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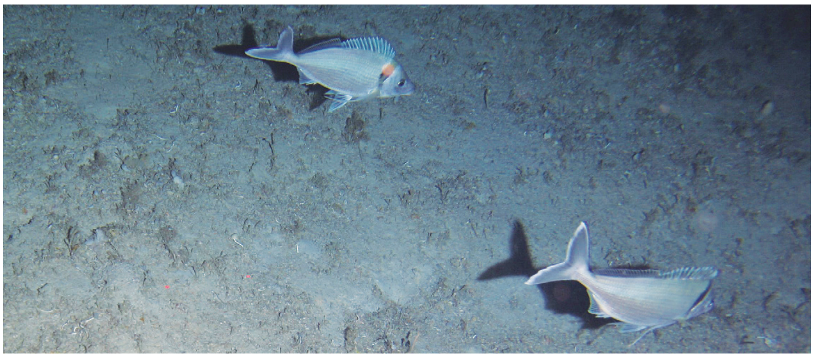
Australian Fisheries Management Authority

2017/0824 June 2020

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



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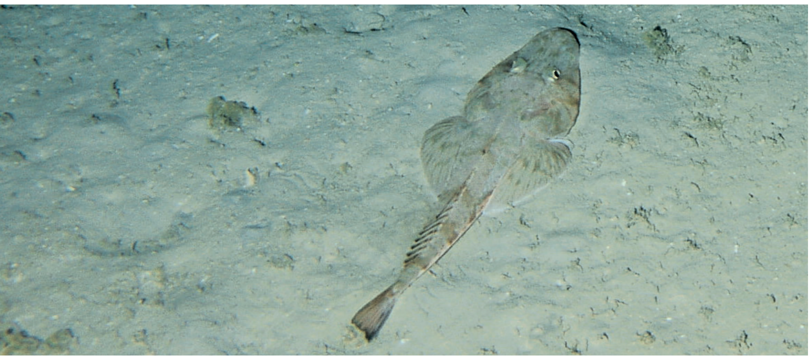

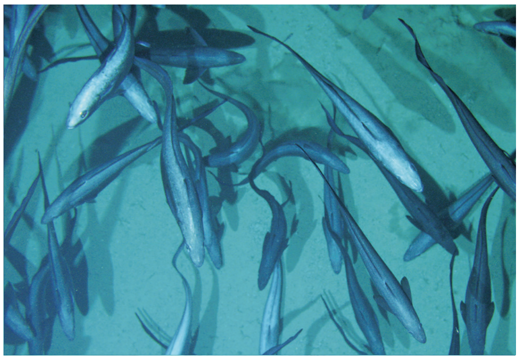

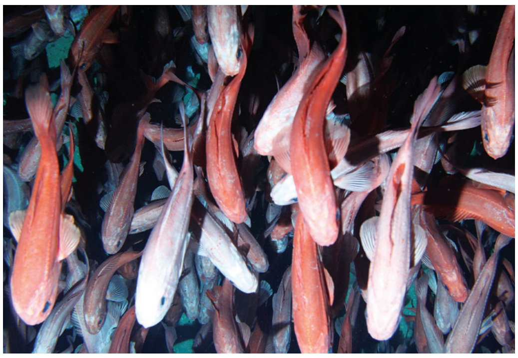

Principal investigator **G.N. Tuck**

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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 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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7. Tiger flathead (*Neoplatycephalus richardsoni)* stock assessment based on data up to 2018

Jemery Day

CSIRO Oceans and Atmosphere, Castray Esplanade, Hobart TAS 7000, Australia

7.1 Executive Summary

This document updates the 2016 assessment of tiger flathead (*Neoplatycephalus richardsoni*) to provide estimates of stock status in the SESSF at the start of 2020. This assessment was performed using the stock assessment package Stock Synthesis (version SS-V3.30.14). The 2016 stock assessment has been updated with the inclusion of data up to the end of 2018, comprising an additional three years of catch, discard, CPUE, length and age data and ageing error updates. An additional 2016 survey point is included from the Fishery Independent Survey (FIS) and FIS length frequencies have been included from the winter 2016 FIS and summer 2008, 2010 and 2012 FIS. A range of sensitivities were explored.

The base case assessment estimates that current spawning stock biomass is 34% of unexploited stock biomass (SSB_0), compared to 42% in the 2016 assessment (Day, 2017) and 50% from the 2013 assessment (Day and Klaer, 2013). Under the agreed 20:35:40 harvest control rule, the 2020 recommended biological catch (RBC) is 2,334 t, and is below the long-term yield (assuming average recruitment in the future) of 2,986 t. The average RBC over the three-year period 2020-2022 is 2,563 t and over the five-year period 2020-2024, the average RBC is 2,648 t.

Exploration of model sensitivity showed a variation in spawning biomass from 27% to 41% of SSB_0, which occurred when natural mortality was fixed at values of 0.22 and 0.32 respectively. For the other standard sensitivities explored, the variation in spawning biomass was much narrower, ranging between 32% and 34%.

Changes to the last stock assessment include: using the FIS3 abundance indices; including summer FIS length frequencies; incorporation of conditional age-at-length data for 2008 from the FIS; and updating the tuning method and bias ramp estimation. This change in stock status is largely due to below average newly estimated recruitment events, particularly in 2013 but also in 2014, and a revision to the previously estimated 2012 recruitment event. The 2013 poor recruitment is supported both by the age and length data and by the recent index data, and the updated assessment fits all of these data sources well.

7.2 Introduction

7.2.1 *The fishery*

Tiger flathead have been caught commercially in the south eastern region of Australia since the development of the trawl fishery in 1915. They are endemic to Australian waters and are caught mainly on the continental shelf and upper slope waters from northern NSW to Tasmania and through Bass Strait. Historical records (e.g. Fairbridge, 1948; Allen, 1989; Klaer, 2005) show that steam trawlers caught tiger flathead from 1915 to about 1960. A Danish seine trawl fishery developed in the 1930s (Allen, 1989) and continues to the present day. Modern diesel trawling commenced in the 1970s.

7.2.2 *Previous assessments*

Prior to 2001, the previous quantitative assessment for tiger flathead was from the late 1980s (Allen, 1989). In that report, the assessment for tiger flathead was conducted based on catch and effort data using a surplus production model. The estimate of Maximum Sustainable Yield, MSY, for NSW and eastern Bass Strait was about 2,500 t.

Between 1989 and 2001, assessments of tiger flathead involved examination of trends in catches, catch rates, and in age and length data, but no quantitative assessments were undertaken. Assessments from 1993 to 2001 can be found in the annual reports of SEFAG (the South East Fishery Assessment Group). For example, the 1993 assessment noted that tiger flathead catches from south-east Tasmanian waters contained higher proportions of larger, older fish than those from eastern Bass Strait. This suggested that tiger flathead resources off Tasmania were either more lightly fished than those in the main fishing areas, or that there was a separate stock with different population characteristics off Tasmania.

During the period 2001-2004, data for tiger flathead were collated, summarized and presented at workshops (see Cui *et al*. (2004) for a detailed summary of these workshops and the analyses presented to them). These workshops led to revisions of the data series, analyses of the data, and to suggestions for revisions to the data sets and research priorities. The 2004 assessment (Cui *et al.*, 2004) used 89 years (1915–2003) of data to estimate the virgin spawning stock biomass and the 2004 spawning stock biomass relative to that in 1915 and provided, for the first time, a complete picture of the dynamics of the tiger flathead fishery.

A number of changes to both the input data and some model structural changes were made and presented in the assessments developed in 2005 (Punt 2005a, Punt 2005b). These assessments considered tiger flathead caught off eastern Tasmania in SEF zone 30 as either separate to, or part of the same stock in zones 10 (E NSW), 20 (E Bass Strait) and 60 (Bass Strait) combined. In the scenario where eastern Tasmanian flathead are part of the same stock, a separate fleet was constructed to account for catches made there. Modifications to estimates of historical catches from Klaer (2005) were incorporated into catch series used in the assessments. Length-frequency data for 1945-1967 and 1971-1984 were obtained, and uncertainty in discard rates was estimated using a bootstrap procedure.

Part of the intention for the 2006 assessment (Klaer, 2006a) was initially to duplicate as far as possible the assessment results from 2005 (Punt, 2005a, Punt 2005b) while implementing the assessment using the Stock Synthesis (SS2) framework. The same assumptions were made about stock structure, i.e. tiger flathead off eastern Tasmania may or may not be the same stock as those off NSW and Victoria. Steepness was treated as an estimable parameter and annual age frequencies were added directly into the model as samples independent to length frequencies. The 2006 Shelf RAG selected the model that treated Tasmanian trawl as a separate fleet fishing the same east coast stock as the most appropriate base case.

The 2009 assessment (Klaer, 2009) moved the model from Stock Synthesis version SS-V2.1.21 (June 2006) to Stock Synthesis version SS-V3.03 (May 2009). Major changes to previous assessments were the use of age-at-length data to estimate growth parameters, correction to discard estimation for steam trawl, allowing selectivity change in 1985 for diesel trawl and 1978 for Danish seine, and estimation of recruitment 3 years prior to the last year (2005) for the 2009 assessment that used data to the end of 2008.

The 2009 assessment was updated in 2010 (Klaer, 2010) using Stock Synthesis version SS-V3.11a, (Methot, 2010). For the 2010 assessment, changes were made to the treatment of discards prior to 1980, an additional growth parameter was estimated and the assumed value for natural mortality, M, was changed from 0.22 to 0.27.

The 2010 assessment was updated in 2013 (Day and Klaer, 2013) using Stock Synthesis version SS-V3.24f, (Methot, 2011). Results from three years of the winter Fishery Independent Survey (FIS) were included as an additional abundance index in the 2013 assessment, but no FIS length data were included.

The most recent full quantitative assessment for tiger flathead was performed in 2016 (Day, 2016) using Stock Synthesis version SS-V3.24Z, (Methot, 2015). This was the first ever use of SESSF FIS length data in a stock assessment, incorporating length data from four FIS surveys from 2008-2014.

7.2.3 *Modifications to the previous assessments*

This assessment uses the current version of Stock Synthesis, SS-V3.30.14.05 (Methot et. al, 2019). The number of growth parameters estimated and assumptions about mortality and early discarding rates in this assessment are identical to the 2016 assessment (Day, 2016). Three growth parameters are estimated (CV, K and $l_{\min}$), natural mortality is assumed to be 0.27 and the discarded catch for steam trawl and for Danish seine prior to 1960 is assumed to be 20% of the retained catch, which translates to a discard ratio (disc/[ret+disc]) of 17%.

An abundance index from the fishery independent survey (FIS) for the winter surveys for four years: 2008, 2010, 2012 and 2014 (Knuckey *et al.*, 2015) was included in the 2016 assessment and this index is retained in this assessment with one additional data point (2016). As the summer FIS was discontinued after 2012, the three data points from the summer FIS abundance index have not been included in this assessment or in any of the sensitivities. Additional FIS length frequency data was included in this assessment, including the 2016 winter FIS length frequency data and the summer FIS length frequency data from 2008, 2010 and 2012. In using the summer length frequencies, it is assumed that the winter and summer FIS surveys have the same selectivity and length frequencies from both seasons contribute to the selectivity estimates. While both surveys use the same gear, it is possible that different seasonal availability means this assumption may not be valid. With only three points in the summer abundance series and no prospect of additional points being added in future, this series is too short to include as a separate abundance index in the assessment. The same problem does not apply to the use of summer FIS length frequencies, as these three years of summer FIS lengths are combined with five years of winter FIS lengths to estimate selectivity.

Updates to data used in the previous assessment resulted from changes AFMA have made to their observer database (affecting data for all years) and changes, improvements and corrections in the processing of data and filtering of records (Thomson et al., 2019). However, some historical length frequency data used in the 2016 assessment are not present in the database. These length frequencies are included in the current assessment, by using data from the 2016 assessment for the following retained length frequencies:

1. Steam Trawl, Sydney Fish Market – 1953-1958
2. Eastern Trawl, Sydney Fish Market – 1965-1967

3. Danish seine, onboard – 1993-1994

In addition to this historical data, retained for this assessment, there appear to be some changes in the Tasmanian Trawl length frequencies in 2009 and 2010 which may warrant future investigation. Only one shot was recorded from each of the 2009 and 2010 onboard samples, so these length frequencies were excluded, as they were unlikely to be representative. Similarly, the 2009 port length frequency came from less than 100 fish so this length frequency was also excluded. These sample sizes are different to those produced by the 2013 automatic processing, so this may require further investigation.

Discard length frequencies from Danish seine in 1994 and 1995 and eastern trawl from 1994-1996 were excluded in previous assessments as these appear to have unrepresentative distributions. These discard length frequencies were also excluded from the current assessment.

Other substantial changes from the 2016 assessment include:

1. further modifications to the tuning procedures using latest agreed tuning protocols
2. inclusion of length frequency data from the fishery independent surveys from 2016 and summer length frequencies from 2008, 2010 and 2012.

When shots or trip were not known (Sydney Fish Market, Kapala or Blackburn data), the number of fish measured was divided by 10 and capped at 200. When the number of trips or shots was available, a cap of 120 trips and 200 shots was used to set an upper limit on the sample size, although the limit on trip numbers was never exceeded.

The Tier 1 discard estimates have been updated in 2019 to more closely match the discard calculations in Bergh et al. (2009). These estimates use ratios of total discards to (retained plus discard) catch on a per shot basis, rather than aggregated across a whole stratum, which are then weighted up according to Catch Disposal Records (CDR) landings within zone and season (N. Klaer, pers. comm.). These changes and other data updates produced some modifications to estimates of discards, especially for the Tasmanian trawl fleet where some very small values were excluded, with resulting higher estimates of discards for this fleet. To achieve reasonable levels of predicted discards, years with very low (<1%) discard rate data were excluded.

An updated estimate of the ageing error matrix constructed from the new ageing data was used (A Punt, pers. comm.). The only changes to age-at-length data were the addition of three years of new data from 2016 to 2018. Minor revisions were made to the catch history from 2001 onwards, with minor modifications to recent state catch history and some reallocation of catch between fleets due to misclassification of some vessels. Updates to the preliminary 2015 and assumed 2016 catches were made and new 2017 and 2018 catch data was included, with the 2019 catch data (required to calculate a 2020 RBC) assumed to be the same as the 2018 catch data.

Inclusion of the new data and tuning procedures resulted in changes to the estimates of recruitment and to the spawning biomass time series.

The usual process of bridging to a new model by adding new data piecewise and analysing which components of the data could be contributing to changes in the assessment outcome was conducted (Day, 2019).

7.3 Methods

7.3.1 *The data and model inputs*

7.3.1.1 Biological parameters

As male and female tiger flathead have different growth patterns (females are substantially larger), a two-sex model has been used.

The parameters of the von Bertalanffy growth equation are estimated by sex within the model-fitting procedure from age-at-length data. This approach accounts for the impact of gear selectivity on the age-at-length data collected from the fishery and the impact of ageing error. Three growth parameters are estimated for females (CV, K and l_{min}), with only one growth parameter fixed (l_{max} = 55.9), with this valued based on the estimate of l_∞ obtained by Punt (2005a) by fitting von Bertalanffy growth curves to data from SESSF Zones 10 and 20 (NSW and eastern Bass Strait). An offset to K is estimated separately for males, with the other growth parameters using the same values as for female growth.

Estimates of the rate of natural mortality, M, reported in the literature vary from 0.21 to 0.46 yr^{-1}. This assessment uses a value of 0.27 yr^{-1} as the base case estimate of M as used in the previous assessment (Day, 2016) and as previously agreed to by SERAG. Sensitivity to this value is tested. The steepness of the stock-recruitment relationship, h, is estimated by the model, and for the base case is estimated to be 0.72.

Female tiger flathead become sexually mature at about three years of age, which corresponds to a length of about 30 cm (Klaer, 2010). Maturity is modelled as a logistic function, with 50% maturity fixed at 30 cm. Fecundity-at-length is assumed to be proportional to weight-at-length.

The parameters of the length-weight relationship are the same as those used in the previous assessment a=5.88 x 10^{-6}, b=3.31 (Day, 2016), with these parameters originally obtained by fitting von Bertalanffy growth curves to data from SESSF Zones 10 and 20, NSW and eastern Bass Strait (Punt, 2005a).

7.3.1.2 Fleets

The assessment data for tiger flathead have been separated into five ‘fleets’, which represent one or more gear, regional, or temporal differences in the fishery. Landings data from eastern Tasmania were separated from the catches from the other regions in the east, because the length compositions of catches from this area indicate that it lands larger fish.

1. Steam trawl – steam trawlers (1915 – 1961)
2. Danish seine – Danish seine from NSW, eastern Victoria and Bass Strait (1929 – 2018)
3. Eastern trawl – diesel otter trawlers from NSW, eastern Victoria and Bass Strait (1971 – 2018)
4. Tasmanian trawl – diesel otter trawlers from eastern Tasmania (1985 – 2018)
5. Fishery Independent Survey – (2008-2016)

7.3.1.3 Landed catches

A landed catch history for tiger flathead, separated into the four ‘fleets’, is available for all years from 1915 to 2018 (Table 7.1, Figure 7.1 and Figure 7.2). Landings from the FIS fleet were assumed to be zero, with the actual FIS catch included in the scaling up of logbook catches to landed catches.

Klaer (2005) describes the sources of information used to construct the historical landed catch record for each of the fleets to 1986. Quotas were introduced into the fishery in 1992, and from then onwards, records of landed catches as well as estimated catches from the logbook are available. The landings data give a more accurate measure of the landed catch than do the logbook data, but the logbook data contain more detail. For example, it is usually possible to separate logbook records, but not landing records, by fleet. The logbook catches for each fleet from 1992 onwards have been scaled up by the ratio of landed catches to logbook catches in each year (Thomson, 2002). Prior to 1992, the unscaled logbook catches are used.

In 2007 the quota year was changed from calendar year to the year extending from 1 May to 30 April, however the assessment is based on calendar years. All catches for recent years continue to be those made by calendar year, which may conflict with the fishing year TACs.

Small quantities of tiger flathead are caught in state waters. NSW and Victorian state catches have been added to the eastern trawl fleet, and Tasmanian state catches have been added to the Tasmanian fleet.

Non-trawl CDR are ignored in this assessment, as has been the case with previous tiger flathead assessments. These non-trawl catches have averaged 0.6 t per year between 2001-2010 and less than 2 t per year since 2011 so represent a very small proportion of the total catch. If these catches were to be included, they would need to be allocated to an existing fleet, with associated selectivity. It is not clear which fleet included in the assessment would most closely match the selectivity of this very small non-trawl catch.

In order to calculate the Recommended Biological Catch (RBC) for 2020, it is necessary to estimate the Commonwealth calendar year catch for 2019. The TAC (Table 7.2) was almost unchanged from 2018 to 2019 and the state catches are unknown for 2019. Hence, assuming that the same ratio of the TAC will be caught in 2019 as in 2018, with the same state catches as 2018, is equivalent to assuming that the catch in 2019 is identical to the 2018 catch. This gives estimated 2019 catches for the eastern fleet, the Tasmanian fleet, and the Danish seine fleet of 921 t, 268 t and 1,107 t, respectively.

7.3.1.4 Species composition for the “tiger flathead” assessment

The Commonwealth quota basket for “tiger flathead” actually comprises six separate CAAB codes (Thomson and Day 2019a). Two CAAB codes have commonly been used for the majority of the catch, usually well over 99%: tiger flathead (37296001) and generic (undifferentiated) flathead (37296000). While the use of these two codes has changed since the introduction of e-logs, both codes are thought to largely contain tiger flathead (*Platycephalus richardsoni*). The remaining four CAAB codes consist of toothy flathead, southern sand flathead, bluespotted flathead and southern bluespotted flathead. Of these, southern sand flathead catches ranged between 10 t and 20 t from 1985-1989 and less than 10 t since 1990. Catches of southern bluespotted flathead were 5 t in 1995, 1 t in 2017 and less than 1 t in all other years. Catches of southern sand flathead and bluespotted flathead were less than 1 t in all years. The Commonwealth catch of these four species which are not tiger flathead usually comprises well less than 1% of the total Commonwealth catch. As such, the Commonwealth component of this catch is considered to be essentially tiger flathead catches.

State catches used in this assessment generally occur in shallower waters than Commonwealth and hence are more likely to contain sand flathead and bluespotted flathead. State catches from NSW, Victoria and Tasmania report tiger flathead separately from other flathead species and only tiger flathead catches are requested by CSIRO.

Small quantities (less than 2% of the total CDR in all years from 1985-2018, and usually less than 1%) of tiger flathead are reported in logbook catches from zones 40 (western Tasmania) and 50 (western Bass Strait). It seems that some of these records could be deepwater flathead (Thomson and Day 2019b), potentially misreported in the logbooks as tiger flathead. These western logbook catches are included in the total catch (the CDR), but are allocated to fleets as if these catches were taken in the east. The relative proportion of the catch by fleet (Danish seine, eastern trawl, Tasmanian trawl) for each year can only be obtained from the logbook records. However, the total Commonwealth catch comes from the CDR totals, as this is considered to be more accurate than the logbook totals. Hence the annual proportions of catch by (eastern) fleet are applied to the annual CDR (which includes western catches), but actually assumes all of the catch comes from the eastern fleets. Given the western catch is relatively small, this is unlikely to have a large impact, and follows the precedent used to distribute this (western) catch used in tiger flathead assessments in recent years.

7.3.1.5 Updated landed catches 2001-2018

A slightly different catch history was used in both the preliminary base case presented to SERAG in October 2019 and the proposed base case presented to SERAG in December 2019, referred to here as the old base case, with differences in catches in the period 2001-2018.

Corrections to this catch history involved increasing the catch by an average of 76 t per year from 2001-2018, with the increases ranging from a minimum of 30 t in 2002 to a maximum of 128 t in 2008. The annual increases in catch were around 40 t to the Tasmanian trawl fleet and just under 20 t each for the Danish seine and eastern trawl fleets. These corrections were discovered late in the assessment process. All of the diagnostic plots, fits, discard estimates and RBC calculations presented here are for the updated base case with the corrected catch series. However, the likelihood profiles, retrospectives and sensitivities were calculated using the incorrect (lower) catch series from 2001-2018. The general principles and comparisons in these analyses with the lower catch series are not expected to show qualitative differences. The increase in annual catches from 2001-2018 averages 2.6% and ranges from 0.9% to 4.8%. Catches are unchanged for the period from 1915-2000.

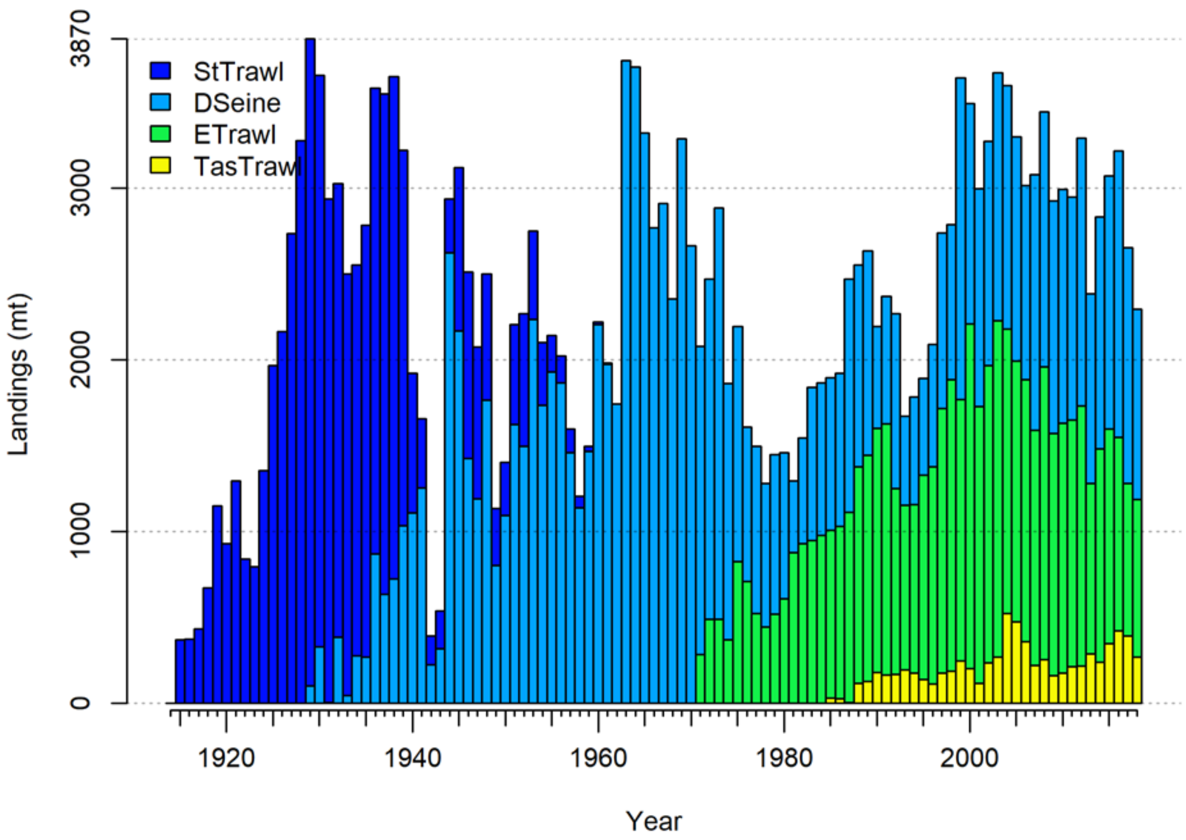


Figure 7.1. Total landed catch of tiger flathead by fleet (stacked) from 1915-2018.

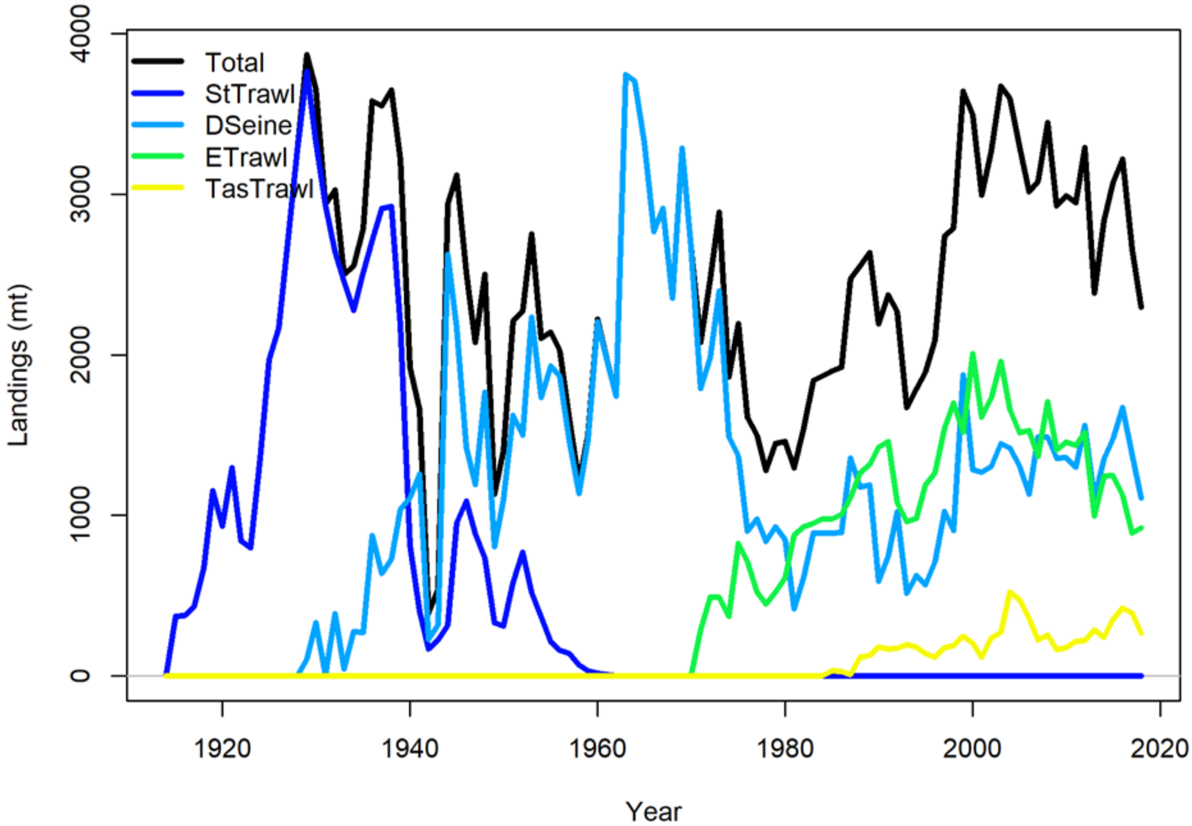


Figure 7.2. Total landed catch of tiger flathead by fleet from 1915-2018.

Table 7.1. Total retained catches (tonnes) of tiger flathead per fleet for calendar years from 1915-2019, with updated totals from the December SERAG meeting shown in bold.

Year	Fleet St Trawl	D Seine	E Trawl	Tas Trawl	Year	Fleet St Trawl	D Seine	E Trawl	Tas Trawl	Year	Fleet St Trawl	D Seine	E Trawl	Tas Trawl
1915	371	0	0	0	1951	583	1,625	0	0	1987	0	1,358	1,109	6
1916	373	0	0	0	1952	769	1,499	0	0	1988	0	1,177	1,263	116
1917	432	0	0	0	1953	517	2,235	0	0	1989	0	1,189	1,318	128
1918	671	0	0	0	1954	366	1,737	0	0	1990	0	591	1,425	178
1919	1,151	0	0	0	1955	211	1,932	0	0	1991	0	746	1,461	166
1920	931	0	0	0	1956	157	1,868	0	0	1992	0	1,019	1,080	170
1921	1,297	0	0	0	1957	139	1,459	0	0	1993	0	516	962	194
1922	840	0	0	0	1958	68	1,138	0	0	1994	0	626	982	178
1923	796	0	0	0	1959	32	1,467	0	0	1995	0	564	1,189	139
1924	1,356	0	0	0	1960	15	2,206	0	0	1996	0	711	1,265	114
1925	1,969	0	0	0	1961	9	1,974	0	0	1997	0	1,023	1,542	175
1926	2,167	0	0	0	1962	0	1,742	0	0	1998	0	905	1,700	186
1927	2,735	0	0	0	1963	0	3,745	0	0	1999	0	1,873	1,520	248
1928	3,277	0	0	0	1964	0	3,707	0	0	2000	0	1,286	2,006	349
1929	3,768	102	0	0	1965	0	3,322	0	0	2001	0	**1,269**	**1,612**	**115**
1930	3,329	330	0	0	1966	0	2,769	0	0	2002	0	**1,305**	**1,731**	**236**
1931	2,932	4	0	0	1967	0	2,912	0	0	2003	0	**1,446**	**1,957**	**270**
1932	2,642	385	0	0	1968	0	2,355	0	0	2004	0	**1,418**	**1,658**	**522**
1933	2,456	44	0	0	1969	0	3,289	0	0	2005	0	**1,307**	**1,516**	**476**
1934	2,278	276	0	0	1970	0	2,667	0	0	2006	0	**1,132**	**1,526**	**359**
1935	2,514	270	0	0	1971	0	1,793	286	0	2007	0	**1,488**	**1,368**	**223**
1936	2,712	872	0	0	1972	0	1,981	491	0	2008	0	**1,487**	**1,705**	**255**
1937	2,912	637	0	0	1973	0	2,397	490	0	2009	0	**1,358**	**1,408**	**163**
1938	2,924	725	0	0	1974	0	1,493	369	0	2010	0	**1,359**	**1,458**	**175**
1939	2,185	1,035	0	0	1975	0	1,367	827	0	2011	0	**1,300**	**1,435**	**214**
1940	815	1,108	0	0	1976	0	900	712	0	2012	0	**1,560**	**1,516**	**217**
1941	403	1,255	0	0	1977	0	977	522	0	2013	0	**1,103**	**995**	**287**
1942	167	225	0	0	1978	0	836	446	0	2014	0	**1,352**	**1,244**	**239**
1943	223	317	0	0	1979	0	928	520	0	2015	0	**1,476**	**1,248**	**348**
1944	315	2,624	0	0	1980	0	851	609	0	2016	0	**1,671**	**1,126**	**422**
1945	953	2,168	0	0	1981	0	418	877	0	2017	0	**1,377**	**887**	**392**
1946	1,088	1,425	0	0	1982	0	615	930	0	2018	0	**1,107**	**921**	**268**
1947	884	1,193	0	0	1983	0	889	950	0	2019*	0	**1,107**	**921**	**268**
1948	735	1,767	0	0	1984	0	890	978	0					
1949	330	804	0	0	1985	0	890	978	30					
1950	310	1,095	0	0	1986	0	892	1,005	26					

*2019 catches are estimated

Table 7.2. Total allowable catch (t) from 1992 to 2019/20.

Year	TAC Agreed
1992	3000
1993	3000
1994	3500
1995	3500
1996	3500
1997	3500
1998	3500
1999	3500
2000	3500
2001	3500
2002	3500
2003	3500
2004	3500
2005	3150
2006	3000
2007	3015
2008/09	2850
2009/10	2850
2010/11	2750
2011/12	2750
2012/13	2750
2013/14	2750
2014/15	2878
2015/16	2860
2016/17	2882
2017/18	2712
2018/19	2507
2019/20	2468

7.3.1.6 Discard rates

Information on the discarding rate of tiger flathead was available from the PIRVic-run Integrated Scientific Monitoring Program (ISMP) for 1992-2006. From 2007 the ISMP was run by AFMA. The discard data are summarised in Table 7.3. Generally, discards of tiger flathead were in the order of 8% for Danish seine, 10% for eastern trawl and 3% for Tasmanian trawl.

There is limited information on discarding for the early steam trawl fleet (1915-61) and the early Danish seine fleet (1929-67). However, it is known that total discards for all species from steam trawl in the 1920s was in the order of 20% of the retained catch (Klaer, 2001). As there is no way to determine the species catch composition of the discards, Shelf RAG made the decision to apply this ratio to tiger flathead, which translates to a discard fraction of 17%. For the base case, all steam trawl (1915-1961) and early Danish seine (1929-1960) were assigned a constant discard fraction of 17% to apply equally to all selected fish (Figure 7.3). The discard fraction for Danish seine from 1961 to present was set using recent observed discard ratios since 1994. Recent observations were used to estimate discard fractions for the east coast and Tasmanian diesel trawl fleets.

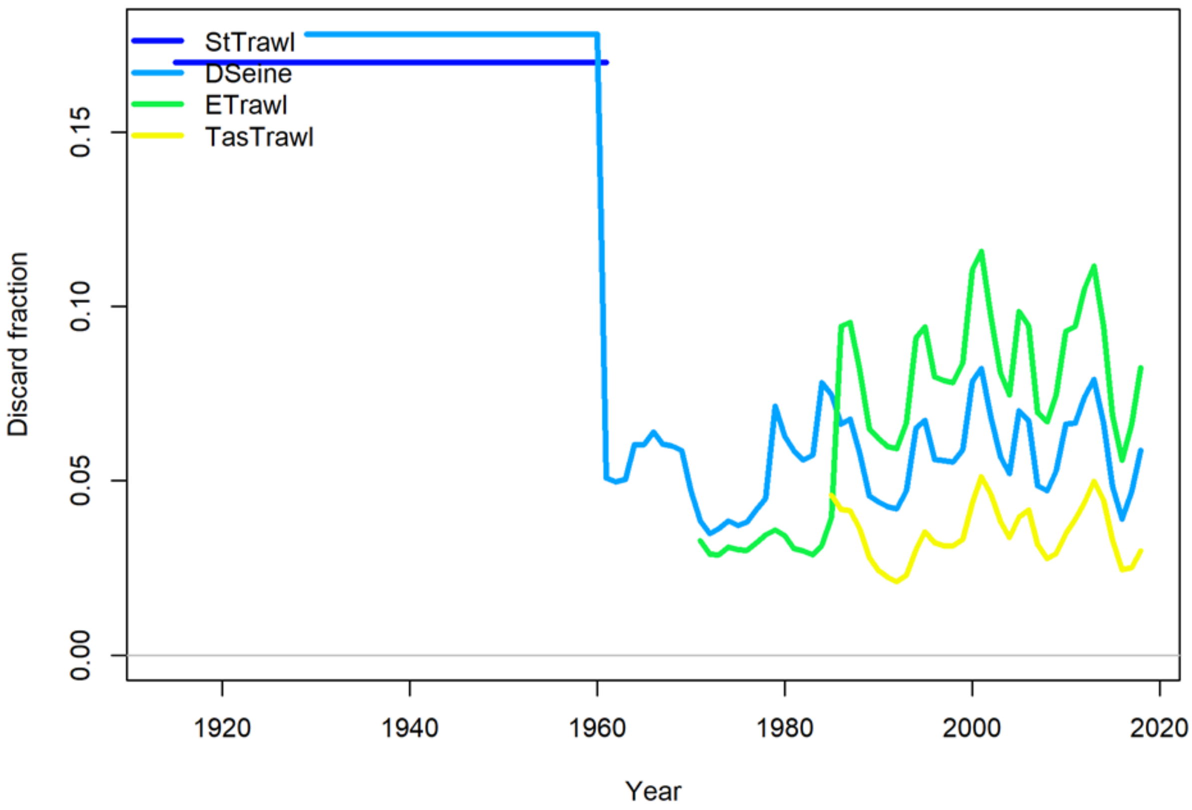


Figure 7.3. Model estimates of discard fractions per fleet.

Table 7.3. Proportion of catch discarded by fleet, with sample sizes.

Year	Fleet D Seine	n	E Trawl	n	Tas Trawl	n
1992			0.111655	11		
1993			0.071441	195		
1994	0.080965	79	0.091485	267	0.061636	18
1995	0.101318	44	0.108100	129		
1996			0.073031	240		
1997			0.044715	383		
1998	0.063355	23	0.100813	246		
1999	0.015514	34	0.111664	382		
2000	0.038976	27	0.088278	395		
2001	0.010290	41	0.052686	457		
2002	0.102959	30	0.058272	385		
2003	0.033118	113	0.060926	470		
2004		39	0.091059	387		
2005	0.064790	61	0.074755	461		
2006	0.034561	125	0.085904	369		
2007	0.036619	47	0.044946	106		
2008	0.043842	38	0.036190	214		
2009	0.114579	32	0.088945	200		
2010	0.140487	75	0.061709	171	0.029004	20
2011	0.267978	123	0.108886	140		
2012	0.066264	70	0.080755	118		
2013	0.126057	102	0.089382	128	0.012441	22
2014	0.156979	109	0.102284	112		
2015	0.036815	78	0.087488	204		
2016	0.039054	123	0.079863	111		
2017	0.065042	86	0.084152	157		
2018	0.032167	62	0.022506	120	0.013982	25

7.3.1.7 Catch rate indices

A standardised catch rate (CPUE) index is available for the historical steam trawl fleet for the years 1919-23, 1937-42, and 1952-57 (Klaer, 2006b; Table 7.4). An unstandardised catch rate index for early Danish seine has been used in tiger flathead assessments since Cui *et al.* (2004) (Table 7.5).

Catch and effort data from the SEF1 logbook database were standardised using GLMs to obtain indices of relative abundance (Sporcic 2019b; Table 7.6) from the period 1986-2018 for recent Danish seine, eastern and Tasmanian trawl fleets.

Abundance indices from the Fishery Independent Survey from 2008-2016 were also used, separated into zones 10 and 20, to match the eastern trawl fleet, and zone 30, to match the Tasmanian trawl fleet (Table 7.7). These abundance indices use the FIS3 abundance index (Sporcic et al., 2019) which reconditions the original FIS abundance index, as used in the 2016 assessment and all previous SESSF stock assessments which included FIS abundance indices, and accounts for within year variation in catch rates.

In this stock synthesis assessment, the coefficient of variation for the more recent abundance indices (CPUE from recent Danish seine, eastern and Tasmanian trawl fleets and both FIS3 abundance series) is initially set to a value equal to the root mean squared deviation from a loess fit (Sporcic, 2019a, 2019b) and additional variance is estimated for each abundance index to tune the input and output variances.

Table 7.4. Standardised catch rates for the steam trawl fleet (Klaer 2006b).

Year	Value	CV
1919	1.618	0.31
1920	1.732	0.31
1921	1.806	0.31
1922	1.758	0.31
1923	1.646	0.31
1937	0.635	0.31
1938	0.749	0.31
1939	0.723	0.31
1940	0.611	0.31
1941	0.618	0.31
1942	0.401	0.31
1952	0.262	0.31
1953	0.208	0.31
1954	0.232	0.31
1955	0.219	0.31
1956	0.208	0.31
1957	0.169	0.31

Table 7.5. Unstandardised catch rates for the early Danish seine fleet.

Year	Value	CV
1950	38.7	0.33
1951	27.6	0.33
1952	31.8	0.33
1953	52.0	0.33
1954	34.4	0.33
1955	47.4	0.33
1956	46.5	0.33
1957	32.1	0.33
1958	22.5	0.33
1959	28.7	0.33
1960	43.6	0.33
1965	38.2	0.33
1966	41.5	0.33
1967	62.5	0.33
1968	61.2	0.33
1969	77.8	0.33
1970	67.1	0.33
1971	69.9	0.33
1972	114.0	0.33
1973	88.0	0.33
1974	58.1	0.33
1975	56.6	0.33
1976	41.9	0.33
1977	55.5	0.33
1978	51.9	0.33

Table 7.6. Standardised catch rates for the Danish seine, eastern and Tasmanian diesel trawl fleets from 1986-2018. The coefficient of variation is initially set at a value equal to the root mean squared deviation from a loess fit (Sporcic, 2019a, Sporcic 2019b).

Year	Fleet					
					Tas	
	D Seine	CV	E Trawl	CV	Trawl	CV
1986	1.1123	0.168	0.8007	0.143	0.9347	0.195
1987	1.5651	0.168	1.0671	0.143	0.5687	0.195
1988	1.7082	0.168	1.1680	0.143	0.9572	0.195
1989	1.4892	0.168	1.1685	0.143	0.7056	0.195
1990	0.9999	0.168	1.3918	0.143	0.7060	0.195
1991	1.3621	0.168	1.3097	0.143	0.6682	0.195
1992	1.4277	0.168	1.0334	0.143	0.6390	0.195
1993	0.8820	0.168	1.0476	0.143	0.5984	0.195
1994	0.7631	0.168	0.7605	0.143	0.6218	0.195
1995	0.7798	0.168	0.8031	0.143	0.6983	0.195
1996	0.7329	0.168	0.7158	0.143	0.6374	0.195
1997	0.9572	0.168	0.7171	0.143	0.7924	0.195
1998	0.8096	0.168	0.7581	0.143	0.9440	0.195
1999	1.1704	0.168	0.9150	0.143	1.0559	0.195
2000	0.8738	0.168	1.0067	0.143	0.8695	0.195
2001	0.8211	0.168	0.9701	0.143	0.7328	0.195
2002	0.9752	0.168	1.0530	0.143	1.3397	0.195
2003	1.0117	0.168	1.0389	0.143	1.3809	0.195
2004	1.0027	0.168	0.9040	0.143	1.8667	0.195
2005	1.0167	0.168	0.7764	0.143	1.6984	0.195
2006	0.9976	0.168	0.9400	0.143	1.3764	0.195
2007	1.2135	0.168	1.1402	0.143	1.1150	0.195
2008	1.0918	0.168	1.2005	0.143	1.0479	0.195
2009	1.1256	0.168	1.1085	0.143	1.0302	0.195
2010	1.0180	0.168	1.0686	0.143	1.0081	0.195
2011	0.9423	0.168	1.0539	0.143	0.9668	0.195
2012	0.8945	0.168	1.1600	0.143	1.2107	0.195
2013	0.6616	0.168	0.8776	0.143	1.1713	0.195
2014	0.7191	0.168	1.0301	0.143	1.3479	0.195
2015	0.7585	0.168	1.1597	0.143	1.2654	0.195
2016	0.7935	0.168	1.0627	0.143	1.0769	0.195
2017	0.7443	0.168	0.8791	0.143	1.1634	0.195
2018	0.5790	0.168	0.9138	0.143	0.8042	0.195

Table 7.7. FIS3 derived abundance indices for tiger flathead with corresponding coefficient of variation (cv) eastern trawl fleet (zones 10 and 20); and Tasmanian trawl fleet (zone 30). The coefficient of variation is initially set at a value equal to the root mean squared deviation from a loess fit (Sporcic, 2019a, Sporcic 2019b).

Year	FIS East Z 10, 20	CV	FIST Tas Z 30	CV
2008	11496.27	0.23	6019.18	0.07
2010	8585.84	0.23	7868.28	0.07
2012	16344.18	0.23	7808.31	0.07
2014	9574.55	0.23	9102.49	0.07
2016	8500.62	0.23	12961.75	0.07

7.3.1.8 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 7.8).

Age-at-length measurements, based on sectioned otoliths, provided by Fish Ageing Services, were available for the years 1998, 2000-2018 for the Danish seine fleet; 1998-2002, 2004-2018 for the eastern diesel trawl fleet; and 1999, 2000, 2002, 2005-2008, 2010 and 2012-2018 for the Tasmanian diesel trawl fleet (Table 7.9). Years for which the total number of fish aged was less than 10 were not used. No age information was available for the earlier fleets.

Table 7.8. Standard deviation of age reading error (A Punt pers. comm. 2019).

Age	sd
0.5	0.251046
1.5	0.274642
2.5	0.298508
3.5	0.322648
4.5	0.347064
5.5	0.371760
6.5	0.396738
7.5	0.422002
8.5	0.447555
9.5	0.473401
10.5	0.499543
11.5	0.525984
12.5	0.552728
13.5	0.579777
14.5	0.607137
15.5	0.634810
16.5	0.662799
17.5	0.691109
18.5	0.719743
19.5	0.748704
20.5	0.777997

7.3.1.9 Length composition data

Length composition information for the onboard retained components of catches is available for: the Danish seine fleet 1993-1994, 1998-2007 and 2009-2018; the eastern trawl fleet from 1977, 1993, 1996-2015; and the Tasmanian trawl fleet for 1998-2006, 2008, 2010-2018 along with the numbers of fish measured and numbers of shots in each year (Table 7.10). Length composition information from port data is available for: the steam trawl fleet from 1945-1958; the Danish seine fleet from 1945-1967, 1992 and 1994-2018; the eastern trawl fleet from 1965-1967, 1969-2018; and the Tasmanian trawl fleet for 1999-2000, 2002-2006, 2011-2013 and 2015-2016, along with the numbers of fish measured and numbers of trips in each year (Table 7.11 and Table 7.12). Length composition information from the ISMP for the discarded components of catches is available for: the Danish seine fleet 1998-2000, 2002-2003, 2006-2007, 2011-2016 and 2018; and the eastern trawl fleet from 1992-1993, 1997-2006 and 2008-2018; along with the numbers of fish measured and numbers of shots in each year (Table 7.13). In line with current standard practice in the SESSF, both port and onboard length frequencies are used when they are available.

Table 7.9. Number of age-length otolith samples included in the base case assessment by fleet 1998-2018.

Year	Fleet				
	D Seine	E Trawl	Tas Trawl	FIS East	Total
1998	101	212			313
1999		146	46		192
2000	192	544	56		792
2001	30	180			210
2002	558	588	149		1,295
2003	102				102
2004	174	152			326
2005	603	268	11		882
2006	312	64	141		517
2007	159	302	8		469
2008	363	229	66	48	706
2009	386	698			1,084
2010	617	423	88		1,128
2011	715	410			1,125
2012	468	696	131		1,295
2013	440	278	65		783
2014	583	451	162		1,196
2015	496	724	23		1,243
2016	487	456	180		1,123
2017	350	278	82		710
2018	299	353	134		786

Table 7.10. Number of onboard retained lengths and number of shots for length frequencies included in the base case assessment by fleet 1977-2018.

Year	Fleet	# fish		Fleet	# shots	
	D Seine	E Trawl	Tas Trawl	D Seine	E Trawl	Tas Trawl
1977		2,136			200	
1993	356	1,347		4	17	
1994	1,950			20		
1996		494			7	
1997		6,797			191	
1998	1,706	9,364	959	30	139	8
1999	1,765	18,771	3,066	26	259	26
2000	707	21,686	492	15	235	5
2001	238	21,952	383	3	213	4
2002	332	17,229	477	8	181	4
2003	4,158	18,187	399	72	201	3
2004	3,595	11,836	562	26	122	5
2005	5,353	18,745	1,692	38	176	10
2006	13,202	12,137	4,588	103	107	34
2007	1,593	1,243		9	35	
2008		1,482	101		45	6
2009	672	1,374		11	32	
2010	678	1,909	239	28	68	9
2011	1,303	1,881	334	52	74	11
2012	1,821	2,226	348	49	72	8
2013	2,479	1,880	410	66	45	10
2014	2,064	1,999	972	73	44	21
2015	1,925	4,393	741	40	110	20
2016	2,329	2,573	1,284	61	47	34
2017	960	1,803	683	24	47	10
2018	701	1,602	514	18	41	17

Table 7.11. Number of port retained lengths and number of trips used for length frequencies included in the base case assessment by fleet 1945-1991.

Year	Fleet	# fish		Fleet	# trips	
	St Trawl	D Seine	E Trawl	St Trawl	D Seine	E Trawl
1945	5,076	21,735		200	200	
1946	10,916	26,475		200	200	
1947	15,488	20,287		200	200	
1948	11,973	20,721		200	200	
1949	10,863	23,316		200	200	
1950	18,057	16,640		200	200	
1951	25,843	21,423		200	200	
1952	32,188	28,941		200	200	
1953	14,880	16,264		200	200	
1954	13,167	26,263		200	200	
1955	2,313	9,966		200	200	
1956	343	14,878		34	200	
1957	150	15,283		15	200	
1958	149	17,291		15	200	
1959		20,354			200	
1960		25,334			200	
1961		18,623			200	
1962		20,255			200	
1963		15,988			200	
1964		17,882			200	
1965		17,861	14,310		200	200
1966		19,101	23,222		200	200
1967		7,233	11,798		200	200
1969			96			10
1970			187			19
1971			610			61
1972			1,223			122
1973			435			44
1974			5,590			200
1975			11,684			200
1976			14,881			200
1977			18,017			200
1978			16,335			200
1979			12,189			200
1980			8,757			200
1981			6,184			200
1982			5,893			200
1983			5,140			200
1984			6,702			200
1985			2,633			200
1986			12,513			200
1987			8,154			200
1988			6,274			200
1989			3,999			200
1990			1,398			140
1991			4,040			200

Table 7.12. Number of port retained lengths and number of trips used for length frequencies included in the base case assessment by fleet 1992-2018.

Year	Fleet	# fish		Fleet	# trips	
	D Seine	E Trawl	Tas Trawl	D Seine	E Trawl	Tas Trawl
1992	1,442	873		13	5	
1993		502			3	
1994	292	156		3	1	
1995	1,566	1,418		20	10	
1996	3,760	2,520		31	16	
1997	11,857	5,106		115	26	
1998	11,346	11,302		112	84	
1999	5,079	12,747	519	22	94	3
2000	3,566	6,698	362	20	53	2
2001	5,690	11,087		35	88	
2002	3,569	6,208	5,201	32	35	27
2003	1,896	4,686	649	11	35	6
2004	4,280	10,247	1,520	38	71	7
2005	3,542	13,035	769	12	74	3
2006	1,375	13,029	1,323	5	116	6
2007	505	3,024		3	20	
2008	435	132		3	1	
2009	428	735	87	7	7	1
2010	751	2,107	64	15	17	1
2011	1,066	1,061	204	35	24	6
2012	884	771	188	32	22	4
2013	1,055	885	185	41	26	3
2014	1,691	1,288		52	22	
2015	2,401	1,099	232	54	19	3
2016	2,001	748	296	38	10	5
2017	2,481	1,265	92	48	19	1
2018	2,135	1,206	80	41	21	1

Table 7.13. Number of discarded lengths and number of shots used for length frequencies included in the base case assessment by fleet 1992-2018.

Year	Fleet	# fish	Fleet	# shots
	D Seine	E Trawl	D Seine	E Trawl
1992		131		7
1993		896		45
1997		139		55
1998	126	2,155	21	94
1999	104	3,988	7	151
2000	110	2,890	5	93
2002	235	2,834	11	89
2003	102	2,622	7	89
2004		3,098		56
2005		1,478		31
2006	119	2,116	10	30
2007	218		1	
2008		99		12
2009		376		19
2010		175		24
2011	132	546	4	48
2012	212	388	15	35
2013	125	477	10	23
2014	254	700	29	18
2015	175	1,504	14	60
2016	176	361	10	14
2017	57	599	1	17
2018	103	195	3	8

Table 7.14. Number of FIS length measurements and number of shots containing tiger flathead by fleet and year.

Year	FIS East	(Z 10,20)	FIST Tas	(Z 30)
	# fish	# shots	# fish	# shots
2008	2202	27	907	15
2010	3384	44	1281	17
2012	3722	42	287	3
2014	3403	39	588	5
2016	2491	37	894	12
Sum 2008	1750	20	363	3
Sum 2010	3042	31	591	9
Sum 2012	1675	29	810	14

7.3.1.10 Input data summary

The data used in this assessment is summarised in Figure 7.4, indicating which years the various data types were available.

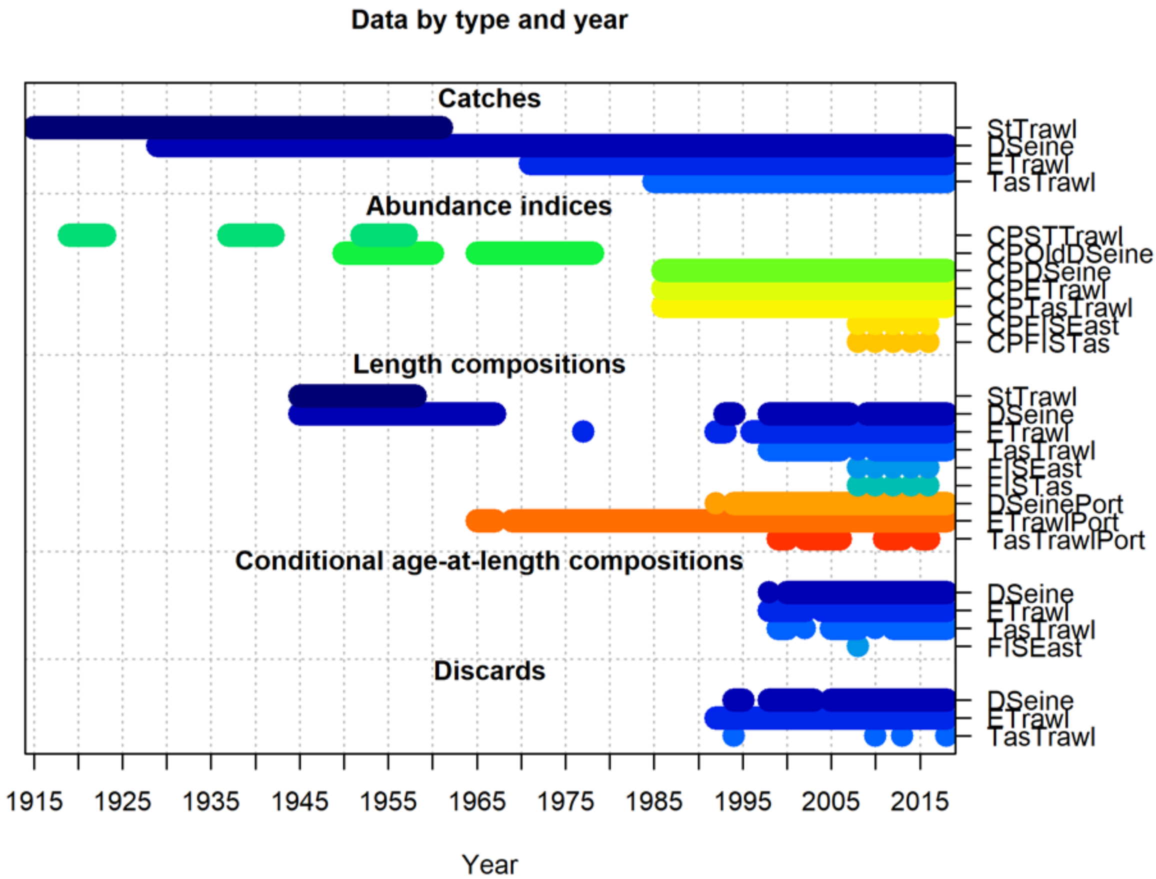


Figure 7.4. Summary of input data used for the tiger flathead assessment.

7.3.2 ***Stock assessment method***

7.3.2.1 Population dynamics model and parameter estimation

A two-sex stock assessment for tiger flathead was conducted using the software package Stock Synthesis version SS-V3.30.14.05, (Methot et. al, 2019). Stock Synthesis is a statistical age- and length-structured model which allows multiple fishing fleets and can be fitted simultaneously to the range of data available for tiger flathead. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, are given fully in the SS technical description (Methot, 2005) and are not reproduced here. Some key features of the population dynamics model underlying Stock Synthesis which are pertinent to this assessment are discussed below.

a) Tiger flathead constitute a single stock within the area of the fishery, from zone 10 off Sydney, through zone 20 (eastern Bass Strait), zone 60 (Bass Strait) and zone 30 (eastern Tasmania). While alternative stock structures have been previously suggested, with the eastern Tasmanian stock potentially a separate stock (Cui et al. 2004, Punt 2005a, Klaer 2006a, Klaer 2009, Klaer 2010, Day and Klaer 2013, Day 2016), this single stock is the stock structure currently agreed by SERAG.

b) The stock is assumed to be unexploited at the start of 1915 when the steam trawl fishery commenced. Catches prior to this are thought to have been minimal.

c) The CVs of all abundance indices (including the FIS) were initially set to the root mean squared deviation from a loess fit to the fleet specific indices (Sporcic 2019a, Sporcic 2019b) and then tuned to match the model-estimated standard errors by estimating an additional variance parameter within Stock Synthesis.

d) Four fishing fleets are modelled.

e) Selectivity is assumed to vary among fleets, but the selectivity pattern for each separate fleet is modelled as length-specific, logistic and mostly time-invariant. The selectivity for Danish seine is allowed to change in 1978, and eastern diesel trawl in 1985. The two parameters of the selectivity function for each fleet are estimated within the assessment.

f) Retention is also defined as a logistic function of length, and the inflection and slope of this function are estimated for the three fleets where discard information is available (Danish seine, eastern trawl and Tasmanian trawl). Retention for the steam trawl fleet was implicitly assumed to be independent of length as no length frequency composition data is available on discards for this fleet.

g) The rate of natural mortality, *M*, is assumed to be constant with age, and also time-invariant. The value for *M* is fixed within the model at 0.27 yr^{-1} as in the previous assessment (Day, 2016).

h) 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 is estimated within the model for the base case analysis. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1915 to 2015. Deviations are not estimated after 2015 because there are insufficient data to permit reliable estimation of recruitment residuals outside of this time period.

i) The value of the parameter determining the magnitude of the process error in annual recruitment, σ_R, is set equal to 0.7 in the base case. 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).

j) A plus-group is modelled at age twenty years.

k) Growth of tiger flathead is assumed to be time-invariant, that is there has been no change over time in the mean size-at-age, with the distribution of size-at-age determined from fitting the growth curve within the assessment using the age-at-length data. Differences in growth by gender are modelled.

l) The sample sizes for length and age frequencies were tuned for each fleet so that the input sample size was approximately equal to the effective sample size calculated by the model. Before this retuning of length frequency data was performed by fleet, any sample sizes with a sample size greater than 100 trips or 200 shots were individually down-weighted to a maximum sample size of 100 and 200 respectively. This is because the appropriate sample size for length frequency data is probably more closely related to the number of shots sampled, rather than the number of fish measured.

7.3.2.2 Relative data weighting

Iterative reweighting of input and output CVs or input and effective sample sizes is an imperfect but objective method for ensuring that the expected variation is comparable to the input (Pacific Fishery Management Council, 2018). This makes the model internally consistent, although some argue against this approach, particularly if it is believed that the input variance is well measured and potentially accurate. It is not necessarily good to down weight a data series just because the model does not fit it, if in fact, that series is reliably measured. On the other hand, most of the indices we deal with in fisheries underestimate the true variance by only reporting measurement and not process error.

Data series with a large number of individual measurements such as length or weight frequencies tend to overwhelm the combined likelihood value with poor fits to noisy data when fitting is highly partitioned by area, time or fishing method. These misfits to small samples mean that simple series such as a single CPUE might be almost completely ignored in the fitting process. This model behaviour is not optimal, because we know, for example, that the CPUE values are in fact derived from a very large number of observations.

Length compositions were initially weighted using trip and shot numbers, where available, instead of numbers of fish measured and by adopting the Francis weighting method (Francis 2011) for age and length composition data.

Shot or trip number is not available for all data, especially for some of the early length frequency data. In these cases, the number of trips was inferred from the number of fish measured using the average number of fish per trip for the relevant gear type for years where both data sources were available, or in some of the earlier years, dividing the number of fish by 10 and capping the resulting number at 200. The number of trips were also capped at 100 and the number of shots capped at 200. Samples with less than 100 fish measured per year were excluded.

These initial sample sizes, based on shots and trips, are then iteratively reweighted so that the input sample size is equal to the effective sample size calculated by the model using the Francis weighting method for length data and the Punt weighting method for conditional age-at-length data.

7.3.2.3 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 for tiger flathead. 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.

7.3.2.4 Calculating the RBC

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

The Tier 1 harvest control rule specifies a target and a limit biomass reference point, as well as a target fishing mortality rate. Since 2005 various values have been used for the target and the breakpoint in the rule. 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}. Once this point is reached, the fishing mortality is set at F_{48}. Day (2008) 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.

Previously, a preliminary economic analysis was used as a basis for using a 20:35:41 rule for tiger flathead (Klaer 2010). As steepness is an estimated parameter in the tiger flathead assessment, it is one of the few SESSF stocks where an MSY estimate may be taken from the base case stock assessment. SESSFRAG in 2010 determined that a tiger flathead RBC may be calculated using a rule that incorporates application of the default 1.2 multiplier to the MSY depletion level to determine a minimum value for an MEY depletion level. It was also agreed at SESSFRAG that if this level was below 40% of B_0, that the 40% level be used to generate an RBC to maintain the biological precaution implicit in the 40% level. As with the 2013 assessment, SERAG agreed that the default RBC for tiger flathead is calculated under the 20:35:40 strategy.

7.3.2.5 Sensitivity tests and alternative models

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. $M = 0.22$ yr^{-1}.
2. $M = 0.32$ yr^{-1}.
3. 50% maturity at 27 cm.
4. 50% maturity at 33 cm.
5. σ_R set to 0.4.
6. σ_R set to 0.6.
7. σ_R set to 0.8.
8. First year of recruitment changed from 1915 to 1925.
9. Fix steepness (*h*) at 0.75 and estimate natural mortality (*M*).
10. Fix steepness (*h*) at 0.75 and fix natural mortality (*M*) at 0.27.

11. Fix steepness (h) at 0.65 and fix natural mortality (M) at 0.27.
12. Fix steepness (h) at 0.85 and fix natural mortality (M) at 0.27.
13. Double the weighting on the length composition data.
14. Halve the weighting on the length composition data.
15. Double the weighting on the age-at-length data.
16. Halve the weighting on the age-at-length data.
17. Double the weighting on the survey (CPUE) data.
18. Halve the weighting on the survey (CPUE) data.

The results of the sensitivity tests are summarized by the following quantities (Table 26):

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. Steepness: the estimated steepness of the stock-recruitment relationship.
5. SSB_{MSY}/SSB_0: the female spawning biomass depletion level at maximum sustainable yield (MSY).
6. RBC_{2020}: the recommended biological catch (RBC) for 2020.
7. $\mathrm{RBC}_{2020\text{-}22}$: the mean RBC over the three years from 2020-2022.
8. $\mathrm{RBC}_{2020\text{-}23}$: the mean RBC over the five years from 2020-2023.
9. $\mathrm{RBC}_{\mathrm{longterm}}$: the longterm RBC.

The base case in this section refers only to the old base case. Hence, the RBC values were calculated for the old base case only. All sensitivities were calculated relative to the old base case, using the incorrect (lower) catch series from 2001-2018. The general principles and comparisons in these sensitivities to the old base case are not expected to show qualitative differences to similar sensitivities conducted with the updated base case.

It is possible that the eastern Tasmanian component of the stock could have different growth to the rest of the stock or could be assessed as a separate stock and these options could be explored in future assessments. The current assessment assumes a single stock and a single growth curve per sex for the whole stock, an assumption also made in previous assessments.

7.4 Results and discussion

7.4.1 The base case analysis

7.4.1.1 Parameter estimates

Figure 7.5 shows the estimated growth curve for female and male tiger flathead. All growth parameters are estimated by the model except for l_{max} (parameter values are listed in Table 7.15).

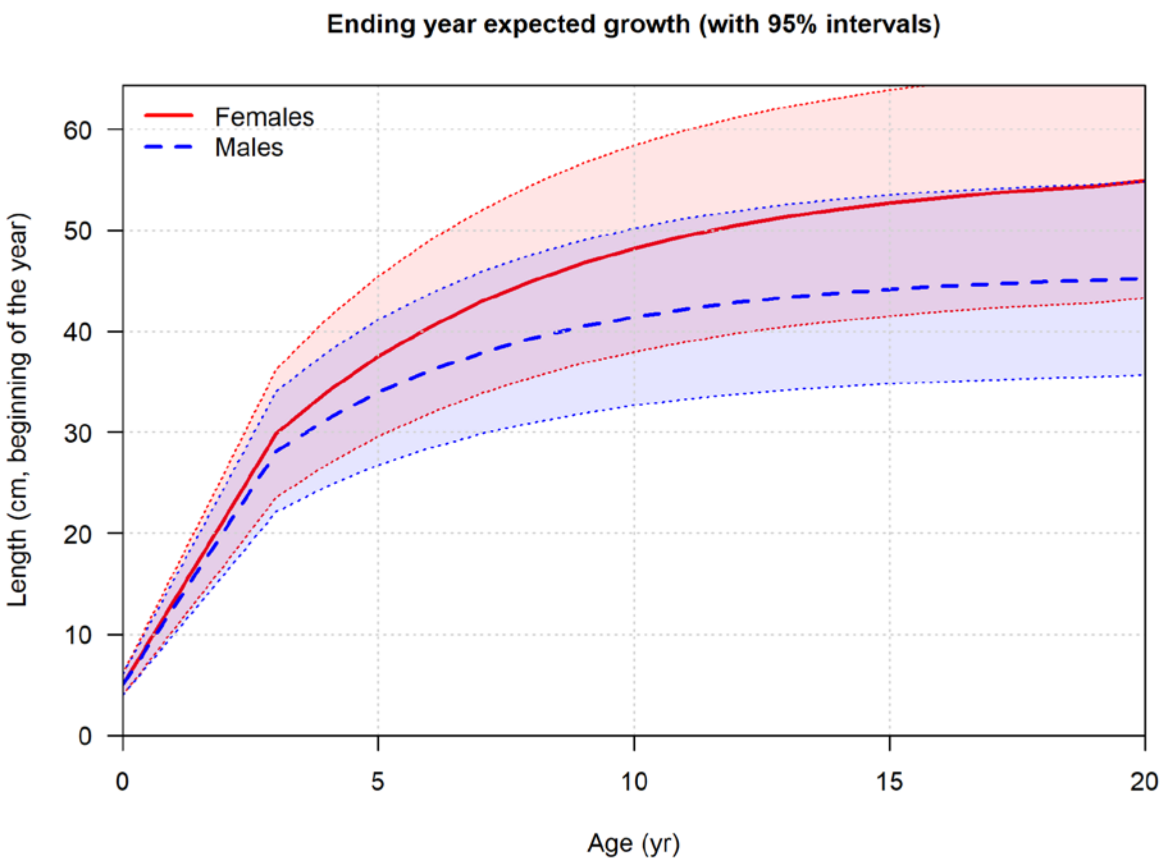


Figure 7.5. The model-estimated growth curves.

Table 7.15. Summary of parameters of the base case model.

Feature	Details	
Fleets	Steam trawl	Fixed discard rate of 17%
	Danish seine	Fixed discard rate of 17% to 1960, fitted thereafter
		Selectivity change in 1978 from early to modern Danish seine
	East coast trawl	Selectivity change in 1985 from early to modern diesel trawl
	Tasmanian trawl	Diesel trawl in Zone 30
Natural mortality *M*	fixed	0.27
Steepness *h*	estimated	0.72
σ_R in	fixed	0.70
Recruitment devs	estimated	1915-2015, bias adjustment ramps 1933-1942 and 2015
CV growth	estimated	0.108
Growth *K*	estimated	Female 0.172, Male 0.154
Growth l_{min}	estimated	Female age 2 29.89
Growth l_{max}	fixed	Female 55.9

Selectivity is assumed to be logistic for all 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 7.6 shows the selectivity and retention functions for each of the commercial fleets. Figure 7.7 shows the selectivity for the two FIS fleets, FISEast (Zones 10 and 20) and FISTas (Zone 30). The difference in the selectivity patterns when the FIS fleet is split suggests different characteristics in the fish caught by the FIS in Zone 30 from fish caught by the FIS in zones 10 and 20, reflecting similar patterns seen in the commercial trawl data in these regions.

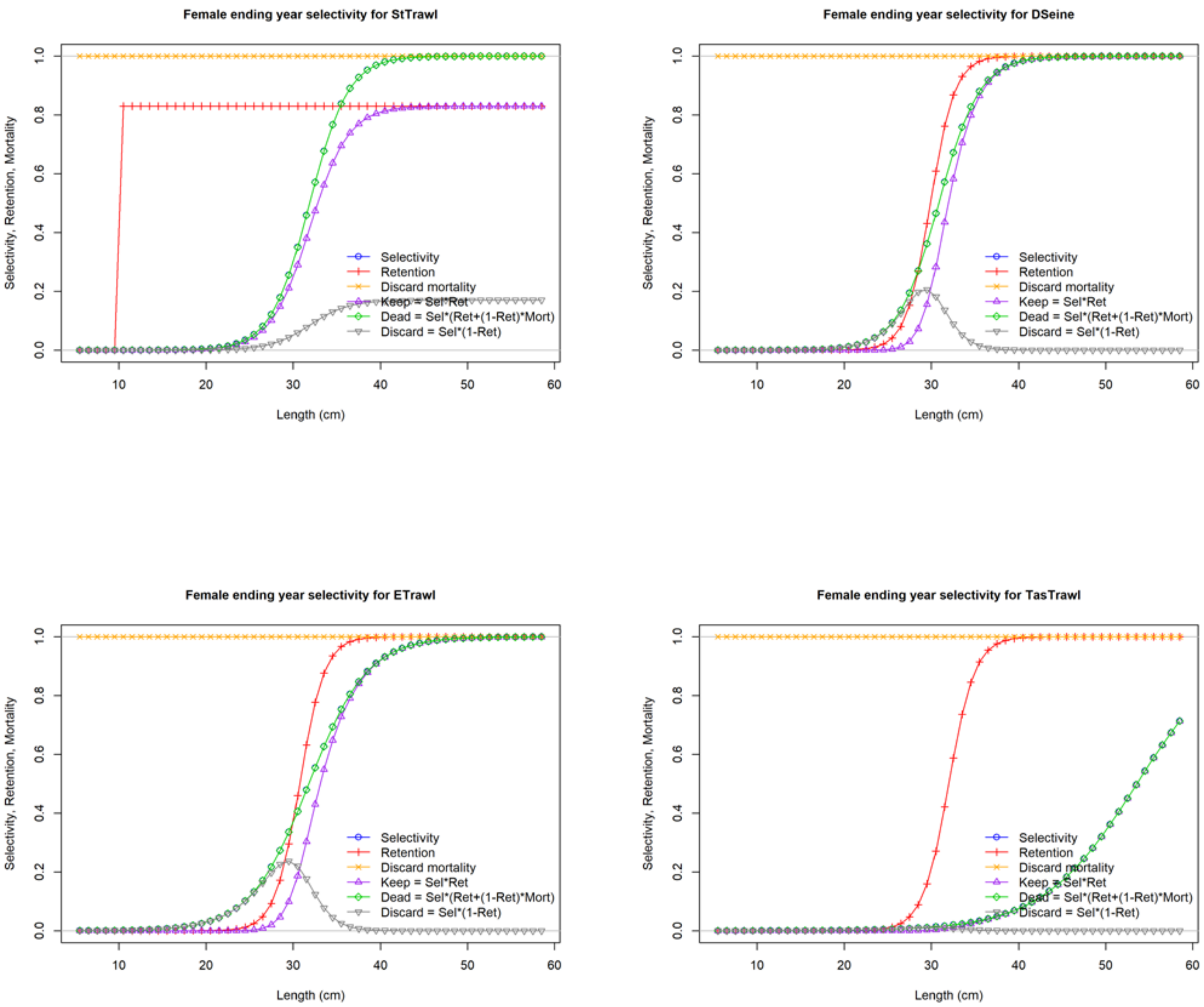


Figure 7.6. Selectivity (blue/green) and retention (red) functions for the four commercial fleets.

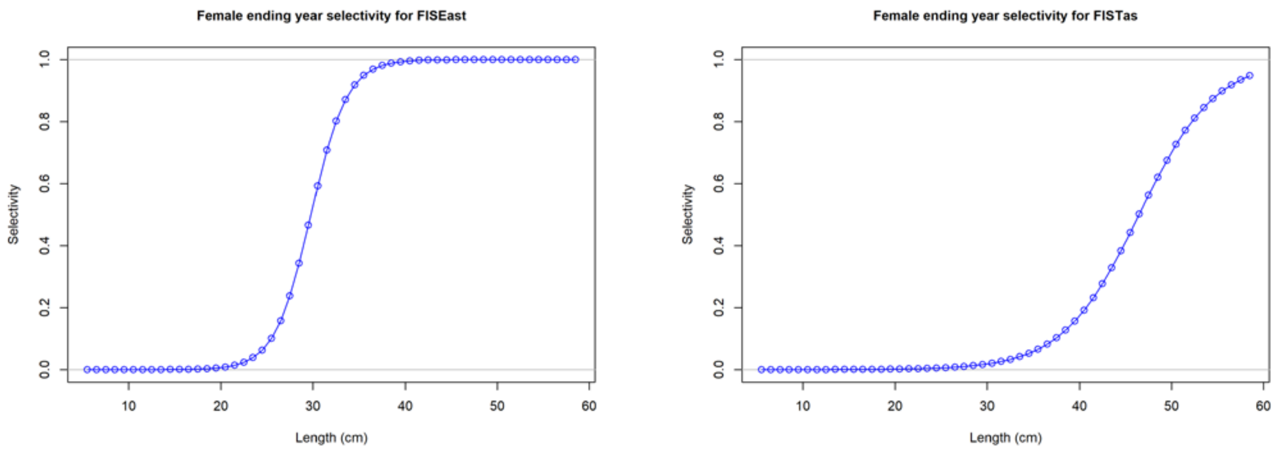


Figure 7.7. Selectivity for the eastern (left) and Tasmanian (right) FIS fleets when the FIS length frequencies are separated into zones.

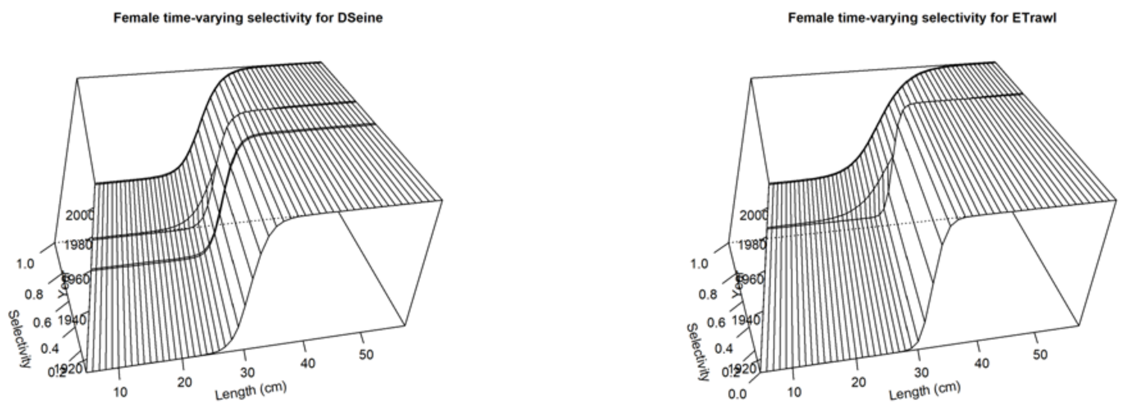


Figure 7.8. Time variation in selectivity for Danish seine and eastern diesel trawl.

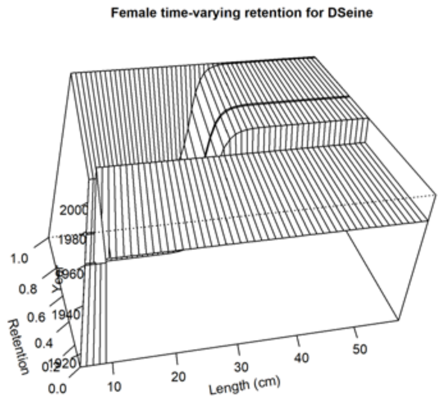


Figure 7.9. Time variation in retention for Danish seine.

7.4.1.2 Fits to the data

The fits to the catch rate indices (Figure 7.10) are variable in quality. The catch rate indices for the steam trawl fleet shows a considerable decline from 1915 to 1950, consistent with overexploitation during that time (see Fairbridge, 1948, Klaer, 2006b). The early Danish seine index from 1950 to 1978 was relatively flat or increasing over that period. Recent abundance indices from 1986 to present also show reasonably flat trends. The Tasmanian trawl fleet index is the worst fit for the recent indices, but the catch contribution by that fleet is also the smallest.

Inclusion of the new data and tuning procedures resulted in changes to the estimates of recruitment and to the spawning biomass time series. With increased flexibility to vary recruitment early in the time series, the fits to the steam trawl indices improved considerably and there were several modifications to estimated recruitment deviations, most noticeably a downward revision to the 2012 recruitment estimate. The estimated spawning biomass in the 1920s increased from around 1.05 times virgin biomass in the 2016 assessment to around 1.2 times the virgin biomass in the 2019 assessment, allowing a much better fit to the early steam trawl CPUE time series.

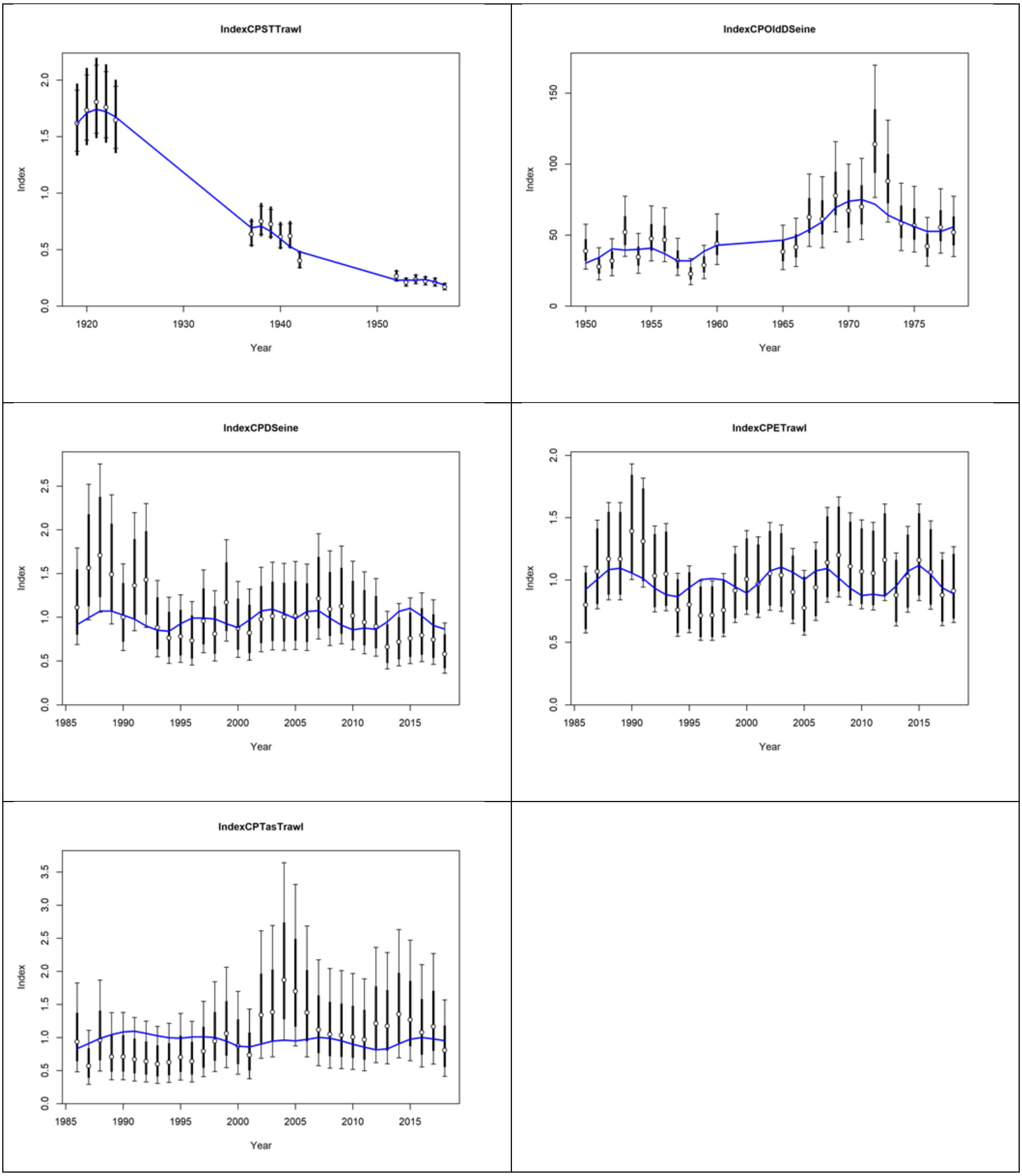


Figure 7.10. Observed (circles) and model-estimated (lines) catch rates vs year, with approximate 95% asymptotic intervals.

The fits to the FIS abundance indices separated into and eastern (zones 10 and 20) and Tasmanian (zone 30) fleets are shown in Figure 7.11. Variability between years and inconsistent patterns between the two regions makes it difficult to achieve any better fit to these data points, especially when three other indices are being fit simultaneously over the same time period.

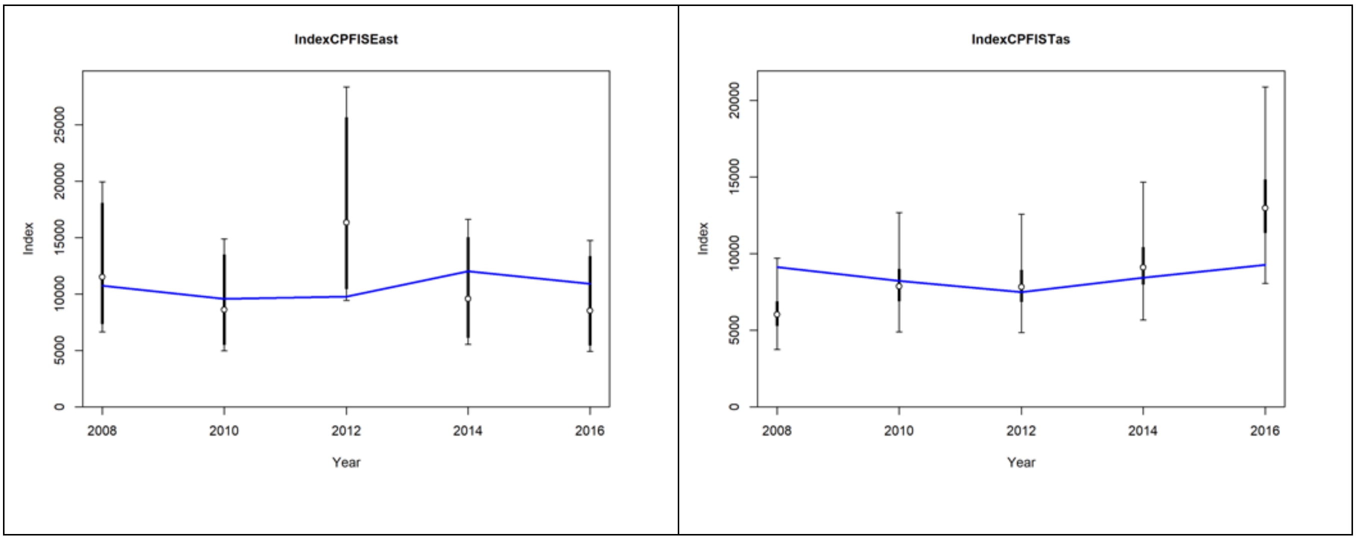


Figure 7.11. Observed (circles) and model-estimated (lines) catch rates vs year, with approximate 95% asymptotic intervals for the FIS abundance index separated into eastern (zones 10 and 20) and Tasmanian (zone 30) fleets.

The fits to the discard fractions (Figure 7.12) are reasonable given the variability in the data, with some very low data points (less than 2%) and others up to 20% for Danish seine and eastern trawl and up to 8% for Tasmanian trawl. The fits to the discard fractions for the eastern trawl and Danish seine fleets are considerably better than in the 2016 assessment, although this is helped by exclusion of some very small values (< 1%) from the Tasmanian trawl fleet. Including these low discard rates results in much lower overall predicted discard rates compared to the mean of the discard rates over all years with discard data for each fleet. Excluding these very small discard estimates has become standard practice in SESSF stock assessments in recent years.

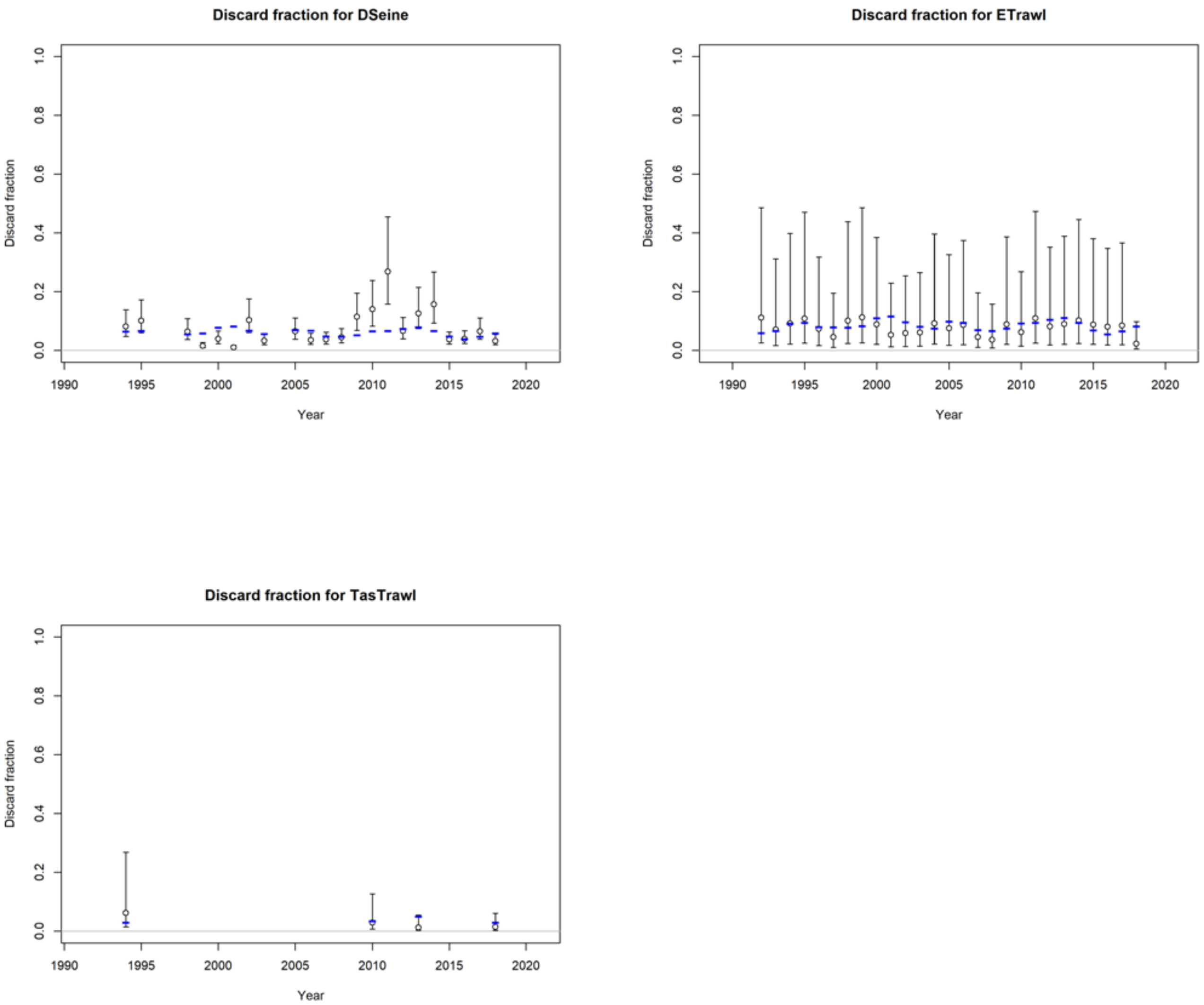


Figure 7.12. Observed (circles) and model-estimated (blue lines) discard estimates versus year, with approximate 95% asymptotic intervals.

The base case model is able to fit the aggregated retained and discarded length-frequency distributions very well (Figure 7.13 and Appendix A), with the exception of the Tasmanian trawl fleet, for which the actual sample sizes are relatively small. The fits to the historical steam trawl and early Danish seine fleets are better than those for the more recent data (except for steam trawl in 1957 and 1958). The number of fish measured for the historical data is generally very high, which leads to smoother observed distributions. The fits to the discarded length compositions are variable (Figure 7.13 and Appendix A). This is not surprising, as the observed discard length frequencies are quite variable from year to year, and actual sample sizes are small in comparison to the retained length frequencies.

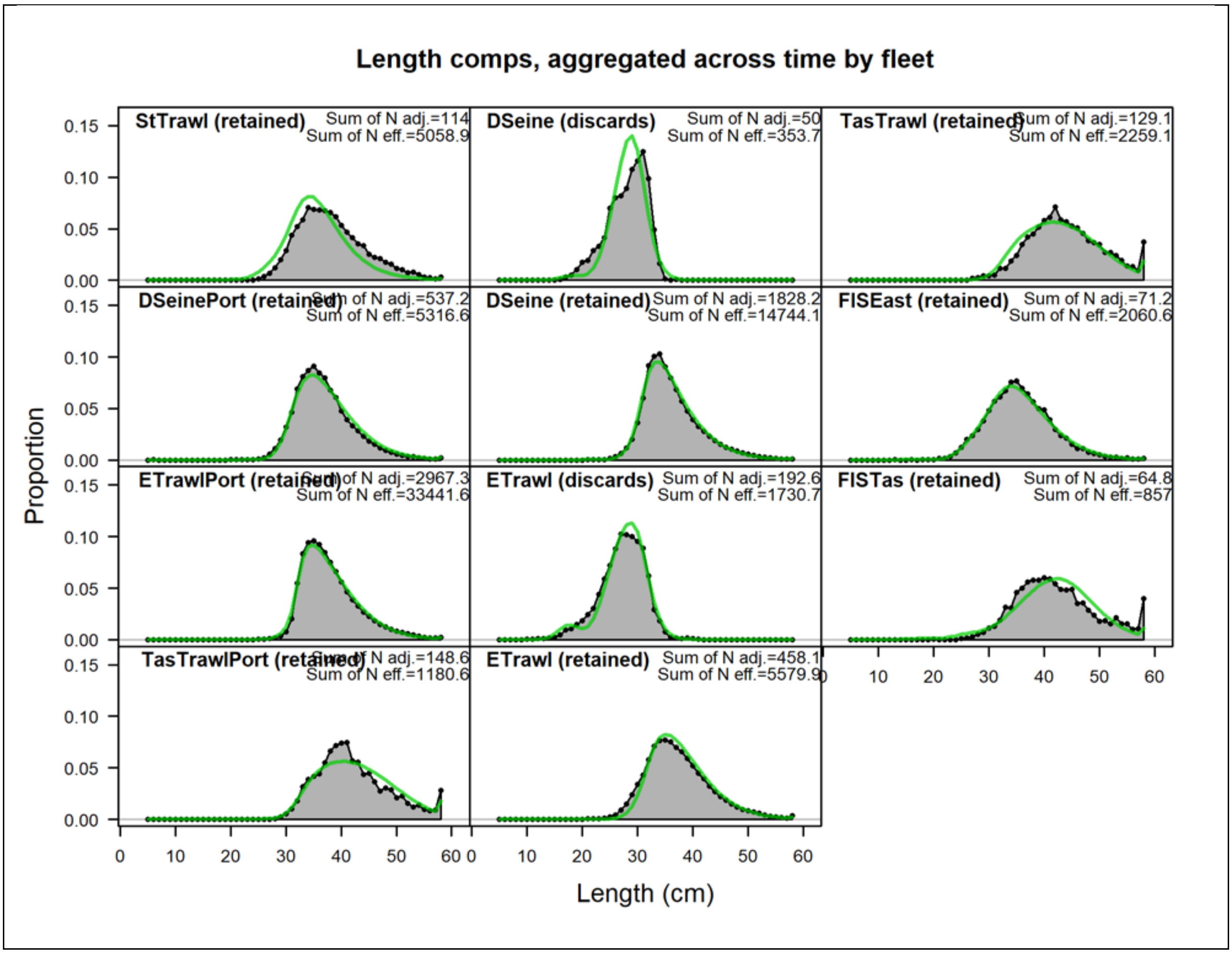


Figure 7.13. Fits to retained and discarded length compositions by fleet, separated by port and onboard samples, aggregated across all years. Observed data are grey and the fitted value is the green line.

The implied fits to the age composition data 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 for all three recent fleets for both retained and discarded age data.

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, as the age data is not representative of the stock as a whole. 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.

The conditional age-at-length data is a little noisy between years, especially for the fleets with smaller catches. The mean age varies between 3 and 6 years for eastern trawl and Danish seine and between 6 and 11 years for the Tasmanian trawl fleet. This variability in the age-at-length data may be due to spatial or temporal variation in collection of age samples. The fits to conditional age-at-length are reasonable.

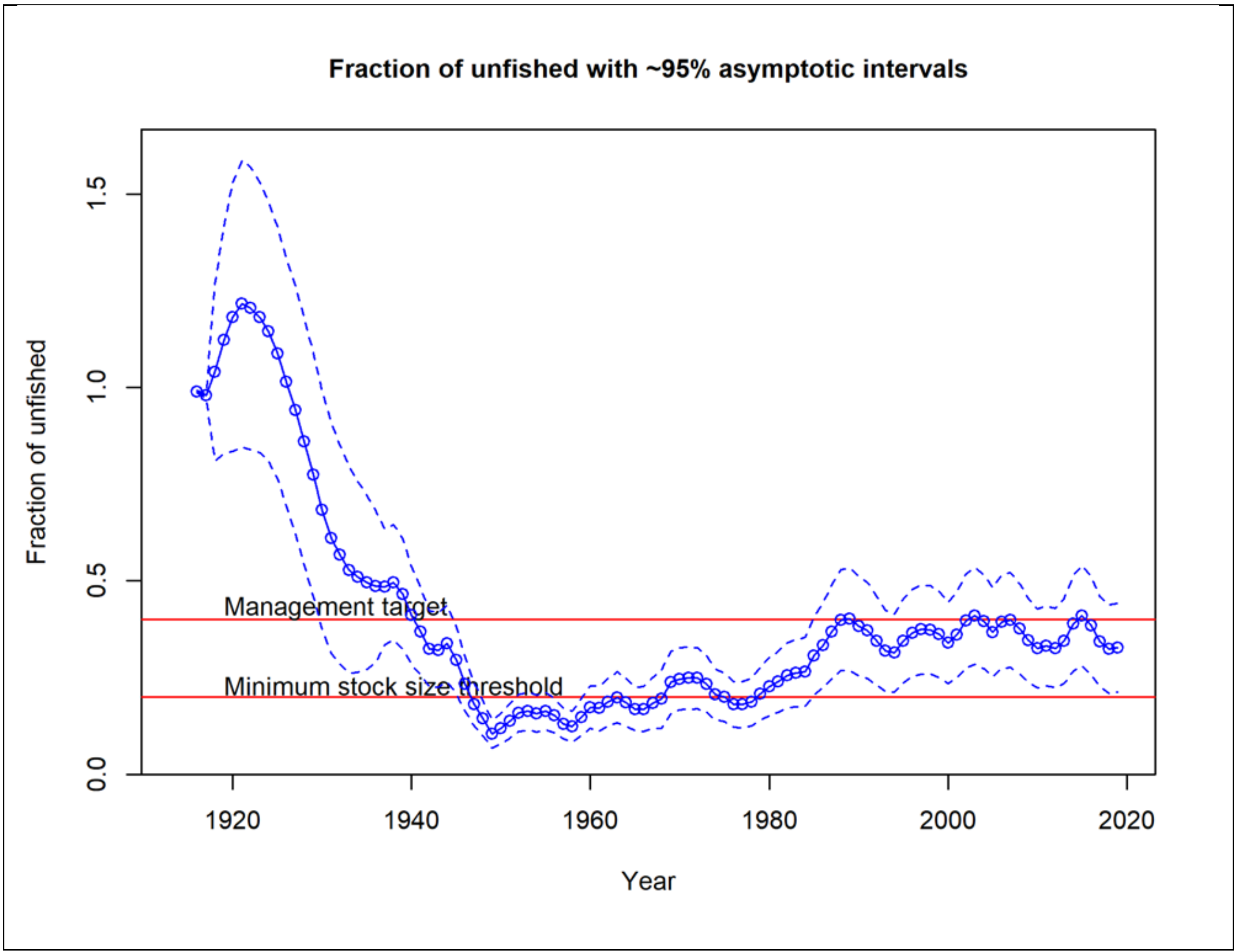


Figure 7.14. Time-trajectory of spawning biomass depletion (with approximate 95% asymptotic intervals) corresponding to the MPD estimates for the base case analysis for tiger flathead.

7.4.1.3 Assessment outcomes

Figure 7.14 shows the trajectory of spawning stock status. The stock declines substantially from the beginning of the fishery in 1915 to 1950, fluctuates near the minimum threshold of 20% SSB_0 during the 1950s, 1960s and 1970s, before an increase to near 40% SSB_0 by the 1990s. This increase in the 1980s was driven by a combination of favourable recruitments (Figure 7.16) and total landings of less than 2,000t in the late 1970s and early 1980s. The stock has fluctuated between 30% and 40% SSB_0 since around 1990 with a slight decrease in the last three years. The comparison to the base case from the 2016 assessment is shown in Figure 7.15.

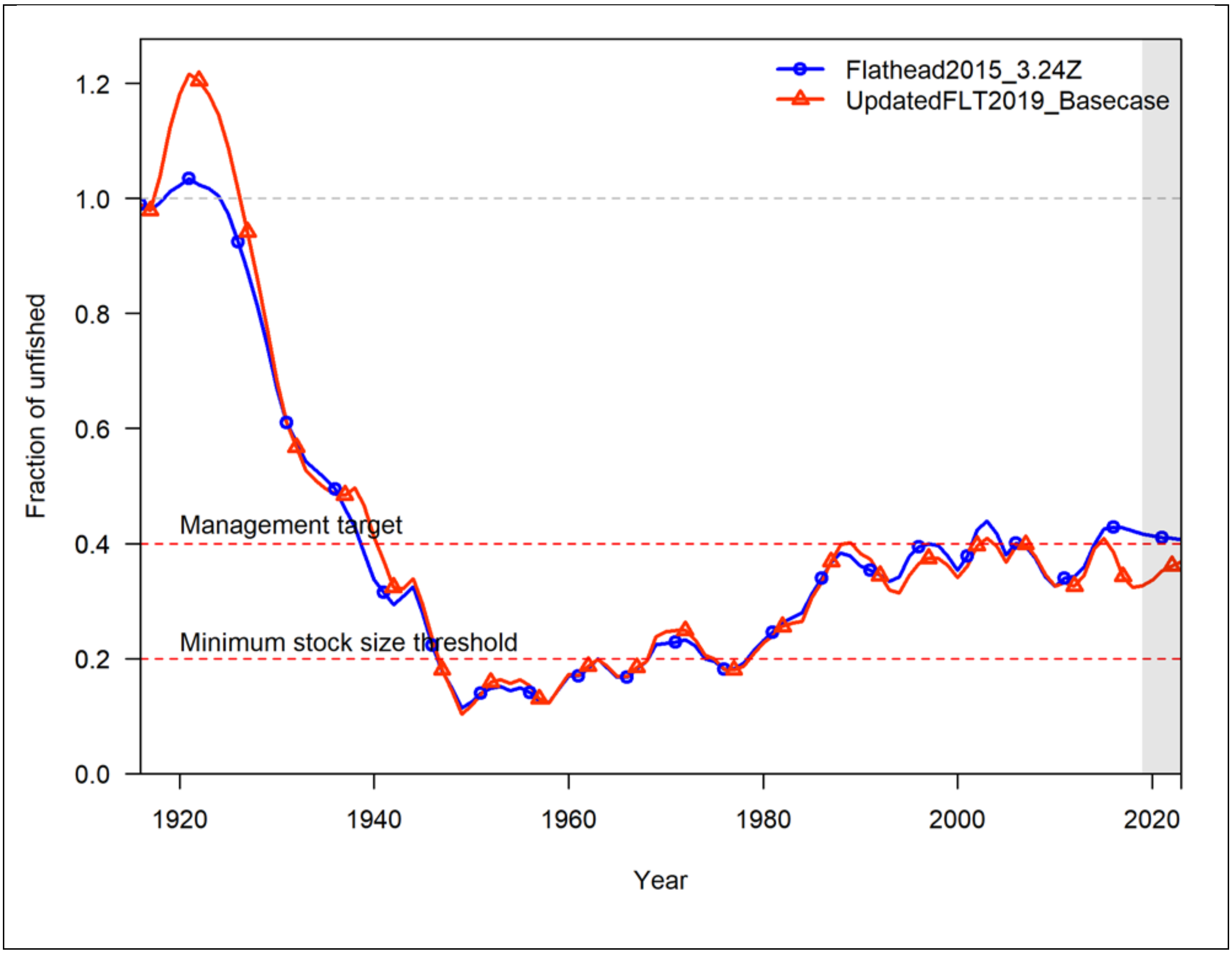


Figure 7.15. Time-trajectory of spawning biomass depletion corresponding to the MPD estimates for the base case analysis for the two base cases for the tiger flathead assessment in 2016 and in 2019.

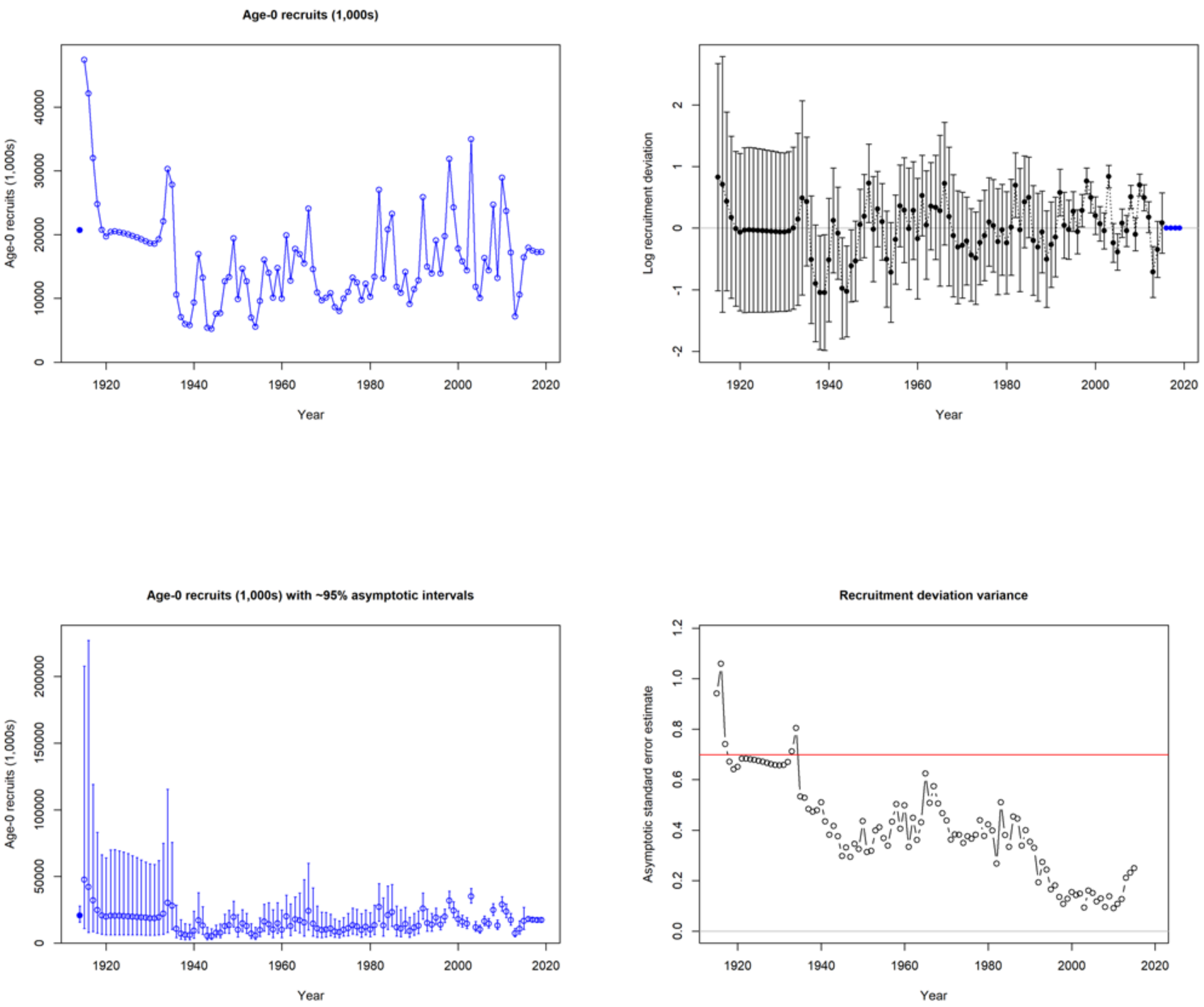


Figure 7.16. Recruitment estimation for the base case analysis. Top left: Time-trajectories of estimated recruitment numbers; top right: time trajectory of estimated recruitment deviations; bottom left: time-trajectories of estimated recruitment numbers with approximate 95% asymptotic intervals; bottom right: the standard errors of recruitment deviation estimates.

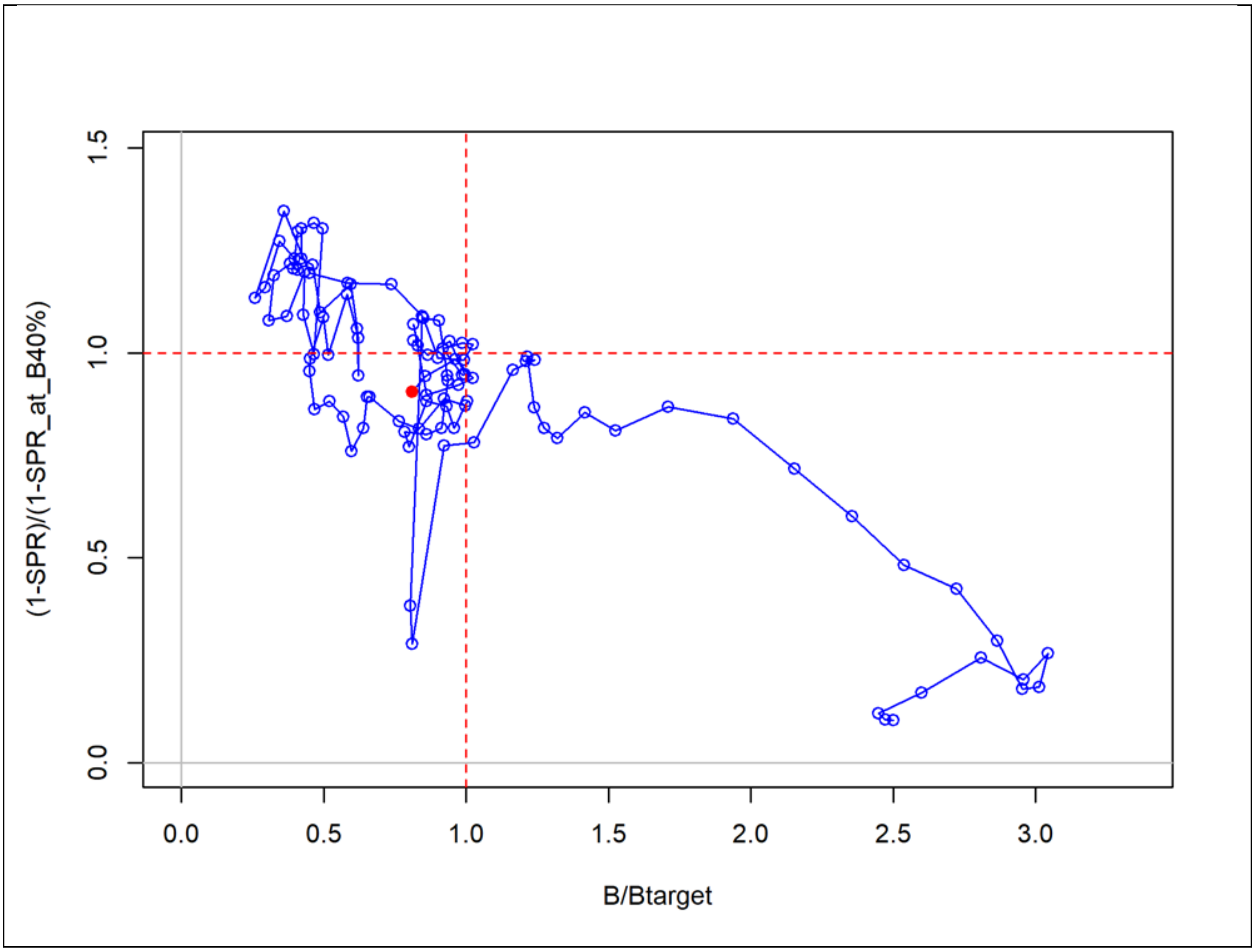
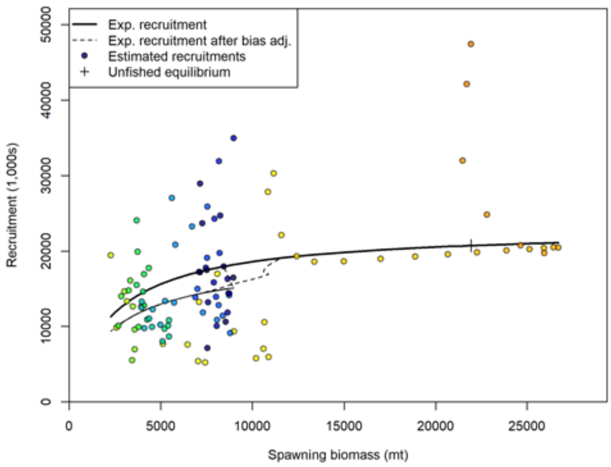


Figure 7.17. Kobe plot for the base case analysis, showing the trajectory of spawning biomass (relative to B_0) plotted against (1-SPR) as a ratio of the target, which is a proxy for fishing mortality, essentially integrating fishing mortality across fleets in the fishery.

Figure 7.17 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). This trajectory shows an increase in overall fishing mortality and a decrease in biomass from 1915 to about 1950, with movement from the bottom right corner to the top left corner, when the biomass was well below the target and the fishing mortality was above the target rate. The years 1942 and 1943 stand out in this trajectory when fishing effort dropped notably, with the biomass at around 75% of the target (or 30% of B_0). Apart from this short period of reduced fishing effort during World War II, fishing mortality stayed above the target rate until 1978, when fishing mortality reduced considerably, and stayed around or below the target until the late 1990s. This allowed the spawning biomass to recover to near the target (40% of B_0) in the late 1990s. Since the late 1990s, fishing mortality has increased again, with a slight drop in the last six years. This period has been supported by relatively strong recruitment over the last 20 years.



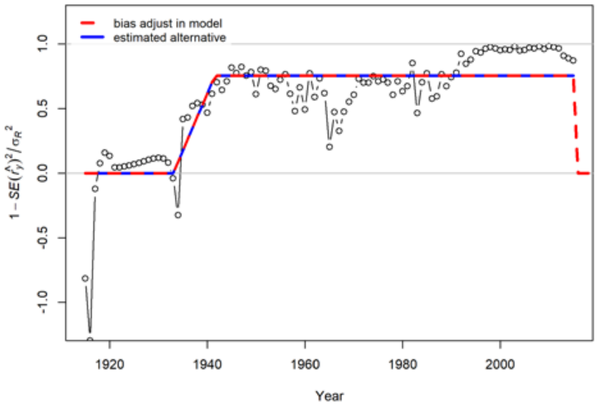


Figure 7.18. Recruitment estimation for the base case analysis. Left: the stock-recruit curve and estimated recruitments; right: bias adjustment.

The time-trajectories of recruitment and recruitment deviation are shown in Figure 7.16. Estimates of recruitments since about 1940 are generally variable, but periods of above and below average recruitment levels appear for periods of up to eight years. Long-term regular cycles are not evident however. Recruitment in the past 30 years is estimated to have been highly variable. The variability in estimated recent recruitment is likely to be a result of the model attempting to fit the increased quantity of data in recent years, particularly the age data.

The base case assessment estimates that current spawning stock biomass is 34% of unexploited stock biomass (SSB_0), compared to 42% from the 2016 assessment (Day, 2017) and 50% from the 2013 assessment (Day and Klaer, 2013). The 2020 recommended biological catch (RBC) under the 20:35:40 harvest control rule is 2,334 t (Table 7.16) and the long term yield (assuming average recruitment in the future) is 2,986 t. Averaging the RBC over the three year period 2020-2022, the average RBC is 2,563 tand over the five year period 2020-2024, the average RBC is 2,648 t. The RBCs for each individual year from 2020-2024 are listed in Table 7.16 for the base case.

Table 7.16. Yearly projected RBCs (tonnes) across all fleets under the 20:35:40 harvest control rules for the updated base case, assuming average recruitment from 2016.

RBCs Year	Base
2020	2,334
2021	2,648
2022	2,706
2023	2,755
2024	2,796

7.4.1.4 Discard estimates

Model estimates for discards for the period 2020-24 with the 20:35:40 Harvest Control Rule are listed in Table 7.17 for the base case, with a range of 164 to 183 t.

Table 7.17. Yearly projected discards (tonnes) across all fleets under the 20:35:40 harvest control rules with catches set to the calculated RBC for each year from 2020 to 2024 rules for the updated base case, assuming average recruitment from 2016.

Discards Year	Base
2020	164
2021	181
2022	181
2023	182
2024	183

7.4.2 *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 mortality (M) and steepness (h) 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 or indeed support for estimating that parameter. If the parameter is within the entire range of the 95% confidence interval (within 1.92 units of likelihood), 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).

Initial likelihood profiles (for mortality and virgin biomass on the 2019 preliminary base case) were presented at the October 2019 SERAG meeting (Day, 2019). These are repeated here for the 2019 old base case, using the incorrect (lower) catch series from 2001-2018, with additional likelihood profile on steepness, spawning biomass in 2018 and relative spawning biomass status (depletion). The comparisons in these analyses with the old base case are not expected to show qualitative differences to updated comparisons with the corrected catch series.

7.4.2.1 Natural mortality

For tiger flathead, the likelihood profile for natural mortality, *M*, a parameter fixed in the model, is shown in Figure 7.19 with the total likelihood shown in black and components of the total likelihood from different data sources shown in a range of colours. This likelihood profile suggests that there is little information in the model that can be used to inform this parameter (fixed at 0.27 in the model). The index and length data (which both suggest higher mortality) and the recruitment and discard data (which both suggest lower mortality) are in conflict and the likelihood profile suggests higher values of mortality are preferred. However, this likelihood profile is essentially uninformative when the biological consequences of mortality values greater than 0.3 are considered on the expected maximum age for this species.

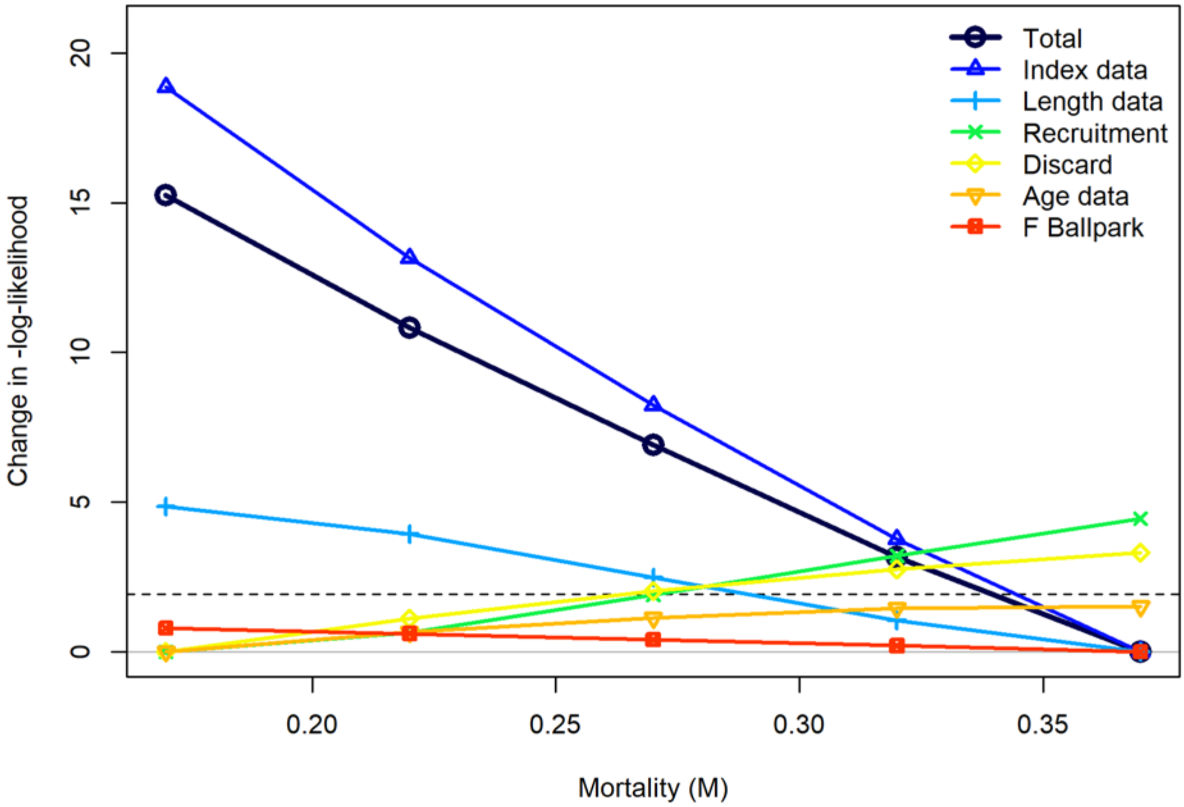


Figure 7.19. The likelihood profile for natural mortality, with *M* ranging from 0.17 to 0.37. The fixed value for *M* is 0.27yr^{-1}.

7.4.2.2 Steepness

A likelihood profile for steepness, *h*, a parameter estimated in the model, is shown in Figure 7.20 with the total likelihood shown in black and components of the total likelihood from different data sources shown in a range of colours. This likelihood profile gives information on the components of the data which are most influential in estimating *h* and gives an indication of how precisely *h* can be estimated, and perhaps whether *h* should be estimated.

The likelihood profile in Figure 7.20 is relatively flat, with very little difference in likelihood values between 0.6 and 0.95. While the model can obtain an estimate for *h*, this profile would suggest that a wide range of values cannot be distinguished by the data. This suggest that *h* should not be estimated in the next tiger flathead stock assessment. Steepness is often impossible to estimate in stock assessment models. Being able to estimate steepness is more likely if recruitment has been estimated at both high biomass levels and, with a recovery, from low biomass levels. Despite this assessment having all of these features, it appears steepness is not estimated very precisely here, so it may be better to fix this value (*h*=0.75) in the next tiger flathead stock assessment.

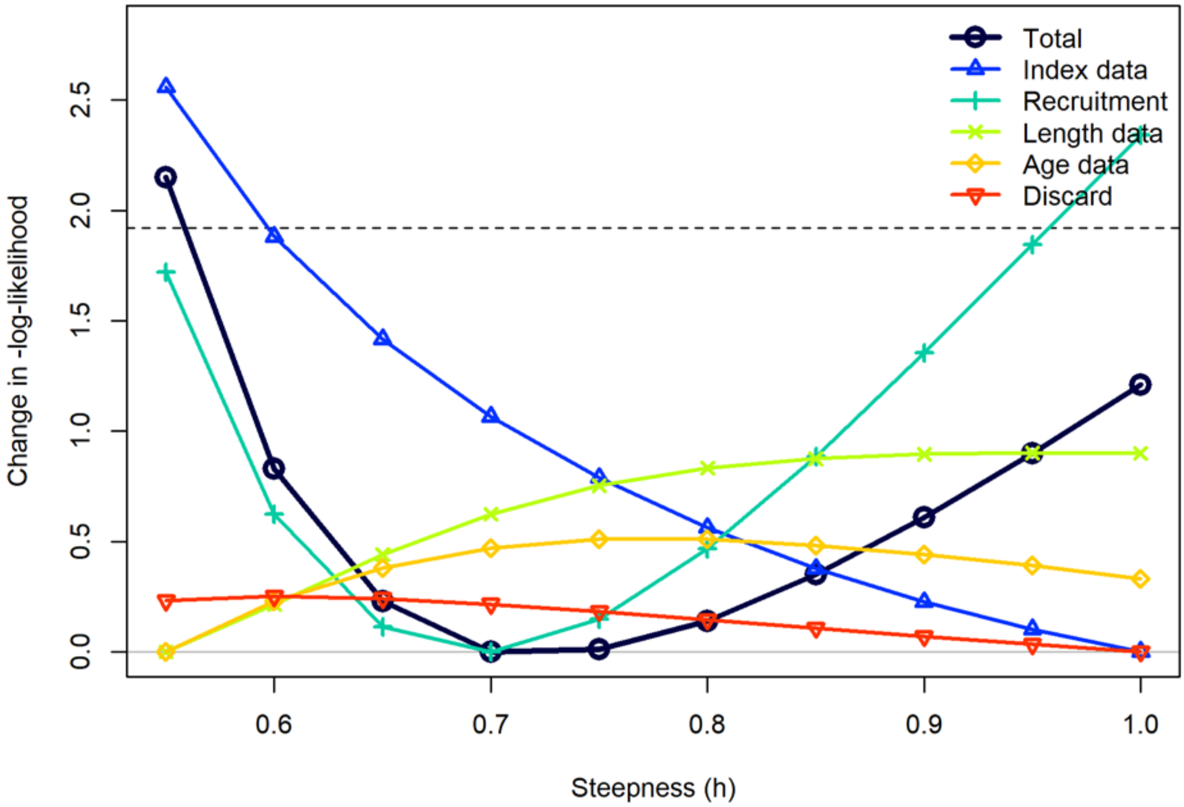


Figure 7.20. The likelihood profile for steepness, with *h* ranging from 0.55 to 1. The estimated value for *h* is 0.72.

The most important data sources in providing information on *h* are the index data and recruitment deviations (Figure 7.20). While neither data source is that influential, the index data support a higher value of steepness (a more productive stock) than the recruitment data (which support a less productive stock). The steam trawl CPUE data has the most influence on the index component of this likelihood (Figure 7.21).

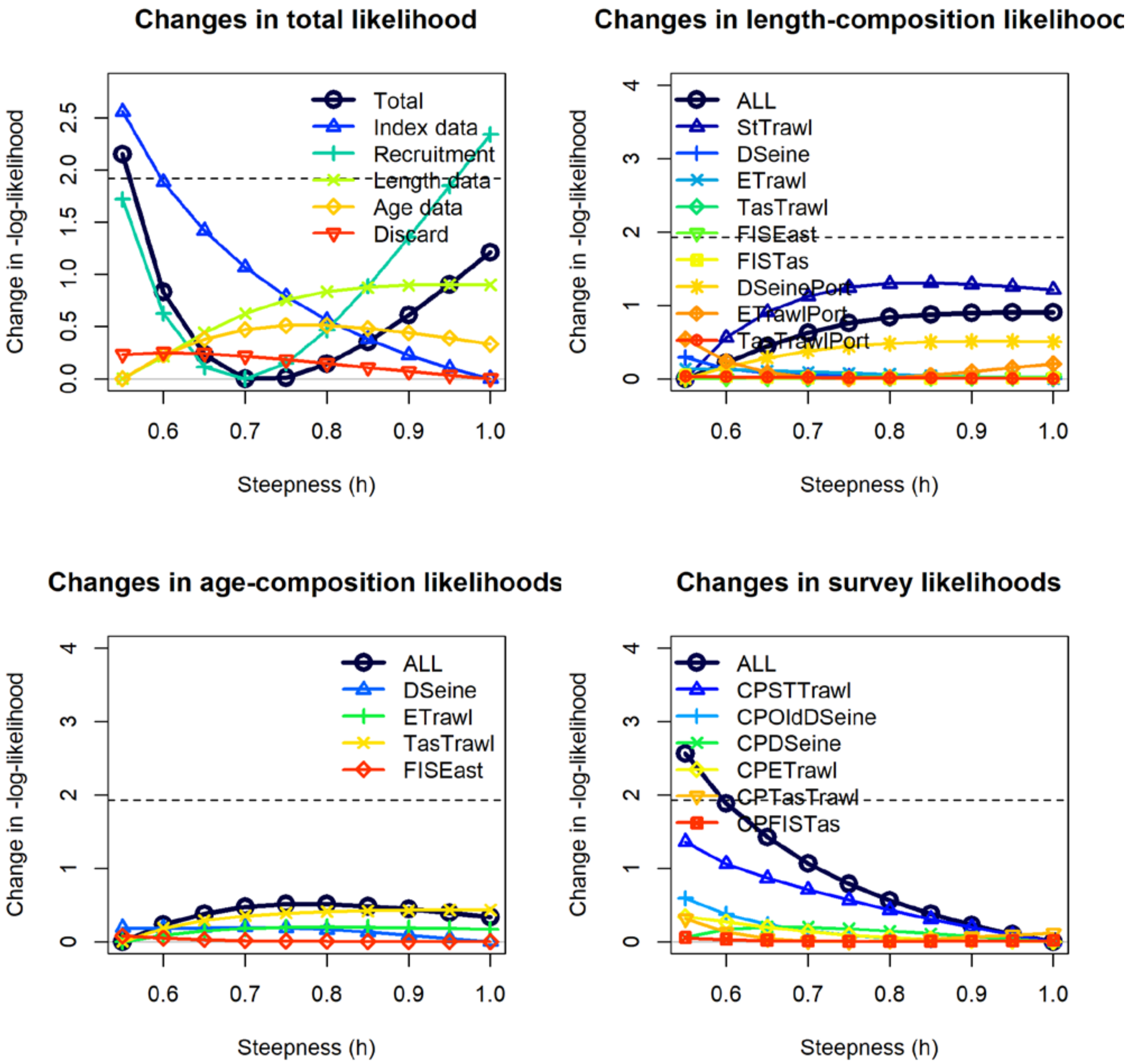


Figure 7.21. Piner plot for the likelihood profile for virgin spawning biomass, showing components of the change in likelihood for length, age and indices (CPUE) in addition to the changes in the total likelihood.

7.4.2.3 Virgin spawning biomass

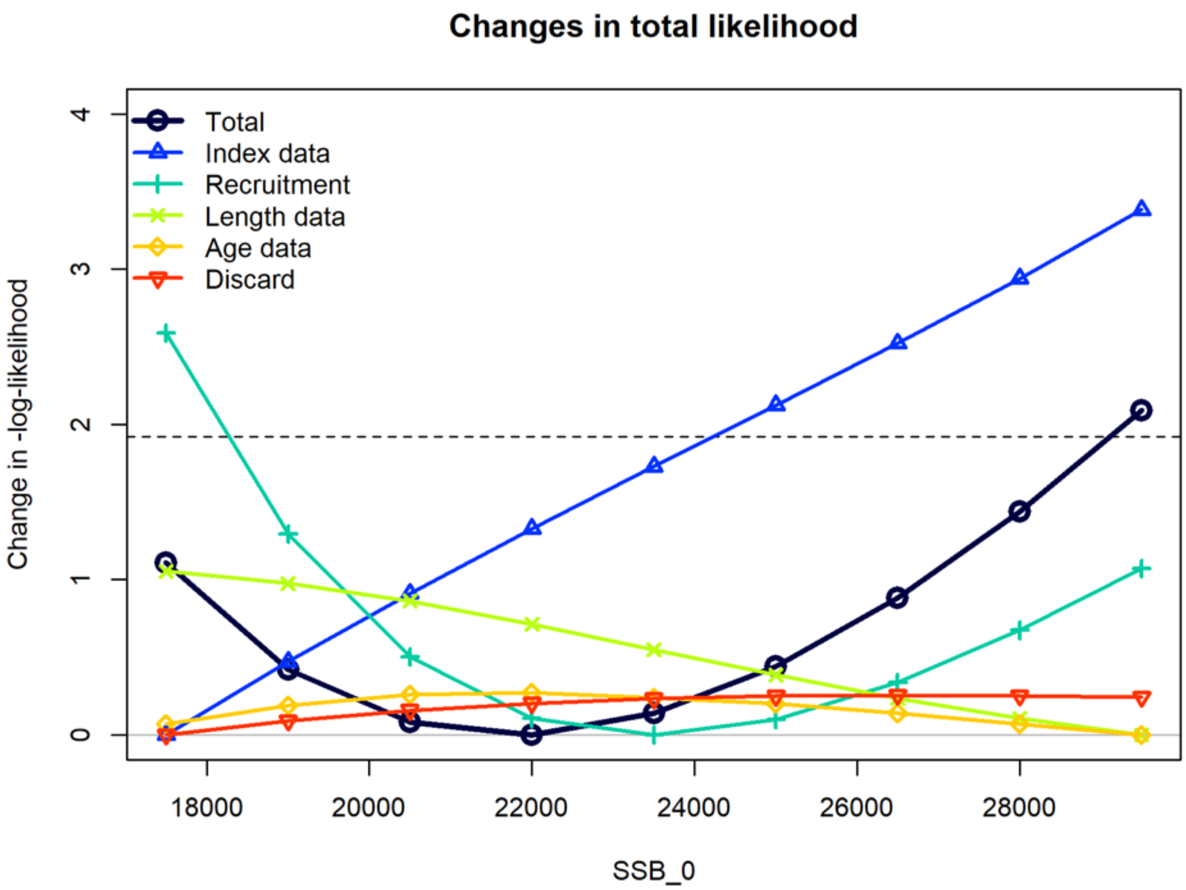


Figure 7.22. The likelihood profile for virgin spawning biomass, with SSB_0 ranging from 17,500 to 29,500 t. The estimated value for SSB_0 is 21,737 t.

A likelihood profile for virgin spawning biomass (SSB_0) is shown in Figure 7.22 with the total likelihood shown in black and components of the total likelihood from different data sources shown in a range of colours. SSB_0 is a derived parameter which is linked to the estimated parameter R_0, which is the average equilibrium recruitment. To construct a likelihood profile on SSB_0 requires setting up an additional “fleet” with a single data point (in 1915) with very low standard error, essentially adding a “highly precise survey” of spawning biomass, setting the selectivity type to 30 (an index of *SSB*) and then allowing this spawning biomass value to vary between runs. This likelihood profile suggests a broad range of plausible values for SSB_0 ranging between around 15,000 and 29,000 t with the most likely value at around 22,000 t.

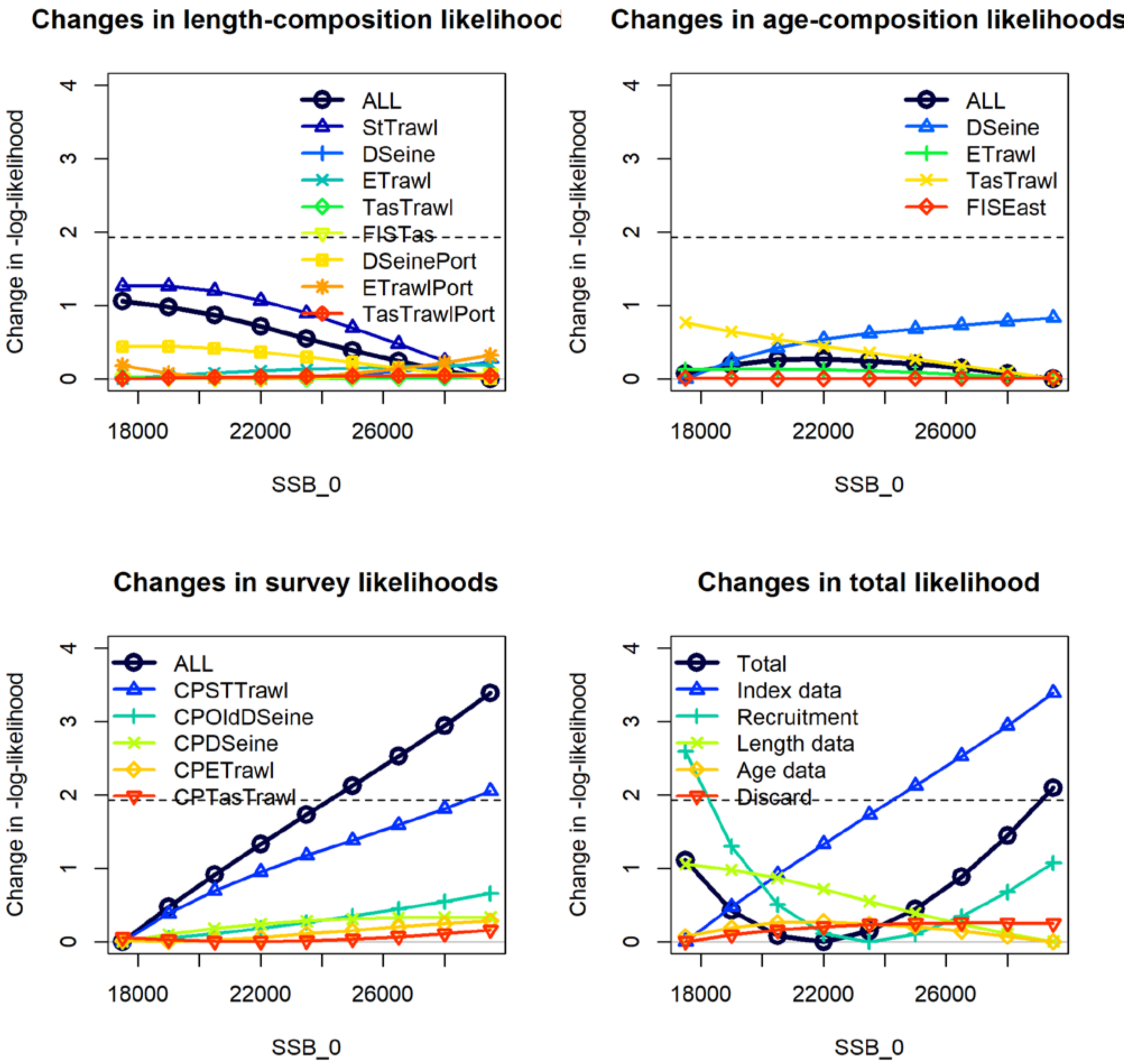


Figure 7.23. Piner plot for the likelihood profile for virgin spawning biomass, showing components of the change in likelihood for length, age and indices (CPUE) in addition to the changes in the total likelihood.

The important data sources in providing information on SSB_0 are the index data and recruitment deviations (Figure 7.22). SSB_0 needs to be sufficiently high to enable the historical catches to be sustained, so this results in the recruitment component of the likelihood providing a lower bound on SSB_0. The fits to the index data deteriorate with larger values of SSB_0. Not surprisingly, the steam trawl CPUE data has the most influence on the index component of this likelihood (Figure 7.23).

7.4.2.4 *Current (2018) spawning biomass*

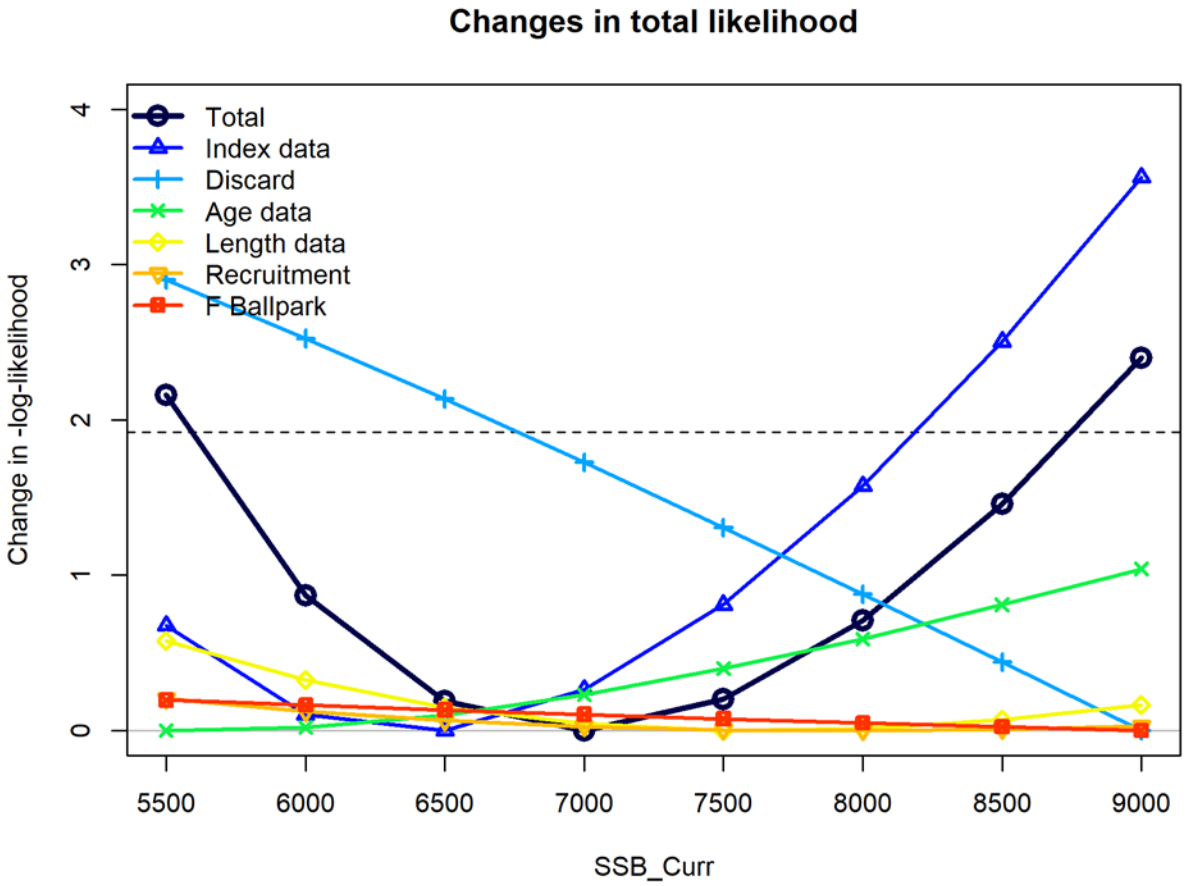


Figure 7.24. The likelihood profile for 2018 spawning biomass, ranging from about 5,500 to 8,750 t. The estimated value for 2018 spawning biomass is 6,970 t.

A likelihood profile for current spawning biomass (SSB_{2018}) is shown in Figure 7.24 with the total likelihood shown in black and components of the total likelihood from different data sources shown in a range of colours. Like SSB_0, SSB_{2018} is a derived parameter which is linked to the estimated parameter R_0, which is the average equilibrium recruitment. To construct a likelihood profile on SSB_{2018} requires setting up an additional "fleet" with a single data point (in 2018) with very low standard error, essentially adding a "highly precise survey" of spawning biomass, setting the selectivity type to 30 (an index of *SSB*) and then allowing this spawning biomass value to vary between runs. This likelihood profile suggests a broad range of plausible values for SSB_{2018} ranging between around 5,500 and 8,750 t with the most likely value at around 7,000 t.

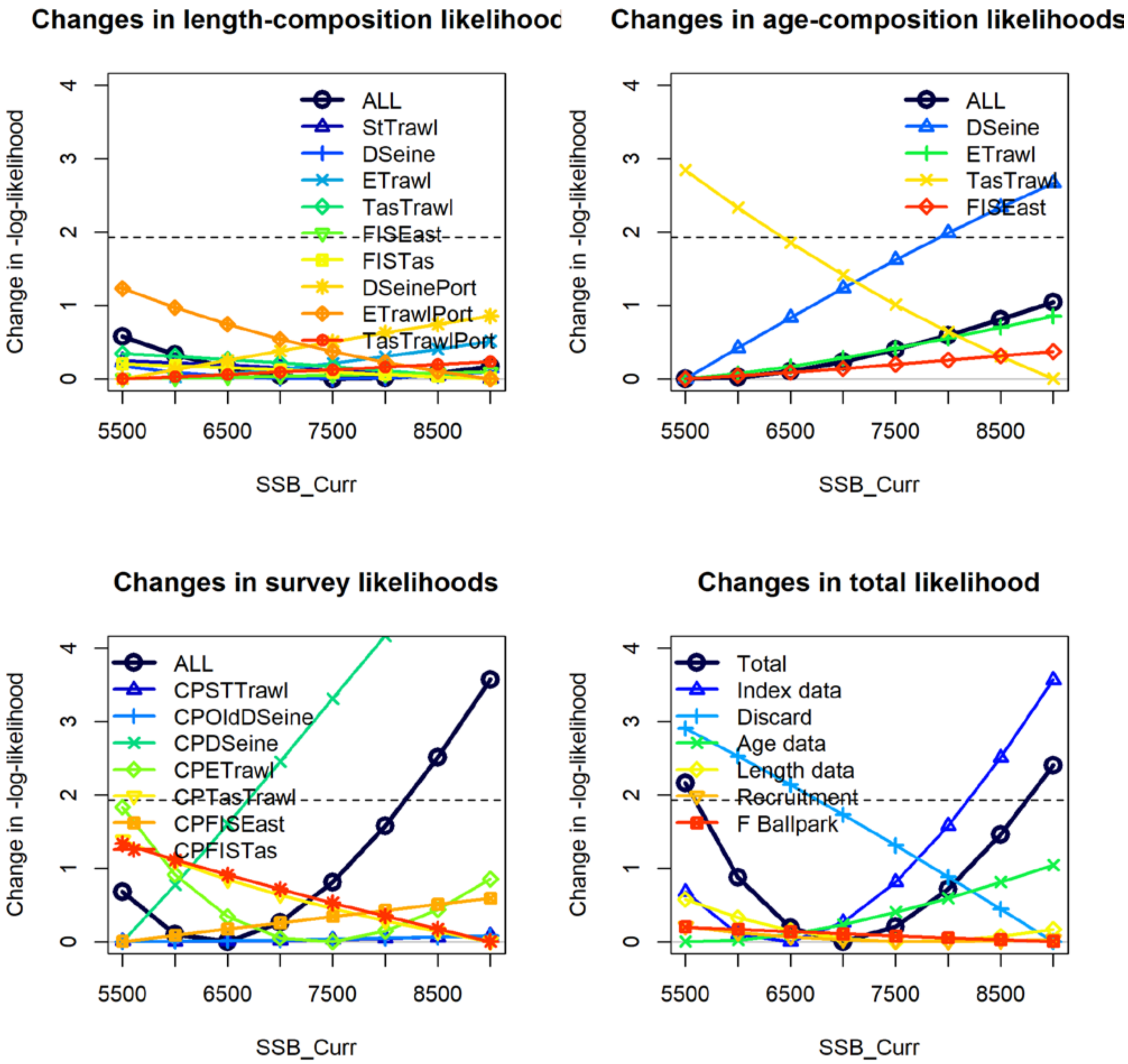


Figure 7.25. Piner plot for the likelihood profile for 2018 spawning biomass, showing components of the change in likelihood for length, age and indices (CPUE) in addition to the changes in the total likelihood.

The important data sources in providing information on SSB_{2018} are the index data and discard data (Figure 7.24). Within the index data, the Danish seine data appears to be in conflict with the other indices, supporting a lower SSB_{2018}, while the Tasmanian indices (both CPUE and FIS) support a higher value of SSB_{2018} (Figure 7.24). This same conflict between Danish seine and Tasmanian trawl data also appears in the age data (Figure 7.25).

7.4.2.5 Relative spawning biomass (depletion)

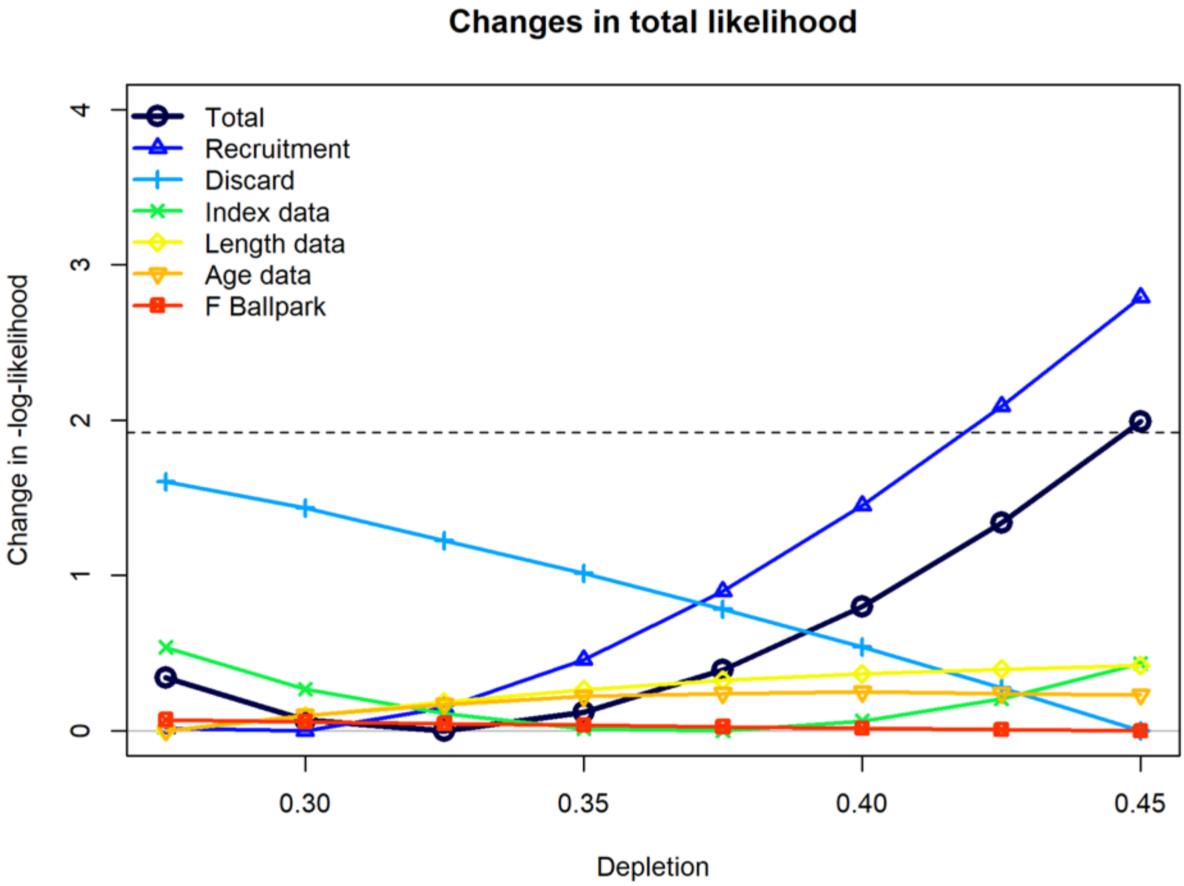


Figure 7.26. The likelihood profile for relative spawning stock biomass (depletion) in 2018, ranging from about 20% to 45%. The estimated value for depletion in 2018 is 32%.

A likelihood profile for current spawning biomass (SSB_{2018}) relative to SSB_0 is shown in Figure 7.26 with the total likelihood shown in black and components of the total likelihood from different data sources shown in a range of colours. Like SSB_0 and SSB_{2018} , relative spawning biomass is a derived parameter. To construct a likelihood profile on relative spawning biomassrequires setting up an additional "fleet" with a value of 1.0 in 1915 and an additional data point at the end of the series (2018), specifying a depletion level with a very low standard error, essentially adding a "highly precise survey" of depletion, setting the selectivity type to 34 (an index of *SSB*) and then allowing this relative spawning biomass value to vary between runs. This likelihood profile suggests a broad range of plausible values for depletion in 2018 ranging between around 20% and 45%, with the most likely value at around 32%. The model did not converge for values of depletion below 27.5%, but the minimum of the likelihood profile appears to be above this value. Recruitment and discard data have the most influence.

Ideally this likelihood profile would be produced for depletion at the start of 2020, as with the likelihood profile on current biomass (2020 rather than 2018). However, likelihood profiles can only be constructed on parameters that are associated with likelihood values (requiring actual data) and not projected values, so 2018 is the last year that a likelihood profile can be constructed, either for spawning biomass or depletion.

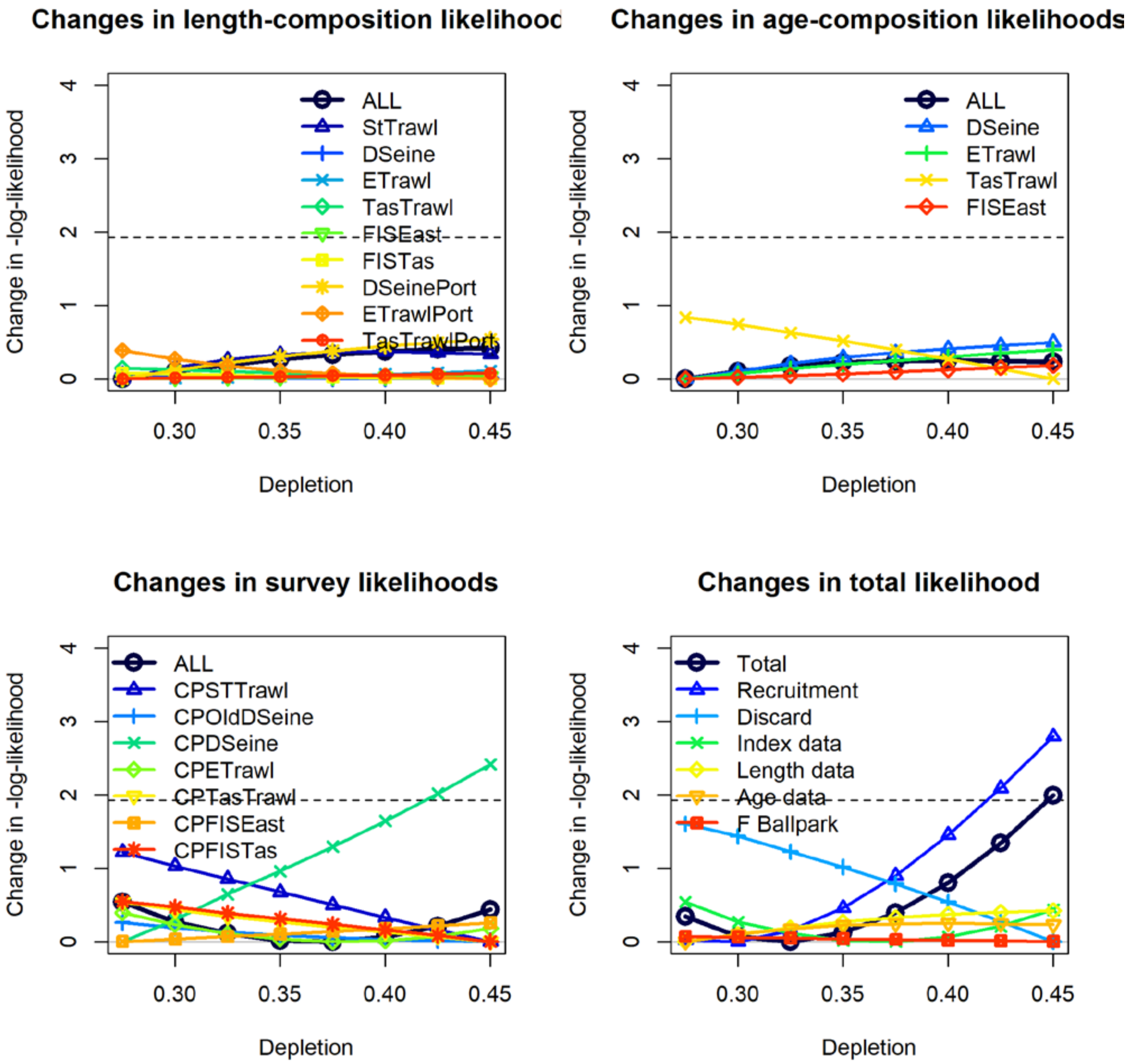


Figure 7.27. Piner plot for the likelihood profile for spawning stock biomass (depletion) in 2018, showing components of the change in likelihood for length, age and indices (CPUE) in addition to the changes in the total likelihood.

The important data sources in providing information on relative spawning stock biomass are the recruitment and discard data (Figure 7.26). While not very influential, within the index data, the modern Danish seine and steam trawl indices appear to be in conflict with each other (Figure 7.27).

7.4.3 *Retrospectives*

Preliminary retrospective analyses were presented at the October 2019 SERAG meeting (Day, 2019). These used an automated retrospective function in Stock Synthesis and r4ss. This automated procedure allows quick production of retrospective plots, but unfortunately has some problems where not all data is not correctly removed at each step of the process. These retrospective analyses were repeated

manually, and the corrected plots are included here, albeit with the old base case, using the incorrect (lower) catch series from 2001-2018.
The comparisons in these retrospective analyses with the old base case are not expected to show qualitative differences to updated comparisons with the corrected catch series. Retrospective analyses involve working backward in time and removing successive years of data from the assessment, starting from the most recent year of data. This analysis can highlight potential problems and instability in an assessment, or some features that appear from the data. While the qualitative nature of the initial retrospective analysis (Day, 2019) has not changed, some quantitative features have been corrected.

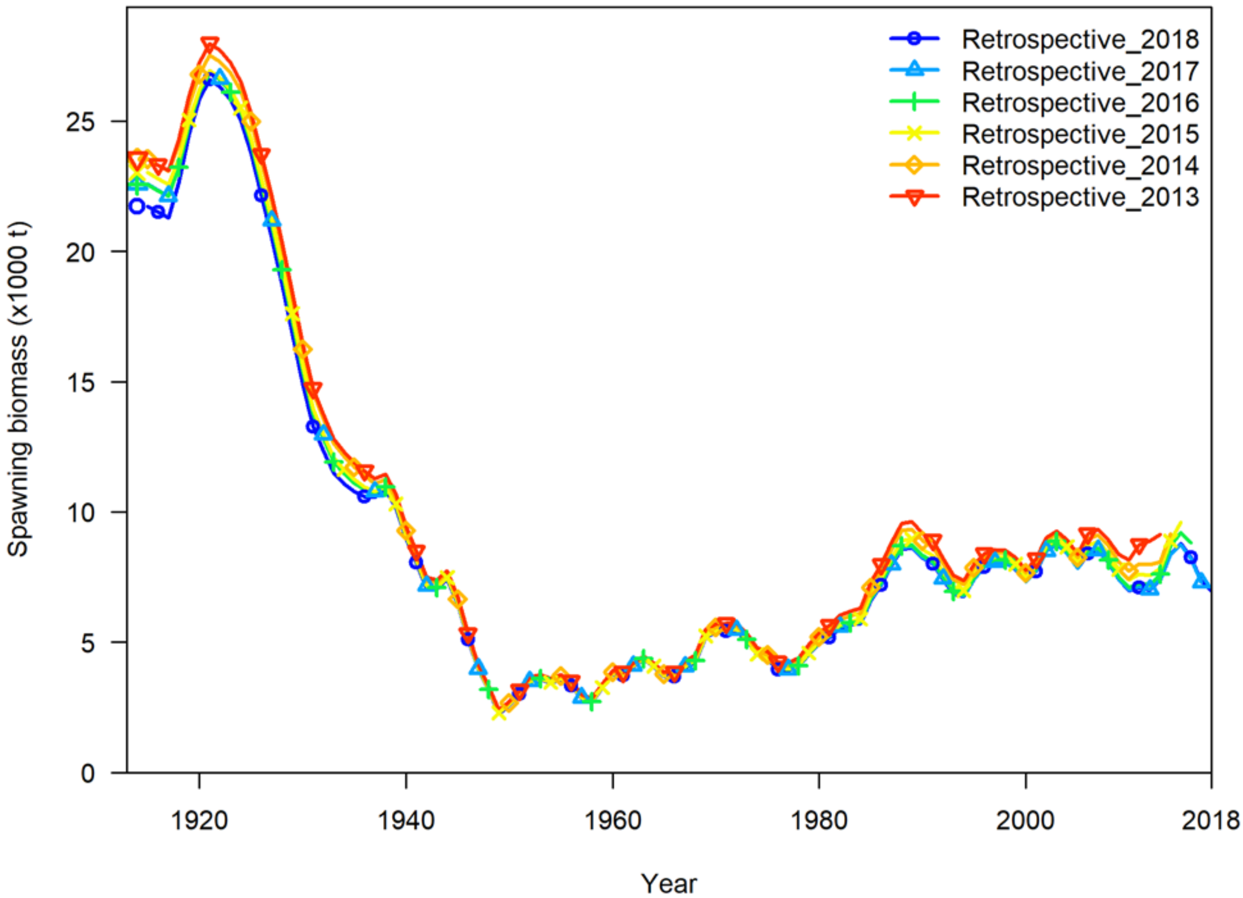


Figure 7.28. Retrospectives for absolute spawning biomass for tiger flathead, with data removed back to 2017 (light blue) and then successive years removed back to 2013 (red).

A retrospective analysis for absolute spawning biomass is shown in Figure 7.28, with the data after 2017 removed initially (shown in light blue), then successive years of data removed back to 2013 (shown in red). The same analysis is plotted in terms of relative spawning biomass in Figure 7.29. In both cases the changes are minor with the largest change at the end of the retrospectives deleting all data after 2013 (orange, minor change) and 2014 (red, slightly larger change), at the end of both time series. These show a slight downward revision of the relative spawning biomass in the period 2010-2015, as more years of additional data are added to the assessment. However, the effect is relatively small, and is only shown for these two retrospectives where a lot of data is removed.

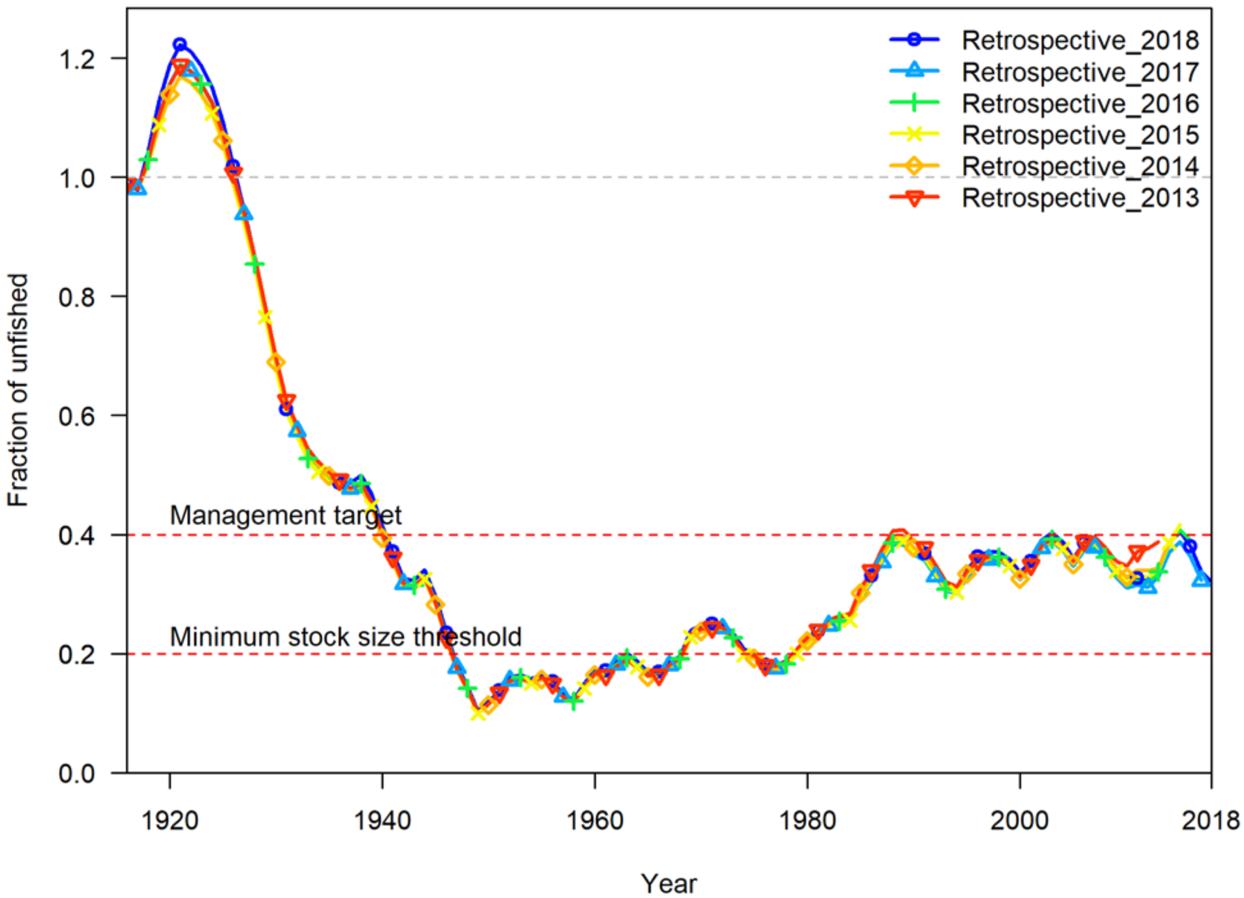


Figure 7.29. Retrospectives for relative spawning biomass for tiger flathead, with data removed back to 2017 (light blue) and then successive years removed back to 2013 (red).

When this retrospective analysis is applied to the recruitment time series (Figure 7.30), the more recent data results in a downward revision to the recruitment estimate in 2012. This recruitment is first estimated in the retrospective to 2015 (which corresponds to the data used in the 2016 assessment, shown in yellow), and this revision downwards is supported by data in 2016, 2017 and 2018. The first estimate of the 2013 recruitment is made in the 2016 retrospective (green) and is well below average. This estimate of 2013 recruitment is revised further downwards when data from 2017 and 2018 is added.

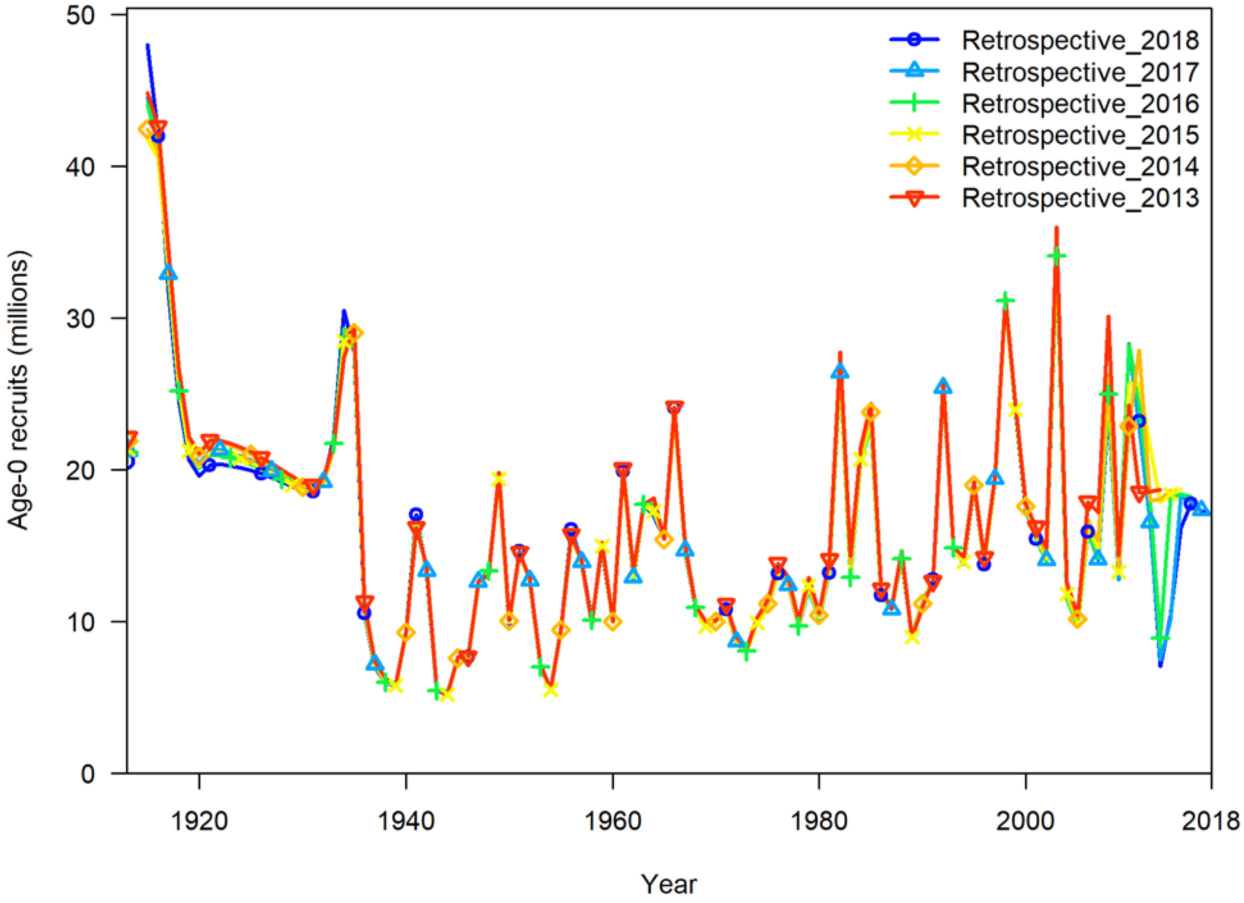


Figure 7.30. Retrospectives for relative spawning biomass for tiger flathead, with data removed back to 2017 (light blue) and then successive years removed back to 2013 (red).

An alternative presentation of the retrospective analysis applied to the recruitment time series is shown in a “squid plot” (Figure 7.31), which follows changes in the recruitment deviations for particular cohorts as the last five years of data is successively removed. Each coloured string corresponding to a cohort only includes a maximum of six points, one for the old base case and one for each retrospective. Each string can be followed from right to left as successive years of data are removed. The changes to the recruitment deviation estimate, as each year of data is removed, are measured by changes in the y-axis, with a negative value indicting a revision downwards and a positive value indicating a revision upwards, relative to the most recent estimate. For the cohorts spawned in years 2011-2015, the point on the far left of each string represents average recruitment, as this corresponds to a year when the recruitment deviation for this cohort can not be estimated. Hence the corresponding y-values, for these left most points for cohorts spawned in 2011-2015, represent the magnitude of the final recruitment deviation estimated in the old base case, with positive y-values corresponding to negative recruitment deviations (for the old base case using all data) and negative y-values corresponding to positive recruitment deviations. The variation along each string indicates how the recruitment deviation estimate changes as each year of successive data is added (moving to the right) or removed (moving to the left). Changes to estimates of deviations for the older birth years (e.g. 2005 and 2006) are smaller than more recent birth years, as there is little additional information on the size of these cohorts from data obtained in the period 2013-2018. These cohort birth years are largely flat on the right-hand side of this “squid plot”.

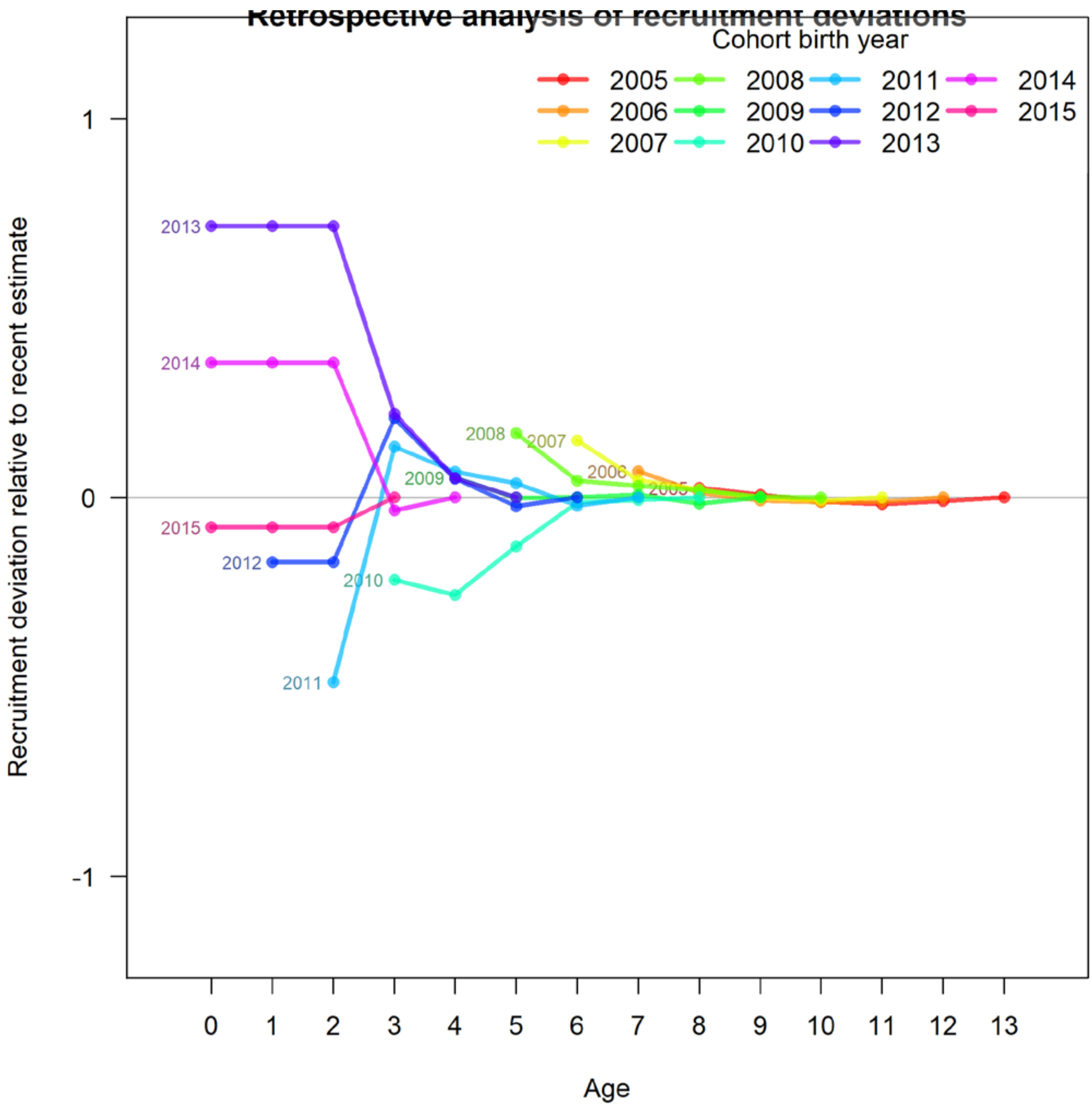


Figure 7.31. Retrospective analysis of recruitment deviations (squid plot) for tiger flathead, with data removed in successive years back to 2013.

Examples of pathological patterns in a squid plot would include a one-sided plot where all the adjustments to recent recruitment events were in the same direction (e.g. all positive or all negative), indicating a trend that may warrant further exploration and may indicate some model mis-specification. There is no indication of this here. The pattern seen in the cohort from 2013 indicates that the data in 2016, the first year that data informs this recruitment deviation, is the most influential (largest change in the y axis), and this poor recruitment is confirmed and estimated to be successively slightly worse as additional data from 2017 and 2018 is added (moving to the right on the x-axis).

These retrospective analyses do not reveal any pathological patterns or apparent biases in the estimates at the end of the time series due to the addition of new data, which provides additional confidence in the stability of this assessment.

7.4.4 *Alternative catch series and recruitment scenarios*

All alternative catch series analyses in this section were conducted before the catch series was updated from 2001-2018 (see Section 7.3.1.5), so is based on the incorrect (lower) catch series described earlier, which produced a depletion estimate of 33% at the start of 2020, compared to 34% with the revised catches. While the details may change marginally, the general principles and relative results are expected to remain largely unchanged with the corrected catch series.

7.4.4.1 Alternative fixed catch projections 2020-2022

With the change in estimated stock status, from 42% (Day, 2017) in the 2016 assessment to 34% in the 2019 assessment, SERAG requested a range of fixed catch three-year projections be run to examine the effect of stepping down the RBC from the values calculated in 2016 (2866 t) to the new RBC values calculated in 2019 for the old base case (that used the incorrect (lower) catch series). This enables the risk to the stock to be assessed if the RBC was to be exceeded during the years 2020-2022. The relative stock status is compared between these scenarios for each year between 2020 and 2023.

The values of the projected catches for each of the four catch scenarios for the period 2020-22, and the subsequent (calculated) 2023 RBC, are listed in Table 7.18, with fixed catches (those set differently to the RBC calculated from Stock Synthesis) indicated in bold. Scenario 1 is the old base case, with the "projected catch" equal to the calculated RBC values (assuming the calculated RBC is caught each year). Scenario 4 shows the catch under the 2016 three-year multi-year RBC, fixed for the period 2020-2022. Scenarios 2 and 3 show fixed intermediate catch values equally spaced between the catch in scenarios 1 and 4.

Table 7.18. Fixed catch projections for 2020-2022 and the RBC calculated for 2023 for the 2019 old base case and after applying projected catches for the three fixed catch scenarios.

Average	Fix Catch			
catch from: Year	1 base case 2019 RBC	2 fixed	3 fixed	4 fixed 2016 RBC
2019	2,426	2,426	2,426	2,426
2020	2,254	**2,458**	**2,662**	**2,866**
2021	2,616	**2,699**	**2,782**	**2,866**
2022	2,675	**2,738**	**2,802**	**2,866**
2023	2,724	2,677	2,629	2,511

The calculated stock status level at the beginning of each year from 2019-2023, assuming average recruitment, is shown in Table 7.19 and displayed in Figure 7.32, showing the relative stock status from 2010-2023.

Table 7.19. Calculated stock status for the 2019 old base case and after applying projected catches for 2020-2022 (under average recruitment) for the three fixed catch scenarios.

	Depletion (%)			
	1	2	3	4
catch from:	base case	fixed	fixed	fixed
Year	2019 RBC			2016 RBC
2019	32.4	32.4	32.4	32.4
2020	33.4	33.4	33.4	33.4
2021	35.1	34.6	34.2	33.7
2022	36.0	35.4	34.8	34.1
2023	36.7	36.0	35.3	34.6

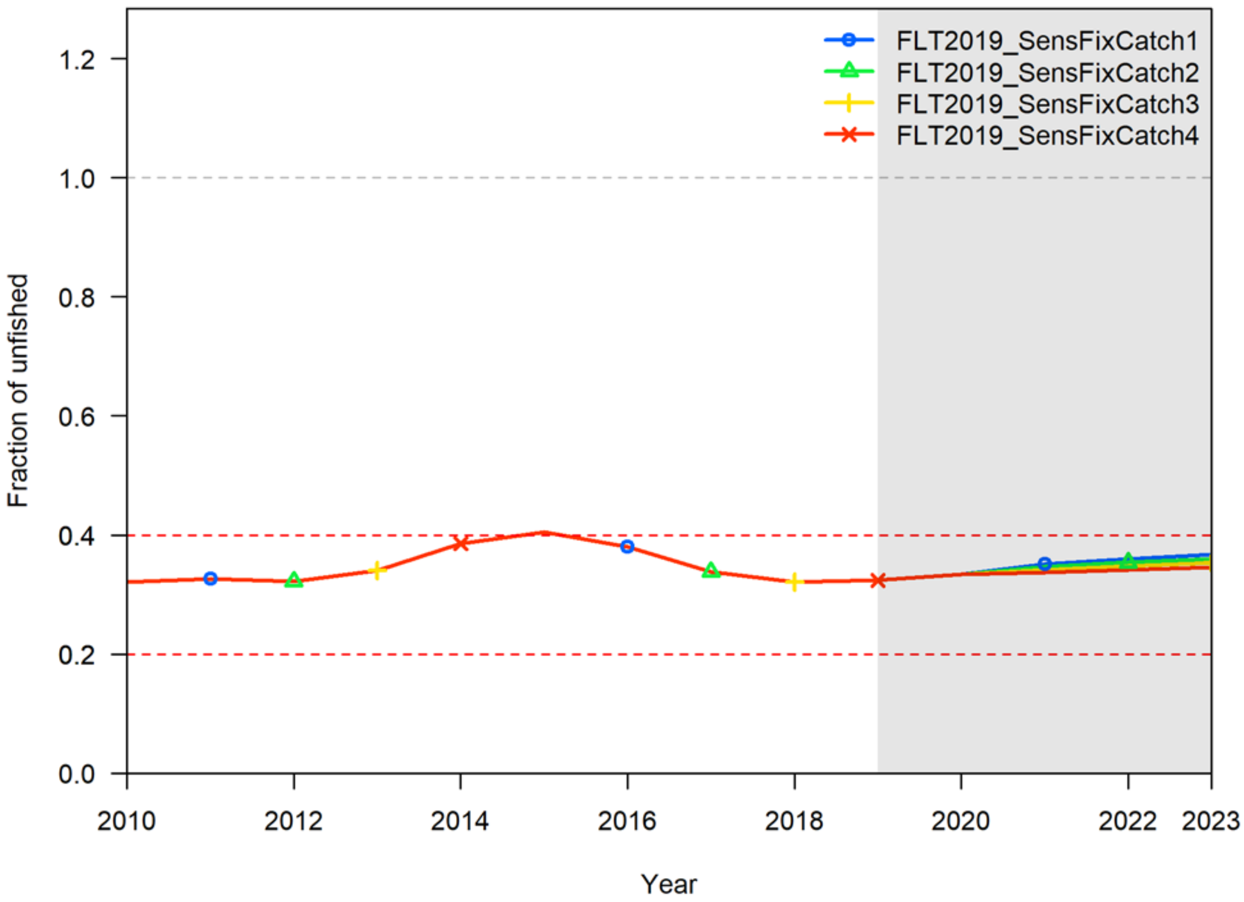


Figure 7.32. Relative spawning biomass (2010-2023) for the four fixed catch projections under average recruitment.

The 2023 stock status varies between 34.6% and 36.7% in these four scenarios.

7.4.4.2 Fixed catch projections 2020-2022 under a low recruitment scenario

Similar projections were also run for a low recruitment scenario, for the old base case, using the incorrect (lower) catch series, where recruitment deviations were fixed for the seven-year period from 2016-2022. This covers the period where recruitment is not estimated by the model and where standard projections involve average recruitment, taken directly from the stock recruitment curve. The recruitment deviations used were the 25th percentile of the recruitment deviations estimated between 1945 and 2015, a period where recruitment is considered to be well estimated. The value used for the 25th percentile (low recruitment) is -0.223.

The values of the projected catches for each of the four catch scenarios for the period 2020-22, run for the low recruitment scenario, and the subsequent (calculated) 2023 RBC, are listed in Table 7.20, with fixed catches (those set differently to the RBC calculated from Stock Synthesis) indicated in bold. Scenario 1 is the old base case, using the incorrect (lower) catch series, with the “projected catch” equal to the calculated RBC values (assuming the calculated RBC is caught each year). Scenario 2 is a mismatch where the RBC is calculated every year (expecting average recruitment into the future), but with poor recruitment every year during this projected period. Scenario 3 has the (retained) catches fixed by the RBC from the 2019 old base case, under poor recruitment. Scenario 4 has the (retained) catches fixed by the RBC from the 2016 three-year multi-year RBC for the period 2020-2022, under poor recruitment.

Table 7.20. Fixed catch projections for 2020-2022 and the RBC calculated for 2023 after applying these projected catches for the four fixed catch scenarios for the low recruitment scenario.

Low	Fix Catch			
	1	2	3	4
catch from:	base case	mismatch	fixed	fixed
Year	2019 RBC	RBC (low)	2019 RBC	2016 RBC
2019	2,426	2,405	2,426	2,426
2020	2,254	1,731	**2,254**	**2,866**
2021	2,616	1,963	**2,603**	**2,852**
2022	2,675	2,262	**2,651**	**2,839**
2023	2,724	2,523	1,817	1,403

The calculated stock status level at the beginning of each year from 2019-2023, assuming low recruitment for scenarios 2, 3 and 4, is shown in Table 7.21 and displayed in Figure 7.33, showing the relative stock status from 2010-2023.

Table 7.21. Calculated stock status following application of fixed catch projections for 2020-2022 (under low recruitment) for the four fixed catch scenarios under low recruitment.

Low	Depletion (%)			
	1	2	3	4
catch from:	base case	mismatch	fixed	fixed
Year	2019 RBC	RBC (low)	2019 RBC	2016 RBC
2019	32.4	31.4	31.4	31.4
2020	33.4	31.0	31.0	31.0
2021	35.1	32.2	30.9	29.6
2022	36.0	32.7	30.1	28.2
2023	36.7	32.5	29.2	27.0

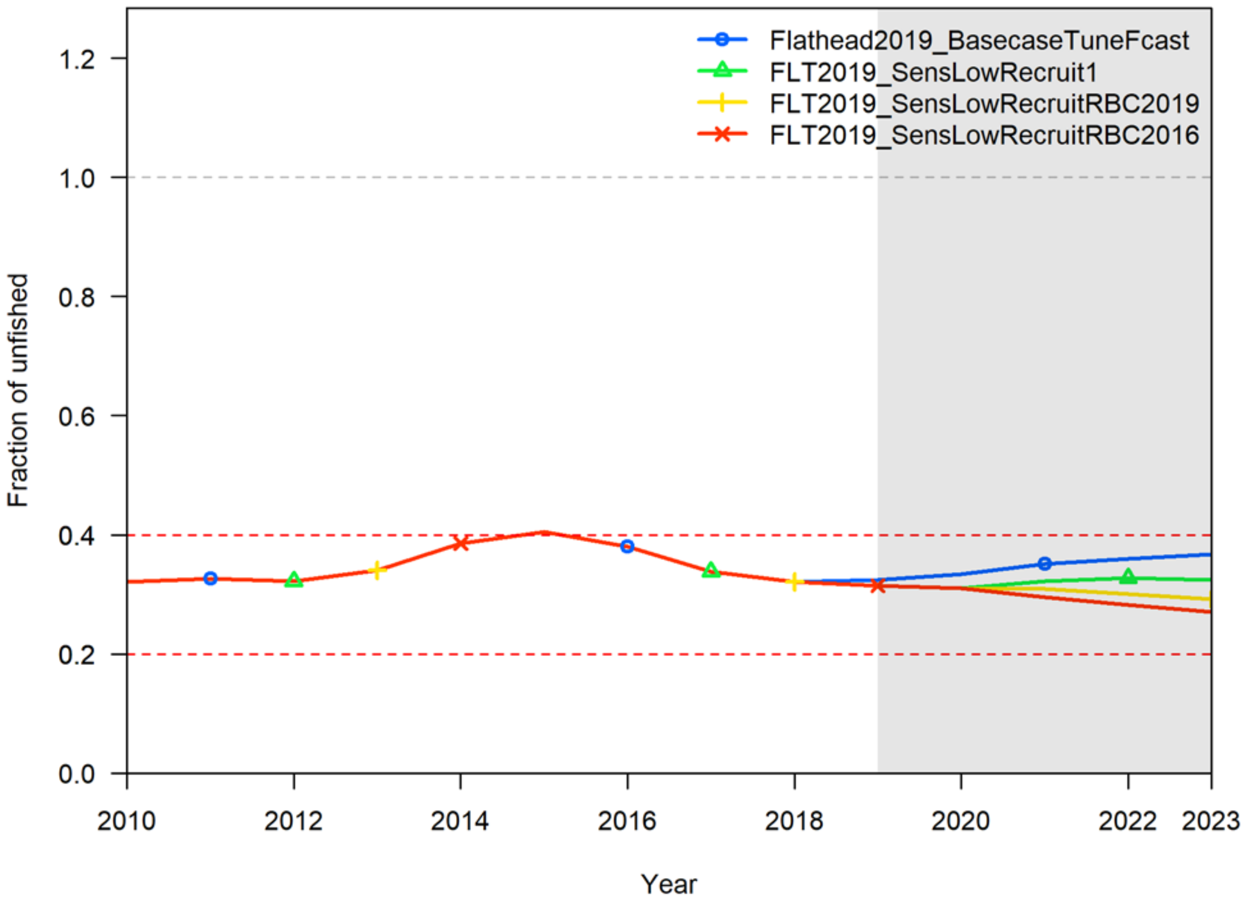


Figure 7.33. Relative spawning biomass (2010-2023) for the four fixed catch projections under low recruitment.

The results are shown in Figure 7.33, with the blue series (BasecaseTuneFcast) showing the projections applying the RBC calculated under average recruitment to dynamics under average recruitment (for the old base case, using the incorrect (lower) catch series). The other three series all show projections with the dynamics projected with poor recruitment from 2016 up until 2022, with a range of catch scenarios. The green series (SensLowRecruit1) shows the projections applying the RBC calculated with this low recruitment, where the calculation of each RBC point is made with the expectation that future recruitment will return to average. The yellow series (SensLowRecruit1RBC2019) shows the projections using the catch calculated under the RBC from the 2019 old base case (assuming average recruitment). The red series (SensLowRecruit1RBC2016) shows the projections using the catch calculated under the RBC from the 2016 assessment, continued on for an additional 3 years.

The 2023 stock status varies between 27.0% and 32.5% in these three low recruitment scenarios.

7.4.4.3 Fixed catch projections 2020-2022 under a high recruitment scenario

Similar projections were also run for a high recruitment scenario, for the old base case, using the incorrect (lower) catch series, where recruitment deviations were fixed for the seven-year period from 2016-2022. This covers the period where recruitment is not estimated by the model and where standard projections involve average recruitment, taken directly from the stock recruitment curve. The recruitment deviations used were the 75th percentiles of the recruitment deviations estimated between

1945 and 2015, a period where recruitment is considered to be well estimated. The value used for the 75th percentile (high recruitment) is 0.292.

The values of the projected catches for each of the four catch scenarios for the period 2020-22, run for the high recruitment scenario, and the subsequent (calculated) 2023 RBC, are listed in Table 7.22, with fixed catches (those set differently to the RBC calculated from Stock Synthesis) indicated in bold. Scenario 1 is the old base case, using the incorrect (lower) catch series, with the "projected catch" equal to the calculated RBC values (assuming the calculated RBC is caught each year). Scenario 2 is a mismatch where the RBC is calculated every year (expecting average recruitment into the future), but with good recruitment every year during this projected period. Scenario 3 has the (retained) catches fixed by the RBC from the 2019 old base case, under good recruitment. Scenario 4 has the (retained) catches fixed by the RBC from the 2016 three-year multi-year RBC for the period 2020-2022, under good recruitment.

Table 7.22. Fixed catch projections for 2020-2022 and the RBC calculated for 2023 after applying these projected catches for the four fixed catch scenarios.

High	Fix Catch			
	1	2	3	4
catch from:	base case	mismatch	fixed	fixed
Year	2019 RBC	RBC (high)	2019 RBC	2016 RBC
2019	2,426	2,459	2,426	2,426
2020	2,254	2,834	**2,255**	**2,867**
2021	2,616	3,057	**2,631**	**2,883**
2022	2,675	3,157	**2,704**	**2,898**
2023	2,724	3,168	3,377	3,232

The calculated stock status level at the beginning of each year from 2019-2023, assuming high recruitment for scenarios 2, 3 and 4, is shown in Table 7.23 and displayed in Figure 7.34, showing the relative stock status from 2010-2023.

Table 7.23. Calculated stock status following application of fixed catch projections for 2020-2022 (under average recruitment) for the four fixed catch scenarios.

High	Depletion (%)			
	1	2	3	4
catch from:	base case	mismatch	fixed	fixed
Year	2019 RBC	RBC (high)	2019 RBC	2016 RBC
2019	32.4	33.9	33.9	33.9
2020	33.4	37.4	37.5	37.5
2021	35.1	40.8	42.2	40.8
2022	36.0	43.8	46.1	44.2
2023	36.7	46.6	49.8	47.5

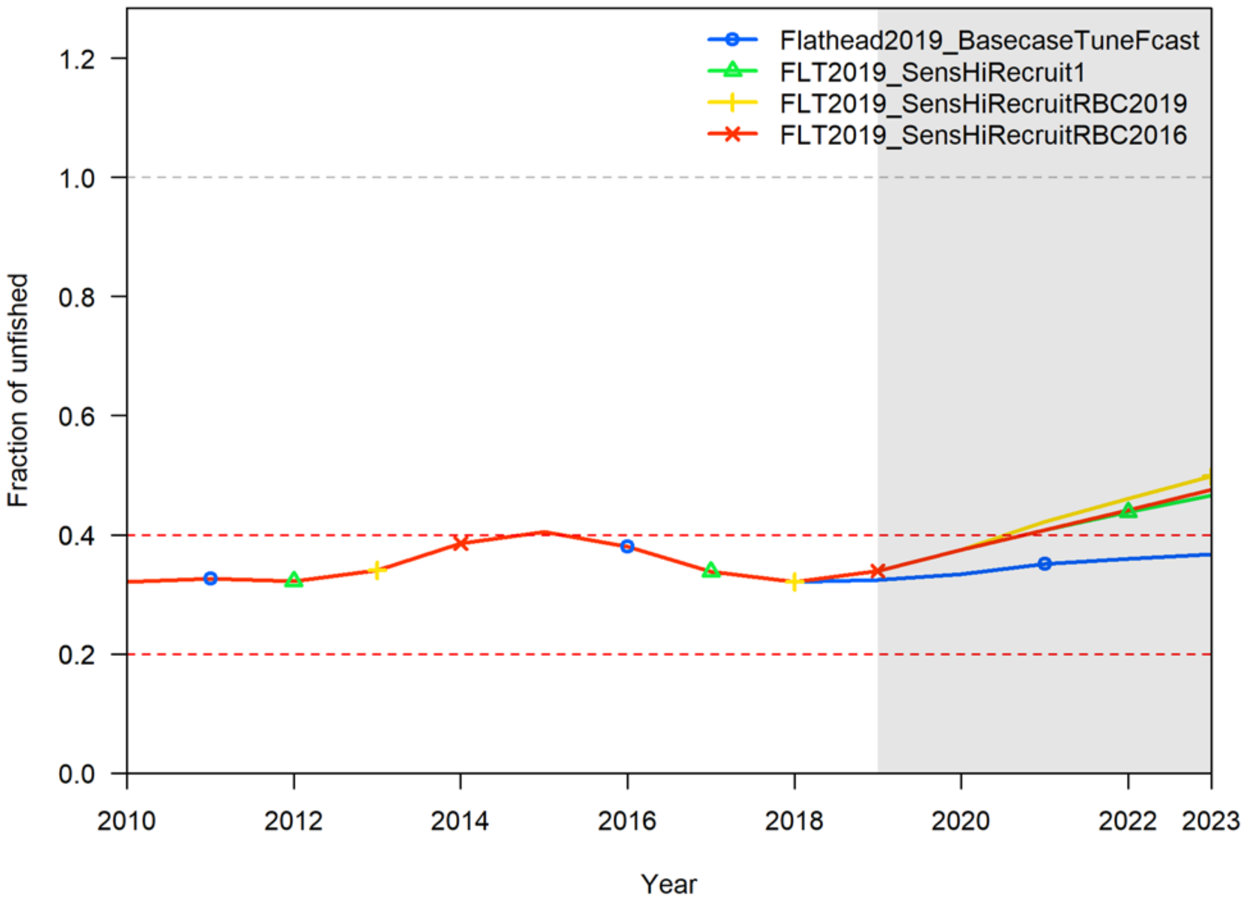


Figure 7.34. Relative spawning biomass (2010-2023) for the four fixed catch projections under high recruitment.

The results are shown in Figure 7.34, with the blue series (BasecaseTuneFcast) showing the projections applying the RBC calculated under average recruitment to dynamics under average recruitment (the old base case, using the incorrect (lower) catch series). The other three series all show projections with the dynamics projected with poor recruitment from 2016 up until 2022, with a range of catch scenarios. The green series (SensHiRecruit1) shows the projections applying the RBC calculated with this low recruitment, where the calculation of each RBC point is made with the expectation that future recruitment will return to average. The yellow series (SensHiRecruit1RBC2019) shows the projections using the catch calculated under the RBC from the 2019 old base case (assuming average recruitment). The red series (SensHiRecruit1RBC2016) shows the projections using the catch calculated under the RBC from the 2016 assessment, continued on for an additional 3 years.

The 2023 stock status varies between 46.6% and 49.8% in these three high recruitment scenarios.

7.4.4.4 Fixed catch projections using the average RBC for 2020-2022

Fixed catch projections for the old base case using a constant RBC for the period 2020-2022, set to the mean of the calculated RBC from the same period 2020-2022, were explored, with the values of these fixed and calculated catches listed in Table 7.24. This enables a comparison of the stock status obtained by setting the RBC annually compared to setting the RBC to a 3 year fixed value, and these results are shown in Table 7.25. The difference in stock status is small, ranging from 0.6% to 0.1% from 2021-2023.

Table 7.24. Fixed catch projections for 2020-2022 and the RBC calculated for 2023 after applying these projected catches for the four fixed catch scenarios.

	Fix Catch	
Year	2019 RBC	3 yr avg
2020	2,254	2,515
2021	2,616	2,515
2022	2,675	2,515
2023	2,724	2,729

Table 7.25. Calculated stock status following application of fixed catch projections for 2020-2022 (under average recruitment) for the four fixed catch scenarios.

	Depletion (%)	
Year	2019 RBC	3 yr avg
2020	33.4	33.4
2021	35.1	34.5
2022	36.0	35.7
2023	36.7	36.8

7.4.5 *Sensitivity tests and alternative models*

Results of the sensitivity tests are shown in Table 7.26. These sensitivities were conducted relative to the old base case, using the incorrect (lower) catch series (see Section 7.3.1.5). The results are very sensitive to the assumed value for natural mortality (M). Much of this variability is due to the estimated current depletion level, which can be as low as 27% SSB_0 when M is 0.22. For all other standard sensitivities, there is less variability in current depletion.

Unweighted likelihood components for the old base case and differences for the sensitivities reveal several points (Table 7.27). The overall likelihood is not improved for a smaller value of M, in contrast to the results from Day and Klaer (2013), but in line with the most recent assessment (Day, 2016) and earlier results in Klaer (2010). Steepness and M are highly correlated, and it is normally not possible to estimate both of these parameters. The base case is essentially uninformative about the value of M, which needs to be sourced independently of the stock assessment if steepness is estimated, but these results suggests that the fixed value of M should not be reduced.

In contrast to the 2016 assessment, a few sensitivities show an overall improvement to the fit, notably when M is fixed at 0.32, for lower values of σ_R, outside the period where the bias ramp is estimated, and when M is estimated and h fixed. Note that likelihood profiles suggest that neither M nor h should be estimated in future assessments.

Exploration of model sensitivity showed a variation in spawning biomass from 27% to 41% of SSB_0 when natural mortality was fixed at values of 0.22 and 0.32 respectively. When recruitment is first estimated in 1925, to avoid possible spurious large estimates of recruitment early in the series, supported only by improved fits to the steam trawl CPUE, the spawning biomass was also estimated to be 27% of SSB_0. When M is estimated and h fixed, the spawning biomass was also estimated to be 41% of SSB_0. For all other sensitivities explored, the variation in spawning biomass was much narrower, ranging between 32% and 37%.

For the old base case (20:35:40 Harvest Control Rule with recruitment estimated to 2015), SSB_{MSY} is estimated to be 27% of SSB_0. If the standard MEY proxy multiplier of 1.2 is applied to this MSY estimate, the SSB_{MEY} estimate for the old base case is 32% of SSB_0. This proxy for SSB_{MEY} is rounded up to 40% of SSB_0 by agreement at SESSFRAG, with a 20:35:40 Harvest Control Rule used for tiger flathead.

7.4.6 *Future work*

7.4.6.1 Danish seine mesh size

The Danish seine fleet has made changes to the mesh size used for the flathead gear in recent years, with a transition to a slightly larger mesh size. While there is little evidence in the length frequency data to suggest a large change to selectivity as a result, it would be possible to use a time block with a transitional period and examine the resulting selectivity. The impact of such a change on both the selectivity and the spawning biomass could be explored in a future assessment. Given that the Danish seine length frequency distributions do not seem to have changed yet, it would be surprising if this produced very different results. It may be worth closely examining Danish seine length frequency data in future years to look for evidence of a change in size distribution for this fleet.

7.4.6.2 Tasmanian trawl growth parameters

In 2006, Shelf RAG selected the model that treated Tasmanian trawl as a separate fishing fleet fishing the same east coast stock as the most appropriate base case. It appears that growth may differ for the fish caught by the Tasmanian trawl and the Tasmanian FIS fleets, so the single stock assumption for this model could be revisited in future. Options to consider include modelling the Tasmanian stock as a separate stock, estimating growth independently for the Tasmanian stock and excluding the Tasmanian data from the assessment.

7.4.6.3 Historical length frequencies

Some historical length frequencies from the 2013 assessment appear to have been lost due to changes to the database or the data processing. These distributions were included in this assessment, by using the same data used in 2013. This issue needs to be investigated to make sure the original data is not lost and that the most appropriate data is used in future assessments.

7.4.6.4 Steam trawl length frequencies

Length frequency data from the steam trawl fleet in the 1950s includes two sources of data which overlap for the period 1953-1955. Fits to the Sydney Fish Market data (1953-1958) are not as good as the fits to the Blackburn data (1945-1955), but there is some conflict between the data from these two sources. These data sources could potentially be treated differently to improve these fits to the steam trawl fleet.

7.4.6.5 Fix the value for steepness

Steepness is not estimated very precisely in this assessment, as demonstrated in the likelihood profile on steepness, with a wide range of values for steepness unable to be distinguished by the data. It is recommended that steepness is fixed at 0.75 in future tiger flathead stock assessments. This default value for steepness of 0.75 is a value chosen for many species where steepness is not known and cannot be estimated.

Table 7.26. Summary of results for the old base case (using the incorrect (lower) catch series) and sensitivity tests to this old base case. Recommended biological catches (RBCs) are only shown for the old base case.

Case		SSB_0	SSB_{2020}	SSB_{2020}/SSB_0	Steepness	SSB_{MSY}/SSB_0	RBC_{2020}	RBC_{2020-2}	RBC_{2020-4}	$RBC_{longterm}$
0	base case 20:35:40 *M* 0.27	21,737	7,260	0.33	0.72	0.27	2,254	2,515	2,607	2,959
1	*M* 0.22	21,580	5,838	0.27	0.86	0.22				
2	*M* 0.32	22,991	9,332	0.41	0.61	0.31				
3	50% maturity at 27cm	22,900	7,861	0.34	0.70	0.28				
4	50% maturity at 33cm	20,156	6,467	0.32	0.75	0.25				
5	$\sigma_R = 0.4$	22,096	7,227	0.33	0.63	0.30				
6	$\sigma_R = 0.6$	22,102	7,227	0.33	0.68	0.28				
7	$\sigma_R = 0.8$	21,335	7,314	0.34	0.78	0.24				
8	first recruit est. in 1925	27,406	7,346	0.27	0.59	0.32				
9	estimate *M* (0.30), *h* 0.75	20,053	8,298	0.41	0.75	0.25				
10	fix *M* 0.27, fix *h* 0.75	21,081	7,244	0.34	0.75	0.26				
11	fix *M* 0.27, fix *h* 0.65	24,091	8,370	0.35	0.65	0.30				
12	fix *M* 0.27, fix *h* 0.85	19,201	7,159	0.37	0.85	0.21				
13	wt x 2 length comp	22,754	7,465	0.33	0.69	0.28				
14	wt x 0.5 length comp	21,051	7,123	0.34	0.75	0.26				
15	wt x 2 age comp	21,731	7,159	0.33	0.72	0.27				
16	wt x 0.5 age comp	21,729	7,368	0.34	0.73	0.27				
17	wt x 2 CPUE	19,707	6,934	0.35	0.79	0.24				
18	wt x 0.5 CPUE	22,916	7,911	0.35	0.69	0.28				

Table 7.27. Summary of likelihood components for the old base case (using the incorrect (lower) catch series) and sensitivity tests to this old base case. Likelihood components are unweighted, and cases 1-18 are shown as differences from the old base case. A negative value indicates a better fit, a positive value a worse fit.

Case		Likelihood TOTAL	Survey	Discard	Length comp	Age comp	Recruitment	Parm_priors
0	base case 20:35:40 *M* 0.27	1621.52	-160.81	54.58	499.01	1231.62	-3.54	0.00
1	*M* 0.22	3.90	4.92	-0.93	1.45	-0.48	-1.27	0.00
2	*M* 0.32	-3.75	-4.47	0.73	-1.44	0.33	1.31	0.00
3	50% maturity at 27cm	-0.05	0.05	0.00	-0.02	0.00	-0.08	0.00
4	50% maturity at 33cm	0.06	-0.06	0.00	0.02	0.00	0.10	0.00
5	$\sigma_R = 0.4$	-5.58	10.15	-0.59	3.89	0.37	-19.39	0.00
6	$\sigma_R = 0.6$	-3.03	2.16	-0.14	0.80	-0.01	-5.83	0.00
7	$\sigma_R = 0.8$	3.50	-1.56	0.12	-0.60	0.05	5.49	0.00
8	first recruit est. in 1925	2.21	2.52	0.11	-0.24	0.08	-0.25	0.00
9	estimate *M* (0.30), *h* 0.75	-2.06	-3.14	0.38	-0.77	0.20	1.39	0.00
10	fix *M* 0.27, fix *h* 0.75	0.02	-0.14	-0.02	0.06	0.01	0.10	0.00
11	fix *M* 0.27, fix *h* 0.65	0.24	0.49	0.04	-0.25	-0.11	0.07	0.00
12	fix *M* 0.27, fix *h* 0.85	0.37	-0.55	-0.09	0.18	-0.01	0.84	0.00
13	wt x 2 length comp	5.23	6.22	4.29	-11.62	4.68	1.63	0.00
14	wt x 0.5 length comp	3.31	-2.80	-2.38	11.69	-1.98	-1.20	0.00
15	wt x 2 age comp	3.59	7.62	0.03	4.18	-8.46	0.17	0.00
16	wt x 0.5 age comp	3.09	-5.03	-0.29	-2.29	10.70	0.04	0.00
17	wt x 2 CPUE	8.69	-19.59	6.11	7.10	9.63	5.42	0.00
18	wt x 0.5 CPUE	6.67	22.67	-4.69	-3.25	-4.29	-3.74	0.00

7.5 Acknowledgements

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7.7 Appendix A

A.1 Data source summary and fits to length composition data

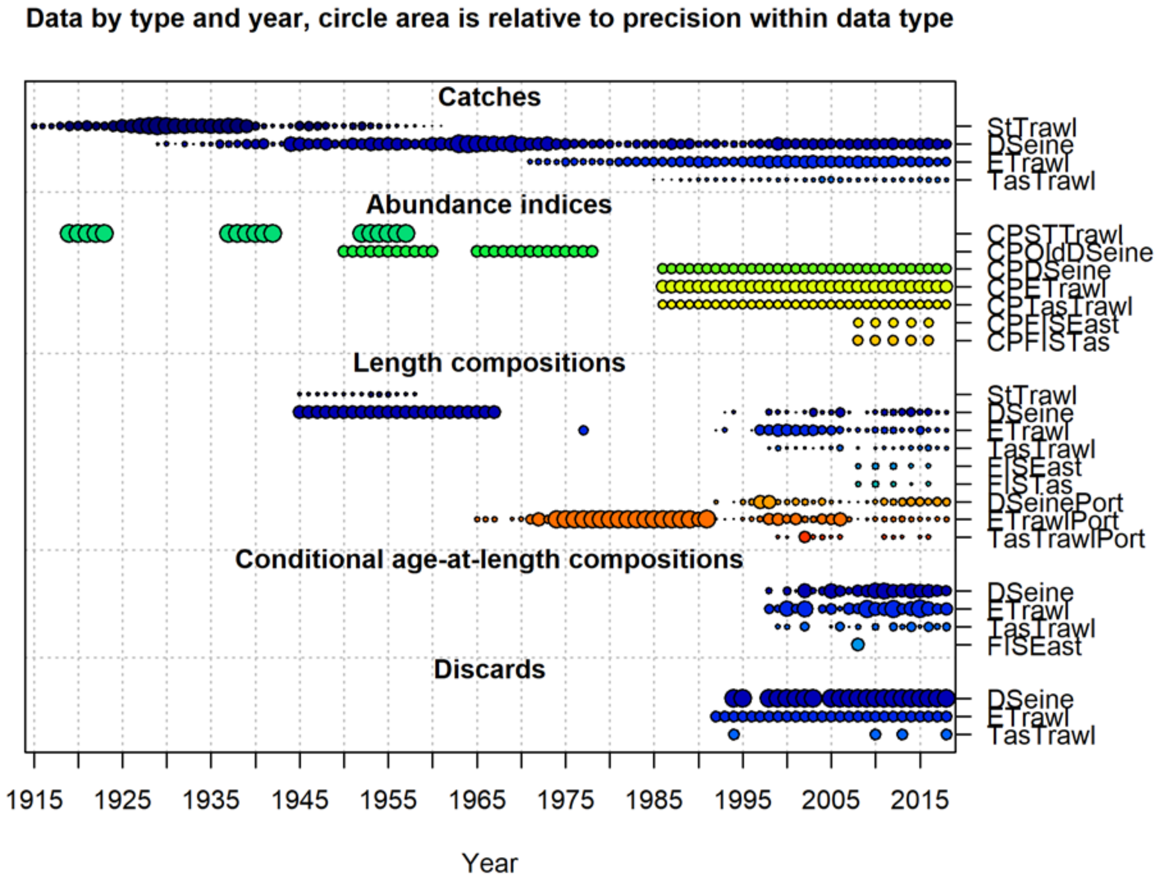

Figure A 7.1. Summary of data sources for tiger flathead stock assessment.

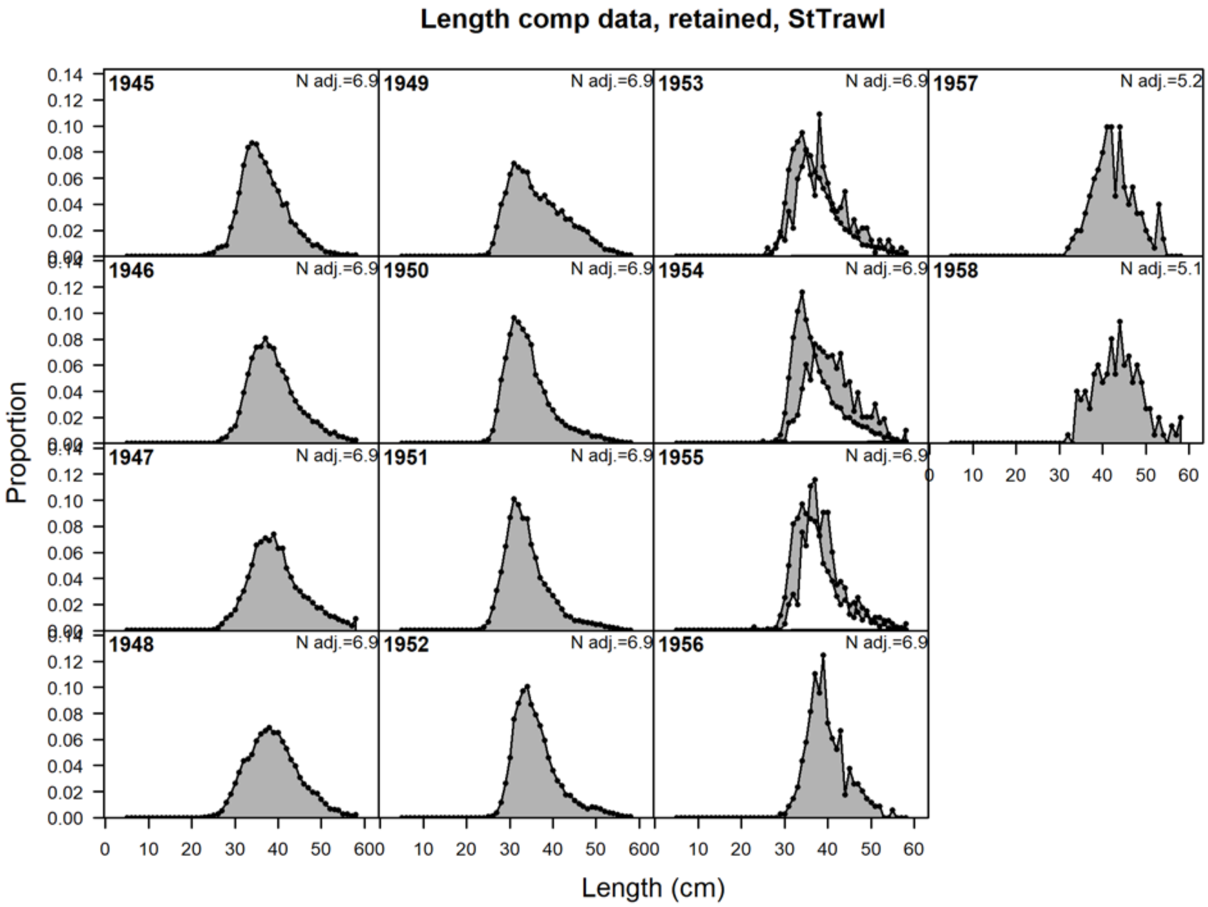

Figure A 7.2. Tiger flathead length composition fits: steam trawl retained.

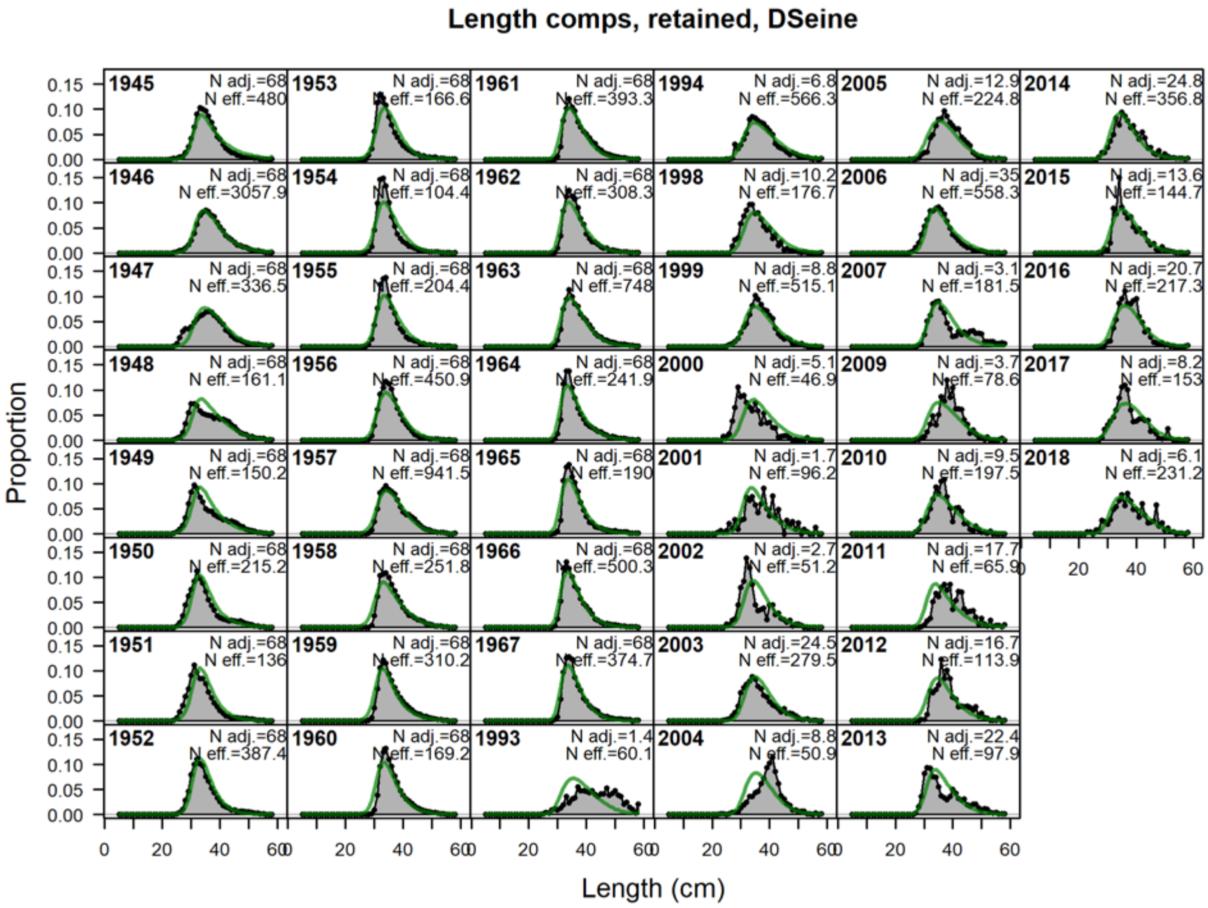

Figure A 7.3. Tiger flathead length composition fits: Danish seine retained onboard.

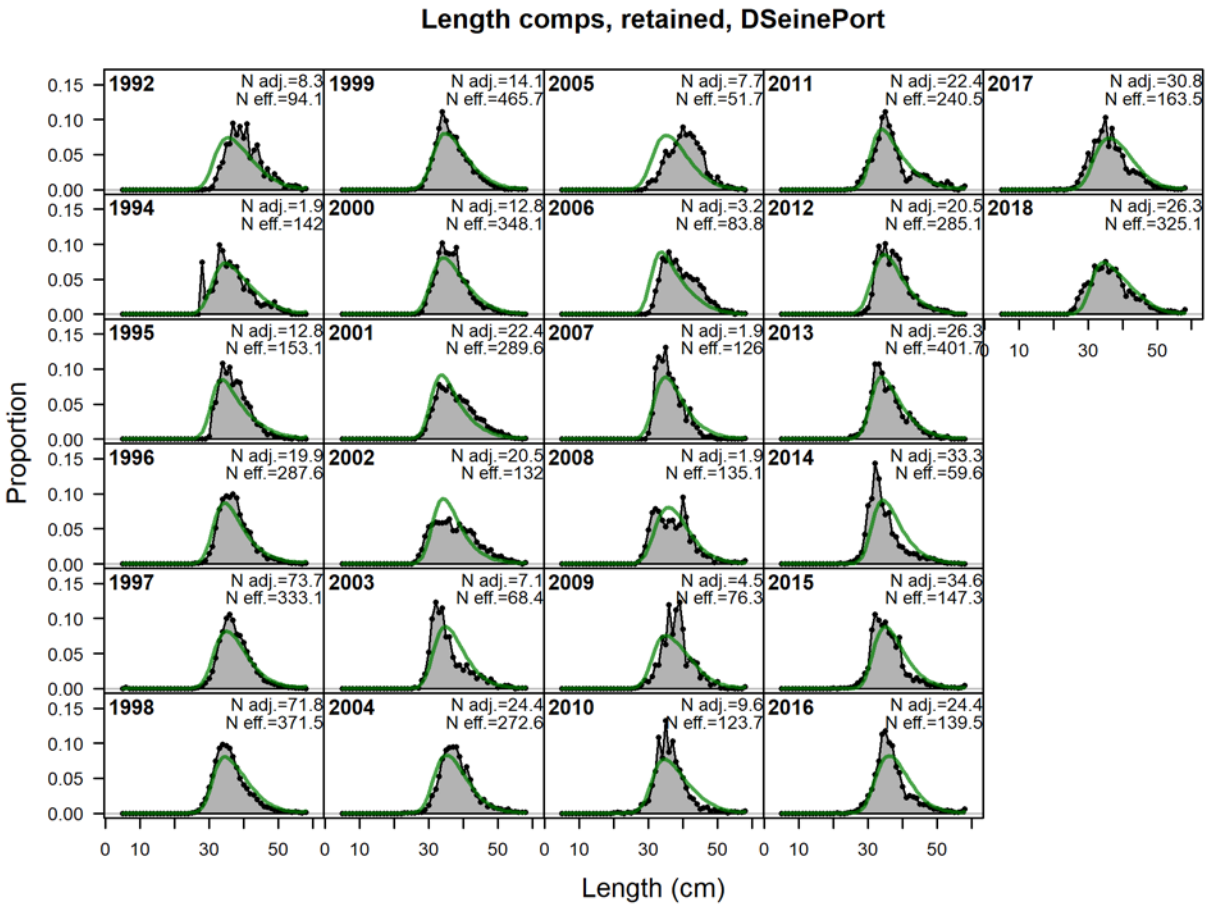

Figure A 7.4. Tiger flathead length composition fits: Danish seine retained port.

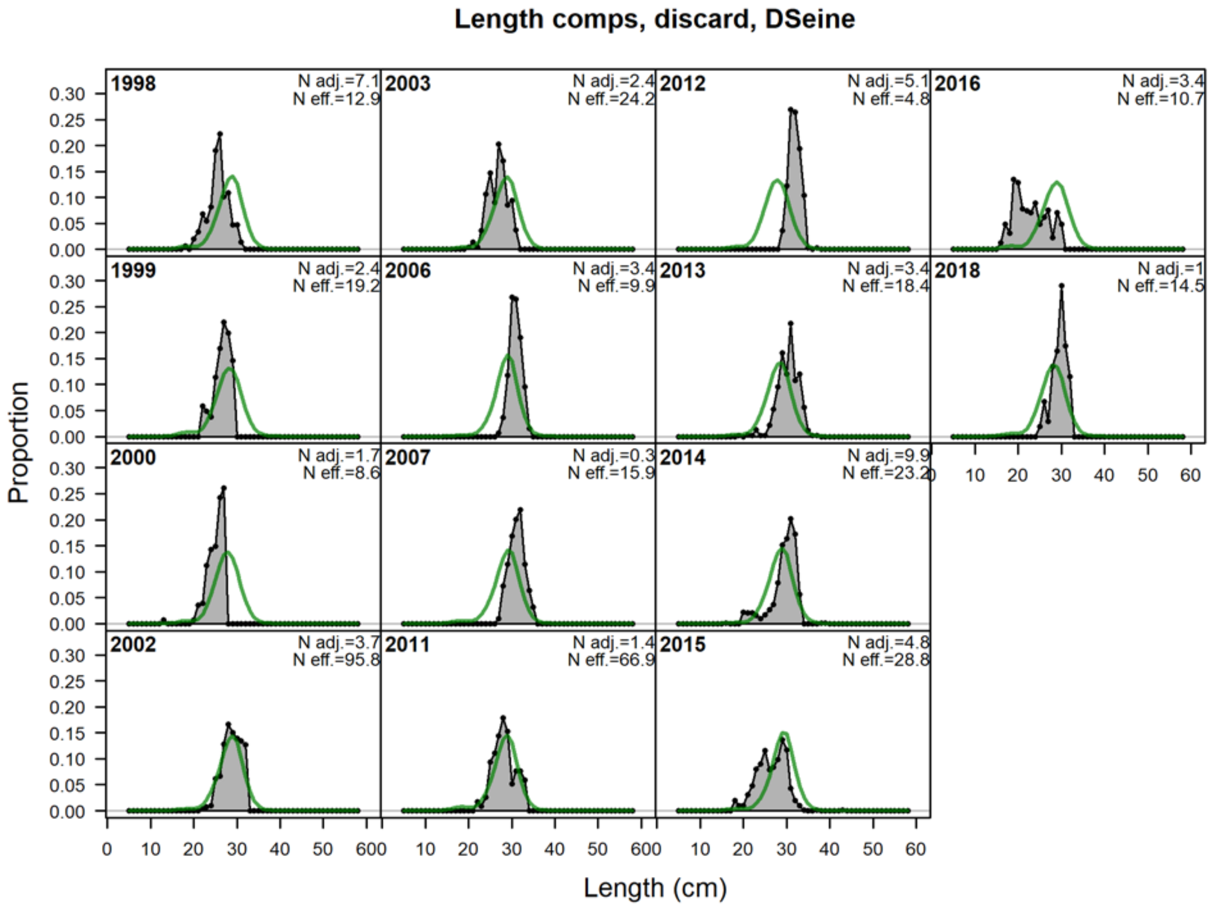

Figure A 7.5. Tiger flathead length composition fits: Danish seine discarded.

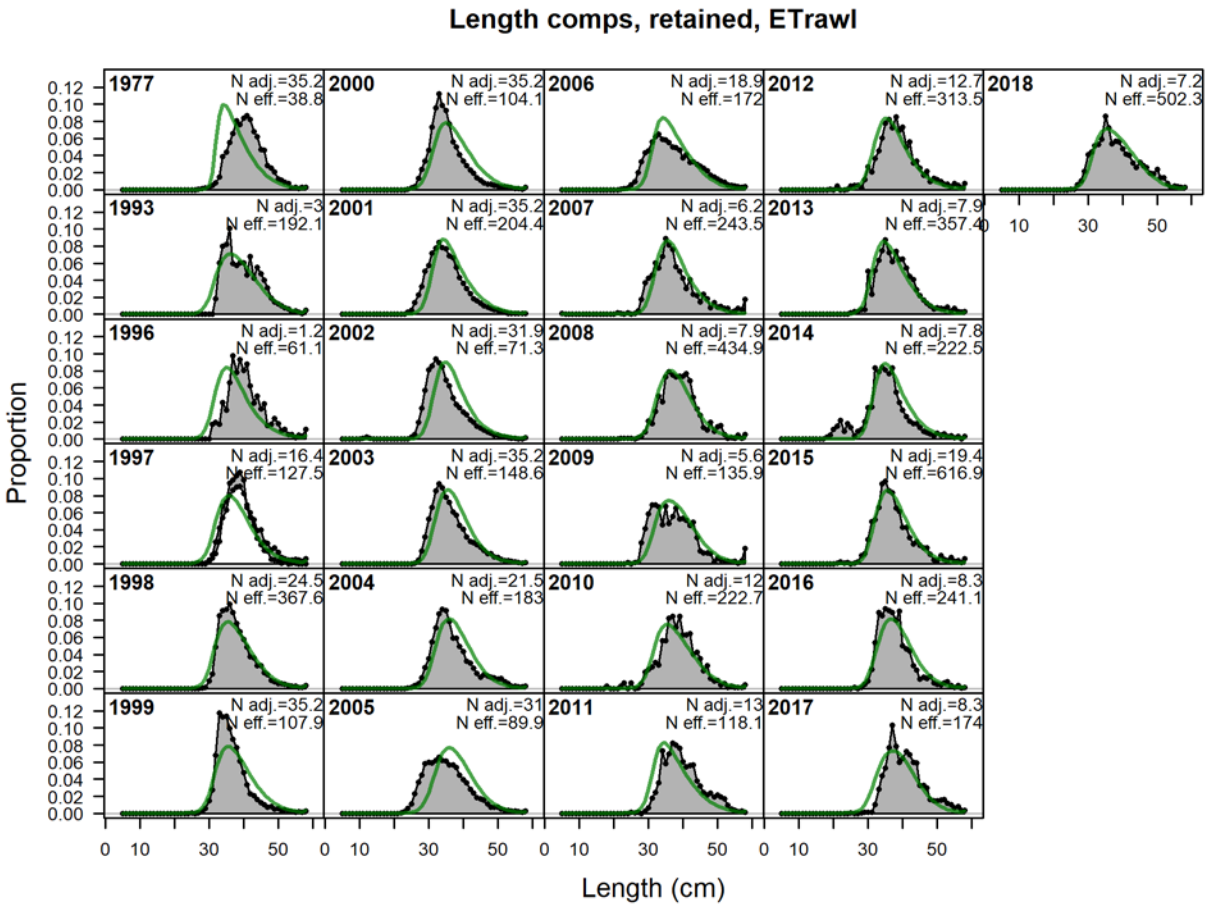

Figure A 7.6. Tiger flathead length composition fits: eastern trawl retained onboard.

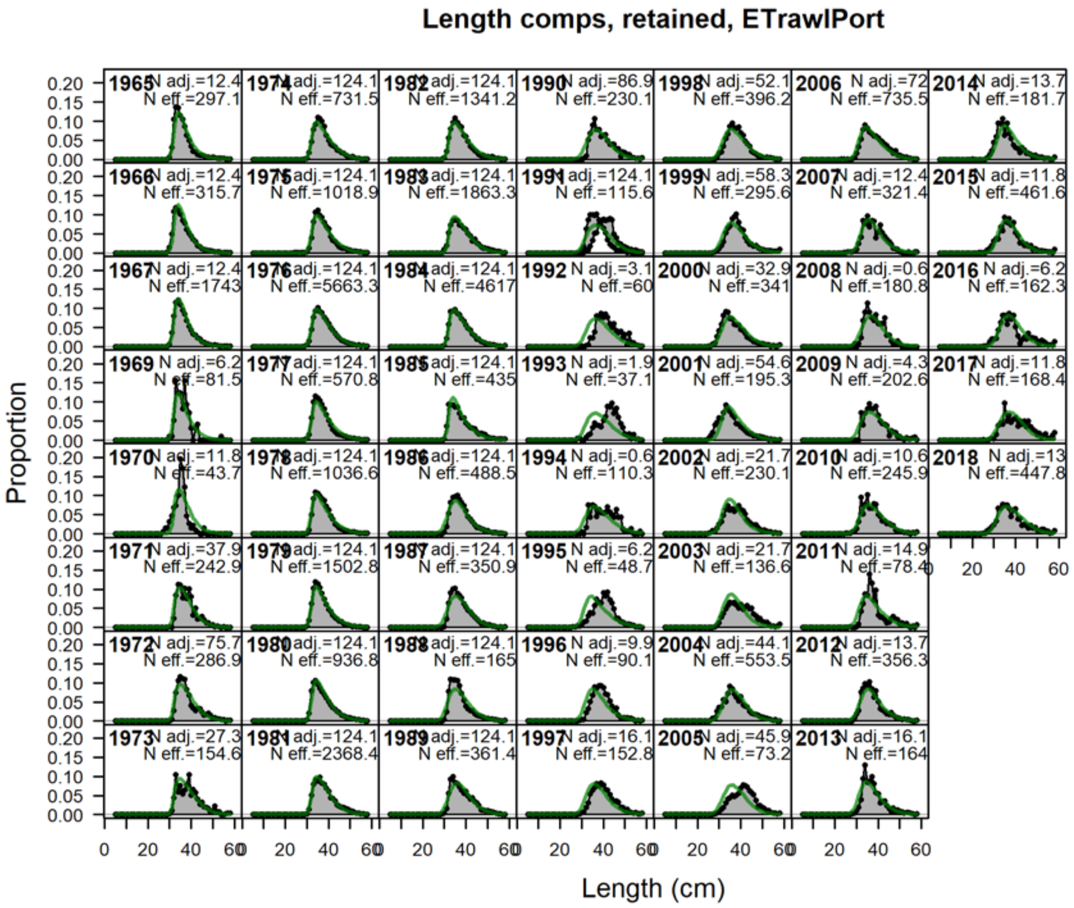

Figure A 7.7. Tiger flathead length composition fits: eastern trawl retained port.

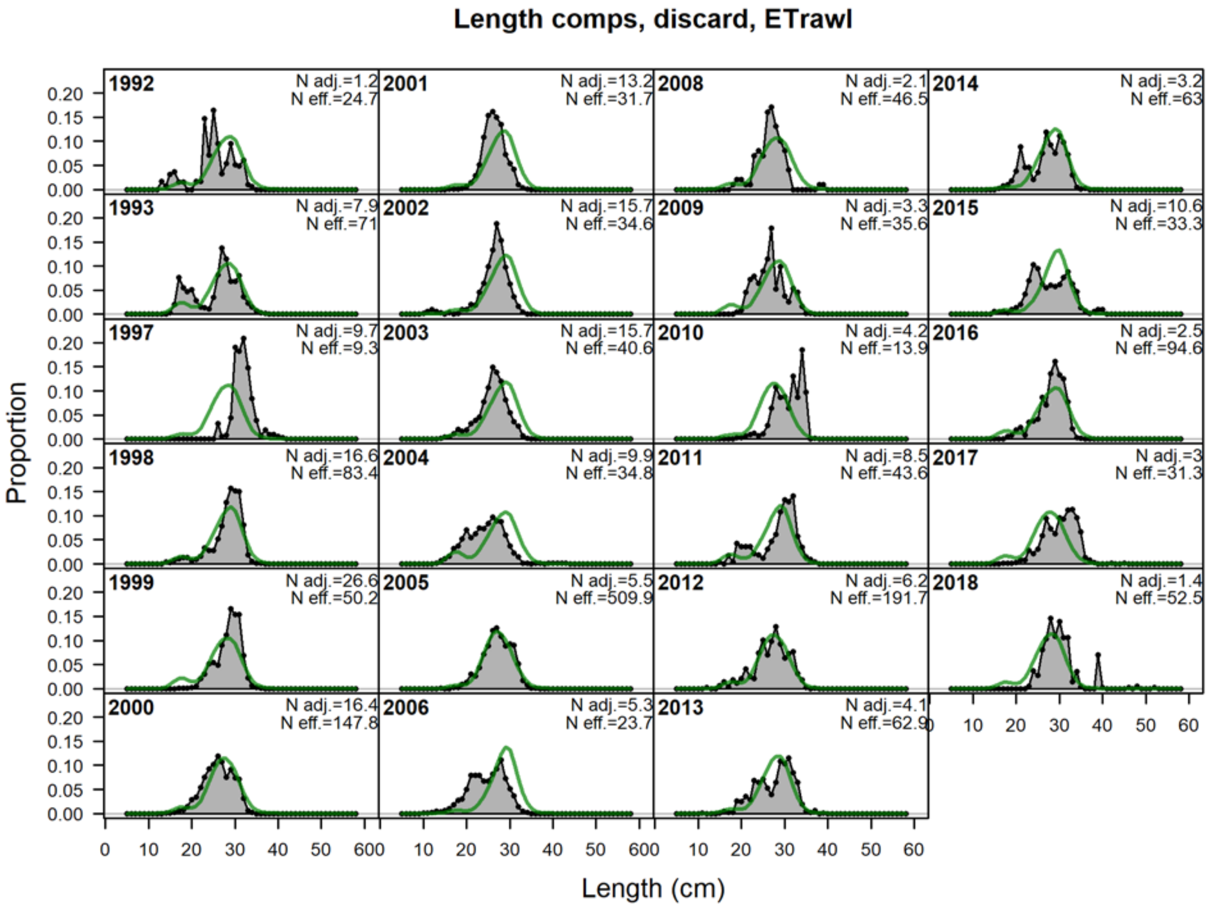

Figure A 7.8. Tiger flathead length composition fits: eastern trawl discarded.

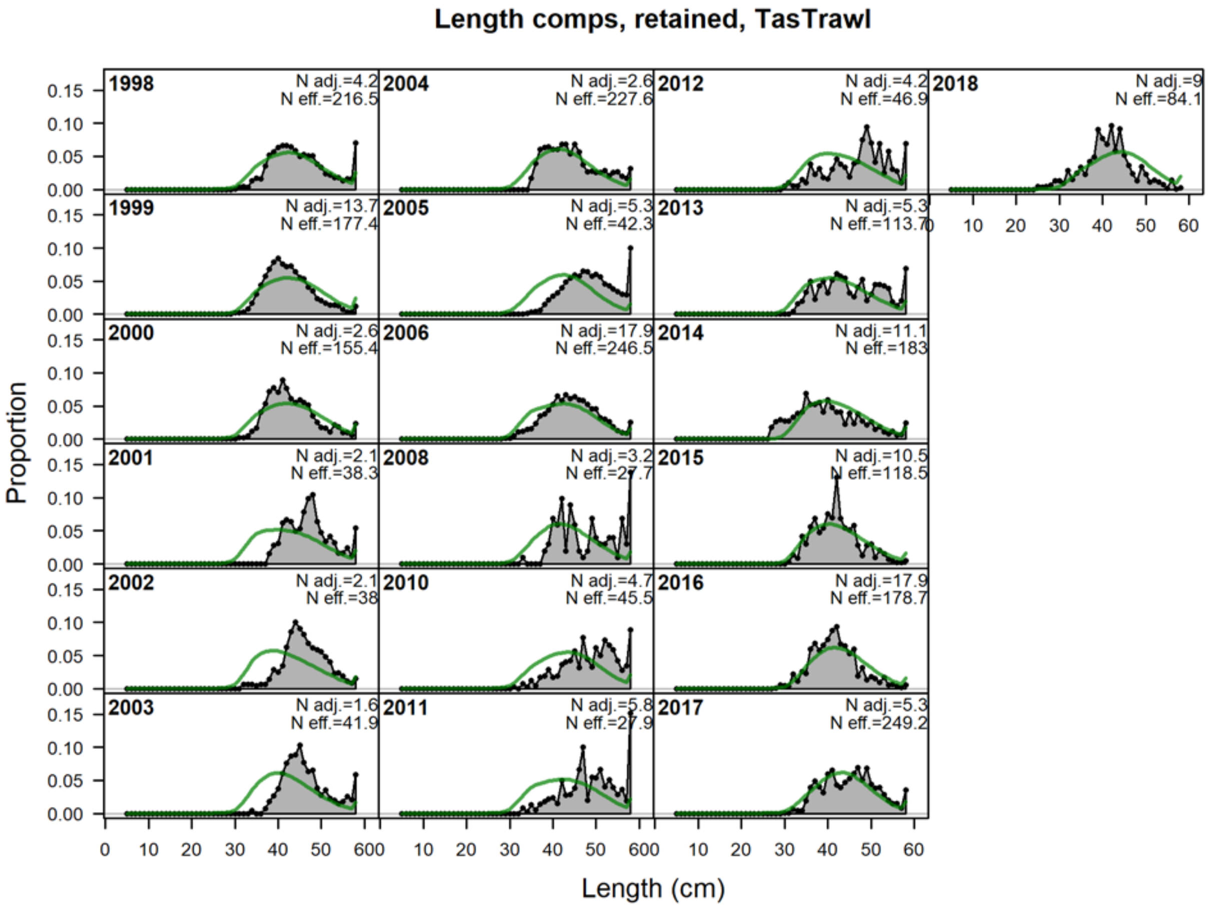

Figure A 7.9. Tiger flathead length composition fits: Tasmanian trawl retained onboard.

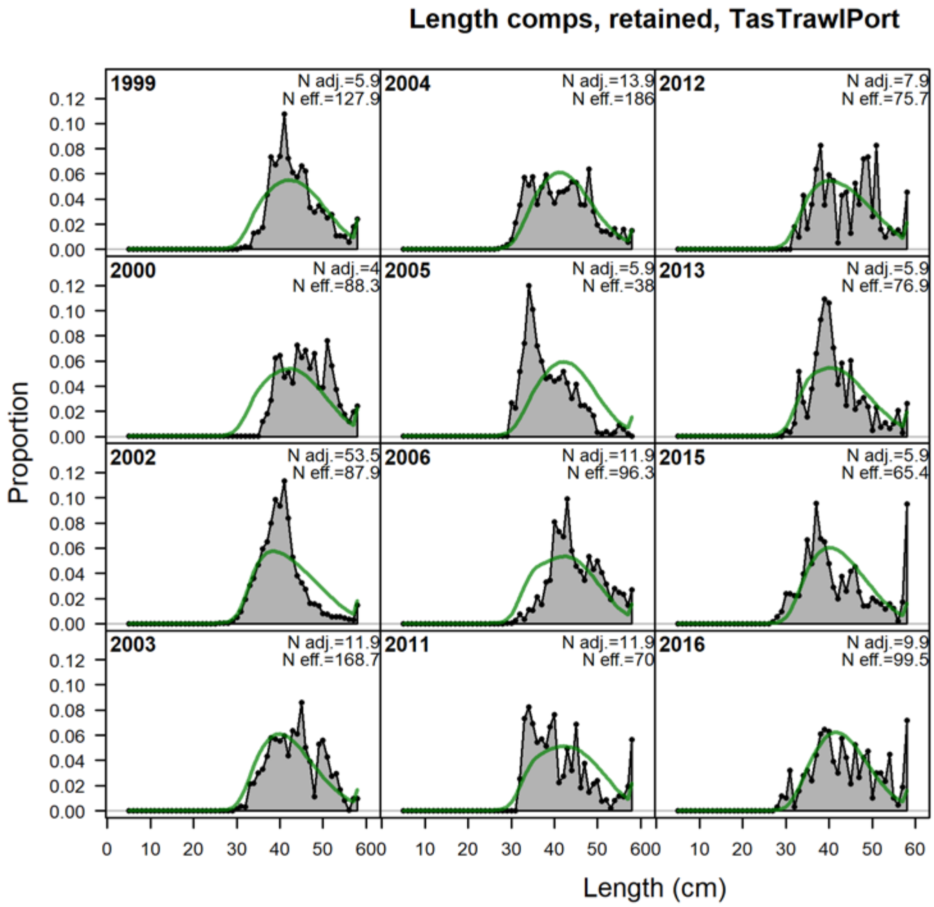

Figure A 7.10. Tiger flathead length composition fits: Tasmanian trawl retained port.

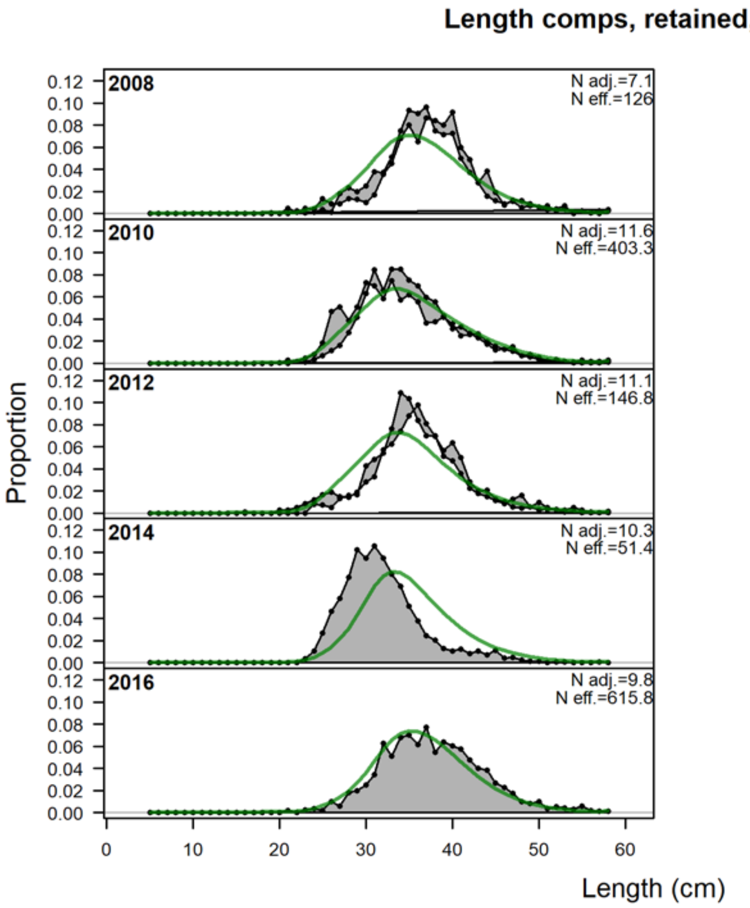

Figure A 7.11. Tiger flathead length composition fits: eastern FIS (zones 10 and 20).

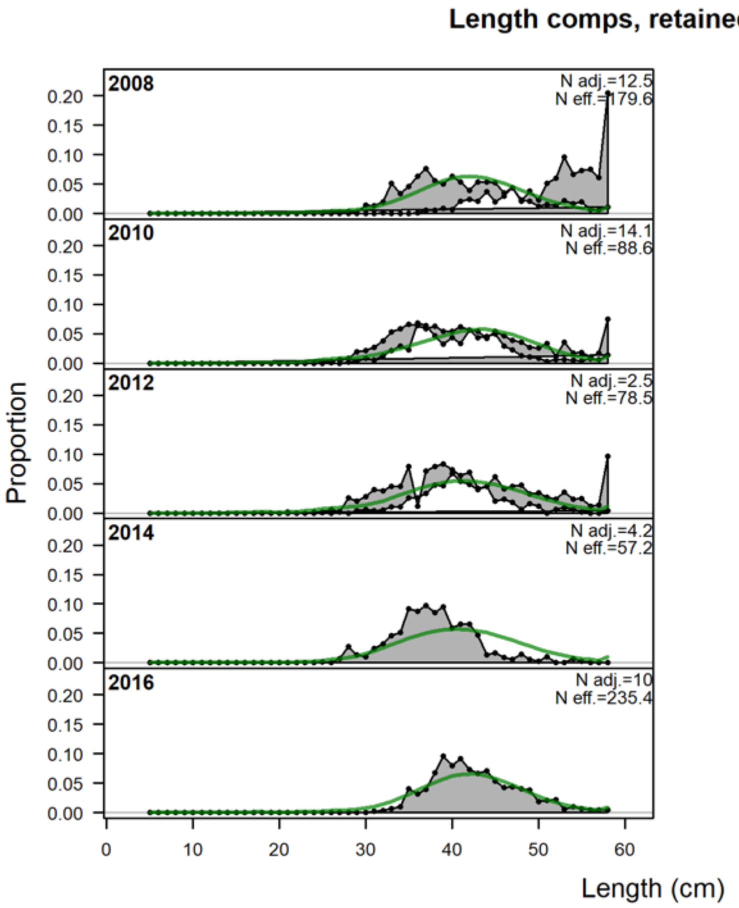

Figure A 7.12. Tiger flathead length composition fits: Tasmanian FIS (zone 30 only).

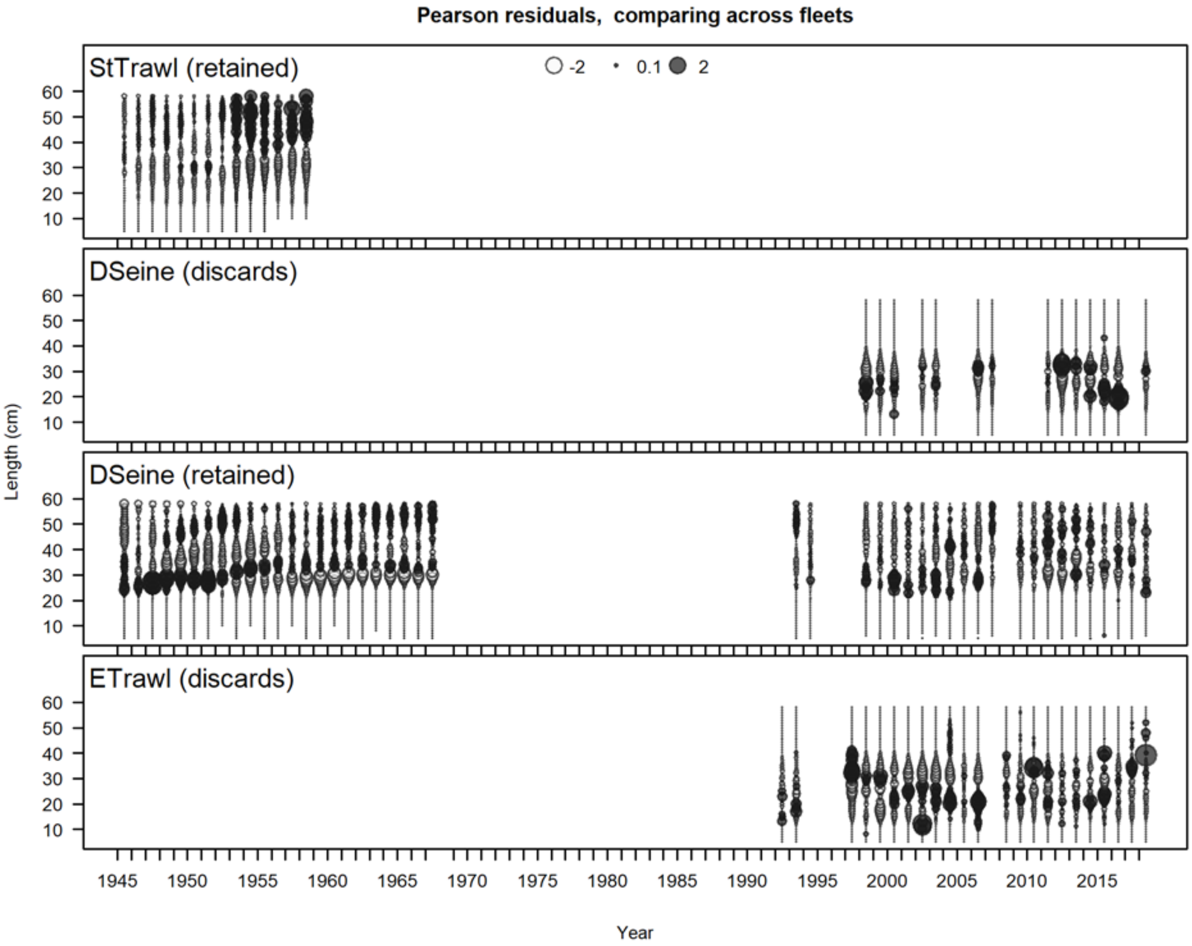

Figure A 7.13. Residuals from the annual length compositions for tiger flathead displayed by year and fleet: onboard fleets, retained and discarded.

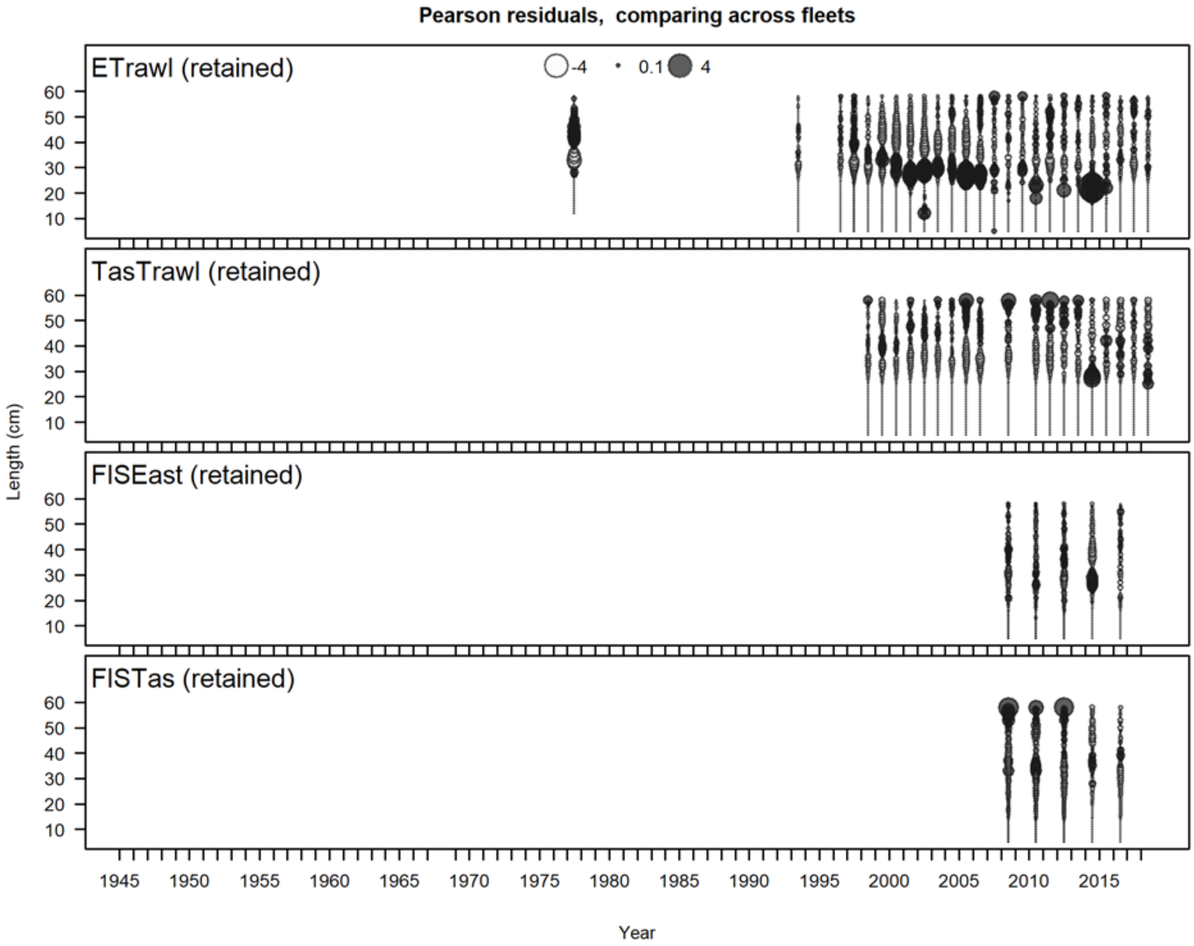

Figure A 7.14. Residuals from the annual length compositions for tiger flathead displayed by year and fleet: onboard fleets and FIS.

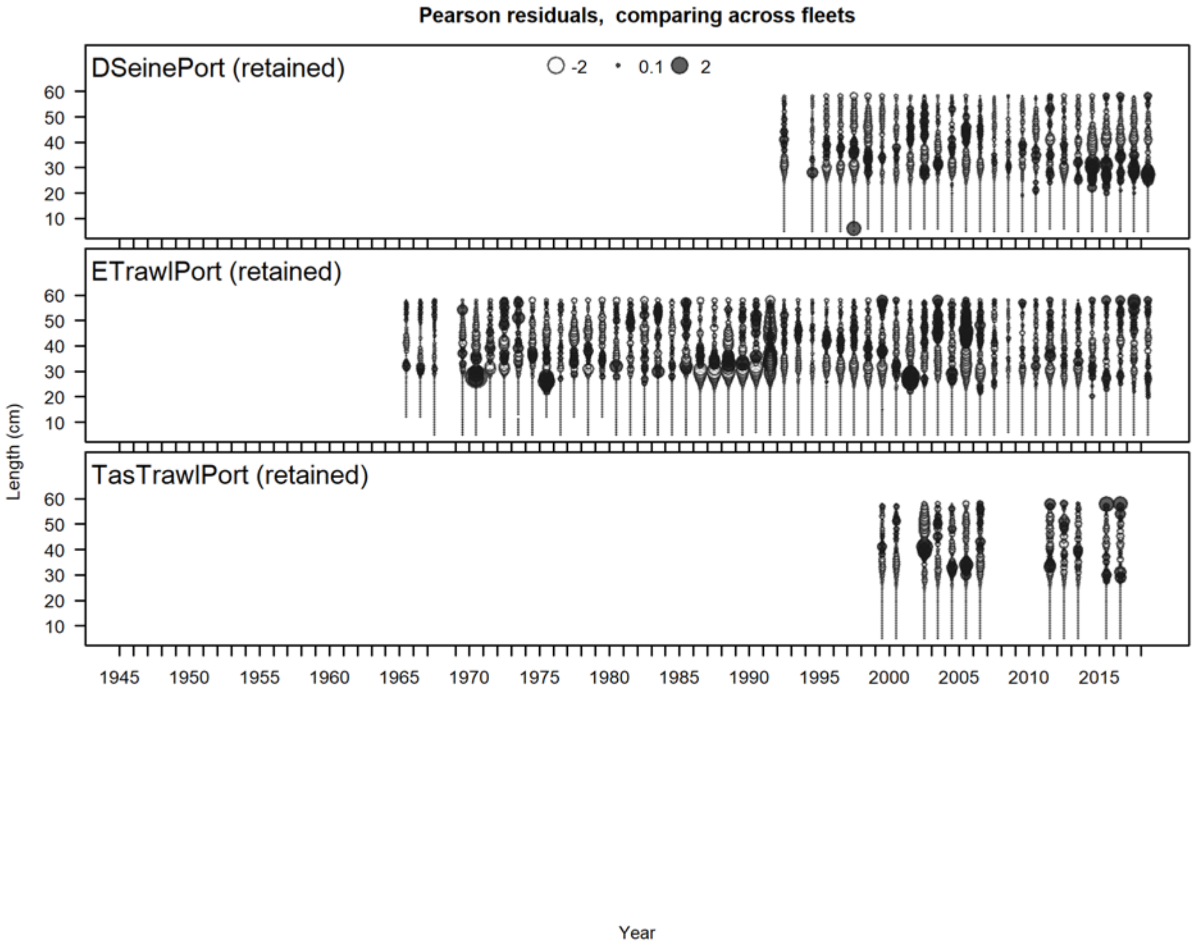

Figure A 7.15. Residuals from the annual length compositions for tiger flathead displayed by year and fleet: Port.

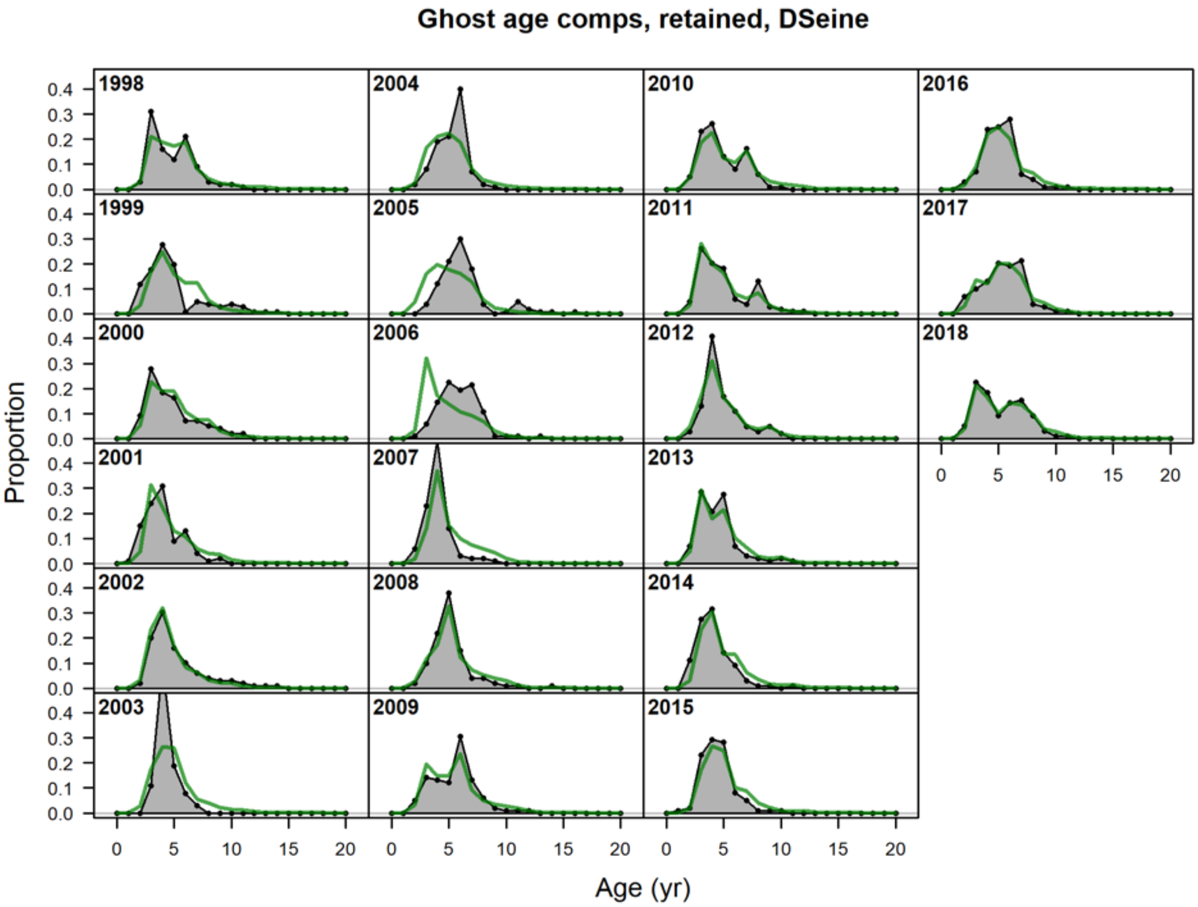

Figure A 7.16. Implied fits to age compositions for tiger flathead Danish seine (retained).

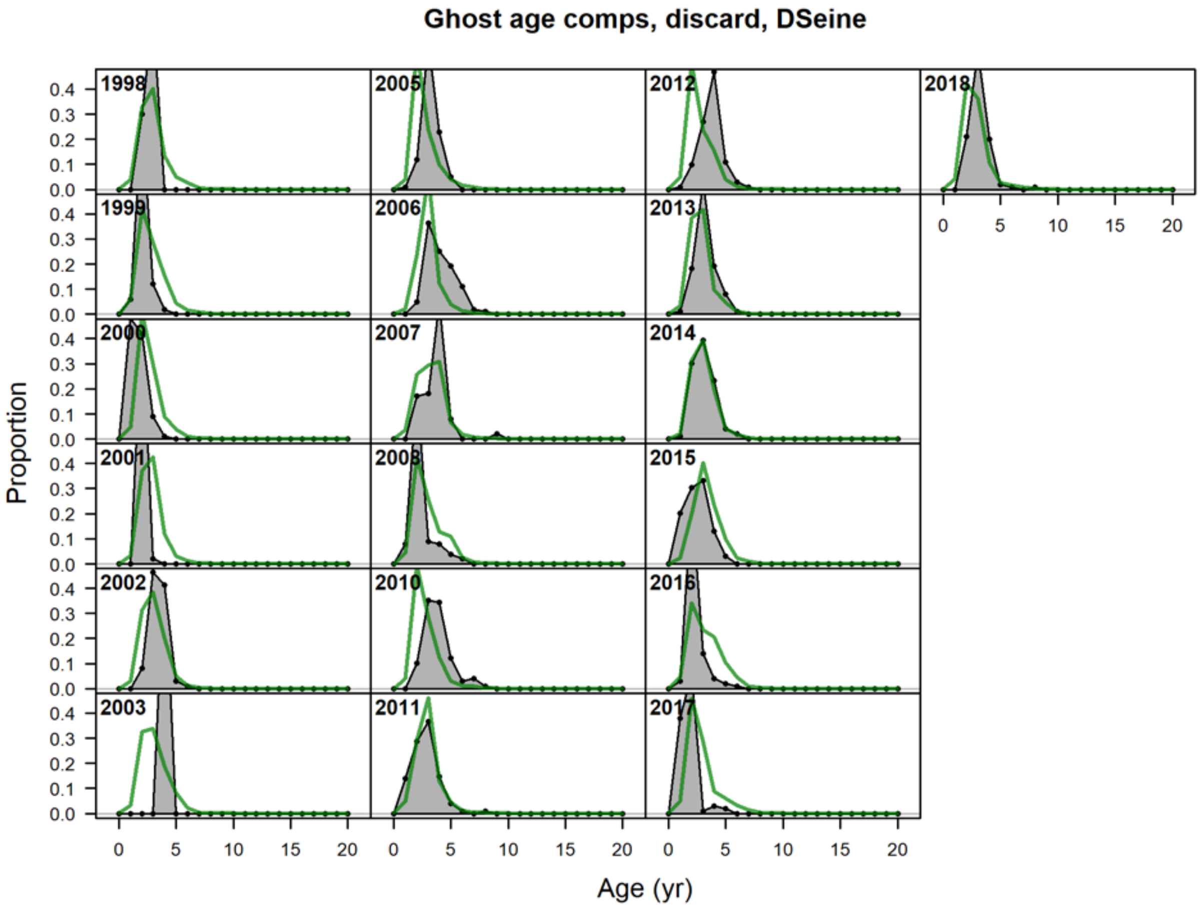

Figure A 7.17. Implied fits to age compositions for tiger flathead Danish seine (discarded).

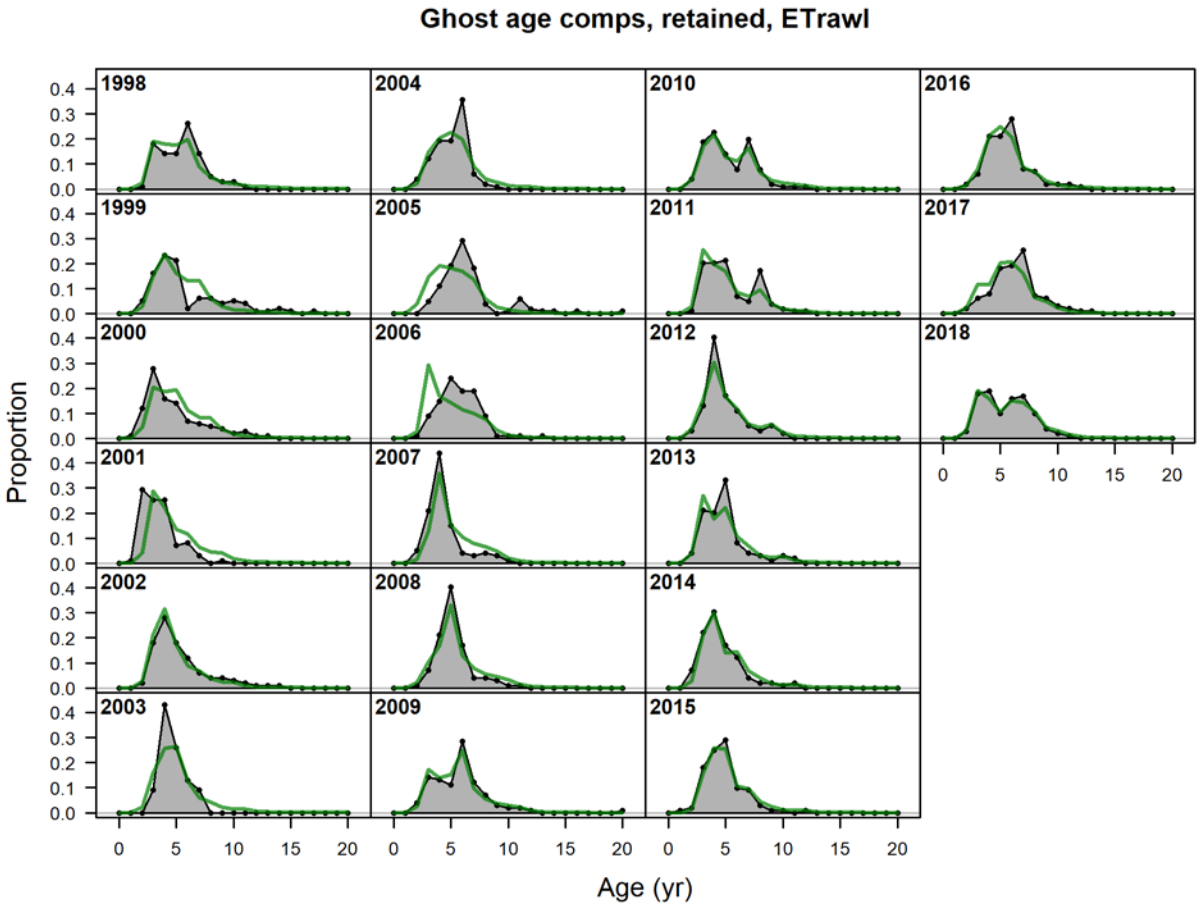

Figure A 7.18. Implied fits to age compositions for tiger flathead eastern trawl (retained).

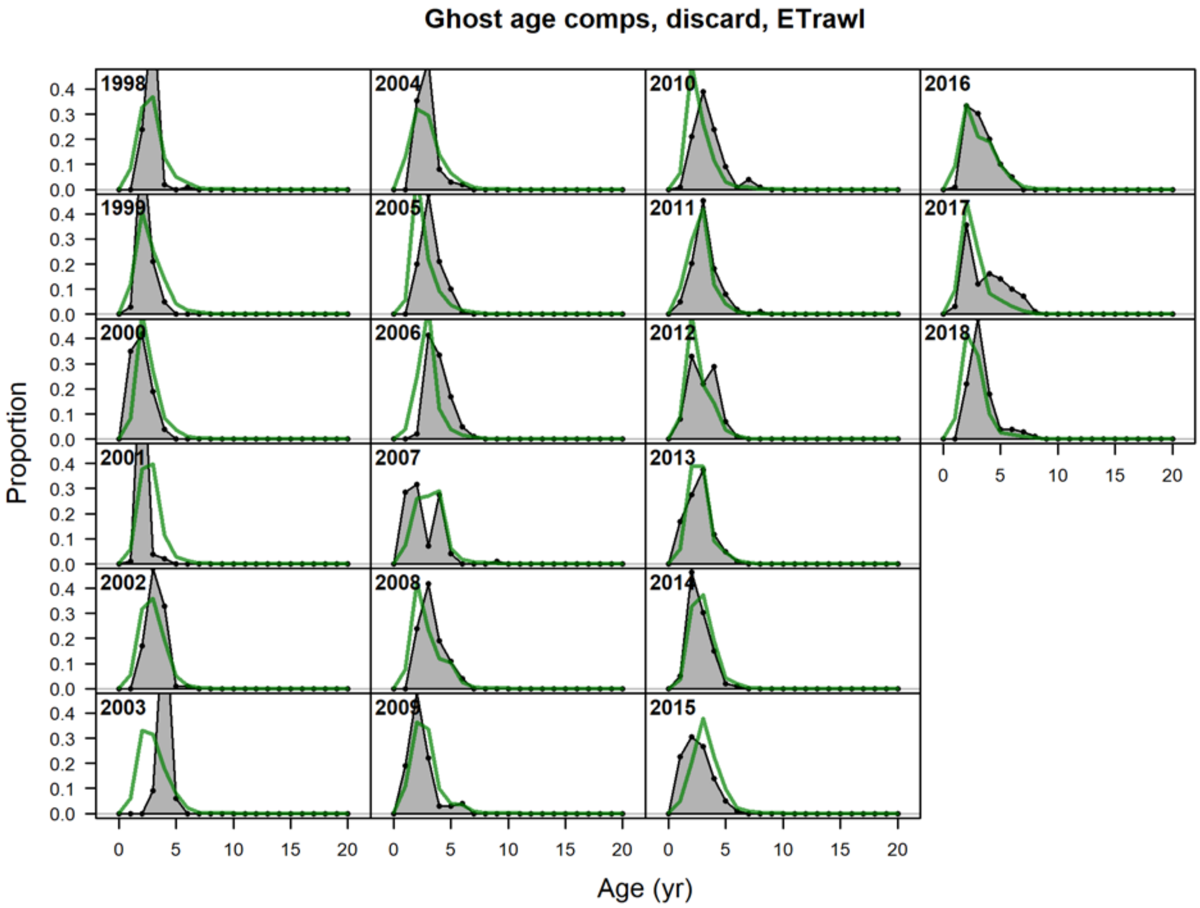

Figure A 7.19. Implied fits to age compositions for tiger flathead eastern trawl (discarded).

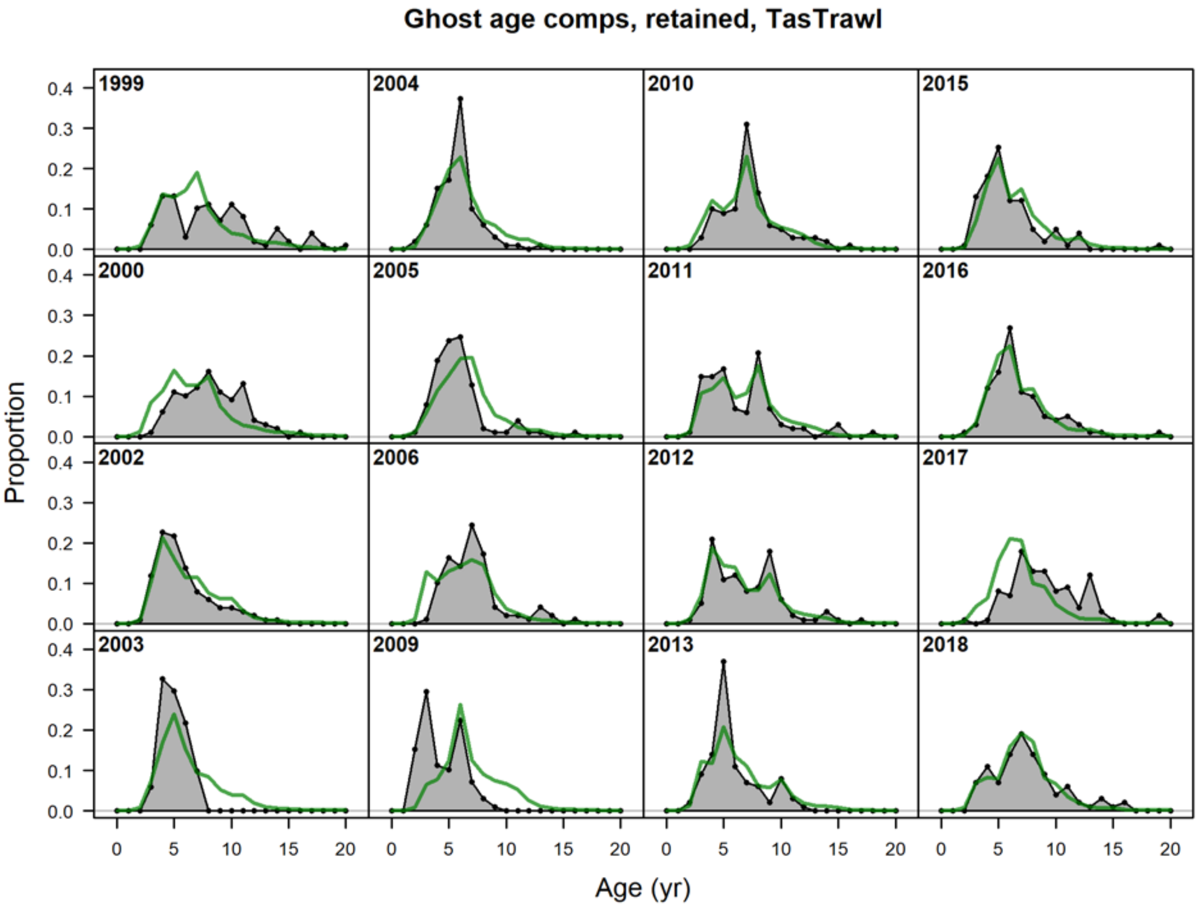

Figure A 7.20. Implied fits to age compositions for tiger flathead Tasmanian trawl (retained).

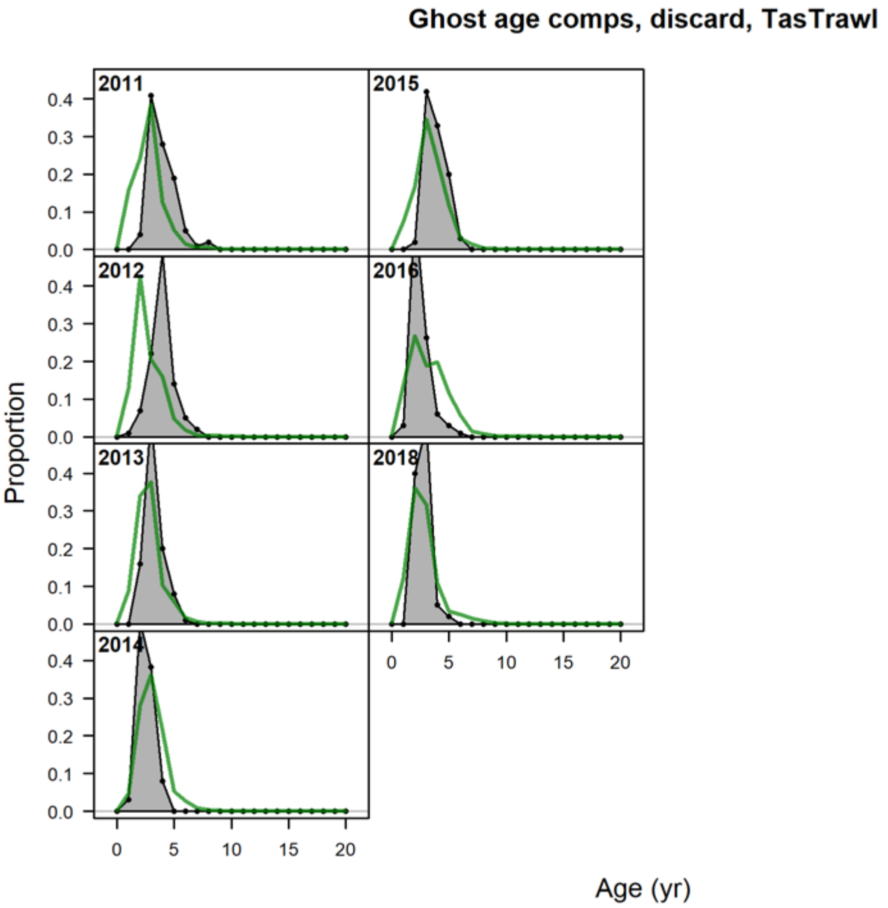

Figure A 7.21. Implied fits to age compositions for tiger flathead Tasmanian trawl (discarded).

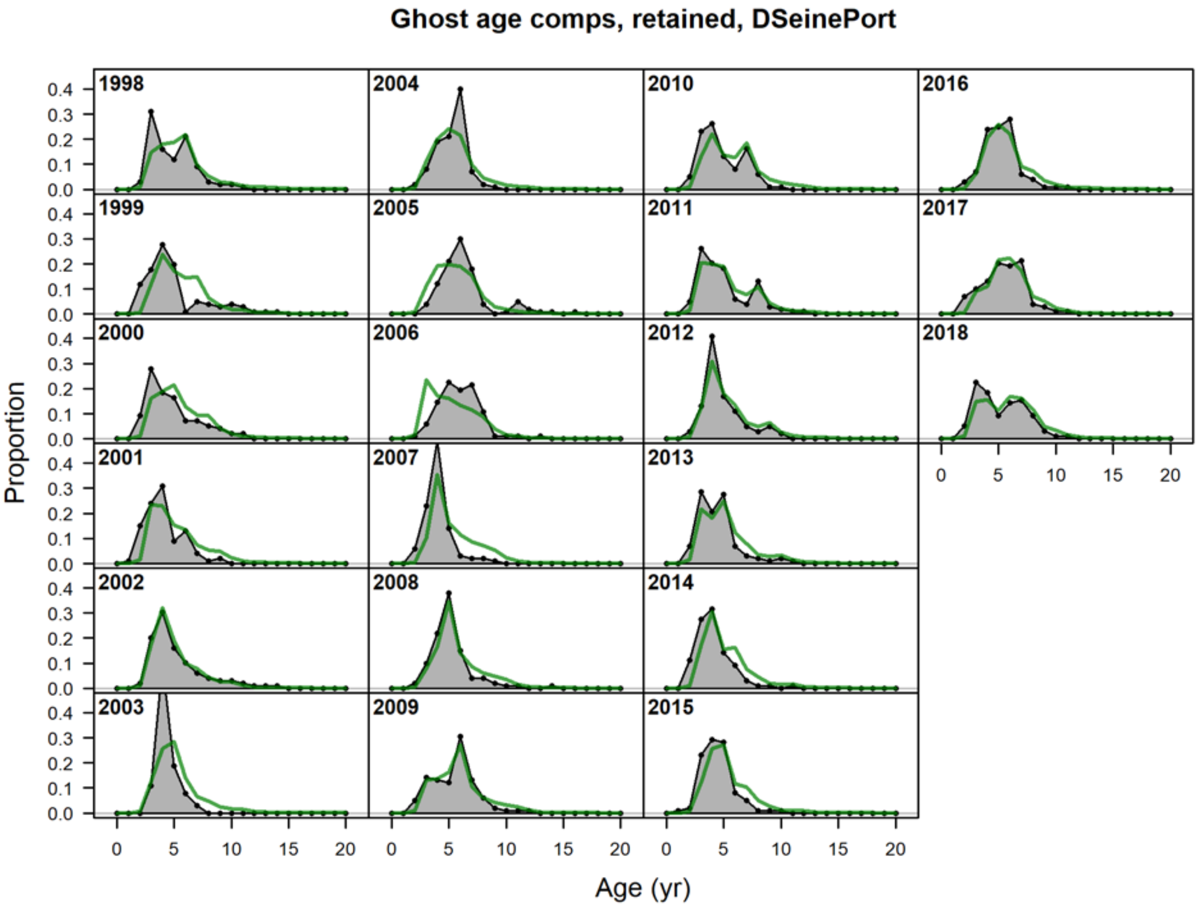

Figure A 7.22. Implied fits to age compositions for tiger flathead Danish seine port (retained).

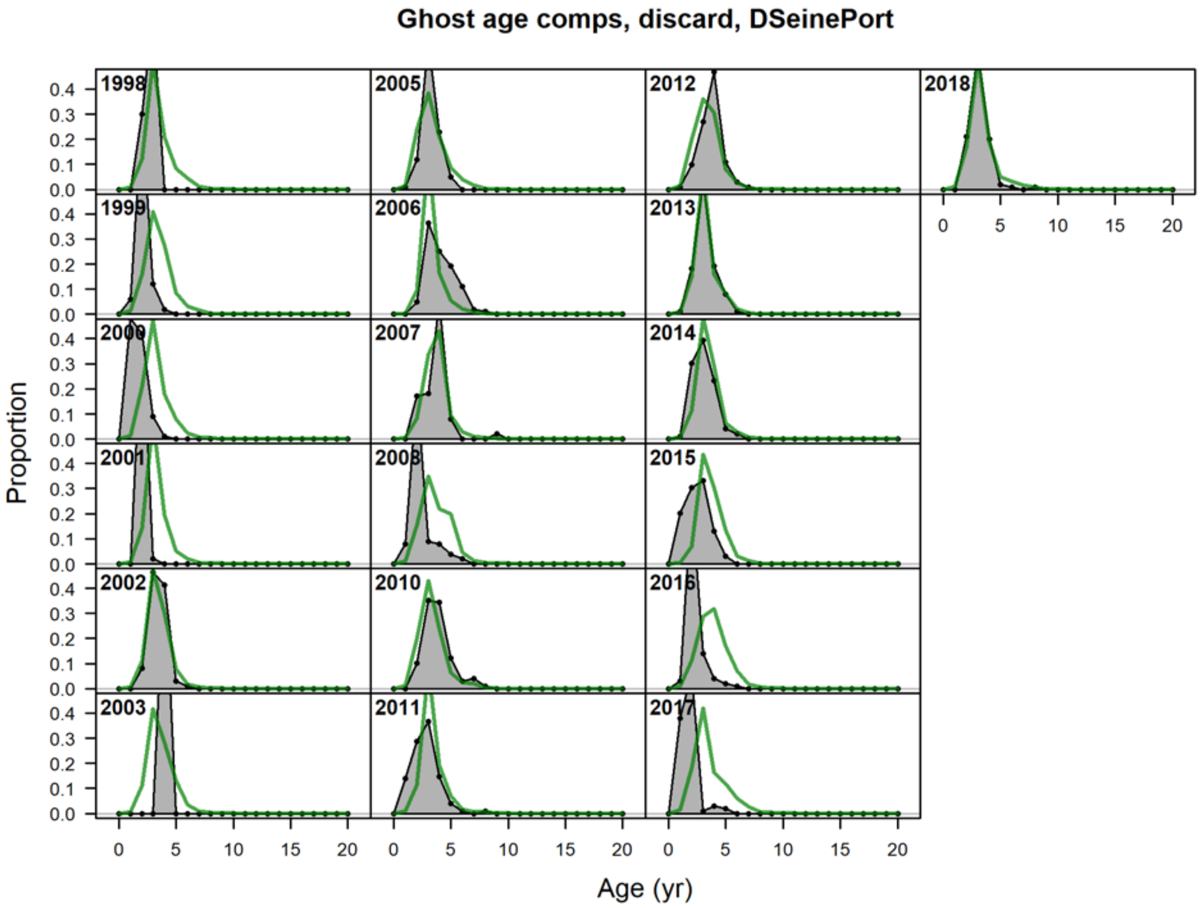

Figure A 7.23. Implied fits to age compositions for tiger flathead Danish seine port (discarded).

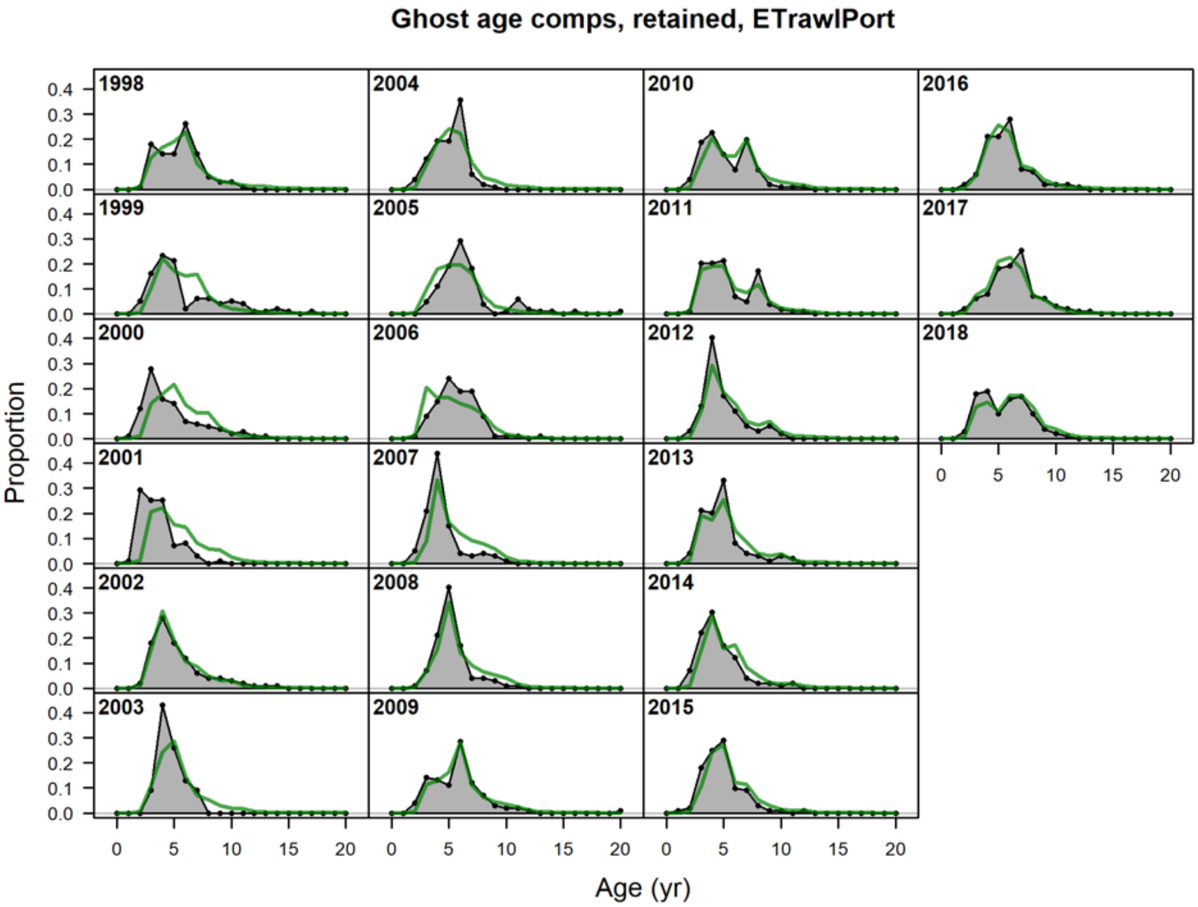

Figure A 7.24. Implied fits to age compositions for tiger flathead eastern trawl port (retained).

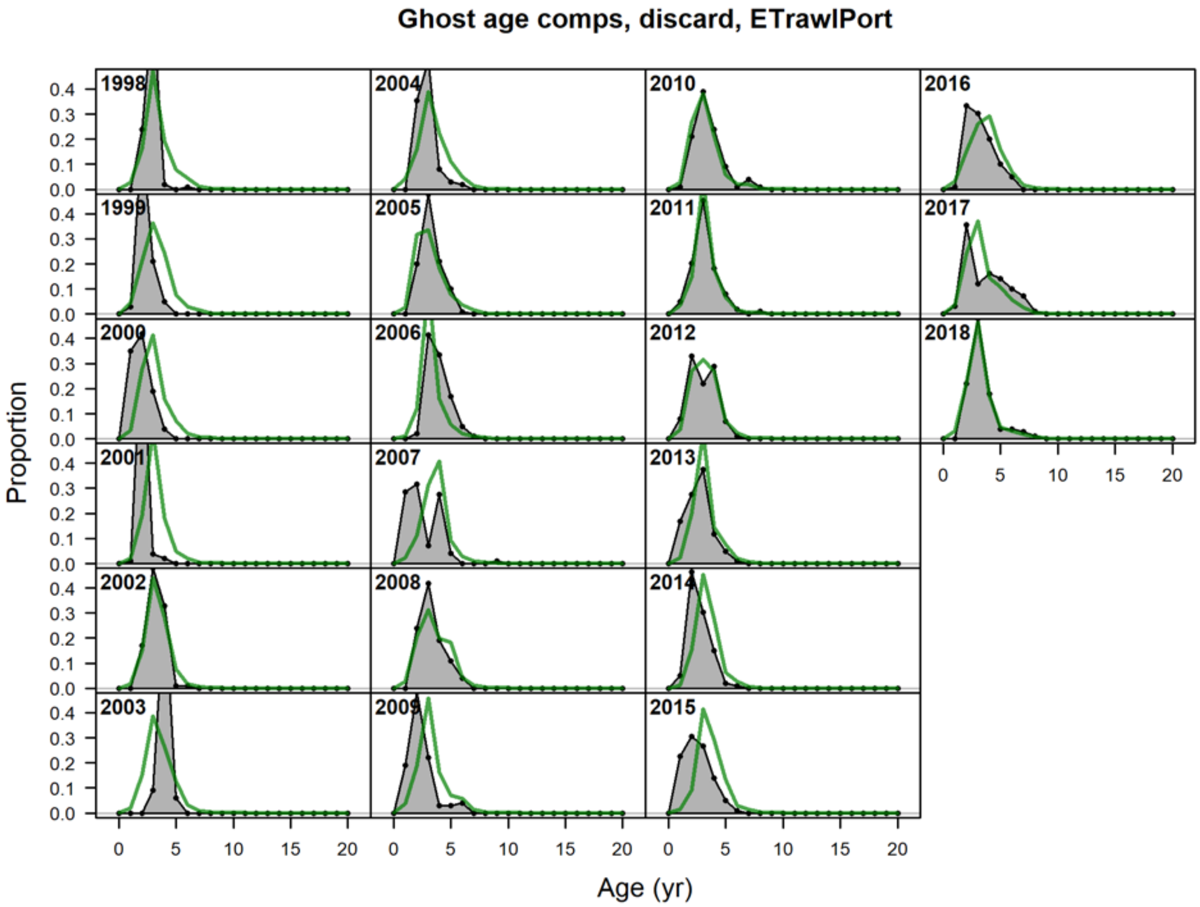

Figure A 7.25. Implied fits to age compositions for tiger flathead eastern trawl port (discarded).

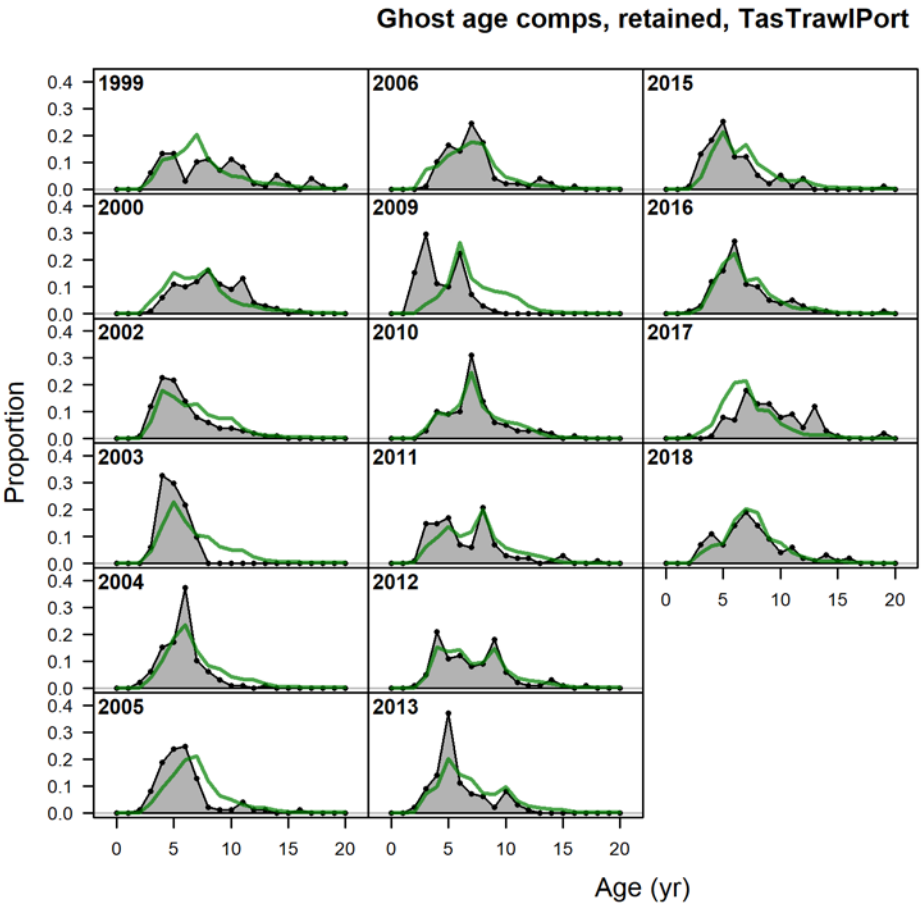

Figure A 7.26. Implied fits to age compositions for tiger flathead Tasmanian trawl port (retained).

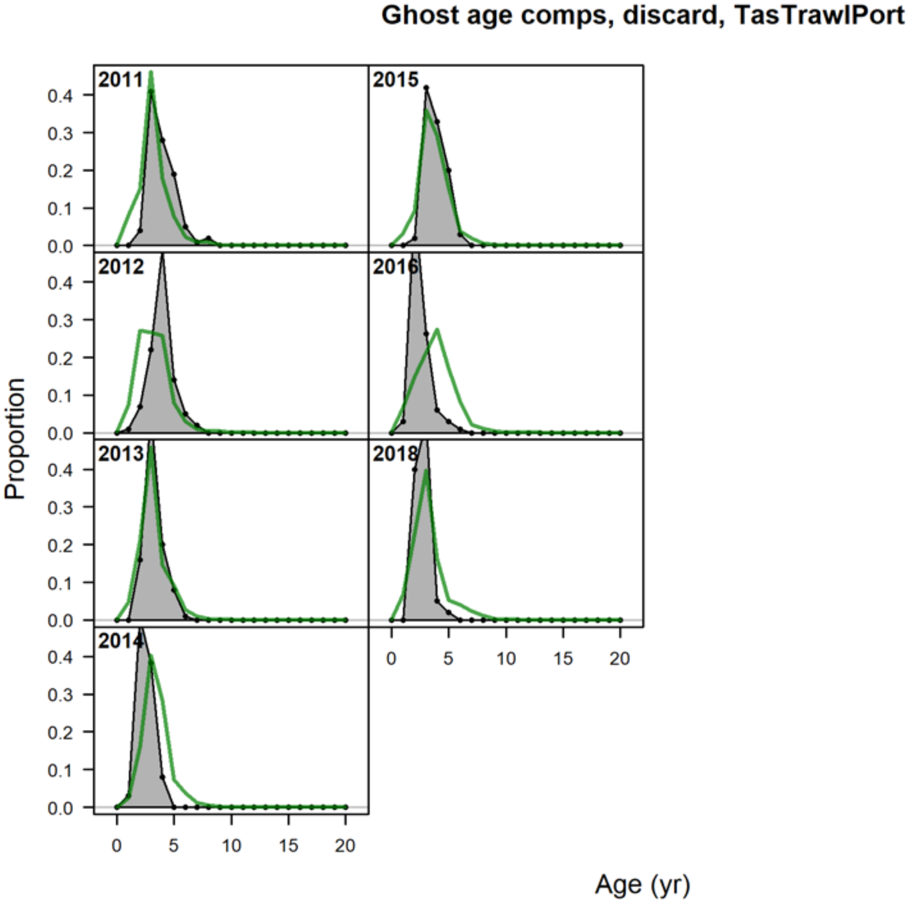

Figure A 7.27. Implied fits to age compositions for tiger flathead Tasmanian trawl port (discarded).