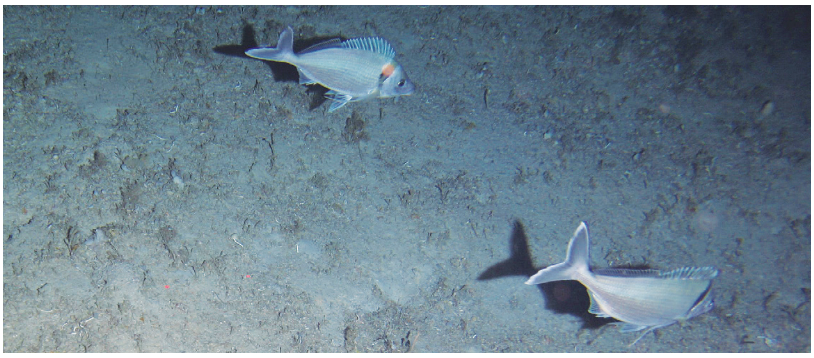
Cite as:
Tuck, G., Day, J. and Burch, P. (2019) Deepwater Flathead (*Neoplatycephalus conatus*) stock assessment based on data to 2018/19. pp 318 - 348 *in* Tuck, G.N. (ed.) 2020. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2018 and 2019*. Part 1, 2019. Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere, Hobart. 353p.

Australian Government
Australian Fisheries Management Authority

2017/0824 June 2020

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



PART 1

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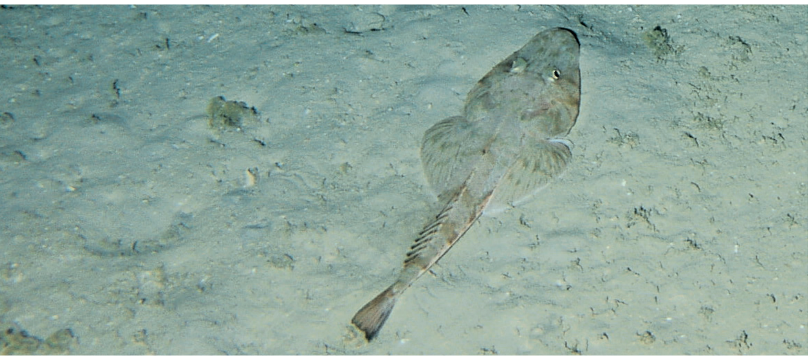

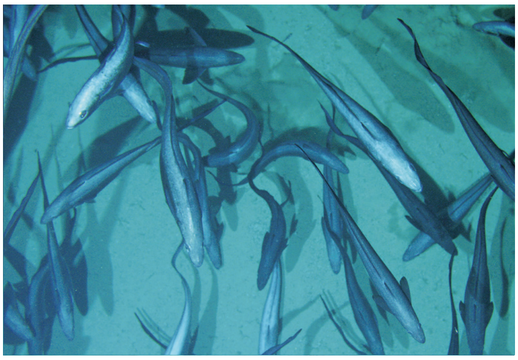

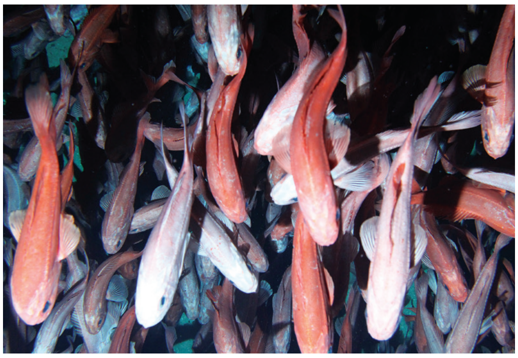

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Stock assessment for the southern and eastern scalefish and shark fishery 2018 and 2019. Report ref# 2017/0824. By PI: Tuck, G.N. June 2020 - ONLINE

ISBN 978-1-925994-07-0

Preferred way to cite this report

Tuck, G.N. (ed.) 2020. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2018 and 2019. Part 1, 2019. Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere, Hobart. 353p.

Acknowledgements

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

Cover photographs

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

Report structure

Part 1 of this report describes the Tier 1 assessments of 2019. 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 2019.

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

Part 1: 2019

G.N. Tuck
June 2020
Report 2017/0824

Australian Fisheries Management Authority

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

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12. Deepwater flathead (*Neoplatycephalus conatus*) stock assessment based on data up to 2018/19

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12.1 Executive Summary

This document presents the agreed base case for the Tier 1 deepwater flathead (*Neoplatycephalus conatus*) assessment for presentation at GABRAG in December 2019. The last full assessment was presented in Haddon (2016). The base case has been updated by the inclusion of data up to the end of 2018/19, which entails an additional 3 years of catch, CPUE, length and age data and ageing error updates since the 2016 assessment, and incorporation of survey results from the Fishery Independent Survey (GABFIS). The process used to develop a preliminary base case for deepwater flathead through the sequential updating of recent data and updating the stock assessment package Stock Synthesis (SS-V3.30.14) was presented in November 2019. This document provides further detail of the agreed base case, with RBC values and sensitivities to the base case model structure.

As seen in November 2019, the base case provides reasonably good fits to the catch rate data, length data and conditional age-at-length data, however, the fit to the two most recent GABFIS points is poor. The inclusion of new and updated data in the current assessment has led to some changes in the shape of the spawning biomass trajectory, but the depletion remains near the target of 43%. The assessment estimates that the projected 2020/21 spawning stock biomass will be 45% of virgin stock biomass (projected assuming 2018/19 catches in 2019/20), compared to 45% at the start of 2016/17 from the 2016 assessment (Haddon, 2016). The 2020/21 Recommended Biological Catch (RBC) under the 20:35:43 harvest control rule is 1,253 t. The average RBC over the three-year period 2020/21 - 2022/23 is 1,238 t. The long-term RBC is 1,218 t.

A number of sensitivities to the base case model structure were conducted. These included a model with Danish seine as a separate fleet (presented in November 2019) and a model with interpolated GABFIS biomass indices where the FIS was not conducted in recent years. The former model, while showing promise as a future base case model, was unusually sensitive to the inclusion of the Danish seine fleet even though this fleet catches only a small proportion of the total GAB catch. If this fleet continues to operate in the GAB, then it is important that sufficient samples are collected. At the moment, only three years of Danish seine length frequency data and two years of age data are available. The interpolated GABFIS model was suggested to look at how influential the FIS data points are to the estimated biomass trajectories. Results conclude that the GABFIS can have a strong influence on the biomass predicted by the model. This result can contribute to discussions regarding the frequency of FIS surveys in both the GAB and SESSF.

12.2 Introduction

12.2.1 *The fishery*

The trawl fishery in the GAB primarily targets two species, Bight redfish (*Centroberyx gerrardi*) and deepwater flathead (*Neoplatycephalus conatus*), and these have been fished sporadically in the Great Australian Bight (GAB) since the early 1900s (Kailola et al., 1993). The GAB trawl fishery (GABTF) was set up and managed as a developmental fishery in 1988, and since then a permanent fishery has been established with increasing catches of both species, although catches of Bight Redfish have declined recently. Deepwater flathead are endemic to Australia and inhabit waters from NW Tasmania, west to north of Geraldton in WA in depths from 70m to more than 510m (Kailola et al., 1993; Gomon et al., 2008; www.fishbase.org). Bight Redfish are also endemic to southern Australia, occurring from off Lancelin in WA to Bass Strait in depths from 10m to 500m. The two species are often caught in the same trawl tows although Bight redfish is most commonly taken in the east of the GAB. This document focusses on the stock assessment for deepwater flathead.

12.2.2 *Previous assessments*

An initial stock assessment workshop for the GABTF held in 1992 focused on the status of deepwater Flathead and Bight Redfish. Sources of information for the workshop included historical data, logbook catch data, observer data and biological information. With so few years of data available at that time catch-per-unit-area (kg/km^2) was calculated for quarter-degree squares and then scaled to the total area in which the species had been recorded. The approximate exploitable biomass estimates for deepwater flathead and Bight Redfish obtained by this relatively informal method were 32,000t and 12,000t respectively (Tilzey and Wise 1999). Error bounds on these estimates could not be calculated.

Wise and Tilzey (2000) summarised the data for the GABTF focusing on deepwater flathead and Bight Redfish, the two principle commercial species in shelf waters. They produced the first attempt to assess the status of these deepwater flathead and Bight Redfish populations using age- and sex-structured stock assessment models. The virgin total biomass estimates for the deepwater flathead base case model were 53,760t (95% confidence interval is 2,488-105,032t). In 2002 an updated assessment was carried out including data up to 2001. The unexploited biomass estimates for the deepwater flathead base case model was then 12,876t (95%CI=11,928-13,824).

GABTF assessments in 2005 (Wise and Klaer, 2006; Klaer, 2007) used a custom-designed integrated assessment model developed using the AD Model Builder software (Fournier *et al*., 2012). A series of fishery-independent resource surveys was also commenced in 2005, providing a single annual biomass estimate for Bight Redfish and deepwater flathead (Knuckey *et al*., 2015), plus extra samples of length and age composition data. Initially, attempts were made to make absolute abundance estimates using classical swept area methods from the survey data. The unexploited biomass levels estimated for the base case models from the assessment models were 20,418t and 13,932t for deepwater flathead and Bight Redfish, respectively. The absolute biomass estimate from the survey at that time was consistent with other fishery data for deepwater flathead, but was much greater than the biomass modelled without the survey for Bight redfish. Survey estimates are now treated as indices of relative abundance separate from that obtained from the standardized commercial catch-per-unit-effort data.

The 2006 assessment (Klaer and Day, 2007) duplicated as far as possible the assessment results from 2005 using the Stock Synthesis (SS) framework. Although it was possible to replicate 2005 results reasonably well, there were a few differences in the model structure implemented in Stock Synthesis most importantly the calculation of recruitment residuals independently and allowing recruitment residuals to occur prior to the commencement of the fishery.

An attempt was made to incorporate as much previously unused data as possible into the 2007 assessment - particularly length-frequencies (Klaer, 2007). Age-frequencies were no longer used explicitly but conditional age-at-length distributions were obtained from age-length keys. In addition, the model used original age-at-length measurements to fit growth curves within the model, to better allow for the interaction between selectivity and the growth parameters. The depletion of deepwater flathead in 2007 was estimated at 56%, and the unexploited female spawning biomass was estimated at 8,836t (Klaer, 2007).

The 2010 assessment (Klaer 2011a, b) included all available port and on-board collected length data combined. Following agreement by the RAG, the 2010 assessment included the FIS as a relative index for the first time. Unexploited female spawning biomass, SSB_0, was estimated as 10,366t and current depletion at 62% of SSB_0. The long-term RBC estimate was 1,137t. This assessment indicated that the stock had been more depleted than previously predicted in 2005/06, being down near the 20% B_0 limit. Previous assessments had all indicated a stock in fish-down, but always above the target biomass.

The 2012 deepwater flathead assessment (Klaer 2013a, b) estimated an unexploited spawning stock biomass of 8,921t and a depletion at that time of 39% of SSB_0. The 2013/14 recommended biological catch (RBC) under the 20:35:43 harvest control rule was 979t and the long-term yield (assuming average recruitment in the future) was 1,051 t. An assessment was conducted in 2013 using data to the end of 2012/2013 (Klaer, 2014a, b). This estimated the unexploited spawning stock biomass of 9,320t and a depletion at the start of 2014/2015 of 45% of SSB_0. The 2014/15 RBC under the 20:35:43 harvest control rule was 1,146t and the long-term yield (assuming average recruitment in the future) was 1,105 t.

The previous deepwater flathead assessment was conducted in 2016 using data to the end of 2015/16 (Haddon, 2016). For the first time the ISMP data was divided into the on-board and Port based samples, the length and age composition data from the FIS was used, and the industry collected length composition data were also included. The base-case assessment estimated that the female spawning stock biomass at the start of 2016/2017 was 45.0% of unexploited female spawning stock biomass (SSB_0). The 2017/2018 recommended biological catch (RBC) under the agreed 20:35:43 harvest control rule was 1,155 t and the long-term yield (assuming average recruitment in the future) was 1,093 t. The unexploited female spawning biomass in 2016/2017 was estimated as 11,046 t.

Table 12.1. A summary of stock assessment outcomes for deepwater flathead. B_0 is the unfished female spawning biomass. The yield is the RBC for the following year with the long term estimated sustainable yield (LTY) in brackets for some years (prior to 2009 these are MSY estimates). The 1999 biomass estimate is of exploitable biomass while the rest reflect female spawning biomass.

Year	Authors	B_0 (t)	Depletion	RBC (LTY) (t)
1999	Tilzey and Wise (1999)	~32,000	-	
2000	Wise and Tilzey (2000)	53,760		
2002	Wise and Tilzey	12,876		
2005	Wise and Klaer (2006)	20,418	>79%	(670)
2006	Klaer and Day (2007)	10,084	50	1,070
2007	Klaer (2007)	8,841	56	1,524
2010	Klaer (2011b)	10,366	62	1,463 (1,137)
2012	Klaer (2013b)	8,921	39	979 (1,051)
2013	Klaer (2013b)	9,320	45	1,146 (1,105)
2016	Haddon (2016)	11,046	45	1,155 (1,093)
2019	Tuck et al. (2019b)	9,008	45	1,253 (1,218)

12.3 Methods

12.3.1 *Modifications to the previous assessment*

An initial base case quantitative Tier 1 deepwater flathead assessment was developed and presented to the GABRAB on the 21st November 2019 (Tuck et al., 2019); this was used to describe the changes from the previous assessment by the sequential addition of the new data now available (known as a bridging analysis) along with other structural changes. The last full assessment was presented in Haddon (2016).

The preliminary base case was updated by the inclusion of data up to the end of 2018/19, which entails an additional 3 years of catch, CPUE, length and age data and ageing error updates since the 2016 assessment, and incorporation of survey results from the Fishery Independent Survey (GABFIS) and using the stock assessment package Stock Synthesis (SS3-V3.30.14.05). It was agreed by members of GABRAG (November 2019) that the preliminary base case should be taken as the base case for RBC recommendations at the December GABRAG meeting. This document provides further details of the base case model, RBC recommendations and sensitivities.

12.3.2 *Model structure*

A two-sex stock assessment for deepwater flathead was implemented using the software package Stock Synthesis (SS; Methot and Wetzel, 2013). SS is a statistical age- and length-structured model that can be used to fit the various data streams now available for deepwater flathead, simultaneously. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, are described in the SS operating manual (Methot, 2015) and technical description (Methot and Wetzel, 2013) and are not reproduced here.

A single stock of deepwater flathead was assumed to occur across the GAB. The stock was assumed to have been unexploited prior to 1988/1989. The selectivity pattern for the trawl fleet was modelled as not changing through time. The two parameters of the logistic selectivity function were estimated within the assessment. Now that FIS length and age composition data are included as data streams, a separate logistic selectivity was able to be estimated for the FIS.

Male and female deepwater flathead are assumed to have the same biological parameters except for their growth and the length-weight relationship (Table 12.2). Three of the four parameters relating to the von Bertalanffy growth equation are estimated within the model-fitting procedure from the observed age-at-length data; all male growth parameters are fitted as offsets to the female parameters. Fitting growth within the assessment model attempts to account for the impact of gear selectivity on the age-at-length data collected from the fishery and any impacts of ageing error.

The rate of natural mortality, *M*, was assumed to be constant with age, and also constant through time. The natural mortality rate is estimated in the base-case model, with the estimated value being close to 0.263 yr^{-1}. Maturity is modelled as a logistic function, with 50% maturity at 40 cm. Fecundity-at-length is assumed to be proportional to weight-at-length. Recruitment was 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 was assumed to be 0.75. Deviations from the average recruitment at a given spawning biomass (recruitment deviations) were estimated from 1980/1981 to 2013/2014. The value of the parameter determining the magnitude of the potential variation in annual recruitment, σ_R (SigmaR) was set equal to 0.7, as is standard practice. Age 29 is treated as a plus group into which all animals predicted to survive to ages greater than 29 are accumulated.

Table 12.2. Summary of selected parameters from the 2019 base case model for deepwater flathead. Sources: (1) Analyses of biological samples collected during the 2004 GAB reproductive study (Brown and Sivakumaran, 2007), (2) length and age samples collected between 2000-2003 and (3) length samples collected during the 2001 FRDC project. Years represent the first year of each financial year i.e. 2015 = 2015/2016 (adapted from Haddon, 2016).

Description	Source	Parameter	Combined Male/Female	
Years		y	1988-2018	
Recruitment Deviates		*r*	estimated 1980 - 2013	
Fleets			1 trawl only	
Discards			none significant, not fitted	
Age classes		*a*	0 – 29 years	
Sex ratio		p_s	0.5 (1:1)	
Natural mortality		*M*	estimated (0.263) per year	
Steepness		*h*	0.75	
Recruitment variation		σ_r	0.7	
Female maturity	1		40 cm (TL)	
Growth	2	L_{max}	65.0258 cm (TL)	fitted
		K	fitted	fitted
		L_{min}	fitted	fitted
		CV	Fitted (M & F assumed equal)	
			Female	Male
Length-weight (based	3	f_1	0.002 cm (TL)/gm	0.002
on standard length)		f_2	3.332	3.339

12.3.3 *Available data*

An array of different data sources are available for the deepwater flathead assessment including catch, standardized commercial CPUE, an index of relative abundance from the GAB Fishery Independent

Survey (FIS), age composition data from the Integrated Scientific Monitoring Program (ISMP) and from the FIS, and length composition data from four sources: the ISMP (keeping port sampling separate from the on-board sampling), from the FIS, and from on-board crew sampling (Figure 12.1). Age-at-length composition data for the fleet designated Trawl and the FIS were calculated from the available length compositions and conditional age-at-length data (age-length keys). Implied age compositions do not comprise additional data and are not included in the fitting of the model but are shown for information.

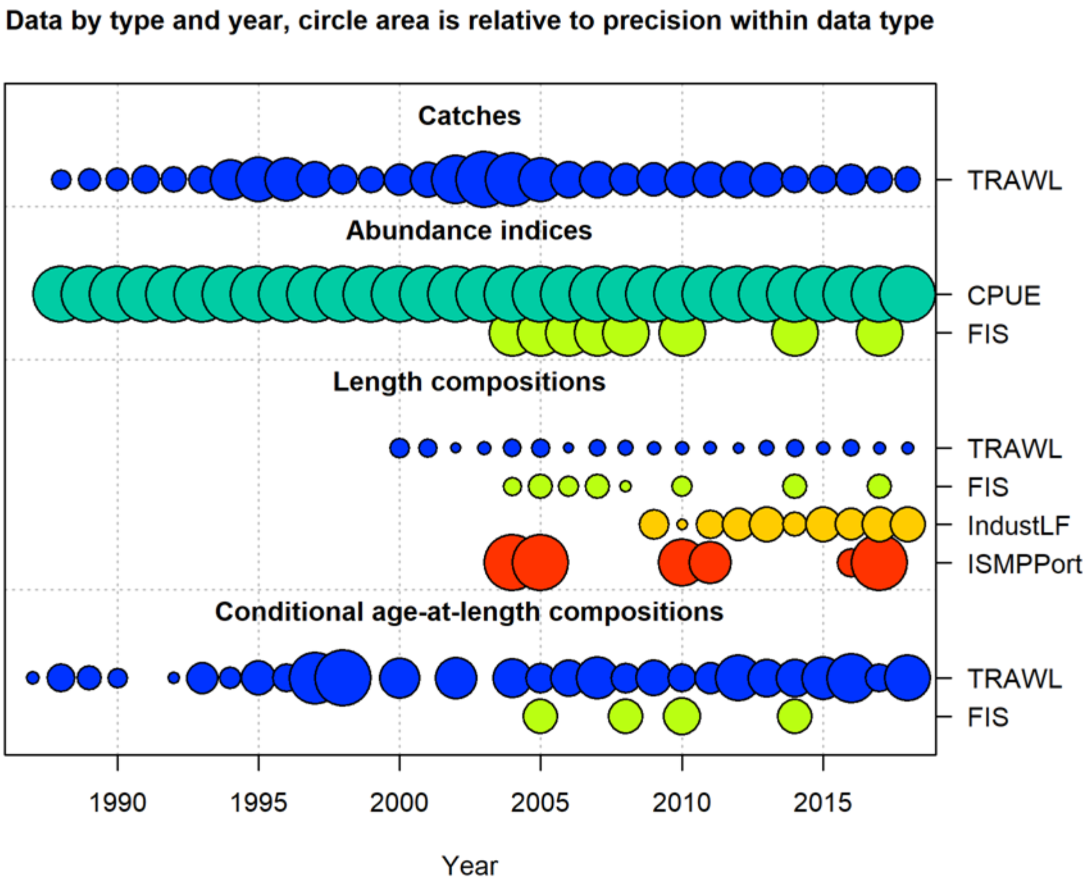

Figure 12.1. Summary of data sources for the 2019 base case deepwater flathead stock assessment.

The assessment data, other than catches, for deepwater flathead comes from a single trawl fleet; although there is a Danish seine vessel operating in the fishery. For the base case model, Danish seine catches are added into the trawl time series to fully account for removals. A sensitivity to the inclusion of a Danish Seine fleet is also provided. A landed catch history for deepwater flathead is available for the years from 1988/1989 to 2018/19. Landed catches were derived from GAB logbook records for the years to 2005 and catch disposal records have been the source of total landings since then. All landings were aggregated by financial year. In all figures, where single years are illustrated these represent the first year of the financial year. The 2018/19 catch value was used for the 2019/20 catch for projections and calculation of the 2020/21 RBC.

Catch rates from the trawl fishery were updated according to Sporcic (2019). The updated catch and catch rate data are in Table 12.3.

Table 12.3. Financial year values and estimates of catch and the standardized trawl CPUE for deepwater flathead in the GAB from 1988/1989 – 2018/2019. Catch is taken from logbook estimates until 2005/06 (Klaer, 2013; Haddon, 2016). Subsequently CDR catches are used. Discards are assumed to be negligible. Danish seine catches are added into the trawl catch for the base case assessment. Standardized CPUE is from Sporcic (2019).

Season	Catch (t)	CPUE
88/89	312.5	1.0601
89/90	394.7	1.0343
90/91	420.2	1.0106
91/92	608.1	0.9717
92/93	508.2	1.2351
93/94	585.1	1.6637
94/95	1254.8	2.0538
95/96	1551.6	1.9618
96/97	1459.3	1.3052
97/98	1010.4	0.9045
98/99	680.7	0.6969
99/00	545.0	0.8223
00/01	776.9	0.9019
01/02	963.6	1.082
02/03	1866.0	1.492
03/04	2482.1	1.4886
04/05	2264.1	1.1745
05/06	1545.6	0.7455
06/07	1029.9	0.6848
07/08	1025.4	0.7631
08/09	799.7	0.9111
09/10	851.3	0.8043
10/11	968.0	1.0191
11/12	973.4	0.8144
12/13	1027.8	0.8161
13/14	886.6	0.7165
14/15	567.1	0.6606
15/16	616.1	0.7405
16/17	732.0	0.7792
17/18	538.2	0.5878
18/19	517.7	0.5753

12.3.3.1 Fishery independent survey abundance estimates

There are now eight estimates of relative abundance from the trawl Fishery Independent Survey (Knuckey et al., 2018). The CV estimates for the abundance estimates are initially set at 0.10, but in the process of balancing the output variability with that input, these values are expanded (Table 12.4).

Table 12.4. FIS relative abundance estimates for deepwater flathead, with each survey estimate's coefficient of variation (taken from Knuckey *et al*., 2018).

Year	2004/05	2005/06	2006/07	2007/08	2008/09	2010/11	2014/15	2017/18
Estimate	12,152	8,415	8,540	7,725	9,942	9,227	5,065	3,396
CV (original)	0.05	0.06	0.05	0.06	0.05	0.05	0.09	0.06

12.3.3.2 Age composition data

An estimate of the standard deviation of age reading error was calculated by Andre Punt (pers. comm., 2019) from data supplied by Kyne Krusic-Golub of Fish Ageing Services (Table 12.5).

Age data exist from the ISMP sampling program and the GABFIS. Ages from the trawl ISMP program exist from 1987/88 to 2018/19, and for the FIS from 2005/06, 2008/09, 2010/11, and 2014/15 (Table 12.6). Age compositions (a combination of the age data and lengths for a particular year) are illustrated in the Appendix. These implied ages are not fit in the model, as the model uses the age-at-length data.

Table 12.5. The estimated standard deviation of normal variation (age-reading error) around age-estimates for the different age classes of deepwater flathead for two readers (1) and (2).

Age	StDev (1)	StDev (2)	Age	StDev (1).	StDev (2)	Age	StDev (1).	StDev (2)
0	0.217633	0.224181	10	0.566769	0.534678	20	1.04301	0.709502
1	0.217633	0.224181	11	0.609909	0.558339	21	1.09652	0.721021
2	0.253167	0.269406	12	0.653988	0.580356	22	1.1512	0.73174
3	0.289475	0.311491	13	0.699027	0.600845	23	1.20707	0.741715
4	0.326574	0.350653	14	0.745048	0.619911	24	1.26416	0.750997
5	0.364481	0.387095	15	0.792071	0.637652	25	1.32249	0.759634
6	0.403214	0.421006	16	0.840119	0.654161	26	1.38209	0.767671
7	0.442791	0.452562	17	0.889213	0.669524	27	1.44299	0.775151
8	0.48323	0.481926	18	0.939376	0.68382	28	1.44299	0.775151
9	0.524549	0.509251	19	0.990633	0.697123	29	1.44299	0.775151

Table 12.6. Number of age-length otolith samples included in the base case assessment by fleet.

Year	ISMP	FIS
1987	61	
1988	290	
1989	214	
1990	146	
1991		
1992	50	
1993	358	
1994	178	
1995	430	
1996	287	
1997	972	
1998	1162	
1999		
2000	599	
2001		
2002	639	
2003		
2004	563	
2005	326	229
2006	484	
2007	650	
2008	328	225
2009	465	
2010	290	262
2011	367	
2012	787	
2013	528	
2014	519	224
2015	666	
2016	877	
2017	293	
2018	774	

12.3.3.3 Length composition data

Length data exist from ISMP sampling (onboard and port), the GABFIS and industry sampling programs (Table 12.7). As is standard practice, the ISMP onboard and port length samples are separately fit in the model. A single selectivity is estimated as a function of length using length data from the ISMP and the industry sampling program. The GABFIS has a separate selectivity using the FIS lengths alone. The length compositions for each source are illustrated in the Appendix.

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; Francis (2011)), with a cap of 200. For port samples, numbers of trips were used as the sampling unit, with a cap of 100. For industry samples, numbers of days of sampling were used as the sampling unit, with a cap of 200. 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), trips (port) or days (industry) sampled, rather than the number of fish measured.

Table 12.7. Number of onboard retained lengths and number of shots, days or trips for length frequencies included in the base case assessment by fleet.

Year	Trawl Onboard		FIS		Industry Sampling		Port	
	Shots	Fish	Shots	Fish	Days	Fish	Trips	Fish
2000	66	6885						
2001	58	6402						
2002	17	2273						
2003	29	3124						
2004	55	3060	28	1131			27	3009
2005	58	3547	50	1738			27	2823
2006	17	980	35	937				
2007	45	1575	51	2399				
2008	41	1470	11	1332				
2009	29	1827			144	11760		
2010	30	837	36	959	19	1637	19	1637
2011	27	1352			134	10795	15	1006
2012	20	1372			170	10448		
2013	41	1721			200	10499		
2014	51	2614	51	1337	94	4826		
2015	29	1209			196	16092		
2016	47	2274			161	12826	7	1164
2017	24	1171	51	1052	200	25258	27	2378
2018	25	1009			200	24756		

12.3.4 *Tuning procedure*

In iterative reweighting, the effective annual sample sizes are tuned/adjusted so that the input sample size is equal to the effective sample size calculated by the model. In SS-V3.30 there is an automatic adjustment made to survey CVs (CPUE).

1. Set the standard error for the log of the relative abundance indices (CPUE, acoustic abundance survey, or FIS) to their estimated standard errors for each survey or for CPUE (and FIS values) to the root mean squared deviation of a loess curve fitted to the original data (which will provide a more realistic estimate to that obtained from the original statistical analysis). SS-V3.30 then 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 0.7, reflecting the variation in recruitment. 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 Methot and Taylor (2011).

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

3. Multiply the initial sample sizes for the conditional age-at-length data by the sample size multipliers using the approach of Punt (2017).

4. Similarly multiply the initial samples sizes by the sample size multipliers for the length composition data using the 'Francis method' (Francis, 2011).
5. Repeat steps 3 and 4, until all are converged and stable (proposed changes are < 1%).

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

12.3.5 *Calculating the RBC*

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. In 2009, AFMA directed that the 20:40:40 (B_{lim}: B_{MSY}: F_{targ}) form of the rule is used up to where fishing mortality reaches F_{48}, the default economic target of B_{MEY}. Once this point is reached, the fishing mortality is set at F_{48}. Day (2009) determined that for most SESSF stocks where the proxy values of B_{40} and B_{48} are used for B_{MSY} and B_{MEY} respectively, this form of the rule is equivalent to a 20:35:48 (B_{lim}: Inflection point: F_{targ}) strategy. For deepwater flathead the B_{MEY} value is 43% of B_0, as reported in Kompas et al. (2011), and therefore a 20:35:43 harvest control rule is used.

12.3.6 *Sensitivity tests and alternative models*

12.3.6.1 Standard sensitivities

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

1. M = 0.28 yr^{-1}.
2. M = 0.24 yr^{-1}.
3. Fix steepness (h) at 0.85.
4. Fix steepness (h) at 0.65.
5. σ_R set to 0.8.
6. σ_R set to 0.6.
7. Double the weighting on the length composition data.
8. Halve the weighting on the length composition data.
9. Double the weighting on the age-at-length data.
10. Halve the weighting on the age-at-length data.
11. Double the weighting on the survey (CPUE) data.
12. Halve the weighting on the survey (CPUE) data.
13. Interpolated FIS abundance values (tuned).
14. Include Danish seine (tuned).

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

1. SSB_0: the average unexploited female spawning biomass.
2. SSB_{2020}: the female spawning biomass at the start of 2020.

3. SSB_{2020}/SSB_0: the female spawning biomass depletion level at the start of 2020.
4. RBC_{2020}: the recommended biological catch (RBC) for 2020.
5. $RBC_{2020\text{-}22}$: the mean RBC over the three years from 2020-2022.
6. $RBC_{longterm}$: the longterm RBC.

The RBC values were calculated for the agreed base case only.

12.3.6.2 Interpolated FIS abundance values

To consider the potential influence of GABFIS abundance indices on model outcomes, GABRAG members suggested filling in years where there was no GABFIS by linearly interpolating the GABFIS points surrounding the missing years (from 2010). This results in the abundance indices shown in Figure 12.2.

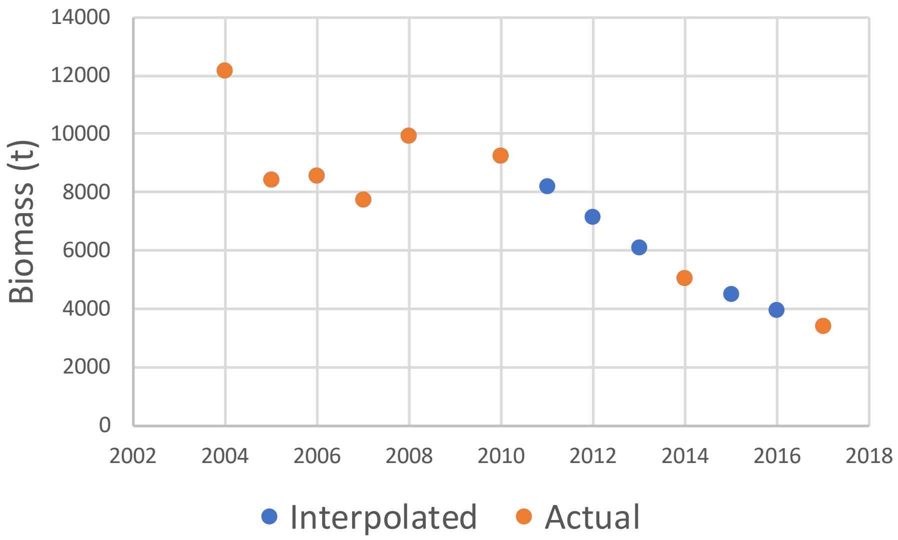

Figure 12.2. The GABFIS abundance values (orange) with linearly interpolated values from 2010 (blue).

12.3.6.3 Danish seine

The inclusion of a separate Danish seine (DS) fleet as an alternative to the base case model structure was considered at the November GABRAG meeting (Tuck et al., 2019). Diagnostics of this model will not be repeated here. However, standard sensitivity metrics are provided for this model. In past assessments, the DS fleet has not been included in the model structure due to a paucity of additional information (on lengths and ages for example, nor is there an index of abundance from this fleet). For this sensitivity, DS catches were separated from trawl, using the proportion of each fleet's logbook catch apportioned to the CDR landings (Table 3 of Tuck et al., 2019). There were also two years of age-at-length data (2016 and 2017) and lengths from years 2012, 2016 and 2017 available. A separate selectivity function was estimated. Results from this model showed an increase in the magnitude of spawning biomass across the mid-years of the time-series, but has a similar final year depletion level to the base case model.

12.3.6.4 Zone 50

An additional sensitivity provided in November 2019 considered the addition of catches (logbook) of deepwater flathead from Zone 50 (Z50) to the GAB catch series. There was little difference to the time-series of spawning biomass or relative spawning biomass under this scenario and so it is not considered further here.

12.4 Results

12.4.1 The base case

12.4.1.1 Parameter estimates

Figure 12.3 shows the estimated growth curve for female and male deepwater flathead.

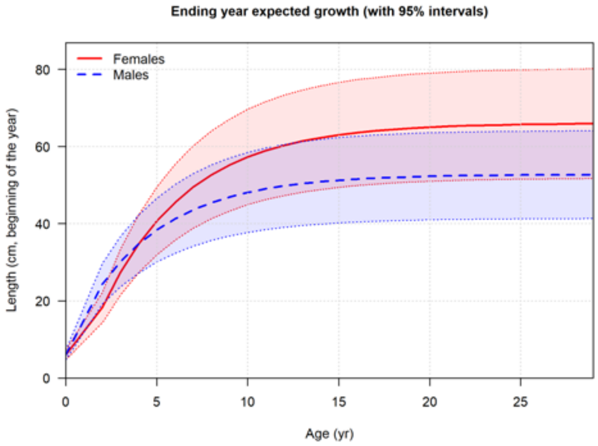

Figure 12.3. The model estimated growth curves for the base case deepwater flathead assessment.

Selectivity is assumed to be logistic for the trawl and FIS fleets. The parameters that define the selectivity function are the length at 50% selection and the spread (the difference between length at 50% and length at 95% selection).

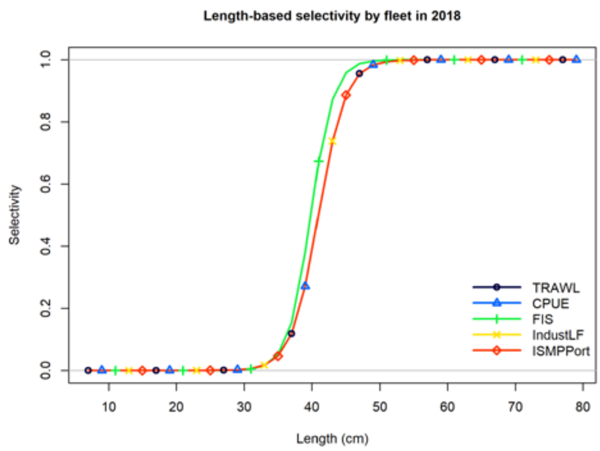

Figure 12.4. Estimated selectivity curves for deepwater flathead. There are only two different selectivity patterns listed here, with Industry, port and onboard fleets having the same selectivity, but the FIS fleet having a separate estimated selectivity.

12.4.1.2 Fits to the data

Results show reasonably good fits to the catch rate data (since 2005), length data and conditional age-at-length data. The fits to the FIS abundance indices show a fairly poor fit to the final two years, which may also have influenced the under-fit to the initial 5 years of FIS indices (Figure 12.5).

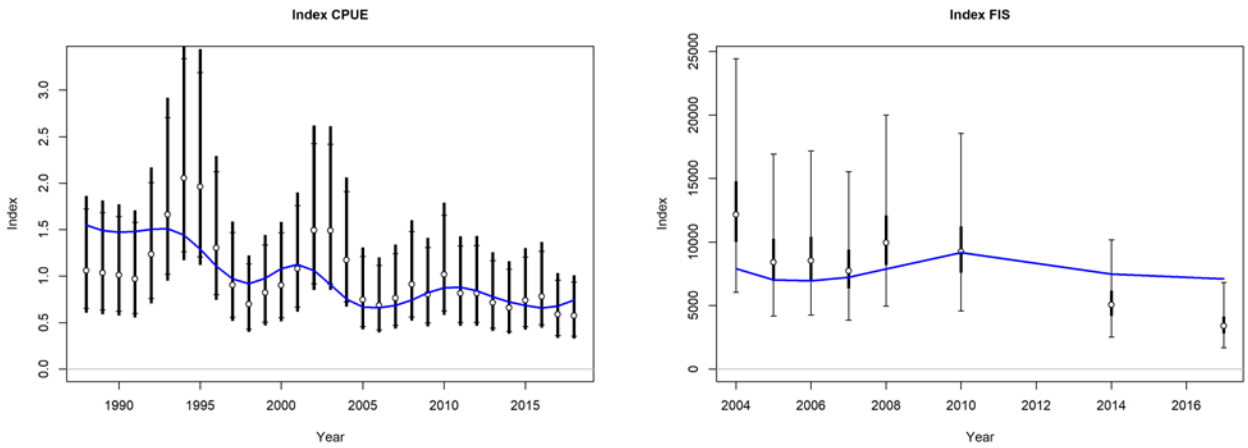

Figure 12.5. Fits to CPUE and GABFIS for deepwater flathead.

The base-case model is able to fit the aggregated retained length-frequency distributions very well (Figure 12.6). The annual length and age composition fits are shown in Appendix A. The age compositions were not fitted to directly, as age-at-length data were used. However, the model is capable of outputting the implied fits to these data for years where length frequency data are also available, even though they are not included directly in the assessment. The model fits the observed age data reasonably well. Note that there are separate implied fits to age for the port and onboard data. There is only one set of age data, but this needs to be scaled up to length data (using an age-length key) to get implied fits to age. This scaling up to length data can be done using either the onboard length data or the port length data, so it appears that there are two sets of age data.

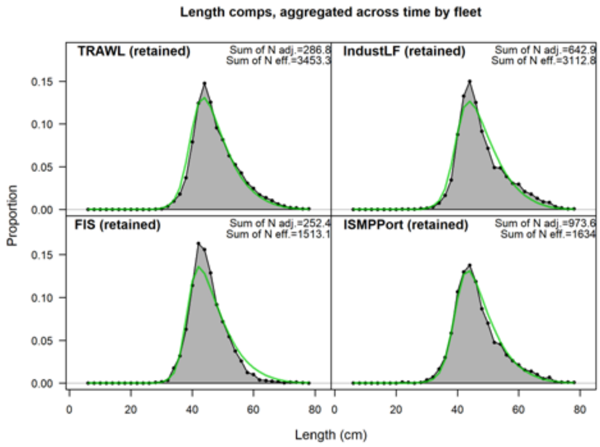

Figure 12.6. Aggregated fits (over all years) to the length compositions for deepwater flathead displayed by fleet.

12.4.1.3 Assessment outcomes

This assessment estimates that the projected 2020/21 spawning stock biomass will be 45% of virgin stock biomass (projected assuming 2018/19 catches in 2019/20; Figure 12.7), compared to 45% at the start of 2016/17 from the 2016 assessment (Haddon, 2016). The inclusion of new and updated data in the current assessment has led to changes in the shape of the spawning biomass trajectory, but the depletion remains near the target of 43%. The base case assessment estimated the unexploited female spawning biomass, *SSBo*, to be 9,008t. Recruitments show a fluctuating pattern, with a recent period of poor recruitment from 2008 to 2011. However, the 2012 and 2013 estimated recruitments are closer to average (Figure 12.8).

Figure 12.9 shows a Kobe plot for the base case analysis. This plot shows a time series of spawning biomass plotted against spawning potential ratio, which provides a measure of overall fishing mortality, and shows the stepwise movement in this space from the start of the fishery, in the bottom right corner, when there was low fishing mortality and high biomass, to the present day (the red dot) where the biomass is just below the target (to the left of the vertical red dashed line) and the fishing mortality is below the target fishing level (below the horizontal red dashed line).

The 2020 recommended biological catch (RBC) under the 20:35:43 harvest control rule is 1,253 t and the long-term yield (assuming average recruitment in the future) is 1,218 t. Averaging the RBC over the three-year period 2020/21 – 2022/23, the average RBC is 1,238 t (Table 12.8).

Table 12.8. Yearly projected RBCs (tonnes) under the 20:35:43 harvest control rule.

RBCs Year	Base
2020	1,253
2021	1,238
2022	1,224
2023	1,214
2024	1,211

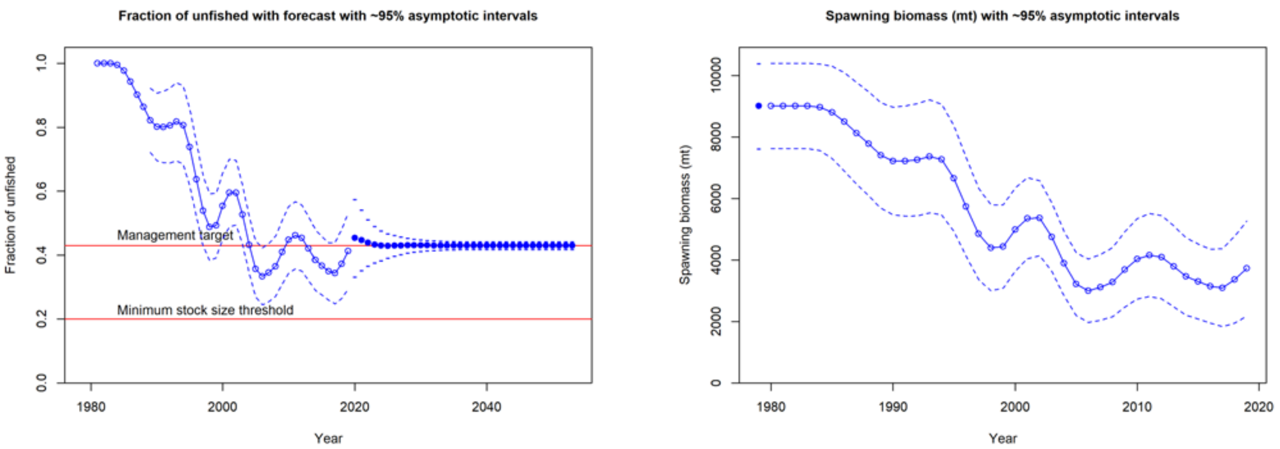

Figure 12.7. The projected relative spawning biomass trajectory (left) and magnitude of spawning biomass (right) for the deepwater flathead base case assessment.

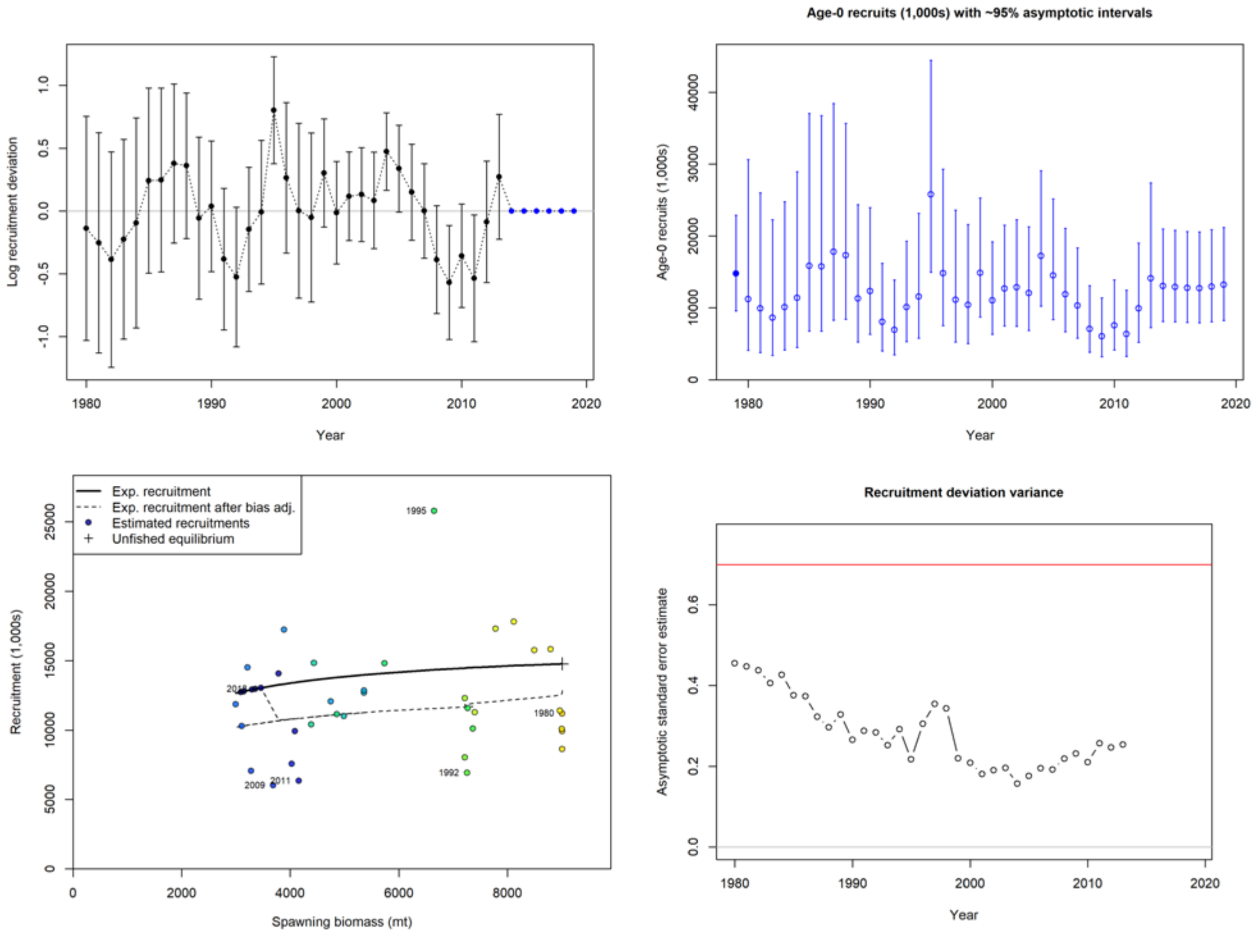

Figure 12.8. Recruitment deviations and estimates with confidence intervals (top), stock recruitment curve and recruitment deviation variance check (bottom) for deepwater flathead.

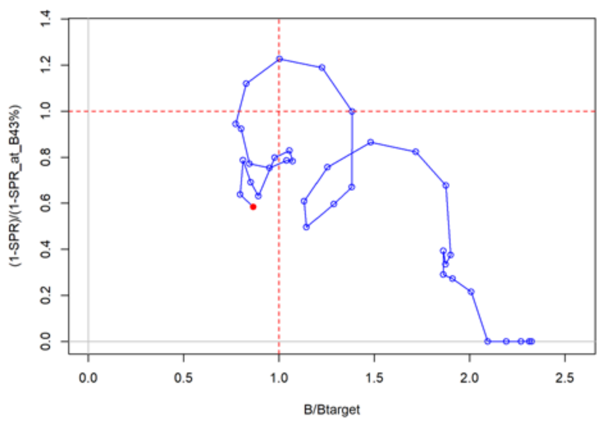

Figure 12.9. Phase plot of biomass vs SPR ratio.

12.4.2 *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 for a parameter of interest. 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).

Likelihood profiles for key parameters of interest (such as natural mortality (*M*), steepness (*h*) and virgin spawning biomass) were provided in Tuck et al. (2019) for the agreed base case. These, and the retrospective analyses, are not repeated here. However, a likelihood profile for 2018 depletion was not available for the November GABRAG meeting and is shown in Figure 12.10, with the total likelihood shown in black and components of the total likelihood from different data sources shown in a range of colours. The index data suggest a lower value of depletion, whereas the length data suggest a higher value. However, the confidence intervals of 2018 depletion are reasonably broad, being between 0.28 and 0.5 of virgin biomass.

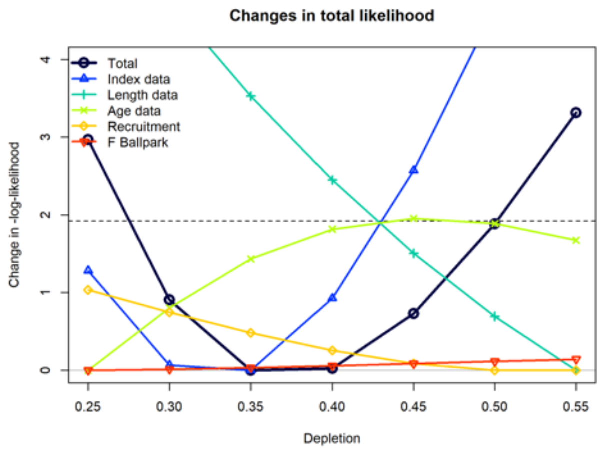

Figure 12.10. The likelihood profile for 2018 depletion.

12.4.3 *Sensitivity tests and alternative models*

12.4.3.1 Standard sensitivities

Results of the sensitivities to the potential base case are listed in Table 12.9. The usual set of sensitivities are provided (which includes sensitivities on mortality, steepness, σ_R and halving and doubling the weighting on length, age and index data) and the sensitivities to the inclusion of Danish seine and the interpolated FIS abundance values. Results are not overly sensitive to varying key parameters, with depletion estimates ranging between 41% and 53% of virgin biomass, but with most around 45%.

Unweighted likelihood components for the base case and differences for the sensitivities are shown in Table 12.8. This table tends to show that for most alternatives, the fit to the data is degraded by moving away from base case model values or weighting schemes.

12.4.3.2 Interpolated FIS abundance values

Including interpolated values since 2010 for the GABFIS for years in which there was no FIS led to a slight decline in the recent spawning biomass series. This is not too surprising, as the model is attempting to fit to a greater number of GABFIS points that show a declining relative abundance trend (Figure 12.11). While the fit to the recent GABFIS abundance may have improved, the fit to the earlier GABFIS abundance points has degraded. These results show that annual FIS points can have a strong influence on results, but it needs to be recognised that the imputed signal (from the linearly interpolated points) provided a strong and consistent signal of a declining relative biomass trend which may not have eventuated in reality given uncertainties associated with FIS surveys.

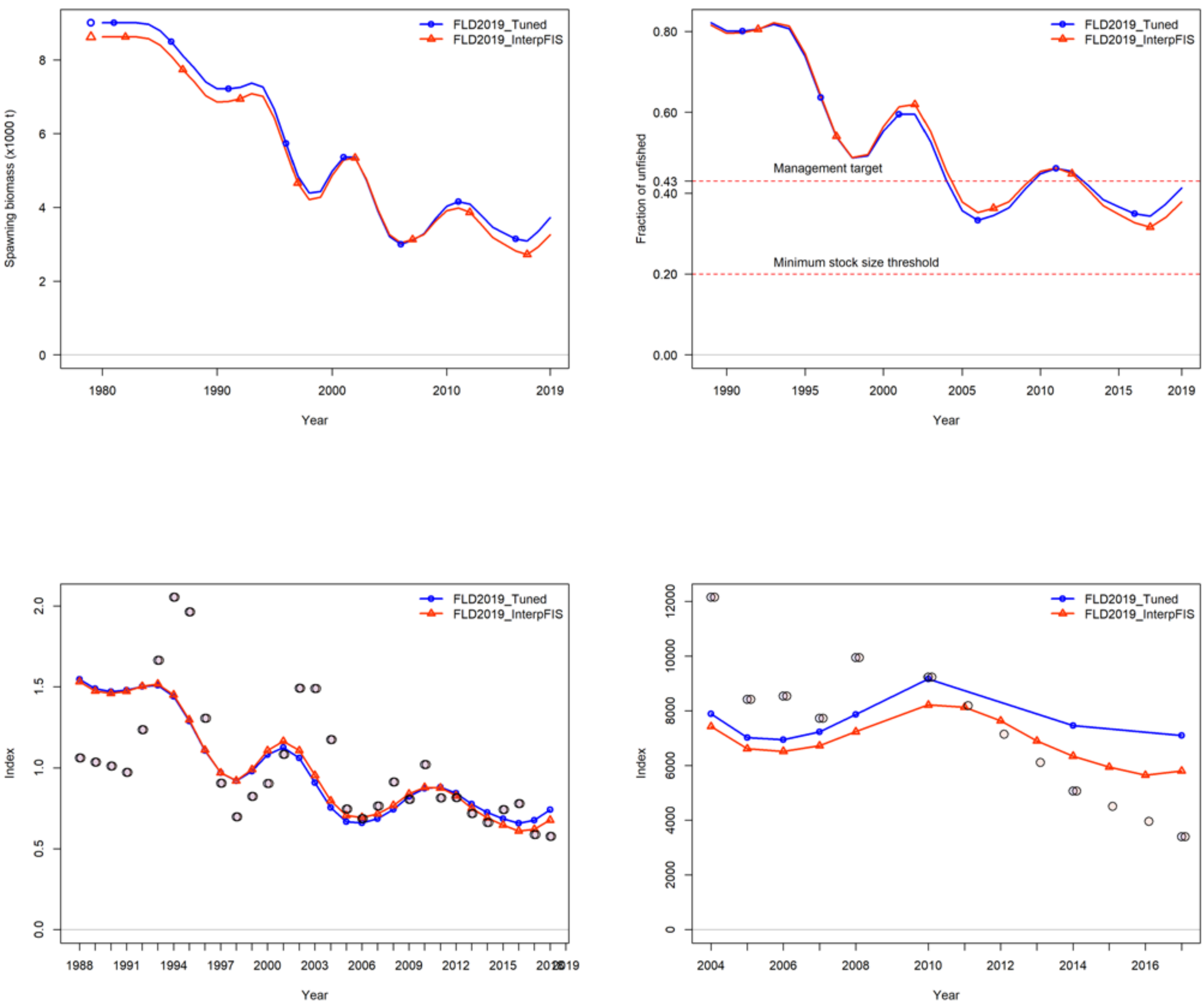

Figure 12.11. The magnitude of spawning biomass trajectory and relative spawning biomass (top), and fits to the catch rate data and FIS (bottom) for the deepwater flathead base case assessment (FLD2019_Tuned) and the sensitivity that includes interpolated FIS abundance values (FLD2019_InterpFIS).

Table 12.9. Summary of results for the base-case and sensitivity tests. Recommended biological catches (RBCs) are only shown for the base case.

Case		SSB0	SSB2020	SSB2020/SSB0	RBC2020	RBC2020-22	RBClongterm
0	base case (M 0.26, h 0.75)	9,008	4,083	0.45	1,253	1,238	1,218
1	M 0.28	9,235	4,470	0.48			
2	M 0.24	8,879	3,654	0.41			
3	h 0.85	8,757	4,131	0.47			
4	h 0.65	9,364	4,038	0.43			
5	σR = 0.8	9,679	4,292	0.44			
6	σR = 0.6	8,516	3,956	0.46			
7	wt x 2 length comp	9,945	5,251	0.53			
8	wt x 0.5 length comp	8,558	3,465	0.40			
9	wt x 2 age comp	9,030	3,922	0.43			
10	wt x 0.5 age comp	9,352	4,441	0.47			
11	wt x 2 index	8,298	3,562	0.43			
12	wt x 0.5 index	9,726	5,068	0.52			
13	interp FIS	8,622	3,607	0.42			
14	include Danish seine	9,257	4,529	0.49			

Table 12.10. Summary of likelihood components for the base-case and sensitivity tests. Likelihood components are unweighted, and cases 1-14 are shown as differences from the base case. A negative value indicates a better fit, a positive value a worse fit.

Case		Likelihood TOTAL	Survey	Length comp	Age comp	Recruitment
0	base case (*M* 0.26, *h* 0.75)	544.81	-31.99	131.25	452.12	-6.63
1	*M* 0.28	0.42	-1.05	-0.37	1.85	-0.04
2	*M* 0.24	0.81	1.85	0.61	-1.73	0.11
3	*h* 0.85	0.14	0.07	0.14	-0.07	0.01
4	*h* 0.65	-0.11	-0.08	-0.19	0.13	0.02
5	$\sigma_R = 0.8$	3.53	0.38	0.12	-0.03	3.06
6	$\sigma_R = 0.6$	-3.60	-0.03	-0.11	-0.05	-3.41
7	wt x 2 length comp	5.35	1.94	-11.11	14.49	-0.01
8	wt x 0.5 length comp	2.48	-0.81	8.91	-5.82	0.21
9	wt x 2 age comp	4.49	7.61	8.62	-11.45	-0.27
10	wt x 0.5 age comp	6.87	-6.98	-9.40	22.31	0.89
11	wt x 2 index	4.41	-10.27	1.69	10.86	2.12
12	wt x 0.5 index	2.38	9.13	-1.13	-5.03	-0.59
13	interp FIS	-17.37	-7.13	-3.62	-7.08	0.46
14	include Danish seine	267.23	-6.15	0.55	272.10	0.60

12.5 Acknowledgments

Age data was provided by Kyne Krusic-Golub (Fish Ageing Services), ISMP and AFMA logbook and CDR data were provided by John Garvey (AFMA). Mike Fuller, Roy Deng, Franzis Althaus and Robin Thomson (CSIRO) pre-processed the data. Miriana Sporcic, Robin Thomson, Malcolm Haddon (CSIRO), Claudio Castillo-Jordán (UW) and Ian Taylor (NOAA) are thanked for helpful discussions on this work. André Punt updated the ageing error matrix. Malcolm Haddon provided code for auto-tuning and Athol Whitten provided R code for organising plots.

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12.7 Appendix A

A.1 Base case diagnostics

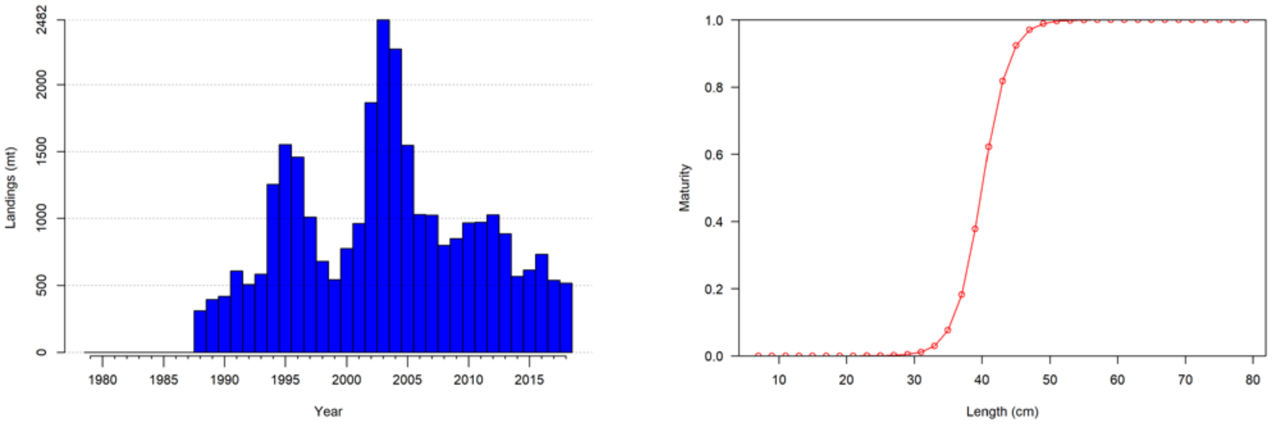

Figure A 12.1. Maturity and landings for deepwater flathead.

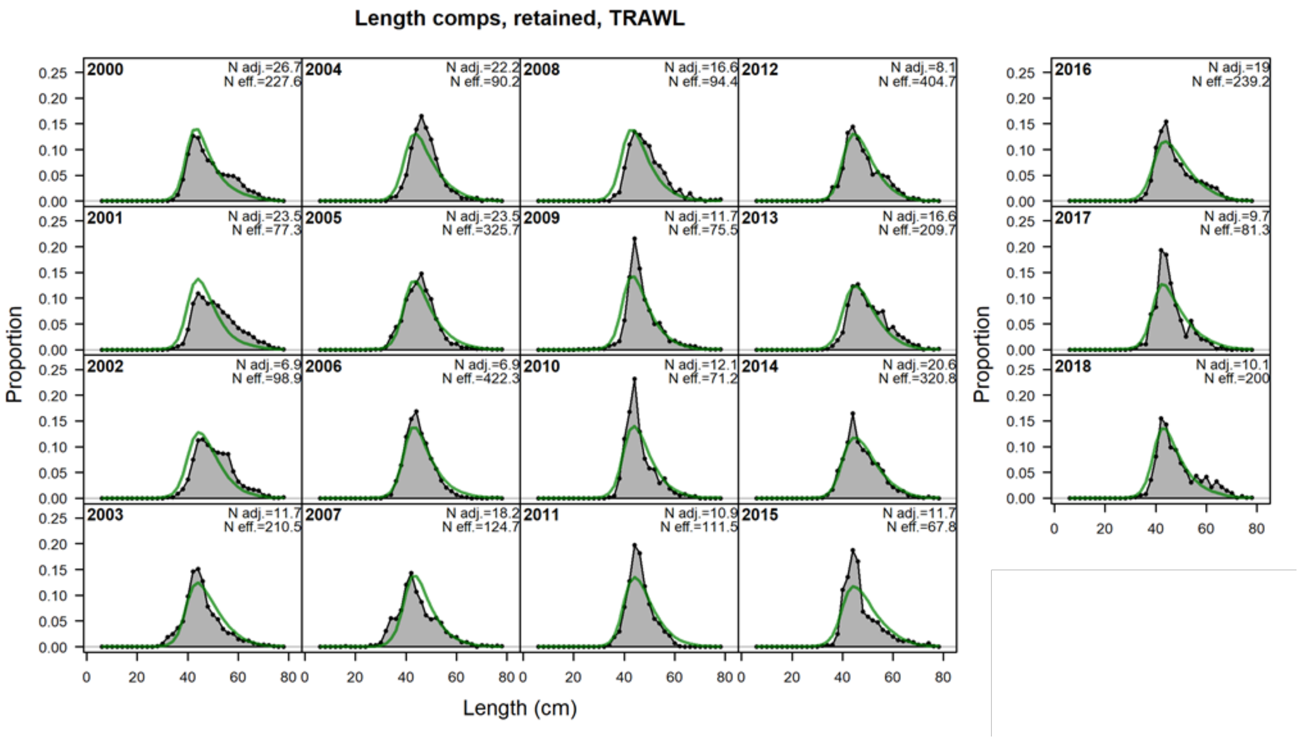

Figure A 12.2. Deepwater flathead length composition fits: retained trawl onboard.

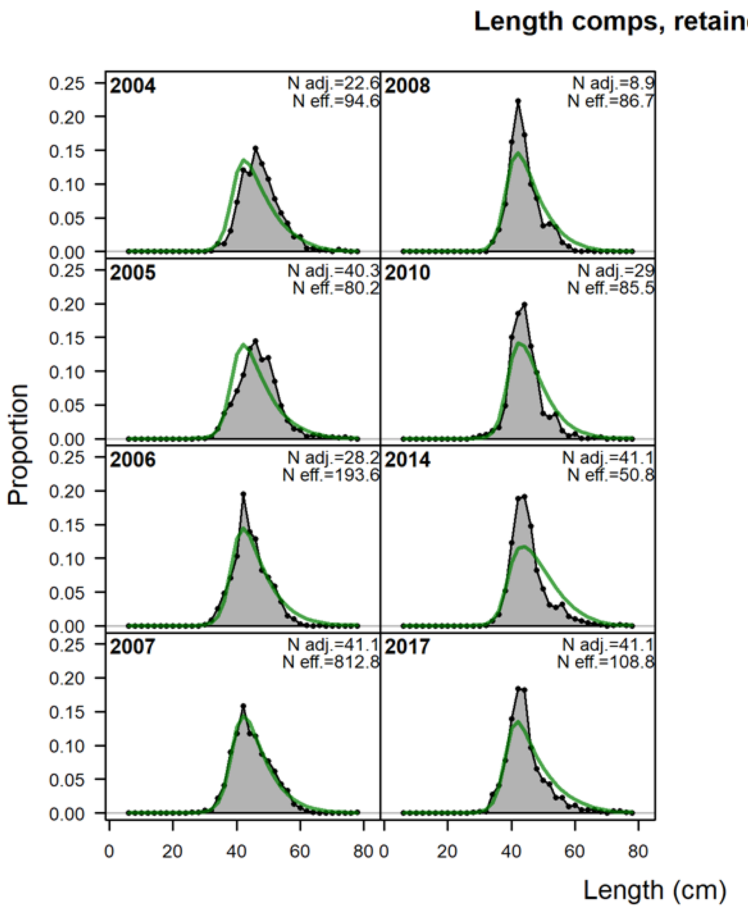

Figure A 12.3. Deepwater flathead length composition fits: FIS retained.

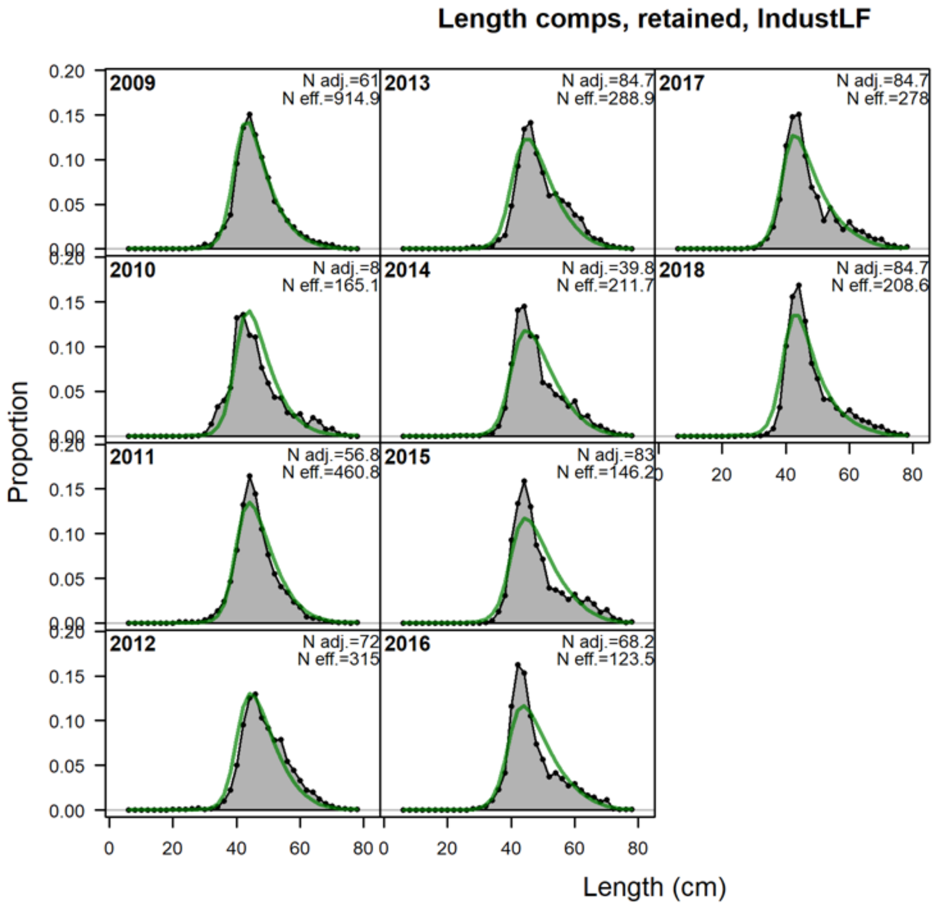

Figure A 12.4. Deepwater flathead length composition fits: Industry lengths.

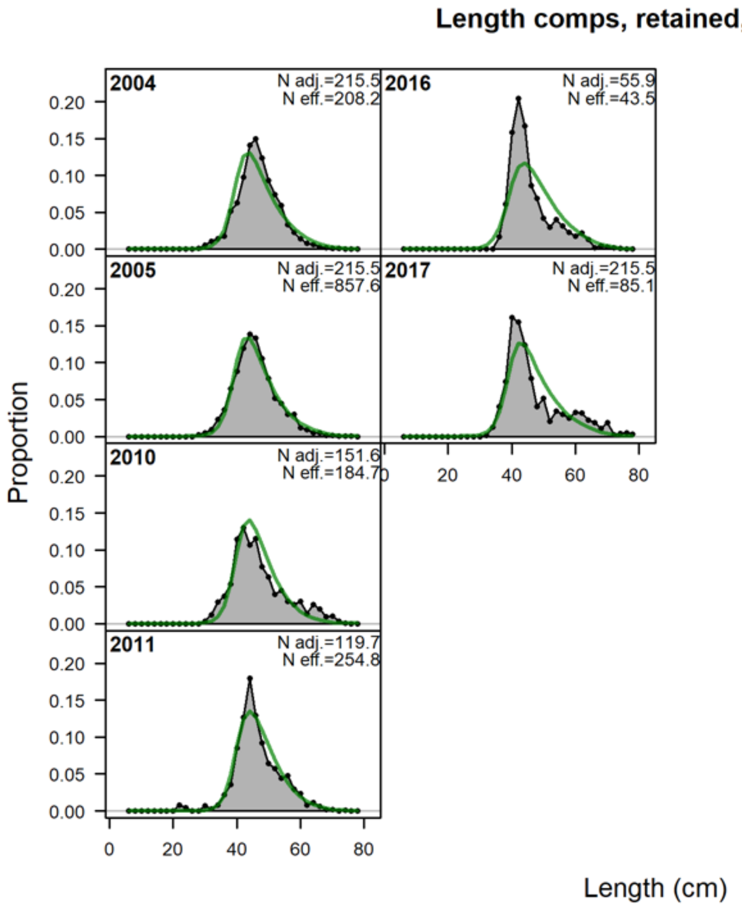

Figure A 12.5. Deepwater flathead length composition fits: Port.

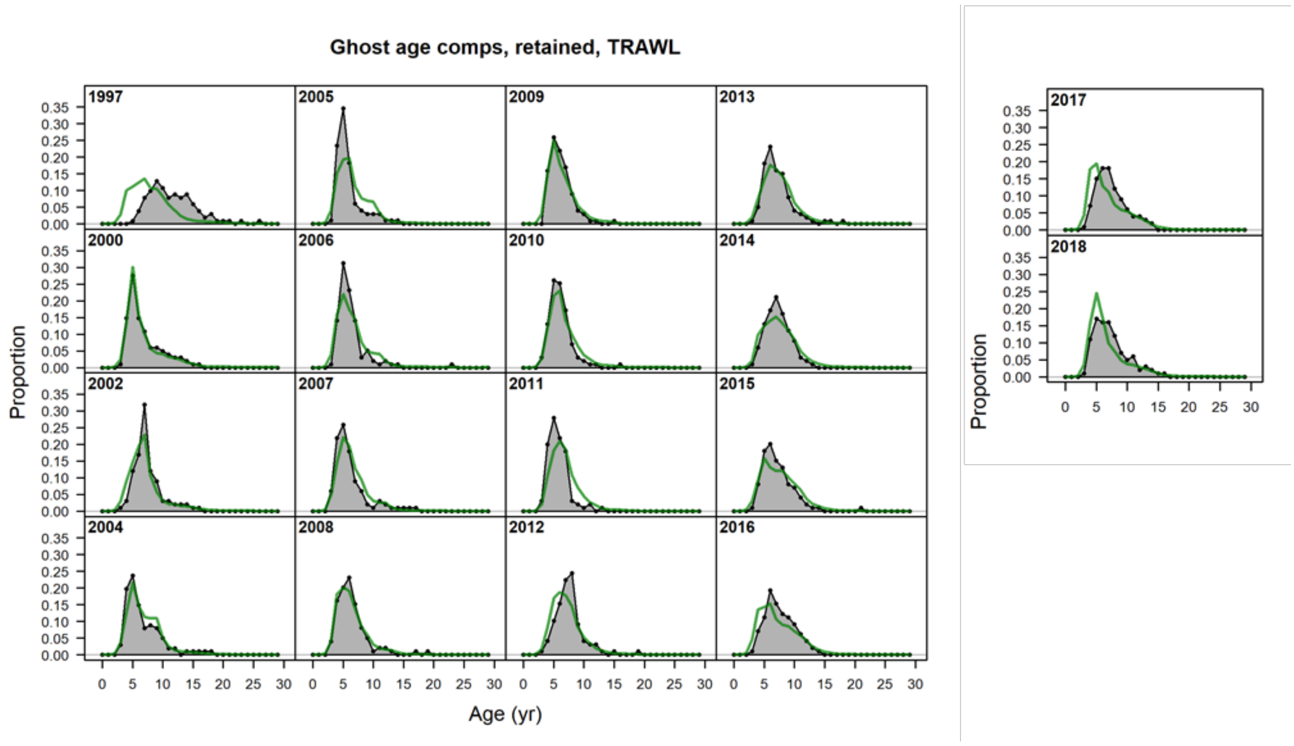

Figure A 12.6. Deepwater flathead implied fits to age: Trawl onboard retained.

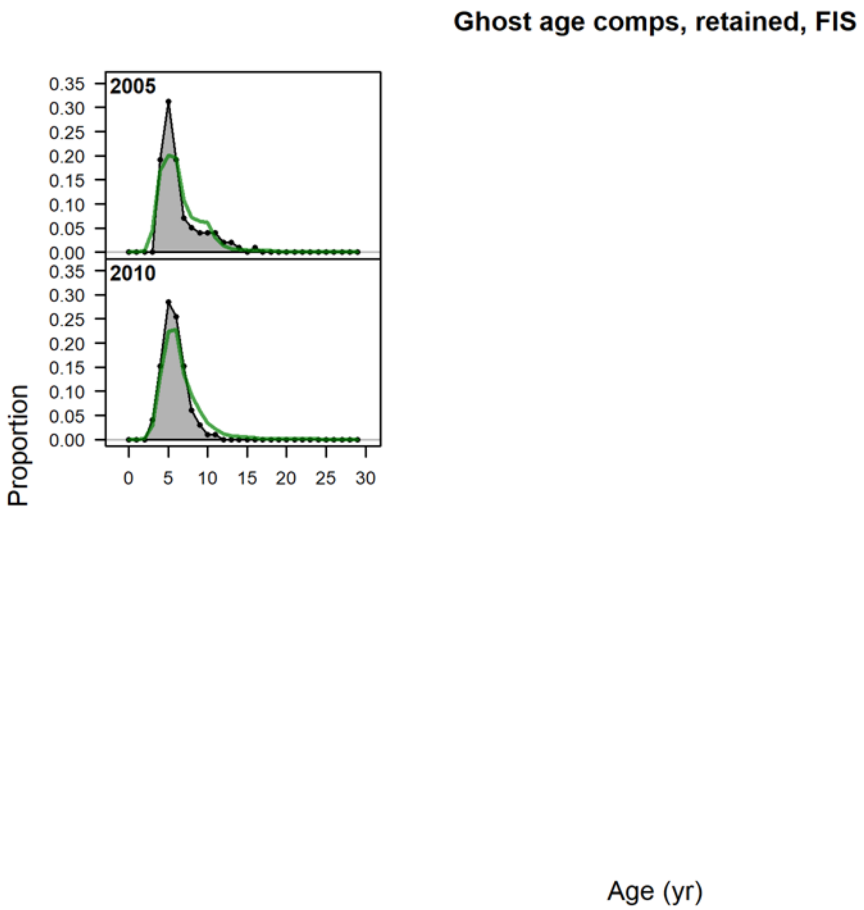

Figure A 12.7. Deepwater flathead implied fits to age: FIS

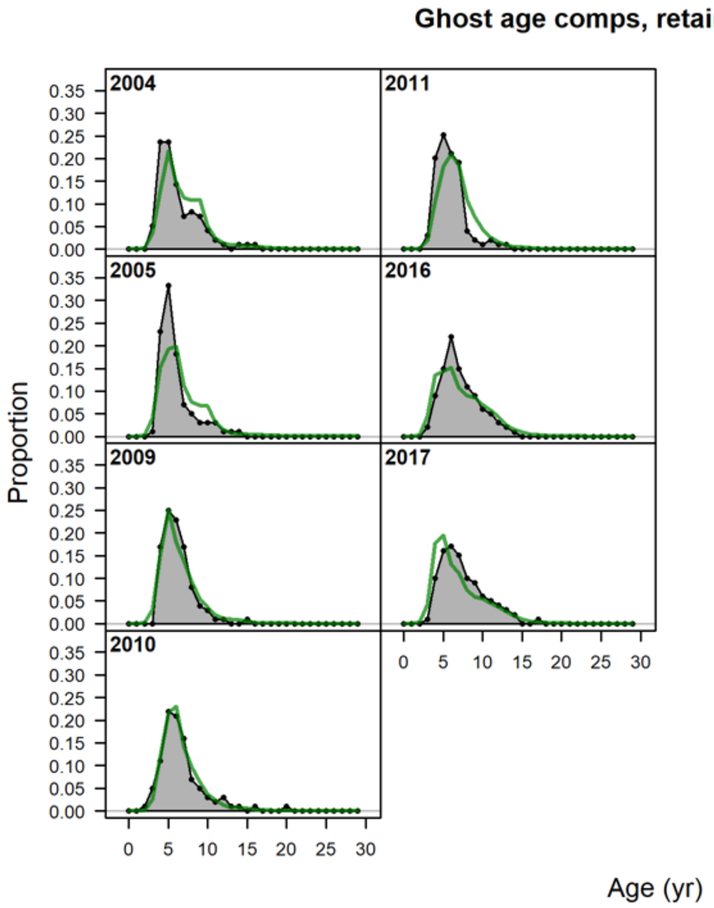

Figure A 12.8. Deepwater flathead implied fits to age: Port.

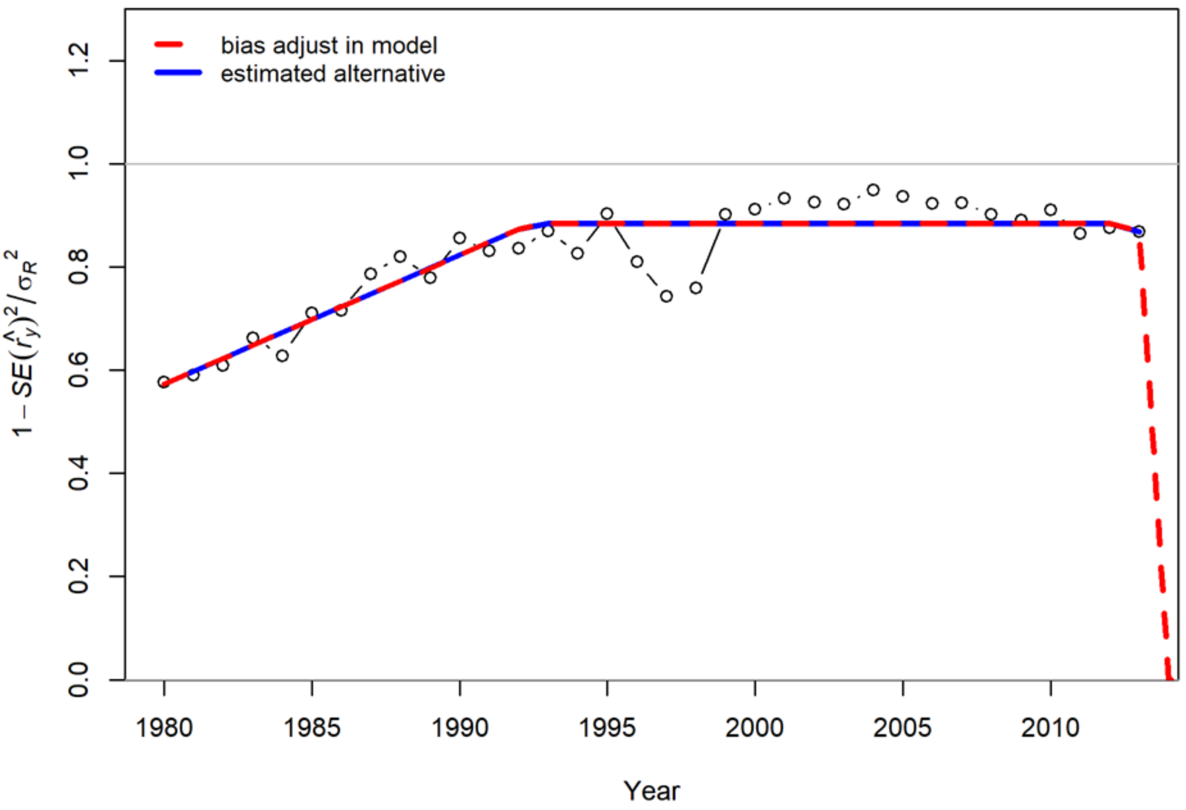

Figure A 12.9. Bias ramp adjustment for deepwater flathead.