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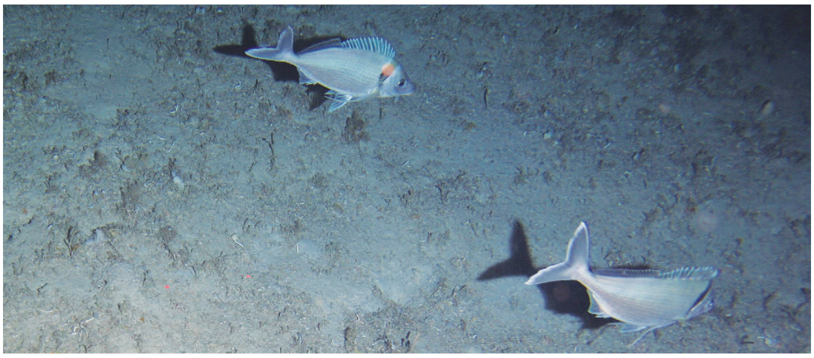
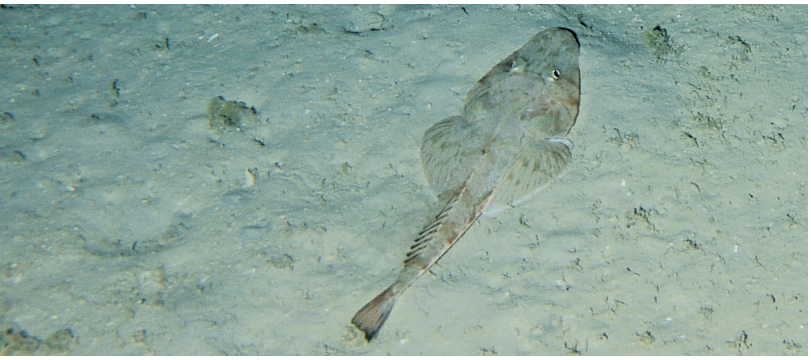
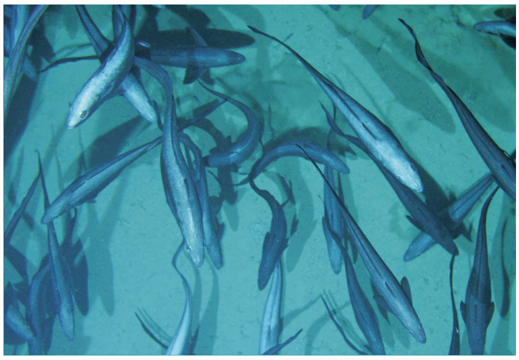
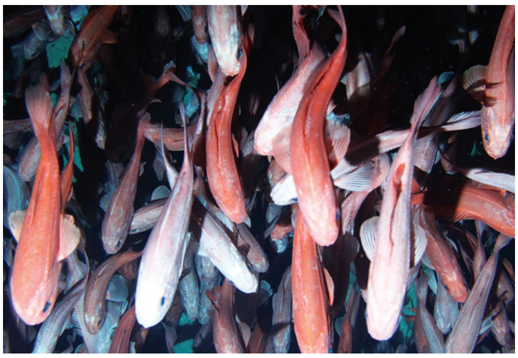
Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2015

PART 1









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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 2015. 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 2015.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2015

Part 1: Tier 1 assessments

G.N. Tuck
June 2016
Report 2014/0818

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2015 Part 1

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9. Assessment of the eastern stock of Jackass Morwong (*Nemadactylus macropterus*) based on data up to 2014

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9.1 Summary

This chapter presents the data and results from a Tier 1 assessment of the eastern stock of jackass morwong *Nemadactylus macropterus* in the Southern and Eastern Scalefish and Shark Fishery (SESSF). The assessment uses an age- and size-structured model implemented using the generalized stock assessment software package, Stock Synthesis (SS). The assessment includes data up to the end of the 2014 calendar year. Data include annual landings, catch rates, discard rates, and length/age compositions.

The 2015 assessment of the eastern stock of jackass morwong estimates the 2016 spawning biomass to be 36.5% of the 1988 equilibrium stock biomass. The female equilibrium spawning biomass in 1988 is estimated to be 3,977 t and in 2016 the female spawning biomass is estimated to be 1,451 t. In comparison, the last full assessment in 2011 estimated the 2012 spawning biomass to be 35% of the 1988 equilibrium stock biomass.

The 2016 recommended biological catch (RBC) under the 20:35:48 harvest control rule for the base-case model is 314 t for the eastern stock of jackass morwong. The long-term RBC is 407 t.

9.2 Introduction

An integrated analysis model, implemented using the generalized stock assessment software package, Stock Synthesis (SS) (Methot, 2011; Methot and Wetzel, 2013. V3.24U), was applied to the eastern stock of jackass morwong of the SESSF, with data from the 1915 to the 2014 calendar year (length and age data; age-error, catch rate series; landings and discard rates). The model fits directly to length frequencies and conditional age-at-length data.

The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, is outlined fully in the SS user manual (Methot, 2005; 2011) and is not reproduced here.

9.2.1 *The Fishery*

Jackass morwong 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). 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 between 1915 and 1957 reached a peak of about 2,000 t during the late 1940s (Table 9.3).

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 9.4), 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).

Since the introduction of management measures into the South East Fishery in 1985, the recorded catch of jackass morwong has ranged between 174 t (2014; east only) to 1,565 t (1989). Annual landings of jackass morwong in the eastern zones declined to around 1,000 t during the 1990s and are now (2014) at their lowest recorded levels (Table 9.5).

The catches have been constrained by the TAC since 2008. In 1992, an initial TAC was set at 1,500 t (Smith and Wayte, 2002). The agreed TAC was reduced to 1,200 t in 2000, to 960 t in 2001, increased to 1,200 t in 2006, and has decreased since then in response to stock assessments showing the stock to be at a low level. The 2009/10 and 2010/11 TAC of 450 t were set 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, 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).

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 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 (ET) – otter trawlers from NSW, eastern Victoria and Bass Strait (1986 – 2014)
2. Danish seine (DS) – Danish seine from NSW, eastern Victoria and Bass Strait (1986 – 2014)
3. Tasmanian trawl (TT) – otter trawlers from eastern Tasmania (1986 – 2014)
4. Steam trawl – steam trawlers (1915 – 1961)
5. Early Danish seine – Danish seine (1929 – 67). These landings may include a small amount of motor trawl catches.
6. Mixed – mixed Danish seine and diesel trawl catch (1968 – 85).

9.2.2 *Stock Structure*

Genetic studies conducted by the CSIRO have found no evidence of separate stocks 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).

9.2.3 *Previous Assessments*

This text is largely taken from the discussion of assessments by Wayte (2011). 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 using a combination of trawl surveys and VPA to be about 10,000 t in the mid-1980s (Smith, 1989). 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.

Recently, Klaer (MS) 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 biomass of 21,600 tonnes, with a 1962 depletion level of 71%.

The first formal quantitative assessment of jackass morwong was conducted by Fay (2004) during 2004 based on data to 2002. 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 rate in the late 1980s with catches during this period.

The 2004 assessment was updated in 2006 using the same software package 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 2006 spawning depletion 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 2007 recommended biological catches (RBCs) 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 2006 spawning depletion estimated to be 35% of the unexploited state.

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 current spawning stock biomass was 19% of unexploited stock biomass. This assessment was largely driven by the recent catch rate indices, which indicate 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 have largely been 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 has declined in recent years as fishing pressure has increased, but spawning stock biomass was still considerably higher than the target level. The long-term RBCs estimated for the western stock were comparable with the 2007 catch levels.

The 2008 base-case assessment for the eastern stock (Wayte and Fay, 2009) estimated that current 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 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 fish spawned two and three years before the end of the data will not be well-represented in the data, and this problem has been compounded in recent years by poor data collection. The eastern trawl CPUE index showed a slight increase, and the 2003 recruitment continued to be estimated to be above average – leading to a slight recovery in the current status of the stock to above the limit reference level (24%). Catch rates have 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 were not 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 is required before this model is considered plausible.

The 2010 base-case assessment for the eastern stock (Wayte, 2011) 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 RBC. The western stock assessment was considered to be increasingly uncertain, due to lack of recent data. 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 have 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).

9.3 Methods

9.3.1 Data

The data inputs to the assessment come from multiple sources: length (port and onboard) and age-at-length data from the trawl and Danish Seine fisheries, updated cpue series (Sporcic and Haddon, 2015), the FIS, the annual total mass landed and discard rates, and age-reading error. Data were formulated by calendar year (i.e. 1 Jan to 31 Dec).

9.3.1.1 Catch and discard rates

Both the landed catch tonnage and predicted discard tonnage for eastern jackass morwong from the six fleets are shown in Figure 9.1 and Table 9.3 to Table 9.5.

Landed catch data by fleet since 2011 were updated by scaling up logbook data using the ratio of total landed morwong catch to total logbook morwong catch. The catches for the years prior to 2012 were the same as those on which the 2011 assessment was based. Discard rates are provided in Table 9.6.

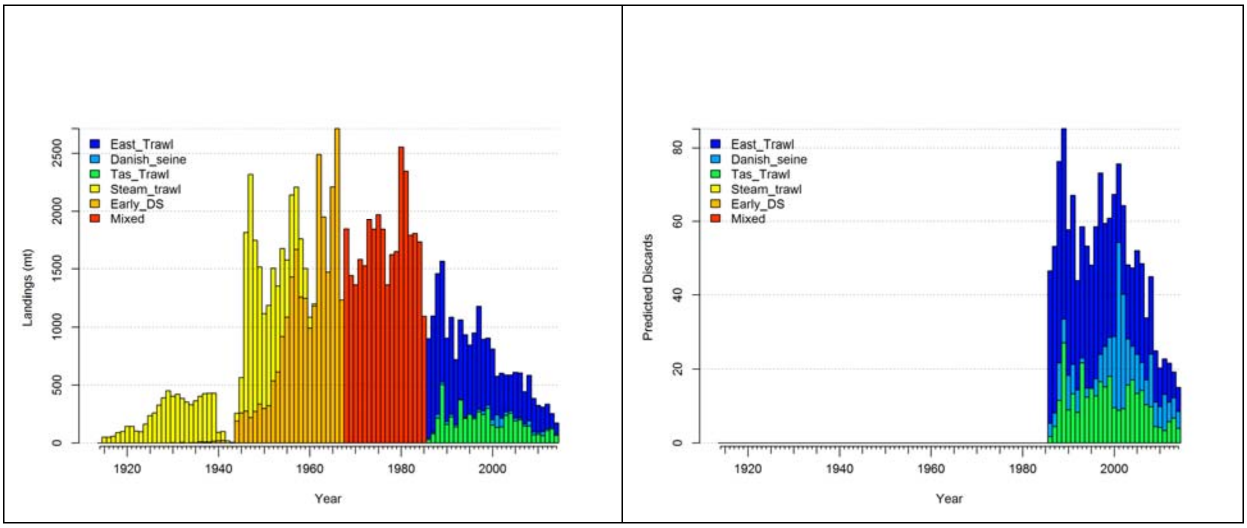
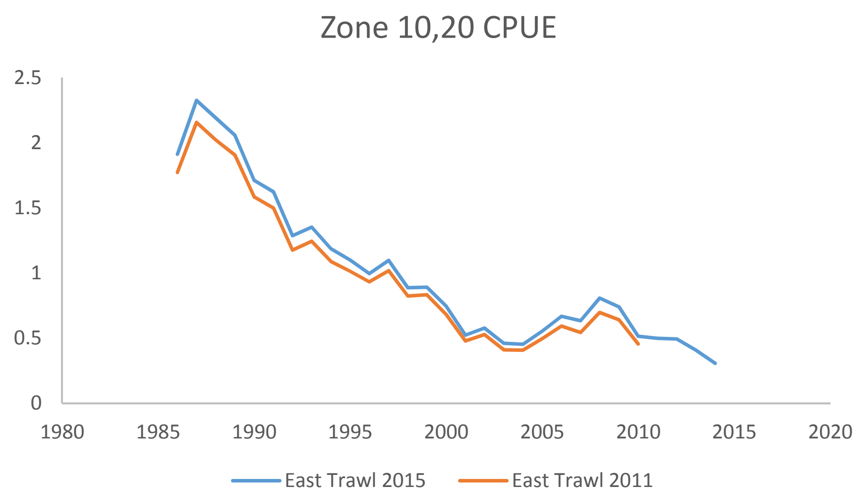


Figure 9.1. Landed morwong catches (mt) for all fleets by calendar year from 1915 and corresponding predicted discard mass (mt). Catches are shown as stacked bars.

CATCH RATES

Sporcic and Haddon (2015) provide the updated standardized catch rate series for the eastern stock of jackass morwong for the east trawl (Zones 10/20) and Tasmanian trawl (Zone 30) fleets (Figure 9.2; Table 9.7). After a substantial decline in catch rate from the mid-1980s to 2000, the catch rate for both regions levelled before showing an apparent further decline in recent years. The catch rate series from the updated analysis is similar to that from the last assessment in 2011 (Wayte, 2011).



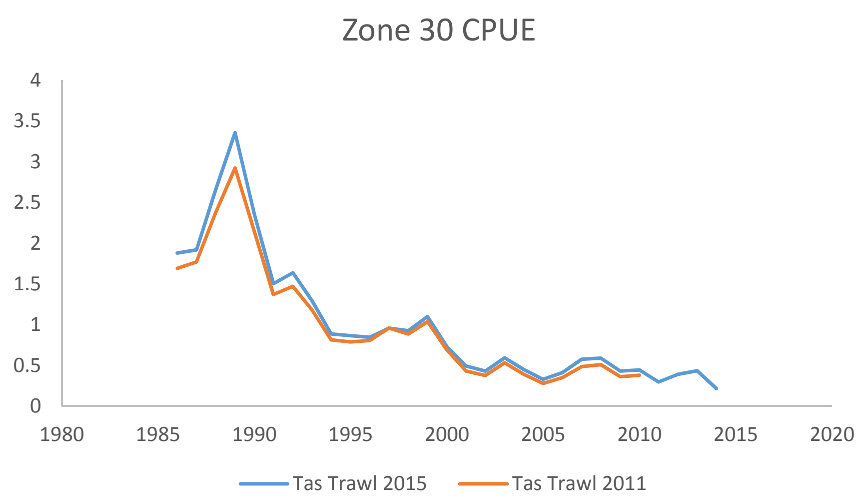


Figure 9.2. Eastern Jackass Morwong standardised CPUE for the NSW/Vic, and Tasmanian trawl fleets (Sporcic and Haddon, 2015). This figure shows a comparison between the series used in the 2011 assessment and that used in the current assessment (2015).

Wayte (2011) provides a standardized index of abundance for the steam trawl fleet from 1920 to 1957 (Table 9.8). Smith (1989) presented a standardized catch rate index for jackass morwong for 1948-66. This index standardizes for gear type during a period of overlap between the steam trawl fishery and the onset of Danish seine vessels. In the assessment model, this index is treated as a survey of the early Danish Seine fleet (Table 9.9). Smith (1989) also provided a standardized CPUE index for all vessels for the period 1977-84 (Table 9.10). This index corresponds to the mixed fleet.

9.3.1.2 Length frequencies and age data

Length and age data have been included in the model as length frequency data and conditional age-at-length data, separated by those collected in port and onboard commercial fishing vessels. Age composition data are included in diagnostic plots, but are not used directly within the fitting procedure (Appendix 2). The observed length and age data are shown in later figures (Figure 9.8 and Figure 9.9, and Appendices 1 and 2), along with the corresponding model predicted values. Table 9.11 to Table 9.15 show (by year) the number of fish sampled onboard and in port with corresponding counts of shots or trips for each fleet.

9.3.1.3 Age-reading error

Fish age (derived from reading otoliths) are assumed to be unbiased but subject to random age-reading errors. Standard deviations for aging error by reader have been estimated, producing the age-reading error matrix of Table 9.16 (A.E. Punt, pers. comm.).

9.3.1.4 Fishery independent survey (FIS) estimates

Abundance indices for jackass morwong for the FIS surveys conducted in 2008, 2010, 2012 and 2014 are provided in Knuckey et al. (2015). Indices from the FIS were re-estimated for Zones 10/20 and Zone 30 (Table 9.1). The length data from the FIS have not been included and the FIS is assumed to mirror their respective trawl fleets.

Table 9.1. FIS derived abundance indices of eastern jackass morwong with corresponding coefficient of variation (cv).

	2008	2010	2012	2014
Zone 10/20	6.92	6.52	3.55	1.24
c.v.	0.39	0.28	0.44	0.40
Zone 30	52.4	31.5	34.7	15.1
c.v.	0.30	0.32	0.31	0.36

9.3.2 ***The assessment model and biological parameters***

A single-sex stock assessment for jackass morwong was conducted using the software package Stock Synthesis (SS, version 3.24U). A single stock of jackass morwong was assumed for the eastern assessment, with an assumption of two recruitment regimes, or stock-recruitment relationships: the first from 1915 when the steam trawl fishery commenced, and the second, lower recruitment regime, from 1988 when recruitment became lower (Wayte, 2011; 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.

The assessment of the eastern stock modelled the impact of six fishing fleets on the morwong population. Selectivity was assumed to vary among fleets, but the selectivity pattern for each fleet was modelled as being time-invariant and modelled as a logistic function of length. Separate logistic functions were used for the selectivity ogives for each fleet. The two parameters of the selectivity function for each fleet were estimated within the assessment. Retention was also defined as a logistic function of length, and the inflection and slope of this function were estimated for those fleets where discard information was available, NSW/Vic trawl, Tasmanian trawl and Danish seine (not for base case model; see below). Retention was assumed to be 100% for the remaining fleets.

Initial model results indicated that the selectivity of the Danish seine fleet was not well estimated (flat) due to a conflict between the high values for discard rates (Table 9.6) and the larger than expected onboard discard lengths (from only three years). To approximate the large discard rates, the model seeks more small fish from the seine gear, leading to an unrealistic selectivity function and poor fit to discard lengths. As such, while a model with Danish seine onboard data and discard rates is kept as a sensitivity, the base case model adds the estimated discard mass into the landings for Danish seine (for this fleet only). Assumptions were made regarding the discard rates in years where there were not sufficient observations. Namely (i) pre-1994 the discard rate was small (0.07), and akin to 1994, (ii) from 1995 to 2001 a linear increase is assumed, and (iii) the discard rate is assumed to be 0.4 for years 2007-09, 2014; this is the average of years 2002-13. Adding the discard mass into landings assumes that discarding is largely market driven (as the length composition from the port data is then assumed representative of the discard and retained lengths for this fleet).

The natural mortality rate, M, was assumed to be constant with age, and also time-invariant. The rate of natural mortality for the base-case analysis was set to 0.15 yr^{-1} in accordance with previous assessments (Table 9.2).

Recruitment was assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterized by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, h. For the eastern assessment, the recruitment shift was modelled by estimating two R_0 values: one at the start of the fishery in 1915, and the other at the start of the lower recruitment regime in 1988. Steepness for the base-case analysis was set to 0.7 for both recruitment periods, in accordance with previous assessments (Wayte, 2011). Deviations from the average recruitment at a given spawning biomass (recruitment deviations) were estimated for 1945-2011. Deviations were not estimated prior to 1945, because there is insufficient data prior to this date to estimate them (Wayte, 2011).

Recruitment deviations are estimated to 2011, as the recruitment signal from young fish must have appeared in the catch in sufficient numbers. The value of the parameter determining the magnitude of the process error in annual recruitment, σ_R, was set equal to 0.40 for the eastern assessment.

A plus-group was modelled at age 25. Growth of morwong was assumed to be time-invariant - that is, there has been no change over time in the mean size-at-age, with the distribution of size-at-age being determined from the fitting of the growth curve within the assessment using the age-at-length data. No differences in growth by gender are modelled, as the stock was modelled as a single-sex. The parameters of the length-weight relationship are the same as those used in previous assessments ($a=1.7\times10^{-5}$, b=3.031). These values are taken from Smith and Robertson (1995).

All sample sizes for port and onboard length frequency data less than 100 were not included in the model fitting procedure as they were deemed to be insufficient samples. As the appropriate sample size for length frequency data is probably more related to the number of shots sampled for onboard data and trips for port data, these values are used as the initial effective sample sizes, with a cap of 200 and 100 respectively for onboard and port length frequency data. The length frequency data would be given too much weight relative to other data sources if the numbers of fish measured were used. The historical length data (Sydney Fish Market, Blackburn), where only numbers of fish were available (not trips) were converted to a trip measure by dividing the number of fish sampled for the historical series by the average number of fish sampled per trip for the eastern trawl port lengths (123 fish per trip). The sample sizes for the six fleets (with port and onboard lengths separately fit for East Trawl, Danish Seine and Tas Trawl) were also individually tuned according to the method TA1.8 outlined in Francis (2011).

The assessment presented at the September RAG (Tuck, Day and Wayte, 2015) largely tuned to the onboard length data for the Danish seine fleet. This led to a considerably poor fit to the port length data. However, the port data consists of more annual records of length compositions (14) compared to the onboard data (3 retained, 3 discard length composition records). As stated in Francis (2011), having a small number of records can lead to poor performance of the tuning algorithm. As a consequence, the assumed base case assessment tunes to port length data for Danish seine and assumes a low weighting value for Danish seine onboard lengths (0.1). We recognize that even though there may be more annual records of port length composition for Danish seine, they may not (or may) be representative of the population lengths. It is not possible to distinguish this at this stage. As such, due to the known poor performance of the tuning algorithm when few length records exist, we chose to emphasize the Danish seine port length data in preference to the onboard data.

The CVs of the CPUE indices for the East and Tas Trawl fleets were initially set at a low value (0.1) to encourage a fit to the abundance data, before being re-tuned to the model-estimated standard errors after tuning to length and age data (see the tuning procedure below).

The values assumed for some of the (non-estimated) parameters of the base case models are shown in **Table 9.2**.

Table 9.2. Parameter values assumed for some of the non-estimated parameters of the base-case model.

Parameter	Description	Value
M	Natural mortality	0.15
σ_r	Initial c.v. for the recruitment residuals (re-tuned)	0.6
h	“steepness” of the Beverton-Holt stock-recruit curve	0.7
x	age observation plus group	25 years
a	allometric length-weight equations	1.7×10^{-5}
b	allometric length-weight equations	3.031
l_m	Female length at 50% maturity	24.5cm
l_s	Female length maturity slope	1cm

9.3.3 *The tuning procedure*

The tuning procedure used (Andre Punt pers comm.) was to:

1. Set the CV for the commercial CPUE value 0.1 for all years (set those for the FIS to the estimated CVs) (this relatively low value is used to encourage a good fit to the abundance data)
2. Simultaneously tune the sample size multipliers for the length frequencies and ages using Francis weights for the LFs and Francis B (the larger of the Francis A and B factors, Francis 2011). Iterate to convergence.
3. Adjust the recruitment variance (σ_r) by replacing it with the RMSE and iterating to convergence (keep altering the recruitment bias adjustment ramps at the same time)

4. Weight the commercial CPUE and FIS abundance indices by replacing these with the relevant variance adjustment factors. Iterate to convergence;
5. Reweight the age data using the Francis A adjustment factor once (no iterating);
6. Repeat steps 3 and 4. Finish.

9.4 Results and Discussion

9.4.1 Base case parameter estimates and model fits

A comparison of the biomass trajectories and recruitment estimates from the last full assessment in 2011 (Wayte, 2011) with an assessment with updated data to 2014 and a similar model structure showed negligible deviation over the overlapping years, indicating consistency in the data and consistent results across updated assessment platforms (Stock Synthesis) (Tuck, Day and Wayte, 2015). This work was presented to the Shelf RAG in September 2015 and is not repeated here.

A listing of the data is shown in Figure 9.3, and the growth, length-weight, and selectivity functions for the various fleets are shown in Figure 9.4 and Figure 9.5. Fits to the data are shown in Figure 9.6 to Figure 9.11 (and the Appendix).

Selectivity is assumed to be logistic for all fleets (Figure 9.4). 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 base-case model do not vary greatly between fleets, with Danish seine showing selection of somewhat small fish.

Figure 9.5 shows the estimated growth curve for the eastern stock of jackass morwong. All growth parameters are estimated in this model. The estimated values for each parameter are *Lmin*=22.0 cm (length at age 3), *Lmax*=35.2cm (length at age 20), *K*=0.217, cv of growth = 0.104.

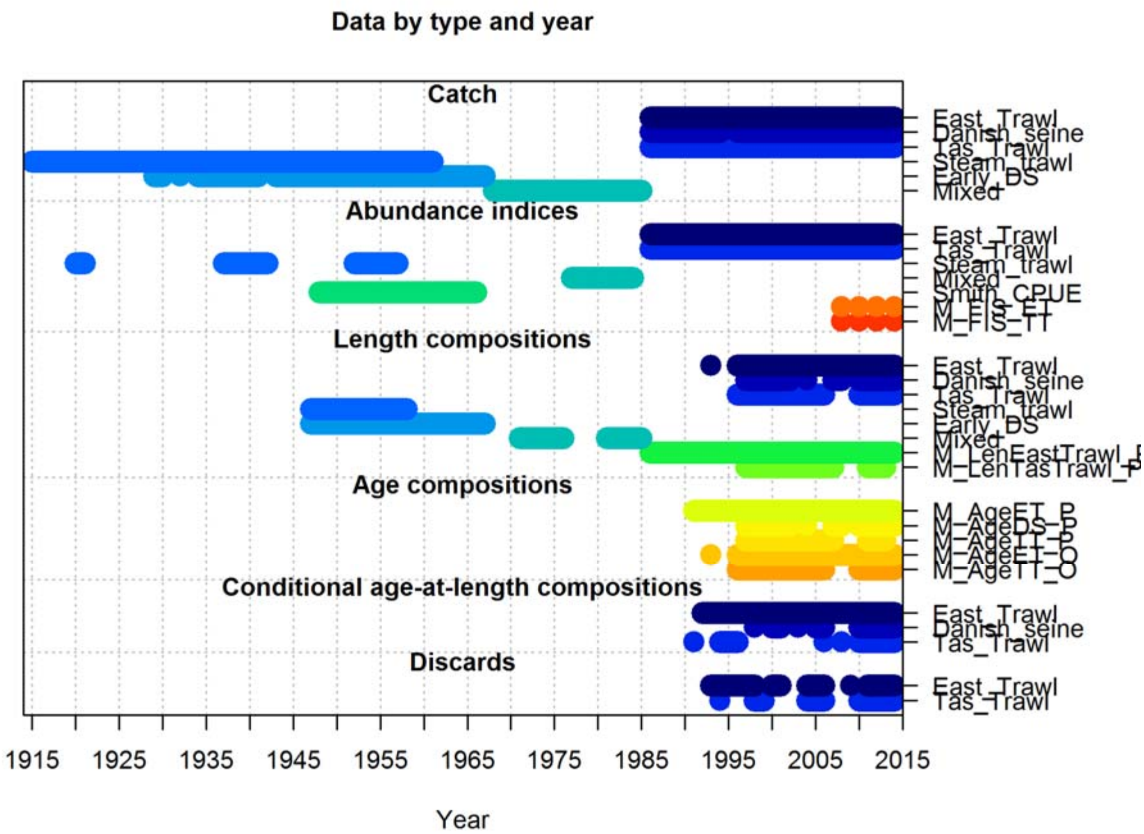


Figure 9.3. The various data types by fleet for the assessment of the eastern stock of jackass morwong.

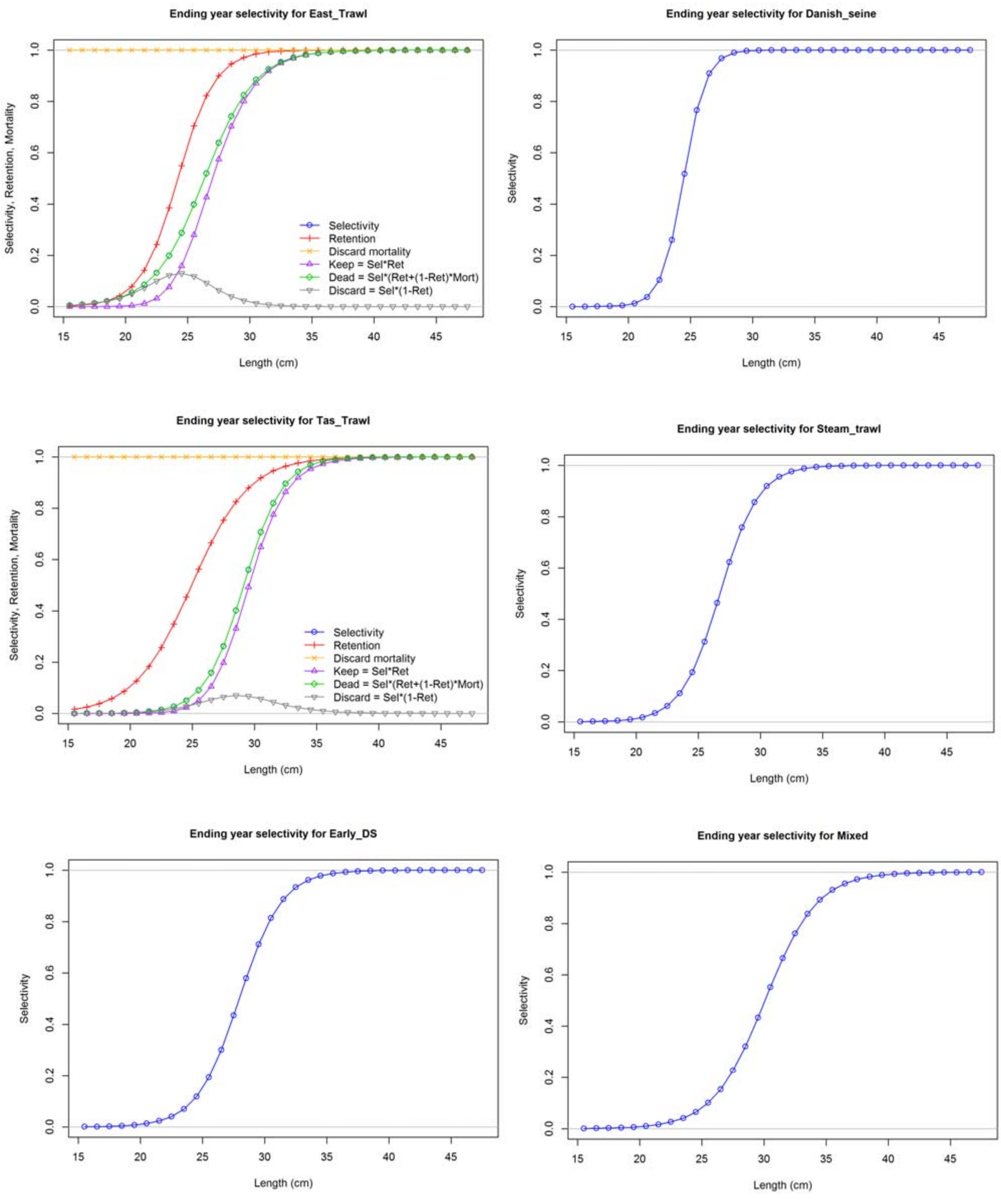


Figure 9.4. Selectivity (blue circle; overlayed by green in the ET and TT plots) and retention functions (red) for the six fleets

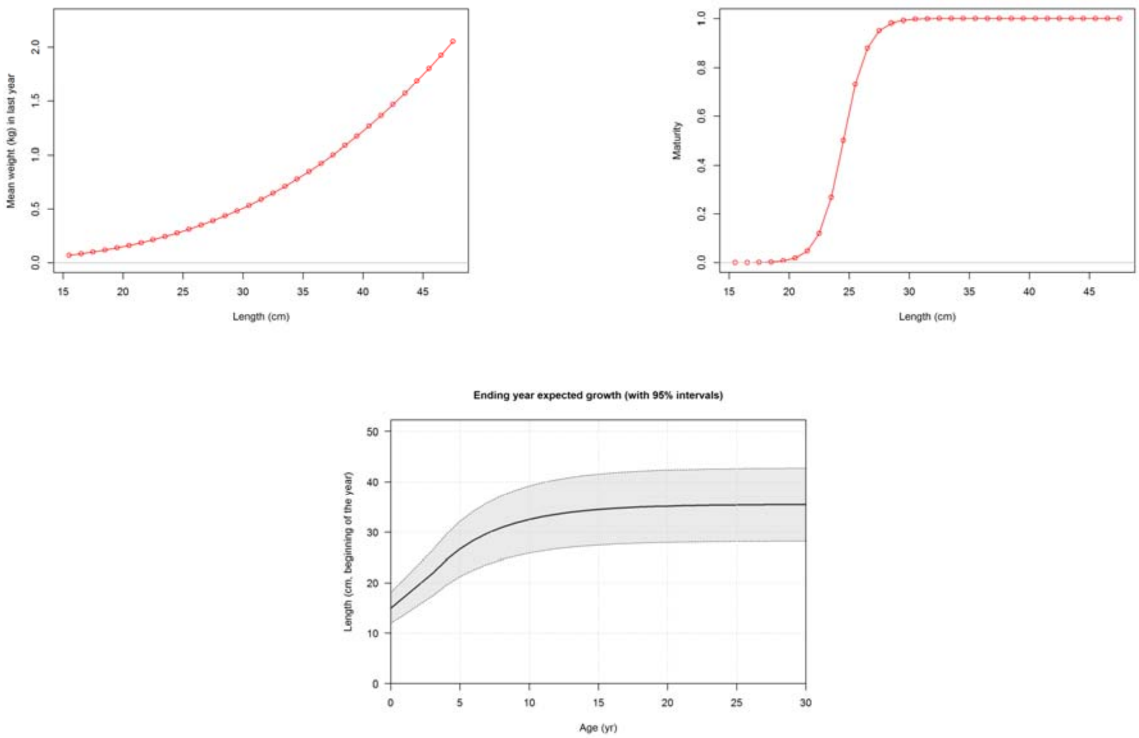


Figure 9.5. The length-weight (left), maturity ogive (right) and length-age relationships (bottom) for the eastern jackass morwong base case assessment.

9.4.2 *Fits to the data*

The fits to the catch rate indices (Figure 9.6 and Figure 9.7) and discard rates are reasonable. The catch rate indices for the earlier fleets show little change in stock abundance. The mixed fleet catch rate index shows that abundance is relatively constant over 1977 to 1984, but the model has estimated that stock is declining. The fit to the east trawl fleet catch rates is adequate. For the Tasmanian trawl fleet the model is unable to mimic the initial hump, but otherwise provides a good fit. While the point estimate of the abundance index from the FIS for eastern morwong has generally declined since 2008, the model, when combined with all other data sources, produced a relatively stable abundance trajectory in comparison.

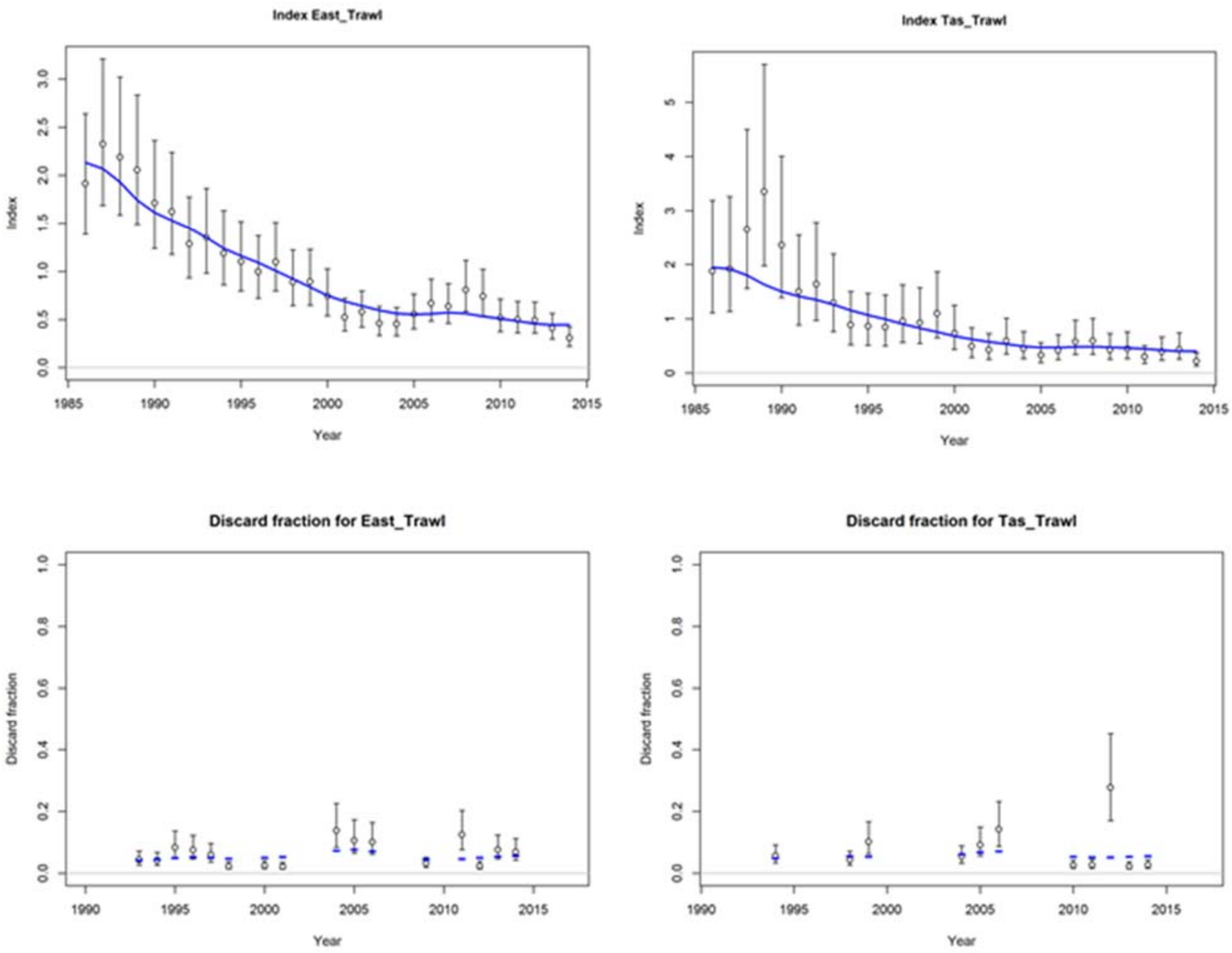


Figure 9.6. Fits to the standardized CPUE for the eastern and Tasmanian trawl fisheries, with the associated discard rates and fit. The fit to the Danish seine discard rates is also shown.

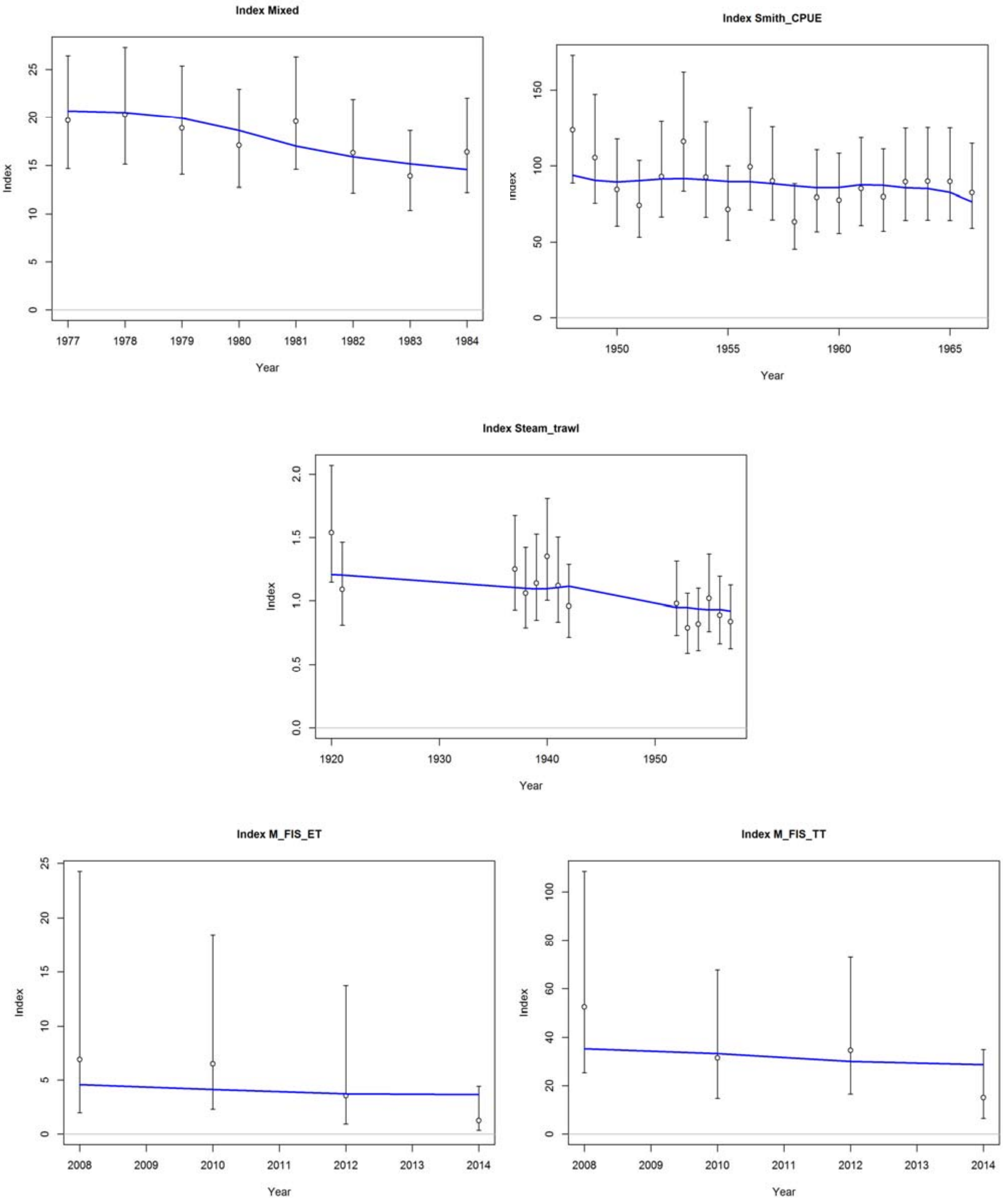
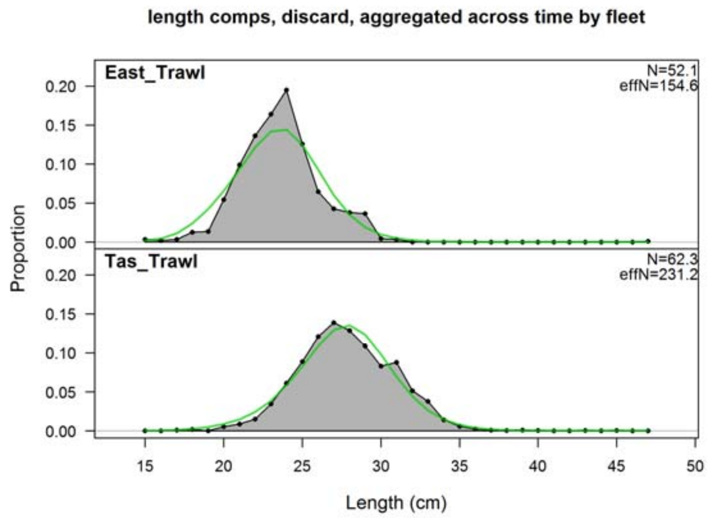


Figure 9.7. Fits to the index data for the mixed fleet, the steam trawl fleet, the Smith CPUE index and the FIS abundance indices from the east (Zones 10/20) and Tas (Zone 30).

The base-case model is able to mimic the retained length-frequency distributions adequately (Figure 9.8; Appendix 1), with perhaps the exception of the recent Danish seine fleet, for which sample sizes are very small and on which the model places little emphasis. The fits to the historical steam trawl and early Danish seine fleets are better than those for the more recent data. The number of fish measured for the historical data is generally very high, which leads to smoother observed distributions when compared to the recent fleets, which can have considerable year to year fluctuations in length distributions (Appendix 1). The fits to the annual discarded length compositions are variable (Appendix 1). This is not surprising, as the observed discard length frequencies are quite variable from year to year, and sample sizes are small.



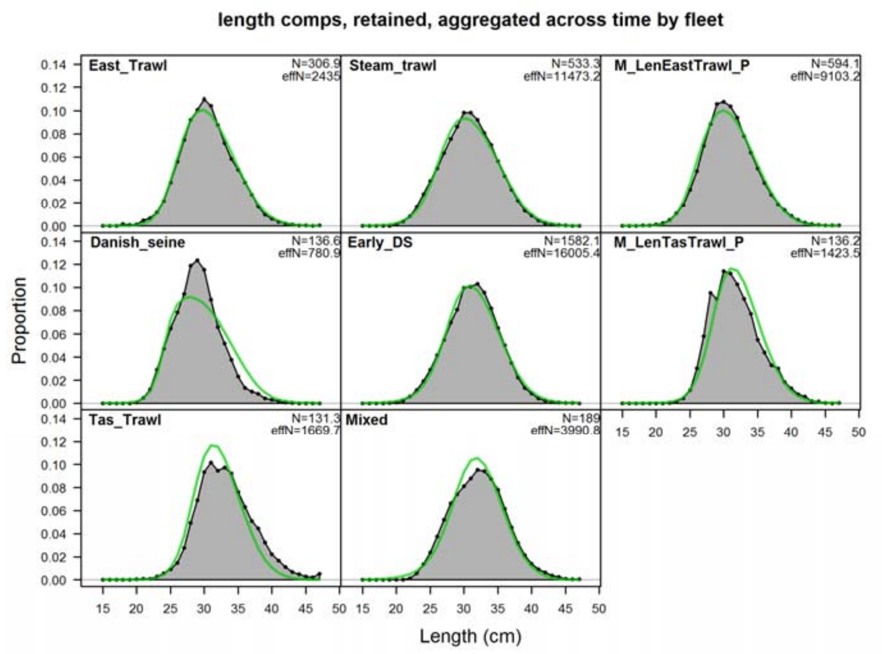


Figure 9.8. Fits to the discard and retained length by fleet (P = Port, Danish_seine is also Port).

The implied fits to the age composition data are shown in Figure 9.9 and Appendix 2. The age compositions were not fitted to directly, as age-at-length data were used. However, the model is capable of outputting the implied fits to these data for years where length frequency data are also available, even though they are not included directly in the assessment. The model mimics the observed age data moderately well. Diagnostics showing fits to mean lengths from using the Francis tuning algorithm are shown in Appendix 3. These indicate reasonable fits to mean lengths across all fleets.

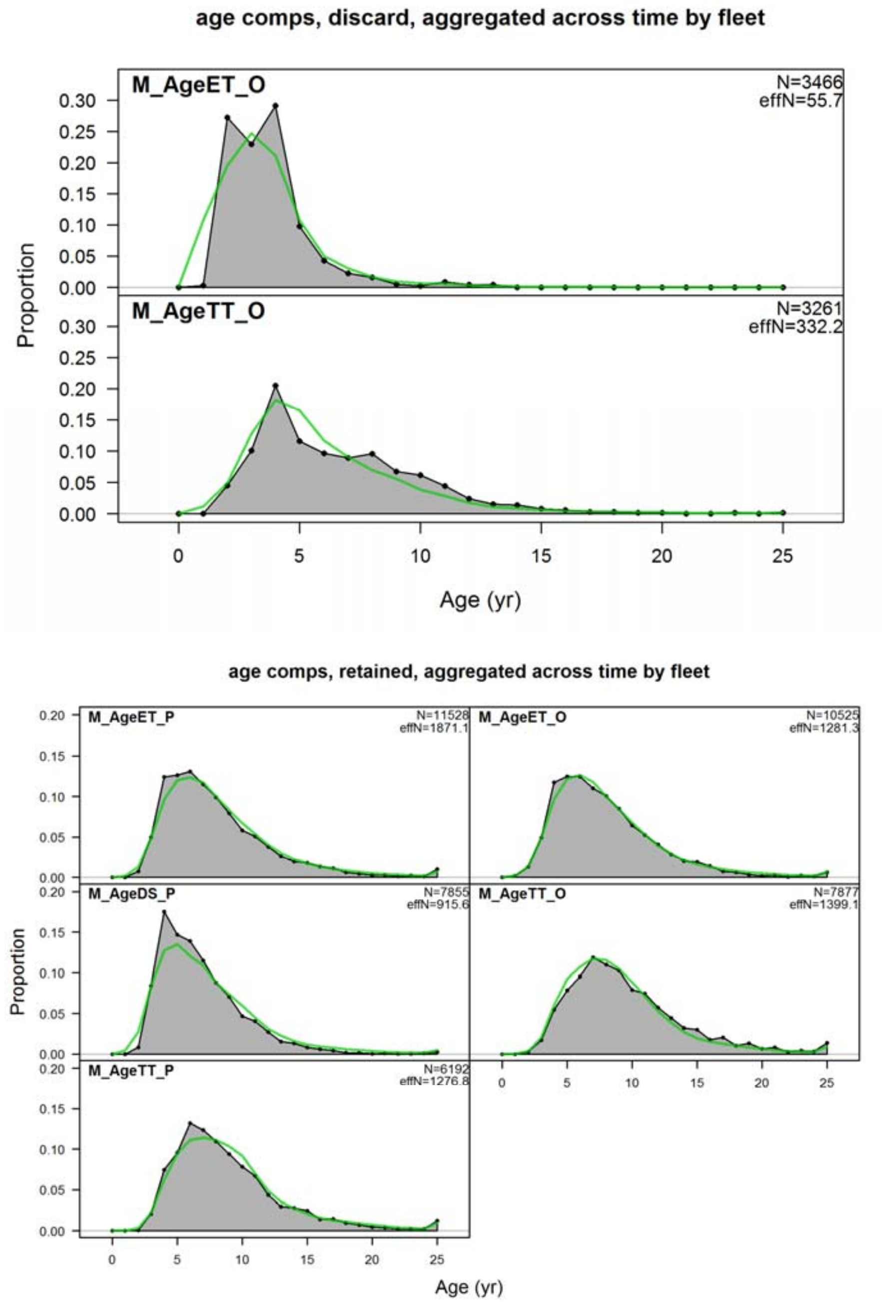


Figure 9.9. Fits to the implied age compositions for discard and retained (P = Port, O= onboard)

9.4.3 *Assessment outcomes*

Figure 9.10 shows the trajectory of spawning stock depletion. The current spawning biomass values in this plot are compared to the equilibrium spawning biomass corresponding to the lower recruitment regime starting in 1988. The stock declines slowly from the beginning of the fishery in 1915, fluctuates during the 1940s, 50s and 1960s, before a sharp decline in the mid-1960s, after a period of low recruitments and high catches. The recovery in the early 1970s is driven by the very high recruitment around 1968 (Figure 9.11), which appears to be well-supported by both the age and length data. After this, the stock continues to decline until the early 2000s when it levels off, in response to reduced catches.

The time-trajectories of recruitment and recruitment deviation are shown Figure 9.11. The model now has two stock-recruitment relationships. The recruitment deviations under the recruitment shift model no longer show serial correlation in recent years. Even under the productivity shift model introduced in 2011, the recruitment series shows low values in recent years (with 5 of the last 7 years well below expected recruitment from the stock-recruitment curve; Figure 9.11 middle).

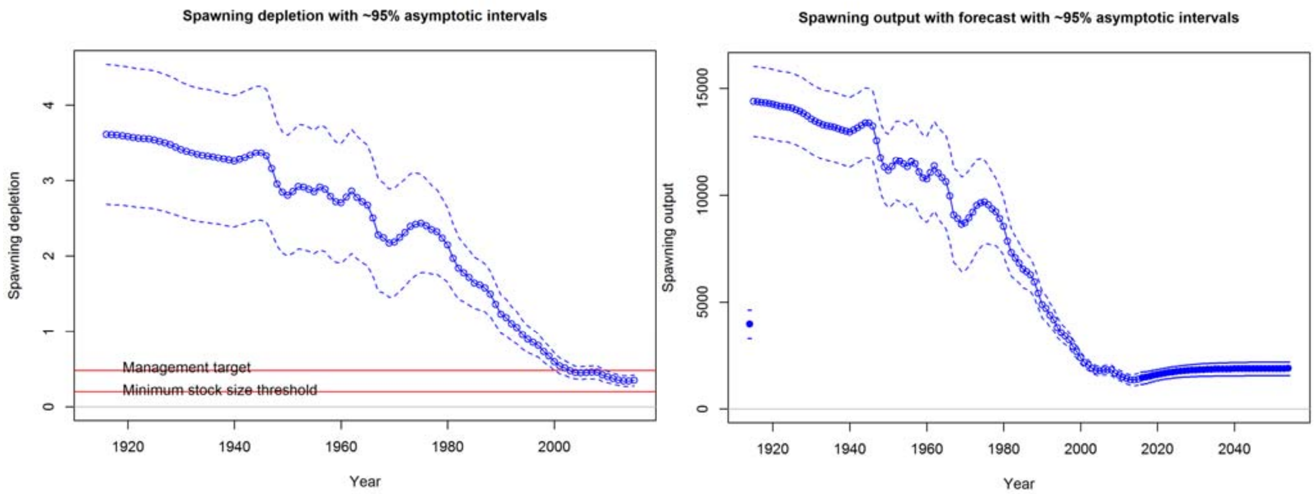


Figure 9.10. Time trajectories of spawning biomass depletion (left) and spawning biomass (right) with 95% confidence intervals for the base case assessment of the eastern stock of jackass morwong.

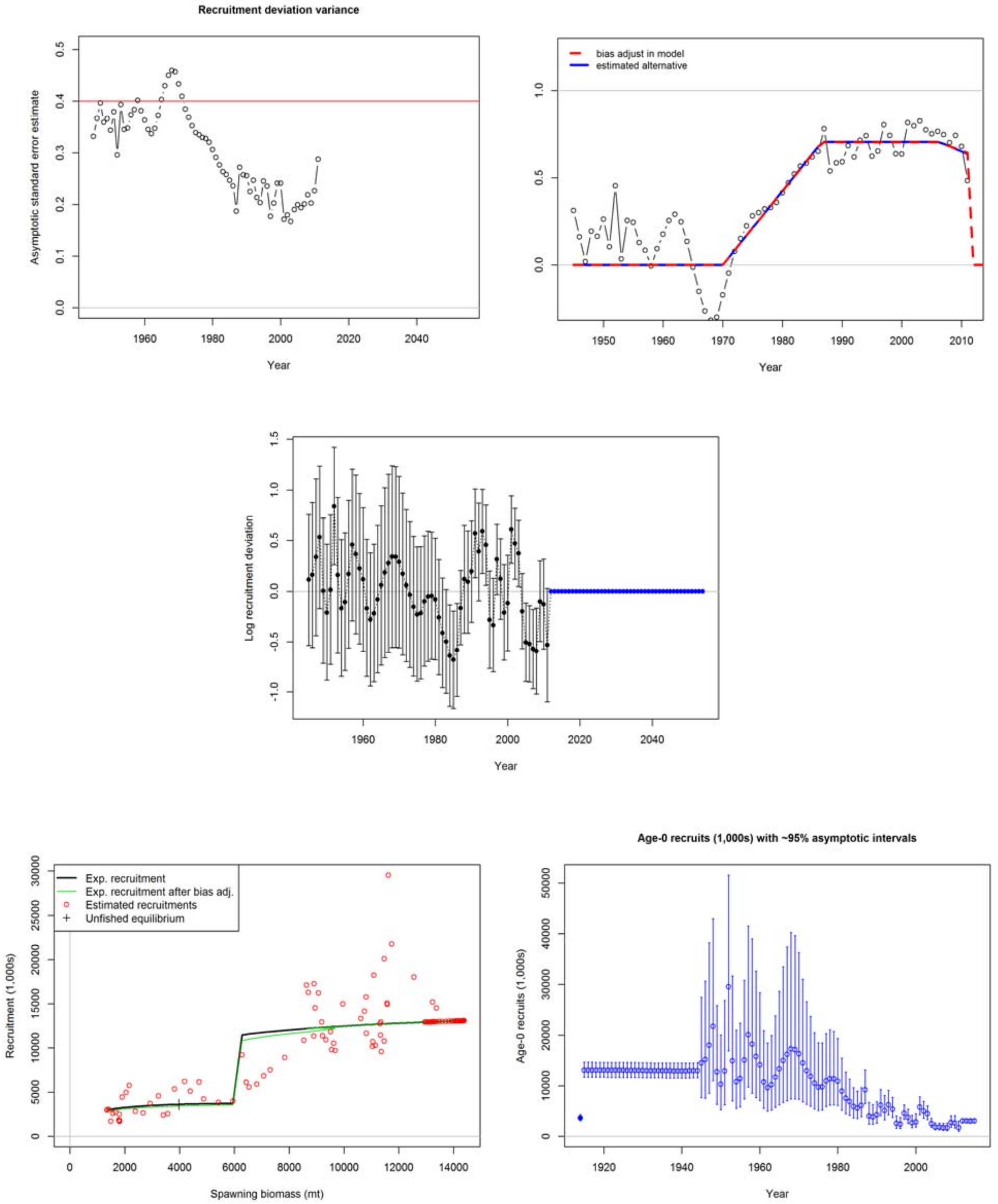


Figure 9.11. Diagnostics for recruitment, the stock–recruitment relationship and annual estimates of recruitment numbers with confidence intervals.

9.4.4 *Discussion*

The 2015 assessment of the eastern stock of jackass morwong estimates the 2016 spawning biomass to be 36.5% of the 1988 equilibrium stock biomass (projected assuming 2014 catches in 2015). The female equilibrium spawning biomass in 1988 is estimated to be 3,977 t and in 2016 the female spawning biomass is estimated to be 1,451 t. In comparison, the last full assessment in 2011 (Wayte, 2011) estimated the 2012 spawning biomass to be 35% of the 1988 equilibrium stock biomass.

The 2016 recommended biological catch (RBC) under the 20:35:48 harvest control rule for the base-case model is 314 t for the eastern stock of jackass morwong. The long-term RBC is 407 t. The 10 year projected RBCs and depletion levels are provided in Table 9.17.

9.4.5 *Sensitivities*

Results of the sensitivity tests are shown in Table 9.18. This table indicates that biomass depletion is not overly sensitive to changes in parameters or weightings, except for natural mortality. Two additional model structures were tuned where the onboard Danish seine data and discard rate data remained in the model. These models have the length at 50% selectivity for Danish seine (i) fixed at 20cm or (ii) estimated. In each case the spawning biomass depletion and 2016 estimated RBC are very similar (Table 9.18). This is not overly surprising as the Danish seine catch data generally comprise only a small part of the overall removals for this fishery.

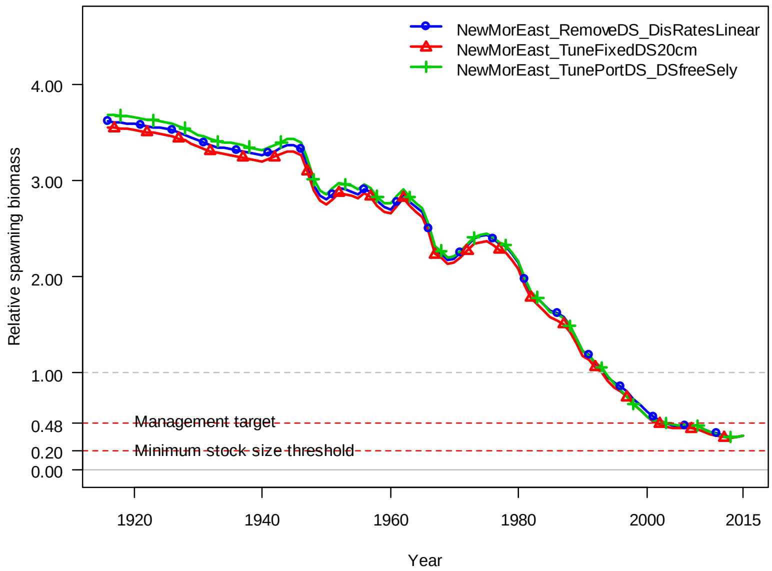


Figure 9.12. The relative female spawning biomass trajectory for the base case model (NewMorEast_RemoveDS_DisRatesLinear; blue) and two other models where the length at 50% selectivity for Danish seine is either fixed at 20cm (red) or estimated (green).

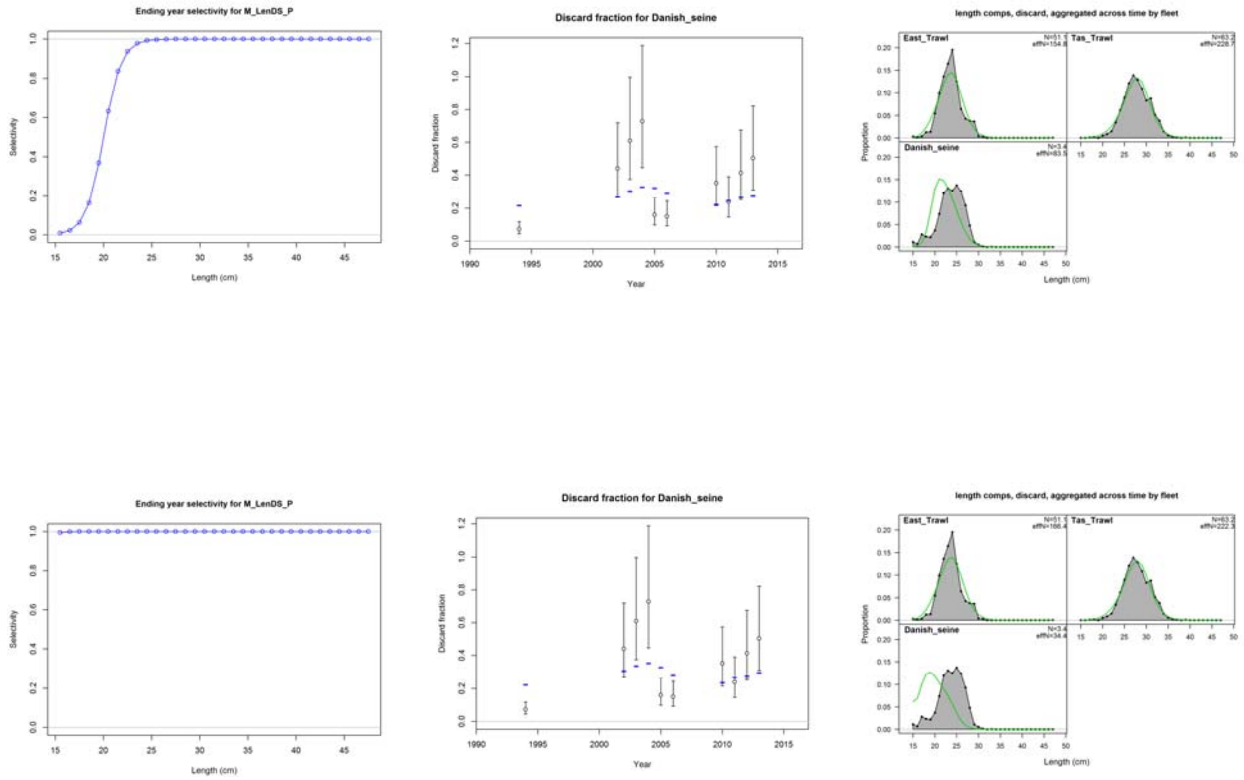


Figure 9.13 The selectivity for Danish seine, estimated discard rates and length fits for (i) a model where the length at 50% selectivity for Danish seine is fixed at 20cm (top row) and (ii) where the length at 50% selectivity is estimated (bottom row).

9.5 Acknowledgements

Many thanks are due to the CSIRO SESSF-WG: Robin Thomson, Judy Upston, Malcolm Haddon and André Punt for their assistance with model discussions and development. Miriana Sporcic is thanked for providing catch rate indices, Mike Fuller, Robin Thomson and Neil Klaer for their advice on data matters. Kyne Krusic-Golub (Fish Aging Services) and the AFMA observer section are thanked for providing the aging data and length frequency data respectively.

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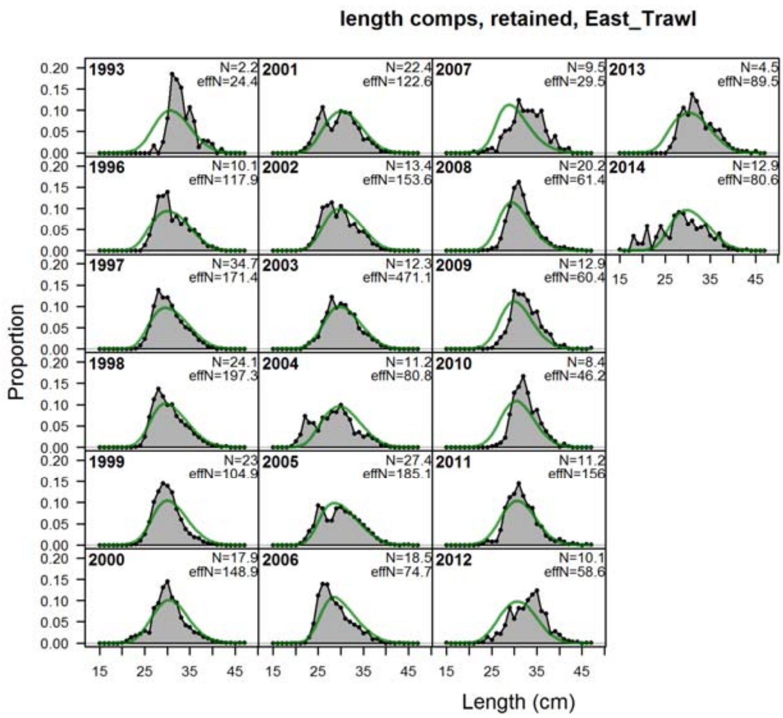
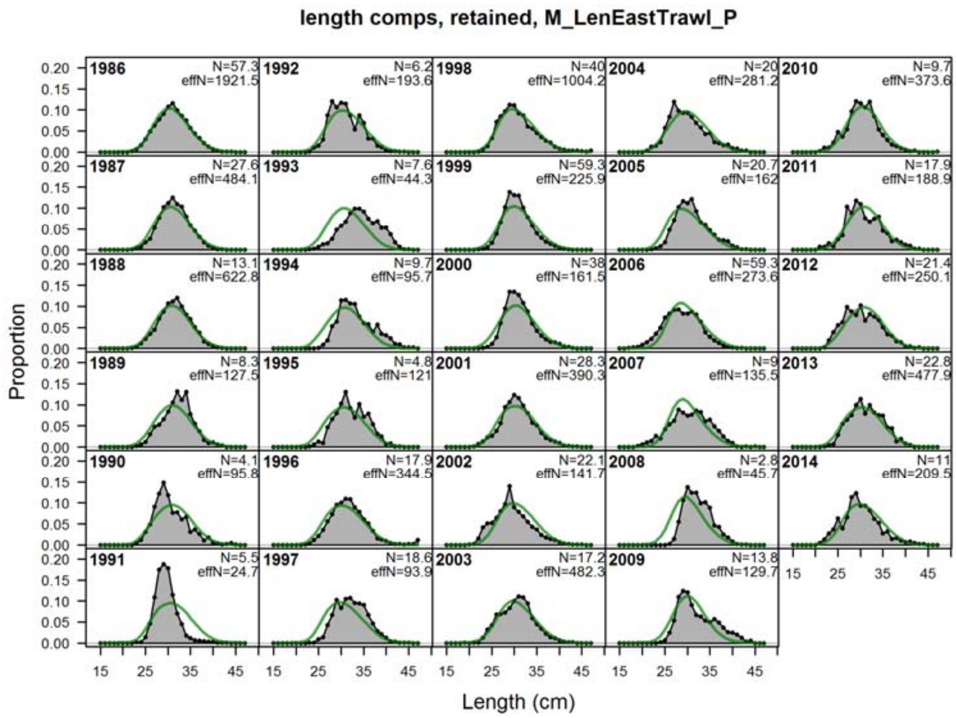
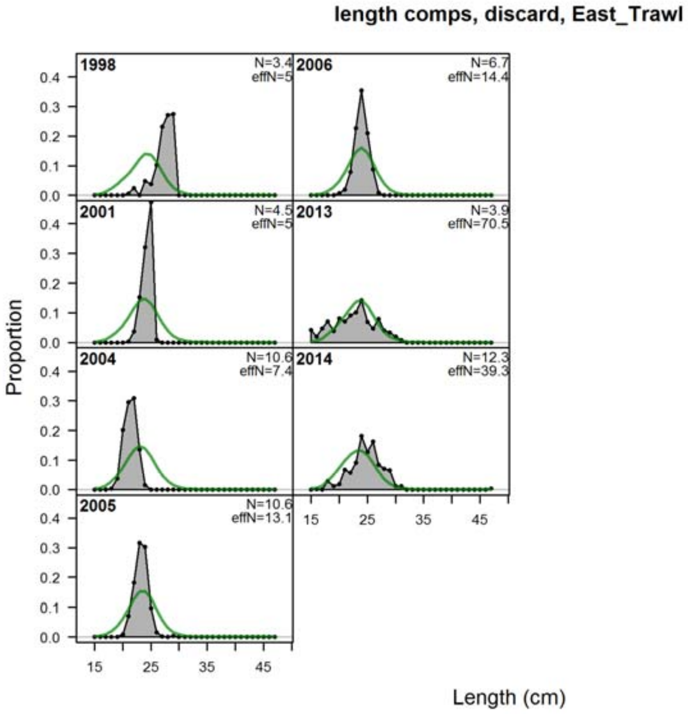
Wayte, S.E. and Fay, G. 2009. Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2007. In: Tuck, G.N. (Ed.) 2009. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2008. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric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

9.7 Appendix 1: Base case length fits

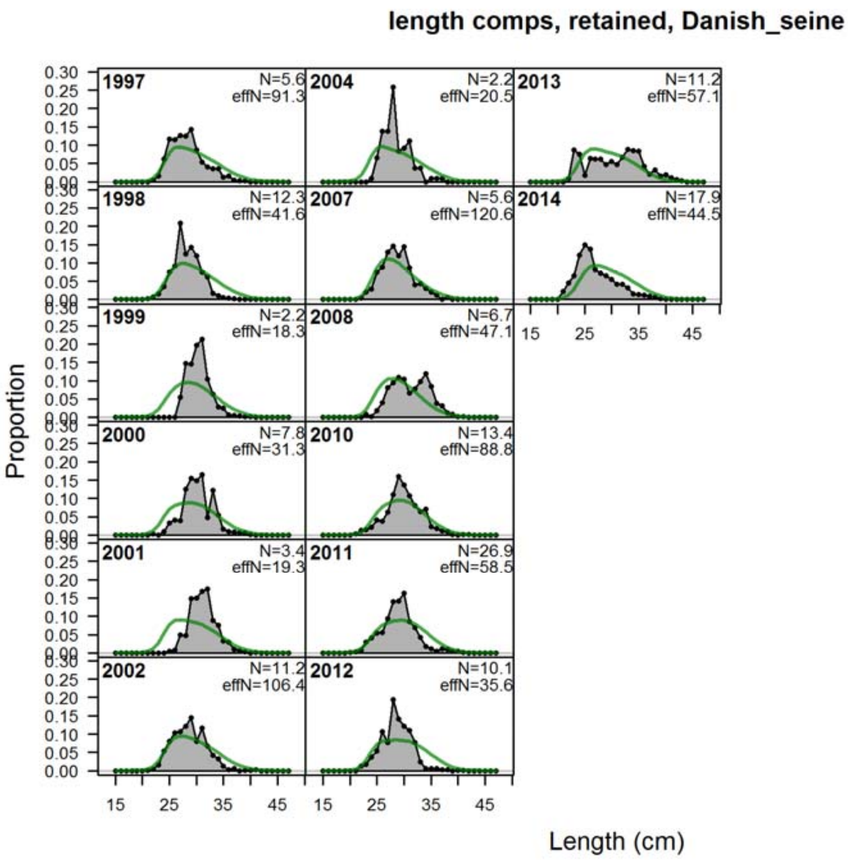




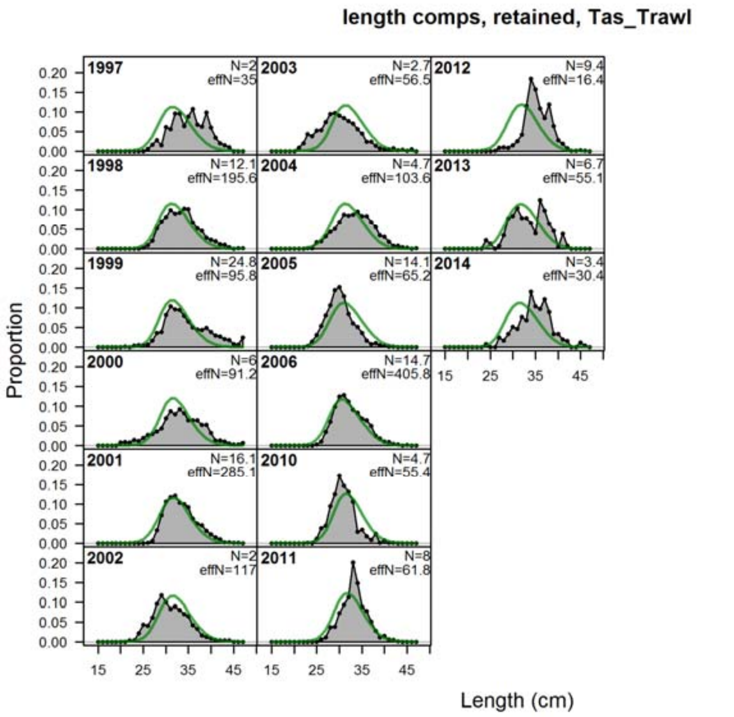
Length composition fits for the eastern trawl fleet. Onboard retained (top) and Port (bottom).

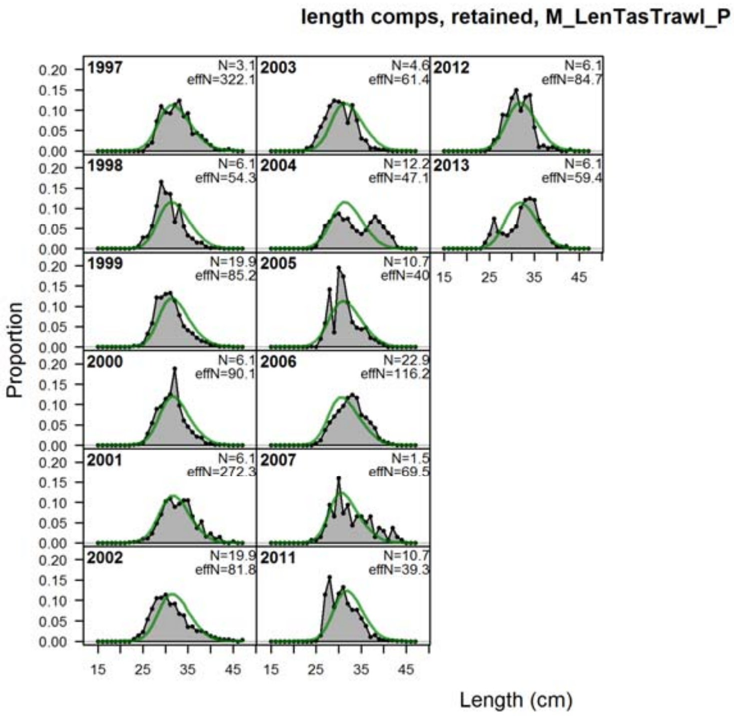


Length composition fits for discarded fish from the eastern trawl fleet.

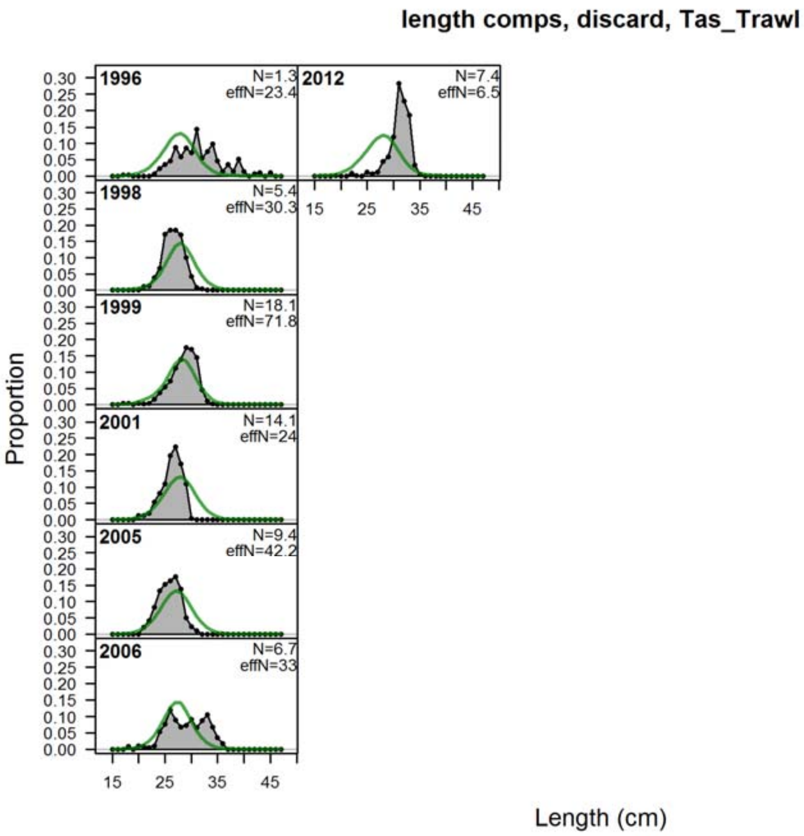


Length composition fits for the Danish seine fleet (Port).

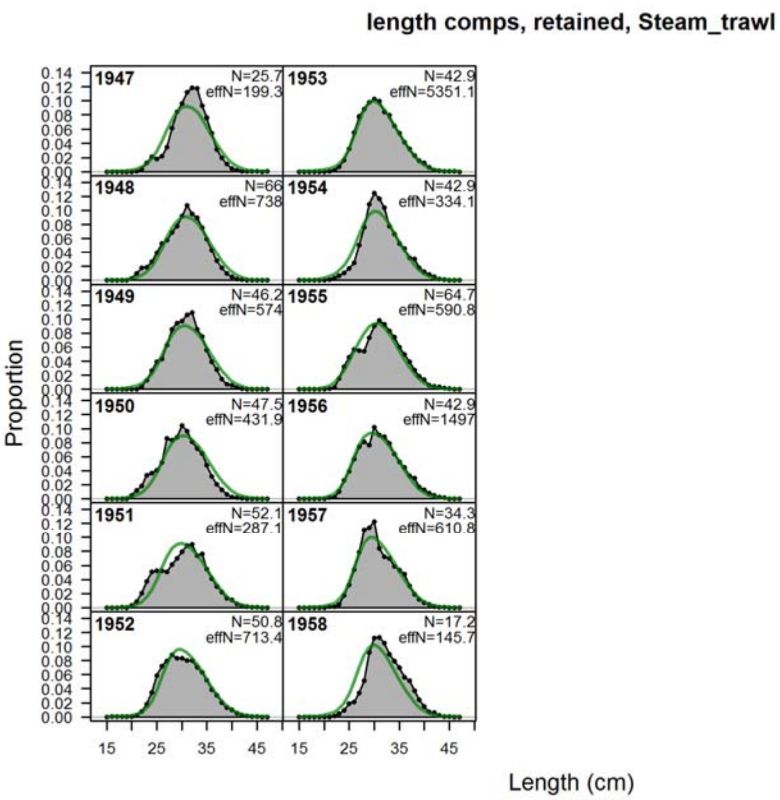




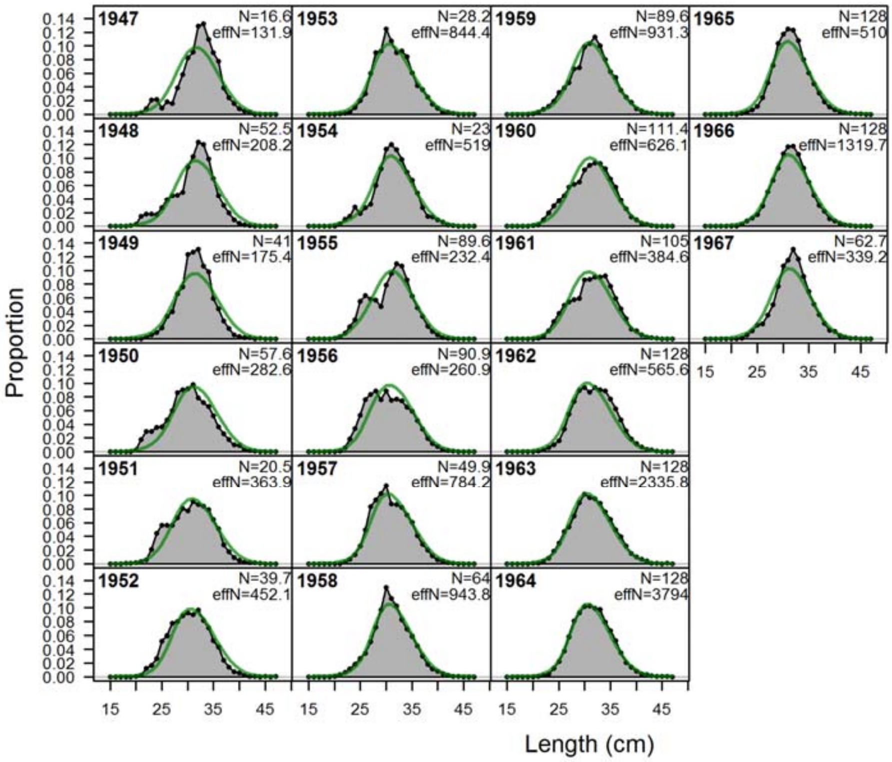
Length composition fits for the Tas trawl fleet. Onboard retained (top) and Port (bottom).



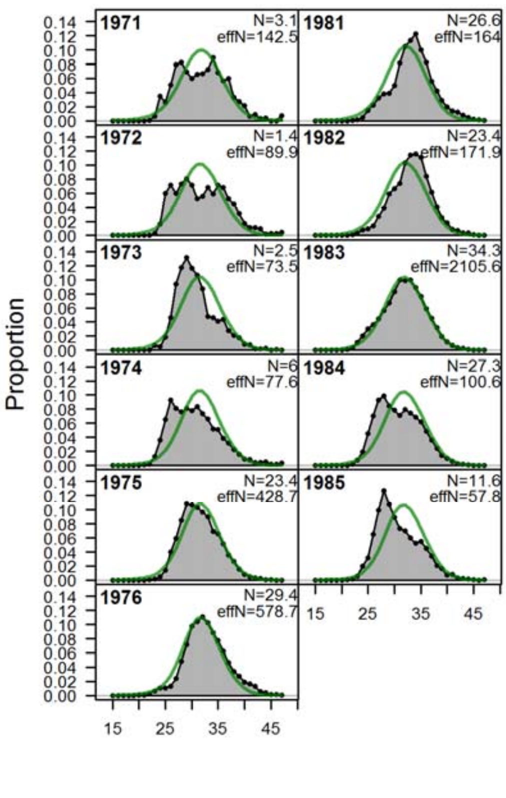
Length composition fits for discarded fish from the Tas trawl fleet.



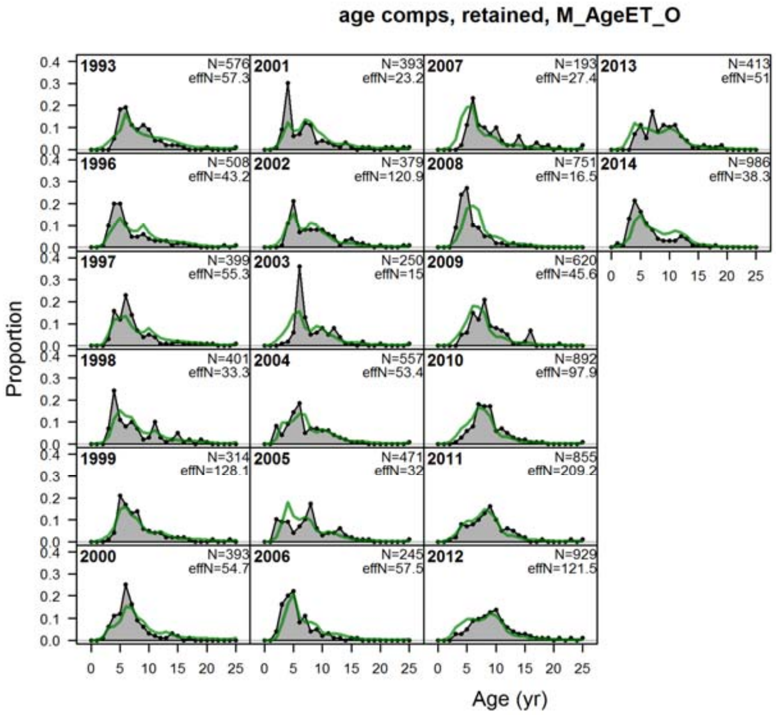
length comps, retained, Early_DS

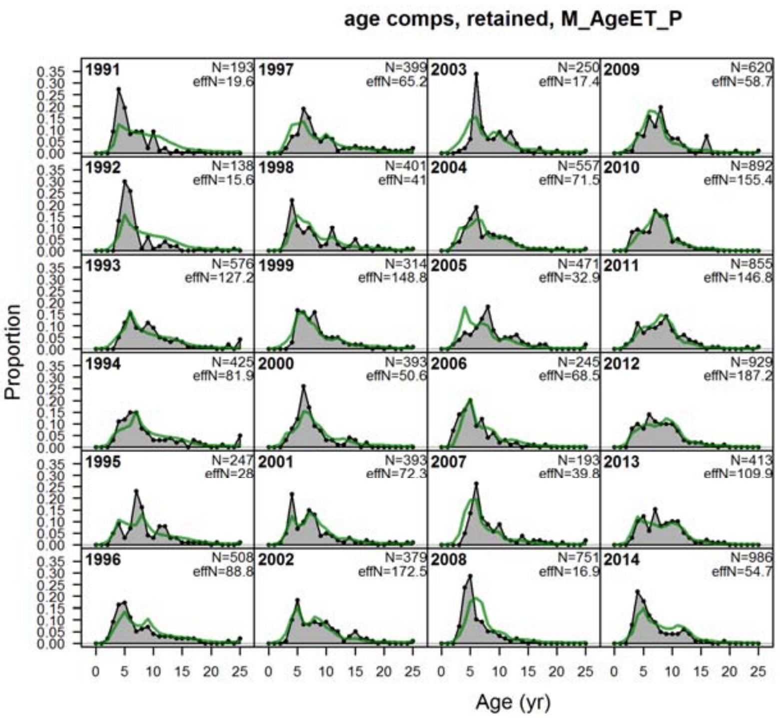


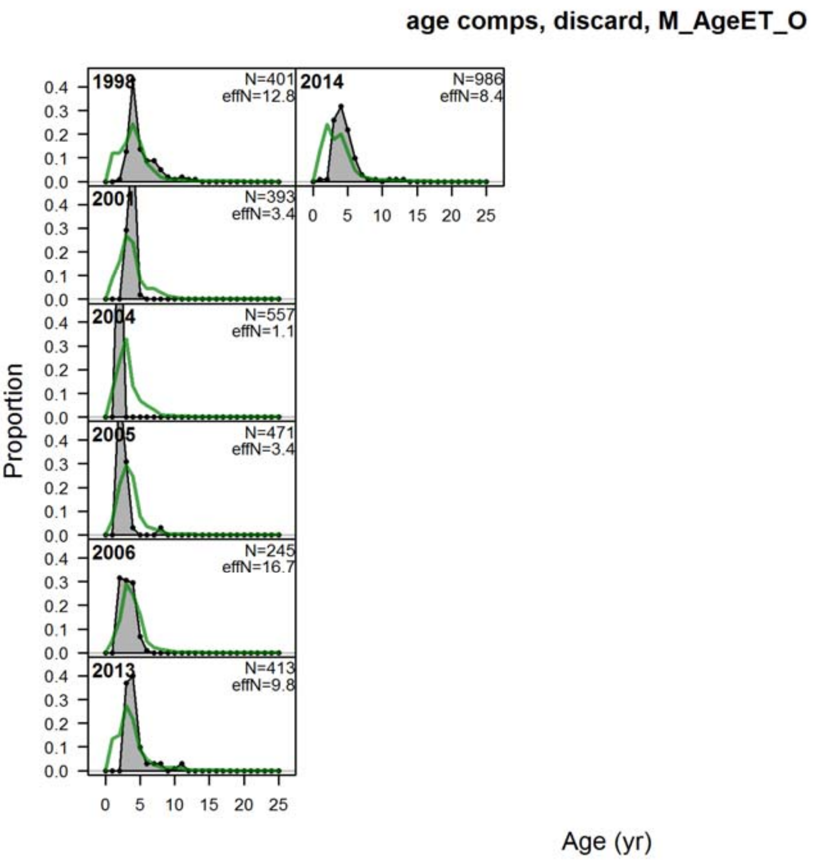
length comps, retained, Mixed

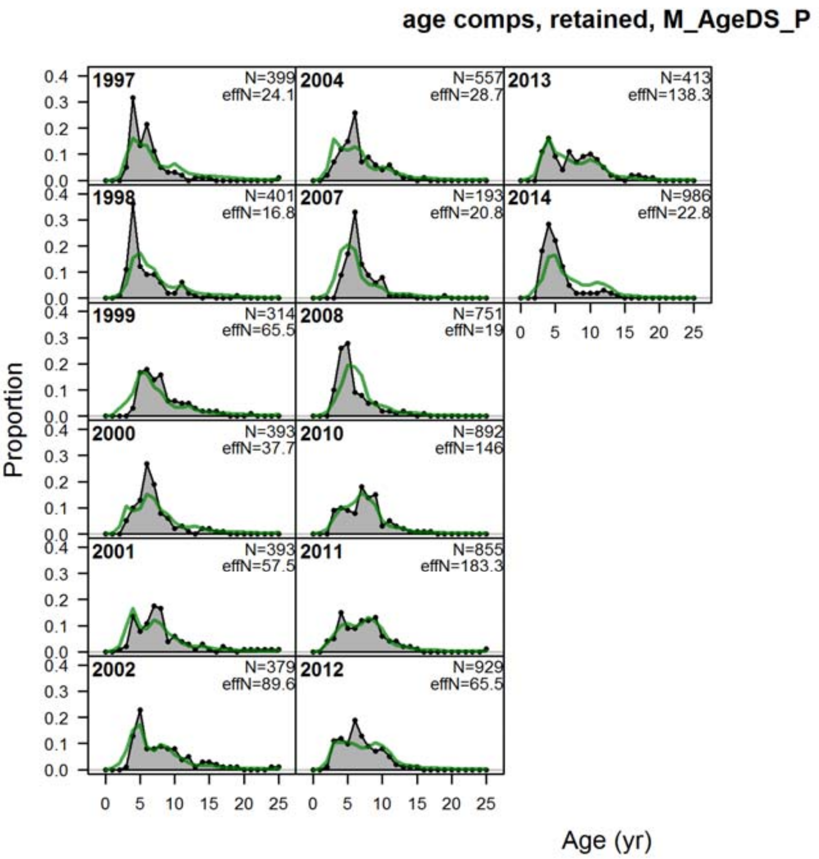


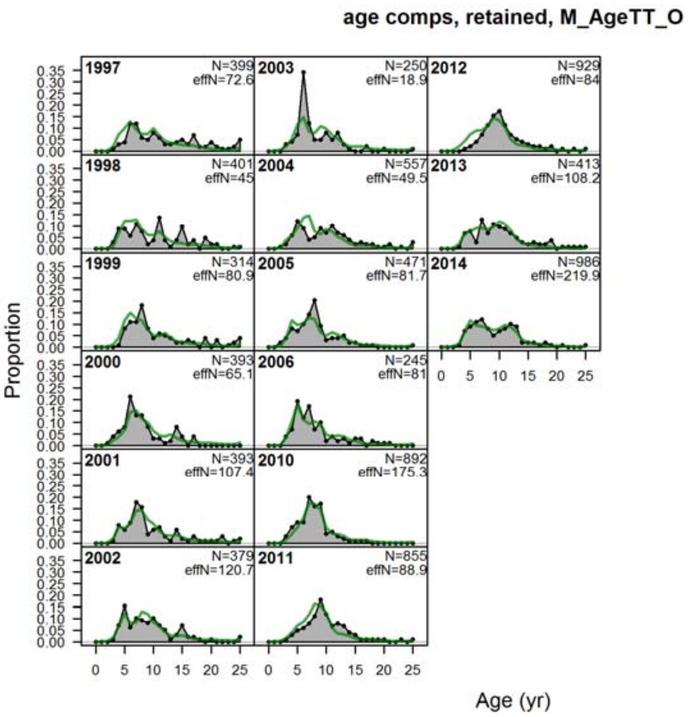
9.8 Appendix 2: base case age fits

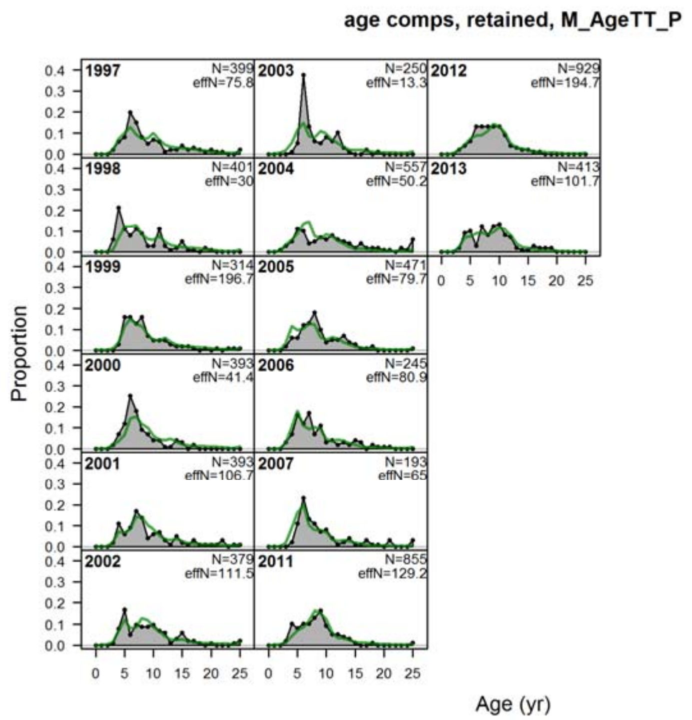


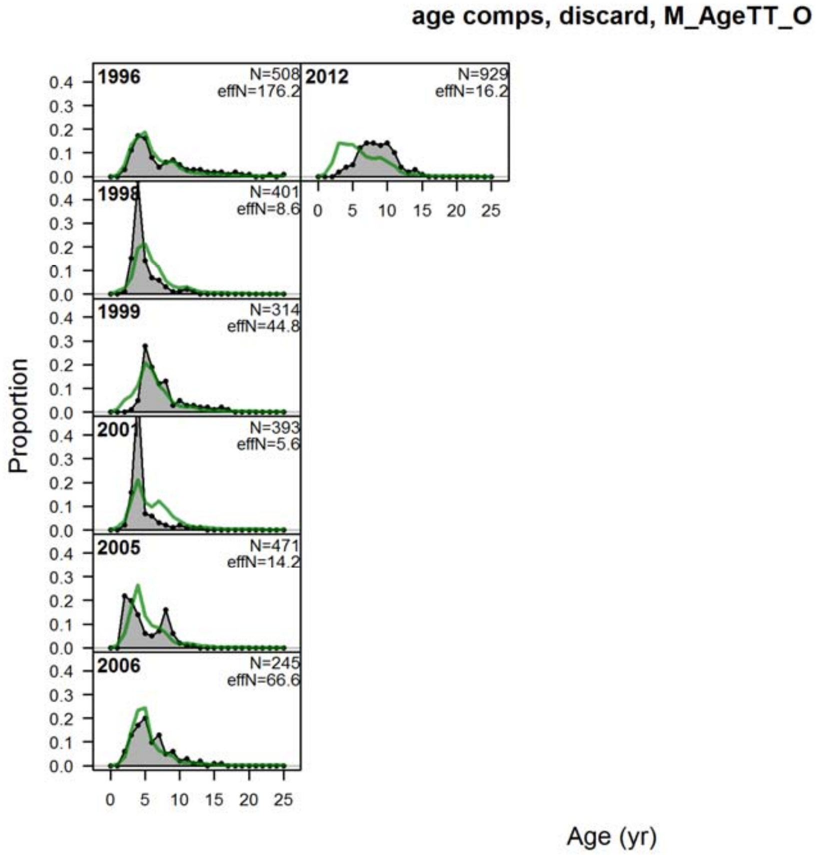



age comps, discard, M_AgeET_O
1998 N=401 effN=12.8
2014 N=986 effN=8.4
2001 N=393 effN=3.4
2004 N=557 effN=1.1
2005 N=471 effN=3.4
2006 N=245 effN=16.7
2013 N=413 effN=9.8
Proportion
Age (yr)

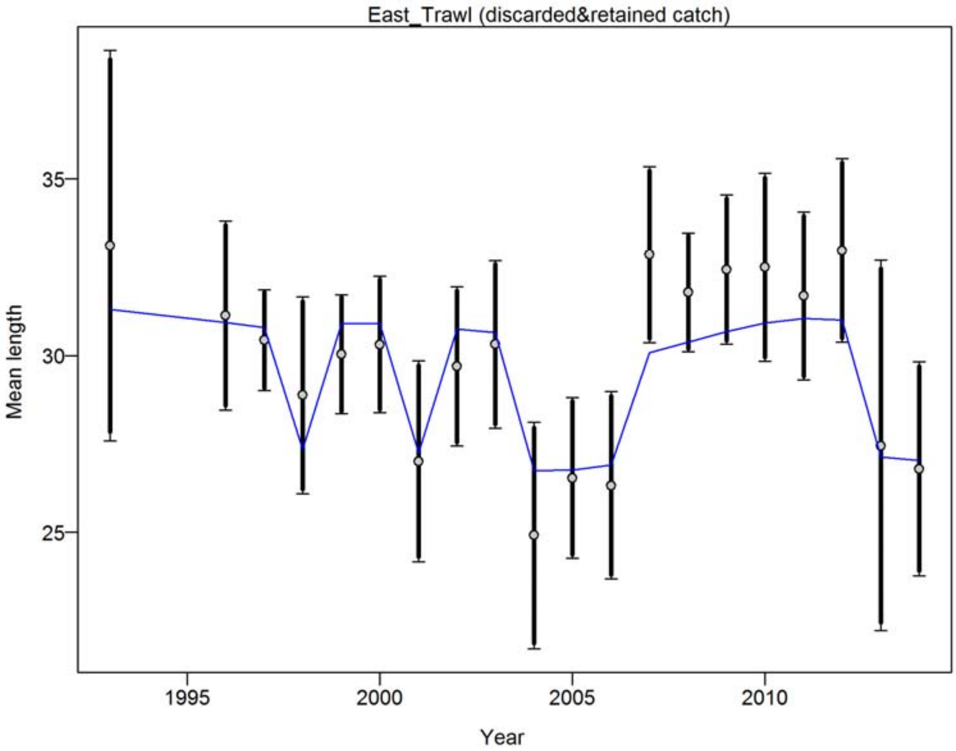

age comps, retained, M_AgeDS_P
1997 N=399 effN=24.1
2004 N=557 effN=28.7
2013 N=413 effN=138.3
1998 N=401 effN=16.8
2007 N=193 effN=20.8
2014 N=986 effN=22.8
1999 N=314 effN=65.5
2008 N=751 effN=19
2000 N=393 effN=37.7
2010 N=892 effN=146
2001 N=393 effN=57.5
2011 N=855 effN=183.3
2002 N=379 effN=89.6
2012 N=929 effN=65.5
Proportion
Age (yr)

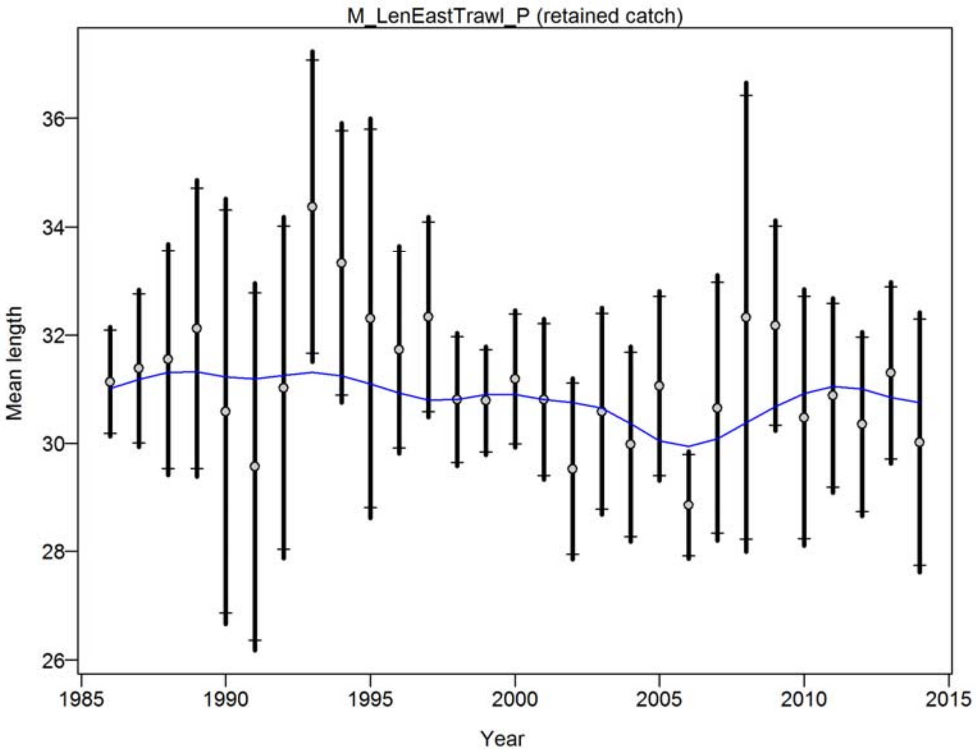

age comps, retained, M_AgeTT_O
Proportion
Age (yr)
1997 N=399 effN=72.6
2003 N=250 effN=18.9
2012 N=929 effN=84
1998 N=401 effN=45
2004 N=557 effN=49.5
2013 N=413 effN=108.2
1999 N=314 effN=80.9
2005 N=471 effN=81.7
2014 N=986 effN=219.9
2000 N=393 effN=65.1
2006 N=245 effN=81
2001 N=393 effN=107.4
2010 N=892 effN=175.3
2002 N=379 effN=120.7
2011 N=855 effN=88.9

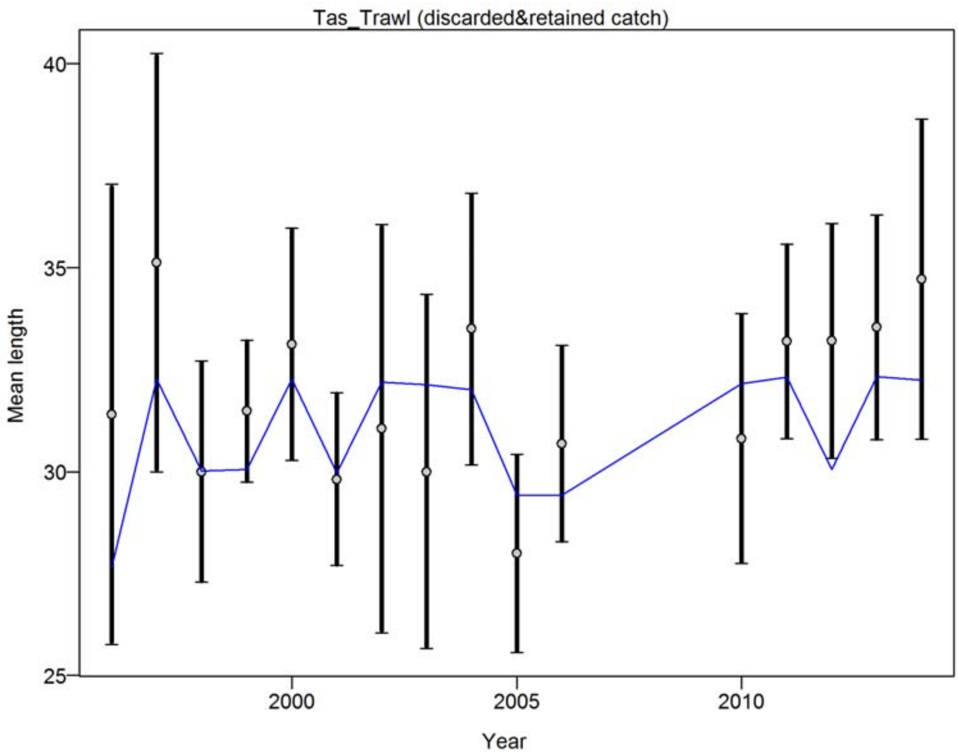

age comps, retained, M_AgeTT_P
Proportion
Age (yr)
1997 N=399 effN=75.8
2003 N=250 effN=13.3
2012 N=929 effN=194.7
1998 N=401 effN=30
2004 N=557 effN=50.2
2013 N=413 effN=101.7
1999 N=314 effN=196.7
2005 N=471 effN=79.7
2000 N=393 effN=41.4
2006 N=245 effN=80.9
2001 N=393 effN=106.7
2007 N=193 effN=65
2002 N=379 effN=111.5
2011 N=855 effN=129.2

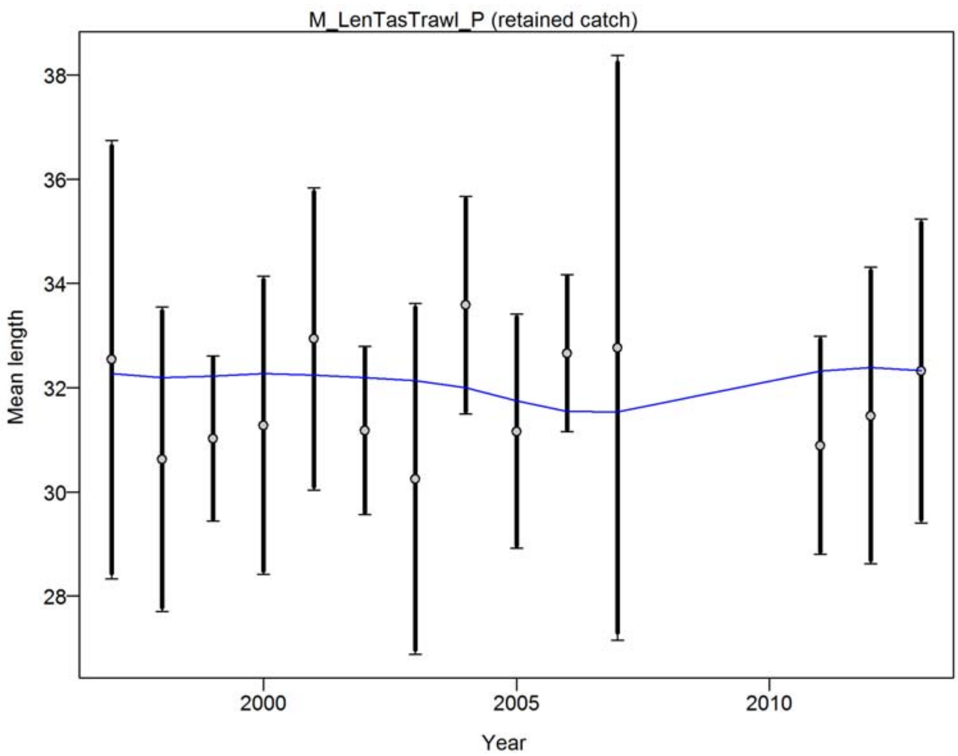

age comps, discard, M_AgeTT_O
1996
N=508
effN=176.2
2012
N=929
effN=16.2
1998
N=401
effN=8.6
1999
N=314
effN=44.8
2001
N=393
effN=5.6
2005
N=471
effN=14.2
2006
N=245
effN=66.6
Proportion
Age (yr)

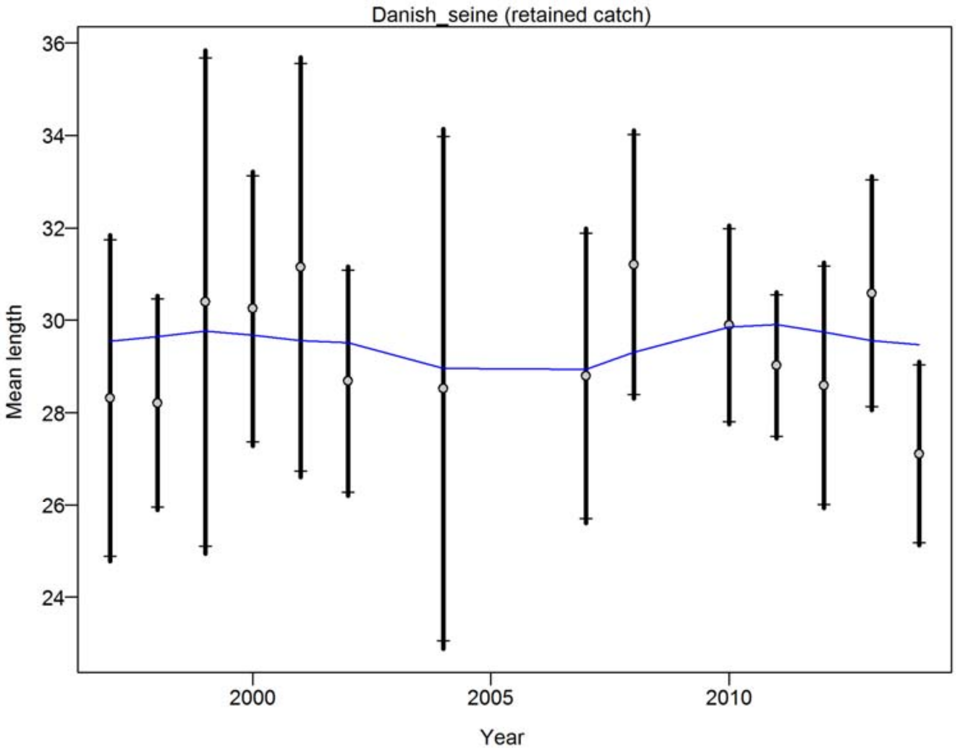
9.9 Appendix 3: base case length fit diagnostics (Francis mean length fits from method TA1.8)

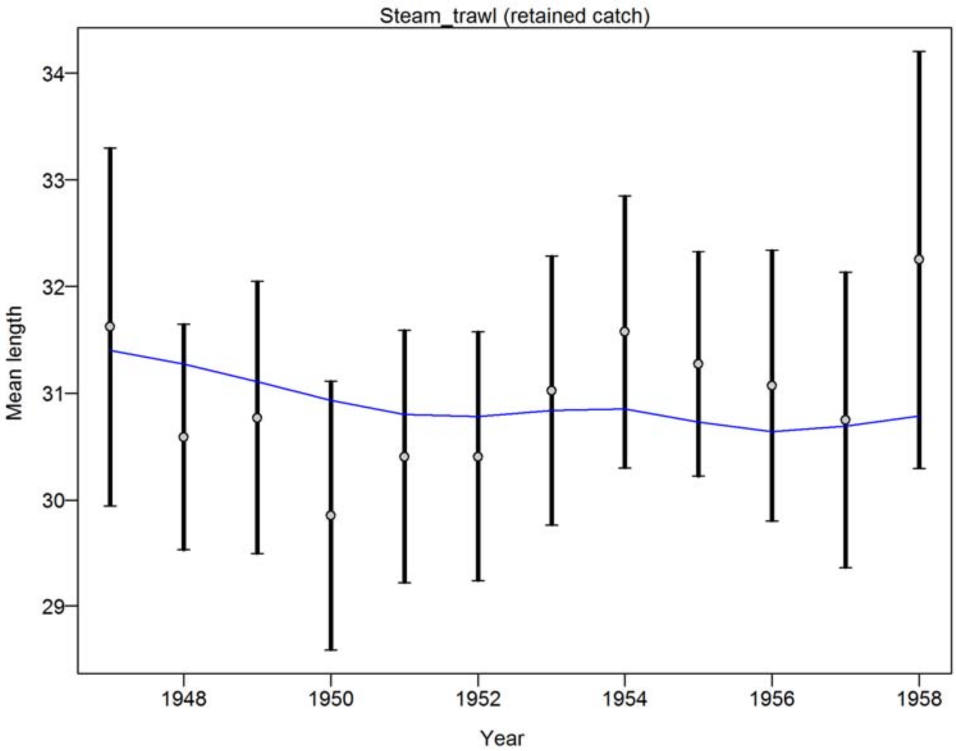


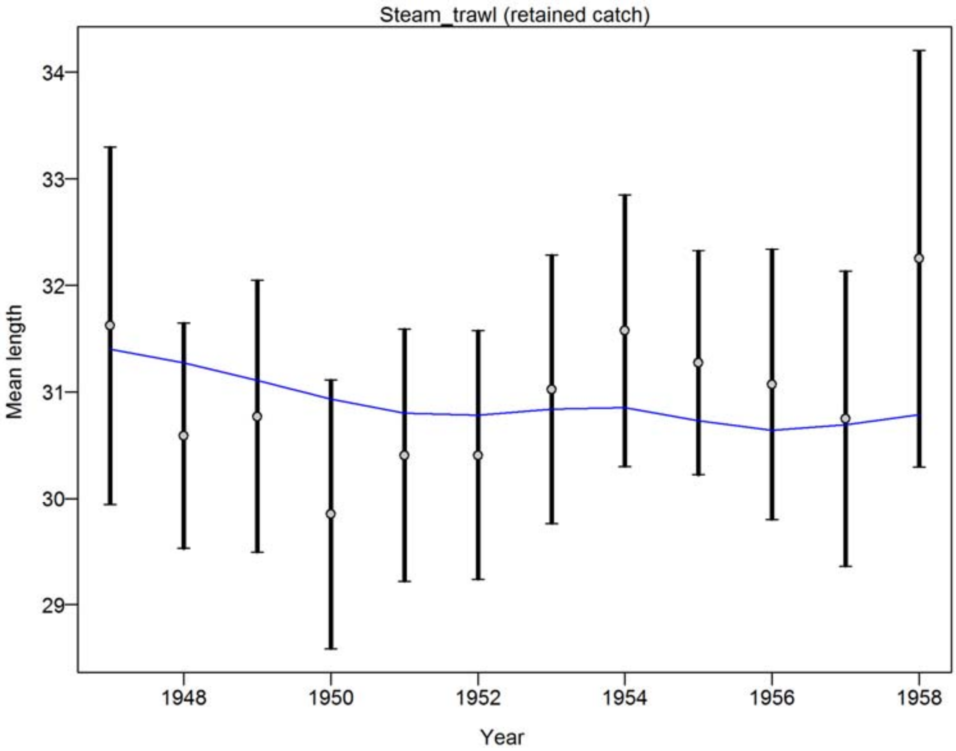


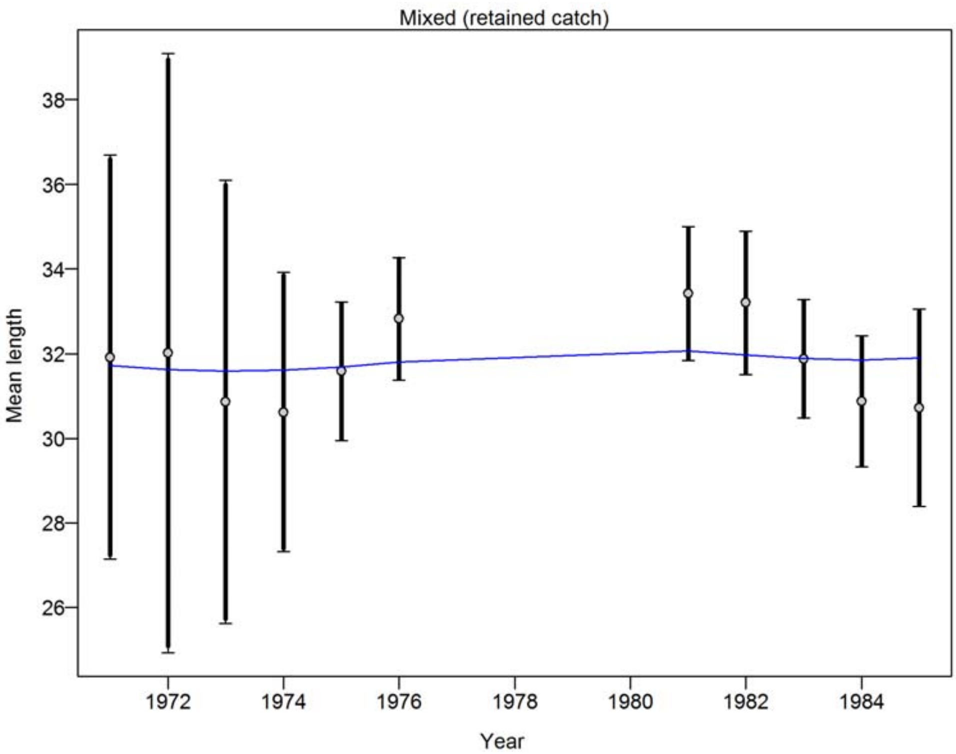

Tas_Trawl (discarded&retained catch)
Mean length
Year
25
30
35
40
2000
2005
2010


M_LenTasTrawl_P (retained catch)
Mean length
Year
28
30
32
34
36
38
2000
2005
2010


Danish_seine (retained catch)
Mean length
Year
36
34
32
30
28
26
24
2000
2005
2010


Steam_trawl (retained catch)
Mean length
Year
34
33
32
31
30
29
1948
1950
1952
1954
1956
1958


Steam_trawl (retained catch)
34
33
32
31
30
29
Mean length
1948
1950
1952
1954
1956
1958
Year


Mixed (retained catch)
38
36
34
32
30
28
26
Mean length
1972
1974
1976
1978
1980
1982
1984
Year

9.10 Appendix 4: tables

Table 9.3 Total catches (landed plus discards) (tonnes) of jackass morwong by steam trawlers and early Danish seine vessels, 1915 – 67

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

Table 9.4 Total catches (landed plus discards) (tonnes) of jackass morwong by the mixed fleet of Danish seine and diesel trawlers, 1968 – 85

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

Table 9.5. Landed catches (tonnes) of jackass morwong for the NSW/Vic trawl fleet (Commonwealth catches in NSW/east Victoria plus NSW state catches), the Tasmanian trawl fleet (Commonwealth catches in eastern Tasmania plus Tasmanian state catches), the Danish seine fleet in Bass Strait/eastern Victoria and NSW, 1986 – 2014

Year	NSW/Vic trawl	Tasmanian trawl	Danish seine
1986	861	30	12
1987	1006	80	13
1988	1209	214	36
1989	1039	505	21
1990	722	159	27
1991	839	226	23
1992	564	140	18
1993	687	372	4
1994	717	213	7
1995	599	249	0
1996	729	210	13
1997	892	269	21
1998	620	245	32
1999	578	298	30
2000	611	154	48
2001	331	135	108
2002	387	139	76
2003	318	237	31
2004	310	256	21
2005	394	192	23
2006	389	198	17
2007	278	147	17
2008	394	148	42
2009	290	72	22
2010	232	73	20
2011	214	62	34
2012	211	107	17
2013	120	120	15
2014	98	65	11

Table 9.6. Proportion of total catch that was discarded, with sample sizes in parenthesis. The data indicated by asterisks were not used in the analysis due to low sample sizes (<=15) or values below 0.02. Grey shaded cells for Danish seine indicate assumed values (for this fleet only) for the base case assessment.

Year	NSW/Vic trawl	Tasmanian trawl	Danish seine
1993	0.044 (139)	0.005 (32)*	0.07
1994	0.041 (228)	0.056 (17)	0.072 (16)
1995	0.084 (97)	-	0.116
1996	0.075 (175)	0.011 (23)*	0.163
1997	0.059 (324)	0.011 (16)*	0.209
1998	0.023 (187)	0.043 (40)	0.255
1999	0.014 (222)*	0.102 (58)	0.301
2000	0.024 (199)	0.002 (27)*	0.348
2001	0.021 (275)	0.013 (33)*	0.394
2002	0.002 (224)*	0.021 (9)*	0.440 (18)
2003	0.016 (220)*	0.010 (10)*	0.610 (40)
2004	0.138 (177)	0.054 (19)	0.728 (15)
2005	0.106 (261)	0.092 (16)	0.159 (22)
2006	0.101 (209)	0.142 (60)	0.150 (33)
2007	0.000 (70)*	-	0.4
2008	0.018 (126)*	-	0.4
2009	0.032 (83)	0.006 (9)*	0.4
2010	0.01 (84)*	0.026 (18)	0.352 (17)
2011	0.125 (69)	0.027 (22)	0.238 (58)
2012	0.024 (48)	0.277 (28)	0.414 (27)
2013	0.076 (40)	0.023 (20)	0.503 (41)
2014	0.069 (50)	0.027 (20)	0.4

Table 9.7. Standardised catch rates for the NSW/Vic and Tasmanian trawl fleets.

Year	NSW/Vic trawl	Tasmanian trawl
1986	1.8797	1.8797
1987	1.9201	1.9201
1988	2.6523	2.6523
1989	3.3567	3.3567
1990	2.3584	2.3584
1991	1.5026	1.5026
1992	1.6388	1.6388
1993	1.2944	1.2944
1994	0.8837	0.8837
1995	0.8653	0.8653
1996	0.8458	0.8458
1997	0.9564	0.9564
1998	0.9266	0.9266
1999	1.1004	1.1004
2000	0.7353	0.7353
2001	0.4903	0.4903
2002	0.4301	0.4301
2003	0.593	0.593
2004	0.4493	0.4493
2005	0.3295	0.3295
2006	0.4134	0.4134
2007	0.5738	0.5738
2008	0.5908	0.5908
2009	0.4293	0.4293
2010	0.4444	0.4444
2011	0.2971	0.2971
2012	0.3919	0.3919
2013	0.4344	0.4344
2014	0.2163	0.2163

Table 9.8 Standardised catch rates for the steam trawl fleet.

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

Table 9.9. Standardised catch rates calculated by Smith (1989) for the overlap years of the early Danish seine fleet and the steam trawl fleet.

Year	catch rate
1948	123.7
1949	105.4
1950	84.4
1951	74.2
1952	92.8
1953	116.1
1954	92.6
1955	71.6
1956	99.2
1957	90.1
1958	63.3
1959	79.3
1960	77.6
1961	85
1962	79.7
1963	89.5
1964	89.8
1965	89.6
1966	82.4

Table 9.10. Standardised catch rates for the mixed fleet.

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

Table 9.11. The number of fish sampled, shots and estimated trips for the Steam Trawl and Early Danish Seine fleet. * Based on the average number of fish sampled per trip from eastern trawl.

	Steam Trawl	
	Number fish	Trips*
1947	4836	39
1948	13960	100
1949	8577	70
1950	8823	72
1951	9721	79
1952	9456	77
1953	7956	65
1954	8033	65
1955	12010	98
1956	7997	65
1957	6351	52
1958	3243	26

	Early DS	
	Number fish	Trips*
1947	1590	13
1948	5070	41
1949	3882	32
1950	5511	45
1951	1933	16
1952	3779	31
1953	2749	22
1954	2231	18
1955	8627	70
1956	8769	71
1957	4826	39
1958	6205	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

Table 9.12. The number of fish sampled and estimated trips for the Mixed fleet. * Based on the average number of fish sampled per trip from eastern trawl.

	Retained Mixed fleet	
	Number fish	Trip*
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 9.13. The number of fish sampled and shots for onboard (top) and trips for port (bottom) sampled fish for the Danish seine fleet. Grey cells indicate length records that were excluded due to small sample sizes (fish sampled <100).

Retained DS Onboard		
	Number fish	Shots
#1994	2	1
#2000	24	1
2003	142	9
#2005	62	7
#2006	60	6
#2009	50	1
#2010	64	2
2011	153	4
2013	207	11

Discard DS Onboard		
	Number fish	Shots
#1993	7	1
#1994	5	2
#2000	34	1
#2001	6	1
2002	131	6
2003	335	10
2013	197	14
#2014	62	1

DS Port		
	Number fish	Trips
#1992	51	1
#1996	33	1
1997	340	5
1998	1088	11
1999	295	2
2000	374	7
2001	315	3
2002	487	10
#2003	61	1
2004	108	2
#2005	78	1
2007	753	5
2008	635	6
2010	428	12
2011	512	24
2012	216	9
2013	288	10
2014	800	16

Table 9.14. The number of fish sampled and shots for onboard sampled fish for the eastern trawl fleet; retained (left) and discarded (right). Grey cells indicate length records that were excluded due to small sample sizes (fish sampled <100).

Retained east trawl Onboard		
	Number fish	Shots
1993	144	4
1996	864	18
1997	3099	62
1998	3416	43
1999	3596	41
2000	1962	32
2001	3183	40
2002	2172	24
2003	1540	22
2004	609	20
2005	3381	49
2006	1950	33
2007	273	17
2008	1824	36
2009	781	23
2010	537	15
2011	604	20
2012	690	18
2013	207	8
2014	427	23

Discard east trawl Onboard		
	Number fish	Shots
1998	148	6
#1999	57	5
#2000	82	2
2001	118	8
#2003	10	2
2004	374	19
2005	692	19
2006	458	12
#2007	1	1
#2008	10	7
#2010	10	1
#2011	63	7
#2012	9	1
2013	200	7
2014	338	22

Table 9.15. The number of fish sampled and trips for port sampled fish for the eastern trawl fleet. * Sydney Fish Market records. Trips estimated from average number of fish sampled per trip from the eastern trawl data.

	East Trawl Port	
	Number fish	Trip
1986	13441	83*
1987	4900	40*
1988	3649	19*
1989	1786	12*
1990	901	6*
1991	1181	8
1992	1355	9
1993	2359	11
1994	1124	14
1995	667	7
1996	2990	26
1997	3190	27
1998	8060	58
1999	12659	86
2000	7974	55
2001	5603	41
2002	5757	32
2003	4066	25
2004	3544	29
2005	5747	30
2006	13123	86
2007	2029	13
2008	651	4
2009	1644	20
2010	1436	14
2011	758	26
2012	1116	31
2013	1008	33
2014	931	16

Table 9.16. The standard deviation (StDev) of age reading error.

Age	St Dev	Age	St Dev
0	0.216	16	0.699
1	0.216	17	0.732
2	0.247	18	0.765
3	0.279	19	0.798
4	0.311	20	0.831
5	0.343	21	0.864
6	0.375	22	0.897
7	0.407	23	0.931
8	0.439	24	0.964
9	0.471	25	0.997
10	0.504	26	1.031
11	0.536	27	1.065
12	0.568	28	1.098
13	0.601	29	1.132
14	0.634	30	1.166
15	0.666		

Table 9.17. The 10-year projected RBC and depletion (current relative to 1988 female spawning biomass) from the base case model of the eastern stock of jackass morwong.

Year	RBC	Depletion
2016	314	0.36
2017	320	0.37
2018	327	0.38
2019	336	0.39
2020	344	0.40
2021	352	0.41
2022	359	0.42
2023	365	0.43
2024	371	0.43
2025	375	0.44

Table 9.18 Summary of results for the base-case and sensitivity tests. Lower log-likelihood values indicate a better fit to the data. Likelihood values for sensitivities are shown as differences from the base-case. Log-likelihood (-ln L) values in italics are not comparable with the base-case. A negative value indicates a better fit, a positive value a worse fit.

East	female SB_0 (1988)	female SB_{2016}	SB_{2016}/SB_0	2016 RBC 20:35:48	Likelihood total diff	CPUE	Discard	Length	Age	Recruit
base-case (M=0.15, h=0.7, 50% mat=24.5)	3977	2903	36%	314	1123	-125.6	49.9	250.6	942.8	3.5
Base from Sept 2015 (tune onboard DS)	4184	2682	32%		*158.3*	*-0.37*	*32.12*	*127.48*	*-0.02*	*-0.86*
DS sely fixed 20cm	3974	2914	37%	314	*18.55*	*0.65*	*22.52*	*2.92*	*-5.79*	*-1.82*
DS sely estimated	3793	2779	37%	302	*405.51*	*0.85*	*24.9*	*4.42*	*376.36*	*-1.17*
$M = 0.1$ yr^{-1}	5511	2286	21%		4.26	2.94	0.29	1.23	0.6	-0.75
$M = 0.2$ yr^{-1}	3775	3889	52%		-1.47	-1.83	-0.15	0.96	0.3	-0.68
$h = 0.6$	4128	2802	34%		-2.43	-0.09	0	-0.03	-0.81	-1.49
$h = 0.8$	3883	2984	38%		1.86	0.1	0	0.04	0.61	1.13
50% maturity at 22 cm	4228	3317	39%		0.24	-0.01	0.02	0.04	0.01	0.19
Double weight on CPUE	3822	2651	35%		*2.19*	*-5.10*	*-0.77*	*1.05*	*5.04*	*1.92*
Halve weight on CPUE	4176	3241	39%		*1.90*	*6.50*	*0.34*	*-0.73*	*-3.20*	*-0.94*
Double weight on LF data	3903	2879	37%		*3.92*	*1.47*	*0.36*	*-8.98*	*3.58*	*7.46*
Halve weight on LF data	4027	2922	36%		*2.63*	*-0.45*	*-0.51*	*9.39*	*-1.81*	*-3.97*
Double weight on age data	3907	2941	38%		*4.30*	*4.76*	*3.00*	*3.10*	*-10.30*	*3.67*
Halve weight on age data	3992	2880	36%		*3.82*	*-3.17*	*-2.90*	*-1.78*	*13.31*	*-1.61*