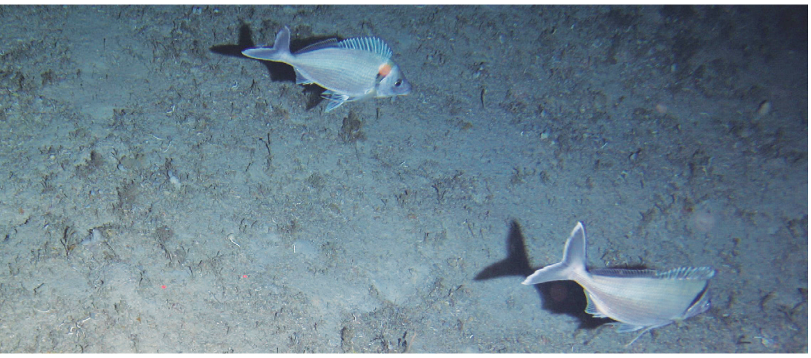
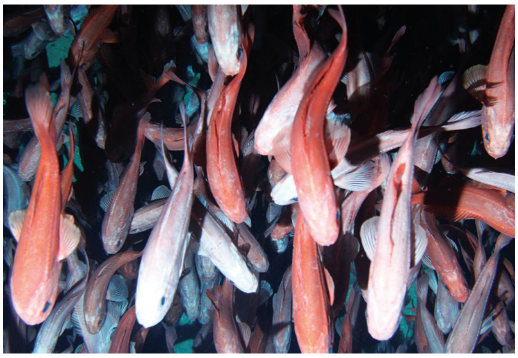
Cite as:
Tuck, G. (2013) Preliminary updated stock assessment of blue grenadier *Macruronus novaezelandiae* based on data up to 2012. pp 13 - 60 *in* Tuck, G.N. (ed.) 2014. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2013.* Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 313p.

Australian Government
Australian Fisheries Management Authority

2011/0814 June 2014

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013

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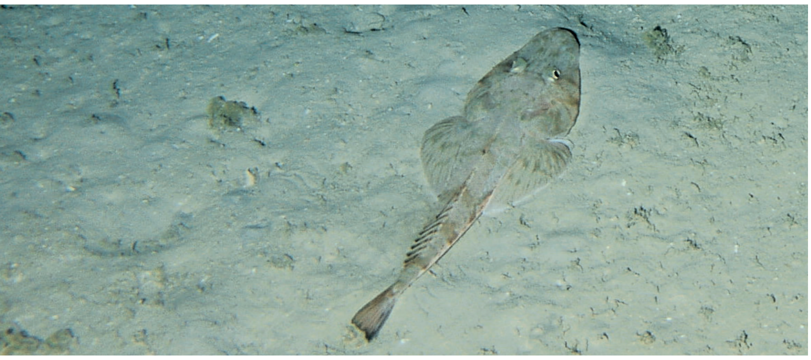
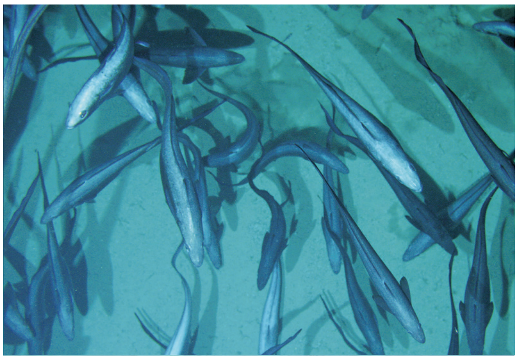


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Tuck, Geoffrey N. (Geoffrey Neil).
Stock assessment for the southern and eastern scalefish and shark fishery: 2013.

ISBN 978-1-4863-0337-3

Preferred way to cite this report

Tuck, G.N. (ed.) 2014. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2013. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 313p.

Acknowledgements

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). Jemery Day and Louise Bell are also greatly thanked for their 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 2012. 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 2013.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013

Part 1: Tier 1 assessments

G.N. Tuck
June 2014
Report 2011/0814

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013 Part 1

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5. Preliminary updated stock assessment of blue grenadier *Macruronus novaezelandiae* based on data up to 2012[1]

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5.1 Summary

The 2013 assessment of blue grenadier *Macruronus novaezelandiae* uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS) (NOAA, 2011). As with previous methods used to assess blue grenadier, the methods utilised in SS are based on the integrated analysis paradigm (Punt et al., 2001). The assessment has been updated by the inclusion of data up to the 2012 calendar year. Estimates of spawning biomass from acoustic surveys from 2003-2010 (with 2 times turnover) and egg survey estimates of female spawning biomass from 1994-1995 (base-case estimates) are included.

Results conclude that for the proposed base case model the female spawning biomass in 2012 is around 77% of the unexploited stock biomass and the depletion in 2014, used for the harvest control rules, will be approximately 90%. The marked increase in biomass is due to the estimation of a large cohort in 2010. While a promising sign for the fishery, the existence and magnitude of this recruitment should be treated with some caution until it can be verified by the addition of further data from future years. If the 2010 recruitment is not estimated and instead assumed to be of average magnitude, then the depletion estimates are considerably lower.

5.2 Introduction

An integrated analysis model, implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Methot, 2011; Methot and Wetzel, 2013), was applied to the blue grenadier stock of the Southern and Eastern Scalefish and Shark Fishery (SESSF), with data updated by the inclusion of data up to the 2012 calendar year (length and age data; age-error, catch rate series; landings and discard catch weight) and information from acoustic surveys of spawning biomass (series from 2003-2010, pertaining to total spawning biomass) with an assumption of 2-times turnover on the spawning ground (Russell and Smith, 2006). The base-case egg survey estimates of female (only) spawning biomass for 1994 and 1995 are included. The model fits directly to lengths frequencies (by sex where possible) and conditional age-at-length

[1] Paper presented at the Slope/Deep RAG meeting 23-25 September2014

data by fleet. Retained length frequency data are from port and onboard samples combined (where data were available).

The assessment model presented in 2011 (Tuck, Whitten and Punt 2001; Tuck 2011) was the first for blue grenadier to be implemented using SS. The use of SS allows the implementation of a model very similar to that used in previous assessments, but additionally presents an opportunity to improve the estimation of length-based selectivity and temporal variability in growth, avoiding the use of simplified assumptions regarding selectivity and modified age-length keys that were necessary in previous assessments. SS can allow for multiple fishing fleets, and can be fitted simultaneously to several data sources and types of information available for blue grenadier. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, is outlined fully in the SS user manual (Methot, 2005; 2011) and is not reproduced here. This document updates the assessment presented in 2011.

5.3 The fishery

Blue grenadier are found from New South Wales around southern Australia to Western Australia, including the coast of Tasmania. Blue grenadier is a moderately long-lived species with a maximum age of about 25 years. Age at maturity is approximately 4 years for males and 5 years for females (length at 50% maturity for females is 57cm and 64cm respectively) based upon 32,000 blue grenadier sampled between February 1999 and October 2001 (Russell and Smith, 2006). There is also evidence that availability to the gear on the spawning ground differs by sex, with a higher proportion of small males being caught than females (Figure 5.1). This is most likely due to the arrival of males on the spawning ground at a smaller size (and younger age) than females. This was also noted by Russell and Smith (2006) who state that "young males entered the fishery one year earlier than females" and is consistent with hoki from New Zealand (Annala et al., 2003). Large fish arrive earlier in the spawning season than small fish. Spawning occurs predominantly off western Tasmania in winter (the peak spawning period based upon mean GSIs calculated by month was estimated to be between June and August according to Russell and Smith (2006). There is some evidence that a high proportion of fish remain spawning in September. Variations in spawning period noted by Gunn et al (1989) may occur due to inter-annual differences in the development of coastal current patterns around Tasmania. Adults disperse following the spawning season and while fish are found throughout the south east region during the non-spawning season, their range is not well defined. Spawning fish have recently been caught off the east coast of Australia and larvae from a likely eastern spawning area have been described by Bruce et al. (2001). Further analyses (eg sampling, acoustics) of these fish will need to be conducted before they can be included in the current stock assessment.

Blue grenadier are caught by demersal trawling. The global agreed TAC in 2012/13 was 5,208 tonnes. The annual TACs are show in Table 5.1. There are two defined sub-fisheries: the spawning (Zone 40, months June, July and August) and non-spawning fisheries (all other months and zones).

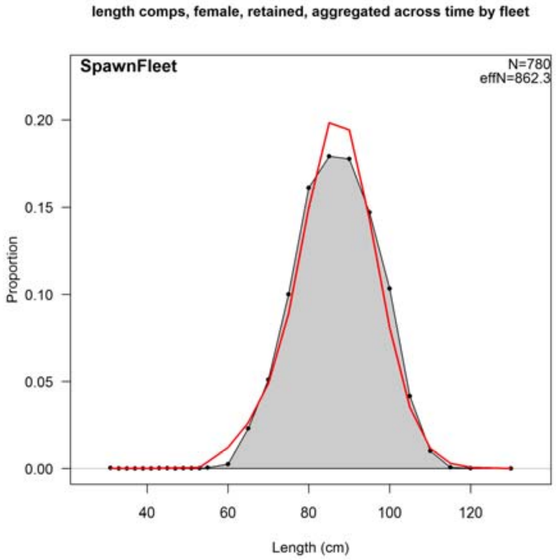
5.4 Data

The assessment has been updated since the previous assessment (Tuck, 2011) by the inclusion of length and age-at-length data from the spawning and non-spawning fisheries; updated cpue series (Haddon, 2013), the total mass landed and discarded, and update age-reading error. Acoustic estimates of spawning biomass (2003-2010) and estimates of the female spawning biomass in 1994 and 1995 from egg surveys (Bulman et al., 1999) are included. Data were formulated by calendar year (i.e. 1 Jan to 31 Dec) as in previous models.

5.4.1 *Catch*

The landings from the SEF1 logbook data were used to apportion catches to the spawning and non-spawning fisheries. The SEF1 landings have been adjusted upwards to take account of differences between logbook and landings data (multiple of 1.4 for the non-spawning fishery, based on 40% conversion from headed and gutted to whole, since 1986 and up to and including 1997 (reliable CDR data were available from 1998); 1.2 for the spawning fishery from 1986 up to and including 1996 (when factory vessels entered the spawning fishery)) (D. Smith, pers. comm.). As stated by Thomson and He (2001), the factor is lower for the spawning fleet than the non-spawning fleet because some fish in the spawning fishery, landed headed and gutted, were recorded as being landed whole. These factors were chosen by the Blue Grenadier Assessment Group (BGAG) (Chesson and Staples (1995), as cited by Punt (1998)). The adjusted logbook catches were then scaled up to the SEF2 data. As historical SEF2 data were only available from 1992, the average scaling factor from 1992 to 1996 was used to scale the data for years between 1986 and 1991 (Figure 5.2). Note that in years 2008 to 2012 logbook data were greater than landings from the CDR. In these cases the tonnage from the CDR was used as the total catch (AFMA, pers. comm. 2011). Table 5.1 lists the annual catches used in the assessment and the annual TAC. The annual logbook catches by sub-fishery and the adjustments made to determine the catches used in the assessment are shown in Table 5.2.

Discard rates 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). The discard values from 1995 to 2002 are based on estimates calculated from ISMP data by MAFRI and reported in He et al (1999) and Tuck, Smith and Talman (2004). As agreed by Slope RAG (2011), since 2003 discard rates are taken from those estimated by the methods described in Thomson and Klaer (2011). The mass of the discard is calculated from the annual discard rate and the retained catch from the non-spawning fishery. The MAFRI estimates of discards were made accounting for differences in sampling and discard rates according to the ISMP zones. The more recent estimates are simple ratios of total discards to (retained + discard) catch (N. Klaer, pers comm.). Information in support of the historical values was not able to be obtained and further exploration of the methods and data used to estimate these values should be encouraged. The discard data are provided in Table 5.1.



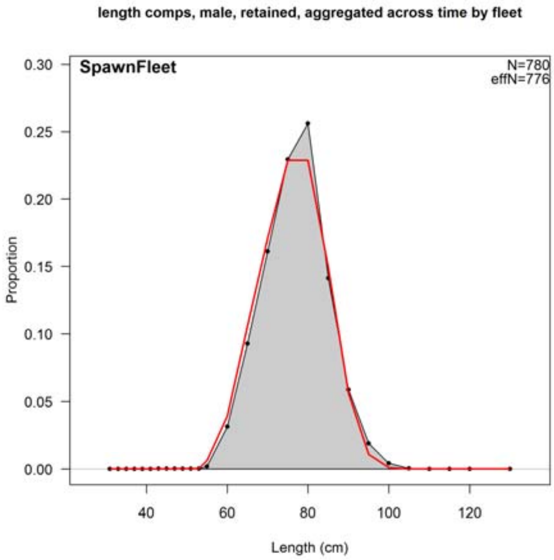


Figure 5.1. The aggregated length composition of females (top) and males (bottom) on the spawning ground. The red line indicates a model fit with sex-specific selectivity.

Table 5.1. Landed and discarded catches for the winter spawning and non-spawning sub-fisheries by calendar year. These estimates have been adjusted scaled up to the landings data (see text and Table 5.2). Standardised CPUE (Haddon, 2013) and number of records for the non-spawning sub-fisheries by calendar year are shown, along with the TAC. 1 a voluntary industry reduction to 4,200 t was implemented in 2005. 2 This was a 16 month TAC. 3 The TACs cover the fishing year 1 May to 30 April. In the table below, 2008 refers to 2008/09. 4 This is an estimate of retained catch based on the 2012/2013 TAC and relative split of catch between spawning and non-spawning fisheries of 2012.

Year	Landings		Discards	TAC		
	Spawning	Non-spawning	Non-spawning		Records	CPUE
1979	245	245				
1980	410	410				
1981	225	225				
1982	390	390				
1983	450	450				
1984	675	675				
1985	600	600				
1986	317	1807			3189	1.505
1987	1006	2183			3569	1.978
1988	410	2228			3961	2.143
1989	46	2745			4309	2.219
1990	733	2508			3577	2.190
1991	819	3764			4308	1.576
1992	710	2549			3228	1.298
1993	994	2368			4203	0.980
1994	1211	1940		10000	4491	0.881
1995	1205	1570	80	10000	5076	0.607
1996	1496	1544	975	10000	5370	0.554
1997	2947	1569	3716	10000	6194	0.573
1998	3746	1986	1329	10000	6599	0.941
1999	6775	2549	123	10000	8045	0.995
2000	6608	2047	69	10000	7679	0.710
2001	8004	1120	10	10000	7279	0.406
2002	7843	1318	2	10000	6344	0.407
2003	7745	726	3	9000	5675	0.341
2004	5064	1327	15	7000	6393	0.573
2005	3024	1259	310	5000[1]	5346	0.686
2006	2193	1420	104	3730	4362	0.911
2007	1891	1280	5	4113[2]	3659	0.811
2008	2692	1239	19	4368[3]	3407	0.890
2009	2295	964	15	4700[3]	3443	0.826
2010	3119	1066	10	4700[3]	3308	0.810
2011	3342	859	126	4700[3]	3968	0.657
2012	3447	557	192	5208[3]	3210	0.533
2013	4484[4]	724[4]				

Table 5.2. Logbook and CDR landings for the spawning and non-spawning sub-fisheries by calendar year and adjustments made to account for logbooks being less than landings and incorrect reporting process code. Shaded CDR are historical landings values.

Year	Logbook		CDR	H&G Multiplier		Adjusted Logbook			CDR / logbook	Catch for assessment	
	Spawning	Non-spawning		Spawning	Non-spawning	Spawning	Non-spawning	Total		Spawning	Non-spawning
1979	245	245		1	1	245	245	490	1	245	245
1980	410	410		1	1	410	410	820	1	410	410
1981	225	225		1	1	225	225	450	1	225	225
1982	390	390		1	1	390	390	780	1	390	390
1983	450	450		1	1	450	450	900	1	450	450
1984	675	675		1	1	675	675	1350	1	675	675
1985	600	600		1	1	600	600	1200	1	600	600
1986	246	1204		1.2	1.4	295	1685	1981	1.04	317	1807
1987	782	1455		1.2	1.4	939	2036	2975	1.04	1006	2183
1988	319	1485		1.2	1.4	383	2079	2462	1.04	410	2228
1989	36	1829		1.2	1.4	43	2561	2604	1.04	46	2745
1990	570	1671		1.2	1.4	684	2340	3023	1.04	733	2508
1991	637	2508		1.2	1.4	764	3511	4275	1.04	819	3764
1992	509	1565	3259	1.2	1.4	730	2208	2938	1.11	710	2549
1993	812	1659	3362	1.2	1.4	1056	2349	3405	0.99	994	2368
1994	974	1338	3151	1.2	1.4	1185	1914	3100	1.02	1211	1940
1995	911	1017	2775	1.2	1.4	1114	1460	2574	1.08	1205	1570
1996	1200	1061	3040	1.2	1.4	1442	1535	2978	1.02	1496	1544
1997	2623	997	4516	1	1.4	2623	1442	4065	1.11	2947	1569
1998	2739	1452	5733	1	1	3463	1491	4954	1.16	3746	1986
1999	5460	2054	9324	1	1	5649	2115	7763	1.20	6775	2549
2000	5665	1755	8655	1	1	5670	1820	7490	1.16	6608	2047
2001	7309	1022	9124	1	1	7331	1063	8393	1.09	8004	1120
2002	6825	1147	9161	1	1	6850	1185	8035	1.14	7843	1318
2003	7239	679	8471	1	1	7255	691	7946	1.07	7745	726
2004	4647	1218	6392	1	1	4653	1275	5928	1.08	5064	1327
2005	2880	1199	4283	1	1	2903	1221	4124	1.04	3024	1259
2006	2058	1332	3614	1	1	2069	1369	3439	1.05	2193	1420
2007	1815	1228	3171	1	1	1815	1228	3044	1.04	1891	1280
2008	2838	1306	3931	1	1	2838	1306	4143	0.95	2692	1239
2009	2723	1144	3259	1	1	2712	1144	3856	0.85	2295	964
2010	3384	1157	4185	1	1	3384	1157	4540	0.92	3119	1066
2011	3554	913	4201	1	1	3554	913	4467	0.94	3342	859
2012	3838	620	4004	1	1	3838	620	4458	0.90	3447	557

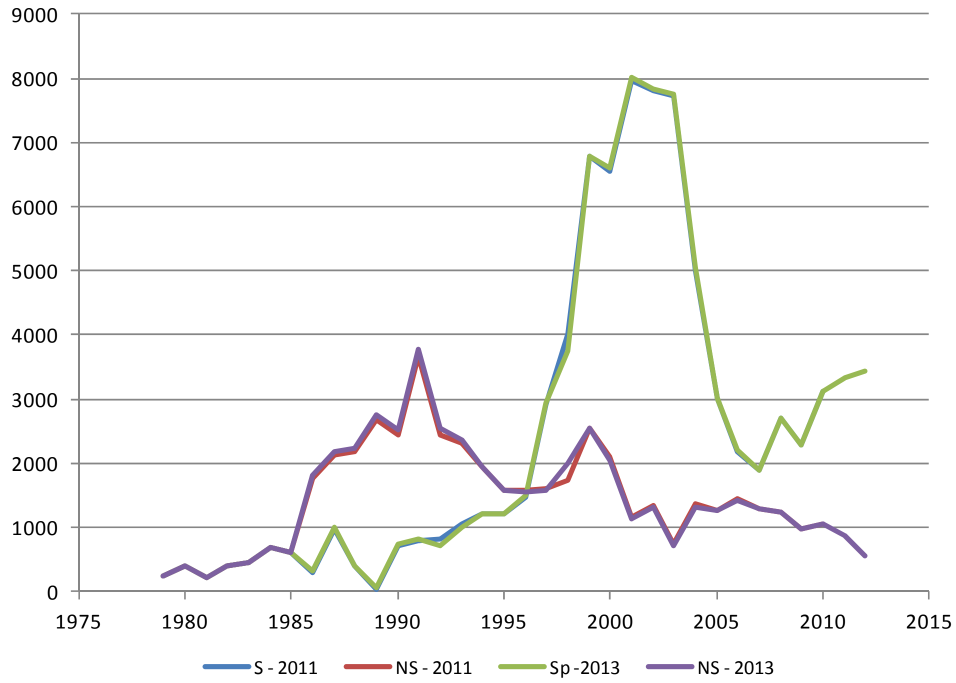


Figure 5.2 The 2013 annual catch series (tonnes) for the spawning (S-2013) and non-spawning (NS-2013) blue grenadier fisheries in comparison to the series for 2011 (Tuck, 2011).

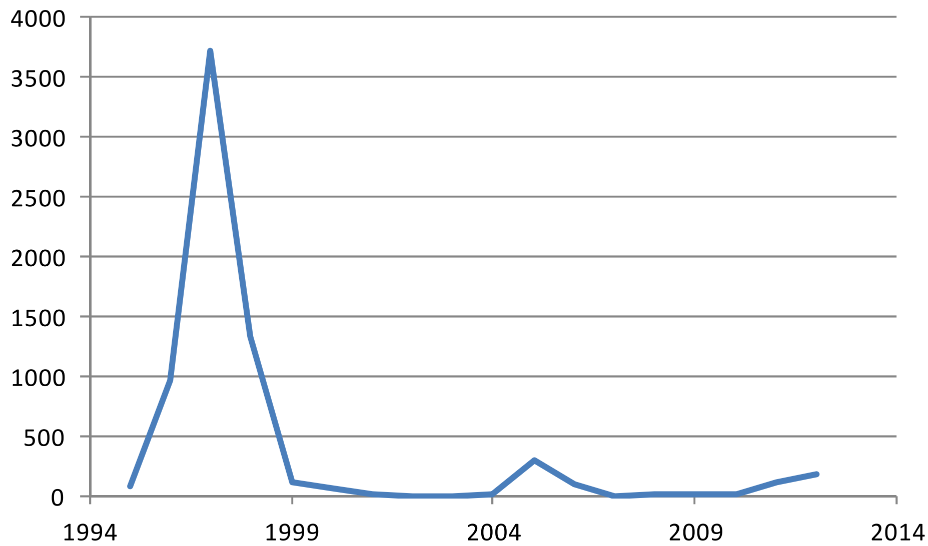


Figure 5.3 The 2013 annual discard series (tonnes) for the non-spawning blue grenadier fishery.

5.4.2 *Catch rates*

Haddon (2013) provides the updated catch rate series for blue grenadier (Table 5.1, Figure 5.4). The spawning fishery catch rate series is not used in the assessment as it is not believed to be a good indicator of available biomass for this component of the stock.

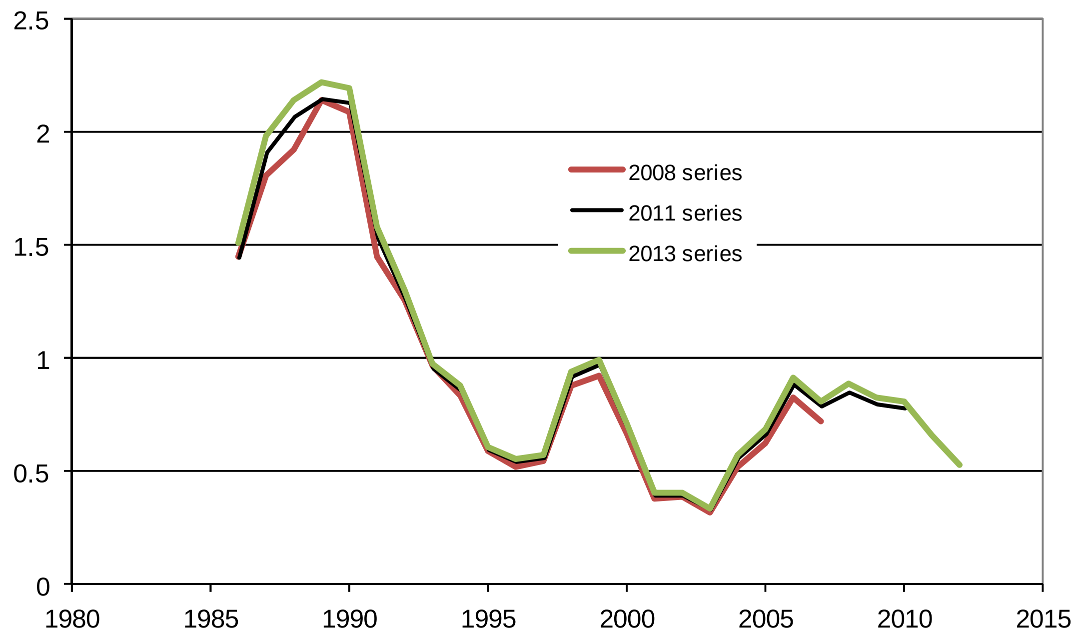


Figure 5.4 The calendar year catch-rate indices for the non-spawning blue grenadier fisheries (Haddon, 2013) in comparison to the series for 2008 and 2011 (Haddon 2008; 2011).

5.4.3 *Length frequencies and age data*

Length and age data are been included in the model as length frequency data and conditional age-at-length data by fleet and sex (when available). Age composition data is included in diagnostic plots but is not used directly within the fitting procedure. On-board and port lengths, when available, were combined to create length frequencies. In previous years, only port samples had been used to create the length frequency. Length data from 1997 were removed from the analyses as there appeared to be data having the DSL process code with lengths that corresponded to the standard length (STL) measurement. This led to unrealistically large lengths when converted from DSL to STL. Discard lengths from 2010 were removed as there were only 16 samples. Figures of the observed length and age data are shown in later figures with the corresponding model predicted values.

5.4.4 *Age-reading error*

Updated standard deviations for aging error by reader (A and B) have been estimated, producing the age-reading error matrix of Table 5.3 (A. Punt, pers. comm.). Reader A applied to years 1991-93 and 2007-2012, and reader B to 1984-1990 and 1994-2006.

Table 5.3. The standard deviation of age reading error.

	St Dev	
Age	A	B
0	0.150	0.286
1	0.150	0.286
2	0.243	0.302
3	0.310	0.319
4	0.359	0.338
5	0.395	0.358
6	0.420	0.381
7	0.439	0.406
8	0.452	0.433
9	0.462	0.463
10	0.469	0.495
11	0.474	0.531
12	0.478	0.570
13	0.480	0.613
14	0.482	0.660
15	0.484	0.712
16	0.485	0.768
17	0.485	0.830
18	0.486	0.898
19	0.486	0.973
20	0.487	1.054

5.4.5 ***Acoustic survey estimates***

Estimates of spawning biomass for 2003-2010 are provided in Ryan and Kloser (2012). There are no acoustic estimates for 2011 (not funded) and 2012 (technical issues). Table 5.4 shows the estimates of spawning biomass with their corresponding cv's used in the assessment. Sampling cv's of less than 0.3 were increased to 0.3 to account for process error. Low sampling cvs (of 0.19 for example) were considered too low for an acoustic survey and a minimum of 0.3 should be used to reflect the total uncertainty (D. Smith, pers comm., Tuck et al. 2004; Slope RAG 2011). Of 22 acoustic cvs used for hoki in New Zealand none are lower than 0.3 (Francis, 2009). It is assumed that the spawning ground experiences a turnover rate equal to 2 (i.e. for the model applied here, the spawning biomass estimates are doubled) (Russell and Smith, 2006).

Table 5.4. The estimated biomass (tonnes) of blue grenadier on the spawning grounds in years 2003 to 2010 (Ryan and Kloser, 2012).

	2003	2004	2005	2006	2007	2008	2009	2010
biomass (t)	24690	16295	18852	42882	56330	24450	24787	20622
c.v. in assessment model	0.30	0.46	0.30	0.30	0.52	0.30	1	0.33
Sample cv	0.16	0.46	0.14	0.14	0.52	0.22	1	0.33

5.4.6 *Egg survey estimates*

Egg survey estimates of female spawning biomass are available for 1994 and 1995 (Bulman et al., 1999). The egg-estimates (cv) for 1994 and 1995 respectively are: 57,772 (0.18) and 41,409 (0.29). For the analysis considered here, the base-case egg estimates were used.

5.4.7 *Biological parameters*

The assessment assumes that the proportion of females that spawn in each year is 0.84 and a length at 50% maturity of 63.7cm for females (Russell and Smith, 2006). The female maturity ogive is shown in Figure 5.5.

The length weight relationship for males and females was estimated from spawning fishery data over years 1999 to 2008 (Figure 5.5). Natural mortality for females was estimated and male natural mortality is assumed to be 20% greater than this value based upon assumptions made for hoki in New Zealand (McAllister et al. 1994).

Francis (2009) reviews the values of steepness used in New Zealand hoki assessments, where a value of h=0.9 had been used since 1994. This value of steepness was derived from work of Punt et al. (1994) using 45 stocks of gadiform species (0.9 is the median). Following an analysis of the profile likelihood, the effect of steepness on the 2007 assessment and additional information of Myers et al. (1999; 2002) beyond that used by Punt et al. (1994), Francis (2009) concludes that steepness should be reduced to h=0.75. This value of steepness was assumed in the previous blue grenadier assessment in 2011 (Tuck, 2011) and in this assessment.

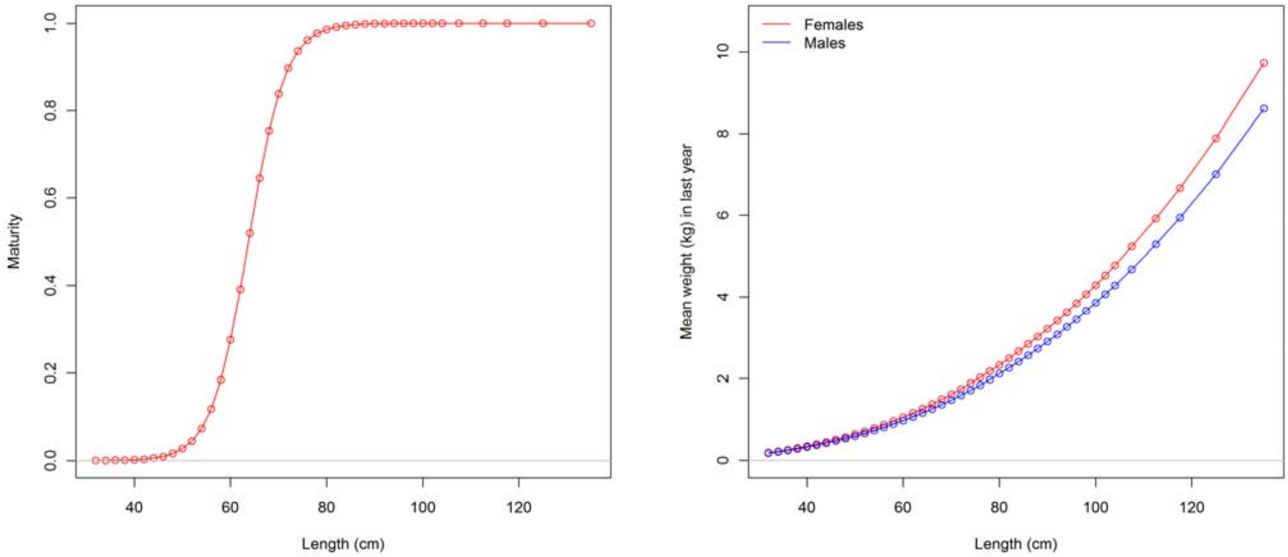


Figure 5.5 The maturity ogive by length for female blue grenadier (parameters from Russell and Smith (2006)) and the length-weight relationship for males and females.

5.5 Analytic approach

5.5.1 The population dynamics model

The 2013 assessment of blue grenadier uses 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. The assessment of blue grenadier takes advantage of the ability of SS to account for multiple fleet allocations to represent the different dynamics of the spawning and non-spawning fisheries. 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, catch length-frequencies, surveys, 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).

This assessment follows the agreements made at the October and November 2011 meetings of Slope RAG. These were: include gender specific selectivity for the spawning fishery, estimate natural mortality for females, use historical discard tonnages estimated by MAFRI, include cohort dependent growth, and set steepness at 0.75.

The base–case model includes the following key features:

(a) Two sub-fisheries are included in the model – the spawning sub-fishery that operates during winter (June – August inclusive) off western Tasmania (zone 40), and the non-spawning sub-fishery that operates during other times of the year and in other areas throughout the year.
(b) The selectivity pattern was assumed to be length-specific, logistic and time-invariant for the spawning fleet and dome-shaped for the non-spawning fleet. The parameters of the selectivity function for each fleet were estimated within the assessment. A change in selectivity from 2005 was considered as a sensitivity for the non-spawning fleet, however this did not substantially affect the fits nor management quantities of interest.
(c) Blue grenadier consists of a single stock within the area of the fishery.
(d) The model accounts for males and females separately.
(e) The population was at its unfished biomass with the corresponding equilibrium (unfished) age-structure at the start of 1960.
(f) The CVs of the CPUE indices for the non-spawning fleet were initially set at a low value (0.1) to encourage a fit to the abundance data, before being re-tuned to the model-estimated standard errors (0.64).
(g) Discard tonnage was estimated through the assignment of a retention function for the non-spawning fleet. This was defined as a logistic function of length, and the inflection and slope of this function were estimated where discard information was available
(h) The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The value for female M is estimated within the model. Following previous assessments, male natural mortality is assumed be 20% greater than that of females.
(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. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1974 to 2010. Deviations are not estimated before 1974 or after 2010 because there are insufficient data to permit reliable estimation of recruitment residuals outside of this time period.
(j) The value of the parameter determining the magnitude of the process error in annual recruitment, σ_r, is set equal to 1.0 in the base case reflecting the large variation in recruitment observed for blue grenadier
(k) The population plus-group is modelled at age 20 years. The maximum age for observations was 15 years, reflecting that used in previous assessments
(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 inside the assessment model. Growth is also assumed to vary through time and be cohort (year class) specific. Evidence for time-varying and cohort specific growth in blue grenadier has been accumulating for over a decade (see Punt and Smith 2001; Whitten et al., 2013). As such, mean length- and mass-at-age by cohort has been derived for previous assessments from age-length keys, the mass-length relationship and length frequency data (Method 2 of Punt and Smith, 2001) and specified directly as mean length- and mass-at-age matrices in the assessment models. The data upon which these matrices were based was treated as being subject to sampling error. Therefore, whilst the previous method allowed for explicit accounting of variability in mean-size through time, it was not conceptually consistent with the Integrated Analysis estimation procedure, which assumes that

mean length- and mass-at-age matrices input into an assessment are known exactly. This method also relied on interpolated length- and mass-at-age estimates for years in which actual data were not available and ignored any age-length relationship. The implementation of the base-case assessment using SS can account for temporal variation in growth, and therefore temporal variation in mean length- and mass-at-age. Following the 2011 assessment, the 2013 base-case model treats length-at-age information as data, and predicts the expected length-at-age for each year. This is achieved by estimating the parameters of a von Bertalanffy growth function that describe the mean expected length-at-age across all years and then introducing an extra parameter that describes cohort specific deviations from mean expected length-at-age for a specified range of year classes. Cohort specific deviations from average growth are estimated in the base case model for year classes 1978 to 2009, the year classes for which there are sufficient length-at-age data to permit reliable estimates.

(m) The sample sizes for length frequencies were tuned for each fleet so that the input sample size was approximately equal to the effective sample size calculated by the model. Before the retuning of length frequency data was performed by fleet, retained length sample sizes were set at 50 and discard length sample sizes to 10. This is because the appropriate sample size for length frequency data is probably more 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. Discard length sample sizes were set at 10 based approximately upon the ratio of discard to (retained + discard) samples multiplied by 50. Discard length frequencies with samples sizes <200 were removed. The age data sample sizes for a particular year were decreased to 50. The relative frequency of age samples across lengths within a year was maintained. Length, age and cpue data were tuned.

The values assumed for some of the (non-estimated) parameters of the base case models are shown in Table 5.5.

Table 5.5. Parameter values assumed for some of the non-estimated parameters of the base-case model.

Parameter	Description	BC
M_f	Natural mortality for females	Estimated
M_m	Natural mortality for males	1.2* M_f
σ_r	c.v. for the recruitment residuals	1.0
σ_g	Input standard deviation for the cohort growth deviations	0.1
h	"steepness" of the Beverton-Holt stock-recruit curve	0.75
x	age observation plus group	15 years
μ	fraction of mature population that spawn each year	0.84
aa	Female allometric length-weight equations	0.01502 g^{-1}.cm
bb	Female allometric length-weight equations	2.728
aa	Male allometric length-weight equations	0.0168 g^{-1}.cm
bb	Male allometric length-weight equations	2.680
l_m	Female length at 50% maturity	63.7cm
l_s	Parameter defining the slope of the maturity ogive	-0.261

5.6 Results and discussion

5.6.1 *Transition from the 2011 to the 2013 assessment*

A sequential analysis was conducted to determine the influence of each of the input data sources to the changes observed in the biomass trajectories caused by the inclusion of the 2011 and 2012 calendar year data. A re-examination of the 2011 diagnostic of the standard errors of recruitment residuals showed that recruitments were poorly estimated before 1974 (Figure 5.6). As such, in developing the 2013 base case, recruitment residuals were only estimated from 1974. An examination of the impact of removing estimation of recruitments is shown in the comparison plots of SSB and recruitment (Figure 5.7).

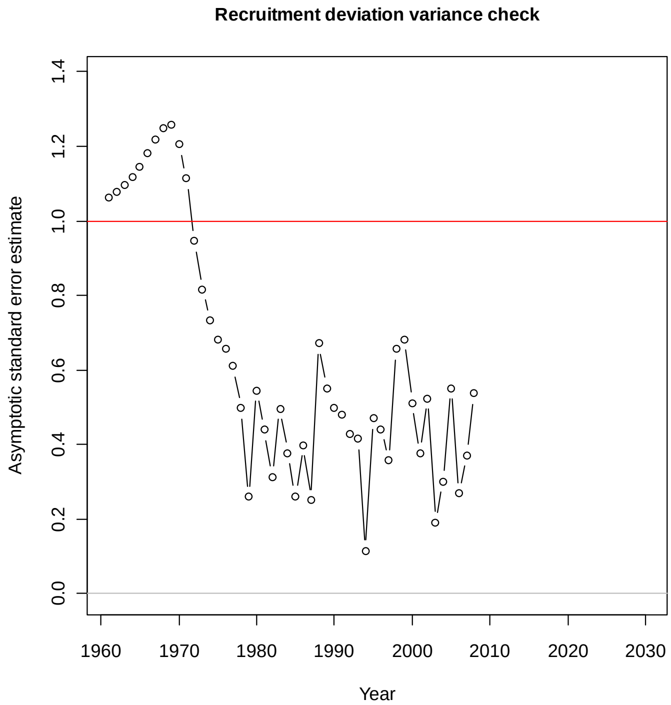


Figure 5.6. Standard errors of recruitment residual estimates for the base case model of 2011 (Tuck, 2011).

Figure 5.7 and Figure 5.8 show the SSB time series as each data source (listed and labelled below) is added and an assessment conducted, while holding the weighting parameters from the tuned model of 2011 fixed. The various transitional assessments and their data-source changes are:

1. The 2011 assessment result (**2011**)
2. The 2011 assessment data with recruitments estimated from 1974 (not 1961) (**R74_2011**)
3. The 2011 assessment data with the addition of the updated catches, including those for 2011 and 2012 (**R74_C**)
4. Option 3 with the updated catch rate series for 2013 (**R74_C_Cpue**)
5. Option 3 with the addition of the updated age data (**R74_C_Age**)
6. Option 3 with the addition of the updated length data (**R74_C_Length**)
7. Option 6 with the addition of the updated age data (**R74_C_Age_ Length**)
8. Option 7 with the addition of the updated catch rate data (**R74_C_Age_Length_Cpue**)

9. Option 8 with the addition of the updated discard masses (**R74_C_Age_Length_Cpue_D**)

10. Option 9 with recruitment estimated to 2010 (**R74_C_Age_Length_Cpue_D_R**)

11. Option 10 with updated age-reading error updated (**R74_C_Age_Length_Cpue_D_R_AE**)

12. Option 11 with Cohort Dependent Growth (CDG) updated (**R74_C_Age_Length_Cpue_D_R_AE_CDG**)

13. The tuned 2013 assessment result (**2013 Tuned BC**)

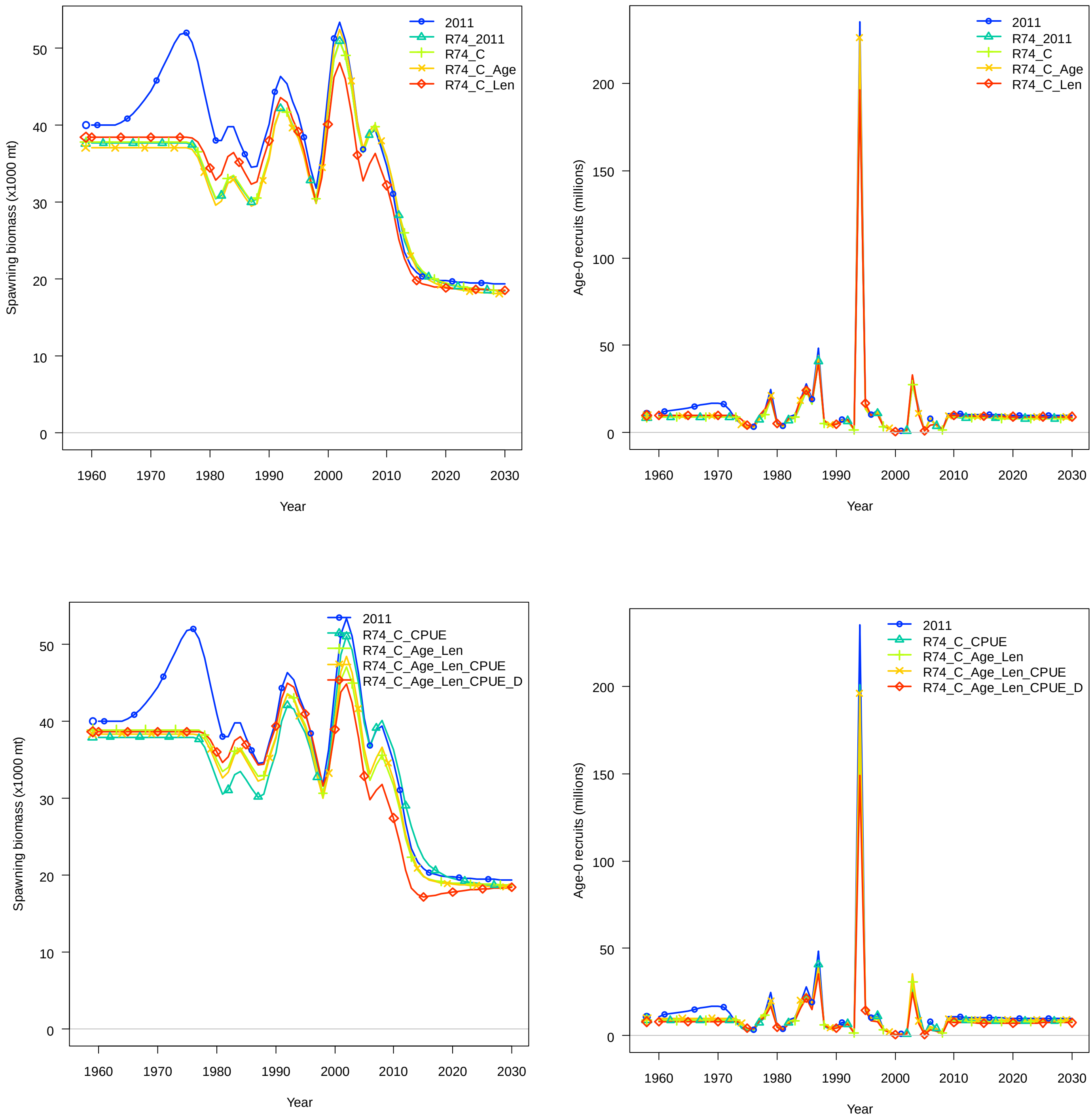


Figure 5.7. The effect on spawning biomass (left) and recruitment estimates (right) of sequentially adding in new data from 2013.

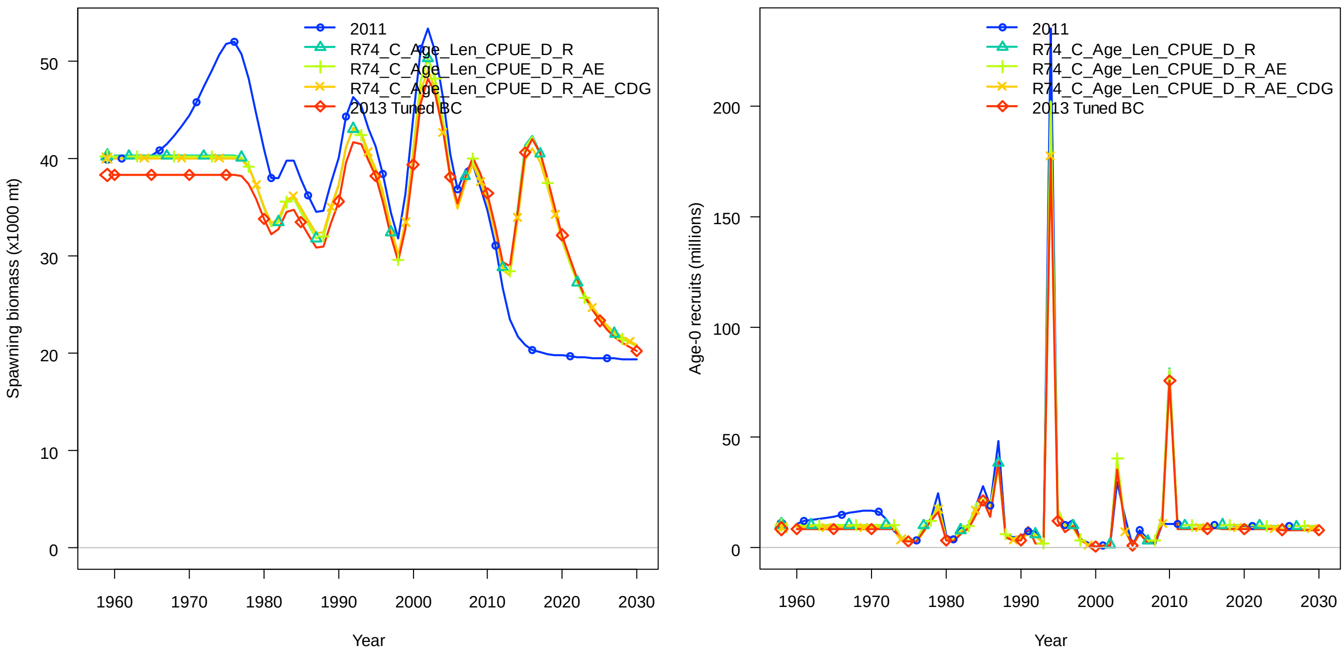


Figure 5.8. The effect on spawning biomass (left) and recruitment estimates (right) of sequentially adding in new data from 2013. The 2013 base case model is labelled '2013 Tuned BC'.

The transition from the 2011 to the 2013 base case models illustrated in Figure 5.7 and Figure 5.8 show that for most updated datasets there is little impact on the trend or magnitude in biomass or the recruitment. The largest influence has been the non-estimation of recruitments prior to 1974. The 2011 assessment estimates above average recruitment through to 1974, leading to an initial marked rise in spawning biomass. With these estimates now being deterministic and taken directly from the stock-recruitment curve, the spawning biomass does not deviate from equilibrium until after 1974 (when non-equilibrium recruitment estimates begin to influence the spawning biomass). However, the initial and final biomass differs little between the models (Figure 5.8).

There is also a marked increase in future spawning biomass once the additional years (2009 and 2010) of recruitment are estimated (Figure 5.8). The 2010 recruitment is substantial, second only to the large recruitment of the 1990's. While a promising sign, it is most likely too early to be sure that this large recruitment will persist, as additional data will need to verify its existence in future assessments.

5.6.2 ***The Base Case Stock Assessment***

5.6.2.1 Parameter estimates

Figure 5.9 shows how the expected mean length-at-age values change over time for the base case model. The ridges reflect the impact of some cohorts growing faster or slower than average. This figure also shows the expected mean length-at-age values for the end-year of the model. The impact of slower than average growth is visible by the decrease in expected size of 9 and 18 yo fish, corresponding to the larger than average recruitments in years 2003 and 1994 respectively. Natural mortality for females was estimated to be M_f =0.15 and males therefore was M_m =0.18.

The selectivity for the spawning and non-spawning fisheries and the retention function for the non-spawning fishery are shown in Figure 5.10. Selectivity is assumed to be time-invariant, sex-specific and logistic for the spawning fleet and dome-shaped for the non-spawning fleet. Note that the estimated female length-specific selectivity for the spawning ground shows an ascending limb that includes much larger fish than the maturity ogive estimated by Russell and Smith (2006), which has an estimate of 50% maturity of 63.7cm. This result implies that, to a large extent, small mature females do not appear to be evident on the spawning ground. Russell and Smith (2006) present length frequencies during their study of blue grenadier reproductive biology showing that very few female fish less than 60cm were caught (also see Figure 5.12). However those that were caught were included in the study and a proportion of these fish were shown to be mature.

5.6.2.2 Fits to the data

Figure 5.11 shows the model fit to the non-spawning catch rate series. The model fits intersect most of the 95% confidence intervals for the data, indicating that adjustments to the CV for the indices performed as expected. As has been seen in all previous assessment models for blue grenadier, the model is not able to fit the rise in catch rate following the large recruitment of the mid-1990s. The fit to the discard mass is able to replicate the increase in discarding through the late 1990s and mid 2000s, however the magnitude is under-estimated in the mid 1990s (as has been the case with previous assessments). The inability of the model to fit to the catch rate data has been investigated (in previous assessments and here) by fixing the cpue cv (0.1) and forcing a better fit to these data (Appendix 2). However, this leads to significantly poorer fits to other data series and spawning biomass trajectories that appear unlikely. Including a separate 'discard fleet' will be considered as a sensitivity leading up to the coming RAG meeting. Fits to the biomass estimates from the acoustic surveys and egg surveys were reasonable.

The model is able to replicate the implied age-composition data and the length composition data well (Figure 5.12 and Figure 5.13; Appendix 1). Predicted age-compositions are able to track the strong cohorts typical of blue grenadier as they move through both the non-spawning fishery and the spawning fishery. The inclusion of sex-specific selectivity has allowed a better fit to the observations of length and age by sex.

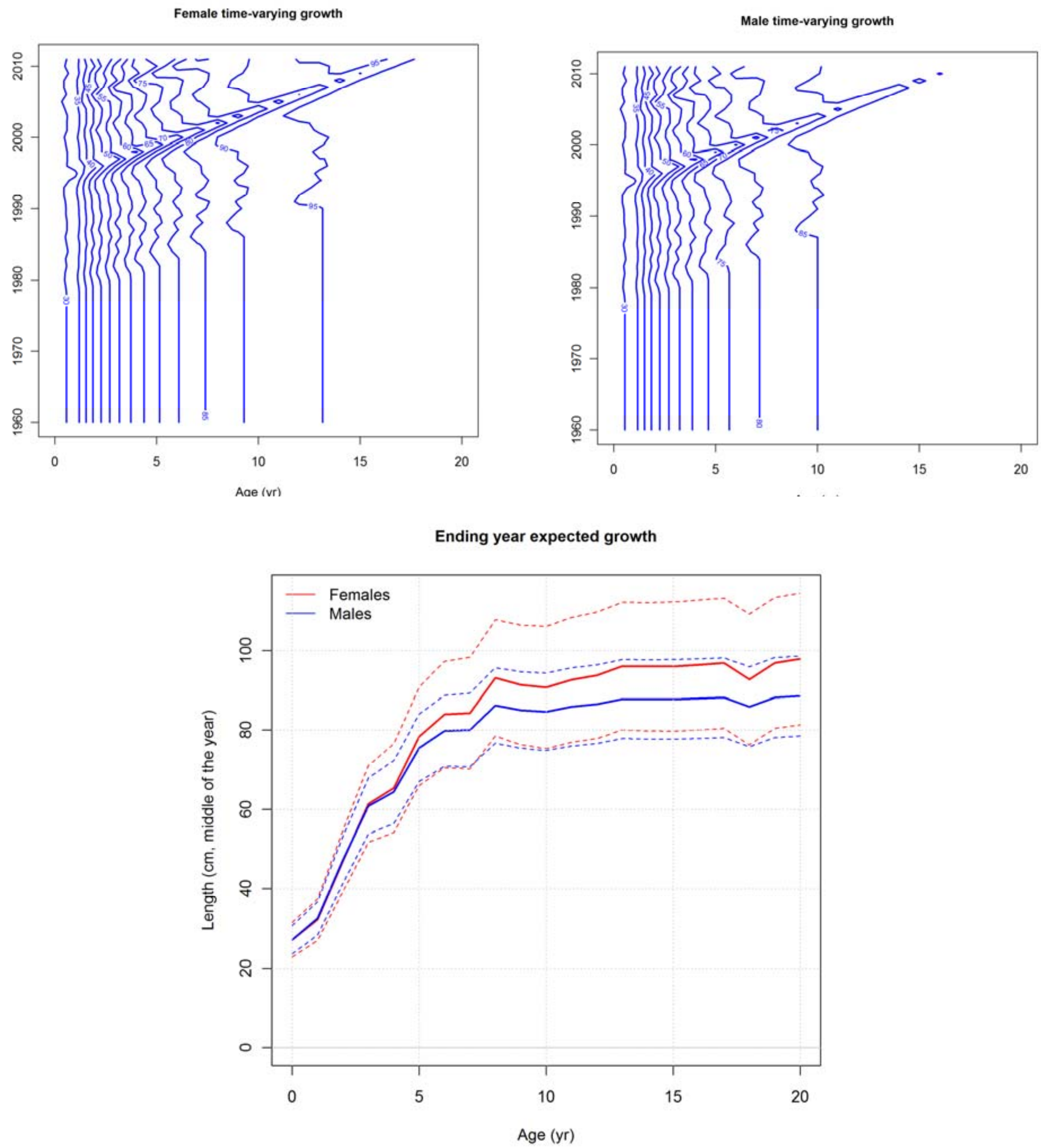


Figure 5.9. The base case predicted length at age relationship.

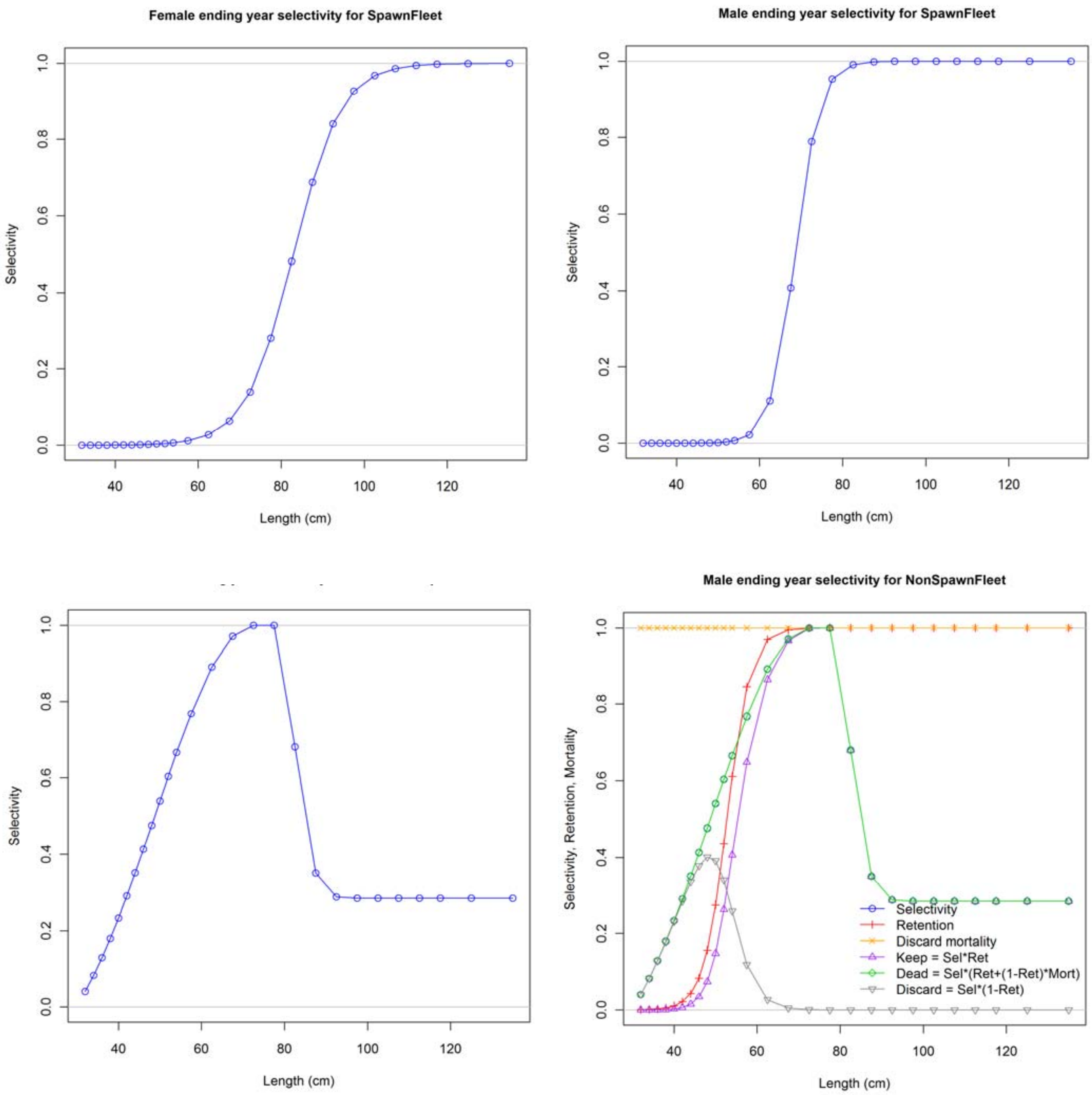


Figure 5.10. The base case model sex-specific selectivity for the spawning fishery (top). Females (left) and males (right). The selectivity for the non-spawning fishery (bottom left) and the retention function (bottom right – red).

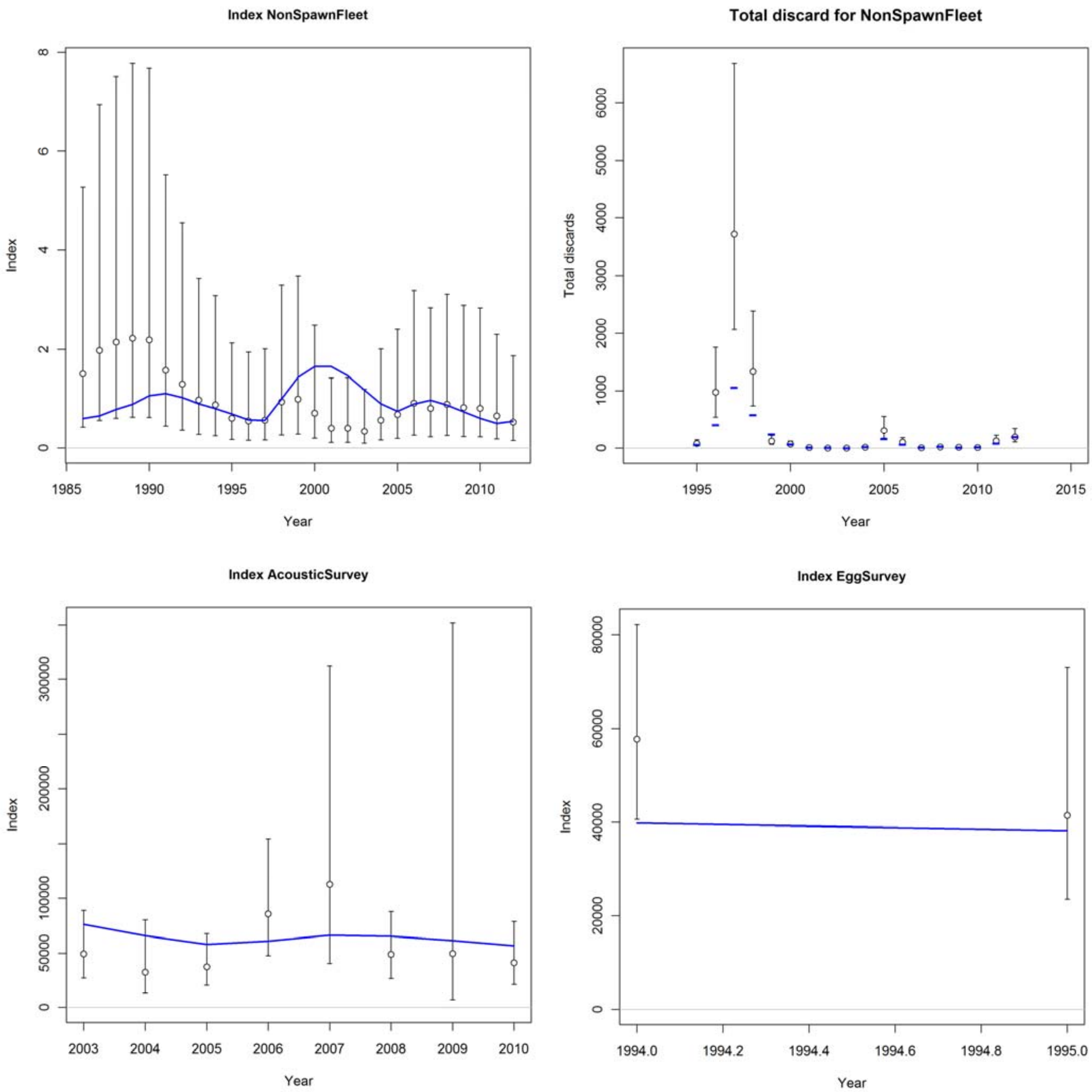


Figure 5.11. The base case model fit to the non-spawning catch rate series (top left), the discard mass (top right), the acoustic survey (bottom left) and the egg survey (bottom right).

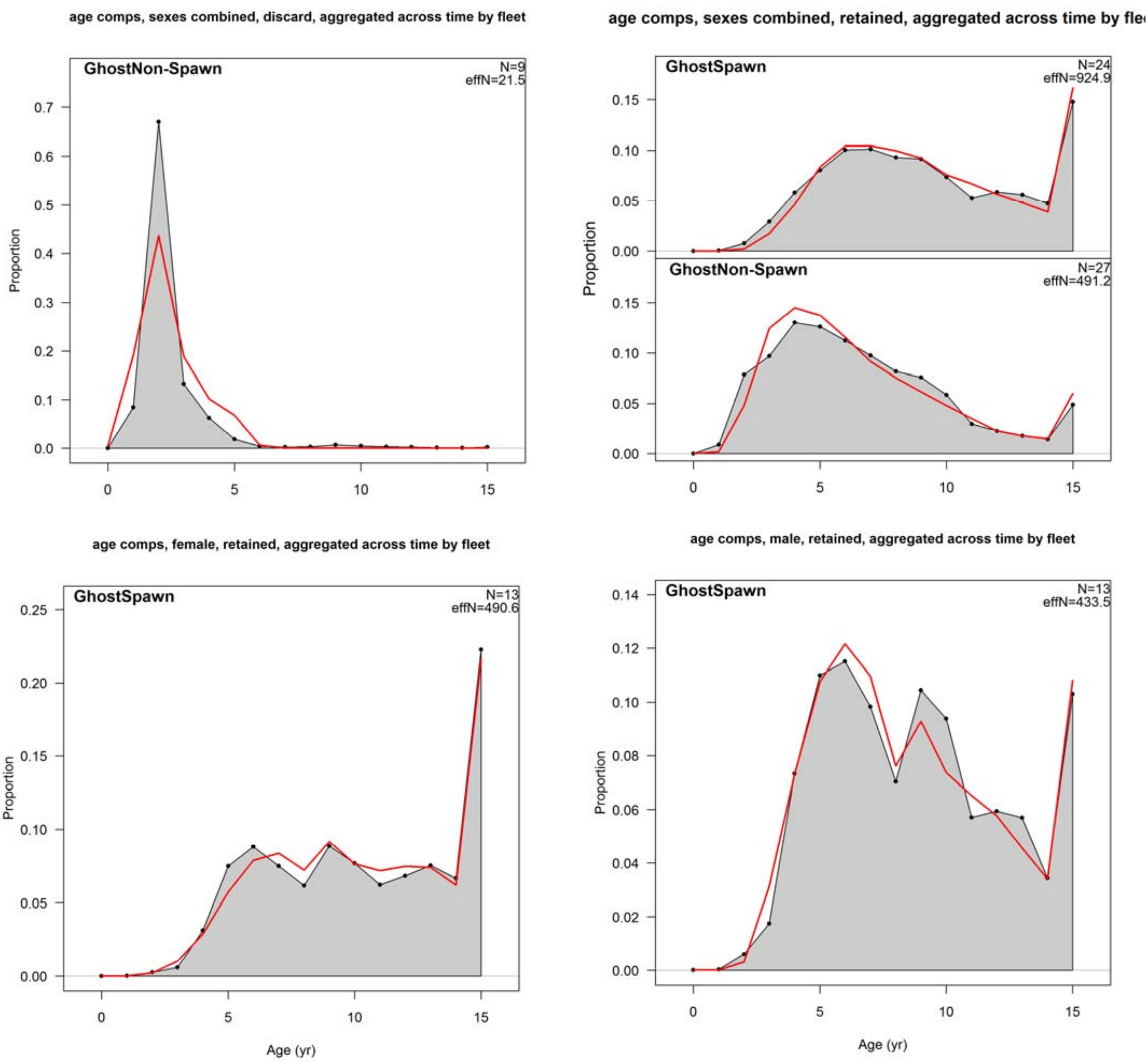


Figure 5.12. The base case model fit to the year-aggregated age-composition data.

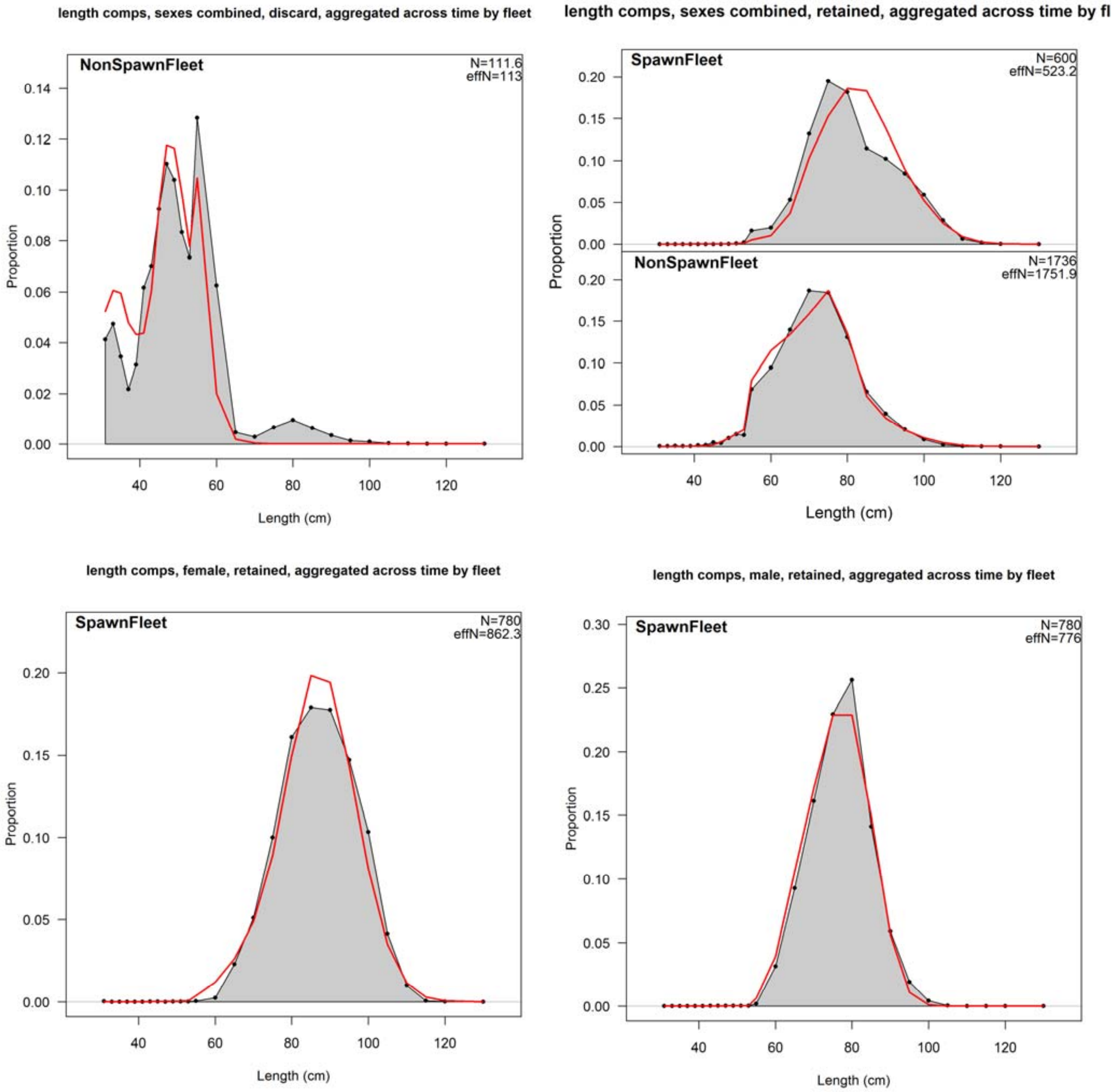


Figure 5.13. The base case model fit to the year-aggregated length composition data.

5.6.2.3 Assessment outcomes

The estimated time series of recruitment under the base-case parameter set shows the typical episodic nature of blue grenadier recruitment, with strong year-classes in 1979, the mid-1980s, 1994, 2003 and now 2010, and with very little recruitment between these years (Figure 5.14). The magnitude of the recruitment of 2010 will remain somewhat poorly estimated until these fish move well into the available stock of the fishery.

The trajectories of spawning biomass and spawning biomass depletion are shown in Figure 5.15. This shows the increases and decreases in spawning biomass as the strong cohorts move into and out of the spawning population. The estimated virgin female biomass is 38,365 tonnes (compared to 39,983 t in the 2011 assessment). In 2011, the estimated depletion level under the base-case scenario for 2010 was 87% and the depletion in 2012, which was used in the harvest control rule, was approximately 67%. In the 2013 assessment, the estimated depletion level under the base-case scenario for 2012 is 77% and the depletion in 2014, which is used in the harvest control rule, is approximately 90%.

The more optimistic outlook from this assessment is largely being driven by the addition of 2 further years of data and the substantial estimated recruitment in 2010. While a promising sign for the fishery, some caution should be exercised with regard to this recruitment estimate and its implication on future stock status, until clear further indications of its existence (and magnitude) are evident in future years' data. If the 2010 recruitment is not estimated, then the (un-tuned) model instead estimates an above average recruitment in 2009 (Appendix 3). The model fit to the age composition data is poorer for fish of age 1 in 2011 and 2 in 2012. The depletion levels also differ substantially, being 69% in 2012 and 59% in 2014.

5.6.2.4 Further development

1) Explore the lack of fit to the catch rate series of the non-spawning fishery using a discard fleet in SS.

2) Further explore the impact of the 2010 recruitment on model outcomes.

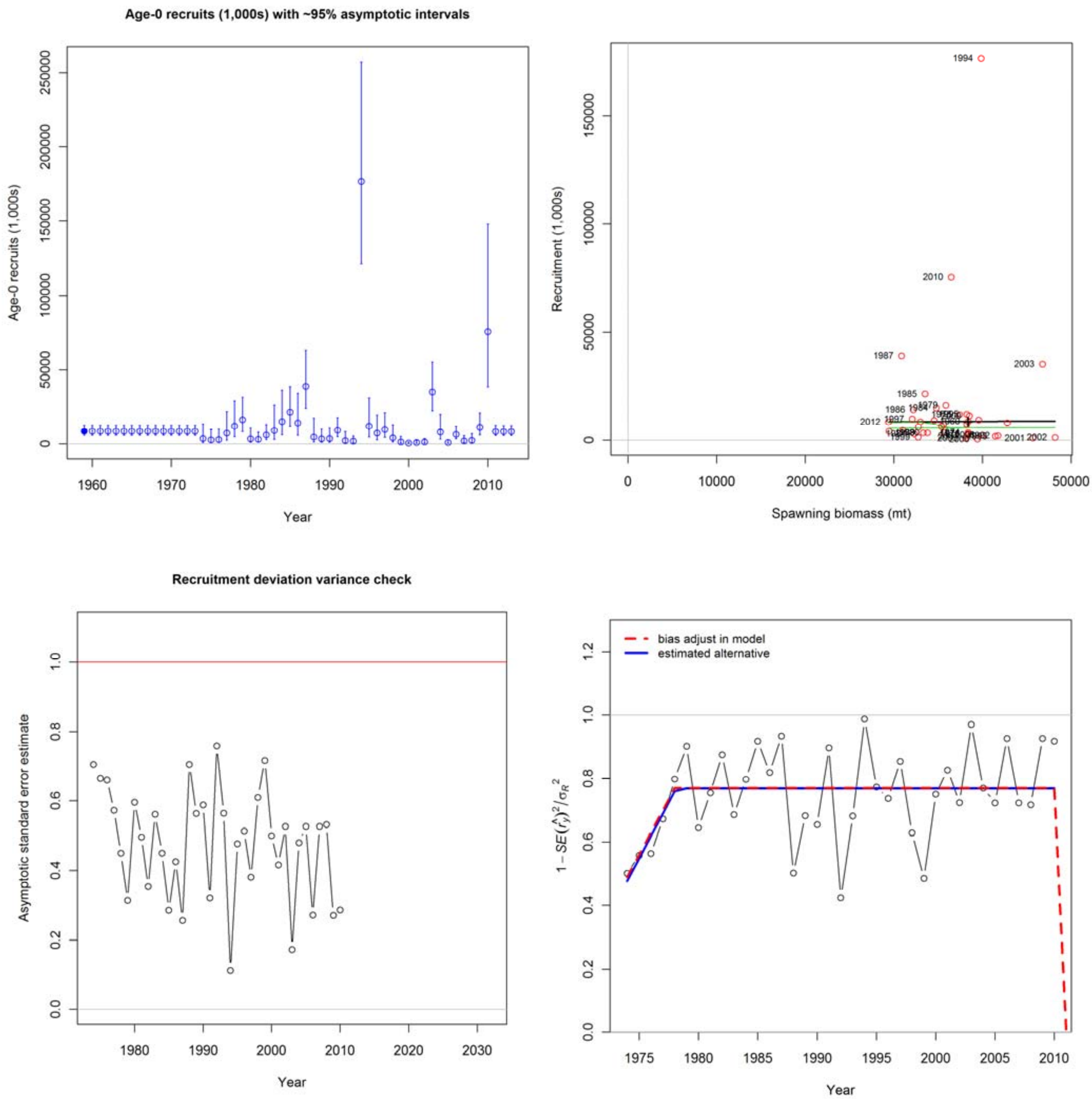


Figure 5.14. Recruitment estimation for the base case analysis. Time-trajectories of estimated recruitment numbers (top left). The stock-recruit curve and estimated recruitments (top right). Recruitment diagnostics recruitment deviation variance check (bottom left) and bias adjustment check (bottom right).

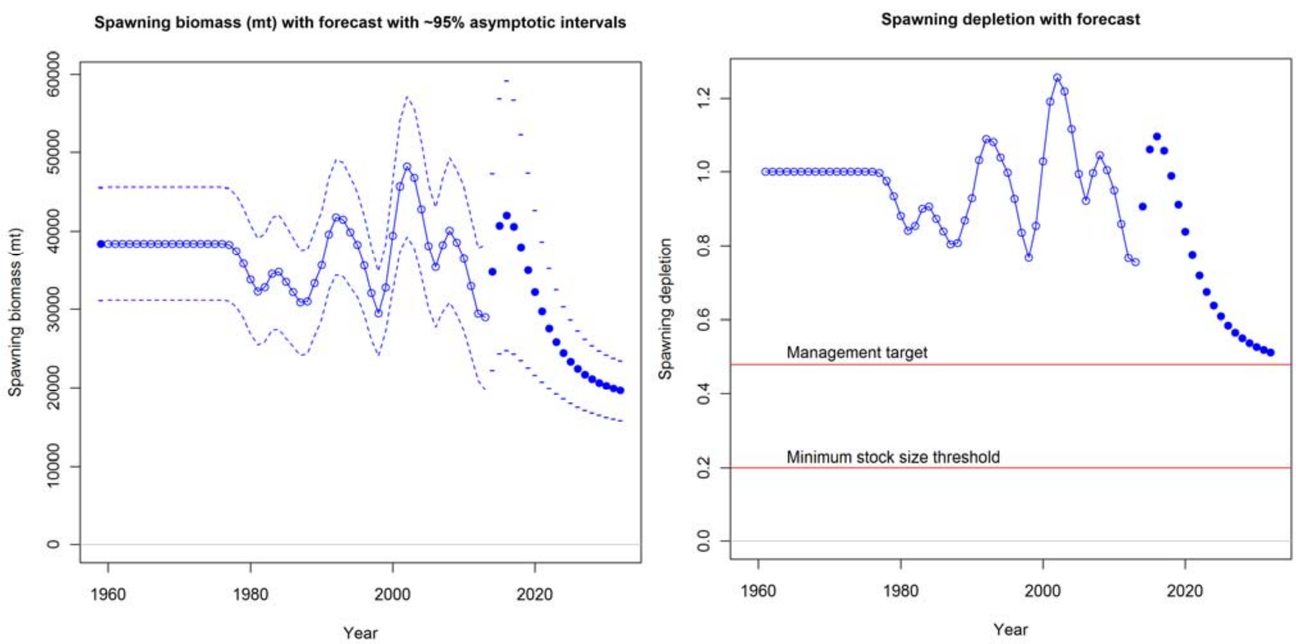


Figure 5.15. The time-series of spawning biomass and spawning biomass depletion for the base case model.

5.7 Acknowledgements

Many thanks are due to the SESSF-WG for their assistance with model discussions and development. Andre Punt and Athol Whitten are thanked for model development advice, Malcolm Haddon for providing catch rate indices, Andre Punt for age-reading error updates, and Mike Fuller 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.

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5.9 Appendix 1: length and age compositions and other diagnostics for the base case model

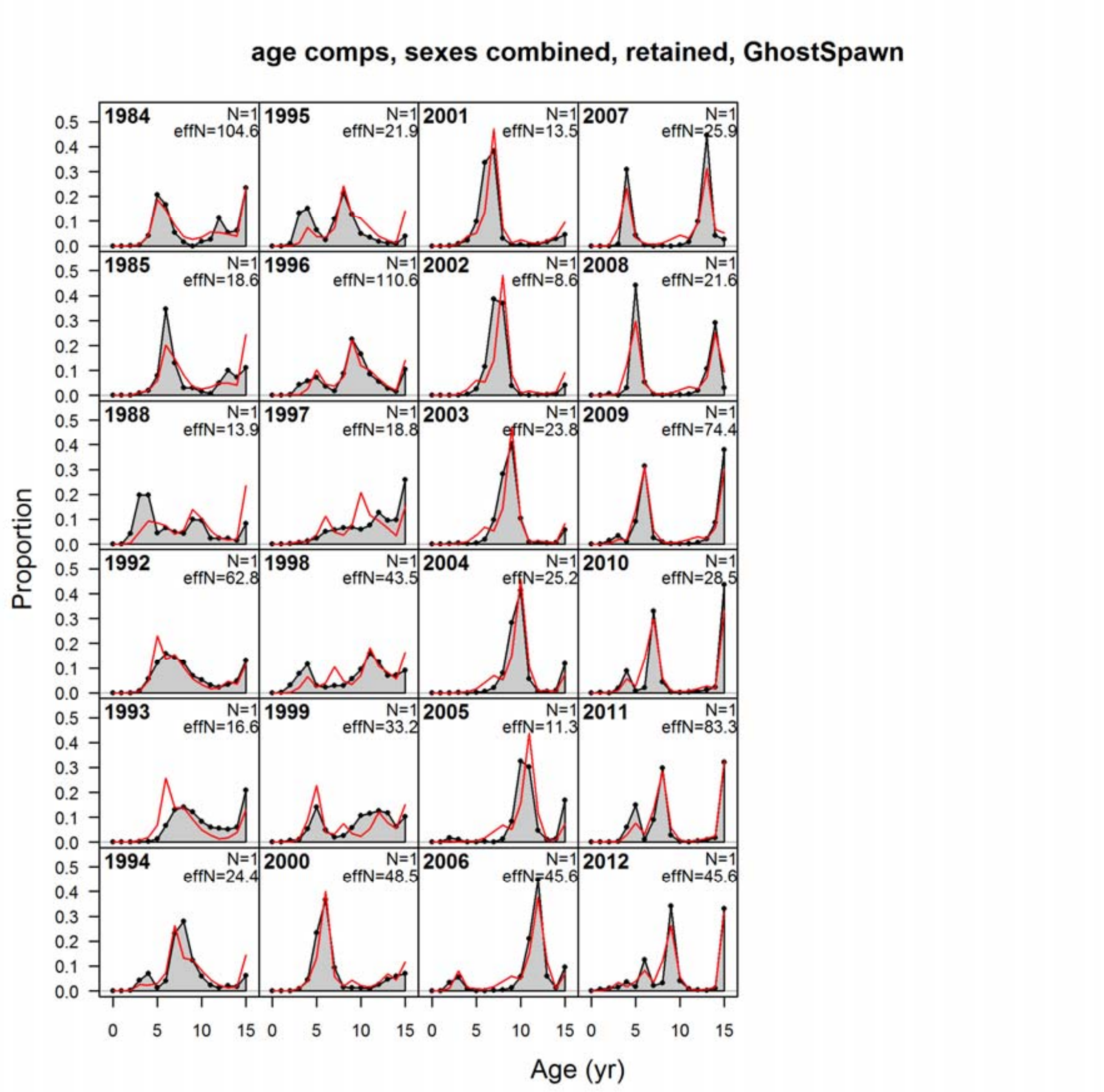


Figure 5.16. The base case model fit to the age-composition data for the spawning fishery. Sexes combined.

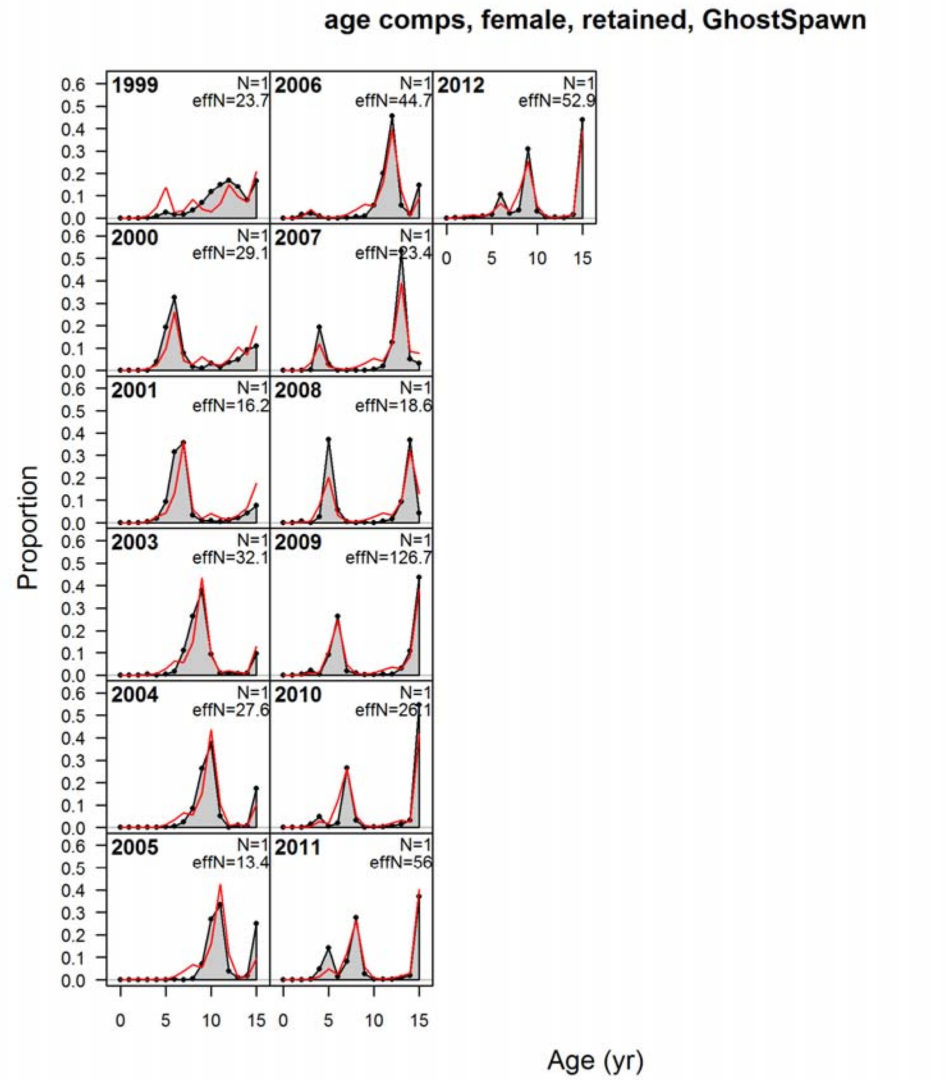


Figure 5.17. The base case model fit to the female age-composition data for the spawning fishery.

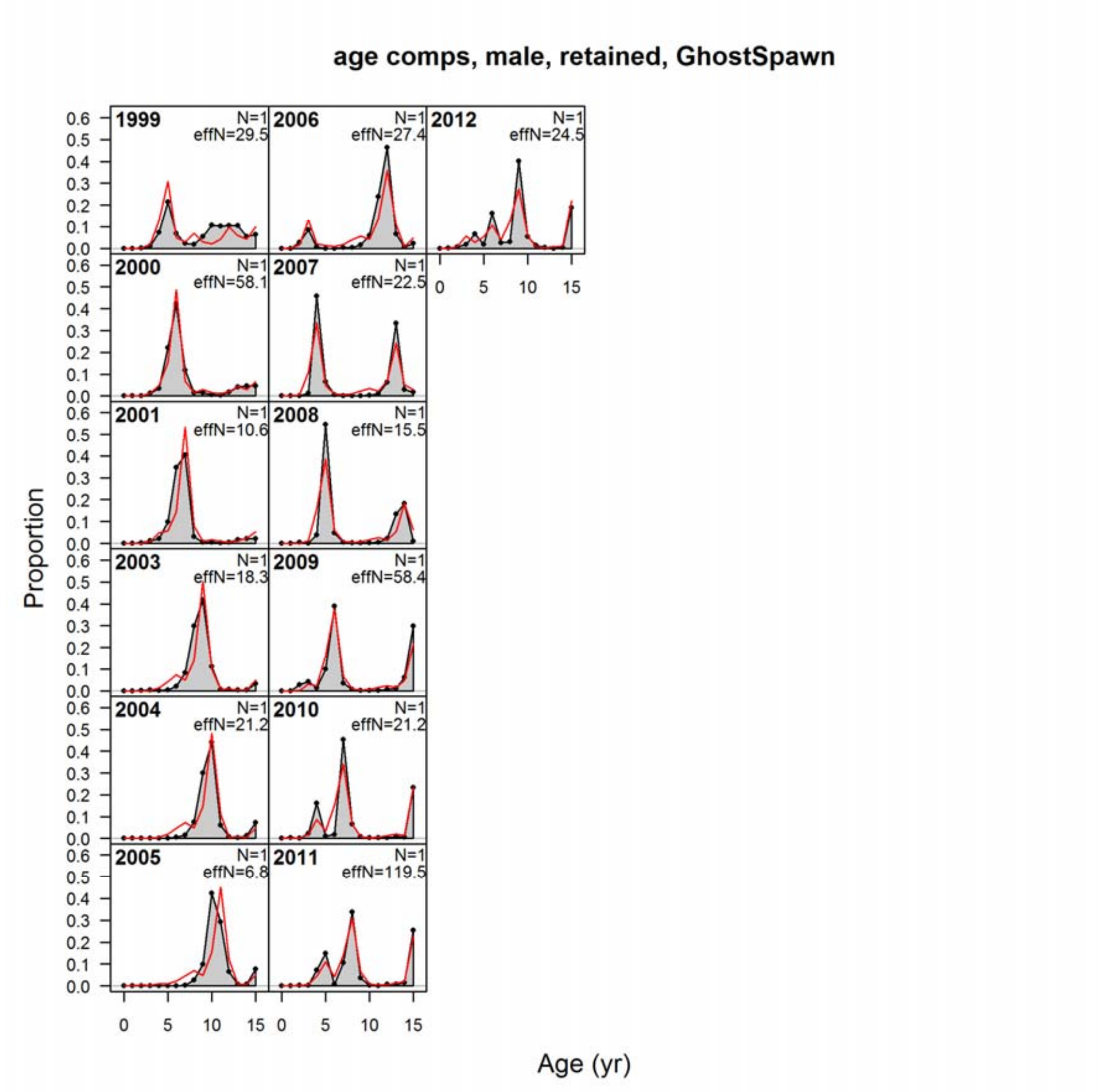


Figure 5.18. The base case model fit to the male age-composition data for the spawning fishery.

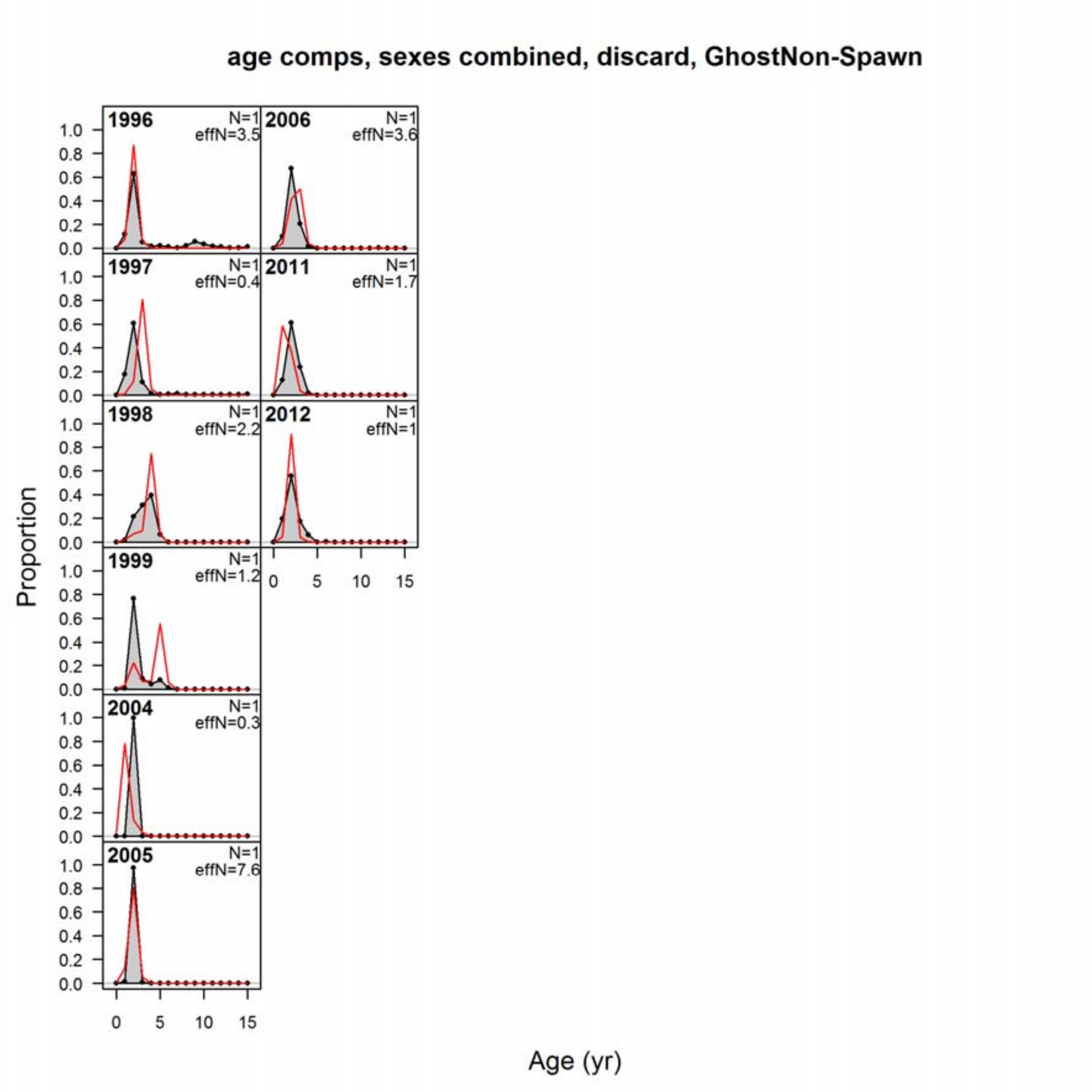


Figure 5.19. The base case model fit to the discard age-composition data for the non-spawning fishery.

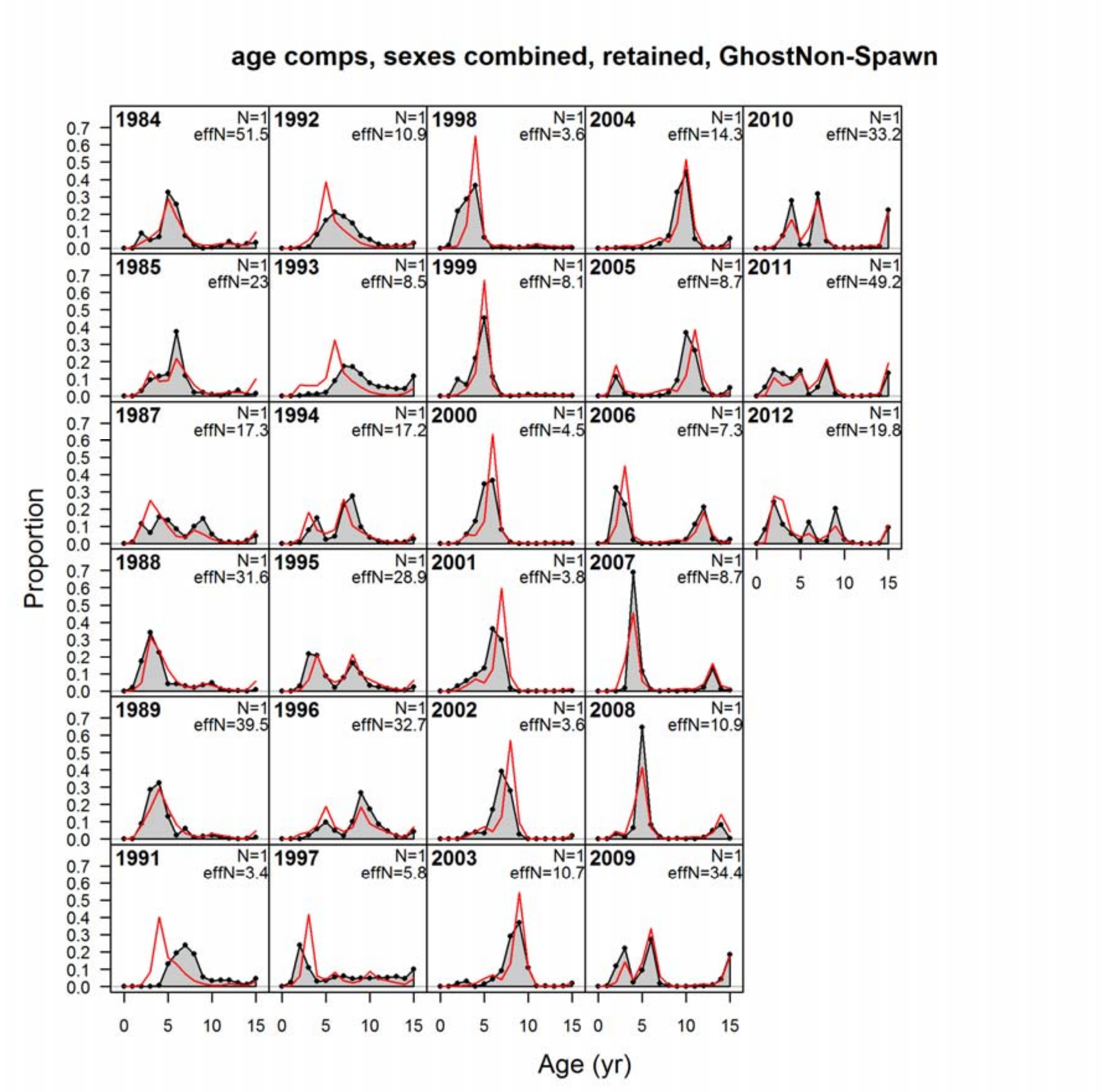


Figure 5.20. The base case model fit to the retained age-composition data for the non-spawning fishery.

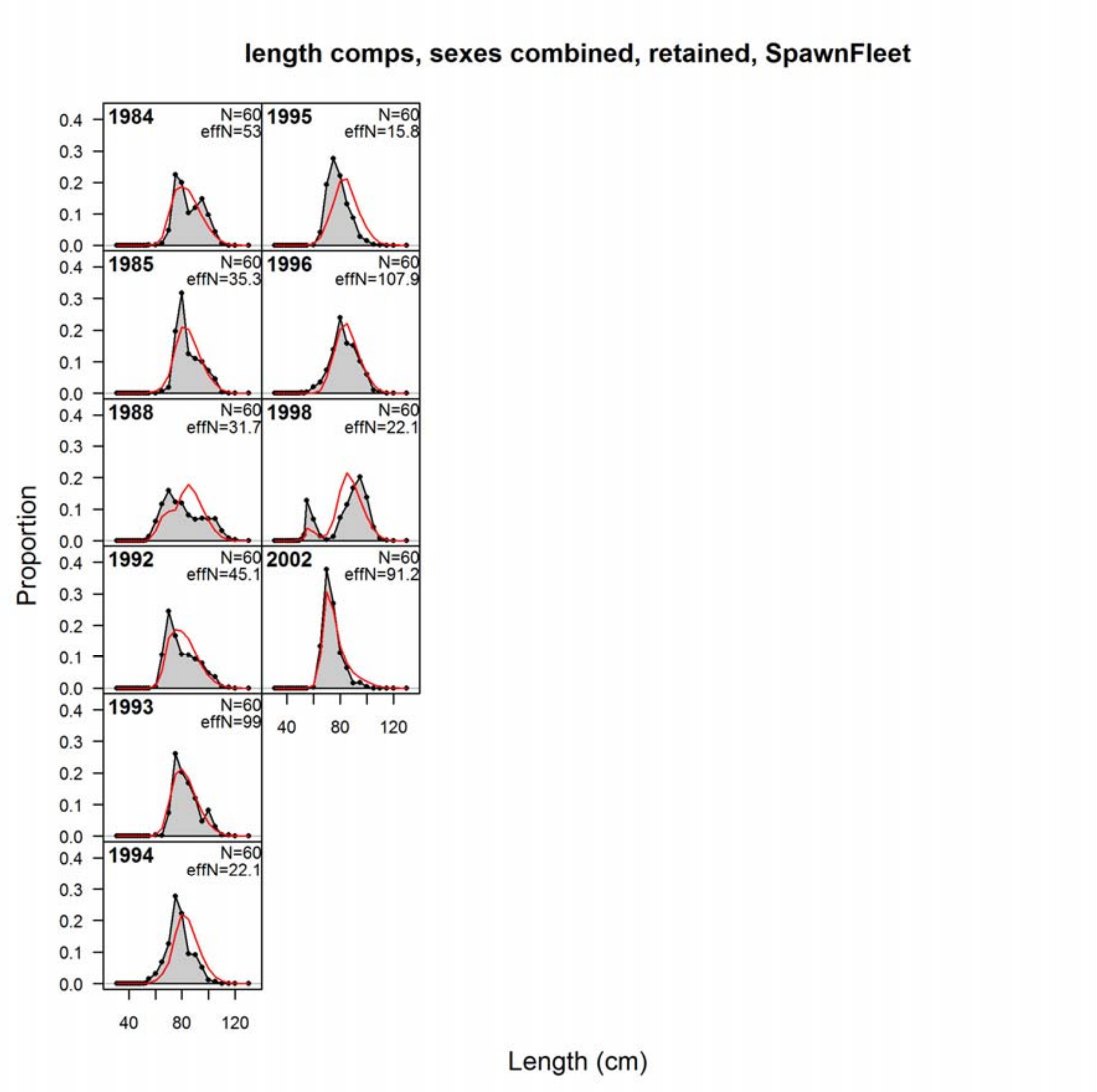


Figure 5.21. The base case model fit to the retained length-composition data for the spawning fishery.

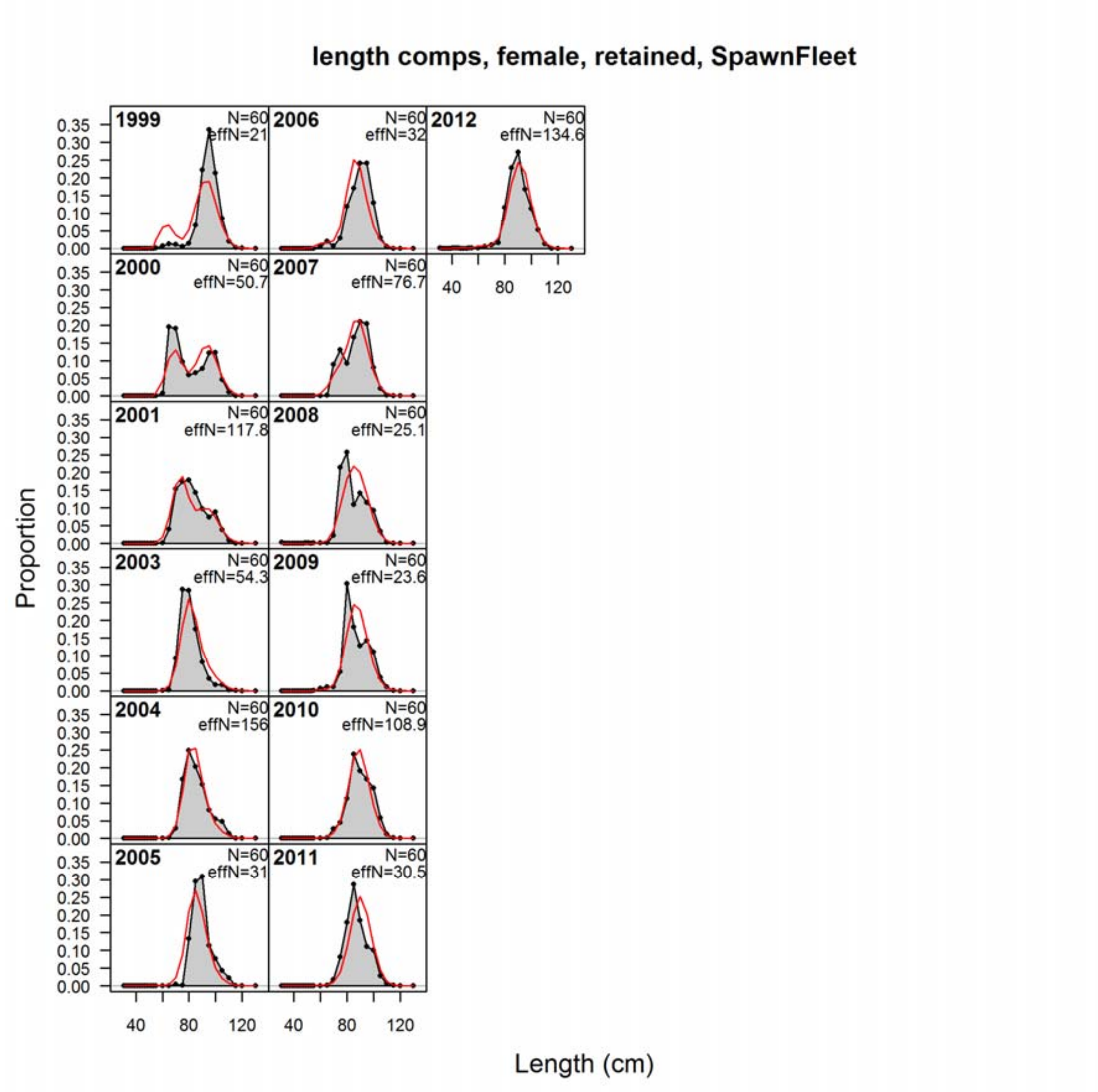


Figure 5.22. The base case model fit to the retained female length-composition data for the spawning fishery.

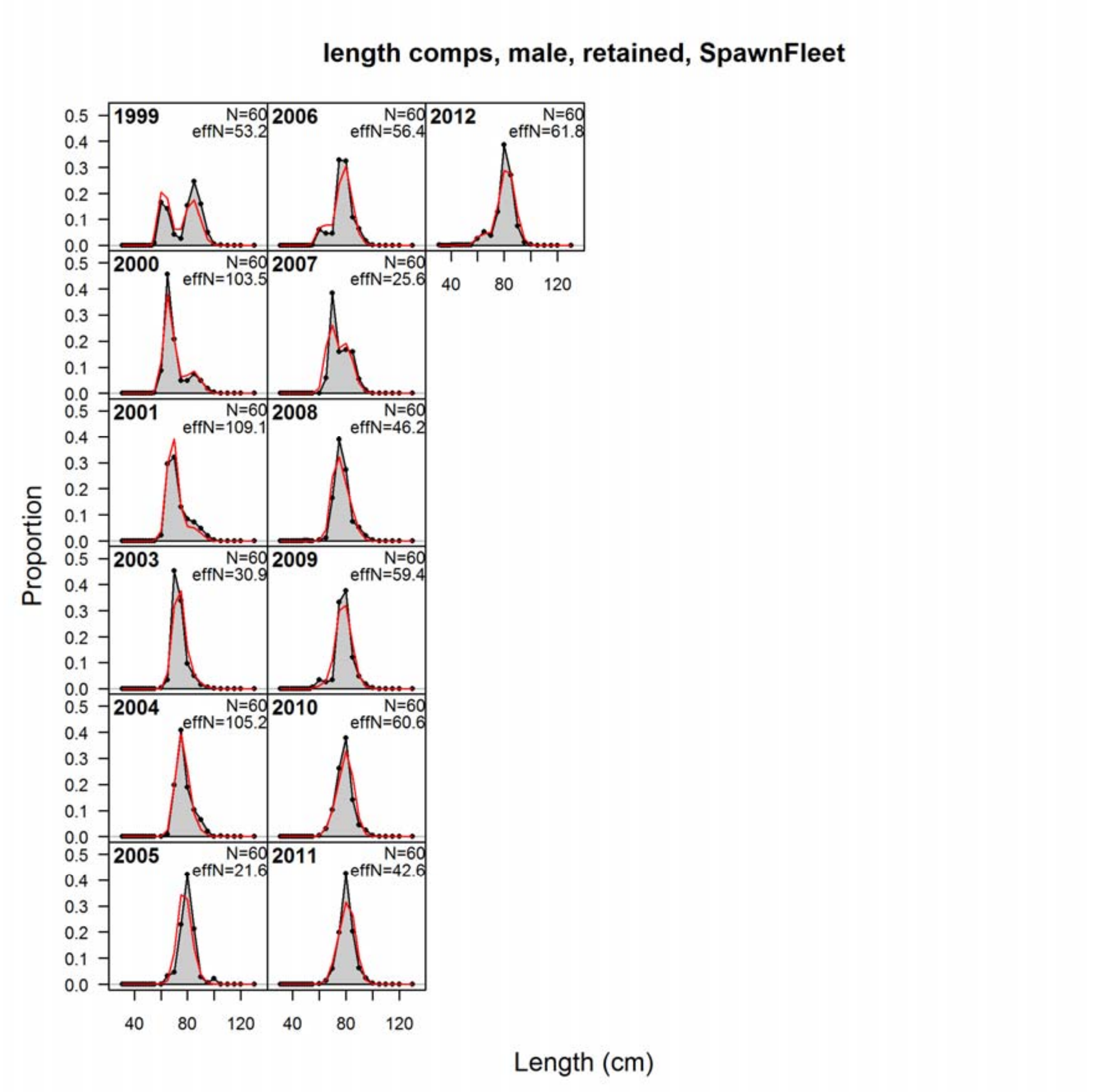


Figure 5.23. The base case model fit to the retained male length-composition data for the spawning fishery.

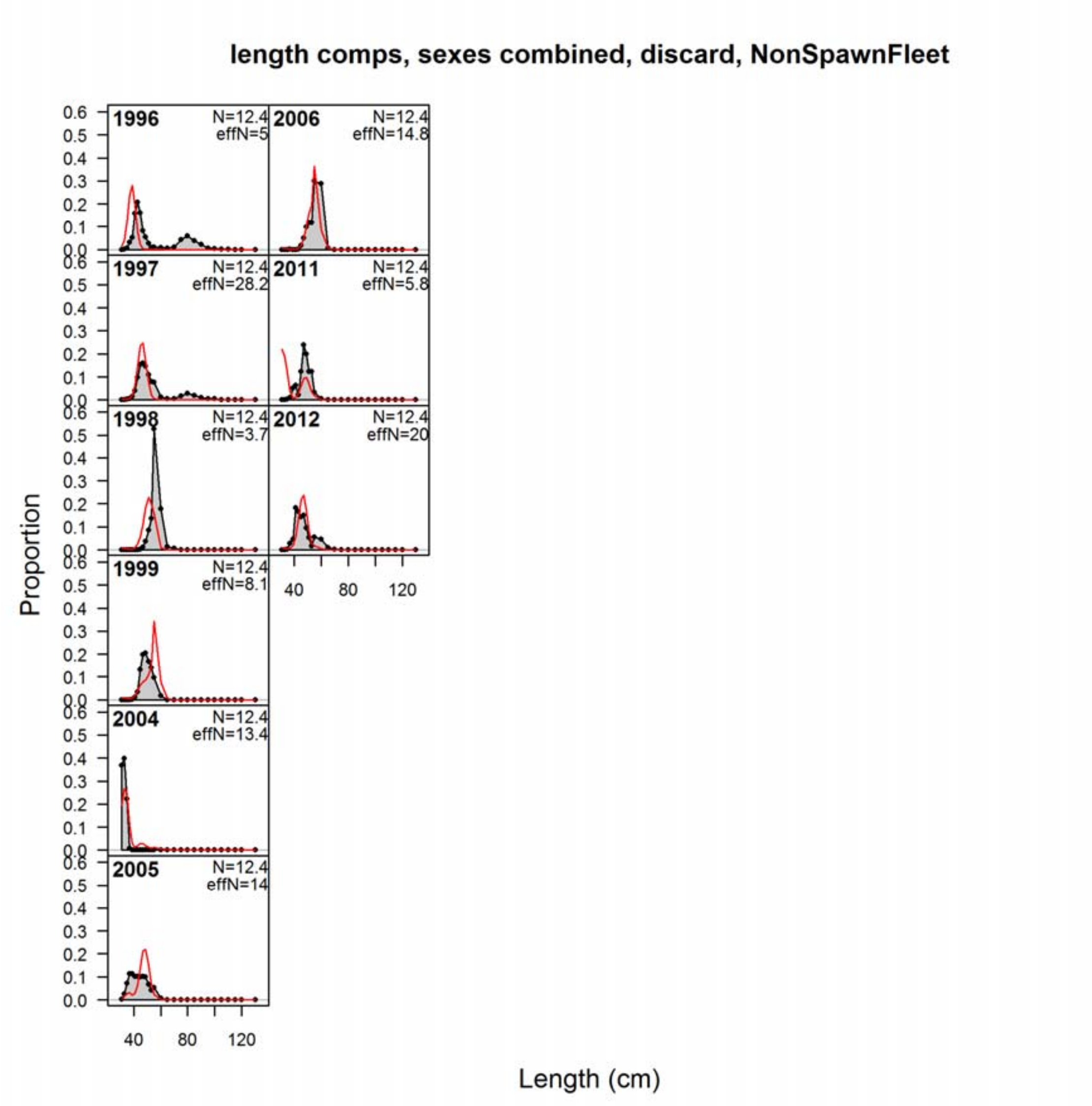


Figure 5.24. The base case model fit to the discard length-composition data for the non-spawning fishery.

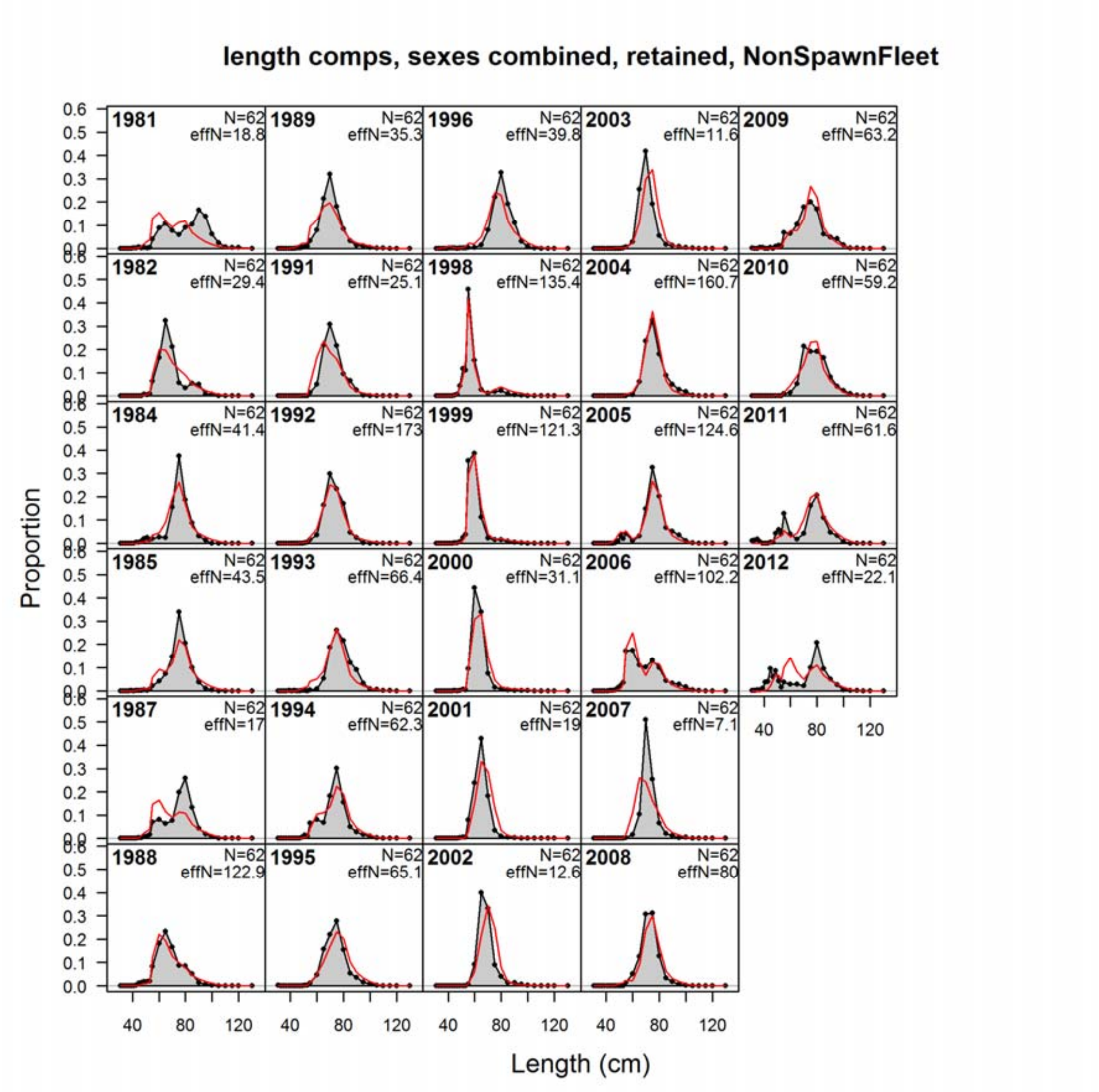


Figure 5.25. The base case model fit to the retained length-composition data for the non-spawning fishery.

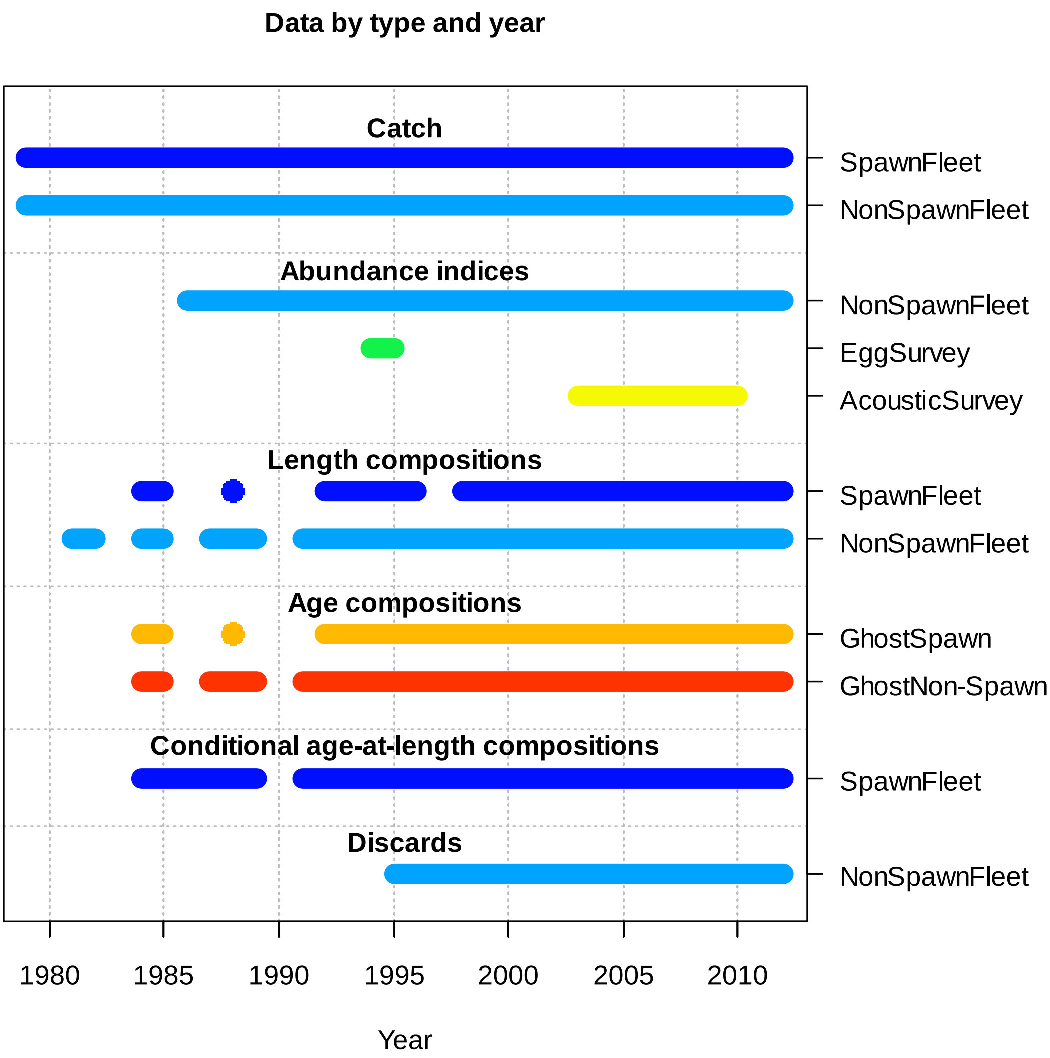


Figure 5.26. The input data available for the base case blue grenadier model.

```
$index_variance_tuning_check
              Fleet           Q  N r.m.s.e. Input+VarAdj+extra  New_VarAdj
1452  NonSpawnFleet 1.89463e-005 27 0.639028               0.64    0.539028
1453      EggSurvey            1  2 0.268734             0.2345   0.0342337
1454 AcousticSurvey     0.840003  8 0.433121            0.43875 -0.00562883

$Length_comp_Eff_N_tuning_check
         FleetName Fleet mean_effN mean(inputN*Adj) HarMean(effN) Mean(effN/inputN) MeaneffN/MeaninputN Var_Adj HarEffN/MeanInputN
1578    SpawnFleet     1   60.0391          60.0000       41.3290           1.00065             1.00065    1.20          0.6888167
1579 NonSpawnFleet     2   50.4003          49.9351       18.9918           1.00987             1.00932    1.24          0.3803297

$Age_comp_Eff_N_tuning_check
          FleetName Fleet mean_effN mean(inputN*Adj) HarMean(effN) Mean(effN/inputN) MeaneffN/MeaninputN Var_Adj HarEffN/MeanInputN
2168     SpawnFleet     1   15.0580          14.9469       1.87307            2.2067             1.00743  0.0525          0.1253149
2172     GhostSpawn     5   36.9799           1.0000      23.59650           36.9799            36.97990  0.0000         23.5965000
2173 GhostNon-Spawn     6   14.2419           1.0000       2.88264           14.2419            14.24190  0.0000          2.8826400

$SBzero
[1] 38364.6
```

Figure 5.27. Diagnostics for tuning the base case model.

5.10 Appendix 2: cpue cv=0.1

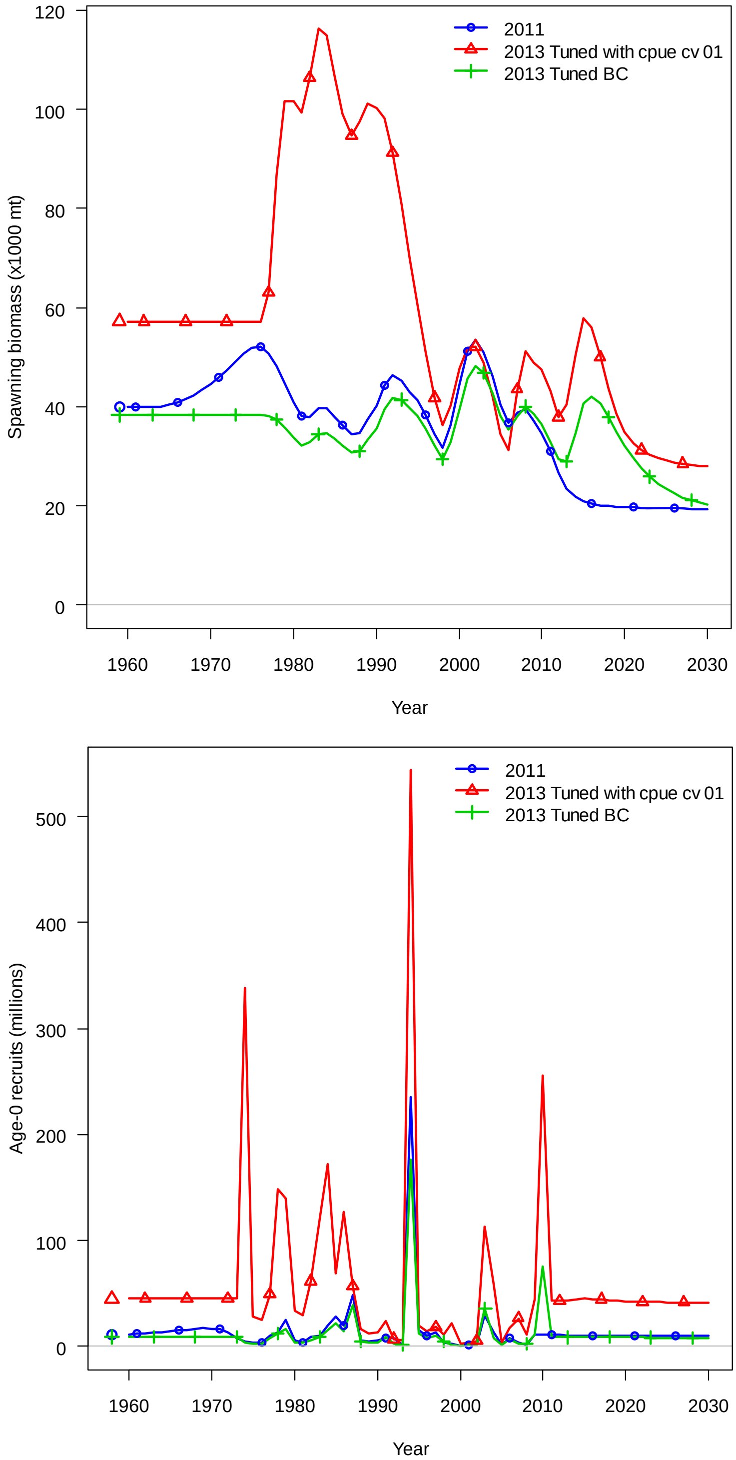


Figure 5.28. The spawning biomass trajectory and estimated recruitment time series compared across the 2011 and 2013 base case models and a model where the cpue cv is fixed at cv=0.1.

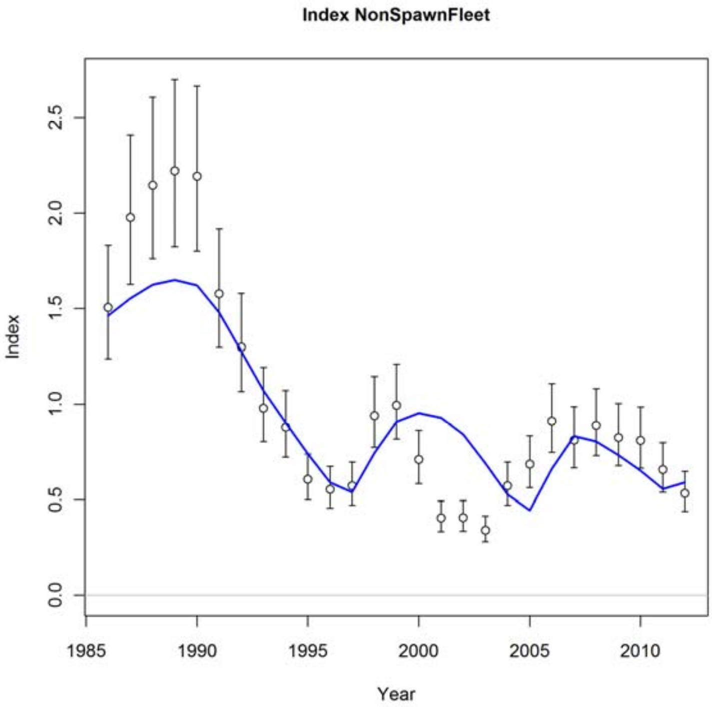
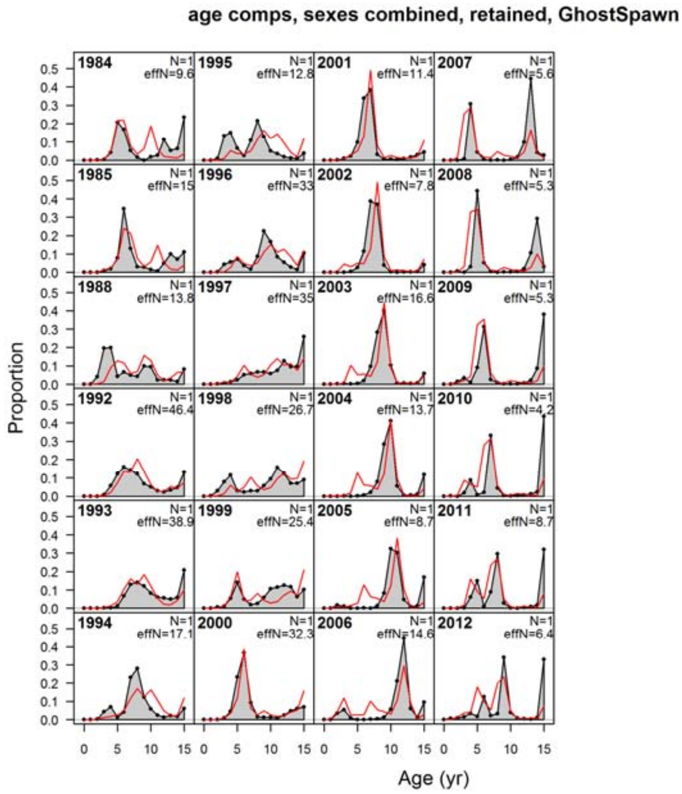
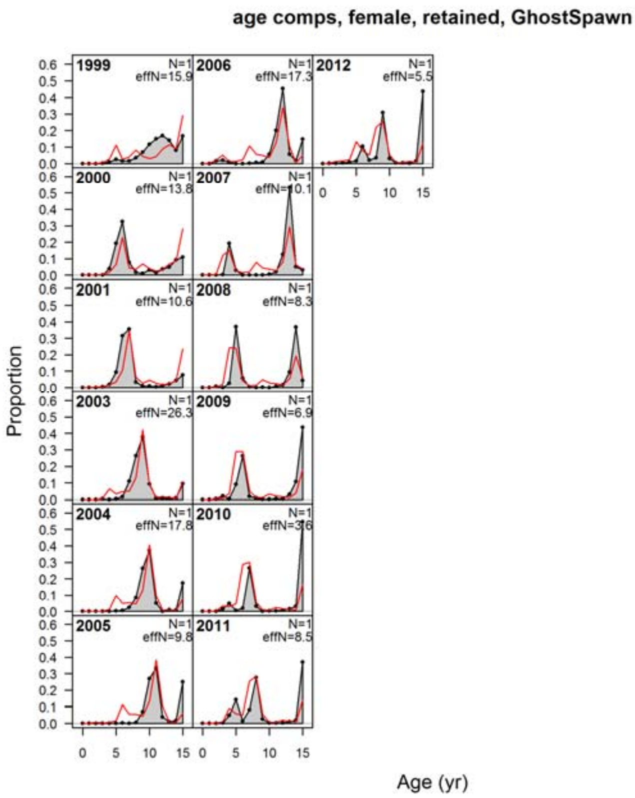
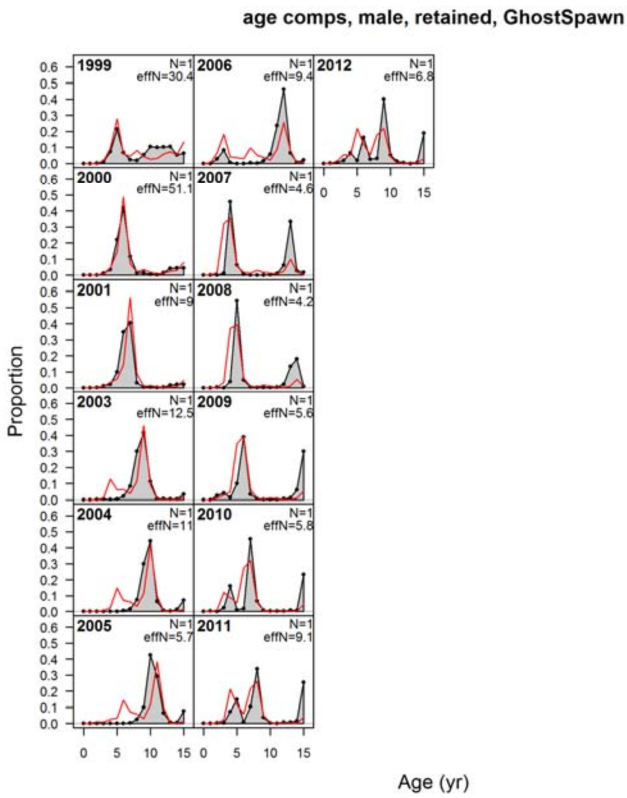
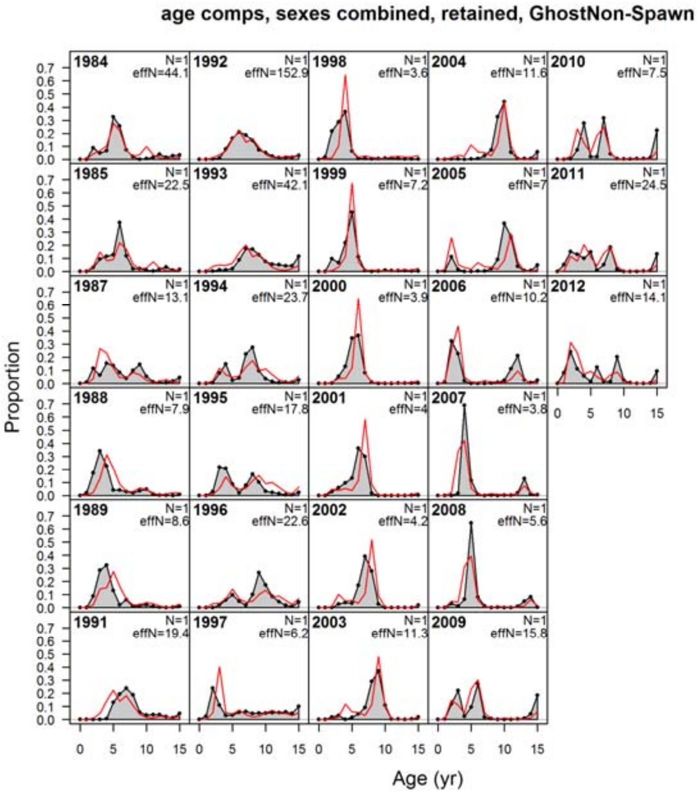


Figure 5.29. The fit to the cpue time series when the cpue cv is fixed at cv=0.1.


age comps, sexes combined, retained, GhostSpawn
Proportion
Age (yr)


age comps, female, retained, GhostSpawn
Proportion
Age (yr)


age comps, male, retained, GhostSpawn
Proportion
Age (yr)



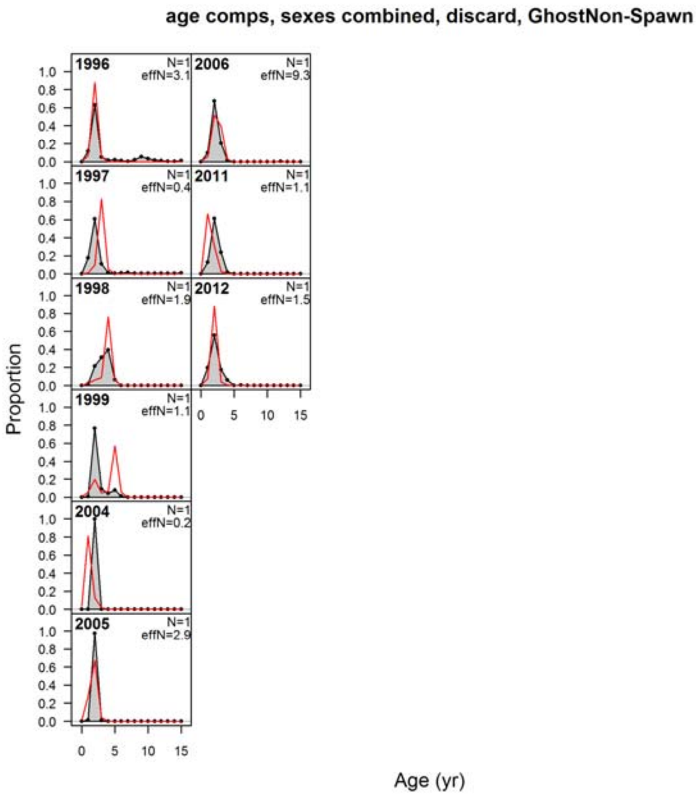


Figure 5.30. The implied fits to the age-composition data for a model with cpue cv=0.1.

5.11 Appendix 3: No estimation of 2010 recruitment

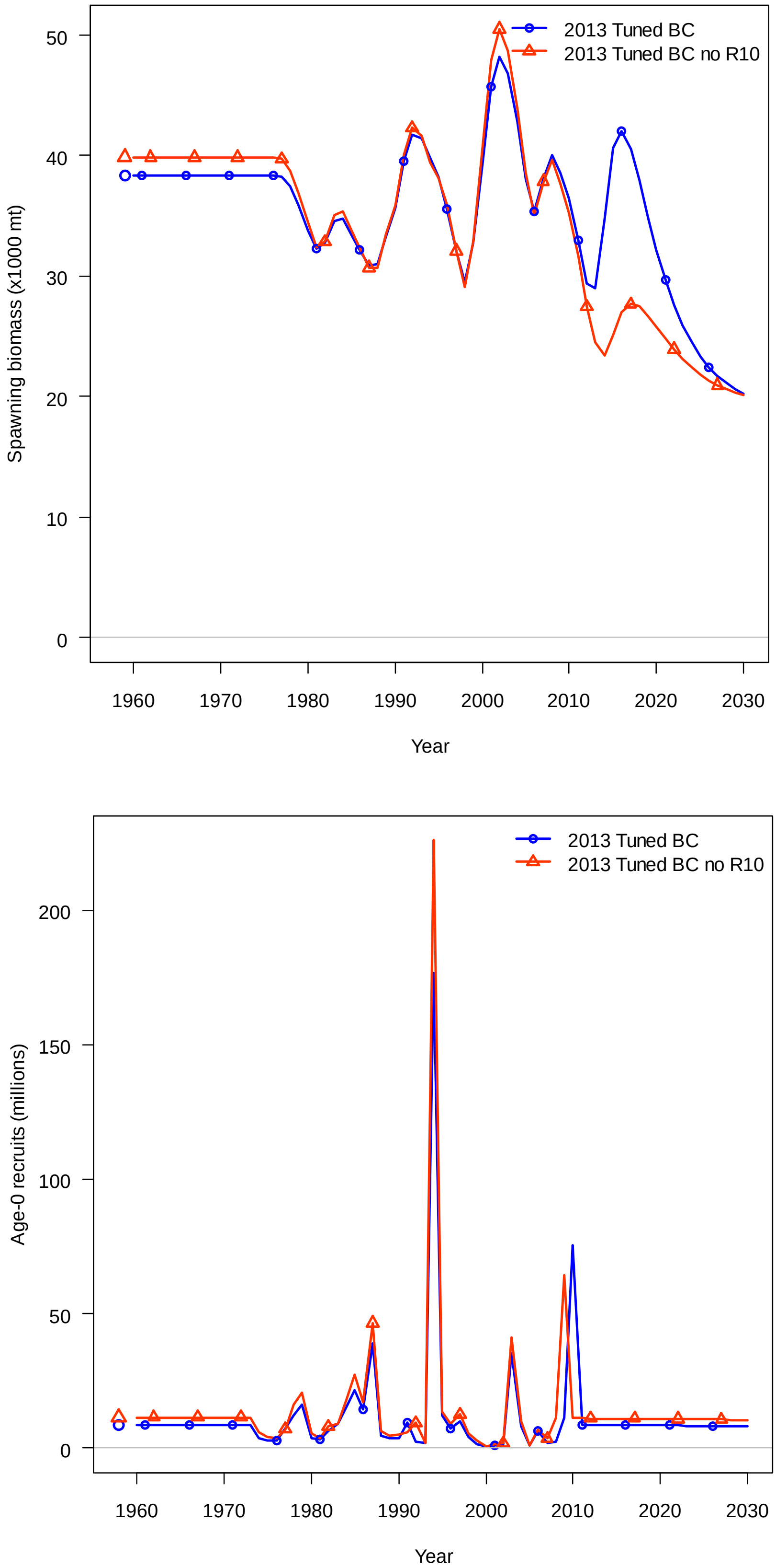
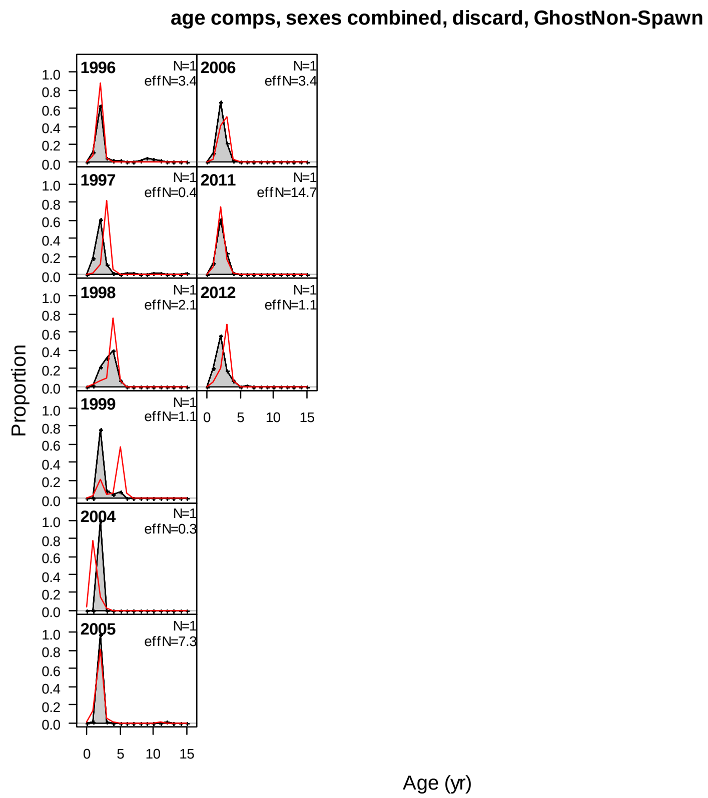


Figure 5.31. The spawning biomass and recruitment time series comparing the tuned 2013 based case model with a model that does not estimate the 2010 recruitment.



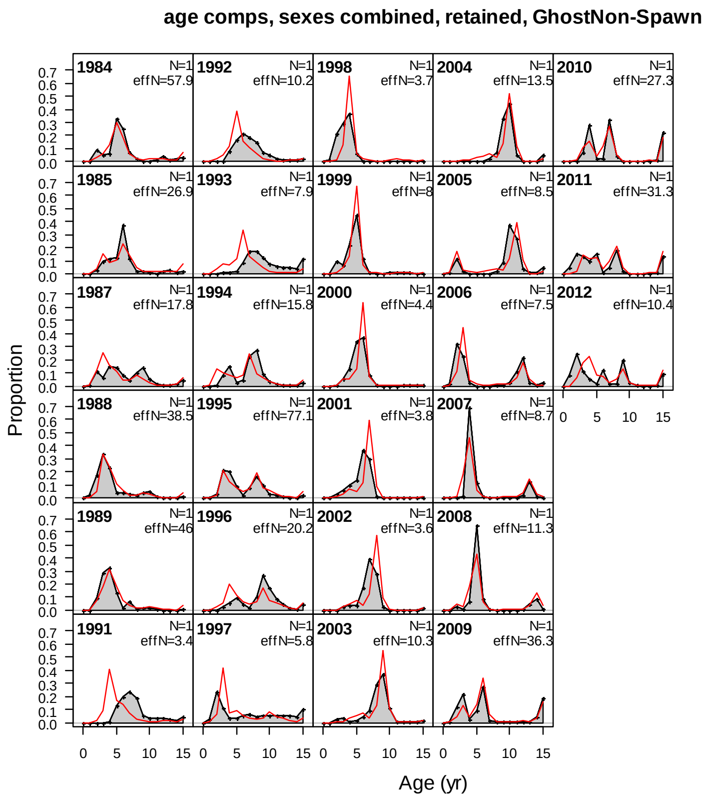


Figure 5.32. The age compositions for the non-spawning fishery showing the degraded fit to the age 1 and 2 fish for the 2011 and 2010 age compositions when the 2010 recruitment is not estimated.

Cite as:
Tuck, G. (2013) Stock assessment of blue grenadier *Macruronus novaezelandiae* based on data up to 2012. pp 61 - 115 *in* Tuck, G.N. (ed.) 2014. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2013.* Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 313p.

6. Stock assessment of blue grenadier *Macruronus novaezelandiae* based on data up to 2012[2]

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6.1 Summary

The 2013 assessment of blue grenadier *Macruronus novaezelandiae* uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS) (NOAA 2011). As with previous methods used to assess blue grenadier, the methods utilised in SS are based on the integrated analysis paradigm (Punt et al., 2001; Tuck, 2011). The assessment has been updated by the inclusion of data up to the 2012 calendar year. Estimates of spawning biomass from acoustic surveys from 2003-2010 (with 2 times turnover) and egg survey estimates of female spawning biomass from 1994-1995 (base-case estimates) are included.

Results conclude that for the base case model the female spawning biomass in 2012 is around 77% of the unexploited spawning stock biomass (*SBo*) and in 2014 will be approximately 94%*SBo*. The marked increase in biomass is due to the estimation of a large cohort in 2010. While a promising sign for the fishery, the existence and magnitude of this recruitment should be treated with some caution until it can be verified by the addition of further data from future years. If the 2010 recruitment is not estimated and instead is taken from the stock-recruitment curve, then the spawning biomass estimates relative to un-exploited biomass and RBCs are lower.

For the base case model, the 2014 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 8138t, with the predicted retained portion of the RBC being 8065t. Note that this is greater than 150% of the current TAC (5208t). The long-term RBC is 4155. A risk assessment was conducted whereby the forecast catches from the base case model (with the 2010 recruitment estimated) were placed into the model with no 2010 recruitment estimation (and vice versa). Results indicated that the SSB trajectory would not move below the target reference point even if the larger forecast catches from the BC model were applied to the model with no 2010 recruitment estimation.

6.2 Introduction

An integrated analysis model, implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Methot, 2011; Methot and Wetzel, 2013), was applied to the blue grenadier stock of the Southern and Eastern Scalefish and Shark Fishery (SESSF), with data updated by the inclusion of data up to the 2012 calendar

[2] Paper presented at the Slope/Deep RAG meeting 6-8 November 2013

year (length and age data; age-error, catch rate series; landings and discard catch weight) and information from acoustic surveys of spawning biomass (series from 2003-2010, pertaining to total spawning biomass) with an assumption of 2-times turnover on the spawning ground (Russell and Smith, 2006). The base-case egg survey estimates of female (only) spawning biomass for 1994 and 1995 are included. The model fits directly to lengths frequencies (by sex where possible) and conditional age-at-length data by fleet. Retained length frequency data are from port and onboard samples combined (where data were available).

The assessment model presented in 2011 (Tuck, Whitten and Punt 2001; Tuck 2011) was the first for blue grenadier to be implemented using SS. The use of SS allows the implementation of a model very similar to that used in previous assessments, but additionally presents an opportunity to improve the estimation of length-based selectivity and temporal variability in growth, avoiding the use of simplified assumptions regarding selectivity and modified age-length keys that were necessary in previous assessments. SS can allow for multiple fishing fleets, and can be fitted simultaneously to several data sources and types of information available for blue grenadier. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, is outlined fully in the SS user manual (Methot, 2005; 2011) and is not reproduced here. This document updates the assessment presented in 2011.

6.3 The fishery

Blue grenadier are found from New South Wales around southern Australia to Western Australia, including the coast of Tasmania. Blue grenadier is a moderately long-lived species with a maximum age of about 25 years. Age at maturity is approximately 4 years for males and 5 years for females (length at 50% maturity for females is 57cm and 64cm respectively) based upon 32,000 blue grenadier sampled between February 1999 and October 2001 (Russell and Smith, 2006). There is also evidence that availability to the gear on the spawning ground differs by sex, with a higher proportion of small males being caught than females (Figure 12.1). This is most likely due to the arrival of males on the spawning ground at a smaller size (and younger age) than females. This was also noted by Russell and Smith (2006) who state that “young males entered the fishery one year earlier than females” and is consistent with hoki from New Zealand (Annala et al., 2003). Large fish arrive earlier in the spawning season than small fish. Spawning occurs predominantly off western Tasmania in winter (the peak spawning period based upon mean GSIs calculated by month was estimated to be between June and August according to Russell and Smith (2006). There is some evidence that a high proportion of fish remain spawning in September. Variations in spawning period noted by Gunn et al (1989) may occur due to inter-annual differences in the development of coastal current patterns around Tasmania. Adults disperse following the spawning season and while fish are found throughout the south east region during the non-spawning season, their range is not well defined. Spawning fish have recently been caught off the east coast of Australia and larvae from a likely eastern spawning area have been described by Bruce et al. (2001). Further analyses (eg sampling, acoustics) of these fish will need to be conducted before they can be included in the current stock assessment.

Blue grenadier are caught by demersal trawling. The global agreed TAC in 2012/13 was 5,208 tonnes. The annual TACs are show in Table 6.1. There are two defined sub-fisheries: the spawning (Zone 40, months June, July and August) and non-spawning fisheries (all other months and zones).

6.4 Data

The assessment has been updated since the previous assessment (Tuck, 2011) by the inclusion of length and age-at-length data from the spawning and non-spawning fisheries; updated cpue series (Haddon, 2013), the total mass landed and discarded, and update age-reading error. Acoustic estimates of spawning biomass (2003-2010) and estimates of the female spawning biomass in 1994 and 1995 from egg surveys (Bulman et al., 1999) are included. Data were formulated by calendar year (i.e. 1 Jan to 31 Dec) as in previous models.

6.4.1 *Catch*

The landings from the SEF1 logbook data were used to apportion catches to the spawning and non-spawning fisheries. The SEF1 landings have been adjusted upwards to take account of differences between logbook and landings data (multiple of 1.4 for the non-spawning fishery, based on 40% conversion from headed and gutted to whole, since 1986 and up to and including 1997 (reliable CDR data were available from 1998); 1.2 for the spawning fishery from 1986 up to and including 1996 (when factory vessels entered the spawning fishery)) (D. Smith, pers. comm.). As stated by Thomson and He (2001), the factor is lower for the spawning fleet than the non-spawning fleet because some fish in the spawning fishery, landed headed and gutted, were recorded as being landed whole. These factors were chosen by the Blue Grenadier Assessment Group (BGAG) (Chesson and Staples (1995), as cited by Punt (1998)). The adjusted logbook catches were then scaled up to the SEF2 data. As historical SEF2 data were only available from 1992, the average scaling factor from 1992 to 1996 was used to scale the data for years between 1986 and 1991 (Figure 6.2). Note that in years 2008 to 2012 logbook data were greater than landings from the CDR. In these cases the tonnage from the CDR was used as the total catch (AFMA, pers. comm. 2011). Table 6.1 lists the annual catches used in the assessment and the annual TAC. The annual logbook catches by sub-fishery and the adjustments made to determine the catches used in the assessment are shown in Table 6.2.

Discard rates 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). The discard values from 1995 to 2002 are based on estimates calculated from ISMP data by MAFRI and reported in He et al (1999) and Tuck, Smith and Talman (2004). As agreed by Slope RAG (2011), since 2003 discard rates are taken from those estimated by the methods described in Thomson and Klaer (2011). The mass of the discard is calculated from the annual discard rate and the retained catch from the non-spawning fishery. The MAFRI estimates of discards were made accounting for differences in sampling and discard rates according to the ISMP zones. The more recent estimates are simple ratios of total discards to (retained + discard) catch (N. Klaer, pers comm.). Information in support of the historical values was not able to be obtained and further exploration of the methods and data used to estimate these values should be encouraged. The discard data are provided in Table 6.1.

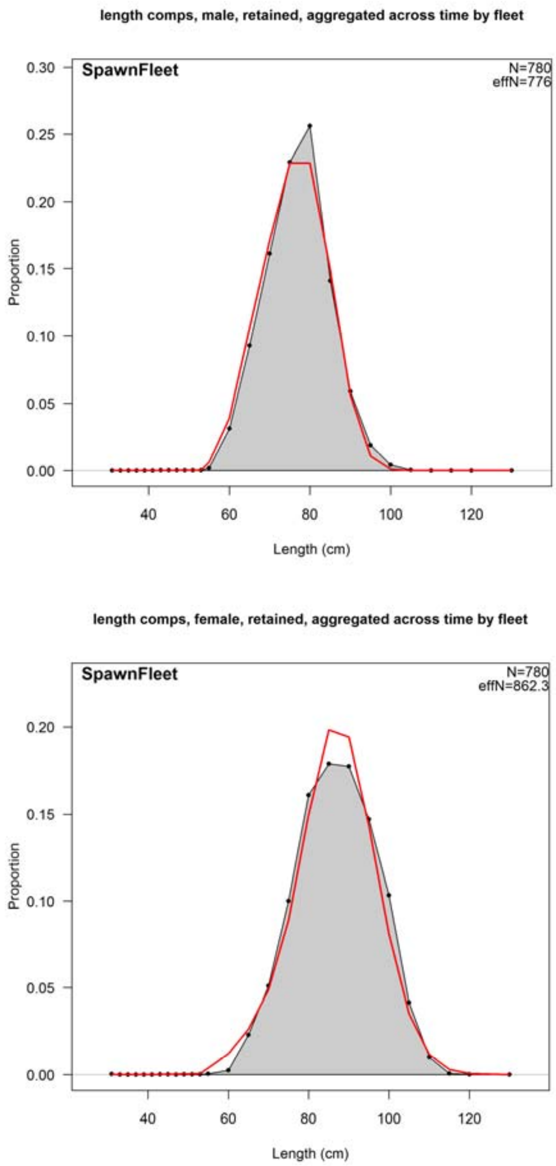


Figure 6.1. The aggregated length composition of females (top) and males (bottom) on the spawning ground. The red line indicates a model fit with sex-specific selectivity.

Table 6.1. Landed and discarded catches for the winter spawning and non-spawning sub-fisheries by calendar year. These estimates have been adjusted scaled up to the landings data (see text and Table 6.2). Standardised CPUE (Haddon, 2013) and number of records for the non-spawning sub-fisheries by calendar year are shown, along with the TAC. [1] a voluntary industry reduction to 4,200 t was implemented in 2005. [2] This was a 16 month TAC. [3] The TACs cover the fishing year 1 May to 30 April. In the table below, 2008 refers to 2008/09. [4] This is an estimate of retained catch based on the 2012/2013 TAC and relative split of catch between spawning and non-spawning fisheries of 2012.

Year	Landings		Discards	TAC		
	Spawning	Non-spawning	Non-spawning		Records	CPUE
1979	245	245				
1980	410	410				
1981	225	225				
1982	390	390				
1983	450	450				
1984	675	675				
1985	600	600				
1986	317	1807			3189	1.505
1987	1006	2183			3569	1.978
1988	410	2228			3961	2.143
1989	46	2745			4309	2.219
1990	733	2508			3577	2.190
1991	819	3764			4308	1.576
1992	710	2549			3228	1.298
1993	994	2368			4203	0.980
1994	1211	1940		10000	4491	0.881
1995	1205	1570	80	10000	5076	0.607
1996	1496	1544	975	10000	5370	0.554
1997	2947	1569	3716	10000	6194	0.573
1998	3746	1986	1329	10000	6599	0.941
1999	6775	2549	123	10000	8045	0.995
2000	6608	2047	69	10000	7679	0.710
2001	8004	1120	10	10000	7279	0.406
2002	7843	1318	2	10000	6344	0.407
2003	7745	726	3	9000	5675	0.341
2004	5064	1327	15	7000	6393	0.573
2005	3024	1259	310	5000[1]	5346	0.686
2006	2193	1420	104	3730	4362	0.911
2007	1891	1280	5	4113[2]	3659	0.811
2008	2692	1239	19	4368[3]	3407	0.890
2009	2295	964	15	4700[3]	3443	0.826
2010	3119	1066	10	4700[3]	3308	0.810
2011	3342	859	126	4700[3]	3968	0.657
2012	3447	557	192	5208[3]	3210	0.533
2013	4484[4]	724[4]				

Table 6.2. Logbook and CDR landings for the spawning and non-spawning sub-fisheries by calendar year and adjustments made to account for logbooks being less than landings and incorrect reporting process code. Shaded CDR are historical landings values.

Year	Logbook		CDR	H&G Multiplier		Adjusted Logbook			CDR / logbook	Catch for assessment	
	Spawning	Non-spawning		Spawning	Non-spawning	Spawning	Non-spawning	Total		Spawning	Non-spawning
1979	245	245		1	1	245	245	490	1	245	245
1980	410	410		1	1	410	410	820	1	410	410
1981	225	225		1	1	225	225	450	1	225	225
1982	390	390		1	1	390	390	780	1	390	390
1983	450	450		1	1	450	450	900	1	450	450
1984	675	675		1	1	675	675	1350	1	675	675
1985	600	600		1	1	600	600	1200	1	600	600
1986	246	1204		1.2	1.4	295	1685	1981	1.04	317	1807
1987	782	1455		1.2	1.4	939	2036	2975	1.04	1006	2183
1988	319	1485		1.2	1.4	383	2079	2462	1.04	410	2228
1989	36	1829		1.2	1.4	43	2561	2604	1.04	46	2745
1990	570	1671		1.2	1.4	684	2340	3023	1.04	733	2508
1991	637	2508		1.2	1.4	764	3511	4275	1.04	819	3764
1992	509	1565	3259	1.2	1.4	730	2208	2938	1.11	710	2549
1993	812	1659	3362	1.2	1.4	1056	2349	3405	0.99	994	2368
1994	974	1338	3151	1.2	1.4	1185	1914	3100	1.02	1211	1940
1995	911	1017	2775	1.2	1.4	1114	1460	2574	1.08	1205	1570
1996	1200	1061	3040	1.2	1.4	1442	1535	2978	1.02	1496	1544
1997	2623	997	4516	1	1.4	2623	1442	4065	1.11	2947	1569
1998	2739	1452	5733	1	1	3463	1491	4954	1.16	3746	1986
1999	5460	2054	9324	1	1	5649	2115	7763	1.20	6775	2549
2000	5665	1755	8655	1	1	5670	1820	7490	1.16	6608	2047
2001	7309	1022	9124	1	1	7331	1063	8393	1.09	8004	1120
2002	6825	1147	9161	1	1	6850	1185	8035	1.14	7843	1318
2003	7239	679	8471	1	1	7255	691	7946	1.07	7745	726
2004	4647	1218	6392	1	1	4653	1275	5928	1.08	5064	1327
2005	2880	1199	4283	1	1	2903	1221	4124	1.04	3024	1259
2006	2058	1332	3614	1	1	2069	1369	3439	1.05	2193	1420
2007	1815	1228	3171	1	1	1815	1228	3044	1.04	1891	1280
2008	2838	1306	3931	1	1	2838	1306	4143	0.95	2692	1239
2009	2723	1144	3259	1	1	2712	1144	3856	0.85	2295	964
2010	3384	1157	4185	1	1	3384	1157	4540	0.92	3119	1066
2011	3554	913	4201	1	1	3554	913	4467	0.94	3342	859
2012	3838	620	4004	1	1	3838	620	4458	0.90	3447	557

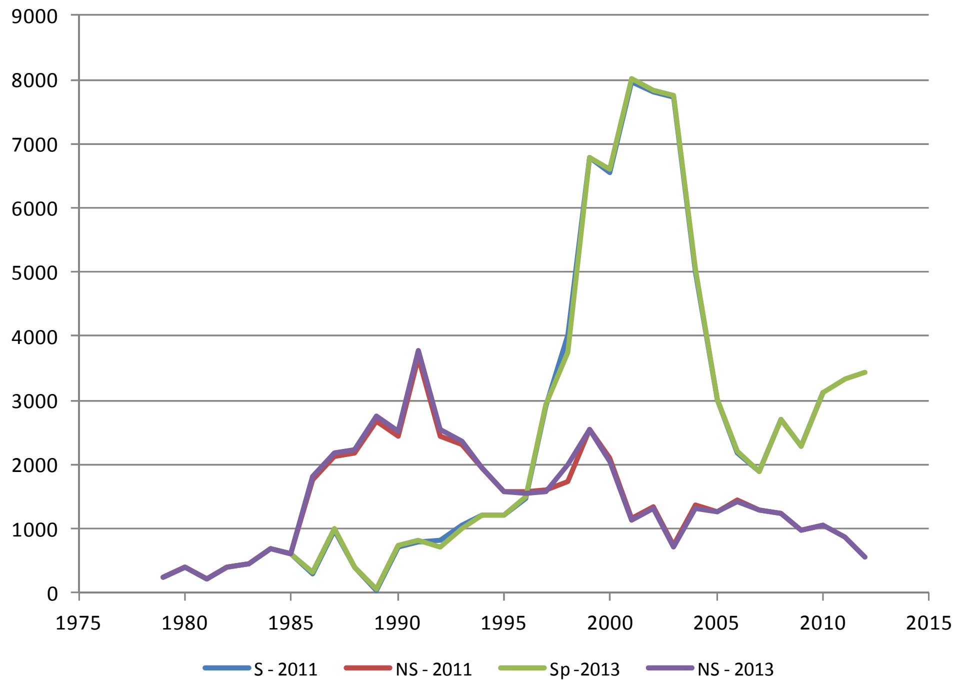


Figure 6.2 The 2013 annual catch series (tonnes) for the spawning (S-2013) and non-spawning (NS-2013) blue grenadier fisheries in comparison to the series for 2011 (Tuck, 2011).

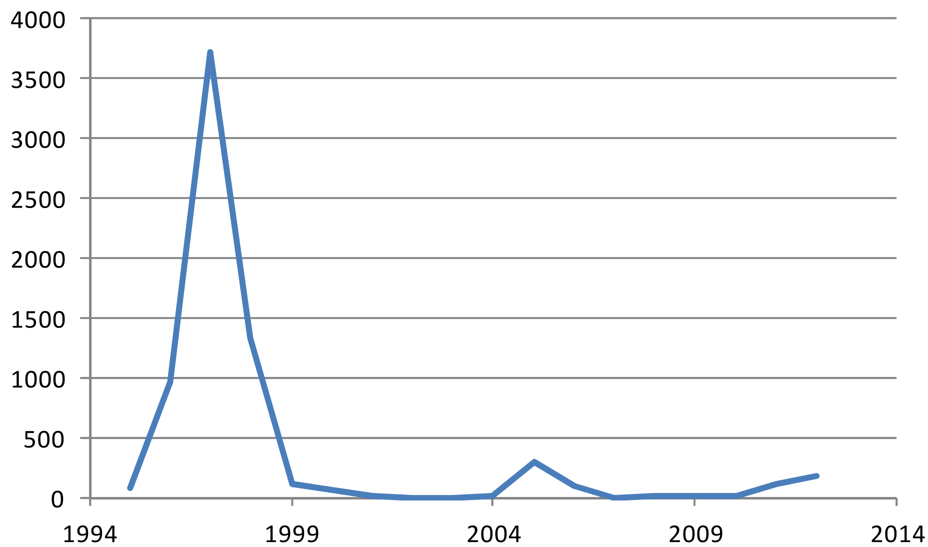


Figure 6.3 The 2013 annual discard series (tonnes) for the non-spawning blue grenadier fishery.

6.4.2 *Catch rates*

Haddon (2013) provides the updated catch rate series for blue grenadier (Table 6.1, Figure 6.4). The spawning fishery catch rate series is not used in the assessment as it is not believed to be a good indicator of available biomass for this component of the stock.

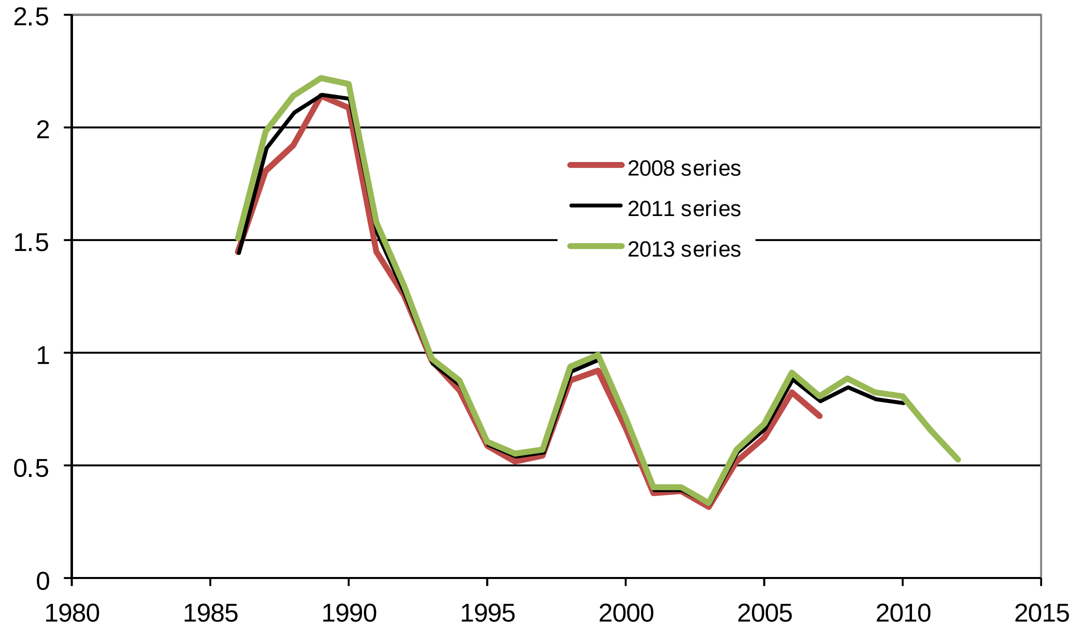


Figure 6.4 The calendar year catch-rate indices for the non-spawning blue grenadier fisheries (Haddon, 2013) in comparison to the series for 2008 and 2011 (Haddon 2008; 2011).

6.4.3 *Length frequencies and age data*

Length and age data are been included in the model as length frequency data and conditional age-at-length data by fleet and sex (when available). Age composition data is included in diagnostic plots but is not used directly within the fitting procedure. On-board and port lengths, when available, were combined to create length frequencies. In previous years, only port samples had been used to create the length frequency. Length data from 1997 were removed from the analyses as there appeared to be data having the DSL process code with lengths that corresponded to the standard length (STL) measurement. This led to unrealistically large lengths when converted from DSL to STL. Discard lengths from 2010 were removed as there were only 16 samples. Figures of the observed length and age data are shown in later figures with the corresponding model predicted values.

6.4.4 *Age-reading error*

Updated standard deviations for aging error by reader (A and B) have been estimated, producing the age-reading error matrix of Table 6.3 (A. Punt, pers. comm.). Reader A applied to years 1991-93 and 2007-2012, and reader B to 1984-1990 and 1994-2006.

Table 6.3. The standard deviation of age reading error.

	St Dev	
Age	A	B
0	0.150	0.286
1	0.150	0.286
2	0.243	0.302
3	0.310	0.319
4	0.359	0.338
5	0.395	0.358
6	0.420	0.381
7	0.439	0.406
8	0.452	0.433
9	0.462	0.463
10	0.469	0.495
11	0.474	0.531
12	0.478	0.570
13	0.480	0.613
14	0.482	0.660
15	0.484	0.712
16	0.485	0.768
17	0.485	0.830
18	0.486	0.898
19	0.486	0.973
20	0.487	1.054

6.4.5 *Acoustic survey estimates*

Estimates of spawning biomass for 2003-2010 are provided in Ryan and Kloser (2012). There are no acoustic estimates for 2011 (not funded) and 2012 (technical issues). Table 6.4 shows the estimates of spawning biomass with their corresponding cv's used in the assessment. Sampling cv's of less than 0.3 were increased to 0.3 to account for process error. Low sampling cvs (of 0.19 for example) were considered too low for an acoustic survey and a minimum of 0.3 should be used to reflect the total uncertainty (D. Smith, pers comm., Tuck et al. 2004; Slope RAG 2011). Of 22 acoustic cvs used for hoki in New Zealand none are lower than 0.3 (Francis, 2009). It is assumed that the spawning ground experiences a turnover rate equal to 2 (i.e. for the model applied here, the spawning biomass estimates are doubled) (Russell and Smith, 2006).

Table 6.4. The estimated biomass (tonnes) of blue grenadier on the spawning grounds in years 2003 to 2010 (Ryan and Kloser, 2012).

	2003	2004	2005	2006	2007	2008	2009	2010
biomass (t)	24690	16295	18852	42882	56330	24450	24787	20622
c.v. in assessment model	0.30	0.46	0.30	0.30	0.52	0.30	1	0.33
Sample cv	0.16	0.46	0.14	0.14	0.52	0.22	1	0.33

6.4.6 *Egg survey estimates*

Egg survey estimates of female spawning biomass are available for 1994 and 1995 (Bulman et al., 1999). The egg-estimates (cv) for 1994 and 1995 respectively are: 57,772 (0.18) and 41,409 (0.29). For the analysis considered here, the base-case egg estimates were used.

6.4.7 *Biological parameters*

The assessment assumes that the proportion of females that spawn in each year is 0.84 and a length at 50% maturity of 63.7cm for females (Russel and Smith, 2006). The female maturity ogive is shown in Figure 6.5

The length weight relationship for males and females was estimated from spawning fishery data over years 1999 to 2008 (Figure 6.5). Natural mortality for females was estimated and male natural mortality is assumed to be 20% greater than this value based upon assumptions made for hoki in New Zealand (McAllister et al. 1994).

Francis (2009) reviews the values of steepness used in New Zealand hoki assessments, where a value of h=0.9 had been used since 1994. This value of steepness was derived from work of Punt et al. (1994) using 45 stocks of gadiform species (0.9 is the median). Following an analysis of the profile likelihood, the effect of steepness on the 2007 assessment and additional information of Myers et al. (1999; 2002) beyond that used by Punt et al (1994), Francis (2009) concludes that steepness should be reduced to h=0.75. This value of steepness was assumed in the previous blue grenadier assessment in 2011 (Tuck, 2011) and in this assessment.

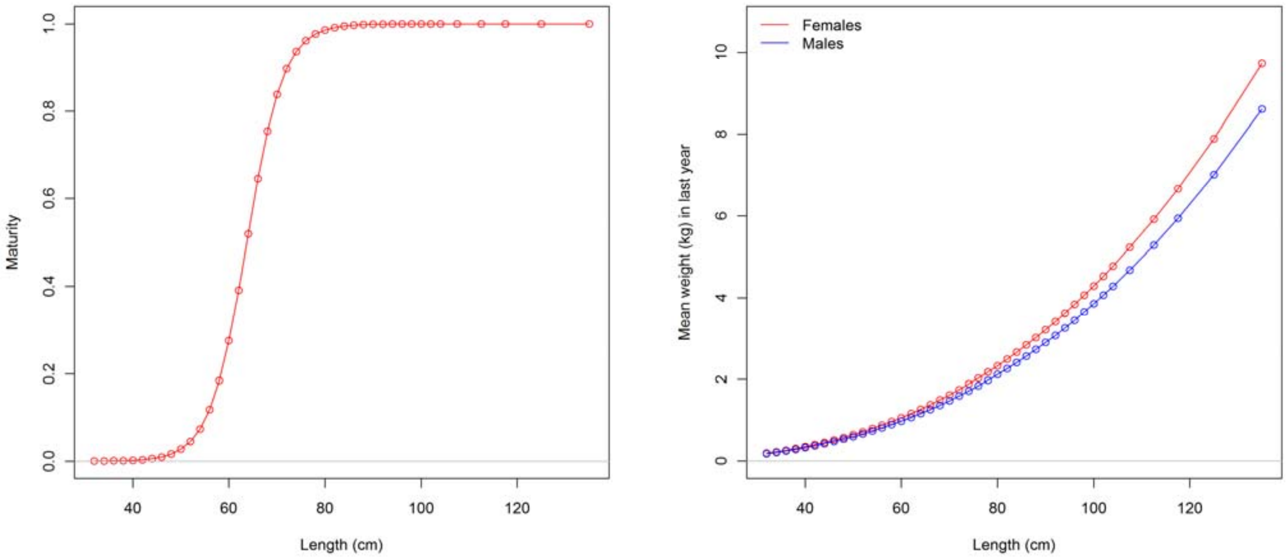


Figure 6.5 The maturity ogive by length for female blue grenadier (parameters from Russell and Smith (2006)) and the length-weight relationship for males and females.

6.5 Analytic approach

6.5.1 The population dynamics model

The 2013 assessment of blue grenadier uses 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. The assessment of blue grenadier takes advantage of the ability of SS to account for multiple fleet allocations to represent the different dynamics of the spawning and non-spawning fisheries. 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, catch length-frequencies, surveys, 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).

This assessment follows the agreements made at the October and November 2011 meetings of Slope RAG. These were: include gender specific selectivity for the spawning fishery, estimate natural mortality for females, use historical discard tonnages estimated by MAFRI, include cohort dependent growth, and set steepness at 0.75.

The base–case model includes the following key features:

(a) Two sub-fisheries are included in the model – the spawning sub-fishery that operates during winter (June – August inclusive) off western Tasmania (zone 40), and the non-spawning sub-fishery that operates during other times of the year and in other areas throughout the year.

(b) The selectivity pattern was assumed to be length-specific, logistic and time-invariant for the spawning fleet and dome-shaped for the non-spawning fleet. The parameters of the selectivity function for each fleet were estimated within the assessment. A change in selectivity from 2005 was considered as a sensitivity for the non-spawning fleet, however this did not substantially affect the fits nor management quantities of interest.

(c) Blue grenadier consists of a single stock within the area of the fishery.

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

(e) The population was at its unfished biomass with the corresponding equilibrium (unfished) age-structure at the start of 1960.

(f) The CVs of the CPUE indices for the non-spawning fleet were initially set at a low value (0.1) to encourage a fit to the abundance data, before being re-tuned to the model-estimated standard errors (0.64).

(g) Discard tonnage was estimated through the assignment of a retention function for the non-spawning fleet. This was defined as a logistic function of length, and the inflection and slope of this function were estimated where discard information was available

(h) The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The value for female M is estimated within the model. Following previous assessments, male natural mortality is assumed be 20% greater than that of females.

(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. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1974 to 2010. Deviations are not estimated before 1974 or after 2010 because there are insufficient data to permit reliable estimation of recruitment residuals outside of this time period.

(j) The value of the parameter determining the magnitude of the process error in annual recruitment, σ_r, is set equal to 1.0 in the base case reflecting the large variation in recruitment observed for blue grenadier

(k) The population plus-group is modelled at age 20 years. The maximum age for observations was 15 years, reflecting that used in previous assessments

(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 inside the assessment model. Growth is also assumed to vary through time and be cohort (year class) specific. Evidence for time-varying and cohort specific growth in blue grenadier has been accumulating for over a decade (see Punt and Smith 2001; Whitten et al., 2013). As such, mean length- and mass-at-age by cohort has been derived for previous assessments from age-length keys, the mass-length relationship and length frequency data (Method 2 of Punt and Smith, 2001) and specified directly as mean length- and mass-at-age matrices in the assessment models. The data upon which these matrices were based was treated as being subject to sampling error. Therefore, whilst the previous method allowed for explicit accounting of variability in mean-size through time, it was not conceptually consistent with the Integrated Analysis estimation procedure, which assumes that mean length- and mass-at-age matrices input into an assessment are known exactly. This method also relied on interpolated length- and mass-at-age estimates for years in which actual data were not available and ignored any age-length relationship. The implementation of the base-case assessment using SS can account for temporal variation in growth, and therefore temporal variation in mean length- and mass-at-age. Following the 2011 assessment, the 2013 base-case model treats length-at-age information as data, and predicts the expected length-at-age for each year. This is achieved by estimating the parameters of a von Bertalanffy growth function that describe the mean expected length-at-age across all years and then introducing an extra parameter that describes cohort specific deviations from mean expected length-at-age for a specified range of year classes. Cohort specific deviations from average growth are estimated in the base case model for year classes 1978 to 2009, the year classes for which there are sufficient length-at-age data to permit reliable estimates.

(m) The sample sizes for length frequencies were tuned for each fleet so that the input sample size was approximately equal to the effective sample size calculated by the model. Before the retuning of length frequency data was performed by fleet, retained length sample sizes were set at 50 and discard length sample sizes to 10. This is because the appropriate sample size for length frequency data is probably more 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. Discard length sample sizes were set at 10 based approximately upon the ratio of discard to (retained + discard) samples multiplied by 50. Discard length frequencies with samples sizes <200 were removed. The age data sample sizes for a particular year were decreased to 50. The relative frequency of age samples across lengths within a year was maintained. Length, age and cpue data were tuned.

The values assumed for some of the (non-estimated) parameters of the base case models are shown in Table 6.5

Table 6.5. Parameter values assumed for some of the non-estimated parameters of the base-case model.

Parameter	Description	BC
M_f	Natural mortality for females	Estimated
M_m	Natural mortality for males	1.2* M_f
σ_r	c.v. for the recruitment residuals	1.0
σ_g	Input standard deviation for the cohort growth deviations	0.1
h	“steepness” of the Beverton-Holt stock-recruit curve	0.75
x	age observation plus group	15 years
μ	fraction of mature population that spawn each year	0.84
aa	Female allometric length-weight equations	0.01502 g^{-1}.cm
bb	Female allometric length-weight equations	2.728
aa	Male allometric length-weight equations	0.0168 g^{-1}.cm
bb	Male allometric length-weight equations	2.680
l_m	Female length at 50% maturity	63.7cm
l_s	Parameter defining the slope of the maturity ogive	-0.261

6.5.2 *Calculating the RBC*

The SESSF Harvest Strategy Framework (HSF) was developed during 2005 (Smith et al.2008) and has been used as a basis for providing advice on TACs in the SESSF quota management system for fishing years 2006–2013. The HSF uses harvest control rules to determine a recommended biological catch (RBC) for each stock in the SESSF quota management system. Each stock is assigned to one of four Tier levels depending on the basis used for assessing stock status or exploitation level for that stock. Blue grenadier is assessed as a Tier 1 stock as it has an agreed quantitative stock assessment.

The Tier 1 harvest control rule specifies a target and a limit biomass reference point, as well as a target fishing mortality rate. Since 2005 various values have been used for the target and the breakpoint in the rule. For the 2014 TACs AFMA has directed that the 20:40:40 (Blim:Bmsy:Ftarg) form of the rule will be used up to where fishing mortality reaches F48. Once this point is reached, the fishing mortality is set at F48. Day (2008) has determined that for most SESSF stocks where the proxy values of B40 and B48 are used for BMSY and BMEY this form of the rule is equivalent to a 20:35:48 strategy.

This document reports RBCs calculated under the 20:35:48 strategy.

6.5.3 *Sensitivity tests and alternative models*

A number of tests were used to examine the sensitivity of the results of the model to some of the assumptions and data inputs:

1. *M* = 0.2 yr-1, estimated. (0.17 in the base case)
2. *h* = 0.9 (0.75 in the base case)
3. CPUE series cv = 0.1 (tuned in the base case)
4. Discard tonnage cv=0.1 (0.3 in base case)
5. Double and halve the weighting on the length composition data.
6. Double and halve the weighting on the age-at-length data.
7. Remove egg survey estimates

The results of the sensitivity tests are summarized by the following quantities:

1. SB_0 the average equilibrium female spawning biomass.
2. SB_{2014} the female spawning biomass at the start of 2014.
3. SB_{2014}/SB_0 the depletion level at the start of 2014, i.e. the 2014 spawning biomass expressed as a fraction of the unexploited spawning biomass.
4. *2014 RBC* - the 2014 RBC, calculated using the 20:35:48 harvest rule.
5. *Longterm RBC* the long-term RBC calculated using the 20:35:48 harvest rule.

6.6 Results and discussion

6.6.1 The base case stock assessment

6.6.1.1 Parameter estimates

Figure 6.6 shows how the expected mean length-at-age values change over time for the base case model. The ridges reflect the impact of some cohorts growing faster or slower than average. This figure also shows the expected mean length-at-age values for the end-year of the model. The impact of slower than average growth is visible by the decrease in expected size of 9 and 18 yo fish, corresponding to the larger than average recruitments in years 2003 and 1994 respectively. Natural mortality for females was estimated to be M_f=0.15 and males therefore was M_m=0.18.

The selectivity for the spawning and non-spawning fisheries and the retention function for the non-spawning fishery are shown in Figure 6.8. Selectivity is assumed to be time-invariant, sex-specific and logistic for the spawning fleet and dome-shaped for the non-spawning fleet. Note that the estimated female length-specific selectivity for the spawning ground shows an ascending limb that includes much larger fish than the maturity ogive estimated by Russell and Smith (2006), which has an estimate of 50% maturity of 63.7cm. This result implies that, to a large extent, small mature females do not appear to be evident on the spawning ground. Russell and Smith (2006) present length frequencies during their study of blue grenadier reproductive biology showing that very few female fish less than 60cm were caught (also see Figure 6.12). However those that were caught were included in the study and a proportion of these fish were shown to be mature.

6.6.1.2 Fits to the data

Figure 6.9 shows the model fit to the non-spawning catch rate series. The model fits intersect most of the 95% confidence intervals for the data, indicating that adjustments to the CV for the indices performed as expected. As has been seen in all previous assessment models for blue grenadier, the model is not able to fit the rise in catch rate following the large recruitment of the mid-1990s. The fit to the discard mass is able to replicate the increase in discarding through the late 1990s and mid 2000s, however the magnitude is under-estimated (as has been the case with previous assessments). Re-weighting the CVs on the discard mass was not able to improve the fit to the discard data. Fits to the biomass estimates from the acoustic surveys and egg surveys were reasonable. The predicted biomass trajectory intersects all of the 95% confidence intervals (Figure 6.10).

The model is able to replicate the implied age-composition data well (Figure 6.11, Figure 6.16 to Figure 6.20). Predicted age-compositions are able to track the strong cohorts typical of blue grenadier as they move through both the non-spawning fishery and the spawning fishery. Length composition data are also well estimated by the model (Figure 6.12, Figure 6.21 to Figure 6.25). The inclusion of sex-specific selectivity now allows a better fit to the observations of length and age by sex.

6.6.1.3 Assessment outcomes

The estimated time series of recruitment under the base-case parameter set shows the typical episodic typical episodic nature of blue grenadier recruitment, with strong year-classes in 1979, the mid-1980s, the mid-1980s, 1994, 2003 and now 2010, and with very little recruitment between these years (

these years (

Figure 6.13). The magnitude of the recruitment of 2010 will remain somewhat poorly estimated until these fish move well into the available stock of the fishery.

The trajectories of spawning biomass and spawning biomass relative to the un-exploited level are shown in Figure 6.14. This shows the increases and decreases in spawning biomass as the strong cohorts move into and out of the spawning population. The estimated virgin female biomass is 36,815 tonnes (compared to 39,983 t in the 2011 assessment). In 2011, the estimated spawning biomass level under the base-case scenario for 2010 was 87% of un-exploited levels and in 2012, which was used in the harvest control rule, was approximately 67% *SBo*. In the 2013 assessment, the estimated spawning biomass level under the base-case scenario for 2012 is 77% of unexploited levels and the estimated spawning biomass in 2014, which is used in the harvest control rule, is approximately 94% *SBo*.

The more optimistic outlook from this assessment is largely being driven by the addition of 2 further addition of 2 further years of data and the substantial estimated recruitment in 2010. While a promising While a promising sign for the fishery, some caution should be exercised with regard to this recruitment this recruitment estimate and its implication on future stock status, until clear further indications of its indications of its existence (and magnitude) are evident in future years' data. But note that the 2010 that the 2010 recruitment estimate does appear to be well estimated (

Figure 6.13; bottom left). If the 2010 recruitment is not estimated, then the (tuned) model instead estimates an above average recruitment in 2009 (Appendix 3). The model fit to the age composition data is poorer for fish of age 1 in 2011 and 2 in 2012. The estimated spawning biomass as a percentage of unexploited levels also differ substantially, being 70% *SBo* in 2012 and 61% *SBo* in 2014.

For the base case model BC the 2014 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 8138. The long-term retained catch is 4106t. The retained portion of the RBC for 2014 is estimated to be 8065t (Figure 6.15; Table 6.6). Note that the retained catch for 2014 is greater than 150% of the current TAC (5208 t). This would imply an adjusted retained catch of 7812t for 2014.

Table 6.6. The estimated retained portion of the RBC and the RBC for blue grenadier under the base case model BC. Note that the 2014 RBC is over 150% of the 2013 TAC of 5208t and so would be capped at 7812t.

Year	Retained catch	RBC
2014	8065*	8138
2015	9116	9172
2016	9249	9303
2017	8807	8861
2018	8149	8203
2019	7455	7509
2020	6811	6864
2021	6253	6306
2022	5788	5841
2023	5412	5464
2024	5110	5162
2025	4871	4922
2026	4680	4731
2027	4528	4578
2028	4406	4456
2029	4307	4357
2030	4226	4276
2031	4160	4210
2032	4106	4155

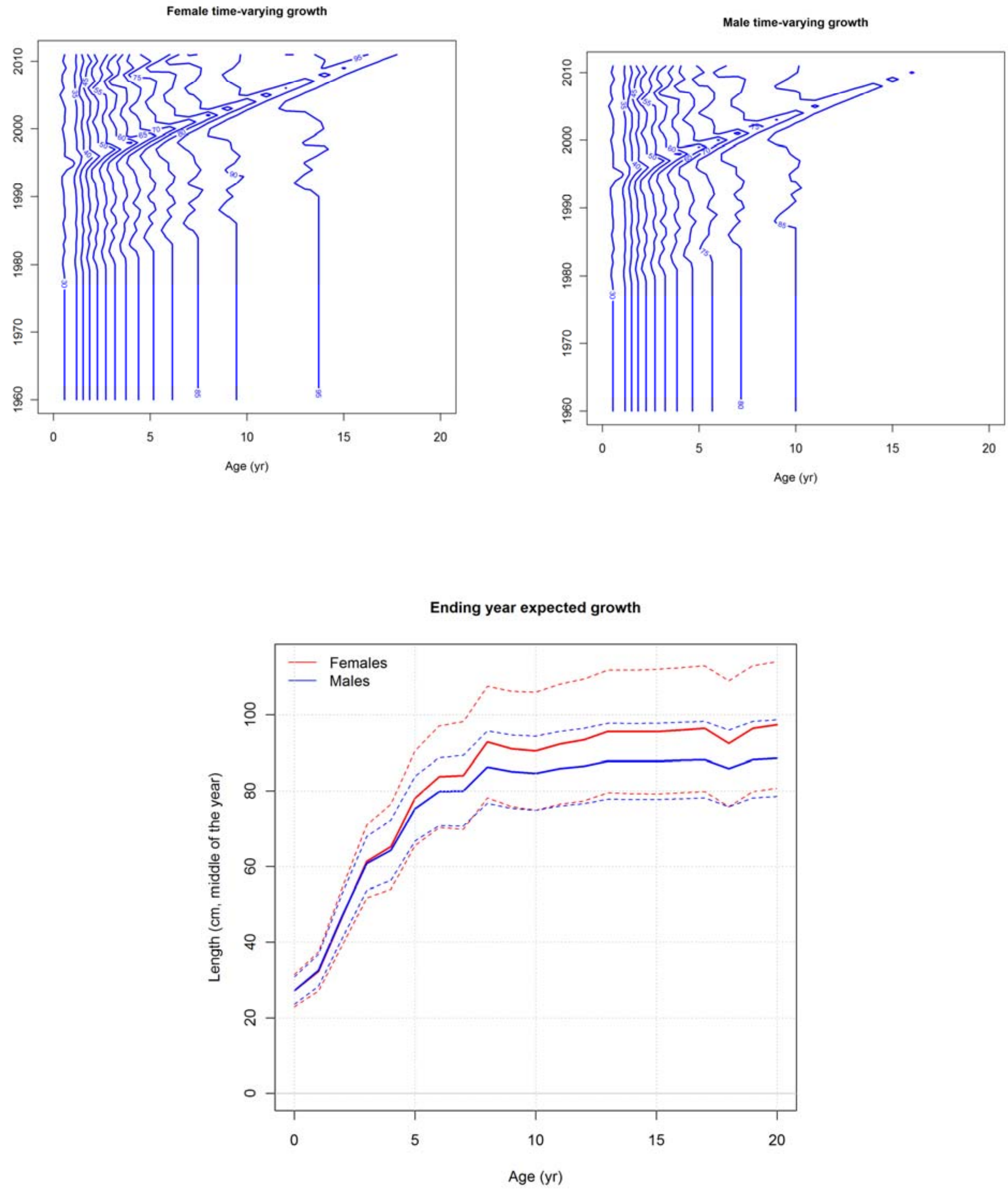


Figure 6.6 The base case model predicted length at age relationship.

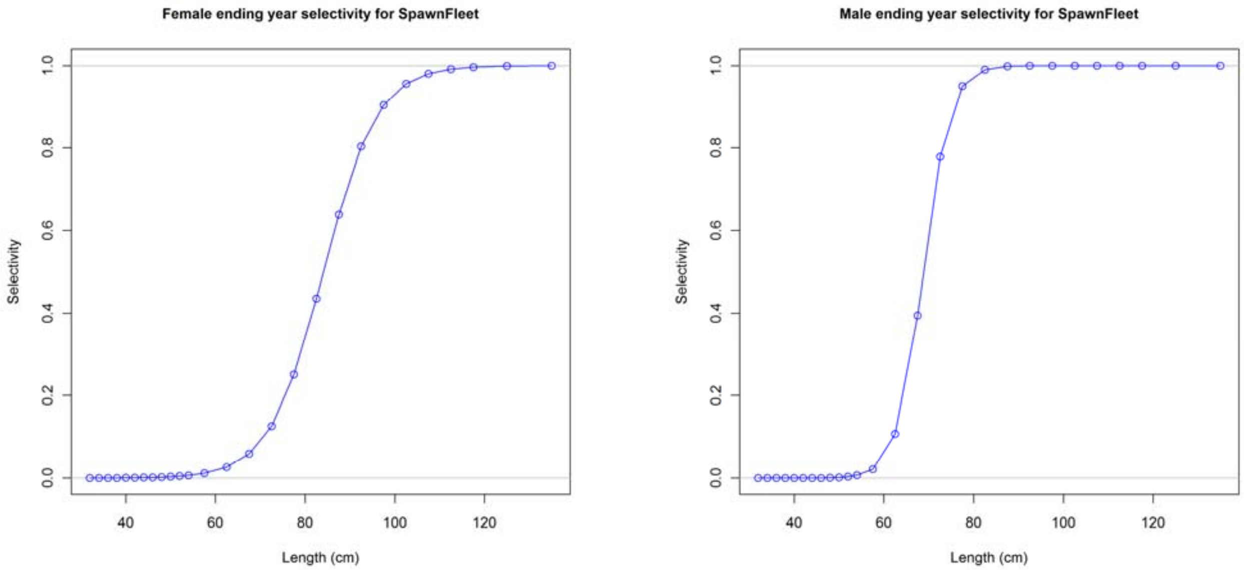


Figure 6.7. The base case model sex-specific selectivity for the spawning fishery. Females (left) and males (right).

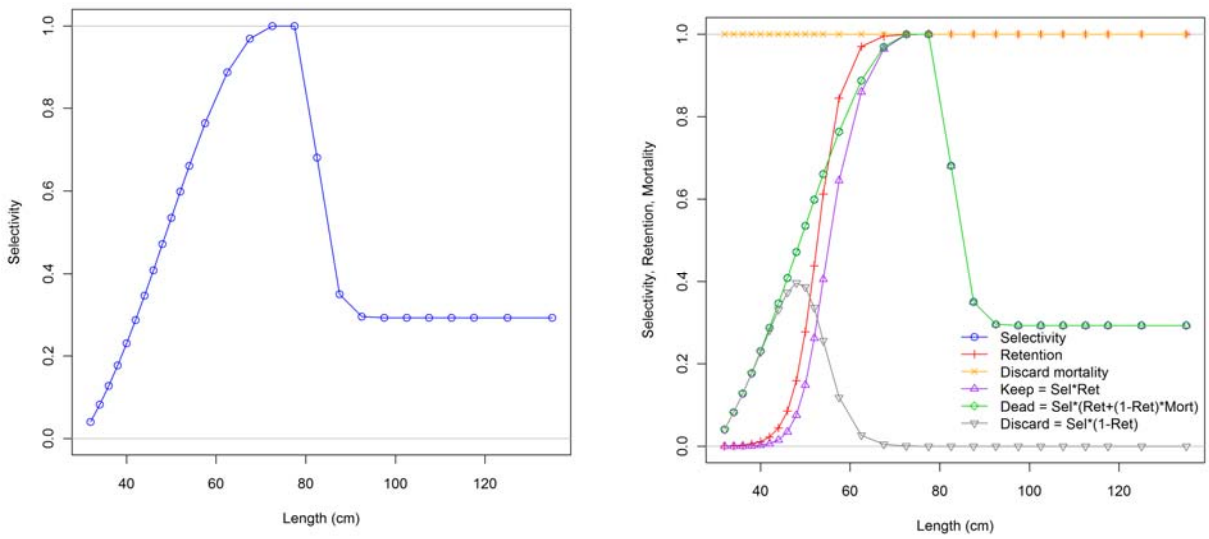


Figure 6.8 The base case model predicted selectivity-at-length for the non-spawning fleet (left) and the retention function for the non-spawning fleet (right – red).

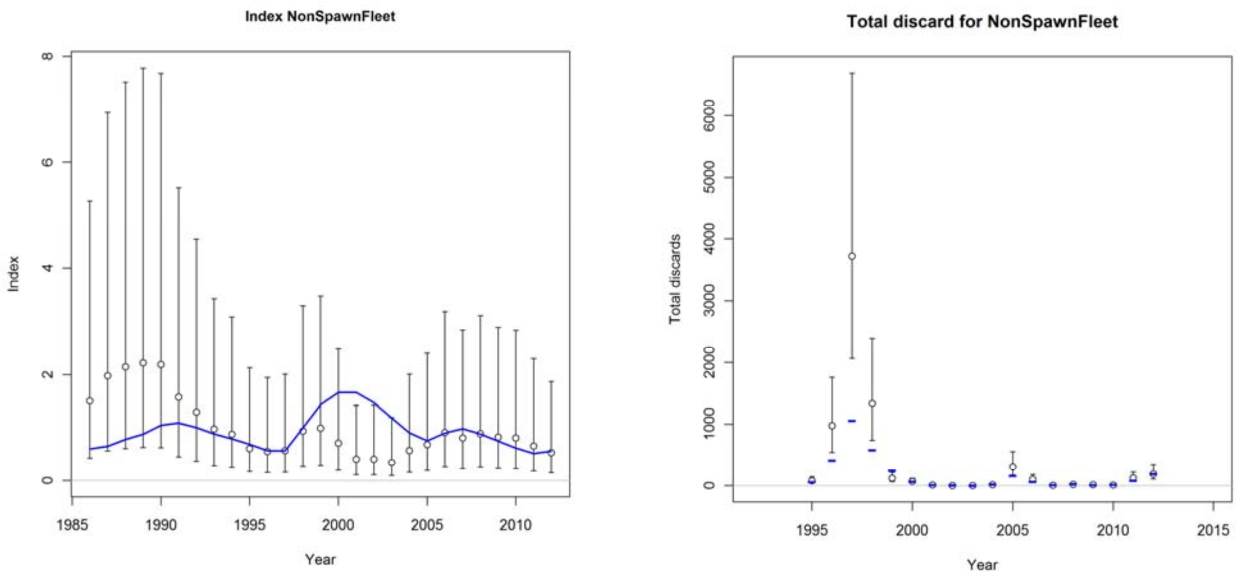


Figure 6.9. The base case model fit to the non-spawning catch rate series (left) and the discard mass (right).

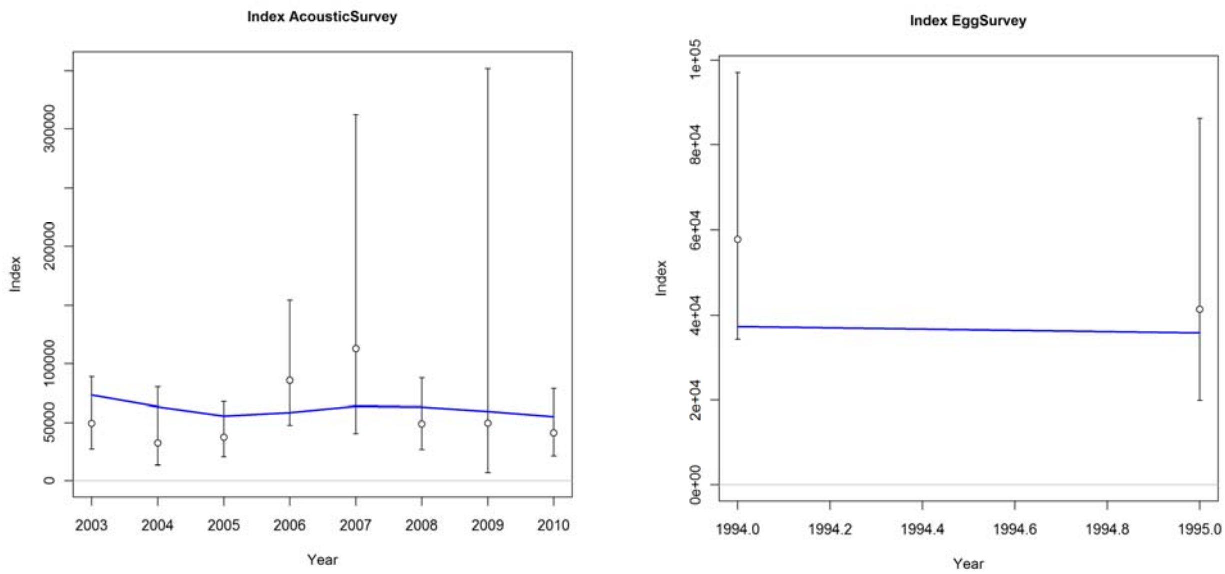


Figure 6.10. The base case model fit to the acoustic survey data (top left) and the egg survey estimates of female biomass (bottom left) with the corresponding fits from the 2008 assessment.

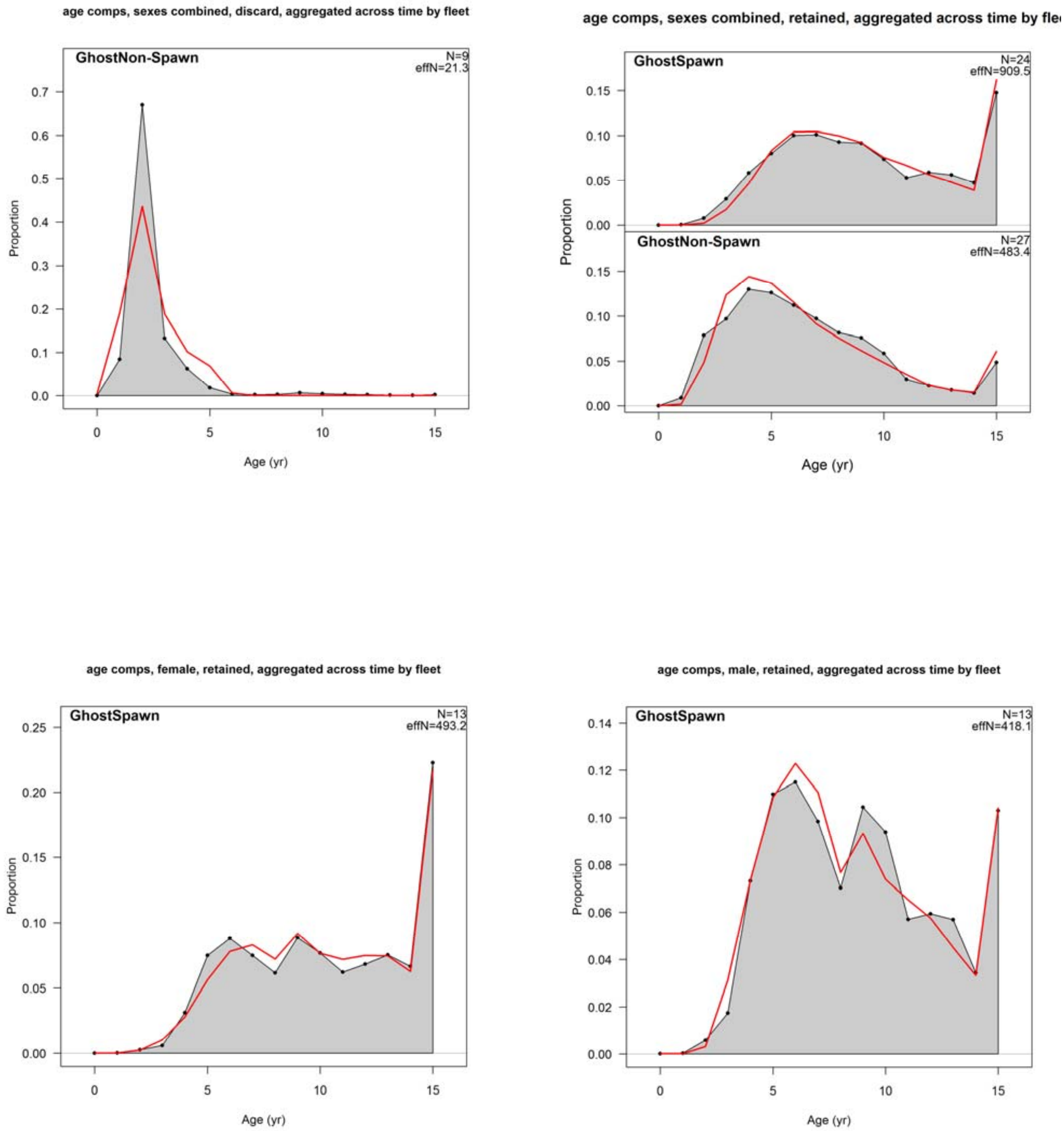


Figure 6.11. The base case model fit to the year aggregated age-composition data.

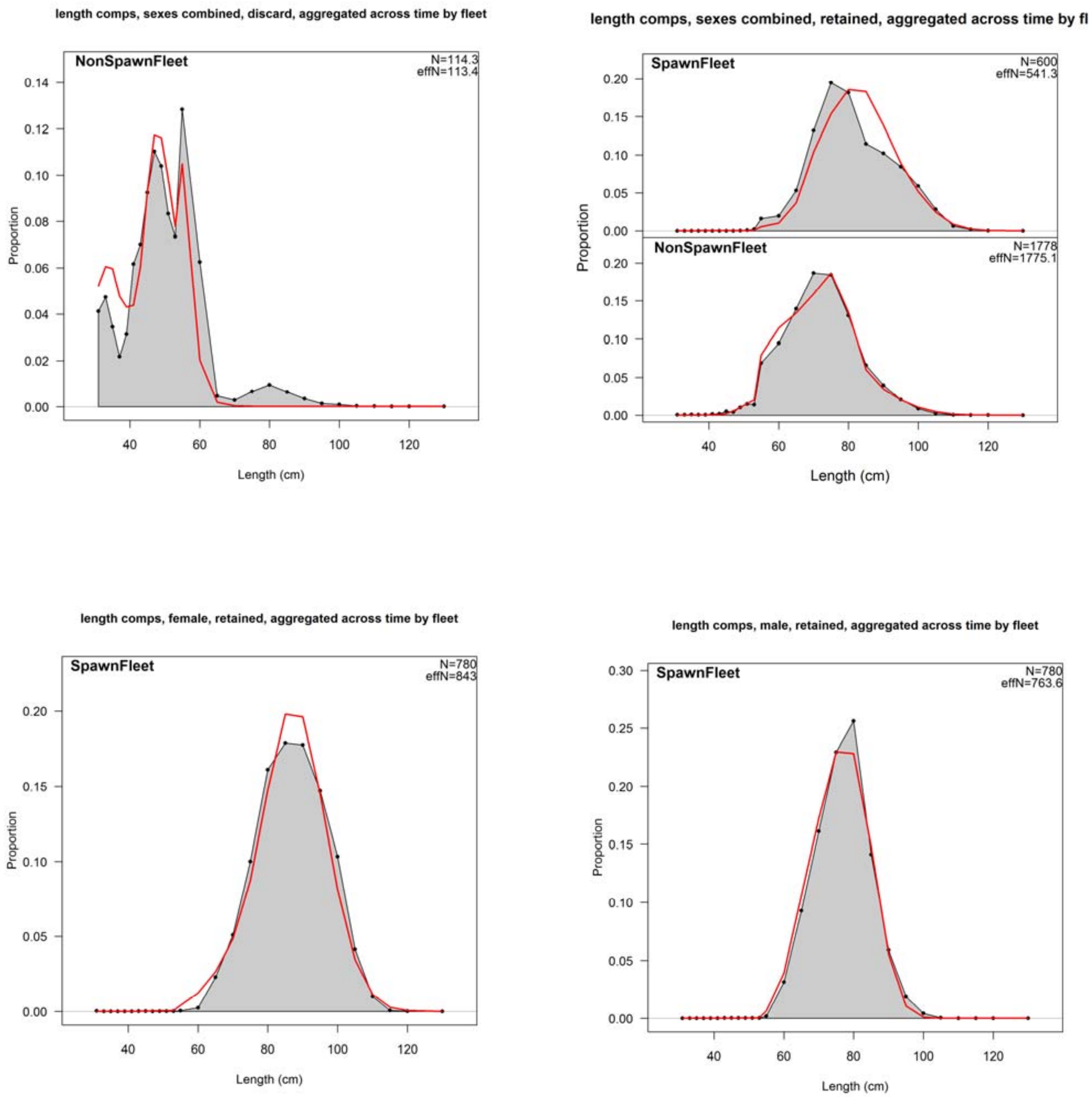


Figure 6.12. The base case model fit to the year aggregated length-composition data.

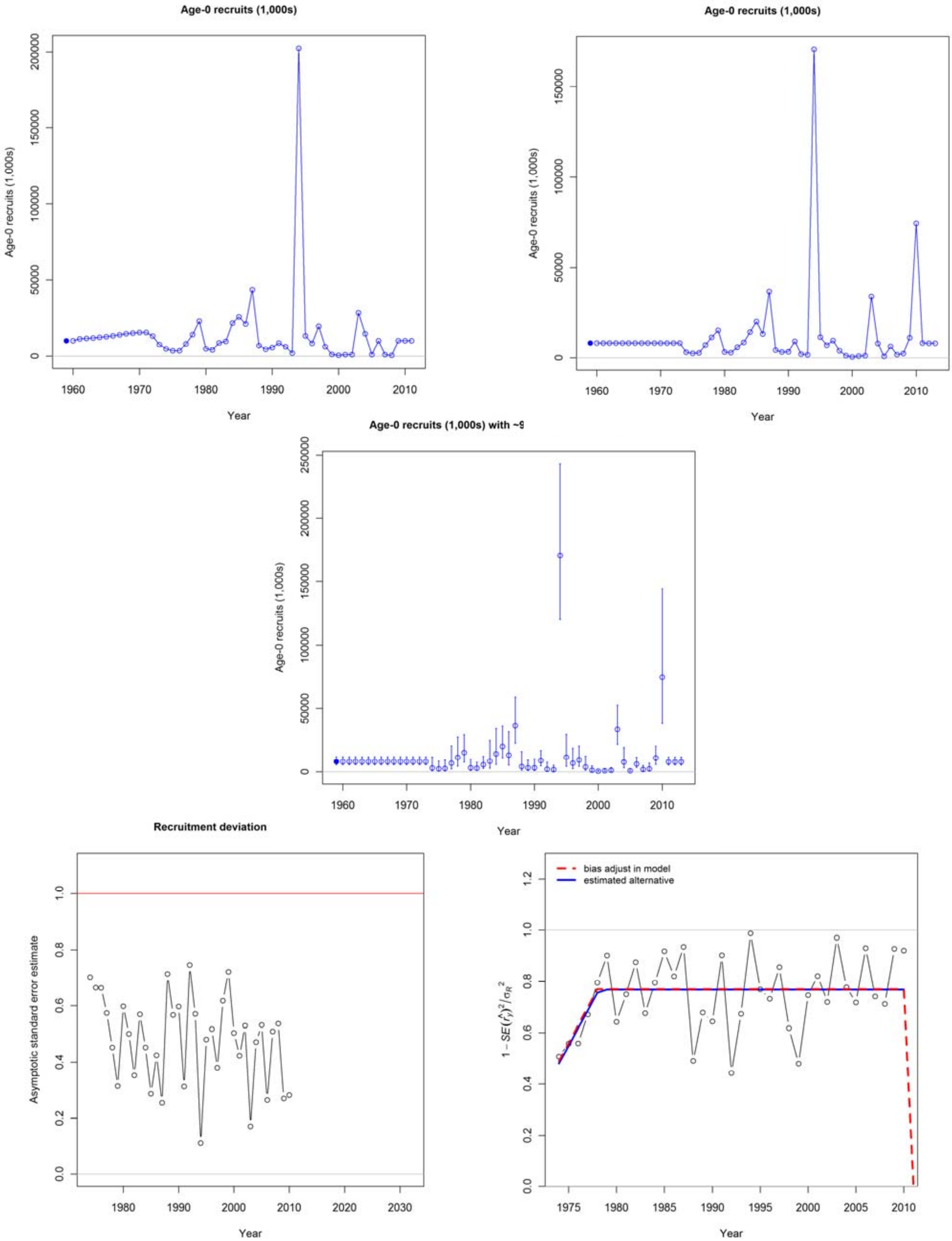


Figure 6.13 The base case model predicted time-series of recruitment for blue grenadier (top right and middle) with the corresponding figure from the 2011 assessment (top left) (Tuck, 2011). Recruitment diagnostics: recruitment deviation variance check (bottom left) and bias adjustment check (bottom right).

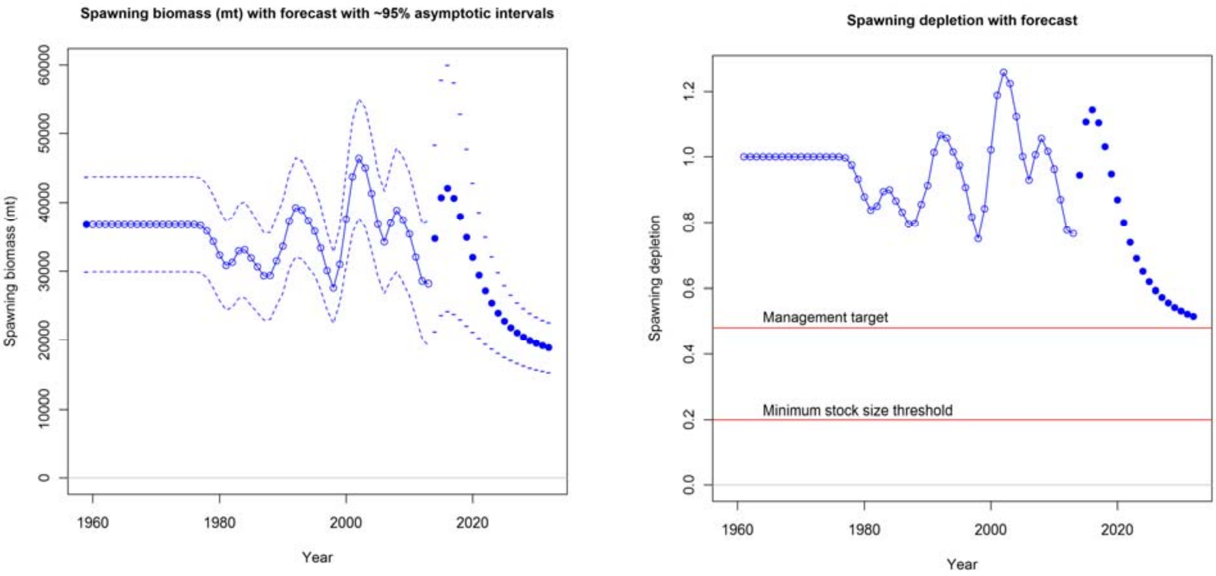


Figure 6.14 The base case model time-series of spawning biomass and relative spawning biomass.

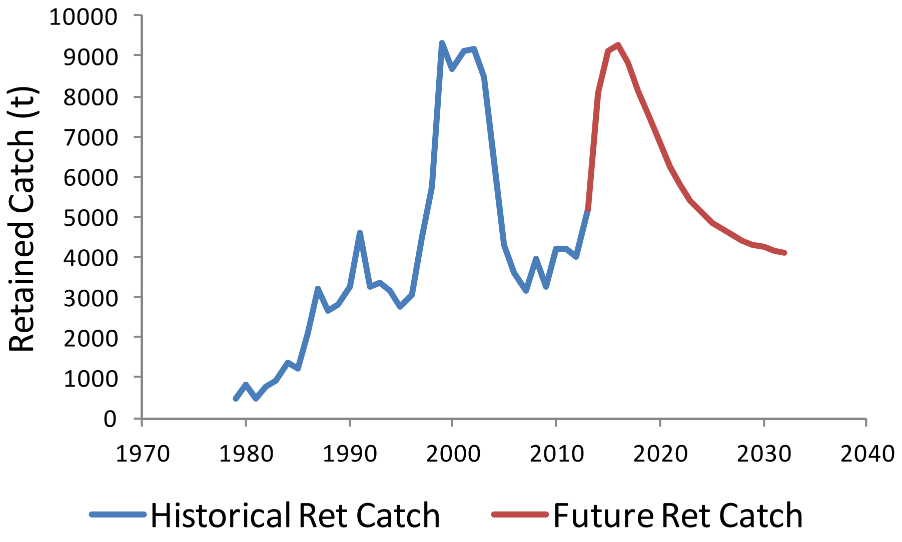


Figure 6.15. The time series of retained catches including the predicted retained catch (RBC less predicted discards) for the base case model.

6.6.1.4 Sensitivity tests

Results of the sensitivity tests are shown in Table 6.7. Steepness is not well estimated as the model estimated spawning biomass does not decrease to low enough magnitudes to inform the estimation of this parameter. Increasing the weight on the catch rate index (cpue cv=0.1) leads to a markedly poorer fit to the composition data. All model sensitivities show relative spawning biomass levels well above the target biomass level (48% *SBo*)), except for a model where no 2009 and 2010 recruitments are estimated. This is not surprising, given the large expected recruitment from 2010 is predicted to increase spawning biomass into the future.

Table 6.7 Summary of results for the base case model BC and sensitivity tests. * This RBC is more than 150% of the current TAC, and so will need to be capped at 7812t in 2014 if applied. ^This is the retained catch at 2032. The long term catch had not yet stabilised by year 2032. Ret C = retained catch. Ret C 2014-16 is the average 3-year retained catch. Ret C 2014-18 is the average 5-year retained catch. The upper six models have been tuned.

Model	Female SB_0	Female SB_{2014}	SB_{2014}/SB_0	2014 RBC	2014 Ret C	Ret C 2014-16	Ret C 2014-18	Ret C Long-term
Model BC (M_f=est, h=0.75)	36815	34781	0.94	8138*	8065*	8810*	8677*	4106^
No est of 2010 rect	38545	23540	0.61	6164	6031	6241	6383	4800^
No est of 2009 and 10 rect	38167	14772	0.39	2894	2831	2979	3115	3606^
Discard Fleet	44493	47780	1.07	16313*	15891*	18188	17587	6860^
Francis wt	98013	79526	0.81	7707	7594	7771	7642	5349^
Model BC2 2011	39983	21740	0.54	4881	4773	4644	4622	4436
h=0.90	36656	34800	0.95					
M_f=0.20	38918	39260	1.01					
M_f=0.17	37794	36893	0.98					
M_f=0.12	39175	30374	0.78					
Cpue cv=0.1	58910	59639	1.01					
Discard cv=0.1	36772	29930	0.81					
No egg survey	35130	33384	0.95					
Halve weight on LF data	39275	27451	0.70					
Double weight on LF data	36716	47875	1.30					
Halve weight on Age data	36373	36930	1.01					
Double weight on Age data	38172	33583	0.88					
Sigma R 0.8	35046	35962	1.02					
Sigma R 1.2	40456	34311	0.85					

Table 6.8. Summary of likelihood components for the base-case BC and sensitivity tests. Likelihood components are unweighted, and sensitivities from the BC are shown as differences from the base case. A negative value indicates a better fit, a positive value a worse fit. Note that the upper five models are tuned and so likelihoods are not comparable.

Model	TOTAL	Survey	Discard	Length comp	Age comp	Recruitment
Model BC (M_f=est=0.15, h=0.75)	6406.72	-1.73	17.94	522.84	5809.15	28.61
No est of 2010 rect	961.95	0.51	12.07	8.51	916.00	-3.60
No est of 2009 and 10 rect	743.40	-1.16	8.31	20.25	703.46	-6.41
Discard Fleet	-53.42	-3.30	-	38.09	-68.70	-4.07
Francis wt	-3203.38	-8.16	-22.27	-421.77	-2742.28	0.84
h=0.90	0.02	0.03	-0.02	0.01	0.06	-0.02
M_f=0.20	119.31	1.40	3.06	-9.80	117.69	-3.55
M_f=0.17	-14.42	0.85	0.35	-8.56	-13.86	-2.43
M_f=0.12	111.07	-0.96	-4.14	3.66	110.87	1.12
Cpue cv=0.1	2114.65	76.04	23.73	54.55	1941.06	2.39
Discard cv=0.1	348.88	1.74	-31.62	47.59	314.22	8.13
No egg survey	29.51	0.67	-0.32	-0.25	29.18	0.51
Halve weight on LF data	-204.63	-1.30	-14.45	35.47	-216.65	-0.67
Double weight on LF data	922.21	5.12	25.08	-52.11	912.80	-0.21
Halve weight on Age data	2538.47	0.47	0.89	-3.27	2540.71	-0.30
Double weight on Age data	-1432.04	-0.06	-0.60	-0.49	-1435.99	-1.18
Sigma R 0.8	6.95	0.90	2.02	-6.19	-0.81	1.26
Sigma R 1.2	11.80	-0.45	-1.25	-1.19	17.17	-1.02

6.6.2 ***Risk assessment to recruitment uncertainty***

The 2013 stock assessment for blue grenadier is the first to show a substantial recruitment event in 2010. The estimated 2010. The estimated magnitude of this recruitment is predicted to be second only to the large recruitment of the mid recruitment of the mid 1990s (

Figure 6.13; top right). While it appears this recruitment is well estimated (

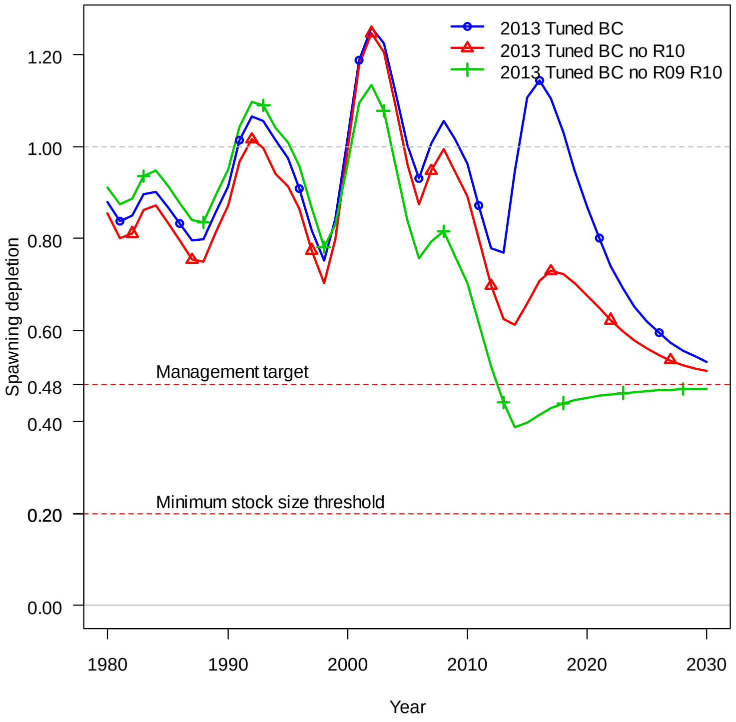
Figure 6.13) and is an encouraging sign for the fishery, the consequent RBCs are a substantial increase over those seen recently and could have major consequences for the stock if the magnitude of this recruitment is less than expected. As such, a risk assessment to this uncertainty was conducted. Models that did not estimate the 2010 recruitment (noR10) and did not estimate the 2009 and 2010 (no R09 R10) were run (and tuned) (Table 6.7; Section 6.10).

In order to fit to the length data of 2011 and 2012, the noR10 model shifts the recruitment back into 2009 (Figure 6.16). It also estimates that this cohort is very slow growing in order to fit to the length data, which would otherwise have come from the 2010 cohort (Figure 6.17). Thus the length frequency resulting from the 2009 cohort shows a smaller mode than it would otherwise, allowing the model to fit to the 2011 and 2012 length data. In addition, as the growth is slower, the maximum size of fish from the 2009 cohort is lower which translates into a smaller biomass than seen when the 2010 recruitment is estimated (Figure 6.16). As a consequence of placing the large cohort in 2009, as opposed to 2010, the fit to the age data is poor, as the age data want to place the strong cohort in 2010 (Table 6.8). This implies that a considerable signal exists indicating a strong recent cohort, and most likely a 2010 cohort. Assuming average recruitment for 2009 and 2010 (and not estimating these recruitments; no R09 R10) does not result in a large recent cohort, as the model has no flexibility to fit to the recent length and age data (Figure 6.16). As a result, a substantially more pessimistic result occurs, as the biomass from the mid-1990s cohort succumbs to mortality and recent recruitments (eg 2003) are not sufficient to maintain the biomass above the target reference point (Figure 6.16).

The retained portion of the RBCs from each of the base case model (BC) and the model that does not estimate a 2010 recruitment (noR10) are provided in Table 6.9. Also included in this table are the 3- and 5-year averages of the retained catches. Note that the 2014 retained catch is greater than 150% of the current TAC (5208t) and so has been capped at 7812t.

For the risk assessment, each of the 3- and 5-year retained catch, and 3- and 5-year averages of the retained catch were used as forecast catches in each of the two models (BC and noR10), leading to 16 combinations (8 forecast catches and 2 models). The risk assessment can then explore the consequence of placing the large forecast catches from model BC into the noR10 model which predicts a lower spawning biomass (Figure 6.16).

Results show, not surprisingly, that when the smaller catches of the R10 model (green and black) are placed into the BC model, that the predicted SSB trajectory is higher than if the catches from the BC model (red) are used (in the BC model) (Figure 6.18). If the BC model catches (red and black) are applied in the model that does not estimate a 2010 recruitment (noR10) then the SSB trajectory is lower than if catches from this model are used (green). However, in no case does the median trajectory move below the target reference point (48%).



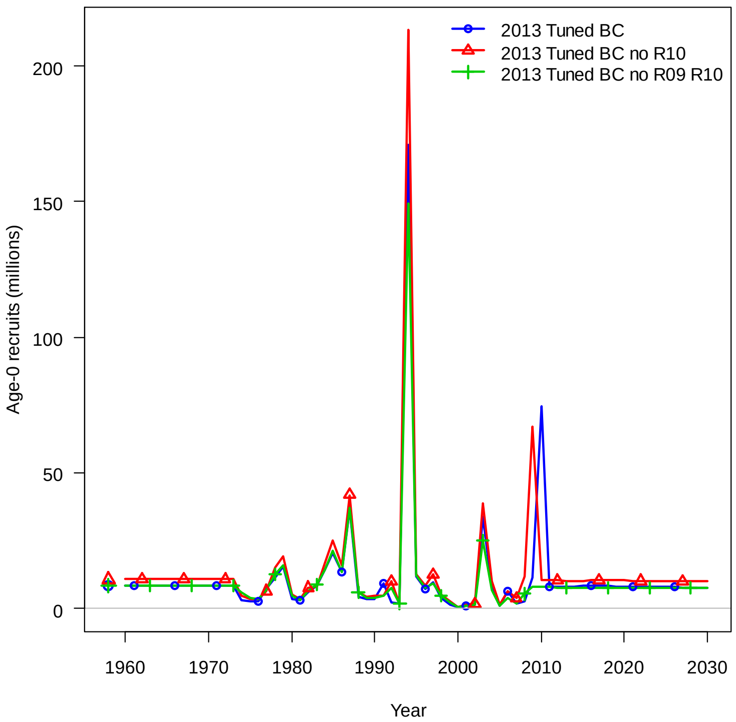


Figure 6.16. The trajectory of female spawning biomass for the base case model (Blue: 2013 Tuned BC) and models with no estimation of the 2010 recruitment (Red: R10) and no estimation of the 2009 and 2010 recruitment (Green: R09 R10)

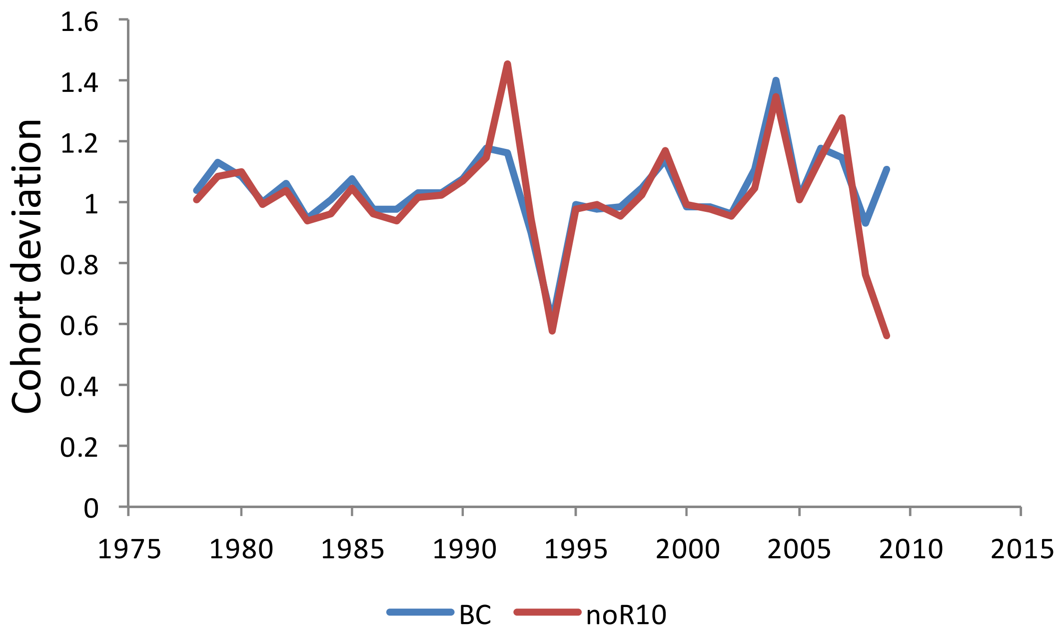


Figure 6.17. The estimated cohort deviations showing the much slower growing 2009 cohort if the recruitment of 2010 is not estimated (noR10) compared to the base case model where the 2010 recruitment is estimated (BC).

Table 6.9. The estimated retained portion of the RBC for blue grenadier under the base case model BC and where the 2010 recruitment is not estimated (noR10). Shown are retained values of catch and 3 and 5 year averages. *Note that the 2014 Retained catch of 8605t is over 150% of the 2013 TAC of 5208t

	BC			noR10		
Year	Annual	3-Year	5-year	Annual	3-Year	5-year
2014	7812*	7812*	7812*	6031	6241	6383
2015	9116	8810	8677	6201	6241	6383
2016	9249	8810	8677	6490	6241	6383
2017	8807		8677	6629		6383
2018	8149		8677	6564		6383

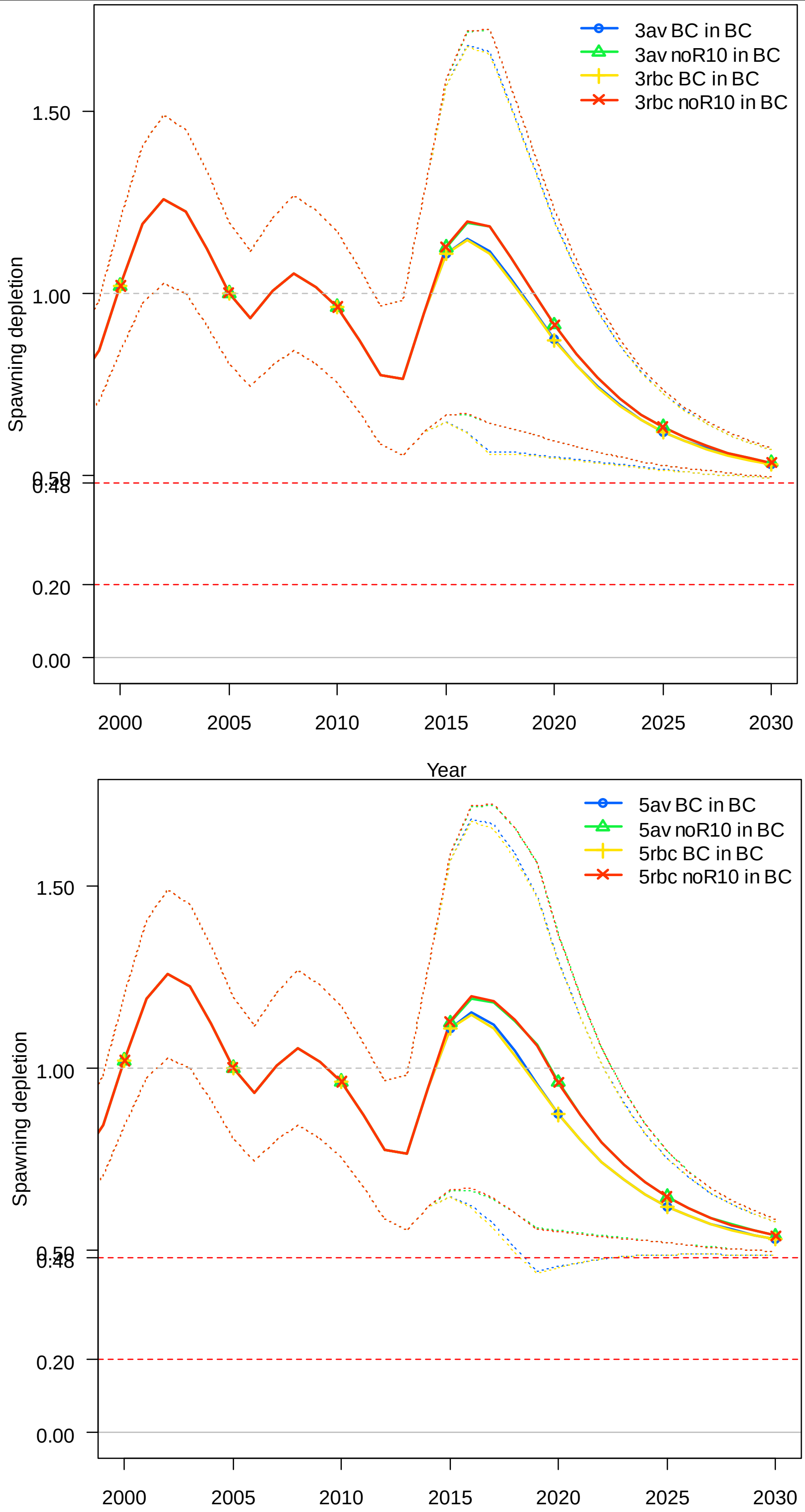


Figure 6.18. The consequence of alternative forecast catch series on the time series of female SSB (t) when placed in the base case model (BC). 3av = 3-year average, 5av = 5-year average, 3rbc = 3-years of annual retained catch, 5rbc = 5-years of annual retained catch. X in Y = catches from model X are placed into model Y.

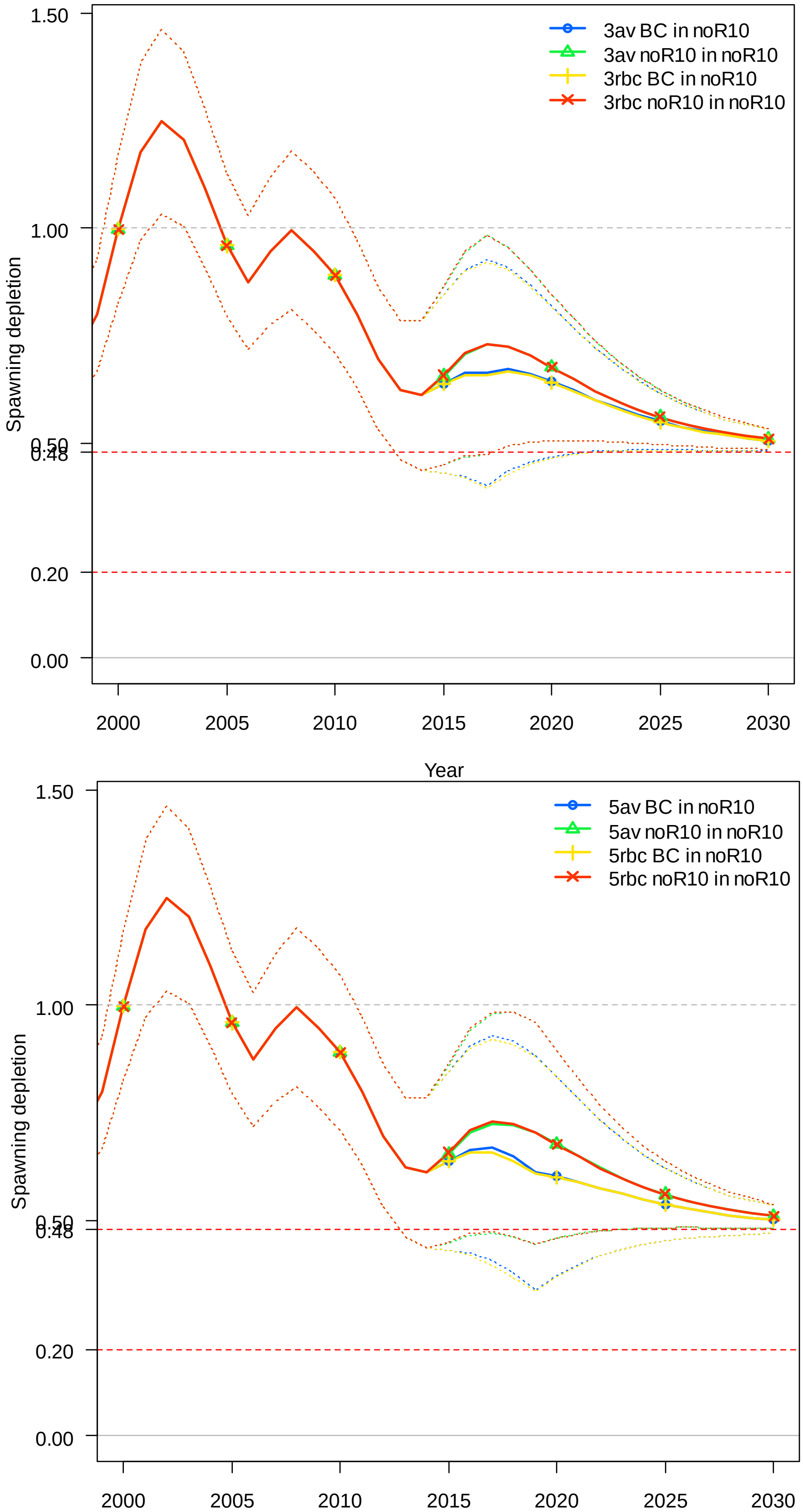


Figure 6.19. The consequence of alternative forecast catch series on the time series of female SSB (t) when placed in the model that does not estimate a 2010 recruitment (noR10). 3av = 3-year average, 5av = 5-year average, 3rbc = 3-years of annual retained catch, 5rbc = 5-years of annual retained catch. X in Y = catches from model X are placed into model Y.

6.6.3 *Further development*

1) Investigate the utility of the Francis weighting method.

2) Explore the lack of fit to the catch rate series of the non-spawning fishery and whether the poor fit is a data issue or model structure issue. Develop a model with a discard fleet so that the discard mass is removed from the population. This may resolve fits to the cpue and discard data, but is a rather brute force mechanism to do this.

6.7 Acknowledgements

Many thanks are due to the SESSF-WG for their assistance with model discussions and development. Malcolm Haddon is thanked for providing catch rate indices, Mike Fuller 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.

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6.9 Appendix 1: Age and length compositions for the base case model (BC)

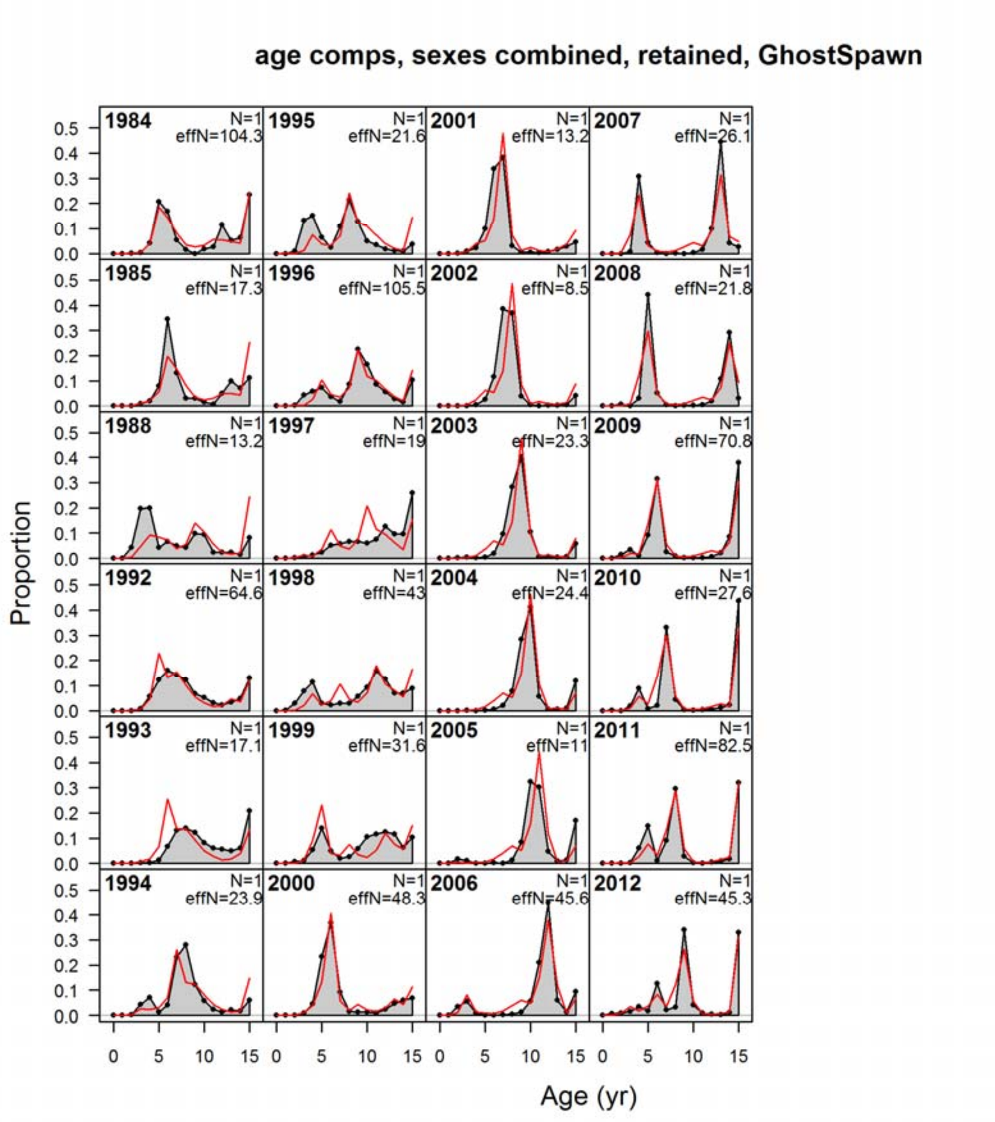

Figure 6.20. The Model BC fit to the age-composition data for the spawning fishery. Sexes combined.

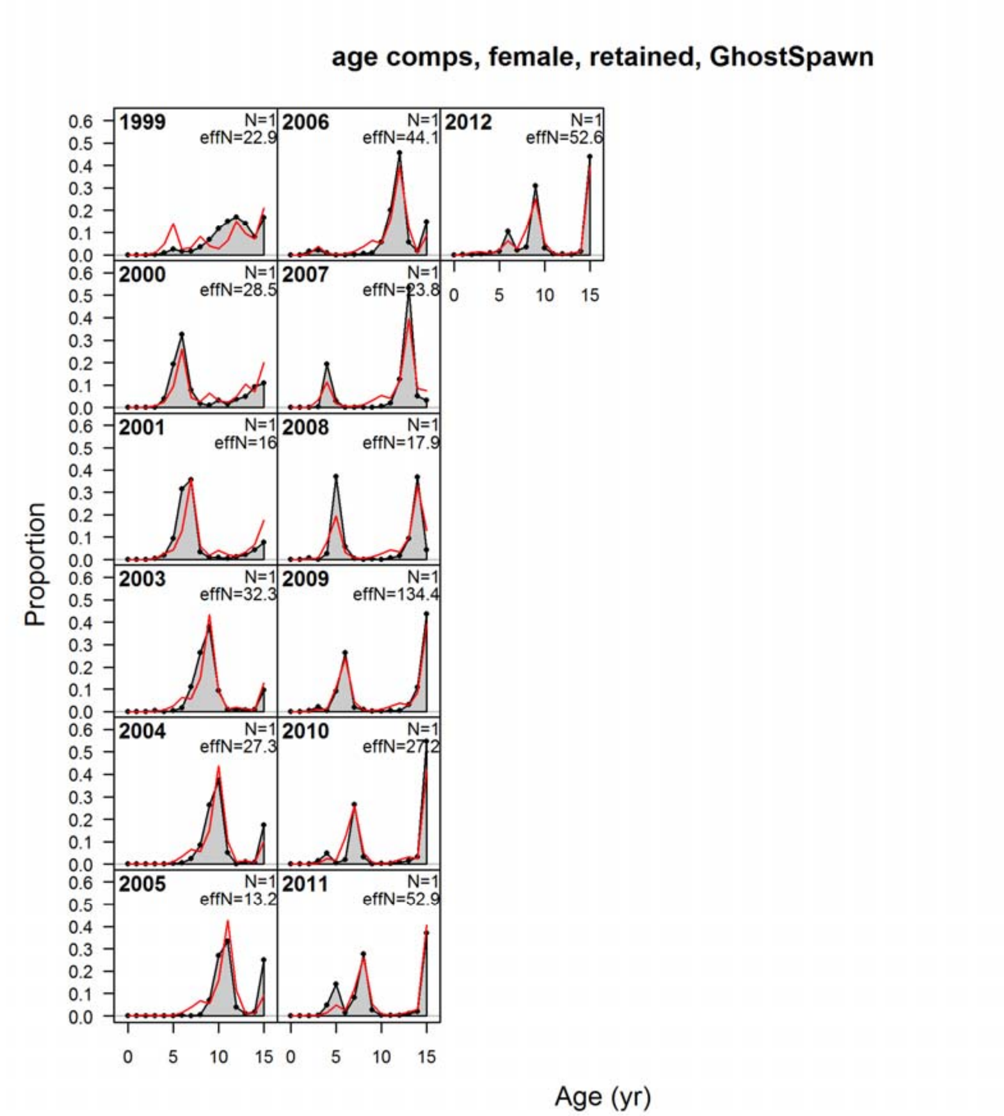

Figure 6.21. The Model BC fit to the female age-composition data for the spawning fishery.

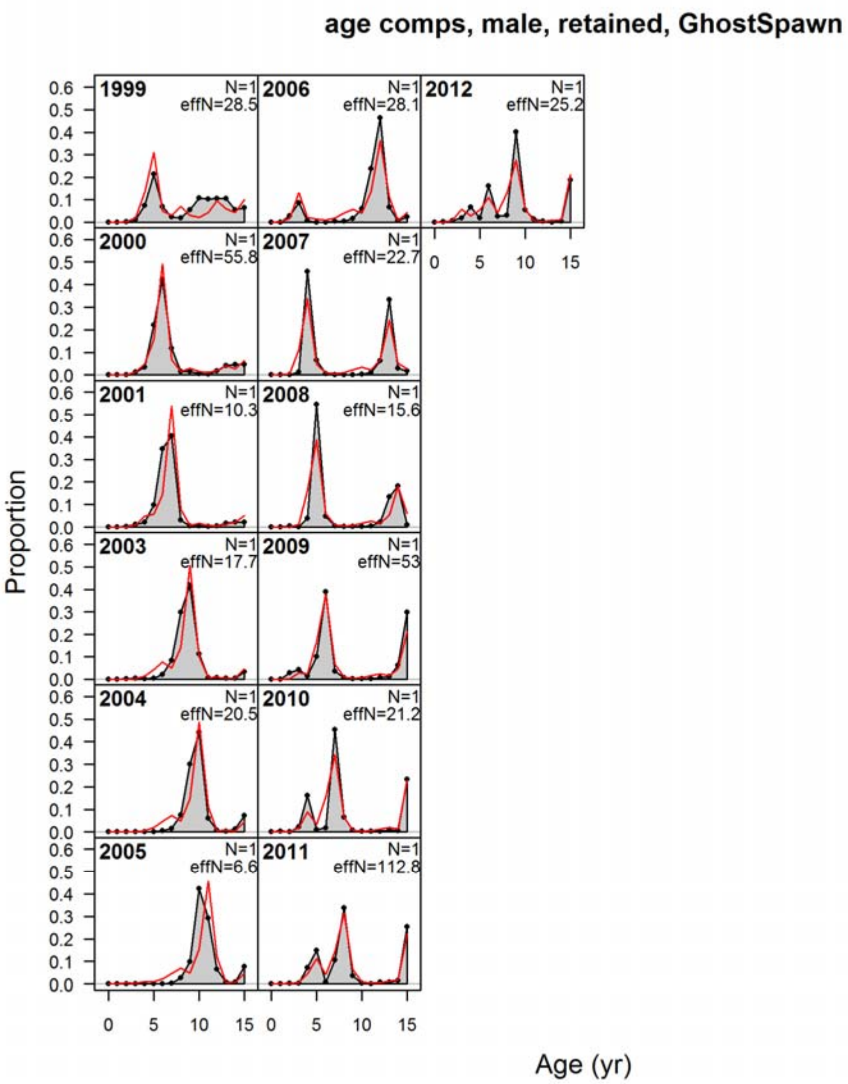

Figure 6.22. The Model BC fit to the male age-composition data for the spawning fishery.

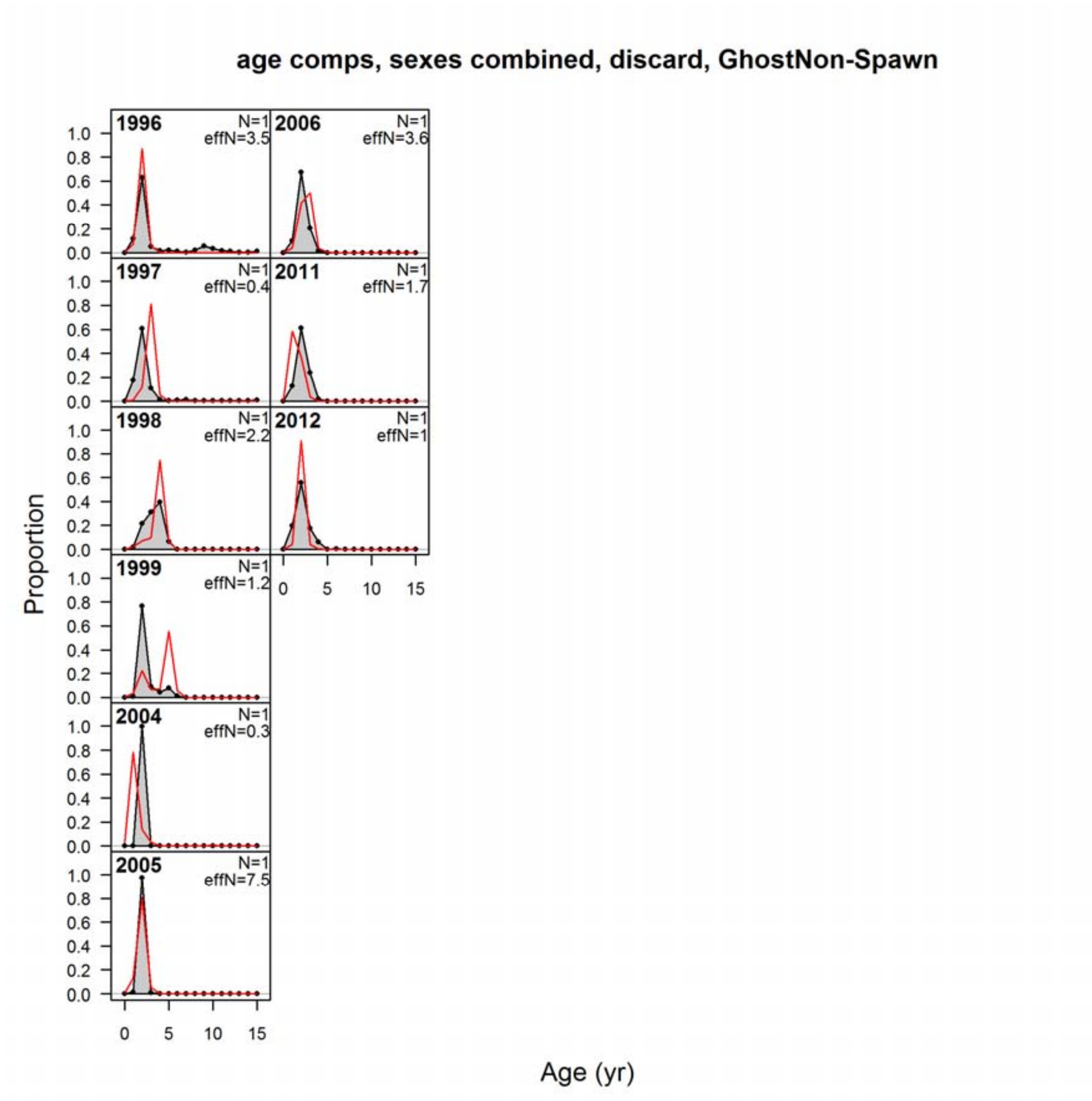

Figure 6.23. The Model BC fit to the discard age-composition data for the non-spawning fishery.

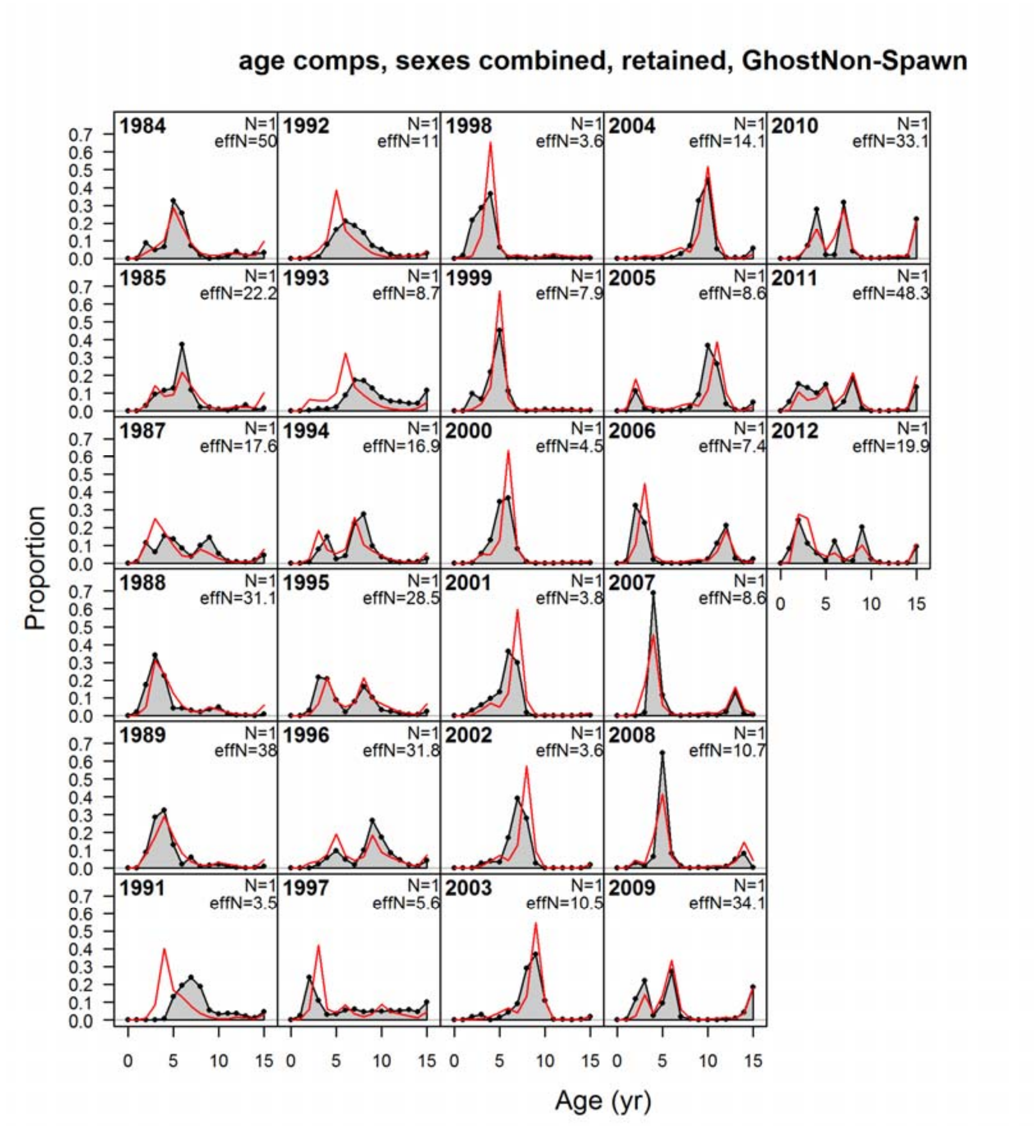

Figure 6.24. The Model BC fit to the retained age-composition data for the non-spawning fishery.

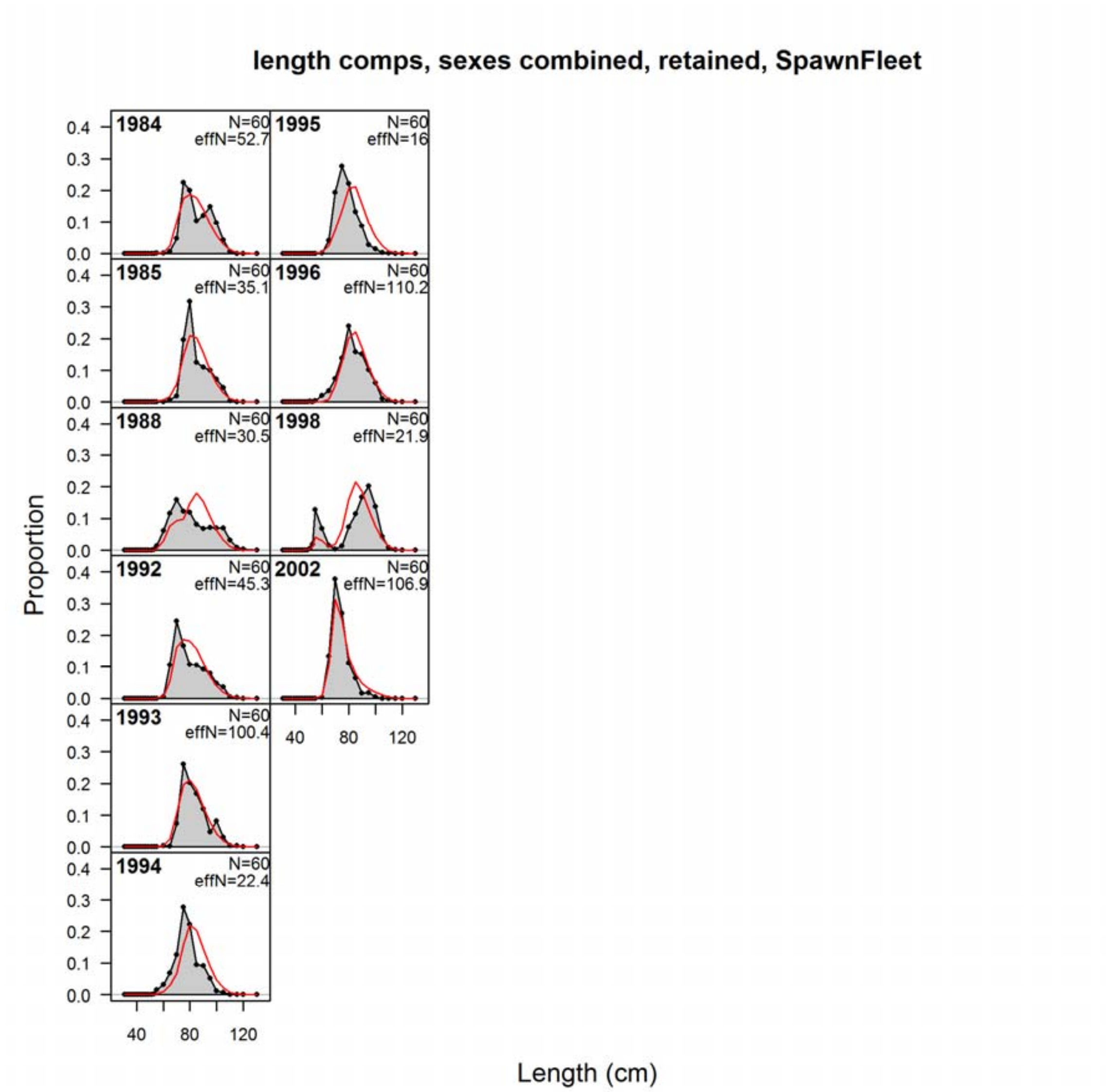

Figure 6.25. The Model BC fit to the retained length-composition data for the spawning fishery.

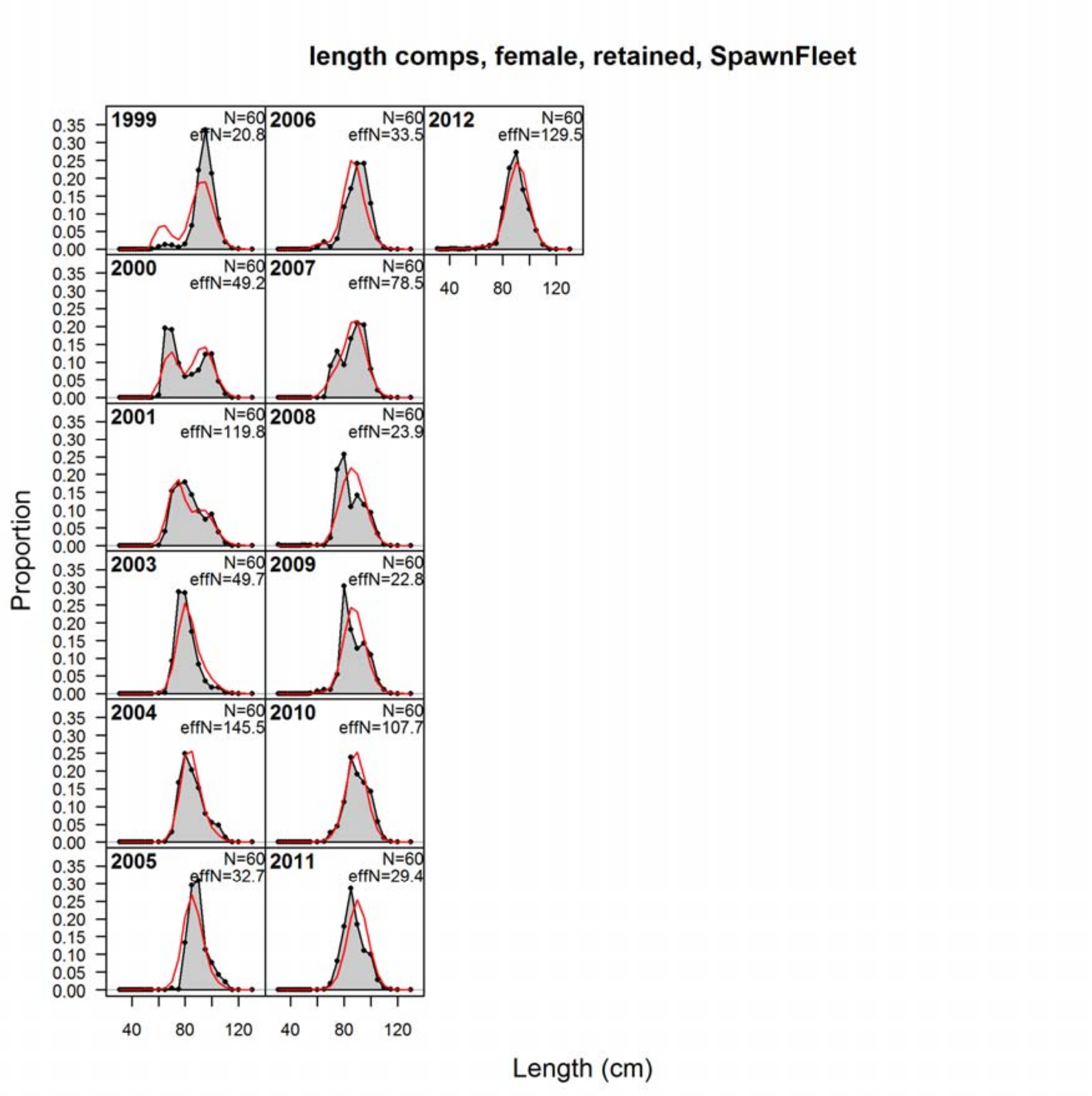

Figure 6.26. The Model BC fit to the retained female length-composition data for the spawning fishery.

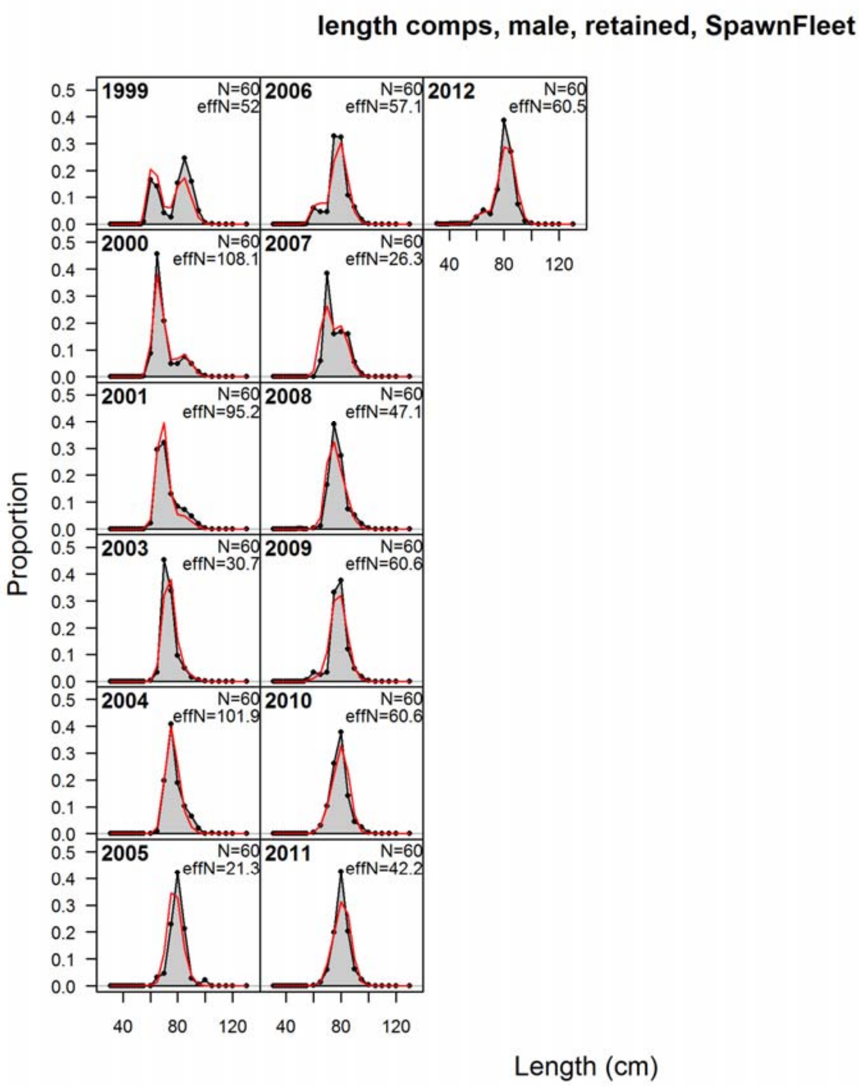

Figure 6.27. The Model BC fit to the retained male length-composition data for the spawning fishery.

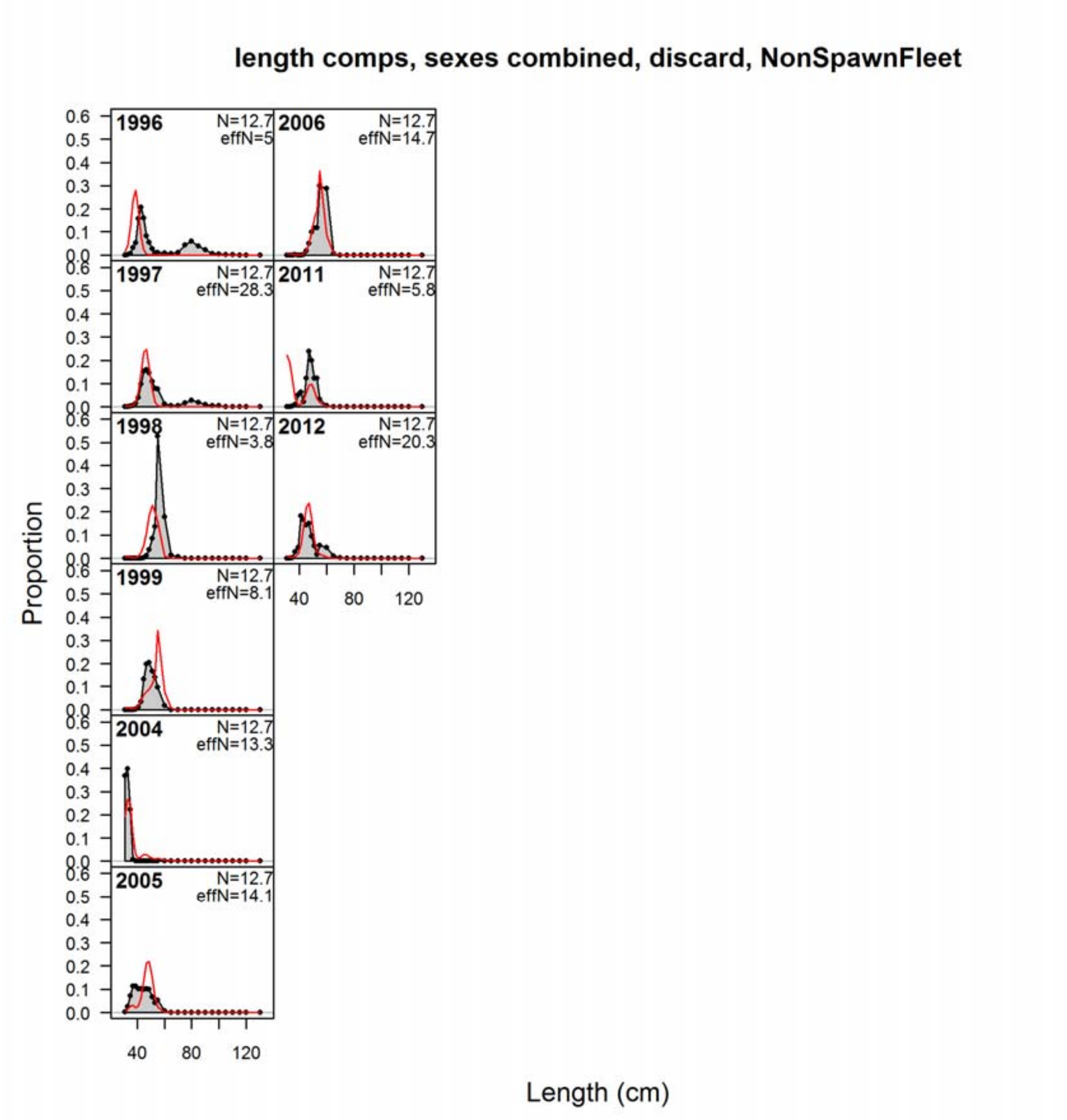

Figure 6.28. The Model BC fit to the discard length-composition data for the non-spawning fishery.

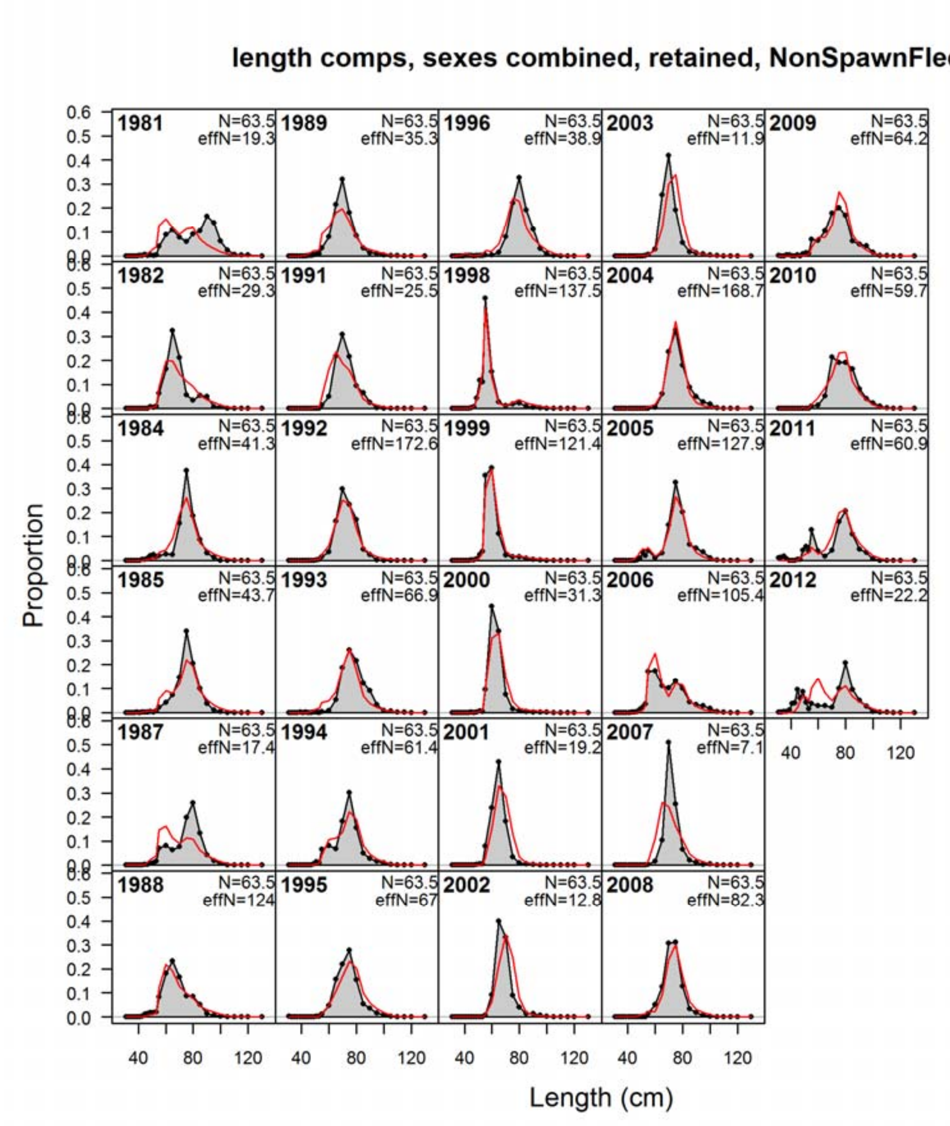

Figure 6.29. The Model BC fit to the retained length-composition data for the non-spawning fishery.

6.10 Appendix 2: Age and length compositions for model with 2010 recruitment not estimated (noR10)

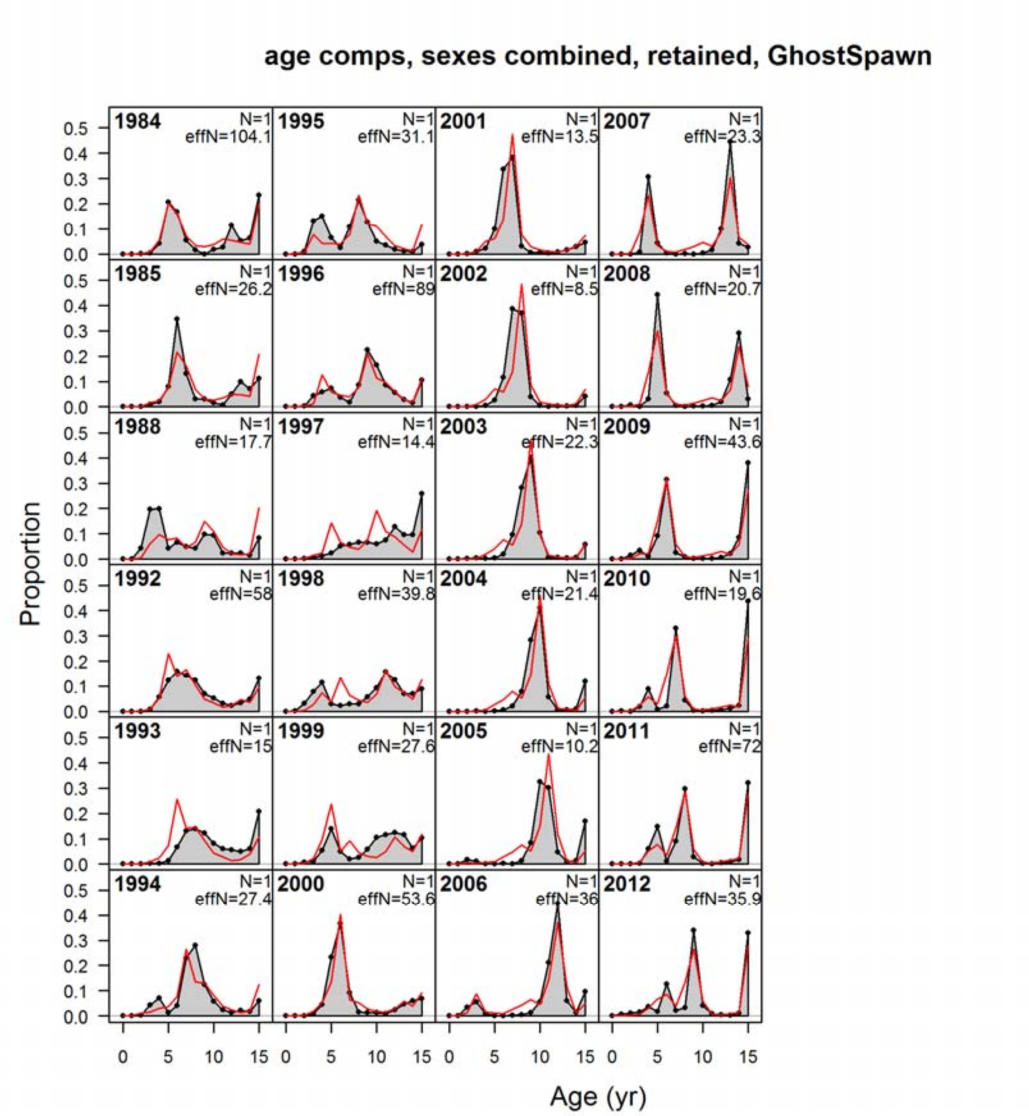

Figure 6.30. The Model noR10 fit to the age-composition data for the spawning fishery. Sexes combined.

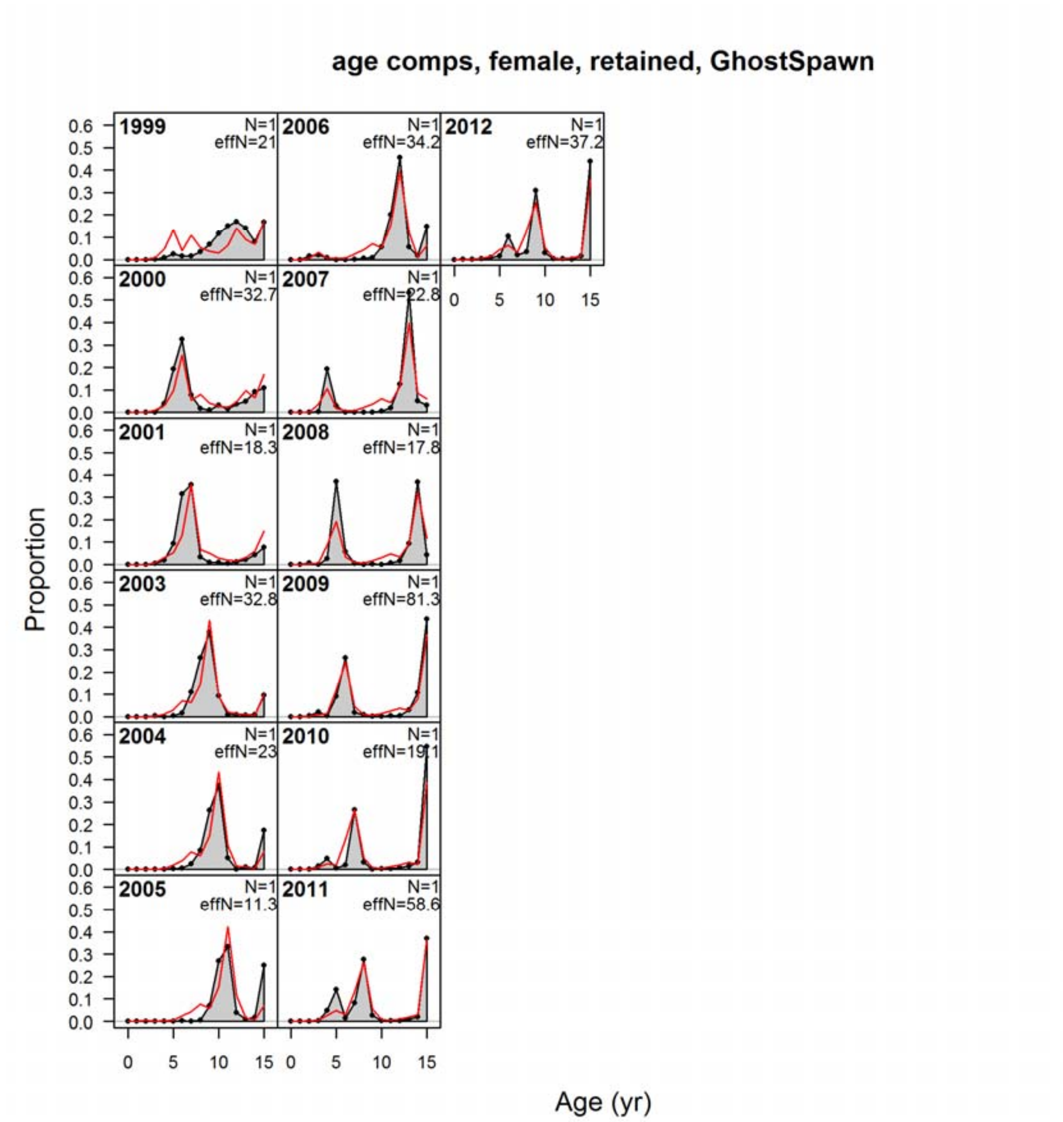

Figure 6.31. The Model noR10 fit to the female age-composition data for the spawning fishery.

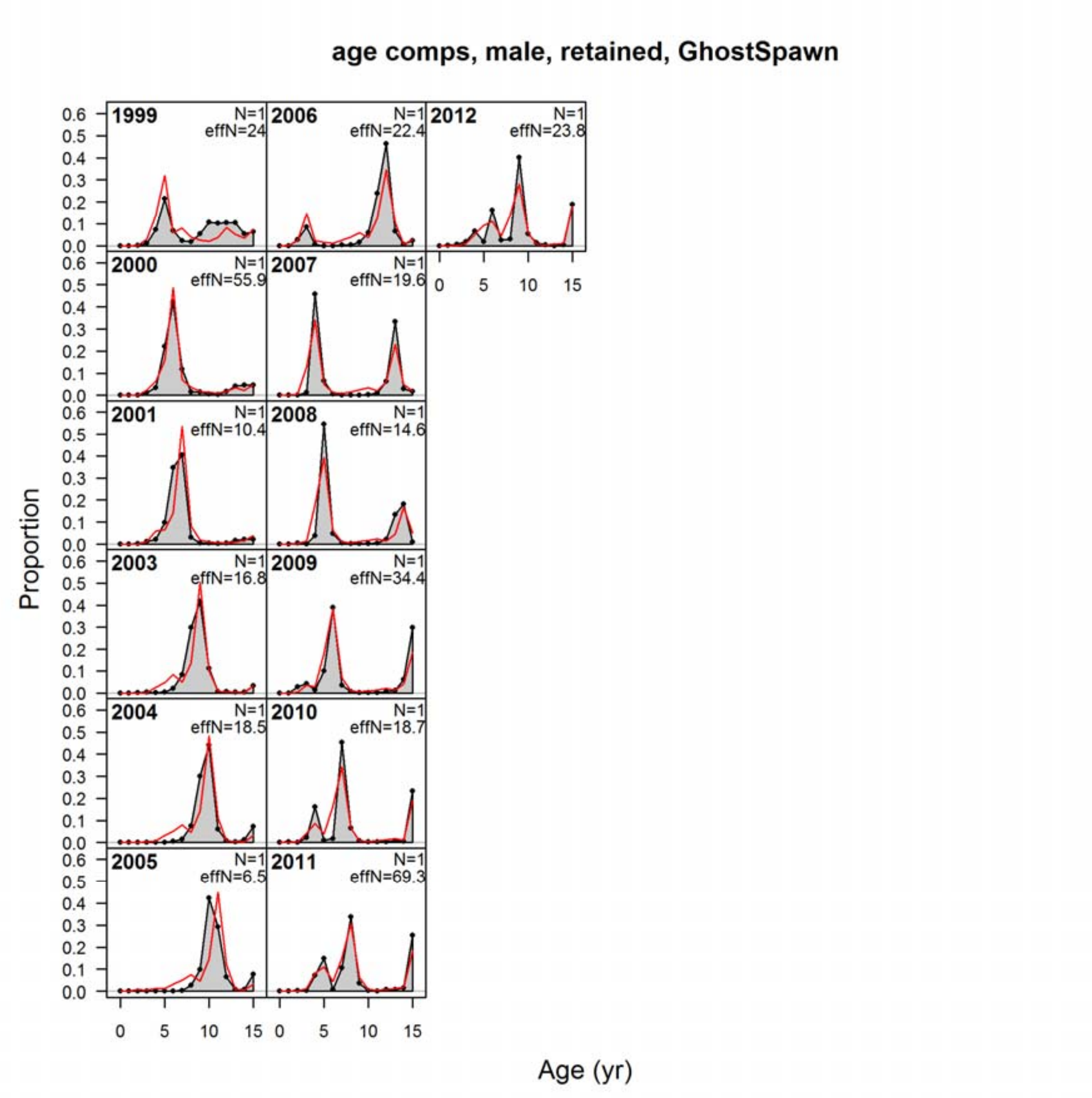

Figure 6.32. The Model noR10 fit to the male age-composition data for the spawning fishery.

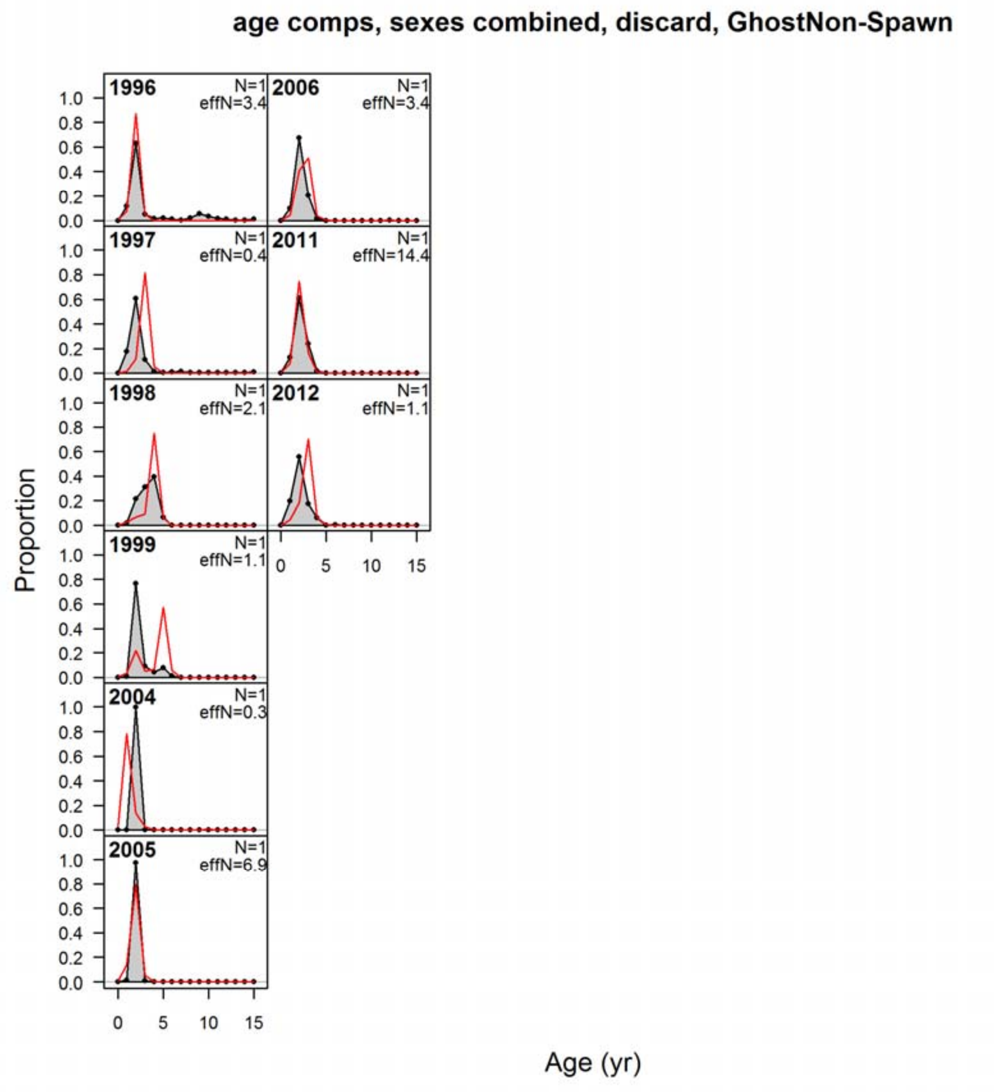

Figure 6.33. The Model noR10 fit to the discard age-composition data for the non-spawning fishery.

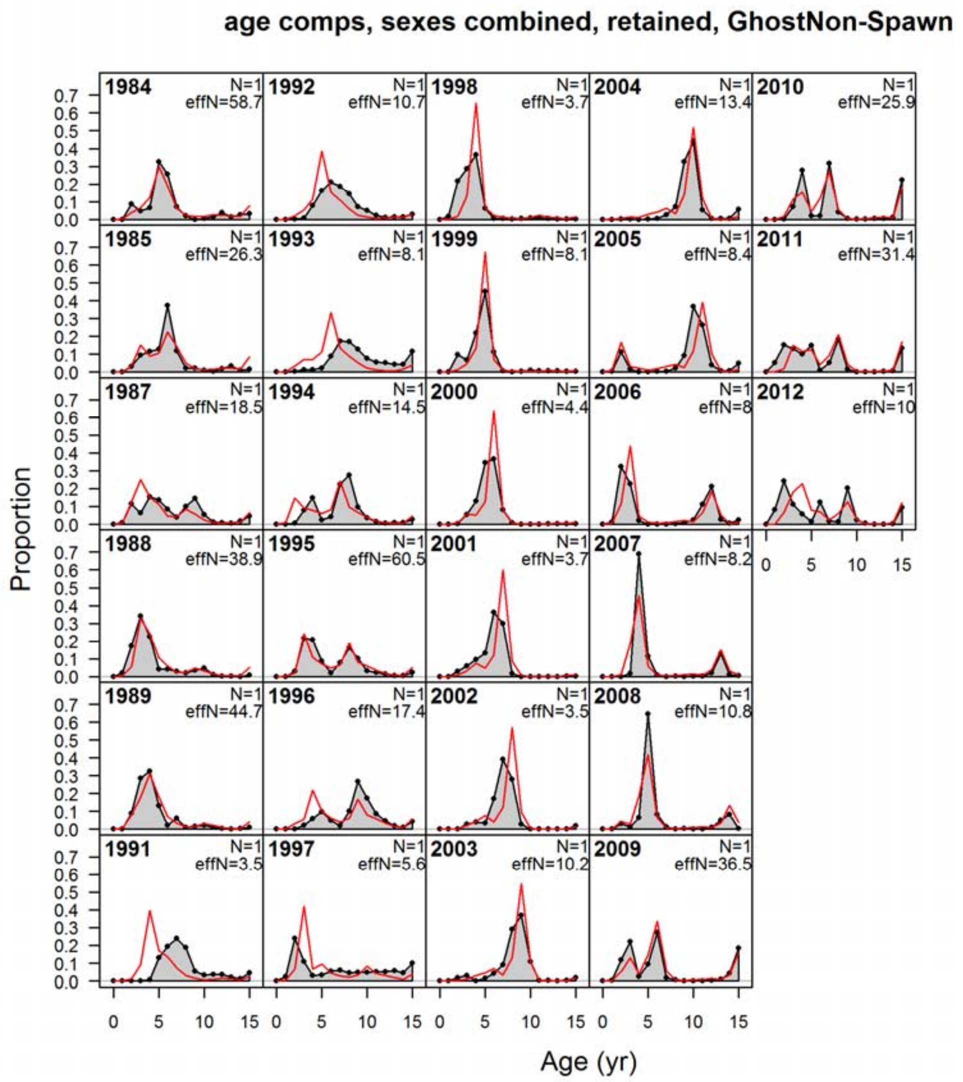

Figure 6.34. The Model noR10 fit to the retained age-composition data for the non-spawning fishery.

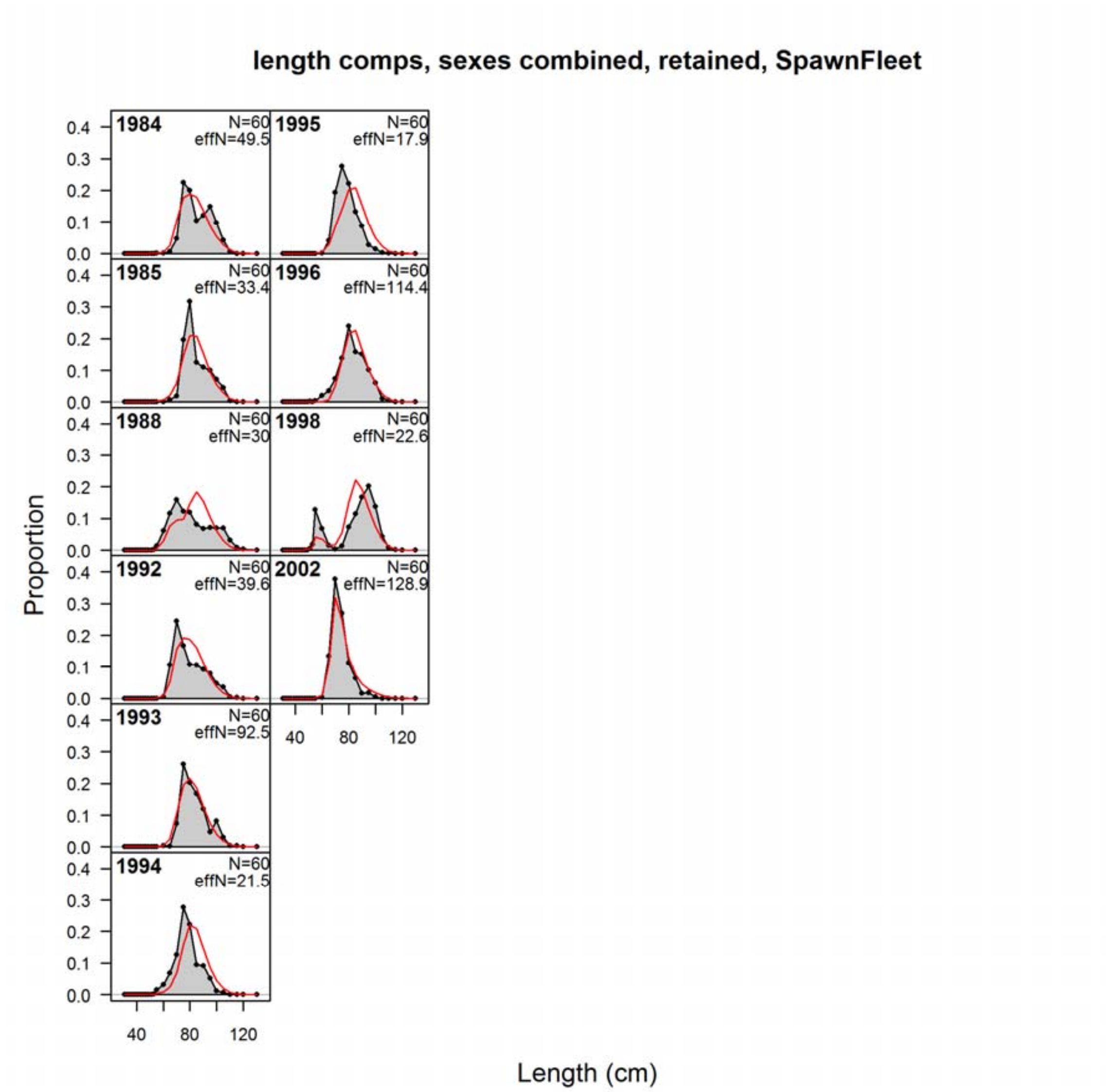

Figure 6.35. The Model noR10 fit to the retained length-composition data for the spawning fishery.

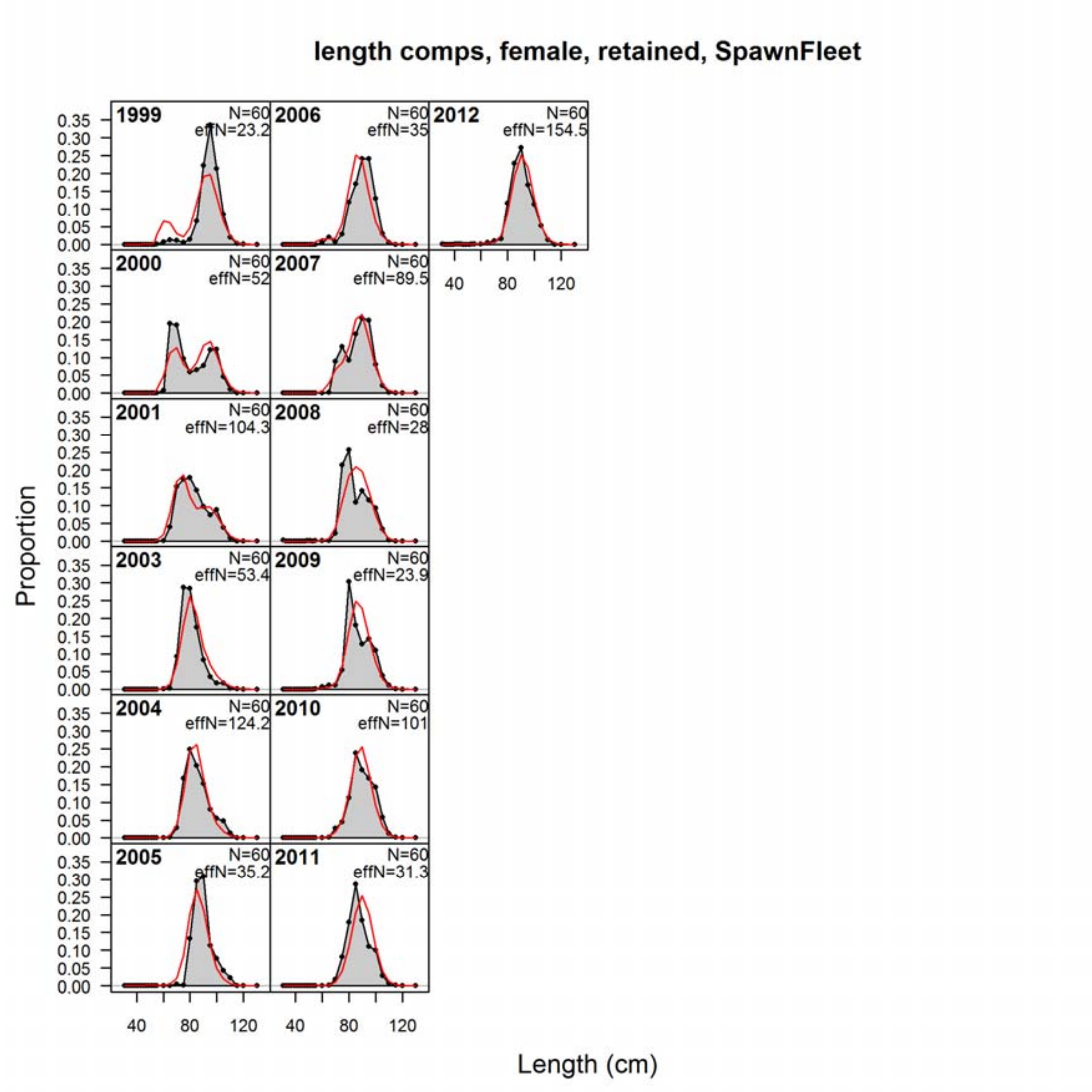

Figure 6.36. The Model noR10 fit to the retained female length-composition data for the spawning fishery.

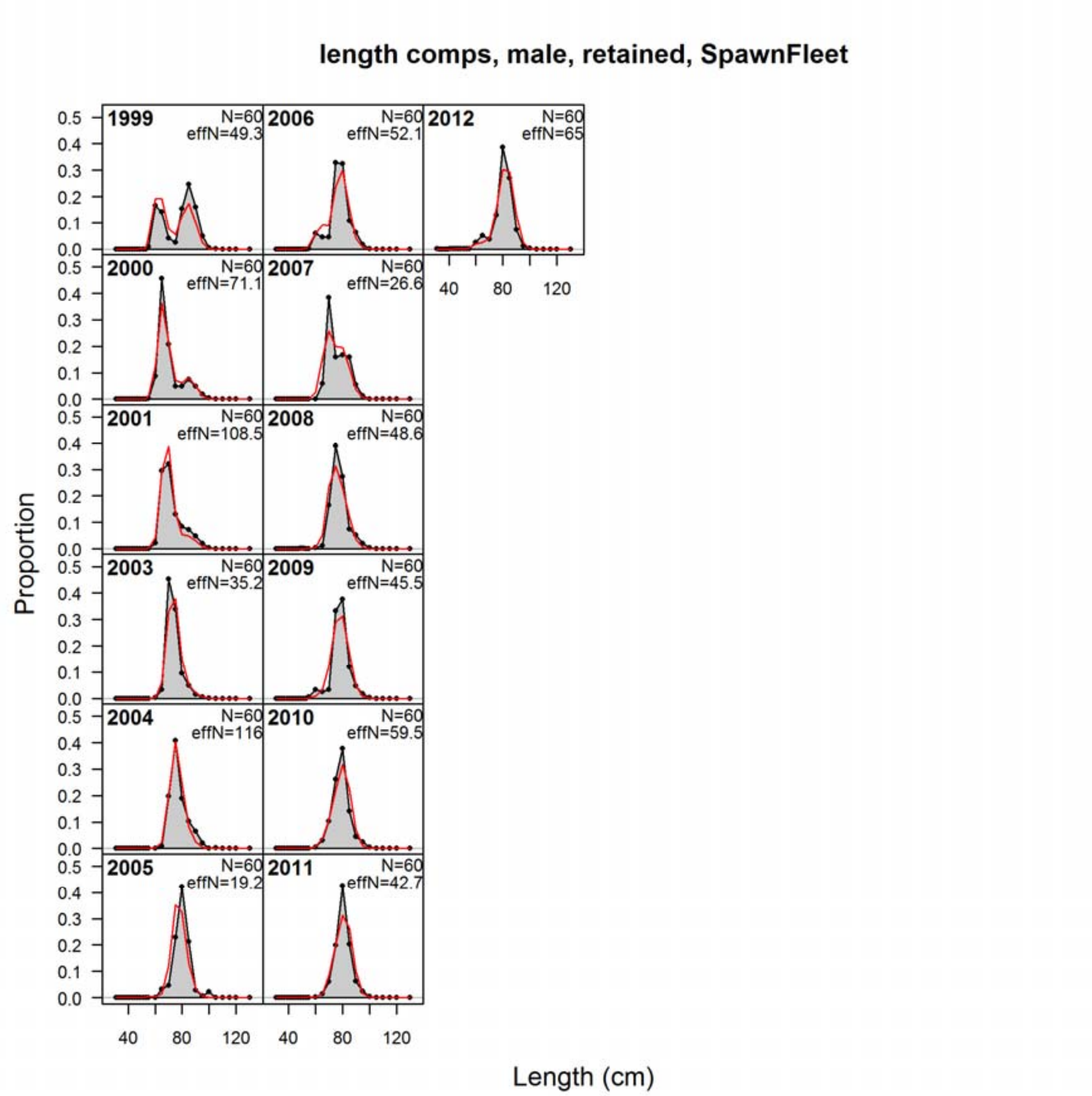

Figure 6.37. The Model noR10 fit to the retained male length-composition data for the spawning fishery.

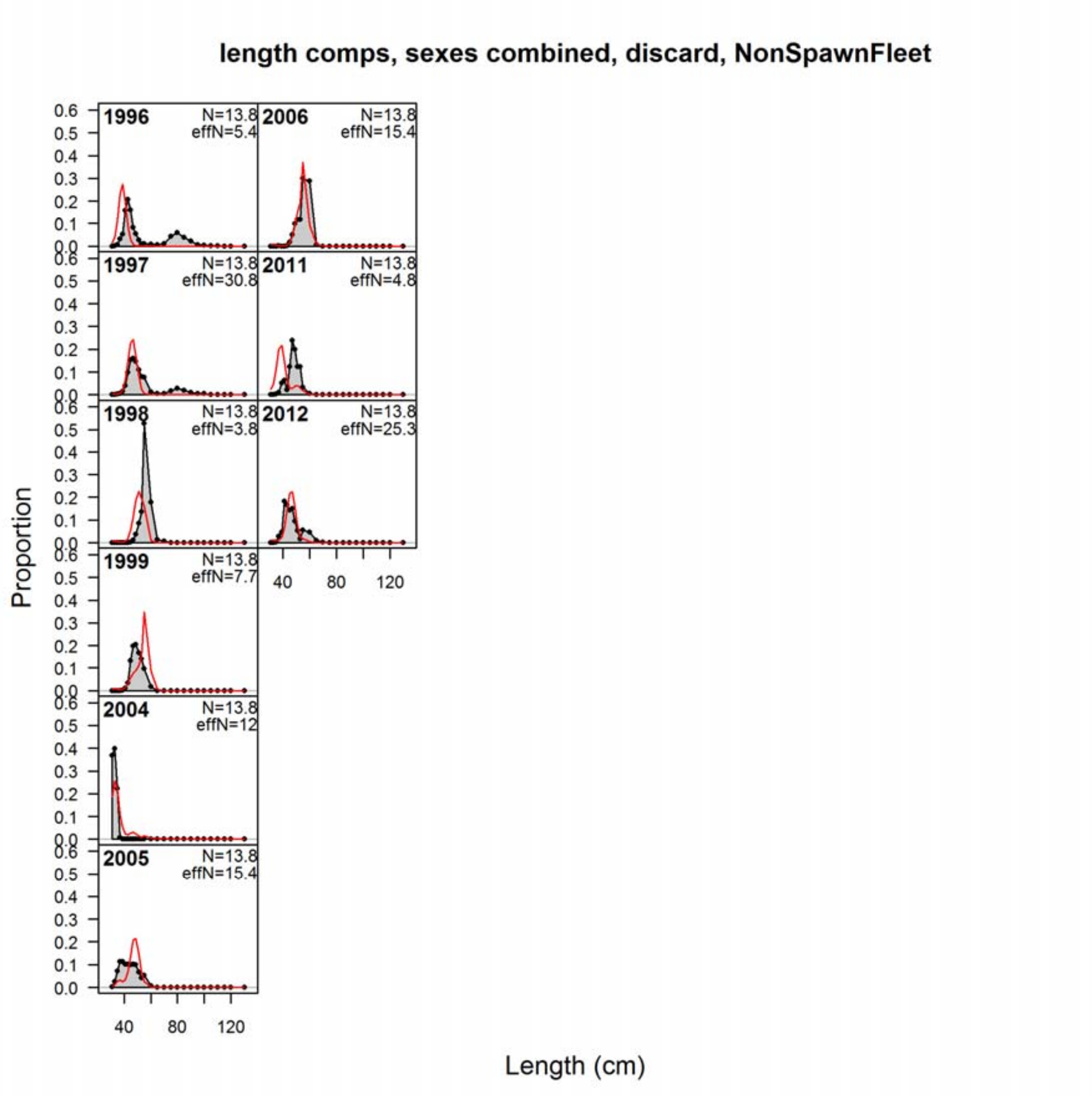

Figure 6.38. The Model noR10 fit to the discard length-composition data for the non-spawning fishery.

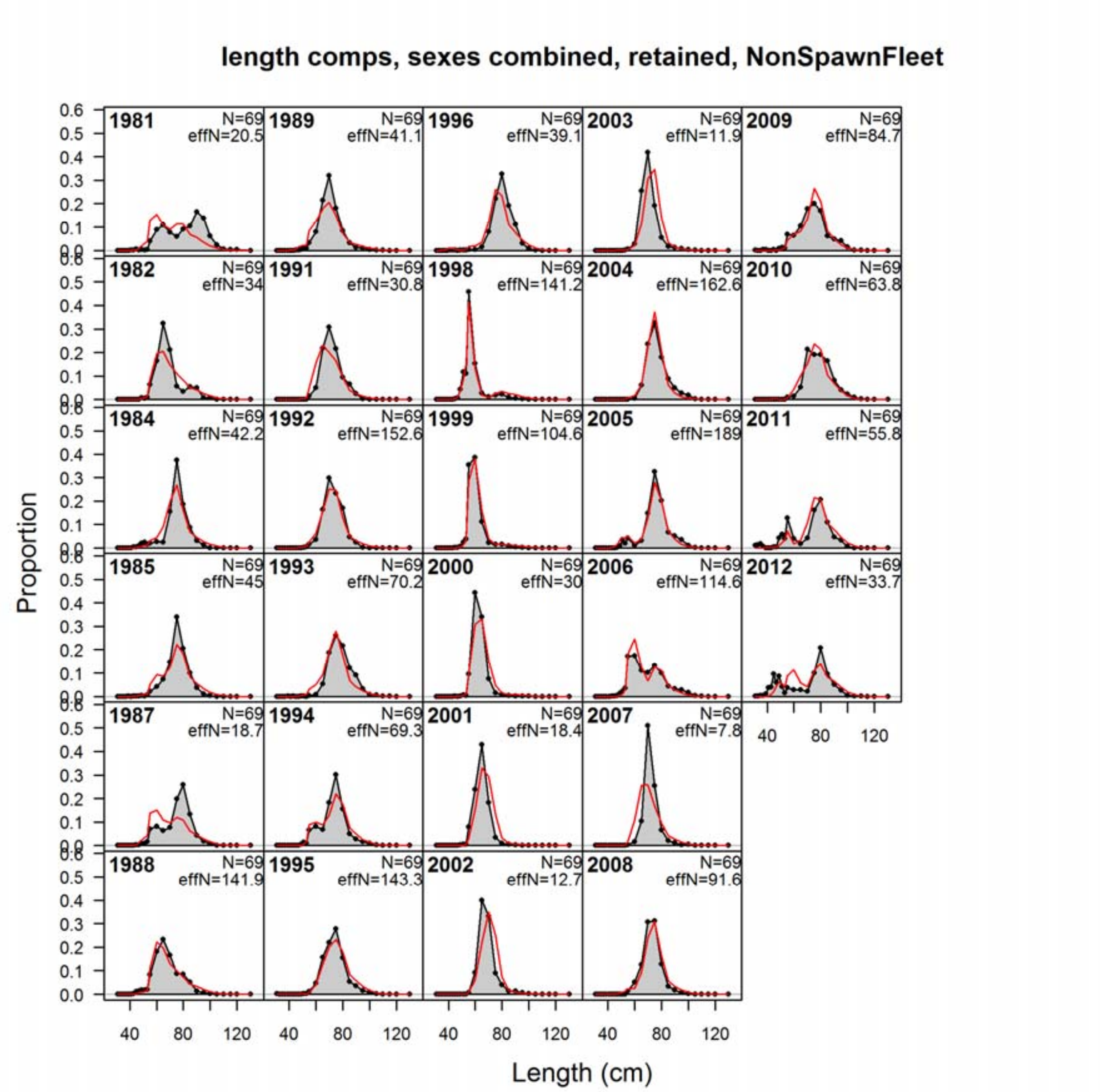

Figure 6.39. The Model noR10 fit to the retained length-composition data for the non-spawning fishery.