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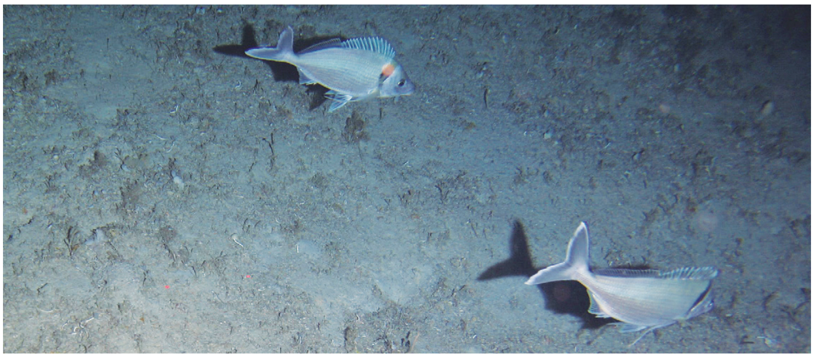
Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2018 and 2019



PART 1

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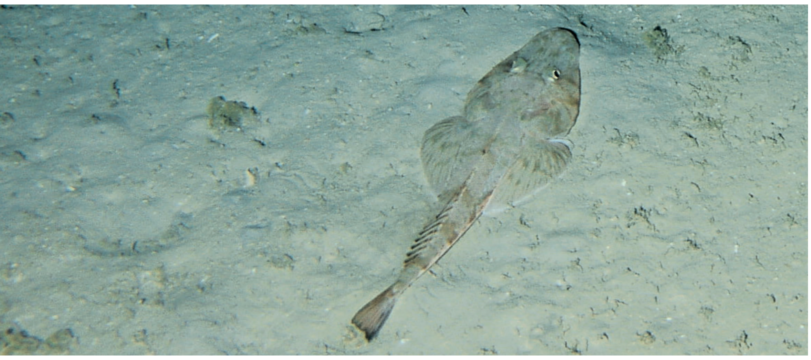

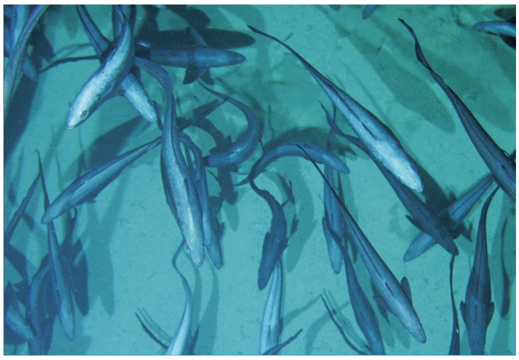

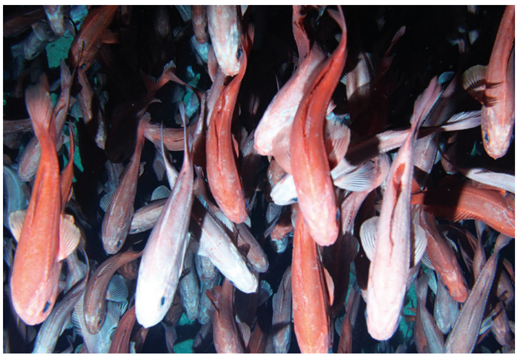

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Cover photographs

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

Report structure

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

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

Part 1: 2018

G.N. Tuck
June 2020
Report 2017/0824

Australian Fisheries Management Authority

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

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8. Western Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2017

Jemery Day and Claudio Castillo-Jordán

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

8.1 Executive Summary

This document updates the 2015 assessment Tier 1 assessment of western jackass morwong (*Nemadactylus macropterus*) to provide estimates of stock status in the SESSF at the start of 2019 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 V3.30.12.00). The 2015 stock assessment has been updated with the inclusion of data up to the end of 2017, 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 current spawning stock biomass is 68% of unexploited stock biomass (SSB_0). Under the agreed 20:35:48 harvest control rule, the 2019 recommended biological catch (RBC) is 235 t, with the long term yield (assuming average recruitment in the future) of 158 t. The average RBC over the three year period 2019-2021 is 223 t and over the five year period 2019-2023, the average RBC is 212 t.

Exploration of model sensitivity showed variation in spawning biomass across all sensitivities ranging from 33% to 102% of SSB_0 with greatest sensitivity to natural mortality. Excluding this sensitivity to natural mortality, the other sensitivities showed a much narrower range, from 60% to 75% of SSB_0.

Changes to the 2015 stock assessment include: estimating discards and retention rather than simply adding discards to landed catches; and using the latest agreed best practice tuning method. The updated assessment is consistent with the results from the 2015 assessment, despite an additional three years of data, improvements to data processing and modifications to Stock Synthesis. As in the 2015 assessment, results show poor fits to the abundance data (catch rate and Fishery Independent Survey (FIS)), but acceptable fits to the length composition and conditional age-at-length data.

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 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 Castillo-Jordán, 2018b).

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 morwong then dropped to around 1,000 t by the mid-1980s (Table 8.4), 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 has ranged between 111 t in 2015 (102 t in the east and 9 t in the west) to 1,652 t in 1989 (1567 t in the east and 85 t in the west). Annual landings of jackass morwong in the eastern zones declined to around 1,000 t during the 1990s and in 2017 are near their lowest recorded levels (Day and Castillo-Jordán, 2018b). 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 varied 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 morwong that could be expected from fishing for other species. Klaer and Smith (2008) calculated that in 2006, 59% of morwong trawl catch was caught as bycatch (mainly from flathead fishing). From the logbook data in 2006, the morwong trawl catch was 763 t. Thus 59% of this, or 450 t, is bycatch that is unavoidable if catches of species that have morwong as a bycatch stay the same as 2006 levels (Wayte, 2011).

Catches of jackass morwong in the west have been recorded since 1986 (153 t) with less than 100t caught annually in the west from 1987-1999, then catch totals exceeding 100t in the period 2000-2008 (with a peak of 320 t in 2001). All catches have been less than 100t since 2009, indeed less than 50 t in the period 2012-2016, with a 2017 western catch of 87 t. 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, (combined with a non-zero RBC from the western stock) still allowed a non-zero TAC to be set for the combined stock, and allowed some of that TAC to be taken in the eastern part of the stock.

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. This assessment does not consider landings from vessels in the non-trawl sector. The state catches have been added to the Commonwealth catches in the appropriate zone.

The assessment data for the western stock of jackass morwong comprises a single western trawl fleet. In the west, 50% recruitment to the fishery occurs at around 8 years old, compared to between three and seven years in the east.

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).

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 morwong were longer lived (35 years) than previously thought (20 years).

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 lead to a point estimate of unexploited total recruited biomass of 29,400 tonnes, which is larger than spawning biomass, with a 1961 depletion level of 70%.

The first formal quantitative assessment of jackass morwong was conducted by Fay (2004) based on data to 2002, using Coleraine, a 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 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 species, also endeavoured to select targeted shots by selecting shots with ≥1kg of morwong from vessels that had reported catches of morwong for three or more years and whose median annual catch was greater than 2 tonnes.

Base-case estimates of spawning depletion in 2006 when the model was fit to the ≥1kg 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 spawning depletion 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 ≥ 30 kg cut-off for catch and effort data was reasonable for morwong. However, the increasing trend in the number of shots catching small amounts of 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 species.

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 to 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. Depletion 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 (0t) and west (297t) stocks) was 297t (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, 2008) 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, 2008), 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 (0t) and west (381t) stocks) was 381t (using the 20:35:48 control rule), with this RBC coming entirely from the western part of the stock.

The 2009 assessment (Wayte, 2009) 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 morwong (Myers et al 1999). The regime shift model gave a more optimistic picture of current stock status than the other models, but the long term catch estimate was 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, 2009), 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 stock biomass. The single RBC calculated for jackass morwong (combining the east (143t) and west (367t) stocks) increased to 510t, 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 continued to be 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 morwong in the Great Australian Bight were found to be at a similar level to western morwong catches, but it is not known whether the GAB morwong form a separate stock.

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. 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 uses the same assumptions as in previous years (no recruitment shift).

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 2010 spawning stock biomass was 70% of unexploited stock biomass. The single RBC calculated for jackass morwong (combining the east (228t) and west (329t) stocks) increased to 557t, with this RBC coming from both the eastern and western part of the stock.

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 western stock assessment continued to be considered as increasingly uncertain, with no recent length frequency data (for 2007-2010).

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 2011 spawning stock biomass was 67% of unexploited stock biomass. The single RBC calculated for jackass morwong (combining the east (358t) and west (282t) stocks) increased to 640t, 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 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 2015 spawning stock biomass was estimated to be 69% of unexploited stock biomass. The single RBC calculated for jackass morwong (combining the east (314t) and west (249t) stocks) increased to 563t, with this RBC coming from both the eastern and western part of the stock.

8.2.4 *Modifications to the previous assessments*

The 2018 assessment uses Stock Synthesis version SS-V3.30.12.00, (Methot et al., 2018), updated from version SS-V3.24U (Methot and Wetzel, 2013) that was used in the 2015 assessment. New catch, discard, length and conditional age at-length data is available from the three year period from 2015-2017. In addition to these new and updated data, there is an updated standardised CPUE series for the western trawl fleets (Zones 40 and 50), each with three additional data points and updated estimates for the ageing error matrix.

8.2.4.1 Data-related issues

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 is a single catch-rate time series dating back to 1986, western trawl (SESSF Zones 40 and 50).
4. No state catches have been included for the western assessment, with relevant state catches added into the appropriate fleets in the eastern assessment.
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 2015-2017. The historical catch series (up until 2014) was also revised to incorporate changes in the catch database.

8.2.4.2 Model-related issues

1. Growth is assumed to follow a von Bertalanffy type length-at-age relationship, with all four growth parameters fixed at values obtained in the eastern assessment (Day and Castillo-Jordán, 2018b).
2. Natural mortality, M, is fixed (0.15) in the model.
3. Recruitment residuals are estimated from 1989-2012, with the last recruitment event estimated five years before the most recent available data, compared to 3 years before the most recent data in the 2015 assessment.
4. An updated tuning procedure has been used to balance the weighting of each of the data sources that contribute to the overall likelihood function, using Francis weighting for length data (Francis, 2011), Punt weighting for the conditional age-at-length data (Punt, 2017), balancing the CPUE series within Stock Synthesis, and improvements to the recruitment bias ramp adjustment.
5. Discards were estimated separately, using estimates of discard rates and retention estimated from discard length frequencies. The 2015 assessment ignored discarding in the west.
6. 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 (Burch et al., 2018) cannot be used in Tier 1 assessments. The discards from Burch et al. (2018) 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.
7. The Tier 1 discard estimates have been updated in 2018 to more closely match the discard calculations in Bergh et al. (2009). These estimates use ratios of total discards to (retained + discard) catch on a per shot basis, rather than aggregated across a whole strata, 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 (Day and Castillo-Jordán, 2018a).

8.3 Methods

8.3.1 The data and model inputs

8.3.1.1 Biological parameters

A single-sex model (i.e. both sexes combined) was used, as the length composition data for jackass morwong are not available by sex.

Age-at-length data was used as an input, with all four parameters of the von Bertalanffy growth equation fixed at the values obtained for the eastern stock (Day and Castillo-Jordán, 2018b). This follows the approach first adopted in the 2015 assessment (Tuck et al., 2015b), which was due to limited data and inconsistencies between different years of data leading to poor fits to the growth curve estimated for the west.

As in the 2015 assessment, M was fixed in the model at 0.15 and the base-case value for the steepness of the Beverton-Holt stock-recruitment relationship, h, is 0.7.

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 western stock of jackass morwong comprises a single fleet:

1. Western trawl – otter trawlers from SESSF Zones 40 and 50 (1986 – 2017).

8.3.1.3 Landed catches

The model uses a calendar year for all catch data. Landings data come from the Commonwealth logbook records for SESSF Zones 40 and 50, scaled up to the Catch Disposal Records (CDRs), in the same proportion as the ratio of the logbook totals for the same zones to the logbook total for all zones. Annual landed catches used in this assessment are shown in Figure 8.1, Figure 8.2 and listed in Table 8.1.

In order to calculate the RBC for 2019, it is necessary to estimate the calendar year catch for 2018. Without any other information, the 2018 catch was assumed to be the same as the 2017 catch. The recent TAC history, which only applies to the combined eastern and western stocks, is also listed in Table 8.1, alongside the catches of western stock of jackass morwong. The percentage of total catch taken in the west is quite variable, averaging around 20% since 1998, but ranging from 7% (in both 1998 and 2014) to 39% (2017).

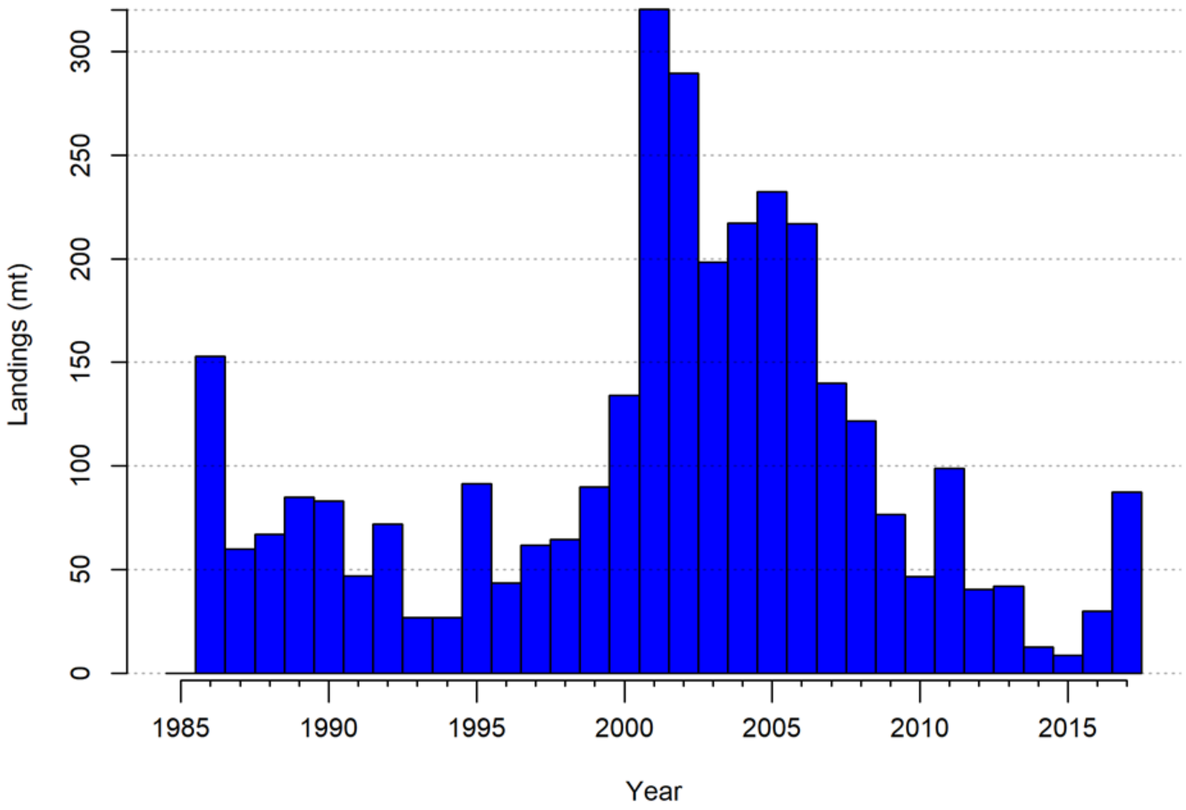

Figure 8.1. Total landed catch (tonnes) of western jackass morwong from 1986-2017 (stacked).

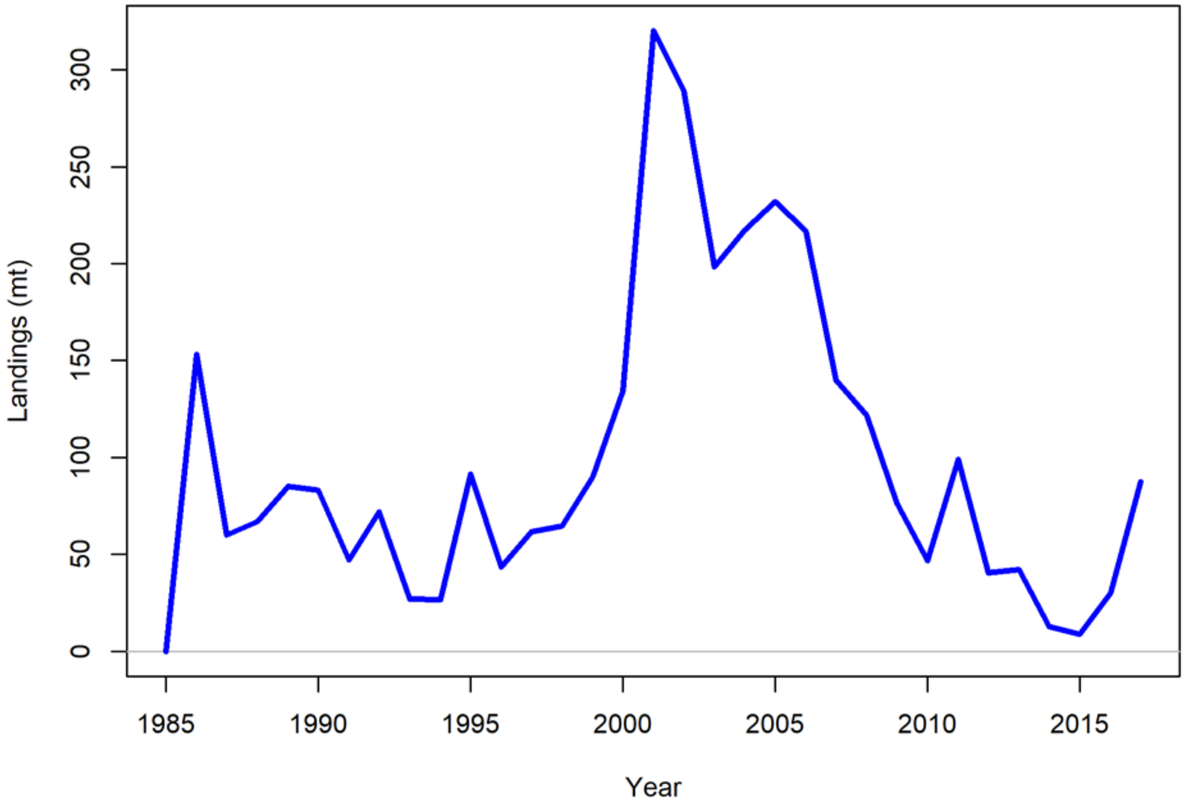

Figure 8.2. Total landed catch (tonnes) of western jackass morwong from 1986-2017 (lines).

Table 8.1. Total retained catches (tonnes) of western jackass morwong for calendar years from 1986-2017 and TAC (combined eastern and western stocks) for 1992-2018.

Year	Catch	TAC
1986	153	
1987	60	
1988	67	
1989	85	
1990	83	
1991	47	
1992	72	1500
1993	27	1500
1994	27	1500
1995	91	1500
1996	44	1500
1997	62	1500
1998	65	1500
1999	90	1500
2000	134	1200
2001	320	1185
2002	289	950
2003	198	960
2004	217	960
2005	232	960
2006	217	1200
2007	140	878
2008	122	560
2009	77	450
2010	47	450
2011	99	450
2012	41	568
2013	42	568
2014	13	568
2015	9	598
2016	30	474
2017	87	513
2018		505

8.3.1.4 Discard rates

Information on the discard proportions of jackass morwong by fleet is available from the ISMP for 1994-2016. This program was run by PIRVic from 1992-2006 and by AFMA from 2007. These data are summarised in Table 8.2. Discard rates were estimated from on-board data which gives the weight of the retained and discarded component of those shots that were monitored (Burch et al., 2018). Discard proportions vary amongst years and have been as high as 12% (in 2012).

Table 8.2. Discard proportions from 1994 to 2017 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 – although there are none of these here) or because the value is too close to zero (less than 0.01).

Year	discard proportion	n
1994	0.0111	46
1995		
1996	0.0129	53
1997		
1998	0.0042	29
1999		
2000	0.0413	17
2001	0.0011	45
2002	0.0013	38
2003	0.0560	17
2004	0.0003	49
2005	0.0058	111
2006	0.0063	29
2007		
2008	0.0072	23
2009	0.0087	12
2010		
2011	0.0362	32
2012	0.1210	18
2013	0.0286	33
2014	0.0748	16
2015		
2016	0.0290	21
2017	0.0644	22

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

Observations were then used to estimate discard rates (Figure 8.3) and hence discarded catches for each fleet (Figure 8.4), with estimated discard rates of between 3% and 5% for the trawl fleet, and less than 10 t in all years.

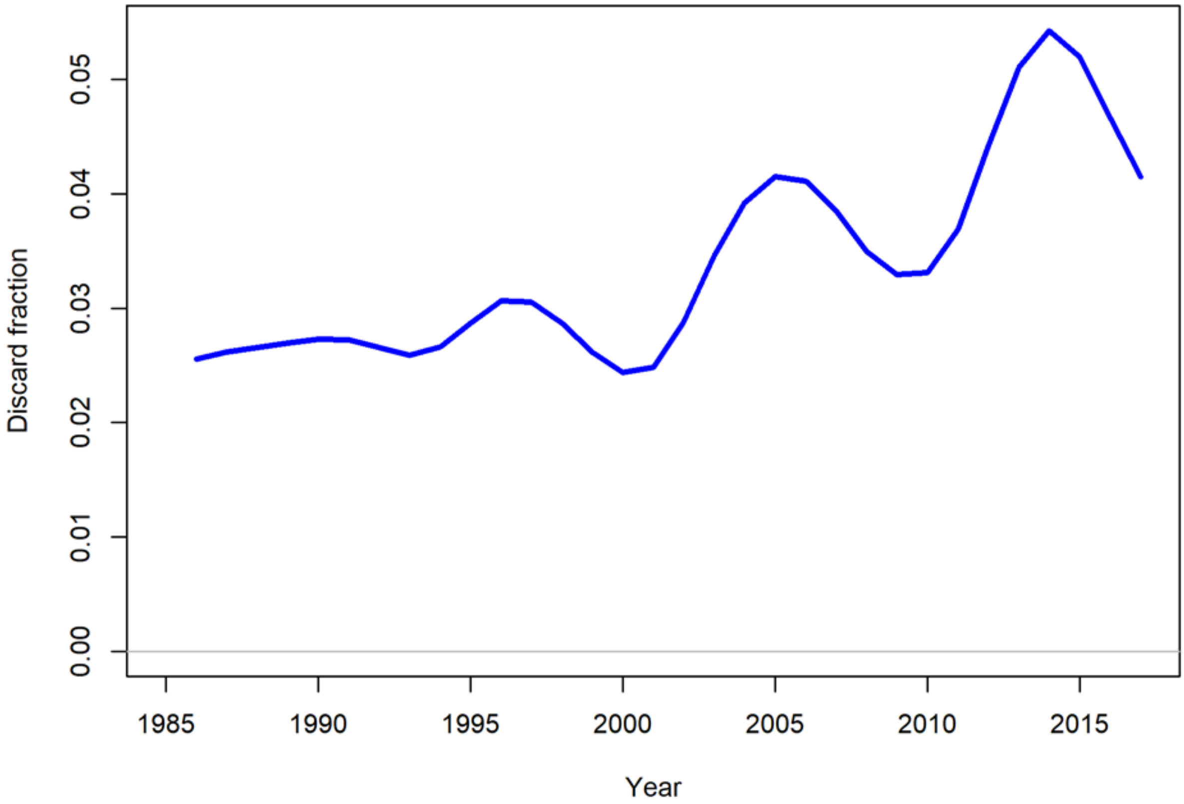

Figure 8.3. Model estimates of discard fractions by fleet, western trawl (blue).

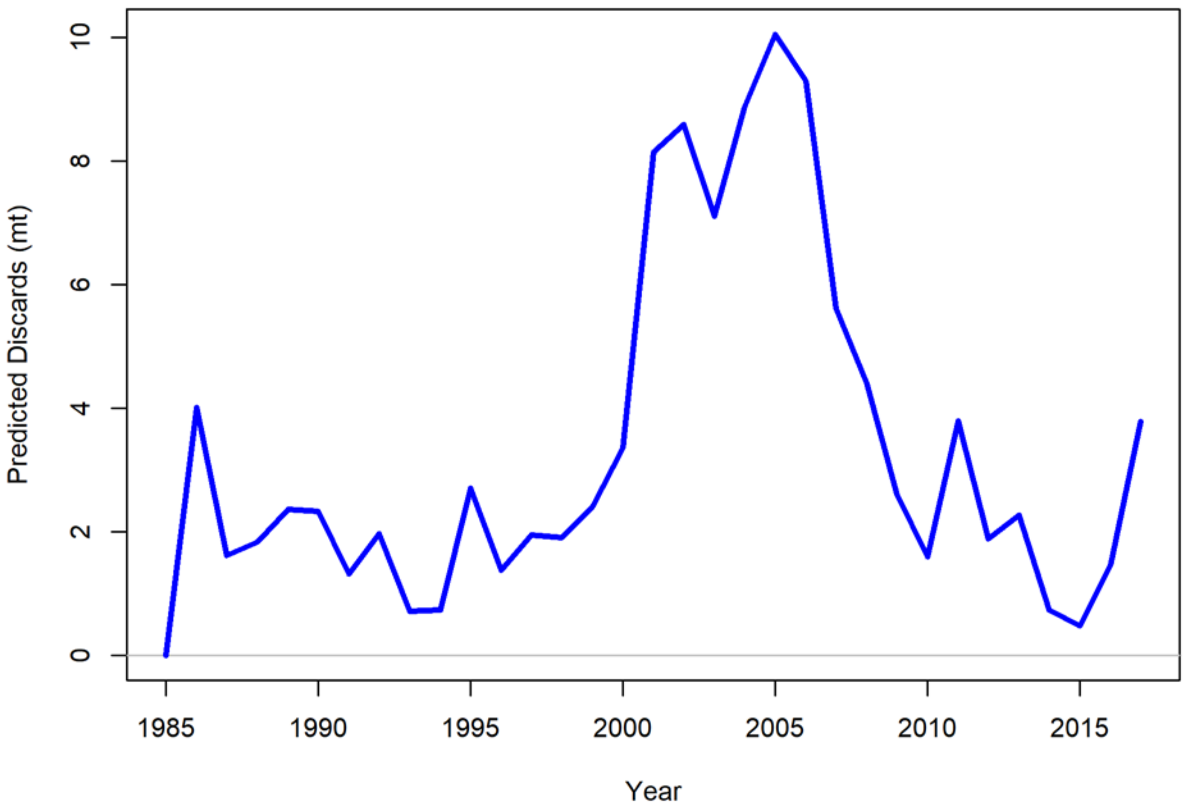

Figure 8.4. Estimated discards (tonnes) of jackass morwong (Zones 40 and 50) in the SESSF from 1986-2017, otter trawl (blue).

8.3.1.5 Catch rate and FIS abundance indices

Catch and effort data from the SEF1 logbook database were standardised using GLMs to obtain indices of relative abundance (Sporcic and Haddon (2018b); Table 8.3) from the period 1986-2017 for the western trawl fleet. 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 and Haddon, 2018a) and additional variance is estimated for this CPUE index to tune the input and output variances.

Table 8.3. Standardised catch rate indices and coefficient of variation (Sporcic and Haddon, 2018b) for the western trawl fleet for western jackass morwong and the FIS abundance indices. The coefficient of variation is initially set at a value equal to the root mean squared deviation from a loess fit (Sporcic and Haddon, 2018a).

Year	Catch rate	cv	FIS	cv
1986	2.060	0.192		
1987	1.617	0.192		
1988	2.392	0.192		
1989	1.728	0.192		
1990	1.751	0.192		
1991	1.183	0.192		
1992	0.969	0.192		
1993	0.924	0.192		
1994	0.902	0.192		
1995	0.931	0.192		
1996	1.043	0.192		
1997	0.822	0.192		
1998	0.833	0.192		
1999	0.755	0.192		
2000	1.195	0.192		
2001	1.273	0.192		
2002	1.281	0.192		
2003	1.085	0.192		
2004	1.151	0.192		
2005	1.247	0.192		
2006	0.988	0.192		
2007	0.824	0.192		
2008	0.845	0.192	51.564	0.335
2009	0.669	0.192		
2010	0.497	0.192	25.525	0.335
2011	0.525	0.192		
2012	0.392	0.192	39.263	0.335
2013	0.369	0.192		
2014	0.288	0.192	7.269	0.335
2015	0.369	0.192		
2016	0.432	0.192	7.031	0.335
2017	0.664	0.192		

8.3.2 *Stock assessment method*

The restrictions used in selecting data for analysis for Danish seine 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 and (c) catches in zone 40 and 50 only.

Abundance indices for western jackass morwong for the FIS surveys conducted between 2008 and 2016 are provided in Table 8.3. FIS 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 only separated into zones reflecting the fleets used in Tier 1 assessments in 2016 in this report. The 2016 value for western jackass morwong (Knuckey et al., 2017) is listed in Table 8.3, along with values calculated previously for the earlier FIS years and first reported here. As with the CPUE indices, the coefficient of variation is initially set at a value equal to the root mean squared deviation from a loess fit (Sporcic and Haddon, 2018a) and additional variance is estimated for this abundance index to tune the input and output variances.

8.3.2.1 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 2018 assessment, the initial sample size associated with each length frequency in the assessment is the number of shots or trips.

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 8.4 and Table 8.5). Sample sizes for retained length frequencies, including both the number of individuals measured and number of trips are listed in Table 8.5 for each fleet and year for the period 1996-2017 and for discarded length frequencies in Table 8.4 for the period 1994-2016.

Length composition information for the retained component of the catch by the western Commonwealth trawl fleet is available from port sampling for the period 1996-2017 and from onboard sampling from 1997-2017. Onboard data collected by the ISMP were used to calculate the length frequency of the discarded component of the catch for six years only from 1994-2016.

Table 8.4. Number of onboard discarded lengths and number of shots for length frequencies included in the base case assessment by fleet 1994-2016. Entries in grey indicate data that are not used due to small sample size (less than 100 fish measured) or, in the case of the 1994 sample, because SERAG decided that the sample looked unrepresentative.

year	fleet	(discard)
	western trawl	western trawl
	# fish	# shots
1994	233	2
2009	112	1
2011	9	2
2012	59	10
2013	23	8
2016	86	4

Table 8.5. Number of port and onboard retained lengths and number of shots or trips for length frequencies included in the base case assessment by fleet 1996-2017. Entries in grey indicate data that are not used due to small sample size (less than 100 fish measured).

year	fleet trawl onboard # fish	(retained) trawl port # fish	FIS # fish	trawl onboard # shots	trawl port # trips	FIS # shots
1996		364			3	
1997	245	505		2	4	
1998	373	2		4	1	
1999	412	341		4	3	
2000	124	572		1	5	
2001	1434	2232		11	18	
2002	859	1918		4	12	
2003	124	1680		1	10	
2004	397	873		3	10	
2005	2116	1426		15	14	
2006	820	690		6	7	
2008	47	109	512	2	1	15
2009	140			4		
2010	72		300	2		16
2011	208			9		
2012	318		362	17		14
2013	723	53		25	1	
2014	241	61	434	6	1	19
2015	151			3		
2016	284	359	366	5	8	15
2017	324	210		6	5	

8.3.2.2 Age composition data

An estimate of the standard deviation of age-reading error was calculated by André Punt (pers. comm., 2018) using data supplied by Kyne Krusic-Golub and a variant of the method of Richards *et al*. (1992) (Table 8.6). Age-at-length measurements provided by Kyne Krusic-Golub of Fish Ageing Services Pty Ltd, are available from 1991-2017 for the western trawl fleet (Table 8.7).

Table 8.6. Standard deviation of age reading error (A Punt pers. comm. 2018).

Age	sd
0.5	0.255696
1.5	0.255696
2.5	0.27765
3.5	0.300684
4.5	0.324851
5.5	0.350208
6.5	0.376813
7.5	0.404727
8.5	0.434015
9.5	0.464744
10.5	0.496985
11.5	0.530813
12.5	0.566306
13.5	0.603546
14.5	0.642618
15.5	0.683613
16.5	0.726626
17.5	0.771756
18.5	0.819106
19.5	0.868787
20.5	0.920913
21.5	0.975604
22.5	1.03299
23.5	1.09319
24.5	1.15636
25.5	1.22264
26.5	1.29218
27.5	1.36514
28.5	1.4417
29.5	1.52202
30.5	1.60629

Table 8.7. Number of age-length otolith samples included in the base case assessment for the western trawl fleet 1991-2017.

Year	otoliths
1991	94
1992	83
1993	42
1995	28
2003	83
2004	474
2005	282
2006	156
2007	51
2009	49
2011	41
2012	87
2013	118
2014	37
2015	71
2016	103
2017	59

Implied age distributions for retained and discarded fish are obtained by transforming length frequency data to age data by using the information contained in the conditional age-at-length data from each year and the age-length relationship. Implied age distributions can be calculated separately for both onboard and port fleets and for the retained and discarded length frequencies, and can be calculated from 1997-2017 for the western trawl fleet.

8.3.2.3 Input data summary

The data used in this assessment is summarised in Figure 8.5, indicating which years the various data types were available.

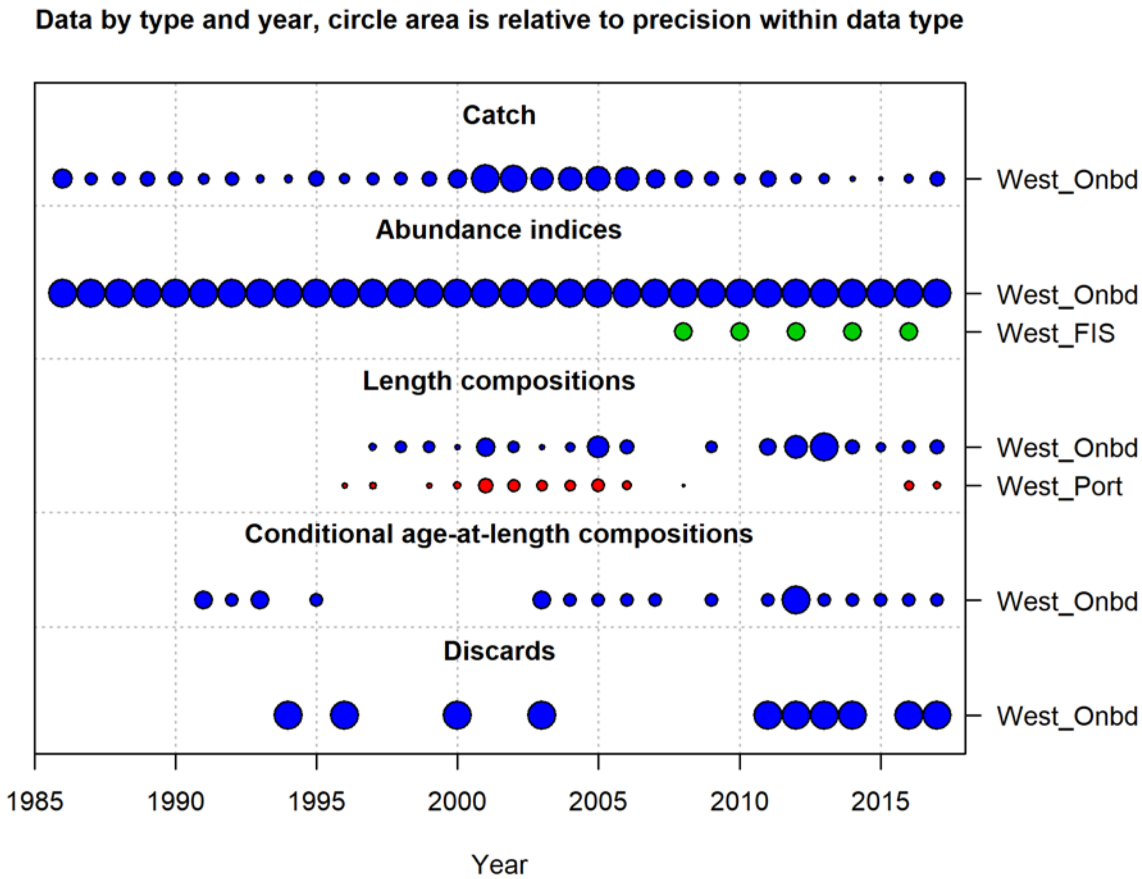

Figure 8.5. Summary of input data used for the western jackass morwong assessment.

8.3.3 *Stock assessment method*

8.3.3.1 Population dynamics model and parameter estimation

A single-sex stock assessment for western jackass morwong was conducted using the software package Stock Synthesis (version SS-V3.30.12.00, Methot *et al*. 2018). 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 (Methot, 2005) and are not reproduced here. Some key features of the base-case model are:

a) Jackass morwong constitute a single stock within the area of the fishery (SESSF Zones 40 and 50).

b) The population was at its unfished biomass with the corresponding equilibrium (unfished) age-structure at the start of 1986.

c) The CVs of the CPUE indices for the western trawl fleets were initially set to the root mean squared deviation from a loess fit to the fleet specific indices (Sporcic and Haddon, 2018a) and then tuned to match the model-estimated standard errors by estimating an additional variance parameter within Stock Synthesis.

d) One fishing fleet is modelled.

e) The selectivity pattern for the western trawl fleet was modelled as length-specific, logistic and time-invariant. The two parameters of the selectivity function for this 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.

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 1989 to 2012. Deviations are not estimated prior to 1989 or after 2012 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 gender are modelled, because the stock is modelled as a single-sex.

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

8.3.3.2 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.

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 weighting method for length data and the Punt weighting method for conditional age-at-length data.

8.3.3.3 Tuning procedure

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

1. Set the standard error for the 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.

8.3.3.4 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 for fishing years 2006-2016. The HSF uses harvest control rules to determine a recommended biological catch (RBC) for each stock in the SESSF quota management system. Each stock is assigned to one of four Tier levels depending on the basis used for assessing stock status or exploitation level for that stock. 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.

8.3.3.5 Sensitivity tests and alternative models

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

1. $M = 0.1$ 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. Estimate growth.
9. Double the weighting on the length composition data.
10. Halve the weighting on the length composition data.
11. Double the weighting on the age-at-length data.
12. Reduce the weighting on the age-at-length data.
13. Double the weighting on the survey (CPUE) data.
14. Halve the weighting on the survey (CPUE) data.
15. Exclude the Fishery Independent Survey abundance indices.
16. Include the Fishery Independent Survey length frequency data and estimate selectivity for the FIS.

The results of the sensitivity tests are summarized by the following quantities (Table 8.11):

1. SSB_0: the average unexploited female spawning biomass.
2. SSB_{2019}: the female spawning biomass at the start of 2019.
3. SSB_{2019}/SSB_0: the female spawning biomass depletion level at the start of 2019.

4. Mortality: the model estimated value for mortality.
5. RBC_{2019}: the recommended biological catch (RBC) for 2019.
6. $RBC_{2019\text{-}21}$: the mean RBC over the three years from 2019-2021.
7. $RBC_{2019\text{-}23}$: the mean RBC over the five years from 2019-2023.
8. $RBC_{longterm}$: the longterm RBC.

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

8.4 Results and Discussion

8.4.1 *The base-case analysis*

8.4.1.1 Transition from the 2015 base case to the 2017 base case

Development of a preliminary base case and a bridging analysis from the 2015 assessment (Tuck et al., 2015b), was presented at the September 2017 SERAG meeting (Day and Castillo-Jordán, 2018a), 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 8.6 shows the estimated growth curve for jackass morwong. All growth parameters are fixed in the model, based on values estimated in the 2018 eastern jackass morwong assessment (Day and Castillo-Jordán, 2018b). The parameter values are listed in Table 8.8.

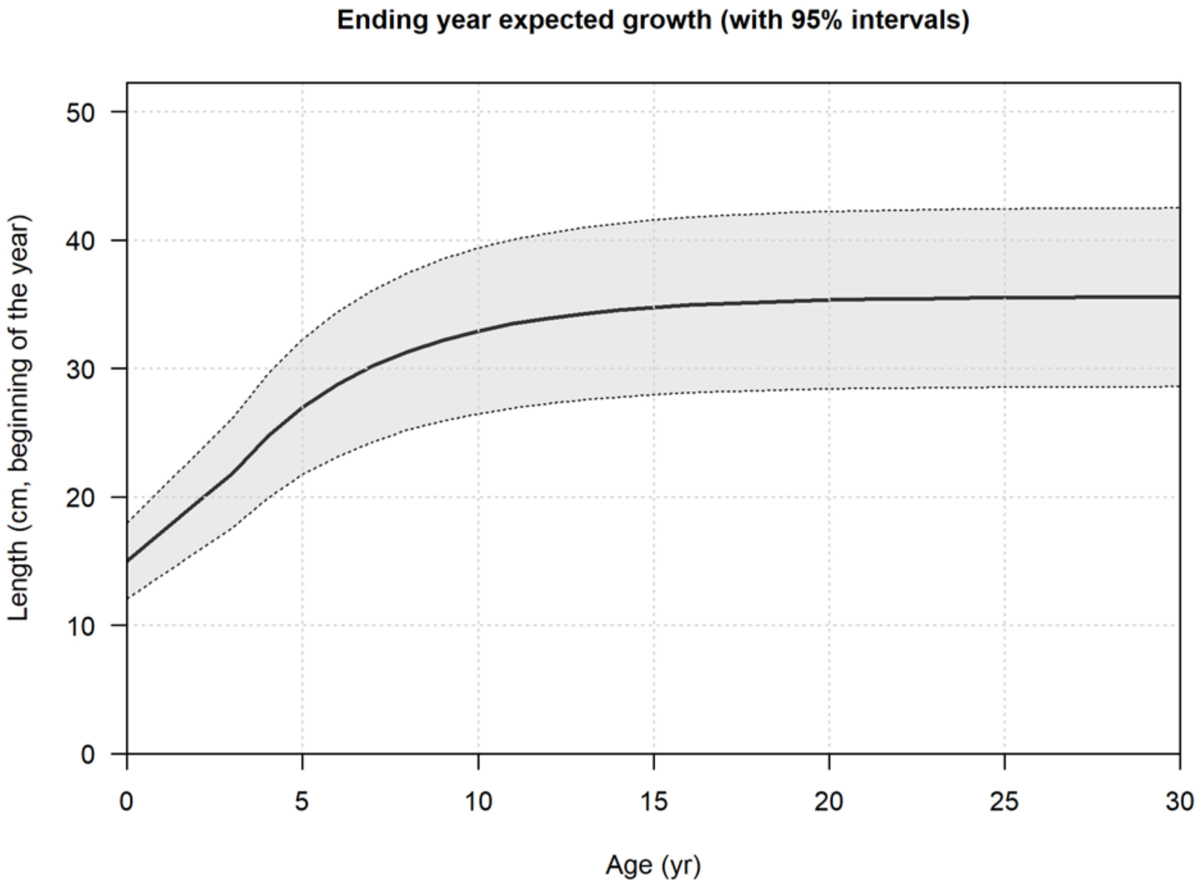

Figure 8.6. Fixed growth curve for western jackass morwong, using parameters estimated from the eastern morwong stock assessment.

Table 8.8. Summary of parameters of the base case model.

Feature	Details	
Natural mortality	fixed	0.15
Steepness *h*	fixed	0.7
σ_R in	fixed	0.7
Recruitment devs	estimated	1989-2012, bias adjustment ramps 1981-91 and 2017-19
CV growth	fixed	0.104
Growth *K*	fixed	0.217
Growth l_{min} (cm)	fixed	22
Growth l_{max} (cm)	fixed	35.2

Selectivity is assumed to be logistic for the western trawl fleet. 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 western trawl fleet are 31.8cm and 6.34cm, slightly larger than the selectivity estimated in the 2015 assessment. Figure 8.7 shows the selectivity and retention functions for each of the commercial fleets. The estimate of the parameter that defines the initial numbers (and biomass), $ln(R_0)$, is 7.09 for the base case.

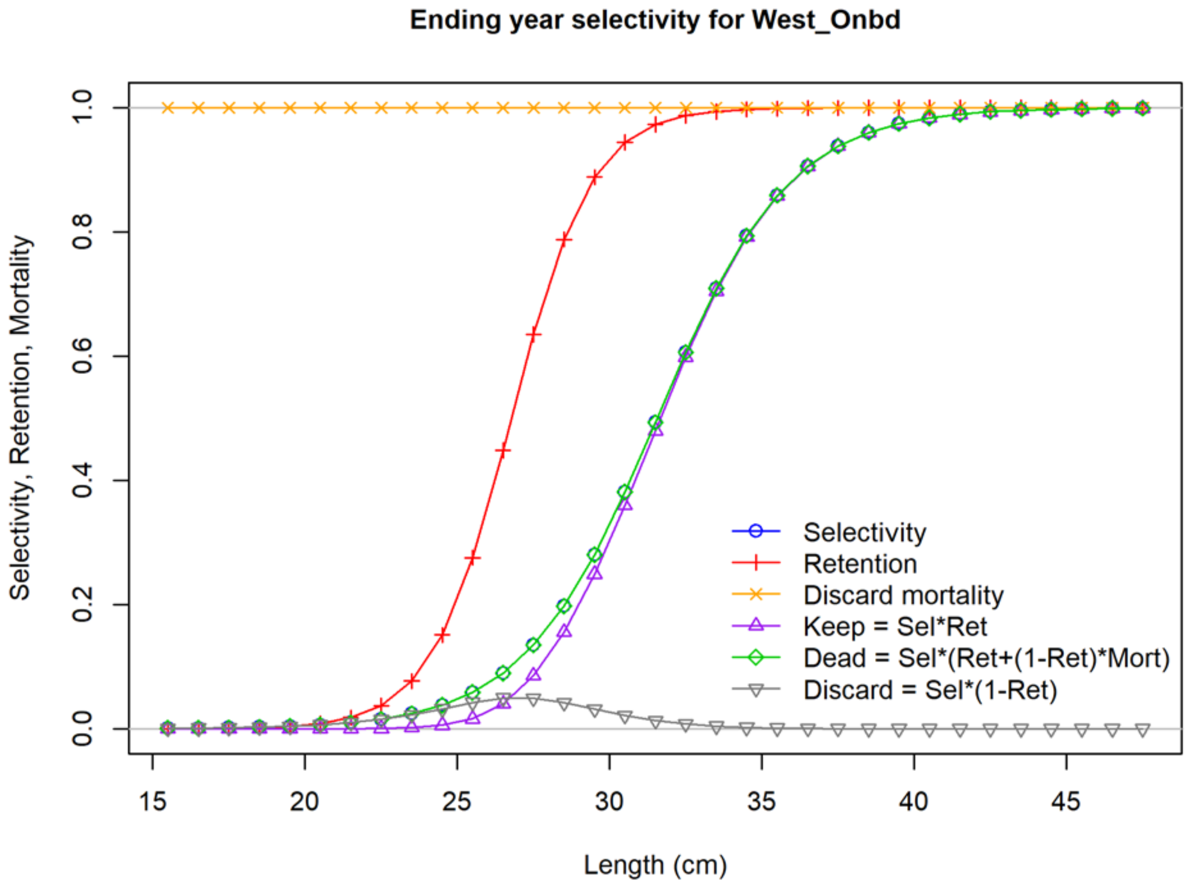

Figure 8.7. Selectivity (blue/green) and retention (red) functions for the western trawl fleet.

8.4.1.3 Fits to the data

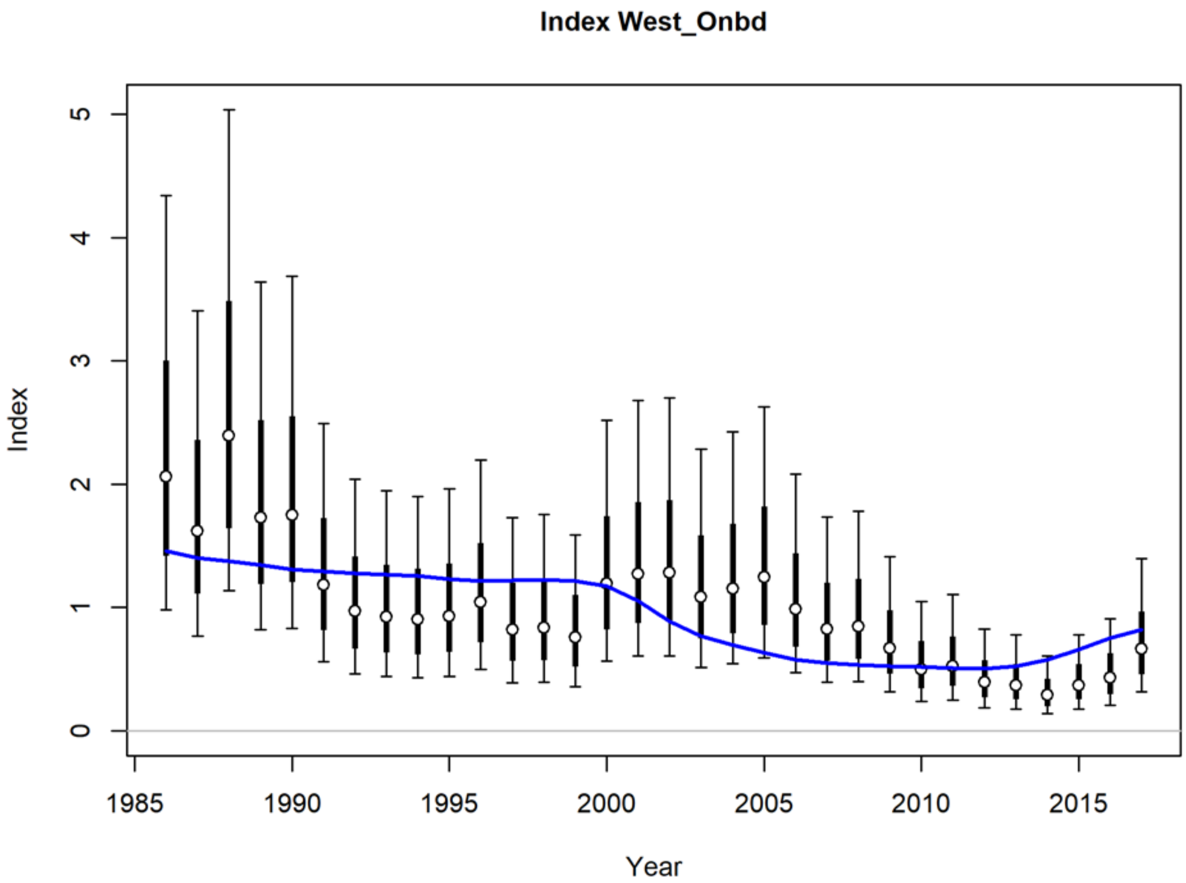

Figure 8.8. Observed (circles) and model-estimated (blue line) catch rates vs year, with approx 95% asymptotic intervals for the western trawl fleet. The thin lines with capped ends should match the thick lines for a balanced model. This index is balanced by estimating an additional variance parameter within Stock Synthesis which in this case is positive, suggesting the model requires more variance than the initial values from the loess fit to achieve a good fit.

The fits to the catch rate indices are poor for the western trawl fleet, with the fitted values all too low from 1986-1990, switching to all too high from 1992-1999, switching to all too low from 2001-2009 and then too high from 2012-2017. Further the fitted values do not really reflect the trends and the changes in the catch rate data, missing the step down seen in the data around 1991 and the step up around 2000, missing the gradual decline from 2005-2014. The only trend that seems reasonably well captured is the short term increase at the end of the series (2014-2017) and the overall decline in the complete time series. The fit in the 2015 assessment was of similar poor quality, as noted by Tuck et al, (2015b), perhaps indicating some conflict between data sources, insufficient quality or quantity of data to enable a quality assessment to be produced or possibly a CPUE series that is not tracking abundance.

It is notable that the standardised catch rate series shows an increase in the recent years (2014-2017), which breaks the pattern seen in recent assessments where the catch rate index continued to decline as new data points were added. From 2008-2014, the FIS abundance series shows a steeper decline than the CPUE series, and the assessment also fails to fit the FIS abundance series well (Figure 8.8). The last two points in the FIS abundance series (2014 and 2016) do not show the short term increase seen both in the CPUE series (2014-2017) and in the abundance predicted by the model.

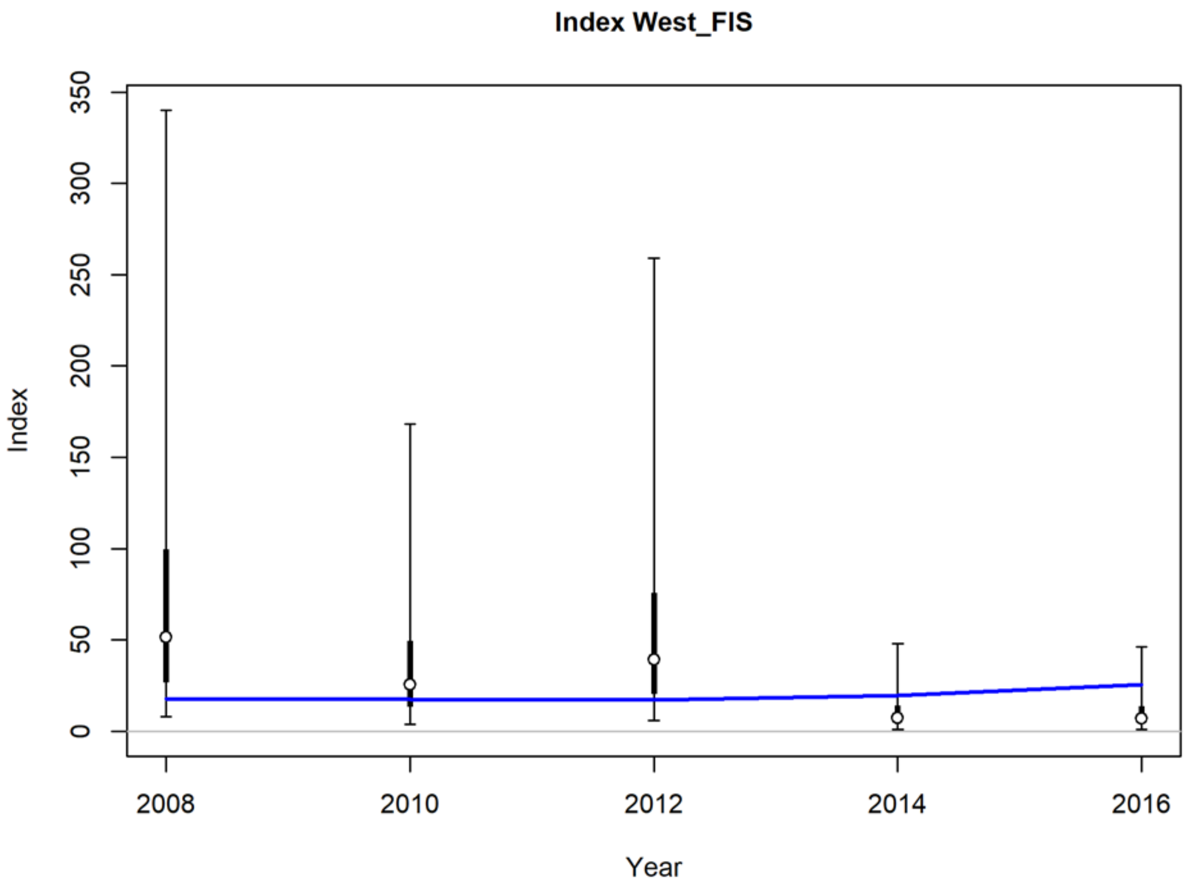

Figure 8.9. Observed (circles) and model-estimated (blue line) catch rates vs year, with approx 95% asymptotic intervals for western FIS. The thin lines with capped ends should match the thick lines for a balanced model. This index is balanced by estimating an additional variance parameter within Stock Synthesis, which in this case is positive and large, suggesting the model requires much more variance than the initial values from the loess fit to achieve a good fit.

The fits to the discard rate data (Figure 8.10) are reasonable, given the variability in the data. The discarding rate and the fits suggest that discarding is generally low (around 5% maximum). Fits to the age and length composition data for discarded catches are shown in Appendix A. Fits to the length composition and conditional age-at-length data seem reasonable, and it appears there is some conflict between fits to the abundance indices and these other data sources.

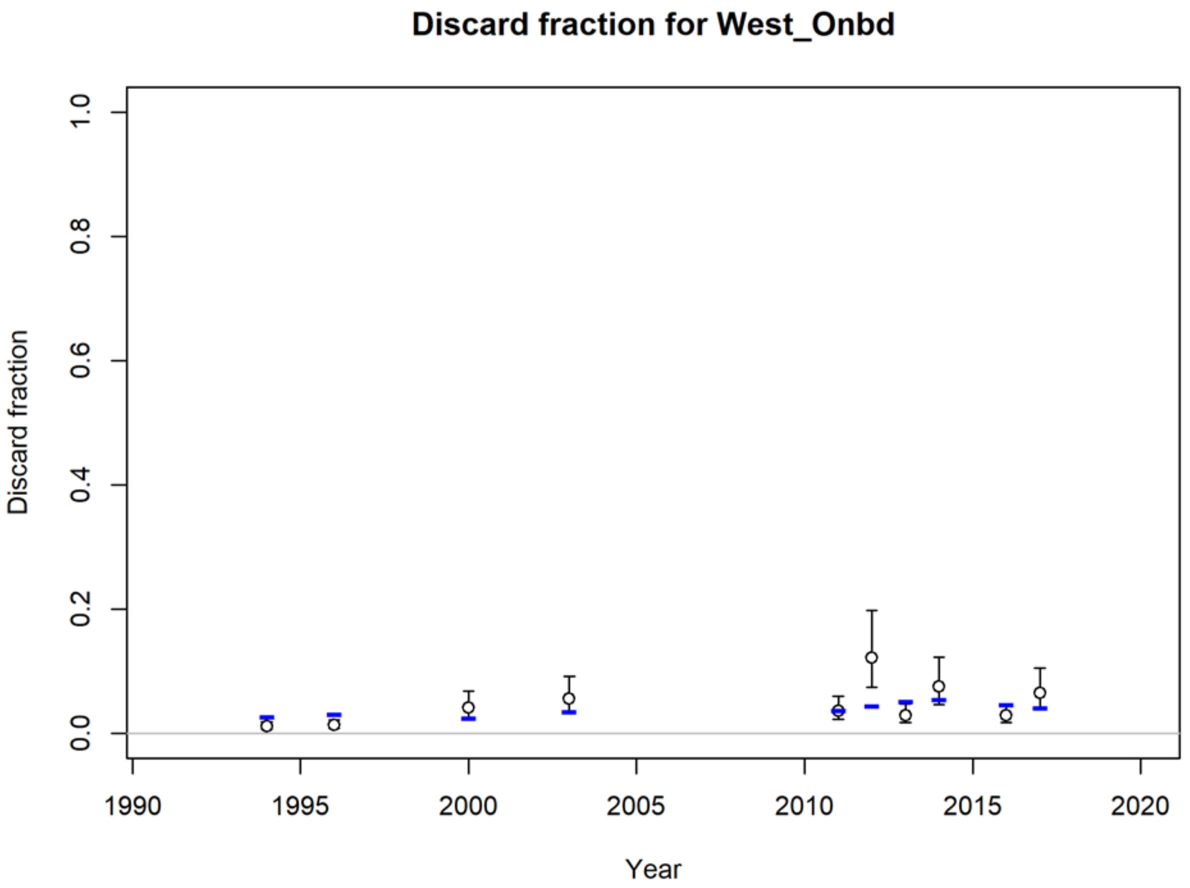

Figure 8.10. Observed (circles) and model-estimated (blue line) catch rates vs year, with approx 95% asymptotic intervals for western FIS. The thin lines with capped ends should match the thick lines for a balanced model. This index is balanced by estimating an additional variance parameter within Stock Synthesis, which in this case is positive and large, suggesting the model requires much more variance than the initial values from the loess fit to achieve a good fit.

The base-case model is able to fit the aggregated (across years) retained length-frequency distributions quite well (Figure 8.11 and Appendix A). The fits to the discard length frequencies come from a single year, and do not fit as well as the retained length data.

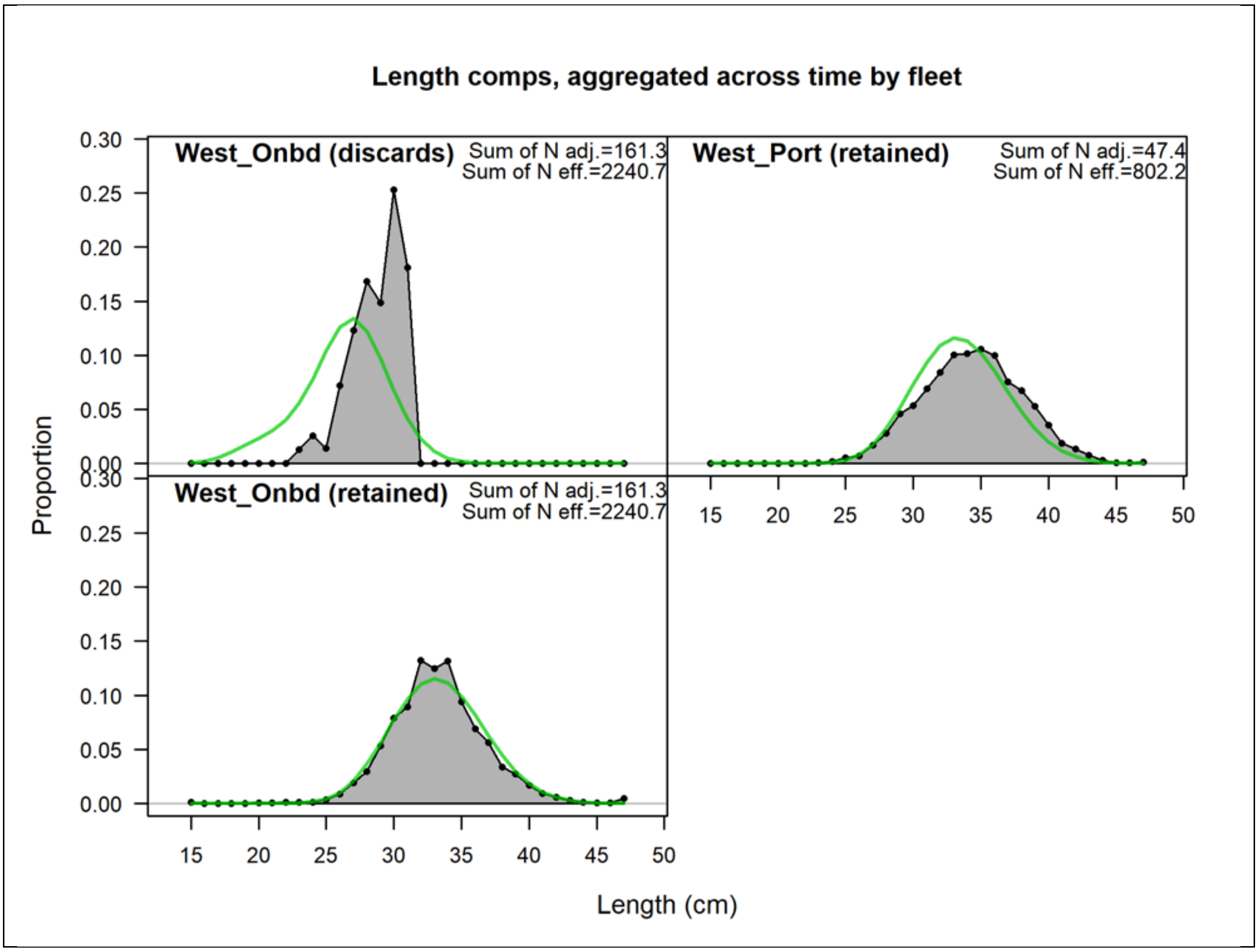

Figure 8.11. Fits to retained and discarded length compositions, separated by port and onboard samples, aggregated across all years. Observed data are grey and the fitted value is the green line.

The implied fits to the age composition data are shown in Appendix A. The age compositions were not fitted to directly, as age-at-length data were used. However, the model is capable of producing implied fits to these data for years where length frequency data are also available, even though they are not fitted directly in the assessment. The model fits the observed age data reasonably well for both retained and discarded age data.

Note that there are separate implied fits to age for the port and onboard data. There is only one set of age data, but this needs to be scaled up to length data (using an age-length key) to get implied fits to age, as the age data is not representative of the stock as a whole. This scaling up to length data can be done using either the onboard length data or the port length data – so it appears that there are two sets of age data.

The conditional age-at-length data is quite noisy between years, with occasionally quite large changes in mean age between adjacent years, in some instances larger changes than would be expected through biology and fishing mortality. The mean age varies between 8 and 15 years for western 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 as good as can be expected, considering the noise in the data. Residuals for these fits and mean age for each year, aggregated across length bins, are shown in Appendix A.

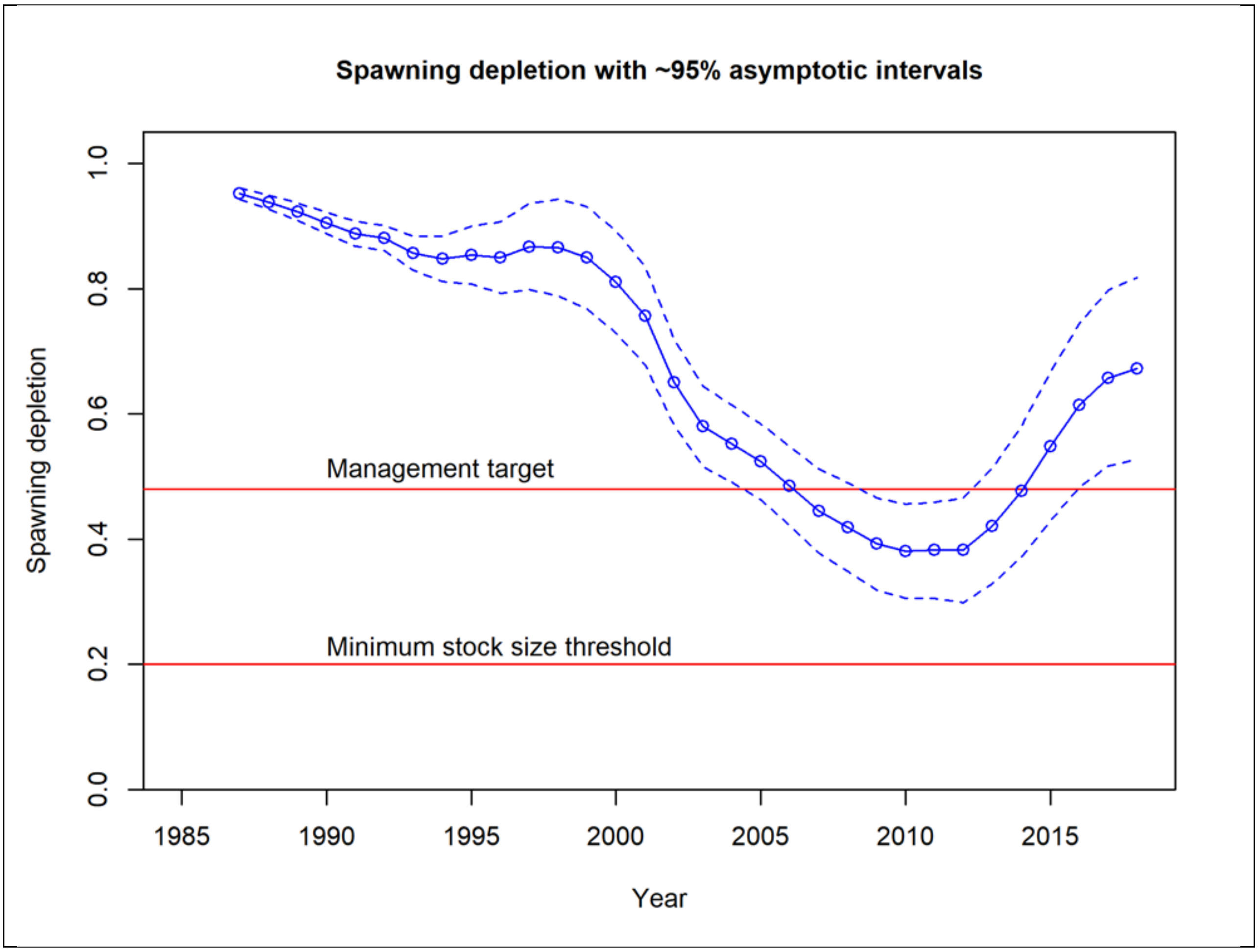

Figure 8.12. Time-trajectory of spawning biomass depletion (with approximate 95% asymptotic intervals) corresponding to the MPD estimates for the 2018 base-case analysis for jackass morwong.

8.4.1.4 Assessment outcomes

The current spawning stock biomass (Figure 8.12) is estimated to be 68% of unfished stock biomass (i.e. 2019 spawning biomass relative to unfished spawning biomass), albeit with considerable uncertainty (with 95% asymptotic intervals from around 55% to 80%). This compares to an estimate of 69% at the start of 2016 obtained from the last assessment (Tuck et al., 2015). The stock declines slowly from the beginning of the fishery in 1986, before a sharp decline beginning in the early 2000s corresponding to an increase in catch. The stock is estimated to decline to below 40% SSB_0 in 2012, before increasing to over 60% SSB_0 since 2015 and gradually increasing since then. These changes in estimated spawning biomass occur during a period of rapid rises in catches, increasing by a factor of 6 in a 5 year period to 2001 (from less than 50 t to over 300 t), and then a tenfold decline in catches to 2015 (less than 30 t). Catches have increased in 2016 and 2017, notably while catch rates were also increasing.

Recruitment has been variable, but the most recent 5 estimated recruitment events have all been above average, with the estimate of the 2011 recruitment revised upwards from the value obtained in the 2015 assessment.

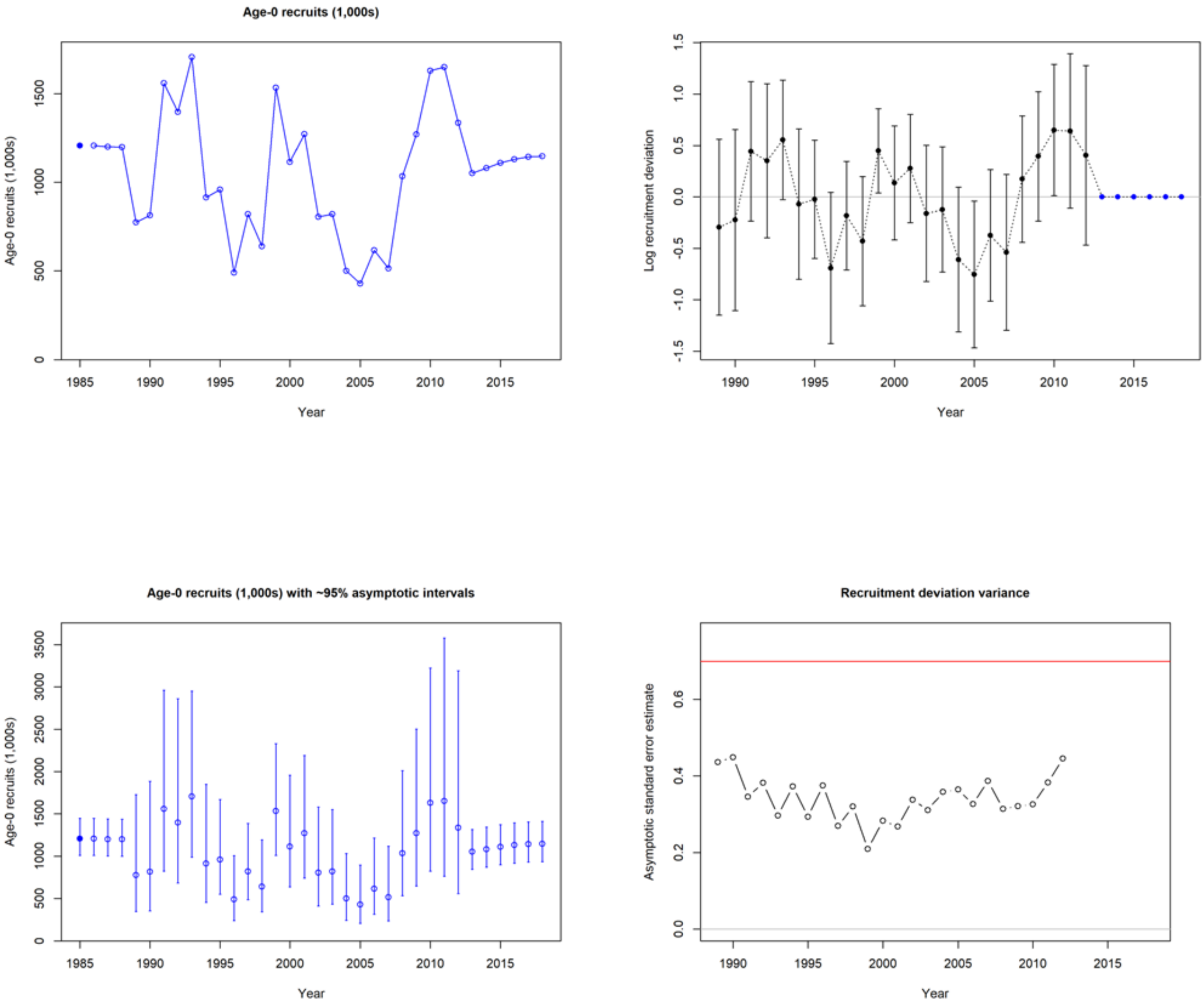

Figure 8.13. Recruitment estimation for the base case analysis. Top left : Time-trajectories of estimated recruitment numbers; top right : time trajectory of estimated recruitment deviations; bottom left : time-trajectories of estimated recruitment numbers with approximate 95% asymptotic intervals; bottom right: the standard errors of recruitment deviation estimates.

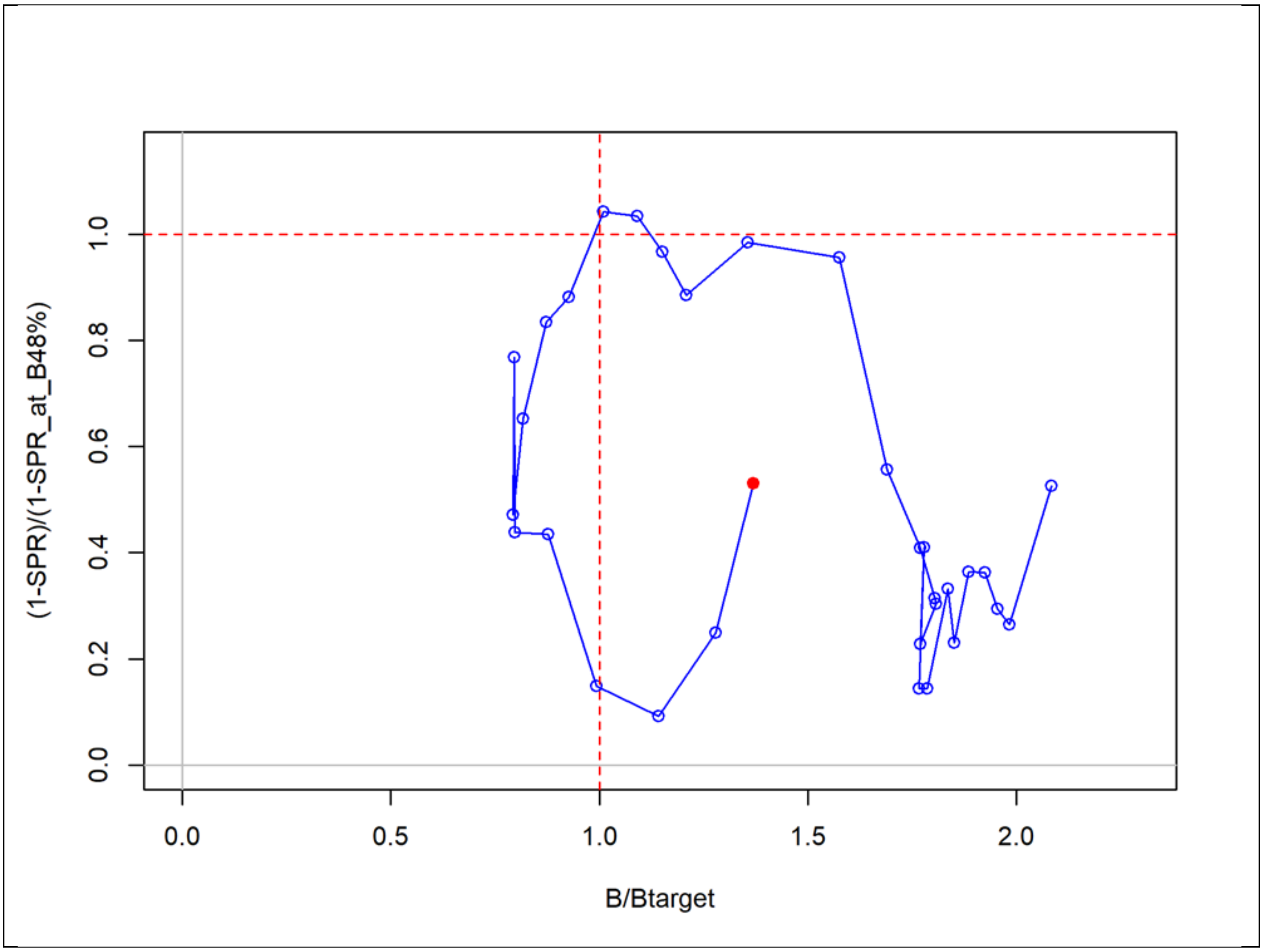

Figure 8.14. Kobe plot base case, showing the trajectory of spawning biomass (relative to B_0) plotted against 1-SPR, which is a proxy for fishing mortality, essentially integrating fishing mortality across fleets in the fishery.

Figure 8.14 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 right, when there was low fishing mortality and high biomass to 2018 (the red dot) where the biomass is above the target (to the right of the vertical red dashed line) and the fishing mortality is below the target fishing level (below the horizontal red dashed line). This trajectory shows an increase in overall fishing mortality as the fishery developed from 1986, with movement from the bottom right corner towards the top left corner, when the biomass is below the target and the fishing mortality is above the target rate. The fishing mortality was gradually reduced from around 2005 and had been below the "overfishing limit" for the last 11 years, with the spawning biomass stabilising and then increasing over this same period.

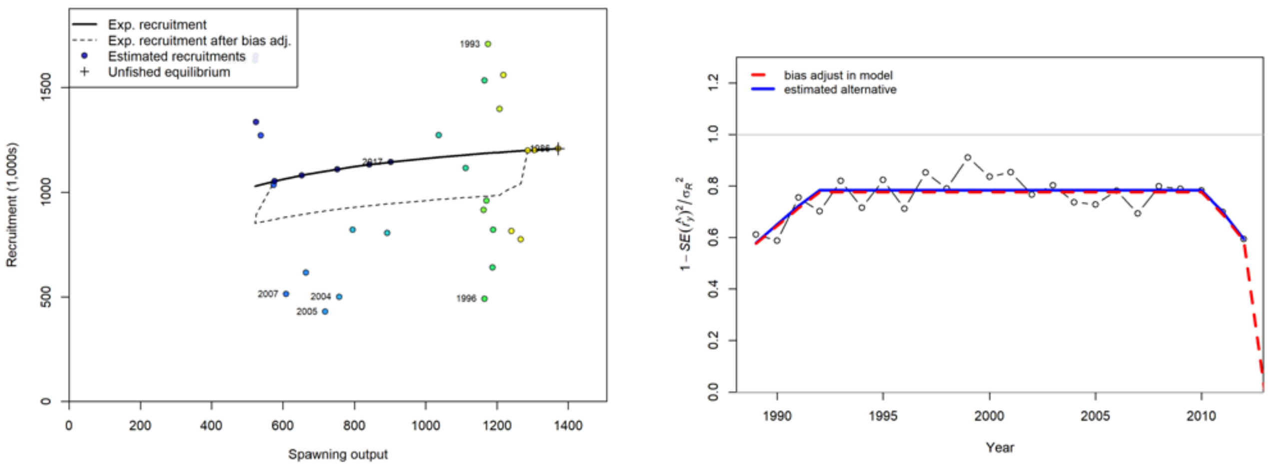

Figure 8.15. Recruitment estimation for the base case analysis. Left: the stock-recruit curve and estimated recruitments; right: bias adjustment.

The time-trajectories of recruitment and recruitment deviation are shown in Figure 8.13. Estimates of recruitments since 1989 are variable. They feature three periods with above average recruitment for at least three consecutive years, around 1993, 1999 and 2010 with other periods with several years of consecutive below average recruitment.

The base-case assessment estimates that current spawning stock biomass is 68% of unexploited stock biomass (SSB_0). The 2019 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 235 t (Table 8.9) and the long term yield (assuming average recruitment in the future) is 158 t (Table 8.11). Averaging the RBC over the three year period 2019-2021, the average RBC is 223 t and over the five year period 2019-2023, the average RBC is 212 t (Table 8.11). The RBCs for each individual year from 2019-2023 are listed in Table 8.9 for the base case.

Table 8.9. Yearly projected RBCs (tonnes) across all fleets under the 20:35:48 harvest control rules all assuming average recruitment from 2014 for the agreed base case with January spawning and improved fits to growth (sensitivity 17).

Year	RBC
2019	235
2020	223
2021	211
2022	201
2023	192

8.4.1.5 Discard estimates

Model estimates for discards for the period 2019-23 with the 20:35:48 harvest control rule are listed in Table 8.10 for the for the base case, with a range of 8 to 9 t.

Table 8.10. Yearly projected discards (tonnes) across all fleets under the 20:35:48 harvest control rules with catches set to the calculated RBC for each year from 2019 to 2023 for the base case.

Year	Discards
2019	8.6
2020	8.3
2021	8.1
2022	8.0
2023	7.9

8.4.2 *Sensitivity tests and alternative models*

Results of the sensitivity tests are shown in Table 8.11. As with the 2015 assessment, biomass depletion is not overly sensitive to changes in parameters, except for natural mortality. Estimating the growth parameters improves the fit to age data, but at the expense of producing a growth curve that does not seem biologically reasonable.

This assessment is also not very sensitive to the weighting placed on the length compositions. However it is more sensitive to changing weightings on age and CPUE data, with the increased weight on the CPUE leading to lower spawning biomass values (depletion 60%) and increased weight on the age data suggesting higher spawning biomass values (depletion 75%), suggesting that these data sources are in conflict. Despite these changes in biomass depletion, the changes in likelihood values with changes to the weighting of different data sources, are relatively small (Table 8.12). 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 being relatively large (in absolute terms) but in the opposite direction to changes in weighting in either the length, age or survey data.

The base case includes FIS abundance indices. Two sensitivities to inclusion of FIS data include removing all FIS data, and including FIS length frequencies and FIS abundance indices, and then estimating selectivity for the FIS. The changes to the biomass depletion are minimal in each case. This may be due to the relatively short FIS abundance time series, with only 5 data points, compared to 32 data points for the standardised CPUE index and 21 years of length frequency data and 17 years of conditional age-at-length data.

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

8.4.3.1 Quality and quantity of input data

Any results from this assessment should be treated with considerable caution given the limited data quality and data quantity available for this assessment and the quality of the trawl CPUE data (Sporcic and Haddon 2018a). Given several sudden (step) changes in this time series, it may not be a very reliable index of abundance and instead may be reflecting other changes in the fishery that are not incorporated in this model. Sporcic and Haddon (2018a) indicate that the vessel factor changed its influence from 2001 onwards, suggesting a change in the fishery at that time.

Note that the base case model fit to the index of abundance is poor (Figure 8.8), as is the fit to the FIS abundance indices (Figure 8.9), with additional CVs on these abundance series estimated within the model at 0.19 and 0.63 respectively. It is possible that the data are neither sufficiently representative nor sufficiently rich to adequately assess this stock, or that one or both are not good indices of abundance. Alternatively, there may be other unknown issues with the fishery dynamics and the stock dynamics that have not been adequately represented in this model.

8.4.3.2 Non-representative length data

Some length frequencies still appear to have a small amount of suspicious data, which may require further checking and quality control. The onboard length frequency in 2011 has a small outlying spike of fish of length 15cm or less, which may have been measured in cm but recorded in mm. At the other end of the spectrum, there is a spike of large fish in the 2014 length frequency, which was not present in the data in the 2015 assessment. This may represent additional large fish erroneously added to the database since 2015. Neither anomaly is having a large impact on the assessment but improving the data quality where there are potential recording errors would be preferable and would improve the overall fits to the data.

8.4.3.3 Likelihood profiles

Likelihood profiles were conducted on natural mortality, steepness and R_0 for the preliminary base case (Day and Castillo-Jordán, 2018a), and have not been repeated for the final base case. These likelihood profiles suggested that the fixed value for natural mortality was supported by the data, there was little information about steepness and the initial biomass is quite uncertain. The base case virgin spawning biomass is estimated at 2,743 t with the likelihood profile on R_0 suggesting 95% confidence intervals at around 2,000 t and 3,300 t.

8.4.3.4 Retrospectives

Preliminary retrospective analyses were also conducted on the preliminary base case (Day and Castillo-Jordán, 2018a). This analysis showed some patterns suggesting revisions to both the timing and the value of the lowest point in depletion, as additional recent data was removed, and revisions to the timing for when the spawning biomass begins to recover. Further analysis of these patterns would be useful in future.

Table 8.11. Summary of results for the base-case and sensitivity tests. Recommended biological catches (RBCs) are only shown for agreed base case model models (Case 17).

Case		SSB_0	SSB_{2019}	SSB_{2019}/SSB_0	RBC_{2019}	$RBC_{2019\text{-}21}$	$RBC_{2019\text{-}23}$	$RBC_{longterm}$
0	base case (*M* 0.15, *h* 0.7, 50% mat 24.5cm)	2,743	1,868	0.68	235	223	212	158
1	*M* 0.1	2,128	707	0.33				
2	*M* 0.2	5,688	5,814	1.02				
3	*h* 0.6	2,761	1,740	0.63				
4	*h* 0.8	2,734	1,969	0.72				
5	50% maturity at 22cm	2,922	2,053	0.70				
6	σ_R = 0.65	2,728	1,909	0.70				
7	σ_R = 0.75	2,762	1,821	0.66				
8	estimate growth	3,012	1,957	0.65				
9	wt x 2 length comp	2,744	1,840	0.67				
10	wt x 0.5 length comp	2,730	1,854	0.68				
11	wt x 2 age comp	2,763	2,074	0.75				
12	wt x 0.5 age comp	2,673	1,672	0.63				
13	wt x 2 CPUE	2,501	1,505	0.60				
14	wt x 0.5 CPUE	2,879	2,101	0.73				
15	no FIS	2,754	1,895	0.69				
16	include FIS length frequencies	2,741	1,889	0.69				

Table 8.12. Summary of likelihood components for the base-case and sensitivity tests. Likelihood components are unweighted, and cases 1-17 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 24.5cm)	475.19	-12.66	17.34	37.28	434.97	-1.98
1	*M* 0.1	14.91	-0.11	-3.13	-0.09	16.31	2.07
2	*M* 0.2	2.41	5.63	0.64	0.16	-4.88	0.20
3	*h* 0.6	-0.29	-0.55	-0.10	0.02	0.26	0.07
4	*h* 0.8	0.28	0.45	0.08	-0.02	-0.19	-0.05
5	50% maturity at 22cm	0.03	0.05	-0.01	0.00	-0.02	0.00
6	$\sigma_R = 0.65$	-0.23	0.36	0.10	-0.05	0.30	-0.95
7	$\sigma_R = 0.75$	0.28	-0.36	-0.12	0.05	-0.22	0.93
8	estimate growth	-23.30	0.05	-1.16	1.18	-22.73	-0.64
9	wt x 2 length comp	0.34	-0.34	1.04	-0.79	0.59	-0.16
10	wt x 0.5 length comp	0.37	0.14	-0.86	1.20	-0.11	0.01
11	wt x 2 age comp	1.52	1.28	1.50	0.46	-3.93	2.19
12	wt x 0.5 age comp	2.43	-1.52	-2.37	-0.14	7.94	-1.43
13	wt x 2 CPUE	1.81	-3.75	2.53	-0.24	2.90	0.41
14	wt x 0.5 CPUE	0.52	2.08	-1.22	0.20	-0.72	0.17
15	no FIS	-2.32	-2.07	-0.18	0.01	-0.15	0.07
16	include FIS length frequencies	12.99	-0.15	0.25	4.99	7.63	0.27

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). Franzis Althaus, Mike Fuller, Roy Deng, Claudio Castillo-Jordán, and Paul Burch (CSIRO) pre-processed the data. André Punt, Geoff Tuck, Sandra Curin-Osorio, Paul Burch, Malcolm Haddon, Robin Thomson and Miriana Sporcic are thanked for helpful discussions on this work. Ian Taylor, Richard Methot and Chantel Wetzel (NOAA Fisheries) are thanked for all the Stock Synthesis support and advice. Malcolm Haddon provided useful code for auto-tuning, Athol Whitten provided useful R code for organising plots.

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8.7 Appendix A

A.1 Fits to length composition, implied fits to age composition, and diagnostics for fits to conditional age-at-length data.

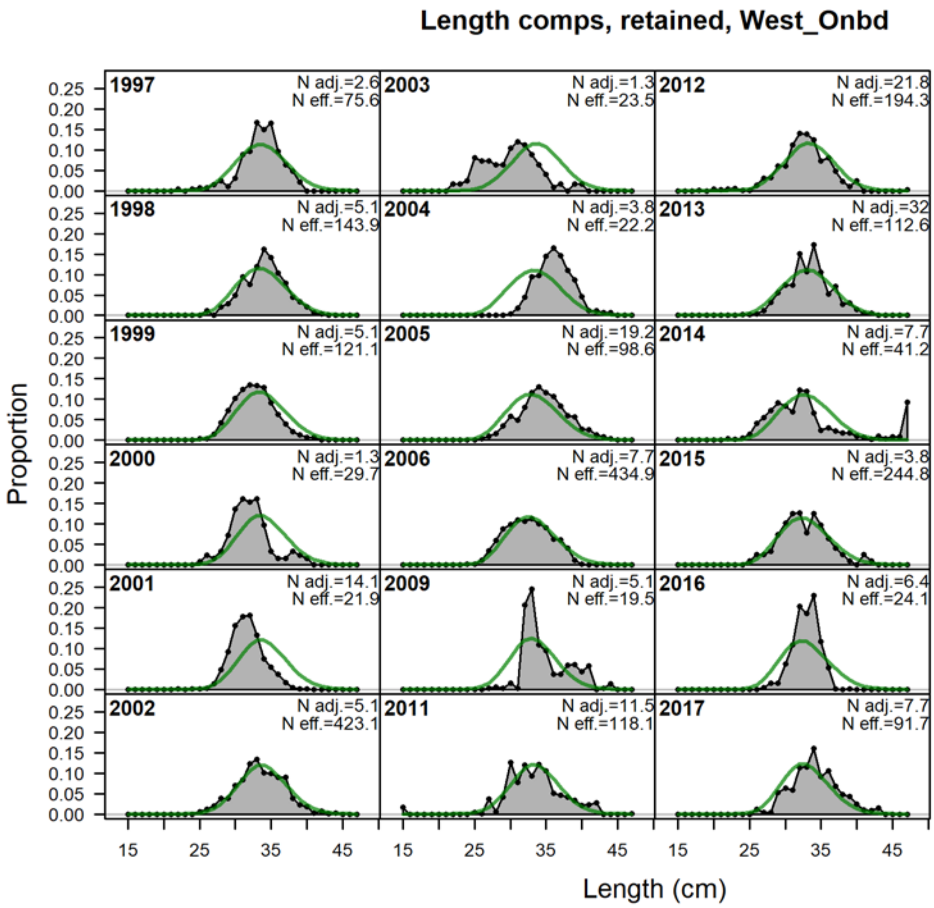

Figure A 8.1. Jackass morwong length composition fits: western trawl onboard retained.

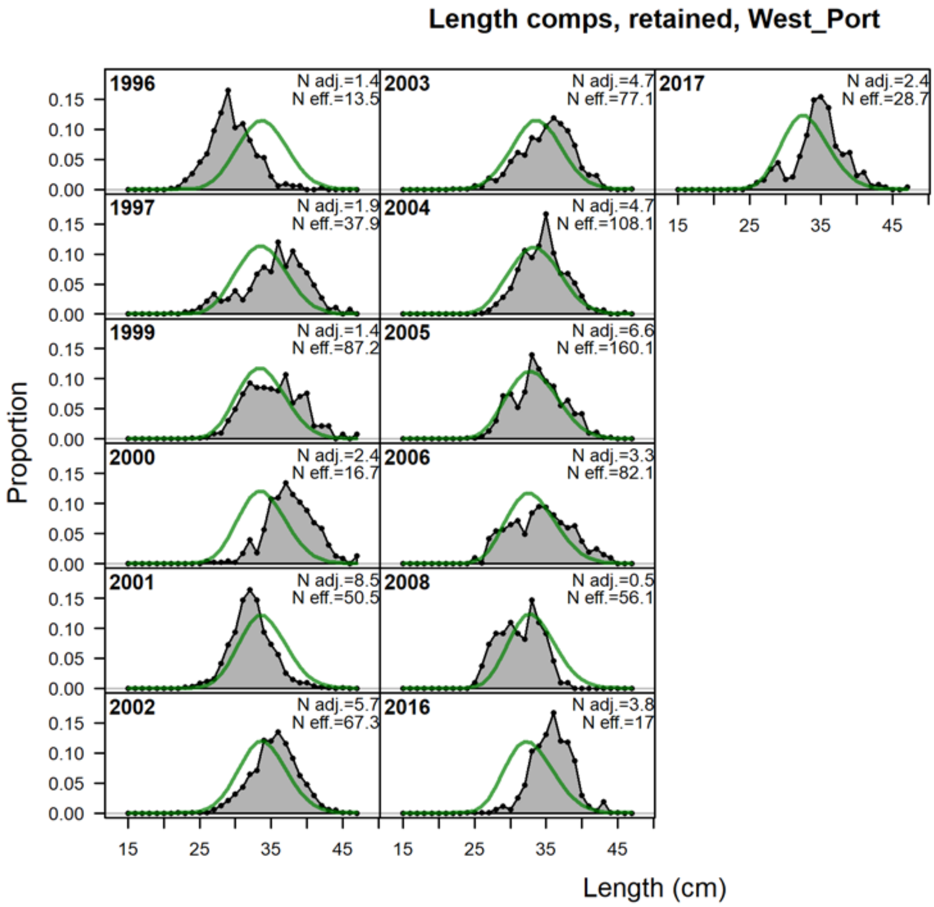

Figure A 8.2. Jackass morwong length composition fits: western trawl port retained.

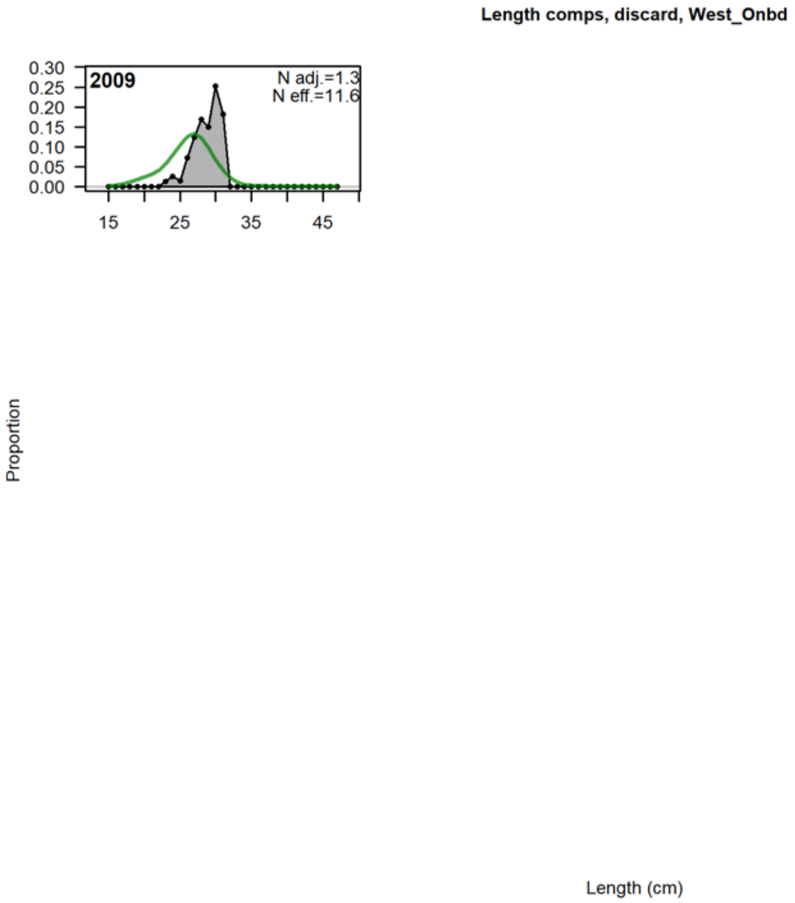

Figure A 8.3. Jackass morwong length composition fits: western trawl discarded.

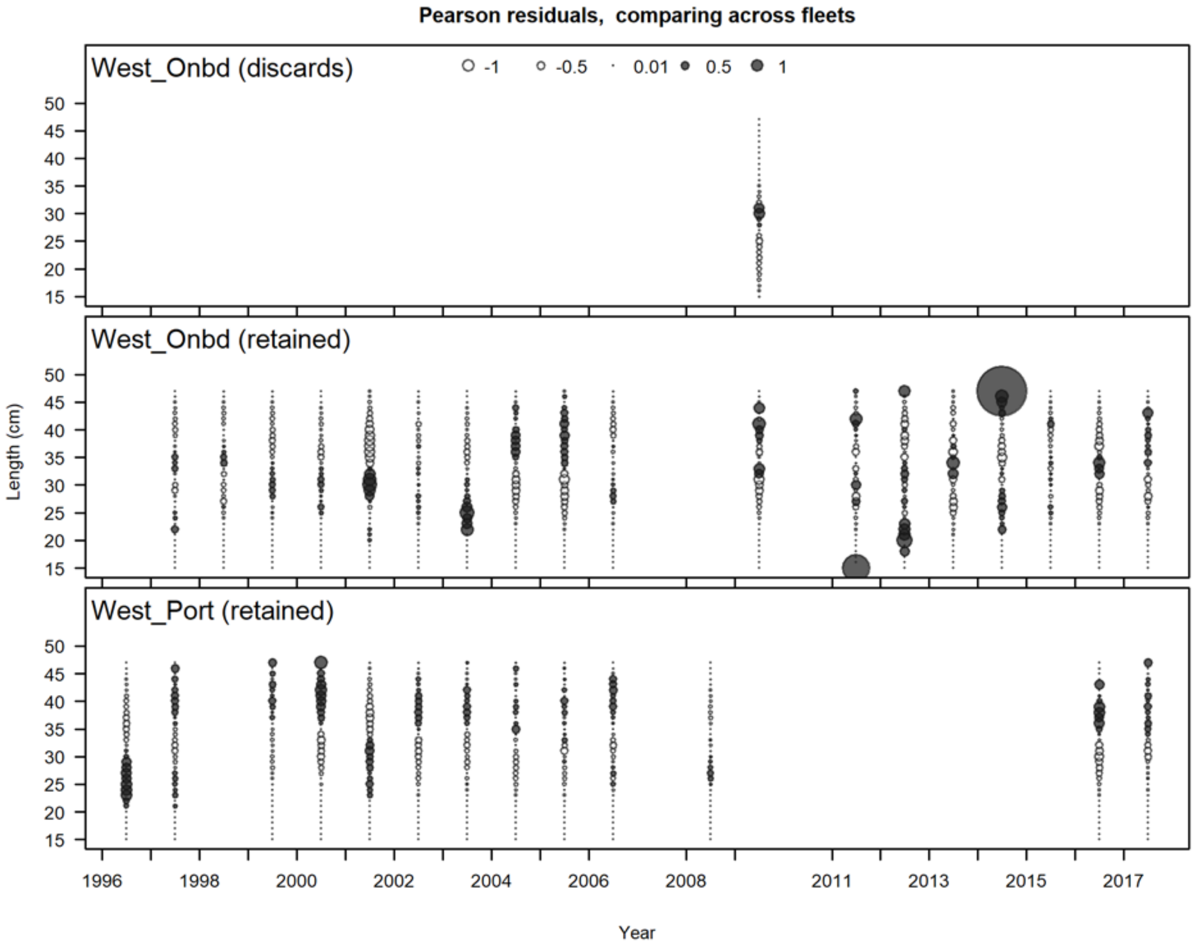

Figure A 8.4. Residuals from the annual length composition data for jackass morwong displayed by year and fleet for western trawl fleets (retained and discarded).

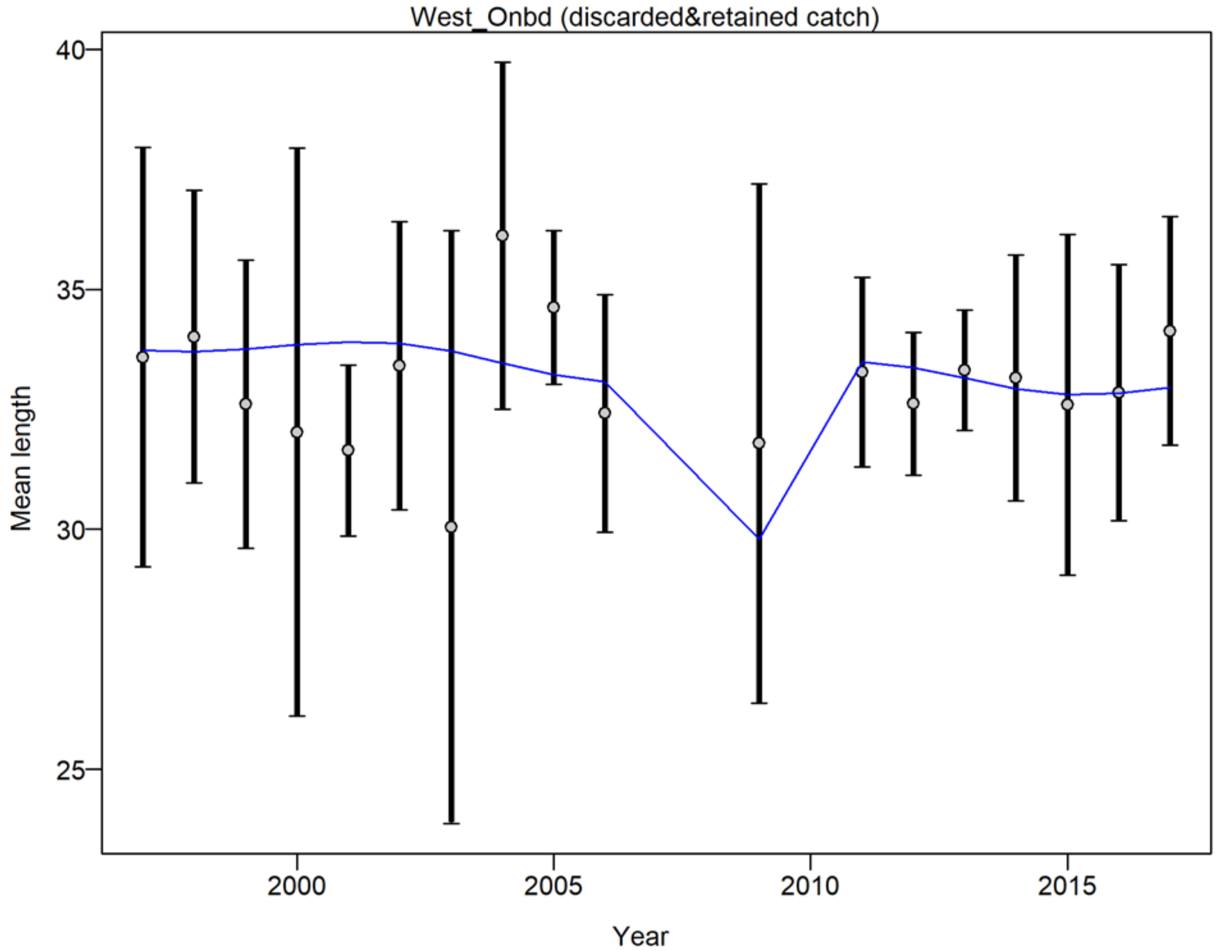

Figure A 8.5. Mean length for jackass morwong from western trawl onboard with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced.

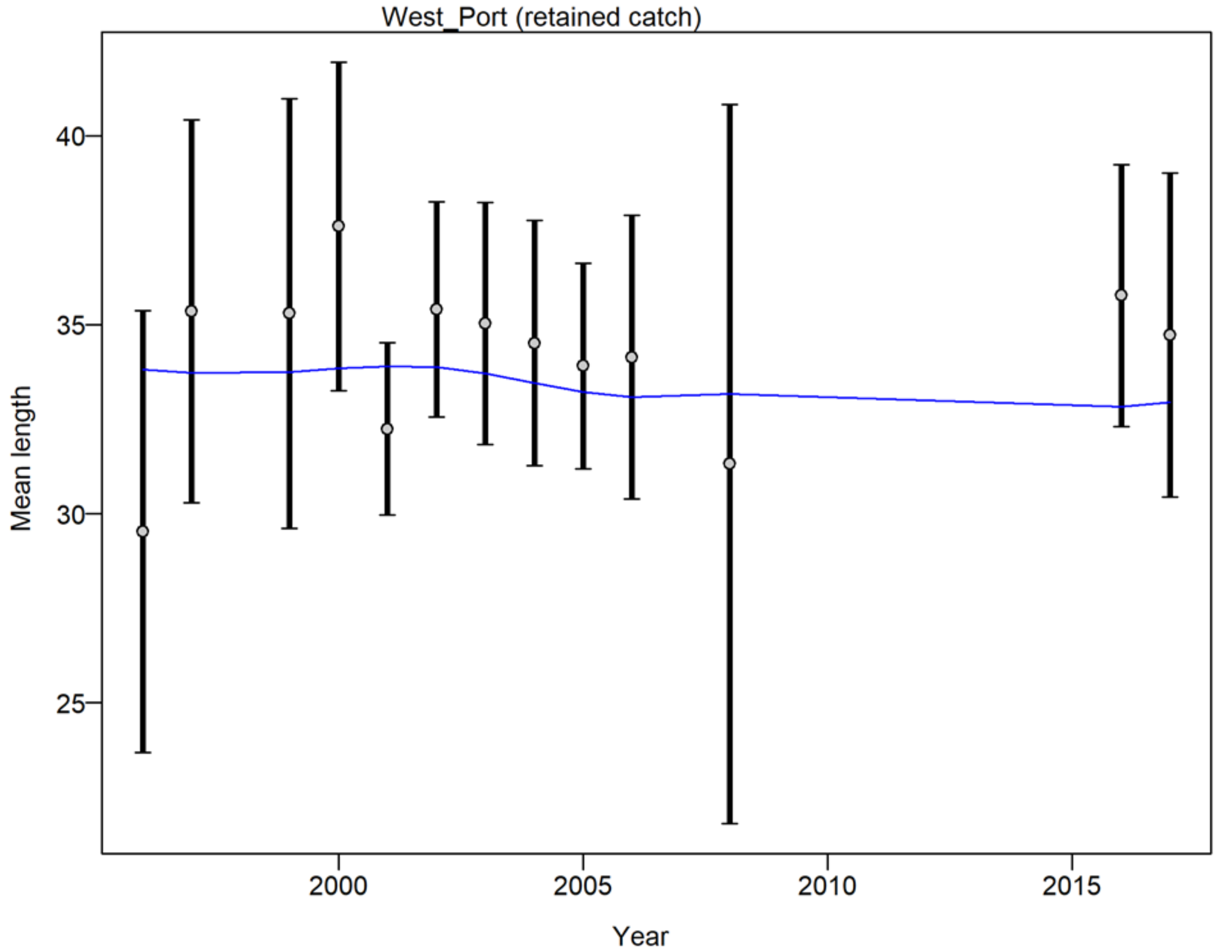

Figure A 8.6. Mean length for jackass morwong from western trawl port with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced.

Figure A 8.7. Implied fits to age compositions for jackass morwong western trawl onboard (retained).

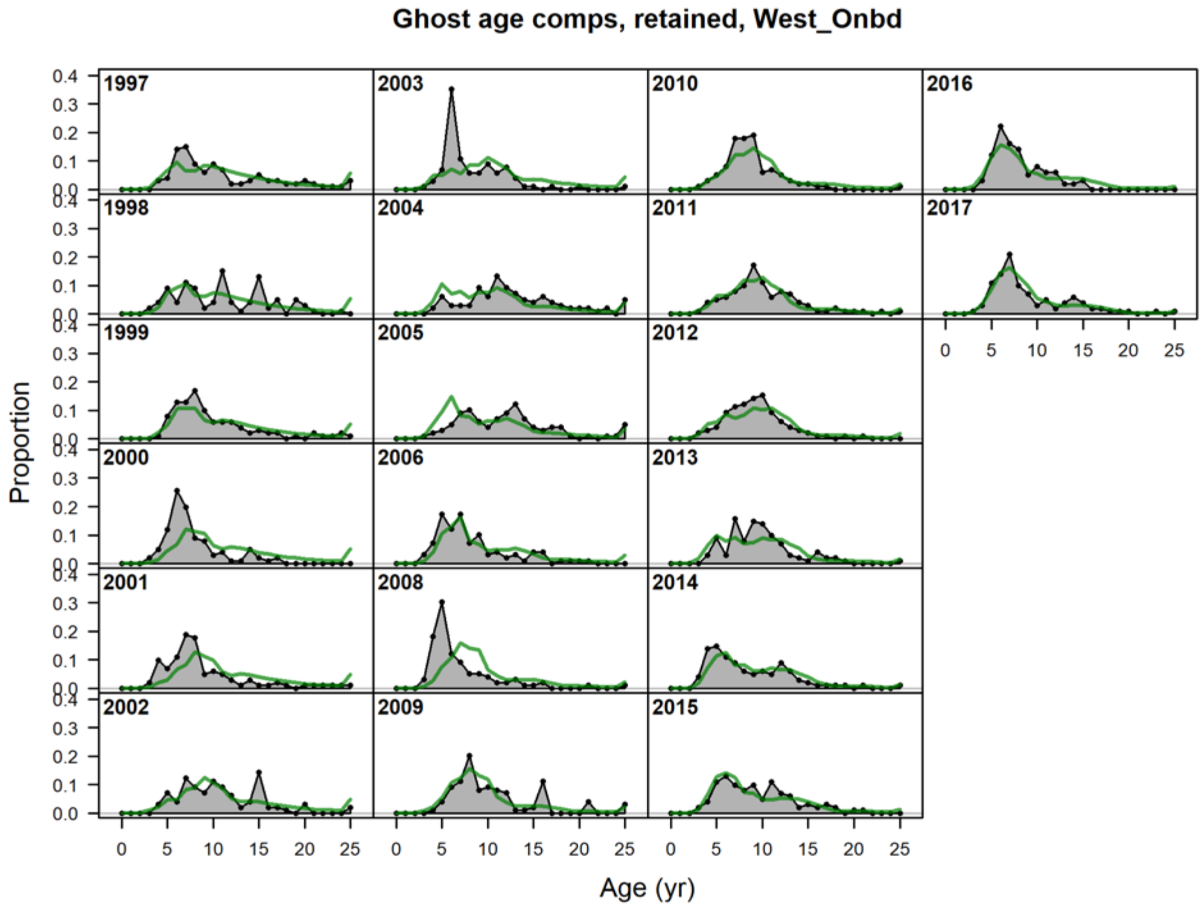

Figure A 8.8. Implied fits to age compositions for jackass morwong western trawl onboard (retained).

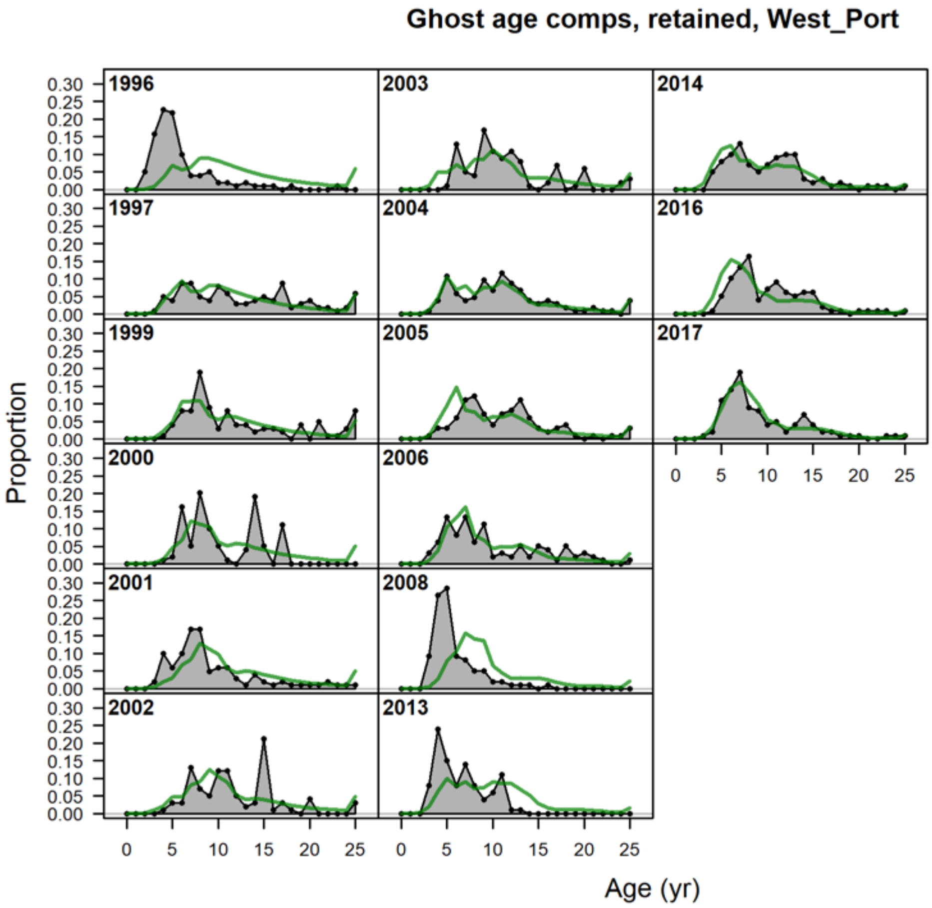

Figure A 8.9. Implied fits to age compositions for jackass morwong western trawl port (retained).

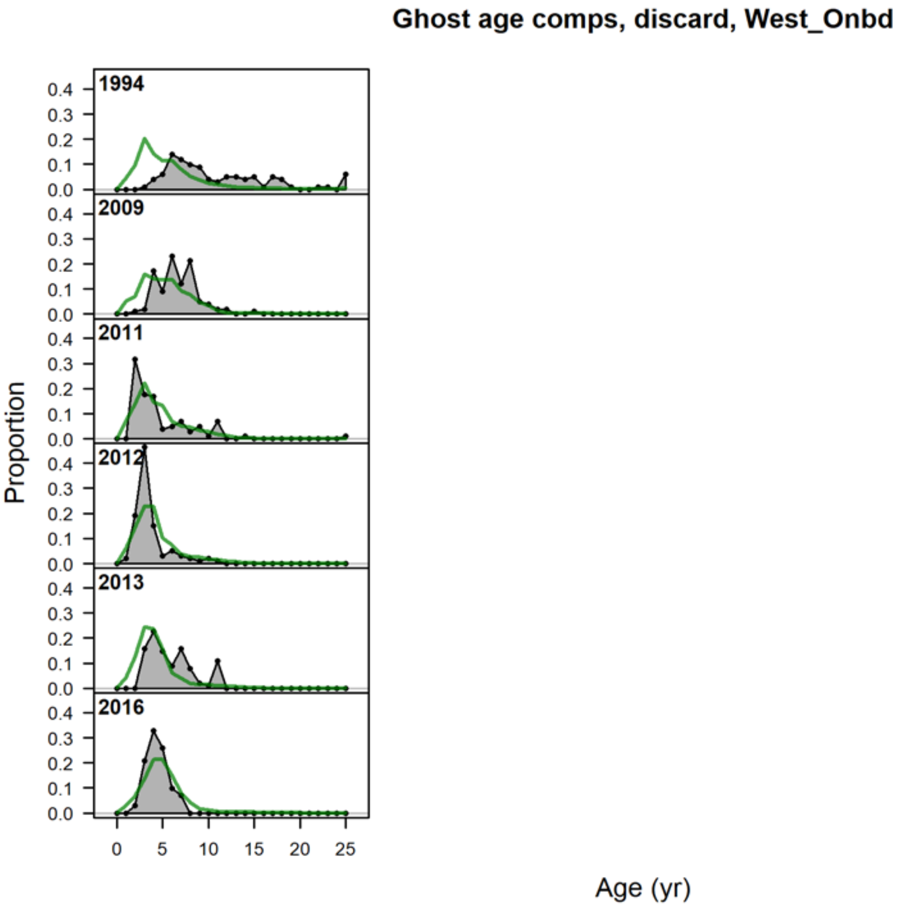

Figure A 8.10. Implied fits to age compositions for jackass morwong western trawl (discarded).

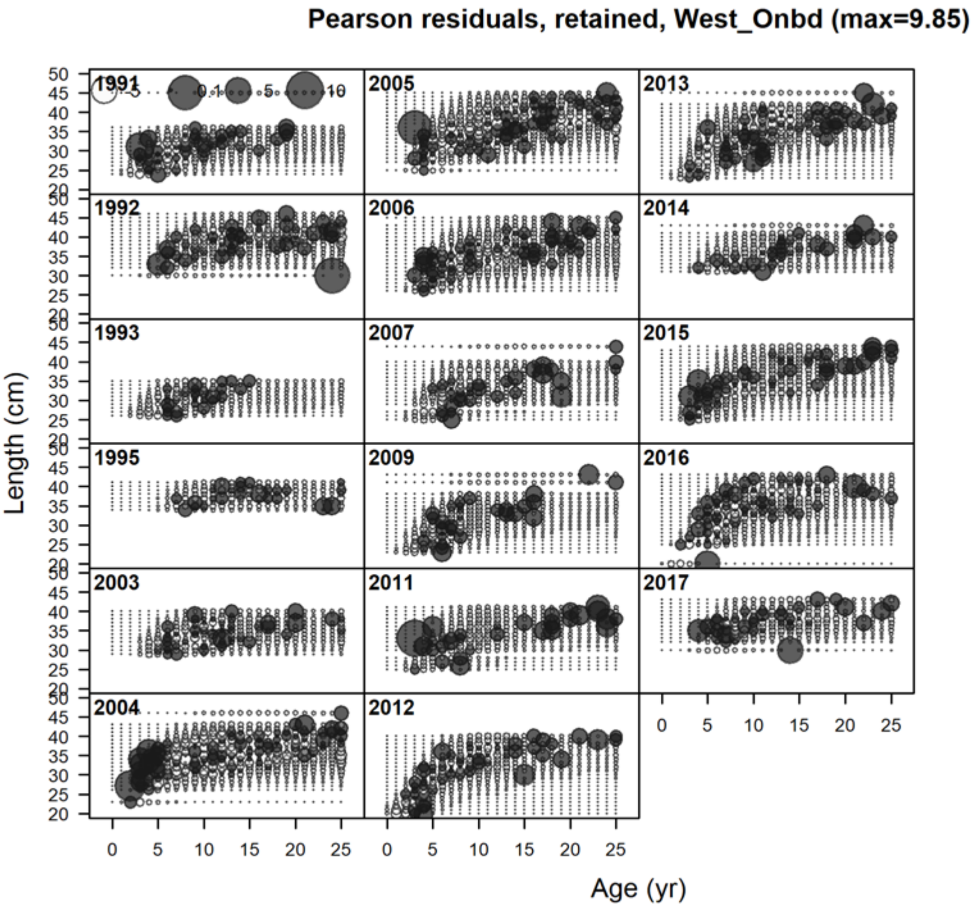

Figure A 8.11. Residuals from the fits to conditional age-at-length for jackass morwong western trawl onboard. This plot gives some indication of the variability in the age samples from year to year.

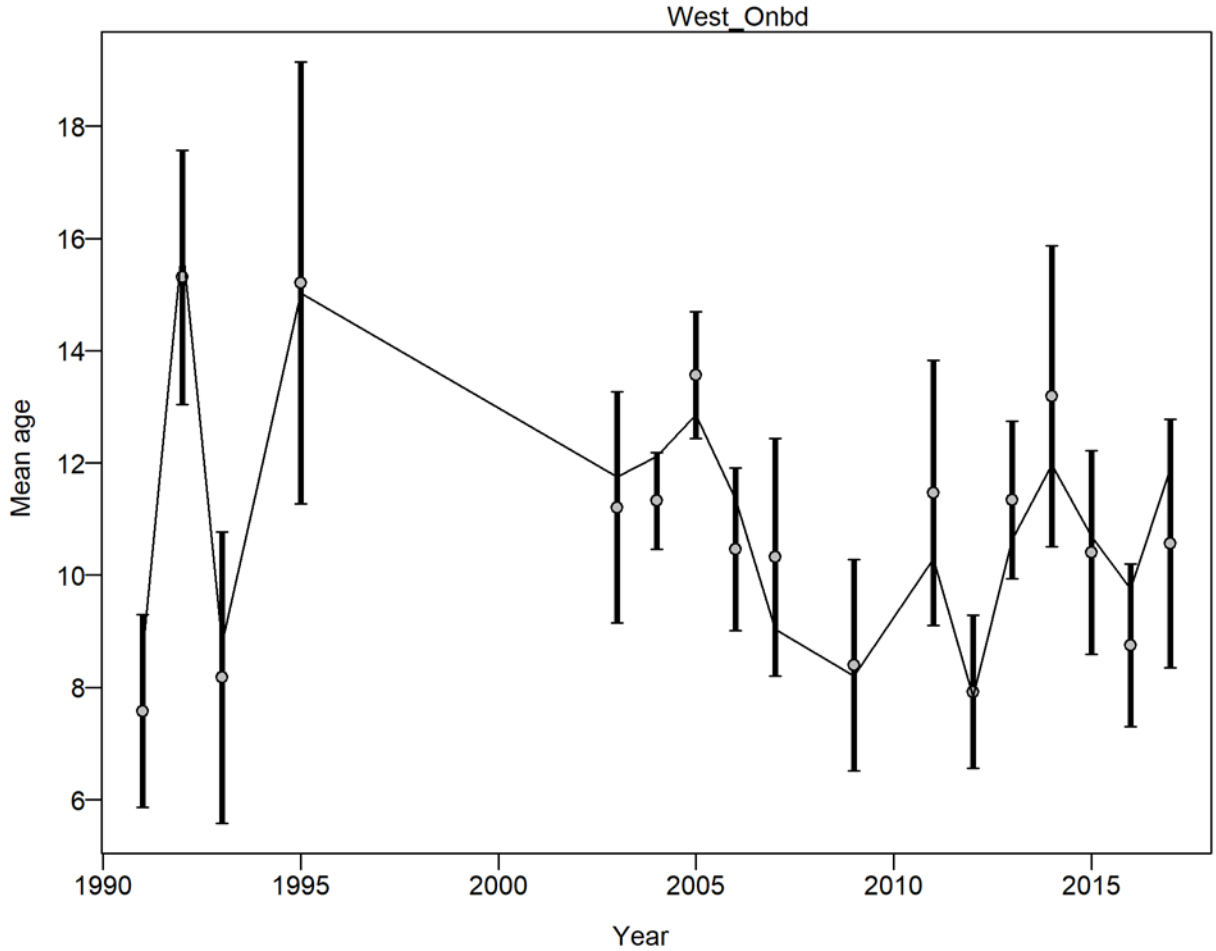

Figure A 8.12. Mean age (aggregated across length bins) for jackass morwong from western trawl with 95% confidence intervals based on current samples sizes. Punt data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced. Yearly variation in the data is shown in changes in mean age, which can be large over a short period (e.g. 1991-1996).