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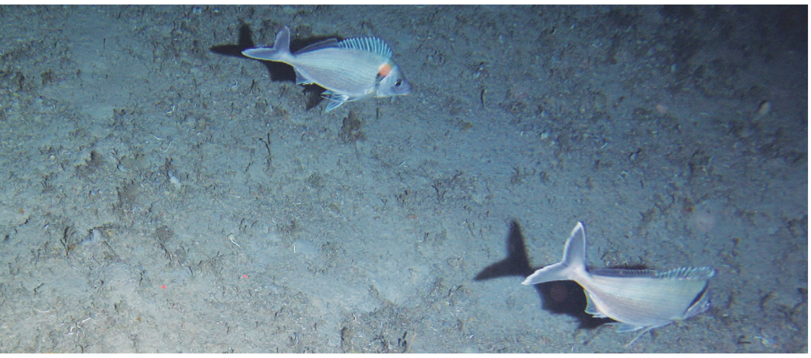
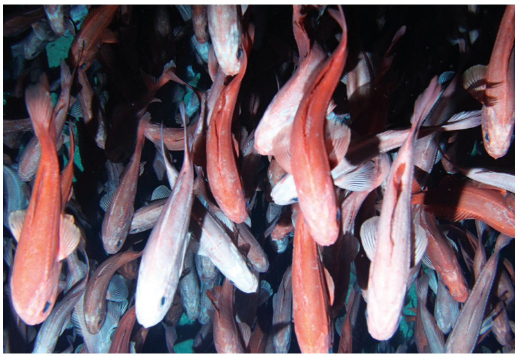
Australian Government
Australian Fisheries Management Authority

2013/0010 June 2015

# Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2014

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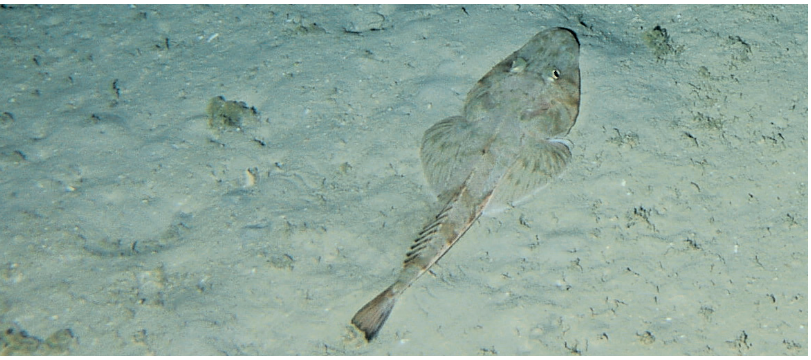
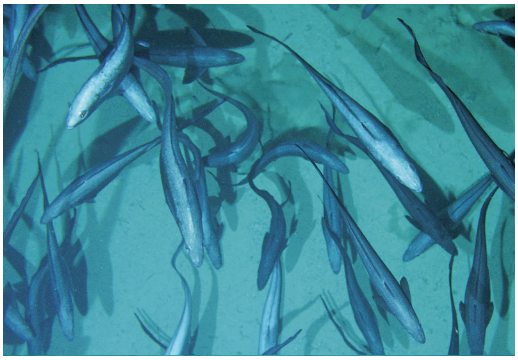


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*All authors wish to thank the science, management and industry members of the slope-deepwater, shelf, GAB and shark resource assessment groups for their contributions to the work presented in this report. Authors also acknowledge support from Fish 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). Tania Cesile is greatly thanked for her assistance with the production of this report and Tim Ryan and Bruce Barker for the cover photographs of SESSF fish. Neil Klaer and Sally Wayte are thanked for their enormous contribution to the assessment and management of SESSF stocks.*

***Cover photographs***

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

***Report structure***

*Part 1 of this report describes the Tier 1 assessments of 2014. Part 2 describes the Tier 3 and Tier 4 assessments, catch rate standardisations and other general work contributing to the assessment and management of SESSF stocks in 2014.*

# Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2014

## Part 1: Tier 1 assessments

G.N. Tuck
June 2015
Report 2013/0010

Australian Fisheries Management Authority

# Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2014
## Part 1

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# 8. Stock assessment of redfish *Centroberyx affinis* based on data up to 2013: Supplement to the October 2014 Shelf RAG paper

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## *8.1 Summary*

This report supplements the previous eastern redfish (*Centroberyx affinis*) stock assessments presented in Tuck and Day (2014) by the inclusion of NSW state catch data from 2005 to 2013 inclusive. The catch data of Tuck and Day (2014) were those RAG agreed catch records from previous redfish assessment group meetings that included state and Commonwealth catches (see Rowling 1999; Klaer 2005) and Commonwealth CDR data from 2005. The NSW (state) recorded catch data from 2005 to 2013 in total were 297 t, compared to 2167 t in total from Commonwealth catch records over the same period. This supplementary report provides a comparison of assessment results between the BC3 redfish stock assessment (the RAG agreed base case from October 2014) and the BC3 model with the addition of NSW catch data (hereafter referred to as BC4).

A comparison of BC3 and BC4 showed only minor differences in outcomes across all metrics. The estimated virgin female spawning biomass was 14,615 t under BC3 compared to 14,558 t under BC4. The estimated stock status in 2015 for BC3 was 11.7%, compared to 10.8% for BC4. The estimated stock status is below the limit reference point of 20% for both base-case models BC3 and BC4 assuming the 20:35:48 harvest control rule, and the RBCs are consequently zero.

As described in Tuck and Day (2014), empirical evidence in the aging data suggests that there have been two recent years of improved recruitment (i.e. in 2011 and 2012). While a small improvement in catch rates may also have occurred as a consequence of these fish moving into the available biomass, the existence and magnitude of these recruitments should be monitored over the ensuing years to verify what may be a positive sign for the stock.

### *8.2 Introduction*

An integrated analysis model, implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Methot, 2011; Methot and Wetzel, 2013. V3.24f), was applied to the eastern redfish stock of the SESSF, with data from 1975 to the 2013 calendar year (length and age data; age-error, catch rate series; landings and discard rates). The model fits directly to catch rates, discard rates, length frequencies (by sex where possible) and conditional age-at-length data.

This paper supplements Tuck and Day (2014) by considering an alternative base-case model with the inclusion of NSW state data from 2005 to 2013.

### *8.3 Data*

The data inputs to the assessment come from multiple sources: length and age-at-length data from the trawl fishery, updated standardized CPUE series (Sporcic and Haddon, 2014), 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), as sufficiently strong evidence to suggest a north-south split did not exist (Shelf RAG agreement, September 2014; Haddon, 2014). Data here are the same as that described in Tuck and Day (2014) except for the inclusion of catch data from NSW from 2005 to 2013. As such, descriptions of the other data sources are not repeated (see Tuck and Day (2014)).

### 8.3.1 *Catch data*

Total annual catches (t) for redfish has been estimated in the past 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 8.1. Where available, previously agreed catch tonnages from RAGs were used (Rowling, 1999; Klaer, 2005), and CDR records and NSW state catch data are used from 2005 for base-case model BC4. Figure 8.1 shows the consequence of the inclusion of NSW state catch data on the total catch time-series. Table 8.1 shows the annual catch values used in the assessment.

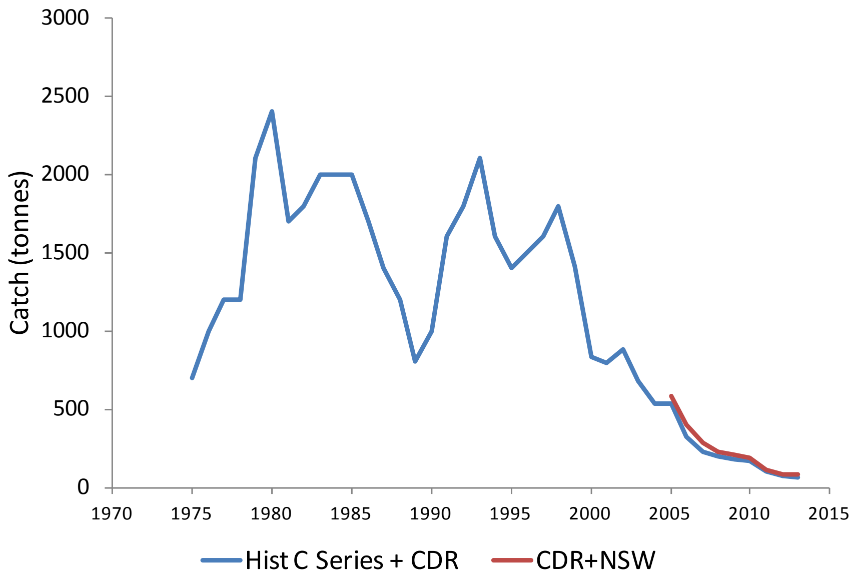



Figure 8.1. The time series of catches for redfish estimated by the various redfish assessment groups and supplemented by AFMA CDR data (blue) and with the addition of NSW state catch data (red).

Table 8.1. Estimated landings (t), discard rates and standardized CPUE (Sporcic and Haddon, 2014) 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. Sate 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 | 1.696 |
| 1987 | 1400 | | 1400 | 0.15 | 1.435 |
| 1988 | 1200 | | 1200 | 0.15 | 1.598 |
| 1989 | 800 | | 800 | 0.15 | 1.184 |
| 1990 | 1000 | | 1000 | 0.10 | 1.562 |
| 1991 | 1600 | | 1600 | 0.10 | 1.691 |
| 1992 | 1800 | | 1800 | 0.25 | 2.024 |
| 1993 | 2100 | | 2100 | 0.580 | 2.457 |
| 1994 | 1600 | | 1600 | 0.540 | 1.830 |
| 1995 | 1400 | | 1400 | 0.758 | 1.182 |
| 1996 | 1500 | | 1500 | 0.279 | 1.044 |
| 1997 | 1600 | | 1600 | 0.062 | 1.090 |
| 1998 | 1800 | | 1800 | 0.202 | 1.318 |
| 1999 | 1406 | | 1406 | 0.039 | 1.106 |
| 2000 | 835 | | 835 | 0.118 | 0.746 |
| 2001 | 794 | | 794 | 0.370 | 0.716 |
| 2002 | 880 | | 880 | 0.568 | 0.685 |
| 2003 | 677 | | 677 | 0.316 | 0.568 |
| 2004 | 538 | | 538 | 0.392 | 0.516 |
| 2005 | 532 | 47 | 579 | 0.219 | 0.563 |
| 2006 | 321 | 76 | 397 | 0.034 | 0.528 |
| 2007 | 230 | 54 | 284 | 0.159 | 0.509 |
| 2008 | 201 | 29 | 230 | 0.018 | 0.458 |
| 2009 | 182 | 25 | 207 | 0.357 | 0.412 |
| 2010 | 166 | 22 | 188 | 0.117 | 0.388 |
| 2011 | 99 | 16 | 115 | 0.143 | 0.273 |
| 2012 | 73 | 14 | 87 | 0.038 | 0.198 |
| 2013 | 66 | 14 | 80 | 0.259 | 0.225 |

## 8.4 Analytic approach

### 8.4.1 *The population dynamics model*

For completeness, the analytical approach described in Tuck and Day (2014) has been included here. The approach has not changed from this previous work. The 2014 assessment of eastern redfish used an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Version 3.24f, NOAA 2011). 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 ($\sigma_r$). SS allows the user to choose among a large number of age- and length-specific selectivity patterns. The values for these and other 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 models (BC3 and BC4) include the following key assumptions:

(a) A single region, single stock model is considered, aggregated across zones 10, 20 and 30.

(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.

(c) The model accounts for males and females separately.

(d) Initial and final years are 1975 and 2013 respectively. 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. A beginning year of 1960 is also considered in the sensitivities.

(e) The CVs of CPUE indices for the non-spawning fleet were initially set at a low value to encourage a fit to the abundance data, before being re-tuned to the model-estimated standard errors after tuning to length and age data. The Francis method (Francis, 2011) has been applied as a sensitivity.

(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: 1975 – 1985 and 1986 – 2013. This model is termed base-case 3 (BC3).

(g) Use model derived discard rates to fit to estimates over the period 1975-1985. Include a logistic retention function with a cap less than 1.0 (i.e. larger fish do not reach full retention and can be discarded; fixed at 0.8). This is model Scenario S1 in Tuck and Day (2014).

(h) The natural mortality rate, *M*, is assumed to be constant with age, and also time-invariant. The value for *M* is 0.1 $y^{-1}$. Alternative values, including estimating natural mortality, are considered as sensitivities.

(i) Recruitment to the stock is assumed to follow a Beverton-Holt stock-recruitment relationship. Steepness (*h*) for the base-case analysis is set to 0.75.

(j) The value of the parameter determining the magnitude of the process error in annual recruitment, $\sigma_r$, is set to 0.6.

(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 length-at-age relationship, with the parameters of the growth function being estimated separately for females and males inside the assessment model.

(m) Retained and discard length sample sizes were capped at 200 and required to have a minimum of 100 samples to be included. The sample size is reduced to a maximum of 200 because the appropriate sample size for length frequency data is probably more closely related to the number of shots sampled, rather than the number of fish measured. The length frequency data is given too much weight relative to other data sources if the number of fish measured were used. Length, age, and CPUE data were tuned.

Assumed values for some of the (non-estimated) parameters of the base case models (BC3 and BC4) are shown in Table 8.2.

Table 8.2. Parameter values assumed for some of the non-estimated parameters of the base-case models.

| Parameter | Description | Value |
|---|---|---|
| $M$ | Natural mortality | 0.1 |
| $\sigma_r$ | CV for the recruitment residuals | 0.6 |
| $h$ | “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 | 19 cm |

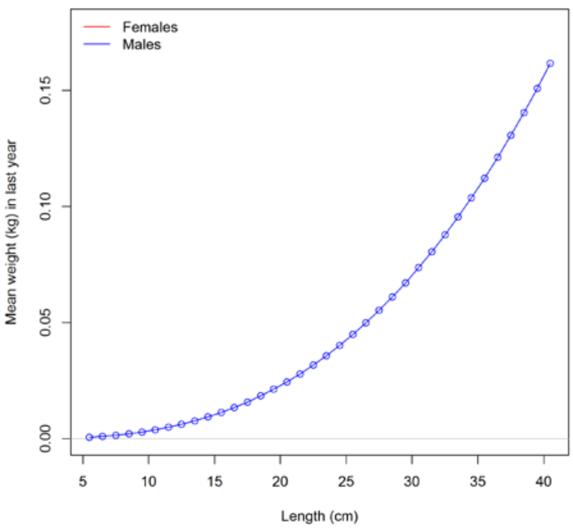
## 8.5 Results and discussion

### 8.5.1 Base-case stock assessment BC4

#### *8.5.1.1 Parameter estimates*

The length-weight relationships, maturity-at-length and growth are shown in Figure 8.2 and Figure 8.3. Note that these figures are indistinguishable to those of BC3 (see previous analysis of Tuck and Day, 2014) and so BC3 results are not repeated here. The von Bertalanffy growth parameter $k$ was estimated to be 0.236, with a CV on growth of 0.146. The initial fishing mortality ($F_{init}$) was estimated to be 0.016.

A single logistic selectivity function is estimated for the trawl fleet (Figure 8.4). Retention has two 'time-blocks' to account for the varying discarding behaviours documented (Figure 8.4; Tuck and Day, 2014).



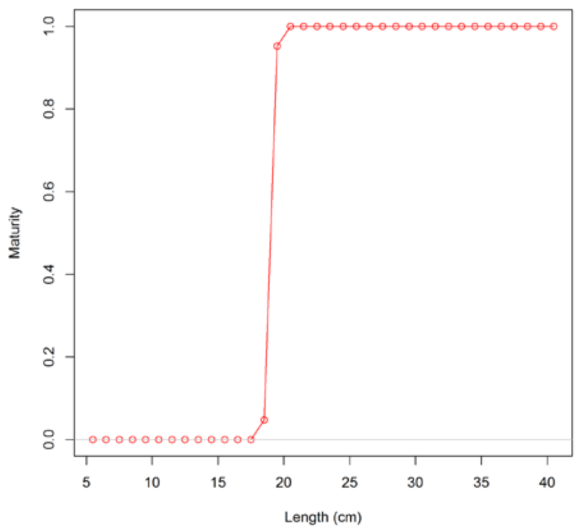




Figure 8.2. The length-weight relationship (left) and maturity (right) functions for eastern redfish.

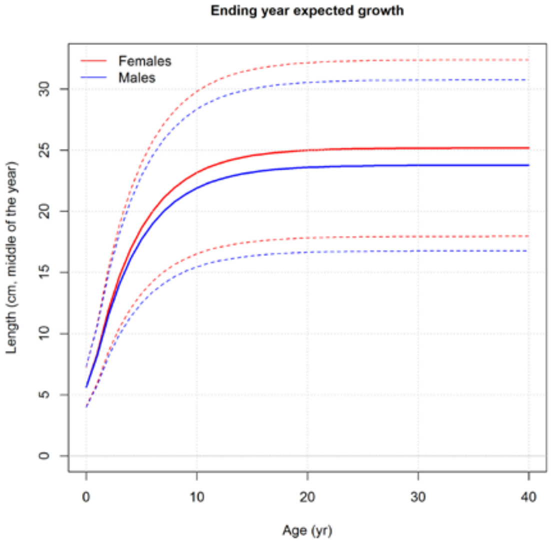
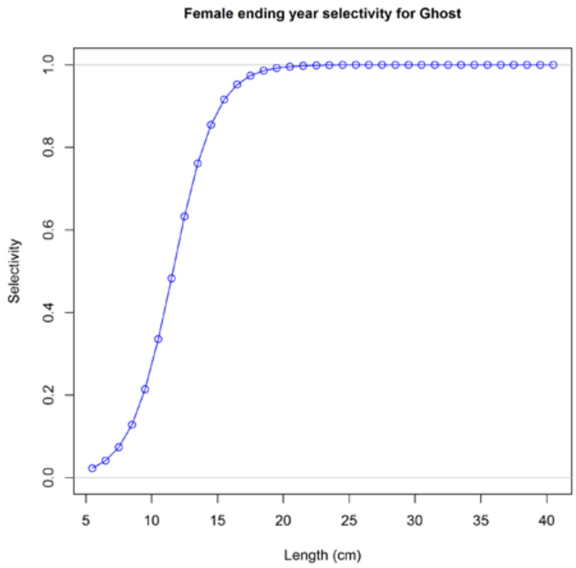



Figure 8.3. Estimated length-at-age relationship for males (blue) and females (red) under BC4 and corresponding 95% confidence intervals (dashed lines).



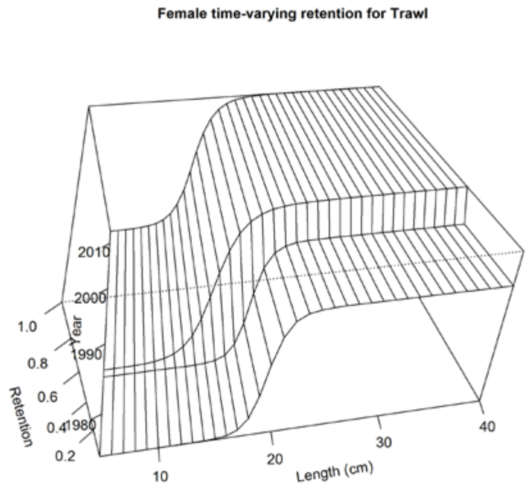




Figure 8.4. The estimated selectivity (left) and retention (right) functions for eastern redfish under BC4.

*8.5.1.2 Fits to the data*

The model fit to discard rates shows some correspondence as the model attempts to fit to the various changes in discarding over time (Figure 8.5), and the model fit to the catch rate series shows good correspondence to the observations.

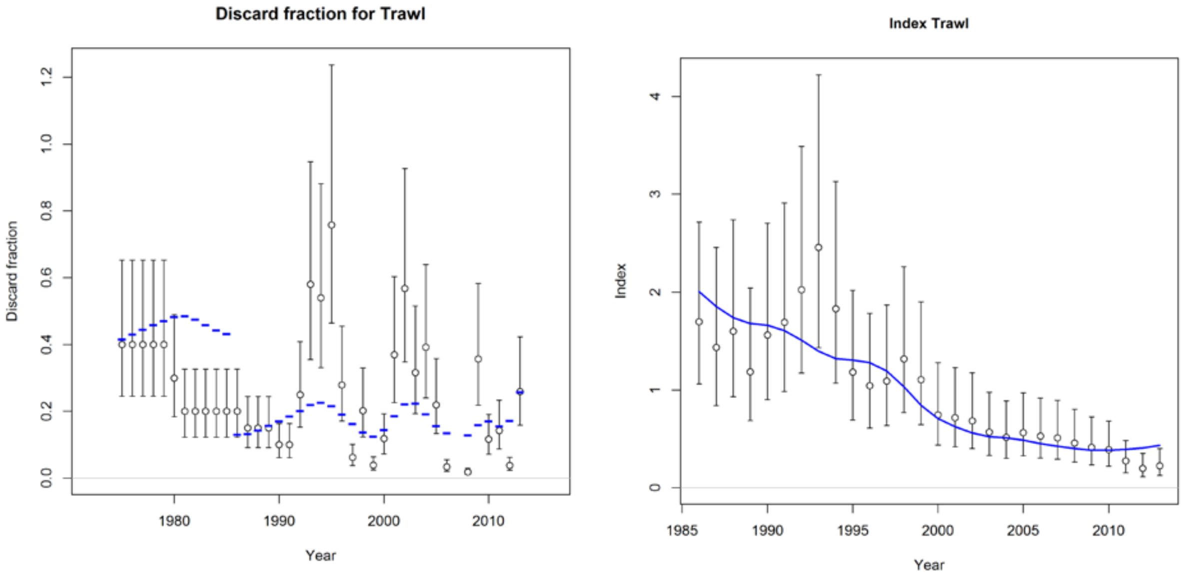



Figure 8.5.The fit to the discard rate data (left) and the catch rate data (right) under BC4; blue dashes/lines are the model fitted estimates.

The model is able to replicate the implied age-composition data reasonably well, particularly where the samples were from the separate sexes in the retained catch (Appendix 1). A comparison between BC3 and BC4 is not made as the fits are essentially indistinguishable. Age compositions from 2012 and 2013 seem to suggest that a recent relatively large recruitment may have moved into the available stock. This is also evident in the model estimates of recruitment. Length composition data are not as well estimated by the model, with early years showing an over-estimation of small fish, and later years showing a much narrower distribution of observed lengths compared to the model estimates (Appendix 1). Length composition data for this stock vary markedly from one year to the next; making model fitting difficult (e.g. 1991 and 1993; 1997 and 1998).

### 8.5.2 *A comparison of the base case stock assessments BC3 and BC4*

Figure 8.6 to Figure 8.8 show a comparison between model outcomes of BC3 and BC4 for the fit to catch rate data, annual recruitments and spawning biomass trajectories. In general, only minor differences are noticeable during the last 3 to 4 years.

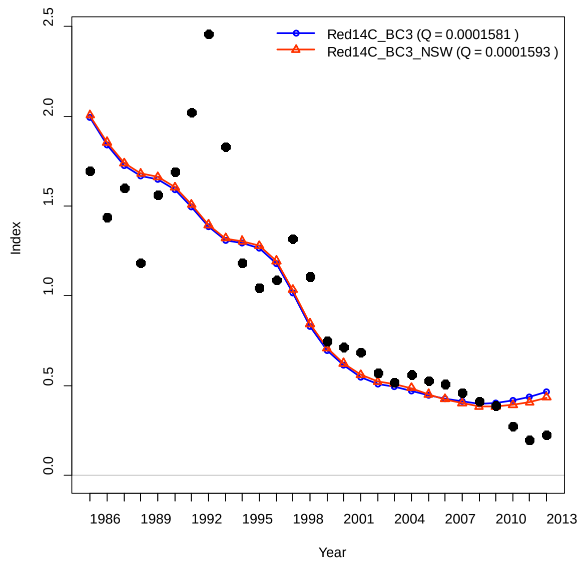



Figure 8.6. A comparison of the fit to the catch rate series for base-case models BC3 (blue) and BC4 (Red14C_BC3_NSW; red).

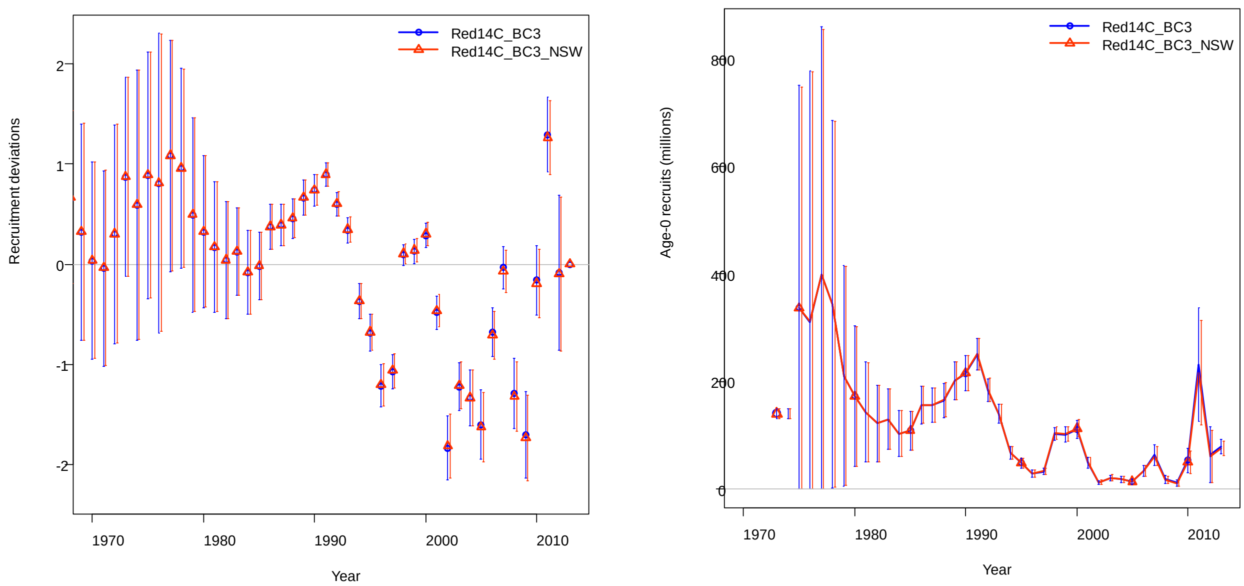
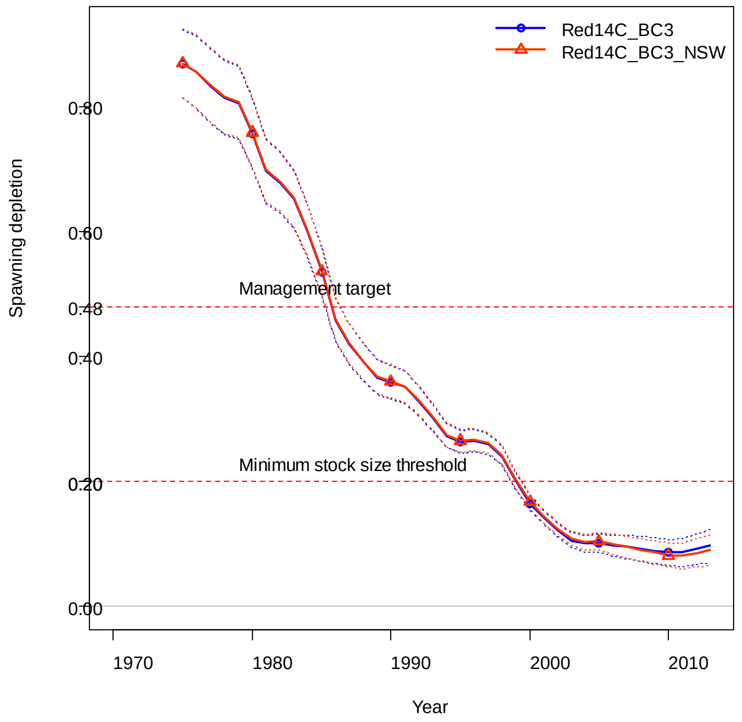



Figure 8.7. A comparison of the annual estimated recruitment series with corresponding approximate 95% asymptotic intervals (vertical lines) (deviations, LHS; age-0 recruits, RHS) for base-case models BC3 (blue) and BC4 (Red14C_BC3_NSW; red).



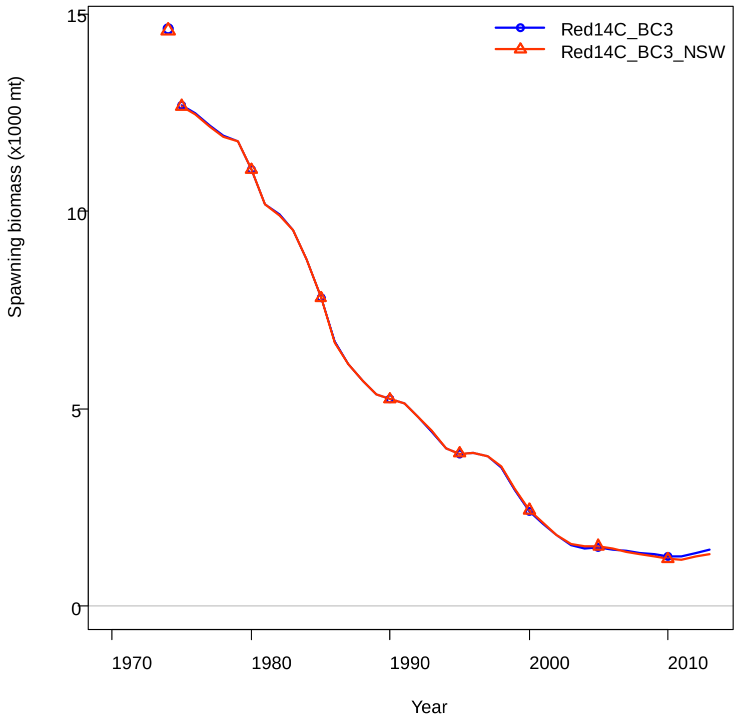




Figure 8.8.A comparison of the annual estimated spawning biomass trajectories (relative, top; absolute, bottom) for base-case models BC3 (blue) and BC4 (Red14C_BC3_NSW; red). Top: dashed blue and red lines correspond to approximate 95% asymptotic intervals for models BC3 and BC4 respectively. Red dashed lines at 0.2 and 0.48 correspond to limit and target reference points respectively.

### 8.5.3 *Assessment outcomes for BC4*

Estimated annual recruitment under the base-case assessment model BC4 shows periods of strong recruitment, amongst a general declining trend (Figure 8.9; Appendix 1). The model estimates a recent large recruitment, which is also evident in the age composition data for 2013 (Appendix 1).

The spawning biomass trajectories (Figure 8.9 and spawning biomass relative to the un-exploited level show a general declining trend of stock status since 1975. The model shows stock status moving below the limit reference point of 20% in 1999, with current stock status well below the limit.

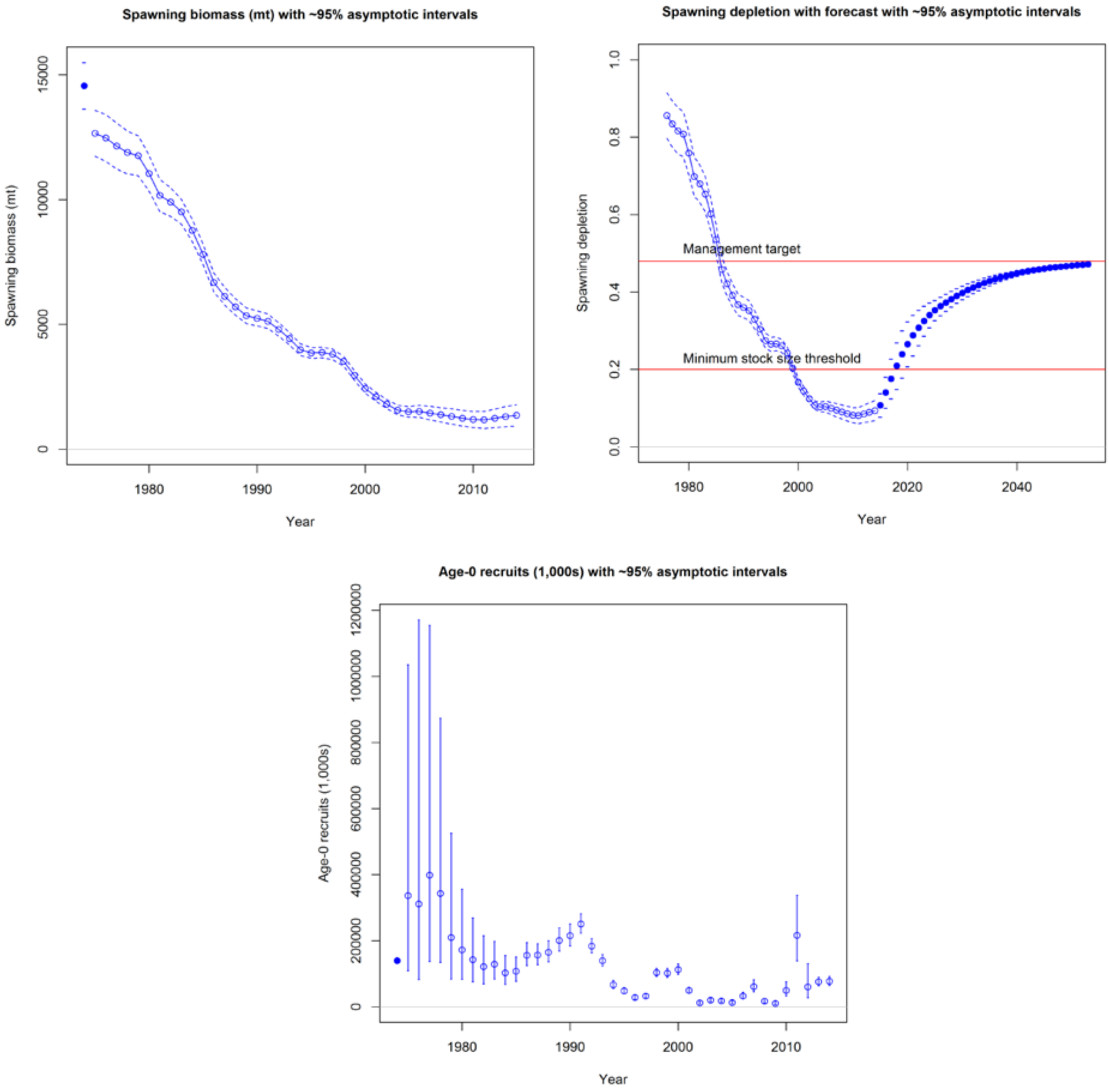



Figure 8.9.The annual time-series of female spawning biomass (absolute left and relative right) and recruitment (bottom) under BC4. Vertical bars correspond to approximate 95% asymptotic intervals.

The estimated time-series of fishing mortality, *F*, is shown in Figure 8.10. This shows that estimated fishing mortality has been below target levels since 2011. The mean generation time is defined as the mean age of the female mature unfished stock,

$$T_{gen} = \sum_a a f_a N_a / \sum_a f_a N_a$$

where $f_a$ is fecundity at age and $N_a$ are numbers at age for the unfished population. The mean generation time for redfish is $T_{gen}$ = 16.7 years.

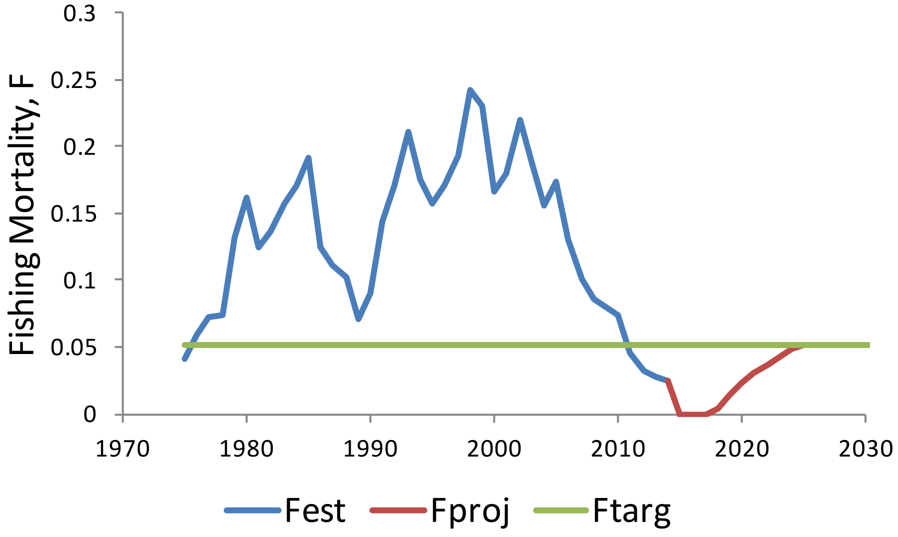



Figure 8.10. The annual estimated fishing mortality for redfish under base-case model BC4. The estimated fishing mortality is shown in blue, and the projected fishing mortality under the 20:35:48 harvest control rule is shown in red. The target fishing mortality (for B48) is shown in green.

### 8.5.4 *Management outcomes for the base-case model BC4*

The estimated virgin female biomass is 14,558 t, and the 2015 estimated spawning biomass level is 10.8% of un-exploited levels for the base-case model BC4. Under the previous base-case 3 (BC3) assessment (Tuck and Day, 2014), the estimated virgin spawning biomass is 14,615 t, with estimated 2015 stock status of 11.7% of unexploited levels. As the estimated stock status is below the limit reference point of 20% for both base-case models BC3 and BC4, assuming the 20:35:48 control rule, the RBCs are consequently zero. All models that have been tuned, including models tuned using the Francis method, similarly led to zero RBCs for 2015. The long-term RBC, assuming a return to a 48% stock status, for the BC4 model is 836 t.

### 8.5.5 *Fixed catch projections for the base-case model BC4*

Figure 8.11, Figure 8.12 and Table 8.3 show the time-series of female spawning biomass assuming mean future recruitment and under three deterministic fixed catch projections: 50t, 100t and 150t. In each instance, the stock is projected to move above 20% of unexploited levels by year 2018 or 2019.

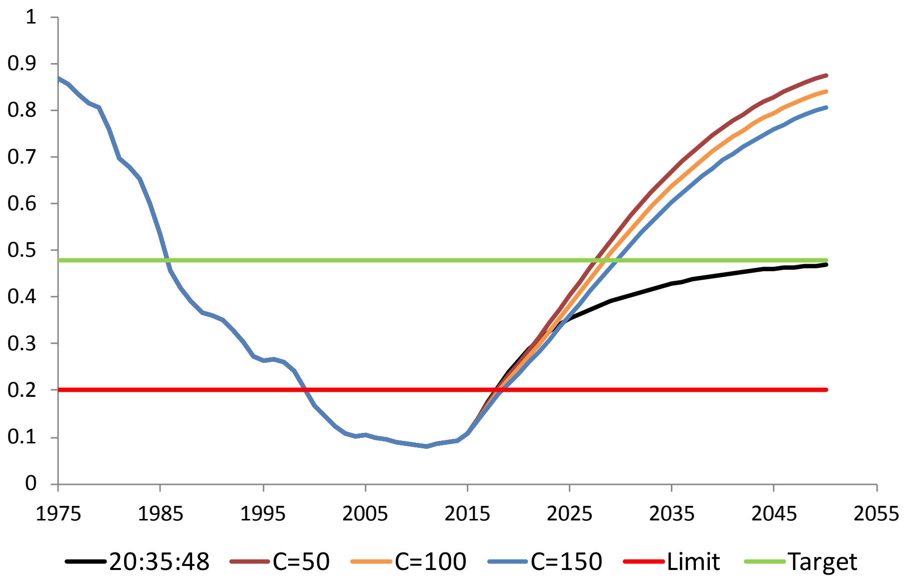



Figure 8.11.Annual relative female spawning biomass for base case BC4 under the 20:35:48 harvest control rule and fixed catch projections of 50, 100, and 150 t. Red line (20% limit reference); green line (48% target reference).

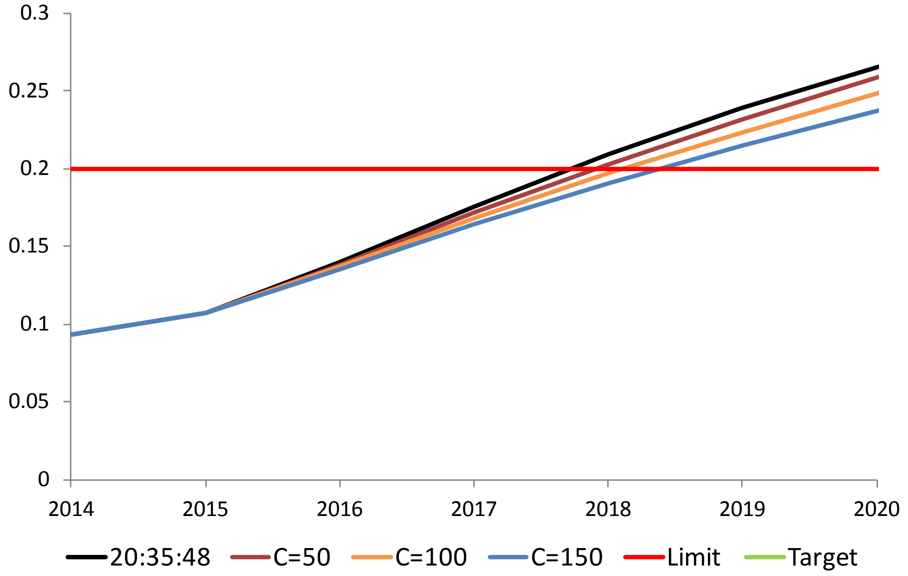



Figure 8.12.Annual projected relative female spawning biomass for base case BC4 under the 20:35:48 harvest control rule and fixed catch projections of 50, 100, and 150 t (between 2014 and 2020). Red line (20% limit reference).

Table 8.3 The annual projected female spawning biomass under the 20:35:48 Tier 1 harvest control rule, and fixed catch (C) projections of 50, 100, 150 t. Shaded values are above the 20% unexploited biomass limit reference point.

| Year | 20:35:48 | C=50 | C=100 | C=150 |
|---|---|---|---|---|
| 2015 | 0.108 | 0.108 | 0.108 | 0.108 |
| 2016 | 0.140 | 0.138 | 0.137 | 0.135 |
| 2017 | 0.176 | 0.172 | 0.168 | 0.164 |
| 2018 | 0.209 | 0.203 | 0.197 | 0.191 |
| 2019 | 0.239 | 0.232 | 0.223 | 0.215 |
| 2020 | 0.265 | 0.259 | 0.248 | 0.237 |

### 8.5.6 *Sensitivities*

Results of the various sensitivity tests are shown in Table 8.4 for BC4. The definitions of each sensitivity test can be found in Tuck and Day (2014). The base-case models and sensitivities all have stock status less than the limit reference point of 20% of virgin spawning biomass, and generally vary between 6% and 16%. The largest variation in stock status occurs with larger fixed values of natural mortality and steepness. However, estimating these parameters led to $M \approx 0.1$ (approximately the base-case value used), and a steepness of $h \approx 0.59$ (lower than the base-case assumed value of 0.75). Using the Francis (2011) weighting procedure led to considerable down-weighting of the length and age data, a lower long-term RBC and slightly lower estimated stock status.

Table 8.4. Summary of sensitivity results (i.e. Case 2-22) for the base-case model structure BC4 (Case 0). Long-term RBCs are only provided for models that have been tuned.

| Case | Model and/or sensitivity description | $SSB_0$ | $SSB_{2015}$ | $SSB_{2015}/SSB_0$ | $RBC_{2015}$ | $RBC_{longterm}$ |
|---|---|---|---|---|---|---|
| 0 | BC4 (20:35:48 *M*=0.10 *h*=0.75) | 14,558 | 1,567 | 0.11 | 0 | 836 |
| 1 | BC3 | 14,615 | 1,714 | 0.12 | 0 | 840 |
| 2 | *M*=0.08 | 15,803 | 1,009 | 0.06 | 0 | |
| 3 | *M*=0.12 | 13,409 | 2,267 | 0.17 | 0 | |
| 4 | estimate *M* (0.100), *h*=0.75 | 14,586 | 1,554 | 0.11 | 0 | |
| 5 | steepness, *h* =0.65 | 15,662 | 1,277 | 0.08 | 0 | |
| 6 | steepness, *h*=0.85 | 13,806 | 1,891 | 0.14 | 0 | |
| 7 | estimate *h* (0.589), *M*=0.10 | 16,525 | 1,120 | 0.07 | 0 | |
| 8 | 50% maturity at 18 cm | 15,073 | 1,791 | 0.12 | 0 | |
| 9 | 50% maturity at 20 cm | 13,887 | 1,365 | 0.10 | 0 | |
| 10 | $\sigma_R$ = 0.8 | 15,181 | 1,209 | 0.08 | 0 | |
| 11 | begin model in 1960 | 15,562 | 2,469 | 0.16 | 0 | |
| 12 | alternative discards | 14,552 | 1,506 | 0.10 | 0 | |
| 13 | Kapala lengths | 14,558 | 1,535 | 0.11 | 0 | |
| 15 | wt x 2 length composition | 14,794 | 1,576 | 0.11 | 0 | |
| 16 | wt x 0.5 length composition | 14,224 | 1,509 | 0.11 | 0 | |
| 17 | wt x 2 age composition | 14,136 | 1,378 | 0.10 | 0 | |
| 18 | wt x 0.5 age composition | 14,844 | 1,654 | 0.11 | 0 | |
| 19 | wt x 2 CPUE | 14,262 | 1,339 | 0.09 | 0 | |
| 20 | wt x 0.5 CPUE | 15,023 | 1,983 | 0.13 | 0 | |
| 21 | cap retention at 0.6 (1975-85) | 16,419 | 1,709 | 0.10 | 0 | |
| 22 | Francis weighting | 13,724 | 1,125 | 0.08 | 0 | 751 |

### 8.5.7 *Further development*

- Further refinement of the Francis (2011) method, in particular for assessments with age-at-length data.
- Agree to a model structure, with regard to discard function.
- Explore what may be causing the variations in year-to-year length data.

### 8.5.8 *Conclusion*

This report supplements the previous eastern redfish (*Centroberyx affinis*) stock assessments presented in Tuck and Day (2014) by the inclusion of NSW state catch data from 2005 to 2013 inclusive. The catch data of Tuck and Day (2014) were those RAG agreed catch records from previous redfish assessment group meetings (that included Commonwealth and state data; see Rowling 1999; Klaer 2005) and Commonwealth CDR data from 2005. The NSW (state) recorded catch data from 2005 to 2013, in total were 297 t, compared to 2167 t in total from Commonwealth catch records. This supplementary report provides a comparison of assessment results between the BC3 redfish stock assessment (the RAG agreed base case from October 2014) and the BC3 model with the addition of NSW catch data (hereafter referred to as BC4).

A comparison of BC3 and BC4 showed only minor differences in outcomes across all metrics. The estimated virgin female spawning biomass was 14,615 t under BC3 compared to 14,558 t under BC4. The estimated stock status in 2015 for BC3 was 11.7%, compared to 10.8% for BC4. The estimated stock status is below the limit reference point of 20% for both base-case models BC3 and BC4 assuming the 20:35:48 harvest control rule, and the RBCs are consequently zero.

### *8.6 Acknowledgements*

Many thanks are due to the CSIRO SESSF-WG: Jemery Day, Sally Wayte, Neil Klaer, Robin Thomson, Judy Upston, Malcolm Haddon and André Punt for their assistance with model discussions and development. Miriana Sporcic and Malcolm Haddon are thanked for providing catch rate indices, Mike Fuller, Robin Thomson and Neil Klaer for their advice on data matters. Kyne Krusic-Golub (Fish Aging Services) and the AFMA observer section are thanked for providing the aging data and length frequency data respectively. Kevin Rowling, Ian Knuckey and Tony Lavalle provided invaluable advice on historical catch and discarding practices. Miriana Sporcic is also thanked for her review of this report.

## 8.7 References

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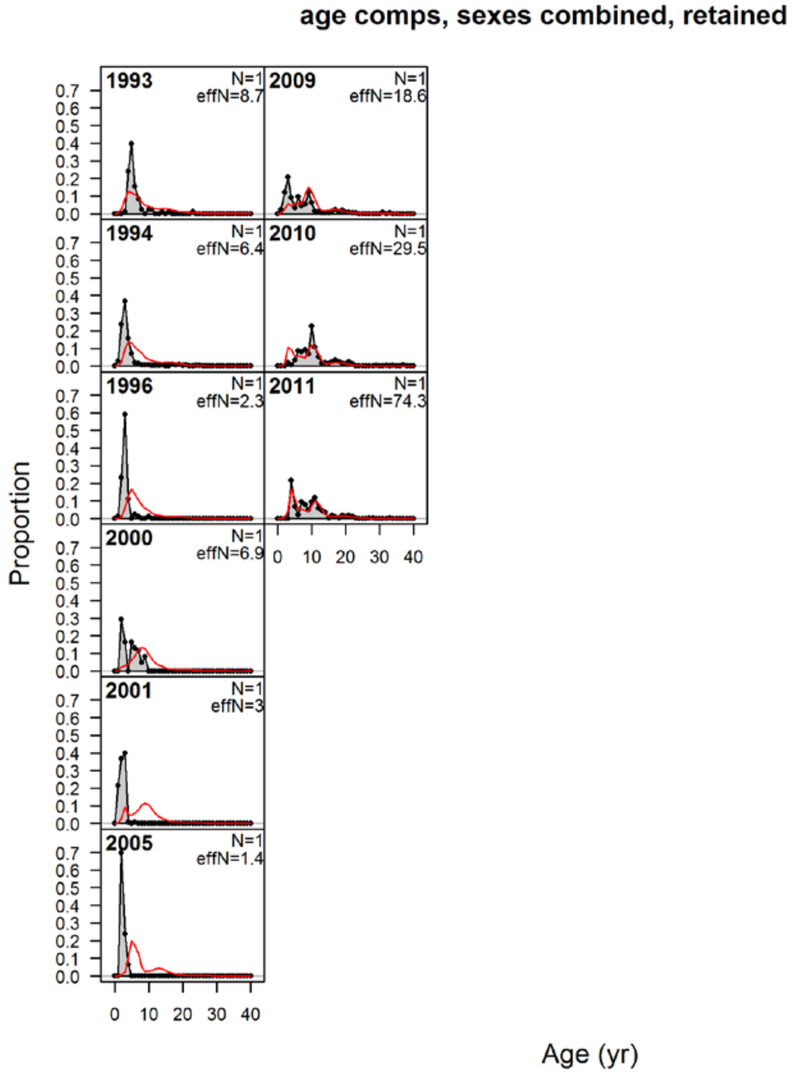
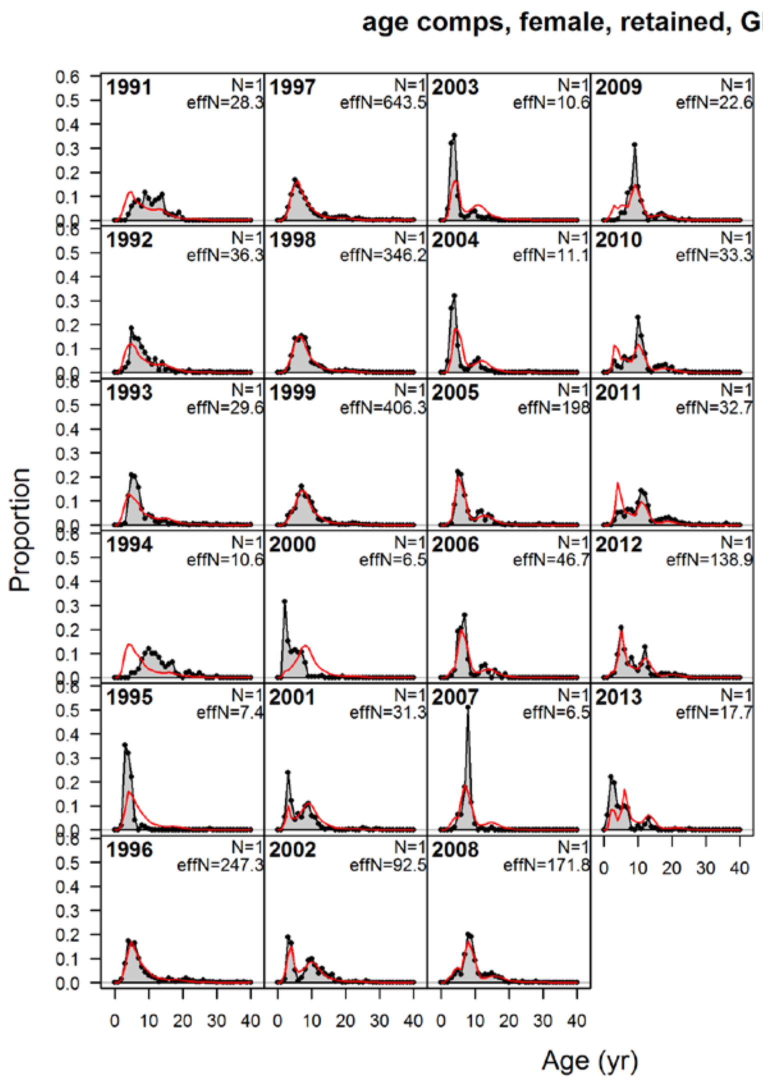
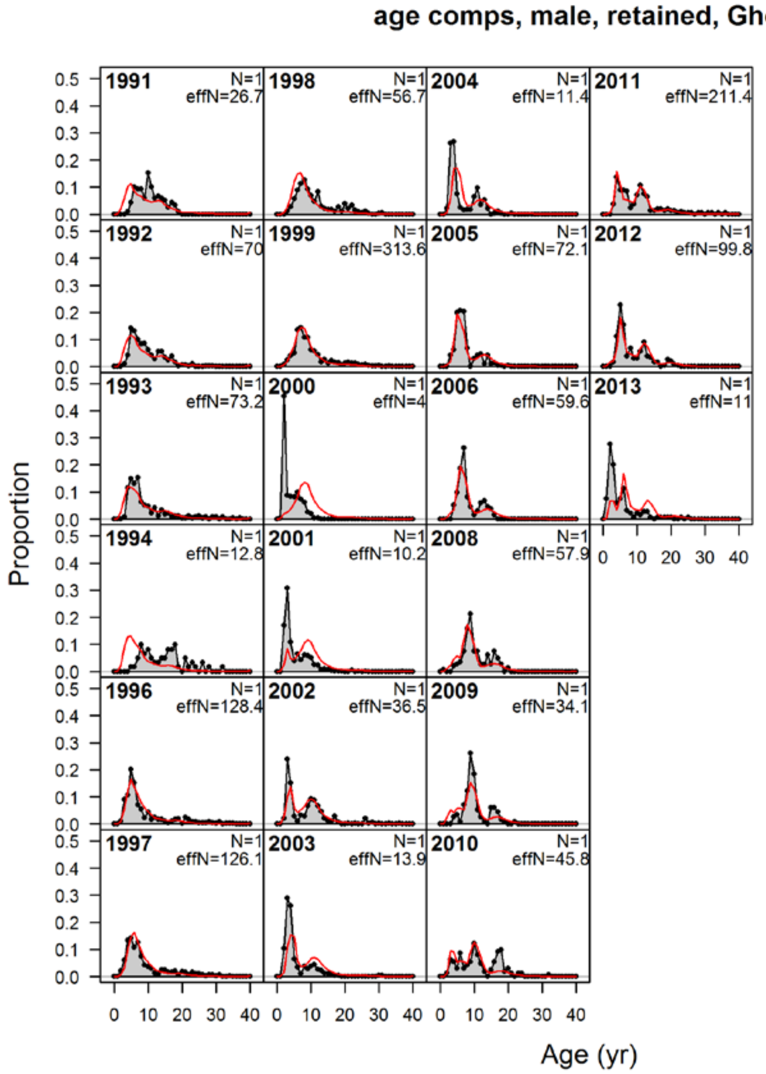
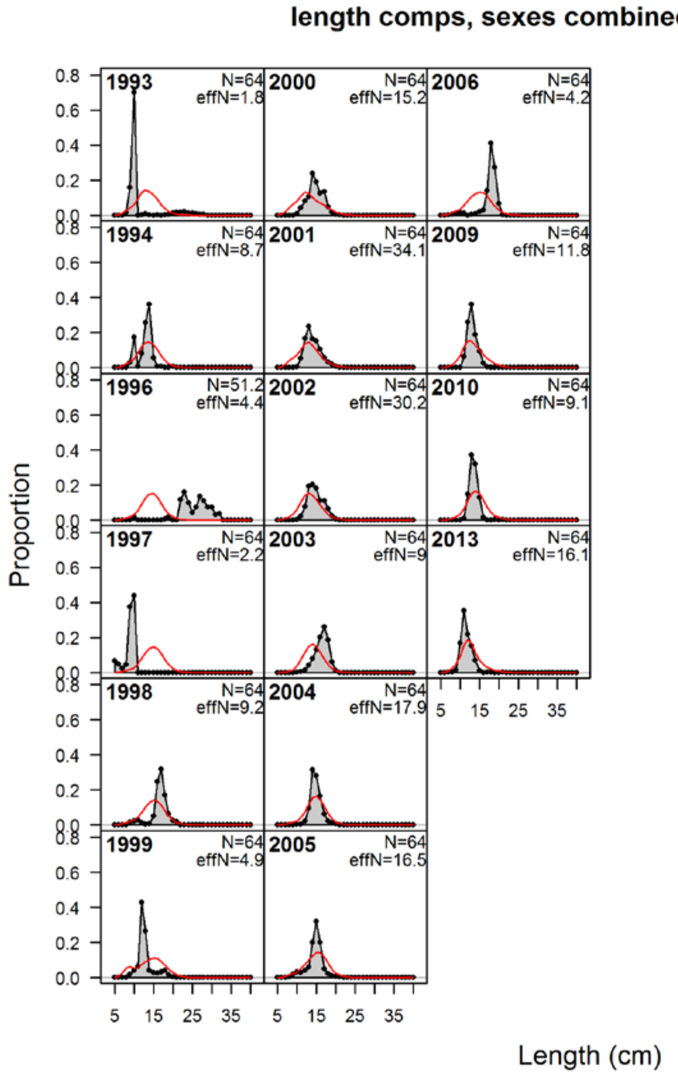
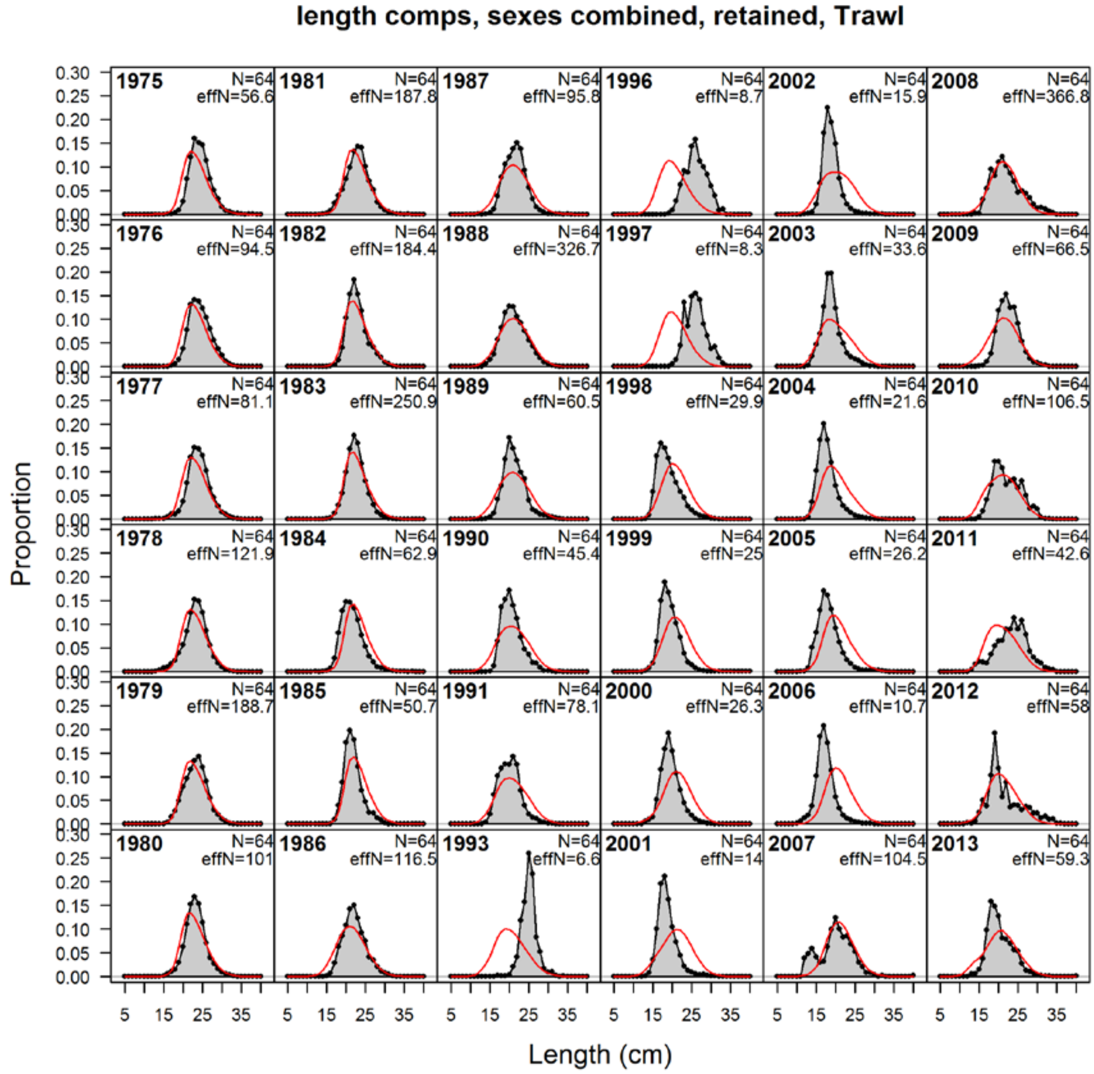
## 8.8 Appendix 1: Base case 4 (BC4)

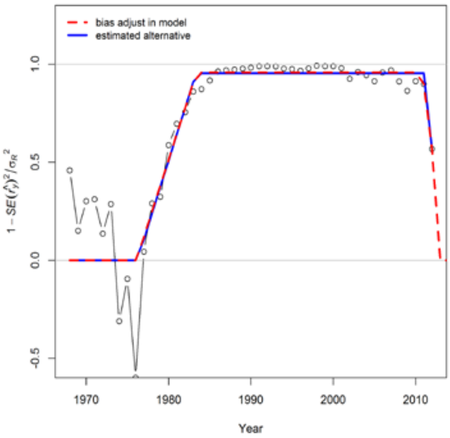


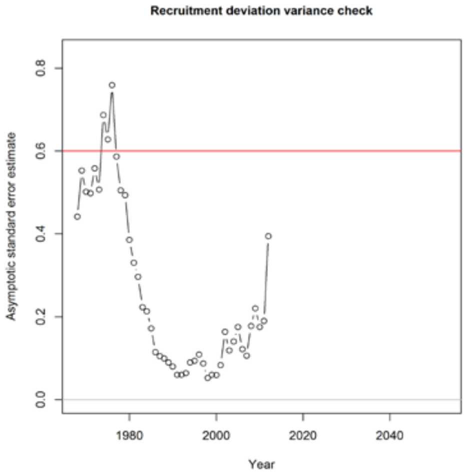

age comps, female, retained, Ghost
1991 N=1 effN=28.3
1997 N=1 effN=643.5
2003 N=1 effN=10.6
2009 N=1 effN=22.6
1992 N=1 effN=36.3
1998 N=1 effN=346.2
2004 N=1 effN=11.1
2010 N=1 effN=33.3
1993 N=1 effN=29.6
1999 N=1 effN=406.3
2005 N=1 effN=198
2011 N=1 effN=32.7
1994 N=1 effN=10.6
2000 N=1 effN=6.5
2006 N=1 effN=46.7
2012 N=1 effN=138.9
1995 N=1 effN=7.4
2001 N=1 effN=31.3
2007 N=1 effN=6.5
2013 N=1 effN=17.7
1996 N=1 effN=247.3
2002 N=1 effN=92.5
2008 N=1 effN=171.8
Proportion
Age (yr)

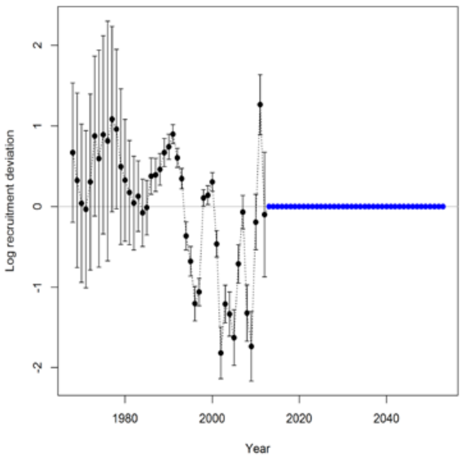

age comps, male, retained, Ghost
Proportion
Age (yr)
1991 N=1 effN=26.7
1998 N=1 effN=56.7
2004 N=1 effN=11.4
2011 N=1 effN=211.4
1992 N=1 effN=70
1999 N=1 effN=313.6
2005 N=1 effN=72.1
2012 N=1 effN=99.8
1993 N=1 effN=73.2
2000 N=1 effN=4
2006 N=1 effN=59.6
2013 N=1 effN=11
1994 N=1 effN=12.8
2001 N=1 effN=10.2
2008 N=1 effN=57.9
1996 N=1 effN=128.4
2002 N=1 effN=36.5
2009 N=1 effN=34.1
1997 N=1 effN=126.1
2003 N=1 effN=13.9
2010 N=1 effN=45.8

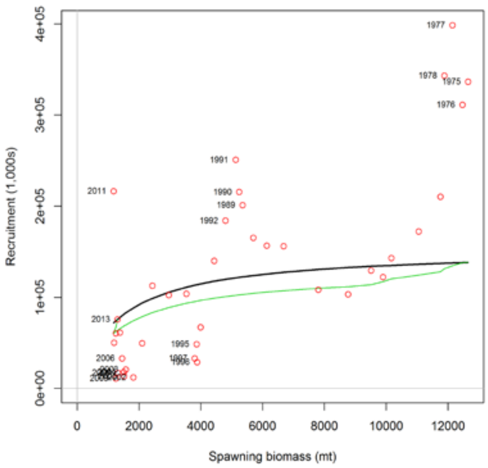

length comps, sexes combined, discard, Trawl
Proportion
Length (cm)
1993 N=64 effN=1.8
2000 N=64 effN=15.2
2006 N=64 effN=4.2
1994 N=64 effN=8.7
2001 N=64 effN=34.1
2009 N=64 effN=11.8
1996 N=51.2 effN=4.4
2002 N=64 effN=30.2
2010 N=64 effN=9.1
1997 N=64 effN=2.2
2003 N=64 effN=9
2013 N=64 effN=16.1
1998 N=64 effN=9.2
2004 N=64 effN=17.9
1999 N=64 effN=4.9
2005 N=64 effN=16.5


length comps, sexes combined, retained, Trawl
Proportion
Length (cm)
1975 N=64 effN=56.6
1981 N=64 effN=187.8
1987 N=64 effN=95.8
1996 N=64 effN=8.7
2002 N=64 effN=15.9
2008 N=64 effN=366.8
1976 N=64 effN=94.5
1982 N=64 effN=184.4
1988 N=64 effN=326.7
1997 N=64 effN=8.3
2003 N=64 effN=33.6
2009 N=64 effN=66.5
1977 N=64 effN=81.1
1983 N=64 effN=250.9
1989 N=64 effN=60.5
1998 N=64 effN=29.9
2004 N=64 effN=21.6
2010 N=64 effN=106.5
1978 N=64 effN=121.9
1984 N=64 effN=62.9
1990 N=64 effN=45.4
1999 N=64 effN=25
2005 N=64 effN=26.2
2011 N=64 effN=42.6
1979 N=64 effN=188.7
1985 N=64 effN=50.7
1991 N=64 effN=78.1
2000 N=64 effN=26.3
2006 N=64 effN=10.7
2012 N=64 effN=58
1980 N=64 effN=101
1986 N=64 effN=116.5
1993 N=64 effN=6.6
2001 N=64 effN=14
2007 N=64 effN=104.5
2013 N=64 effN=59.3


bias adjust in model
estimated alternative
Year
1970
1980
1990
2000
2010
-0.5
0.0
0.5
1.0


Recruitment deviation variance check
Asymptotic standard error estimate
Year
1980
2000
2020
2040
0.0
0.2
0.4
0.6
0.8


Log recruitment deviation
Year
1980
2000
2020
2040
-2
-1
0
1
2


Recruitment (1,000s)
Spawning biomass (mt)
0
2000
4000
6000
8000
10000
12000
0e+00
1e+05
2e+05
3e+05
4e+05
1977
1978
1975
1976
1991
2011
1990
1989
1992
2013
2006
1995