control rule and recruitment model (that uses recruitments from the stock-recruitment curve), the spawning biomass is estimated to pass 20% of initial biomass levels by approximately 2024. With a fixed annual catch of 100t from 2018 and the standard recruitment model, the spawning biomass is estimated to pass 20% of initial biomass levels by approximately 2026 (Table 17.4). The two year delay in passing 20% of initial biomass is because the standard HCR assumes no retained catch when the biomass is below the limit reference point (compared to a fixed 100t for all future years for the C100 aveR scenario).

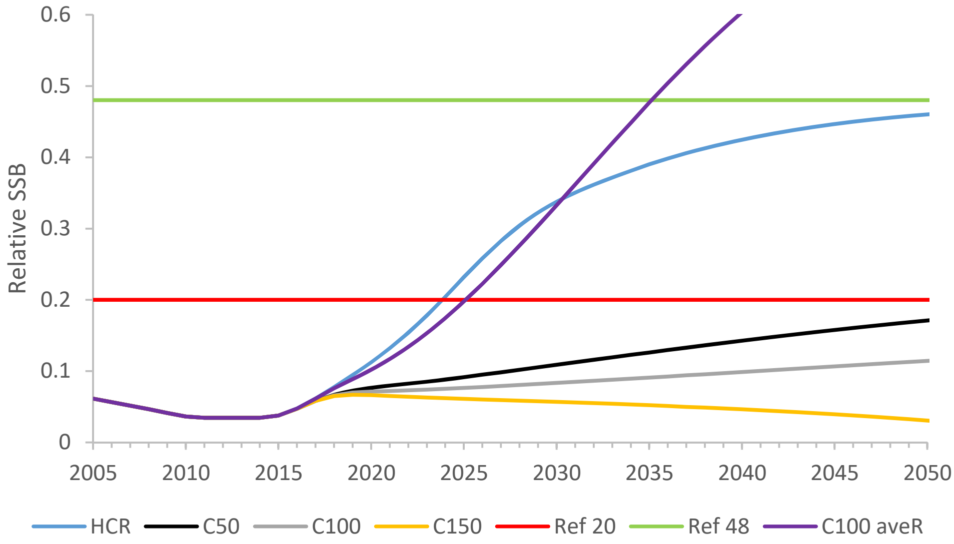


Figure 17.7. Relative spawning biomass time-series for standard SESSF harvest control rule (blue HCR), and four alternative constant catch scenarios: three with low recruitment (catches of 50t, 100t, 150t; black, grey and orange respectively) and one with standard recruitment drawn from the S-R curve with 100t annual catch from 2018 onwards (purple C100 aveR). The red and green lines are the limit (Ref 20) and target (Ref 48) biomass depletion levels.

Table 17.4. The depletion levels corresponding to the projection scenarios of Figure 17.7.

Year	HCR	C50	C100	C150	C100 aveR
2017	0.061	0.058	0.058	0.058	0.061
2018	0.077	0.067	0.066	0.065	0.076
2019	0.094	0.073	0.070	0.067	0.089
2020	0.112	0.076	0.071	0.066	0.102
2021	0.132	0.079	0.072	0.065	0.117
2022	0.154	0.082	0.073	0.064	0.134
2023	0.178	0.085	0.074	0.063	0.153
2024	0.204	0.088	0.075	0.062	0.174
2025	0.232	0.091	0.076	0.061	0.198
2026	0.258	0.095	0.078	0.060	0.222
2027	0.282	0.098	0.079	0.059	0.249
2028	0.304	0.102	0.080	0.058	0.276
2029	0.322	0.105	0.082	0.058	0.304
2030	0.338	0.109	0.083	0.057	0.333

17.3.3 *Sensitivities to the base case model*

Standard sensitivities to alternative natural mortality values (M=0.08, 0.12, and M estimated), steepness (h=0.65, 0.85, and h estimated), and σ_R (0.6, 0.8) were considered (Table 17.5 and Table 17.6). The base-case model and sensitivities all have stock status less than the limit reference point of 20% of virgin spawning biomass, and generally vary between 5% and 12%. Results from a comparison of likelihoods (Table 17.5) suggest that lower values of natural mortality and steepness should be considered in future assessments.

Table 17.5. Summary of sensitivity results for the base-case model.

Case		SSB_0	SSB_{2018}	SSB_{2018}/SSB_0
0	base case 20:35:48 *M*=0.10 *h*=0.75	12005	928	0.08
1	*M*=0.08	14604	832	0.06
2	*M*=0.12	9707	1069	0.11
3	estimate *M* (0.077), *h*=0.75	15014	820	0.05
4	steepness, *h* =0.65	13324	820	0.06
5	steepness, *h*=0.85	10244	1208	0.12
6	estimate *h* (0.55), *M*=0.10	15106	760	0.05
7	$\sigma_R = 0.8$	12171	898	0.07

Table 17.6. Summary of likelihood components for the base-case model structure and sensitivity tests. Sensitivities from the base case are shown as differences from the base case. A negative value indicates a better fit, a positive value a worse fit.

		TOTAL	CPUE	Discard	Length comp	Age comp	Recruit	Parm priors
0	base case 20:35:48 *M*=0.10 *h*=0.75	630.41	-21.39	93.09	201.97	340.79	14.90	0.05
1	*M*=0.08	-3.13	-0.23	-0.74	-1.56	0.52	-1.16	0.00
2	*M*=0.12	4.62	0.28	-1.74	3.55	-0.83	3.47	-0.01
3	estimate *M* (0.100), *h*=0.75	-3.16	-0.26	-0.88	-1.72	0.77	-1.16	0.04
4	steepness, *h* =0.65	-5.71	-1.25	-1.20	0.87	-1.32	-2.74	-0.01
5	steepness, *h*=0.85	8.49	2.11	-1.92	2.61	-1.08	6.83	-0.01
6	estimate *h* (0.593), *M*=0.10	-7.42	-2.15	-1.75	1.21	-1.14	-4.21	0.77
7	$\sigma_R = 0.8$	-3.64	-0.73	-3.01	0.70	0.00	-0.57	0.00

17.3.4 *Single selectivity model sensitivity*

As part of the process of identifying an acceptable base-case when fits to the agreed model structure were poor, a number of alternative model structures were attempted, including having a single selectivity for both port and onboard lengths. This model was able to balance according to the new tuning methods, however the fit to the port lengths was poor as the model cannot fit concurrently to the larger port lengths and the smaller onboard lengths (a model with no EBass port lengths or SFM lengths was able to provide good fits to both port and onboard lengths, but removed much of the data that informs the model about early recruitment). Additional diagnostic plots are in Appendix B. According to this model, the 2018 depletion is 7% of original female spawning biomass levels.

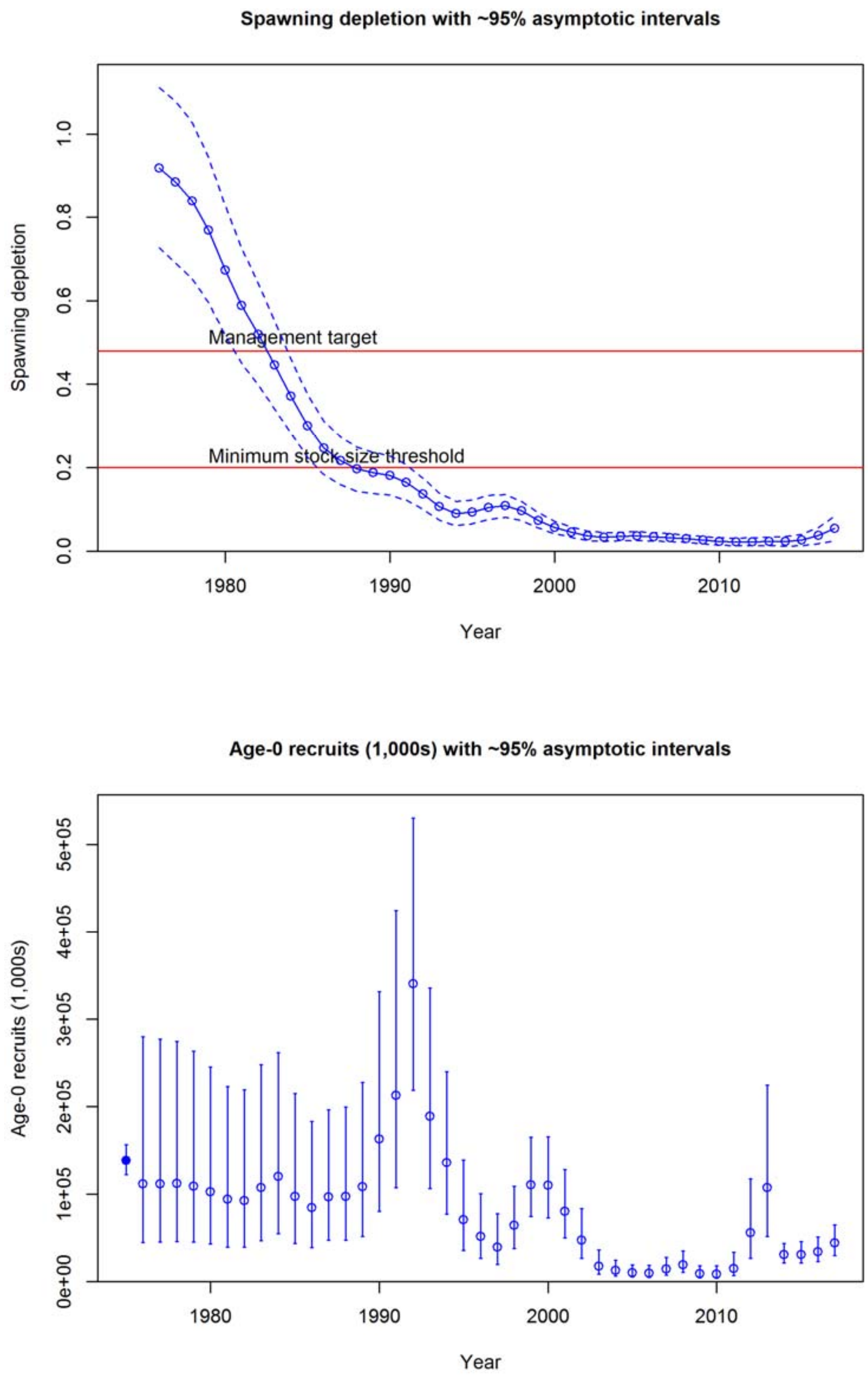


Figure 17.8. The estimated time-series of relative spawning biomass and annual recruitment for the single selectivity model.

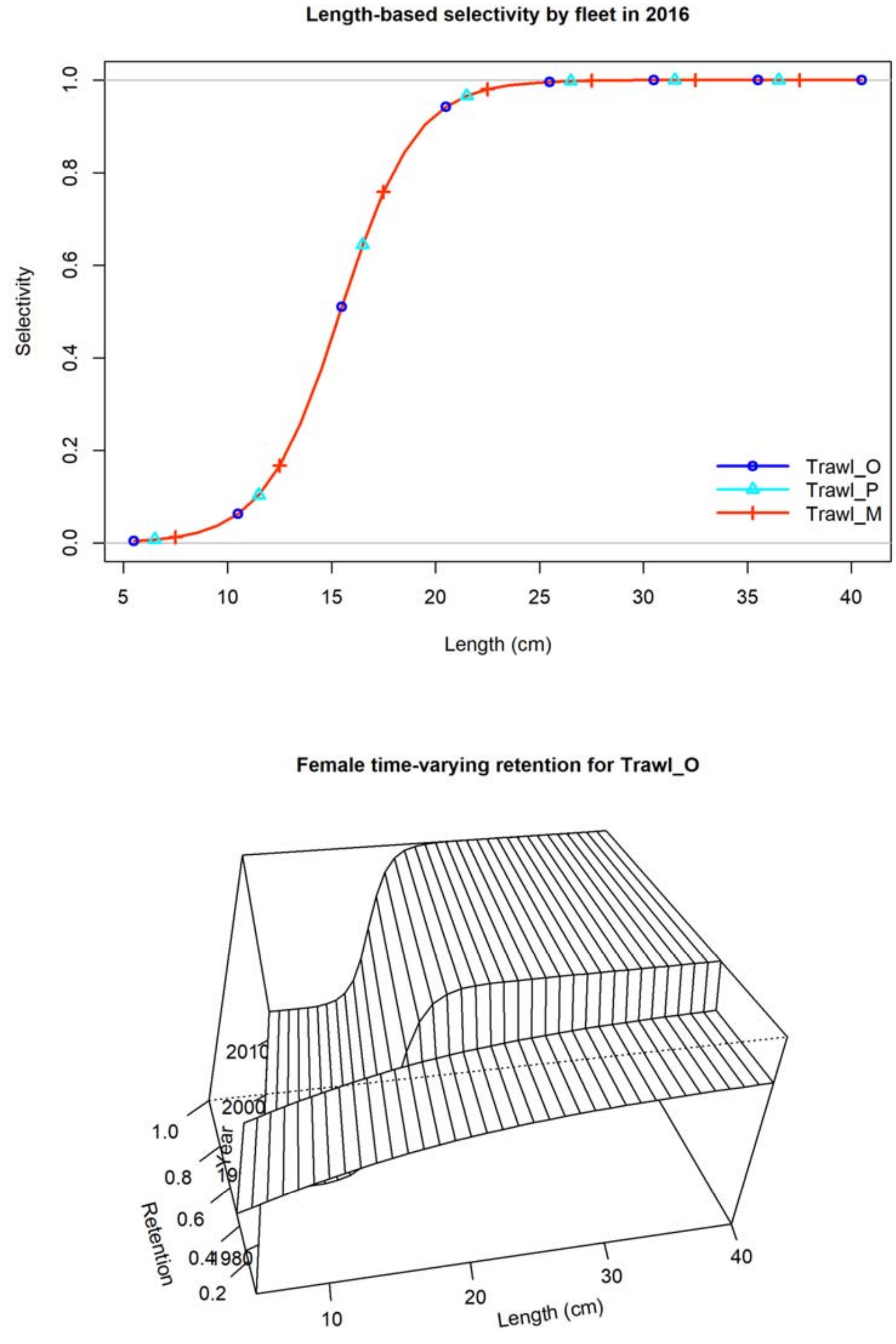


Figure 17.9. The estimated selectivity and retention for lengths for the single selectivity model.

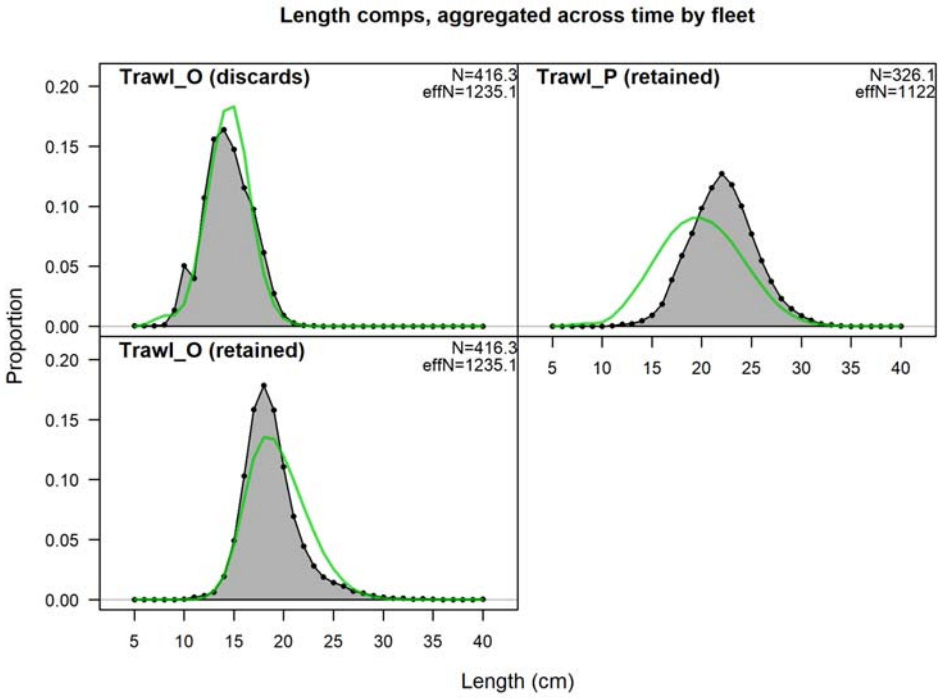


Figure 17.10. Redfish length composition data and fits (green line) aggregated across years for the single selectivity model.

17.4 Future directions

As part of the more detailed exploration of the data brought about by the apparent poor fit to length data, differences were observed between port length compositions from Eastern Bass (EBass, Z20) and NSW (Z10). As can be seen from the Zone by Month figures, even though similar lengths of fish are caught (as seen from the similar onboard length compositions in EBass and NSW; Figure 17.10), the EBass port length compositions appear to suggest that much larger fish are being landed than in NSW (Figure 17.11). This may imply different discarding practices in each zone, whereby a high proportion of fish of lengths less than 15cm are discarded in EBass. However, in NSW some fish below 15cm are landed. Figure 17.12 shows the year aggregated lengths by zone for onboard retained and discarded and port retained lengths. This shows the generally broader distributions of lengths discarded in EBass and that few fish are landed below 15 cm in EBass. It was also evident that Sydney Fish Market lengths (1975 to 1991) were considerably larger than more recent ISMP length samples from NSW (Figure 17.13).

As far as a future Tier 1 assessment is concerned, a model that separates data inputs by zone, including catch, catch rates, discard rates and lengths by zone (to allow alternative discard functions), may be a promising way forward for the redfish assessment.

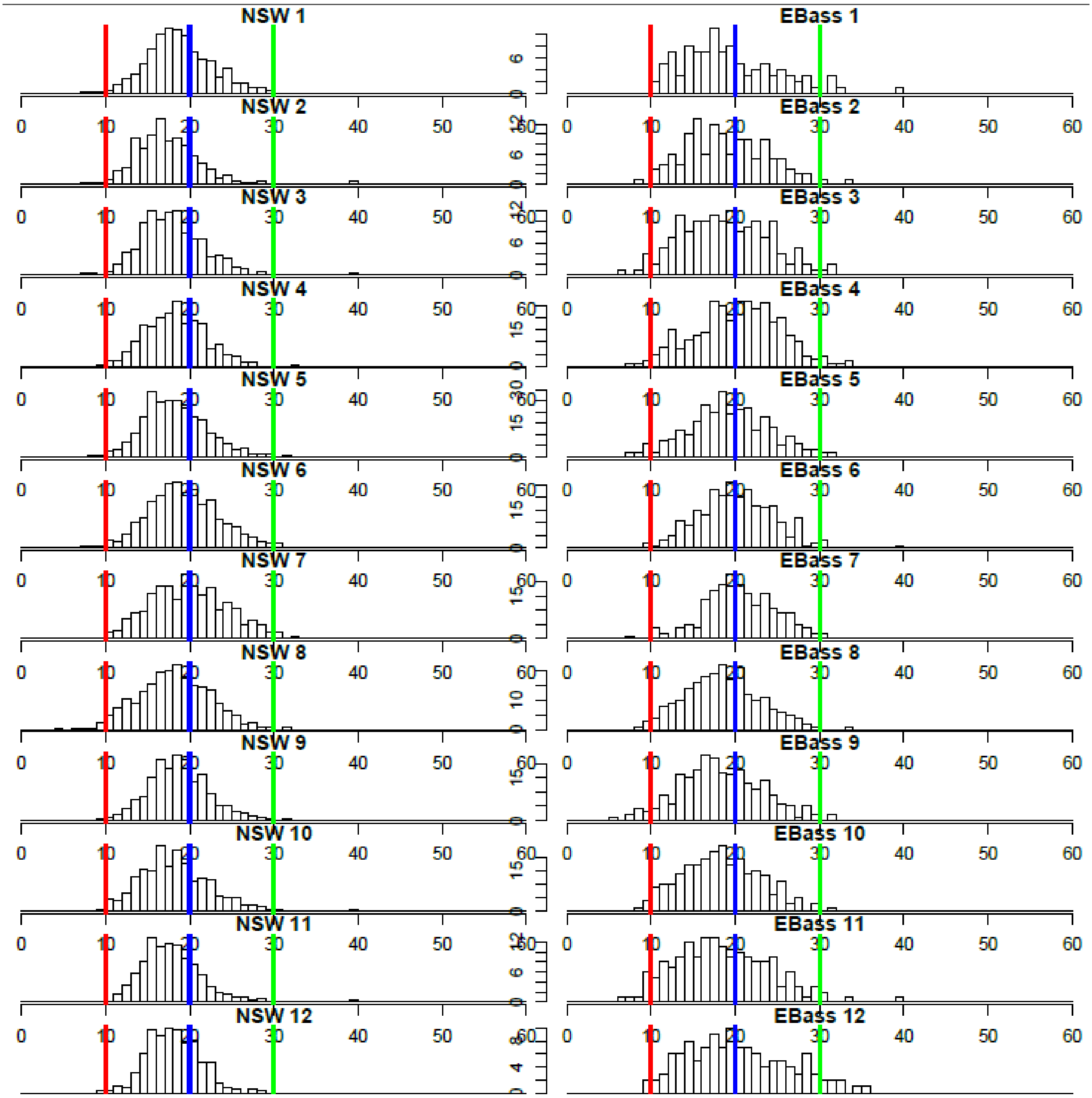


Figure 17.11. Onboard (retained and discard) length distributions of redfish by month and zone (NSW and Eastern Bass). Red (10cm), Blue (20cm) and Green (30cm).

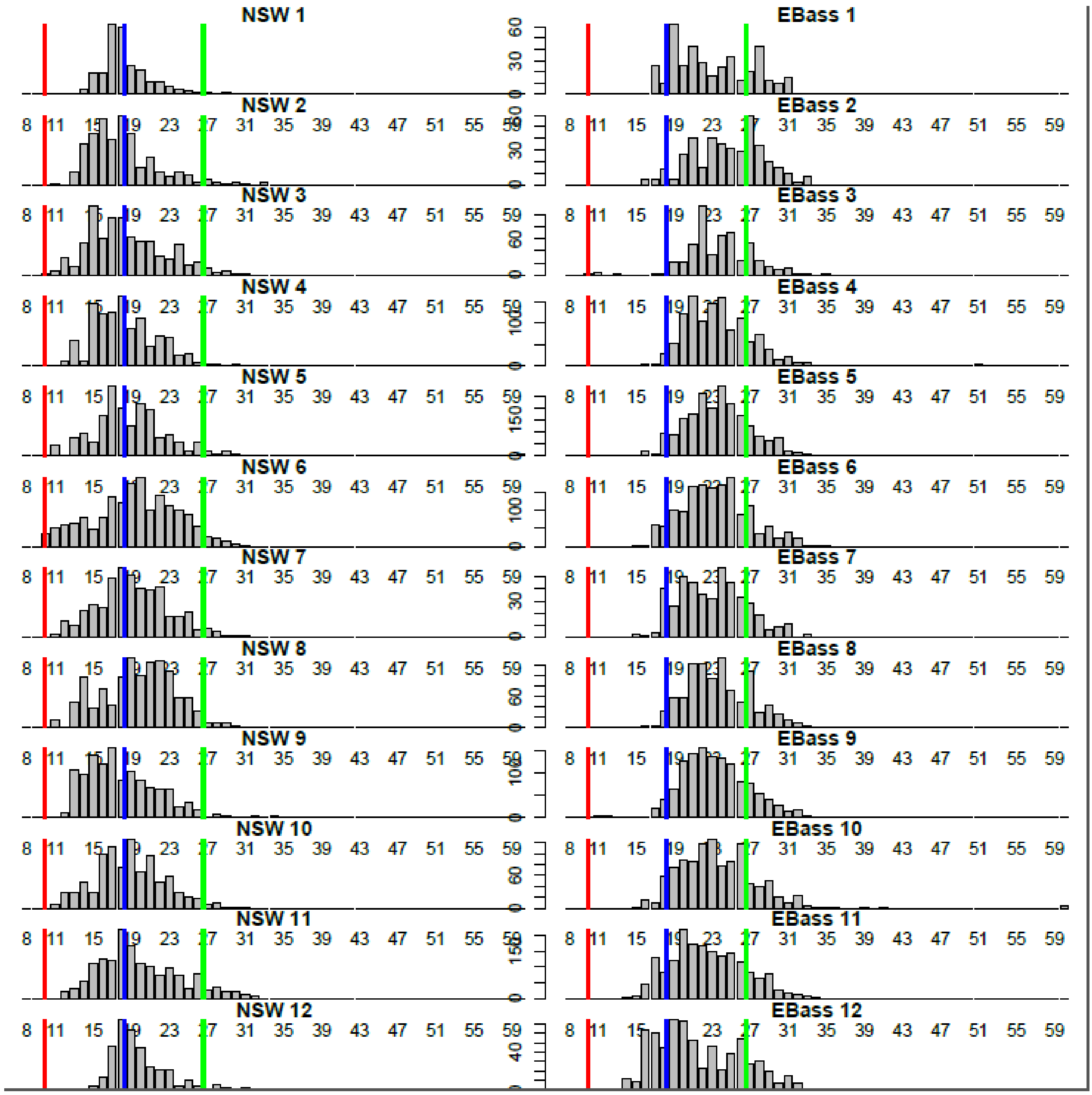


Figure 17.12. Port length distributions of redfish by month and zone (NSW and Eastern Bass). Red (10cm), Blue (20cm) and Green (30cm).

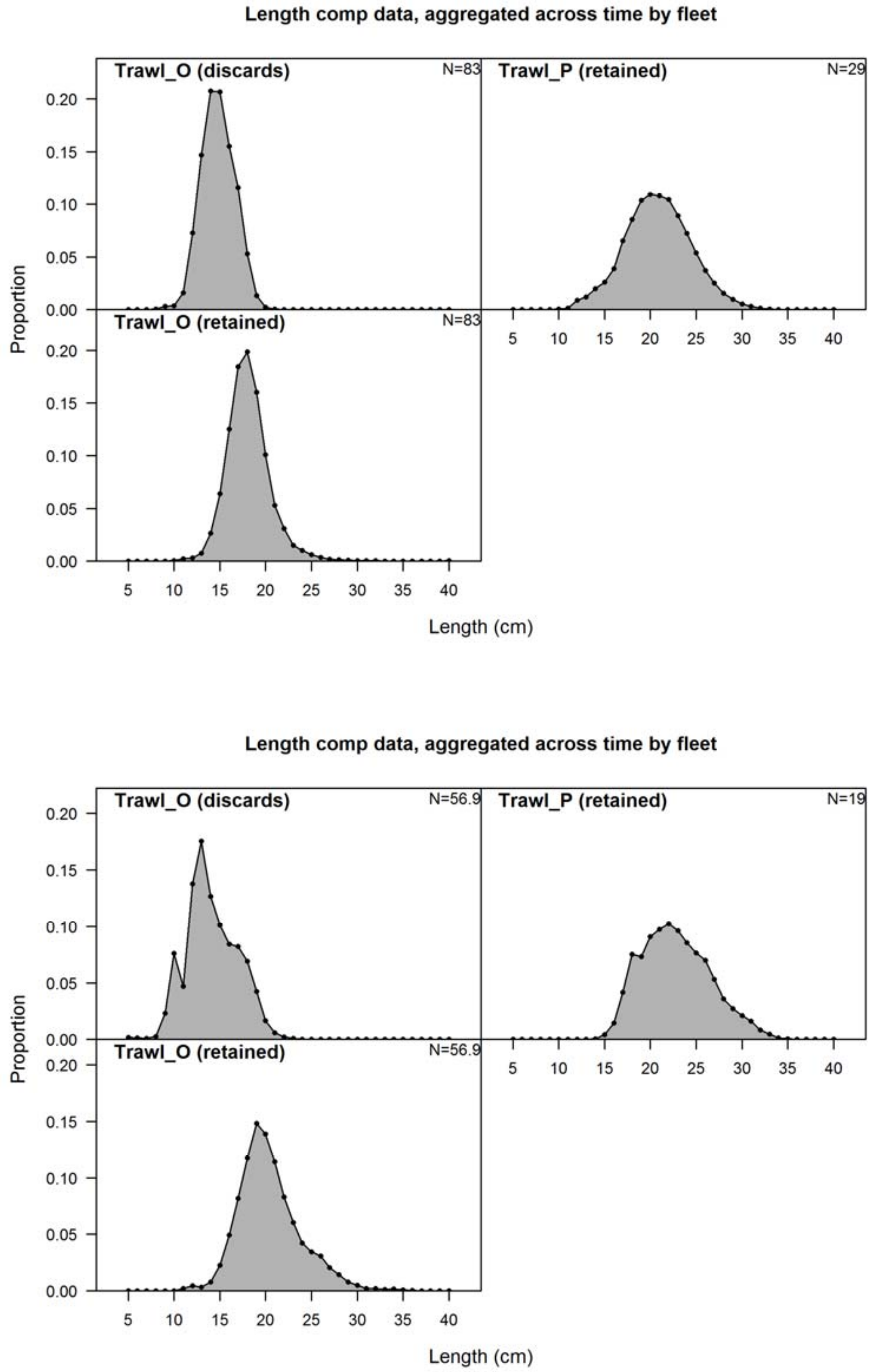


Figure 17.13. The length data aggregated across year for (top) NSW (Zone 10) and (bottom) EBass (Zone 20).

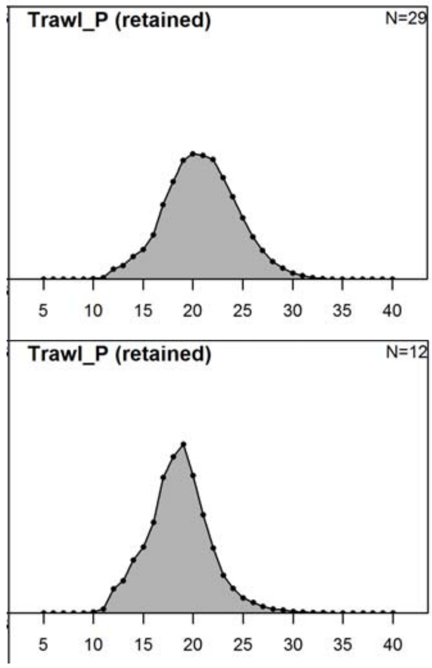


Figure 17.14. The length distribution from port samples from NSW with Sydney Fish Market lengths from 1975 to 1991 (top) and without SFM lengths (bottom).

17.5 Acknowledgements

Age data was provided by Kyne Krusic-Golub (Fish Ageing Services), ISMP and AFMA logbook and CDR data were provided by John Garvey (AFMA). Mike Fuller, Roy Deng and Franzis Althaus (CSIRO) pre-processed the data. The CSIRO SESSF Team and Kev Rowling are thanked for helpful discussions on this work. This work greatly benefitted from the generous help of Ian Taylor and Rick Methot (NOAA).

17.6 References

Francis, R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68: 1124-1138.

Haddon, M. 2014. Length at Age for Redfish (*Centroberyx affinis*). CSIRO, Oceans and Atmosphere, Hobart, Australia. 34p.

Haddon, M and Sporcic, M. 2017. Catch Rate Standardizations 2017 (for data 1986 – 2016). Technical paper presented to SESSF Resource Assessment Group. August 2017. Hobart, Tasmania.

Hilborn, R., Maunder, M., Parma, A., Ernst, B., Payne, J. and Starr, P. 2000. Coleraine – A generalized age structured stock assessment model. http://www.fish.washington.edu/research/coleraine/

Methot, R.D. 2005 Technical Description of the Stock Synthesis II Assessment Program. NOAA Fisheries Service, Seattle. 54 pp.

Methot, R.D. 2011. User manual for Stock Synthesis Model Version 3.2. NOAA Fisheries Service, Seattle. 165 pp.

Methot, R.D. and C.R. Wetzel. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142: 86–90.

Rowling, K.R. 1994. Redfish, *Centroberyx affinis* in R.D.J. Tilzey (ed) The South East Fishery, Bureau of Resource Sciences, Canberra.

Rowling, K.R. 1999 Stock Assessment Report for Redfish, 1999. Redfish Assessment Group, South East Fishery Assessment Group, Australian Fisheries Management Authority, Canberra.

Thomson, R.B. 2002. Integrated Analysis of redfish in the South East Fishery, including the 2001 fishing data. Report to Redfish Assessment Group, Bermagui, 27-28 June 2002.

Tuck, G.N. 2014. Stock assessment of redfish *Centroberyx affinis* based on data up to 2013: Supplement to the October 2014 Shelf RAG paper. Technical document presented to the Shelf RAG, 22 November 2014.

Tuck, G.N. and Day, J.R. 2014. Development of a base-case Tier 1 assessment of redfish *Centroberyx affinis* based on data up to 201. Technical document presented to the Shelf RAG, Hobart, 22 September 2014.

Tuck, G.N. 2017. Redfish (*Centroberyx affinis*) stock assessment based on data up to 2016 – development of a preliminary base case. Technical paper presented to the SERAG, 20-22 September 2017, Hobart, Australia.

17.7 Appendix A

17.7.1 ***Base base (2 Selectivity) model diagnostics***

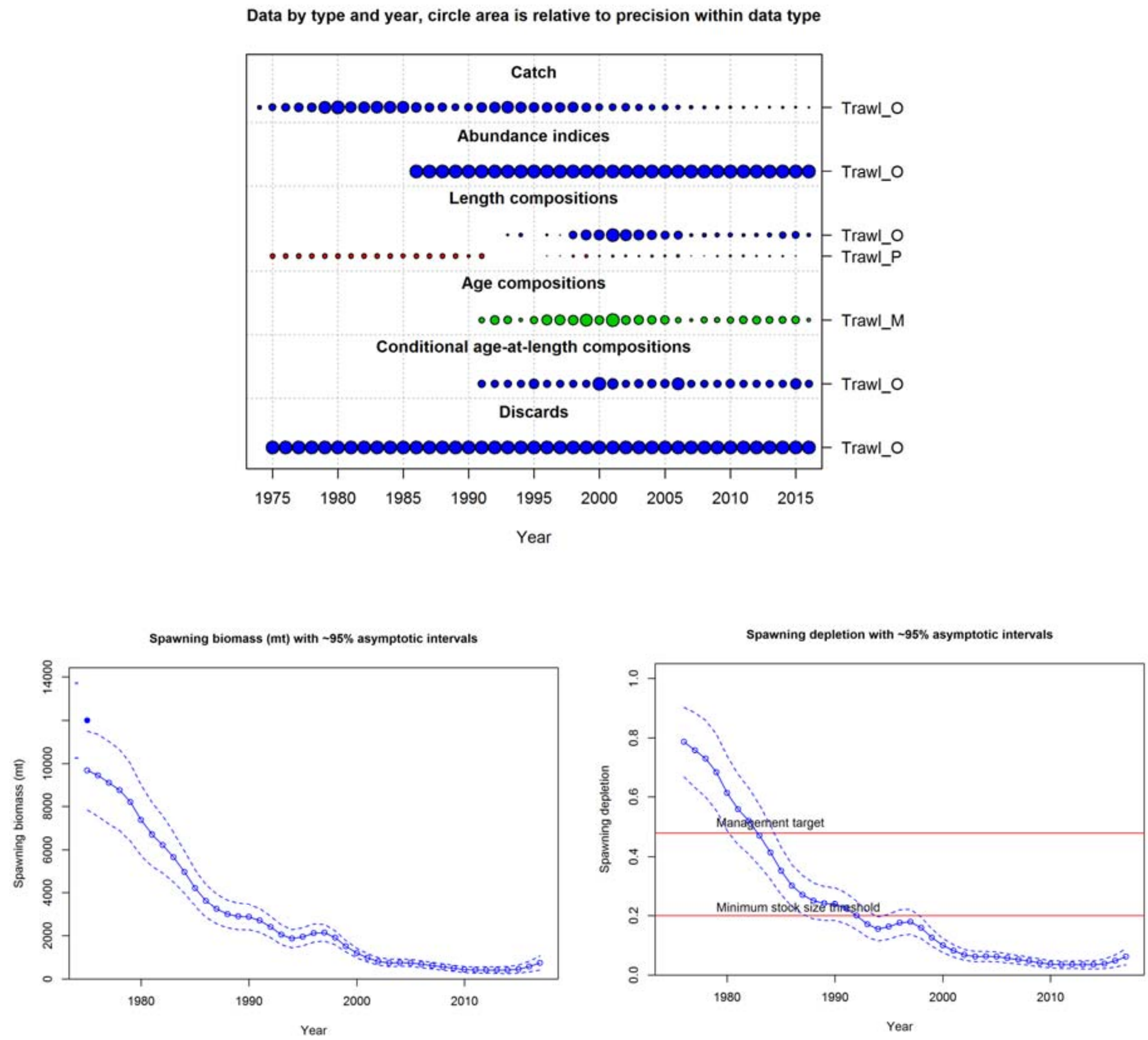
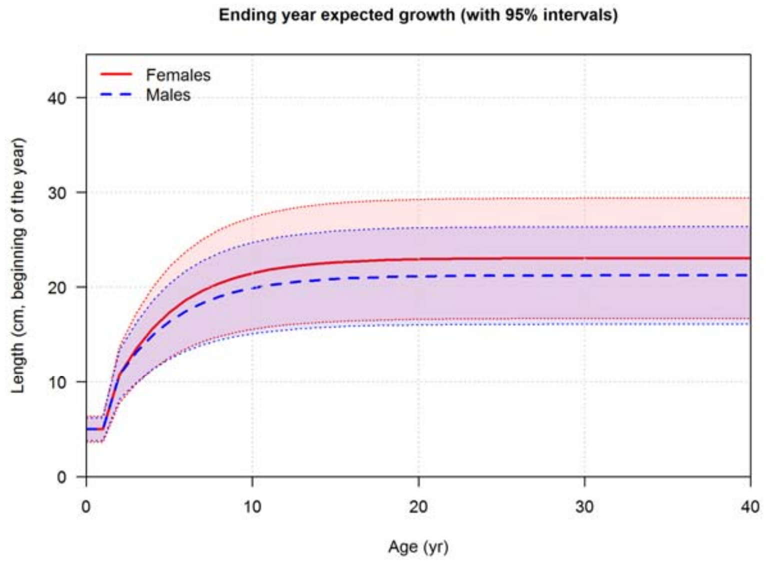


Figure A 17.1. Summary of data sources (top) for the 2 selectivity base case assessment. O = on board, P = port, M = mirrored (used to observe age composition fits). The time-series of absolute and relative female spawning biomass for the redfish base case stock assessment model (bottom).



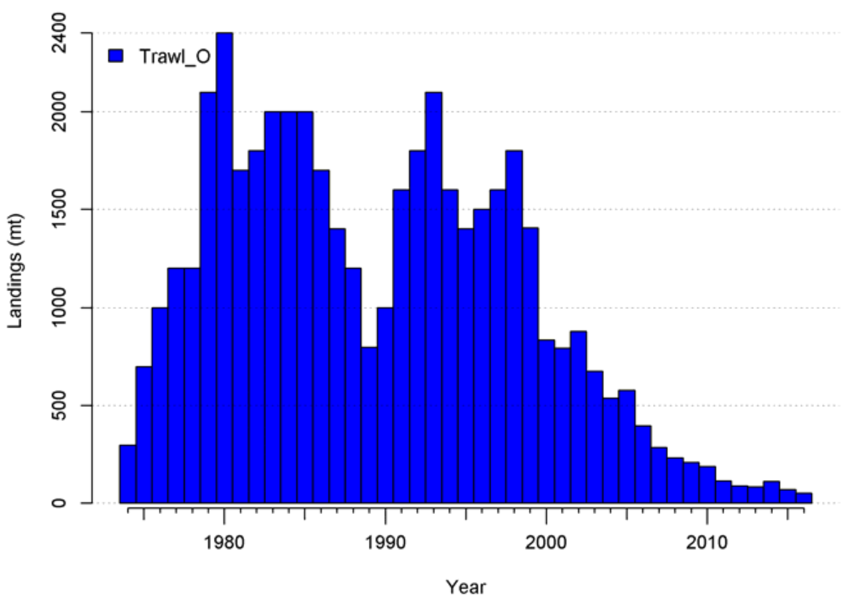


Figure A 17.2. Growth and landings for redfish.

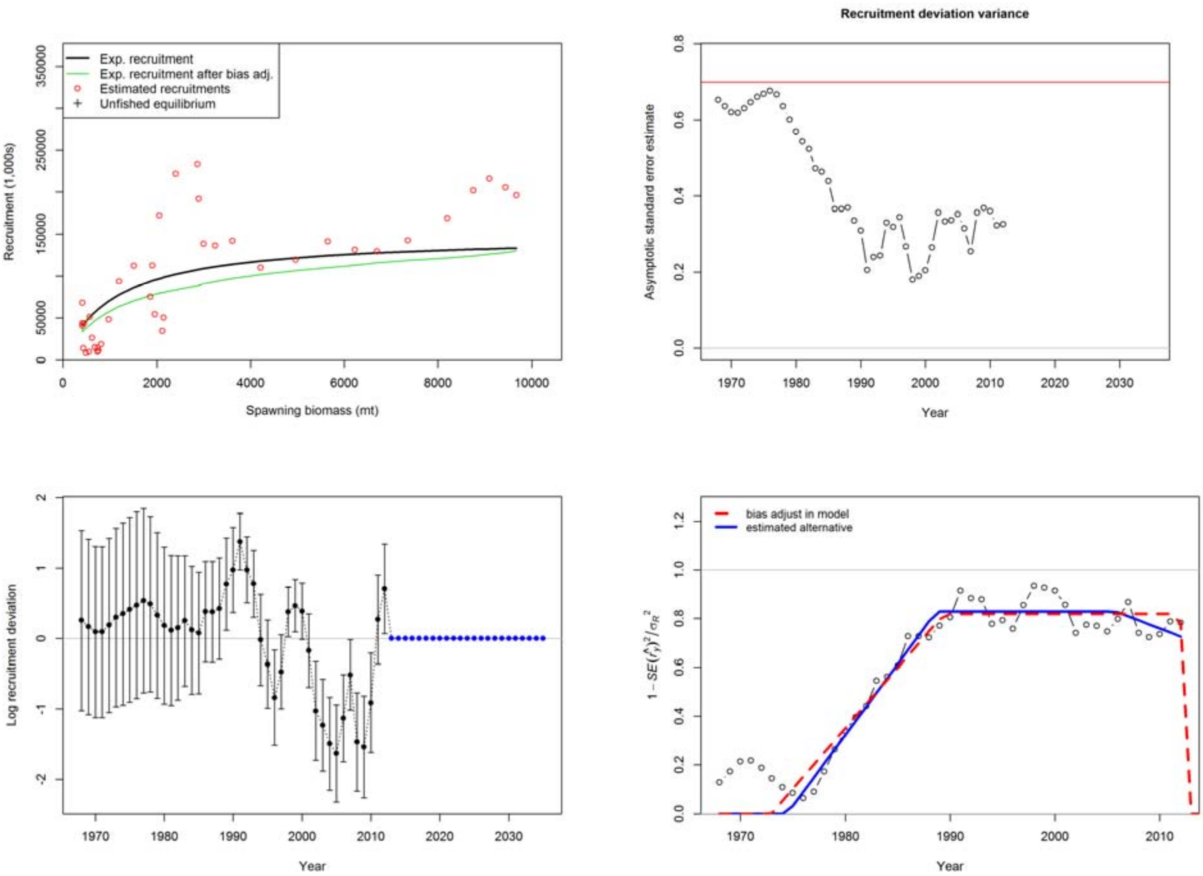


Figure A 17.3. Time series showing the stock recruitment curve, recruitment deviations and recruitment deviation variance check for redfish.

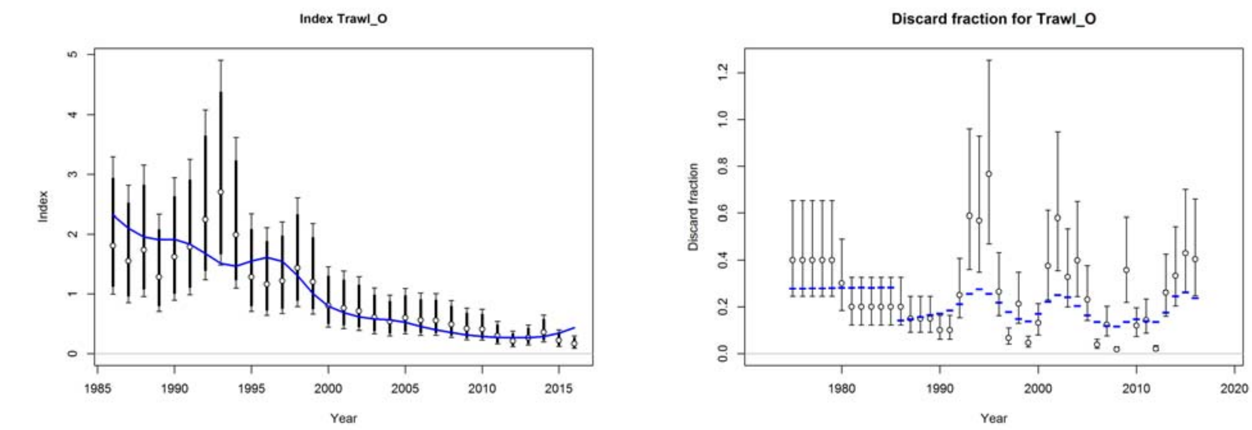


Figure A 17.4. Fits to trawl CPUE and discards for redfish.

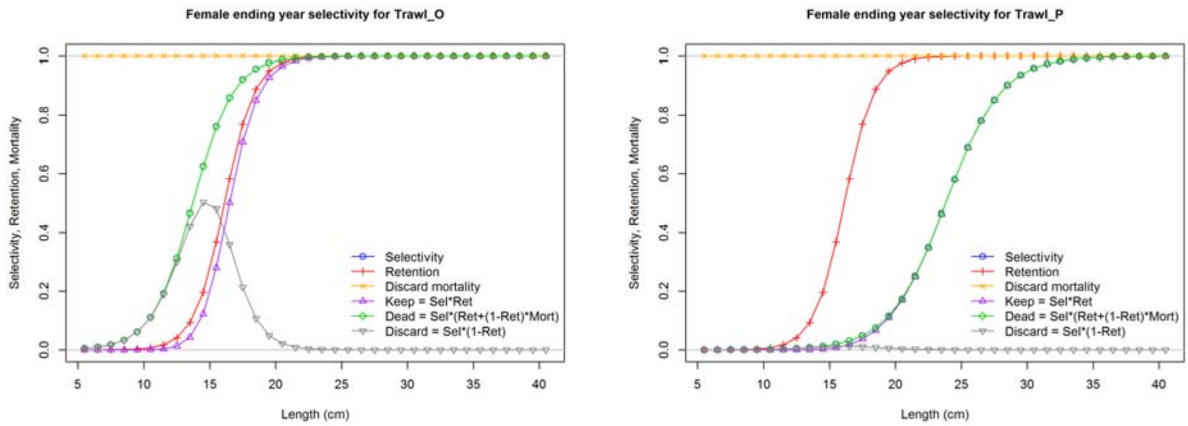


Figure A 17.5. Estimated trawl selectivity for port (P) and onboard (O) and the retention function for redfish.

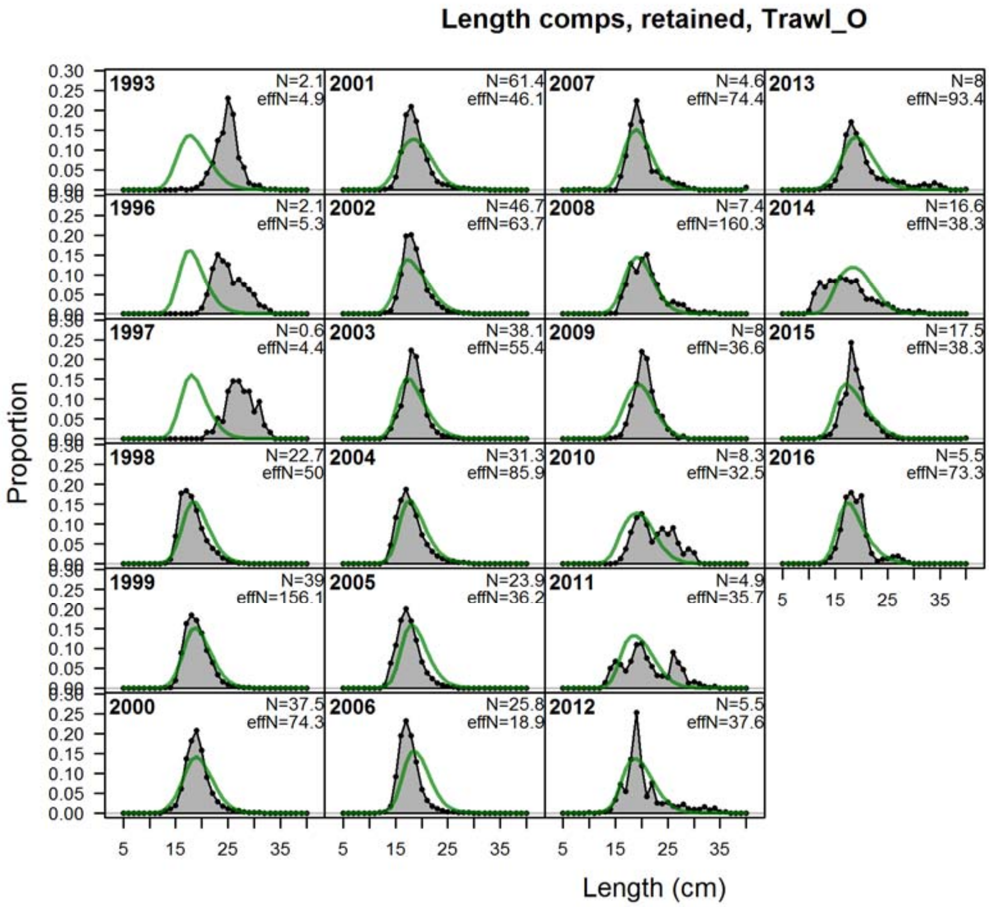


Figure A 17.6. Redfish length composition fits: onboard trawl retained.

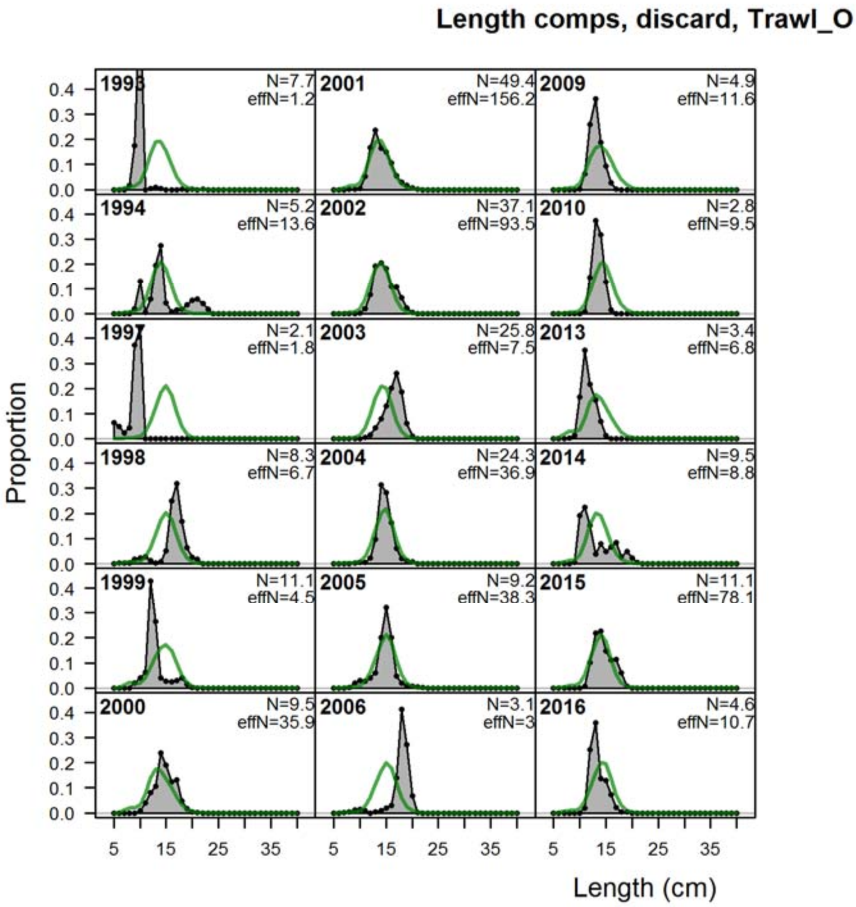


Figure A 17.7. Redfish length composition fits: onboard trawl discard.

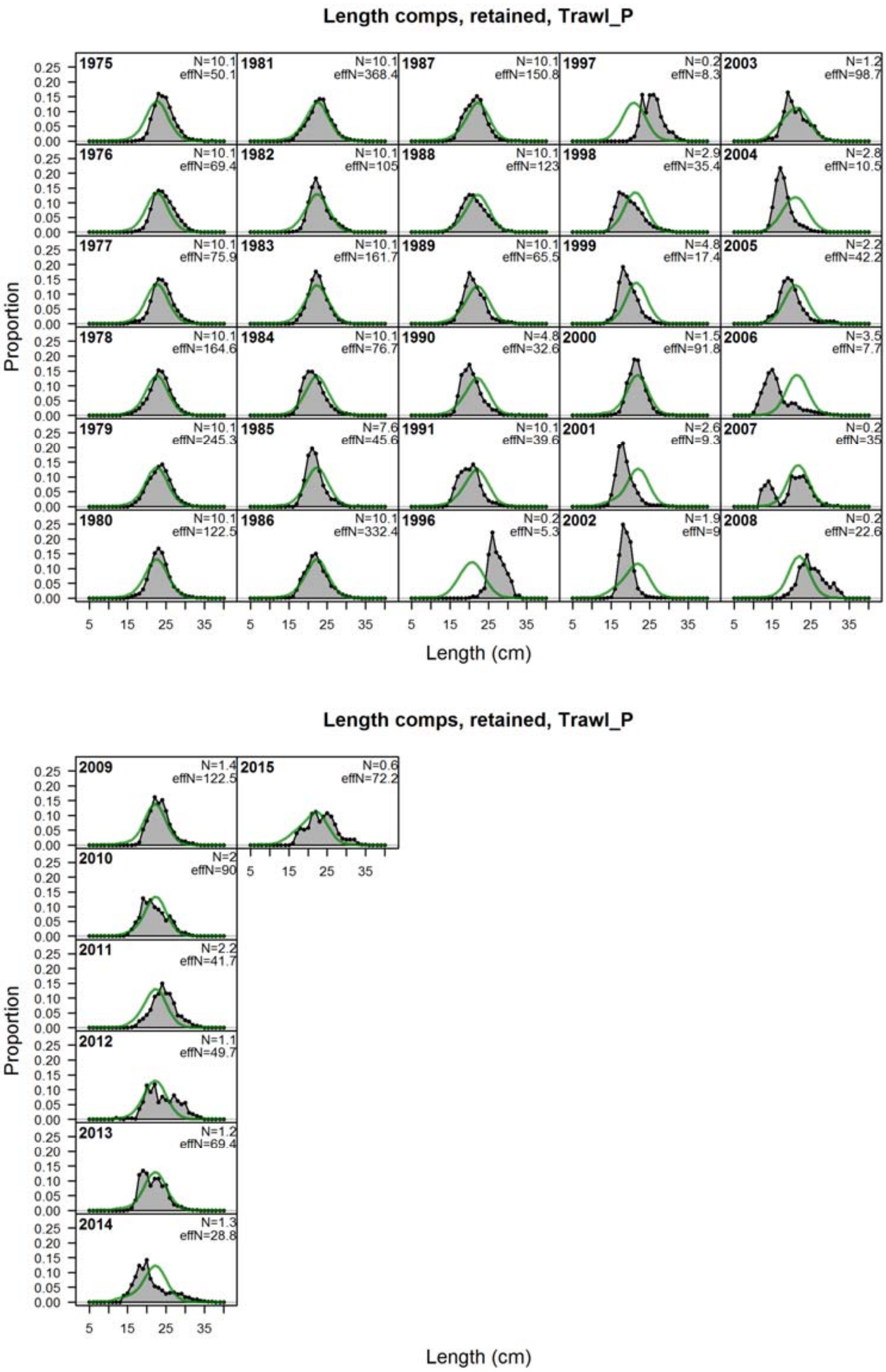


Figure A 17.8. Redfish length composition fits: Port trawl.

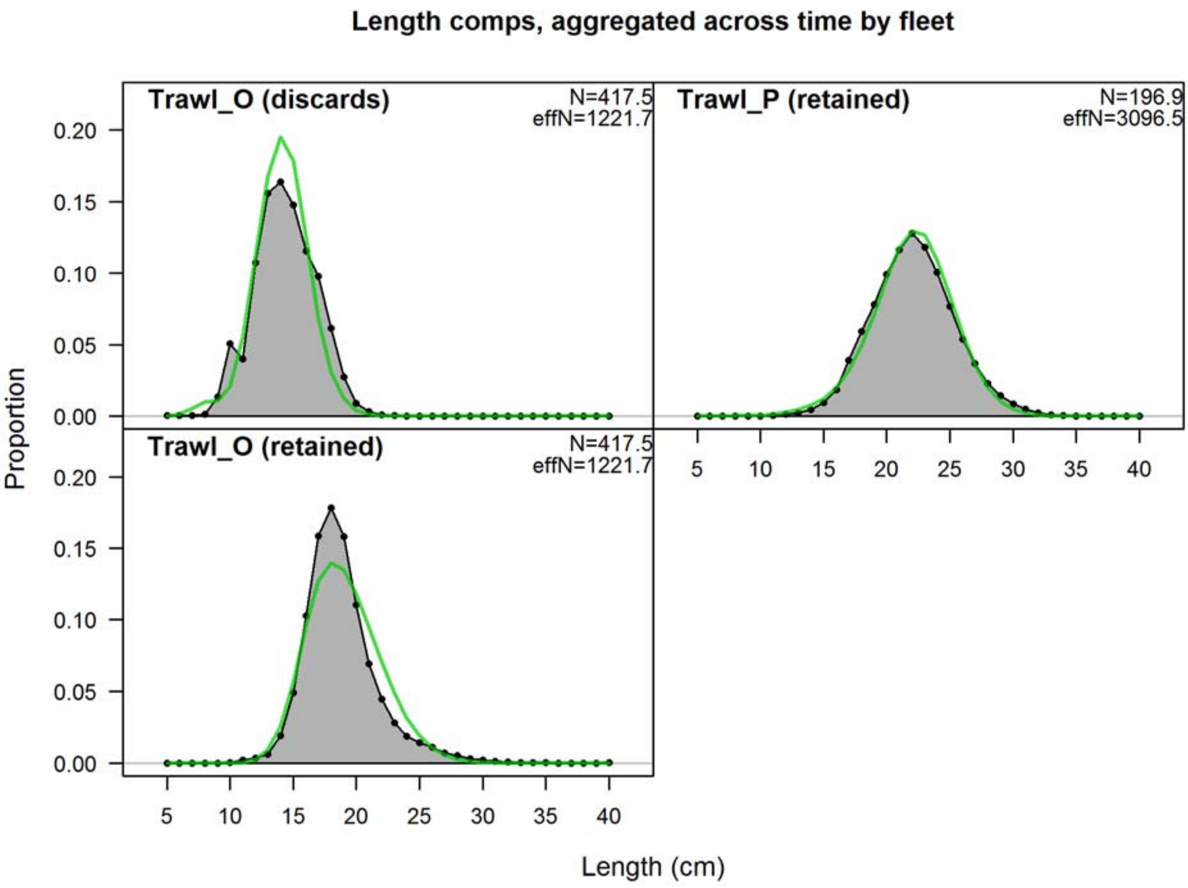


Figure A 17.9. Redfish length composition fits aggregated across years.

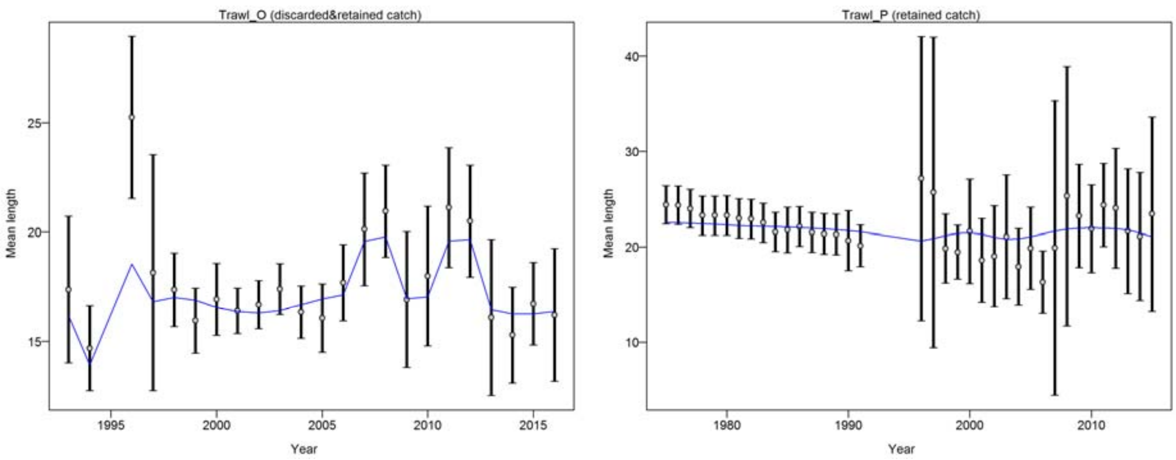


Figure A 17.10. Redfish length composition fit diagnostics from tuning. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for length data.

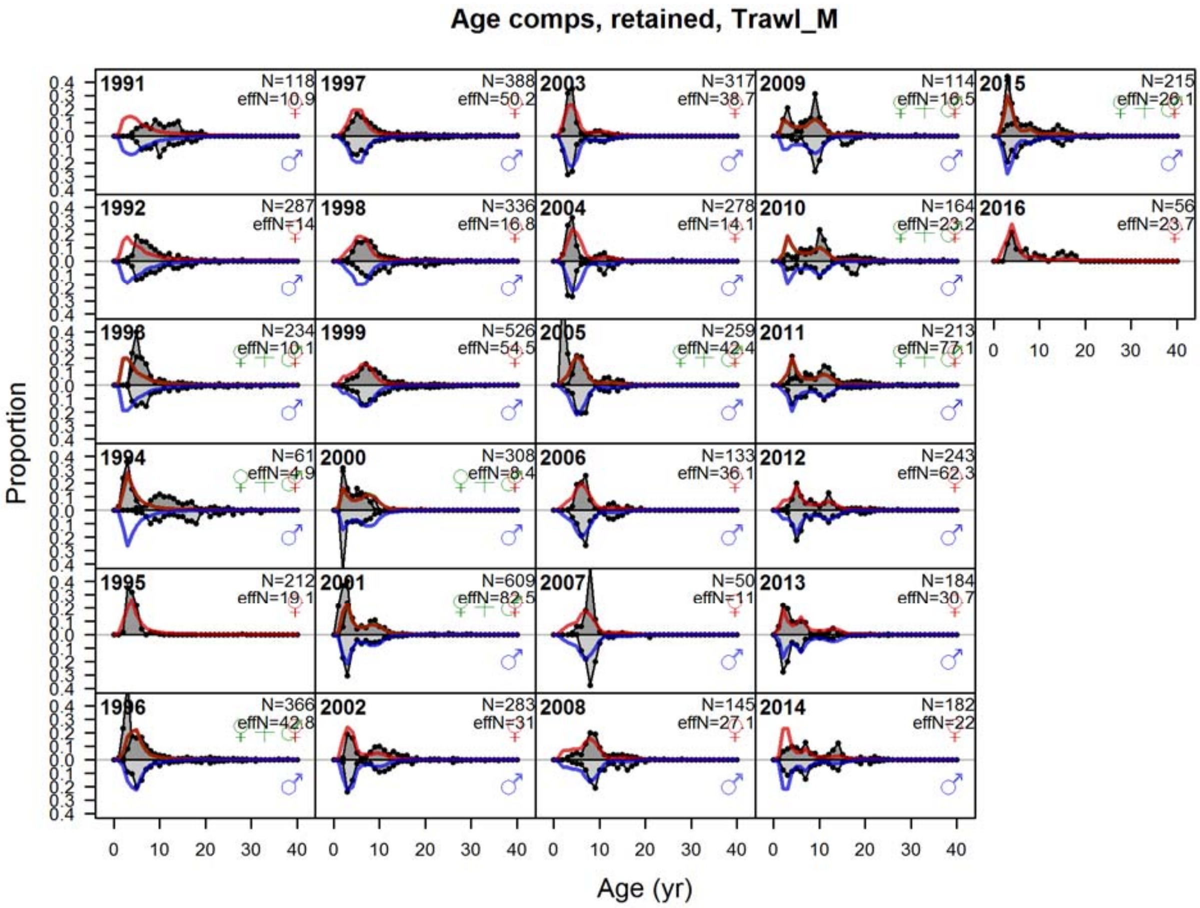


Figure A 17.11. Redfish age composition fits.

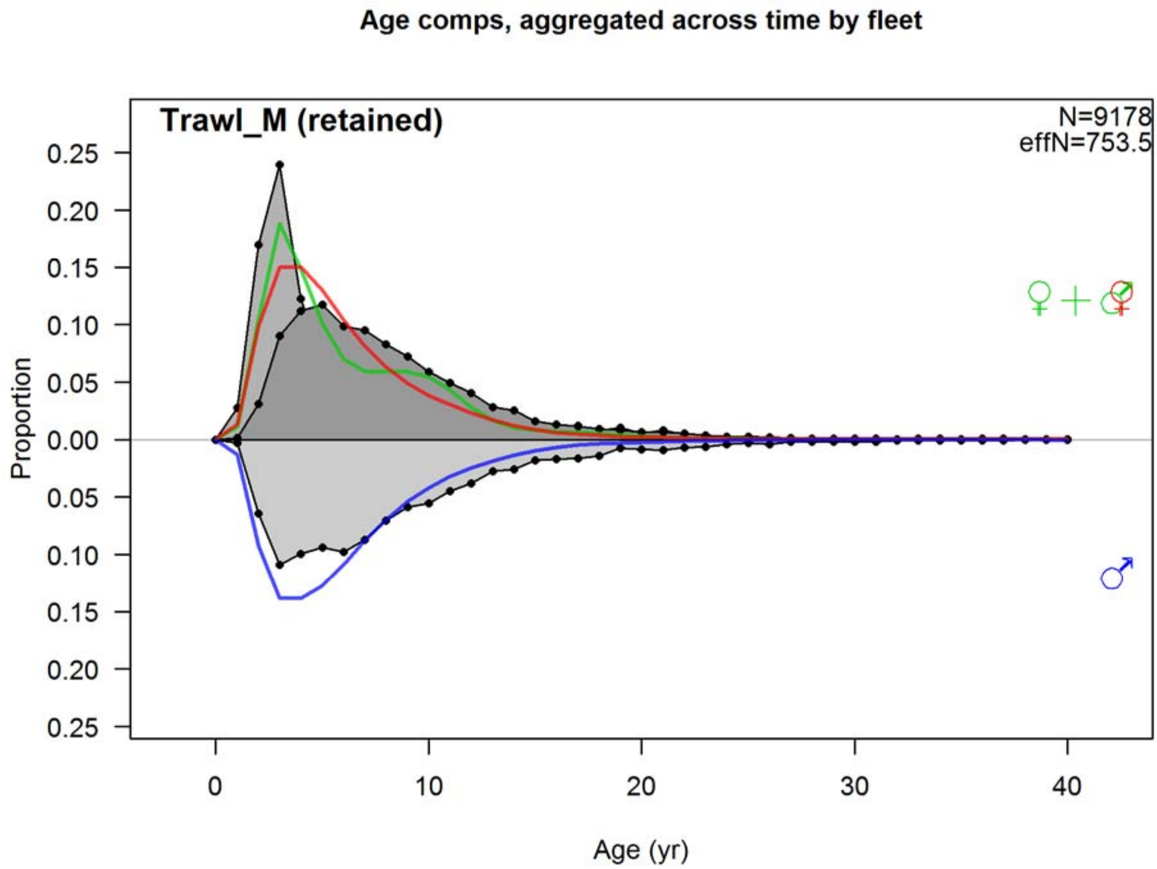


Figure A 17.12. Redfish age composition fit aggregated across years.

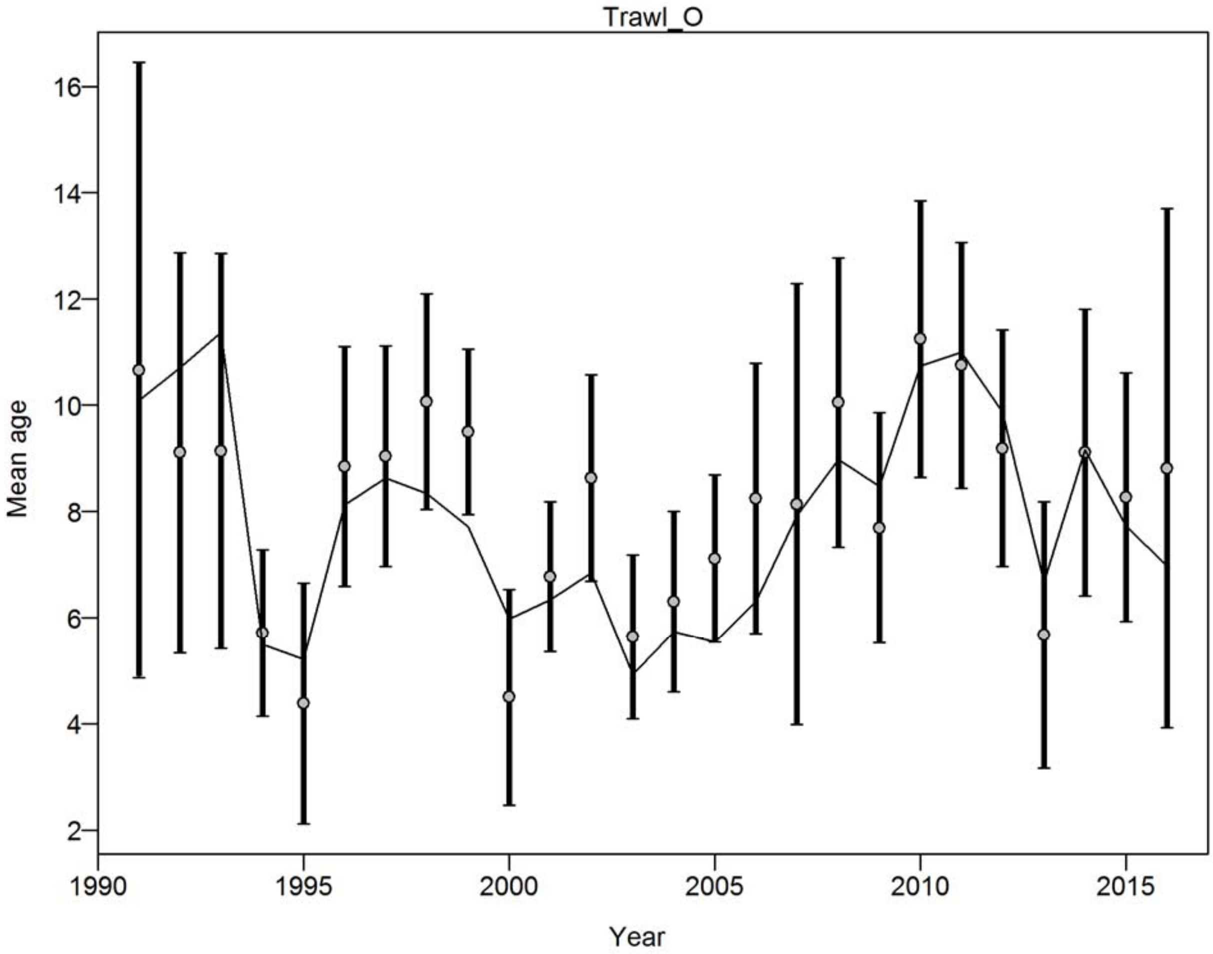


Figure A 17.13. Redfish conditional age at length fit diagnostics from tuning. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for conditional age-at-length data.

17.8 Appendix B

17.8.1 *Single selectivity model diagnostics*

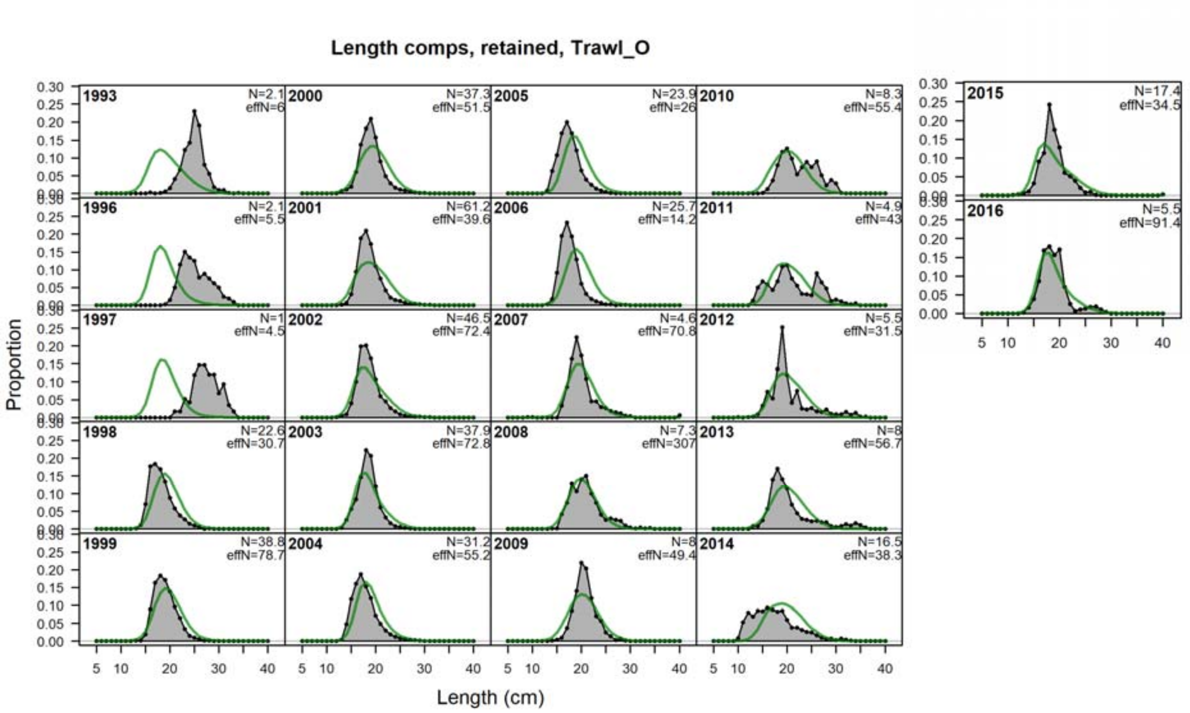
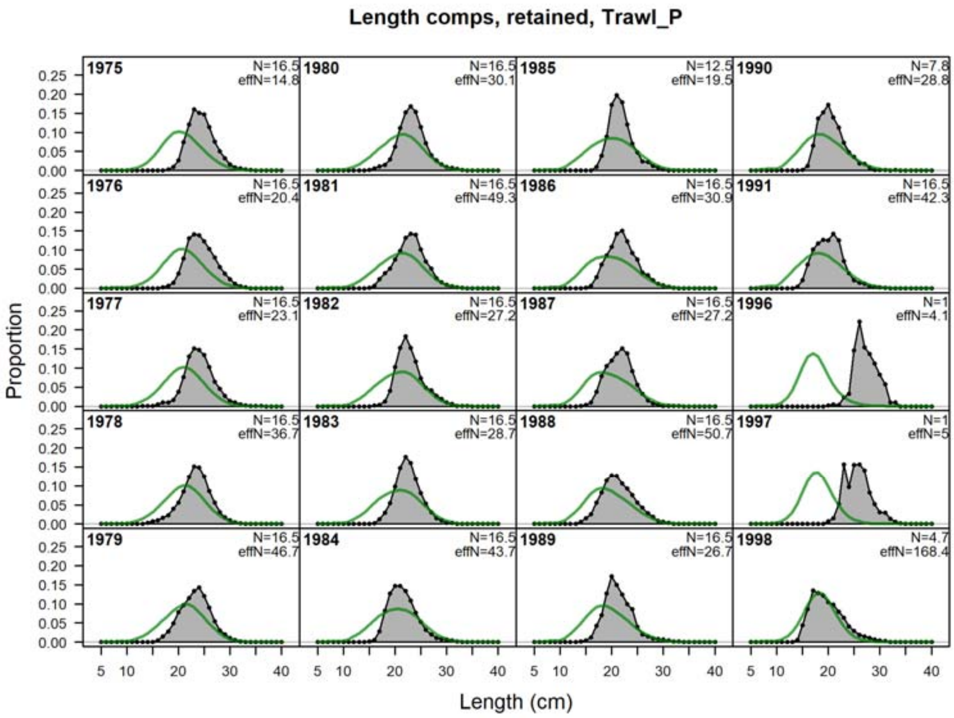


Figure B 17.1. Redfish length composition fits: onboard trawl retained.



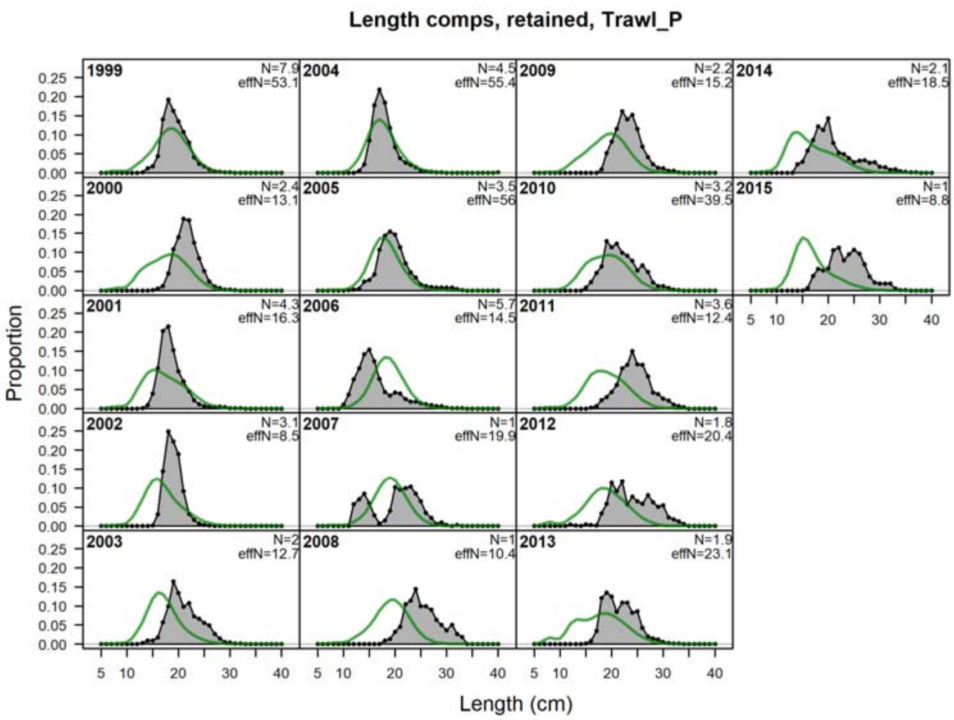


Figure B 17.2. Redfish length composition fits: port trawl.

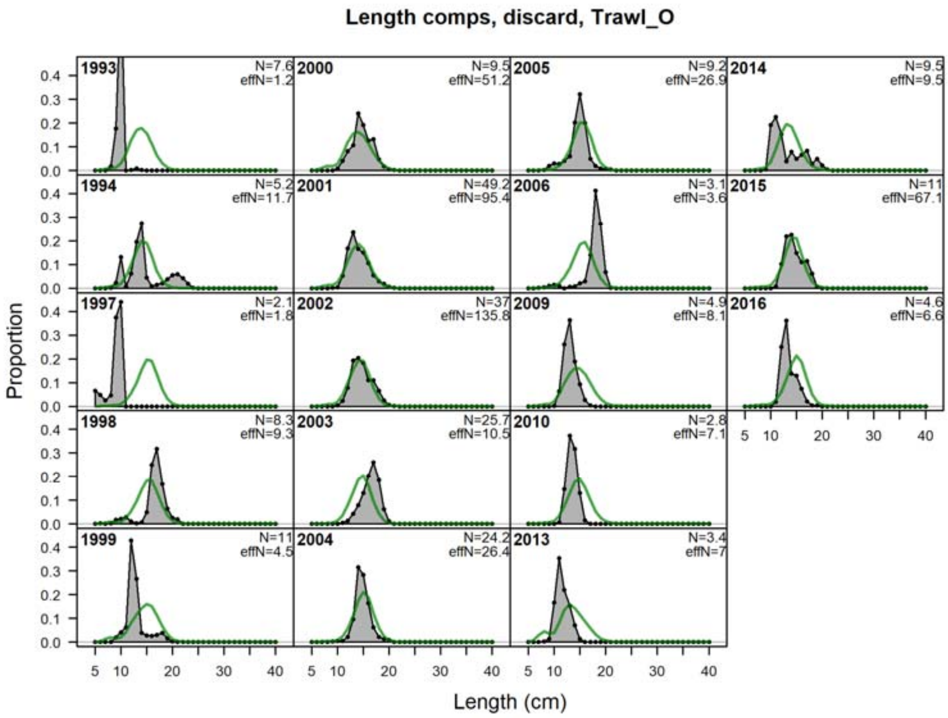


Figure B 17.3. Redfish length composition fits: onboard trawl discard.

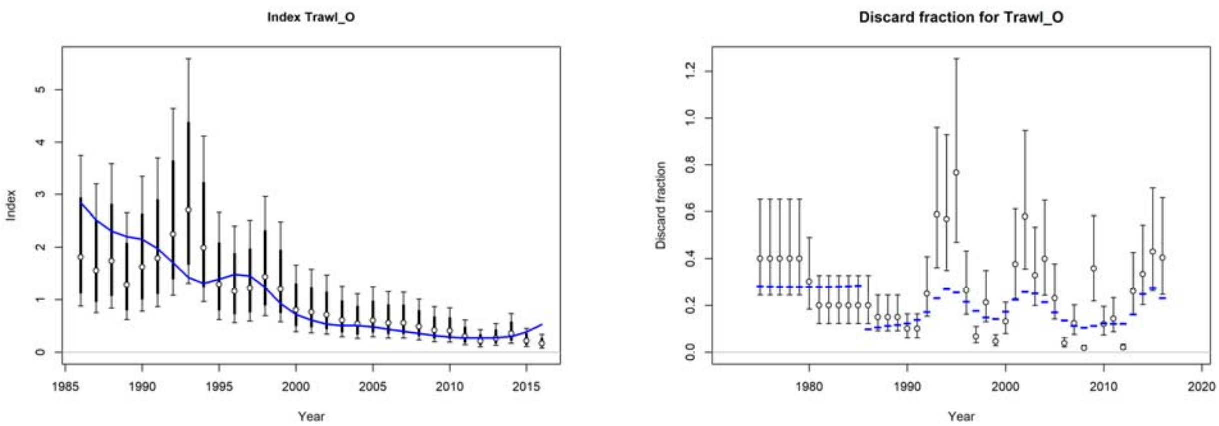


Figure B 17.4. Fits to trawl CPUE and discards for redfish.

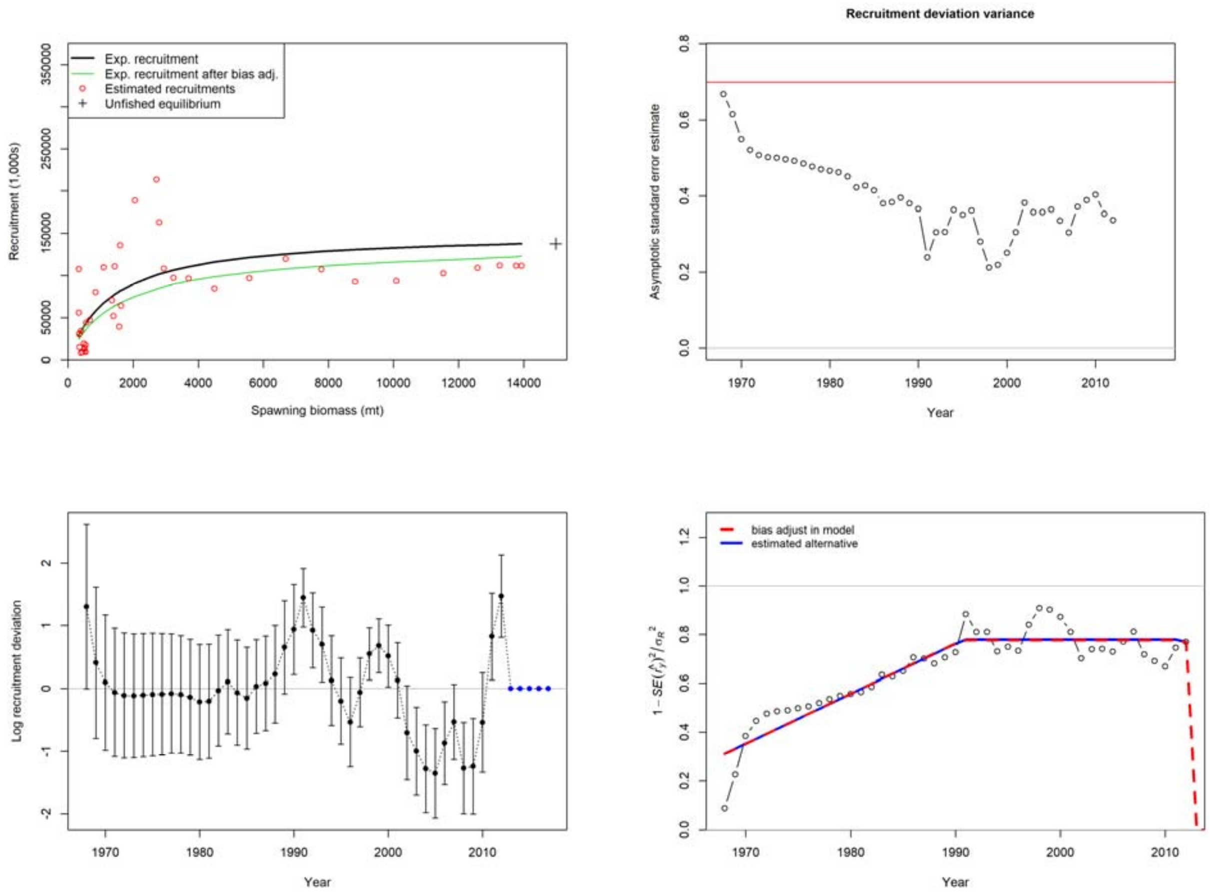


Figure B 17.5. Time series showing the stock recruitment curve, recruitment deviations and recruitment deviation variance check for redfish.

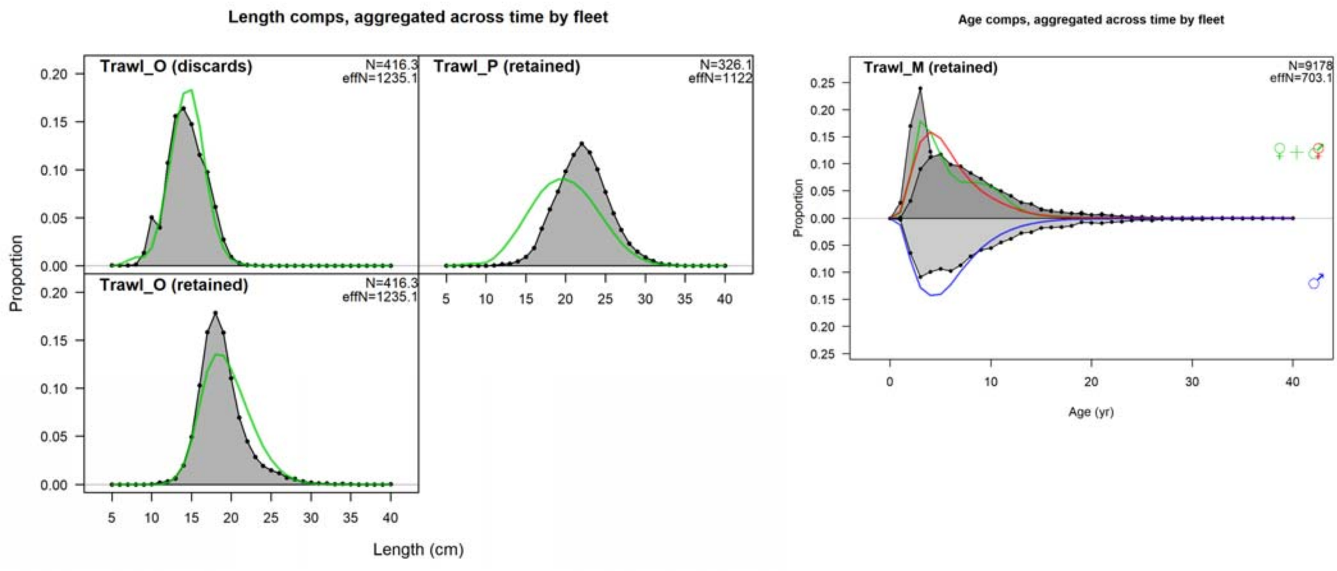


Figure B 17.6. Redfish length and age composition fit aggregated across years.

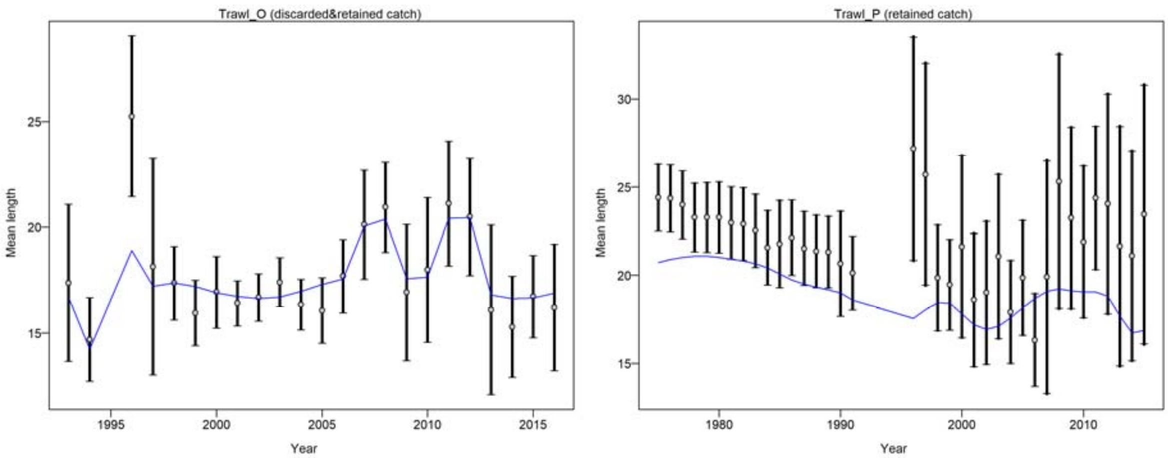


Figure B 17.7. Redfish length composition fit diagnostics from tuning. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for length data.

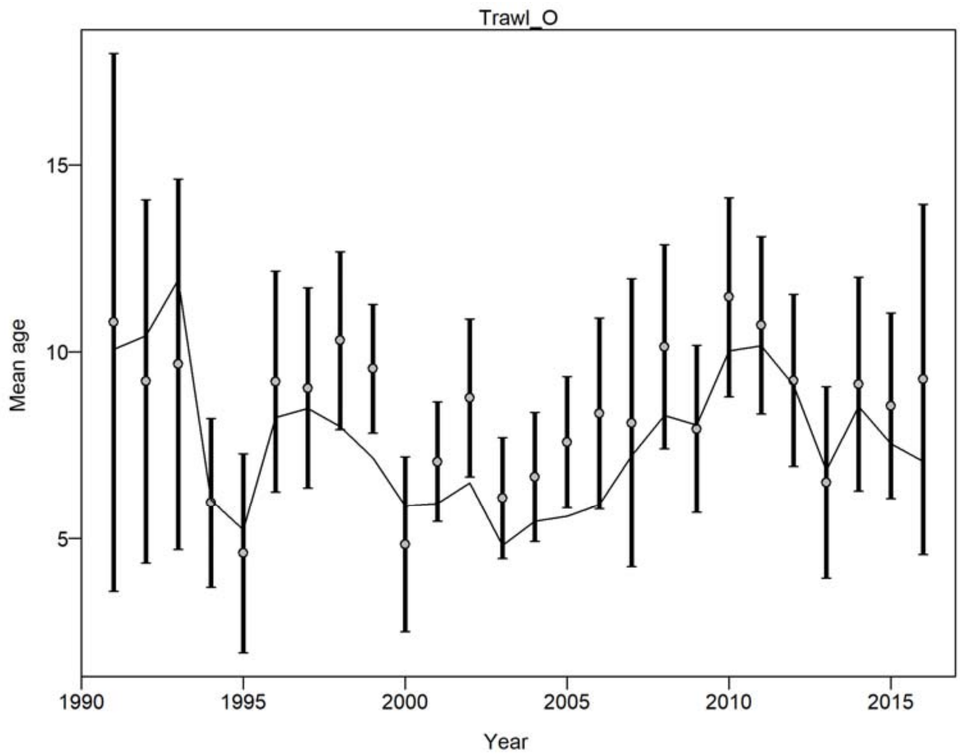


Figure B 17.8. Redfish conditional age at length fit diagnostics from tuning. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for conditional age-at-length data.