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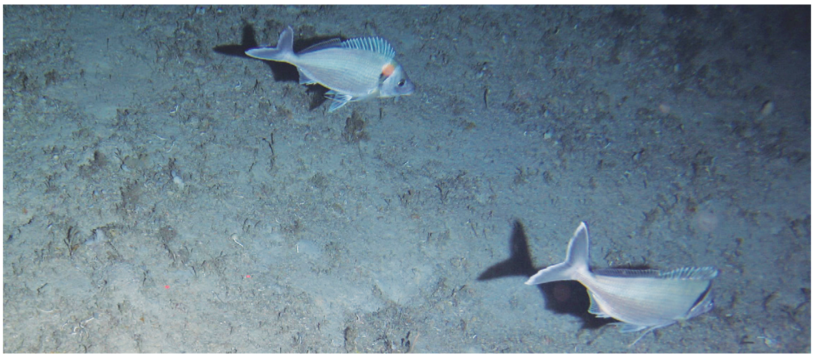
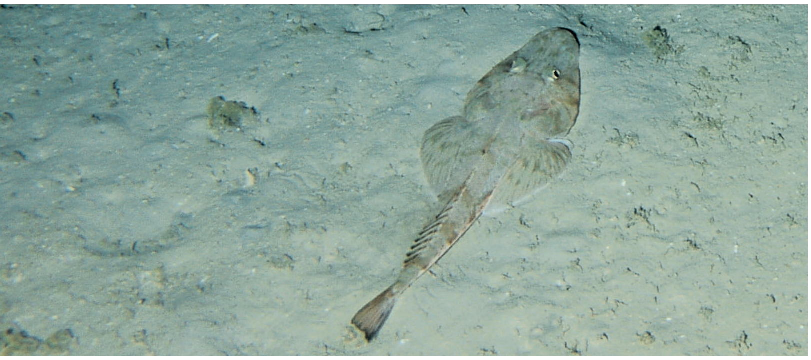
2017/0824 June 2020

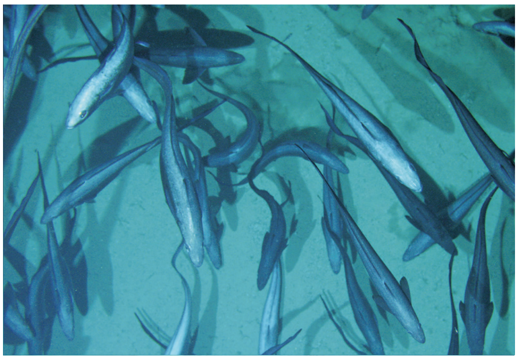
Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2018 and 2019

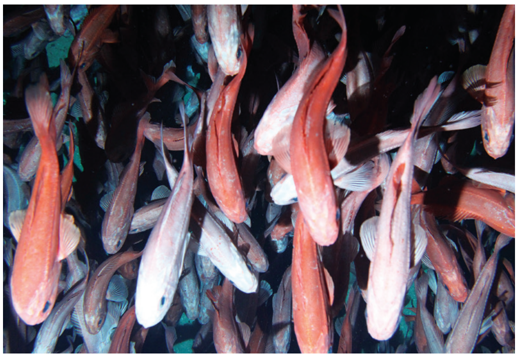
PART
1

2018









Principal investigator **G.N. Tuck**

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Box 7051, Canberra Business Centre, ACT 2610 Tel **(02) 6225 5555** Fax (02) 6225 5500 **AFMA Direct 1300 723 621**

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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.

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Part 1: 2018

G.N. Tuck
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Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2018

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1. Non-Technical Summary

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

PRINCIPAL INVESTIGATOR: Dr Geoffrey N. Tuck

ADDRESS:
CSIRO Oceans and Atmosphere Flagship
GPO Box 1538
Hobart, TAS 7001
Australia
Telephone: 03 6232 5222 Fax: 03 6232 5053

OBJECTIVES:

- Provide quantitative and qualitative species assessments in support of the four SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework
- 2018: Provide Tier 1 assessments for Blue grenadier, Jackass morwong (east and west), School shark, and Silver warehou; Tier 3 assessment for Alfonsino; Tier 4 assessments for Blue eye trevalla and Deepwater shark (east and west); and Tier 5 for Smooth oreo.
- 2019: Provide Tier 1 assessments for Deepwater flathead, Tiger flathead, Western gemfish, and Gummy shark; and Tier 4 for Mirror Dory

Outcomes Achieved - 2018

The 2018 assessments of stock status of the key Southern and Eastern Scalefish and Shark fishery (SESSF) species are based on the methods presented in this report. Documented are the latest quantitative assessments for the SESSF quota species. Typical assessment results provide indications of current stock status, in addition to an application of the recently introduced Commonwealth fishery harvest control rules that determine a Recommended Biological Catch (RBC). These assessment outputs are a critical component of the management and Total Allowable Catch (TAC) setting process for these fisheries. The results from these studies are being used by SESSFRAG, industry and management to help manage the fishery in accordance with agreed sustainability objectives.

1.1 Slope, Shelf and Deepwater Species

Jackass Morwong

The 2015 Tier 1 assessment of eastern and western jackass morwong (*Nemadactylus macropterus*) was updated to provide estimates of stock status in the SESSF at the start of 2019. The 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. One additional year in the abundance index (2016) for the Fishery Independent Survey (FIS) was included.

The base-case assessment for eastern jackass morwong estimates that current spawning stock biomass is 35% of unexploited stock biomass (SSB0). Under the agreed 20:35:48 harvest control rule, the 2019 recommended biological catch (RBC) is 261 t, with the long-term yield (assuming average recruitment in the future) of 356 t. The average RBC over the three-year period 2019-2021 is 270 t and over the five-year period 2019-2023, the average RBC is 279 t. Exploration of model sensitivity showed variation in spawning biomass across all sensitivities ranging from 18% to 52% of SSB0 with greatest sensitivity to natural mortality. Excluding this sensitivity to natural mortality, the other sensitivities showed a much narrower range, from 29% to 40% of SSB0.

The base-case assessment for western jackass morwong estimates that current spawning stock biomass is 68% of unexploited stock biomass (SSB0). 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 SSB0 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 SSB0. 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.

Blue grenadier

The base case Tier 1 assessment for blue grenadier (*Macruronus novaezelandiae*) was updated from the last full assessment in 2013. Relative to the 2013 assessment, the base case is updated by the inclusion of data to the end of 2017, which entails an additional five years of catch, discard, CPUE, length-composition and conditional age-at-age data and ageing error.

The base case specifications agreed in 2013 were generally maintained in the final base case. The main differences are: separating length-composition into onboard- and port- collected components, assigning stage-1 weights to length-compositions by shots (onboard) and trips (port); and using the latest methods for assigning final weights to the various data sources and the extent of variation in recruitment. The estimated time series of recruitment under the base-case parameter set shows the typical episodic nature of blue grenadier recruitment, with strong year-classes in 1979, the mid-1980s, 1994, and 2003, with relatively low recruitment between these years. However, recent estimated recruitments are more stable than has been observed before. The fit to the discard mass has improved compared to the 2013 assessment result. As has been noted in previous blue grenadier assessments, the fit to the standardized non-spawning catch-rate index is generally poor; the model is unable to fit to the high early catch rates and over-estimates catch rates during the early 2000s.

The estimated spawning biomass in 2019 which is used in the harvest control rule, is approximately 122% *SBo.* The optimistic outlook from this assessment is largely being driven by the addition of 5 further years of data and the substantial estimates of recruitment since 2010. While a promising sign for the fishery, some caution should be exercised regarding these recruitment estimates and its implication on future stock status, until clear further indications of its existence (and magnitude) are evident in future years' data. For the base case model the 2019 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 13,260t. The long-term retained catch is 4,899t. The retained portion of the RBC for 2019 is estimated to be 12,671t.

Silver warehou

A quantitative Tier 1 assessment of silver warehou (*Seriolella punctata*) in the SESSF using data up to 31 December 2017 was updated from the last assessment in 2015. The 2018 assessment has been updated by the inclusion of data up to the end of 2017, which entails an additional three years of catch, discard, CPUE, length-composition and conditional age-at-length data and ageing error updates.

Agreed changes to the 2018 base case included: the use of a re-estimated discard fractions split between the eastern and western trawl fleets, accounting for the observed discarding practices of factory trawlers, the inclusion of conditional age-at-length data for the western onboard trawl fleet, removal of length data from the small pelagic fishery (SPF) and inclusion of non-trawl catches in the existing eastern and western trawl fleets.

This assessment has seen a continuation of below average recruitment noted in the last two assessments with the last 11 years of estimated recruitment all below average. While the current assessment estimates that spawning biomass in 2019 will be 31% of unfished levels, previous assessments have shown that optimistic recent recruitments have been revised downwards in subsequent assessments. A retrospective assessment suggested that the increase in spawning biomass seen in the most recent years of the 2018 assessment may be overly optimistic and that the stock may currently be near the limit reference point.

This assessment estimates that the projected 2019 spawning stock biomass will be 31.3% of virgin stock biomass. The recommended biological catch (RBC) from the base case model for 2019 is 942t for the 20:35:48 harvest control rule, increasing to 1,353t in 2020 and 1,420t in 2021. The long-term yield is 1,772t. At its November 2018 meeting, SERAG agreed to recommend a TAC for silver warehou based on the assumption that recruitment will remain below average in the next few years. SERAG chose to assume that recruitment would remain at the mean of the last five years of estimated recruitments in the base case model (2010 – 2014). Projections assuming this low recruitment were run for scenarios of constant landed catch that were between the catch in the most recent year for which data is available (348 t) and the RBCs from the base case model which assumes average recruitment (942 t in 2019). Scenarios with constant annual catches of 750 t or more led to the estimated spawning biomass declining under the low recruitment scenario. Under the low recruitment scenario with constant annual catches between 348 t and 600 t, spawning biomass is predicted to increase, albeit more slowly than the base case which assumes average recruitment.

Eastern orange roughy

A cross-catch risk assessment for eastern orange roughy was presented based upon the model structure of the last full quantitative assessment in 2017. Two models are considered that differ only by the assumed value of natural mortality, M. The base-case model has M=0.04 and an alternative has M=0.032. The alternative value for natural mortality was chosen to define a low productivity model, and used the value with highest likelihood from the likelihood profile. The catches input to the two model structures were the predicted projected catches from each model, and a fixed 3-year catch series proposed by industry; thus three projected catch scenarios associated with each natural mortality were used. The purpose of the risk assessment was to identify if any of the catch series led to biomass trajectories that may be perceived as a risk to the long-term sustainability of the stock. The consequent six scenarios (2 models × 3 catch series) were projected 55 years into the future.

Results showed that the model with lower productivity (the M=0.032 model) and with the highest catches (from the M=0.04 model) had the lowest long-term biomass series (in terms of annual tonnage of female spawning biomass). This series stabilised at approximately 30% of virgin biomass. All other scenarios had biomass levels that were considerably greater than this. As far as short-term catches and depletion were concerned, the differences between biomass trajectories across catch series were minimal within a model structure (i.e. for a particular value of M). For example, by 2025, the depletion ranged between 0.40 and 0.42 for the M=0.04 models, whereas the depletion ranged between 0.31 and 0.34 for the M=0.032 model.

1.2 Shark Species

School shark

Sampling for the school shark close kin project is complete, with approximately 3,000 sharks collected and genetically sequenced. A total of 3 parent offspring pairs (POPs, two mothers and one father) were found along with 34 full sibling pairs (FSPs) and 65 half sibling pairs (HSPs, i.e. two offspring with one parent in common) of which 27 were paternal and 38 maternal. The ratio of full to half siblings is relatively high, suggesting a large “litter effect” whereby some cohorts have unusually high survival due (possibly) to favourable environmental conditions (these are not expected to bias our estimates of abundance). There also seem to be a modest proportion of litters that have more than one father. All animals sequenced were also aged by counting vertebral “rings”. Relatively large ageing error was found (CV 0.08) and mature animals are known to have slower growth rates and to accumulate less than one vertebral ring per year of age.

Simple analyses of the proportion of half sibling pairs born since 2000, based on the facts that (1) each animal had exactly one mother and one father at birth, and (2) mothers and fathers may die over time, give a ballpark estimate for recent adult abundance. We constructed an age-structured population dynamics model that uses commercial catch and discard data, length frequencies from port measured gillnet catches (although these were given negligible weight), estimates of gear selectivity and several biological parameters used by the sharkRAG stock assessment model for school shark, as well as the close kin data. The model follows the same approach used for close kin mark recapture (CKMR) for Southern Bluefin Tuna (SBT) and several other species, whereby the probability that each pairwise comparison of two animals will prove to be a close kin pair is computed based on the working values of the population dynamics parameters, taking account of the ring counts, years of capture, and sex of the two animals concerned. The actual outcome of that comparison (e.g. that it was a maternal half sibling pair) is then compared with the computed probability, and parameters are adjusted to give the best fit between observed and expected values. Probability distributions were constructed for the age of each animal, given its ring count and accounting for ageing error and ring deposition rates at age.

Compared with the 2012 projection of the stock assessment model for school shark, which assumed catches of 225t after 2011, the analyses and the close kin model both estimate a substantially lower adult abundance. The assessment projection and the close kin model (as well as the simple approaches) both indicate an upward trend in abundance since 2000, of a similar rate (although the confidence interval on trend is quite wide).

The close kin model requires assumptions which may not hold far back into the history of this fishery, particularly those regarding density dependence. We therefore restricted attention (for now) to the 2000-2017 period, when most of the close kin samples were born and where the information content is strongest. This was done by restricting the (estimated) age of included samples, leaving out the oldest. This did reduce the “sample size” (to 1,627 out of 2,438 original samples, and 29 out of 40 maternal half-sibling pairs, and a shorter window). The restriction led to satisfactory model fits, but more uncertainty about abundance than might be obtained with the complete dataset. In addition, because we had no prior estimates of whether male fecundity varies much through adulthood, and not enough POPs to estimate it, we took a conservative approach, of not considering the 27 paternal half siblings and the single father-offspring pair. If the model can be expanded to include the historical data adequately and include more of the samples, the CVs will improve.

The stock assessment model used by sharkRAG has been limited by the absence of an index of relative abundance after 1997, and has never been able to disentangle abundance from productivity without the use of a prior based on “expert opinion”. Close kin data provides a fishery-independent estimate of absolute abundance, productivity, and spawning stock trend, and can thus obviate the need for the prior.

KEYWORDS: fishery management, southern and eastern scalefish and shark fishery, stock assessment, trawl fishery, non-trawl fishery

2. Background

The Southern and Eastern Scalefish and Shark Fishery (SESSF) is a Commonwealth-managed, multi-species and multi-gear fishery that catches over 80 species of commercial value and is the main provider of fresh fish to the Sydney and Melbourne markets. Precursors of this fishery have been operating for more than 85 years. Catches are taken from both inshore and offshore waters, as well as offshore seamounts, and the fishery extends from Fraser Island in Queensland to south west Western Australia.

Management of the SESSF is based on a mixture of input and output controls, with over 20 commercial species or species groups currently under quota management. For the previous South East Fishery (SEF), there were 17 species or species groups managed using TACs. Five of these species had their own species assessment groups (SAGs) – orange roughy (ORAG), eastern gemfish (EGAG), blue grenadier (BGAG), blue warehou (BWAG), and redfish (RAG). The assessment groups comprise scientists, fishers, managers and (sometimes) conservation members, meeting several times in a year, and producing an annual stock assessment report based on quantitative species assessments. The previous Southern Shark Fishery (SSF), with its own assessment group (SharkRAG), harvested two main species (gummy and school shark), but with significant catches of saw shark and elephantfish.

In 2003, these assessment groups were restructured and their terms of reference redefined. Part of the rationale for the amalgamation of the previous separately managed fisheries was to move towards a more ecosystem-based system of fishery management (EBFM) for this suite of fisheries, which overlap in area and exploit a common set of species. The restructure of the assessment groups was undertaken to better reflect the ecological system on which the fishery rests. To that end, the assessment group structure now comprises:

- SESSFRAG (an umbrella assessment group for the whole SESSF)
- South East Resource Assessment Group (Slope, Shelf and Deep RAG)
- Shark Resource Assessment Group (Shark RAG)
- Great Australian Bight Resource Assessment Group (GAB RAG)

Each of the depth-related assessment groups is responsible for undertaking stock assessments for a suite of key species, and for reporting on the status of those species to SESSFRAG. The plan for the resource assessment groups (South East, GAB and Shark RAGs) is to focus on suites of species, rather than on each species in isolation. This approach has helped to identify common factors affecting these species (such as environmental conditions), as well as consideration of marketing and management factors on key indicators such as catch rates.

The quantitative assessments produced annually by the Resource Assessment Groups are a key component of the TAC setting process for the SESSF. For assessment purposes, stocks of the SESSF currently fall under a Tier system whereby those with better quality data and more robust assessments fall under Tier 1, while those with less reliable available information are in Tiers 3 and 4. To support the assessment work of the four Resource Assessment Groups, the aims of the work conducted in this report were to develop new assessments if necessary (under all Tier levels), and update and improve existing ones for priority species in the SESSF.

3. Need

A stock assessment that includes the most up-to-date information and considers a range of hypotheses about the resource dynamics and the associated fisheries is a key need for the management of a resource. In particular, the information contained in a stock assessment is critical for selecting harvest strategies and setting Total Allowable Catches.

4. Objectives

- These Objectives include the SESSFRAG agreed changes to the assessment schedule:

- Provide quantitative and qualitative species assessments in support of the four SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework
- 2018: Provide Tier 1 assessments for Blue grenadier, Jackass morwong (east and west), School shark, and Silver warehou; Tier 3 assessment for Alfonsino (removed); Tier 4 assessments for Blue eye trevalla (addition of T5 for seamounts) and Deepwater shark (east and west); and Tier 5 for Smooth oreo (removed).
- 2019: Provide Tier 1 assessments for Deepwater flathead, Tiger flathead, Western gemfish (moved to T4), Bight redfish (addition) and Gummy shark (delayed); and Tier 4 for Mirror Dory.

5. Eastern Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2017 – development of a preliminary base case

Jemery Day and Claudio Castillo-Jordán

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

5.1 Executive Summary

This document presents a suggested base case for an updated quantitative Tier 1 assessment of eastern jackass morwong (*Nemadactylus macropterus*) for presentation at the first SERAG meeting in 2018. The last full assessment was presented in Tuck et al. (2015). The preliminary base case has been updated by the inclusion of data up to the end of 2017, which entails an additional three years of catch, discard, CPUE, length-composition and conditional age-at length data and updates to the ageing error matrices since the 2015 assessment. One additional abundance index (2016) for the Fishery Independent Survey (FIS) was included. This document describes the process used to develop a preliminary base case for jackass morwong through the sequential updating of recent data to the stock assessment, using the stock assessment package Stock Synthesis (SS-V3.30.12).

Changes to the last stock assessment include: improvement to the method of estimating the bias ramp and using an updated tuning method.

Results show good fits to the abundance data (catch rate and FIS), and good fits to the length composition and conditional age-at-length data. This assessment estimates that the projected 2019 spawning stock biomass will be 35% of virgin stock biomass (projected assuming 2017 catches in 2018), a slightly lower relative biomass level than the depletion of 37% at the start of 2016 obtained from the last assessment (Tuck et al., 2015).

5.2 Introduction

5.2.1 *Bridging from 2015 to 2018 assessments*

The previous full quantitative assessment for eastern jackass morwong was conducted during 2015 (Tuck et al., 2015) using Stock Synthesis (version SS-V3.24U, Methot and Wetzel, 2013). The 2018 assessment uses the current version of Stock Synthesis (version SS-V3.30.12, Methot et. al, 2018), which includes some changes from SS-V3.24U.

As a first step in the process of bridging to a new model, the model was translated from version SS-V3.24U (Methot and Wetzel, 2013) to version SS-V3.30.12 (Methot et. al, 2018) using the same data and model structure used in the 2015 assessment. Once this translation was complete, improved features unavailable in SS-V3.24U were incorporated into the SS-V3.30.12 assessment. These included allowing smaller lower bounds on minimum sample sizes and estimating a parameter that tunes the standard deviation to abundance indices. Following this step, the model was re-tuned using the most recent tuning protocols, thus allowing the examination of changes to both assessment practices and the tuning procedure on the previous model structure. These changes to software and tuning practices are likely to lead to changes to key model outputs, such as the estimates of depletion and the trajectory of spawning biomass. This initial bridging phase (Bridge 1) highlights changes that have occurred since 2015 simply through changes to software and assessment practices. The subsequent bridging exercise (Bridge 2) then sequentially updates the model with new data through to 2017.

The second part of the bridging analysis includes updating historical data (up to 2014), followed by including the data from 2015-2017 into the model. These additional data included new catch, discard, CPUE, FIS abundance indices, length composition data, conditional age-at-length data, an updated ageing error matrix and an additional CPUE index (trawl). The last year of recruitment estimation was extended to 2012 (2011 in the 2015 assessment). The use of updated software and the inclusion of additional data resulted in some differences in the fits to CPUE, conditional age-at-length data and length composition data. The usual process of bridging to a new model by adding new data piecewise and analysing which components of the data could be attributed to changes in the assessment outcome was conducted with the details outlined below.

5.2.2 *Update to Stock Synthesis SSV-3.30.12 and updated catch history (Bridge 1)*

The 2015 eastern jackass morwong assessment (East2015_24U) was initially translated to the most recent version of the software, Stock Synthesis version SS-V3.30.12 (East2015_30_12). Figure 5.1 shows that the differences in the assessment results from this step were minimal.

New features available in the new version of Stock Synthesis, such as allowing smaller lower bounds on minimum sample sizes and estimating additional standard deviation to abundance indices were then incorporated (East2015_30_12New), followed by retuning using the latest tuning protocol (East2015_30_12Tuned). Details of the tuning procedure used are listed in Section 5.2.2.1. Revisions to the historical catches, up to 2014, and replacing the estimated 2015 catch with the actual 2015 catch were then added to this tuned version of the 2015 model (East2015_30_12ReviseCatch). This process demonstrates the outcomes that could theoretically have been achieved with the last assessment if we had the latest, software, tuning protocols and corrected data available in 2015. This initial bridging step, Bridge 1, does not incorporate any data after 2014 or any structural changes to the assessment.

When these time series are plotted together, there are relatively minor changes in the translation to SS-V3.30.12, largely due to differences in implementation of regime shifts in the new version, but considerable changes when the new features were added, and further changes when the model was retuned using current model tuning protocols. Revising the catch history to 2014 had very little effect (Figure 5.2 and Figure 5.3).

This process demonstrates the outcomes that could theoretically have been achieved during the last assessment if we had the latest software, tuning protocols and corrected data available in 2015. Bridge 1 does not incorporate any new data after 2014 or any structural changes to the assessment. The results of Bridge 1 suggest that the stock was more depleted in 2016 than the 2015 assessment indicated. This is almost entirely due to changes in parameters that can be tuned, including variances that can be estimated internally and in the tuning procedure itself, rather than changes to the data or to the software.

Fits to the abundance indices (Figure 5.4 to Figure 5.8) show changes through this process, most with small improvements to the fit during Bridge 1. However the FIS indices show very little noticeable change to fits (Figure 5.9 to Figure 5.10). The estimated recruitment series shows little change in broad trends from using the new features in Stock Synthesis and using the new tuning procedure (Figure

5.11). However, while most of the recent recruitment estimates are largely unchanged, those in 2009 and 2010 have been notably revised downwards during Bridge 1.

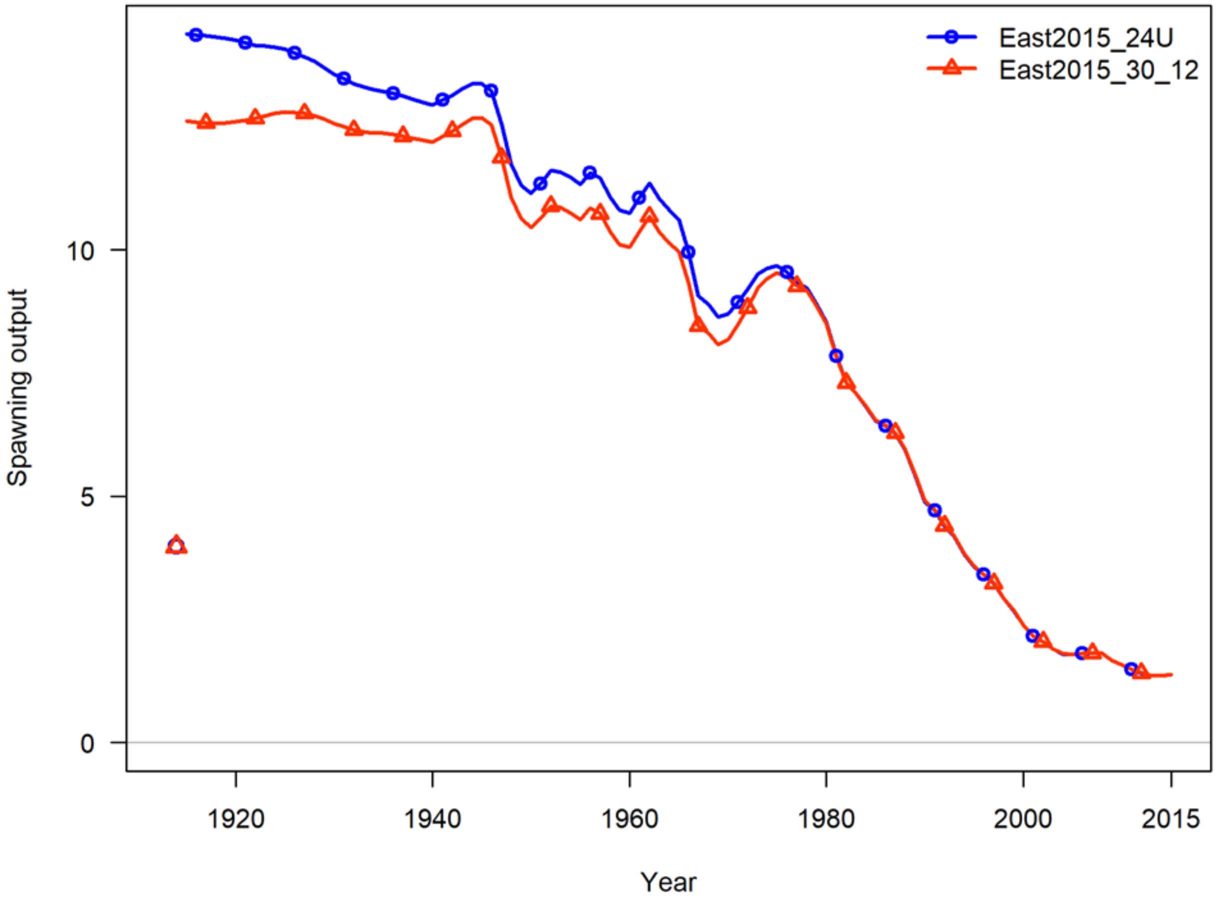

Figure 5.1. Comparison of the time series of absolute spawning biomass from the 2015 assessment (East2015_24U – in blue), and a model with the same data converted to SS-V3.30 (East2015_30_12 – in red). The changes shown are largely due to changes in the implementation of a regime shift in the updated version of Stock Synthesis.

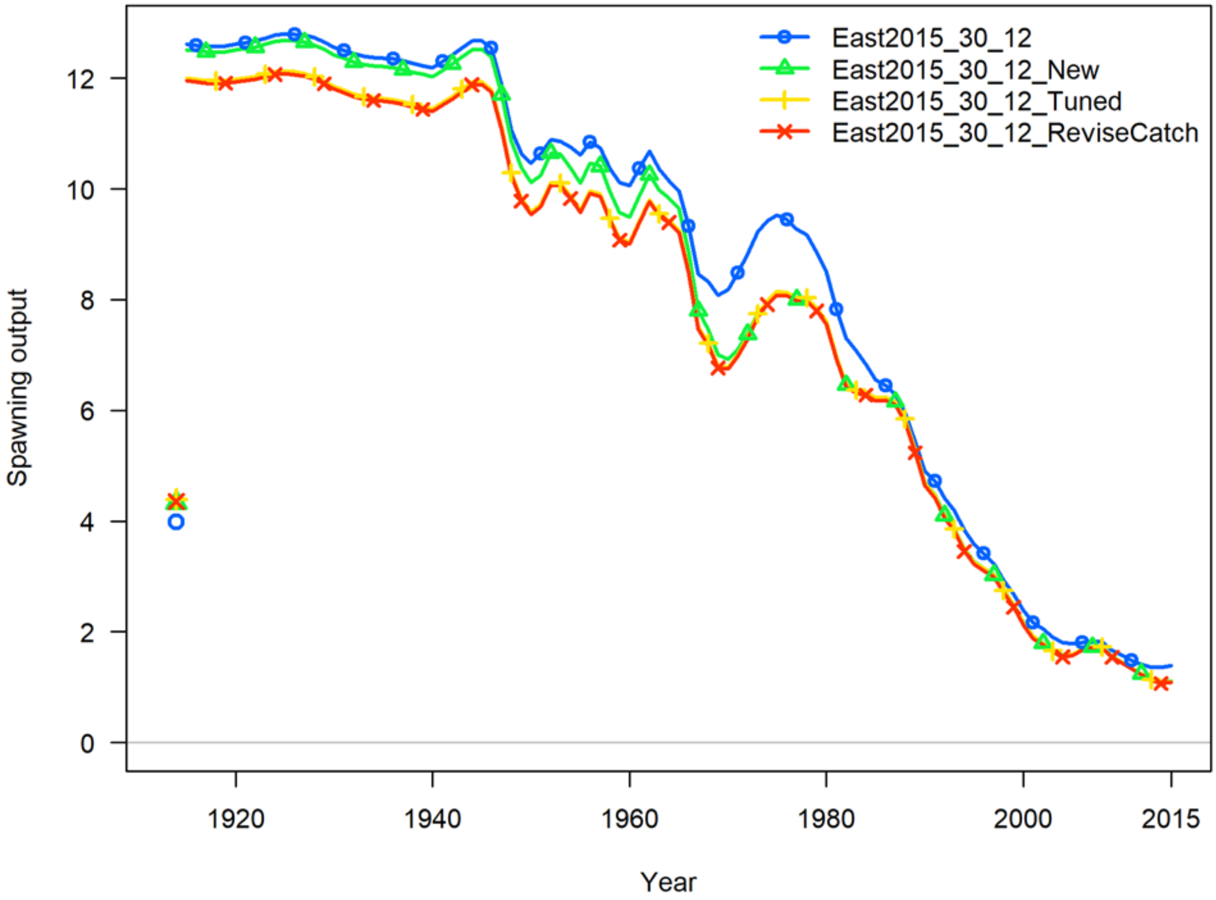

Figure 5.2. Comparison of the time-series of absolute spawning biomass from the 2015 assessment (East2015_30_12 – in blue), incorporating new features (East2015_30_12_New – in green), retuning the model using the latest tuning protocols (East2015_30_12_Tuned – in yellow) and revising the historical catch to 2014 and the projected catch in 2015 (East2015_30_12_ReviseCatch – in red).

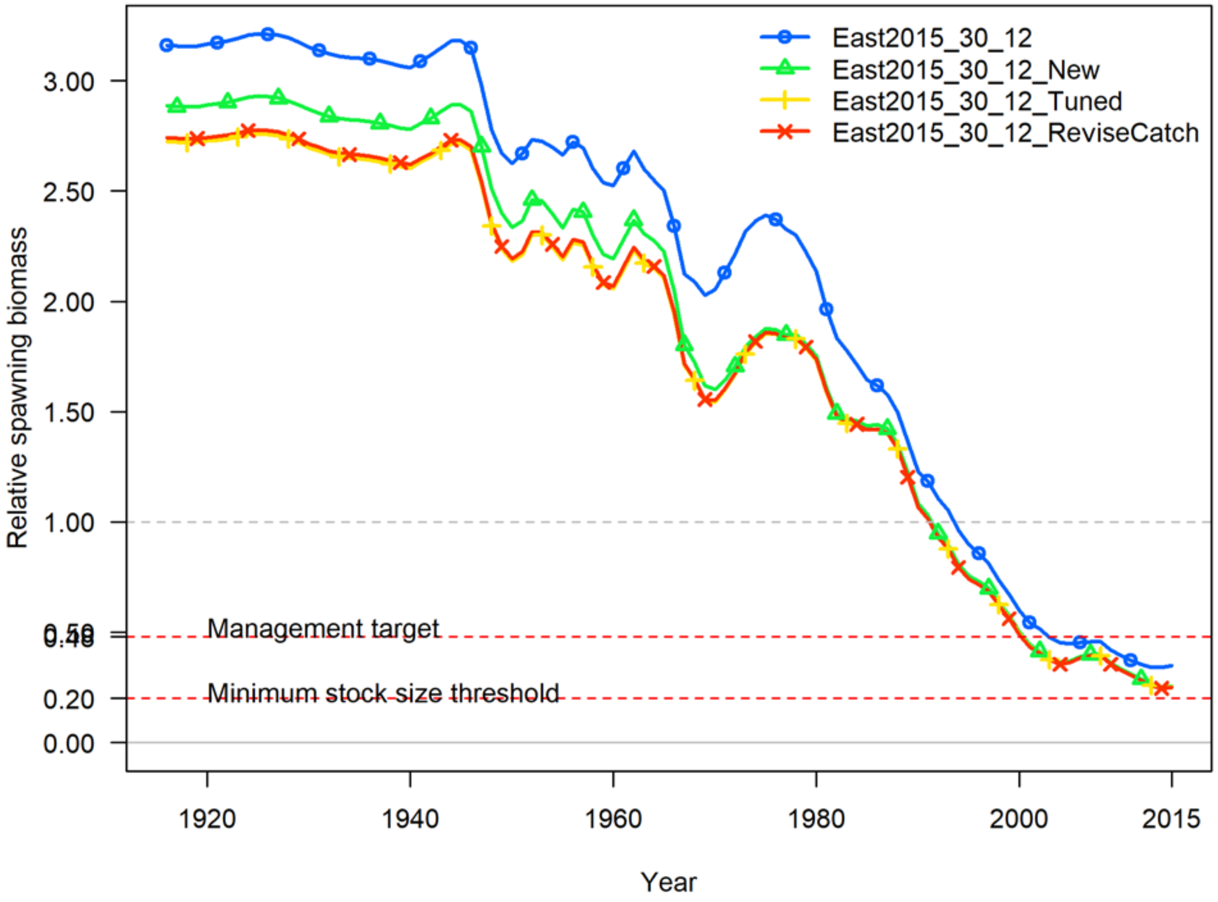

Figure 5.3. Comparison of the time-series of relative spawning biomass from the 2015 assessment (East2015_30_12 – in blue), incorporating new features (East2015_30_12_New – in green), retuning the model using the latest tuning protocols (East2015_30_12_Tuned – in yellow) and revising the historical catch to 2014 and the projected catch in 2015 (East2015_30_12_ReviseCatch – in red).

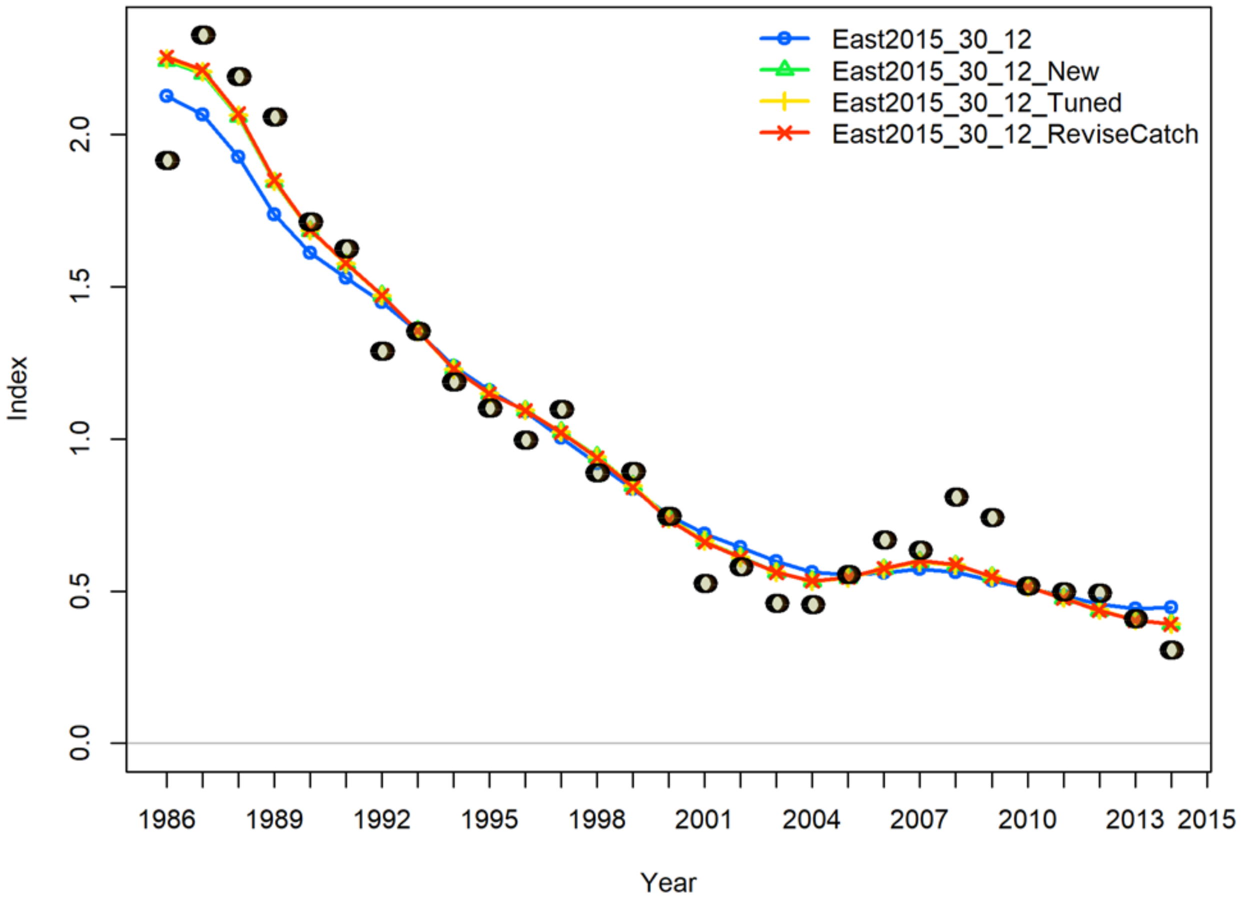

Figure 5.4. Comparison of the fit to the Eastern trawl CPUE index for the 2015 assessment (East2015_30_12 – in blue), incorporating new features (East2015_30_12_New – in green), retuning the model using the latest tuning protocols (East2015_30_12_Tuned – in yellow) and revising the historical catch to 2014 and the projected catch in 2015 (East2015_30_12_ReviseCatch – in red).

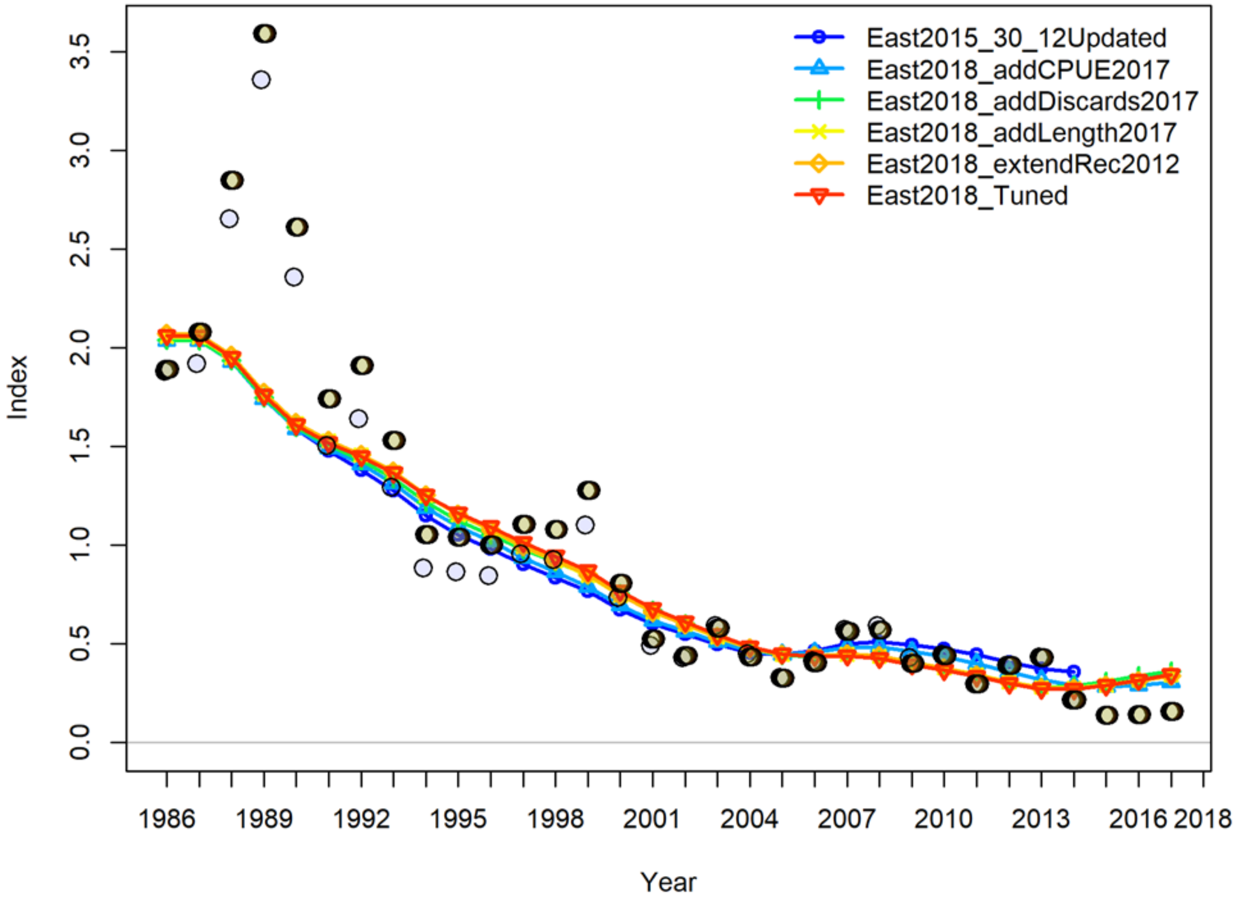

Figure 5.5. Comparison of the fit to the Tasmanian trawl CPUE index for the 2015 assessment (East2015_30_12 – in blue), incorporating new features (East2015_30_12_New – in green), retuning the model using the latest tuning protocols (East2015_30_12_Tuned – in yellow) and revising the historical catch to 2014 and the projected catch in 2015 (East2015_30_12_ReviseCatch – in red).

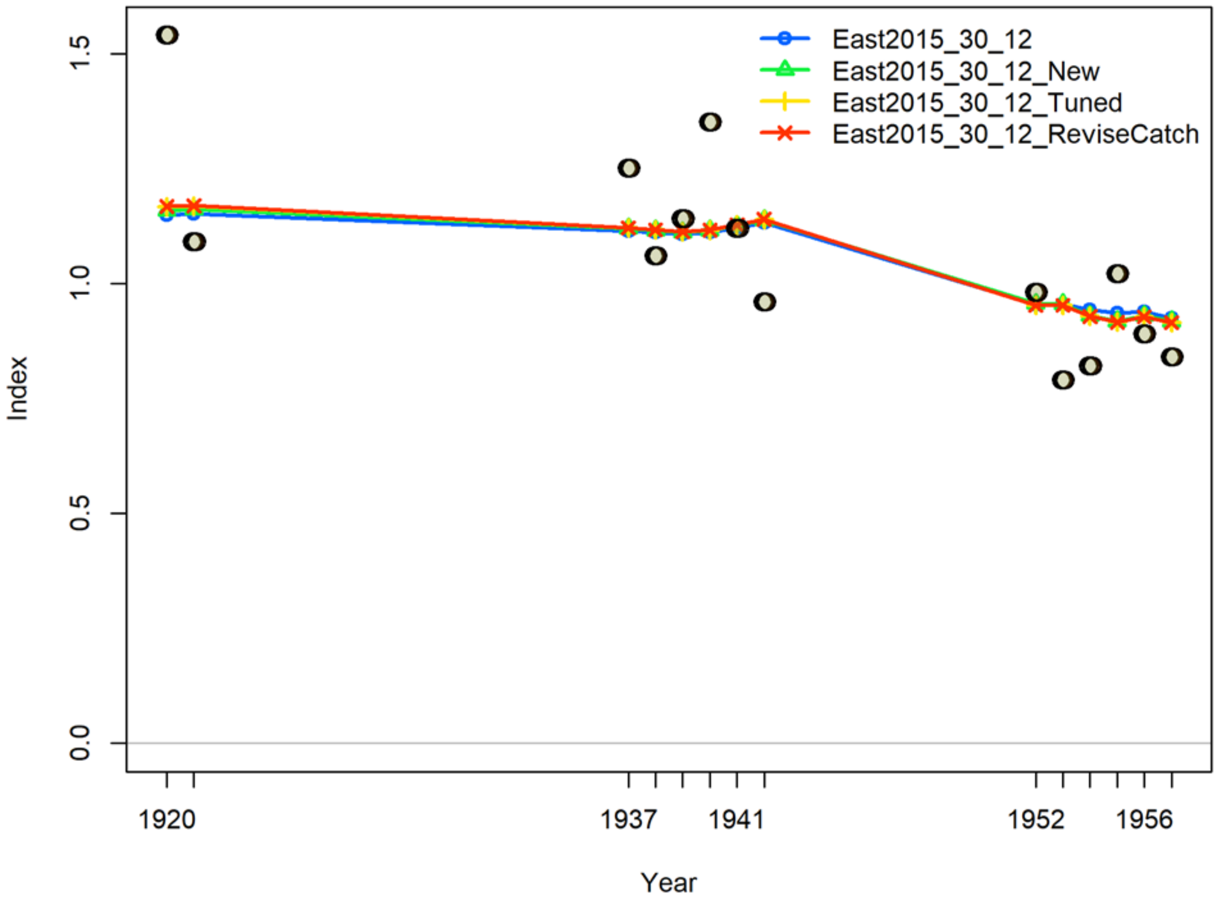

Figure 5.6. Comparison of the fit to the Steam trawl CPUE index for the 2015 assessment (East2015_30_12 – in blue), incorporating new features (East2015_30_12_New – in green), retuning the model using the latest tuning protocols (East2015_30_12_Tuned – in yellow) and revising the historical catch to 2014 and the projected catch in 2015 (East2015_30_12_ReviseCatch – in red).

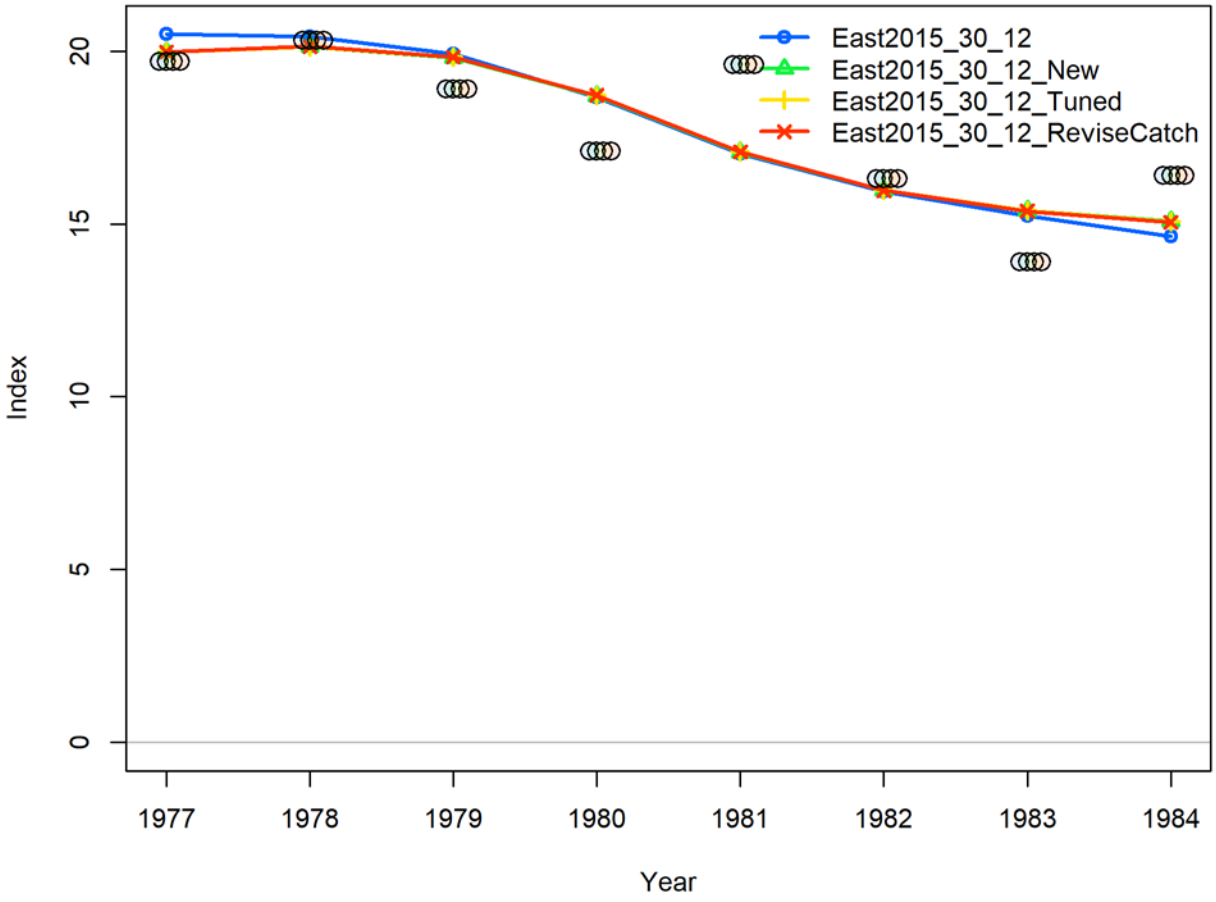

Figure 5.7. Comparison of the fit to the mixed CPUE index for the 2015 assessment (East2015_30_12 – in blue), incorporating new features (East2015_30_12_New – in green), retuning the model using the latest tuning protocols (East2015_30_12_Tuned – in yellow) and revising the historical catch to 2014 and the projected catch in 2015 (East2015_30_12_ReviseCatch – in red).

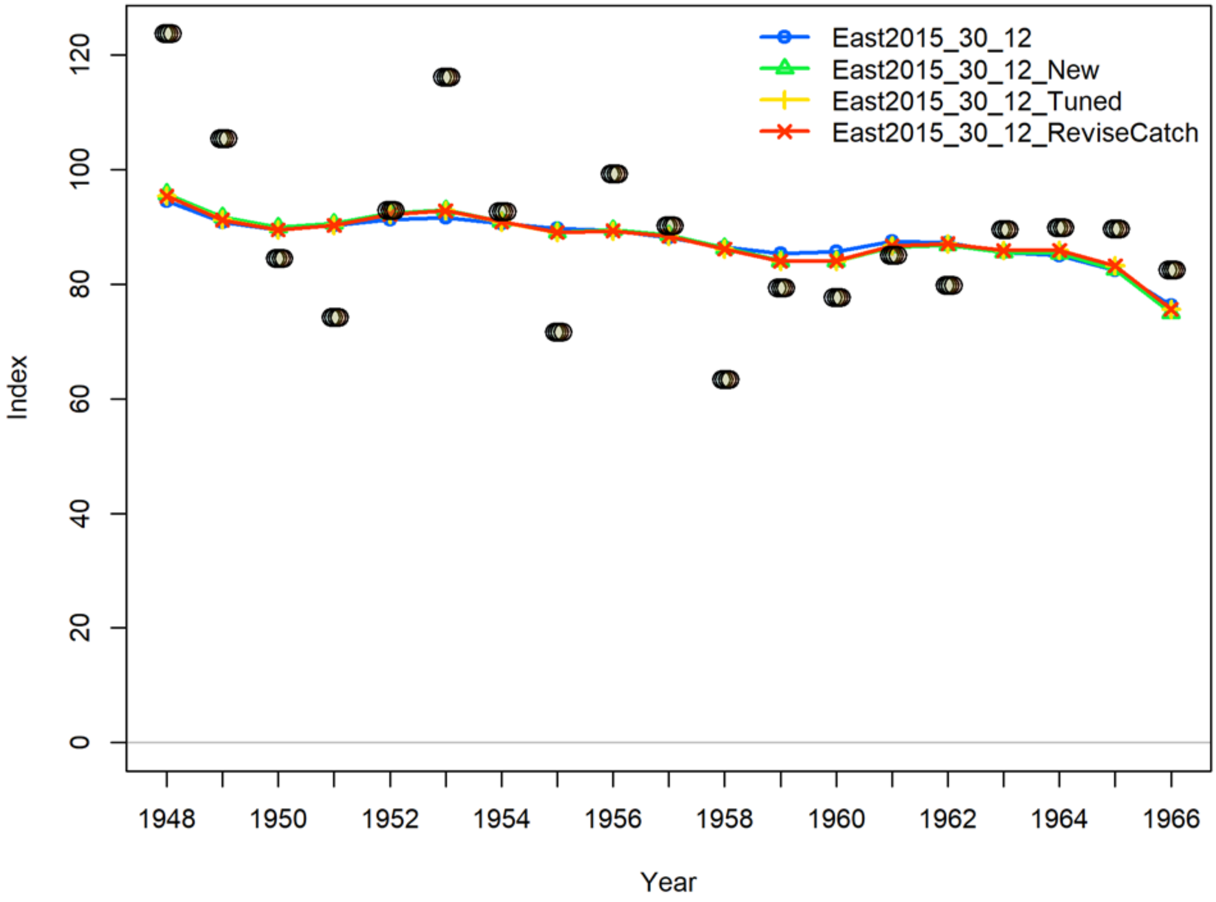

Figure 5.8. Comparison of the fit to the Smith CPUE index for the 2015 assessment (East2015_30_12 – in blue), incorporating new features (East2015_30_12_New – in green), retuning the model using the latest tuning protocols (East2015_30_12_Tuned – in yellow) and revising the historical catch to 2014 and the projected catch in 2015 (East2015_30_12_ReviseCatch – in red).

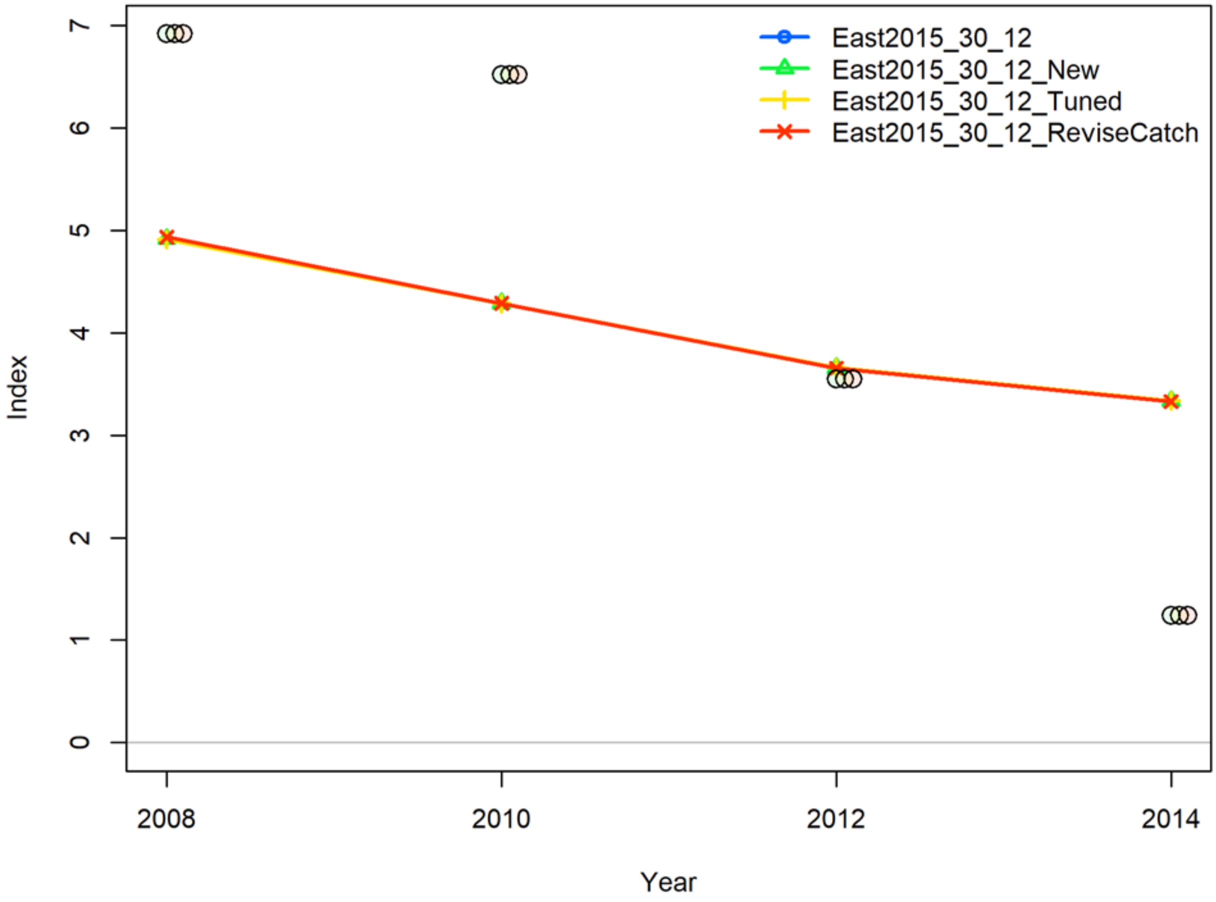

Figure 5.9. Comparison of the fit to the FIS_East (zones 10 and 20) abundance index for the 2015 assessment (East2015_30_12 – in blue), incorporating new features (East2015_30_12_New – in green), retuning the model using the latest tuning protocols (East2015_30_12_Tuned – in yellow) and revising the historical catch to 2014 and the projected catch in 2015 (East2015_30_12_ReviseCatch – in red).

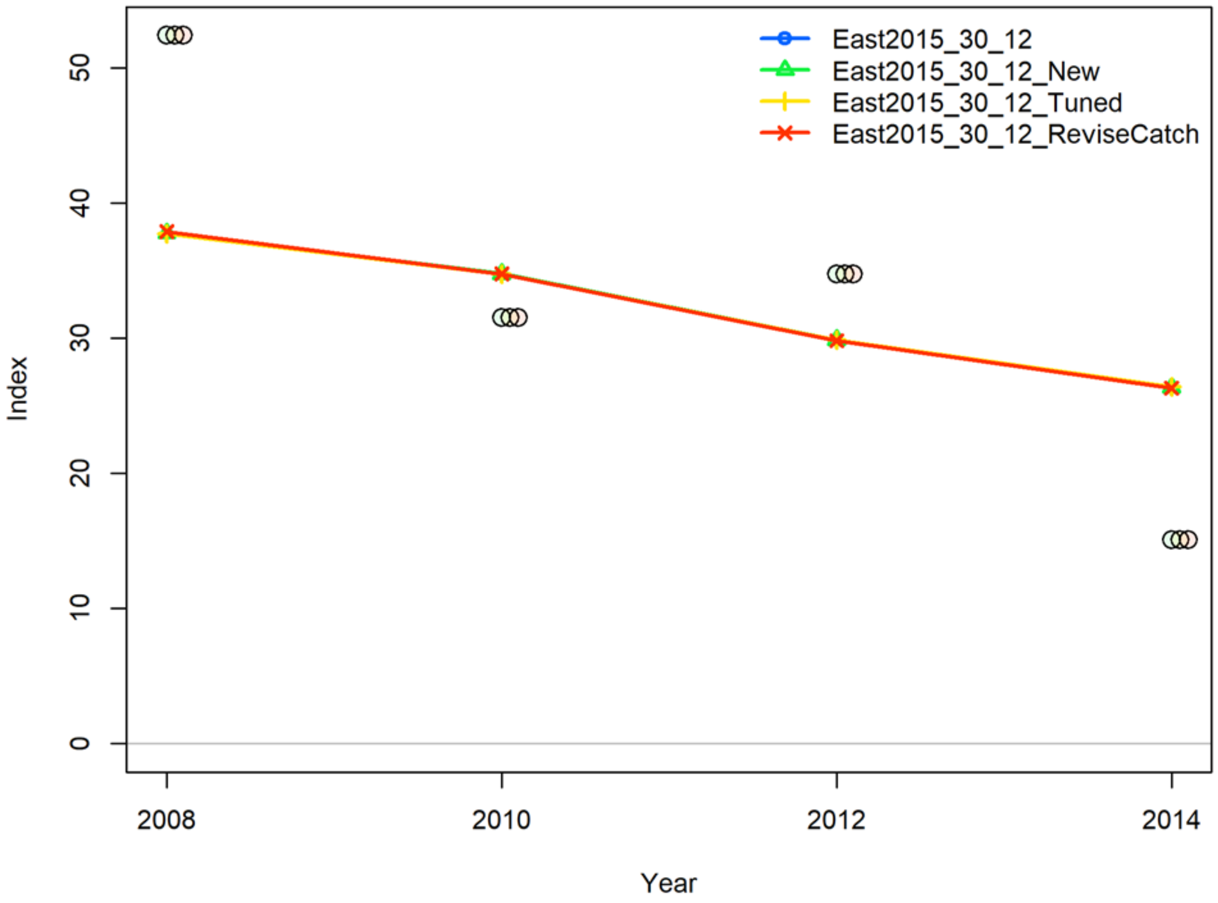

Figure 5.10. Comparison of the fit to the FIS_Tas (zone 30) abundance index for the 2015 assessment (East2015_30_12 – in blue), incorporating new features (East2015_30_12_New – in green), retuning the model using the latest tuning protocols (East2015_30_12_Tuned – in yellow) and revising the historical catch to 2014 and the projected catch in 2015 (East2015_30_12_ReviseCatch – in red).

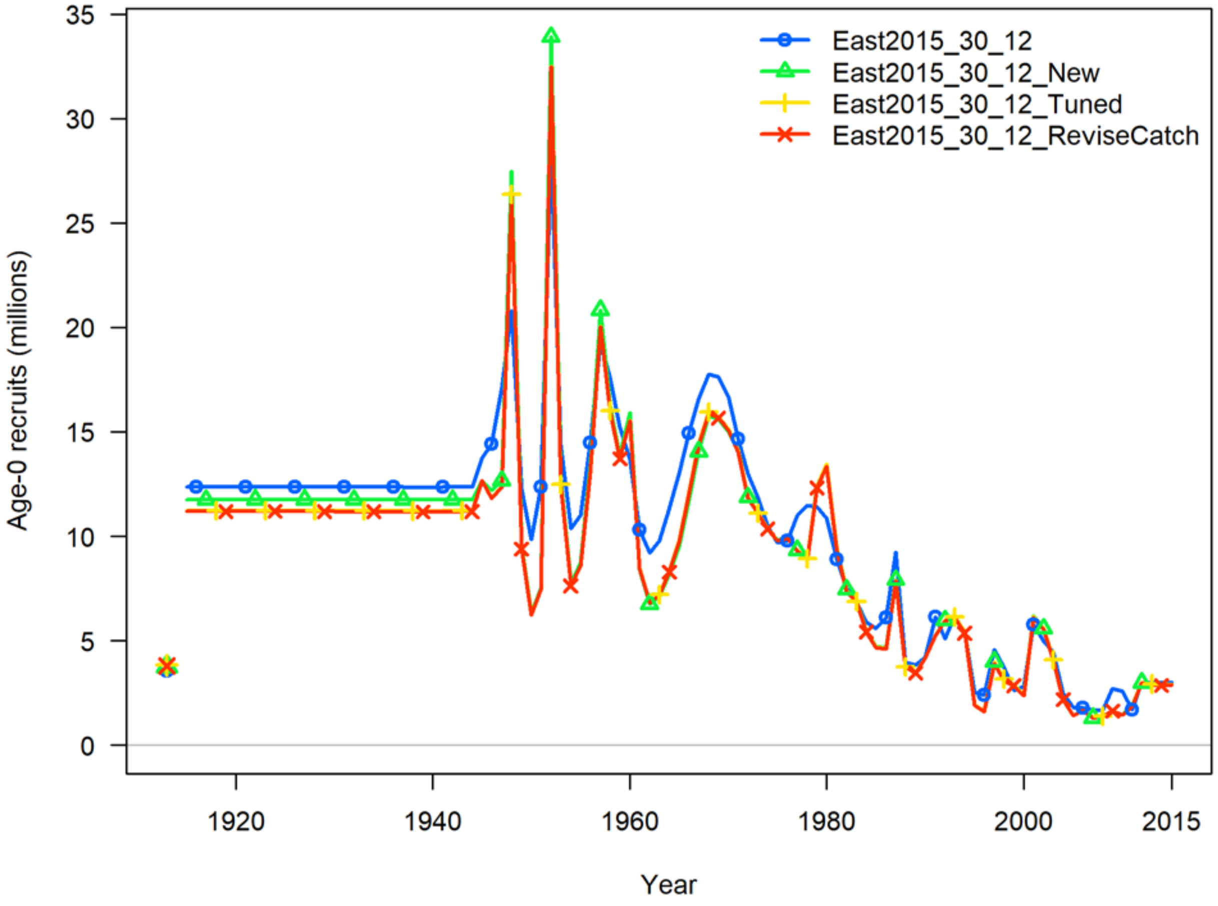

Figure 5.11. Comparison of the time series of recruitment from the 2015 assessment (East2015_30_12 – in blue), incorporating new features (East2015_30_12_New – in green), retuning the model using the latest tuning protocols (East2015_30_12_Tuned – in yellow) and revising the historical catch to 2014 and the projected catch in 2015 (East2015_30_12_ReviseCatch – in red).

5.2.2.1 Tuning method

Iterative rescaling (reweighting) of input and output CVs or input and effective sample sizes is a repeatable method for ensuring that the expected variation of the different data streams is comparable to what is input (Pacific Fishery Management Council, 2018). Most of the indices (CPUE, surveys and composition data) used in fisheries underestimate their true variance by only reporting measurement or estimation error and not including process error.

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 it is possible to estimate an additional standard deviation parameter to add to the input CVs for the abundance indices (CPUE).

1. Set the standard error for the log of relative abundance indices (CPUE or FIS) to their estimated standard errors to the standard 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. SSV-3.30 then allows an estimate to be made for an additional adjustment to the relative abundance variances appropriately.

An automated iterative tuning procedure was used for the remaining adjustments. For the recruitment bias adjustment ramps:

2. Adjust the maximum bias adjustment and the start and finish bias adjustment ramps as predicted by SSv3.30 at each step.

For the age and length composition data:

3. Multiply the stage-1 (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 2 – 4, until all are converged and stable (with proposed changes < 1 – 2%).

This procedure constitutes current best practice for tuning assessments.

5.2.3 *Inclusion of new data: 2015-2017*

Starting from the translated, retuned 2015 base case model with updated data to 2014 (previously referred to as "East2015_30_12ReviseCatch", but simplified to "East2015_30_12Updated" from here on), additional data from 2015-2017 were added sequentially to build a preliminary base case for the 2018 assessment:

1. Change final assessment year to 2017, add catch to 2017 (East2018_addCatch2017).
2. Add CPUE to 2017 (from Sporcic and Haddon (2018b)), and the FIS abundance index for 2016 (Knuckey et al 2017) (East2018_addCPUE2017).
3. Add new discard fraction estimates from 1994 to 2017 (East2018_addDiscards2017).
4. Add updated length frequency data to 2017 (East2018_addLength2017).
5. Add updated age error matrix and conditional age-at-length data to 2017 (East2018_addAge2017).
6. Change the final year for which recruitments are estimated from 2011 to 2012 (East2018_extendRec2012).
7. Retune using current tuning protocols, including Francis weighting on length-compositions and conditional age-at-length data (East2018_Tuned).

Inclusion of the new data resulted in a series of changes to the estimates of recruitment and the time-series of absolute and relative spawning biomass (Figure 5.12, Figure 5.13 and Figure 5.14), with relatively small changes to these series as more data is added. The most significant change to the absolute biomass series relates to the estimate of 1988 equilibrium spawning biomass (post productivity shift), see the lower left points in Figure 5.12. These changes are amplified in the initial depletion level in 1914, which is shown relative to the 1988 equilibrium spawning biomass in Figure 5.13, which changes slightly as data is added, effectively producing a pivot point around the 1988 equilibrium spawning biomass. Fits to the CPUE indices (Figure 5.15 to Figure 5.19) and the FIS abundance index (Figure 5.20 and Figure 5.21) feature minor changes as data is added, and with minimal changes to the historical fleets which have no new data. Both the Eastern trawl and Tasmanian trawl improve marginally as more data is added. Adding discard data appears to have the largest influence, most likely due to changes to the methods for calculating discard estimates. The fits to the FIS abundance index (Figure 5.20 and Figure 5.21) are not very good. Given the variability from point to point, it would be hard to get good fits to these series, and to fit the species biology and the rest of the data in the assessment. It appears that the fits to the much longer recent trawl CPUE indices are much more influential. The fits to the historic CPUE indices are reasonable and the fit to the eastern trawl CPUE series even matches the increase seen in the last 3 data points

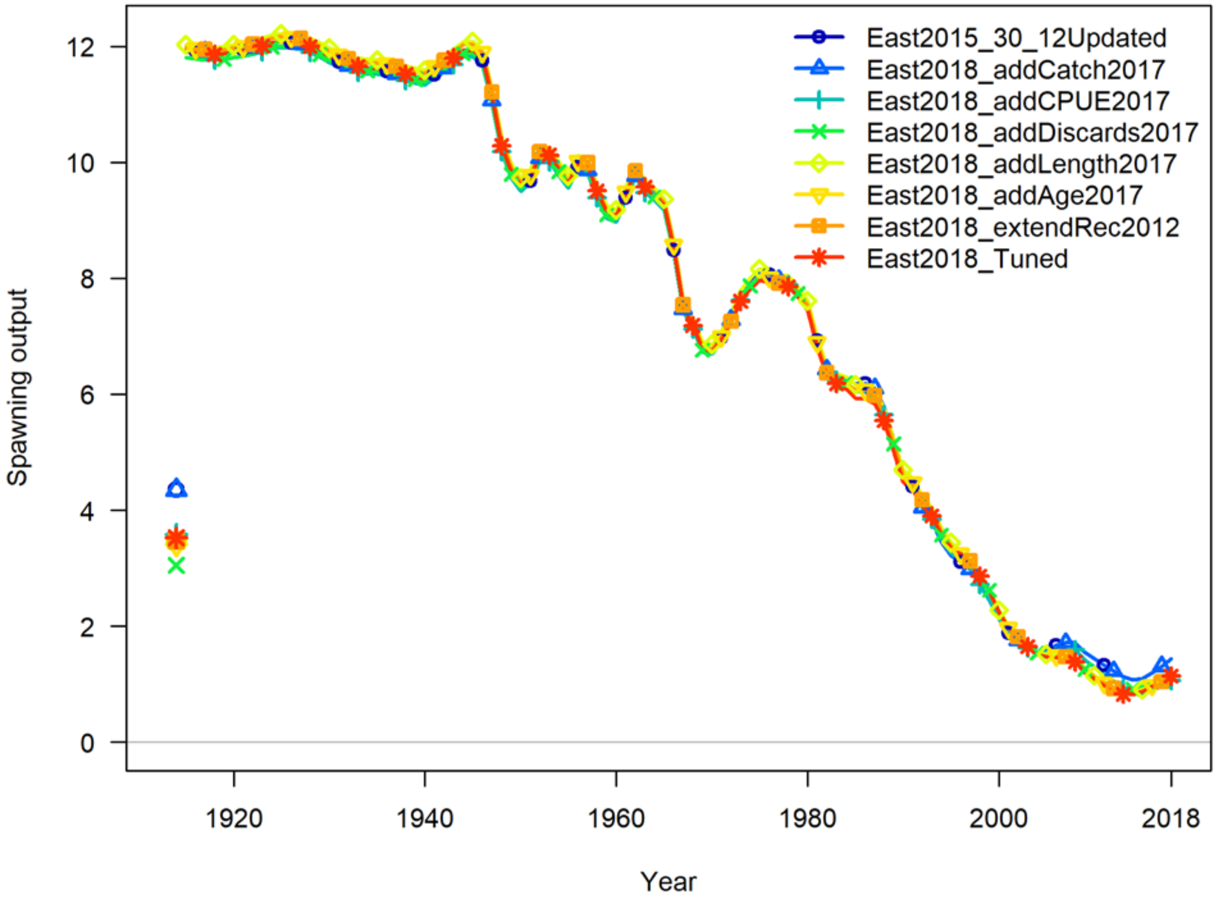

Figure 5.12. Comparison of the time series of absolute spawning biomass for the updated 2015 assessment model converted to SS-V3.30.12 (East2015_30_12_updated- blue) with various bridging models leading to a proposed 2018 base case model (East2018_Tuned - red).

Since the 2015 assessment, standard changes to the procedures used in the Stock Synthesis assessments in the SESSF include:

1. Revised tuning procedures, still including use of Francis weighting for length-composition and conditional age-at-length data, but tuning the weight assigned to the CPUE series within Stock Synthesis, and
2. Improvements to how the recruitment bias ramp adjustment is calculated.

Inclusion of three years of new data resulted in relatively small changes to estimates of recruitment and the spawning biomass time series, although the time series of spawning biomass now appears to have shifted a little lower in recent years with a minimum stock biomass level in 2013 and 2014 of around 23% but with an apparent recovery since then, with stronger recruitment and low fishing pressure in recent years. Recruitment was only able to be estimated for one additional year, despite using three more years of additional data, with upward revisions to the recruitment estimates from 2010 and 2011 and slightly higher than average recruitment estimated for 2012. These latest recruitment estimates may be further revised with the inclusion of additional data in future assessments, with new data that may help inform these recruitment estimates. The 2015 assessment estimated the depletion at the start of 2016 at 37%. This provisional base case has an estimate of depletion at the start of 2019 (projected assuming 2017 catches in 2018) of 35% of unexploited stock biomass, *SSB*$_0$. The equilibrium female spawning biomass in 1988 (post productivity shift) equilibrium female spawning biomass of 3,523 t (reduced from 3,977 t from the 2015 assessment) and in 2019 the female spawning biomass is projected to be 1,237t.

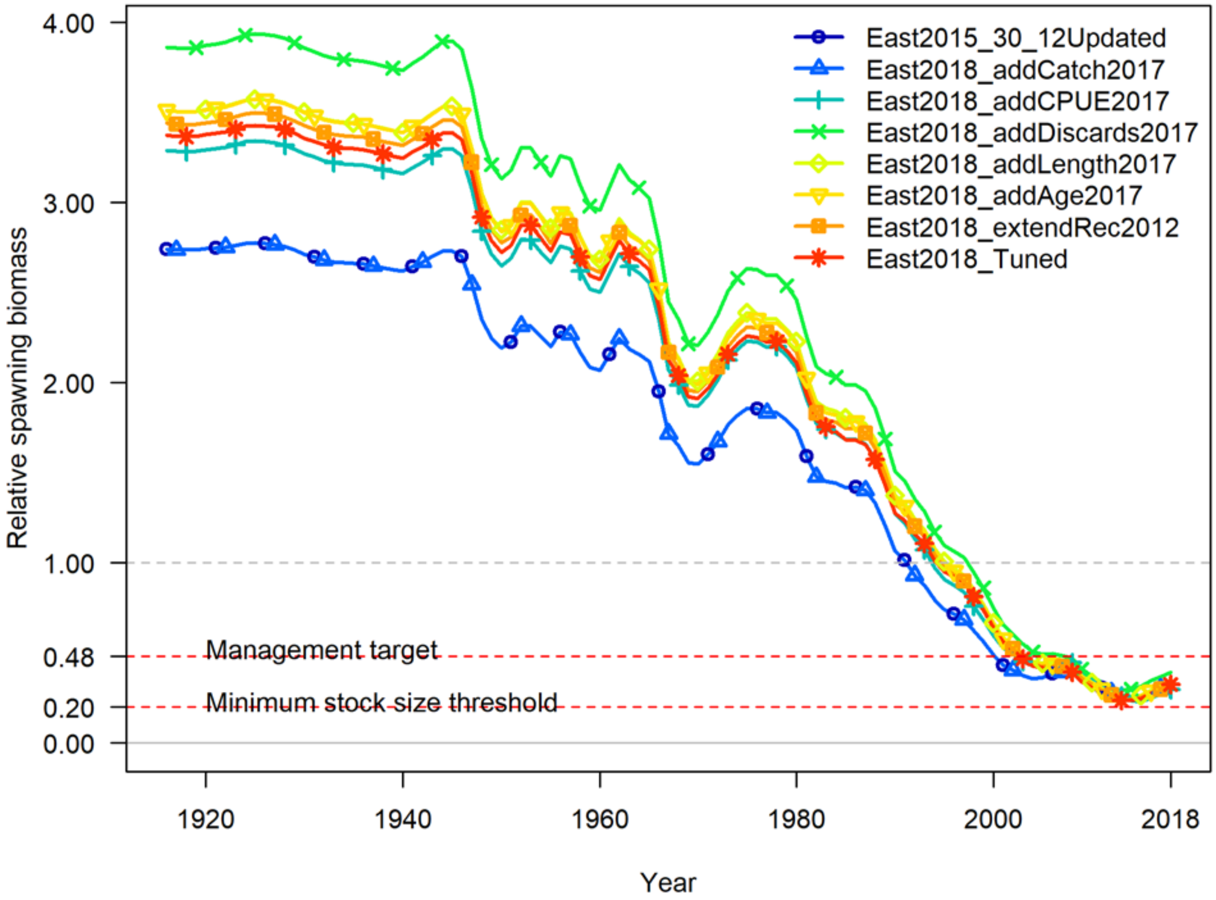

Figure 5.13. Comparison of the time series of relative spawning biomass for the updated 2015 assessment model converted to SS-V3.30.12 (East2015_30_12_updated - blue) with various bridging models leading to a proposed 2018 base case model (East2018_Tuned - red).

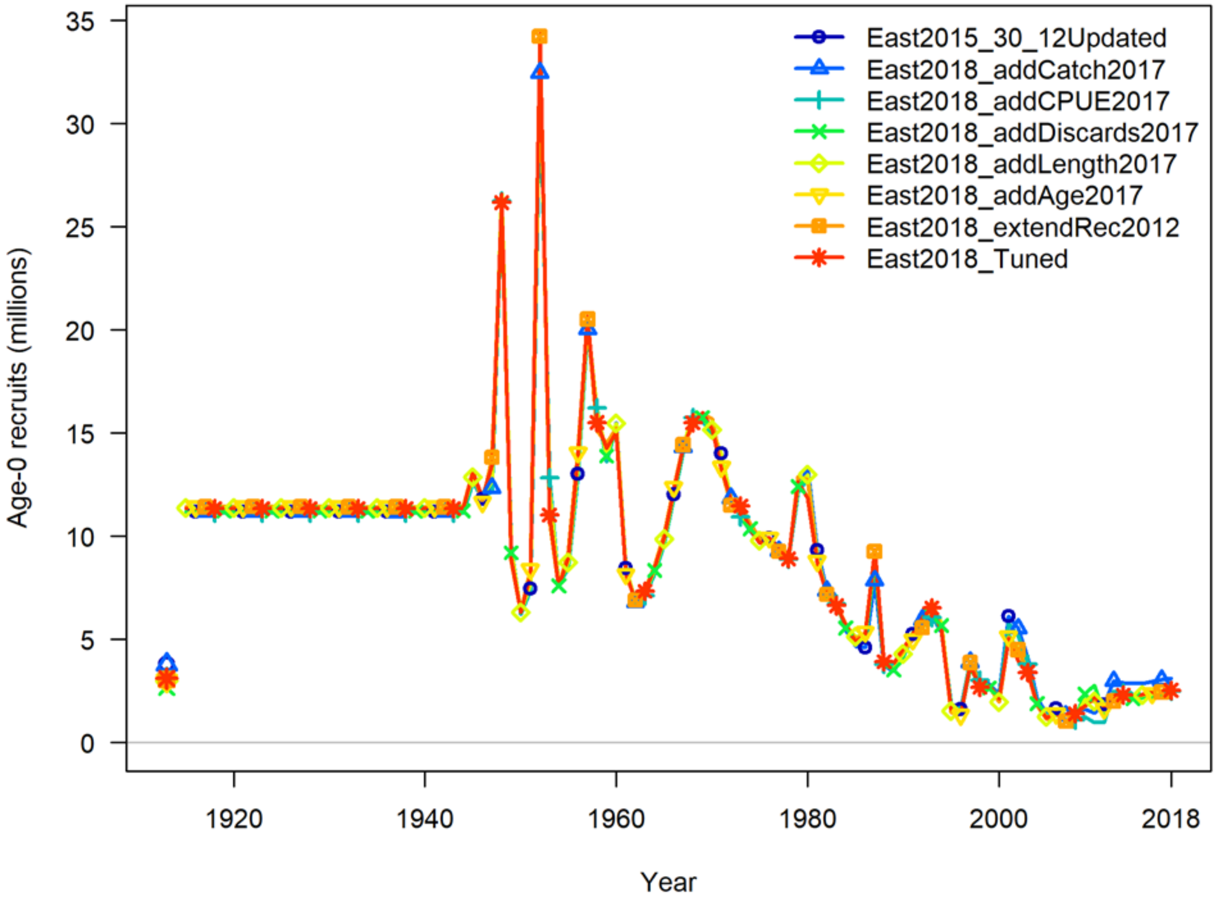

Figure 5.14. Comparison of the time series of recruitment from the updated 2015 assessment model converted to SS-V3.30.12 (East2015_30_12_updated - blue) with various bridging models leading to a proposed 2018 base case model (East2018_Tuned - red).

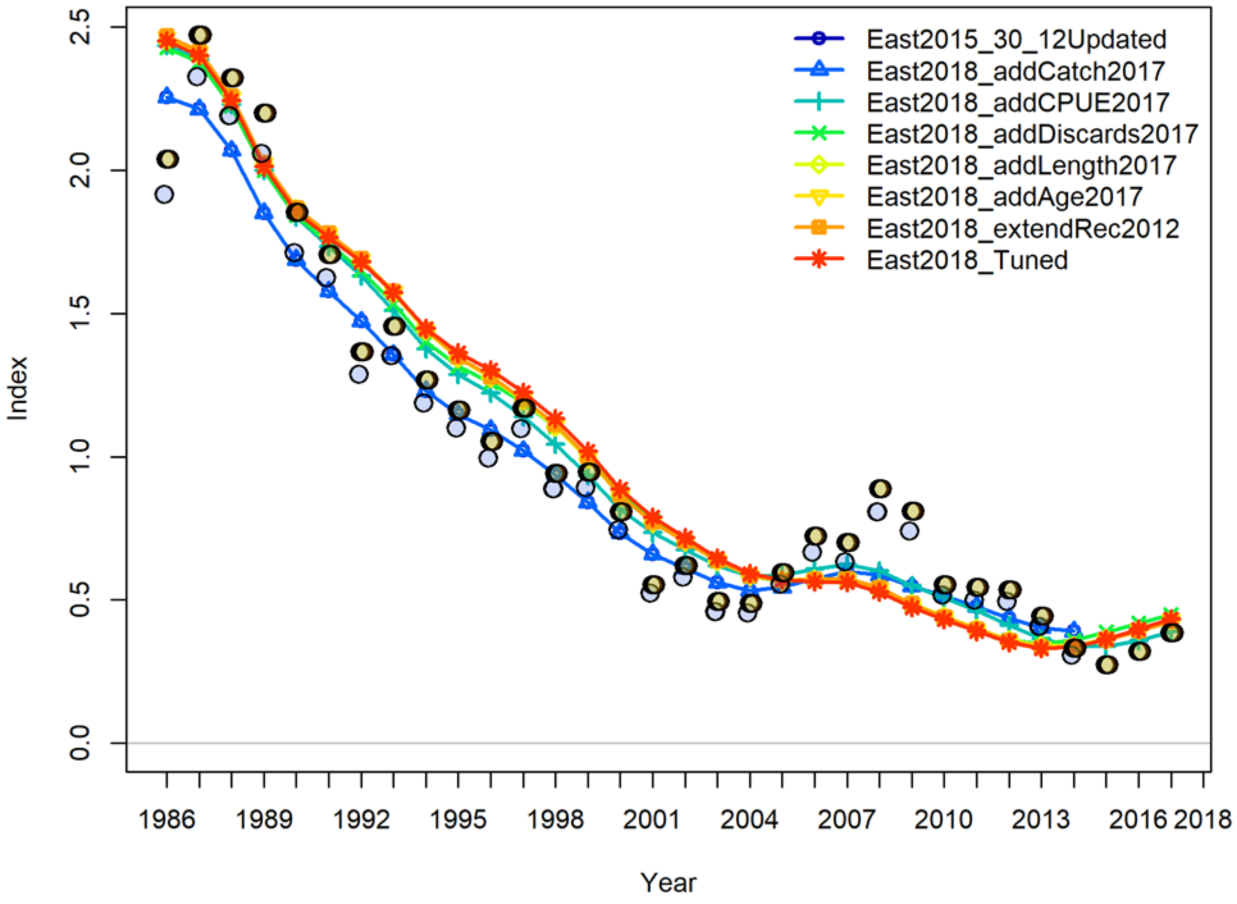

Figure 5.15. Comparison of the fit to the eastern trawl CPUE index for the updated 2015 assessment model converted to SS-V3.30.12 (East2015_30_12_updated - blue) with various bridging models leading to a proposed 2018 base case model (East2018_Tuned - red).

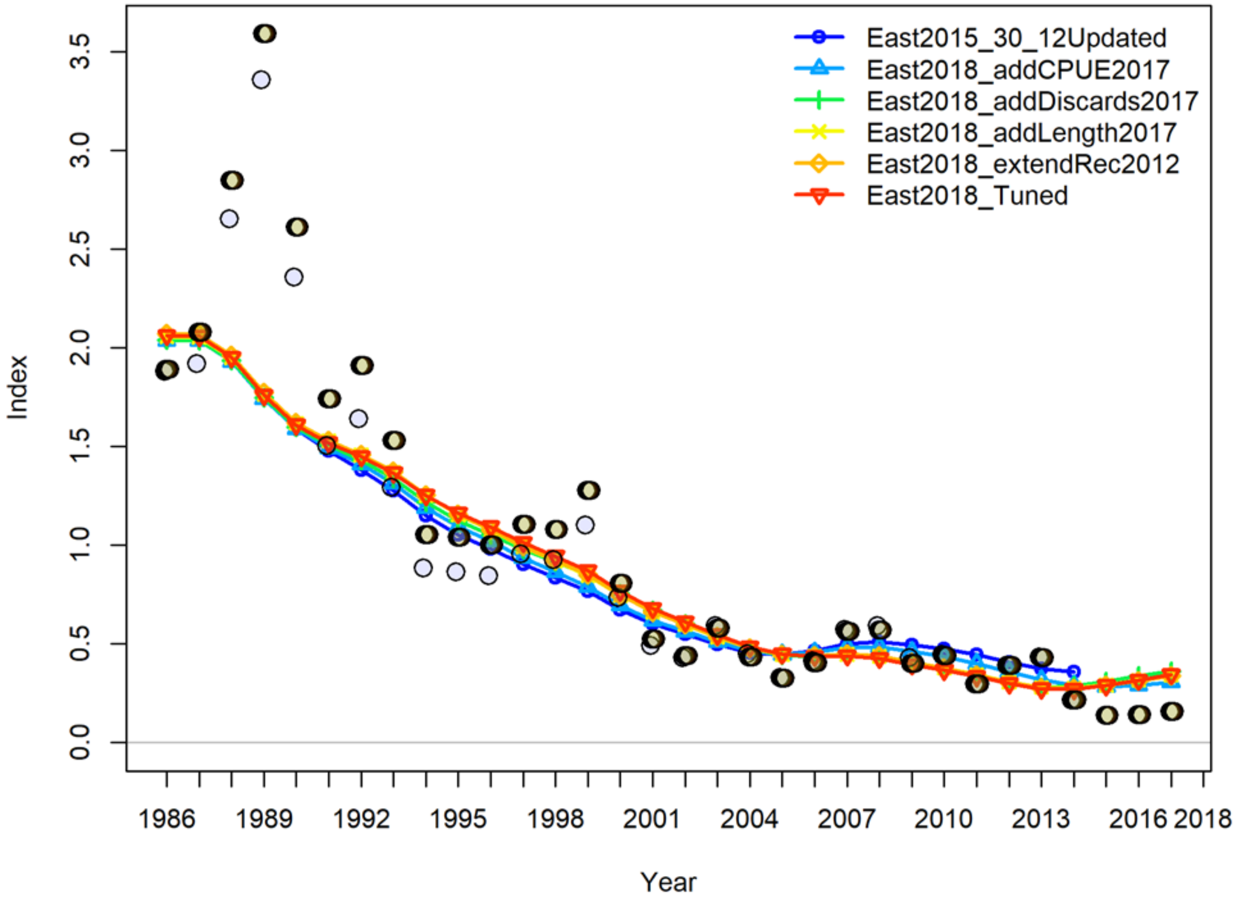

Figure 5.16. Comparison of the fit to the Tasmanian trawl CPUE index for the updated 2015 assessment model converted to SS-V3.30.12 (East2015_30_12_updated - blue) with various bridging models leading to a proposed 2018 base case model (East2018_Tuned - red).

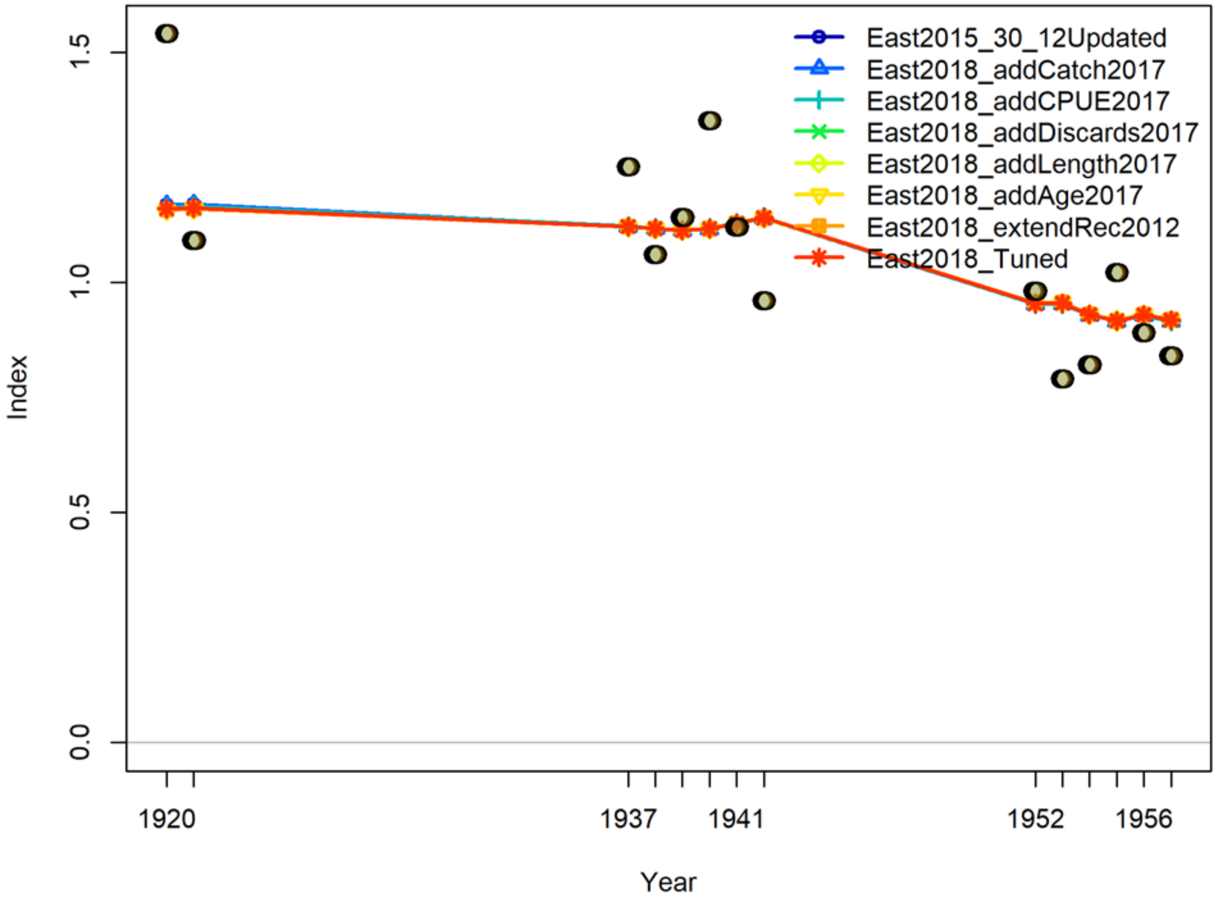

Figure 5.17. Comparison of the fit to the steam trawl CPUE index for the updated 2015 assessment model converted to SS-V3.30.12 (East2015_30_12_updated - blue) with various bridging models leading to a proposed 2018 base case model (East2018_Tuned - red).

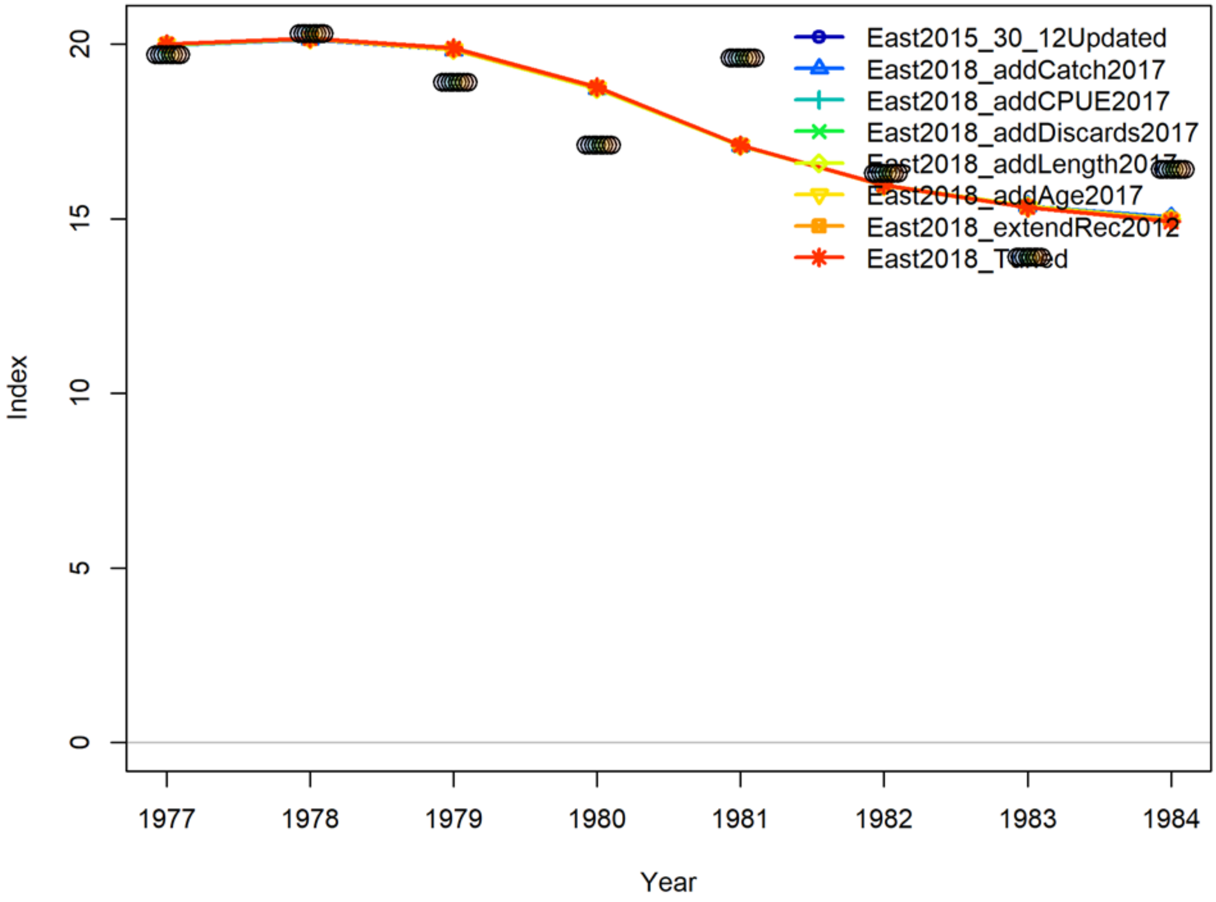

Figure 5.18. Comparison of the fit to the mixed CPUE index for the updated 2015 assessment model converted to SS-V3.30.12 (East2015_30_12_updated - blue) with various bridging models leading to a proposed 2018 base case model (East2018_Tuned - red).

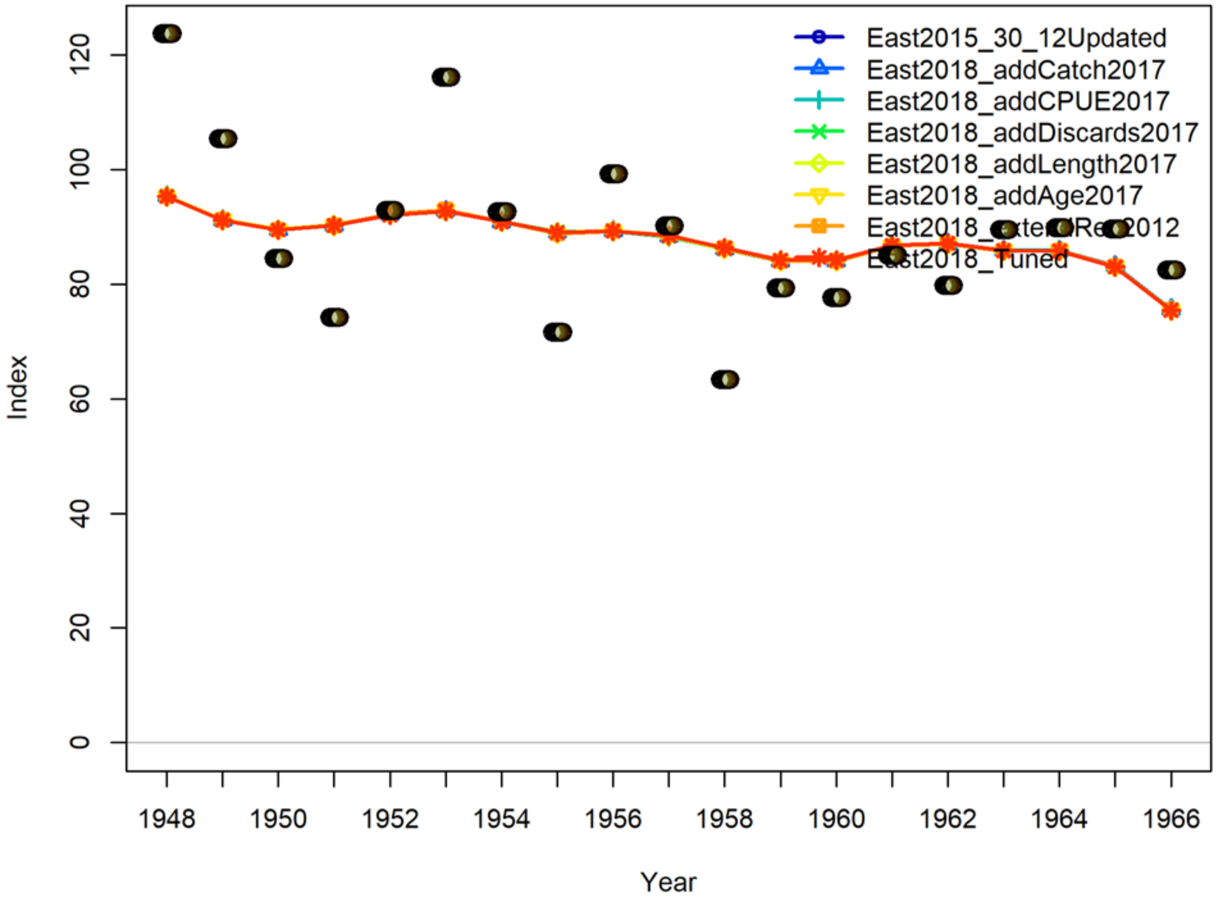

Figure 5.19. Comparison of the fit to the Smith CPUE index for the updated 2015 assessment model converted to SS-V3.30.12 (East2015_30_12_updated - blue) with various bridging models leading to a proposed 2018 base case model (East2018_Tuned - red).

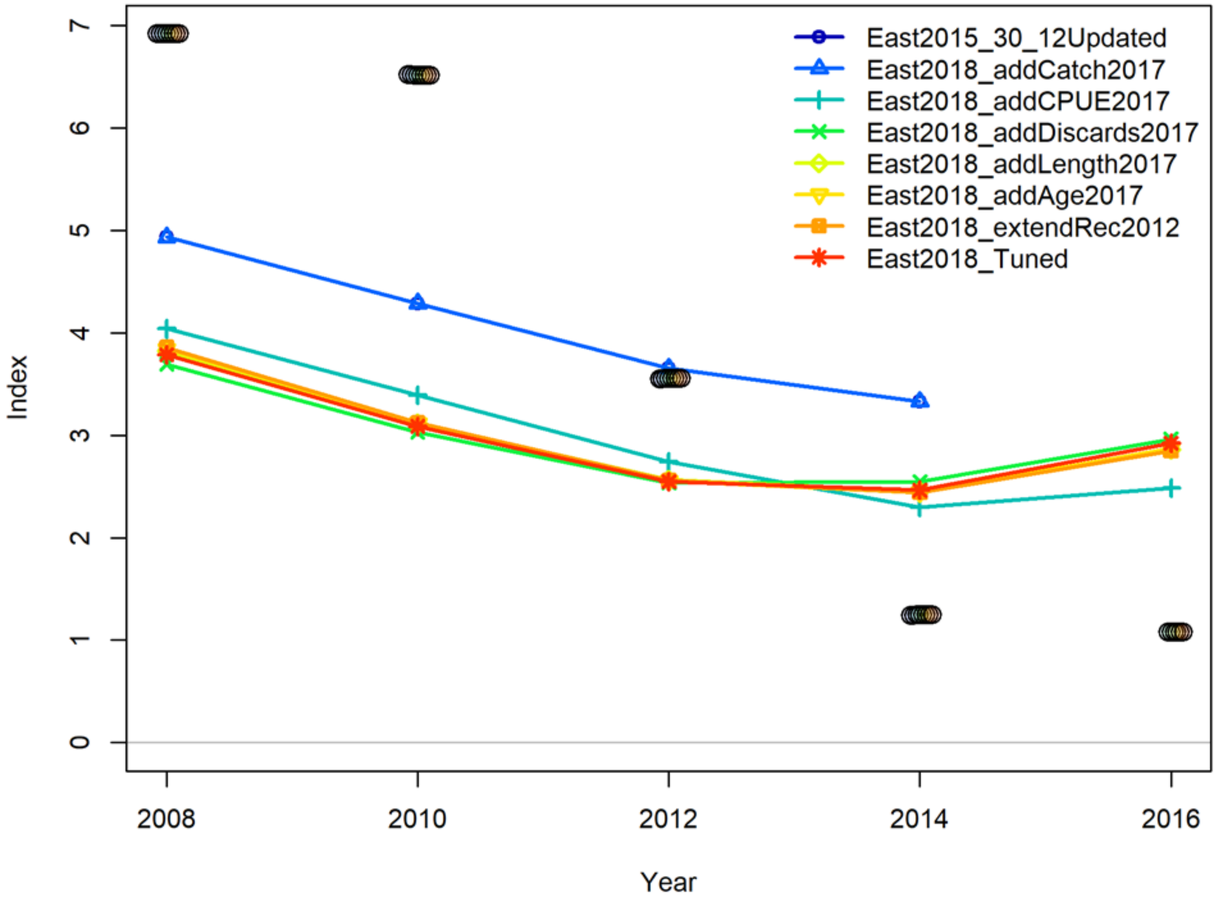

Figure 5.20. Comparison of the fit to the FIS east (Zones 10 and 20) index for the updated 2015 assessment model converted to SS-V3.30.12 (East2015_30_12_updated - blue) with various bridging models leading to a proposed 2018 base case model (East2018_Tuned - red).

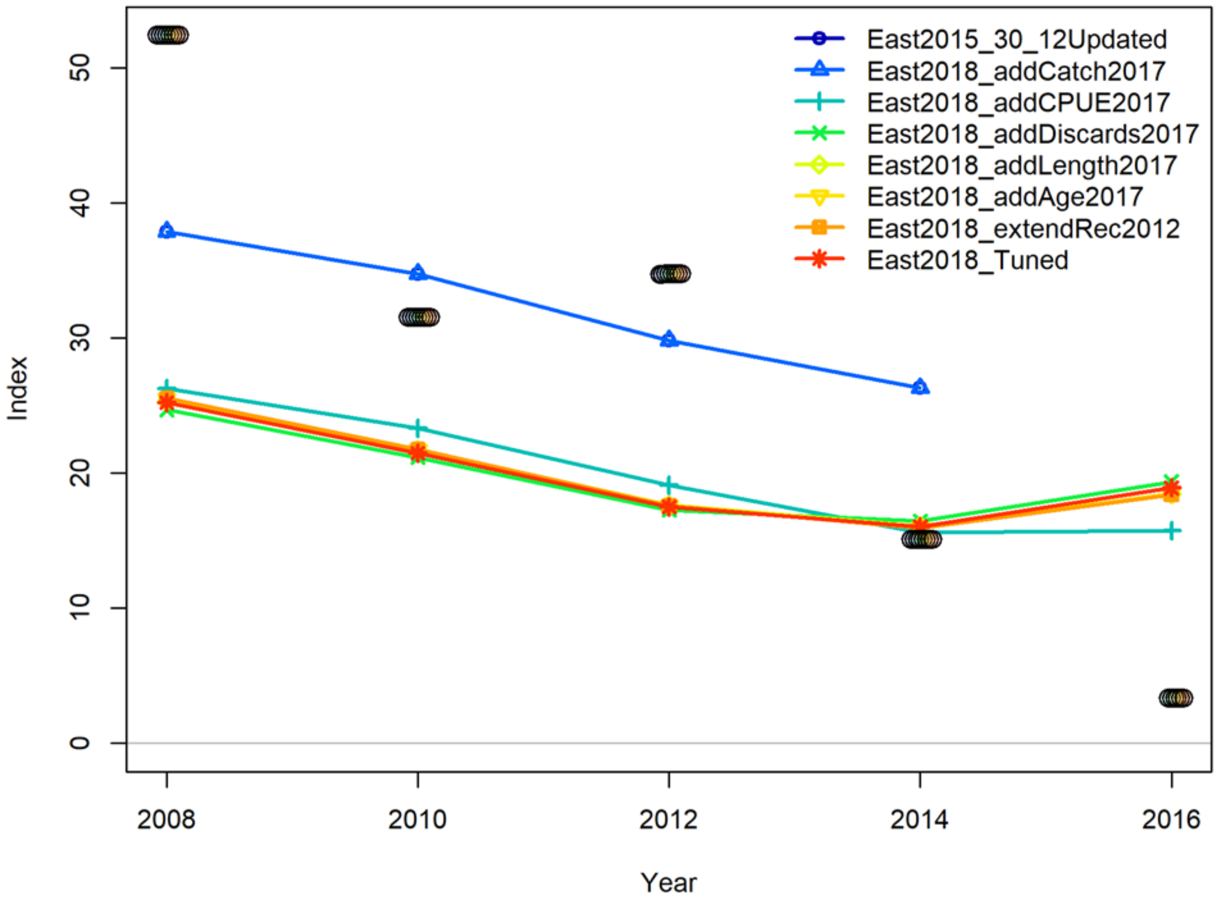

Figure 5.21. Comparison of the fit to the FIS Tas (Zone 30) index for the updated 2015 assessment model converted to SS-V3.30.12 (East2015_30_12_updated - blue) with various bridging models leading to a proposed 2018 base case model (East2018_Tuned - red).

5.2.4 ***Likelihood profiles***

As stated by Punt (2018), likelihood profiles are a standard component of the toolbox of applied statisticians. They are most often used to obtain a 95% confidence interval. Many stock assessments “fix” key parameters such as M and steepness based on *a priori* considerations. Likelihood profiles can be used to evaluate whether there is evidence in the data to support fixing a parameter at a chosen value. If the parameter is within the entire range of the 95% confidence interval, this provides no support in the data to change the fixed value. If the fixed value is outside the 95% confidence interval, it would be reasonable for a review panel to ask why the parameter was fixed and not estimated, and if the value is to be fixed, on what basis and why should what amounts to inconsistency with the data be ignored. Integrated stock assessments include multiple data sources (e.g., commonly catch-rates, length-compositions, and age-compositions) that may be in conflict, due for example to inconsistencies in sampling, but more commonly owing to incorrect assumptions (e.g., assuming that catch-rates are linearly related to abundance), i.e. model-misspecification. Likelihood profiles can be used as a diagnostic to identify these data conflicts (Punt, 2018).

Standard parameters to consider are natural mortality (M), steepness (h) and the logarithm of the unfished recruitment ($\ln R_0$).

For jackass morwong east, the likelihood profile for natural mortality, *M*, a parameter fixed in the model, is shown in Figure 5.22, with the total likelihood shown in black and components of the total likelihood from different data sources shown in a range of colours. This shows that the fixed value chosen for *M* (0.15yr^{-1}) is outside the 95% confidence interval suggested by the likelihood profile (approximately 0.18-0.34). However, this is driven largely by the fits to the CPUE index, and in particular by the Eastern trawl fleet. In contrast the discard, age and length data all suggest a lower value of natural mortality than suggested by the fits to the CPUE index, albeit with lower contributions to the overall likelihood. This suggests that better fits to the eastern trawl CPUE index could be obtained with a higher value of natural mortality. This could be explained by changes in targeting practice or indeed a potential change in natural mortality in recent years, neither of which are incorporated in the model, or by suggesting that there is insufficient information in the data to be able to reliably inform an estimate of natural mortality. The maximum age observed in the data and the biology of jackass morwong should certainly be considered when making decisions on the value used for natural mortality.

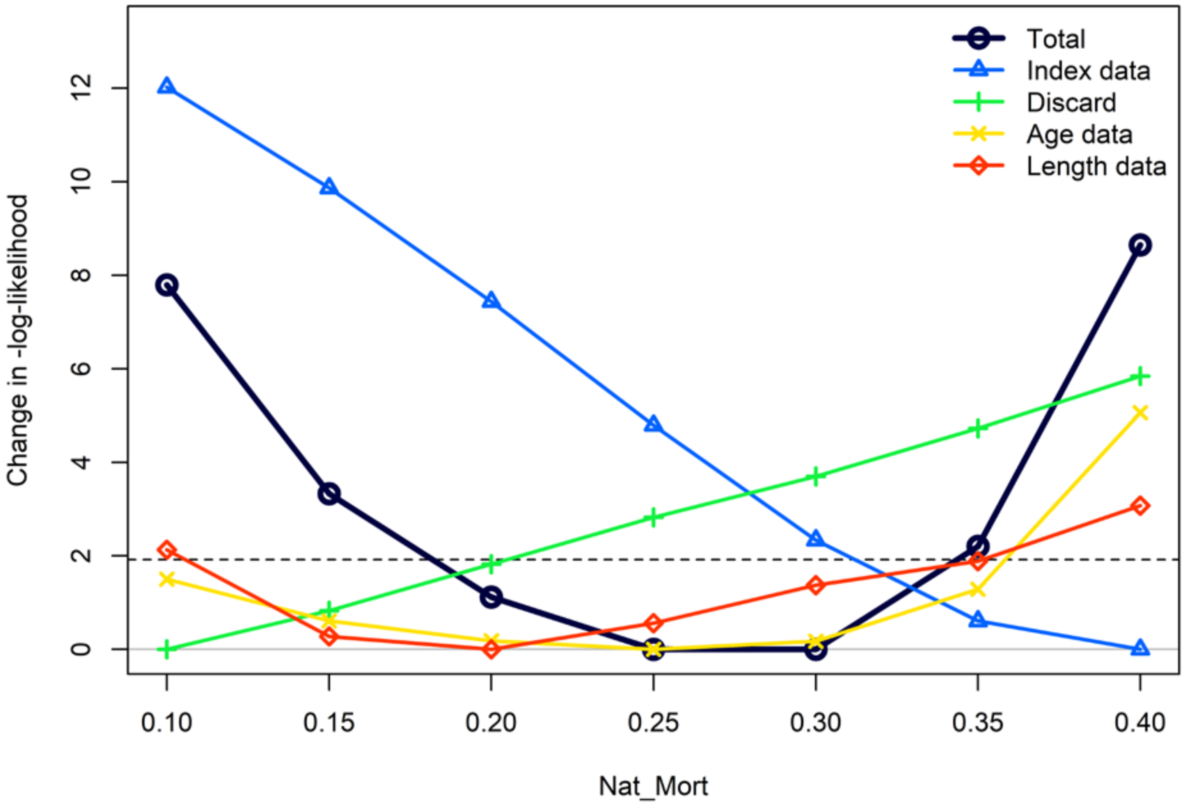

Figure 5.22. The likelihood profile for natural mortality. The fixed value for *M* is 0.15yr^{-1}.

The likelihood profile for steepness, *h*, (Figure 5.23) suggests that there is little information in the model that can be used to inform this parameter (fixed at 0.7 in the model). The length data (higher steepness, but a small change in absolute value of likelihood) and recruitment data (lower steepness) are in conflict, and the likelihood profile, suggests lower values of steepness are preferred, but this is essentially uninformative when the biological consequences of a steepness of 0.3 or less are considered.

The likelihood profile for the logarithm of the unfished recruitment (lnR_0) would be a useful addition to this analysis.

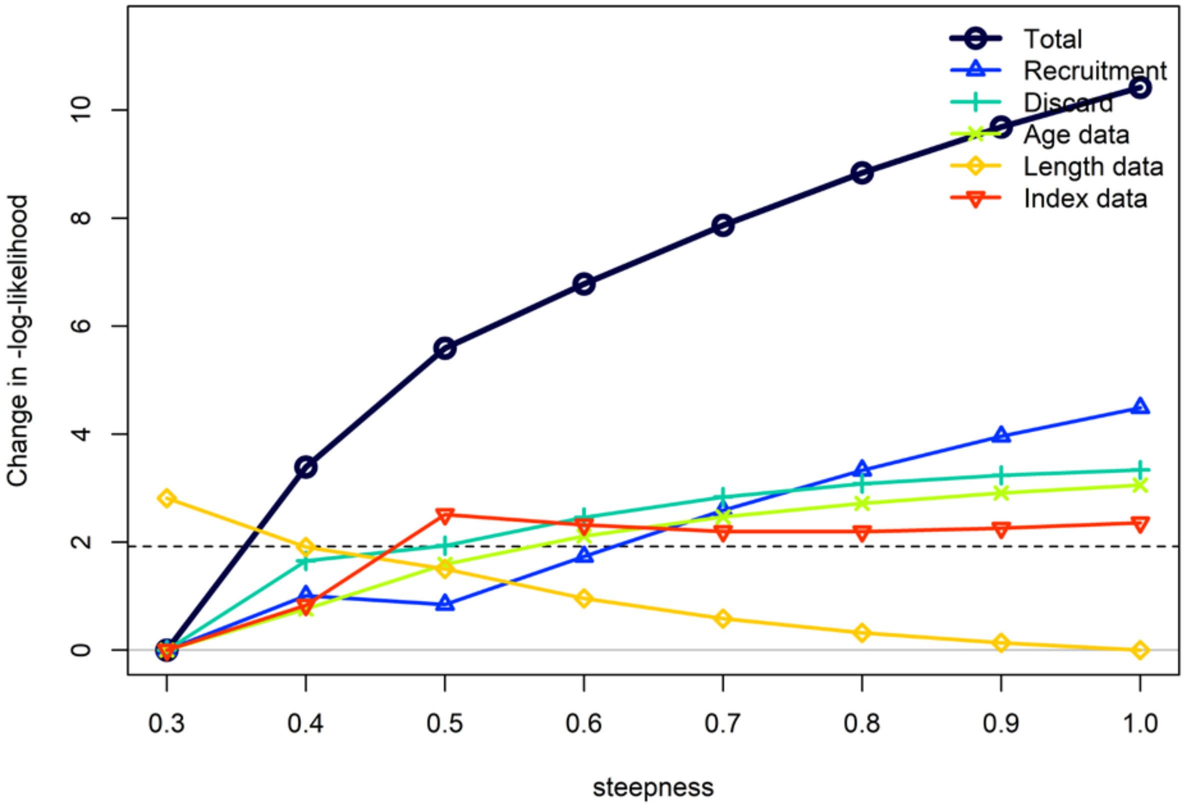

Figure 5.23. The likelihood profile for steepness. The fixed value for h is 0.7.

5.2.5 *Retrospectives*

A retrospective analysis was completed, starting from the most recent year of data, working backward in time and removing successive years of data from the assessment. This analysis can highlight potential problems and instability in an assessment, or some features that appear from the data.

A retrospective analysis for absolute spawning biomass is shown in Figure 5.24, with initially the data after 2017 removed (shown in blue), then successive years of data removed back to 2012 (shown in red). While these time series look very similar, the points in the lower left of the plot indicate changes in the 1988 equilibrium spawning biomass, which is used to determine the current stock status. This suggests that this value is not well determined as it is being decreased in a systematic way as more years of data are included in the assessment. This is clearer when this analysis is presented in terms of relative spawning biomass (Figure 5.25), with minor changes at the end of the series (up to 2018) but much larger changes at the start of the series, and perhaps a larger effect from removing the 2017 and 2016 data than removing earlier years. In this plot, the recent spawning biomass is plotted relative to the 1988 equilibrium spawning biomass, and the initial spawning biomass is also plotted relative to the 1988 equilibrium spawning biomass, and this is much greater than one due to the productivity shift implemented in this model. When this retrospective analysis is applied to the recruitment time series (Figure 5.26), the more recent data results in a revision downward to the recruitment estimates in the period 2009-2012. This analysis should probably have also included a change to the last year that recruitment is being estimated to prevent this pattern from occurring, and spurious recruitments being estimated at the end of the time series, with little data available to inform these estimates.

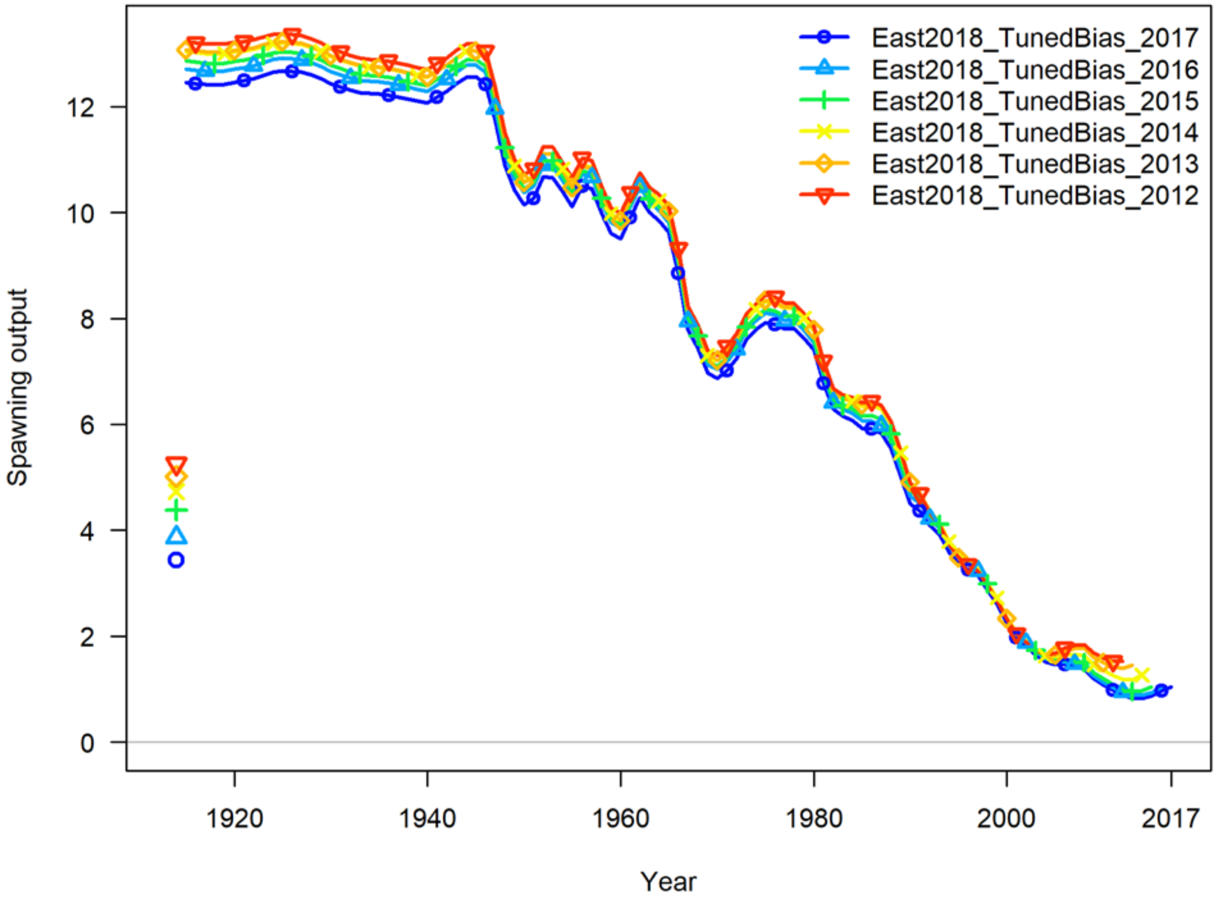

Figure 5.24. Retrospectives for absolute spawning biomass for eastern jackass morwong, with data removed back to 2017 (blue) and then successive years removed back to 2012 (red).

5.2.6 *Future work and unresolved issues*

There are some unresolved issues relating to recent state catches for the period 2015-2017, but these catches are relatively small and any future revisions are unlikely to have much influence on the assessment outcomes.

Two other sensitivities relating to the Fishery Independent Survey (FIS) would be useful.

1. Excluding all FIS data.
2. Including FIS length frequency data and estimating selectivity for the FIS fleet.

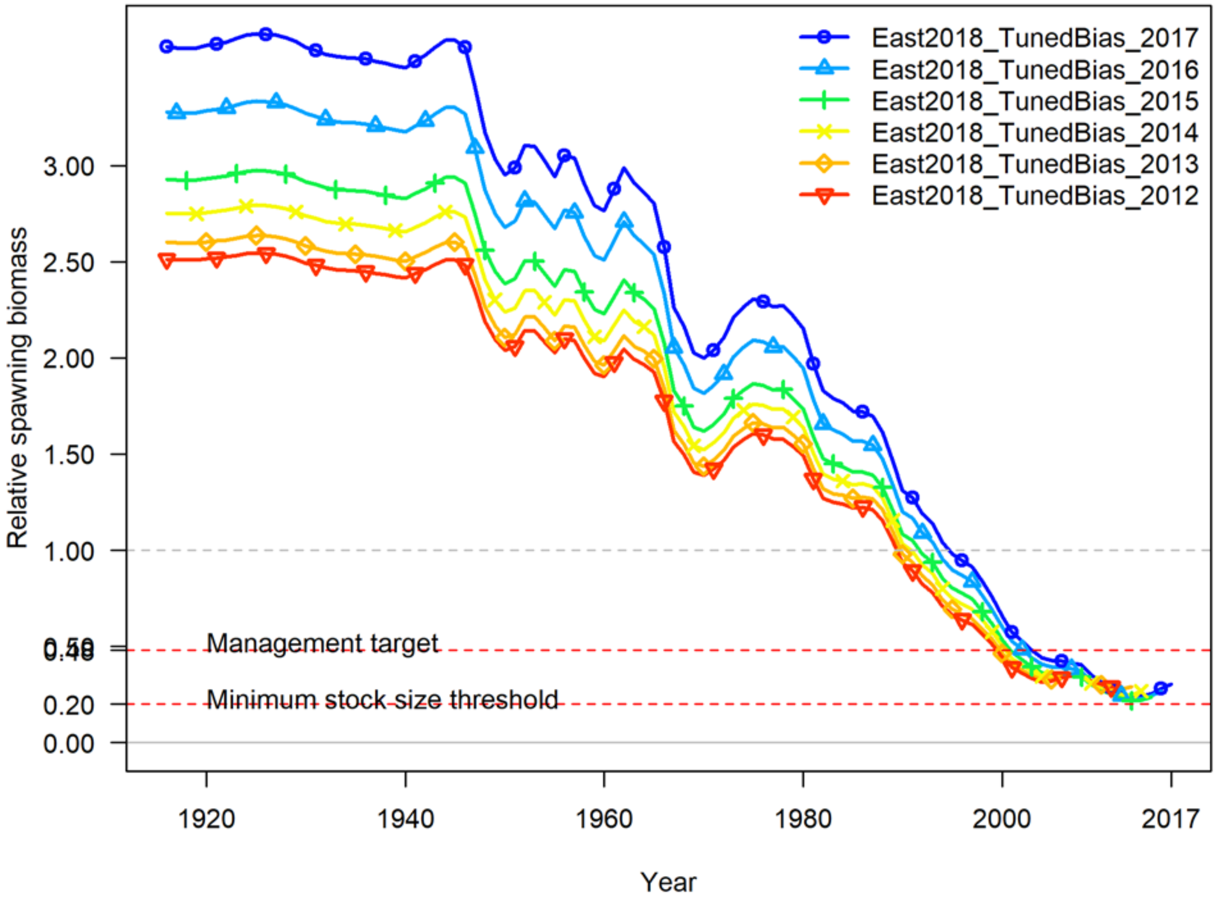

Figure 5.25. Retrospectives for relative spawning biomass for eastern jackass morwong, with data removed back to 2017 (blue) and then successive years removed back to 2012 (red).

Any results from this assessment should be treated with some caution given the recent data quality available for this assessment and the quality of the trawl CPUE data. Sporcic and Haddon (2018a) indicate that “the structural adjustment altered the effect of the vessel factor on the standardised result. However, log(CPUE) has also changed in character from 2014 - 2017, with spikes of low catch rates arising”.

Note that the preliminary base case model fit to the FIS abundance indices (Figure 5.20 and Figure 5.21) with additional CVs on these abundance series estimated within the model at 0.54 and 0.74 respectively. The additional CV estimated to the eastern trawl CPUE index was 0.09, with a negative value estimated for all other CPUE indices, indicating the initial CV values were too broad for these other fleets.

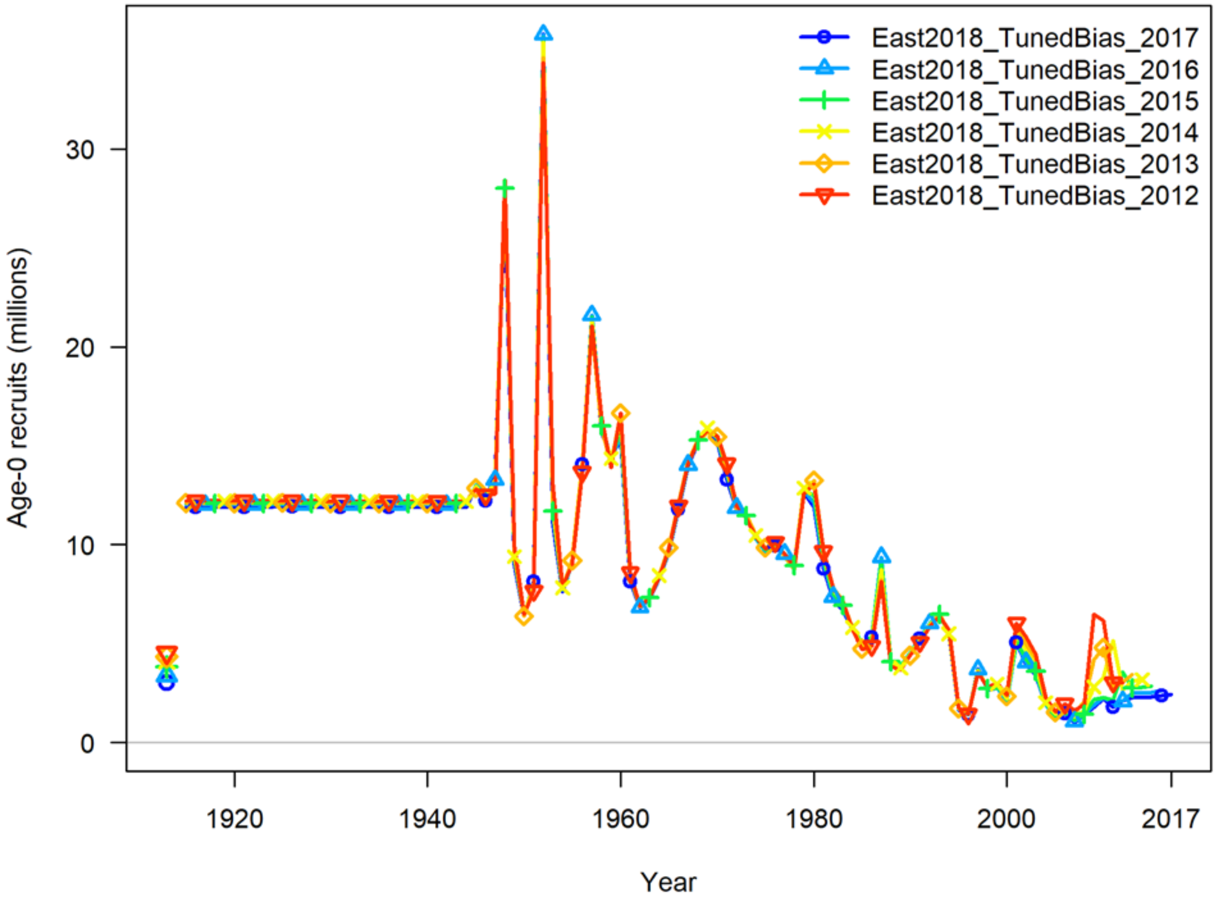

Figure 5.26. Retrospectives for recruitment for eastern jackass morwong, with data removed back to 2017 (blue) and then successive years removed back to 2012 (red).

5.3 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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5.5 Appendix A

A.1 Preliminary base case diagnositcs

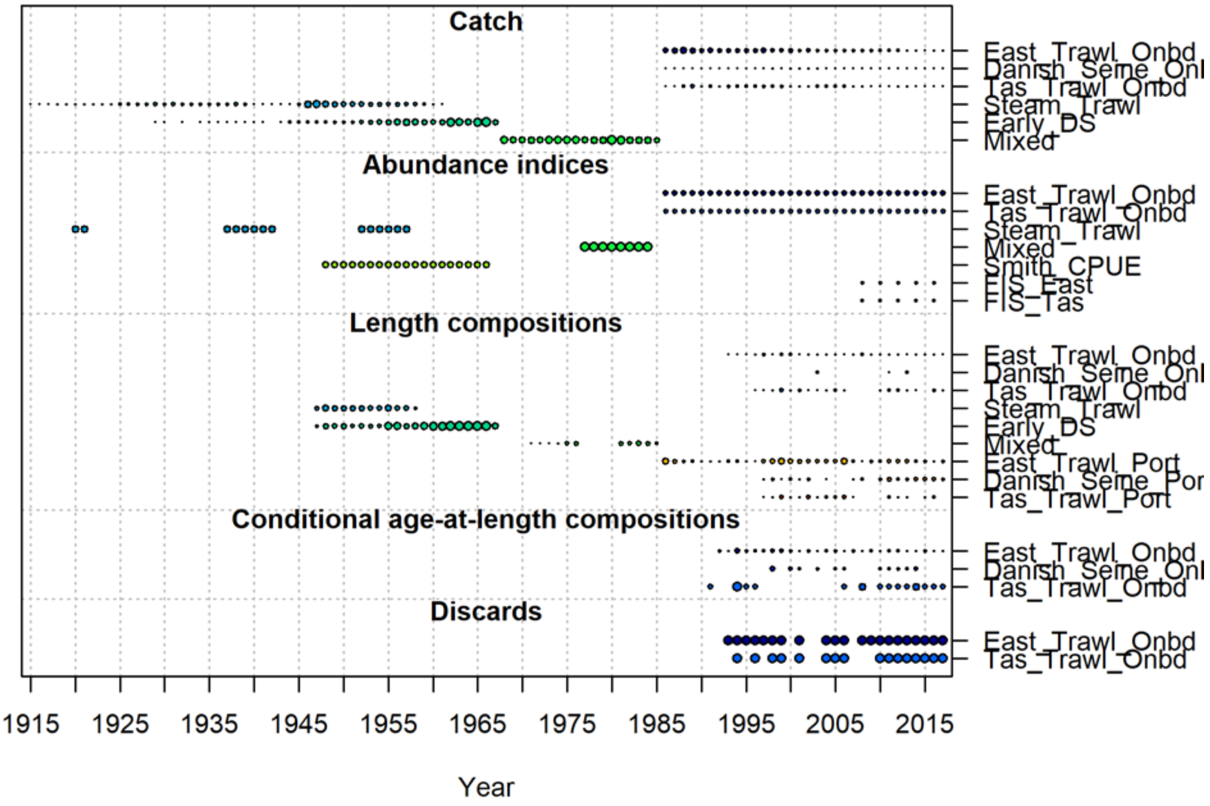


Figure A 5.1. Summary of data sources for eastern jackas morwong stock assessment.

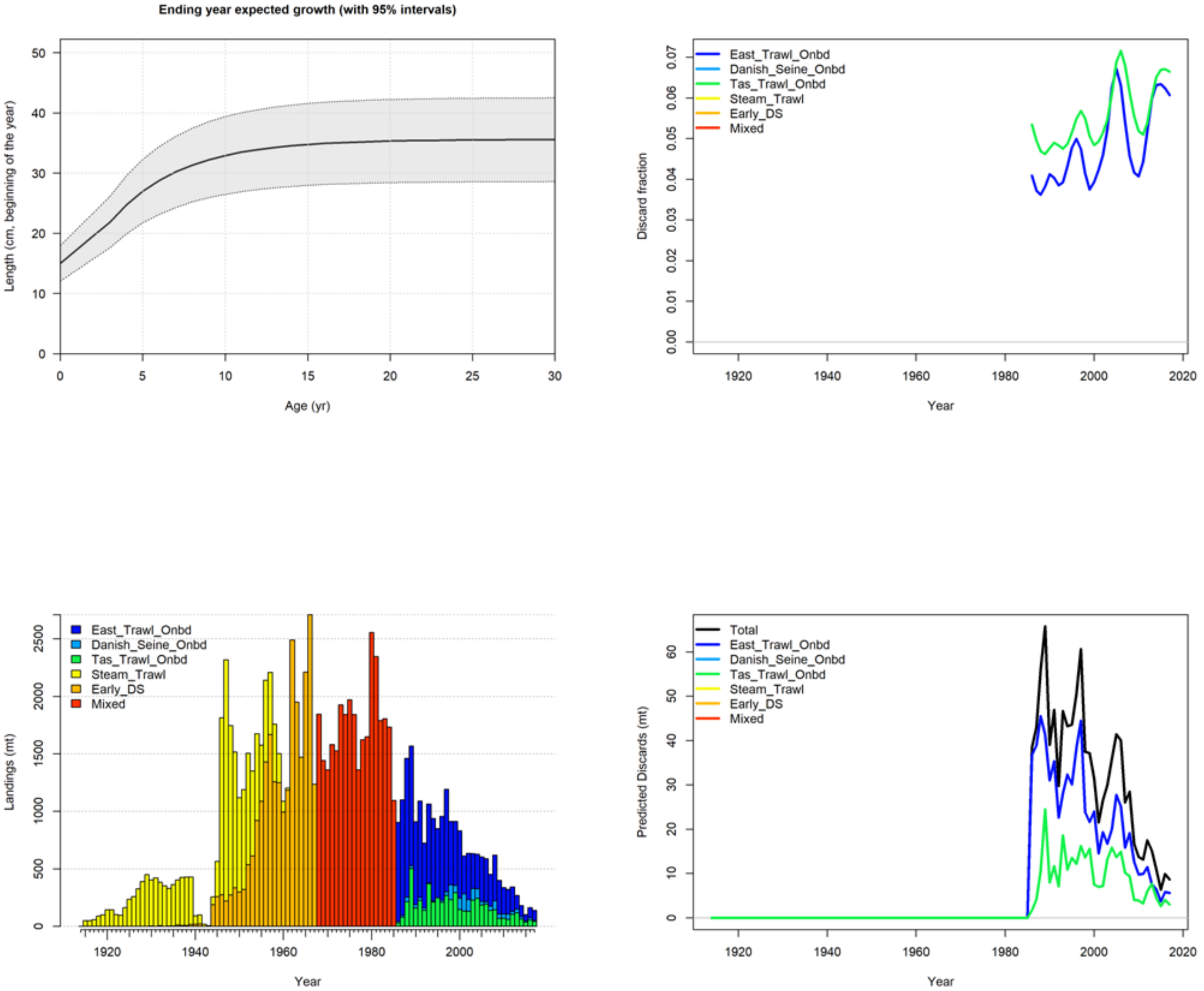


Figure A 5.2. Growth, discard fraction estimates, landings by fleet and predicted discards by fleet for eastern jackass morwong.

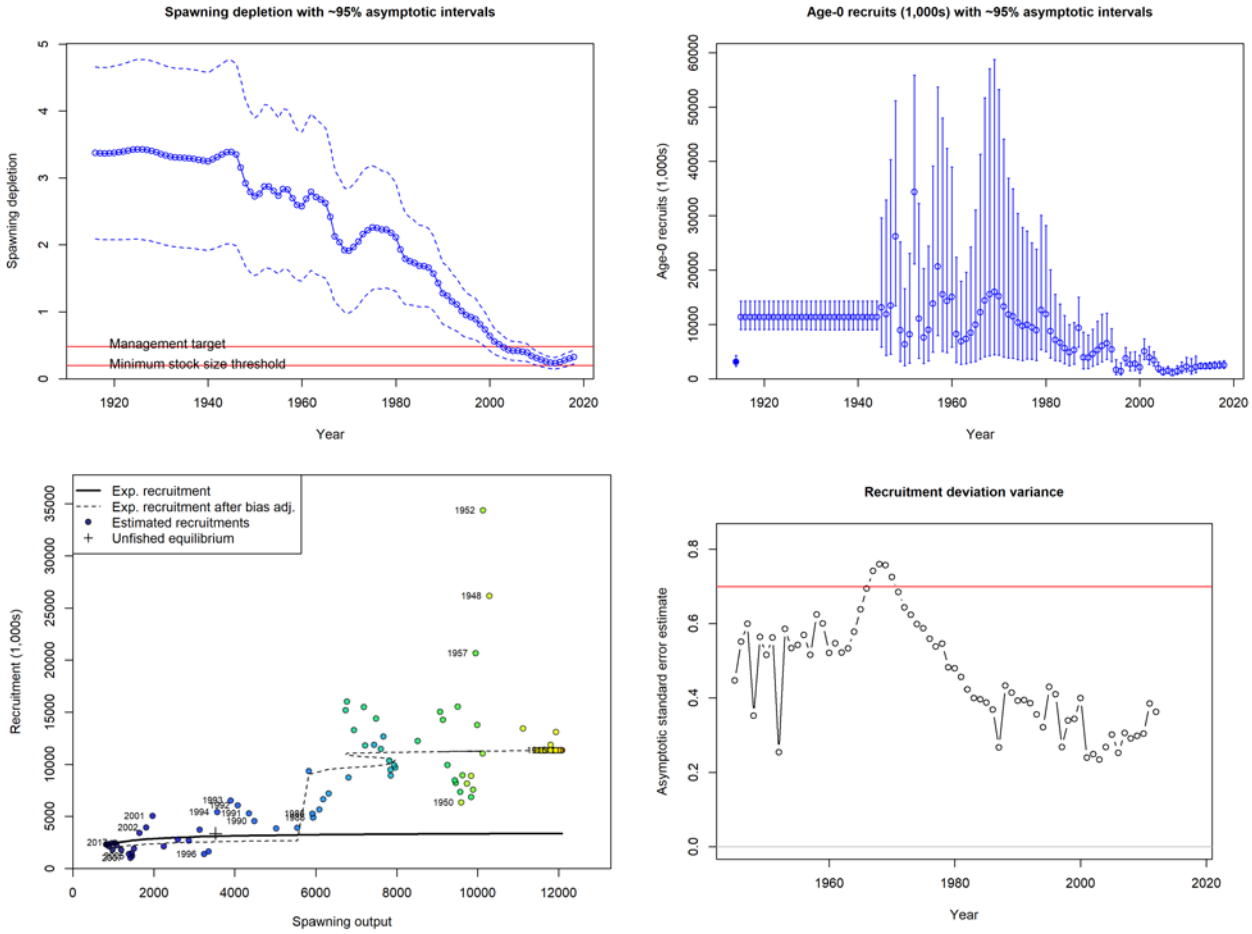
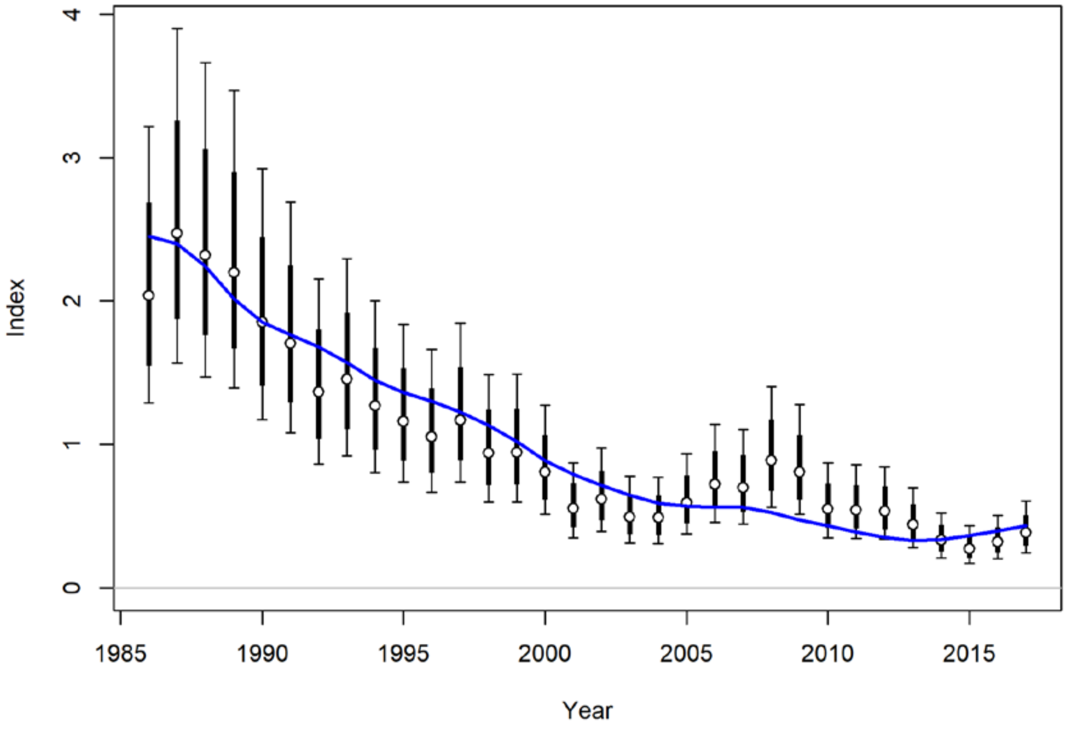


Figure A 5.3. Time series showing depletion of spawning biomass with confidence intervals, recruitment estimates with confidence intervals, stock recruitment curve and recruitment deviation variance check for eastern jackass morwong.



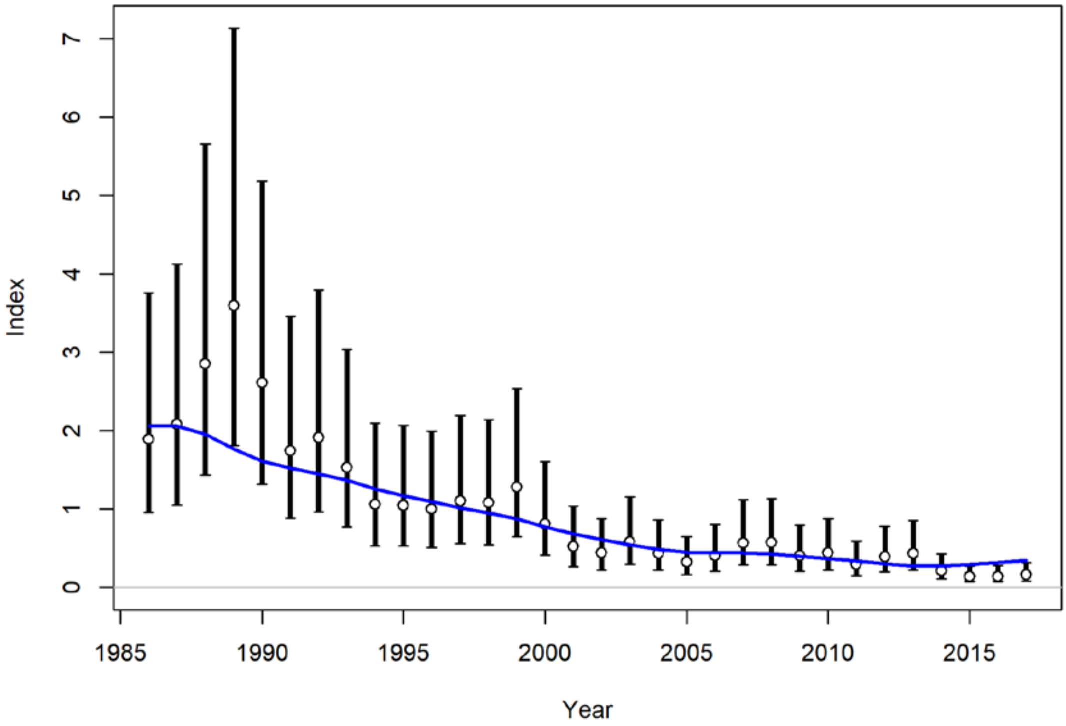
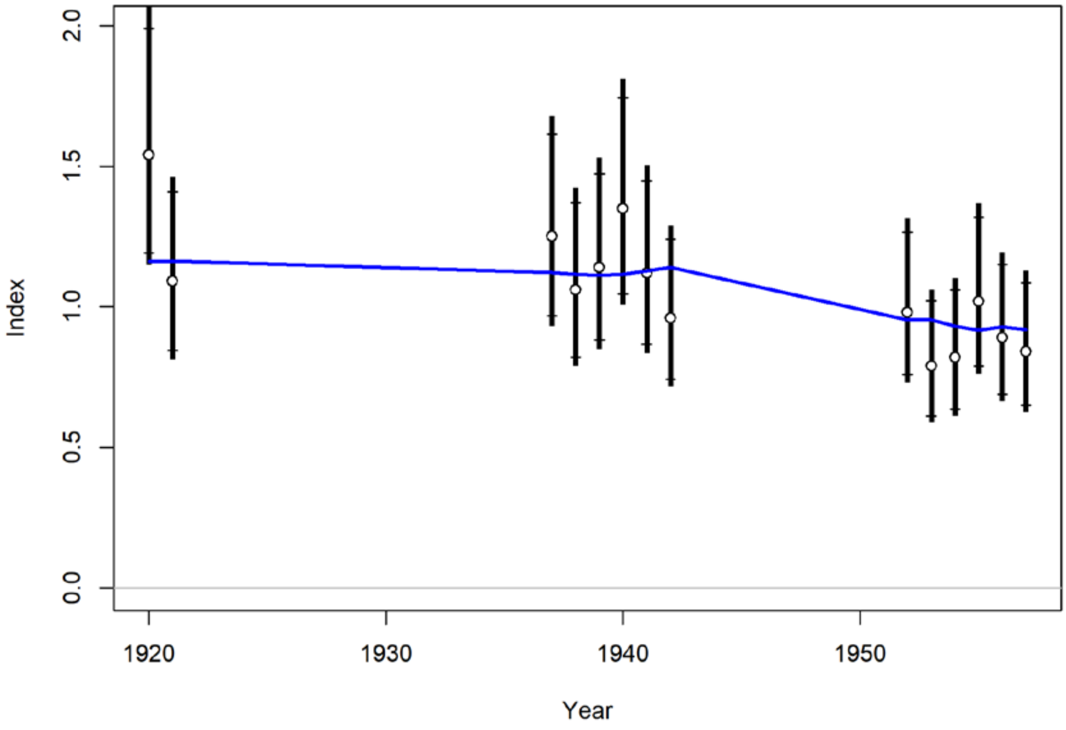


Figure A 5.4. Fits to CPUE by fleet for eastern jackass morwong: eastern trawl (top) and Tasmanian trawl (bottom).



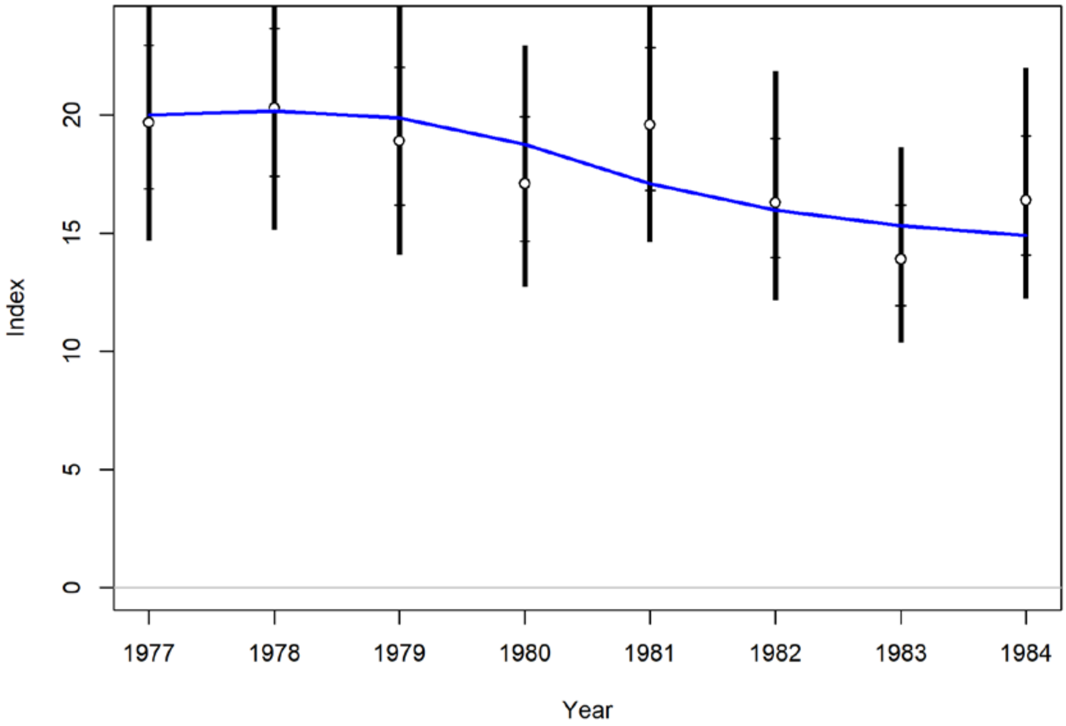


Figure A 5.5. Fits to CPUE by fleet for eastern jackass morwong: steam trawl (top) and mixed (bottom).

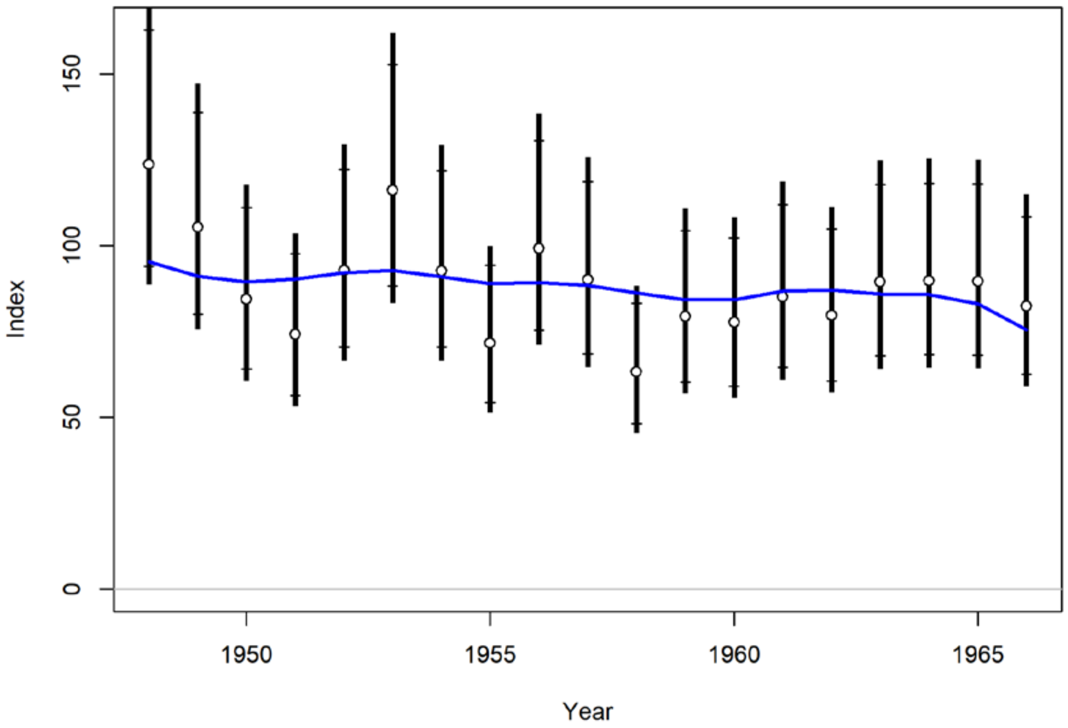
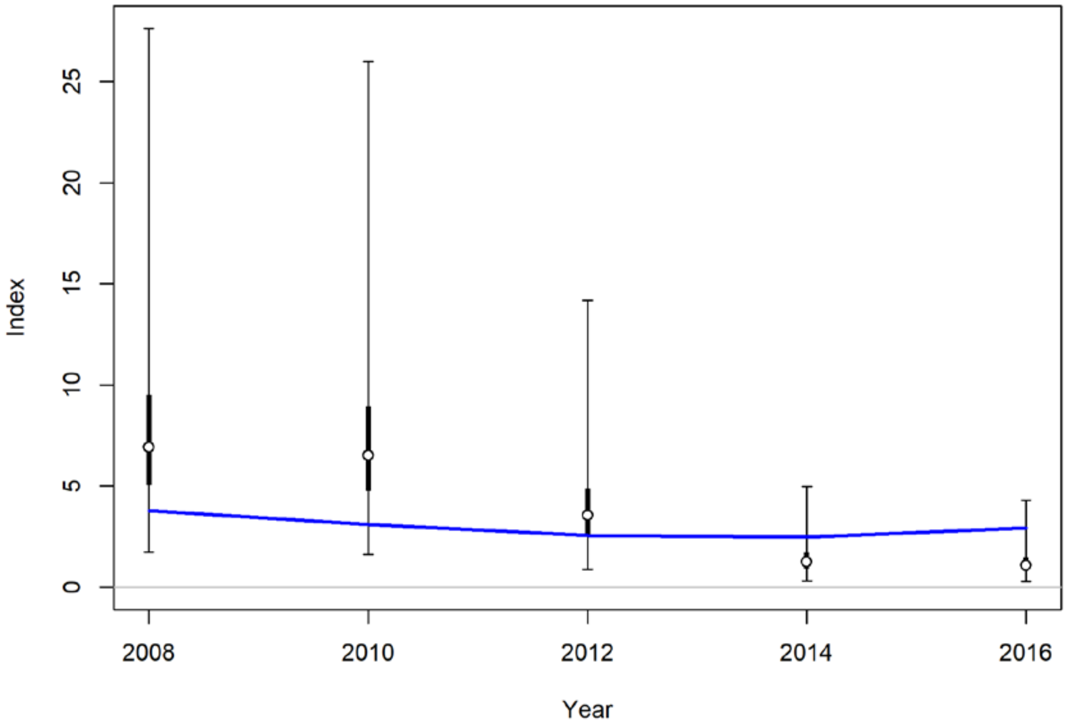


Figure A 5.6. Fits to CPUE by fleet for eastern jackass morwong: Smith CPUE.



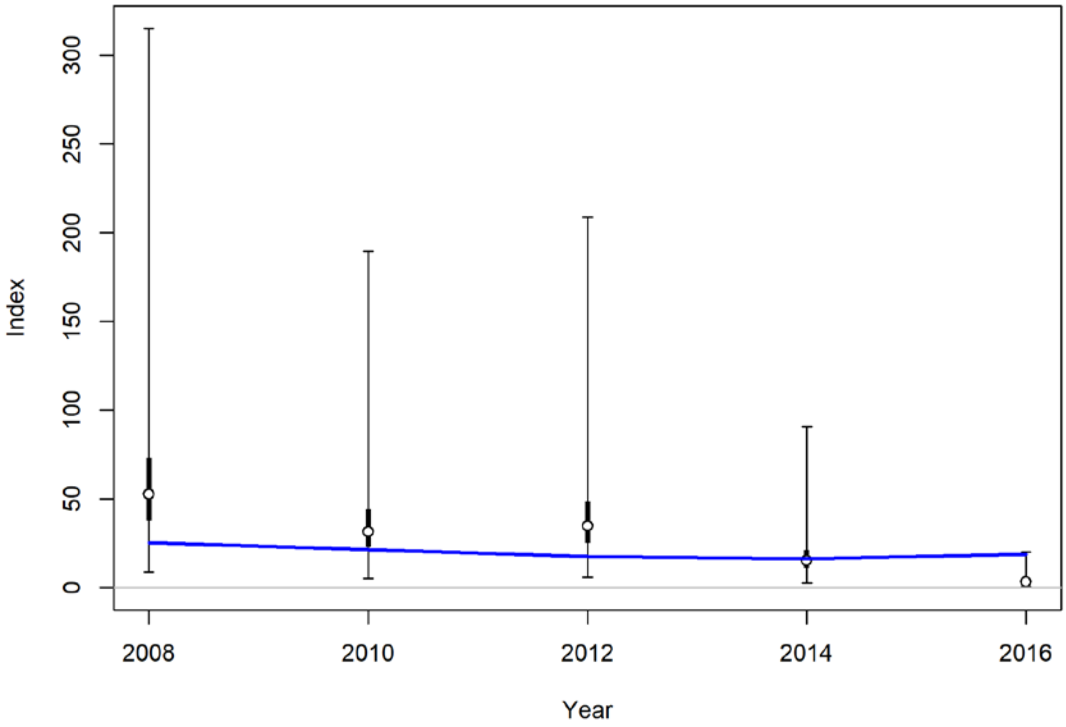
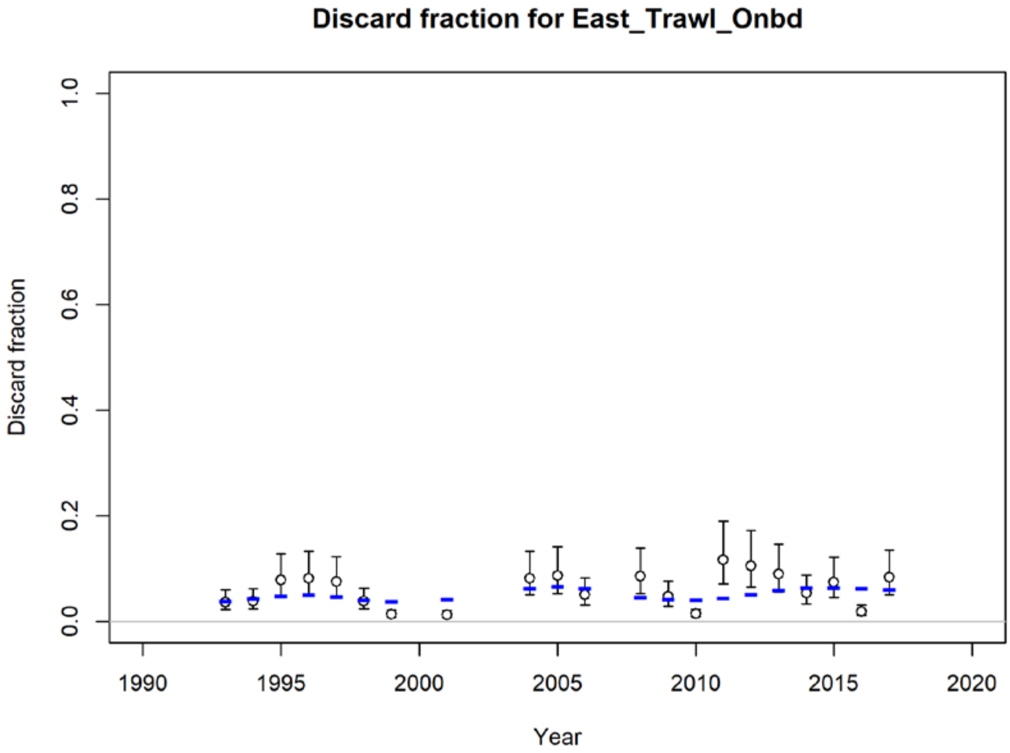


Figure A 5.7. Fits to FIS by fleet for eastern jackass morwong: eastern trawl (top) and Tasmanian trawl (bottom).



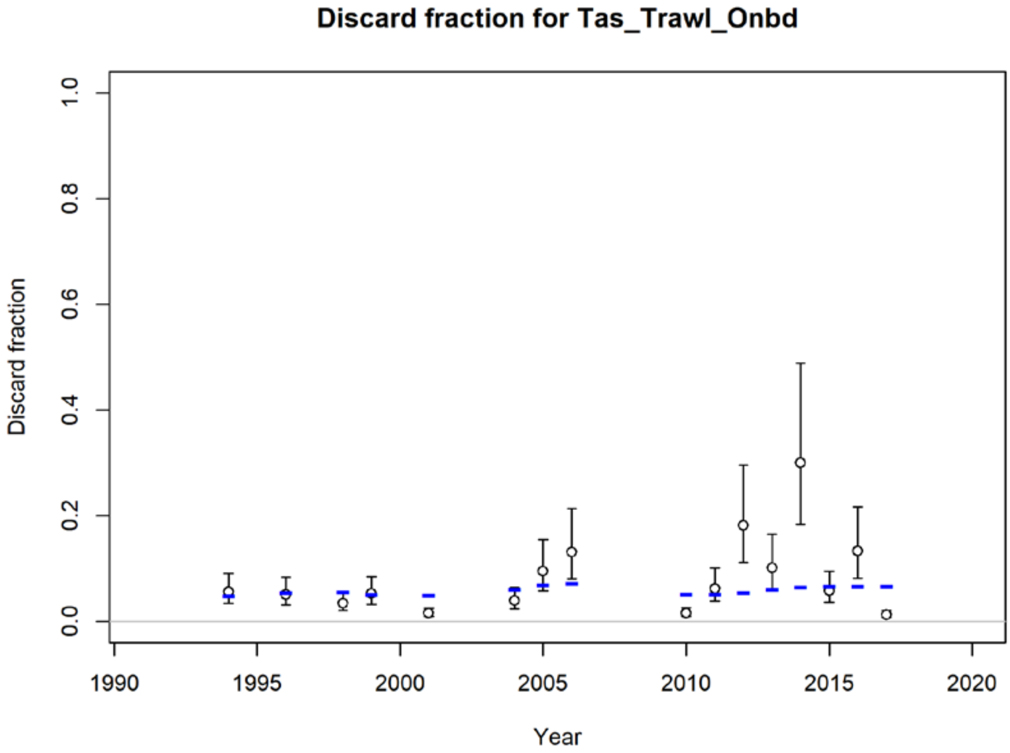


Figure A 5.8. Fits to discard rates for eastern trawl (top) and Tasmanian trawl (bottom) for eastern jackass morwong.

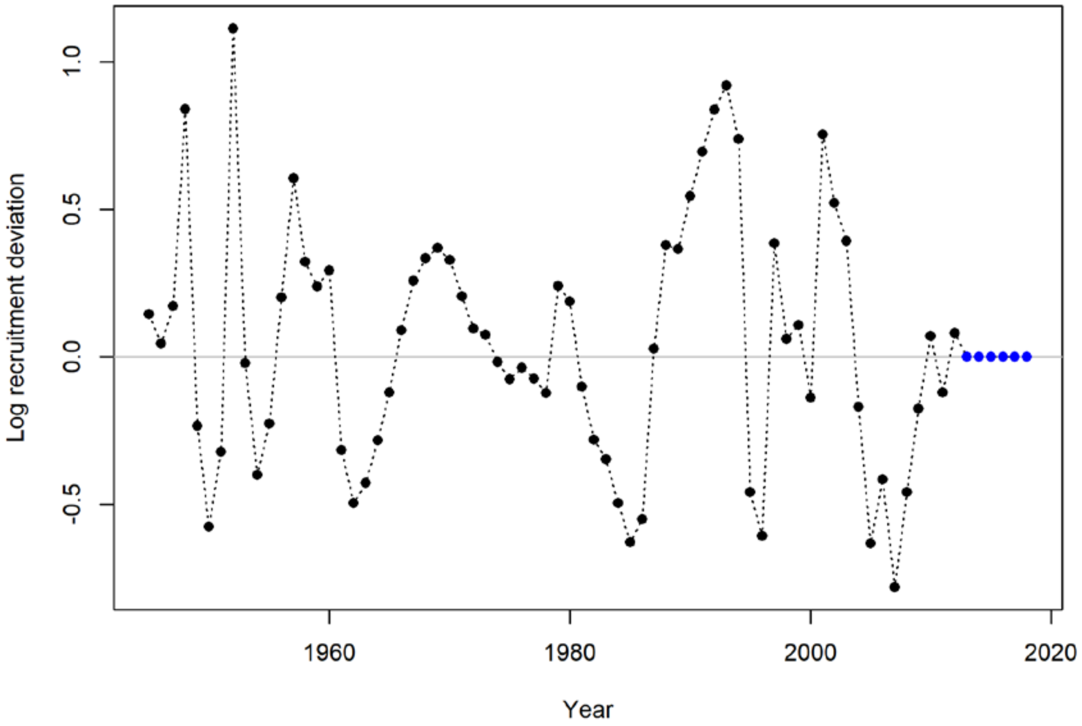


Figure A 5.9. Recruitment deviations for eastern jackass morwong.

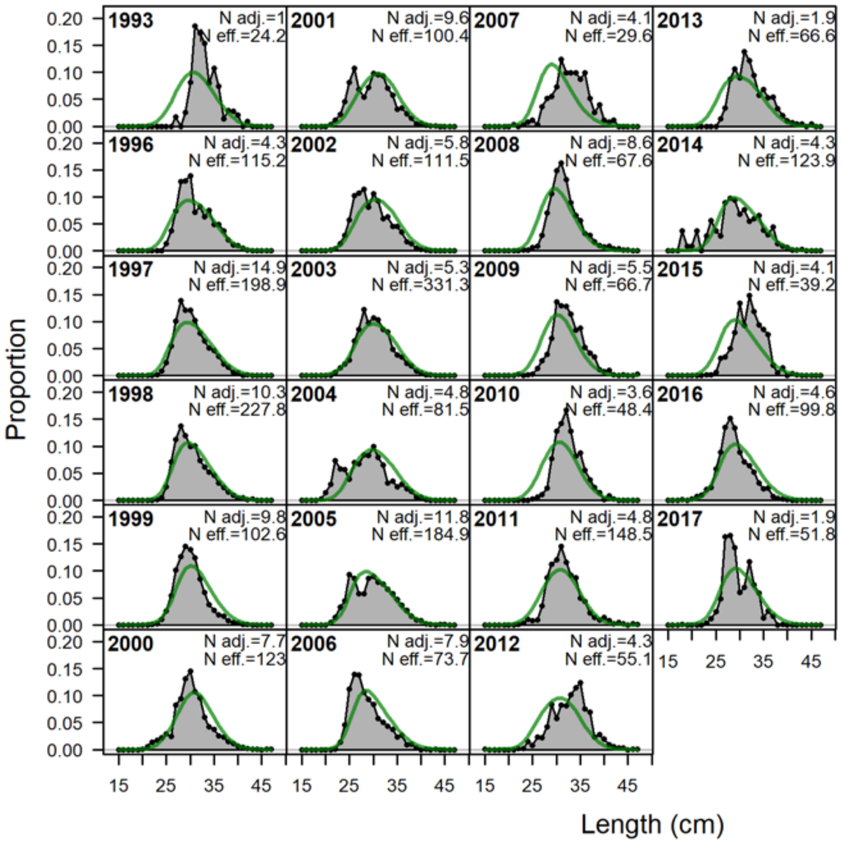


Figure A 5.10. Eastern jackass morwong length composition fits: eastern trawl onboard retained.

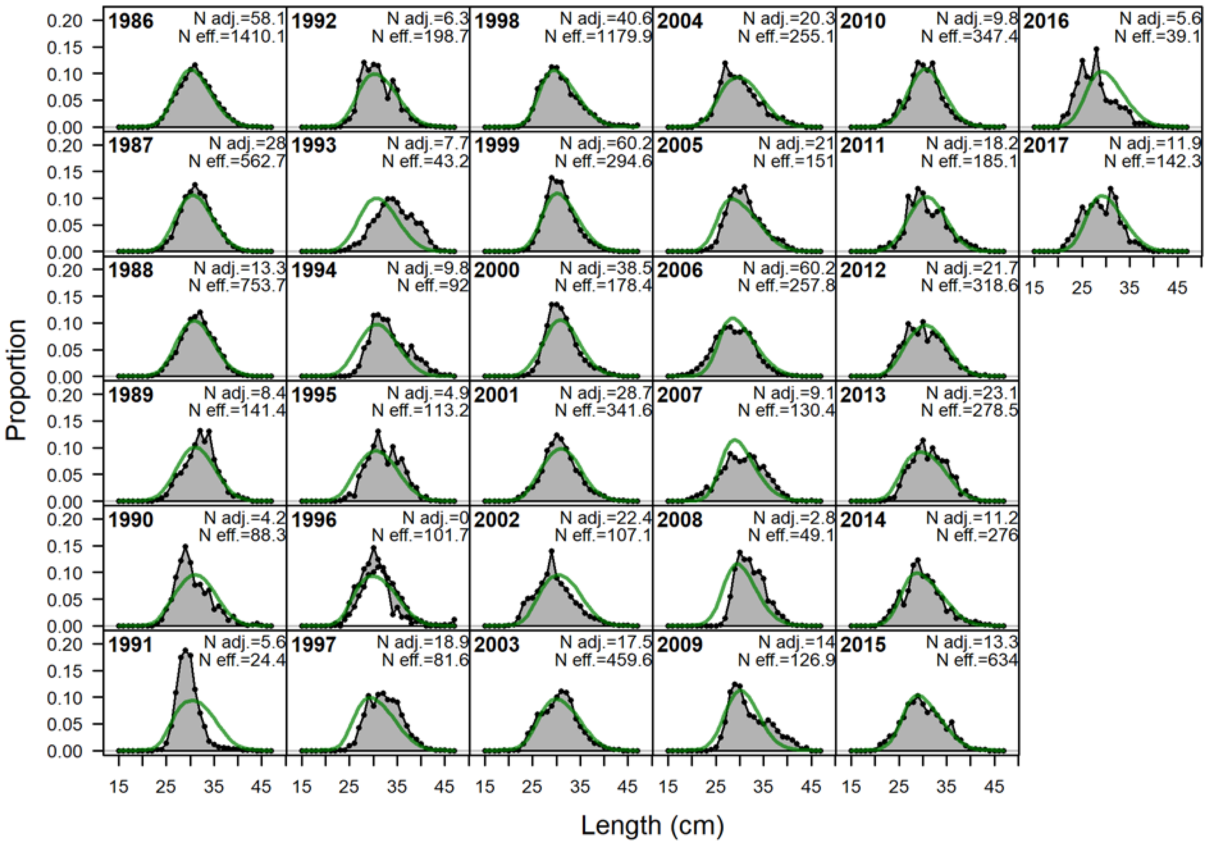
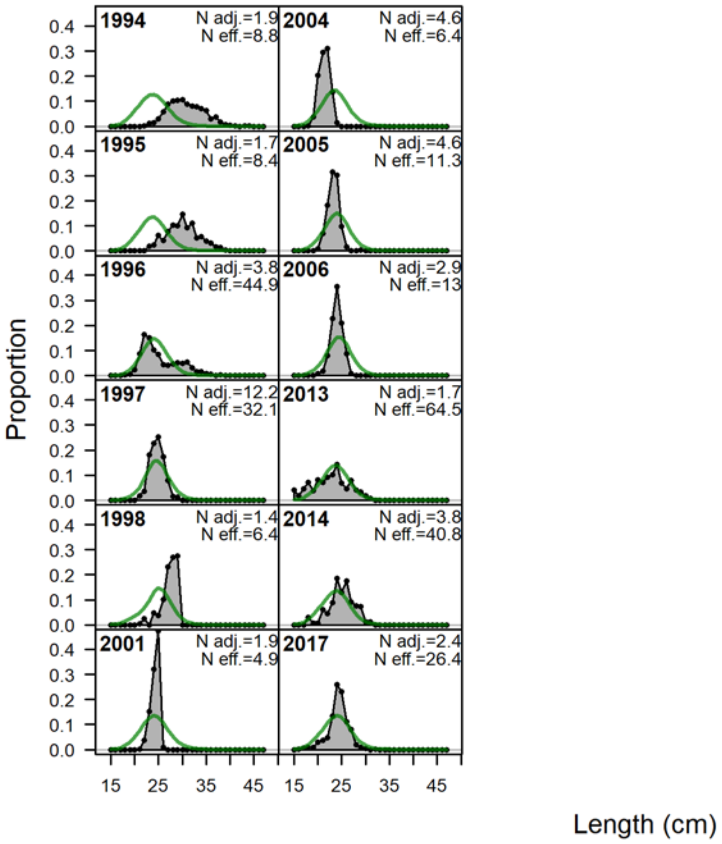


Figure A 5.11. Eastern jackass morwong length composition fits: eastern trawl port retained.



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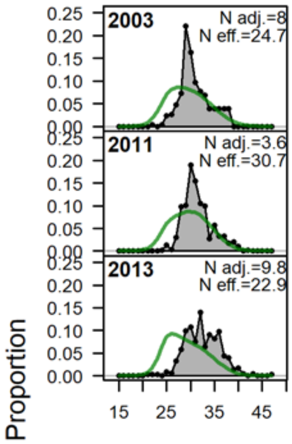
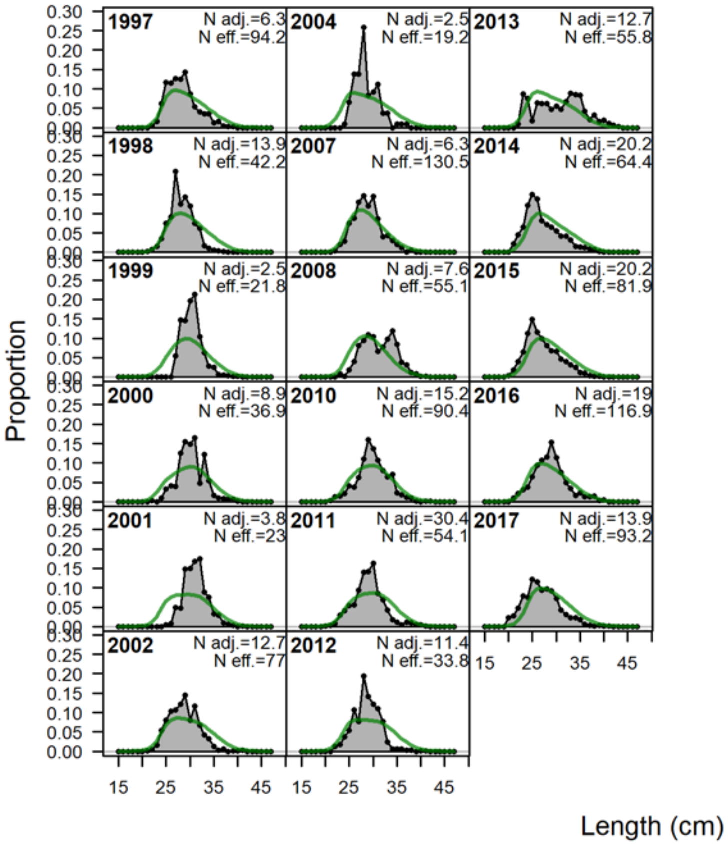


Figure A 5.13. Eastern jackass morwong length composition fits: Danish seine onboard retained.



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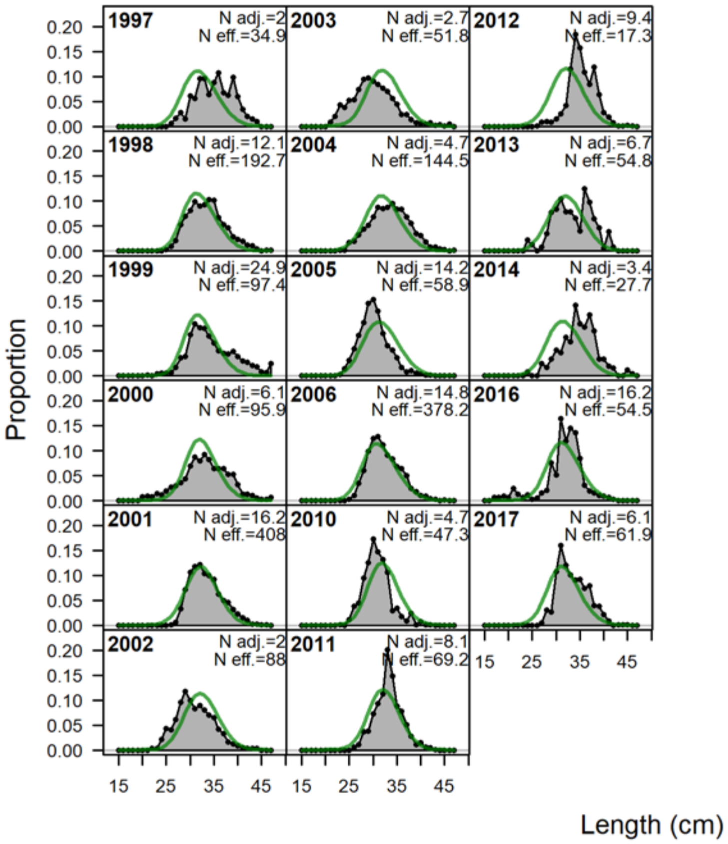


Figure A 5.15. Eastern jackass morwong length composition fits: Tasmanian trawl onboard retained.

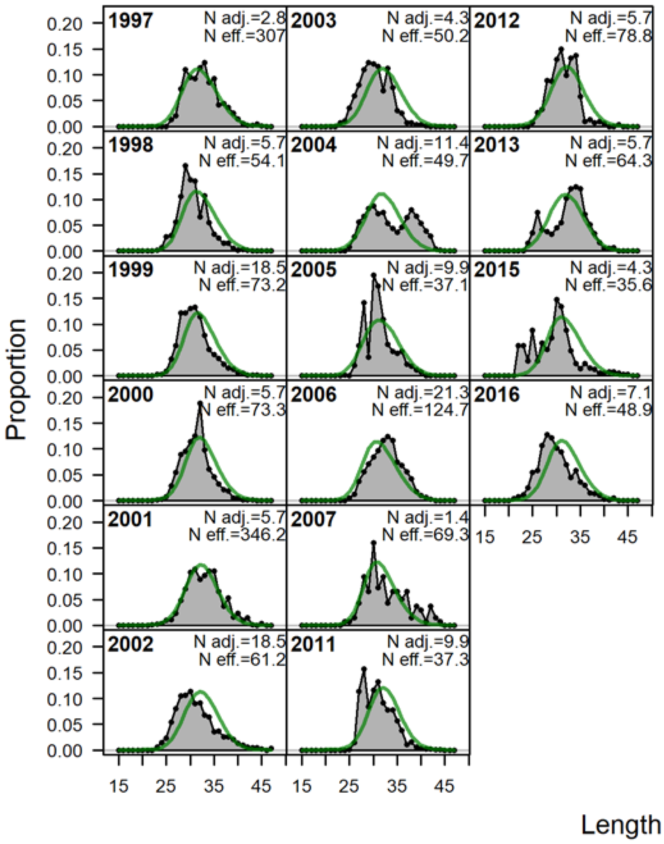


Figure A 5.16. Eastern jackass morwong length composition fits: Tasmanian trawl port retained.

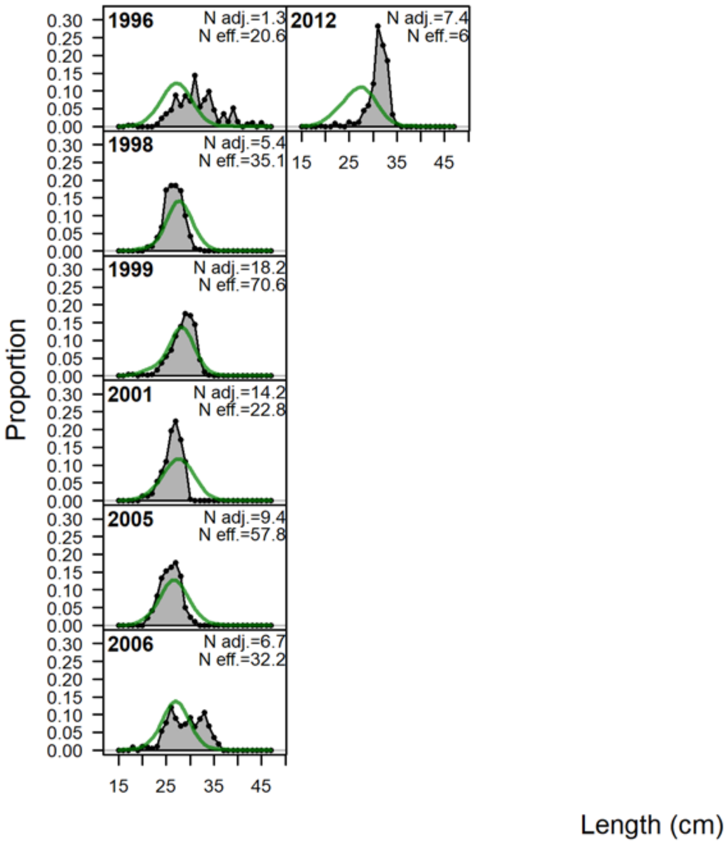


Figure A 5.17. Eastern jackass morwong length composition fits: Tasmanian trawl discarded.

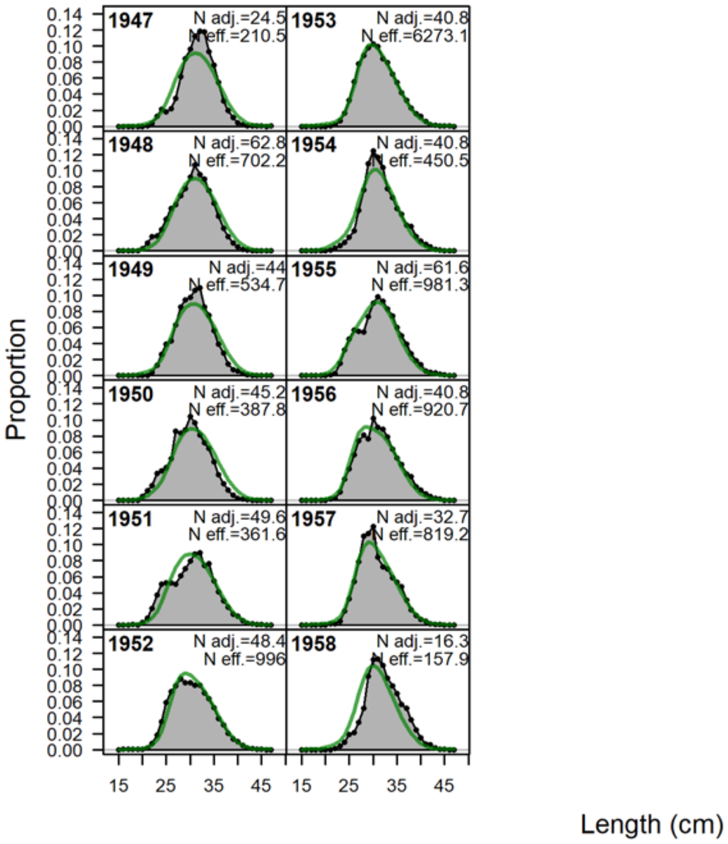


Figure A 5.18. Eastern jackass morwong length composition fits: steam trawl retained.

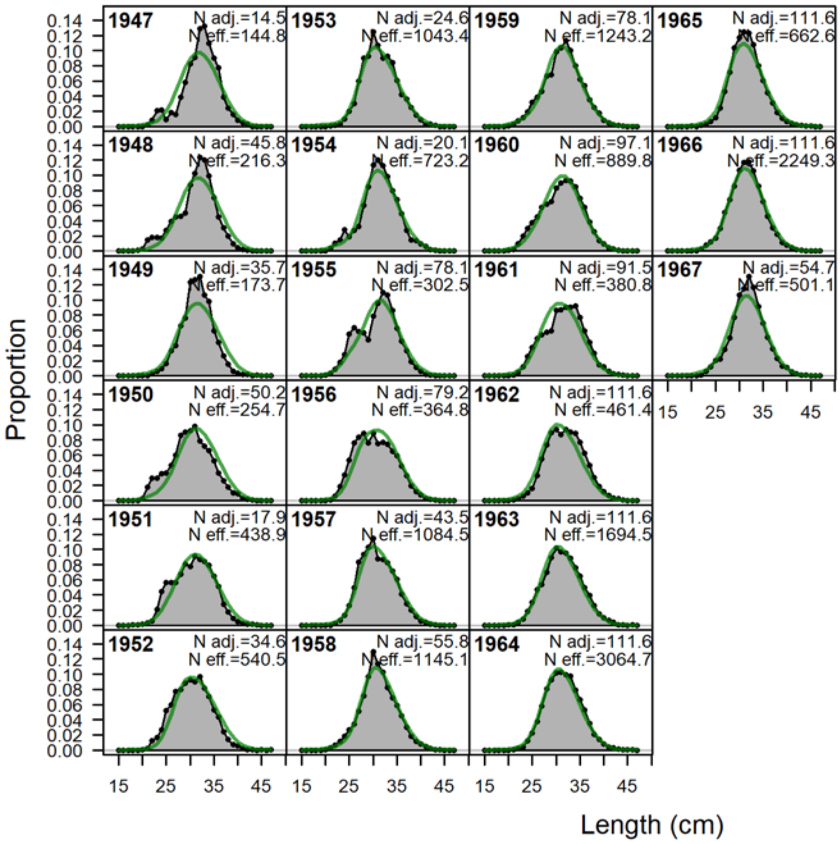


Figure A 5.19. Eastern jackass morwong length composition fits: early Danish seine retained.

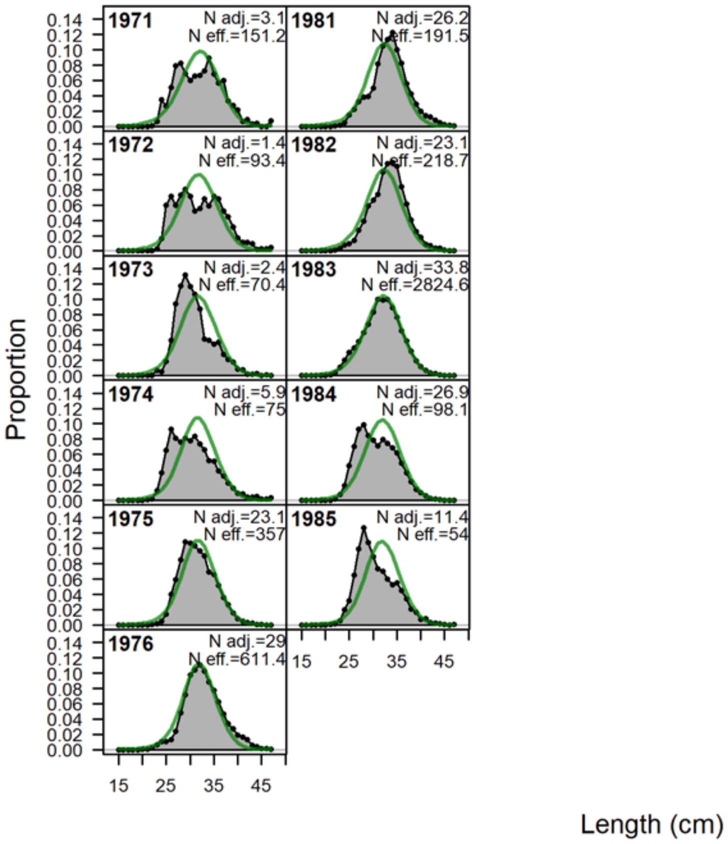


Figure A 5.20. Eastern jackass morwong length composition fits: mixed retained.

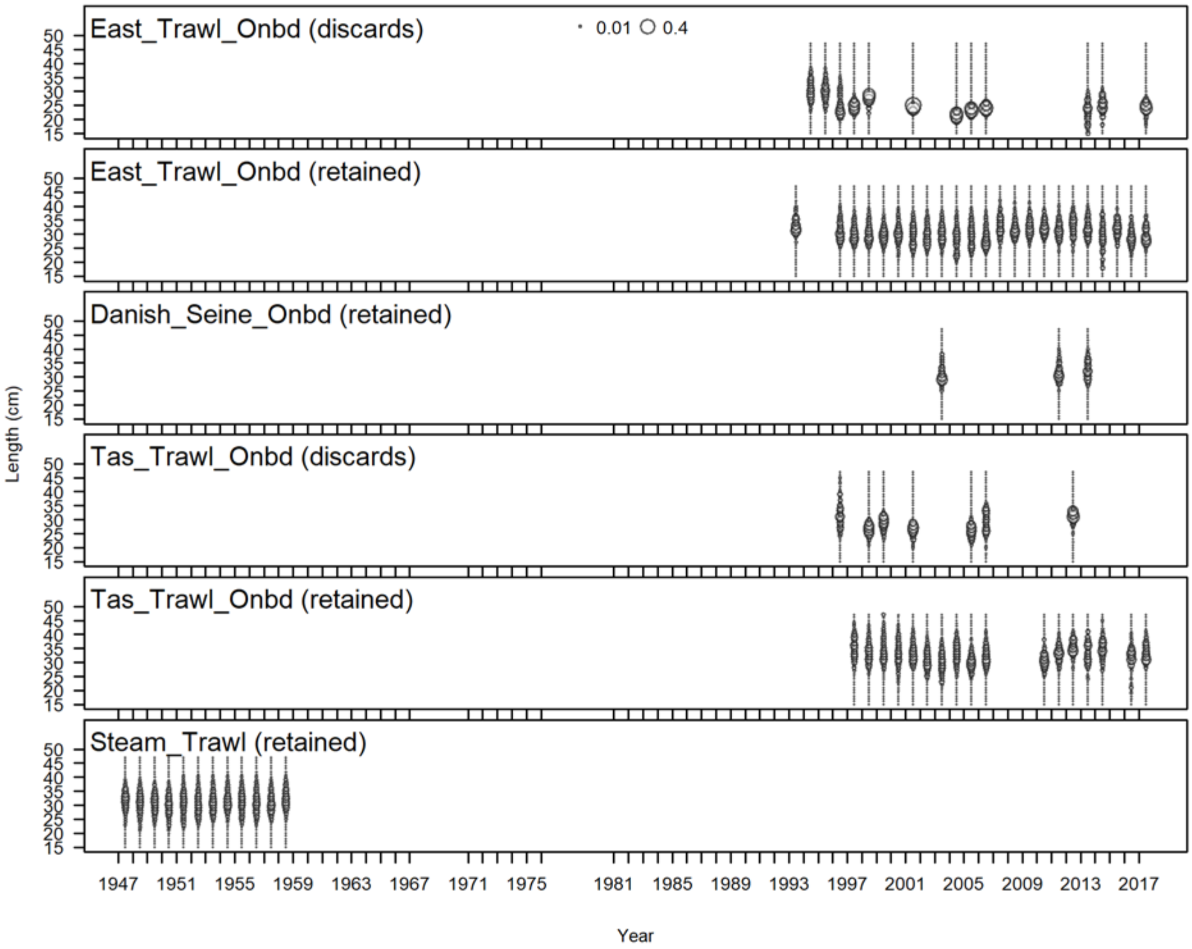


Figure A 5.21. Residuals from the annual length compositions (retained and discarded) for eastern jackass morwong displayed by year for trawl fleets.

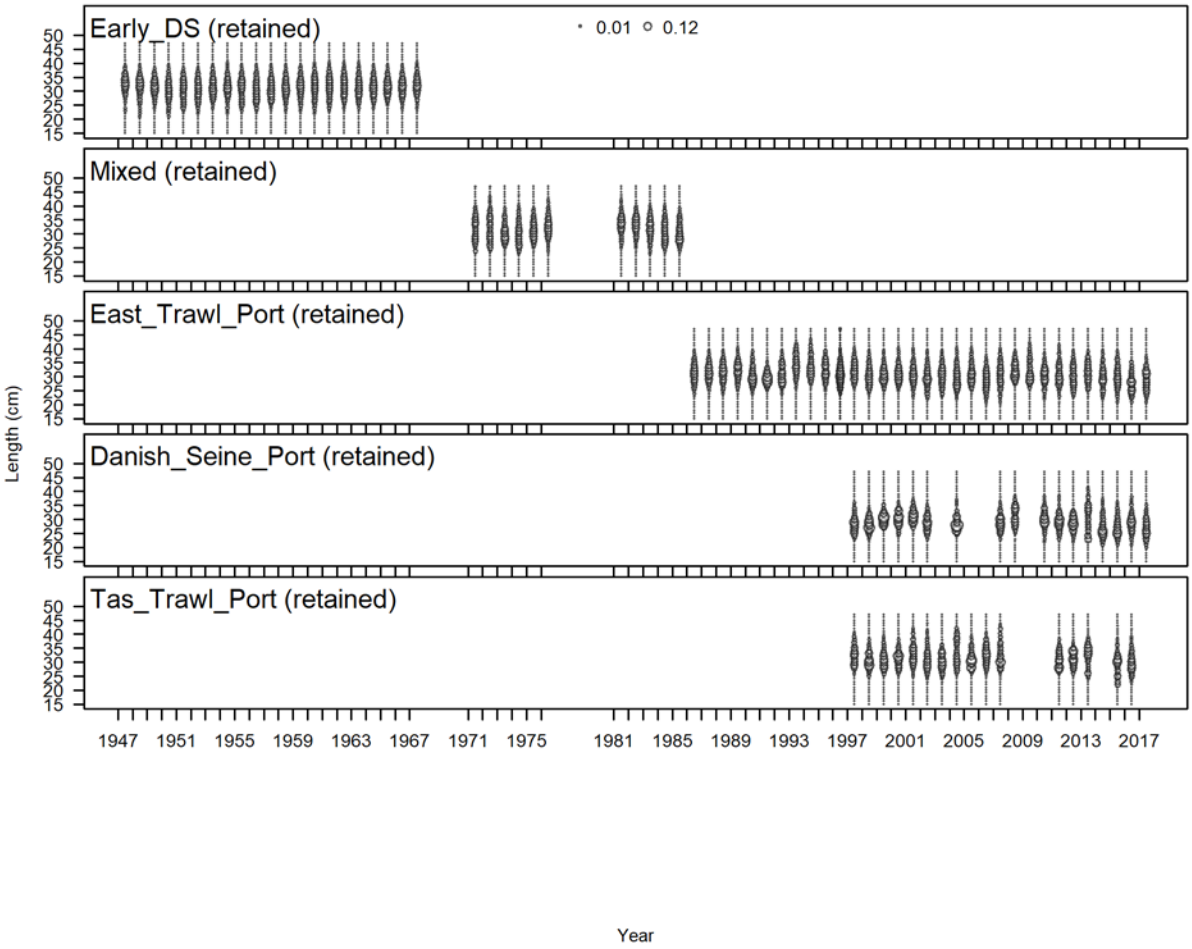


Figure A 5.22. Residuals from the annual length compositions (retained and discarded) for eastern jackass morwong displayed by year for trawl fleets.

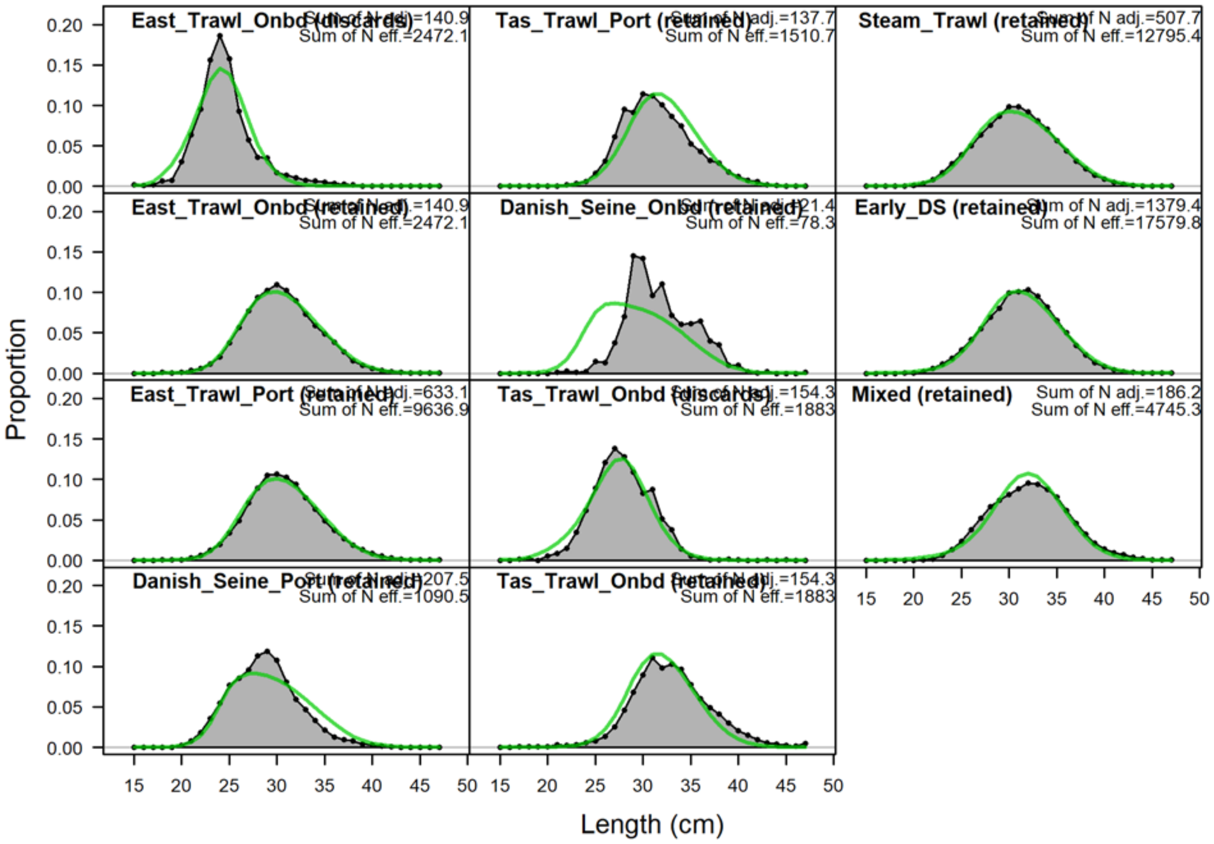


Figure A 5.23. Aggregated fits (over all years) to the length compositions for eastern jackass morwong displayed by fleet.

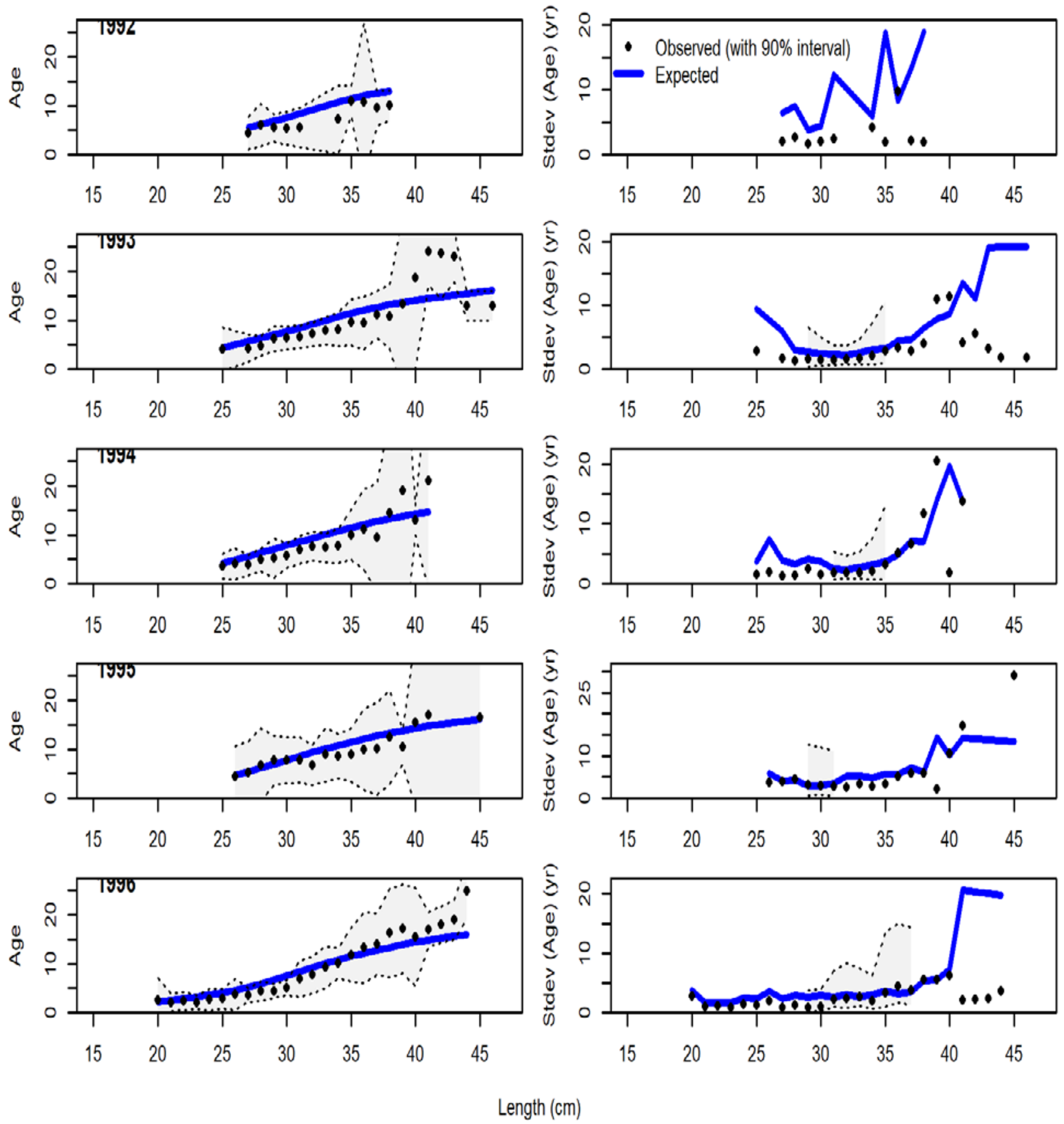


Figure A 5.24. Eastern jackass morwong conditional age-at-length fits: eastern trawl part 1.

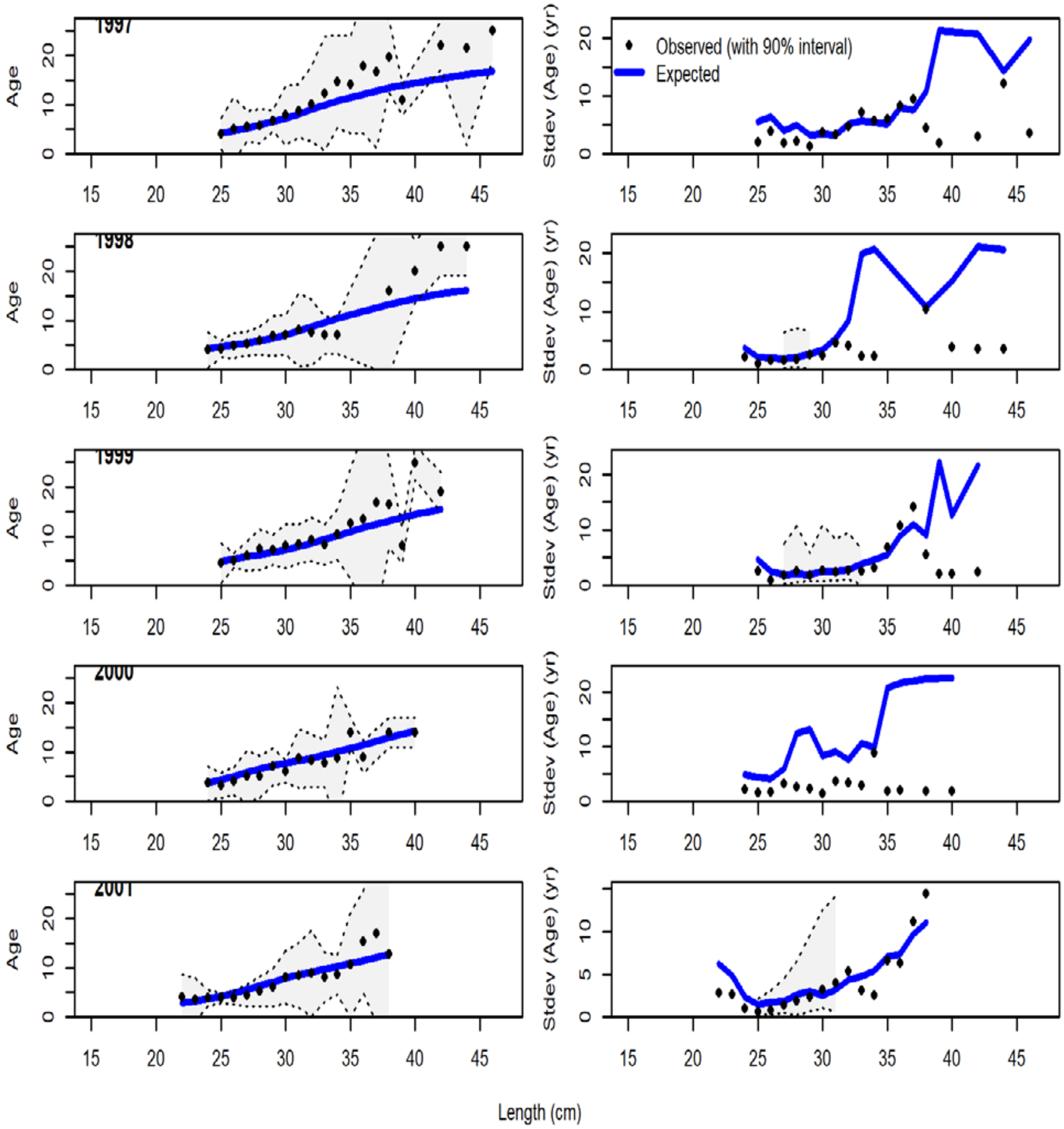


Figure A 5.25. Eastern jackass morwong conditional age-at-length fits: eastern trawl part 2.

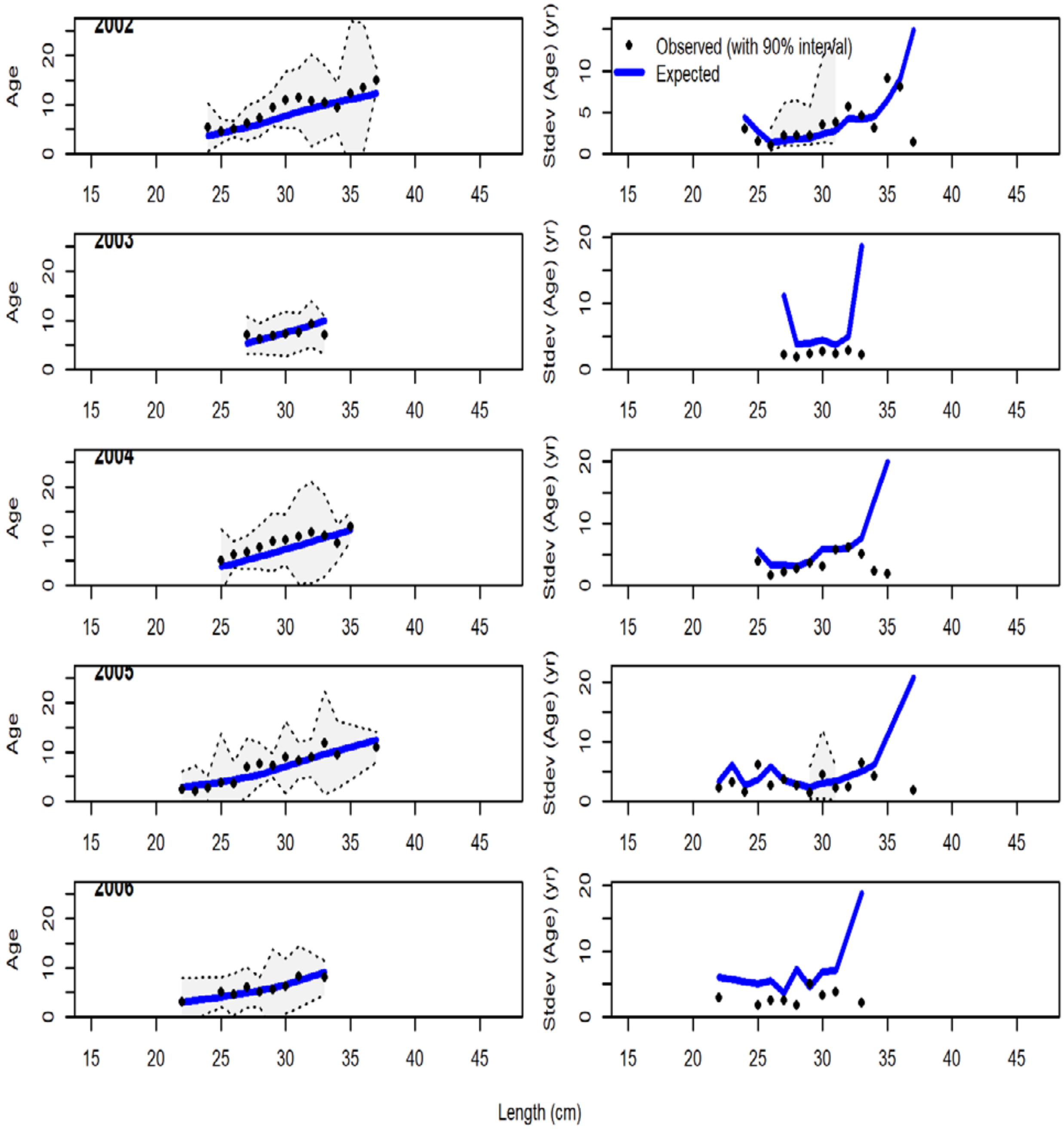


Figure A 5.26. Eastern jackass morwong conditional age-at-length fits: eastern trawl part 3.

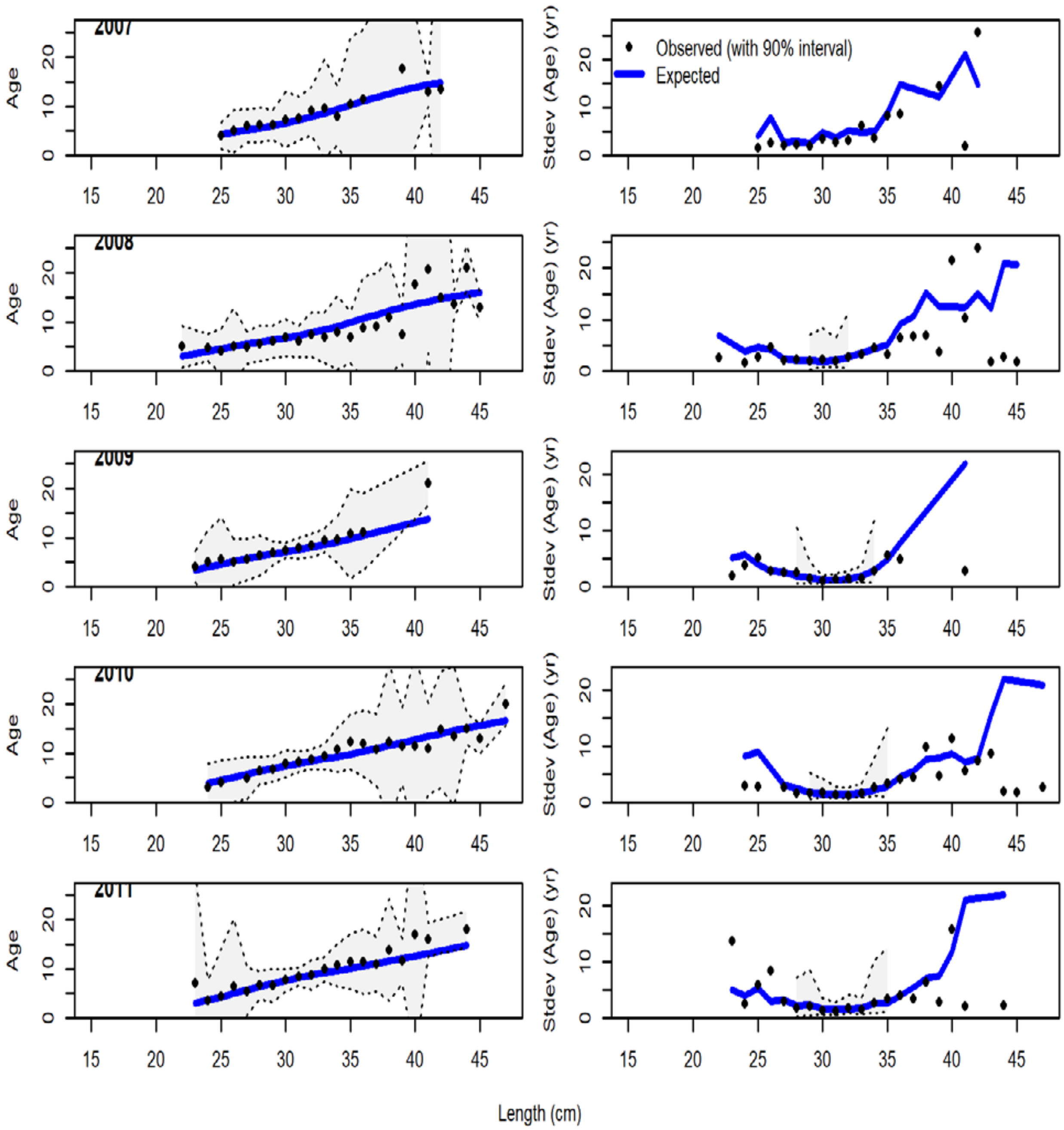


Figure A 5.27. Eastern jackass morwong conditional age-at-length fits: eastern trawl part 4.

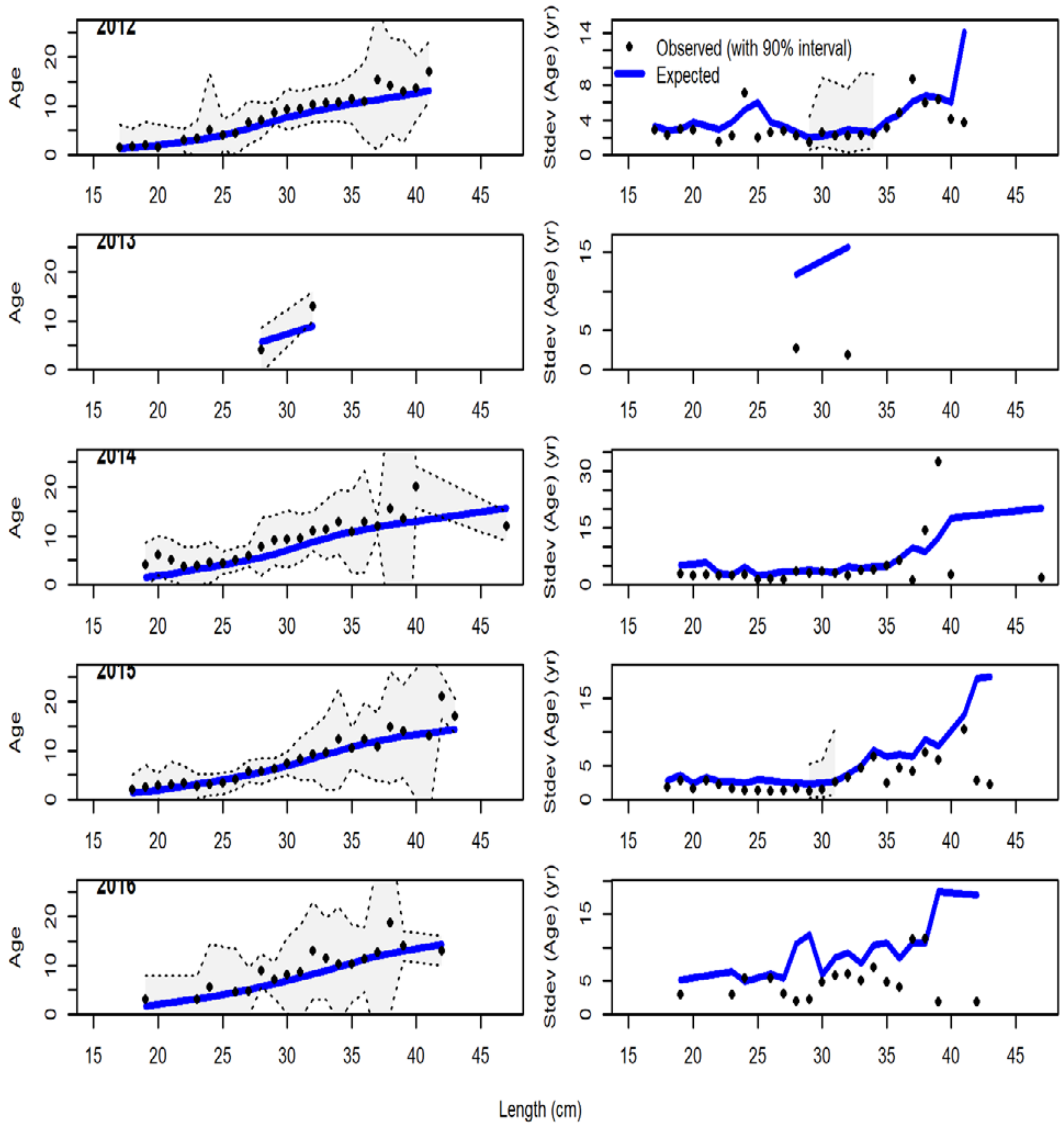


Figure A 5.28. Eastern jackass morwong conditional age-at-length fits: eastern trawl part 5.

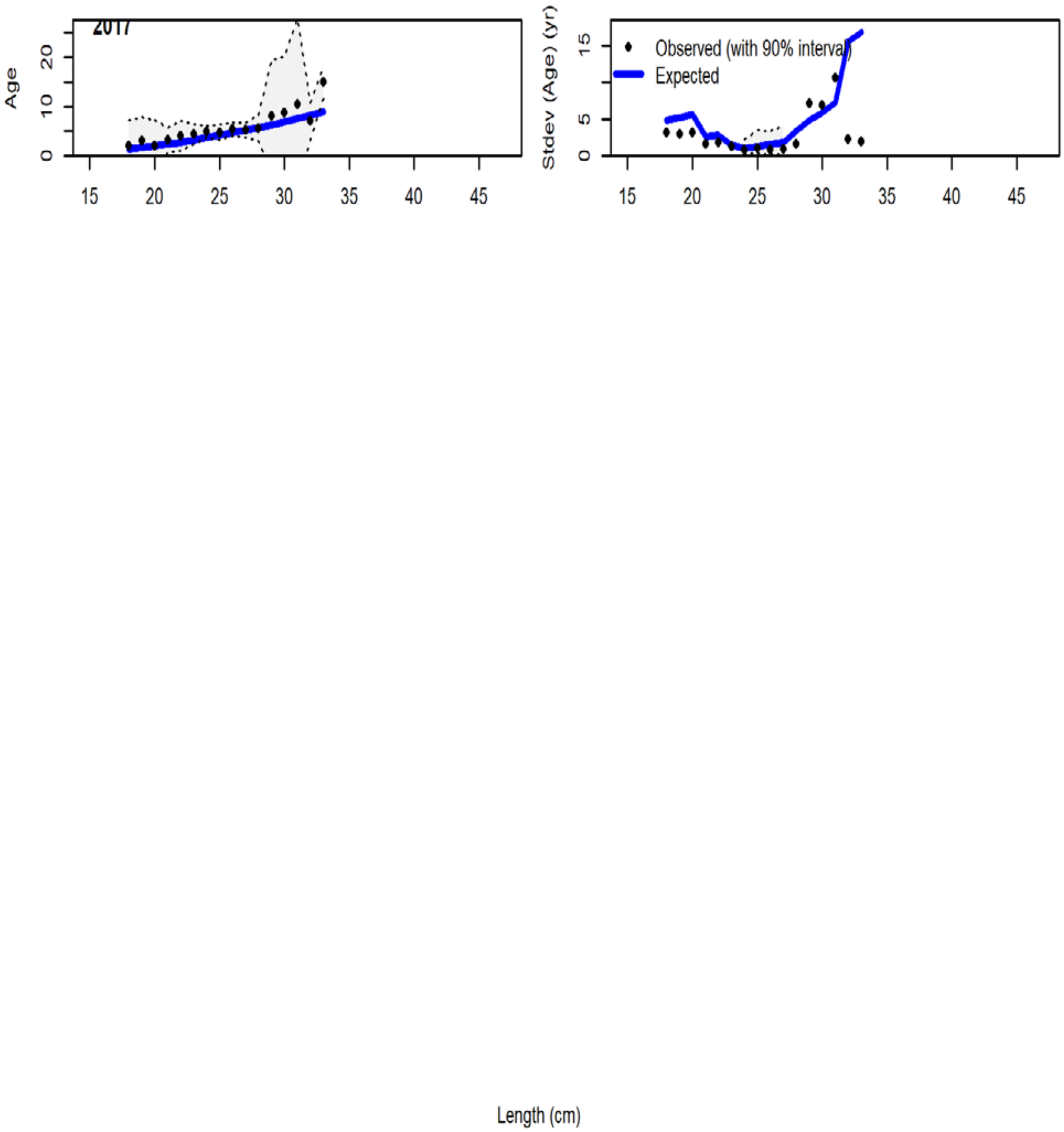


Figure A 5.29. Eastern jackass morwong conditional age-at-length fits: eastern trawl part 6.

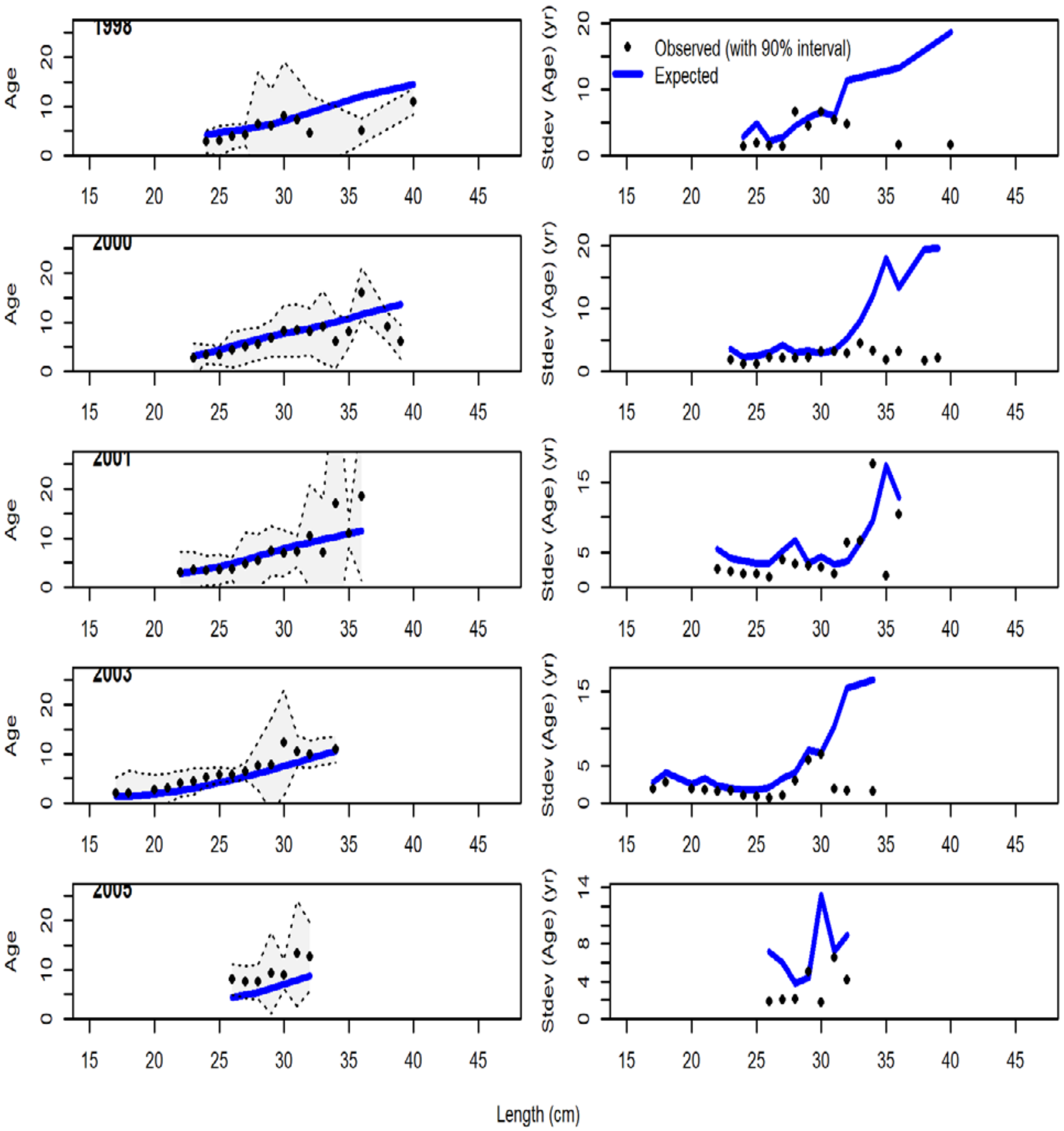


Figure A 5.30. Eastern jackass morwong conditional age-at-length fits: Danish seine part 1.

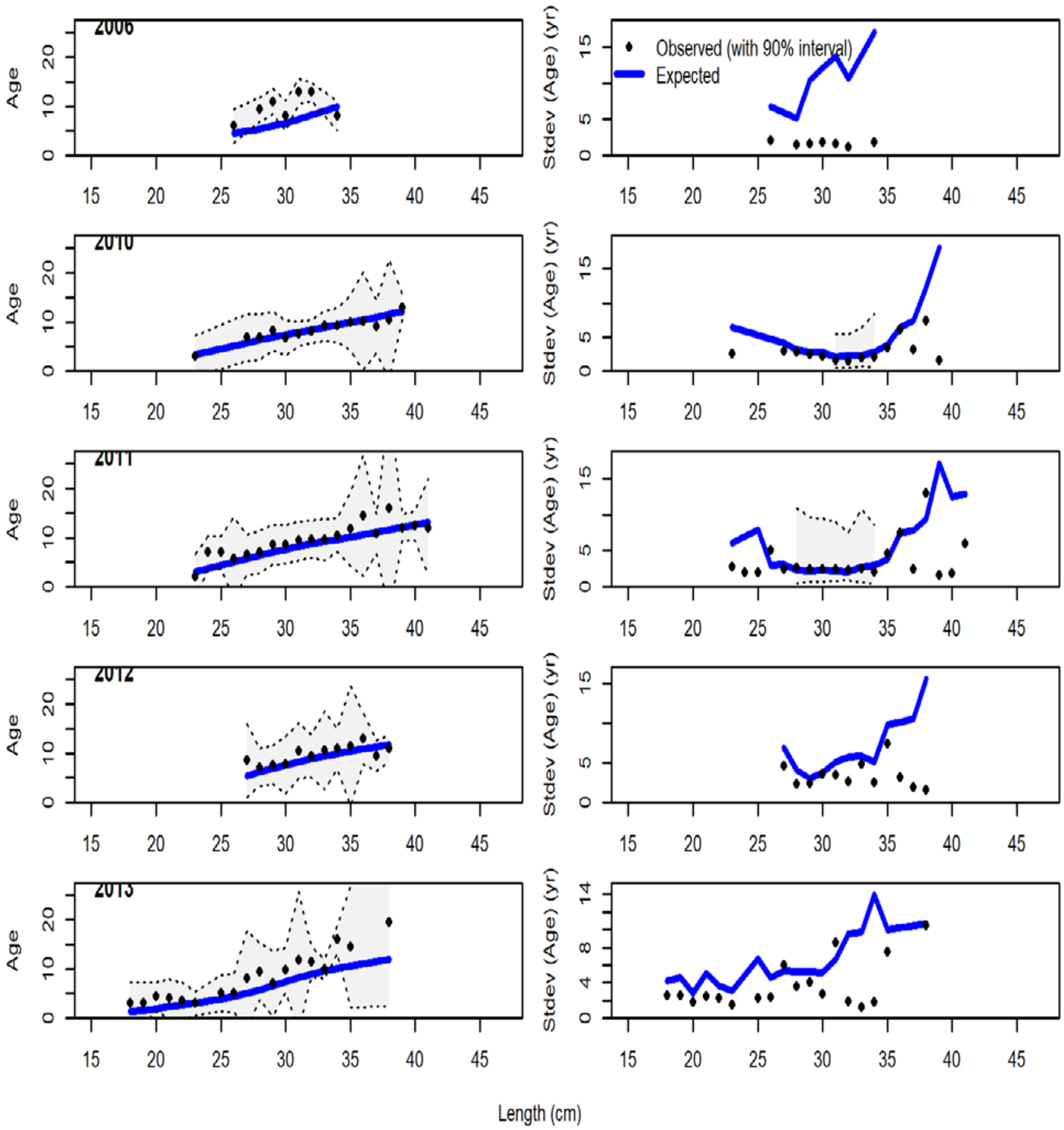


Figure A 5.31. Eastern jackass morwong conditional age-at-length fits: Danish seine part 2.

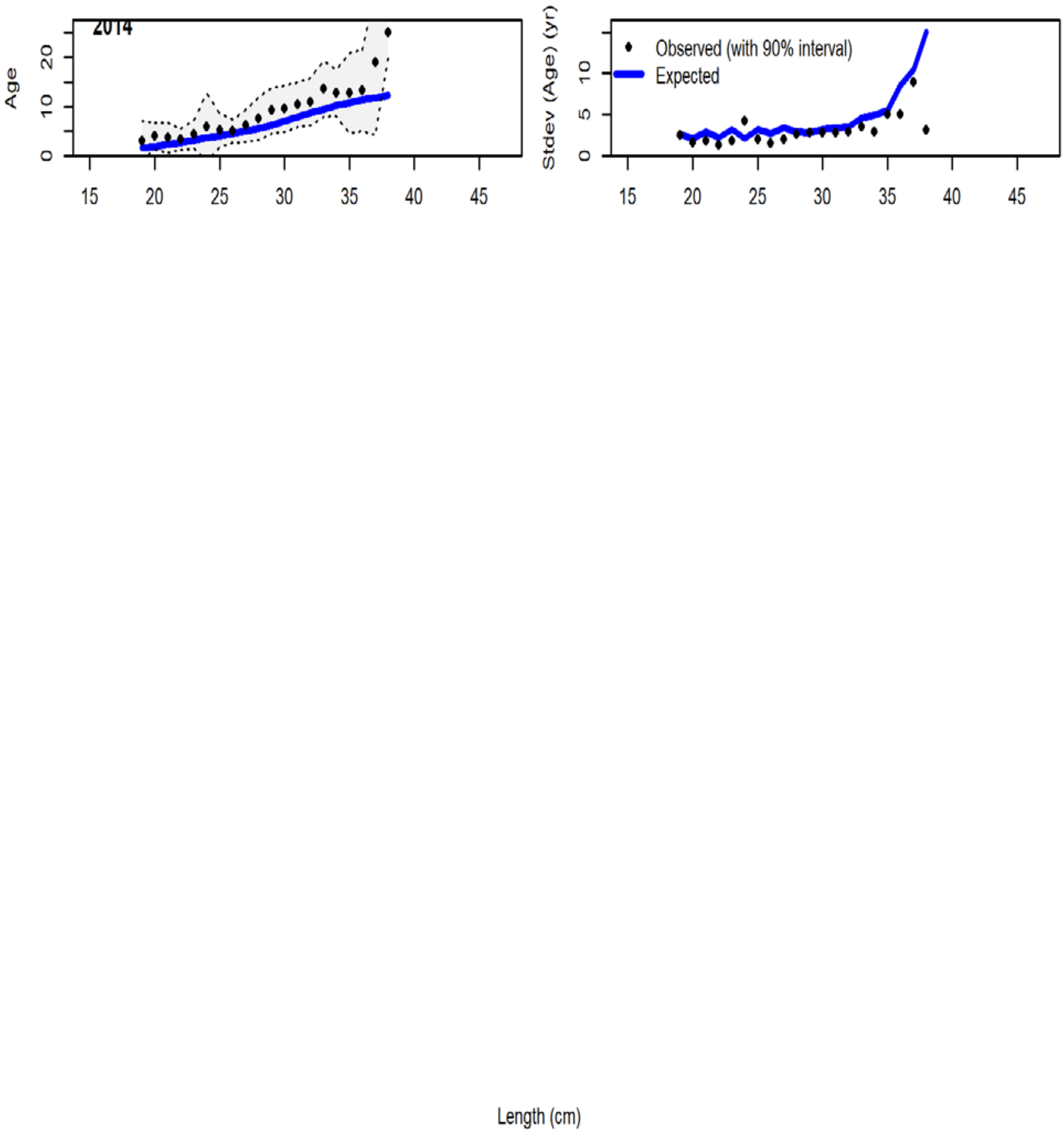


Figure A 5.32. Eastern jackass morwong conditional age-at-length fits: Danish seine part 3.

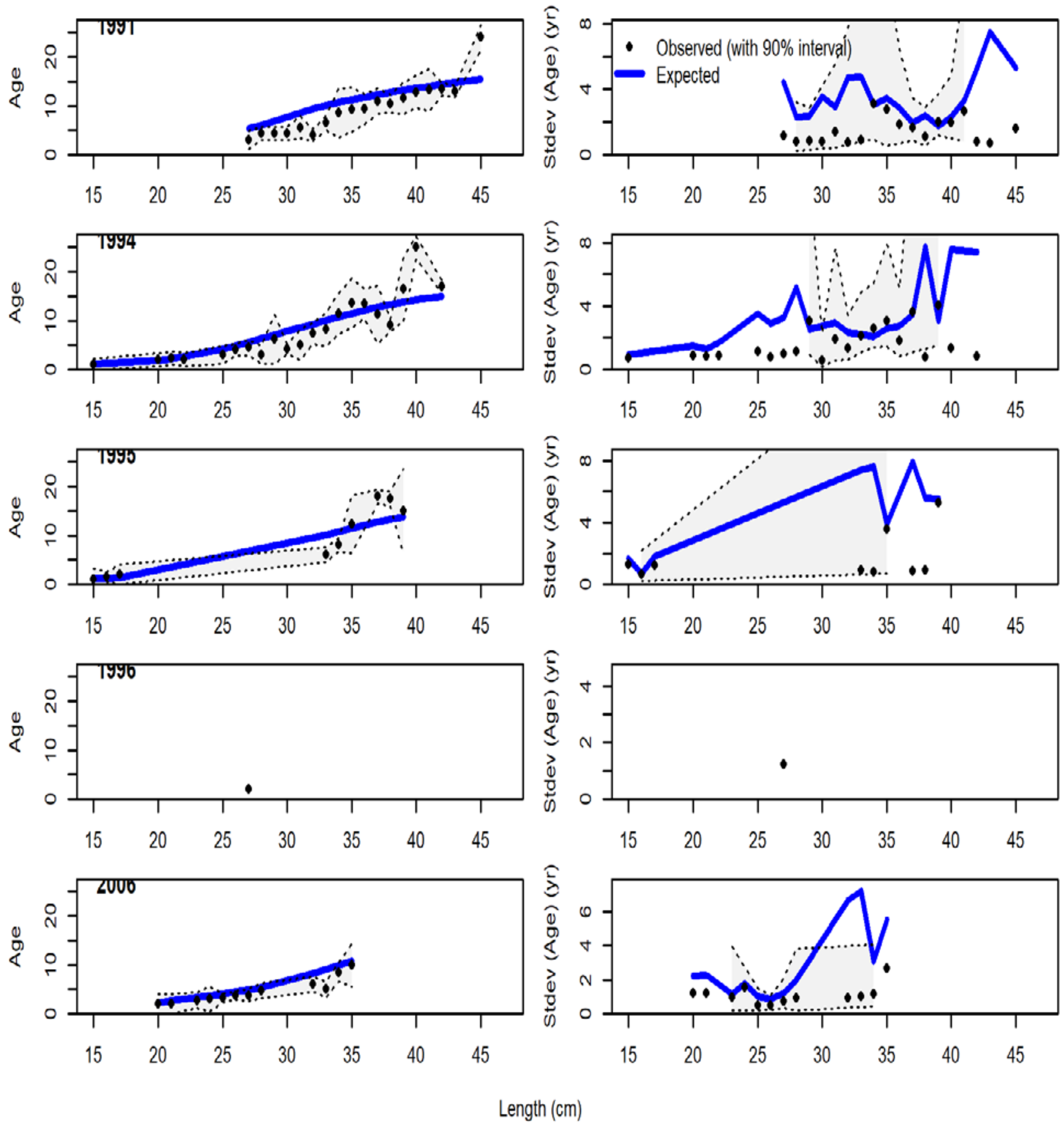


Figure A 5.33. Eastern jackass morwong conditional age-at-length fits: Tasmanian trawl part 1.

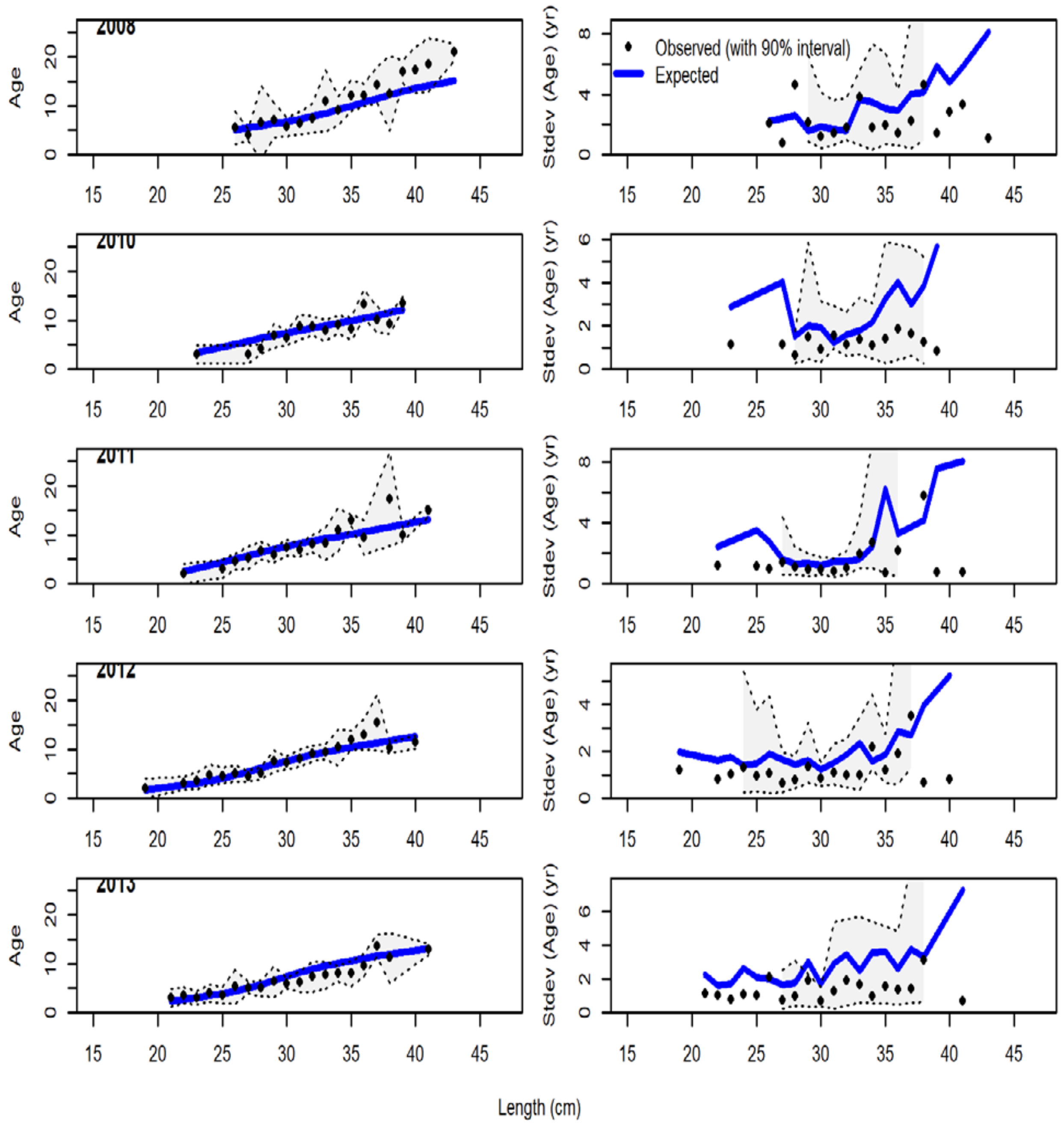


Figure A 5.34. Eastern jackass morwong conditional age-at-length fits: Tasmanian trawl part 2.

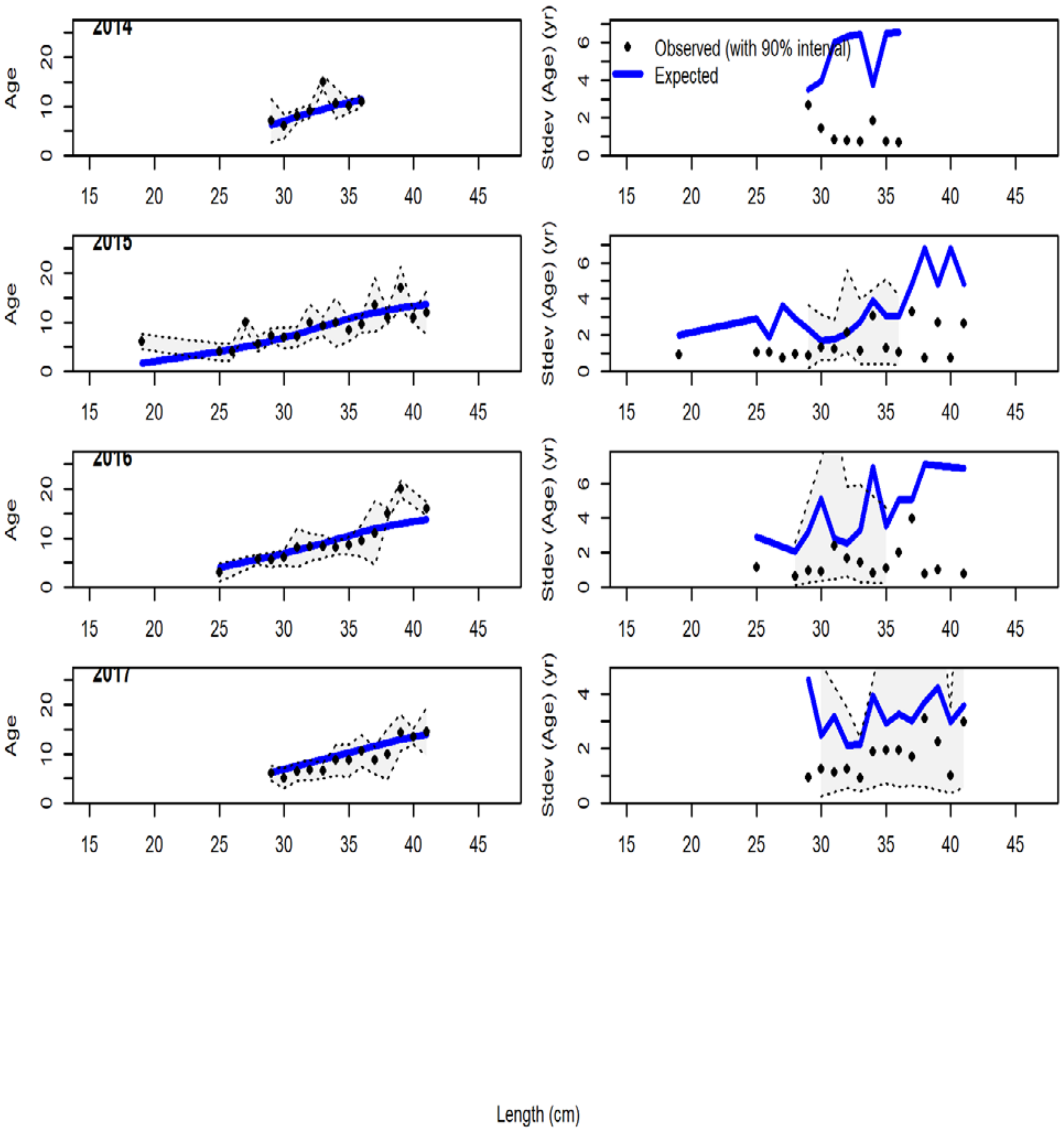


Figure A 5.35. Eastern jackass morwong conditional age-at-length fits: Tasmanian trawl part 3.

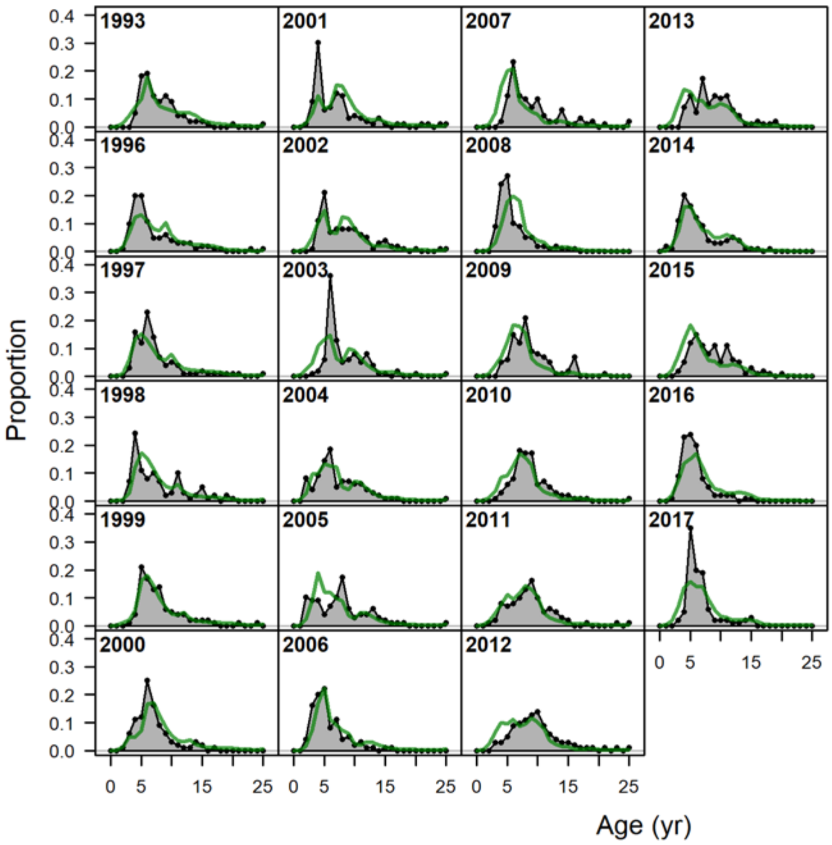


Figure A 5.36. Eastern jackass morwong implied fits to age: eastern trawl onboard retained.

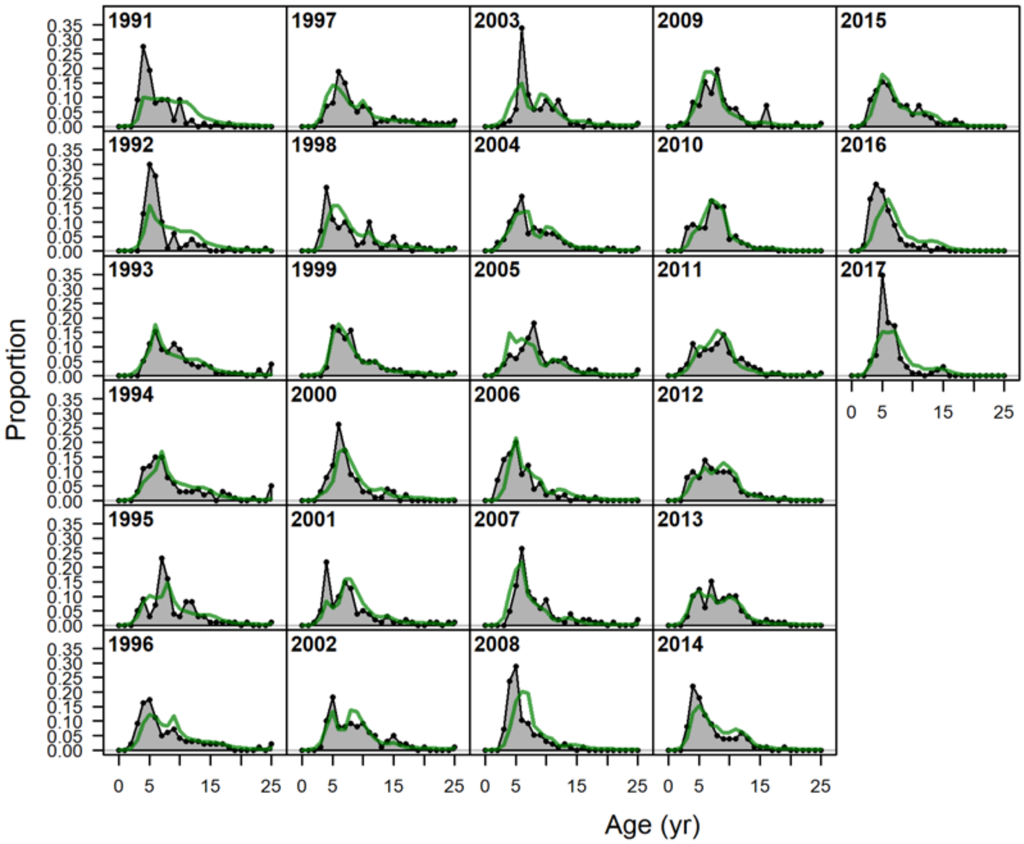


Figure A 5.37. Eastern jackass morwong implied fits to age: eastern trawl port retained.

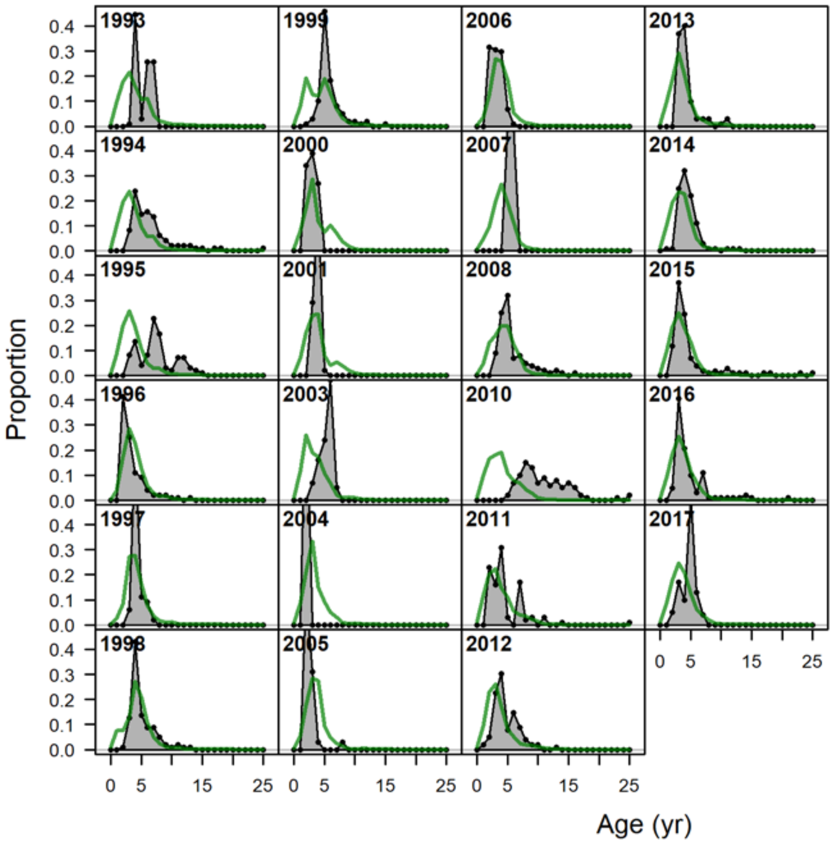


Figure A 5.38. Eastern jackass morwong implied fits to age: eastern trawl onboard discarded.

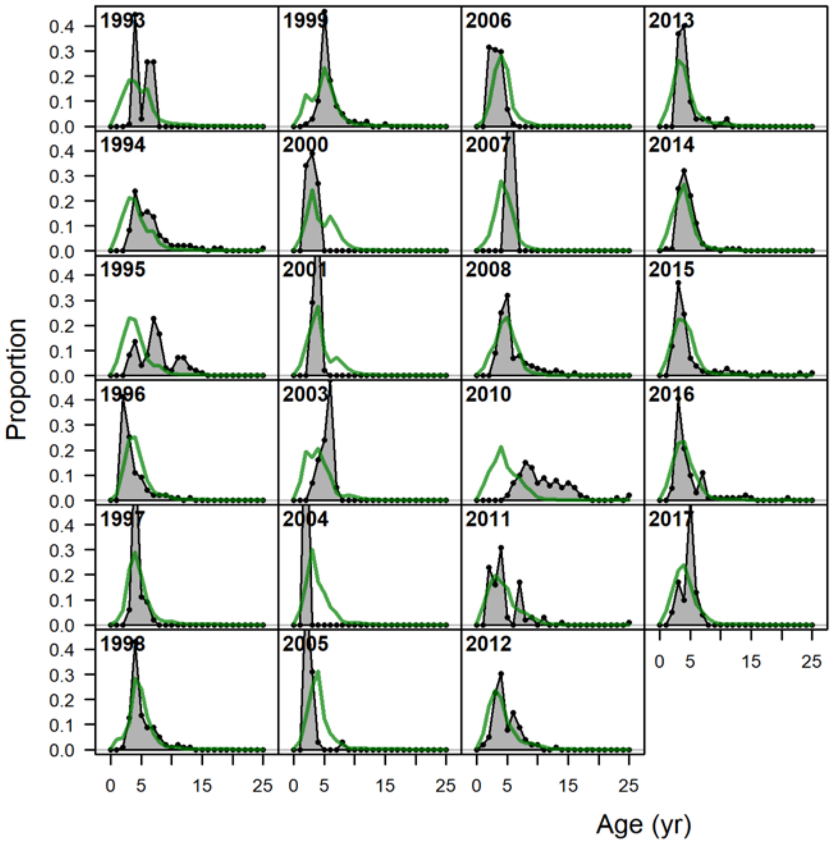


Figure A 5.39. Eastern jackass morwong implied fits to age: eastern trawl port discarded.

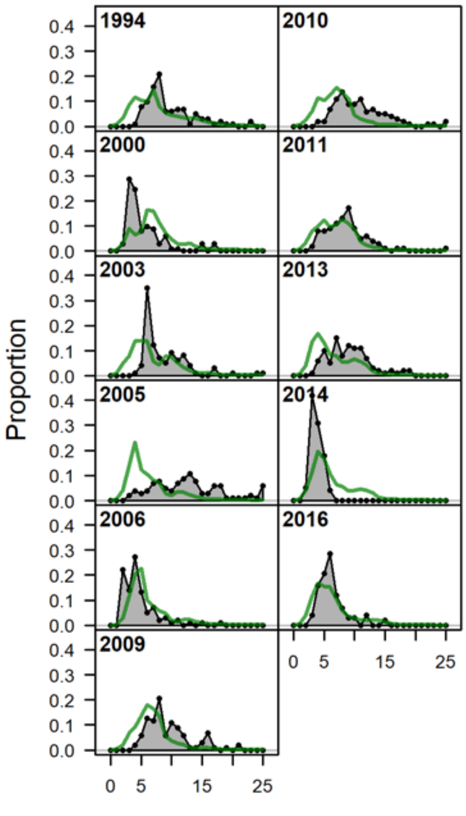


Figure A 5.40. Eastern jackass morwong implied fits to age: Danish seine onboard retained.

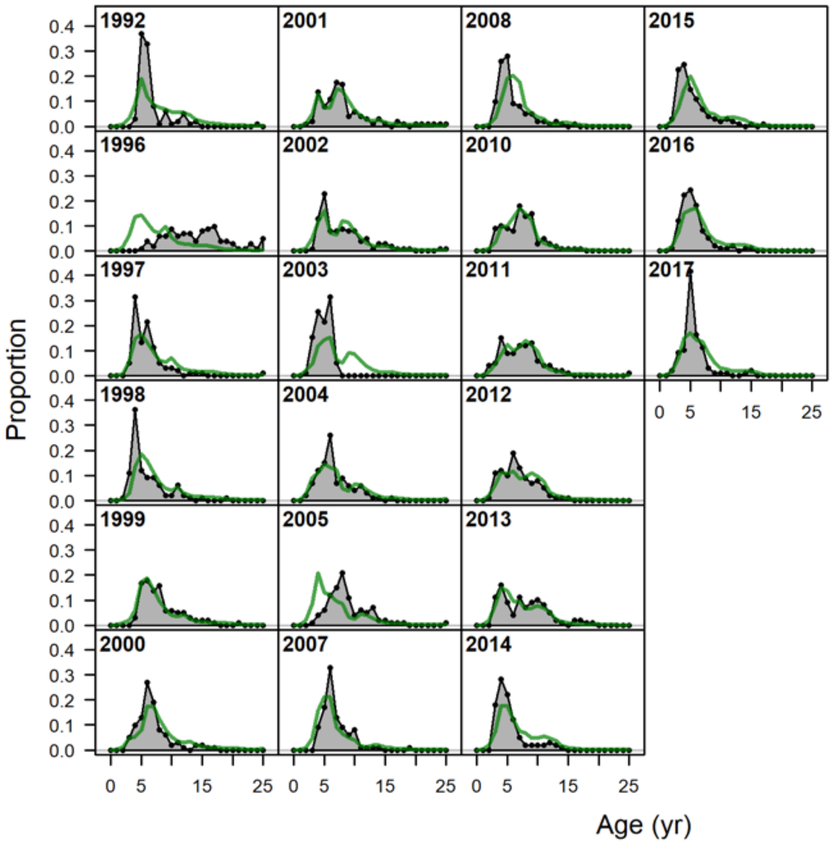


Figure A 5.41. Eastern jackass morwong implied fits to age: Danish seine port retained.

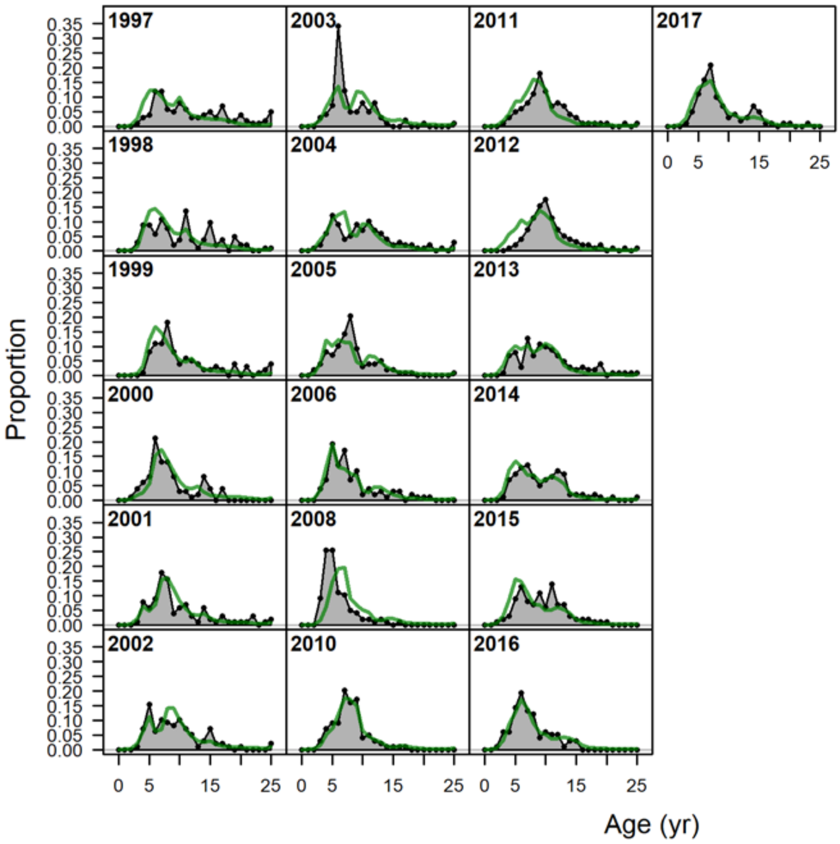


Figure A 5.42. Eastern jackass morwong implied fits to age: Tasmanian trawl onboard retained.

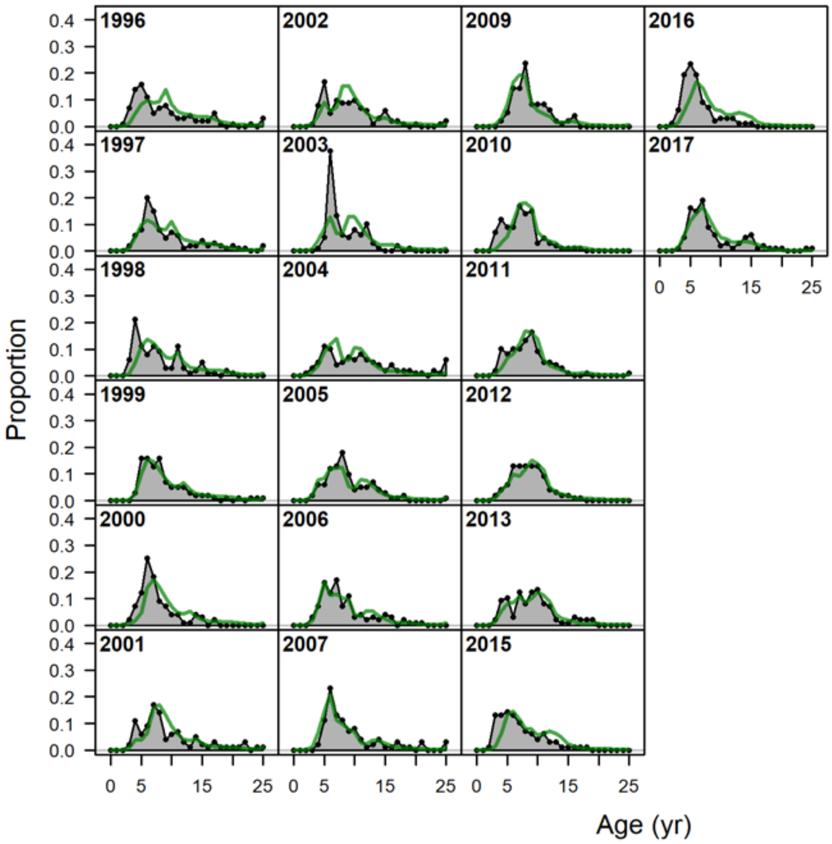


Figure A 5.43. Eastern jackass morwong implied fits to age: Tasmanian trawl port retained.

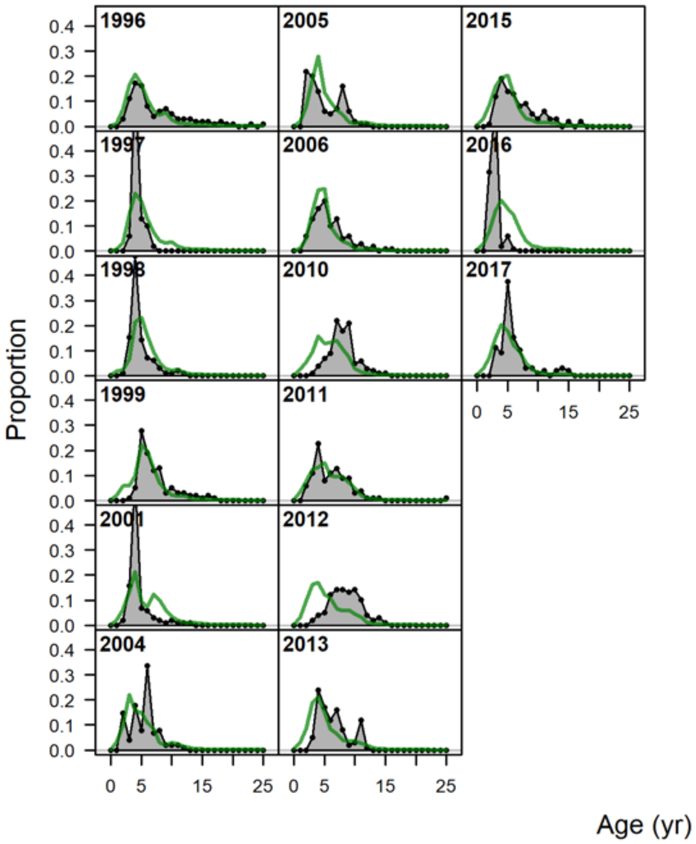


Figure A 5.44. Eastern jackass morwong implied fits to age: Tasmanian trawl onboard discarded.

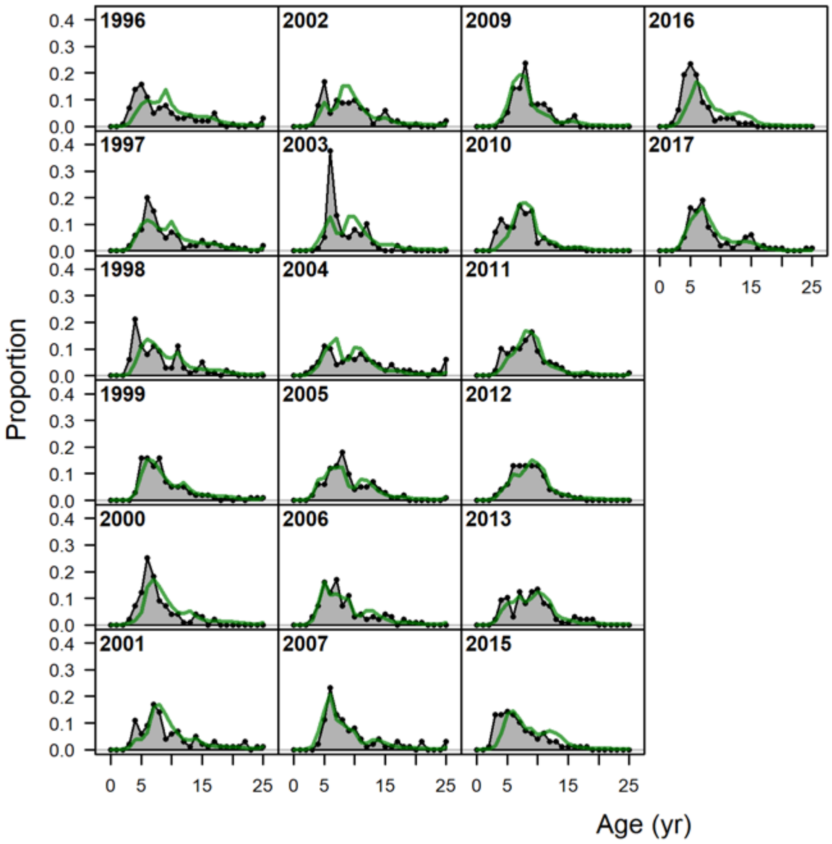


Figure A 5.45. Eastern jackass morwong implied fits to age: Tasmanian trawl port discarded.

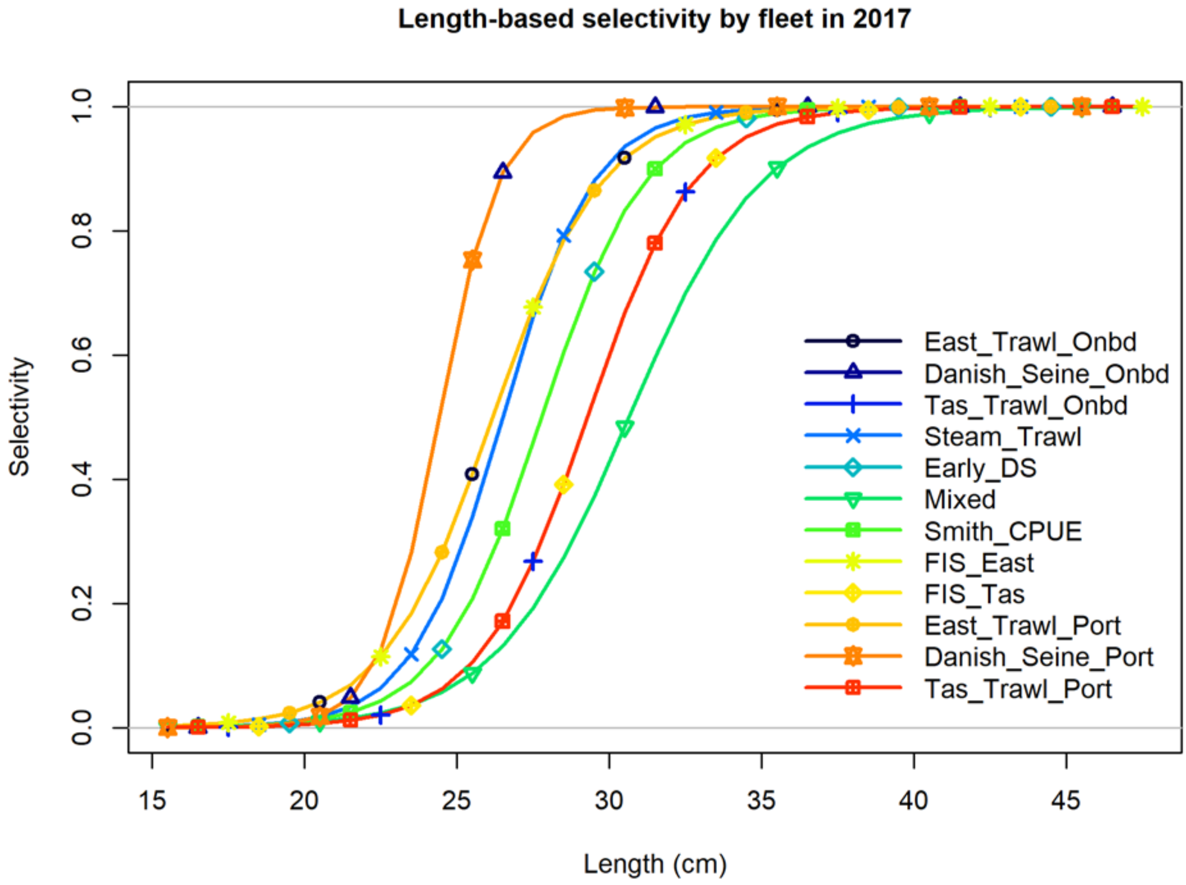


Figure A 5.46. Estimated selectivity and retention curves for eastern jackass morwong trawl fleet.

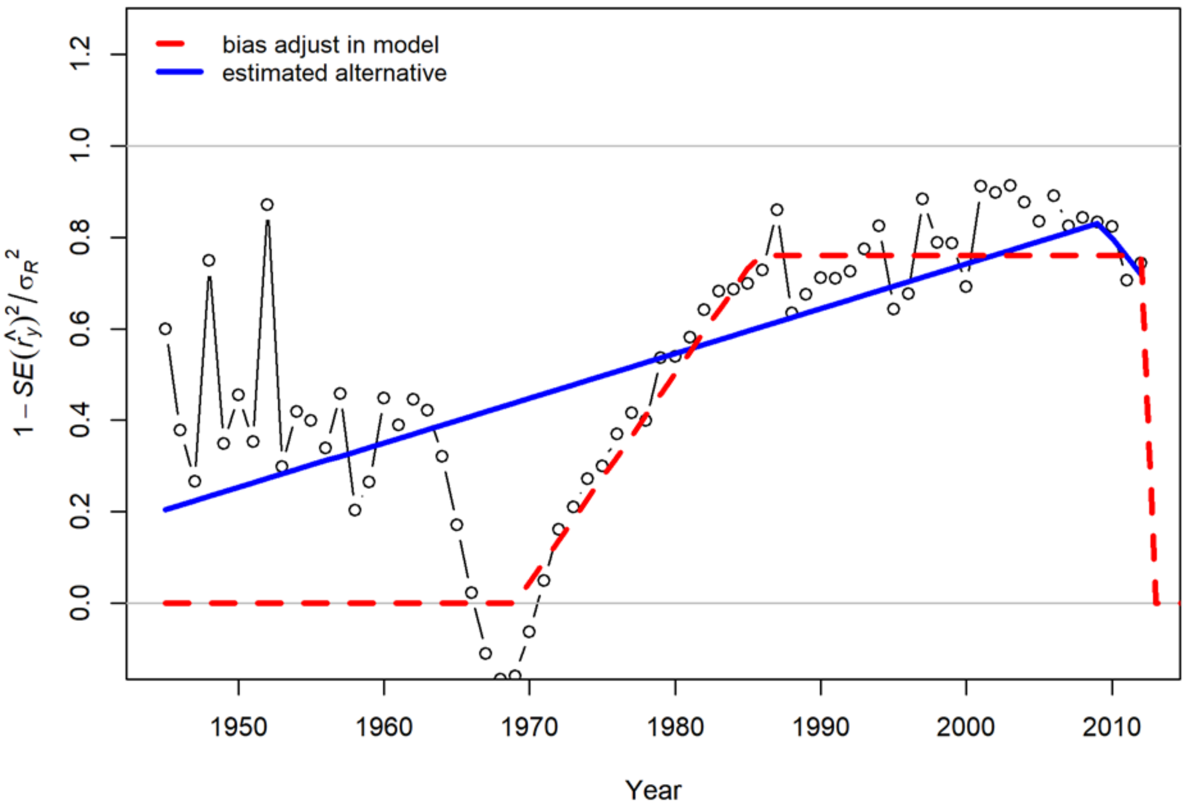


Figure A 5.47. Bias ramp adjustment for eastern jackass morwong.

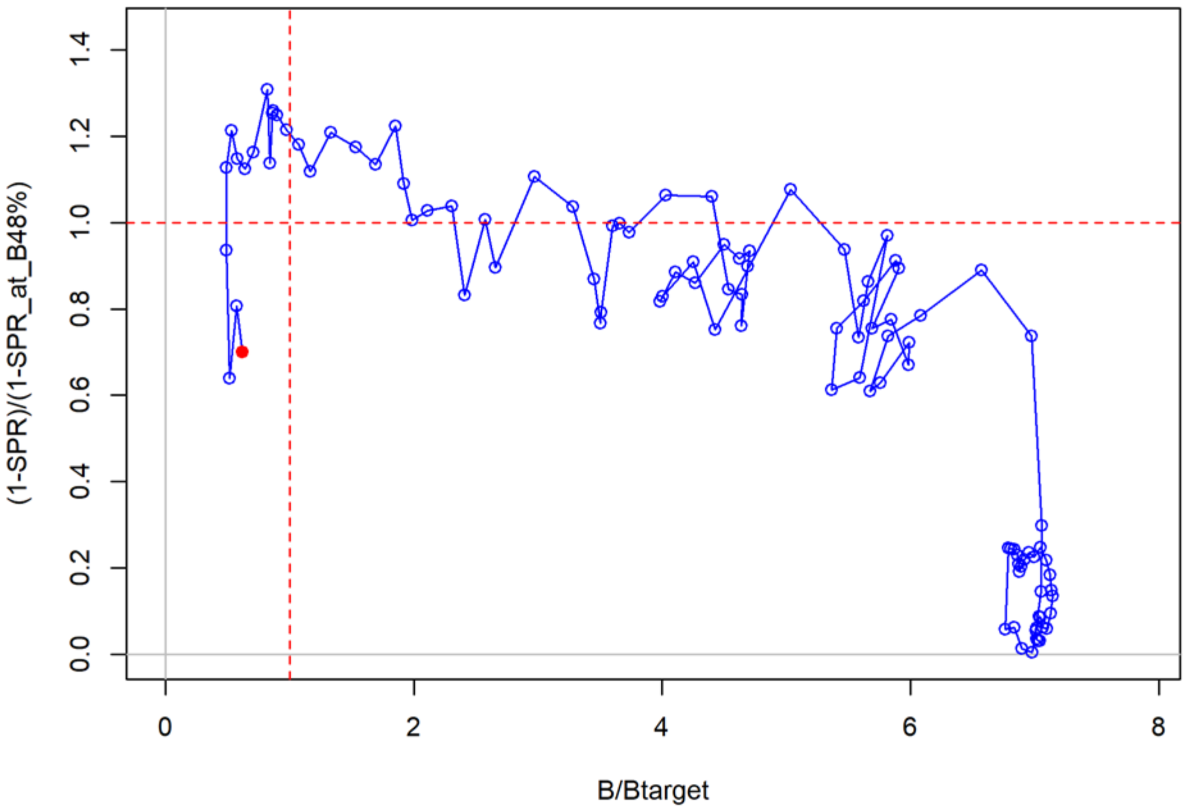


Figure A 5.48. Phase plot of biomass vs SPR ratio.

6. Eastern 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, TAS 7000, Australia

6.1 Executive Summary

This document updates the 2015 Tier 1 assessment of eastern 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. One additional year in the abundance index (2016) for the Fishery Independent Survey (FIS) was included. A range of sensitivities were explored.

The base-case assessment estimates that current spawning stock biomass is 35% of unexploited stock biomass (SSB_0). Under the agreed 20:35:48 harvest control rule, the 2019 recommended biological catch (RBC) is 261 t, with the long term yield (assuming average recruitment in the future) of 356 t. The average RBC over the three year period 2019-2021 is 270 t and over the five year period 2019-2023, the average RBC is 279 t.

Exploration of model sensitivity showed variation in spawning biomass across all sensitivities ranging from 18% to 52% of SSB_0 with greatest sensitivity to natural mortality. Excluding this sensitivity to natural mortality, the other sensitivities showed a much narrower range, from 29% to 40% of SSB_0.

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 reasonable fits to the catch rate data, relatively poor fits to the FIS abundance data, but good fits to the length composition and conditional age-at-length data.

6.2 Introduction

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 6.4), 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 2010-2016, 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 eastern stock of jackass morwong have been separated into six ‘fleets’, which represent one or more gear, regional, or temporal differences in the fishery. In the east, 50% recruitment to the fishery occurs between three and seven years of age, depending on gear type, compared to around eight years in the west.

6.2.1 *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).

6.2.2 *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 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.

6.2.3 *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 are updated standardised CPUE series for the eastern (Zones 10 and 20) and Tasmanian (Zone 30) trawl fleets, each with three additional data points and updated estimates for the ageing error matrix.

6.2.3.1 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 are five catch-rate time series, with the oldest dating back to 1920 (steam trawl) and the most recent time series derived from logbook data for otter trawl, separated into Eastern trawl (SESSF Zones 10 and 20) and Tasmanian trawl (SESSF Zone 30).
4. State catches have been added to catches from the appropriate fleets.
5. The ageing error matrix has been updated.
6. Catch, discard, length-composition, age-at-length, and catch rate data have been added for the period 2015-2017. The historical catch series (up until 2014) was also revised to incorporate changes in the catch database.

6.2.3.2 Model-related issues

1. Growth is assumed to follow a von Bertalanffy type length-at-age relationship, with all four growth parameters estimated separately, based primarily on the age-at-length data from fish that were measured and aged from extracted otoliths.
2. Natural mortality, M, is fixed (0.15) in the model.
3. Recruitment residuals are estimated from 1945-2012, 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. 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.
6. 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 plus 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).

6.3 Methods

6.3.1 The data and model inputs

6.3.1.1 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., 2015), 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).

6.3.1.2 Fleets

The assessment data for the eastern stock of jackass morwong have been separated into six ‘fleets’, which represent one or more gear, regional, or temporal differences in the fishery. Landings data from eastern Tasmania were separated from the catches from the other regions in the east, because the length compositions of catches from this area indicate that it lands larger fish (Wayte, 2011). The six fleets are:

1. Eastern trawl – otter trawlers from NSW, eastern Victoria and Bass Strait (1986 – 2017).
2. Danish seine – Danish seine from NSW, eastern Victoria and Bass Strait (1986 – 2017).
3. Tasmanian trawl – otter trawlers from eastern Tasmania (1986 – 2017).
4. Steam trawl – steam trawlers (1915 – 1961).
5. Early Danish seine – Danish seine (1929 – 1967). These landings may include a small amount of motor trawl catches.
6. Mixed – mixed Danish seine and diesel trawl catch (1968 – 1985).

6.3.1.3 Landed catches

The model uses a calendar year for all catch data. Annual landed catches by fleet used in this assessment are shown in Figure 6.1, Figure 6.2 and listed in Table 6.1, Table 6.2 and Table 6.3, which also includes the catches for the western trawl fleet used only in the western jackass morwong assessment (Day and Castillo-Jordán 2018b).

Klaer (2006) used a compilation of catch data from historical steam trawlers (Klaer and Tilzey, 1996) to recreate a catch history for jackass morwong for this sector of the fishery from 1915 to 1961 (Table

6.1). Estimates of total annual landings of jackass morwong from the eastern zones by Danish seine vessels during 1929-67 (Table 6.1), and the mixed fleet during 1968-85 (Table 6.2) were compiled from Klaer (2006) and Allen (1989).

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

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

The landings for the more recent years (NSW/Vic trawl, Danish seine, Tasmanian trawl and western trawl) (Table 6.3) are extracted from the SESSF logbook database. Quotas were introduced into the fishery in 1992 (Table 6.8), and from then onwards, records of landed catches as well as estimated catches from the logbook are available. The landings data give a more accurate measure of the landed catch than do the logbook data, but the logbook data contain more detail. For example, it is usually possible to separate logbook records, but not landing records, by fleet. The logbook catches for each fleet from 1992 onwards have been scaled up by the ratio of landed catches to logbook catches in each year. Prior to 1992, the unscaled logbook catches are used.

In 2007 the quota year was changed from calendar year to the year extending from 1 May to 30 April; however the assessment is based on calendar years. The total catch for the 2008 calendar year was 708 t which was larger than the actual 2008-09 TAC of 641 t. In 2008, catches were high in January-April. These months are part of the 2007-08 quota year.

Small amounts of morwong are caught in state waters. NSW trawl and trap catches have been added to the NSW/Vic trawl fleet, and Tasmanian state catches have been added to the Tasmanian trawl fleet.

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 applies to the combined eastern and western stocks, is also listed in Table 6.3, 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).

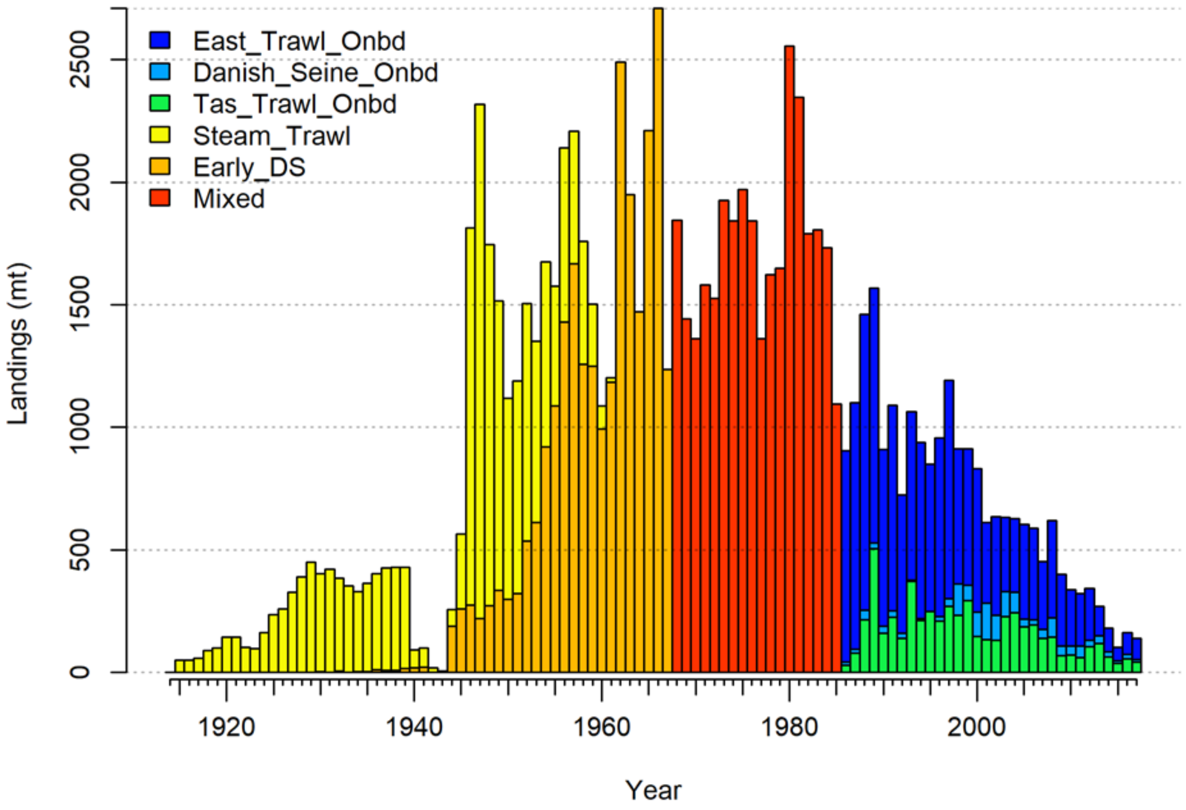


Figure 6.1. Total landed catch (tonnes) of eastern jackass morwong by fleet (stacked) from 1915-2017.

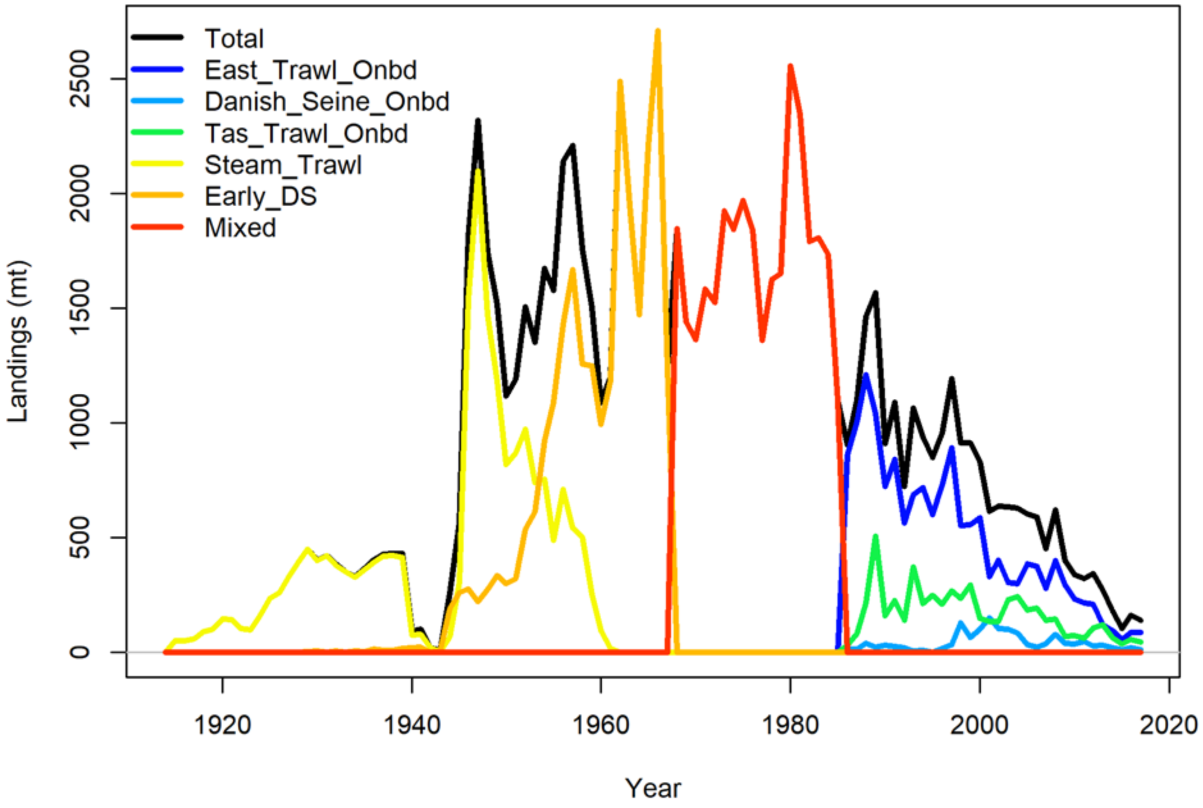


Figure 6.2. Total landed catch of eastern jackass morwong in the SESSF from 1915-2017.

Table 6.1. Total retained catches (tonnes) of jackass morwong by steam trawlers and early Danish seine vessels, 1915 – 1967.

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

Table 6.2. Total retained catches (tonnes) of jackass morwong by the mixed fleet of Danish seine and diesel trawlers, 1968 – 1985.

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

Table 6.3. Total retained catches (tonnes) from 1986 – 2017 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; the western trawl fleet (Commonwealth catches in western Tasmania and Victoria – used in the western jackass morwong assessment); and TAC (combined eastern and western stocks) from 1992 – 2018.

Year	eastern trawl	Danish seine	Tas trawl	western trawl	TAC
1986	861	13	30	153	
1987	1006	14	80	60	
1988	1209	39	214	67	
1989	1039	23	505	85	
1990	722	29	159	83	
1991	839	25	226	47	
1992	564	19	140	72	1500
1993	687	4	372	27	1500
1994	717	8	213	27	1500
1995	599	0	249	91	1500
1996	729	17	210	44	1500
1997	892	32	269	62	1500
1998	551	127	234	65	1500
1999	556	64	292	90	1500
2000	585	99	147	134	1200
2001	329	149	134	320	1185
2002	401	102	132	289	950
2003	303	101	229	198	960
2004	300	84	243	217	960
2005	385	33	185	232	960
2006	374	21	193	217	1200
2007	277	36	139	140	878
2008	398	78	144	122	560
2009	291	40	69	77	450
2010	232	35	71	47	450
2011	214	48	60	99	450
2012	210	26	106	41	568
2013	119	31	119	42	568
2014	96	20	64	13	568
2015	55	10	36	9	598
2016	87	18	57	30	474
2017	87	9	43	87	513
2018					505

6.3.1.4 Discard rates

Information on the discard proportions of jackass morwong by fleet is available from the ISMP for 1994-2017, for the eastern and Tasmanian trawl fleets. This program was run by PIRVic from 1992-2006 and by AFMA from 2007 onwards. These data are summarised in Table 6.4. 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 30% in 2014 for the Tasmanian Trawl and 12% in 2011 for the eastern trawl.

Table 6.4. Discard proportions for eastern trawl and Tasmanian trawl fleets from 1993 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) or because the value is too close to zero (less than 0.02).

Year	eastern trawl	n	Tas trawl	n
1993	0.0362	139	0.0020	32
1994	0.0380	228	0.0557	17
1995	0.0781	97		
1996	0.0811	175	0.0508	23
1997	0.0750	324	0.0100	16
1998	0.0383	187	0.0341	40
1999	0.0133	222	0.0519	58
2000	0.0050	199	0.0021	27
2001	0.0126	275	0.0150	33
2002	0.0038	224	0.0377	9
2003	0.0062	220	0.0093	10
2004	0.0816	177	0.0389	19
2005	0.0863	261	0.0946	16
2006	0.0503	209	0.1304	60
2007	0.0001	70		
2008	0.0854	126		
2009	0.0468	83	0.0154	9
2010	0.0140	84	0.0156	18
2011	0.1162	69	0.0615	22
2012	0.1053	48	0.1813	28
2013	0.0898	40	0.1012	20
2014	0.0537	37	0.2994	20
2015	0.0742	50	0.0578	42
2016	0.0185	33	0.1323	37
2017	0.0829	47	0.0126	32

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 2%) are excluded as inputs to stock synthesis (the greyed figures in the proportion columns in Table 6.4) giving more believable estimates of discarding in general. Note that any annual 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, for each fleet (Figure 6.3) and hence discarded catches for each fleet (Figure 6.4, Figure 6.5), with estimated discard rates between 4% and 7% for both the eastern trawl and Tasmanian trawl fleets.

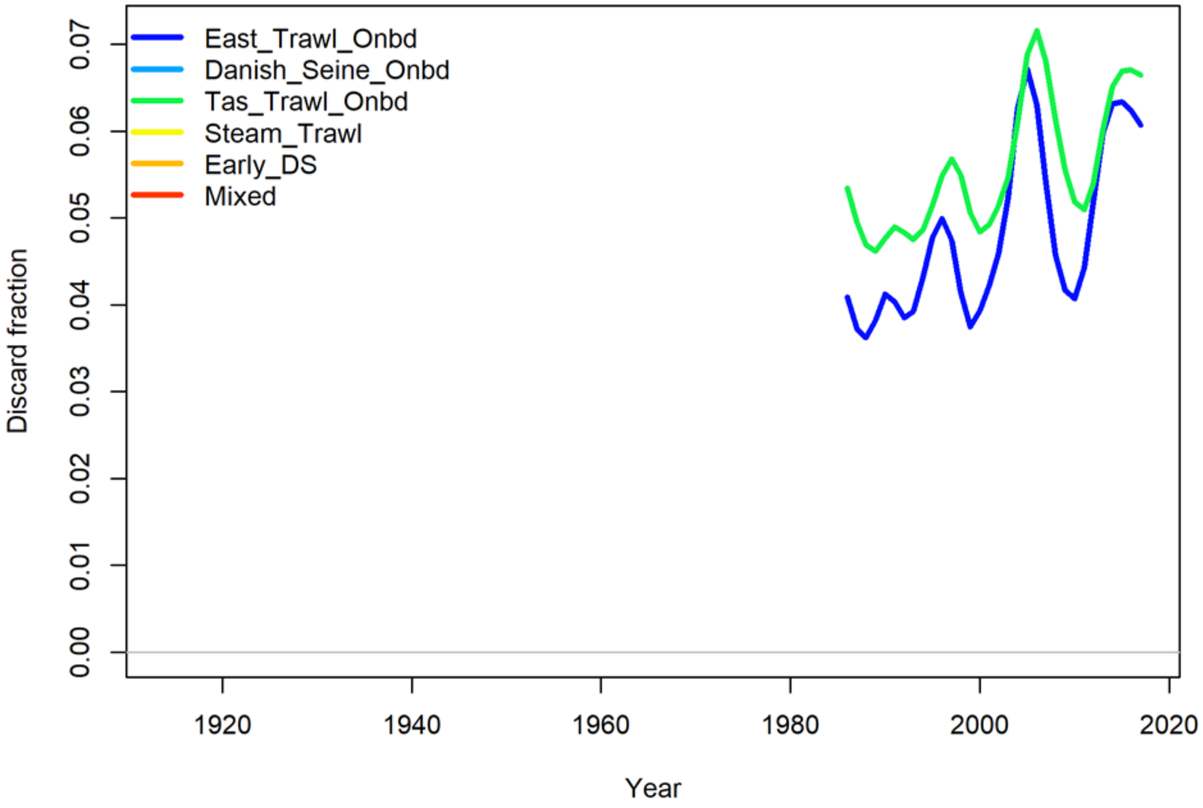


Figure 6.3. Model estimates of discard fractions by fleet, eastern trawl (blue) and Tasmanian trawl (green).

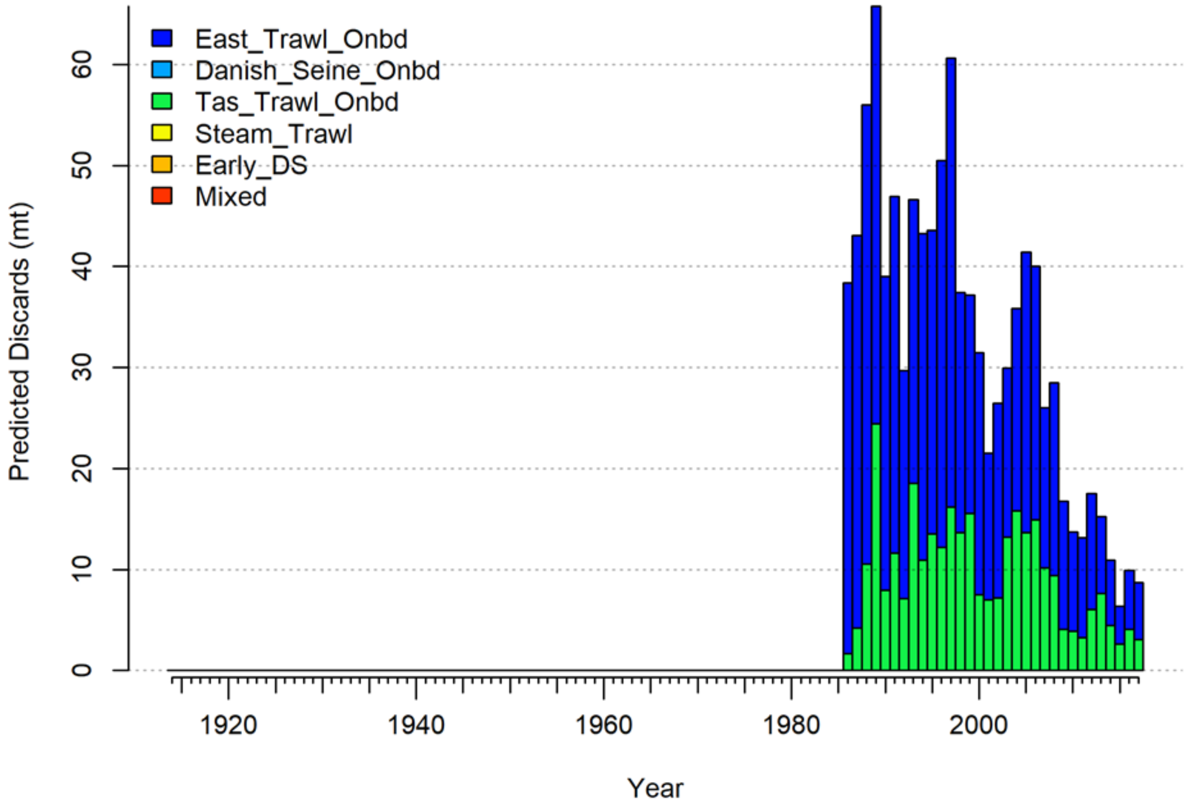


Figure 6.4. Estimated discards (tonnes, stacked) of eastern jackass morwong in the SESSF from 1993-2017, eastern trawl (blue) and Tasmanian trawl (green).

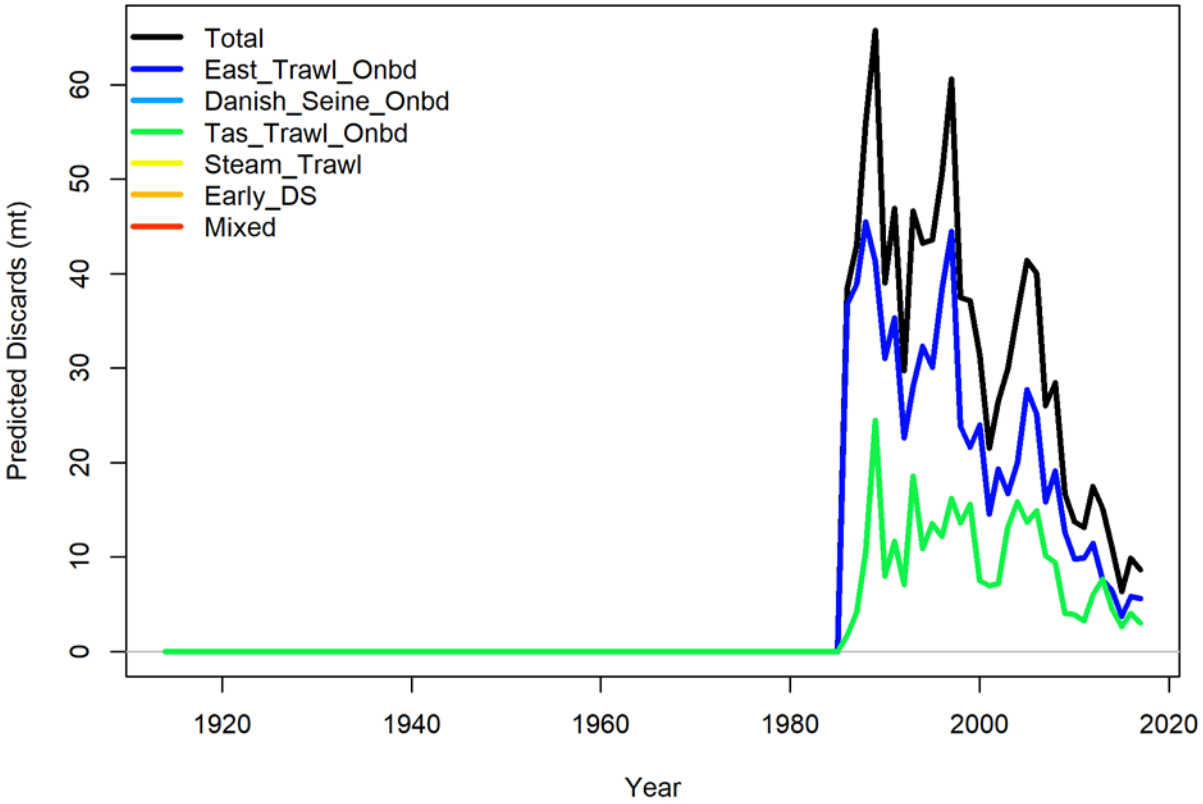


Figure 6.5. Estimated discards (tonnes) of eastern jackass morwong in the SESSF from 1947-2016, eastern trawl (blue) and Tasmanian trawl (green). combined total (black).

6.3.1.5 Catch rate and FIS abundance indices

A standardised catch rate (CPUE) index is available for the historical steam trawl fleet for the years 1920-21, 1937-42, and 1952-57 (Klaer, 2006; Table 6.5). Smith (1989) presented a standardised catch rate index for jackass morwong for 1948-66 (Table 6.6). This index standardises for gear type during a period of overlap between the steam trawl fishery and the onset of Danish seine vessels. Smith (1989) also provided a standardised CPUE index for all vessels for the period 1977-84 (Table 6.7). This index corresponds to the mixed fleet.

Catch and effort data from the SEF1 logbook database were standardised using GLMs to obtain indices of relative abundance (Sporcic and Haddon 2018b; Table 6.5) from the period 1986-2017 for the eastern and Tasmanian trawl fleets. In the stock synthesis assessment, the coefficient of variation is initially set at a value equal to the root mean squared deviation from a loess fit (Sporcic and Haddon, 2018a) and additional variance is estimated for this CPUE index to tune the input and output variances.

Table 6.5. Standardised catch rate indices and coefficient of variation Standardised catch rates for the steam trawl fleet.

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

Table 6.6. Standardised catch rate indices and coefficient of variation calculated by Smith (1989) for the overlap years of the early Danish seine fleet and the steam trawl fleet.

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

Table 6.7. Standardised catch rate indices and coefficient of variation calculated by Smith (1989) for the overlap years of the steam trawl fleet and the early Danish seine fleet.

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

Table 6.8. Standardised catch rate indices and coefficient of variation (Sporcic and Haddon, 2018b) for eastern and Tasmanian trawl fleets fleet for eastern 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	eastern trawl		Tas trawl		eastern FIS		TAS FIS	
	Catch rate	cv	Catch rate	cv	abundance	cv	abundance	cv
1986	2.037	0.141	1.890	0.35				
1987	2.471	0.141	2.078	0.35				
1988	2.321	0.141	2.848	0.35				
1989	2.198	0.141	3.592	0.35				
1990	1.853	0.141	2.611	0.35				
1991	1.705	0.141	1.742	0.35				
1992	1.365	0.141	1.910	0.35				
1993	1.454	0.141	1.531	0.35				
1994	1.268	0.141	1.054	0.35				
1995	1.163	0.141	1.040	0.35				
1996	1.053	0.141	1.001	0.35				
1997	1.168	0.141	1.104	0.35				
1998	0.941	0.141	1.079	0.35				
1999	0.946	0.141	1.277	0.35				
2000	0.808	0.141	0.808	0.35				
2001	0.553	0.141	0.522	0.35				
2002	0.619	0.141	0.439	0.35				
2003	0.494	0.141	0.580	0.35				
2004	0.488	0.141	0.432	0.35				
2005	0.594	0.141	0.324	0.35				
2006	0.723	0.141	0.402	0.35				
2007	0.700	0.141	0.564	0.35				
2008	0.888	0.141	0.569	0.35	6.919	0.162	52.425	0.170
2009	0.809	0.141	0.399	0.35				
2010	0.551	0.141	0.439	0.35	6.515	0.162	31.536	0.170
2011	0.544	0.141	0.295	0.35				
2012	0.535	0.141	0.392	0.35	3.552	0.162	34.725	0.170
2013	0.442	0.141	0.430	0.35				
2014	0.332	0.141	0.215	0.35	1.244	0.162	15.084	0.170
2015	0.274	0.141	0.137	0.35				
2016	0.321	0.141	0.139	0.35	1.077	0.162	3.318	0.170
2017	0.384	0.141	0.158	0.35				

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

The restrictions used in selecting data for analysis for Tasmanian trawl fleet were: (a) vessels had to have been in the fishery for three or more years, (b) the catch rate had to be larger than zero, (c) catches in zone 30 only and (d) catches in between 0 and 500m depth.

Abundance indices for eastern jackass morwong for the FIS surveys conducted between 2008 and 2016 are provided in Table 6.8. 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 6.8, 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.

6.3.1.6 Length composition data

Port and onboard length composition data are both used separately, with the gear selectivity estimated jointly from both port and onboard data, as is the standard practice in the SESSF stock assessments. For onboard data, the number of shots, is considered to be more representative of the information content in the length frequencies than the number of fish measured. For port data, the number of shots is not available, but the number of trips can be used instead. In the 2018 assessment, the initial sample size associated with each length frequency in the assessment is the number of shots or trips.

Length composition information for the discarded component of the catch is available from 1993-2017 for the eastern trawl, Tasmanian trawl and Danish seine fleets (Table 6.9). Length composition information for the retained component of the catch is available from 1947-1967 from Blackburn (1978) samples for the steam trawl and early Danish seine fleets and from 1971-1985 for the mixed fleet (Table 6.10). Length composition information for the retained component of the catch is available for a range of years from 1986-2017 for the three current fleets, eastern trawl, Tasmanian trawl and Danish seine for port (1986-1990 for eastern trawl from the Sydney Fish Market, and for most years in the range 1991-2017 for all three current fleets including both port and onboard samples (Table 6.11).

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 6.9 and Table 6.11). Sample sizes for retained length frequencies, including both the number of individuals measured and number of trips (inferred numbers of trips listed in blue) are listed in in Table 6.10 and Table 6.11 for each fleet and year for the period 1947-2017 and for discarded length frequencies in Table 6.9 for the period 1993-2017. For years and gear types where the number of trips is not available (i.e. for fish measured in the Sydney Fish Market (1971-1990) or from Blackburn data (1947-1967)), the number of trips is inferred from the number of fish measured per trip for years where this data is available for each gear type.

Table 6.9. Number of onboard discarded lengths and number of shots for length frequencies included in the base case assessment by fleet 1993-2017. Entries in grey indicate data that are not used due to small sample size (either less than 100 fish measured or Danish seine discards, which are not used due to high variability in Danish seine discard rates).

year	**fleet**	**(discard)**				
	eastern trawl	**Tas trawl**	**DS**	**eastern trawl**	**Tas trawl**	**DS**
	# fish	**# fish**	**# fish**	**# shots**	**# shots**	**# shots**
1993	70		7	6		1
1994	727		5	8		2
1995	686			7		
1996	482	209		16	2	
1997	342	10		51	2	
1998	148	427		6	8	
1999	57	588		5	27	
2000	82		34	2		1
2001	118	419	6	8	21	1
2002			131			6
2003	10		335	2		10
2004	374	84		19	2	
2005	692	431		19	14	
2006	458	227		12	10	
2007	1			1		
2008	10			7		
2010	10	24		1	1	
2011	63	58		7	8	
2012	9	512		1	11	
2013	200	84	197	7	10	14
2014	179		221	16		7
2015	46	42		8	6	
2016	37	9	5	10	3	2
2017	542	66		10	2	

Table 6.10. Number of port (Sydney Fish Market (SFM)) and onboard (Blackburn) retained lengths and implied number of shots or trips for length frequencies included in the base case assessment by fleet 1947-1985. The number of shots or trips in this table (in blue) is inferred from numbers of fish measured.

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

Table 6.11. Number of port and onboard retained lengths and number of shots or trips for length frequencies included in the base case assessment by fleet 1986-2017. The number of trips from early NSW data (SFM, 1986-1990, in blue) is inferred from numbers of fish measured. Entries in grey indicate data that are not used due to small sample size (less than 100 fish measured) or due to data quality issues (2015 Tas trawl onboard).

year	**fleet east onbd # fish**	**(retained) east port # fish**	**Tas onbd # fish**	**Tas port # fish**	**DS onbd # fish**	**DS port # fish**	**east onbd # shots**	**east port # trips**	**Tas onbd # shots**	**Tas port # trips**	**DS onbd # shots**	**DS port # trips**
1986		13441						83				
1987		4900						40				
1988		3649						19				
1989		1786						12				
1990		901						6				
1991		1181						8				
1992		1355				51		9				1
1993	144	2359					4	11				
1994		1124			2			14			1	
1995		667						7				
1996	864	2990		87		33	18	26		1		1
1997	3099	3190	257	282		340	62	27	3	2		5
1998	3416	8060	1514	835		1088	43	58	18	4		11
1999	3596	12659	1509	2384		295	41	86	37	13		2
2000	1962	7974	934	762	24	374	32	55	9	4	1	7
2001	3183	5603	1881	664		315	40	41	24	4		3
2002	2172	5757	647	2116		487	24	32	3	13		10
2003	1540	4066	691	424	142	61	22	25	4	3	9	1
2004	609	3544	1042	1248		108	20	29	7	8		2
2005	3381	5747	1621	1391	62	78	49	30	21	7	7	1
2006	1950	13123	1961	2757	60		33	86	22	15	6	
2007	273	2029		137		753	17	13		1		5
2008	1824	651	43			635	36	4	3			6
2009	781	1644		80	50		23	20		1	1	
2010	537	1436	252	89	64	428	15	14	7	1	2	12
2011	604	758	292	263	153	512	20	26	12	7	4	24
2012	690	1116	630	141		216	18	31	14	4		9
2013	207	1008	248	214	207	288	8	33	10	4	11	10
2014	370	931	147		57	800	18	16	5		5	16
2015	495	1445	168	154		902	17	19	11	3		16
2016	687	600	295	240	5	810	19	8	24	5	2	15
2017	337	1029	486	55		530	8	17	9	1		11

6.3.1.7 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 6.12). Age-at-length measurements, provided by Kyne Krusic-Golub of Fish Ageing Services Pty Ltd, are available from 1992-2017 for the eastern trawl fleet, from 1991-2017 for the Tasmanian trawl fleet and from 1998-2014 for the Danish seine fleet.

Table 6.12. Standard deviation of age reading error (A Punt pers. comm. 2017).

Age	**sd**
0.5	0.393081
1.5	0.393081
2.5	0.397428
3.5	0.402548
4.5	0.408577
5.5	0.415676
6.5	0.424036
7.5	0.433881
8.5	0.445474
9.5	0.459126
10.5	0.475203
11.5	0.494134
12.5	0.516427
13.5	0.542679
14.5	0.573594
15.5	0.609998
16.5	0.652867
17.5	0.703348
18.5	0.762795
19.5	0.832799
20.5	0.915234
21.5	1.01231
22.5	1.12662
23.5	1.26124
24.5	1.41976
25.5	1.60643
26.5	1.82625
27.5	2.0851
28.5	2.38993
29.5	2.74889
30.5	3.17159

Table 6.13. Number of age-length otolith samples included in the base case assessment by fleet 1991-2017.

Year	**Fleet**		
	Eastern trawl	**Danish seine**	**Tasmanian trawl**
1991			98
1992	55		
1993	412		
1994	330		95
1995	200		19
1996	505		1
1997	169		
1998	166	52	
1999	314		
2000	43	118	
2001	301	92	
2002	379		
2003	72	95	
2004	83		
2005	164	25	
2006	30	10	49
2007	117		
2008	262		77
2009	546		
2010	558	183	86
2011	481	224	108
2012	337	63	134
2013	2	46	71
2014	174	151	12
2015	244		69
2016	46		34
2017	203		62

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 1993-2017 for eastern trawl, from 1996-2017 for Tasmanian trawl and from 1994-2016 for Danish seine.

6.3.1.8 Input data summary

The data used in this assessment is summarised in Figure 6.6 and Figure 6.7, indicating which years the various data types were available.

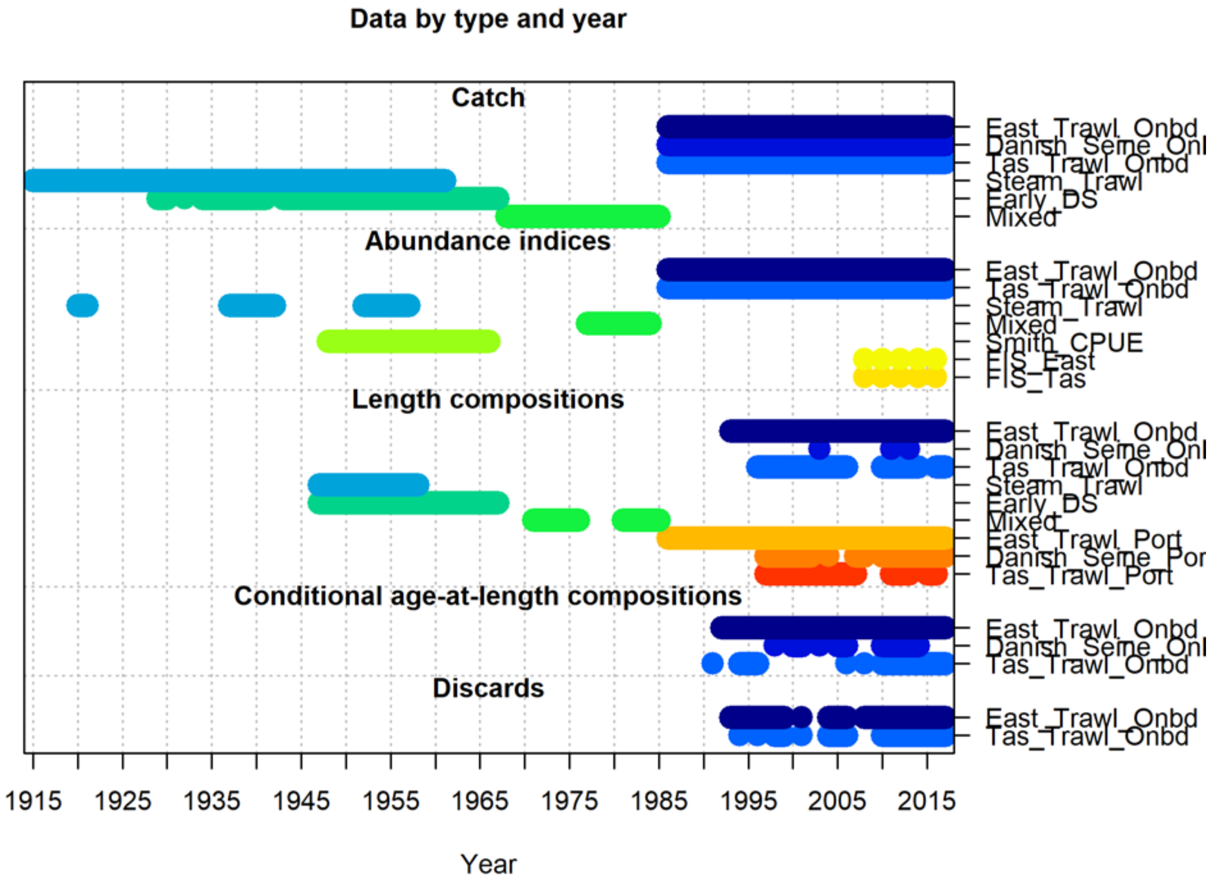


Figure 6.6. Summary of input data used for the eastern jackass morwong assessment.

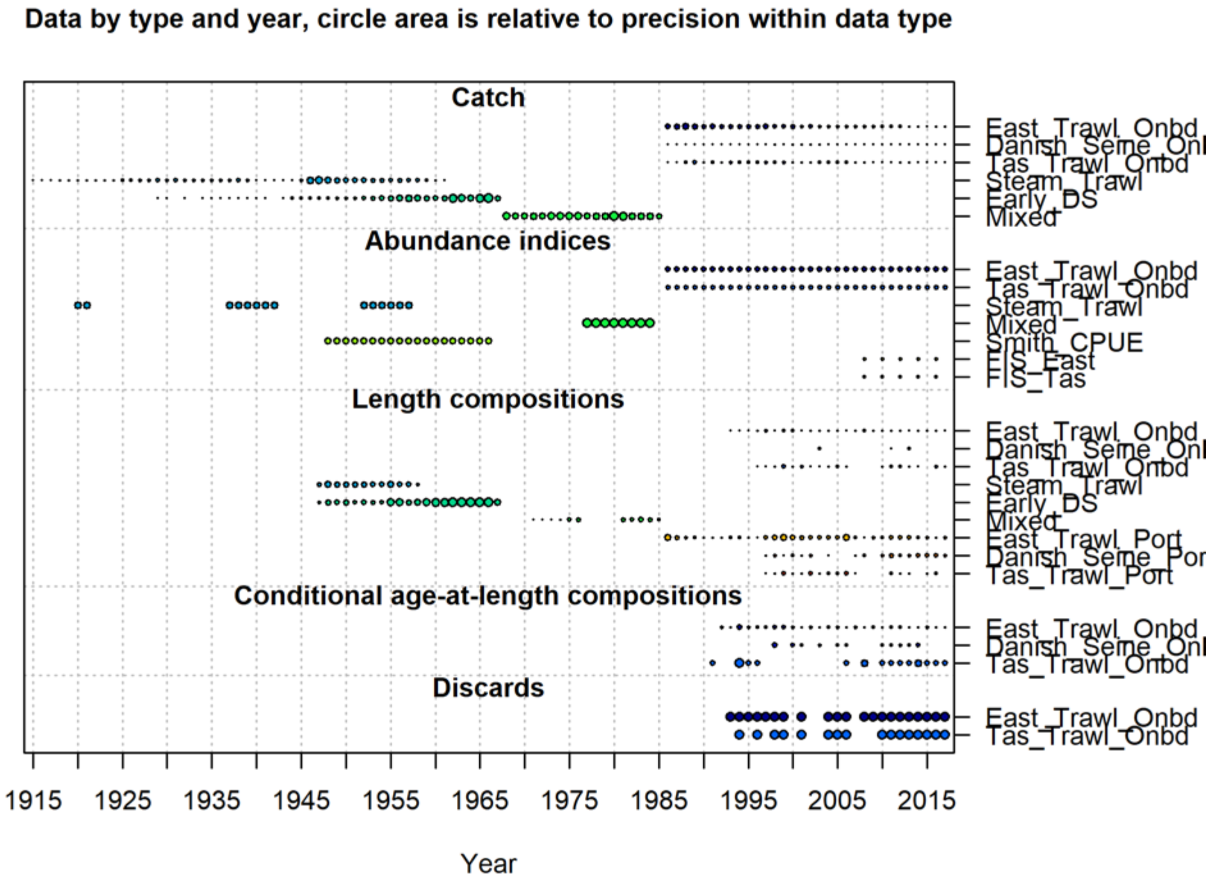


Figure 6.7. Summary of input data used for the eastern jackass morwong assessment.

6.3.2 *Stock assessment method*

6.3.2.1 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.

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.

Some key features of the base-case model are:

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

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

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

d) Six fishing fleets are modelled.

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

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

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

h) Recruitment to the stock is assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, h. Steepness for the base-case analysis is set to 0.7. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1945 to 2012. Deviations are not estimated prior to 1945 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.

6.3.2.2 Relative data weighting

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

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

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

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.

6.3.2.3 Tuning procedure

In iterative reweighting, the effective annual sample sizes are tuned/adjusted so that the input sample size is equal to the effective sample size calculated by the model. In SSv3.30 there is an automatic adjustment made to survey CVs (CPUE).

1. Set the standard error for the log of the relative abundance indices (CPUE, acoustic abundance survey, or FIS) to their estimated standard errors for each survey or for CPUE (and FIS values) to the root mean squared deviation of a loess curve fitted to the original data (which will provide a more realistic estimate to that obtained from the original statistical analysis). SSv3.30 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.

6.3.2.4 Calculating the RBC

The SESSF Harvest Strategy Framework (HSF) was developed during 2005 (Smith *et al*. 2008) and has been used as a basis for providing advice on TACs in the SESSF quota management system for fishing years 2006-2018. 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.

6.3.2.5 The base case model

SERAG accepted the model structure of the preliminary base case assessment for eastern jackass morwong presented in September 2018. The base case presented here, and the various diagnostic plots come from the preliminary base case from September 2018.

6.3.2.6 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. Double the weighting on the length composition data.
9. Halve the weighting on the length composition data.
10. Double the weighting on the age-at-length data.
11. Reduce the weighting on the age-at-length data.
12. Increase the weighting on the survey (CPUE) data.
13. Halve the weighting on the survey (CPUE) data.
14. Exclude the Fishery Independent Survey abundance indices.

15. Include the Fishery Independent Survey length frequency data and estimate selectivity for the FIS.

he results of the sensitivity tests are summarized by the following quantities (Table 6.17):

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. $\mathrm{RBC}_{2019\text{-}21}$: the mean RBC over the three years from 2019-2021.
7. $\mathrm{RBC}_{2019\text{-}23}$: the mean RBC over the five years from 2019-2023.
8. $\mathrm{RBC}_{\mathrm{longterm}}$: the longterm RBC.

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

6.4 Results and Discussion

6.4.1 The base-case analysis

6.4.1.1 Transition from 2009 base case to 2017 base case

Development of a preliminary base case and a bridging analysis from the 2015 assessment (Tuck et al., 2015a), 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.

6.4.1.2 Parameter estimates

Figure 6.8 shows the estimated growth curve for jackass morwong. All growth parameters are estimated by the model (parameter values are listed in Table 6.14).

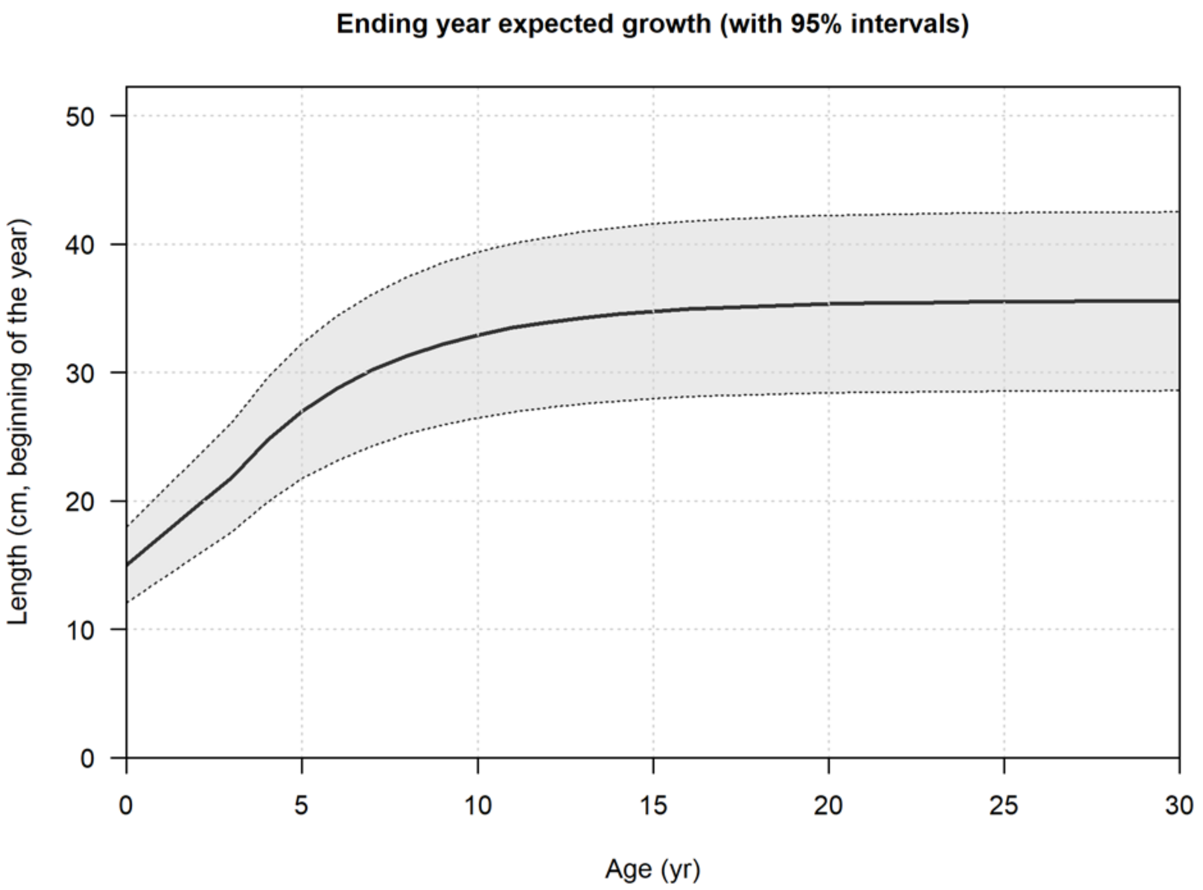


Figure 6.8. Fixed growth curve for western jackass morwong, using parameters estimated from the eastern morwong stock assessment.

Table 6.14. 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	1945-2012, bias adjustment ramps 1969-86 and 2012-13
CV growth	estimated	0.0999
Growth *K*	estimated	0.235
Growth l_{min} (cm)	estimated	21.8
Growth l_{max} (cm)	estimated	35.3

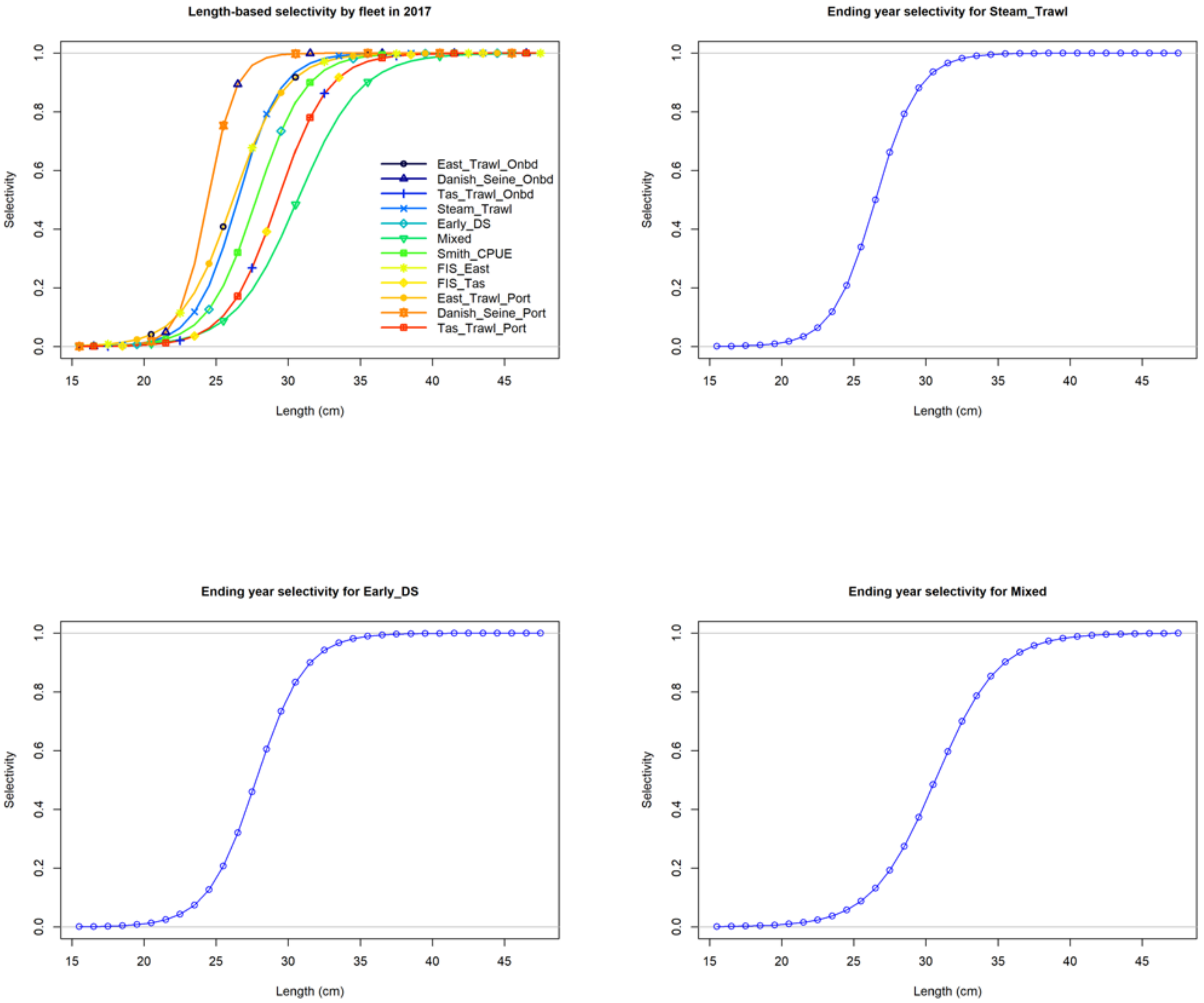


Figure 6.9. Selectivity for all six fleets (top left: note that the FIS and port fleets are mirrored to the selectivity of other fleets) and selectivity functions for the three historical fleets (steam trawl (top right); early Danish seine (bottom left); mixed (bottom right)).

Selectivity is assumed to be logistic for all fleets. The parameters that define the selectivity function are the length at 50% selection and the spread (the difference between length at 50% and length at 95% selection). The estimates of these parameters for the current fleets are as follows: for eastern trawl fleet are 26.2cm and 5.28cm; for Danish seine fleet are 24.4cm and 2.88cm; and for Tasmanian trawl are 29.3cm and 5.18cm. For the historical fleets the parameters are as follows: for steam trawl 26.5cm and 4.39cm; for early Danish seine fleet are 27.8cm and 4.99cm; and for the mixed fleet are 30.6cm and 6.46cm. All of these values are all very similar to the values for the selectivity parameters estimated in the 2015 assessment. Figure 6.9 and Figure 6.10 show 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 8.04 for the base case.

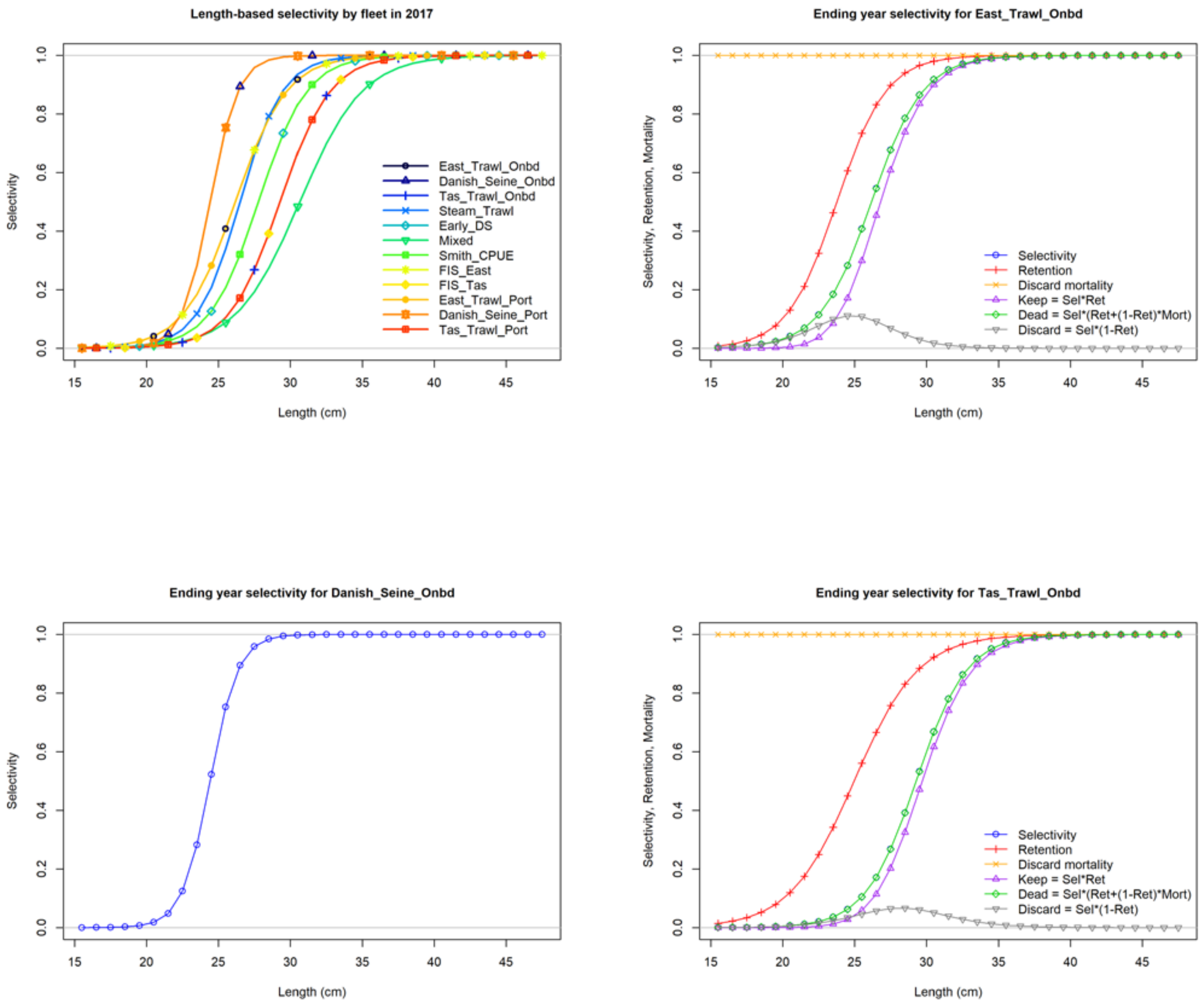


Figure 6.10. Selectivity for all six fleets (top left: note that the FIS and port fleets are mirrored to the selectivity of other fleets) and selectivity (blue/green) and retention (red) functions for the three current fleets (eastern trawl (top right); Danish seine (bottom left); Tasmanian trawl (bottom right)).

6.4.1.3 Fits to the data

The fits to the steam trawl fleet catch rate indices are good (Figure 6.11), with the series suggesting some decline in biomass apparent by the 1950s. The Smith indices (Figure 6.12) suggest abundance is generally relatively constant, with the model estimating a decline in abundance in the early 1980s. These fits to the historical abundance indices are largely unchanged from the fits from the 2015 assessment. The fits to the recent catch rate series from the trawl fleets are remarkably good (Figure 6.13), with the model generally matching the decline in these series, albeit struggling to fit the hump at the start of the Tasmanian trawl series, and a smaller hump from 2003-2008 for the eastern trawl series. The last four years suggest a flattening or slight increase in abundance in both the current trawl indices and the fits from 2014 onwards. While the point estimates of the abundance indices from the FIS for eastern jackass morwong have generally declined since 2008, the model, which also fits to a number of other data sources, produces a relatively stable abundance trajectory over this period (Figure 6.14). In general the fits to abundance series are very similar to the fits in the 2015 assessment, with the exception of the most recent years, which suggest a flattening or slight increase in spawning biomass.

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

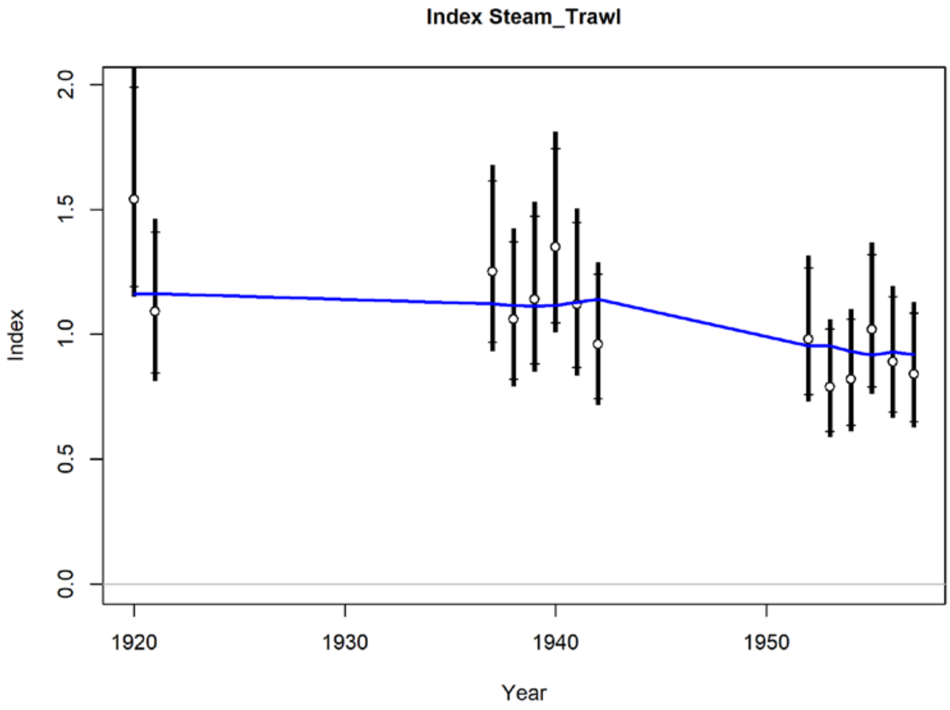
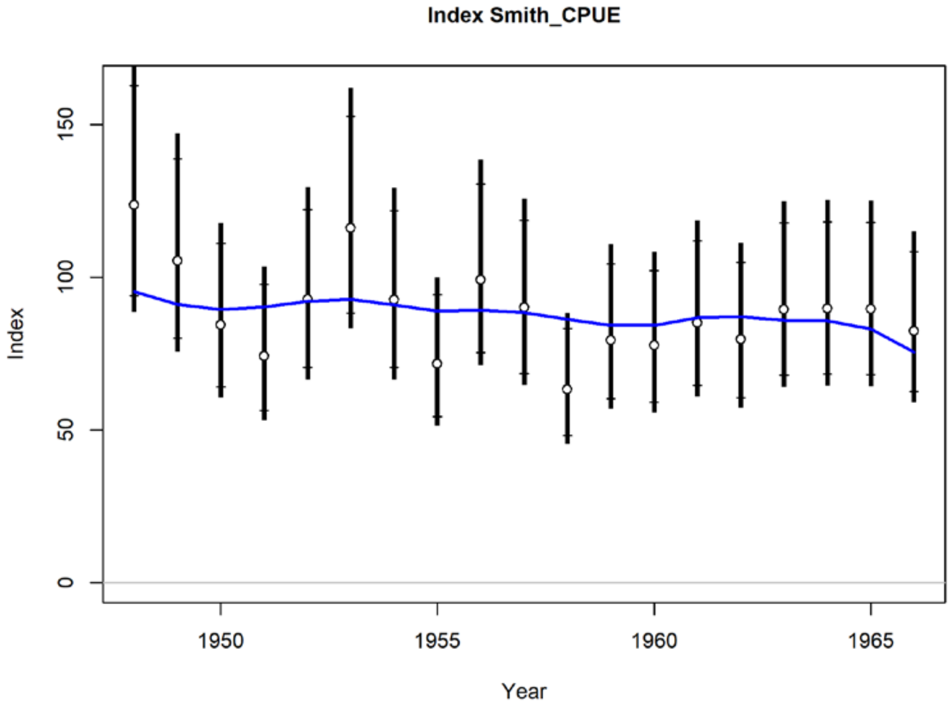


Figure 6.11. Observed (circles) and model-estimated (blue line) catch rates vs year, with approx 95% asymptotic intervals for steam trawl fleet. The thin lines with capped ends should match the thick lines for a balanced model. This index is balanced by estimating an additional variance parameter within Stock Synthesis, which in this case is positive, suggesting the model requires more variance than the initial values from the loess fit to achieve a good fit.



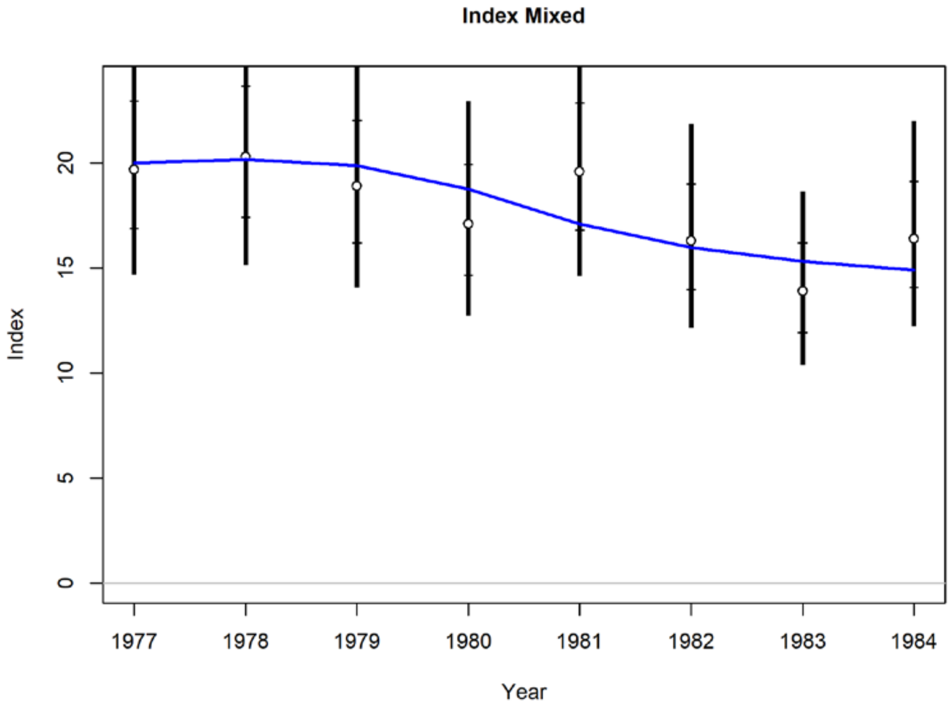


Figure 6.12. Observed (circles) and model-estimated (blue line) catch rates vs year, with approx 95% asymptotic intervals for the Smith CPUE indices for the overlap between steam trawl and Danish seine (top) and the later mixed fleet (bottom). The thin lines with capped ends should match the thick lines for a balanced model. These indices are balanced by estimating an additional variance parameter within Stock Synthesis, which in these cases are both negative, suggesting the models fit well with less variance than the initial values from the loess fit.

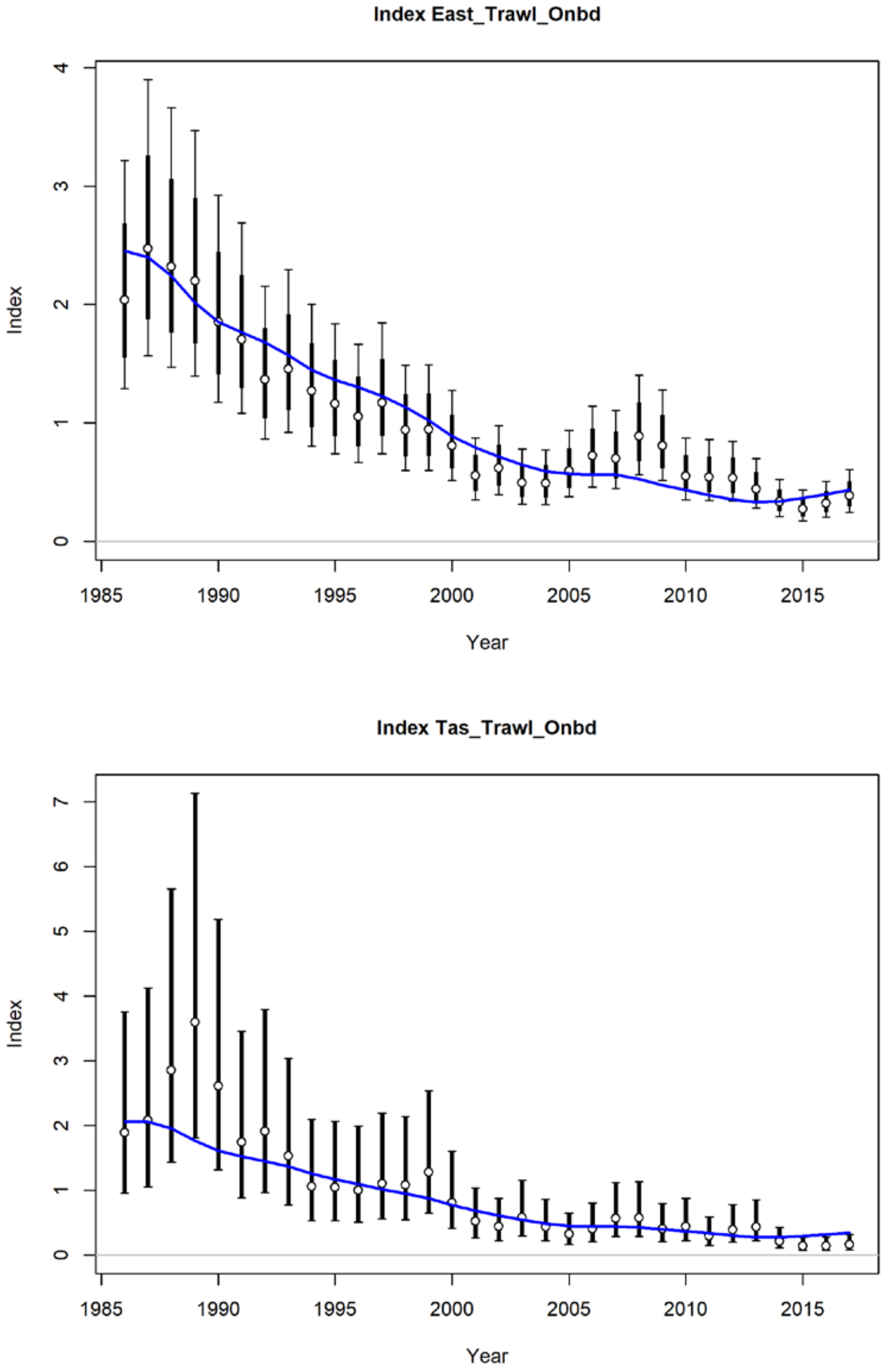
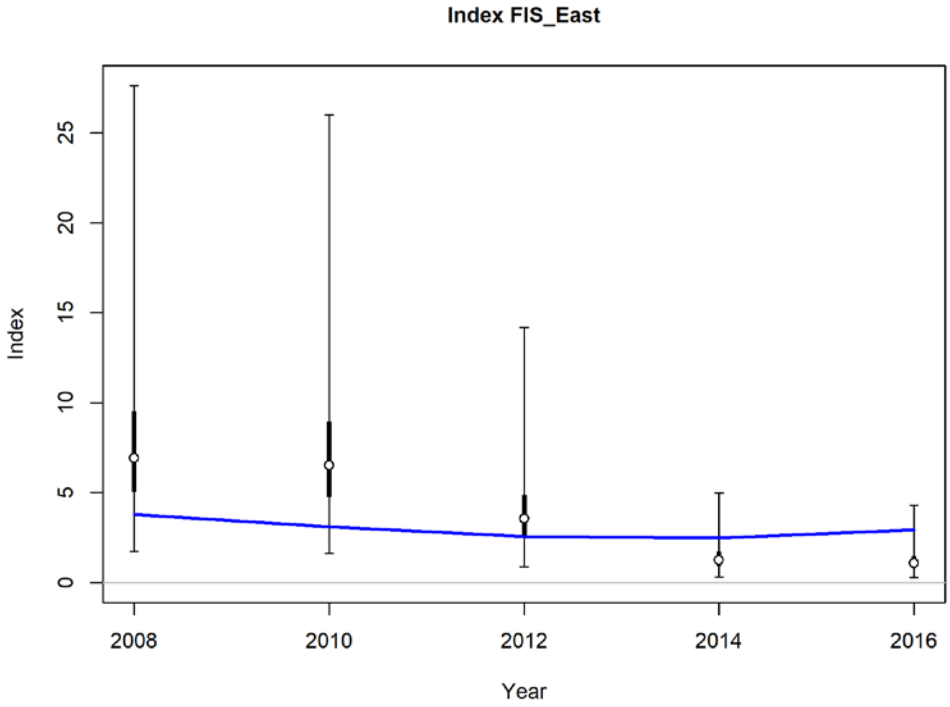


Figure 6.13. Observed (circles) and model-estimated (blue line) catch rates vs year, with approx 95% asymptotic intervals for the eastern trawl fleet (top) and the Tasmanian trawl fleet (bottom). The thin lines with capped ends should match the thick lines for a balanced model. These indices are balanced by estimating an additional variance parameter within Stock Synthesis, which for eastern trawl is positive, suggesting the model requires more variance than the initial values from the loess fit to achieve a good fit.



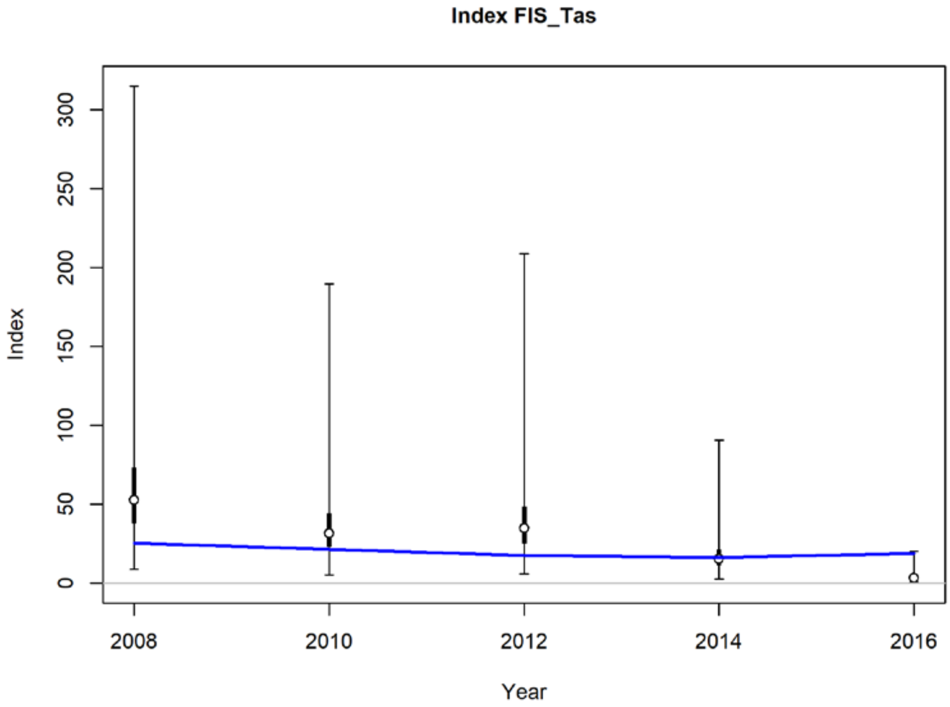
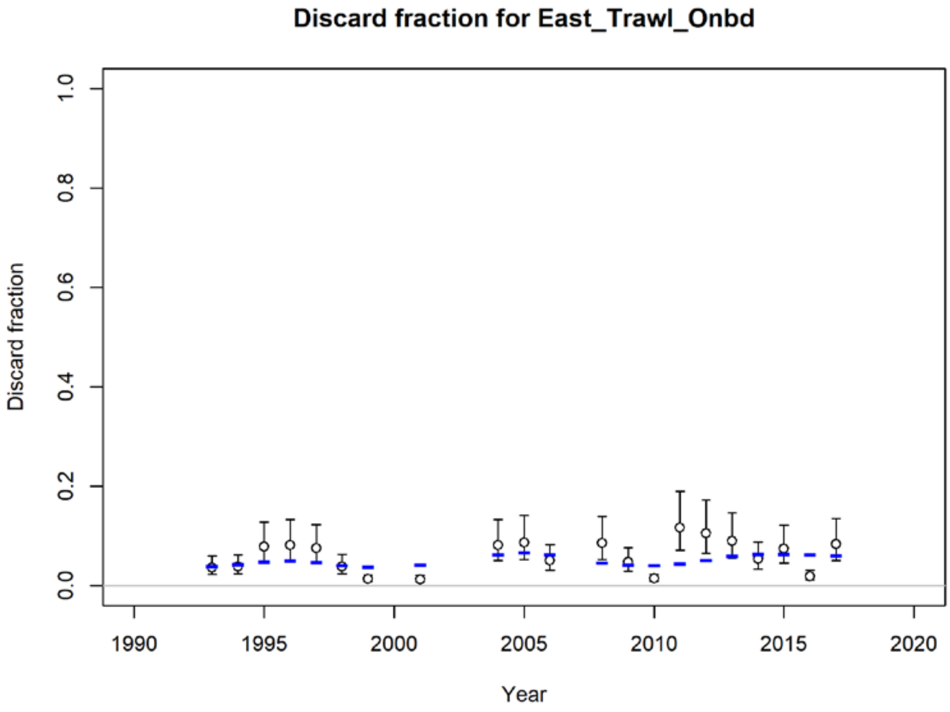


Figure 6.14. Observed (circles) and model-estimated (blue line) catch rates vs year, with approx 95% asymptotic intervals for the eastern FIS fleet (top) and the Tasmanian FIS fleet (bottom). The thin lines with capped ends should match the thick lines for a balanced model. These indices are balanced by estimating an additional variance parameter within Stock Synthesis, which in these cases are both positive, suggesting the models require more variance than the initial values from the loess fit to achieve a good fit.

The fits to the discard rate data for the current trawl fleets (Figure 6.15) are reasonable given the variability in the data, and again produce similar to the fits from the 2015 assessment, with estimated discarding rates less than 10%. To achieve predicted discard rates which have a better match to the overall discard rates, four years of very low (<2%) discard rate data (Table 6.4) were excluded from the eastern trawl fleet (2000, 2002, 2003 and 2007), another four years of very low (<2%) discard rate data from the Tasmanian trawl fleet (1993, 1997, 2000 and 2002) and two years because the number of samples to estimate the discard rate was less than 10 (2003 and 2009). If these very low discard rates are included in the model, the fitted discard rates match these very low rates well but give very poor fits to all other years with discard rates >2%. Including these low discard rates results in much lower overall predicted discard rates compared to the mean of the discard rates over all years with discard data for each fleet Fits to the age and length composition data for discarded catches are shown in Appendix A.

The base-case model is able to fit the aggregated retained and discarded length-frequency distributions very well (Figure 6.16 and Appendix A), with the exception of the retained length frequencies from Danish seine onboard. Note that a single selectivity is estimated for the combined port and onboard fleet in this case and, with the variation in data apparent between these different sources, the fits to both the port and onboard data require some compromise. The aggregated fits to the historical length frequency measurements are excellent.



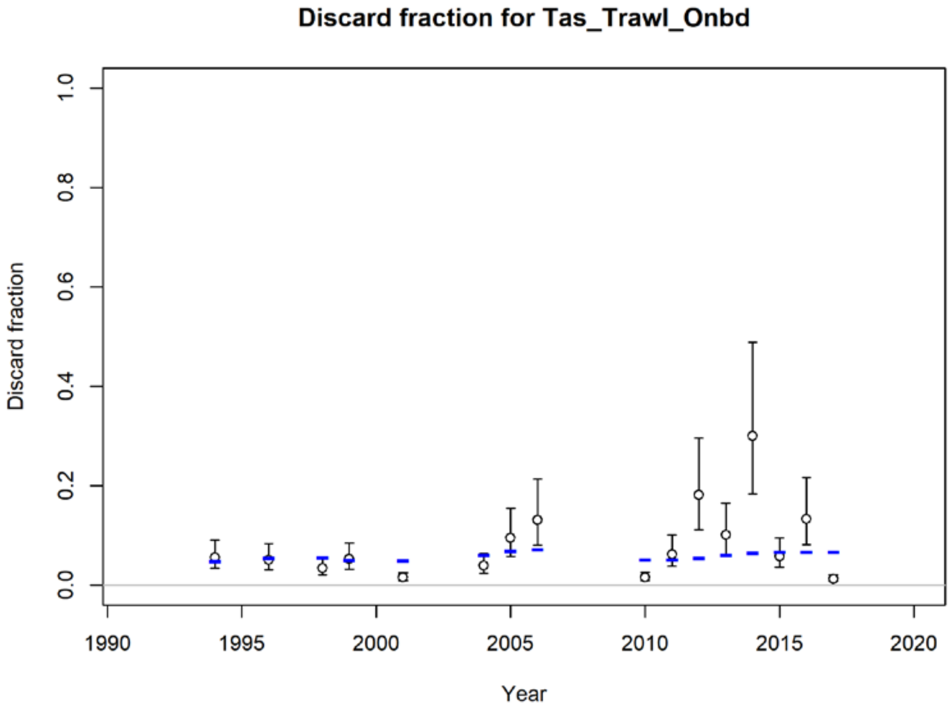


Figure 6.15. Observed (circles) and model-estimated (blue lines) discard estimates versus year for the Victorian Danish seine fleet (top) and the otter trawl fleet (bottom), with approximate 95% asymptotic intervals.

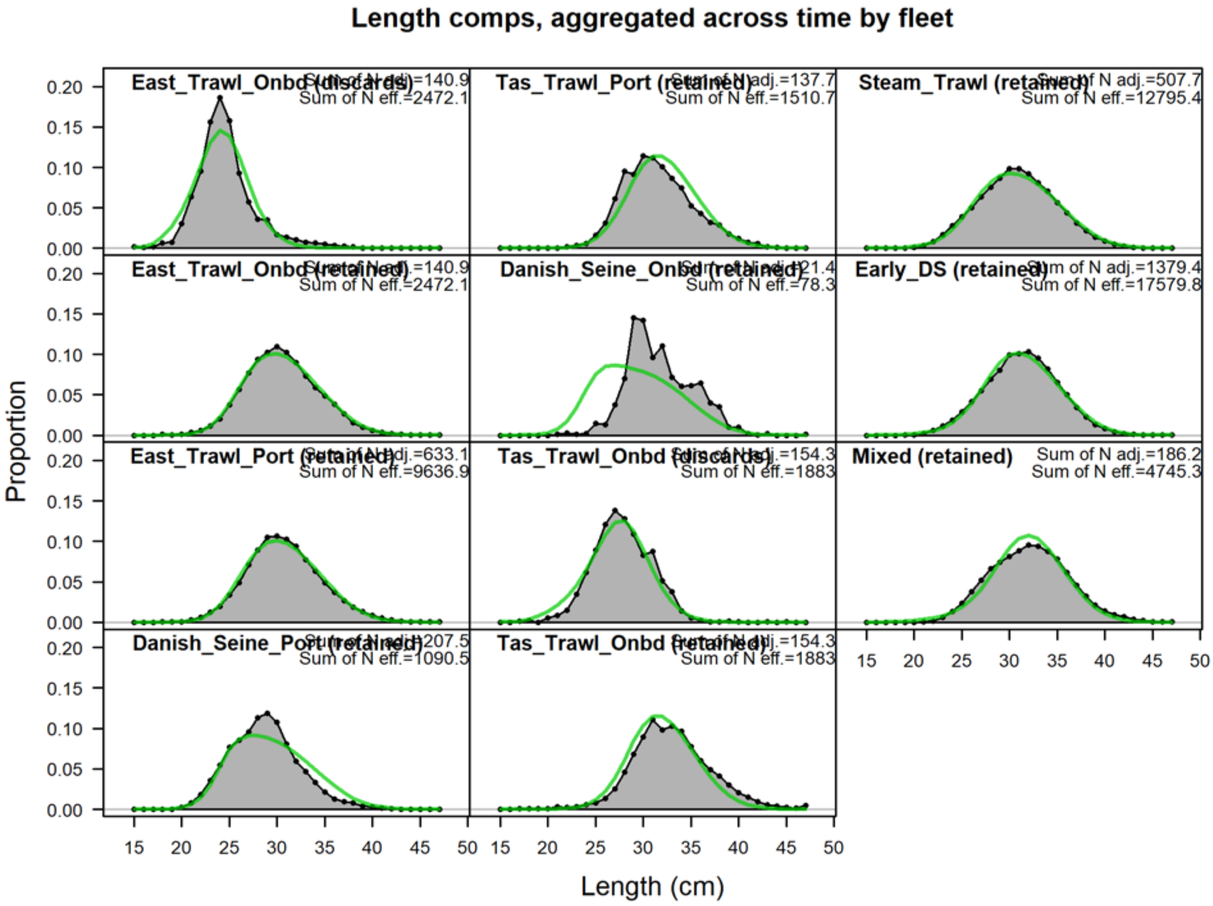


Figure 6.16. Fits to retained and discarded length compositions by fleet, separated by port and onboard samples, aggregated across all years. Observed data are grey and the fitted value is the green line.

The implied fits to the age composition data are shown in Appendix A. The age compositions were not fitted to directly, as age-at-length data were used. However, the model is capable of 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 a little noisy between years, especially for the fleets with smaller catches. The mean age varies between 5 and 10 years for eastern trawl. This variability in the age-at-length data is likely to be due to spatial or temporal variation in collection of age samples. The fits to conditional age-at-length are reasonable. Residuals for these fits and mean age for each year, aggregated across length bins, are shown in Appendix A.

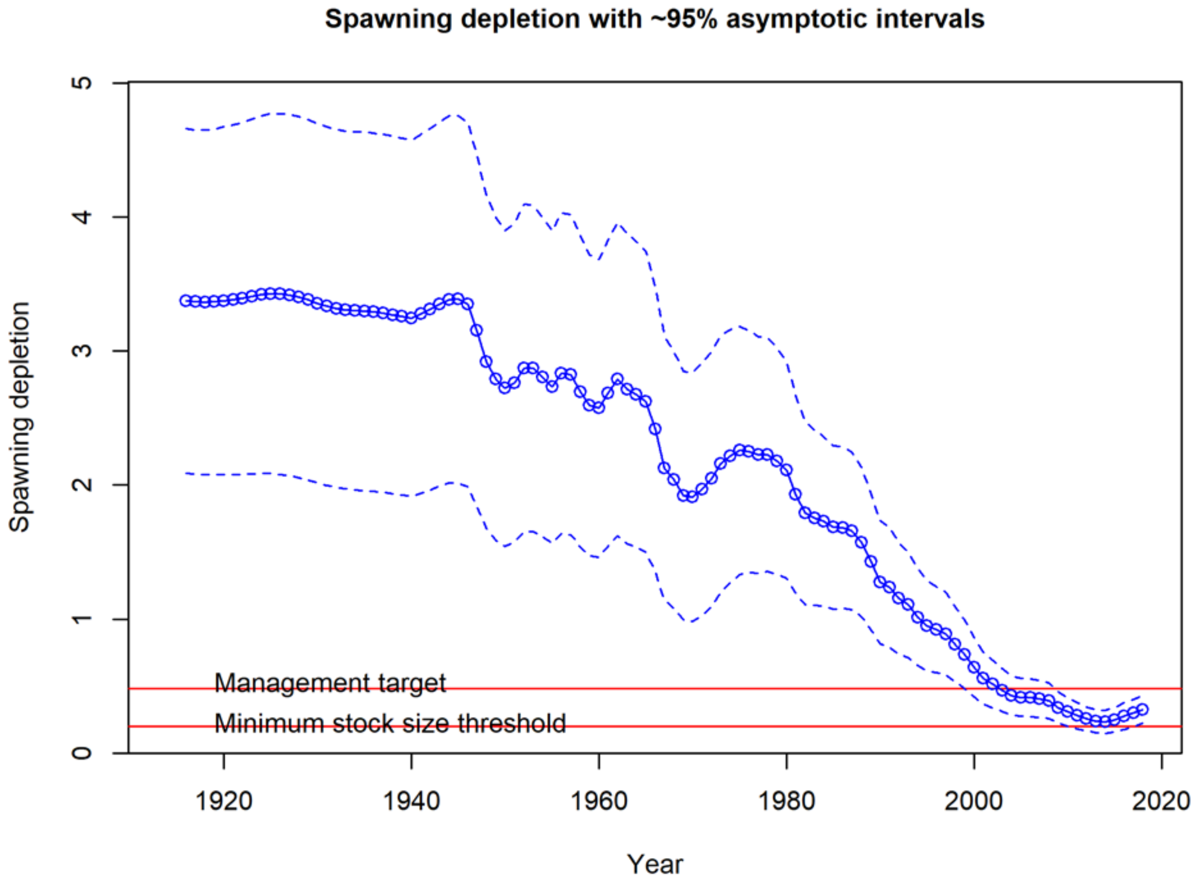


Figure 6.17. Time-trajectory of spawning biomass depletion (with approximate 95% asymptotic intervals) corresponding to the MPD estimates for the base-case analysis for eastern jackass morwong.

6.4.1.4 Assessment outcomes

The current spawning stock biomass (Figure 6.17) is estimated to be 35% of unfished stock biomass (i.e. 2018 spawning biomass relative to 1988 spawning biomass), albeit with considerable uncertainty (with 95% asymptotic intervals from around 25% to 45%). In comparison, the last full assessment in 2015 (Tuck et al., 2015) estimated the 2016 spawning biomass to be 36% of the 1988 equilibrium stock biomass, with an expectation to continue to recover through to 2019. The current assessment estimates that the stock is steady for the first 30 years of the fishery then has a steady decline through to 2014, when the stock was just above the limit reference point at 23% SSB_{1988}, from which time there has been a gradual recovery. Recruitment has been variable, but seven of the last nine estimated recruitment events have been below average, with the other two only just above average (2010 and 2012), even with the productivity shift model first accepted in the 2011 stock assessment model (Figure 6.18).

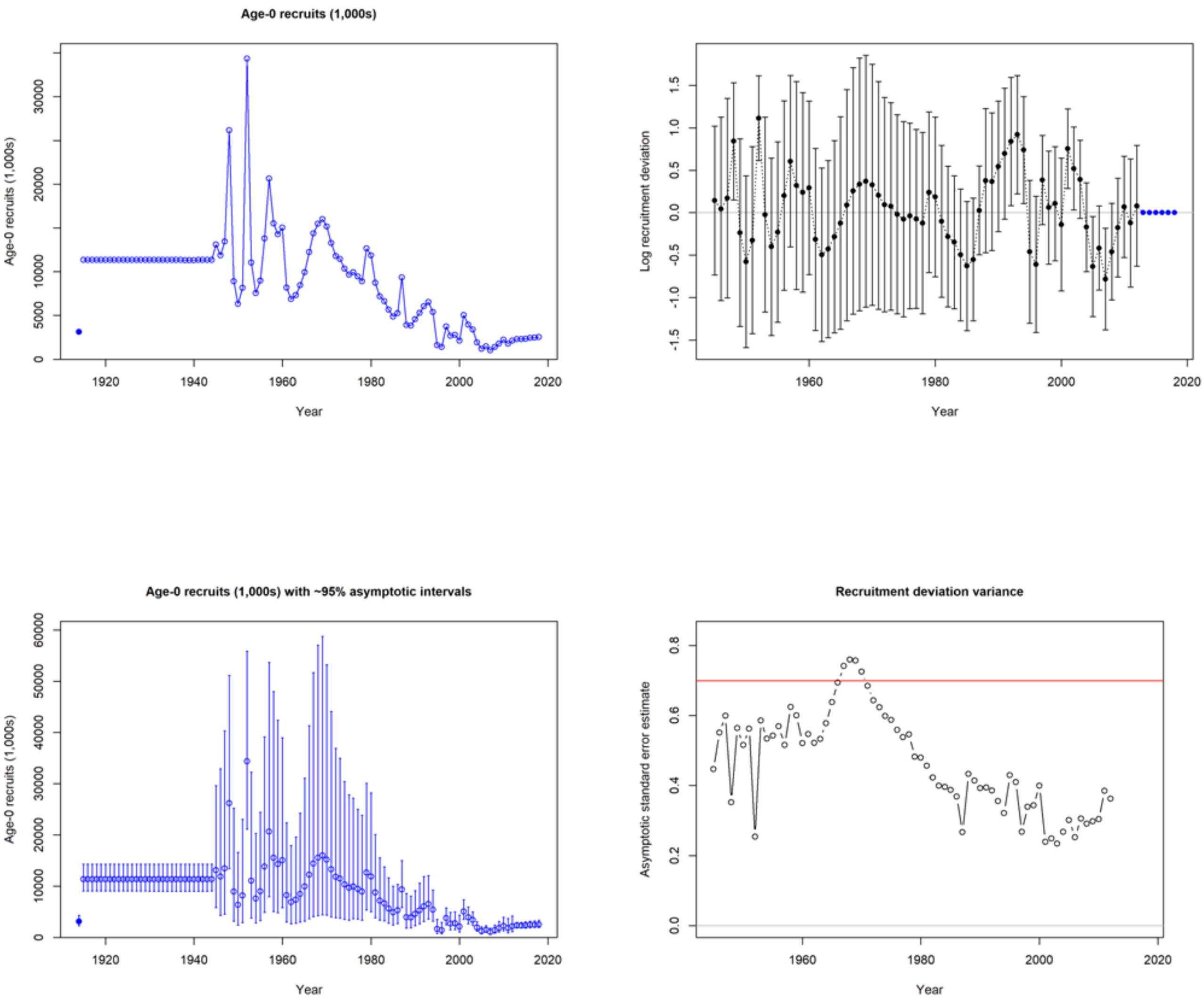


Figure 6.18. Recruitment estimation for the base case analysis. Top left: Time-trajectories of estimated recruitment numbers; top right: time trajectory of estimated recruitment deviations; bottom left : time-trajectories of estimated recruitment numbers with approximate 95% asymptotic intervals; bottom right: the standard errors of recruitment deviation estimates.

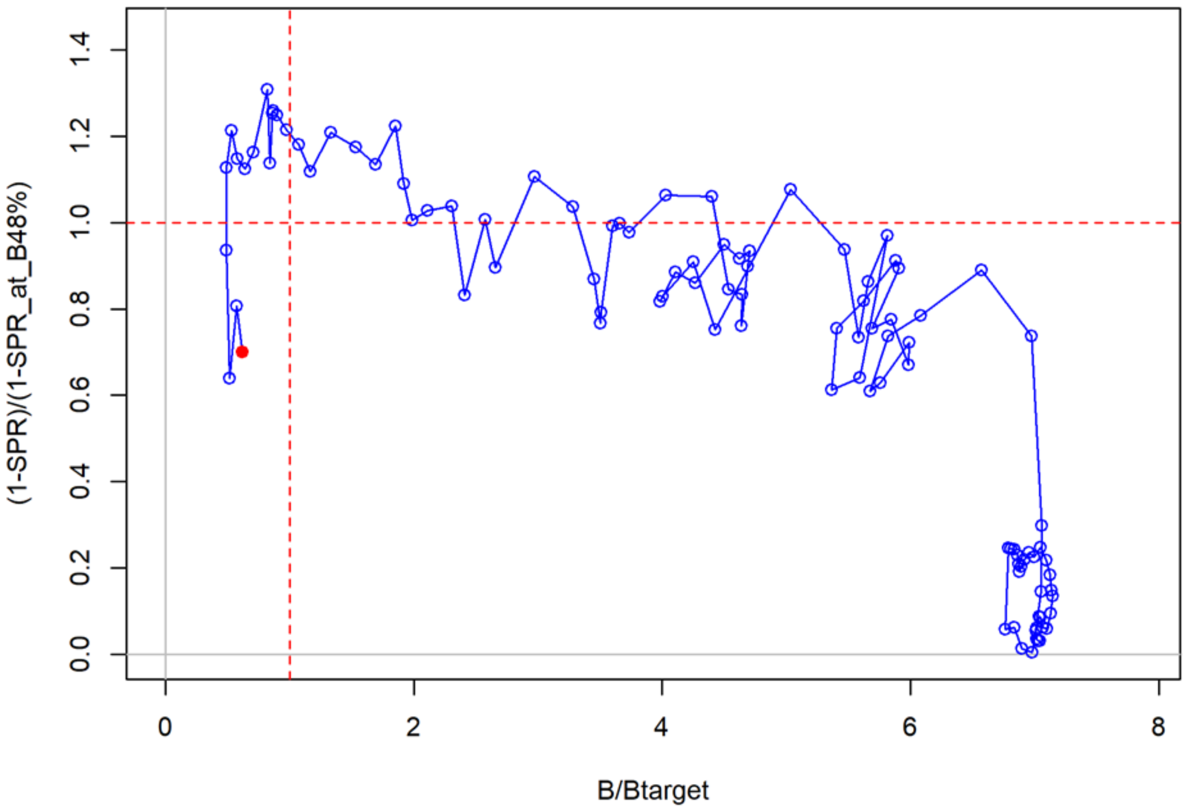


Figure 6.19. Kobe plot base case, showing the trajectory of spawning biomass (relative to B_0) plotted against 1-SPR, which is a proxy for fishing mortality, essentially integrating fishing mortality across fleets in the fishery.

Figure 6.19 shows a Kobe plot for the base case. This plot shows a time series of spawning biomass plotted against spawning potential ratio, which provides a measure of overall fishing mortality, and shows the stepwise movement in this space from the start of the fishery, in the bottom right corner, when there was low fishing mortality and high biomass to the 2017 (the red dot) where the biomass is below the target (to the left of the vertical red dashed line) and the fishing mortality is below the target fishing level (below the horizontal red dashed line, the “overfishing limit”). Note that this plot indicates the fishing mortality for the eastern stock of jackass morwong has been below the target fishing level for the last four years, following a period of around 20 years when the fishing mortality above this target.

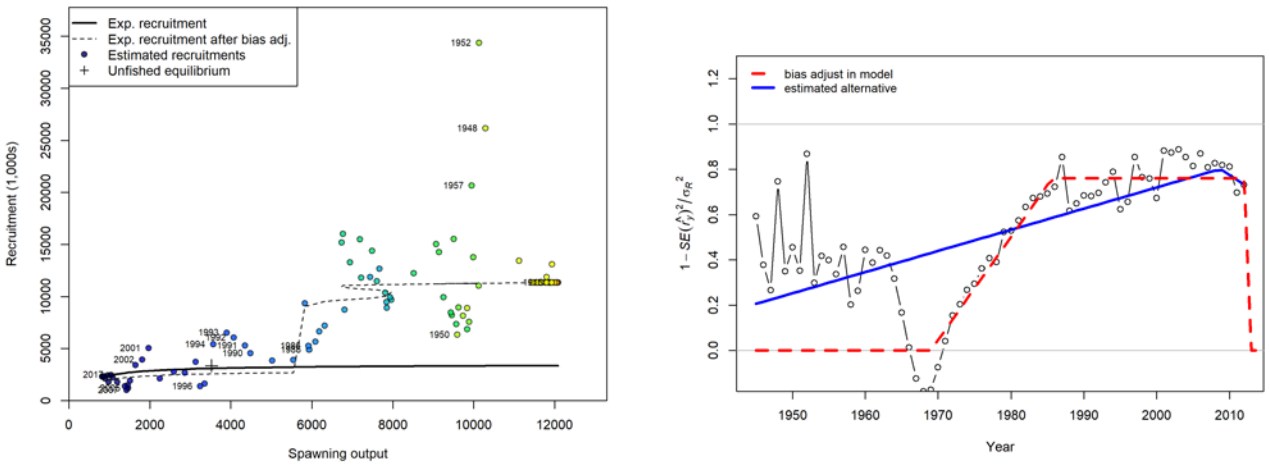


Figure 6.20. Recruitment estimation for the base case analysis. Left: the stock-recruit curve and estimated recruitments; right: bias adjustment.

The time-trajectories of recruitment and recruitment deviation are shown in Figure 6.18. The model now has two stock-recruitment relationships, before and after 1988 (Figure 6.20). While the productivity shift (from 1988) which is incorporated into this model improves the residuals for the recruitment estimates from 1988 onwards, there appears to be considerable serial correlation and some patterns that may require further exploration. It is a possible that a sudden step change in productivity in 1988 is not the best explanation for the recruitment patterns observed, and there may have been further changes to the productivity since then. The first seven years after the recruitment shift (1988-1994) show recruitment that is well above average (Figure 6.18), followed by six years with variable recruitment (1995-2000), another three years with well above average recruitment (2001-2003), followed by nine years of mostly below average recruitment (2004-2012).

The base-case assessment estimates that current spawning stock biomass is 35% of unexploited stock biomass (SSB_0). The 2018 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 261 t (Table 6.15) and the long term yield (assuming average recruitment in the future) is 356 t (Table 6.17). Averaging the RBC over the three year period 2019-2021, the average RBC is 270 t and over the five year period 2019-2023, the average RBC is 279 t (Table 6.17). The RBCs for each individual years from 2019-2024 are listed in Table 6.15 for the base case.

Table 6.15. Yearly projected RBCs (tonnes) across all fleets under the 20:35:48 harvest control rules all assuming average recruitment from 2013 for the agreed base.

Year	RBC
2019	261
2020	271
2021	280
2022	288
2023	296

6.4.1.5 *Discard estimates*

Model estimates for discards for the period 2019-23 with the 20:35:48 Harvest Control Rule are listed in Table 6.16 for the base case, with a range of 14 to 16 t.

Table 6.16. 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.

Discards Year	Jan growth
2019	14
2020	15
2021	15
2022	15
2023	16

6.4.2 ***Sensitivity tests and alternative models***

Results of the sensitivity tests are shown in Table 6.17. This table indicates that biomass depletion is not overly sensitive to changes in parameters or weightings, except for natural mortality.

This assessment is also not very sensitive to the weighting placed on the age compositions. However it is moderately sensitive to changing weightings on length and CPUE data, and in both cases, increasing the weighting on these data sources results in lower depletion estimates (33% and 32% respectively) 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 6.18). 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) and 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 current standardised CPUE indices (eastern trawl and Tasmanian trawl) and many years of data from the historical CPUE series, not to mention many years of length frequency data and 26 years of conditional age-at-length data.

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

6.4.3.1 *Quality and quantity of input data*

The base case model fit to the indices of abundance are generally very good (Figure 6.11, Figure 6.12 and Figure 6.13). However, while the fits to the recent abundance indices look reasonable, Sporcic and Haddon (2018a) indicate that “the structural adjustment altered the effect of the vessel factor on the standardised result. However, log(CPUE) has also changed in character from 2014 - 2017, with spikes of low catch rates arising”.

In contrast, the fits to the FIS abundance indices (Figure 6.14), even with additional CVs on these abundance series estimated within the model (0.54 and 0.74 respectively). The additional CV estimated to the eastern trawl CPUE index was 0.09, with a negative value estimated for all other CPUE indices, indicating the initial CV values were too broad for these other fleets.

Improved sampling of recent length and age data, ensuring it is both adequate and representative, could improve the model fits and results.

6.4.3.2 Likelihood profiles

Likelihood profiles were conducted on natural mortality and steepness for the preliminary base case (Day and Castillo-Jordán, 2018a), and have not been repeated for the final base case. The likelihood profiles on steepness suggested there was little information in the data to inform the value for steepness. The likelihood profile on natural mortality showed that the fixed value chosen for M (0.15yr^{-1}) was outside the 95% confidence interval suggested by the likelihood profile (approximately 0.18-0.34). However, this is driven largely by the fits to the CPUE index, and in particular by the Eastern trawl fleet. In contrast the discard, age and length data all suggest a lower value of natural mortality than suggested by the fits to the CPUE index, albeit with lower contributions to the overall likelihood. This suggests that better fits to the eastern trawl CPUE index could be obtained with a higher value of natural mortality. This could be explained by changes in targeting practice or indeed a potential change in natural mortality in recent years, neither of which are incorporated in the model, or by suggesting that there is insufficient information in the data to be able to reliably inform an estimate of natural mortality. The maximum age observed in the data and the biology of jackass morwong should certainly be considered when making decisions on the value used for natural mortality

6.4.3.3 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 the future.

Table 6.17. Summary of results for the base-case and sensitivity tests. Recommended biological catches (RBCs) are only shown for agreed base case model.

Case		**SSB_0**	**SSB_{2019}**	**SSB_{2019}/SSB_0**	**RBC_{2019}**	**$RBC_{2019-21}$**	**$RBC_{2019-23}$**	**$RBC_{longterm}$**
0	base case (*M* 0.15, *h* 0.7, 50% mat 24.5)	7,047	2,475	0.35	261	270	279	356
1	*M* 0.1	10,333	1,857	0.18				
2	*M* 0.2	6,403	3,354	0.52				
3	*h* 0.6	7,930	2,335	0.29				
4	*h* 0.8	6,546	2,586	0.40				
5	50% maturity at 22cm	7,374	2,835	0.38				
6	$\sigma_R = 0.65$	7,033	2,491	0.35				
7	$\sigma_R = 0.75$	7,067	2,461	0.35				
8	wt x 2 length comp	7,388	2,459	0.33				
9	wt x 0.5 length comp	6,753	2,545	0.38				
10	wt x 2 age comp	6,823	2,487	0.36				
11	wt x 0.5 age comp	7,060	2,443	0.35				
12	wt x 2 CPUE	6,591	2,133	0.32				
13	wt x 0.5 CPUE	7,548	2,878	0.38				
14	no FIS	7,193	2,594	0.36				
15	include FIS length frequencies	7,048	2,490	0.35				

Table 6.18. Summary of likelihood components for the base-case and sensitivity tests. Likelihood components are unweighted, and cases 1-15 are shown as differences from the base case. A negative value indicates a better fit, a positive value a worse fit.

Case		**Likelihood**					
		TOTAL	**Survey**	**Discard**	**Length comp**	**Age comp**	**Recruitment**
0	base case (*M* 0.15, *h* 0.7, 50% mat 24.5)	696.15	-111.18	103.46	248.38	452.32	2.85
1	*M* 0.1	4.47	2.16	-0.83	1.85	0.89	0.21
2	*M* 0.2	-2.21	-2.43	0.99	-0.28	-0.43	0.10
3	*h* 0.6	-1.09	0.12	-0.38	0.38	-0.35	-0.85
4	*h* 0.8	0.97	0.00	0.25	-0.26	0.25	0.74
5	50% maturity at 22cm	0.29	-0.04	0.25	-0.08	0.03	0.14
6	$\sigma_R = 0.65$	-0.09	0.09	0.08	0.62	-0.03	-0.85
7	$\sigma_R = 0.75$	0.27	-0.07	-0.06	-0.55	0.04	0.90
8	wt x 2 length comp	4.98	2.18	9.79	-11.85	1.63	3.17
9	wt x 0.5 length comp	4.88	1.10	-12.44	16.48	1.19	-1.41
10	wt x 2 age comp	2.50	1.82	5.58	0.63	-6.05	0.50
11	wt x 0.5 age comp	2.24	-1.04	-5.22	0.51	7.84	0.15
12	wt x 2 CPUE	6.30	-13.08	12.69	1.61	3.67	1.36
13	wt x 0.5 CPUE	2.89	10.42	-6.12	-0.32	-0.86	-0.21
14	no FIS	-2.91	-1.86	-1.31	0.45	0.02	-0.21
15	include FIS length frequencies	17.02	0.43	-1.19	14.47	3.11	0.22

6.5 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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6.7 Appendix A

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

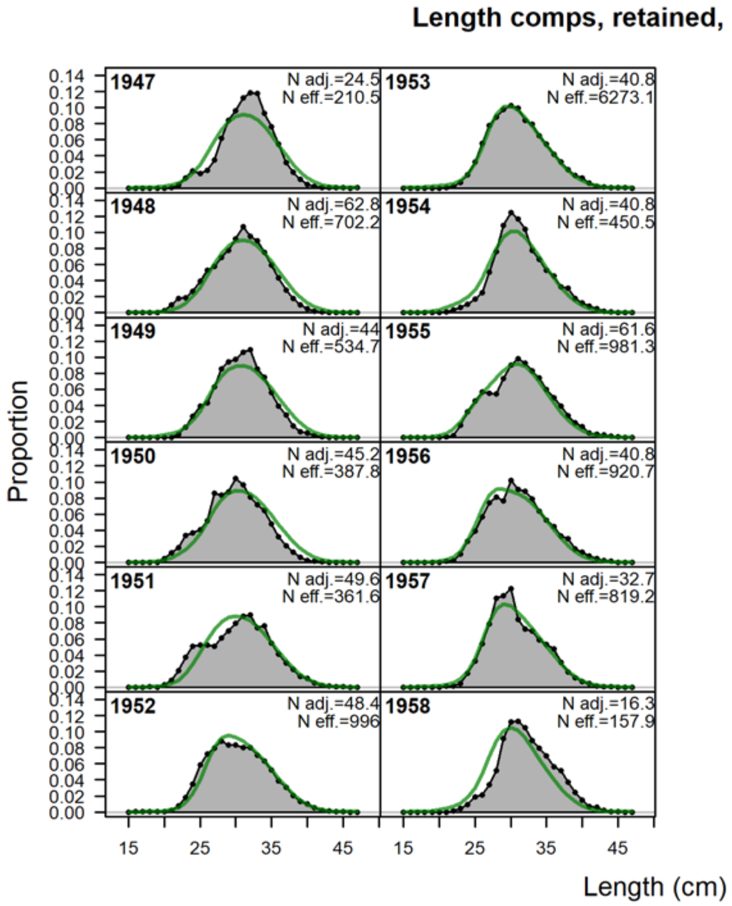

Figure A 6.1. Eastern jackass morwong length composition fits: steam trawl fleet retained.

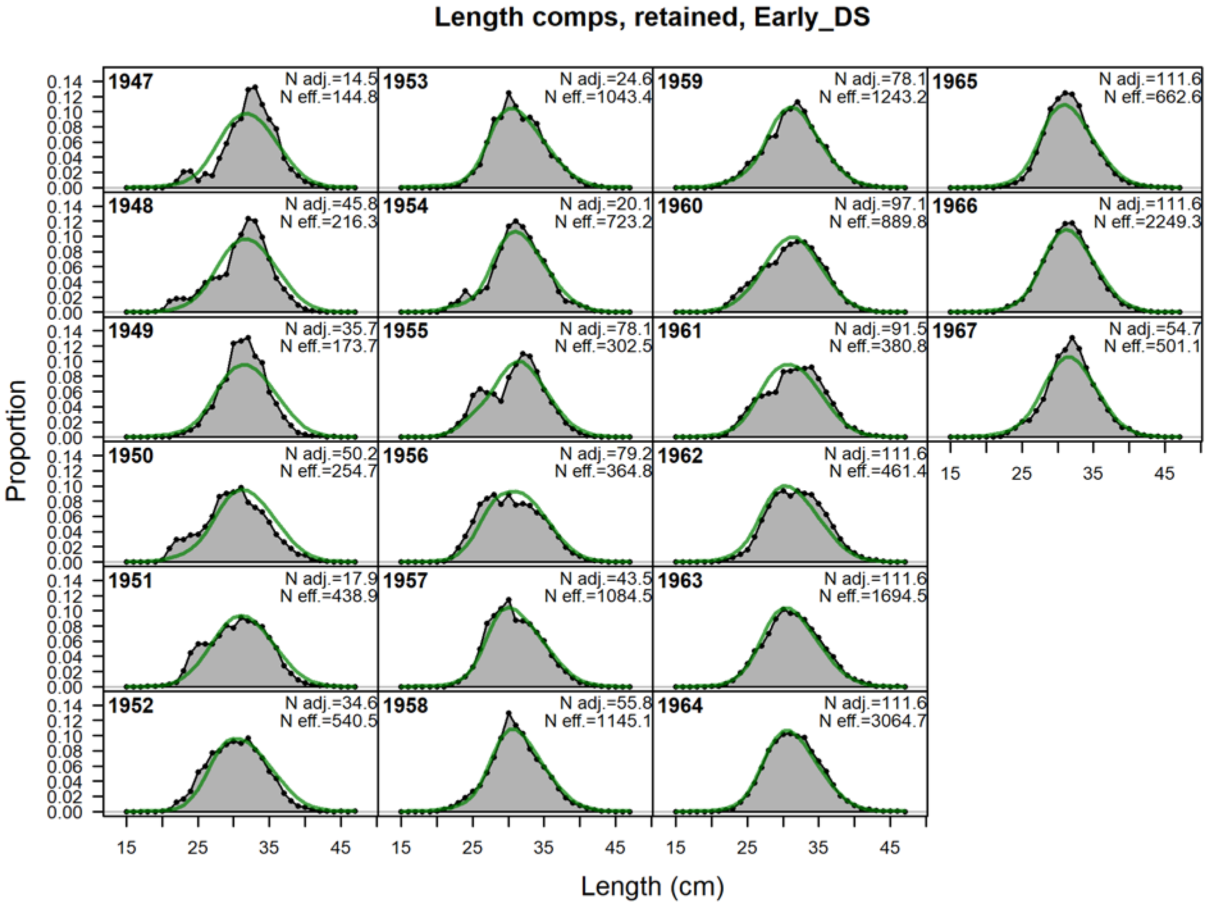

Figure A 6.2. Eastern jackass morwong length composition fits: early Danish seine fleet retained.

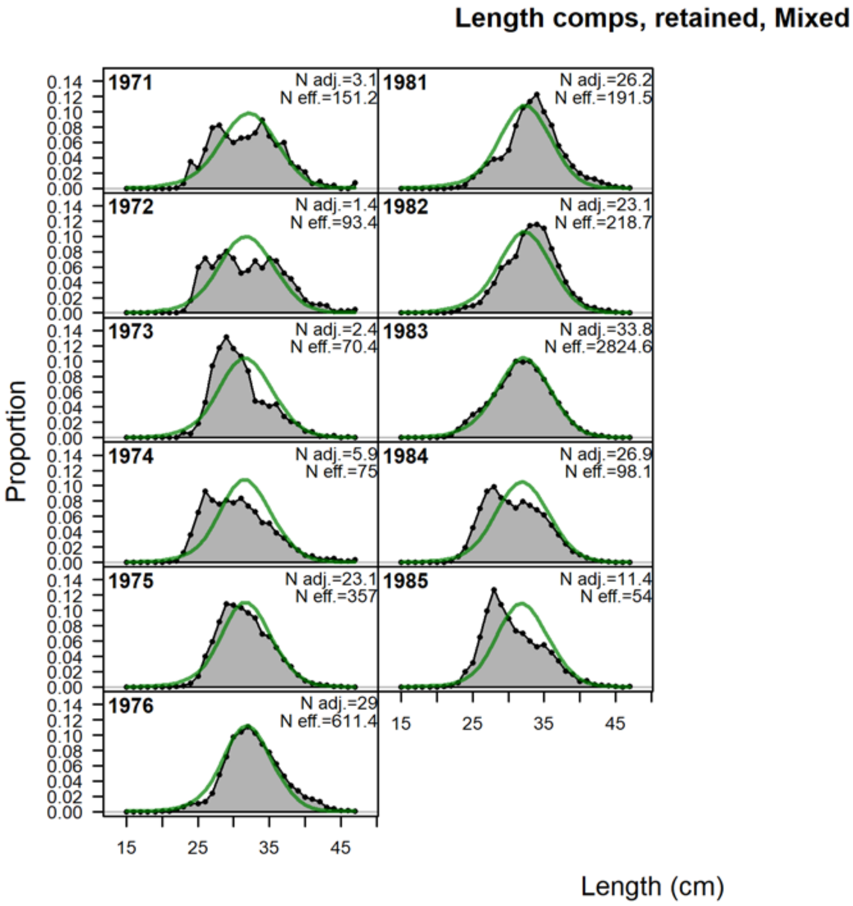

Figure A 6.3. Eastern jackass morwong length composition fits: mixed fleet retained.

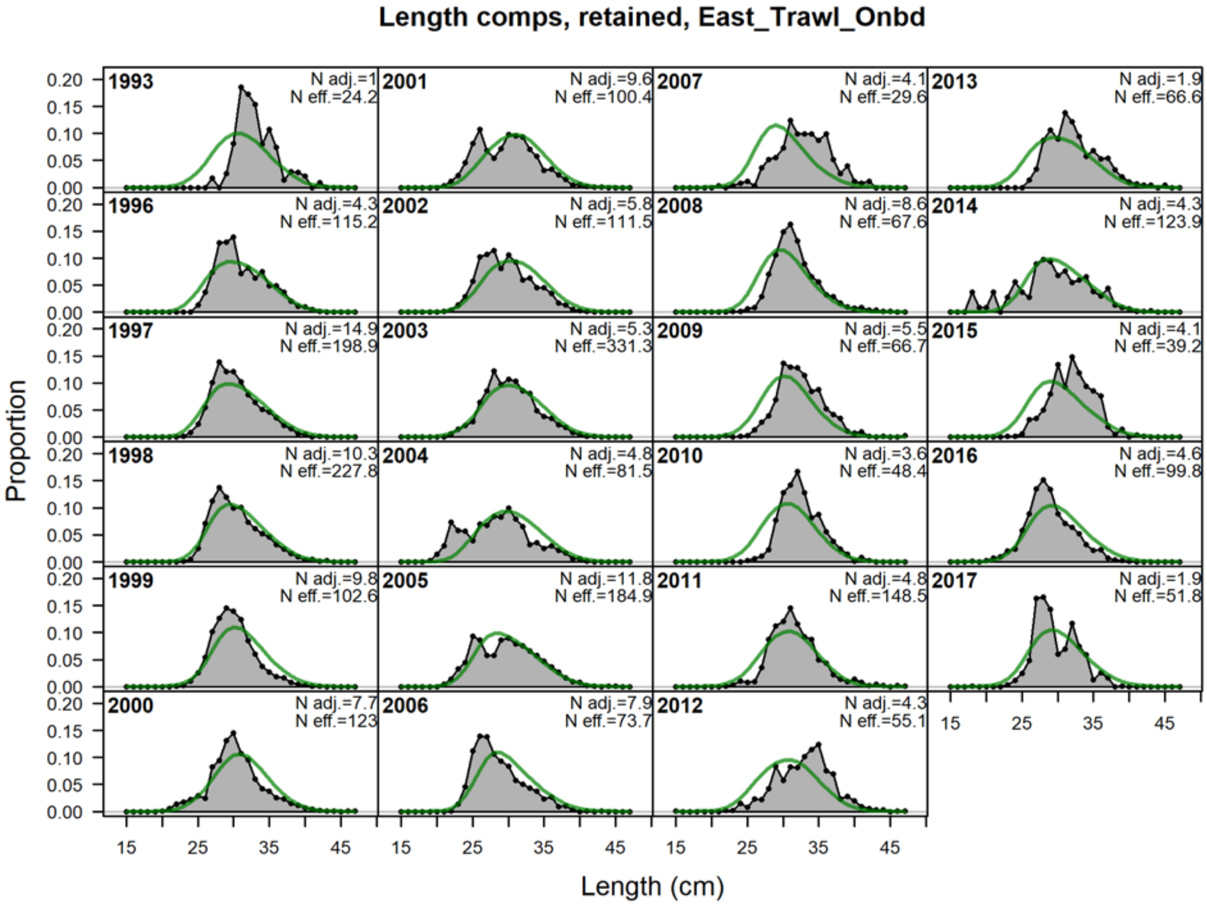

Figure A 6.4. Eastern jackass morwong length composition fits: eastern trawl fleet onboard retained.

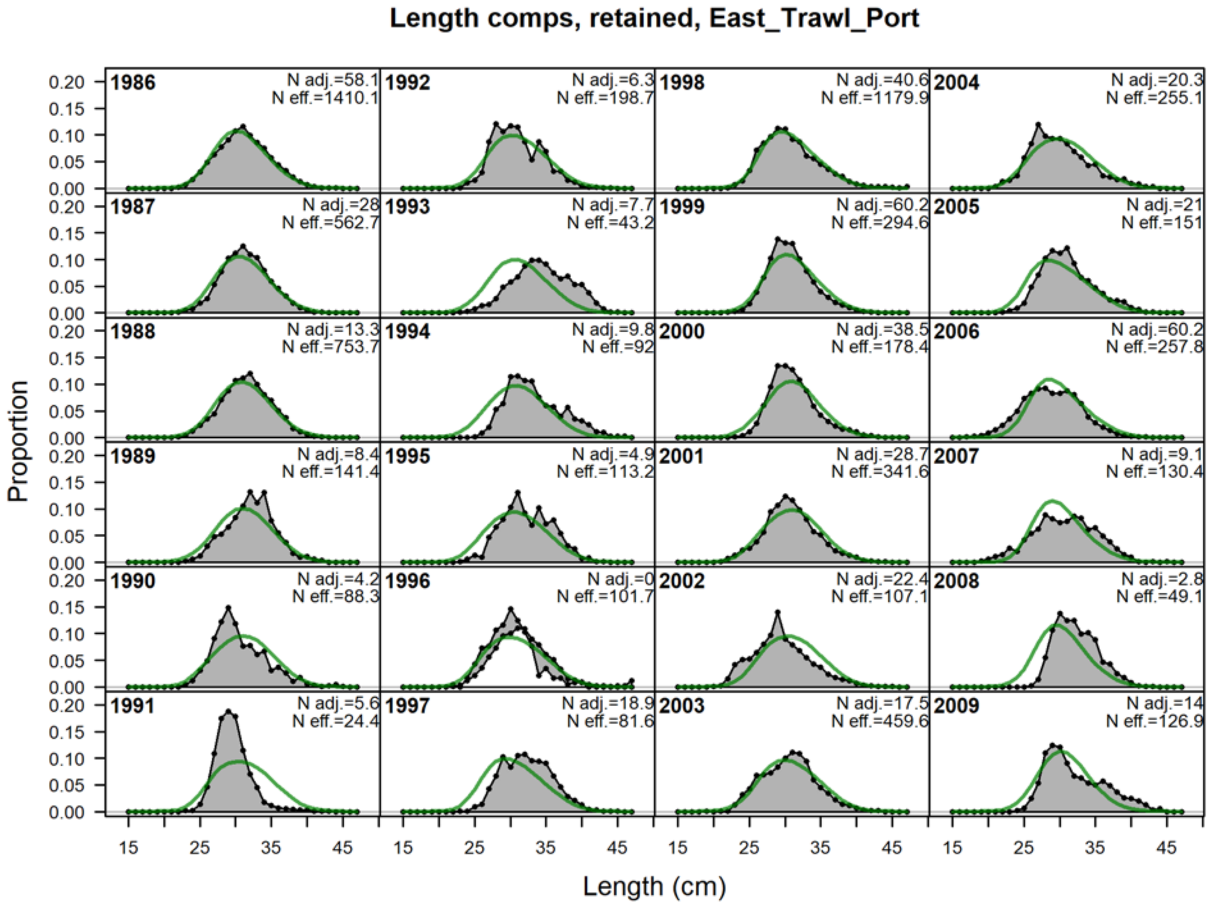

Figure A 6.5. Eastern jackass morwong length composition fits: eastern trawl fleet port retained (1/2).

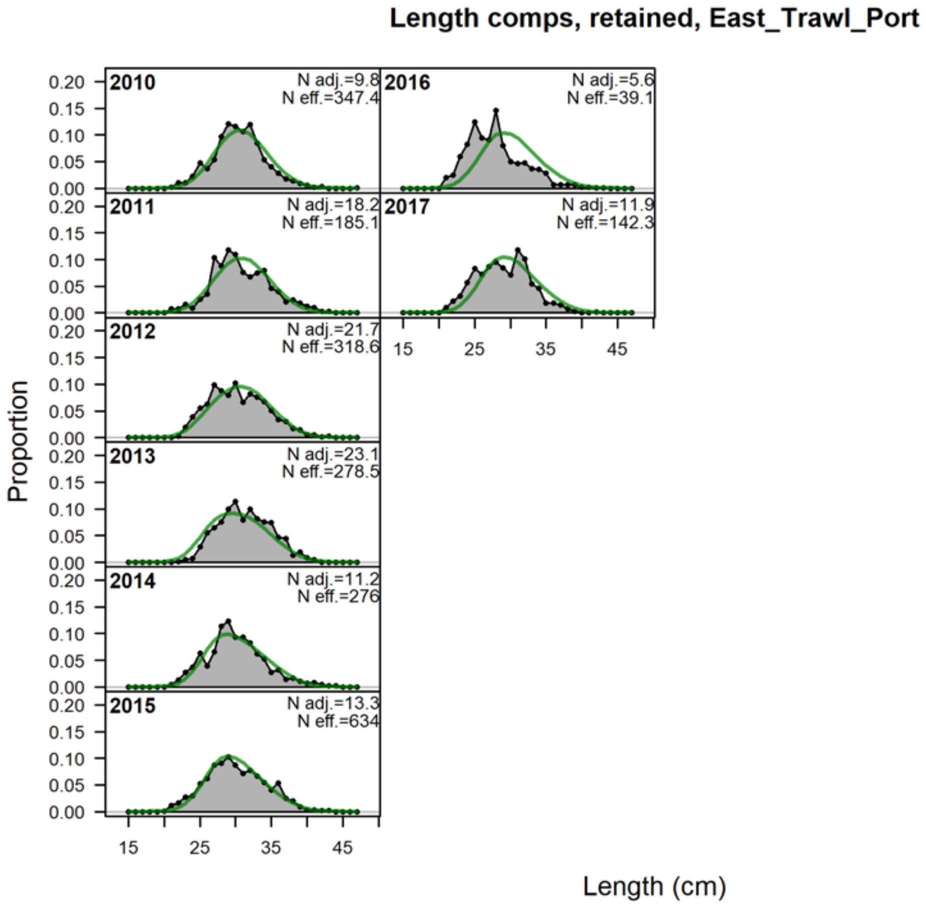

Figure A 6.6. Eastern jackass morwong length composition fits: eastern trawl fleet port retained (2/2).

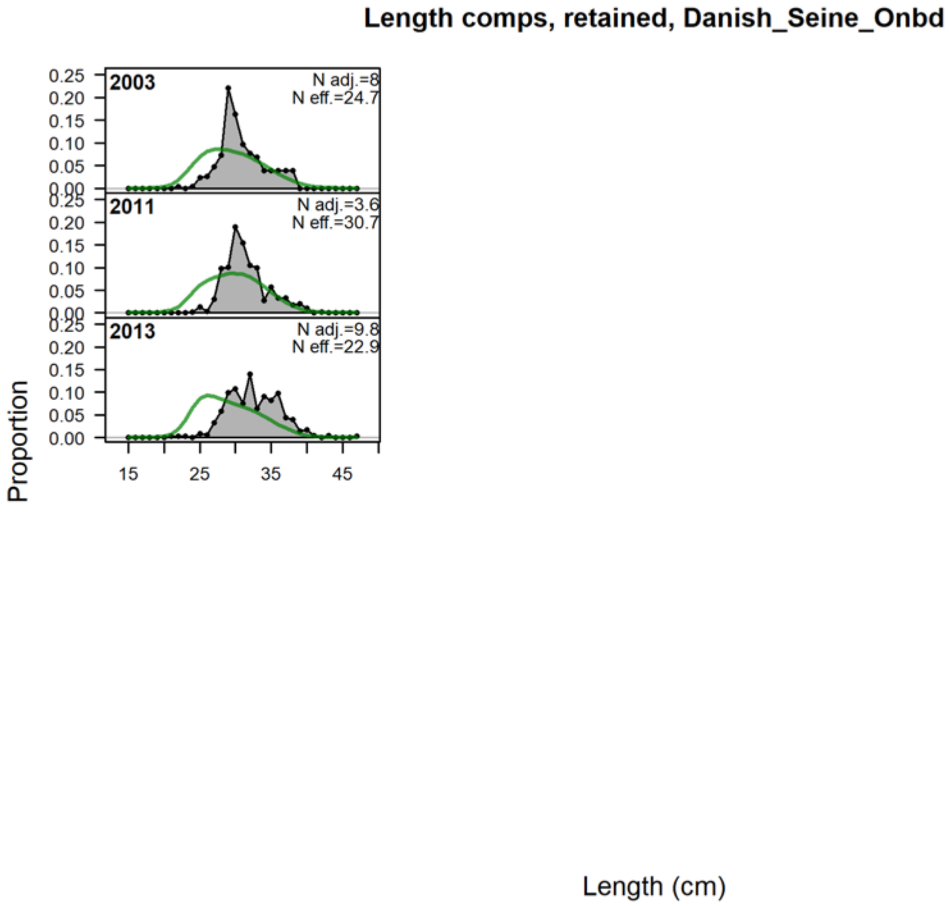

Figure A 6.7. Eastern jackass morwong length composition fits: Danish seine fleet onboard retained.

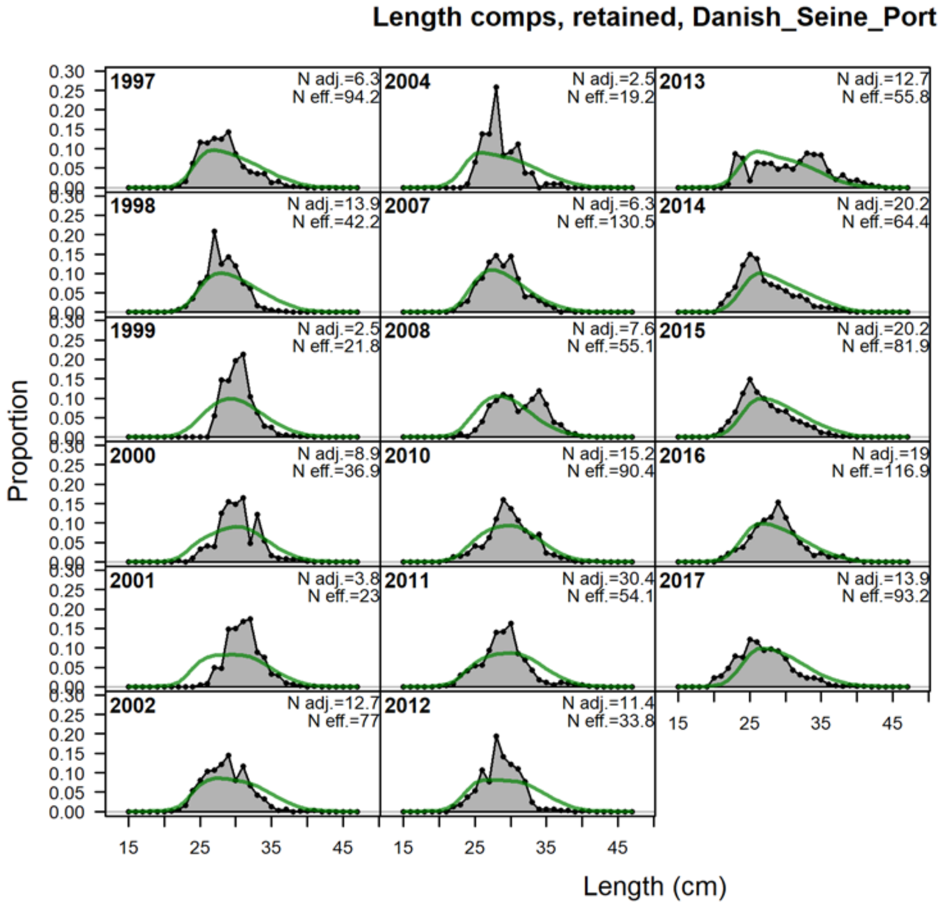

Figure A 6.8. Eastern jackass morwong length composition fits: Danish seine fleet port retained.

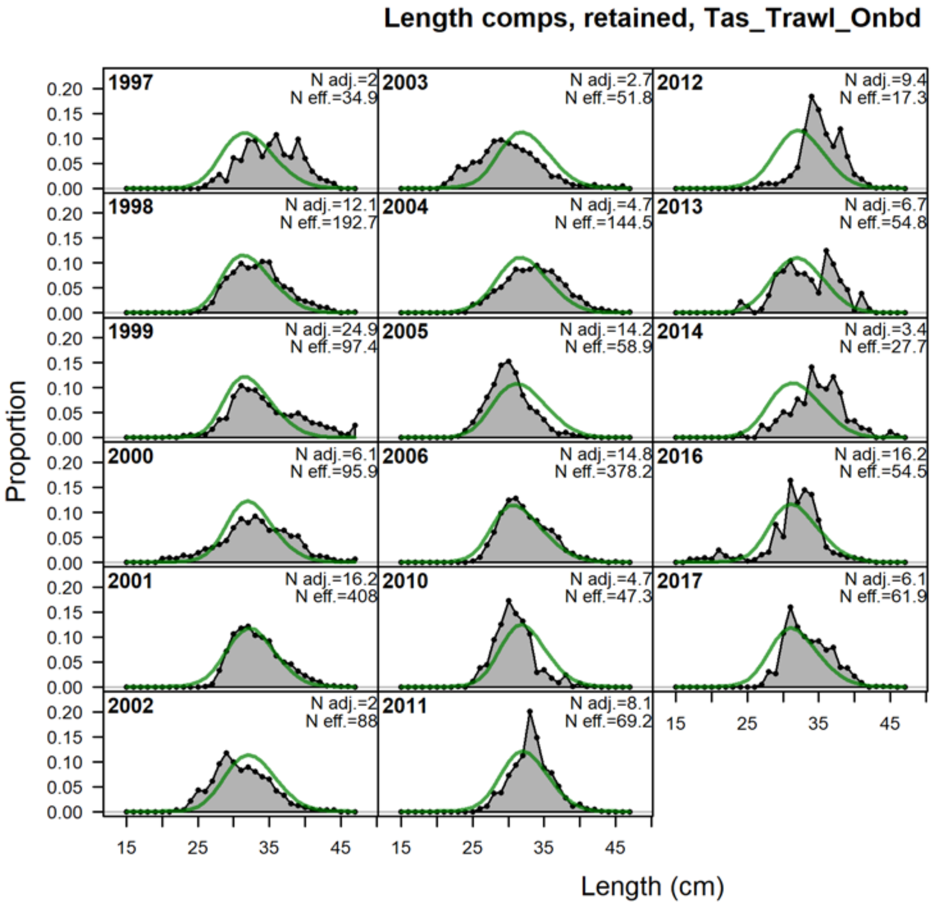

Figure A 6.9. Eastern jackass morwong length composition fits: Tasmanian trawl fleet onboard retained.

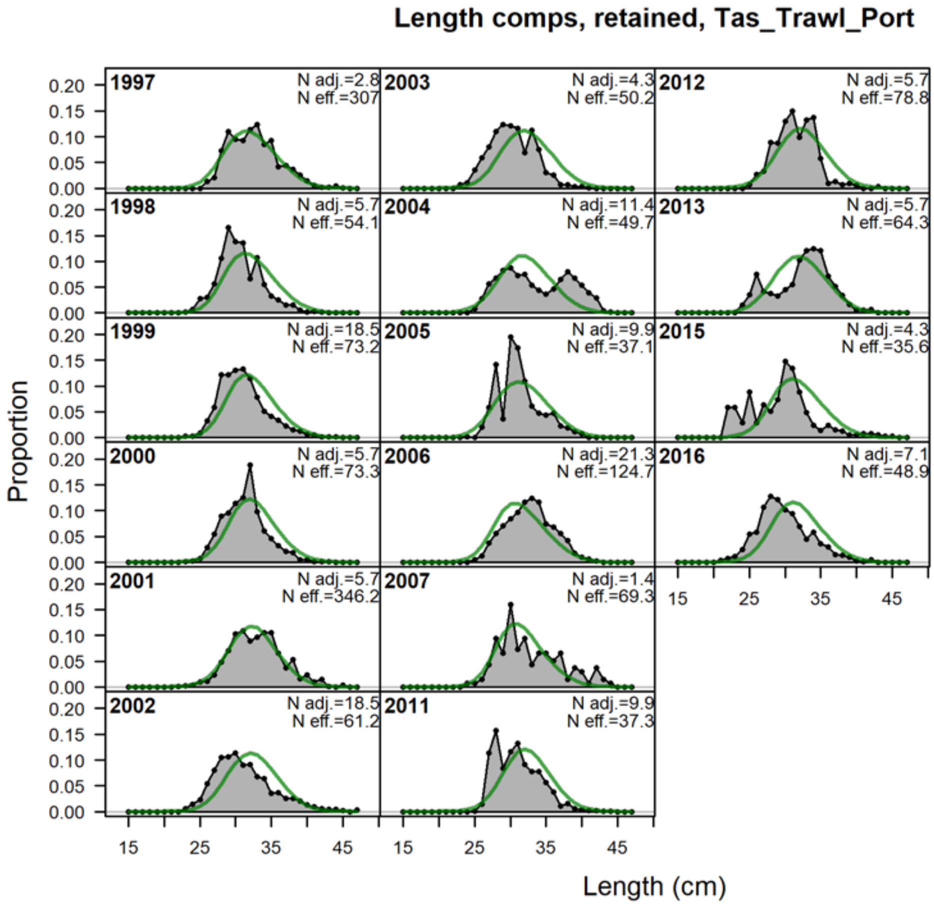

Figure A 6.10. Eastern jackass morwong length composition fits: Tasmanian trawl fleet port retained.

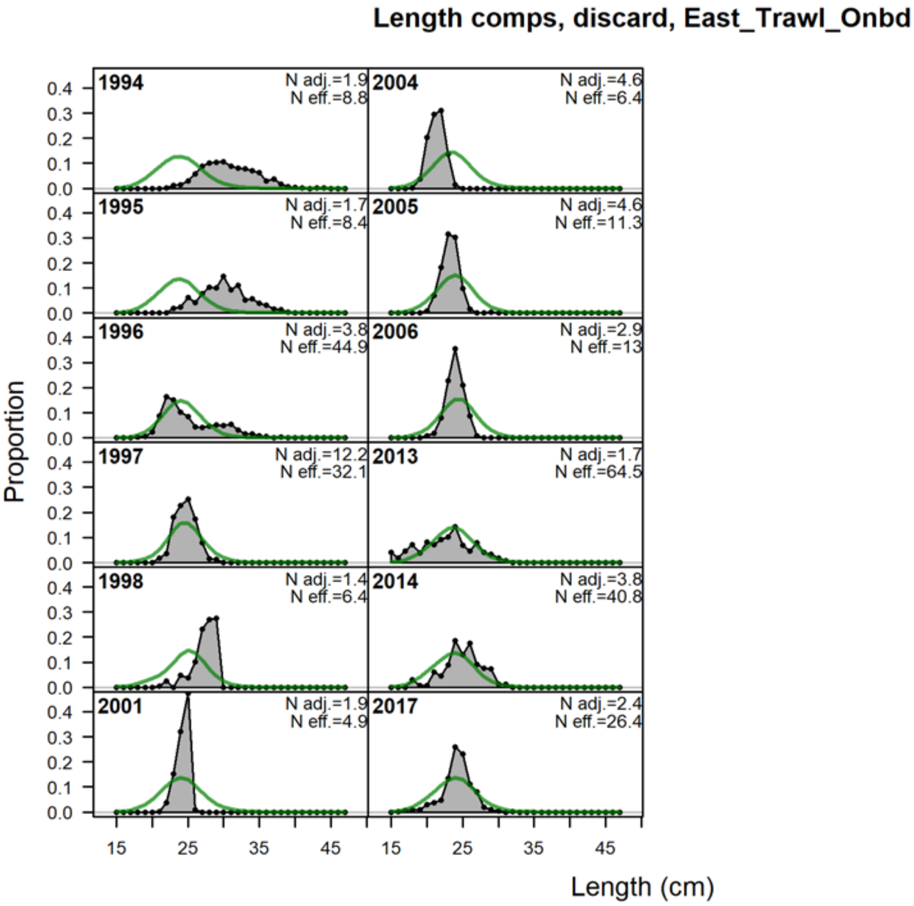

Figure A 6.11. Eastern jackass morwong length composition fits: eastern trawl discarded.

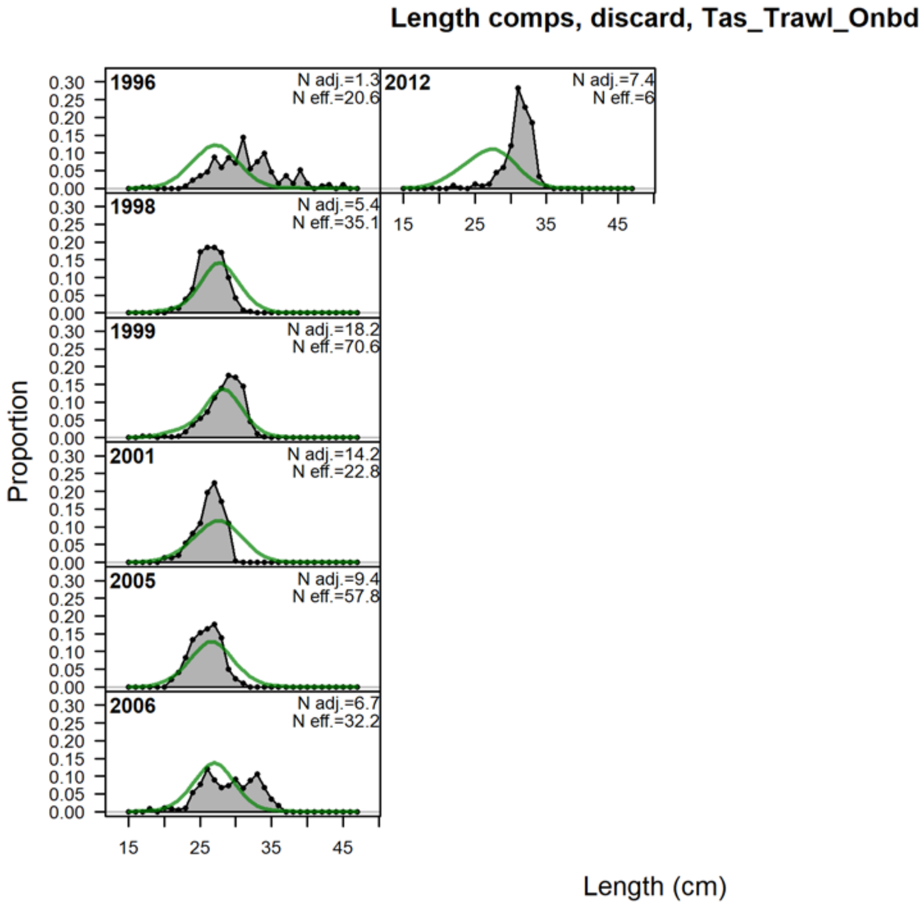

Figure A 6.12. Eastern jackass morwong length composition fits: Tasmanian trawl discarded.

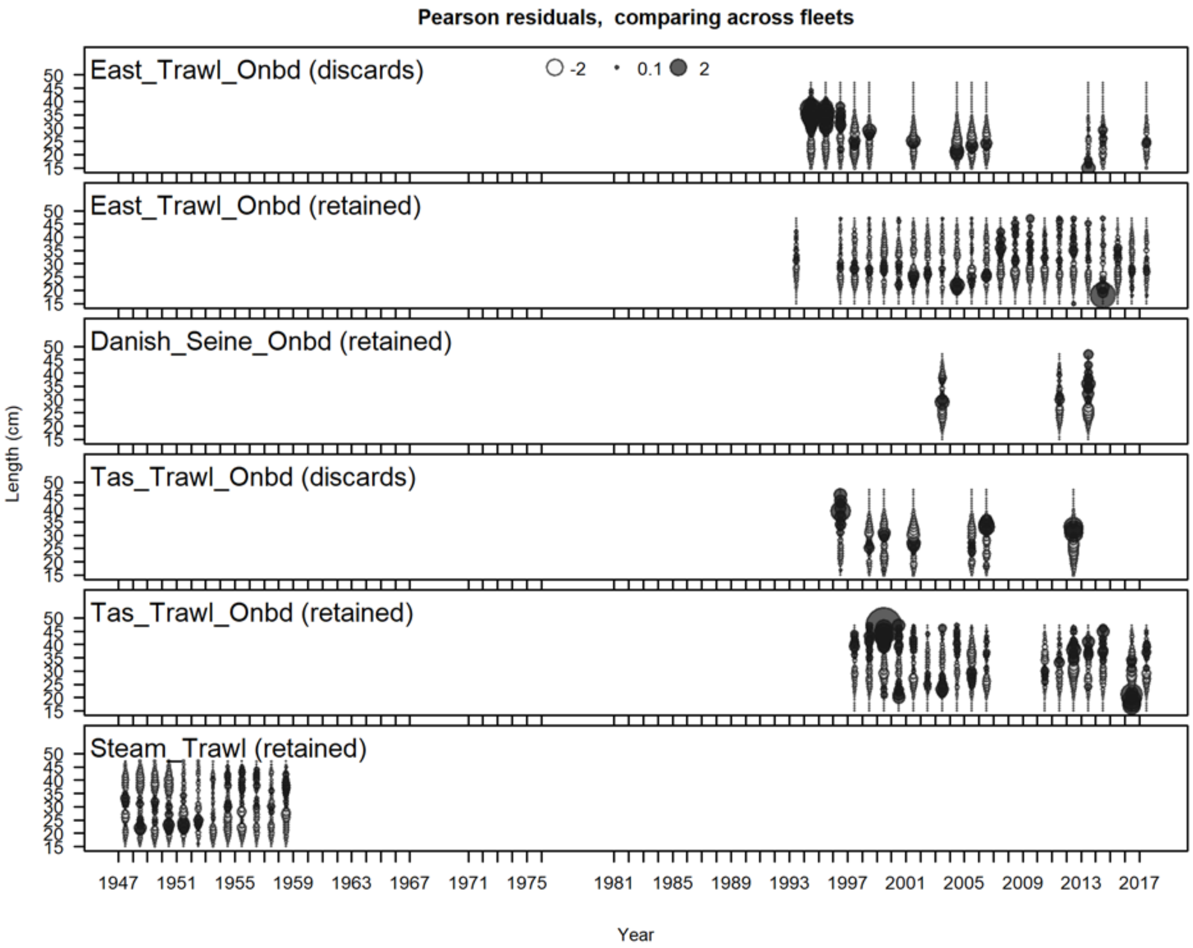

Figure A 6.13. Residuals from the annual length composition data for eastern jackass morwong (onboard) displayed by year and fleet for eastern and Tasmanian trawl fleets (retained and discarded), Danish seine and steam trawl fleets (retained).

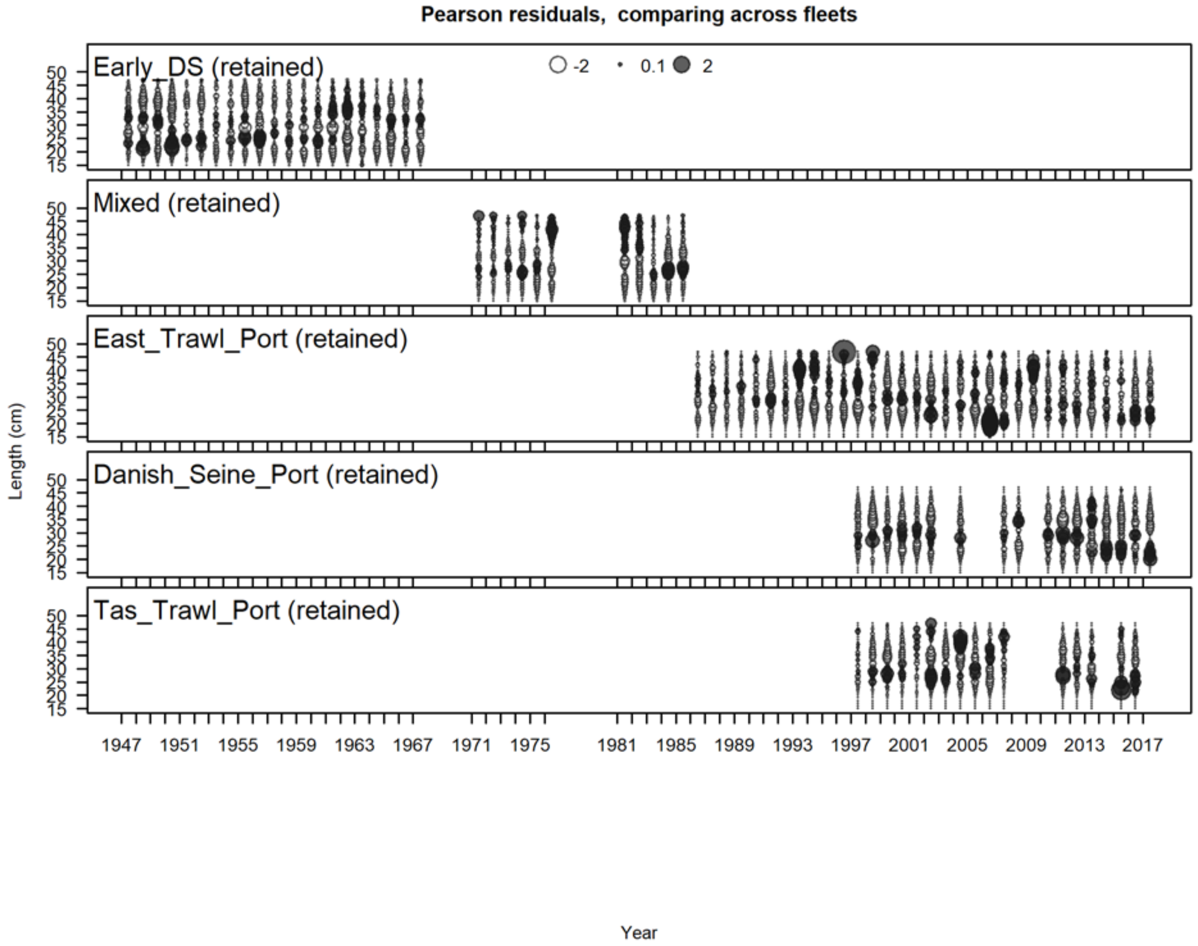

Figure A 6.14. Residuals from the annual length composition data for eastern jackass morwong displayed by year and fleet for the early Danish seine and mixed fleets (retained onboard) and the eastern trawl, Danish seine and Tasmanian trawl fleets (retained port).

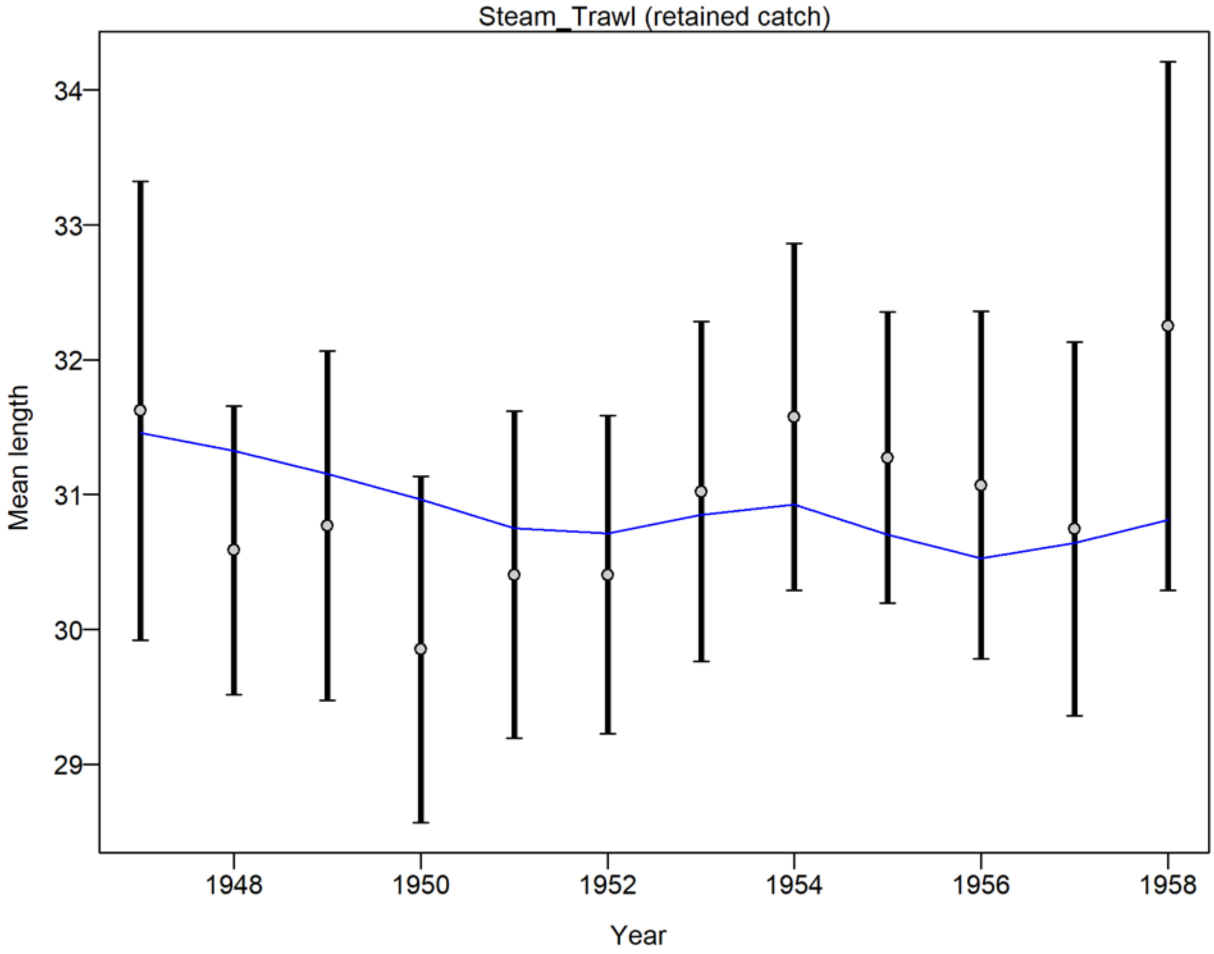

Figure A 6.15. Mean length for eastern jackass morwong from steam trawl with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced.

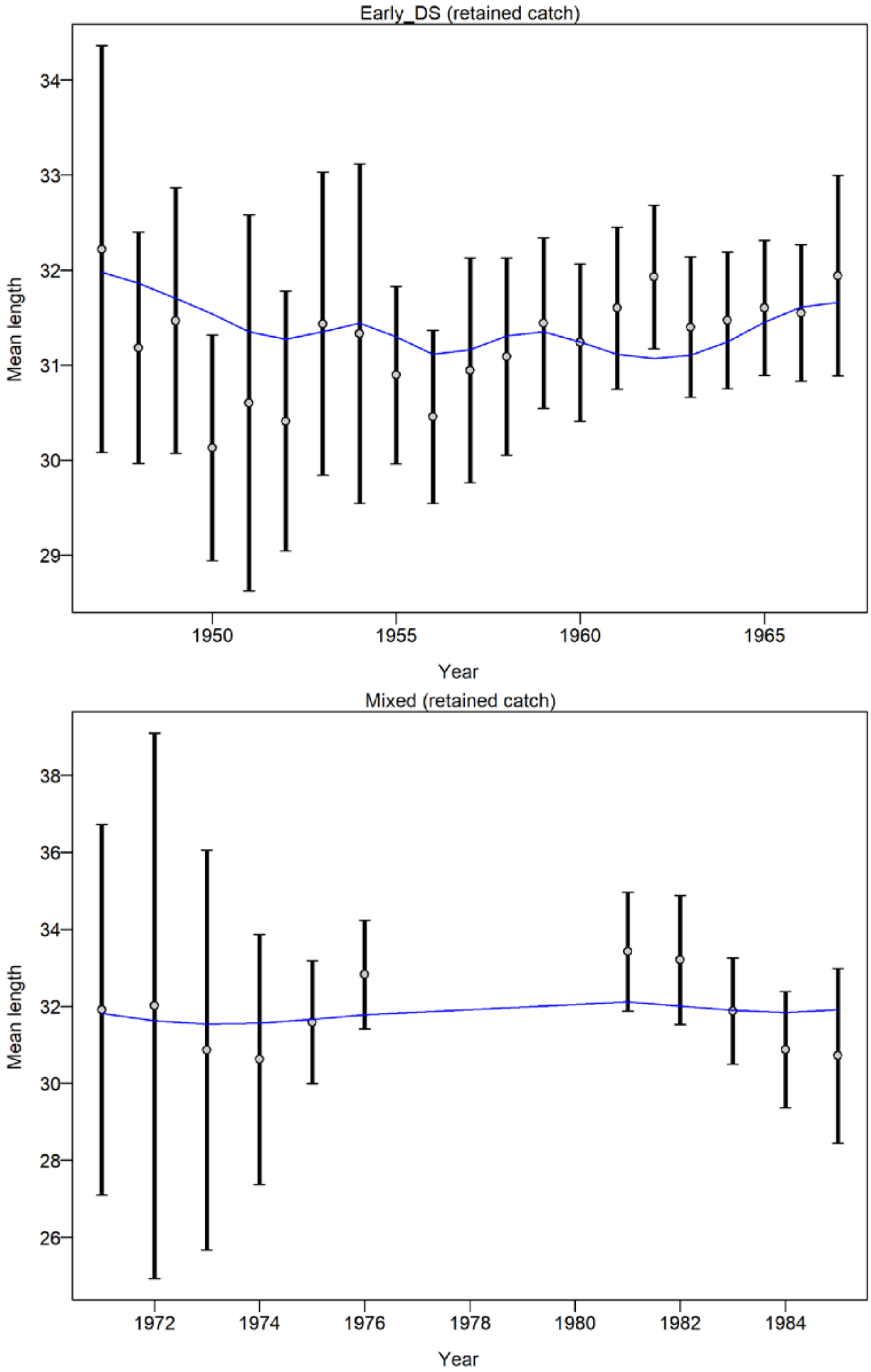

Figure A 6.16. Mean length for eastern jackass morwong from early Danish seine (top) and the mixed fleet (bottom) with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced.

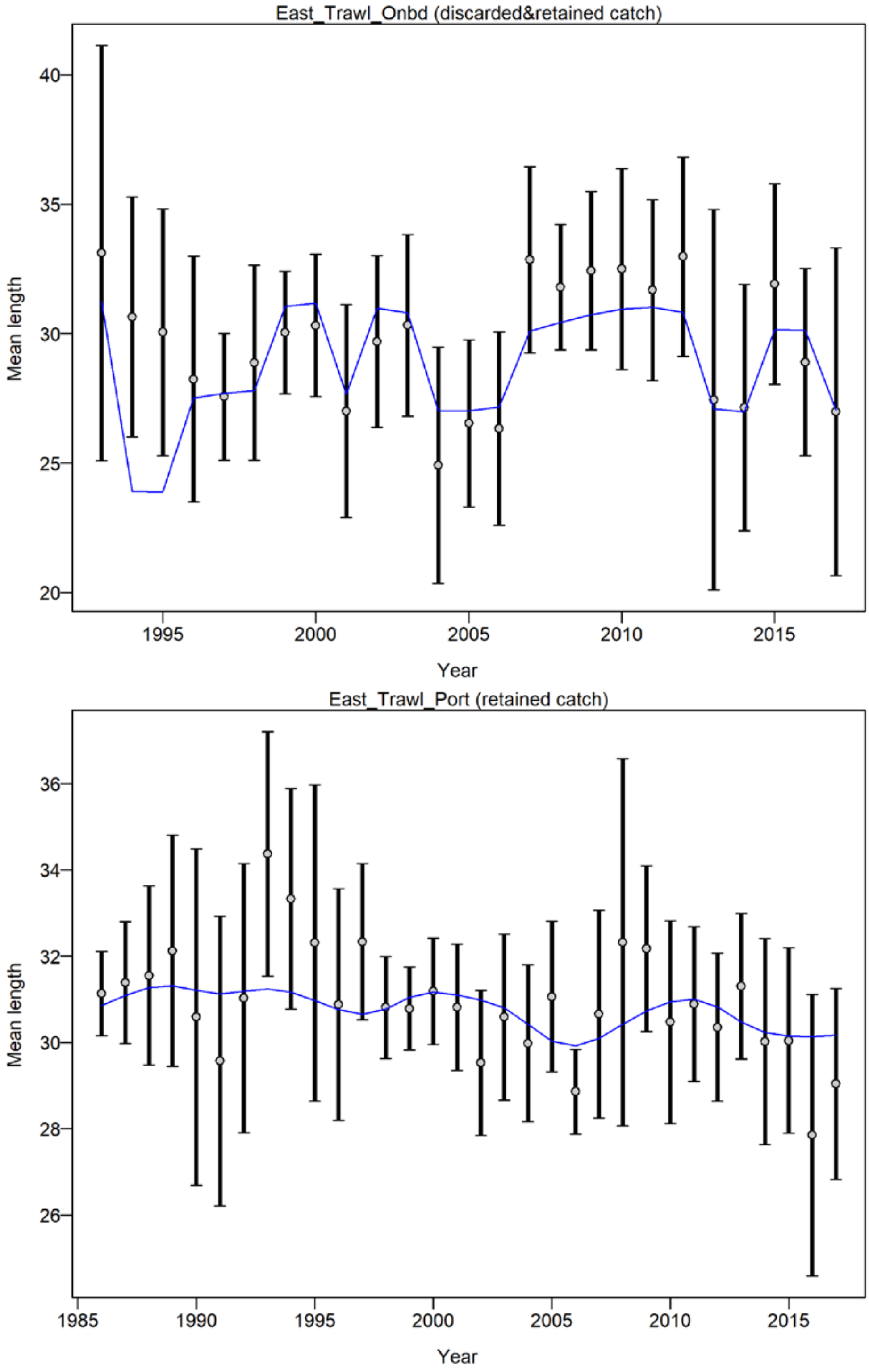

Figure A 6.17. Mean length for eastern jackass morwong from the eastern trawl fleet: onboard (top) and port (bottom) with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced.

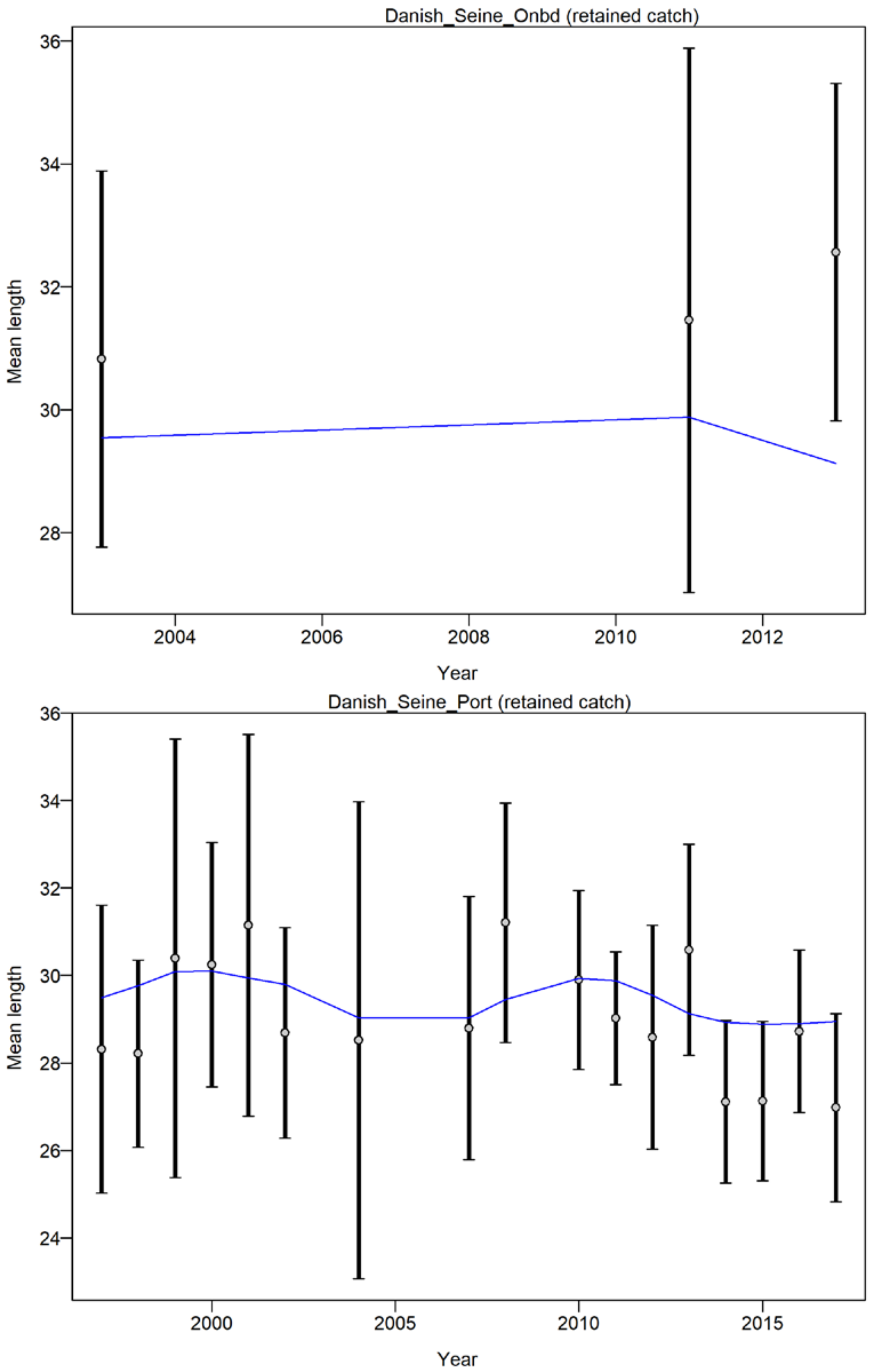

Figure A 6.18. Mean length for eastern jackass morwong from the Danish seine fleet: onboard (top) and port (bottom) with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced.

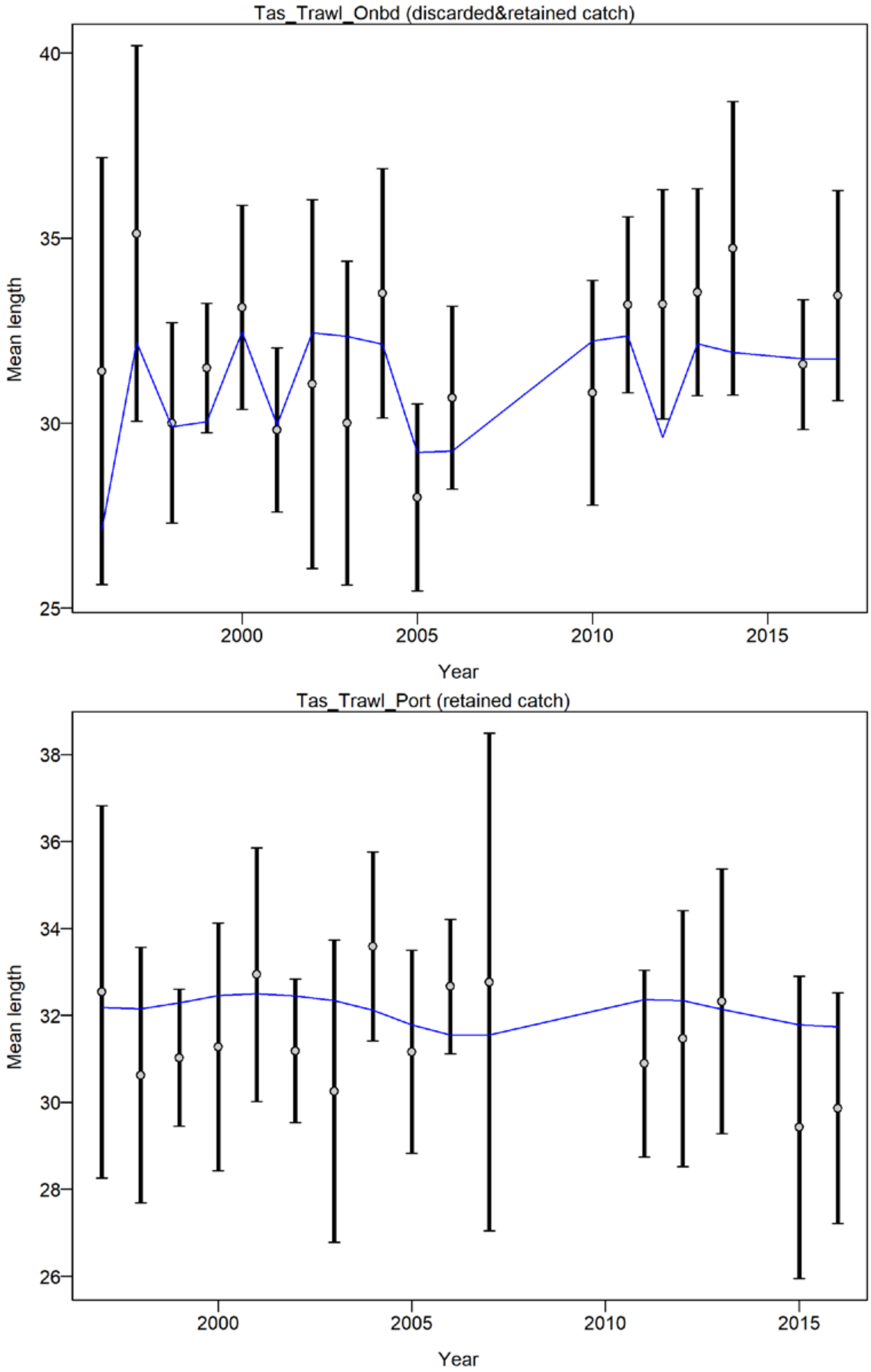

Figure A 6.19. Mean length for eastern jackass morwong from the Tasmanian trawl fleet: onboard (top) and port (bottom) with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced.

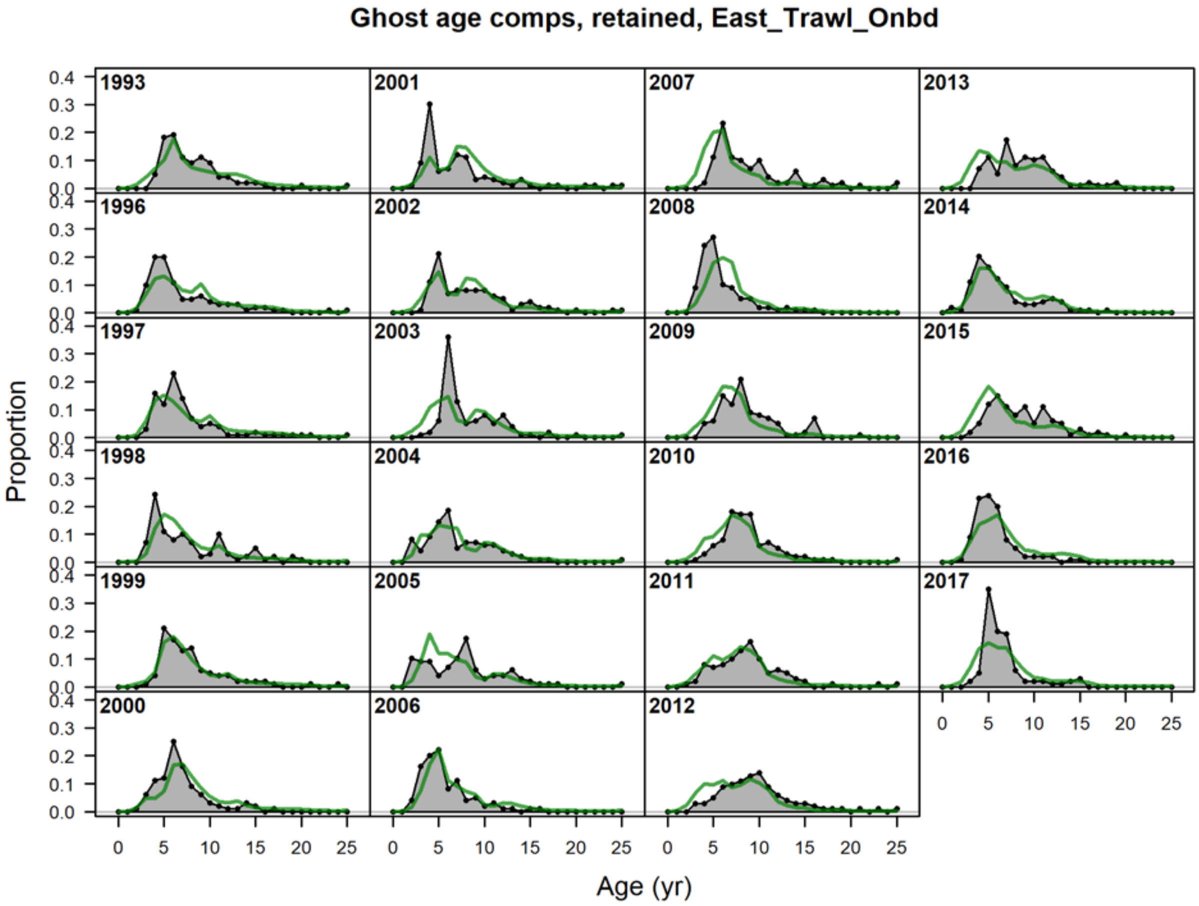

Figure A 6.20. Implied fits to age compositions for eastern jackass morwong eastern trawl onboard (retained).

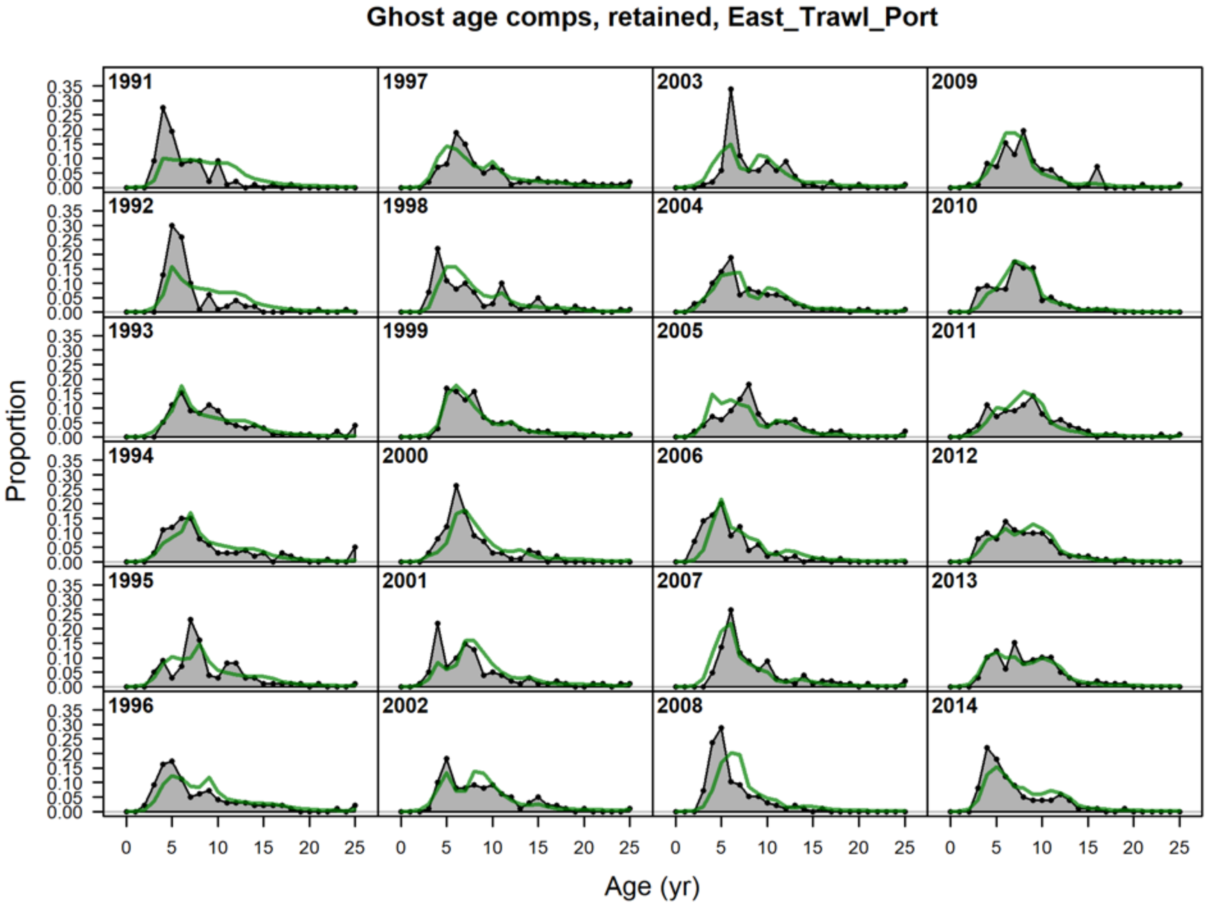

Figure A 6.21. Implied fits to age compositions for eastern jackass morwong eastern trawl port (retained) (1/2).

Figure A 6.22. Implied fits to age compositions for eastern jackass morwong eastern trawl port (retained) (2/2).

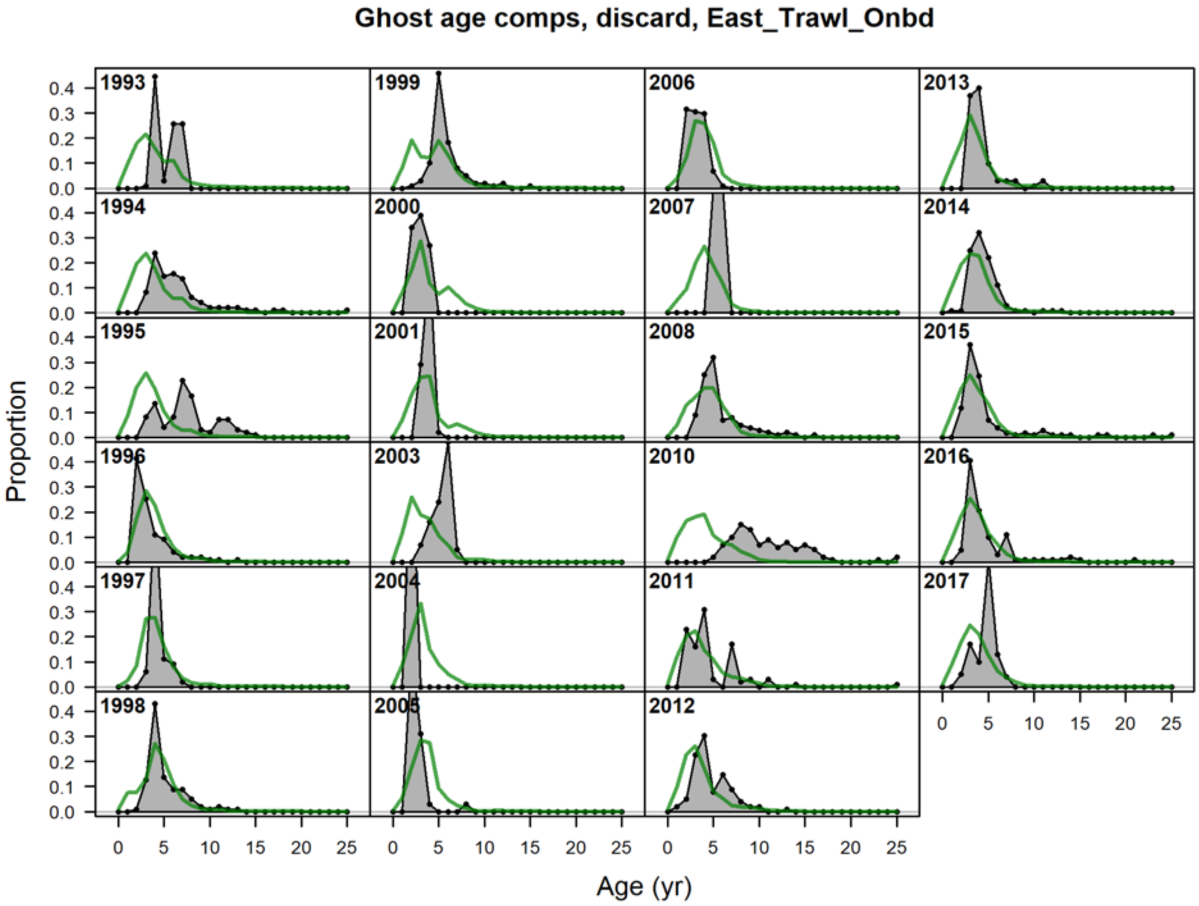

Figure A 6.23. Implied fits to age compositions for eastern jackass morwong eastern trawl onboard (discarded).

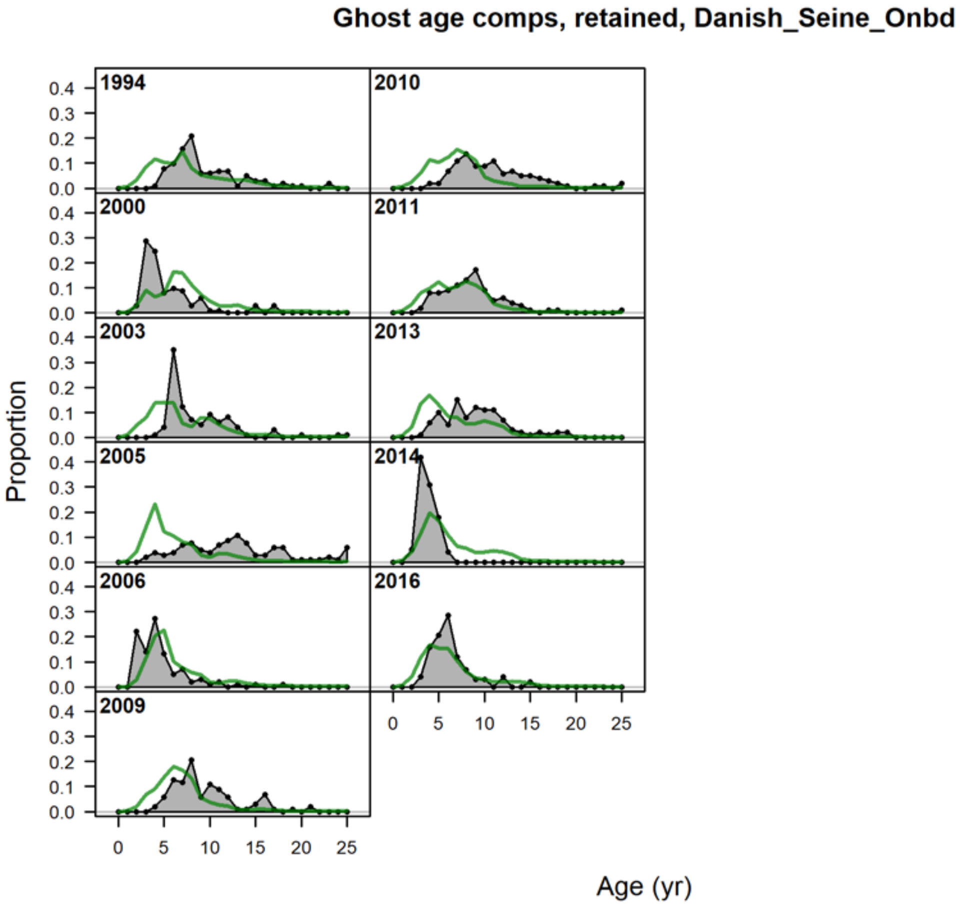

Figure A 6.24. Implied fits to age compositions for eastern jackass morwong Danish seine onboard (retained).

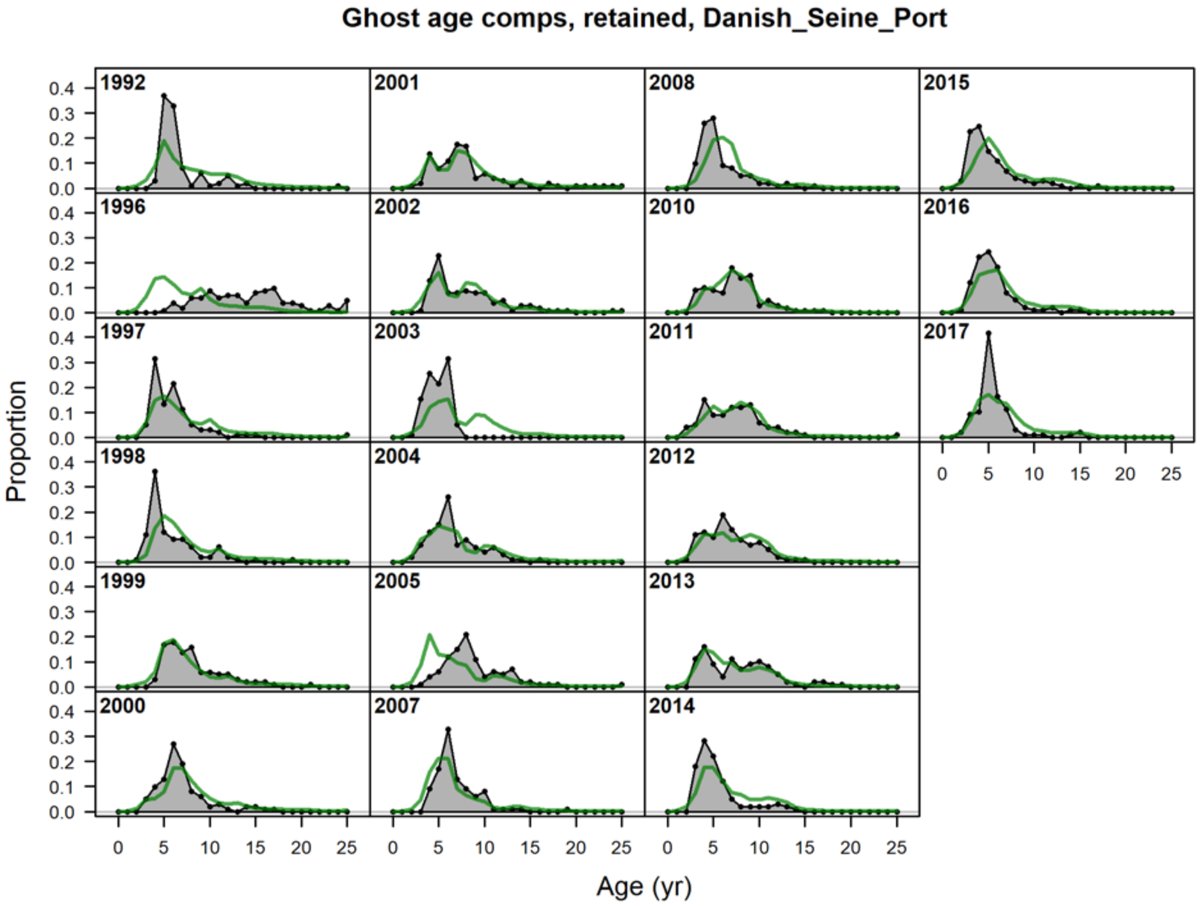

Figure A 6.25. Implied fits to age compositions for eastern jackass morwong Danish seine port (retained).

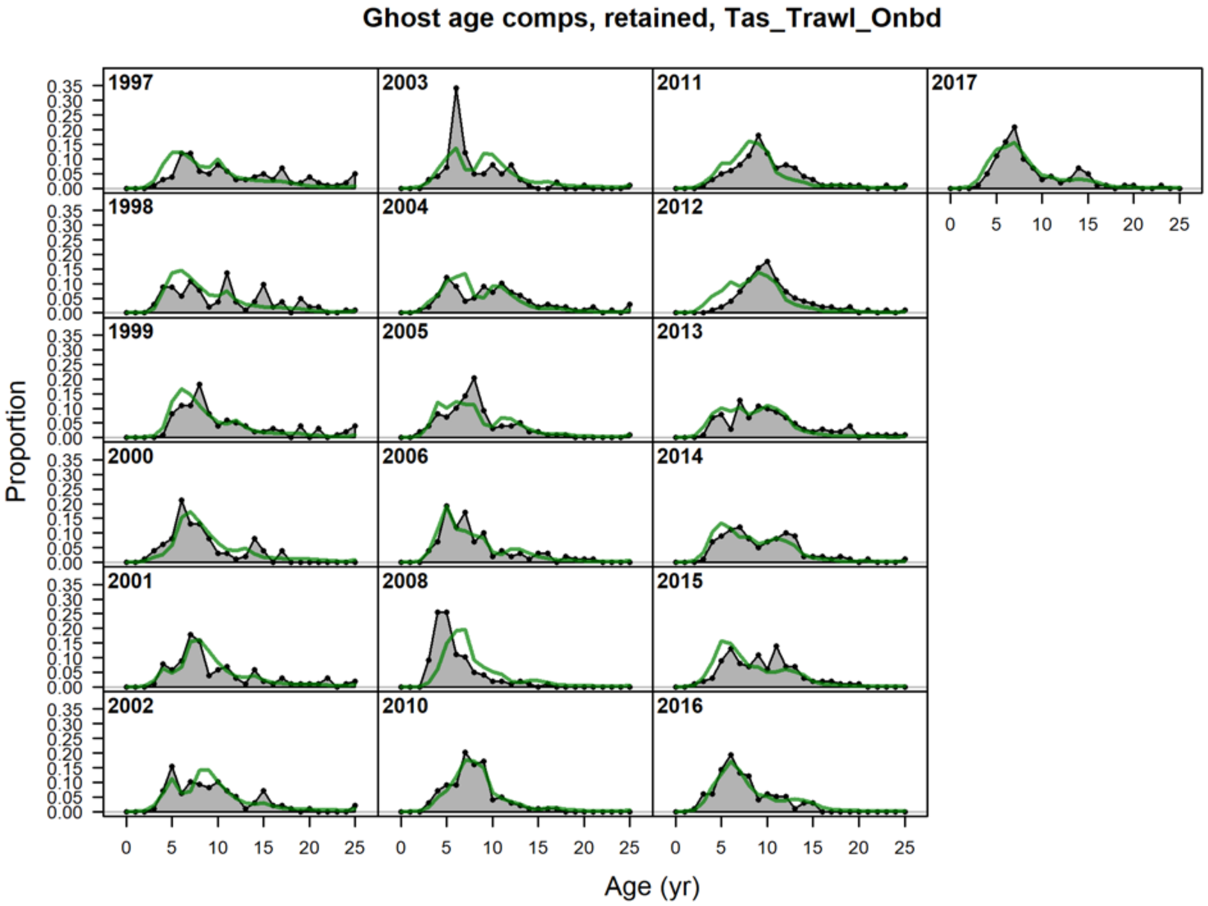

Figure A 6.26. Implied fits to age compositions for eastern jackass morwong Tasmanian trawl onboard (retained).

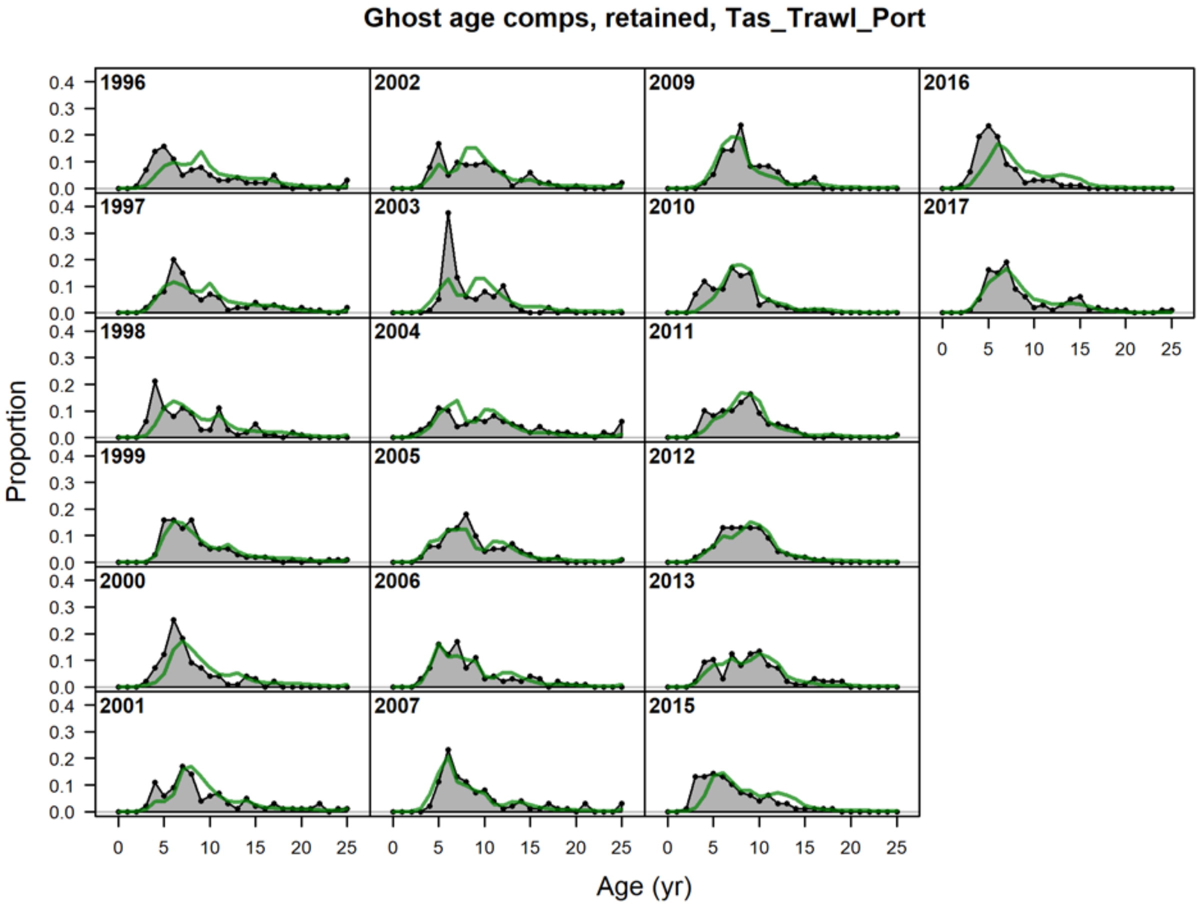

Figure A 6.27. Implied fits to age compositions for eastern jackass morwong Tasmanian trawl port (retained).

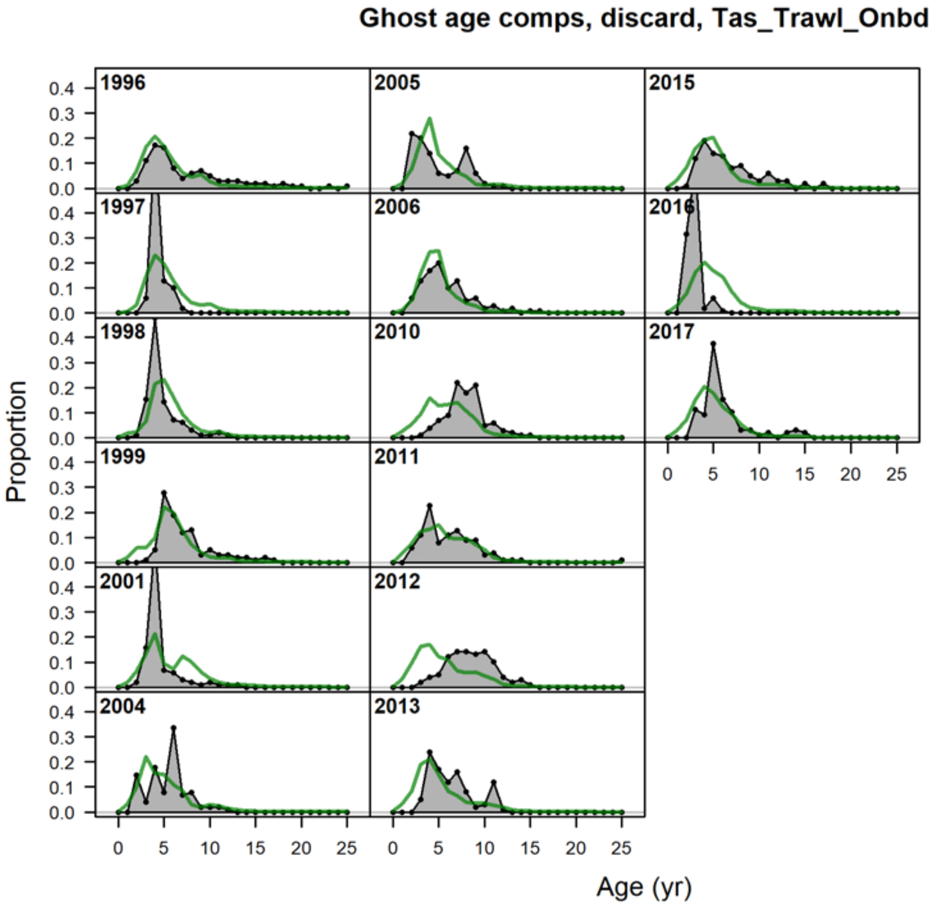

Figure A 6.28. Implied fits to age compositions for eastern jackass morwong Tasmanian trawl onboard (discarded).

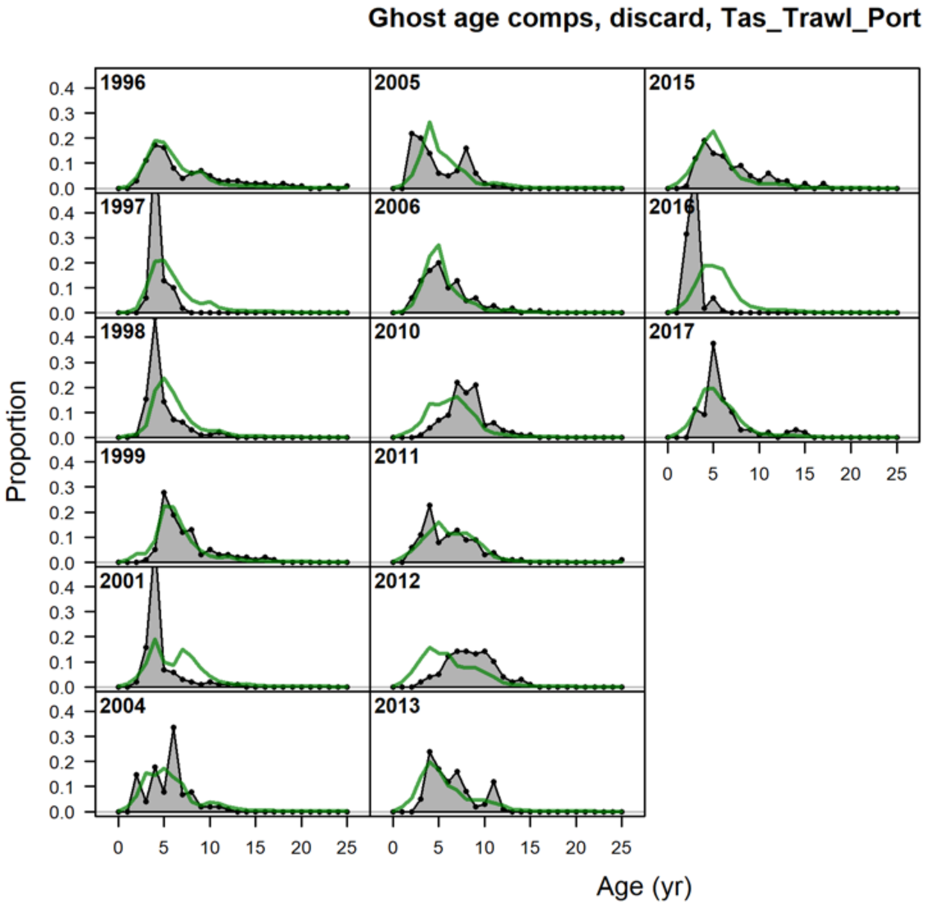

Figure A 6.29. Implied fits to age compositions for eastern jackass morwong Tasmanian trawl port (discarded).

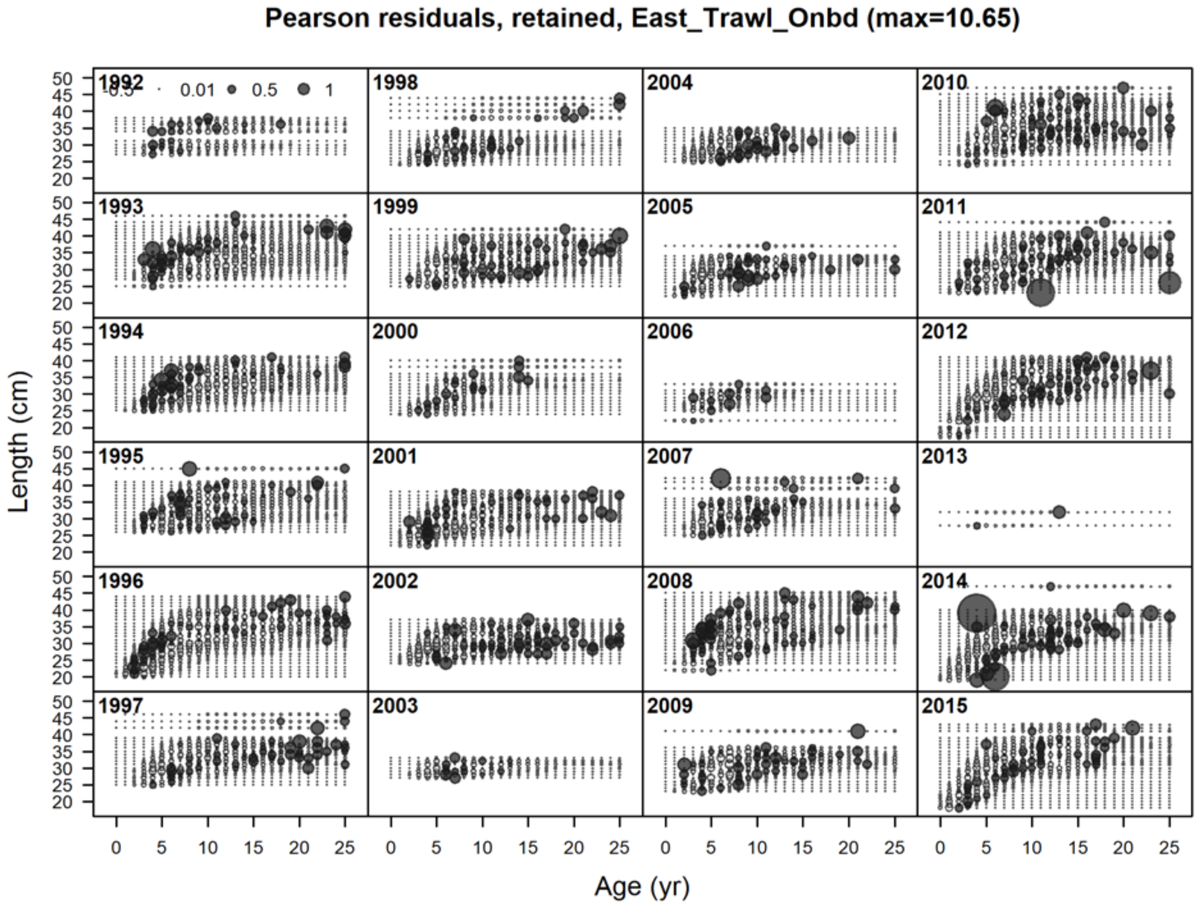

Figure A 6.30. Residuals from the fits to conditional age-at-length for eastern trawl (1/2). This plot gives some indication of the variability in the age samples from year to year.

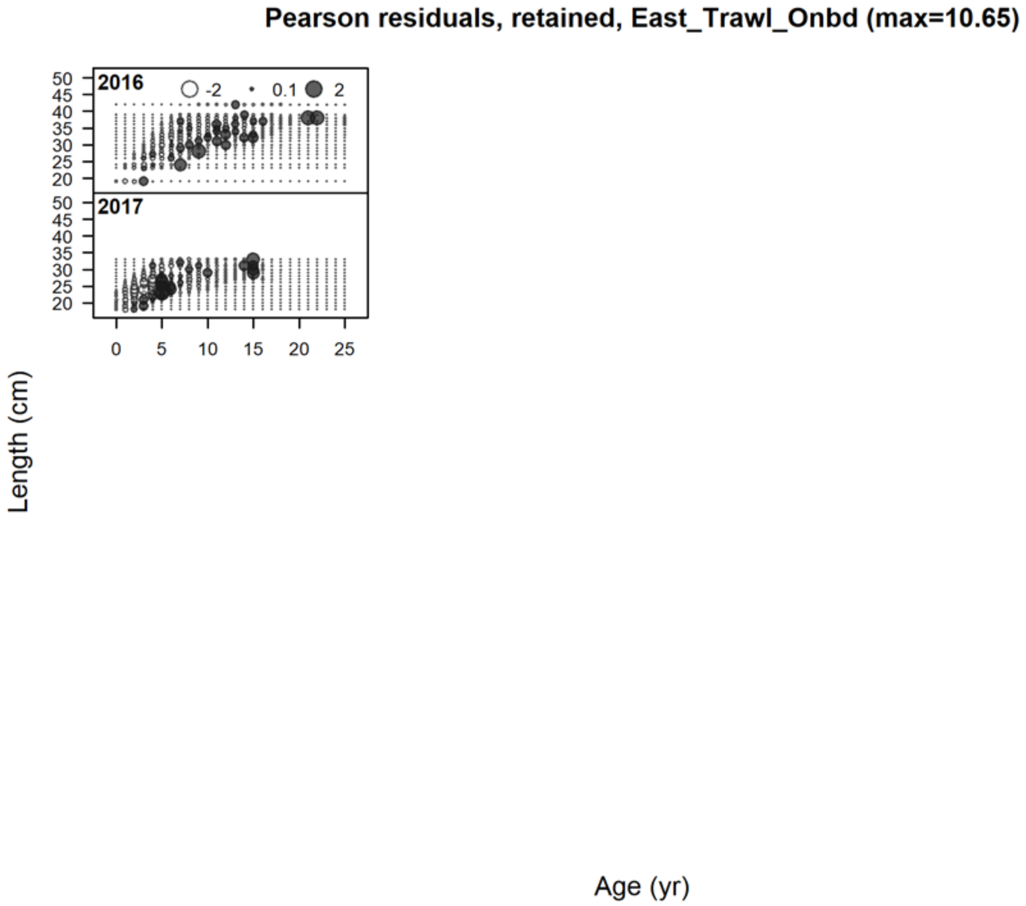

Figure A 6.31. Residuals from the fits to conditional age-at-length for eastern trawl (2/2). This plot gives some indication of the variability in the age samples from year to year.

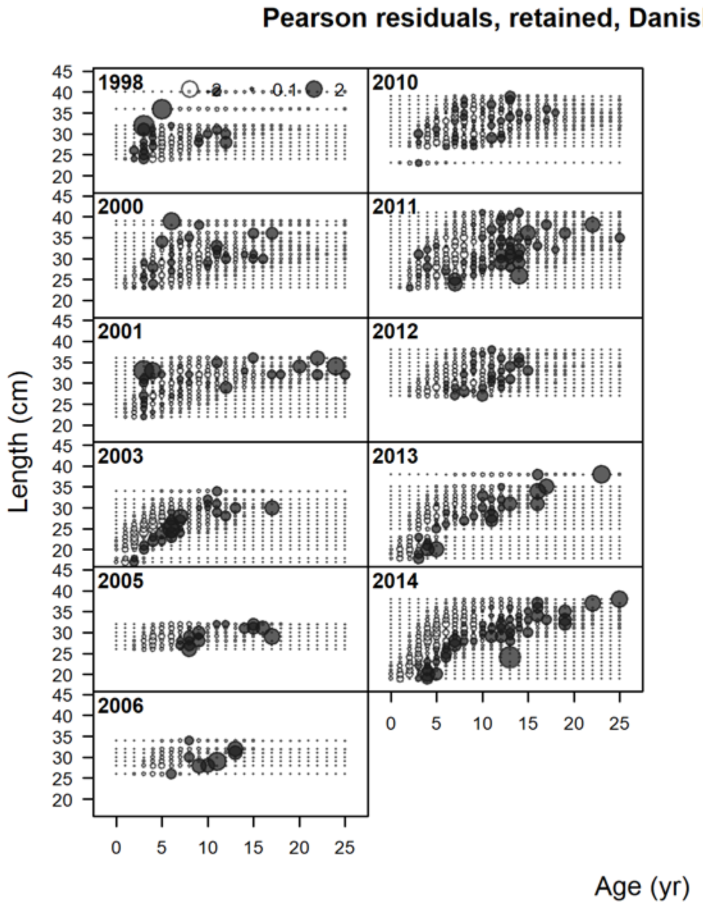

Figure A 6.32. Residuals from the fits to conditional age-at-length for Danish seine. This plot gives some indication of the variability in the age samples from year to year.

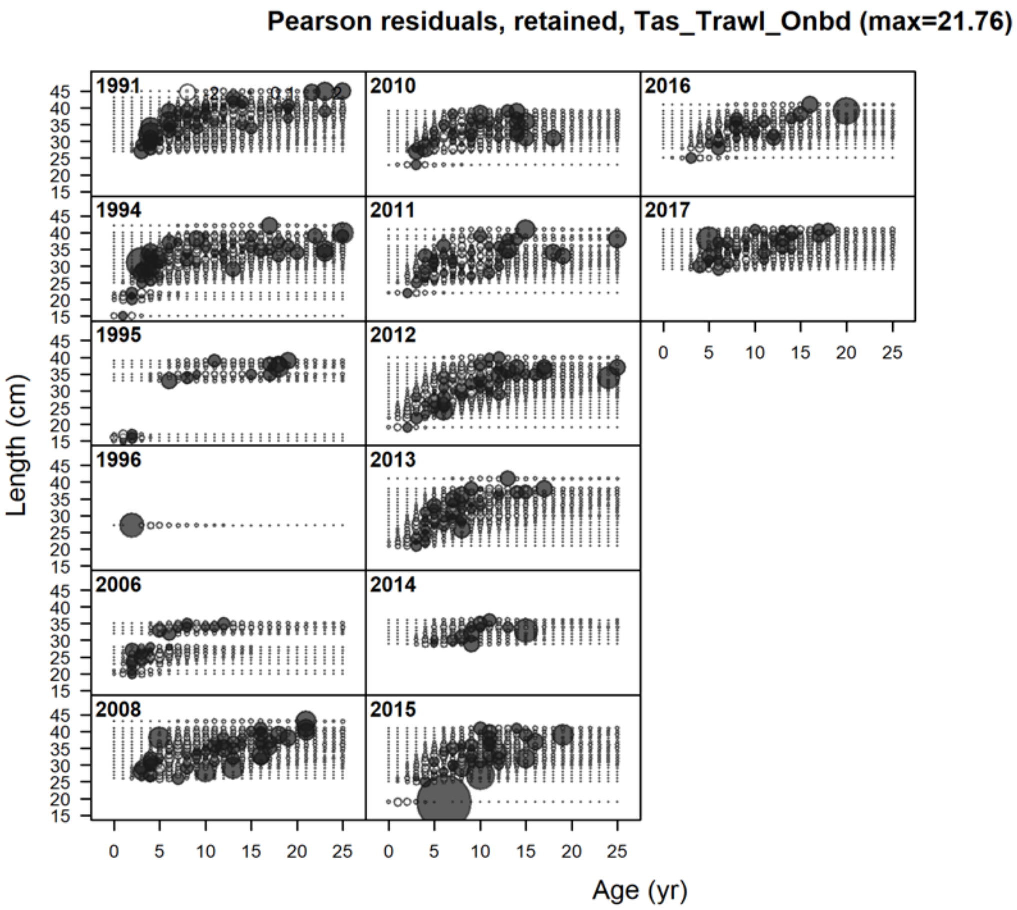

Figure A 6.33. Residuals from the fits to conditional age-at-length for Tasmanian trawl. This plot gives some indication of the variability in the age samples from year to year.

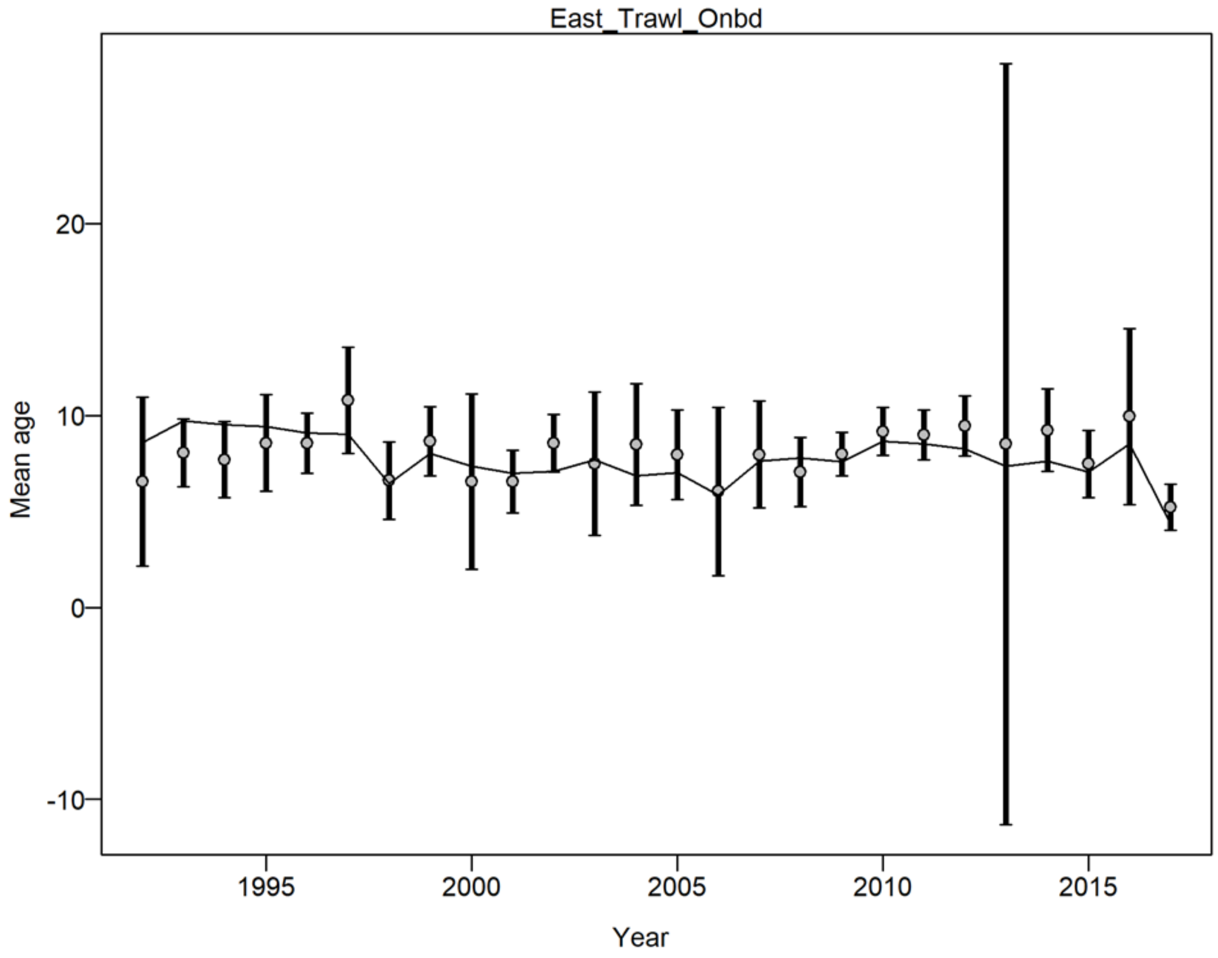

Figure A 6.34. Mean age (aggregated across length bins) for eastern jackass morwong from eastern trawl with 95% confidence intervals based on current samples sizes. Punt data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced. Yearly variation in the data is shown in changes in mean age, which can be large over a short period.

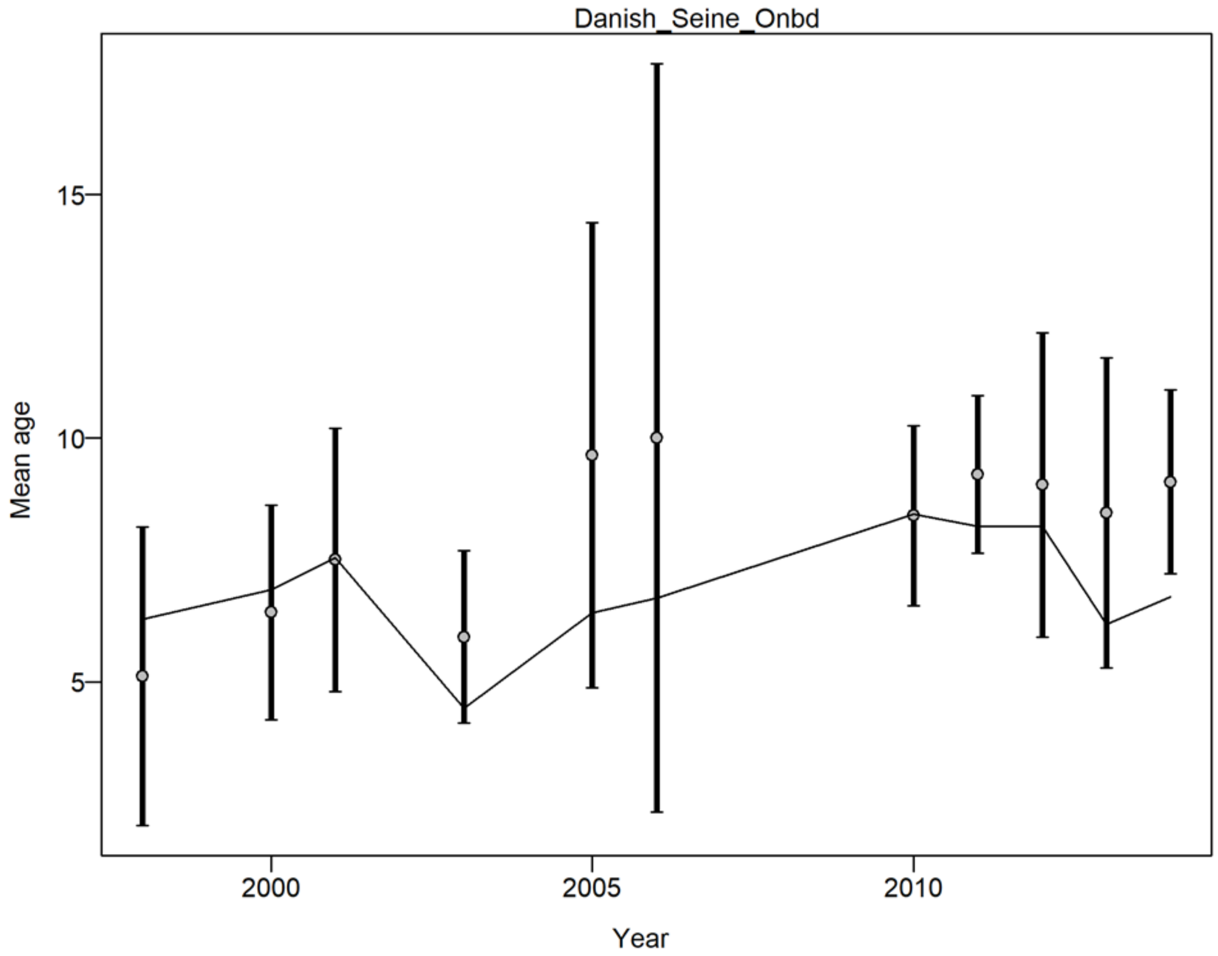

Figure A 6.35. Mean age (aggregated across length bins) for eastern jackass morwong from Danish seine with 95% confidence intervals based on current samples sizes. Punt data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced. Yearly variation in the data is shown in changes in mean age, which can be large over a short period.

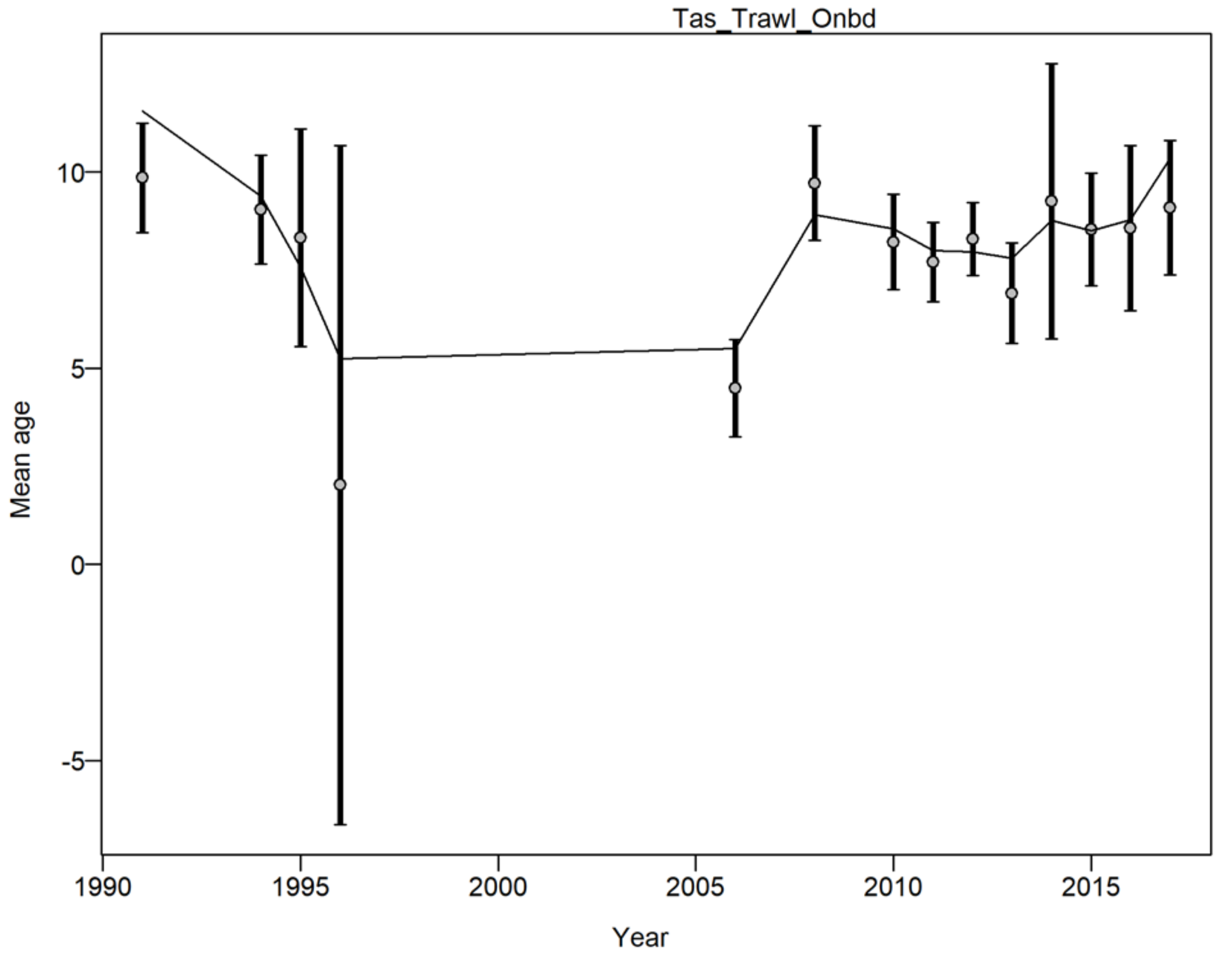

Figure A 6.36. Mean age (aggregated across length bins) for eastern jackass morwong from Tasmanian trawl with 95% confidence intervals based on current samples sizes. Punt data weighting method TA1.8: Thin capped lines matching thick lines indicate this is well balanced. Yearly variation in the data is shown in changes in mean age, which can be large over a short period.