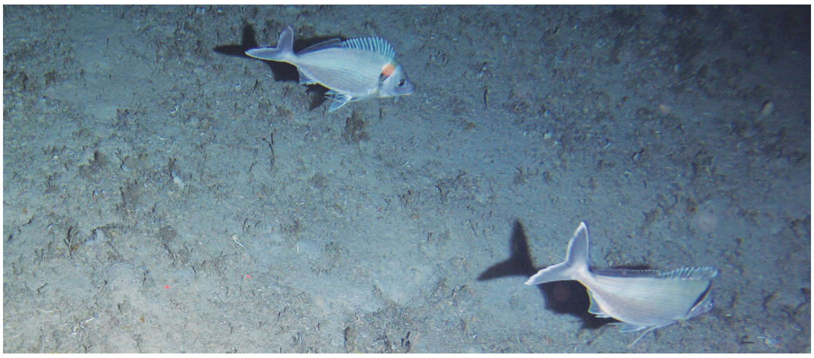
Cite as:

Day, J., Bessell-Browne, P. and Curin-Osorio, S. (2021) Eastern Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2020 in Tuck, G. and Bessell-Browne, P. (2021) Blue Grenadier (*Macruronus novaezelandiae*) stock assessment based on data up to 2020 in *Tuck, G.N. (ed.) 2022. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2020 and 2021. Part 1, 2021. Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere, Hobart. 731p.*

Australian Government
Australian Fisheries Management Authority

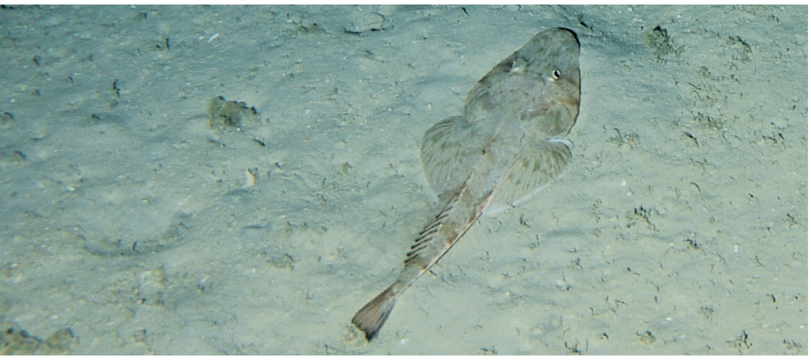
2019/0800 May 2022

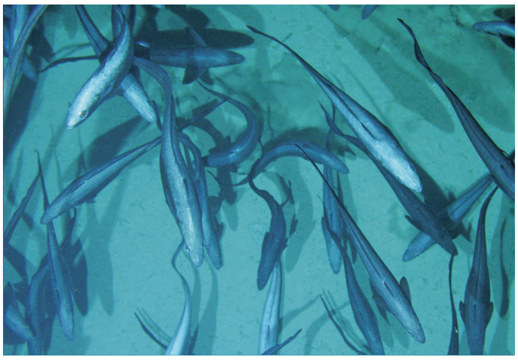
Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2020 and 2021

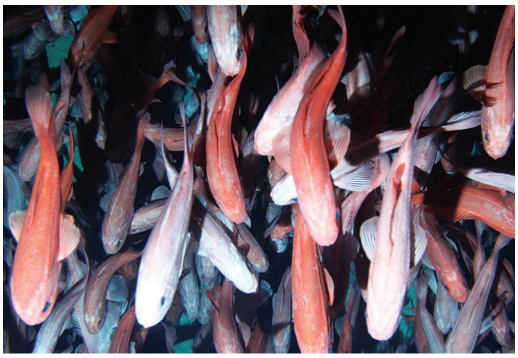


PART 1

2021







Principal investigator **G.N. Tuck**

CSIRO

www.afma.gov.au

Protecting our fishing future

Box 7051, Canberra Business Centre, ACT 2610 Tel **(02) 6225 5555** Fax (02) 6225 5440 **AFMA Direct 1300 723 621**

Preferred way to cite this report

Tuck, G.N. (ed.) 2022. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2020 and 2021. Part 1, 2021. Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere, Hobart. 731p.

Acknowledgements

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

Cover photographs

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

Report structure

Part 1 of this report describes the Tier 1 assessments of 2021. Part 2 describes the Tier 4 and Tier 5 assessments, catch rate standardisations and other work contributing to the assessment and management of SESSF stocks in 2021.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2020 and 2021

Part 1: 2021

G.N. Tuck
May 2022
Report 2019/0800

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2021

TABLE OF CONTENTS

8. Eastern Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2020

Jemery Day[1], Pia Bessell-Browne[1] and Sandra Curin-Osorio[1,2]

[1]CSIRO Oceans and Atmosphere, Castray Esplanade, Hobart TAS 7000, Australia
[2]Institute for Marine and Antarctic Studies, University of Tasmania, Private Bag 49, Hobart TAS 7001, Australia

8.1 Executive Summary

This document updates the 2018 Tier 1 assessment of eastern Jackass Morwong (*Nemadactylus macropterus*) to provide estimates of stock status in the SESSF at the start of 2022 and describes the base case assessment and some of the issues encountered during development. This assessment was performed using the stock assessment package Stock Synthesis (version V3.30.17). The 2018 stock assessment has been updated with the inclusion of data up to the end of 2020, comprising an additional three years of catch, discard, CPUE, length and age data and ageing error updates, including revisions to historical catch series, length frequencies and discard rates. A range of sensitivities were explored.

The base-case assessment estimates that the projected 2022 spawning stock biomass will be 15% of unexploited spawning stock biomass (SSB_0), with recruitment from 2016 onwards projected using a low recruitment scenario, using the average of the ten most recently estimated recruitment deviations, from 2006-2015. Under the agreed 20:35:48 harvest control rule, the 2022 recommended biological catch (RBC) is 0 t, with the long-term yield (assuming low recruitment in the future) of 91 t. The average RBC over the three-year period 2022-2024 is 0 t and over the five-year period 2022-2026, the average RBC is 1 t. If recruitment from 2016 onwards is assumed to be average, the projected 2022 spawning stock biomass would be 22% of SSB_0.

Exploration of model sensitivity showed variation in spawning biomass across all sensitivities ranging from 7% to 24% of SSB_0 with greatest sensitivity to natural mortality. Excluding this sensitivity to natural mortality, the other sensitivities showed a much narrower range, from 13% to 17% of SSB_0.

The updated assessment produces markedly different results from the 2018 assessment, under both the average and the low recruitment scenarios. This is due to downward revisions to the 13 of most recent 15 years of recruitment estimates from the 2018 assessment (for the period 1998-2012), poor recruitment estimates for the three new years of recruitment estimated in the 2021 assessment (for the years 2013-2015), a continuing decline in recent catches, a continuing decline in the recent CPUE indices and an improved fit (compared to the 2018 assessment) to the most recent CPUE data points, partly due to the implementation of a low recruitment scenario. As in the 2018 assessment, results show good fits to the CPUE data, poor fits to the FIS2 abundance data for the Tasmanian trawl fleet and good fits to the length composition and conditional age-at-length data. In contrast to the 2018 assessment, the 2021 assessment features improved fits to the FIS2 abundance data for the eastern trawl fleet.

Given the recent series of 12 years of below average recruitment, low recruitment projections are expected to produce much more realistic predictions in the near future. Incorporating low recruitment into the base case, marginally improves the retrospective patterns, which indicate significant change to quantities estimated by the model through the addition of recent data, with possible model misspecification and/or recent temporal changes to recruitment and/or biological parameters. Incorporating low recruitment projections complicates the technical calculations of sensitivities, likelihood profiles and retrospectives, but this approach is likely to give much more realistic results and avoid an overly optimistic short-term outlook, which typically gets revised downwards when the next assessment is conducted.

Likelihood profiles indicate there is some conflict within and between data sources contributing to the likelihood components. As with the retrospectives, this could indicate some model misspecification, possibly related to unaccounted spatial and or temporal variation. Likelihood profiles also indicate information on the uncertainty in estimates of stock status in 2020 and provide information on the data sources which are most influential in informing the estimation of some parameters and some derived quantities. Results from likelihood profiles could be used to help guide future data collection which could increase the quality and quantity of data which is most informative for future stock assessment models. For Jackass Morwong, it appears the estimates of discard proportions are quite informative, and increased focus on collecting this data could potentially improve future assessments.

8.2 Introduction

8.2.1 *The fishery*

Jackass Morwong (*Nemadactylus macropterus*) have been landed in southern Australia since the inception of the steam trawl fishery off New South Wales in the early twentieth century (Fay 2004), with the initial fishery concentrating in the east (SESSF Zones 10, 20 and 30). Jackass Morwong were not favoured during the initial years of this fishery, when the main target species was Tiger Flathead (*Neoplatycephalus richardsoni*). Declines in Tiger Flathead catches, and improved market acceptance, led to increased targeting of Jackass Morwong during the 1930s and later years of the steam trawl fishery (Klaer, 2001). Annual estimates of landings of Jackass Morwong from the steam trawl fishery in the east between 1915 and 1957 reached a peak of about 2,000 t during the late 1940s (Day and Bessell-Browne, 2021).

The fishery expanded greatly during the 1950s, with Danish seine vessels becoming the main vessels in the fishery. Landings of Jackass Morwong in NSW and eastern Victoria increased following WWII, and, at their peak in the 1960s, annual landings were of the order of 2,500 t. The fishery shifted southwards during this time, with the majority of the landed catches coming from eastern Victoria. Landings of Jackass Morwong then dropped to around 1,000 t by the mid-1980s (Table 8.2 and Table 8.3), with landings in eastern Tasmania becoming an increasing proportion of catches. By the mid-1980s, the majority of Jackass Morwong was being landed by modern otter trawlers; with small landings by Danish seine vessels in eastern Victoria and eastern Bass Strait (Smith and Wayte, 2002). Catches were not recorded in the west (SESSF zones 40 and 50) until 1986.

Since the introduction of management measures into the South East Fishery in 1985, the recorded catch of Jackass Morwong (combining catches from the east and the west) has ranged between 1,648 t in 1989 (1,563 t in the east and 85 t in the west) down to 112 t in 2015 (103 t in the east and 9 t in the west). Annual landings of Jackass Morwong in the east have declined steadily since 1968, averaging 1,650 t from 1968-1989, then dropping to average 900 t during the 1990s, declining to average 600 t from 2000-2009, then declining further to average 300t from 2010-2014 and finally averaging less than 150 t per year since 2015 (Table 8.2 and Table 8.3). The catch in 2020 is the second lowest combined total since World War II (114 t, with 103 t in the east and 11 t in the west) and the equal lowest catch for the east since World War II (103 t in both 2015 and 2020) (Table 8.2 and Table 8.3).

The catches appear to have been constrained by the total allowable catch (TAC) in the periods 2002-2005 and 2008-2011. In 1992, an initial TAC was set at 1,500 t (Smith and Wayte, 2002), with this single TAC set to cover catches in both the east and the west. The agreed TAC was reduced to 1,200 t in 2000, to 960 t in 2003, briefly increased to 1,200 t in 2006, then further decreased to 878t in 2007. Since 2008 the TAC has fluctuated between 450-600t. These changes to the TAC have been in response to stock assessments showing the stock to be at declining levels. The TAC was set at 450 t from 2009-2011 as a bycatch TAC i.e. the amount of unavoidable bycatch of Jackass Morwong that could be expected from fishing for other species. Klaer and Smith (2008) calculated that in 2006, 59% of Jackass Morwong trawl catch was caught as bycatch (mainly from flathead fishing). From the logbook data in 2006, the Jackass Morwong trawl catch was 763 t. Thus 59% of this, or 450 t, would be bycatch that is unavoidable, assuming catches of species that have Jackass Morwong as a bycatch stayed the same as 2006 levels (Wayte, 2011).

Catches of Jackass Morwong in the west have been recorded since 1986 (153 t) with less than 100 t of catch taken annually in the west from 1987-1999, then catch totals exceeding 100 t in the period 2000-2008 (with a peak of 322 t in 2001). All catches in the west have been less than 100 t since 2009, with the exception of 101 t caught in 2011, with only four years where the catches exceed 50 t in this period (2009, 2011, 2017 and 2018) and catches as low as 10 t in 2015 and 13 t in 2020. While the western catches were not included in stock assessments conducted before 2007, the TAC has always been set for the combined eastern and western stocks. Since 2007, the recommended biological catches (RBC) used to determine the TAC (for the combined stock) is simply the sum of the RBC for the eastern stock and the RBC for the western stock. The eastern and western stocks have been managed under a single TAC, so an RBC of zero for the eastern stock in 2008 and 2009, (combined with a non-zero RBC from the western stock) still allowed a non-zero TAC to be set for the combined stock in those years, and allowed some of that TAC to be taken in the eastern part of the stock.

Jackass Morwong is also caught in small quantities in state waters off NSW and Tasmania, and by the non-trawl sector of the fishery, although these landings are not large. These non-trawl catches are relatively small, compared to catches from the trawl sector, averaging 17 t per year from 1985-1994 and less than 1 t per year since 1995. In the 2021 assessment, these non-trawl catches have been included in the catch totals, with the non-trawl catch allocated to the eastern trawl and Tasmanian trawl fleet in the same proportion as the records of the trawl catch disposal record (CDR) catches allocated to these two fleets. Previous Jackass Morwong assessments excluded CDR totals from vessels in the non-trawl sector. State catches have been added to the Commonwealth catches, with NSW state catches included in the eastern trawl fleet, Victorian state catches split equally between the eastern and western trawl fleets and Tasmanian state catches split equally between the Tasmanian and western trawl fleets. The small quantity of state catch from Victoria and Tasmania allocated to the western trawl fleet was not included in the western trawl fleet catch totals in the 2018 assessment report (Day and Castillo-Jordán, 2018b), but is included in the western trawl catch totals here (Table 8.3).

The assessment data for the eastern stock of Jackass Morwong have been separated into six ‘fleets’, which represent one or more gear, regional, or temporal differences in the fishery. In the east, 50% recruitment to the fishery occurs between three and seven years of age, depending on gear type, compared to around eight years in the west.

8.2.2 Stock Structure

Genetic studies conducted by the CSIRO have found no evidence of separate stocks of Jackass Morwong in Australian waters. New Zealand and Australian stocks are however, distinct (Elliott et al., 1992). Analysis of otolith microstructure (Proctor et al., 1992) found differences between Jackass Morwong from southern Tasmania and those off NSW and Victoria, but it is unclear if such differences indicate separate stocks. Differences among Jackass Morwong in the western and eastern zones have been suggested (D.C. Smith, MAFRI, pers. comm. 2004; I. Knuckey, Fishwell, pers. comm. 2004), and it is assumed for the purposes of this assessment that there are separate stocks of Jackass Morwong in the eastern and western zones (Wayte, 2011). Bessell-Browne et al., (2021) reviewed stock structure for three SESSF species and report that "Jackass Morwong are not genetically different between the two regions and there is no current evidence supporting differences in otolith microchemistry. Mixing of Jackass Morwong is unknown although differences in recruitment between regions suggests some separation of populations along with differences in length and age distributions. While there has been limited research at the appropriate spatial scale to determine splits in stock structure, the differences in recruitment patterns between the two regions were considered adequate to justify conducting separate assessments to the east and west."

8.2.3 Previous assessments

Smith (1989) analysed catch and effort data for the Eden fishery (1971-72 to 1983-84), finding a significant decline in catch-per-unit-effort (CPUE) to 1980. Lyle (1989) analysed logbook data for Tasmania and western Bass Strait from 1976-84. No trends were apparent in these data.

The biomass of Jackass Morwong in the eastern zone was estimated to be about 10,000 t in the mid-1980s (Smith, 1989), using a combination of trawl surveys and VPA. Age-structured modelling of the NSW component of the fishery indicated that Maximum Sustainable Yield (MSY) is approached with a fishing mortality (F) between 0.2 and 0.3 yr^{-1}, and that the fishery was at optimum levels in the mid-1980s (Smith, 1989).

At the 1993 meeting of SEFSAG, the recent age data (from the Central Ageing Facility, CAF) and length data were presented together with new age and length data from southeastern Tasmania. Estimates of total mortality from catch curve analyses were similar to previous estimates in the early 1980s. Length and age data from southeastern Tasmania were characterised by a greater proportion of larger and older fish. Preliminary ageing data from sectioned otoliths were tabled at SEFAG in 1994 which suggested that Jackass Morwong were longer lived (35 years) than previously thought (20 years). Subsequent ageing has resulted in a maximum age records of 46 years for a male and 43 years for a female (K Krusic-Golub, pers. comm., 2020).

Smith (1994) reported a range of maximum sustainable yield estimates with annual "sustainable catches" for Jackass Morwong at levels ranging from 1,150 – 3,800 t and also suggested that "the most urgent need it to fully define the stock structure in the SEF". Smith (1994) also reported estimates of maximum spawning stock biomass ranging from 40,000 t to 78,000 t.

In 1995, catch and unstandardised effort by major area in the fishery were derived from logbook records for the period 1986-94. Whereas the 1994 assessment stated that catch rates had remained relatively stable for the previous 4 years, GLM-standardized trawl catch rates exhibited a slow decline from 1987. Indeed, Smith and Wayte (2002) note that the mean unstandardised catch rate of Jackass Morwong has continued to decline, and, since 1996, has triggered AFMA's catch rate performance criterion.

An assessment in 1997 was based on the collation and analysis of catch and effort data, combined with new biological information on growth rates of Jackass Morwong. Information on length frequencies and the retained and discarded catch of Jackass Morwong was obtained from SMP data and the FRDC report by Liggins (1996). Further length-frequency data were available from NSW and Tasmanian state projects. Catch curve analysis on fish between 5 and 26 years old produced an estimate for total mortality of 0.18 yr^{-1}. This was considerably lower than previous estimates of 0.6 to 0.77 yr^{-1} and was a direct result of the "new" maximum age. It is also lower than the values obtained by applying the 1993/94 age-length key (0.3 yr^{-1}) to length composition data. Using a value for M of 0.09 yr^{-1}, a fishing mortality (F) of 0.09 yr^{-1} was estimated.

Klaer (2006) used a stock reduction analysis (SRA) method to model the population of Jackass Morwong off NSW using catch history data from 1915-61. This analysis led to a point estimate of unexploited total recruited biomass, which is larger than spawning biomass, of 29,400 t, with a 1961 stock status of 70%.

The first formal quantitative assessment of Jackass Morwong was conducted by Fay (2004) based on data to 2002, using Coleraine, an integrated stock assessment software package. It used a generalised age-structured modelling approach to assess the status and trends of the Jackass Morwong trawl fishery in the eastern zones, using data from the period 1915-2002. The 2004 assessment indicated that the spawning biomass of Jackass Morwong was between 25 – 45% of the 1915 unexploited biomass. The base-case model estimated the current spawning biomass was 37% of the unexploited biomass. The model could not adequately reconcile changes in catch rates in the late 1980s with catches during this same period.

The 2004 assessment was updated in 2006 using Coleraine with additional data that had become available since the previous assessment (Fay, 2006). Two recent (1986-2005) catch rate series were explored in the 2006 assessment. ShelfRAG originally chose to use a catch rate standardisation that was restricted to vessels which caught Jackass Morwong for at least 5 years and had a median annual catch of at least 5 t. Only shots in which at least 30 kg of Jackass Morwong were caught were included. The new standardized catch rate time series, which was chosen to be consistent with other SESSF assessments, also endeavoured to select targeted shots by selecting shots with ≥1 kg of Jackass Morwong from vessels that had reported catches of Jackass Morwong for three or more years and whose median annual catch was greater than 2 t.

Base-case estimates of stock status in 2006 when the model was fit to the ≥1 kg catch rate series indicated that the stock was at a low level, around 15% of the unexploited equilibrium state. This led to RBCs in 2007 of zero under all Tier 1 and Tier 2 harvest control rules (HCRs). If the model was fitted to the new age and length data but used the ≥30 kg catch rate index, estimates of current stock status were more optimistic, with stock status in 2006 estimated to be 35% of the unexploited state. This assessment also recommended "accounting for the western areas of the SESSF" in future assessments.

The results of the 2006 assessment were clearly sensitive to the catch and effort data used to calculate a catch rate index that is representative of changes in biomass. As the estimated population trend is primarily driven by this catch rate index, the choice of data included is key to estimates of stock status for this population. For the 2004 assessment, it was considered that a greater than 30 kg cut-off for catch and effort data was reasonable for Jackass Morwong. However, the increasing trend in the number of shots catching small amounts of Jackass Morwong from those vessels targeting the species (Day 2006) suggests that this might not be the case. The analysis by Day showed that the increase in small shots is not due to a change in reporting practices. In 2006, ShelfRAG decided to use the ≥ 1 kg catch rate as input to the base-case, as this was the more precautionary approach, no evidence against using this series was presented, and it is consistent with the approach used for other SESSF assessments.

The 2007 base-case assessment (Wayte and Fay, 2007) for the eastern stock estimated that the 2008 spawning stock biomass was 19% of unexploited stock biomass. This assessment was largely driven by the recent catch rate indices, which indicated a 70% decline in the stock over the last 20 years. The age and length data when fitted in the absence of the catch rate indices did not indicate the same magnitude of decline. In order to fit the catch rate indices, the model estimated that recruitments were largely below average in the last 25 years, although there was some evidence for an above average recruitment in 2003. Stock status across all sensitivities varied between 11% and 28%.

A preliminary assessment for the western stock in 2007 indicated that the stock had declined in recent years as fishing pressure has increased, but spawning stock biomass was 63%, still considerably higher than the target level. The long-term RBCs estimated for the western stock were comparable with the 2007 catch levels. The single RBC calculated for Jackass Morwong (combining the east (0 t) and west (297 t) stocks) was 297 t (using the 20:40:48 control rule), with this RBC coming entirely from the western part of the stock. The TAC was set allowing for unavoidable bycatch of Jackass Morwong in the east.

The 2008 base-case assessment for the eastern stock (Wayte and Fay, 2009) estimated that the 2009 spawning stock biomass was 19% of unexploited stock biomass. The 2007 assessment had estimated good recruitments for both 2003 and 2004. However, the limited amount of 2007 data used in the 2008 assessment did not support the high 2004 recruitment estimate. Several data types were not available for 2007, and, for the data that were available, sample sizes were lower than in previous years. The 2008 CPUE indices indicated that the stock abundance was unchanged from the previous year.

The 2008 base-case assessment for the western stock (Wayte and Fay, 2009), was still considered to be preliminary, due to limited data, and estimated that the 2009 spawning stock biomass was 68% of unexploited stock biomass. The single RBC calculated for Jackass Morwong (combining the east (0 t) and west (381 t) stocks) was 381 t (using the 20:35:48 control rule), with this RBC coming entirely from the western part of the stock.

The 2009 assessment (Wayte, 2010) estimated recruitment deviations up to four years before the end of the data instead of two years as in previous assessments. This change was made because it was recognised that fish spawned two and three years before the end of the data will not be well-represented in the data, and this problem had been compounded in the years leading up to the 2009 assessment by poor data collection. The eastern trawl CPUE index showed a slight increase, and the 2003 recruitment continued to be estimated as above average – leading to a slight recovery in the current status of the stock to above the limit reference level (24%). Catch rates had declined in recent years, despite lower catches than in the past. To reconcile this information the 2009 base-case assessment estimated recruitments to have been consistently below average since the early 1980s. The 2009 assessment examined two other possible reasons for this decline: that recruitment is more closely related to stock size than previously assumed (i.e. steepness is lower); or that a regime shift has occurred. Both these models led to a better fit to the data than the base-case, but neither were accepted as a new base-case. The best estimate of lower steepness was considered to be unrealistically low for a Perciforme species such as Jackass Morwong (Myers et al 1999). The regime shift model gave a more optimistic picture of current stock status than the other models, because it revised down the estimate of unfished equilibrium spawning stock biomass, but the estimate of sustainable long-term catch was also greatly reduced. It was considered that more evidence for the existence of a regime shift was required before this model was considered plausible.

The 2009 base-case assessment for the western stock (Wayte, 2010), was considered to be increasingly uncertain, with no recent length frequency data (for 2007 and 2008), and estimated that the 2010 spawning stock biomass was 70% of unexploited spawning stock biomass. The single RBC calculated for Jackass Morwong (combining the east (143 t) and west (367 t) stocks) increased to 510 t, with this RBC coming from both the eastern and western part of the stock.

The 2010 base-case assessment for the eastern stock (Wayte, 2010) estimated that current spawning stock biomass was 26% of unexploited stock biomass. Concern was expressed that catches in the east had remained above the eastern component of the (combined) RBC. The western stock assessment continued to be considered as increasingly uncertain, with no recent length frequency data (for 2007-2009). Catches of Jackass Morwong in the Great Australian Bight (GAB) were found to be at a similar level to western Jackass Morwong catches, but it is not known whether the GAB Jackass Morwong form a separate stock and these GAB catches were not included in the western Jackass Morwong assessment.

In 2010 the RAG decided to include both port and onboard retained length frequency data (for both historic and current years) in future assessments, whereas previously only port data had been used. The 2010 assessment was run with this change in length frequency data (as well as any other changes to the data up to 2009), and very little change to the assessment result was seen.

The 2010 base-case assessment for the western stock (Wayte, 2010), continued to be considered increasingly uncertain, with no recent length frequency data (for 2007-2009), and estimated that the current spawning stock biomass was 70% of unexploited stock biomass. The single RBC calculated for Jackass Morwong (combining the east (228 t) and west (329 t) stocks) increased to 557 t, with this RBC coming from both the eastern and western part of the stock.

At the ShelfRAG meeting on October 3-4, 2011, an alternative base-case assuming that eastern Jackass Morwong has undergone a shift to lower recruitment was presented and accepted and was used as the base-case for the eastern assessment (Wayte, 2011). The justification for this switch is well described in Wayte (2011), including MSE testing implications of assuming (or not) the recruitment shift. The western assessment used the same assumptions as in previous years (no recruitment shift).

The 2011 base-case assessment for the eastern stock (Wayte, 2011) accepted that there was a productivity shift for the eastern stock of Jackass Morwong and estimated that current spawning stock biomass was 35% of 1988 equilibrium stock biomass.

The 2011 base-case assessment for the western stock (Wayte, 2011), continued to be considered increasingly uncertain, with no recent length frequency data (for 2007-2010), and estimated that the current spawning stock biomass was 67% of unexploited stock biomass. The single RBC calculated for Jackass Morwong (combining the east (358 t) and west (282 t) stocks) increased to 640 t, with this RBC coming from both the eastern and western part of the stock.

The 2015 base-case assessment for the eastern stock (Tuck et al., 2015a) estimated that current spawning stock biomass (i.e. to the beginning of 2016) was 37% of 1988 equilibrium stock biomass. The western stock assessment (Tuck et al., 2015b) continued to be considered as increasingly uncertain, with no length frequency data for 2007-2010, limited age data, low samples size for length compositions, very low catches and conflict between the length and catch rate data. In this assessment, growth parameters were not estimated, and instead were fixed at the values estimated from the eastern assessment. The current spawning stock biomass (i.e. to the beginning of 2016) was estimated to be 69% of unexploited stock biomass. The single RBC calculated for Jackass Morwong (combining the east (314 t) and west (249 t) stocks) increased to 563 t, with this RBC coming from both the eastern and western part of the stock.

The 2018 base-case assessment for the eastern stock (Day and Castillo-Jordán, 2018a) estimated that current spawning stock biomass (i.e. to the beginning of 2019) was 35% of 1988 equilibrium stock biomass. The western stock assessment (Day and Castillo-Jordán, 2018b) continued to be considered as increasingly uncertain, with poor fits to the CPUE index (and concerns about whether this index was tracking abundance), unrepresentative sampling and generally poor data quality and quantity, limited age data, low samples size for length compositions, very low catches, conflict between fits to the length and age data and the fits to the catch rate data. In this assessment, growth parameters were not estimated, and instead were fixed at the values estimated from the eastern assessment and retrospective patterns that warranted further attention. The current spawning stock biomass (i.e. to the beginning of 2019) was estimated to be 68% of unexploited stock biomass. The single RBC calculated for Jackass Morwong (combining the east 261 t) and west (235 t) stocks) increased to 496 t, with this RBC coming from both the eastern and western part of the stock.

8.2.4 *Modifications to the previous assessments*

The 2021 assessment uses Stock Synthesis version SS-V3.30.17.00, (Methot et al., 2021), updated from version SS-V3.30.12 (Methot et al., 2021) that was used in the 2018 assessment. New catch, discard, length and conditional age at-length data is available from the three-year period from 2018-2020. In addition to these new and updated data, there are updated standardised CPUE series for the eastern (Zones 10 and 20) and Tasmanian (Zone 30) trawl fleets, each with three additional data points and updated estimates for the ageing error matrix.

8.2.4.1 Data-related notes

1. Length-frequency data are included separately for onboard and port data by fleet. Port and onboard fleets share a single selectivity pattern.
2. Length frequency data are weighted by shot or trip numbers rather than numbers of fish measured. A cap of 100 trips and 200 shots was used to set an upper limit on the sample size.
3. There are five CPUE time series, with the oldest dating back to 1920 (steam trawl) and the most recent time series derived from logbook data for otter trawl, separated into Eastern trawl (SESSF Zones 10 and 20) and Tasmanian trawl (SESSF Zone 30).
4. State catches have been added to catches from the appropriate fleets.
5. The ageing error matrix has been updated.
6. Catch, discard, length-composition, age-at-length, and catch rate data have been added for the period 2018-2020. The historical catch series (from 1986-2017) was also revised to incorporate changes in the catch database.

8.2.4.2 Model-related notes

1. Growth is assumed to follow a von Bertalanffy type length-at-age relationship, with all four growth parameters estimated separately, based primarily on the age-at-length data from fish that were measured and aged from extracted otoliths.

2. Natural mortality, *M*, is fixed (0.15) in the model.
3. Recruitment residuals are estimated from 1945-2015, with the last recruitment event estimated five years before the most recent available data.
4. An updated tuning procedure is used to balance the weighting of each of the data sources that contribute to the overall likelihood function, using the method of Francis (2011) for weighting length data and the method of Punt (2017) for weighting age data. The CPUE series is balanced within Stock Synthesis, by estimating additional variance to each CPUE series, and improvements have been incorporated in the treatment of recruitment variance (σ_R) and the recruitment bias ramp adjustment.
5. Discard rates for Tier 1 assessments are required by fishing fleet. This means that the discard estimates for TAC purposes used for Tier 3 and 4 assessments which are provided in the discard report (Deng et al., 2021) cannot be used in Tier 1 assessments. The discards from Deng et al. (2021) are produced using a set of rules to determine, for the entire quota fishery, whether sufficient data are available to make an annual fishery wide discard estimate. The discard rates calculated for and input to Tier 1 stock assessments are used to fit retention selectivity curves, so individual year values are not greatly influential on model estimated discard rates.
6. The Tier 1 discard estimates have been updated in 2021 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 CDR landings within zone and season (N. Klaer, pers. comm.).

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 by Day and Bessell-Browne (2021).

8.3 Methods

8.3.1 *The data and model inputs*

The 2021 base case assessment of Jackass Morwong uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (Version 3.30.17.00, Methot et al. (2021)). The methods utilised in Stock Synthesis are based on the integrated analysis paradigm. Stock Synthesis can allow for multiple seasons, areas and fleets, but most applications are based on a single season and area. Recruitment is governed by a stochastic Beverton-Holt stock-recruitment relationship, parameterised in terms of the steepness of the stock-recruitment function (h), the expected average recruitment in an unfished population (R_0), and the degree of variability about the stock-recruitment relationship (σ_R). Stock Synthesis allows the user to choose among a large number of age- and length-specific selectivity patterns. The values for the parameters of Stock Synthesis are estimated by fitting to data on catches, catch-rates, discard rates, discard and retained catch length-frequencies, and conditional age-at-length data. The population dynamics model and the statistical approach used in fitting the model to the various data types are given in the SS technical documentation (Methot, 2005).

The base case model includes the following key features:

A single region, single stock model is considered with six fleets. Selectivity is modelled separately for each fleet, with selectivity patterns assumed to be length-specific and logistic. The parameters of the selectivity function for each fleet were estimated within the assessment.

The model does not account for males and females separately and fits one growth curve across both sexes.

The initial and final years are 1915 and 2020.

8.3.1.1 Biological parameters

A single-sex model (i.e. both sexes combined) was used, which assumes growth and other biological parameters do not vary between males and females in the population.

Age-at-length data was used as an input, and all four parameters of the von Bertalanffy growth equation were estimated within the model fitting procedure. This is more appropriate than pre-specifying these values because it accounts for the impact of gear selectivity on the age-at-length data collected from the fishery and the impact of ageing error.

As in the 2018 assessment, M was fixed in the model at 0.15, and assumed to be time invariant and independent of age. The base-case value for the steepness of the Beverton-Holt stock-recruitment relationship, h, is fixed at 0.7.

Growth is assumed to follow a von Bertalanffy length-at-age relationship, with the parameters of the growth function estimated together for females and males inside the assessment model.

Jackass Morwong become sexually mature at a length of about 24.5 cm, when the fish are around four years of age. Maturity is modelled as a logistic function, with 50% maturity at 24.5 cm fixed in the assessment. Fecundity-at-length is assumed to be proportional to weight-at-length. The parameters of the length-weight relationship are obtained from Smith and Robertson (1995) (a=1.7 × 10^{-5}, b=3.031).

8.3.1.2 Fleets

The assessment data for the eastern stock of Jackass Morwong have been separated into six '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 (Wayte, 2011). The six fleets are:

1. Eastern trawl – otter trawlers from NSW, eastern Victoria and Bass Strait (1986 – 2020)
2. Danish seine – Danish seine from NSW, eastern Victoria and Bass Strait (1986 – 2020)
3. Tasmanian trawl – otter trawlers from eastern Tasmania (1986 – 2020)
4. Steam trawl – steam trawlers (1915 – 1961)
5. Early Danish seine – Danish seine (1929 – 1967). These landings may include a small amount of motor trawl catches.
6. Mixed – mixed Danish seine and diesel trawl catch (1968 – 1985).

8.3.1.3 Landed catches

The model uses a calendar year for all catch data. Annual landed catches by fleet used in this assessment are shown in Figure 8.1, Figure 8.2 and listed in Table 8.1, Table 8.2 and Table 8.3, which also includes the catches for the western trawl fleet, used only in the western Jackass Morwong assessment which has not been updated since 2018 (Day and Castillo-Jordán, 2018b).

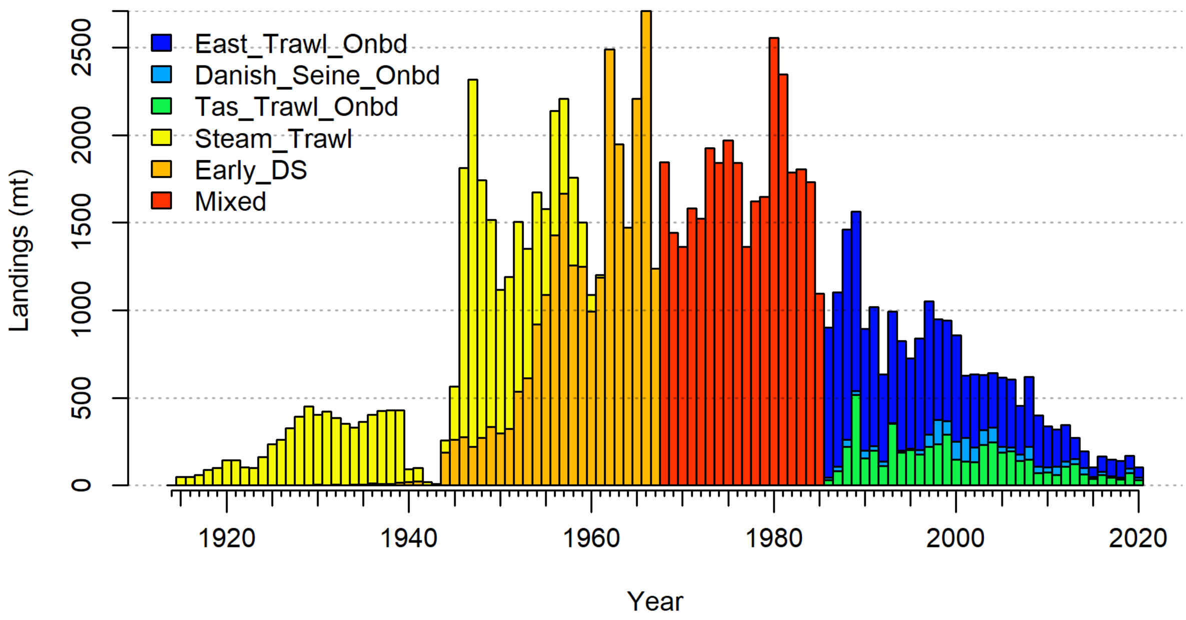


Figure 8.1. Total landed catch (tonnes) of eastern Jackass Morwong by fleet (stacked) from 1915-2020.

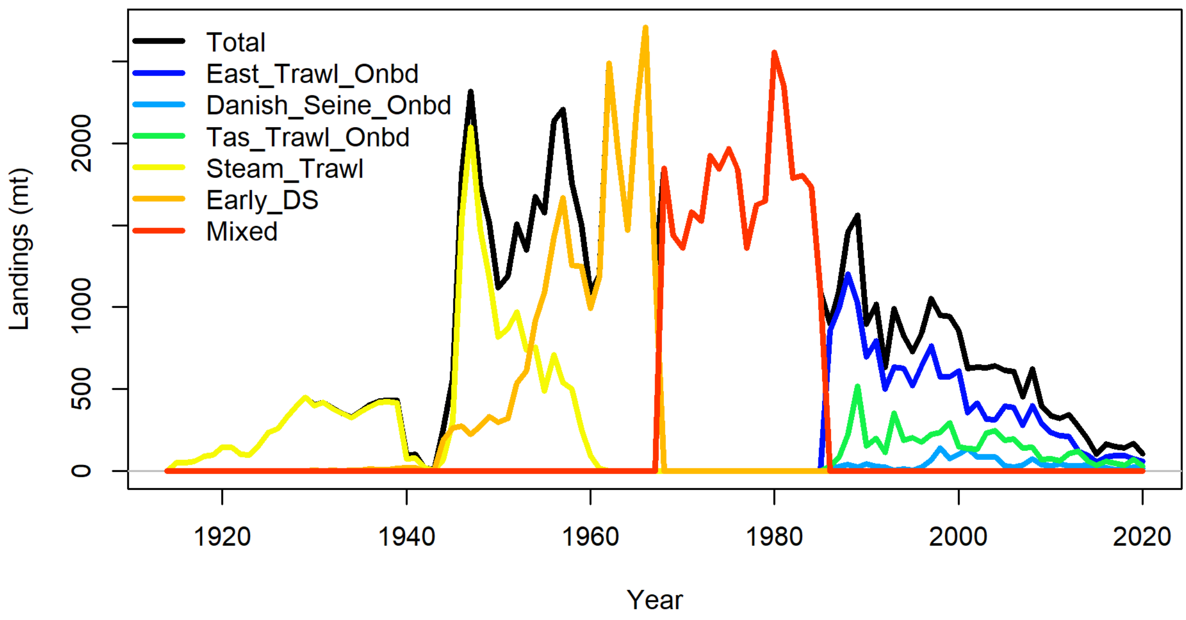


Figure 8.2. Total landed catch of eastern Jackass Morwong by fleet from 1915-2020.

Table 8.1. Total retained catches (tonnes) of eastern Jackass Morwong by steam trawlers and early Danish seine vessels, 1915–1967.

Year	Steam trawl trawl	Early Danish seine	Year	Steam trawl trawl	Early Danish seine
1915	49		1942	20	0
1916	50		1943	2	5
1917	58		1944	67	189
1918	89		1945	305	260
1919	99		1946	1538	275
1920	145		1947	2096	221
1921	143		1948	1472	273
1922	102		1949	1182	334
1923	98		1950	819	299
1924	162		1951	867	322
1925	235		1952	971	535
1926	259		1953	740	612
1927	327		1954	754	920
1928	391		1955	489	1088
1929	449	1	1956	709	1430
1930	398	4	1957	540	1668
1931	420	0	1958	501	1257
1932	380	5	1959	253	1249
1933	352	0	1960	95	993
1934	326	4	1961	16	1185
1935	361	3	1962		2489
1936	390	12	1963		1950
1937	419	8	1964		1472
1938	421	9	1965		2210
1939	413	17	1966		2709
1940	74	18	1967		1237
1941	79	21			

Klaer (2006) used a compilation of catch data from historical steam trawlers (Klaer and Tilzey, 1996) to recreate a catch history for Jackass Morwong for this sector of the fishery from 1915 to 1961 (Table 8.1). Estimates of total annual landings of Jackass Morwong from the eastern zones by Danish seine vessels during 1929-67 (Table 8.1), and the mixed fleet during 1968-85 (Table 8.2) were compiled from Klaer (2006) and Allen (1989).

The landings for the 'early Danish seine' fleet may include some catches from small motor trawlers which began to appear in the fishery in about 1954 (Blackburn, 1978), but it is believed that these catches are small in comparison to the Danish seine catches (N. Klaer, pers. comm., 2012).

The 'mixed' fleet consisted primarily of Danish seine vessels until the mid-1970s when the first modern otter diesel trawlers entered the fishery (Klaer, 2006), but no separation of landings by gear type is available for this period. For the purposes of this assessment, therefore, landings during 1968-85 were treated as coming from one fleet with a single selectivity pattern.

Table 8.2. Total retained catches (tonnes) of eastern Jackass Morwong by the mixed fleet of Danish seine and diesel trawlers, 1968 – 1985.

Year	mixed
1968	1846
1969	1442
1970	1362
1971	1582
1972	1525
1973	1925
1974	1843
1975	1969
1976	1841
1977	1361
1978	1624
1979	1649
1980	2556
1981	2347
1982	1789
1983	1806
1984	1733
1985	1096

The landings for the more recent years (eastern trawl, Danish seine, Tasmanian trawl and western trawl) (Table 8.3) are extracted from the SESSF logbook database, CDRs and state catches. Quotas were introduced into the fishery in 1992 (Table 8.8), and from then onwards, both CDRs and estimated catches from the logbook are available. The CDRs give a more accurate measure of the landed catch than the logbook data, but the logbook data contain detail on the relative catch by gear type. It is usually possible to separate logbook records by fleet, but CDRs cannot be separated 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. 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. The total catch for the 2008 calendar year was 708 t which was larger than the actual 2008-09 TAC of 641 t. In 2008, catches were high in January-April. These months are part of the 2007-08 quota year.

Small totals of Jackass Morwong are caught in state waters. In previous assessments, NSW trawl and trap catches were added to the eastern trawl fleet, Tasmanian state catches were added to the Tasmanian trawl fleet, and the small quantities of Victorian state catches were excluded as they were thought to be "negligible and questionable" (S. Wayte, pers. comm., 2012). Victorian state catches have now been included in catch totals in this assessment, added to the eastern trawl fleet from 2000 onwards and added to the western trawl fleet from 1994 onwards. In this assessment, NSW state catches (both trap and trawl) are still included in the catch for the eastern trawl fleet. Data processing changes resulted in the Victorian and Tasmanian state catches being split into eastern and western components for the 2021 assessment, with the assumption that these catches should be allocated equally between the appropriate eastern fleets (eastern trawl fleet for the Victorian catch and Tasmanian trawl fleet for the Tasmanian state catch) and the western fleet (western trawl fleet).

Table 8.3. Total retained catches (tonnes) from 1986 – 2020 of Jackass Morwong (east and west) for: the eastern trawl fleet (Commonwealth catches in SESSF zones 10 and 20 plus NSW state catches and eastern Victorian state catches); the Tasmanian trawl fleet (Commonwealth catches in eastern Tasmania plus eastern Tasmanian state catches); the Danish seine fleet in Bass Strait/eastern Victoria and NSW (with discards added into the catch totals for this fleet); the total for these three eastern fleets; the western trawl fleet (Commonwealth catches in western Tasmania and western Victorian and western Tasmanian state catches included – the 2018 assessment excluded estimated western trawl state catches);total Commonwealth catches (excluding discards); total state catches (excluding discards) and the TAC (combined eastern and western stocks) from 1992 – 2021.

Year	eastern trawl	Danish seine	Tas trawl	Total (eastern)	western trawl	Commonwealth (east + west) (no discards)	state (east + west) (no discards)	TAC
1986	858	13	31	902	153	813	88	
1987	993	26	82	1101	60	1014	85	
1988	1201	39	221	1462	67	1372	86	
1989	1024	23	516	1563	85	1521	41	
1990	697	44	153	894	83	855	36	
1991	793	28	198	1018	47	977	39	
1992	500	23	112	635	72	586	47	1500
1993	635	5	351	991	27	939	53	1500
1994	626	10	188	824	27	745	78	1500
1995	519	5	203	727	99	657	69	1500
1996	640	25	175	840	50	742	92	1500
1997	763	67	221	1051	70	931	95	1500
1998	577	139	234	950	73	811	72	1500
1999	576	74	292	941	97	844	55	1500
2000	610	101	147	858	139	745	60	1200
2001	356	136	135	627	326	494	69	1185
2002	416	84	133	633	294	560	37	950
2003	315	85	230	629	204	544	33	960
2004	313	84	245	642	223	539	40	960
2005	395	32	187	614	239	569	40	960
2006	389	22	196	606	222	560	43	1200
2007	279	35	141	454	144	427	12	878
2008	401	75	146	621	124	581	9	560
2009	292	38	69	400	80	376	7	450
2010	233	31	72	336	49	321	5	450
2011	215	44	61	320	101	307	3	450
2012	210	29	107	346	42	326	8	568
2013	119	31	120	270	43	250	5	568
2014	96	35	64	195	14	167	4	568
2015	56	11	37	103	10	91	7	598
2016	87	19	58	164	31	145	7	474
2017	93	9	45	147	90	128	14	513
2018	95	12	33	141	54	129	5	505
2019	74	23	72	169	31	146	9	469
2020	60	14	29	103	13	86	8	468
2021								463

Ideally, the Victorian and Tasmanian state catches would be split in a proportion that better reflects the catch by region (perhaps in a future assessment), as around 95% of the Tasmanian state catch is thought to be taken from eastern Tasmania, east of longitude 147° East (F. Seaborn, pers. comm., 2021). Given Tasmanian state catches have only averaged 5.5 t per year since 1995 (and only 2 t per year since 2008), and Victorian state catches have averaged 0.1 t per year since 1994, the effects of changing the allocation of the catch east and west of longitude 147° East are likely to be minimal.

Since the 2018 assessment, the catch history has been revised from 1986 onwards to incorporate several minor changes to the catch history. These include revisions to the filtering of records and allocations of catches to fleets from the Commonwealth logbook records in the period 1986-2020. Non-trawl CDRs were also incorporated into the catch history for the period 1985-2020, allocated to the eastern and Tasmanian trawl fleets in the same proportion as the logbook catches from those fleets for each year with non-trawl CDR data. Catches from the Danish seine fleet include estimates of discards (as retention is not estimated for this fleet), so revisions to the discard rate estimates in this period resulted in revisions to the Danish seine catch history from 1986-2017. Victorian state catches were added to the catch history for the period 1994-2015 (Althaus et al., 2021), with average catches of 0.1 t in that period, with half of these annual catch totals allocated to the eastern trawl fleet and half to the western trawl fleet (which is not used in this eastern Jackass Morwong assessment). Victorian state catches from 1986-1993 were not incorporated in this catch history as they were considered to be “negligible and questionable” (S. Wayte, pers. comm, 2012). Tasmanian state catches were added from 1995-2020 (Althaus et al., 2021), again with half of these annual catch totals allocated to the Tasmanian trawl fleet and half to the western trawl fleet. The allocation of Victorian and Tasmanian state catches to eastern and western fleets could be reviewed in future assessments, either to match the allocation from earlier assessments, or to match a better estimate of the split of the catches east and west of longitude 147° East, but the effects on the assessment results from any changes to these proportions would be minor given the size of these catches.

NSW state catch records from 1986-1999 were determined by Kevin Rowling and Sally Wayte (Wayte, 2012) to address issues relating to potential double counting of catches recorded NSW state and Commonwealth waters in that period, and these catches have not been modified. NSW state catch records from 2000-2020 were obtained from Althaus et al. (2021). Catches from the NSW trap fishery were added to the eastern trawl fleet for the period 1986-2006 (S. Wayte, pers. comm.).

In order to calculate the RBC for 2022, it is necessary to estimate the catch for 2021. Without any other information, the 2021 catch is assumed to be identical to the 2020 catch. The recent TAC history, which applies to the combined eastern and western stocks, is also listed in Table 8.3, alongside the total catches (Commonwealth plus state) of the western stock of Jackass Morwong. The percentage of the total catch taken in the west is quite variable, averaging around 20% since 2000, but ranging from 7% (in 2014) to 38% in 2017. Total catches (excluding discards) are listed separated into catches by Commonwealth and by state (with catches from all states combined) in Table 8.3. The percentage of the total catch since 1986 which is caught by state registered vessels averages 6%, declining to an average of 5% since 2001.

8.3.1.4 Discard rates

Information on the discard proportions of Jackass Morwong by fleet is available from the ISMP for 1994-2021, for the eastern and Tasmanian trawl fleets. This program was run by PIRVic from 1992-2006 and by AFMA from 2007 onwards. These data are summarised in Table 8.4. Discard rates were estimated from onboard data which gives the weight of the retained and discarded component of those shots that were monitored (Deng et al., 2021). Discard proportions vary amongst years and have been as high as 28% in 2012 for the Tasmanian Trawl and 35% in 2020 for the eastern trawl.

Table 8.4. Discard proportions for eastern trawl and Tasmanian trawl fleets from 1993 to 2021 with sample sizes for each data point. Entries in grey indicate data that are not used either due to small sample size (less than 10 samples) or because the value is too close to zero (less than 0.01).

Year	eastern trawl	n	Tas trawl	n
1992	1.0000	1		
1993	0.0622	167	0.0068	34
1994	0.0536	291	0.0744	25
1995	0.0998	123		
1996	0.0951	235	0.0134	30
1997	0.0720	414	0.0146	21
1998	0.0347	208	0.0463	53
1999	0.0219	238	0.1318	79
2000	0.0294	220	0.0030	32
2001	0.0272	295	0.0139	44
2002	0.0032	233	0.0302	12
2003	0.0241	242	0.0105	15
2004	0.1593	220	0.0608	30
2005	0.1263	338	0.0930	29
2006	0.1133	246	0.1656	82
2007	0.0002	75		
2008	0.0162	174	0.0000	8
2009	0.0370	89	0.0062	9
2010	0.0160	88	0.0352	24
2011	0.1364	81	0.0331	36
2012	0.0397	56	0.2780	45
2013	0.0803	54	0.0252	34
2014	0.0689	53	0.0359	23
2015	0.0350	57	0.0176	48
2016	0.0323	40	0.2471	49
2017	0.0681	64	0.0393	36
2018	0.0825	63	0.0423	15
2019	0.1850	92	0.0663	60
2020	0.3481	32	0.1440	39

Discard practices can be variable between years for reasons that are difficult to model, such as changes in market demands or issues with quota availability, with some years having very low discard rates and others having considerable discard rates. Without a mechanism to explain these years of very low discarding, discarding practices are assumed to be constant through time. Including those years with very low discard rates forces the model to fit very low discard rates to all years, due to the low absolute variation associated with low discard rates, even those years when discarding is known to be higher, and underestimates discarding over all years. As a result, years with very low discard proportions (less than 1%) are excluded as inputs to stock synthesis (the greyed figures in the proportion columns in

Table 8.4) giving more believable estimates of discarding in general. Note that any annual discard estimate coming from a sample size of less than 10 is also excluded as it is unlikely to be representative of typical discarding practices.

Observations were then used to estimate discard rates, for each fleet (Figure 8.3) and hence discarded catches for each fleet (Figure 8.4, Figure 8.5), with estimated discard rates between 4% and 9% for the eastern trawl fleet and between 4% and 6% for the Tasmanian trawl fleets.

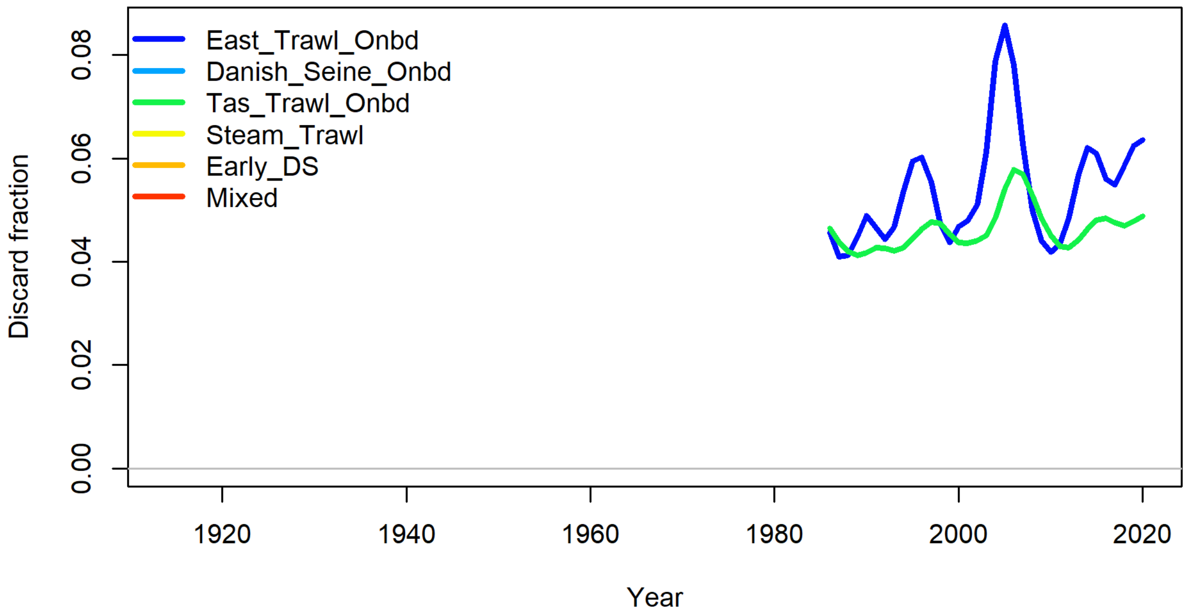


Figure 8.3. Model estimates of discard fractions by fleet, eastern trawl (blue) and Tasmanian trawl (green).

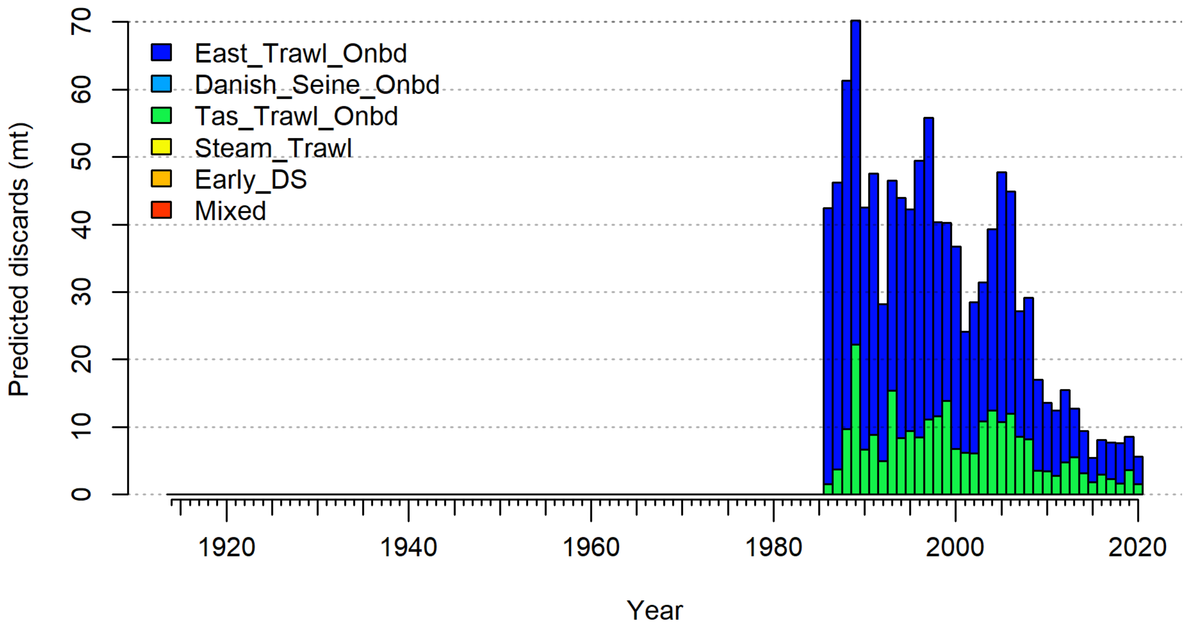


Figure 8.4. Estimated discards (tonnes, stacked) of eastern Jackass Morwong in the SESSF from 1986-2020, eastern trawl (blue) and Tasmanian trawl (green).

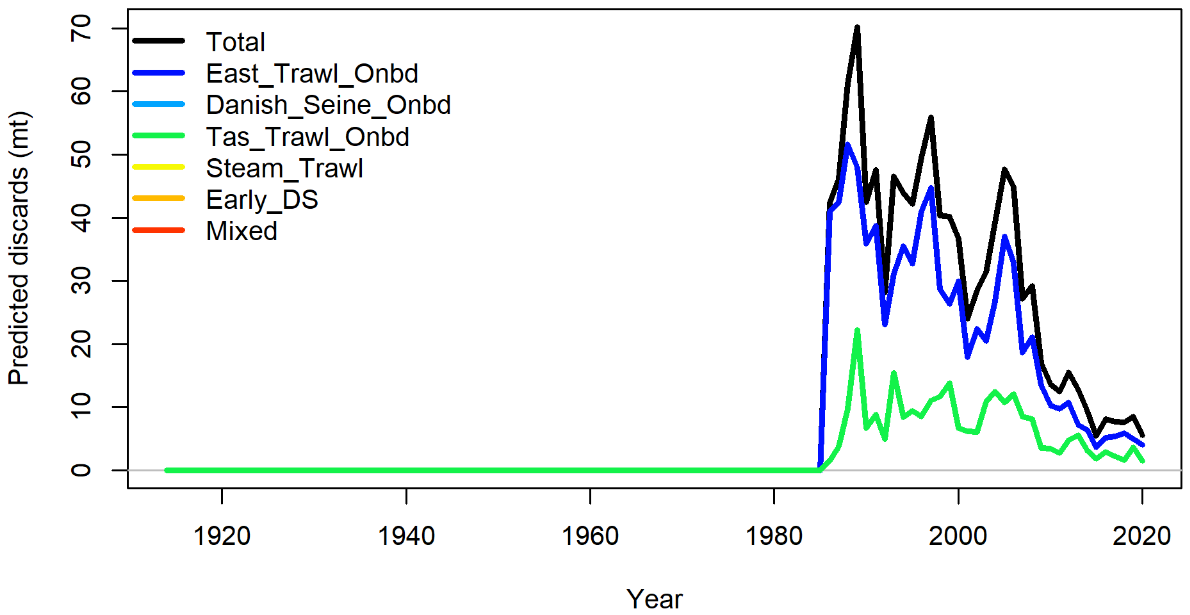


Figure 8.5. Estimated discards (tonnes) of eastern Jackass Morwong in the SESSF from 1986-2020, eastern trawl (blue) and Tasmanian trawl (green). combined total (black).

8.3.1.5 Catch rate and FIS abundance indices

A standardised catch rate (CPUE) index is available for the historical steam trawl fleet for the years 1920-21, 1937-42, and 1952-57 (Klaer, 2006; Table 8.5). Smith (1989) presented a standardised catch rate index for Jackass Morwong for 1948-66 Table 8.6). This index standardises for gear type during a period of overlap between the steam trawl fishery and the onset of Danish seine vessels. Smith (1989) also provided a standardised CPUE index for all vessels for the period 1977-84 (Table 8.7). This index corresponds to the mixed fleet.

Catch and effort data from the SEF1 logbook database were standardised using GLMs to obtain indices of relative abundance (Sporcic 2021a; Table 8.5) from the period 1986-2020 for the eastern and Tasmanian trawl fleets. In the stock synthesis assessment, the coefficient of variation is initially set at a value equal to the root mean squared deviation from a loess fit (Sporcic, 2021b) and additional variance is estimated for this CPUE index to tune the input and output variances.

Table 8.5. Standardised catch rate indices and coefficient of variation Standardised catch rates for the steam trawl fleet.

Year	Catch rate	cv
1920	1.54	0.15
1921	1.09	0.15
1937	1.25	0.15
1938	1.06	0.15
1939	1.14	0.15
1940	1.35	0.15
1941	1.12	0.15
1942	0.96	0.15
1952	0.98	0.15
1953	0.79	0.15
1954	0.82	0.15
1955	1.02	0.15
1956	0.89	0.15
1957	0.84	0.15

Table 8.6. Standardised catch rate indices and coefficient of variation calculated by Smith (1989) for the overlap years of the early Danish seine fleet and the steam trawl fleet.

Year	Catch rate	cv
1948	123.7	0.17
1949	105.4	0.17
1950	84.4	0.17
1951	74.2	0.17
1952	92.8	0.17
1953	116.1	0.17
1954	92.6	0.17
1955	71.6	0.17
1956	99.2	0.17
1957	90.1	0.17
1958	63.3	0.17
1959	79.3	0.17
1960	77.6	0.17
1961	85.0	0.17
1962	79.7	0.17
1963	89.5	0.17
1964	89.8	0.17
1965	89.6	0.17
1966	82.4	0.17

Table 8.7. Standardised catch rate indices and coefficient of variation calculated by Smith (1989) for the overlap years of the steam trawl fleet and the early Danish seine fleet.

Year	Catch rate	cv
1977	19.7	0.15
1978	20.3	0.15
1979	18.9	0.15
1980	17.1	0.15
1981	19.6	0.15
1982	16.3	0.15
1983	13.9	0.15
1984	16.4	0.15

Table 8.8. Standardised catch rate indices and coefficient of variation (Sporcic, 2021a) for eastern and Tasmanian trawl fleets fleet for eastern Jackass Morwong and the FIS2 abundance indices (Sporcic et al, 2019). The coefficient of variation is initially set at a value equal to the root mean squared deviation from a loess fit (Sporcic, 2021b).

Year	eastern trawl		Tas trawl		eastern FIS		TAS FIS	
	Catch rate	cv	Catch rate	cv	Catch rate	cv	Catch rate	cv
1986	2.159	0.143	2.009	0.367				
1987	2.618	0.143	2.248	0.367				
1988	2.457	0.143	3.064	0.367				
1989	2.334	0.143	3.884	0.367				
1990	1.963	0.143	2.805	0.367				
1991	1.800	0.143	1.889	0.367				
1992	1.461	0.143	2.097	0.367				
1993	1.558	0.143	1.679	0.367				
1994	1.356	0.143	1.163	0.367				
1995	1.244	0.143	1.153	0.367				
1996	1.128	0.143	1.097	0.367				
1997	1.251	0.143	1.197	0.367				
1998	1.009	0.143	1.176	0.367				
1999	1.013	0.143	1.401	0.367				
2000	0.863	0.143	0.862	0.367				
2001	0.594	0.143	0.545	0.367				
2002	0.664	0.143	0.447	0.367				
2003	0.528	0.143	0.596	0.367				
2004	0.523	0.143	0.446	0.367				
2005	0.633	0.143	0.338	0.367				
2006	0.774	0.143	0.416	0.367				
2007	0.749	0.143	0.588	0.367				
2008	0.948	0.143	0.597	0.367	11.695	0.098	98.878	0.200
2009	0.860	0.143	0.415	0.367				
2010	0.587	0.143	0.459	0.367	10.471	0.098	50.073	0.200
2011	0.587	0.143	0.314	0.367				
2012	0.574	0.143	0.415	0.367	7.695	0.098	55.575	0.200
2013	0.477	0.143	0.456	0.367				
2014	0.355	0.143	0.240	0.367	4.854	0.098	23.518	0.200
2015	0.298	0.143	0.147	0.367				
2016	0.342	0.143	0.161	0.367	6.452	0.098	4.989	0.200
2017	0.406	0.143	0.176	0.367				
2018	0.333	0.143	0.138	0.367				
2019	0.272	0.143	0.247	0.367				
2020	0.283	0.143	0.139	0.367				

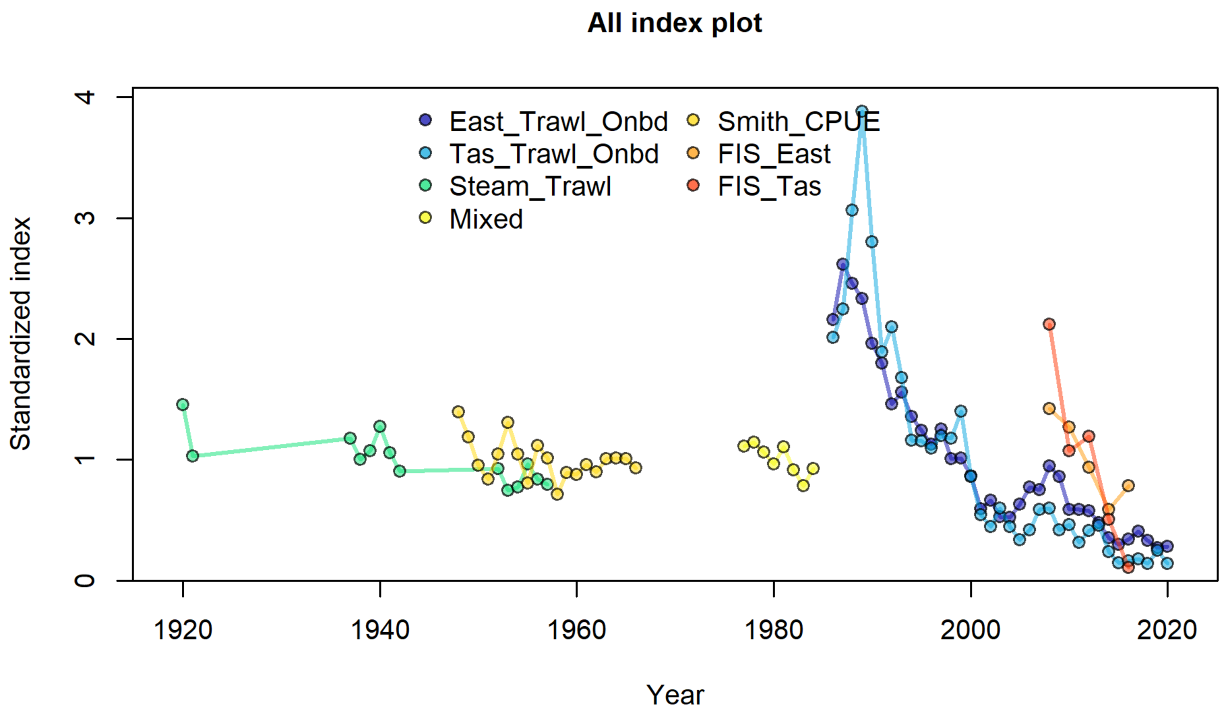


Figure 8.6. All seven CPUE and abundance series plotted on a normalised scale (mean of each series equals 1), enabling comparison of trends between time series.

The restrictions used in selecting data for analysis for eastern trawl fleet were: (a) vessels had to have been in the fishery for three or more years, (b) the catch rate had to be larger than zero, (c) catches in SESSF zone 10 and 20 only and (d) catches in between 70 and 300 m depth.

The restrictions used in selecting data for analysis for Tasmanian trawl fleet were: (a) vessels had to have been in the fishery for three or more years, (b) the catch rate had to be larger than zero, (c) catches in SESSF zone 30 only and (d) catches in between 70 and 300 m depth.

Abundance indices for eastern Jackass Morwong for the FIS2 surveys (Sporcic et al, 2019) conducted between 2008 and 2016 are provided in Table 8.8. The FIS2 indices are updated from the FIS1 indices used in the 2018 assessment and are conditioned on more appropriate logbook data from a period after the SESSF structural adjustment in 2007. FIS1 abundance values are reported for all years for Jackass Morwong for the whole fishery (east and west, Knuckey et al., 2015, Knuckey et al., 2017), but are separated into zones reflecting the fleets used in Tier 1 assessments in 2016 for both FIS1 and FIS2 series in Sporcic et al. (2019). The FIS2 abundance series for eastern and Tasmanian Jackass Morwong (Sporcic et al., 2019) are listed in Table 8.8. As with the CPUE indices (Sporcic, 2021b), the coefficient of variation is initially set at a value equal to the root mean squared deviation from a loess fit (Sporcic et al, 2019) and additional variance is estimated for this abundance index to tune the input and output variances.

All seven CPUE and abundance indices are plotted on the same normalised scale for easy comparison in Figure 8.6.

8.3.1.6 Length composition data

Port and onboard length composition data are both used separately, with the gear selectivity estimated jointly from both port and onboard data, as is the standard practice in the SESSF stock assessments. For onboard data, the number of shots, is considered to be more representative of the information content in the length frequencies than the number of fish measured. For port data, the number of shots is not available, but the number of trips can be used instead. In the 2021 assessment, the initial sample size associated with each length frequency in the assessment is the number of shots or trips.

Length composition data for the discarded component of the catch is available from 1993-2020 for the eastern trawl, Tasmanian trawl and Danish seine fleets (Table 8.9), although discard length composition data is not used for the Danish seine fleet, due to sporadic data availability and highly variable discard rate estimates for this fleet. Length composition data for the retained component of the catch is available from 1947-1967 for the steam trawl and early Danish seine fleets (Blackburn, 1978) and from 1971-1985 for the mixed fleet (Table 8.10). Length composition data for the retained component of the onboard catch is available for a range of years from 1996-2020 for the three current fleets, eastern trawl, Tasmanian trawl and Danish seine, with two extra years of data outside this range (1993 for eastern trawl, and a small (unusable) sample in 1994 for Danish seine). Length composition data for the FIS fleets is available for every second year from 2008-2016, separated into FIS fleets to match the eastern trawl and Tasmanian trawl fleets (Table 8.11), although the samples in 2016 are too small to be used in the assessment for either FIS fleet, and also too small in 2014 for the eastern trawl FIS fleet.

Length composition data for the retained component of the port measured catch is available for a range of years from 1996-2020 for the three current fleets, eastern trawl, Tasmanian trawl and Danish seine. This data includes some revisions to the port collected length composition data for the years 1996-2016 and three years of new port collected length composition data (2018-2020). Unfortunately, this updated port collected length composition data was accidentally excluded from the base case, so the port length composition collected data used in the 2021 base case (Table 8.12) is identical to that used in the 2018 assessment. The numbers of shots and fish measured by year for the new and revised port length data (1996-2020) is listed in Table 8.13, and this data was included in a sensitivity to the base case, after the base case runs were completed, to examine the impact of failing to include these data in the assessment. Fortunately, this impact was minimal.

Port length composition data is also available for earlier years, from 1986-1990 for eastern trawl, from the Sydney Fish Market, and from 1991-1995 for eastern trawl, with again a small unusable port sample in 1992 for the Danish seine fleet (Table 8.12 and Table 8.13) and for this historical data, there were no revisions to the port length composition data, so the numbers of shots and numbers of fish measured per year listed in Table 8.12 and Table 8.13 is identical for the period 1986-1995.

Length data were excluded for years with less than 100 individual fish measured, as this was considered to be unrepresentative (with excluded data listed in grey in Table 8.9, Table 8.11, Table 8.12 and Table 8.13). Sample sizes for retained length frequencies, including both the number of individuals measured and number of trips (inferred numbers of trips listed in blue) are listed in in Table 8.10, Table 8.11, Table 8.12 and Table 8.13 for each fleet and year for the period 1947-2020 and for discarded length frequencies in Table 8.9 for the period 1993-2020. For years and gear types where the number of trips is not available (i.e. for fish measured in the Sydney Fish Market (1971-1990) or from Blackburn data (1947-1967)), the number of trips is inferred from the number of fish measured per trip for years where this data is available for each gear type.

Table 8.9. Number of onboard discarded lengths and number of shots for length frequencies included in the base case assessment by fleet 1993-2020. Entries in grey indicate data that are not used due to small sample size (either less than 100 fish measured or Danish seine discards, which are not used due to high variability in Danish seine discard rates).

year	fleet eastern trawl # fish	(discard) Tas trawl # fish	DS # fish	eastern trawl # shots	Tas trawl # shots	DS # shots
1993	72	745	79	6	7	2
1994	1516		262	18		13
1995	778			8		
1996	564	488		13	5	
1997	342	10		21	2	
1998	152	427		6	5	
1999	57	588		5	4	
2000	276		34	2		1
2001	118	419	6	6	9	1
2002						
2003	10		131	2		6
2004	374	84	363	15	1	11
2005	692	431		15	3	
2006	458	227		9	4	
2007	1			1		
2008	10			3		
2009						
2010	10	24		1	1	
2011	63	58		5	3	
2012	9	512		1	8	
2013	200	84	197	5	7	13
2014	179		221	5		4
2015	46	42		8	5	
2016	37	9	5	4	3	2
2017	542	66		10	2	
2018	169			7		
2019	151	82	131	10	6	10
2020	68	169	5	4	17	1

Table 8.10. Number of port (Sydney Fish Market (SFM)) and onboard (Blackburn) retained lengths and implied number of shots or trips for length frequencies included in the base case assessment by fleet 1947-1985. The number of shots or trips in this table (in blue) is inferred from numbers of fish measured

year	fleet steam trawl (Blackburn) # fish	(retained) early DS (Blackburn) # fish	mixed (SFM) # fish	steam trawl (Blackburn) # shots	early DS (Blackburn) # shots	mixed (SFM) # trips
1947	4836	1590		39	13	
1948	13960	5070		100	41	
1949	8577	3882		70	32	
1950	8823	5511		72	45	
1951	9721	1933		79	16	
1952	9456	3779		77	31	
1953	7956	2749		65	22	
1954	8033	2231		65	18	
1955	12010	8627		98	70	
1956	7997	8769		65	71	
1957	6351	4826		52	39	
1958	3243	6205		26	50	
1959		8569			70	
1960		10660			87	
1961		10038			82	
1962		15498			100	
1963		17887			100	
1964		24744			100	
1965		16586			100	
1966		19328			100	
1967		5980			49	
1971			1127			9
1972			631			4
1973			1080			7
1974			3614			17
1975			5388			67
1976			7971			84
1981			8684			76
1982			7911			67
1983			13608			98
1984			11552			78
1985			4825			33

Table 8.11. Number of lengths and number of shots for FIS length frequencies included in the base case assessment by fleet 2008-2016. Entries in grey indicate data that are not used due to small sample size (less than 100 fish measured).

year	FIS fleet Eastern trawl # fish	Tas trawl # fish	Eastern trawl # shots	Tas trawl # shots
2008	347	251	9	10
2010	388	426	12	13
2012	166	439	4	4
2014	67	368	2	3
2016	3	31	1	1

Table 8.12. Number of port and onboard retained lengths and number of shots or trips for length frequencies included in the base case assessment by fleet 1986-2020. The number of trips from early NSW data (SFM, 1986-1990, in blue) is inferred from numbers of fish measured. Entries in grey indicate data that are not used due to small sample size (less than 100 fish measured) or due to accidental omission (port samples from 2018-2020).

year	fleet east onbd # fish	(retained) east port # fish	Tas onbd # fish	Tas port # fish	DS onbd # fish	DS port # fish	east onbd # shots	east port # trips	Tas onbd # shots	Tas port # trips	DS onbd # shots	DS port # trips
1986		13441						83				
1987		4900						40				
1988		3649						19				
1989		1786						12				
1990		901						6				
1991		1181						8				
1992		1355				51		9				1
1993	147	2359					5	11				
1994		1124			3			14			2	
1995		667						7				
1996	864	233/ 2990		87		33	13	1 / 26		1		1
1997	3099	3190	257	282		340	32	27	3	2		5
1998	3416	8060	1514	835		1088	42	58	15	4		11
1999	3596	12659	1509	2384		295	41	86	14	13		2
2000	1969	7974	934	762	24	374	32	55	9	4	1	7
2001	3183	5603	1881	664		315	38	41	12	4		3
2002	2172	5757	647	2116		487	24	32	3	13		10
2003	1540	4066	691	424	142	61	22	25	4	3	9	1
2004	609	3544	1042	1248		108	16	29	6	8		2
2005	3381	5747	1621	1391	120	78	45	30	10	7	8	1
2006	1950	13123	1961	2757	60		30	86	16	15	6	
2007	1008	2029		137	30	753	26	13		1	1	5
2008	2241	651	207		15	635	42	4	5		1	6
2009	915	1644		80	50		23	20		1	1	
2010	603	1436	268	89	141	428	16	14	8	1	3	12
2011	611	758	292	263	153	512	19	26	7	7	4	24
2012	690	1116	630	141		216	18	31	11	4		9
2013	207	1008	347	214	163	288	6	33	7	4	9	10
2014	370	931	159		57	800	7	16	6		1	16
2015	495	1445	202	154		902	17	19	9	3		16
2016	687	600	295	240	5	810	13	8	23	5	2	15
2017	337	1029	486	55		530	7	17	9	1		11
2018	268	1100	76	87		860	8	18	7	1		19
2019	170	732	429	103	144	676	7	12	12	2	5	13
2020	242	1426	136	319		369	11	25	4	4		8

Table 8.13. Number of port and onboard retained lengths and number of shots or trips for length frequencies which should have been included in the base case assessment by fleet 1986-2020. The number of trips from early NSW data (SFM, 1986-1990, in blue) is inferred from numbers of fish measured. Entries in grey indicate data that are not used due to small sample size (less than 100 fish measured).

year	fleet east onbd # fish	(retained) east port # fish	Tas onbd # fish	Tas port # fish	DS onbd # fish	DS port # fish	east onbd # shots	east port # trips	Tas onbd # shots	Tas port # trips	DS onbd # shots	DS port # trips
1986		13441						83				
1987		4900						40				
1988		3649						19				
1989		1786						12				
1990		901						6				
1991		1181						8				
1992		1355				51		9				1
1993	147	2359					5	11				
1994		1124			3			14			2	
1995		667						7				
1996	864	233 / 2990		87		33	13	1 / 20		1		1
1997	3099	3190	257	282		340	32	23	3	2		4
1998	3416	8060	1514	835		1088	42	51	15	4		9
1999	3596	12659	1509	2384		295	41	73	14	13		2
2000	1969	7974	934	762	24	374	32	52	9	4	1	4
2001	3183	5603	1881	664		315	38	41	12	4		3
2002	2172	5757	647	2116		487	24	32	3	13		9
2003	1540	4066	691	424	142	61	22	21	4	3	9	1
2004	609	3544	1042	1316		108	16	28	6	9		2
2005	3381	5747	1621	1391	120	78	45	30	10	7	8	1
2006	1950	13604	1961	2757	60		30	84	16	15	6	
2007	1008	1530		464	30	753	26	11		4	1	5
2008	2241	651	207		15	635	42	4	5		1	6
2009	915	2119		80	50	12	23	42		1	1	1
2010	603	1867	268	122	141	622	16	40	8	3	3	22
2011	611	1125	292	351	153	731	19	37	7	9	4	28
2012	690	1423	630	188		291	18	35	11	5		10
2013	207	1209	347	247	163	383	6	30	7	5	9	9
2014	370	931	159		57	800	7	15	6		1	14
2015	495	1597	202	176		1043	17	20	9	3		14
2016	687	617	295	240	5	810	13	8	23	5	2	14
2017	337	1029	486	55		530	7	17	9	1		11
2018	268	1100	76	87		860	8	18	7	1		19
2019	170	732	429	103	144	676	7	12	12	2	5	13
2020	242	1426	136	319		369	11	25	4	4		8

8.3.1.7 Age composition data

An estimate of the standard deviation of age-reading error was calculated by André Punt (pers. comm., 2021) using data supplied by Kyne Krusic-Golub and a variant of the method of Richards *et al*. (1992) (Table 8.14). This age data, with multiple reads of individual otoliths, which was used to estimate the ageing error had some obvious discrepancies. One record featured an otolith aged as either six or zero years old, but this otolith was unreadable on the second read, and should not have been recorded as age zero (J. Barrow, pers. Comm., 2021). To ensure convergence of the ageing error estimation, other records with large variation between the first and second read were excluded. These records and the convergence of the ageing error estimate should be examined more carefully when the ageing error is next updated. Age-at-length measurements, provided by Kyne Krusic-Golub of Fish Ageing Services Pty Ltd, are available from 1992-2020 for the eastern trawl fleet, from 1991-2020 for the Tasmanian trawl fleet and from 1998-2020 for the Danish seine fleet (Table 8.15).

Table 8.14. Standard deviation of age reading error (A Punt pers. comm. 2021).

Age	**sd**
0.5	0.146691
1.5	0.146691
2.5	0.22875
3.5	0.279308
4.5	0.316403
5.5	0.349419
6.5	0.382902
7.5	0.418765
8.5	0.45756
9.5	0.499182
10.5	0.543257
11.5	0.589336
12.5	0.636991
13.5	0.685851
14.5	0.735615
15.5	0.786048
16.5	0.836969
17.5	0.888242
18.5	0.939769
19.5	0.991477
20.5	1.04331
21.5	1.09524
22.5	1.14723
23.5	1.19926
24.5	1.25132
25.5	1.30341
26.5	1.35551
27.5	1.40762
28.5	1.45973
29.5	1.51185
30.5	1.56398

Table 8.15. Number of age-length otolith samples included in the base case assessment by fleet 1991-2020.

Year	Fleet		
	Eastern trawl	Danish seine	Tasmanian trawl
1991			99
1992	55		
1993	412		
1994	330		19
1995	200		96
1996	507		
1997	169		
1998	166	52	
1999	314		
2000	43	118	
2001	301	92	
2002	379		
2003	72	95	
2004	83		
2005	164	25	
2006	30	10	49
2007	117		
2008	262		77
2009	554		
2010	558	183	86
2011	482	224	108
2012	337	63	206
2013	2	46	71
2014	174	151	12
2015	244	153	72
2016	46	11	34
2017	203	16	62
2018	96	34	42
2019	131	105	91
2020	369	26	36

8.3.1.8 Input data summary

The data used in this assessment is summarised in Figure 8.7 and Figure 8.8, indicating which years the various data types were available.

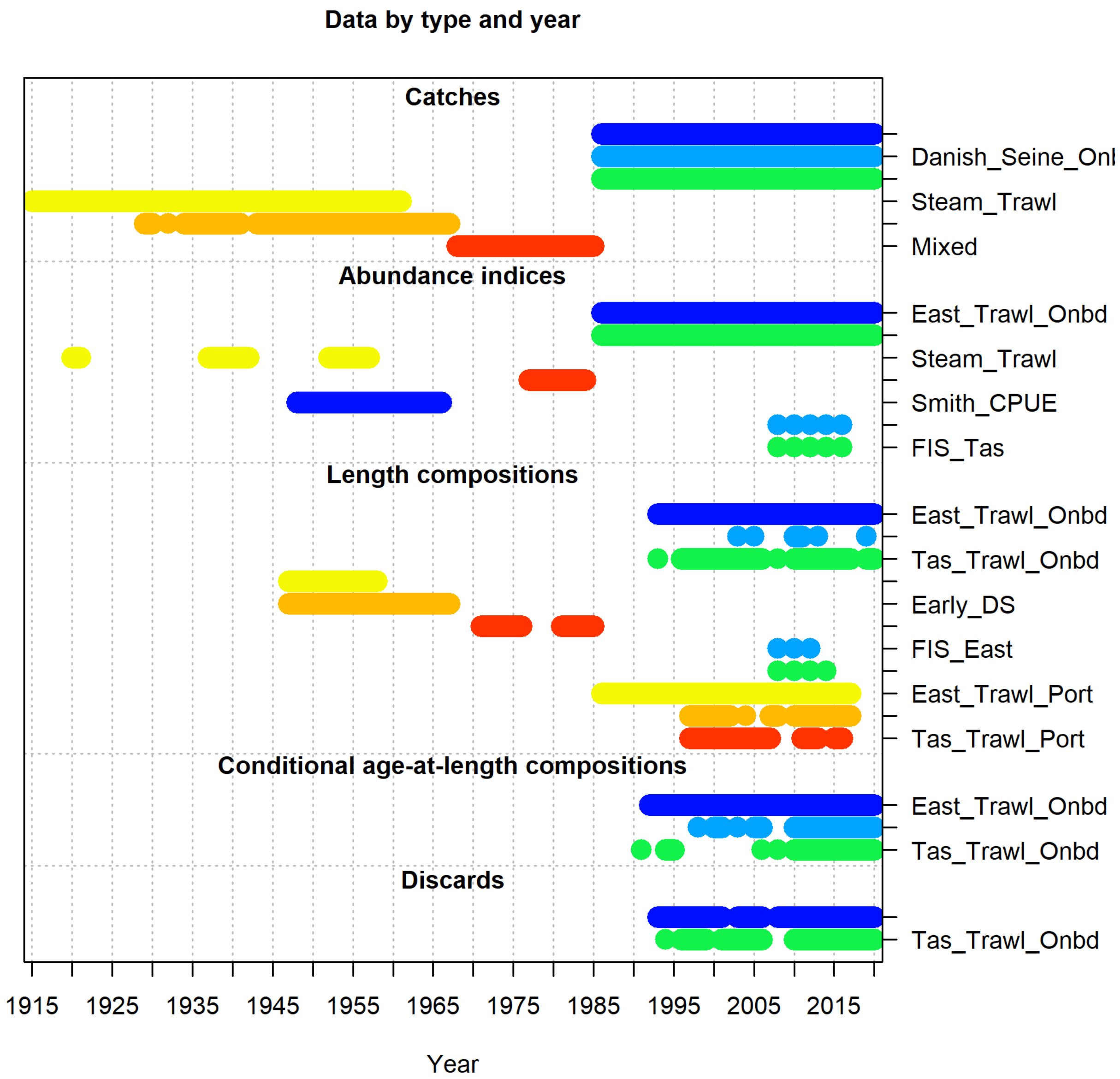


Figure 8.7. Summary of input data used for the eastern Jackass Morwong assessment base case (which accidentally excluded the port length composition data from 2018-2020).

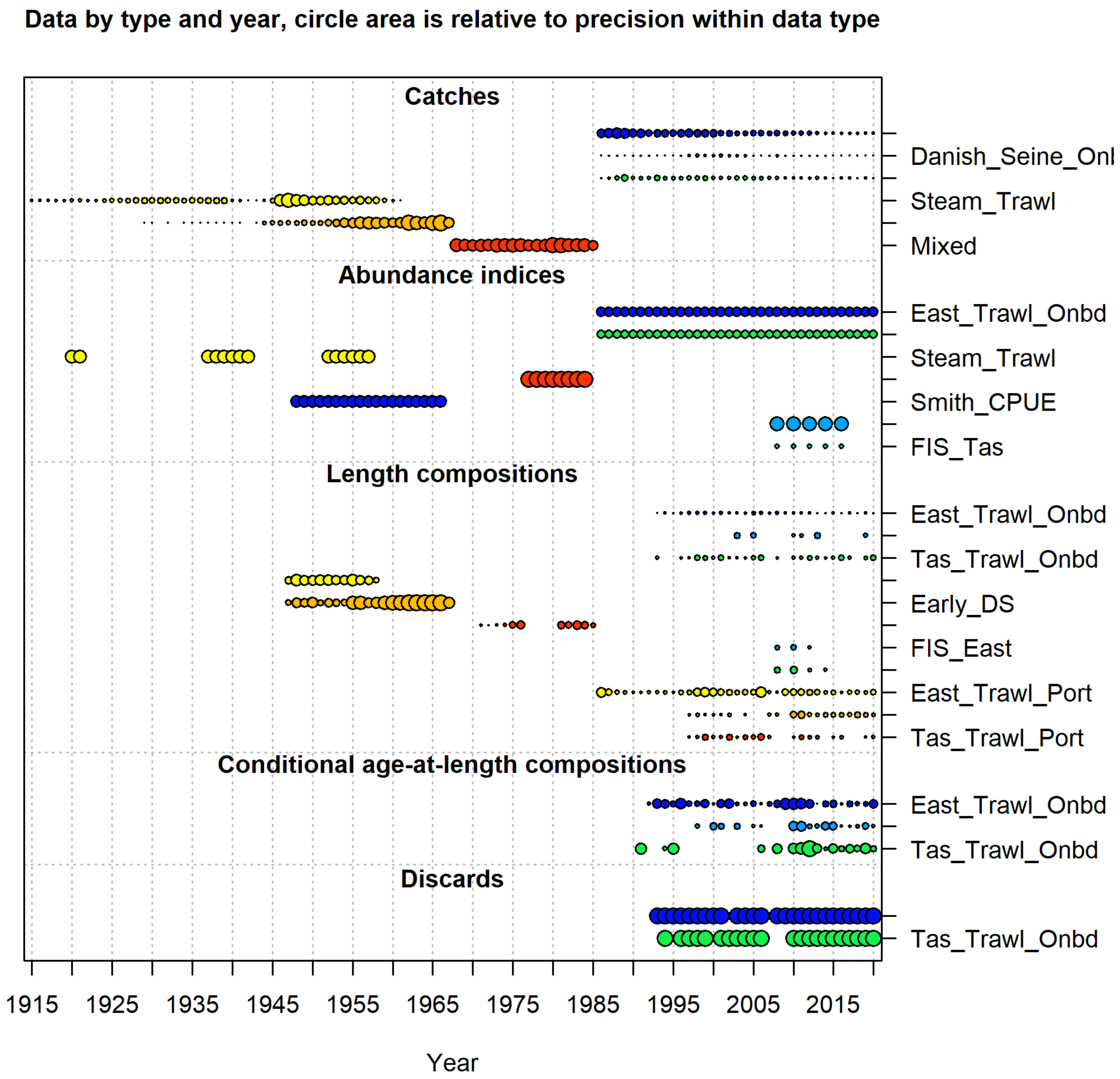


Figure 8.8. Summary of input data used for the eastern Jackass Morwong assessment, including the port length composition data from 2018-2020, which should have been included in the base case.

8.3.2 *Stock assessment method*

8.3.2.1 Population dynamics model and parameter estimation

A single-sex stock assessment for eastern Jackass Morwong was conducted using the software package Stock Synthesis (version SS-V3.30.17.00, Methot *et al*. 2021, Methot and Wetzel, 2013). Stock Synthesis is a statistical age- and length-structured model which can allow for multiple fishing fleets and can be fitted simultaneously to the types of information available for Jackass Morwong. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, are described in the SS technical documentation and (Methot, 2005), and are not reproduced here.

A single stock of Jackass Morwong was assumed for the eastern assessment, with an assumption of two productivity regimes, with different stock-recruitment relationships: the first from 1915 when the steam trawl fishery commenced, and the second, lower productivity regime, from 1988 when productivity and recruitment became lower (Wayte, 2011; Wayte, 2013). Catches from western Tasmania and western Victoria were assumed to come from a separate stock and are therefore not considered in the eastern assessment.

Some key features of the base-case model are:

a) Jackass Morwong constitute a single stock within the area of the fishery (SESSF Zones 10, 20 and 30).

b) The population was at its unfished biomass with the corresponding equilibrium (unfished) age-structure at the start of 1915.

c) The CVs of the CPUE indices for the eastern and Tasmanian trawl fleets and the FIS abundance indices were initially set to the root mean squared deviation from a loess fit to the fleet specific indices (Sporcic, 2021b) and then tuned to match the model-estimated standard errors by estimating an additional variance parameter within Stock Synthesis.

d) Six fishing fleets are modelled.

e) Selectivity was assumed to vary among fleets, but the selectivity pattern for each fleet was modelled as length-specific, logistic and time-invariant. The two parameters of the selectivity function for each fleet were estimated within the assessment.

f) Retention was also defined as a logistic function of length, and the inflection and slope of this function were estimated for the two fleets where discard information was available (eastern trawl and Tasmanian trawl).

g) The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The value for M was fixed (0.15) within the model in this assessment.

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 for the base-case analysis is set to 0.7. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1945 to 2015. Deviations are not estimated prior to 1945 or 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 thirty years.

k) Growth of Jackass Morwong is assumed to be time-invariant, meaning there is no change over time in mean size-at-age, with the distribution of size-at-age being estimated along with the remaining growth parameters within the assessment. No differences in growth related to sex are modelled, because the stock is modelled as a single-sex model.

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 downweighted to a maximum sample size of 100 and 200 respectively.

8.3.2.2 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 apparently 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 and the approach of Punt (2017) for conditional age-at-length 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. 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 (2011) weighting method for length data and the Punt (2017) weighting method for conditional age-at-length data.

8.3.2.3 Iterative reweighting 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). The iterative reweighting method is outlined below:

1. Set the standard error for 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 Jackass Morwong. 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 (Pacific Fishery Management Council, 2018).

8.3.2.4 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 a Tier level depending on the basis used for assessing stock status or exploitation level for that stock. Jackass Morwong 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. This document reports RBCs calculated under the 20:35:48 strategy.

8.3.2.5 The base case model

SERAG accepted the model structure of the preliminary base case assessment for eastern Jackass Morwong presented in October 2021 (Day and Bessell-Browne, 2021), with the stipulation that the base case assumed recruitment from 2016 onwards had fixed recruitment deviations equal to the mean of the estimated recruitment deviations from 2006-2015 (-0.754).

Estimates of recruitment for Jackass Morwong have been below average since the early 2000s, with this potentially a consequence of directional environmental change. If this below average recruitment trend continues into the future, assuming a return to average recruitment would result in overly optimistic biomass and stock status estimates. Due to these concerns the base case for this assessment incorporates low, rather than average, recruitment projected into the future. The more usual "average recruitment" scenario, with recruitment deviations set to zero from 2016 onwards, is included as a sensitivity.

8.3.2.6 Retrospective analyses

A retrospective analysis Mohn (1999) has been undertaken to identify whether below average recruitment and declining stock size would have been identified by previous assessments using the same assumptions, data and tuning as this assessment.

The retrospective analysis was undertaken using the following procedure:

1. One year of data was removed sequentially from the 2021 base case assessment;
2. Time dependent model parameters (e.g. last year of recruitment) were changed to be one year earlier;
3. The model was run to determine stock status estimates when less data is available;
4. Steps 1–3 were repeated for five years, removing one year of data at each step.

Trends in spawning biomass and estimated recruitment are then examined to help understand how reliable the most recent few years of estimated recruitments and spawning biomass are in the current assessment. Mohn's rho values are then calculated to quantitatively determine the severity of the retrospective pattern (Hurtado-Ferro et al., 2015).

8.3.2.7 Likelihood profiles

Likelihood profiles are a standard component of the toolbox of applied statisticians and are most often used to obtain a 95% confidence interval for a parameter of interest (Punt, 2018). Many stock assessments "fix" key parameters such as natural mortality and steepness based on a priori considerations. Likelihood profiles can be used to evaluate whether there is evidence in the data to support fixing a parameter at a chosen value. If the parameter is within the range of the 95% confidence interval of the total likelihood profile, this provides no support from the data to change the fixed value. If the fixed value is outside the 95% confidence interval, and there is evidence that the data holds information about this parameter, 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 should 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 to inconsistencies in sampling, but more commonly owing to incorrect assumptions or model misspecification (e.g., assuming that catch-rates are linearly related to abundance). Likelihood profiles can be used as a diagnostic to identify these data conflicts (Punt, 2018).

Likelihood profiles were constructed for the base case with low recruitment for mortality, steepness, unexploited spawning biomass, 2020 spawning biomass and 2020 stock status.

8.3.2.8 Jitter analysis

Jitter analysis is a technique used to test the optimality, robustness and stability of the maximum likelihood estimate obtained for a particular model. This involves randomly changing the starting values used for all estimated parameters and re-running the model, to test what alternative solutions may be found by the optimisation algorithm from different initial locations, which is sometimes referred to as sensitivity to initial conditions. Two diagnostics are of interest with a jitter analysis, initially a check on whether a better "optimal solution" may be found, with a higher likelihood value, and also to see how frequently the optimal solution is found. As all estimated parameters are randomly modified, or "jittered", simultaneously, this can sometimes result in a model either failing to converge or finding a local maximum in a different (suboptimal) part of the multi-dimensional parameter space. A jitter analysis was conducted with 25 replications, modifying initial values by 0.1.

8.3.2.9 Sensitivity tests and alternative models

The following sensitivity tests were used to examine the sensitivity of the results to model assumptions and data inputs:

1. $M = 0.1$ yr^{-1}.
2. $M = 0.2$ yr^{-1}.
3. $h = 0.6$.
4. $h = 0.8$.
5. 50% maturity at 22 cm.
6. σ_R set to 0.65.
7. σ_R set to 0.75.
8. Double the weighting on the length composition data.
9. Halve the weighting on the length composition data.
10. Double the weighting on the age-at-length data.
11. Reduce the weighting on the age-at-length data.
12. Double the weighting on the survey (CPUE) data.
13. Halve the weighting on the survey (CPUE) data.
14. Rerun the model without a productivity shift in 1988.
15. Assume average recruitment from 2016 onwards (recruitment deviations fixed at zero).

The results of the sensitivity tests are summarized by the following quantities (Table 8.23):

1. SSB_0: the average unexploited female spawning biomass.
2. SSB_{2022}: the female spawning biomass at the start of 2022.
3. SSB_{2022}/SSB_0: the female stock status level at the start of 2022.
4. RBC_{2022}: the recommended biological catch (RBC) for 2022.
5. $\text{RBC}_{2022\text{-}24}$: the mean RBC over the three years from 2022-2024.
6. $\text{RBC}_{2022\text{-}26}$: the mean RBC over the five years from 2022-2026.
7. $\text{RBC}_{\text{longterm}}$: the longterm RBC.

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

8.4 Results and discussion

8.4.1 The base-case analysis

8.4.1.1 Transition from 2018 base case to 2021 base case

The development of a preliminary base case, and a bridging analysis from the 2018 assessment (Day and Castillo-Jordán, 2018a), was presented at the October 2021 SERAG 2 meeting (Day and Bessell-Browne, 2021), including updating the version of Stock Synthesis and sequentially updating data. This bridging analysis is not repeated in this report.

8.4.1.2 Parameter estimates

Figure 8.9 shows the estimated growth curve for Jackass Morwong. All growth parameters are estimated by the model (parameter values are listed in Table 8.16).

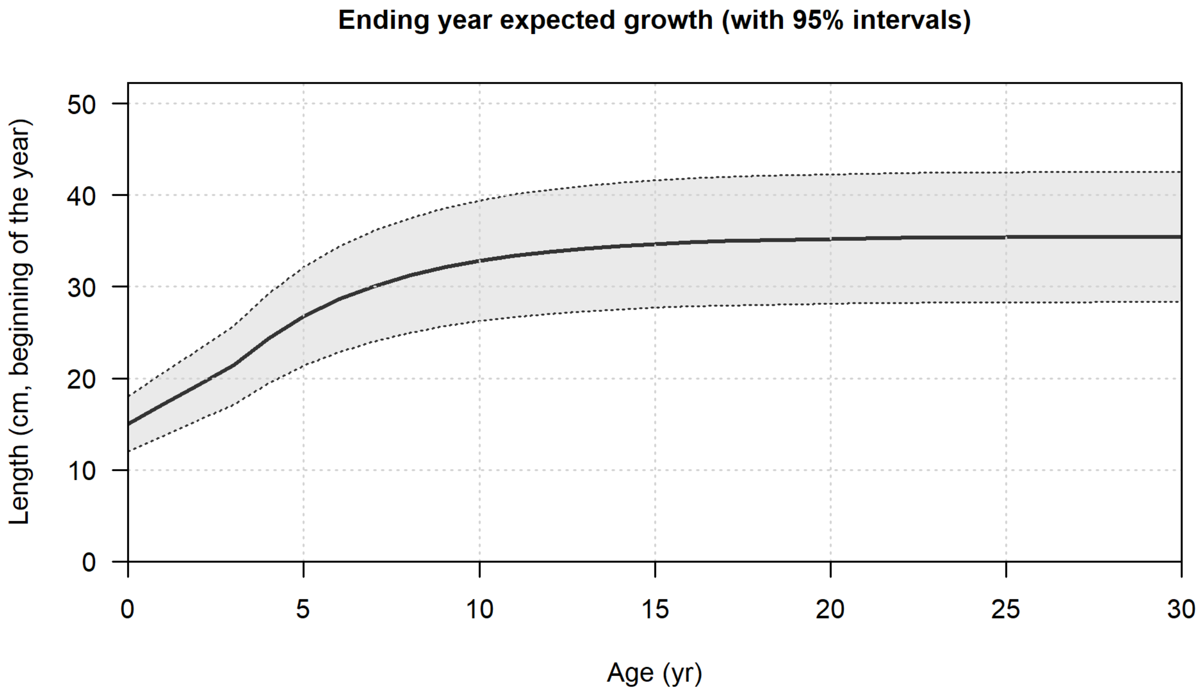


Figure 8.9. Fixed growth curve for eastern Jackass Morwong, using parameters estimated from the eastern morwong stock assessment.

Table 8.16. Summary of parameters of the base case model.

Feature	Details	
Natural mortality *M*	fixed	0.15
Steepness *h*	fixed	0.7
σ_R in	fixed	0.7
Recruitment devs	estimated	1945-2015, bias adjustment ramps 1969-86 and 2012-13
CV growth	estimated	0.102
Growth *K*	estimated	0.239
Growth l_{min} (cm)	estimated	21.4
Growth l_{max} (cm)	estimated	35.2

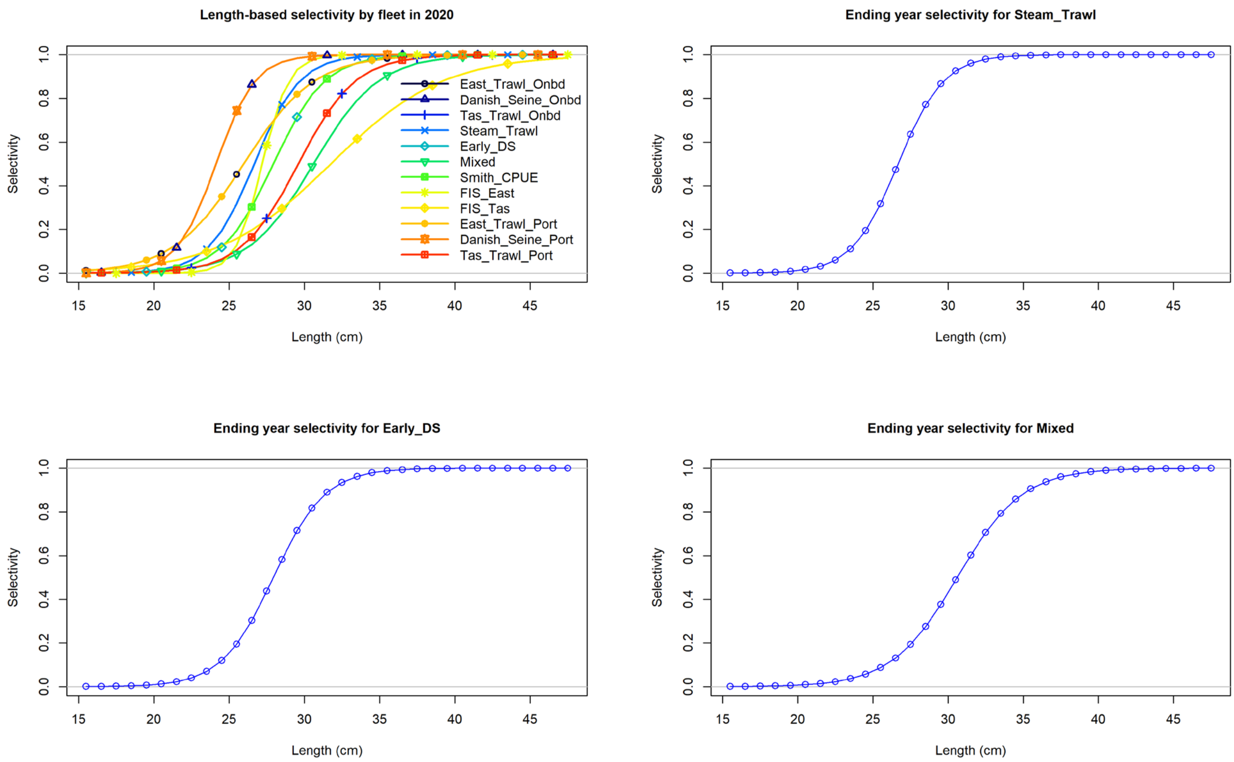


Figure 8.10. Selectivity for all six fleets (top left: note that the port fleets are mirrored to the selectivity of other fleets) and selectivity functions for the three historical fleets (steam trawl (top right); early Danish seine (bottom left); mixed (bottom right)).

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). The estimates of these parameters for the current fleets are as follows: for the eastern trawl fleet are 26.0 cm and 6.92 cm; for the Danish seine fleet are 24.1 cm and 3.81 cm; and for the Tasmanian trawl are 29.6 cm and 5.61 cm. For the FIS fleets the parameters are as follows: for the eastern trawl fleet are 27.2 cm and 2.59 cm; and for the Tasmanian trawl are 31.7 cm and 11.0 cm. For the historical fleets the parameters are as follows: for the steam trawl fleet are 26.7 cm and 4.47 cm;

for the early Danish seine fleet are 27.9 cm and 5.04 cm; and for the mixed fleet are 30.6 cm and 6.39 cm. All of these values are similar to the values for the selectivity parameters estimated in the 2018 assessment. Figure 8.10 and Figure 8.11 show the selectivity and retention functions for each fleet with selectivity estimated. The estimate of the parameter that defines the initial numbers (and biomass), *ln*(R_0), is 8.11 for the base case.

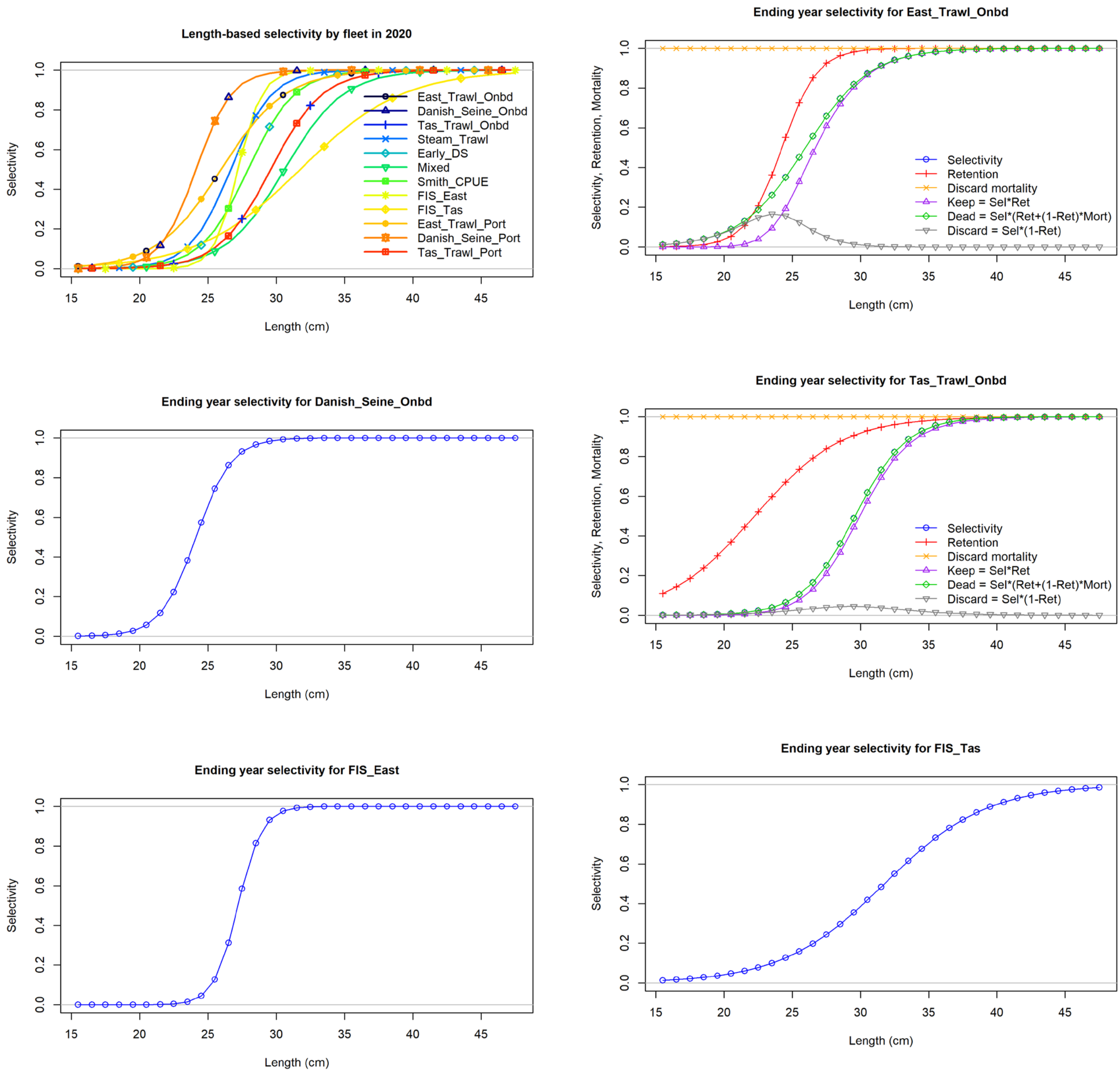


Figure 8.11. Selectivity for all six fleets (top left: note that port fleets are mirrored to the selectivity of other fleets) and selectivity (blue/green) and retention (red) functions for the three current fleets (eastern trawl (top right); Danish seine (middle left); Tasmanian trawl (middle right)) and for the two FIS fleets (eastern trawl FIS fleet (bottom left); Tasmanian trawl FIS fleet (bottom right)).

8.4.1.3 Fits to the data

The fits to the steam trawl fleet catch rate indices are good (Figure 8.12), with the series suggesting some decline in biomass apparent by the 1950s. The Smith indices (Figure 8.13) suggest abundance is generally relatively constant, with the model estimating a decline in abundance in the early 1980s. These fits to the historical abundance indices are largely unchanged from the fits from the 2018 assessment. The fits to the recent catch rate series from the trawl fleets are remarkably good (Figure 8.14), with the model generally matching the decline in these series, albeit struggling to fit the hump at the start of the Tasmanian trawl series, and a smaller hump from 2003-2008 for the eastern trawl series. The fits to both of these series suggest a steady decline in abundance from 1986-2015, with a flattening of the abundance from 2015-2020, albeit at very low levels. While the point estimates of the abundance indices from the FIS2 for eastern Jackass Morwong have generally declined since 2008, the model, which also fits to a number of other data sources, produces a declining abundance trajectory over this period (Figure 8.15), fitting the eastern trawl FIS2 abundance series very well, but being unable to fit the steeper decline seen in the FIS2 abundance series for the Tasmanian trawl fleet.

In general, the fits to abundance series are very similar to the fits in the 2018 assessment, with the exception to improved fits to the most recent years, and no longer any suggestion of an increase in spawning biomass at the end of the time series.

The fits to the historical abundance indices generally estimate negative additional variance, indicating that the variance supplied is sufficient for reasonable fits. This parameter is negative for the Tasmanian trawl fleet and close to zero for the eastern trawl FIS2 abundance index (well balanced) but is positive for the eastern trawl fleet and the Tasmanian trawl FIS2 abundance index, suggesting the model requires more variance than the initial values from the loess fit to achieve an acceptable fit.

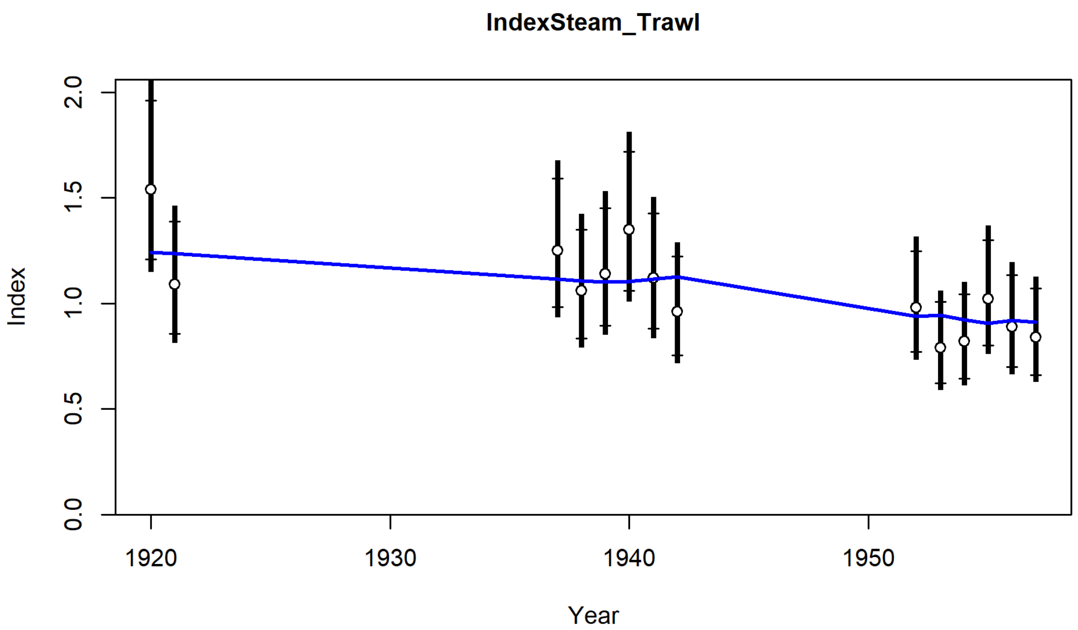


Figure 8.12. Observed (circles) and model-estimated (blue line) catch rates vs year, with approximate 95% asymptotic intervals for steam trawl fleet. The thin lines with capped ends should match the thick lines for a balanced model. This index is balanced by estimating an additional variance parameter within Stock Synthesis, which in this case is negative, suggesting the model fits well with less variance than the initial values from the loess fit.

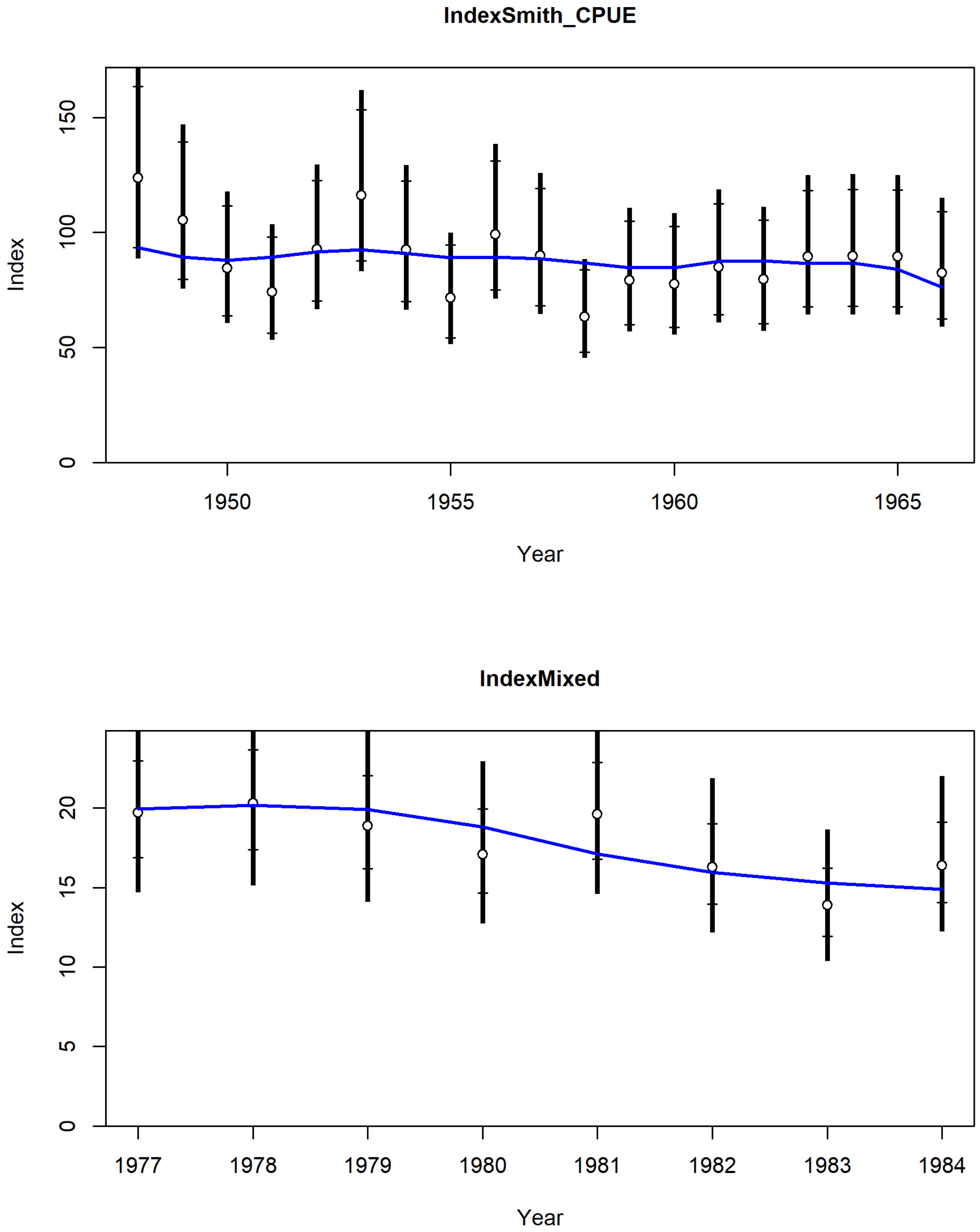
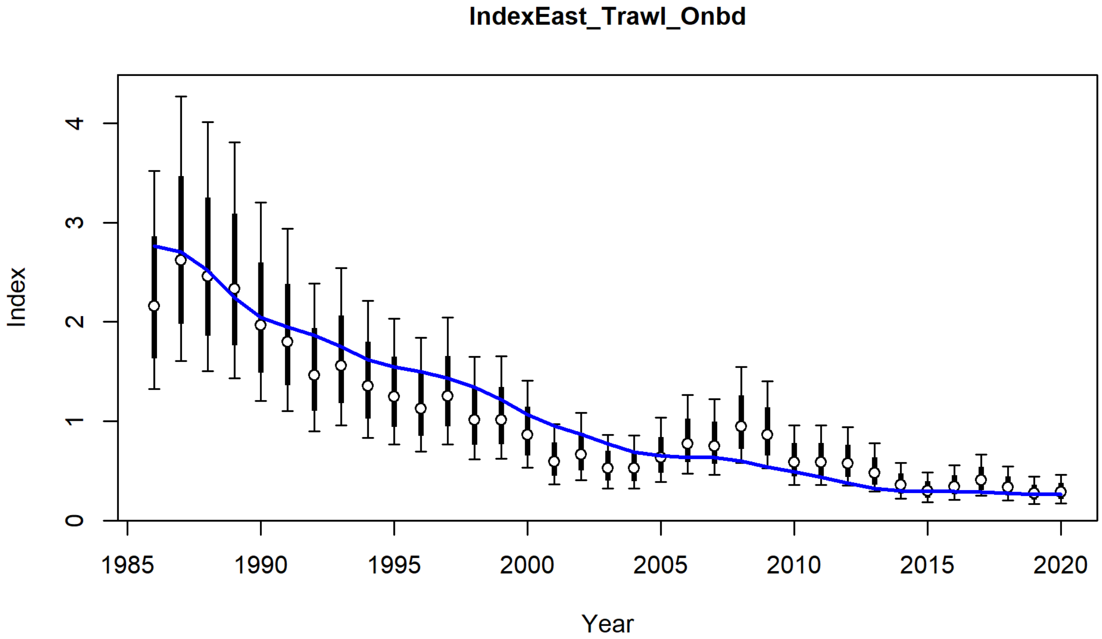


Figure 8.13. Observed (circles) and model-estimated (blue line) catch rates vs year, with approximate 95% asymptotic intervals for the Smith CPUE indices for the overlap between steam trawl and Danish seine (top) and the later mixed fleet (bottom). The thin lines with capped ends should match the thick lines for a balanced model. These indices are balanced by estimating an additional variance parameter within Stock Synthesis, which in these cases are both negative, suggesting the models fit well with less variance than the initial values from the loess fit.



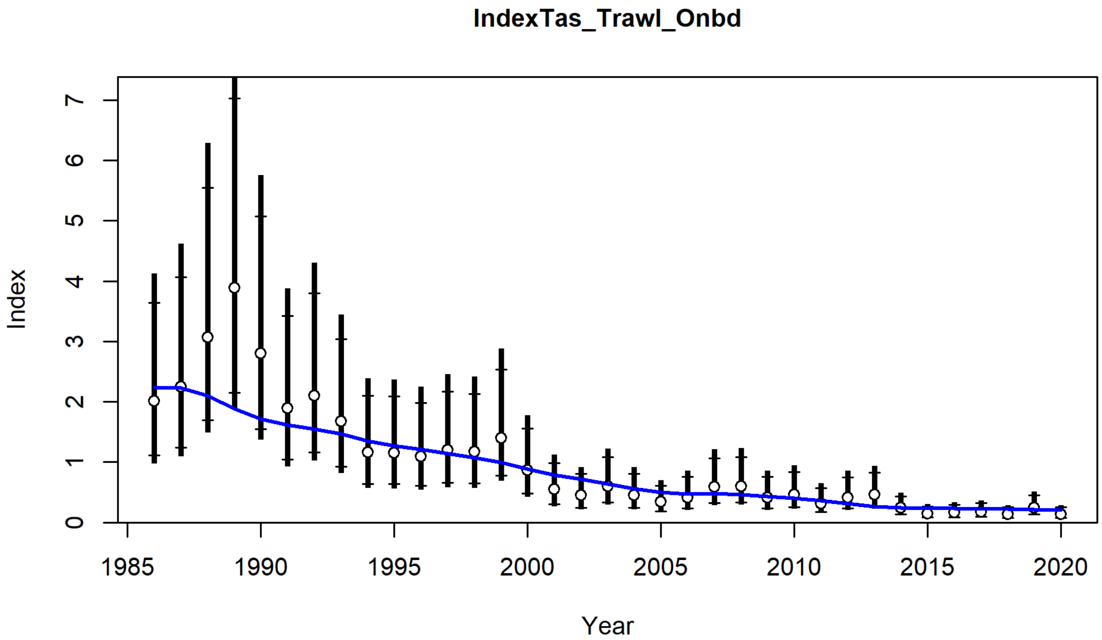
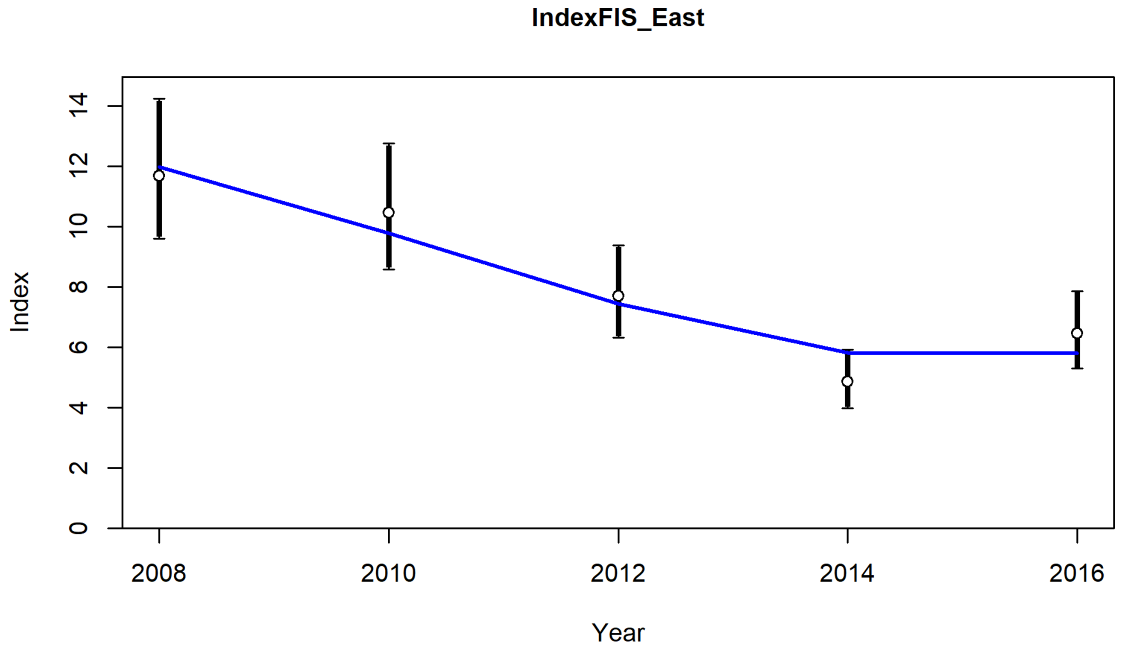


Figure 8.14. Observed (circles) and model-estimated (blue line) catch rates vs year, with approximate 95% asymptotic intervals for the eastern trawl fleet (top) and the Tasmanian trawl fleet (bottom). The thin lines with capped ends should match the thick lines for a balanced model. These indices are balanced by estimating an additional variance parameter within Stock Synthesis, which for eastern trawl is positive, suggesting the model requires more variance than the initial values from the loess fit to achieve a good fit. For the Tasmanian trawl fleet, the additional variance estimated is negative, suggesting the model fits well with less variance than the initial values from the loess fit.



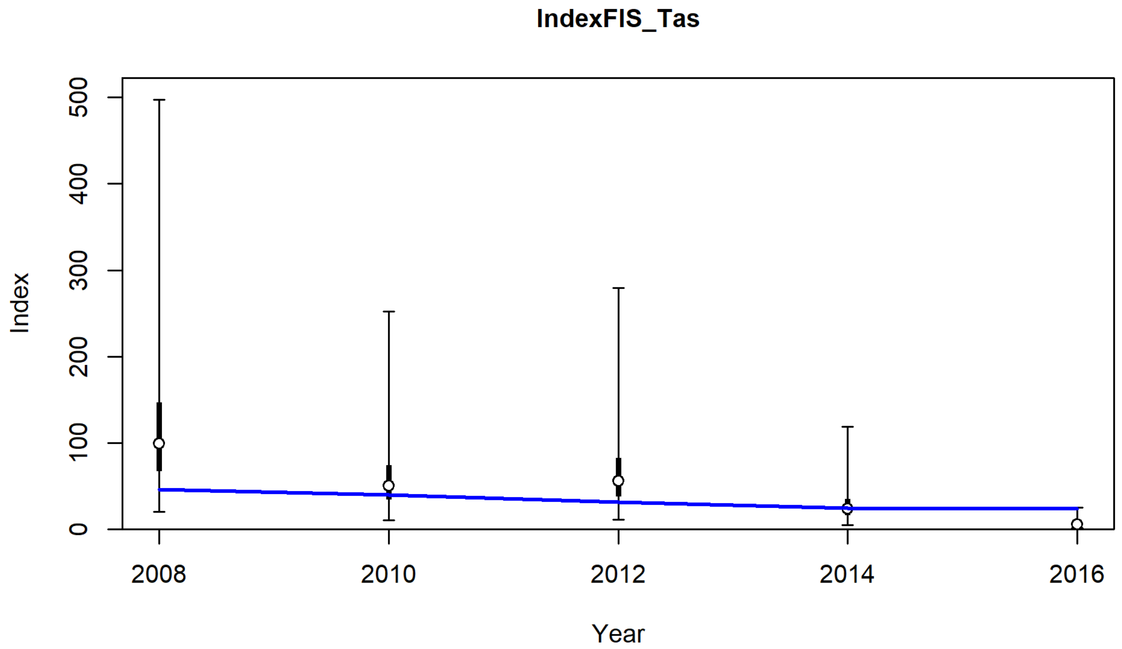


Figure 8.15 Observed (circles) and model-estimated (blue line) catch rates vs year, with approximate 95% asymptotic intervals for the eastern FIS fleet (top) and the Tasmanian FIS fleet (bottom). The thin lines with capped ends should match the thick lines for a balanced model. These indices are balanced by estimating an additional variance parameter within Stock Synthesis, which in the Tasmanian trawl case is positive, suggesting the model requires more variance than the initial values from the loess fit to achieve a good fit.

The total standard error, comprising the input standard error (Table 8.5, Table 8.6, Table 8.7 and Table 8.8) plus the additional standard error estimated within Stock Synthesis, gives some measure of how well each CPUE series is fit.

This total standard error is lowest for the mixed fleet with 0.079, followed by the steam trawl fleet mixed fleet with 0.12, the mixed fleet with 0.14, the eastern trawl FIS fleet with 0.17, the eastern trawl fleet with 0.25, the Tasmanian trawl fleet with 0.30 and the Tasmanian trawl FIS fleet with 0.72. It is generally easier to fit shorter time series, and conflicting signals between multiple CPUE series also adds to the difficulty of fitting to CPUE.

Overall, the fits to all CPUE series are remarkably good, except for the eastern trawl CPUE, as shown by the patterns in residual plots in Figure 8.16. The residual patterns are markedly different between the two longest time series from the eastern and Tasmanian trawl CPUE series, which both cover 25 years. The residual pattern for the Tasmanian trawl series looks well balanced, in contrast to the residual pattern for the eastern trawl series over the same time period. The eastern trawl CPUE residuals indicate some potential problems, with an initial long run where the fitted values are below the data points (1990-2006), followed by another long run with the fitted values above the data points (2007-2020). While this residual pattern indicates a possible problem with this fit to the eastern trawl CPUE, the model is simultaneously balancing the fits to the Tasmanian trawl CPUE series, with associated good residual patterns for this series, so this appears to be the best overall result that can be achieved to fit both series simultaneously.

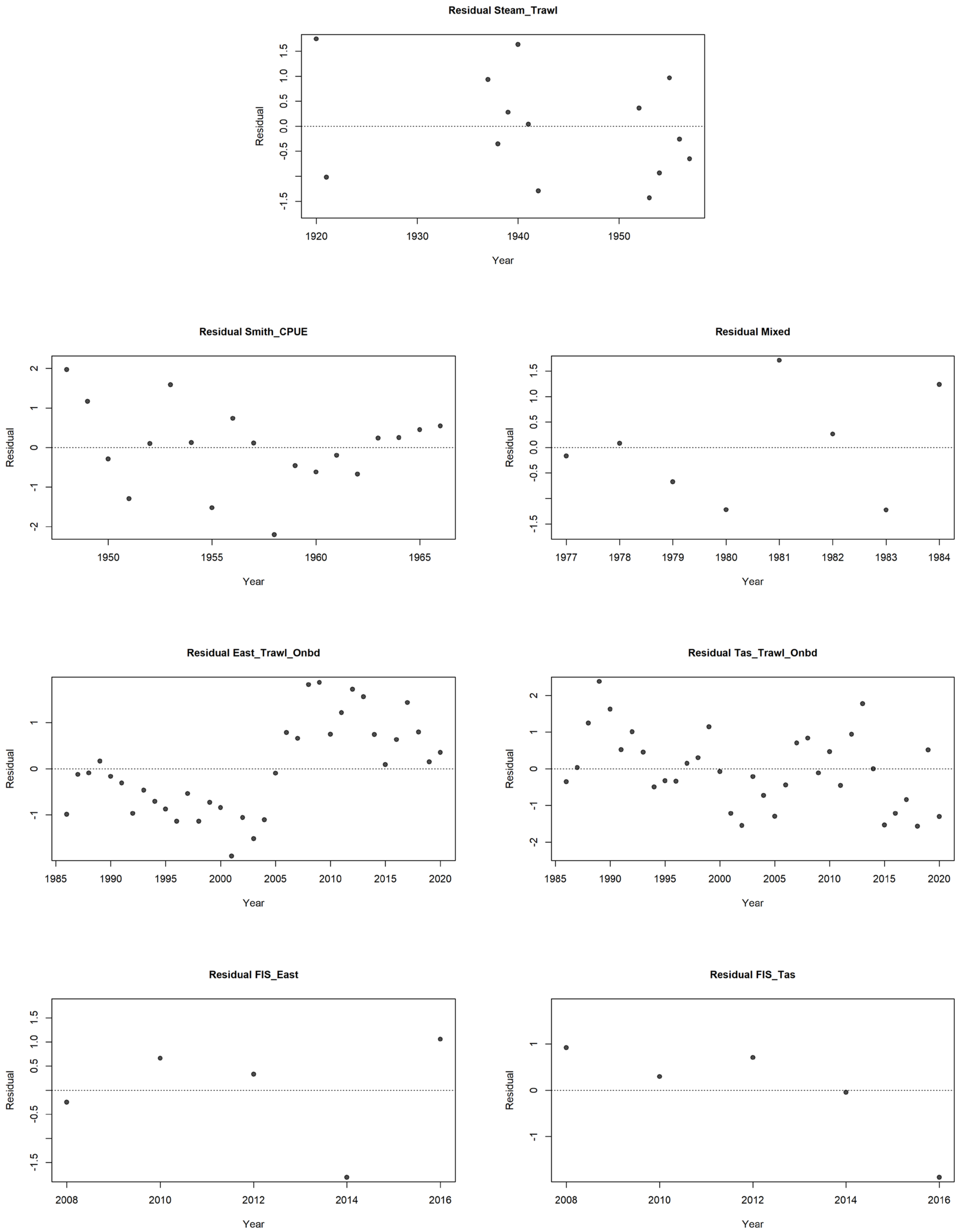


Figure 8.16. Residual patterns for fits to the seven CPUE series: steam trawl (top); Smith CPUE (second row, left); mixed fleet (second row, right); eastern trawl (third row, left); Tasmanian trawl (third row, right); FIS eastern trawl (bottom row, left); FIS Tasmanian trawl (bottom row, right).

The fits to the discard rate data for the current trawl fleets (Figure 8.17) are reasonable given the variability in the data. The discard proportion series has been revised since 2018, so the fits are quite different to those from the 2015 assessment, with estimated discarding rates less than 10% for both fleets. The discard rate for the eastern trawl fleet has increased in 2019 and 2020 to the highest rates on record. These discarding rates in the eastern trawl fleet warrant close attention in future years. To achieve predicted discard rates which have a better match to the overall discard rates, two years of very low (<1%) discard rate data (Table 8.4) were excluded from the eastern trawl fleet (2002 and 2007) and one additional year of discard rate data was excluded because the number of samples to estimate the discard rate was less than 10 (1992). Four years of very low (<1%) discard rate data were also excluded from the Tasmanian trawl fleet (1993, 2000, 2008 and 2009). If these very low discard rates are included in the model, the fitted discard rates match these very low rates well but give very poor fits to all other years with discard rates >1%. 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. Fits to the age and length composition data for discarded catches are shown in Appendix A.

The base-case model fits the aggregated retained and discarded length-frequency distributions very well (Figure 8.18 and Appendix A), with the exception of the retained length frequencies from Danish seine onboard. Note that a single selectivity is estimated for the combined port and onboard fleet in this case and, with the variation in data apparent between these different sources, the fits to both the port and onboard data require some compromise. The aggregated fits to the historical length frequency measurements are excellent (Figure 8.18).

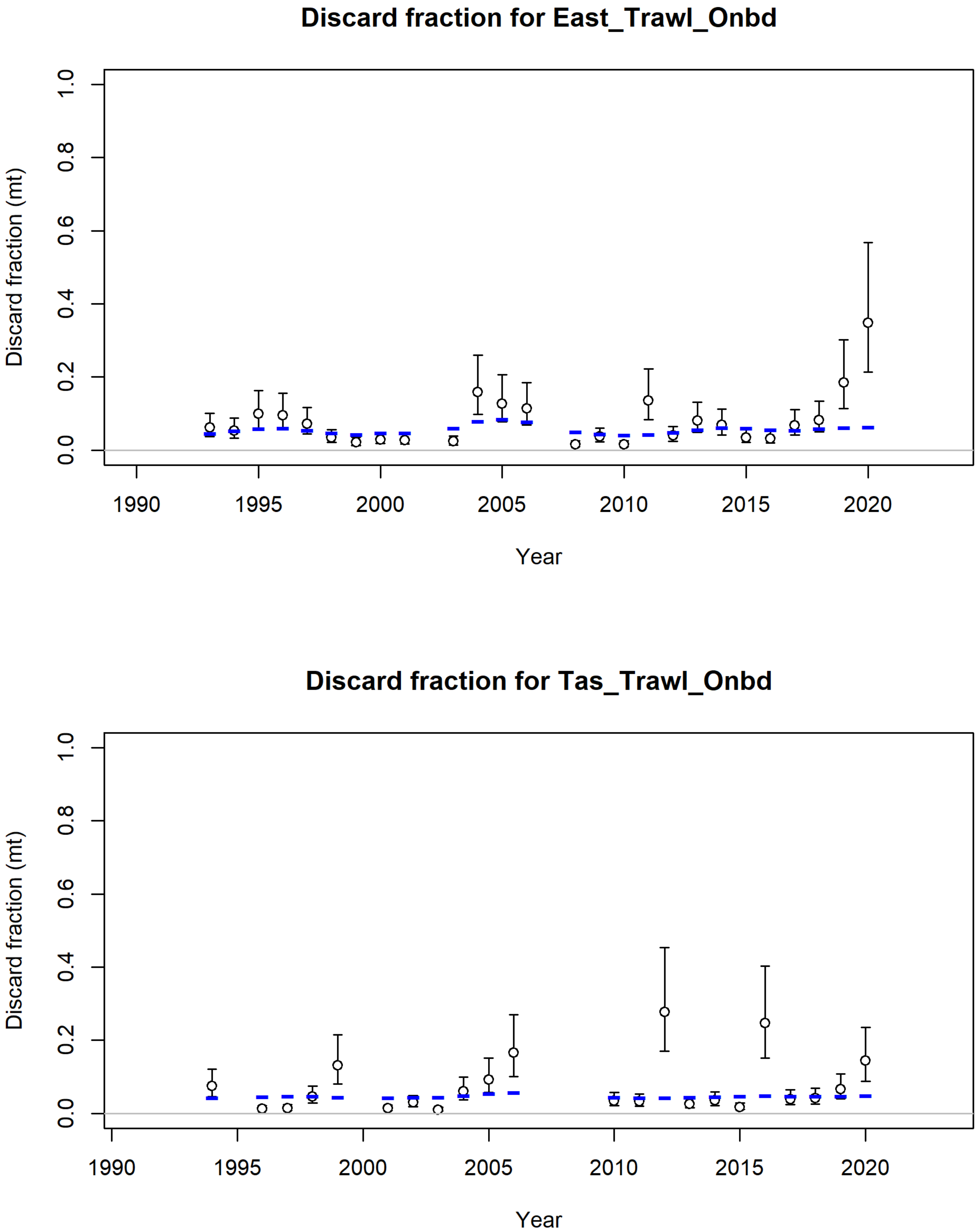


Figure 8.17. Observed (circles) and model-estimated (blue lines) discard estimates versus year for the eastern trawl fleet (top) and the Tasmanian trawl fleet (bottom), with approximate 95% asymptotic intervals.

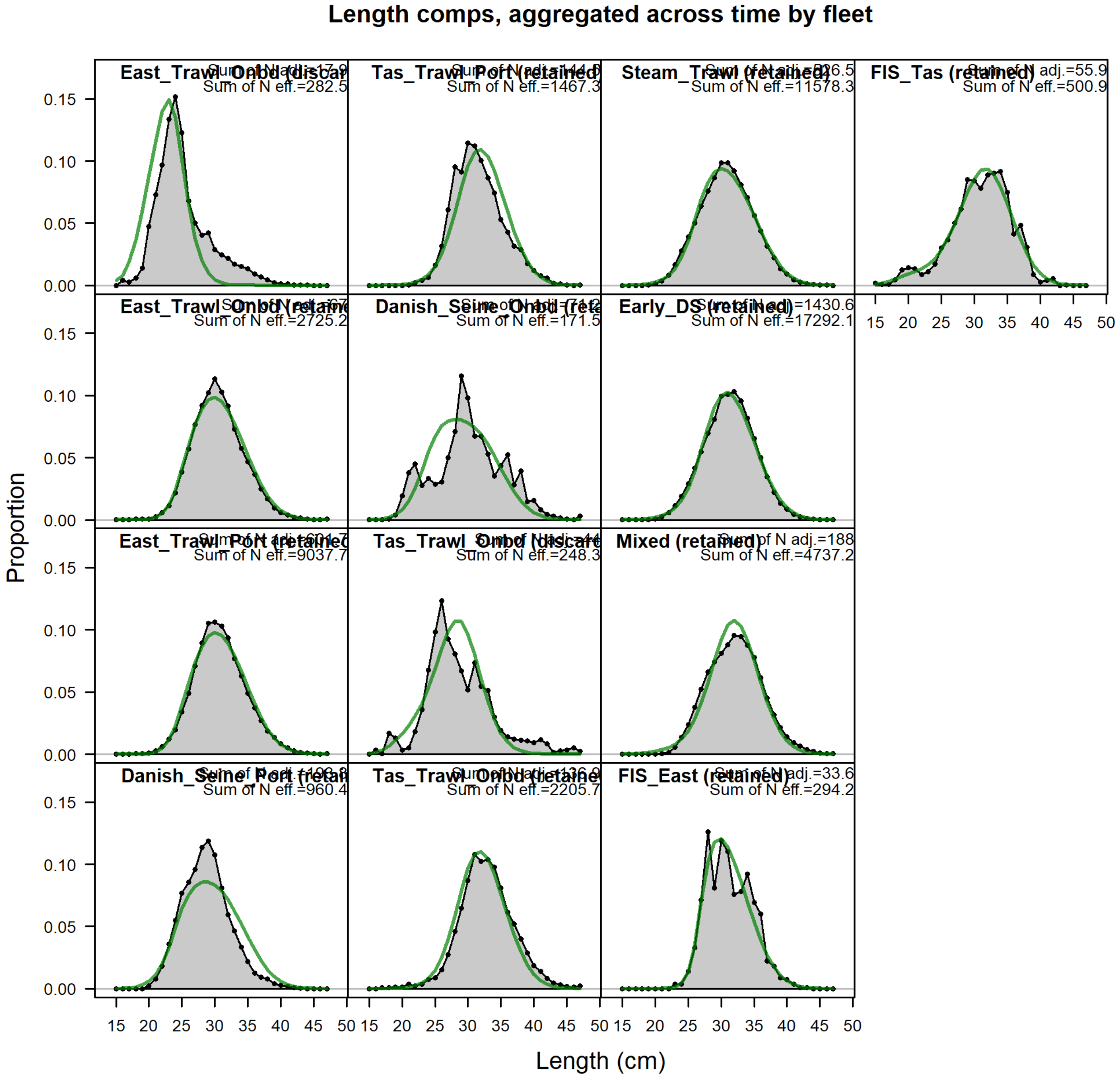


Figure 8.18. Fits to retained and discarded length compositions by fleet, separated by port and onboard samples, aggregated across all years. Observed data are grey and the fitted value is the green line.

The conditional age-at-length data is a little noisy between years, especially for the fleets with smaller catches. The mean age varies between seven and 11 years for eastern trawl, three and ten years for Danish seine, and four and 11 years for Tasmanian trawl. This variability in the age-at-length data is likely to be due to spatial or temporal variation in collection of age samples. The fits to conditional age-at-length are reasonable. Residuals for these fits and mean age for each year, aggregated across length bins, are shown in Appendix A.

The contributions to the total negative log likelihood by fleet and data source is shown in Table 8.17. This gives an indication of the contribution to the total negative log likelihood from different data components. These likelihood components decrease as the fit improves yet increase as the number of data points used for this fit increases, so a direct comparison is not always useful. The eastern trawl and Tasmanian trawl CPUE series have the same number of data points, so in this case, the lower values (negative, but larger in absolute magnitude, in this case) for the eastern trawl CPUE indicates a better fit than the Tasmanian trawl CPUE. Similarly, the fit to the Eastern trawl FIS abundance series is better than the fit to the Tasmanian trawl FIS abundance series, and the comparison is meaningful as they both have five data points. Comparing pairs from the other CPUE series is more nuanced and is only meaningful if the likelihood is smaller (more negative) from a series with a smaller number of CPUE data points. In this case, no conclusions can be drawn from the fits to the steam trawl CPUE, the mixed fleet CPUE and the Smith CPUE. For the length data, the only relevant comparison is between the two FIS fleets, as they each have the same number of years of data, and in this case the fits to the eastern trawl FIS lengths are better than those for the Tasmanian trawl FIS lengths.

Table 8.17. Negative log likelihood contributions by fleet and data source.

Likelihood component	Discard	Length	Age	CPUE
Fleet				
Eastern trawl (onboard)	59.5	25.3	181.3	-31.0
Eastern trawl (port)		39.7		
Danish seine (onboard)		32.8	130.2	
Danish seine (port)		33.7		
Tasmanian trawl (onboard)	116.8	57.4	301.9	-24.6
Tasmanian trawl (port)		22.7		
Steam trawl		15.7		-22.3
Early Danish seine		34.5		
Mixed		11.9		-16.3
Smith CPUE				-27.5
Eastern trawl FIS2		3.6		-9.0
Tasmanian trawl FIS2		7.9		1.5

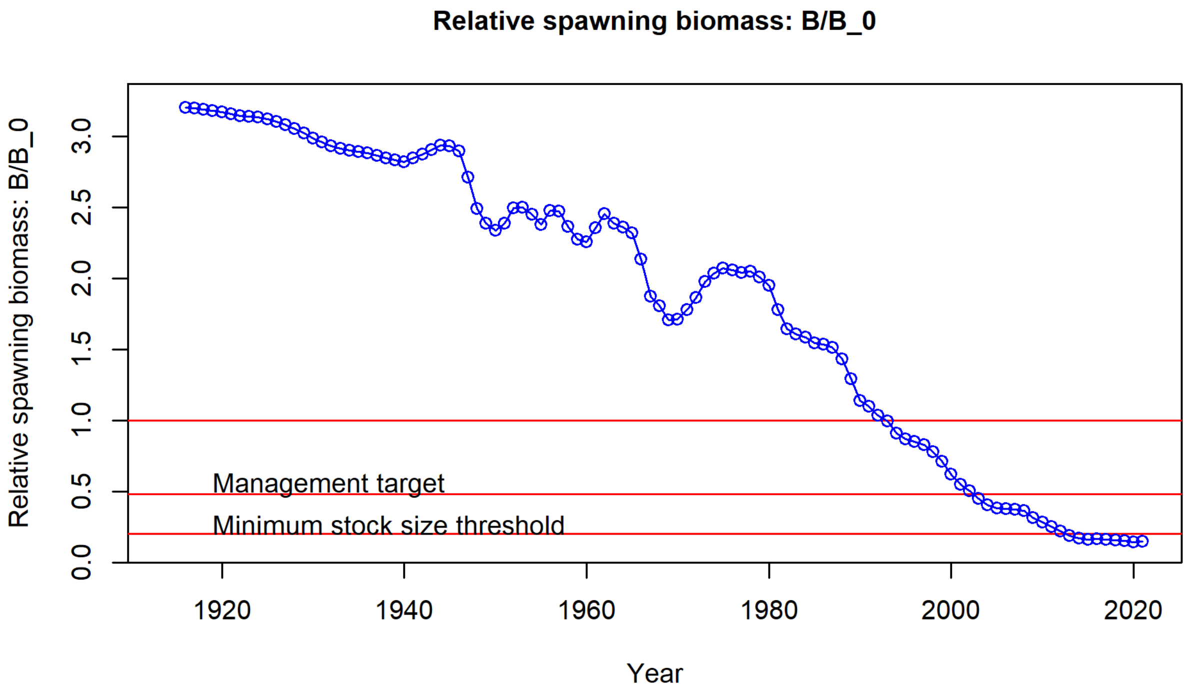


Figure 8.19. Time-trajectory of spawning biomass stock status corresponding to the MPD estimates for the base case analysis for eastern Jackass Morwong. Approximate 95% asymptotic intervals cannot be produced for the low recruitment scenario used in the base case.

8.4.1.4 Assessment outcomes (2021)

The current spawning stock biomass (Figure 8.19) is estimated to be 15% of unfished spawning stock biomass (i.e. spawning stock biomass at the start of 2022 relative to 1988 equilibrium spawning stock biomass), apparently with limited uncertainty, (the 95% asymptotic intervals cannot be calculated for the low recruitment base case to confirm this). The updated assessment estimates that the stock status first fell below B_{20} in 2013 and has remained below B_{20} ever since. In comparison, the last full assessment in 2018 (Day and Castillo-Jordán, 2018a) estimated the 2016 spawning biomass to be 35% of the 1988 equilibrium spawning stock biomass, with an expectation of continued recovery through to 2019. The current assessment estimates that the stock has a gradual decline for the first 30 years of the fishery, in contrast to the 2018 assessment results which estimated a much flatter trajectory in the same time period. The stock biomass then follows a variable trajectory through until the mid-1970s, followed by a steady decline through to 2020. In 1993, the stock first falls below the 1988 equilibrium spawning stock biomass, in 2003, the stock was estimated to first fall below the adjusted target reference point, B_{48}, relative to the 1988 equilibrium biomass, and in 2013 it first falls below the limit reference point, B_{20}, and has remained below B_{20} ever since.

In the 2018 stock assessment, seven of the last nine estimated recruitment events were below average (Figure 8.20 and Figure 8.21), with the other two only just above average (2010 and 2012). These recruitment deviations have been revised and all nine of these recruitment events, in addition to the three additional newly estimated recruitment events (2013-2015), are all estimated below average (the most recent 12 recruitments estimated to be below average), even with the productivity shift model implemented, as first accepted in the 2011 stock assessment model (Figure 8.21).

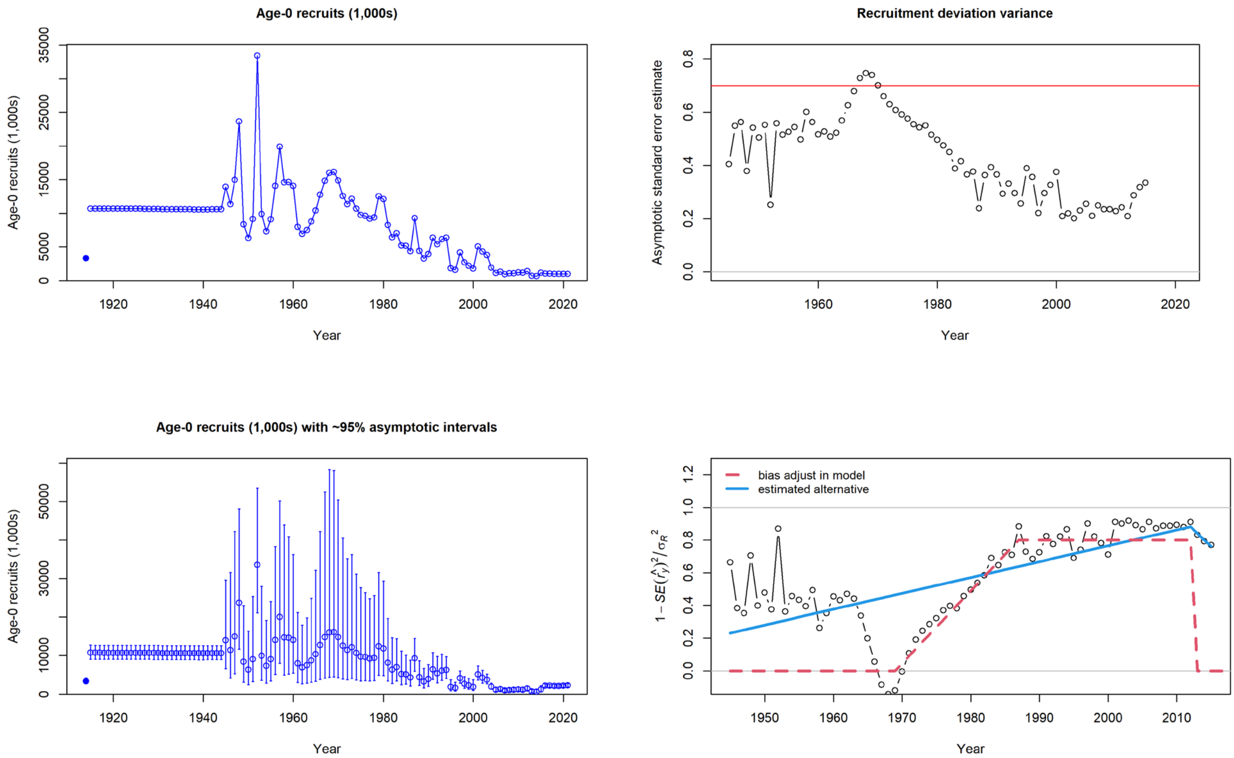
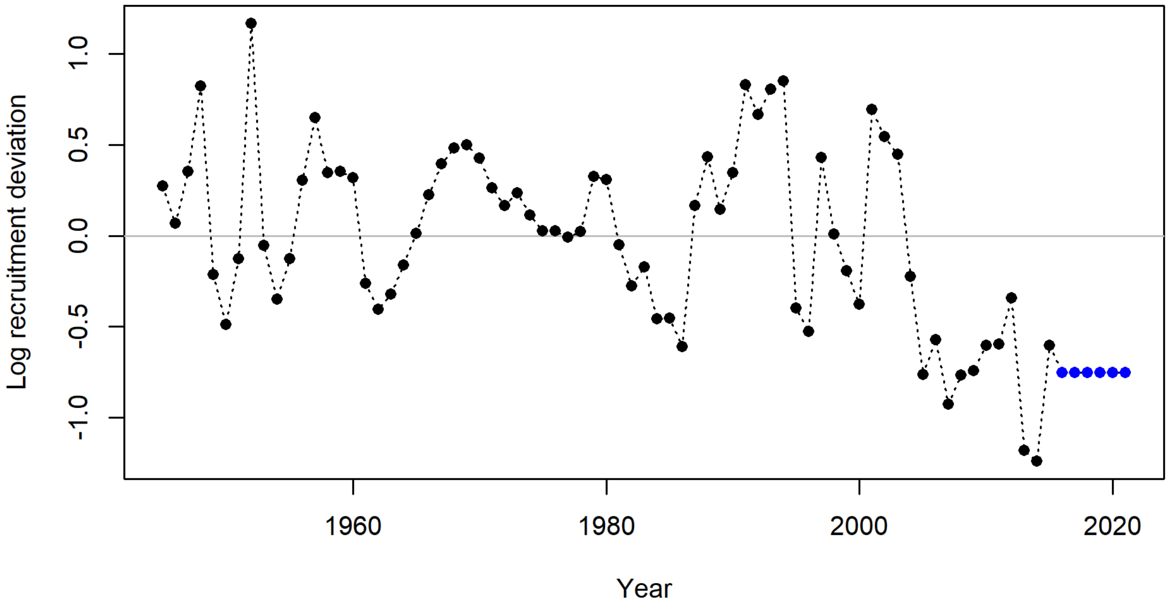


Figure 8.20. Recruitment estimation for the base case analysis. Top left: Time-trajectories of estimated recruitment numbers for the low recruitment base case; top right: the standard errors of recruitment deviation estimates; bottom left: time-trajectories of estimated recruitment numbers with approximate 95% asymptotic intervals for the modified base case, with average recruitment from 2016 onwards; bottom right: bias adjustment.

As the base case requires recruitment deviations to be fixed from 2016 onwards, it is not possible to calculate a hessian and estimate asymptotic uncertainty for this model. As a result, figures in this report requiring estimates of uncertainty are based on the modified base case, where recruitment from 2016 onwards is assumed to be average, allowing uncertainty estimates to be calculated for all parameters. This gives an indication of the type of uncertainty which may be expected from the low recruitment base case, although this modified base case is a different model, and values of the estimated parameters may vary slightly from the base case, with greater differences expected in the model outputs towards the end of the time series, from 2016 onwards. This is illustrated clearly in Figure 8.21, where the top plot (base case without uncertainty) has the recruitment deviations fixed below average from 2016 onwards and the bottom plot (modified base case, with uncertainty) has the recruitment deviations fixed at zero (equivalent to average recruitment) from 2016 onwards. The effect of these assumptions on absolute recruitment can also be seen in the left column plots in Figure 8.20.



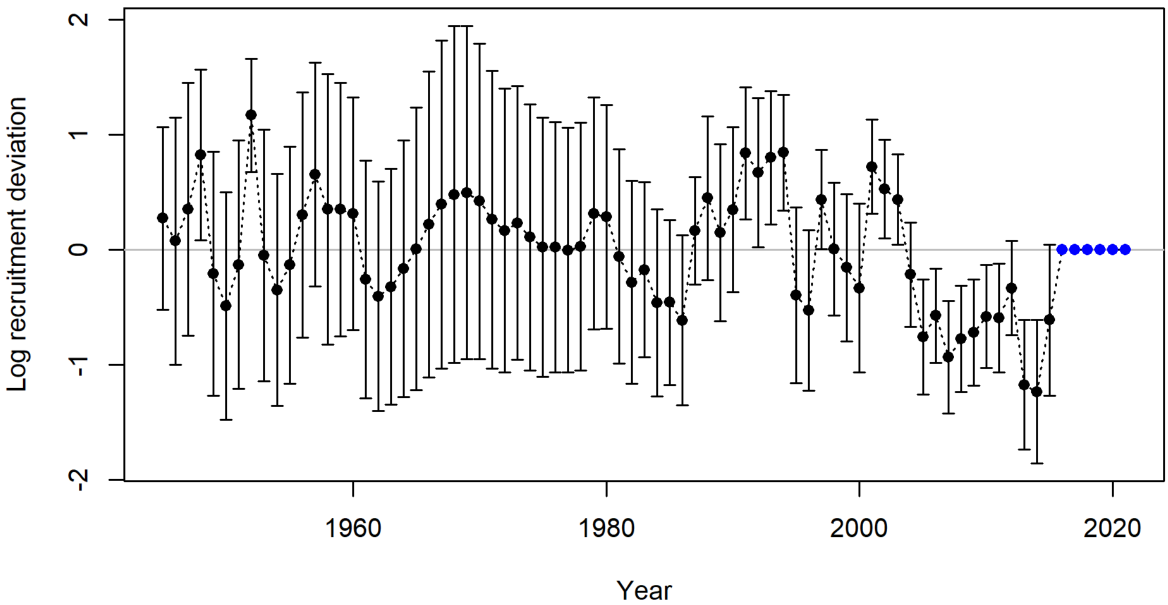


Figure 8.21. Time trajectory of estimated recruitment deviations for the base case, low recruitment from 2016 onwards (top) and of estimated recruitment deviations for the modified base case, average recruitment from 2016 onwards, with 95% confidence intervals.

The time-trajectories of estimated recruitment and estimated recruitment deviations are shown in Figure 8.20 and Figure 8.21. Estimates of recruitments appear to be correlated in the 1960s and 1970s, where there is limited information to inform these estimates and recruitment deviations are more variable since the 1980s and after the productivity shift (Figure 8.21). Recruitment is variable from 1986-2003 with recruitment deviations estimated both above and below zero. This is followed by a period of 12 years of below average estimated recruitment between 2004 and 2015, when the mean estimated recruitment deviation is -0.7, and a period of below average recruitment from 2006 to 2012 when the mean estimated recruitment deviation is -0.26. For the low recruitment base case, recruitment deviations from 2016 onwards are fixed at the mean recruitment deviation for the ten-year period 2006-2015, giving a fixed low future recruitment deviation of -0.75396 used in the base case (with low recruitments). These fixed low recruitments from 2016 onwards affect the projections beyond 2022, but also affect the biomass trajectory from 2016-2022, as these modelled recruitment events from the below average recruitment from 2016 onwards begin to flow into the spawning stock biomass prior to 2022, as these recruits reach maturity.

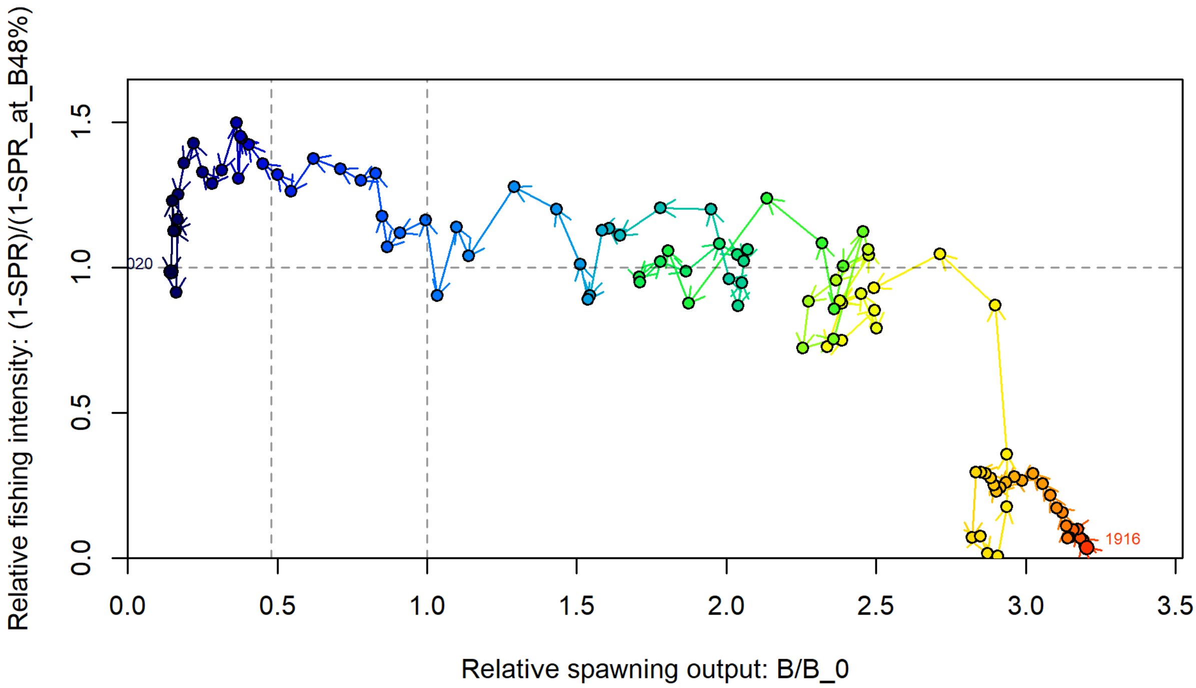


Figure 8.22. Kobe plot for the base case, showing the trajectory of spawning biomass (relative to B_0) plotted against 1-SPR, which is a proxy for fishing mortality, essentially integrating fishing mortality across fleets in the fishery. The horizontal line indicates the target fishing intensity that should theoretically result in the population reaching B_{48}.

Figure 8.22 shows a Kobe plot for the base case. 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 2020 (the red dot) where the biomass is below the limit reference point (less than 0.2 on the x-axis) and the fishing mortality is below the target fishing level (below the horizontal dashed line, the "target fishing value" which will achieve B_{48}). The fishing mortality has been below the target fishing mortality for only three of the last 30 years, in 1992, just before the biomass fell below the 1988 equilibrium unfished biomass, and again in 2015 and 2020. Fishing mortality first exceeded the target fishing mortality just before 1950, and varied above and below this mortality up until 1992, when there was a series of 23 consecutive years fishing above the target fishing mortality. In contrast, the Kobe plot from the 2018 assessment indicated that indicates the fishing mortality for the eastern stock of Jackass Morwong has been below the target fishing level for the last four years, following a period of around 20 years when the fishing mortality was above this target.

The spawning potential ratio is also plotted against year (Figure 8.23), which shows the time series above and below the target fishing mortality more clearly. Figure 8.23 indicates that the fishing mortality was at the historically highest levels in the period from 1997-2012, with only a slight reduction in fishing intensity in the most recent seven years and has been above the "target fishing mortality" for 27 out of the last 30 years.

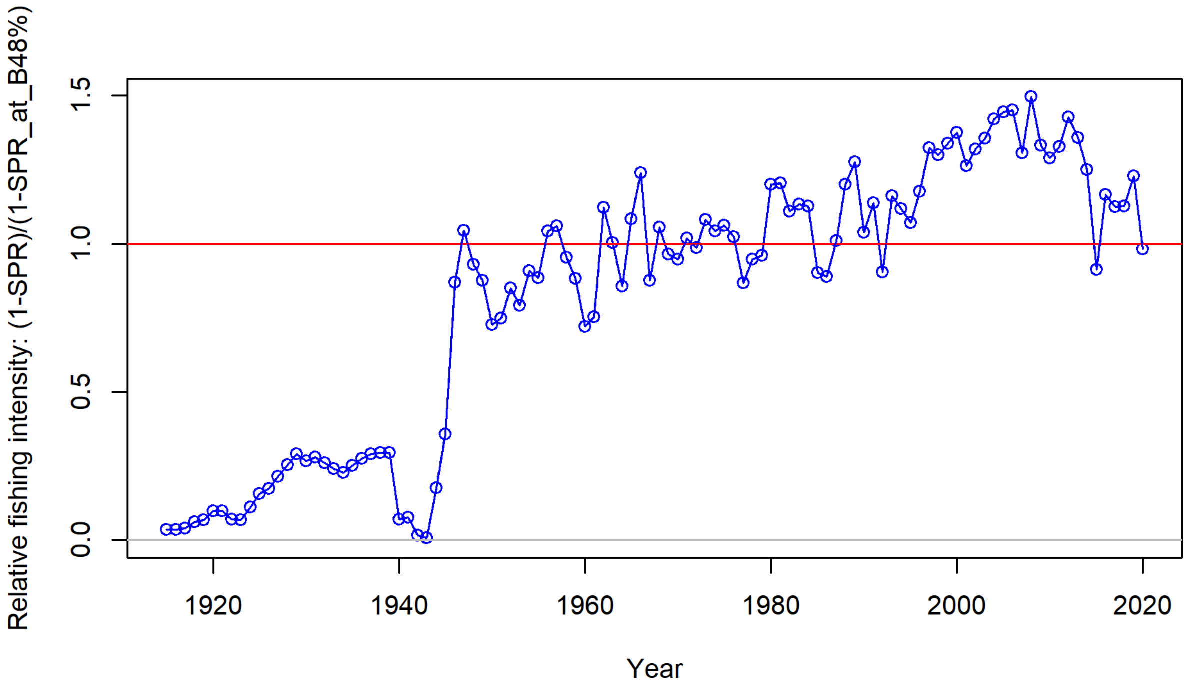


Figure 8.23. Time series of 1-SPR ratio, a proxy for fishing mortality, integrating fishing mortality across fleets in the fishery. The horizontal red line indicates the target fishing intensity that should theoretically result in the population reaching B_{48}.

The time-trajectories of recruitment and recruitment deviation are shown in Figure 8.20 and Figure 8.21. The model now has two stock-recruitment relationships, before and after 1988 (Figure 8.24). While the productivity shift (from 1988) which is incorporated into this model improves the residuals for the recruitment estimates from 1988 onwards, there appears to be considerable serial correlation and some patterns that may require further exploration (see the concentration of below average residuals for the years 2004-2015 in the bottom left hand corner of the right panel of Figure 8.24). It seems clear that a sudden step change in productivity in 1988 is not the best explanation for the recruitment patterns observed here, and there may have been further changes to the productivity since 1988. The first seven years after the recruitment shift (1988-1994) show recruitment that is well above average (Figure 8.21), followed by six years with variable recruitment (1995-2000), another three years with well above average recruitment (2001-2003), followed by 12 years of below average recruitment (2004-2015).

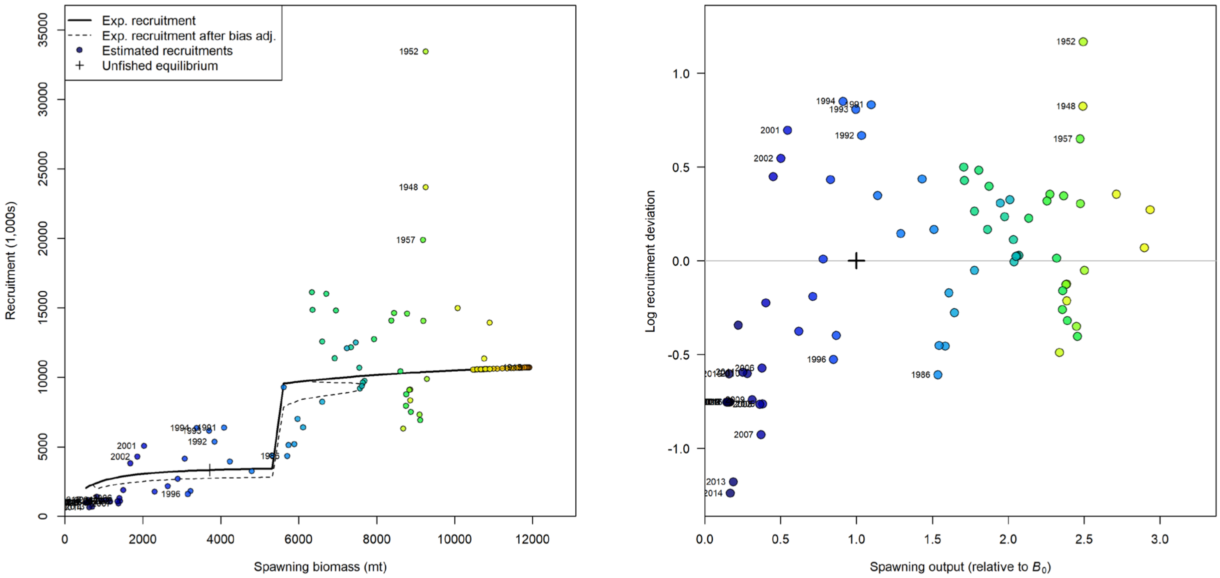


Figure 8.24. Recruitment estimation for the base case analysis. Left: the stock-recruit curve and estimated recruitments; right: log recruitment deviations from the stock recruitment curve.

8.4.1.5 Historical assessment outcomes

Table 8.18. Estimated stock status for the year the RBC was calculated (one year after each assessment was conducted) listed by assessment year and primary assessment author for eastern and western stocks of Jackass Morwong for assessments conducted between 2004 and 2021.

	stock status (%)		
Assessment year	east	west	Comments
2004 (Fay)	25-45		assessment was preliminary and uncertain (Coleraine)
2006 (Fay)	15		overfished in east - partly due to new CPUE series, which included previously excluded “small shots” (< 30kg) (SS)
2007 (Wayte)	19	63	still overfished in the east, not overfished in the west
2008 (Wayte)	19	68	still overfished in the east, not overfished in the west
2009 (Wayte)	24	70	no longer overfished in the east
2010 (Wayte)	26	70	gradual recovery continues
2011 (Wayte)	35	67	productivity shift accepted (aiding "recovery" in east) - new target and limit reference points applied in east
2015 (Tuck)	37	69	stable?
2018 (Day)	35	68	still stable?
2021 (prelim)	22		average recruitment assumed from 2016 onwards
2021 (base case)	15		overfished in east, low recruitment assumed from 2016 onwards

Table 8.18 summarises the estimated stock status for the year following each assessment (the year for which the RBC is calculated), for assessments conducted between 2004 and 2021, indicating stock status in the east and the west, with comments on notable changes to the assessment. All assessments from 2006 onwards were conducted in Stock Synthesis. The 2021 results include the preliminary base case which incorporates average recruitment from 2016 onwards (also sensitivity 15) and the adopted

base case with low recruitment assumed from 2016 onwards. Assessments were not conducted for the western stock prior to 2007. A western stock assessment was not conducted in 2021 due to limited data, poor data quality, concerns about the adequacy of the CPUE series to index the stock abundance and repeated concerns about the inability of previous western stock assessments to fit to the CPUE series. The initial western stock assessments were considered "preliminary" and then later classified as "increasingly uncertain" with concerns expressed about limited sampling effort, unrepresentative sampling, conflict between different data sources (highlighting potential unrepresentative sampling), very low catches and problematic retrospective patterns.

Comparison of base case results for the 2015, 2018 and 2021 assessments are show for absolute biomass (Figure 8.25), relative biomass or stock status (Figure 8.26 and Figure 8.27) and recruitment (Figure 8.28 and Figure 8.29).

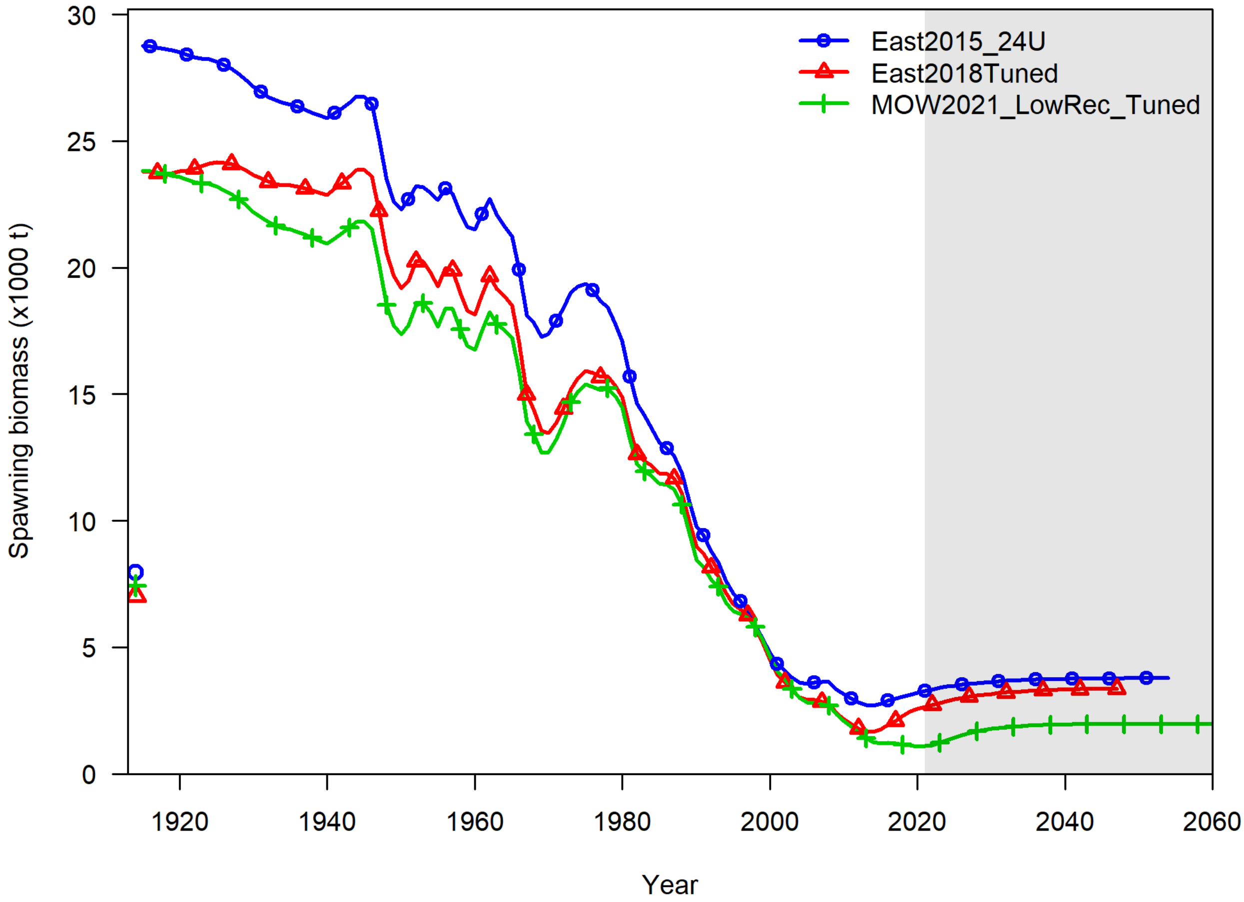


Figure 8.25. Comparison of estimated absolute spawning stock biomass times series for the last three eastern Jackass Morwong stock assessments: 2015 base case (blue); 2018 base case (red); and 2018 base case (green).

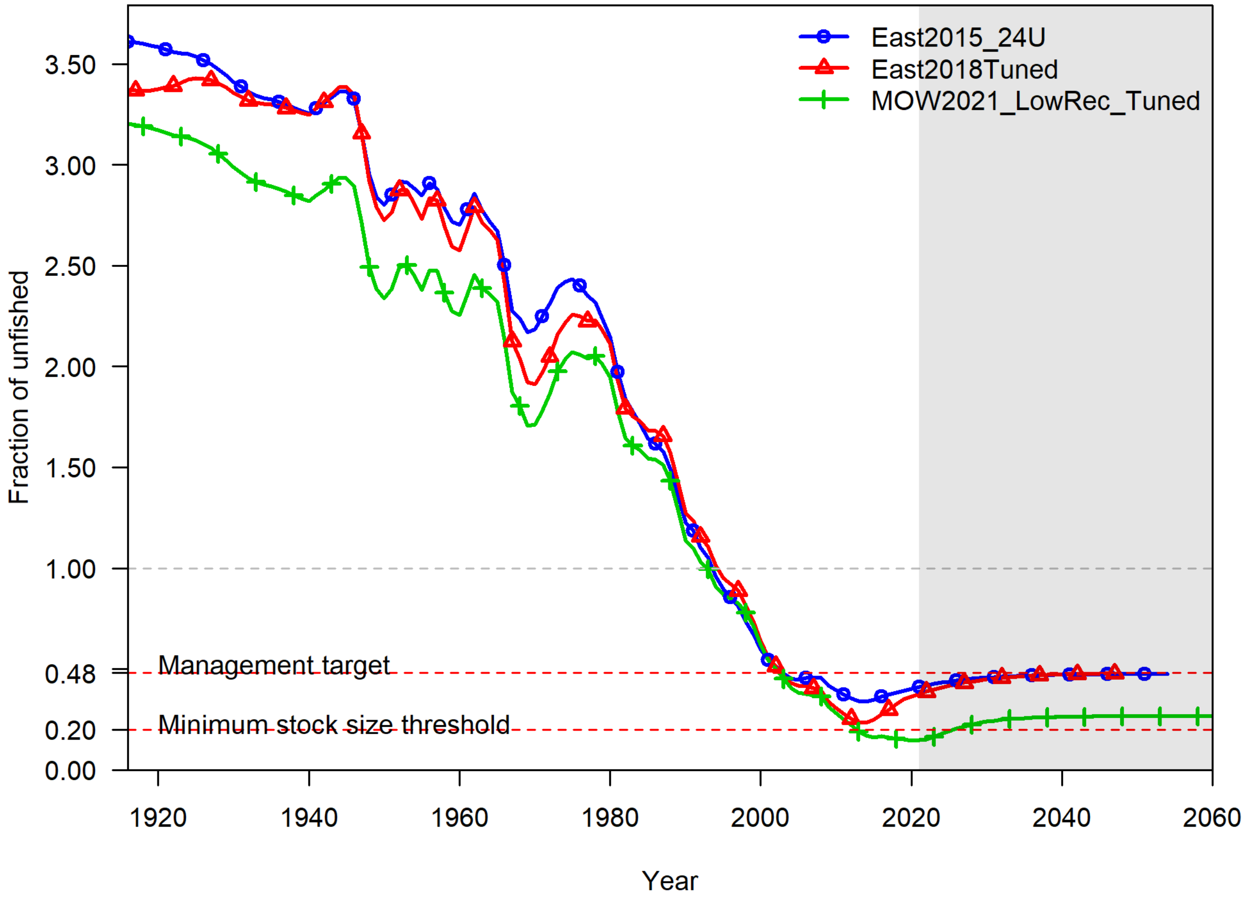


Figure 8.26. Comparison of estimated relative biomass (stock status) times series for the last three eastern Jackass Morwong stock assessments: 2015 base case (blue); 2018 base case (red); and 2018 base case (green).

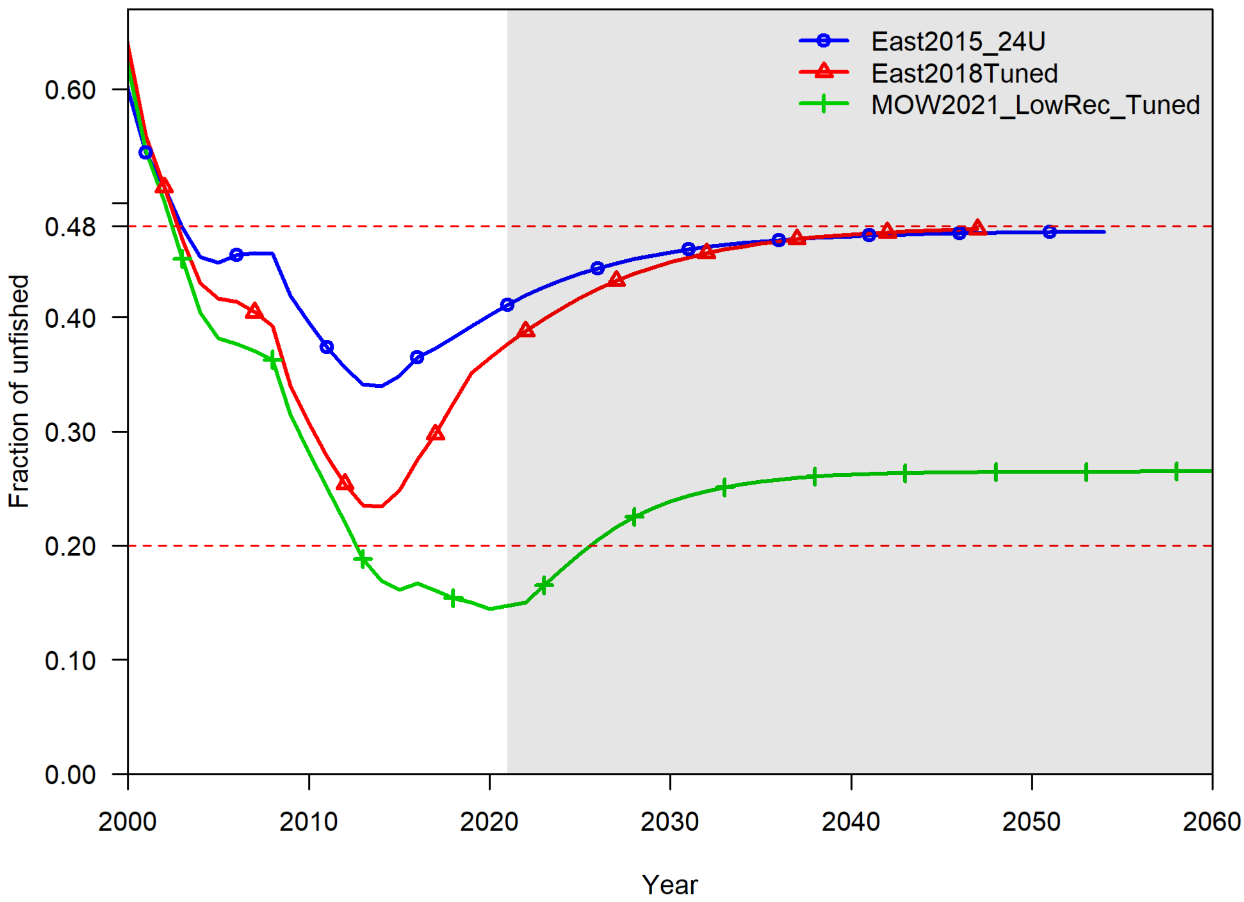


Figure 8.27. Comparison of estimated relative biomass (stock status) times series for the last three eastern Jackass Morwong stock assessments from 2000 onwards: 2015 base case (blue); 2018 base case (red); and 2018 base case (green).

Figure 8.27 highlights the revisions to the estimates of stock status as more data became available to successive assessments, especially in the period from 2010 to 2020, and also indicates that the projected catches for the low recruitment 2021 base case (using the SESSSF Harvest Control Rule, which assumes average future recruitment) do not allow the stock to recover to the target reference point (SSB_{48}) in the projection period.

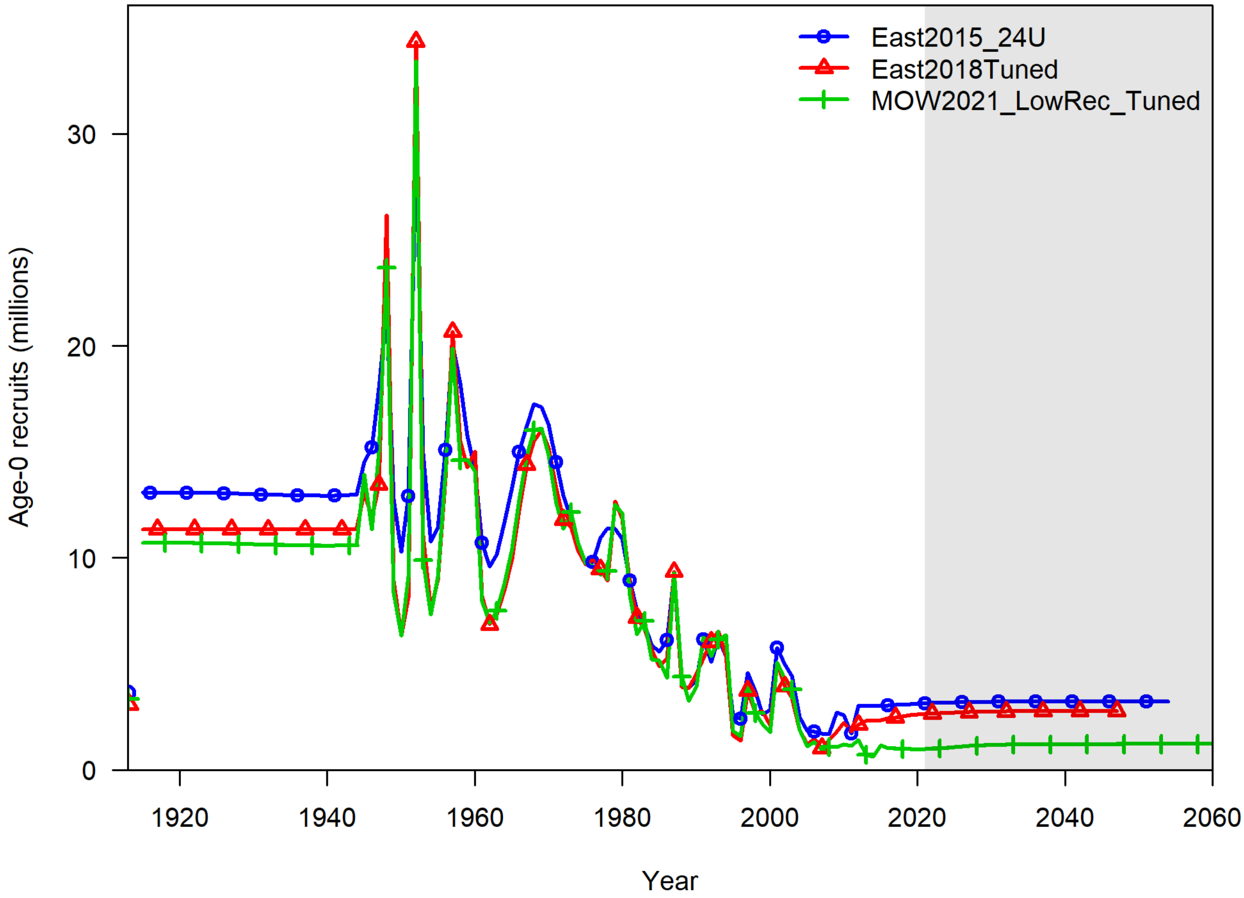


Figure 8.28. Comparison of estimated absolute recruitment times series for the last three eastern Jackass Morwong stock assessments: 2015 base case (blue); 2018 base case (red); and 2018 base case (green).

Figure 8.28 and Figure 8.29 highlight the fixed low recruitment from 2016 onwards for the 2021 assessment. The downwards revision of recent deviations in the 2021 assessment is also clear in Figure 8.28, with the recruitment deviations from 2021 (green crosses) often revised downwards towards the end of the time series. Compared to the 2018 assessment (Figure 8.28, red triangles), 13 of the last 15 estimated recruitment deviations (1998-2012) have been revised downwards in the 2021 assessment compared to the 2018 assessment, with an average downward revision of recruitment deviations of -0.27 compared to an upwards revision of 0.04 for the two exceptions.

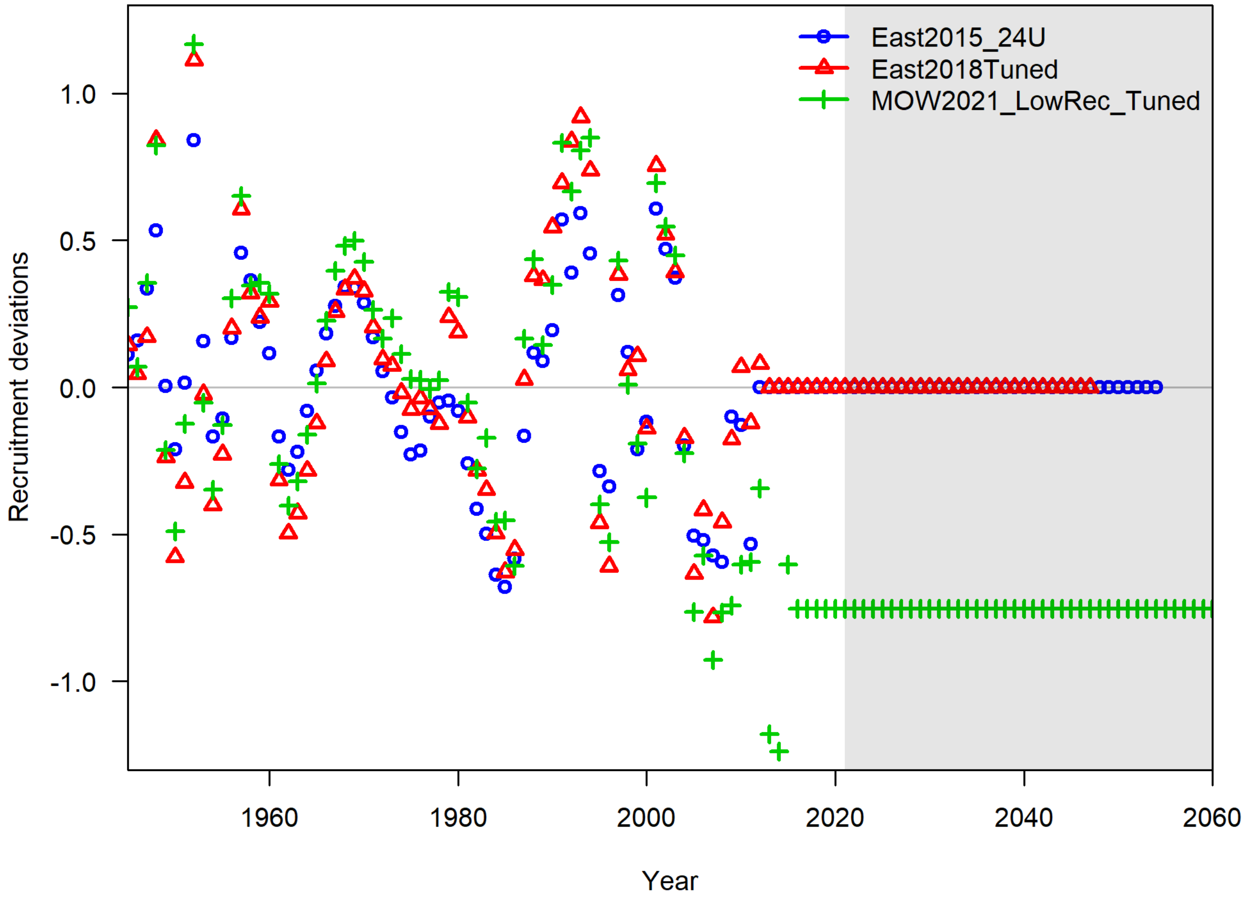


Figure 8.29. Comparison of estimated recruitment deviations for the last three eastern Jackass Morwong stock assessments: 2015 base case (blue); 2018 base case (red); and 2018 base case (green).

8.4.2 *Application of the HCR*

An estimate of the catch for the 2021 calendar year is needed to run the model forward to calculate the 2022 spawning biomass and estimated stock status. We assume the same catch by fleet in 2021 as was caught in 2020, which was a total catch of 103 t, comprising 60 t from the eastern trawl fleet, 14 t from the Danish seine fleet and 19 t from the Tasmanian trawl fleet.

The base-case assessment estimates that current spawning stock biomass is 15% of unexploited stock biomass (SSB_0). The 2022 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 0 t (Table 8.19) and the long-term yield (assuming low recruitment from 2016 onwards) is 91 t (Table 8.23). Averaging the RBC over the three-year period 2019-2021, the average RBC is 0 t and over the five-year period 2019-2023, the average RBC is 1 t (Table 8.23). The RBCs for each individual year from 2022-2026 are listed in Table 8.19 for the base case, with low recruitment assumed from 2016 onwards.

Table 8.19. Yearly projected RBCs (tonnes) across all fleets under the 20:35:48 harvest control rules all assuming low recruitment from 2016 for the agreed base.

Year	RBC
2022	0
2023	0
2024	0
2025	0
2026	6

8.4.3 *Discard estimates*

Model estimates for discards for the period 2022-26 with the 20:35:48 harvest control rule, assuming that the catch is equal to the RBC from 2022-2026, are listed in Table 8.20 for the base case, with a range of 0.0 to 0.2 t for these projected years. Historical values are also listed back to 2017 for estimated discard mass. Table 8.20 also lists the stock status from 2017-2026 (estimated and projected stock status (assuming that the RBC is caught for projections).

Table 8.20. Yearly estimated (bold) and projected (grey) values for (i) stock status (%) and (ii) discards (tonnes) across all fleets under the 20:35:48 harvest control rule, with catches set to the calculated RBC for each projected year from 2022 to 2026 for the low recruitment base case, and with catches in 2021 assumed to be the same values as the catches from 2020.

Year	Stock status (%)	Discards (t)
2017	**16.1**	**7.7**
2018	**15.4**	**7.6**
2019	**15.0**	**8.6**
2020	**14.4**	**5.6**
2021	14.7	5.5
2022	15.0	0.0
2023	16.5	0.0
2024	17.9	0.0
2025	19.3	0.0
2026	20.5	0.2

8.4.4 *Fixed catch, low recruitment projections*

Estimates of recruitment deviations for Jackass Morwong have been below average since the early 2000s (Figure 8.21), which is possibly a consequence of directional environmental change. If below average recruitment continues into the future, producing model projections which assume average recruitment from 2016 onwards would result in overly optimistic estimates of biomass and stock status. Due to these concerns, the base case for this assessment incorporates low, rather than average, fixed recruitment deviations from 2016 onwards. The projected value for low recruitments is based on the average recruitment deviations between 2004 and 2015 (producing an average recruitment deviation value of= -0.754). A range of fixed annual catches for a series of constant catch projection scenarios, with total retained catch set at 0 t, 50 t, 100 t and 150 t, were projected through to 2060 with this low recruitment level to explore biomass trajectories. The fixed historical recruitment deviation time series used for low projections is the same as that shown in Figure 8.21.

As the low recruitment scenario markedly reduces stock productivity, the population is no longer able to recover to unfished levels in the absence of fishing, or indeed even to recover to B_{48}, as is apparent from the 0 t catch projection scenario, under which the population only recovers near to 40% of SSB_0 (Figure 8.30, blue line). When various fixed catches are projected (0 t, 50 t, 100 t, 150 t and the RBC obtained from applying the HCR), the equilibrium stock status declines accordingly (32% for 50 t, 21% for 100 t, 0 % for 150 t and 26.5 % for the RBC, Table 8.21). The RBC is applied using the standard SESSF Harvest Control Rule, which assumes that all future recruitment will be average. When the RBC is calculated, the assumed low recruitment from 2016 to the year before the RBC is set is properly accounted for, but the (expected) low recruitment in the future is not considered, as the current RBC calculation, which is built in to Stock Synthesis, does not allow for anything other than average recruitment in the future. It appears that catches of around 100 t only just allows the stock to recover to B_{20} and catches above 100 t result in a continued decline in stock size (Figure 8.30).

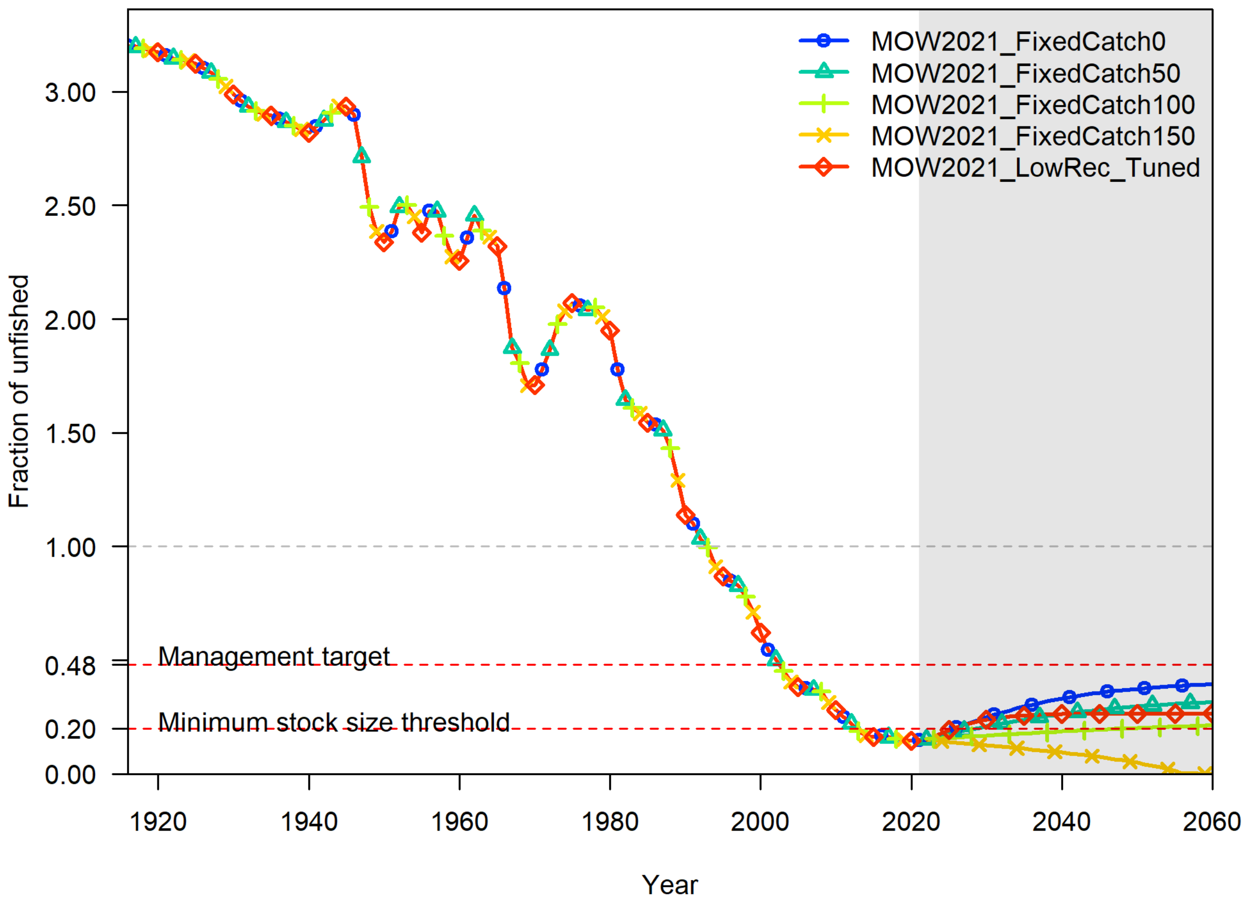


Figure 8.30. Stock status time-series for the RBC calculated by the SESSF harvest control rule (red), and four alternative constant catch scenarios 0 t, 50 t, 100 t, 150 t. All scenarios assume low recruitment for the entire forecast period.

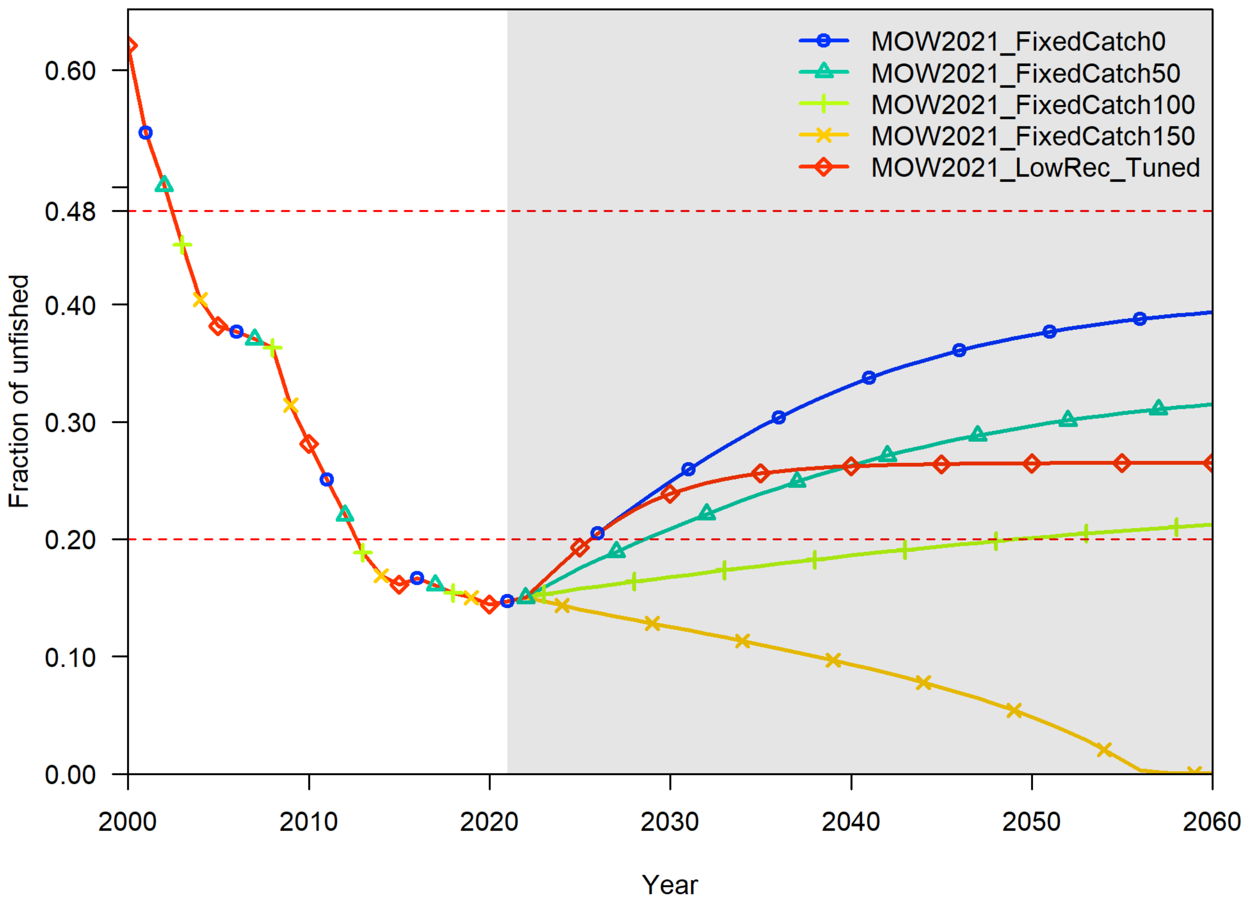


Figure 8.31. Stock status time-series (2000-2060) for the RBC calculated by the SESSF harvest control rule (red), and four alternative constant catch scenarios 0 t, 50 t, 100 t, 150 t. All scenarios assume low recruitment for the entire forecast period.

Table 8.21 provides stock status, retained catches and estimated discards for the low recruitment scenarios with zero catch (0 t), 50 t, 100 t and 150 t catches and applying the standard SESSF harvest control rule (HCR).

Table 8.21. Stock status (SS, %), retained catch (RET, t) and estimated discards (DIS, t) corresponding to the low recruitment, fixed catch projection scenarios with the zero catch (0 t), 50 t constant catch, 100 t constant catch, 150 t constant catch and applying the HCR.

Catch	0 t			50 t			100 t			150 t			HCR		
Year	SS	RET	DIS	SS	RET	DIS	SS	RET	DIS	SS	RET	DIS	SS	RET	DIS
2022	15.0	0.0	0.0	15.0	50.0	2.6	15.0	100.0	5.2	15.0	150.0	7.9	15.0	0.0	0.0
2023	16.5	0.0	0.0	15.9	50.0	2.5	15.3	100.0	5.1	14.7	150.0	8.0	16.5	0.0	0.0
2024	17.9	0.0	0.0	16.7	50.0	2.4	15.5	100.0	5.1	14.4	150.0	8.1	17.9	0.0	0.0
2025	19.3	0.0	0.0	17.5	50.0	2.3	15.8	100.0	5.0	14.0	150.0	8.2	19.3	0.0	0.0
2026	20.5	0.0	0.0	18.2	50.0	2.3	16.0	100.0	5.0	13.7	150.0	8.3	20.5	5.5	0.2
2027	21.7	0.0	0.0	18.9	50.0	2.2	16.2	100.0	5.0	13.4	150.0	8.4	21.6	18.6	0.7
2028	22.8	0.0	0.0	19.6	50.0	2.2	16.4	100.0	4.9	13.1	150.0	8.5	22.5	30.4	1.2
2029	23.9	0.0	0.0	20.3	50.0	2.2	16.6	100.0	4.9	12.8	150.0	8.6	23.3	40.7	1.6
2030	24.9	0.0	0.0	20.9	50.0	2.2	16.8	100.0	4.9	12.5	150.0	8.7	23.9	49.5	1.9
2031	25.9	0.0	0.0	21.5	50.0	2.1	17.0	100.0	4.9	12.2	150.0	8.8	24.4	57.1	2.2
2032	26.9	0.0	0.0	22.1	50.0	2.1	17.2	100.0	4.8	11.9	150.0	8.9	24.8	63.5	2.4
2033	27.9	0.0	0.0	22.7	50.0	2.1	17.4	100.0	4.8	11.6	150.0	9.0	25.1	68.8	2.6
2034	28.7	0.0	0.0	23.3	50.0	2.1	17.5	100.0	4.8	11.3	150.0	9.1	25.4	73.2	2.8
2035	29.6	0.0	0.0	23.8	50.0	2.0	17.7	100.0	4.8	11.0	150.0	9.2	25.6	76.8	2.9
2036	30.4	0.0	0.0	24.4	50.0	2.0	17.9	100.0	4.7	10.7	150.0	9.3	25.8	79.7	3.0
2037	31.1	0.0	0.0	24.9	50.0	2.0	18.1	100.0	4.7	10.4	150.0	9.5	25.9	82.0	3.1
2038	31.8	0.0	0.0	25.4	50.0	2.0	18.3	100.0	4.7	10.0	150.0	9.6	26.1	83.9	3.2
2039	32.5	0.0	0.0	25.8	50.0	2.0	18.4	100.0	4.7	9.7	150.0	9.8	26.1	85.5	3.3
2040	33.1	0.0	0.0	26.3	50.0	1.9	18.6	100.0	4.7	9.3	150.0	10.0	26.2	86.7	3.3
2041	33.7	0.0	0.0	26.7	50.0	1.9	18.8	100.0	4.6	9.0	150.0	10.1	26.3	87.6	3.3
2042	34.3	0.0	0.0	27.1	50.0	1.9	18.9	100.0	4.6	8.6	150.0	10.3	26.3	88.4	3.4
2043	34.8	0.0	0.0	27.5	50.0	1.9	19.1	100.0	4.6	8.2	150.0	10.6	26.3	89.0	3.4
2044	35.2	0.0	0.0	27.9	50.0	1.9	19.2	100.0	4.6	7.8	150.0	10.8	26.4	89.5	3.4
2045	35.7	0.0	0.0	28.2	50.0	1.9	19.4	100.0	4.6	7.4	150.0	11.1	26.4	89.8	3.4
2046	36.1	0.0	0.0	28.5	50.0	1.9	19.5	100.0	4.6	6.9	150.0	11.4	26.4	90.1	3.4
2047	36.5	0.0	0.0	28.8	50.0	1.9	19.7	100.0	4.5	6.4	150.0	11.8	26.4	90.4	3.4
2048	36.8	0.0	0.0	29.1	50.0	1.8	19.8	100.0	4.5	5.9	150.0	12.3	26.4	90.6	3.4
2049	37.1	0.0	0.0	29.4	50.0	1.8	20.0	100.0	4.5	5.4	150.0	12.9	26.5	90.7	3.4
2050	37.4	0.0	0.0	29.7	50.0	1.8	20.1	100.0	4.5	4.8	150.0	13.6	26.5	90.8	3.5
2051	37.7	0.0	0.0	29.9	50.0	1.8	20.2	100.0	4.5	4.2	150.0	14.6	26.5	90.9	3.5
2052	37.9	0.0	0.0	30.1	50.0	1.8	20.4	100.0	4.5	3.6	150.0	16.1	26.5	91.0	3.5
2053	38.2	0.0	0.0	30.3	50.0	1.8	20.5	100.0	4.5	2.8	150.0	18.4	26.5	91.1	3.5
2054	38.4	0.0	0.0	30.5	50.0	1.8	20.6	100.0	4.4	2.0	150.0	23.2	26.5	91.1	3.5
2055	38.6	0.0	0.0	30.7	50.0	1.8	20.7	100.0	4.4	1.2	137.8	34.2	26.5	91.1	3.5
2056	38.8	0.0	0.0	30.9	50.0	1.8	20.8	100.0	4.4	0.3	54.3	17.7	26.5	91.2	3.5
2057	38.9	0.0	0.0	31.1	50.0	1.8	20.9	100.0	4.4	0.1	34.6	8.3	26.5	91.2	3.5
2058	39.1	0.0	0.0	31.2	50.0	1.8	21.0	100.0	4.4	0.0	12.6	2.1	26.5	91.2	3.5
2059	39.2	0.0	0.0	31.4	50.0	1.8	21.1	100.0	4.4	0.0	-2.7	0.4	26.5	91.2	3.5
2060	39.3	0.0	0.0	31.5	50.0	1.8	21.2	100.0	4.4	0.1	5.7	0.2	26.5	91.2	3.5

8.4.5 *Retrospective analysis*

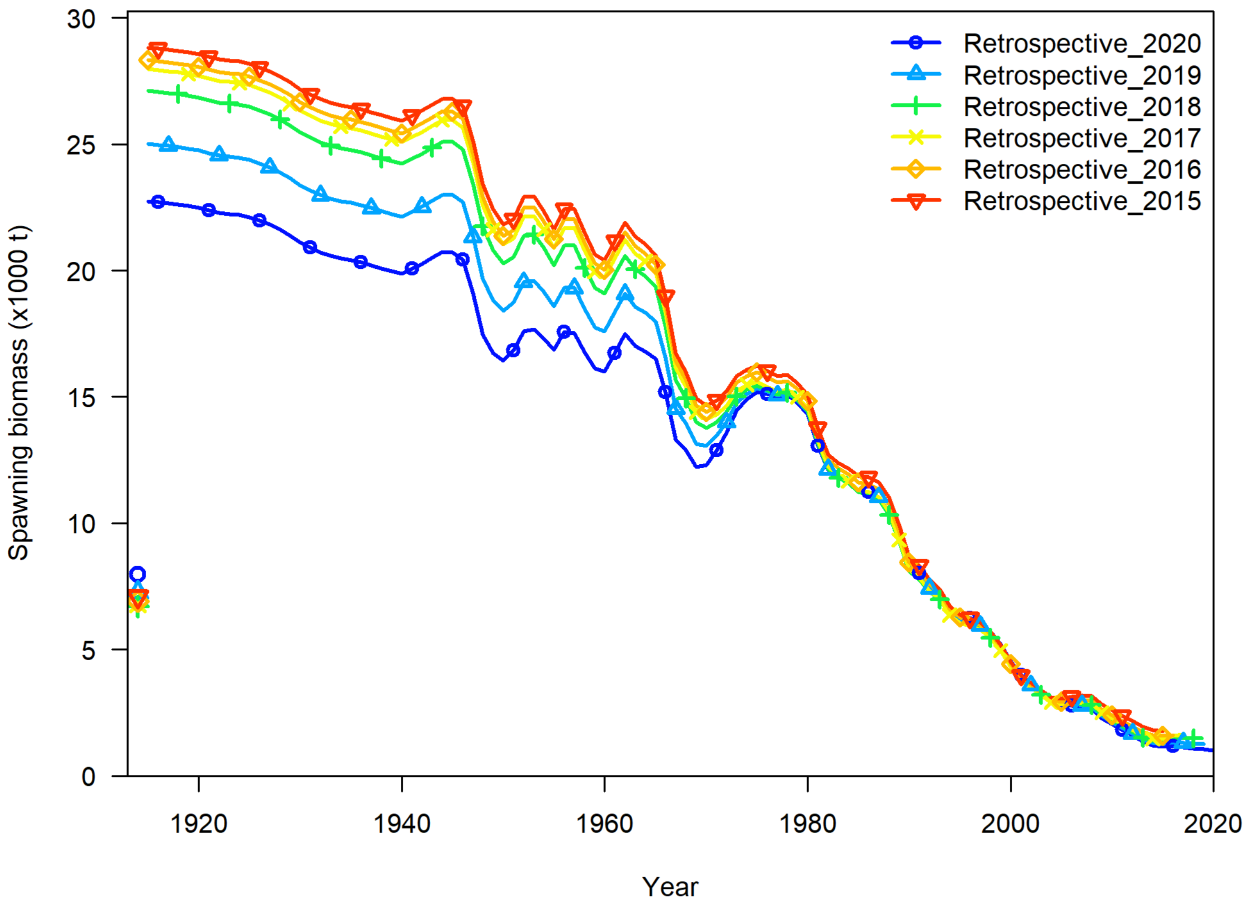


Figure 8.32. Retrospectives for absolute spawning biomass for Jackass Morwong, with data included to 2020 (blue) and then successive years removed back to 2015 (red).

A retrospective analysis for absolute spawning biomass is shown in Figure 8.32, with the data after 2019 removed initially (shown in light blue), then successive years of data removed back to 2015 (shown in red). The same analysis is plotted in terms of relative spawning biomass in Figure 8.33. In both cases the changes are largest for the first two years of data removal, with a slightly larger initial spawning stock biomass estimated as each successive year of data is removed, but with apparently small differences in recent years (Figure 8.32). This change becomes clearer when plotted as relative stock status (Figure 8.33), normalised to the 1988 equilibrium spawning biomass, in which case the 1915 equilibrium biomass, is revised substantially when the first two years of data is removed, with minimal changes as further years of data are removed. This suggests that the most recent two years of data have been most influential in revising the initial stock status downward (translated into 1988 equilibrium spawning stock biomass). The changes in the most recent years are hard to distinguish in Figure 8.33, given the scale of the 1915 spawning stock biomass and stock status, so the same retrospective trajectories, showing the last 20 years only, is presented in Figure 8.34.

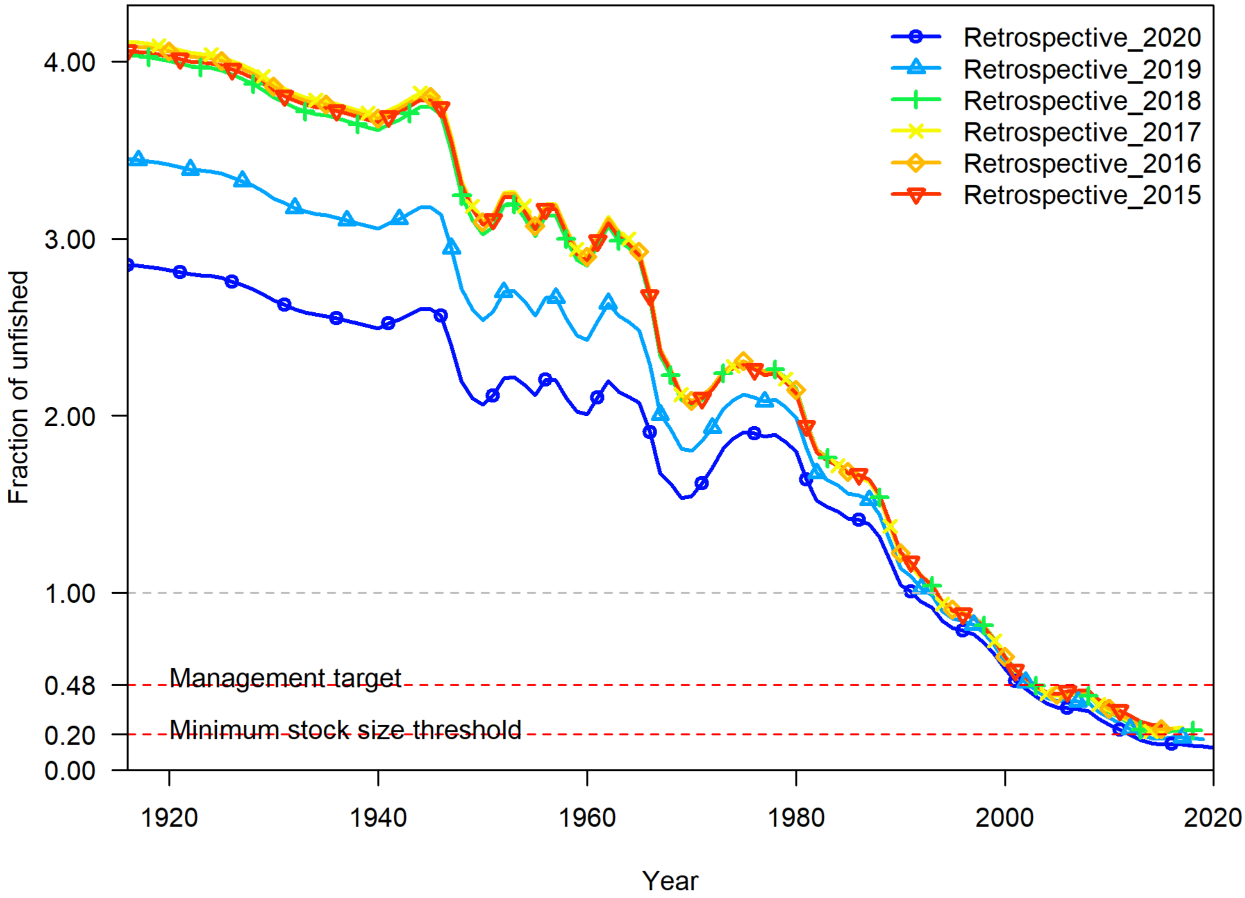


Figure 8.33. Retrospectives for relative stock status for Jackass Morwong, with data included to 2020 (blue) and then successive years removed back to 2015 (red).

When this retrospective analysis is applied to the absolute recruitment time series (Figure 8.35), the most significant changes appear to predominantly affect the initial equilibrium recruitment level, R_0, with again the largest changes seen when the data from 2020 and 2019 are removed.

However, there are some more subtle changes that can be drawn out when examining the plot showing recruitment residuals (Figure 8.36), rather than absolute recruitment, which indicates a gradual change in the estimates of the recent recruitment events (over a period of around 20 years), with a clear pattern where the most recent residuals are continually revised down as more data is used to estimate them, with larger downward revisions to the most recent estimates of recruitment deviations. This suggests that the inclusion of the most recent years of data included in this assessment supports successively more pessimistic estimates of recent recruitment.

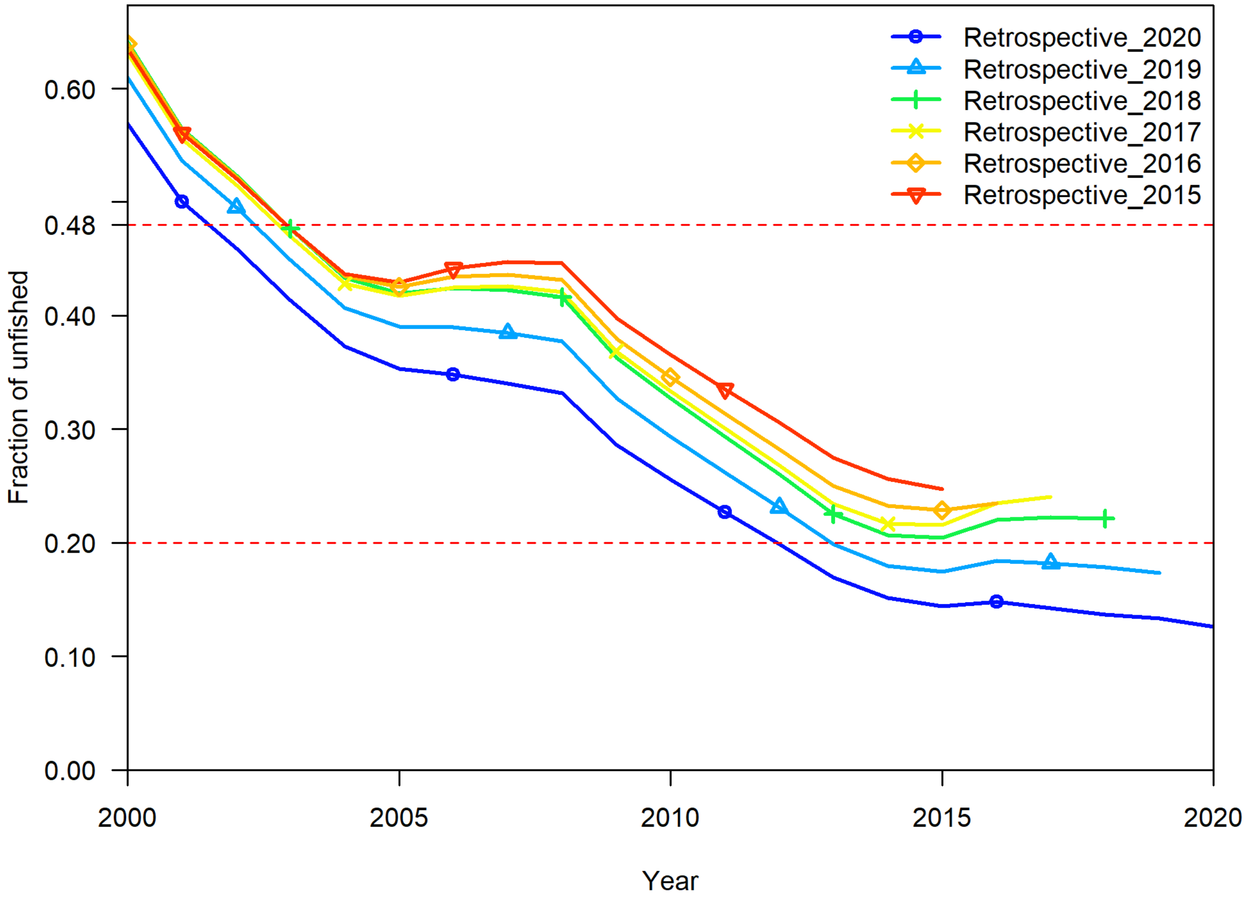


Figure 8.34. Retrospectives for relative stock status for Jackass Morwong, with data included to 2020 (blue) and then successive years removed back to 2015 (red) – plotted from 2000-2020.

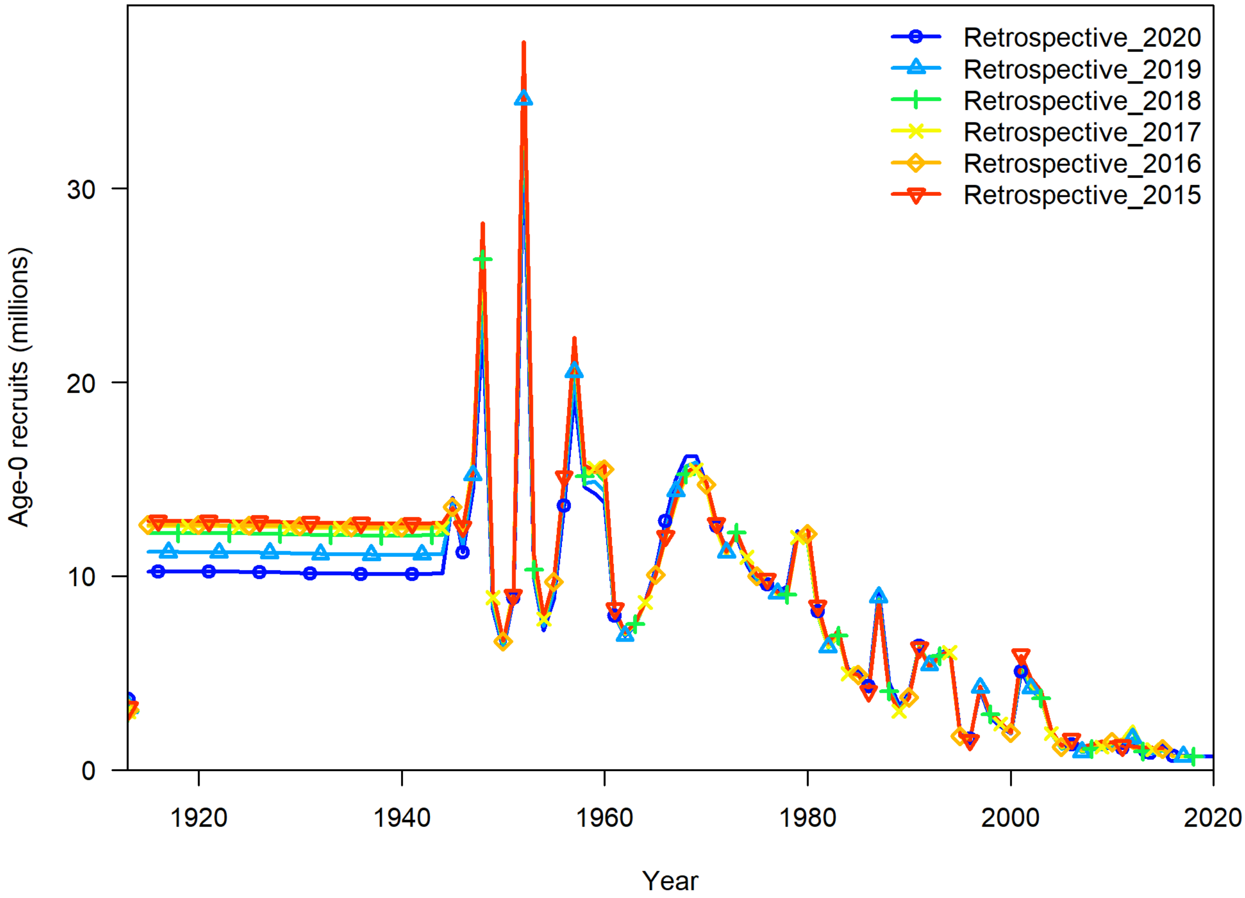


Figure 8.35. Retrospectives for absolute recruitment for Jackass Morwong, with data included to 2020 (blue) and then successive years removed back to 2015 (red).

An alternative presentation of the retrospective analysis applied to the recruitment time series is shown in a "squid plot" shown here for retrospectives with average recruitment from 2016 onwards (Figure 8.37) and low recruitment from 2016 onwards (Figure 8.38). Under average recruitment, the squid pot is very unbalanced, indicating that the revisions to recent recruitment deviations are consistently in the same direction, in this case clearly showing that revisions to the recruitment deviations are all in the same direction (downwards) as more data is considered, indicating a pattern that is not being adequately modelled, potentially model misspecification or temporal changes to parameters (e.g. time varying unidirectional biological changes that could potentially be environmentally driven) that are not considered or allowed for in the assumptions of this model. This pattern is partially alleviated with low recruitment projections, for the last five cohorts (fish spawned in the years 2011-2015), where the initial estimate of cohort strength is now compared to the expected low recruitment, rather than to the (rather unlikely) average recruitment.

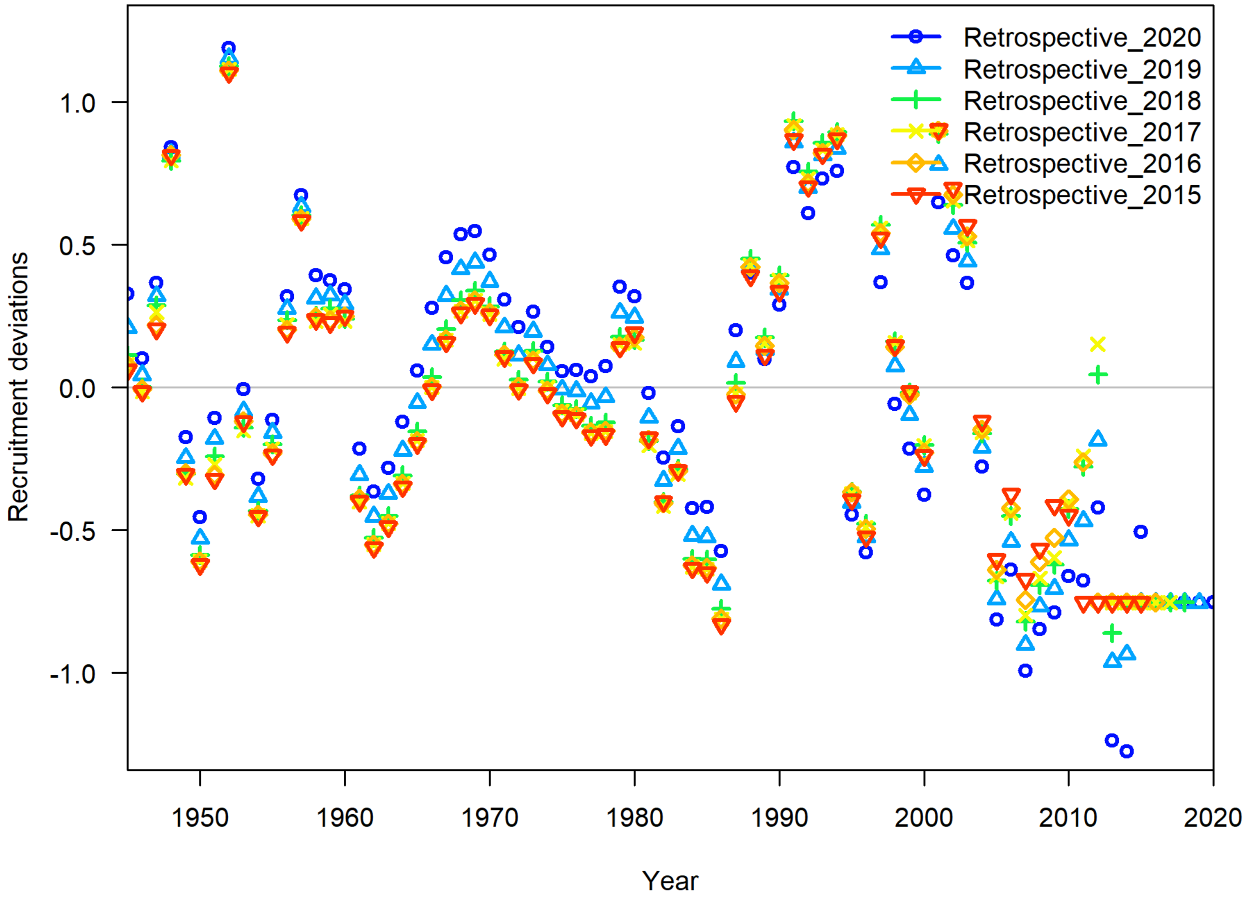


Figure 8.36. Retrospectives for recruitment deviations for Jackass Morwong, with data included to 2020 (blue) and then successive years removed back to 2015 (red).

Squid plots 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 base case model using data up to 2020 and then one more point one for each of the five different retrospectives. Each string can be followed from right to left as successive years of data are removed. The changes to the estimates of recruitment deviation, 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. Large changes on the y-axis indicate large revisions, and if all the changes have the same sign (positive or negative) this indicates a series of changes in the same direction, so indicating some bias rather than somewhat random revisions). In this case, most of the change (vertically, in the y-axis) is in the first two points (as you move from right to left on each string), indicating that most recent two years of data is having the largest influence on these revisions.

For 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 cannot 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 base case with positive y-values corresponding to negative recruitment deviations 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 (although still largest when the 2020 and 2019 data is removed), as there is less additional information on the size of these cohorts from data obtained in the period 2015-2018, although these recruitments are still generally revised downwards, albeit by smaller amounts by data in the years 2015-2018.

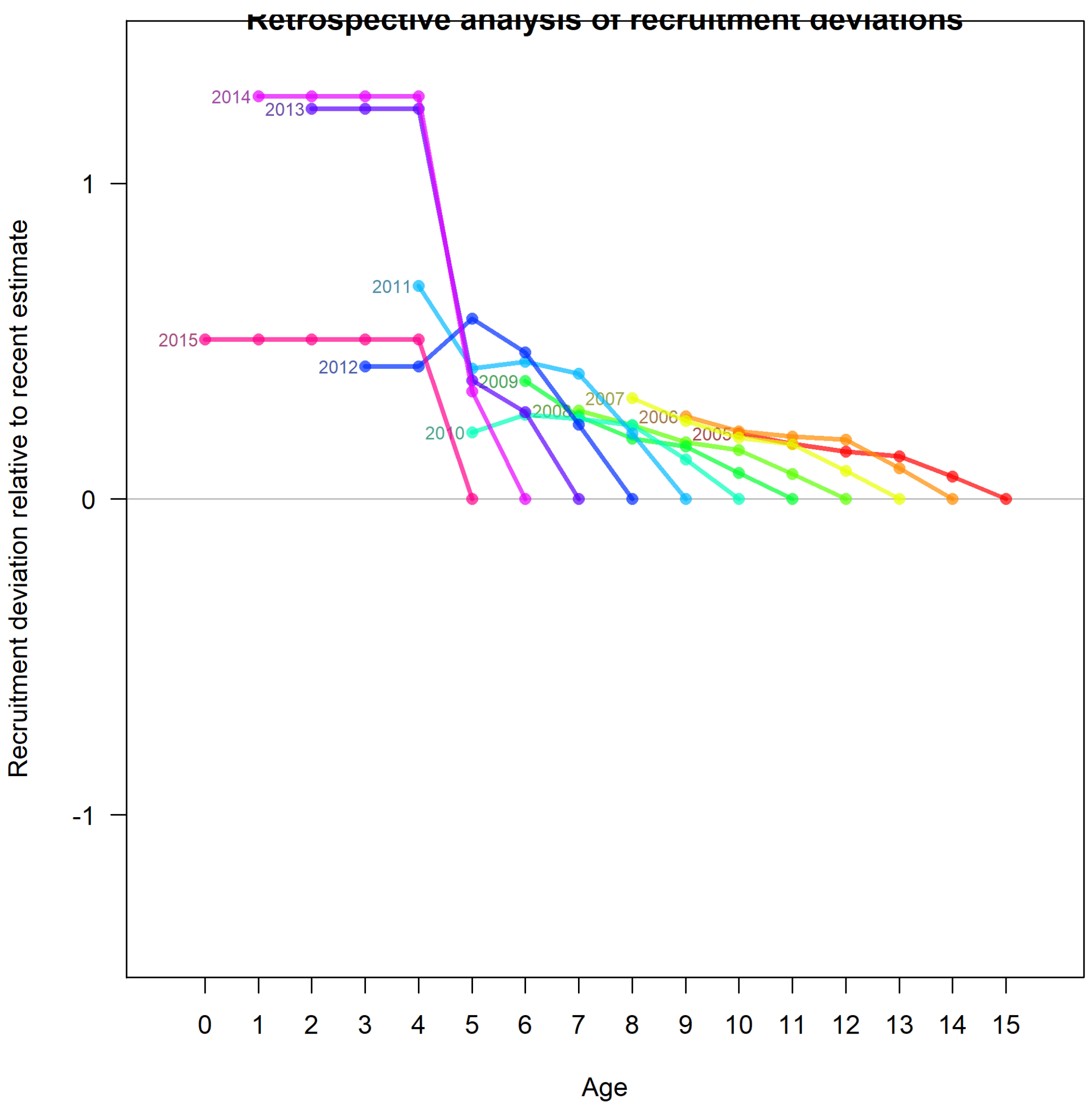


Figure 8.37. Retrospective analysis of recruitment deviations (squid plot) for Jackass Morwong with average recruitment and data removed in successive years back to 2015.

There are only three revisions of recruitment deviations upwards in this whole series (Figure 8.37, movements downwards on the y-axis) and these are all minor revisions. The 2010 cohort is revised upwards from the 2015 data and the 2011 and 2012 cohorts are revised upwards when data from 2016 is added, but all three cohorts have their recruitment revised downwards later as subsequent years of data are added.

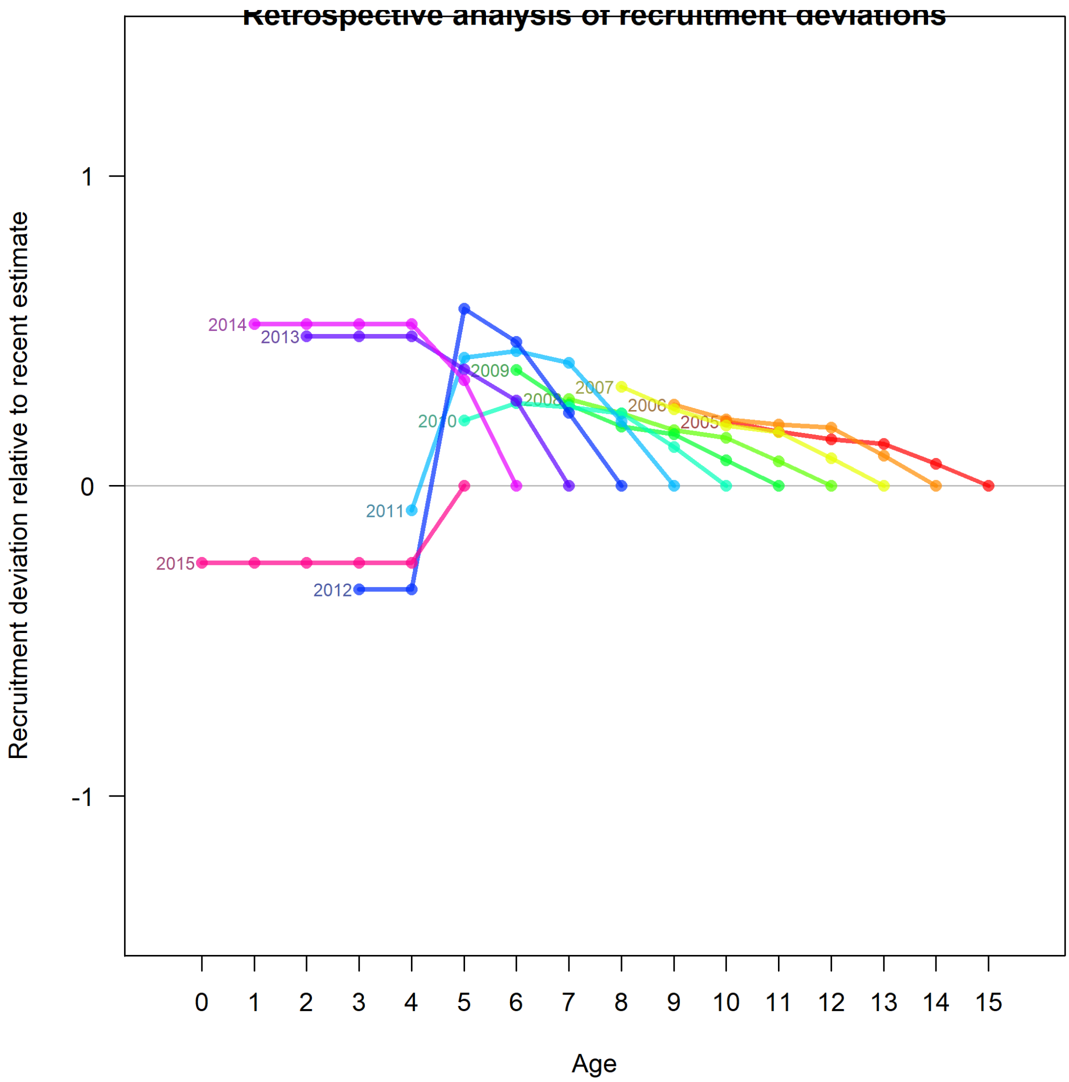


Figure 8.38. Retrospective analysis of recruitment deviations (squid plot) for Jackass Morwong with low recruitment and data removed in successive years back to 2015.

In the most recent School Whiting assessment report, Day et al (2020) state "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 misspecification." The one-sided squid plots shown here are a classic example of just such a pathological pattern.

Fits to the eastern and Tasmanian trawl CPUE series, (Figure 8.39 and Figure 8.40) for these retrospective analyses show a clear pattern, especially when plotted on a log scale, where an optimistic increase at the end of the time series get successively revised downwards as additional years of data are added, and the model "expected" increase in the subsequent new CPUE data points is not realised.

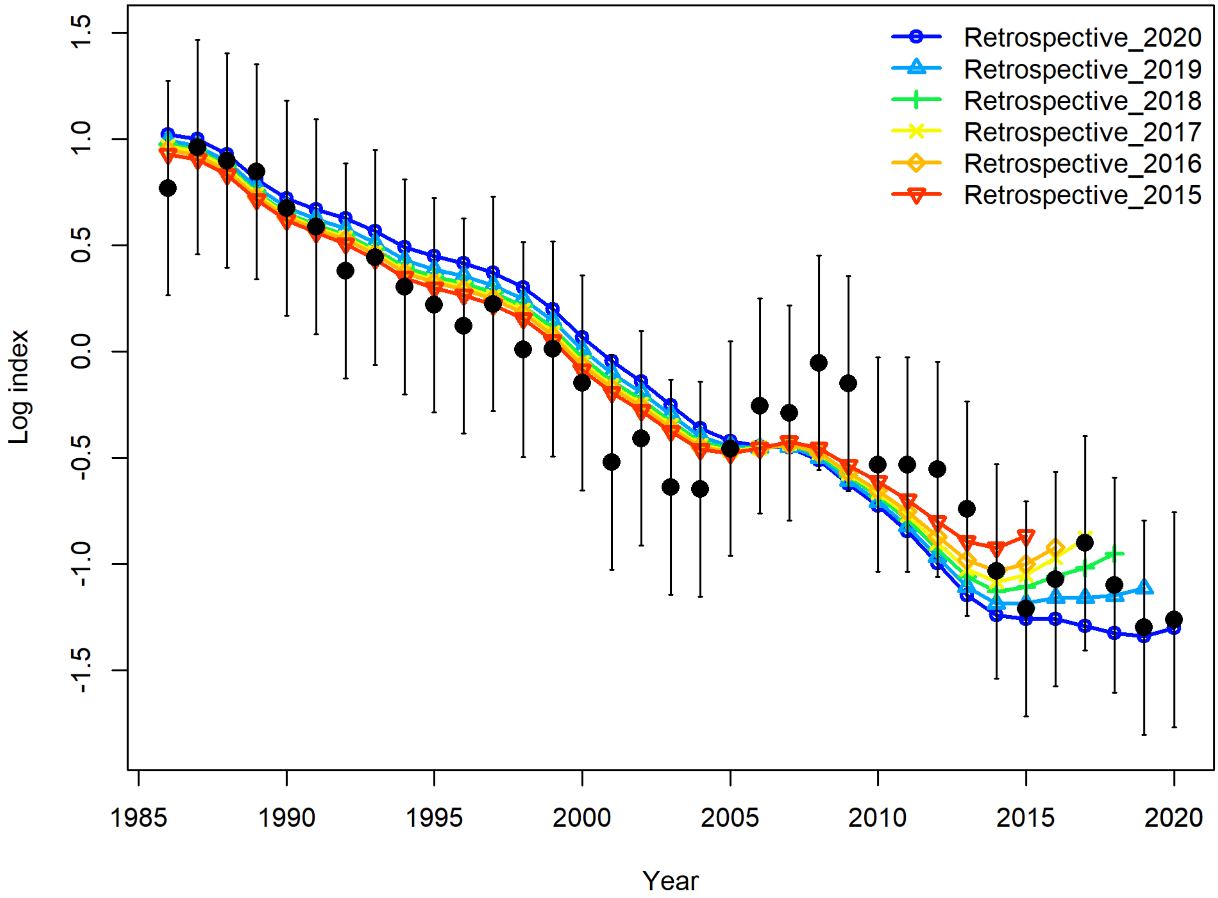


Figure 8.39. Retrospective fits to the log of the for the eastern trawl CPUE fits for Jackass Morwong, for the base case with low recruitment and data removed in successive years back to 2015.

The severity of retrospective patterns can be quantified using Mohn's rho, a statistic which is defined as the average of the relative differences between an estimate obtained from an assessment with a truncated time series and an estimate of the same quantity from an assessment using the full time series (Hurtado-Ferro et al., 2015). Mohn's rho values are calculated for a range of quantities, including spawning stock biomass, recruitment, fishing mortality and stock status. As a general rule of thumb, values of Mohn’s rho higher than 0.20 or lower than -0.15 are cause for concern in an assessment (Hurtado-Ferro et al., 2015).

A retrospective analysis was conducted for the base case with the assumption of average recruitment, with only the squid plot (Figure 8.37) shown for this analysis, and also for the base case with low recruitment (Figure 8.32-Figure 8.36, Figure 8.38-Figure 8.40). The values of Mohn’s rho, for both the low and average recruitment scenarios, are listed in Table 8.22, and this indicates retrospective patterns in the assessment under average recruitment for spawning stock biomass, fishing mortality and stock status. The statistics all improve under the assumption of low recruitment from 2016 onwards, compared to the average recruitment scenario, as the values are all smaller in absolute value, with Mohn’s rho for recruitment, -0.051, now indicating that the retrospective pattern for recruitment is even less of a concern under low recruitment. However, there are still issues with retrospective patterns for spawning stock biomass, fishing mortality and stock status.

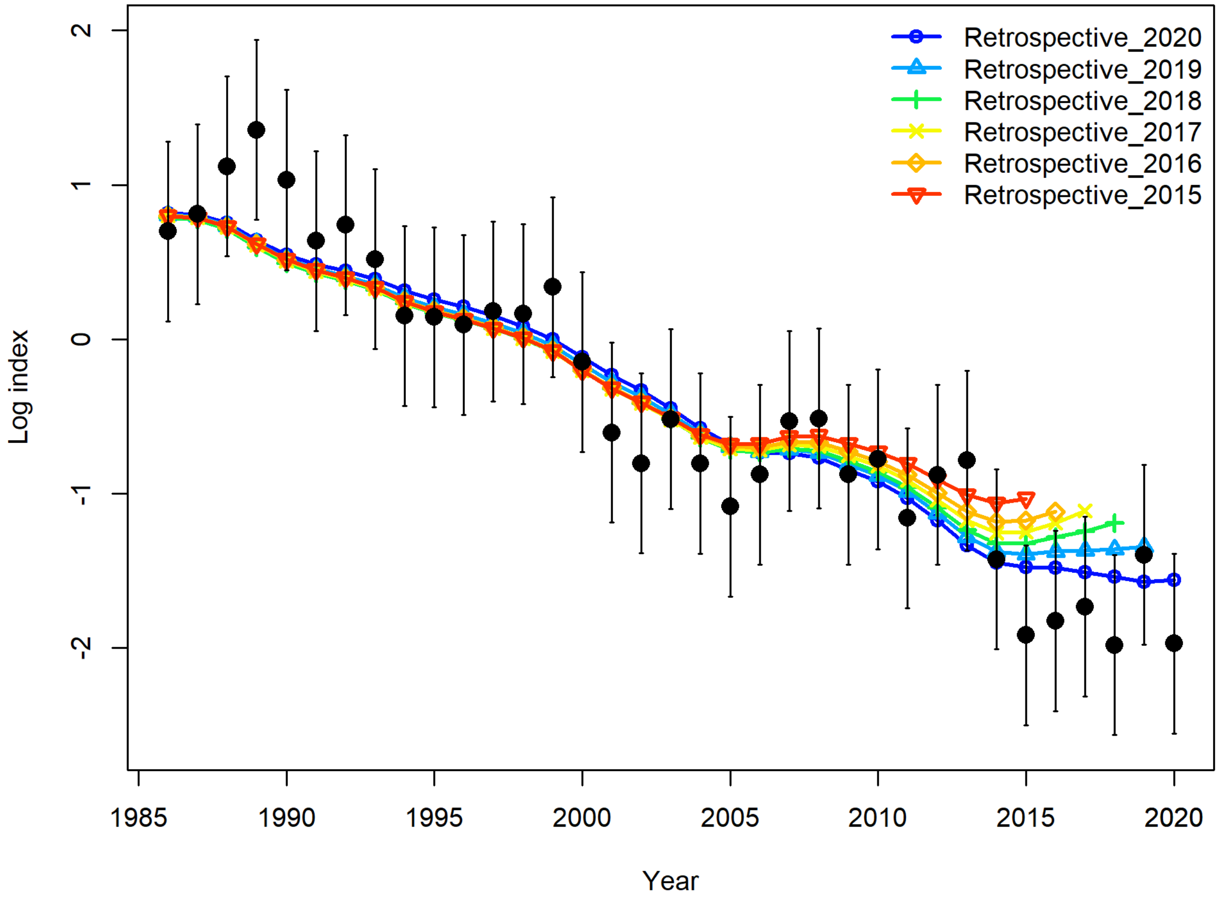


Figure 8.40. Retrospective fits to the log of the for the Tasmanian trawl CPUE fits for Jackass Morwong, for the base case with low recruitment and data removed in successive years back to 2015.

Table 8.22. Mohn's rho values for the average recruitment and low recruitment retrospectives.

	Average recruitment	Low recruitment
SSB	0.501	0.378
Recruitment	0.165	-0.051
F	-0.364	-0.256
Stock status	-0.723	0.582

8.4.6 *Likelihood profiles*

8.4.6.1 Natural mortality

For Jackass Morwong the likelihood profile for natural mortality, *M*, a parameter fixed in the base case at 0.15 yr^{-1}, is shown in Figure 8.41 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 *M* could vary between around 0.22 to 0.36 yr^{-1} with this range higher than the fixed value in the model.

The index data support higher values for *M*, driven entirely by the eastern trawl fleet CPUE (Figure 8.42). The length data support lower values for *M*, driven largely by the length data from the mixed fleet. The eastern trawl fleet discard data give some support to lower values of *M*. Overall, the age data gives very limited support to lower *M* values, but there is conflict within this data source, with the Tasmanian trawl age data supporting higher values for *M* and the eastern trawl age data supporting lower values for *M*.

Overall, there is conflicting data, within and between data sources, to inform the estimation of *M*. The apparent support in the data for higher values of *M* appears biologically unreasonable, given individuals are known to live to over 40 years of age.

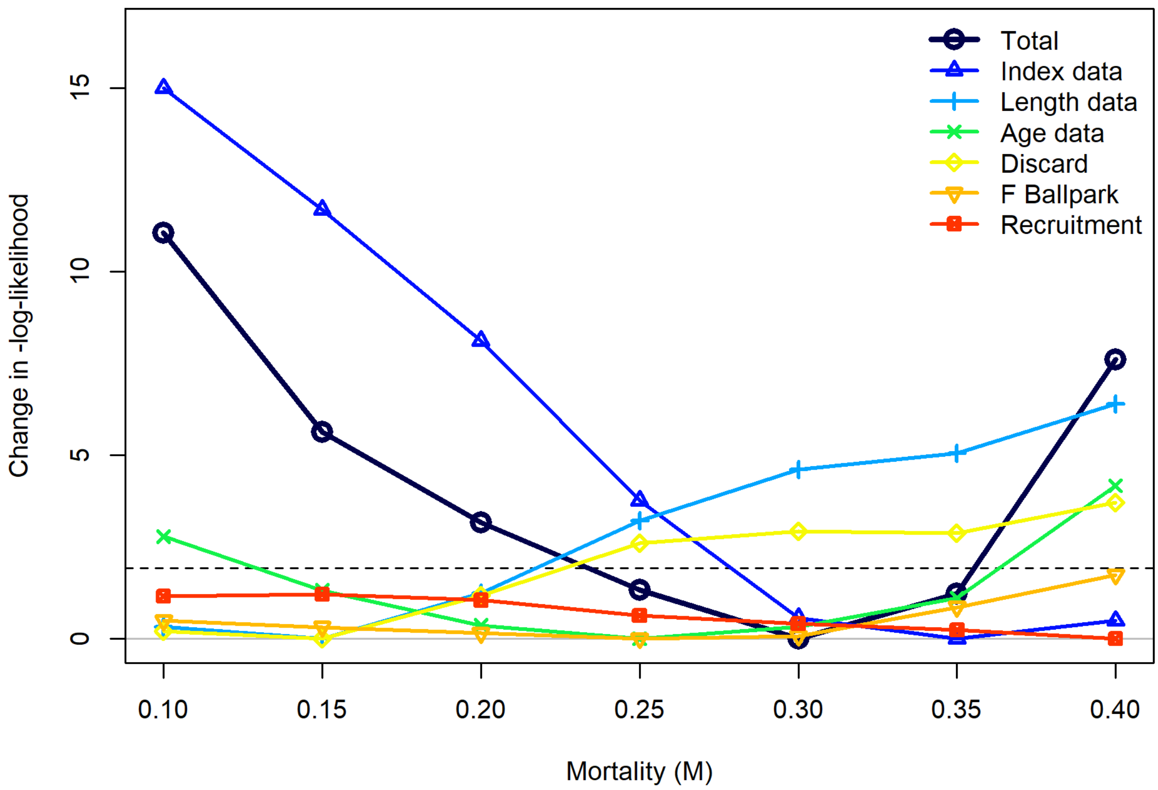


Figure 8.41. The likelihood profile for natural mortality for the base case with low recruitment, with *M* ranging from 0.1 to 0.4. *M* is fixed in the base case at 0.15 yr^{-1}.

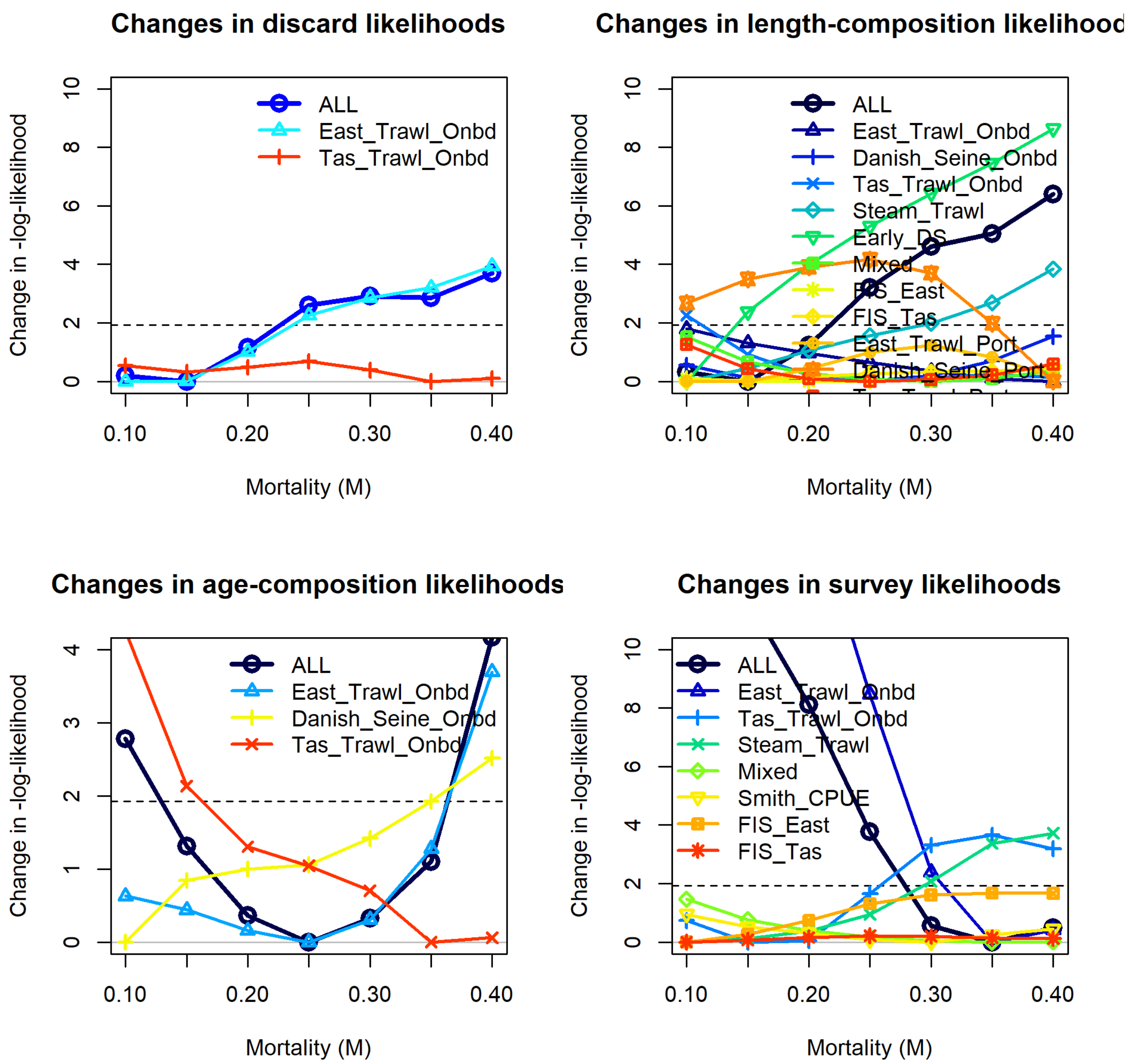


Figure 8.42. Piner plot for the likelihood profile for natural mortality for the base case with low recruitment, showing components of the change in likelihood for discard rate estimates, length, age, and surveys (CPUE) by fleet.

8.4.6.2 Steepness

For Jackass Morwong the likelihood profile for steepness, *h*, a parameter fixed in the base case at 0.7, is shown in Figure 8.43 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 indeed whether *h* should be estimated.

This likelihood profile in Figure 8.43 is uninformative as it is relatively flat, with very little difference in likelihood values between 0.3 and 0.8, with the only real information suggesting that a value of 0.9 is too high. This suggests that there is insufficient information contained in the data used in this model to inform a value for *h*, so this parameter should be fixed in this model. It is common that *h* is unable to be estimated in stock assessment models. There appears to be no benefit in repeating a likelihood profile on *h* for future stock assessments for Jackass Morwong, nor in attempting to estimate this parameter, at least in the foreseeable future.

Of the limited information in the model that can be used to inform steepness, the most influential data sources in providing information on *h* are the discard data and recruitment (Figure 8.43). While neither data source is that influential, the discard data (mostly through the eastern trawl fleet, Figure 8.44) support a higher value of *h* (a more productive stock) than the recruitment (which takes the form of a penalised log likelihood on deviations from the Beverton-Holt stock recruitment relationship) which supports a lower values *h*. Other components of the likelihood appear to have little to inform the value of *h*.

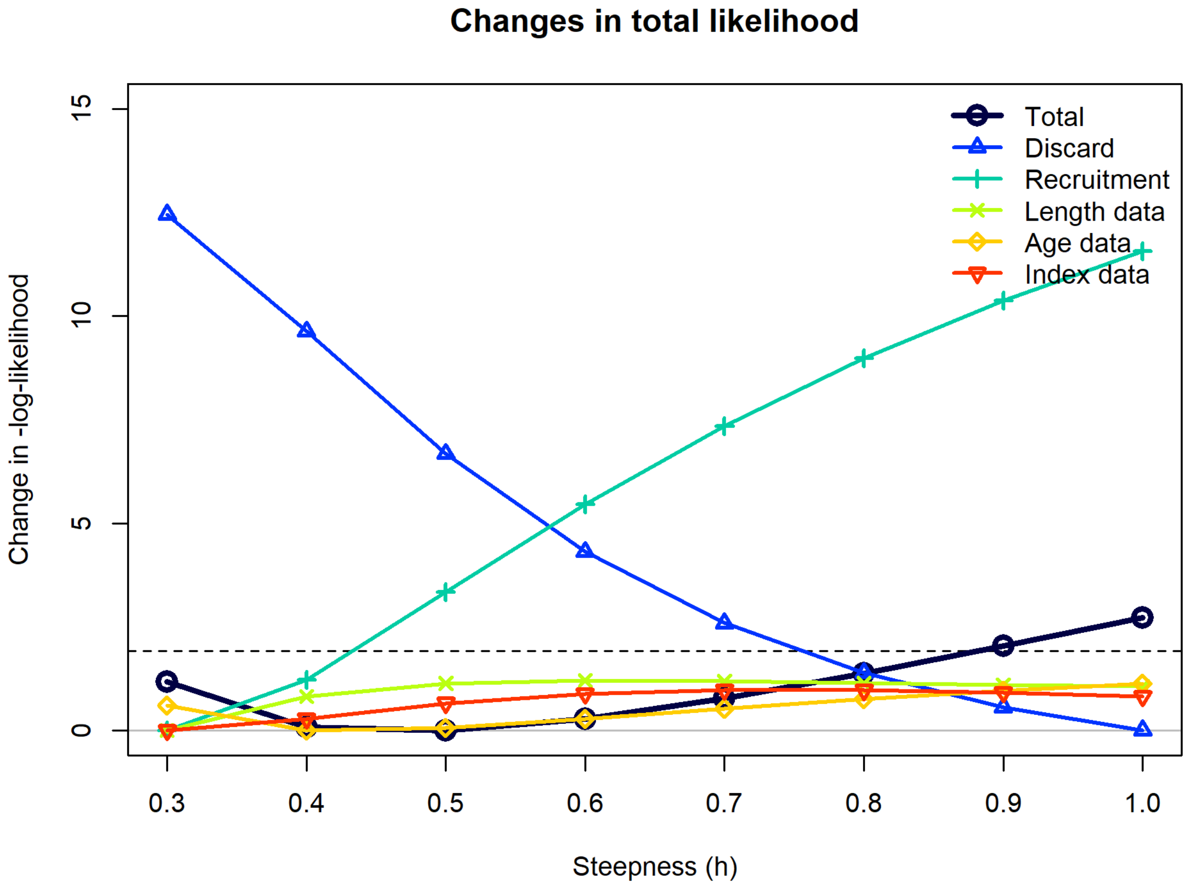


Figure 8.43. The likelihood profile for steepness for the base case with low recruitment, with *h* ranging from 0.3 to 1.0. *h* is fixed in the base case at 0.7.

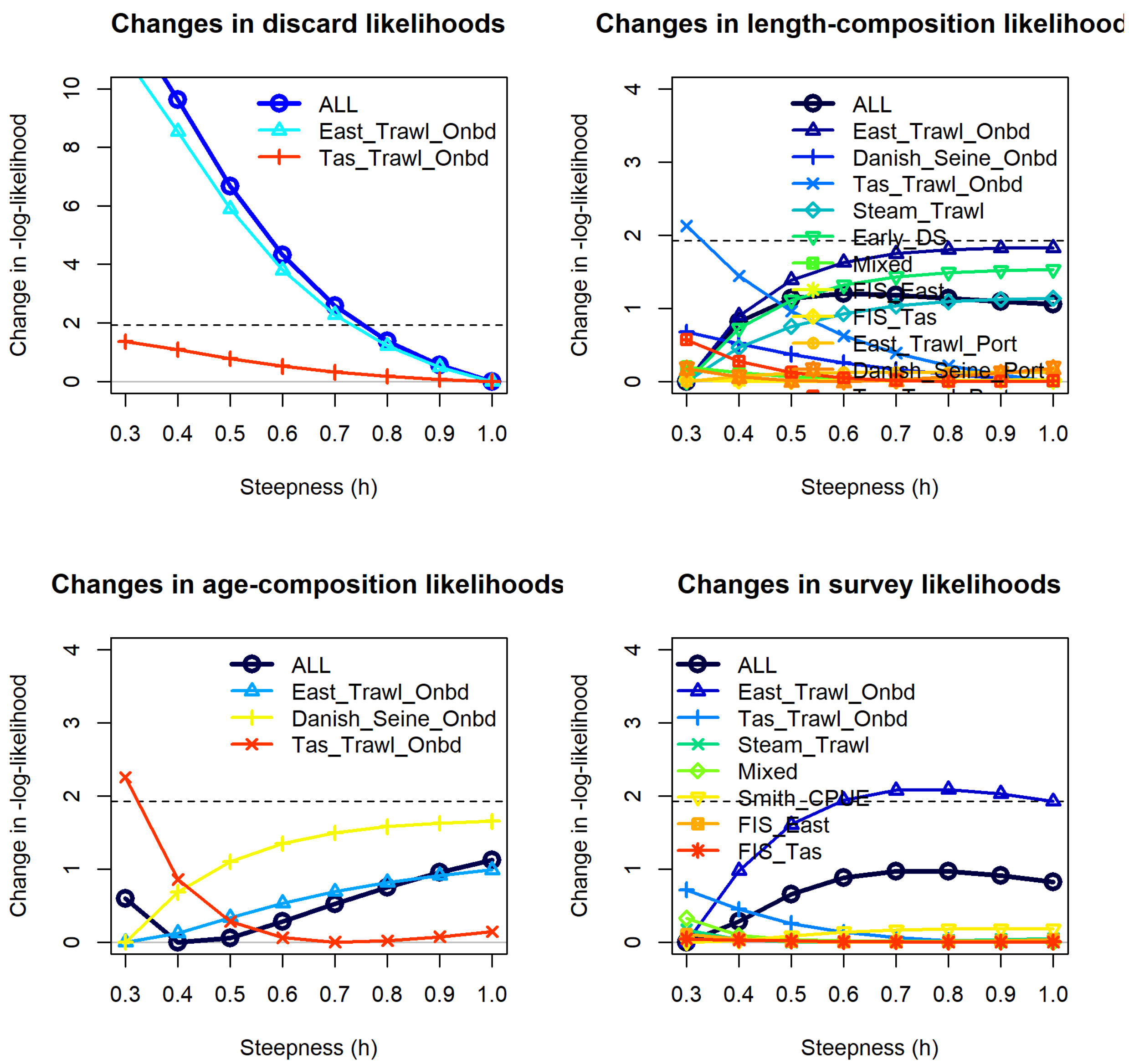


Figure 8.44. Piner plot for the likelihood profile for steepness for the base case with low recruitment, showing components of the change in likelihood for discard rate estimates, length, age, and surveys (CPUE) by fleet.

8.4.6.3 Unexploited spawning biomass

A likelihood profile for unexploited spawning stock biomass (SSB_0) is shown in Figure 8.45 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 19,000 t and 27,000 t with the most likely value at around 23,000 t. The asymptotic approximations, which makes some strong assumptions, suggest a symmetric distribution of plausible values ranging between 20,000 t and 28,000 t, and a most likely value at around 24,000 t.

The important data sources in providing information on SSB_0 are the recruitment (penalised log-likelihood) and the discard data (Figure 8.45). The recruitment supports a higher value for SSB_0, and the discard data support a lower value for SSB_0, driven entirely by discard rates from through the eastern trawl fleet (Figure 8.46). Recruitment essentially provides a lower bound on SSB_0 while the discard data provide an upper bound. SSB_0 is estimated with considerable uncertainty.

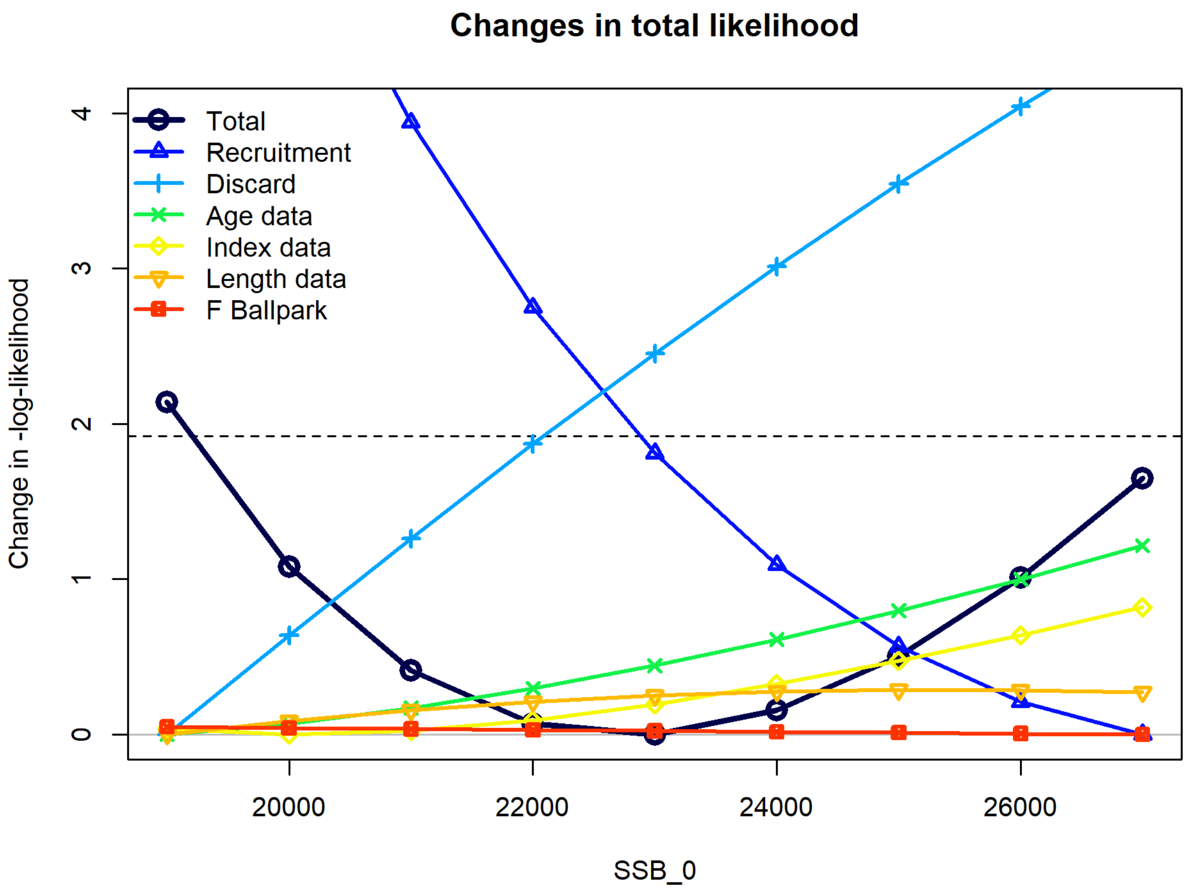


Figure 8.45. The likelihood profile for unexploited spawning stock biomass for the base case with low recruitment, with unexploited spawning stock biomass ranging from 19,000 t to 27,000 t. The base case estimate for SSB_0 is 23,841 t.

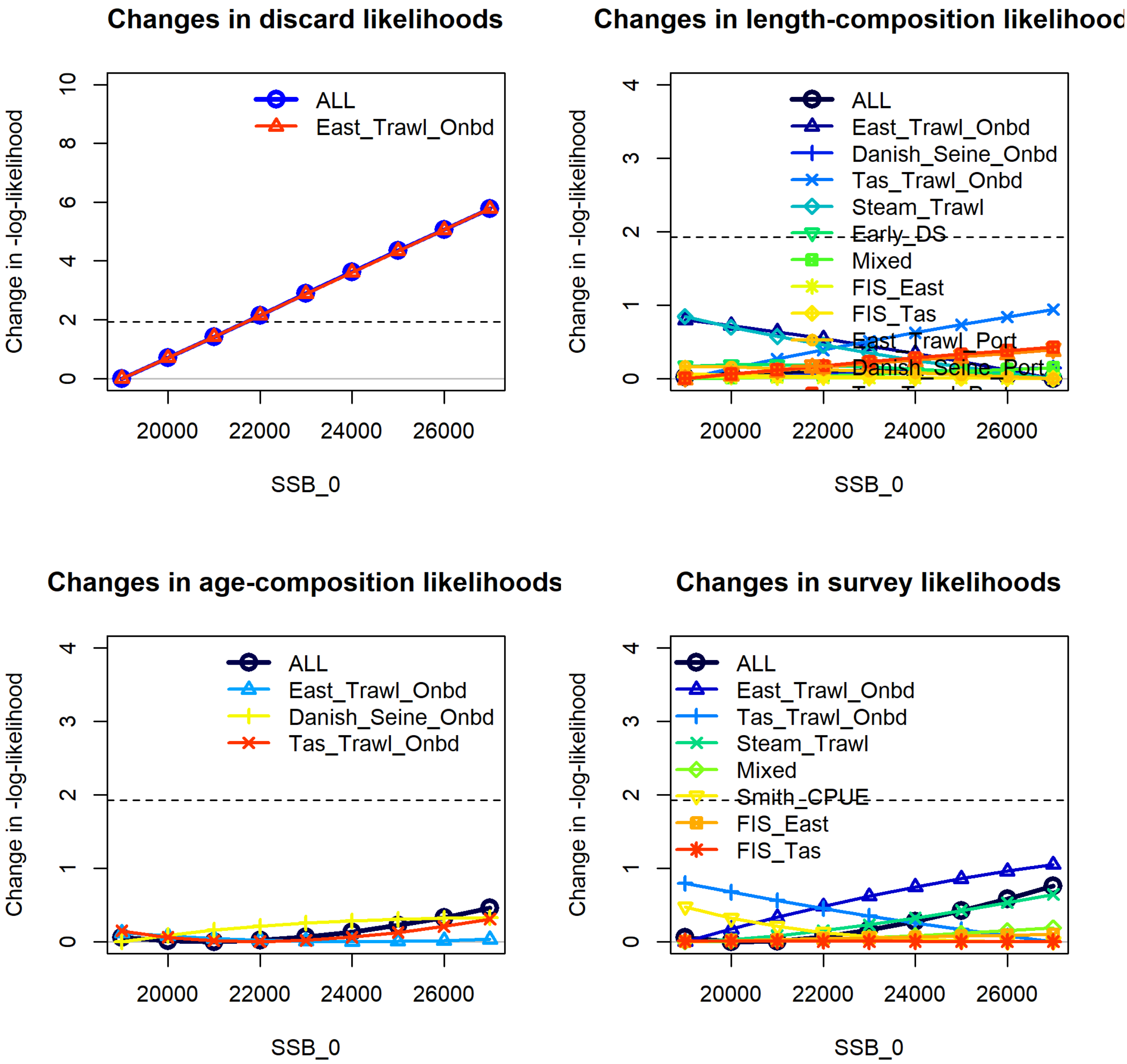


Figure 8.46. Piner plot for the likelihood profile for unexploited spawning stock biomass for the base case with low recruitment, showing components of the change in likelihood for discard rate estimates, length, age, and surveys (CPUE) by fleet.

8.4.6.4 2020 spawning biomass

A likelihood profile for current spawning biomass (SSB_{2020}) is shown in Figure 8.47 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_{2020} 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_{2020} requires setting up an additional "fleet" with a single data point (in 2020) 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_{2020} ranging between around 900 t and 1,650 t with the most likely value at around 1,200 t. In contrast, the asymptotics, which make some strong assumptions, suggest an estimate of 1, 075 t with apparently tight confidence intervals, although technically these cannot be calculated for the base case with low recruitment.

The important data sources in providing information on SSB_{2020} are the index and discard data (Figure 8.47). The index data support a higher value for SSB_{2020}, mainly through data from the eastern trawl fleet, although the Tasmanian trawl fleet apparently supports a lower value for SSB_{2020}, (Figure 8.48), while the discard data support a lower value for SSB_{2020}, entirely through the eastern trawl fleet discard data (Figure 8.48). The index data essentially provides a lower bound on SSB_{2020} while the discard data provide an upper bound. While having a smaller influence the recruitment data support a higher value of SSB_{2020} and the age data support a lower value (Figure 8.47). SSB_{2020} is estimated with considerable uncertainty, but it is clearly an order of magnitude lower than SSB_0. It is notable that there is considerable conflict both between and within likelihood components, which may suggest that there may be issues with unrepresentative data or potential model misspecification, possibly due to unaccounted for spatial or temporal effects.

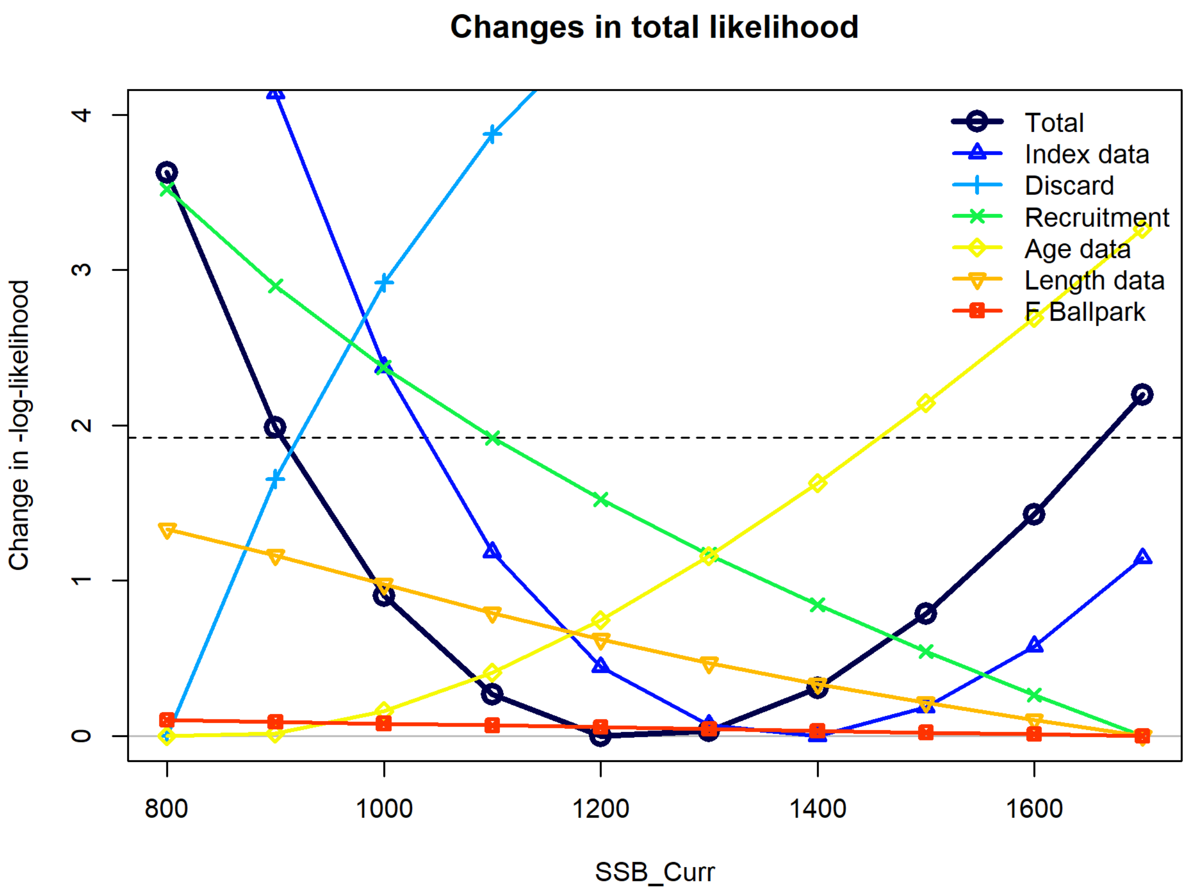


Figure 8.47. The likelihood profile for 2020 spawning stock biomass for the base case with low recruitment, with 2020 spawning stock biomass ranging from 800 t to 1,700 t. The base case estimate for SSB_{0020} is 1,115 t.

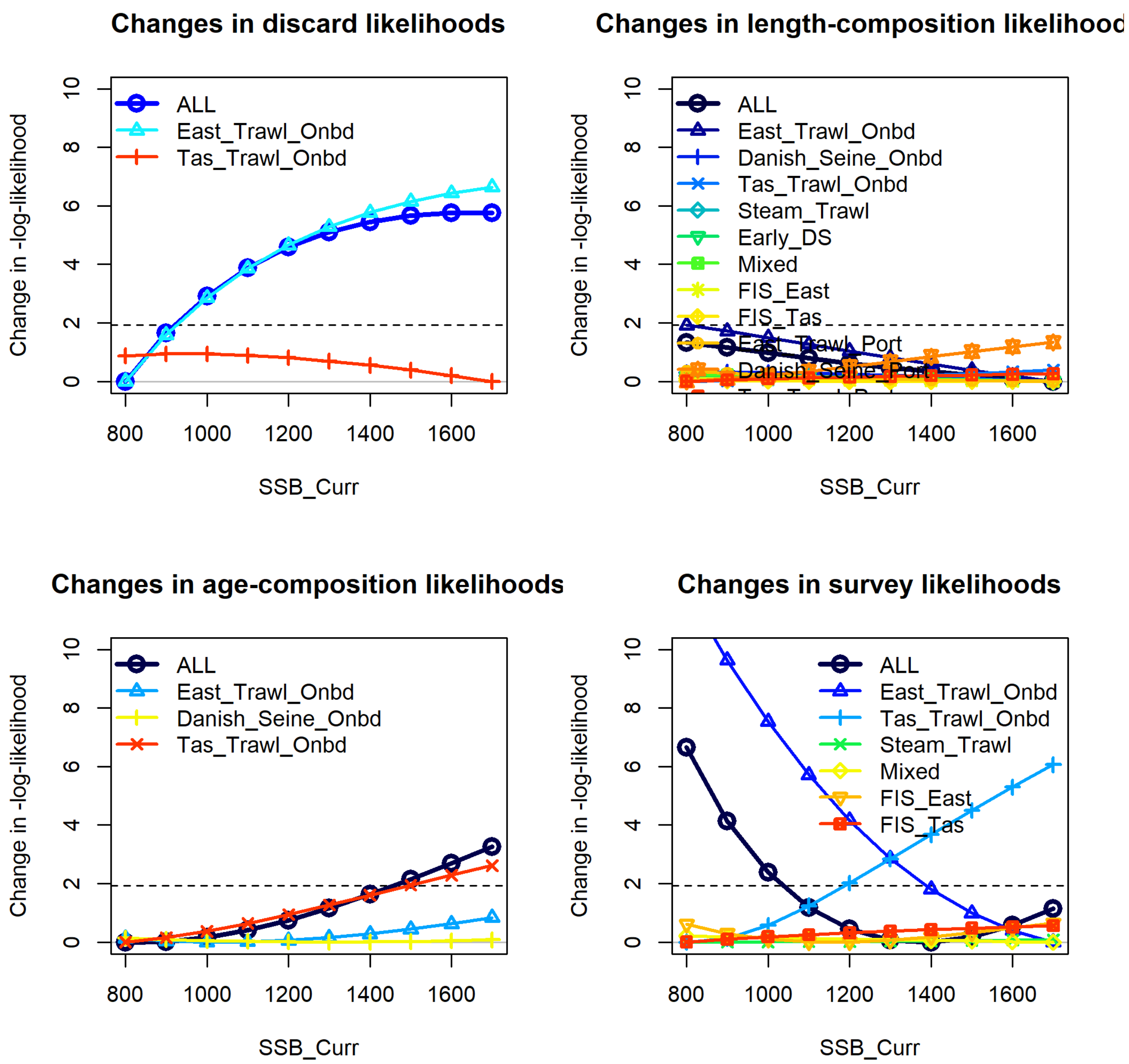


Figure 8.48. Piner plot for the likelihood profile for 2020 spawning stock biomass for the base case with low recruitment, showing components of the change in likelihood for discard rate estimates, length, age, and surveys (CPUE) by fleet.

8.4.6.5 2020 stock status

A likelihood profile for 2020 stock status is shown in Figure 8.49 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_{2020}, 2020 stock status is a derived parameter. To construct a likelihood profile on 2020 stock status requires setting up an additional “fleet” with a value of 1.01 in 1989 and an additional data point where the stock status (relative to the 1988 productivity shift) is close to one, which is seen in the base case in 1989, specifying this stock status with a very low standard error, essentially adding a “highly precise survey” of stock status, 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 range of plausible values for stock status in 2020 ranging between around 11% and 20%, with the most likely value at around 15%. Discard, recruitment and index have the most influence (Figure 8.49).

Ideally this likelihood profile would be produced for stock status at the start of 2022, as with the likelihood profile on current biomass (2022 rather than 2020). However, likelihood profiles can only be constructed on parameters that are associated with likelihood values (requiring actual data) and not projected values, so 2020 is the last year that a likelihood profile can be constructed, either for spawning biomass or stock status.

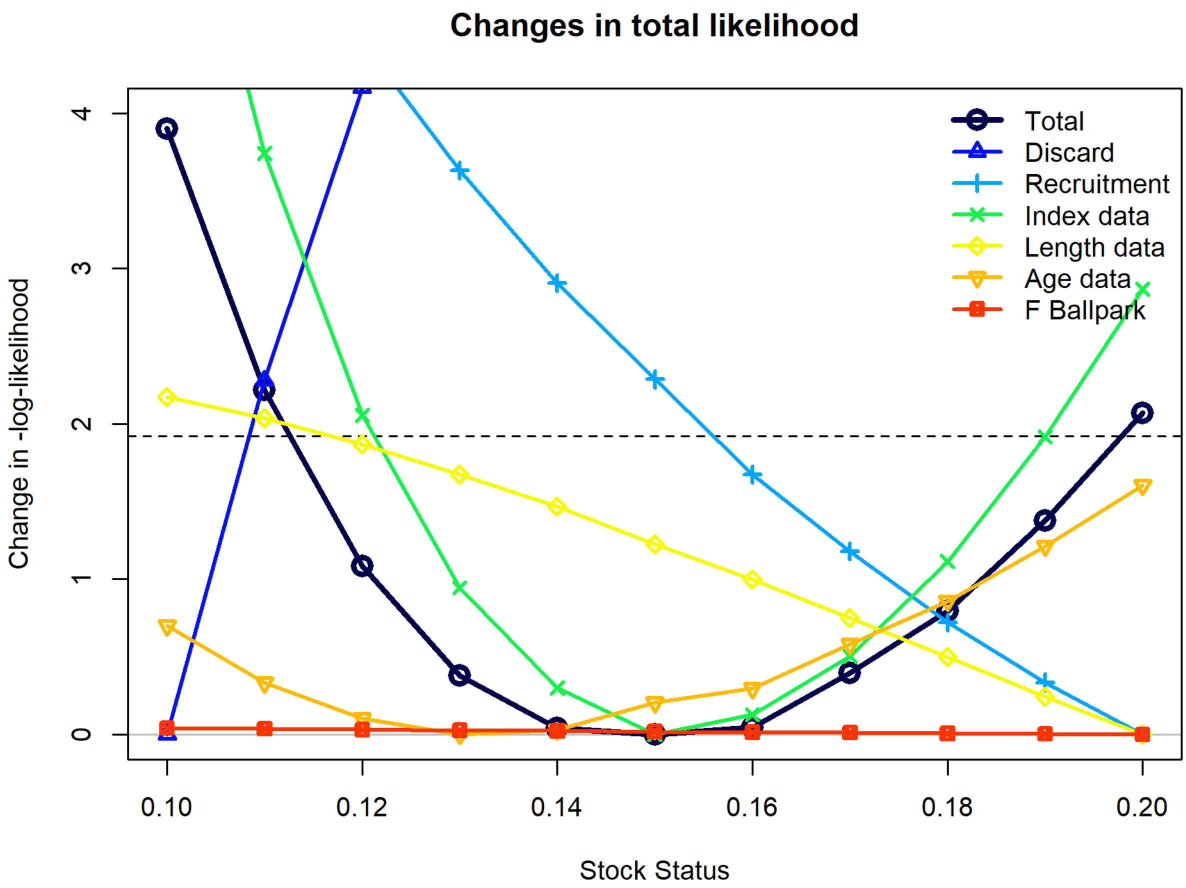


Figure 8.49. The likelihood profile for 2020 stock status for the base case with low recruitment, with 2020 stock status ranging from 10% to 20%. The base case estimate for 2020 stock status is 14%.

The important data sources in providing information on stock status are the discard, recruitment and index data (Figure 8.49). As with current spawning biomass, both the recruitment and index data support a higher value for relative spawning stock biomass, mainly through data from the eastern trawl fleet, although once again, in contrast, the Tasmanian trawl fleet apparently supports a lower value for stock status (Figure 8.50), while the discard data support a lower value for stock status, based entirely on the eastern the trawl fleet discard rates (Figure 8.50). The recruitment and index data essentially provide a lower bound on relative spawning stock biomass while the discard data provide an upper bound. Relative spawning stock biomass is estimated with considerable uncertainty. However, there is strong evidence to suggest that the stock status was below 20% in 2020. As with the likelihood profile on SSB_{2020}, there is considerable conflict both between and within likelihood components, which again supports the hypothesis that there may be issues with unrepresentative data or potential model misspecification, possibly due to unaccounted for spatial or temporal effects. Temporal changes in fishing, targeting practices or biological changes such as changes in recruitment or natural mortality in recent years, could potentially explain the problems fitting the data, and producing a coherent consistent explanation of model outputs, given the assumptions being used in the model. Incorporating such modelling changes ought to be justified by some clear evidence of these changes, and this may require additional data that is not currently available.

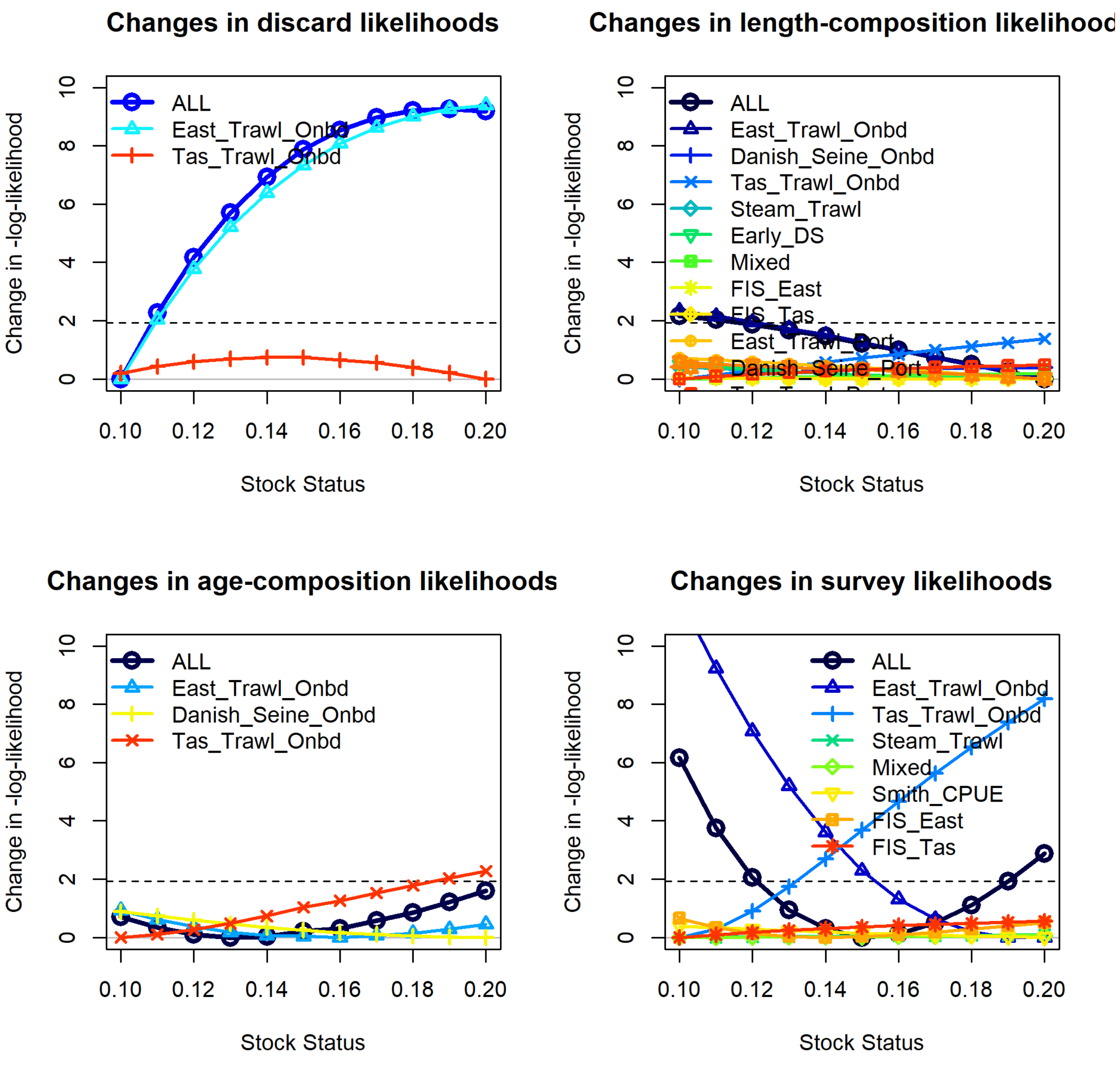


Figure 8.50. Piner plot for the likelihood profile for 2020 stock status for the base case with low recruitment, showing components of the change in likelihood for discard rate estimates, length, age, and surveys (CPUE) by fleet.

8.4.7 *Jitter analyses*

For the base case, 23 of the 25 jitter replicates found the same optimal solution, with negative log likelihood of 943.449. The remaining two replicates found different (worse) “optimal” solutions, with negative log likelihood values of 968 and 993. This result gives confidence that the solutions found with the chosen parameter starting values for the base case are the optimal solutions.

8.4.8 *Sensitivity tests and alternative models*

Results of the sensitivity tests are shown in Table 8.23. This table indicates that stock status is not overly sensitive to changes in parameters or weightings, with the exception for changes to natural mortality.

This assessment is also insensitive to the weighting placed on the age compositions, with no change to the stock status by doubling or halving the weight on age data. However, it has some sensitivity to changing weightings on length and CPUE data. In both cases, increasing the weighting on length and CPUE data results in higher stock status estimates (16% in both cases). The decreased weight on CPUE data leads to lower stock status estimates than the base case (14%), with no change in stock status by decreasing the weighting on the length data. These patterns when changing the weighting on length and CPUE data suggest that there is no conflict in the information provided from these two data sources. Despite these changes in stock status, the changes in likelihood values with changes to the weighting of different data sources, are relatively small (Table 8.24). This likelihood table also suggests that there is often conflict between the discard likelihood and other components, with the likelihood change to the discard component generally being relatively large (in absolute terms) and in the opposite direction to changes in weighting in either the length, age or survey data.

There are two additional "average recruitment" sensitivities listed in Table 8.23 and Table 8.24. The first shows the results from a model with no productivity shift implemented, with average recruitment from 2016 onwards (sensitivity 14) and the second keeps the 1988 productivity shift in place and simply fixes recruitment to average from 2016 onwards (sensitivity 15). The "no productivity shift" sensitivity has very different behaviour to the base case (Figure 8.51 - Figure 8.54), and it appears to be purely coincidental that the 2022 stock status (14%) is very similar to the base case. The sensitivity with average recruitment from 2016 onwards results in a higher 2022 stock status (22%), due to the relative increase in contribution to spawning stock biomass as the higher recruitment from 2016 enters the spawning stock biomass. This sensitivity results in a lower negative log likelihood, through improvements to the fit to the discard data and, to a lesser extent, improvements to the fits to the age data, but with poorer fits to the length data. However, the sensitivity tables do not indicate the improvements to the poor retrospective patterns, illustrated in Table 8.22, when the low recruitment scenario is compared to the average recruitment scenario.

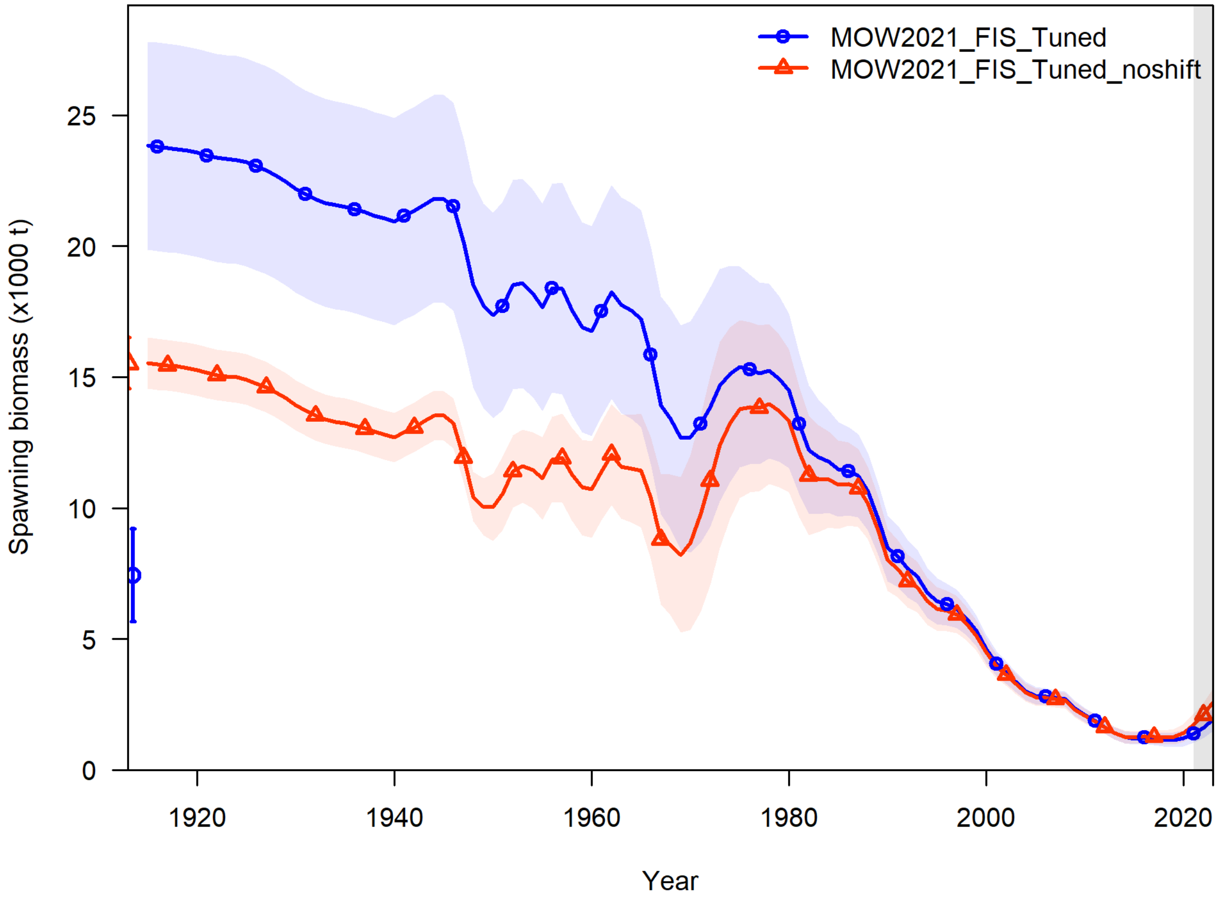


Figure 8.51. Comparison of the absolute biomass series for the no productivity shift model (red, with average recruitment from 2016 onwards) and the average recruitment base case (blue, a single productivity shift in 1988).

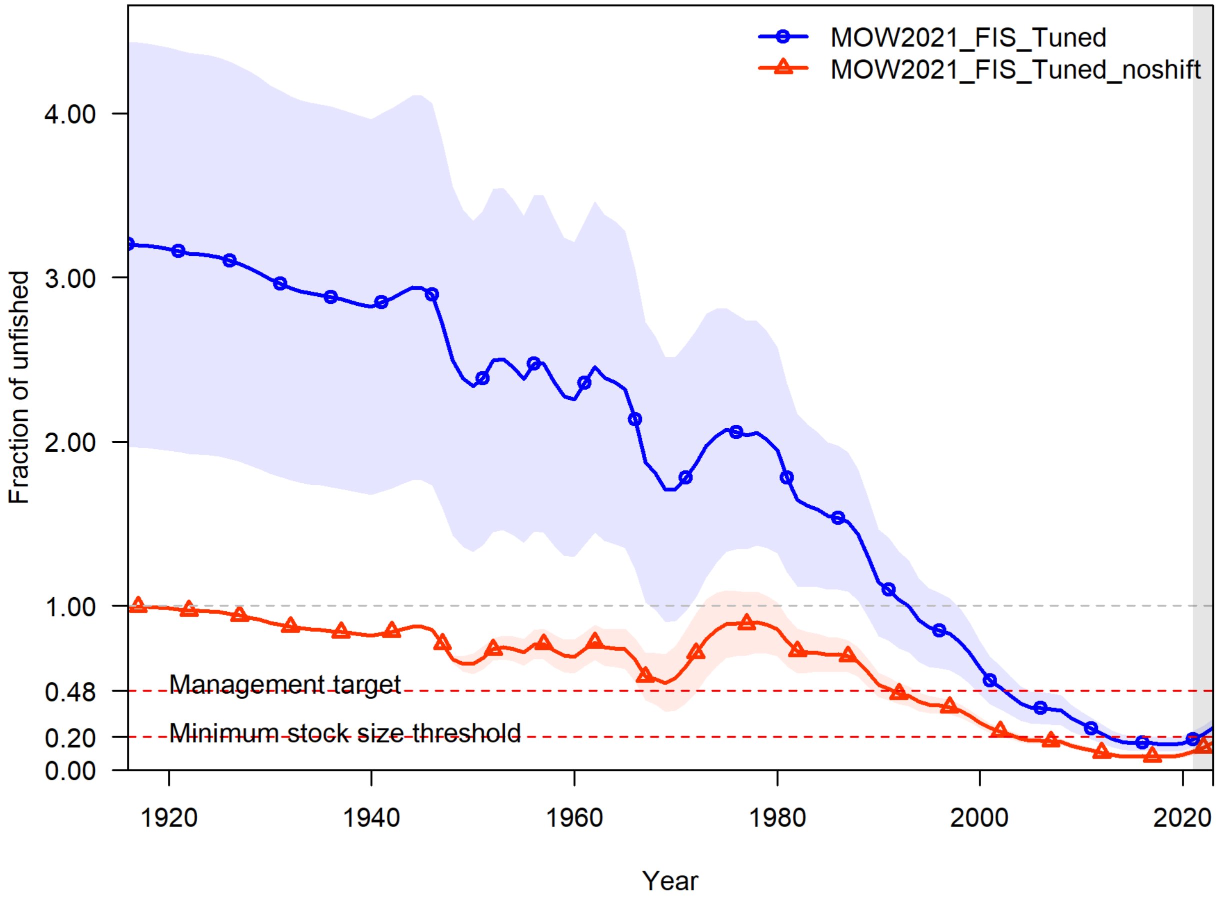


Figure 8.52. Comparison of the relative biomass series for the no productivity shift model (red, with average recruitment from 2016 onwards) and the average recruitment base case (blue, a single productivity shift in 1988).

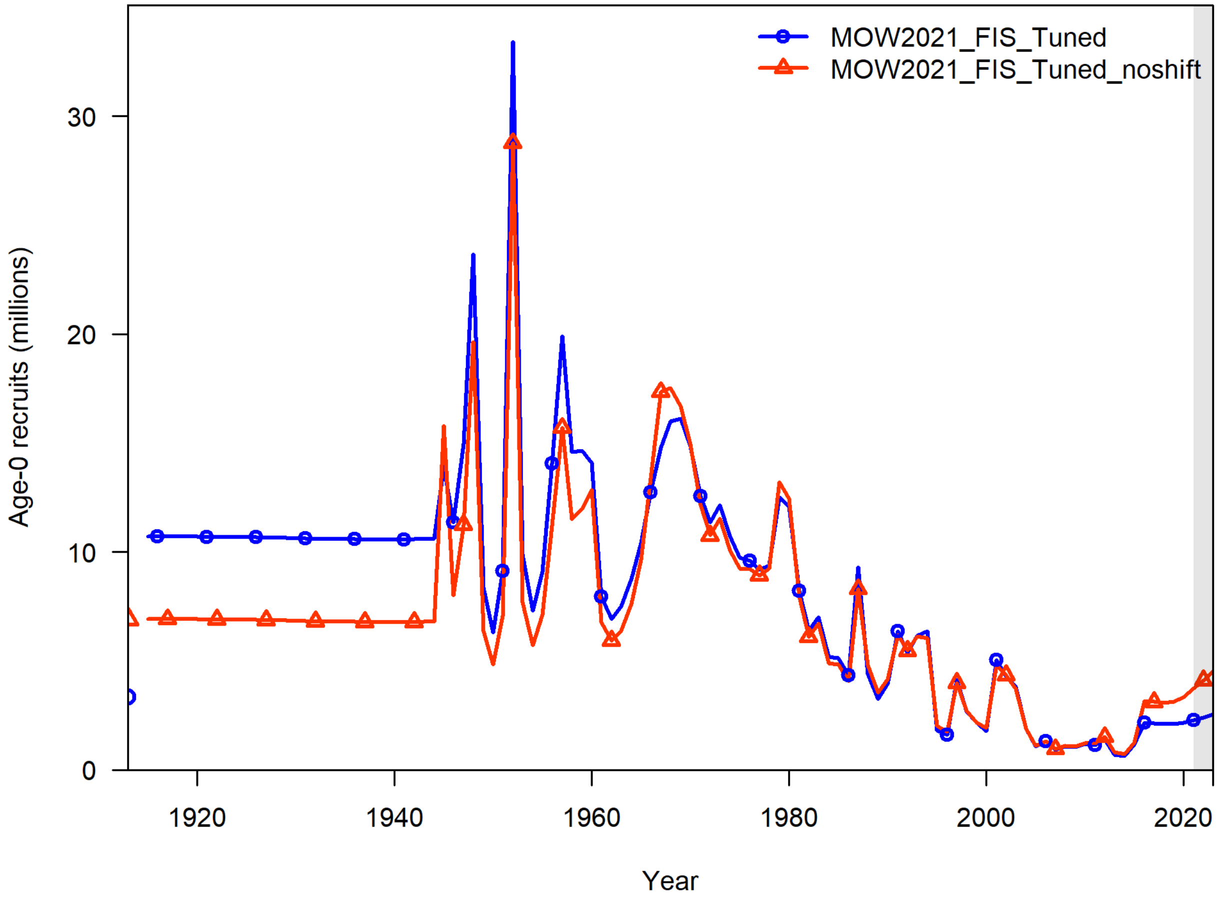


Figure 8.53. Comparison of the absolute recruitment series for the no productivity shift model (red, with average recruitment from 2016 onwards) and the average recruitment base case (blue, a single productivity shift in 1988).

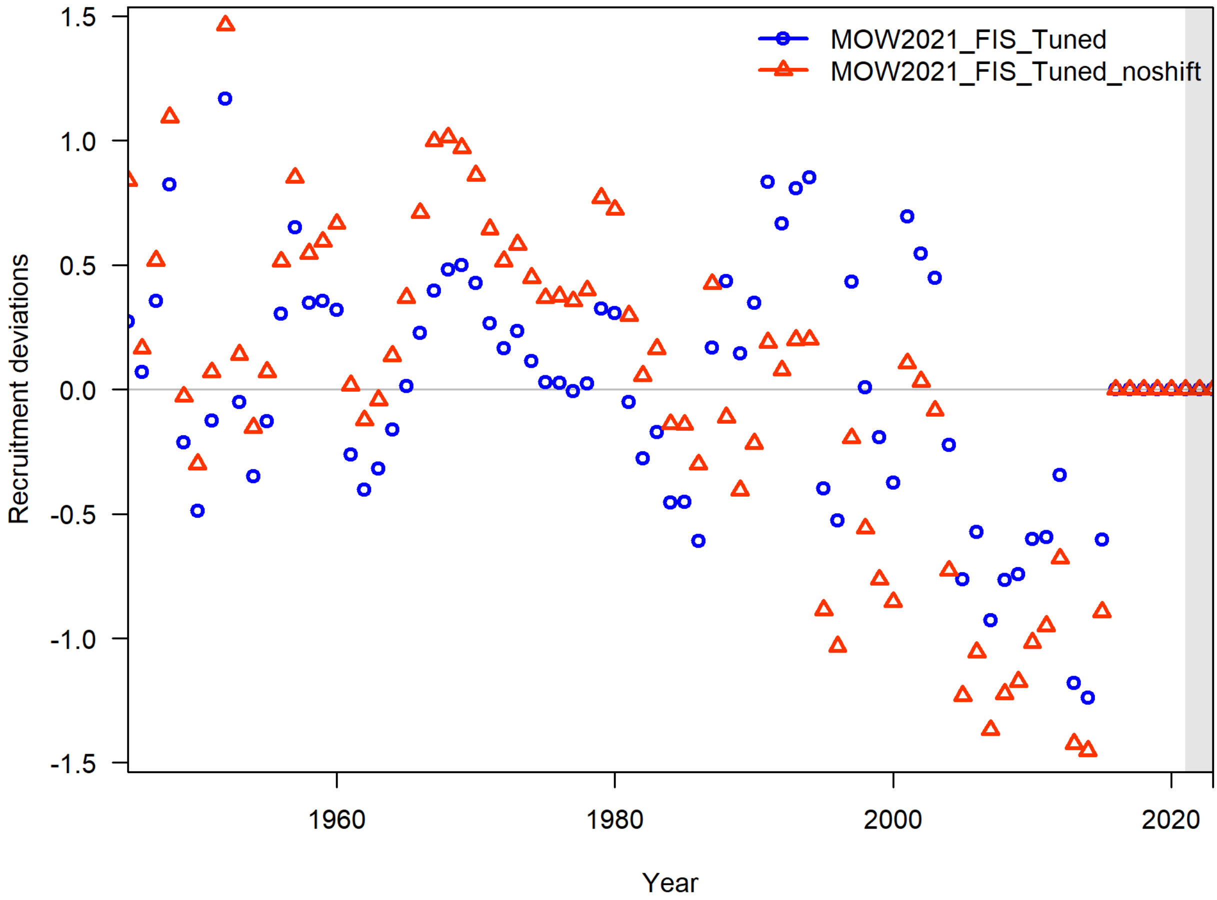


Figure 8.54. Comparison of the recruitment deviations for the no productivity shift model (red, with average recruitment from 2016 onwards) and the average recruitment base case (blue, a single productivity shift in 1988).

Table 8.23. Summary of results for the base-case and sensitivity tests. Recommended biological catches (RBCs) are only shown for agreed base case model.

Case		SSB_0	SSB_{2022}	SSB_{2022}/SSB_0	RBC_{2022}	$RBC_{2022-24}$	$RBC_{2022-26}$	$RBC_{longterm}$
0	base case (*M* 0.15, *h* 0.7, 50% mat 24.5)	7,429	1,115	0.15	0	0	1	91
1	*M* 0.1	11,834	830	0.07				
2	*M* 0.2	6,526	1,568	0.24				
3	*h* 0.6	8,118	1,052	0.13				
4	*h* 0.8	6,910	1,165	0.17				
5	50% maturity at 22cm	7,800	1,251	0.16				
6	$\sigma_R = 0.6$	6,912	1,126	0.16				
7	$\sigma_R = 0.8$	8,016	1,107	0.14				
8	wt x 2 length comp	7,112	1,132	0.16				
9	wt x 0.5 length comp	7,585	1,100	0.15				
10	wt x 2 age comp	7,271	1,099	0.15				
11	wt x 0.5 age comp	7,393	1,121	0.15				
12	wt x 2 CPUE	7,285	1,162	0.16				
13	wt x 0.5 CPUE	7,273	1,012	0.14				
14	no productivity shift (avg recruitment)	15,534	2,105	0.14				
15	average recruitment from 2016 onwards	7,429	1,603	0.22				

Table 8.24. Summary of likelihood components for the base-case and sensitivity tests. Likelihood components are unweighted, and cases 1-15 are shown as differences from the base case. A negative value indicates a better fit, a positive value a worse fit.

Case		Likelihood					
		TOTAL	Survey	Discard	Length comp	Age comp	Recruitment
0	base case (M 0.15, h 0.7, 50% mat 24.5)	980.45	-129.20	176.34	285.13	613.38	8.31
1	M 0.1	7.61	3.41	3.23	0.37	0.72	-0.31
2	M 0.2	-3.71	-3.73	0.72	1.01	-1.36	-0.19
3	h 0.6	1.57	-0.02	4.43	0.12	-1.10	-1.87
4	h 0.8	-1.35	-0.27	-2.04	-0.55	0.06	1.43
5	50% maturity at 22cm	-0.24	-0.10	0.51	-0.26	-0.46	0.06
6	$\sigma_R = 0.6$	2.70	-0.08	2.66	0.81	-0.44	-0.26
7	$\sigma_R = 0.8$	-1.88	-0.16	-0.87	-1.02	-0.43	0.59
8	wt x 2 length comp	3.35	4.61	9.78	-14.28	1.13	2.07
9	wt x 0.5 length comp	7.15	-1.90	-7.49	17.65	0.19	-1.27
10	wt x 2 age comp	3.81	2.80	8.96	0.53	-8.72	0.21
11	wt x 0.5 age comp	2.84	-2.30	-6.11	0.45	10.86	-0.05
12	wt x 2 CPUE	5.57	-10.65	6.43	4.45	4.67	0.61
13	wt x 0.5 CPUE	1.90	9.25	-2.40	-3.18	-2.11	0.35
14	no productivity shift (avg recruitment)	-6.12	3.48	-24.20	35.53	-36.87	15.91
15	average recruitment from 2016 onwards	-12.09	0.25	-20.42	15.58	-7.49	0.00

8.4.9 *Omissions to the base case: port length composition data and right hand side of bias adjustment*

Two minor issues were discovered in the development of the 2021 base case after the initial stock assessment and analysis was already complete, with two minor steps in the bridging from the 2018 assessment overlooked.

1. The port collected length composition data was not updated from the 2018 assessment, so the 2021 base case does not include: (i) the revisions to these data from 1986-2016; and (ii) the new port collected length composition data for 2018-2020.
2. The bias adjustment was not updated from the 2018 assessment, an update to the right-hand side of the bias adjustment was overlooked in developing the base case. Instead of switching to a bias adjustment of zero in 2016, to match the additional three years of estimated recruitment deviations, the base case switched to zero in 2013, using the same bias adjustment as used in the 2018 assessment.

The bias adjustment used for Jackass Morwong is somewhat unusual, in that it ignores the apparent information on recruitment in the period from the 1940s to the 1960s, so as not to overestimate the precision from the 1960s to the 1980s, where there is no length composition data and hence limited information on recruitment in this period. Hence this bias adjustment diverges slightly from the recommended approach of Methot and Taylor (2011), in the left-hand ramp of this bias adjustment (Figure 8.55). This is consistent with the approach used in the previous Jackass Morwong assessments in 2018. When applied to the data in the 2015 assessment, applying the approach of Methot and Taylor (2011) resulted in a bias adjustment, with no bias adjustment prior to 1969, and the form of this bias adjustment was maintained for consistency in both the 2018 and 2021 assessments. However, the right-hand side of this bias adjustment should have been modified in the 2021 base case.

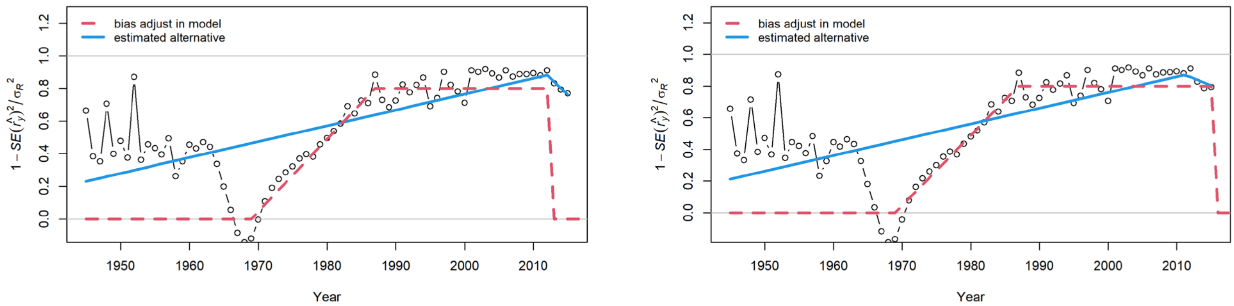


Figure 8.55. Bias adjustment used in the 2021 base case (left), with no bias adjustment from 2013 onwards and bias adjustment that should have been used in the 2021 base case (right), with no bias adjustment from 2016 onwards.

To explore the effect of updating these two data sources, these were first addressed independently, with the base case (MOW2021_LowRec_Tuned) modified to address only one issue at a time (MOW2021_LowRec_Tuned_bias_2 and MOW2021_LowRec_Tuned_port_2), followed by addressing both issues simultaneously (MOW2021_LowRec_Tuned_Updated), with all models iteratively reweighted. Changes to stock status were relatively minor (Figure 8.56 and Figure 8.57), with most of the change due to the updates to the port collected length composition data, and not due to the changes due to the bias ramp adjustment, with slightly higher stock status in 2022 (16%).

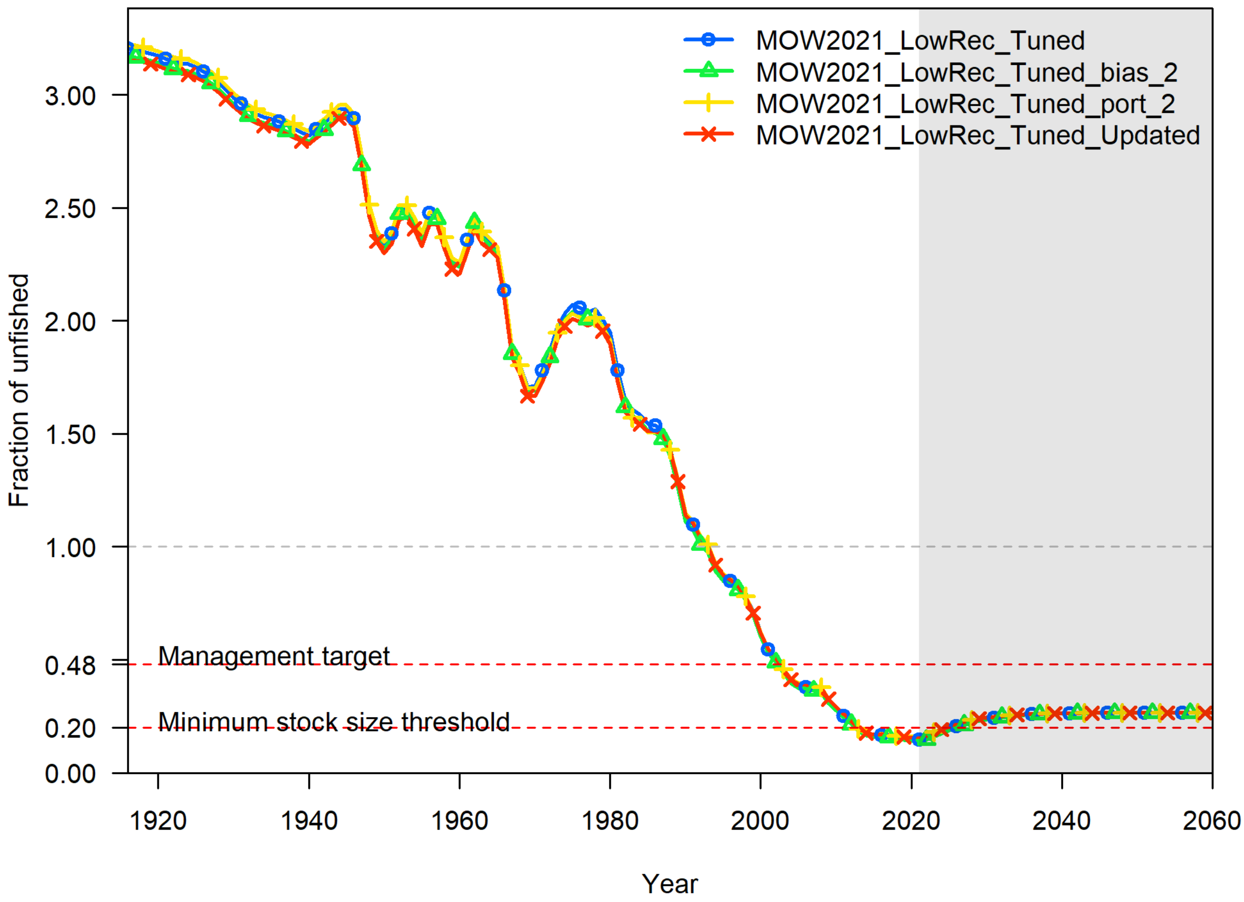


Figure 8.56. Comparison of the stock status time series for the 2021 base case (blue, MOW2021_LowRec_Tuned), the base case with the updated bias adjustment (green, MOW2021_LowRec_Tuned_bias_2), the base case with the updated port length composition data (yellow, MOW2021_LowRec_Tuned_port_2), and the base case with the both the updated bias adjustment and the updated port length composition data (red, MOW2021_LowRec_Tuned_Updated).

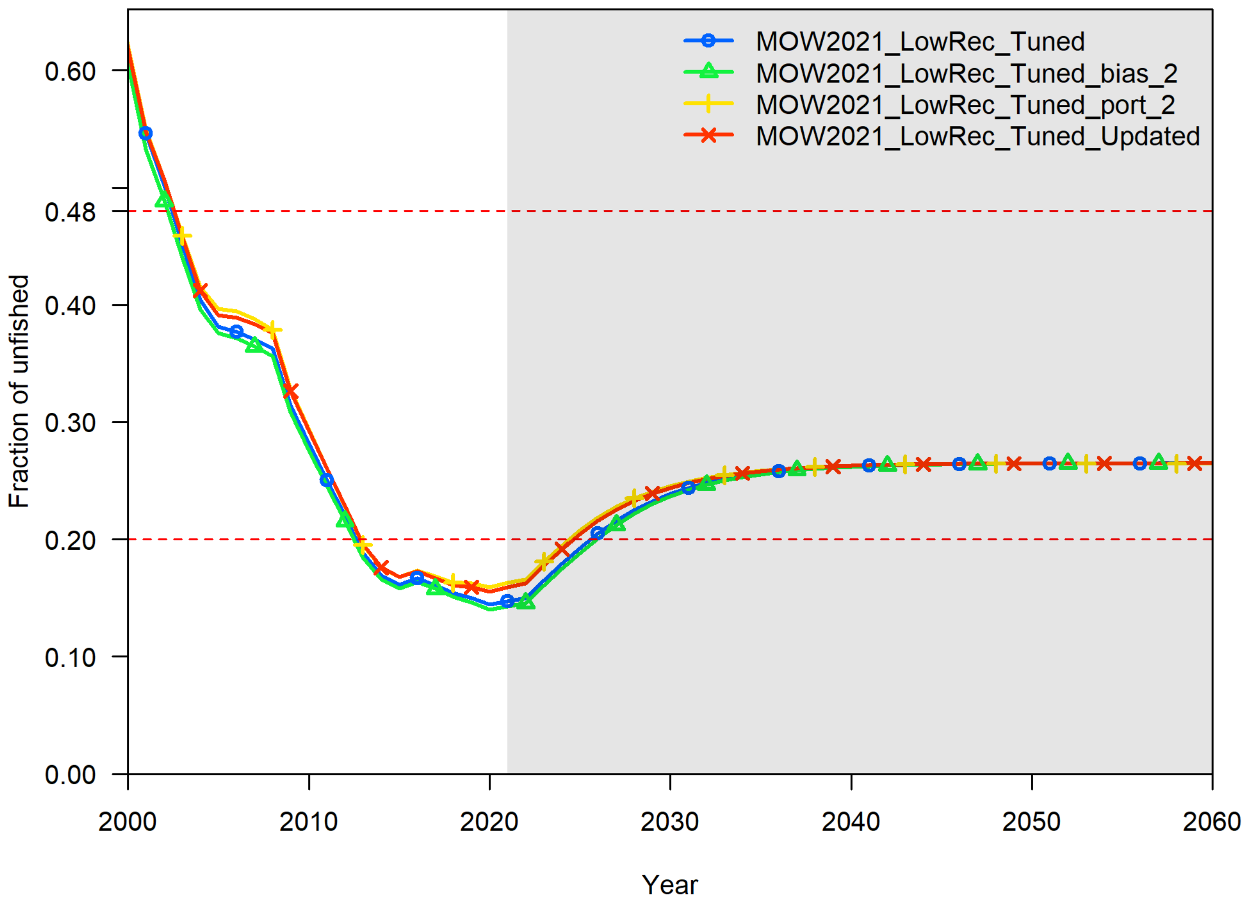


Figure 8.57. Comparison of the stock status time series (2000-2060 only) for the 2021 base case (blue, MOW2021_LowRec_Tuned), the base case with the updated bias adjustment (green, MOW2021_LowRec_Tuned_bias_2), the base case with the updated port length composition data (yellow, MOW2021_LowRec_Tuned_port_2), and the base case with the both the updated bias adjustment and the updated port length composition data (red, MOW2021_LowRec_Tuned_Updated).

The changes to the absolute recruitment time series were minimal (Figure 8.58) with the largest changes to the estimated recruitment deviations in the period 2013-2015 (Figure 8.59), with contributions from both the adjustment to the bias ramp and the additional port collected length composition data. As a result of these changes, the average recruitment deviation for the last 10 years of estimated recruitment should be revised from -0.754 to -0.706.

While the changes to the estimated stock status in 2022 and the average recruitment deviation used for low recruitment projections resulting from these updates would both lead to a slightly more optimistic projected "recovery" of Jackass Morwong in the next few years, there would be no change to the likely classification of overfished in 2022, and the pathway and projected time to recovery would be qualitatively similar to the results from the base case, if the updated base case was to be used. The stock status is projected to "recover" to 20% in 2025 for the updated base case, albeit with future low recruitment using the recruitment deviation of -0.754. The base case is projected to "recover" to 20% one year later (2026) than this updated base case. Given the uncertainties in the assumed projected recruitment, and the uncertainties in the estimates of stock status, the change between the results from the base case and the updated base case are small, compared to the known margins of uncertainty in the model output.

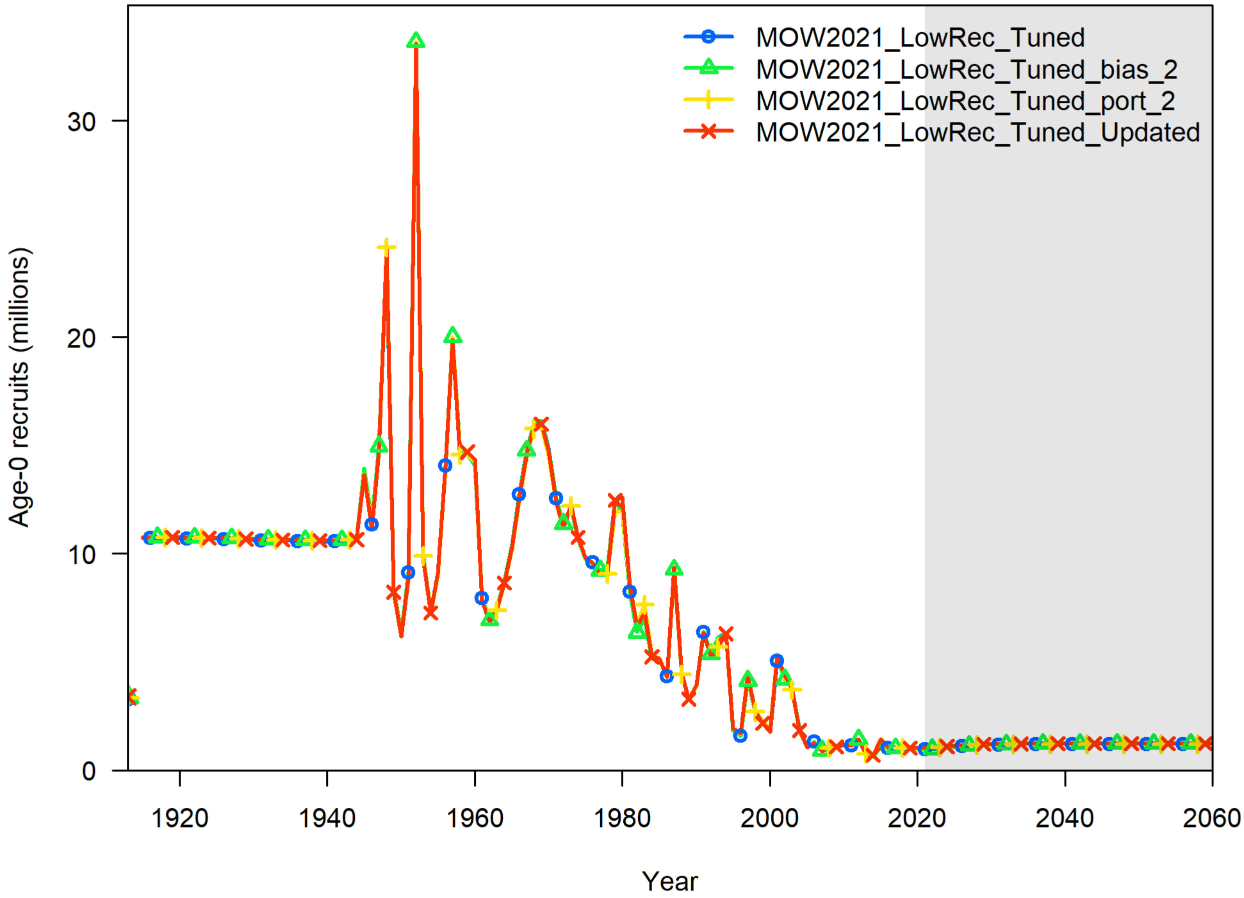


Figure 8.58. Comparison of absolute recruitment for the 2021 base case (blue, MOW2021_LowRec_Tuned), the base case with the updated bias adjustment (green, MOW2021_LowRec_Tuned_bias_2), the base case with the updated port length composition data (yellow, MOW2021_LowRec_Tuned_port_2), and the base case with the both the updated bias adjustment and the updated port length composition data (red, MOW2021_LowRec_Tuned_Updated).

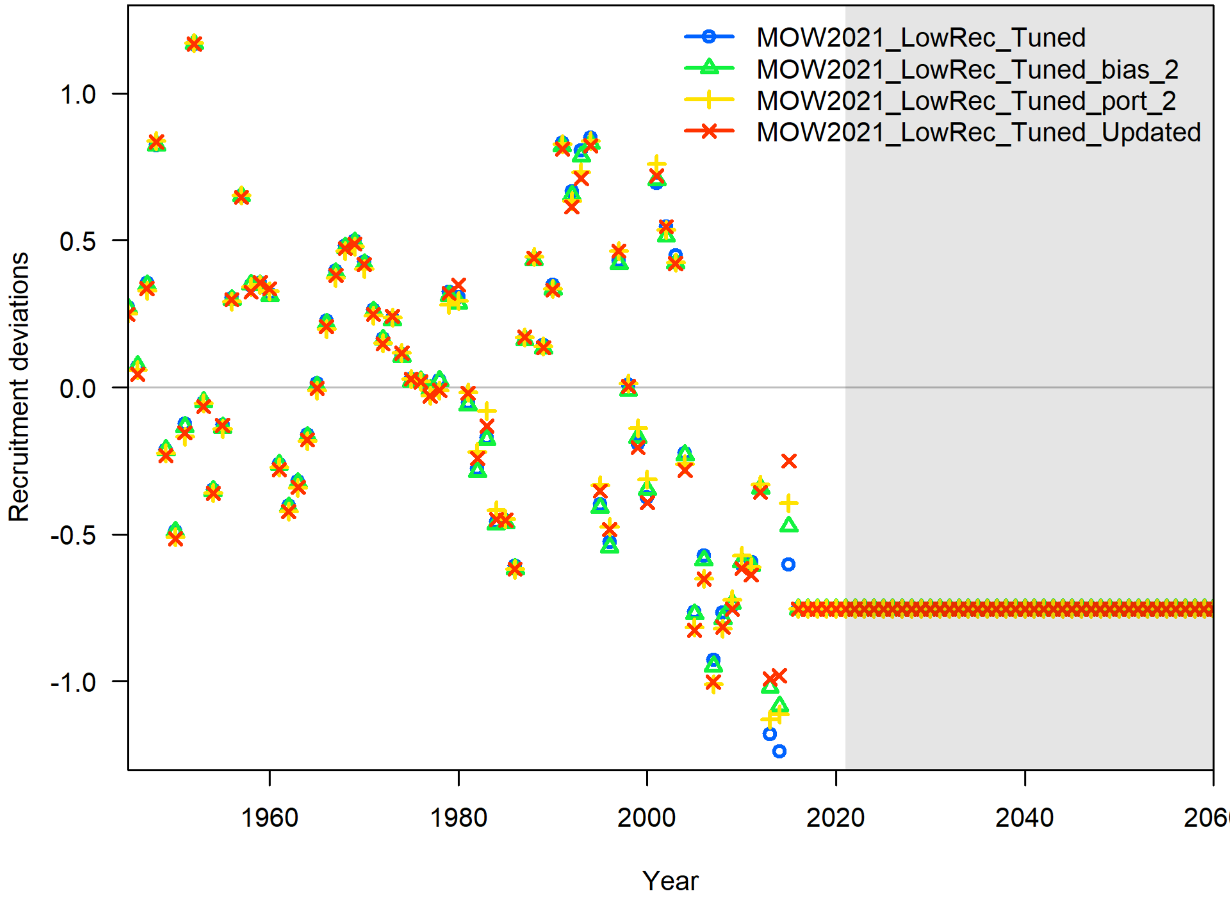


Figure 8.59. Comparison of the recruitment deviations for the 2021 base case (blue, MOW2021_LowRec_Tuned), the base case with the updated bias adjustment (green, MOW2021_LowRec_Tuned_bias_2), the base case with the updated port length composition data (yellow, MOW2021_LowRec_Tuned_port_2), and the base case with the both the updated bias adjustment and the updated port length composition data (red, MOW2021_LowRec_Tuned_Updated).

8.4.10 *Dynamic B_0*

It is possible to calculate dynamic B_0 (Bessell-Browne et al., 2021, in prep.) by projecting the population forward from its initial state without applying fishing mortality, assuming that the deviations in recruitment about the stock-recruitment relationship are not influenced by fishing pressure and are only influenced by non-fishing related factors, such as environmental drivers. These annual deviations are therefore assumed to be the same in both the fished and unfished cases. This explicitly assumes that fishing affects the numbers-at-age, but not the deviations in biological parameters about their expected values for any particular year. Dynamic B_0 is another way to account for the changing productivity of a stock without having to specify a specific year to implement a productivity shift, as is done in the current assessment. It also allows for trends in productivity to occur through time, rather than assuming a step function where there is a disconnect between two different productivity states. This analysis was conducted on the preliminary base case, with the assumption of average recruitment from 2016 onwards.

Dynamic B_0 for Jackass Morwong is initially the same as static B_0 between 1915 and 1945 as recruitment deviations are not estimated over this period (Figure 8.60, top panel). Between 1946 and 1988 dynamic B_0 is higher than static B_0, before dropping sharply for the remainder of the timeseries (Figure 8.60, top panel). Note that in the assessment model a productivity shift is implemented in 1988, altering the estimated value of B_0.

Estimated relative stock status varies considerably between the base case model with a productivity shift using static B_0 compared to that estimated using dynamic B_0 (Figure 8.60, bottom panel). Under dynamic B_0 the relative stock status falls below the target reference point (B_{48}) initially in the late 1960s, then recovers to values just above B_{48} in the early 1970s, then in 1981 falls below B_{48} and stays below B_{48} until the end of the time series. Relative to the limit reference point (B_{20}), the relative stock status under dynamic B_0 drops below the B_{20} from 2013-2015, and then increases to above (B_{20}) at the end of the time series (2020 in this case). This series is in stark contrast to the relative stock status series estimated using the productivity shift, where stock status is not estimated to fall below the target reference point until 2003, then falling below the limit reference point in 2013, the same year as estimated using dynamic B_0 (Figure 8.60, lower plot). Stock status using the productivity shift is then estimated to stay below the limit reference point until 2022, when it is projected to recover to a value greater than B_{20}, seven years after the population was estimated to recover to a value greater than B_{20} under dynamic B_0 (Figure 8.60).

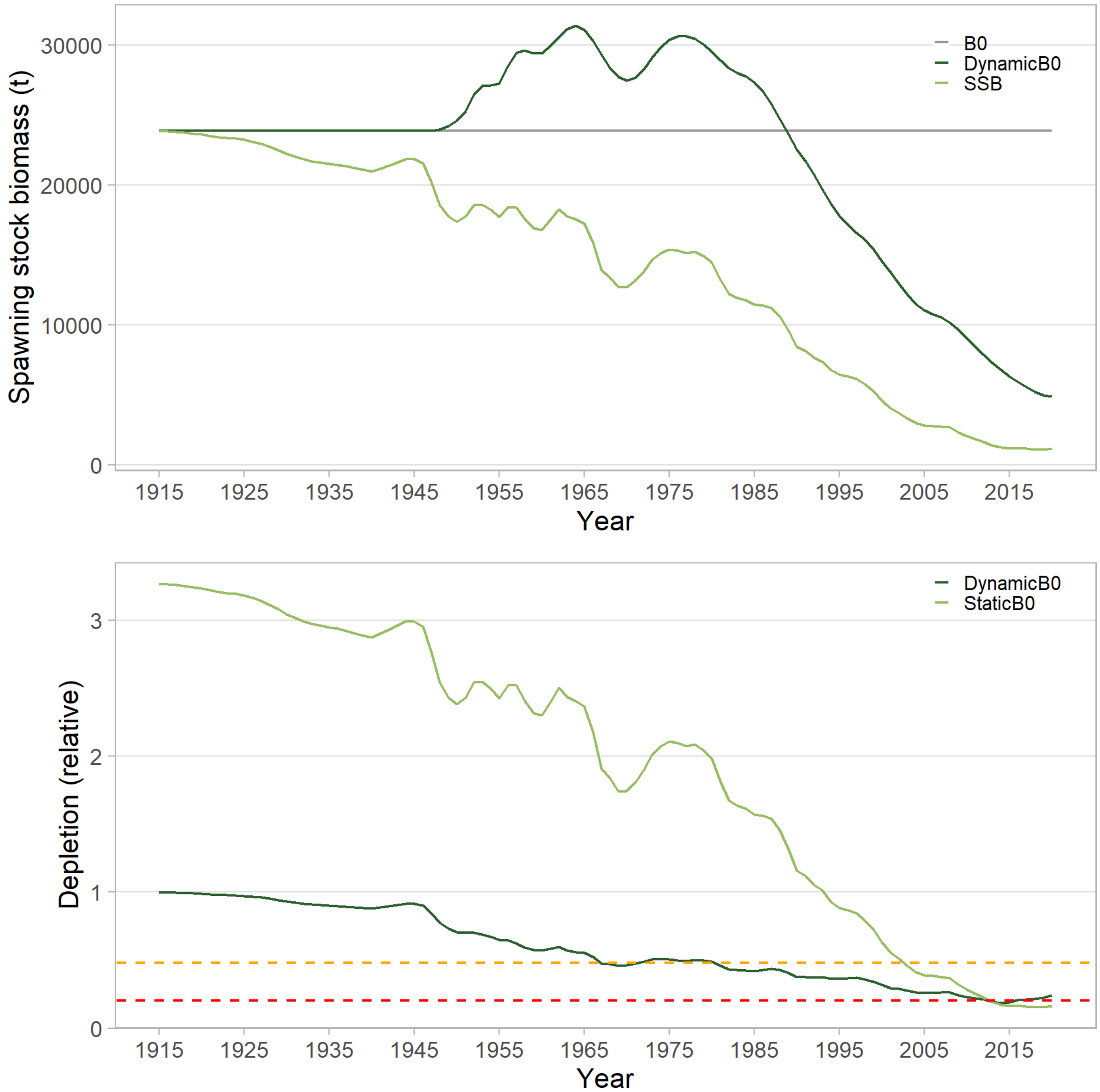


Figure 8.60. Dynamic B_0 for Jackass Morwong: spawning stock biomass (top) showing the trajectory of "dynamic B_0" (dark green) and the preliminary base case model predicted spawning stock biomass (light green), and; stock status (bottom) showing the trajectory of relative stock status, with a productivity shift implemented as a step function in 1988, under static B_0 (light green) and under dynamic B_0 (dark green). The orange dashed line is the target reference point (B_{48}) and the red dashed line is the limit reference point (B_{20}).

8.4.11 *MCMC analysis*

8.4.11.1 MCMC analysis

Markov chain Monte Carlo (MCMC) methods can be used for approximating the posterior distribution for parameters of interest in a Bayesian framework (Gelman et al. 2003). This enables estimation of the probability distribution of quantities such as stock status. An MCMC simulation should be run long enough so that the model converges, in the sense that the parameter vectors are random independent samples from the posterior (i.e. the distribution of draws is close enough to the target posterior distribution $p(\theta | y)$ (Gelman et al, 2003)).

As MCMC analysis requires estimation of all parameters, making use of the variance associated with parameter estimation, including variance in estimates of future recruitment deviations, it is not possible to run an MCMC analysis on the low recruitment scenario, in which recruitment from 2016 onwards is fixed. An alternative model was set up to attempt to mimic the appropriate behaviour, by imposing an additional productivity shift in 2016, but essentially fixing the value of the new “2016 equilibrium biomass” and tuning this value in an attempt to match the spawning biomass trajectory for the base case and the “double recruitment shift MCMC model”. While the results are not perfect, this may give an indication of the range of uncertainty in estimates of stock status in the period of most interest, 2010-2026. The reasons for running an MCMC analysis was to estimate the probability that the stock status is below SSB_{20} in the period 2010-2026, and this double recruitment shift MCMC model seemed to be a reasonable approximation for these purposes (Figure 8.61 and Figure 8.62).

MCMC simulations were run for 24 million cycles, with every 10,000th iteration saved. This gave 2,400 samples from the posterior distribution. The first 400 samples were omitted from the chain, which resulted in 2,000 posterior samples. The total run time was three days using a standard scientific personal computer.

Model convergence was assessed using the following statistics: (i) the extent of batch auto-correlation (examined using trace plots), as high autocorrelations indicate slow mixing and slow convergence, (ii) whether the posterior distribution was approximately multivariate normal (we examined the plot of the posterior distribution), and whether the distribution of the chain is stationary, as judged by the p-value computed from the Geweke statistic (which should be close to ±1.96) and (iii) whether the Heidelberger and Welch test is passed or not (Heidelberger and Welch 1983, Gelman et al. 2003). The R package, coda (Plummer et al., 2006) and r4ss (Taylor et al., 2014), were used to produce the plots and statistics.

8.4.11.2 MCMC results for low recruitment scenario

Diagnostic statistics and plots show that the MCMC run appears to have converged sufficiently, with 93% of the parameters passing the Geweke test, indicating no significant differences in the median values between the first and last parts of the chain, only one parameter having an autocorrelation greater than 0.4, and only one parameter failed (Q_extraSD_East_Trawl_Onbd.1) the Heidelberger and Welch test.

The median of the posterior distribution (MPD) from the MCMC simulations from the double recruitment shift MCMC model is close to the maximum likelihood estimate (MLE) for the low recruitment base case, for 1988 equilibrium biomass and spawning stock biomass from 2022-2026 (Table 8.25) and for stock status from 2022-2026 (Table 8.26), noting that the two models are not identical. The MLE estimates are outside of the 95% credibility intervals, in all cases, but the width of the credibility interval is indicative of the likely confidence bounds on the MLE estimate from the base case, at least for the 2022 stock status.

The spawning stock biomass time series (top panels) and stock status time series (bottom panels) are shown in Figure 8.61, with the left panels showing these series for the period 1915-2060, and the right panels expanded to show the details in the period 2010-2026, with the MLE from the base case shown in red and the MPD estimate from the double recruitment shift MCMC model shown in black with 50% credibility intervals (shaded) and 95% credibility intervals (dotted lines).

The absolute recruitment time series (top panels) and recruitment deviation time series (bottom panels) are shown in Figure 8.62, with the left panels showing these series for the period 1915-2060, and the right panels expanded to show the details in the period 2010-2026, with the MLE from the base case shown in red and the MPD estimate from the double recruitment shift MCMC model shown in black with 50% credibility intervals (shaded) and 95% credibility intervals (dotted lines).

Table 8.25. Spawning stock biomass from the MLE for the base case (low recruitment) and for the MPD with 95% credibility intervals for the double recruitment shift MCMC model.

	MLE	MPD	95% credible intervals	
Year	SSB		low	high
1988	7964.83	8200.55	8132	8264
2022	1308.98	1205.66	1192	1218
2023	1433.01	1300.13	1288	1311
2024	1523.31	1370.90	1359	1381
2025	1585.96	1421.98	1411	1432
2026	1640.69	1463.99	1453	1474

Table 8.26. Stock status from the MLE for the base case (low recruitment) and for the MPD with 95% credibility intervals for the double recruitment shift MCMC model.

	MLE	MPD	95% credible intervals	
Year	stock status		low	high
2022	16.4	14.7	14.5	14.8
2023	18.0	15.9	15.7	16
2024	19.1	16.7	16.6	16.9
2025	19.9	17.3	17.3	17.5
2026	20.6	17.9	17.8	17.9

While this MCMC analysis is indicative only, as it applies to a model which is different to the base case, this analysis gives an indication on the likely confidence intervals that should apply to the MLE estimates. If that assumptions holds, the probability of the stock status reaching B_{20} by 2024 is likely to be less than 5%, but will be close to 50% by 2025, and over 95% by 2026, assuming the catch is zero (no bycatch) for the next four years.

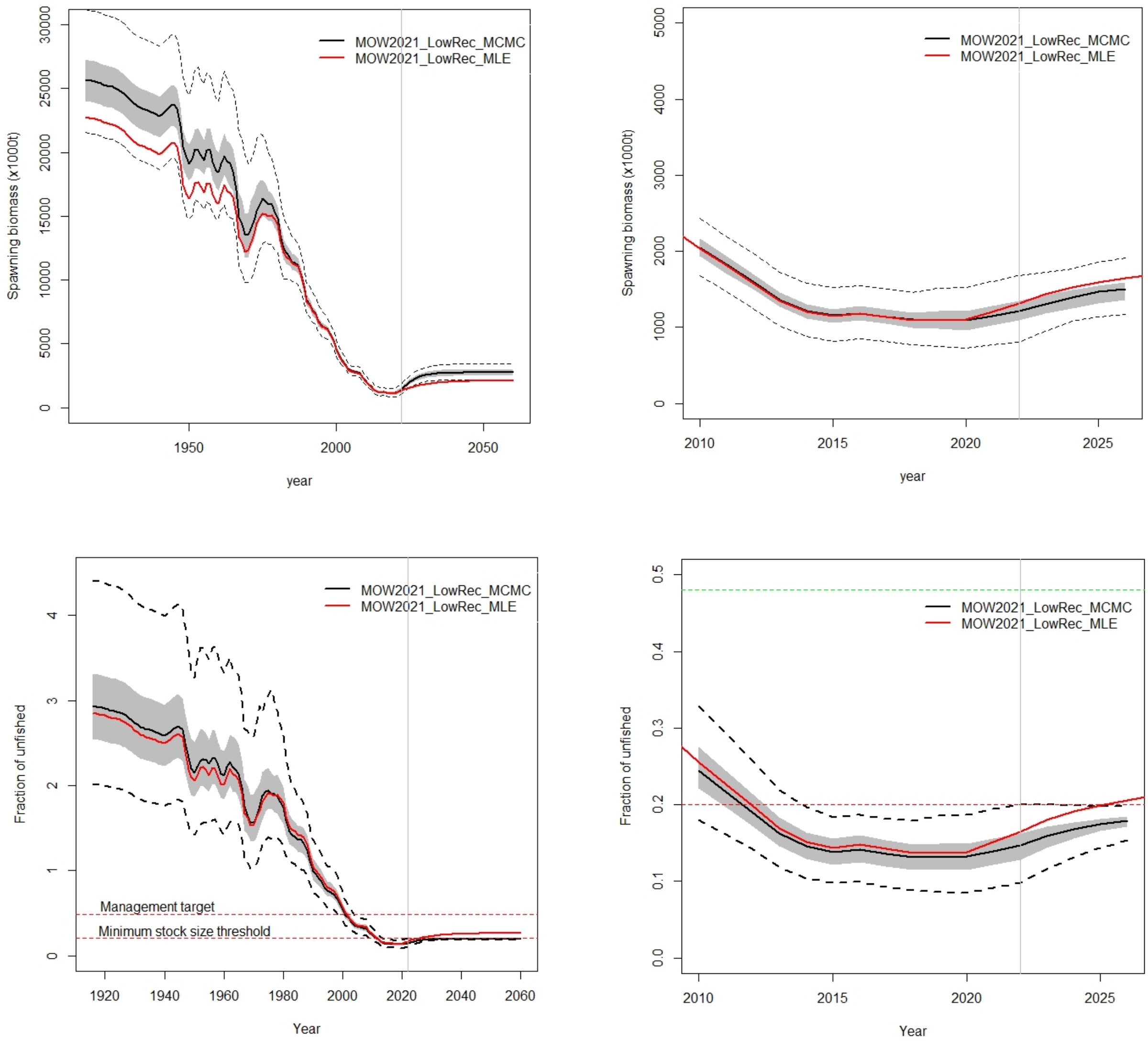


Figure 8.61. Absolute spawning biomass (top) and stock status (bottom) for the maximum likelihood estimate (MLE, red line) from the low recruitment base case and the median of the posterior distribution (MPD, black line) for the double recruitment shift MCMC model, with 50% (grey shaded area) and 95% credible intervals (dashed lines). The right panels focus on the time series from 2010-2016.

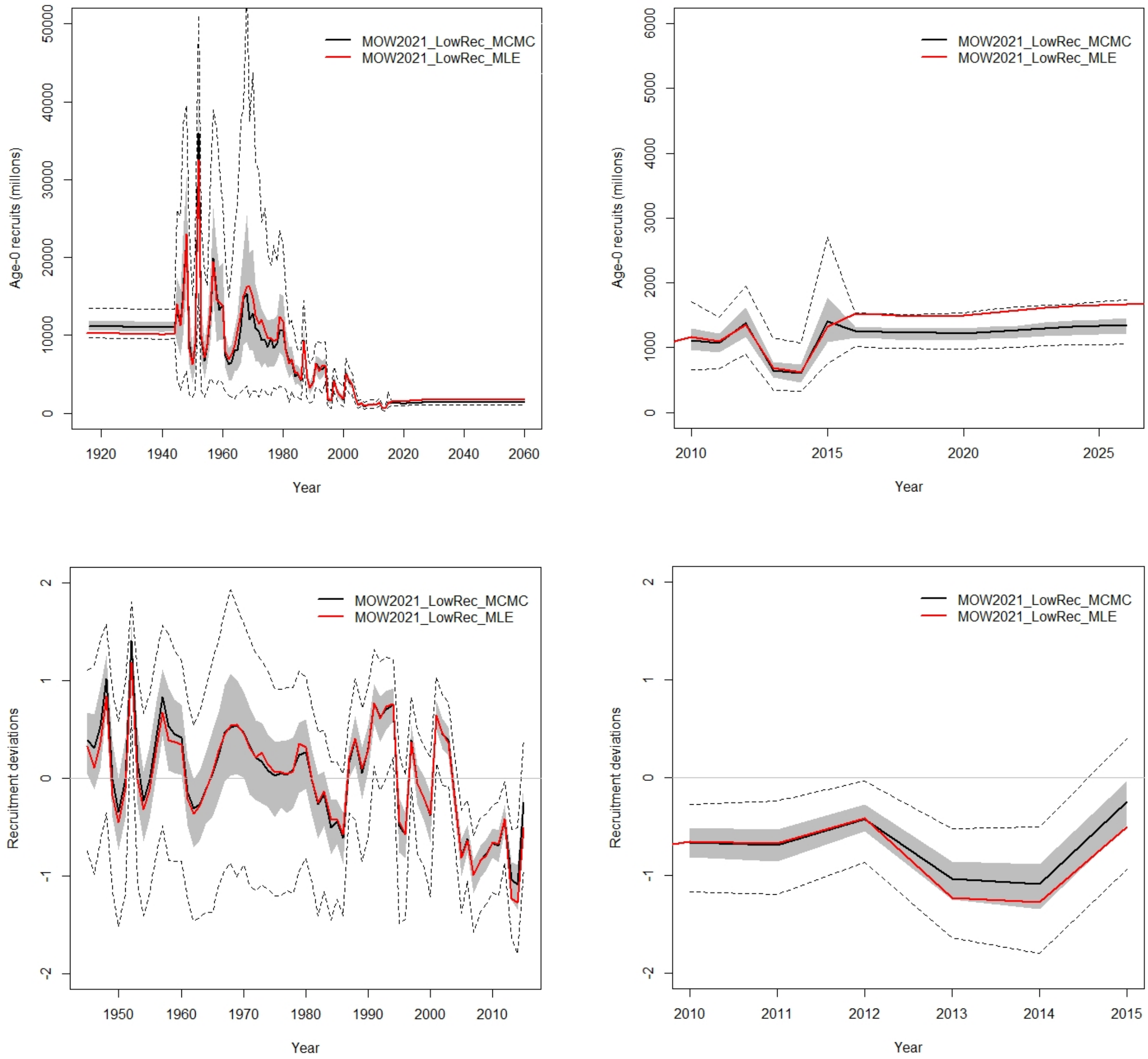


Figure 8.62. Absolute recruitment estimates (top) and recruitment deviations (bottom) for the maximum likelihood estimate (MLE, red line) from the low recruitment base case and the median of the posterior distribution (MPD, black line) for the double recruitment shift MCMC model, with 50% (grey shaded area) and 95% credible intervals (dashed lines). The right panels focus on the time series from 2010-2016.

Table 8.27. Summary statistics for parameters from the MCMC analysis.

Label	autocor	Geweke	N_{eff}/N	Heidel-Welsch
L_at_Amin_Fem_GP_1	-0.021	-2.416	995	Passed
L_at_Amax_Fem_GP_1	0.036	-2.775	995	Passed
VonBert_K_Fem_GP_1	-0.021	2.647	995	Passed
CV_young_Fem_GP_1	0.011	3.000	911	Passed
SR_LN.R0.	0.012	-0.875	995	Passed
SR_LN.R0._BLK2add_1914	0.001	1.207	995	Passed
Q_extraSD_East_Trawl_Onbd.1.	0.034	-1.901	797	Failed
Q_extraSD_Tas_Trawl_Onbd.3.	0.039	-0.379	995	Passed
Q_extraSD_Steam_Trawl.4.	-0.026	-0.807	995	Passed
Q_extraSD_Mixed.6.	0.228	0.330	626	Passed
Q_extraSD_Smith_CPUE.7.	0.005	-0.963	995	Passed
Q_extraSD_FIS_East.8.	0.381	-0.292	389	Passed
Q_extraSD_FIS_Tas.9.	-0.012	0.905	995	Passed
Size_inflection_East_Trawl_Onbd.1.	-0.012	-1.404	995	Passed
Size_95.width_East_Trawl_Onbd.1.	-0.007	-1.479	995	Passed
Retain_L_infl_East_Trawl_Onbd.1.	0.017	-0.623	995	Passed
Retain_L_width_East_Trawl_Onbd.1.	0.023	0.274	995	Passed
Size_inflection_Danish_Seine_Onbd.2.	-0.005	-0.471	995	Passed
Size_95.width_Danish_Seine_Onbd.2.	-0.054	0.126	995	Passed
Size_inflection_Tas_Trawl_Onbd.3.	0.012	0.009	995	Passed
Size_95.width_Tas_Trawl_Onbd.3.	0.033	-0.197	995	Passed
Retain_L_infl_Tas_Trawl_Onbd.3.	0.099	-1.906	816	Passed
Retain_L_width_Tas_Trawl_Onbd.3.	0.095	2.023	822	Passed
Size_inflection_Steam_Trawl.4.	-0.001	-0.857	995	Passed
Size_95.width_Steam_Trawl.4.	0.016	0.185	995	Passed
Size_inflection_Early_DS.5.	0.033	-1.869	995	Passed
Size_95.width_Early_DS.5.	-0.018	-1.462	995	Passed
Size_inflection_Mixed.6.	0.007	-0.270	995	Passed
Size_95. Width_Mixed.6.	-0.018	0.010	995	Passed
Size_inflection_FIS_East.8.	**0.492**	3.000	253	No test
Size_95.width_FIS_East.8.	0.354	-0.606	360	Passed
Size_inflection_FIS_Tas.9.	-0.003	-0.598	995	Passed
Size_95.width_FIS_Tas.9.	-0.016	1.563	995	Passed

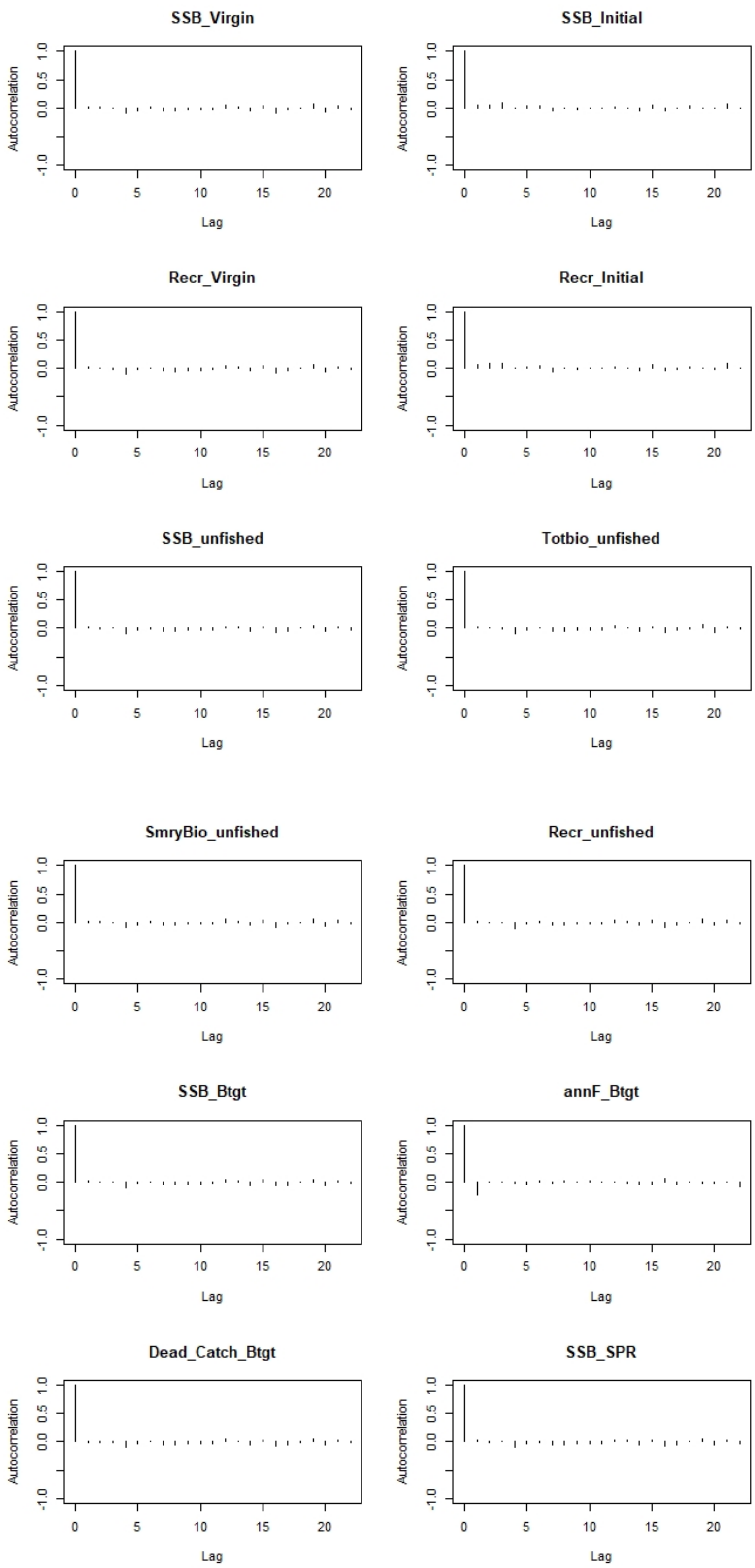


Figure 8.63. Autocorrelation plots for the double recruitment shift MCMC model.

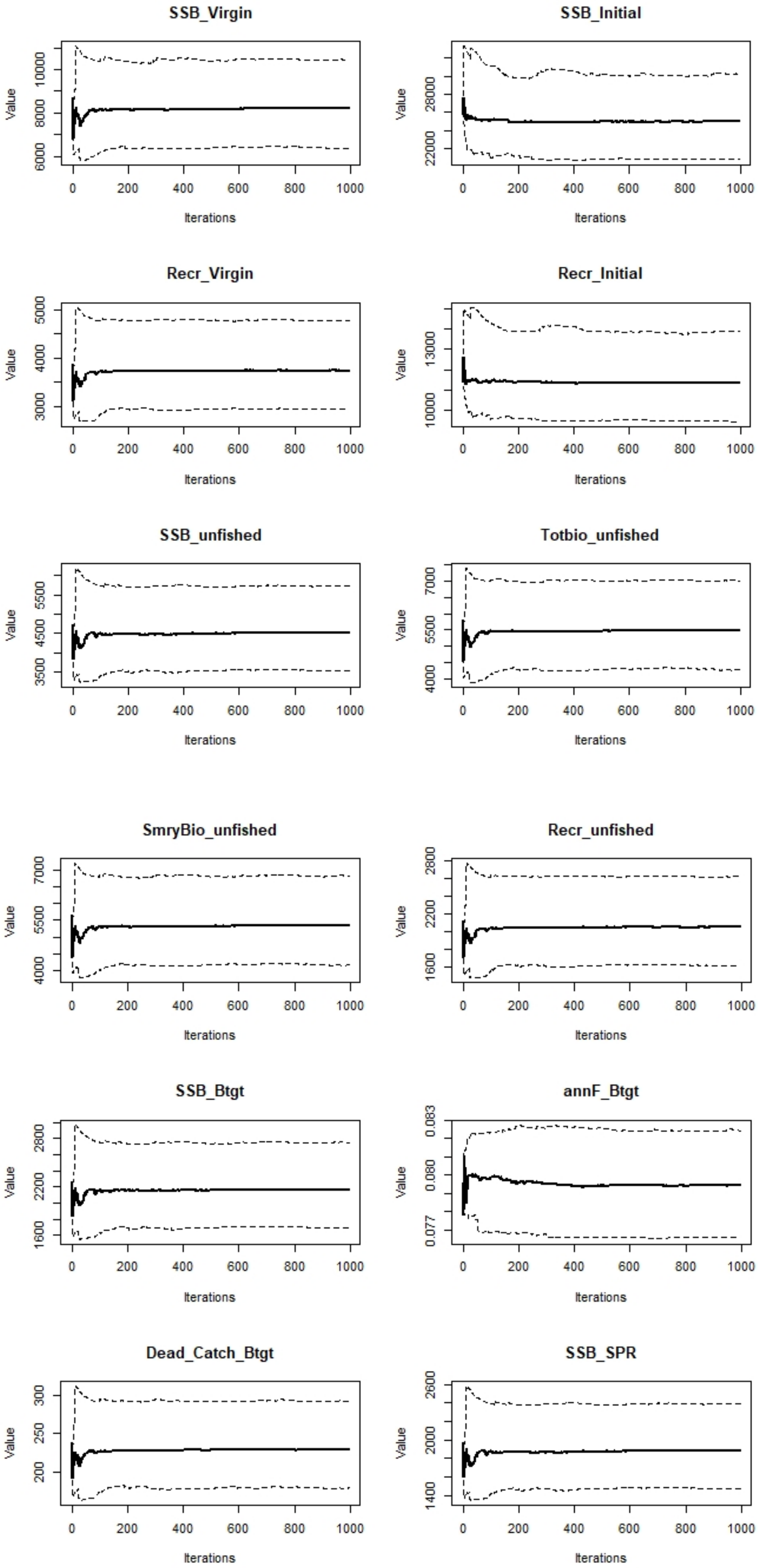


Figure 8.64. Trace plots (part 1): iterations vs sampled values for the double recruitment shift MCMC model.

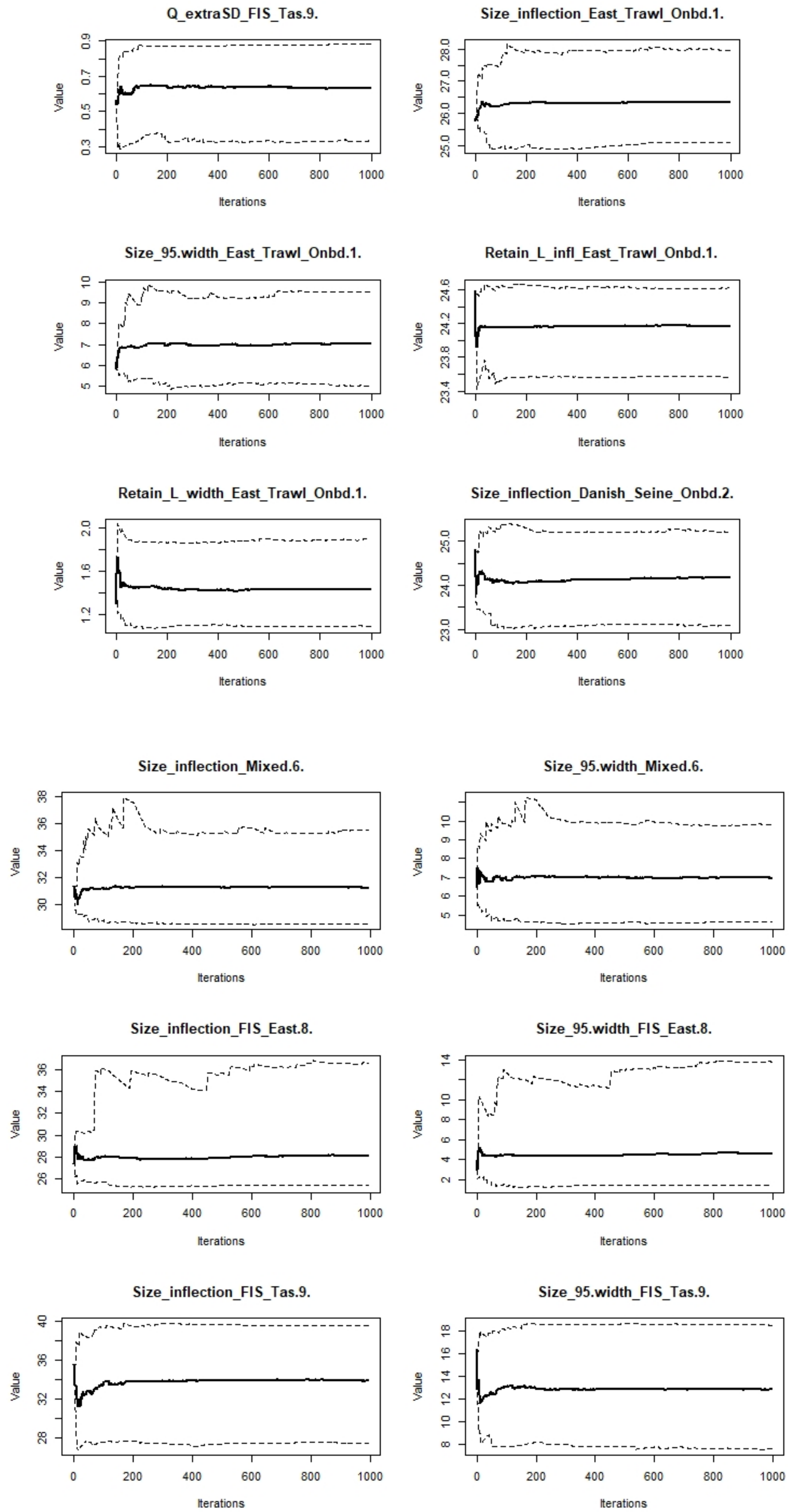


Figure 8.65. Trace plots (part2): iterations vs sampled values for the double recruitment shift MCMC model.

8.4.12 *Future work and potential issues with this assessment and data*

There are still some unresolved issues relating to allocation of recent state catches for the period 2014-2020 between eastern and western fleets (noting that the western fleet is used only for the western Jackass Morwong assessment), especially for Tasmanian and Victorian state catches, but these catches are relatively small compared to other catches in the same period, and any future revisions are unlikely to have a noticeable influence on the assessment outcomes. Some of these catches are currently masked, with assumptions made about this catch data, due to concerns about use of confidential data and the five-boat rule. Ideally, appropriate use of the actual data will be negotiated for future assessments, ensuring that the confidentiality requirements of the data owners are respected. It would be good to resolve these issues to ensure the best possible data is available for use in the future stock assessments.

There are also some unresolved issues relating to NSW state catches in the period 1986-1999. In 2007, an attempt was made to account for double counting (i.e. recording catches in both state and Commonwealth logbooks) catches reported to NSW state in the period 1986-2009 (Kevin Rowling, pers comm. 2021, Sally Wayte, pers. comm. 2021). While the details are not fully documented in the relevant stock assessment reports, and alternative catch series could be constructed for this period using different assumptions to account for double counting, it appears that the changes to these potential catch series would be relatively small. Larger revisions to the catch history back to 1986 incorporated in Bridge 2 in 2021 (Day and Bessell-Browne, 2021) had very little impact on both the spawning biomass time series and the recruitment estimates, so it is likely such revisions would have no material impact on the assessment results.

There appear to be convergence issues with the updated ageing error matrix, relating to potential outliers in the data. This requires further investigation.

Any results from this assessment should be treated with some caution given the recent data quality available for this assessment and the quality of the eastern trawl CPUE data. Sporcic (2021) states that "The structural adjustment altered the effect of the vessel factor on the standardised result. However, log(CPUE) has also changed in character from 2014-2020, with spikes of low catch rates arising" and "Annual standardized CPUE has been below the long-term average since about 2000 with apparent periodicity. Both the recorded catch (36.6 t) and number of records (956) in 2020 were the lowest in the series."

8.5 Acknowledgements

Age data were provided by Kyne Krusic-Golub (Fish Ageing Services), ISMP and AFMA logbook and CDR data were provided by John Garvey (AFMA). Mike Fuller, Paul Burch, Robin Thomson, Roy Deng, Franzis Althaus, Toni Cannard and Caroline Sutton (CSIRO) were all involved in pre-processing the data. Malcolm Haddon provided useful code for auto-tuning, Athol Whitten provided useful R code for organising plots. André Punt and Paul Burch helped provide an updated ageing error matrix. André Punt, Geoff Tuck, Miriana Sporcic, Paul Burch, Robin Thomson and Brett Stacy and are thanked for helpful discussions on this work. Ian Taylor, Richard Methot and Chantel Wetzel and Kathryn Doering (NOAA Fisheries) are thanked for support and advice using Stock Synthesis. The r4ss package maintained by Ian Taylor (https://github.com/r4ss/r4ss) was critical for producing multiple diagnostic plots, and tuning models. Thanks to Ian Taylor for his patient advice on using this package and for answering numerous technical questions on Stock Synthesis over a number of years. Geoffrey Liggins contributed to useful discussions on the catch history.

8.6 References

Allen KR. 1989. Stock Assessments for Four Species in the Southeastern Trawl.

Althaus F Thomson R and Sutton C. 2021. Southern and Eastern Scalefish and Shark Fishery catches and discards for TAC purposes using data until 2020 – DRAFT. Prepared for the SESSFRAG Data Meeting, 24-26 August 2021. CSIRO, Australia.

Bergh M Knuckey I Gaylard J Martens K Koopman M. 2009. A revised sampling regime for the Southern and Eastern Scalefish and Shark Fishery – Final Report. OLRAC; Fishwell Consulting.

Bessell-Browne P Day J Sporcic M and Appleyard S (2021). SESSF species stock structure review: Jackass Morwong, Pink Ling and Blue Warehou. Technical report for AFMA, April 2021. 80p.

Blackburn M. 1978. Changes in size composition, indicative of stock conditions in the New South Wales trawl fishery, from 1945/46 to 1966/67. CSIRO Division of Fisheries and Oceanography Report No. 97.

Day J. 2006. Small shots and related CPUE series for Jackass Morwong (*Nemadactylus macropterus*) 2006, prepared for Shelf Assessment Group, August 14-15, 2006.

Day J 2008. Modified breakpoint for the 2008 Tier 1 harvest control rule. pp 153 – 157 *in* Tuck, G.N. (ed.) 2009. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2008.* Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 344p.

Day J and Bessell-Browne P. 2021. Eastern Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2020 – development of a preliminary base case. For discussion at SERAG 2, October 2021.

Day J, Hall K, Bessell-Browne P and Sporcic M 2020. School Whiting (*Sillago flindersi*) stock assessment based on data to 2019. Unpublished report to SERAG. 158 pp.

Day J and Castillo-Jordán C. 2018a. Eastern Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2017. pp 86 – 174 *in* Tuck, G.N. (ed.) 2020. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2018 and 2019.* Part 1, 2018. Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere, Hobart. 526p.

Day J and Castillo-Jordán C. 2018b. Western Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2017. Pp 217 – 268 *in* Tuck, G.N. (ed.) 2020. *Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2018 and 2019.* Part 1, 2018. Australian Fisheries Management Authority and CSIRO Oceans and Atmosphere, Hobart. 526p.

Deng RA Cannard T and Burch P. 2021. Integrated Scientific Monitoring Program for the Southern and Eastern Scalefish and Shark Fishery – discards for 2020 DRAFT. Prepared for the SESSFRAG Data Meeting, 24-26 August 2021. CSIRO, Australia.

Elliott NG Grewe PM Smolenski AJ and Ward RD. 1992. Stock delineation in Jackass Morwong, 2. Genetic results. Newsletter of the Australian Society for Fish Biology **22**(2): 32.

Fay G. 2004. Stock assessment for Jackass Morwong (*Nemadactylus macropterus*) based on data up to 2002. In: Tuck, G.N. and Smith, A.D.M. (Eds.) Stock assessment for south east and southern shark fishery species. Fisheries Research and Development Corporation and CSIRO Marine Research, Hobart 412 p.

Fay G. 2006. Stock assessment of Jackass Morwong (*Nemadactylus macropterus*) and RBC calculations for 2007 using data up to 2005. In: Tuck, G.N. (Ed.) 2007. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2006-2007. Volume 1: 2006. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 570pp.

Francis RICC. 2011. Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. **68**: 1124 – 1138.

Gelman A Carlin JB Stern HS and Rubin DB. 2003. Bayesian Data Analysis. 2nd Edition. Chapman & Hall/CRC Press, Florida. 668 p.

Heidelberger P and Welch PD. 1983. A spectral method for confidence interval generation and run length control in simulations. Commun. ACM, **24**: 233–45.

Hurtado-Ferro F Szuwalski CS Valero JL Anderson SC Cunningham CJ Johnson KF Licandeo R McGilliard CR Monnahan CC Muradian ML Ono K Vert-Pre KA Whitten AR and Punt AE. 2015. Looking in the rear-view mirror: bias and retrospective patterns in integrated, age-structured stock assessment models. ICES Journal of Marine Science **72**: 99 – 110.

Klaer NL. 2001 Steam trawl catches from south-eastern Australia from 1918 to 1957: trends in catch rates and species composition. Marine and Freshwater Research 52, 399-410.

Klaer NL. 2006. Changes in the Structure of Demersal Fish Communities of the South East Australian Continental Shelf from 1915 to 1961. PhD thesis. University of Canberra. 187pp.

Klaer NL and Smith DC. 2008 Species associations and companion TACs in the SESSF. Report for the Australian Fisheries Management Authority, Canberra. 54 pp.

Klaer NL and Tilzey RDJ. 1996. Catalogue and analysis of South East Fishery historic data. Final Report to the Australian Fisheries Research and Development Corporation. Project No. 90/023.

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

Knuckey I Koopman M Boag S Day J and Peel D. 2015. Continuation of a fishery independent survey for the Southern and Eastern Scalefish and Shark Fishery — 2014. AFMA Project 2014/0816. Fishwell Consulting 50 pp.

Liggins GW. 1996. The interaction between fish trawling in NSW and other commercial and recreational fisheries. Final Report to FRDC. Project 92/79.

Lyle JM. 1989. A review of catch and effort data for the South West Sector of the South East Trawl Fishery: Based on the Tasmanian logbook prior to 1984. Report to DPFRG 28. Division of Sea Fisheries, Department of Primary Industry, Tasmania.

Methot RD. 2005. Technical Description of the Stock Synthesis II Assessment Program Version 1.17 – March 2005. NOAA Fisheries Internal Report.

Methot RD, Taylor IG. 2011 Adjusting for bias due to variability of estimated recruitments in fishery assessment models. Can.J.Fish.Aquat.Sci. **68**: 1744 – 1760.

Methot RD and Wetzel CR. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fisheries Research **142**: 86 – 90.

Methot RD Wetzel CR and Taylor I. 2018. Stock Synthesis User Manual Version 3.30.12. NOAA Fisheries, Seattle, WA USA. 230pp.

Methot RD Wetzel CR Taylor I Doering KL and Johnson KF. 2021. Stock Synthesis User Manual Version 3.30.17. NOAA Fisheries, Seattle, WA USA. 238pp.

Mohn R. 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. ICES Journal of Marine Science: Journal du Conseil **56**, 473 – 488.

Myers RA Bowen KG Barrowman NJ. 1999. Maximum reproductive rate of fish at low population sizes. Can.J.Fish.Aquat.Sci. **56**:2404-2419.

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

Plummer M, Best N, Cowles K and Vines K. 2006. Coda: Convergence diagnosis and output analysis for MCMC. R News, 6, 7–11. URL: https: //journal.r-project.org/archive/.

Proctor CH Thresher RE and Mills DJ. 1992. Stock delineation in Jackass Morwong, 1. Otolith chemistry results. Newsletter of the Australian Society for Fish Biology **22**(2): 47-48.

Punt AE. 2017. Some insights into data weighting in integrated stock assessments. Fisheries Research **192**: 52-65.

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

Smith DC. 1989. The fisheries biology of Jackass Morwong (*Nemadactylus macropterus* Bloch and Schneider) in southeastern Australian waters. PhD Thesis University of New South Wales.

Smith DC. 1994. Jackass morwong, *Nemadactylus macropterus*. In: Tilzey, R.D.J. (Ed.), The South East Fishery – A Scientific Review with Particular Reference to Quota Management. BRS, Canberra, pp. 168 – 178.

Smith DC and Robertson DA. 1995. Jackass Morwong, Stock Assessment Report, South East Fishery Assessment Group. Australian Fisheries Management Authority, Canberra. 40 pp.

Smith ADM, Smith DC, Tuck GN, Klaer N, Punt AE, Knuckey I, Prince J, Morison A, Kloser R, Haddon M, Wayte S, Day J, Fay G, Fuller M, Taylor B and Little LR. 2008. Experience in implementing harvest strategies in Australia's south-eastern fisheries. Fish. Res. **94**: 373 – 379.

Smith ADM and Wayte S (eds). 2002. The South East Fishery 2001. Fishery Assessment Report compiled by the South East Fishery Assessment Group. Australian Fisheries Management Authority, Canberra.

Sporcic M. 2021a. Statistical CPUE Standardizations for selected SESSF species (data to 2021). Hobart, 341 p. Report for the Australian Fisheries Management Authority. CSIRO Oceans and Atmosphere.

Sporcic, M. 2021b. Executive Summary: CPUE standardizations for selected SESSF Species (data to 2020). Technical paper presented at SESSFRAG, 24-26 August 2021. CSIRO Oceans and Atmosphere, Hobart. 12p.

Sporcic M Day J Peel D. (2019). A re-examination of underlying model assumptions and resulting abundance indices of the Fishery Independent Survey (FIS) in Australia's SESSF. CSIRO Oceans and Atmosphere. FRDC Final report 2017-010. Hobart. 137 p.

Taylor IG Stewart IJ Hicks A Garrison TM Punt AE Wallace JR and Wetzel CR 2014. r4ss: R code for Stock Synthesis. R package version 1.16. http://R-Forge.R-project.org/ projects/r4ss/.

Tuck GN Day J and Wayte S. 2015a. Assessment of the eastern stock of Jackass Morwong (*Nemadactylus macropterus*) based on data up to 2014. Report to the Shelf Resource Assessment Group, October 2015. CSIRO Oceans and Atmosphere, Hobart. 60 pp.

Tuck GN Day J Thomson R and Wayte S. 2015b. Assessment of the western stock of Jackass Morwong (*Nemadactylus macropterus*) based on data up to 2014. Report to the Shelf Resource Assessment Group, October 2015. CSIRO Oceans and Atmosphere, Hobart. 26 pp.

Wayte SE. 2010. Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2008. In: Tuck GN (Ed.) 2010. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2009. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 334pp.

Wayte S. 2011. Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2010. Technical report to the Shelf RAG, 7-8 November 2011

Wayte SE. 2013. Management implications of including a climate-induced recruitment shift in the stock assessment for Jackass Morwong (*Nemadactylus macropterus*) in south-eastern Australia. Fisheries Research. Fisheries Research. **142**: 47-55.

Wayte SE and Fay G. 2007. Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2006. In: Tuck GN (Ed.) 2007. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2006-2007. Volume 2: 2007. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 584pp.

Wayte SE and Fay G. 2009. Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2007. In: Tuck GN (Ed.) 2009. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2008. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart. 344pp.

8.7 Appendix A

8.7.1 Fits to length composition, implied fits to age composition and diagnostics for fits to conditional age-at-length data

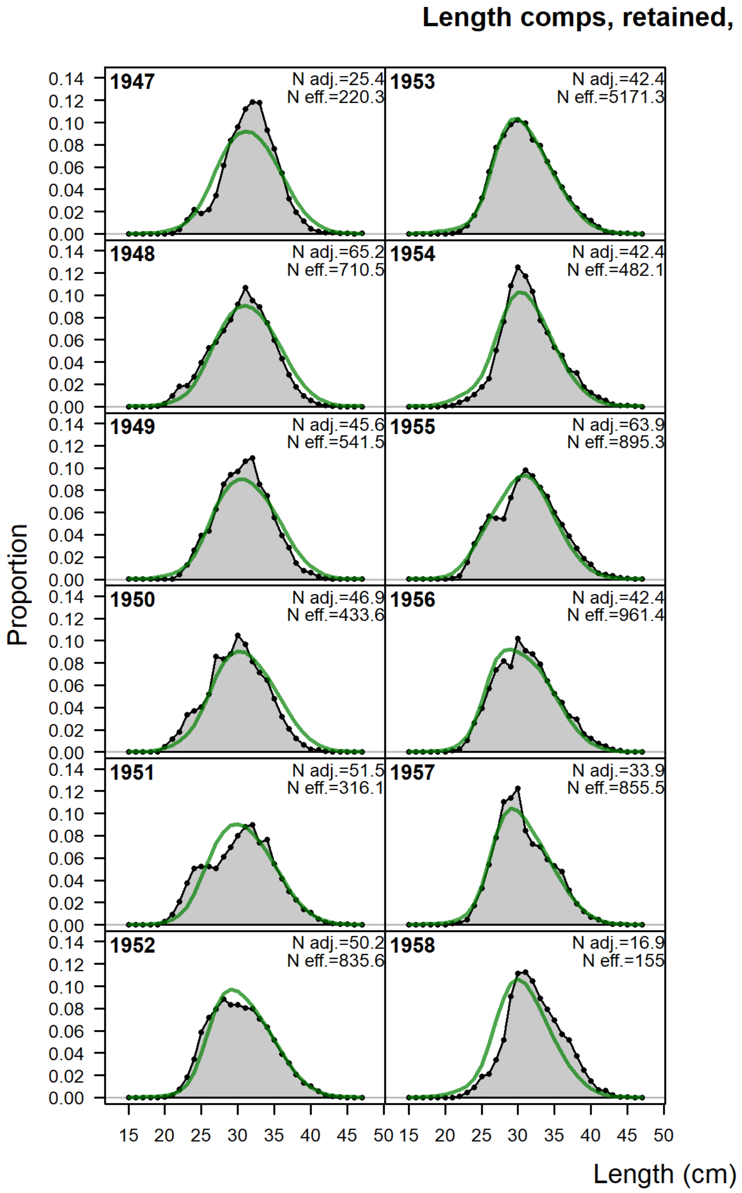


Figure A 8.1. Eastern Jackass Morwong length composition fits: steam trawl fleet retained.

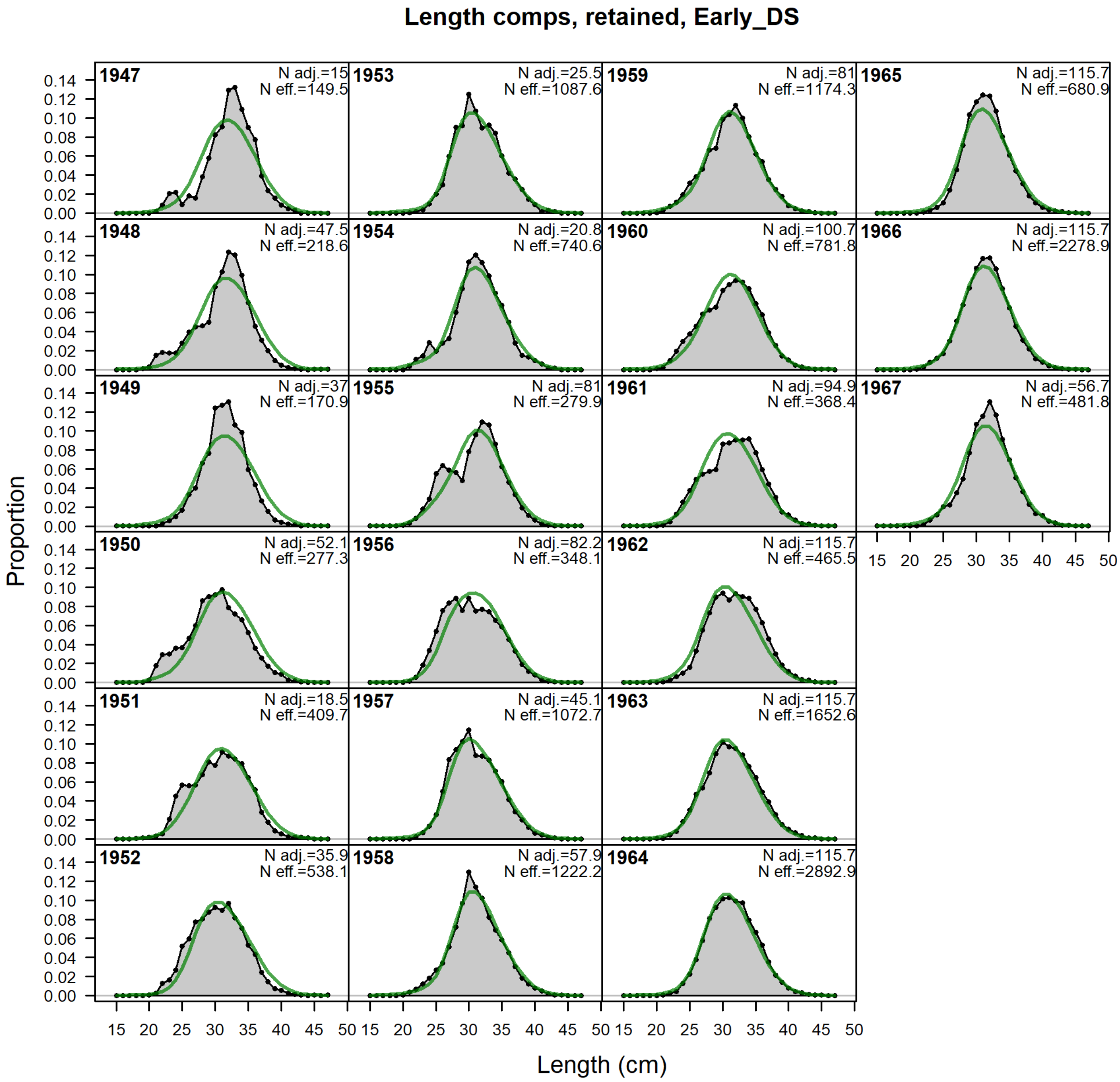


Figure A 8.2. Eastern Jackass Morwong length composition fits: early Danish seine fleet retained.

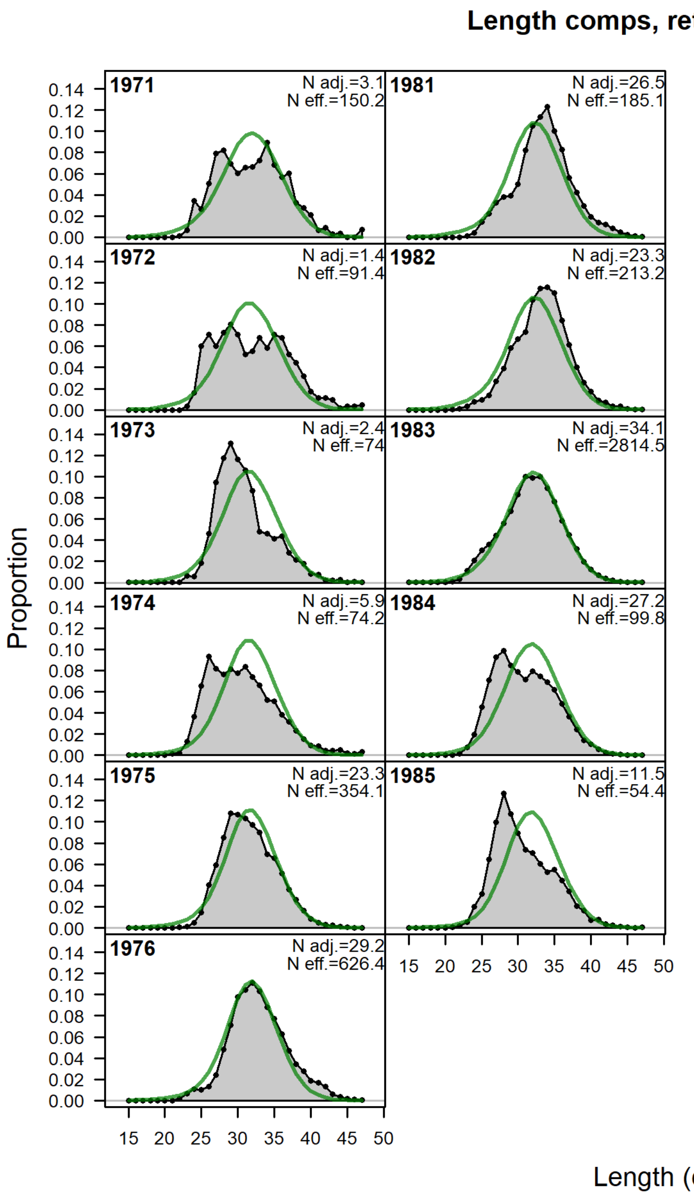


Figure A 8.3. Eastern Jackass Morwong length composition fits: mixed fleet retained.

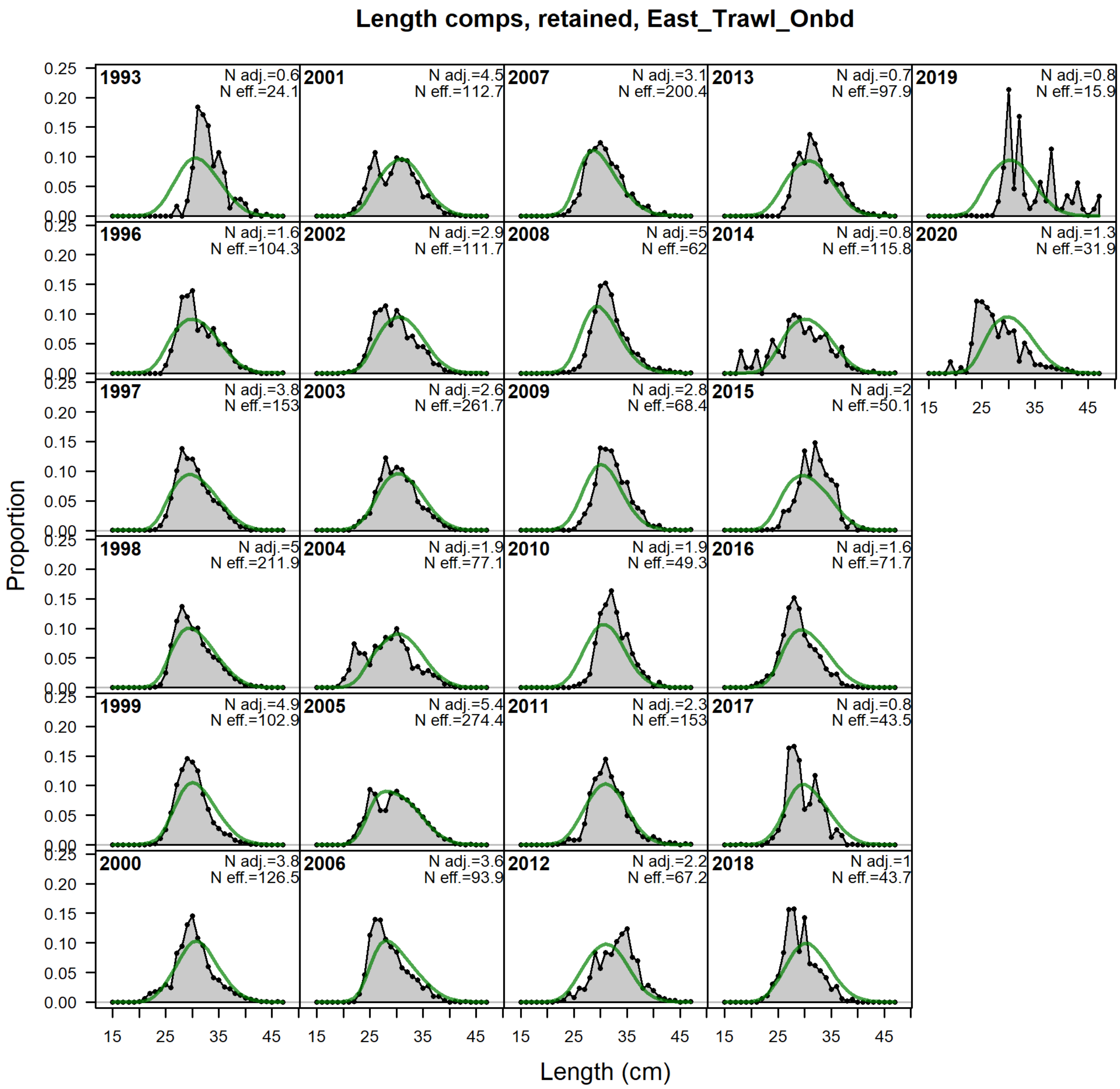


Figure A 8.4. Eastern Jackass Morwong length composition fits: eastern trawl fleet onboard retained.

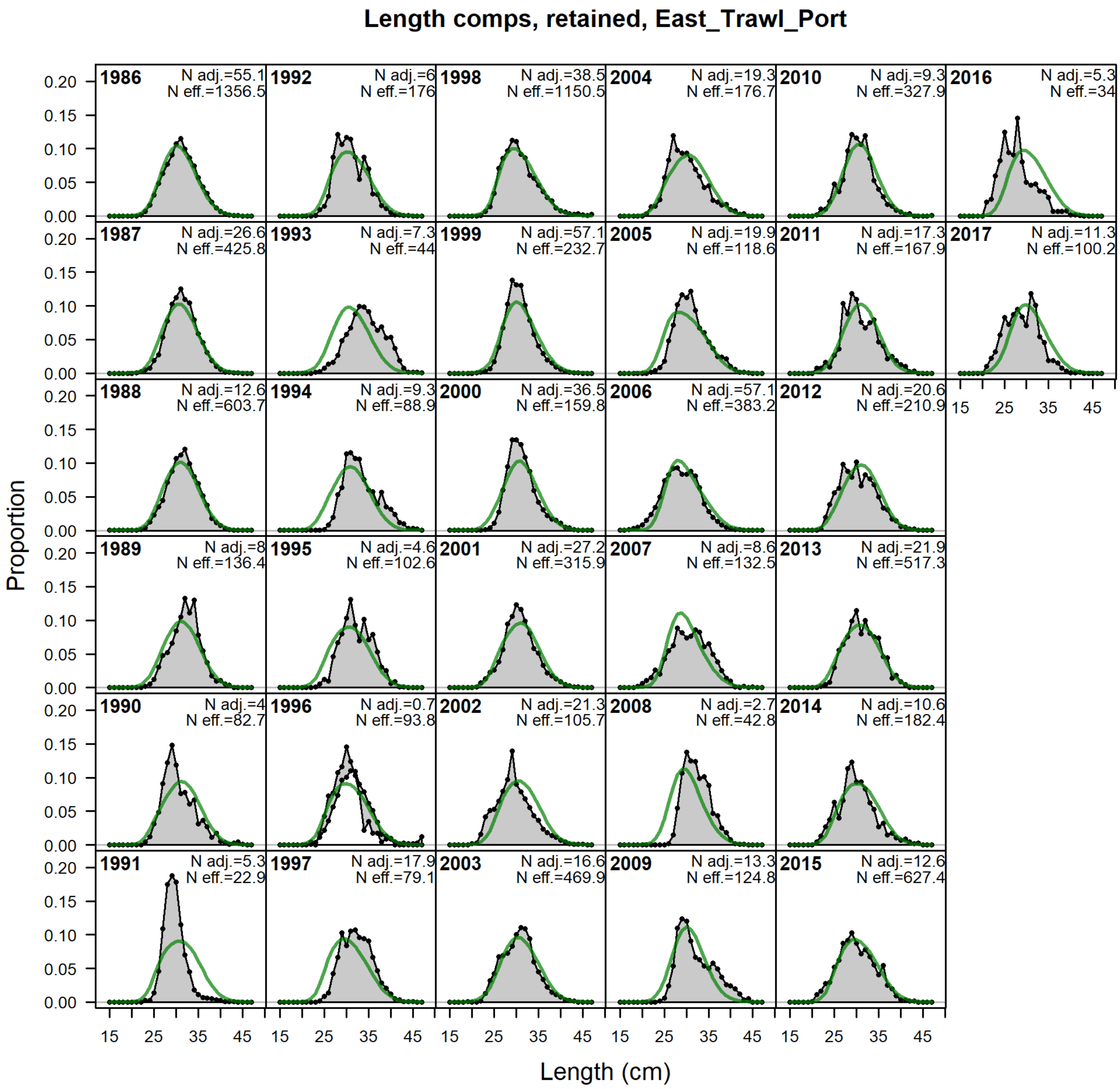


Figure A 8.5. Eastern Jackass Morwong length composition fits: eastern trawl fleet port retained.

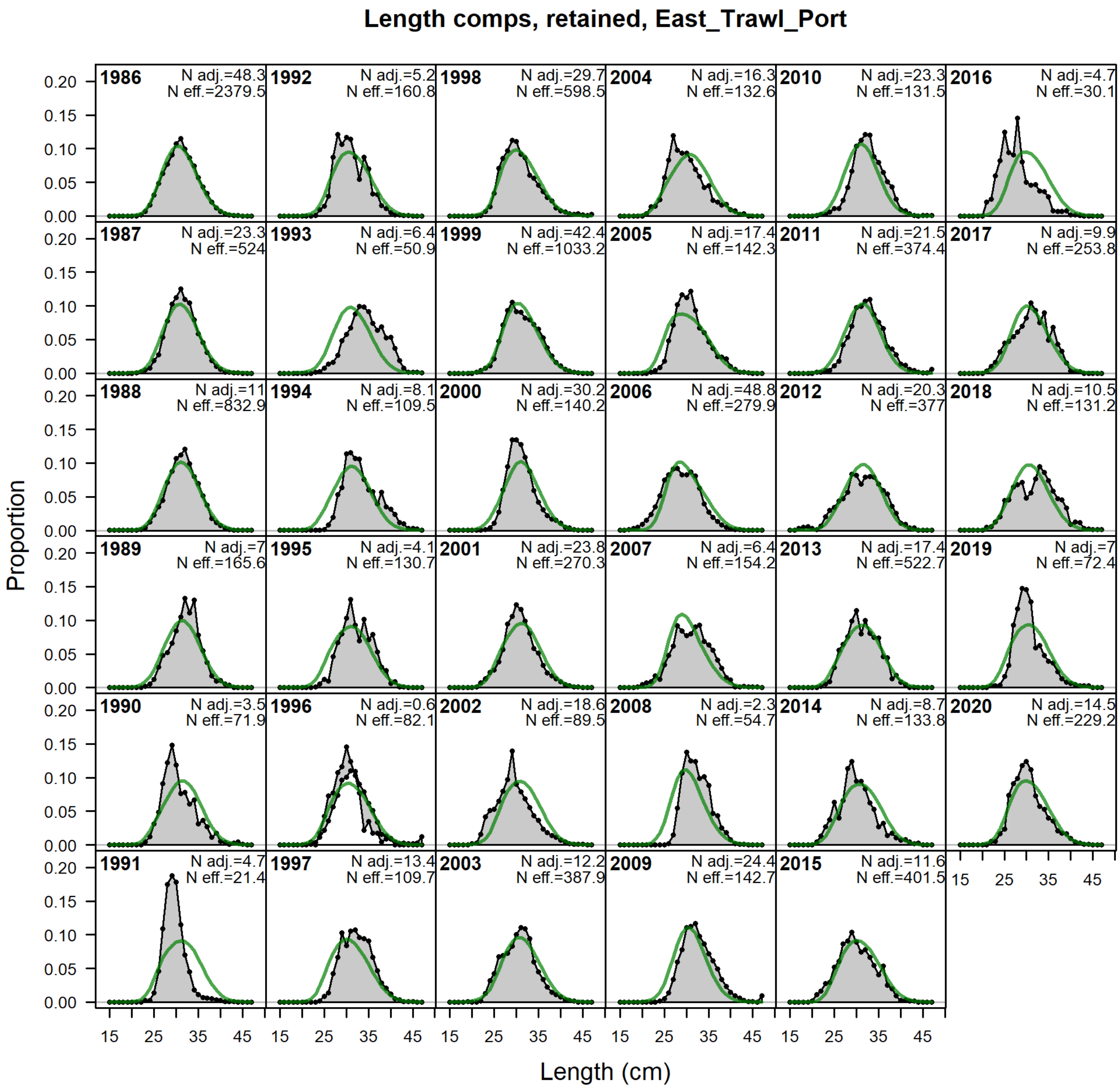


Figure A 8.6. Eastern Jackass Morwong length composition fits for the “updated base case” with revised port length composition data: eastern trawl fleet port retained.

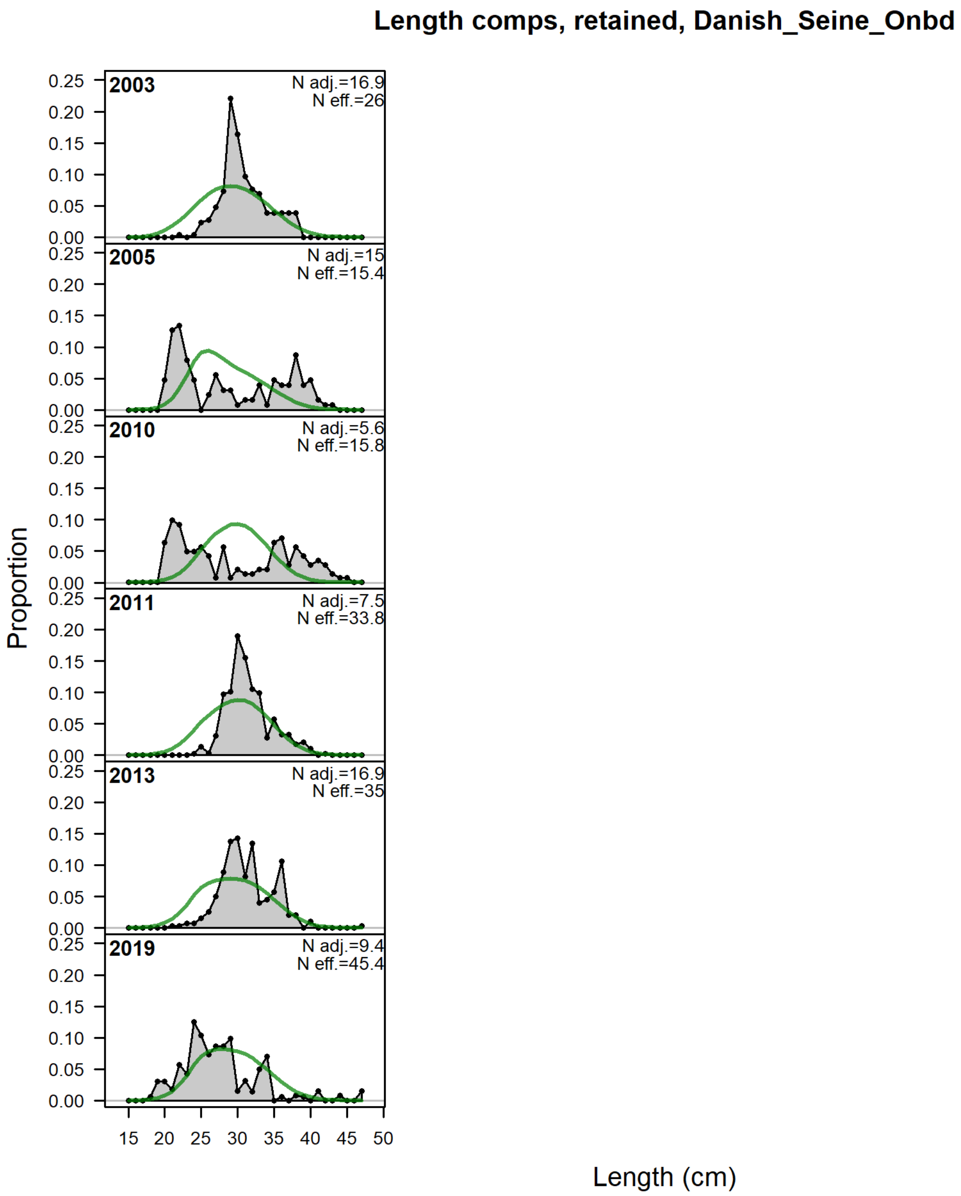


Figure A 8.7. Eastern Jackass Morwong length composition fits: Danish seine fleet onboard retained.

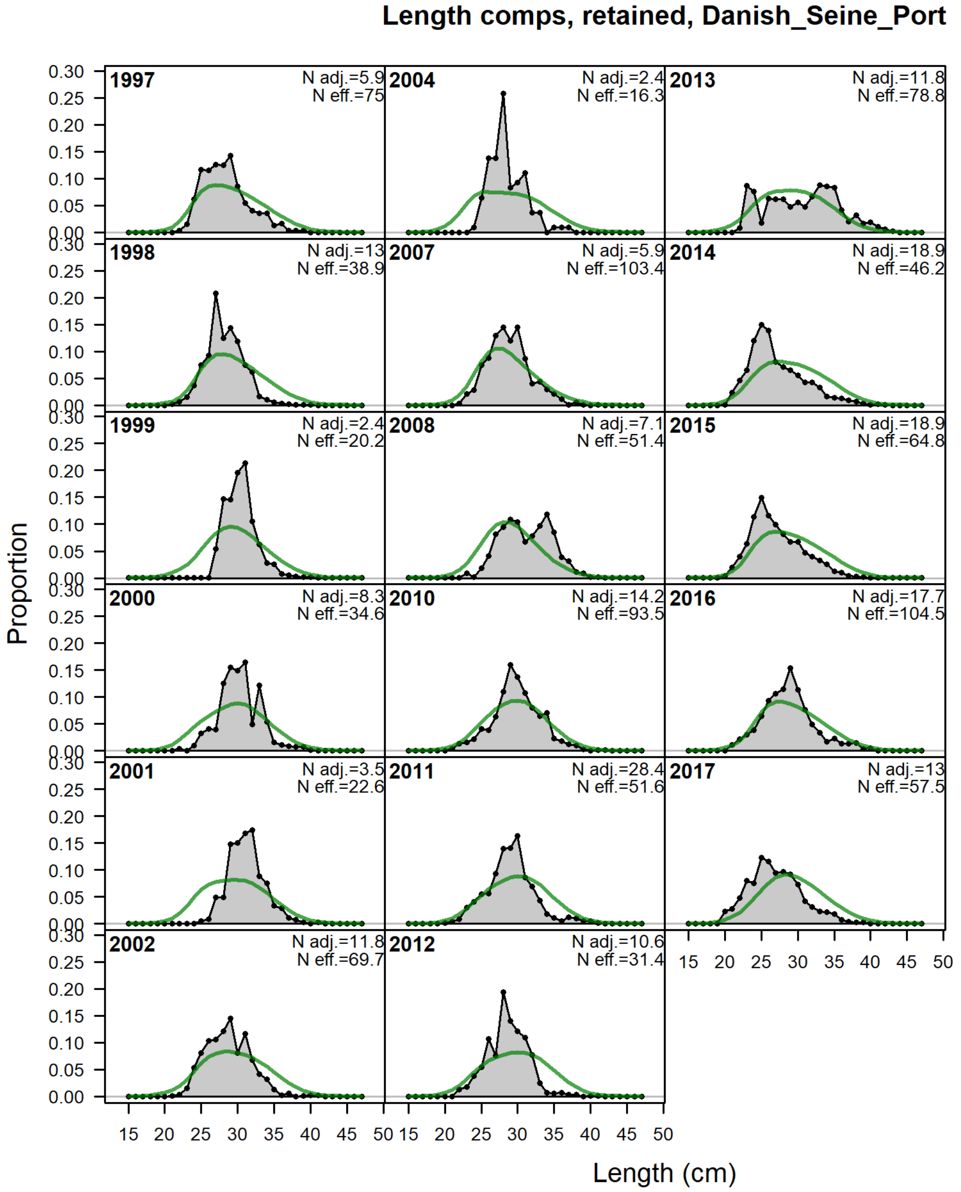


Figure A 8.8. Eastern Jackass Morwong length composition fits: Danish seine fleet port retained.

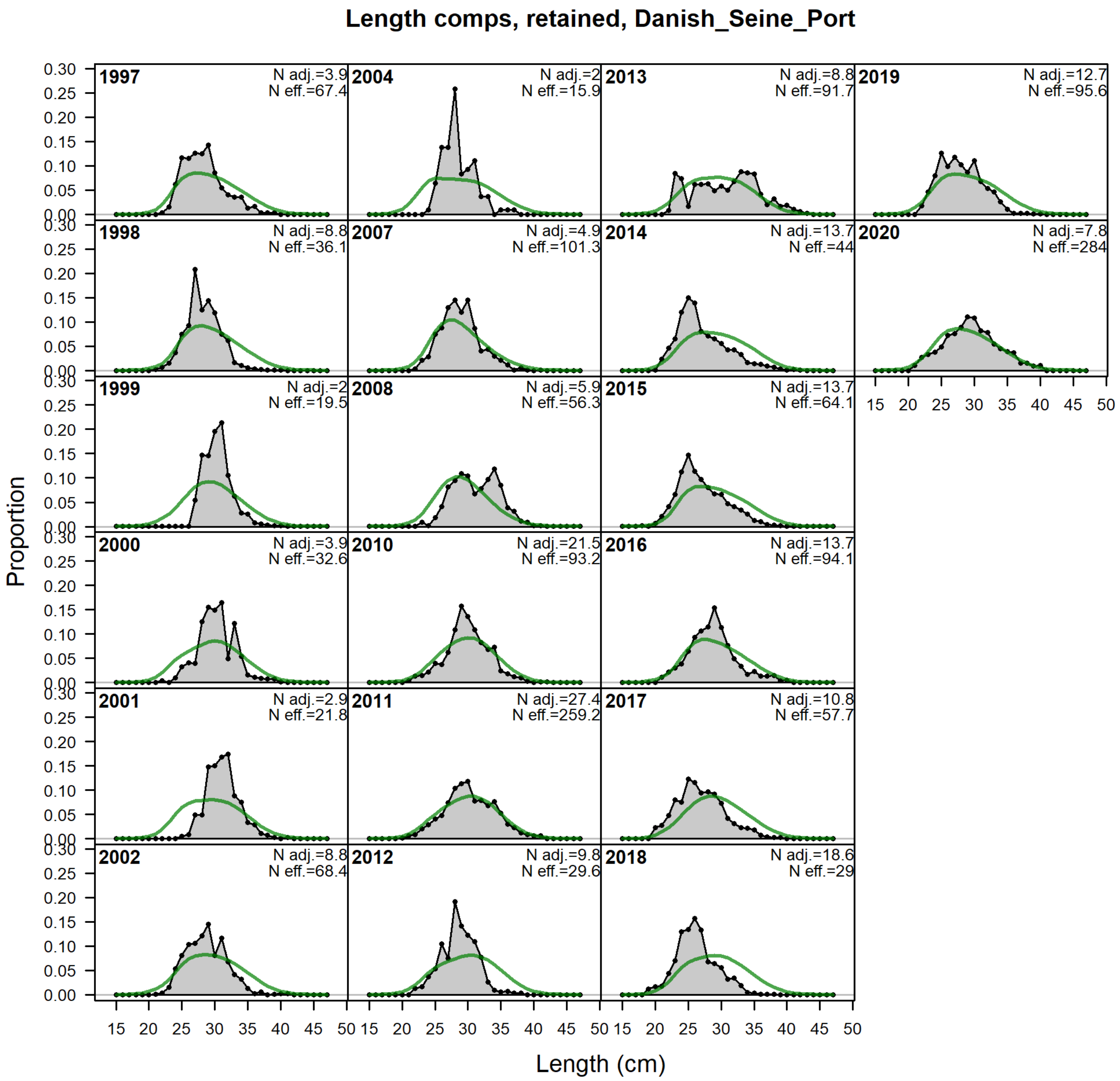


Figure A 8.9. Eastern Jackass Morwong length composition fits for the "updated base case" with revised port length composition data: Danish seine fleet port retained.

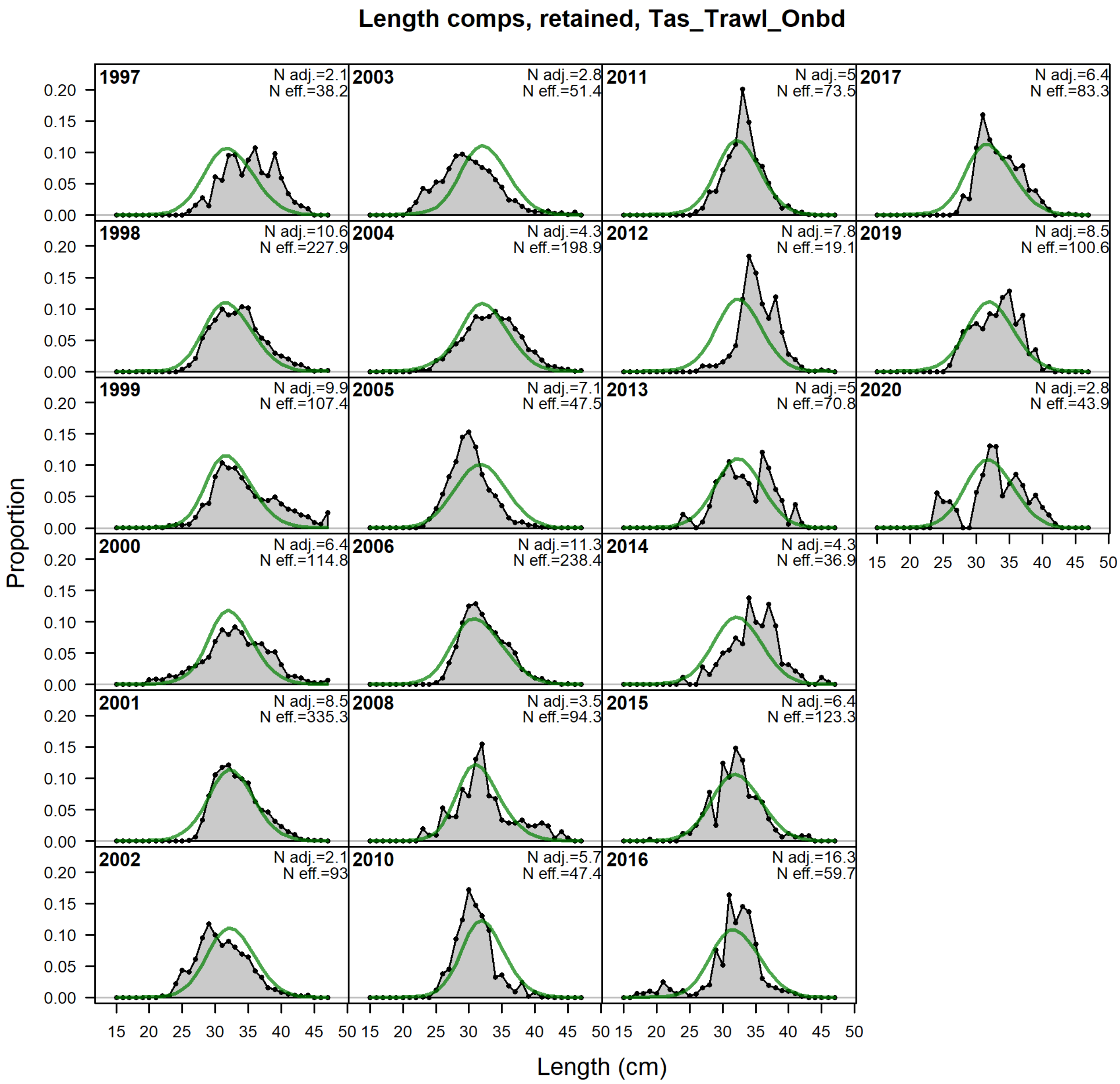


Figure A 8.10. Eastern Jackass Morwong length composition fits: Tasmanian trawl fleet onboard retained.

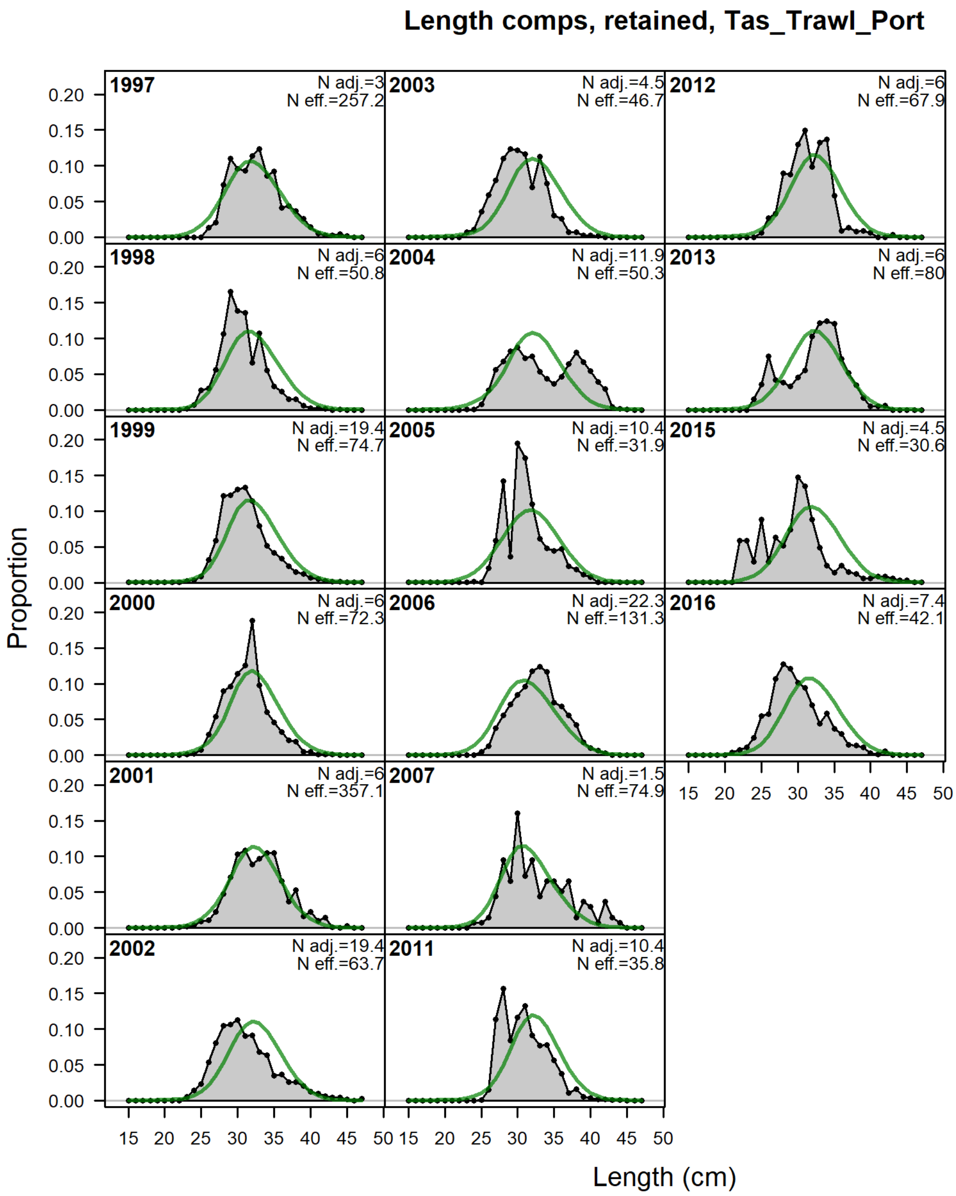


Figure A 8.11. Eastern Jackass Morwong length composition fits: Tasmanian trawl fleet port retained.

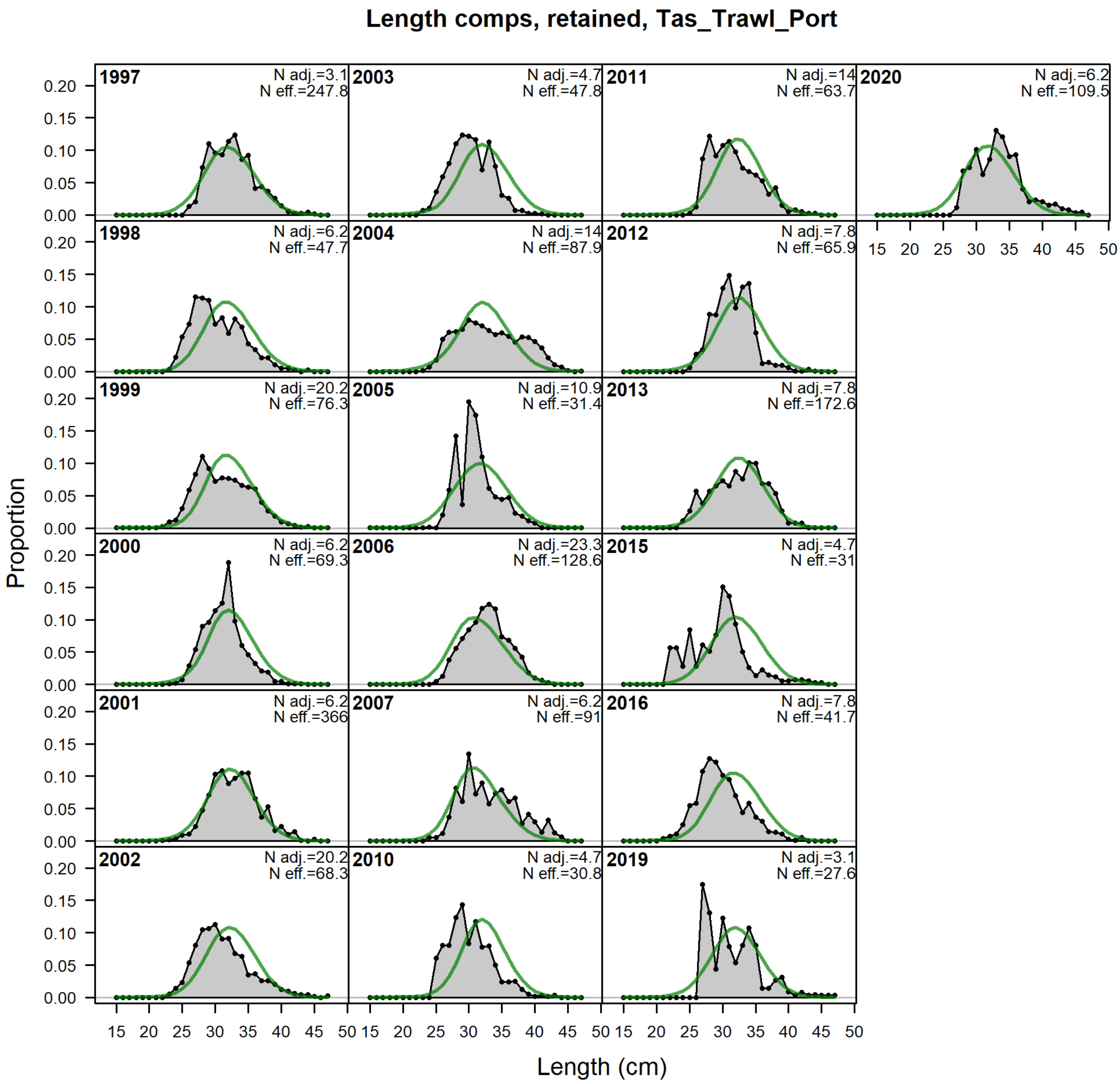


Figure A 8.12. Eastern Jackass Morwong length composition fits for the “updated base case” with revised port length composition data: Tasmanian trawl fleet port retained.

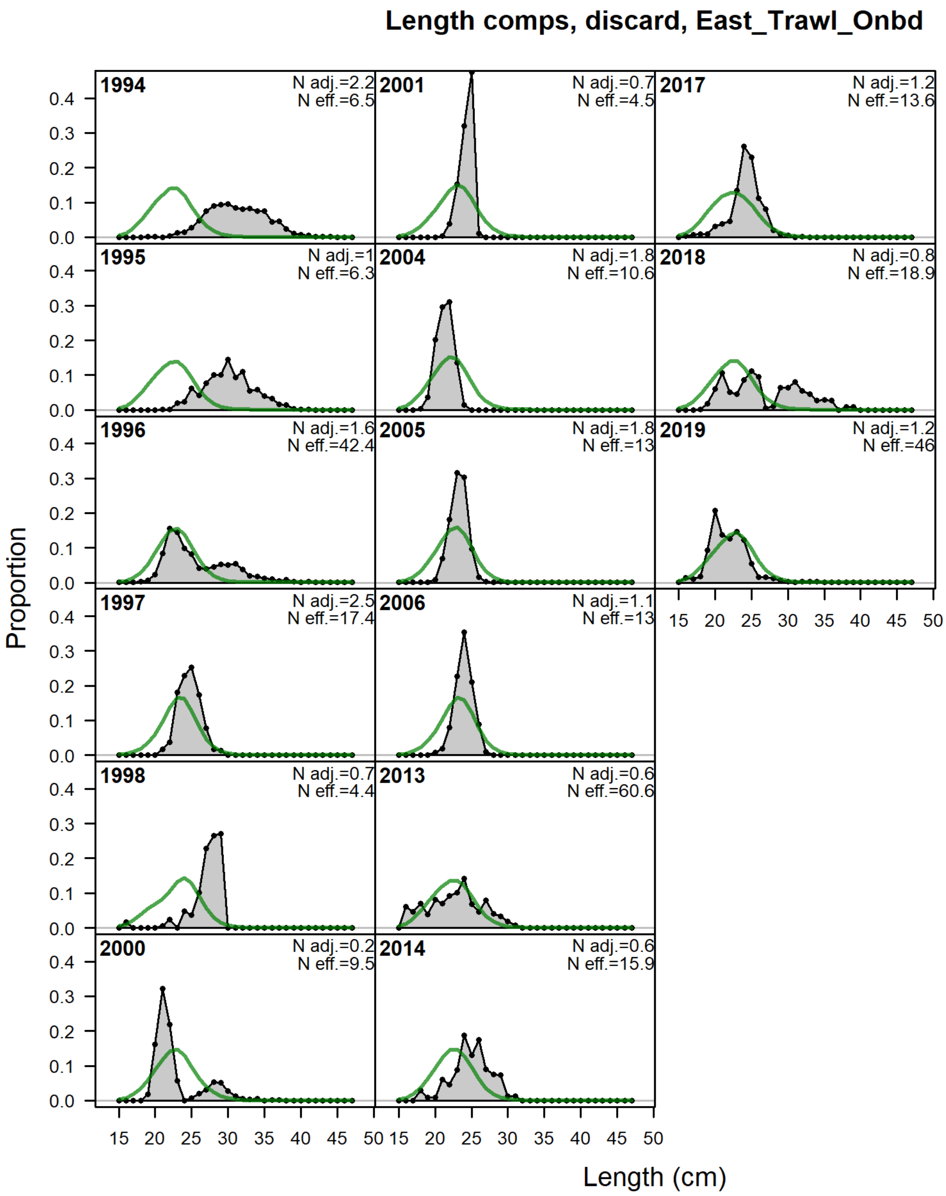


Figure A 8.13. Eastern Jackass Morwong length composition fits: eastern trawl discarded.

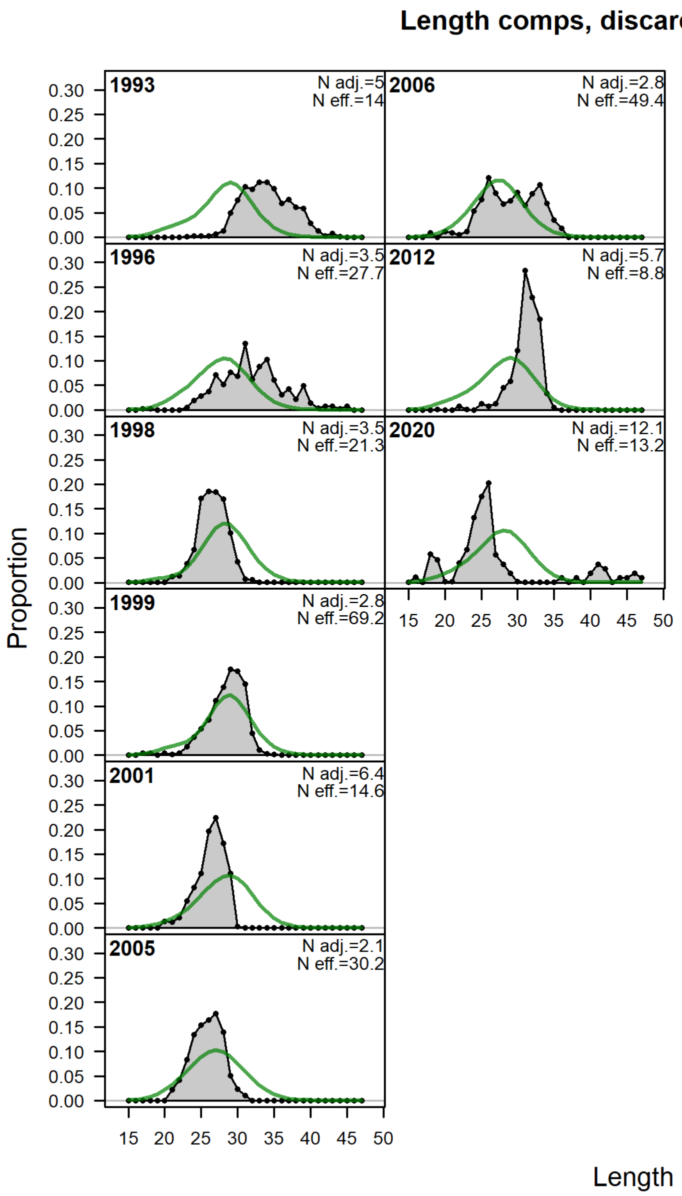


Figure A 8.14. Eastern Jackass Morwong length composition fits: Tasmanian trawl discarded.

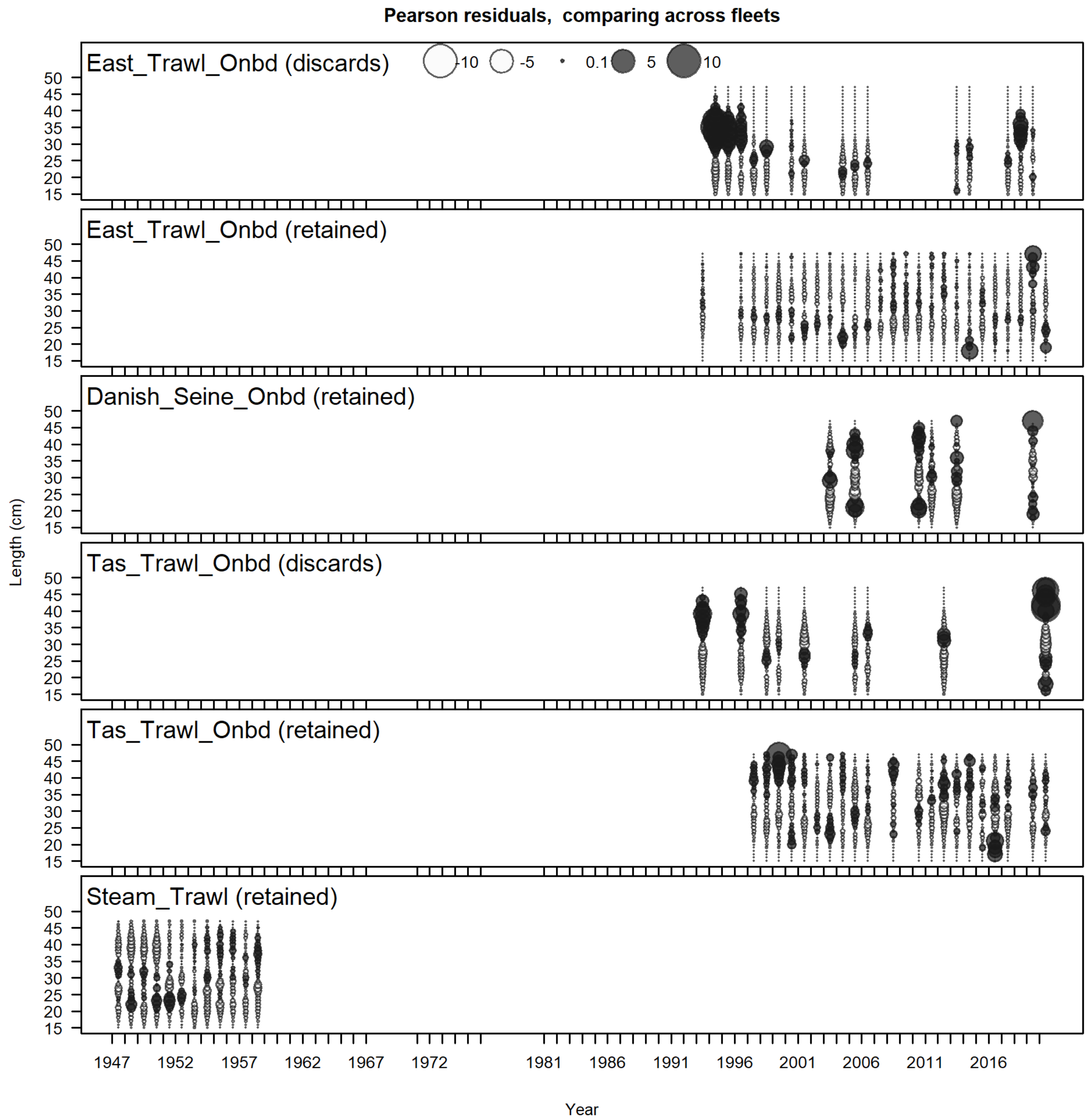


Figure A 8.15. Residuals from the annual length composition data for eastern Jackass Morwong (onboard) displayed by year and fleet for eastern and Tasmanian trawl fleets (retained and discarded), Danish seine and steam trawl fleets (retained).

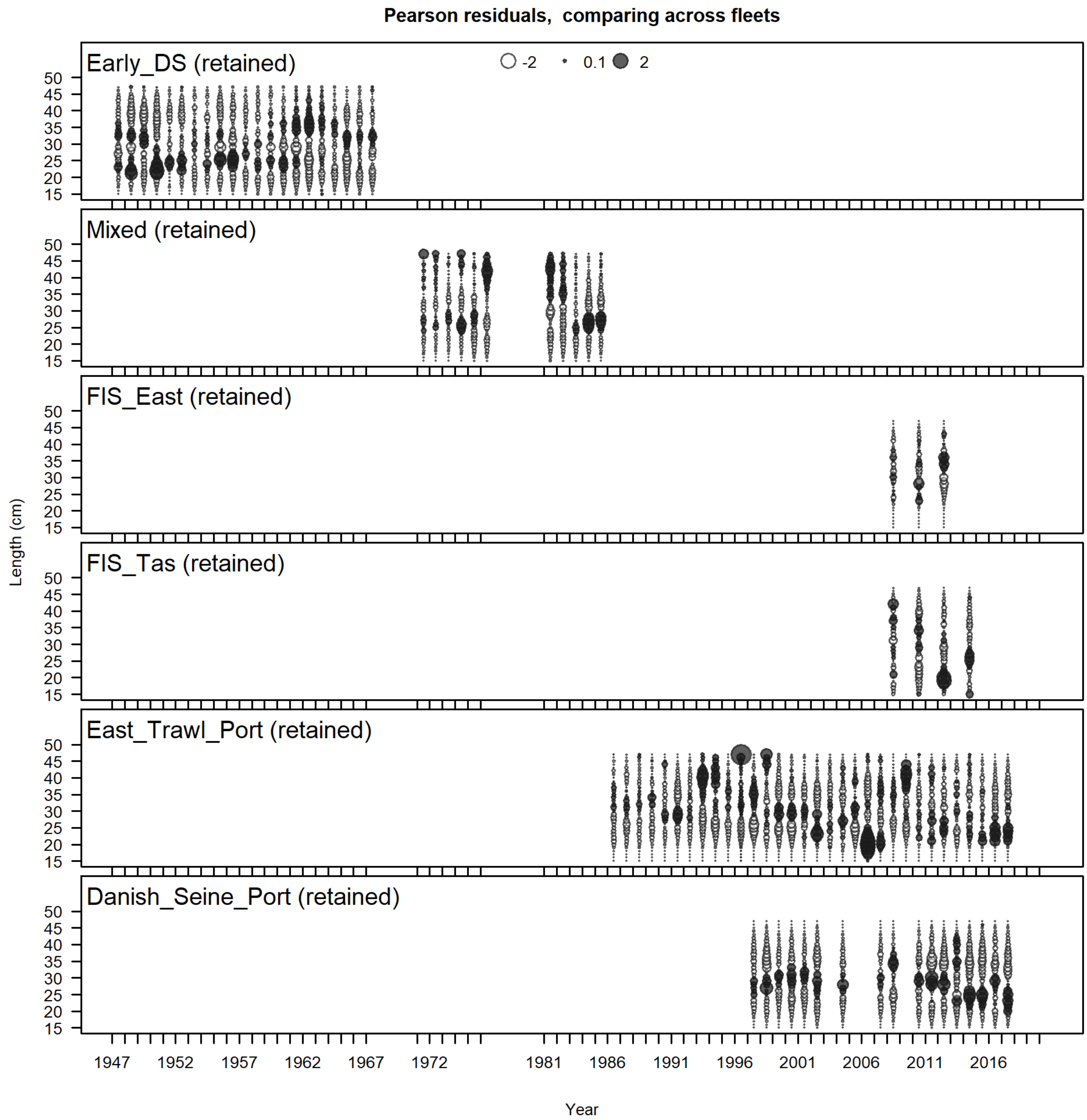


Figure A 8.16. Residuals from the annual length composition data for eastern Jackass Morwong displayed by year and fleet for the early Danish seine and mixed fleets (retained onboard), eastern trawl FIS and Tasmanian trawl FIS fleets and the eastern trawl and Danish seine fleets (retained port).

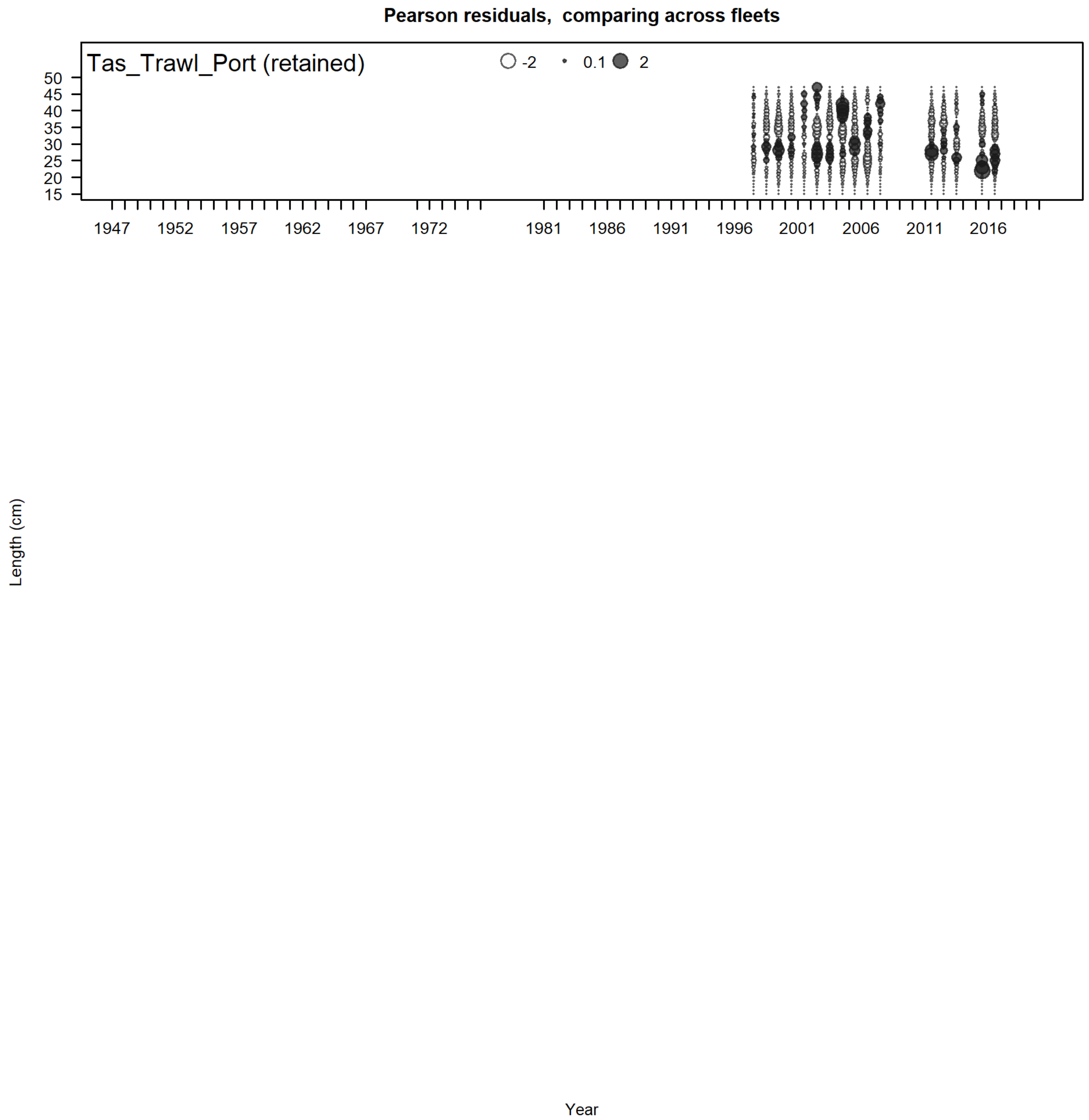


Figure A 8.17. Residuals from the annual length composition data for eastern Jackass Morwong displayed by year and fleet Tasmanian trawl fleet (retained port).

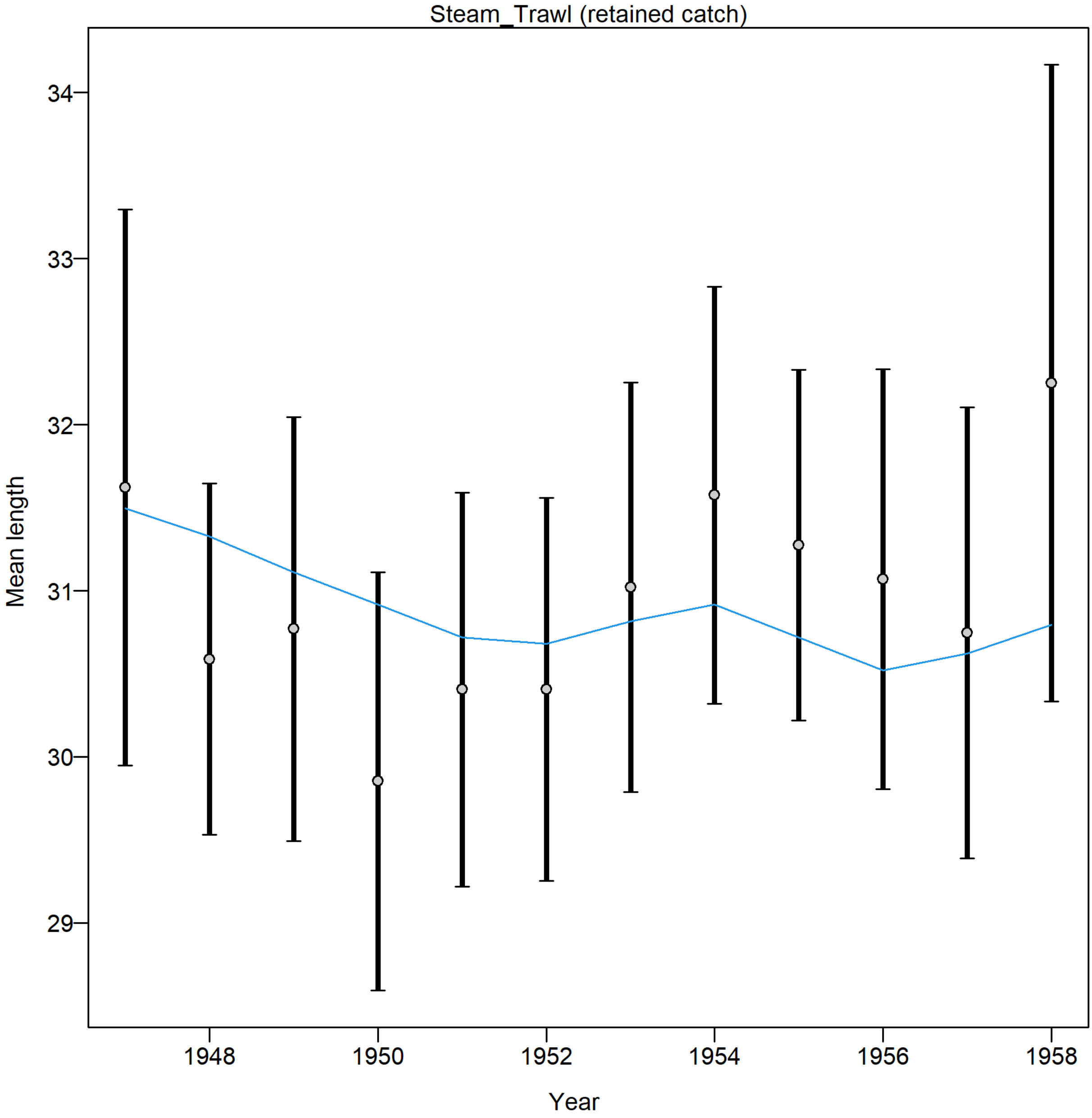
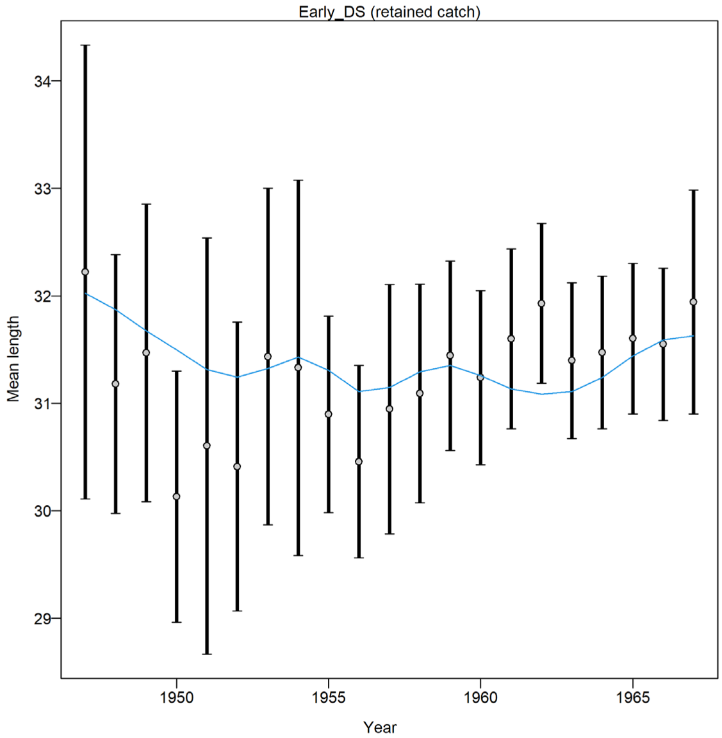


Figure A 8.18. Mean length for eastern Jackass Morwong from steam trawl with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced.



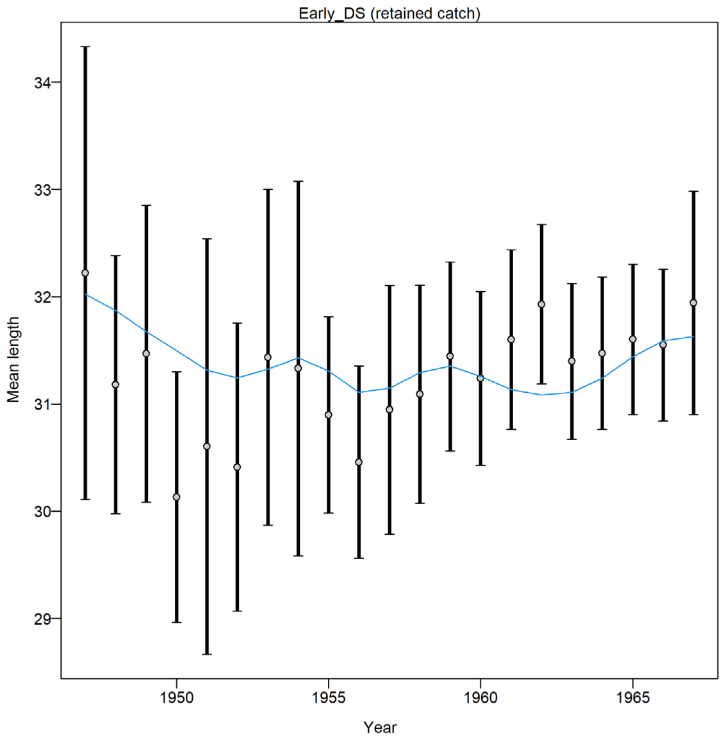


Figure A 8.19. Mean length for eastern Jackass Morwong from early Danish seine (top) and the mixed fleet (bottom) with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced.

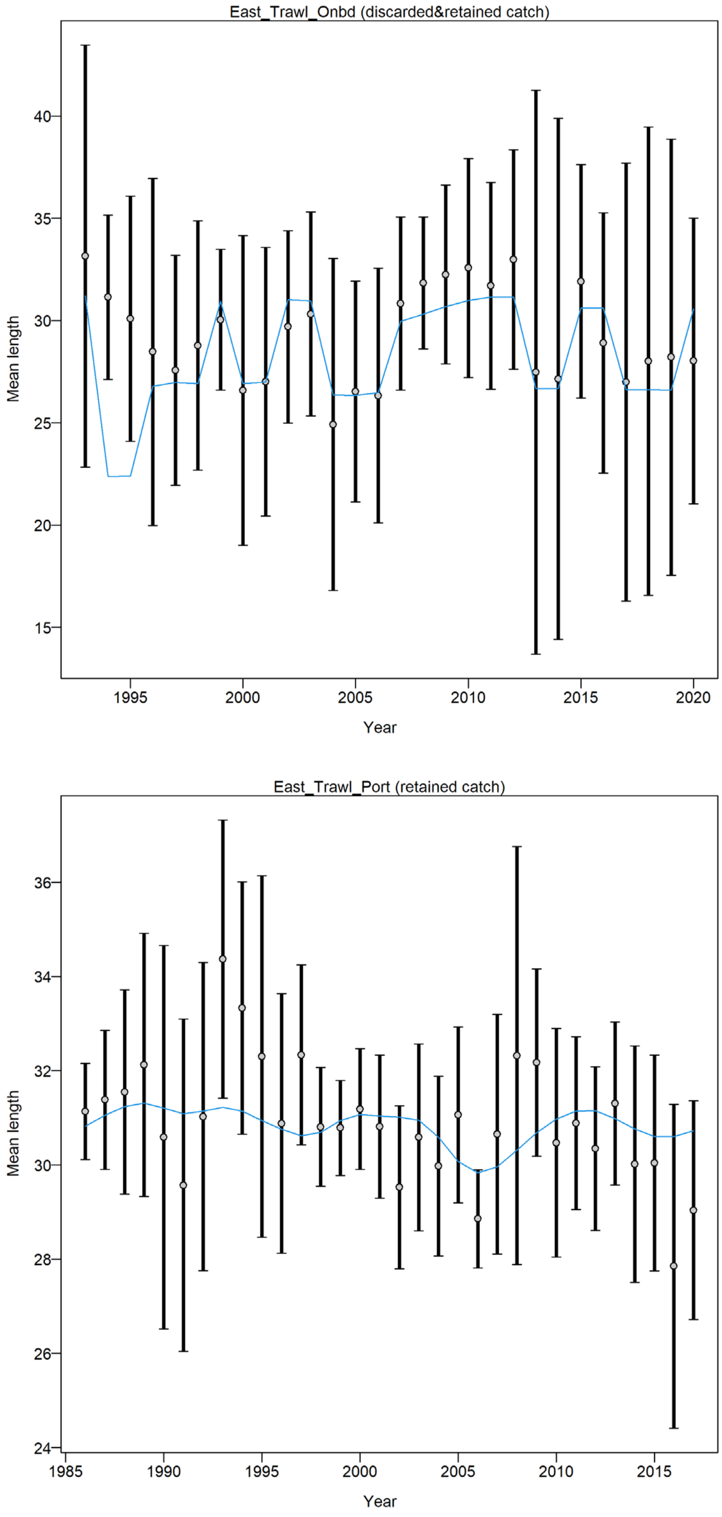


Figure A 8.20. Mean length for eastern Jackass Morwong from the eastern trawl fleet: onboard (top) and port (bottom) with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced.

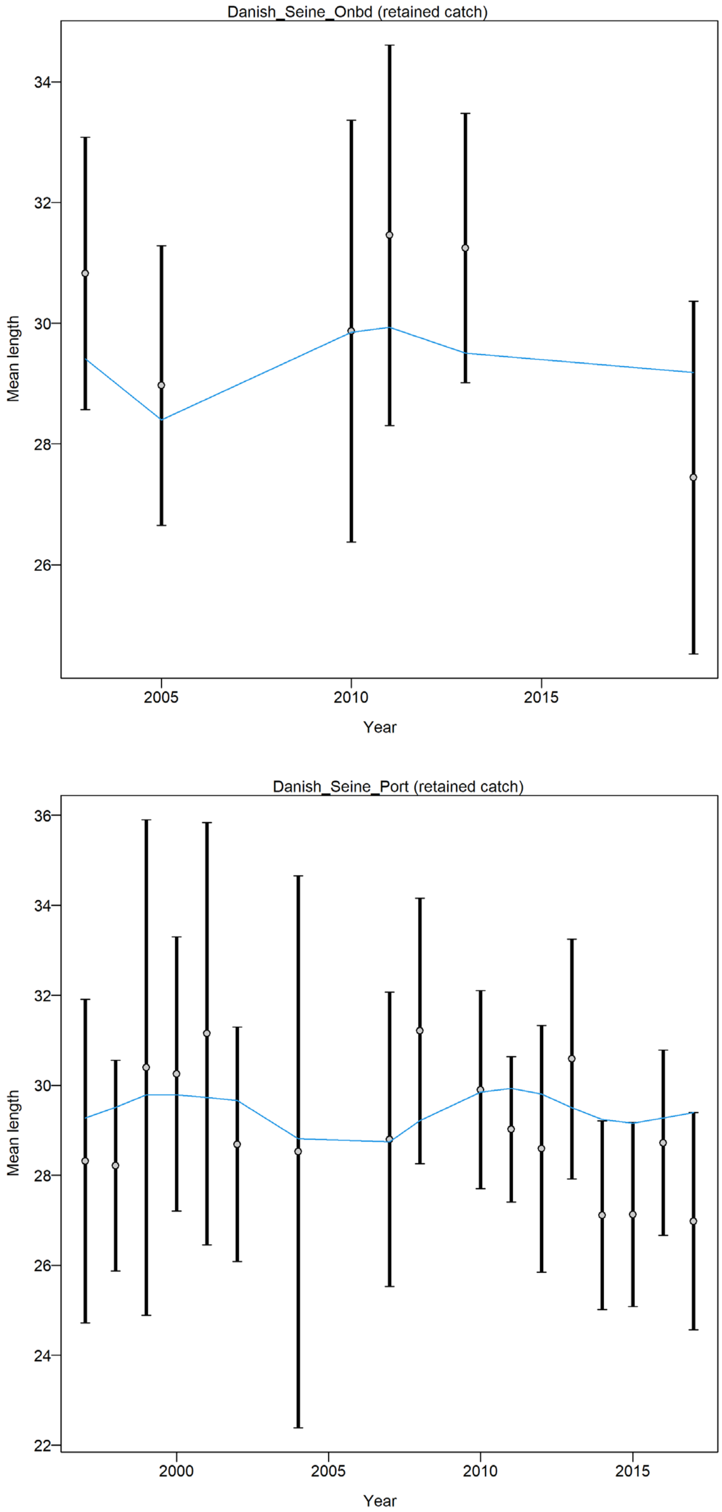
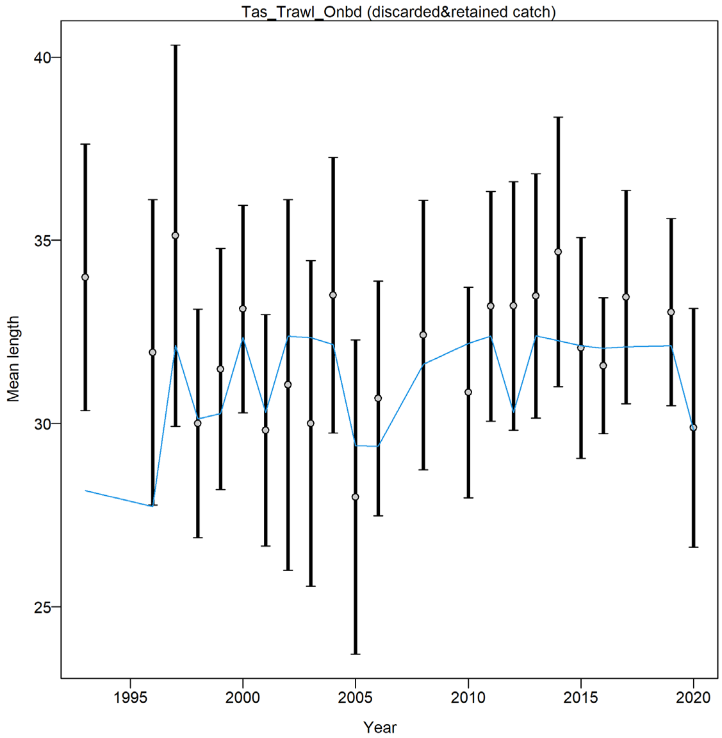


Figure A 8.21. Mean length for eastern Jackass Morwong from the Danish seine fleet: onboard (top) and port (bottom) with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced.



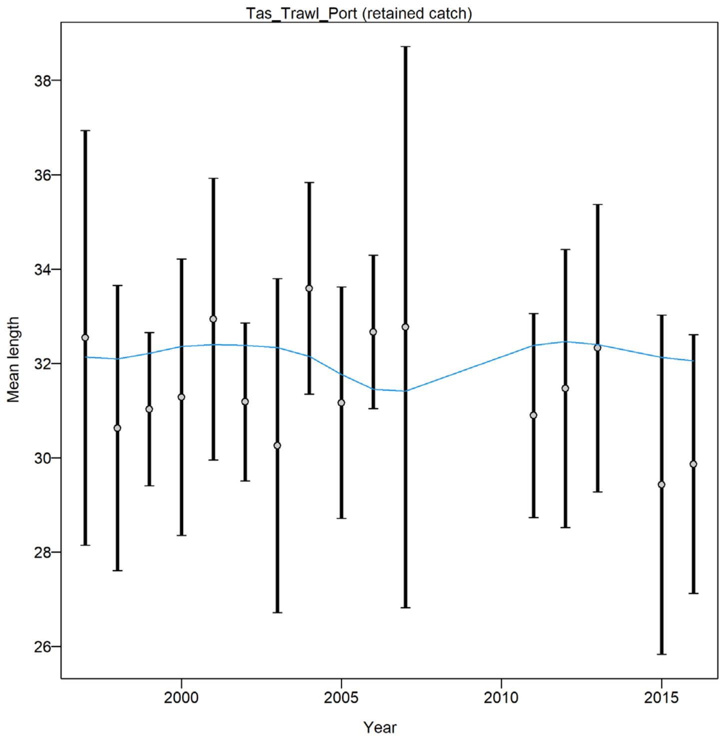


Figure A 8.22. Mean length for eastern Jackass Morwong from the Tasmanian trawl fleet: onboard (top) and port (bottom) with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced.

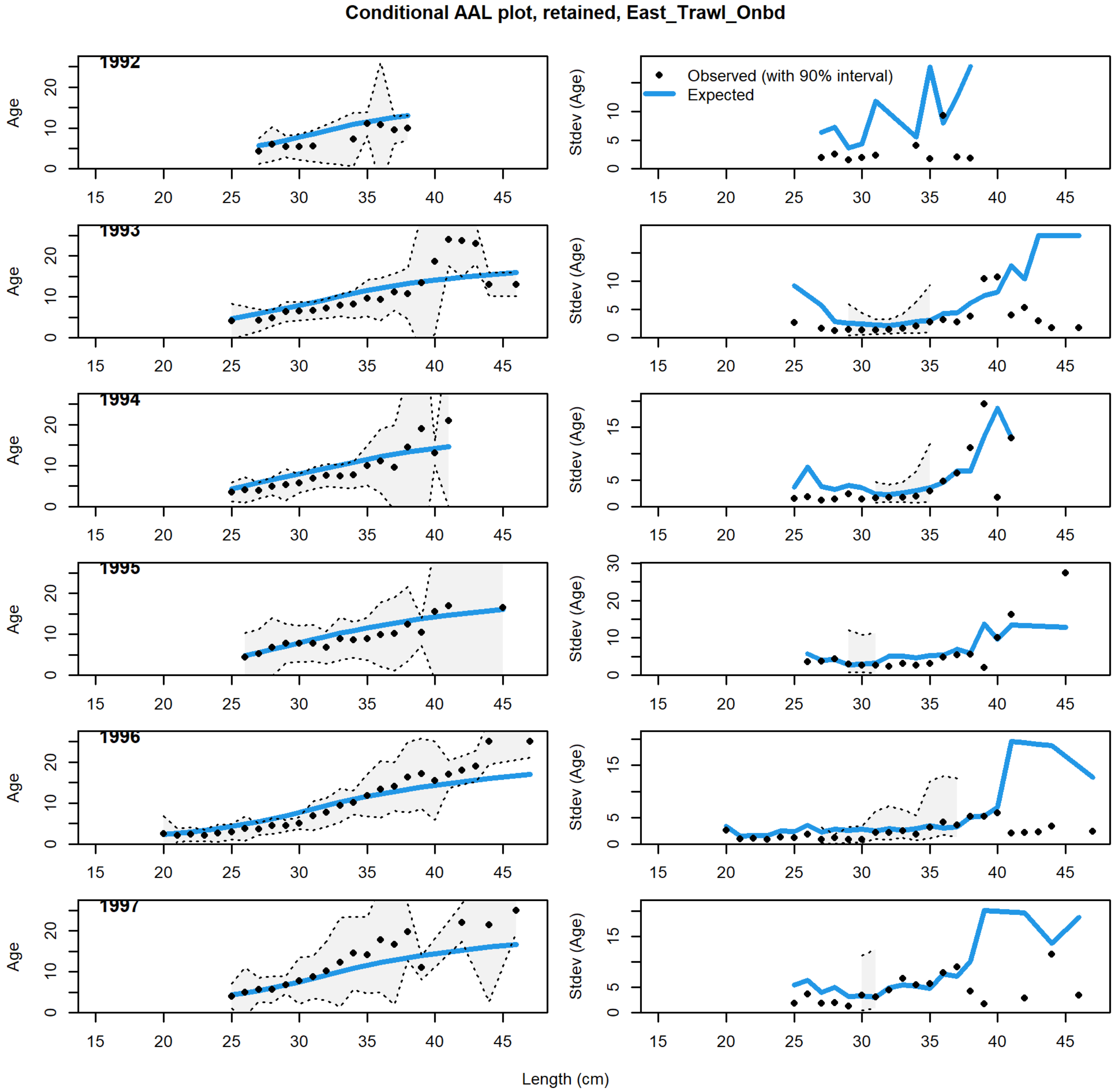


Figure A 8.23. Fits to conditional age-at-length data for eastern Jackass Morwong eastern trawl onboard (retained 1/5).

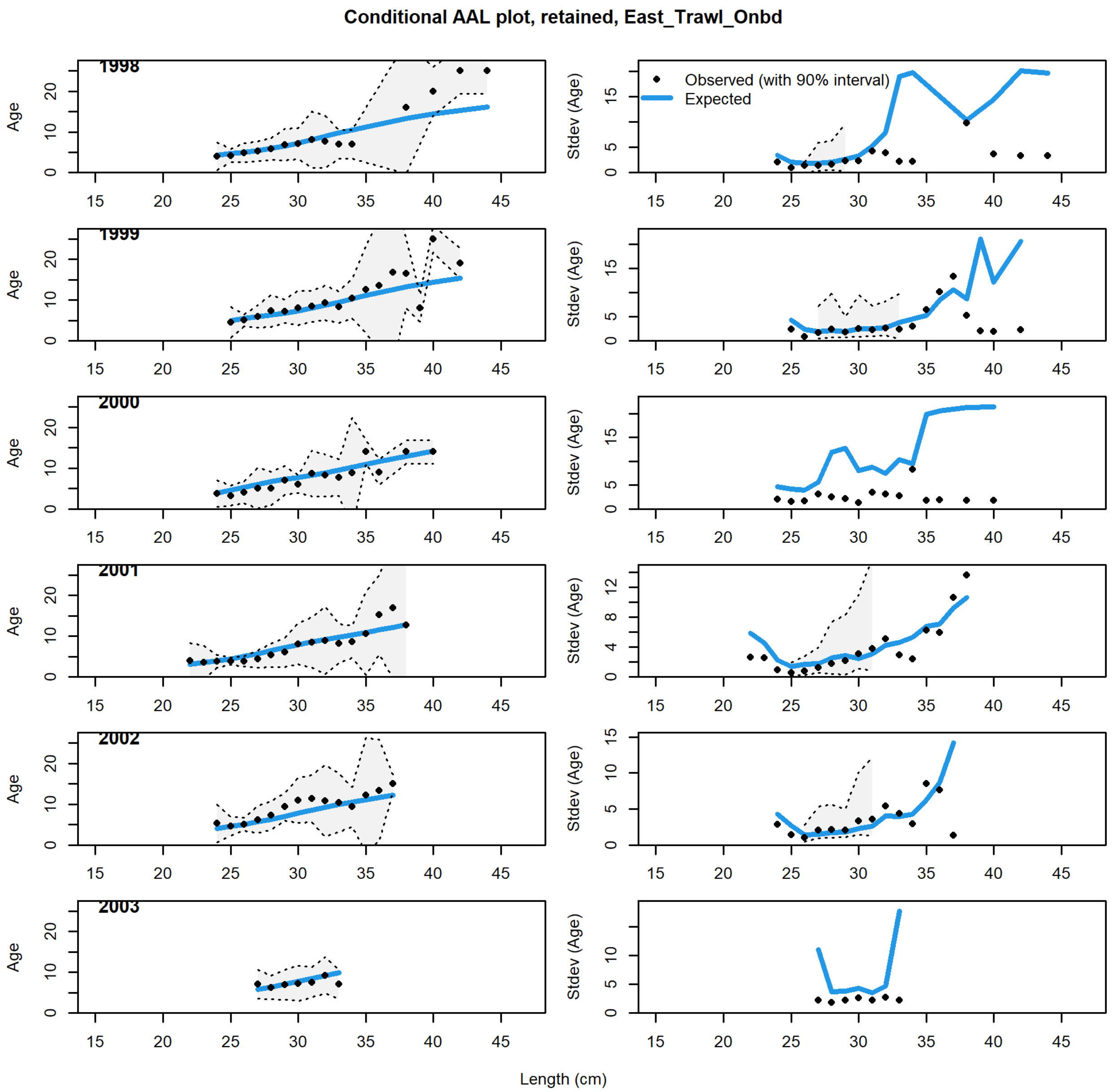


Figure A 8.24. Fits to conditional age-at-length data for eastern Jackass Morwong eastern trawl onboard (retained 2/5).

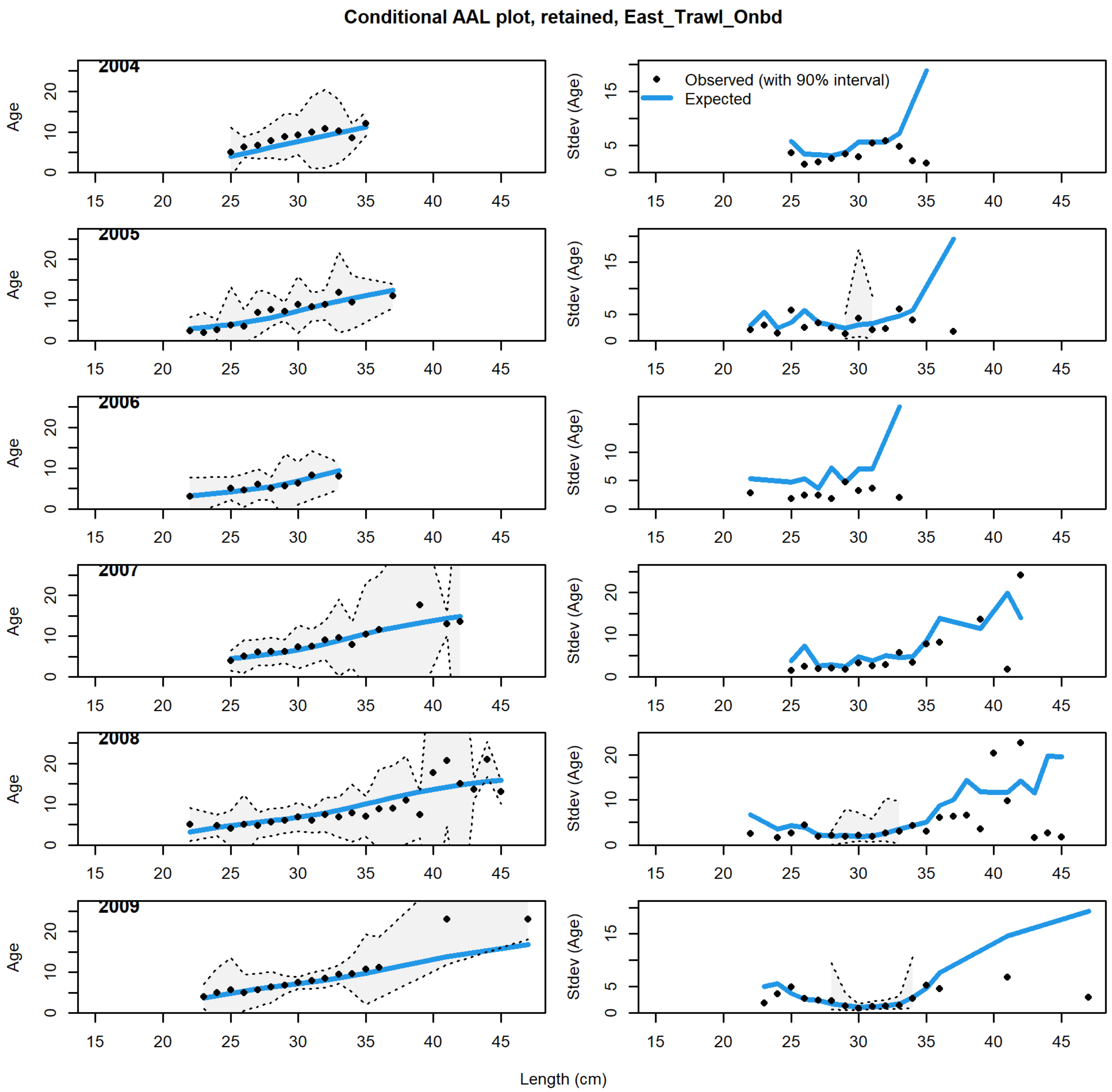


Figure A 8.25. Fits to conditional age-at-length data for eastern Jackass Morwong eastern trawl onboard (retained 3/5).

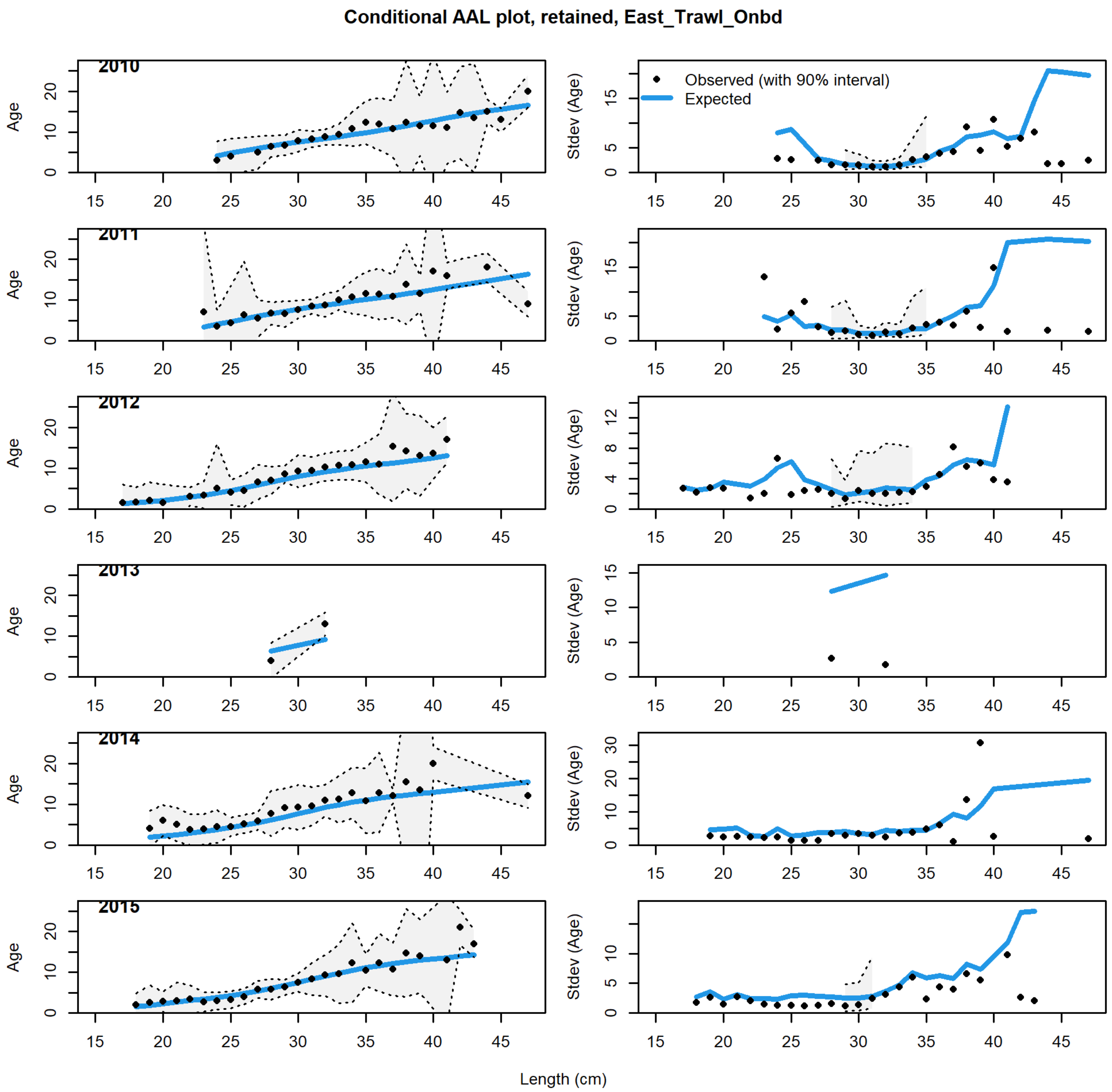


Figure A 8.26. Fits to conditional age-at-length data for eastern Jackass Morwong eastern trawl onboard (retained 4/5).

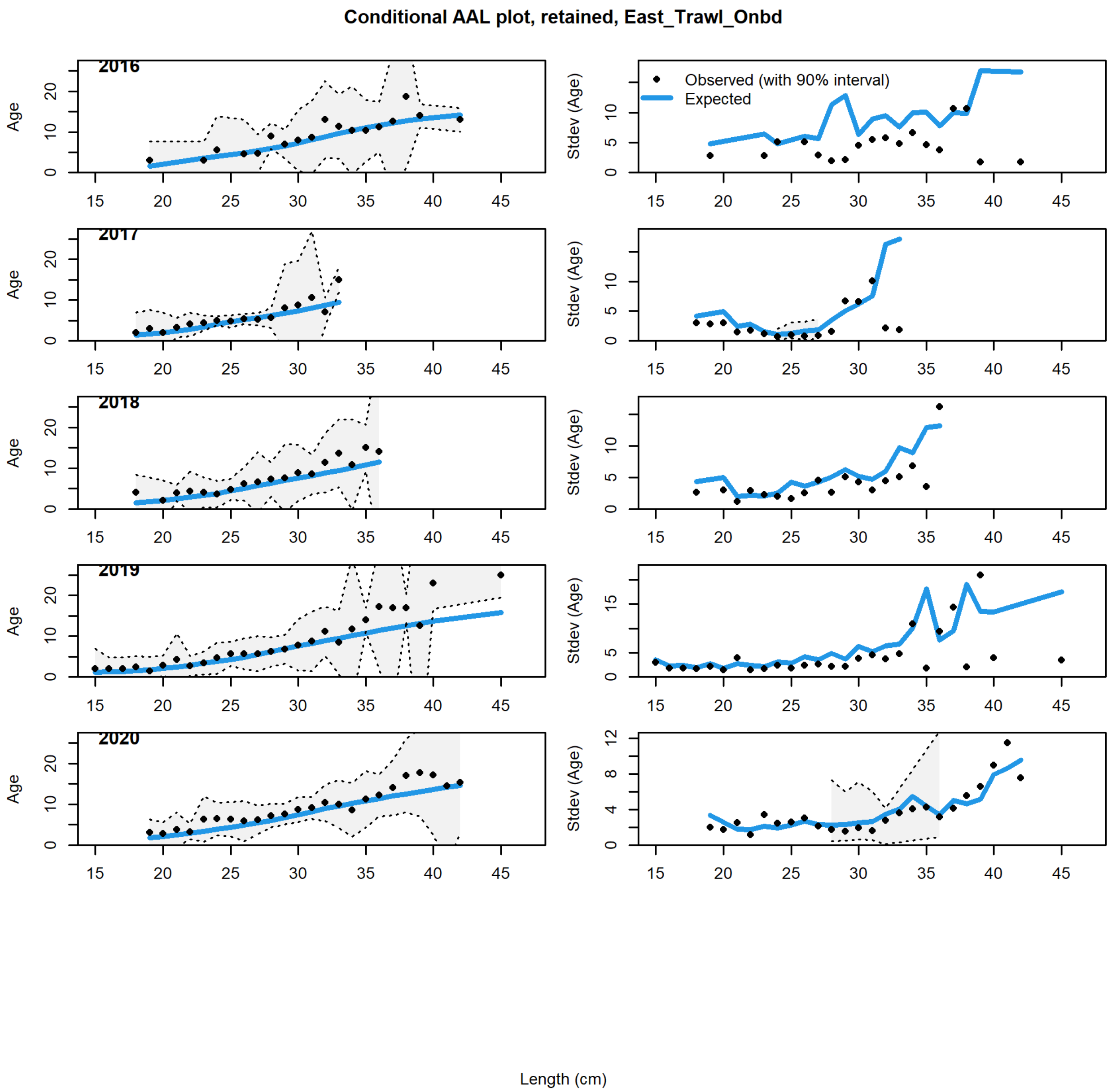


Figure A 8.27. Fits to conditional age-at-length data for eastern Jackass Morwong eastern trawl onboard (retained 5/5).

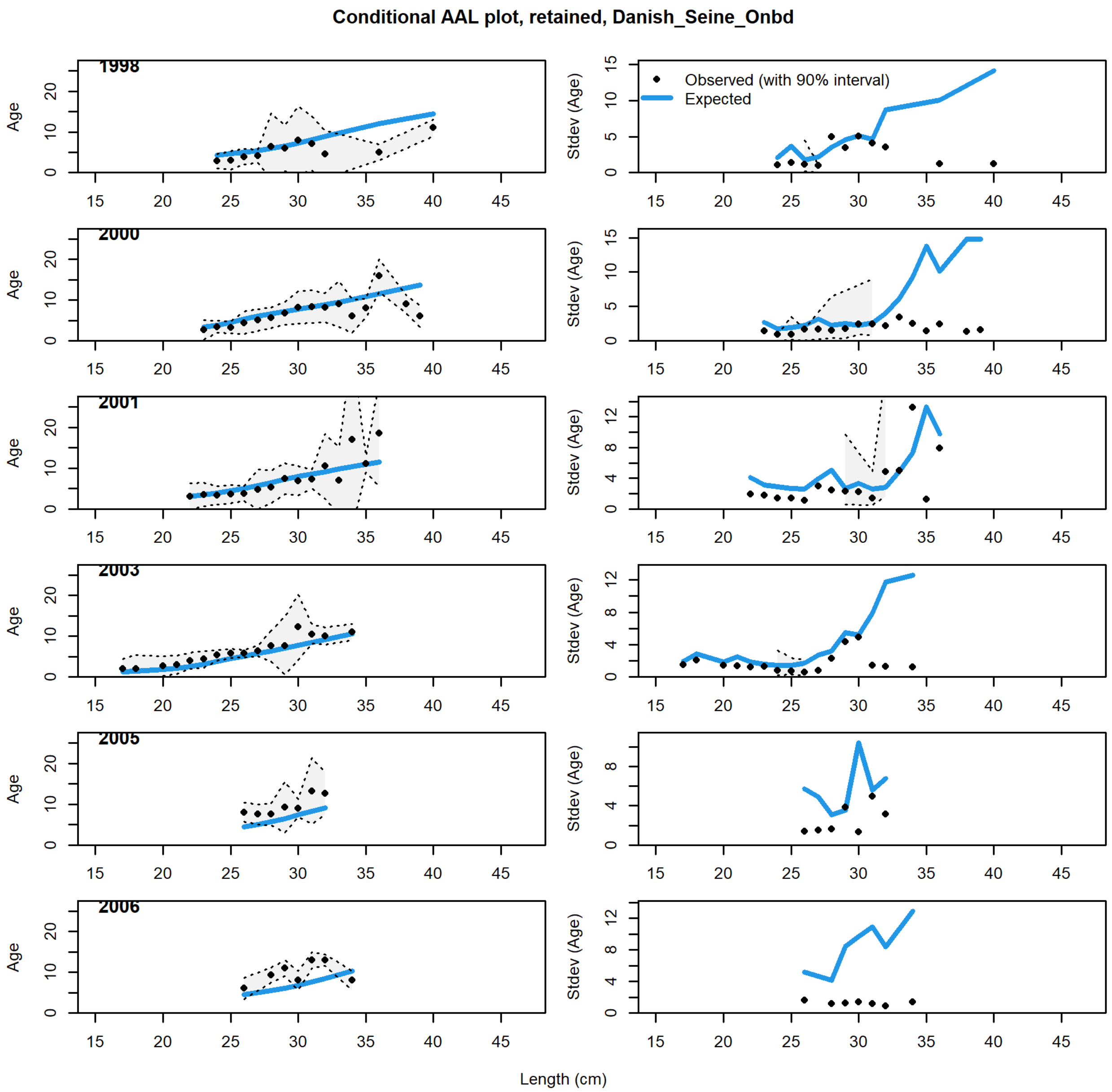


Figure A 8.28. Fits to conditional age-at-length data for eastern Jackass Morwong Danish seine onboard (retained 1/3).

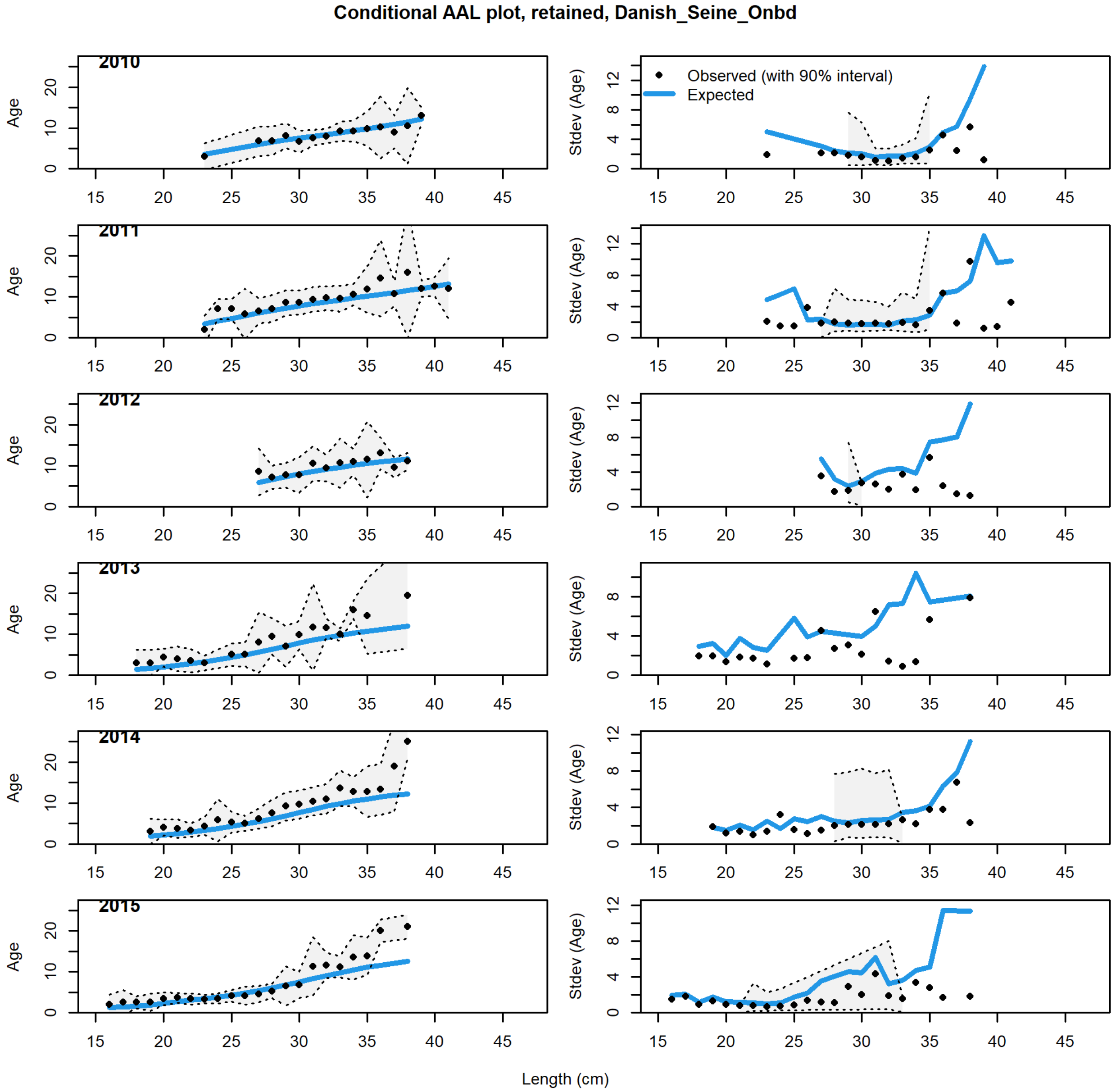


Figure A 8.29. Fits to conditional age-at-length data for eastern Jackass Morwong Danish seine onboard (retained 2/3).

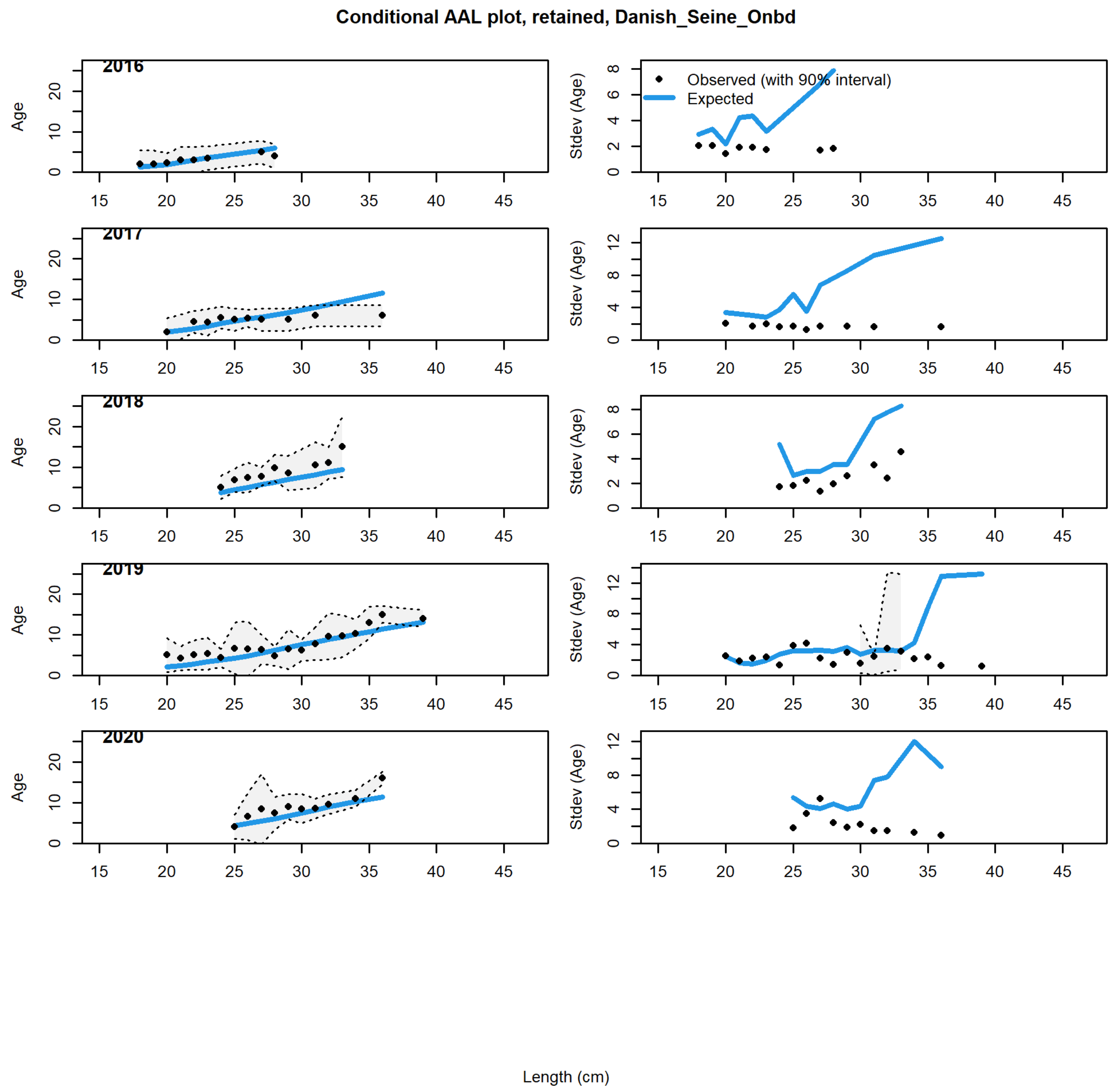


Figure A 8.30. Fits to conditional age-at-length data for eastern Jackass Morwong Danish seine onboard (retained 3/3).

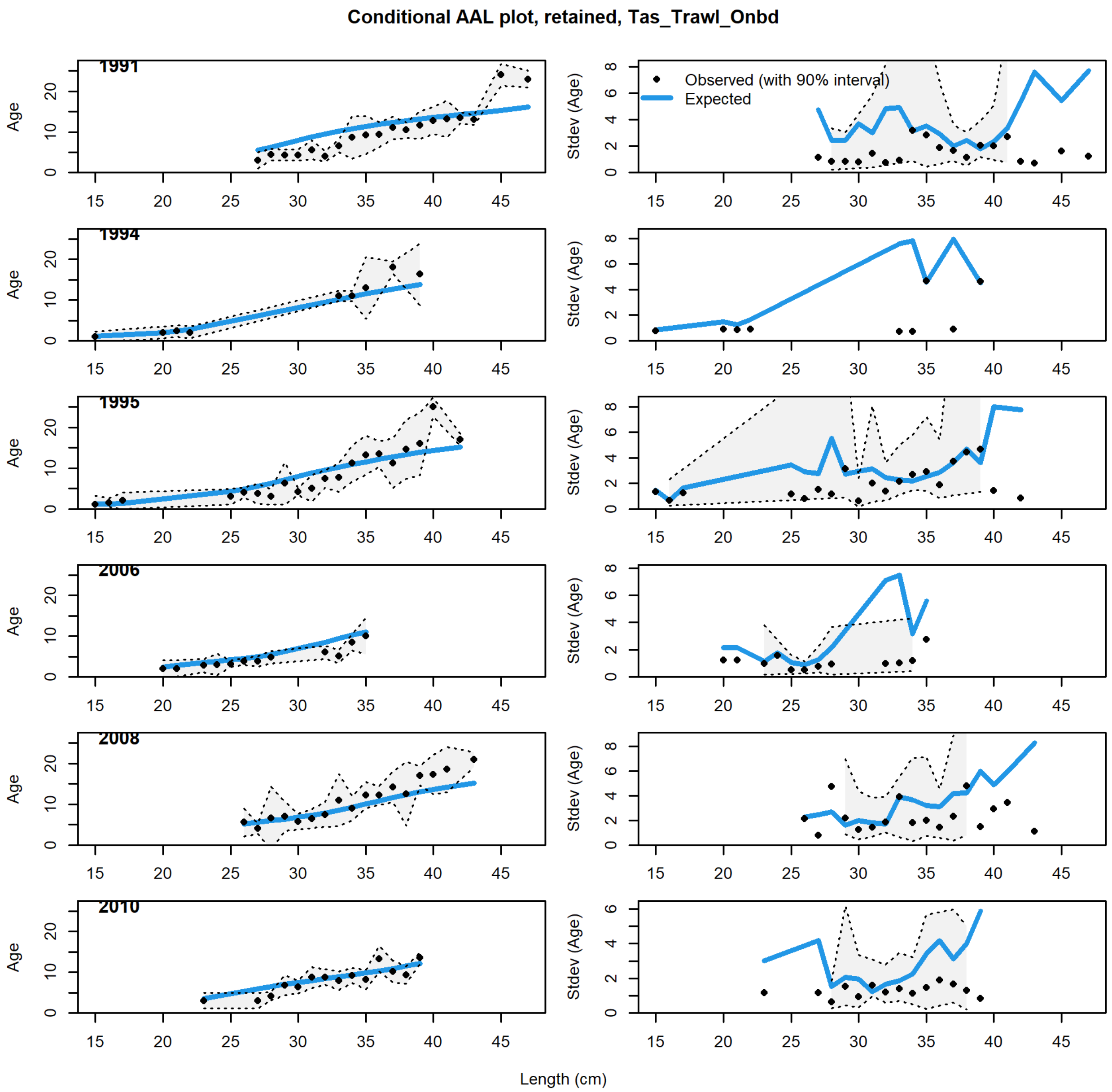


Figure A 8.31. Fits to conditional age-at-length data for eastern Jackass Morwong Tasmanian trawl onboard (retained 1/3).

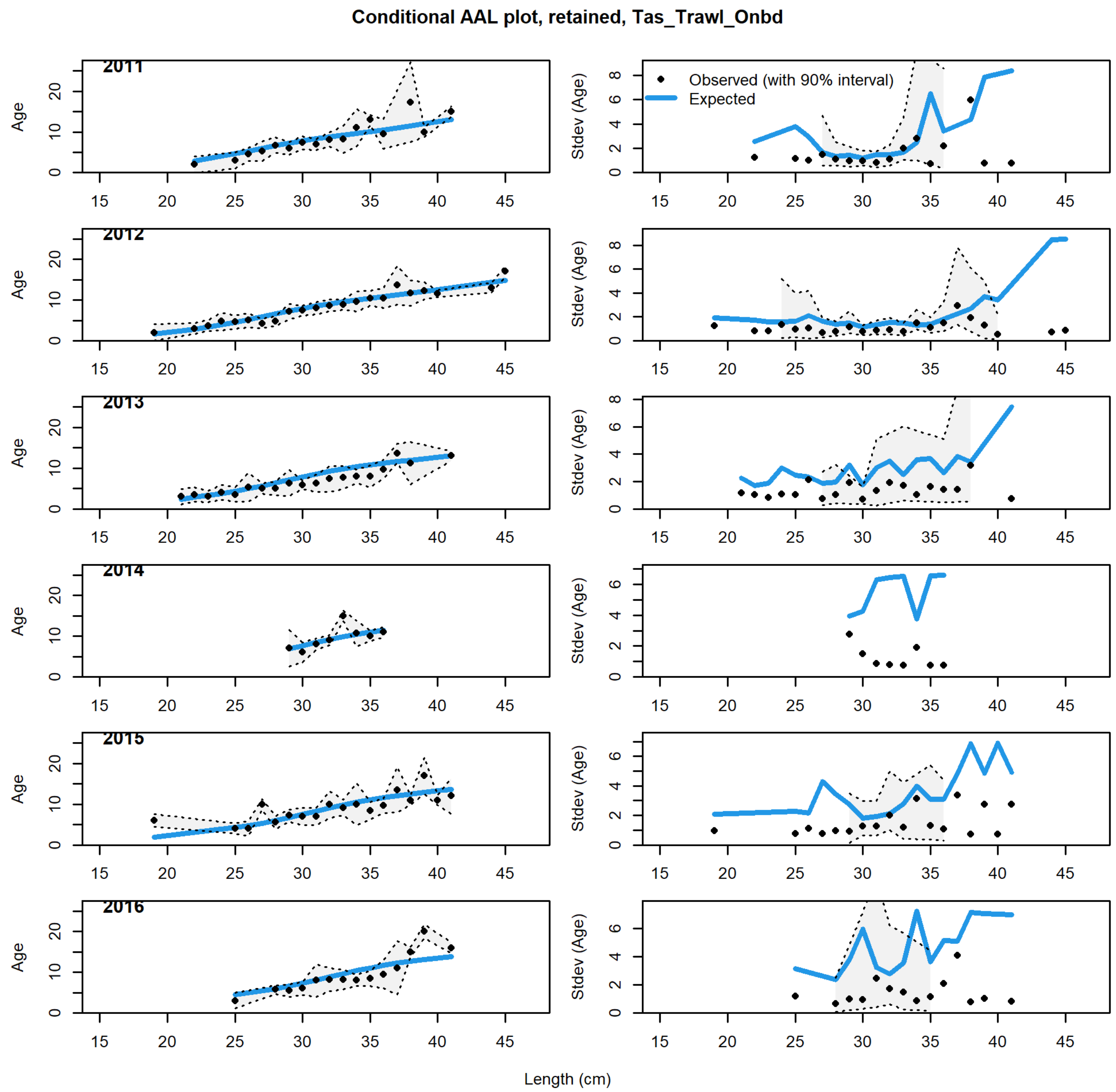


Figure A 8.32. Fits to conditional age-at-length data for eastern Jackass Morwong Tasmanian trawl onboard (retained 2/3).

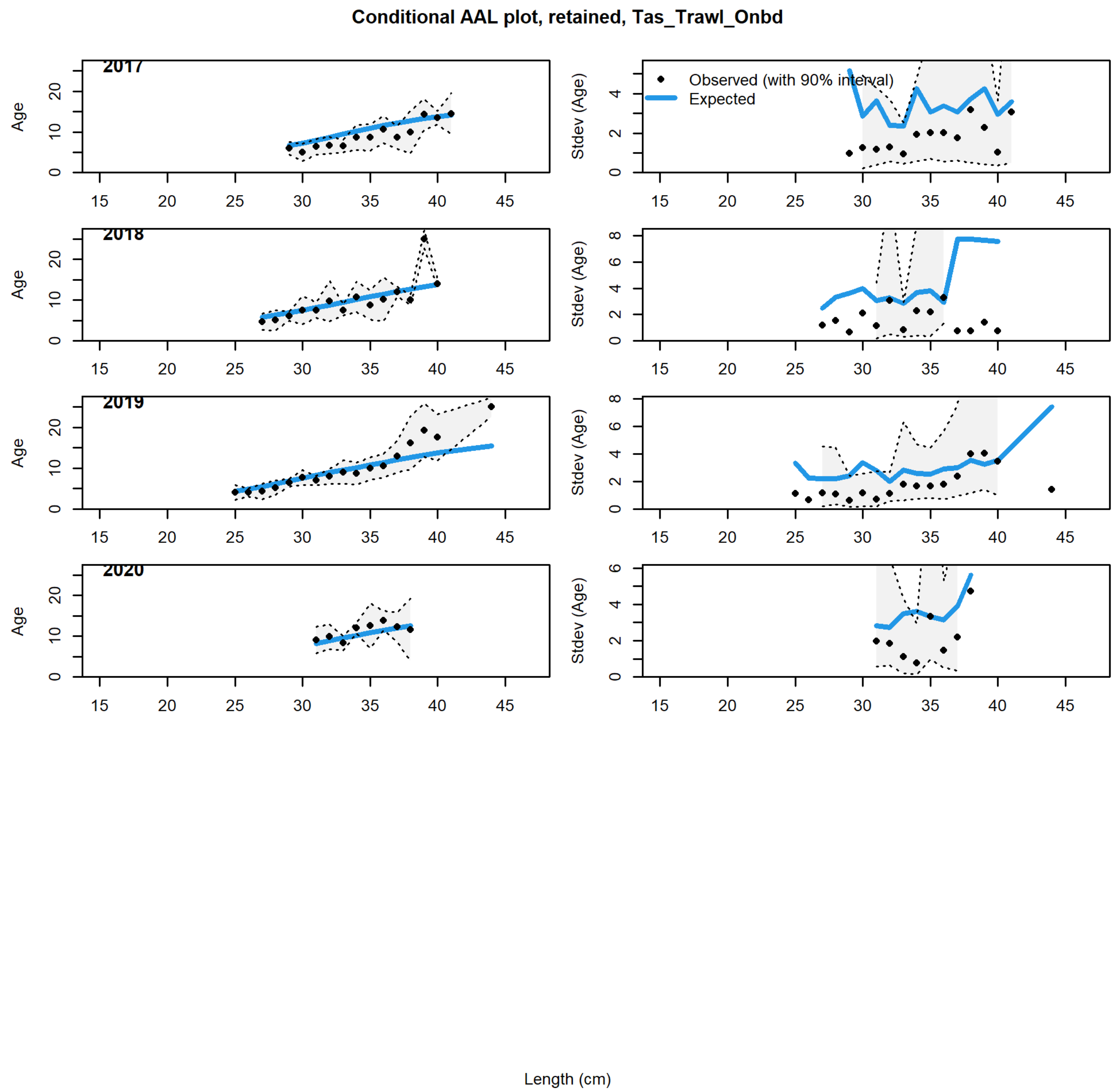


Figure A 8.33. Fits to conditional age-at-length data for eastern Jackass Morwong Tasmanian trawl onboard (retained 3/3).

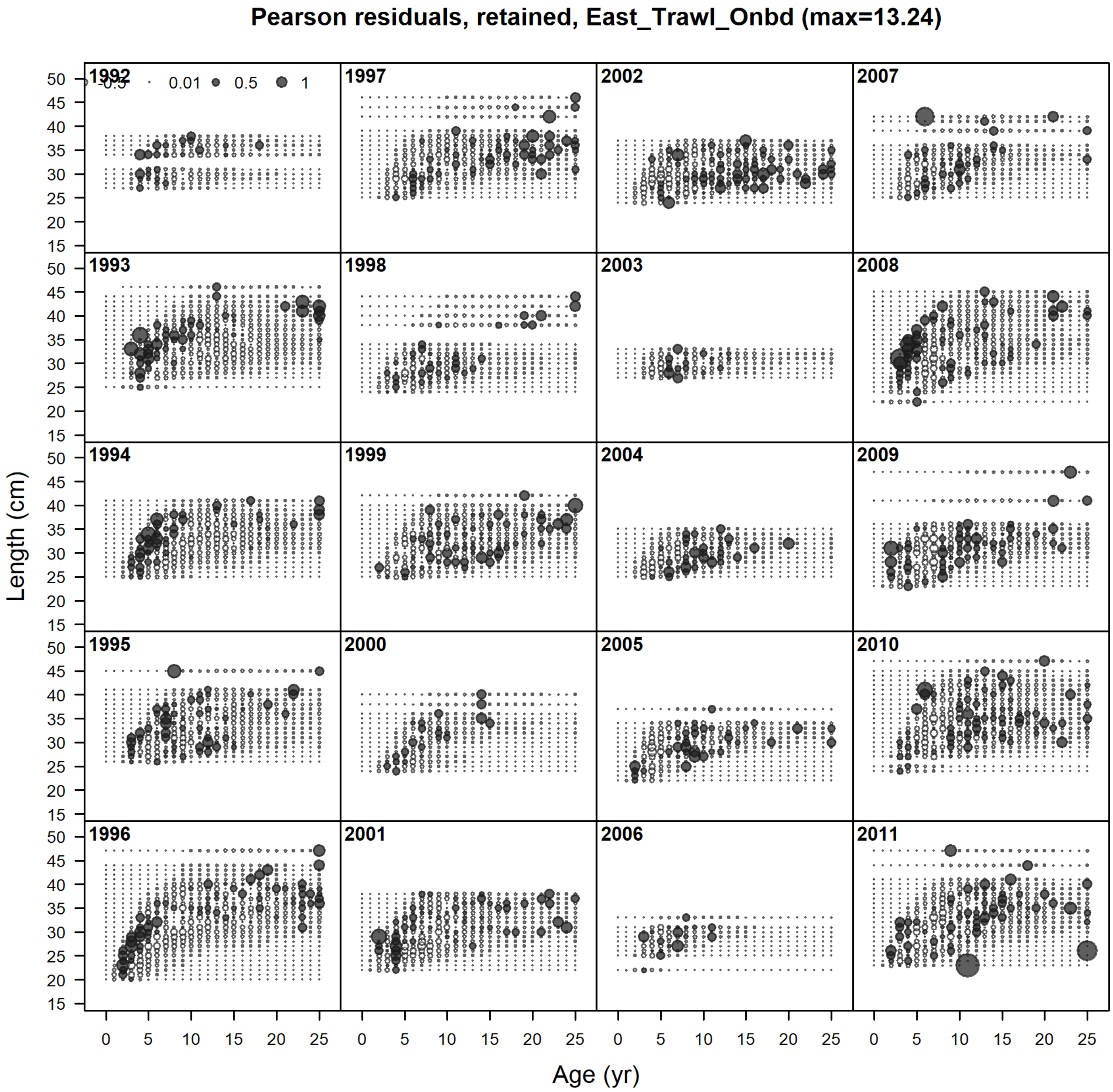


Figure A 8.34. Residuals from the fits to conditional age-at-length for eastern trawl (1/2). This plot gives some indication of the variability in the age samples from year to year.

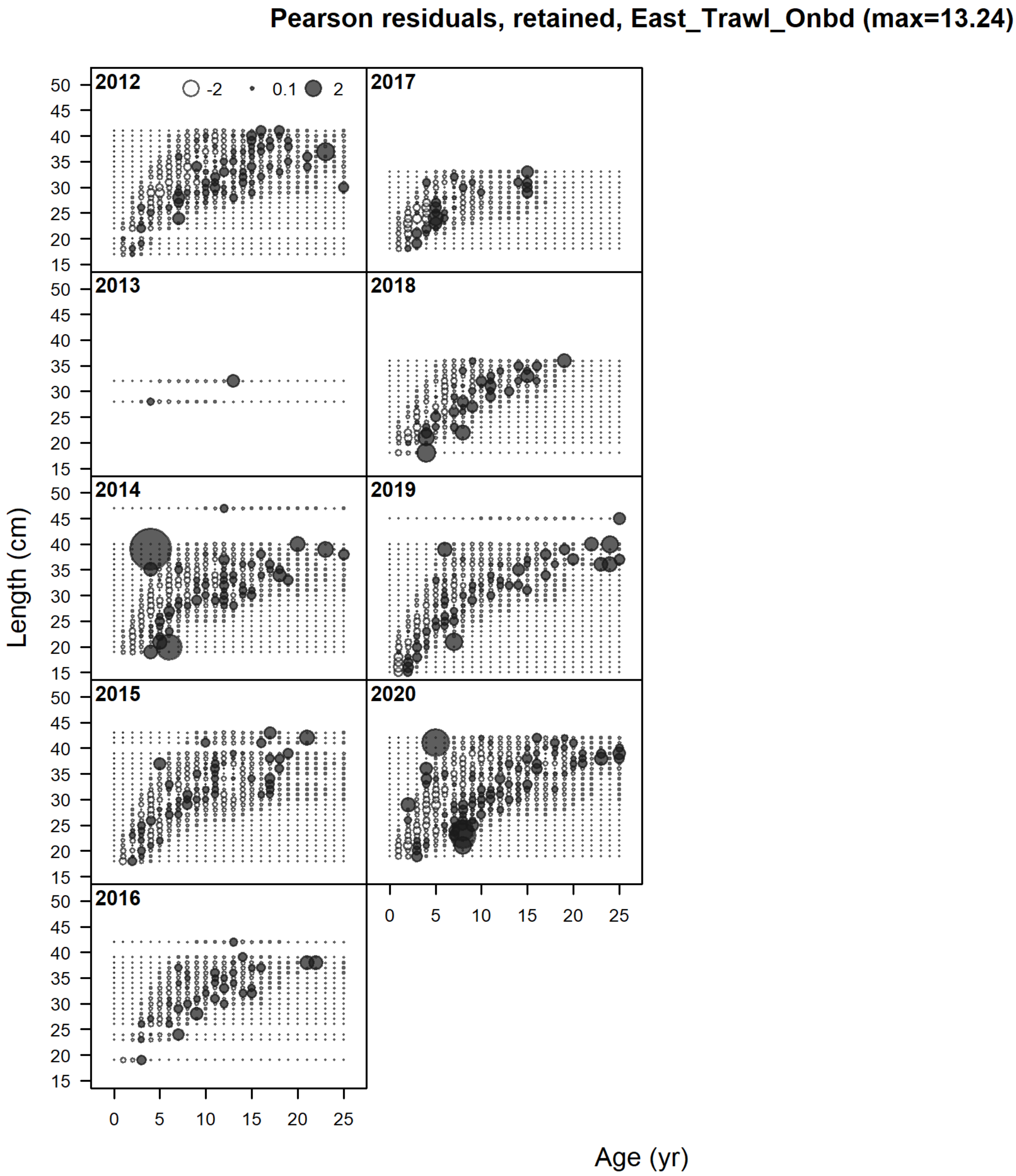


Figure A 8.35. Residuals from the fits to conditional age-at-length for eastern trawl (2/2). This plot gives some indication of the variability in the age samples from year to year.

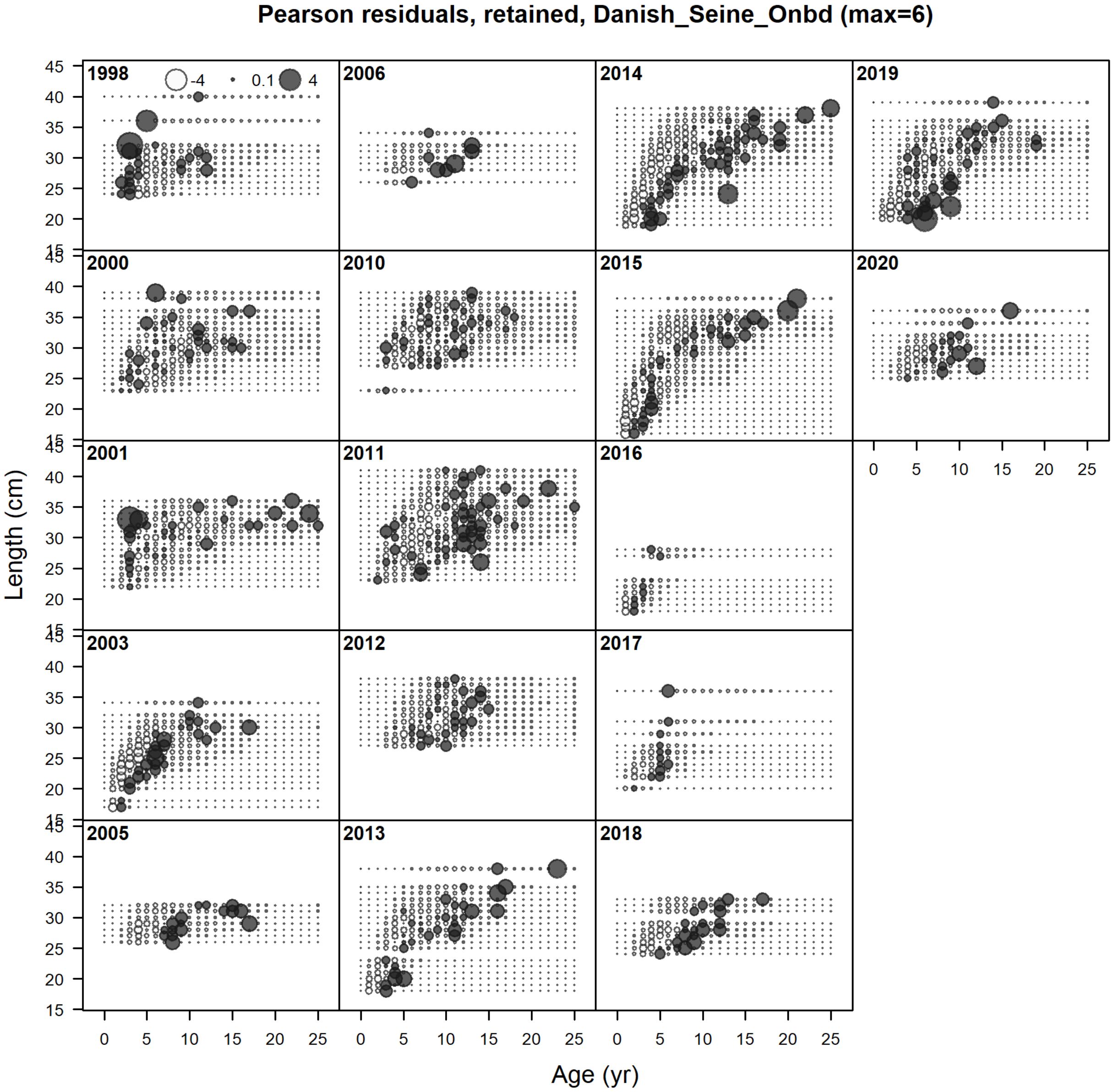


Figure A 8.36. Residuals from the fits to conditional age-at-length for Danish seine. This plot gives some indication of the variability in the age samples from year to year.

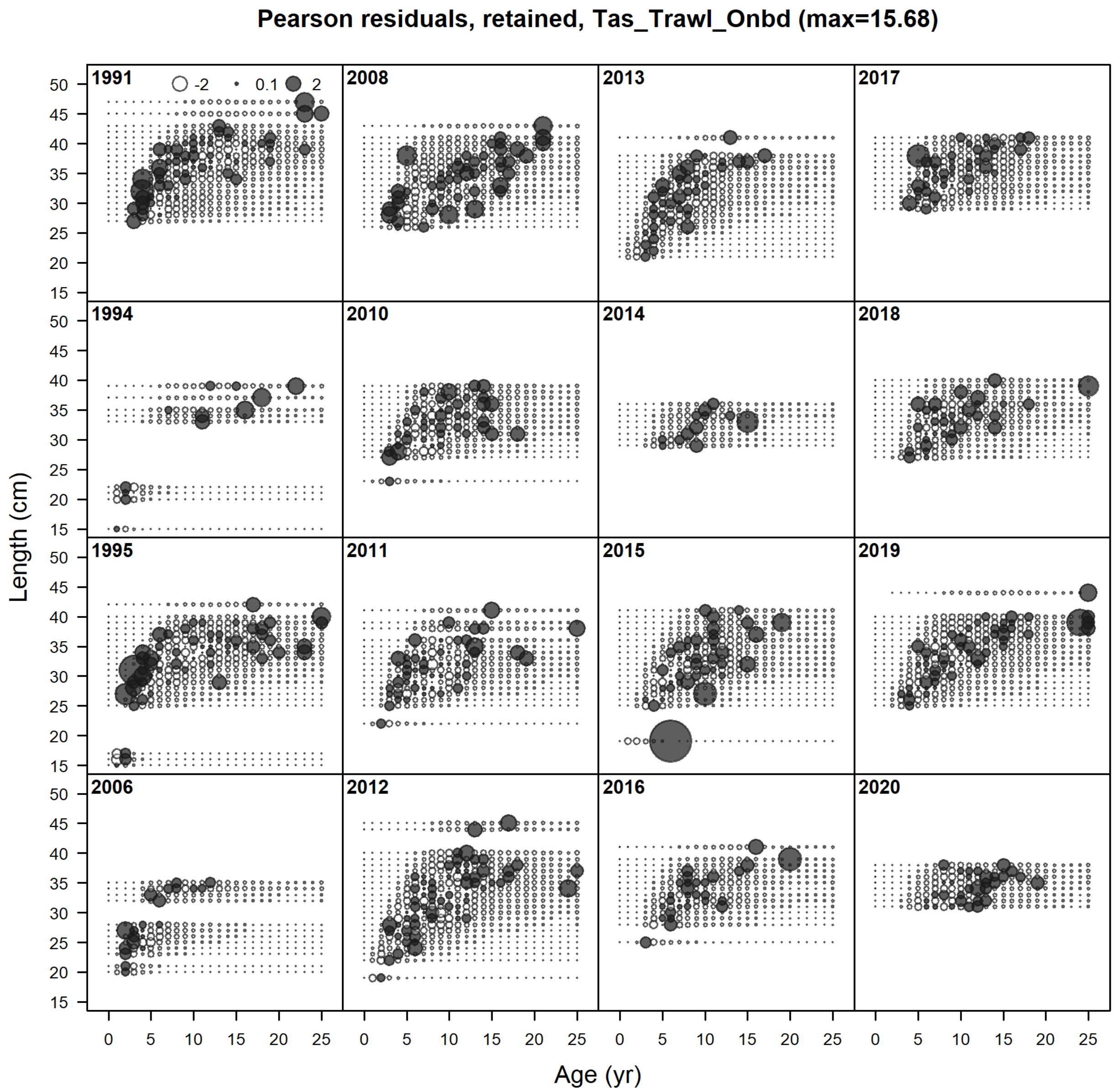


Figure A 8.37. Residuals from the fits to conditional age-at-length for Tasmanian trawl. This plot gives some indication of the variability in the age samples from year to year.

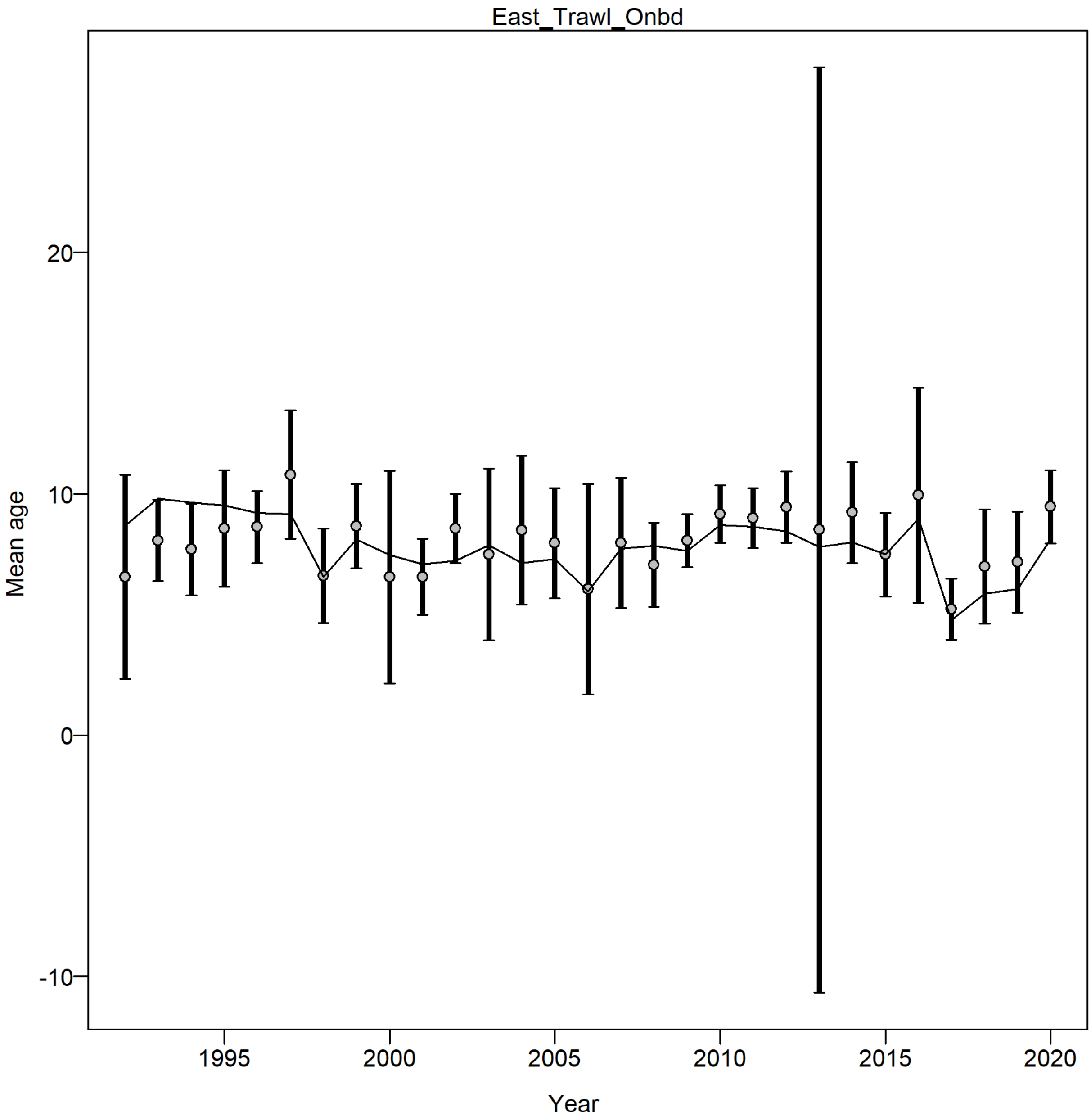


Figure A 8.38. Mean age (aggregated across length bins) for eastern Jackass Morwong from eastern trawl with 95% confidence intervals based on current samples sizes. Punt data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced. Yearly variation in the data is shown in changes in mean age, which can be large over a short period.

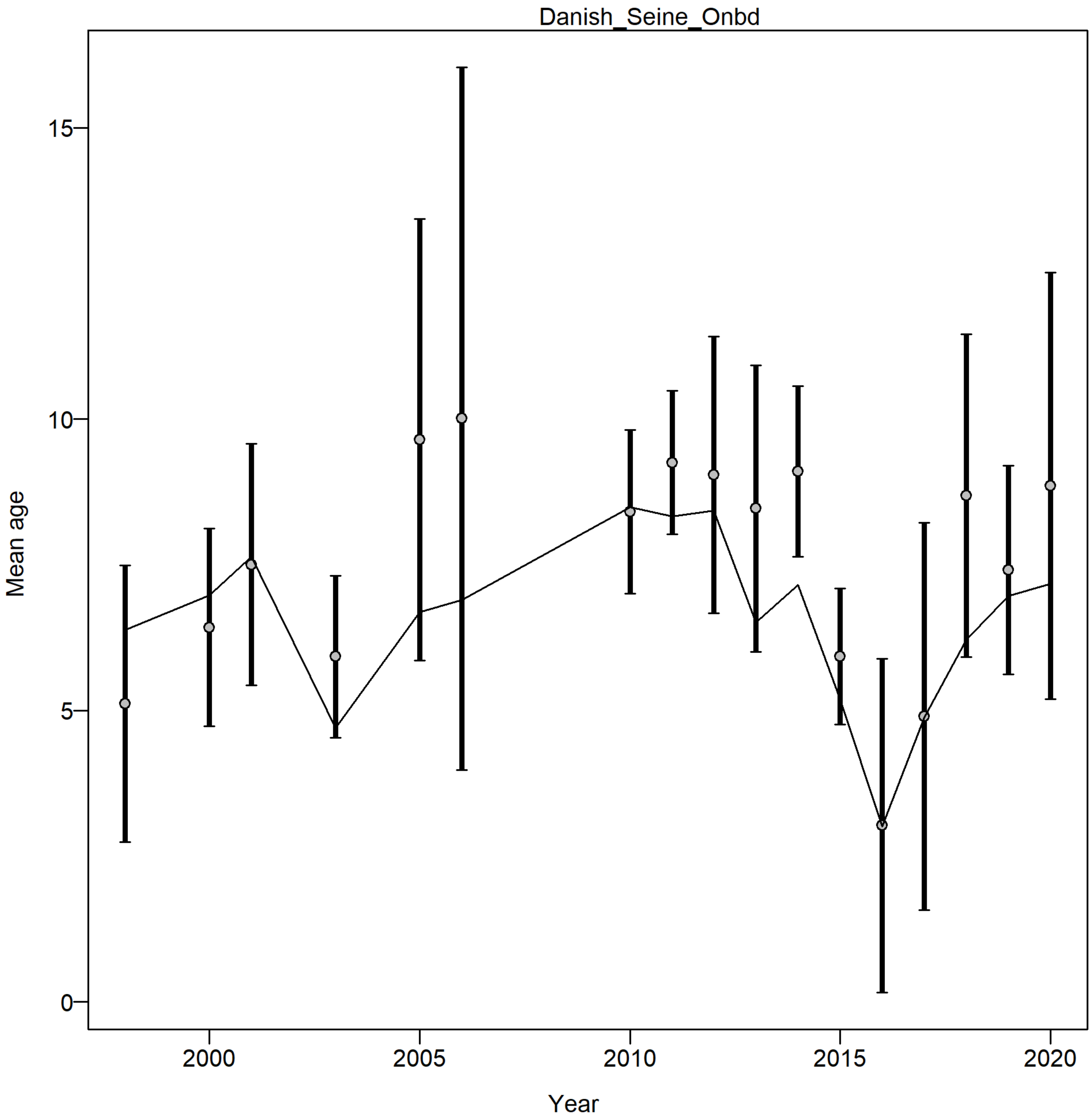


Figure A 8.39. Mean age (aggregated across length bins) for eastern Jackass Morwong from Daish seine with 95% confidence intervals based on current samples sizes. Punt data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced. Yearly variation in the data is shown in changes in mean age, which can be large over a short period.

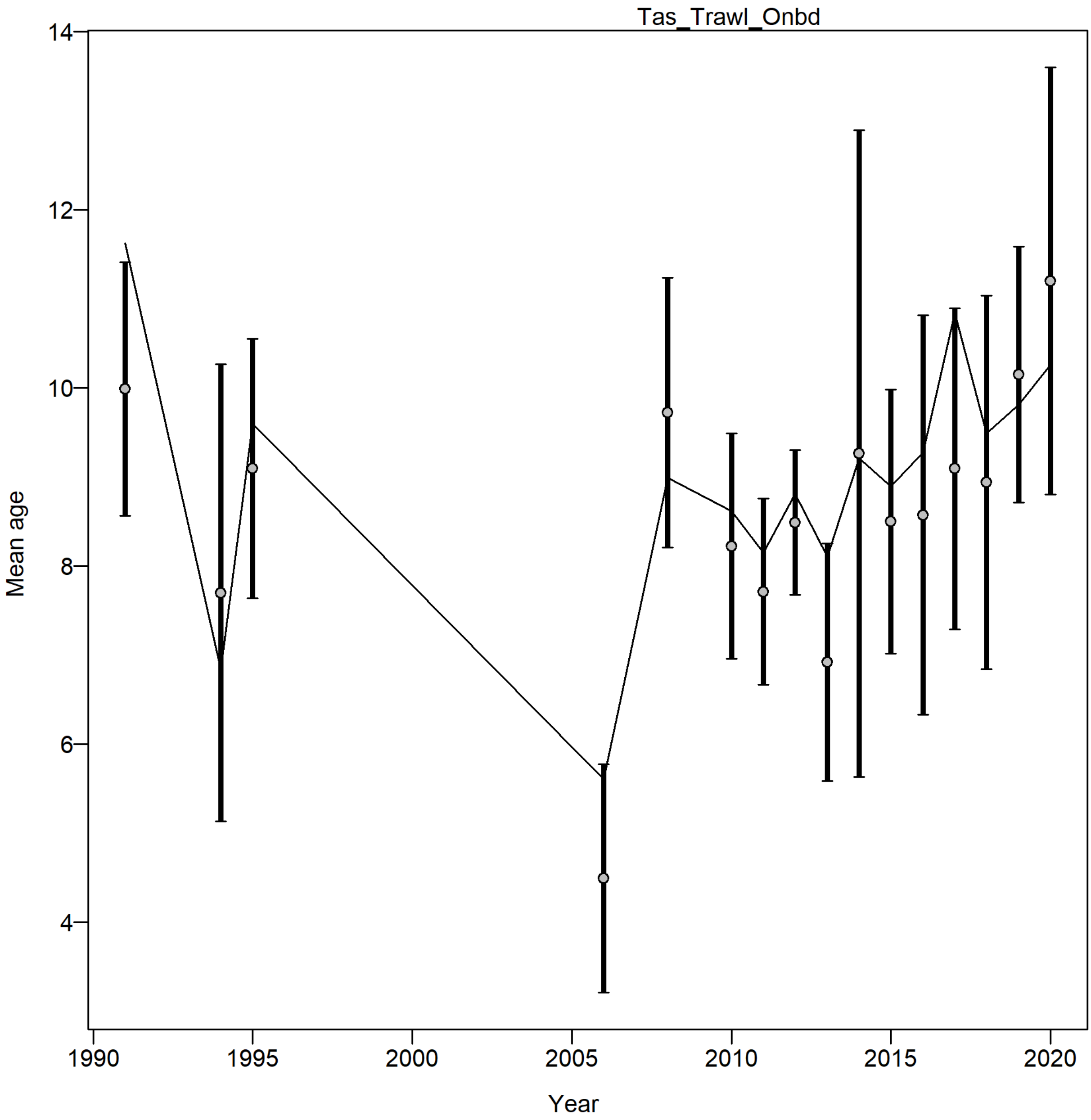


Figure A 8.40. Mean age (aggregated across length bins) for eastern Jackass Morwong from Tasmanian trawl with 95% confidence intervals based on current samples sizes. Punt data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced. Yearly variation in the data is shown in changes in mean age, which can be large over a short period.