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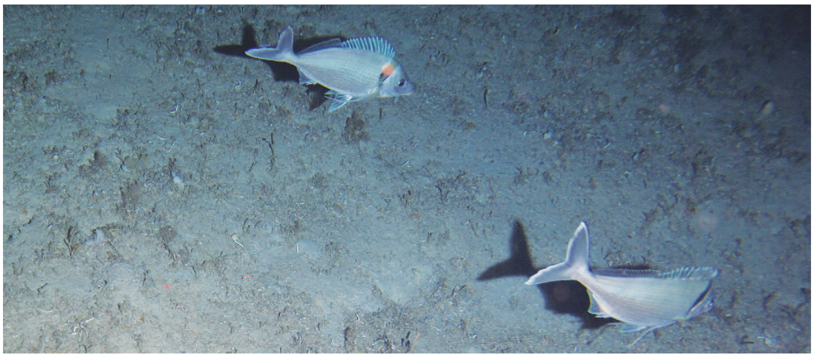
Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2018 and 2019



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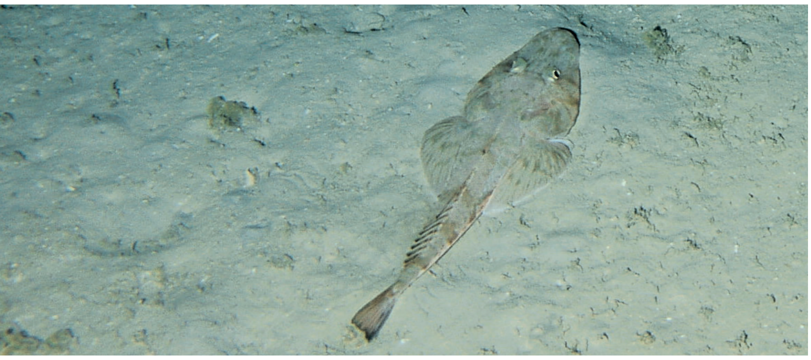
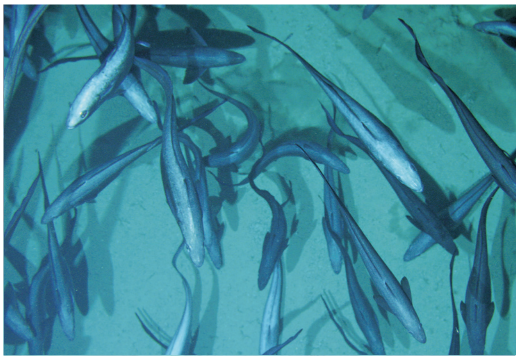

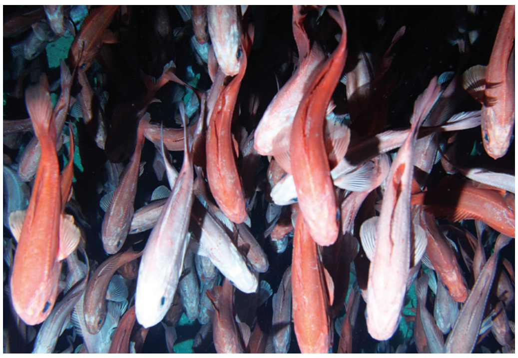

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Cover photographs

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

Report structure

Part 1 of this report describes the Tier 1 assessments of 2018. Part 2 describes the Tier 3 and Tier 4 assessments, catch rate standardisations and other work contributing to the assessment and management of SESSF stocks in 2018.

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

Part 1: 2018

G.N. Tuck
June 2020
Report 2017/0824

Australian Fisheries Management Authority

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

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9. Blue grenadier (*Macruronus novaezelandiae*) stock assessment based on data up to 2017 – development of a preliminary base case

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9.1 Executive Summary

This document presents the preliminary base case for an updated quantitative Tier 1 assessment of blue grenadier (*Macruronus novaezelandiae*) for presentation at the first SERAG meeting in 2018. The last full assessment was conducted during 2013 (Tuck, 2013). Relative to the 2013 assessment, this preliminary base case reflects updates by the inclusion of data to the end of 2017, which entails an additional five years of catch, discard, CPUE, length-composition and conditional age-at-age data and ageing error. This document describes the process used to develop a preliminary base case for blue grenadier through the sequential updating of recent data in the stock assessment, using the stock assessment package Stock Synthesis (SS-V3.30.12.00-safe).

The base case specifications agreed by the SlopeRAG in 2013 were generally maintained into the preliminary base case presented here. The main differences are: separating length-composition into onboard- and port- collected components, assigning stage-1 weights to length-compositions by shots (onboard) and trips (port); and using the latest methods for assigning final weights to the various data sources and the extent of variation in recruitment.

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, and 2003, with very little recruitment between these years. However, the recent recruitments are more stable than has been observed before. The trajectories of spawning biomass show increases and decreases in spawning biomass as strong cohorts move into and out of the spawning population.

Results show reasonably good fits to the length-composition data, implied age compositions, egg survey and acoustic survey. The fit to the discard mass has improved compared to the 2013 assessment result. As has been noted in previous blue grenadier assessments, the fit to the standardized non-spawning catch-rate index is generally poor; the model is unable to fit to the high early catch rates and over-estimates catch rates during the early 2000s.

The estimated virgin female spawning biomass (B_o) is 57,638t tonnes (SD 7,943t) and the projected 2019 spawning stock biomass will be 138% (SD 28.5%) of virgin female spawning biomass.

Further development and sensitivity testing should include the addition of the FIS data, time blocking of the discard mass data, an exploration of the observed differences between port and onboard length-compositions and testing the sensitivity of the model to not estimating recruitment for the most recent years.

9.2 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 stock of blue grenadier in the Southern and Eastern Scalefish and Shark Fishery (SESSF), with data updated by the inclusion of data up to the 2017 calendar year (length-composition and conditional age-at-length data; age reading-error matrices, standardized 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 length-composition data (by sex where possible) and conditional age-at-length data by fleet. Retained length-composition data from port and onboard samples are separated (a change from the last assessment following current protocols).

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 2013 assessment updated this assessment using SS-V3.22a (Tuck, 2013). Considerable changes to both the software and the tuning methods have occurred since the last assessment five years ago. As such, changes to key model outputs, such as the estimates of depletion and of the trajectory of spawning biomass, should be expected. The first bridging exercise (Bridge 1) will highlight changes that have occurred since 2013 simply through changes to software and assessment practices. The subsequent bridging exercise (Bridge 2) then sequentially updates the assessment model with new data through to 2017.

The use of SS allows for multiple fishing fleets and can fit simultaneously to several data sources and types of information. 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; Methot et al. 2018) and is not reproduced here. This document updates the assessment presented in 2013.

9.3 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. 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 information for 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 been caught off the east coast of Australia, and larvae from a likely eastern spawning area have been described by Bruce et al. (2001).

Blue grenadier are caught by demersal trawling. The global agreed TAC for the 2017/18 fishing season was 8,810 tonnes. The annual TACs are show in Table 9.2. There are two defined sub-fisheries: the spawning (Zone 40, months June, July and August) and non-spawning fisheries (all other months and zones).

9.4 Data

The assessment has been updated since the previous assessment (Tuck, 2013) by including recent length-composition and conditional age-at-length data from the spawning and non-spawning fisheries; updated standardized CPUE series (Sporcic and Haddon, 2018), the total mass landed and discarded, and updated age-reading error matrices. 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 as before. Data were formulated by calendar year (i.e. 1 Jan to 31 Dec) as in previous models.

9.4.1 *Catch data*

9.4.1.1 Landings

The landings from the logbook data were used to apportion catches to the spawning and non-spawning fisheries (Table 9.1). The logbook landings have been adjusted upwards to the CDRs 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 (CDR). As historical CDR data were only available from 1992, the average scaling factor from 1992 to 1996 (1.07) was used to scale the data for years between 1986 and 1991. Note that in years 2008 to 2013 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 9.2 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 9.1.

9.4.1.2 Discards

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 estimated using 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 9.2.The discard data were assumed to have standard error (on the log-scale) of 0.3.

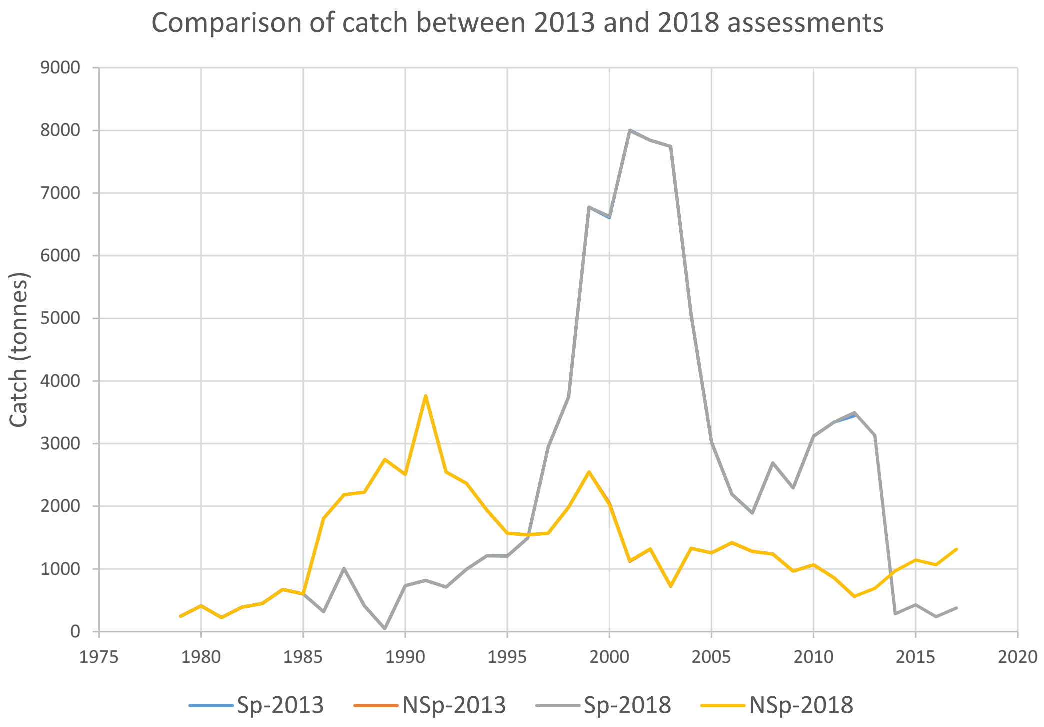


Figure 9.1. A comparison of total annual catches from the 2013 base case assessment and the updated catch used in the 2018 assessment for the spawning (Sp) and non-spawning (NSp) fisheries.

Table 9.1. 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. [1] average of CDR/logbook ratio from 1992 to 1996.

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	1.00	245	245
1980	410	410		1	1	410	410	820	1.00	410	410
1981	225	225		1	1	225	225	450	1.00	225	225
1982	390	390		1	1	390	390	780	1.00	390	390
1983	450	450		1	1	450	450	900	1.00	450	450
1984	675	675		1	1	675	675	1350	1.00	675	675
1985	600	600		1	1	600	600	1200	1.00	600	600
1986	246	1204		1.2	1.4	295	1685	1981	1.07	317	1806
1987	782	1455		1.2	1.4	939	2036	2975	1.07	1006	2183
1988	319	1485		1.2	1.4	383	2079	2461	1.07	410	2228
1989	36	1829		1.2	1.4	43	2560	2604	1.07	46	2745
1990	570	1671		1.2	1.4	684	2340	3023	1.07	733	2508
1991	637	2508		1.2	1.4	764	3511	4275	1.07[1]	819	3764
1992	509	1565	3259	1.2	1.4	610	2191	2802	1.16	710	2549
1993	812	1659	3362	1.2	1.4	975	2323	3298	1.02	994	2368
1994	974	1338	3151	1.2	1.4	1169	1873	3042	1.04	1211	1940
1995	911	1017	2775	1.2	1.4	1093	1424	2517	1.10	1205	1570
1996	1200	1061	3040	1.2	1.4	1439	1485	2925	1.04	1496	1544
1997	2623	997	4516	1	1.4	2623	1396	4019	1.12	2947	1569
1998	2739	1452	5733	1	1	2739	1452	4191	1.37	3746	1986
1999	5460	2054	9324	1	1	5460	2054	7514	1.24	6775	2549
2000	5735	1755	8655	1	1	5735	1755	7490	1.16	6627	2028
2001	7309	1032	9124	1	1	7309	1032	8340	1.09	7995	1129
2002	6825	1148	9161	1	1	6825	1148	7973	1.15	7842	1319
2003	7239	679	8471	1	1	7239	679	7918	1.07	7745	726
2004	4647	1219	6392	1	1	4647	1219	5865	1.09	5064	1328
2005	2880	1199	4283	1	1	2880	1199	4079	1.05	3024	1259
2006	2058	1332	3614	1	1	2058	1332	3390	1.07	2193	1420
2007	1815	1228	3176	1	1	1815	1228	3044	1.04	1894	1282
2008	2838	1304	3931	1	1	2838	1304	4141	0.95	2693	1237
2009	2723	1145	3259	1	1	2723	1145	3868	0.84	2295	965
2010	3384	1158	4185	1	1	3384	1158	4541	0.92	3118	1067
2011	3554	914	4201	1	1	3554	914	4467	0.94	3342	859
2012	3838	620	4060	1	1	3838	620	4458	0.91	3495	565
2013	3443	759	3821	1	1	3443	759	4201	0.91	3131	690
2014	271	928	1251	1	1	271	928	1200	1.04	283	968
2015	393	1054	1570	1	1	393	1054	1447	1.08	426	1144
2016	216	968	1305	1	1	216	968	1184	1.10	238	1068
2017	354	1237	1693	1	1	354	1237	1591	1.06	376	1316

Table 9.2. Landed and discarded catches for the spawning and non-spawning sub-fisheries by calendar year. These estimates have been scaled up to the landings data. Standardised CPUE (Sporcic and Haddon, 2018) 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 2017/2018 TAC and relative split of catch between the spawning and non-spawning fisheries of 2017.

Year	Spawning (t)	Non-spawning (t)	Discards (t)	TAC	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			1.5611
1987	1006	2183			1.994
1988	410	2228			2.1709
1989	46	2745			2.1776
1990	733	2508			2.166
1991	819	3764			1.545
1992	710	2549			1.252
1993	994	2368			0.9511
1994	1211	1940		10000	0.8586
1995	1205	1570	80	10000	0.5937
1996	1496	1544	975	10000	0.5361
1997	2947	1569	3716	10000	0.5574
1998	3746	1986	1329	10000	0.901
1999	6775	2549	123	10000	0.9466
2000	6627	2028	69	10000	0.6815
2001	7995	1129	10	10000	0.3927
2002	7842	1319	2	10000	0.391
2003	7745	726	8	9000	0.3258
2004	5064	1328	34	7000	0.5474
2005	3024	1259	294	5000[1]	0.6594
2006	2193	1420	175	3730	0.8803
2007	1894	1282	72	4113[2]	0.782
2008	2693	1237	18	4368[3]	0.8643
2009	2295	965	57	4700[3]	0.8004
2010	3118	1067	13	4700[3]	0.7975
2011	3342	859	169	4700[3]	0.6511
2012	3495	565	277	5208[3]	0.5187
2013	3131	690	469	5208[3]	0.9243
2014	283	968	680	6800[3]	1.1316
2015	426	1144	1032	8796[3]	1.2303
2016	238	1068	512	8810[3]	1.0448
2017	376	1316	718	8765[3]	1.1656
2018	378[4]	1323[4]		8810[3]	

9.4.2 *Catch rates*

Sporcic and Haddon (2018) provide the updated standardised catch rate series for the non-spawning fishery of blue grenadier (Table 9.2; Figure 9.2). The catch rate generally follows the fluctuations of stock size driven by large, but sporadic, recruitments. The standard deviation of log-CPUE is assumed to be 0.25, but an extra variance component is estimated for the CPUE index.

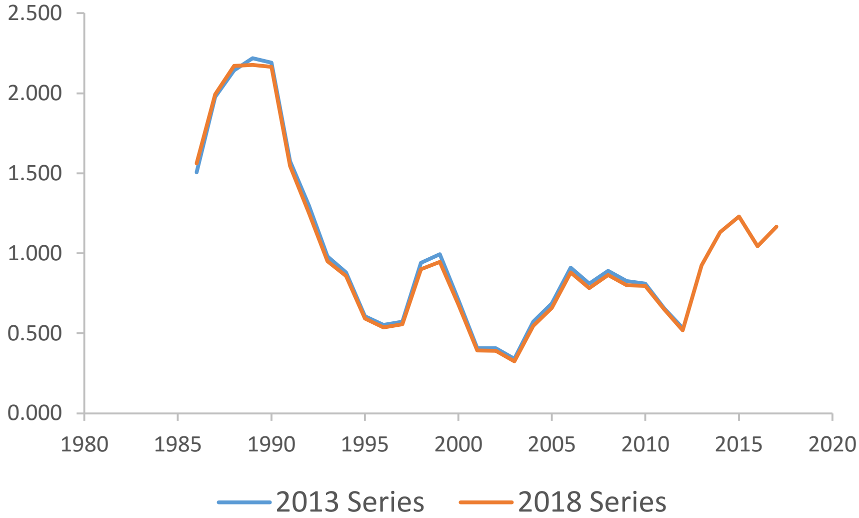


Figure 9.2. A comparison of the annual catch rates series for blue grenadier between the 2013 assessment (2013 Series) and 2018 (2018 Series).

9.4.3 *Length-composition and age data*

Length and age data are been included in the assessment as length-composition data and conditional age-at-length data by fleet and sex (the latter when available). Age-composition data are included in diagnostic plots but are not used directly when estimating the parameters of the population dynamics model. On-board and port length-compositions, when available, are used separately. This is a change in data protocol from the last assessment, where lengths from port and onboard measurements were combined. Prior to 2013, only port samples had been used to create the length-compositions. Plots of the observed length and age data are shown in later figures, with the corresponding model predicted values.

There had to be at least 100 measured fish for a retained and/or discard onboard and port length-composition data to be included in the assessment. For onboard samples, numbers of shots were used as the sampling unit (i.e. the stage-1 weights), with a cap of 200. For port samples, numbers of trips were used as the sampling unit, with a cap of 100. The number of fish measured is not used as the sample size because the appropriate sample size for length-composition data is probably more closely related to the number of shots (onboard) or trips (port) sampled, rather than the number of fish measured (Table 9.3).

Table 9.3. The years for which length data were available for the sub-fleets (spawning onboard = 1; spawning port = 3; non-spawning onboard = 2; non-spawning port = 4), sex (0 = no gender specified; female =1; male =2), partition (discard = 1; retained = 2). N is the number of shots (onboard) or trips (port). Red length data were excluded due to low sample sizes. [1] the average number of fish from years 1984 and 1988. [2] as no shot data were available, these estimates were based upon the average number of fish per shot for un-sexed fish for Fleet 1 (84.4). [3] the average number of fish from years 1984 and 1987-89. 4 as no shot data were available, these estimates were based upon the average number of fish per shot for Fleet 2 (40.7). [5] the average of 1980s samples, as no fish numbers or shot data were available.

Year	Nfish	Fleet	Sex	Part	N
1984	1,046	1	0	2	12[2]
1985	1,090[1]	1	0	2	12[2]
1988	1,133	1	0	2	12[2]
1998	1,948	1	0	2	29
1999	4,147	1	1	2	49
1999	5,929	1	2	2	70
2000	2,672	1	1	2	32
2000	2,956	1	2	2	35
2001	3,620	1	1	2	43
2001	4,256	1	2	2	50
2002	760	1	0	2	3
2003	2,700	1	1	2	32
2003	2,853	1	2	2	34
2004	1,307	1	1	2	15
2004	1,370	1	2	2	16
2005	198	1	1	2	2
2005	141	1	2	2	2
2006	3,184	1	1	2	38
2006	3,081	1	2	2	36
2007	2,957	1	1	2	35
2007	1,897	1	2	2	22
2008	3,073	1	1	2	36
2008	2,177	1	2	2	26
2009	3,868	1	1	2	46
2009	3,374	1	2	2	40
2010	2,488	1	1	2	29
2010	1,453	1	2	2	17
2011	4,207	1	1	2	50
2011	3,266	1	2	2	39
2012	3,939	1	1	2	47
2012	3,060	1	2	2	36
2013	6,371	1	0	2	76
2014	927	1	0	2	27
2015	1,861	1	0	2	19
2017	1,020	1	0	2	16

Year	Nfish	Fleet	Sex	Part	N
1993	207	2	0	1	2
1995	2,216	2	0	1	21
1996	5,225	2	0	1	73
1997	6,504	2	0	1	159
1998	2,212	2	0	1	97
1999	940	2	0	1	45
2000	132	2	0	1	4
2004	1,077	2	0	1	21
2005	5,139	2	0	1	51
2006	1,225	2	0	1	81
2007	16	2	0	1	3
2008	106	2	0	1	17
2009	97	2	0	1	10
2010	16	2	0	1	2
2011	792	2	0	1	47
2012	1,261	2	0	1	80
2013	1,450	2	0	1	119
2014	864	2	0	1	57
2015	500	2	0	1	51
2016	1,323	2	0	1	100
2017	531	2	0	1	12
1981	NA	2	0	2	100[5]
1982	NA	2	0	2	100[5]
1984	3,035	2	0	2	75[4]
1985	4,046[3]	2	0	2	99[4]
1987	4,063	2	0	2	100[4]
1988	6,660	2	0	2	164[4]
1989	2,424	2	0	2	60[4]
1996	829	2	0	2	40
1997	2,501	2	0	2	128
1998	7,771	2	0	2	146
1999	8,768	2	0	2	117
2000	8,036	2	0	2	65
2001	6,293	2	0	2	48
2002	5,325	2	0	2	43
2003	2,558	2	0	2	27
2004	5,499	2	0	2	46
2005	5,698	2	0	2	62
2006	6,098	2	0	2	117
2007	219	2	0	2	14
2008	575	2	0	2	29
2009	1,944	2	0	2	80
2010	1,801	2	0	2	45
2011	1,643	2	0	2	84
2012	1,707	2	0	2	85
2013	1,785	2	0	2	125
2014	1,358	2	0	2	72
2015	1,525	2	0	2	79
2016	2,822	2	0	2	121
2017	951	2	0	2	17

Year	Nfish	Fleet	Sex	Part	N
1992	774	3	0	2	6
1994	1,038	3	0	2	9
1995	465	3	0	2	4
1996	927	3	0	2	7
1997	851	3	0	2	7
1998	1,648	3	0	2	9
1999	1,079	3	0	2	9
2000	339	3	0	2	2
2014	82	3	0	2	1
2016	74	3	0	2	1
1991	927	4	0	2	10
1992	3,832	4	0	2	31
1993	1,487	4	0	2	10
1994	8,604	4	0	2	78
1995	6,938	4	0	2	61
1996	5,397	4	0	2	51
1997	11,191	4	0	2	85
1998	16,234	4	0	2	100
1999	13,286	4	0	2	100
2000	13,613	4	0	2	91
2001	11,959	4	0	2	87
2002	9,416	4	0	2	77
2003	5,023	4	0	2	37
2004	4,392	4	0	2	41
2005	6,310	4	0	2	48
2006	2,874	4	0	2	30
2007	809	4	0	2	7
2008	1,320	4	0	2	11
2009	1,035	4	0	2	18
2010	698	4	0	2	25
2011	1,678	4	0	2	54
2012	999	4	0	2	29
2013	1,457	4	0	2	35
2014	1,611	4	0	2	30
2015	1,799	4	0	2	24
2016	1,790	4	0	2	27
2017	1,808	4	0	2	27

9.4.4 *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 9.4 shows the estimates of spawning biomass with their corresponding cv's used in the assessment. Sampling cv's 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 cv's 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; Punt et al., 2015). The acoustic survey selectivity is matched to the maturity ogive, as it is assumed the acoustic survey observes mature fish on the spawning ground.

Table 9.4. 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)	24,690	16,295	18,852	42,882	56,330	24,450	24,787	20,622
c.v. in assessment model	0.30	0.46	0.30	0.30	0.52	0.30	1	0.33
Sampling cv	0.16	0.46	0.14	0.14	0.52	0.22	1	0.33

9.4.5 *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) tonnes. For the analysis considered here, the base-case egg estimates were used.

9.4.6 *The Fishery Independent Survey (FIS)*

Abundance indices for blue grenadier for the FIS surveys conducted between 2008 and 2016 are provided in Table 9.5 (Knuckey et al., 2017; J. Day, pers comm.). The length-composition data from the FIS are shown in Figure 9.3. These data have not been included in the preliminary base case model presented here but will be considered as a sensitivity in a subsequent report.

Table 9.5. FIS-derived abundance indices for blue grenadier with corresponding coefficient of variation (cv).

	2008	2010	2012	2014	2016
Blue grenadier (all)	15.83	3.38	10.75	19.65	58.20
c.v.	0.30	0.28	0.23	0.21	0.23
Spawning	65.06	17.97	15.12	44.52	211.29
c.v.	0.59	0.35	0.34	0.32	0.26
Non-spawning	30.26	9.25	10.57	50.26	10.39
c.v	0.57	2.31	0.93	2.19	0.34

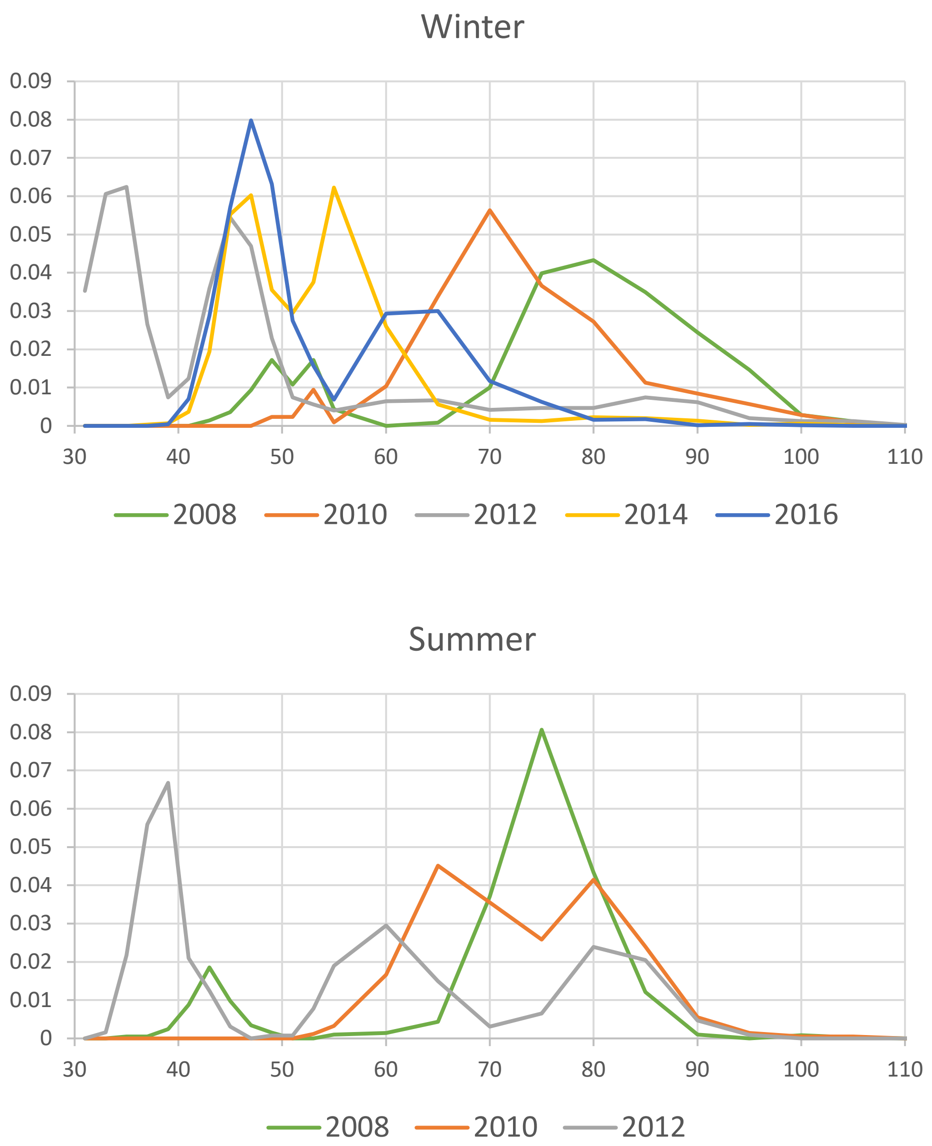


Figure 9.3. The length-compositions for blue grenadier from the FIS from the winter (top) and summer (bottom) surveys.

9.4.7 *Biological parameters and stock structure assumptions*

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 9.4.

The length weight-relationship for males and females was estimated from spawning fishery data over years 1999 to 2008 (Figure 9.4). Natural mortality for females is estimated when fitting the model and male natural mortality is assumed to be 20% greater than the value for females 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 assessments in 2011 and 2013 (Tuck, 2011; 2013) and in this assessment.

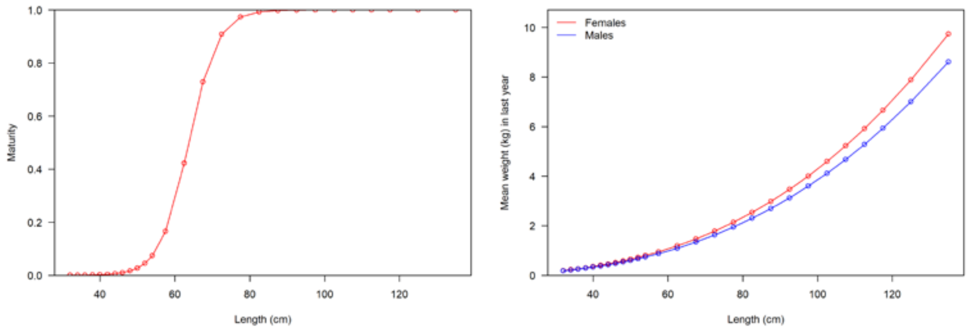


Figure 9.4. The maturity ogive by length for female blue grenadier (parameters from Russell and Smith (2006)) and the length-weight relationship for males and females.

9.4.8 *Age-reading eror*

Updated standard deviations for aging error by reader (A and B) have been estimated, producing the age-reading error matrix of Table 9.6 (A. Punt, pers. comm.). Reader A applied to years 1991-93 and 2007-17, and reader B to years 1984-90 and 1994-2006.

Table 9.6. The standard deviation of age reading error.

	St Dev	
Age	A	B
0	0.223	0.282
1	0.223	0.282
2	0.266	0.299
3	0.301	0.318
4	0.331	0.338
5	0.357	0.359
6	0.378	0.383
7	0.396	0.408
8	0.412	0.435
9	0.424	0.464
10	0.435	0.495
11	0.444	0.529
12	0.452	0.565
13	0.459	0.604
14	0.464	0.646
15	0.469	0.692
16	0.473	0.741
17	0.476	0.793
18	0.479	0.850
19	0.481	0.911
20	0.483	0.976

9.4.9 *Analytic approach*

The 2018 preliminary base case assessment of blue grenadier uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Version 3.30.12.00-safe, NOAA 2018). The methods utilised in SS are based on the integrated analysis paradigm. SS can allow for multiple seasons, areas and fleets, but most applications are based on a single season and area. Recruitment is governed by a stochastic Beverton-Holt stock-recruitment relationship, parameterized in terms of the steepness of the stock-recruitment relationship (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, acoustic and egg surveys, discard mass, discard and retained catch length-compositions, 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 2013 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 were initially set at a value equal to the standard error from a loess fit (0.25; Sporcic and Haddon, 2018), before being re-tuned to the model-estimated standard errors within SS. The acoustic estimates were tuned through the estimation of an extra parameter that adds to the model input standard errors. This is done within SS.

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 assessment. 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 2015. Deviations are not estimated before 1974 or after 2015 because there are insufficient data to permit reliable estimation of recruitment residuals outside of this time period.

j) The initial value of the parameter determining the magnitude of the process error in annual recruitment, σ_r, is set to 1.0, reflecting the large variation in recruitment observed for blue grenadier. The magnitude of bias-correction depends on the precision of the estimate of recruitment and time-dependent bias-correction factors were estimated following the approach of Taylor and Method (2011).

k) The population plus-group is modelled at age 20 years. The maximum age for age 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 several decades (see Punt and Smith 2001; Whitten et al., 2013). The 2018 base-case model treats conditional age-at-length 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 where the expected annual growth increment is based on the von Bertalanffy growth function but with a growth rate parameter that is determined by an expected value and a cohort-specific deviation. Cohort-specific deviations from average growth are estimated in the base case model for year classes 1978 to 2015.

m) Retained and discard onboard length sample sizes were capped at 200 and a minimum of 100 fish measured was required for length-composition data to be included in the assessment. For port samples, numbers of trips were used as the sampling unit, with a cap of 100. The number of fish measured is not used as the sample size because the appropriate sample size for length-composition data is probably more closely related to the number of shots (onboard) or trips (port) sampled, rather than the number of fish measured (Table 9.3).

The values assumed for some of the parameters of the preliminary base case model are shown in Table 9.7.

Table 9.7. Parameter values assumed for some of the non-estimated parameters of the base-case model (BC).

Parameter	Description	BC
M_f	Natural mortality for females	Estimated
M_m	Natural mortality for males	1.2* M_f
σ_r	Initial 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

9.4.9.1 Tuning method

Iterative rescaling (reweighting) of input CVs or input sample sizes is a repeatable method for ensuring that the expected variation of the different data streams is comparable to what is input (Pacific Fishery Management Council, 2018). Sampling standard deviations/ CVs and stage-1 effective sample sizes for most of the data (CPUE, survey indices, composition data) used in fisheries assessments underestimate their true variance by only reflecting measurement or estimation error and not including process (or model) error.

In iterative reweighting, the effective annual sample sizes are tuned/adjusted so that the input sample size was equal to the effective sample size calculated within the model. In SS3.30 there is an automatic adjustment made to survey CVs (CPUE).

1. Set the standard error for the log of relative abundance indices (CPUE, acoustic abundance survey, or FIS) to their estimated standard errors for each survey or for CPUE (and FIS values) to the standard deviation of a loess curve fitted to the logs of original data (which will provide a more realistic estimate compared to that obtained from the original statistical analysis). SS3.30 then re-balances the relative abundance variances appropriately.
2. The initial value of the parameter determining the magnitude of the process error in annual recruitment, σ_r, is set to 1.0, reflecting the large variation in recruitment observed for blue grenadier. The magnitude of bias-correction depends on the precision of the estimate of recruitment and time-dependent bias-correction factors were estimated following the approach of Taylor and Method (2011).

An automated tuning procedure was used for the remaining adjustments. For the conditional age-at-length and length-composition data:

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

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

9.5 Bridging

9.5.1 Bridging from the 2013 to 2018 assessments

The previous full quantitative assessment for blue grenadier was conducted in 2013 (Tuck, 2017) using Stock Synthesis (version SS-V3.22a, Methot, August 2012). The 2018 assessment uses the current version of Stock Synthesis (version SS-V3.30.12.00-safe, Methot et al., 2018).

As a first step in the process of bridging to a new model (referred to as Bridge 1), minor refinements and corrections (based on current best practice) were made to input values, and the data from the 2013 assessment were used with the new software (SS-V3.30). Bridging then continued (Bridge 2) by the inclusion in the model of updated data (pre-2013) and new data from 2013-17. These additional data included new catch, CPUE, length-composition and conditional age-at-length data, age-reading error and discard mass. The last year of recruitment estimation was extended to 2015 (from 2010 in the 2013 assessment). The usual process of bridging to a new model by adding new data piecewise and analysing which components of the data could be attributed to changes in the assessment outcome was conducted. Details of this process are provided below.

9.5.1.1 Bridge 1 – initial bridging steps from the 2013 assessment

The 2013 assessment was first updated and converted to the latest version of Stock Synthesis and the latest tuning method because the 2013 blue grenadier assessment used methods and software appropriate for that time (denoted "2013_Updated"). This allows a comparison of what the assessment would have produced in 2013 had current methods been applied. The most recent version of the software is Stock Synthesis version SS-V3.30.12.00-safe.

9.5.1.2 Bridge 2 – inclusion of new data

The data inputs to the assessment come from multiple sources: length-composition and conditional age-at-length data from the trawl fishery, updated standardized CPUE series (Sporcic and Haddon, 2018), the annual total mass landed and discarded, and age-reading error matrices. Data were formulated by calendar year (i.e. 1 Jan to 31 Dec) and separated by sub-fishery, being the spawning fleet (Zone 40; months 6, 7, 8) and the non-spawning fleet (all other periods and zones; excluding the GAB).

Starting from the converted and re-tuned 2013 base case model (2013_New_Tuned), additional and updated data to 2017 were added sequentially to develop a preliminary base case for the 2018 assessment:

1. Start with the re-tuned 2013 assessment (2013_Tuned).
2. Change final assessment year to 2017, add landed catch until 2017 (addCatch2017).
3. Add CPUE to 2017 (from Sporcic and Haddon (2018)) (addCPUE2017).
4. Update length-composition data, including both port and onboard length-compositions (addLength2017).
5. Add the updated age-reading error matrix and conditional age-at-length data to 2017 (addAge2017).
6. Change the final year for which recruitments are estimated from 2010 to 2015 (extendRecruitment).
7. Change the final year of cohort growth deviation estimation from 2009 to 2015 (extendCGD).
8. Add updated discard mass estimates to 2017 (addDiscard2017).
9. Retune using latest tuning protocols (2018_BC_Tuned).

9.6 Results

9.6.1 Bridging

9.6.1.1 Bridge 1 – initial bridging steps from the 2013 assessment

While the current year depletion has changed little, the magnitude of the spawning biomass has changed under the new tuning method (Figure 9.5). Changes to the absolute magnitude of spawning biomass are not uncommon in blue grenadier. Previous assessments illustrated by a retrospective analysis by Punt et al. (2017) have shown initial spawning biomass estimates of between 40,000t and 55,000t (Figure 9.5).

9.6.1.2 Bridge 2 – inclusion of new data

The inclusion of new catch and CPUE data does not influence the trajectory of female spawning biomass substantially (Figure 9.6). However, subsequent data sources (length, conditional age-at-length, recruitment, discards) all imply a reduction in relative and absolute biomass (Figure 9.6). Extending recruitment estimation to 2015 leads to a marked increase in recent spawning biomass. This is not surprising because this feature allows considerable additional flexibility to fit the available data, which then flow into the spawning and available biomass. Recruitment estimates over the last five to six years are generally large and stable (Figure 9.7). There was concern in 2013 (Tuck, 2013) regarding the actuality of the estimated recruitments for the 2009 and 2010 cohorts. With the addition of new data (lengths and ages in particular), it appears these recruitments have been maintained, and in fact have been followed by further strong annual cohorts, through to 2015. As before, the estimates magnitudes of the most recent recruitments should be treated with some caution. However, it is an encouraging sign for the stock that stable strong recruitment is evident (compared to historical period of recruitment failure that have been observed for this stock; Figure 9.7).

While current spawning depletion is estimated to be at or above virgin levels, the updated assessment illustrates that the spawning biomass trajectory dropped below the target from 2012 to 2015; a period when no assessment was conducted (Figure 9.6). The decline in biomass (and magnitude of the recruitments) can be seen through each addition of data, implying that it is not being driven by one data source (such as the discard mass) and is a consistent signal across data inputs.

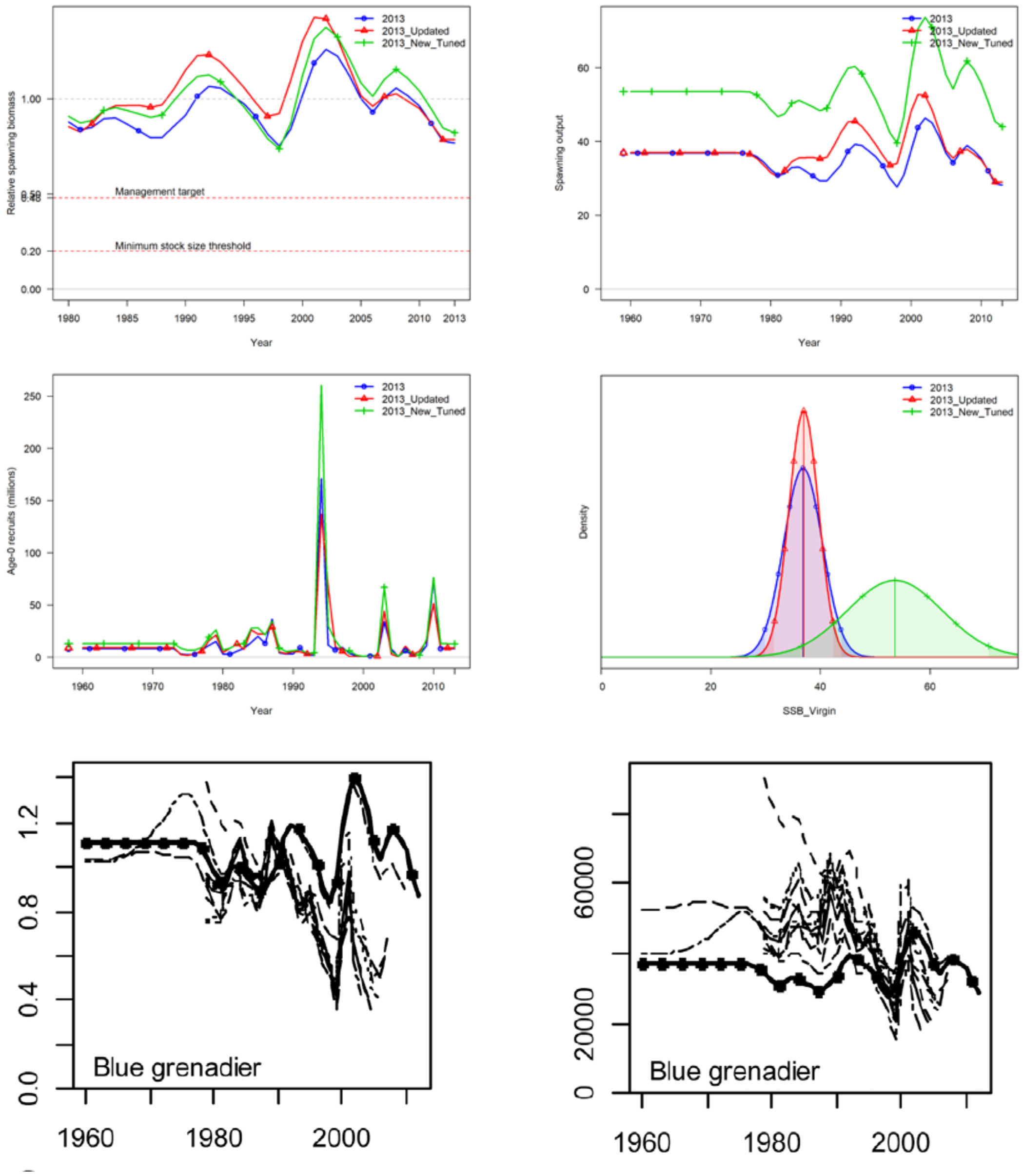


Figure 9.5. Comparison of the relative and absolute spawning biomass (top), recruitment time series (middle left) and virgin biomass estimate (middle right) for the 2013 assessment (2013), updates (2013_Updated, including the new version of SS) and the new tuning method applied (2013_New_Tuned). The lower figures show the relative (bottom left) and absolute (bottom right) spawning biomass trajectories for blue grenadier assessments dating back to the 1990s (from Punt et al. 2017). The solid line is the 2013 assessment.

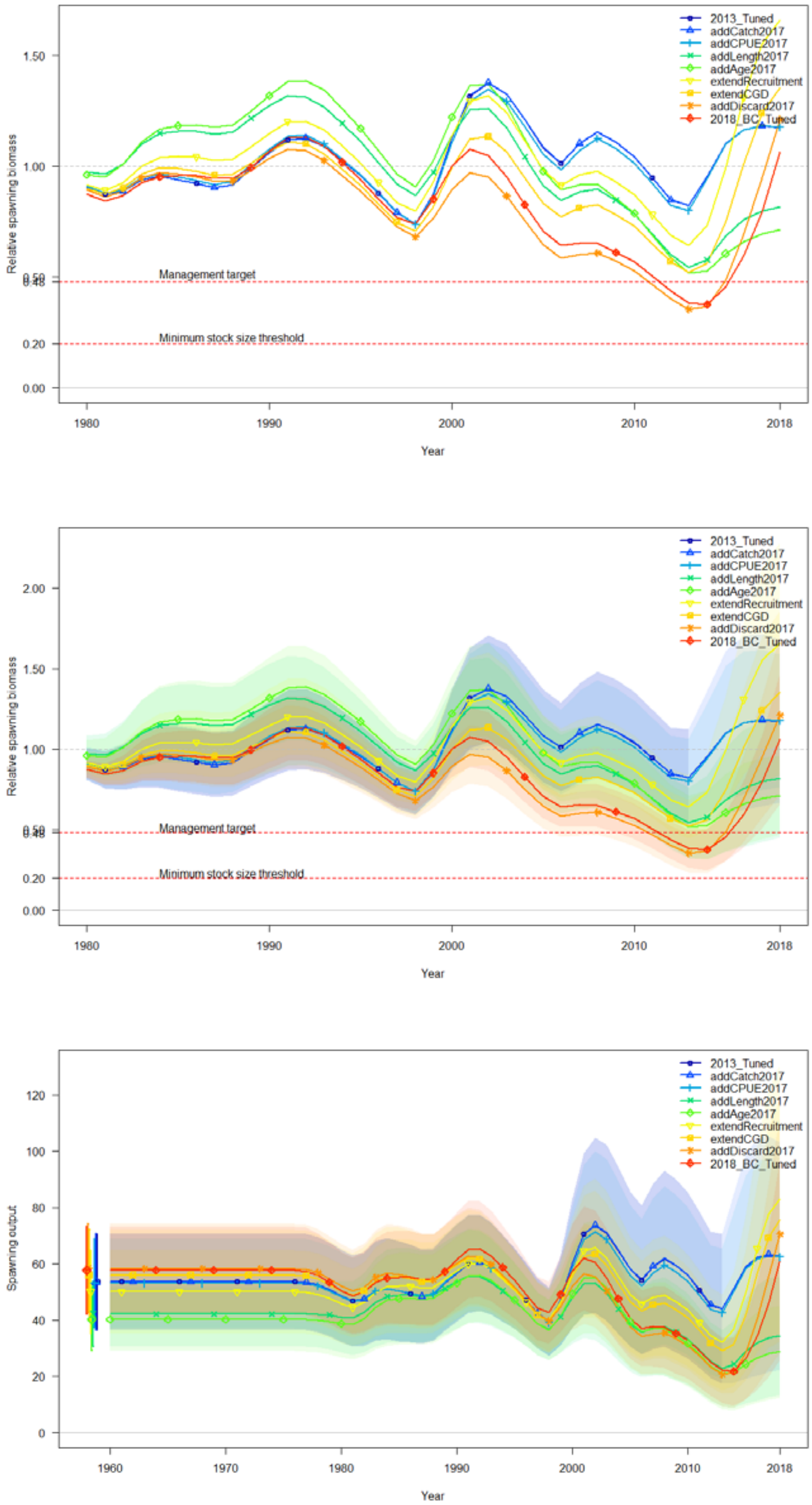


Figure 9.6. The relative (top, middle) and absolute (bottom) female spawning biomass trajectory for Bridge 2, moving from the re-tuned 2013 assessment (2013_Tuned), adding data sequentially through to the 2018 tuned base case (2018_BC_Tuned).

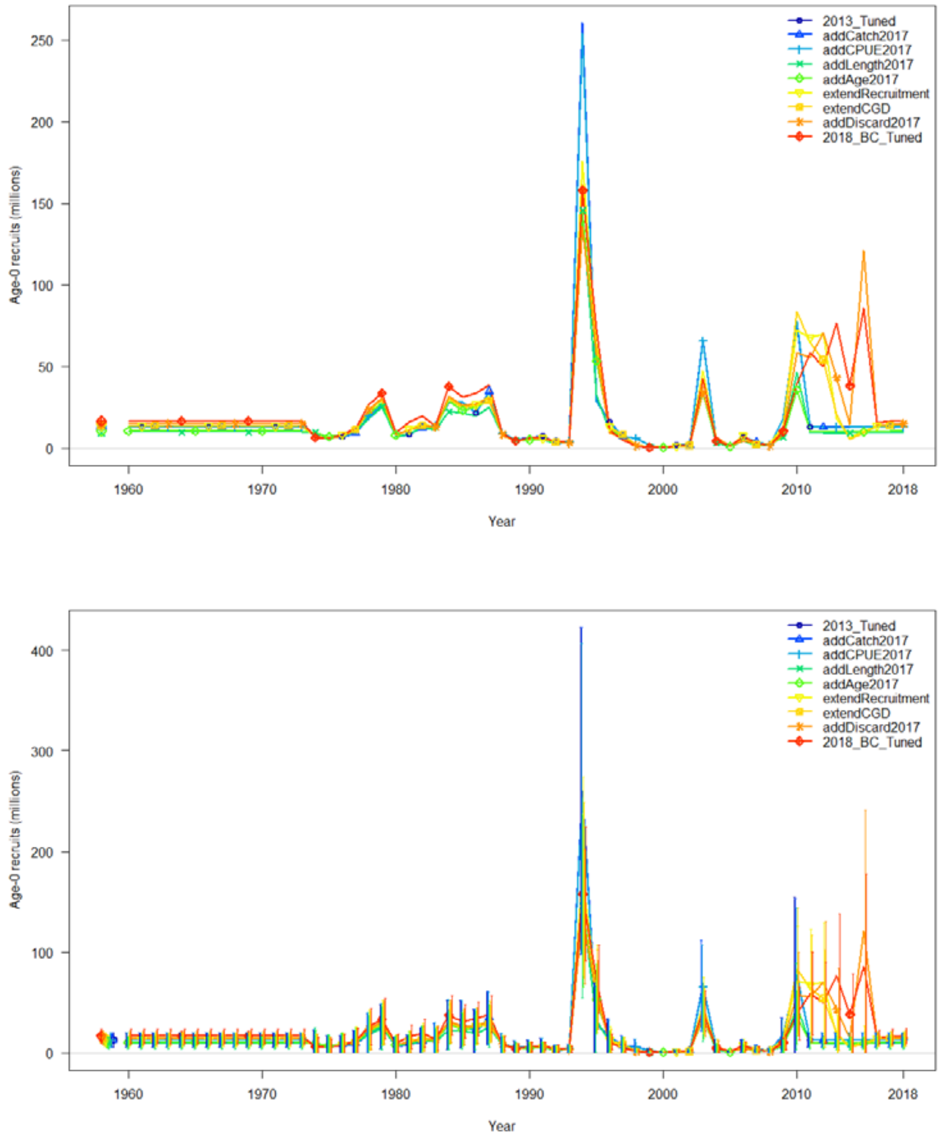


Figure 9.7. The time series of recruitments for blue grenadier for Bridge 2, moving from the re-tuned 2013 assessment (2013_Tuned), adding data sequentially through to the 2018 tuned base case (2018_BC_Tuned).

9.6.2 *The 2018 preliminary base case*

The base case specifications agreed by the SlopeRAG in 2013 were largely maintained into the 2018 preliminary base case presented here. The main differences are: separating length-compositions into onboard and port collected components, weighting length-compositions by shots (onboard) and trips (port) rather than fish measured; and using the latest new tuning methods.

The estimated time series of recruitment from the preliminary base-case assessment shows the typical episodic nature of blue grenadier recruitment, with strong year-classes in 1979, the mid-1980s, 1994, and 2003 with very little recruitment between these years. However, the more recent recruitments show a more stable level of annual recruitment than has been observed before. Noting there is now good evidence for strong recruitments in the early 2010s, the magnitude of the most recent recruitments (e.g.

2015) will remain somewhat poorly estimated until these fish move well into the available stock of the fishery (Figure 9.8).

The trajectories of spawning biomass and spawning biomass relative to the un-exploited level are shown in Figure 9.8. This shows the increases and decreases in spawning biomass as the strong cohorts move into and out of the spawning population. Results show reasonably good fits to the length-composition data, implied age compositions, egg survey and acoustic survey (Appendix). The fit to the discard mass has improved compared to the 2013 assessment. This is a result of a change in the shape of the non-spawning selectivity function that allows more small fish to be caught and subsequently discarded than the functions described in the 2013 assessment. As has been noted in previous blue grenadier assessments, the fit to the non-spawning CPUE is generally poor; the model is unable to fit to the high early catch rates and over-estimates catch rates in the early 2000s. However, fits improve from 2005 onwards. Fits to length compositions using onboard samples are generally very good. Port data show some mis-alignment, with the model expecting fish of a larger length. However, the implied age fits for both onboard and port samples are excellent across both fleets.

The estimated virgin female biomass is 57,638 tonnes (SD 7,943) (compared to 36,815 tonnes in the 2013 assessment). While a substantial increase in initial biomass compared to the 2013 assessment, this level of initial biomass has been observed before in blue grenadier stock assessments (see retrospective analysis in Figure 9.5). There is also clearly a degree of uncertainty regarding the initial biomass as can be seen from the likelihood profile for ln*Ro* (Figure 9.15) and the 95% confidence intervals of the biomass trajectory (Figure 9.8, middle). Also, the estimated biomass when fit to the 2018 egg survey, which influences the magnitude of biomass, has moved closer to the estimated point in 1994 and is larger (in terms of biomass) than the corresponding estimate in 2013 (see Appendix, comparison of 2013 and 2018 assessments), and in doing so has improved the fit to the egg survey points.

In the 2013 assessment, the estimated spawning biomass under the base-case scenario for 2012 was 77% of virgin stock biomass (SB_0) and the estimated spawning biomass in 2014, which was used in the harvest control rule, was approximately 94% SB_0.

The 2018 preliminary assessment estimates that the projected 2019 spawning stock biomass will be 138% SB_0. (SD 28.5%).

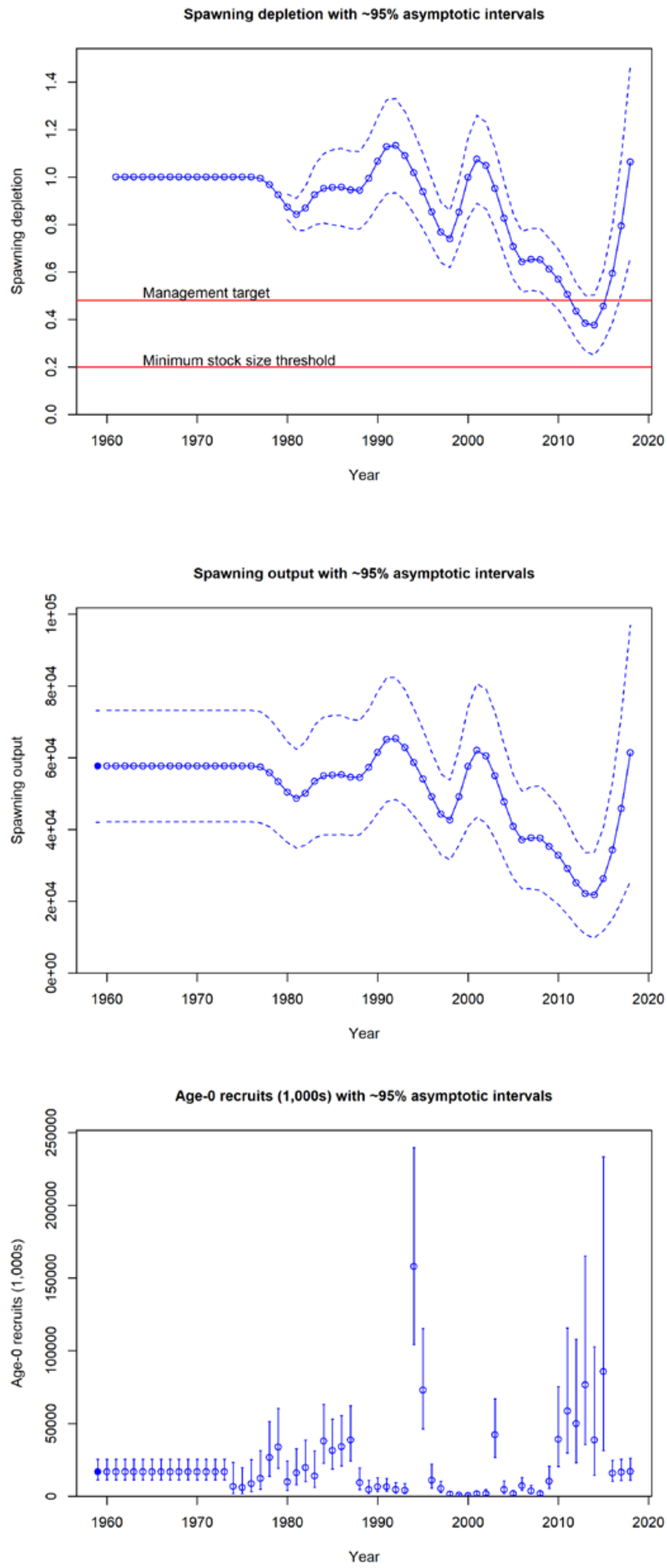


Figure 9.8. The estimated time-series of relative spawning biomass and annual recruitment for the 2018 preliminary base case assessment for blue grenadier.

9.6.3 *Retrospective analysis*

There are two types of analyses that are often called retrospective analysis. The first takes the base-case assessment and re-runs the assessment sequentially removing a year's data. The second type of retrospective analysis (historical analysis) displays the assessment results from previous years when an assessment was conducted (Punt et al., 2017). Both of these retrospective analyses are shown below.

9.6.3.1 Sequential removal of annual data

Sequentially removing each year's data from 2017 to 2012 (i.e. all data up to year 2012 are removed) illustrates that from 2012 to 2017, the addition of annual data sources all support evidence for a gradual decrease in the relative biomass trajectory and a gradual increase in initial biomass (Figure 9.9).

9.6.3.2 Previous assessment results

Punt et al. (2017) provided a retrospective investigation of assessment uncertainty for fish stocks in the SESSF. This involve reporting the spawning biomass trajectories of every previous assessment (Tier 1) conducted in the SESSF (Figure 9.5). This was reproduced in more detail for blue grenadier in Figure 9.10, showing each trajectory with associated year of the assessment. This shows that assessment outputs of biomass have varied considerably among assessments. Relative trends in spawning biomass show consistent fluctuations between assessments as recruitments enter and leave the fishery. However, the magnitude of the biomass varies.

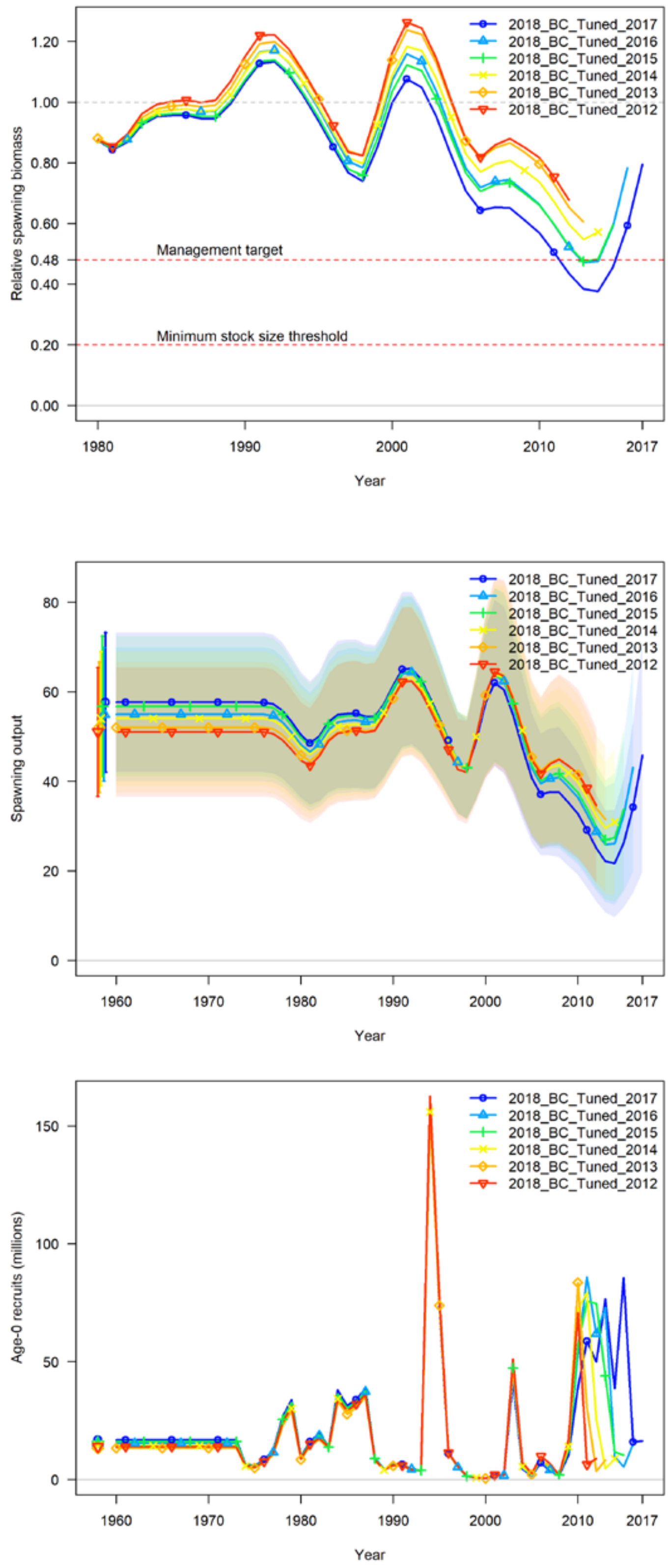


Figure 9.9. A retrospective analysis showing spawning biomass and recruitment time-series as each year's data are removed from the assessment.

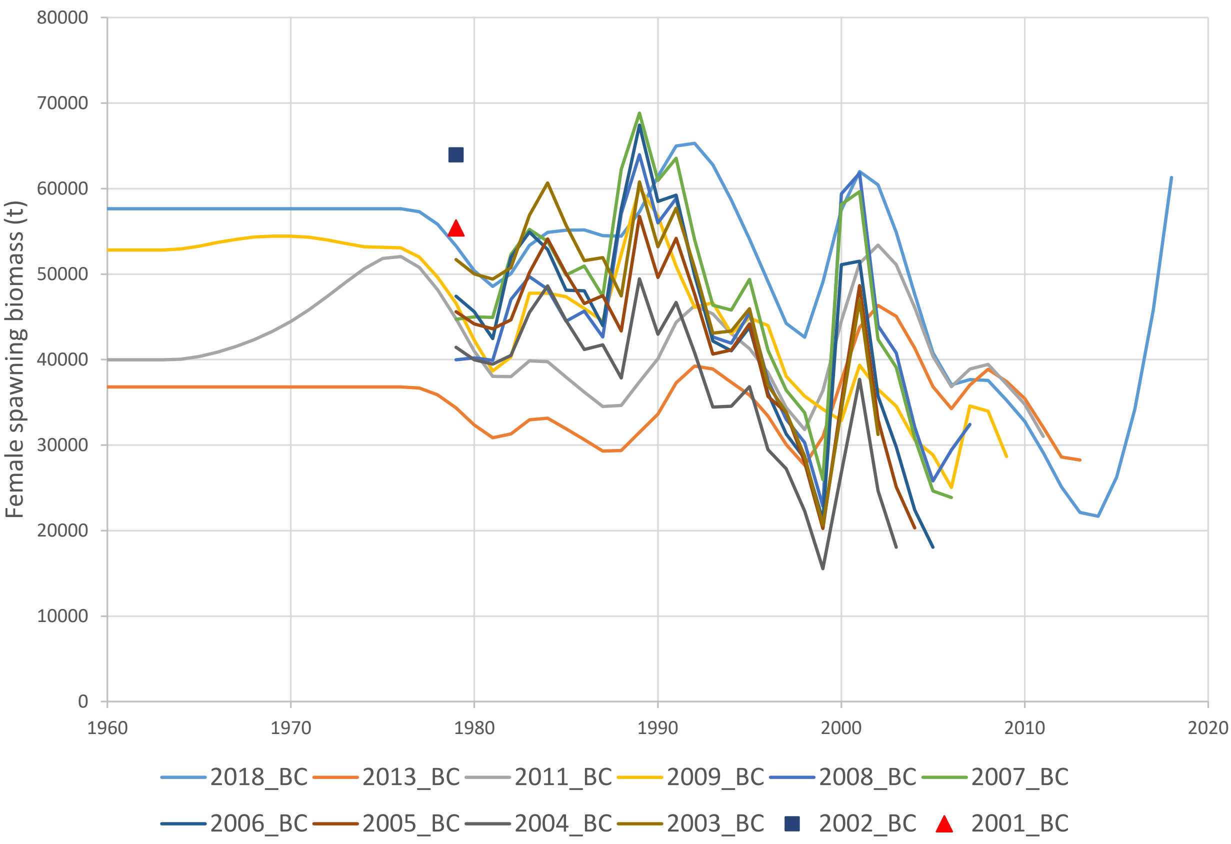


Figure 9.10. A retrospective of assessment outputs of female spawning biomass from each stock assessment from 2001 to 2018. Note that for 2001 and 2002 only values of biomass at 1979 were available.

9.6.4 *Likelihood profiles*

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

Standard parameters to consider are natural mortality (*M*), steepness (*h*) and the logarithm of the unfished recruitment (ln*Ro*). For blue grenadier, the likelihood profile for female natural mortality, M_f, an estimated parameter, is shown in Figure 9.11. This shows that M_f is generally well estimated with conditional age-at-length, length composition and the index data all consistent in terms of the relative support for the estimated value of M_f. Spawning biomass trajectories under alternative values for M_f

show a considerable spread of initial biomass of ~40,000t for M_f =0.1 through to 80,000t for M_f =0.3. Larger values for M_f lead to larger estimates of recruitment (not shown).

The likelihood profile on steepness confirms that it is not a well-defined parameter. The 95% confidence intervals are very broad, starting at 0.6 and going beyond what would be considered reasonable values for this parameter (Figure 9.13). The spawning biomass trajectory for alternative values of steepness is invariant to values greater than 0.5 (Figure 9.14).

The likelihood profile for lnR_0 shows a 95% confidence interval between 9.3 and 10.2 (Figure 9.15). The estimated value is 9.73. This is a broad range and corresponds to values of initial female spawning biomass between 46,800t and 70,000t. This matches much of the variation already observed in estimated values of initial biomass from the retrospective analysis of previous stock assessments of blue grenadier (Figure 9.10). Conflicts in the data signals can be seen in Figure 9.15, with the length-composition and discard data showing opposite trends to recruitment and the survey data.

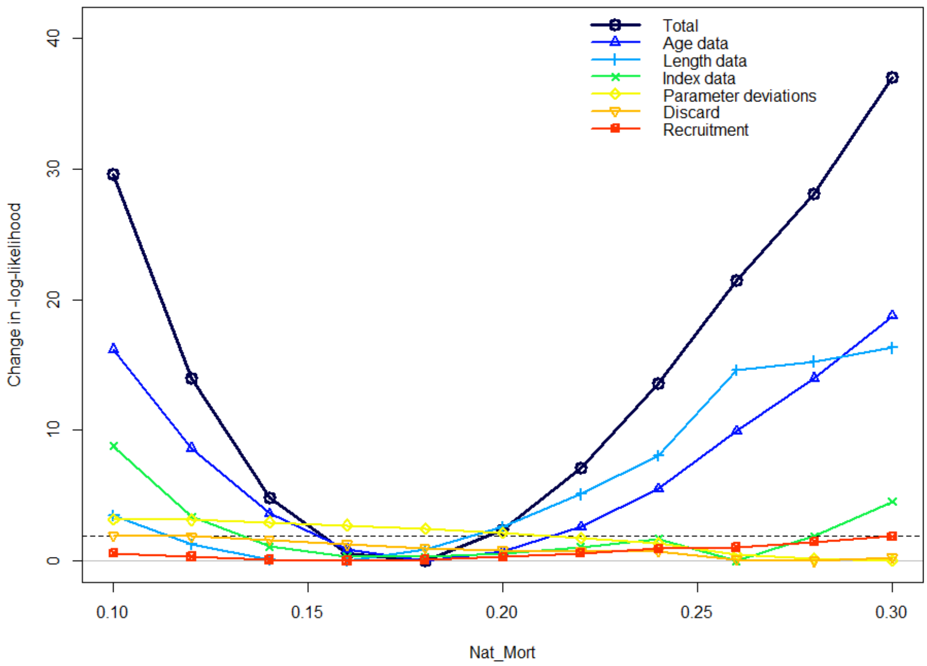


Figure 9.11. The likelihood profile for female natural mortality. The optimal value from the base case is M=0.173yr^{-1}.

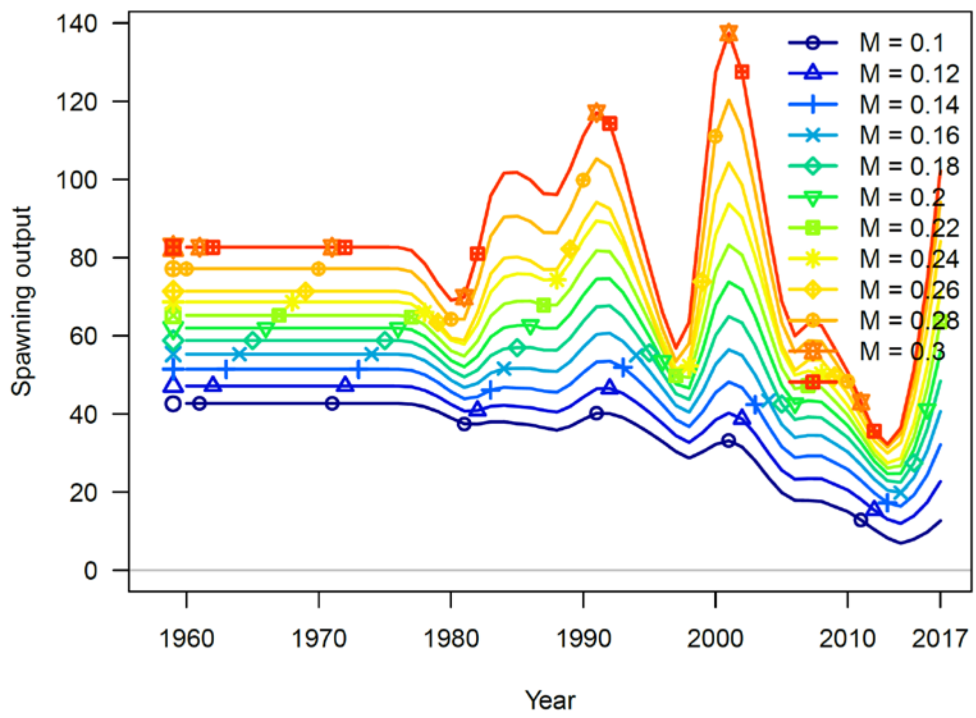


Figure 9.12. The female spawning biomass trajectories under alternative fixed values of M.

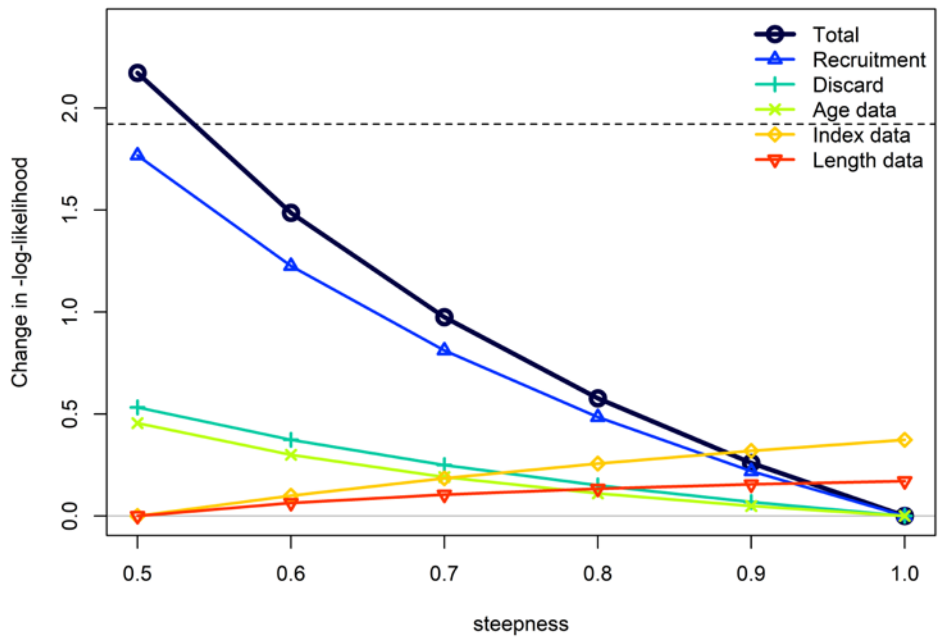


Figure 9.13. The likelihood profile for steepness. The fixed value used in the base case is *h*=0.75.

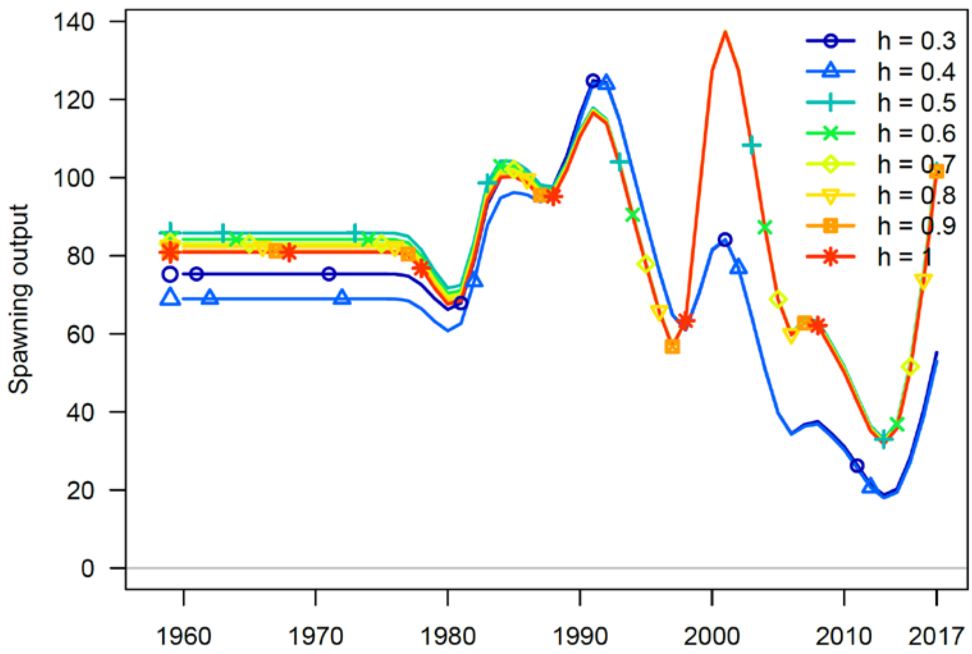


Figure 9.14. The female spawning biomass trajectories under alternative fixed values of steepness, *h*.

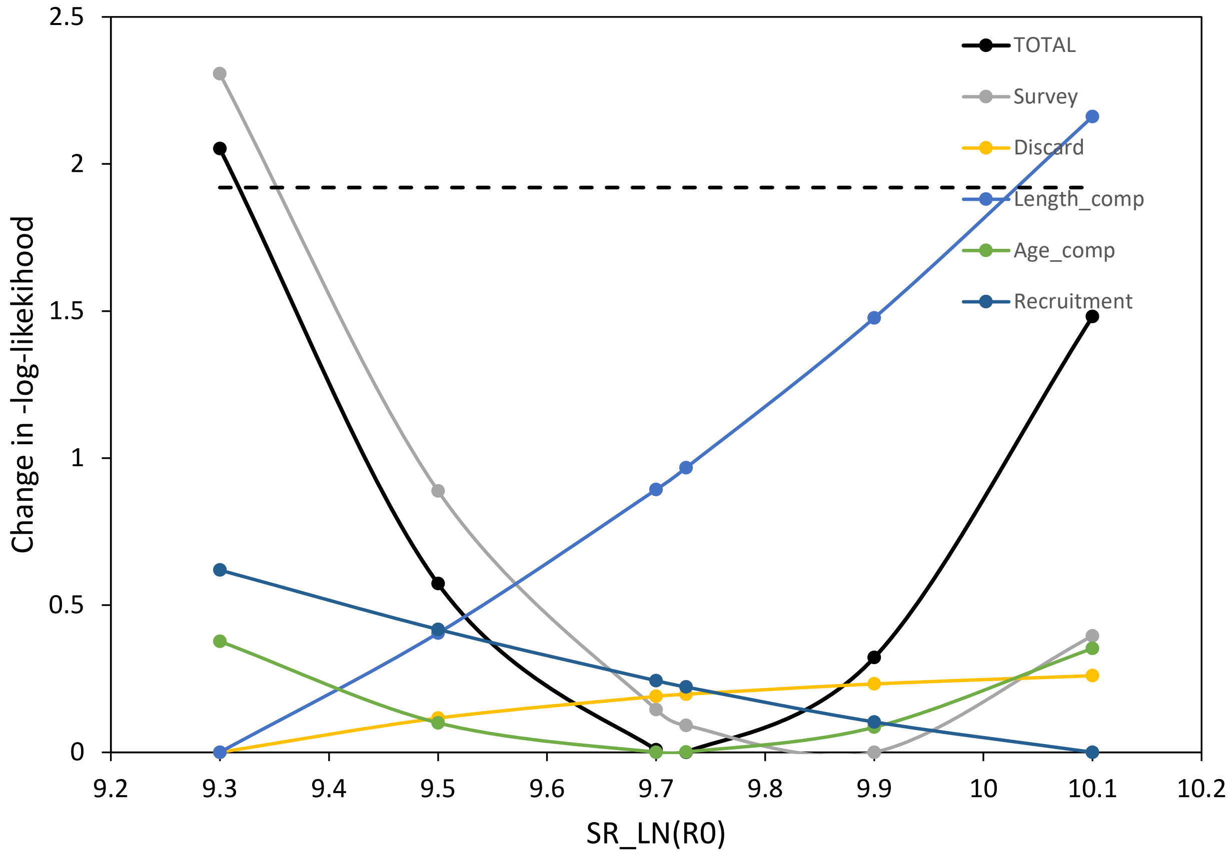


Figure 9.15. The likelihood profile for lnR_0. The estimated value in the base case is lnR_0=9.73.

9.7 Acknowledgements

Age data were provided by Kyne Krusic-Golub (Fish Ageing Services), ISMP and AFMA logbook and CDR data were provided by John Garvey (AFMA). Franzis Althaus, Mike Fuller, Roy Deng, and Paul Burch (CSIRO) pre-processed the data. Jemery Day, André Punt, Sandra Curin-Osorio, Paul Burch, Malcolm Haddon, Robin Thomson and Miriana Sporcic are thanked for helpful discussions on this work. Richard Methot, Chantel Wetzel and Ian Taylor (NOAA Fisheries) are thanked for all the Stock Synthesis support and advice. Malcolm Haddon provided useful code for auto-tuning, Athol Whitten provided useful R code for organising plots.

9.8 References

Annala, J. H., Sullivan, K. J., O'Brien, C. J., Smith, N. W. M., and Greyling, S. M. 2003. Report from the Fishery Assessment Plenary, May 2003: stock assessment and yield estimates. Part 1: Albacore to Ling. (Unpublished report held in NIWA library: Wellington, New Zealand.).

Bruce, B.D., Condie S.A., Sutton, C.A. 2001. Larval distribution of blue grenadier (*Macruronus novaezelandiae* Hector) in south-eastern Australia: further evidence for a second spawning area. Marine and Freshwater Research. 52: 603-610.

Bulman, C. M., Koslow, J. A., and Haskard, K. A. 1999. Estimation of the spawning stock biomass of blue grenadier (*Macruronus novaezelandiae*) off western Tasmania based upon the annual egg production method. Marine and Freshwater Research. 50:197-207.

Day, J. 2008. Modified breakpoint for the 2008 Tier 1 harvest control rule. Unpublished report to Shelf RAG. 6 pp.

Chesson, J., and Staples, D. J. 1995. Blue Grenadier 1994, Stock Assessment Report, Blue Grenadier Assessment Group, South East Fishery Assessment Group. Australian Fisheries Management Authority: Canberra.

Francis, R.I.C.C. 2009. Assessment of hoki (*Macruronus novaezelandiae*) in 2008.New Zealand Fisheries Assessment Report 2009/7. February 2009.

Gunn, J. S., Bruce, B. D., Furlani, D. M., Thresher, R. E., and Blaber, S. J. M. 1989. Timing and location of spawning of blue grenadier, *Macruronus novaezelandiae* (Teloestei: Merlucciidae), in Australian coastal waters. Australian Journal of Marine and Freshwater Research 40: 97-112.

Haddon, M. 2008. Catch Rate Standardizations 2008 (for data 1986 – 2007). Technical paper presented to Slope Resource Assessment Group. 17-18 November 2008. Hobart, Tasmania.

Haddon, M. 2011. Catch Rate Standardizations 2011 (for data 1986 – 2010). Technical paper presented to SESSF Resource Assessment Group. August 2011. Hobart, Tasmania.

Haddon, M. 2013. Catch Rate Standardizations 2013 (for data 1986 – 2012). Technical paper presented to SESSF Resource Assessment Group. October 2013. Hobart, Tasmania.

He, X., Punt, A.E., Thomson, R.B., Smith, D.C. and Haddon, M. 1999. Stock assessment of the blue grenadier fishery off south-east Australia, 1979-1998. FRDC Project cp77 and South East Fishery Blue Grenadier Assessment Group. June 1999.

Knuckey, I., Koopman, M. and Boag, S. 2017. Fishery Independent Survey for the Southern and Eastern Scalefish and Shark Fishery — Winter 2016. AFMA Project RR2016/0802. Fishwell Consulting 58 pp.

McAllister, M. K., Pikitch, E. K., Punt, A. E., and Hilborn, R. 1994. A Bayesian approach to stock assessment and harvest decisions using the sampling/importance resampling algorithm. Canadian Journal of Fisheries and Aquatic Sciences 51: 2673–87.

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

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

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

Methot, R.D, Wetzel, C.R, Taylor, I. 2018. Stock Synthesis User Manual Version 3.30.12. NOAA Fisheries, Seattle, WA USA. 230pp.

Myers, R.A., Barrowman, N.J., Hilborn, R., Kehler, D.G. 2002. Inferring Bayesian priors with limited direct data: applications to risk analysis. North American Journal of Fisheries Management. 22: 351-364.

Myers, R.A., Bowen, K.G., Barrowman, N.J. 1999. Maximum reproductive rate of fish at low population sizes. Canadian Journal of Fisheries and Aquatic Sciences 56: 2404-2419.

Pacific Fishery Management Council. 2018. Terms of Reference for the Groundfish and Coastal Pelagic Species Stock Assessment Review Process for 2017-2018 http://www.pcouncil.org/wp-content/uploads/2017/01/Stock_Assessment_ToR_2017-18.pdf.

Punt, A.E. 1998. An assessment for 1998 of the blue grenadier resource off Southern Australia. Technical report to the Blue Grenadier Assessment Group 20-21 January 1998. Meeting 978/1.

Punt, A.E. 2018. On the Use of Likelihood Profiles in Fisheries Stock Assessment. Technical paper for SESSFRAG, August 2018.

Punt, A.E. 2017. Some insights into data weighting in integrated stock assessments. Fisheries Research192, 52-65.

Punt, A.E., Day, J.R., Fay, G., Haddon, M., Klaer, N.L. etc. 2017. Retrospective investigation of assessment uncertainty for fish stocks off southeast Australia. Fisheries Research. 198: 117-128.

Punt, A.E., McAllister, M.K., Pikitch, E.K. and Hilborn, R. 1994. Stock assessment and decision analysis for hoki (*Macruronus novaezelandiae*) for 1994. New Zealand Fisheries Assessment Report 94/13.

Punt, A.E., Smith, D.C., Haddon, M., Russell, S., Tuck, G.N. and Ryan, T. 2015. Estimating the dynamics of spawning aggregations using biological and fisheries data. Marine and Freshwater Research. 66: 1 – 15.

Punt, A.E., Smith, D.C., Thomson, R.B., Haddon, M., He. X and Lyle, J.M. 2001. Stock assessment of the blue grenadier *Macruronus novaezelandiae* resource off south eastern Australia. Marine and Freshwater Resources. 52:701-717.

Russell, S. and Smith, D.C. 2006. Spawning and Reproductive Biology of Blue Grenadier in South-Eastern Australia and the Winter Spawning Aggregation off Western Tasmania. FRDC 2000/201.

Ryan, T.E. and Kloser, R.J. 2010. Industry based acoustic surveys of Tasmanian West Coast blue grenadier during the 2009 spawning season. CSIRO and Petuna Sealord Pty. Ltd. September 2010.

Ryan, T.E. and Kloser, R.J. 2012. Industry based acoustic surveys of Tasmanian West Coast blue grenadier during the 2010 spawning season. CSIRO and Petuna Sealord Pty. Ltd. March 2012.

Smith, A.D.M., Smith, D.C., Tuck, G.N., Klaer, N.,Punt, A.E., Knuckey, I., Prince, J., Morison, A.,Kloser, R., Haddon, M., Wayte, S., Day, J., Fay, G., Fuller, M., Taylor, B. and Little, L.R. 2008. Experience in implementing harvest strategies in Australia's south-eastern fisheries. Fisheries Research 94: 373-379.

Sporcic, M. and Haddon, M. 2018. Draft CPUE standardizations for selected SESSF Species (data to 2017). CSIRO Oceans and Atmosphere, Hobart. 331 p.

Thomson, R.B. and Klaer, N. 2011. South East Fishery data for stock assessment purposes. Technical document.

Tuck, G.N. 2008. Updated stock assessment of blue grenadier *Macruronus novaezelandiae* based on data up to 2007: November 2008. Report to the Slope Resource Assessment Group. 17-18 November 2008.

Tuck, G.N. 2011. Stock assessment of blue grenadier *Macruronus novaezelandiae* based on data up to 2010. Addendum with Model BC2. Supplementary report to the Slope Resource Assessment Group 9-11 November 2011. Hobart Tasmania.

Tuck, G.N. 2013. Stock assessment of blue grenadier *Macruronus novaezelandiae* based on data up to 2012. Technical report to the Slope Resource Assessment Group 6-8 November 2013. Hobart Tasmania.

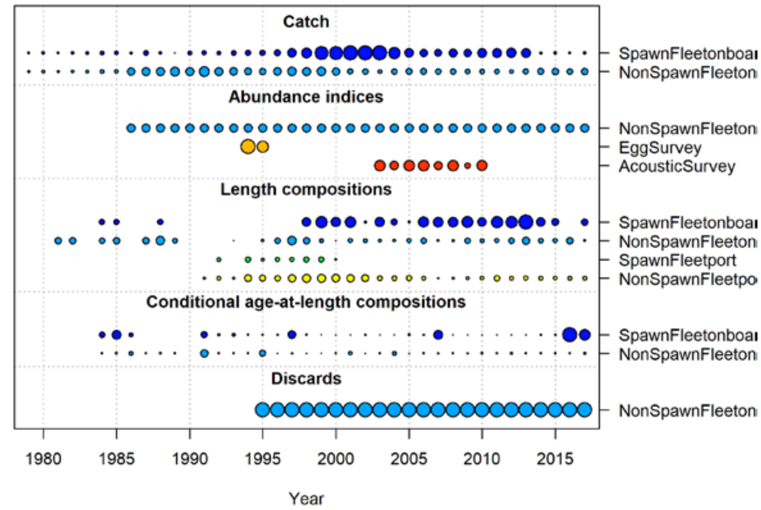
Tuck, G.N., Smith, D.C and Talman, S. 2004. Updated stock assessment for blue grenadier *Macruronus novaezelandiae* in the South East Fishery: August 2004. Report to the Slope Fishery Assessment Group, August 2004.

Tuck, G.N. and Whitten, A. 2011. Preliminary updated stock assessment of blue grenadier *Macruronus novaezelandiae* based on data up to 2010. Report to the Slope Resource Assessment Group. 5-7 October 2011. Hobart Tasmania.

Whitten, A.R., Klaer, N.L., Tuck, G.N. and R. Day. 2013. Accounting for cohort-specific variable growth in fisheries stock assessments: A case study from south-eastern Australia. Fisheries Research. 142: 27-36.

9.9 Appendix A

A.1 Preliminary base case diagnostics



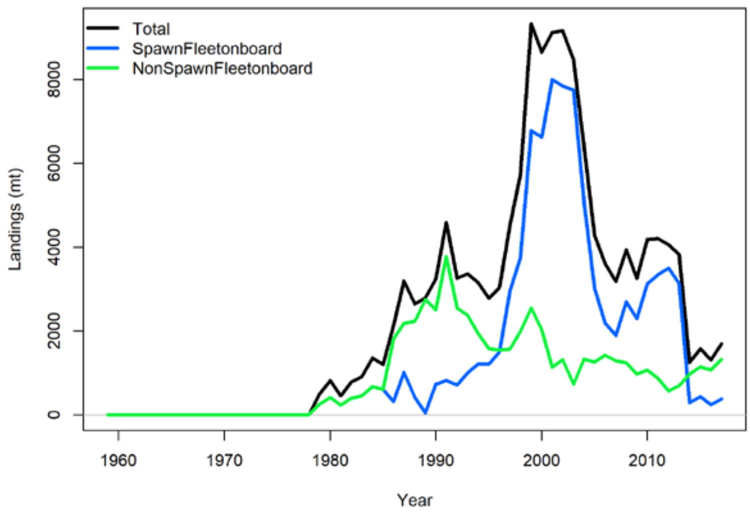


Figure A 9.1. Summary of data sources and the catch time-series for the preliminary base case assessment.

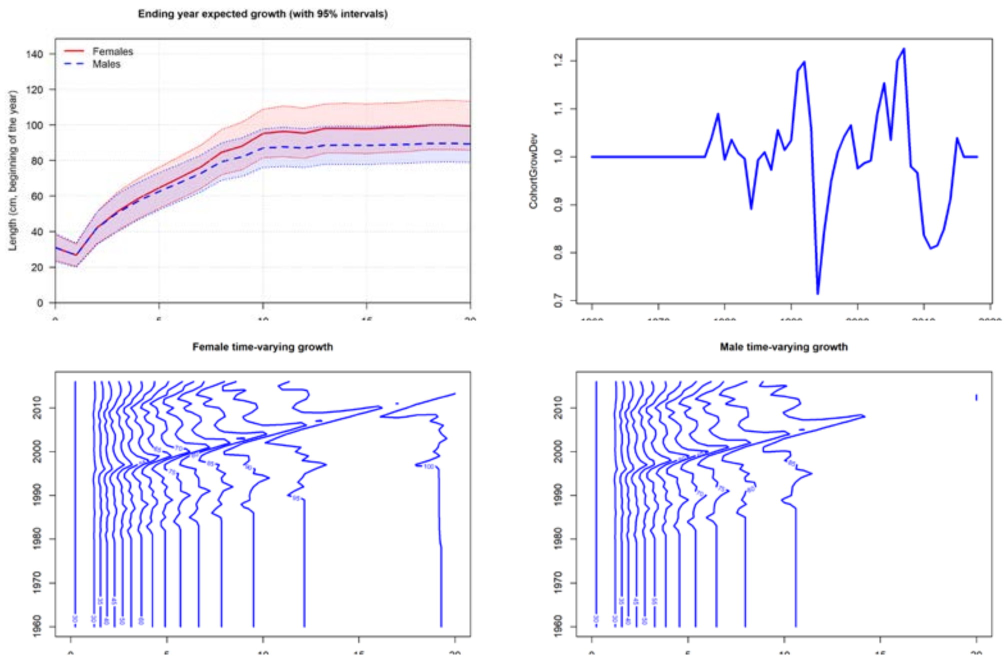


Figure A 9.2. Growth for blue grenadier.

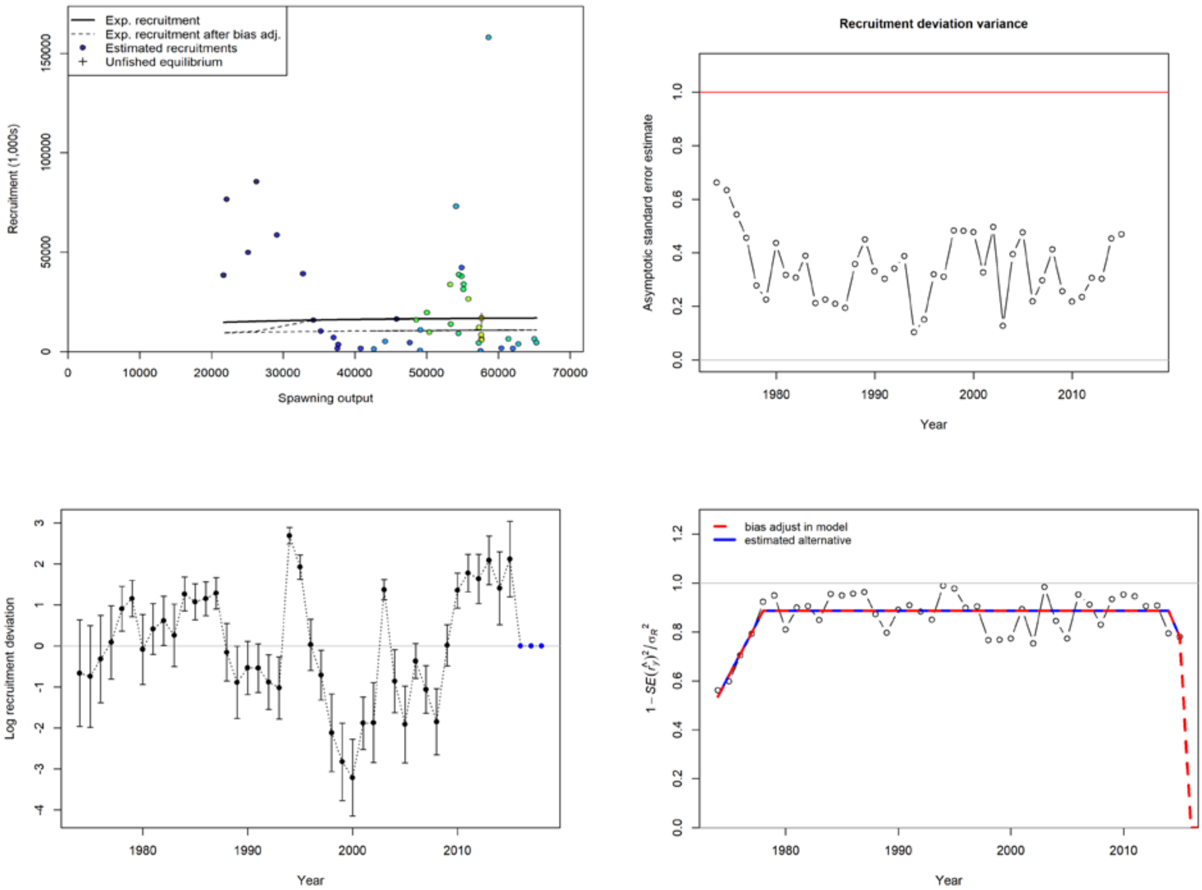


Figure A 9.3. Time series showing the stock recruitment curve, recruitment deviations and recruitment deviation variance check for blue grenadier.

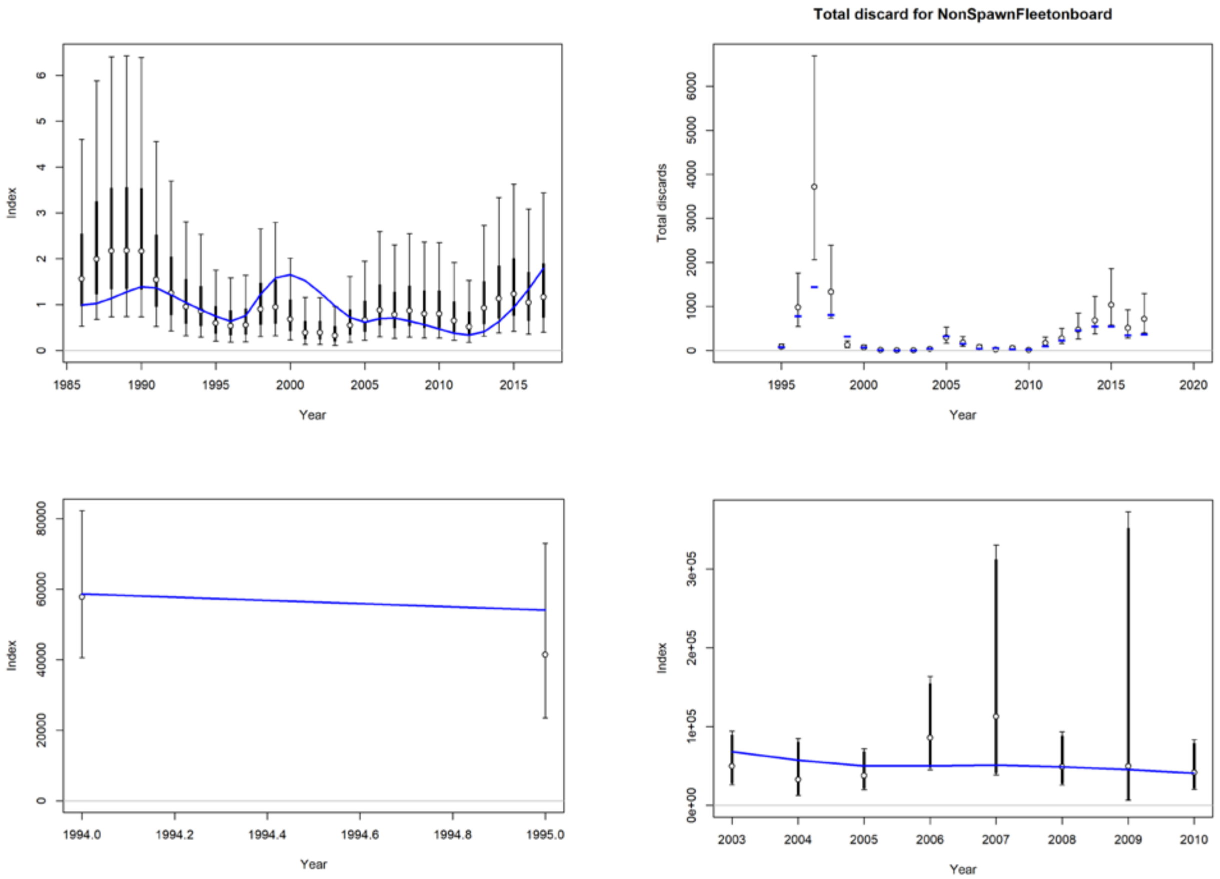


Figure A 9.4. Fits to the non-spawning CPUE index, discard mass, egg survey and acoustic survey.

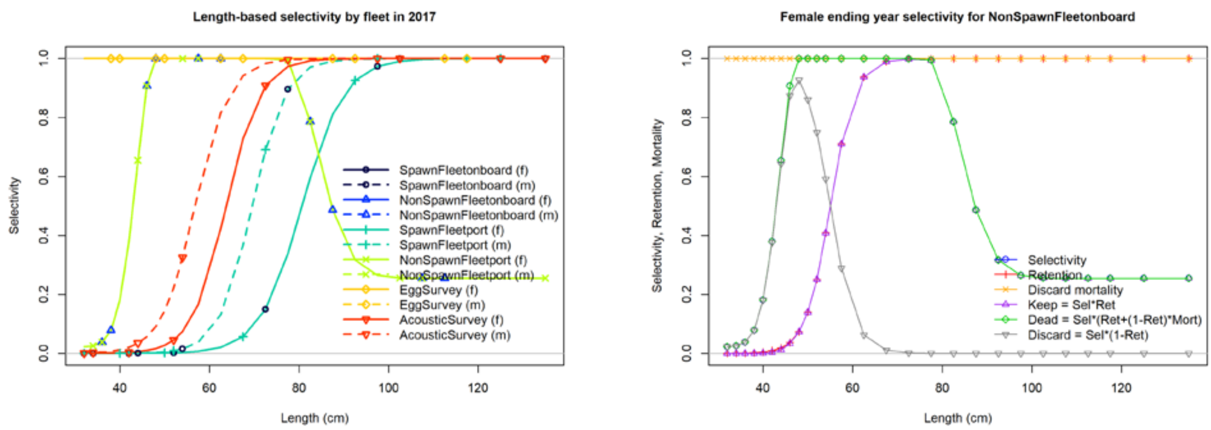


Figure A 9.5. Estimated selectivity for the spawning and on-spawning fleets using port and onboard samples and for males (m) and females (f) and the retention function.

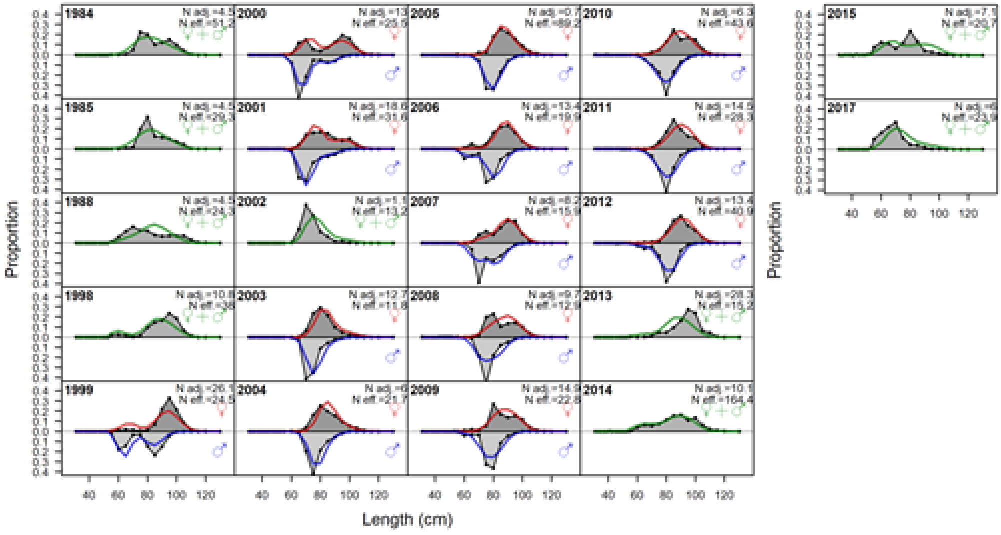


Figure A 9.6. Length composition fits: spawning fleet onboard retained.

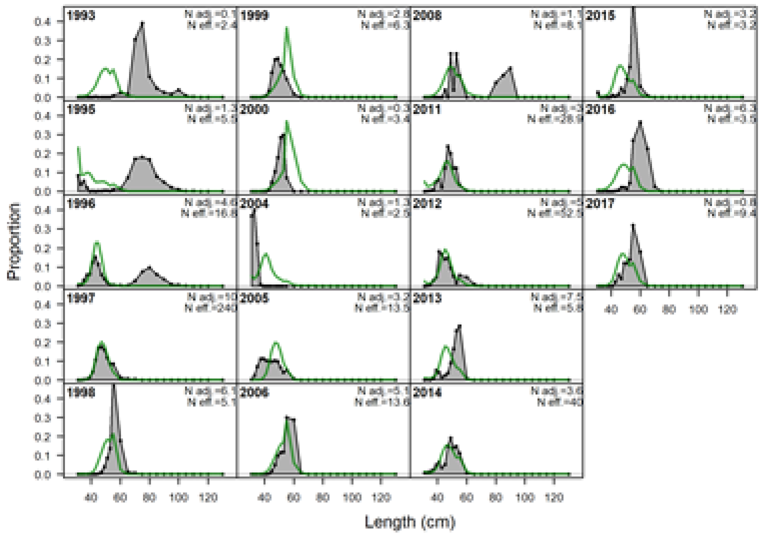


Figure A 9.7. Length composition fits: onboard non-spawning fleet discard.

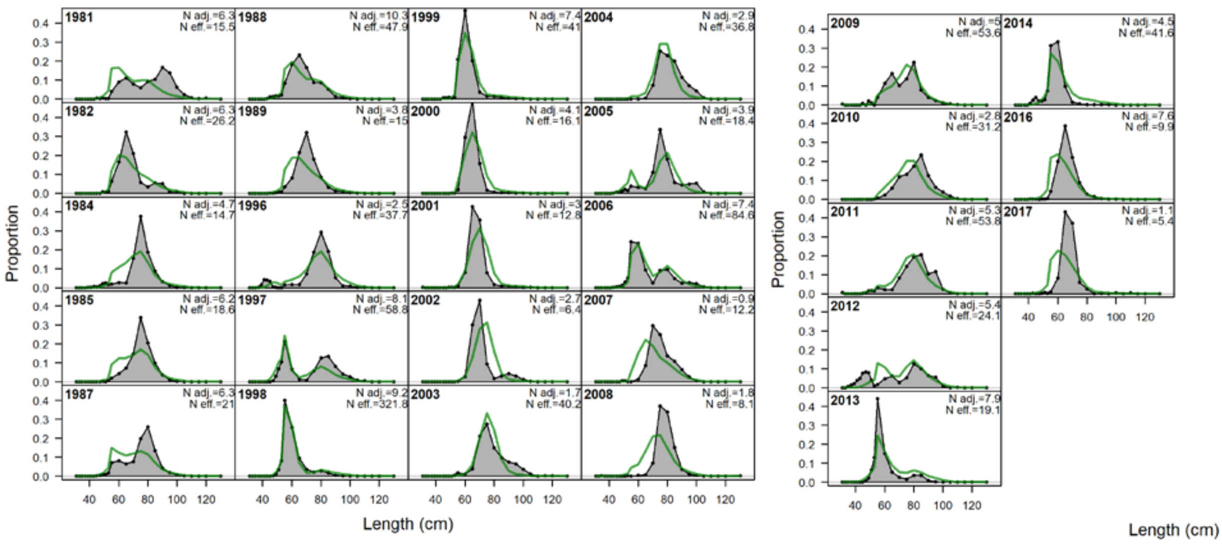


Figure A 9.8. Length composition fits: onboard non-spawning fleet retained.

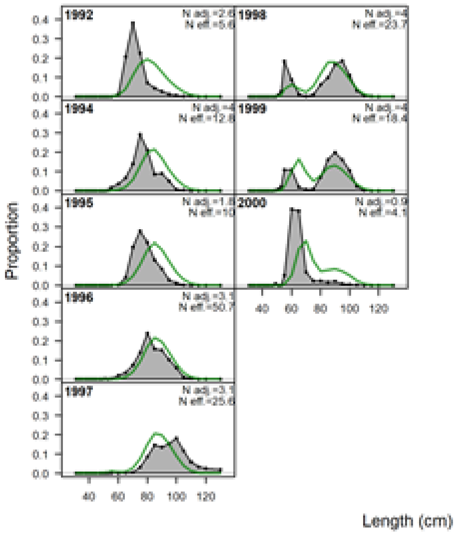


Figure A 9.9. Length composition fits: port spawning fleet retained.

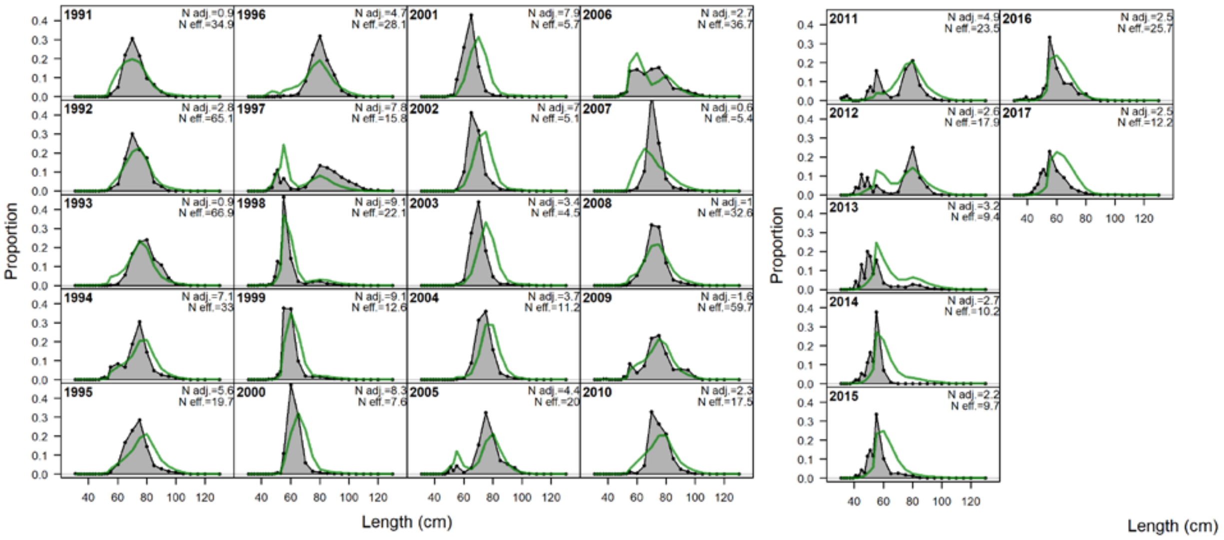


Figure A 9.10. Length composition fits: port non-spawning fleet retained.

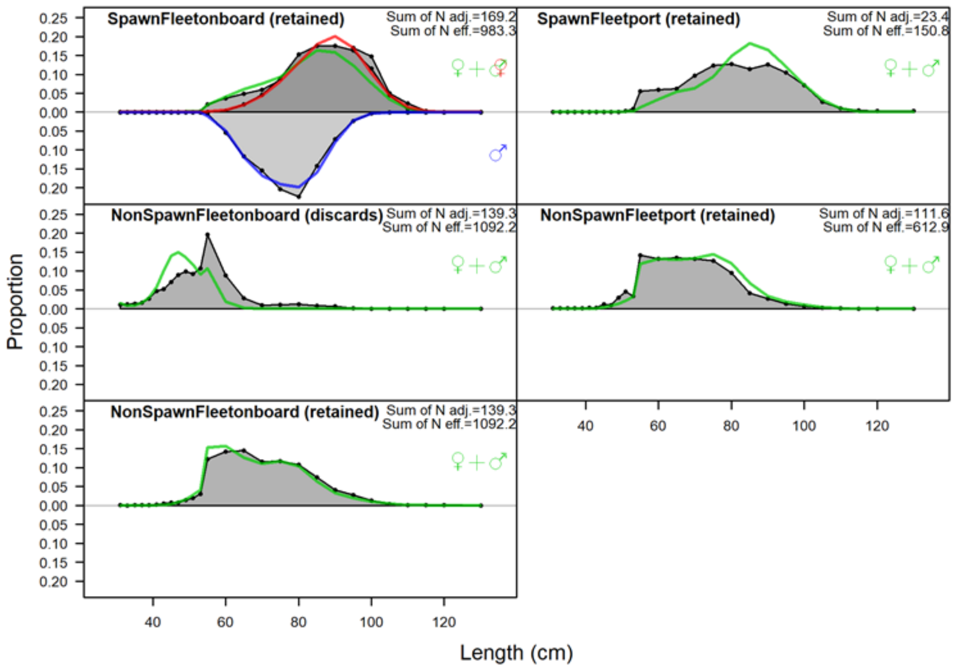


Figure A 9.11. Length composition fits aggregated across years.

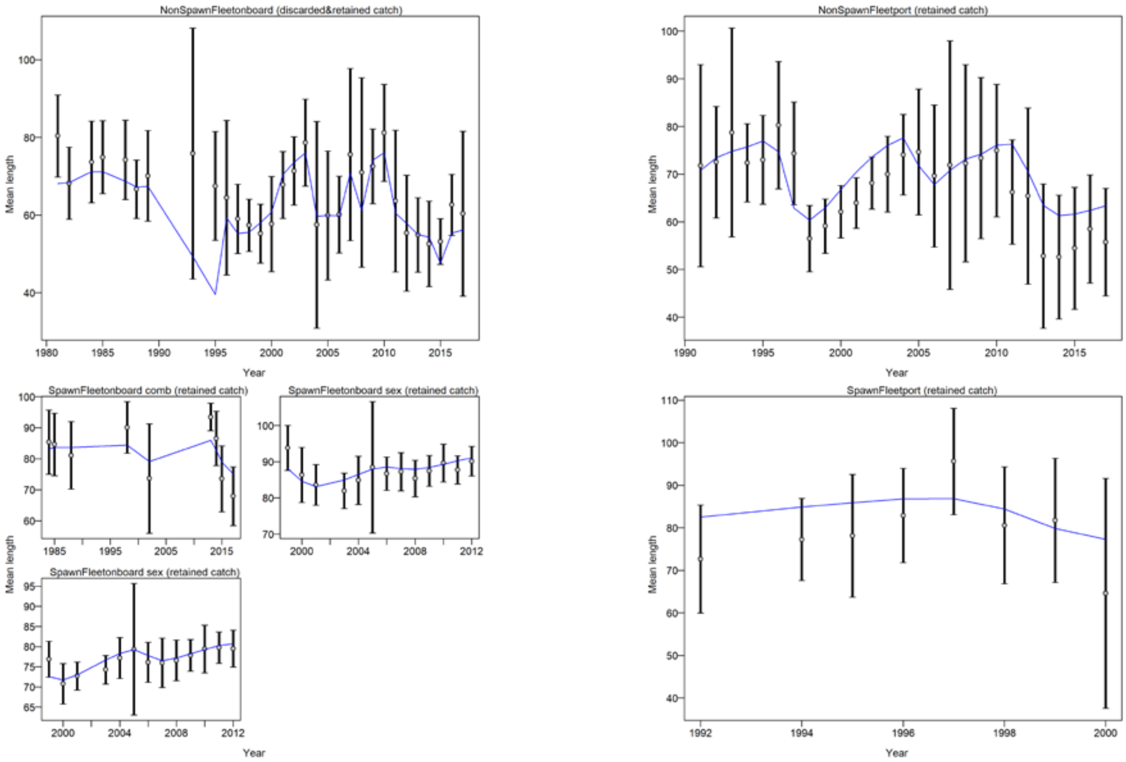


Figure A 9.12. Length composition fit diagnostics from tuning. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for length data.

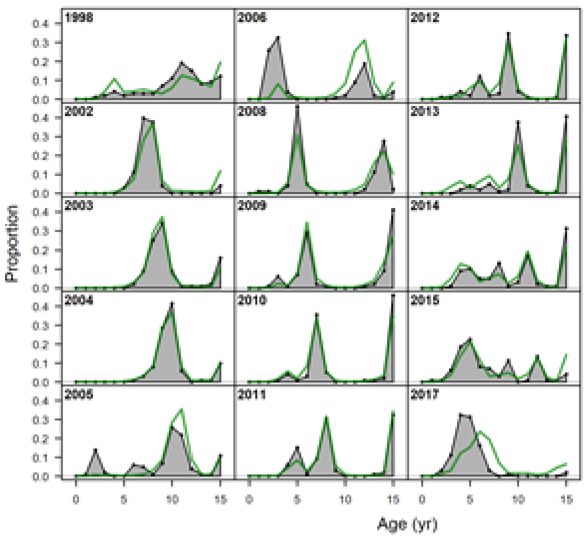


Figure A 9.13. Age composition fits: spawning fleet onboard retained.

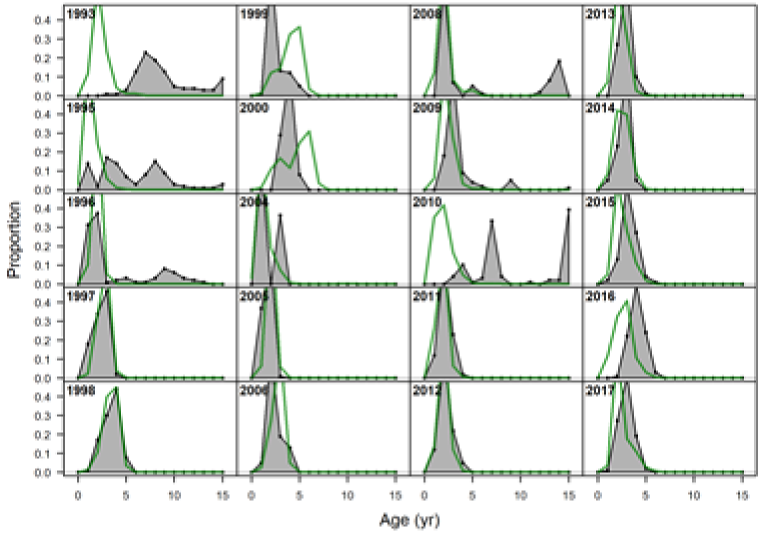


Figure A 9.14. Age composition fits: non-spawning fleet onboard discard.

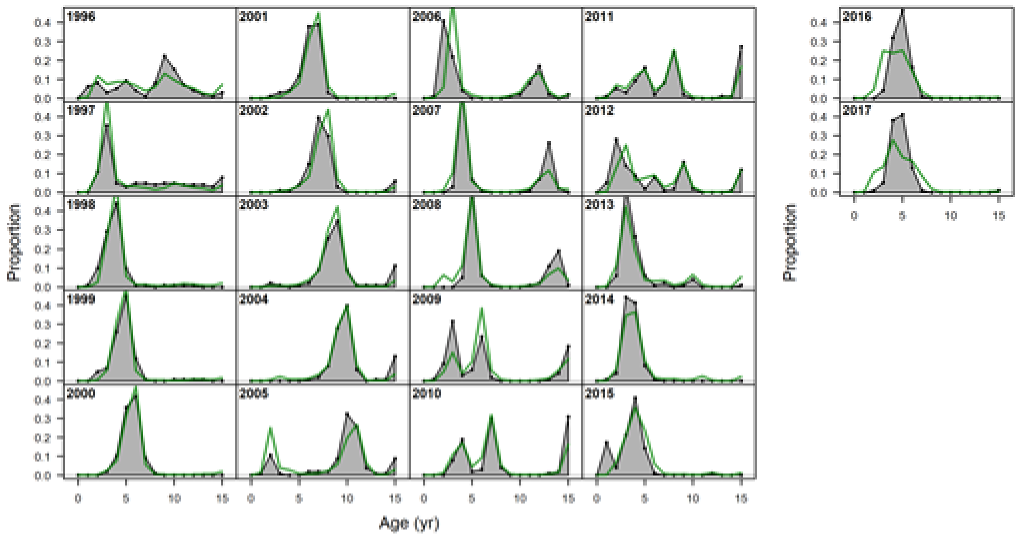


Figure A 9.15. Age composition fits: non-spawning fleet onboard retained.

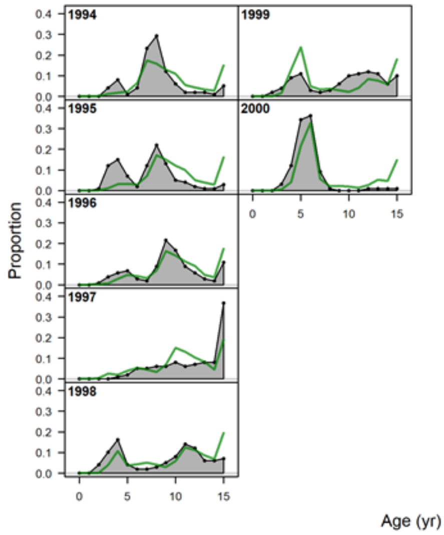


Figure A 9.16. Age composition fits: spawning fleet port retained.

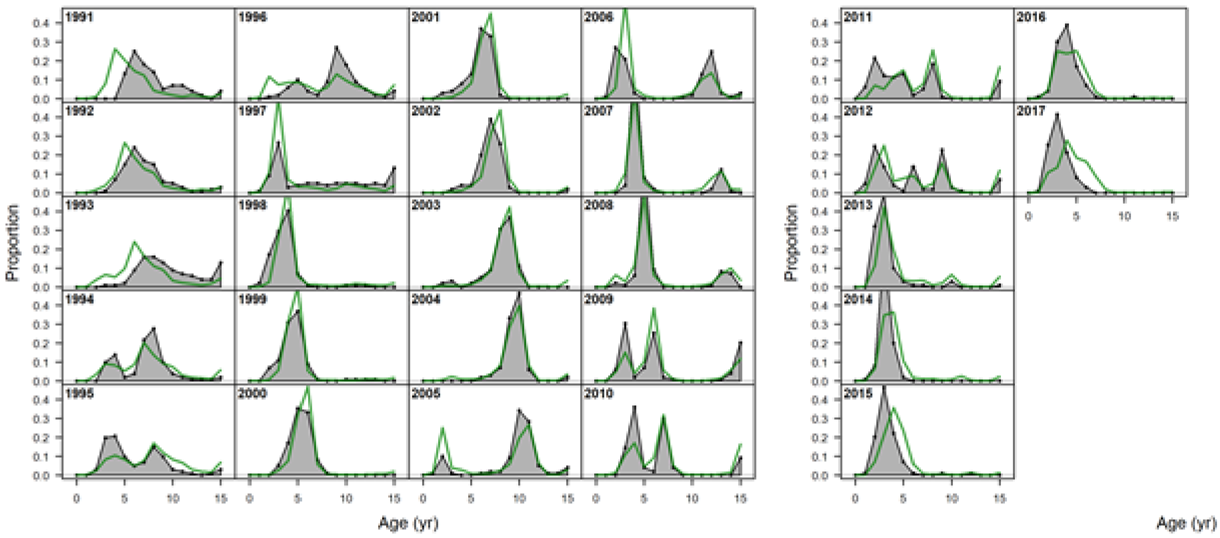


Figure A 9.17. Age composition fits: non-spawning fleet port retained.

A.2 Comparison between 2013 and 2018 assessment results

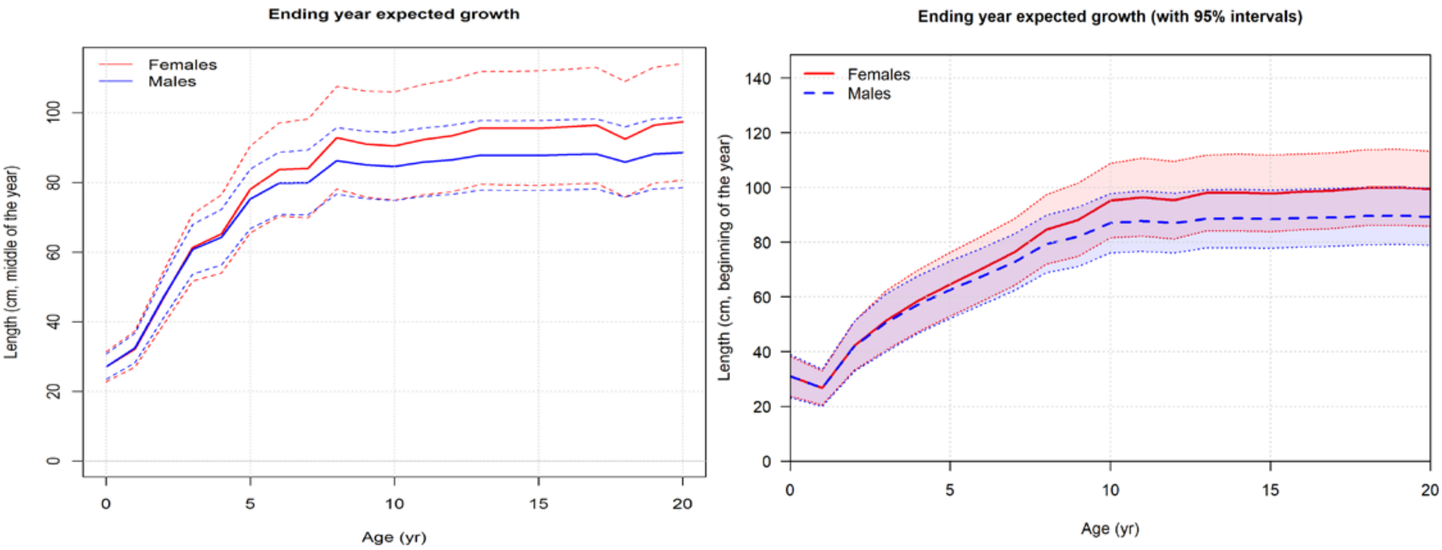


Figure A 9.18. Growth function for blue grenadier. 2013 (left) 2018 (right).

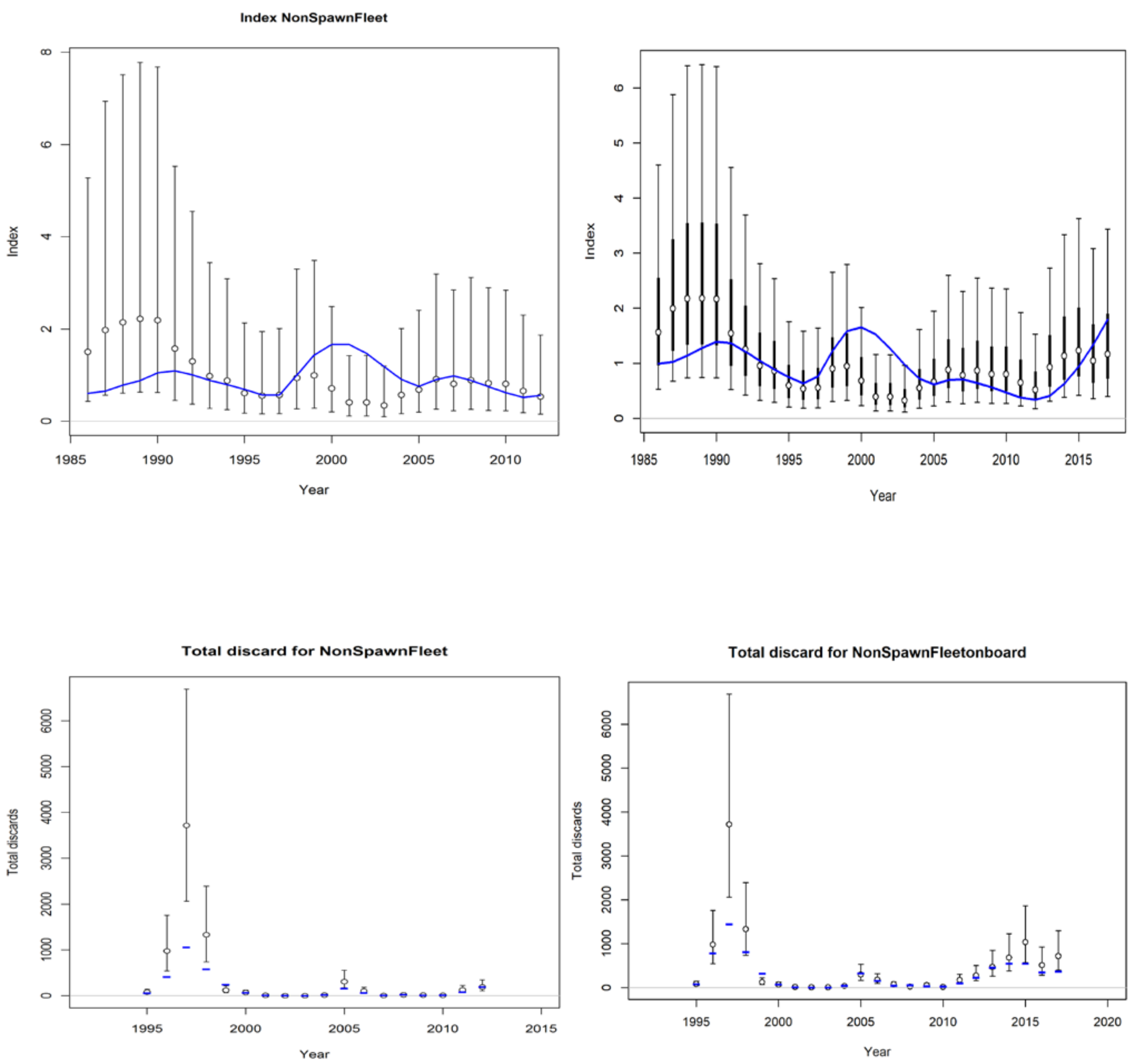


Figure A 9.19. Fits to the cpue and discard mass for blue grenadier. 2013 (left) 2018 (right).

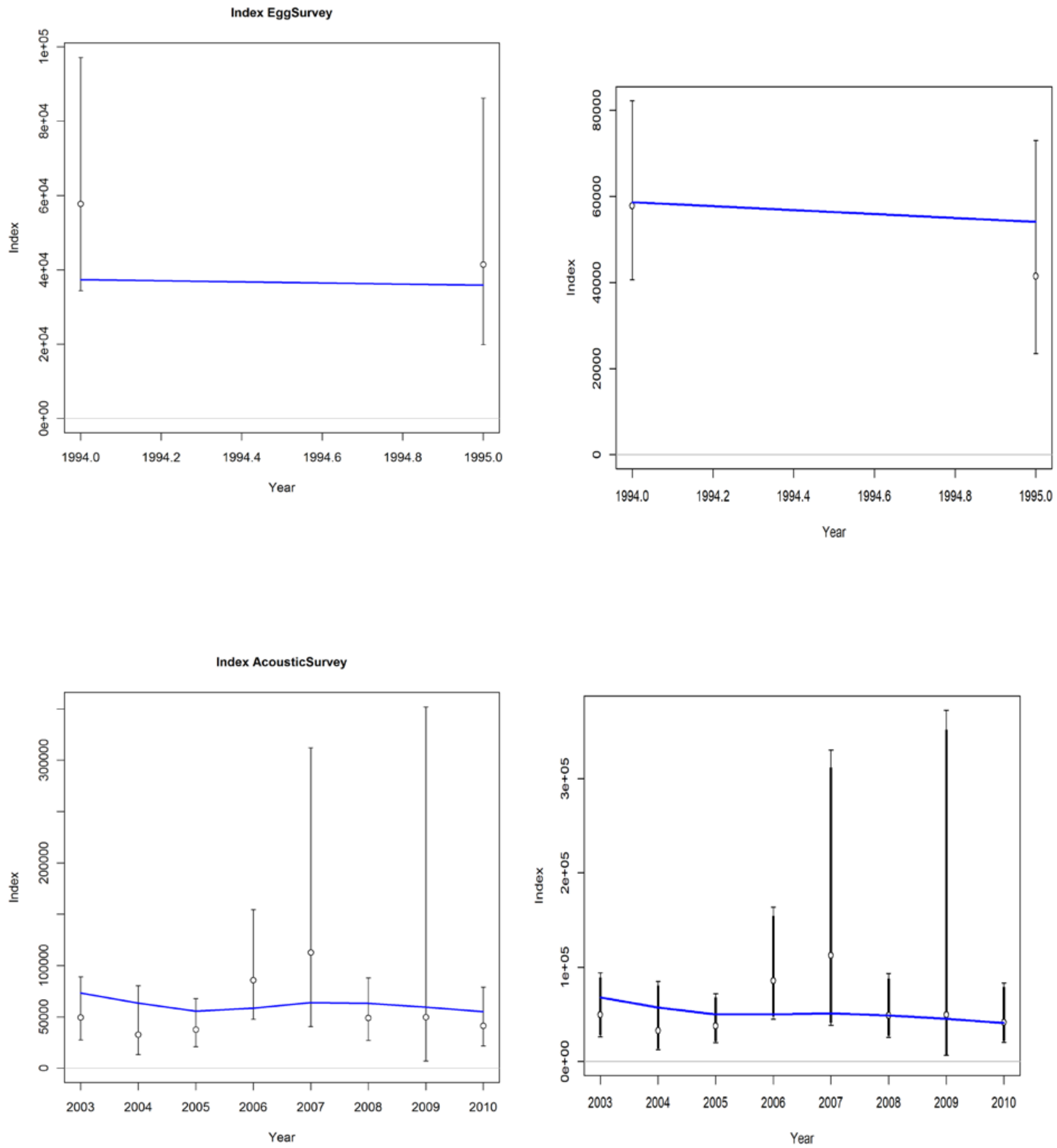
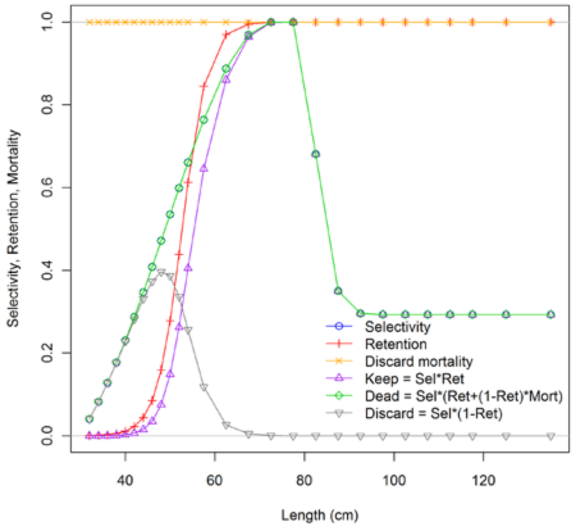


Figure A 9.20. Fits to the egg (top) and acoustic (bottom) surveys for blue grenadier. 2013 (left) 2018 (right).



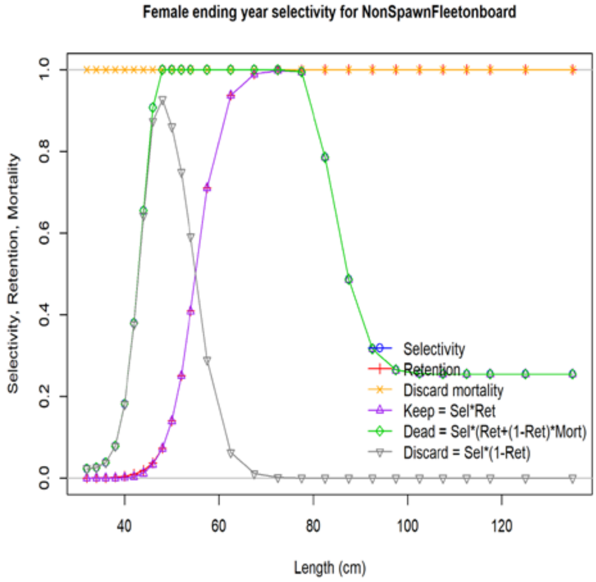


Figure A 9.21. The base case predicted selectivity-at-length for the non-spawning fleet (green) and the retention function for the non-spawning fleet (red/purple). The proportion discarded at length is grey. 2013 (left) 2018 (right).