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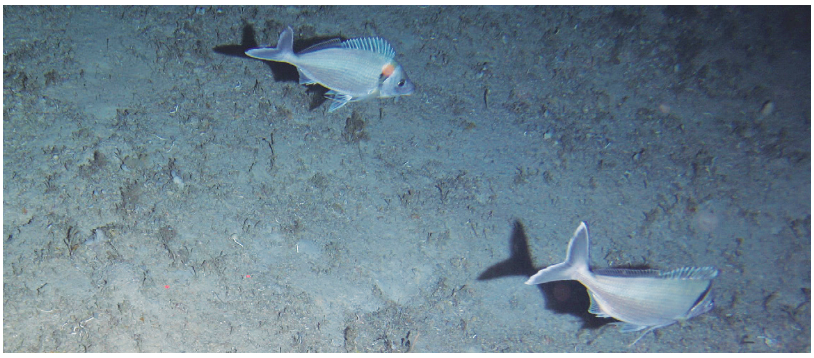
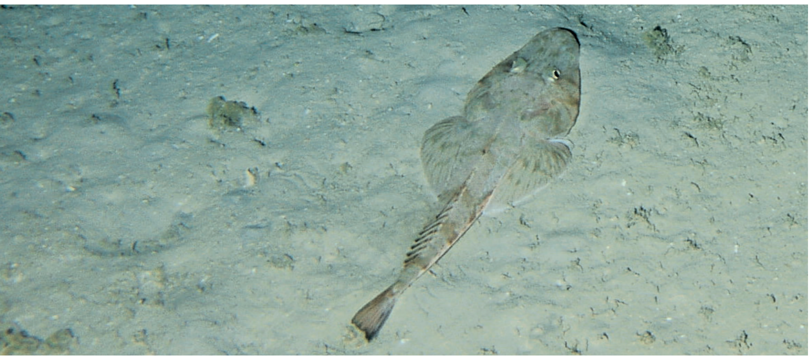
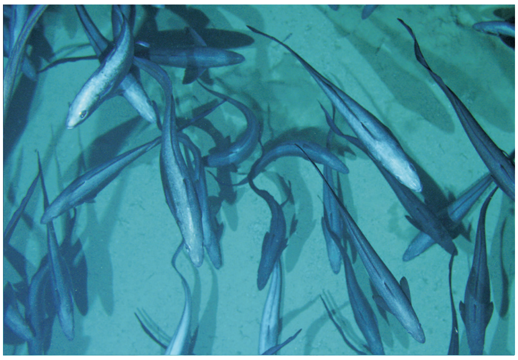
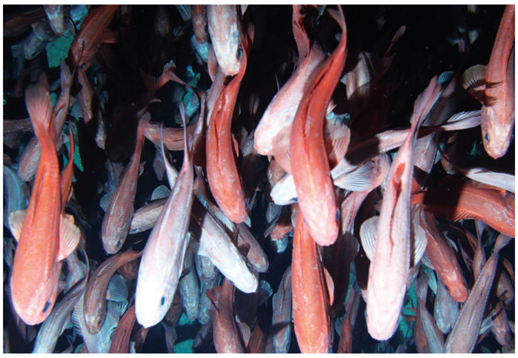
Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2015



PART 1







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Cover photographs

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

Report structure

Part 1 of this report describes the Tier 1 assessments of 2015. Part 2 describes the Tier 3 and Tier 4 assessments, catch rate standardisations and other work contributing to the assessment and management of SESSF stocks in 2015.

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

Part 1: Tier 1 assessments

G.N. Tuck
June 2016
Report 2014/0818

Australian Fisheries Management Authority

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

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1. Non-Technical Summary

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

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OBJECTIVE:

- Provide quantitative and qualitative species assessments in support of the five SESSF resource assessment groups.

1.1 Outcomes Achieved

The 2015 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.

1.2 General

Examination of break out rules of a multi-year TAC

An examination was made of whether recent actual CPUE trends are consistent with projected trends from the most recent Tier 1 stock assessments. Only species not planned for assessment in 2015 were examined, to allow RAG judgement of whether an assessment may be warranted. Of the species examined, observed CPUE does not fall within the forecast prediction interval for flathead (Danish Seine) and eastern gemfish, and is close to the lower bound for redfish. Observed CPUE lies within the forecast PI for school whiting, blue grenadier and, for the most part, pink ling. Standard CPUE breakout analyses were also conducted for deepwater flathead and Bight redfish in the GAB. Neither species was close to the edge of the projected 95% confidence intervals around the CPUE predicted from the projected Tier 1 assessments from earlier years. Western gemfish did not exhibit any exceptional deviations in CPUE from the long term average.

Breakout rules for gummy shark, given it is currently under a multi-year TAC (MYTAC), evaluate whether (1) the CPUE for the major component of the fishery (in Bass Strait) has fallen to a low level; (2) catches have fallen to a low level; (3) the new line sector is taking many more large and small sharks than forecast. The length-based breakout rule for gummy shark is designed to ensure that the size selectivity by the growing hook sector does not violate the assumptions on which the current MYTAC is based. None of the three breakout rules have been triggered during 2015.

Catch rate standardisations

Catch-per-unit-effort (CPUE) data is an important input to many of the stock assessments conducted within the South East and Southern Shark Fishery (SESSF), where it is used as an index of relative abundance through time. The catch and effort logbook data from the SESSF, which is the source of CPUE data, constitutes shot by shot data derived from a wide range of vessels, areas (zones), months, depths, and fishing gears. Catch rates used in the assessments are standardized to reduce the effects of factors such as which vessel fished, where and when fishing occurred, the gear used, at what depths fishing was conducted, and whether fishing occurred during the day or night. The intent is to focus on any changes in catch rates that occurred between years as a result of changes in stock size rather than changes that occur in any of these other factors. This intent is not always realized when there are unknown influential factors or factors for which we have no data, so interpretation of the catch rate trends should not necessarily be taken at face value. This is especially the case when there have been major management changes, such as the introduction of quotas or the more recent structural adjustment. Such large events can greatly influence fishing behaviour, which in turn influences catch rates. Because these changes affected the whole fleet at the same time it is not possible to standardize for their effects.

Catch rates, generally as kilograms per hour fished (though sometimes as catch per shot *e.g.* Danish Seine, or non-trawl methods), were natural log-transformed to normalize the data and stabilize the variance before standardization. A General Linear Model was used rather than using a Generalized Linear Model with a log-link. This simple analytical approach means that the exact same methods can be applied to all species/stock combinations in a relatively robust manner. The statistical models fitted were of the form: LnCE = Year + Vessel + Month + Depth Category + Zone + DayNight. There were interaction terms which could sometimes be fitted, such as Month:Zone or Month:Depth_Category. Data from all vessels reporting catches of a species were included although a preliminary data selection was made on a given depth range for each species for the zones of interest to focus attention on those depths contributing significantly to the fishery for each assumed stock and to reduce the number of empty categories within the statistical models.

Documented are the statistical standardization of the commercial catch and effort data for 23 species, distributed across 43 different combinations of stocks and fisheries ready for inclusion in the annual round of stock assessments. These include School Whiting, Eastern Gemfish, Jackass Morwong, Flathead, Redfish, Silver Trevally, Royal Red Prawn, Blue Eye, Blue Grenadier, Spotted/Silver Warehou, Blue Warehou, Pink Ling, Western Gemfish, Ocean Perch, John Dory, Mirror Dory, Ribaldo, Ocean Jackets, Deepwater Flathead and Bight Redfish.

Out of 43 stocks, there were nine whose catch rates have increased over the last 10 years; 13 stocks where catch rates were stable and 21 stocks whose catch rates have declined over the last 10 years. There were nine stocks whose catch rates have increased since the 2007 corresponding to the structural adjustment and introduction of the Harvest Strategy Policy; six stocks whose catch rates were stable and 28 stocks whose catch rates have declined over last seven year period. Many of the species were also examined for trends in catches and geometric catch rates between zones; this was to provide a check that there were only minor Year x Zone interactions (differences in catch rate trends between zones). The results from the standardisations are a key input to Tier 4 and Tier 1 assessments.

Tier 4 analyses 1986 - 2013

The Tier 4 harvest control rule is applied to species for which there is no reliable information on either current biomass levels or current exploitation rates. Ideally, in line with the notion of being more precautionary in the absence of information, the outcome from these analyses should be more conservative than those available from higher Tier analyses; this is now explicitly implemented by imposing a 15% discount factor on the RBC as a precautionary measure, unless there are good reasons for not imposing such a discount on particular species. The default procedure will now be to apply the discount factor unless RAGs generate advice that alternative and equivalent precautionary measures are in place (such as spatial or temporal closures) or that there is evidence of historical stability of the stock at current catch levels. Tier 4 analyses require, as a minimum, knowledge of the time series of total catches and of standardized catch rates.

Seven Tier 4 analyses were conducted and applied to Blue eye, western Jackass morwong and Mirror Dory. Jackass Morwong West generated a zero RBC, which reflects the recent strong reduction in CPUE in the western zones (40 and 50). The blue-eye trevalla analyses used two new time-series of standardized CPUE, which were based upon catch-per-hook rather than catch-per-record. These new CPUE analyses have flattened the time series in recent years and have produced a larger RBC than has been produced previously. In addition, a sensitivity analysis was conducted with the blue-eye analysis in which estimates of whale depredation on the auto-line fishery when it was developing are included to illustrate their potential impact. That analysis demonstrates that whale depredations would act to bias the actual kill and the CPUE low, and consequently would bias the RBC low. However, the estimate relates to a single vessel and extrapolating to the fleet adds a great deal of uncertainty. The analysis remains useful in demonstrating the potential bias, but the uncertainty means that care would be required if considering to use the whale depredation sensitivity to modify any catch recommendation. The analyses for Mirror Dory have been conducted for the whole of the Mirror Dory stock, treating the west and east as separate stocks, and also including the high levels of discards that occur in the east. The Mirror Dory RBCs were 488t (all areas), 129t (West only), and 362t (east only).

1.3 Slope and Deepwater Species

Silver warehou

The 2015 assessment for silver warehou (*Seriolella punctata*) first examined the data relating to the stock. Work examined data trends from the east and west regions (catch records, vessels, cpue), and data availability that may support proposed splits for assessment purposes. This work was used to assist the structural development of the base case assessment model used. The assessment was updated by the inclusion of data up to the end of 2014, which entails an additional three years of catch, discard, CPUE, length and age data since the 2012 assessment. Length frequency data collected onboard commercial trawl vessels was separated from those collected in port, but a joint selectivity pattern is estimated. Data collected east and west of 147˚ longitude have been separated in east and west fleets, each with its own selectivity pattern. Abundance time series for the east and west from the trawl Fishery Independent Survey were added. The model was restructured to allow estimation of size-base discarding, and recognises a change in the pattern of discarding from 2002. This, along with the addition of three more years of data, allows the estimation of five additional years of recruitment.

Results from the base-case assessment show reasonably good fits to the catch rate data. However, when comparing the observed and expected catch rate data points for the last 2 years in the series, the model may be overly optimistic and the stock could break out again in a relatively short time period. This assessment estimates that the projected 2016 spawning stock biomass will be 40% of virgin stock biomass. The RBC from the base case model for 2016 is 1,958t for the 20:35:48 harvest control rule, with a long-term yield of 2,281t. However, these scenarios assume recruitment will return to average levels. If future recruitment continues at a similar level to recruitment since 2003, then depletion could fall to around 30% before 2020. However, if landed catches continue at levels well below the TAC, then the depletion is likely to remain between 35% and 45% for the next 5 years.

Blue eye

Various issues relating to the standardisation of catch rates for blue eye (*Hyperoglyphe antarctica*) and its implications for management (including Tier 4) were reported. The 2013 standardizations, and the Tier 4 analyses dependent upon them, were no longer considered to provide an adequate representation of trends within, and hence the status of, the Blue-Eye fishery. The reported expansion of whale depredations on long-line catches in association with the changed behaviour of the fishing vessels in the presence of whales, along with the restriction of fishing location options due to an increase in the number of marine closures that were impacting on the availability of fishing grounds, and the recent movement of fishing effort much further north off the east coast of New South Wales and Queensland has altered the reliability of the current CPUE analyses as an indicator of Blue-Eye relative abundance.

Catch-per-record has been used for blue-eye CPUE since 2009. In 2009, the recording of effort in the two methods was a mixture of total number of hooks, number of lines with number of hooks per line, and other combinations (the main reason for moving to catch-per-record). Since then the data entry has been more consistent leading the way for an attempt at generating CPUE as catch-per-hook.

1.4 Shelf Species

Jackass morwong

The 2015 assessment of jackass morwong (*Nemadactylus macropterus*) included annual landings, catch rates, discard rates, and length/age compositions data up to the 2014 calendar year. Limited data were available for western morwong. The final assessment of the eastern stock of jackass morwong estimates the 2016 spawning biomass to be 36.5% of the 1988 equilibrium stock biomass. The female equilibrium spawning biomass in 1988 is estimated to be 3,977 t and in 2016 the female spawning biomass is estimated to be 1,451 t. The 2016 recommended biological catch (RBC) under the 20:35:48 harvest control rule for the base-case model is 314 t for the eastern stock of jackass morwong. The long-term RBC is 407 t. The 2015 base case assessment of the western stock of jackass morwong estimates the 2016 spawning biomass to be 69% of unexploited biomass. The female equilibrium spawning biomass in 1986 is estimated to be 1,349 t and in 2016 the female spawning biomass is estimated to be 936 t. The RBC for the base case assessment for the western stock of jackass morwong under the 20:35:48 harvest control rule is 249 t. The long-term RBC is 159 t.

Eastern gemfish

Work considered the potential influence of an additional survey point on the stock biomass estimation and recovery for eastern gemfish (*Rexea solandri*). Various levels of survey (above and below the 2008 estimate) were considered for the 2015 point. Depletion estimates varied between 0.12 and 0.16 in 2015; all were below the 0.20 limit reference point.

1.5 Shark Species

Shark fishery characterisation

The shark fishing industry are required to adhere to a catch ratio of 20% school shark : gummy shark by weight, as a means to achieve the management objectives of preventing targeting and minimising discarding. SharkRAG are in the process reviewing this ratio, to assess whether it is the optimal method for achieving the management objectives. A pertinent issue is whether school (*Galeorhinus galeus*) to gummy shark (*Mustelus antarcticus*) catch ratios differ spatially, and this was examined. Results showed that this ratio did vary spatially and also by gear, with line fishing for scalefish showing the largest ratios.

A description of standardised catch rates for elephant fish, saw, gummy and school shark was provided. Reported catches of school shark are low and those by trawler do not appear to be targeted, as evidenced by the large proportion of < 30 kg shots present in the logbook data. Nevertheless, the areas in which they are caught has not changed greatly and yet the standardized catch-per-unit effort has begun to increase significantly, with the exception of 2014 (although above the long-term average and associated with a 40% reduction in catch). This is a positive sign, which when combined with the observation of increased proportions of smaller school sharks in the ISMP sampling are a first clear evidence of school sharks showing some signs of increasing.

There has been an increase in reported gillnet catches of gummy shark and standardized CPUE in South Australia and Bass Strait during 2014. By contrast, standardized CPUE of gillnet caught gummy shark around Tasmania remained flat in 2014. Reported catches by bottom line remained at 228 t for both 2013 and 2014, while there was a drop of ~7 t reported (i.e. 18 t to 11 t) in 2014 relative to 2013 for trawl. CPUE standardizations for bottom line remained flat relative to the previous year, while those for trawl declined, but remain above the long-term average.

Elephant fish also constitute a non-targeted species, again with a large proportion of small shots (i.e. <30 kg). Gillnet standardized CPUE is also flat and noisy, however this analysis ignores discarding and uses number of shots instead of net length as a unit of effort. In the last few years discard rates for elephant fish have been very high, which may imply that their CPUE are in fact increasing. Catches of saws sharks are considered to be a bycatch and this is supported by the high proportion of reported < 30 kg catches reported in both gillnet and trawl caught fish. The standardized CPUE for gillnets exhibits a steady decline since about 2001. However, a detailed analysis should be considered towards using net length as an effort unit instead of shot. Trawl caught saw shark standardized indices exhibit a noisy but flat trend, with an increase in 2014 reaching the long term average. By contrast, saw shark standardized CPUE by Danish seine (which has the highest proportion of shots < 30 kg among methods) has been flat since 2006.

Saw shark and elephant fish Tier 4 analyses

The Tier 4 control rule is used to calculate RBCs for saw sharks (*Pristiophorus* sp.) and elephant fish (*Callorhinchus milii*). Standardized CPUE for both species were estimated using the Commonwealth logbook database only (instead of including earlier data into the same time series). This reflects the fact that the reference periods selected by SharkRAG derive from periods that are covered using the Commonwealth logbook data. Tier 4 analyses assume the target CPUE is a proxy for 48% of unfished biomass for both species (groups). However, neither species are reported as being targeted in the fishery (when using any method), so the calculated RBCs are inherently conservative. Alternative estimates based on a proxy target of 40% were therefore calculated, with RBCs varying between 127t and 429t for elephantfish and 226t (gillnet) and 650t (trawl) for sawshark.

1.6 GAB Species

Bight redfish

The 2015 assessment of Bight redfish (*Centroberyx gerrardi*) updates the 2011 assessment to provide estimates of stock status in the Great Australian Bight at the start of 2015/16 (end of 2014/2015). The base-case assessment estimates that the female spawning stock biomass at the start of 2015/2016 was 63% of unexploited female spawning stock biomass (SSB0). The 2016/2017 recommended biological catch (RBC) under the agreed 20:35:41 harvest control rule is 862 t and the long-term yield (assuming average recruitment in the future) is 537 t. The unexploited female spawning biomass was estimated as 5,451 t, with a total unfished equilibrium exploitable biomass of 16,042 t. This major reduction in the estimate from that made in 2012 reflects the fact that the data now available are more informative about the unfished biomass and stock status.

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)
- Slope and Deepwater Resource Assessment Group (Slope and Deep RAG)
- Shelf Resource Assessment Group (Shelf 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 (Slope/Deep, Shelf, 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 five 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

- Provide quantitative and qualitative species assessments in support of the five SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework.

5. Bight redfish (*Centroberyx gerrardi*) stock assessment using data to 2014/2015

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5.1 Summary

This chapter updates the 2011 assessment of Bight redfish (*Centroberyx gerrardi*) to provide estimates of stock status in the Great Australian Bight at the start of 2015/16 (end of 2014/2015). This assessment was performed using the stock assessment package Stock Synthesis (v3.24u) and included data from AFMA log-books, the ISMP sampling program, the ageing facility, and from Industry sampling programs.

The base-case assessment estimates that the female spawning stock biomass at the start of 2015/2016 was 63% of unexploited female spawning stock biomass (SSB_0). The 2016/2017 recommended biological catch (RBC) under the agreed 20:35:41 harvest control rule is 862 t and the long-term yield (assuming average recruitment in the future) is 537 t. Averaging the RBC over the three year period 2016/2017 – 2018/2019, generates a three year RBC of 828 t and over the five year period 2016/2017 – 2020/2021, the average RBC would be 797 t. The reduction reflects the gradually declining RBC predicted when projecting the assessment model to a depletion level of 41%B_0. Lower RBCs are generated using a 20:35:48 harvest control rule.

The acoustic indices are considered to be relative indices in the model in the sense that there are several factors that can lead to the acoustic biomass estimate differing from the biomass available to survey on average. Informative prior distributions were developed for the catchability coefficient for the acoustic surveys, and the Francis (2011) data weighting method was applied to select the weights for the age composition data, which led to more weight being assigned to the acoustic survey indices when the model was fitted. The other new data inputs were a revised egg survey estimate, a catchability coefficient for that survey, and an updated ageing error matrix using data from a recent re-ageing experiment (by Fish Ageing Services). The re-ageing experiment, which was designed to investigate between-year bias in age reads, found no evidence of a major bias in the early age readings for Eastern Zone orange roughy.

The unexploited female spawning biomass was estimated as 5,451 t, with a total unfished equilibrium exploitable biomass of 16,042 t. This major reduction in the estimate from that made in 2012 reflects the fact that the data now available are more informative about the unfished biomass and stock status.

Exploration of model sensitivity showed a variation in spawning biomass of between 57% and 69% of SSB_0, with this uncertainty largely driven by uncertainty over the estimate of natural mortality and size at maturity. These results are less uncertain than the previous assessments but now that the fisheries data are finally being informative about the state of the stock it remains possible that further data may enable the assessment to stabilize the RBC estimates between assessments.

5.2 Introduction

5.2.1 The Fishery

The trawl fishery in the GAB primarily targets two species, Bight redfish (*Centroberyx gerrardi*) and deepwater flathead (*Neoplatycephalus conatus*), and these have been fished sporadically in the Great Australian Bight (GAB) since the early 1900s (Kailola *et al*., 1993). The GAB trawl fishery (GABTF) was set up and managed as a developmental fishery in 1988, and since then a permanent fishery has been established with increasing catches of both species, although catches of Bight redfish have declined recently. Bight redfish are endemic to southern Australia, occurring from off Lancelin in WA to Bass Strait in depths from 10m to 500m. Deepwater flathead are also endemic to Australia and inhabit waters from NW Tasmania, west to north of Geraldton in WA in depths from 70m to more than 490m (Kailola *et al*., 1993; www.fishbase.org). The two species are often caught in the same trawl tows although Bight redfish is most commonly taken in the east of the GAB.

5.2.2 Previous Assessments

An initial stock assessment workshop for the GABTF held in 1992 focused on the status of deepwater flathead and Bight redfish. Sources of information for the workshop included historical data, logbook catch data, observer data and biological information. With so few years of data available at that time catch-per-unit-area (kg/km^2) was calculated for quarter-degree squares and then scaled to the total area in which the species had been recorded. The approximate exploitable biomass estimates for deepwater flathead and Bight redfish obtained by this crude method were 32,000t and 12,000t respectively (Tilzey and Wise 1999). Large uncertainties in the method prevented calculation of error bounds.

Wise and Tilzey (2000) produced the first attempt to assess the status of Bight redfish using an age- and sex-structured stock assessment model. The virgin total biomass estimates for the base case model was 9,095t (4,924 – 13,266t). In 2002 an updated assessment was carried out for Bight redfish and the unexploited biomass estimates for the base case model was then 9,563t (8,368 – 10,759).

GABTF assessments in 2005 (Wise and Klaer, 2006; Klaer, 2006) used a custom-designed integrated assessment model developed using the AD Model Builder software (Fournier *et al*., 2012). A series of fishery-independent resource surveys was also commenced in 2005, providing a single annual biomass estimate for Bight redfish and deepwater flathead (Knuckey *et al*., 2015), plus extra samples of length and age composition data. Initially, attempts were made to make absolute abundance estimates using classical swept area methods from the survey data. The unexploited biomass level estimated using this approach was 13,932t and current depletion level was estimated at 75% for Bight redfish.

The 2006 assessment (Klaer and Day, 2007) duplicated as far as possible the assessment results from 2005 using the Stock Synthesis (SS) framework. Although it was possible to replicate 2005 results reasonably well, there were a few differences in the model structure implemented in SS2 including calculation of recruitment residuals independently and allowing recruitment residuals to occur prior to the commencement of the fishery.

An attempt was made to incorporate as much previously unused data as possible into the 2007 assessment - particularly length-frequencies (Klaer, 2007). Age-frequencies were no longer used explicitly but conditional age-at-length distributions were obtained from age-length keys. In addition, the model used original age-at-length measurements to fit growth curves within the model, to better allow for the interaction between selectivity and the growth parameters. Depletion of Bight redfish in 2007 was estimated at 82%, and the unexploited female spawning biomass was estimated at 18,685t.

The model structure for the 2009 assessment for Bight redfish (Klaer 2010) was similar to the 2007 assessment, but used a more recent version of Stock Synthesis - SS3. Differences were the use of the fishery independent survey as a relative abundance index, estimation of fewer growth parameters, estimation of the natural mortality rate, and adjustment of the relative weighting of abundance indices versus length and age composition information. The unexploited female biomass was estimated at 12,272t and the depletion at 77%.

Finally, in 2011, the Bight redfish assessment was updated using the latest version of SS3 (SS3.21d) and the latest data on ISMP collected length and age composition as well as the standardized CPUE and FIS estimates of relative abundance (Klaer, 2012a,b). This led to an estimate of unfished female spawning biomass of 26,210 t and a spawning biomass depletion estimate of 90% (Table 5.1).

Table 5.1. A summary of previous stock assessment outcomes for Bight redfish. The year of assessment usually relates to the final year of data collection, which is the fishing year involved (thus, 2011 is for the year 2010/2011). B0 is the unfished female spawning biomass. The yield is the RBC for the following year with the long term estimated sustainable yield in brackets for some years. The 1999 biomass estimate is of exploitable biomass while the rest reflect female spawning biomass.

Year	Authors	B0 (t)	Depletion	Yield (t) RBC
1999	Tilzey and Wise(1999)	~12000	-	200 - 400
2000	Wise and Tilzey(2000)	9095		
2002	Wise and Tilzey	9563		
2005	Wise and Klaer (2006)	12323	>79%	
2005	Klaer (2006)	24282		
2006	Klaer and Day (2007)	31660	94	4040 ()
2007	Klaer (2007)	18685	82	1524 ()
2009	Klaer (2010)	12272	77	1653 (948)
2011	Klaer (2012b)	26210	90	4407 (2143)

5.2.3 *Modifications to the Previous Assessment*

An initial base case was developed and presented to the GAB RAB in October 2015; this was used to describe the changes wrought on the previous assessment by the sequential addition of the new data now available along with other minor structural changes.

The latest version of the SS3 software was applied (SS3.24u; Methot and Wetzel, 2013) and then an array of data updates were applied, including some data streams that had not been used previously. The estimate of unfished female spawning biomass was greatly changed so a number of extra steps were included to ensure the changes were only due to the addition of new data.

The changes are described in a set different manipulations and changes to the old assessment:

1. Repeat the assessment from 2011 using the new software version SS3.24u
2. Use the older version of SS3 (SS3.24f) to test the effect of using new software.
3. Add catch and commercial CPUE to 2014/15.

4. Add survey abundance estimates to 2014/15.
5. Add length composition data from 2011/12 to 2014/15; a new step this year was to keep the port and on-board ISMP data separate. In addition, length composition data from all surveys were included and, again new this year, the on-board length composition data obtained through crew sampling from 2010/2011 – 2014/2015 were also included.
6. Estimate the selectivity curve for the Fishery Independent Survey.
7. Add age composition data from 2011/12 to 2014/15.
8. Add the ageing error matrix.
9. Estimate $L_{\min}$ (a growth curve parameter).
10. Again use the older version of SS3 (SS3.24f) to test the effect of using new software.
11. New to this assessment, add the age composition data from the FIS for the years 2008/2009, 2010/2011, and 2014/2015, in which it is available.
12. Use variance estimates around the recruitment deviates to set the last estimated recruitment to 2004/2005. Accept fitted recruitment deviation bias adjustment values.
13. The variance of the different length and age composition data and the CPUE data were balanced to generate the initial base case. The balancing procedure this year attempts to apply more emphasis to the CPUE time series. The model balancing also involved increasing the recruitment variation from 0.2 to 0.34 as further bias adjustments were required after adjusting the variance estimates on different data streams.

Once the base case was completed its dynamics were projected forwards for 40 years to estimate the long term RBC that would, at equilibrium, keep the stock to the MEY proxy target of 41%B_0 (Kompas *et al*., 2011).

Following the projections, 18 sensitivity analyses were conducted to provide a test of the structural assumptions made in the formulation of the assessment model. Likelihood profiles were also produced for natural mortality and for the size at 50% maturity.

5.3 Methods

5.3.1 The Data and Model Inputs

5.3.1.1 Biological Parameters

Male and female Bight redfish are assumed to have the same biological parameters except for the length-weight relationship (Table 5.2).

Three of the four parameters relating to the Von Bertalanffy growth equation are estimated within the model-fitting procedure from the observed age-at-length data. This approach attempts to account for the impact of gear selectivity on the age-at-length data collected from the fishery and any impacts of ageing error.

The rate of natural mortality per year, M, is estimated in the base-case model, with the estimated value being close to 0.1; the model outcomes are so sensitive to this parameter that a likelihood profile, where M is given a series of fixed values and all other parameters are re-fitted to determine the effect on the total likelihood and other model outputs was conducted.

Maturity is modelled as a logistic function, with 50% maturity at 25 cm. Changing the size at maturity has almost no effect on the quality of the model fit but has a large effect on the estimates of stock biomass and status so a likelihood profile of size-at-maturity was also conducted. Fecundity-at-length is assumed to be proportional to weight-at-length.

The assessment data for Bight redfish comes from a single trawl fleet; although there is now a Danish seine vessel operating and some pair-trawling occurring in the GAB.

Table 5.2. Summary of selected parameters from the base case model. Sources: (1) Analyses of biological samples collected during the 2004 GAB reproductive study (Brown and Sivakumaran, 2007), (2) length and age samples collected between 2000-2003 and (3) length samples collected during the 2001 FRDC project

Description	Source	Parameter	Combined Male/Female	
Years		y	1960-2014	
Recruitment Deviates		r	est 1960 - 2005	
Fleets			1 trawl only	
Discards			none significant, not Fitted	
Age classes		a	0-65 years	
Sex ratio		p_s	0.5 (1:1)	
Natural mortality		M	estimated (0.1) per year	
Steepness		h	0.75	
Recruitment variation		σ_r	0.35	
Female maturity	1		25 cm (SL)	
Growth	2	L_{max}	37.939 cm (SL)	
		K	fitted	
		L_{min}	fitted	
		CV	fitted	
			Female	Male
Length-weight (based	3	f_1	0.000128 cm (SL)/gm	0.000144
on standard length)		f_2	2.559	2.522

5.3.1.2 Available Data

An array of different data sources are available for the Bight redfish assessment including catch (landings plus discards), standardized commercial CPUE, an index of relative abundance from the Fishery Independent Survey (FIS), age composition data from the Integrated Scientific Monitoring Program (ISMP) and from the FIS, and length composition data from the ISMP (keeping port sampling separate from the on-board sampling), from the FIS, and from crew sampling from on-board (Figure 5.1). Age-at-length composition data for the fleet designated Trawl and the FIS were calculated from the available length compositions and conditional age-at-length data (age-length keys). These do not comprise additional data and are not included in the fitting of the model but are shown for information.

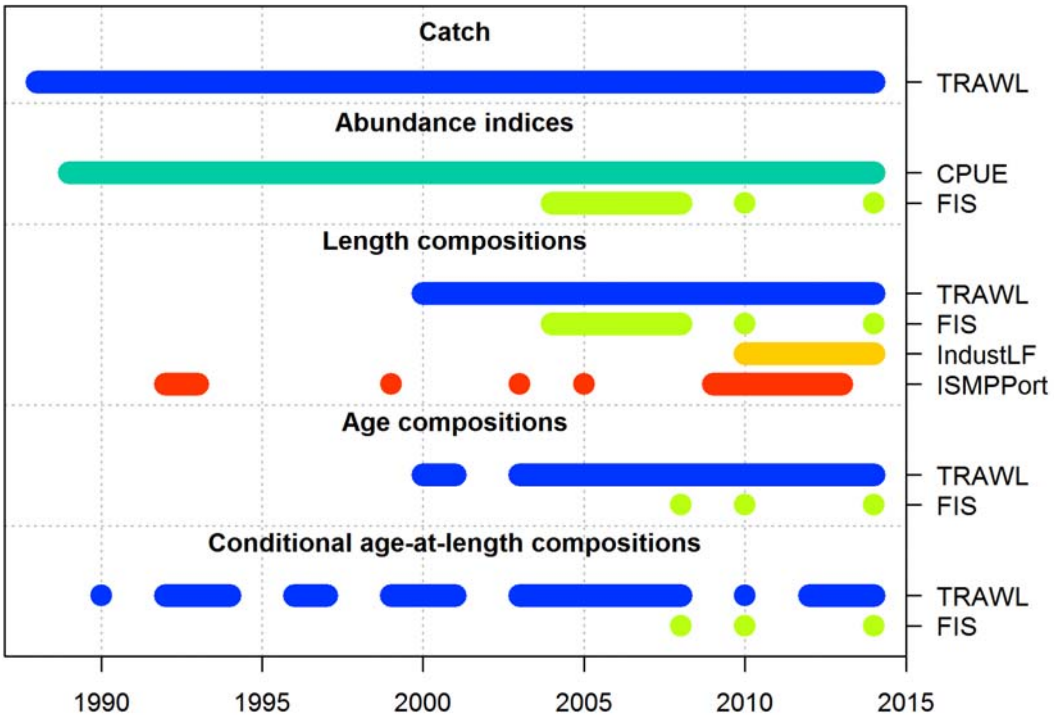

Figure 5.1. Data availability by type and year. The year axis denotes the first year of the financial year, thus 1995 = 1995/1996.

A landed catch history for Bight redfish is available for the years from 1988/1989 to 2014/2015 (Figure 5.2; Table 5.3). Landed catches were derived from GAB logbook records for the years to about 2000, and catch disposal records have been the source of total landings since then. All landings were aggregated by financial year.

In 2007 the quota year was changed from calendar year to the year extending from 1 May to 30 April. As the assessment is conducted according to financial year, the recent quota year change has resulted in closer alignment of the assessment and quota years. In the intervening year the quota year was extended to 16 months to allow for this change, which is one reason catches were elevated in the 2006/2007 year (Table 5.3).

In order to calculate the Recommended Biological Catch (RBC) for 2016/2017, it is necessary to estimate the financial year catch for 2015/2016. TACs have been substantially under-caught in recent years and so the 2015/2016 catch was assumed to be the same as the catch in 2014/2015 - 238t.

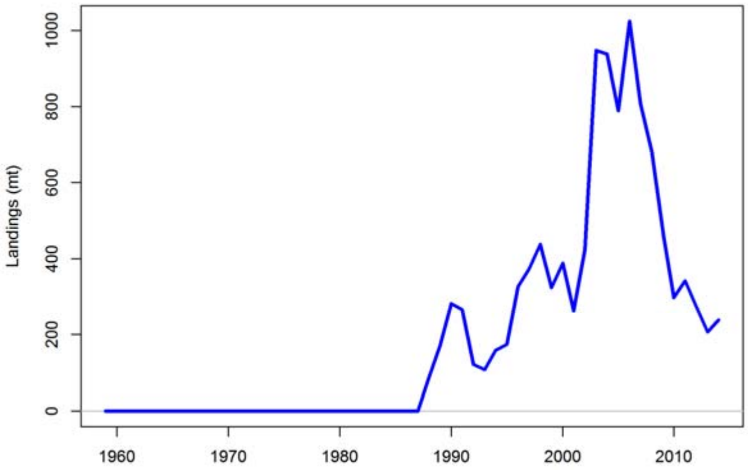

Figure 5.2. Total reported landed catch of Bight redfish 1987/1988 – 2014/2015 (see Table 5.3).

Table 5.3. Financial year values and estimates of total catch, standardized CPUE, the geometric mean CPUE, and number of vessels reporting Bight redfish in the GAB from 1988/1989 – 2014/2015. Discards are assumed to be trivial. Standardized CPUE is from Sporcic (2015).

Fishing Year	Catch	CPUE	Geometric Mean	Vessels
1988/1989	85.651			
1989/1990	170.833	1.744	31.605	7
1990/1991	281.808	1.580	36.646	8
1991/1992	265.612	1.507	27.318	8
1992/1993	120.698	1.144	18.338	3
1993/1994	107.472	1.046	16.240	5
1994/1995	157.803	0.724	11.724	6
1995/1996	173.922	0.860	11.802	5
1996/1997	327.177	0.969	15.335	6
1997/1998	372.617	1.039	16.023	7
1998/1999	437.788	1.204	20.206	7
1999/2000	323.641	1.077	17.185	7
2000/2001	387.879	0.925	15.649	5
2001/2002	262.613	0.675	10.857	5
2002/2003	424.672	0.742	13.466	8
2003/2004	946.477	1.087	20.110	10
2004/2005	937.456	1.010	18.368	9
2005/2006	789.704	0.972	17.406	10
2006/2007	1023.908	1.057	21.764	10
2007/2008	808.024	1.016	20.099	6
2008/2009	681.885	1.101	21.905	4
2009/2010	469.696	0.959	17.379	4
2010/2011	297.596	0.797	14.267	4
2011/2012	341.481	0.802	14.426	4
2012/2013	273.451	0.694	15.270	4
2013/2014	207.051	0.646	14.613	4
2014/2015	238.327	0.625	10.462	4

5.3.1.3 Catch Rate Indices

Previously, commercial catch rates have been standardised using Generalised Additive Models (GAMs) (Hobsbawn et al. 2002a, 2002b) and a log-linear model (Klaer, 2007). Standardisations for a range of SESSF species are carried out each year (see Haddon, 2014a,b; Sporcic, 2015) and Bight redfish is now included in the list of species analysed each year.

"Data from the GAB fishery used in the analysis was based on depths between 0 – 1000 m, taken by Trawl. Also, analyses were restricted to vessels present for more than two years and which caught an average annual catch > 4 t, and that trawled for more than one hour but less than 10 hours. Instead of 5 degree zones across the GAB, 2.5 degree zones were employed to allow better resolution of location based differences in CPUE. An examination of the depth distribution of catches suggests that this could be modified to become 100 – 250 m with essentially no loss of information and the outcomes do not differ from the base case adopted here; All vessels and 0 – 1000 m). Catches in 1986/1987 were relatively low and only taken by a single vessel and so were omitted from analysis." (Sporcic, 2015, p209)

The point about the depth categories used is important, as the inclusion of relatively empty depth categories introduces more noise than information into an analysis (Table 5.4). It is recommended that the depth range used in the standardization should be reduced at least to 0 – 500m in future analyses.

Table 5.4. The number of records and catch reported by different depth categories. Approximately 3 t of catch has been reported from below 1000m across the duration of the fishery, and 6.381 t has been reported from depths greater than 500m.

50 m Depth Categories					25 m Depth Categories		
Depth	Records	Catch (t)	Percent	Cumulative%	Depth	Records	Catch (t)
0	107	2.584	0.025	0.025	0	93	2.295
50	4963	40.066	0.383	0.407	25	1515	10.788
100	11432	1444.128	13.790	14.197	50	3462	29.567
150	40580	8515.162	81.309	95.506	75	1898	37.178
200	2975	424.509	4.054	99.560	100	7246	1050.813
250	299	22.563	0.215	99.775	125	33298	7103.245
300	49	3.876	0.037	99.812	150	9570	1768.056
350	31	1.223	0.012	99.824	175	2162	357.659
400	28	0.746	0.007	99.831	200	777	65.668
450	17	3.269	0.031	99.862	225	210	10.168
500	15	5.044	0.048	99.911	250	125	13.577
550	16	2.012	0.019	99.930	275	32	1.939
600	9	1.378	0.013	99.943	300	17	1.937
650	7	1.556	0.015	99.958	325	17	0.418
700	1	0.040	0.000	99.958	350	14	0.805
750	3	0.480	0.005	99.963	375	18	0.295
800	1	0.020	0.000	99.963	400	10	0.451
850	1	0.010	0.000	99.963	425	9	0.971
900	3	0.355	0.003	99.966	450	8	2.298
950	2	0.500	0.005	99.971	475	5	0.613
1000	1	0.030	0.000	99.971	500	10	4.432

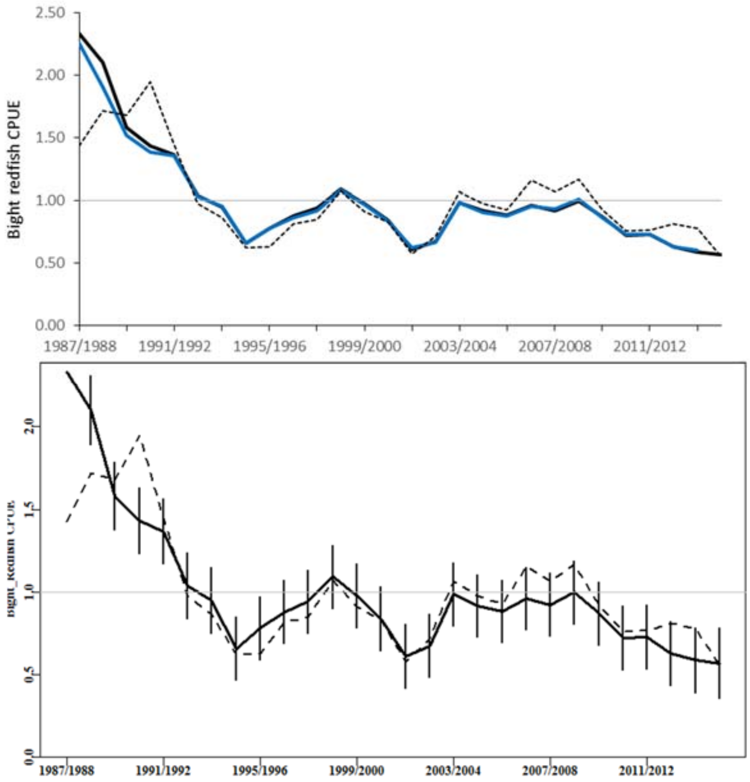

Figure 5.3. The standardized CPUE for Bight Redfish from the trawl fishery in the GAB (copied from Sporcic, 2015, p 212). Upper graph: solid black line the standardized catch rates (relative to the mean of the standardized catch rates). The blue line corresponds to last year's standardized catch rates. Lower graph: Standardized indices (solid black line), 95% CI (vertical lines) and geometric mean (dashed black line). This illustrates the impact on the relative uncertainty of the relatively small number of records, especially in the early years.

5.3.1.4 Fishery Independent Survey Abundance Estimates

There are now seven estimates of relative abundance from the FIS (Table 5.5; Knuckey, *et al*., 2015). The variation relative to the individual abundance estimates are used initially, but in the process of balancing the output variability with that input, these values were greatly expanded. These data were included in the assessment as they were previously (Klaer, 2012).

Table 5.5. FIS relative abundance estimates for Bight redfish, with each survey estimate's coefficient of variation.

Year	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2010/2011	2014/2015
Estimate	20887	25380	25713	14591	27610	13189	3633
CV	0.13	0.16	0.16	0.11	0.18	0.13	0.20

5.3.1.5 Age Composition Data

Previously (Klaer, 2012), age composition data from the ISMP sampling was mixed up with three years of FIS age data. In this current assessment the ISMP age composition data is included as previously but now the ageing data from three years of the FIS are included separately (2008/2009, 2010/2011, and 2014/2015).

The ISMP ageing data illustrates that since about 2006/2007 the proportion of older fish has declined (Table 5.4). While a comparison of the age composition seen in the FIS years and the ISMP samples from the same financial year (Figure 5.5) suggests similarities, although the progression of two modes of age classes appears clearer in the FIS data and, at least in the last two years of the FIS, there appear to be a higher proportion of older fish present in the FIS samples.

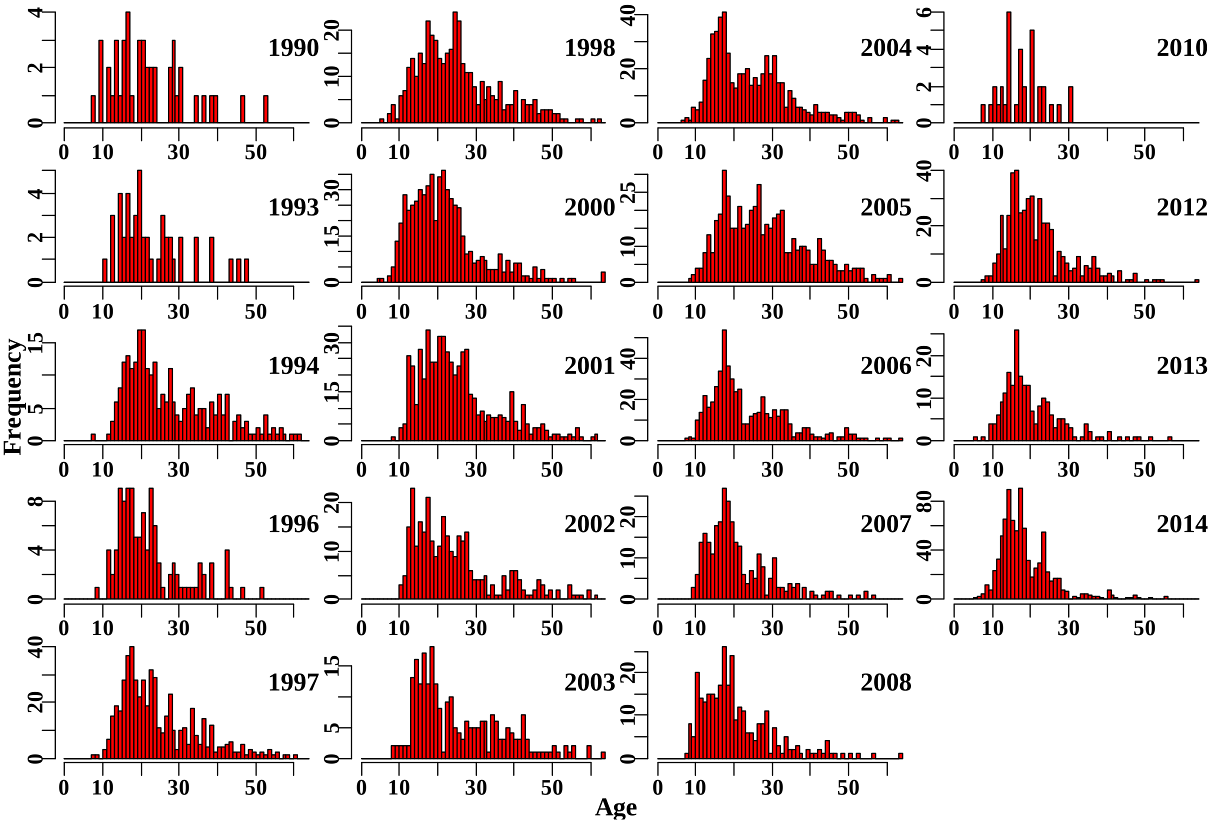

Figure 5.4. All ISMP ageing data used by year, illustrating the relative sample size and the relatively recent contraction in the older age classes. Each year label relates to the first year of the financial year; 2000 = 2000/2001.

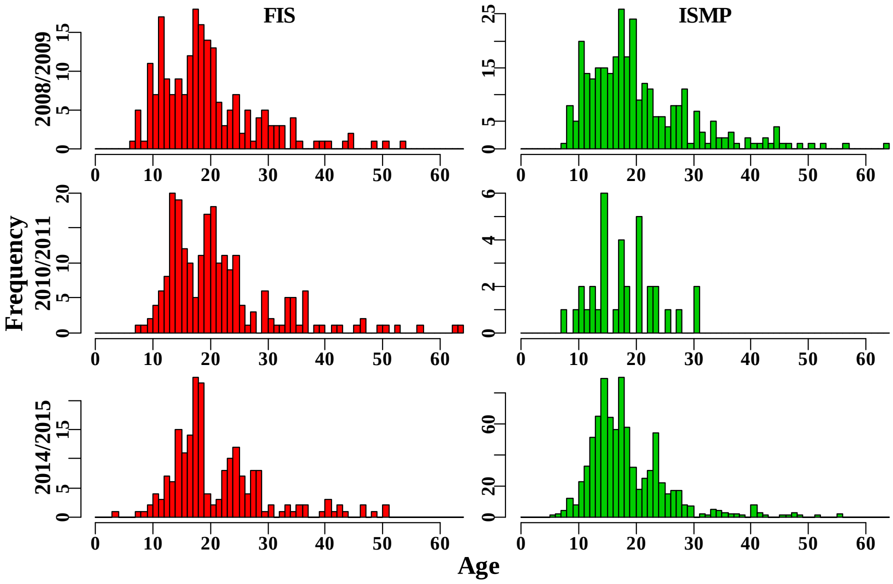

Figure 5.5. A comparison of the age composition of Bight redfish from the FIS and from the ISMP from the same financial years.

5.3.1.6 *Length Composition Data*

Previously (Klaer, 2012), only length composition data from the ISMP sampling were used, and port and on-board samples were considered together. In this current assessment the port and on-board ISMP length samples are kept separate, and there are further length composition data available from the FIS and from crew-member collected data (Figure 5.1).

The crew collected length composition data exhibited an unusual and atypical distribution in sample from 2009 and this was therefore omitted from consideration (Figure 5.6), however, the data from 2010/2011 to 2014/2015 were included using the same selectivity as for the ISMP data. Over a longer time frame the length composition data from the FIS also exhibits variation through time (Figure 5.7).

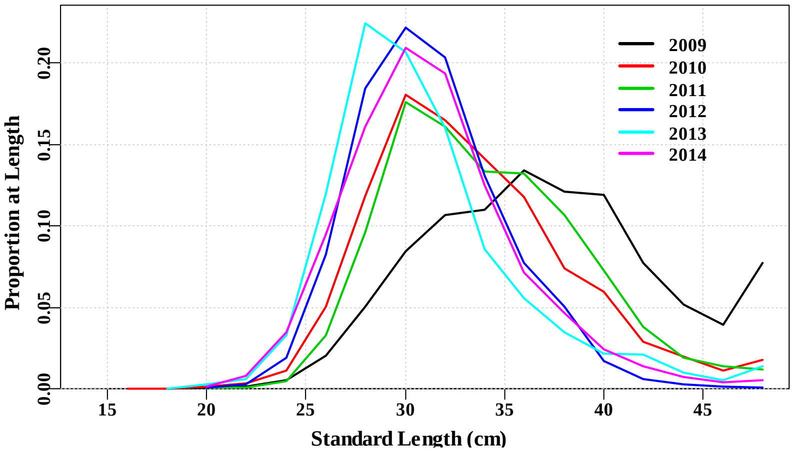

Figure 5.6. Length composition data obtained from crew sampling on-board. The data for 2009 was exceptional and constituted a relatively small sample and hence was omitted from consideration.

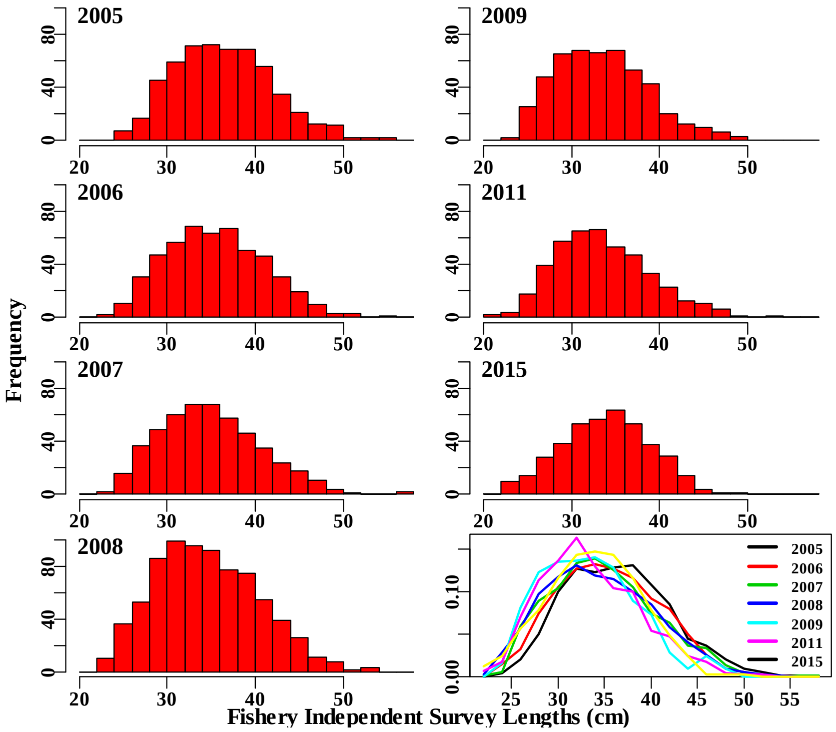

Figure 5.7. The length composition data from the seven FIS that have occurred in the GAB. The plot at bottom right illustrates the contrast between years.

The length composition data from the ISMP also varies considerably from year to year in both the on-board and port data (Figure 5.8, Figure 5.9).

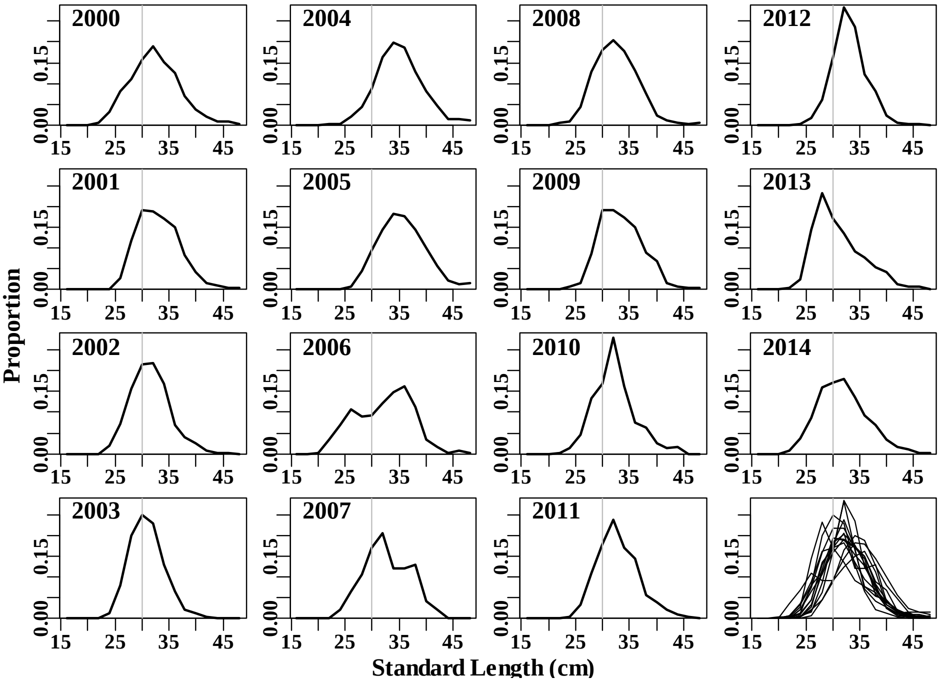

Figure 5.8. The proportional distribution of on-board length composition data for Bight redfish from the ISMP. The vertical grey line at 30cm is to ease visual comparisons. The plot at bottom right is a combination of all the plots to illustrate the variation between years.

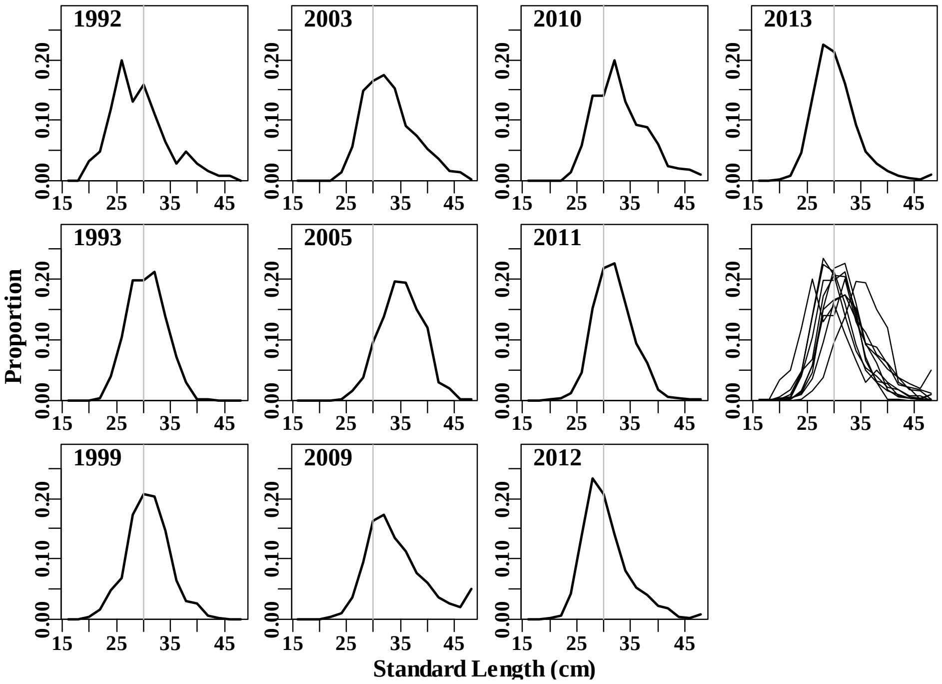

Figure 5.9. The proportional distribution of Port sampled length composition data for Bight redfish from the ISMP. The vertical grey line at 30cm is to ease visual comparisons. The plot at bottom right is a combination of all the plots to illustrate the variation between years.

Table 5.6. Original sample sizes for the length and age composition data for Bight redfish.

Financial Year	ISMP Port LF	ISMP on-Board LF	Industry LF	FIS LF	ISMP Ages	FIS Ages
1992/1993	246					
1993/1994	516					
1999/2000	5324					
2000/2001		3440			630	
2001/2002		2618			474	
2002/2003		1173				
2003/2004	2706	1511			602	
2004/2005		3362		550	571	
2005/2006	541	2271		512	566	
2006/2007		781		499	481	
2007/2008		141		763	443	
2008/2009		716		489	561	202
2009/2010	978	2089			668	
2010/2011	179	217	11033	439	371	223
2011/2012	1652	2167	7443		337	
2012/2013	1873	577	8488		490	
2013/2014	182	1147	10105		334	
2014/2015		1518	5143	405	712	208

5.3.1.7 Age-Reading Error

The age estimates are assumed to be unbiased but subject to random age-reading errors (Punt et al., 2008). Standard deviations for aging error by reader have been estimated, producing the age-reading error matrix (A.E. Punt, pers. comm.). Selectivity is low for ages below 10.

Table 5.7. The estimated standard deviation of normal variation (age-reading error) around age-estimates for the different age classes.

Age	StDev.	Age	StDev.	Age	StDev.	Age	StDev.
0	0.0066	11	0.8096	22	0.8422	33	0.8432
1	0.0066	12	0.8188	23	0.8425	34	0.8432
2	0.2365	13	0.8255	24	0.8427	35	0.8432
3	0.4033	14	0.8304	25	0.8428	36	0.8432
4	0.5242	15	0.8339	26	0.8429	37	0.8432
5	0.6119	16	0.8365	27	0.8430	38	0.8432
6	0.6754	17	0.8383	28	0.8431	39	0.8432
7	0.7215	18	0.8397	29	0.8431	40	0.8432
8	0.7550	19	0.8406	30	0.8431	41	0.8432
9	0.7792	20	0.8413	31	0.8432	42	0.8432
10	0.7968	21	0.8419	32	0.8432	43 - 65	0.8432

5.3.2 ***Stock Assessment***

5.3.2.1 Population Dynamics Model and Parameter Estimation

A two-sex stock assessment for Bight redfish has been implemented using the software package Stock Synthesis (SS, version 3.24u; Methot and Wetzel, 2013). SS is a statistical age- and length-structured model that can be used to fit the various data streams now available for Bight redfish, simultaneously. 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 operating manual (Methot, 2015) and technical description (Methot and Wetzel, 2013) and are not reproduced here.

A single stock of Bight redfish was assumed to occur across the GAB. The stock was assumed to have been unexploited prior to 1988/1989, although minor catches have been recorded back to 1986/1987. The input CVs of the catch rate index and the biomass survey were initially set to fixed values which are effectively arbitrary in the final phase of the model fitting. These values are revised using an iterative process to reweight the variances of the different data streams once parameter estimates have been obtained. Within each abundance index, the variation of all of the annual estimates is assumed to be equal.

The selectivity pattern for the trawl fleet was modelled as not changing through time. The two parameters of the selectivity function were estimated within the assessment. A separate selectivity was estimated for the FIS, and now that FIS length and age composition data are included as data streams this selectivity was found to differ from the rest of the trawl fishery.

The rate of natural mortality, *M*, was assumed to be constant with age, and also constant through time. The natural mortality rate is estimated in the base-case analysis.

Recruitment was 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 was assumed to be 0.75. Deviations from the average recruitment at a given spawning biomass (recruitment deviations) were estimated from 1959/1960 to 2004/2005. The value of the parameter determining the magnitude of the potential variation in annual recruitment, σ_R (SigmaR) was set equal to 0.2 to begin with, which is low relative to many other species, however, after balancing and recruitment deviate bias adjustment (Methot and Taylor, 2011) it ended at 0.335, which remains relatively low. The recruitment deviates for more recent years cannot be estimated well because it can take 10 or more years for larval fish to grow and then enter the fishery. Hence, it can take 10 years before information about relative recruitment levels becomes available to the model.

Age 65 is treated as a plus group into which all animals predicted to survive to ages greater than 65 are accumulated. Growth of Bight redfish was also assumed to be time-invariant, that is there has been no change over time in the mean size-at-age, with the distribution of size-at-age being determined from the fitting of the growth curve within the assessment using the age-at-length data. The potential for age-reading errors (Punt *et al*., 2008) is accounted for within the model by the inclusion of an age-reading error matrix (Table 5.7). The only difference in growth by sex was the length-weight relationship.

5.3.2.2 *Relative Data Weighting*

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. Most of the indices (CPUE, composition data) used in fisheries underestimate their true variance by only reporting measurement and not process error.

Sample sizes for length frequency data, this year, were the number of shots from which measurements were made rather than the absolute number of measurements obtained. The reason is that a set of observations from any particular shot or landing will tend to be correlated such that individuals within a sample are more likely to be similar than individuals between samples, so that true variation is underestimated. This is the reason why, to obtain a more representative sample of a population, it is generally better to take relatively small samples from many different landings than large samples from just a few landings. Treating each shot as a single sample is a better approximation to the effective sample size that simply counting each measurement as an independent observation.

In iterative reweighting, the effective annual sample sizes are tuned/adjusted so that the input sample size was equal to the effective sample size calculated by the model.

The tuning procedure now used (Andre Punt pers comm.; after Day *et al.* 2015) was to:

1. Set the CV for the commercial CPUE value 0.2 for all years (set those for the FIS to the estimated CVs) (this relatively low value is used to encourage a good fit to the abundance data).
2. Simultaneously tune the sample size multipliers for the length frequencies and ages using Francis weights for the LFs and Francis B (the larger of the Francis A and B factors, Francis 2011). Iterate to convergence.
3. Adjust the recruitment variance (σ_R) by replacing it with the RMSE and iterating to convergence (keep altering the recruitment bias adjustment ramps at the same time).

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

This procedure may change in the future. For example, it was found that adjusting all of these variance adjustments and the bias adjustment on the recruitment all at the same time led to the same outcomes as doing the process sequentially (at least for the Bight redfish assessment).

5.3.2.3 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 2006-2015. The HSF uses harvest control rules to determine a recommended biological catch (RBC) for each stock in the SESSF quota management system. Within the SESSF tier system (Smith et al., 2014) Bight redfish 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 be used up to where fishing mortality reaches F_{48}. Once this point is reached, the fishing mortality is set at F_{48}. Day (2009) 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.

An economic analysis was used as a basis for using a 20:35:41 rule for Bight redfish (Kompas et al., 2012).

Estimating the following year's RBC entails calculating the catch that would be equivalent to a fishing mortality that would, at equilibrium, give rise to a spawning biomass depletion level of 41%B_0. Estimating the long term RBC entails projecting the stock assessment forward imposing catches calculated using the Tier 1 harvest control rule (Day, 2009) until the target of 41%B_0 is achieved and citing that final catch level.

5.3.2.4 The Development of the Base-Case Assessment

Fourteen sequential changes were made to the 2011 assessment (Table 5.8). Some had only very minor effects, others had much larger effects. While it was possible to closely match the original assessment spawning biomass time-series (Klaer, 2012b) using the SS3.24f version the outcome, in terms of absolute spawning biomass, changes dramatically when no new data were included and the only change made was to use the latest version of SS3 (SS3.24u). This could have been because the earlier data was uninformative about the spawning biomass levels or because there was a flaw in the software. Other assessments using similarly changed SS3 versions have been conducted this year (Jackass Morwong, Tuck *et al*, 2015; Silver Warehou; Day *et al*, 2015), where such differences did not occur. A further test was made by applying the older SS3 version (SS3.24f) to the scenario after all the age related changes had been made (Age2015_24f). The fact that no discernible differences were seen between the dynamics expressed by that scenario and that expressed by the Age2015 scenario (combined with the ageing error and estLmin scenarios) demonstrate that the differences in the earlier comparison were due to the data being unable to estimate the starting unfished biomass (B_0) with any precision rather than a flaw in the software.

Table 5.8. The thirteen sequential changes made to the 2011 assessment model. Further results for the ageing error matrix and for the re-estimation of the lower growth curve parameters will not be included as these were almost indistinguishable from the outcome of the Age2015 addition. The final base-case is the balanced model.

Index	Name	Description
1	Klaer2011	The spawning biomass estimates from Klaer (2012a)
2	origbase24f	Application of the previous version of SS3 - SS3.24f
3	origbase	Application of the current version of SS3 - SS3.24u
4	CatCE2015	Inclusion of the new catch and CPUE from the fishery
5	Surv2015	Inclusion of the new relative abundance index from the FIS
6	Len2015	Inclusion of new length frequency information; ISMP, FIS, Industry
7	FISsel	Check the need for a separate selectivity curve for the FIS
8	Age2015	Add the new ISMP ageing data
9	ageingerror	Include new ageing error matrix
10	estLmin	re-estimate the lower growth curve parameter
11	Age2015_24f	A repeat of the Age2015 (with the addition of ageing error and estimate of Lmin, but using the older version of SS3.
12	AgeFIS	Include the ageing data from the FIS: 2009, 2011, and 2015
13	Rlast98	Estimate more recent recruitment deviates
14	Balanced	iteratively balance the variance across the various data streams and adjustment the recruitment levels and bias adjustment

5.3.2.5 Sensitivity Tests

A number of tests were used to examine the sensitivity of the results of the model to some of the assumptions and data inputs (Table 5.9). Model outcomes were sensitive to the value of natural mortality, so a further likelihood profile (Venzon and Moolgarkar, 1988) was made for that parameter.

Table 5.9. Changes used to test the model's sensitivity to modified assumptions and data inputs.

1. M = 0.075 yr^{-1}. (relative to the base-case model estimate of 0.1077)
2. M = 0.977 yr^{-1} (because the effect of M = 0.075 was very
3. M = 0.125 yr^{-1}.
4. 50% maturity at 23cm.
5. 50% maturity at 27 cm.
6. σ_R set to 0.235
7. σ_R set to 0.435
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. Halve the weighting on the age-at-length data.
12. Double the weighting on the abundance (CPUE) data.
13. Halve the weighting on the abundance (CPUE) data.
14. Derive the RBC using the 20:35:48 harvest control rule.
15. Fix steepness (h) at 0.65
16. Fix steepness (h) at 0.85
17. No Survey Data (remove index, age- and length-composition data)
18. Estimate Recruitment deviates 1960 – 2003

The results of the sensitivity tests are summarized by the effects on the absolute likelihoods associated with each data stream, the total likelihoods, which includes the effect of changes to the Lambdas or weights applied, and the following quantities (see Table 5.14):

1. SSB0: the average unexploited female spawning biomass.
2. SSB_{2014}: the female spawning biomass at the start of 2015/2016.
3. SSB_{2014}/SSB_0: female spawning biomass depletion at the start of 2015/2016
4. M: natural mortality
5. $RBC_{2016/2017}$

5.4 Results and Discussions

5.4.1 *The Base-Case Analysis*

Stepping sequentially through the different scenarios leading from the 2011 assessment to the current base-case the general result was that most scenarios, that had an observable influence on the outcome, led to declines in the estimated unfished spawning biomass. The exception was the final balancing of variances between the data streams and adjustment of the recruitment bias adjustment and variation of recruitment deviates, which increased current spawning biomass by about 25% from 2697 t to 3432 t (Table 5.10).The reduction in biomass from the earlier assessment implied that the catches that had been removed had imposed a higher fishing mortality rate than estimated previously so the final depletion level of 63%B_0 was closer to the target reference point of 41%B_0 (81% down to 63%B_0; Table 5.10).

Table 5.10. The spawning biomass at the end of 2014/2015, with the 2014 depletion obtained during the development of the 2015 variance balanced base-case assessment for Bight redfish.

Scenario	B_0	2014SpB	2014StDev	Depletion	2014CV
origbase24f	21182.2	17124.9	12320.5	0.808	0.719
origbase	12659.3	9790.7	3713.8	0.773	0.379
CatCE2015	8980.0	6624.8	1492.1	0.738	0.225
Surv2015	8976.6	6586.8	1322.0	0.734	0.201
Len2015	7573.0	5196.3	978.3	0.686	0.188
FISsel	7317.4	4948.7	917.6	0.676	0.185
Age2015	5707.7	3627.6	415.0	0.636	0.114
Age2015_24	5819.6	3731.8	436.0	0.641	0.117
AgeFIS	4850.0	2654.8	161.1	0.547	0.061
Rlast03	4895.1	2697.9	238.8	0.551	0.089
Base-Case	**5451.0**	**3436.8**	**421.9**	**0.630**	**0.123**

5.4.1.1 Comparison of the Outcomes from Different Scenarios

To examine the effect of each data component on the model output the predicted female spawning biomass, as both biomass (t) and depletion were plotted, each on the same scale (Figure 5.10) to enable simple visual comparisons between scenarios. Using SS3.24f instead of SS3.21d, as used by Klaer, 2012a), led to a minor change in the unfished biomass (B_0) but the time-series of depletion levels were effectively identical with the lines for 'Klaer2011' and 'origbase24f' lying on top of each other. Similarly, AgeFIS and Rlast03 also lie on top of each other with only minor variations (Figure 5.10). The use of the more recent version of SS3 led immediately to reduced (improved) variation (a smaller CV), which continued to decline as more data and options were added (Table 5.10).

The relatively low catches in the most recent years have led to a degree of stock building since 2009/2010 or 2010/2011. This pattern of depletion and recovery suggests that the catch levels of ~800 – 1000 t are too high to be maintained for long periods but also that catches could be more than ~300 t and still be sustainable in the long term (Figure 5.10).

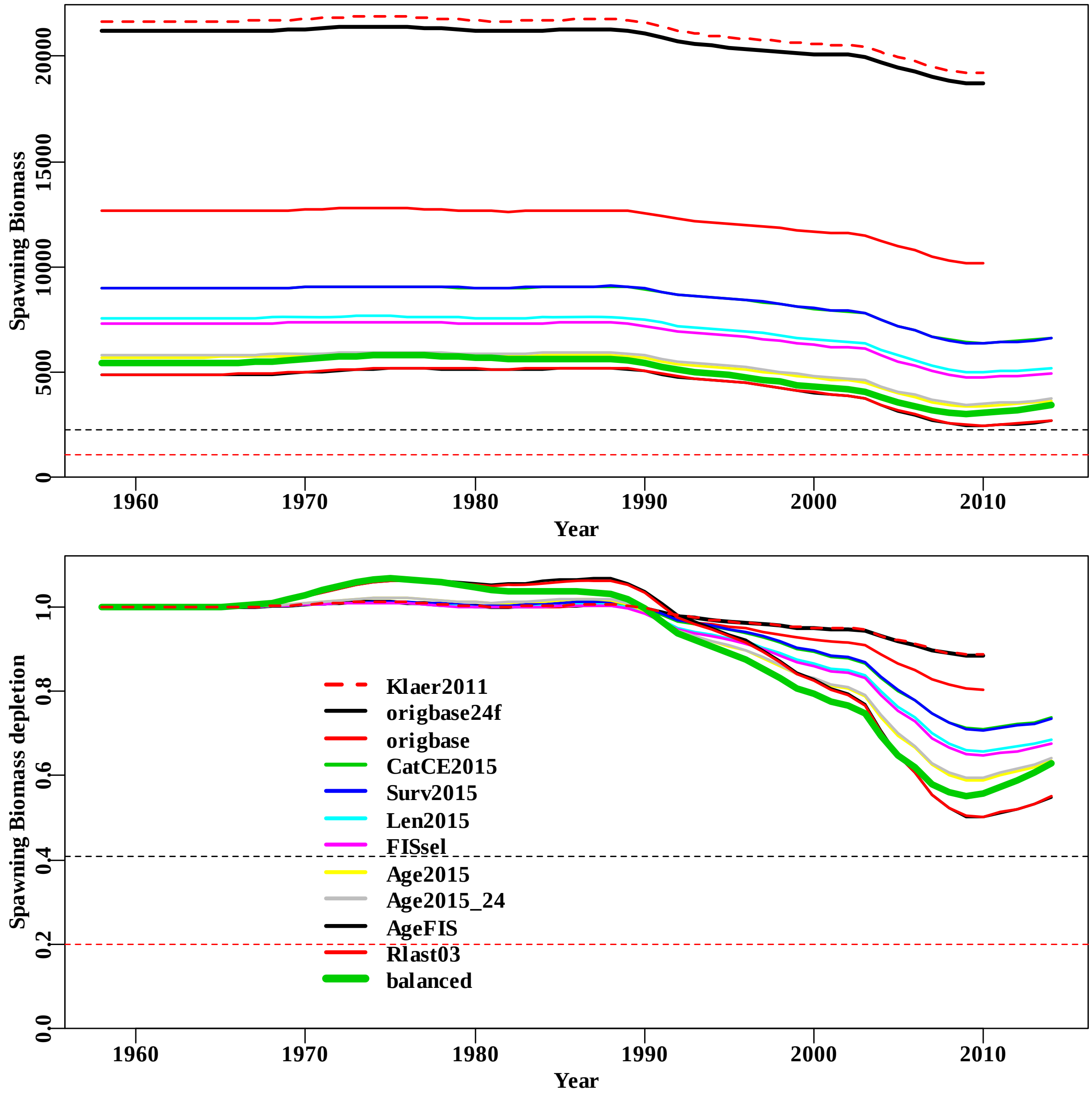

Figure 5.10. The predicted female spawning biomass and relative depletion level for the main scenarios describing the inclusion of different data and alternative assessment software. Some lines sit almost exactly on top of each other (for example the Age2015 and Age2015_24), the thicker green line is the balanced outcome from the base-case (see Table 5.8 for an explanation of each scenario).

5.4.2 *Model Fits*

The estimated growth curve for female and male Bight redfish is assumed to be the same (Figure 5.11). All growth parameters are estimated by the model except for L_{max} (Table 5.11).

With only a trawl fleet and Trawl run FIS, selectivity is assumed to be logistic. 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). A different selectivity was found to be required to appropriately describe the FIS length and age data (Figure 5.11; Table 5.11).

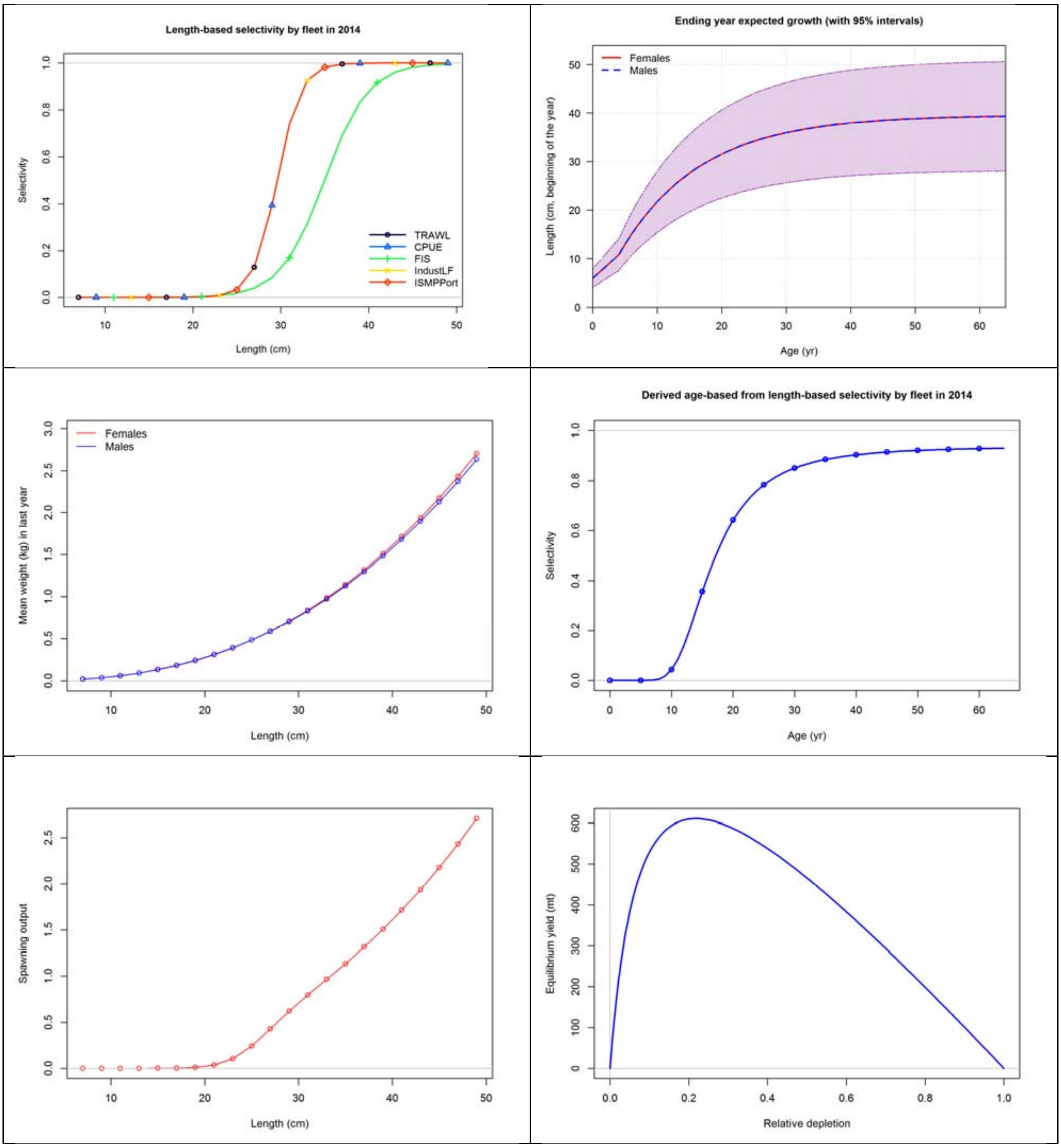

Figure 5.11. The selectivity curves for the trawl fishery and related length frequency data and of the FIS, and the predicted expected growth curves. The predicted mean weight at length, and derived age-based, length-based selectivity, the predicted depletion level of the balanced model with the 95% asymptotic confidence intervals, and the Age-0 recruit levels, again with the 95% asymptotic confidence intervals.

Table 5.11. Estimates for parameters other than recruitment deviates, with some fixed parameters for clarity. St.Dev is the approximate standard deviation for each estimate.

Parameter/Feature	Value	St.Dev.	Comment
Natural mortality *M*	0.1077	0.0023	estimated
Recruitment			
σ_R	0.335		balanced
deviates	1960 - 2005		estimated
Ln(R0)	8.5328	0.1063	estimated
First bias adjustment	1915 - 1982		estimated
Final bias adjustment	1989 - 2008		estimated
maximum bias adjustment	0.736		estimated
Growth			
CV	0.1414	0.0034	estimated
K	0.069	0.0026	estimated
L_{min}	12.4723	0.3686	estimated
L_{max}	37.939		fixed
Selectivity			
Trawl L50	29.5126	0.2146	estimated
Trawl inter-quartile	3.5381	0.2729	estimated
FIS L50	34.8884	0.6140	estimated
FIS inter-quartile	7.1225	0.4066	estimated

5.4.3 *Fits to the Data*

5.4.3.1 CPUE Data

The fits to the catch rate indices (Figure 5.12) are poor with the predicted commercial CPUE trajectory not reflecting the ups and downs of the time series from 1988/1989 – 2003/2004, and effectively taking the inverse trend to the observed CPUE trend between 2004/2005 – 2014/2015. The FIS relative abundance index follows the same trend as the commercial CPUE across their over-lapping period and the only way that the predicted FIS CPUE can fit is to expand the CV values for each data point during the re-balancing process.

The current approach used when fitting assessment models is to attempt to place emphasis on the relative index of abundance data (Francis, 2011). However, up to about 2000/2001 the degree of stock depletion was relatively minor and it was only once catches rose to about 1000 t that the depletion trajectory began to steepen (Figure 5.10). At the time of the increased catches the number of active vessels in the fishery increased from an average of about 6 (from 1989/1990 – 2001/2002) to about 9 (from 2002/2003 – 2007/2008) and then down to an average of 4 vessels to the present day (Table 5.3). A number of the vessels that left the fishery following the structural adjustment (Nov 2005 – Nov 2006) were catching significant proportions of the total Bight redfish catch (Figure 5.13). Such changes may have contributed to the failure of CPUE to reflect the predicted state of the stock. This lack of fit to the CPUE (Figure 5.12) suggests that there is some form of conflict between the CPUE data and the age and length composition data such that despite trying to push for a close fit to the relative abundance indices the model puts more emphasis on the composition data, or rather, can only fit to the age- and length-composition data. However, both the jackass morwong and silver warehou stock assessments conducted this year using the weighting procedure used here also found that the procedure failed to give the CPUE data the intended weight, instead giving the age and length data undue emphasis.

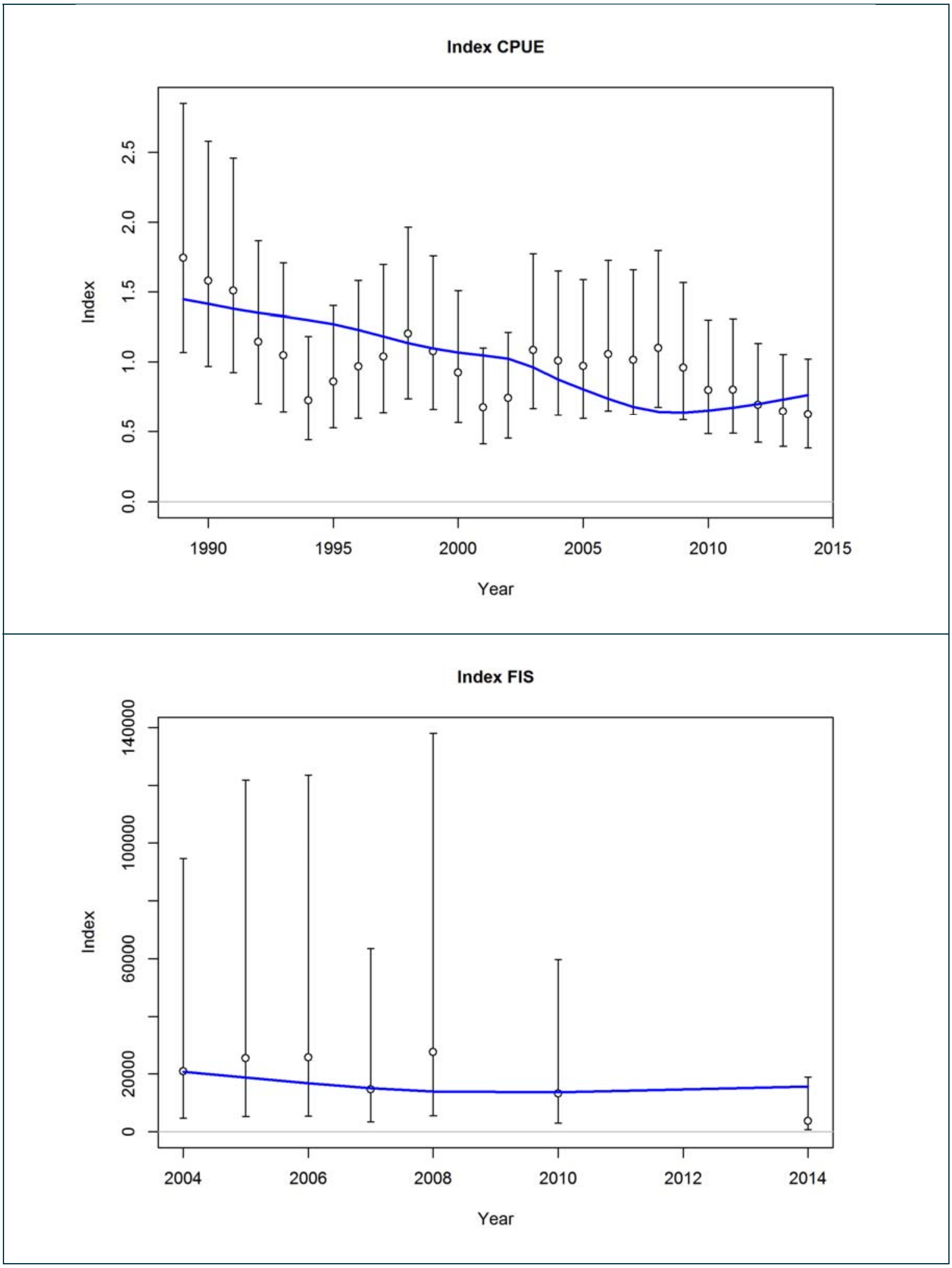

Figure 5.12. The balanced model fit to the commercial CPUE index of relative abundance and to the FIS index of relative abundance. Each year in the figures relates to the first year of each financial year combinations; e.g. 2001 = 2001/2002.

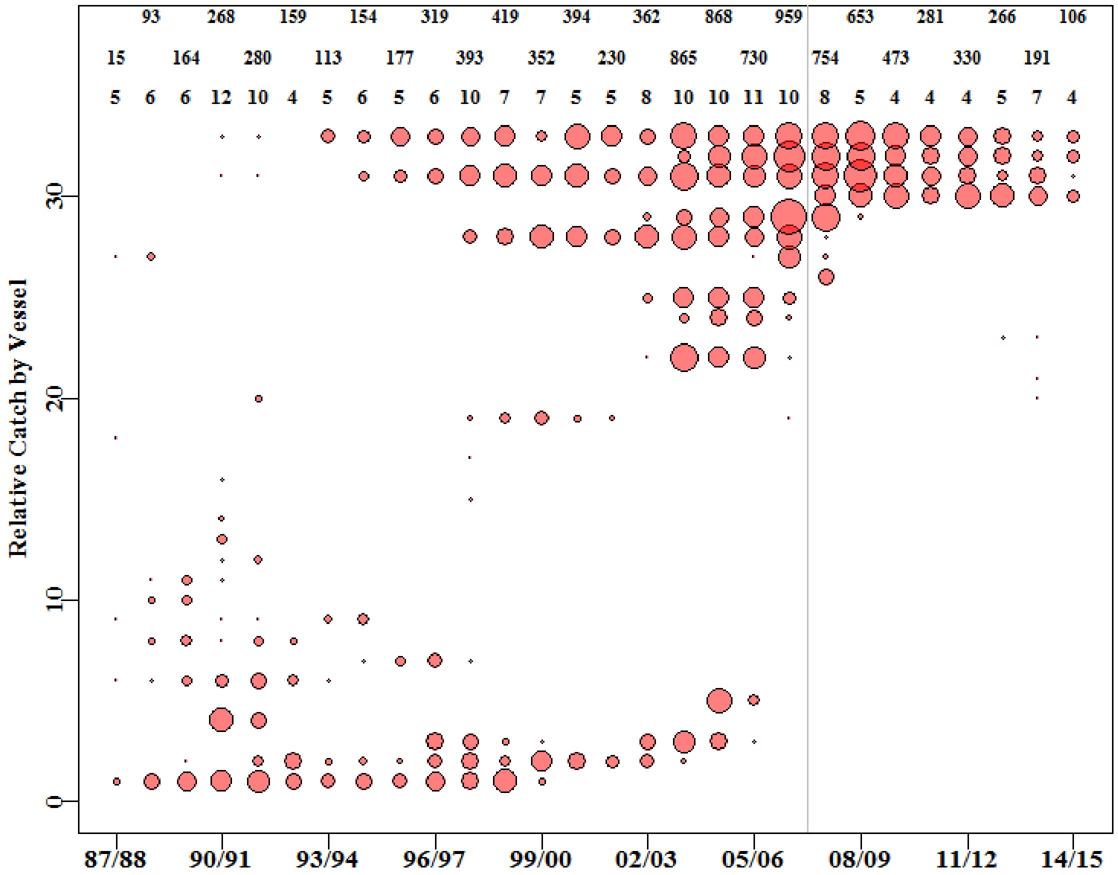

Figure 5.13. The relative catch (square root of catch) of Bight redfish per trawl vessel in the GAB fishery, with the vertical line depicting the advent of the structural adjustment. The lowest of the top three lines lists the number of vessels reporting > 1 t across all years, and the other two lines are the reported catches, staggered to improve readability.

5.4.3.2 Length Composition Data

The length composition data from the FIS shows that those fish were slightly larger on average than those from the commercial fishery (Figure 5.14) and this is reflected in their respective selectivity curves (Figure 5.11). Bight redfish tend to be selected at about 25cm and above implying that they can be 10 years or older before they are strongly selected by the fishery. This is about the same size and age at which they mature, which implies there is a proportion of the mature population not selected by the fishery and this should give the population an extra degree of resilience (Figure 5.11).

There are some years of ISMP sampling, both on-board and port samples, that appear to be inconsistent with previous and following years (on-board 2004/2005 – 2006/2007, and port 1992/1993 and 2005/2006; Figure 5.14), however the data from the FIS and the crew-member samples are more sequentially consistent, although they sometimes fail to meet the same peak levels of relative frequency. Despite these internal inconsistencies the relative fit to the length composition data, when considered across all years is close in all data streams (Figure 5.14). Further illustrations of the relative fit to the length-composition data are provided in the Appendix.

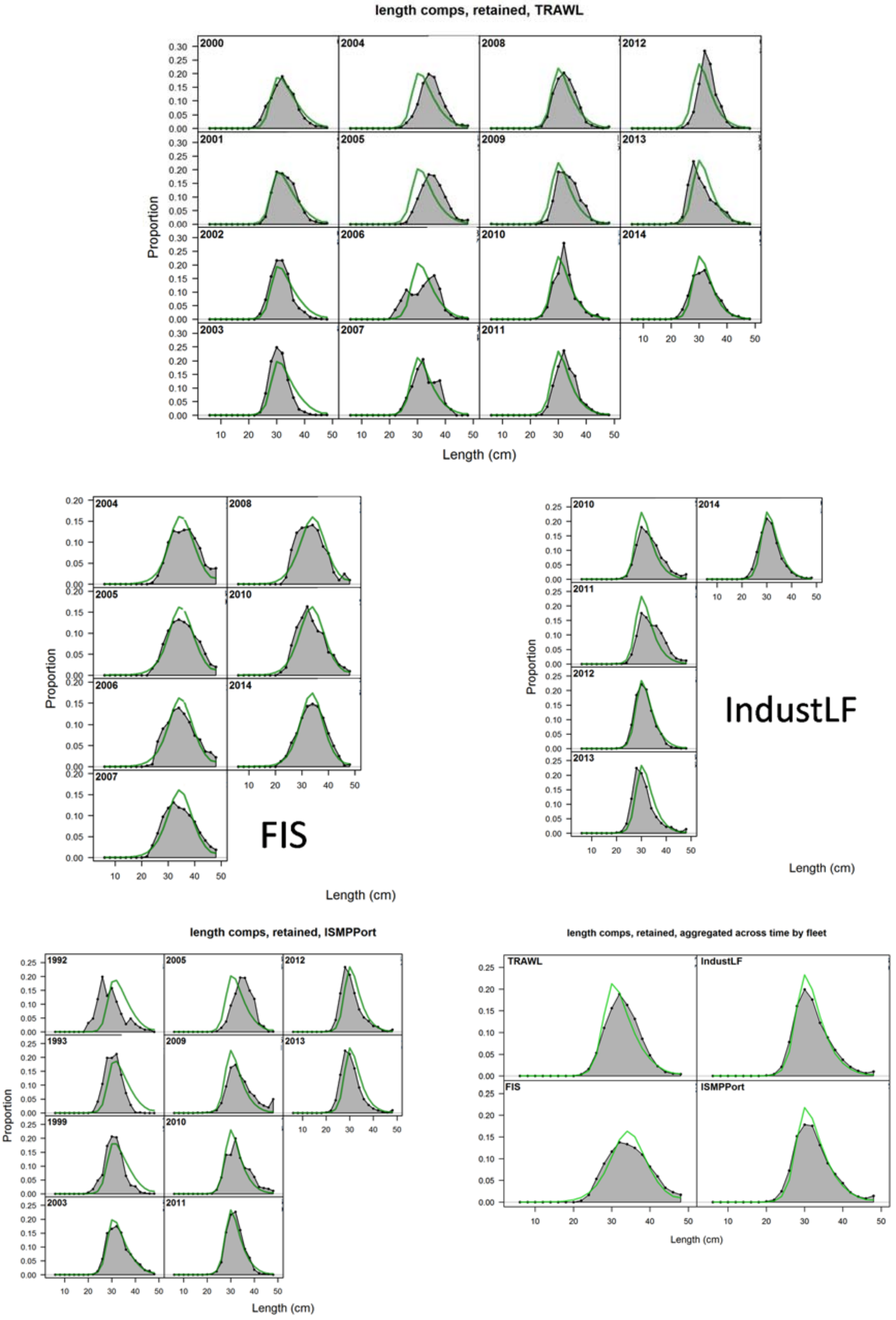

Figure 5.14. The base-case model fit to the different time-series of length-frequency composition data for the ISMP on-board data (Trawl), the FIS data, the industry on-board data (industLF), the ISMP Port data, and the summary across years for each data set. Each year in the figures relates to the first of the financial year combinations; e.g. 2001 = 2001/2002.

5.4.3.3 *Age Composition Data*

Age-at-Length keys are used in the model so the fits to the age-composition data are indirect. What this means is that the model can produce the implied fits to the age composition data in those years where both age- and length composition data are available (a separate age-length key should be used for each year). The model mimics the observed age data reasonably well for both the ISMP samples and the three years of the FIS (Figure 5.15).

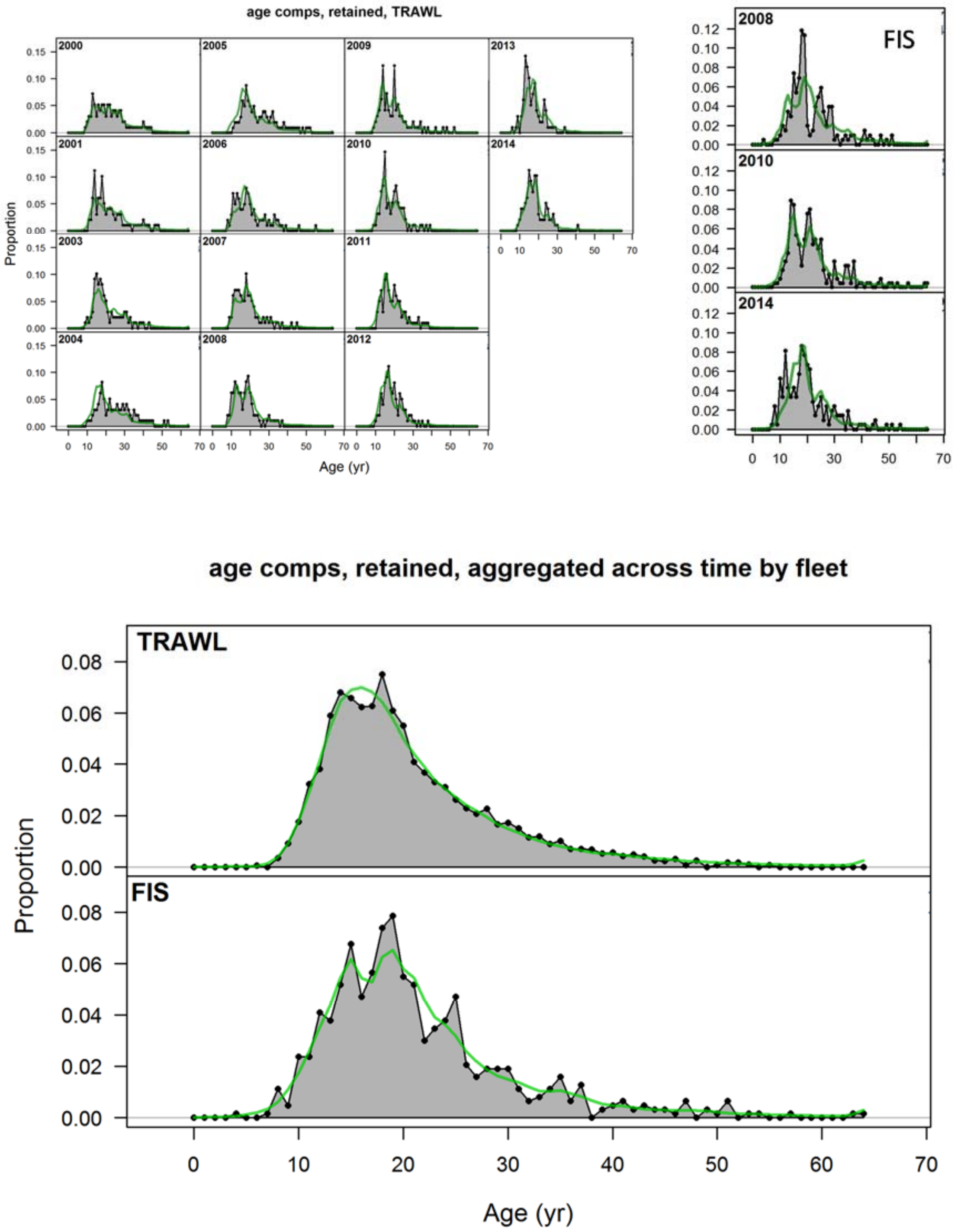

Figure 5.15. The balanced model fits to the age-composition data in each year and across all years combined. Each year in the top figure relates to the first of the financial year combinations; e.g. 2001 = 2001/2002.

The FIS data especially illustrates the progression of age classes quite well with the approximate mode of 13 – 14 year olds in 2008/2009 moving to be about 15 – 16 year olds in 2010/2011, and the approximate mode at 12 – 14 in 2010/2011 moving to be about 2013 – 2016 in 2014/2015 (Figure 5.15).

Given the far fewer number of observations from the FIS, the model still does a reasonable job of fitting to all years, as seen in the graphs of all data combined across years (Figure 5.15).

Further illustrations of the relative fit to the age-composition data are provided in the Appendix.

5.4.4 *Base-Case Assessment Outcomes*

The stock depletion level at the end of 2014/2015 is estimated to be approximately 3,437 t or 63%B_0, (Table 5.10), while the estimated, approximate MEY biomass level is 41%B_0 (Kompas *et al*., 2011). The asymptotic confidence intervals, and the standard deviation and CVs around the biomass estimates, are likely to under-estimate the true uncertainty about the estimated biomass levels (Figure 5.16). This is why the confidence bounds are relatively tight about the median estimated spawning biomass levels. The upturn in spawning biomass following the reduction in catches from 2009/2010 is driven by reduced fishing pressure and not by greater recruitment as recruitment during this period is close to the average predicted by the stock recruitment curve in the years 2006/2007 – 2014/2015 (Figure 5.17), as fish spawning in those years would barely have entered the fishery from 2009/2010 until 2014/2015. In addition, recruitment levels are not particularly variable (Figure 5.17) and the current median stock recruitment level has barely been depressed from the maximum by the reduction of spawning biomass down to 63%B_0 (Figure 5.17).

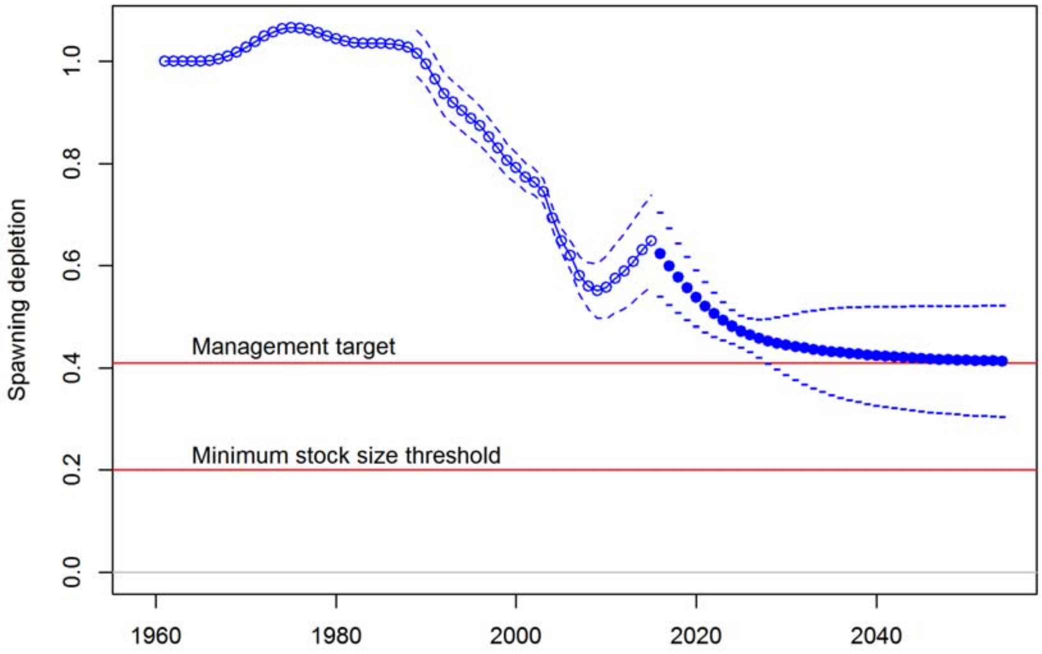

Figure 5.16 The trajectory of spawning stock depletion, including 40 years of projection used to estimate the current RBC and the long-term RBC. The stock only begins to decline slowly when fishing first begins and then accelerates downwards once catches reach about 800 – 1000t per year. With the more recent drop in catches from about 2009/2010, the stock is predicted to have increased to the present day until it ended at about 63%B_0 at the end of 2014/2015. If catches adhere to the predicted RBCs then it will take approximately 40 years for the stock to decline to the estimate MEY at 41%B_0.

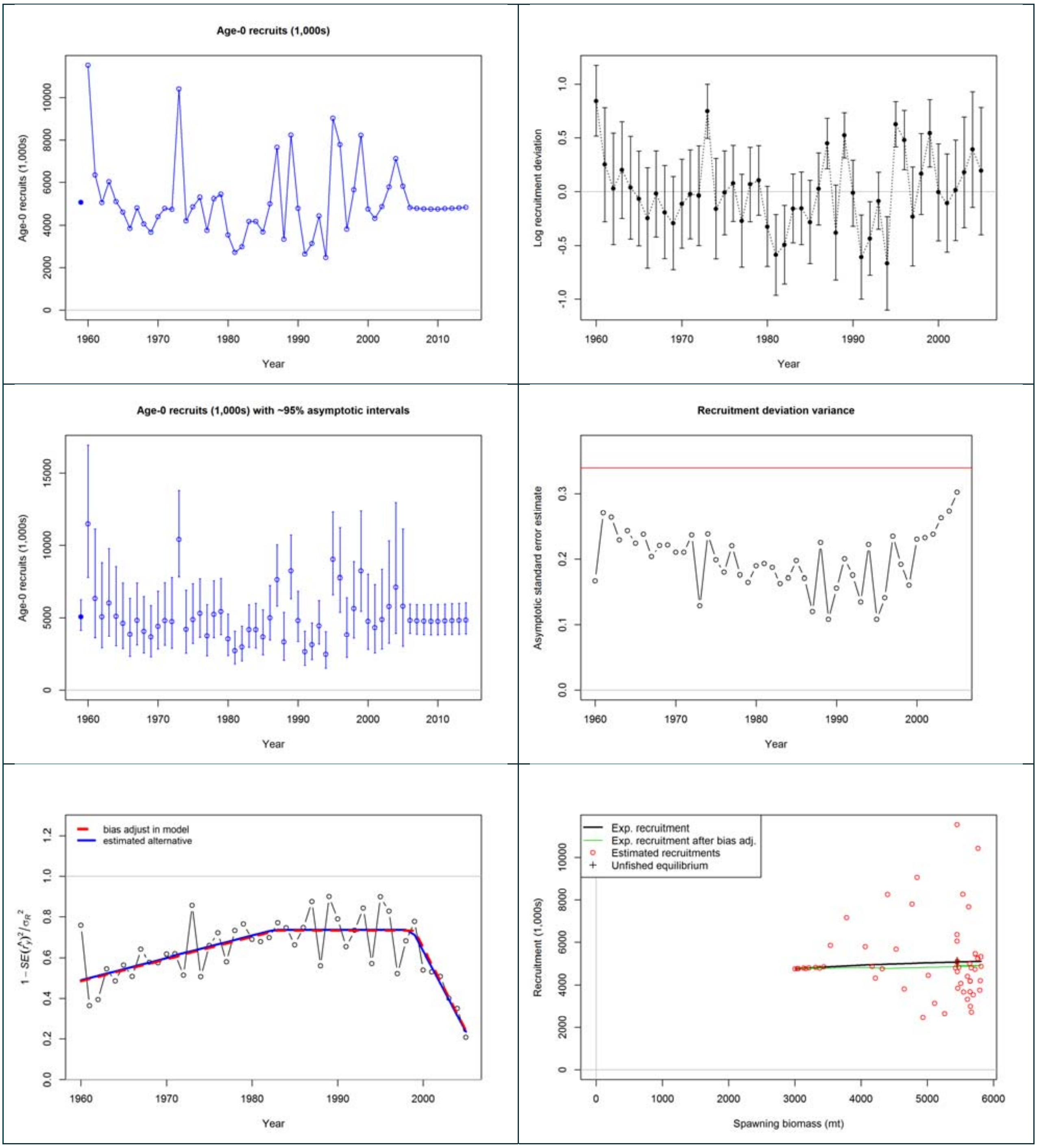

Figure 5.17. Estimation of recruitment and recruitment deviates for the base-case assessment with time trajectories given in both nominal and log-space. The final nine deviates in the middle left are not estimated but are estimated by the implied Beverton-Holt stock recruitment curve. The asymptotic standard errors of the recruitment deviates (middle right) are sufficiently low to indicate that all estimated deviates have sufficient data to allow for an adequate estimate. The bias-adjustment graph illustrates the degree to which the estimates of recruitment deviates require correction for their level of variation (Methot and Taylor, 2011). The implied stock recruitment curve (bottom right) illustrates that the stock depletion level has not been sufficient to alter the average recruitment levels significantly.

The predicted recruitment dynamics differ from those previously estimated, which may be related to the advent of more ageing data from the FIS and additional length-composition data streams. The increases in the suggested level of SigmaR means that the recruitment deviates are more free to vary. In the period between 1960 and 1970 there are now predicted to be some minor jumps in recruitment and these appear to be a direct result of the inclusion of the ageing data from the FIS (the yellow line in Figure 5.18). In addition this has split the major mode of recruitment in about 1988 into two spikes with a low in between.

The inclusion of recruitment estimates for more recent years also, not surprisingly, indicates some relatively low and some relatively high values. There are no prolonged periods of high or low recruitment apparent in the time series (Figure 5.18).

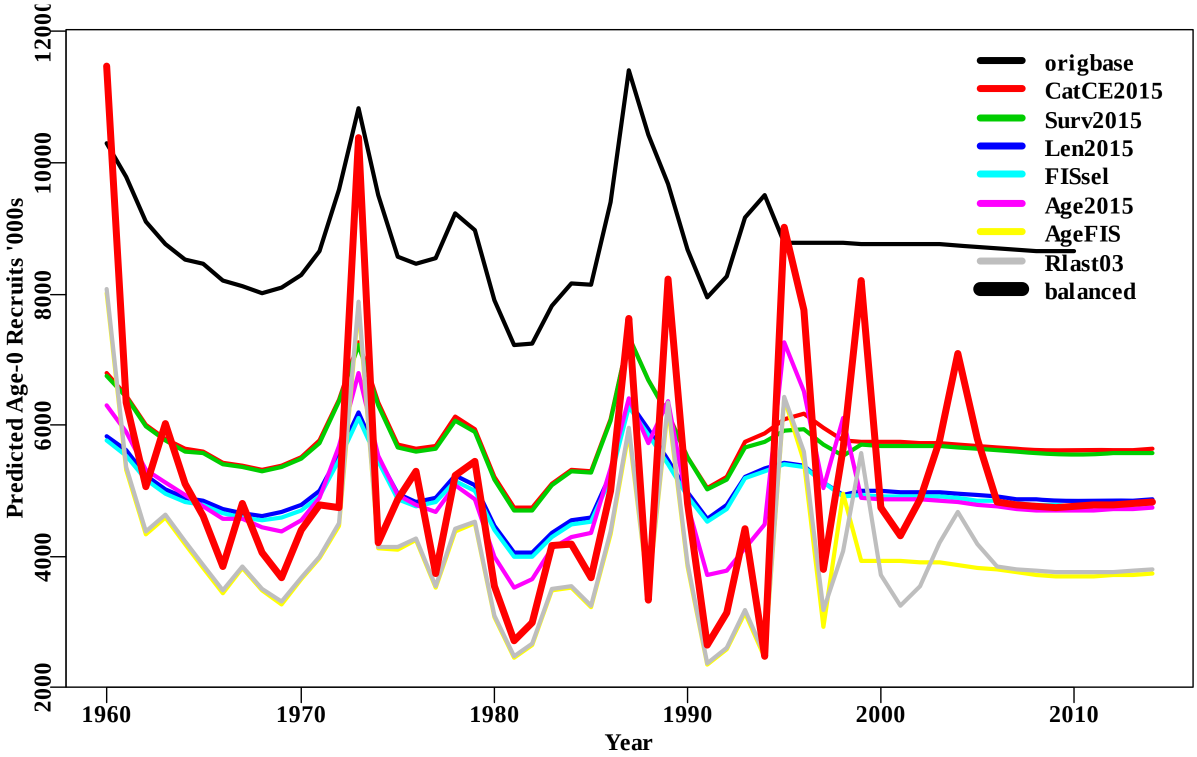

Figure 5.18. The sequence of expected recruitment levels through time in the different scenarios.

This upswing in spawning biomass when catches declined should be informative about the relative productivity of the stock and how it responds to changes in fishing mortality. Across the period of the forty year projection the predicted decline in projected spawning biomass is initially relatively rapid (although taking ten years to drop into the low 40% levels) and then tailing off as the median levels approach the target biomass depletion level. This predicted trajectory, however, depends upon the estimated RBC being caught each year, which, given recent catches and reports of difficulty in catching the fish, seems unlikely.

The recruitment levels and recruitment deviates through the period of the fishery have not varied to any extreme extent (Figure 5.17). There have been no extensive periods of below or above average recruitment levels predicted throughout the fishery. In fact, the variability in the recruitment (σ_R = 0.335) considered optimal in the model fitting and balancing process is low in absolute terms relative to many other species assessed within the SESSF. The effect of increasing and decreasing this variation is examined in the sensitivities (Table 5.14).

The 2016/2017 recommended biological catch (RBC) under the 20:35:41 harvest control rule is 862 t and the long term yield (assuming average recruitment in the future) is 537 t (Table 5.12; Table 5.14).

Averaging the RBC over the three year period 2016-2018, the average RBC is 828 t and over the five year period 2016-2020, the average RBC is 797 t (Table 5.12; Table 5.14).

Even though the precision of this assessment is much improved over earlier assessments (Table 5.10), given that the data has only now become informative about the stock depletion levels and the impact of the fishing catch history on the stock, the estimates of stock biomass and current depletion level must still be treated as approximate until further data collections confirm the revisions in the model outputs.

Table 5.12. The predicted total exploitable biomass, the Female Spawning Biomass, and the observed and predicted catches from the forecast projections. The bolded rows represent the predicted RBCs for the 2016/2017 fishing year and the long-term RBC that should maintain the stock at the target of 41%B_0. See Table 5.17 for the projection outcomes for all years.

Year	Total Exploitable Biomass	Spawning Biomass	Catch	Depletion
Unfished	16041.700	5451.190	0	1
1988	15730.500	5604.690	85.651	1.028
1989	15509.600	5537.390	170.833	1.016
1990	15336.600	5426.020	281.808	0.995
1991	15048.300	5264.040	265.612	0.966
1992	14769.100	5108.240	120.698	0.937
2014	12047.600	3436.760	238.327	0.630
2015	12186.500	3537.980	238.327	0.649
2016	**11782.800**	**3396.370**	**862.091**	**0.623**
2017	11421.300	3265.200	827.194	0.599
2018	11099.200	3143.400	795.039	0.577
2019	10813.900	3030.83	765.023	0.556
2020	10563.100	2927.96	736.909	0.537
2052	8873.250	2258.830	538.026	0.414
2053	8867.130	2256.700	537.437	0.414
2054	**8861.560**	**2254.770**	**536.903**	**0.414**

5.4.5 *Sensitivity Tests*

The sensitivity tests demonstrate that the assessment outcomes are very sensitive to the assumed value for *M*, the natural mortality (Figure 5.19; Table 5.14). In addition, although not as extreme as the effects of the natural mortality altering the size at median maturity and doubling the weight on CPUE were also influential on the absolute estimates of B_0 and hence of the final depletion.

The other sensitivities considered remained grouped relatively closely around the balanced base-case outcomes (Figure 5.19; Table 5.14 - Table 5.16).

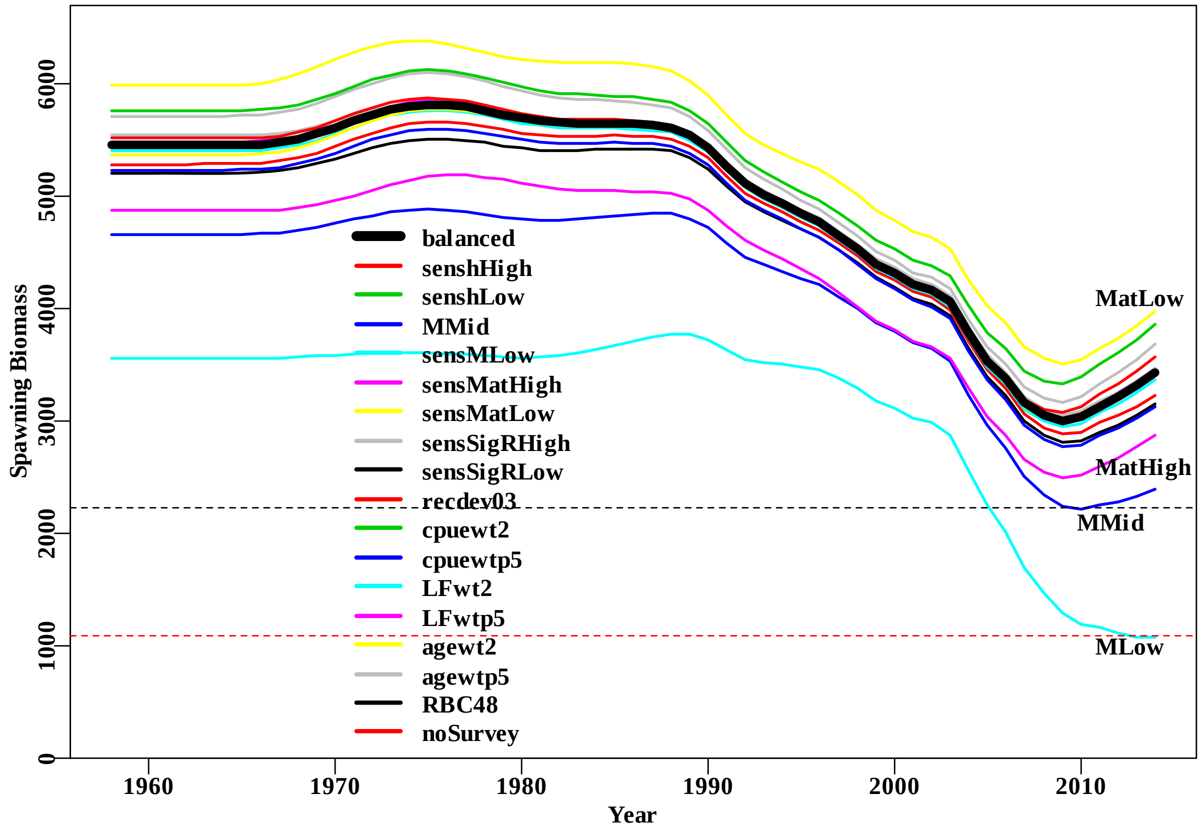

Figure 5.19. The effect on the predicted spawning biomass trajectory of the sensitivity tests on different assumptions and data weightings. The sensitivity that tested a relatively high natural mortality was omitted as its low point in about 2008 was almost at the high point of the next highest.

Altering the weights on the different data streams had some effects on the model outcomes especially the halving and doubling the weights on the length composition data, which increased and decreased the depletion levels rather more than other treatments (Table 5.14). However, it is not valid to compare the likelihoods from such sensitivity tests although the unweighted likelihoods can still sometimes be illuminating, and a consideration of their effects on the model's implications for the stock status remains useful. The overall fit of the model improved with greater weight on the length composition data and declined with a lower weight.

With the different weights on the CPUE indices (log-books and FIS) the reverse was true in that the model fit improved when less weight was placed on the CPUE. Care is needed with such statements however. A consideration of the different weights applied to the age-composition data illustrate the reasons why total likelihood comparisons can be misleading (and are invalid). Because the age-related likelihoods are large to start with including a multiplier alters their values enormously (Table 5.15) even though they have only a small effect on the biomass related model outcomes (Table 5.14).

The sensitivity tests on the particular parameters in the model (steepness, natural mortality, size at 50% maturity, and the permissible variation of the recruitment deviates (SigmaR) are directly comparable, although it needs to be remembered that the sensitivities are not rebalanced and so the comparisons remain only approximate.

The effect of varying steepness was relatively minor on both the likelihoods and the stock status, while the effect of varying the size at 50% maturity was also very minor on the likelihood of the model fit but was more influence on the stock status with the base-case depletion being 63% in 2014/2015 which dropped to 59% with a smaller size-at-maturity and rose to 66.4% with a higher size-at-maturity.

The effect of changing the SigmaR value alters how variable the recruitment deviates can be from year to year. Not surprisingly therefore, when SigmaR is increased the age-component likelihood improves and when it is decreased that likelihood increases in size (smaller is better). However, once again the effect on the stock depletion status is minor varying the estimate from 60% – 64%.

Far more influential is the effect of varying the natural mortality. As one of the major factors affecting productivity this influenced the likelihoods for all data streams although it did so in different directions. A higher *M* value improved the fit to the two CPUE series and to the age-composition data but decreased the quality of fit to the length-composition data, and visa-versa when *M* was reduced.

Because the sensitivity tests demonstrated that the assessment model is relatively sensitive to the value of natural mortality this was examined more closely by estimating a likelihood profile for natural mortality (Figure 5.20; Table 5.13). Approximate 95% confidence intervals can be obtained and these suggest that, in terms of the uncertainty related to natural mortality, with the best estimate of the mean current depletion of 63% at the end of 2014/2015, the 95% confidence interval bounds would be between 57% and 69%.

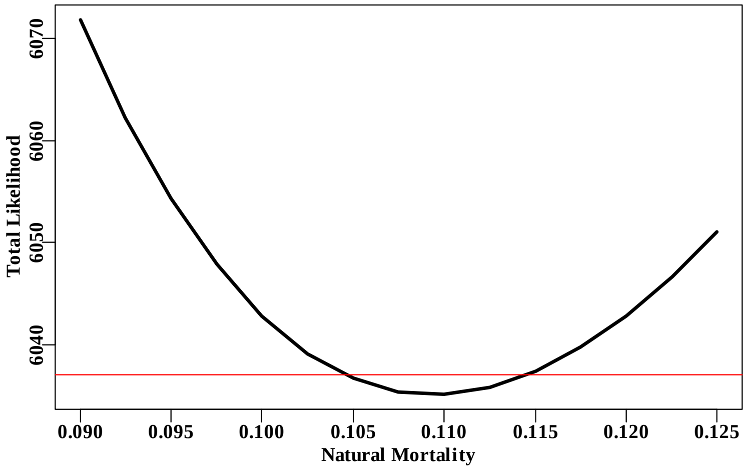

Figure 5.20. A likelihood profile for natural mortality. The values for natural mortality are fixed in the model instead of being estimated and all other parameters estimated as usual. The red line denotes the approximate 95% confidence bounds (Venzon and Moolgavkar, 1988).

Table 5.13. The outcomes for a likelihood profile on natural mortality. The approximate likelihood profile confidence intervals are bounded where the total likelihood is 6037.0 (6035.08 + 1.92).

M	TotalLike	TotalCE	TotalLF	TotalAge	B0	Bcurr	Depletion
0.09	6071.84	-10.00	47.56	6034.28	4210.790	1830.260	0.435
0.0925	6062.23	-11.89	47.93	6026.20	4344.780	1997.800	0.460
0.095	6054.26	-13.61	48.29	6019.58	4489.370	2181.050	0.486
0.0975	6047.83	-15.15	48.64	6014.34	4646.040	2381.830	0.513
0.1	6042.81	-16.52	48.98	6010.36	4816.430	2602.320	0.540
0.1025	6039.13	-17.74	49.30	6007.56	5002.460	2845.080	0.569
0.105	6036.68	-18.79	49.62	6005.85	5206.350	3113.160	0.598
0.1075	6035.36	-19.70	49.92	6005.14	5430.710	3410.240	0.628
0.11	6035.08	-20.46	50.20	6005.34	5678.680	3740.700	0.659
0.1125	6035.76	-21.09	50.47	6006.38	5954.010	4109.900	0.690
0.115	6037.34	-21.58	50.72	6008.19	6261.300	4524.370	0.723
0.1175	6039.72	-21.94	50.96	6010.69	6606.160	4992.150	0.756
0.12	6042.83	-22.17	51.18	6013.81	6995.600	5523.290	0.790
0.1225	6046.62	-22.27	51.39	6017.50	7438.400	6130.390	0.824
0.125	6051.01	-22.26	51.58	6021.69	7945.740	6829.540	0.860

5.4.5.1 The Alternative Harvest Strategy 20:35:48

The inclusion of the projection with a 20:35:48 Harvest Control Rule is not strictly a sensitivity on the model fit as it has no effect on the fit (Table 5.15 and Table 5.16) as it only influences dynamic events during the projection period.

Table 5.14. Summary of the outcomes for the base-case and sensitivity tests. Recommended biological catches (RBCs) are only shown for tuned models (base-case and RBC48). The likelihoods in the italicized cases should not be compared with the other sensitivities.

Case		SSB_0	SSB_{2014}	SSB_{2014}/SSB_0	M	RBC_{2016}	$RBC_{2016\text{-}8}$	$RBC_{2016\text{-}20}$	$RBC_{longterm}$
Base-Case	**base case 20:35:41**	**5451**	**3437**	**0.6305**	**0.10772**	**862**	**828**	**797**	**537**
hHigh	Fix steepness $h = 0.85$	5454	3460	0.6345	0.10773				
hLow	Fix steepness $h = 0.65$	5449	3409	0.6257	0.10771				
MHigh	$M = 0.125$	7946	6830	0.8595	0.12500				
Mmid	$M = 0.0977$	4659	2399	0.5148	0.09770				
MLow	$M = 0.075$	3558	1082	0.3041	0.07500				
MatHigh	50% maturity at 23cm	4868	2880	0.5917	0.10771				
MatLow	50% maturity at 27cm	5980	3970	0.6639	0.10773				
SigRHigh	$\sigma_R = 0.235$	5713	3689	0.6457	0.10919				
SigRLow	$\sigma_R = 0.435$	5205	3148	0.6047	0.10600				
recdev03	rec deviates only to 2003	5284	3228	0.6109	0.10694				
LFwtx2	wt x 2 length comp	5758	3865	0.6712	0.10898				
LFwtx0.5	wt x 0.5 length comp	5232	3129	0.5981	0.10672				
cpuewtx2	wt x 2 CPUE	5402	3372	0.6243	0.10719				
cpuewtx0.5	wt x 0.5 CPUE	5480	3476	0.6343	0.10805				
agewtx2	wt x 2 age comp	5368	3432	0.6393	0.10782				
agewtx0.5	wt x 0.5 age comp	5542	3470	0.6262	0.10732				
RBC48	20:35:48 HCR	5451	3437	0.6305	0.10772	659	648	637	485
noSurvey	No Survey data (CE, LF, age)	5514	3567	0.6469	0.10779				

Table 5.15. Summary of likelihood components for the base-case and sensitivity tests. Except for the four columns of Totals, Likelihood components are unweighted. See Table 5.16 to see how the likelihoods deviate from the base-case. The likelihoods in the italicized cases should not be compared with the other sensitivities.

Sensitivity	TotalLike	TotalCE	TotalLF	TotalAge	CPUE	FISCE	TrawlLF	FISLF	IndustLF	PortLF	TrawlAge	FISAge
Base-Case	6035.31	-19.77	49.94	6005.14	-20.23	0.46	16.17	23.61	3.20	6.96	5235.24	769.90
hHigh	6035.17	-19.83	49.94	6005.05	-20.29	0.46	16.17	23.62	3.20	6.95	5235.20	769.85
hLow	6035.45	-19.70	49.94	6005.21	-20.15	0.45	16.17	23.61	3.20	6.96	5235.28	769.93
MHigh	6051.01	-22.26	51.58	6021.69	-23.13	0.87	16.65	24.53	3.31	7.09	5252.10	769.59
Mmid	6047.37	-15.27	48.66	6013.97	-15.47	0.20	15.74	22.98	3.11	6.83	5243.28	770.70
MLow	6169.37	5.38	45.36	6118.63	5.74	-0.36	14.43	21.51	2.89	6.52	5343.15	775.48
MatHigh	6035.32	-19.76	49.94	6005.14	-20.21	0.46	16.17	23.61	3.20	6.96	5235.25	769.89
MatLow	6035.26	-19.79	49.94	6005.10	-20.25	0.46	16.17	23.62	3.20	6.96	5235.22	769.88
SigRHigh	6030.01	-20.24	49.92	6000.33	-20.75	0.51	16.18	23.60	3.19	6.96	5230.95	769.38
SigRLow	6045.12	-19.07	49.98	6014.21	-19.46	0.39	16.19	23.64	3.21	6.94	5243.57	770.63
recdev03	6037.55	-19.26	49.99	6006.82	-19.67	0.41	16.17	23.62	3.24	6.96	5236.39	770.43
LFwtx2	6013.90	-42.13	50.15	6005.88	-21.61	0.54	16.26	23.73	3.20	6.96	5236.46	769.42
LFwtx0.5	6045.45	-9.24	49.79	6004.90	-18.86	0.38	16.11	23.55	3.19	6.94	5234.76	770.14
cpuewtx2	6084.28	-19.53	96.58	6007.23	-19.98	0.45	15.60	23.07	2.97	6.65	5236.91	770.32
cpuewtx0.5	6009.97	-19.92	25.81	6004.07	-20.38	0.46	16.87	24.03	3.45	7.29	5234.67	769.40
agewtx2	12029.75	-19.48	51.44	11997.80	-19.95	0.46	16.79	23.93	3.43	7.28	5229.85	769.05
agewtx0.5	3036.38	-20.32	48.52	3008.18	-20.78	0.46	15.68	23.22	2.98	6.64	5245.78	770.58
RBC48	6035.31	-19.77	49.94	6005.14	-20.23	0.46	16.17	23.61	3.20	6.96	5235.24	769.90
noSurvey	5235.37	-19.88	25.54	5229.71	-19.88	0.00	15.02	0.00	3.39	7.13	5229.71	0.00

Table 5.16. Summary of likelihood components for the base-case and sensitivity tests with the values from the sensitivity tests subtracted from the base-case values. Negative values denote improved model fits, positive values reduced model fits. Except for the four columns of Totals, Likelihood components are unweighted. The likelihoods in the italicized cases should not be compared with the other sensitivities.

Sensitivity	TotalLike	TotalCE	TotalLF	TotalAge	CPUE	FISCE	TrawlLF	FISLF	IndustLF	PortLF	TrawlAge	FISAge
Base-Case	6035.31	-19.77	49.94	6005.14	-20.23	0.46	16.17	23.61	3.20	6.96	5235.24	769.90
hHigh	-0.14	-0.06	0.00	-0.09	-0.06	0.01	0.00	0.01	0.00	0.00	-0.04	-0.05
hLow	0.14	0.07	0.00	0.07	0.08	-0.01	0.00	-0.01	0.00	0.00	0.04	0.03
MHigh	15.70	-2.49	1.64	16.55	-2.90	0.41	0.48	0.92	0.11	0.14	16.86	-0.30
Mmid	12.06	4.51	-1.28	8.83	4.76	-0.25	-0.44	-0.63	-0.09	-0.12	8.04	0.80
MLow	134.06	25.15	-4.59	113.49	25.97	-0.82	-1.74	-2.10	-0.31	-0.44	107.91	5.58
MatHigh	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
MatLow	-0.05	-0.02	0.00	-0.04	-0.02	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02
SigRHigh	-5.30	-0.47	-0.02	-4.81	-0.52	0.05	0.00	-0.02	-0.01	0.01	-4.29	-0.52
SigRLow	9.81	0.70	0.04	9.07	0.77	-0.07	0.01	0.03	0.01	-0.01	8.33	0.74
recdev03	2.24	0.51	0.05	1.68	0.56	-0.05	0.00	0.01	0.04	0.01	1.15	0.53
LFwtx2	-21.41	-22.36	0.21	0.74	-1.38	0.09	0.09	0.11	0.00	0.01	1.22	-0.48
LFwtx0.5	10.14	10.53	-0.15	-0.24	1.37	-0.07	-0.07	-0.07	-0.01	-0.01	-0.48	0.25
cpuewtx2	48.97	0.24	46.64	2.09	0.25	-0.01	-0.57	-0.54	-0.23	-0.31	1.67	0.43
cpuewtx0.5	-25.34	-0.15	-24.13	-1.07	-0.15	0.01	0.69	0.41	0.25	0.33	-0.57	-0.50
agewtx2	5994.44	0.29	1.49	5992.66	0.28	0.00	0.62	0.32	0.23	0.32	-5.39	-0.85
agewtx0.5	-2998.93	-0.55	-1.42	-2996.96	-0.55	0.01	-0.49	-0.39	-0.22	-0.32	10.54	0.68
RBC48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
noSurvey	-799.94	-0.11	-24.40	-775.43	0.35	-0.46	-1.16	-23.61	0.19	0.18	-5.53	-769.90

Table 5.17. Tabulated deterministic output from the projections. The filled dots in Figure 5.16 are the year and Depletion column values (as proportions not percentages).

Year	Spawning Biomass	RBC 20:35:41	Total Biomass	Exploitable Biomass	Harvest Rate (%)	Depletion (%)
2015	3538.0	900.6	12280.7	12186.5	7.39	64.90
2016	3396.4	862.1	11876.5	11782.8	7.32	62.31
2017	3265.2	827.2	11514.6	11421.3	7.24	59.90
2018	3143.4	795.0	11192.0	11099.2	7.16	57.66
2019	3030.8	765.0	10906.2	10813.9	7.07	55.60
2020	2928.0	736.9	10655.0	10563.1	6.98	53.71
2021	2835.5	710.8	10435.9	10344.5	6.87	52.02
2022	2753.9	686.9	10246.5	10155.4	6.76	50.52
2023	2683.3	665.5	10084.0	9993.4	6.66	49.22
2024	2623.4	646.8	9945.6	9855.2	6.56	48.12
2025	2573.3	630.8	9828.0	9737.9	6.48	47.21
2026	2531.9	617.5	9728.1	9638.2	6.41	46.45
2027	2497.9	606.5	9642.8	9553.2	6.35	45.82
2028	2469.8	597.5	9569.6	9480.1	6.30	45.31
2029	2446.5	590.2	9505.9	9416.6	6.27	44.88
2030	2426.7	584.2	9449.9	9360.7	6.24	44.52
2031	2409.7	579.2	9399.9	9310.9	6.22	44.20
2032	2394.6	575.0	9354.9	9266.0	6.21	43.93
2033	2381.1	571.3	9314.0	9225.1	6.19	43.68
2034	2368.8	568.0	9276.6	9187.8	6.18	43.45
2035	2357.3	565.0	9242.3	9153.5	6.17	43.24
2036	2346.7	562.2	9210.8	9122.1	6.16	43.05
2037	2336.8	559.5	9181.8	9093.2	6.15	42.87
2038	2327.7	557.1	9155.3	9066.7	6.14	42.70
2039	2319.2	554.8	9131.0	9042.5	6.14	42.54
2040	2311.3	552.7	9108.9	9020.5	6.13	42.40
2041	2304.2	550.7	9088.8	9000.4	6.12	42.27
2042	2297.6	548.9	9070.6	8982.3	6.11	42.15
2043	2291.7	547.3	9054.1	8965.8	6.10	42.04
2044	2286.4	545.8	9039.2	8951.0	6.10	41.94
2045	2281.5	544.4	9025.8	8937.5	6.09	41.85
2046	2277.2	543.2	9013.6	8925.4	6.09	41.77
2047	2273.3	542.1	9002.6	8914.4	6.08	41.70
2048	2269.8	541.1	8992.7	8904.5	6.08	41.64
2049	2266.6	540.2	8983.7	8895.5	6.07	41.58
2050	2263.8	539.4	8975.5	8887.4	6.07	41.53
2051	2261.2	538.7	8968.1	8880.0	6.07	41.48
2052	2258.8	538.0	8961.3	8873.2	6.06	41.44
2053	2256.7	537.4	8955.2	8867.1	6.06	41.40
2054	2254.8	536.9	8949.6	8861.6	6.06	41.36

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5.6 Appendix A

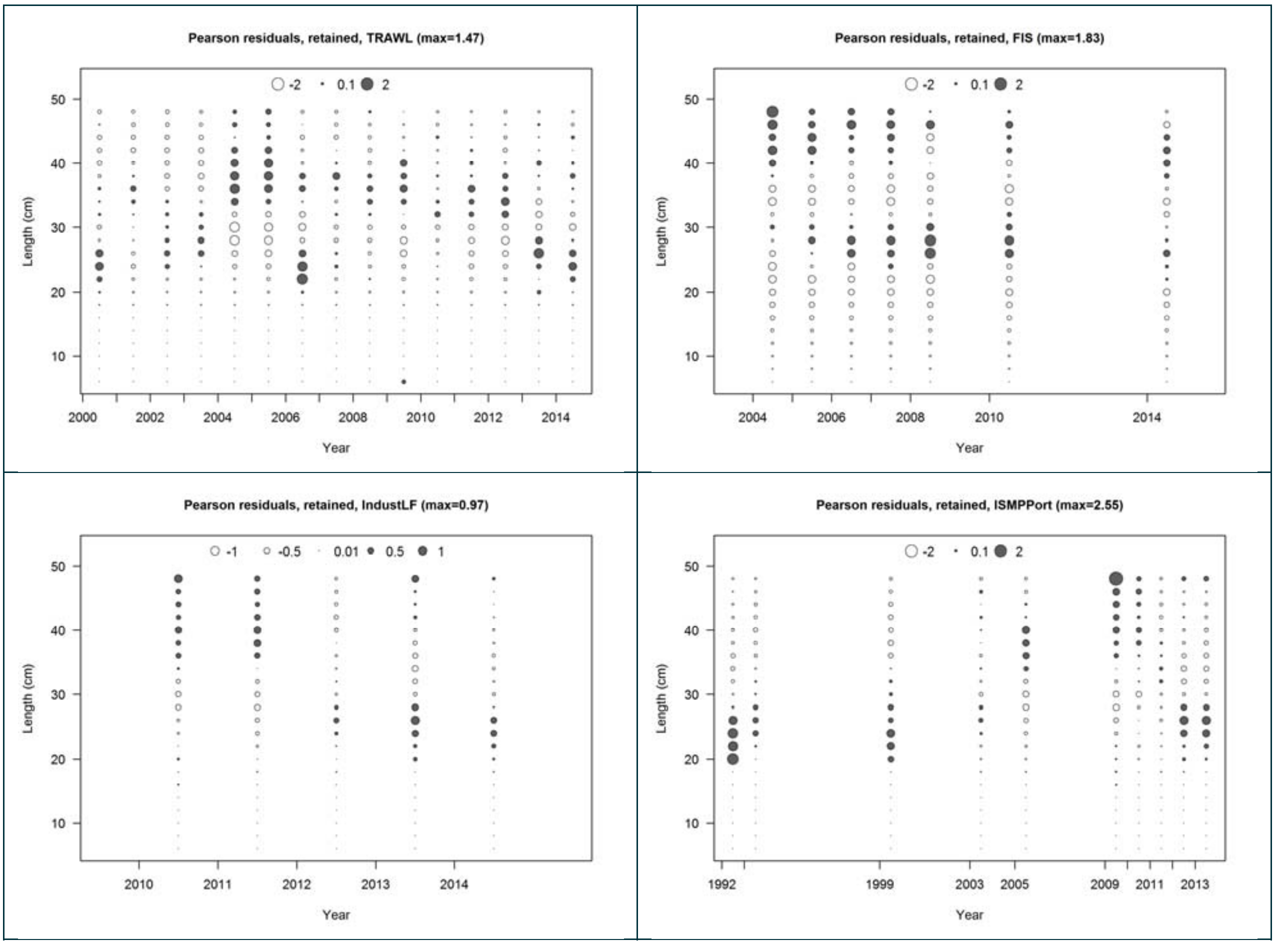

Figure 5.21. Residuals from the annual length composition data (retained) for Bight redfish displayed by year and fleet (TRAWL – ISMP_onboard).

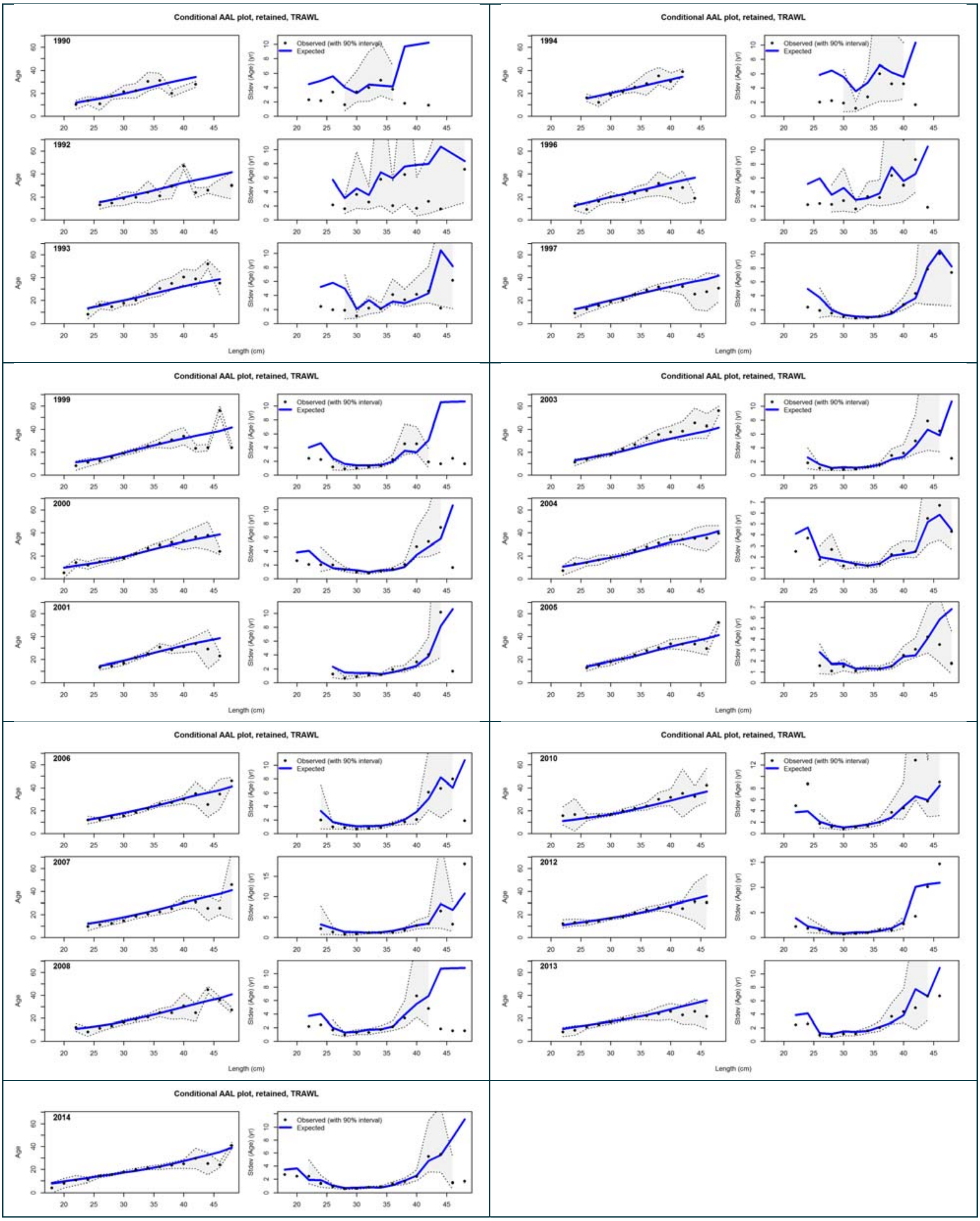

Figure 5.22. Conditional age-at-length plots illustrating the ages expected each year from the sampled length composition data and the age-length key for the year.

6. Silver Warehou (*Seriolella punctata*) stock assessment based on data up to 2014 – development of a preliminary base case

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6.1 Summary

This chapter presents a suggested base case for an updated silver warehou assessment. The assessment has been updated by the inclusion of data up to the end of 2014, which entails an additional three years of catch, discard, CPUE, length and age data since the 2012 assessment. Length frequency data collected onboard commercial trawl vessels has been separated from those collected in port, but a joint selectivity pattern is estimated. Data collected east and west of 147° longitude have been separated in east and west fleets, each with its own selectivity pattern. Abundance time series for the east and west from the trawl Fishery Independent Survey (FIS, Knuckey et al 2015) have been added.

The model has been restructured to allow estimation of size-base discarding, and recognises a change in the pattern of discarding from 2002. This, along with the addition of three more years of data, allows the estimation of five additional years of recruitment. These are estimated to have been poor to average in size. The model estimate of depletion for 2015 is 35% and for the start of 2016 is 40% (projected assuming 2014 catches in 2015). The selectivity patterns indicate that much smaller fish are caught in the east compared with the west, which strongly supports the separation of the data in to east and west fleets.

6.2 Background

The first integrated analysis stock assessment for silver warehou (formerly spotted warehou) in Australia was developed by the Blue Warehou Assessment Group (BWAG) between 2000 and 2002 (e.g. Thomson 2002). The assessment was updated by Taylor & Smith (2004). Tuck & Punt (2007) and Tuck (2008) improved the estimation of natural mortality (increasing it from 0.25y^{-1} to 0.3y^{-1}) and growth, improving fits to the length frequency data (Tuck, 2008). The estimated depletion for 2007/2008 continued at the 2011 level. However, the authors warned that the estimated trend in stock size was not matching that of the observed CPUE index in the most recent years and they cautioned that the stock might "breakout" according to the SESSF Tier 1 projections rules. Their prediction was correct (Figure 6.1, Klaer *et al.* 2014) – the 2012 and 2013 CPUE observations fell well below the forecast 95% prediction interval for silver warehou.

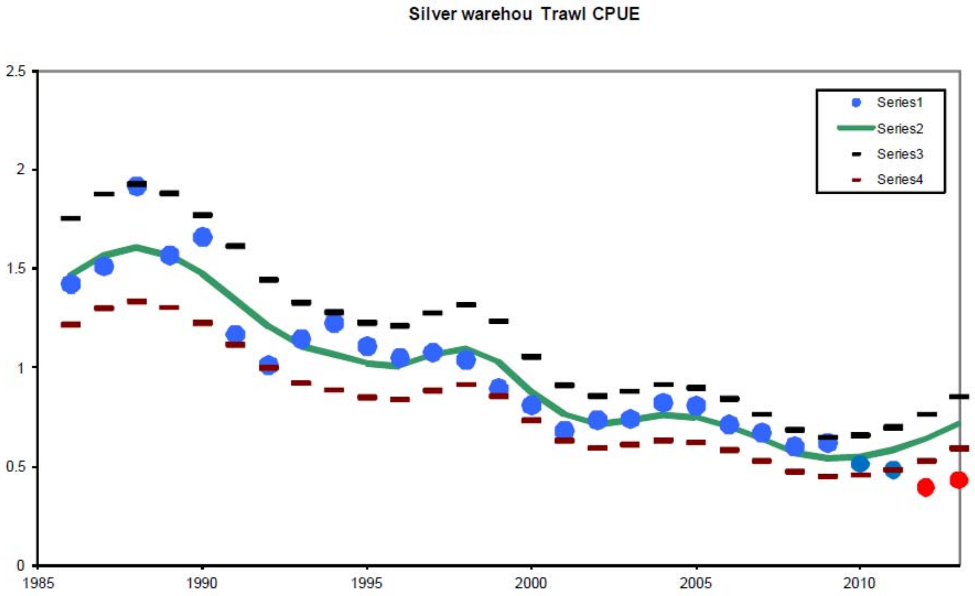

Figure 6.1. “Breakout” for silver warehou (taken from Klaer *et al.* 2014) showing estimated stock abundance (green line with prediction interval) and observed standardised CPUE (blue and red spots.

6.3 Changes to the 2012 Assessment

The assessment model framework used here is based on that of the previous assessment, performed in 2012. The following changes have been made:

1. Catch, discard, length frequency, and age at length data for 2012, 2013 and 2014 have been added.
2. Discarding is being estimated and discard length frequency data have been included in the assessment.
3. Fishery Independent Survey (FIS) abundance series added.
4. Five more years of recruitment are being estimated (note that this is two more than the number of years of data that have been added).
5. Length frequency data have been split into onboard and port collected components (sharing a single selectivity pattern).
6. The single trawl fleet has been split into east and west (of 147°) fleets, each with its own estimated selectivity pattern and discards (retention function).
7. Data collected from non-trawl vessels have been excluded from the dataset (this makes a negligible difference).
8. A new tuning procedure has been used to balance the weighting of each of the data sources that contribute to the overall likelihood function (this is a forerunner of an even newer protocol for tuning expected to be agreed on during a workshop in the USA next month - October 2015).

6.3.1 ***Discarding***

Examination of LFs for the retained and discarded components of the catch, derived from the onboard Observer Program revealed a change in the discarding pattern. During 2000-2002 the Blue (and later the Spotted) Warehou Assessment Group concluded that both size and market related discarding occurred for silver warehou (Thomson 2002) resulting in a decision to combine the discarded with the landed tonnage and not estimate a length-related discard (retention) pattern. This assumption was largely correct, but did ignore the size-relating discarding of small fish that was occurring along with market related discarding of fish of all sizes, as evidenced by the greater proportion of small fish in the discarded LFs relative to the retained LFs prior to 2002 (Figure 6.2).

A shift seems to occur from 2002 with small fish dominating the discard LFs and very few larger fish discarded (Figure 6.2). Day et al (2012) noted that "*the length residuals behave differently before and after 2002, with patterns in these residuals indicating some possible issues with the fits to the length data.*"

Time blocked discarding was introduced to the model, with separate retention (discard) functions estimated for the 1980-2001 and 2002-2014 periods. The model that uses separate east and west fleets allows independent discarding patterns in each area. The retention function used has three parameters: slope, intercept, and asymptote. The slope and intercept were estimated for both time periods but the asymptote parameter had to be treated with greater care. For models that do not use time blocking this parameter is confounded with stock size and therefore has to be fixed at 100% (i.e. 100% retention of the very largest fish). Theoretically, it is possible to estimate the asymptote for the earlier time period, when market related discarding might have reduced retention for even the largest fish below 100%. However, a likelihood profile revealed that the data supported a value of 100% for the asymptote for the model that combines east and west data into a single fleet.

The model that uses separate east and west fleets estimated an asymptote of 99% in the east (this was subsequently fixed at 100%) and 95% in the west.

The observed annual discard rates were assigned low CVs (0.1 for 10980-2001 and 0.05 for 2002-2014) to circumvent the model's tendency to estimate discard rates of approximately 40% in the early period and almost 0 in the later period.

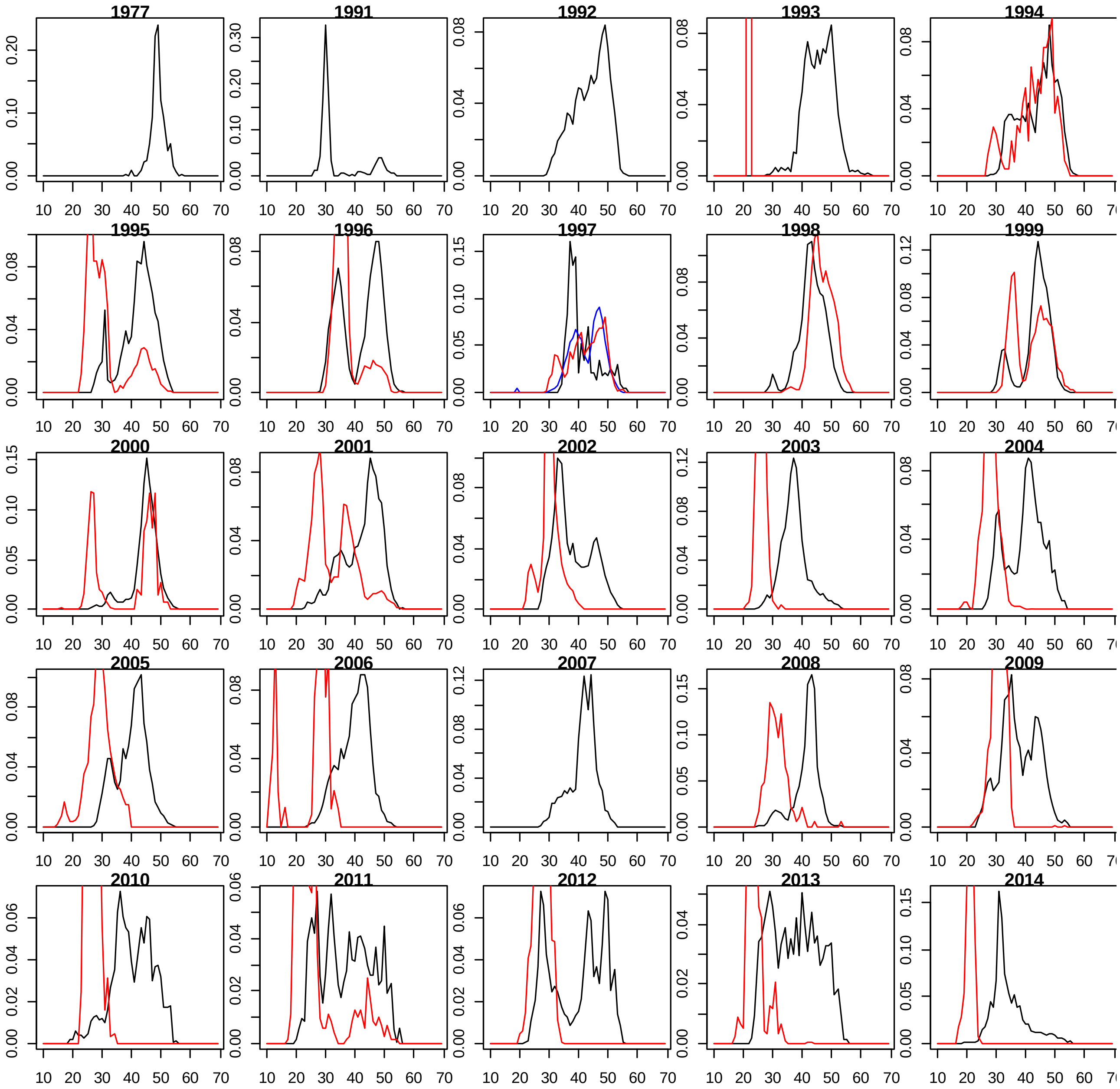

Figure 6.2. Retained (black) and discarded (red) components of the commercial trawl catch of silver warehou. The blue line is a single Kapala LF. Lengths were measured onboard fishing vessels by the AFMA Observer Program and its predecessor the ISMP.

6.3.2 *East and West Fleets*

Noting that silver warehou standardized CPUE was below the 95% prediction interval from the stock assessment model, and this appeared to be a consistent pattern, SlopeRAG suggested that this could be due to separate abundance trends in the east and the west and requested that alternative models that combined, and separated, east and west data be presented to SlopeRAG in September 2015. East and west length and age compositions do appear to differ, and the standardized CPUE trends are also somewhat different (Sporcic *et al.* 2015).

6.3.3 *Tuning Procedure*

Day et al (2012) had difficulties tuning the model, which they were able to solve by down weighting the age data (by multiplying the likelihood component for age by 0.25). This multiplier was removed and the new tuning method converged successfully. The tuning procedure used (Andre Punt pers comm.) was to:

1. Set the CV for the commercial CPUE value 0.1 for all years (set those for the FIS to the estimated CVs shown in Table 6.1)
2. Simultaneously tune the sample size multipliers for the LFs and ages using Francis weights for the LFs and Francis B (the larger of the Francis A and B factors, Francis 2011) - iterate to convergence;
3. Adjust the recruitment variance (σ_R) by replacing it with the RMSE and iterating to convergence (keep altering the recruitment bias adjustment ramps at the same time);
4. Weight the commercial CPUE and FIS abundance indices by replacing these with the relevant variance adjustment factors- iterate to convergence;
5. Reweight the age data using the Francis A adjustment factor, just once (no iterating);
6. Repeat steps 3 and 4.

6.3.4 *Bridging from 2012 to 2015 Assessments*

The previous full quantitative assessment for silver warehou was performed in 2012 (Day *et al.* 2012) using the software Stock Synthesis (SS), version SS-V3.24f (Methot, August 2012). The 2015 assessment uses “SS-V3.24U-fast”. There are only minor changes between these two versions of Stock Synthesis.

The proposed base case model for 2015 was generated from the 2012 assessment by making a series of small (where possible) incremental changes and estimating the parameters of the model after each change. In this way the 2015 assessment was developed in a series of steps. Those steps are listed below (model nicknames are given in italics and the computer files have been placed on a shared CSIRO folder).

1. Run the original assessment using the newest version of *SS [spot12]*.
2. Change the final year for the assessment from 2011 to 2014, revise *catch* data for 2011 and add catch data for 2012, 2013 and 2014 (in keeping with the 2012 assessment, total catches were used, representing landed catches plus estimated discards) [*B1*].
3. Replace *CPUE* series (ending 2011) with updated series ending 2014 (from Sporcic 2015).[*B2*]
4. Replace age-at-*length* data for 1980-2011 (no longer including non-trawl caught fish). [*B3*]
5. Add age-at-*length* data for 2012-2014.[*B4*]
6. Replace *ageing error* matrix with updated matrix (provided by Andre Punt pers comm).[*B5*]
7. Replace length frequencies (LFs, combined onboard and port samples) with *onboard LFs* for 1980-2014 and replace sample size (number of fish) with number of *operations* (shots).[*B6*]
8. Add *port* LFs weighted by number of *operations* (trips).[*B7*]

9. Estimate five more years of *recruitment* and update bias adjustment for recruitment deviations.[*B8*]
10. Separate total catch into landings and discards, add discard LFs and estimate *discarding (no time block)* [*B9*]
11. *Time block* the retention function (discarding) 1980-2001 and 2002-2014 [*B10*]
12. Add *FIS* abundance series for east and west combined and redo bias adjustment (mirror selectivity for east and west FIS fleets to east and west commercial trawl fleets) [*B11 & B12*]
13. Split catch, LF and FIS data between east and west (in the absence of better information, the overall discard rates are assigned to both east and west). [*N1*]
14. Tune the relative weights on the data sources. [*N6*]

The 2015 assessment update assumes that silver warehou constitute a single population (ie a single recruitment pattern) but that fishing fleets in the east and west fish different components of the stock. In keeping with the earlier assessments, only the otter trawl fishery is modelled. The discard proportions used were those calculated by Judy Upston (CSIRO e.g. Upston & Klaer 2014) and were assumed to apply to non-factory trawlers only (factory trawlers are assumed not to discard silver warehou). Natural mortality was fixed at $0.3y^{-1}$. All of these model assumptions were agreed at previous RAG meetings (Day et al 2012).

Relative abundance of silver warehou was calculated from FIS collected data, separately, for the east and west regions. The resulting median values, with their associated CVs, were included in the model (Table 6.1). The inter-annual variability in the estimates, particularly in the east, is much greater than that suggested by the CVs on the individual points in the time series. This is likely to be due to the schooling nature of the fish, resulting in occasional very large shots and consequent high abundance estimates.

Table 6.1. Relative abundance estimates for silver warehou in the east and west, with associated CVs. Calculated using trawl Fishery Independent Survey data (Knuckey et al 2015).

	East		West	
Year	Median	CV	Median	CV
2008	149.0	0.21	110.7	0.18
2010	55.6	0.18	25.9	0.18
2012	218.7	0.28	25.6	0.18
2014	14.7	0.21	32.2	0.15

6.4 Results

Most of the steps in the bridging analysis had very little effect, or made changes that were lost at the very next step. A plot showing all of the steps is very hard to read, consequently Figure 6.3 shows only steps of interest.

Inclusion of all the new data (for 2012, 2013, and 2014) including splitting the LFs into port and onboard components has little effect on the estimated depletion in recent years (B7 vs Spot 12, Figure 6.3), however it substantially alters the size of several recruitments, particularly the very large ones, thus altering the size of the peaks and troughs in the spawning biomass series (B7 vs Spot 12, Figure 6.4). Allowing the model to estimate the retention (discarding) pattern from the discard LFs and estimating five new recruitments results in a declining biomass trend in recent years (B10, Figure 6.3).

Splitting the data into east and west fleets alters the estimated recruitment pattern throughout the time period, increasing or decreasing several estimates thus raising or lowering spawning biomass (N4, Figure 6.3) relative to the original model. However, tuning the model also has a substantial effect, indicating that there are conflicting signals from data sources (N6, Figure 6.3). In particular, the effect of tuning is to increase the size of the estimated recruitments in 2010, 2011 and 2012 (N6, Figure 6.4). The size of many of the recruitments in the series, particularly the older ones, is poorly estimated (Figure 6.4), more so than the recent depletion estimate (Figure 6.3).

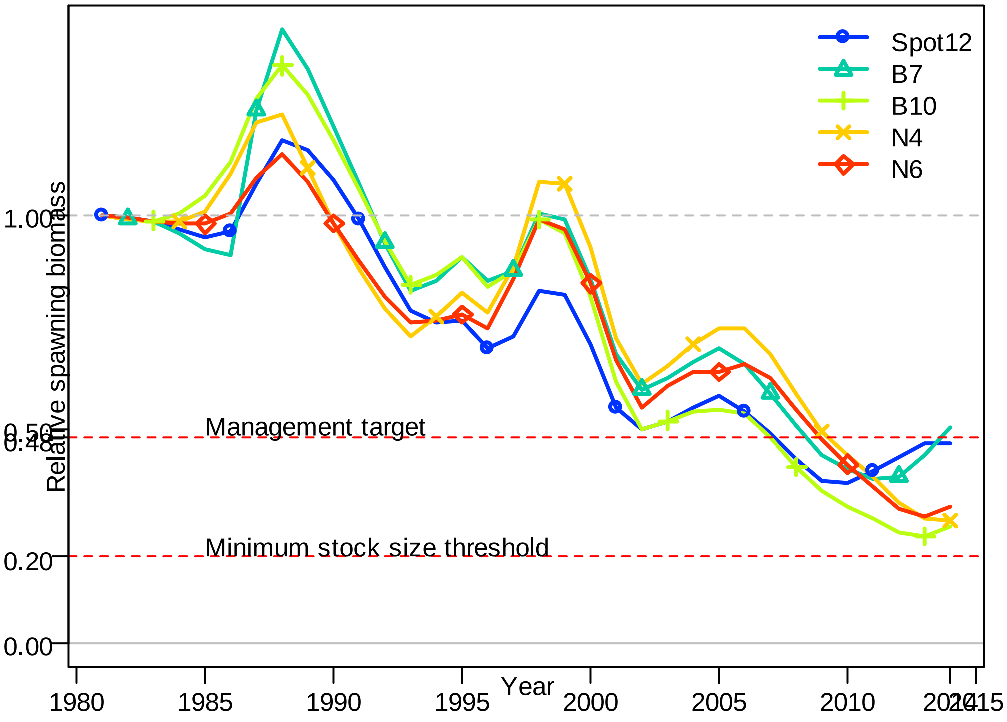

Figure 6.3. Depletion (spawning biomass relative to unfished biomass) for the 2012 base case assessment (Spot12), 2012 base case with updated data including onboard and port LFs (B7), the addition of size related discarding with time blocking (B10); the separation of east and west fleets (N4) and tuning of the final model (N6).

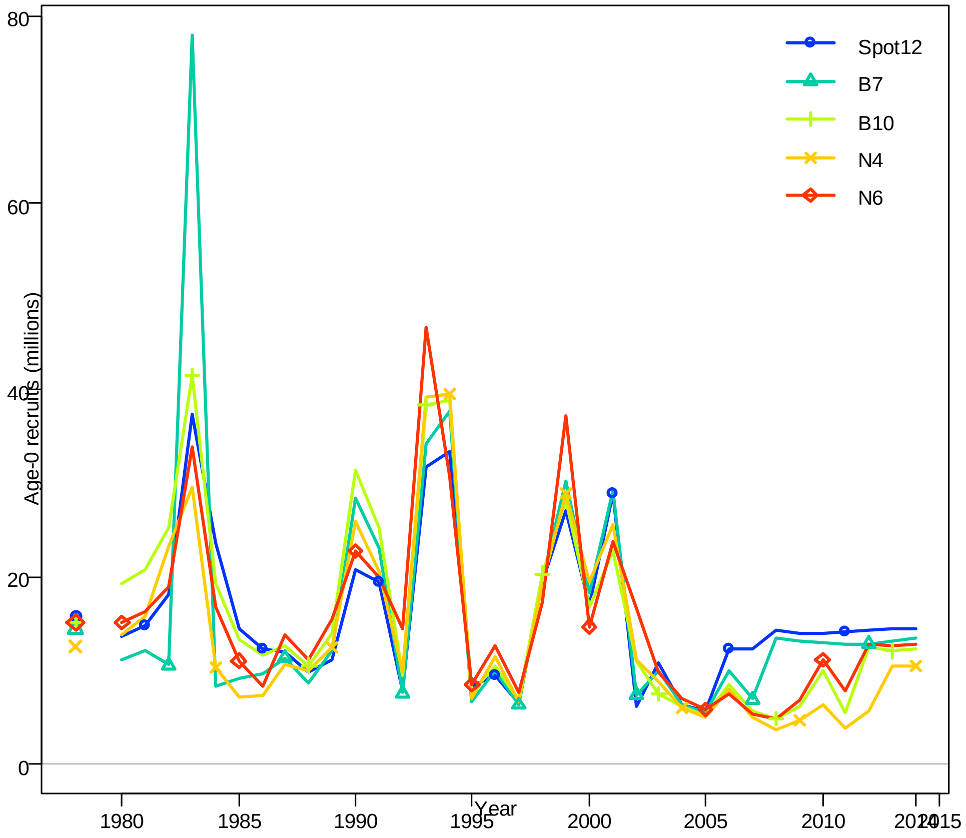

Figure 6.4. Estimated number of recruits for the 2012 base case assessment (Spot12), 2012 base case with updated data including onboard and port LFs (B7), the addition of size related discarding with time blocking (B10); the separation of east and west fleets (N4) and tuning of the final model (N6).

6.4.1 *Sensitivity to Data Weighting*

To better understand the effect of tuning the model, and the conflict between data sources that this implies, each of the LF, age, and commercial CPUE data series was upweighted, one at a time, and the model parameters re-estimated (Figure 6.5. The weight on the FIS abundance index was not altered, as that data series was assigned very low weight by the tuning process and was consequently not influential. Upweighting the LF data leads to a similar relative spawning biomass trajectory to upweighting the CPUE, however a very different trend results from upweighting the age data (Figure 6.5). It is not unusual for LF data to be in conflict with CPUE data, however LF and age date are often in agreement because otoliths are typically drawn from the same samples that are measured. A conflict between the length and age data suggests a possible mis-specification of growth. Thomson (2002) found some evidence for cohort specific (density dependent) growth, and Day et al (2012) recommended and explored the estimation of cohort specific growth. It might be worth investigating that again, particularly now that the estimation of time blocked retention has removed the residual pattern in the post-2002 LF data noted by Day et al (2012).

If the LF data is upweighted, a large recruitment is estimated in 2012 to explain large numbers of small fish seen in the 2013 and 2014 samples (N11, Figure 6.6) but when the age data is upweighted, the 2011 and 2012 recruitments are very small (N9, Figure 6.6). Upweighting the CPUE results in intermediate recruitment levels in those years (N8, Figure 6.6).

The tuning method used here is new, and is still undergoing refinement. Updated methodology is expected to result from a workshop to be held in the USA during October. It is possible, perhaps even probable, that altered tuning methodology would shift the result of this model by changing the relative weights between the conflicting data sources.

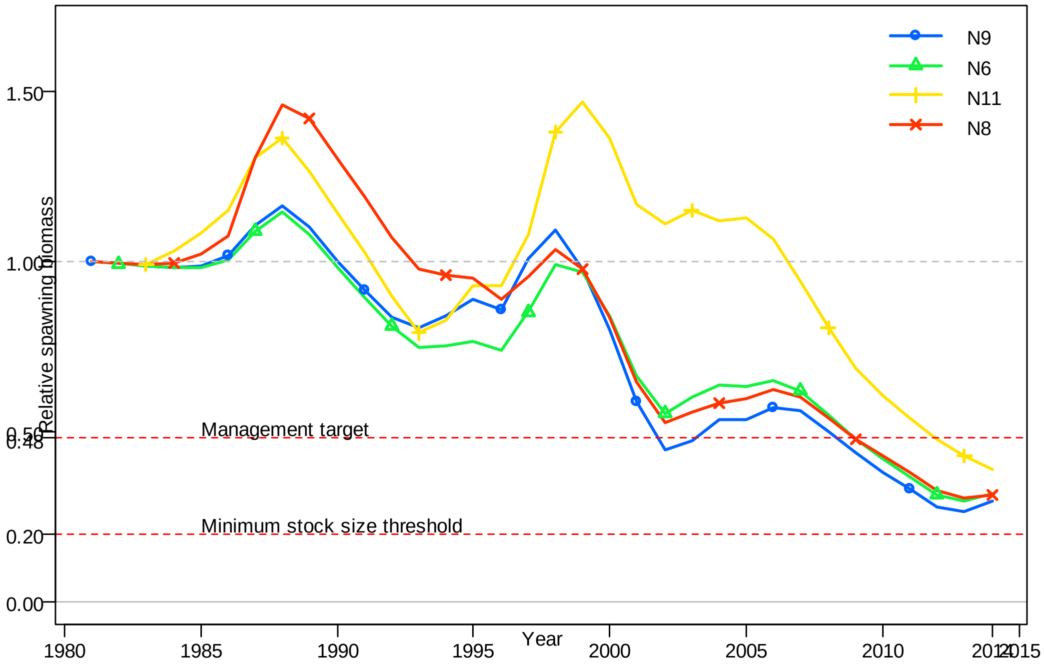

Figure 6.5. Depletion (spawning biomass relative to unfished biomass) for the tuned preliminary base case model (N6), the models that upweight LFs (N9), age data (N11), and commercial CPUE (N8).

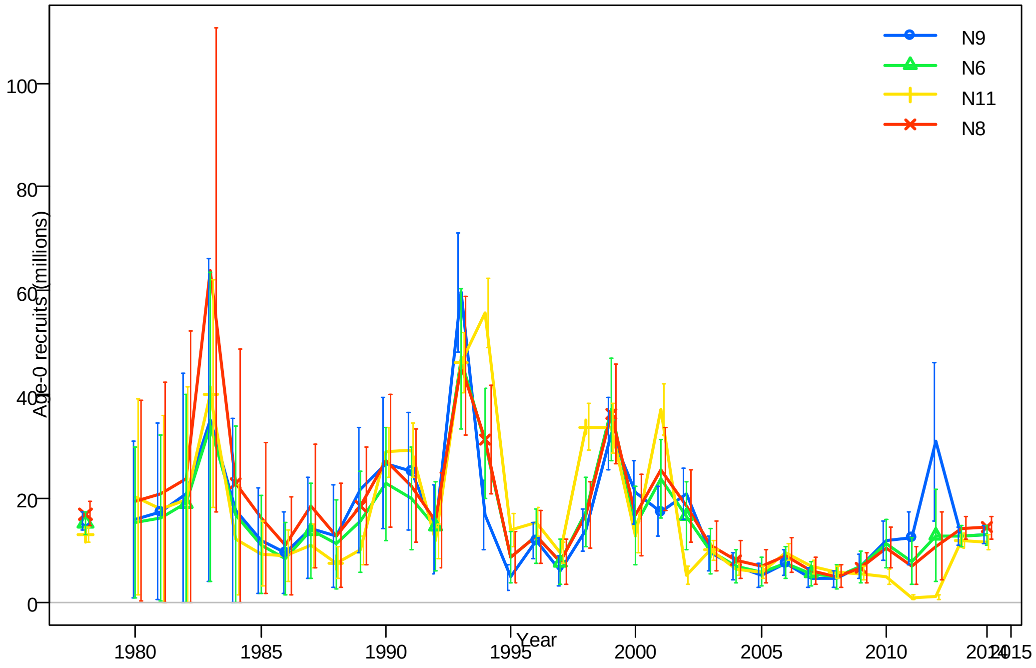

Figure 6.6. Estimated recruitment for the tuned preliminary base case model (N6), the models that upweight LFs (N9), age data (N11), and commercial CPUE (N8).

6.5 Recommendations for the 2015 Base Case

1. Large differences between the selectivity pattern in the east and west (see Appendix), as well as visually better fits (not shown) to all data, support the use of separate east and west fleets.
2. Examination of the LF data support the estimation of size based discarding (retention) after 2002, and a separate pattern prior to 2002. This allows the estimation of two extra recruitments.
3. Model fits to the LF and age data are acceptable, but not impressive and the conflict between the length and age data suggest that the model is not capturing a relatively important dynamic. This could be differing growth rates between cohorts, possibly due to density dependence. It is recommended that cohort specific growth be implemented in this model in order to test the support for this.
4. The trawl gear used by the FIS in the west during 2008 was unable to sink to the desired depth and was subsequently changed (Knuckey et al 2012). It is recommended that the 2008 FIS data in the west be excluded.
5. If newer tuning methodology becomes available prior to the October SlopeRAG meeting, this should be applied to the 2015 silver warehou assessment model.
6. The relative weighting given to the age, length and CPUE data, strongly influences the size of recent recruitments; this has more influence on short term forecasts of spawning biomass than on estimated depletion in 2014. The model estimate of depletion for 2015 is 35% and for the start of 2016 is 40% (projected assuming 2014 catches in 2015). Careful consideration should be given to which forecasts are used to set future RBCs. Moreover, recent recruitments have been poor to, at best, average, suggesting that forecasts that assume average recruitment into the future might be optimistic.
7. The observed discard rates for the east and west combined was assumed to apply to the east and west fleets, separately. It would be preferable to estimate separate discard rates for each fleet (however this is unlikely to strongly influence the results).

6.6 References

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6.7 Appendix A

Input data, model fits, estimated functions, and diagnostics for the preliminary 2015 base case assessment model (N6) that assumes separate trawl fleets in the east and west, allows for time blocked discarding (1980-2001, 2002-2014) and uses data to 2014.

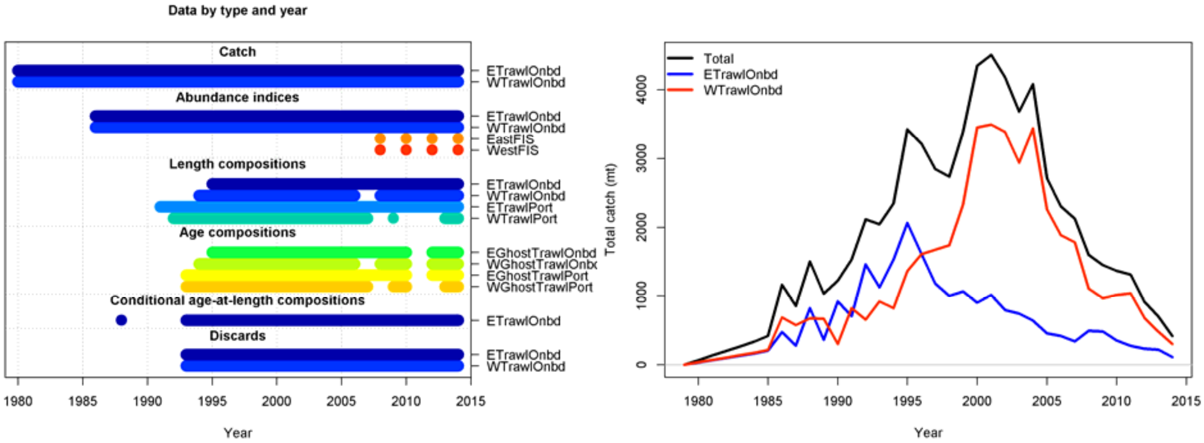


Figure 6A.1. (Left) Data time series used in the preliminary base case assessment; (right) landed catches for east and west fleets and total landings.

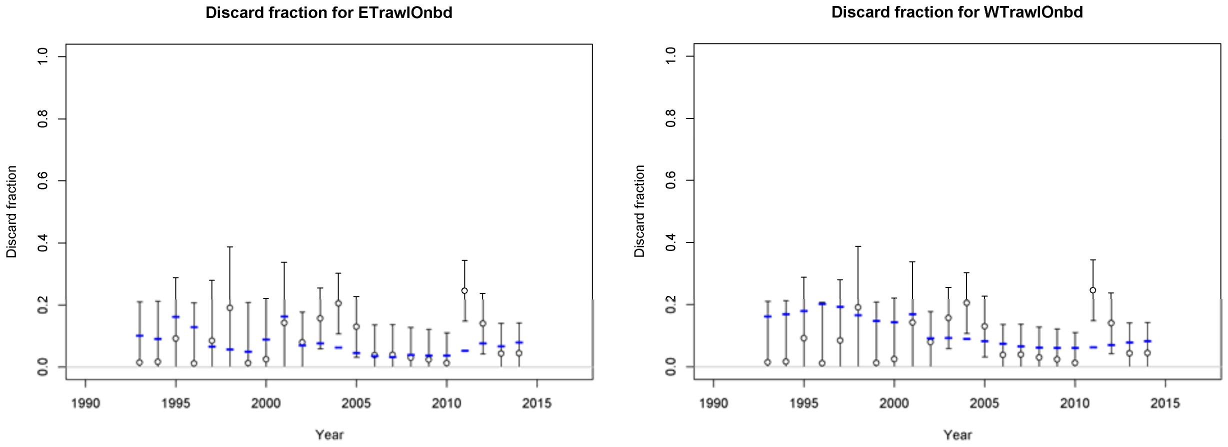


Figure 6A.2. (Left) Observed (black circles with confidence intervals) and model estimated (blue) discard rates for (left) east and (right) west fleets.

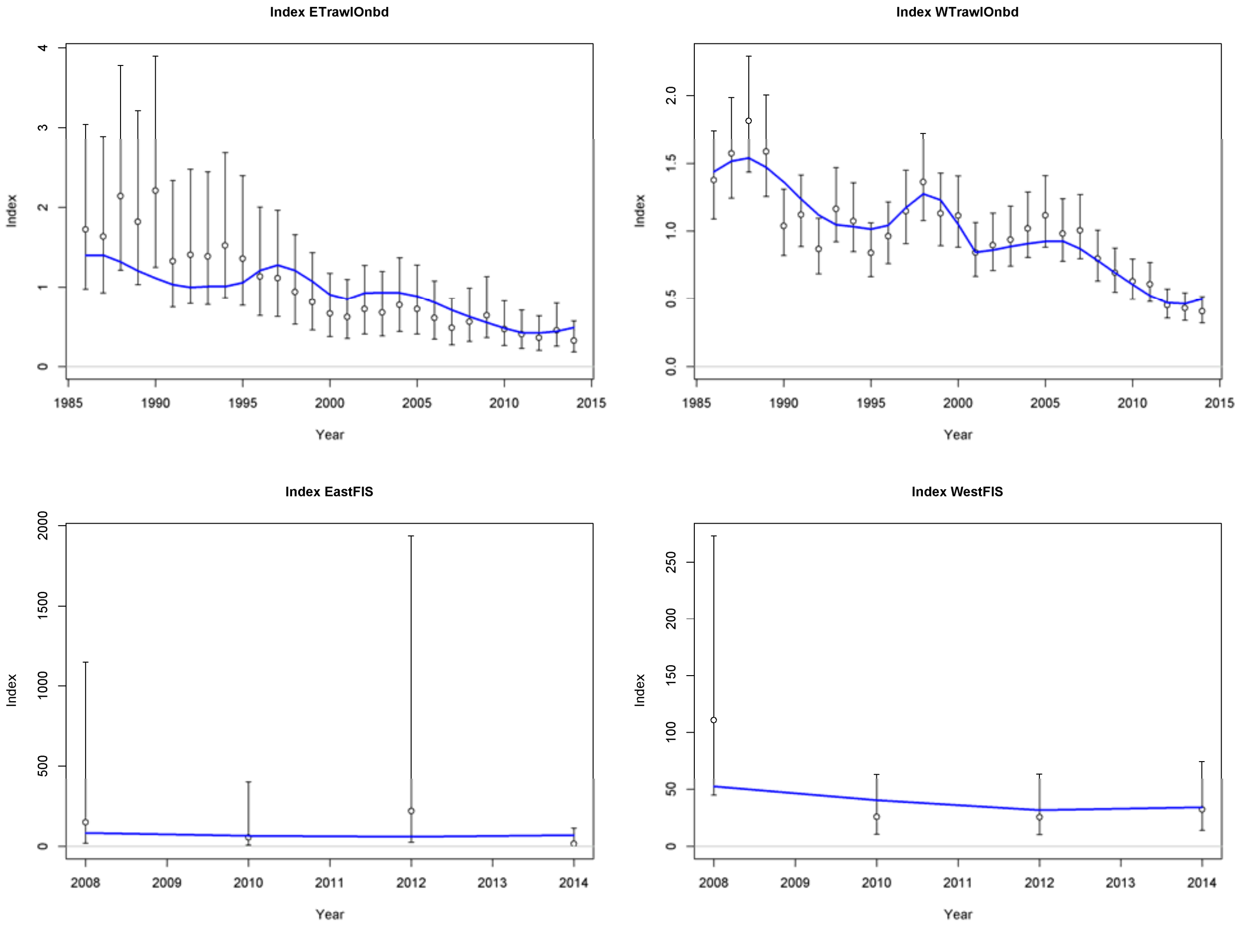


Figure 6A.3. Standardized observed CPUE for the (top left) east and (top right) west commercial trawl fleets; and FIS abundance index for the (bottom left) east and (bottom right) west. Black lines are observed and blue are estimated abundance.

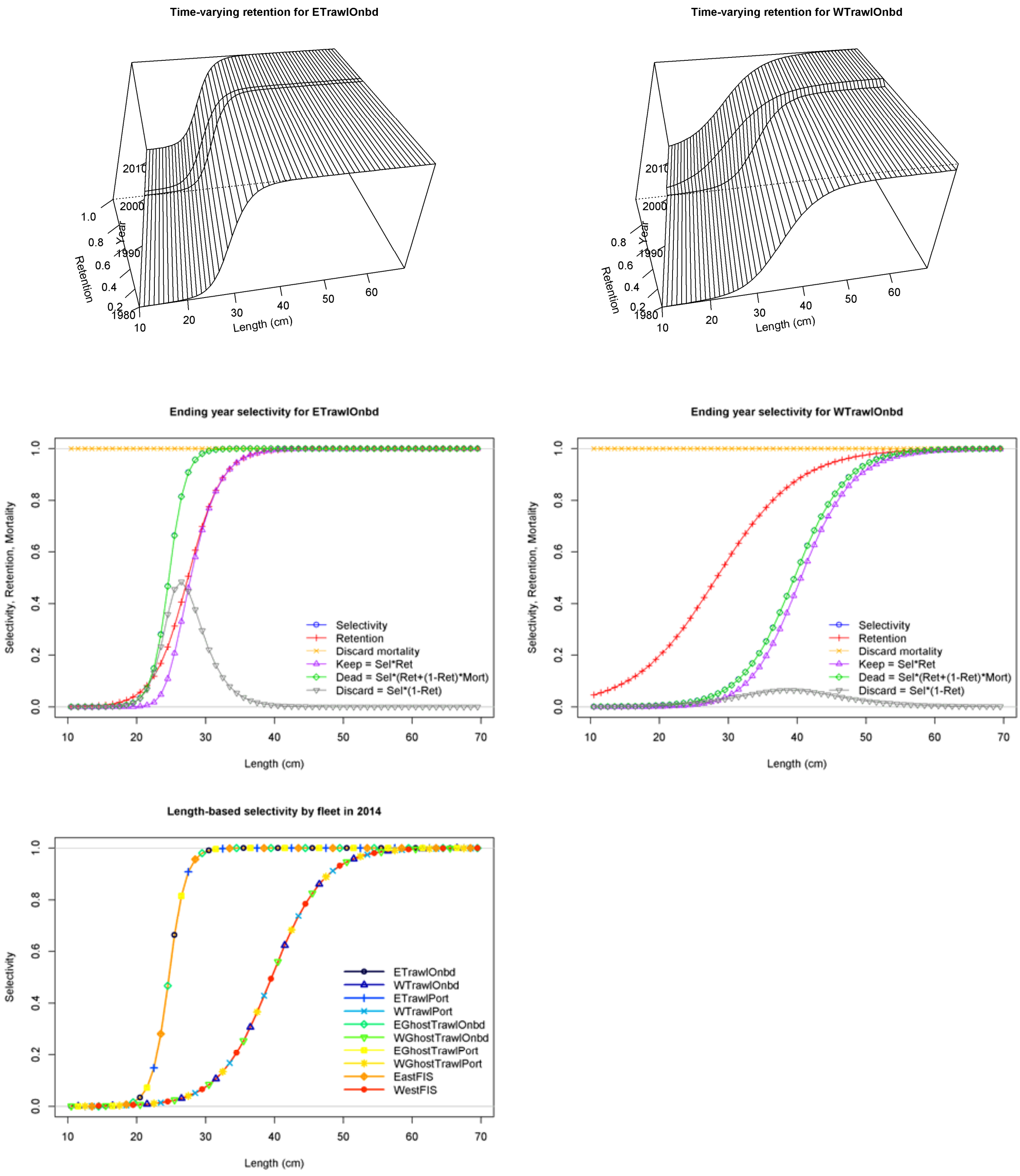


Figure 6A.4. Estimated retention function (discard pattern) for two time blocks (1980-2001, and 2002-2014) for (top left) the east and (top right) the west commercial trawl fleets. Selectivity and discard patterns for (middle left) east and (middle right) west fleets, and east and west selectivity patterns plotted together (bottom).

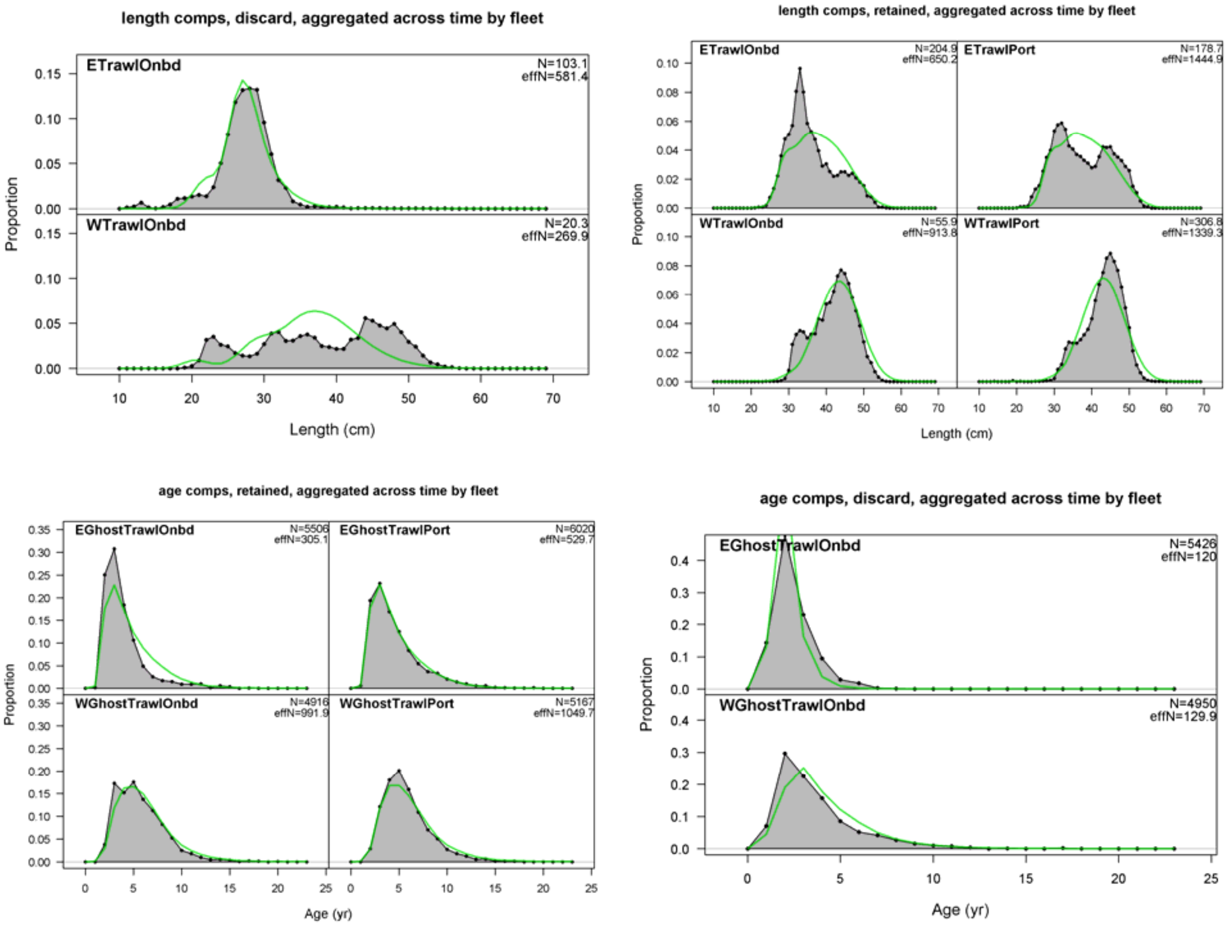


Figure 6A.5. Aggregated length and age compositions for the onboard and port data sources in both the east and west. Observed data are grey and the assessment is a green line. Note that the model is conditioned on the age-at-length data, not on the age compositions themselves.

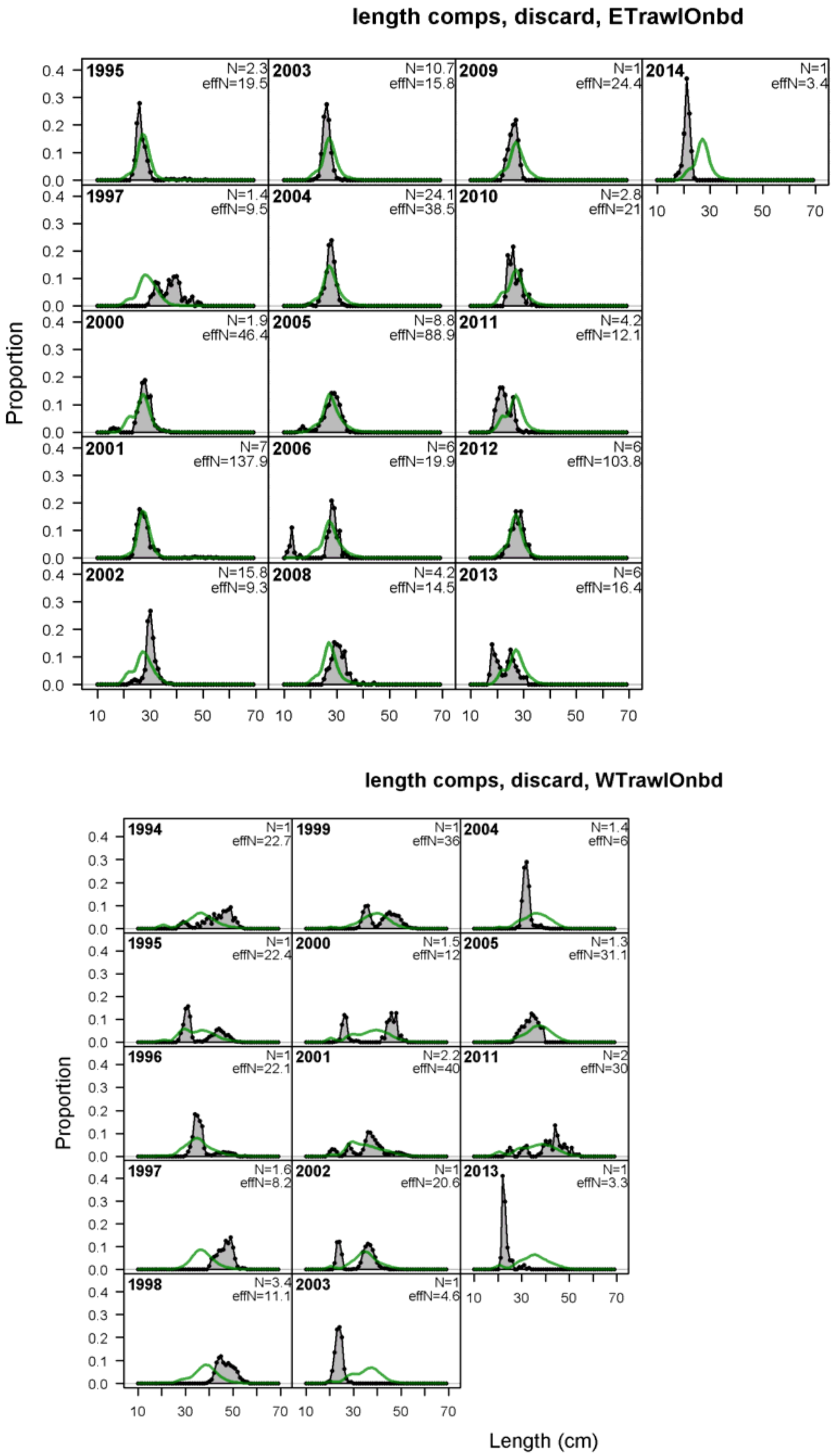
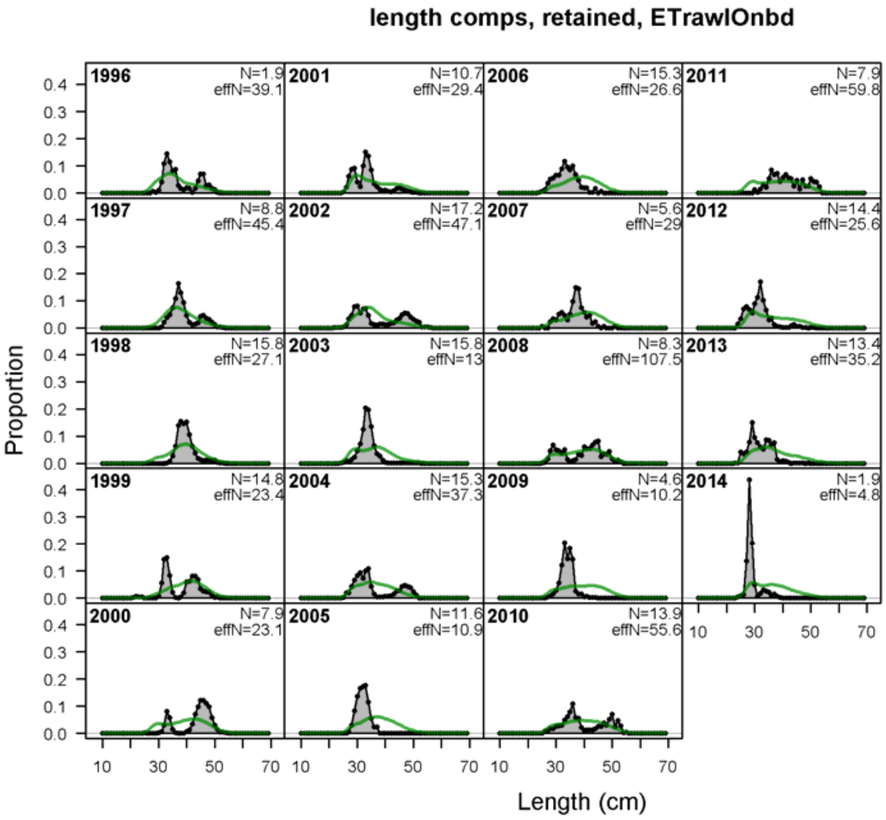
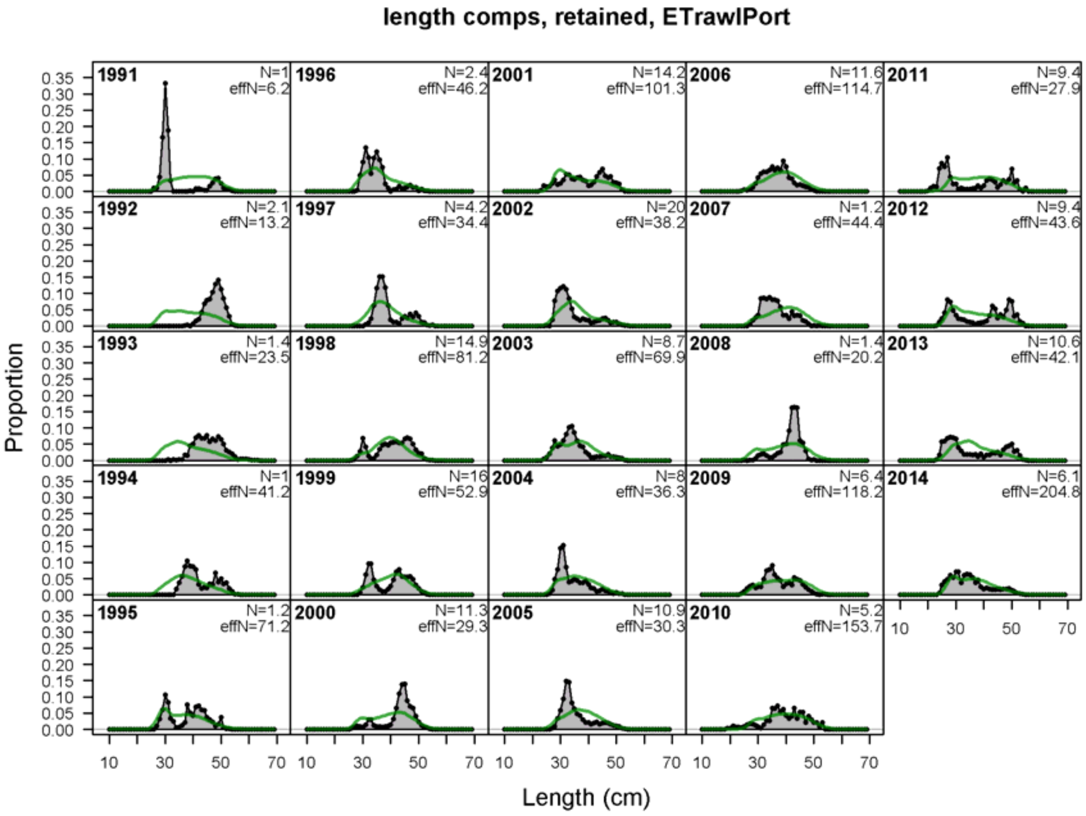


Figure 6A.6. Annual observed (grey) and estimated (green) LFs for the discarded component of the catch of the (top) east and (bottom) west fleets.


length comps, retained, ETrawlOnbd


length comps, retained, ETrawlPort

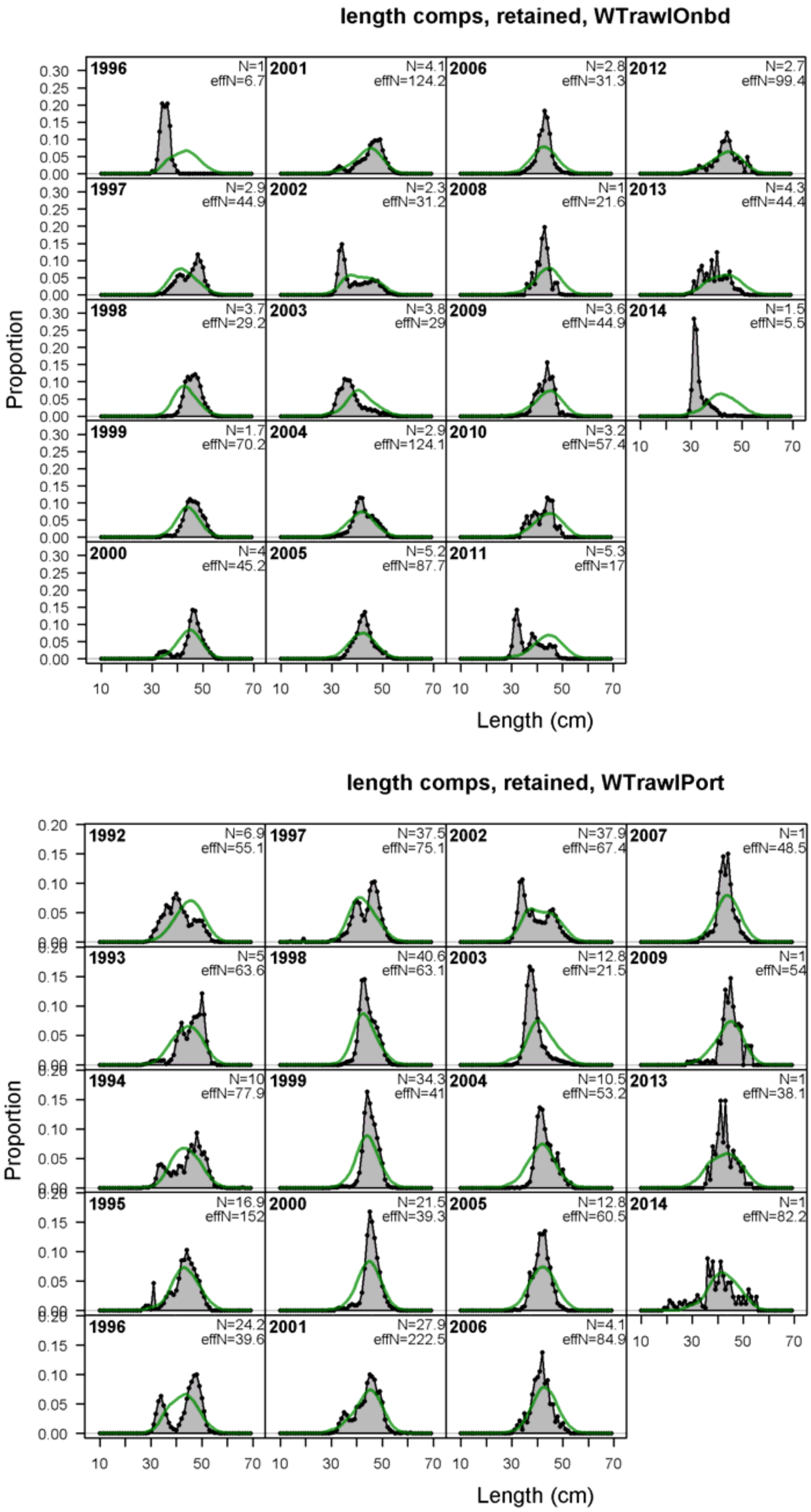


Figure 6A.7. Annual observed (grey) and estimated (green) LFs for the retained component of the catch of the (top) east and (bottom) west fleets for both the onboard and port measurements.

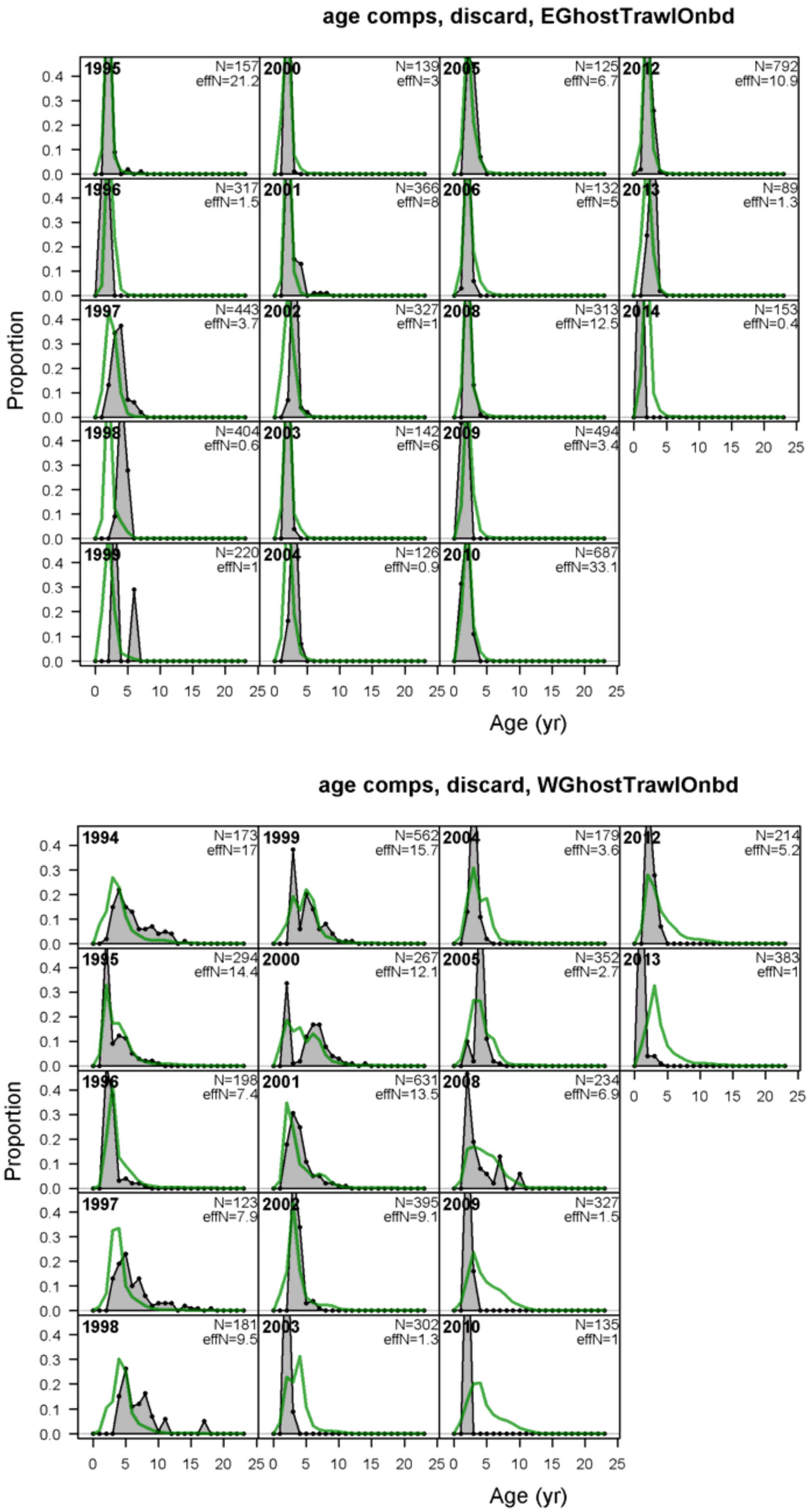
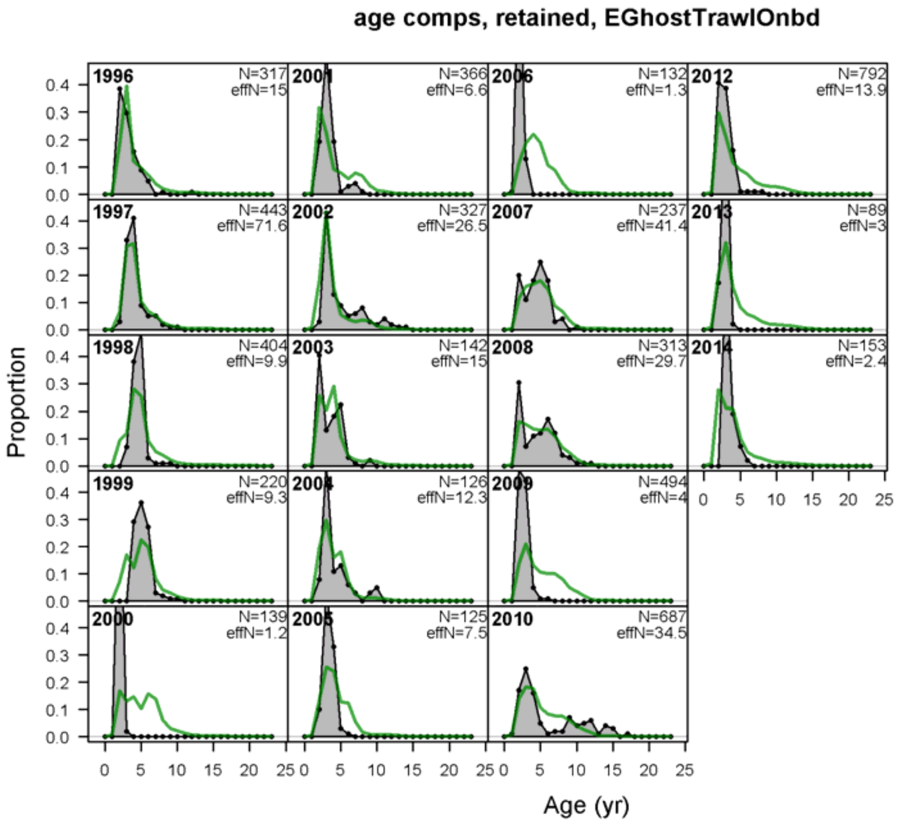
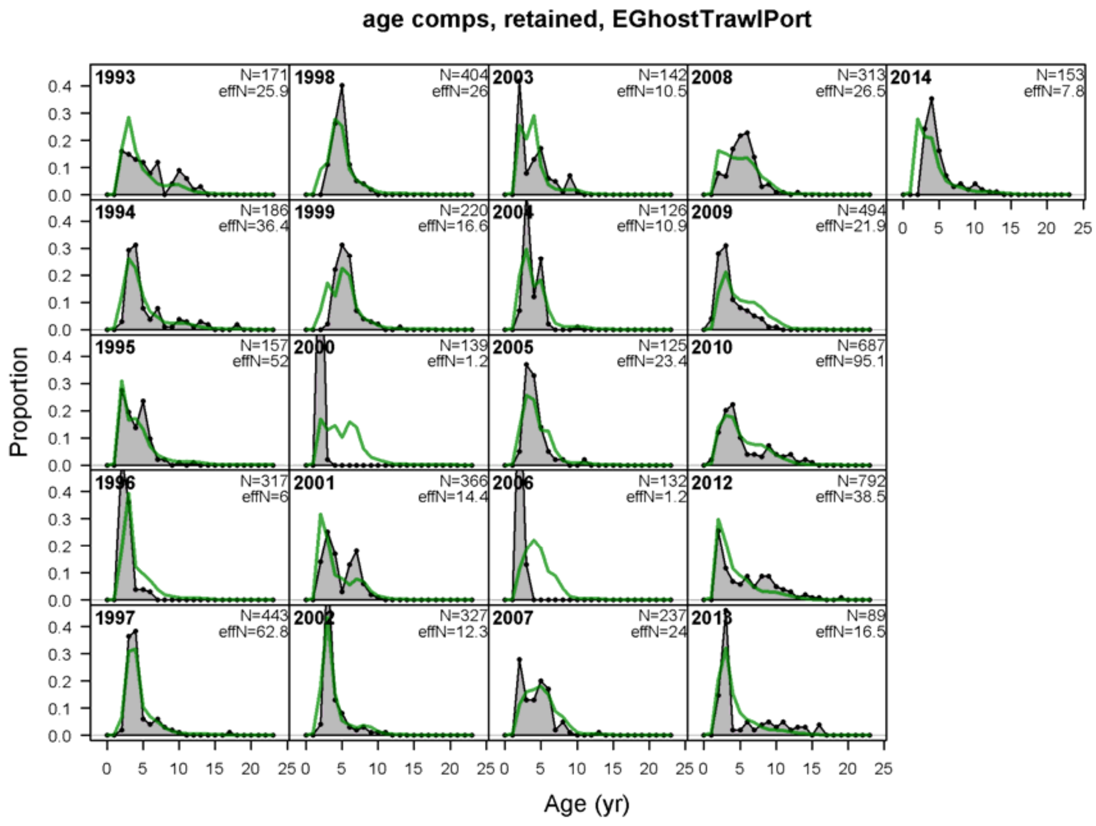


Figure 6A.8. Annual observed (grey) and estimated (green) age composition for the discarded component of the catch of the (top) east and (bottom) west fleets. Note that these are not used in conditioning the model.


age comps, retained, EGhostTrawlOnbd
1996 N=317 effN=15
1997 N=443 effN=71.6
1998 N=404 effN=9.9
1999 N=220 effN=9.3
2000 N=139 effN=1.2
2001 N=366 effN=6.6
2002 N=327 effN=26.5
2003 N=142 effN=15
2004 N=126 effN=12.3
2005 N=125 effN=7.5
2006 N=132 effN=1.3
2007 N=237 effN=41.4
2008 N=313 effN=29.7
2009 N=494 effN=4
2010 N=687 effN=34.5
2012 N=792 effN=13.9
2013 N=89 effN=3
2014 N=153 effN=2.4
Proportion
0.0
0.1
0.2
0.3
0.4
0 5 10 15 20 25
Age (yr)


age comps, retained, EGhostTrawlPort
1993 N=171 effN=25.9
1994 N=186 effN=36.4
1995 N=157 effN=52
1996 N=317 effN=6
1997 N=443 effN=62.8
1998 N=404 effN=26
1999 N=220 effN=16.6
2000 N=139 effN=1.2
2001 N=366 effN=14.4
2002 N=327 effN=12.3
2003 N=142 effN=10.5
2004 N=126 effN=10.9
2005 N=125 effN=23.4
2006 N=132 effN=1.2
2007 N=237 effN=24
2008 N=313 effN=26.5
2009 N=494 effN=21.9
2010 N=687 effN=95.1
2012 N=792 effN=38.5
2013 N=89 effN=16.5
2014 N=153 effN=7.8
Proportion
0.0
0.1
0.2
0.3
0.4
0 5 10 15 20 25
Age (yr)

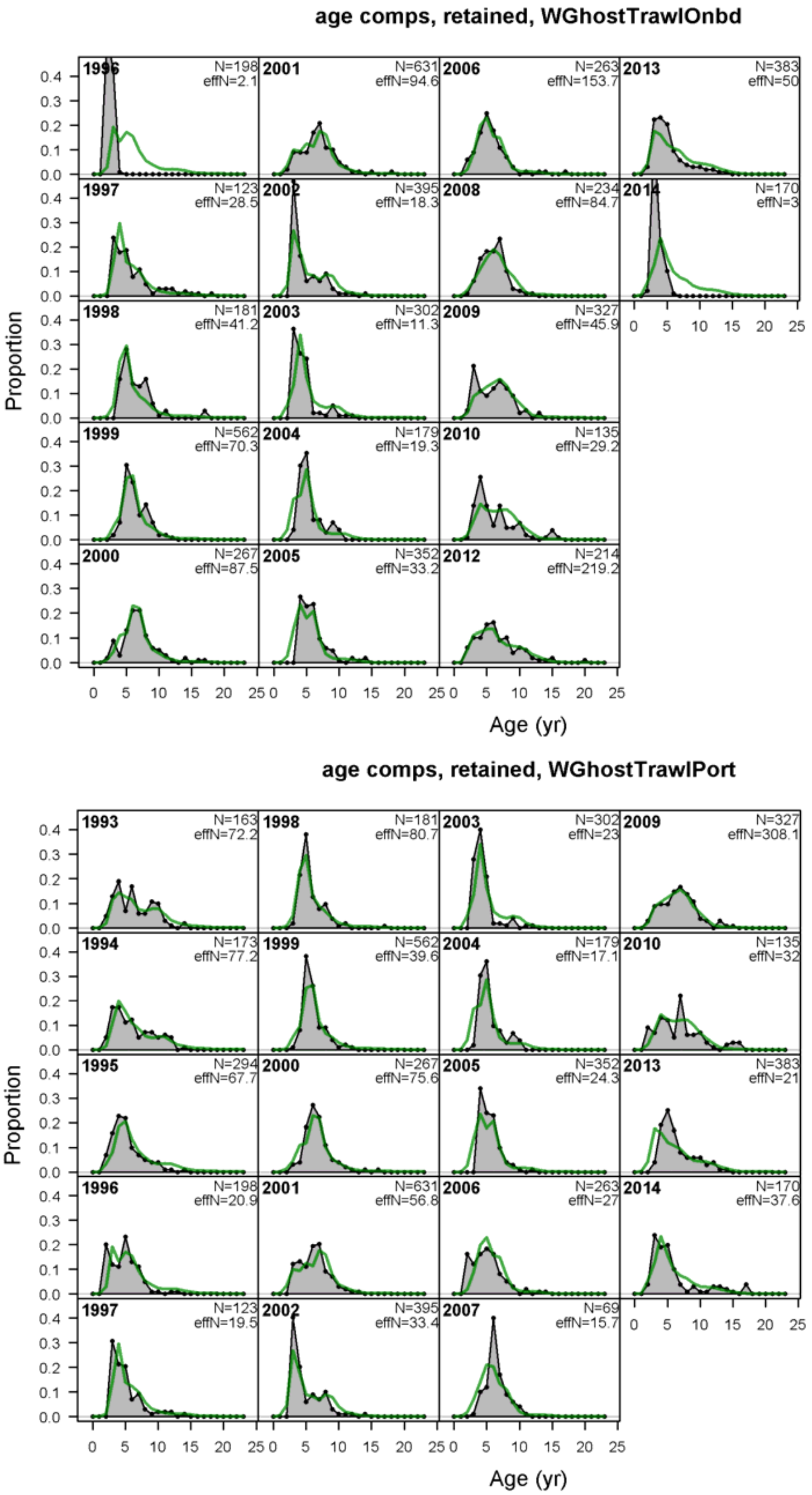


Figure 6A.9. Annual observed (grey) and estimated (green) age compositions for the retained component of the catch of the (top) east and (bottom) west fleets for both the onboard and port measurements. Note that these are not used to condition the model.

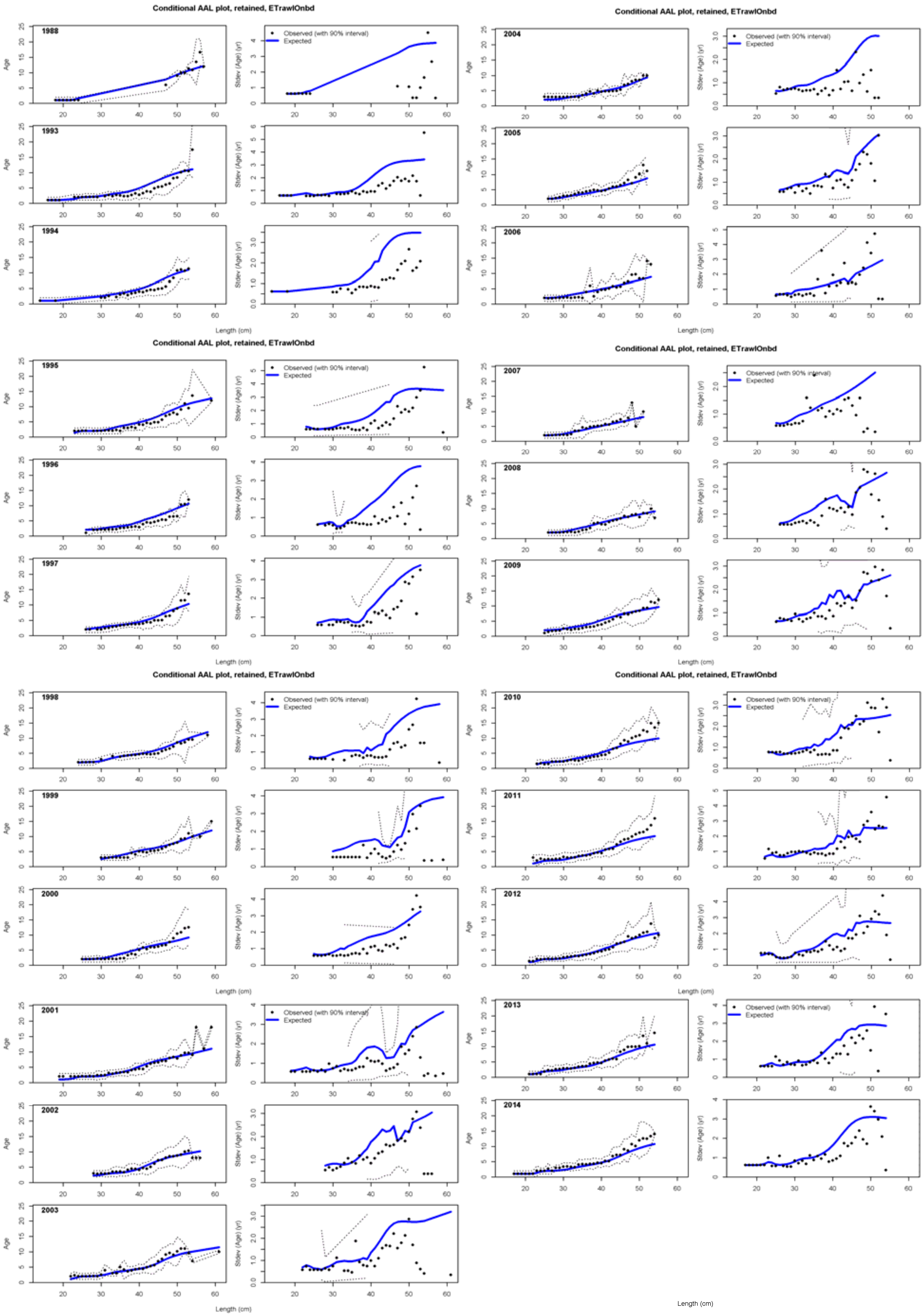


Figure 6A.10. Observed (black with grey shading) and expected (blue lines) age at length.

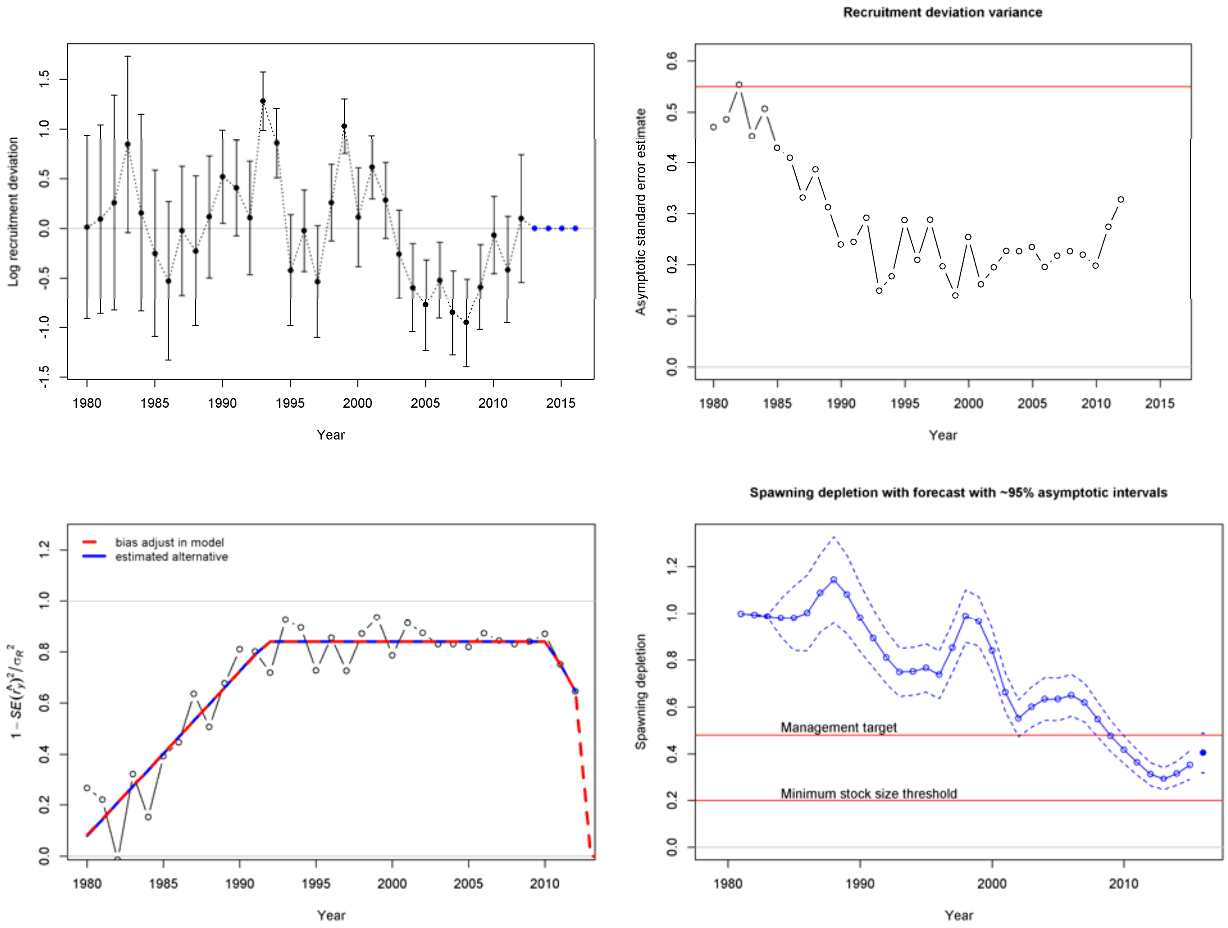


Figure 6A.11. (Top left) Estimated recruitment deviations (plotted on a log scale) with confidence intervals; (top right) standard error on estimated recruitment; (bottom left) bias adjustment factors for recruitment) and (bottom right) estimated depletion (relative spawning biomass) with one year forecast (assuming 2014 catches in 2015).

7. Silver Warehou (*Seriolella punctata)* stock assessment based on data up to 2014

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7.1 Summary

This chapter presents a quantitative Tier 1 assessment of silver warehou (*Seriolella punctata*) in the Southern and Eastern Scalefish and Shark Fishery (SESSF) using data up to 31 December 2014. The last full assessment was presented in Day *et al.* (2012). The 2015 assessment updates all data inputs (catch, discard, length, ageing error, age and catch rate data) and is performed using the stock assessment package Stock Synthesis (SS-V3.24U).

Changes to the last stock assessment include: using discards in the assessment; splitting the trawl fleet into eastern and western components; separating length frequencies into onboard and port collected components; time blocking retention to allow for changes in discarding practice since 2002; including FIS abundance indices; weighting length frequencies by shots and trips rather than fish measured; and using a new tuning method.

Results show reasonably good fits to the catch rate data. However, when comparing the observed and expected catch rate data points for the last 2 years in the series, the model may be overly optimistic and the stock could break out again in a relatively short time period (potentially requiring a further Tier 1 update if it is placed on a multi-year TAC).

This assessment estimates that the projected 2016 spawning stock biomass will be 40% of virgin stock biomass. The RBC from the base case model for 2016 is 1,958t for the 20:35:48 harvest control rule, with a long-term yield of 2,281t. In comparison, the last assessment estimated the 2013 depletion to be 47%, with corresponding RBCs of 2,544t, with a long-term yield of 2,618t. However, these scenarios assume recruitment will return to average levels. If future recruitment continues at a similar level to recruitment since 2003, then depletion could fall to around 30% before 2020. However, if landed catches continue at levels well below the TAC, then the depletion is likely to remain between 35% and 45% for the next 5 years.

7.2 Introduction

7.2.1 *The Fishery*

Silver warehou occur throughout the SESSF in depths to 500m. They are predominantly caught by trawl, although some non-trawl (gillnet) catches occur (Morison *et al.*, 2007). Annual catches (landings by fleet) and discard rates of silver warehou by calendar year are shown in Table 7.1. Large catches of silver warehou were first taken in the 1970’s (Smith, 1994) and landed catches increased to 3,800t in 2002. Landed catches declined to less than 2,000t from 2007 onwards, with further declines to less than 1,000t since 2012. Discard tonnage and length frequency are very variable and appear market driven. Silver warehou have also been captured off western Tasmania as bycatch of the winter spawning blue grenadier fishery.

For 2013 and 2014, the agreed TAC has been 2,329t. This agreed TAC was set following the last assessment in 2012 (Day *et al.*, 2012), with the agreed TAC for 2015 set at 2,417t.

7.2.2 ***Stock Structure***

A recent stock-structure study indicated that a single stock exists east and west of Bass Strait (Morison *et al*. 2007). A common stock had previously been assumed for management purposes and is assumed for the assessment presented here. However, differences were suspected in standardised catch rates, length and age distribution east and west of longitude 147° E, so in this assessment the data was split into two fleets, an eastern fleet (SESSF zones 10, 20 and 30) and a western fleet (SESSF zones 40 and 50) (Thomson *et al.* 2015).

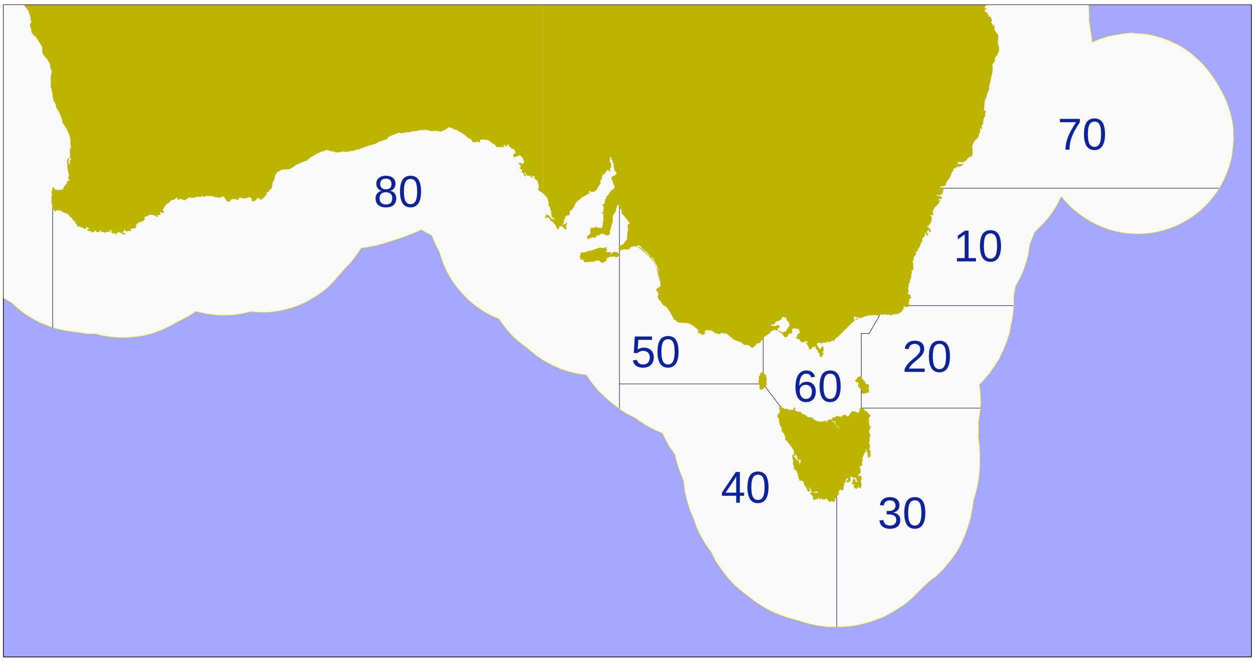


Figure 7.1. Map of the SESSF showing statistical zones.

7.2.3 ***Previous Assessments***

The previous full quantitative assessment for silver warehou was performed in 2012 (Day *et al.*, 2012) using Stock Synthesis (SS-V3.24f, Methot, 2012). The 2012 assessment indicated that the spawning stock biomass levels in 2013 were around 47% of virgin biomass.

This assessment produced reasonably good fits to the catch rate data. However, Day *et al.* (2012) noted that "*when comparing the observed and expected catch rate data points for the last 2 years in the series, the model may be overly optimistic and the stock could break out again (requiring a further Tier 1 update if it is placed on a multi-year TAC) in a relatively short time period*". This prediction turned out to be true as the stock did indeed breakout (Figure 7.2).

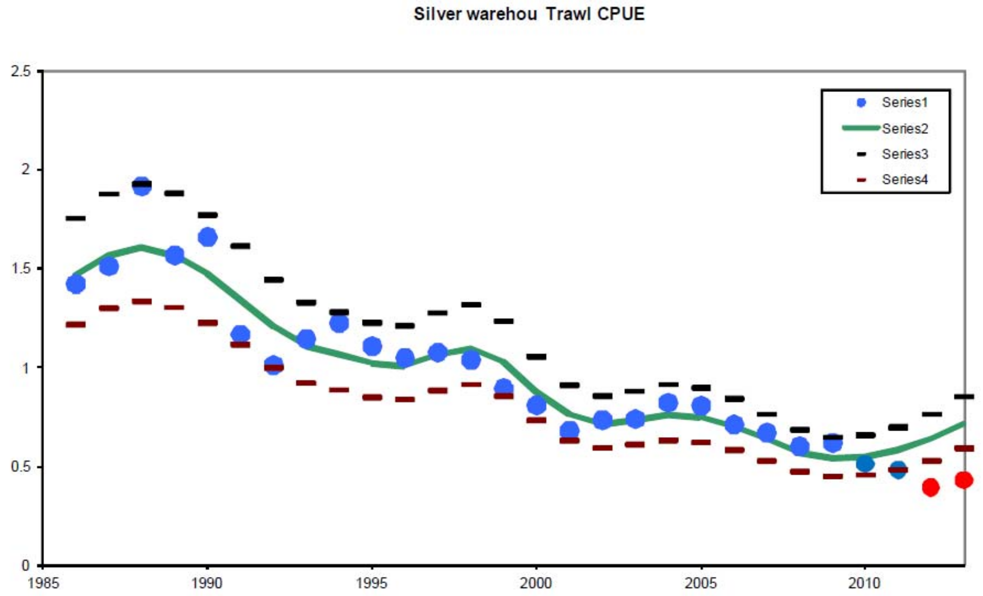


Figure 7.2. “Breakout” for spotted warehou (taken from Klaer *et al.* 2014) showing estimated stock abundance (green line with prediction interval) and observed standardised CPUE (blue and red spots).

Day *et al.* (2012) also warned that “*If recent recruitments (2008-2011), which are not currently estimated by the model, are assumed to be poor and at similar levels to recruitment during the period 2002-2005, then depletion in 2013 could fall below 40%. Under this scenario, setting a multi-year TAC could result in depletion levels falling below 30% by 2015.*” This comment is also still very relevant as the 2008-2011 recruitments have all now been estimated, with the recruitment estimates for 2008 and 2009 around the very low levels of recruitment in the period 2002-2005 and the recruitment estimates for 2010 and 2011 both below average. Furthermore, recruitment estimates for 2006 and 2007 which were estimated in the 2012 assessment, have been revised using additional data which is now available, and have changed from being around average recruitment levels in the 2012 assessment to well below average in the current assessment. The depletion is estimated in the current assessment to be 29% in 2013.

An earlier assessment for silver warehou was performed in 2009 (Tuck and Fay, 2009) using Stock Synthesis (version SS-V3.03a, Methot, May 2009) and this assessment indicated that the spawning stock biomass levels in 2010 were around 48% of virgin biomass. Fits to the length, age, and catch-rate data were reasonable. The fit to the catch rate index was a substantial improvement compared to Tuck and Punt, (2007), with changes to the estimates of mortality and growth. Exploration of model sensitivity showed that the model outputs are sensitive to the value assumed for natural mortality, *M*.

Before the 2009 assessment, other Stock Synthesis based assessments for silver warehou were performed in: 2008 (Tuck, 2008) with a depletion estimate for 2007/8 of 53%; 2007 (Tuck and Punt, 2007) with a depletion estimate for 2007/8 of 49%. Even earlier assessments include Taylor and Smith, (2004) and Thomson, (2002).

7.2.4 *Modifications to the previous assessments*

While the assessment model framework is largely unchanged from the previous assessment, conducted in 2012, with Stock Synthesis updated from version SS-V3.24f to version SS-V3.24U, there are a number of modifications to the data and structure used.

1. Catch, discard, length frequency, and age at length data for 2012, 2013 and 2014 have been added.
2. Discarding is being estimated and discard length frequency data have been included in the assessment.
3. Five more years of recruitment are being estimated (note that this is two more than the number of years of data that have been added). Recruitment is estimated to 2012, two years prior to the most recent data
4. Length frequency data have been split into onboard and port collected components (sharing a single selectivity pattern).
5. The single trawl fleet has been split into east and west (of 147°) fleets, each with its own estimated selectivity pattern and discards (retention function).
6. Catch rate data has been split into eastern and western fleets with additional data added for 2012, 2013 and 2014 (Sporcic *et al.*, 2015).
7. The ageing error matrix has been updated.
8. Retention function has been time blocked, reflecting changes in the discarding practices in the periods 1980-2001 and 2002-2014.
9. Data collected from non-trawl vessels have been excluded from the dataset (this makes a negligible difference).
10. Inclusion of the FIS abundance indices for east and west fleets.
11. A new tuning procedure has been used to balance the weighting of each of the data sources that contribute to the overall likelihood function (this is a forerunner of an even newer tuning protocol for tuning expected to be agreed on during a workshop in the USA in October 2015).

These modifications are described in detail in Thomson *et al.* (2015), especially the more significant changes including the treatment of discards, the east and west fleets, the modified tuning procedure and a bridging analysis from the previous assessment.

Table 7.1. Landed catch by fleet, total landed catch, discard rate, standardised catch rate and the agreed TAC for silver warehou

Year	**East trawl catch (t)**	**West trawl catch (t)**	**Total landed catch (t)**	**Discard rate**	**Catch rate east**	**Catch rate west**	**Agreed TAC (t)**
1979							
1980	30	29	59				
1981	59	59	118				
1982	89	88	177				
1983	118	118	236				
1984	148	147	295				
1985	180	180	360				
1986	437	571	1008		1.7230	1.3771	
1987	263	485	749		1.6346	1.5718	
1988	788	578	1366		2.1414	1.8137	
1989	343	578	920		1.8205	1.5865	
1990	865	260	1126		2.2066	1.0381	
1991	652	711	1363		1.3229	1.1201	
1992	1307	558	1865		1.4036	0.8677	2000
1993	1008	772	1779	0.014	1.3843	1.1638	2000
1994	1387	682	2069	0.016	1.5213	1.0742	2500
1995	1725	1117	2842	0.092	1.3576	0.8413	2500
1996	1402	1282	2684	0.011	1.1338	0.9624	2500
1997	1100	1348	2448	0.084	1.1127	1.1480	2500
1998	942	1448	2389	0.191	0.9391	1.3627	3500
1999	1010	1985	2996	0.012	0.8109	1.1308	4000
2000	820	2954	3774	0.025	0.6641	1.1134	4000
2001	849	2901	3750	0.142	0.6209	0.8437	4400
2002	740	3075	3815	0.079	0.7208	0.8979	4400
2003	686	2667	3353	0.157	0.6770	0.9380	4488
2004	600	3131	3731	0.205	0.7761	1.0205	4039
2005	432	2070	2502	0.130	0.7222	1.1156	4400
2006	403	1744	2147	0.038	0.6092	0.9824	4400
2007	329	1661	1990	0.039	0.4841	1.0064	3088
2008	473	1035	1508	0.030	0.5602	0.7988	3227
2009	463	907	1370	0.023	0.6416	0.6928	3000
2010	341	948	1289	0.012	0.4674	0.6296	2566
2011	257	972	1229	0.246	0.4029	0.6085	2566
2012	215	634	849	0.140	0.3620	0.4537	2566
2013	204	442	646	0.043	0.4532	0.4311	2329
2014	103	278	381	0.044	0.3260	0.4091	2329

7.3 Methods

7.3.1 *The Data and Model Input*

7.3.1.1 Biological Parameters

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

The values of the von Bertalanffy growth parameters were estimated within the model-fitting procedure because Stock Synthesis accepts age-at-length data as an input. Estimating the parameters of the von Bertalanffy growth curve within the assessment is more appropriate because it better accounts for the impact of gear selectivity on the age-at-length data collected from the fishery and the impact of ageing error.

This assessment follows that of Day *et al.* (2012) and Tuck and Fay (2009) in using the base-case value of natural mortality of M=0.3yr^{-1}. The base case vale of the steepness of the stock-recruitment relationship, h, is 0.75 Sensitivities to this value for M and h are considered.

Silver warehou become sexually mature at a length of about 37 cm. Fecundity is assumed to be proportional to spawning biomass. The parameters of the length-weight relationship are the same as those used in previous assessments (a=6.5 x 10^{-6}, b=3.27). These values come from Taylor and Smith (2004) and were provided by David Smith (unpublished data).

7.3.1.2 Fleets

The base case assessment for silver warehou is based on a trawl fleet split into and eastern trawl fleet (SESSSF zones 10, 20 and 30) and a western trawl fleet (SESSF zones 40 and 50), with time-invariant logistic selectivity estimated separately for each fleet. Retention was time blocked.

In all previous assessments, discards were added to the landed catch due to difficulties in distinguishing between sized based discarding and market based discarding. This assumption ignored the size-related discarding of small fish that was occurring along with market related discarding of fish of all sizes, as evidenced by the greater proportion of small fish in the discarded length frequencies from 2002 onwards relative to the retained LFs from 2002 onwards (Thomson *et al.* 2015). This suggests that market based discarding reduced dramatically from 2002 onwards. Parameters for estimating retention were estimated separately for the eastern and western trawl fleets. Separate retention (discard) functions were estimated for the 1980-2001 and 2002-2014 periods. This enables a retention function to be fitted allowing for this apparent change in discarding practice from 2002 onwards. This also resulted in improvements to the fits to the length residuals, which were previously noted to behave differently before and after 2002 (Day *et al.* 2012).

While there is some non-trawl catch, it is small and the results of previous assessments (e.g. Thomson, 2002) were insensitive to the inclusion of the non-trawl catches.

7.3.1.3 Catches

The model uses a calendar year for all catch data. Landings of silver warehou prior to the start of SEF1 record-keeping in 1985 are not considered to have been large. However, a linear increase in catch from 1979 to the first year of SEF1 catches was used as an estimate of pre-SEF1 catch, following Punt *et al.* (2005). Total landings data (including both Commonwealth and state landings) were reliably available from 1985-2014 (Klaer 2009, Upston and Klaer 2012, Upston and Klaer 2014). Annual landed catches by fleet used in this assessment are shown in Table 7.1 and Figure 7.3 and Figure 7.4.

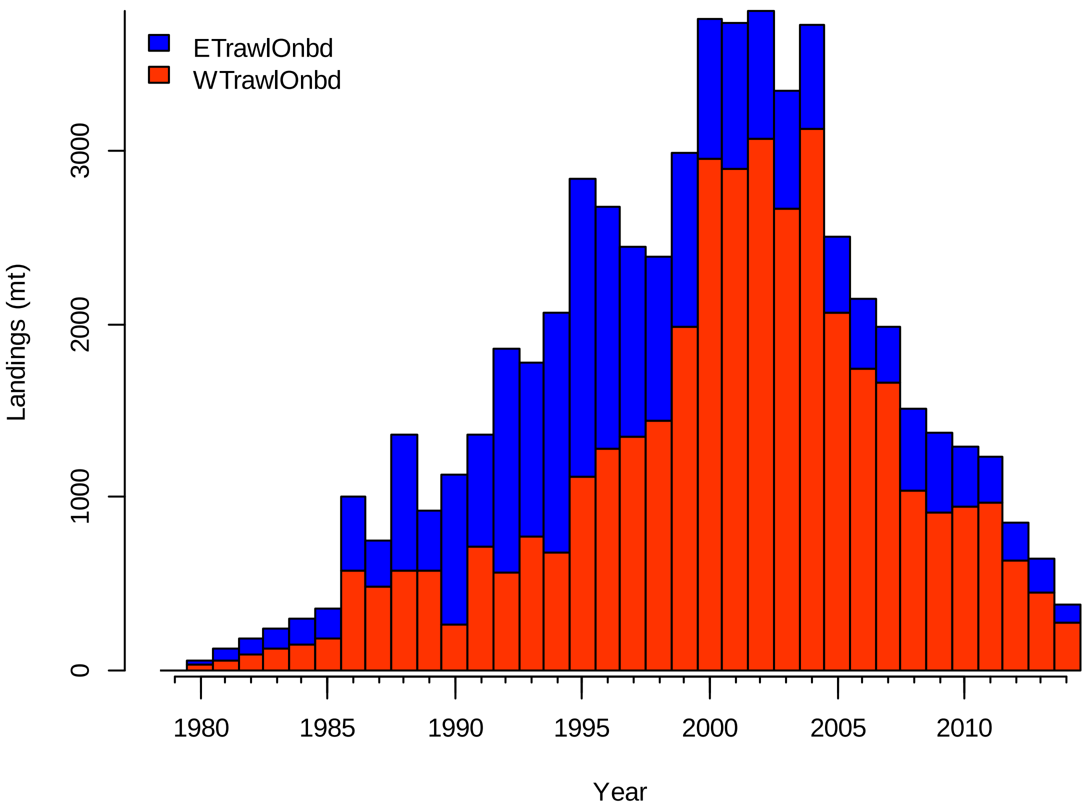


Figure 7.3. Total landed catch by fleet (stacked) of silver warehou in the SESSF from 1979-2014 as used in this assessment.

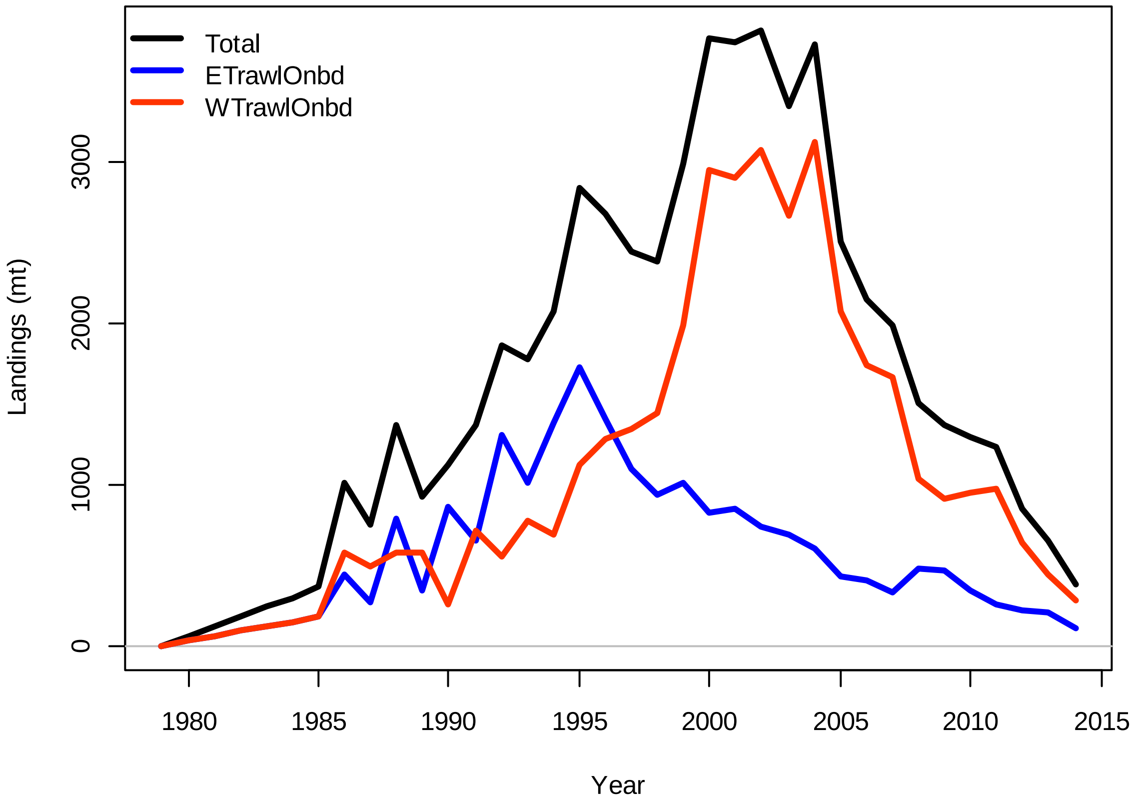


Figure 7.4. Total landed catch by fleet (stacked) of silver warehou in the SESSF from 1979-2014 as used in this assessment.

7.3.1.4 Discard Rates

Information on the discard rate of silver warehou is available from the ISMP for 1993-2014. These data are summarised in Table 7.1. Discard rates vary amongst years, with higher values of around 20-25% (1998, 2004, 2011), moderate values of around 8-16% (1995, 1997, 2001-3, 2005, 2010, 2012) and low values less than 5% for all other years.

Thomson (2002) states that members of the fishing industry had indicated that discarding of silver warehou occurs when market prices are low and is therefore not related to the size of the fish caught. However, examination of the ISMP data on the length frequency of catches and discards shows that there are times when discarding of silver warehou also appears to be size-related (Day *et al.* 2012, Tuck and Fay, 2009). In the 2012 assessment there was no known pattern indicating when discarding was market-driven and when it was size-related, so the mass of fish that were estimated to have been discarded by the trawl fleet was added to the landed. Thomson *et al.* (2015) provide evidence to support a change in discarding practice, from a mixture of market and sized based discarding to just size based discarding from 2002 onwards. Observations were then used to estimate discard rates for each fleet (Figure 7.5) and hence discarded catches for each fleet (Figure 7.6, Figure 7.7), with a change in discarding practice (and estimated retention) assumed from 2002 onwards.

In addition, a number of factory trawlers have operated since 1997 in the spawning fishery for blue grenadier. These trawlers have fishmeal plants which apparently absorb all fish that might otherwise have been discarded. Thus, the factory vessels effectively have zero discard rates (Thomson, 2002b). The discard rates therefore apply to the ‘wet boats’ only. The overall discard rate for the year is therefore computed by adjusting the ‘wet boat’ discard rates by the proportion of the catch not taken by factory vessels. This follows the same procedure for dealing with discards as used by Tuck and Fay (2009) and Day *et al.* (2012). However, there is recent evidence that there may be some discarding by factory vessels and it may be possible to incorporate this into future assessments.

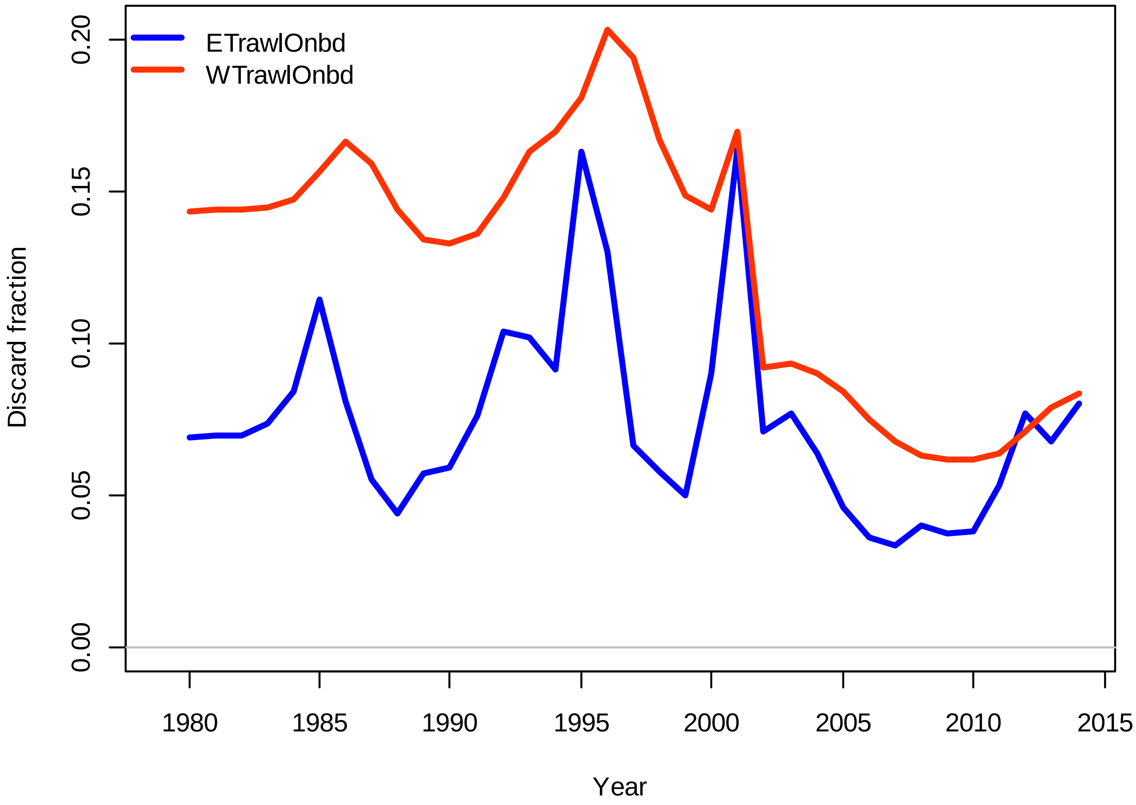


Figure 7.5. Model estimates of discard fractions per fleet for silver warehou in the SESSF from 1979-2014.

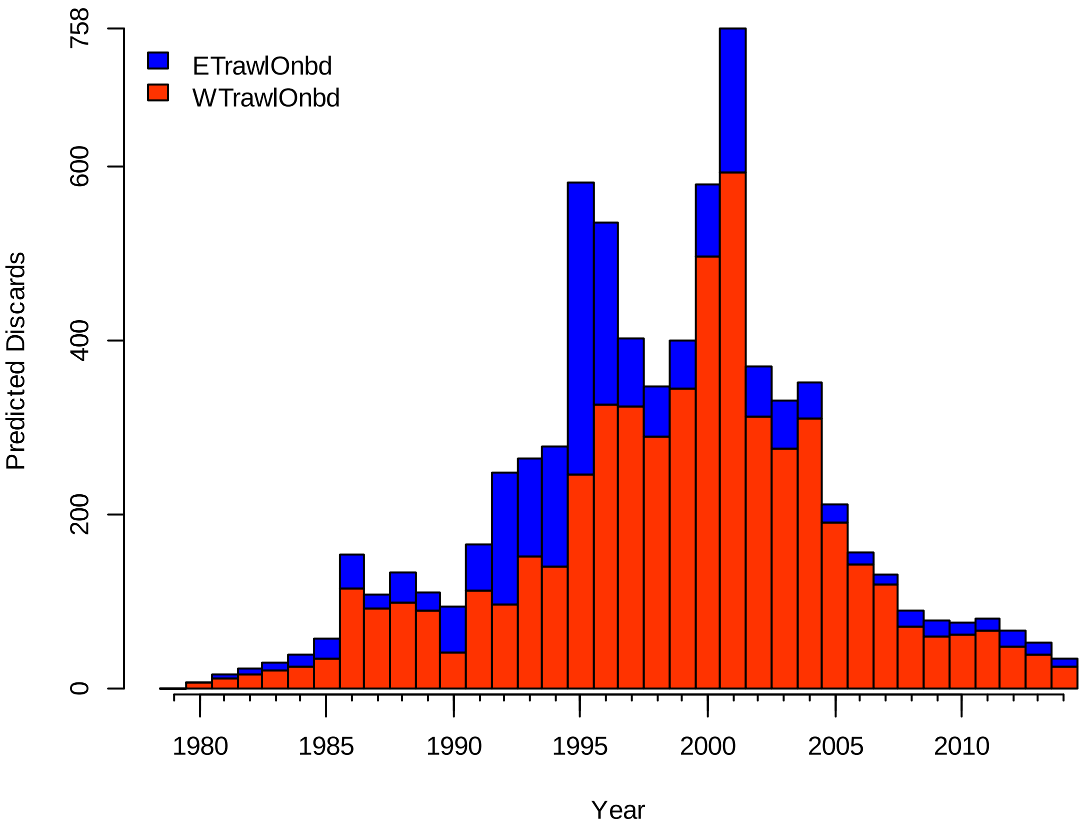


Figure 7.6. Estimated discards (stacked) of silver warehou in the SESSF from 1979-2014.

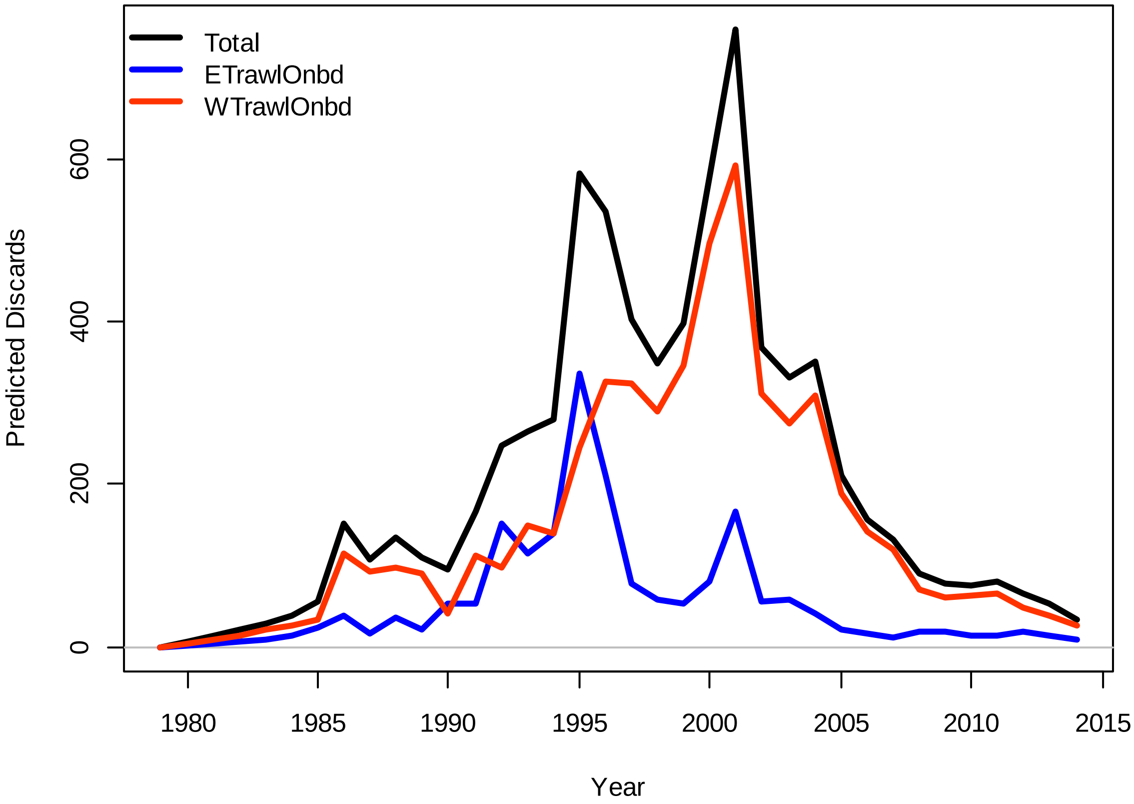


Figure 7.7. Estimated discards of silver warehou in the SESSF from 1979-2014.

7.3.1.5 Catch Rate Indices

Catch and effort data from the SEF1 logbook database from the period 1986 to 2011 were standardised using GLMs to obtain indices of relative abundance (Sporcic, 2015, Sporcic *et al*., 2015) with the results listed in Table 7.1. Data used in this standardisation were restricted to trawl shots in depths between 0 and 600m from zones 10, 20 and 30 for the eastern trawl fleet and zones 40 and 50 for the western trawl fleet.

7.3.1.6 Length Composition Data

In 2010 the RAGs decided to include both port and onboard retained length frequency data (for both historic and current years) in future assessments, whereas in previous assessments only port data have been used (Tuck and Fay, 2009). In 2012, the port and onboard length composition data was combined to give one length distribution for each year of data. For the 2015 assessment, port and onboard length composition data were both used separately, with the gear selectivity estimated jointly from both port and onboard data from each fleet (eastern and western trawl).

The 2012 assessment weighted length samples by the number of fish measured. 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 2015 assessment, the initial sample size associated with each length frequency in the assessment is the number of shots or trips. However, data was excluded for years with less than 100 individual fish measured, as this was considered to be unrepresentative. Sample sizes for retained length frequencies, including both the number of individuals measured and numbers of shots or trips, are listed in Table 7.2 for each fleet and year for the period 1991-2015.

Table 7.2. Number of retained lengths, shots and trips included in the base case assessment by fleet 1991-2014.

year	**fleet**	**(retained)**						
	east onboard # samples	**east port # samples**	**west onboard # samples**	**west port # samples**	**east onboard # shots**	**east port # trips**	**west onboard # shots**	**west port # trips**
1991		273				4		
1992		1648		1769		9		15
1993		1087		1431		6		11
1994		215		1802		4		22
1995		500		4651		5		37
1996	293	1014	122	6023	4	10	1	53
1997	1585	1762	1883	8874	19	18	33	82
1998	2959	6386	2671	9704	34	63	43	89
1999	2449	6347	1952	7742	32	68	19	75
2000	1642	8239	3584	5424	17	48	46	47
2001	1446	7958	4610	6978	23	60	47	61
2002	2554	12979	4047	9064	37	85	26	83
2003	2005	5431	5019	3359	34	37	44	28
2004	2147	4868	3679	2638	33	34	33	23
2005	2028	9007	6617	3319	25	46	60	28
2006	1847	7994	3763	855	33	49	32	9
2007	173	728		491	12	5		2
2008	440	971	198		18	6	8	
2009	370	2135	853	163	10	27	41	2
2010	1391	1139	1285		30	22	37	
2011	371	1288	1140		17	40	61	
2012	807	1252	991		31	40	31	
2013	730	1720	1523	141	29	45	49	1
2014	142	1391	900	152	4	26	17	2

Discarded length frequencies were only available for onboard samples as discarded fish are not landed in port. Sample sizes for discarded length frequencies including both the number of individuals measured and numbers of shots are listed in Table 7.3 for each fleet and year for the period 1994-2015.

7.3.1.7 Length Composition Data Split by Depth

There appear to be differences in length of silver warehou as a function of depth caught. While it was suggested that the catch and length frequency data could be stratified into deep (deeper than 200m) and shallow (shallower than 200m), a preliminary exploration examined whether this variation had already been incorporated through splitting the trawl fleet into eastern and western components. This was achieved by examining all onboard otter trawl retained length frequencies and aggregating them over all years, then splitting these initially into either eastern or western samples, then shallow or deep samples and finally combinations of all four of these variables. The results of this exploration are shown in Figure 7.8 and Figure 7.9.

Table 7.3. Number of discarded lengths and shots included in the base case assessment by fleet 1994-2014.

year	**fleet**	**(discarded)**		
	east onboard # samples	**west onboard # samples**	**east onboard # shots**	**west onboard # shots**
1994	456	224	5	2
1995		930		8
1996		1421		10
1997	234	232	3	18
1998		1998		39
1999		477		6
2000	223	283	4	17
2001	888	1371	15	25
2002	1805	1257	34	8
2003	1364	191	23	3
2004	3319	1111	52	16
2005	1332	658	19	15
2006	140		13	
2007				
2008	150		9	
2009	127		2	
2010	131		6	
2011	159	132	9	23
2012	471		13	
2013	109	178	13	8
2014	163		2	

Figure 7.8 demonstrates a strong relationship between length frequencies caught in the west and those caught in deeper water, and a similar relationship between those caught in the east and in shallow waters, with larger fish generally caught in the west and in deeper water. When these are separated further (Figure 7.9), the majority of the length frequencies come from the deep water in the west, with the next largest group being from the east in shallower water. There are smaller numbers of fish caught in the east in deep water and even fewer in the west in shallow water. These aggregated length frequencies suggest that while there may be some differences in length frequencies between fish caught shallower or deeper than 200m, most of this variation is already captured by splitting the fleet into an eastern and western fleet.

A further exploration would be required to see if there were benefits in splitting this data by depth as well as region, but this brief examination suggests that the benefits would be marginal. Small sample sizes may mean that there would also be problems using all data if it was split both by region and depth, especially for shallow caught fish in the west, but also for deep caught fish in the east. Length frequency data were split by region (east/west) in this assessment, but were not split by depth.

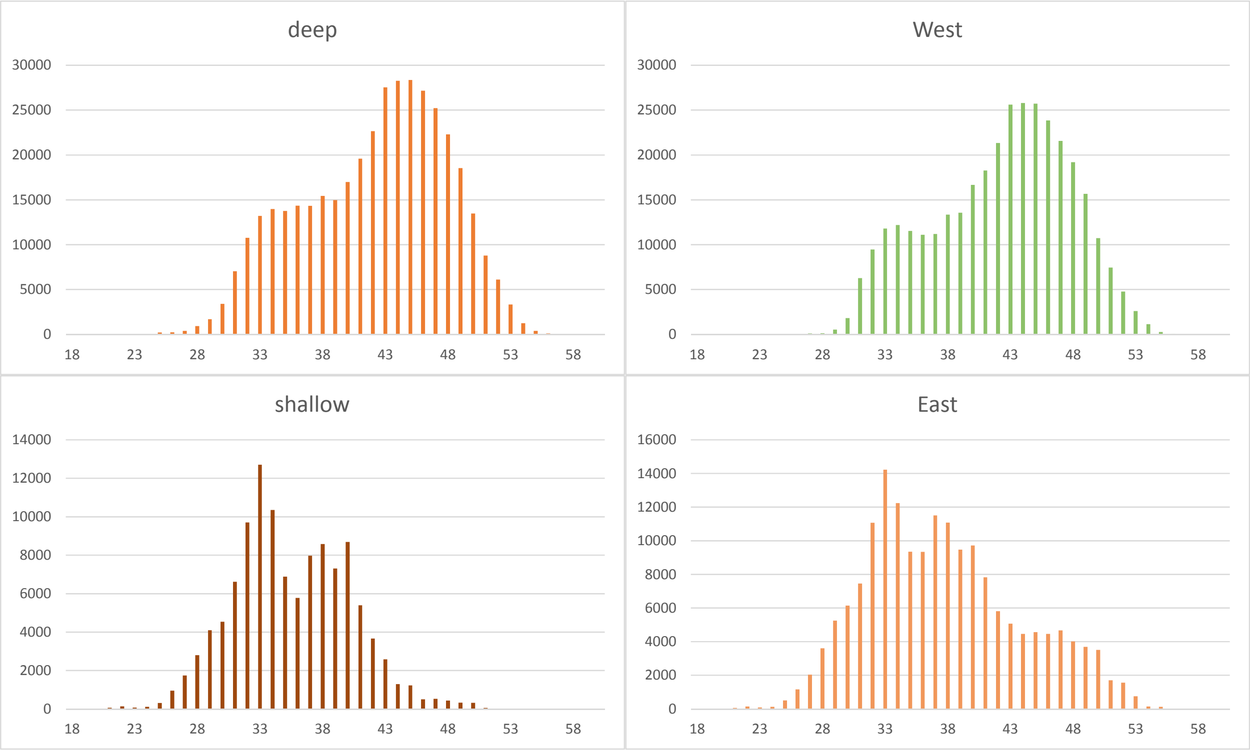


Figure 7.8. Retained otter trawl onboard length frequencies aggregated over all years either by depth (left column) or by location (right column).

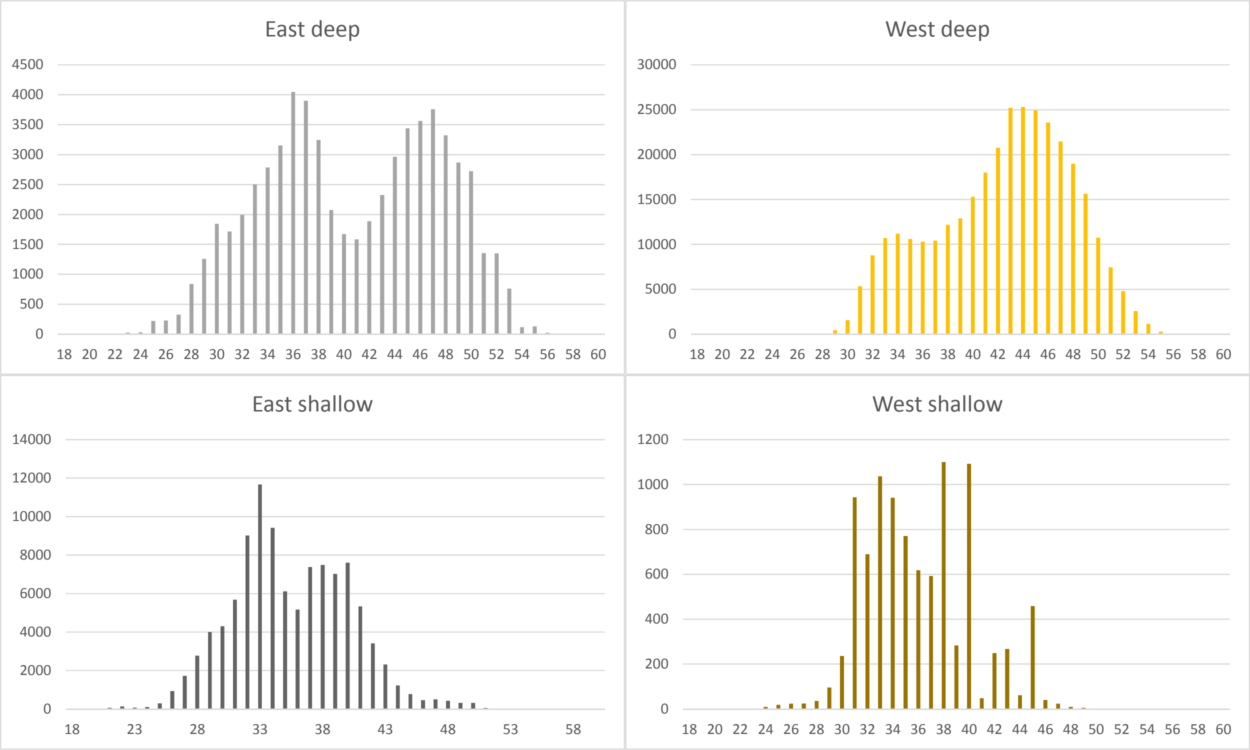


Figure 7.9. Retained otter trawl onboard length frequencies aggregated over all years by depth and by location.

7.3.1.8 Age Composition Data

Age-at-length measurements, based on sectioned otoliths provided by the CAF, were available for the years 1998 and 1993 to 2014 (Table 7.4). An estimate of the standard deviation of age-reading error was calculated by André Punt (pers. comm., 2015) using data supplied by Kyne Krusic-Golub of Fish Ageing Services Pty Ltd and a variant of the method of Richards *et al.* (1992) (Table 7.5).

Table 7.4. Number of samples in the conditional age-at-length data in the base case assessment 1988-2014.

year	**age-at-length samples**
1988	132
1993	334
1994	359
1995	451
1996	515
1997	566
1998	585
1999	782
2000	406
2001	997
2002	722
2003	424
2004	305
2005	477
2006	395
2007	306
2008	547
2009	821
2010	822
2011	852
2012	989
2013	472
2014	306

Table 7.5. Number of samples in the conditional age-at-length data in the base case assessment 1988-2014.

Age	**Std dev.**	**Age**	**Std dev.**
0	0.148461	12	0.96479
1	0.148461	13	1.03015
2	0.230629	14	1.09417
3	0.311106	15	1.15687
4	0.389927	16	1.21828
5	0.467124	17	1.27842
6	0.542732	18	1.33732
7	0.616783	19	1.39502
8	0.68931	20	1.45152
9	0.760344	21	1.50686
10	0.829915	22	1.56106
11	0.898054	23	1.61415

The implied age distributions 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.

7.3.1.9 Fishery Independent Survey (FIS) estimates

Abundance indices for silver warehou for the FIS surveys conducted in 2008, 2010, 2012 and 2014 are provided in Knuckey *et al.* (2015) for the eastern and western fleets combined. Indices from the FIS were re-estimated for the east (SESSF zones 10, 20 and 30) and the west (SESSF zones 40 and 50) with coefficients of variation calculated for each fleet (Table 7.6). The length composition data from the FIS have not been included in this assessment and the FIS is assumed to have the same selectivity as the respective trawl fleets.

Table 7.6. FIS derived abundance indices for silver warehou with corresponding coefficient of variation (cv).

	East		**West**	
year	**abundance**	**cv**	**abundance**	**cv**
2008	148.99	0.21	110.74	0.18
2010	55.56	0.18	25.92	0.18
2012	218.73	0.28	25.56	0.18
2014	14.71	0.21	32.20	0.15

7.3.1.10 Input data summary

The data used in this assessment is summarised in Figure 7.10, indicating which years the various data types were available.

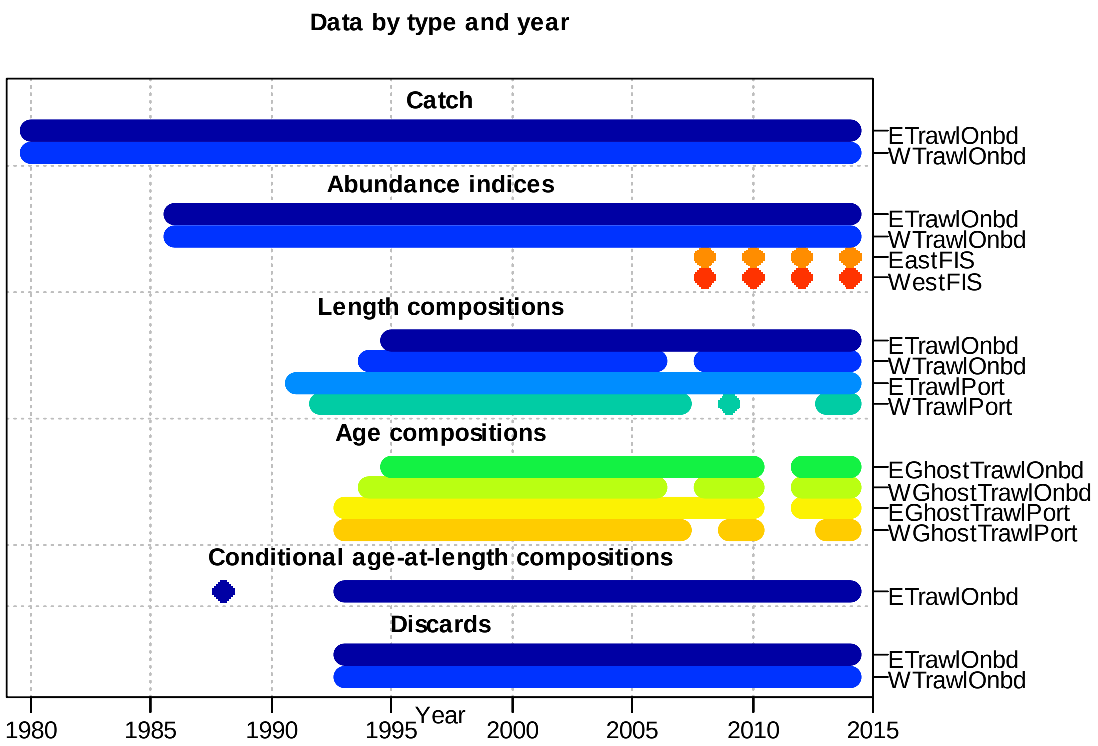


Figure 7.10. Summary of input data used for the silver warehou assessment.

7.3.2 *Stock assessment method*

7.3.2.1 Population dynamics model and parameter estimation

In 2012, a single-sex single-fleet stock assessment for silver warehou was conducted using the software package Stock Synthesis (version SS-V3.24f, Methot 2012). 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 silver warehou. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, is outlined fully in the SS2 user manual (Methot, 2009, Methot, 2012) and is not reproduced here. This year, the model was translated to the latest version of Stock Synthesis (version SS-V3.24U, Methot 2015). A comparison of parameter estimates and population trajectories showed a very close match across the two versions of Stock Synthesis.

Some key features of the base case model are:

(a) Silver warehou constitute a single stock with in the area of the fishery.

(b) The eastern (SESSF zones 10, 20 and 30) and western (SESSF zones 40 and 50) trawl fleets were modelled separately with separate catches, catch rates, length frequencies and selectivity

(c) The population was at its unfished (virgin) biomass with the corresponding equilibrium (unfished) age-structure at the start of 1979.

(d) The CVs of the CPUE indices for the trawl fleets are tuned by adding 0.19 to the initial CVs used (set uniformly to 0.1).

(e) Selectivity for the trawl fleets is length-specific, logistic and time-invariant. The two parameters of the selectivity function were estimated within the assessment for each fleet.

(f) Retention is estimated separately for two time blocks (1980-2001 and 2002-2014) for each fleet. The slope and intercept parameters were estimated for each fleet, but the asymptote was fixed at 100%.

(g) The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The base-case value for M is 0.30 yr^{-1}.

(h) Recruitment to the stock is assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at virgin spawning biomass, R_0, and the steepness parameter, h. Steepness for the base-case analysis is set to 0.75. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1980 to 2012. Deviations are not estimated prior to 1980 because there are insufficient data prior to 1980 to permit reliable estimation of recruitment residuals. Deviations are not estimated after 2012 as there would be insufficient numbers of fish recruited to the fishery or seen in the discards to reliably estimate recruitments from 2013 (the age at which 50% of fish have been recruited to the trawl fishery is approximately four). This final year for estimating recruitment deviations is confirmed by observing the increase in asymptotic standard error estimate of the recruitment deviation produced by Stock Synthesis.

(i) The value of the parameter determining the magnitude of the process error in annual recruitment, σ_R, is tuned (set equal to 0.52 prior to tuning) according to current agreed practice.

(j) A plus-group is modelled at age 23 years.

(k) Any length frequency data with less than 100 individual fish measured in a year were excluded as unrepresentative. The number of shots was used as the sample size for onboard length frequencies and the number of trips for port based length frequencies, with a cap at 100 shots (although in practice this cap was not needed for this assessment). These sample sizes were then further tuned so that the input sample size was equal to the effective sample size calculated by the model.

(l) Onboard and port length frequencies were fitted separately, with a common selectivity estimated from these two sources of length frequency data.

(m) Growth of silver warehou is assumed to be time-invariant, in that 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

This forms the base case model.

7.3.2.2 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- 2012. 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 quality and quantity of data for that stock. Silver warehou is assessed as a Tier 1 stock and 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. For the 2013 TACs AFMA has directed that the 20:40:40 (B_{lim}:B_{msy}:F_{targ}) form of the rule will be used up to where fishing mortality reaches F_{48}. Once this point is reached, the fishing mortality is set at F_{48}. Day (2008) has determined that for most SESSF stocks where the proxy values of B_{40} and B_{48} are used for B_{MSY} and B_{MEY} this form of the rule is equivalent to a 20:35:48 strategy.

7.3.2.3 Sensitivity tests

A number of standard sensitivity tests are used to examine the sensitivity of the results of the 2012 primary base case to some of the assumptions and data inputs:

(a) $M = 0.25$ and 0.35 yr^{-1}.
(b) $h = 0.65$ and 0.85
(c) 50% maturity occurs at length 34 and 40cm.
(d) $\sigma_R = 0.45$ and 0.65.
(e) Recruitment deviations estimated to 2006 and 2008.
(f) Double and halve the weighting on the CPUE series.
(g) Double and halve the weighting on the length composition data.
(h) Double and halve the weighting on the age-at-length data.
(i) Double the reported catch form 1998 to 2002.

The last sensitivity, doubling the reported catch from 1998 to 2002, came about following a suggestion from industry at the September 2015 Slope RAG meeting, to explore the impact of any possible mis-reporting of silver warehou landings in this period.

7.3.2.4 Summary statistics

The results of the base-case analysis and the sensitivity tests are summarized using the following quantities:

(a)	SB_0	the average unexploited spawning biomass,
(b)	SB_{2016}	the spawning biomass at the start of 2016,
(c)	SB_{2016}/SB_0	the depletion level at the start of 2016, i.e. the 2016 spawning biomass expressed as a percentage of the virgin spawning biomass
(d)	$-lnL$	the negative of the logarithm of the likelihood function (this is the value minimised when fitting the model, thus a lower value implies a better fit to the data),
(e)	2016 RBC 20:35:48	the 2016 RBC calculated using the 20:35:48 harvest rule.
(f)	Long term RBC 20:35:48	the long term RBC calculated using the 20:35:48 harvest rule.

7.4 The 2015 assessment of silver warehou

7.4.1 *The base case*

7.4.1.1 Transition from the 2009 base case to the 2015 base case

The assessment models presented in Day *et al.* (2012) used data up to 2011. The major changes in the 2015 assessment are: updating the version of Stock Synthesis; the addition of new data for 2012, 2013 and 2014 (including new catch, discard, CPUE, length frequency and age-at-length data); separating catch, catch rate and length data into eastern and western trawl fleets (each with their own selectivity pattern); estimating discards and including discard length frequencies, (estimating sized based discarding and allowing a change in retention from 2002 onwards to reflect a change in discarding practice); the separation of on board and port length frequencies (and estimating a joint selectivity); using shots and trips to weight the sample sizes of length frequencies; adding abundance time series from the east and west FIS for 2008, 2010, 2012 and 2014; the estimation of five more years of recruitment (an additional two years due to separate treatment of discards); and the implementation of a new tuning procedure.

These revisions, with a bridging analysis, were considered by Thomson *et al*. (2015) and showed relatively minor changes to the assessment outcomes. The most significant change was a revision downwards to the estimates of the last two recruitments estimated in the 2012 assessment (2006 and 2007), with the following five estimated recruitments (2008-2012) all lower than the standard projections used in the 2012 assessment. This results in a more depleted stock, despite the reduction in landed catches since 2012.

The model estimate of depletion for the start of 2015 is 35% and 40% for the start of 2016 (projected assuming 2014 catches in 2015). The 2012 assessment provided a base case with a 2013 spawning stock biomass of 47% of virgin stock biomass. With the revised recruitment time series, the 2015 assessment estimates the 2013 spawning stock biomass to have been 29%.

The selectivity patterns indicate that much smaller fish are caught in the east compared with the west, which strongly supports the separation of the data in to east and west fleets. Separating port and onboard length frequencies, using trips and shots to weight these length frequencies and the revised tuning procedure did not have major changes to the assessment outcomes or the estimated biomass trajectory. While conflicts between the age data and the CPUE and length data resulted in an inability to fully tune the age data in previous assessments (Day et al. 2012, Tuck and Fay 2009), with the structural changes to the 2015 assessment and the revised tuning procedure, this is no longer a problem and there is no need to continue to down-weight the age data in the 2015 assessment. A further scenario was explored for the 2015 base case where the age data was further down weighted, as in the 2012 assessment, but this was abandoned when this did not improve the fit to the CPUE series.

In the 2012 assessment, it was noted that there was some conflict between the length and age data and that the length residuals behave differently before and after 2002, with patterns in these residuals indicating some possible issues with the fits to the length data. Attempts were made to address this using cohort dependent growth in 2012, although this resulted in poorer fits to the CPUE series. Separating the trawl fleets into east and west, treating discards separately and allowing a change in discarding practice from 2002 appears to have adequately addressed this problem with the length residuals. In addition, it was noted in previous assessments that there had been a recent decline in both the catch and the CPUE in previous assessments. That decline in catch and in CPUE has continued with additional data to the end of 2014.

7.4.1.2 Tuning the 2015 base case

The proposed primary base case model needed to be tuned, following the addition of new data and this tuning was done according the following procedure (André Punt pers comm.):

1. Set the CV for the commercial CPUE value 0.1 for all years (set those for the FIS to the estimated CVs) (this relatively low value is used to encourage a good fit to the abundance data)
2. Simultaneously tune the sample size multipliers for the length frequencies and ages using Francis weights for the length frequencies and Francis B (the larger of the Francis A and B factors, Francis (2011) - iterate to convergence
3. Adjust the recruitment variance (σ_R) by replacing it with the RMSE and iterating to convergence (keep altering the recruitment bias adjustment ramps at the same time);
4. Weight the commercial CPUE and FIS abundance indices by replacing these with the relevant variance adjustment factors- iterate to convergence;
5. Reweight the age data using the Francis A adjustment factor, just once (no iterating);
6. Repeat steps 3 and 4.

7.4.1.3 Parameter estimates of the base case model

Figure 7.11 shows the estimated growth curve for silver warehou. All growth parameters are estimated. The estimates of the growth parameters are: (a) L_{min}=15.19cm, (b) L_{max}=50.21cm, (c) K=0.3096 yr^{-1}, and (d) cv of growth = 0.0896. This growth curve is very similar to the growth curve estimated in the 2012 assessment.

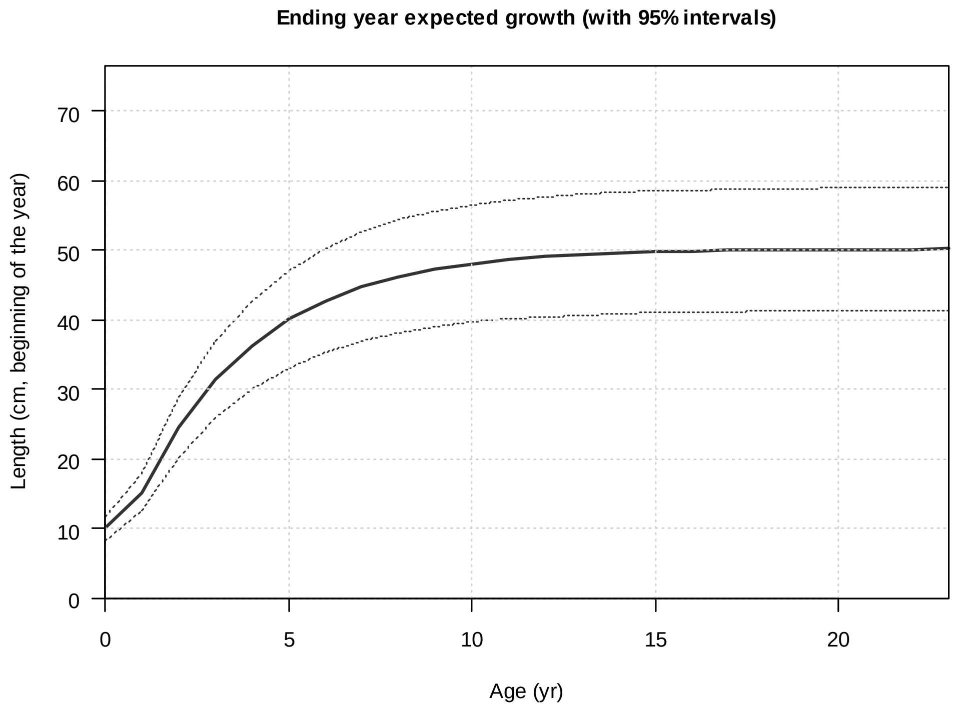


Figure 7.11. The model estimated growth function for silver warehou for the base case.

Figure 7.12 shows the estimated time varying retention and selectivity curves for the east and west trawl fleets for silver warehou. The parameters that define this selectivity function including the length at 50% selection and the spread. The estimates of these parameters for the base-case analysis are 24.66cm and 3.65cm respectively for the east and 39.59cm and 11.18cm for the west. The estimates for the parameters that define in the time block 2002-2014 are 27.44cm and 2.46cm respectively for the east and 28.30cm and 5.88cm for the west. The estimate of the parameter that defines the initial numbers (and biomass), $ln(R_0)$, is 9.626 for the base case.

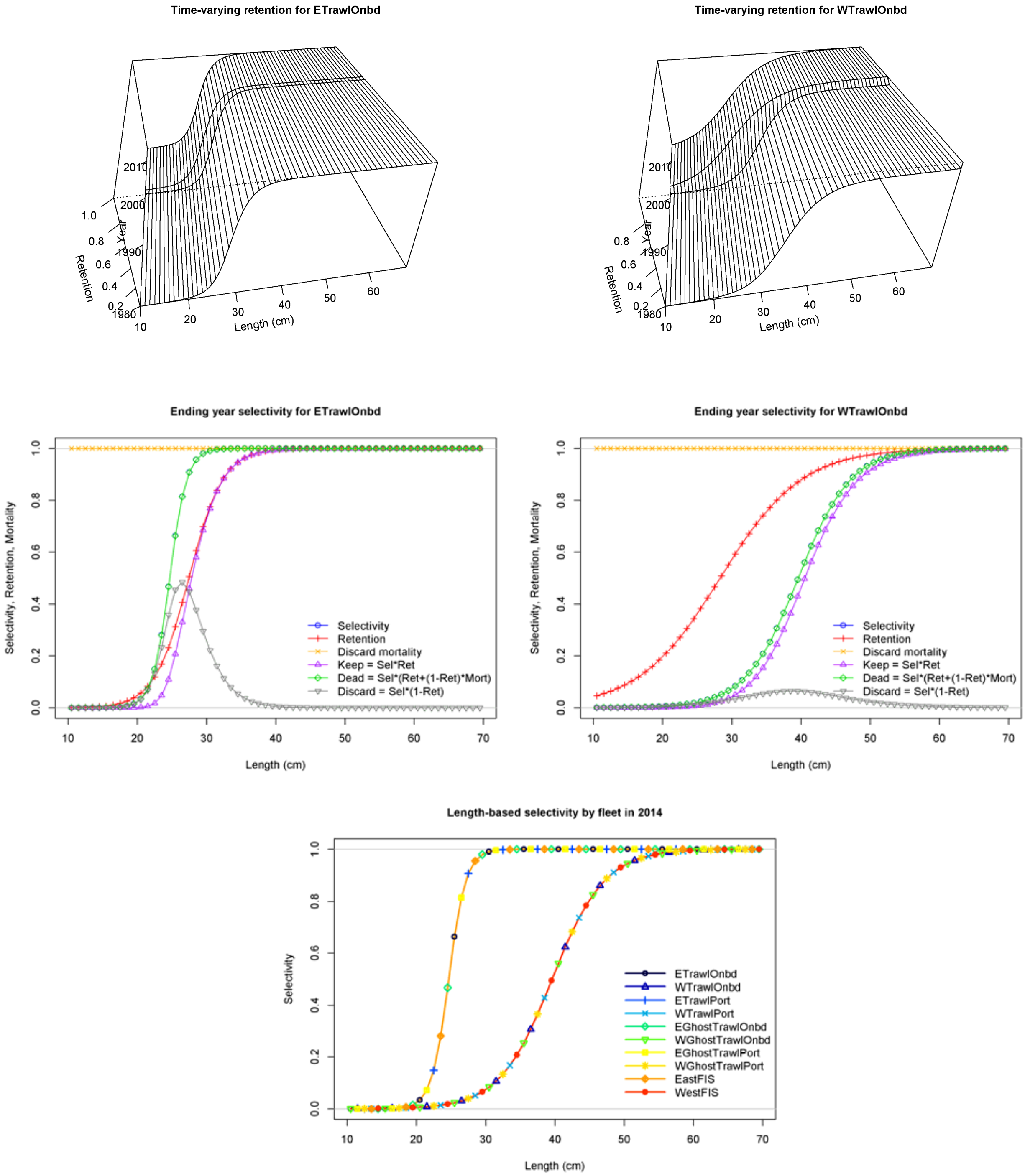


Figure 7.12. Estimated retention function (discard pattern) with two time blocks (1980-2001, and 2002-2014) for east (top left) and west (top right) trawl fleets. Selectivity and discard patterns for east (middle left) and west (middle right) fleets, and east and west selectivity patterns plotted together (bottom).

7.4.1.4 Fits to the data for the base case model

The fits to the catch rate indices (Figure 7.13) for the base case are reasonable for the west trawl fleet and adequate for the east trawl fleet, although in both cases the pattern seen in the previous two assessments where the trends in the data and the fit for the last three data points (2012, 2013 and 2014) suggest some conflict and again the potential for this species to break out in the near future. The data over this period suggests a downwards trend, and yet the model shows an increasing trend, with the model prediction very close to the upper 95% confidence bound in 2014 indicating a good chance of a breakout between the modelled predicted CPUE values and the observed CPUE values in the future.

The fits to the FIS indices are poor, but the FIS indices are confounded by very large variation between years, possibly relating to some FIS survey years having large shots of silver warehou which are absent in other years. The only way to fit these indices adequately is to increase the variance.

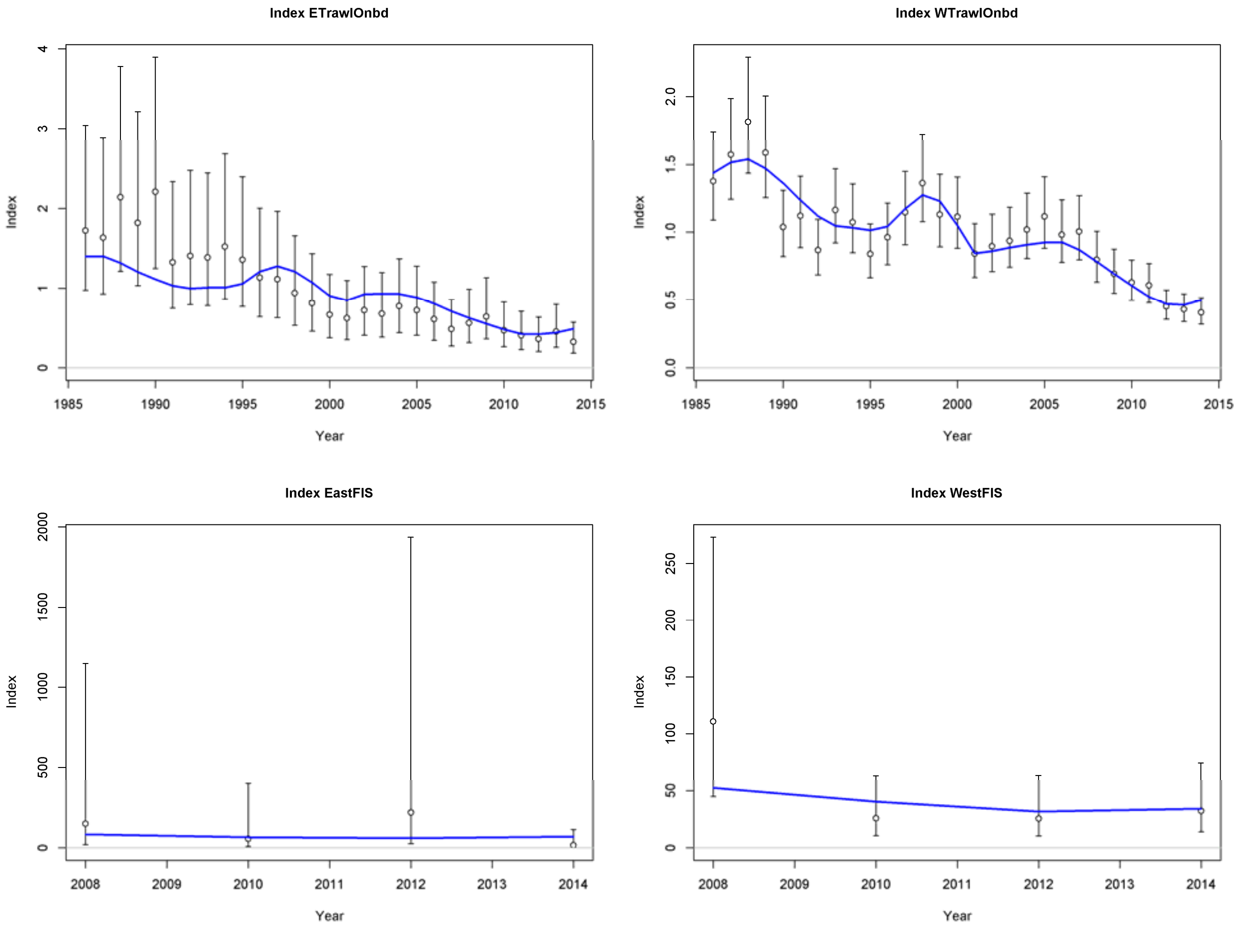


Figure 7.13. Observed (circles) and model-predicted (blue line) catch-rates for silver warehou for the east and west trawl fleet versus year for the base case analysis and for the east and west FIS. The vertical lines indicate approximate 95% confidence intervals for the data.

The base-case is able to fit the aggregated retained and discarded length-frequency distributions adequately in most cases (Figure 7.14, top). The eastern trawl retained fits are not as good as the western trawl, and the western trawl discard length frequencies are quite variable and hence difficult to fit well. Figure 7.14 demonstrates the difference in sizes of silver warehou caught between the eastern and western fleets.

The aggregated fits to the implied age composition are shown in Figure 7.14 (bottom). These age-compositions are not fitted directly, but are essentially fits to the length distributions with the length data transformed to age using a conversion from length to age obtained through the conditional age-at-length data. The fits to the implied age-compositions provide a means of checking the adequacy of the model and the model fits the observed age data very well.

Annual fits and residuals are included in Appendix A. While the annual fits are not as good as the aggregated fits, the length frequency data appears to be very variable, especially for the eastern trawl fleet. This has become more pronounced in this assessment with the separation of length frequencies by fleet and into port and onboard components within fleets. The resulting length frequencies have more inherent variability and smaller samples sizes. This may reflect spatial and temporal differences in collection of this data between years and hence this length frequency data may not be as representative as we would like. Equally, this variation may have been smoothed over by aggregating these length frequencies in the 2012 assessment. Similar comments apply to the implied fits to age, with better fits in the west, then the east, but given this implied fit to age is derived from length frequency data, it is not surprising to see similar trends.

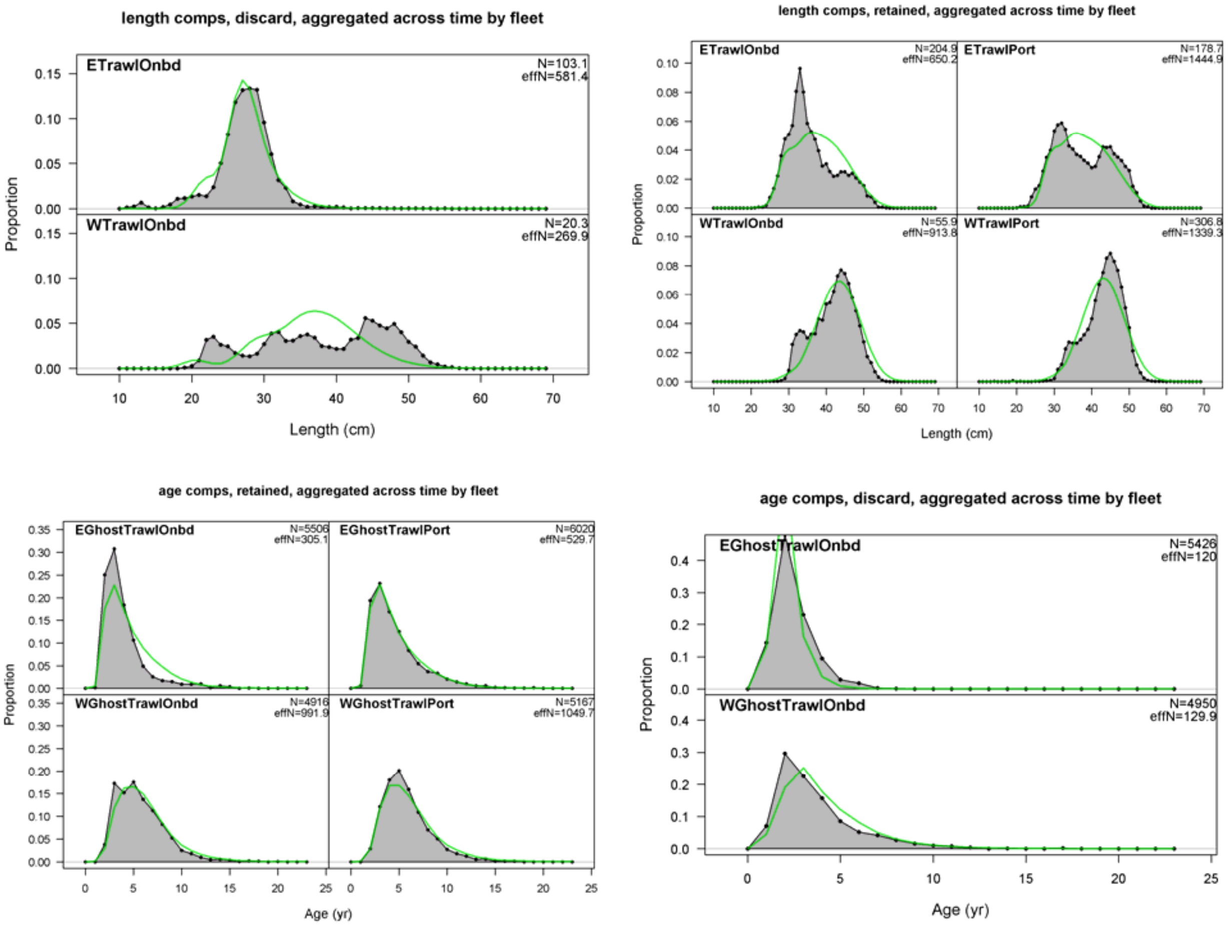
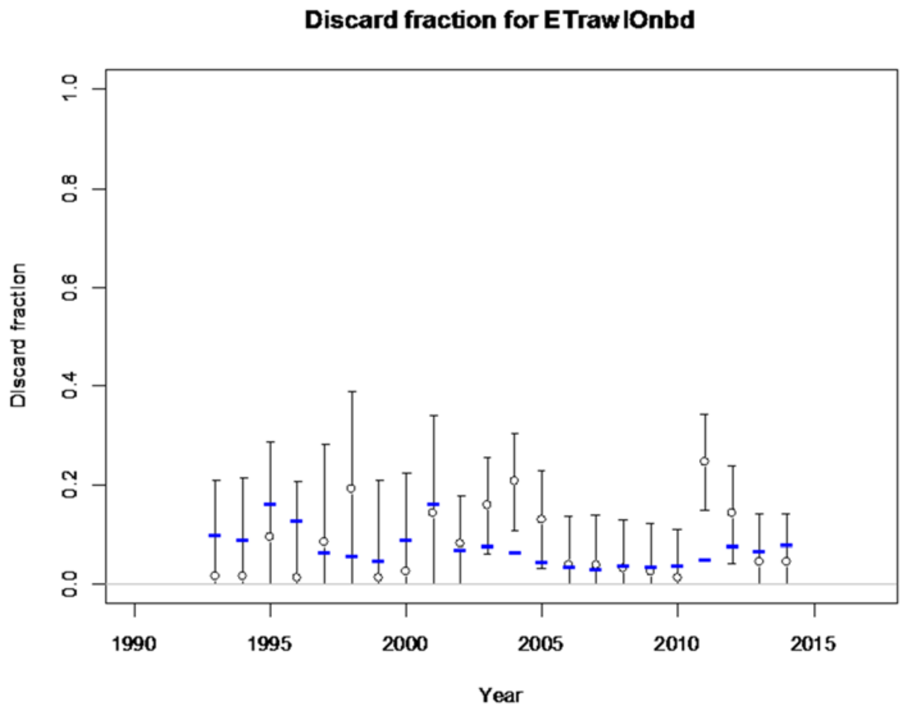


Figure 7.14. Aggregated length and implied age compositions for the onboard and port data sources in both the east and west. Observed data are grey and the fitted value is the green line. Note that the model is conditioned on the age at length data, not on the age compositions themselves.

The fits to the discard fractions (Figure 7.15) are reasonable given the variability in the data, with some very low data points (around 1%) and ranging up to 25%.



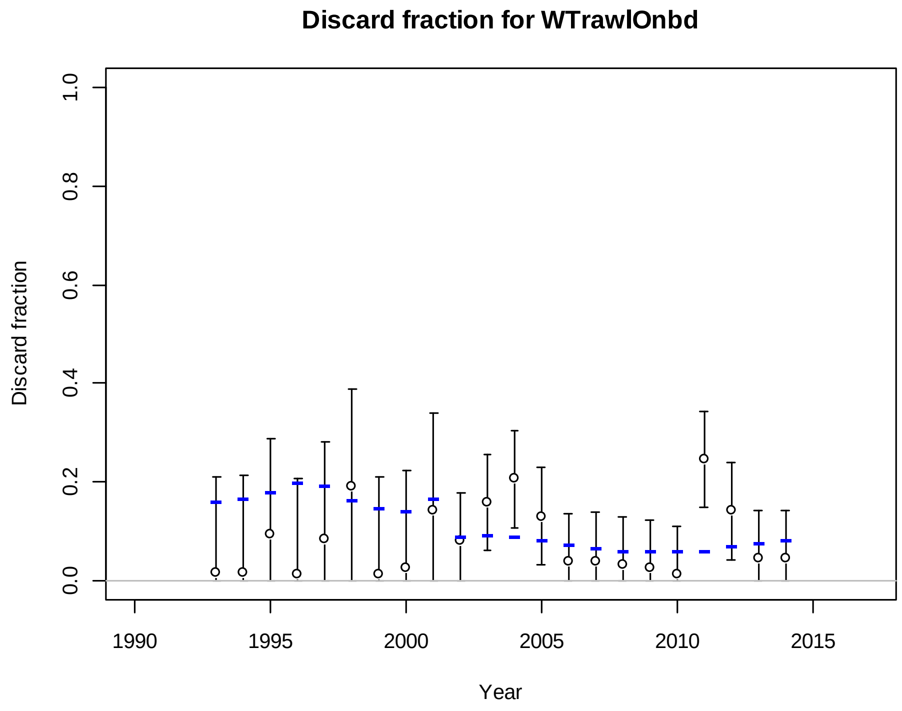


Figure 7.15. Observed (circles) and model-estimated (blue lines) discard estimates versus year, with approximate 95% asymptotic intervals for the Eastern trawl fleet (top) and western trawl fleet (bottom). Note that the observed values fitted were the same for each fleet, the discard data was not separated into eastern and western fleets.

7.4.1.5 Assessment outcomes for the base case model

Figure 7.16 shows the relative spawning stock depletion with the limit and target reference points at 20% and 48% respectively. The increase in stock size in the late 1980s followed by a subsequent decline is a result of the large recruitment in 1983 with below average recruitment in the early and late 1980s. The stock size continues to fluctuate as recruitment varies between periods of good and poor recruitment and as the catch also varies. However there is clearly an overall decline in stock size since the late 1980s. The increase in stock size towards the end of the series should be treated with some caution as this is a result of the model imposed average recruitment from 2013 onwards, when recruitment is unable to be estimated. As data becomes available to inform these recruitment events in future assessments, the increase in stock size from 2012 may need to be revised.

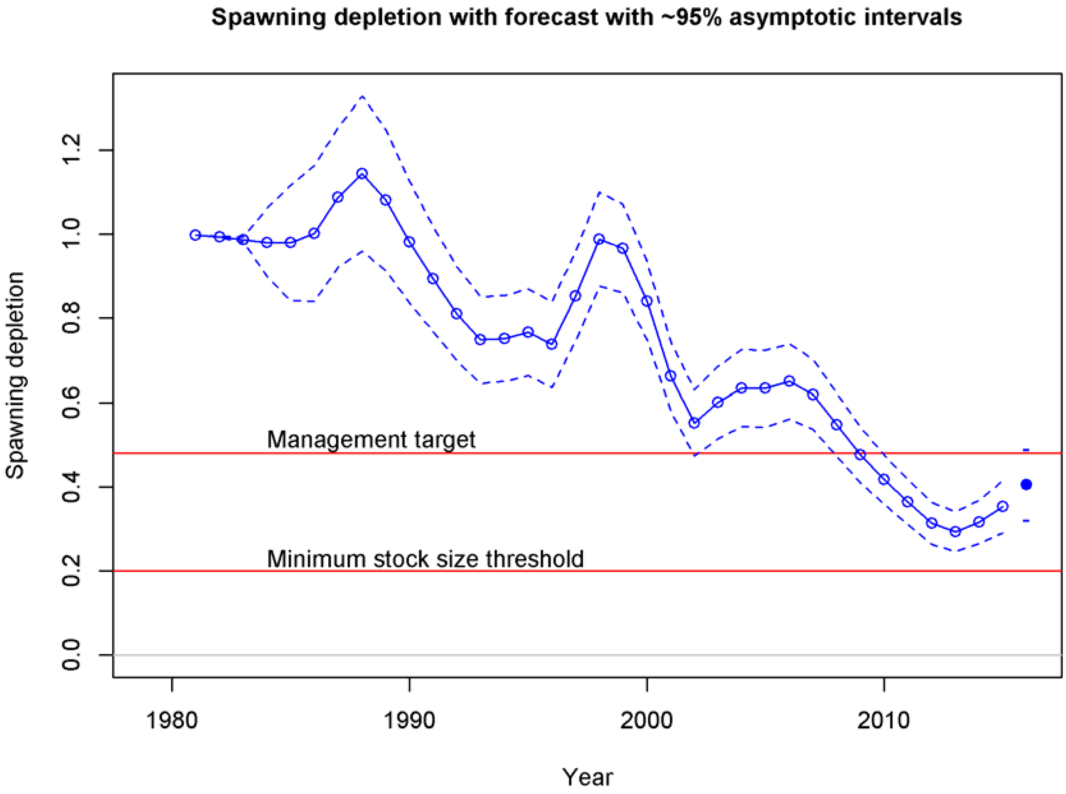


Figure 7.16. Time-trajectory of spawning biomass depletion (with 95% confidence intervals) corresponding to the MPD estimates for silver warehou.

The time-trajectories of recruitment deviations are shown in Figure 7.17 and the bias adjustment and standard errors of recruitment deviation estimates are shown in Figure 7.18. Note that nine of the last ten estimated recruitment events have been below average, with the last recruitment estimate only just above average, and likely to be revised when additional data is added.

The current (2016) spawning stock biomass is estimated to be 40% of unfished stock biomass (i.e. 2016 spawning biomass relative to unfished spawning biomass).

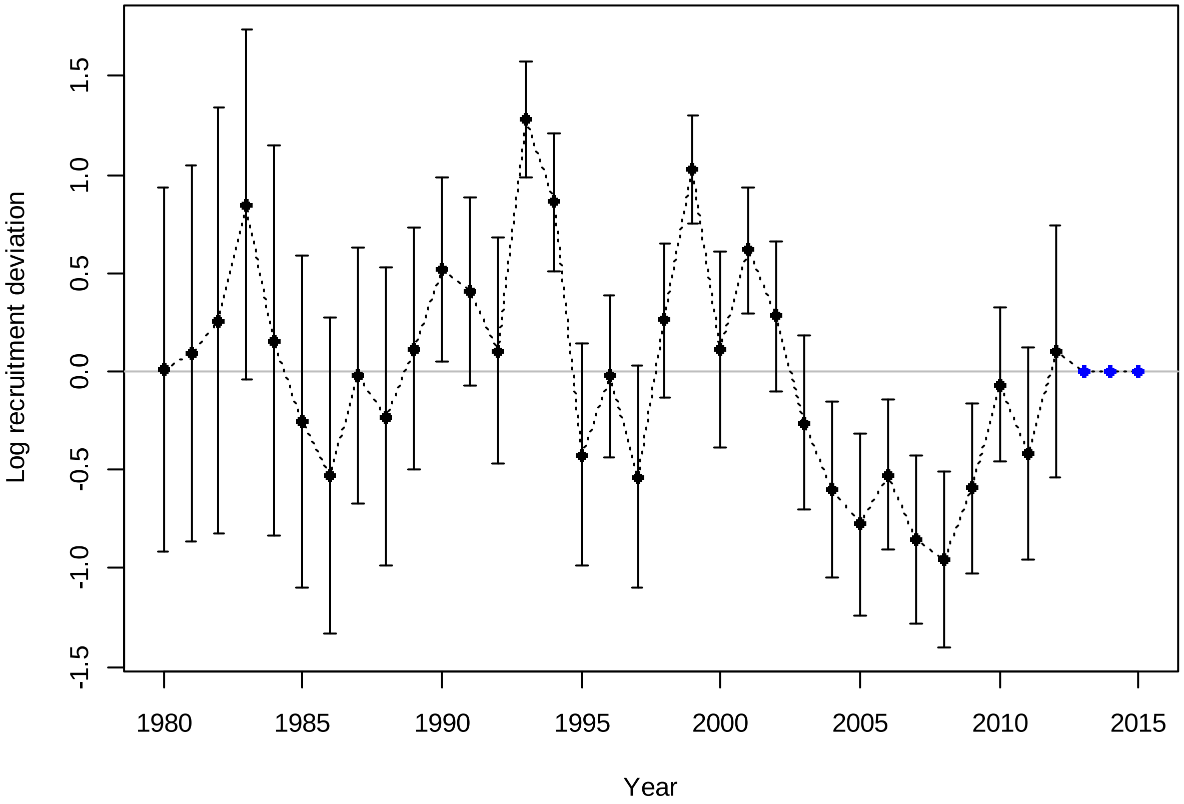


Figure 7.17. Recruitment estimates for the base case for silver warehou. Time trajectories of estimated log recruitment deviations, with approximate error distributions.

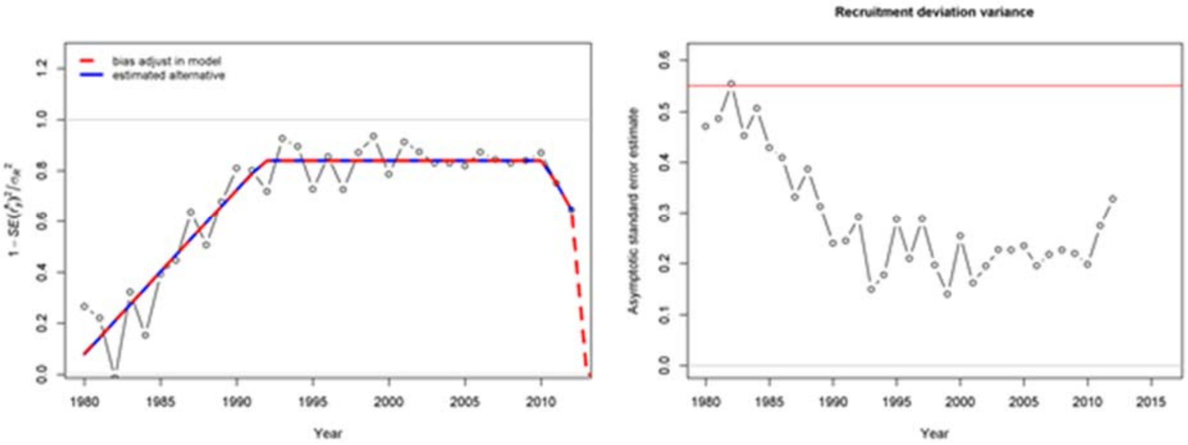


Figure 7.18. Bias adjustment (left) and standard errors of recruitment deviation estimates (right) for the base case for silver warehou.

Table 7.7. Summary of fixed and estimated parameters for the primary base case model.

Feature	Details	
Natural mortality (*M*)	fixed	0.3
Steepness (*h*)	fixed	0.75
σ_R in	fixed	0.55
length-weight scale, *a*	fixed	0.0000065
length-weight power, *b*	fixed	3.27
length at 50% maturity (cm)	fixed	37
maturity slope	fixed	-6
Recruitment deviations	estimated	1980-2012, bias adjustment ramp 1980-1992
CV growth	estimated	0.0896
Growth *K*	estimated	Female 0.310
Growth l_{min}	estimated	Female age 2 15.19
Growth l_{max}	estimated	Female 50.21
length at 50% selectivity (cm)	estimated	24.66 (east) 39.59 (west)
selectivity spread (cm)	estimated	3.65 (east) 11.18 (west)
ln(R_0)	estimated	9.626

7.4.2 *Sensitivities and alternative models*

Results of the sensitivity tests are shown in Table 7.8 and Table 7.9. The results are most sensitive to the assumed value for natural mortality (*M*) and recruitment variance (σ_R). However, even with M=0.35, the improved fits to the survey, discard and age data give an improvement to the overall likelihood of only five units. Similarly with σ_R =0.65, the improved fits to the recruitment give a similar improvement to the overall likelihood of only five units. Changes to the other fixed parameters produce little change to the overall likelihood and only minor changes to the depletion estimates.

Changing the weighting on various data sources has relatively minor impacts on the depletion estimates. The likelihood cannot be compared directly in these cases, but Table 7.9 shows the relative differences between the different components of the total likelihood, attributable to these changes.

This also suggests some conflict between the age and length data as increasing the weight on the age data results in poorer fits to the length data and vice versa.

Table 7.8. Summary of results for the base case and sensitivity tests (log-likelihood (-ln L) values that are comparable are in bold face). Spawning stock biomass includes both male and female biomass in the total.

Model	-ln L	SB_0	SB_{2016}	SB_{2016}/SB_0	2016 RBC (t)	long term RBC (t)
base case	**894**	**23381**	**9464**	**40**	**1958**	**2281**
M=0.25	**901**	22299	7651	34		
M=0.35	**889**	27497	12730	46		
h=0.65	**893**	23844	9322	39		
h=0.85	**894**	23064	9586	42		
50% maturity at 34cm	**894**	25770	11305	44		
50% maturity at 40cm	**894**	20251	7425	37		
σ_R = 0.45	901	22948	9702	42		
σ_R = 0.65	889	24088	9339	39		
est. recruitment to 2011	894	23302	9451	41		
est. recruitment to 2013	894	23442	9464	40		
double weight on CPUE	921	23380	8759	37		
halve weight on CPUE	878	23744	10509	44		
double weight on lengths	1183	22179	9640	43		
halve weight on lengths	737	24819	9661	39		
double weight on age	1389	24376	9738	40		
halve weight on age	638	22700	9311	41		
double catch 1998-2002	906	35182	16095	46		

Table 7.9. Summary of likelihood components for the base case and sensitivity tests. Likelihood components are unweighted and all cases below the primary base case are shown as differences from the base case. A negative value either in the total or individual components of likelihood indicates an improvement in fit compared to the primary base case. A positive value indicates deterioration in the fit.

Model	Likelihood TOTAL	Survey	Discard	Length	Age	Recruitment	parm_priors
base case	893.56	32.98	38.74	301.95	503.75	15.85	0.30
M=0.25	7.68	1.70	1.95	2.60	1.01	0.41	0.31
M=0.35	-4.91	-1.63	-1.64	-1.90	-0.11	0.38	0.29
h=0.65	-0.44	-0.15	0.13	0.24	-0.20	-0.46	0.30
h=0.85	0.38	0.12	-0.10	-0.17	0.15	0.38	0.30
50% maturity at 34cm	0.05	-0.01	0.00	0.01	0.01	0.05	0.30
50% maturity at 40cm	-0.14	0.01	0.00	-0.07	0.04	-0.13	0.30
σ_R = 0.45	7.68	1.40	-0.36	0.97	0.31	5.37	0.30
σ_R = 0.65	-4.88	-0.79	0.24	-0.56	-0.20	-3.57	0.30
est. recruitment to 2011	0.00	0.00	-0.01	0.02	0.00	-0.01	0.30
est. recruitment to 2013	0.00	0.00	0.00	0.01	-0.01	0.01	0.30
double weight on CPUE	1.60	-3.88	3.00	1.39	-0.70	1.77	0.31
halve weight on CPUE	1.42	5.11	-2.04	-1.01	0.90	-1.52	0.29
double weight on lengths	9.62	2.05	8.14	-22.76	19.78	2.42	0.29
halve weight on lengths	8.09	-0.91	-5.70	27.97	-12.70	-0.55	0.29
double weight on age	6.76	0.33	1.56	19.30	-15.48	1.08	0.28
halve weight on age	4.78	1.29	-0.78	-12.94	17.01	0.20	0.30
double catch 1998-2002	11.89	4.64	2.42	7.12	-3.74	1.45	0.30

7.4.3 *Application of the harvest control rules in 2015*

An estimate of the catch for the 2015 calendar year is needed to run the model forward to calculate the 2016 spawning biomass and depletion. Given that recent TACs have been considerably under-caught, the catch in 2015 is assumed to equal that of 2014 (namely 381t).

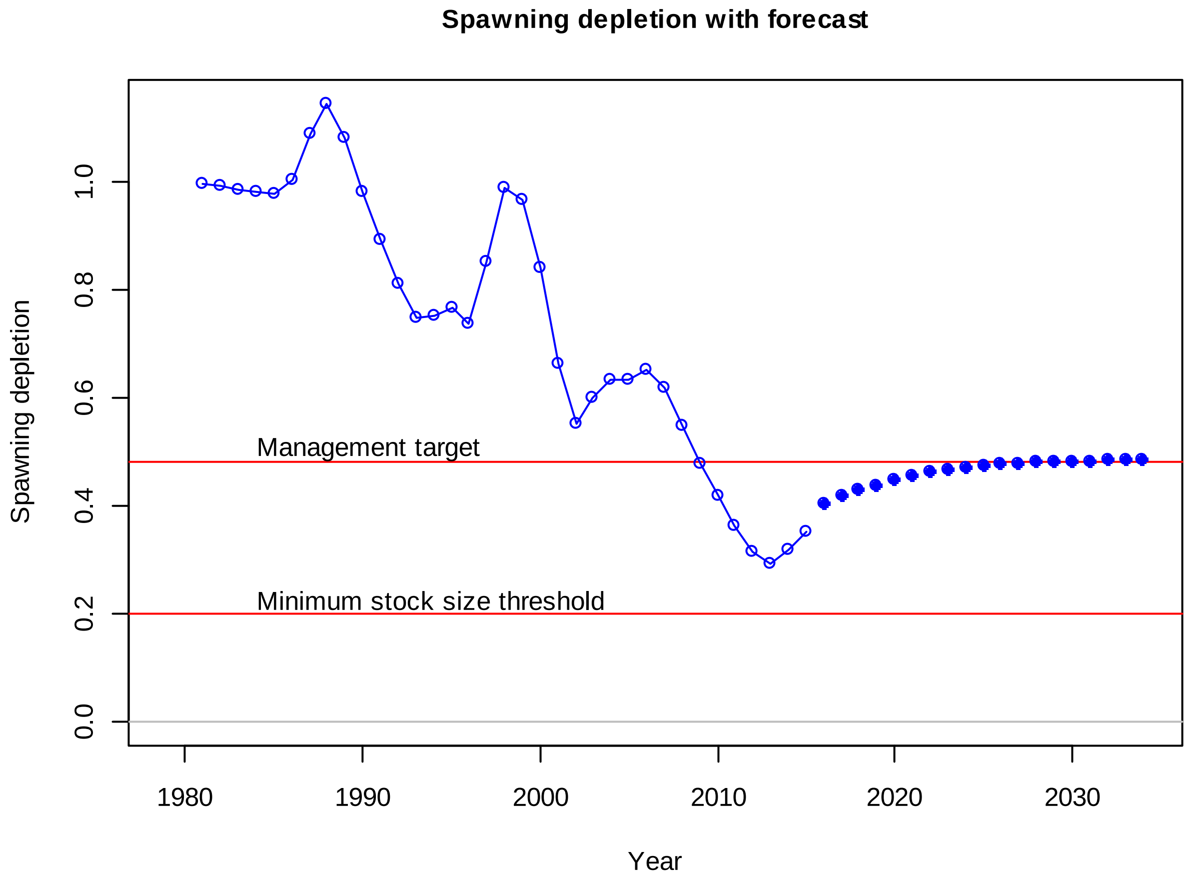


Figure 7.19. The projection of relative spawning biomass (bottom) under the 20:35:48 rule for silver warehou.

The depletion in 2016 under the base-case parameterisation is estimated to be 40.5%. An application of the Tier 1 harvest control rule with a target depletion of 48% leads to the 2016 and long-term RBCs of 1958t and 2281t (Table 7.8). An example of the time-series of RBCs and corresponding spawning biomass corresponding to the calculated RBCs for the 20:35:48 harvest control rule is shown in Figure 7.19. This figure assumes that the full RBC is caught in projected years and that recruitment is deterministically drawn from the stock-recruitment curve. Table 7.10 shows the annual RBCs and depletion estimates under the 20:35:48 harvest control rule.

Model estimated discard rates for 2016-2018 are required for calculation of the TAC from the RBC, and these can be obtained from Stock Synthesis output files. Under the assumption of average recruitment from 2013 onwards and assuming that the RBC is caught in full each year, the estimated discard mass for these years follow: 162t in 2016; 166t in 2017; and 169t in 2018.

Table 7.10. Summary of the annual RBCs and corresponding depletion for the base case under the 20:35:48 harvest control rule.

Year	RBC(t)	Depletion
2015	381	35.2
2016	1958	40.5
2017	2005	41.9
2018	2050	42.9
2019	2091	43.8
2020	2128	44.7
2021	2161	45.5
2022	2187	46.1
2023	2208	46.6
2024	2225	47.0
2025	2238	47.3
2026	2248	47.6
2027	2256	47.8
2028	2263	47.9
2029	2268	48.1
2030	2272	48.2
2031	2275	48.2
2032	2277	48.3
2033	2279	48.3
2034	2281	48.4

7.4.4 *Scenarios with low recruitment for 2013-2020*

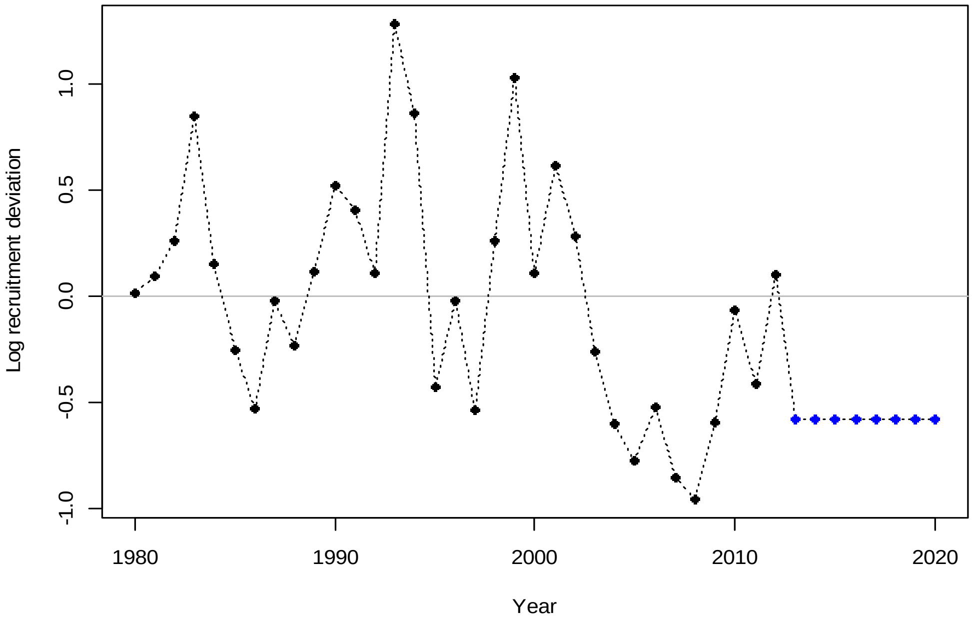
7.4.4.1 Poor and very poor recruitment scenarios

To explore the potential impact of setting a multi-year TAC without updating this assessment, scenarios were run where the recruitment in the period from 2012-2020 was assumed to be poor. When the harvest control rules are applied and forward projections are made, recruitment deviations from 2012 onwards are set to zero, as there is insufficient information to estimate recruitment in this period. This essentially assumes average recruitment for the given level of spawning biomass for the period 2012 onwards.

Given that nine of the last ten recruitment events are estimated to be below average (Figure 7.17) and that the last recruitment estimated (2012) is only just above average and could be revised down in the future with additional data, and given that catches and catch rates have been declining for the last ten years, it seems unlikely that catches will return to the projected RBC levels given in Table 7.10. Indeed, it is possible that recruitment may remain below average for the next few years.

To explore the possible impact of continued poor recruitment, two additional recruitment scenarios were examined where recruitment was assumed to be poor in the period 2013-2020. In this case, the standard forward projections, assuming average recruitment, could produce RBCs that, if caught, could result in a lower spawning biomass than the target level. The first recruitment scenario, referred to as "poor recruitment" took the mean of the log recruitment deviations in the base case estimated from 2007-2011, giving a value of -0.576. This represented a recent period of five poor recruitment events. The second recruitment scenario, referred to as "very poor recruitment" took the mean of the log recruitment deviation from the worst three of these years, 2007-2009, giving a value of -0.799. The recruitment estimates from the poor and very poor recruitment scenarios are shown in Figure 7.20.

A similar scenario was explored in the 2012 assessment (Day *et al.* 2012), where log recruitment deviations were averaged over the period 2002-2005 giving a recruitment deviation of -0.627 projected forward for the period 2008-2011. This 2012 poor recruitment scenario falls between the two recruitment scenarios considered here, but was only projected for four years in 2012.



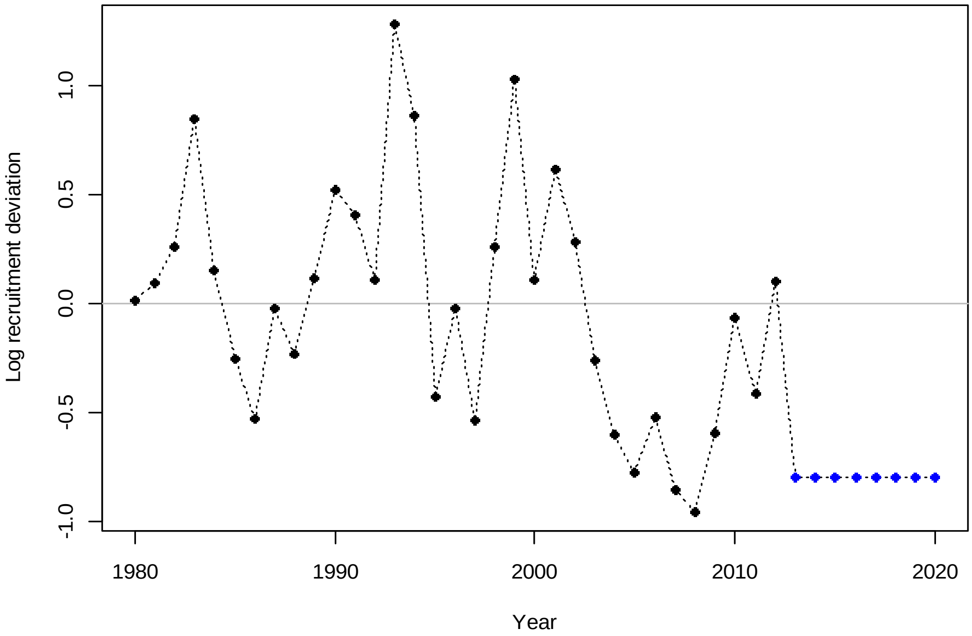


Figure 7.20. Time trajectories of log recruitment deviations estimates for the scenario with poor recruitment (top) and very poor recruitment (bottom).

7.4.4.2 Fixed catch projection to 2020

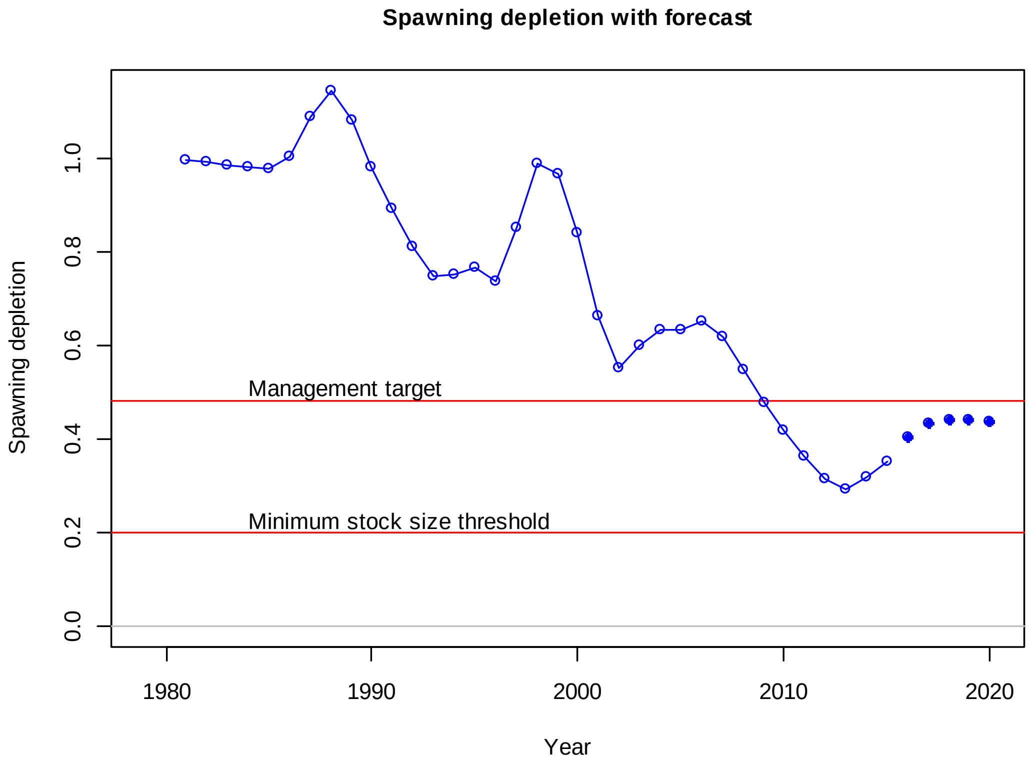
For the two poor recruitment scenarios, the dynamics were projected forward for five additional years, initially with a fixed catch level, set at the 2014 catch, 381t. Note that with discards being estimated, there are additional removals, and while the forecast catch is set to 381t, the actual landed catch is a little higher due to the interaction with discards. Spawning depletion scenarios and actual depletion levels are shown in Figure 7.21, Table 7.11 and Table 7.12. Neither recruitment scenario sees the stock approaching the target biomass by 2020, and the very poor recruitment scenario sees a decline in spawning biomass to a depletion below 40% in 2020.

Table 7.11. Depletion levels assuming poor recruitment from 2013-2020 and a fixed catch of 381t.

Year	Catch	Depletion
2015	381	35.2
2016	381	40.2
2017	384	43.3
2018	386	44.0
2019	387	43.9
2020	386	43.7

Table 7.12. Depletion levels assuming very poor recruitment from 2013-2020 and a fixed catch of 381t.

Year	Catch	Depletion
2015	381	35.2
2016	382	40.2
2017	385	42.4
2018	388	41.7
2019	389	40.2
2020	388	38.7



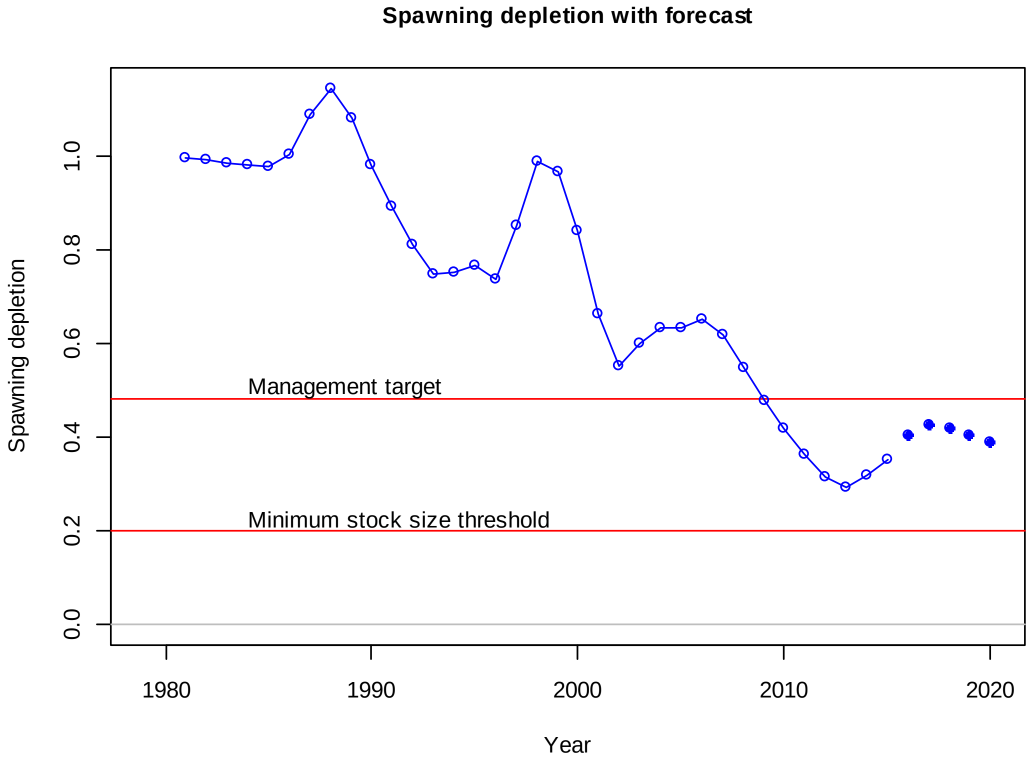


Figure 7.21. The poor (top) and very poor (bottom) recruitment scenario projections of relative spawning biomass with fixed catch of 381t (2014 catch).

7.4.4.3 Additional fixed catch projections to 2020

At the October RAG meeting, some additional fixed catch projections were run for the poor recruitment scenario (recruitment deviations set to -0.576 from 2012-2020), to examine the impact of fixed catches of 1958t, 1206t and 600t. As in the other fixed catch scenarios, with discards being estimated, there are additional removals, and while the forecast catch is set to at 1958t, 1206t and 600t respectively, the actual landed catch is a little higher due to the interaction with discards.

The actual depletion levels resulting from these fixed catches under the poor recruitment scenario are listed in Table 7.13, Table 7.14 and Table 7.15. Note that in all cases, the spawning biomass is projected to increase initially, with a subsequent decline in spawning biomass through to 2020.

Table 7.13. Depletion levels assuming poor recruitment from 2013-2020 and a fixed catch of 1958t.

Year	Catch	Depletion
2015	381	35.2
2016	1960	40.2
2017	1977	37.6
2018	1989	33.0
2019	1990	28.3
2020	1980	24.4

Table 7.14. Depletion levels assuming poor recruitment from 2013-2020 and a fixed catch of 1206t.

Year	Catch	Depletion
2015	381	35.2
2016	1209	40.2
2017	1219	40.3
2018	1225	38.2
2019	1226	35.7
2020	1223	33.6

Table 7.15. Depletion levels assuming poor recruitment from 2013-2020 and a fixed catch of 600t.

Year	Catch	Depletion
2015	381	35.2
2016	601	40.2
2017	605	42.5
2018	608	42.5
2019	609	41.7
2020	608	41.0

7.5 Conclusion

This document presents an updated assessment of silver warehou (*Seriolella punctata*) in the SESSF using data up to 31 December 2014. A full stock assessment for silver warehou was last performed in 2012 by Day *et al.* (2012) using the stock assessment package Stock Synthesis. Changes from the 2012assessment include: (a) migration to the latest version of Stock Synthesis (SS-V3.24U), (b) updates of all catch, discard, length, age and catch rate data and the last year of estimation of recruitment (2012), two years prior to the last year of data (2014), (c) discarded length frequencies incorporated and discarding being estimated by the model, (d) the single trawl fleet split into east and west fleets, each with its own estimated selectivity pattern and discards (retention function), (e) length frequencies being split into onboard and port collected components (sharing a single selectivity pattern) for each fleet, (f) the retention function has been time blocked, reflecting changes in the discarding practices in the periods 1980-2001 and 2002-2014, (g) inclusion of FIS abundance fleets and (h) weighting length frequencies by shots and trips and (i) adopting new model tuning practices.

The fit to the last two CPUE data points suggest that the model may again be overly optimistic at the end of the time series and that this stock could “break out” again in a relatively short time period. Breaking out occurs when the CPUE trends fall outside of the 95% confidence bounds projected from the stock assessment (Klaer, 2012). The 2014 data point is already very close to the lower 95% confidence bound from the stock assessment without any projection. Additional data will help identify if the initial signs of stronger recruitments in 2010 and 2012 are confirmed or not. The last two recruitment events estimated by the 2012 assessment in 2006 and 2007 were revised downwards with the additional data available in this assessment, so revisions of promising recruitment events towards the end of the recruitment series have occurred in the past.

The continued decline in catches and catch rates indicate considerable concern for this species, and the results of this assessment suggest that it is now below the target biomass, and is only likely to return to this biomass if future recruitment returns to average. Nine out of the last ten years of below average recruitment suggest that relying on average recruitment for the stock to recover may be overly optimistic. Poor future recruitment scenarios illustrate the potential dangers to the stock if the calculated RBC is actually caught, although these impacts are reduced if the current low catch levels are maintained.

Future development of the stock assessment for silver warehou could include a depth structured model, although indications are that the east west split already incorporates most of the variability in depth. Incorporating cohort dependent growth to allow for apparent temporal differences in growth seen in the fits to age-at-length data could also be considered. Length frequency distributions from the FIS could also be a useful additional data source, as the annual variation in both onboard and port length frequency data suggests that this data may not be entirely representative.

This assessment estimates that the projected 2016 spawning stock biomass will be 40% of virgin stock biomass. The RBC from the base case model for 2016 is 1,958t for the 20:35:48 harvest control rule, with a long-term yield of 2,281t. In comparison, the last assessment estimated the 2013 depletion to be 47%, with corresponding RBCs of 2,544t, with a long-term yield of 2,618t. However, these scenarios assume recruitment will return to average levels. If future recruitment continues at a similar level to recruitment since 2003, then depletion could fall to around 30% before 2020. However, if landed catches continue at levels well below the TAC, then the depletion is likely to remain between 35% and 45% for the next 5 years.

7.6 Acknowledgements

Age data was provided by Kyne Krusic-Golub (Fish Ageing Services), ISMP and AFMA logbook and CDR data were provided by John Garvey (AFMA). Mike Fuller and Miriana Sporcic (CSIRO) pre-processed the data. Athol Whitten provided very useful R code for organising plots and provided the latest version of Stock Synthesis. Malcolm Haddon and Judy Upston are thanked for helpful discussions of this work.

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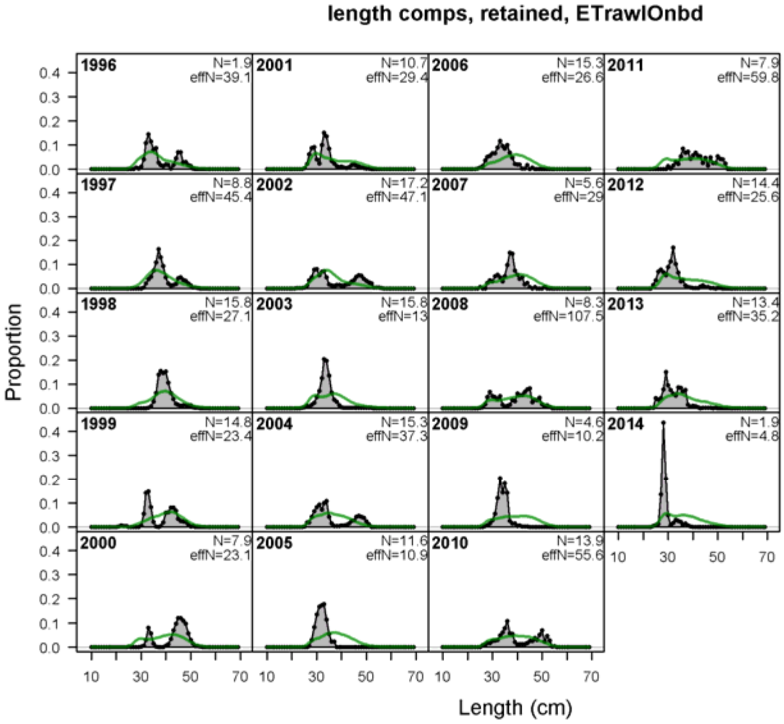
7.8 Appendix A Base case fits

7A.1 Length fits



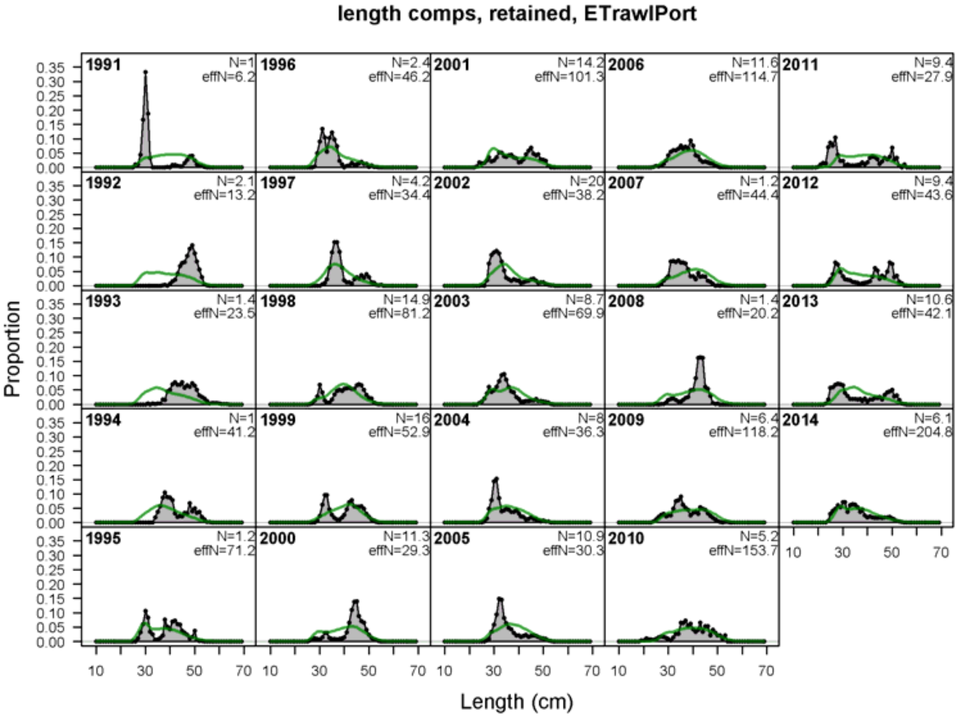


Figure 7A.1 The observed (shaded) and model-predicted (green line) fits to the retained length composition data for silver warehou for the eastern trawl fleet onboard (top) and port (bottom).

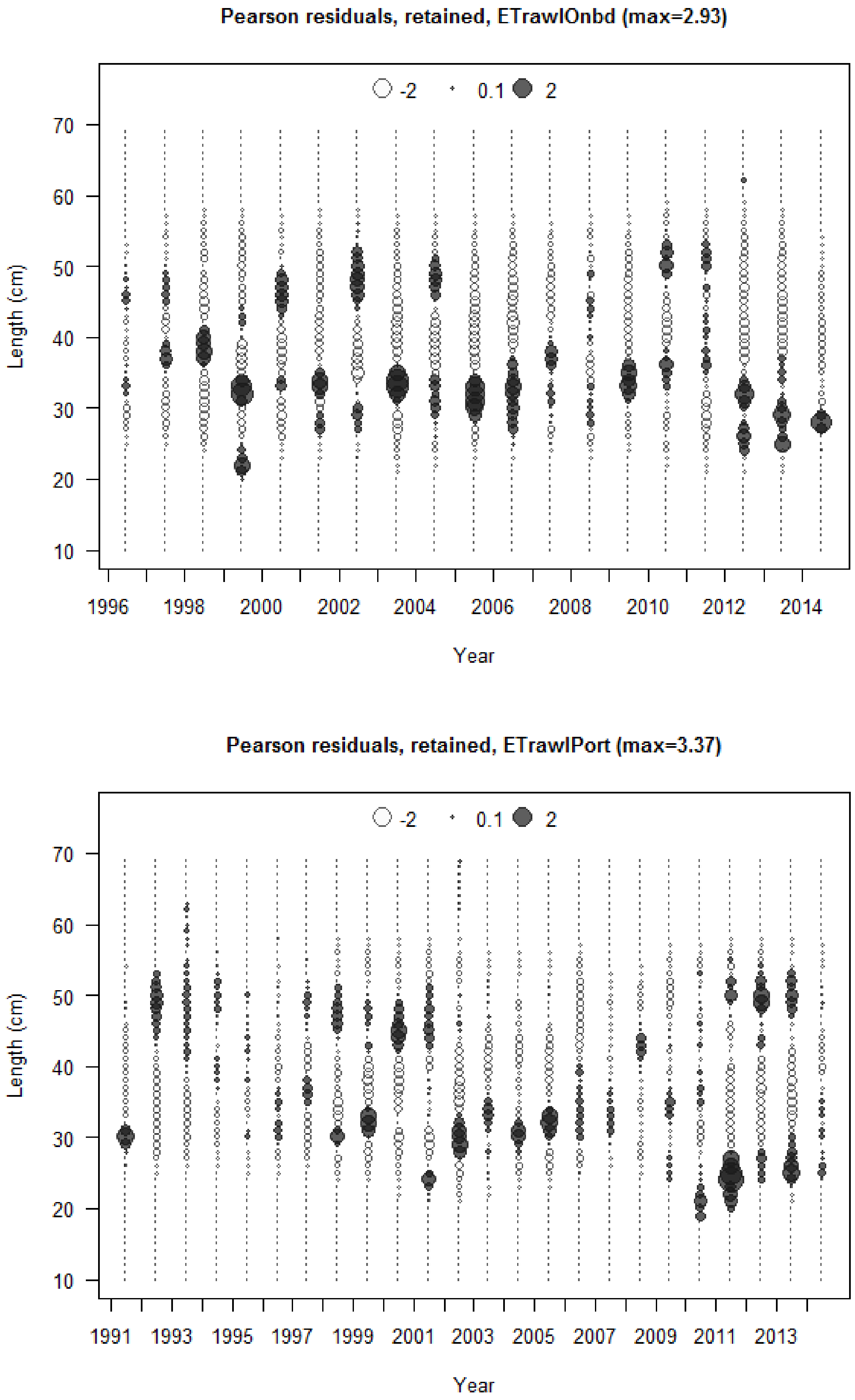
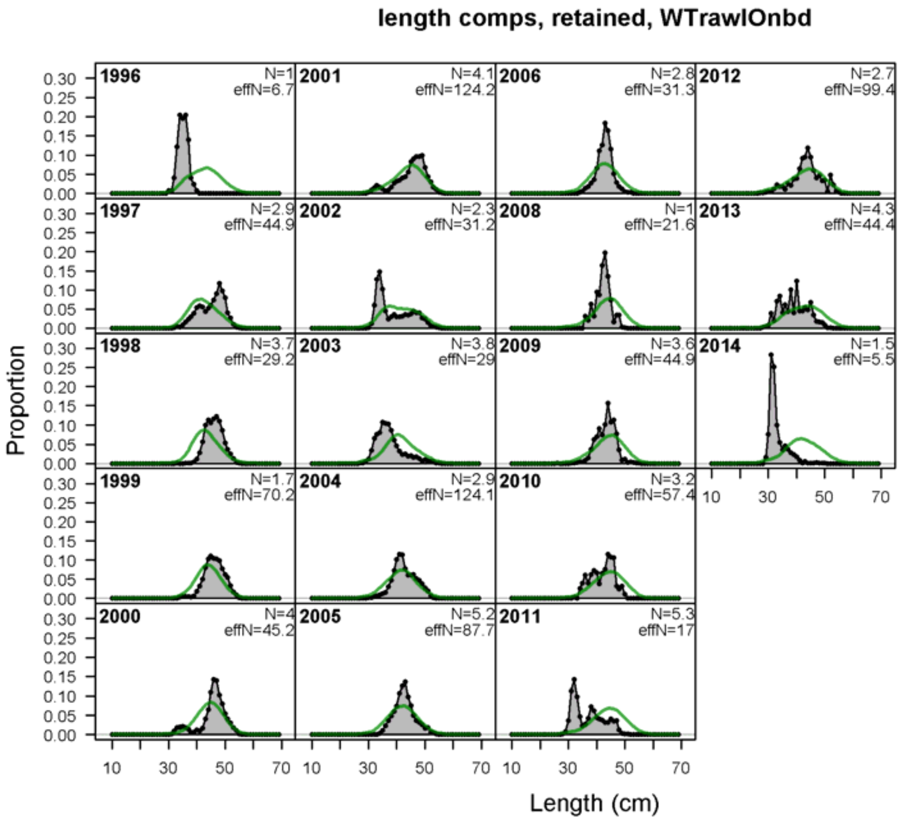


Figure 7A.2 The residual pattern for the retained length composition data for silver warehou for the eastern trawl fleet onboard (top) and port (bottom).



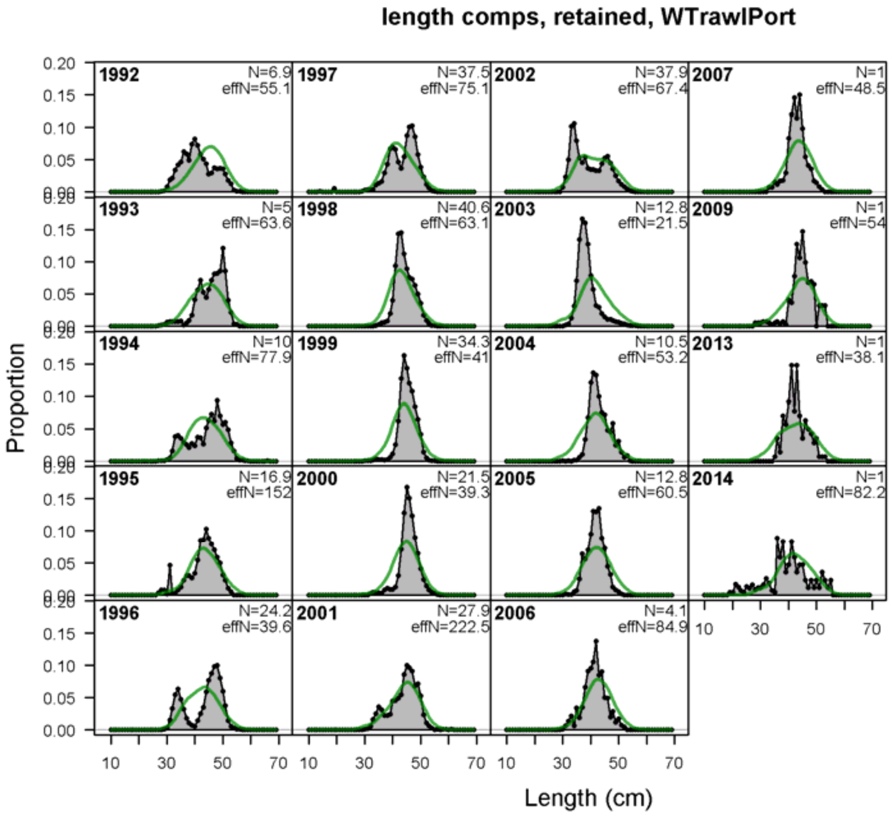
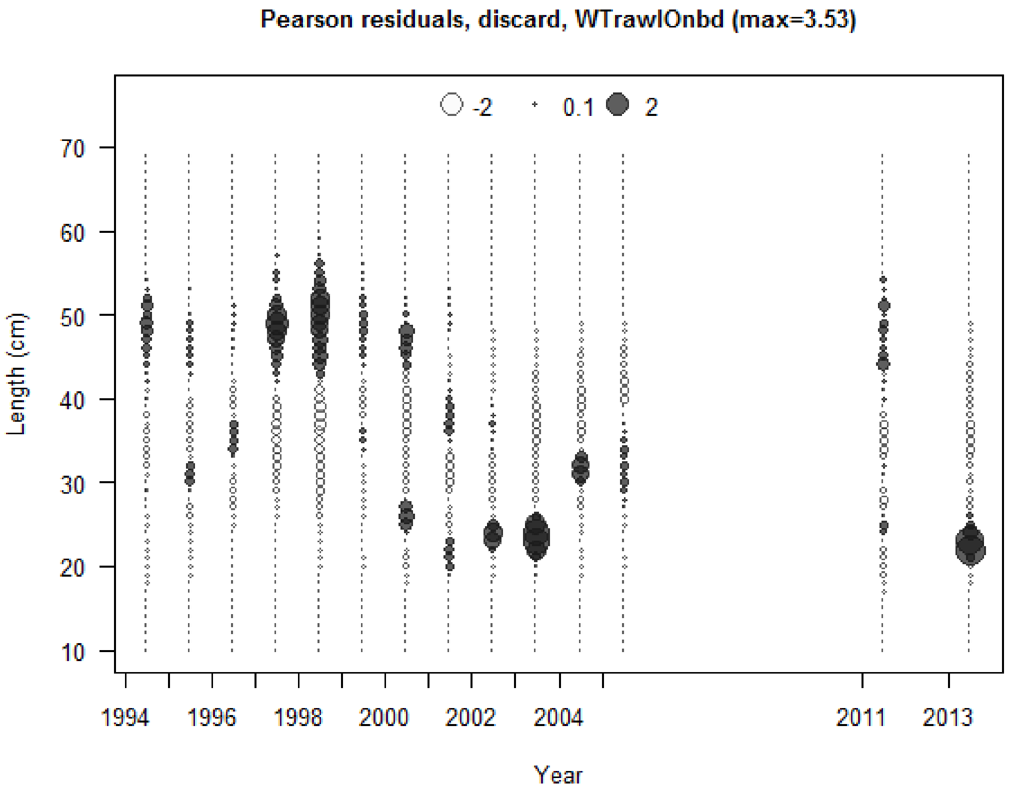


Figure 7A.3 The observed (shaded) and model-predicted (green line) fits to the retained length composition data for silver warehou for the eastern trawl fleet onboard (top) and port (bottom).



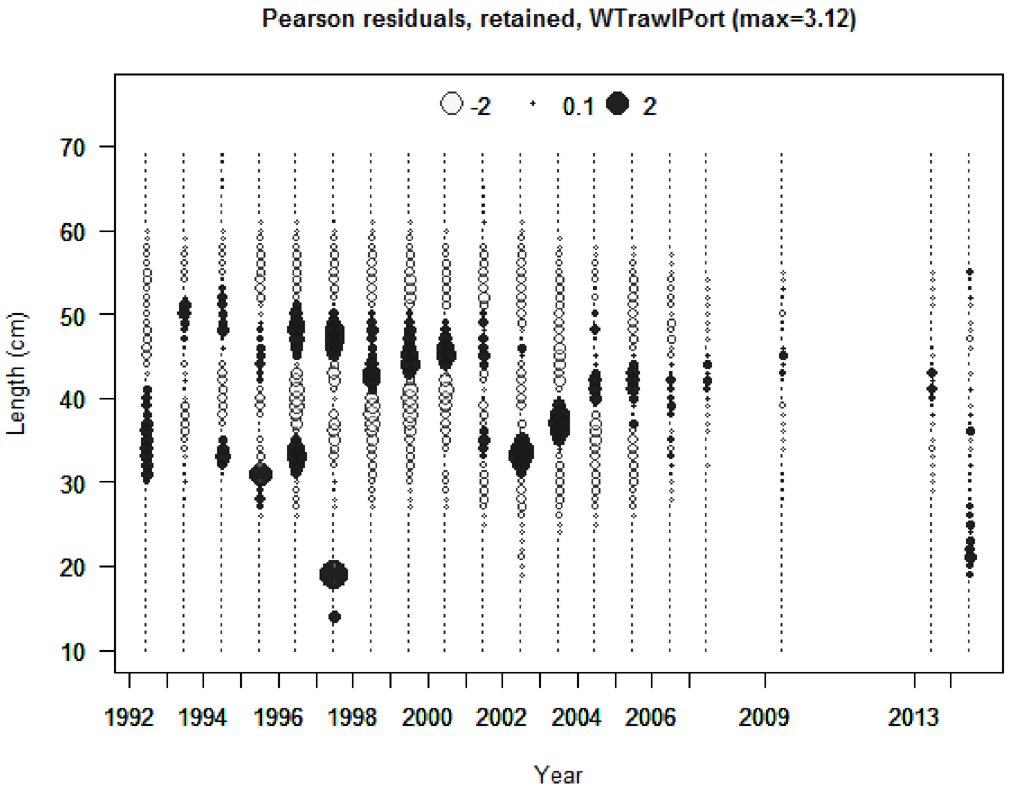
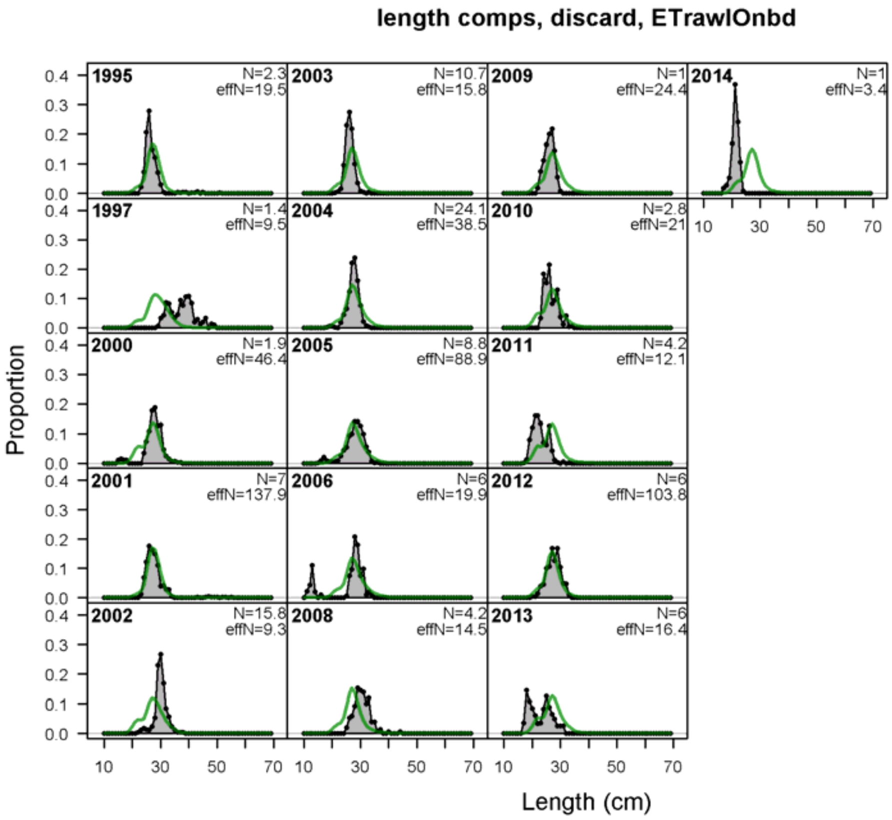


Figure 7A.4 The residual pattern for the retained length composition data for silver warehou for the western trawl fleet onboard (top) and port (bottom).



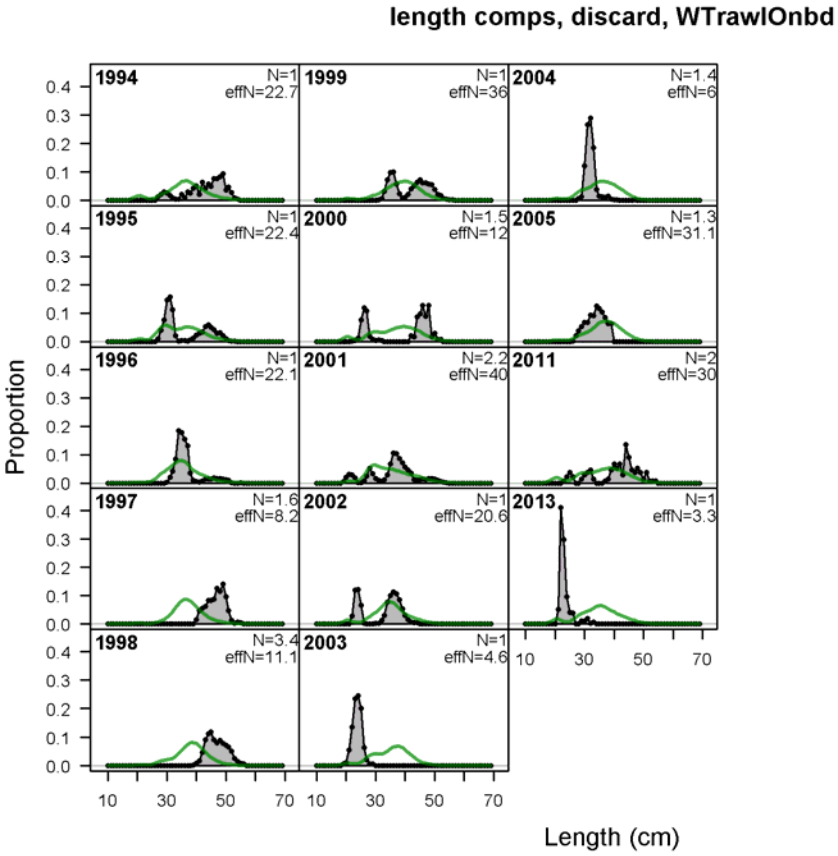
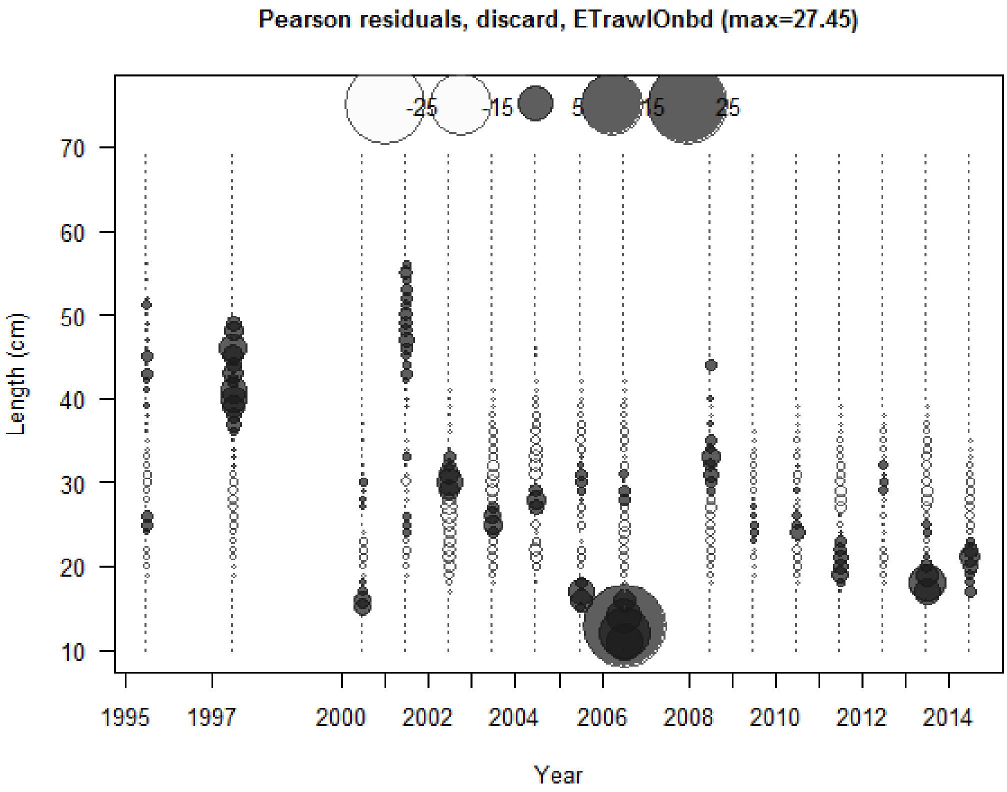


Figure 7A.5 The observed (shaded) and model-predicted (green line) fits to the discarded length composition data for silver warehou for the eastern trawl fleet onboard (top) and western trawl fleet onboard (bottom).



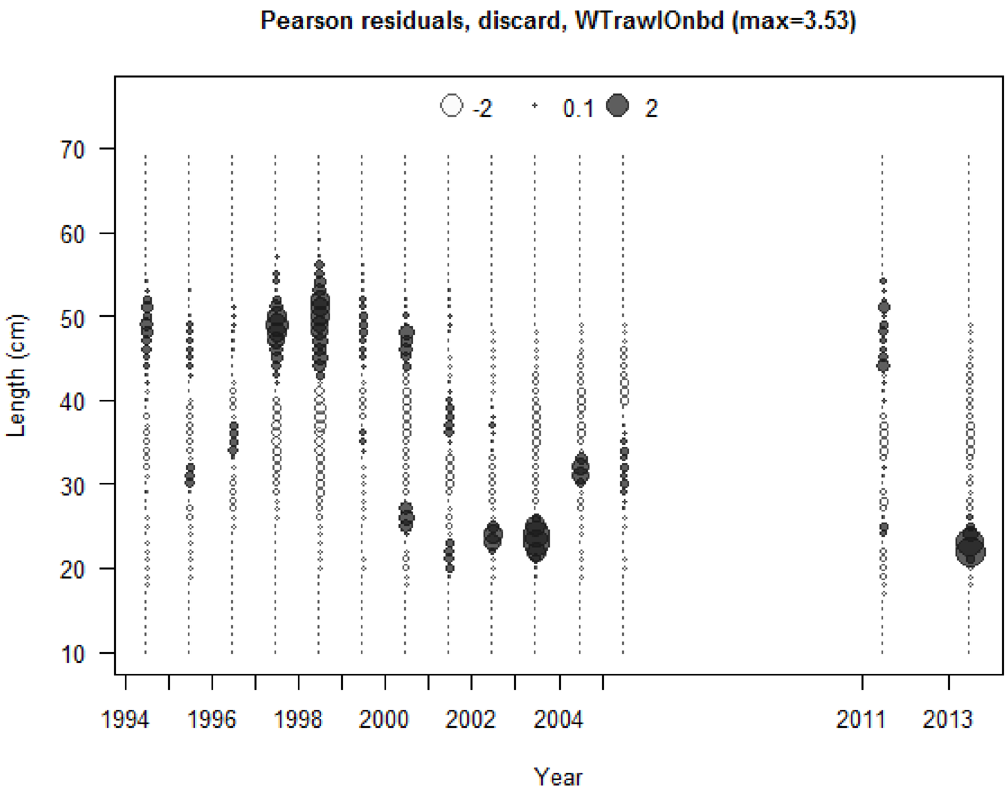


Figure 7A.6 The residual pattern for the discarded length composition data for silver warehou for the eastern trawl fleet onboard (top) and western trawl fleet onboard (bottom).

7A.2 Age fits

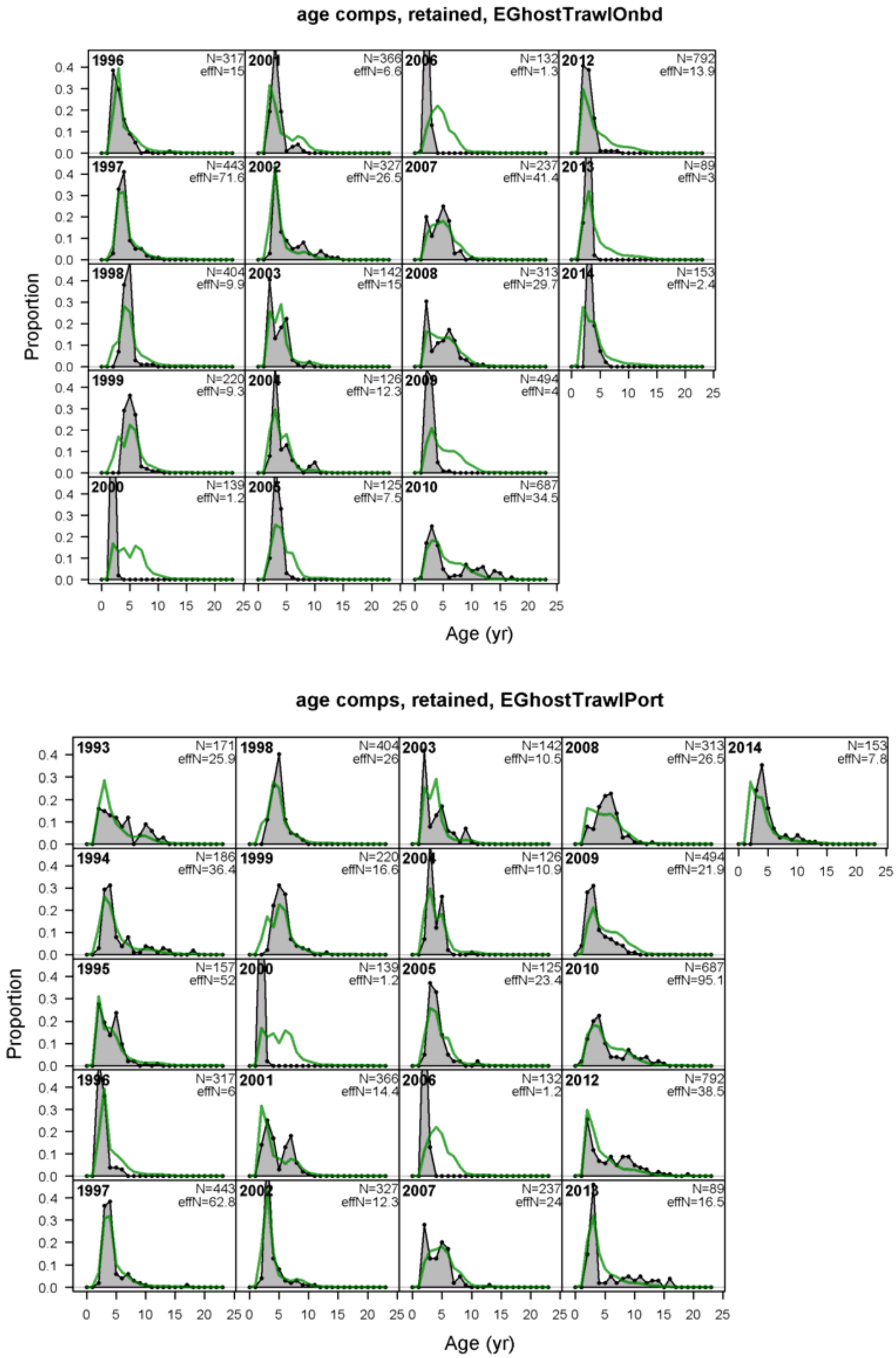
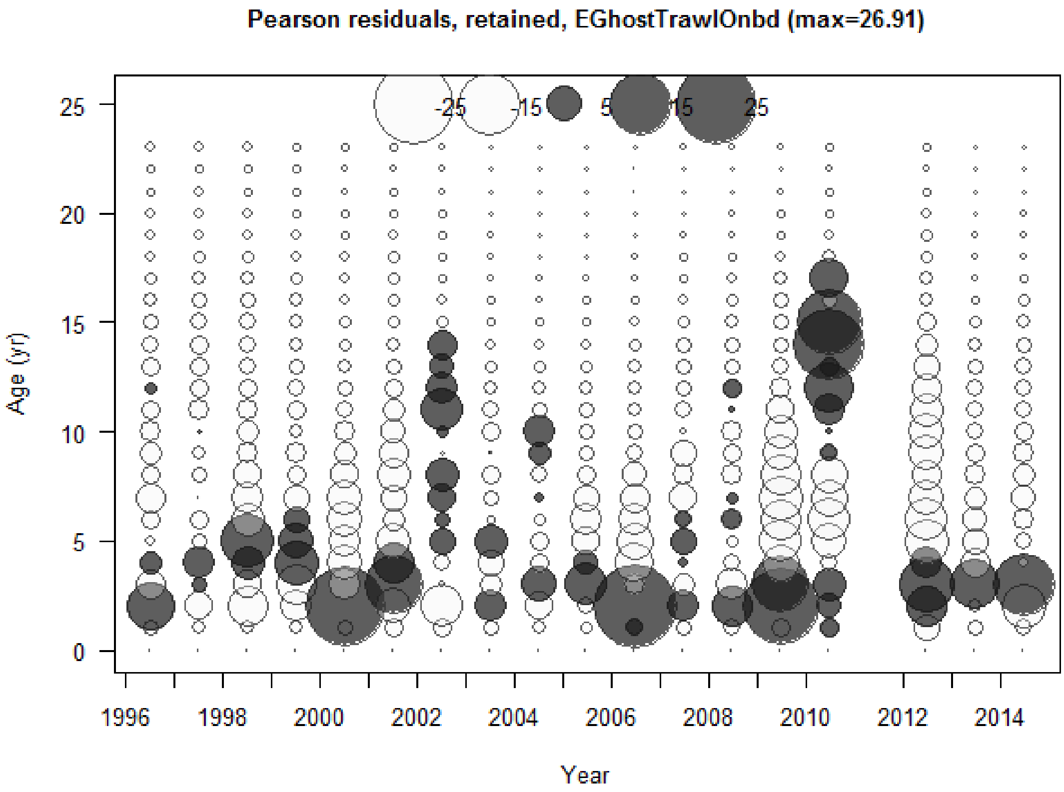


Figure 7A.7 The observed (shaded) and model-predicted (green line) implied fits to the age composition data for silver warehou for the eastern trawl fleet onboard (top) and port (bottom).



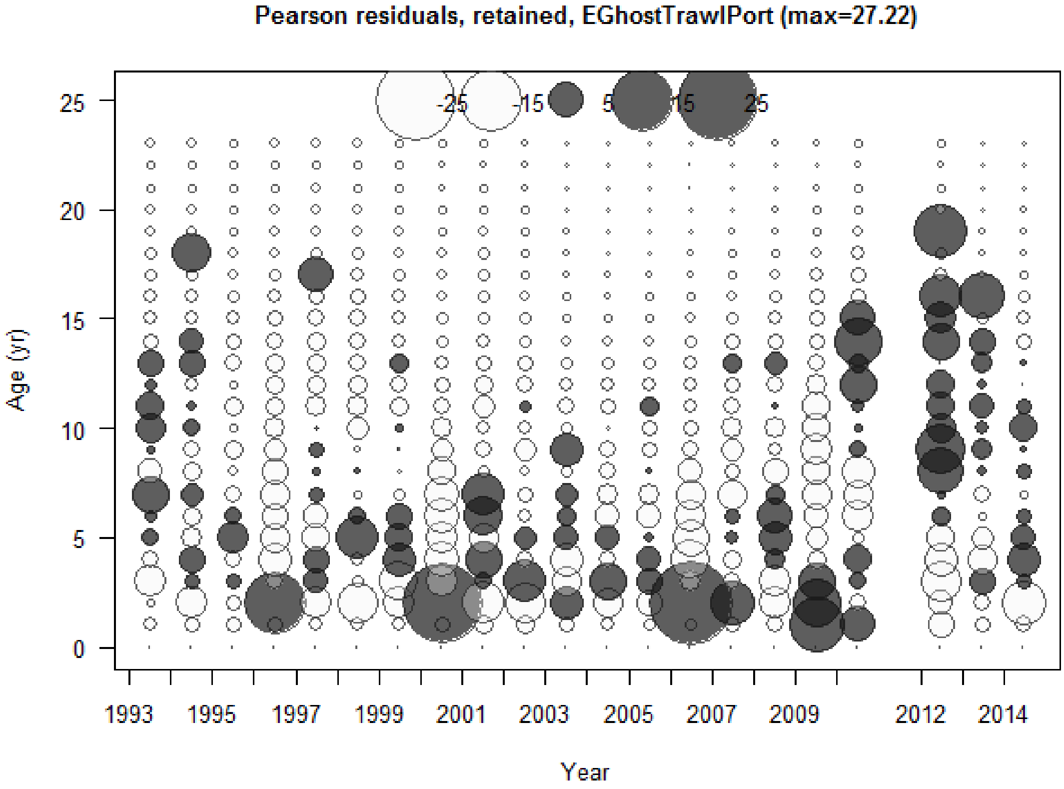
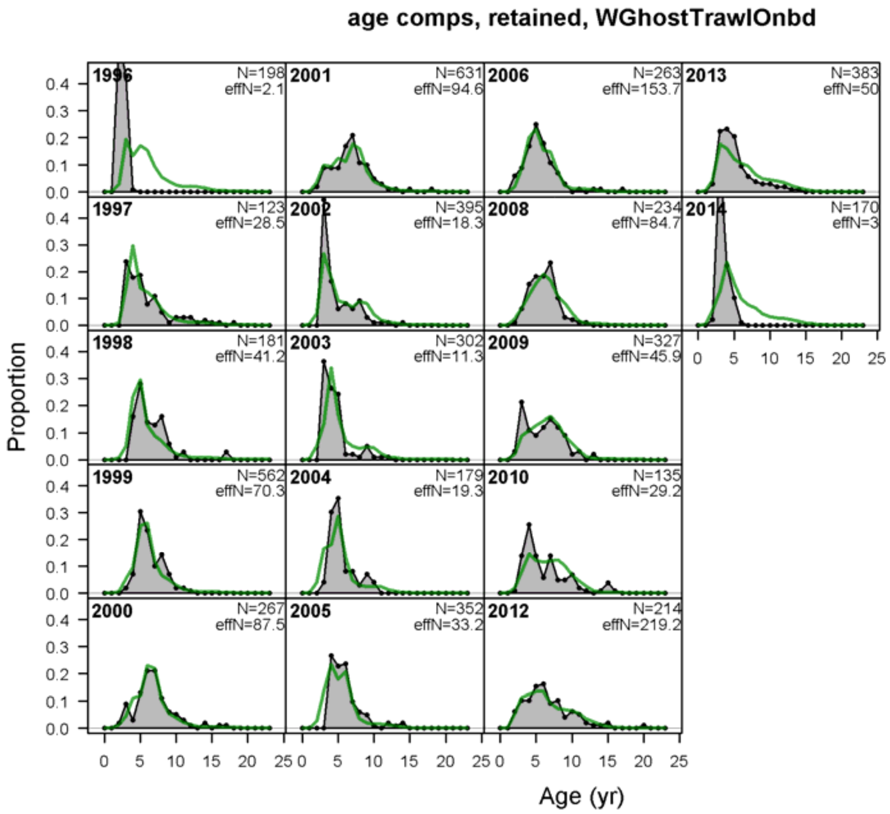


Figure 7A.8 The residual pattern for the age composition data for silver warehou for the eastern trawl fleet onboard (top) and port (bottom).



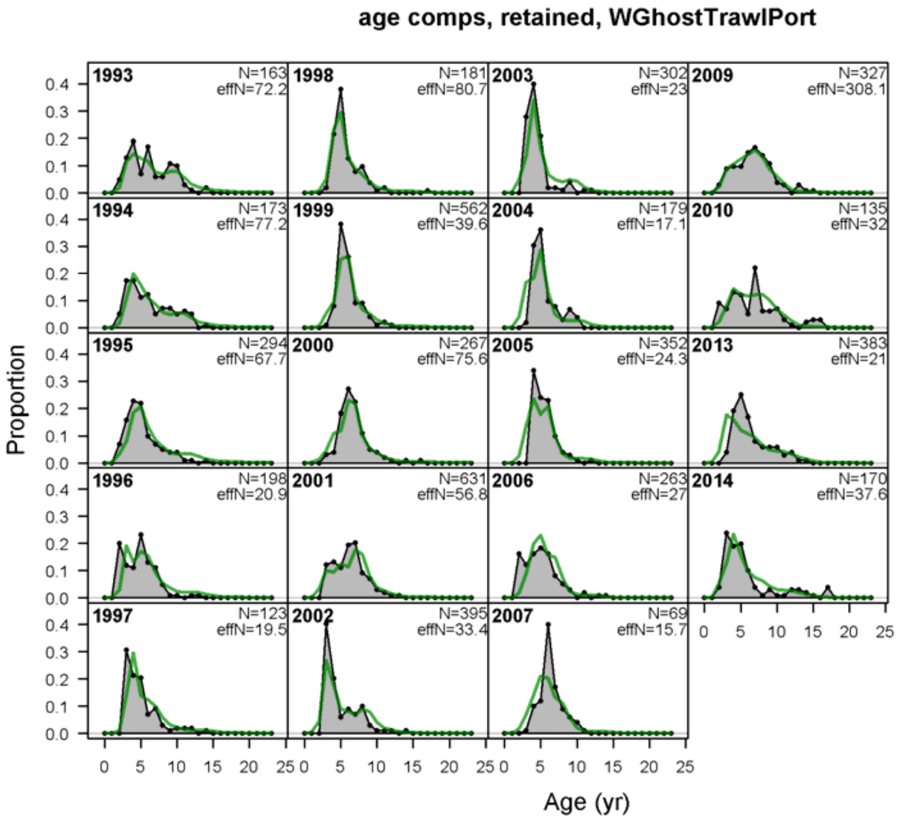
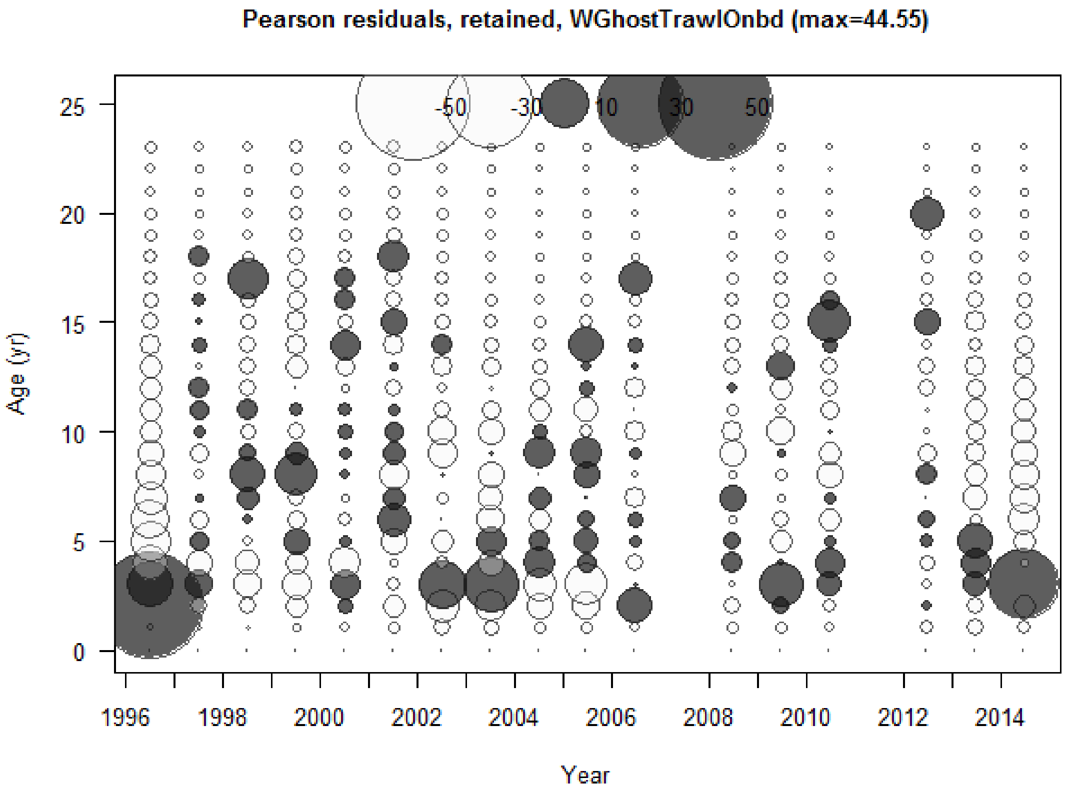


Figure 7A.9 The observed (shaded) and model-predicted (green line) implied fits to the age composition data for silver warehou for the western trawl fleet onboard (top) and port (bottom).



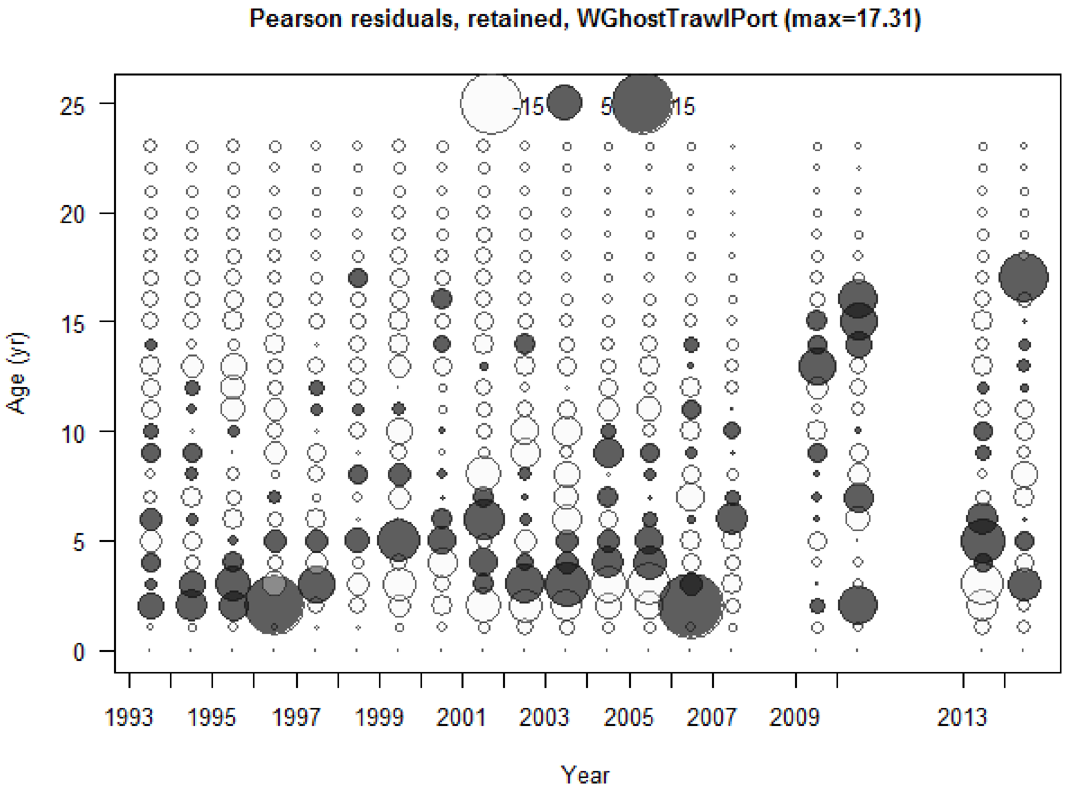


Figure 7A.10 The residual pattern for the age composition data for silver warehou for the western trawl fleet onboard (top) and port (bottom).

7A.3 Age-at-length fits

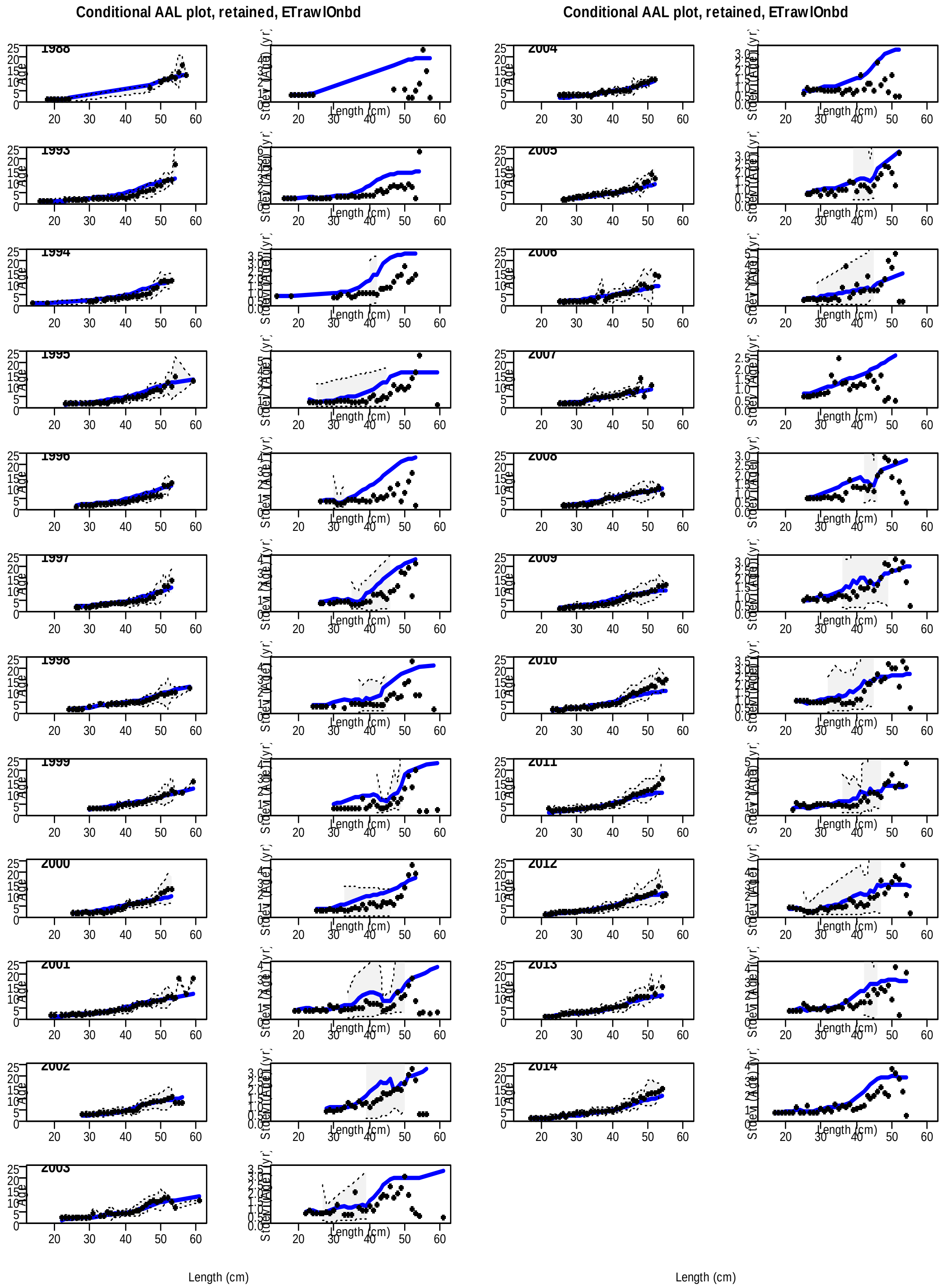
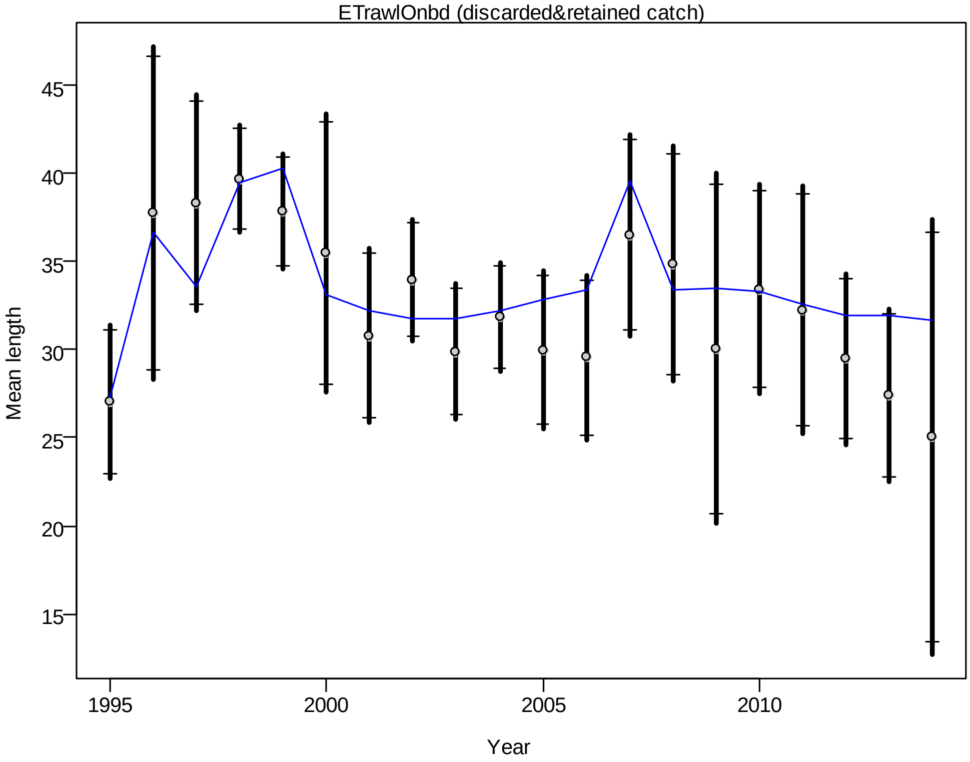


Figure 7A.11 Fits to the conditional age-at-length. Observed in black, expected in blue lines. Second and fourth columns are standard deviations.

7A.4 Length fit diagnostics (Francis mean length fits from method TA1.8)



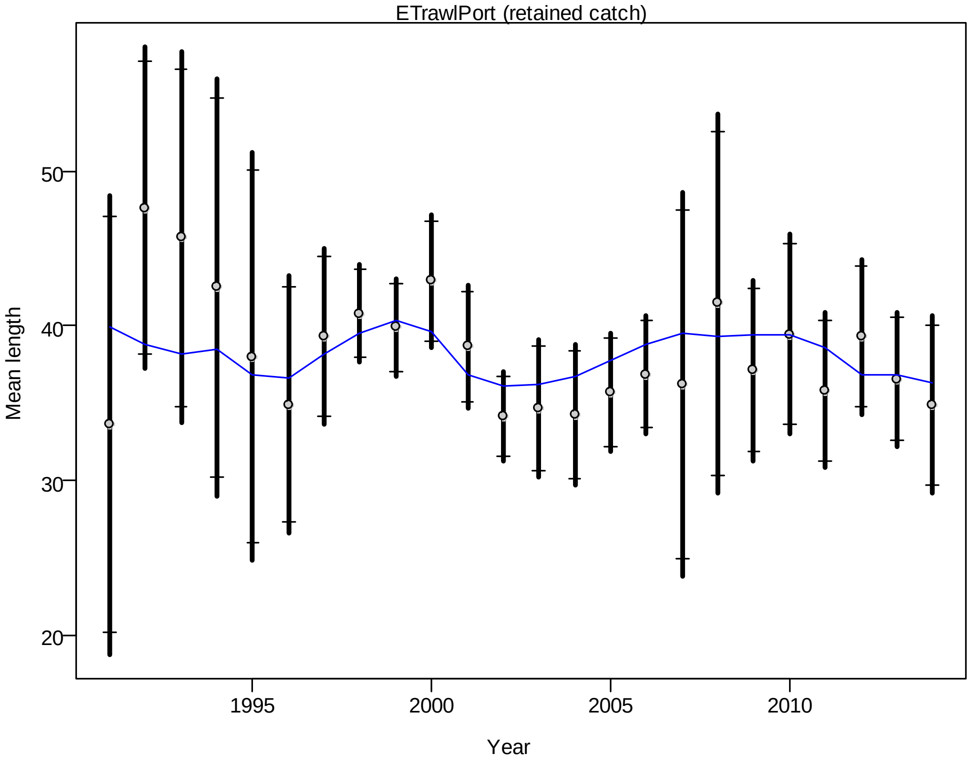


Figure 7A.12 Francis weighting – length fits diagnostics. Eastern trawl fleet onboard (top) and port (bottom).

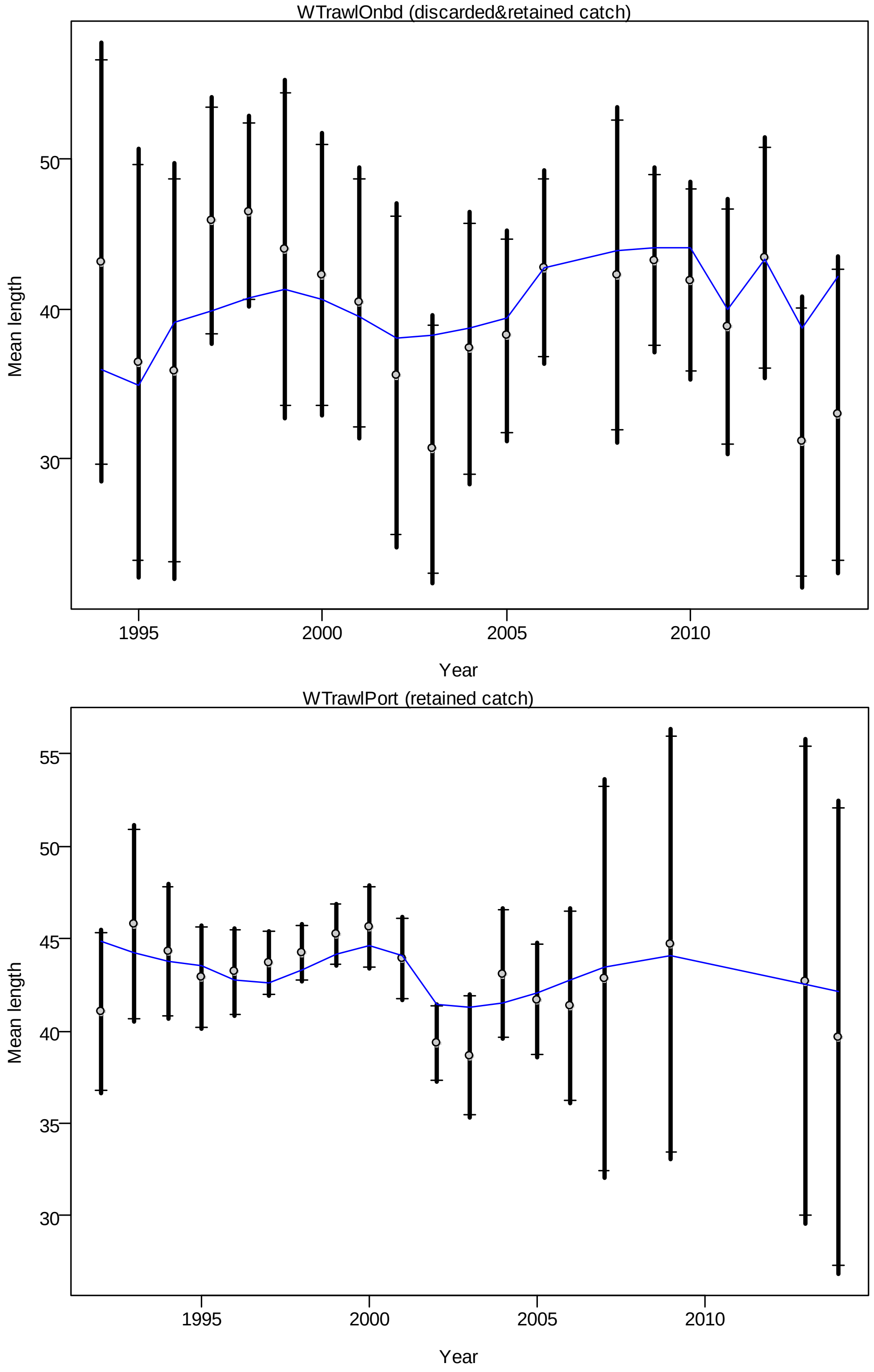


Figure 7A.13 Francis weighting – length fits diagnostics. Western trawl fleet onboard (top) and port (bottom).

7A.5 Age fit diagnostics (Francis mean age fits from method TA1.8)

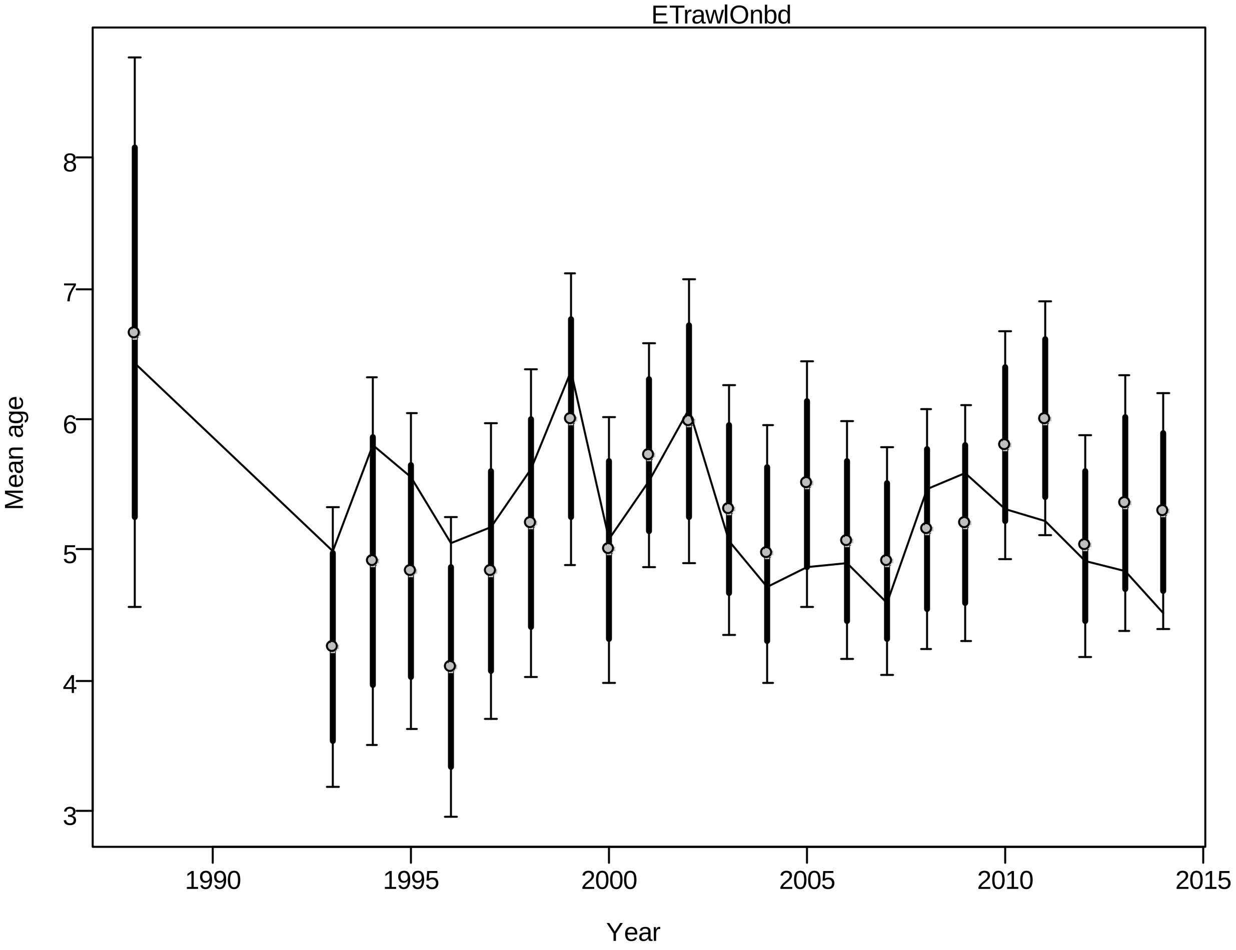


Figure 7A.14 Francis weighting – age fits diagnostics.

8. Development of a base-case Tier 1 assessment of eastern Jackass Morwong (*Nemadactylus macropterus*) based on data up to 2014

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8.1 Summary

This chapter presents the data and results from a preliminary assessment developed to assist the establishment of a 2015 base-case assessment of eastern jackass morwong *Nemadactylus macropterus* in the Southern and Eastern Scalefish and Shark Fishery (SESSF). The assessment uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS). The assessment includes data up to the end of the 2014 calendar year. Data include annual landings, catch rates, discard rates, and length/age compositions. The main purpose of this document is to initiate discussion regarding the data to be used and the assumptions to be included in the base-case model structure.

Results from the 2015 preliminary assessment conclude that the eastern jackass morwong spawning biomass in 2016 will be 32% of the 1988 equilibrium stock biomass. In comparison, the last full assessment in 2011 estimated the 2012 spawning biomass to be 35% of the 1988 equilibrium stock biomass.

8.2 Introduction

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

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

8.3 The Fishery

The assessment data for eastern 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).

1. Eastern trawl (ET) – otter trawlers from NSW, eastern Victoria and Bass Strait (1986 – 2014).

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

8.4 Data

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

8.4.1 *Catch and discard rates*

Both the landed catch tonnage and predicted discard tonnage for eastern jackass morwong from the six fleets are shown in Figure 8.1. Landed catch data by fleet since 2011 was updated by scaling up logbook data using the ratio of total landed morwong catch to total logbook morwong catch.

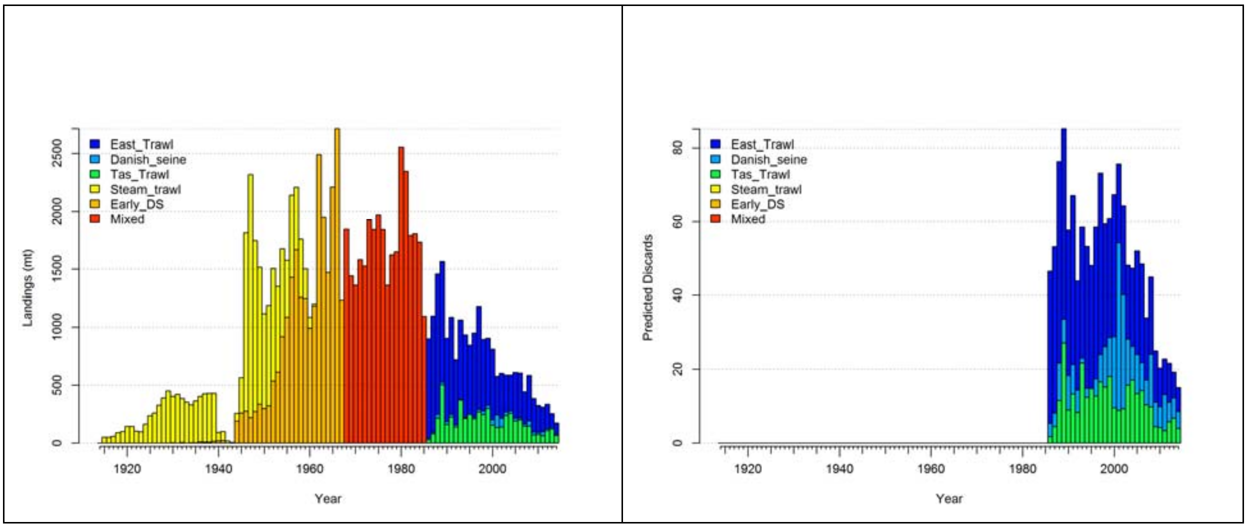
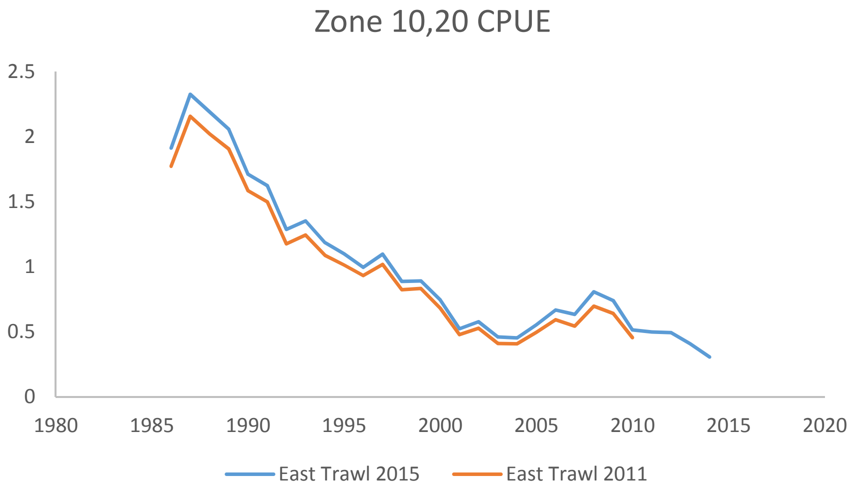


Figure 8.1. Landed morwong catches (mt) for all fleets by calendar year from 1915 and corresponding predicted discard mass (mt).

8.4.2 *Catch rates*

Sporcic and Haddon (2015) provides the updated standardized catch rate series for jackass morwong (Figure 8.2). After a substantial decline in catch rate from the mid-1980s to 2000, the catch rate for both Zones 10/20 and Zone 30 levelled before potentially showing a further decline in recent years. The catch rate from updated analyses compares well with that from the last assessment in 2011 (Wayte, 2011).



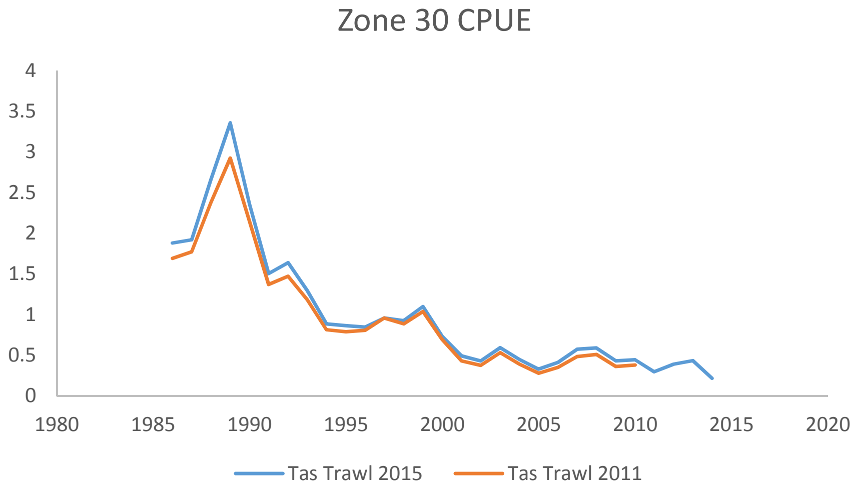


Figure 8.2. Eastern Jackass Morwong standardised CPUE for the NSW/Vic, and Tasmanian trawl fleets (Sporcic and Haddon, 2015). This figure shows a comparison between the series used in the 2011 assessment and the current assessment (2015).

8.4.3 *Length frequencies and age data*

Length and age data have been included in the model as length frequency data and conditional age-at-length data by port and onboard. Age composition data is included in diagnostic plots but is not used directly within the fitting procedure. Figures of the observed length and age data are shown in later figures (Figure 8.9 and Figure 8.10, and the Appendix) with the corresponding model predicted values.

8.4.4 *Age-reading error*

Standard deviations for aging error by reader have been estimated, producing the age-reading error matrix of Table 8.1 (A.E. Punt, pers. comm.).

Table 8.1. The standard deviation (StDev) of age reading error.

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

8.4.5 *Fishery independent survey (FIS) estimates*

Abundance indices for eastern jackass morwong over surveys in 2008, 2010, 2012 and 2014 are provided in Knuckey et al. (2015). Indices from the FIS were re-estimated according to Zones 10/20 and Zone 30 (Table 8.2).

Table 8.2. FIS derived abundance indices of eastern jackass morwong with corresponding coefficient of variation (cv).

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

8.4.6 *Biological parameters*

A single-sex stock assessment for jackass morwong was conducted using the software package Stock Synthesis (SS, version 3.22U). 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. Catches from western Tasmania and western Victoria were assumed to come from a separate stock and are therefore not considered in the eastern assessment.

The eastern assessment modelled the impact of six fishing fleets on the morwong population. Selectivity was assumed to vary among fleets, but the selectivity pattern for each fleet was modelled as being time-invariant and modelled as a function of length. Separate logistic functions were used for the selectivity ogives for each fleet. The two parameters of the selectivity function for each fleet were estimated within the assessment. Retention was also defined as a logistic function of length, and the inflection and slope of this function were estimated for those fleets where discard information was available (NSW/Vic trawl, Tasmanian trawl and Danish seine).

The rate of natural mortality rate, M, was assumed to be constant with age, and also time-invariant. The natural mortality for the base-case analysis was set to 0.15 yr^{-1} following previous assessments (Table 8.3).

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

Recruitment deviations are estimated to 2011, as the recruitment signal from young fish must have appeared in the catch in sufficient numbers. The value of the parameter determining the magnitude of the process error in annual recruitment, σ_R, was set equal to 0.41 for the eastern assessment (to equal the amount of error estimated by the model).

A plus-group was modelled at age 25. Growth of morwong was assumed to be time-invariant - that is, there has been no change over time in the mean size-at-age, with the distribution of size-at-age being determined from the fitting of the growth curve within the assessment using the age-at-length data. No differences in growth by gender are modelled, as the stock was modelled as a single-sex.

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

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

The values assumed for some of the (non-estimated) parameters of the base case models are shown in Table 8.3.

Table 8.3. Parameter values assumed for some of the non-estimated parameters of the base-case model.

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

8.5 Results and Discussion

8.5.1 *The base case stock assessment*

8.5.1.1 Comparison to the 2011 assessment

The base-case model largely uses the same assumptions and settings as the last full assessment in 2011. Recruitment deviations are estimated up until three years before the end of the data.

In 2010, the RAG decided to include both port and onboard retained length frequency data (for both historic and current years) in future assessments, whereas previously only port data have been used (Wayte, 2011). The 2015 assessment separates port and onboard length frequency data but estimates a single selectivity (for ET, DS and TT). Other changes include updates of data to the end of the 2014 calendar year as described earlier. FIS data for ET and TT are also included. Figure 3 shows the biomass and recruitment trajectories from the 2011 assessment, the un-tuned trajectory with updated data to 2014 (and previous weighting parameterization) and the new base case (with Francis weighting). This figure illustrates that there is little change in the historical trajectory between model configurations, and shows a substantial decline since pre-fishing years.

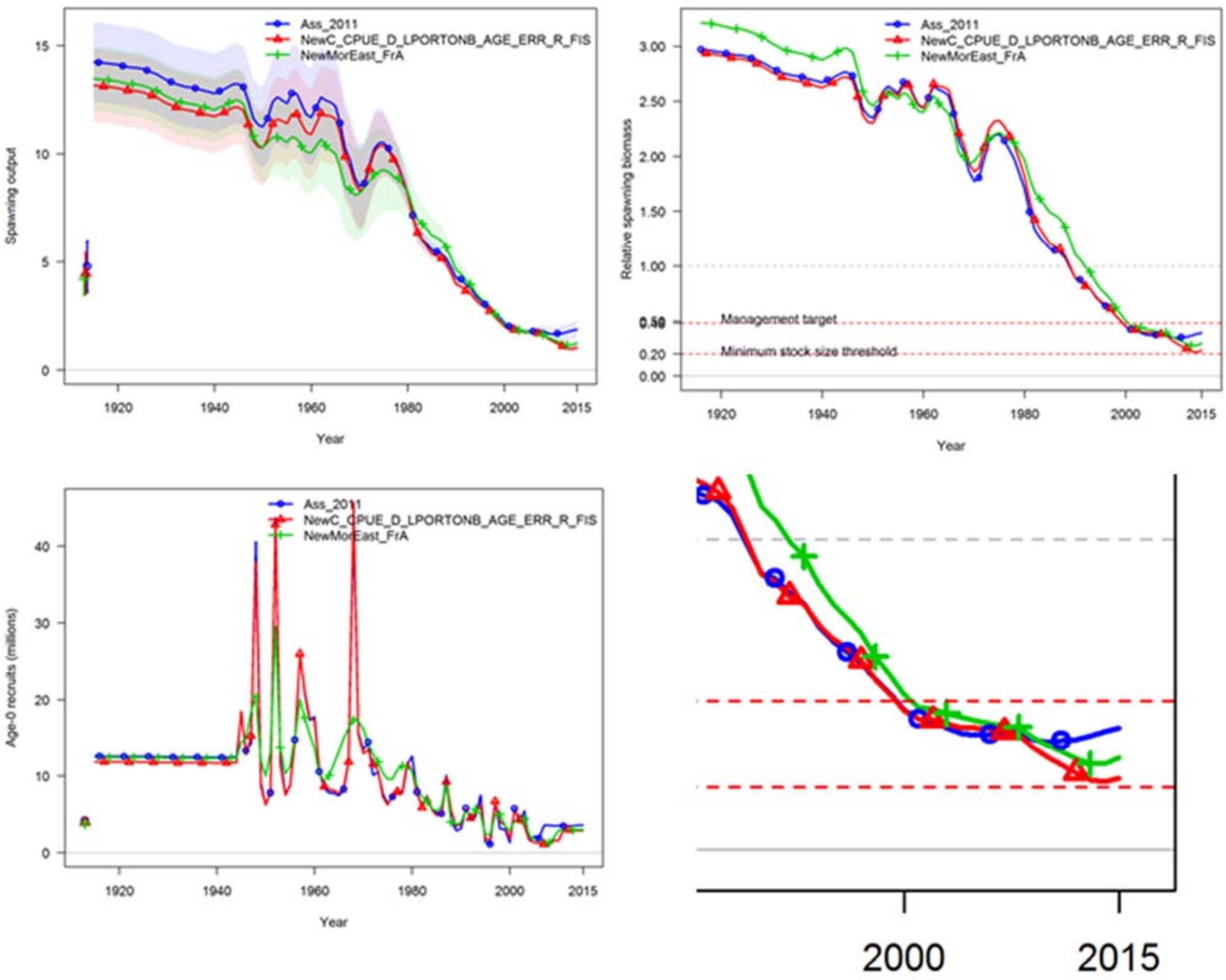


Figure 8.3. The spawning biomass and estimated recruitment trajectories for eastern jackass morwong. Ass_2011 is the assessment from 2011; NewC_CPUE_D_LPORTONB_AGE_ERR_R_FIS is a model with updated data to 2014, but with the same weighting parameterization as the 2011 assessment; NewMorEast_FrA is the new tuned base-case assessment. The recent relative spawning biomass trajectories from the top right hand figure are expanded in the bottom right hand figure.

8.5.1.2 Base case parameter estimates and model fits

A listing of the data is shown in Figure 8.4, and the growth, length-weight, and selectivity functions for the various fleets are shown in Figure 8.5 and Figure 8.6. Fits to the data are shown in Figure 8.7 to Figure 8.11 (and the Appendix), and the estimated spawning biomass trajectory for the base-case model is illustrated in Figure 8.12.

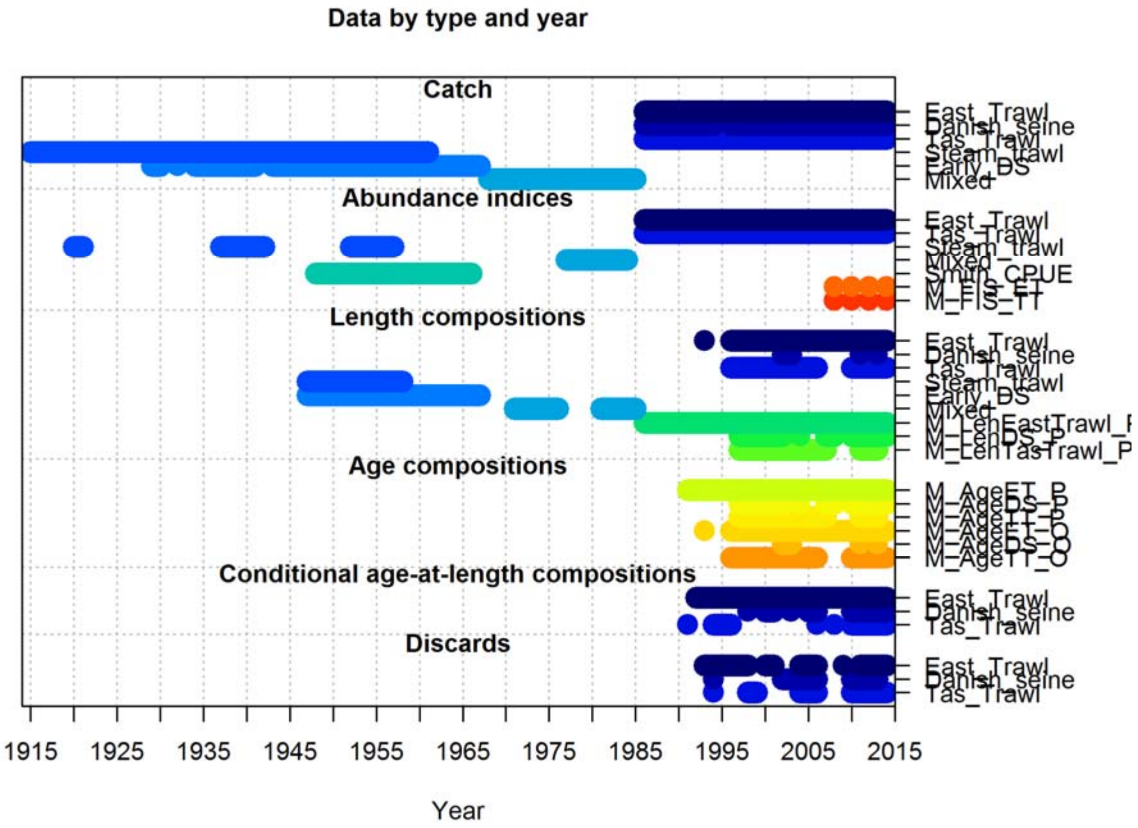


Figure 8.4. The various data types by fleet for eastern jackass morwong.

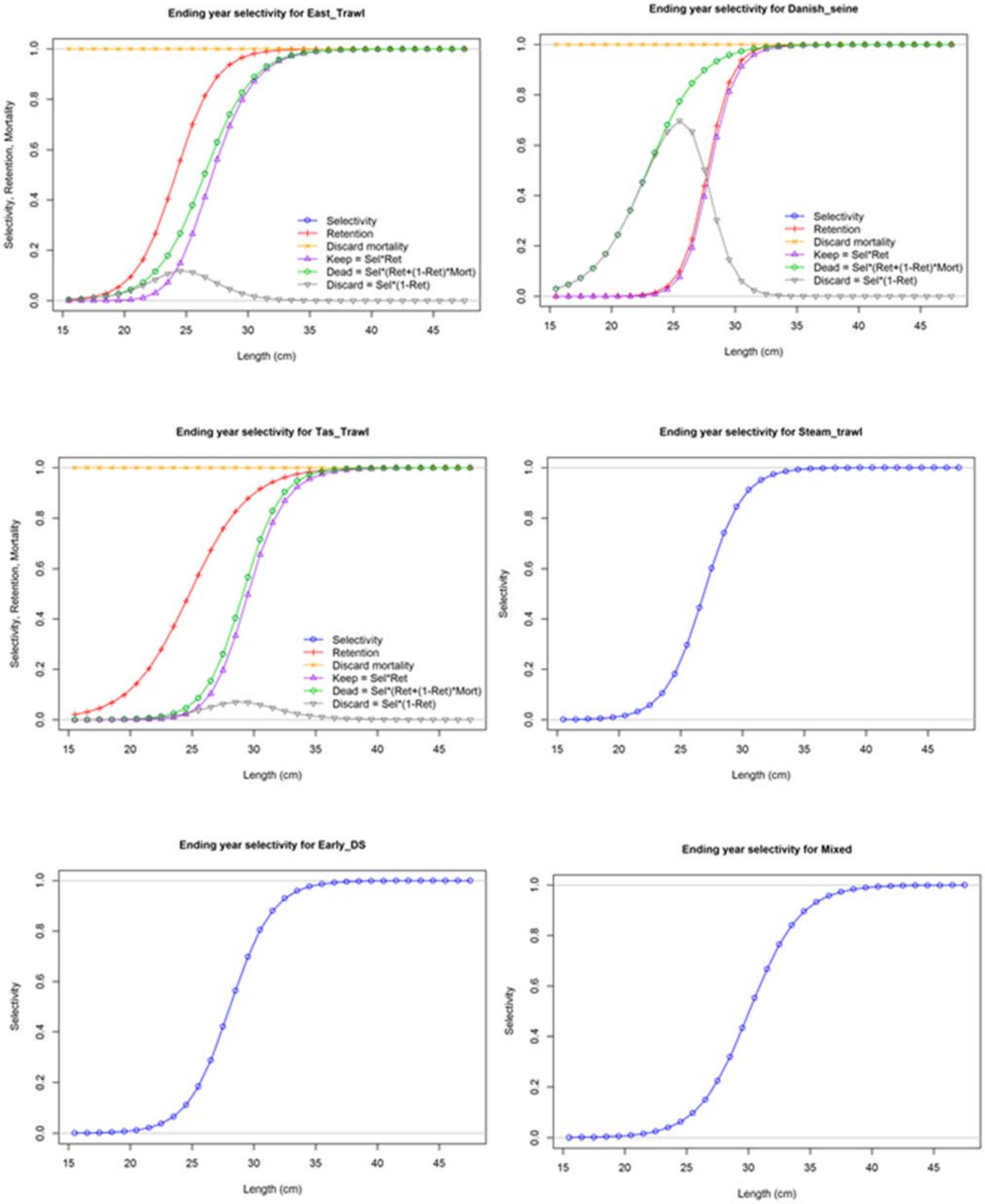


Figure 8.5. Selectivity (blue) and retention functions (red) for the six fleets.

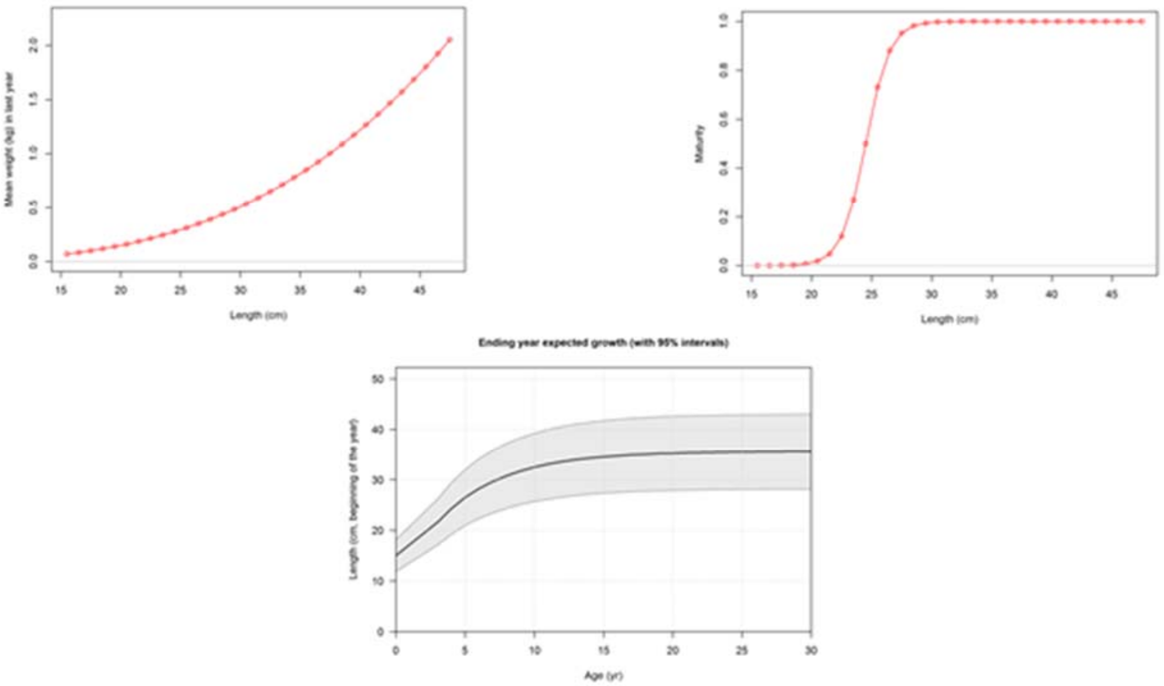


Figure 8.6. The length-weight (left), maturity ogive (right) and length-age relationships (bottom) for the eastern jackass morwong base case assessment.

8.5.1.3 Fits to the data

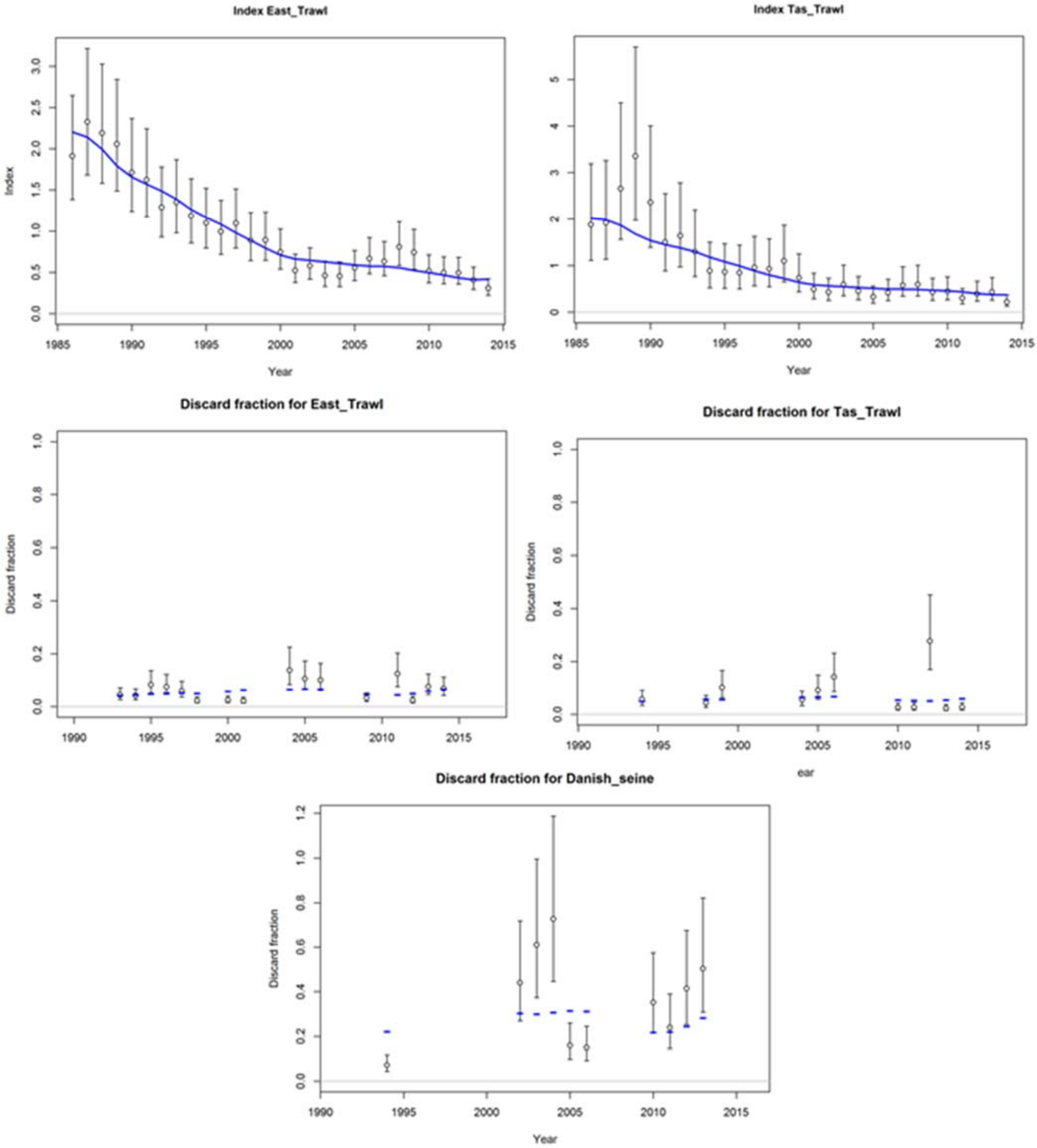


Figure 8.7. Fits to the standardized CPUE for the eastern and Tasmanian trawl fisheries, with the associated discard rates and fit. The fit to the Danish seine discard rates is also shown.

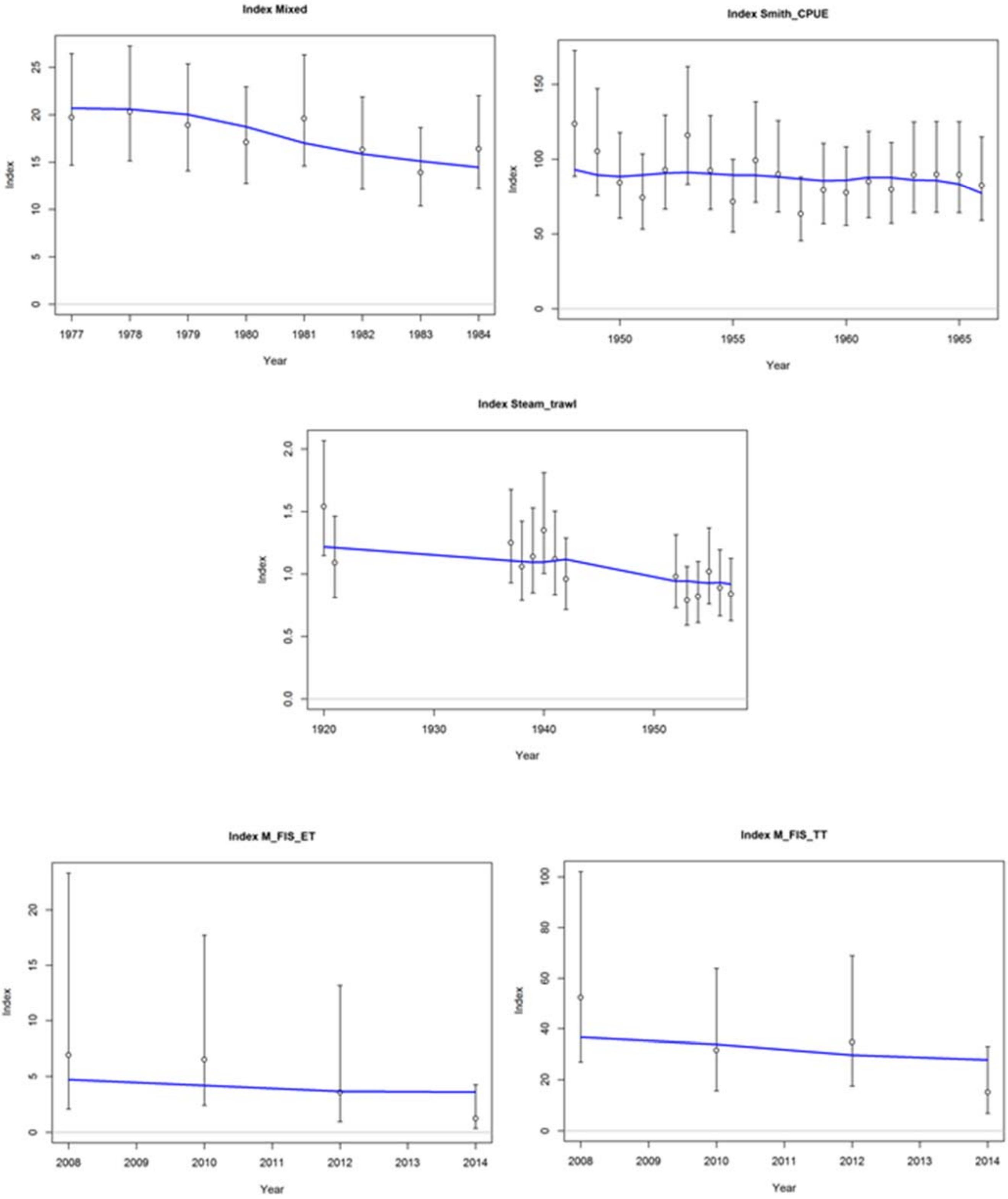


Figure 8.8. Fits to the index data for the mixed fleet, the steam trawl fleet, the Smith CPUE index and the FIS abundance indices from the east (Zones 10/20) and Tas (Zone 30).

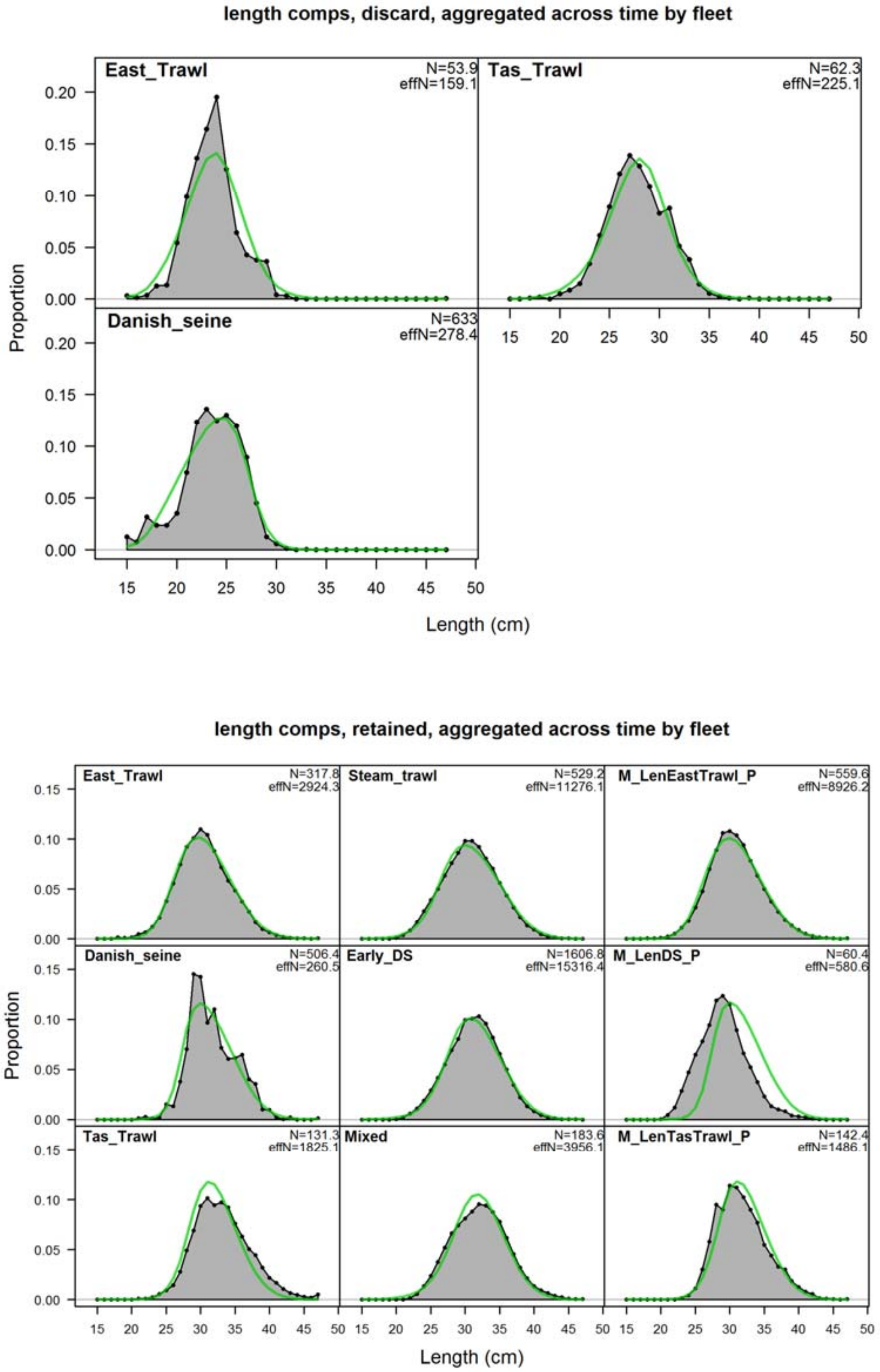


Figure 8.9. Fits to the discard and retained length by fleet (P = Port, otherwise onboard for ET, DS and TT).

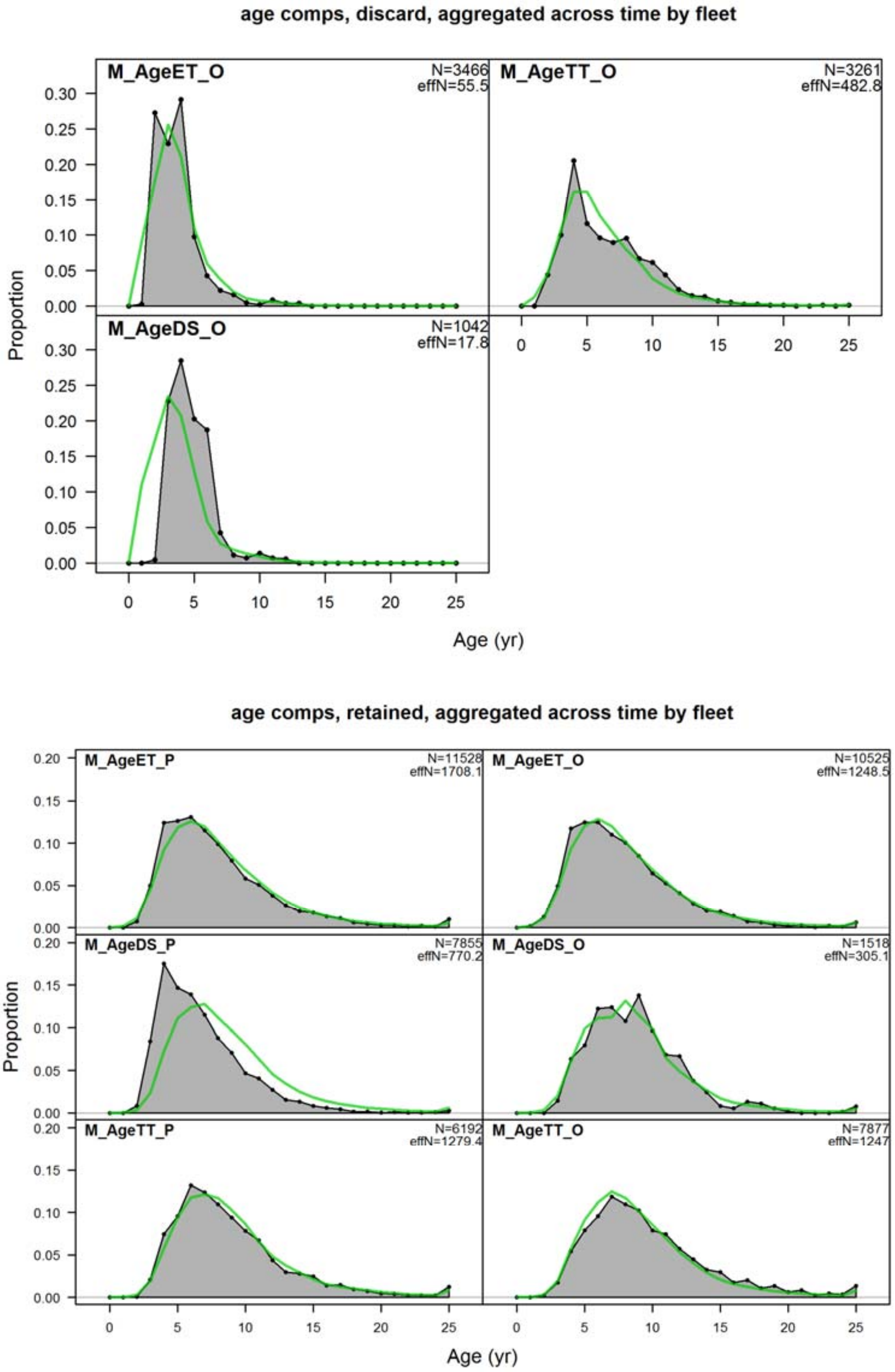


Figure 8.10. Fits to the implied age compositions for discard and retained (P = Port, O= onboard).

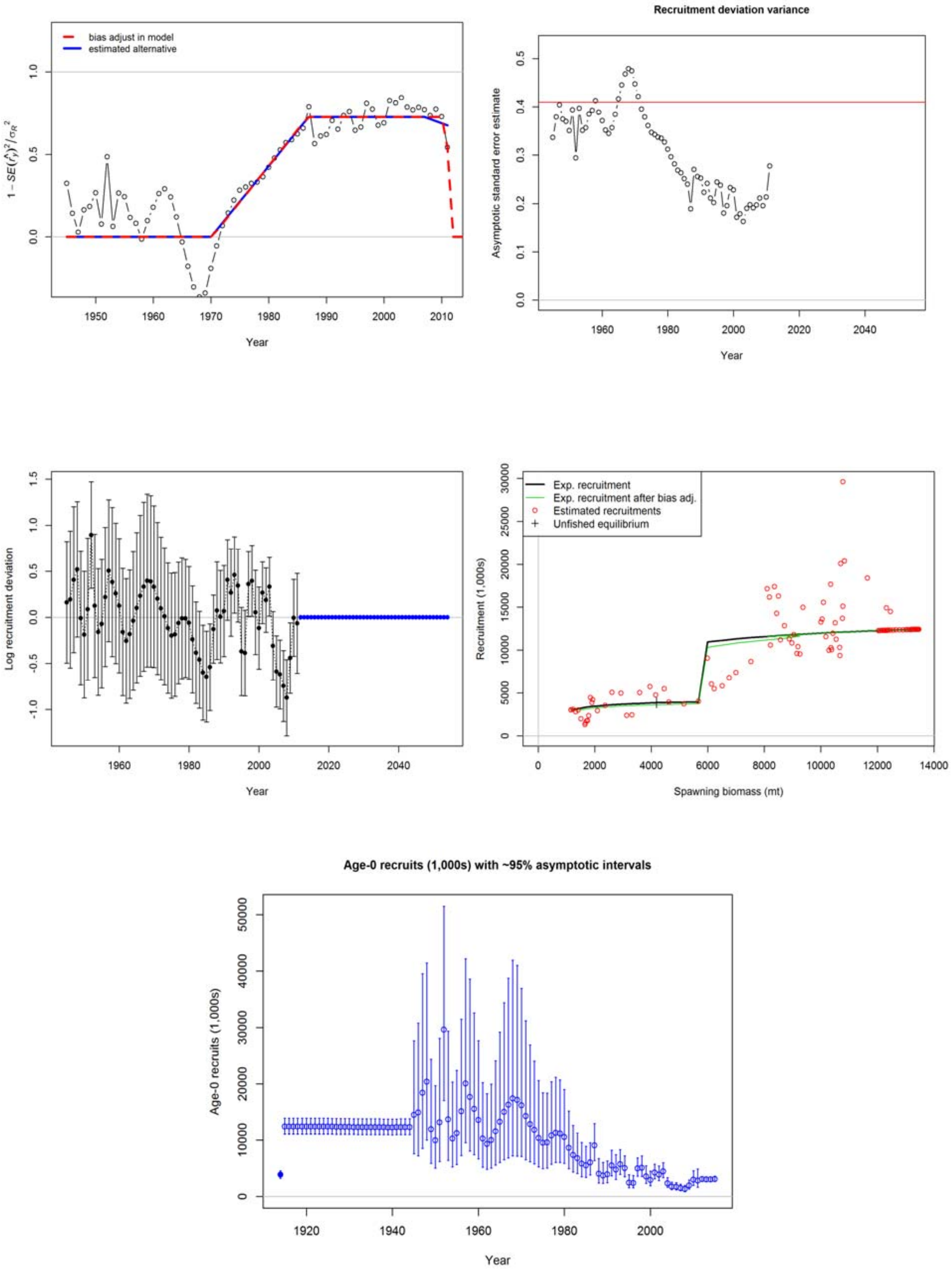


Figure 8.11. Diagnostics for recruitment, the stock–recruitment relationship and annual estimates of recruitment numbers with confidence intervals.

8.5.1.4 Assessment Outcomes

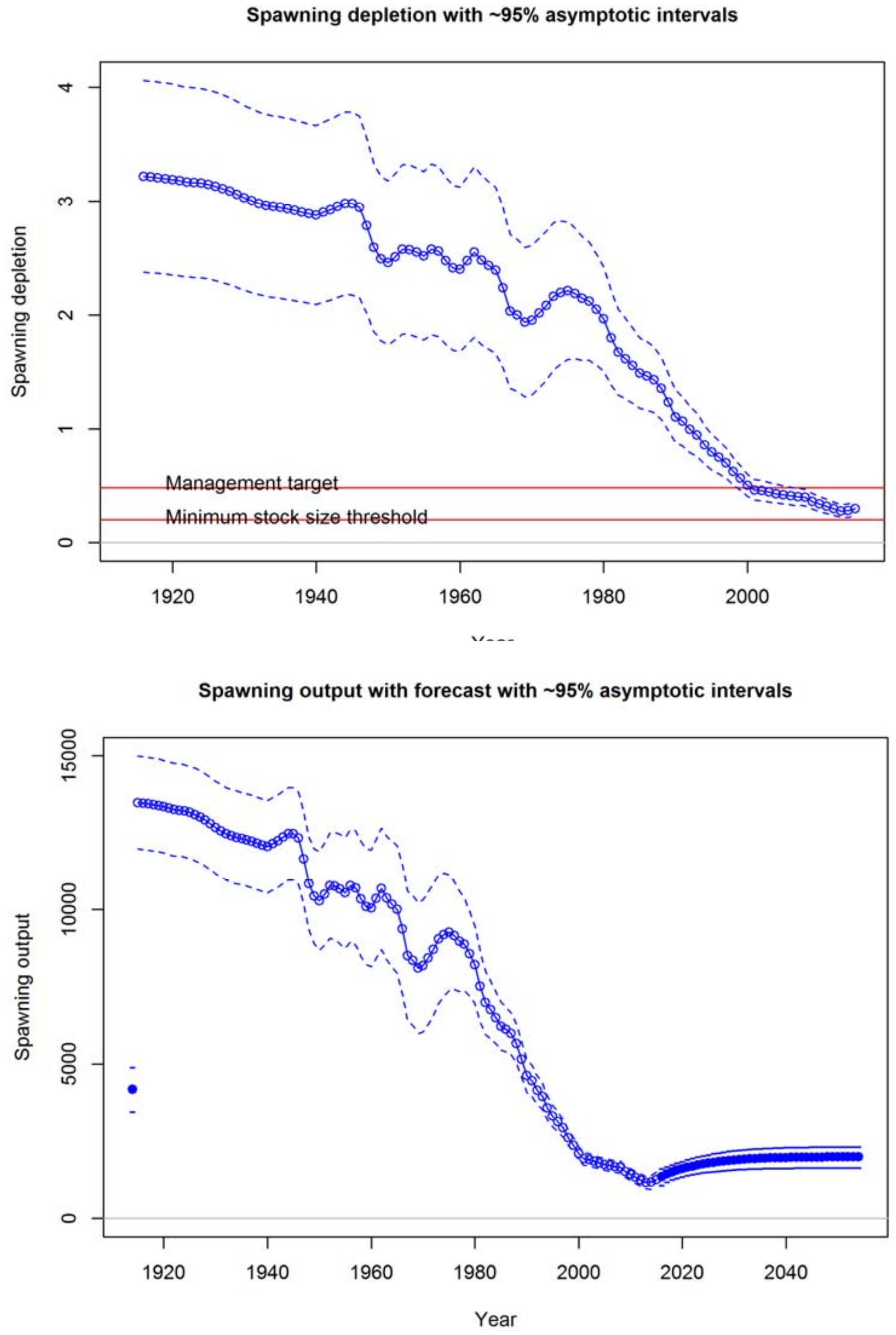


Figure 8.12. Time trajectories of spawning biomass depletion with 95% confidence intervals for the base case assessment of eastern jackass morwong.

8.5.2 ***Discussion***

The 2015 assessment of eastern jackass morwong estimates the 2016 spawning biomass to be 32% of the 1988 equilibrium stock biomass. In comparison, the last full assessment in 2011 (Wayte, 2011) estimated the 2012 spawning biomass to be 35% of the 1988 equilibrium stock biomass. The female equilibrium spawning biomass in 1988 is estimated to be 4,184 t and in 2016 the female spawning biomass is estimated to be 1,340 t.

Further development of the model should consider:

- Refinement of fits to Danish Seine port length data (recognizing however this is now a small part of the fishery in terms of catch)
- Refinement of fits to Eastern Trawl discard length data
- Checking 2014 onboard length data for Eastern Trawl (unusual increase in small fish)
- Lack of small fish in 2012 Tas Trawl fleet length data (onboard and discard)
- Further refinements to the tuning methods (noting that this year the CAPAM workshop will focus on weighting methods, October 2015)

8.6 Acknowledgements

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

8.7 References

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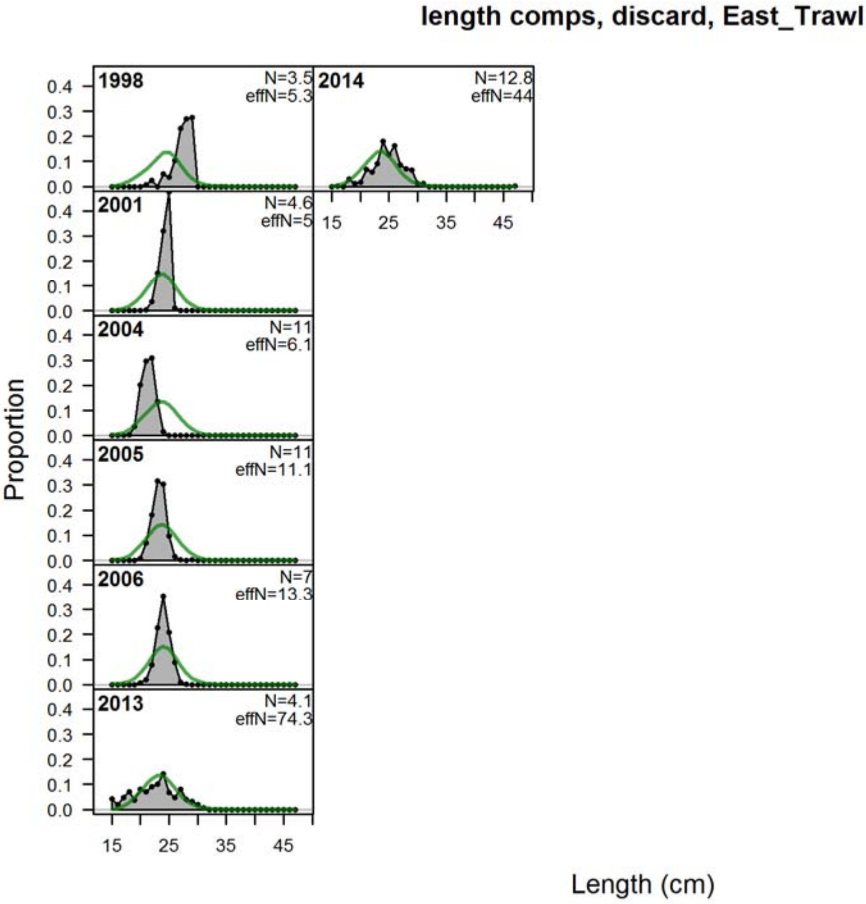
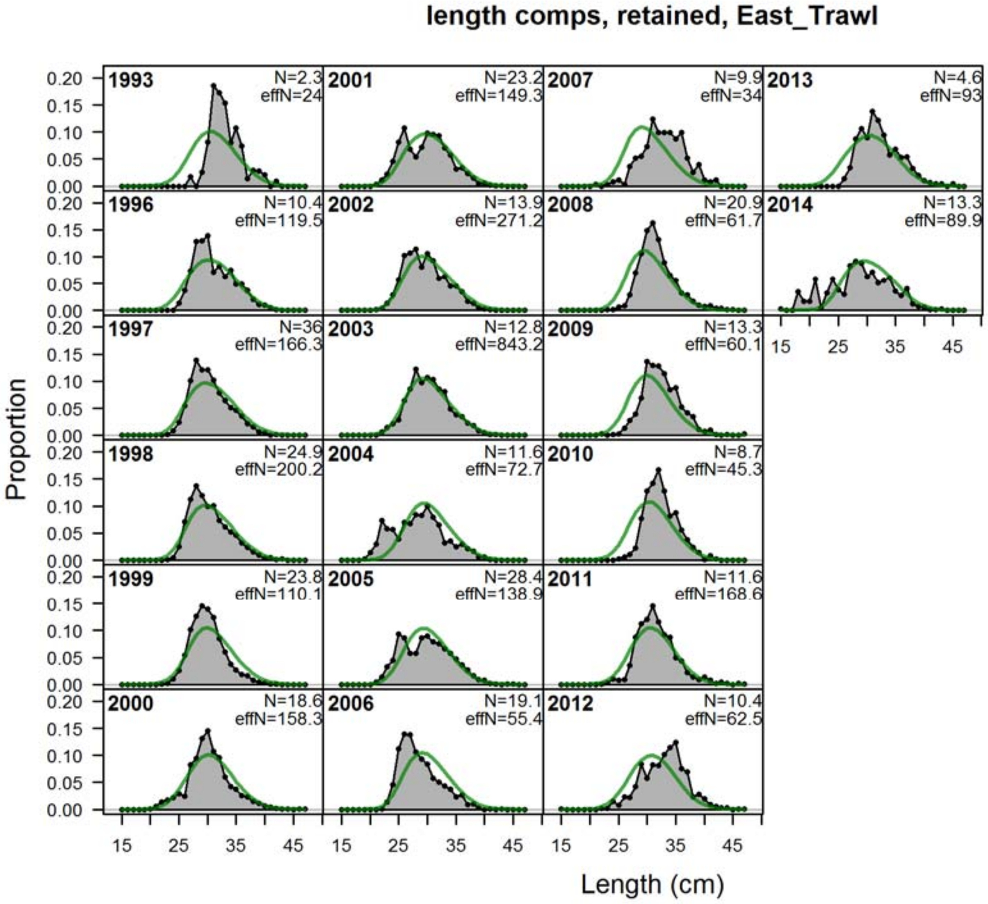
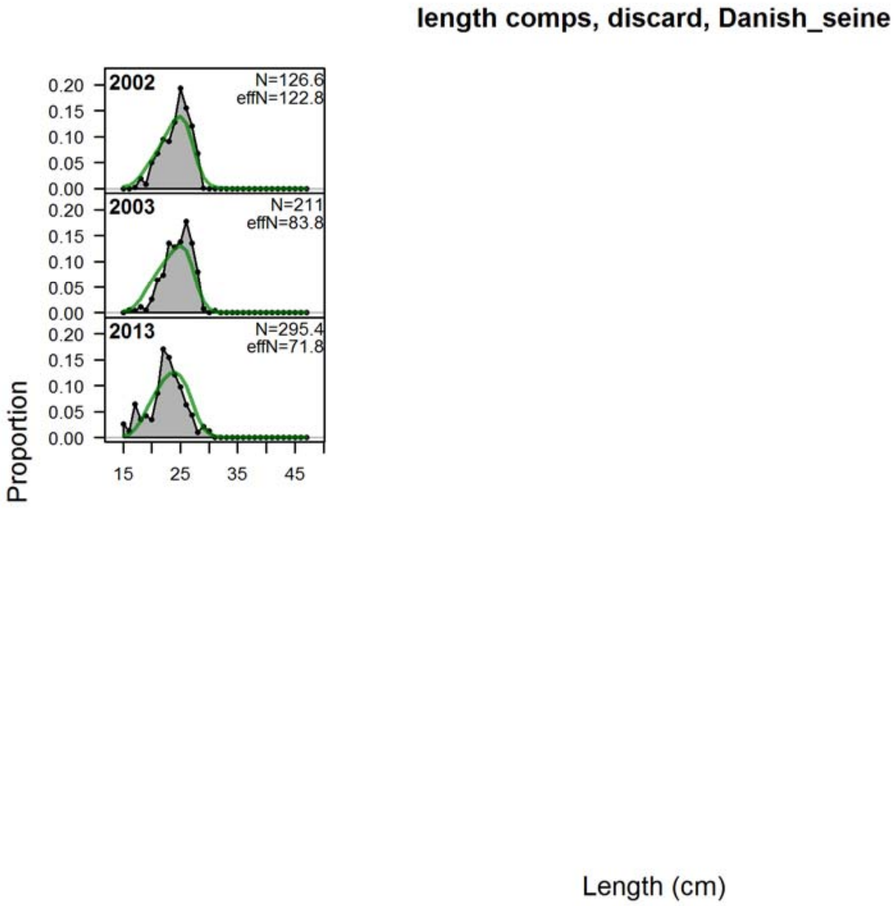
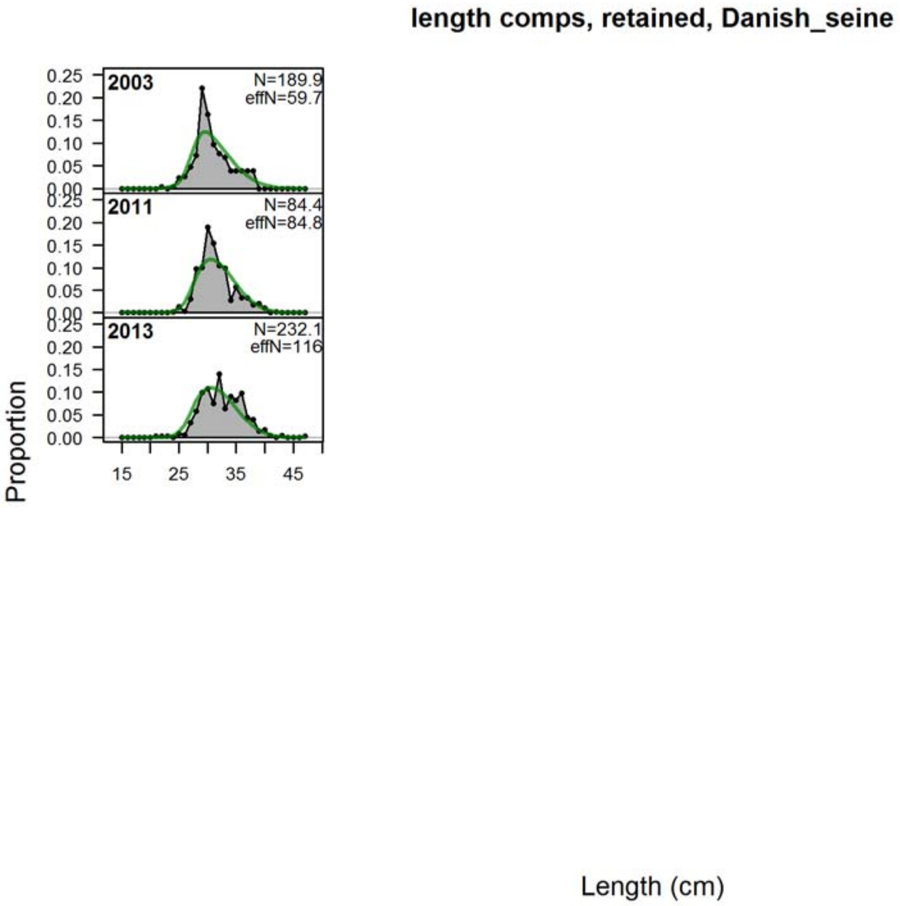
8.8 Appendix: Length fits




length comps, retained, East_Trawl
Proportion
Length (cm)
0.00
0.05
0.10
0.15
0.20
15
25
35
45
1993 N=2.3 effN=24
2001 N=23.2 effN=149.3
2007 N=9.9 effN=34
2013 N=4.6 effN=93
1996 N=10.4 effN=119.5
2002 N=13.9 effN=271.2
2008 N=20.9 effN=61.7
2014 N=13.3 effN=89.9
1997 N=36 effN=166.3
2003 N=12.8 effN=843.2
2009 N=13.3 effN=60.1
1998 N=24.9 effN=200.2
2004 N=11.6 effN=72.7
2010 N=8.7 effN=45.3
1999 N=23.8 effN=110.1
2005 N=28.4 effN=138.9
2011 N=11.6 effN=168.6
2000 N=18.6 effN=158.3
2006 N=19.1 effN=55.4
2012 N=10.4 effN=62.5


length comps, discard, Danish_seine
2002
N=126.6
effN=122.8
2003
N=211
effN=83.8
2013
N=295.4
effN=71.8
0.20
0.15
0.10
0.05
0.00
15
25
35
45
Proportion
Length (cm)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N=189.9
effN=59.7
2011
N=84.4
effN=84.8
2013
N=232.1
effN=116
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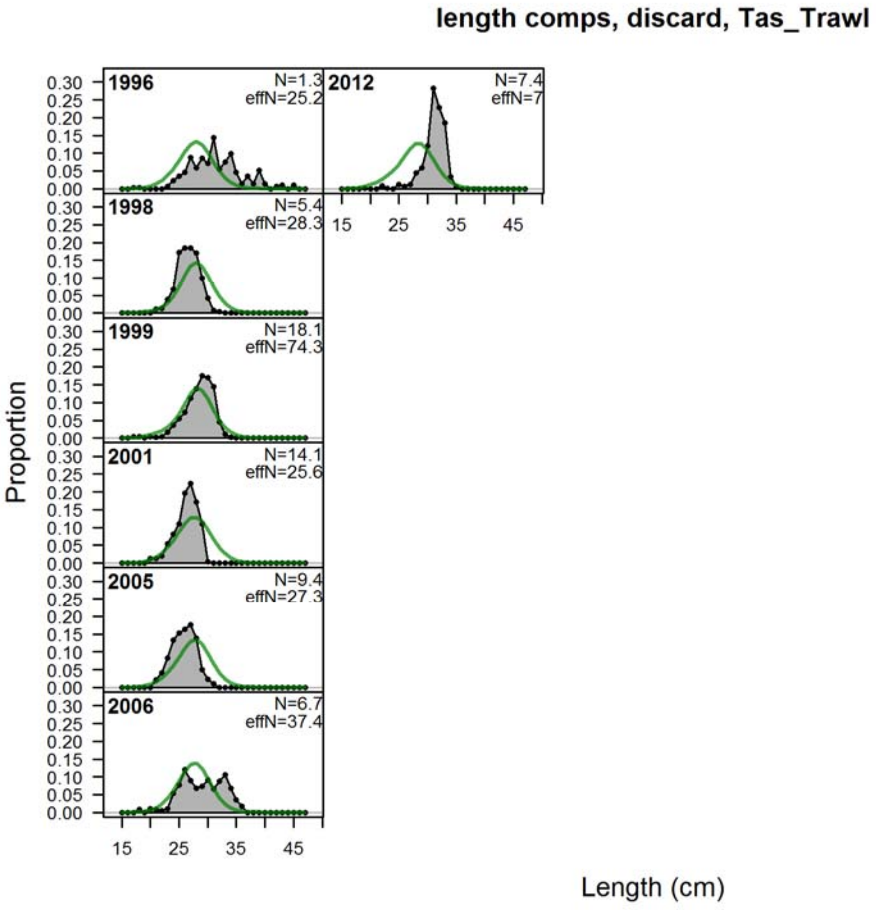
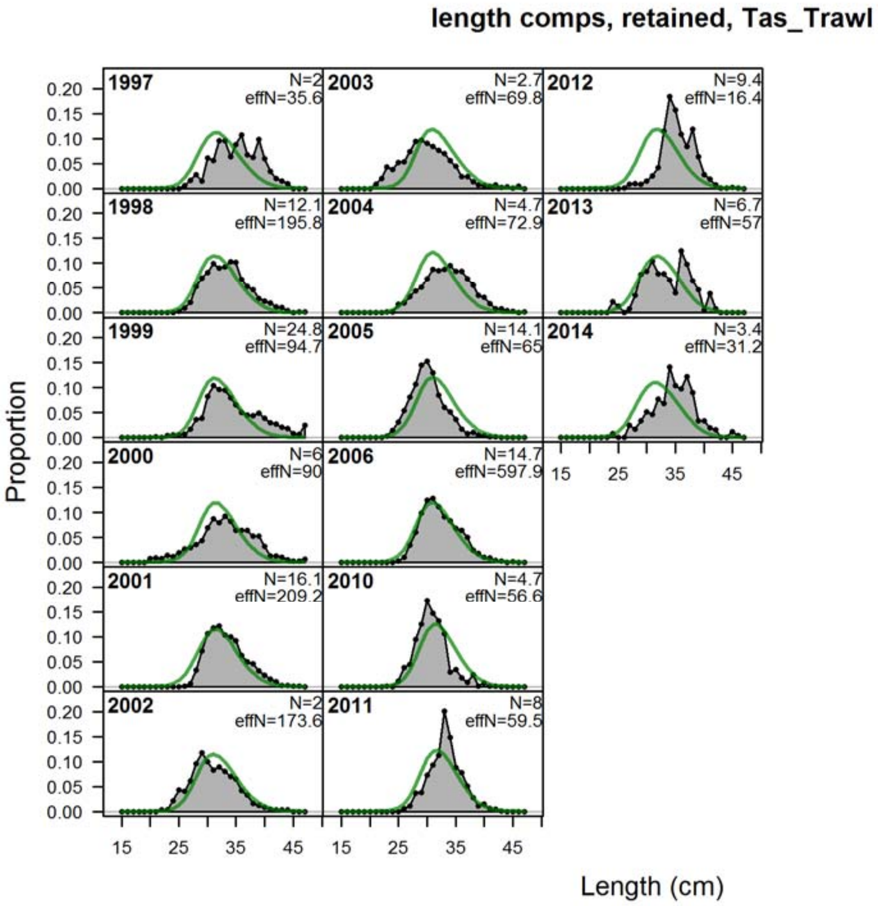
0.20
0.15
0.10
0.05
0.00
Proportion
15
25
35
45
Length (cm)


length comps, discard, Tas_Trawl
Proportion
Length (cm)
1996
N=1.3
effN=25.2
2012
N=7.4
effN=7
1998
N=5.4
effN=28.3
1999
N=18.1
effN=74.3
2001
N=14.1
effN=25.6
2005
N=9.4
effN=27.3
2006
N=6.7
effN=37.4
0.30
0.25
0.20
0.15
0.10
0.05
0.00
15
25
35
45


length comps, retained, Tas_Trawl
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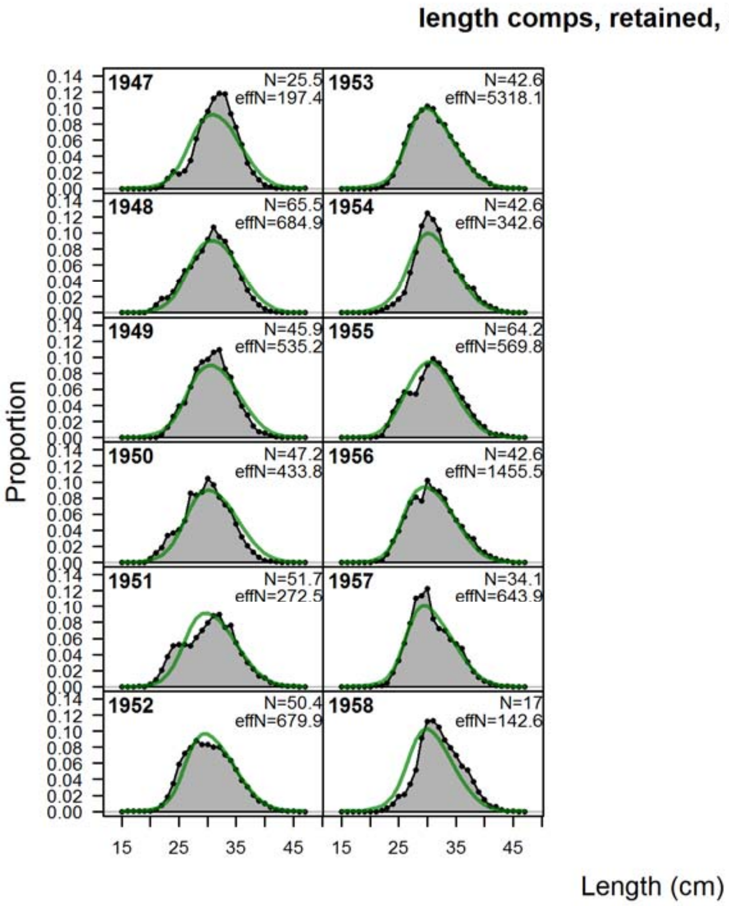
2003 N=2.7 effN=69.8
2012 N=9.4 effN=16.4
1998 N=12.1 effN=195.8
2004 N=4.7 effN=72.9
2013 N=6.7 effN=57
1999 N=24.8 effN=94.7
2005 N=14.1 effN=65
2014 N=3.4 effN=31.2
2000 N=6 effN=90
2006 N=14.7 effN=597.9
2001 N=16.1 effN=209.2
2010 N=4.7 effN=56.6
2002 N=2 effN=173.6
2011 N=8 effN=59.5
0.00
0.05
0.10
0.15
0.20
Proportion
15
25
35
45
Length (cm)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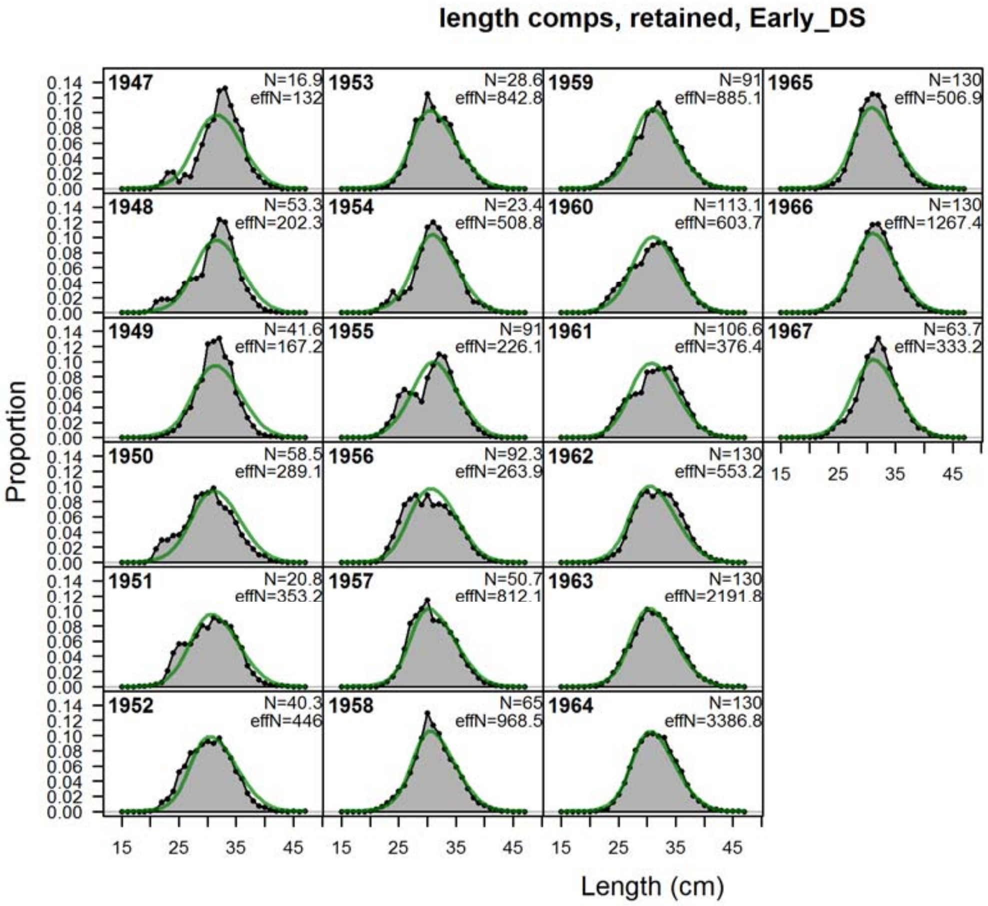
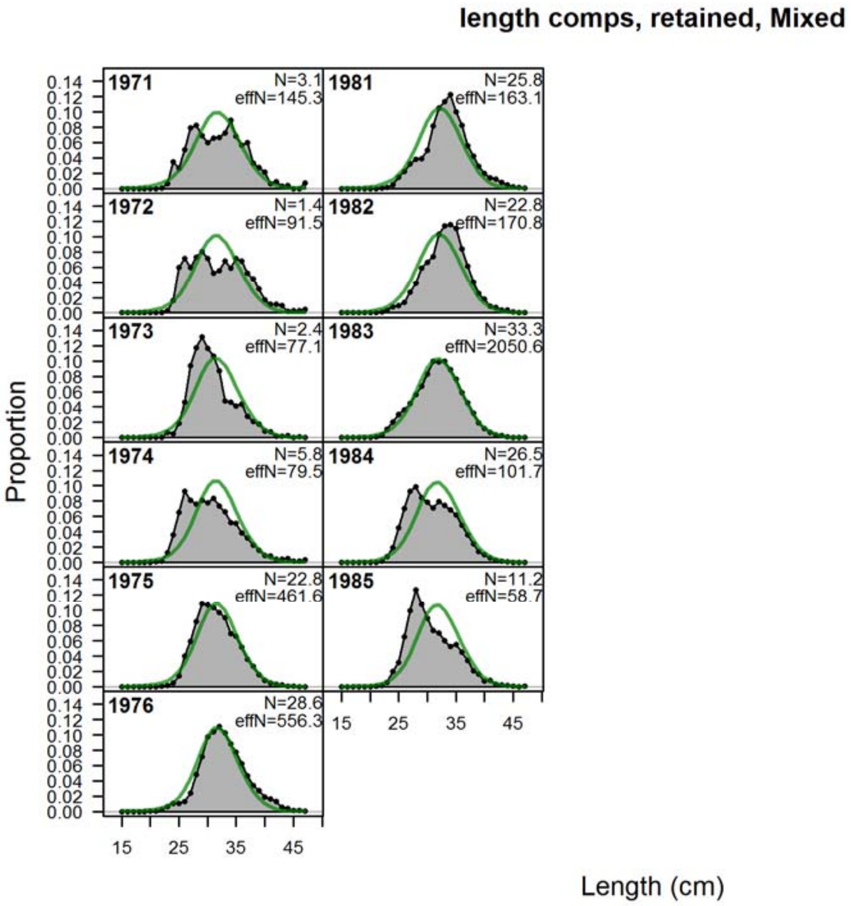
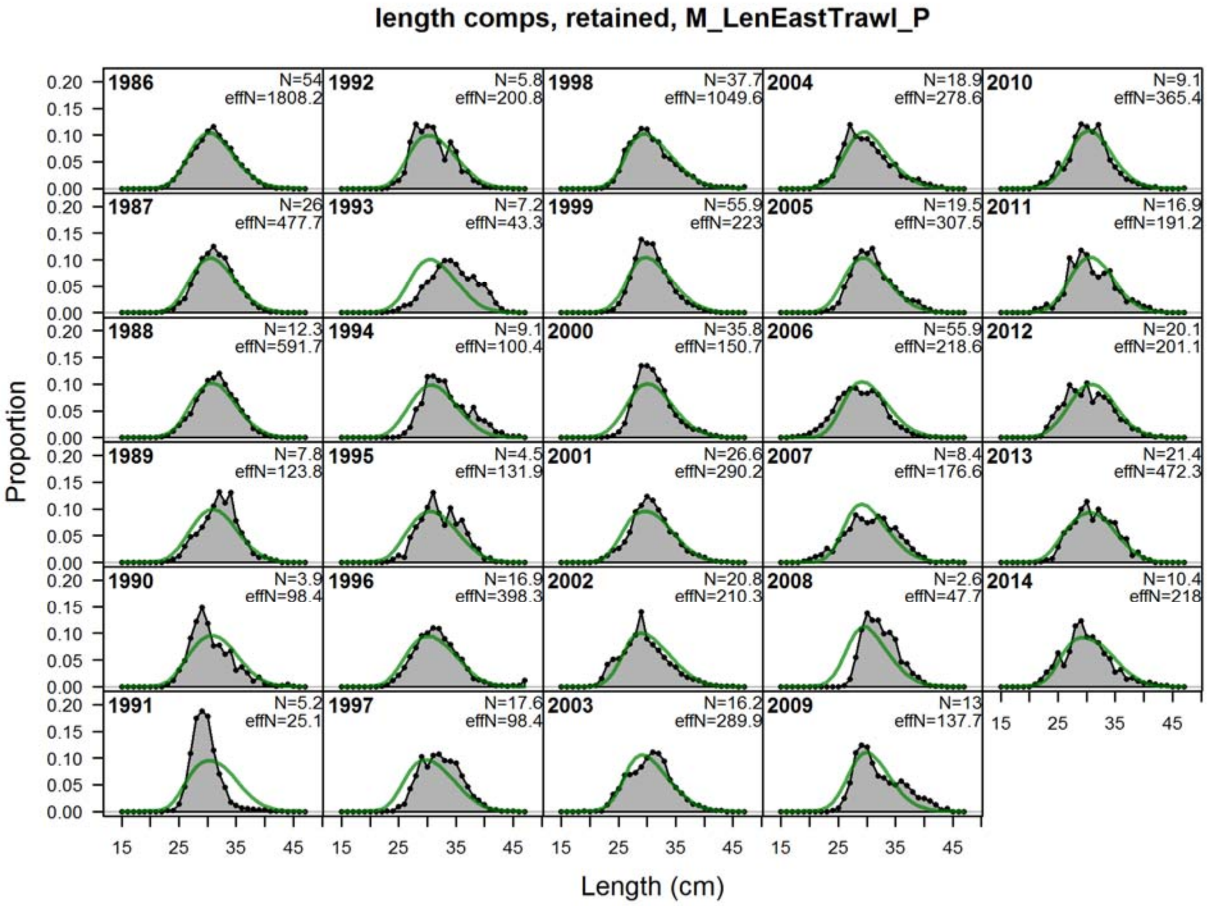
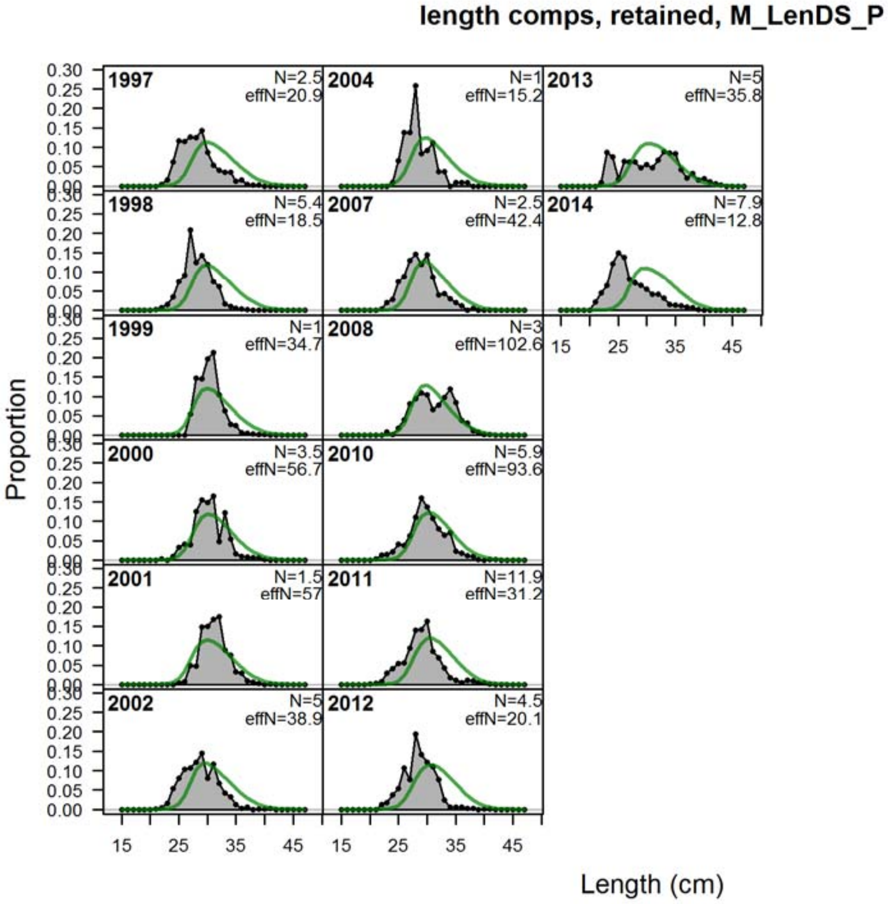
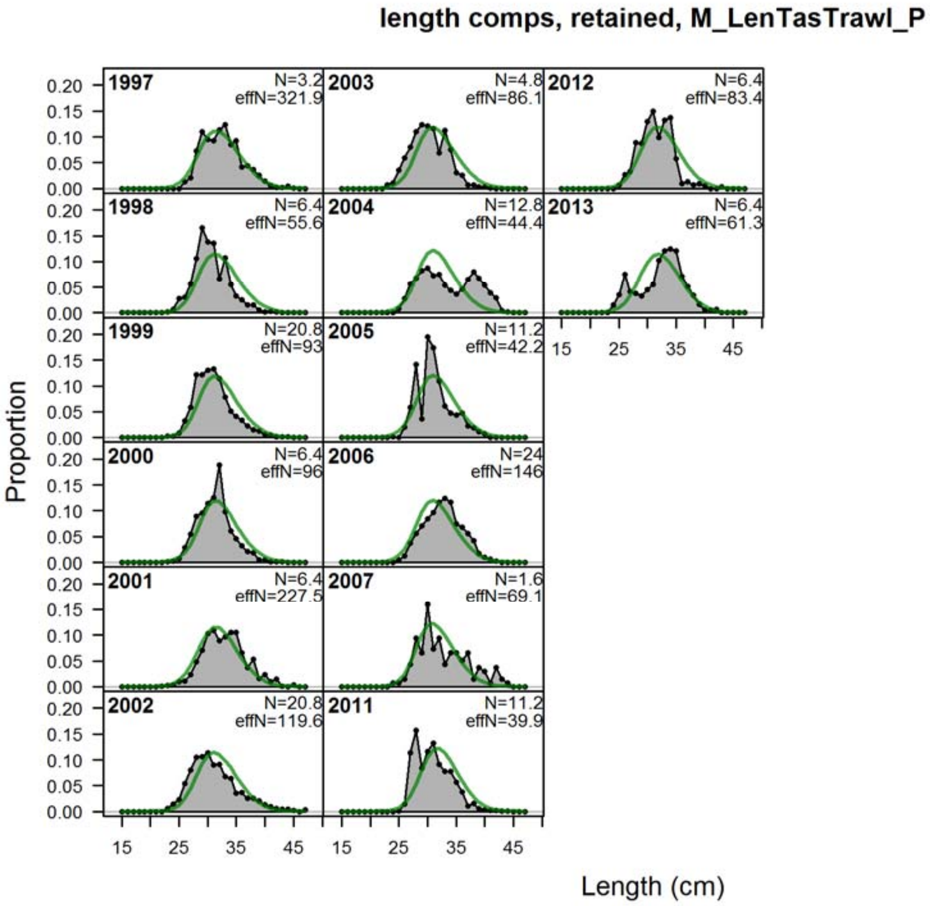
1947
N=25.5
effN=197.4
1953
N=42.6
effN=5318.1
1948
N=65.5
effN=684.9
1954
N=42.6
effN=342.6
1949
N=45.9
effN=535.2
1955
N=64.2
effN=569.8
1950
N=47.2
effN=433.8
1956
N=42.6
effN=1455.5
1951
N=51.7
effN=272.5
1957
N=34.1
effN=643.9
1952
N=50.4
effN=679.9
1958
N=17
effN=142.6
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Proportion
15
25
35
45
Length (cm)


length comps, retained, Early_DS
Proportion
Length (cm)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
15
25
35
45
1947 N=16.9 effN=132
1948 N=53.3 effN=202.3
1949 N=41.6 effN=167.2
1950 N=58.5 effN=289.1
1951 N=20.8 effN=353.2
1952 N=40.3 effN=446
1953 N=28.6 effN=842.8
1954 N=23.4 effN=508.8
1955 N=91 effN=226.1
1956 N=92.3 effN=263.9
1957 N=50.7 effN=812.1
1958 N=65 effN=968.5
1959 N=91 effN=885.1
1960 N=113.1 effN=603.7
1961 N=106.6 effN=376.4
1962 N=130 effN=553.2
1963 N=130 effN=2191.8
1964 N=130 effN=3386.8
1965 N=130 effN=506.9
1966 N=130 effN=1267.4
1967 N=63.7 effN=333.2


length comps, retained, Mixed
Proportion
Length (cm)
1971
N=3.1
effN=145.3
1981
N=25.8
effN=163.1
1972
N=1.4
effN=91.5
1982
N=22.8
effN=170.8
1973
N=2.4
effN=77.1
1983
N=33.3
effN=2050.6
1974
N=5.8
effN=79.5
1984
N=26.5
effN=101.7
1975
N=22.8
effN=461.6
1985
N=11.2
effN=58.7
1976
N=28.6
effN=556.3
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
15
25
35
45


length comps, retained, M_LenEastTrawl_P
Proportion
0.00
0.05
0.10
0.15
0.20
1986 N=54 effN=1808.2
1987 N=26 effN=477.7
1988 N=12.3 effN=591.7
1989 N=7.8 effN=123.8
1990 N=3.9 effN=98.4
1991 N=5.2 effN=25.1
1992 N=5.8 effN=200.8
1993 N=7.2 effN=43.3
1994 N=9.1 effN=100.4
1995 N=4.5 effN=131.9
1996 N=16.9 effN=398.3
1997 N=17.6 effN=98.4
1998 N=37.7 effN=1049.6
1999 N=55.9 effN=223
2000 N=35.8 effN=150.7
2001 N=26.6 effN=290.2
2002 N=20.8 effN=210.3
2003 N=16.2 effN=289.9
2004 N=18.9 effN=278.6
2005 N=19.5 effN=307.5
2006 N=55.9 effN=218.6
2007 N=8.4 effN=176.6
2008 N=2.6 effN=47.7
2009 N=13 effN=137.7
2010 N=9.1 effN=365.4
2011 N=16.9 effN=191.2
2012 N=20.1 effN=201.1
2013 N=21.4 effN=472.3
2014 N=10.4 effN=218
15
25
35
45
Length (cm)


length comps, retained, M_LenDS_P
Proportion
Length (cm)
1997 N=2.5 effN=20.9
2004 N=1 effN=15.2
2013 N=5 effN=35.8
1998 N=5.4 effN=18.5
2007 N=2.5 effN=42.4
2014 N=7.9 effN=12.8
1999 N=1 effN=34.7
2008 N=3 effN=102.6
2000 N=3.5 effN=56.7
2010 N=5.9 effN=93.6
2001 N=1.5 effN=57
2011 N=11.9 effN=31.2
2002 N=5 effN=38.9
2012 N=4.5 effN=20.1
0.00
0.05
0.10
0.15
0.20
0.25
0.30
15
25
35
45


length comps, retained, M_LenTasTrawl_P
1997
N=3.2
effN=321.9
2003
N=4.8
effN=86.1
2012
N=6.4
effN=83.4
1998
N=6.4
effN=55.6
2004
N=12.8
effN=44.4
2013
N=6.4
effN=61.3
1999
N=20.8
effN=93
2005
N=11.2
effN=42.2
2000
N=6.4
effN=96
2006
N=24
effN=146
2001
N=6.4
effN=227.5
2007
N=1.6
effN=69.1
2002
N=20.8
effN=119.6
2011
N=11.2
effN=39.9
Proportion
0.00
0.05
0.10
0.15
0.20
Length (cm)
15
25
35
45

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

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9.1 Summary

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

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

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

9.2 Introduction

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

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

9.2.1 *The Fishery*

Jackass morwong have been landed in southern Australia since the inception of the steam trawl fishery off New South Wales in the early twentieth century (Fay 2004). Jackass morwong were not favoured during the initial years of this fishery, when the main target species was tiger flathead (*Neoplatycephalus richardsoni*). Declines in flathead catches and improved market acceptance led to increased targeting of jackass morwong during the 1930s and later years of the steam trawl fishery (Klaer, 2001). Annual estimates of landings of jackass morwong from the steam trawl fishery between 1915 and 1957 reached a peak of about 2,000 t during the late 1940s (Table 9.3).

The fishery expanded greatly during the 1950s, with Danish seine vessels becoming the main vessels in the fishery. Landings of jackass morwong in NSW and eastern Victoria increased following WWII, and, at their peak in the 1960s, annual landings were of the order of 2,500 t. The fishery shifted southwards during this time, with the majority of the landed catches coming from eastern Victoria. Landings of morwong then dropped to around 1,000 t by the mid-1980s (Table 9.4), with landings in eastern Tasmania becoming an increasing proportion of catches. By the mid-1980s, the majority of jackass morwong was being landed by modern otter trawlers; with small landings by Danish seine vessels in eastern Victoria and eastern Bass Strait (Smith and Wayte, 2002).

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

The catches have been constrained by the TAC since 2008. In 1992, an initial TAC was set at 1,500 t (Smith and Wayte, 2002). The agreed TAC was reduced to 1,200 t in 2000, to 960 t in 2001, increased to 1,200 t in 2006, and has decreased since then in response to stock assessments showing the stock to be at a low level. The 2009/10 and 2010/11 TAC of 450 t were set as a bycatch TAC i.e. the amount of unavoidable bycatch of morwong that could be expected from fishing for other species. Klaer and Smith (2008) calculated that in 2006, 59% of morwong trawl catch was caught as bycatch (mainly from flathead fishing). From the logbook data in 2006, morwong trawl catch was 763 t. Thus 59% of this, or 450 t, is bycatch that is unavoidable if catches of species that have morwong as a bycatch stay the same as 2006 levels (Wayte, 2011).

Morwong is also caught in small quantities in state waters off NSW and Tasmania, and by the non-trawl sector of the fishery, although these landings are not large. This assessment does not consider landings from vessels in the non-trawl sector. The state catches have been added to the Commonwealth catches in the appropriate zone.

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

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

9.2.2 *Stock Structure*

Genetic studies conducted by the CSIRO have found no evidence of separate stocks in Australian waters. New Zealand and Australian stocks are however, distinct (Elliott et al., 1992). Analysis of otolith microstructure (Proctor et al., 1992) found differences between jackass morwong from southern

Tasmania and those off NSW and Victoria, but it is unclear if such differences indicate separate stocks. Differences among jackass morwong in the western and eastern zones have been suggested (D.C. Smith, MAFRI, pers. comm. 2004; I. Knuckey, Fishwell, pers. comm. 2004), and it is assumed for the purposes of this assessment that there are separate stocks of jackass morwong in the eastern and western zones (Wayte, 2011).

9.2.3 *Previous Assessments*

This text is largely taken from the discussion of assessments by Wayte (2011). Smith (1989) analysed catch and effort data for the Eden fishery (1971-72 to 1983-84), finding a significant decline in catch-per-unit-effort (CPUE) to 1980. Lyle (1989) analysed logbook data for Tasmania and western Bass Strait from 1976-84. No trends were apparent in these data.

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

At the 1993 meeting of SEFSAG, the recent age data (from the Central Ageing Facility, CAF) and length data were presented together with new age and length data from southeastern Tasmania. Estimates of total mortality from catch curve analyses were similar to previous estimates in the early 1980s. Length and age data from southeastern Tasmania were characterised by a greater proportion of larger and older fish. Preliminary ageing data from sectioned otoliths were tabled at SEFAG in 1994 which suggested that morwong were longer lived (35 years) than previously thought (20 years).

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

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

Recently, Klaer (MS) used a stock reduction analysis (SRA) method to model the population of jackass morwong off NSW using catch history data from 1915-61. This analysis lead to a point estimate of unexploited biomass of 21,600 tonnes, with a 1962 depletion level of 71%.

The first formal quantitative assessment of jackass morwong was conducted by Fay (2004) during 2004 based on data to 2002. It used a generalised age-structured modelling approach to assess the status and trends of the jackass morwong trawl fishery in the eastern zones, using data from the period

1915-2002. The 2004 assessment indicated that the spawning biomass of jackass morwong was between 25-45% of the 1915 unexploited biomass. The base-case model estimated the current spawning biomass was 37% of the unexploited biomass. The model could not adequately reconcile changes in catch rate in the late 1980s with catches during this period.

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

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

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

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

A preliminary assessment for the western stock in 2007 indicated that the stock has declined in recent years as fishing pressure has increased, but spawning stock biomass was still considerably higher than the target level. The long-term RBCs estimated for the western stock were comparable with the 2007 catch levels.

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

The 2009 assessment (Wayte, 2010) estimated recruitment deviations up to four years before the end of the data instead of two years as in previous assessments. This change was made because fish spawned two and three years before the end of the data will not be well-represented in the data, and this problem has been compounded in recent years by poor data collection. The eastern trawl CPUE index showed a slight increase, and the 2003 recruitment continued to be estimated to be above average – leading to a slight recovery in the current status of the stock to above the limit reference level (24%). Catch rates have declined in recent years, despite lower catches than in the past. To reconcile this information the 2009 base-case assessment estimated recruitments to have been consistently below average since the early 1980s. The 2009 assessment examined two other possible reasons for this decline: that recruitment is more closely related to stock size than previously assumed (i.e. steepness is lower); or that a regime shift has occurred. Both these models led to a better fit to the data than the base-case, but were not accepted as a new base-case. The best estimate of lower steepness was considered to be unrealistically low for a Perciforme species such as morwong (Myers *et al.* 1999). The regime shift model gave a more optimistic picture of current stock status than the other models, but the long term catch estimate was greatly reduced. It was considered that more evidence for the existence of a regime shift is required before this model is considered plausible.

The 2010 base-case assessment for the eastern stock (Wayte, 2011) estimated that current spawning stock biomass was 26% of unexploited stock biomass. Concern was expressed that catches in the east had continued to be above the RBC. The western stock assessment was considered to be increasingly uncertain, due to lack of recent data. Catches of morwong in the Great Australian Bight were found to be at a similar level to western morwong catches, but it is not known whether the GAB morwong form a separate stock.

In 2010 the RAG decided to include both port and onboard retained length frequency data (for both historic and current years) in future assessments, whereas previously only port data have been used. The 2010 assessment was run with this change in length frequency data (as well as any other changes to the data up to 2009), and very little change to the assessment result was seen. At the ShelfRAG meeting on October 3-4 2011, an alternative base-case assuming that eastern jackass morwong has undergone a shift to lower recruitment was presented and accepted and was used as the base-case for the eastern assessment (Wayte, 2011). The justification for this switch is well described in Wayte (2011), including MSE testing implications of assuming (or not) the recruitment shift. The western assessment uses the same assumptions as in previous years (no recruitment shift).

9.3 Methods

9.3.1 Data

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

9.3.1.1 *Catch and discard rates*

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

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

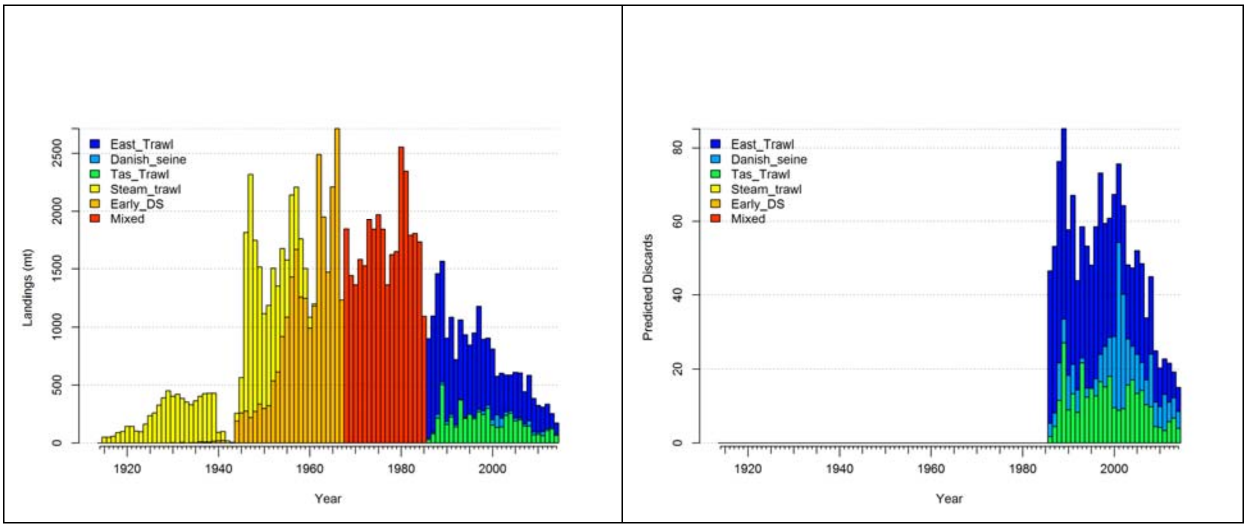
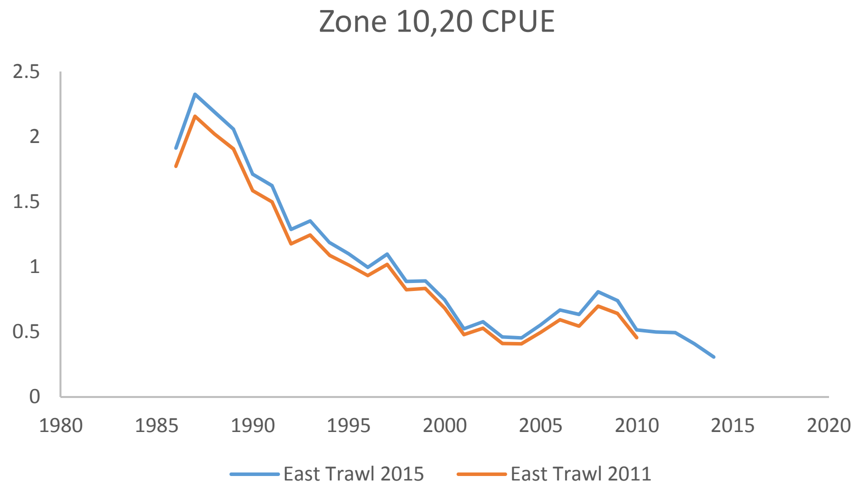


Figure 9.1. Landed morwong catches (mt) for all fleets by calendar year from 1915 and corresponding predicted discard mass (mt). Catches are shown as stacked bars.

CATCH RATES

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



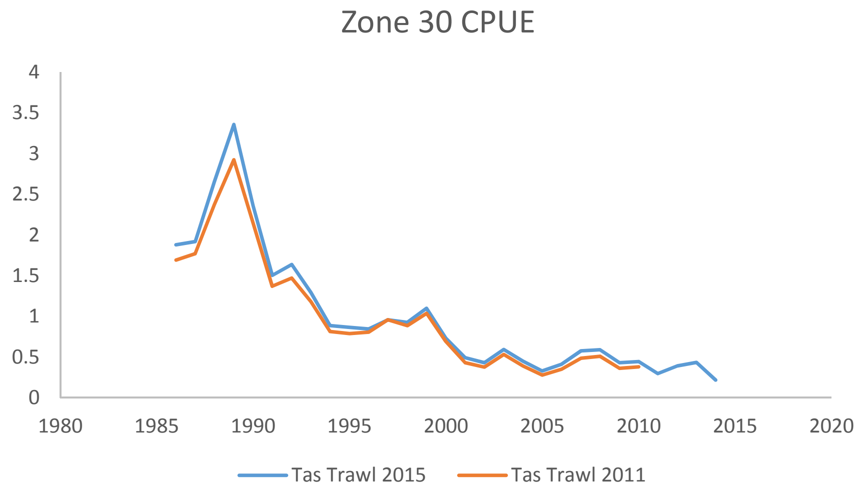


Figure 9.2. Eastern Jackass Morwong standardised CPUE for the NSW/Vic, and Tasmanian trawl fleets (Sporcic and Haddon, 2015). This figure shows a comparison between the series used in the 2011 assessment and that used in the current assessment (2015).

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

9.3.1.2 Length frequencies and age data

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

9.3.1.3 Age-reading error

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

9.3.1.4 Fishery independent survey (FIS) estimates

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

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

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

9.3.2 *The assessment model and biological parameters*

A single-sex stock assessment for jackass morwong was conducted using the software package Stock Synthesis (SS, version 3.24U). A single stock of jackass morwong was assumed for the eastern assessment, with an assumption of two recruitment regimes, or stock-recruitment relationships: the first from 1915 when the steam trawl fishery commenced, and the second, lower recruitment regime, from 1988 when recruitment became lower (Wayte, 2011; 2013). Catches from western Tasmania and western Victoria were assumed to come from a separate stock and are therefore not considered in the eastern assessment.

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

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

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

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

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

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

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

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

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

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

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

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

9.3.3 *The tuning procedure*

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

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

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

9.4 Results and Discussion

9.4.1 Base case parameter estimates and model fits

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

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

Selectivity is assumed to be logistic for all fleets (Figure 9.4). The parameters that define the selectivity function are the length at 50% selection and the spread (the difference between length at 50% and length at 95% selection). The estimates of these parameters for the base-case model do not vary greatly between fleets, with Danish seine showing selection of somewhat small fish.

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

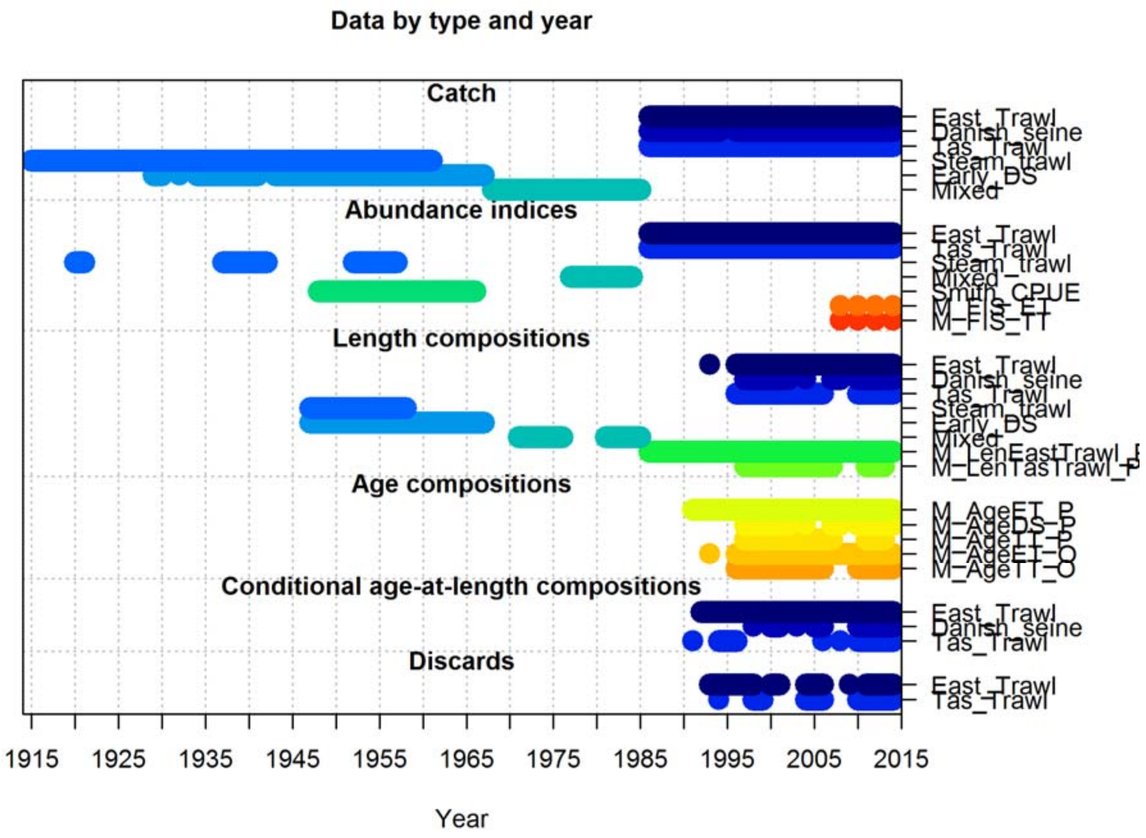


Figure 9.3. The various data types by fleet for the assessment of the eastern stock of jackass morwong.

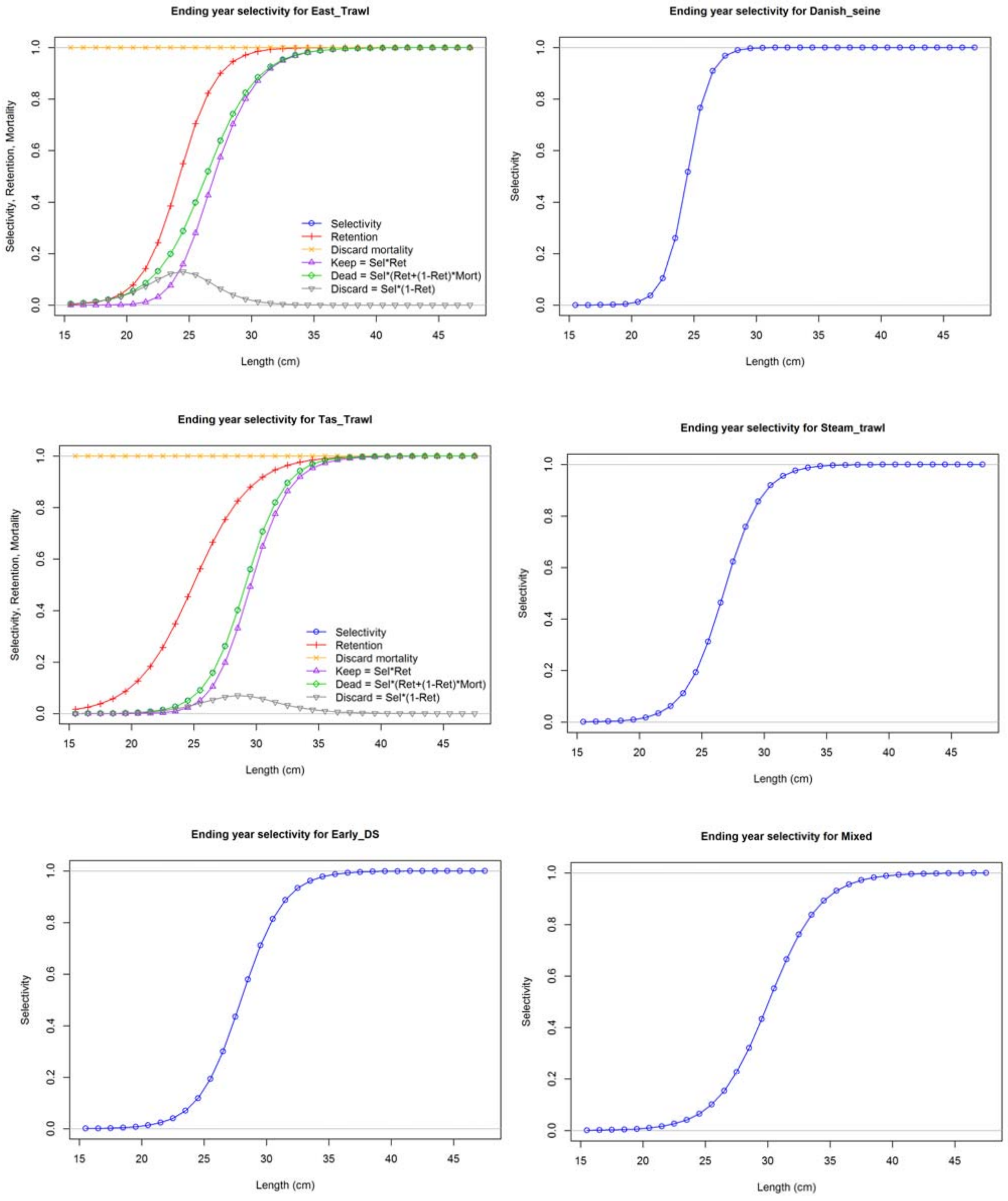


Figure 9.4. Selectivity (blue circle; overlayed by green in the ET and TT plots) and retention functions (red) for the six fleets

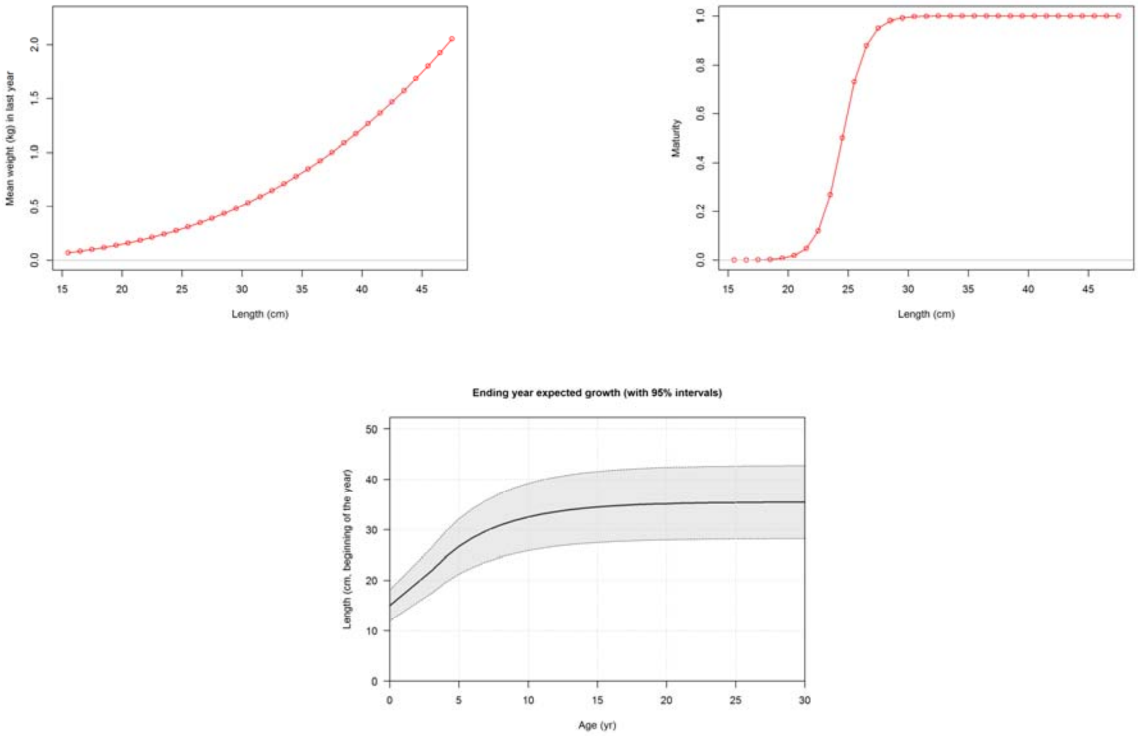


Figure 9.5. The length-weight (left), maturity ogive (right) and length-age relationships (bottom) for the eastern jackass morwong base case assessment.

9.4.2 *Fits to the data*

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

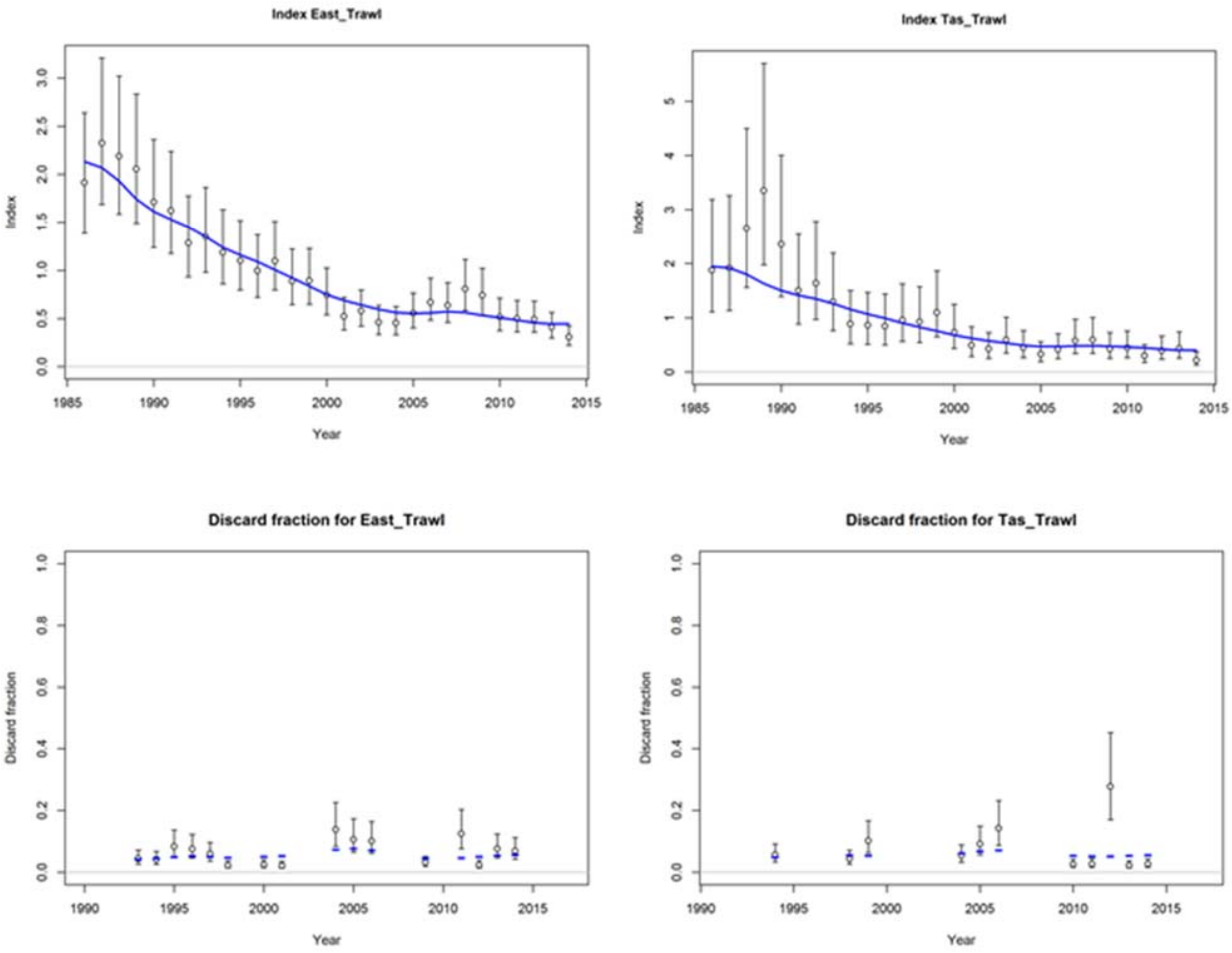


Figure 9.6. Fits to the standardized CPUE for the eastern and Tasmanian trawl fisheries, with the associated discard rates and fit. The fit to the Danish seine discard rates is also shown.

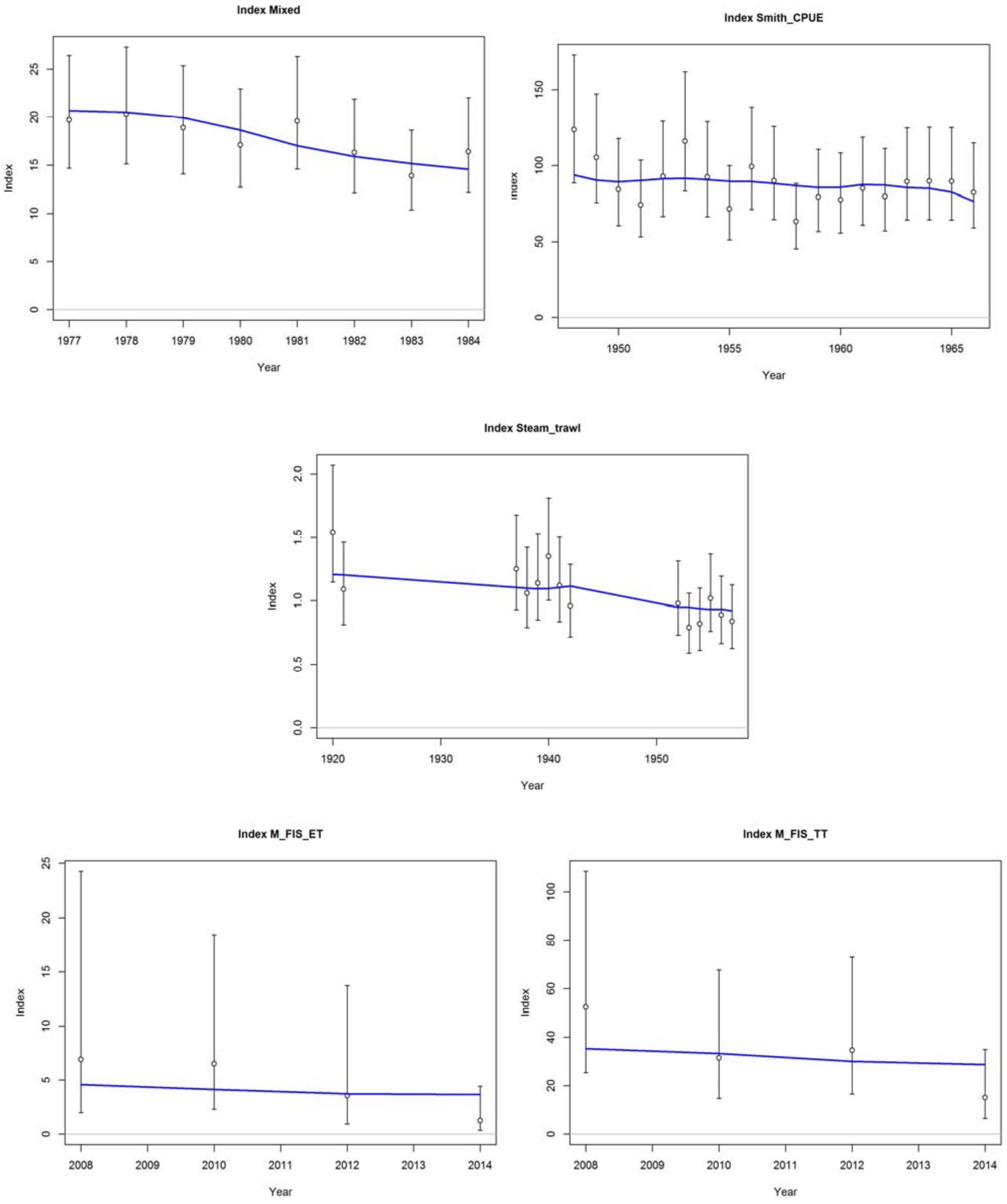


Figure 9.7. Fits to the index data for the mixed fleet, the steam trawl fleet, the Smith CPUE index and the FIS abundance indices from the east (Zones 10/20) and Tas (Zone 30).

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

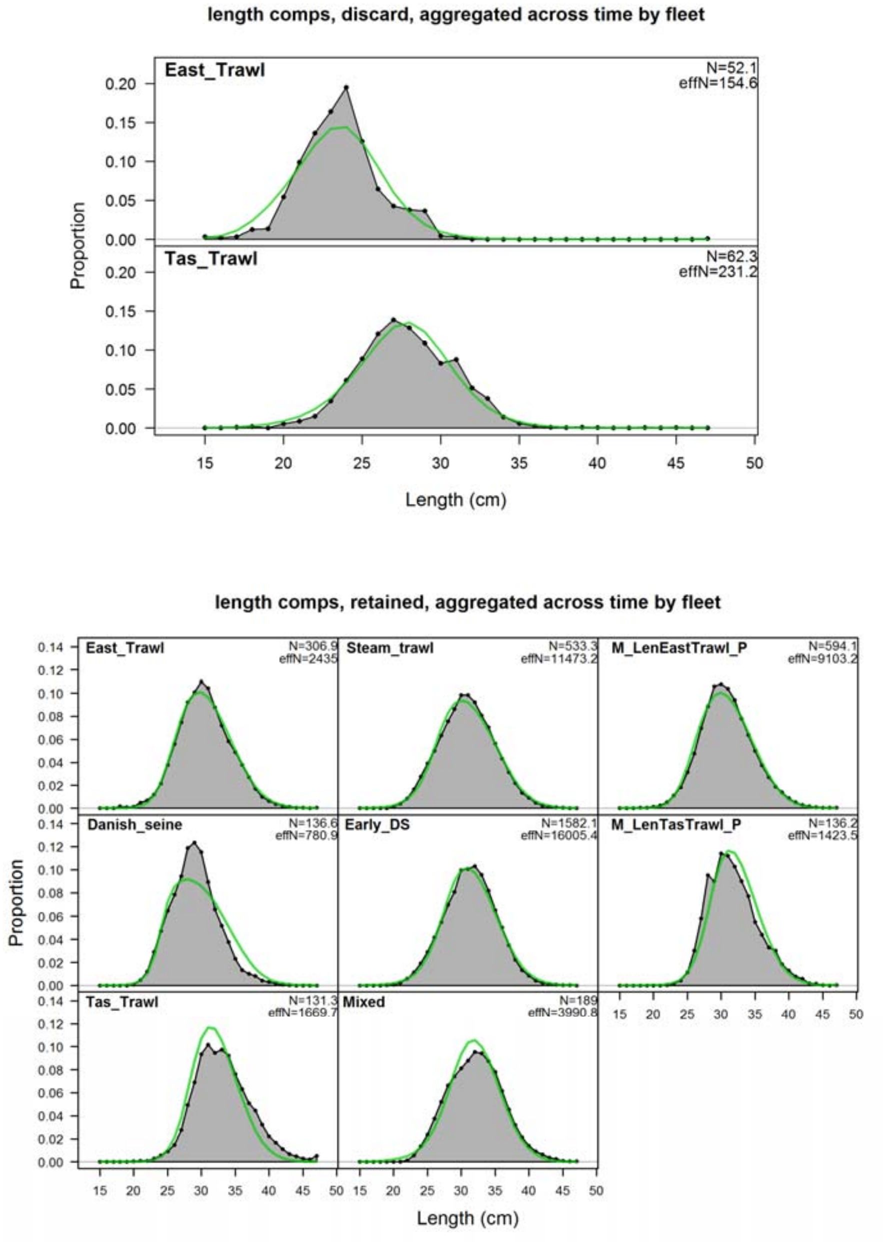


Figure 9.8. Fits to the discard and retained length by fleet (P = Port, Danish_seine is also Port).

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

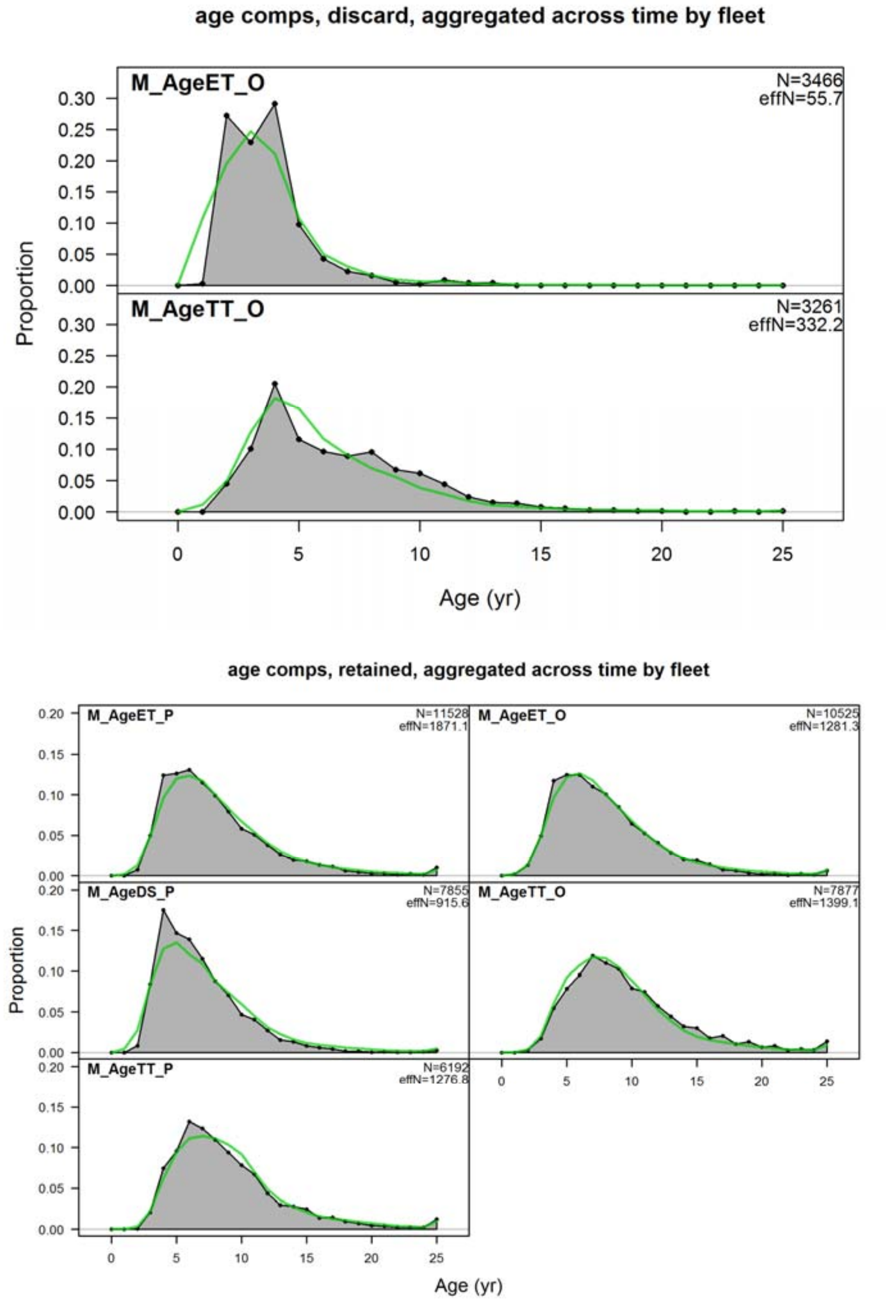


Figure 9.9. Fits to the implied age compositions for discard and retained (P = Port, O= onboard)

9.4.3 *Assessment outcomes*

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

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

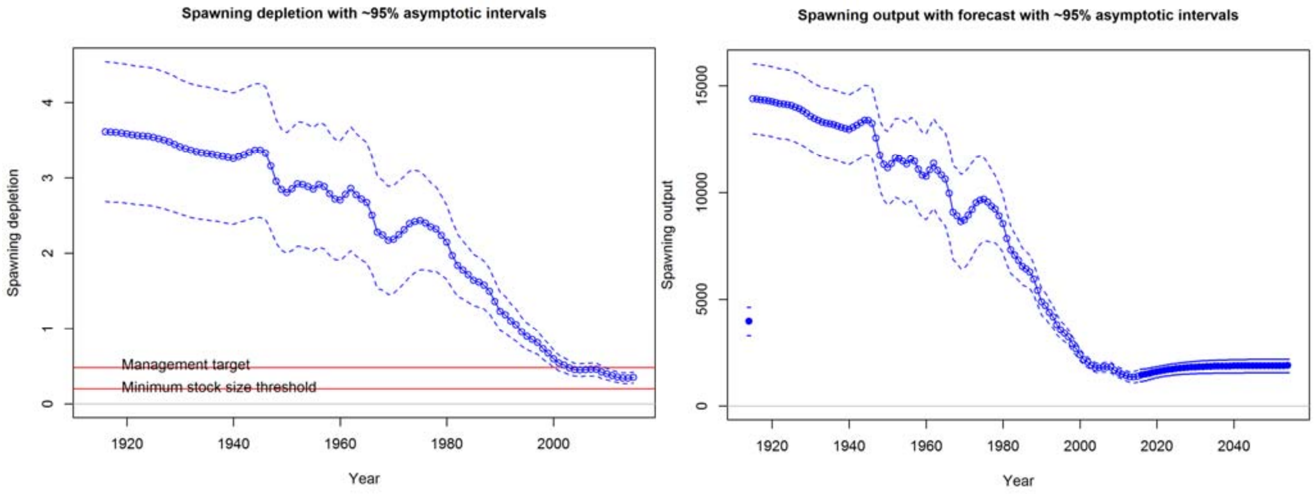


Figure 9.10. Time trajectories of spawning biomass depletion (left) and spawning biomass (right) with 95% confidence intervals for the base case assessment of the eastern stock of jackass morwong.

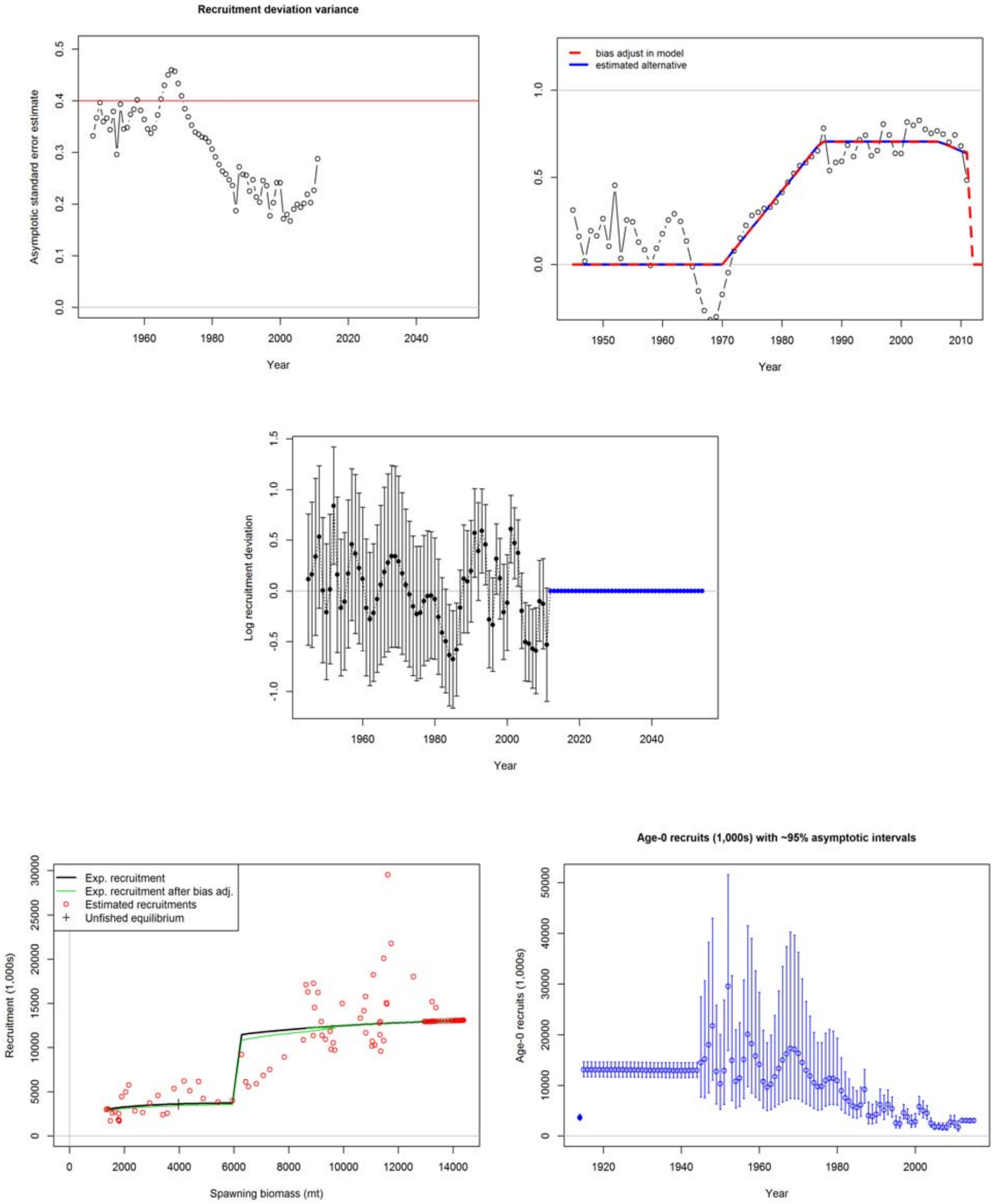


Figure 9.11. Diagnostics for recruitment, the stock–recruitment relationship and annual estimates of recruitment numbers with confidence intervals.

9.4.4 *Discussion*

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

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

9.4.5 *Sensitivities*

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

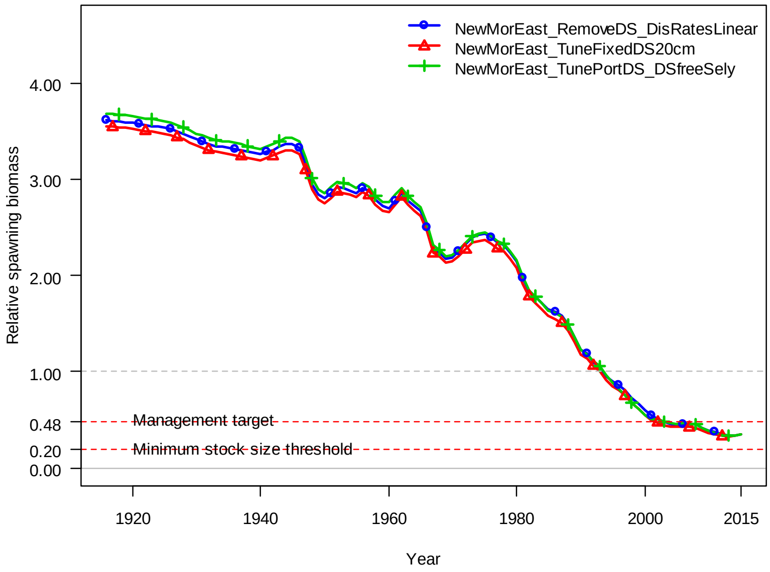


Figure 9.12. The relative female spawning biomass trajectory for the base case model (NewMorEast_RemoveDS_DisRatesLinear; blue) and two other models where the length at 50% selectivity for Danish seine is either fixed at 20cm (red) or estimated (green).

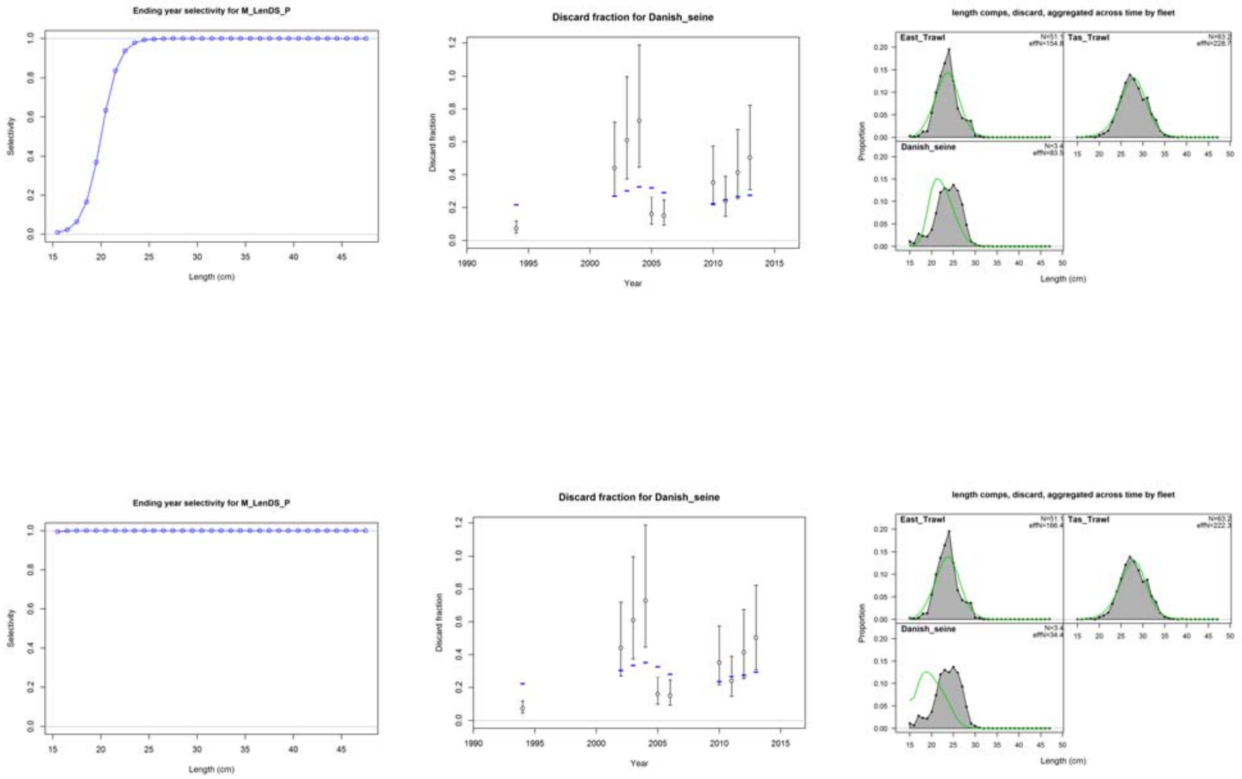


Figure 9.13 The selectivity for Danish seine, estimated discard rates and length fits for (i) a model where the length at 50% selectivity for Danish seine is fixed at 20cm (top row) and (ii) where the length at 50% selectivity is estimated (bottom row).

9.5 Acknowledgements

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

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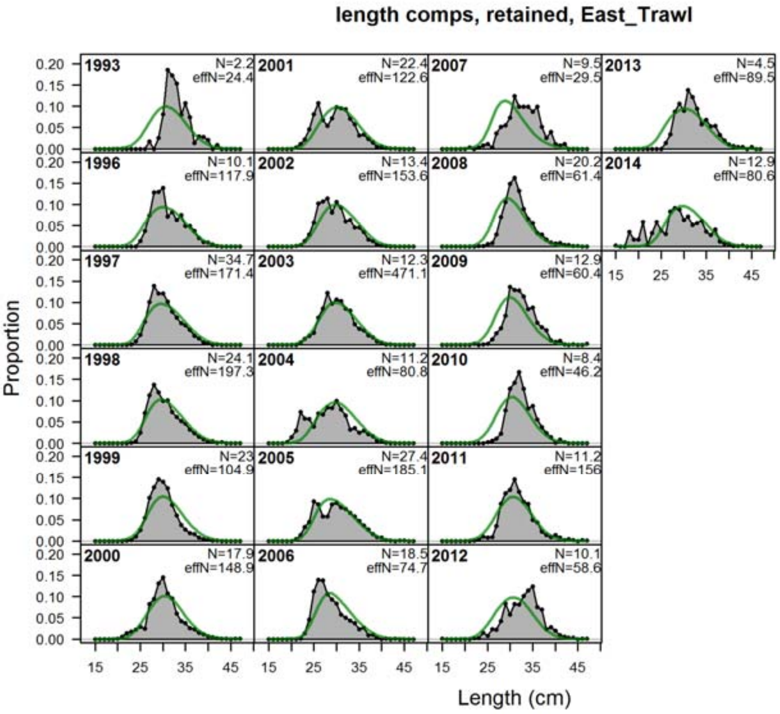
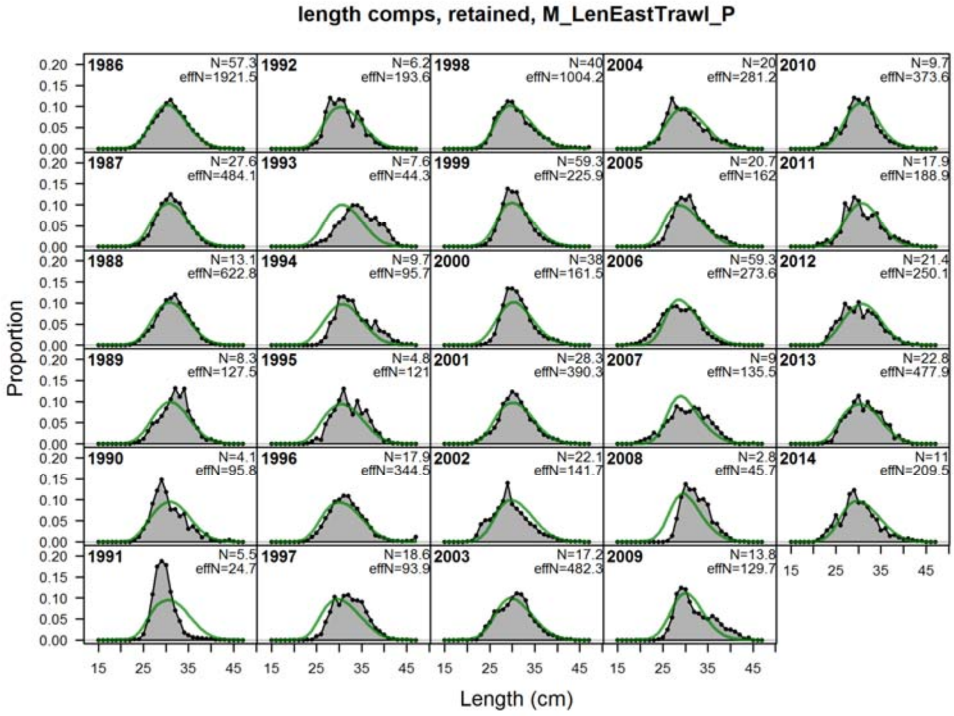
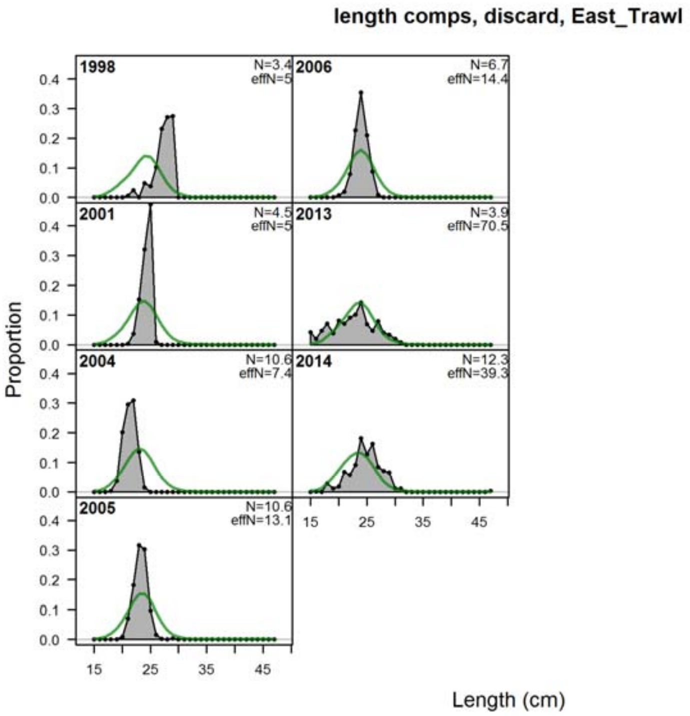
Wayte, S.E. and Fay, G. 2009. Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2007. In: Tuck, G.N. (Ed.) 2009. Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2008. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric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

9.7 Appendix 1: Base case length fits

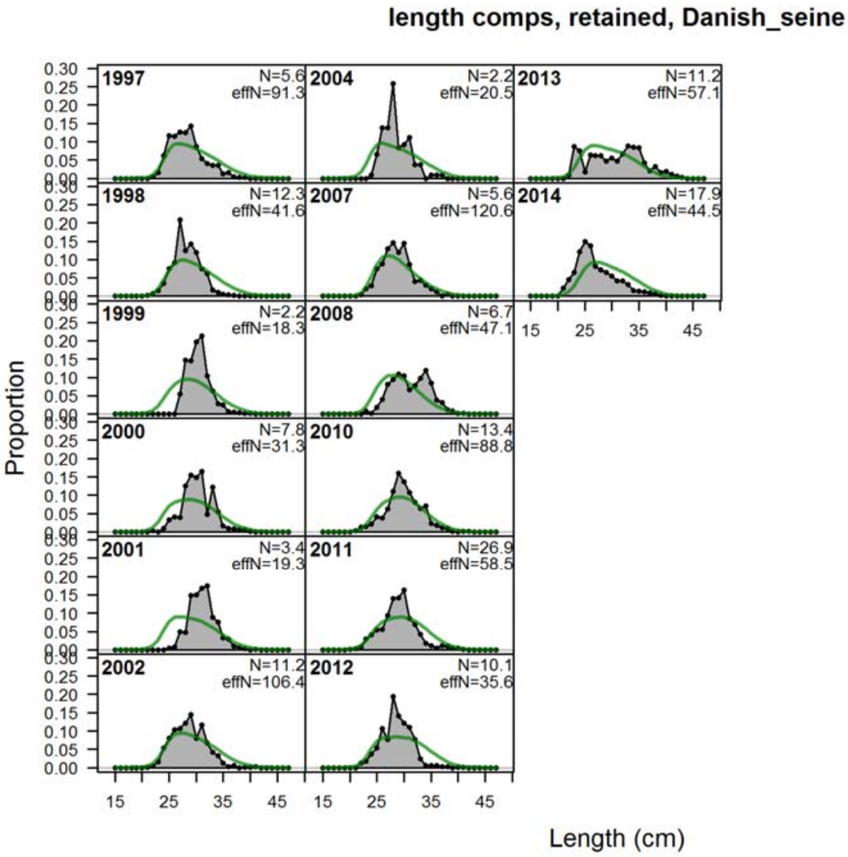




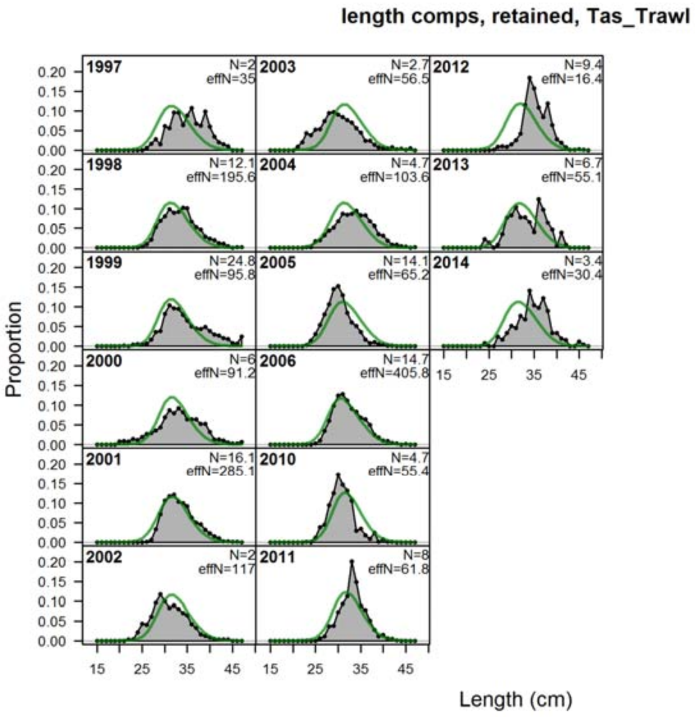
Length composition fits for the eastern trawl fleet. Onboard retained (top) and Port (bottom).

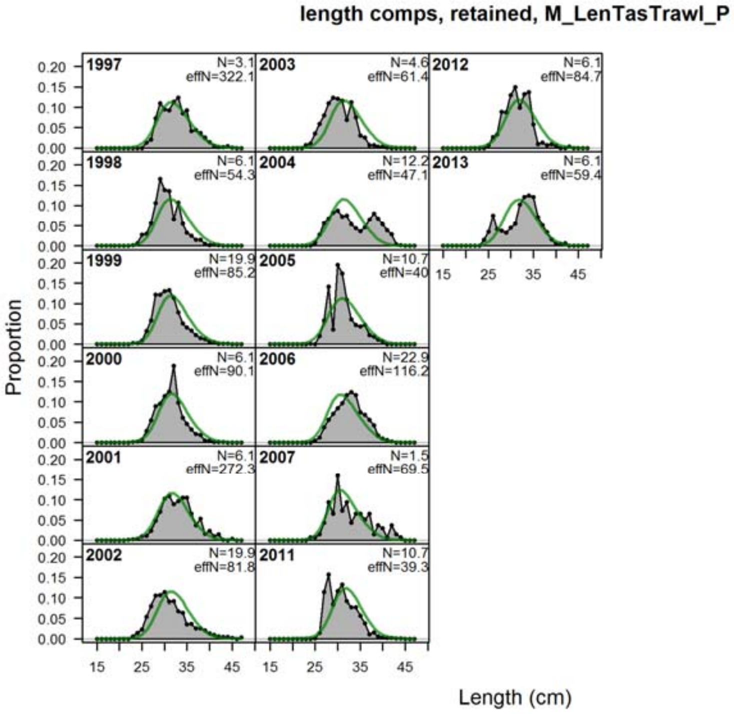


Length composition fits for discarded fish from the eastern trawl fleet.

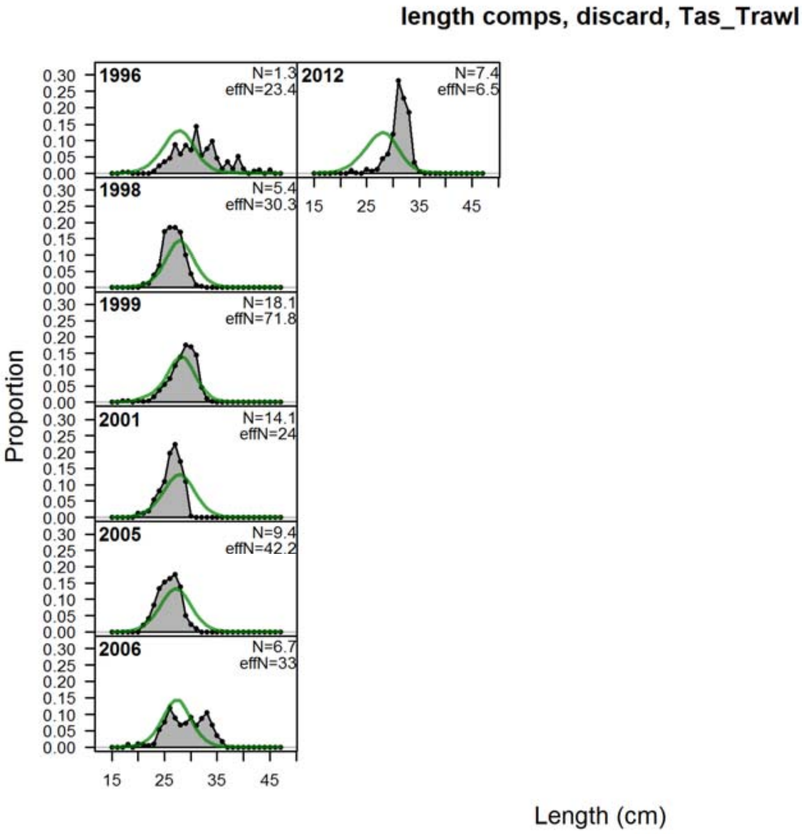


Length composition fits for the Danish seine fleet (Port).

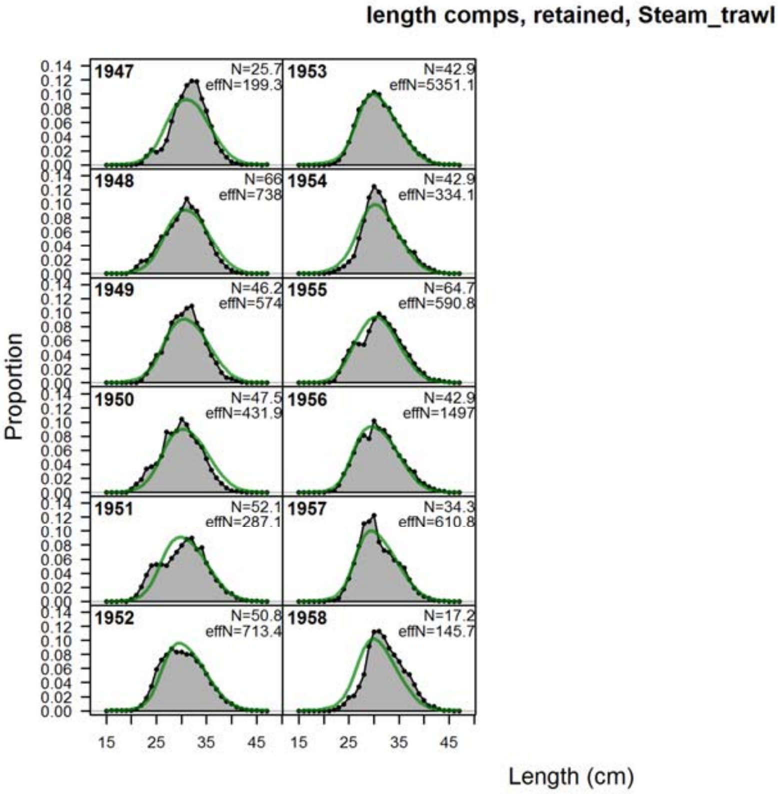


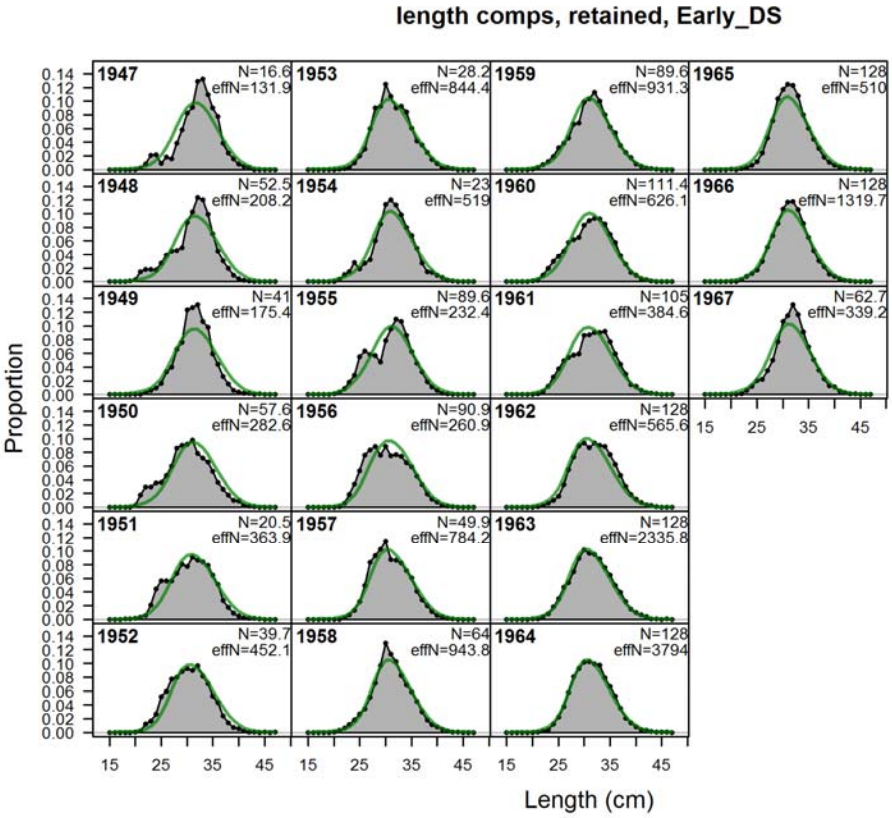


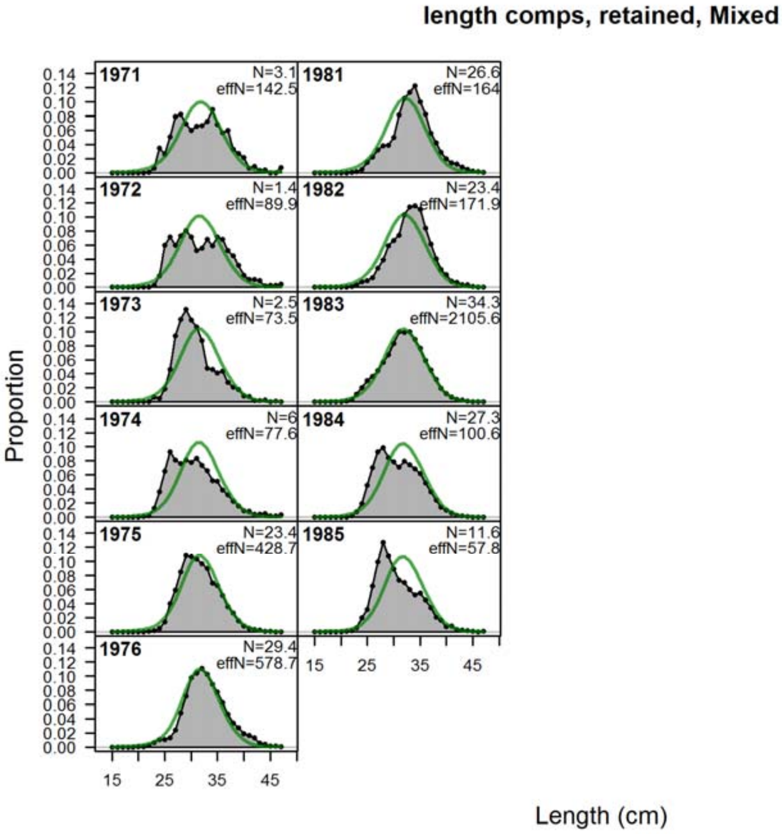
Length composition fits for the Tas trawl fleet. Onboard retained (top) and Port (bottom).



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

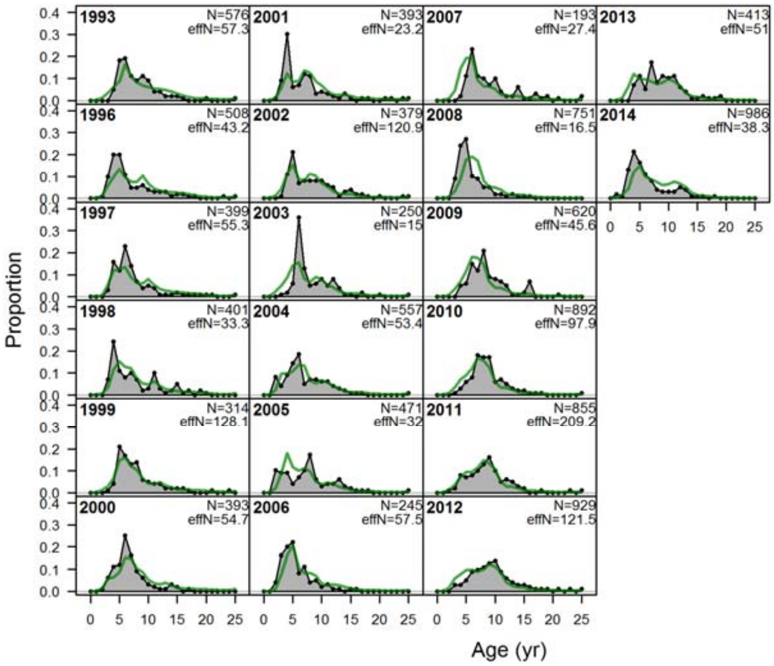



length comps, retained, Early_DS
1947 N=16.6 effN=131.9
1948 N=52.5 effN=208.2
1949 N=41 effN=175.4
1950 N=57.6 effN=282.6
1951 N=20.5 effN=363.9
1952 N=39.7 effN=452.1
1953 N=28.2 effN=844.4
1954 N=23 effN=519
1955 N=89.6 effN=232.4
1956 N=90.9 effN=260.9
1957 N=49.9 effN=784.2
1958 N=64 effN=943.8
1959 N=89.6 effN=931.3
1960 N=111.4 effN=626.1
1961 N=105 effN=384.6
1962 N=128 effN=565.6
1963 N=128 effN=2335.8
1964 N=128 effN=3794
1965 N=128 effN=510
1966 N=128 effN=1319.7
1967 N=62.7 effN=339.2
Proportion
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14
15 25 35 45
Length (cm)

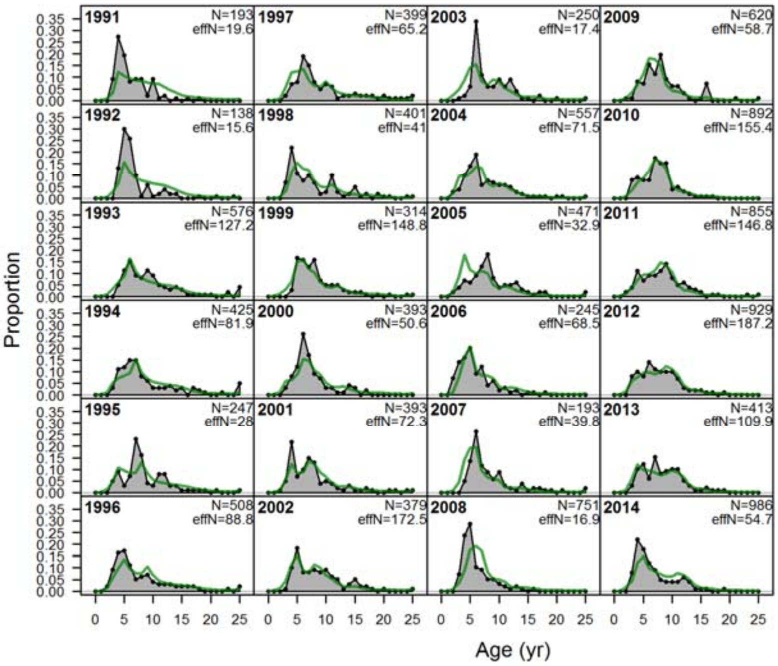

length comps, retained, Mixed
1971 N=3.1 effN=142.5
1972 N=1.4 effN=89.9
1973 N=2.5 effN=73.5
1974 N=6 effN=77.6
1975 N=23.4 effN=428.7
1976 N=29.4 effN=578.7
1981 N=26.6 effN=164
1982 N=23.4 effN=171.9
1983 N=34.3 effN=2105.6
1984 N=27.3 effN=100.6
1985 N=11.6 effN=57.8
Proportion
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14
15 25 35 45
Length (cm)

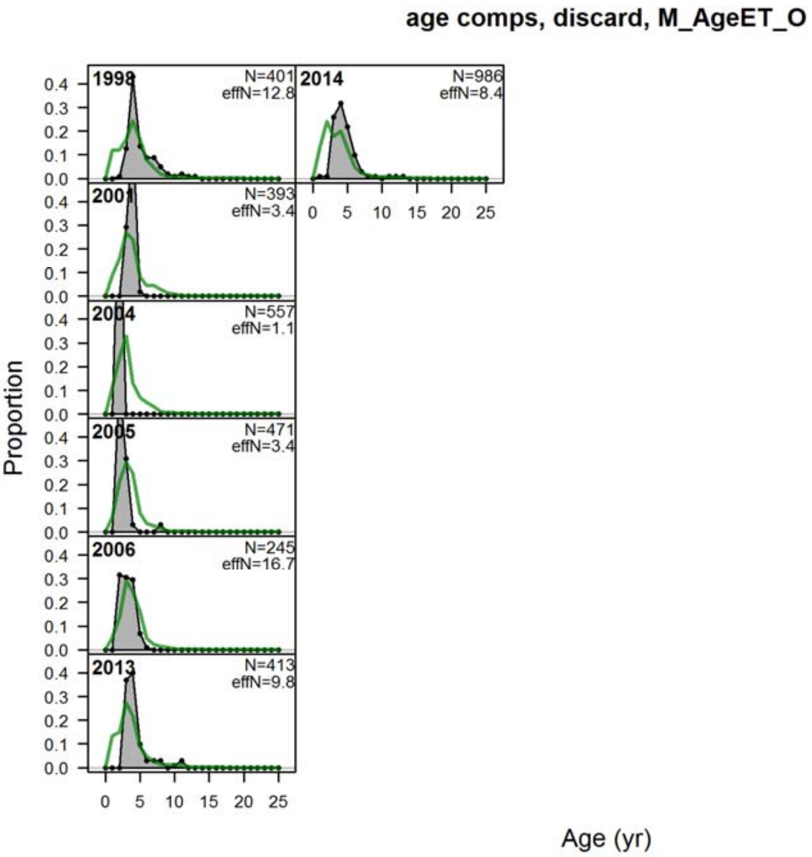
9.8 Appendix 2: base case age fits

age comps, retained, M_AgeET_O

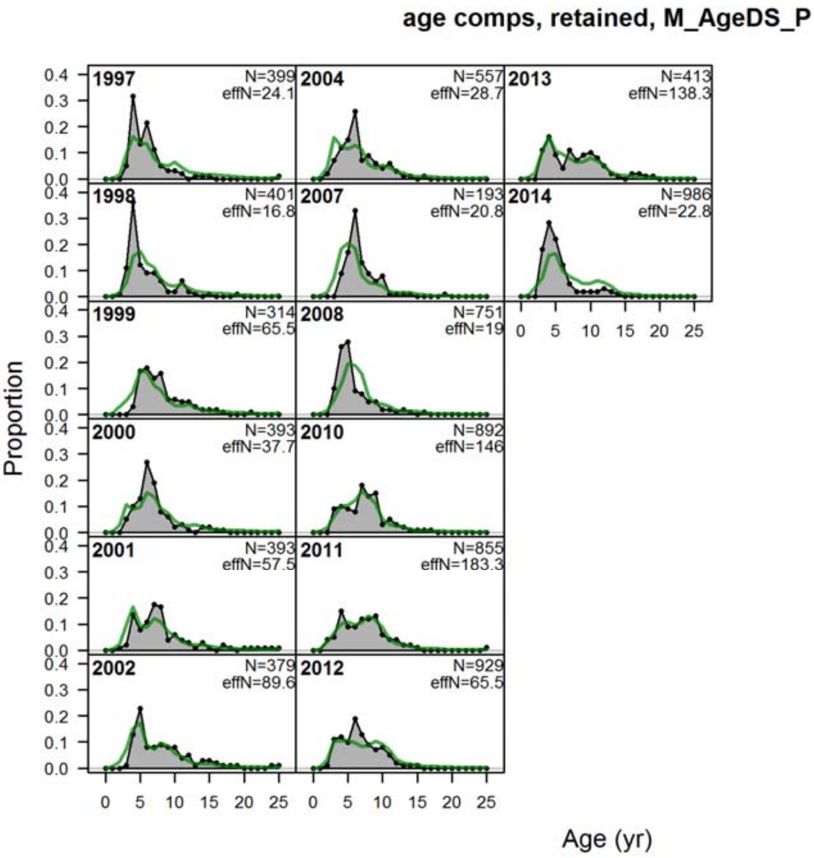


age comps, retained, M_AgeET_P

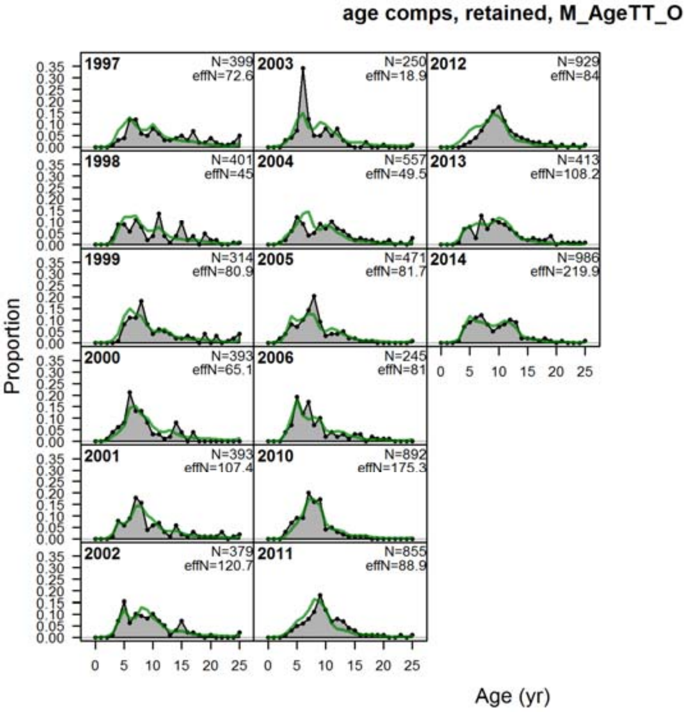


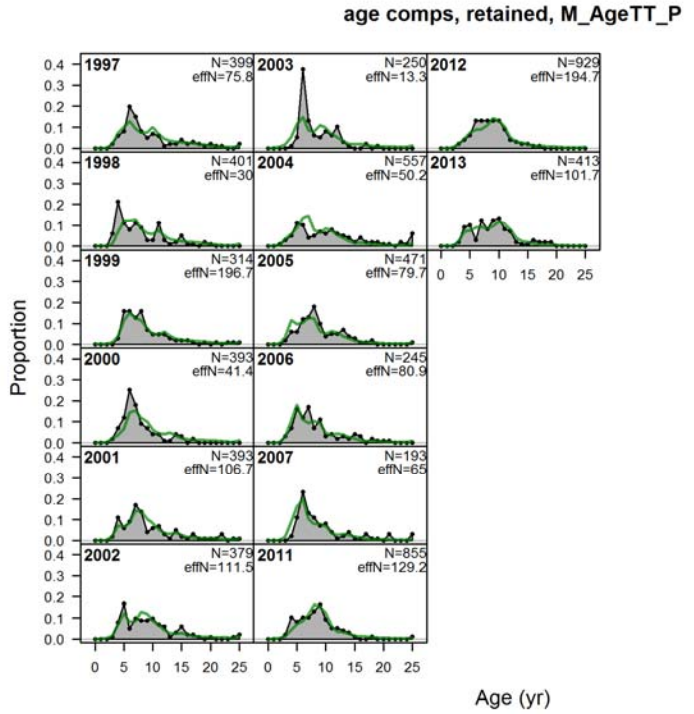


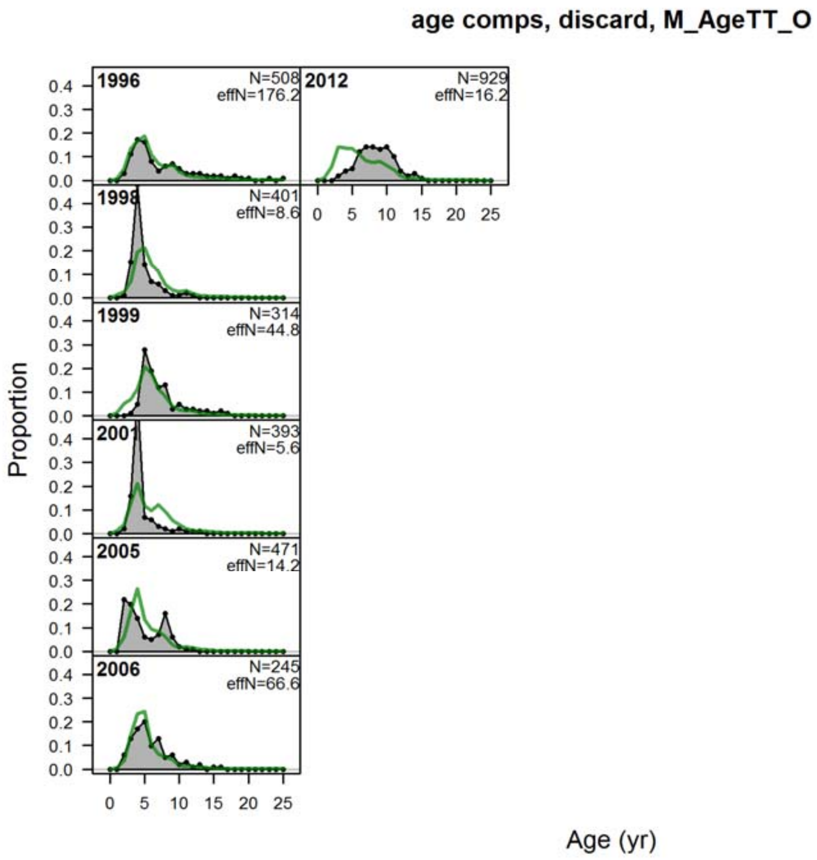
age comps, discard, M_AgeET_O



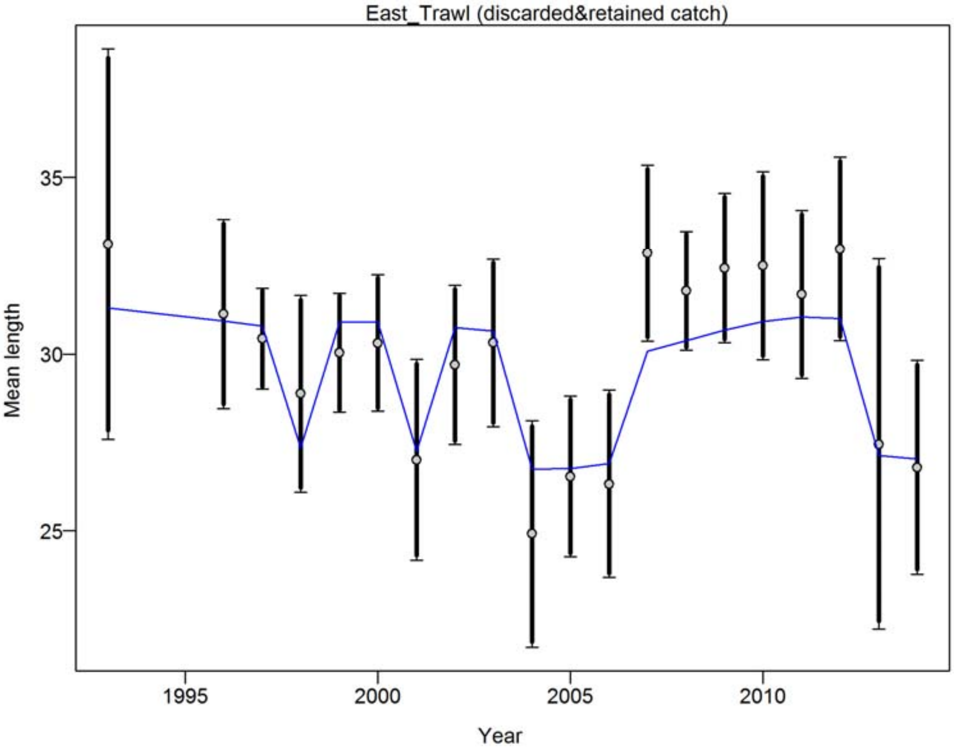
age comps, retained, M_AgeDS_P

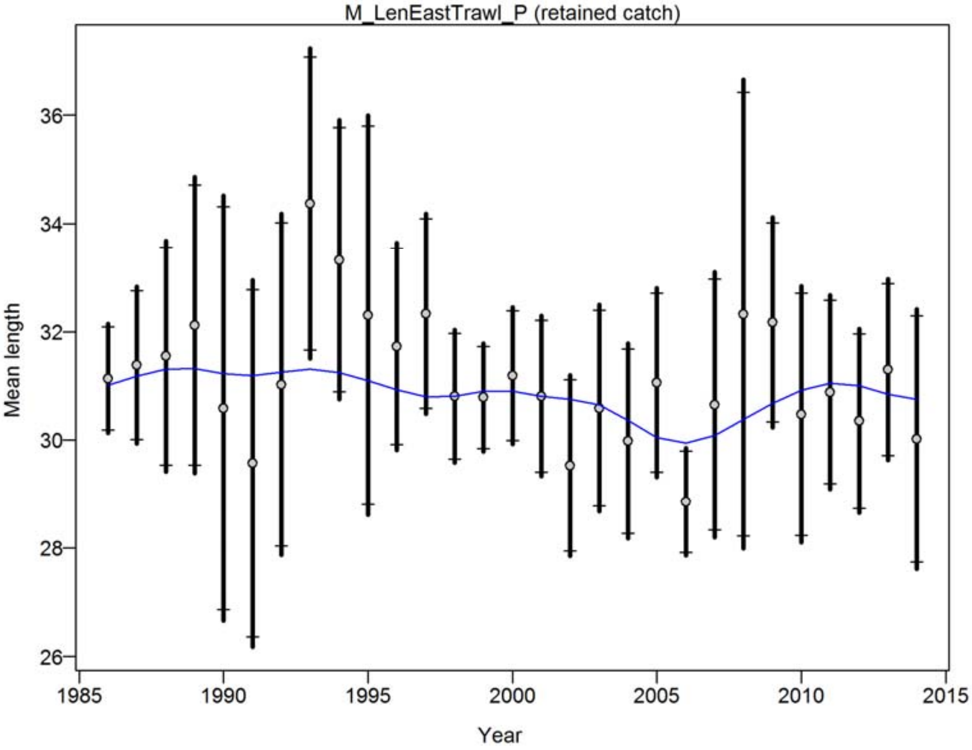

age comps, retained, M_AgeTT_O
1997 N=399 effN=72.6
1998 N=401 effN=45
1999 N=314 effN=80.9
2000 N=393 effN=65.1
2001 N=393 effN=107.4
2002 N=379 effN=120.7
2003 N=250 effN=18.9
2004 N=557 effN=49.5
2005 N=471 effN=81.7
2006 N=245 effN=81
2010 N=892 effN=175.3
2011 N=855 effN=88.9
2012 N=929 effN=84
2013 N=413 effN=108.2
2014 N=986 effN=219.9
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35
0 5 10 15 20 25
Proportion
Age (yr)

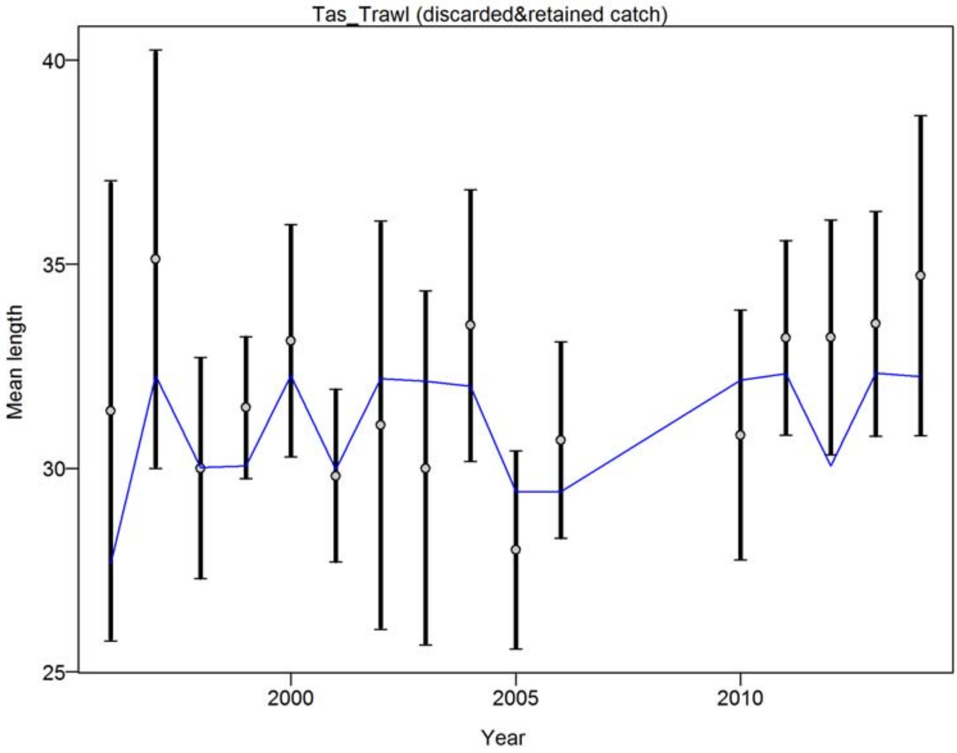

age comps, retained, M_AgeTT_P
1997 N=399 effN=75.8
1998 N=401 effN=30
1999 N=314 effN=196.7
2000 N=393 effN=41.4
2001 N=393 effN=106.7
2002 N=379 effN=111.5
2003 N=250 effN=13.3
2004 N=557 effN=50.2
2005 N=471 effN=79.7
2006 N=245 effN=80.9
2007 N=193 effN=65
2011 N=855 effN=129.2
2012 N=929 effN=194.7
2013 N=413 effN=101.7
0.0 0.1 0.2 0.3 0.4
0 5 10 15 20 25
Proportion
Age (yr)

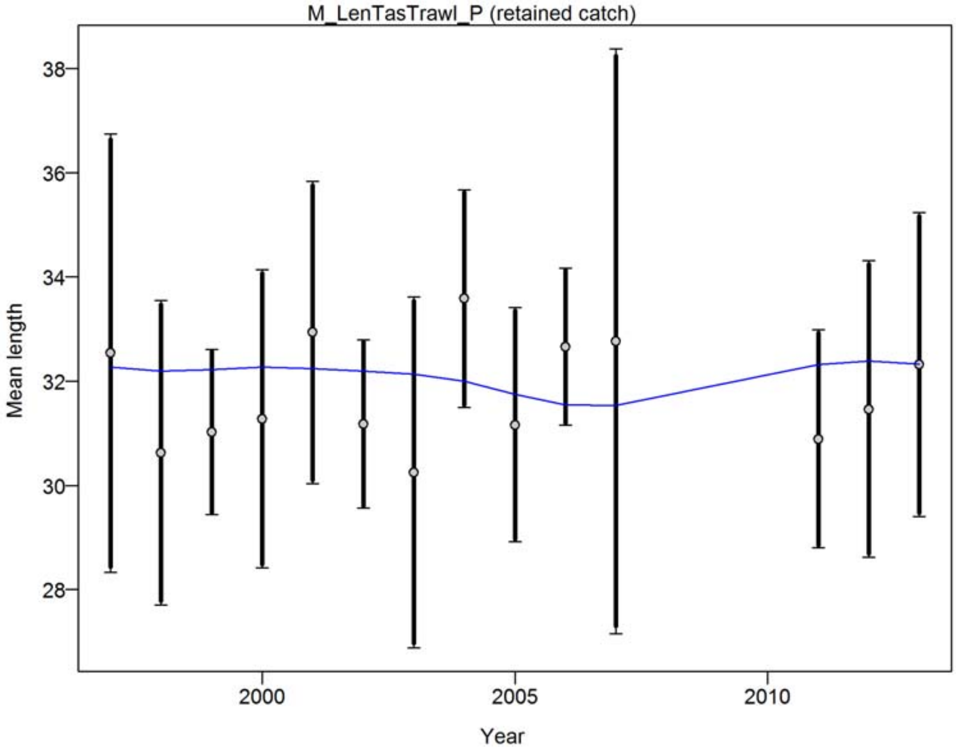

age comps, discard, M_AgeTT_O
1996
N=508
effN=176.2
2012
N=929
effN=16.2
1998
N=401
effN=8.6
1999
N=314
effN=44.8
2001
N=393
effN=5.6
2005
N=471
effN=14.2
2006
N=245
effN=66.6
0.0
0.1
0.2
0.3
0.4
Proportion
0
5
10
15
20
25
Age (yr)

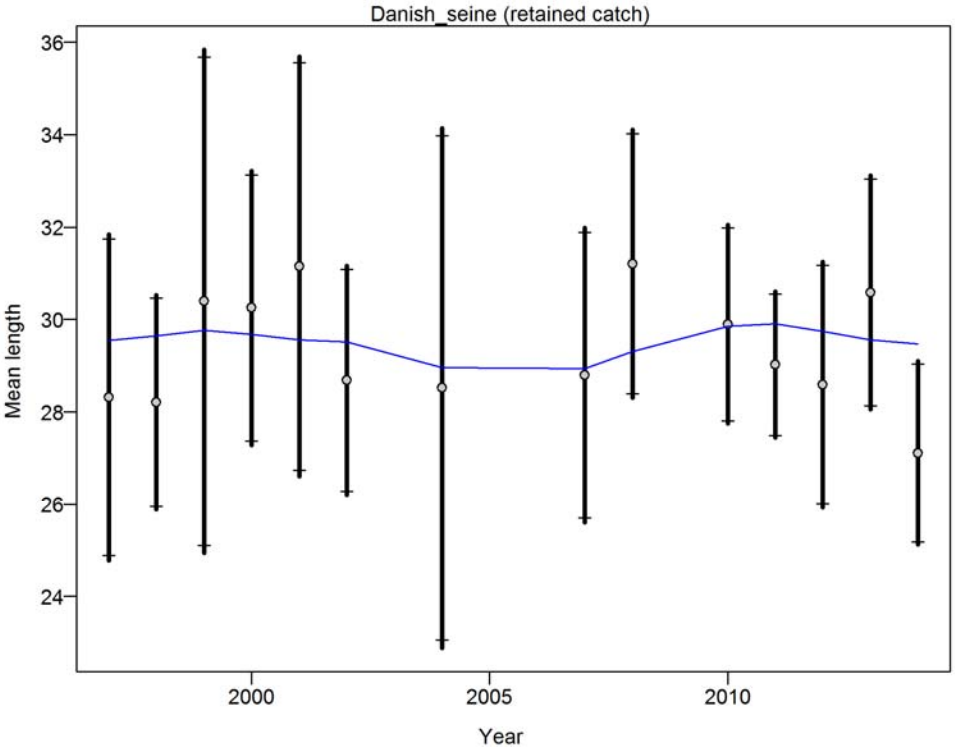
9.9 Appendix 3: base case length fit diagnostics (Francis mean length fits from method TA1.8)

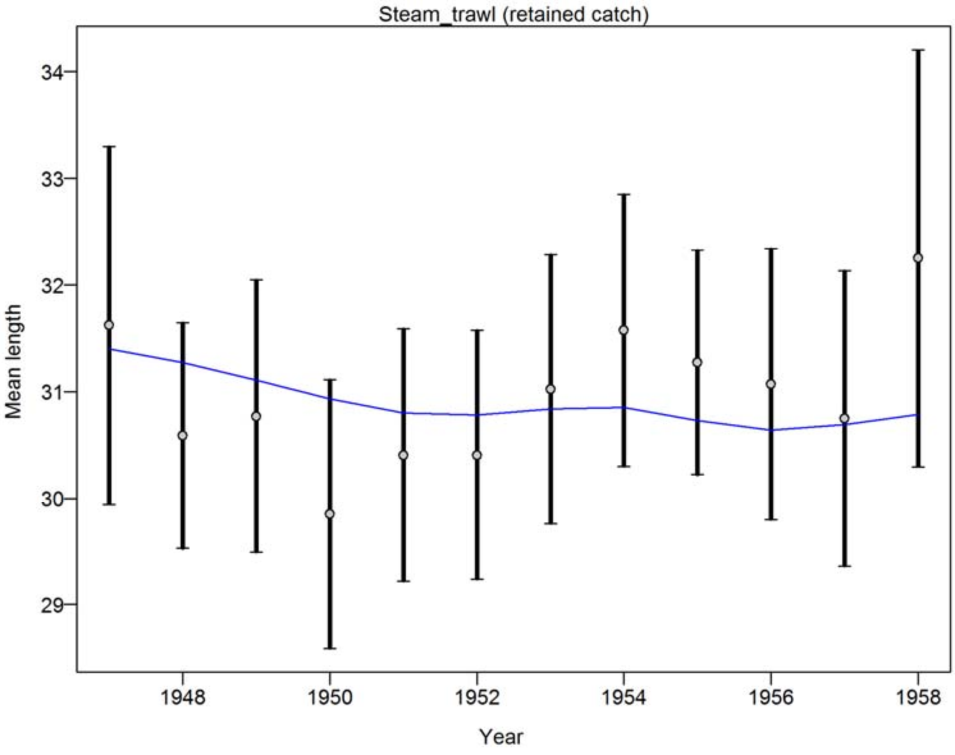


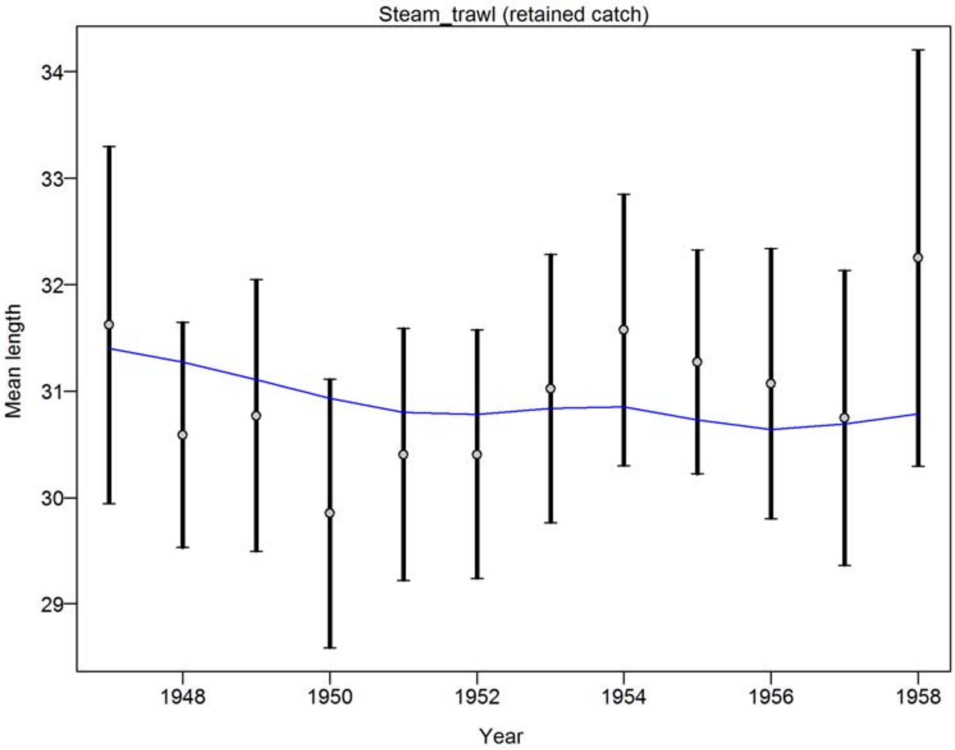


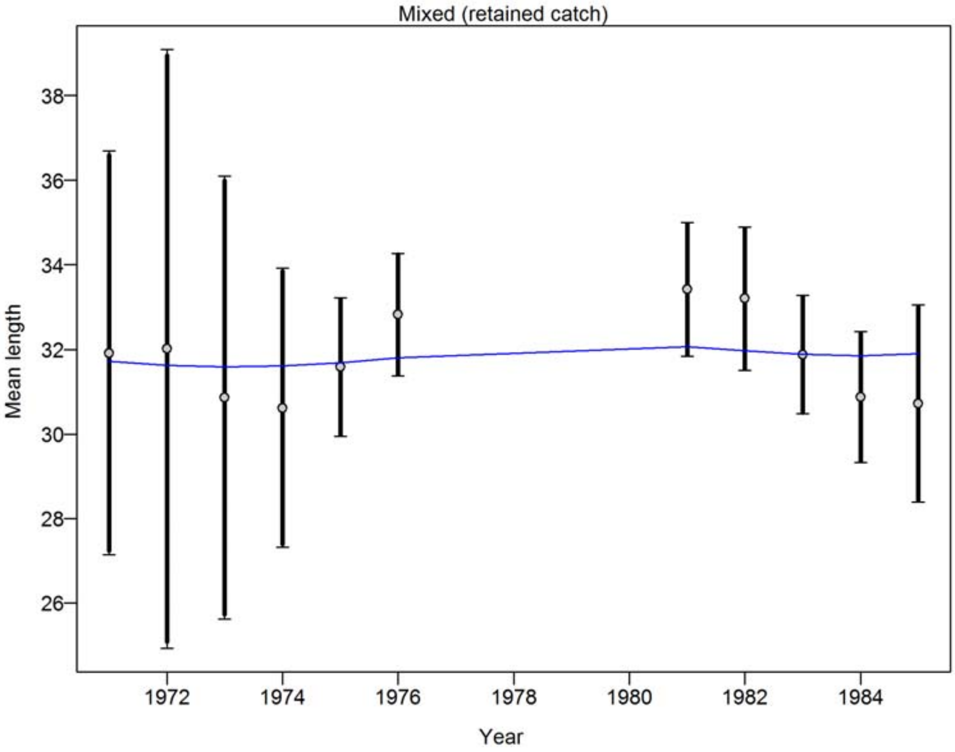

Tas_Trawl (discarded&retained catch)
Mean length
Year
25
30
35
40
2000
2005
2010


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


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


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


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


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

9.10 Appendix 4: tables

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

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

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

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

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

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

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

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

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

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

Table 9.8 Standardised catch rates for the steam trawl fleet.

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

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

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

Table 9.10. Standardised catch rates for the mixed fleet.

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

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

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

	Early DS	
	Number fish	Trips*
1947	1590	13
1948	5070	41
1949	3882	32
1950	5511	45
1951	1933	16
1952	3779	31
1953	2749	22
1954	2231	18
1955	8627	70
1956	8769	71
1957	4826	39
1958	6205	50
1959	8569	70
1960	10660	87
1961	10038	82
1962	15498	100
1963	17887	100
1964	24744	100
1965	16586	100
1966	19328	100
1967	5980	49

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

	Retained Mixed fleet	
	Number fish	Trip*
1971	1127	9
1972	631	4
1973	1080	7
1974	3614	17
1975	5388	67
1976	7971	84
1981	8684	76
1982	7911	67
1983	13608	98
1984	11552	78
1985	4825	33

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

10. Development of a base-case Tier 1 assessment for the western stock of Jackass Morwong (*Nemadactylus macropterus*) based on data up to 2014

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10.1 Summary

This paper presents the data and results from a preliminary assessment developed to assist the establishment of a 2015 base-case assessment of the western stock of jackass morwong *Nemadactylus macropterus* in the Southern and Eastern Scalefish and Shark Fishery (SESSF). The assessment uses an age- and size-structured model implemented using the generalized stock assessment software package, Stock Synthesis (SS). The assessment includes data up to the end of the 2014 calendar year. Data include annual landings, catch rates, and length/age compositions. The main purpose of this document is to initiate discussion regarding the data to be used and the assumptions to be included in the base-case model structure.

Results from the 2015 preliminary assessment conclude that the spawning biomass of the western stock of jackass morwong in 2016 will be 66% of the unexploited biomass. In comparison, the last full assessment in 2011 estimated the 2012 spawning biomass to be 67% of the unexploited equilibrium stock biomass. However, due to limited recent data, very low catches (only 13t in 2014) and the existence of a strong conflict between the length data and the catch rate data, the robustness of model results should be questioned. Models where greater emphasis is given to the trend evident in the abundance index should be considered, including Tier 4 for this stock. In addition, exploration of the data (in particular length and age) should be conducted to see if these data sources are representative, and do not show inconsistencies due to sampling (eg bias from seasonality or spatial variation).

10.2 Introduction

An integrated analysis model, implemented using the generalized stock assessment software package, Stock Synthesis (SS) (Methot, 2011; Methot and Wetzel, 2013. V3.24U), was applied to the western stock of jackass morwong of the SESSF, with data from the 1986 to the 2014 calendar year (length and age data; age-error, catch rate series; Fishery Independent Survey (FIS), and landings). The model fits directly to length frequencies and conditional age-at-length data.

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

10.3 Data

The assessment data for the western (Zones 40/50) stock of jackass morwong assumes a single trawl fleet. Data series have been updated to the end of 2014. Length data have been separated into samples collected in port and onboard commercial trawl vessels, with a single trawl selectivity function estimated. Other data series include age-at-length data, catch rate series (Sporcic and Haddon, 2015), the FIS (Knuckey et al, 2015), the annual total mass landed, and age-reading error.

10.3.1 *Catch and catch rates*

Landed catch data for the western stock of jackass morwong since 2011 were updated by scaling up logbook data using the ratio of total landed morwong catch to total logbook morwong catch. The catches for the years prior to 2012 were the same as those on which the 2011 was based. After peaking in the early 2000s, catch has since declined substantially, to be less than 50 t per year since 2012 (Table 10.1; Figure 10.1).

Table 10.1. Landed morwong catches (mt) and catch rates for the western stock of jackass morwong.

	Catch (mt)	CPUE
1986	153	1.97
1987	60	1.54
1988	67	2.30
1989	85	1.67
1990	83	1.68
1991	47	1.15
1992	72	0.93
1993	27	0.90
1994	27	0.87
1995	91	0.92
1996	44	1.01
1997	62	0.80
1998	65	0.84
1999	89	0.77
2000	134	1.11
2001	316	1.20
2002	289	1.20
2003	199	1.01
2004	216	1.07
2005	230	1.15
2006	217	0.92
2007	140	0.75
2008	124	0.76
2009	77	0.61
2010	47	0.44
2011	99	0.47
2012	41	0.35
2013	42	0.34
2014	13	0.26

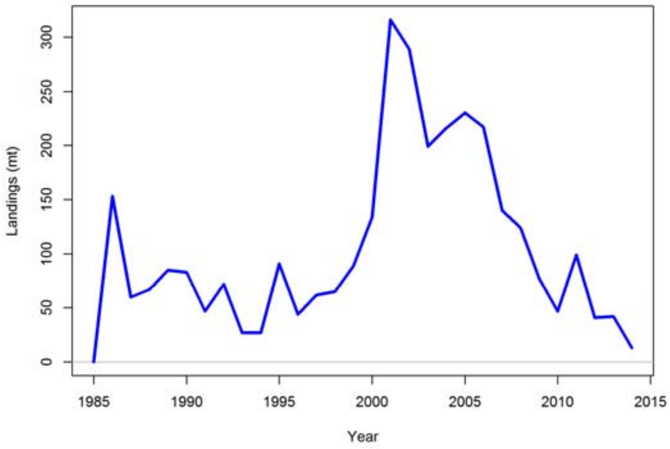


Figure 10.1. Landed morwong catches (mt) for the western stock of jackass morwong

Sporcic and Haddon (2015) provide the updated standardized catch rate series for the western stock of jackass morwong (Figure 10.1 and Figure 10.2). After a substantial decline in catch rate from the mid-1980s to early 1990s, the catch rate levelled before showing a further decline from the mid-2000s. The catch rate series from the updated analysis is similar to that used in the last assessment in 2011 (Wayte, 2011).

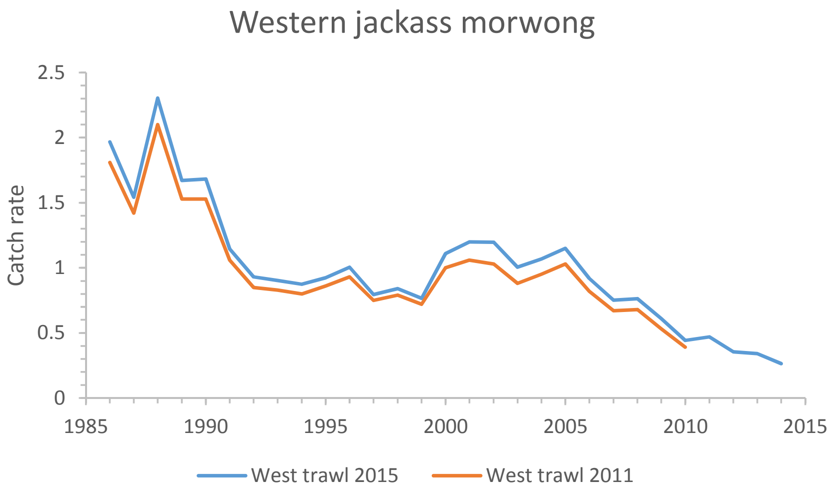


Figure 10.2. The western stock of jackass morwong standardised CPUE for the trawl fleets (Sporcic and Haddon, 2015). This figure shows a comparison between the series used in the 2011 assessment and that used in the current assessment (2015).

10.3.2 *Length frequencies and age data*

Length data have been separated into records collected in port and onboard commercial vessels. Age data have been included in the model as conditional age-at-length data. Age composition data is included in diagnostic plots, but is not used directly within the fitting procedure. Figures of the observed length and age data are shown in later figures (Figure 10.8 to Figure 10.11), with the corresponding model predicted values. Table 10.2 shows (by year) the number of fish sampled onboard and in port with corresponding counts of shots or trips.

Table 10.2. The number of fish sampled, shots and trips for onboard and port length measurements. Grey cells indicate length records that were excluded due to small sample sizes (fish sampled <100).

	Onboard		Port	
Year	Number fish	Number shots	Number fish	Number trips
1996	-	-	364	3
1997	245	2	505	4
1998	373	4	2	1
1999	412	4	341	3
2000	124	1	572	5
2001	1434	11	2232	18
2002	859	4	1918	12
2003	124	1	1680	10
2004	397	3	873	10
2005	2116	15	1426	14
2006	820	6	690	7
2007	-	-	-	-
2008	47	2	109	1
2009	140	4		
2010	72	2		
2011	208	9		
2012	318	17		
2013	723	25	53	1
2014	241	6	61	1

10.3.3 *Age-reading error*

The ages are assumed to be unbiased but subject to random age-reading errors. Standard deviations for aging error by reader have been estimated, producing the age-reading error matrix of Table 10.3 (A.E. Punt, pers. comm.).

Table 10.3. The standard deviation (StDev) of age reading error.

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

10.3.4 *Fishery independent survey (FIS) estimates*

Abundance indices for jackass morwong for the surveys conducted in 2008, 2010, 2012 and 2014 are provided in Knuckey et al. (2015). Indices from the FIS were re-estimated for the western stock of jackass morwong (Zones 40/50) (Table 10.4). The FIS is assumed to mirror the trawl fleet.

Table 10.4. FIS derived abundance indices for the western stock of jackass morwong with corresponding coefficient of variation (cv).

	2008	2010	2012	2014
West Index	51.56	25.52	39.26	7.27
c.v.	0.25	0.26	0.25	0.27

10.3.5 *Biological parameters*

A single-sex single-stock assessment for the western stock of jackass morwong was conducted using the software package Stock Synthesis (SS, version 3.24U). Selectivity of the trawl fleet was modelled as being time-invariant and a logistic function of length. The two parameters of the selectivity function for each fleet were estimated within the assessment.

The rate of natural mortality rate, *M*, was assumed to be constant with age, and also time-invariant. The rate of natural mortality for the base-case analysis was set to 0.15 yr^{-1} in accordance with previous assessments (Table 10.3).

Recruitment was assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterized by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, *h*. Steepness for the base-case analysis was set to 0.7, in accordance with previous assessments (Wayte, 2011). Deviations from the average recruitment at a given spawning biomass (recruitment deviations) were estimated for 1989-2011. Recruitment deviations are estimated to 2011, as the recruitment signal from young fish must have appeared in the catch and length frequency data in sufficient numbers to allow its estimation. The value of the parameter determining the magnitude of the process error in annual recruitment, σ_R, was set equal to 0.46 (Wayte, 2011). Tuning to σ_R suggested lower values, but these were unrealistic and so the value was set at that used in Wayte (2011).

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

Port and onboard length frequency data based on fewer than 100 fish were not included in the model fitting procedure as they were deemed to be insufficient samples. As the effective sample size for length frequency data is probably more related to the number of shots sampled for onboard data and trips for port data, those values are used as the initial effective sample sizes. The length frequency data would be given too much weight relative to other data sources if the number of fish measured were used. The sample sizes (with port and onboard lengths fit separately) were also individually tuned according to the method T1.8 outlined in Francis (2011).

The values assumed for some of the (non-estimated) parameters of the base case models are shown in Table 10.5.

Table 10.5. Parameter values assumed for some of the non-estimated parameters of the base-case model.

Parameter	Description	Value
M	Natural mortality	0.15
σ_r	Initial c.v. for the recruitment residuals	0.46
h	"steepness" of the Beverton-Holt stock-recruit curve	0.7
x	age observation plus group	25 years
a	allometric length-weight equations	1.7×10^{-5}
b	allometric length-weight equations	3.031
l_m	Female length at 50% maturity	24.5cm

10.4 The Tuning Procedure

The tuning procedure used (Andre Punt pers comm.; from Thomson *et al.* 2015) was to:

1. Set the CV for the commercial CPUE value 0.1 for all years (set those for the FIS to the estimated CVs) (this relatively low value is used to encourage a good fit to the abundance data);
2. Simultaneously tune the sample size multipliers for the length frequencies and ages using Francis weights for the LFs and Francis B (the larger of the Francis A and B factors, Francis 2011). Iterate to convergence;
3. Adjust the recruitment variance (σ_r) by replacing it with the RMSE and iterating to convergence (keep altering the recruitment bias adjustment ramps at the same time);
4. Weight the commercial CPUE and FIS abundance indices by replacing these with the relevant variance adjustment factors. Iterate to convergence;
5. Reweight the age data using the Francis A adjustment factor, just once (no iterating);
6. Repeat steps 3 and 4.

10.5 Results and Discussion

10.5.1 *The base case stock assessment*

10.5.1.1 Comparison to the 2011 assessment

The base-case model largely uses the same assumptions and settings as the last full assessment in 2011. Recruitment deviations are estimated up until three years before the end of the data.

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 (Wayte, 2011). The 2015 assessment separates port and onboard length frequency data but estimates a single shared selectivity. Other changes include updates of data to the end of the 2014 calendar year as described earlier. FIS abundance estimates are also included, with the selectivity assumed equal to that of the commercial trawl fleet.

Figure 10.3 shows the biomass and recruitment trajectories from

(i) the 2011 assessment (Wayte, 2011) (Ass_2011_W)

(ii) the un-tuned trajectory with updated data to 2014 (and tuning parameterization from Wayte (2011)), (WNew_C_CPUE_LPORTON_AGE_ERR_R_FIS)

(iii) the new base case (following the tuning procedure in Section 4 above) (WNew_OPS_Tune_Full) and

(iv) a model that only has lengths and ages tuned (CPUE weights are unadjusted, cv=0.1; only steps 1 to 3 in the tuning procedure are conducted; see Discussion) (WNew_Ops_Tune_LAonly)

This figure illustrates that there is little change in the historical trajectory between the first three model configurations.

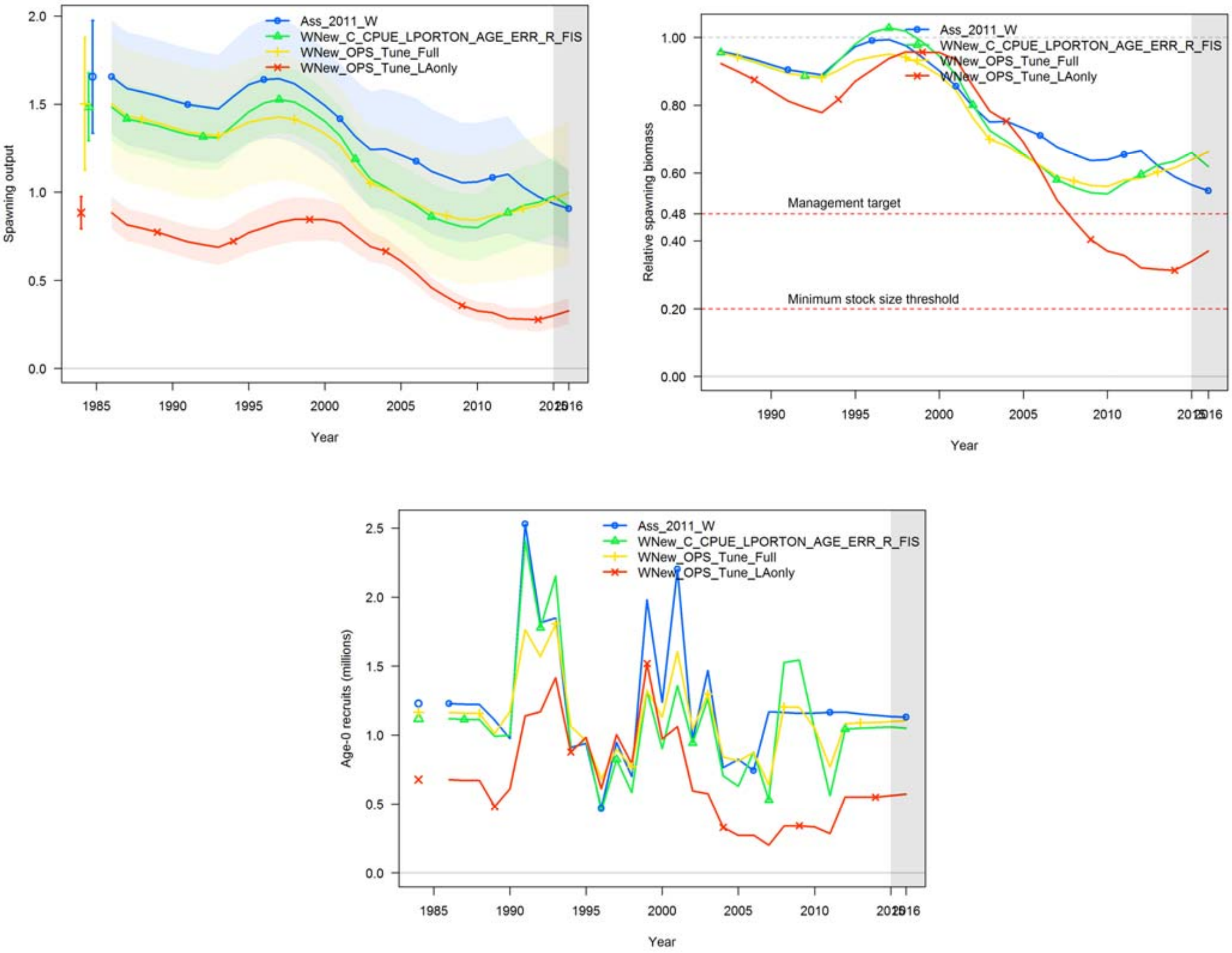


Figure 10.3. The spawning biomass and estimated recruitment trajectories for the western stock of jackass morwong. Ass_2011_W is the assessment from 2011; WNewC_CPUE_LPORTON_AGE_ERR_R_FIS is a model with updated data to 2014, but with the same tuning parameterization as the 2011 assessment; WNew_OPS_Tune_Full is the new fully tuned base-case assessment, and WNew_OPS_Tune_LAonly is a model where only the length/age data have been tuned.

10.5.1.2 *Base case parameter estimates and model fits*

A listing of the data for the fully tuned base case model is shown in Figure 10.4, and the growth, length-weight, and selectivity functions for the various fleets are shown in Figure 10.5 and Figure 10.6. Fits to the data are shown in Figure 10.7 to Figure 10.12 (and the Appendix), and the estimated spawning biomass trajectory for the base-case model is illustrated in Figure 10.3 and Figure 10.13.

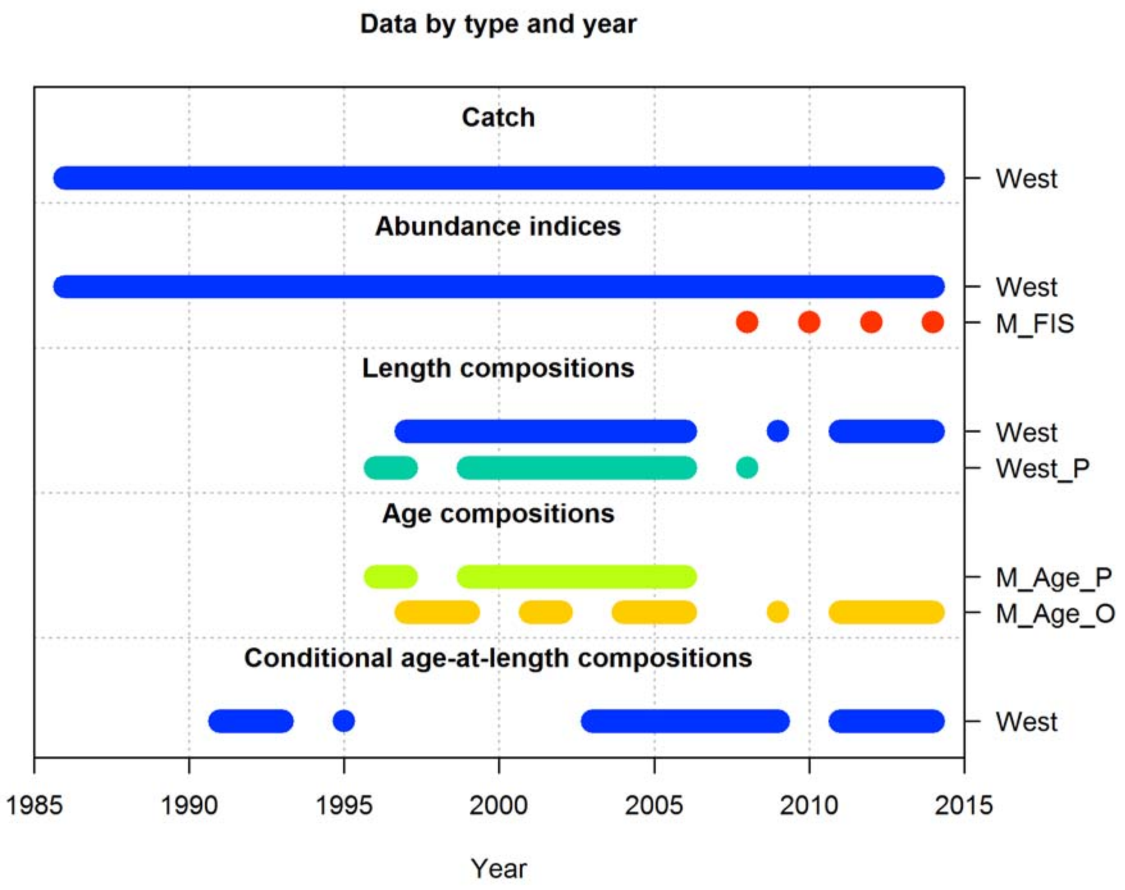


Figure 10.4. The various data types by fleet for the western stock of jackass morwong.

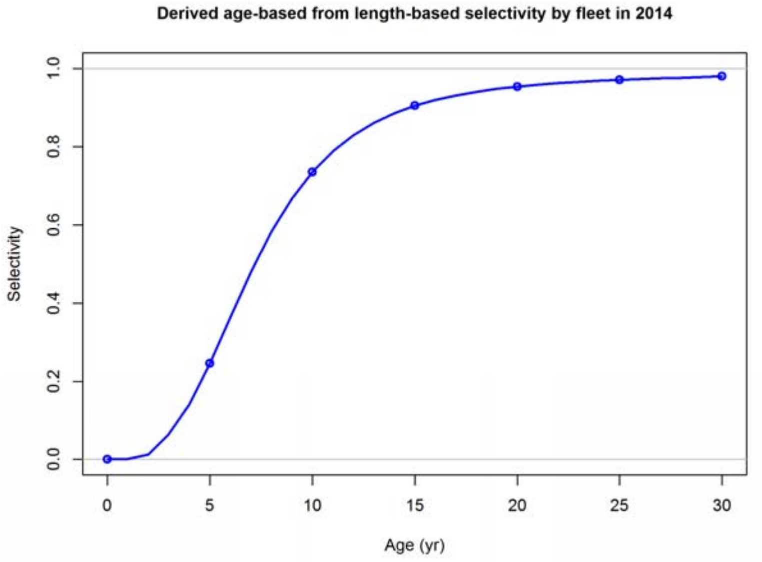


Figure 10.5. Selectivity for the western stock of jackass morwong.

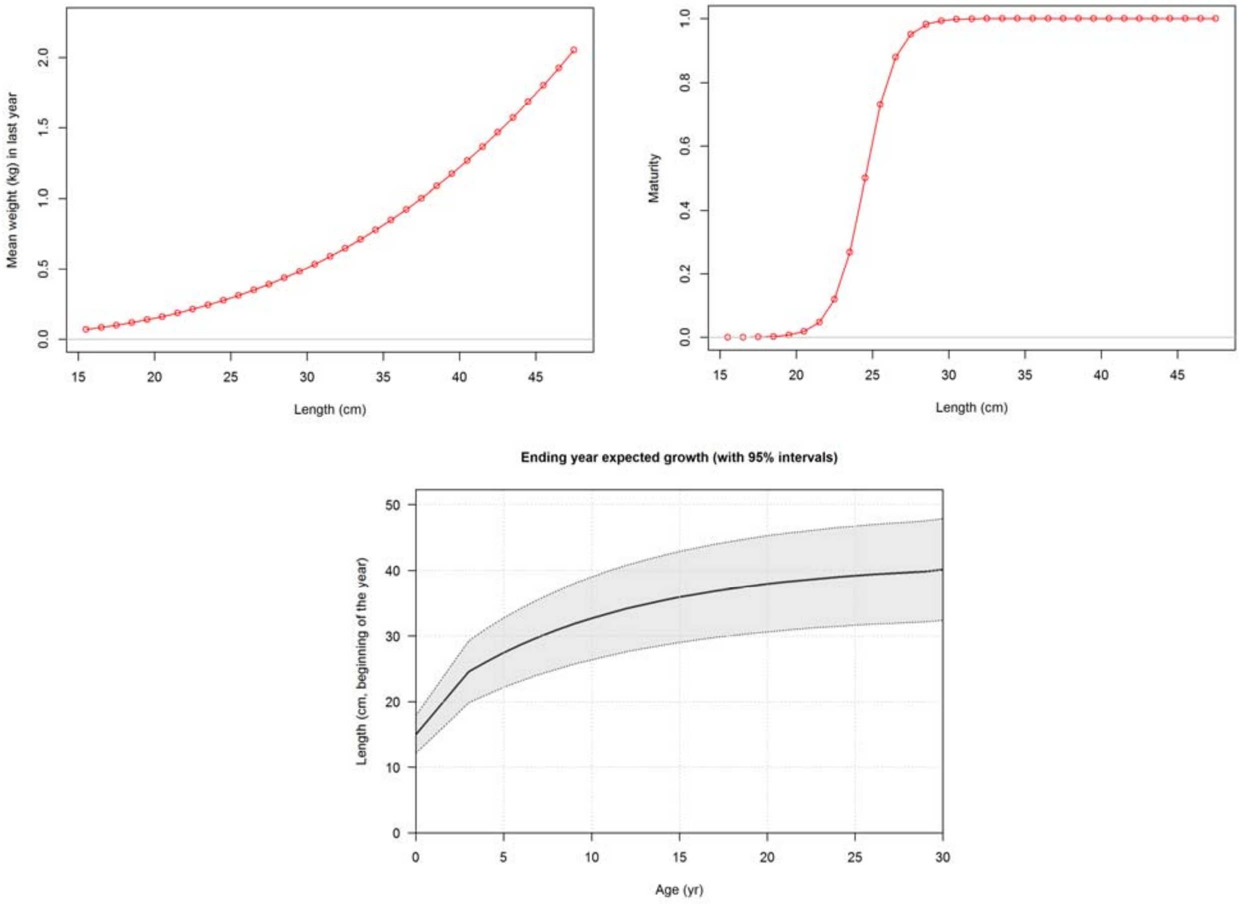


Figure 10.6. The length-weight (left), maturity ogive (right) and length-age relationships (bottom) for the western stock of jackass morwong base case assessment.

10.5.1.3 Fits to the data

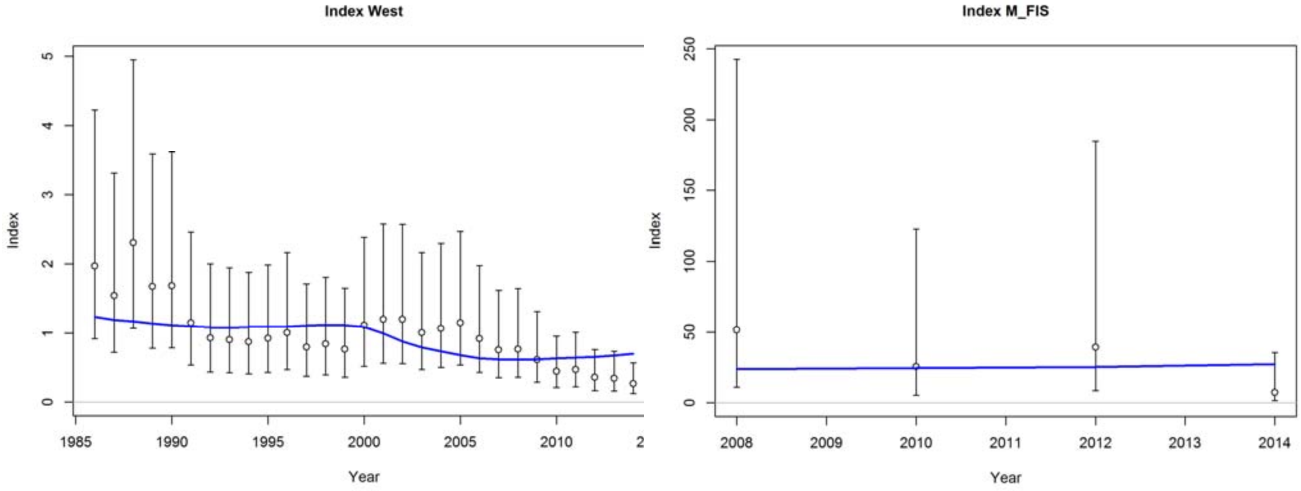


Figure 10.7. Fits to the standardized trawl CPUE (left) and the FIS indices (right) for the western trawl fishery for jackass morwong.

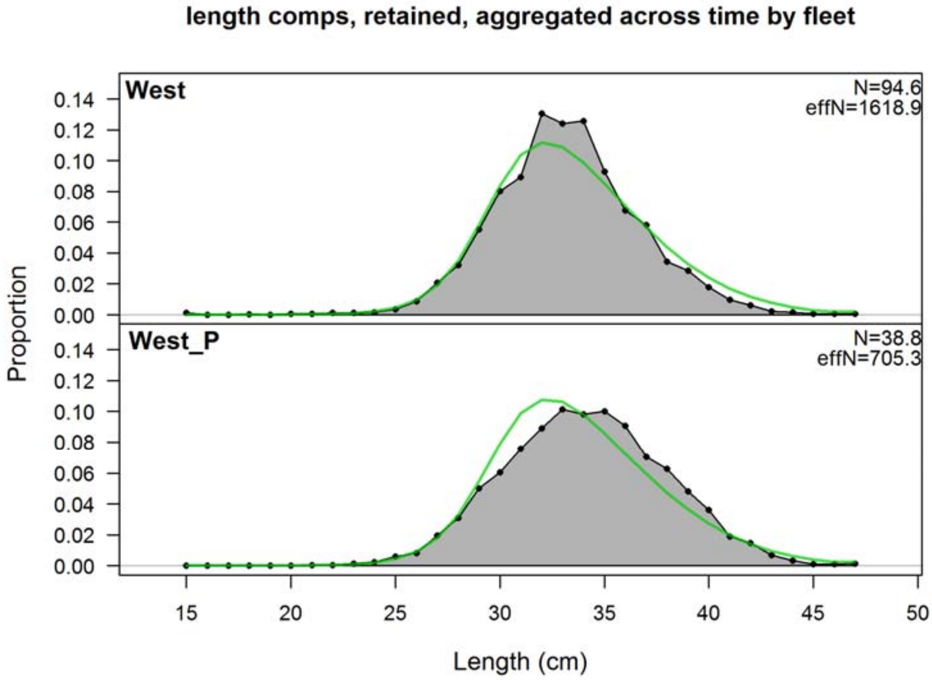
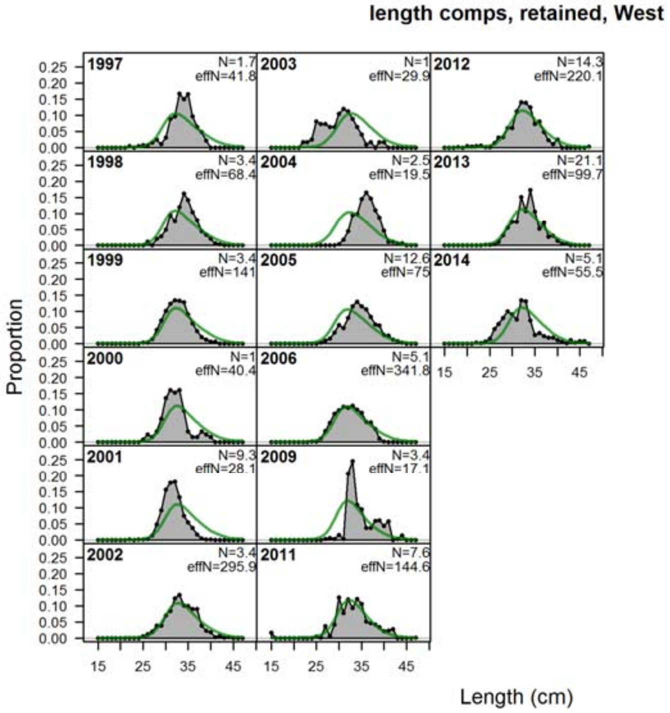


Figure 10.8. Fits to the retained length by fleet (West_P = Port, West = onboard)



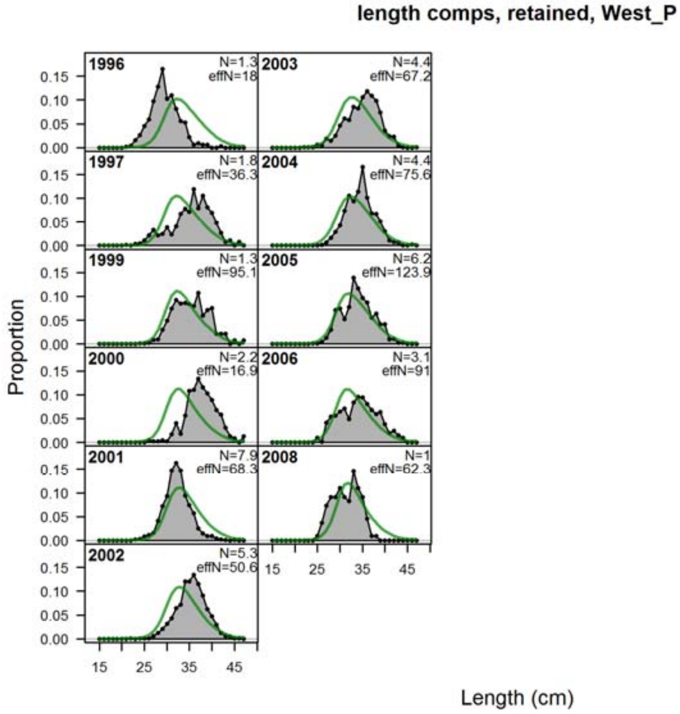


Figure 10.9. Fits to the retained length by year and fleet (West_P = Port, West = onboard).

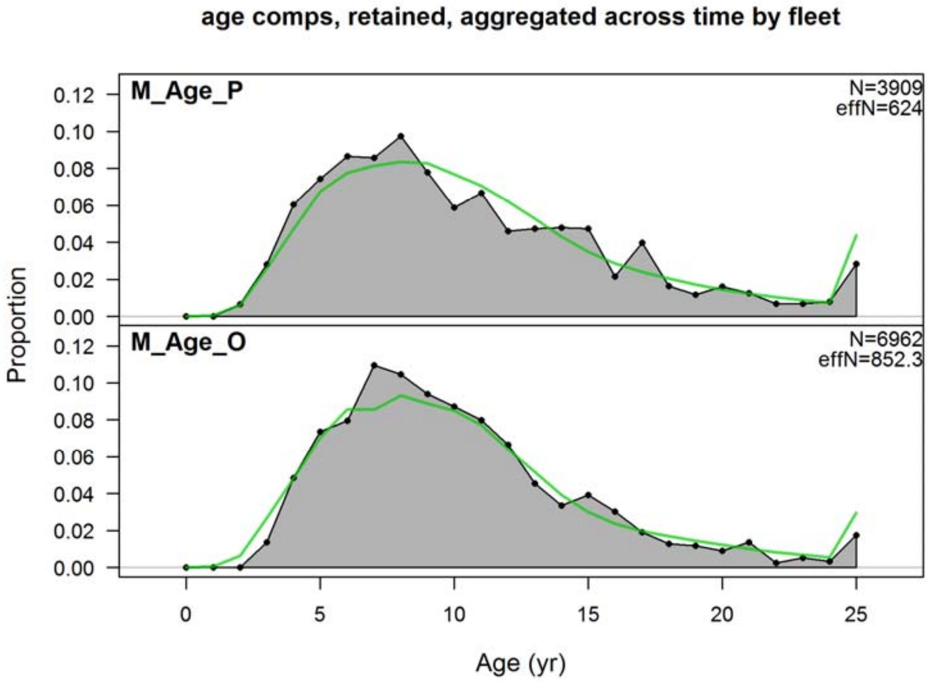


Figure 10.10. The implied fits to port (top) and onboard (bottom) age composition data for the western stock of jackass morwong.

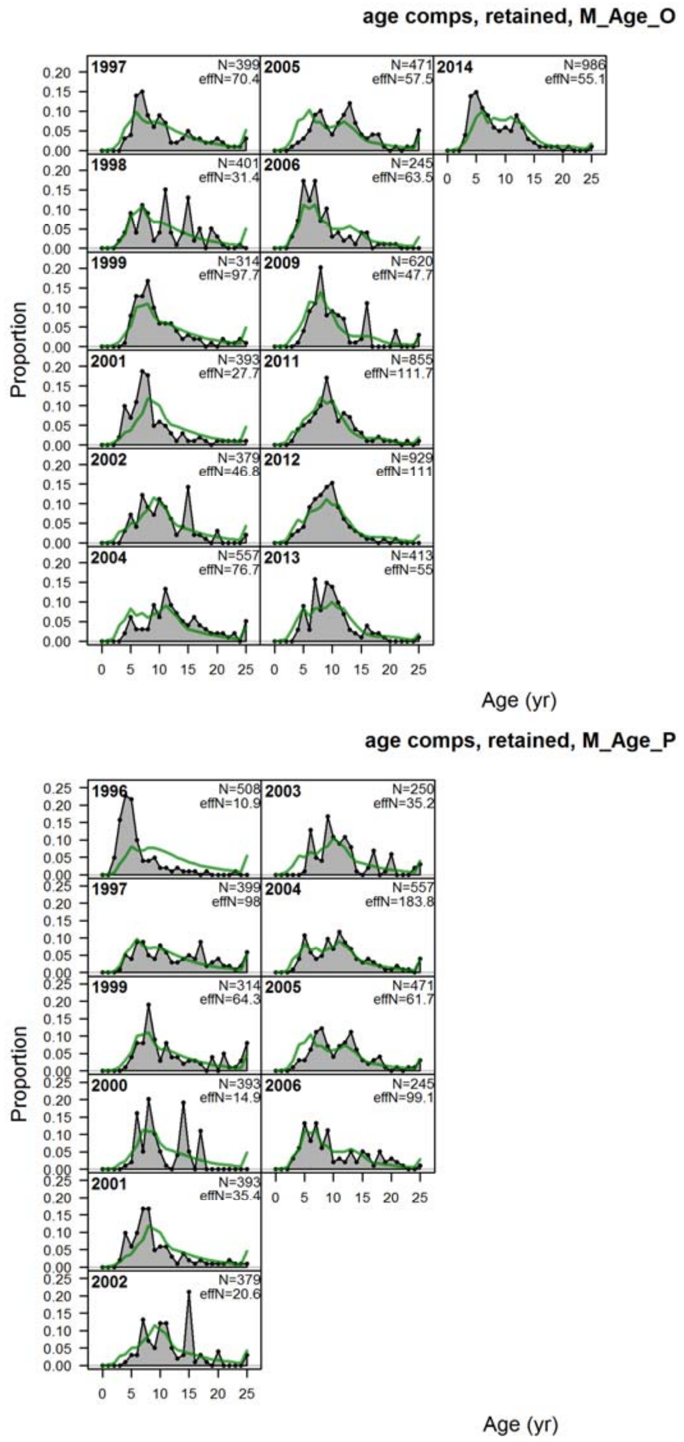


Figure 10.11. The implied fits to onboard (top) and port (bottom) age composition data by year for the western stock of jackass morwong.

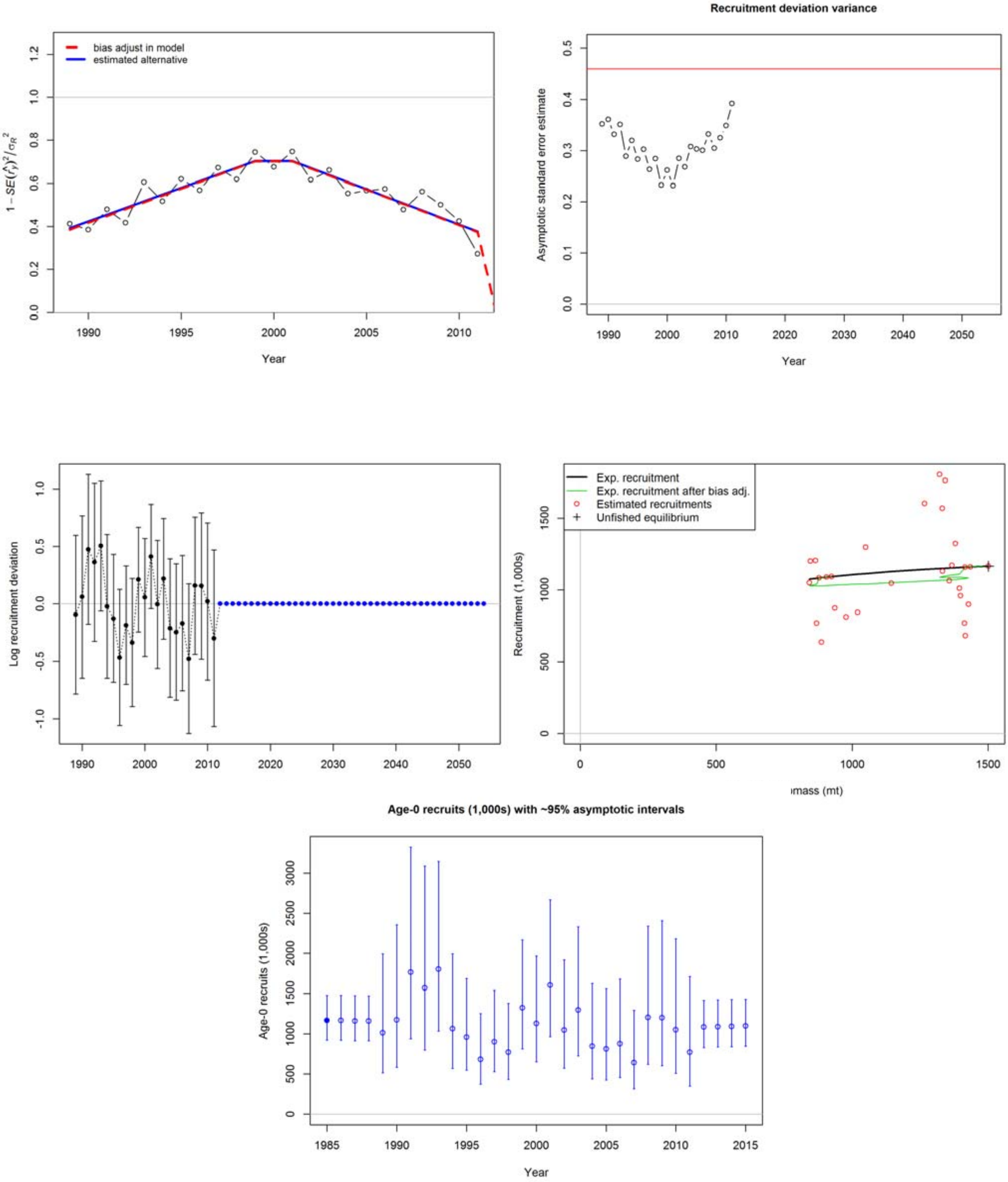


Figure 10.12. Diagnostics for recruitment, the stock–recruitment relationship and annual estimates of recruitment numbers with confidence intervals.

10.5.1.4 Assessment outcomes

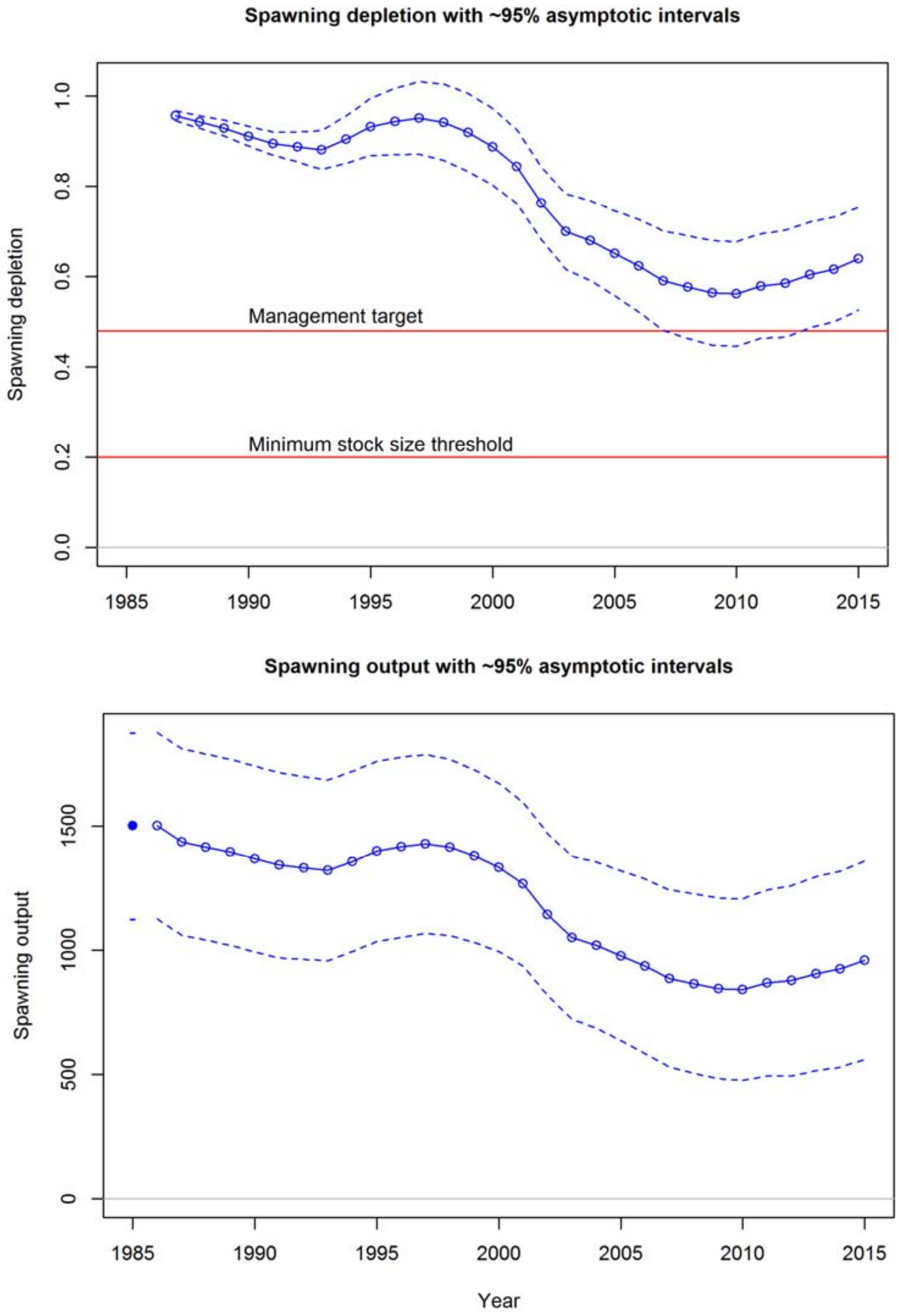


Figure 10.13. Time trajectories of spawning biomass depletion with 95% confidence intervals for the base case assessment of the western stock of jackass morwong.

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

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11.1 Summary

This chapter presents the data and results from the 2015 assessment of the western stock of jackass morwong *Nemadactylus macropterus* in the Southern and Eastern Scalefish and Shark Fishery (SESSF). The assessment uses an age- and size-structured model implemented using the generalized stock assessment software package, Stock Synthesis (SS). The assessment includes data up to the end of the 2014 calendar year. Data include annual landings, catch rates, and length/age compositions.

The 2015 base case assessment of the western stock of jackass morwong estimates the 2016 spawning biomass to be 69% of unexploited biomass. In comparison, the last full assessment in 2011 estimated the 2012 spawning biomass to be 67% of unexploited biomass. The female equilibrium spawning biomass in 1986 is estimated to be 1,349 t and in 2016 the female spawning biomass is estimated to be 936 t. The RBC for the base case assessment for the western stock of jackass morwong under the 20:35:48 harvest control rule is 249 t. The long-term RBC is 159 t.

It should be noted that the assessment for the western stock is increasingly uncertain, as (i) there are only sporadic age data available, (ii) length compositions are based on low numbers of sampled fish and (iii) the catch in the western region is now very low. There is also strong conflict between the length data and the catch rate data. As such, the robustness of model results should be questioned. Models where greater emphasis is given to the trend evident in the abundance index should be considered, including Tier 4 for this stock.

11.2 Introduction

An integrated analysis model, implemented using the generalized stock assessment software package, Stock Synthesis (SS) (Methot, 2011; Methot and Wetzel, 2013. V3.24U), was applied to the western stock of jackass morwong of the SESSF, with data from the 1986 to the 2014 calendar year (length and age data; age-error, catch rate series; Fishery Independent Survey (FIS), and landings). The model fits directly to length frequencies and conditional age-at-length data.

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

11.3 Data

The assessment data for the western (Zones 40/50) stock of jackass morwong assumes a single trawl fleet. Data series have been updated to the end of 2014. Length data have been separated into samples collected in port and onboard commercial trawl vessels, with a single trawl selectivity function estimated. Other data series include age-at-length data, catch rate series (Sporcic and Haddon, 2015), the FIS (Knuckey et al, 2015), the annual total mass landed, and age-reading error.

11.3.1 *Catch and catch rates*

Landed catch data for the western stock of jackass morwong since 2011 were updated by scaling up logbook data using the ratio of total landed morwong catch to total logbook morwong catch. The catches for the years prior to 2012 were the same as those on which the 2011 assessment was based. After peaking in the early 2000s, catch has since declined substantially, to be less than 50 t per year since 2012 (Table 11.1; Figure 11.1).

Table 11.1. Landed morwong catches (mt) and catch rates for the western stock of jackass morwong.

	Catch (mt)	CPUE
1986	153	1.97
1987	60	1.54
1988	67	2.30
1989	85	1.67
1990	83	1.68
1991	47	1.15
1992	72	0.93
1993	27	0.90
1994	27	0.87
1995	91	0.92
1996	44	1.01
1997	62	0.80
1998	65	0.84
1999	89	0.77
2000	134	1.11
2001	316	1.20
2002	289	1.20
2003	199	1.01
2004	216	1.07
2005	230	1.15
2006	217	0.92
2007	140	0.75
2008	124	0.76
2009	77	0.61
2010	47	0.44
2011	99	0.47
2012	41	0.35
2013	42	0.34
2014	13	0.26

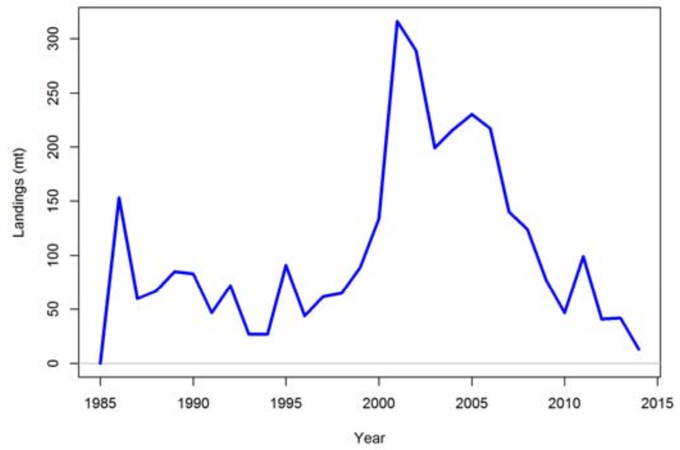


Figure 11.1. Landed morwong catches (mt) for the western stock of jackass morwong

Sporcic and Haddon (2015) provide the updated standardized catch rate series for the western stock of jackass morwong (Figure 11.2). After a substantial decline in catch rate from the mid-1980s to early 1990s, the catch rate levelled before showing a further decline from the mid-2000s. The catch rate series from the updated analysis is similar to that used in the last assessment in 2011 (Wayte, 2011).

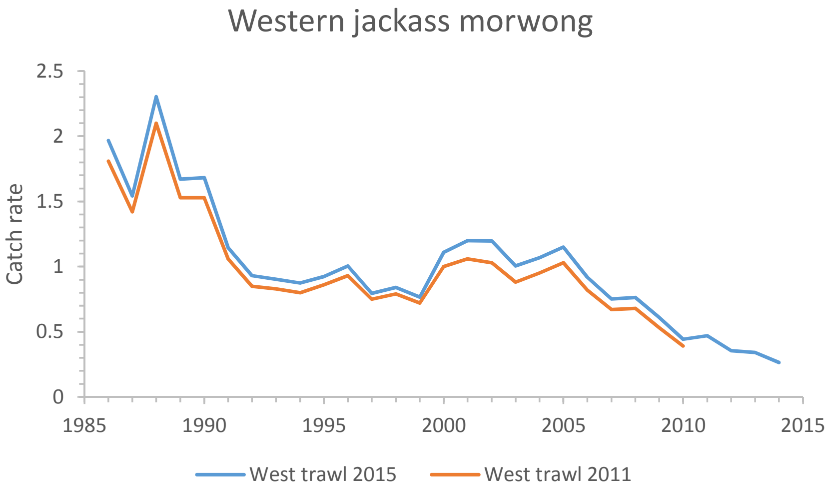


Figure 11.2. The western stock of jackass morwong standardised CPUE for the trawl fleets (Sporcic and Haddon, 2015). This figure shows a comparison between the series used in the 2011 assessment and that used in the current assessment (2015).

11.3.2 *Length frequencies and age data*

Length data have been separated into records collected in port and onboard commercial vessels. Age data have been included in the model as conditional age-at-length data. Age composition data is included in diagnostic plots, but is not used directly within the fitting procedure. Figures of the observed length and age data are shown in later figures (Figure 11.8 to Figure 11.11), with the corresponding model predicted values. Table 11.2 shows (by year) the number of fish lengths sampled onboard and in port with corresponding counts of shots or trips.

Table 11.2. The number of fish sampled, shots and trips for onboard and port length measurements. Grey cells indicate either length records that were excluded due to small sample sizes (fish sampled <100) or age samples less than 50.

	Ages	Onboard Lengths		Port Lengths	
Year	Samples	Number fish	Number shots	Number fish	Number trips
1996		-	-	364	3
1997		245	2	505	4
1998		373	4	2	1
1999		412	4	341	3
2000		124	1	572	5
2001		1434	11	2232	18
2002		859	4	1918	12
2003	83	124	1	1680	10
2004	474	397	3	873	10
2005	282	2116	15	1426	14
2006	156	820	6	690	7
2007	51	-	-	-	-
2008	24	47	2	109	1
2009	49	140	4		
2010		72	2		
2011	41	208	9		
2012	87	318	17		
2013	118	723	25	53	1
2014	37	241	6	61	1

11.3.3 *Age-reading error*

The ages are assumed to be unbiased but subject to random age-reading errors. Standard deviations for aging error by reader have been estimated, producing the age-reading error matrix of Table 11.3 (A.E. Punt, pers. comm.).

Table 11.3. The standard deviation (StDev) of age reading error.

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

11.3.4 *Fishery independent survey (FIS) estimates*

Abundance indices for jackass morwong for the surveys conducted in 2008, 2010, 2012 and 2014 are provided in Knuckey et al. (2015). Indices from the FIS were re-estimated for the western stock of jackass morwong (Zones 40/50) (Table 11.4). The length composition data from the FIS have not been included in this assessment and the FIS is assumed to have the same selectivity as the trawl fleet.

Table 11.4. FIS derived abundance indices for the western stock of jackass morwong with corresponding coefficient of variation (cv).

	2008	2010	2012	2014
West Index	51.56	25.52	39.26	7.27
c.v.	0.25	0.26	0.25	0.27

11.3.5 *Biological parameters*

A single-sex single-stock assessment for the western stock of jackass morwong was conducted using the software package Stock Synthesis (SS, version 3.24U). Selectivity of the trawl fleet was modelled as being time-invariant and a logistic function of length. The two parameters of the selectivity function for each fleet were estimated within the assessment.

The rate of natural mortality rate, M, was assumed to be constant with age, and also time-invariant. The rate of natural mortality for the base-case analysis was set to 0.15 yr^{-1} in accordance with previous assessments (Table 11.3).

Recruitment was assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterized by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, *h*. Steepness for the base-case analysis was set to 0.7, in accordance with previous assessments (Wayte, 2011). Deviations from the average recruitment at a given spawning biomass (recruitment deviations) were estimated for 1989-2011. Recruitment deviations are estimated to 2011, as the recruitment signal from young fish must have appeared in the catch and length frequency data in sufficient numbers to allow its estimation. The value of the parameter determining the magnitude of the process error in annual recruitment, σ_R, was set equal to 0.46 (Wayte, 2011). Tuning to σ_R suggested lower values, but these were unrealistic and so the value was set at that used in Wayte (2011).

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

Port and onboard length frequency data based on fewer than 100 fish were not included in the model fitting procedure as they were deemed to be insufficient samples. As the effective sample size for length frequency data is probably more related to the number of shots sampled for onboard data and trips for port data, those values are used as the initial effective sample sizes. The length frequency data would be given too much weight relative to other data sources if the number of fish measured were used. The sample sizes (with port and onboard lengths fit separately) were also individually tuned according to the method TA1.8 outlined in Francis (2011).

The values assumed for some of the (non-estimated) parameters of the base case models are shown in Table 11.5.

Table 11.5. Parameter values assumed for some of the non-estimated parameters of the base-case model.

Parameter	Description	Value
M	Natural mortality	0.15
σ_r	Initial c.v. for the recruitment residuals	0.4
h	"steepness" of the Beverton-Holt stock-recruit curve	0.7
x	age observation plus group	25 years
a	allometric length-weight equations	1.7×10^{-5}
b	allometric length-weight equations	3.031
l_m	Female length at 50% maturity	24.5cm

11.4 The tuning procedure

The tuning procedure used (Andre Punt pers comm.; from Thomson *et al.* 2015) was to:

1. Set the CV for the commercial CPUE value 0.1 for all years (set those for the FIS to the estimated CVs) (this relatively low value is used to encourage a good fit to the abundance data);
2. Simultaneously tune the sample size multipliers for the length frequencies and ages using Francis weights for the LFs and Francis B (the larger of the Francis A and B factors, Francis 2011). Iterate to convergence;

3. Adjust the recruitment variance (σ_r) by replacing it with the RMSE and iterating to convergence (keep altering the recruitment bias adjustment ramps at the same time);
4. Weight the commercial CPUE and FIS abundance indices by replacing these with the relevant variance adjustment factors. Iterate to convergence;
5. Reweight the age data using the Francis A adjustment factor, just once (no iterating);
6. Repeat steps 3 and 4. Finish.

11.5 Results and Discussion

11.5.1 *The base case stock assessment*

Comparisons between the 2011 assessment results (Wayte, 2011) and updates with data to 2014 and updated assessment software (SS3.24Y) were conducted in the previous report (Tuck et al., 2015b) and not repeated here. These comparisons indicated consistency between data and assessment platforms.

Following recommendations from the September Shelf RAG originating from concerns regarding poor fits to catch rate data and length/age data largely driven by inconsistent year to year observed length and age compositions (which may in turn be related to small sample sizes) the assessment here (referred to as the base case assessment) removes all annual age records where samples are less than 50 (see Table 11.2) and uses the growth parameters from the eastern jackass morwong assessment base cade model (Tuck et al., 2015a). These growth parameters are *Lmin*=22.0 cm (length at age 3), *Lmax*=35.2cm (length at age 20), *K*=0.217, cv of growth = 0.104. The assessment model presented at the September RAG had growth parameters *Lmin*=24.5 cm (length at age 3), *Lmax*=38 cm (length at age 20), *K*=0.095, cv of growth = 0.1. Figure 11.3 shows that little difference exists between the relative biomass trajectories of the new base-case model and the model presented at the September Shelf RAG.

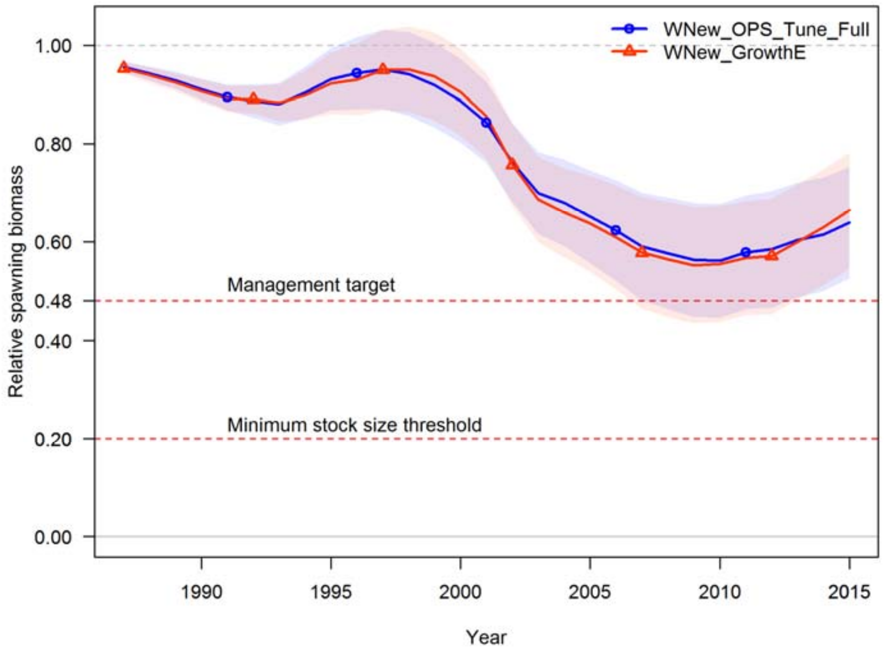


Figure 11.3. The relative spawning biomass trajectories for the western stock of jackass morwong. WNew_OPS_Tune_Full (blue) is the assessment presented at the September Shelf RAG, and WNew_GrowthE (red) is the new base case where growth parameters are taken from the eastern morwong assessment.

11.5.1.1 Base case parameter estimates and model fits

A listing of the data for the fully tuned base case model is shown in Figure 11.4, and the growth, length-weight, and selectivity functions for the various fleets are shown in Figure 11.5 and Figure 11.6. Fits to the data are shown in Figure 11.7 to Figure 11.11 (and the Appendix), and the estimated spawning biomass trajectory for the base-case model is illustrated in Figure 11.3 and Figure 11.13.

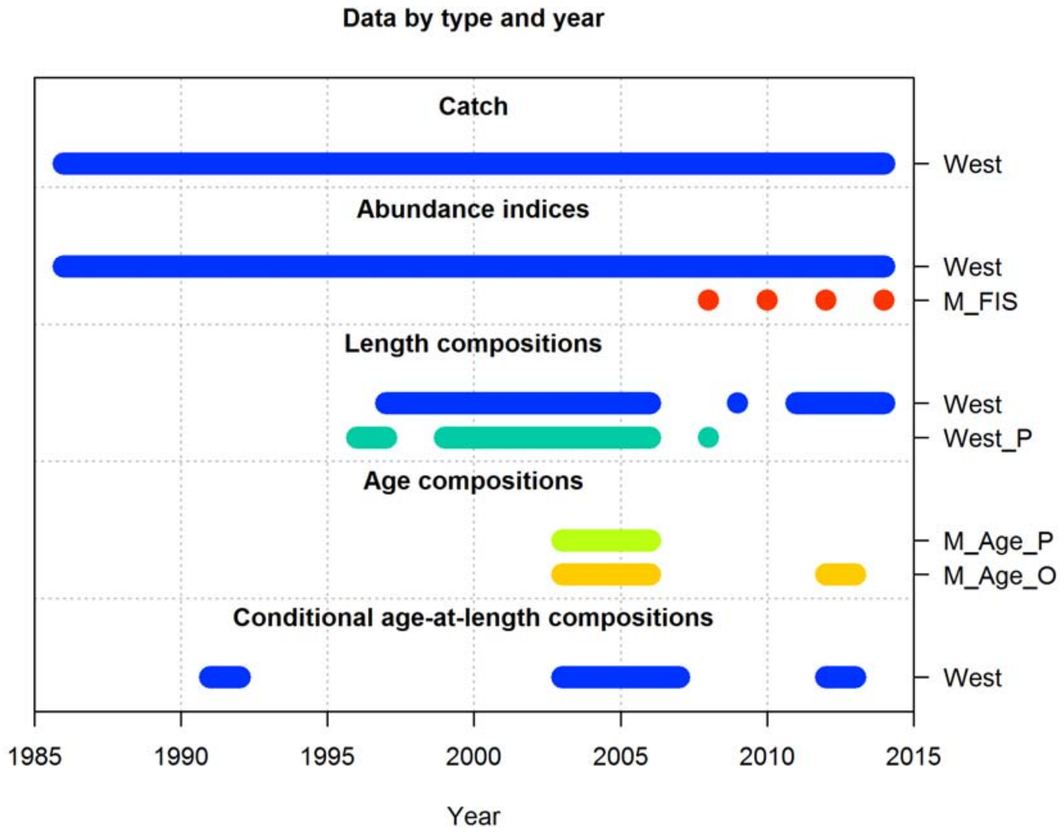


Figure 11.4. The various data types by fleet for the western stock of jackass morwong.

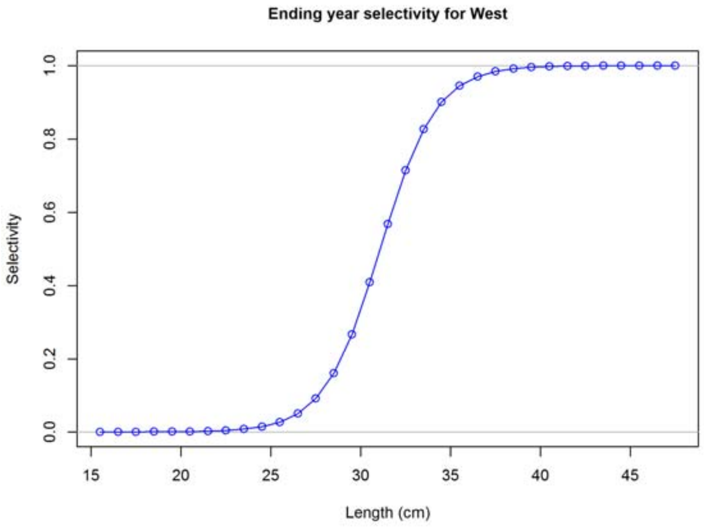


Figure 11.5. Selectivity for the western stock of jackass morwong

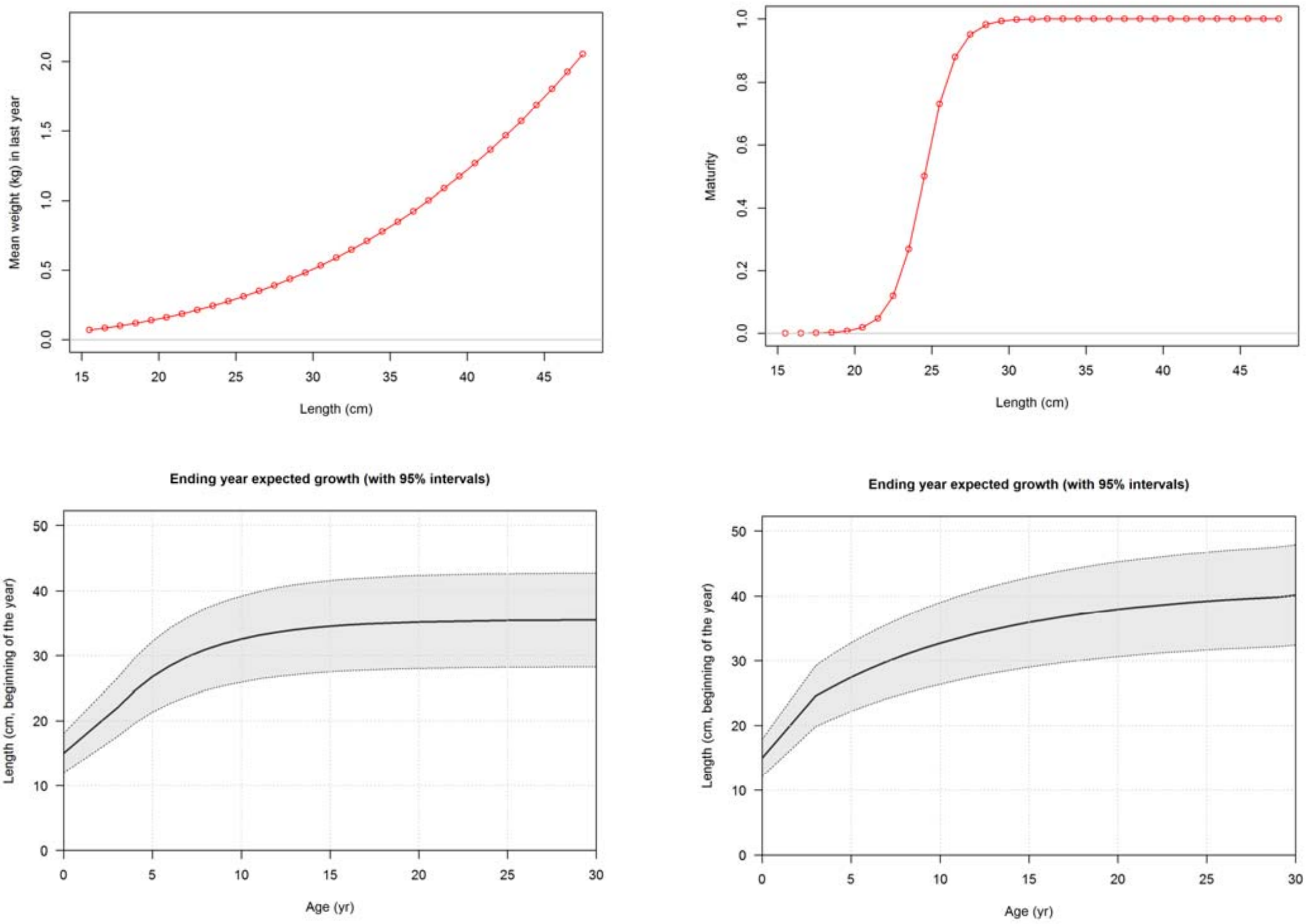


Figure 11.6. The length-weight (top left), maturity ogive (top right) and length-age relationships (bottom left) for the western stock of jackass morwong base case assessment. The length-age relationship from the assessment presented at the September 2015 RAG is shown for comparison (bottom right).

11.5.1.2 Fits to the data

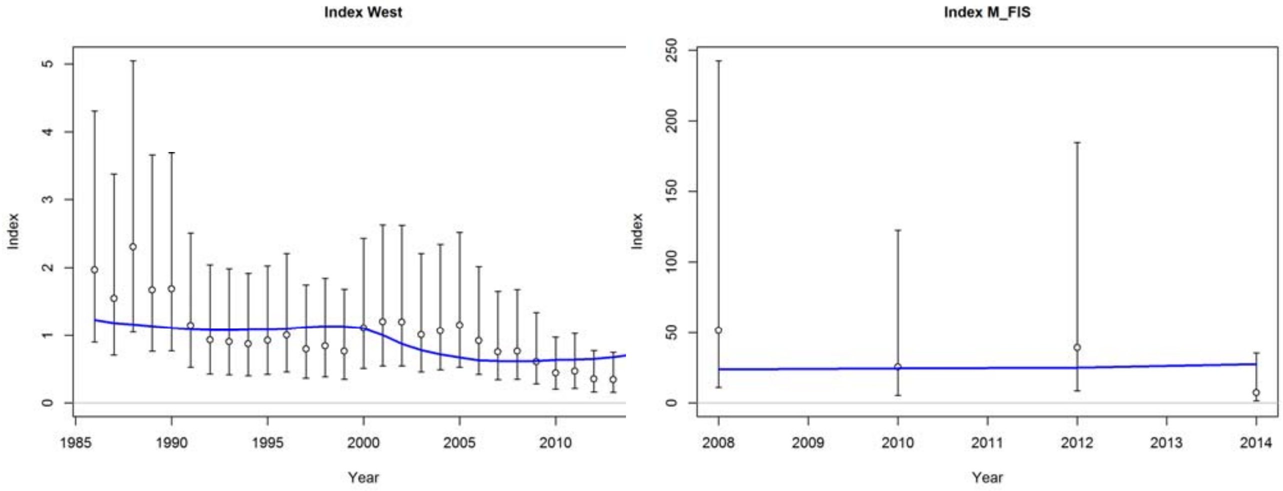


Figure 11.7. Fits to the standardized trawl CPUE (left) and the FIS indices (right) for the western trawl fishery for jackass morwong.

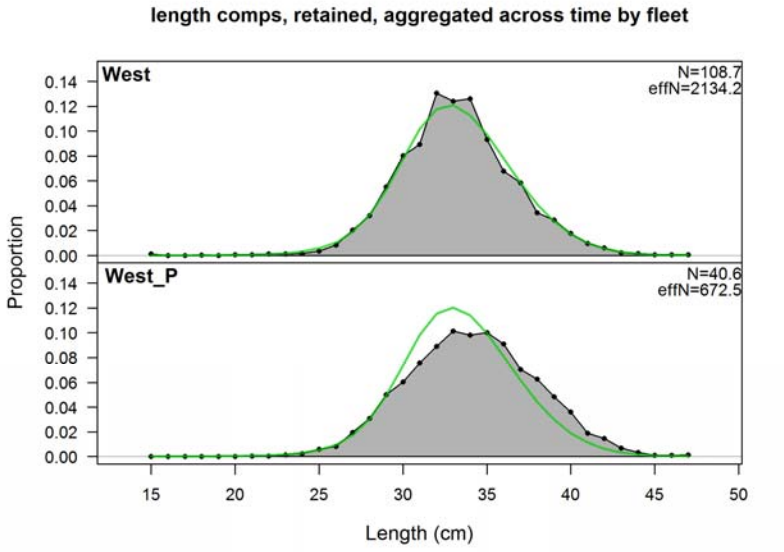
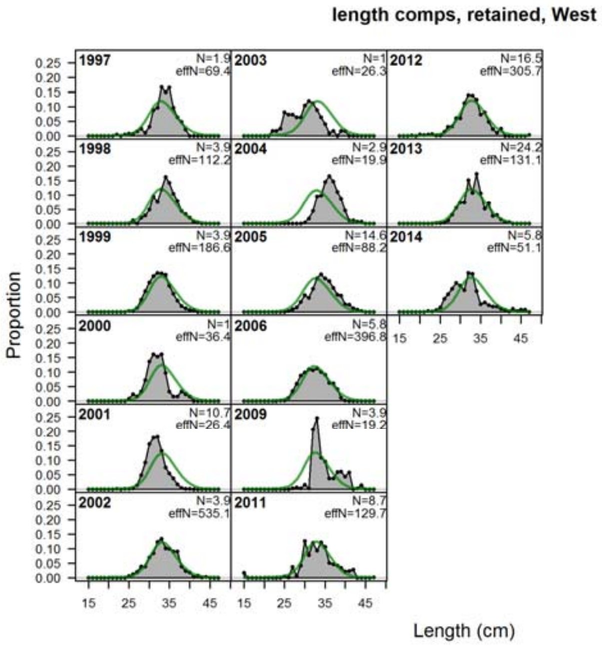


Figure 11.8. Fits to the retained length by fleet (West_P = Port, West = onboard).



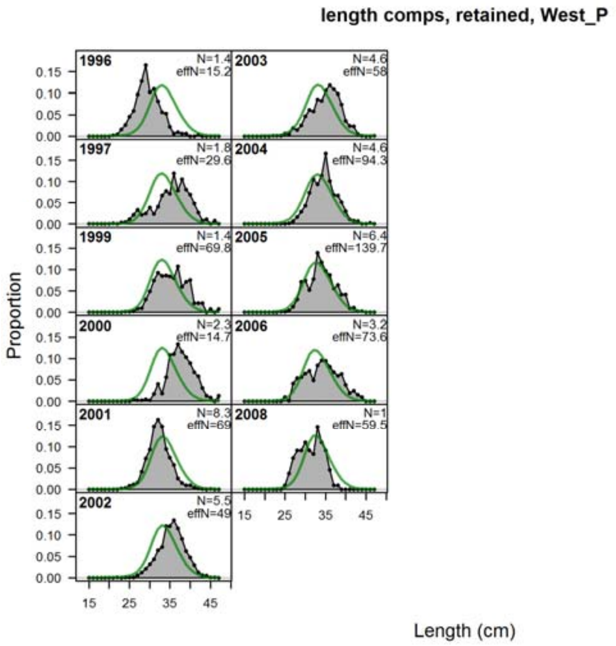


Figure 11.9. Fits to the retained length by year and fleet (West_P = Port, West = onboard).

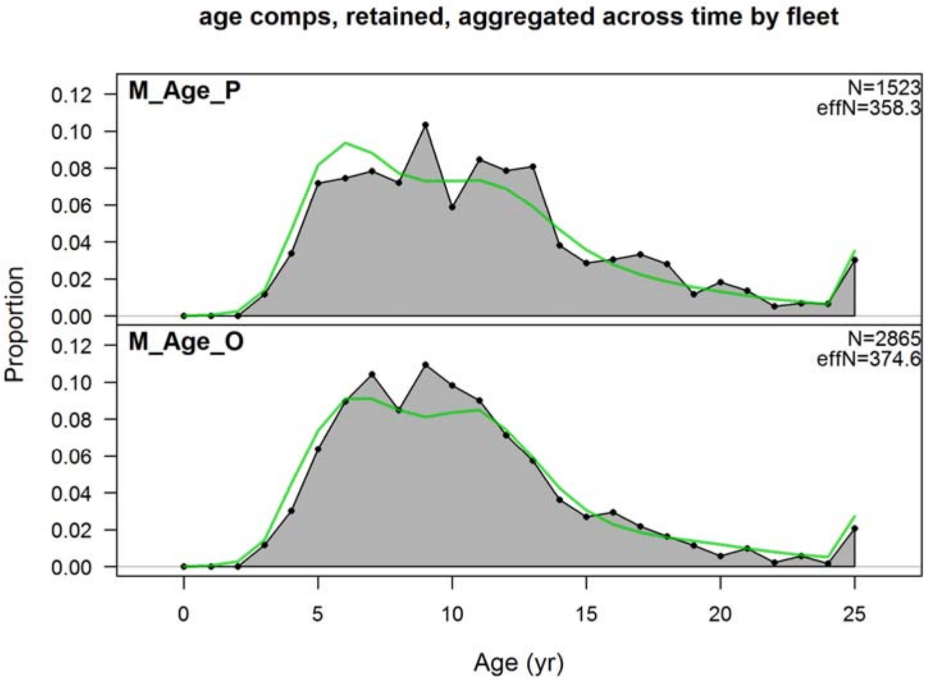


Figure 11.10. The implied fits to port (top) and onboard (bottom) age composition data for the western stock of jackass morwong.

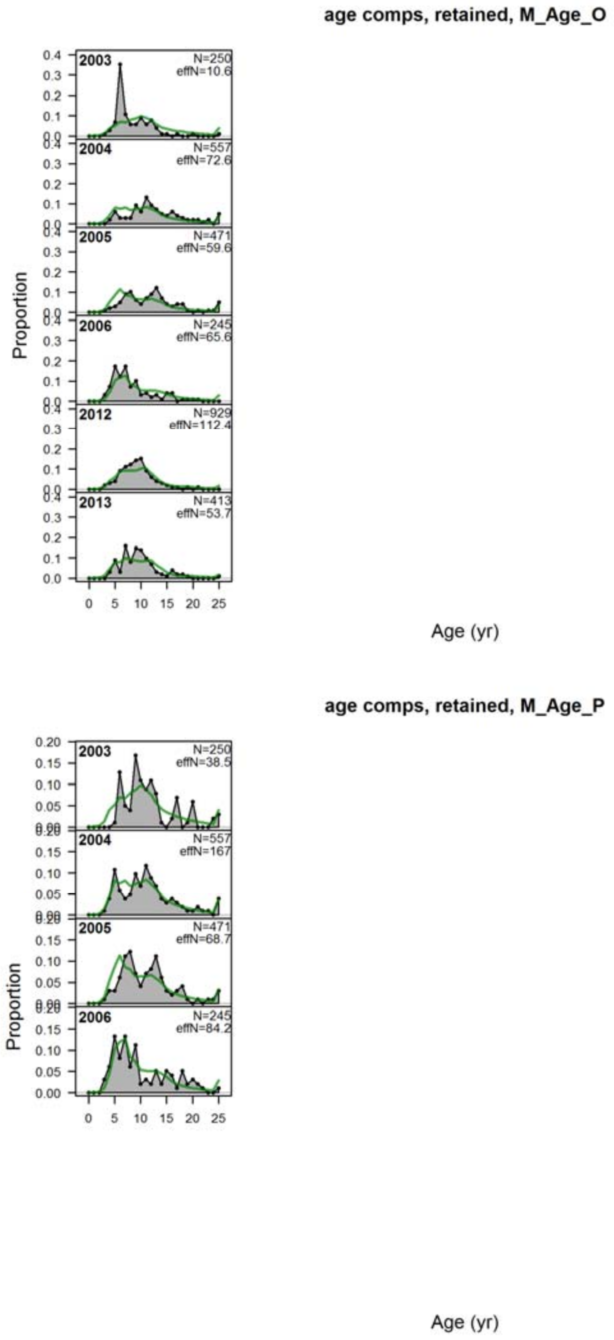


Figure 11.11. The implied fits to onboard (top) and port (bottom) age composition data by year for the western stock of jackass morwong.

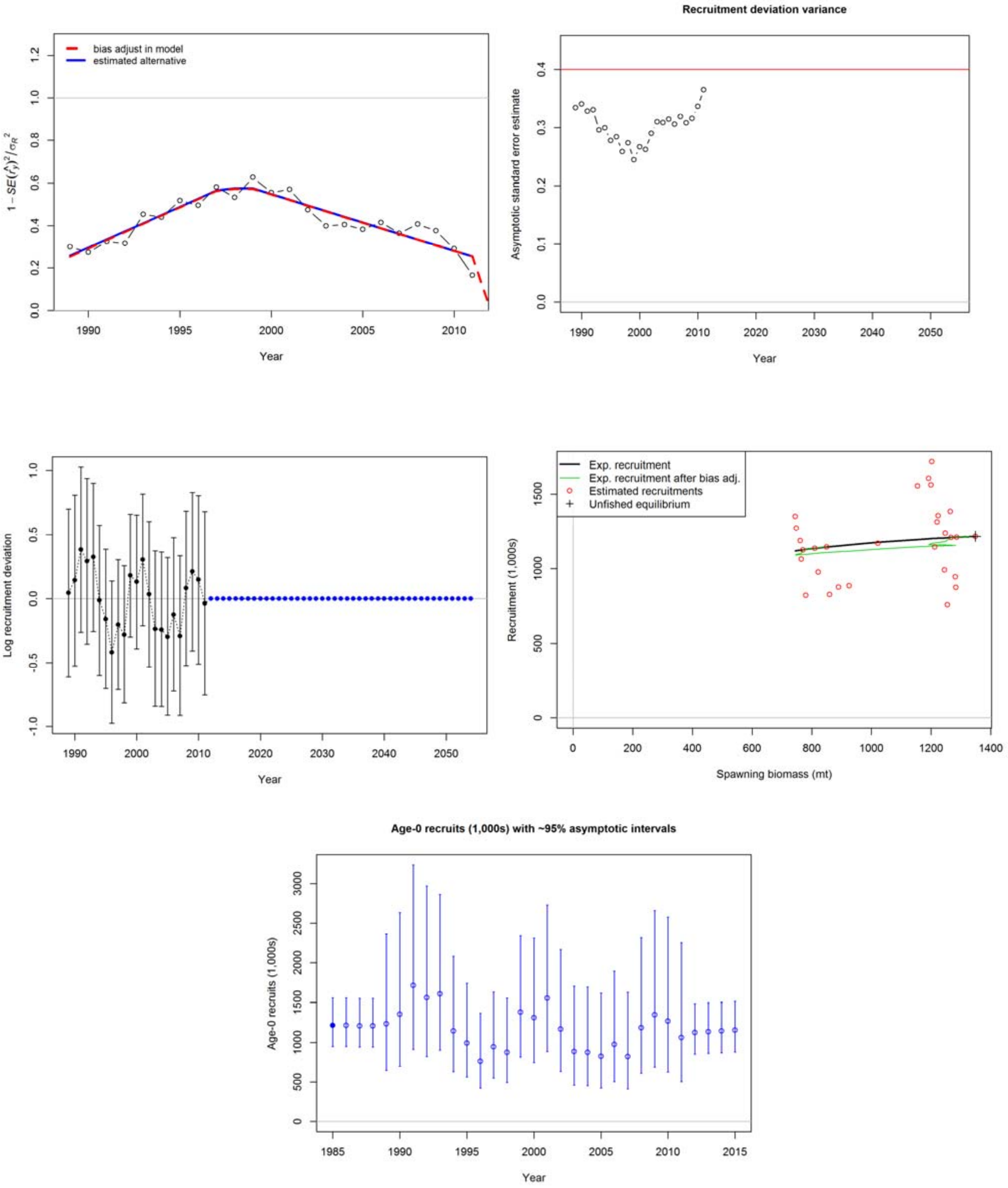


Figure 11.12. Diagnostics for recruitment, the stock–recruitment relationship and annual estimates of recruitment numbers with confidence intervals.

11.5.1.3 Assessment outcomes

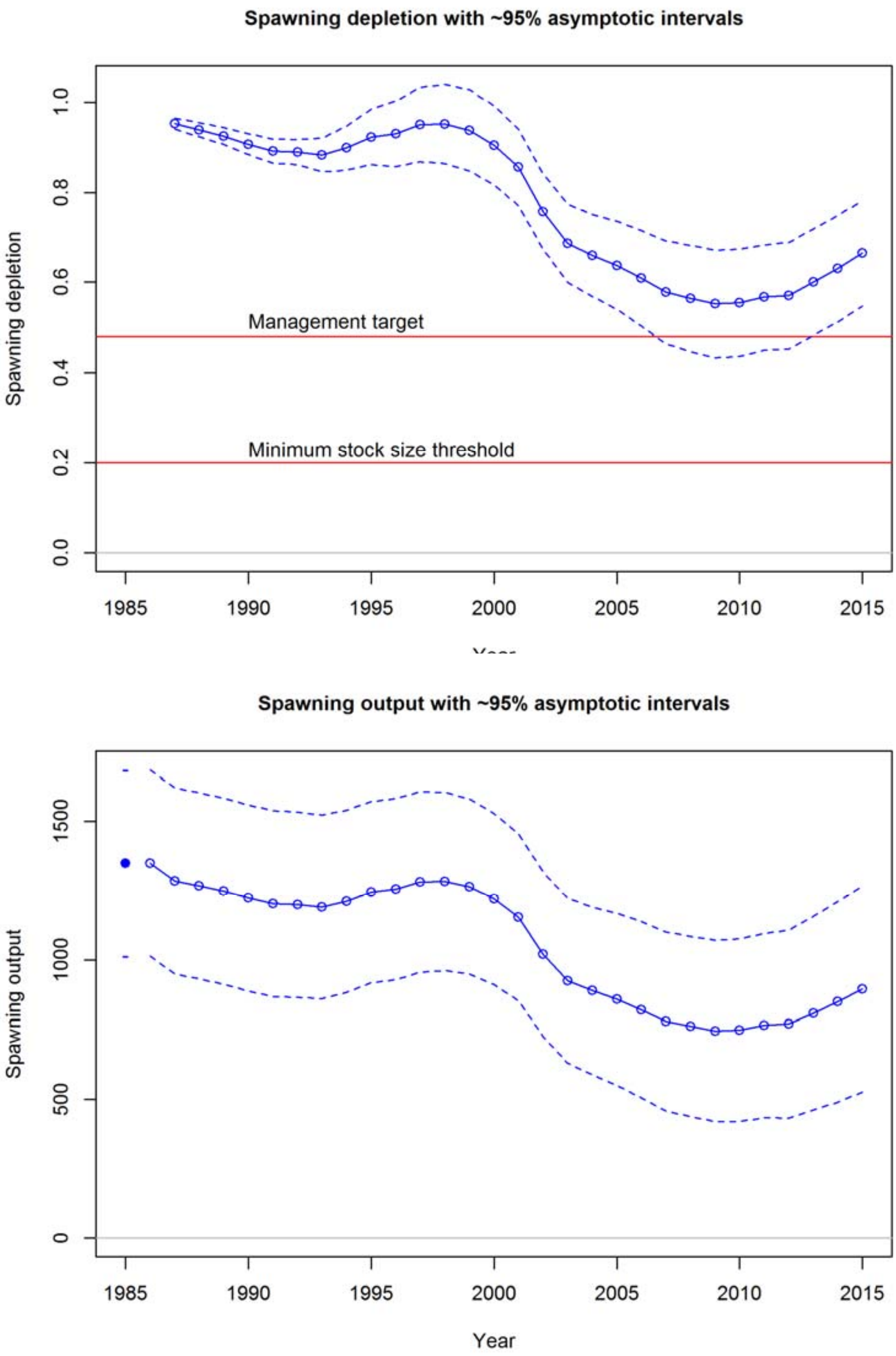


Figure 11.13. Time trajectories of spawning biomass depletion (top) with 95% confidence intervals and magnitude of spawning biomass (bottom) for the base case assessment of the western stock of jackass morwong.

11.5.2 *Discussion*

The 2015 base case assessment of the western stock of jackass morwong estimates the 2016 spawning biomass to be 69% of unexploited biomass (projected assuming 2014 catches in 2015). The female equilibrium spawning biomass in 1986 is estimated to be 1,349 t and in 2016 the female spawning biomass is estimated to be 936 t. The RBC for the base case assessment for the western stock of jackass morwong under the 20:35:48 harvest control rule is 249 t (Table 9.17). The long-term RBC is 159 t. In comparison, the last full assessment in 2011 (Wayte, 2011) estimated the 2012 spawning biomass to be 67% of unexploited biomass (Figure 11.14), with an RBC for 2012 of 282 t.

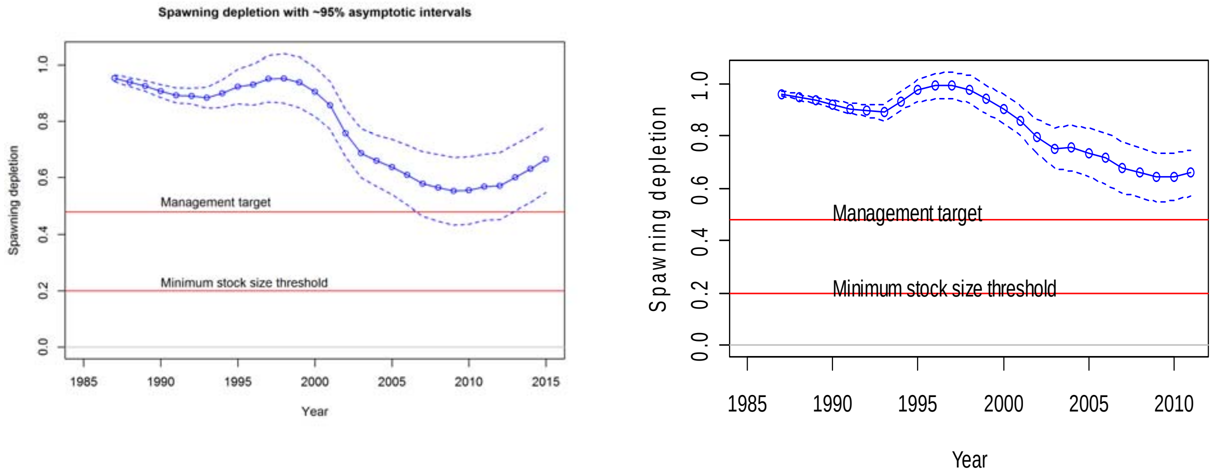


Figure 11.14. A comparison between the 2015 (left) and 2011 (right) assessments of the western stock of jackass morwong.

It should be noted that the assessment for the western stock is increasingly uncertain, as (i) there are only sporadic age data available, (ii) length compositions are based on very low numbers of sampled fish and (iii) the catch in the western region is now very low (Table 11.1 and Table 11.2).

As discussed in the assessment presented at the September Shelf RAG meeting (Tuck et al., 2015), the base case model fit to the index of abundance (Figure 11.7, and Figure 11.15 below) is poor, with an overall declining trend of the point estimates not well reflected in the estimated available biomass trend. A principle espoused by Francis (2011) in his paper on tuning in stock assessments is that modelled estimates of biomass should reflect observations (eg from cpue or surveys). This does not occur for the base case model. Recommendations from the Shelf RAG to use the growth parameters from the eastern jackass morwong assessment and to remove age records where samples were inadequate has not resolved this issue.

The poor fit to the index data (cpue) occurs on tuning the cpue index as part of the adopted tuning method. If the age and length data are tuned (the first steps of the tuning process) and the cpue is not tuned (cvs fixed at 0.1) then the model fit to cpue shows the declining trend of the observations (Figure 11.15). The spawning biomass trend in comparison to the base case (fully tuned) model is shown in Figure 11.16.

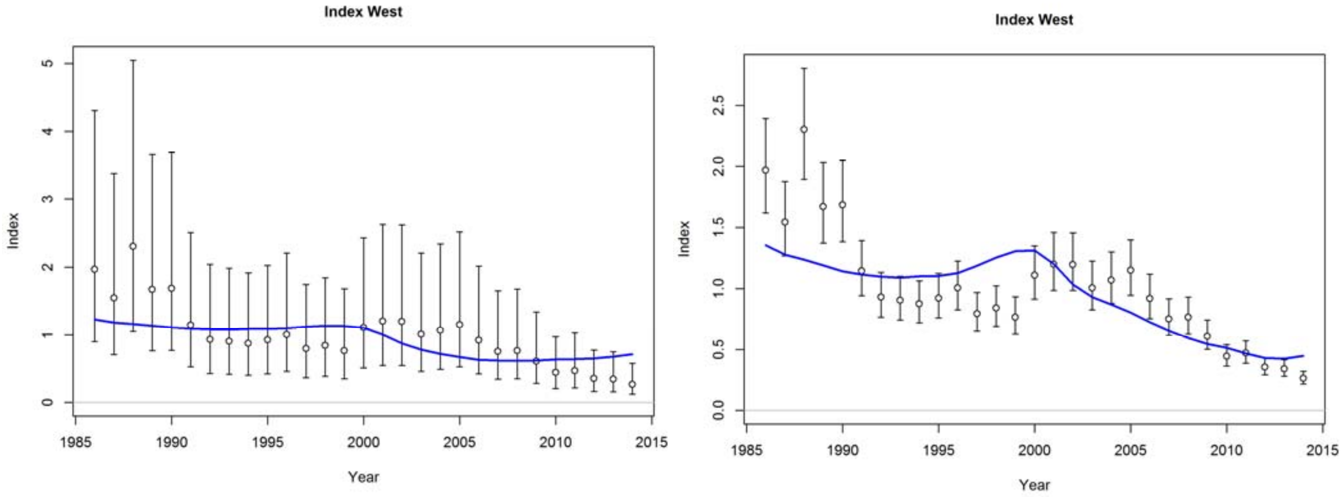


Figure 11.15. Time trajectories of the fit to the standardized catch rate data for the western stock of jackass morwong. Base case (left) and a model where only length and age data are tuned (right) and the catch rate cvs remain at the fixed values of 0.1.

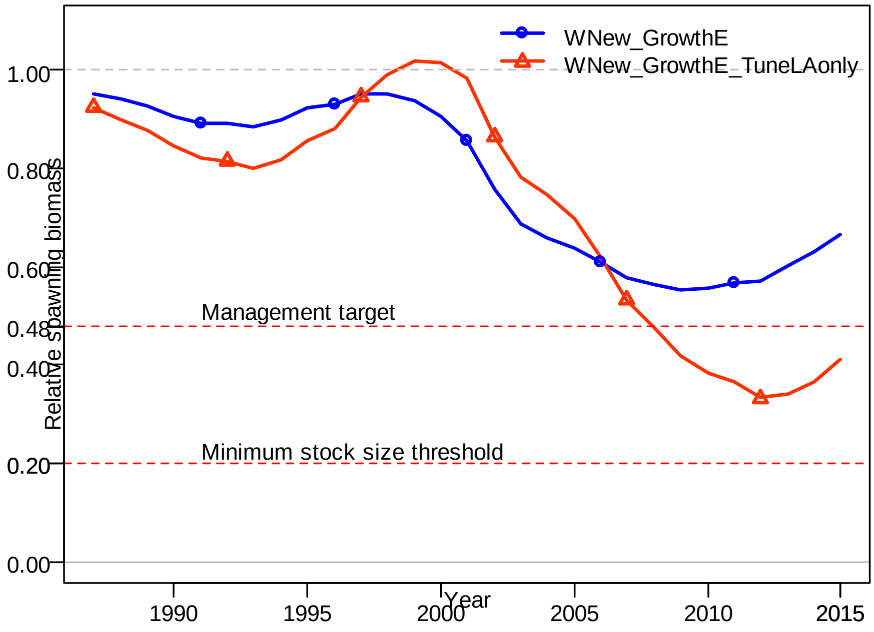


Figure 11.16. Trajectories of relative spawning biomass for the base case model (WNew_GrowthE; blue) and a model where only length and age data are tuned (WNew_GrowthE_TuneLAonly; red).

However, while fits to the catch rate series may appear better, the estimated trend in available biomass does not consistently cross the 95% confidence intervals of the observations, and this model has a considerably poorer fit to the length data (Figure 11.17). This suggests that a strong conflict exists between the input catch rate data and the length data.

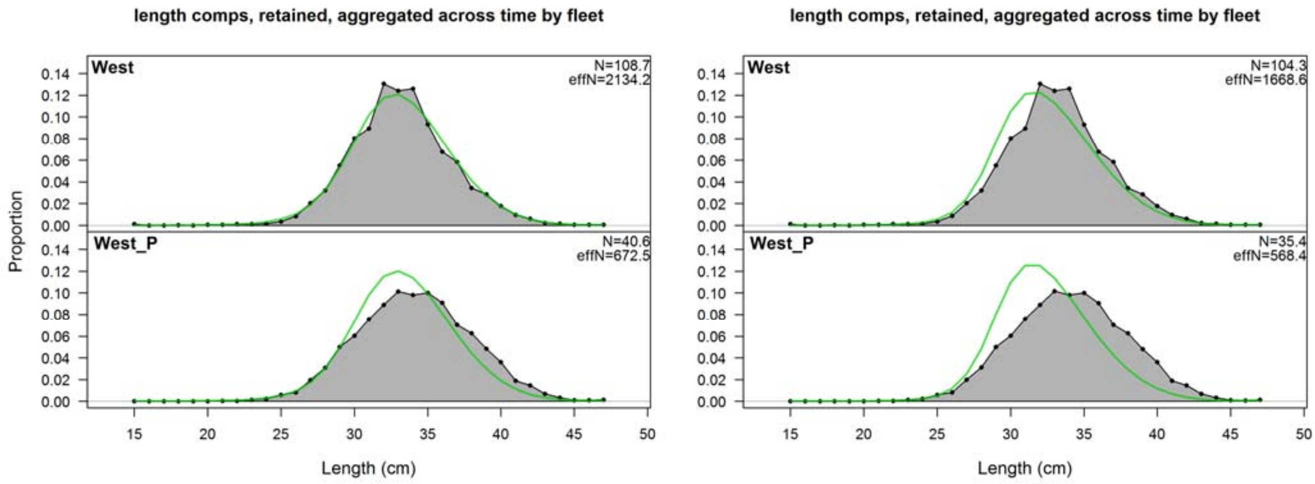


Figure 11.17. The fit to port (West_P) and onboard (West) length data for the western stock of jackass morwong. Base case (left) and a fit where only length and age data are tuned (right).

11.5.3 *Sensitivities*

Results of the sensitivity tests are shown in Table 9.18. This table indicates that biomass depletion is not overly sensitive to changes in parameters or weightings, except for natural mortality. Models with only Zone 50 data led to some changes in biomass trajectory, but did not resolve the issue of the poor fit to the catch rate data (Figure 11.18).

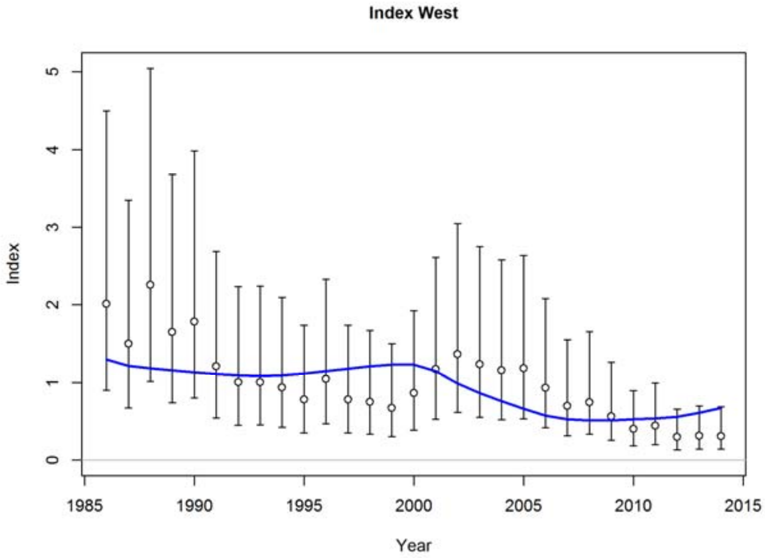


Figure 11.18. The catch rate fit for the assessment model where only Zone 50 data are used.

Table 11.6. The 10-year projected RBC and depletion from the base case model of the eastern (see Tuck et al., 2015b) and western stock of jackass morwong. The jackass morwong TAC (across east and west) for season 2015/16 is currently 598 t.

Year	RBC - east	Depletion	RBC - west	Depletion
2016	314	0.36	249	0.69
2017	320	0.37	231	0.65
2018	327	0.38	216	0.61
2019	336	0.39	204	0.59
2020	344	0.40	195	0.57
2021	352	0.41	188	0.55
2022	359	0.42	182	0.54
2023	365	0.43	178	0.53
2024	371	0.43	175	0.52
2025	375	0.44	172	0.51

11.6 Acknowledgements

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

Table 11.7 Summary of results for the base-case and sensitivity tests. Lower log-likelihood values indicate a better fit to the data. Log-likelihood (-ln L) values in italics are not comparable with the base-case. Likelihood values for sensitivities are shown as differences from the base-case.

West	female SB_0	female SB_{2016}	SB_{2016}/ SB_0	2016 RBC 20:35:48	Likelihood total diff	CPUE	Length	Age	Recruit
Base-case (*M*=0.15, *h*=0.7, 50% mat=24.5)	1349	936	69%	249	275.96	-11.43	22.13	269.71	-5.09
Base from Sept 2015	1501	996	66%	239	*145.54*	*-0.39*	*-1.12*	*146.69*	*-0.51*
Tune Len & Age only	840	384	46%	89	*267.23*	*71.18*	*4.29*	*176.95*	*15.06*
Zone 50 only	725	469	65%	120	*91.70*	*1.35*	*-3.93*	*91.71*	*1.16*
$M = 0.1$ yr^{-1}	1071	454.5	42%		6.89	-2.64	0.03	8.14	1.50
$M = 0.2$ yr^{-1}	2600	2363	91%		4.68	4.27	-0.13	0.01	-0.17
$h = 0.6$	1346	898	67%		-0.30	-0.37	0.03	0.02	-0.04
$h = 0.8$	1352	965	71%		0.32	0.28	-0.03	-0.02	0.03
50% maturity at 22 cm	1445	1030	71%		4.95	0.04	-0.01	0.03	0.01
Double weight on CPUE	1231	795	65%		*0.79*	*-1.71*	*-0.05*	*1.60*	*1.01*
Halve weight on CPUE	1433	1040	73%		*0.31*	*1.19*	*0.08*	*-0.76*	*-0.24*
Double weight on LF data	1375	965	70%		*0.12*	*-0.13*	*-0.28*	*0.50*	*0.01*
Halve weight on LF data	1324	907	69%		*0.13*	*0.02*	*0.42*	*-0.33*	*0.04*
Double weight on age data	1384	1013	73%		*1.30*	*1.27*	*0.48*	*-3.08*	*2.60*
Halve weight on age data	1311	876	67%		*1.05*	*-0.91*	*-0.28*	*3.72*	*-1.44*

11.7 References

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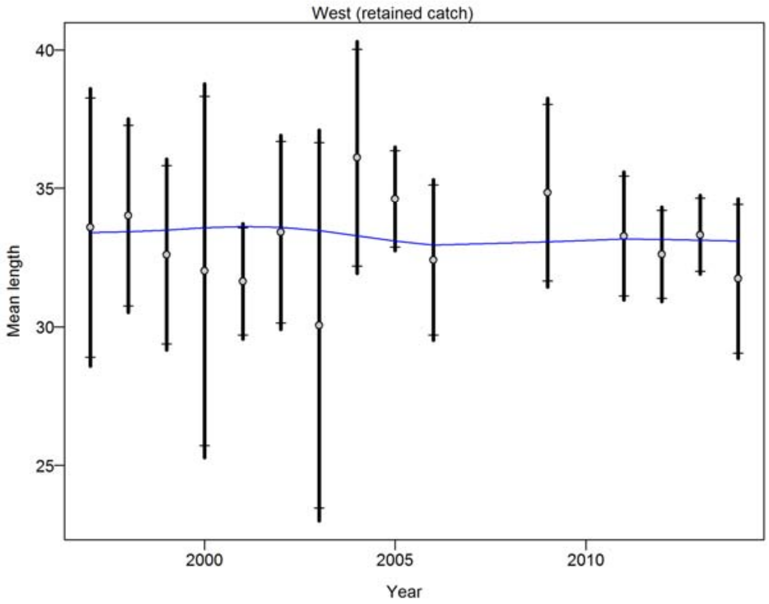
11.8 Appendix: The base case model length fit diagnostics



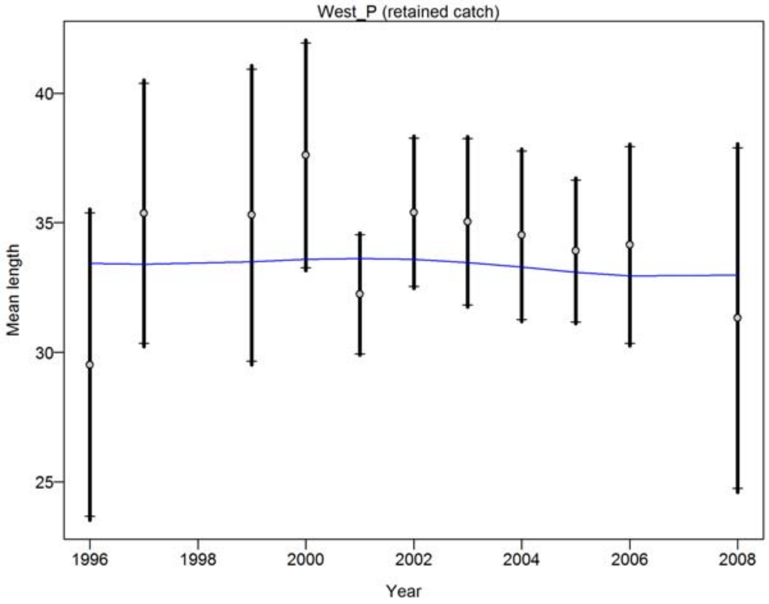


Figure A1. Francis data weighting diagnostic plot for mean lengths of the western stock of jackass morwong onboard (top) and port (bottom) length data