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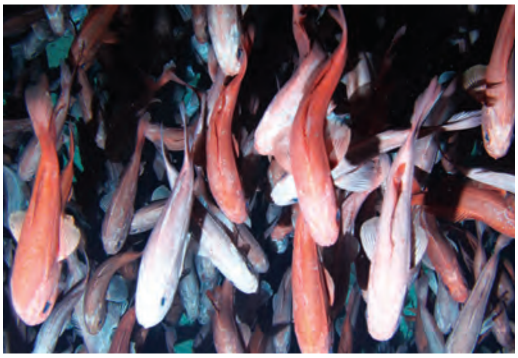
Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013



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 2012. Part 2 describes the Tier 3 and Tier 4 assessments, catch rate standardisations and other general work contributing to the assessment and management of SESSF stocks in 2013.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013

Part 1: Tier 1 assessments

G.N. Tuck
June 2014
Report 2011/0814

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013
Part 1

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Athol R. Whitten and André E. Punt

1. Non-Technical Summary

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2013

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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 2013 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 catch rate indices to determine whether to break out 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 2013 were examined, to allow RAG judgement of whether as assessment may be warranted. Of the species examined, only two showed actual CPUE trends that fell outside of the 95% confidence bounds projected from the stock assessment – jackass morwong and silver warehou. Jackass morwong had results for two areas, and it was the result from the area with the least catch that fell just outside of the bounds, so this species was judged not to have broken out. Silver warehou however, only had one CPUE indicator series, and this had unambiguously broken out for the past two years.

Catch rate standardisations

Catch-per-unit-effort (CPUE) data is an important input to many of the stock assessments conducted within the SESSF where it is used as an index of relative abundance through time. The catch and effort log-book 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. The catch rates used in the assessments are standardized to reduce the effects of factors such as which vessel fished, where and when fishing occurred, what gear was 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.

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 relatively 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 were variants on the form: LnCE = Year + Vessel + Month + DepthCategory + Zone + Daynight. For some fisheries weeknumber or gear type was also included. In addition, there were interaction terms which could sometimes be fitted, such as Month:Zone or Month:DepthCategory. The 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.

The statistical standardization of the commercial catch and effort data is reported for 21 species, distributed across 50 different combinations of stocks and fisheries ready for inclusion in the annual round of stock assessments. These included 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.

Summary graphs are provided across all species as well as more detailed information for each stock. Out of 36 stocks there were 10 whose catch rates have increased over the last 10 years, there were 13 stocks where catch rates were stable (two of which were stable and low; Blue Warehou and Jackass Morwong), and there were 7 stocks whose catch rates have declined over the last 10 years.

Yield, total mortality values and Tier 3 analyses

Yield and total mortality estimates are provided for major commercial fish species from the shelf and slope in the South East Fishery. Yield estimates were made using a yield-per-recruit model with the following input: selectivity-at-age, length-at-age, weight-at-age, age-at-maturity, and natural mortality. Total mortality values corresponding to various reference equilibrium biomass depletions were calculated for each species.

Recent average total mortality was estimated from catch curves constructed from length frequency information. Length frequency data were from ISMP port and/or onboard measurements. The method used to estimate total mortality also estimates average fishery selectivity.

Tier 3 calculations use the estimates of total mortality, natural mortality and average recent catches to decide the Recommended Biological Catch (RBC) for next year. An average length procedure was developed and tested for species where only length data and no age samples are available.

Tier 3 calculations were applied to all SESSF quota species with sufficient available information, regardless of the actual Tier that applies to the species because (a) the Tier that will apply to each species in the current year is decided by the Resource Assessment Groups and (b) it is useful to compare Tier 3 results with those from other Tiers to check performance of the methods.

RBC values for alfonsino, John dory and redfish were greater than reference average catches ($p>1$). The RBC for mirror dory is lower than the reference catch ($p<1$) which is a result very different to that presented in 2012. The reason is a considerable shift in the average Z fit for catch curves in the east caused by a change in emphasis in the overall fit from younger to older fish. This highlights the possible catch variability inherent in a data-poor procedure such as the Tier 3.

Tier 4 analyses 1986 - 2012

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 an 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 catch rates, either standardized or simple geometric mean catch rates. This year, only standardized catch rates were used except where discards were explicitly included in the analyses.

The Tier 4 analyses conducted this year used the analytical method developed and tested in 2008 and 2009. This has the capacity to provide advice that will manage a fishery in such a manner that it should achieve the target catch rate derived from the chosen reference period. However, the TIER 4 control rule can only succeed if catch rates do in fact reflect stock size. Many factors could contribute to make this assumption fail so care needs to be taken when applying this control rule.

Thirty four Tier 4 analyses are documented which included a number of species where spatial information was available (Blue Warehou and Mirror Dory) leading to analyses for the east and west presumed stock regions. There are also Tier 4 analyses for some species where discard estimates were included in the analysis of catch rates. In addition, some non-key commercial species were assessed, at the RAG's request, at a target assuming a proxy of 40%B_0 as well as a proxy target assuming 48%B_0.

Seven fisheries are assessed using Tier 4 methodology: Blue-eye Trevalla, Blue Warehou (split east and west), Inshore Ocean Perch and Offshore Ocean Perch, Redfish, Royal Red Prawns, and Silver Trevally. Three of these fisheries generated zero RBCs and these were Blue Warehou, Jackass Morwong and Redfish. Alternative analyses were provided for Redfish and Inshore Ocean Perch in which discards were included in the estimation of the catch rate trends. The inclusion of discards in estimating catch rates adds a great deal of noise to the CPUE trends so the uncertainty in these analyses expands. At the same time it is not clear whether to remove the discards from the RBC to generate a TAC or not. The use of this approach for setting RBCs needs further discussion and examination.

1.3 Slope and Deepwater Species

Blue grenadier

The 2013 assessment of blue grenadier *Macruronus novaezelandiae* uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS). The assessment has been updated by the inclusion of data up to the 2012 calendar year. Estimates of spawning biomass from acoustic surveys from 2003-2010 (with 2 times turnover) and egg survey estimates of female spawning biomass from 1994-1995 (base-case estimates) are included.

Results conclude that for the base case model the female spawning biomass in 2012 is around 77% of the unexploited spawning stock biomass (*SBo*) and in 2014 will be approximately 94%*SBo*. The marked increase in biomass is due to the estimation of a large cohort in 2010. While a promising sign for the fishery, the existence and magnitude of this recruitment should be treated with some caution until it can be verified by the addition of further data from future years. If the 2010 recruitment is not estimated and instead is taken from the stock-recruitment curve, then the spawning biomass estimates relative to un-exploited biomass and RBCs are lower.

For the base case model, the 2014 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 8138t, with the predicted retained portion of the RBC being 8065t. Note that this is greater than 150% of the current TAC (5208t). The long-term RBC is 4155t. A risk assessment was conducted whereby the forecast catches from the base case model (with the 2010 recruitment estimated) were placed into the model with no 2010 recruitment estimation (and vice versa). Results indicated that the SSB trajectory would not move below the target reference point even if the larger forecast catches from the base-case model were applied to the model with no 2010 recruitment estimation.

Pink ling

An age structured population dynamics model was fitted to data for pink ling (*Genypterus blacodes*) separately for the eastern and western areas (stocks) of the Australian Southern and Eastern Scalefish and Shark Fishery (SESSF). The data used for the assessment were updated from those on which the 2012 assessment was based to include 2012 data (catches, catch-rates, conditional age-at-length data and length-frequencies). A number of revisions to the historical (pre-2012) data, including the way data were assembled, data types, and the years for which some data were included, were modified from previous assessments.

A model similar to that developed for the 2012 assessment was used as the base-case model. The current base-case model differs from the 2012 base-case model in terms of how selectivity is time-blocked for the eastern trawl CPUE series and the exclusion of the non-trawl CPUE indices (for both the eastern and western stocks). The current base-case model also differs from the 2012 model by excluding data from the Kapala surveys, assuming that growth is time-invariant (rather than time-varying) and in how length frequency data is both initially weighted and re- weighted.

Better fits to data were obtained by weighting the length-frequency data by numbers of landings/operations, rather than by number of fish measured (as was the case last year). Model fit diagnostics continue to support time-varying fishery selectivity for the trawl sector. A new model re-weighting (tuning) process, following Francis (2011), was used to configure the final base-case models and applied to the length-frequency data.

In the base-case model, the eastern stock is assessed to be $0.19B_0$ at the start of 2014 and the western stock is assessed to be $0.43B_0$ at this time (under the assumption that the TAC for 2013 of 834t is taken). The RBCs arising from the base-case models are 0 tonnes for the eastern stock and 573 tonnes for the western stock; giving a total RBC of 573 tonnes for the SESSF pink ling stocks. The long term RBC (for the year 2033) is 647 tonnes for the eastern stock and 645 tonnes for the western stock; giving a total long-term RBC of 1292 tonnes.

Note that following consideration at the November 2013 Slope RAG meeting, the base case model presented in this document was not used for management purposes in 2013.

Blue Eye Characterisation

The Blue Eye CPUE standardization for trawls and for the combination of auto-line and bottom-line were not considered to provide an adequate representation of trends within the Blue Eye fishery. The expansion of whale depredations 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 movement of fishing effort in recent years much further north off the north east coast of New South Wales and Queensland has altered the reliability of CPUE as an indicator of relative abundance. The key issue of the reliability of simple CPUE analyses for relating to stock abundance reflects the spatial heterogeneity of both the Blue Eye fishery and of the biological properties of the Blue Eye populations across its spatial distribution.

The fishery itself has included a number of large scale changes in fishing methods and the area of focus for the fishery from around 1997, when improved records from the GHT fishery became available. While trawl catches have continued at a low but steady level since 1986 there has been a switch from Drop-line (alternatively Demersal Line) to Auto-line. In the last three to four years, related to the move of a proportion of the total catch off the east coast, the use of alternative line methods (rod-reel, and hand-line) has increased.

The catch rate trends east and west differ, with the east exhibiting depletion in the last five years while the west appears to remain noisy but relatively flat. When this spatial heterogeneity is included in the Tier 4 analysis it suggests that catches in the east should be reduced while those in the west could be larger.

There are some important assumptions in this analysis. The first is that the CPUE is reflecting changes in the relative stock abundance rather than the influence of the structural adjustment, or reduced catch rates through whale depredations or from whale avoidance behaviour from shifting into less optimal CPUE areas. In addition, the various closures in the south-east are assumed to have little or only minor effects on catch rates.

In reality, the relatively large shift in effort to the north-eastern sea-mounts and repeated industry statements imply that whale depredations do indeed have significant effects on both observed CPUE but also on fisher behaviour, which would be more difficult to identify and isolate as a depressing effect. Closures have undoubtedly shut off some previously popular fishing grounds for Blue Eye, so these extraneous factors, which are not included in the standardizations, can certainly be concluded to have had some negative effects upon CPUE; however, estimating the extent of any such effects remains an intractable problem currently. What it does suggest is that the recommended RBCs from these analyses are inherently conservative because any depressing effects of whales, closures, or even the structural adjustment, are currently being ignored.

1.4 Shelf Species

Jackass morwong

In 2013, the Shelf RAG agreed to not conduct a full jackass morwong (*Nemadactylus macropterus*) stock assessment. To calculate the 2014 RBC, the 2011 Tier 1 Stock Synthesis assessments for both eastern and western morwong have been projected for two more years, using actual catches from 2011 and 2012, and estimated catches for 2013. No other data were added and no new parameter estimation was performed. The ‘recruitment shift’ assessment model accepted as the base-case for the eastern stock in 2011, and the base-case model for the western stock from 2011 were used for the projections.

Current spawning biomass in the eastern stock is projected to be 40% of 1988 equilibrium spawning stock biomass, and the 2014 RBC under the 20:35:48 harvest control rule is 400 t. For the western stock, current spawning biomass is projected to be 68% of unexploited stock biomass, and the 2014 RBC is 292 t. The 2014 combined RBC is 692 t. The model-projected 2014 discards in the east are 17 t. Discards are not modelled in the west due to a lack of data.

Tiger flathead

An update of the 2010 assessment of tiger flathead (*Neoplatycephalus richardsoni*) was conducted providing estimates of stock status in the SESSF at the start of 2014. This assessment was performed using the stock assessment package Stock Synthesis. The 2010 stock assessment has been updated with the inclusion of data up to the end of 2012, comprising an additional 3 years of catch, discard, CPUE, length and age data and ageing error updates and incorporation of survey results from the Fishery Independent Survey (winter). A range of sensitivities were explored, including incorporation of the summer fishery independent survey results for 2008, 2010 and 2012, and estimating recruitment to 2007 instead of 2009.

The base-case assessment estimates that current spawning stock biomass is 50% of unexploited stock biomass (SSB_0). Under the 20:35:40 harvest control rule, the 2014 RBC is 3,428 t and the long term yield (assuming average recruitment in the future) is 2,753 t. The average RBC over the three year period 2014-2016 is 3,334 t and over the five year period 2014-2018, the average RBC is 3,252 t.

Exploration of model sensitivity showed a variation in spawning biomass from 36% to 66% of SSB_0 when natural mortality was fixed at values of 0.2 and 0.35 respectively. When recruitment is only estimated to 2007, excluding the above average recruitment estimates in 2008 and 2009, the spawning biomass was estimated to be 40% of SSB_0. For all other sensitivities explored, the variation in spawning biomass was much narrower, ranging between 47% and 52%.

1.5 Shark Species

Gummy Shark

The most recent gummy shark (*Mustelus antarcticus*) assessment model formulation was updated using data from 2010-2012. The model recognises three separate populations (Bass Strait, South Australia and Tasmania), that share some parameter values. Closures of traditional fishing grounds in South Australia (SA), in order to protect Australian sea lions, began to take effect during 2010 and have caused declines in catches and catch per unit effort (CPUE) in that state. CPUE in Bass Strait (BS) may have been impacted by the entry of South Australian fishers, inexperienced in fishing other grounds. Trial hook fishing for sharks has been permitted, under short term licences, in SA since 2011.

The length frequencies for 2008-2010 that were used by the 2010 assessment were recalculated, in particular, sharks whose fork length were sampled were included in the dataset now that a fork length to total length (LCF-TOT) conversion formula is available.

The sensitivity of the model results to the inclusion or exclusion of a range of data selections was considered. Not fitting the model to tag return data collected after 2005, when return rates appear to have been low, results in the estimation of larger population sizes.

The inclusion of recent CPUE leads to the estimation of a more depleted stock in BS and a less depleted stock in SA. While it is counter-intuitive that CPUE data that shows a fall in SA should lead to the estimation of a less depleted stock, it is reasonable to assume that the reduction in fishing effort in that region should lead to some increase in stock size. Similarly, effort has increased in BS due to the entrance of gillnet vessels that were excluded from traditional fishing grounds in SA.

For the base case gummy shark stock assessment for 2013 (data to 2012) CPUE to 2009 were used (the effects from closures began in 2010) in South Australia and to 2012 in Victoria and Tasmania. RBCs have been calculated for the base case model assuming a range of splits between hook and gillnet fishing in the future. Future hook fishing in SA alone, or in all states, is considered. Higher levels of hook fishing lead to lower RBCs.

Standardised catch rates for gummy shark

Reported catches of gummy sharks have declined from a high in 2008, although interpreting this is made more complex because of the 16 month TAC put in place for the 2007/2008 season. Nevertheless, the recent decline in catches is real and is related to the decline in catches from South Australia being greater than the increase in catches in Tasmania and the now relatively stable catches in Bass Strait. Catches from South Australia started to decline seriously in 2011 and continued to decrease further in 2012 until they are now of the same order as in the early 1980s and are only about 50% the catches in 2009. These changes are related to the introduction of gillnet fishery closures to protect Australian Sea Lions and dolphins in South Australian waters. The proportion of catches taken by gillnets in 2012 remained the same as in 2011, despite catches being down overall.

Standardized catch rates in South Australia have also exhibited a decline since 2008, however, the general trend since 1984 remains flat but noisy. The most recent mean estimate is below the long term average, which again is thought to be related to the influence of the marine closures in South Australia rather than any change in the resource status. However, the recent large reduction in catch and the large changes in the spatial distribution of catches means that accurate knowledge of the status of the South Australian gummy shark stock is currently compromised. How best to include this data in any stock assessment is not immediately obvious and may require further data exploration. There is a difference between the standardized CPUE for positive shots from the CANDE12 data set and the standard extracts from the SESSF database. The confluence of the two trends from 2005 reflects the fact that the CANDE12 data set is updated directly from the SESSF database each year.

In Bass Strait, standardized catch rates have also declined since 2008 but they are now still above or at the long term average depending on how the standardization for positive shots is combined with the standardization of the probability of obtaining a positive shot. Catches in the gummy shark fishery continue to be greatest in Bass Strait.

In Bass Strait there are also differences between the standardized CPUE for positive shots from the CANDE12 data set and the standard extracts from the SESSF database from 1997 to 2004. Again the confluence of the two trends from 2005 reflects the fact that the CANDE12 data set is updated directly from the SESSF database each year.

Standardized catch rates in Tasmania also remain noisy but flat. There is some indication of a very slow decline since about 2000 but given the variation surrounding the mean estimates the apparent decline is not yet statistically significant; for example, the trend in 2012, the latest year, exhibits a very slight upturn. Given the noise in the outcome of the analysis, the differences between the CANDE12 analysis and that based on the SESSF database are not significant.

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*) from the southern shark fishery. Standardized catch rates for both species were estimated using the SESSF logbook data only rather than the earlier data, along with total catches of the respective species in a standard analysis. For saw sharks the reported catches by trawl are now approaching the level of gill net catches so an additional analysis was conducted where the standardized catch rate for trawl saw shark catches was used instead of the gillnet catch rates.

The gillnet catch rates for saw sharks in 2012 were slightly lower than those in 2011 but owing to the initial drop in catch rates in 2010 the Tier 4 analysis, which considers the average catch rate over the last four years, generates a RBC for saw sharks at the 48% target that has now declined to about 59% of the target catch (down from 64% last year). Whether the decline in the gillnet catch rates constitute a reasonable reflection of the stock status remains questionable due to the level of avoidance that occurs in the fishery (due to low and reducing value of saw sharks in the market). Importantly, when the trawl catch rates for saw sharks are standardized a different trend is apparent. In 2000 the catches by trawl were only 20% of all catches by gillnet plus trawl but now make up 40%.

The catch rate data used for elephant fish now relates to the SESSF database, which means the probability of obtaining a positive shot cannot be well identified. The decline in catch rates in elephant fish seen in 2010 continued in 2011 but then recovered its 2011 losses in 2012. However, these values do not include discards in their calculations and since 2007 and especially since 2011 the importance of discards has become particularly influential in elephant fish. When discards are included in the calculation of CPUE as well as total catches then the CPUE increased in both 2011 and 2012, implying a rise in RBC. When discards are not stable, as is the case with elephant fish then this latter analysis more closely reflects the fishery dynamics.

1.6 GAB Species

Catch rates

The change in catch rates for bight redfish between 2011/2012 and July-Feb 2012/2013 is less than 20% (-13.29), therefore the control rule suggests no change should be made to the default TAC.

The change in catch rates for deepwater flathead between 2011/2012 and July-Feb 2012/2013 is relatively slight at -1.45%. However, importantly, it can also be seen that last year's estimate was biased larger than it eventually became. Last year the decrease in catch rates appeared to be about -25% whereas this year, with all available data it appears to be about -17.5%, which would not have triggered a change.

Deepwater Flathead

An update of the 2012 assessment of deepwater flathead (*Neoplatycephalus conatus*) was conducted providing estimates of stock status in the Great Australian Bight at the start of 2014/15. The base-case assessment estimates an unexploited spawning stock biomass (SSB_0) of 9,320t and a current depletion at the start of 2014/15 of 45% of SSB_0. The 2014/15 RBC under the 20:35:43 harvest control rule is 1,146t and the long-term yield (assuming average recruitment in the future) is 1,105 t.

Exploration of model sensitivity showed a variation in depletion levels of between 32% and 54% of SSB_0.

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 warhou (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. Preliminary updated stock assessment of blue grenadier *Macruronus novaezelandiae* based on data up to 2012[1]

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5.1 Summary

The 2013 assessment of blue grenadier *Macruronus novaezelandiae* uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS) (NOAA, 2011). As with previous methods used to assess blue grenadier, the methods utilised in SS are based on the integrated analysis paradigm (Punt et al., 2001). The assessment has been updated by the inclusion of data up to the 2012 calendar year. Estimates of spawning biomass from acoustic surveys from 2003-2010 (with 2 times turnover) and egg survey estimates of female spawning biomass from 1994-1995 (base-case estimates) are included.

Results conclude that for the proposed base case model the female spawning biomass in 2012 is around 77% of the unexploited stock biomass and the depletion in 2014, used for the harvest control rules, will be approximately 90%. The marked increase in biomass is due to the estimation of a large cohort in 2010. While a promising sign for the fishery, the existence and magnitude of this recruitment should be treated with some caution until it can be verified by the addition of further data from future years. If the 2010 recruitment is not estimated and instead assumed to be of average magnitude, then the depletion estimates are considerably lower.

5.2 Introduction

An integrated analysis model, implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Methot, 2011; Methot and Wetzel, 2013), was applied to the blue grenadier stock of the Southern and Eastern Scalefish and Shark Fishery (SESSF), with data updated by the inclusion of data up to the 2012 calendar year (length and age data; age-error, catch rate series; landings and discard catch weight) and information from acoustic surveys of spawning biomass (series from 2003-2010, pertaining to total spawning biomass) with an assumption of 2-times turnover on the spawning ground (Russell and Smith, 2006). The base-case egg survey estimates of female (only) spawning biomass for 1994 and 1995 are included. The model fits directly to lengths frequencies (by sex where possible) and conditional age-at-length

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[1] Paper presented at the Slope/Deep RAG meeting 23-25 September2014

data by fleet. Retained length frequency data are from port and onboard samples combined (where data were available).

The assessment model presented in 2011 (Tuck, Whitten and Punt 2001; Tuck 2011) was the first for blue grenadier to be implemented using SS. The use of SS allows the implementation of a model very similar to that used in previous assessments, but additionally presents an opportunity to improve the estimation of length-based selectivity and temporal variability in growth, avoiding the use of simplified assumptions regarding selectivity and modified age-length keys that were necessary in previous assessments. SS can allow for multiple fishing fleets, and can be fitted simultaneously to several data sources and types of information available for blue grenadier. 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. This document updates the assessment presented in 2011.

5.3 The fishery

Blue grenadier are found from New South Wales around southern Australia to Western Australia, including the coast of Tasmania. Blue grenadier is a moderately long-lived species with a maximum age of about 25 years. Age at maturity is approximately 4 years for males and 5 years for females (length at 50% maturity for females is 57cm and 64cm respectively) based upon 32,000 blue grenadier sampled between February 1999 and October 2001 (Russell and Smith, 2006). There is also evidence that availability to the gear on the spawning ground differs by sex, with a higher proportion of small males being caught than females (Figure 5.1). This is most likely due to the arrival of males on the spawning ground at a smaller size (and younger age) than females. This was also noted by Russell and Smith (2006) who state that “young males entered the fishery one year earlier than females” and is consistent with hoki from New Zealand (Annala et al., 2003). Large fish arrive earlier in the spawning season than small fish. Spawning occurs predominantly off western Tasmania in winter (the peak spawning period based upon mean GSIs calculated by month was estimated to be between June and August according to Russell and Smith (2006). There is some evidence that a high proportion of fish remain spawning in September. Variations in spawning period noted by Gunn et al (1989) may occur due to inter-annual differences in the development of coastal current patterns around Tasmania. Adults disperse following the spawning season and while fish are found throughout the south east region during the non-spawning season, their range is not well defined. Spawning fish have recently been caught off the east coast of Australia and larvae from a likely eastern spawning area have been described by Bruce et al. (2001). Further analyses (eg sampling, acoustics) of these fish will need to be conducted before they can be included in the current stock assessment.

Blue grenadier are caught by demersal trawling. The global agreed TAC in 2012/13 was 5,208 tonnes. The annual TACs are show in Table 5.1. There are two defined sub-fisheries: the spawning (Zone 40, months June, July and August) and non-spawning fisheries (all other months and zones).

5.4 Data

The assessment has been updated since the previous assessment (Tuck, 2011) by the inclusion of length and age-at-length data from the spawning and non-spawning fisheries; updated cpue series (Haddon, 2013), the total mass landed and discarded, and update age-reading error. Acoustic estimates of spawning biomass (2003-2010) and estimates of the female spawning biomass in 1994 and 1995 from egg surveys (Bulman et al., 1999) are included. Data were formulated by calendar year (i.e. 1 Jan to 31 Dec) as in previous models.

5.4.1 ***Catch***

The landings from the SEF1 logbook data were used to apportion catches to the spawning and non-spawning fisheries. The SEF1 landings have been adjusted upwards to take account of differences between logbook and landings data (multiple of 1.4 for the non-spawning fishery, based on 40% conversion from headed and gutted to whole, since 1986 and up to and including 1997 (reliable CDR data were available from 1998); 1.2 for the spawning fishery from 1986 up to and including 1996 (when factory vessels entered the spawning fishery)) (D. Smith, pers. comm.). As stated by Thomson and He (2001), the factor is lower for the spawning fleet than the non-spawning fleet because some fish in the spawning fishery, landed headed and gutted, were recorded as being landed whole. These factors were chosen by the Blue Grenadier Assessment Group (BGAG) (Chesson and Staples (1995), as cited by Punt (1998)). The adjusted logbook catches were then scaled up to the SEF2 data. As historical SEF2 data were only available from 1992, the average scaling factor from 1992 to 1996 was used to scale the data for years between 1986 and 1991 (Figure 5.2). Note that in years 2008 to 2012 logbook data were greater than landings from the CDR. In these cases the tonnage from the CDR was used as the total catch (AFMA, pers. comm. 2011). Table 5.1 lists the annual catches used in the assessment and the annual TAC. The annual logbook catches by sub-fishery and the adjustments made to determine the catches used in the assessment are shown in Table 5.2.

Discard rates were estimated from on-board data which gives the weight of the retained and discarded component of those shots that were monitored (Thomson and Klaer, 2011). The discard values from 1995 to 2002 are based on estimates calculated from ISMP data by MAFRI and reported in He et al (1999) and Tuck, Smith and Talman (2004). As agreed by Slope RAG (2011), since 2003 discard rates are taken from those estimated by the methods described in Thomson and Klaer (2011). The mass of the discard is calculated from the annual discard rate and the retained catch from the non-spawning fishery. The MAFRI estimates of discards were made accounting for differences in sampling and discard rates according to the ISMP zones. The more recent estimates are simple ratios of total discards to (retained + discard) catch (N. Klaer, pers comm.). Information in support of the historical values was not able to be obtained and further exploration of the methods and data used to estimate these values should be encouraged. The discard data are provided in Table 5.1.

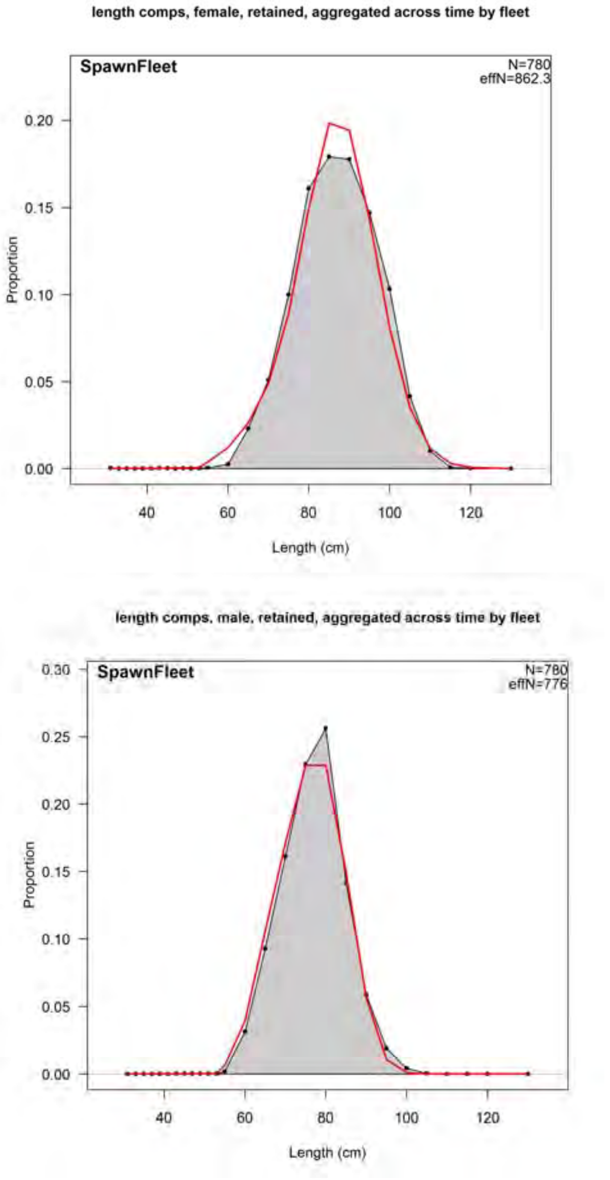

Figure 5.1. The aggregated length composition of females (top) and males (bottom) on the spawning ground. The red line indicates a model fit with sex-specific selectivity.

Table 5.1. Landed and discarded catches for the winter spawning and non-spawning sub-fisheries by calendar year. These estimates have been adjusted scaled up to the landings data (see text and Table 5.2). Standardised CPUE (Haddon, 2013) and number of records for the non-spawning sub-fisheries by calendar year are shown, along with the TAC. 1 a voluntary industry reduction to 4,200 t was implemented in 2005. 2 This was a 16 month TAC. 3 The TACs cover the fishing year 1 May to 30 April. In the table below, 2008 refers to 2008/09. 4 This is an estimate of retained catch based on the 2012/2013 TAC and relative split of catch between spawning and non-spawning fisheries of 2012.

Year	Landings		Discards	TAC		
	Spawning	Non-spawning	Non-spawning		Records	CPUE
1979	245	245				
1980	410	410				
1981	225	225				
1982	390	390				
1983	450	450				
1984	675	675				
1985	600	600				
1986	317	1807			3189	1.505
1987	1006	2183			3569	1.978
1988	410	2228			3961	2.143
1989	46	2745			4309	2.219
1990	733	2508			3577	2.190
1991	819	3764			4308	1.576
1992	710	2549			3228	1.298
1993	994	2368			4203	0.980
1994	1211	1940		10000	4491	0.881
1995	1205	1570	80	10000	5076	0.607
1996	1496	1544	975	10000	5370	0.554
1997	2947	1569	3716	10000	6194	0.573
1998	3746	1986	1329	10000	6599	0.941
1999	6775	2549	123	10000	8045	0.995
2000	6608	2047	69	10000	7679	0.710
2001	8004	1120	10	10000	7279	0.406
2002	7843	1318	2	10000	6344	0.407
2003	7745	726	3	9000	5675	0.341
2004	5064	1327	15	7000	6393	0.573
2005	3024	1259	310	5000[1]	5346	0.686
2006	2193	1420	104	3730	4362	0.911
2007	1891	1280	5	4113[2]	3659	0.811
2008	2692	1239	19	4368[3]	3407	0.890
2009	2295	964	15	4700[3]	3443	0.826
2010	3119	1066	10	4700[3]	3308	0.810
2011	3342	859	126	4700[3]	3968	0.657
2012	3447	557	192	5208[3]	3210	0.533
2013	4484[4]	724[4]				

Table 5.2. Logbook and CDR landings for the spawning and non-spawning sub-fisheries by calendar year and adjustments made to account for logbooks being less than landings and incorrect reporting process code. Shaded CDR are historical landings values.

Year	Logbook		CDR	H&G Multiplier		Adjusted Logbook			CDR / logbook	Catch for assessment	
	Spawning	Non-spawning		Spawning	Non-spawning	Spawning	Non-spawning	Total		Spawning	Non-spawning
1979	245	245		1	1	245	245	490	1	245	245
1980	410	410		1	1	410	410	820	1	410	410
1981	225	225		1	1	225	225	450	1	225	225
1982	390	390		1	1	390	390	780	1	390	390
1983	450	450		1	1	450	450	900	1	450	450
1984	675	675		1	1	675	675	1350	1	675	675
1985	600	600		1	1	600	600	1200	1	600	600
1986	246	1204		1.2	1.4	295	1685	1981	1.04	317	1807
1987	782	1455		1.2	1.4	939	2036	2975	1.04	1006	2183
1988	319	1485		1.2	1.4	383	2079	2462	1.04	410	2228
1989	36	1829		1.2	1.4	43	2561	2604	1.04	46	2745
1990	570	1671		1.2	1.4	684	2340	3023	1.04	733	2508
1991	637	2508		1.2	1.4	764	3511	4275	1.04	819	3764
1992	509	1565	3259	1.2	1.4	730	2208	2938	1.11	710	2549
1993	812	1659	3362	1.2	1.4	1056	2349	3405	0.99	994	2368
1994	974	1338	3151	1.2	1.4	1185	1914	3100	1.02	1211	1940
1995	911	1017	2775	1.2	1.4	1114	1460	2574	1.08	1205	1570
1996	1200	1061	3040	1.2	1.4	1442	1535	2978	1.02	1496	1544
1997	2623	997	4516	1	1.4	2623	1442	4065	1.11	2947	1569
1998	2739	1452	5733	1	1	3463	1491	4954	1.16	3746	1986
1999	5460	2054	9324	1	1	5649	2115	7763	1.20	6775	2549
2000	5665	1755	8655	1	1	5670	1820	7490	1.16	6608	2047
2001	7309	1022	9124	1	1	7331	1063	8393	1.09	8004	1120
2002	6825	1147	9161	1	1	6850	1185	8035	1.14	7843	1318
2003	7239	679	8471	1	1	7255	691	7946	1.07	7745	726
2004	4647	1218	6392	1	1	4653	1275	5928	1.08	5064	1327
2005	2880	1199	4283	1	1	2903	1221	4124	1.04	3024	1259
2006	2058	1332	3614	1	1	2069	1369	3439	1.05	2193	1420
2007	1815	1228	3171	1	1	1815	1228	3044	1.04	1891	1280
2008	2838	1306	3931	1	1	2838	1306	4143	0.95	2692	1239
2009	2723	1144	3259	1	1	2712	1144	3856	0.85	2295	964
2010	3384	1157	4185	1	1	3384	1157	4540	0.92	3119	1066
2011	3554	913	4201	1	1	3554	913	4467	0.94	3342	859
2012	3838	620	4004	1	1	3838	620	4458	0.90	3447	557

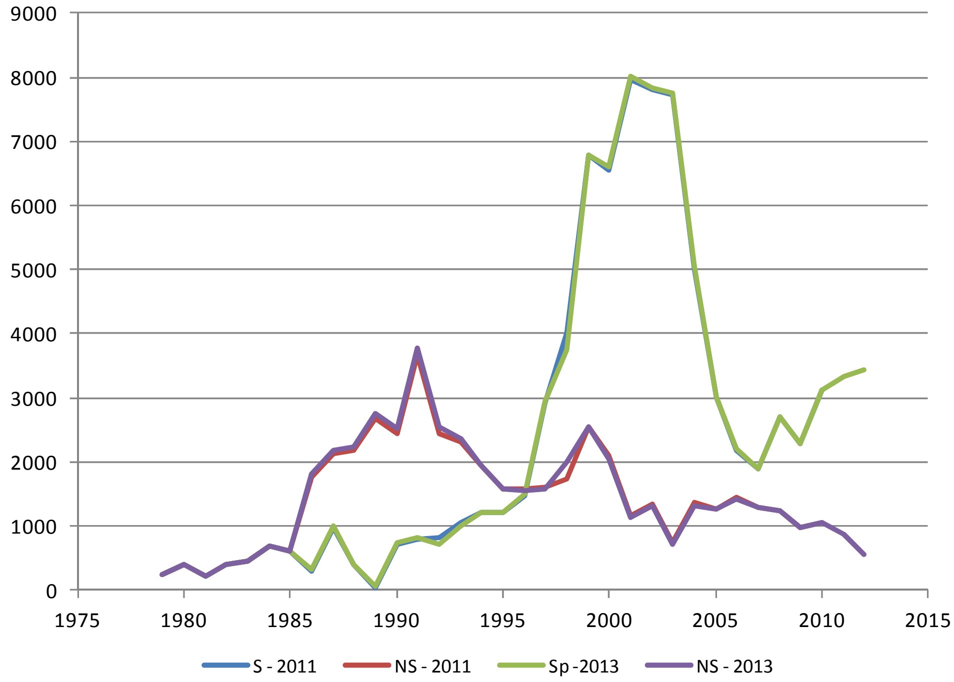

Figure 5.2 The 2013 annual catch series (tonnes) for the spawning (S-2013) and non-spawning (NS-2013) blue grenadier fisheries in comparison to the series for 2011 (Tuck, 2011).

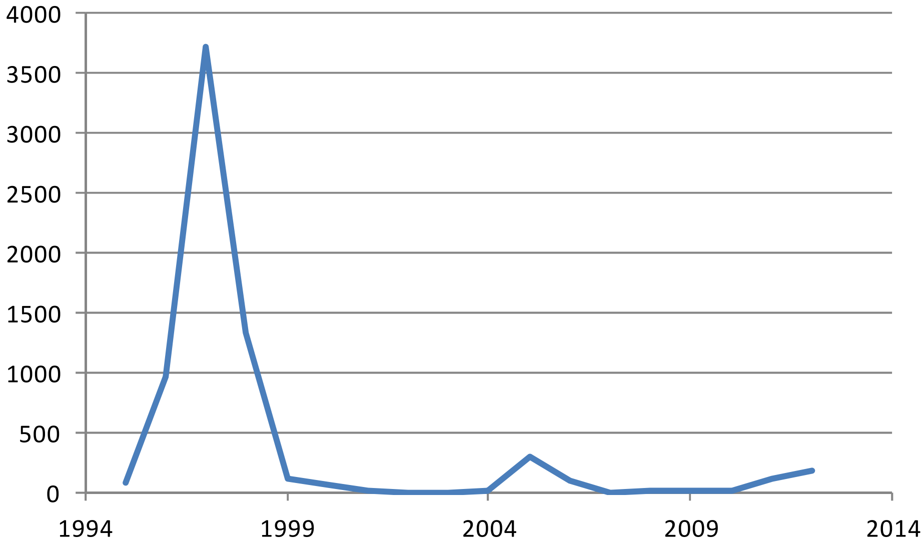

Figure 5.3 The 2013 annual discard series (tonnes) for the non-spawning blue grenadier fishery.

5.4.2 *Catch rates*

Haddon (2013) provides the updated catch rate series for blue grenadier (Table 5.1, Figure 5.4). The spawning fishery catch rate series is not used in the assessment as it is not believed to be a good indicator of available biomass for this component of the stock.

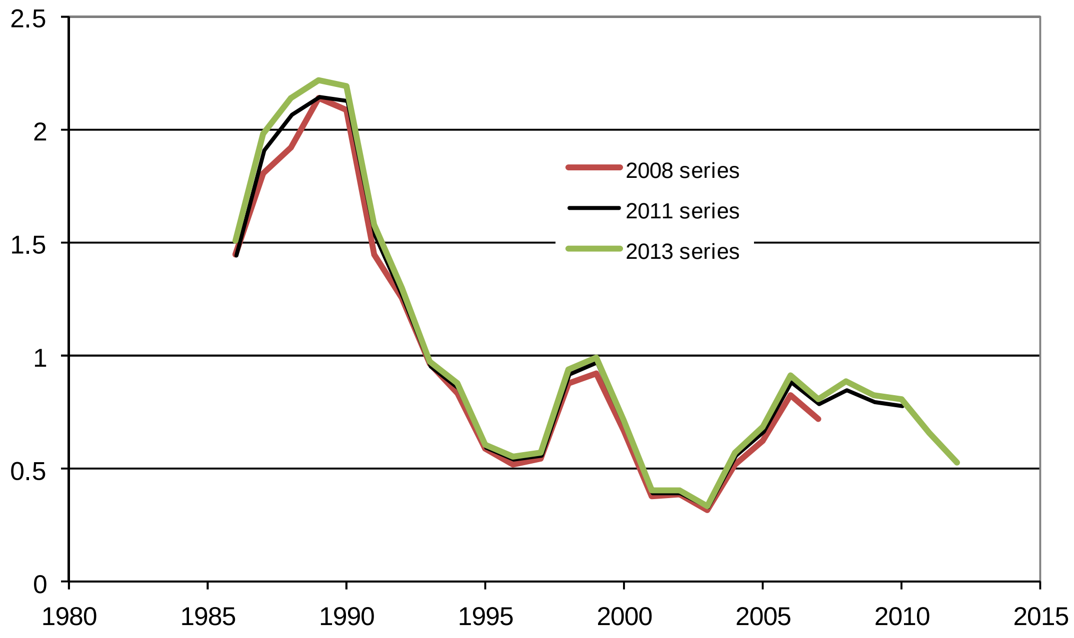

Figure 5.4 The calendar year catch-rate indices for the non-spawning blue grenadier fisheries (Haddon, 2013) in comparison to the series for 2008 and 2011 (Haddon 2008; 2011).

5.4.3 *Length frequencies and age data*

Length and age data are been included in the model as length frequency data and conditional age-at-length data by fleet and sex (when available). Age composition data is included in diagnostic plots but is not used directly within the fitting procedure. On-board and port lengths, when available, were combined to create length frequencies. In previous years, only port samples had been used to create the length frequency. Length data from 1997 were removed from the analyses as there appeared to be data having the DSL process code with lengths that corresponded to the standard length (STL) measurement. This led to unrealistically large lengths when converted from DSL to STL. Discard lengths from 2010 were removed as there were only 16 samples. Figures of the observed length and age data are shown in later figures with the corresponding model predicted values.

5.4.4 *Age-reading error*

Updated standard deviations for aging error by reader (A and B) have been estimated, producing the age-reading error matrix of Table 5.3 (A. Punt, pers. comm.). Reader A applied to years 1991-93 and 2007-2012, and reader B to 1984-1990 and 1994-2006.

Table 5.3. The standard deviation of age reading error.

	St Dev	
Age	A	B
0	0.150	0.286
1	0.150	0.286
2	0.243	0.302
3	0.310	0.319
4	0.359	0.338
5	0.395	0.358
6	0.420	0.381
7	0.439	0.406
8	0.452	0.433
9	0.462	0.463
10	0.469	0.495
11	0.474	0.531
12	0.478	0.570
13	0.480	0.613
14	0.482	0.660
15	0.484	0.712
16	0.485	0.768
17	0.485	0.830
18	0.486	0.898
19	0.486	0.973
20	0.487	1.054

5.4.5 *Acoustic survey estimates*

Estimates of spawning biomass for 2003-2010 are provided in Ryan and Kloser (2012). There are no acoustic estimates for 2011 (not funded) and 2012 (technical issues). Table 5.4 shows the estimates of spawning biomass with their corresponding cv's used in the assessment. Sampling cv's of less than 0.3 were increased to 0.3 to account for process error. Low sampling cvs (of 0.19 for example) were considered too low for an acoustic survey and a minimum of 0.3 should be used to reflect the total uncertainty (D. Smith, pers comm., Tuck et al. 2004; Slope RAG 2011). Of 22 acoustic cvs used for hoki in New Zealand none are lower than 0.3 (Francis, 2009). It is assumed that the spawning ground experiences a turnover rate equal to 2 (i.e. for the model applied here, the spawning biomass estimates are doubled) (Russell and Smith, 2006).

Table 5.4. The estimated biomass (tonnes) of blue grenadier on the spawning grounds in years 2003 to 2010 (Ryan and Kloser, 2012).

	2003	2004	2005	2006	2007	2008	2009	2010
biomass (t)	24690	16295	18852	42882	56330	24450	24787	20622
c.v. in assessment model	0.30	0.46	0.30	0.30	0.52	0.30	1	0.33
Sample cv	0.16	0.46	0.14	0.14	0.52	0.22	1	0.33

5.4.6 *Egg survey estimates*

Egg survey estimates of female spawning biomass are available for 1994 and 1995 (Bulman et al., 1999). The egg-estimates (cv) for 1994 and 1995 respectively are: 57,772 (0.18) and 41,409 (0.29). For the analysis considered here, the base-case egg estimates were used.

5.4.7 *Biological parameters*

The assessment assumes that the proportion of females that spawn in each year is 0.84 and a length at 50% maturity of 63.7cm for females (Russell and Smith, 2006). The female maturity ogive is shown in Figure 5.5.

The length weight relationship for males and females was estimated from spawning fishery data over years 1999 to 2008 (Figure 5.5). Natural mortality for females was estimated and male natural mortality is assumed to be 20% greater than this value based upon assumptions made for hoki in New Zealand (McAllister et al. 1994).

Francis (2009) reviews the values of steepness used in New Zealand hoki assessments, where a value of h=0.9 had been used since 1994. This value of steepness was derived from work of Punt et al. (1994) using 45 stocks of gadiform species (0.9 is the median). Following an analysis of the profile likelihood, the effect of steepness on the 2007 assessment and additional information of Myers et al. (1999; 2002) beyond that used by Punt et al. (1994), Francis (2009) concludes that steepness should be reduced to h=0.75. This value of steepness was assumed in the previous blue grenadier assessment in 2011 (Tuck, 2011) and in this assessment.

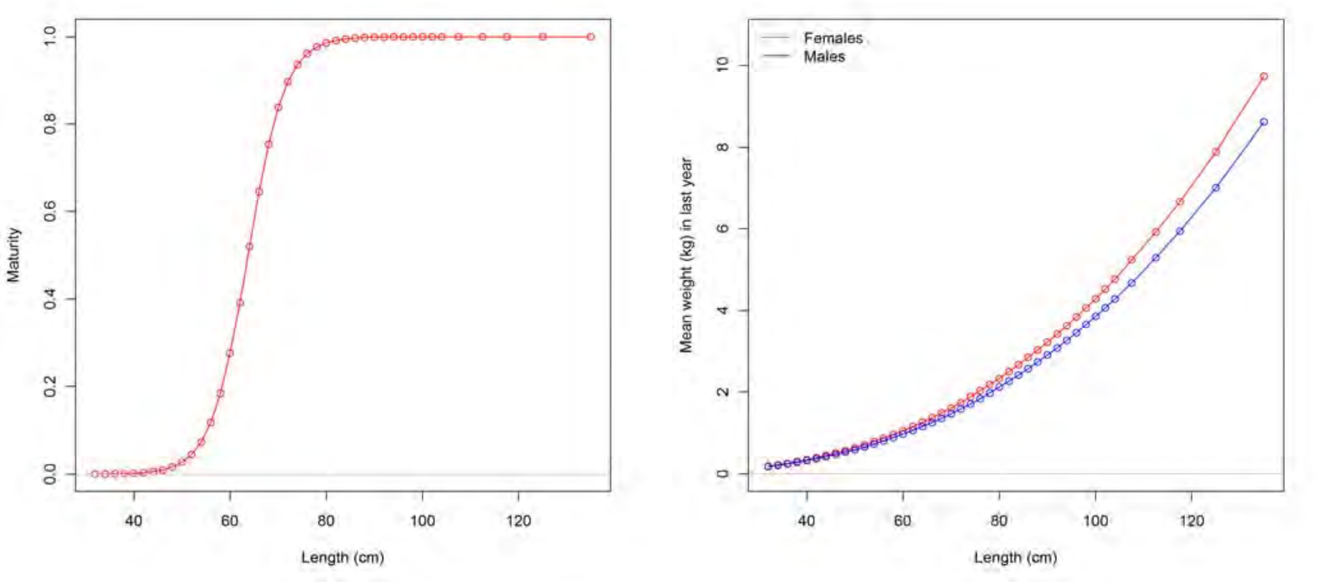

Figure 5.5 The maturity ogive by length for female blue grenadier (parameters from Russell and Smith (2006)) and the length-weight relationship for males and females.

5.5 Analytic approach

5.5.1 The population dynamics model

The 2013 assessment of blue grenadier uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Version 3.24f, NOAA 2011). The methods utilised in SS are based on the integrated analysis paradigm. SS can allow for multiple seasons, areas and fleets, but most applications are based on a single season and area. The assessment of blue grenadier takes advantage of the ability of SS to account for multiple fleet allocations to represent the different dynamics of the spawning and non-spawning fisheries. Recruitment is governed by a stochastic Beverton-Holt stock-recruitment relationship, parameterized in terms of the steepness of the stock-recruitment function (h), the expected average recruitment in an unfished population (R_0), and the degree of variability about the stock-recruitment relationship (σ_r). SS allows the user to choose among a large number of age- and length-specific selectivity patterns. The values for the parameters of SS are estimated by fitting to data on catches, catch-rates, catch length-frequencies, surveys, and conditional age-at-length data. The population dynamics model and the statistical approach used in fitting the model to the various data types are given in the SS technical documentation (Methot, 2005).

This assessment follows the agreements made at the October and November 2011 meetings of Slope RAG. These were: include gender specific selectivity for the spawning fishery, estimate natural mortality for females, use historical discard tonnages estimated by MAFRI, include cohort dependent growth, and set steepness at 0.75.

The base–case model includes the following key features:

(a) Two sub-fisheries are included in the model – the spawning sub-fishery that operates during winter (June – August inclusive) off western Tasmania (zone 40), and the non-spawning sub-fishery that operates during other times of the year and in other areas throughout the year.
(b) The selectivity pattern was assumed to be length-specific, logistic and time-invariant for the spawning fleet and dome-shaped for the non-spawning fleet. The parameters of the selectivity function for each fleet were estimated within the assessment. A change in selectivity from 2005 was considered as a sensitivity for the non-spawning fleet, however this did not substantially affect the fits nor management quantities of interest.
(c) Blue grenadier consists of a single stock within the area of the fishery.
(d) The model accounts for males and females separately.
(e) The population was at its unfished biomass with the corresponding equilibrium (unfished) age-structure at the start of 1960.
(f) The CVs of the CPUE indices for the non-spawning fleet 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 (0.64).
(g) Discard tonnage was estimated through the assignment of a retention function for the non-spawning fleet. This was defined as a logistic function of length, and the inflection and slope of this function were estimated where discard information was available
(h) The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The value for female M is estimated within the model. Following previous assessments, male natural mortality is assumed be 20% greater than that of females.
(i) Recruitment to the stock is assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, h. Steepness for the base-case analysis is set to 0.75. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1974 to 2010. Deviations are not estimated before 1974 or after 2010 because there are insufficient data to permit reliable estimation of recruitment residuals outside of this time period.
(j) The value of the parameter determining the magnitude of the process error in annual recruitment, σ_r, is set equal to 1.0 in the base case reflecting the large variation in recruitment observed for blue grenadier
(k) The population plus-group is modelled at age 20 years. The maximum age for observations was 15 years, reflecting that used in previous assessments
(l) Growth is assumed to follow a von Bertalanffy type length-at-age relationship, with the parameters of the growth function being estimated separately for females and males inside the assessment model. Growth is also assumed to vary through time and be cohort (year class) specific. Evidence for time-varying and cohort specific growth in blue grenadier has been accumulating for over a decade (see Punt and Smith 2001; Whitten et al., 2013). As such, mean length- and mass-at-age by cohort has been derived for previous assessments from age-length keys, the mass-length relationship and length frequency data (Method 2 of Punt and Smith, 2001) and specified directly as mean length- and mass-at-age matrices in the assessment models. The data upon which these matrices were based was treated as being subject to sampling error. Therefore, whilst the previous method allowed for explicit accounting of variability in mean-size through time, it was not conceptually consistent with the Integrated Analysis estimation procedure, which assumes that

mean length- and mass-at-age matrices input into an assessment are known exactly. This method also relied on interpolated length- and mass-at-age estimates for years in which actual data were not available and ignored any age-length relationship. The implementation of the base-case assessment using SS can account for temporal variation in growth, and therefore temporal variation in mean length- and mass-at-age. Following the 2011 assessment, the 2013 base-case model treats length-at-age information as data, and predicts the expected length-at-age for each year. This is achieved by estimating the parameters of a von Bertalanffy growth function that describe the mean expected length-at-age across all years and then introducing an extra parameter that describes cohort specific deviations from mean expected length-at-age for a specified range of year classes. Cohort specific deviations from average growth are estimated in the base case model for year classes 1978 to 2009, the year classes for which there are sufficient length-at-age data to permit reliable estimates.

(m) The sample sizes for length frequencies were tuned for each fleet so that the input sample size was approximately equal to the effective sample size calculated by the model. Before the retuning of length frequency data was performed by fleet, retained length sample sizes were set at 50 and discard length sample sizes to 10. This is because the appropriate sample size for length frequency data is probably more related to the number of shots sampled, rather than the number of fish measured. The length frequency data is given too much weight relative to other data sources if the number of fish measured were used. Discard length sample sizes were set at 10 based approximately upon the ratio of discard to (retained + discard) samples multiplied by 50. Discard length frequencies with samples sizes <200 were removed. The age data sample sizes for a particular year were decreased to 50. The relative frequency of age samples across lengths within a year was maintained. Length, age and cpue data were tuned.

The values assumed for some of the (non-estimated) parameters of the base case models are shown in Table 5.5.

Table 5.5. Parameter values assumed for some of the non-estimated parameters of the base-case model.

Parameter	Description	BC
M_f	Natural mortality for females	Estimated
M_m	Natural mortality for males	1.2* M_f
σ_r	c.v. for the recruitment residuals	1.0
σ_g	Input standard deviation for the cohort growth deviations	0.1
h	“steepness” of the Beverton-Holt stock-recruit curve	0.75
x	age observation plus group	15 years
μ	fraction of mature population that spawn each year	0.84
aa	Female allometric length-weight equations	0.01502 g^{-1}.cm
bb	Female allometric length-weight equations	2.728
aa	Male allometric length-weight equations	0.0168 g^{-1}.cm
bb	Male allometric length-weight equations	2.680
l_m	Female length at 50% maturity	63.7cm
l_s	Parameter defining the slope of the maturity ogive	-0.261

5.6 Results and discussion

5.6.1 Transition from the 2011 to the 2013 assessment

A sequential analysis was conducted to determine the influence of each of the input data sources to the changes observed in the biomass trajectories caused by the inclusion of the 2011 and 2012 calendar year data. A re-examination of the 2011 diagnostic of the standard errors of recruitment residuals showed that recruitments were poorly estimated before 1974 (Figure 5.6). As such, in developing the 2013 base case, recruitment residuals were only estimated from 1974. An examination of the impact of removing estimation of recruitments is shown in the comparison plots of SSB and recruitment (Figure 5.7).

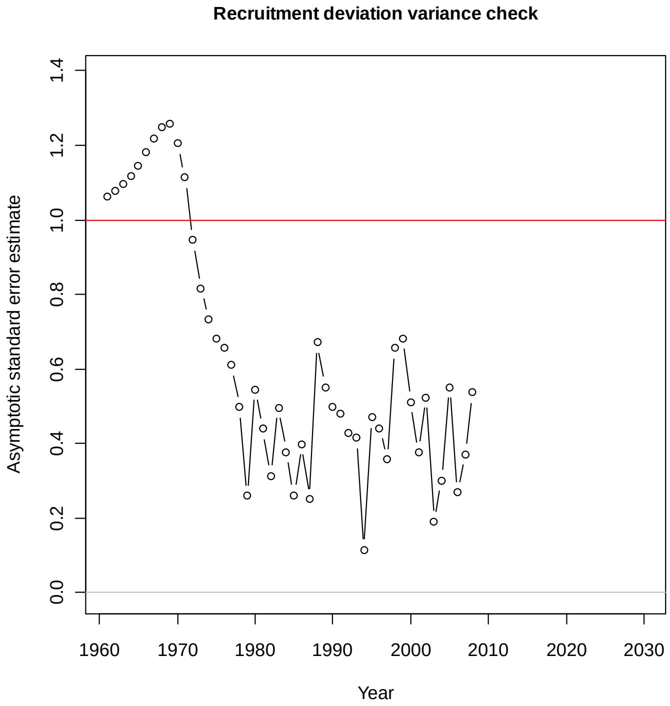

Figure 5.6. Standard errors of recruitment residual estimates for the base case model of 2011 (Tuck, 2011).

Figure 5.7 and Figure 5.8 show the SSB time series as each data source (listed and labelled below) is added and an assessment conducted, while holding the weighting parameters from the tuned model of 2011 fixed. The various transitional assessments and their data-source changes are:

1. The 2011 assessment result (**2011**)

2. The 2011 assessment data with recruitments estimated from 1974 (not 1961) (**R74_2011**)

3. The 2011 assessment data with the addition of the updated catches, including those for 2011 and 2012 (**R74_C**)

4. Option 3 with the updated catch rate series for 2013 (**R74_C_Cpue**)

5. Option 3 with the addition of the updated age data (**R74_C_Age**)

6. Option 3 with the addition of the updated length data (**R74_C_Length**)

7. Option 6 with the addition of the updated age data (**R74_C_Age_ Length**)

8. Option 7 with the addition of the updated catch rate data (**R74_C_Age_Length_Cpue**)

9. Option 8 with the addition of the updated discard masses (**R74_C_Age_Length_Cpue_D**)

10. Option 9 with recruitment estimated to 2010 (**R74_C_Age_Length_Cpue_D_R**)

11. Option 10 with updated age-reading error updated (**R74_C_Age_Length_Cpue_D_R_AE**)

12. Option 11 with Cohort Dependent Growth (CDG) updated (**R74_C_Age_Length_Cpue_D_R_AE_CDG**)

13. The tuned 2013 assessment result (**2013 Tuned BC**)

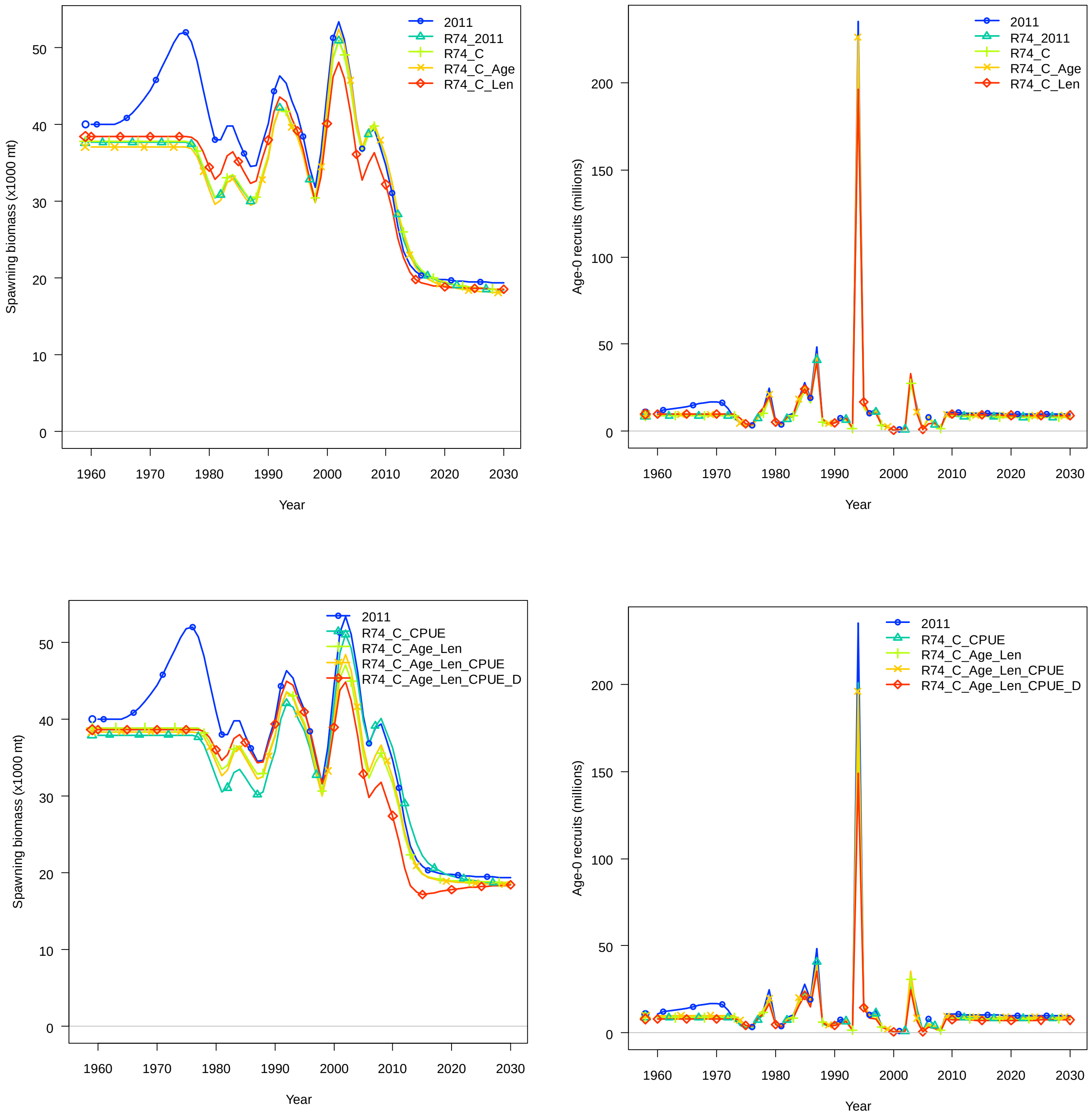

Figure 5.7. The effect on spawning biomass (left) and recruitment estimates (right) of sequentially adding in new data from 2013.

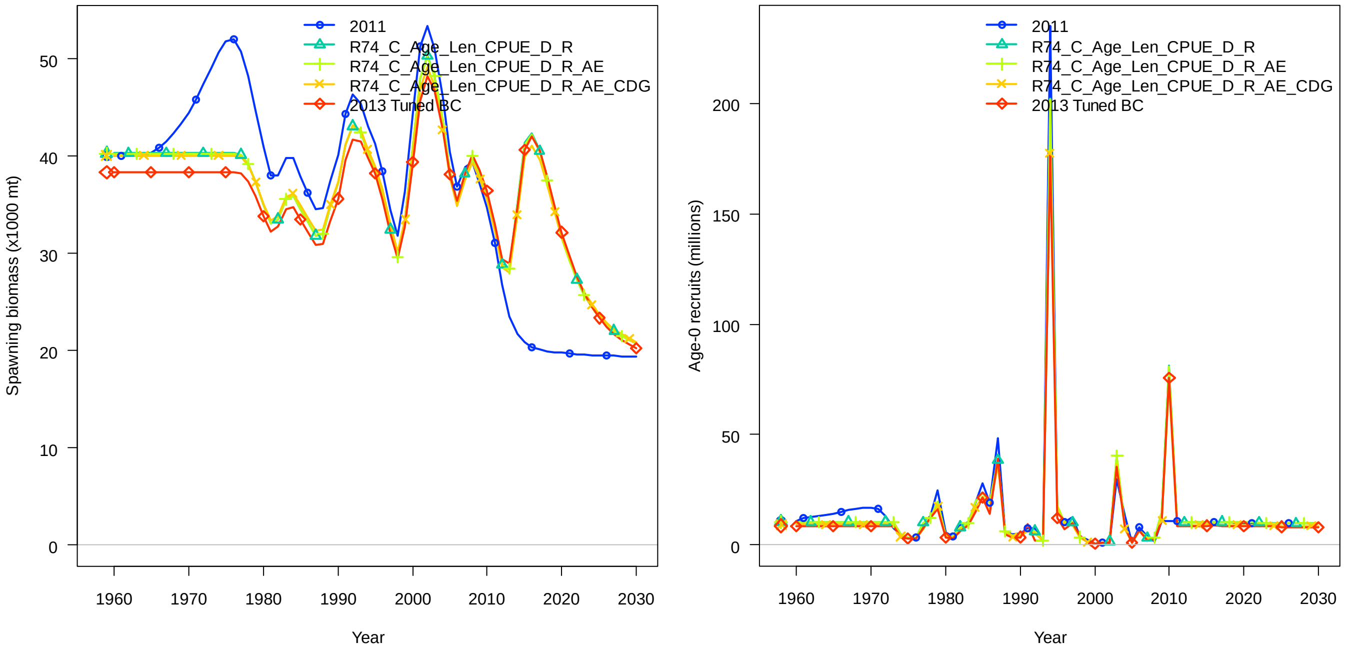

Figure 5.8. The effect on spawning biomass (left) and recruitment estimates (right) of sequentially adding in new data from 2013. The 2013 base case model is labelled ‘2013 Tuned BC’.

The transition from the 2011 to the 2013 base case models illustrated in Figure 5.7 and Figure 5.8 show that for most updated datasets there is little impact on the trend or magnitude in biomass or the recruitment. The largest influence has been the non-estimation of recruitments prior to 1974. The 2011 assessment estimates above average recruitment through to 1974, leading to an initial marked rise in spawning biomass. With these estimates now being deterministic and taken directly from the stock-recruitment curve, the spawning biomass does not deviate from equilibrium until after 1974 (when non-equilibrium recruitment estimates begin to influence the spawning biomass). However, the initial and final biomass differs little between the models (Figure 5.8).

There is also a marked increase in future spawning biomass once the additional years (2009 and 2010) of recruitment are estimated (Figure 5.8). The 2010 recruitment is substantial, second only to the large recruitment of the 1990’s. While a promising sign, it is most likely too early to be sure that this large recruitment will persist, as additional data will need to verify its existence in future assessments.

5.6.2 ***The Base Case Stock Assessment***

5.6.2.1 Parameter estimates

Figure 5.9 shows how the expected mean length-at-age values change over time for the base case model. The ridges reflect the impact of some cohorts growing faster or slower than average. This figure also shows the expected mean length-at-age values for the end-year of the model. The impact of slower than average growth is visible by the decrease in expected size of 9 and 18 yo fish, corresponding to the larger than average recruitments in years 2003 and 1994 respectively. Natural mortality for females was estimated to be M_f =0.15 and males therefore was M_m =0.18.

The selectivity for the spawning and non-spawning fisheries and the retention function for the non-spawning fishery are shown in Figure 5.10. Selectivity is assumed to be time-invariant, sex-specific and logistic for the spawning fleet and dome-shaped for the non-spawning fleet. Note that the estimated female length-specific selectivity for the spawning ground shows an ascending limb that includes much larger fish than the maturity ogive estimated by Russell and Smith (2006), which has an estimate of 50% maturity of 63.7cm. This result implies that, to a large extent, small mature females do not appear to be evident on the spawning ground. Russell and Smith (2006) present length frequencies during their study of blue grenadier reproductive biology showing that very few female fish less than 60cm were caught (also see Figure 5.12). However those that were caught were included in the study and a proportion of these fish were shown to be mature.

5.6.2.2 Fits to the data

Figure 5.11 shows the model fit to the non-spawning catch rate series. The model fits intersect most of the 95% confidence intervals for the data, indicating that adjustments to the CV for the indices performed as expected. As has been seen in all previous assessment models for blue grenadier, the model is not able to fit the rise in catch rate following the large recruitment of the mid-1990s. The fit to the discard mass is able to replicate the increase in discarding through the late 1990s and mid 2000s, however the magnitude is under-estimated in the mid 1990s (as has been the case with previous assessments). The inability of the model to fit to the catch rate data has been investigated (in previous assessments and here) by fixing the cpue cv (0.1) and forcing a better fit to these data (Appendix 2). However, this leads to significantly poorer fits to other data series and spawning biomass trajectories that appear unlikely. Including a separate ‘discard fleet’ will be considered as a sensitivity leading up to the coming RAG meeting. Fits to the biomass estimates from the acoustic surveys and egg surveys were reasonable.

The model is able to replicate the implied age-composition data and the length composition data well (Figure 5.12 and Figure 5.13; Appendix 1). Predicted age-compositions are able to track the strong cohorts typical of blue grenadier as they move through both the non-spawning fishery and the spawning fishery. The inclusion of sex-specific selectivity has allowed a better fit to the observations of length and age by sex.

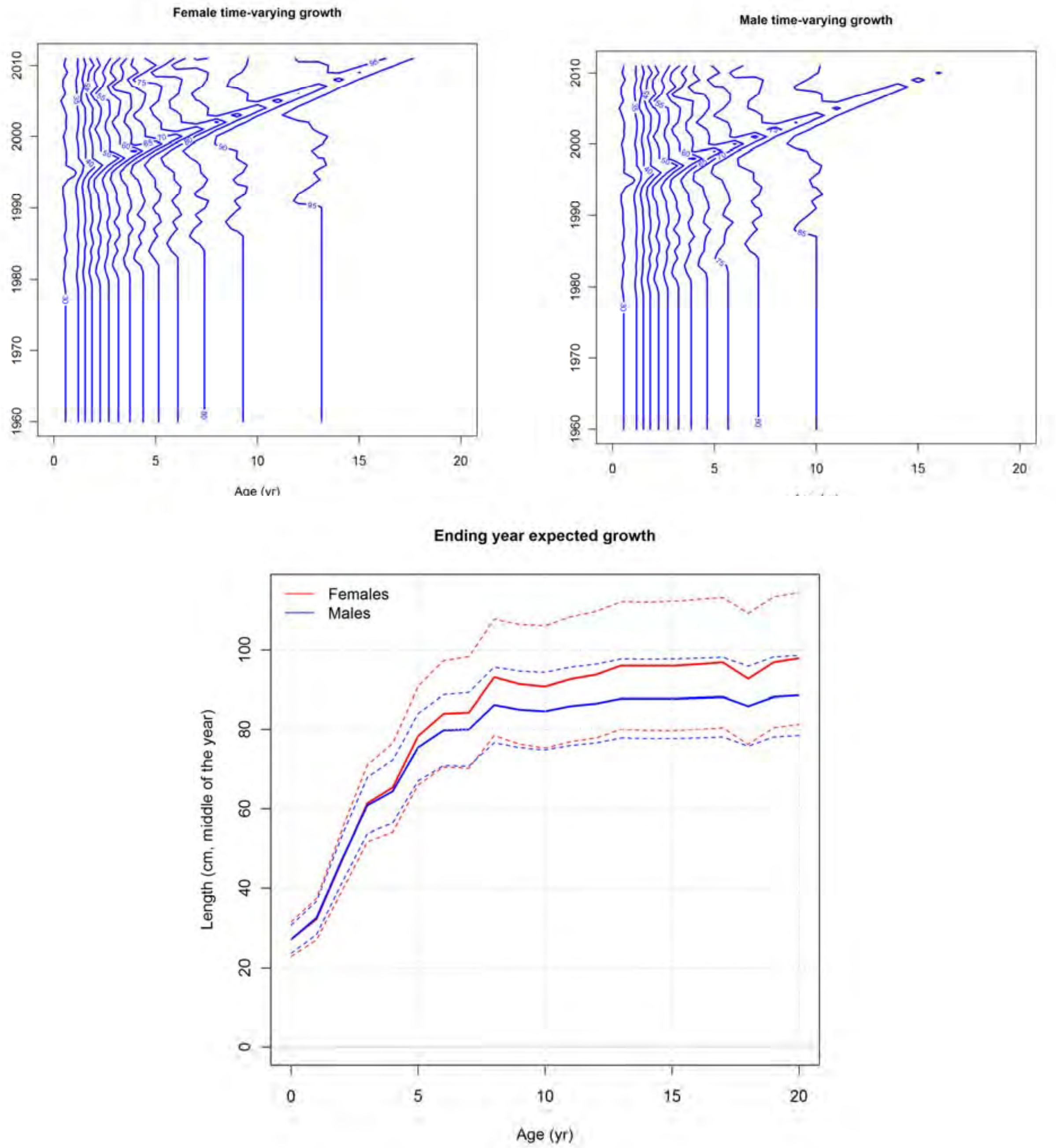

Figure 5.9. The base case predicted length at age relationship.

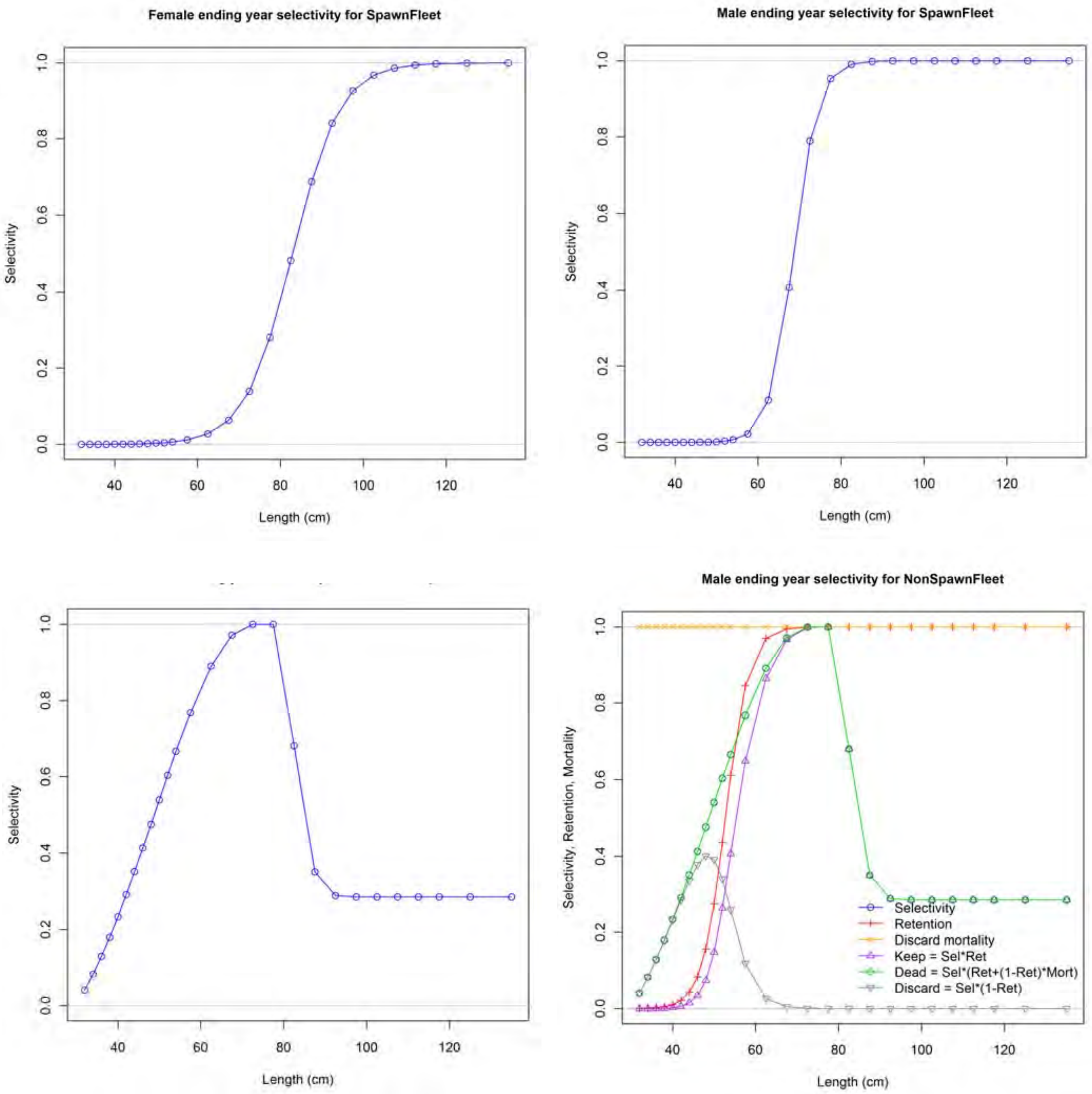

Figure 5.10. The base case model sex-specific selectivity for the spawning fishery (top). Females (left) and males (right). The selectivity for the non-spawning fishery (bottom left) and the retention function (bottom right – red).

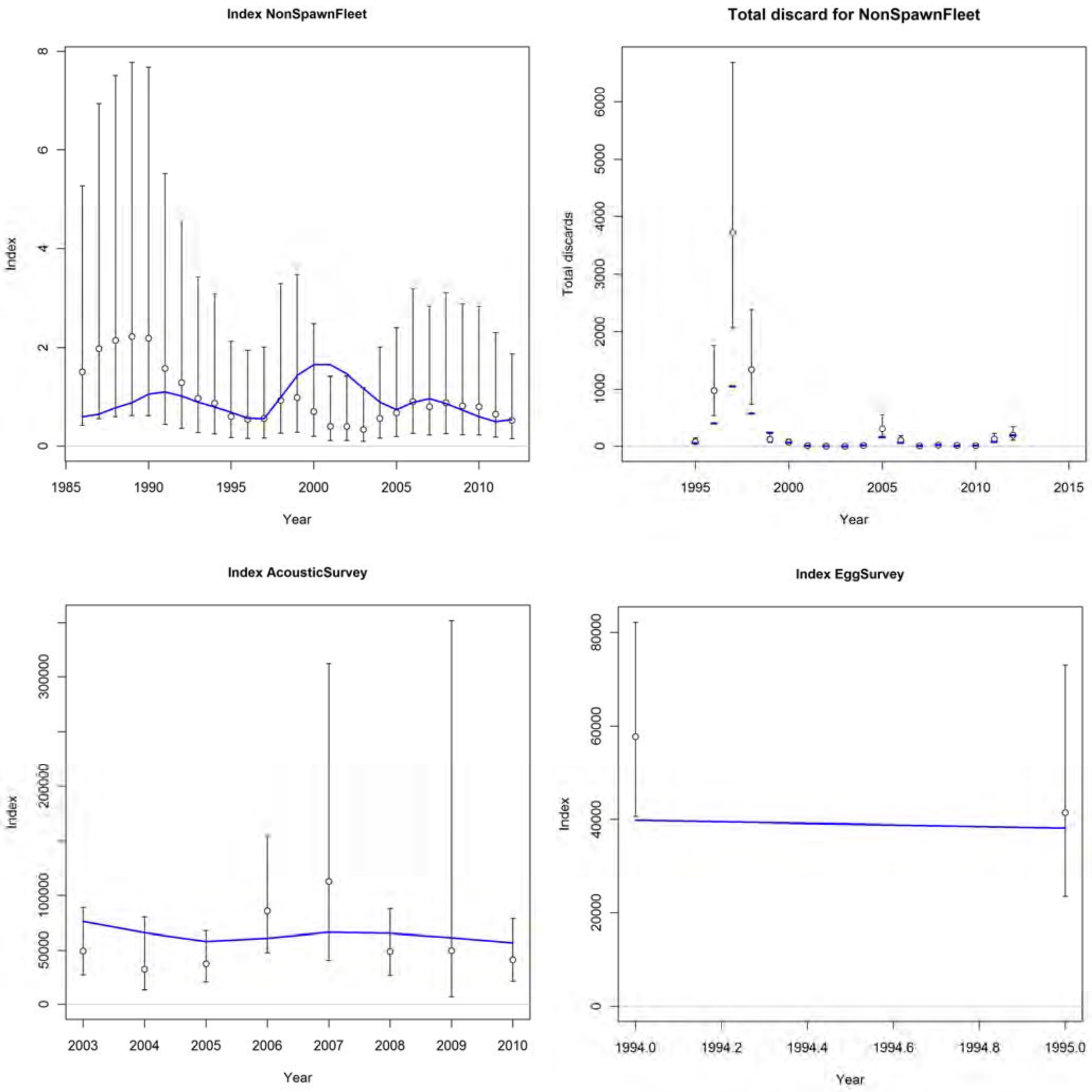

Figure 5.11. The base case model fit to the non-spawning catch rate series (top left), the discard mass (top right), the acoustic survey (bottom left) and the egg survey (bottom right).

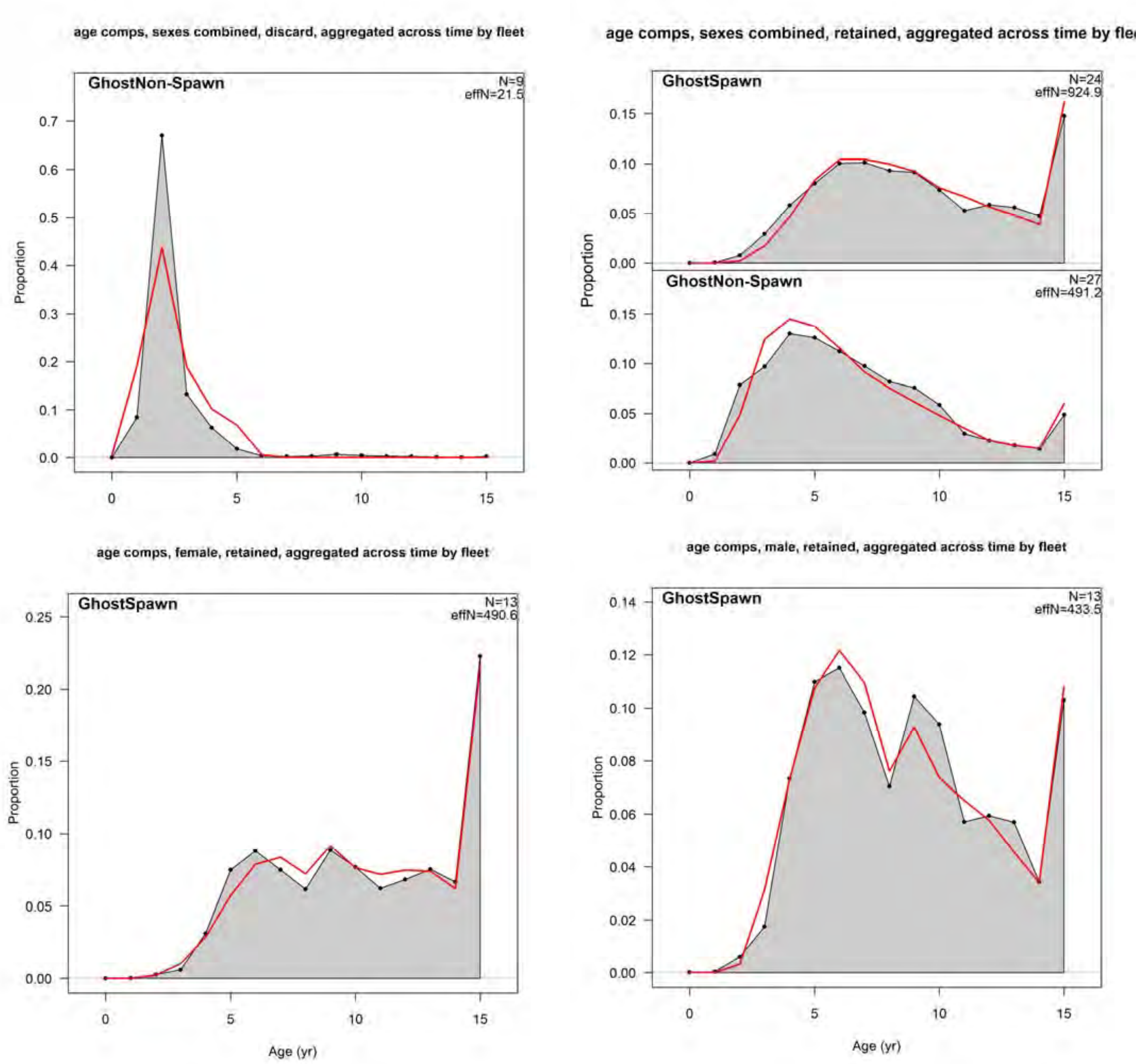

Figure 5.12. The base case model fit to the year-aggregated age-composition data.

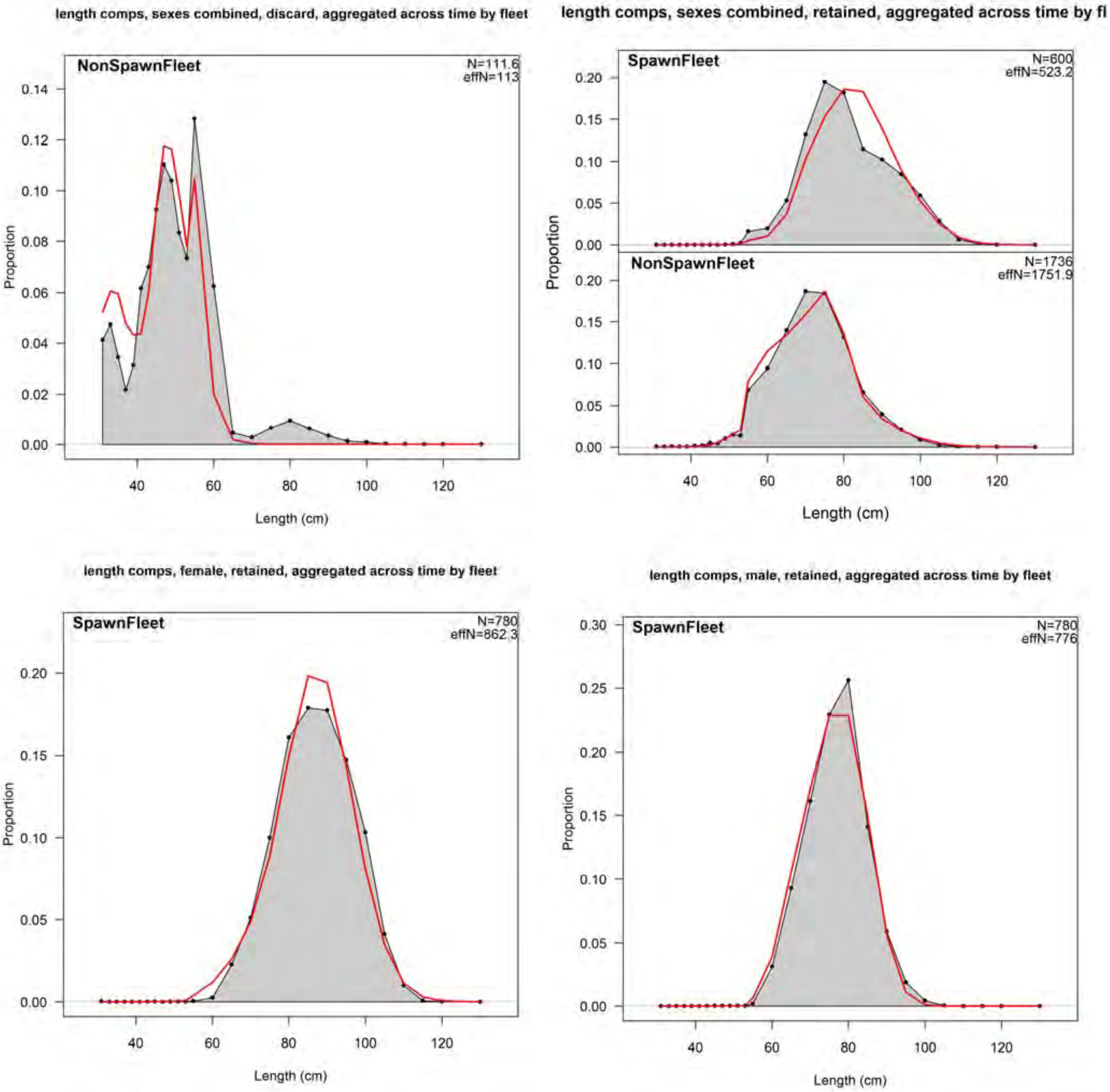

Figure 5.13. The base case model fit to the year-aggregated length composition data.

5.6.2.3 Assessment outcomes

The estimated time series of recruitment under the base-case parameter set shows the typical episodic nature of blue grenadier recruitment, with strong year-classes in 1979, the mid-1980s, 1994, 2003 and now 2010, and with very little recruitment between these years (Figure 5.14). The magnitude of the recruitment of 2010 will remain somewhat poorly estimated until these fish move well into the available stock of the fishery.

The trajectories of spawning biomass and spawning biomass depletion are shown in Figure 5.15. This shows the increases and decreases in spawning biomass as the strong cohorts move into and out of the spawning population. The estimated virgin female biomass is 38,365 tonnes (compared to 39,983 t in the 2011 assessment). In 2011, the estimated depletion level under the base-case scenario for 2010 was 87% and the depletion in 2012, which was used in the harvest control rule, was approximately 67%. In the 2013 assessment, the estimated depletion level under the base-case scenario for 2012 is 77% and the depletion in 2014, which is used in the harvest control rule, is approximately 90%.

The more optimistic outlook from this assessment is largely being driven by the addition of 2 further years of data and the substantial estimated recruitment in 2010. While a promising sign for the fishery, some caution should be exercised with regard to this recruitment estimate and its implication on future stock status, until clear further indications of its existence (and magnitude) are evident in future years' data. If the 2010 recruitment is not estimated, then the (un-tuned) model instead estimates an above average recruitment in 2009 (Appendix 3). The model fit to the age composition data is poorer for fish of age 1 in 2011 and 2 in 2012. The depletion levels also differ substantially, being 69% in 2012 and 59% in 2014.

5.6.2.4 Further development

1) Explore the lack of fit to the catch rate series of the non-spawning fishery using a discard fleet in SS.

2) Further explore the impact of the 2010 recruitment on model outcomes.

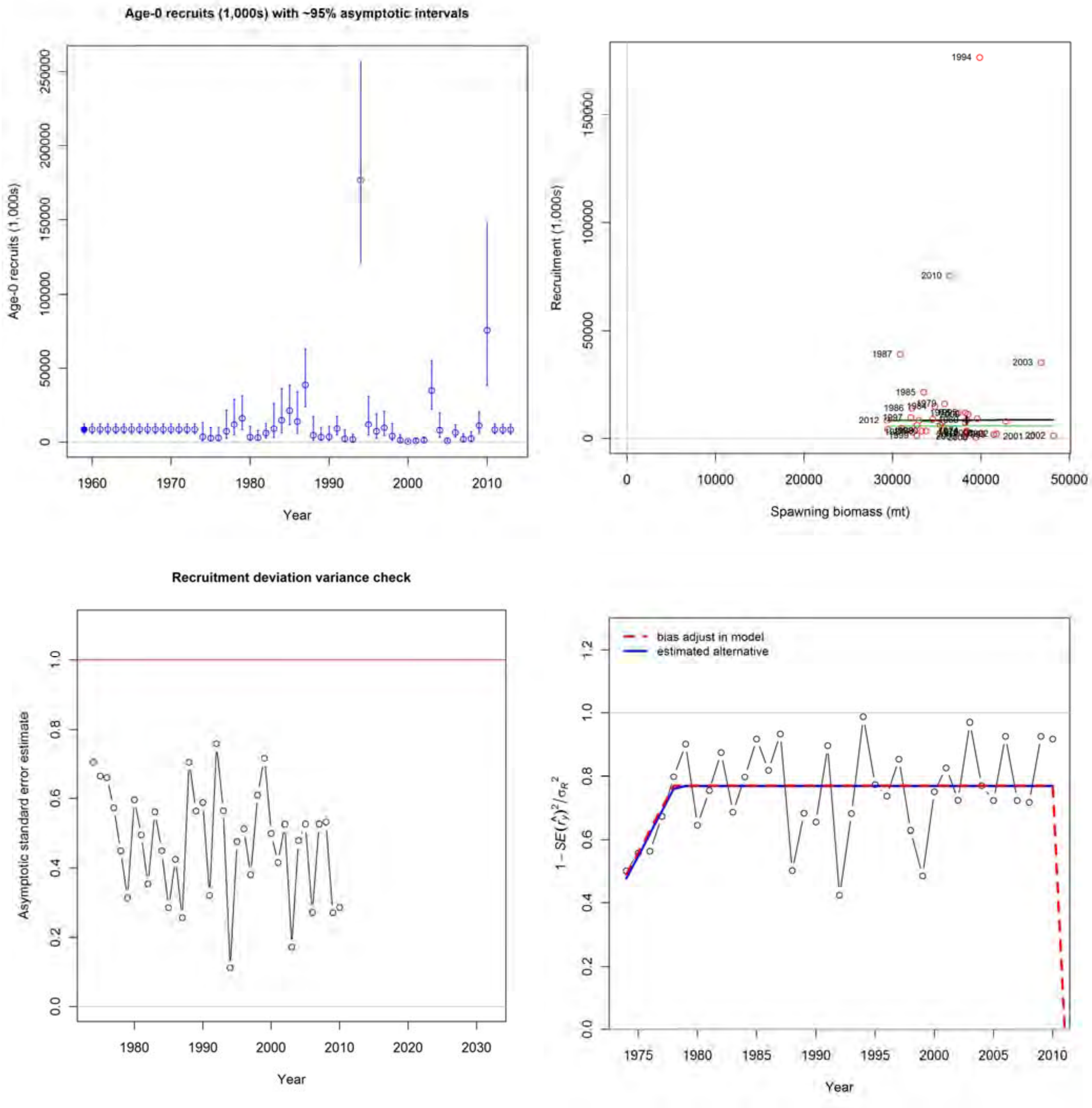

Figure 5.14. Recruitment estimation for the base case analysis. Time-trajectories of estimated recruitment numbers (top left). The stock-recruit curve and estimated recruitments (top right). Recruitment diagnostics recruitment deviation variance check (bottom left) and bias adjustment check (bottom right).

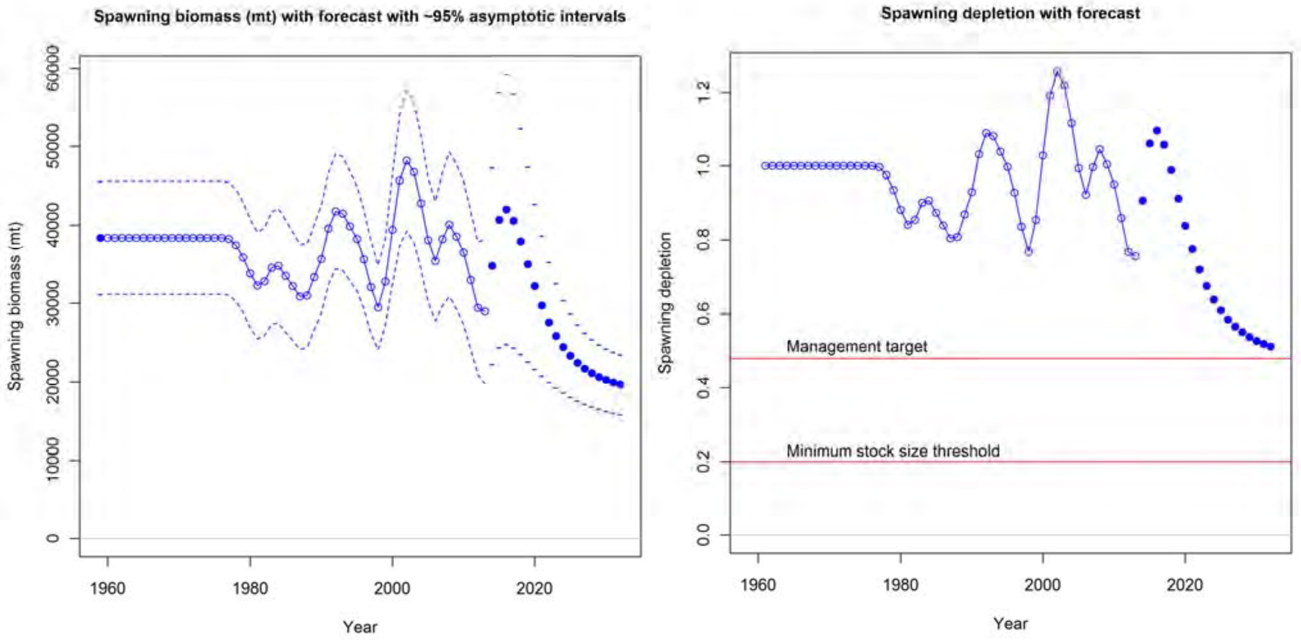

Figure 5.15. The time-series of spawning biomass and spawning biomass depletion for the base case model.

5.7 Acknowledgements

Many thanks are due to the SESSF-WG for their assistance with model discussions and development. Andre Punt and Athol Whitten are thanked for model development advice, Malcolm Haddon for providing catch rate indices, Andre Punt for age-reading error updates, and 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.

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5.9 Appendix 1: length and age compositions and other diagnostics for the base case model

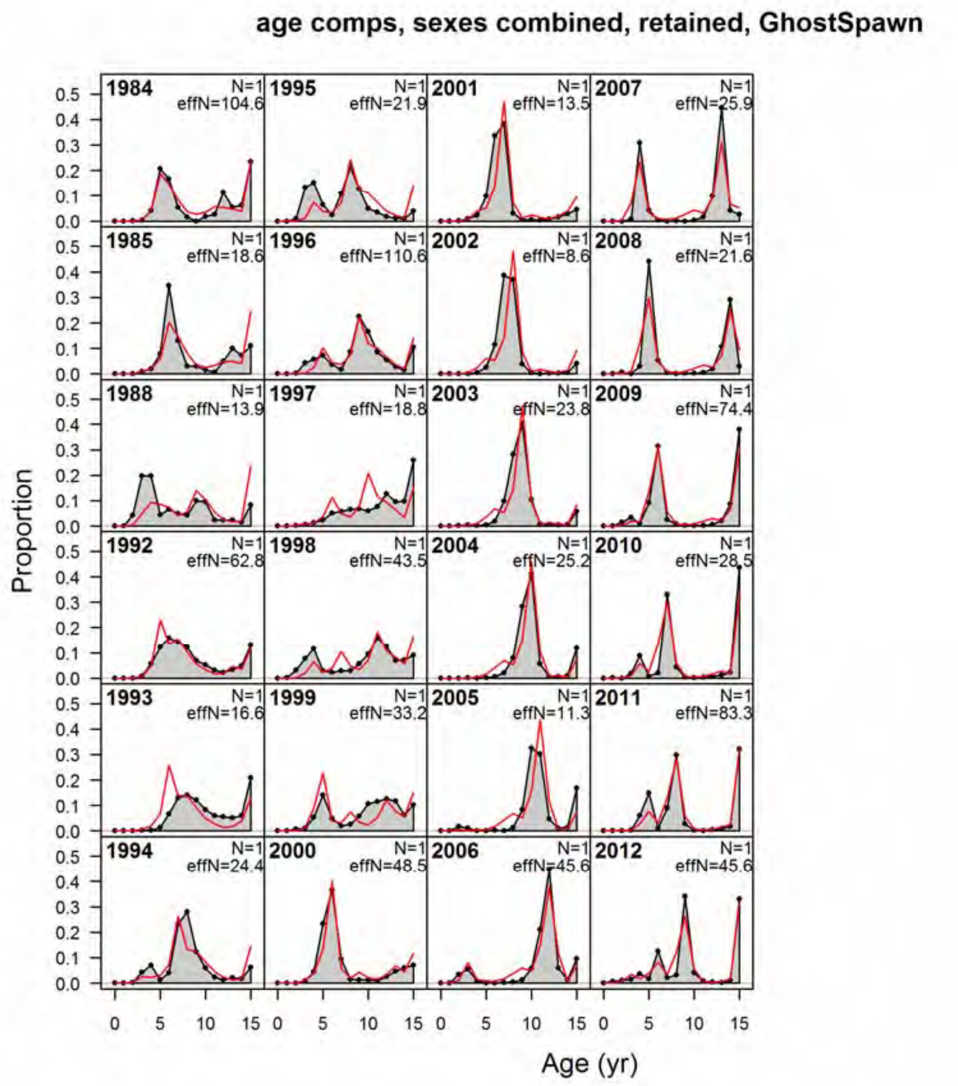


Figure 5.16. The base case model fit to the age-composition data for the spawning fishery. Sexes combined.

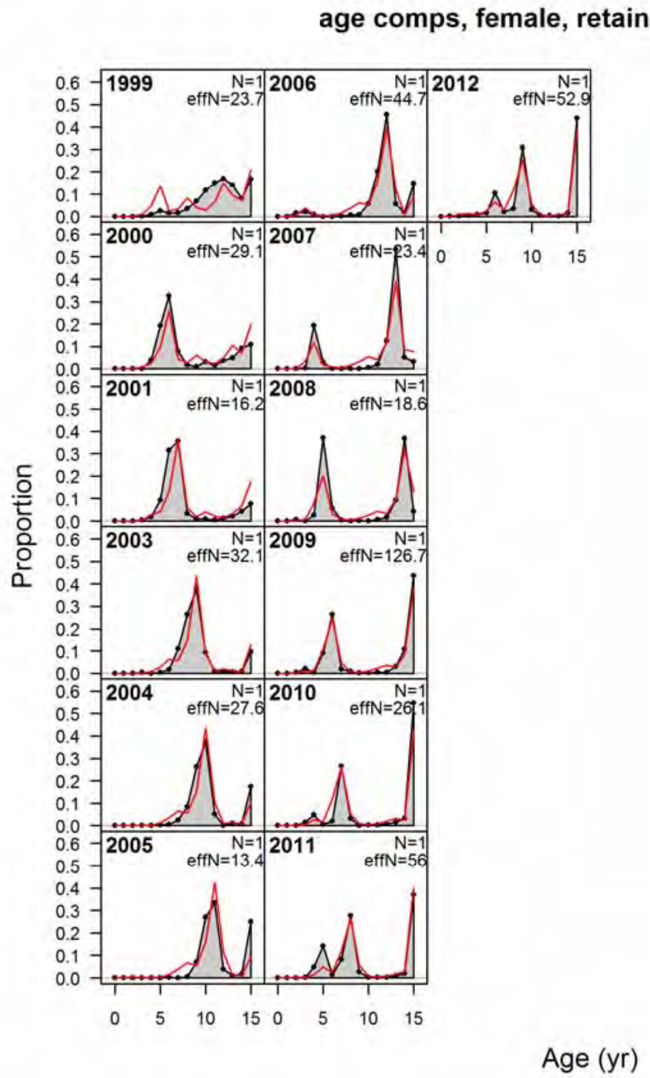


Figure 5.17. The base case model fit to the female age-composition data for the spawning fishery.

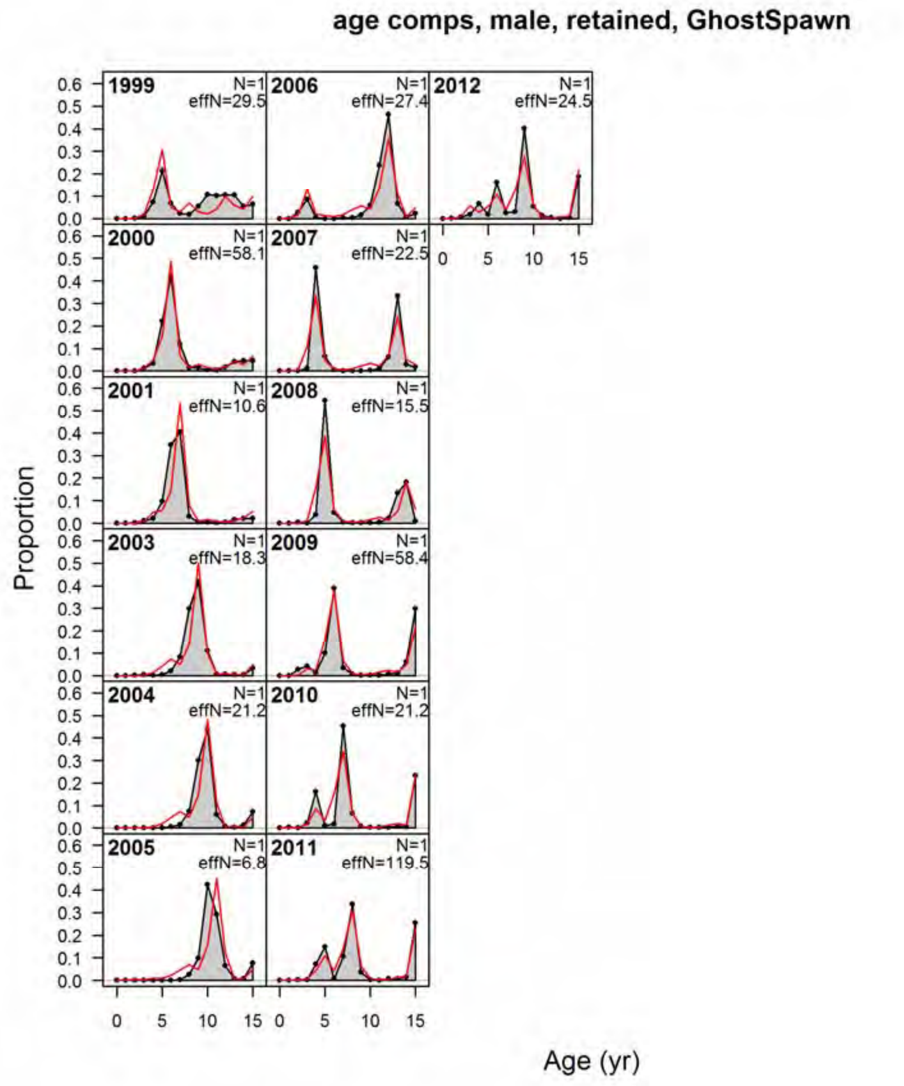


Figure 5.18. The base case model fit to the male age-composition data for the spawning fishery.

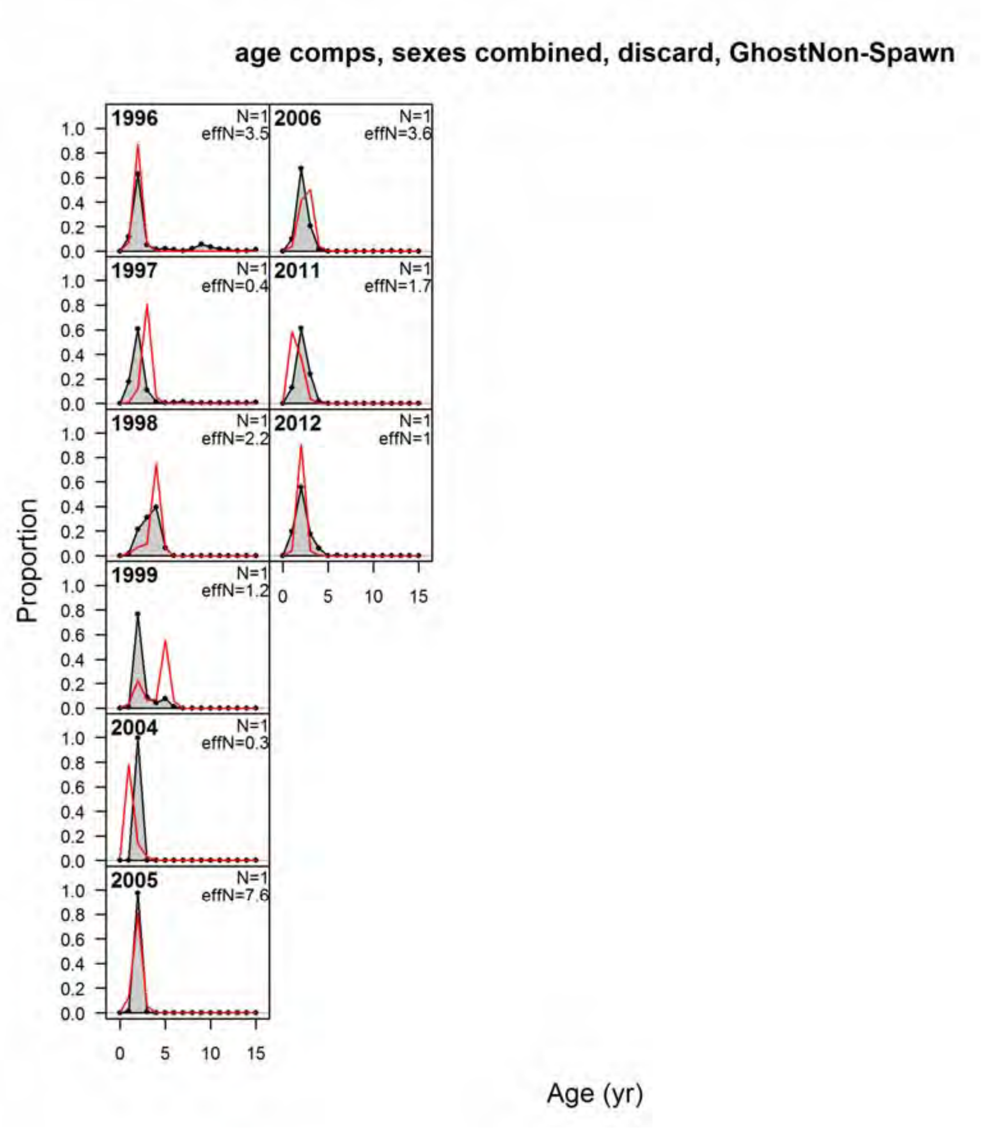


Figure 5.19. The base case model fit to the discard age-composition data for the non-spawning fishery.

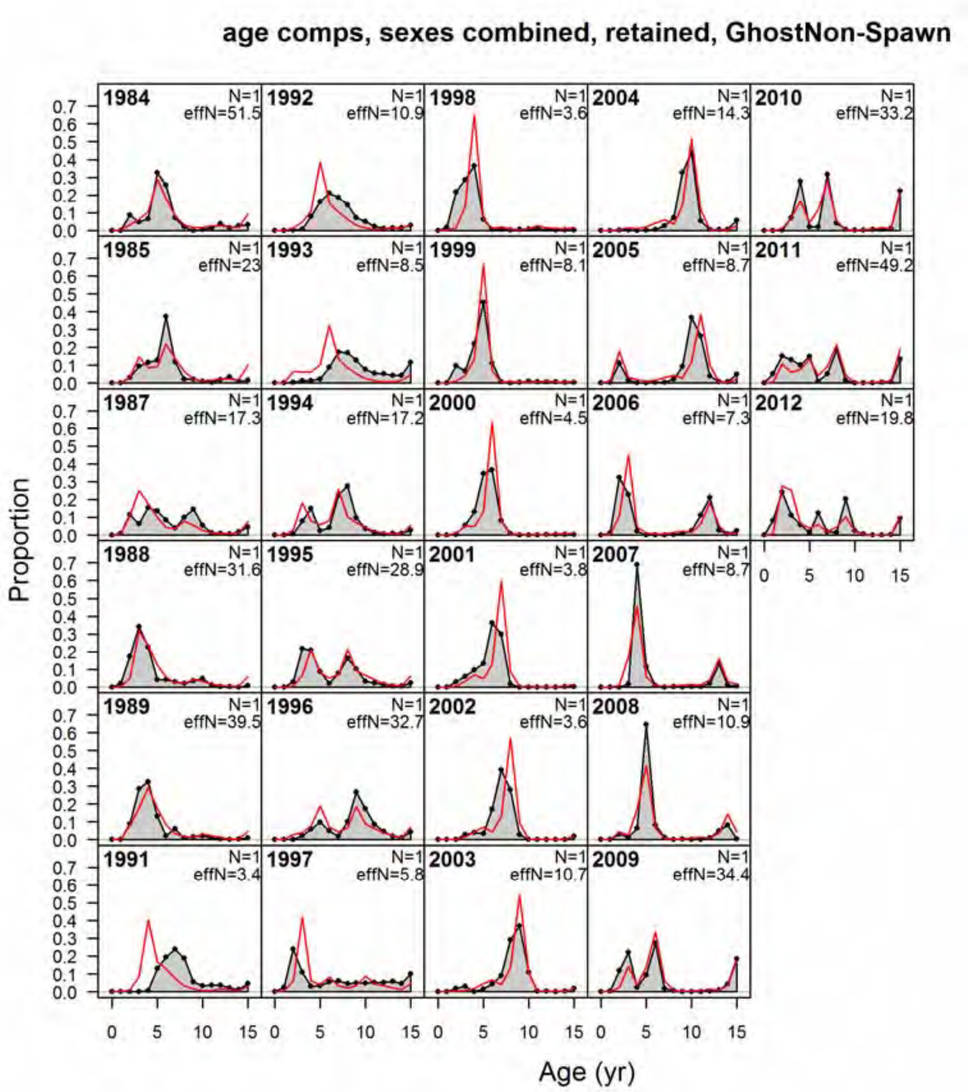


Figure 5.20. The base case model fit to the retained age-composition data for the non-spawning fishery.

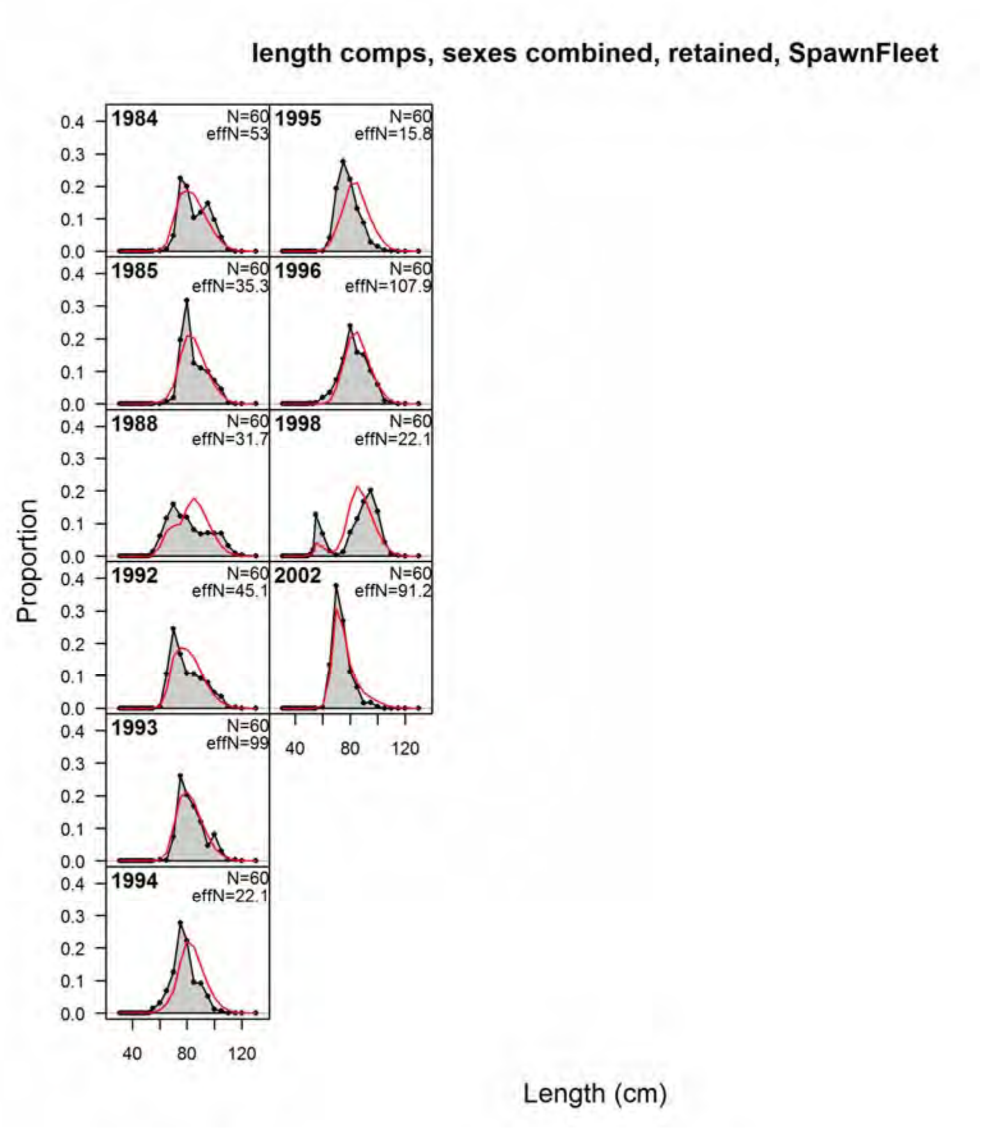


Figure 5.21. The base case model fit to the retained length-composition data for the spawning fishery.

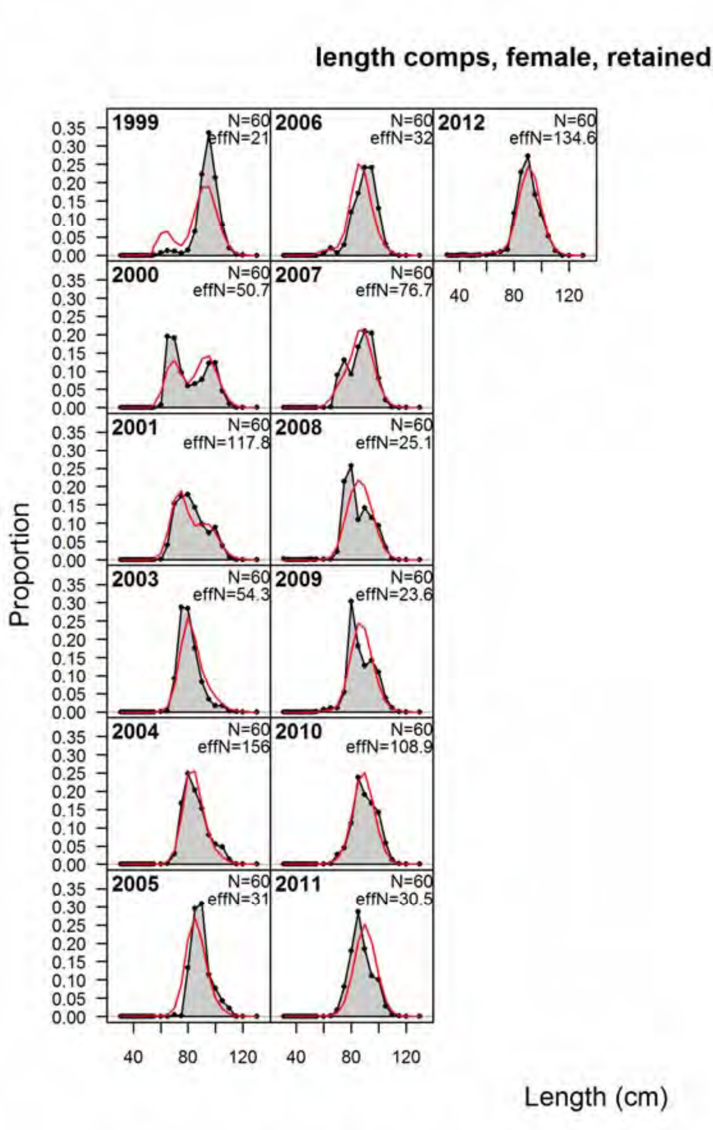


Figure 5.22. The base case model fit to the retained female length-composition data for the spawning fishery.

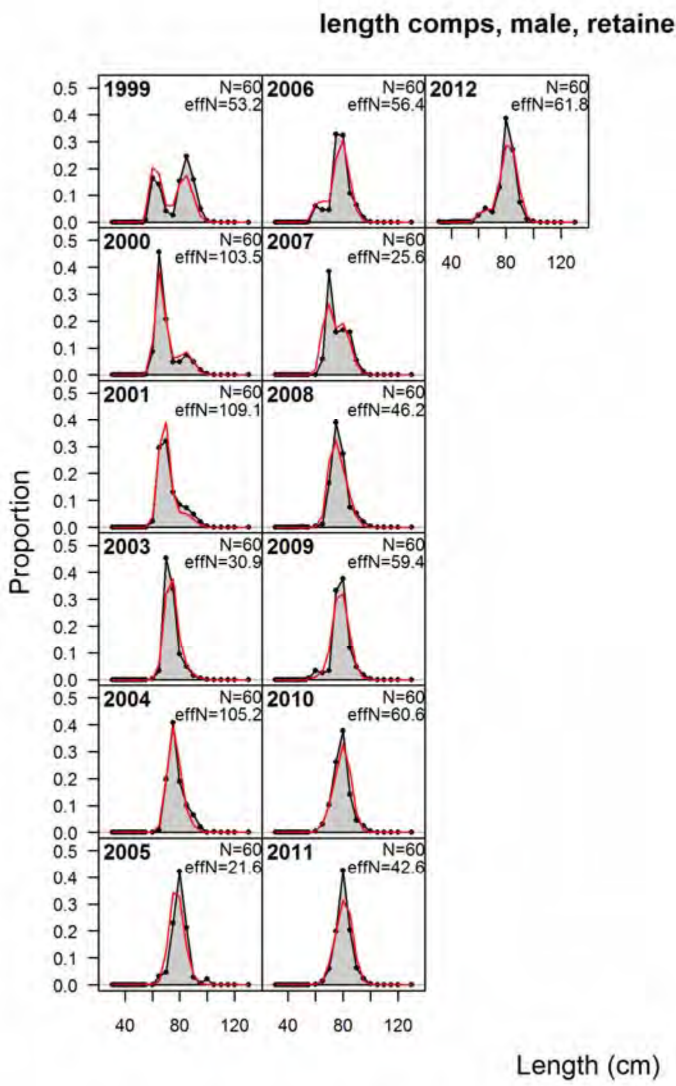


Figure 5.23. The base case model fit to the retained male length-composition data for the spawning fishery.

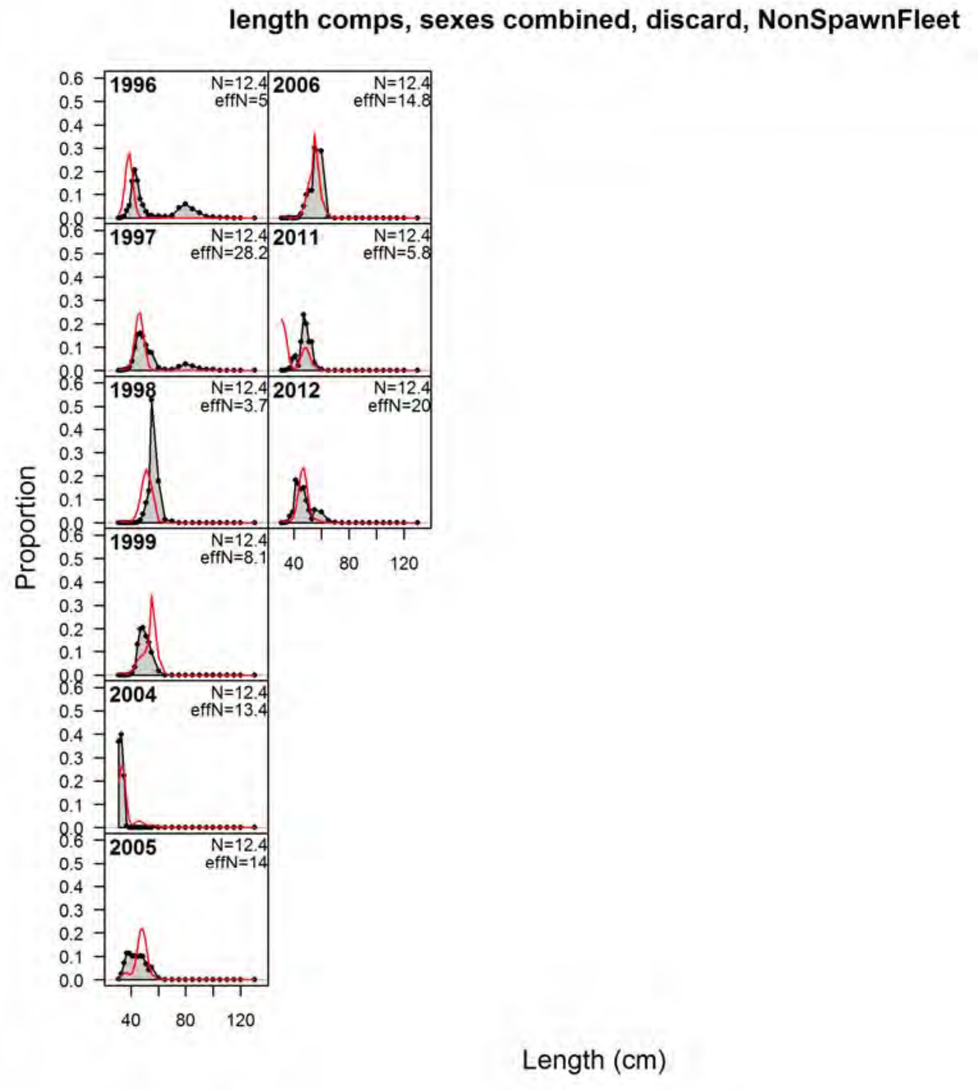


Figure 5.24. The base case model fit to the discard length-composition data for the non-spawning fishery.

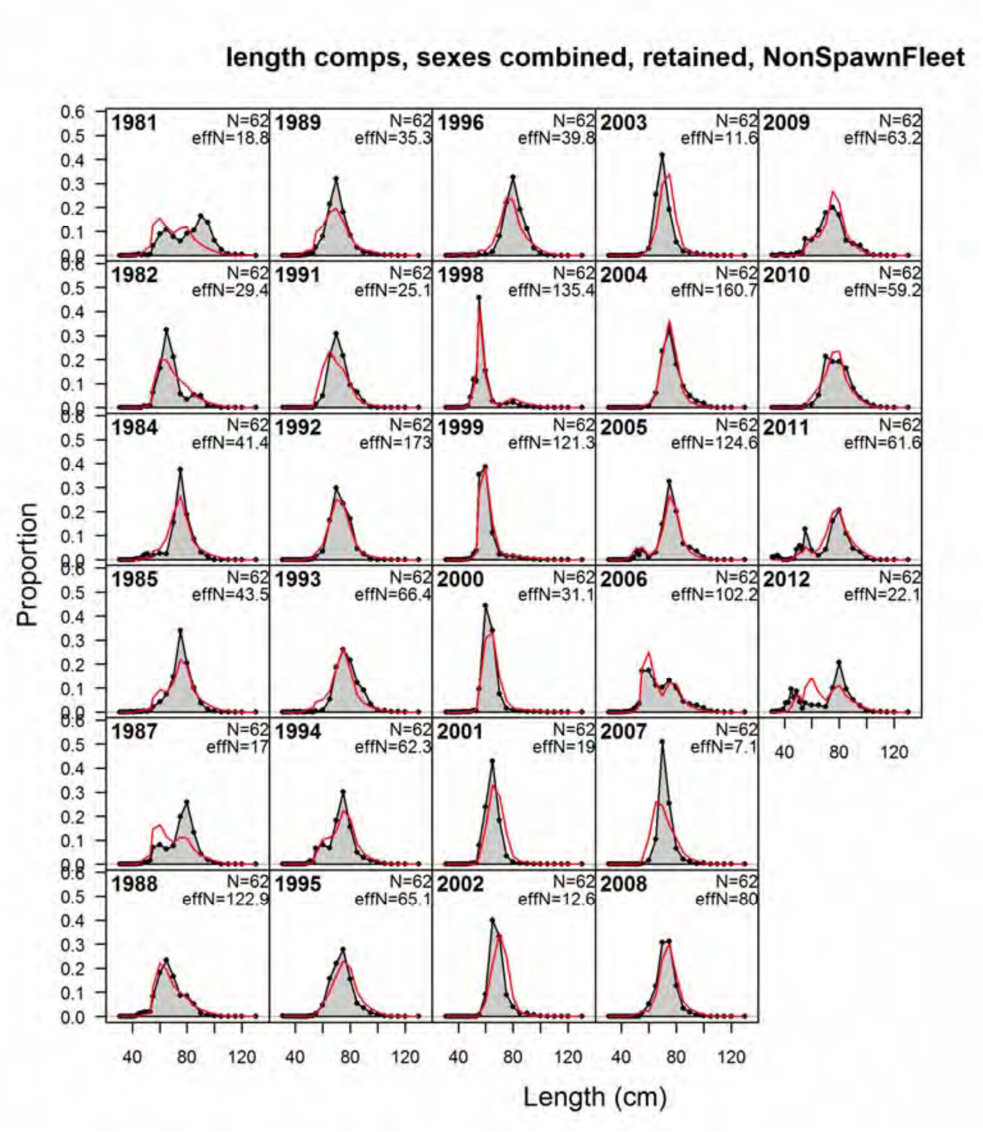


Figure 5.25. The base case model fit to the retained length-composition data for the non-spawning fishery.

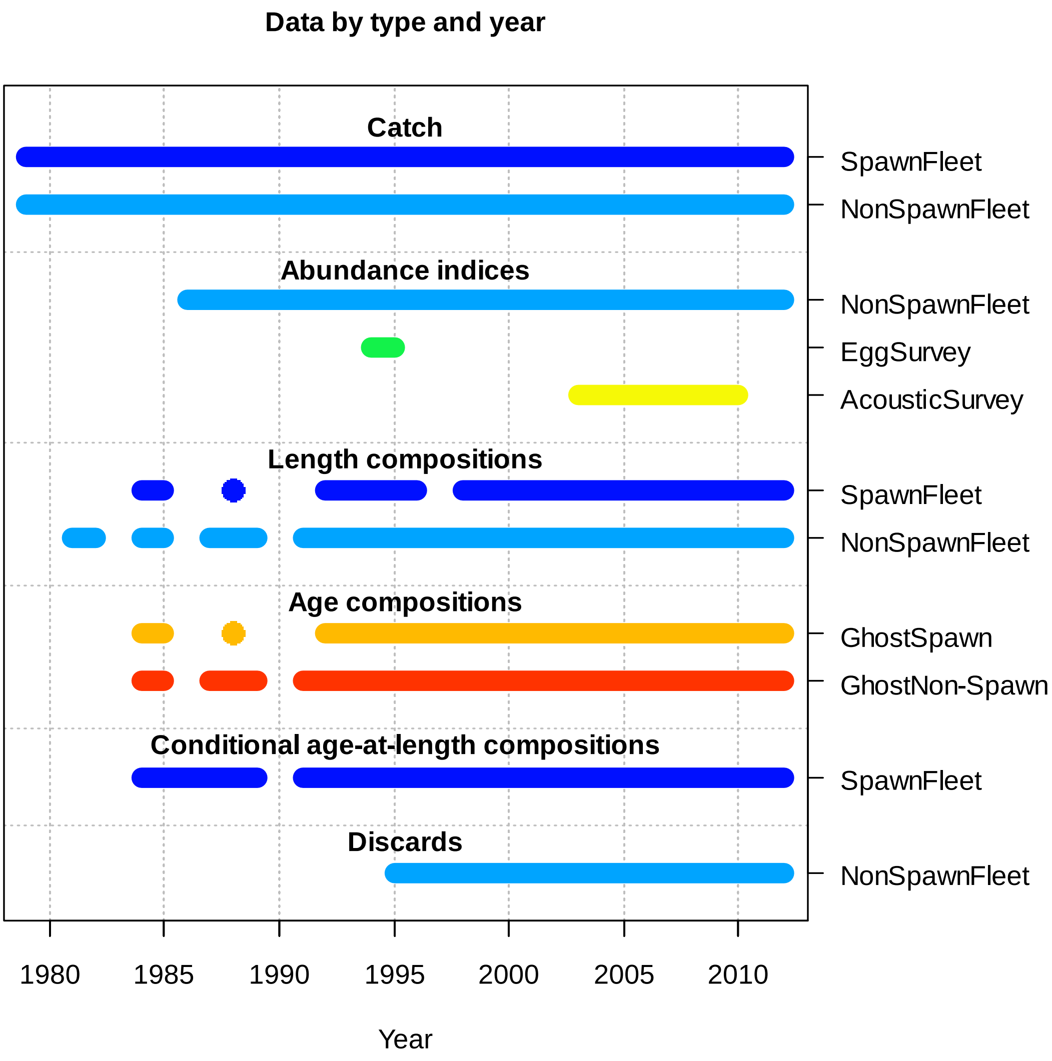
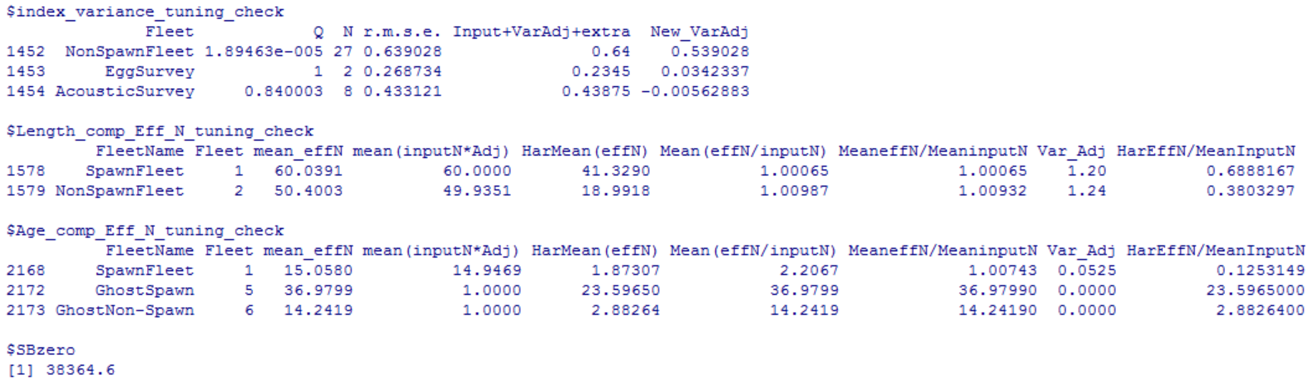


Figure 5.26. The input data available for the base case blue grenadier model.



```
$index_variance_tuning_check
              Fleet            Q  N r.m.s.e. Input+VarAdj+extra  New_VarAdj
1452  NonSpawnFleet 1.89463e-005 27 0.639028               0.64    0.539028
1453      EggSurvey            1  2 0.268734             0.2345   0.0342337
1454 AcousticSurvey     0.840003  8 0.433121            0.43875 -0.00562883

$Length_comp_Eff_N_tuning_check
         FleetName Fleet mean_effN mean(inputN*Adj) HarMean(effN) Mean(effN/inputN) MeaneffN/MeaninputN Var_Adj HarEffN/MeanInputN
1578    SpawnFleet     1   60.0391          60.0000       41.3290           1.00065             1.00065    1.20          0.6888167
1579 NonSpawnFleet     2   50.4003          49.9351       18.9918           1.00987             1.00932    1.24          0.3803297

$Age_comp_Eff_N_tuning_check
          FleetName Fleet mean_effN mean(inputN*Adj) HarMean(effN) Mean(effN/inputN) MeaneffN/MeaninputN Var_Adj HarEffN/MeanInputN
2168      SpawnFleet     1   15.0580          14.9469       1.87307            2.2067             1.00743  0.0525          0.1253149
2172      GhostSpawn     5   36.9799           1.0000      23.59650           36.9799            36.97990  0.0000         23.5965000
2173 GhostNon-Spawn     6   14.2419           1.0000       2.88264           14.2419            14.24190  0.0000          2.8826400

$SBzero
[1] 38364.6
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Figure 5.27. Diagnostics for tuning the base case model.

5.10 Appendix 2: cpue cv=0.1

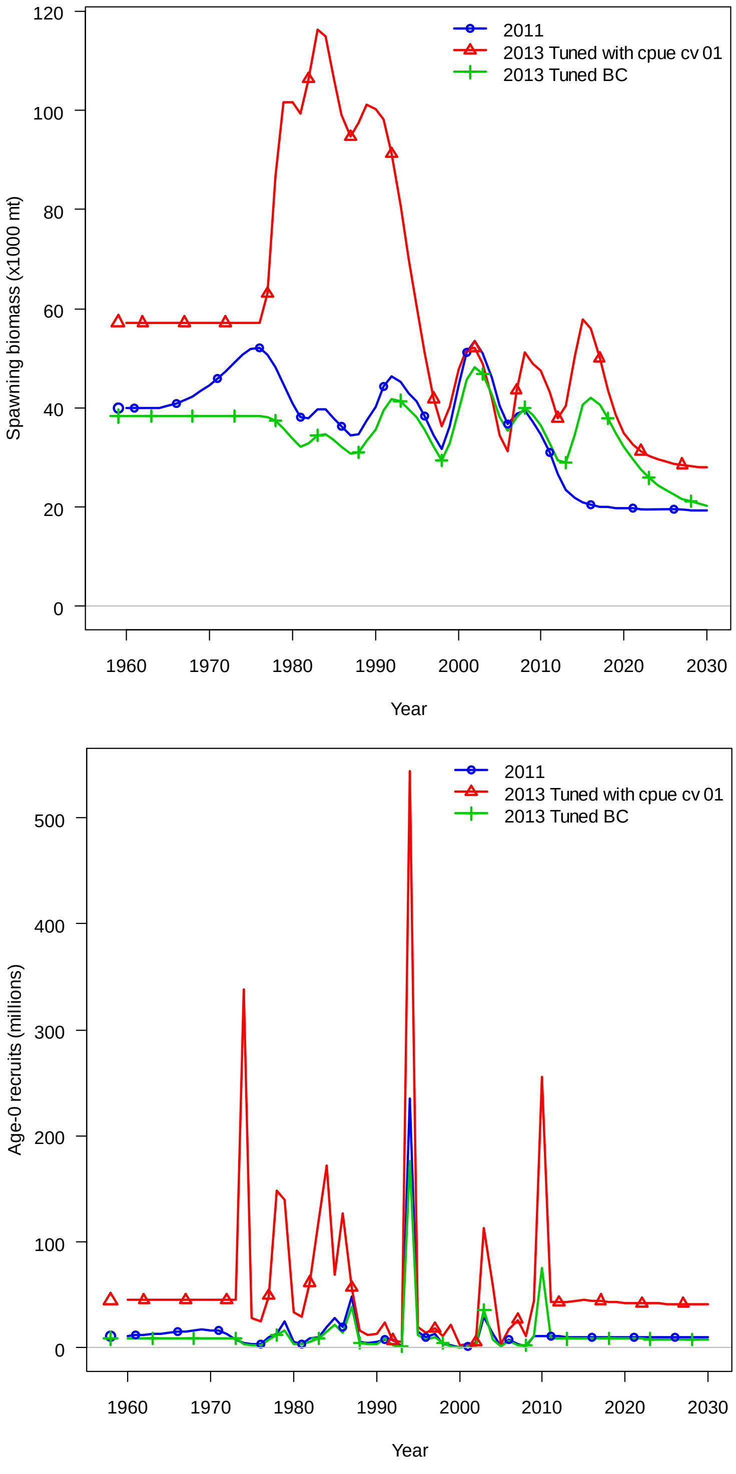


Figure 5.28. The spawning biomass trajectory and estimated recruitment time series compared across the 2011 and 2013 base case models and a model where the cpue cv is fixed at cv=0.1.

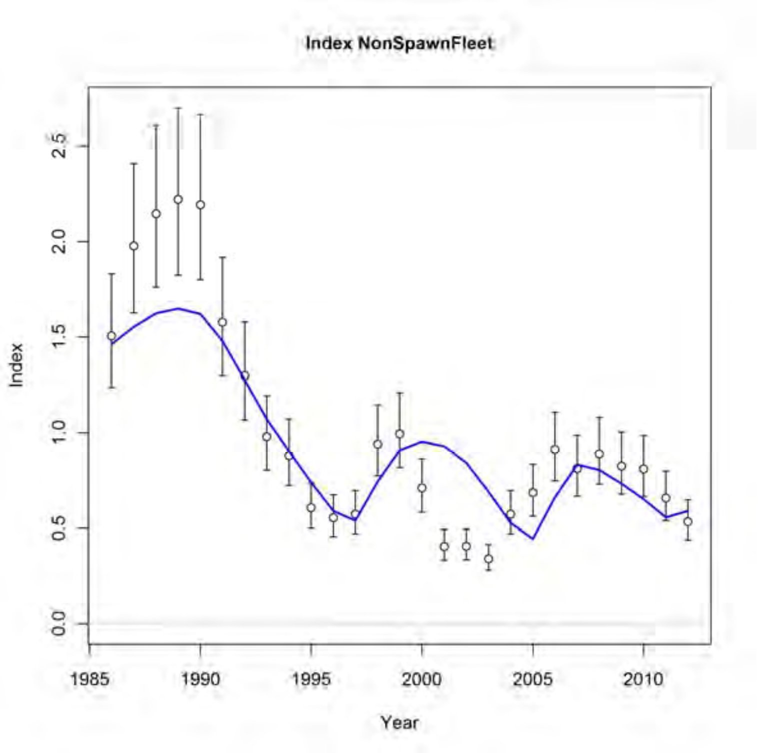
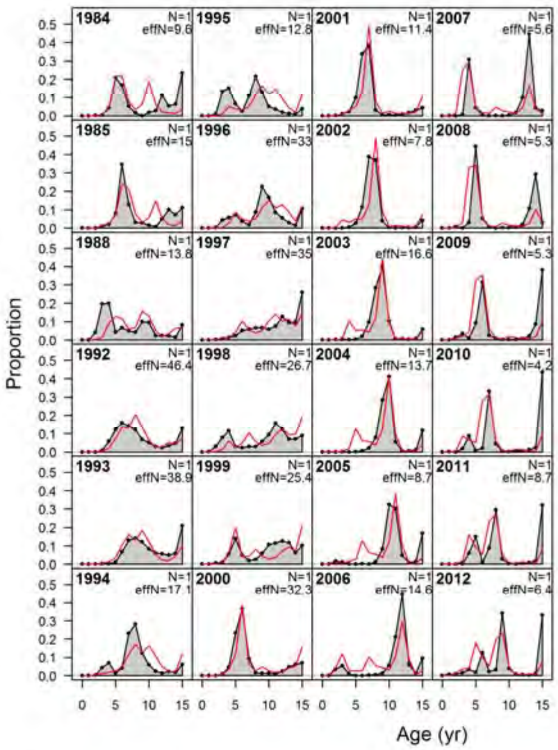
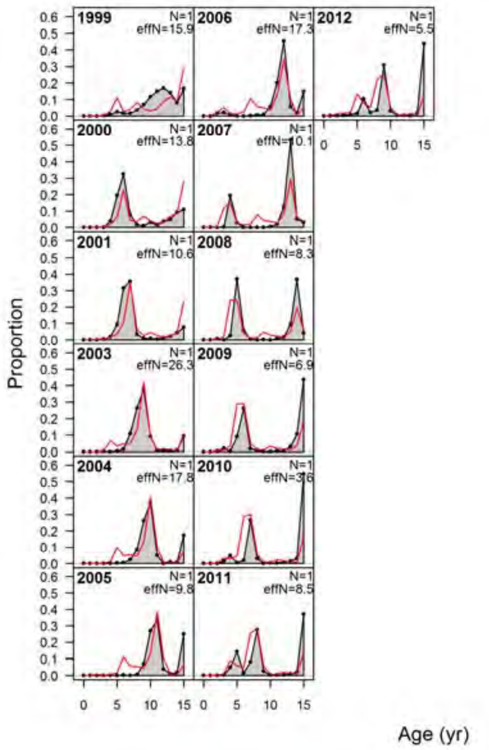
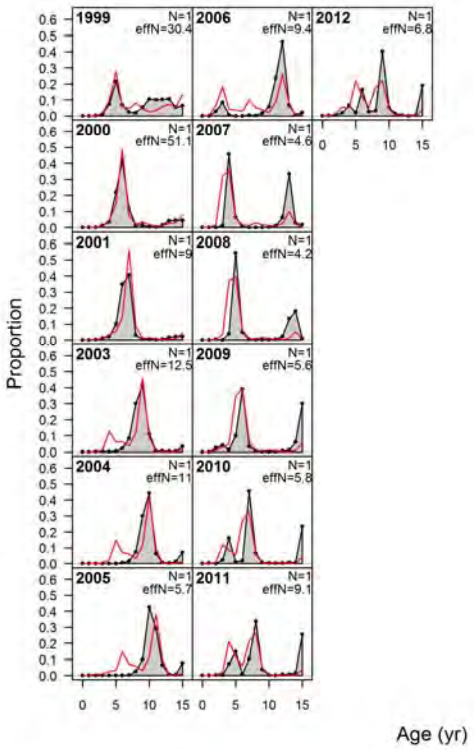
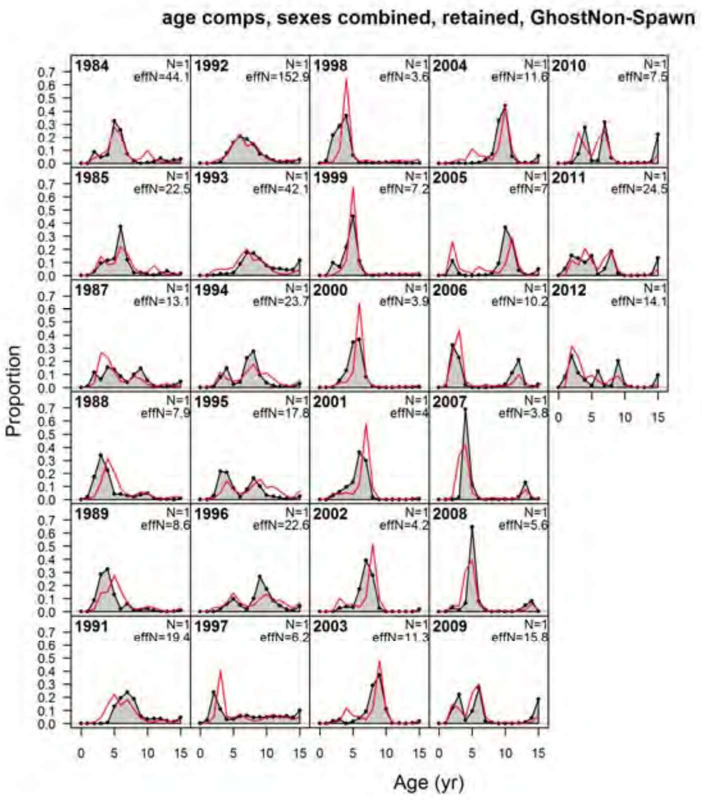


Figure 5.29. The fit to the cpue time series when the cpue cv is fixed at cv=0.1.


age comps, sexes combined, retained, GhostSpawn


age comps, female, retained, GhostSpawn


age comps, male, retained, GhostSpawn



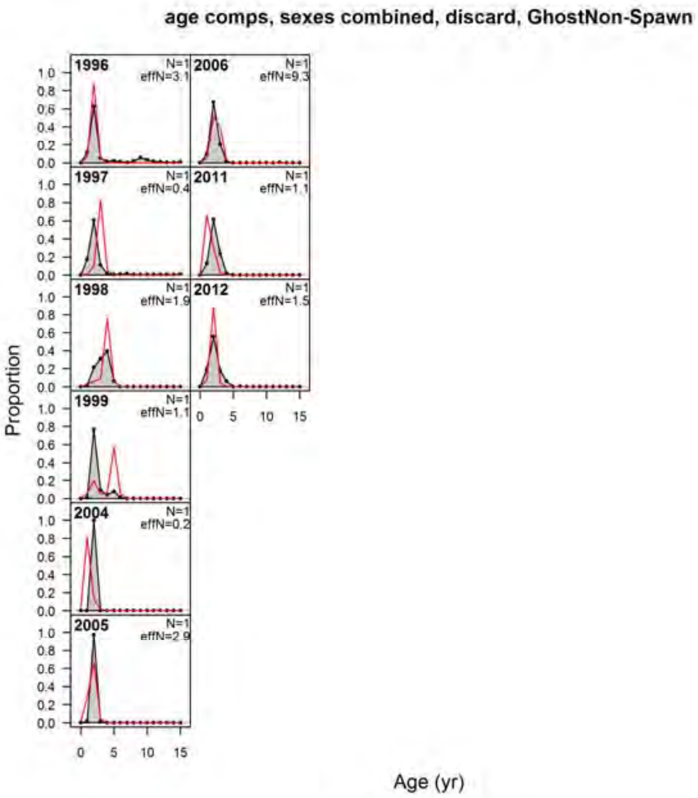
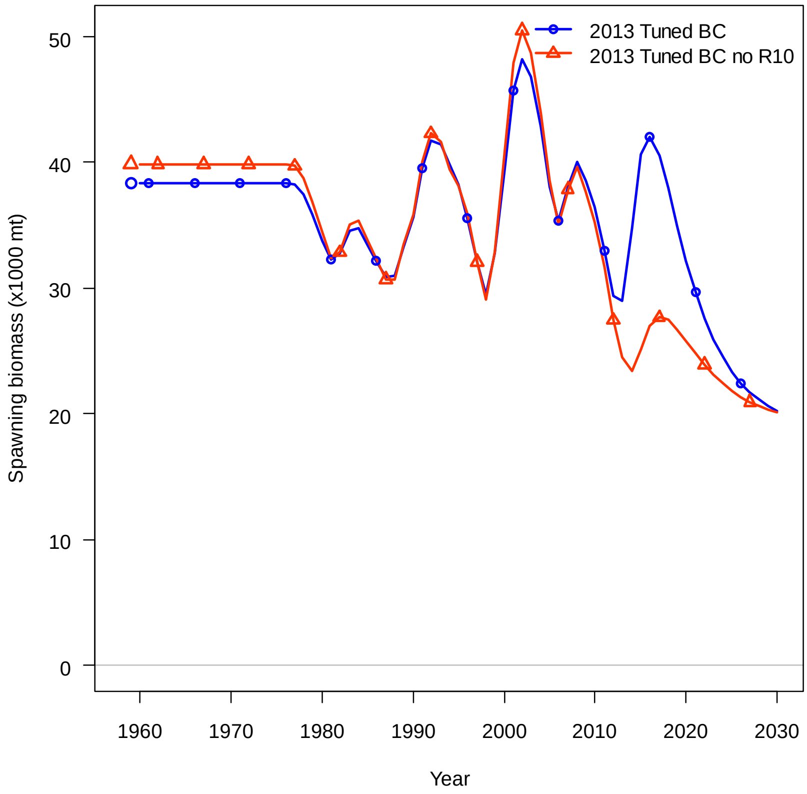


Figure 5.30. The implied fits to the age-composition data for a model with cpue cv=0.1.

5.11 Appendix 3: No estimation of 2010 recruitment



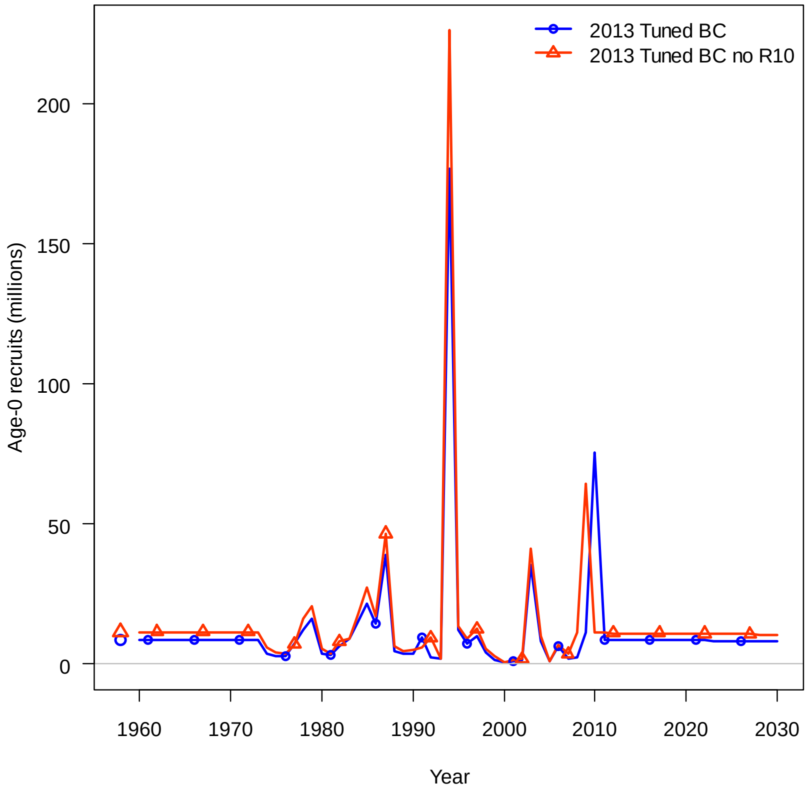


Figure 5.31. The spawning biomass and recruitment time series comparing the tuned 2013 based case model with a model that does not estimate the 2010 recruitment.

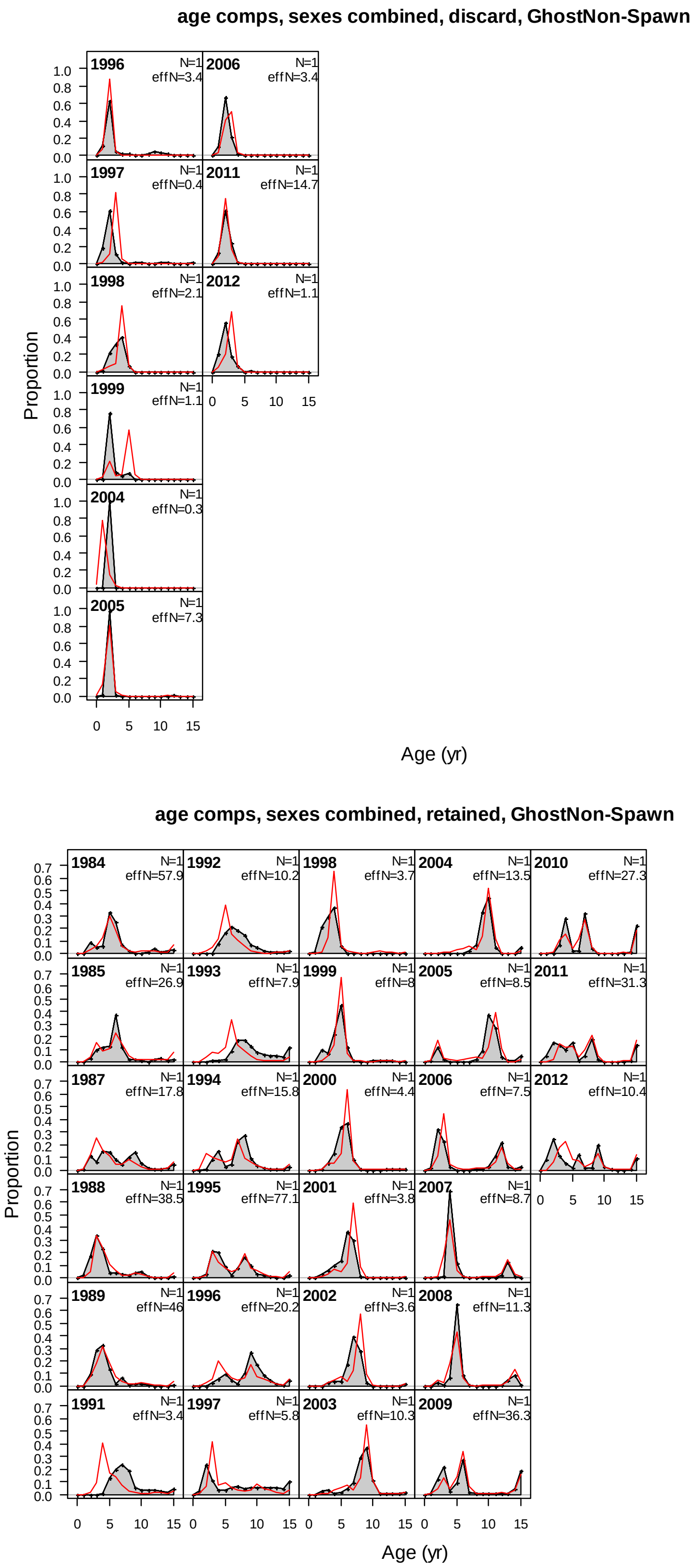


Figure 5.32. The age compositions for the non-spawning fishery showing the degraded fit to the age 1 and 2 fish for the 2011 and 2010 age compositions when the 2010 recruitment is not estimated.

6. Stock assessment of blue grenadier *Macruronus novaezelandiae* based on data up to 2012[2]

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6.1 Summary

The 2013 assessment of blue grenadier *Macruronus novaezelandiae* uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS) (NOAA 2011). As with previous methods used to assess blue grenadier, the methods utilised in SS are based on the integrated analysis paradigm (Punt et al., 2001; Tuck, 2011). The assessment has been updated by the inclusion of data up to the 2012 calendar year. Estimates of spawning biomass from acoustic surveys from 2003-2010 (with 2 times turnover) and egg survey estimates of female spawning biomass from 1994-1995 (base-case estimates) are included.

Results conclude that for the base case model the female spawning biomass in 2012 is around 77% of the unexploited spawning stock biomass (*SBo*) and in 2014 will be approximately 94%*SBo*. The marked increase in biomass is due to the estimation of a large cohort in 2010. While a promising sign for the fishery, the existence and magnitude of this recruitment should be treated with some caution until it can be verified by the addition of further data from future years. If the 2010 recruitment is not estimated and instead is taken from the stock-recruitment curve, then the spawning biomass estimates relative to un-exploited biomass and RBCs are lower.

For the base case model, the 2014 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 8138t, with the predicted retained portion of the RBC being 8065t. Note that this is greater than 150% of the current TAC (5208t). The long-term RBC is 4155. A risk assessment was conducted whereby the forecast catches from the base case model (with the 2010 recruitment estimated) were placed into the model with no 2010 recruitment estimation (and vice versa). Results indicated that the SSB trajectory would not move below the target reference point even if the larger forecast catches from the BC model were applied to the model with no 2010 recruitment estimation.

6.2 Introduction

An integrated analysis model, implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Methot, 2011; Methot and Wetzel, 2013), was applied to the blue grenadier stock of the Southern and Eastern Scalefish and Shark Fishery (SESSF), with data updated by the inclusion of data up to the 2012 calendar

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[2] Paper presented at the Slope/Deep RAG meeting 6-8 November 2013

year (length and age data; age-error, catch rate series; landings and discard catch weight) and information from acoustic surveys of spawning biomass (series from 2003-2010, pertaining to total spawning biomass) with an assumption of 2-times turnover on the spawning ground (Russell and Smith, 2006). The base-case egg survey estimates of female (only) spawning biomass for 1994 and 1995 are included. The model fits directly to lengths frequencies (by sex where possible) and conditional age-at-length data by fleet. Retained length frequency data are from port and onboard samples combined (where data were available).

The assessment model presented in 2011 (Tuck, Whitten and Punt 2001; Tuck 2011) was the first for blue grenadier to be implemented using SS. The use of SS allows the implementation of a model very similar to that used in previous assessments, but additionally presents an opportunity to improve the estimation of length-based selectivity and temporal variability in growth, avoiding the use of simplified assumptions regarding selectivity and modified age-length keys that were necessary in previous assessments. SS can allow for multiple fishing fleets, and can be fitted simultaneously to several data sources and types of information available for blue grenadier. 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. This document updates the assessment presented in 2011.

6.3 The fishery

Blue grenadier are found from New South Wales around southern Australia to Western Australia, including the coast of Tasmania. Blue grenadier is a moderately long-lived species with a maximum age of about 25 years. Age at maturity is approximately 4 years for males and 5 years for females (length at 50% maturity for females is 57cm and 64cm respectively) based upon 32,000 blue grenadier sampled between February 1999 and October 2001 (Russell and Smith, 2006). There is also evidence that availability to the gear on the spawning ground differs by sex, with a higher proportion of small males being caught than females (Figure 12.1). This is most likely due to the arrival of males on the spawning ground at a smaller size (and younger age) than females. This was also noted by Russell and Smith (2006) who state that “young males entered the fishery one year earlier than females” and is consistent with hoki from New Zealand (Annala et al., 2003). Large fish arrive earlier in the spawning season than small fish. Spawning occurs predominantly off western Tasmania in winter (the peak spawning period based upon mean GSIs calculated by month was estimated to be between June and August according to Russell and Smith (2006). There is some evidence that a high proportion of fish remain spawning in September. Variations in spawning period noted by Gunn et al (1989) may occur due to inter-annual differences in the development of coastal current patterns around Tasmania. Adults disperse following the spawning season and while fish are found throughout the south east region during the non-spawning season, their range is not well defined. Spawning fish have recently been caught off the east coast of Australia and larvae from a likely eastern spawning area have been described by Bruce et al. (2001). Further analyses (eg sampling, acoustics) of these fish will need to be conducted before they can be included in the current stock assessment.

Blue grenadier are caught by demersal trawling. The global agreed TAC in 2012/13 was 5,208 tonnes. The annual TACs are show in Table 6.1. There are two defined sub-fisheries: the spawning (Zone 40, months June, July and August) and non-spawning fisheries (all other months and zones).

6.4 Data

The assessment has been updated since the previous assessment (Tuck, 2011) by the inclusion of length and age-at-length data from the spawning and non-spawning fisheries; updated cpue series (Haddon, 2013), the total mass landed and discarded, and update age-reading error. Acoustic estimates of spawning biomass (2003-2010) and estimates of the female spawning biomass in 1994 and 1995 from egg surveys (Bulman et al., 1999) are included. Data were formulated by calendar year (i.e. 1 Jan to 31 Dec) as in previous models.

6.4.1 *Catch*

The landings from the SEF1 logbook data were used to apportion catches to the spawning and non-spawning fisheries. The SEF1 landings have been adjusted upwards to take account of differences between logbook and landings data (multiple of 1.4 for the non-spawning fishery, based on 40% conversion from headed and gutted to whole, since 1986 and up to and including 1997 (reliable CDR data were available from 1998); 1.2 for the spawning fishery from 1986 up to and including 1996 (when factory vessels entered the spawning fishery)) (D. Smith, pers. comm.). As stated by Thomson and He (2001), the factor is lower for the spawning fleet than the non-spawning fleet because some fish in the spawning fishery, landed headed and gutted, were recorded as being landed whole. These factors were chosen by the Blue Grenadier Assessment Group (BGAG) (Chesson and Staples (1995), as cited by Punt (1998)). The adjusted logbook catches were then scaled up to the SEF2 data. As historical SEF2 data were only available from 1992, the average scaling factor from 1992 to 1996 was used to scale the data for years between 1986 and 1991 (Figure 6.2). Note that in years 2008 to 2012 logbook data were greater than landings from the CDR. In these cases the tonnage from the CDR was used as the total catch (AFMA, pers. comm. 2011). Table 6.1 lists the annual catches used in the assessment and the annual TAC. The annual logbook catches by sub-fishery and the adjustments made to determine the catches used in the assessment are shown in Table 6.2.

Discard rates were estimated from on-board data which gives the weight of the retained and discarded component of those shots that were monitored (Thomson and Klaer, 2011). The discard values from 1995 to 2002 are based on estimates calculated from ISMP data by MAFRI and reported in He et al (1999) and Tuck, Smith and Talman (2004). As agreed by Slope RAG (2011), since 2003 discard rates are taken from those estimated by the methods described in Thomson and Klaer (2011). The mass of the discard is calculated from the annual discard rate and the retained catch from the non-spawning fishery. The MAFRI estimates of discards were made accounting for differences in sampling and discard rates according to the ISMP zones. The more recent estimates are simple ratios of total discards to (retained + discard) catch (N. Klaer, pers comm.). Information in support of the historical values was not able to be obtained and further exploration of the methods and data used to estimate these values should be encouraged. The discard data are provided in Table 6.1.

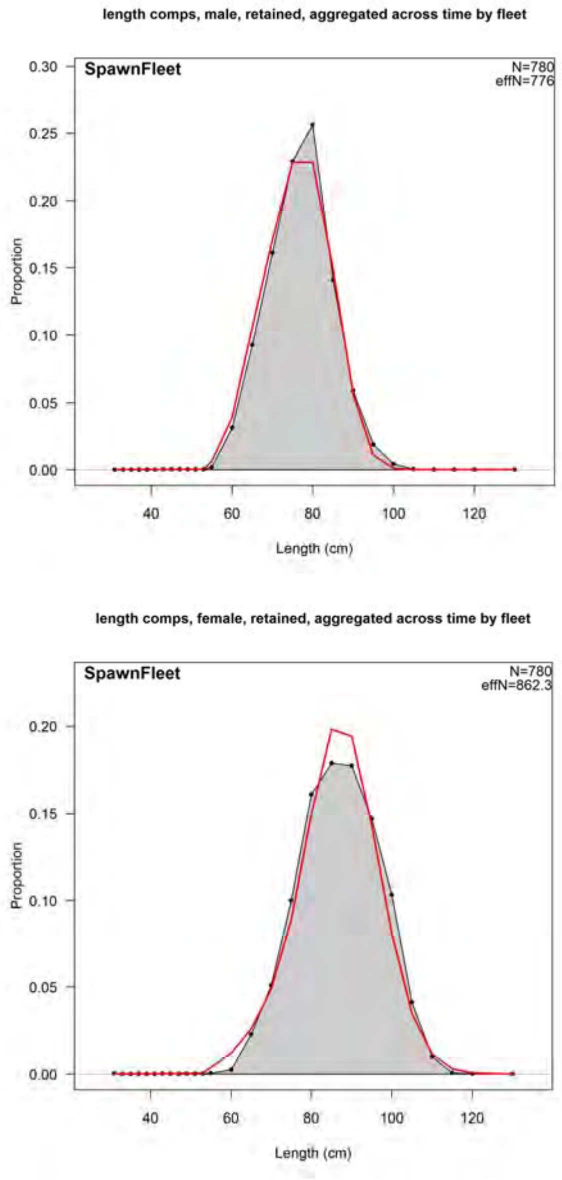


Figure 6.1. The aggregated length composition of females (top) and males (bottom) on the spawning ground. The red line indicates a model fit with sex-specific selectivity.

Table 6.1. Landed and discarded catches for the winter spawning and non-spawning sub-fisheries by calendar year. These estimates have been adjusted scaled up to the landings data (see text and Table 6.2). Standardised CPUE (Haddon, 2013) and number of records for the non-spawning sub-fisheries by calendar year are shown, along with the TAC. [1] a voluntary industry reduction to 4,200 t was implemented in 2005. [2] This was a 16 month TAC. [3] The TACs cover the fishing year 1 May to 30 April. In the table below, 2008 refers to 2008/09. [4] This is an estimate of retained catch based on the 2012/2013 TAC and relative split of catch between spawning and non-spawning fisheries of 2012.

Year	Landings		Discards	TAC		
	Spawning	Non-spawning	Non-spawning		Records	CPUE
1979	245	245				
1980	410	410				
1981	225	225				
1982	390	390				
1983	450	450				
1984	675	675				
1985	600	600				
1986	317	1807			3189	1.505
1987	1006	2183			3569	1.978
1988	410	2228			3961	2.143
1989	46	2745			4309	2.219
1990	733	2508			3577	2.190
1991	819	3764			4308	1.576
1992	710	2549			3228	1.298
1993	994	2368			4203	0.980
1994	1211	1940		10000	4491	0.881
1995	1205	1570	80	10000	5076	0.607
1996	1496	1544	975	10000	5370	0.554
1997	2947	1569	3716	10000	6194	0.573
1998	3746	1986	1329	10000	6599	0.941
1999	6775	2549	123	10000	8045	0.995
2000	6608	2047	69	10000	7679	0.710
2001	8004	1120	10	10000	7279	0.406
2002	7843	1318	2	10000	6344	0.407
2003	7745	726	3	9000	5675	0.341
2004	5064	1327	15	7000	6393	0.573
2005	3024	1259	310	5000[1]	5346	0.686
2006	2193	1420	104	3730	4362	0.911
2007	1891	1280	5	4113[2]	3659	0.811
2008	2692	1239	19	4368[3]	3407	0.890
2009	2295	964	15	4700[3]	3443	0.826
2010	3119	1066	10	4700[3]	3308	0.810
2011	3342	859	126	4700[3]	3968	0.657
2012	3447	557	192	5208[3]	3210	0.533
2013	4484[4]	724[4]				

Table 6.2. Logbook and CDR landings for the spawning and non-spawning sub-fisheries by calendar year and adjustments made to account for logbooks being less than landings and incorrect reporting process code. Shaded CDR are historical landings values.

Year	Logbook		CDR	H&G Multiplier		Adjusted Logbook			CDR / logbook	Catch for assessment	
	Spawning	Non-spawning		Spawning	Non-spawning	Spawning	Non-spawning	Total		Spawning	Non-spawning
1979	245	245		1	1	245	245	490	1	245	245
1980	410	410		1	1	410	410	820	1	410	410
1981	225	225		1	1	225	225	450	1	225	225
1982	390	390		1	1	390	390	780	1	390	390
1983	450	450		1	1	450	450	900	1	450	450
1984	675	675		1	1	675	675	1350	1	675	675
1985	600	600		1	1	600	600	1200	1	600	600
1986	246	1204		1.2	1.4	295	1685	1981	1.04	317	1807
1987	782	1455		1.2	1.4	939	2036	2975	1.04	1006	2183
1988	319	1485		1.2	1.4	383	2079	2462	1.04	410	2228
1989	36	1829		1.2	1.4	43	2561	2604	1.04	46	2745
1990	570	1671		1.2	1.4	684	2340	3023	1.04	733	2508
1991	637	2508		1.2	1.4	764	3511	4275	1.04	819	3764
1992	509	1565	3259	1.2	1.4	730	2208	2938	1.11	710	2549
1993	812	1659	3362	1.2	1.4	1056	2349	3405	0.99	994	2368
1994	974	1338	3151	1.2	1.4	1185	1914	3100	1.02	1211	1940
1995	911	1017	2775	1.2	1.4	1114	1460	2574	1.08	1205	1570
1996	1200	1061	3040	1.2	1.4	1442	1535	2978	1.02	1496	1544
1997	2623	997	4516	1	1.4	2623	1442	4065	1.11	2947	1569
1998	2739	1452	5733	1	1	3463	1491	4954	1.16	3746	1986
1999	5460	2054	9324	1	1	5649	2115	7763	1.20	6775	2549
2000	5665	1755	8655	1	1	5670	1820	7490	1.16	6608	2047
2001	7309	1022	9124	1	1	7331	1063	8393	1.09	8004	1120
2002	6825	1147	9161	1	1	6850	1185	8035	1.14	7843	1318
2003	7239	679	8471	1	1	7255	691	7946	1.07	7745	726
2004	4647	1218	6392	1	1	4653	1275	5928	1.08	5064	1327
2005	2880	1199	4283	1	1	2903	1221	4124	1.04	3024	1259
2006	2058	1332	3614	1	1	2069	1369	3439	1.05	2193	1420
2007	1815	1228	3171	1	1	1815	1228	3044	1.04	1891	1280
2008	2838	1306	3931	1	1	2838	1306	4143	0.95	2692	1239
2009	2723	1144	3259	1	1	2712	1144	3856	0.85	2295	964
2010	3384	1157	4185	1	1	3384	1157	4540	0.92	3119	1066
2011	3554	913	4201	1	1	3554	913	4467	0.94	3342	859
2012	3838	620	4004	1	1	3838	620	4458	0.90	3447	557

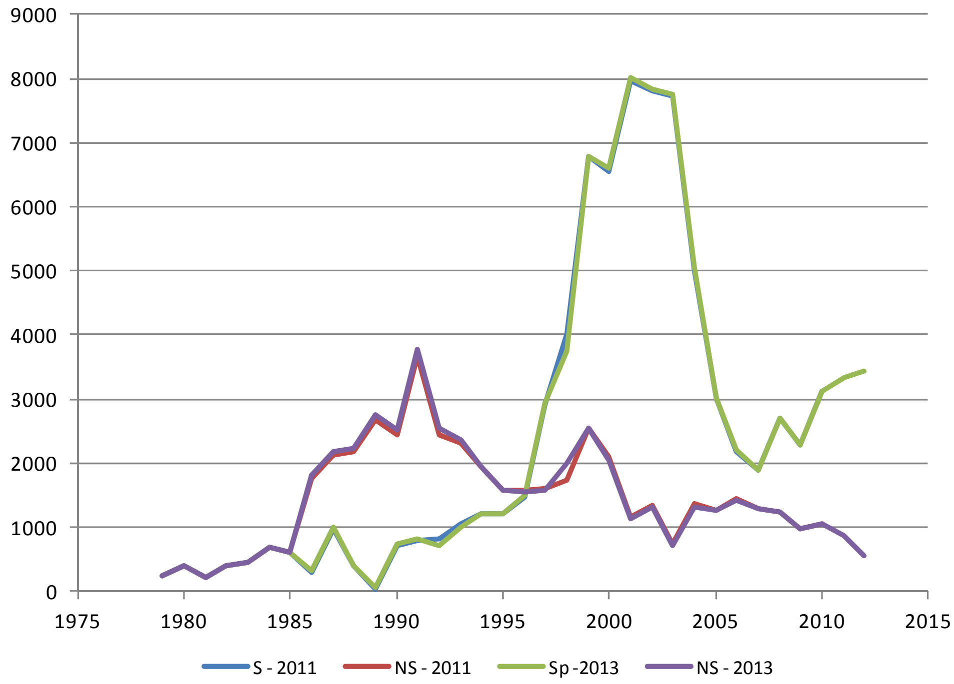


Figure 6.2 The 2013 annual catch series (tonnes) for the spawning (S-2013) and non-spawning (NS-2013) blue grenadier fisheries in comparison to the series for 2011 (Tuck, 2011).

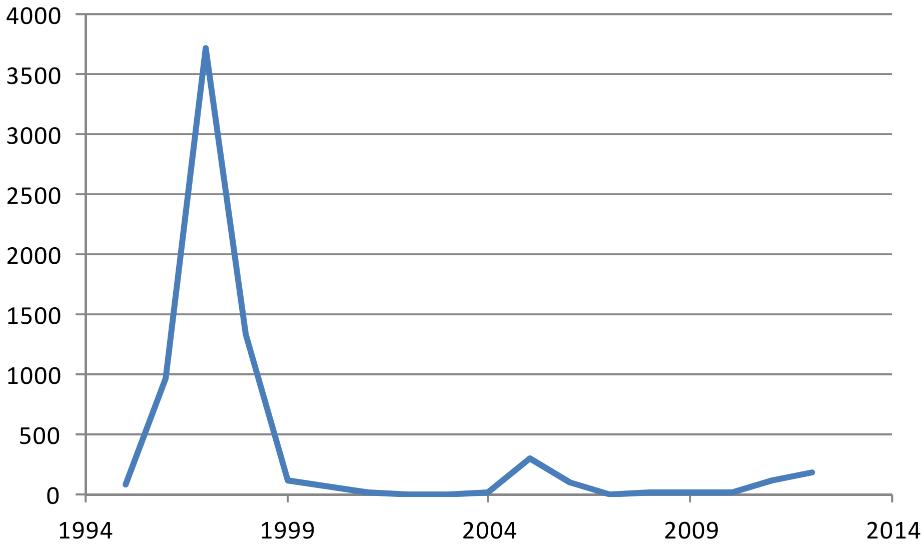


Figure 6.3 The 2013 annual discard series (tonnes) for the non-spawning blue grenadier fishery.

6.4.2 ***Catch rates***

Haddon (2013) provides the updated catch rate series for blue grenadier (Table 6.1, Figure 6.4). The spawning fishery catch rate series is not used in the assessment as it is not believed to be a good indicator of available biomass for this component of the stock.

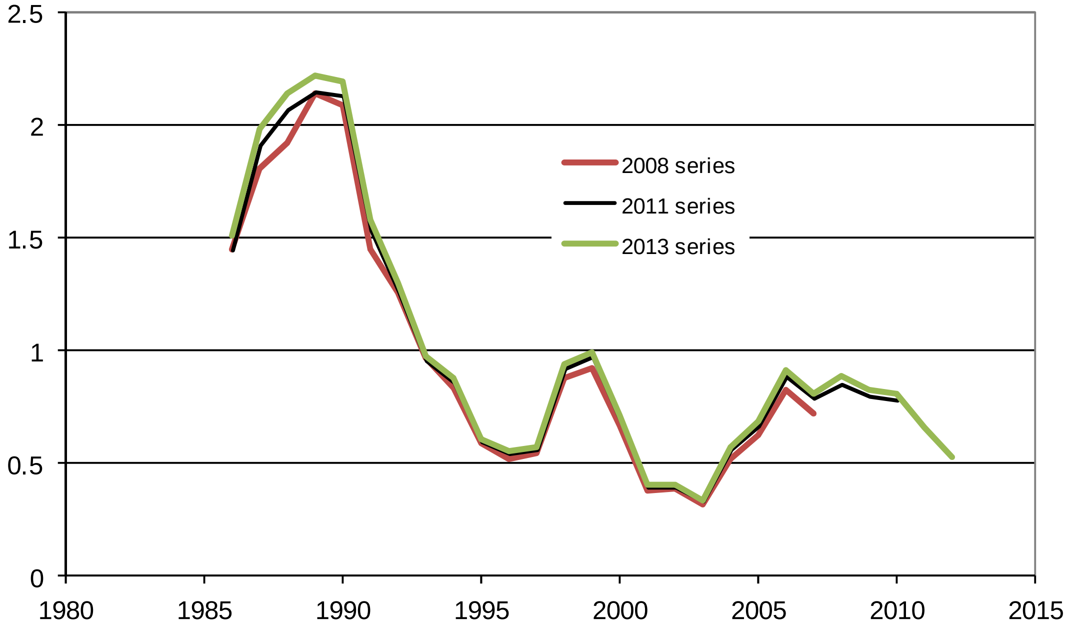


Figure 6.4 The calendar year catch-rate indices for the non-spawning blue grenadier fisheries (Haddon, 2013) in comparison to the series for 2008 and 2011 (Haddon 2008; 2011).

6.4.3 ***Length frequencies and age data***

Length and age data are been included in the model as length frequency data and conditional age-at-length data by fleet and sex (when available). Age composition data is included in diagnostic plots but is not used directly within the fitting procedure. On-board and port lengths, when available, were combined to create length frequencies. In previous years, only port samples had been used to create the length frequency. Length data from 1997 were removed from the analyses as there appeared to be data having the DSL process code with lengths that corresponded to the standard length (STL) measurement. This led to unrealistically large lengths when converted from DSL to STL. Discard lengths from 2010 were removed as there were only 16 samples. Figures of the observed length and age data are shown in later figures with the corresponding model predicted values.

6.4.4 ***Age-reading error***

Updated standard deviations for aging error by reader (A and B) have been estimated, producing the age-reading error matrix of Table 6.3 (A. Punt, pers. comm.). Reader A applied to years 1991-93 and 2007-2012, and reader B to 1984-1990 and 1994-2006.

Table 6.3. The standard deviation of age reading error.

	St Dev	
Age	A	B
0	0.150	0.286
1	0.150	0.286
2	0.243	0.302
3	0.310	0.319
4	0.359	0.338
5	0.395	0.358
6	0.420	0.381
7	0.439	0.406
8	0.452	0.433
9	0.462	0.463
10	0.469	0.495
11	0.474	0.531
12	0.478	0.570
13	0.480	0.613
14	0.482	0.660
15	0.484	0.712
16	0.485	0.768
17	0.485	0.830
18	0.486	0.898
19	0.486	0.973
20	0.487	1.054

6.4.5 ***Acoustic survey estimates***

Estimates of spawning biomass for 2003-2010 are provided in Ryan and Kloser (2012). There are no acoustic estimates for 2011 (not funded) and 2012 (technical issues). Table 6.4 shows the estimates of spawning biomass with their corresponding cv’s used in the assessment. Sampling cv’s of less than 0.3 were increased to 0.3 to account for process error. Low sampling cvs (of 0.19 for example) were considered too low for an acoustic survey and a minimum of 0.3 should be used to reflect the total uncertainty (D. Smith, pers comm., Tuck et al. 2004; Slope RAG 2011). Of 22 acoustic cvs used for hoki in New Zealand none are lower than 0.3 (Francis, 2009). It is assumed that the spawning ground experiences a turnover rate equal to 2 (i.e. for the model applied here, the spawning biomass estimates are doubled) (Russell and Smith, 2006).

Table 6.4. The estimated biomass (tonnes) of blue grenadier on the spawning grounds in years 2003 to 2010 (Ryan and Kloser, 2012).

	2003	2004	2005	2006	2007	2008	2009	2010
biomass (t)	24690	16295	18852	42882	56330	24450	24787	20622
c.v. in assessment model	0.30	0.46	0.30	0.30	0.52	0.30	1	0.33
Sample cv	0.16	0.46	0.14	0.14	0.52	0.22	1	0.33

6.4.6 *Egg survey estimates*

Egg survey estimates of female spawning biomass are available for 1994 and 1995 (Bulman et al., 1999). The egg-estimates (cv) for 1994 and 1995 respectively are: 57,772 (0.18) and 41,409 (0.29). For the analysis considered here, the base-case egg estimates were used.

6.4.7 *Biological parameters*

The assessment assumes that the proportion of females that spawn in each year is 0.84 and a length at 50% maturity of 63.7cm for females (Russel and Smith, 2006). The female maturity ogive is shown in Figure 6.5

The length weight relationship for males and females was estimated from spawning fishery data over years 1999 to 2008 (Figure 6.5). Natural mortality for females was estimated and male natural mortality is assumed to be 20% greater than this value based upon assumptions made for hoki in New Zealand (McAllister et al. 1994).

Francis (2009) reviews the values of steepness used in New Zealand hoki assessments, where a value of h=0.9 had been used since 1994. This value of steepness was derived from work of Punt et al. (1994) using 45 stocks of gadiform species (0.9 is the median). Following an analysis of the profile likelihood, the effect of steepness on the 2007 assessment and additional information of Myers et al. (1999; 2002) beyond that used by Punt et al (1994), Francis (2009) concludes that steepness should be reduced to h=0.75. This value of steepness was assumed in the previous blue grenadier assessment in 2011 (Tuck, 2011) and in this assessment.

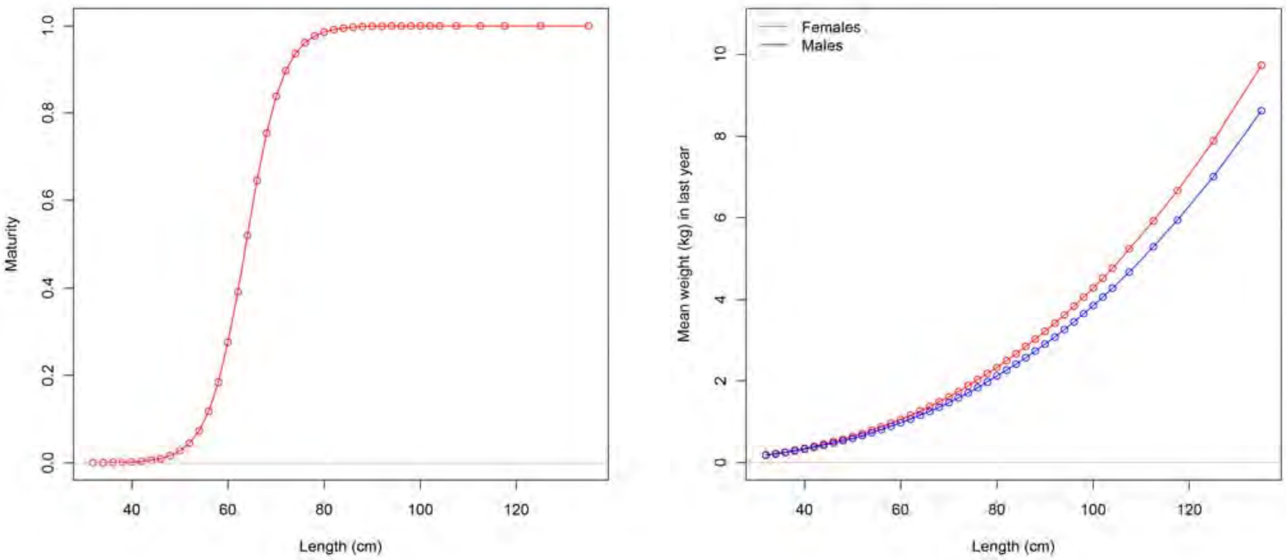


Figure 6.5 The maturity ogive by length for female blue grenadier (parameters from Russell and Smith (2006)) and the length-weight relationship for males and females.

6.5 Analytic approach

6.5.1 The population dynamics model

The 2013 assessment of blue grenadier uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Version 3.24f, NOAA 2011). The methods utilised in SS are based on the integrated analysis paradigm. SS can allow for multiple seasons, areas and fleets, but most applications are based on a single season and area. The assessment of blue grenadier takes advantage of the ability of SS to account for multiple fleet allocations to represent the different dynamics of the spawning and non-spawning fisheries. Recruitment is governed by a stochastic Beverton-Holt stock-recruitment relationship, parameterized in terms of the steepness of the stock-recruitment function (h), the expected average recruitment in an unfished population (R_0)), and the degree of variability about the stock-recruitment relationship (σ_r). SS allows the user to choose among a large number of age- and length-specific selectivity patterns. The values for the parameters of SS are estimated by fitting to data on catches, catch-rates, catch length-frequencies, surveys, and conditional age-at-length data. The population dynamics model and the statistical approach used in fitting the model to the various data types are given in the SS technical documentation (Methot, 2005).

This assessment follows the agreements made at the October and November 2011 meetings of Slope RAG. These were: include gender specific selectivity for the spawning fishery, estimate natural mortality for females, use historical discard tonnages estimated by MAFRI, include cohort dependent growth, and set steepness at 0.75.

The base–case model includes the following key features:

(a) Two sub-fisheries are included in the model – the spawning sub-fishery that operates during winter (June – August inclusive) off western Tasmania (zone 40), and the non-spawning sub-fishery that operates during other times of the year and in other areas throughout the year.

(b) The selectivity pattern was assumed to be length-specific, logistic and time-invariant for the spawning fleet and dome-shaped for the non-spawning fleet. The parameters of the selectivity function for each fleet were estimated within the assessment. A change in selectivity from 2005 was considered as a sensitivity for the non-spawning fleet, however this did not substantially affect the fits nor management quantities of interest.

(c) Blue grenadier consists of a single stock within the area of the fishery.

(d) The model accounts for males and females separately.

(e) The population was at its unfished biomass with the corresponding equilibrium (unfished) age-structure at the start of 1960.

(f) The CVs of the CPUE indices for the non-spawning fleet 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 (0.64).

(g) Discard tonnage was estimated through the assignment of a retention function for the non-spawning fleet. This was defined as a logistic function of length, and the inflection and slope of this function were estimated where discard information was available

(h) The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The value for female M is estimated within the model. Following previous assessments, male natural mortality is assumed be 20% greater than that of females.

(i) Recruitment to the stock is assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, h. Steepness for the base-case analysis is set to 0.75. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1974 to 2010. Deviations are not estimated before 1974 or after 2010 because there are insufficient data to permit reliable estimation of recruitment residuals outside of this time period.

(j) The value of the parameter determining the magnitude of the process error in annual recruitment, σ_r, is set equal to 1.0 in the base case reflecting the large variation in recruitment observed for blue grenadier

(k) The population plus-group is modelled at age 20 years. The maximum age for observations was 15 years, reflecting that used in previous assessments

(l) Growth is assumed to follow a von Bertalanffy type length-at-age relationship, with the parameters of the growth function being estimated separately for females and males inside the assessment model. Growth is also assumed to vary through time and be cohort (year class) specific. Evidence for time-varying and cohort specific growth in blue grenadier has been accumulating for over a decade (see Punt and Smith 2001; Whitten et al., 2013). As such, mean length- and mass-at-age by cohort has been derived for previous assessments from age-length keys, the mass-length relationship and length frequency data (Method 2 of Punt and Smith, 2001) and specified directly as mean length- and mass-at-age matrices in the assessment models. The data upon which these matrices were based was treated as being subject to sampling error. Therefore, whilst the previous method allowed for explicit accounting of variability in mean-size through time, it was not conceptually consistent with the Integrated Analysis estimation procedure, which assumes that mean length- and mass-at-age matrices input into an assessment are known exactly. This method also relied on interpolated length- and mass-at-age estimates for years in which actual data were not available and ignored any age-length relationship. The implementation of the base-case assessment using SS can account for temporal variation in growth, and therefore temporal variation in mean length- and mass-at-age. Following the 2011 assessment, the 2013 base-case model treats length-at-age information as data, and predicts the expected length-at-age for each year. This is achieved by estimating the parameters of a von Bertalanffy growth function that describe the mean expected length-at-age across all years and then introducing an extra parameter that describes cohort specific deviations from mean expected length-at-age for a specified range of year classes. Cohort specific deviations from average growth are estimated in the base case model for year classes 1978 to 2009, the year classes for which there are sufficient length-at-age data to permit reliable estimates.

(m) The sample sizes for length frequencies were tuned for each fleet so that the input sample size was approximately equal to the effective sample size calculated by the model. Before the retuning of length frequency data was performed by fleet, retained length sample sizes were set at 50 and discard length sample sizes to 10. This is because the appropriate sample size for length frequency data is probably more related to the number of shots sampled, rather than the number of fish measured. The length frequency data is given too much weight relative to other data sources if the number of fish measured were used. Discard length sample sizes were set at 10 based approximately upon the ratio of discard to (retained + discard) samples multiplied by 50. Discard length frequencies with samples sizes <200 were removed. The age data sample sizes for a particular year were decreased to 50. The relative frequency of age samples across lengths within a year was maintained. Length, age and cpue data were tuned.

The values assumed for some of the (non-estimated) parameters of the base case models are shown in Table 6.5

Table 6.5. Parameter values assumed for some of the non-estimated parameters of the base-case model.

Parameter	Description	BC
M_f	Natural mortality for females	Estimated
M_m	Natural mortality for males	1.2* M_f
σ_r	c.v. for the recruitment residuals	1.0
σ_g	Input standard deviation for the cohort growth deviations	0.1
h	“steepness” of the Beverton-Holt stock-recruit curve	0.75
x	age observation plus group	15 years
μ	fraction of mature population that spawn each year	0.84
aa	Female allometric length-weight equations	0.01502 g^{-1}.cm
bb	Female allometric length-weight equations	2.728
aa	Male allometric length-weight equations	0.0168 g^{-1}.cm
bb	Male allometric length-weight equations	2.680
l_m	Female length at 50% maturity	63.7cm
l_s	Parameter defining the slope of the maturity ogive	-0.261

6.5.2 *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 2006–2013. The HSF uses harvest control rules to determine a recommended biological catch (RBC) for each stock in the SESSF quota management system. Each stock is assigned to one of four Tier levels depending on the basis used for assessing stock status or exploitation level for that stock. Blue grenadier is assessed 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. For the 2014 TACs AFMA has directed that the 20:40:40 (Blim:Bmsy:Ftarg) form of the rule will be used up to where fishing mortality reaches F48. Once this point is reached, the fishing mortality is set at F48. Day (2008) has determined that for most SESSF stocks where the proxy values of B40 and B48 are used for BMSY and BMEY this form of the rule is equivalent to a 20:35:48 strategy.

This document reports RBCs calculated under the 20:35:48 strategy.

6.5.3 *Sensitivity tests and alternative models*

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

1. M = 0.2 yr-1, estimated. (0.17 in the base case)
2. h = 0.9 (0.75 in the base case)
3. CPUE series cv = 0.1 (tuned in the base case)
4. Discard tonnage cv=0.1 (0.3 in base case)
5. Double and halve the weighting on the length composition data.
6. Double and halve the weighting on the age-at-length data.
7. Remove egg survey estimates

The results of the sensitivity tests are summarized by the following quantities:

1. SB_0 the average equilibrium female spawning biomass.
2. SB_{2014} the female spawning biomass at the start of 2014.
3. SB_{2014}/SB_0 the depletion level at the start of 2014, i.e. the 2014 spawning biomass expressed as a fraction of the unexploited spawning biomass.
4. *2014 RBC* - the 2014 RBC, calculated using the 20:35:48 harvest rule.
5. *Longterm RBC* the long-term RBC calculated using the 20:35:48 harvest rule.

6.6 Results and discussion

6.6.1 The base case stock assessment

6.6.1.1 Parameter estimates

Figure 6.6 shows how the expected mean length-at-age values change over time for the base case model. The ridges reflect the impact of some cohorts growing faster or slower than average. This figure also shows the expected mean length-at-age values for the end-year of the model. The impact of slower than average growth is visible by the decrease in expected size of 9 and 18 yo fish, corresponding to the larger than average recruitments in years 2003 and 1994 respectively. Natural mortality for females was estimated to be $M_f = 0.15$ and males therefore was $M_m = 0.18$.

The selectivity for the spawning and non-spawning fisheries and the retention function for the non-spawning fishery are shown in Figure 6.8. Selectivity is assumed to be time-invariant, sex-specific and logistic for the spawning fleet and dome-shaped for the non-spawning fleet. Note that the estimated female length-specific selectivity for the spawning ground shows an ascending limb that includes much larger fish than the maturity ogive estimated by Russell and Smith (2006), which has an estimate of 50% maturity of 63.7cm. This result implies that, to a large extent, small mature females do not appear to be evident on the spawning ground. Russell and Smith (2006) present length frequencies during their study of blue grenadier reproductive biology showing that very few female fish less than 60cm were caught (also see Figure 6.12). However those that were caught were included in the study and a proportion of these fish were shown to be mature.

6.6.1.2 Fits to the data

Figure 6.9 shows the model fit to the non-spawning catch rate series. The model fits intersect most of the 95% confidence intervals for the data, indicating that adjustments to the CV for the indices performed as expected. As has been seen in all previous assessment models for blue grenadier, the model is not able to fit the rise in catch rate following the large recruitment of the mid-1990s. The fit to the discard mass is able to replicate the increase in discarding through the late 1990s and mid 2000s, however the magnitude is under-estimated (as has been the case with previous assessments). Re-weighting the CVs on the discard mass was not able to improve the fit to the discard data. Fits to the biomass estimates from the acoustic surveys and egg surveys were reasonable. The predicted biomass trajectory intersects all of the 95% confidence intervals (Figure 6.10).

The model is able to replicate the implied age-composition data well (Figure 6.11, Figure 6.16 to Figure 6.20). Predicted age-compositions are able to track the strong cohorts typical of blue grenadier as they move through both the non-spawning fishery and the spawning fishery. Length composition data are also well estimated by the model (Figure 6.12, Figure 6.21 to Figure 6.25). The inclusion of sex-specific selectivity now allows a better fit to the observations of length and age by sex.

6.6.1.3 Assessment outcomes

The estimated time series of recruitment under the base-case parameter set shows the typical episodic typical episodic nature of blue grenadier recruitment, with strong year-classes in 1979, the mid-1980s, the mid-1980s, 1994, 2003 and now 2010, and with very little recruitment between these years (

these years (

Figure 6.13). The magnitude of the recruitment of 2010 will remain somewhat poorly estimated until these fish move well into the available stock of the fishery.

The trajectories of spawning biomass and spawning biomass relative to the un-exploited level are shown in Figure 6.14. This shows the increases and decreases in spawning biomass as the strong cohorts move into and out of the spawning population. The estimated virgin female biomass is 36,815 tonnes (compared to 39,983 t in the 2011 assessment). In 2011, the estimated spawning biomass level under the base-case scenario for 2010 was 87% of un-exploited levels and in 2012, which was used in the harvest control rule, was approximately 67% *SBo*. In the 2013 assessment, the estimated spawning biomass level under the base-case scenario for 2012 is 77% of unexploited levels and the estimated spawning biomass in 2014, which is used in the harvest control rule, is approximately 94% *SBo*.

The more optimistic outlook from this assessment is largely being driven by the addition of 2 further addition of 2 further years of data and the substantial estimated recruitment in 2010. While a promising While a promising sign for the fishery, some caution should be exercised with regard to this recruitment this recruitment estimate and its implication on future stock status, until clear further indications of its indications of its existence (and magnitude) are evident in future years' data. But note that the 2010 that the 2010 recruitment estimate does appear to be well estimated (

Figure 6.13; bottom left). If the 2010 recruitment is not estimated, then the (tuned) model instead estimates an above average recruitment in 2009 (Appendix 3). The model fit to the age composition data is poorer for fish of age 1 in 2011 and 2 in 2012. The estimated spawning biomass as a percentage of unexploited levels also differ substantially, being 70% *SBo* in 2012 and 61% *SBo* in 2014.

For the base case model BC the 2014 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 8138. The long-term retained catch is 4106t. The retained portion of the RBC for 2014 is estimated to be 8065t (Figure 6.15; Table 6.6). Note that the retained catch for 2014 is greater than 150% of the current TAC (5208 t). This would imply an adjusted retained catch of 7812t for 2014.

Table 6.6. The estimated retained portion of the RBC and the RBC for blue grenadier under the base case model BC. Note that the 2014 RBC is over 150% of the 2013 TAC of 5208t and so would be capped at 7812t.

Year	Retained catch	RBC
2014	8065*	8138
2015	9116	9172
2016	9249	9303
2017	8807	8861
2018	8149	8203
2019	7455	7509
2020	6811	6864
2021	6253	6306
2022	5788	5841
2023	5412	5464
2024	5110	5162
2025	4871	4922
2026	4680	4731
2027	4528	4578
2028	4406	4456
2029	4307	4357
2030	4226	4276
2031	4160	4210
2032	4106	4155

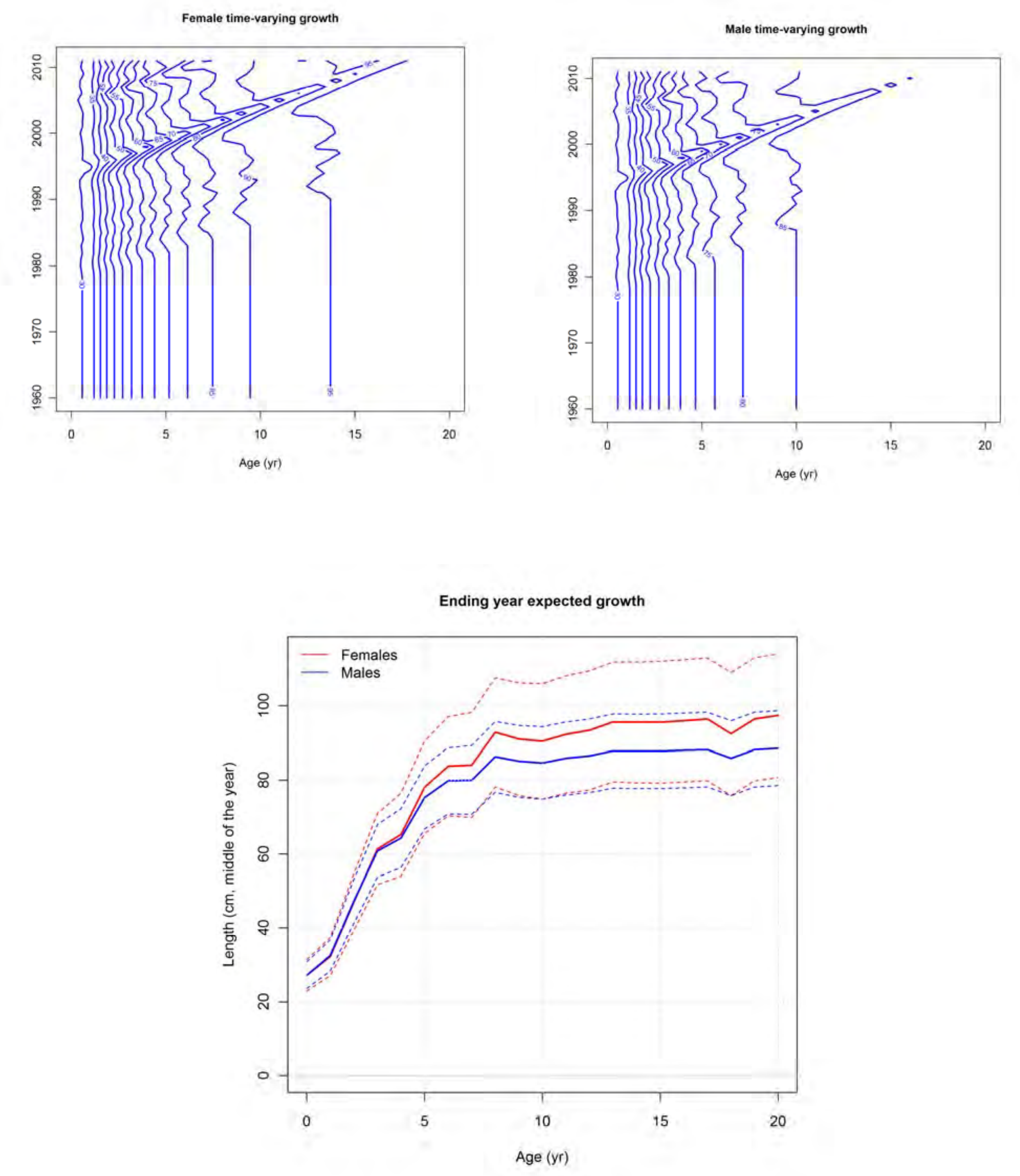


Figure 6.6 The base case model predicted length at age relationship.

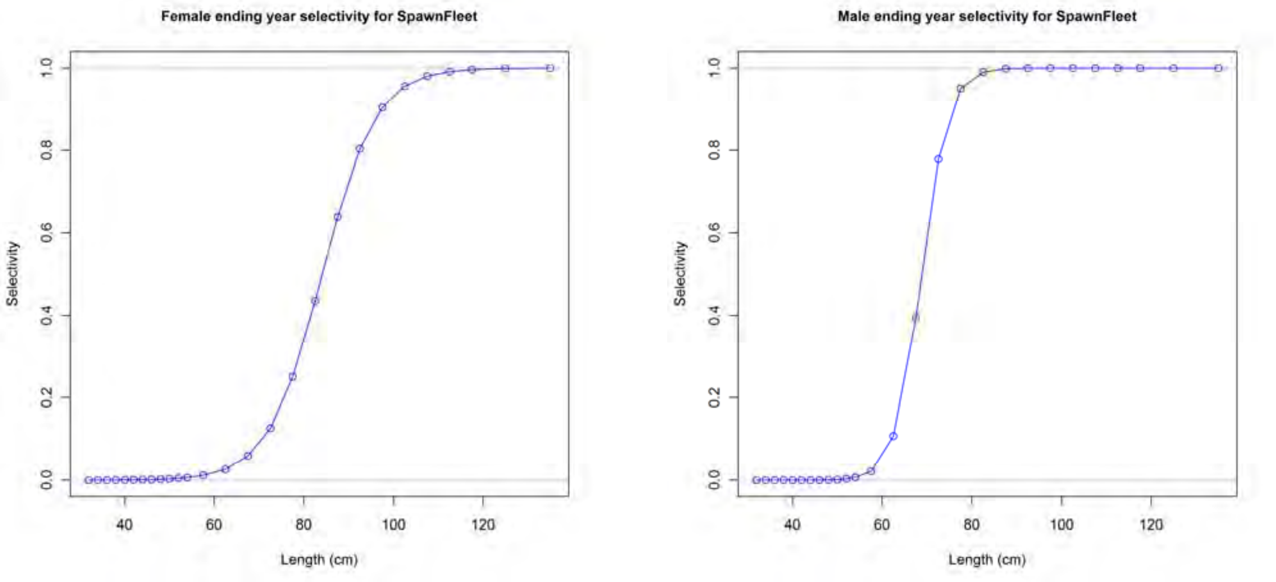


Figure 6.7. The base case model sex-specific selectivity for the spawning fishery. Females (left) and males (right).

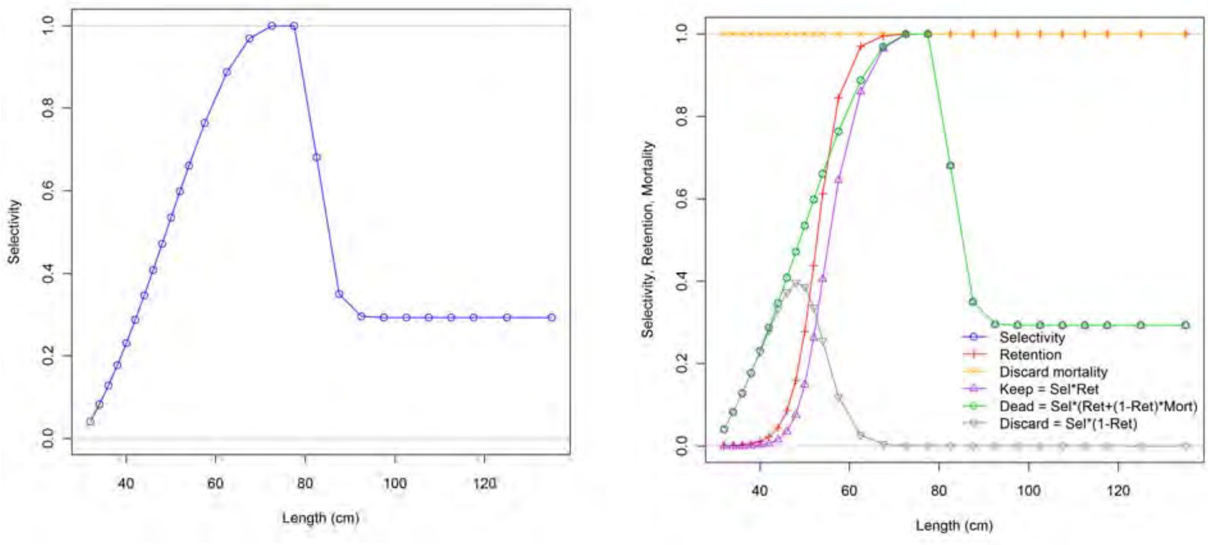


Figure 6.8 The base case model predicted selectivity-at-length for the non-spawning fleet (left) and the retention function for the non-spawning fleet (right – red).

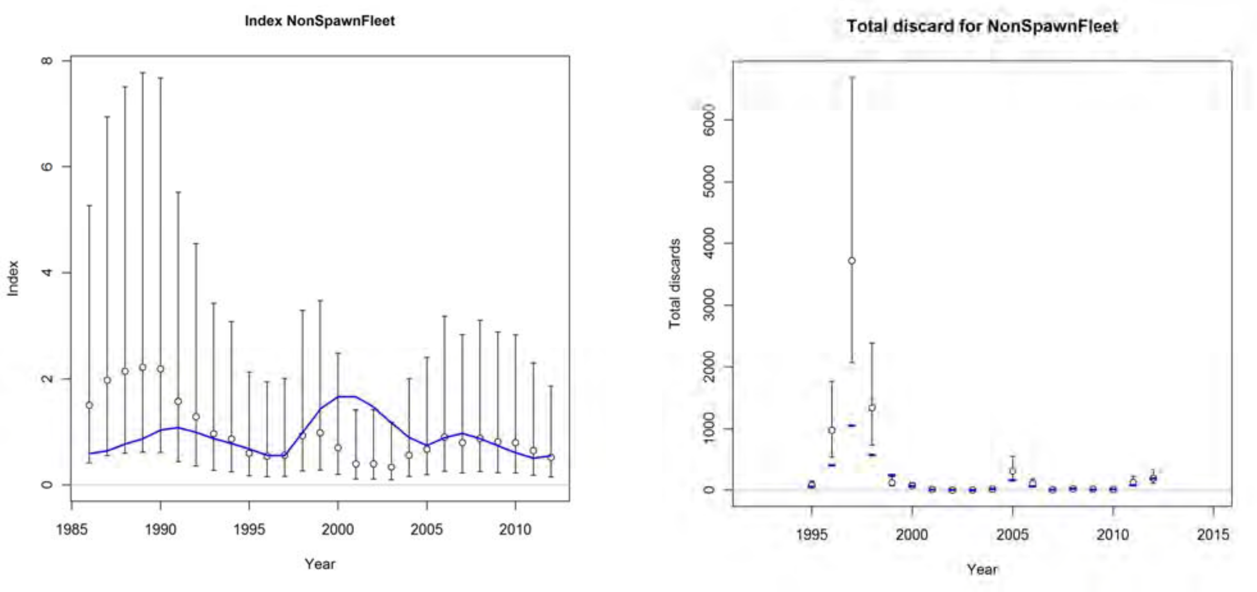


Figure 6.9. The base case model fit to the non-spawning catch rate series (left) and the discard mass (right).

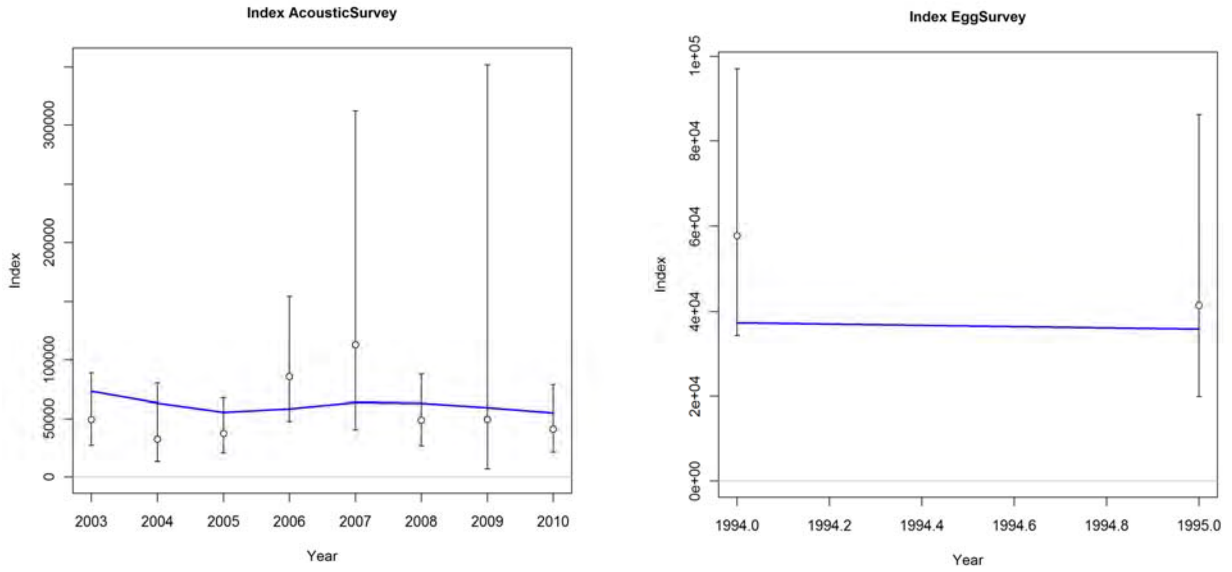
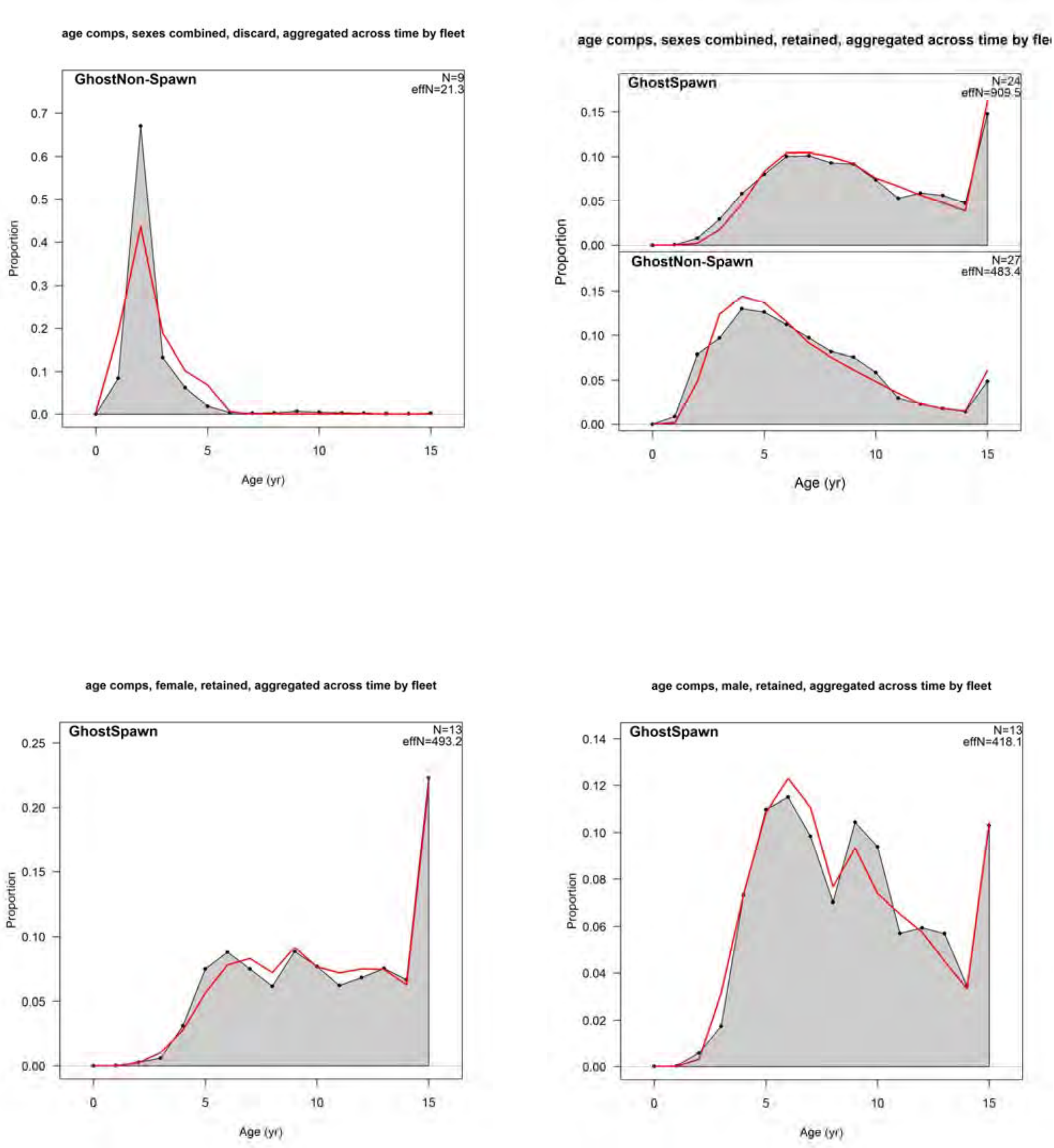


Figure 6.10. The base case model fit to the acoustic survey data (top left) and the egg survey estimates of female biomass (bottom left) with the corresponding fits from the 2008 assessment.


age comps, sexes combined, discard, aggregated across time by fleet

age comps, sexes combined, retained, aggregated across time by fle

age comps, female, retained, aggregated across time by fleet

age comps, male, retained, aggregated across time by fleet

Figure 6.11. The base case model fit to the year aggregated age-composition data.

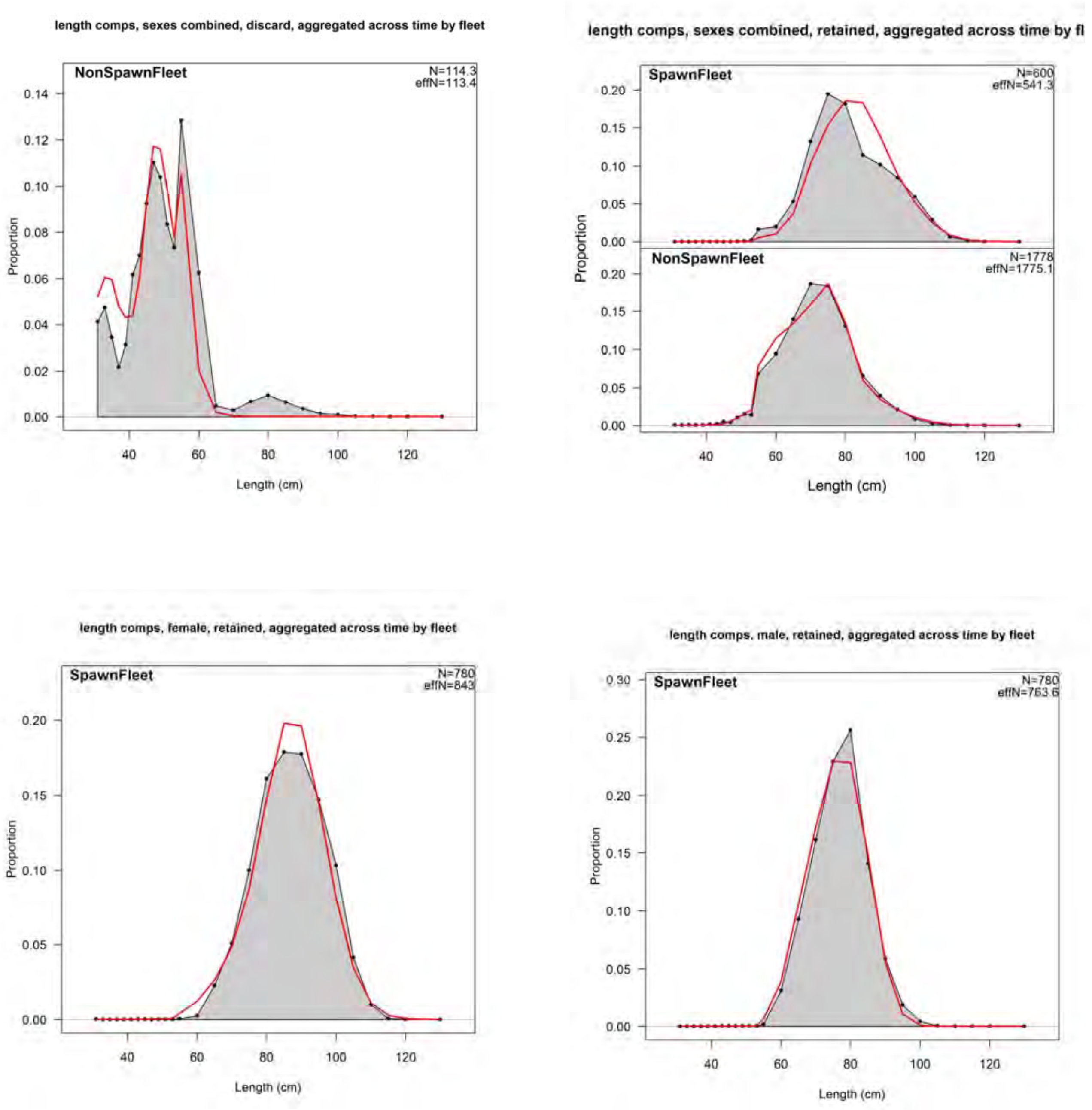


Figure 6.12. The base case model fit to the year aggregated length-composition data.

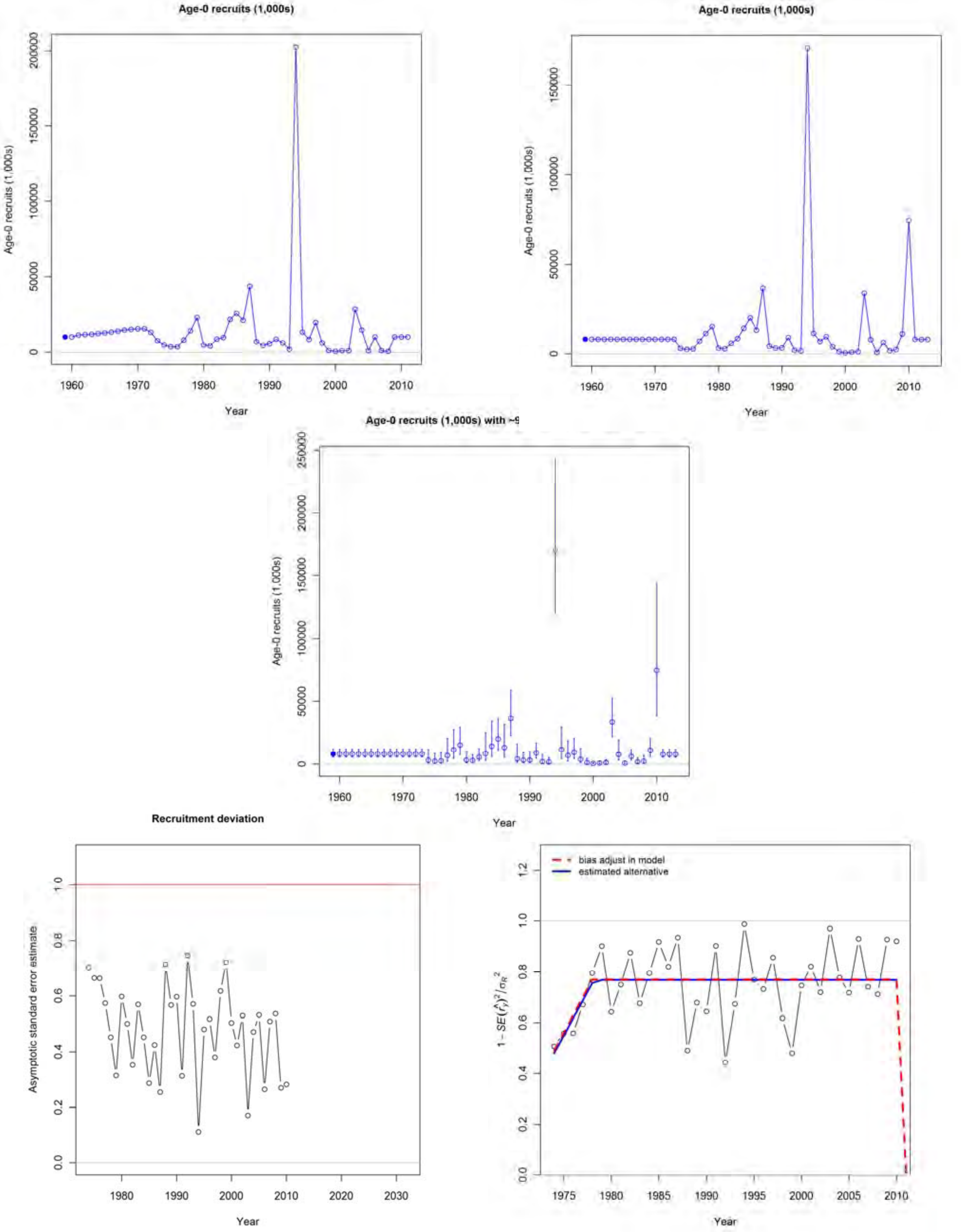


Figure 6.13 The base case model predicted time-series of recruitment for blue grenadier (top right and middle) with the corresponding figure from the 2011 assessment (top left) (Tuck, 2011). Recruitment diagnostics: recruitment deviation variance check (bottom left) and bias adjustment check (bottom right).

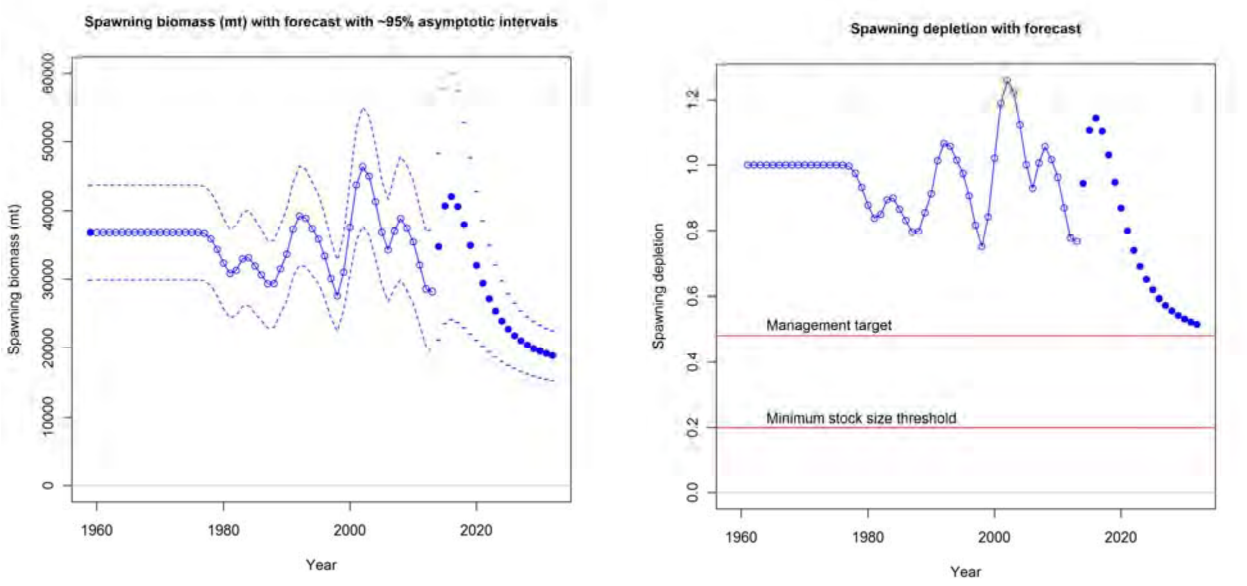


Figure 6.14 The base case model time-series of spawning biomass and relative spawning biomass.

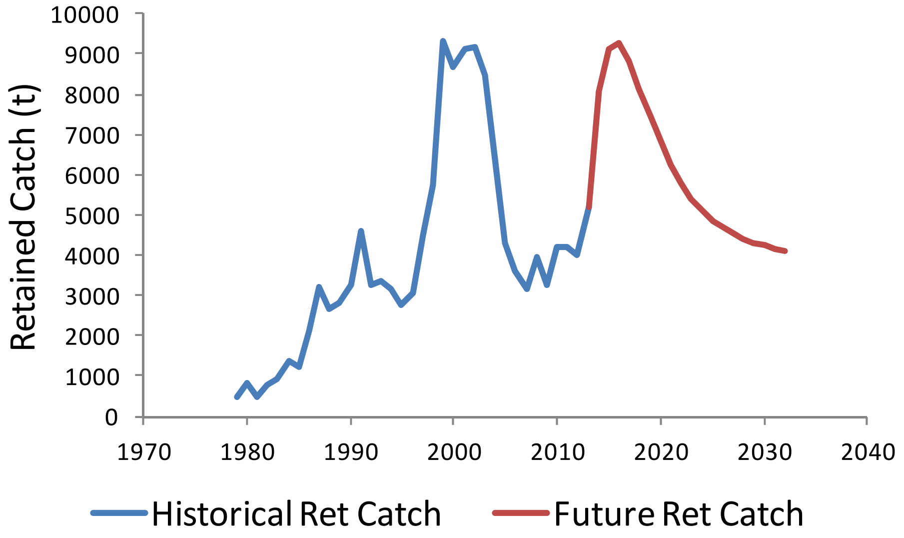


Figure 6.15. The time series of retained catches including the predicted retained catch (RBC less predicted discards) for the base case model.

6.6.1.4 Sensitivity tests

Results of the sensitivity tests are shown in Table 6.7. Steepness is not well estimated as the model estimated spawning biomass does not decrease to low enough magnitudes to inform the estimation of this parameter. Increasing the weight on the catch rate index (cpue cv=0.1) leads to a markedly poorer fit to the composition data. All model sensitivities show relative spawning biomass levels well above the target biomass level (48% *SBo*)), except for a model where no 2009 and 2010 recruitments are estimated. This is not surprising, given the large expected recruitment from 2010 is predicted to increase spawning biomass into the future.

Table 6.7 Summary of results for the base case model BC and sensitivity tests. * This RBC is more than 150% of the current TAC, and so will need to be capped at 7812t in 2014 if applied. ^This is the retained catch at 2032. The long term catch had not yet stabilised by year 2032. Ret C = retained catch. Ret C 2014-16 is the average 3-year retained catch. Ret C 2014-18 is the average 5-year retained catch. The upper six models have been tuned.

Model	Female SB$_0$	Female SB$_{2014}$	SB$_{2014}$/SB$_0$	2014 RBC	2014 Ret C	Ret C 2014-16	Ret C 2014-18	Ret C Long-term
Model BC (M_f=est, h=0.75)	36815	34781	0.94	8138*	8065*	8810*	8677*	4106^
No est of 2010 rect	38545	23540	0.61	6164	6031	6241	6383	4800^
No est of 2009 and 10 rect	38167	14772	0.39	2894	2831	2979	3115	3606^
Discard Fleet	44493	47780	1.07	16313*	15891*	18188	17587	6860^
Francis wt	98013	79526	0.81	7707	7594	7771	7642	5349^
Model BC2 2011	39983	21740	0.54	4881	4773	4644	4622	4436
h=0.90	36656	34800	0.95					
M_f=0.20	38918	39260	1.01					
M_f=0.17	37794	36893	0.98					
M_f=0.12	39175	30374	0.78					
Cpue cv=0.1	58910	59639	1.01					
Discard cv=0.1	36772	29930	0.81					
No egg survey	35130	33384	0.95					
Halve weight on LF data	39275	27451	0.70					
Double weight on LF data	36716	47875	1.30					
Halve weight on Age data	36373	36930	1.01					
Double weight on Age data	38172	33583	0.88					
Sigma R 0.8	35046	35962	1.02					
Sigma R 1.2	40456	34311	0.85					

Table 6.8. Summary of likelihood components for the base-case BC and sensitivity tests. Likelihood components are unweighted, and sensitivities from the BC are shown as differences from the base case. A negative value indicates a better fit, a positive value a worse fit. Note that the upper five models are tuned and so likelihoods are not comparable.

Model	TOTAL	Survey	Discard	Length comp	Age comp	Recruitment
Model BC (M_f=est=0.15, h=0.75)	6406.72	-1.73	17.94	522.84	5809.15	28.61
No est of 2010 rect	961.95	0.51	12.07	8.51	916.00	-3.60
No est of 2009 and 10 rect	743.40	-1.16	8.31	20.25	703.46	-6.41
Discard Fleet	-53.42	-3.30	-	38.09	-68.70	-4.07
Francis wt	-3203.38	-8.16	-22.27	-421.77	-2742.28	0.84
h=0.90	0.02	0.03	-0.02	0.01	0.06	-0.02
M_f=0.20	119.31	1.40	3.06	-9.80	117.69	-3.55
M_f=0.17	-14.42	0.85	0.35	-8.56	-13.86	-2.43
M_f=0.12	111.07	-0.96	-4.14	3.66	110.87	1.12
Cpue cv=0.1	2114.65	76.04	23.73	54.55	1941.06	2.39
Discard cv=0.1	348.88	1.74	-31.62	47.59	314.22	8.13
No egg survey	29.51	0.67	-0.32	-0.25	29.18	0.51
Halve weight on LF data	-204.63	-1.30	-14.45	35.47	-216.65	-0.67
Double weight on LF data	922.21	5.12	25.08	-52.11	912.80	-0.21
Halve weight on Age data	2538.47	0.47	0.89	-3.27	2540.71	-0.30
Double weight on Age data	-1432.04	-0.06	-0.60	-0.49	-1435.99	-1.18
Sigma R 0.8	6.95	0.90	2.02	-6.19	-0.81	1.26
Sigma R 1.2	11.80	-0.45	-1.25	-1.19	17.17	-1.02

6.6.2 *Risk assessment to recruitment uncertainty*

The 2013 stock assessment for blue grenadier is the first to show a substantial recruitment event in 2010. The estimated 2010. The estimated magnitude of this recruitment is predicted to be second only to the large recruitment of the mid recruitment of the mid 1990s (

Figure 6.13; top right). While it appears this recruitment is well estimated (

Figure 6.13) and is an encouraging sign for the fishery, the consequent RBCs are a substantial increase over those seen recently and could have major consequences for the stock if the magnitude of this recruitment is less than expected. As such, a risk assessment to this uncertainty was conducted. Models that did not estimate the 2010 recruitment (noR10) and did not estimate the 2009 and 2010 (no R09 R10) were run (and tuned) (Table 6.7; Section 6.10).

In order to fit to the length data of 2011 and 2012, the noR10 model shifts the recruitment back into 2009 (Figure 6.16). It also estimates that this cohort is very slow growing in order to fit to the length data, which would otherwise have come from the 2010 cohort (Figure 6.17). Thus the length frequency resulting from the 2009 cohort shows a smaller mode than it would otherwise, allowing the model to fit to the 2011 and 2012 length data. In addition, as the growth is slower, the maximum size of fish from the 2009 cohort is lower which translates into a smaller biomass than seen when the 2010 recruitment is estimated (Figure 6.16). As a consequence of placing the large cohort in 2009, as opposed to 2010, the fit to the age data is poor, as the age data want to place the strong cohort in 2010 (Table 6.8). This implies that a considerable signal exists indicating a strong recent cohort, and most likely a 2010 cohort. Assuming average recruitment for 2009 and 2010 (and not estimating these recruitments; no R09 R10) does not result in a large recent cohort, as the model has no flexibility to fit to the recent length and age data (Figure 6.16). As a result, a substantially more pessimistic result occurs, as the biomass from the mid-1990s cohort succumbs to mortality and recent recruitments (eg 2003) are not sufficient to maintain the biomass above the target reference point (Figure 6.16).

The retained portion of the RBCs from each of the base case model (BC) and the model that does not estimate a 2010 recruitment (noR10) are provided in Table 6.9. Also included in this table are the 3- and 5-year averages of the retained catches. Note that the 2014 retained catch is greater than 150% of the current TAC (5208t) and so has been capped at 7812t.

For the risk assessment, each of the 3- and 5-year retained catch, and 3- and 5-year averages of the retained catch were used as forecast catches in each of the two models (BC and noR10), leading to 16 combinations (8 forecast catches and 2 models). The risk assessment can then explore the consequence of placing the large forecast catches from model BC into the noR10 model which predicts a lower spawning biomass (Figure 6.16).

Results show, not surprisingly, that when the smaller catches of the R10 model (green and black) are placed into the BC model, that the predicted SSB trajectory is higher than if the catches from the BC model (red) are used (in the BC model) (Figure 6.18). If the BC model catches (red and black) are applied in the model that does not estimate a 2010 recruitment (noR10) then the SSB trajectory is lower than if catches from this model are used (green). However, in no case does the median trajectory move below the target reference point (48%).

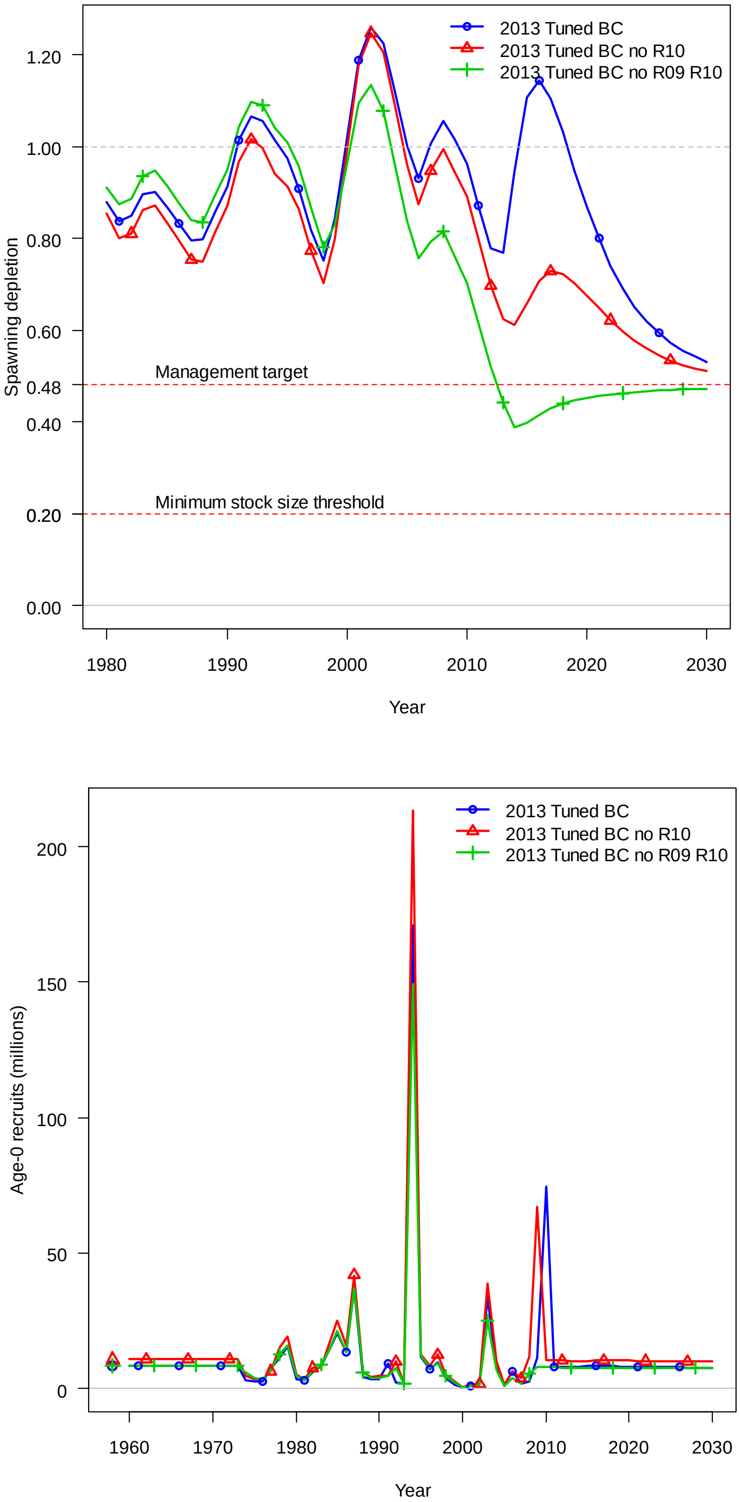


Figure 6.16. The trajectory of female spawning biomass for the base case model (Blue: 2013 Tuned BC) and models with no estimation of the 2010 recruitment (Red: R10) and no estimation of the 2009 and 2010 recruitment (Green: R09 R10)

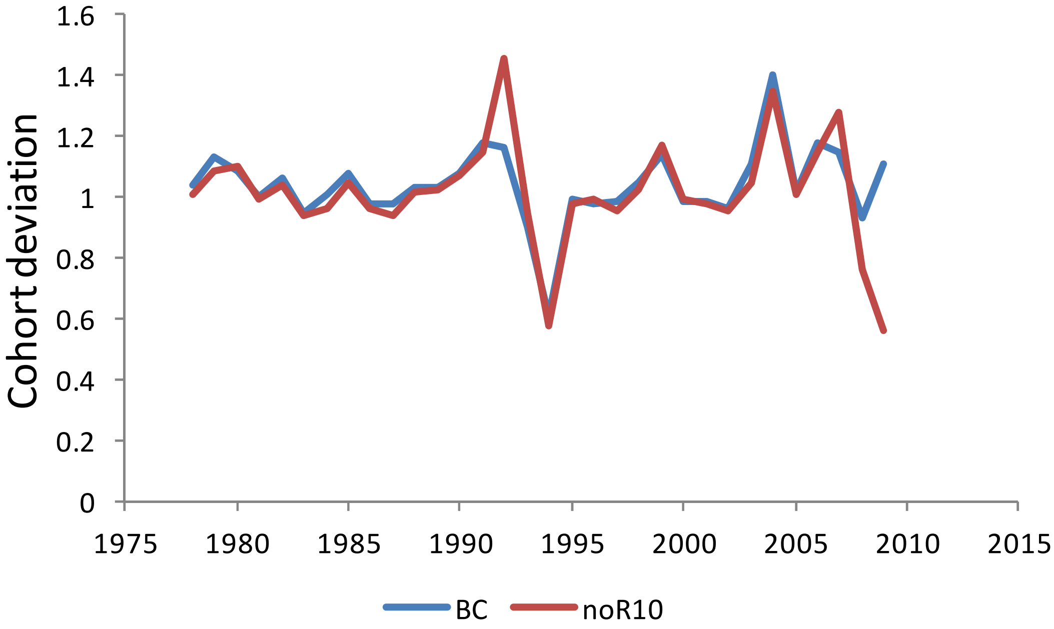


Figure 6.17. The estimated cohort deviations showing the much slower growing 2009 cohort if the recruitment of 2010 is not estimated (noR10) compared to the base case model where the 2010 recruitment is estimated (BC).

Table 6.9. The estimated retained portion of the RBC for blue grenadier under the base case model BC and where the 2010 recruitment is not estimated (noR10). Shown are retained values of catch and 3 and 5 year averages. *Note that the 2014 Retained catch of 8605t is over 150% of the 2013 TAC of 5208t

	BC			noR10		
Year	Annual	3-Year	5-year	Annual	3-Year	5-year
2014	7812*	7812*	7812*	6031	6241	6383
2015	9116	8810	8677	6201	6241	6383
2016	9249	8810	8677	6490	6241	6383
2017	8807		8677	6629		6383
2018	8149		8677	6564		6383

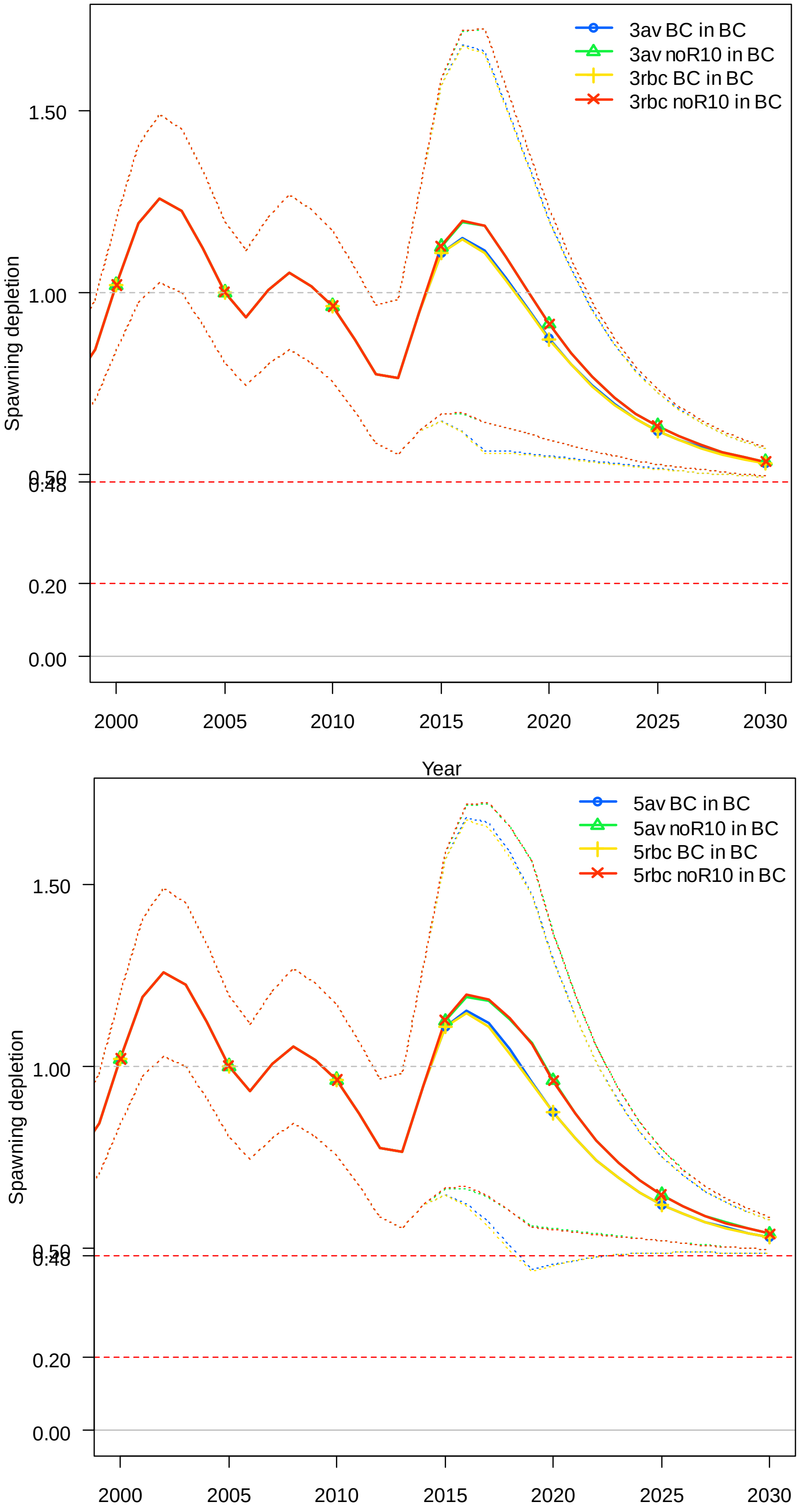


Figure 6.18. The consequence of alternative forecast catch series on the time series of female SSB (t) when placed in the base case model (BC). 3av = 3-year average, 5av = 5-year average, 3rbc = 3-years of annual retained catch, 5rbc = 5-years of annual retained catch. X in Y = catches from model X are placed into model Y.

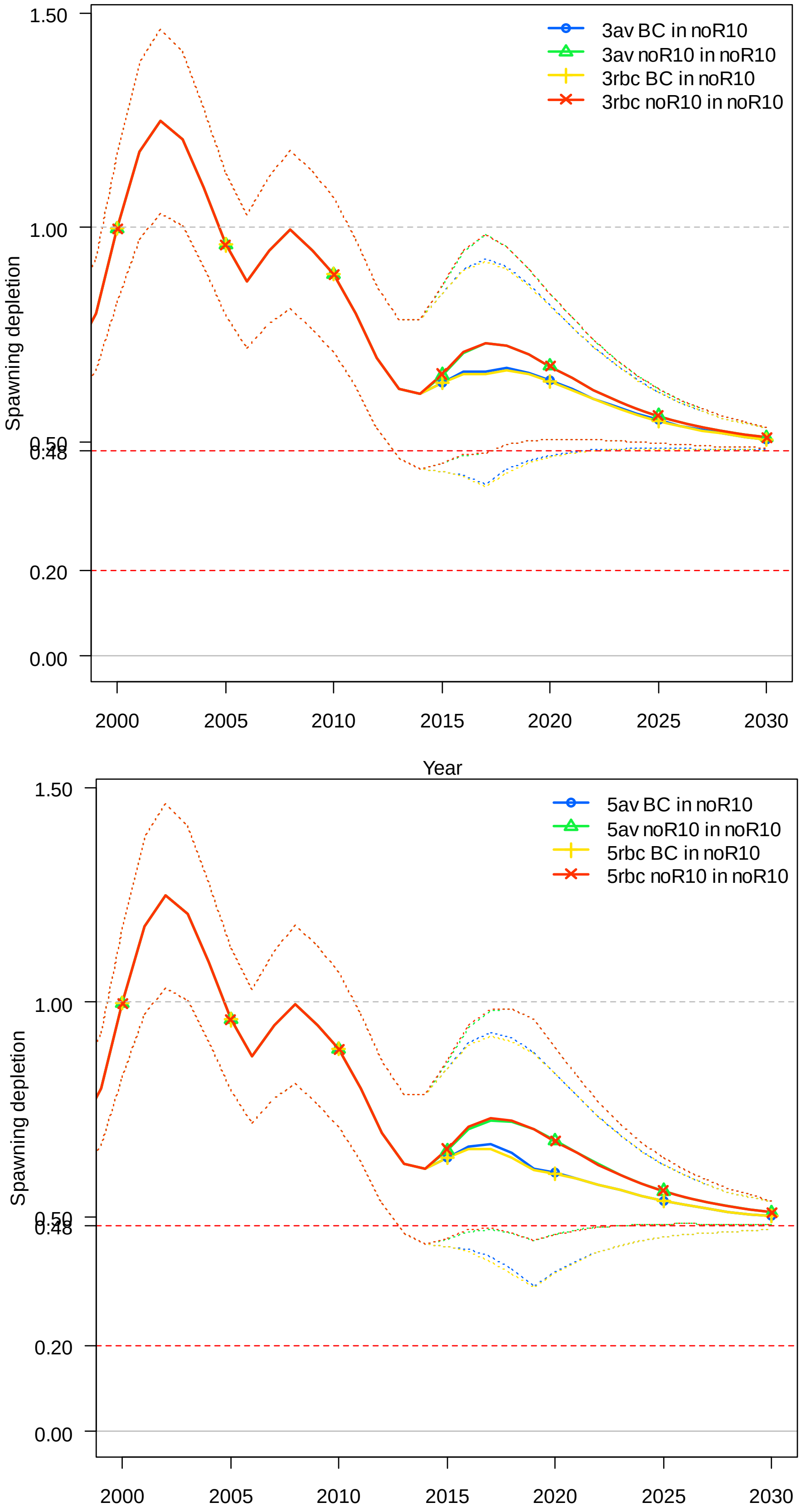


Figure 6.19. The consequence of alternative forecast catch series on the time series of female SSB (t) when placed in the model that does not estimate a 2010 recruitment (noR10). 3av = 3-year average, 5av = 5-year average, 3rbc = 3-years of annual retained catch, 5rbc = 5-years of annual retained catch. X in Y = catches from model X are placed into model Y.

6.6.3 *Further development*

1) Investigate the utility of the Francis weighting method.
2) Explore the lack of fit to the catch rate series of the non-spawning fishery and whether the poor fit is a data issue or model structure issue. Develop a model with a discard fleet so that the discard mass is removed from the population. This may resolve fits to the cpue and discard data, but is a rather brute force mechanism to do this.

6.7 Acknowledgements

Many thanks are due to the SESSF-WG for their assistance with model discussions and development. Malcolm Haddon 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.

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6.9 Appendix 1: Age and length compositions for the base case model (BC)

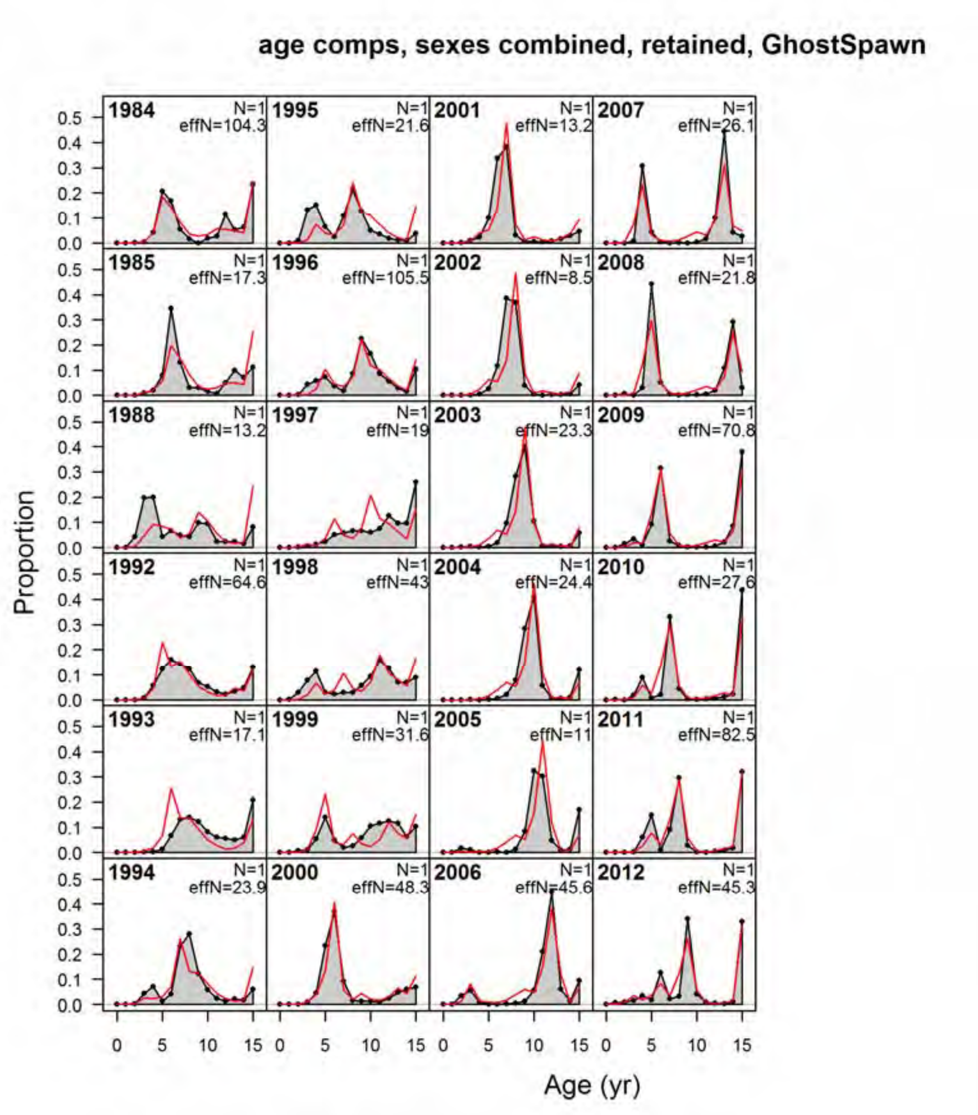

Figure 6.20. The Model BC fit to the age-composition data for the spawning fishery. Sexes combined.

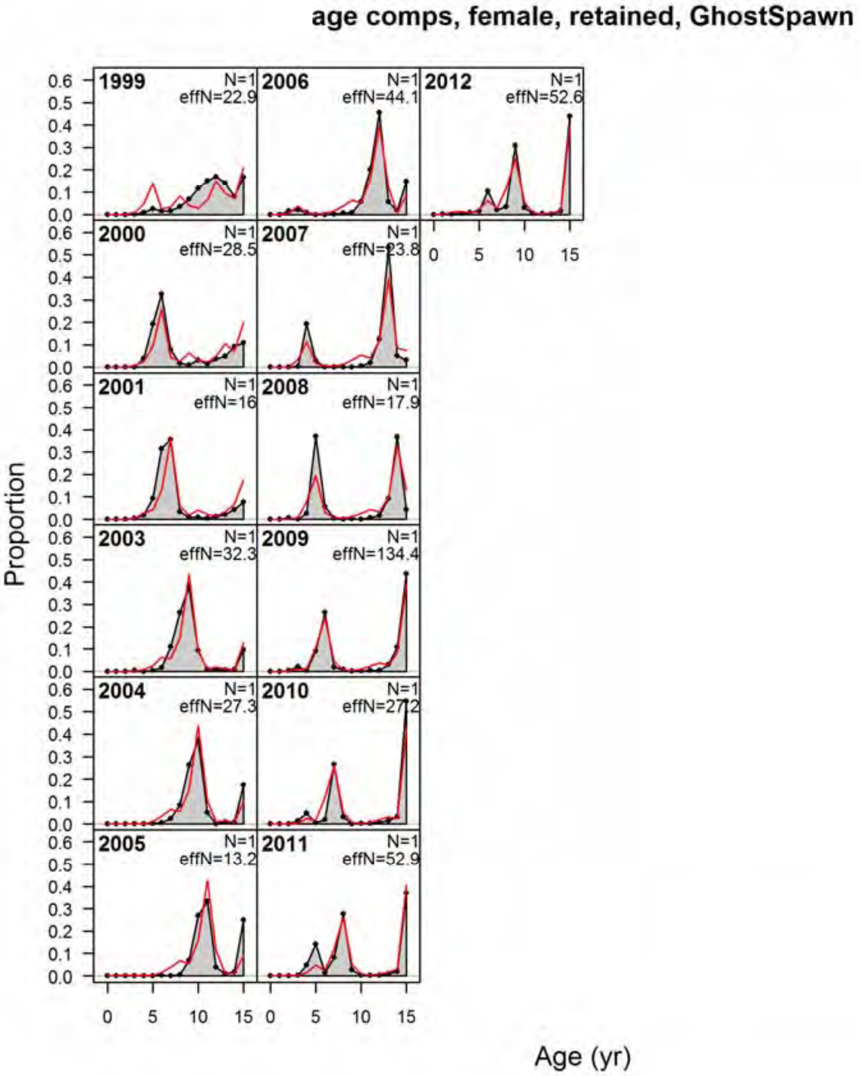

Figure 6.21. The Model BC fit to the female age-composition data for the spawning fishery.

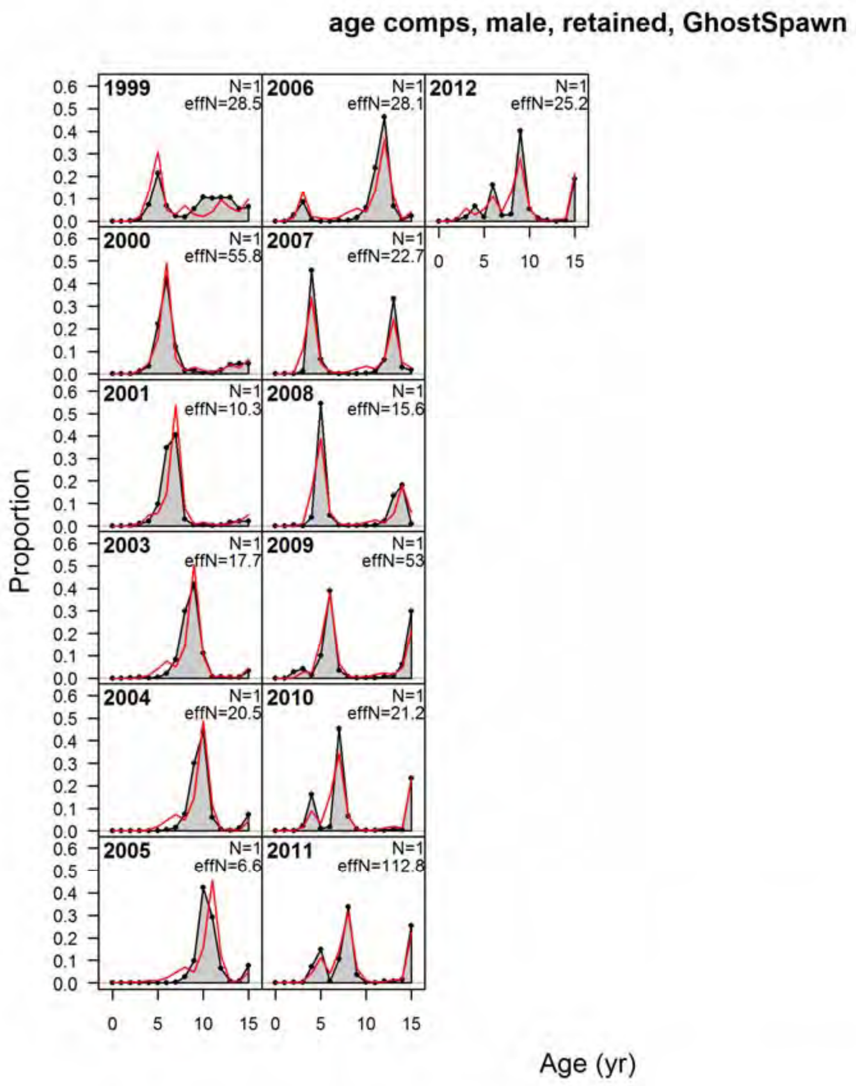

Figure 6.22. The Model BC fit to the male age-composition data for the spawning fishery.

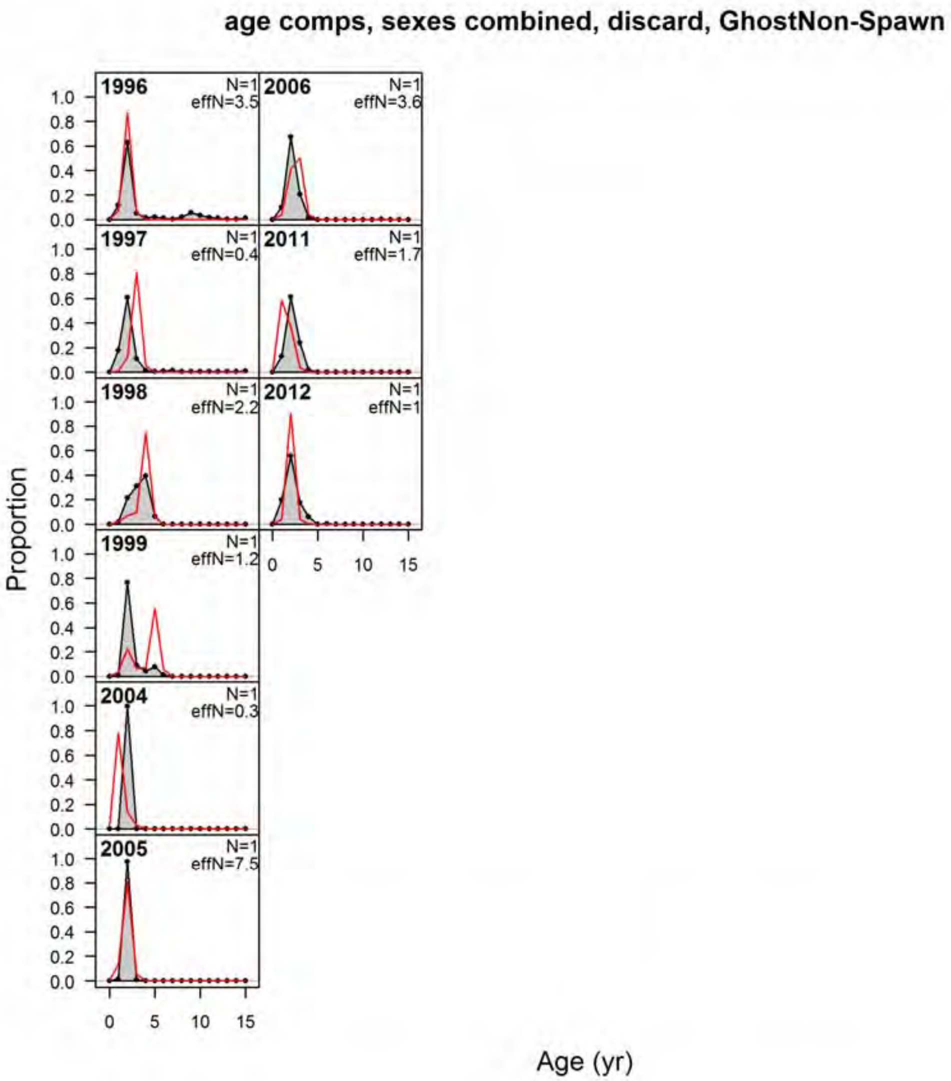

Figure 6.23. The Model BC fit to the discard age-composition data for the non-spawning fishery.

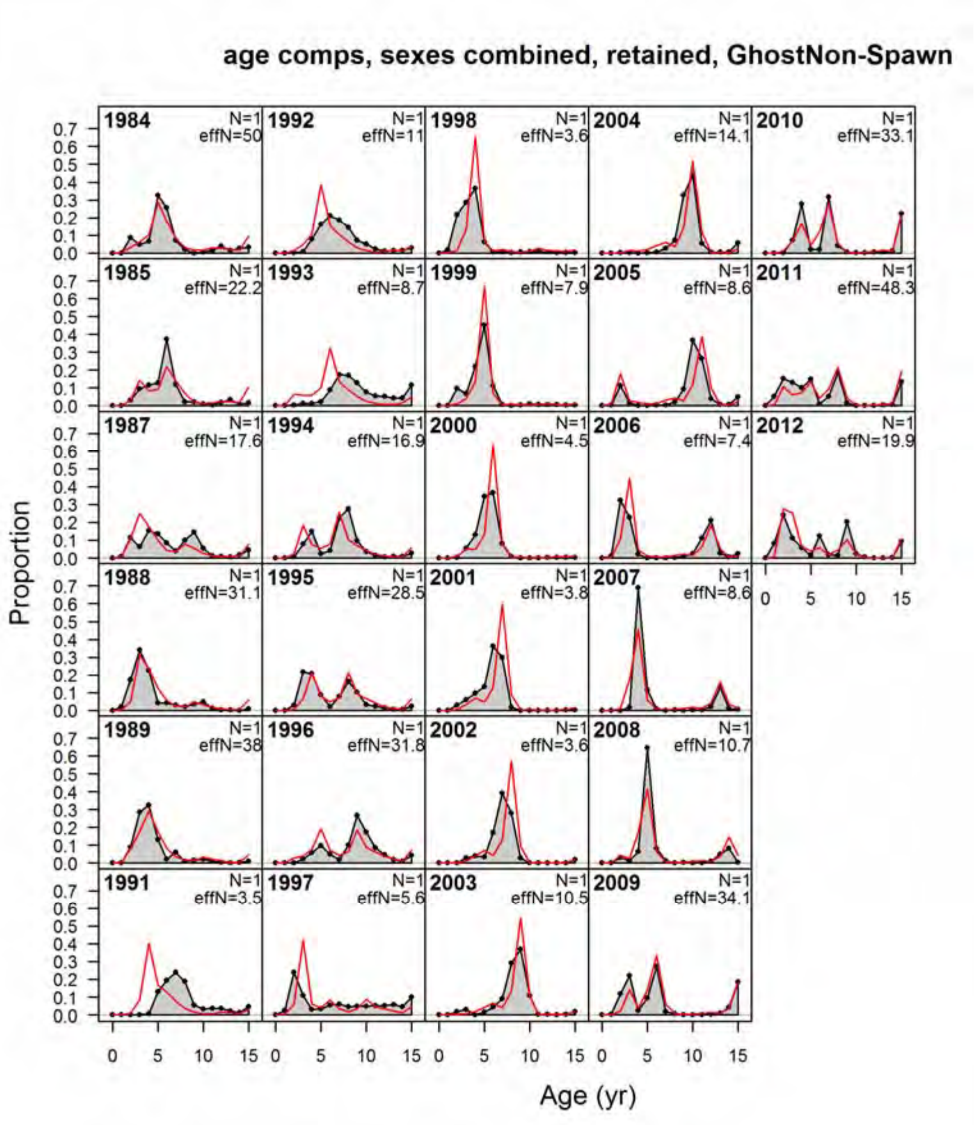

Figure 6.24. The Model BC fit to the retained age-composition data for the non-spawning fishery.

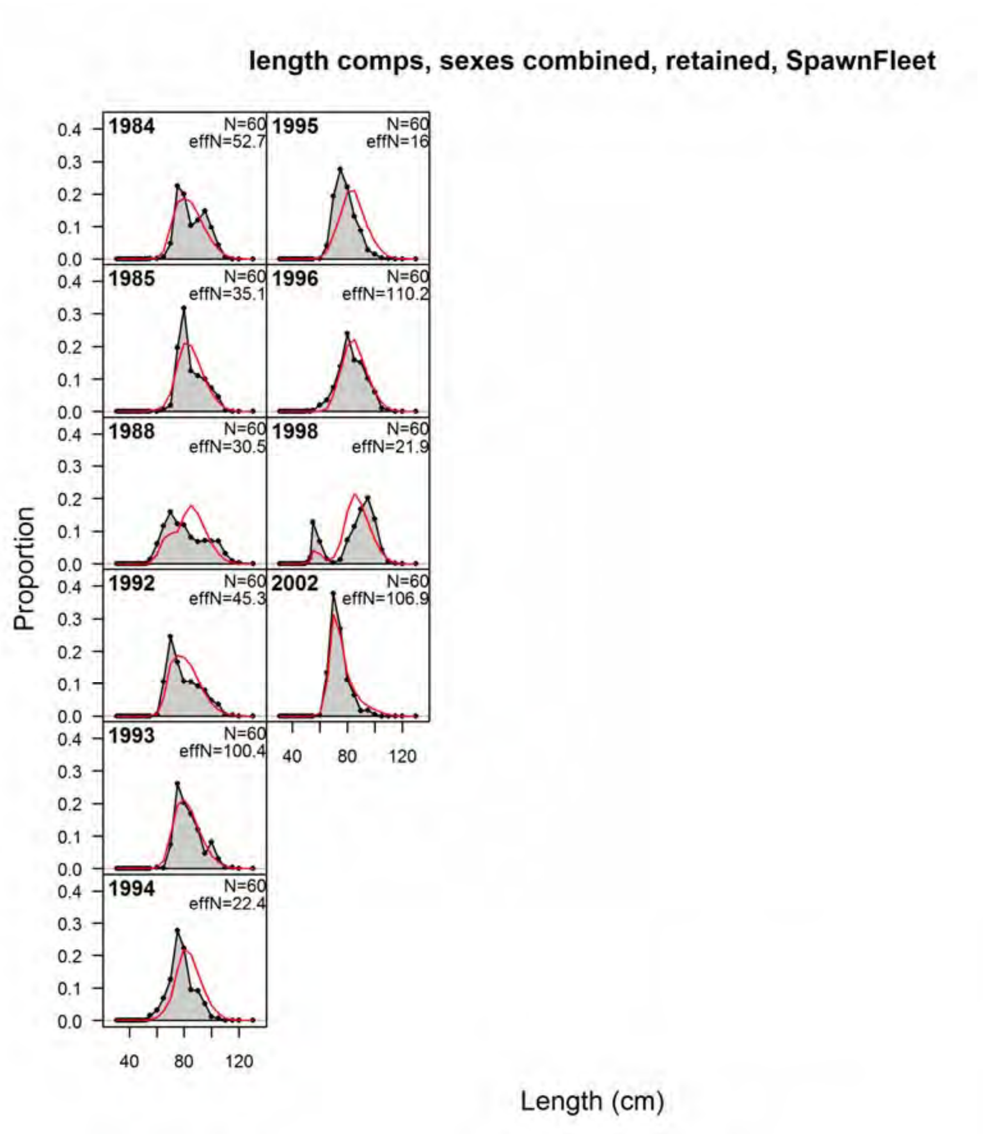

Figure 6.25. The Model BC fit to the retained length-composition data for the spawning fishery.

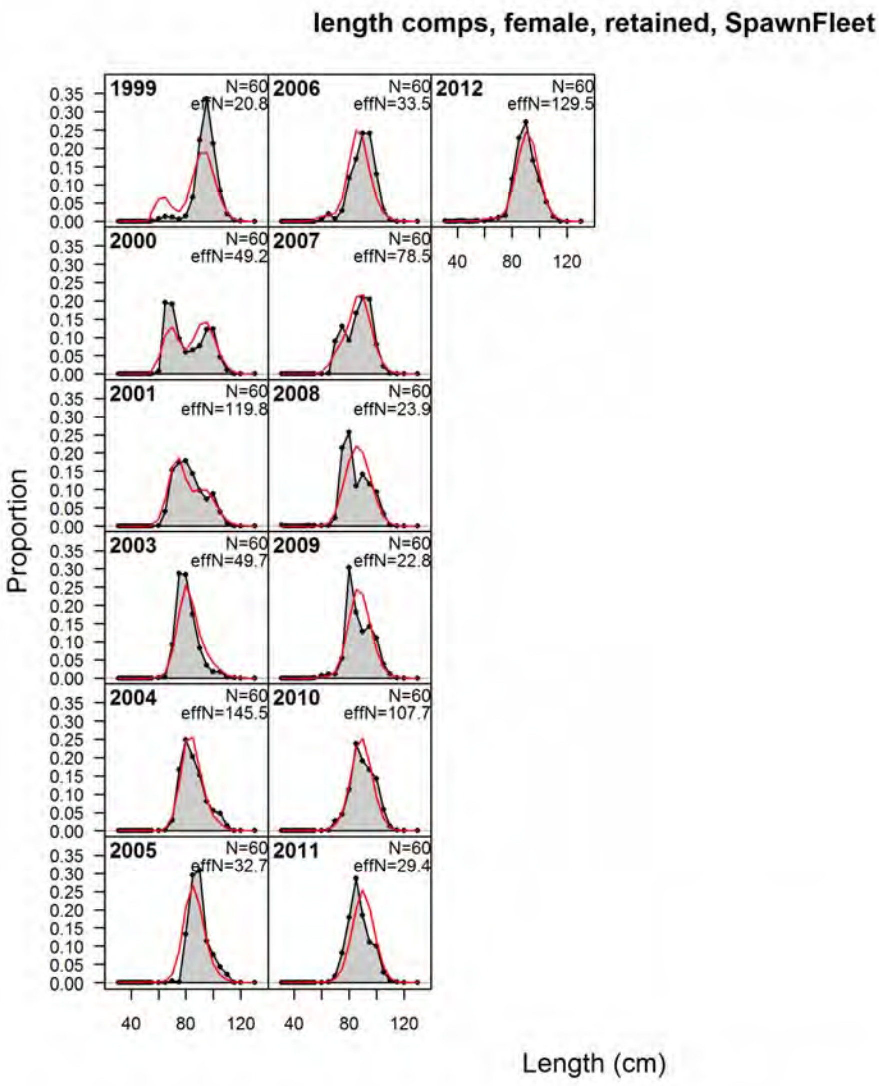

Figure 6.26. The Model BC fit to the retained female length-composition data for the spawning fishery.

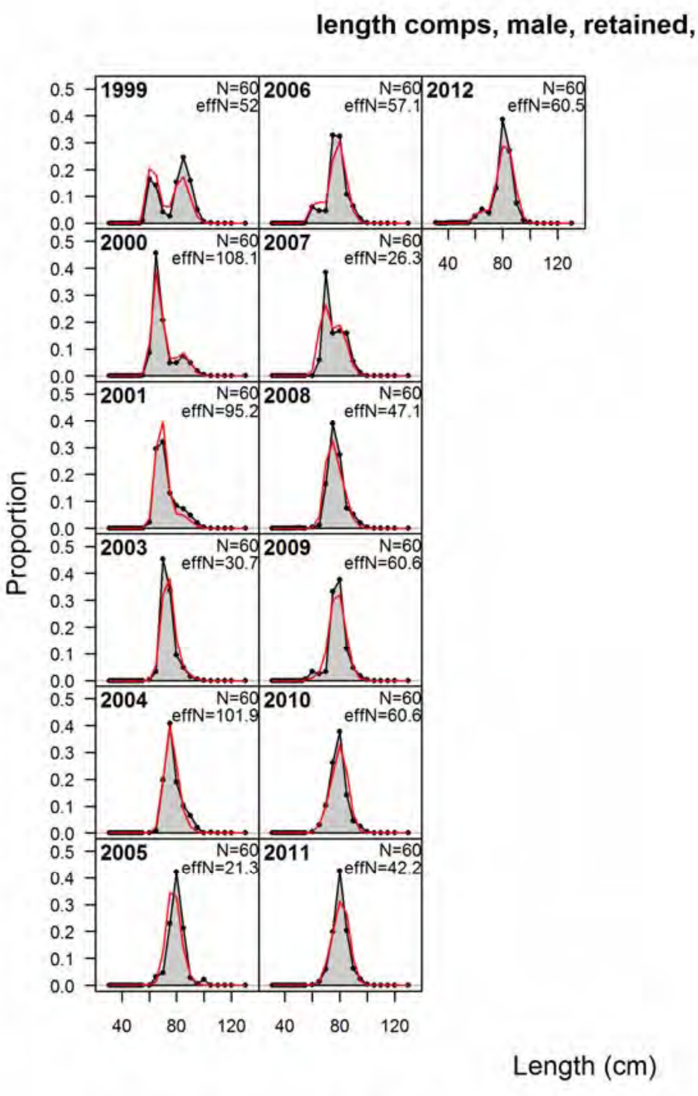

Figure 6.27. The Model BC fit to the retained male length-composition data for the spawning fishery.

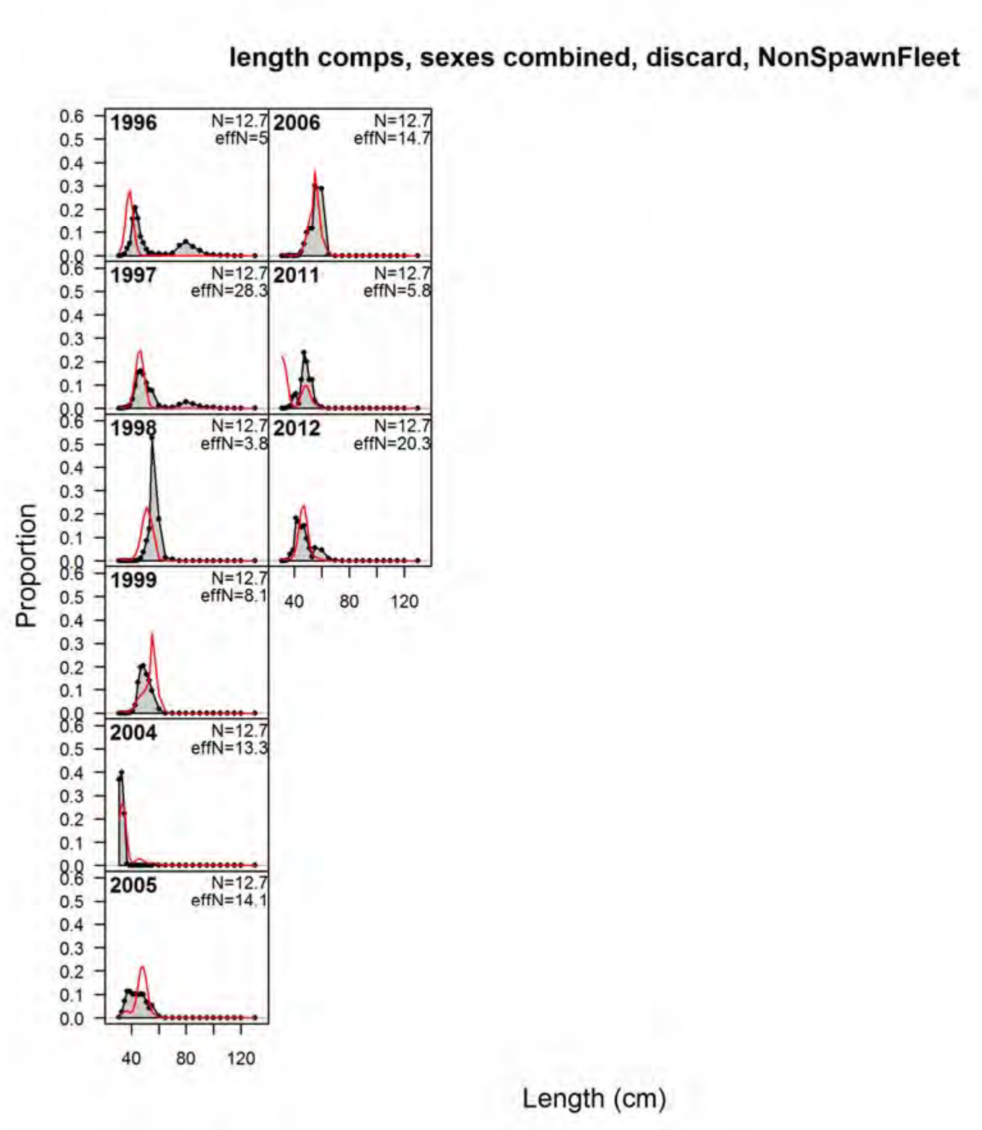

Figure 6.28. The Model BC fit to the discard length-composition data for the non-spawning fishery.

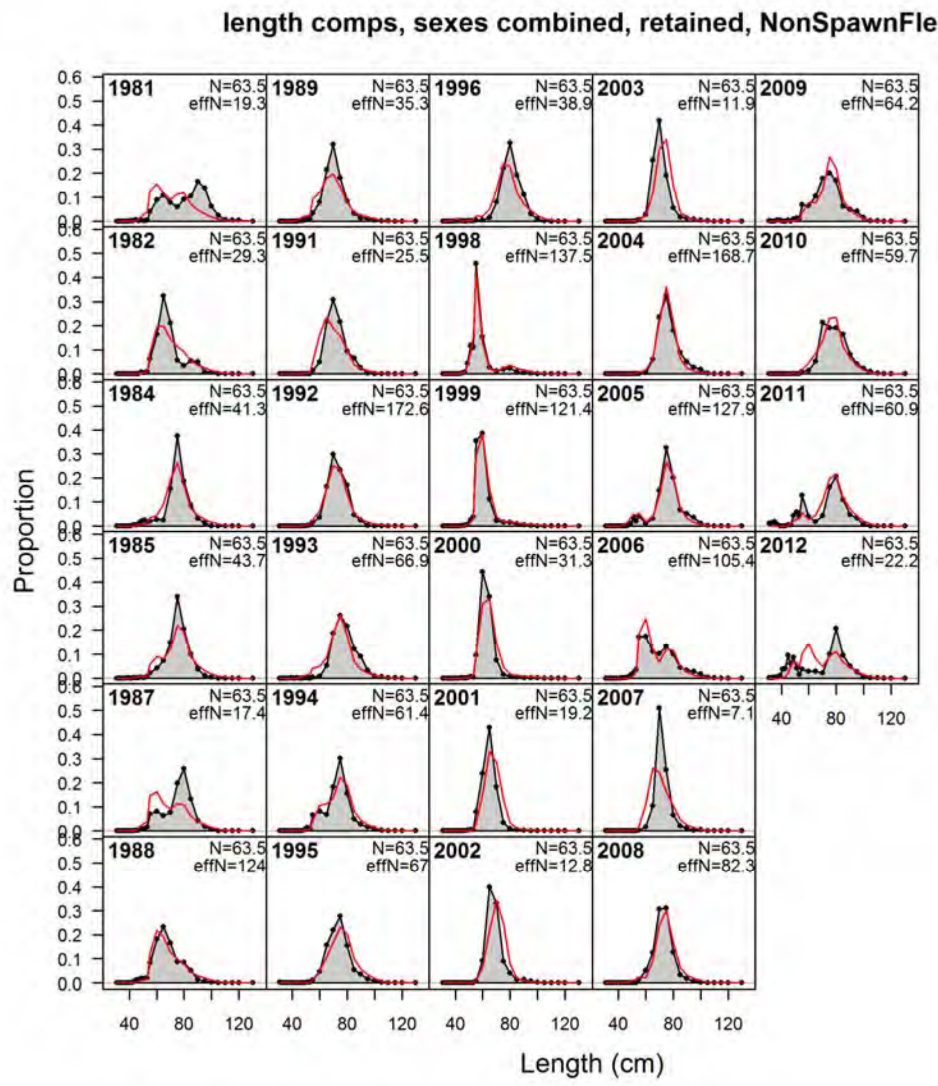

Figure 6.29. The Model BC fit to the retained length-composition data for the non-spawning fishery.

6.10 Appendix 2: Age and length compositions for model with 2010 recruitment not estimated (noR10)

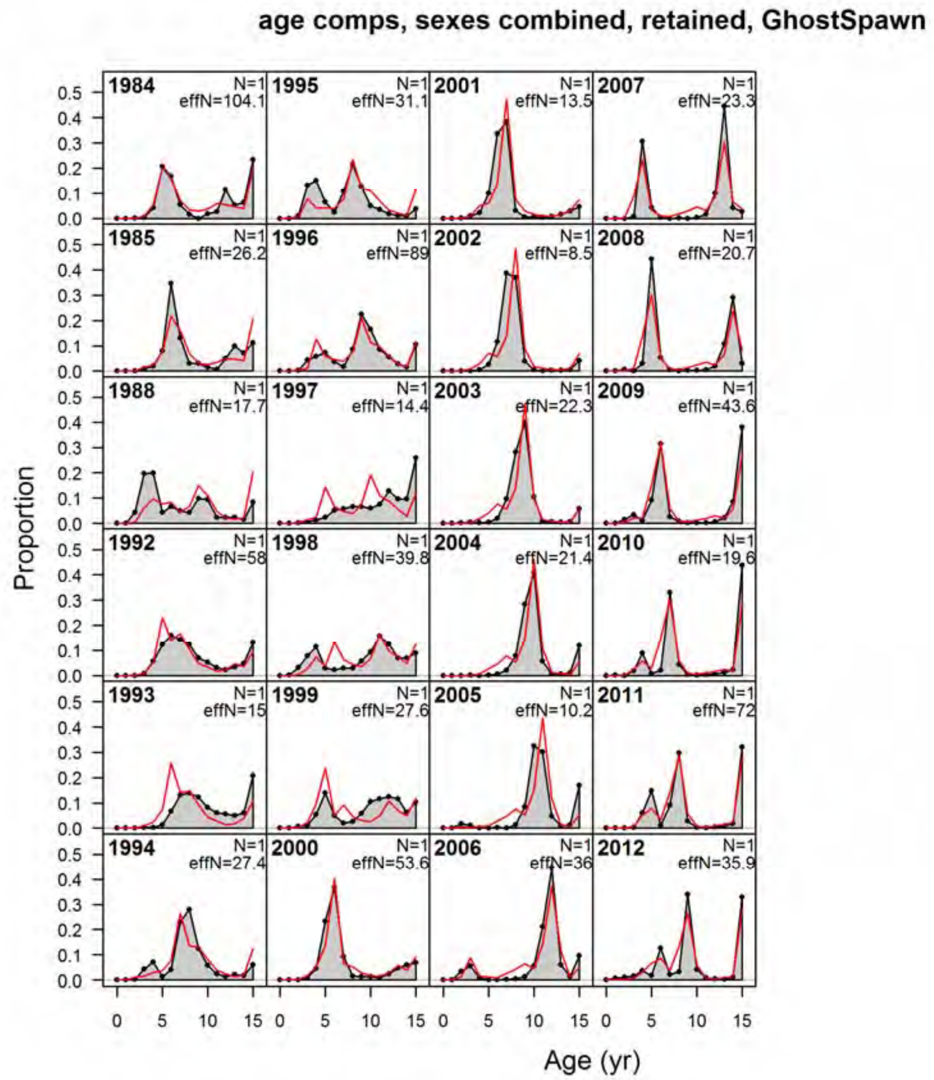

Figure 6.30. The Model noR10 fit to the age-composition data for the spawning fishery. Sexes combined.

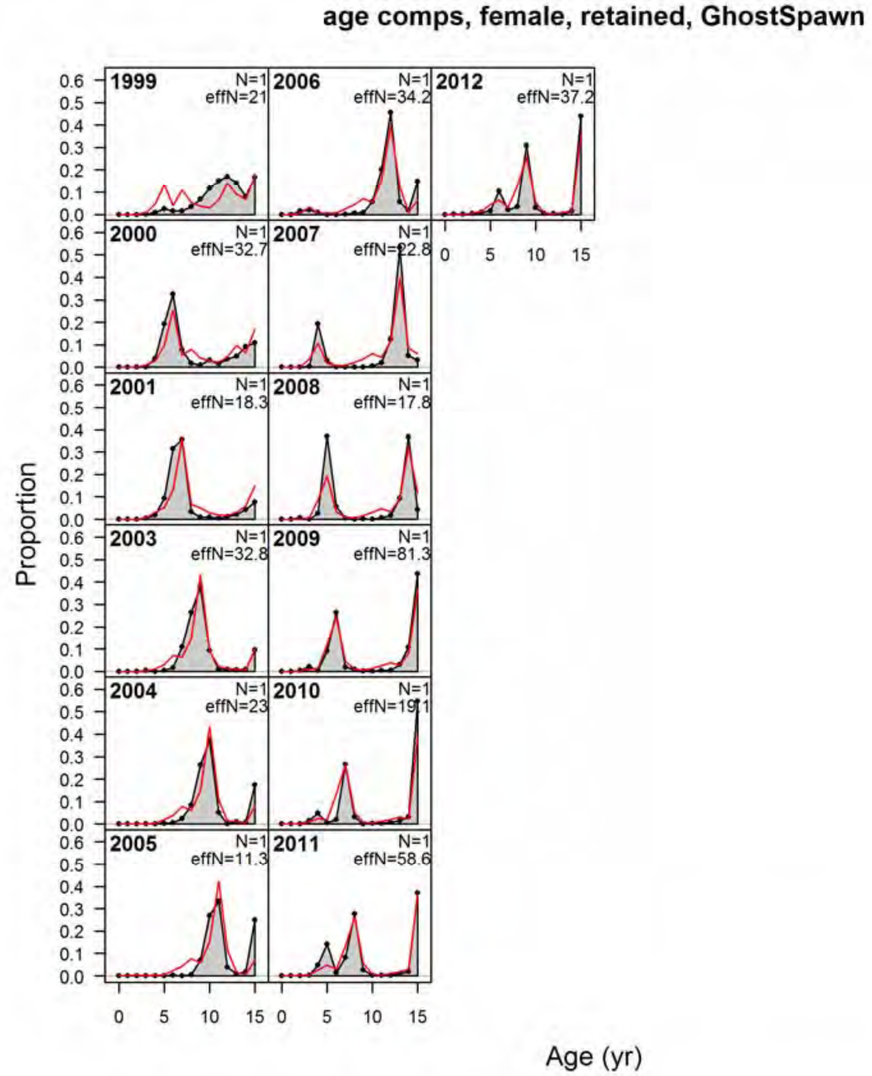

Figure 6.31. The Model noR10 fit to the female age-composition data for the spawning fishery.

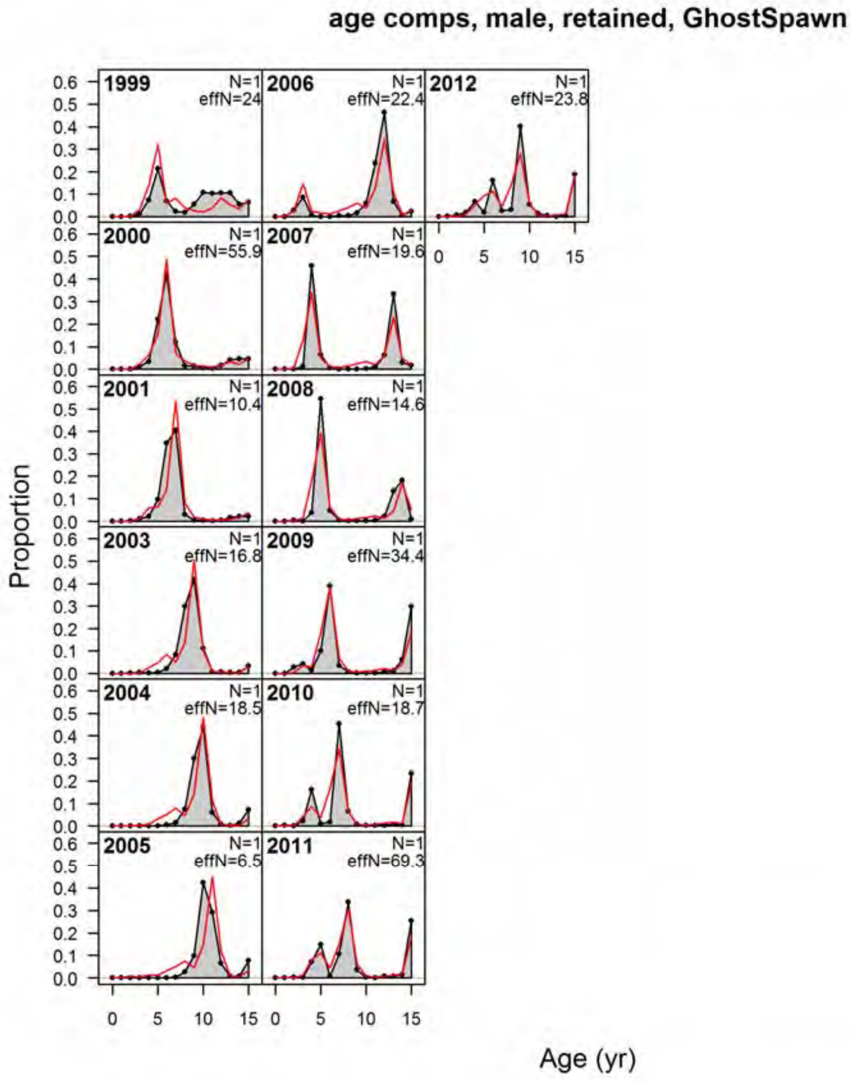

Figure 6.32. The Model noR10 fit to the male age-composition data for the spawning fishery.

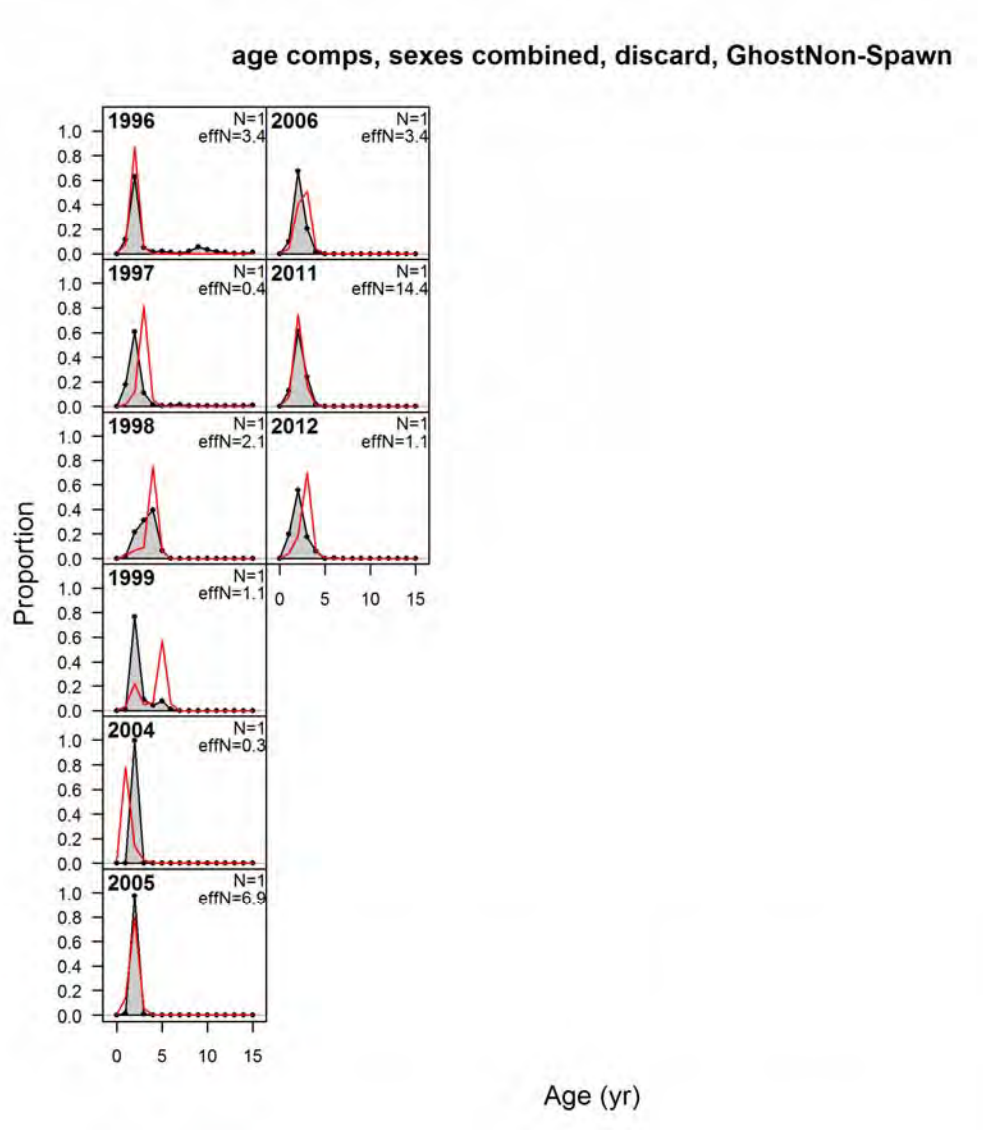

Figure 6.33. The Model noR10 fit to the discard age-composition data for the non-spawning fishery.

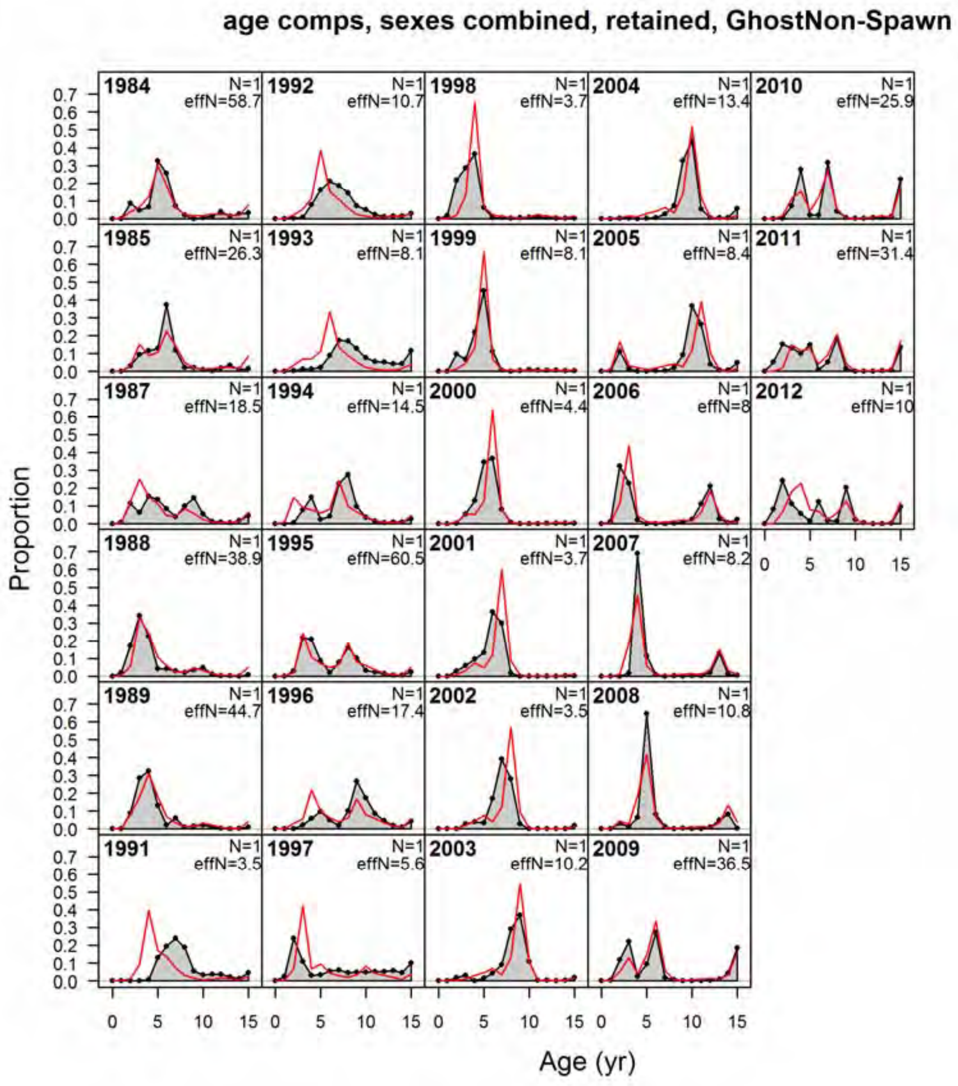

Figure 6.34. The Model noR10 fit to the retained age-composition data for the non-spawning fishery.

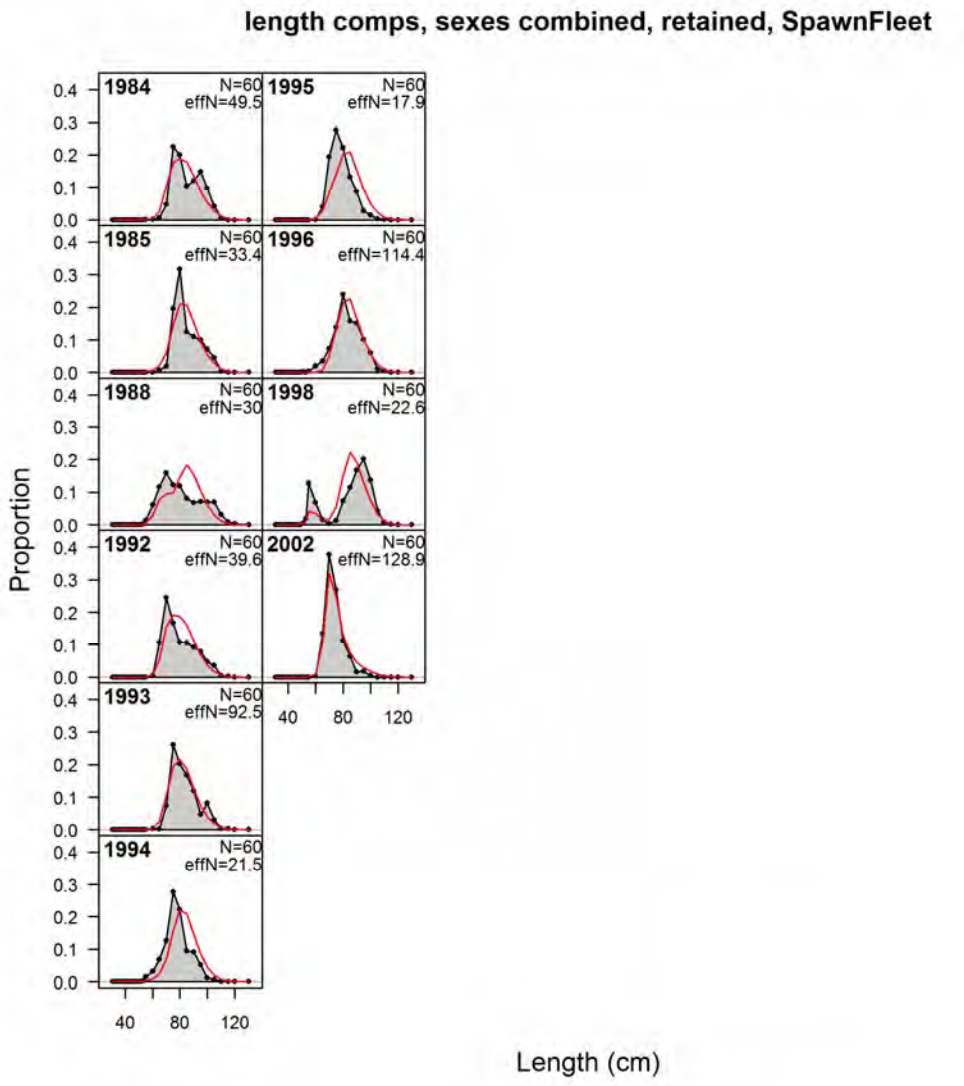

Figure 6.35. The Model noR10 fit to the retained length-composition data for the spawning fishery.

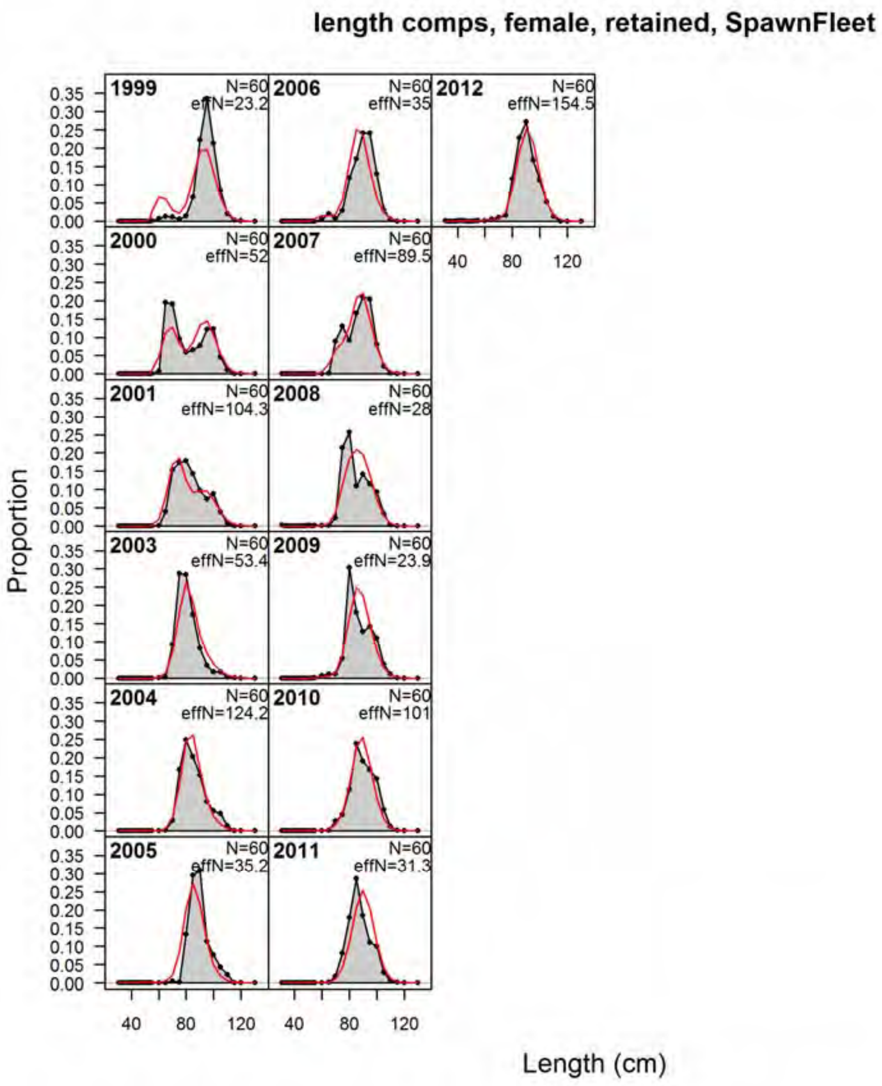

Figure 6.36. The Model noR10 fit to the retained female length-composition data for the spawning fishery.

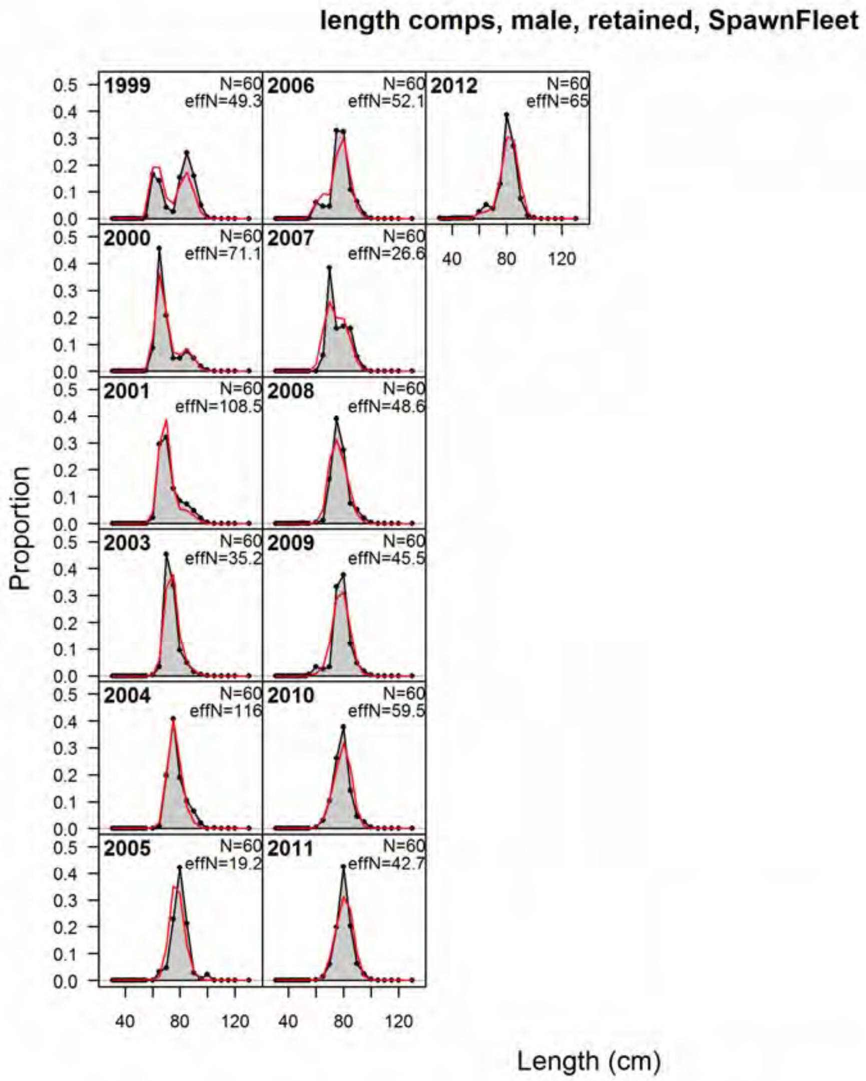

Figure 6.37. The Model noR10 fit to the retained male length-composition data for the spawning fishery.

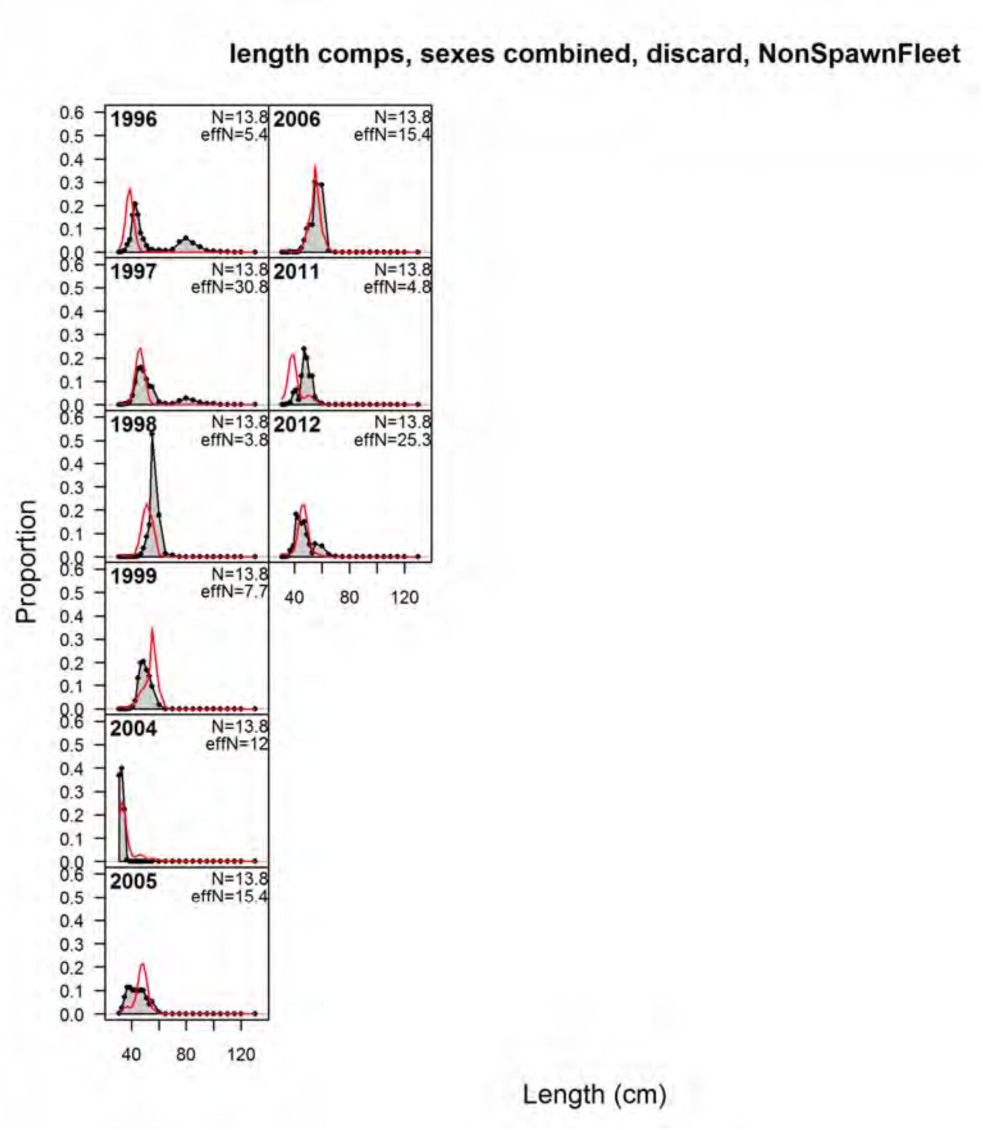

Figure 6.38. The Model noR10 fit to the discard length-composition data for the non-spawning fishery.

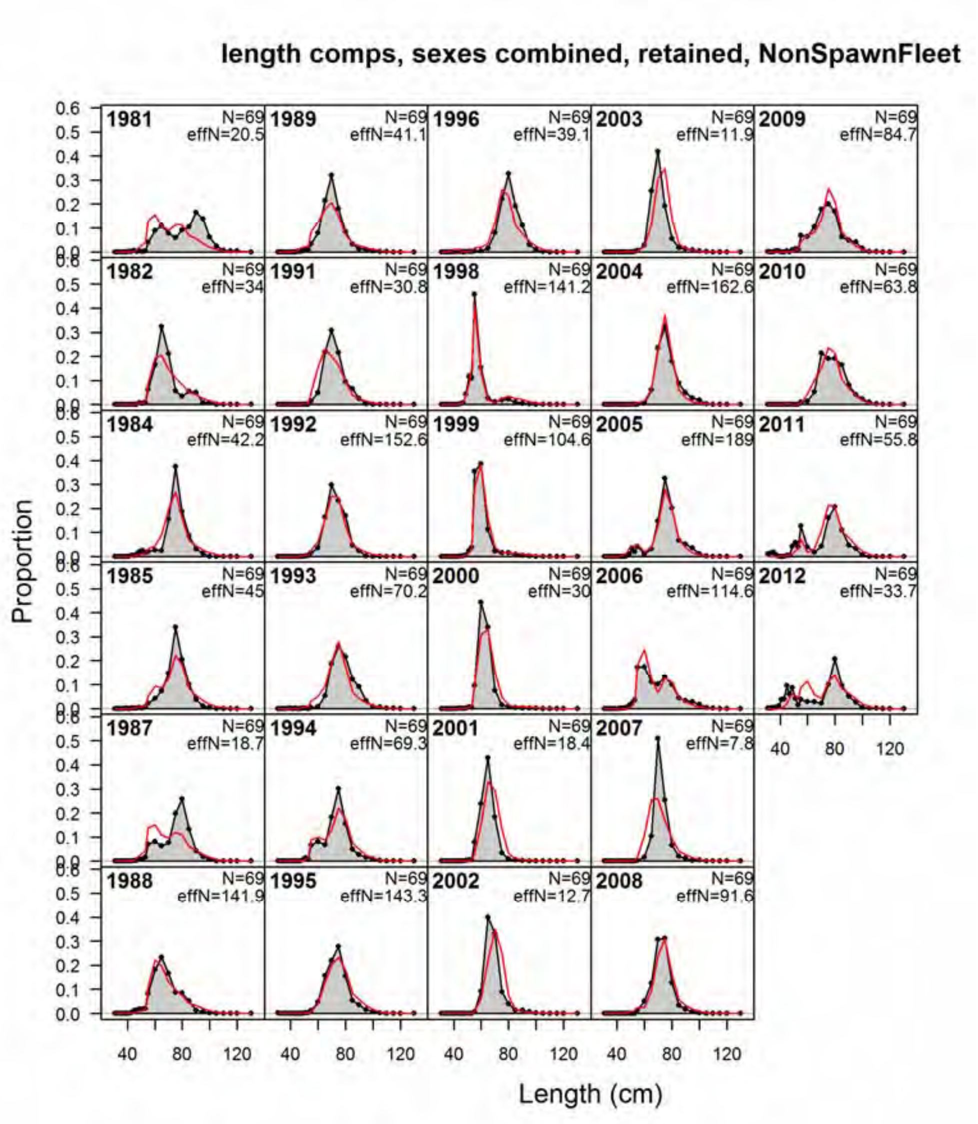

Figure 6.39. The Model noR10 fit to the retained length-composition data for the non-spawning fishery.

7. Pink ling (*Genypterus blacodes*) stock assessment based on data up to 2012[3]

Athol R. Whitten[1] and André E. Punt[2]

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7.1 Summary

An age structured population dynamics model was fitted to data for pink ling (*Genypterus blacodes*) separately for the eastern and western areas (stocks) of the Australian Southern and Eastern Scalefish and Shark Fishery (SESSF). The data used for the assessment were updated from those on which the 2012 assessment was based to include 2012 data (catches, catch-rates, conditional age-at-length data and length-frequencies). A number of revisions to the historical (pre-2012) data, including the way data were assembled, data types, and the years for which some data were included, were modified from previous assessments.

A model similar to that developed for the 2012 assessment was used as the base-case model. The current base-case model differs from the 2012 base-case model in terms of how selectivity is time-blocked for the eastern trawl CPUE series and the exclusion of the non-trawl CPUE indices (for both the eastern and western stocks). The current base-case model also differs from the 2012 model by excluding data from the Kapala surveys, assuming that growth is time-invariant (rather than time-varying) and in how length frequency data is both initially weighted and re- weighted.

Better fits to data were obtained by weighting the length-frequency data by numbers of landings/operations, rather than by number of fish measured (as was the case last year). Model fit diagnostics continue to support time-varying fishery selectivity for the trawl sector. A new model re-weighting (tuning) process, following Francis (2011), was used to configure the final base-case models and applied to the length-frequency data.

In the base-case model, the eastern stock is assessed to be $0.19B_0$ at the start of 2014 and the western stock is assessed to be $0.43B_0$ at this time (under the assumption that the TAC for 2013 of 834t is taken). The Recommended Biological Catches (RBCs) arising from the base-case models are 0 tonnes for the eastern stock and 573 tonnes for the western stock; giving a total RBC of 573 tonnes for the SESSF pink ling stocks. The long term RBC (for the year 2033) is 647 tonnes for the eastern stock and 645 tonnes for the western stock; giving a total long-term RBC of 1292 tonnes.

Note that stock status and RBC values are sensitive to data weighting and assumptions regarding pre-specified parameters. Following consideration at the November 2013 Slope RAG meeting, the base case model presented in this document was not used for management purposes in 2013.

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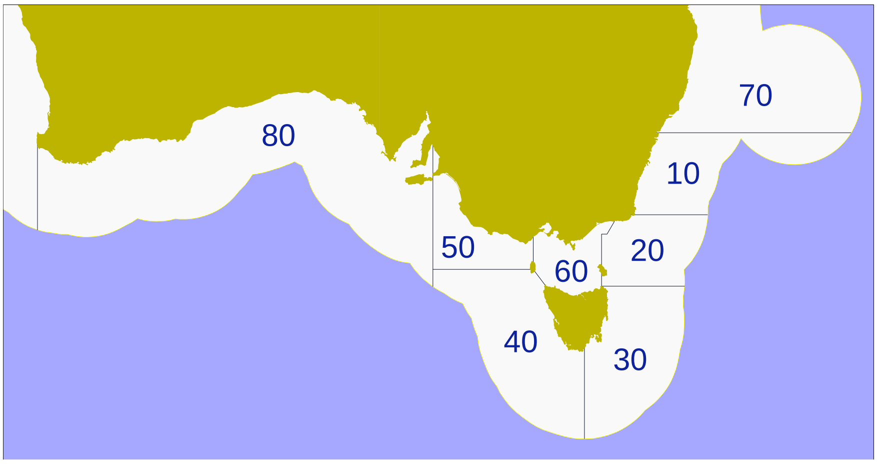
[3] Paper presented at the Slope/Deep RAG meeting 6-8 November 2014

7.2 Introduction

Pink ling (*Genypterus blacodes*) forms the basis of major fisheries off Australia and New Zealand. Pink ling off southeast Australia have been divided into two stocks (eastern and western) for assessment and management purposes because of differences between areas in size- and age-compositions, as well as in trends in catch rates. However, no genetic differences have been identified between pink ling east and west of 1470E (Ward and Reilly, 2001; Ward et al., 2001). It is likely that there is some genetic exchange between the two putative stocks, which, although insufficient to lead to a panmictic population in terms of demography, is sufficient to reduce the power of genetic methods to detect differences. Assessments are similarly conducted for several "management stocks" of pink ling in New Zealand (Anon, 2010).

The first assessment of the SESSF stocks of pink ling (Thomson et al., 2001) was based on a model coded in ADMB which assumed there was a single stock of pink ling (although sensitivity was explored to a scenario with two stocks) while Klaer (2003) based an assessment of pink ling on trends in catch-rates and age-composition data as well as on outputs from the Coleraine package (Hilborn et al., 2000). In contrast, more recent assessments (Taylor 2007, 2010, 2011a/b, Whitten 2013) have been based on Stock Synthesis (Methot and Wetzel, 2013). In addition to two areas, these assessments also explicitly recognized and considered two sectors (trawl and non-trawl). An assessment of pink ling based on a model which considered the fisheries in Zones 10, 20, 30, 40 and 50 as separate fleets was conducted during 2011 and 2012 (Punt, 2012; Punt and Taylor, 2012, Whitten et al., 2013), but this assessment was not accepted for use in management.

The base-case model presented in this report is similar to that on which the 2012 assessment was based. It differs from the 2012 base-case model because the selectivity time-blocks for the eastern trawl fishery are different and the non-trawl CPUE indices (for both the eastern and western stocks) are ignored. Unlike previous models, the current base-case model does not include data from the Kapala surveys, and growth is assumed to be time-invariant. Changes were also made to the way the length frequency data were weighted, both in terms of initial weightings, and in re-weighting of the base-case model. Following consideration at the November 2013 Slope RAG meeting, the base case model presented in this document was not used for management purposes in 2013.



Map of the SESSF showing statistical zones used in stock assessments.

7.3 Data sources

7.3.1 *Catch data*

Catches of pink ling have been recorded since the 1970s when the South East Fishery began to move to waters of 200m and deeper (Tilzey, 1994). Tilzey (1994) reports that pink ling were initially a by-catch of trawlers targeting species such as blue grenadier *Macruronus novaezelandie* and gemfish *Rexea solandri*, as well as by gillnet operators targeting sharks. Catches by the non-trawl sector increased markedly with the introduction of automatic longlining.

Catch data for pink ling are available from a variety of sources. Data were assembled from State and Commonwealth sources, combined with estimates of discards in the Commonwealth fisheries and used to estimate catch time-series by sector (trawl and non-trawl). State catches are available for Victoria, Tasmania, and New South Wales (Table 1). Catches are available from the GN01 (from 1997) and SEF1 (from 1986) logbook systems (non-trawl and trawl respectively). These logbooks provide information on the location of catches (although location is not available for all catches), but these catches are not validated to actual landings. Validated landings data are available from 1997 for the non-trawl sector (Zones 10-80 combined), from 1998 from the trawl sector in Zones 10-60, and from 2001 for the trawl sector in the GAB (Table 2).

The data for 1985 are known to be unreliable owing to changes in reporting systems during that year. For the purposes of this assessment, and owing to the lack of a more rigorous basis to assign catches for 1985, these catches are set to the average of the catches from 1984 and 1986.

7.3.2 *Catch-rate data*

The 2013 base-case model incorporates analysis by ISL of trawl catch and effort data: the analysis filtered catch records based on depth and catches of species other than ling. This was an attempt to define a consistent ‘fishery’ in which ling was a by-catch species. Time-blocking of vessel effects was used to address potential changes in ling catchability from 1999 to 2000 (east only) and from 2006 to 2007 (due to a structural adjustment). The ISL CPUE index also includes specifications for ‘vessel linking’ of vessels with constant vessel effects across two consecutive time blocks. The final chosen indices used three linking vessels, (see Cordue 2013, for details). The CPUE time-series produced by ISL differed considerably from the CSIRO index for the eastern stock, but was almost identical to that produced by CSIRO for the western stock. As such, the CSIRO time-series was used for the western stock. Table 3 shows the CPUE time-series for the eastern and western stocks. A constant CV of 0.15 was assumed for all points in the time-series for each stock.

CPUE indices for the non-trawl fisheries were not used in the base-case assessments: a review of available data revealed limited spatial coverage for each block included in the analysis.

7.3.3 *Length- and age-composition data*

Length data are available from port sampling and from onboard measurements. The data from these two sources were analysed separately because the sampling schemes differ so that the relationship between observed and effective sample sizes would also be expected to differ between these two data sources. Only data that were stated to be collected from Zones 10, 20 and 30 (east) and 40 and 50 (west) and at the Sydney fish market were included in the assessment. Non-trawl length-frequency data were based on samples collected from longline operations only. Previous assessments based on non-trawl length-frequencies used data from a mix of gear types including handline and mesh net. Selecting a common gear type should increase consistency in the non-trawl length-frequency data.

Length-frequency data were first stratified by depth and zone, and used in the analysis when there were at least 6 records available (numbers of operations/landings). The length-frequency data by zone and depth stratum were aggregated to create a length-frequency distribution for a stock by weighting the length-frequency data for a given zone and depth stratum by the catches-in-number by zone and depth stratum. Length-frequency data were initially weighted by numbers of landings/operations, unlike previous assessments, where data were initially weighted by numbers of fished measured. Conditional age-at-length data were included in the assessment and were initially weighted based on the number of samples as was the case in previous assessments. The base-case model included data for unsexed fish that were pooled with the sexed data as part of the conditional age-at-length data to ensure sufficient sampling for all years (for some years, only unsexed data is available). An ageing-error matrix developed for a previous assessment (Appendix A of Punt and Taylor, 2012) was used in this assessment.

7.4 Analytical assessment

The 2013 stock assessment was developed using the open-source software Stock Synthesis version 3.24S. (Methot and Wetzel, 2013).

7.4.1 *Basic structure*

The basic structure of the assessment follows that of the 2010, 2011, and 2012 assessments (Taylor 2011a, 2011b; Punt 2012; Punt and Taylor, 2012; Whitten et al., 2013). There are consequently two base-case models for consideration:

- Base-case East – aggregated over Zones 10, 20, and 30 (4 fleets: trawl and non-trawl fleets for each of onboard and port sampling).
- Base-case West – aggregated over Zones 40, 50 (4 fleets: trawl and non-trawl fleets for each of onboard and port sampling).

Catches from the GAB are included in catch data for the west area, but no other data for the GAB (catch-rate series, length-composition data, and conditional age-length data) are included in the assessment for consistency with past assessments.

7.4.2 *Biological parameters*

Although there is some evidence from catch curves that natural mortality for older ling may be lower than for younger ling (Smith et al., 1996; Morison et al., 1999), this assessment is based on treating natural mortality as constant among ages and estimable with wide bounds. A prior value for M, Normal (0.2yr-1, CV=0.2) was assumed, to assist with estimation.

The parameters of the growth curve were treated as estimable parameters; separate growth curves were estimated for males and females because females are known to grow significantly faster and to a larger size than males. Unlike the 2012 assessment, growth was assumed to the constant over time following gear- and area-specific analysis by ISL that revealed no evidence for time-varying growth (Cordue, 2013). The weight-length relationship $w = 0.00293L^{3.139}$ (w in gm, L in cm) is based on data collected by CSIRO and TAFI as well as data from Withel and Wankowski (1989) [Thomson et al., 2001].

In common with previous assessments of pink ling, this assessment is conducted under the base-case assumptions that the relationship between spawning biomass and subsequent recruitment has the Beverton-Holt form and steepness, h, is 0.75. The standard deviation of the variation about the stock-recruitment relationship (quantified by σ_R) is pre-specified, along with the extent of how bias-correction changes over time. The years for which recruitment deviations are estimated are selected during the model selection process.

Maturity as a function of length has been assumed to be a knife-edged function of length (and hence age) in previous assessments. Thomson et al. (2001) assumed that the length-at-maturity was 67cm (an average of 60cm (Smith and Tilzey, 1995) and 72cm (Lyle and Ford, 1993)). Recent assessments (e.g. Taylor 2011a,b) have assumed that maturity is knife-edged at 72cm. This size is however less than the size-at-first-maturity estimated for *G. blacodes* in Chile (Paredes and Braco, 2005) and corresponds to a much younger age-at-maturity (~5 years) than assumed in assessments of pink ling in New Zealand (8-12 years) [Anon, 2010]. Punt and Taylor (2012) explored sensitivity to a maturity ogive which was not knife-edged and found little difference in results. In common with the 2011 and 2012 assessment, and in the continuing absence of data to quantify how maturity changes with age/length, this assessment is based on setting the parameter which determines how maturity increases with length to “-1”. This leads to the difference in years between first and full maturity of about 4 years, which is consistent with maturity-at-age data for pink ling in New Zealand (Anon, 2010).

7.4.3 *Fishery parameters*

In common with the 2011 and 2012 assessments, this assessment assumes that selectivity for the non-trawl fishery is a time-invariant logistic function of length. Selectivity for the trawl fleet is assumed to be dome-shaped, with changes in the ascending limb of the selectivity pattern occurring in 2000 and 2006.

7.4.4 *Model selection*

Table 4 lists the specifications for the base-case assessment. The model configuration is similar, but not identical, for the western and eastern stocks. The years for which recruitment deviations are estimated were selected separately for each model. The model configurations related to when selectivity changes differ to those for the 2012 assessment: they were chosen to reflect the time-blocking used in the CPUE analysis.

Data weighting can have a substantial impact of the outcomes of stock assessments (Richards, 1991; Francis, 2011). The ‘weighting philosophy’ of this assessment is (a) the model should fit the trends in the abundance indices as well as possible, and (b) the effective sample sizes and CVs assigned to the data should match the variation implied by the residuals. This philosophy is implemented by conducting the initial model selection analyses while imposing high weight (a CV of 0.15) on the abundance indices, modifying the years for which recruitment deviations are estimated, and iteratively re-weighting the data by adjusting the ‘lambda’ values (additional weighting factors) for the length frequency data using the approach of Francis (2011). Conditional age-at-length data were re-weighted more subjectively: a lambda value of 0.25 was used to re-weight those data following analyses that showed that value produced reasonable fits to data (Cordue, 2013).

7.4.5 *Base-case model*

Figure 1 shows the fits of the base-case models to the length-frequency data (see Figure 3 for the fits by year). Two sets of results (A=Onboard; B=Port) are shown for each fleet. The fits to data are generally adequate, but are not as good as has been achieved in previous years with different model specifications. This may be due to the reduced amount of data used, and use of the Francis (2011) weighting system, which reduces the emphasis on fitting to the length and age frequency data and increases the emphasis on fitting to the catch-rate indices.

Figure 2 shows the fits of the base-case models to the catch-rate series for the trawl fisheries. The base-case models generally capture the trends in standardized catch-rates: as expected, the model fits intersect all but a very few of the 95% confidence intervals for the data. This indicates that the Francis model reweighting performed as expected, the increased emphasis on fitting to catch-rate series has meant better fits to this data for both the eastern and western stocks compared with previous assessments. The fit to the catch-rate series for the western stock is good. It captures the qualitative patterns of the series well and follows the trend in the recent years. The model fit exhibits noticeable trends in residuals for the middle years, but this is expected because of the western stock data pattern and attempted smoothing performed by an integrated model of this type. The fit to the catch-rate series for the eastern stock is adequate: there is a good fit to data through the early and middle parts of the time series, but the model does not fit well to the two most recent data points.

There are a considerable number of conditional age-at-length frequencies and the summary plots are too numerous to include. In general, the model captures expected age-given-length quite well (although there are nevertheless some noteworthy misfits; results not shown). The model does not mimic variability in expected age-given-length as well as expected age alone, but the fit is adequate.

Figure 4 summarizes selectivity-at-length for the base-case models. Selectivity for the non-trawl fleets is assumed to be time-invariant whereas selectivity for the trawl fleet is assumed to change in 2000 and 2006. The change in selection away from smaller fish in 2000 and 2006 is consistent between the trawl fleets for the on-board and port sampling methods for both the eastern and western stocks. The degree of change in selectivity over time is also quite consistent between the eastern and western stocks, although the overall patterns of selectivity are quite different.

Figure 5 shows the estimated recruitment time series for each of the base-case models. The estimated recruitment deviations are very similar to those estimated in previous assessments. Both the eastern and western stocks are estimated to have experienced large recruitment pulses in the early and mid-1990s followed by another spike and series of greater-than-average recruitments in the mid-2000s. The western stock is estimated to have experienced average recruitment in recent years (2008-09). However the eastern stock is estimated to have experienced low recruitment in those years.

Figure 6 shows the time-trajectories of spawning biomass and depletion for the base-case models. The time-trajectories of spawning biomass and spawning depletion for both the eastern and western stocks are qualitatively and even quantitatively quite different from those produced by the 2012 assessment.

7.4.6 *Stock Projections*

An estimate of the catch for the 2013 calendar year is required to apply the SESSF Tier 1 Harvest Control Rule, and run the base-case model forward to estimate the 2014 spawning biomass and depletion (Figs. 6 and 7). Stock projections are made under the assumption that the full TAC for 2013 of 834t is taken, and that catches are split between eastern and western stocks and among fleets in the same manner as was reported for 2012.

In the base-case model, the eastern stock is assessed to be $0.19B_0$ at the start of 2014 and the western stock is assessed to be $0.43B_0$ at this time (under the assumption that the TAC for 2013 of 834t is taken). The Recommended Biological Catches (RBCs) arising from the base-case models are 0 tonnes for the eastern stock and 573 tonnes for the western stock; giving a total RBC of 573 tonnes for the SESSF pink ling stocks. The long term RBC (for the year 2033) is 647 tonnes for the eastern stock and 645 tonnes for the

Estimates of historical spawning biomass deletion and stock projections for the base-case models for the eastern and western stocks (Fig. 7) show that both spawning stocks have declined on average since the end of the 1970s. Future stock projections, under the assumption that future catches follow the SESSF Harvest Control Rule, suggest both the eastern and western spawning stocks will recover to their respective management targets over the coming decades. The eastern stock is expected to take more time to reach the management target, being currently below the minimum stock size threshold at $0.19B_0$. The western stock is expected to recover to the management target in a shorter time period, being currently at $0.43B_0$. Each of these stock projections is made under the assumption that recruitment levels will follow a Beverton-Holt stock recruitment relationship (with steepness [h] equal to 0.75) over the coming years. Over the past decade however, recruitment has frequently failed to reach levels expected from the stock-recruitment relationship (Fig. 5). Although catches have consistently followed recommended levels over the past ten years, spawning stocks have not recovered as expected, especially in the east. This trend could continue if recruitment fails to meet levels expected from the fixed stock recruitment relationship over the coming years.

Note: Stock status and RBC values are sensitive to data weighting and assumptions regarding pre-specified parameters.

7.4.7 *Sensitivity to ISL-like model structure*

A full review of the available data, the treatment of those data, and the base-case model structure was performed as part of this stock assessment. As part of that process, a competing assessment model was developed by Patrick Cordue of Innovative Solutions Limited (ISL). The ISL model was developed using CASAL (Bull et al, 2012), and unlike the CSIRO model, incorporated age-specific selectivity. The ISL model also used slightly different data: it had different requirements for the inclusion of length and age frequency data (larger minimum sample sizes) and excluded unsexed ageing data from the analysis. Results of the ISL model were qualitatively similar to those of the CSIRO base case model, including the trajectories of spawning biomass and spawning depletion. However, the two models led to key differences in the estimates of current depletion. Each model produced median estimates within the 95% CI of the alternative model.

An alternative model to the base-case model that more closely resembled the model developed by ISL was developed for comparative purposes. This ISL-like model incorporated age-specific selectivity in an attempt to reproduce the results of the ISL model. The alternative model was fit to data and re-weighted (tuned) in the manner described above for the base-case model.

The SS ISL-like model was able to produce adequate fits to data with age-based time-varying selectivity, but was unable to estimate growth effectively. As such, the ISL-like model specified fixed growth parameters, based upon those estimated by the base-case model. The SS ISL-like model produced qualitatively similar results to the ISL model, but was unable to achieve the same current-depletion estimates as those reported by ISL (Fig. 8). The ISL base-case model produced spawning depletion estimates of 0.25B0 for the eastern stock, whereas the ISL-like model produced spawning depletion estimates of 0.17 B0 for the eastern stock. Spawning depletion estimates between the CSIRO base-case and ISL-like models matched closely (Fig. 8a), fits to the trawl CPUE indices were similar and only diverged at the lowest and highest points in the series (Fig. 8b), and recruitment estimates were qualitatively similar but higher for the earlier part of the time-series for the ISL-like model (Fig. 8c). The most significant differences between CSIRO base and ISL-like models were evident among fits to the length composition data (see Fig 8d for the fits to length composition data aggregated across time). The base-case model fits to length composition data better for the non-trawl fleet for both the port and on-board collected data, and for the on-board trawl data. Only the port-based trawl data were fit better by the ISL-like model.

7.5 Conclusion

This document presents an updated assessment of pink ling (*Genypterus blacodes*) separately for the eastern and western stocks of the SESSF using data up to the end of December 2012. The base-case model presented in this report is similar to the most recently accepted base-case model for pink ling (the 2012 aggregated base-case assessment models), but differs in some important ways. Specifically, the base-case model differs from the 2012 base-case model in terms of how selectivity is time-blocked for the eastern trawl CPUE series and the exclusion of the non-trawl CPUE indices (for both the eastern and western stocks). The latter change was made following an examination of the spatial distribution of non-trawl catches. The current base-case model also differs from last year's base-case model by excluding data from the Kapala surveys, assuming that growth is time-invariant (rather than time-varying) and by the way in which length frequency data is both initially weighted and re- weighted.

Better fits to the catch-rate data were obtained by weighting the length-frequency data by numbers of landings/operations, rather than by number of fish measured (as was the case last year). A new model re-weighting (tuning) process, following Francis (2011), was used to configure the final base-case models and applied to the length-frequency data. This method appears to have improved the model's ability to fit to the catch-rate time series, but has also reduced the degree of fit to the length and conditional-age-at-length composition data.

In common with the 2012 assessment, this assessment assumes that selectivity for the trawl fleet is dome-shaped with changes in the ascending limb of the selectivity pattern occurring in two separate years. Model fit diagnostics continue to support time-varying fishery selectivity for the trawl sector. Whilst the 2012 model assumed changes in 2001 and 2006, the current morel assumes changes to selectivity in 2000 and 2006. This change was introduced because major changes to the TAC for pink ling occurred during 1999-2000 resulting in changes to fishing practices.

Stock projections are made under the assumption that recruitment levels will follow the fixed stock recruitment relationship (with steepness h equal to 0.75) over the coming years. However, recruitment levels have been frequently less than expected from that relationship over the past 5-10 years, especially for the eastern stock. Although catches have consistently followed recommended levels for the previous ten years, poor recruitment may have contributed to continuing declines in the eastern stock. This trend may continue if future recruitment fails to meet the levels expected from the pre-specified stock recruitment. Caution should be taken when considering expected recovery times for the eastern stock. Furthermore, work should be done to better understand the stock recruitment dynamics of these stocks, and to consider the full range of possible stock trajectories given different future recruitment scenarios.

As part of an assessment review process, a competing assessment model was developed by ISL of New Zealand. Unlike the CSIRO model, which specified length-based selectivity, the ISL model incorporated age-specific selectivity and used slightly different data. This report considered an alternative SS model that incorporated age-specific selectivity in an attempt to reproduce the results of the ISL model. The ISL-like model produced qualitatively similar results to the ISL model, but was unable to achieve the same current-depletion estimates as those reported by ISL. Model fits to data were similar between the two models but the CSIRO base-case model provide a better fit to length composition data.

This assessment has been based on preliminary estimates of discards and state catches. While the broad conclusions are unlikely to be sensitive to the final values for these catches, quantitative values (e.g. RBC), may change slightly with the updated final catches.

7.6 Future Work

The 2013 pink link assessment process differed from previous years in that it included the development of a competing assessment from an external modeller. By working together, CSIRO researchers and the ISL consultant were able to thoroughly review pink ling data analyses and model specification. This process led to the identification of a number of areas that should be considered for future work:

- Data Weighting: The weighting and re-weighting approach applied to the conditional age-at-length data was approximate and needs to be addressed. These data should be initially weighted in terms of the numbers of landings/operations, and the re-weighting should be carried out following the Francis (2011) methodology.
- Length and age data:
    - There was insufficient time to evaluate alternative methods to select, and stratify length and age data. Generic methods should be developed to explore spatial effects among length and age data. Such methods could be used to justify assumptions about spatial structure.
    - Sensitivity should be explored to how length- and age-frequency composition data sets are selected and constructed.
    - The utility of age and length data for the development of a more spatially-explicit model and for the inclusion of time-varying and cohort-specific growth should be explored.
- Further explore spatially-structured models. In particular, the “Linked Populations” (Punt, 2013) should be considered as a potential future base-case that captures population dynamics and data structure better than models currently applied. Alternative spatial models for ping ling should be compared using simulations to determine a spatially-structured assessment that is appropriate along with the consequences of applying spatially-structured assessment methods to data from a population which is spatially-structured.
- A model that can simultaneously account for both age- and length-based selectivity should be developed.
- The possibility of changes in catchability (*q*) across many fisheries over time should be explored.
- Sensitivity to the linked vessel CPUE analysis performed by ISL, and included in the base-case model for the eastern stock, should be explored. In particular, sensitivity should be explored to the number of linked vessels.
- The sensitivity to the use of mid- vs. start-year calculation of spawning biomass should be explored. This may require reconfiguring the model as a two-season model.

7.7 Acknowledgements

Age data was provided by Kyne Krusic-Golub (Fish Ageing Services), parts of the ISMP and AFMA logbook data were processed and provided by John Garvey (AFMA). Mike Fuller (CSIRO) loaded and pre-processed AFMA logbook and CDR data.

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7.9 Tables and Figures

Table 1. Catches (t) reported to the States (1977-2012), with allocations to stock (East and West) and sector. Blank values indicate unavailable data. All data have been rounded to the nearest tonne.

	Victoria				Tasmania		NSW
Area	East	East	West	West	East	West	East
Gear	Trawl	Non-trawl	Trawl	Non-trawl	Non-trawl	Non-trawl	Trawl
1977							95
1978							114
1979	1	0	3	0			136
1980	0	0	0	0			215
1981	0	0	0	0			299
1982	8	0	9	0			340
1983	8	0	0	0			419
1984	4	1	0	0			507
1985							
1986	1	9	0	4	18	18	3
1987	10	18	0	0	4	4	2
1988	28	15	0	0	5	5	7
1989	33	22	0	2	7	7	2
1990	17	20	0	2	8	11	3
1991	20	26	0	1	11	5	4
1992	36	114	3	0	51	65	2
1993	67	177	8	1	130	257	2
1994	42	33	0	0	76	244	3
1995	39	81	0	0	9	145	2
1996	36	102	0	2	92	302	6
1997	4	11	0	0	123	102	29
1998	*	*	*	*	3	0	48
1999	*	*	*	*	1	0	49
2000	*	*	*	*	1	0	18
2001	*	*	*	*	1	0	8
2002	*	*	*	*	0	0	15
2003	*	*	*	*	0	0	8
2004	*	*	*	*	0	0	12
2005	*	*	*	*	0	0	21
2006	*	*	*	*	0	0	15
2007	*	*	*	*	0	0	23
2008	*	*	*	*	0	0	32
2009	*	*	*	*	0	0	16
2010	*	*	*	*	0	0	55
2011	*	*	*	*	0	0	36
2012	*	*	*	*	0	0	28

* Essentially zero

Table 2. Commonwealth catches (t) by Zone grouping (area) and sector, and total discards. All data have been rounded to the nearest tonne. The catches in this table have been scaled to the validated landings as outlined in the text.

Year	Landings						Discards
	East	West	East	West	GAB	GAB	Total
	Non-trawl	Non-trawl	Trawl	Trawl	Non-Trawl	Trawl	
1986	0	0	696	142	0	0	
1987	0	0	676	267	0	2	
1988	0	0	580	121	0	19	
1989	1	0	600	230	0	8	
1990	12	0	626	186	0	8	
1991	28	42	574	259	0	2	
1992	44	19	505	128	0	2	
1993	0	0	794	307	0	1	
1994	2	1	793	310	0	1	
1995	0	0	956	536	0	1	
1996	0	3	952	565	0	3	
1997	218	136	1056	725	0	10	
1998	116	86	987	679	0	13	41
1999	167	104	1150	536	0	14	12
2000	194	58	941	647	0	2	11
2001	221	156	685	652	0	11	5
2002	226	296	515	558	0	0	7
2003	250	227	629	485	0	16	1
2004	382	408	493	372	61	38	1
2005	270	298	470	234	75	52	3
2006	184	138	455	241	133	34	3
2007	182	72	299	333	85	18	21
2008	276	45	443	262	122	2	16
2009	184	60	279	307	53	0	49
2010	171	113	336	315	105	5	58
2011	181	166	373	413	83	4	14
2012	152	146	314	363	83	2	16

Table 3. Standardized indices of abundance, and input CV values, for the eastern and western stocks of pink ling.

Year	Eastern Stock		Western Stock	
	Trawl Index	CV	Trawl Index	CV
1986	1.000	0.15	1.175	0.15
1987	1.015	0.15	1.348	0.15
1988	0.956	0.15	1.051	0.15
1989	0.795	0.15	1.085	0.15
1990	1.006	0.15	0.976	0.15
1991	0.917	0.15	1.040	0.15
1992	0.786	0.15	0.775	0.15
1993	0.708	0.15	1.050	0.15
1994	0.721	0.15	1.263	0.15
1995	0.895	0.15	1.294	0.15
1996	0.929	0.15	1.370	0.15
1997	0.961	0.15	1.438	0.15
1998	0.998	0.15	1.422	0.15
1999	0.879	0.15	1.124	0.15
2000	0.723	0.15	1.006	0.15
2001	0.528	0.15	0.899	0.15
2002	0.442	0.15	0.777	0.15
2003	0.466	0.15	0.780	0.15
2004	0.451	0.15	0.728	0.15
2005	0.443	0.15	0.606	0.15
2006	0.551	0.15	0.647	0.15
2007	0.502	0.15	0.712	0.15
2008	0.588	0.15	0.911	0.15
2009	0.433	0.15	0.893	0.15
2010	0.495	0.15	0.860	0.15
2011	0.572	0.15	0.844	0.15
2012	0.567	0.15	0.925	0.15

Table 4. Model specifications for the base-case models for the eastern and western stocks

Parameter	East	West
	Base-case model	Base-case model
Age classes	Ages 0-20+	
Length classes	Lengths 20-120 cm+	
Natural mortality, *M*	Estimated with prior equal to 0.2 yr^{-1}	
Growth parameters	Female growth is estimated first, male growth parameters are estimated as exponential offsets to females	
κ	Estimated (by sex)	
Lmin (a=1)	Estimated (by sex)	
*L*max (a=20)	Estimated (by sex)	
σ (a=1)	Estimated (by sex)	
σ (a=20)	Estimated (by sex)	
Length-weight regression	Fixed	
A	0.00293	
B	3.139	
Maturity ogive	Fixed	
Length-at-50%-maturity	72cm	
Maturity slope	-1	
Stock-recruitment		
Recruitment variance, σ_R	0.7	
Bias-correction	1951, 1997, 2009, 2013	1951, 1997, 2009, 2013
Steepness, *h*	0.75	
Estimated recruitment devs	1970-2009	1970-2009
Selectivity		
Non-trawl	logistic, time-invariant	logistic, time-invariant
Trawl	dome-shaped (1970-1999; 2000-05; 2006+ blocks*)	dome-shaped (1970-1999; 2000-05; 2006+ blocks*)

* Only parameters related to the ascending limb of the selectivity pattern change over time

(A) EAST AREA – BASE-CASE MODEL

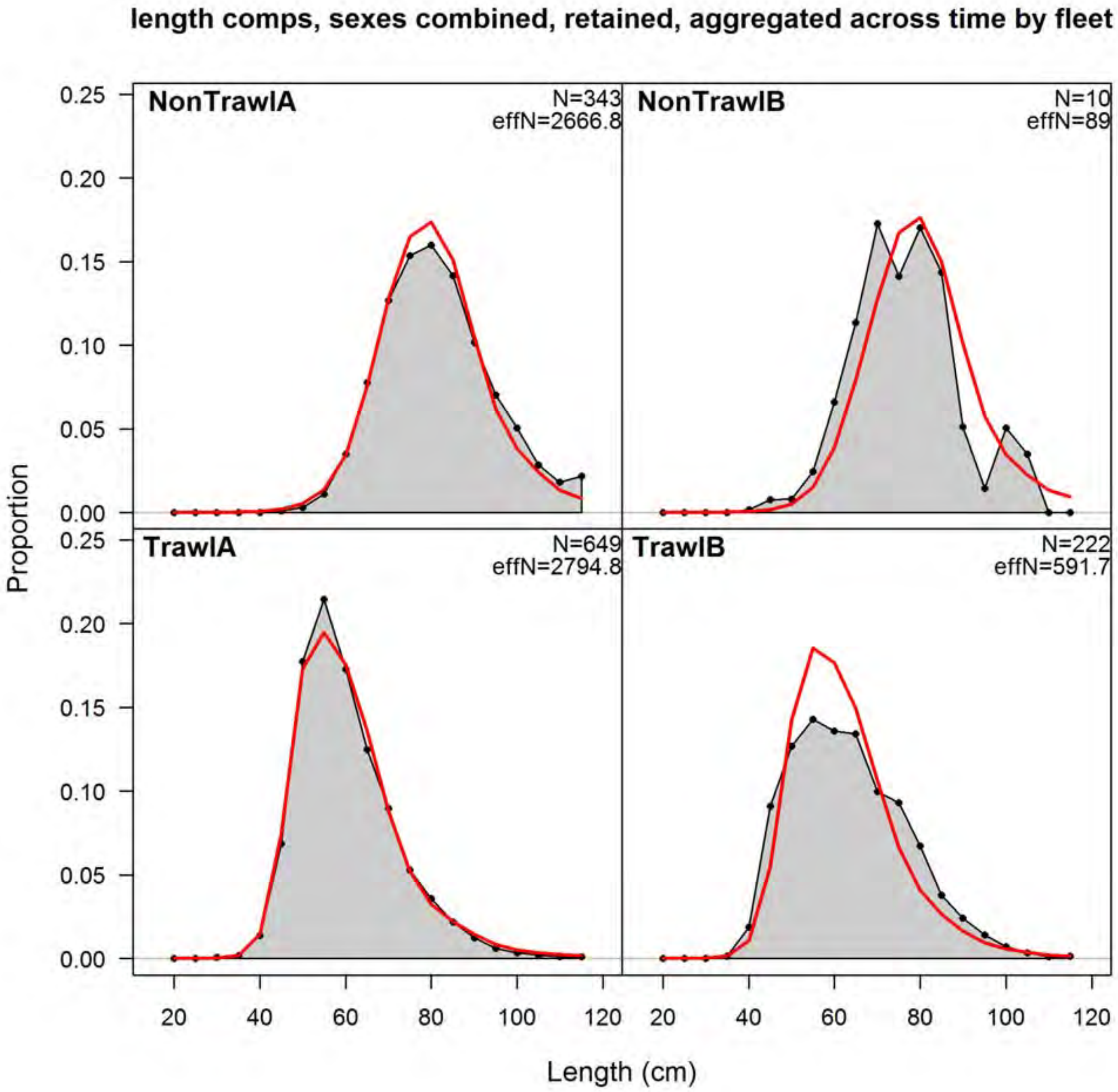


Figure 1. Base-case model fits to the aggregated length-frequency data (“A” denotes onboard and “B” denotes port). Note: Effective Numbers (effN) do not relate to this analysis, as an alternative weighting method (Francis, 2011) was employed.

(B) WEST AREA – BASE-CASE MODEL

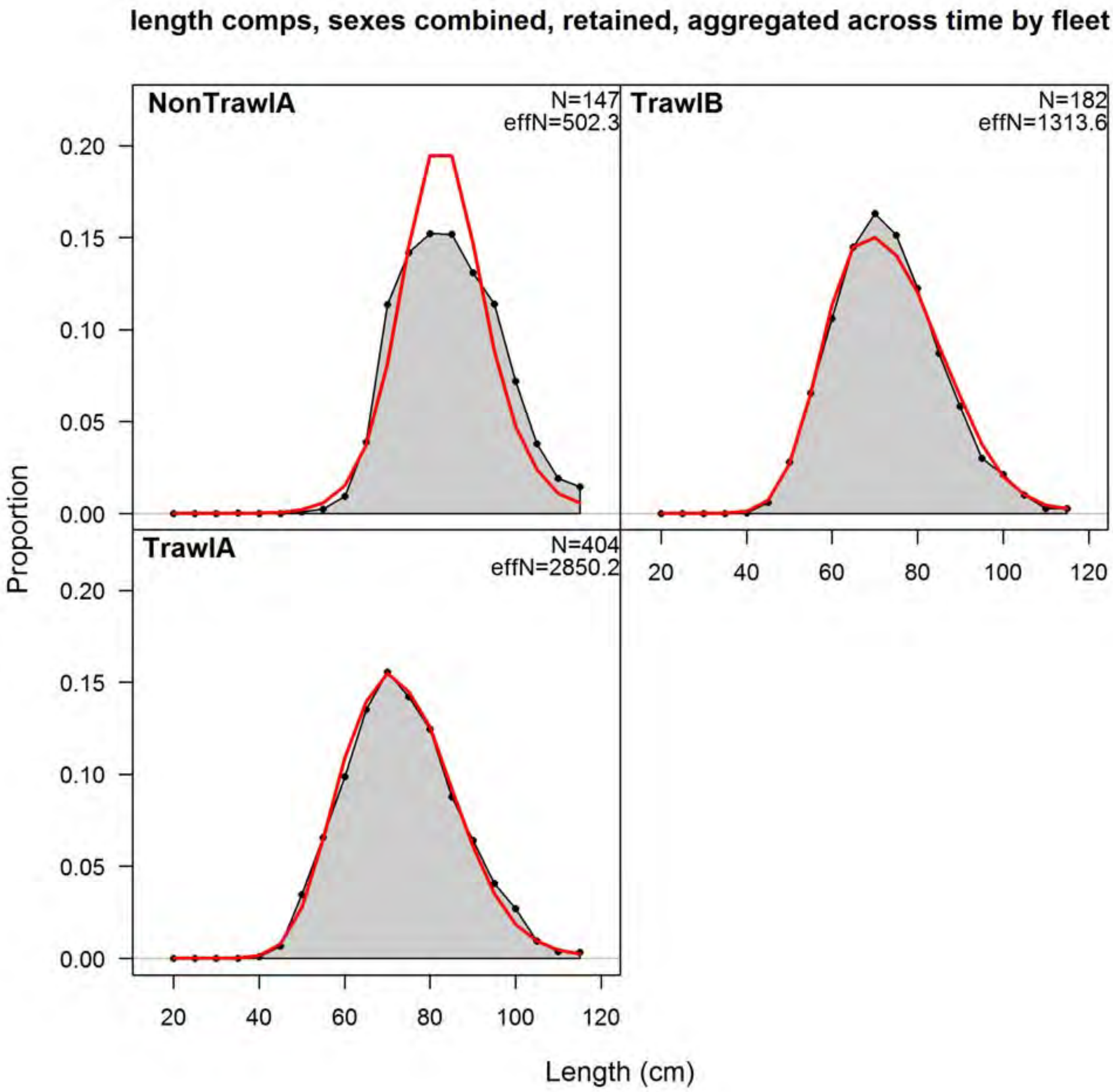
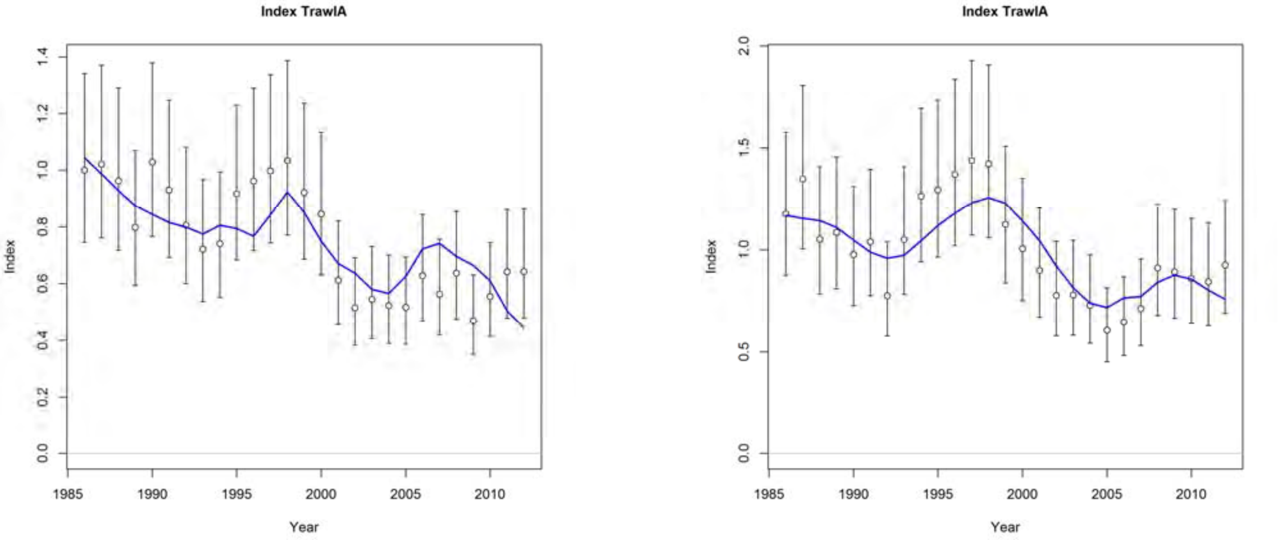


Figure 1 continued

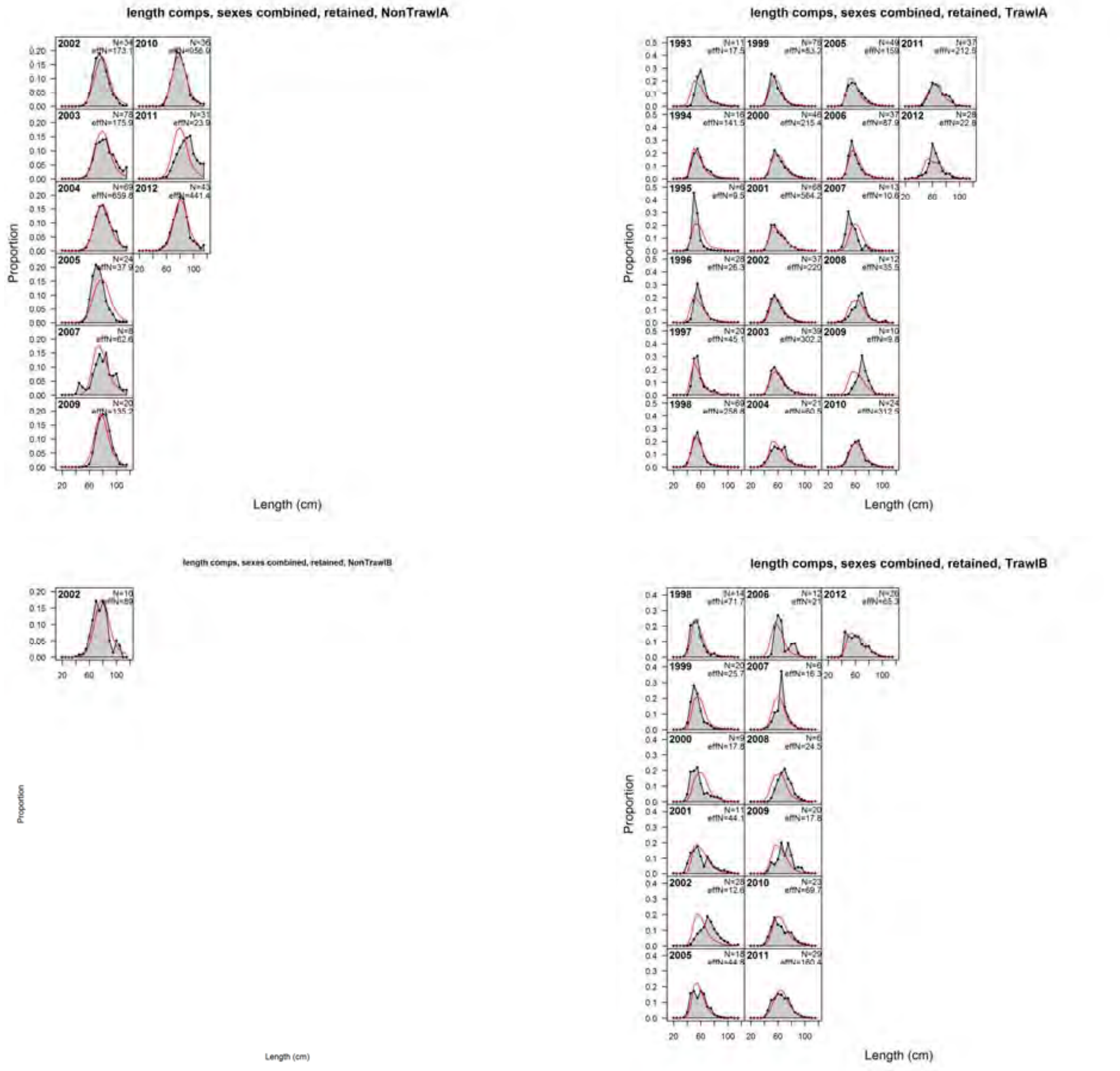


(A) EAST AREA – BASE-CASE MODEL

(B) WEST AREA – BASE-CASE MODEL

Figure 2. Base-case model fits to the standardized catch rate indices.

(A) EAST AREA – BASE CASE MODEL



length comps, sexes combined, retained, NonTrawlA

length comps, sexes combined, retained, TrawlA

length comps, sexes combined, retained, NonTrawlB

length comps, sexes combined, retained, TrawlB

Figure 3. Fits of the base-case models to year-specific length-frequency data

(B) WEST AREA – BASE CASE MODEL

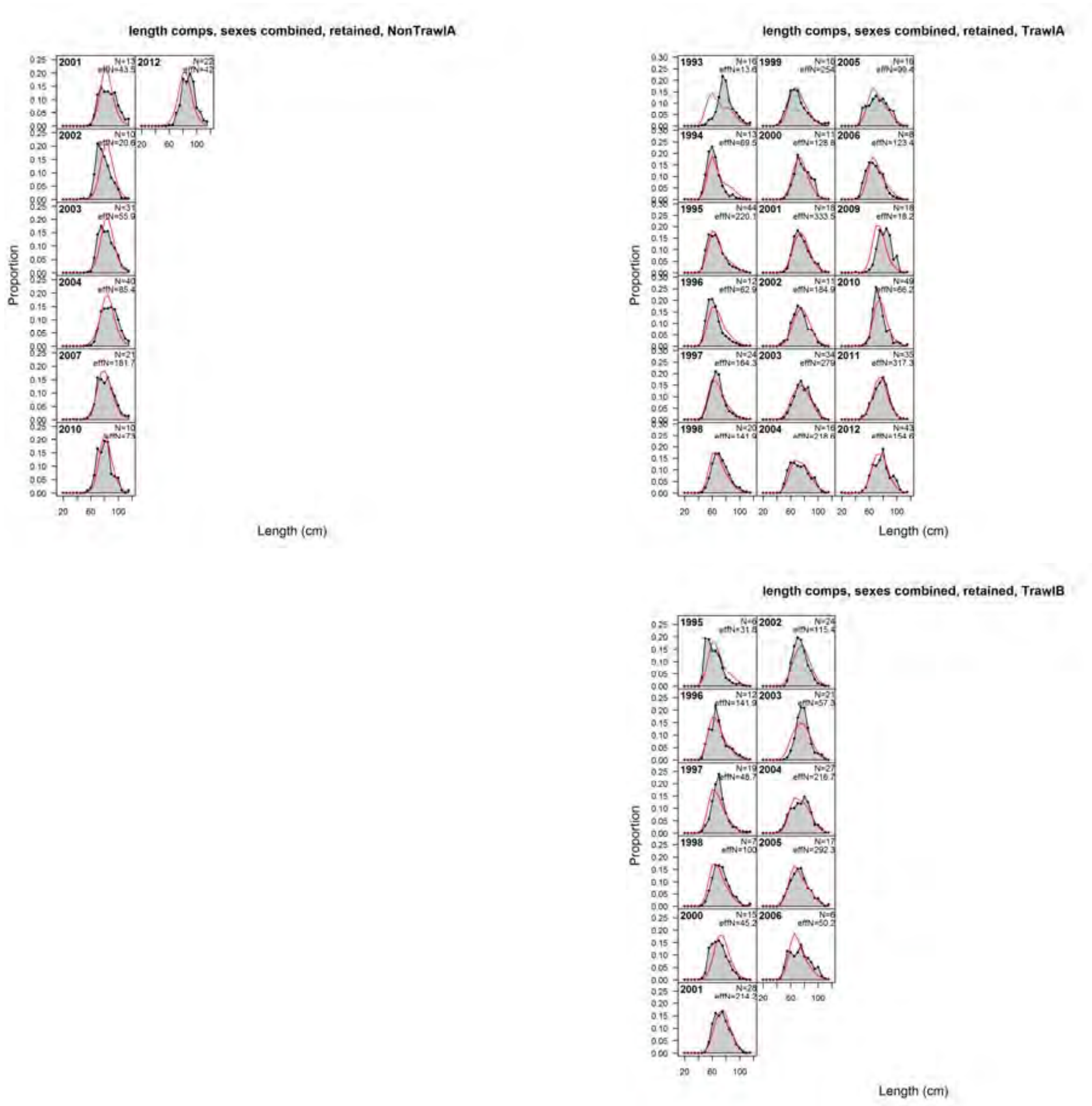
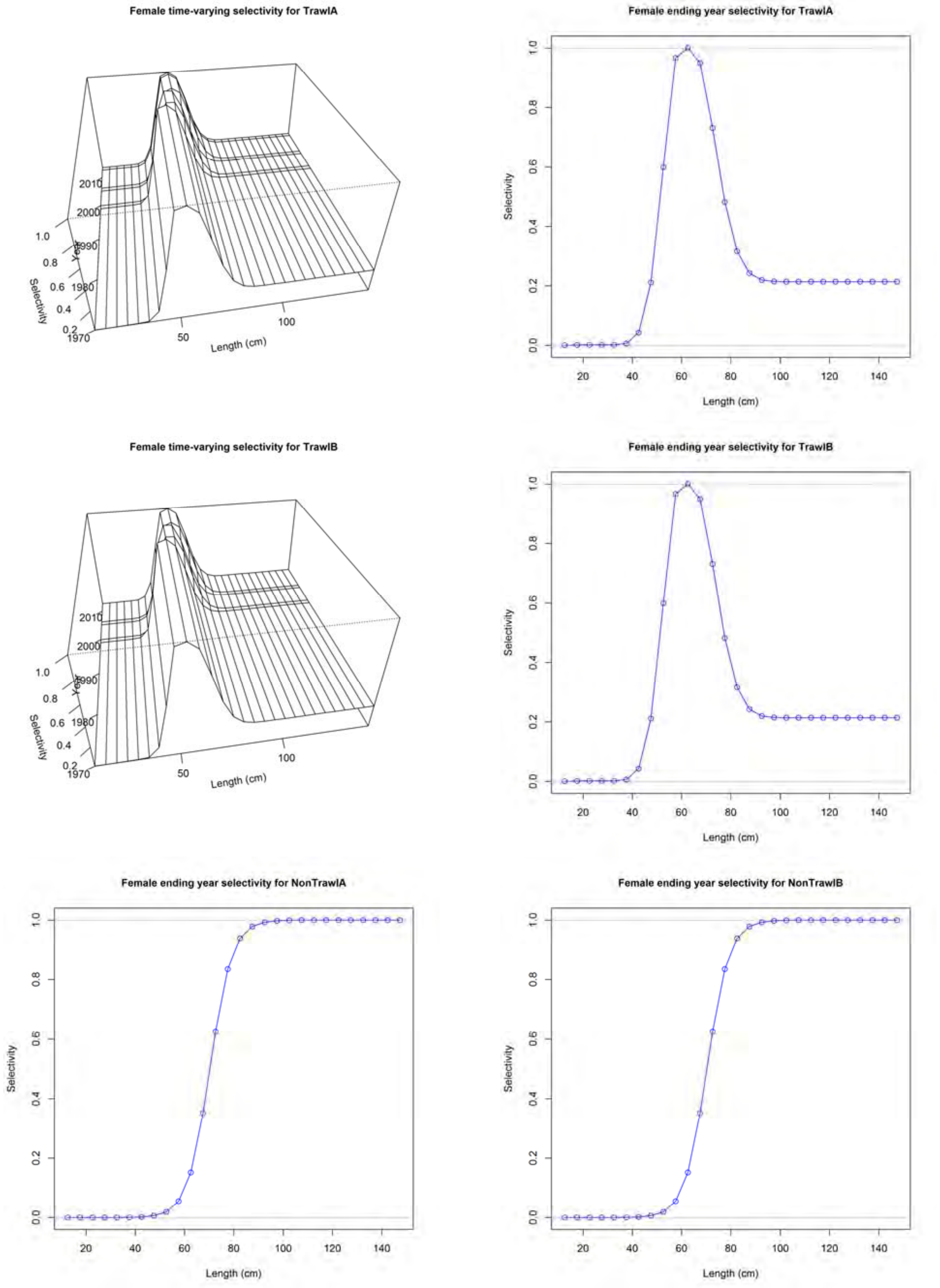


Figure 3 continued.

(A) EAST AREA – BASE-CASE MODEL



Female time-varying selectivity for TrawlA

Female ending year selectivity for TrawlA

Female time-varying selectivity for TrawlB

Female ending year selectivity for TrawlB

Female ending year selectivity for NonTrawlA

Female ending year selectivity for NonTrawlB

Figure 4. Predicted selectivity from the base-case models

(B) WEST AREA – BASE-CASE MODEL

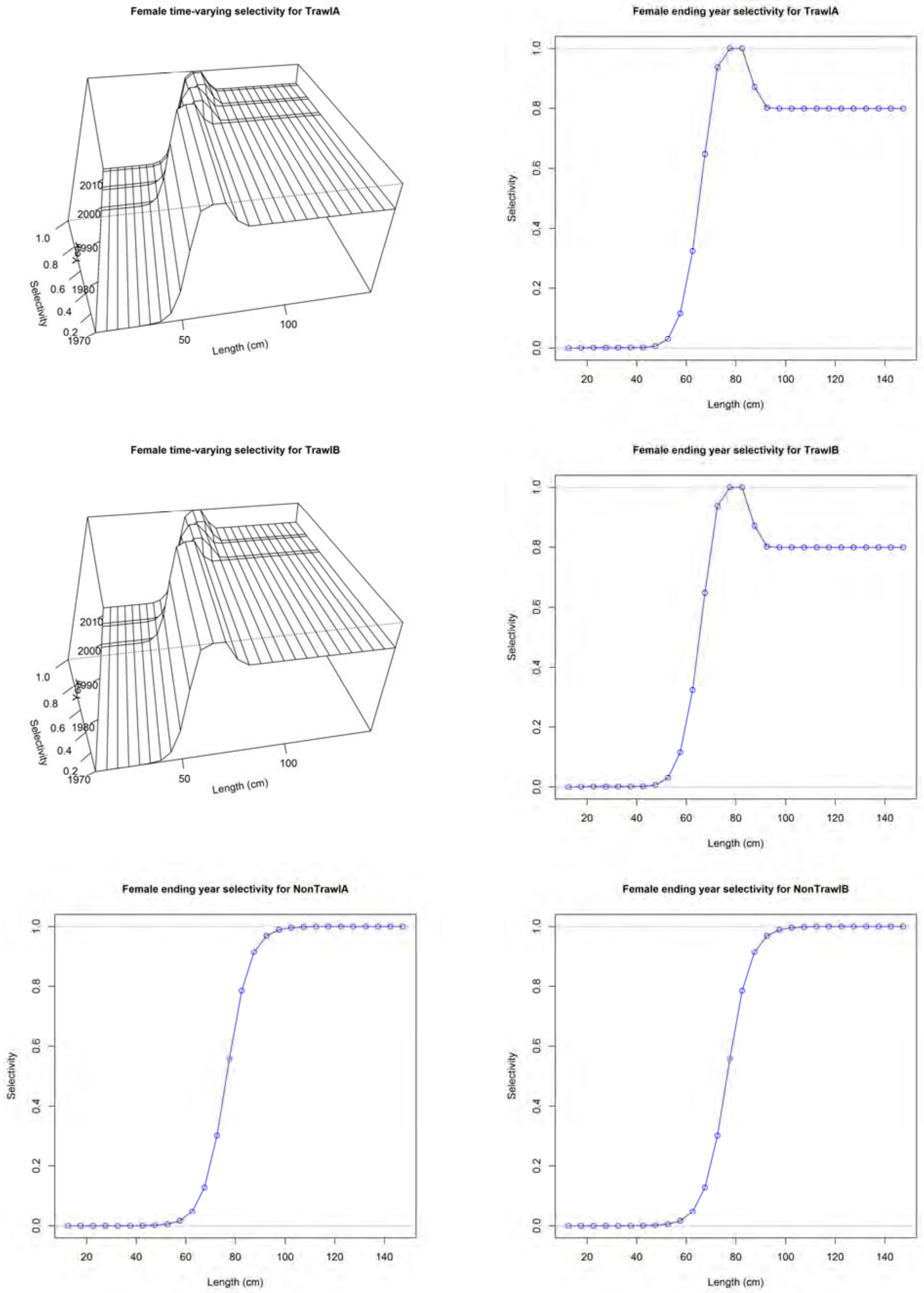


Figure 4 continued

(A) EAST AREA – BASE-CASE MODEL (B) WEST AREA – BASE-CASE MODEL

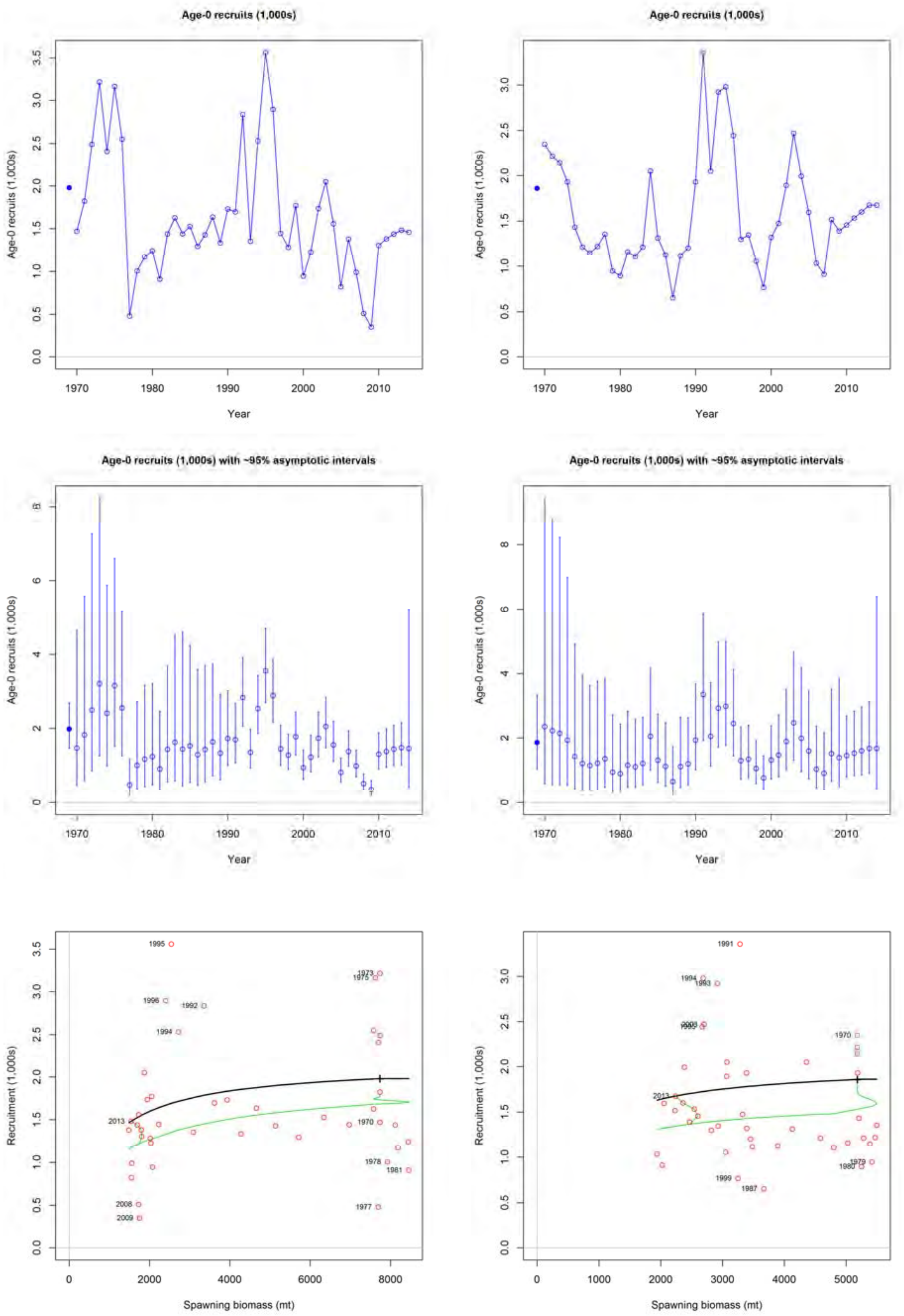


Figure 5. Recruitment estimates from the base-case models.

(A) EAST AREA – BASE-CASE MODEL (B) WEST AREA – BASE-CASE MODEL

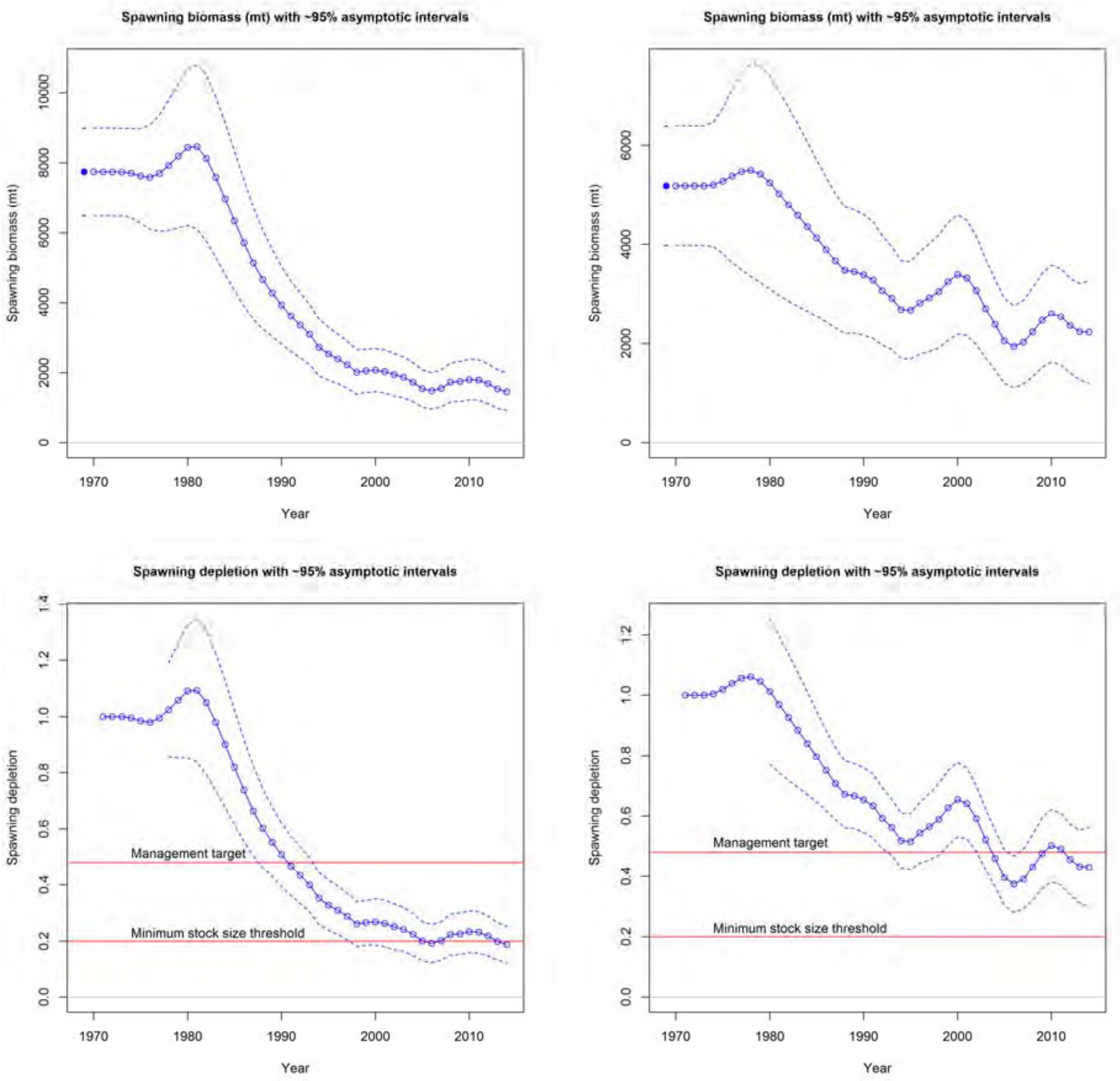
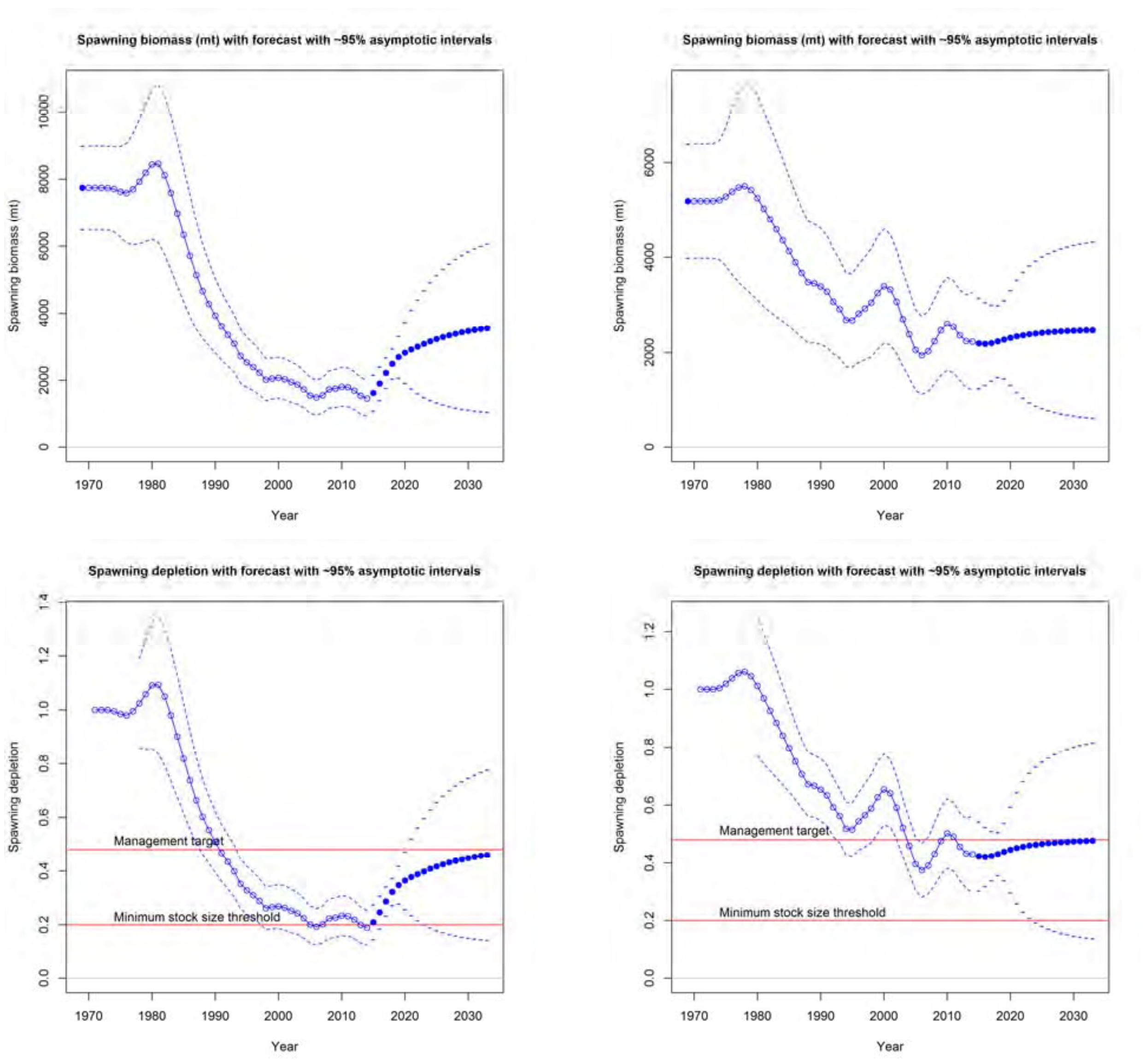


Figure 6.Time-trajectories of spawning biomass and depletion for the east and west base-case models


(A) EAST AREA – BASE-CASE MODEL

(B) WEST AREA – BASE-CASE MODEL

Figure 7. Stock projections of spawning biomass and spawning biomass depletion and associated 95% confidence intervals for the base-case models for the (a) eastern and (b) western pink ling stocks. Projections assume future catches follow the SESSF Harvest Control Rule and that recruitment follows the specified stock-recruitment relationship.

a)

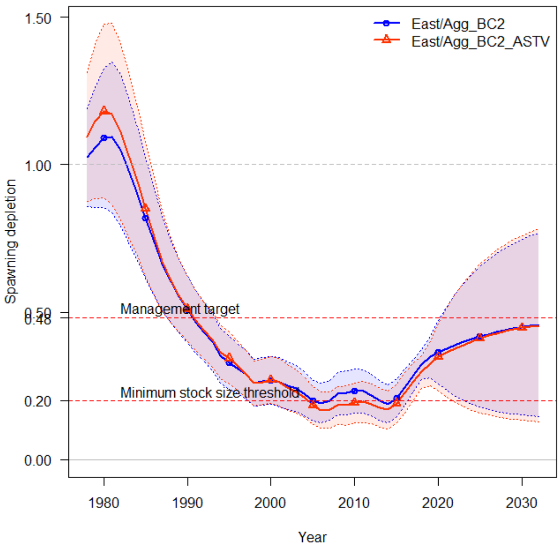
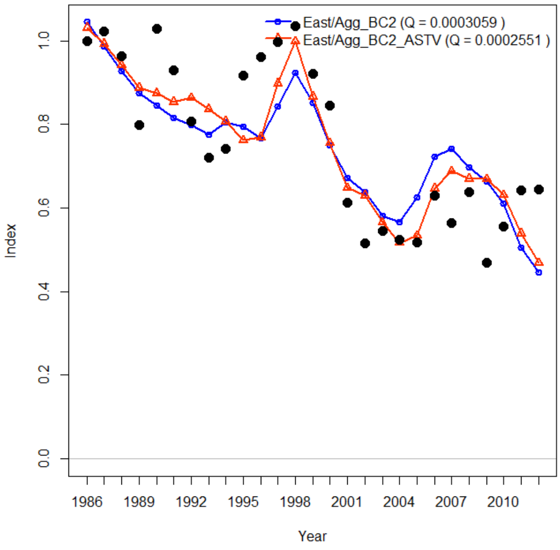


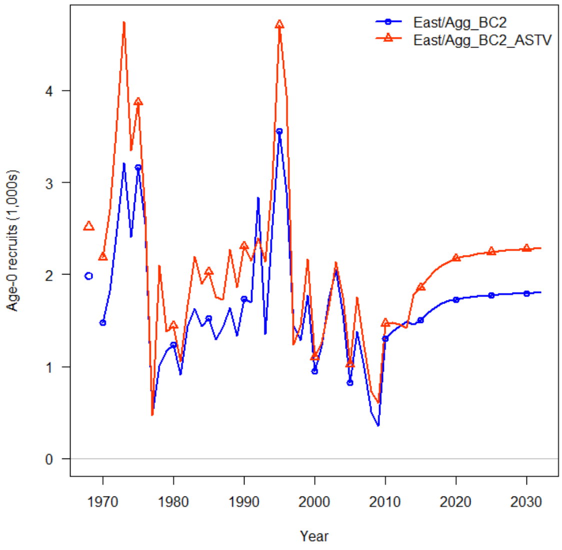
Figure 8. Results of ISL-like model, with age-based time-varying selectivity, compared with the base-case model. BC2 refers to the CSIRO base-case model; ASTV refers to the model with age-based time-varying selectivity (the ISL-like model).

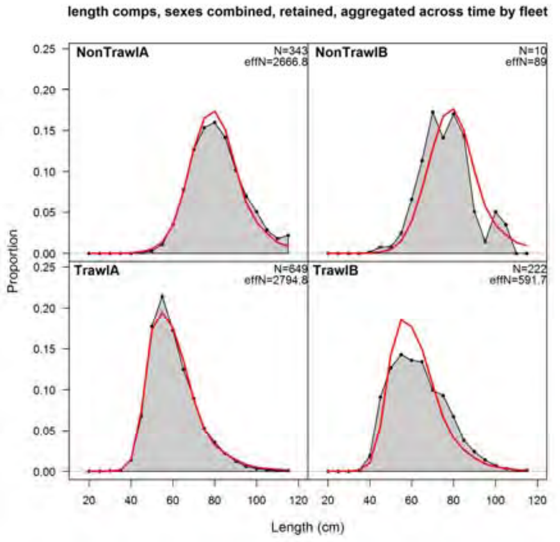
- **a)** Spawning depletion estimates
- **b)** Fits to the trawl CPUE index
- **c)** Recruitment estimates
- **d)** Fits to length composition data for (i) the base-case model and (ii) the ISL-like model.

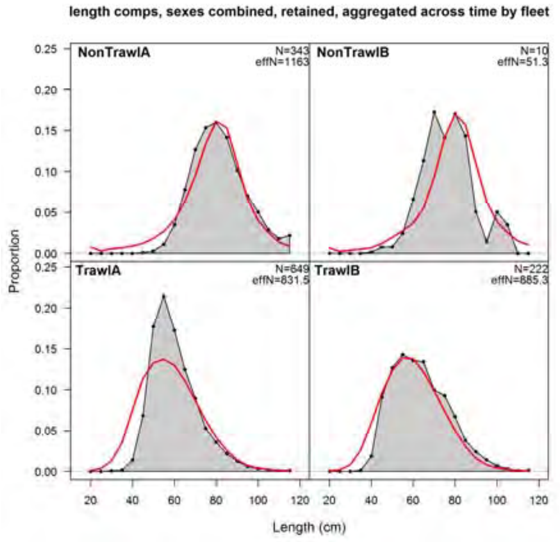
b)



c)





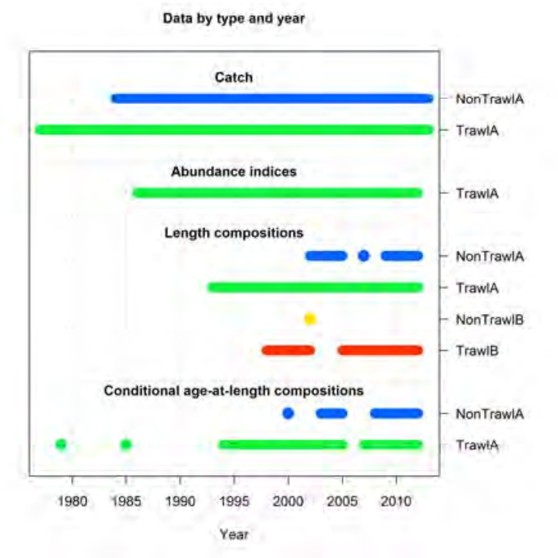


d) i

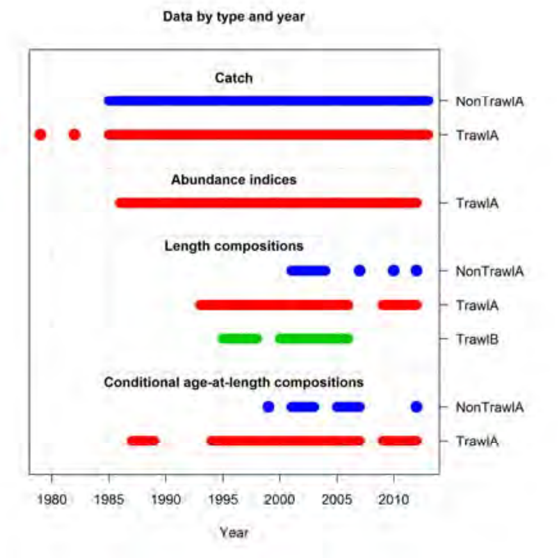
d) ii

7.10 Appendix A: Summary of data used in assessments

(A) EAST AREA – BASE-CASE MODEL



(B) WEST AREA – MODEL



8. Jackass morwong (*Nemadactylus macropterus*) 2014 RBC calculation [4]

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8.1 2014 jackass morwong RBC calculation

In 2013, the Shelf RAG agreed to not conduct a full jackass morwong stock assessment. To calculate the 2014 recommended biological catch (RBC), the 2011 Tier 1 Stock Synthesis assessments for both eastern and western morwong have been projected for two more years, using actual catches from 2011 and 2012, and estimated catches for 2013. No other data were added and no new parameter estimation was performed. The ‘recruitment shift’ assessment model (Wayte, 2013) accepted as the base-case for the eastern stock in 2011, and the base-case model for the western stock from 2011 were used for the projections (Wayte, 2012).

The 2011 and 2012 catches for each fleet (Figure 8 1, Table 8 1) used in the assessment were calculated as in previous years: the logbook catch for each fleet was scaled up by the ratio of landed catches to logbook catches for that year, and state catches were added. The estimated catch in 2013 was the amount of the 2013 calendar year actual Total Allowable Catch (TAC) that is expected to be caught, based on the proportion of TAC caught in 2012. The TACs are for a fishing year starting on 1 May, whereas the model uses calendar year catches. Thus the 2013 calendar year TAC is calculated as one-third of the 2012/2013 TAC plus two-thirds of the 2013/14 TAC. To arrive at the amount expected to be caught in 2013 this is then multiplied by the proportion of the calendar year TAC caught in 2012. This catch is then divided amongst fleets in the same proportions by fleet as caught in 2012.

Current spawning biomass in the eastern stock is projected to be 40% of 1988 equilibrium spawning stock biomass, and the 2014 RBC under the 20:35:48 harvest control rule is 400 t. For the western stock, current spawning biomass is projected to be 68% of unexploited stock biomass, and the 2014 RBC is 292 t (Table 8 2).

The 2014 combined RBC is 692 t. The model-projected 2014 discards in the east are 17 t. Discards are not modelled in the west due to lack of data.

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[4] Paper presented at the Shelf RAG meeting November2014

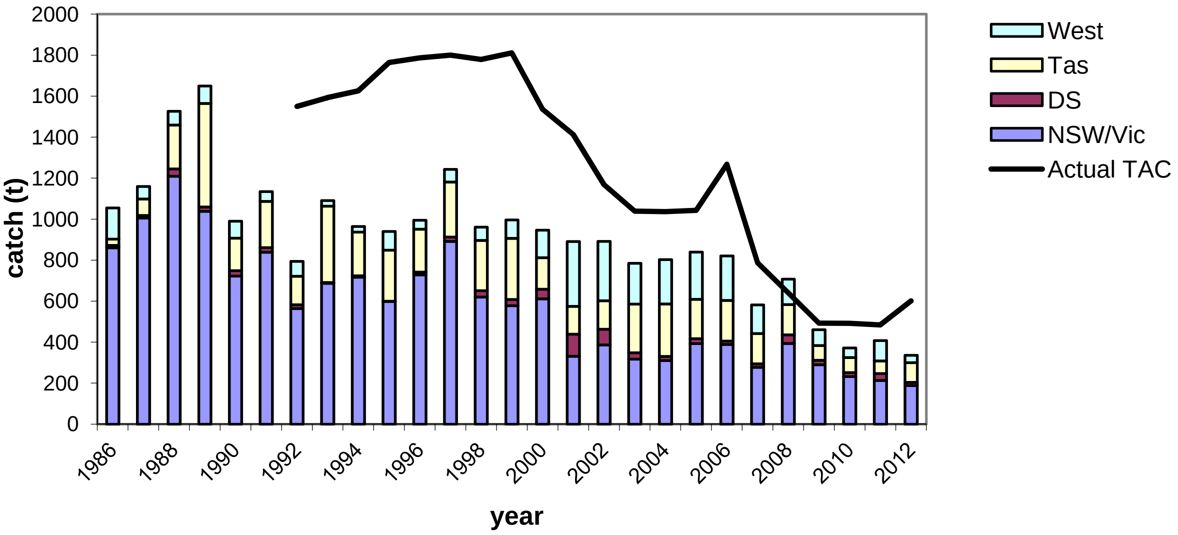

Figure 8 1 Actual (i.e. agreed plus overs and unders) TAC (by fishing year from 2008) and catches of jackass morwong by fleet (calendar year), for 1986 to 2012.

Table 8 1. Landed calendar year 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, and the western trawl fleet (western Victoria and Tasmania), 1986 – 2012. The 2013 catches are the estimated values used in the projection.

YEAR	NSW/VIC TRAWL	TASMANIAN TRAWL	DANISH SEINE	WESTERN TRAWL
1986	861	30	12	153
1987	1006	80	13	60
1988	1209	214	36	67
1989	1039	505	21	85
1990	722	159	27	83
1991	839	226	23	47
1992	564	140	18	72
1993	687	372	4	27
1994	717	213	7	27
1995	599	249	0	91
1996	729	210	13	44
1997	892	269	21	62
1998	620	245	32	65
1999	578	298	30	89
2000	611	154	48	134
2001	331	135	108	316
2002	387	139	76	289
2003	318	237	31	199
2004	310	256	21	216
2005	394	192	23	230
2006	389	198	17	217
2007	278	147	17	140
2008	394	148	42	124
2009	290	72	22	77
2010	232	73	20	47
2011	214	62	33	99
2012	189	96	15	36
2013(est)	*200*	*105*	*18*	*40*

Table 8 2. Relative stock biomass estimates (%), RBCs, actual catches (including State catches) and TACs (tonnes) for the eastern and western jackass morwong stocks.

	CALENDAR YEAR								FISHING YEAR
	EAST			WEST			EAST+WEST		
YEAR	STOCK STATUS	RBC	ACTUAL CATCH	STOCK STATUS	RBC	ACTUAL CATCH	RBC	ACTUAL CATCH	ACTUAL TAC
2007	15	0	442			140		582	787
2008	19	0	584	63	410	124	410	708	641
2009	19	0	384	68	380	77	380	461	493
2010	24	143	325	70	367	47	510	372	492
2011	26	228	309	69	329	99	557	408	484
2012	35*	358	300	67	282	36	640	336	601
2013	38	380		66	275		655		624
2014	40	400		68	292		692		

* Improved stock status from 2012 was due to a change in the model structure, and not necessarily an increase in stock biomass between 2011 and 2012.

8.2 References

Wayte, S.E., 2012. Jackass Morwong (*Nemadactylus macropterus*) stock assessment based on data up to 2010, in: Tuck, G.N. (Ed.), Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2011. Part 1. Australian Fisheries Management Authority and CSIRO Marine and Atmospheric Research, Hobart, pp. 226-283.

Wayte, S.E., 2013. Management implications of including a climate-induced recruitment shift in the stock assessment for jackass morwong (*Nemadactylus macropterus*) in south-eastern Australia. Fish. Res. 142, 47-55.

9. Tiger flathead (*Neoplatycephalus richardsoni*) stock assessment based on data up to 2012 – development of a preliminary base case [5]

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9.1 Summary

This chapter updates the 2010 assessment of deepwater flathead (*Neoplatycephalus conatus*) to provide estimates of stock status in the Great Australian Bight at the start of 2013/14. This assessment is performed using the stock assessment package SS v3.24f.

The base-case assessment estimates an unexploited spawning stock biomass (SSB_0) of 8,921t and a current depletion of 39% of SSB_0. The 2013/14 recommended biological catch (RBC) under the 20:35:43 harvest control rule is 979t and the long-term yield (assuming average recruitment in the future) is 1,051 t.

Exploration of model sensitivity showed a variation in depletion levels of between 25% and 58% of SSB_0.

9.2 Comparison of 2010 assessment with 2013 assessment

9.2.1 *Bridging from 2010 to 2013 assessments*

The previous full quantitative assessment for tiger flathead was performed in 2010 (Klaer, 2010) using Stock Synthesis (version SS-V3.11a, Methot September 2010). The 2013 assessment uses the current version of Stock Synthesis (version SS-V3.24f, Methot August 2012). There are a few structural changes between these two versions of Stock Synthesis.

As a first step in the process of bridging to a new model, the data used in the 2010 assessment was used in the new software (SS-V3.24f) and updates were made to the 2007-2009 catch history. This was followed by including the data from 2010-2012, with three new years of additional data incorporated into the model. This additional data included new catch, discard, CPUE, length frequency and age-at-length data for 2010, 2011 and 2012. The last year of recruitment estimation was extended to 2009 (2006 in the 2010 assessment). The use of updated software and the inclusion of additional data resulted in some differences in the fits to CPUE, age or length data. The usual process of bridging to a new model by adding new data piecewise and analysing which components of the data could be attributed to changes in the assessment outcome was conducted with the details outlined below.

9.2.2 *Update to Stock Synthesis SSV-3.24f*

The 2010 tiger flathead assessment (Base2010_3.11a) was initially converted to the most recent version of the software, Stock Synthesis version SS-V3.24f (2013_3.24f) with minor changes to the

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[5] Paper presented at the Shelf RAG meeting September2014

results (Figure 9.1 and Figure 9.2). These changes appear to be driven by differences in the recruitment deviations, due to minor changes in the internal workings of stock synthesis that are well within the range of uncertainty. This is due to a reduction to the robustify factor in the spawner-recruitment relationship, which in some circumstances is enough to produce slightly more recruits for a given spawning biomass and steepness.

Minor revisions to the 2007, 2008 and 2009 state catch data used in the 2010 assessment were incorporated using more accurate data which became available after the 2010 assessment was completed (Table 9.1). These changes in catch history (2010AdjCatch) were included after the transition to SS-V3.24f with negligible changes to the spawning biomass and recruitment time series (Figure 9.1 and Figure 9.2).

Table 9.1. Total catch (kg) by jurisdiction from 1994 to 2012.

Record type	State	State	State	SEF2	SEF2	SEF2	SEF2	SEF1	SAN2	**Total catch**	scard weight
State	NSW	Vic	Tas	Commonwealth	Tas state	State unknown	Vic state			**kg**	kg
1994	692,950	143,256	0	1,496,269	410,861	0	43,623			**2,786,959**	
1995	576,528	96,088	24,449	1,712,037	301,877	0	24,950			**2,735,929**	
1996	481,765	127,813	749	1,893,239	174,232	0	47,812			**2,725,609**	
1997	295,184	123,780	590	2,506,769	90,274	0	76,701			**3,093,299**	
1998	182,259	46,684	155	2,542,631	31,316	943	130,004			**2,933,991**	291,000
1999	214,314	2,123	1,688	3,457,178	0	0	54,030			**3,729,333**	267,000
2000	188,052	3,375	239	3,221,694	0	0	14,048			**3,427,408**	511,000
2001	124,228	6,137	227	2,844,205	0	0	17,359		281	**2,992,436**	160,000
2002	107,931	7,819	333	3,143,471	0	0	12,680		337	**3,272,572**	193,970
2003	169,190	4,651	208	3,494,182	0	0	1,131		809	**3,670,170**	178,030
2004	198,578	560	8,585	3,381,919	0	0	6,371		858	**3,596,871**	228,380
2005	241,017	467	50,117	3,001,108	0	0	1,970		1,145	**3,295,823**	195,140
2006	273,172	576	45,131	2,697,847	0	0			607	**3,017,332**	201,730
2007	152,871	1,927	25,023	2,847,009	0	0	24,968		486	**3,052,284**	278,562
2008	191,736	1,633	55,237	3,197,355	0	0	524		362	**3,446,847**	43,736
2009	192,555	636	49,591	2,678,525	0	0	3,526		403	**2,925,235**	155,881
2010	201,305	1,863	59,345	2,725,983			1,077		297	**2,989,871**	250,874
2011	192,514	12,806	69,004	2,670,120			1,248		686	**2,946,378**	504,081
2012	169,413	1,720	32,954	2,859,321			544		996	**3,064,948**	205,877

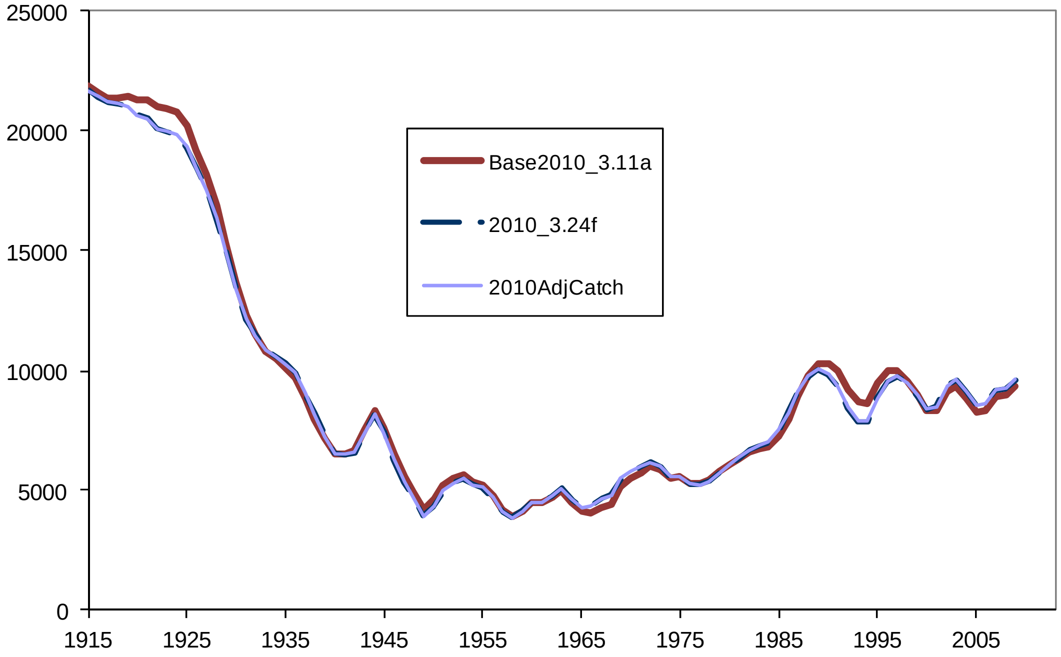


Figure 9.1. Comparison of the spawning biomass time series for the 2010 assessment (Base2010_3.11a) and a model converted to SS-V3.24f (2010_3.24f) and a minor reassignment of the 2007-2009 catches to include data which was unavailable to the 2010 assessment (2010AdjCatch).

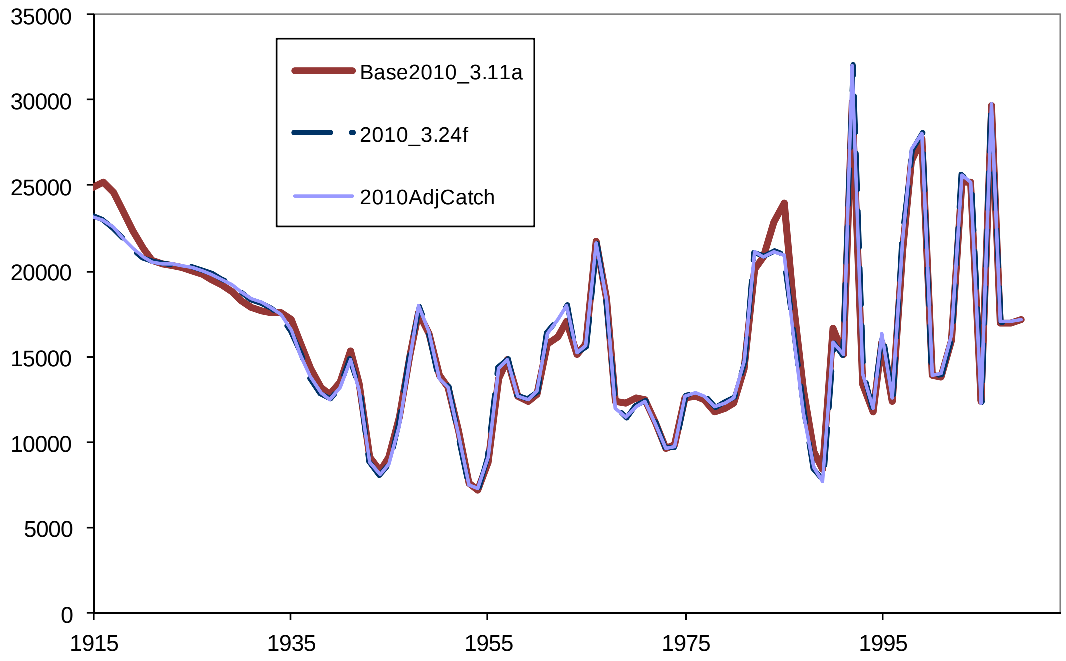


Figure 9.2. Comparison of the recruitment time series for the 2010 assessment (Base2010_3.11a) and a model converted to SS-V3.24f (2010_3.24f) and a minor reassignment of the 2007-2009 state catches to include data which was unavailable to the 2010 assessment (2010AdjCatch).

9.2.3 *Inclusion of new data: 2010-2012*

Starting from the converted 2010 model, the 2010 base case transferred to SS-v3.24f and with revisions to the 2007, 2008 and 2009 state catch data (2010AdjCatch), additional data from 2010-2012 were added sequentially to develop a preliminary base case for the 2013 assessment:

1. Change final assessment year to 2012, add catch and CPUE to 2012 (2013CatCPUE).
2. Add updated discard fraction estimates to 2012 and length frequency data from 2010 to 2012 (2013Len).
3. Add updated age error matrix and age-at-length data from 2010 to 2012 (2013Age).
4. Change the final year for which recruitments are estimated from 2006 to 2009 (2013Rec).
5. Retune model. Set lambda on length and age composition data to 0.1 as in previous assessments. Start with low CV on CPUE and survey, set bias adjustment, tune input and output sample sizes for length and age comps, tune σ_r and tune CV for CPUE (Balance).
6. Add the Fishery Independent Survey data points for 2008, 2010 and 2012 and retune (FIS).

Spawning biomass and recruitment time series were compared as the data was added in the sequence listed above (Figure 9.3 and Figure 9.4).

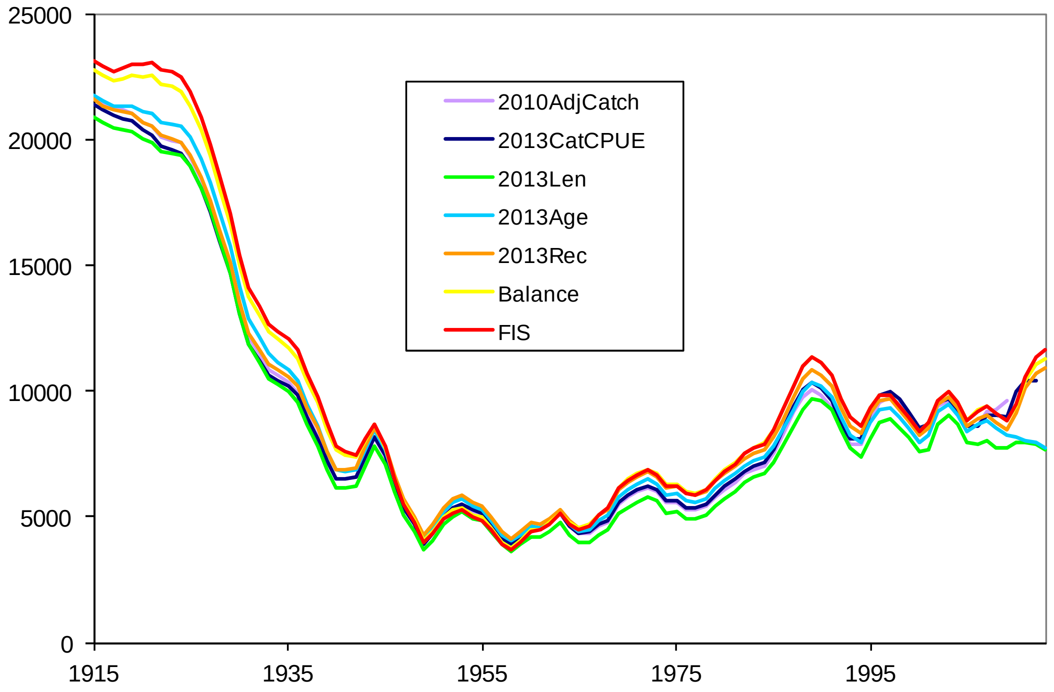


Figure 9.3. Comparison of the spawning biomass time series for the 2010 assessment with adjusted catches (2010AdjCatch) as data to 2012 is sequentially added.

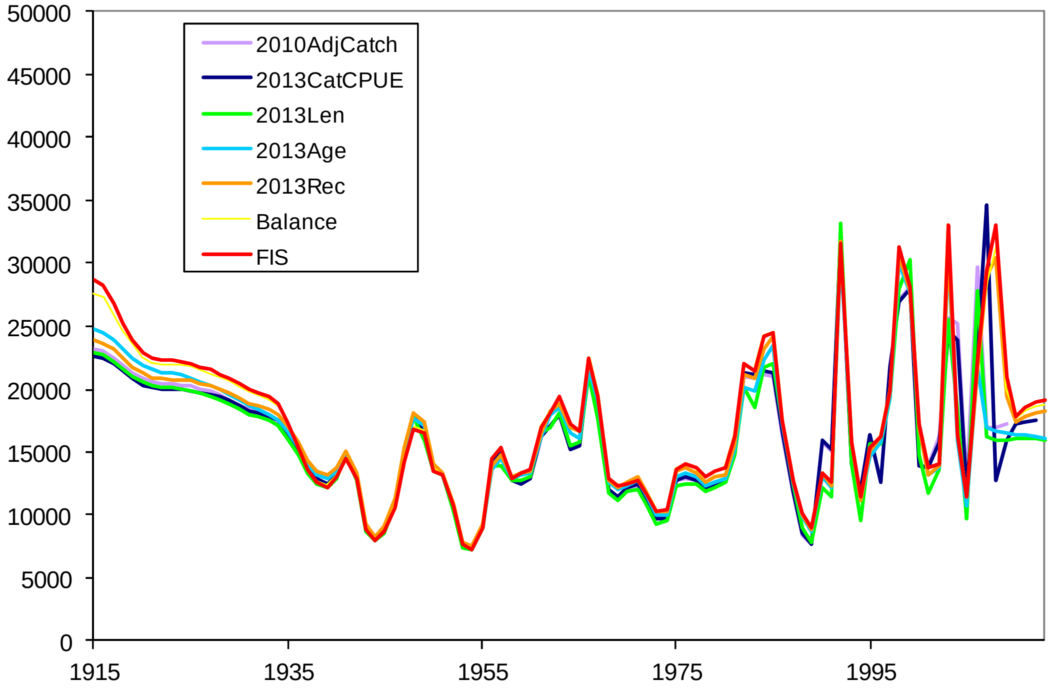


Figure 9.4. Comparison of the recruitment time series for the 2010 assessment with adjusted catches (2010AdjCatch) as data to 2012 is sequentially added.

Inclusion of the new data had relatively minor impacts on the estimates of recruitment and the spawning biomass time series. With recruitment estimated up until 2009, this resulted in a smaller estimate for recruitment in 2006, compared to the 2010 assessment. However, the three new years of estimated recruitment (2007, 2008 and 2009) are all above average, with a particularly strong recruitment estimated in 2008. These strong recruitment events are well estimated and appear to be supported by the recent age data and have resulted in an estimate of the depletion at the start of 2014 of 50% of B_0. While the most recent recruitments are well estimated, they should be treated with some caution as it is possible for future data to result in modifications to estimates of recent recruitment events.

9.3 Acknowledgements

The members of the SESSF stock assessment group: Geoff Tuck, Sally Wayte, Robin Thomson, Rich Little, Judy Upston, Miriana Sporcic, Malcolm Haddon and André Punt are thanked for their generous advice and comments during the development of this work and also Ian Taylor from NOAA for technical advice relating to Stock Synthesis. Thanks also to the providers of data for this work: Malcolm Haddon for the calculation of the catch-rate indices; André Punt for processing the ageing error calculations; Kyne Krusic-Golub (Fish Ageing Services Pty Ltd) for the provision of ageing data; John Garvey (AFMA) for processing parts of the ISMP and AFMA logbook data and Mike Fuller (CSIRO) who loaded and pre-processed AFMA logbook and CDR data. Thanks also to other members of Shelf RAG for their helpful discussion and input to the assessment process throughout the year.

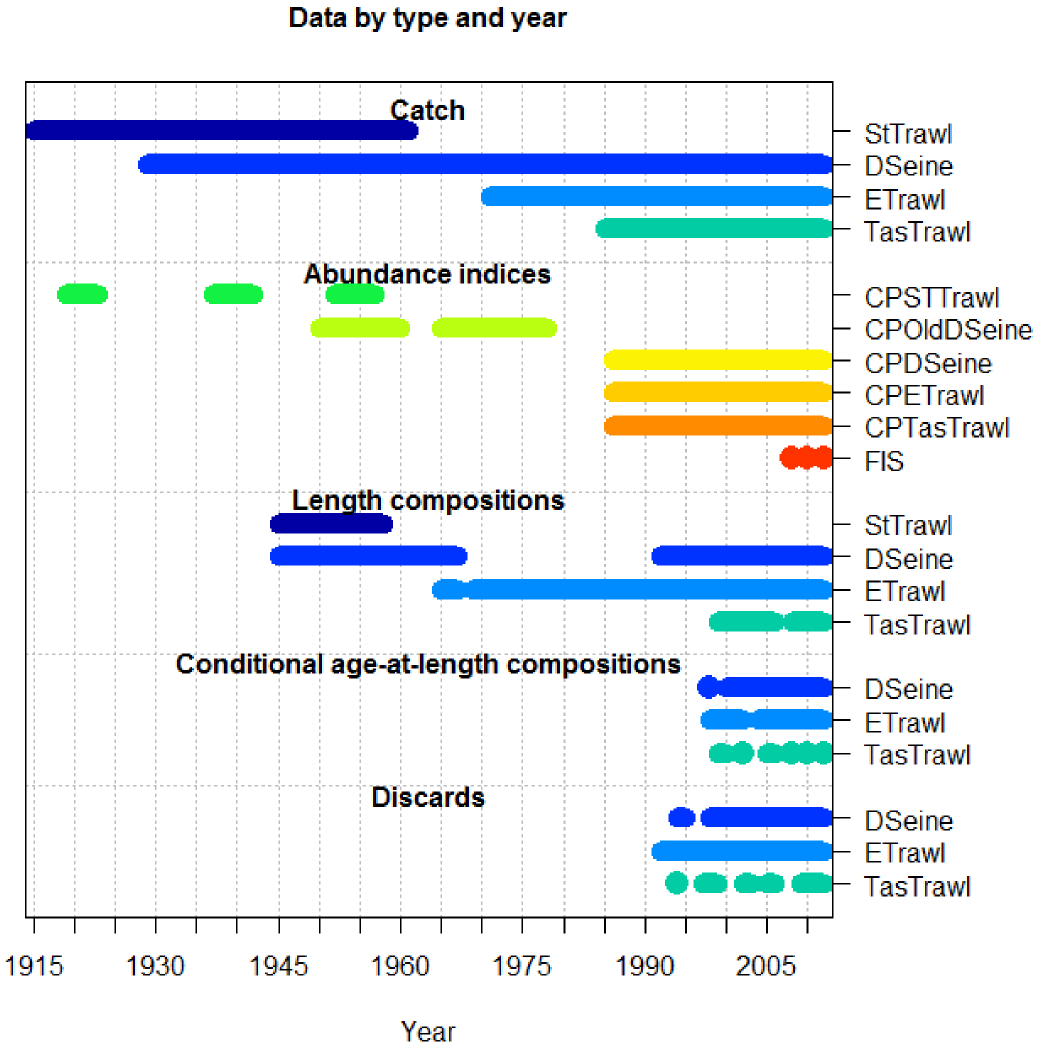
9.4 References

Methot RD (2010) User manual for Stock Synthesis. Model Version 3.11a. NOAA Fisheries Service, Seattle. 159 pp.

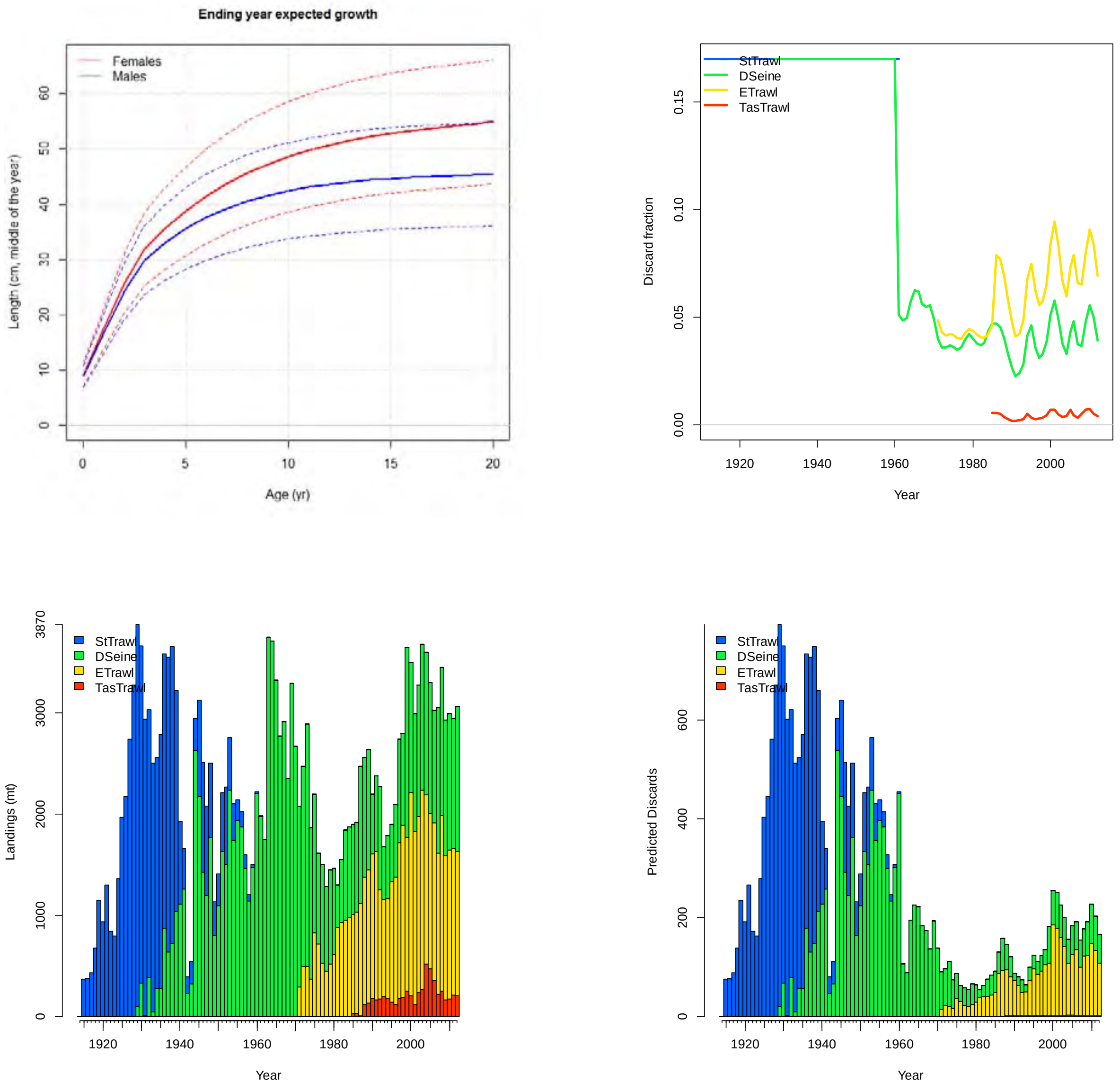
Methot RD (2012) User manual for Stock Synthesis. Model Version 3.24f. NOAA Fisheries Service, Seattle. 150 pp.

Klaer N (2010) Tiger flathead (*Neoplatycephalus richardsoni*) stock assessment based on data up to 2009. Unpublished report to Shelf RAG. 41 pp.

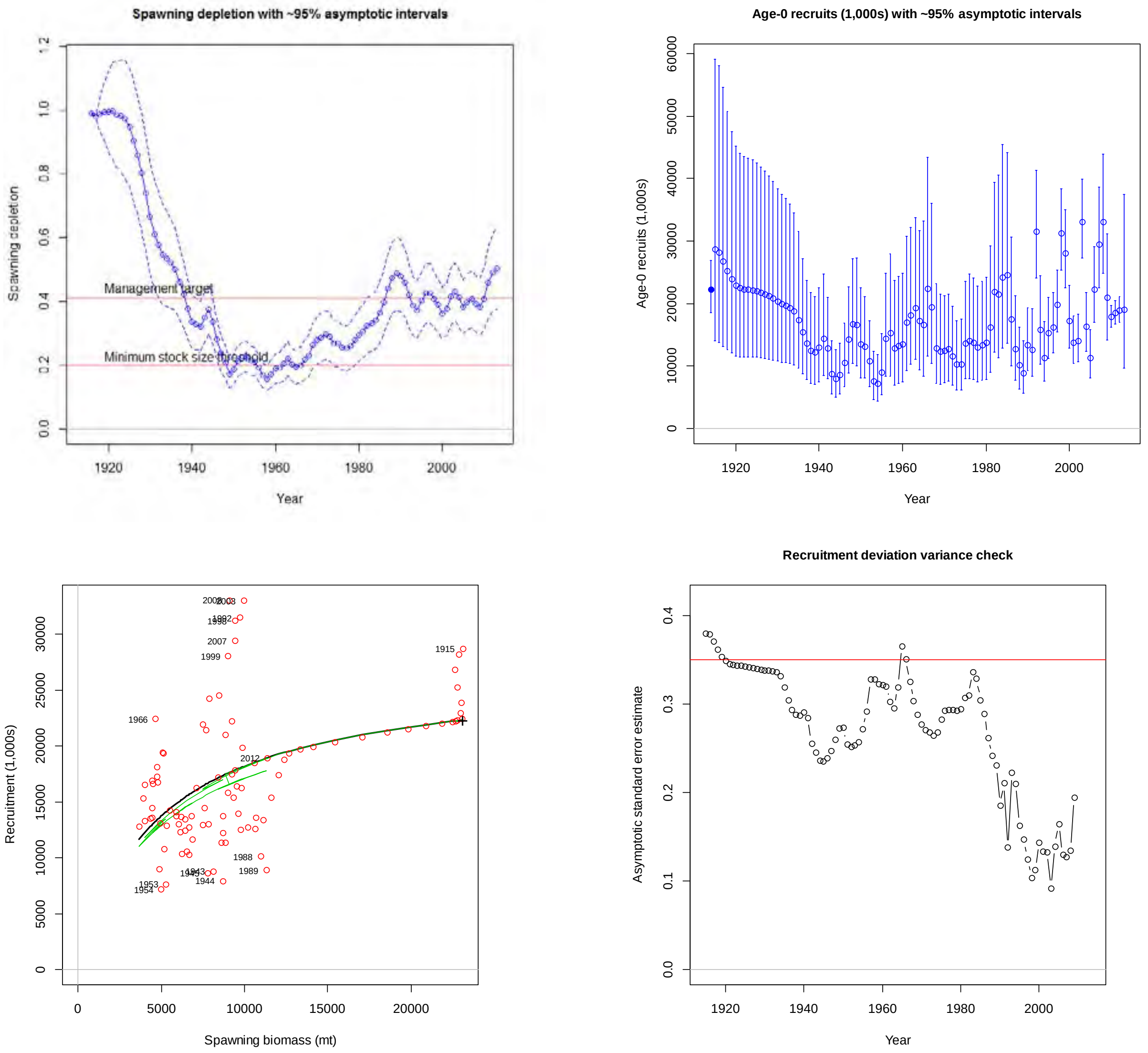
9.5 Appendix A: Preliminary base case diagnostics



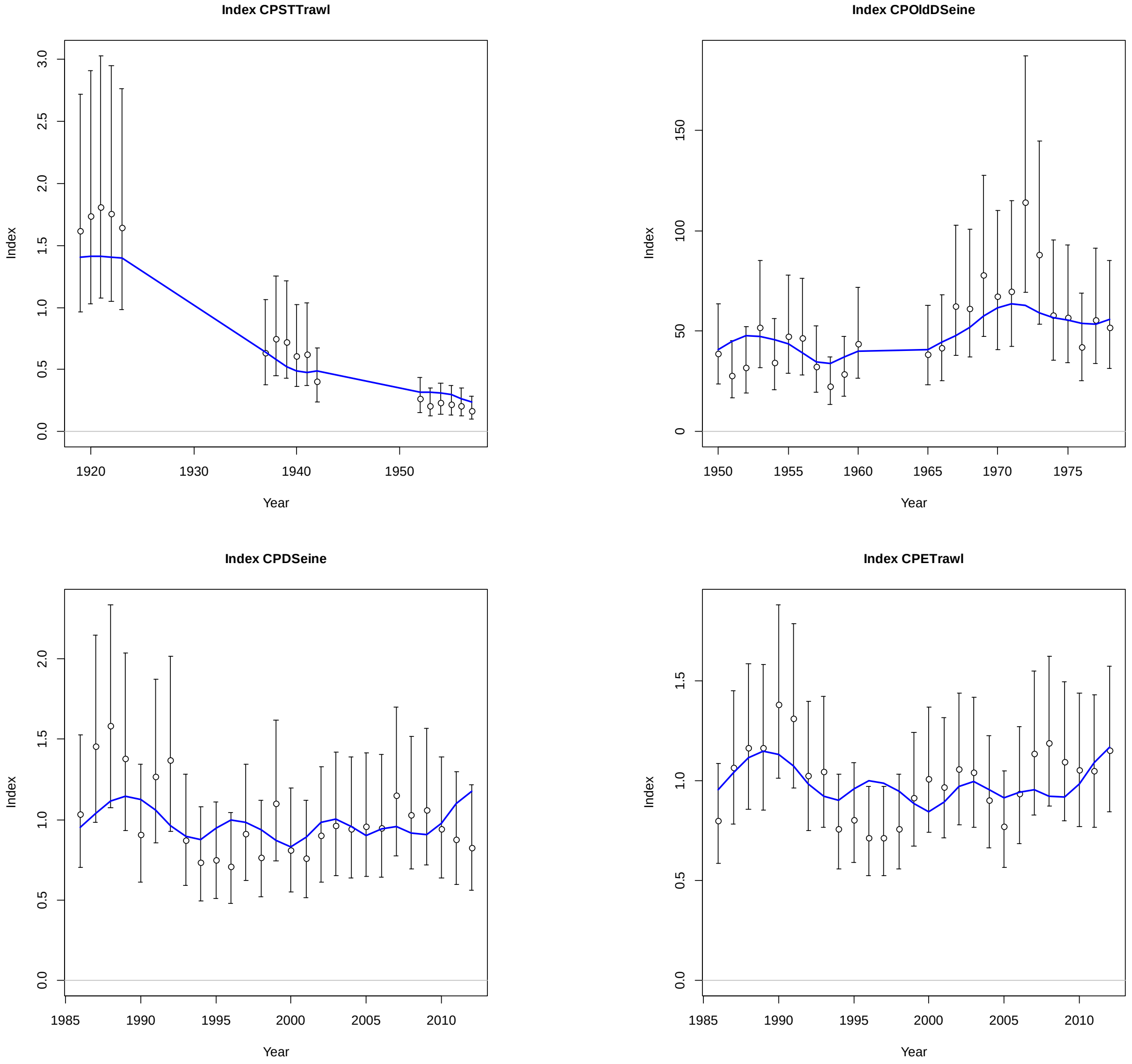
Apx Figure 9.1. Summary of data sources for tiger flathead stock assessment.



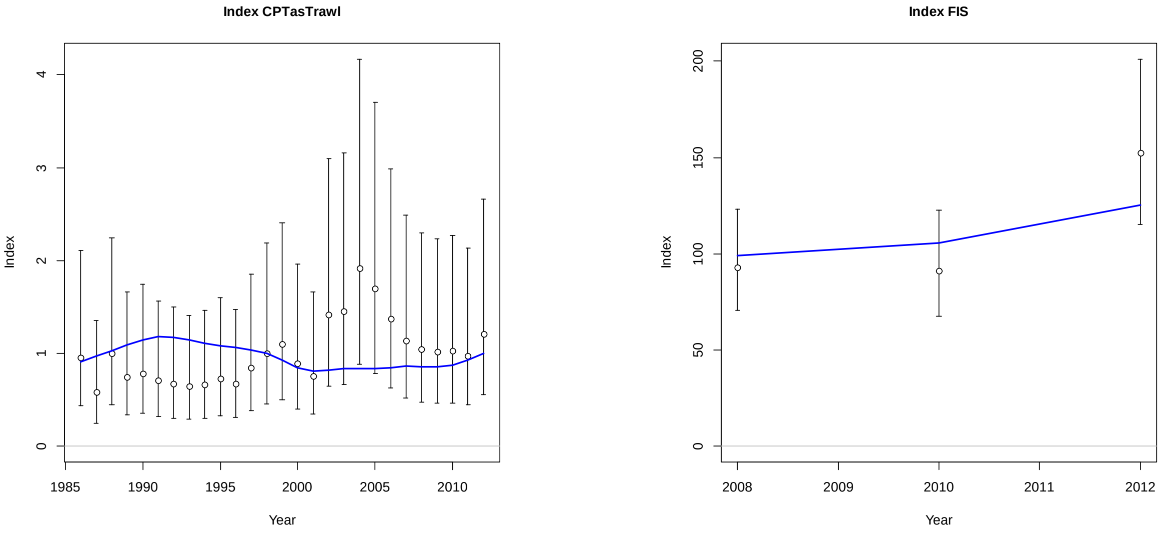
Apx Figure 9.2. Growth, discard fraction estimates, landings by fleet and predicted discards by fleet for tiger flathead.



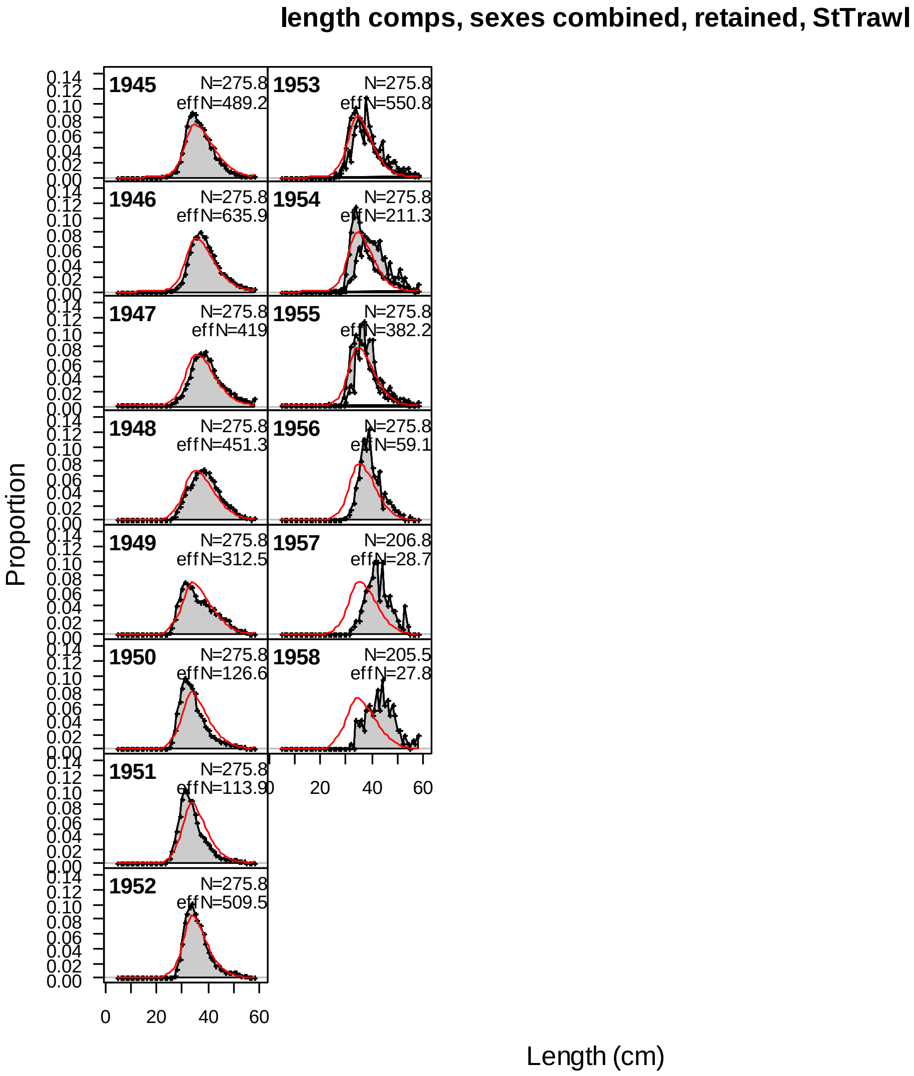
Apx Figure 9.3. Time series showing depletion of spawning biomass with confidence intervals, recruitment estimates with confidence intervals, stock recruitment curve and recruitment deviation variance check for tiger flathead.



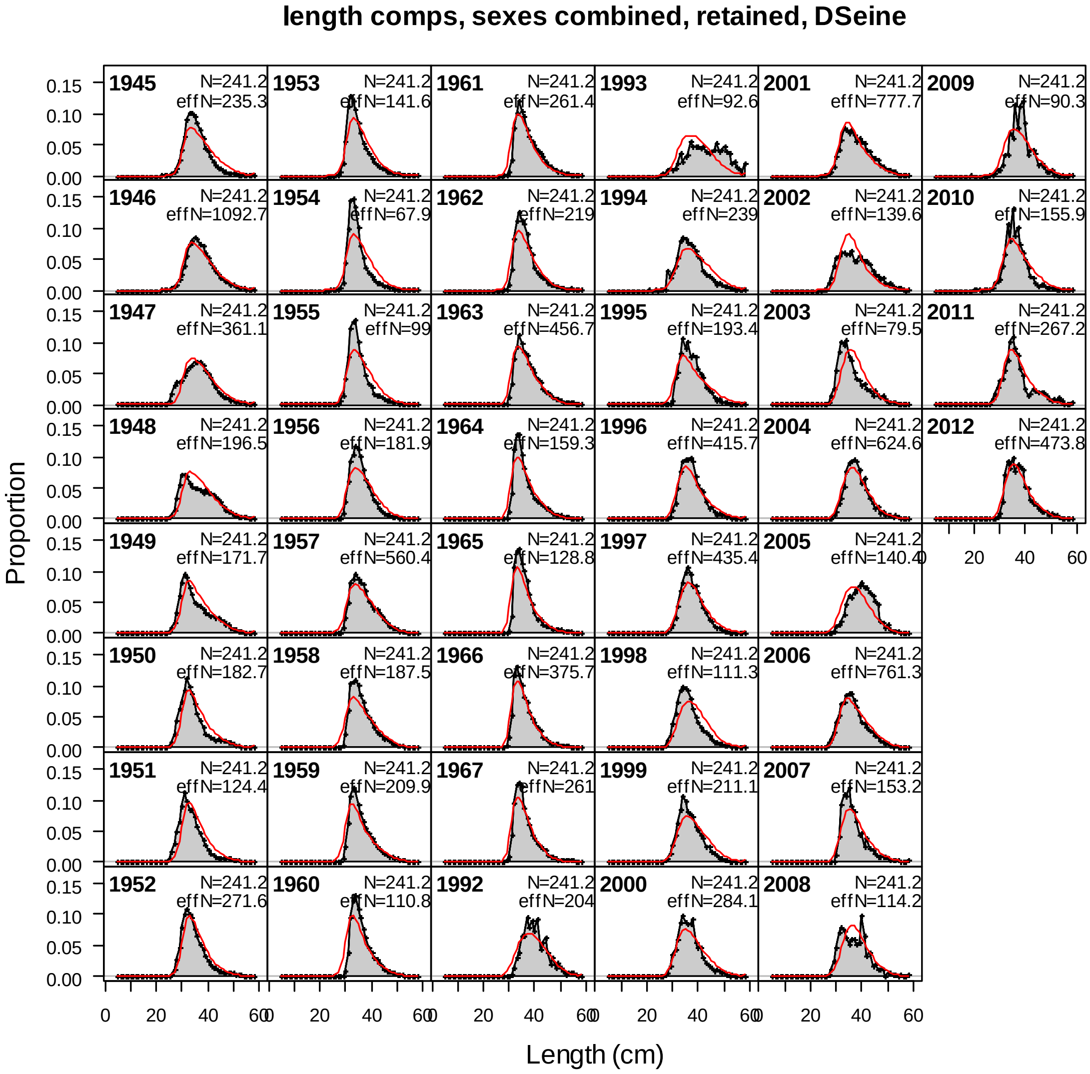
Apx Figure 9.4. Fits to CPUE by fleet for tiger flathead: steam trawl, old Danish seine, Danish seine, eastern trawl.



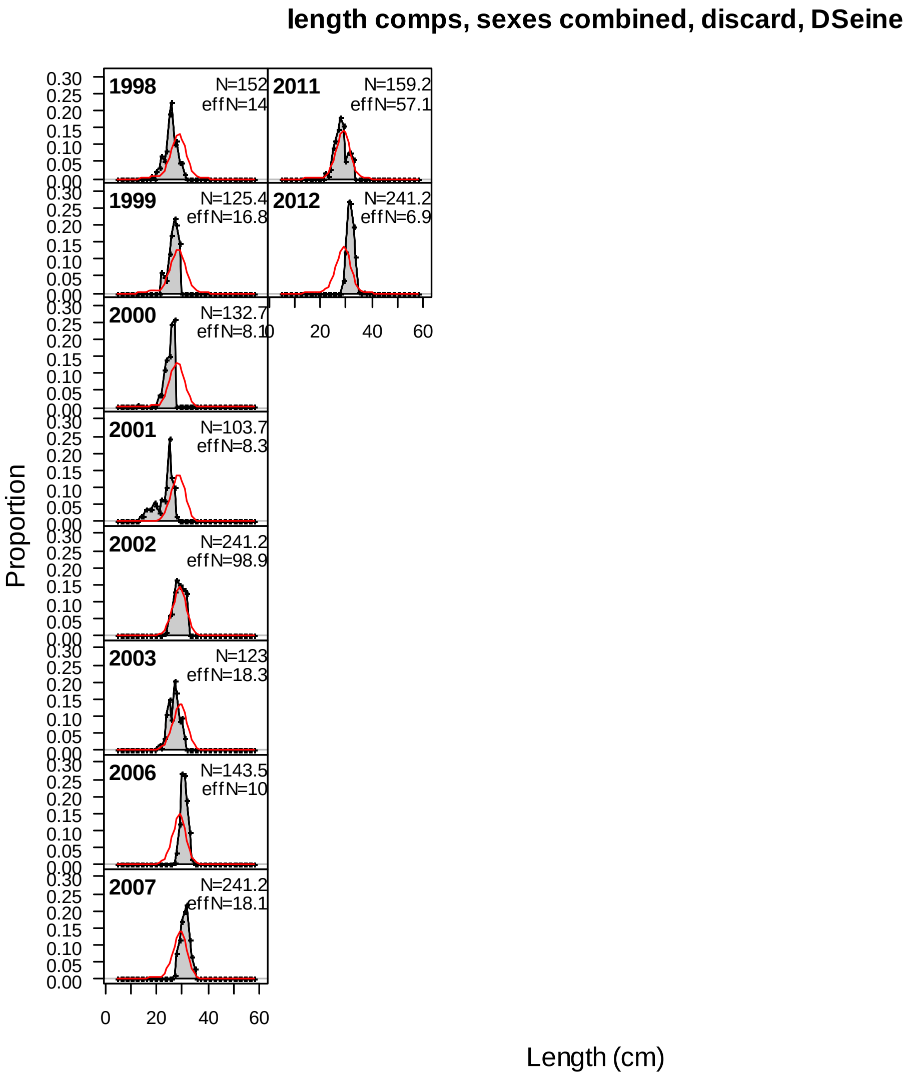
Apx Figure 9.5. Fits to CPUE by fleet for tiger flathead: Tasmanian trawl and the Fishery Independent Survey.



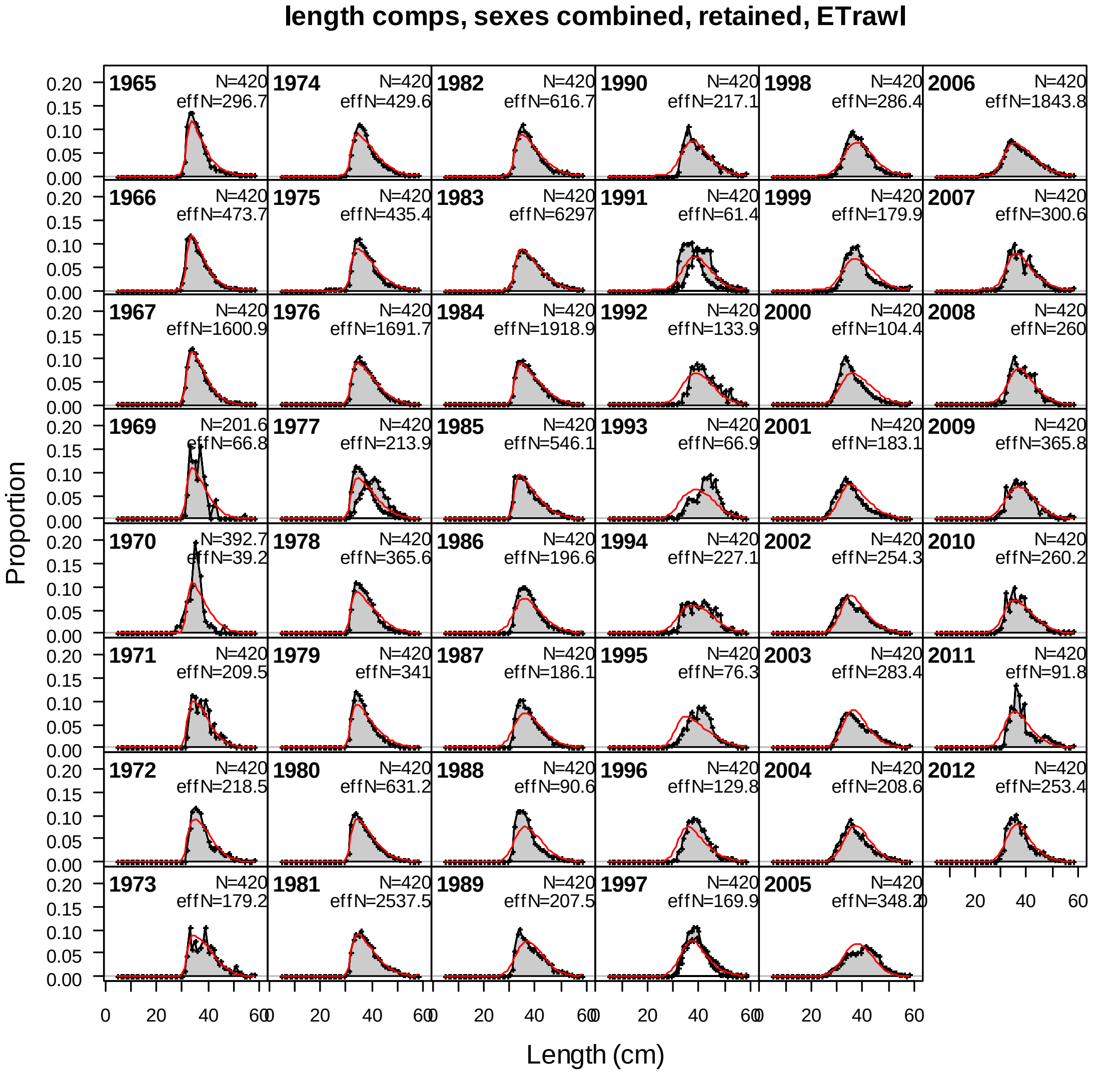
Apx Figure 9.6. Tiger flathead length composition fits: steam trawl retained.



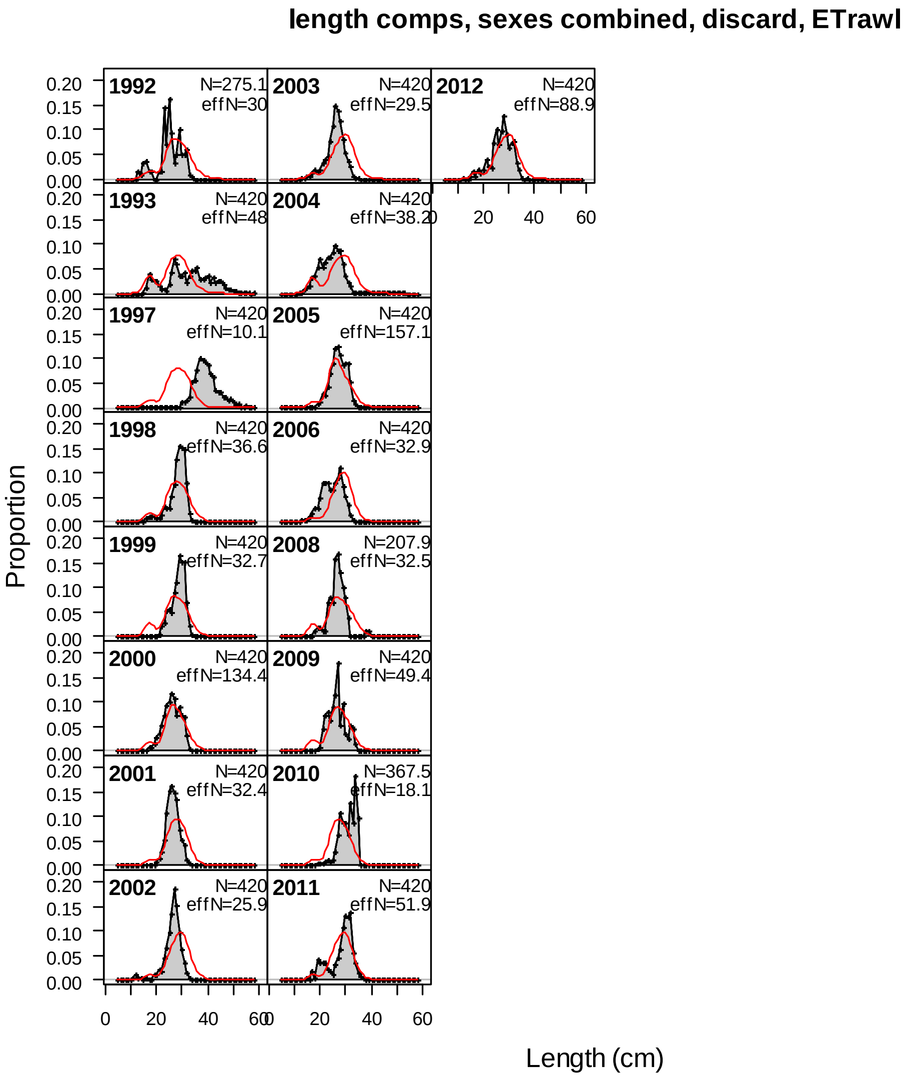
Apx Figure 9.7. Tiger flathead length composition fits: Danish seine retained.



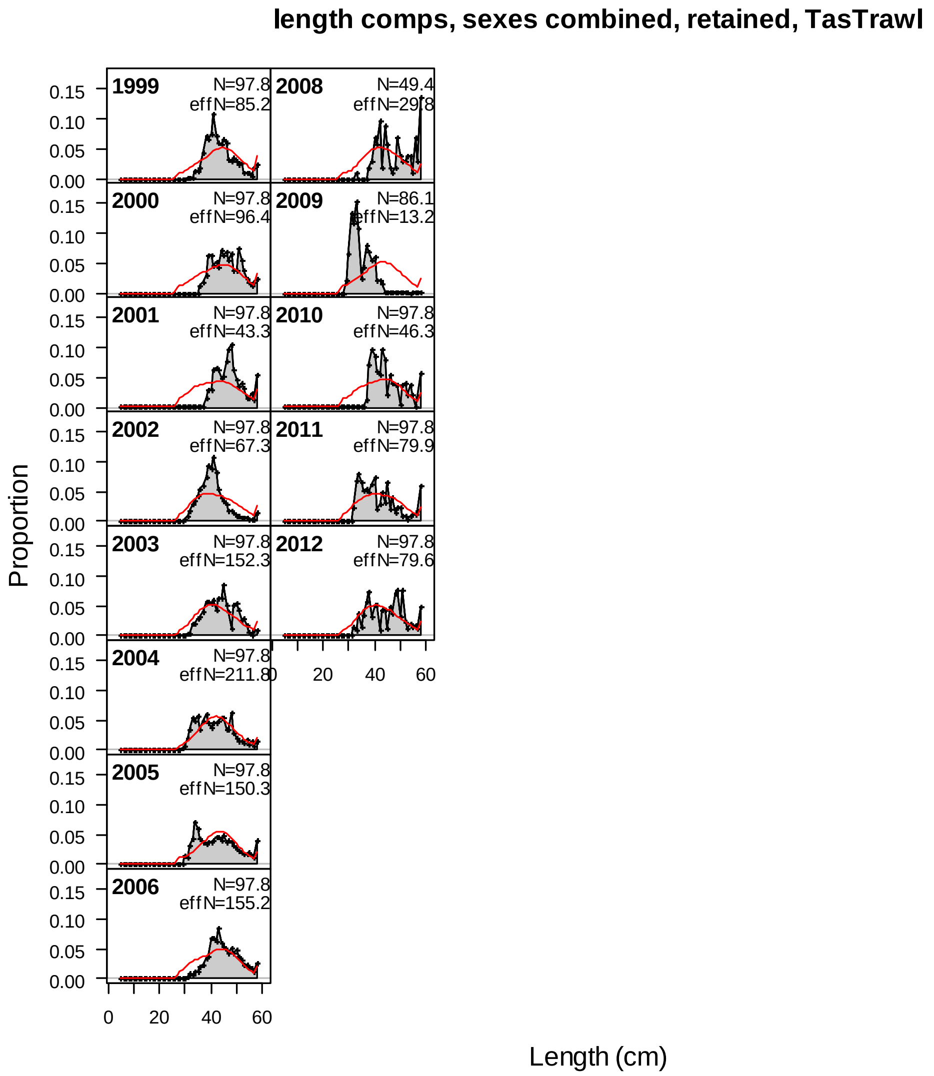
Apx Figure 9.8. Tiger flathead length composition fits: Danish seine discarded.



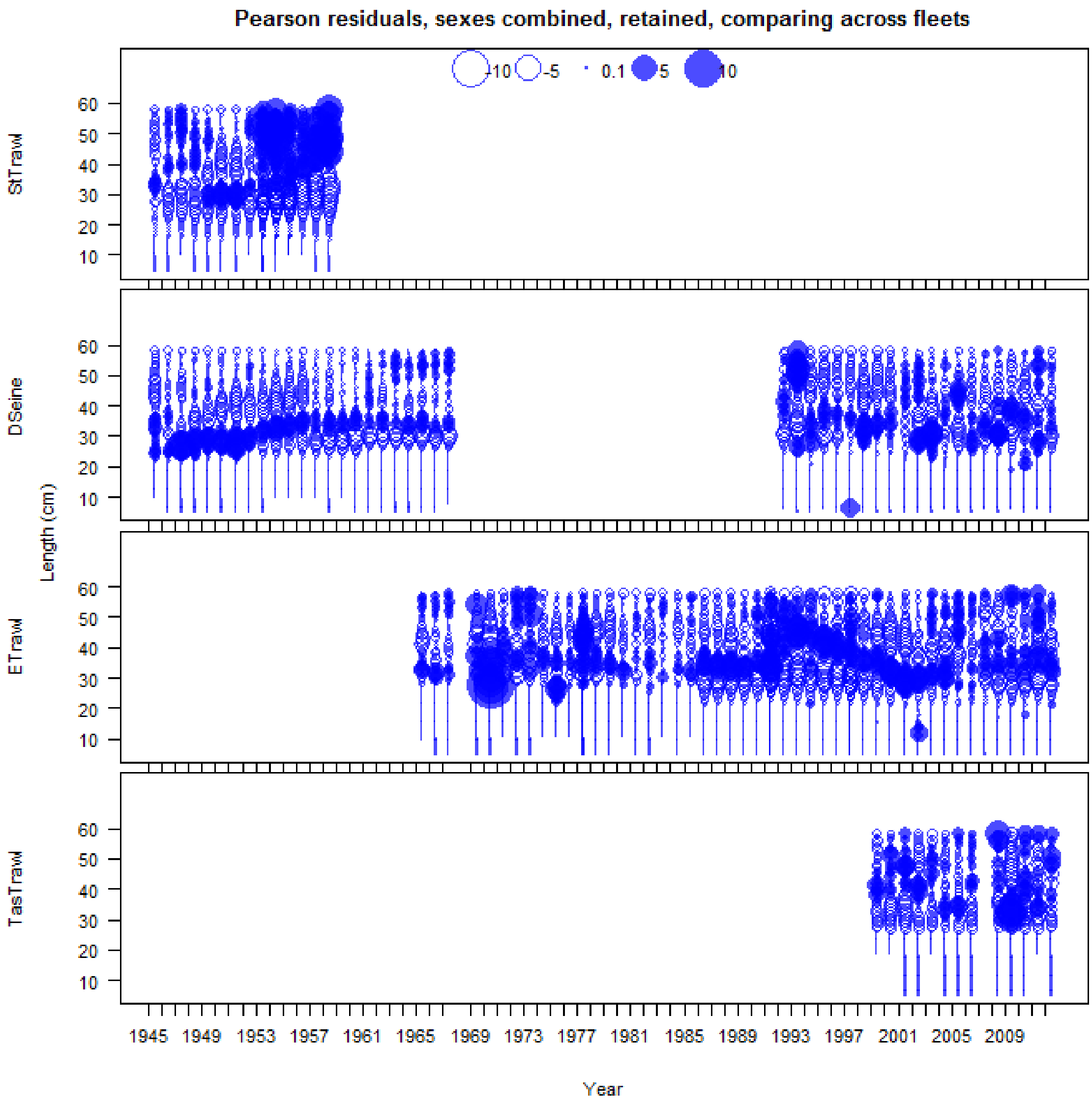
Apx Figure 9.9. Tiger flathead length composition fits: eastern trawl retained.



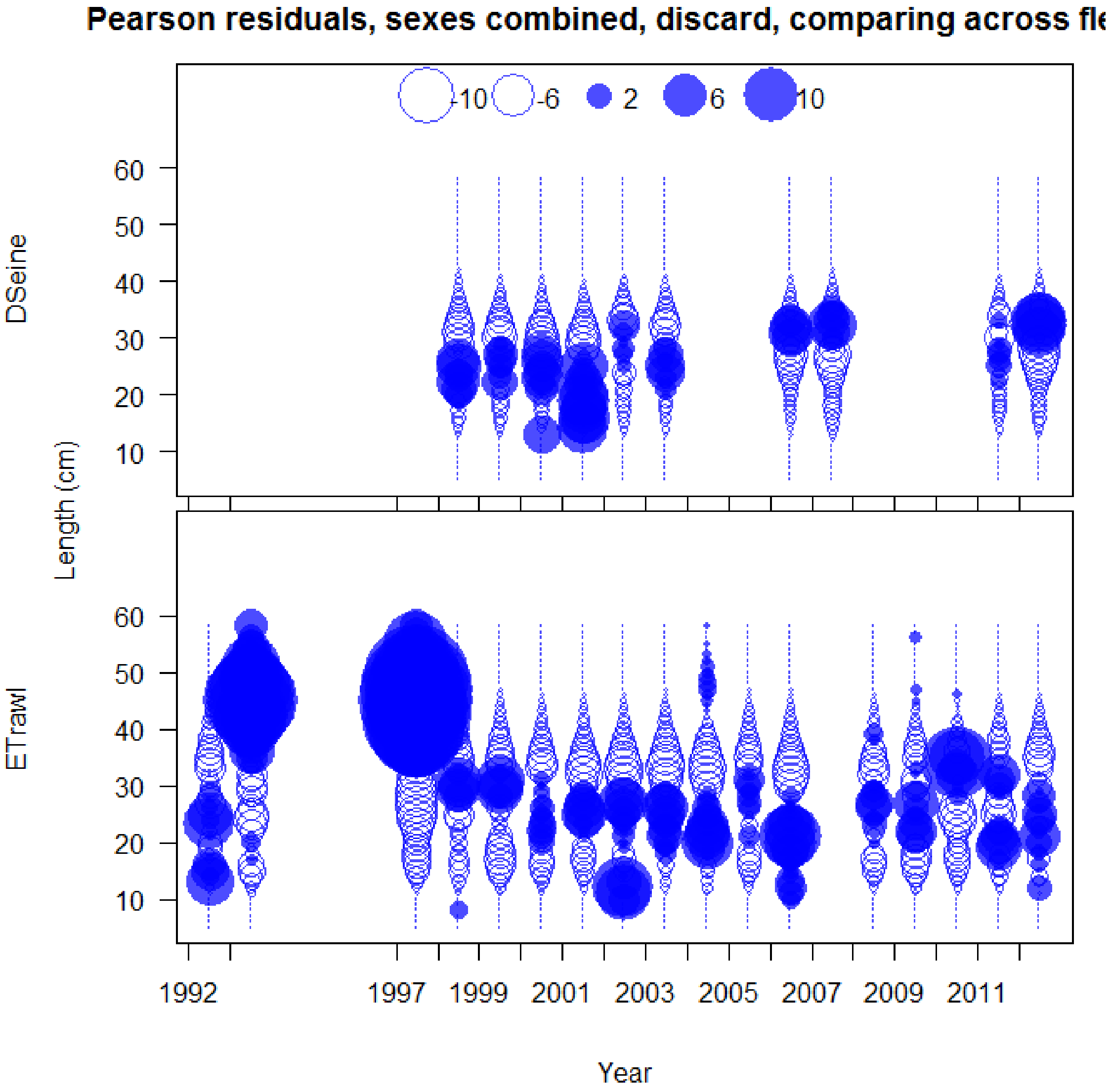
Apx Figure 9.10. Tiger flathead length composition fits: eastern trawl discarded.



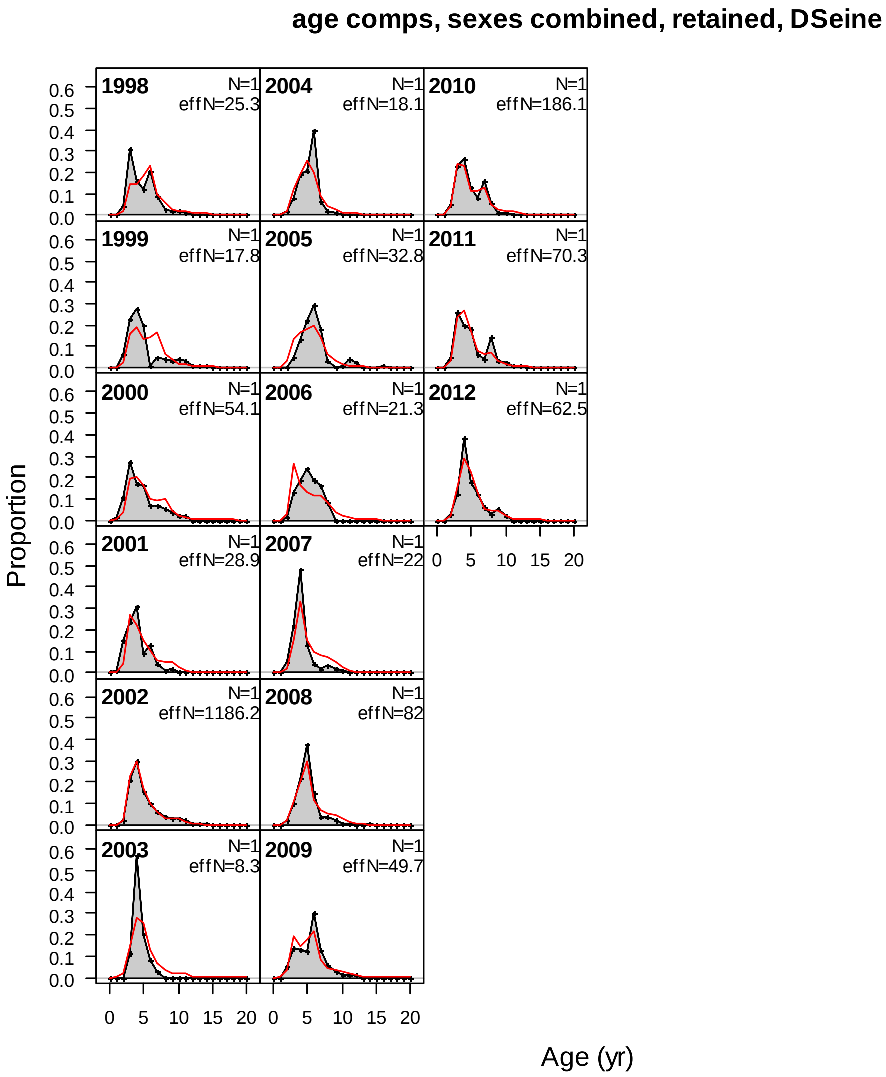
Apx Figure 9.11. Tiger flathead length composition fits: Tasmanian trawl retained.



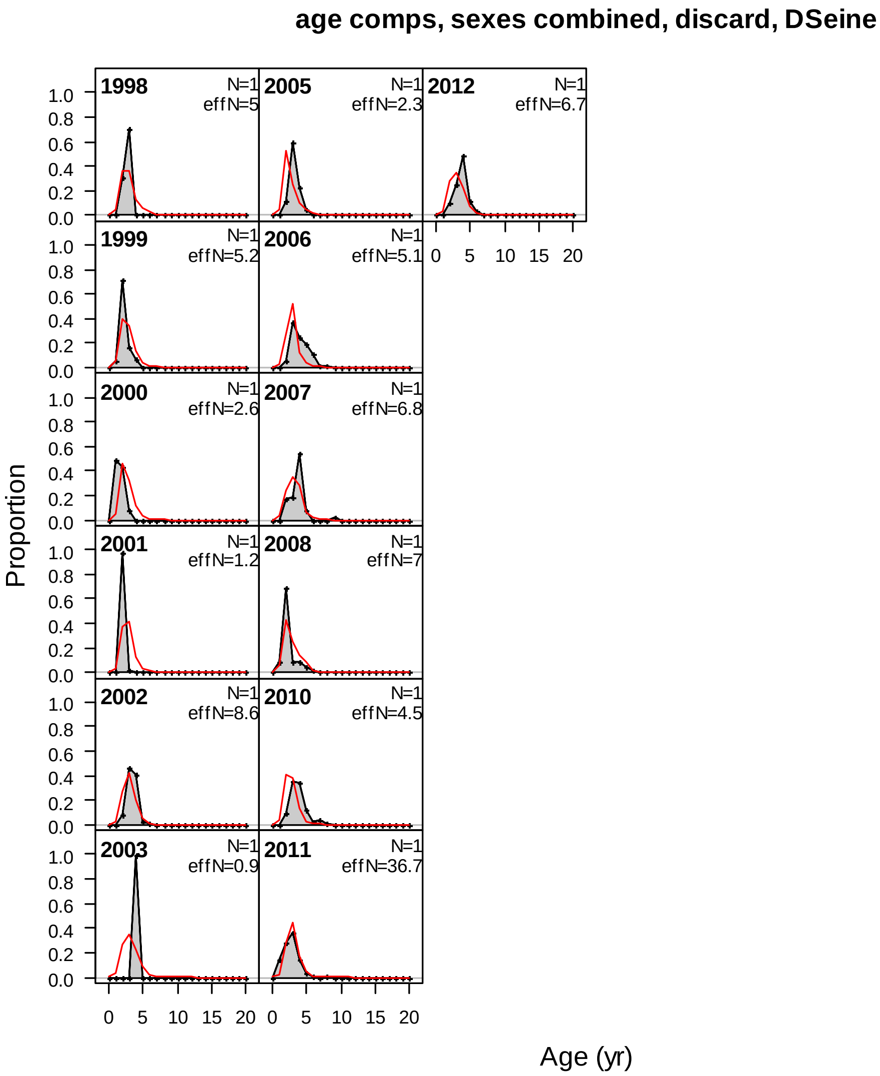
Apx Figure 9.12. Residuals from the annual length compositions (retained) for tiger flathead displayed by year and fleet.



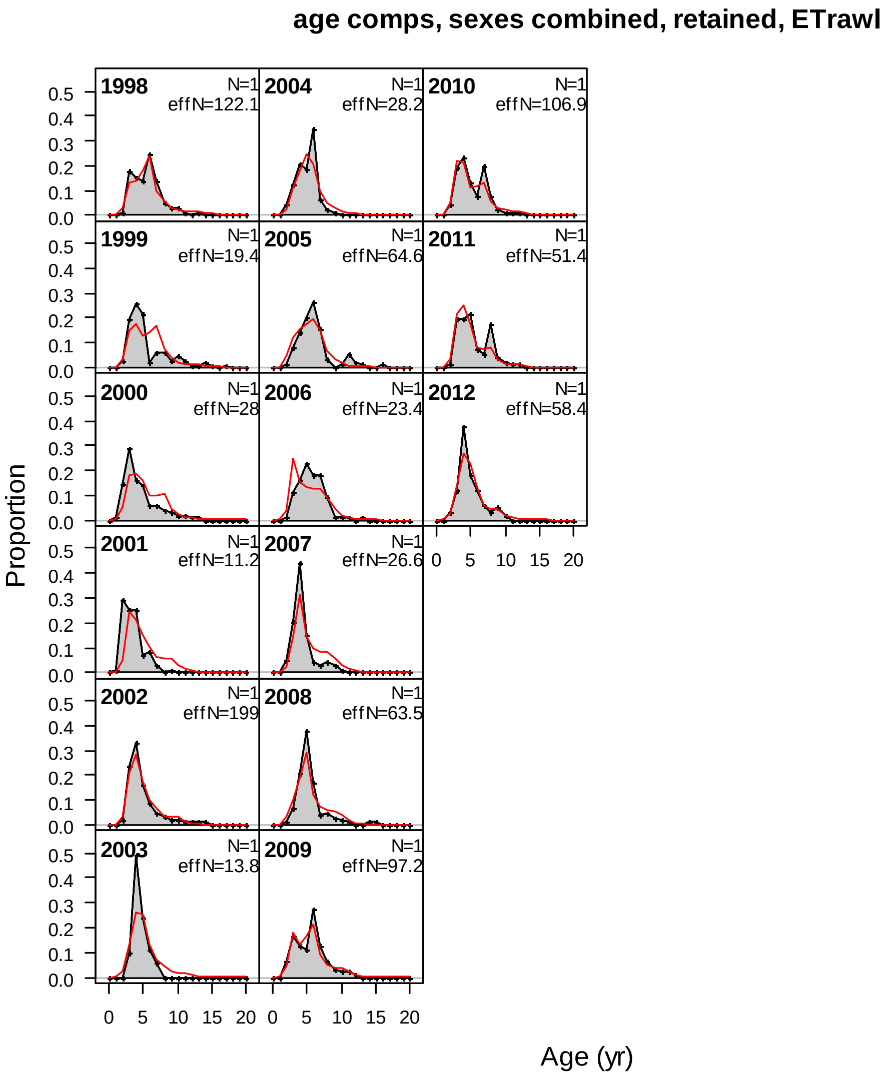
Apx Figure 9.13. Residuals from the annual length compositions (discarded) for tiger flathead displayed by year and fleet.



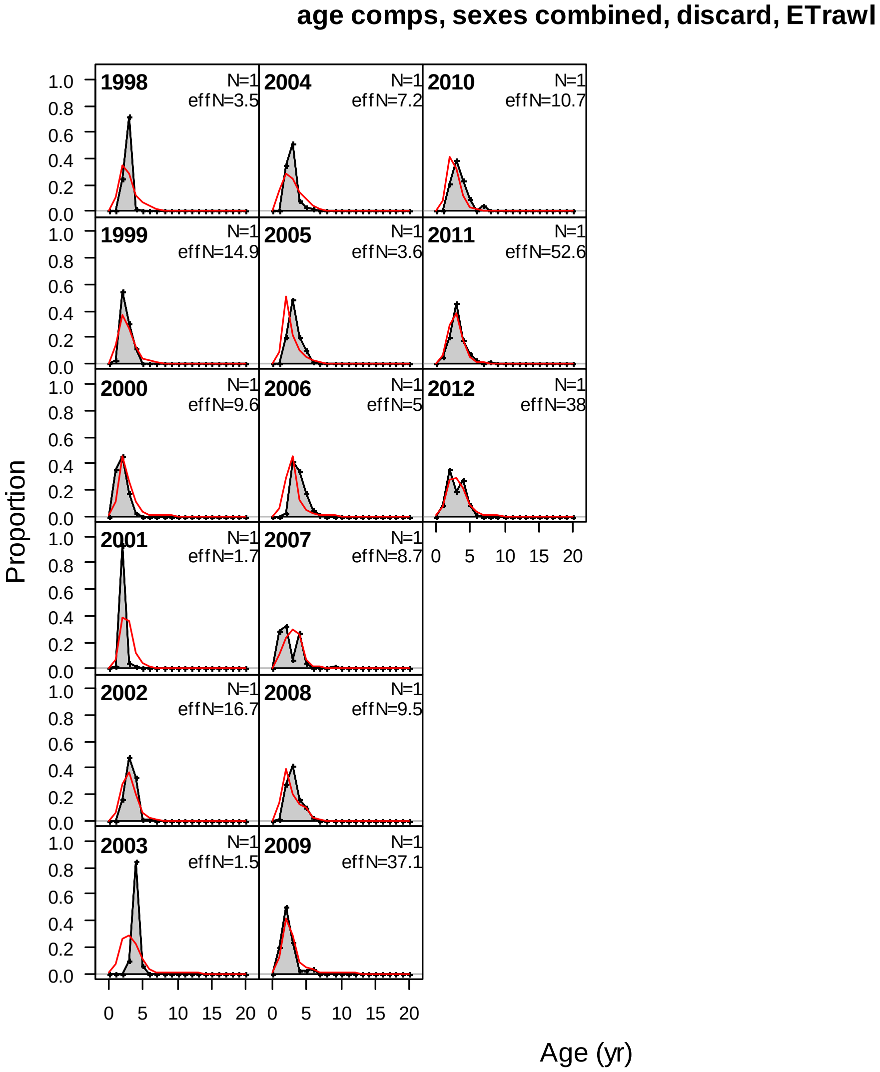
Apx Figure 9.14. Tiger flathead implied age composition fits: Danish seine retained.



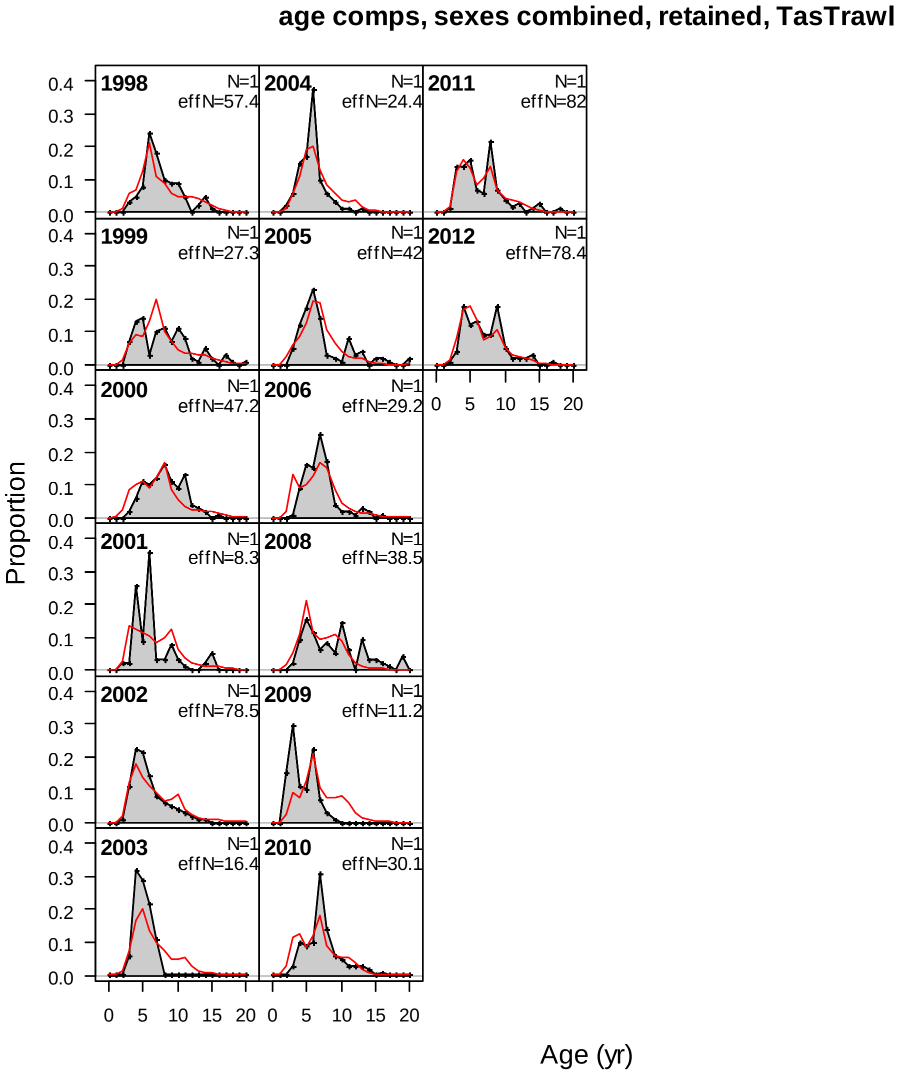
Apx Figure 9.15. Tiger flathead implied age composition fits: Danish seine discarded.



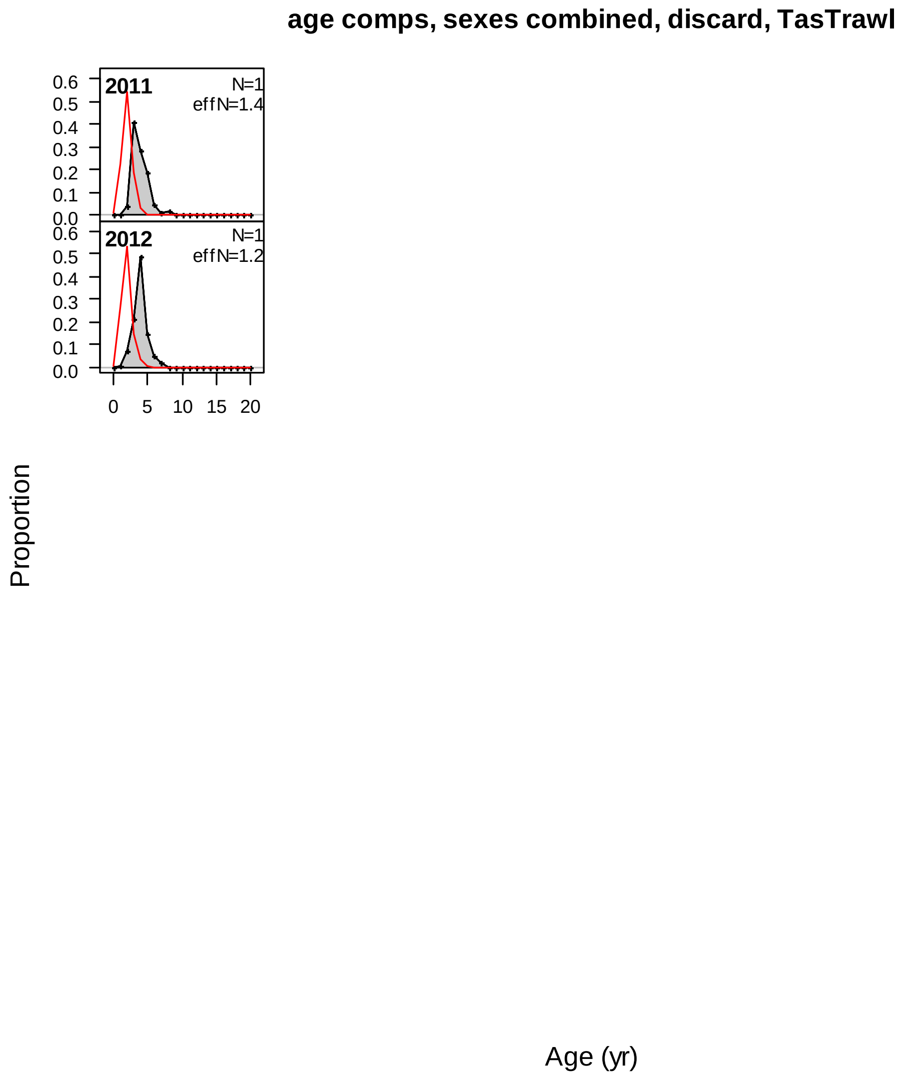
Apx Figure 9.16. Tiger flathead implied age composition fits: eastern trawl retained.



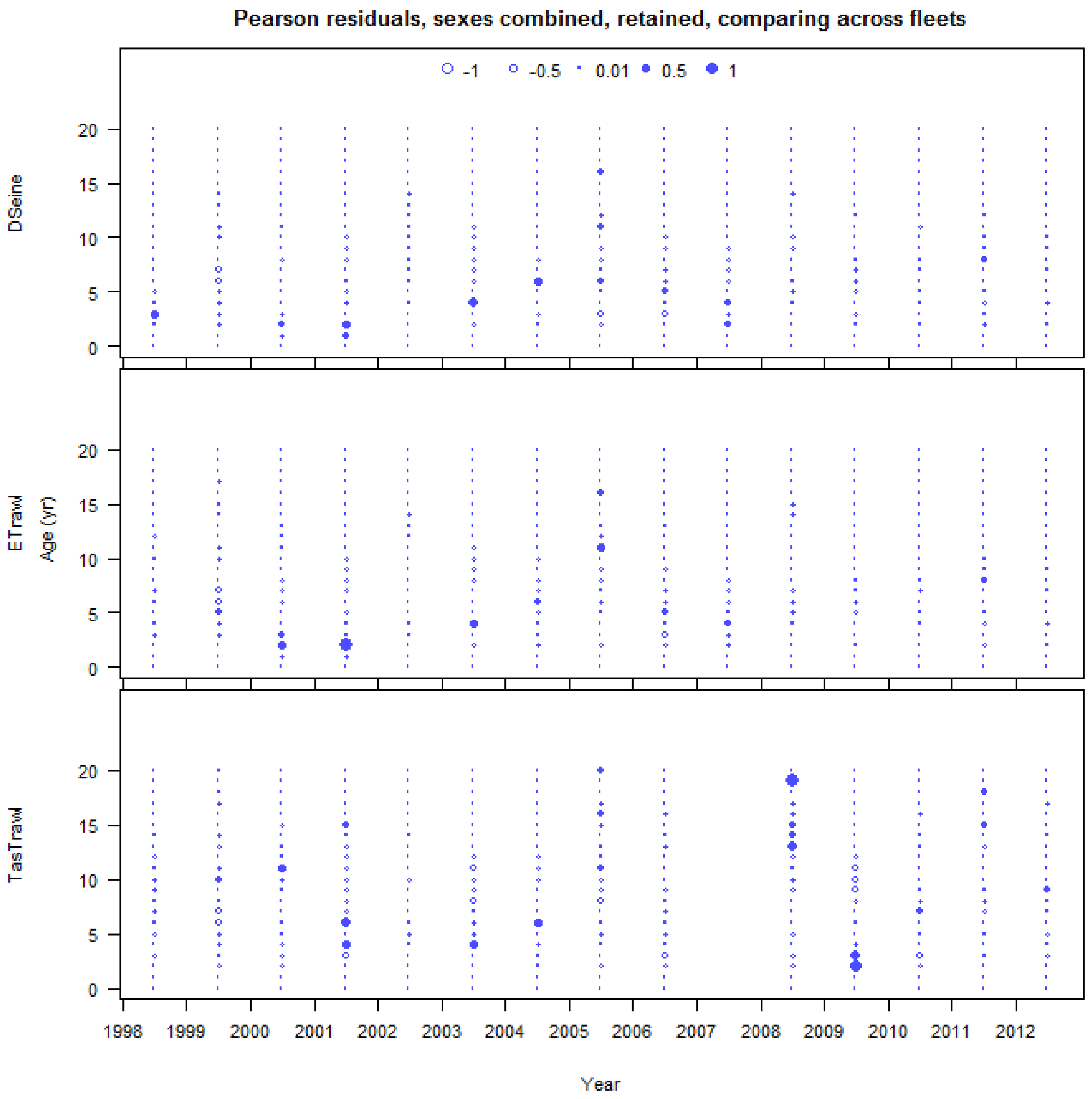
Apx Figure 9.17. Tiger flathead implied age composition fits: eastern trawl discarded.



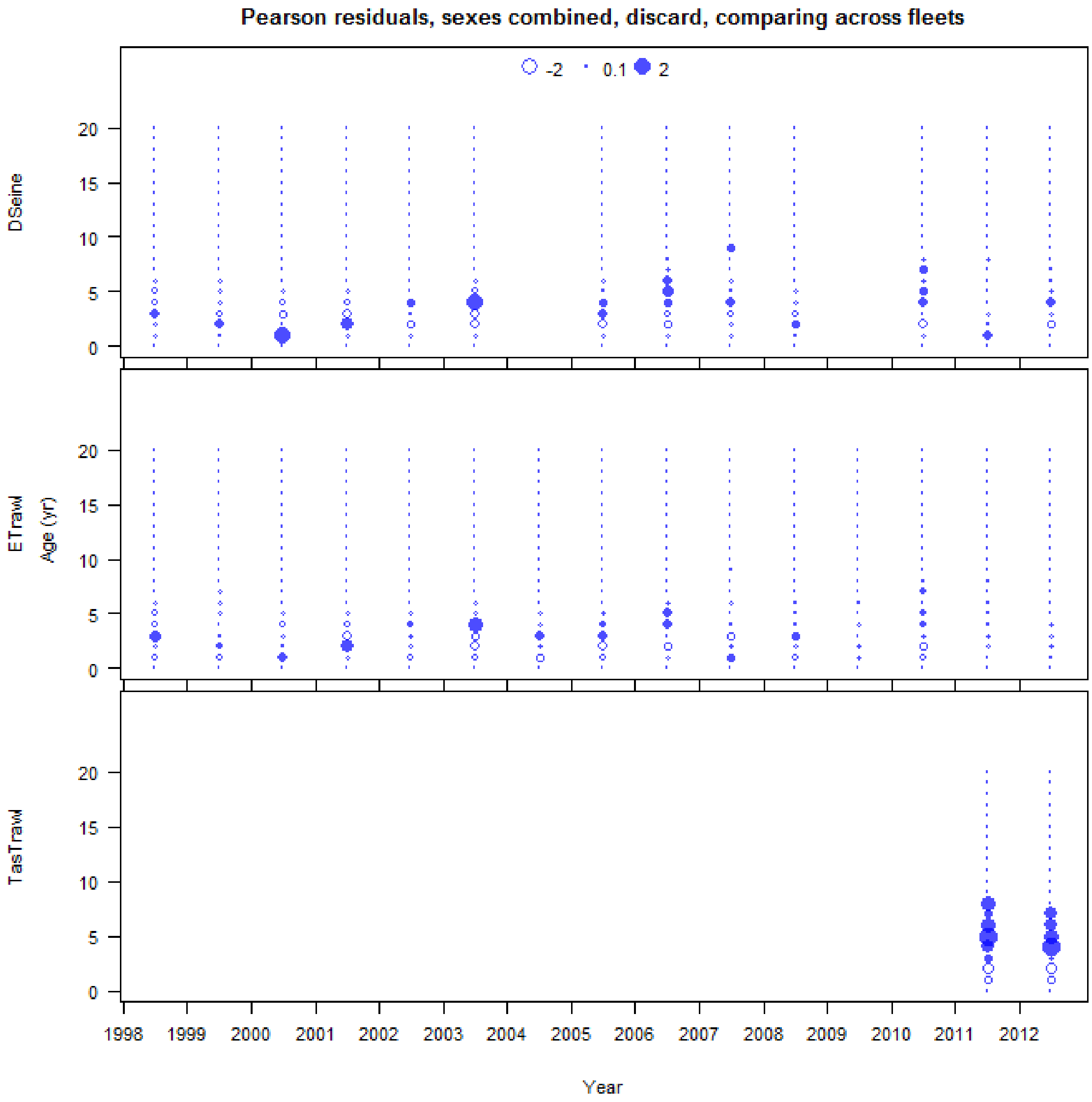
Apx Figure 9.18. Tiger flathead implied age composition fits: Tasmanian trawl retained.



Apx Figure 9.19. Tiger flathead implied age composition fits: Tasmanian trawl discarded.



Apx Figure 9.20. Residuals from the annual implied age compositions (retained) for tiger flathead displayed by year and fleet.



Apx Figure 9.21. Residuals from the annual implied age compositions (discarded) for tiger flathead displayed by year and fleet.

10. Tiger flathead (*Neoplatycephalus richardsoni*) stock assessment based on data up to 2012 [6]

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10.1 Summary

This document updates the 2010 assessment of tiger flathead (*Neoplatycephalus richardsoni*) to provide estimates of stock status in the SESSF at the start of 2014. This assessment was performed using the stock assessment package Stock Synthesis (version SS-V3.24f). The 2010 stock assessment has been updated with the inclusion of data up to the end of 2012, comprising an additional 3 years of catch, discard, CPUE, length and age data and ageing error updates and incorporation of survey results from the Fishery Independent Survey (winter). A range of sensitivities were explored, including incorporation of the summer fishery independent survey results for 2008, 2010 and 2012, and estimating recruitment to 2007 instead of 2009.

The base-case assessment estimates that current spawning stock biomass is 50% of unexploited stock biomass (SSB_0). Under the 20:35:40 harvest control rule the 2014 recommended biological catch (RBC) is 3,428 t and the long term yield (assuming average recruitment in the future) is 2,753 t. The average RBC over the three year period 2014-2016 is 3,334 t and over the five year period 2014-2018, the average RBC is 3,252 t.

Exploration of model sensitivity showed a variation in spawning biomass from 36% to 66% of SSB_0 when natural mortality was fixed at values of 0.2 and 0.35 respectively. When recruitment is only estimated to 2007, excluding the above average recruitment estimates in 2008 and 2009, the spawning biomass was estimated to be 40% of SSB_0. For all other sensitivities explored, the variation in spawning biomass was much narrower, ranging between 47% and 52%.

10.2 Introduction

10.2.1 ***The Fishery***

Tiger flathead have been caught commercially in the south eastern region of Australia since the development of the trawl fishery in 1915. They are endemic to Australian waters and are caught mainly on the continental shelf and upper slope waters from northern NSW to Tasmania and through Bass Strait. Historical records (e.g. Fairbridge, 1948; Allen, 1989; Klaer, 2005) show that steam trawlers caught tiger flathead from 1915 to about 1960. A Danish seine trawl fishery developed in the 1930s (Allen, 1989) and continues to the present day. Modern diesel trawling commenced in the 1970s.

10.2.2 ***Previous Assessments***

Prior to 2001, the previous quantitative assessment for tiger flathead was from the late 1980s (Allen, 1989). In that report, the assessment for tiger flathead was conducted based on catch and

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[6] Paper presented at the Shelf RAG meeting November2014

effort data using a surplus production model. The estimate of Maximum Sustainable Yield, *MSY*, for NSW and eastern Bass Strait was about 2,500 t.

Between 1989 and 2001, assessments of tiger flathead involved examination of trends in catches, catch rates, and age and length data, but no quantitative assessments were undertaken. Assessments from 1993 to 2001 can be found in the annual reports of SEFAG (the South East Fishery Assessment Group). For example, the 1993 assessment noted that tiger flathead catches from south-east Tasmanian waters contained higher proportions of larger, older fish than that those from eastern Bass Strait. This suggested that tiger flathead resources off Tasmania were either more lightly fished than those in the main fishing areas, or that there was a separate stock with different population characteristics off Tasmania.

During the period 2001-2004, data for tiger flathead were collated, summarized and presented at workshops (see Cui *et al.* (2004) for a detailed summary of these workshops and the analyses presented to them). These workshops led to revisions of the data series, analyses of the data, and to suggestions for revisions to the data sets and research priorities. The 2004 assessment (Cui *et al.*, 2004) used 89 years (1915–2003) of data to estimate the virgin spawning stock biomass and the 2004 spawning stock biomass relative to that in 1915 and provided, for the first time, a complete picture of the dynamics of the tiger flathead fishery.

A number of changes to both the input data and some model structural changes were made and presented in the assessments developed in 2005 (Punt 2005a, Punt 2005b). These assessments considered tiger flathead caught off eastern Tasmania in SEF zone 30 as either separate to, or part of the same stock in zones 10 (E NSW), 20 (E Bass Strait) and 60 (Bass Strait) combined. In the scenario where eastern Tasmanian flathead are part of the same stock, a separate fleet was constructed to account for catches made there. Modifications to estimates of historical catches from Klaer (2005) were incorporated into catch series used in the assessments. Length-frequency data for 1945-1967 and 1971-1984 were obtained, and uncertainty in discard rates was estimated using a bootstrap procedure.

Part of the intention for the 2006 assessment (Klaer, 2006a) was initially to duplicate as far as possible the assessment results from 2005 (Punt, 2005a, Punt 2005b) while implementing the assessment using the Stock Synthesis 2 (SS2) framework. The same assumptions were made about stock structure, i.e. tiger flathead off eastern Tasmania may or may not be in the same stock as those off NSW and Victoria. Steepness was treated as an estimable parameter and annual age frequencies were added directly into the model as samples independent to length frequencies. The 2006 Shelf RAG selected the model that treated Tasmanian trawl as a separate fleet fishing the same east coast stock as the most appropriate base case.

The 2009 assessment (Klaer, 2009) moved the model from Stock Synthesis version SS-V2.1.21 (June 2006) to Stock Synthesis version SS-V3.03 (May 2009). Major changes to previous assessments were the use of age-length data to estimate growth parameters, correction to discard estimation for steam trawl, allowing selectivity change in 1985 for diesel trawl and 1978 for Danish seine, and estimation of recruitment 3 years prior to the last year (2005) for the 2009 assessment that used data to the end of 2008.

The most recent full quantitative assessment for tiger flathead was performed in 2010 (Klaer, 2010) using Stock Synthesis version SS-V3.11a, (Methot September 2010). For the 2010 assessment, changes were made to the treatment of discards prior to 1980, an additional growth parameter was estimated and the assumed value for natural mortality, *M*, was changed from 0.22 to 0.27.

10.2.3 *Modifications to the previous assessment*

The 2013 assessment uses the current version of Stock Synthesis, version SS-V3.24f, (Methot August 2012). Structural changes between these two versions of Stock Synthesis resulted in minor changes to the results. These changes appear to be driven by differences in the recruitment deviations, due to minor changes in the internal workings of stock synthesis that are well within the range of uncertainty. This is due to a reduction to the “robustify” factor in the spawner-recruitment relationship, which in some circumstances is enough to produce slightly more recruits for a given spawning biomass and steepness.

The number of growth parameters estimated and assumptions about mortality and early discarding rates in this assessment are identical to the 2010 assessment (Klaer, 2010). Three growth parameters are estimated (CV, K and $l_{\min}$), natural mortality is assumed to be 0.27 and the discarded catch for steam trawl and for Danish seine prior to 1960 is assumed to be 20% of the retained catch, which translates to a discard ratio (disc/[ret+disc]) of 17%.

An abundance index is now available from the fishery independent survey (FIS) for both the winter and summer surveys for three years: 2008, 2010 and 2012 (Knuckey *et al.*, 2013). Results from three years of the winter survey are included as an additional abundance index in the 2013 assessment. As the summer fishery independent survey is unlikely to be continued into the future, these summer results were only included as a sensitivity to the base case.

Updates to data used in the previous assessment resulted from improvements in the automatic processing of data and filtering of records. These data updates produced minor modifications to some of the length frequency distributions from 1992 onwards and minor modifications to estimates of discards. An updated estimate of the ageing error matrix constructed from the new ageing data was used. As in the 2010 assessment, age-at-length frequency distributions were only used when the gender was known. The only changes to age-at-length data were the addition of three years of new data from 2010 to 2012. Minor revisions to the 2007, 2008 and 2009 state catch data used in the 2010 assessment were incorporated using more accurate data which became available after the 2010 assessment was completed.

The usual process of bridging to a new model by adding new data piecewise and analysing which components of the data could be contributing to changes in the assessment outcome was conducted (Day and Klaer, 2013).

10.3 Methods

10.3.1 *The data and model inputs*

10.3.1.1 Biological parameters

As male and female tiger flathead have different growth patterns (females are substantially larger), a two-sex model has been used.

The parameters of the von Bertalanffy growth equation are estimated within the model-fitting procedure from age-at-length data. This approach accounts for the impact of gear selectivity on the age-at-length data collected from the fishery and the impact of ageing error.

Estimates of the rate of natural mortality, M, reported in the literature vary from 0.21 to 0.46 yr^{-1}. This assessment uses a value of 0.27 yr^{-1} as the base-case estimate of M as used in the previous assessment (Klaer 2010) and agreed to by Shelf RAG. Sensitivity to this value is tested. The steepness of the stock-recruitment relationship, *h*, is estimated by the model, and for the base case is estimated to be 0.59.

Three growth parameters are estimated (CV, *K* and l_{min}), with only one growth parameter fixed (l_{max} = 55.9), with this valued based on the estimate of l_∞ obtained by Punt(2005a) by fitting von Bertalanffy growth curves to data from SESSF Zones 10 and 20 (NSW and eastern Bass Strait). Female tiger flathead become sexually mature at about three years of age, which corresponds to a length of about 30 cm (Klaer 2010). Maturity is modelled as a logistic function, with 50% maturity at 30 cm. Fecundity-at-length is assumed to be proportional to weight-at-length.

The parameters of the length-weight relationship are the same as those used in the previous assessment a=5.88 x 10^{-6}, b=3.31 (Klaer 2010), with these parameters originally obtained by fitting von Bertalanffy growth curves to data from SESSF Zones 10 and 20, NSW and eastern Bass Strait, (Punt 2005a).

10.3.1.2 Fleets

The assessment data for tiger flathead have been separated into four ‘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.

1. Steam trawl – steam trawlers (1915 – 1961)
2. Danish seine – Danish seine from NSW, eastern Victoria and Bass Strait (1929 – 2012)
3. Eastern trawl – diesel otter trawlers from NSW, eastern Victoria and Bass Strait (1971 – 2012)
4. Tasmanian trawl – diesel otter trawlers from eastern Tasmania (1985 – 2012)

10.3.1.3 Landed catches

A landed catch history for tiger flathead, separated into the four ‘fleets’, is available for all years from 1915 to 2012 (Table 10.1, Figure 9.1 and Figure 10.2).

Klaer (2005) describes the sources of information used to construct the historical landed catch record for each of the fleets to 1986. Quotas were introduced into the fishery in 1992, and from then onwards, records of landed catches as well as estimated catches from the logbook are available. The landings data give a more accurate measure of the landed catch than do the logbook data, but the logbook data contain more detail. For example, it is usually possible to separate logbook records, but not landing records, by fleet. The logbook catches for each fleet from 1992 onwards have been scaled up by the ratio of landed catches to logbook catches in each year (Thomson 2002). Prior to 1992, the unscaled logbook catches are used.

In 2007 the quota year was changed from calendar year to the year extending from 1 May to 30 April, however the assessment is based on calendar years. All catches for recent years continue to be those made by calendar year, which may conflict with the fishing year TACs.

Small quantities of tiger flathead are caught in state waters. NSW and Victorian state catches have been added to the eastern trawl fleet, and Tasmanian state catches have been added to the Tasmanian fleet.

In order to calculate the Recommended Biological Catch (RBC) for 2014, it is necessary to estimate the Commonwealth calendar year catch for 2013. The TAC was unchanged from 2012 to 2013 and the state catches are unknown for 2013. Hence, assuming that the same ratio of the TAC will be caught in 2013 as in 2012, with the same state catches as 2012, is equivalent to assuming that the catch in 2013 is identical to the 2012 catch. This gives estimated 2013 catches for the eastern fleet, the Tasmanian fleet, and the Danish seine fleet of 1,423 t, 202 t and 1,439 t, respectively.

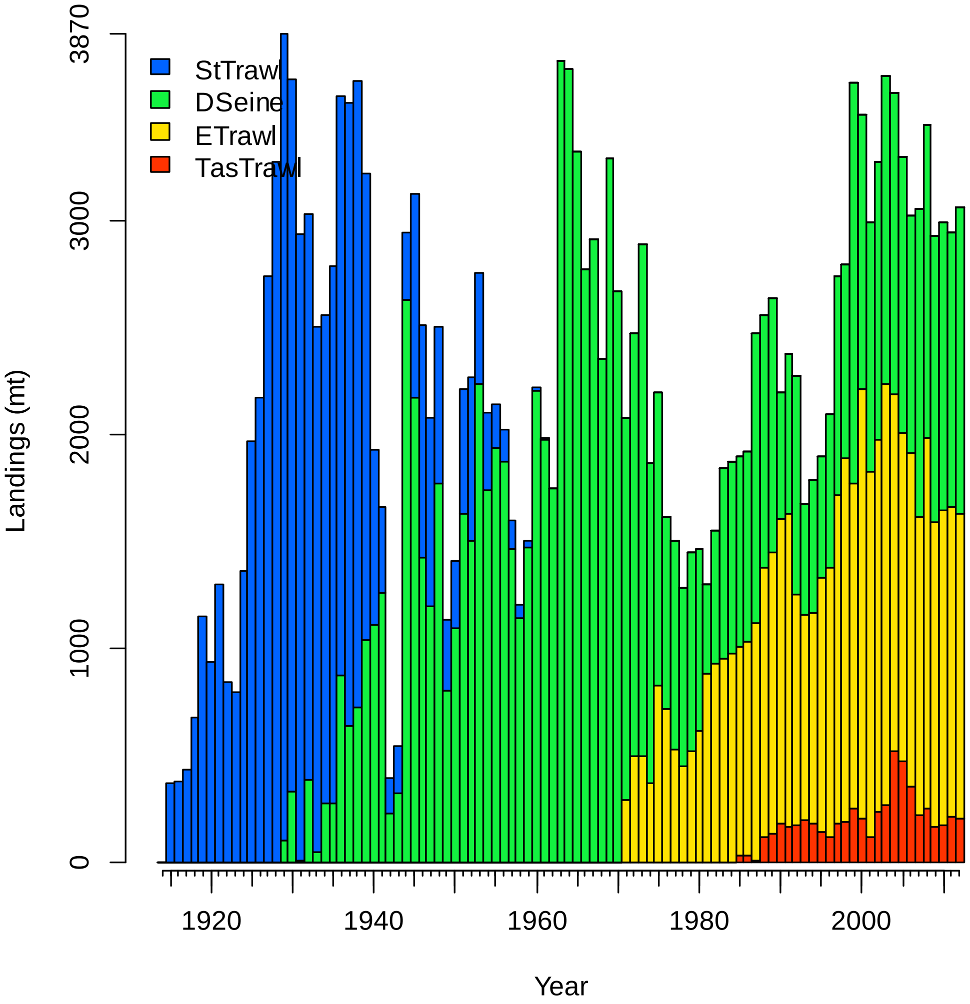

Figure 10.1. Total landed catch of tiger flathead by fleet (stacked) from 1915-2012.

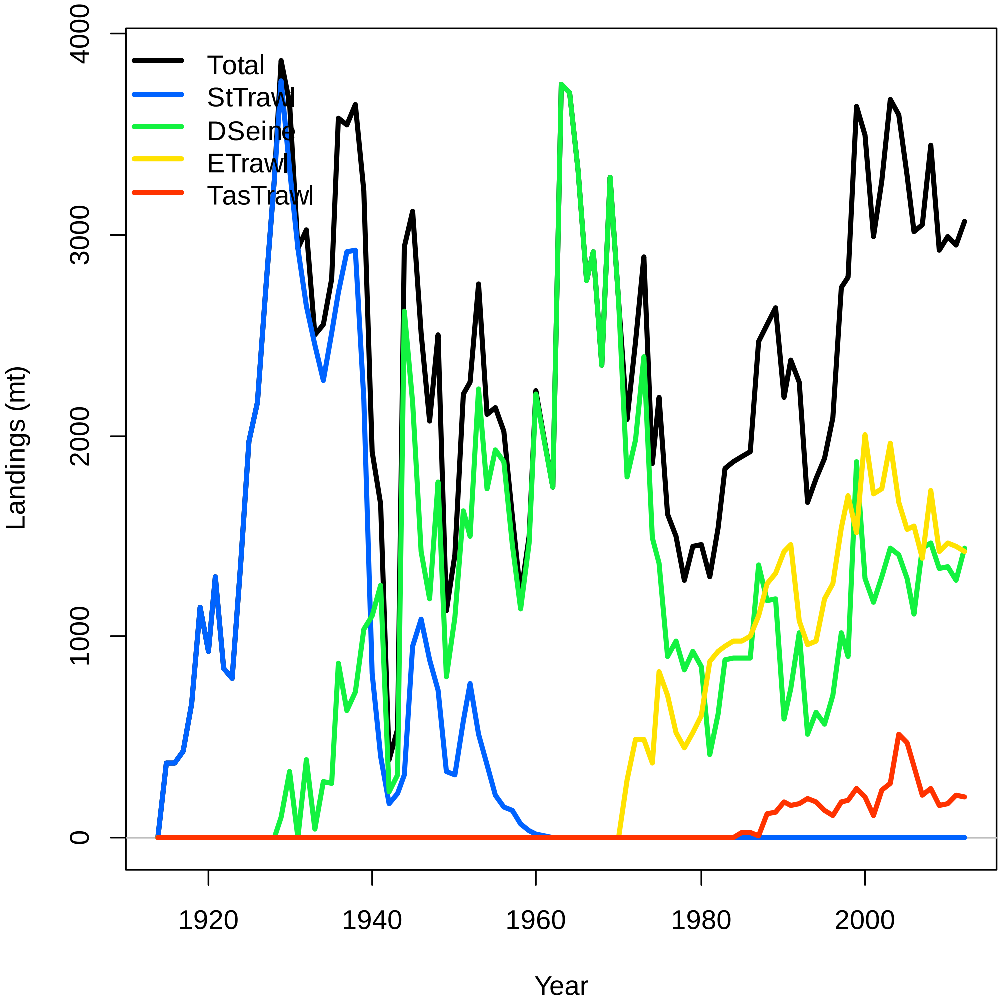

Figure 10.2. Total landed catch of tiger flathead by fleet from 1915-2012.

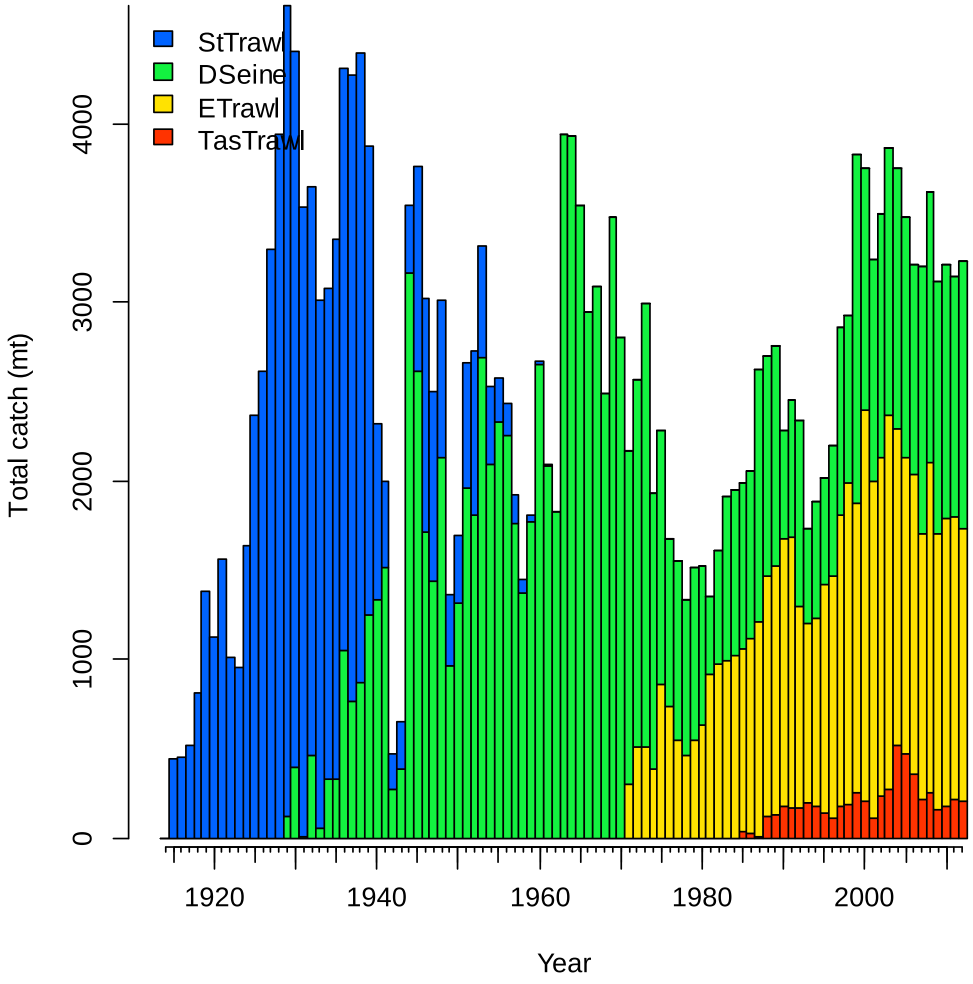

Figure 10.3. Total catch (including discards) of tiger flathead by fleet (stacked) from 1915-2012.

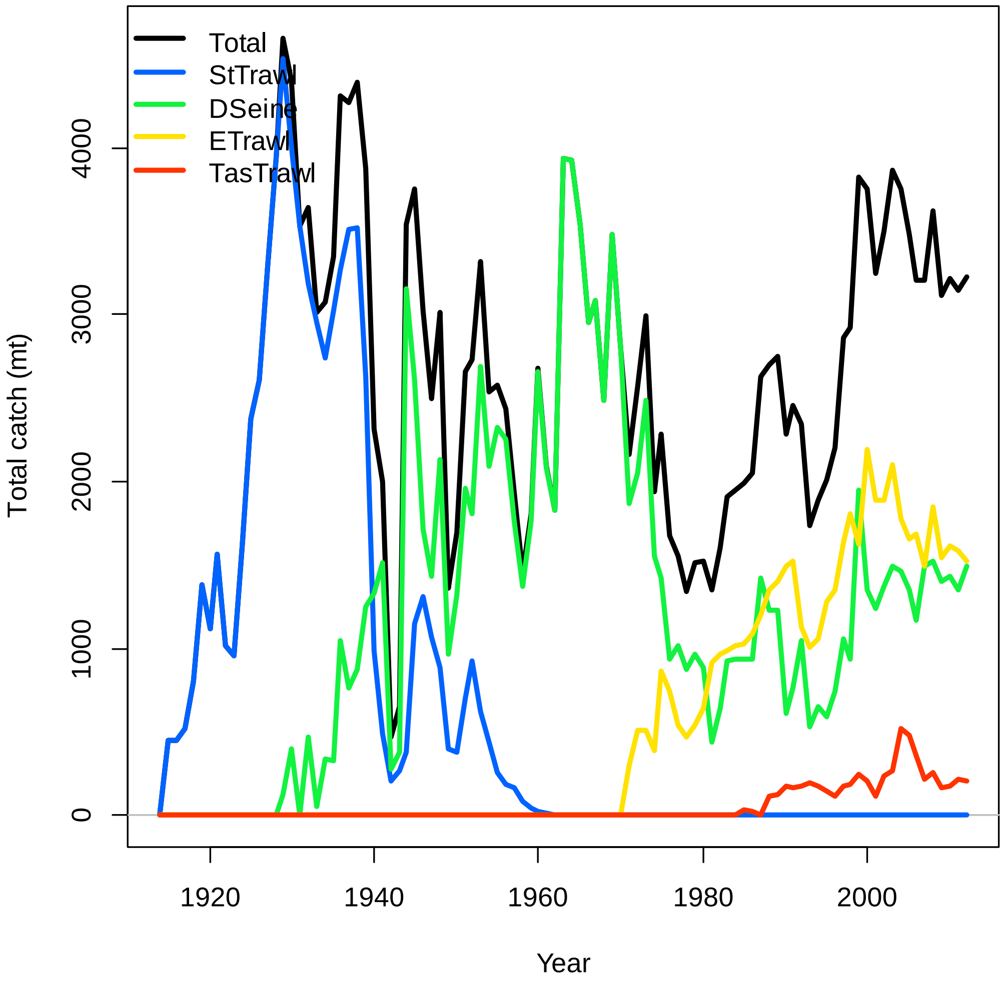

Figure 10.4. Total catch including discards of tiger flathead by fleet from 1915-2012.

10.3.1.4 Discard rates

Information on the discarding rate of tiger flathead was available from the PIRVic-run Integrated Scientific Monitoring Program (ISMP) for 1992-2006. From 2007 the ISMP was run by AFMA. The discard data are summarised in Table 10.3. Generally, discards of tiger flathead were in the order of 8% for Danish seine, 10% for eastern trawl and 1% for Tasmanian trawl.

There is limited information on discarding for the early steam trawl fleet (1915-61) and the early Danish seine fleet (1929-67). However, it is known that total discards for all species from steam trawl in the 1920s was in the order of 20% of the retained catch (Klaer, 2001). As there is no way to determine the species catch composition of the discards, Shelf RAG made the decision to apply this ratio to tiger flathead, which translates to a discard fraction of 17%. For the base-case, all steam trawl (1915-1961) and early Danish seine (1929-1960) were assigned a constant discard fraction of 17% to apply equally to all selected fish (Figure 10.5). The discard fraction for Danish seine from 1961 to present was set using recent observed discard ratios since 1994. Recent observations were used to estimate discard fractions for the east coast and Tasmanian diesel trawl fleets.

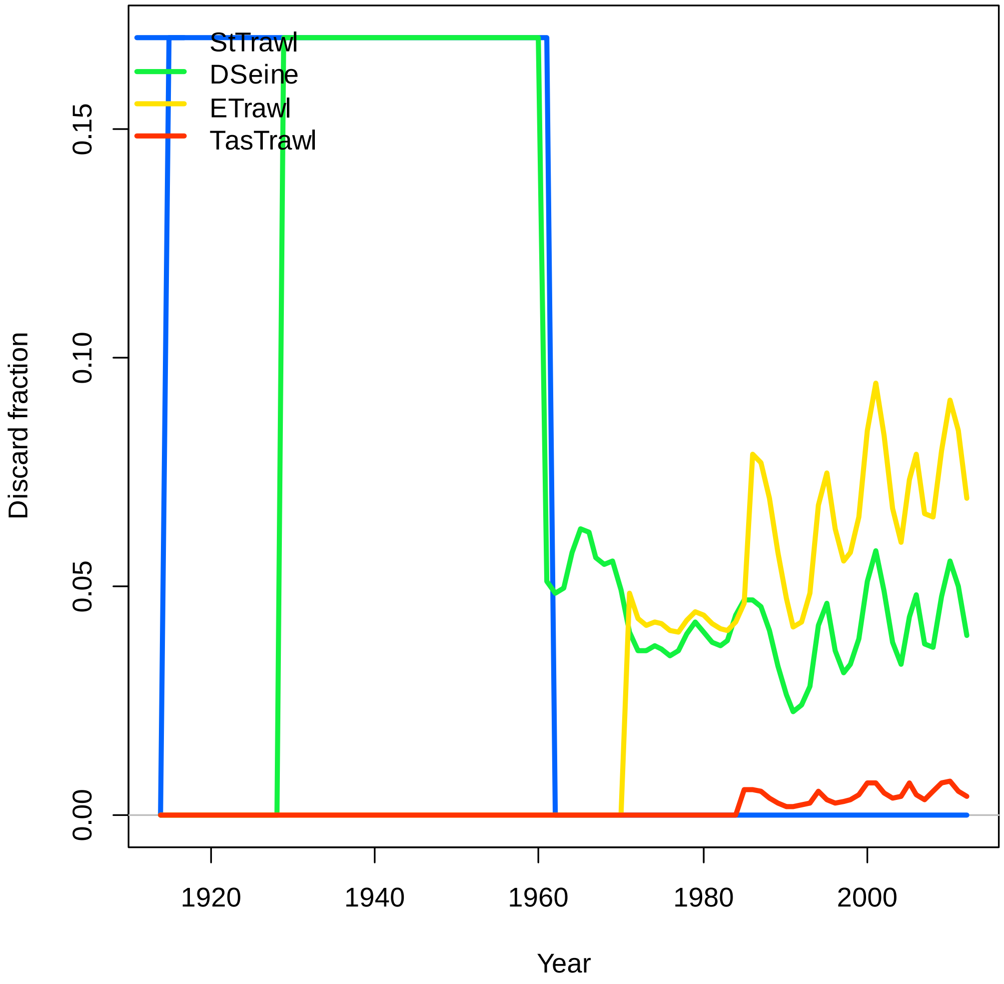

Figure 10.5. Model estimates of discard fractions per fleet.

10.3.1.5 Catch rate indices

A standardised catch rate (CPUE) index is available for the historical steam trawl fleet for the years 1920-21, 1937-42, and 1952-57 (Klaer, 2006b, Table 4). An unstandardised catch rate index for early Danish seine has been used in tiger flathead assessments since Cui *et al.* (2004) (Table 10.5). Catch and effort information from the SEF1 logbook database from the period 1986-2012 were standardised using GLM analysis to obtain indices of relative abundance for recent Danish seine, eastern and Tasmanian trawl fleets (Haddon, 2013; Table 10.6).

10.3.1.6 Age composition data

An estimate of the standard deviation of age reading error was calculated by Andre Punt (pers. comm., 2013) from data supplied by Kyne Krusic Golub of Fish Ageing Services (Table 10.8).

Age-at-length measurements, based on sectioned otoliths, provided by Fish Ageing Services, were available for the years 1998, 2000-2012 for the Danish seine fleet; 1998-2002, 2004-2012 for the eastern diesel trawl fleet, and 1999, 2000, 2002, 2005, 2006, 2008, 2010 and 2012 for the Tasmanian diesel trawl fleet (Table 10.9). Years for which the total number of fish aged was less than 10 were not used. No age information was available for the earlier fleets.

10.3.1.7 Length composition data

Length composition information for the retained component of the steam trawl fleet catch is available from 1945 to 1958, for the early Danish seine fleet from 1945 to 1967, and for eastern diesel trawl fleet from 1965 to 1990 (Table 10.10). On board length samples from the ISMP provide discard length frequencies for Danish seine, eastern trawl and Tasmanian trawl since 1992 (Table 10.11), and both port and onboard sampling was used as the source of retained length samples for those fleets since 1992 (Table 10.10).

In contrast to the procedure adopted for the 2010 assessment, but in line with current standard practice, and at the request of Shelf RAG, both port and onboard length frequencies are used when they are both available since 1992. The on board retained lengths were only included as a sensitivity in the previous assessment.

10.3.2 ***Stock assessment method***

10.3.2.1 Population dynamics model and parameter estimation

A two-sex stock assessment for tiger flathead 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 allows multiple fishing fleets and can be fitted simultaneously to the range of data available for tiger flathead. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, are given fully in the SS technical description (Methot, 2005) and are not reproduced here. Some key features of the population dynamics model underlying Stock Synthesis which are pertinent to this assessment are discussed below.

A single stock of tiger flathead is assumed to occur from zone 10 off Sydney, through zone 20 (eastern Bass Strait), zone 60 (Bass Strait) and zone 30 (eastern Tasmania). The stock is assumed to be unexploited at the start of 1915 when the steam trawl fishery commenced. Catches prior to this are thought to have been minimal. The assessment models the impact of four fishing fleets on the tiger flathead population. The input CVs of the catch rate indices for the pre-1986 fleets were set to fixed values which are largely arbitrary due to the process of iterative reweighting. For the post-

1986 fleets, the standard errors calculated from the catch-rate standardisation are used in the model (Haddon, 2013). Iterative reweighting is used to adjust the standard errors so their average equals those estimated by the model.

Selectivity is assumed to vary among fleets, but the selectivity pattern for each fleet is modelled as time-invariant except for two changes. The selectivity for Danish seine is allowed to change in 1978, and eastern diesel trawl in 1985. Selectivity is modelled as a function of length. Separate logistic functions are used for the selectivity ogives for each fleet. The two parameters of the selectivity function for each fleet are estimated within the assessment. Retention is also defined as a logistic function of length, and the inflection and slope of this function are estimated for those fleets where discard information is available (Danish seine, eastern trawl and Tasmanian trawl).

The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The natural mortality for the base-case analysis is fixed to 0.27 yr^{-1} as in the previous assessment (Klaer, 2010).

Recruitment is assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, h. Steepness for the base-case analysis is estimated at 0.59. Deviations from the average recruitment at a given spawning biomass (recruitment deviations) are estimated for 1915 to 2009. The value of the parameter determining the magnitude of the process error in annual recruitment, σ_R , was set equal to 0.35, which is greater than the amount of error estimated by the model.

A plus-group is modelled at age 20. Growth of tiger flathead is 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 determined from fitting the growth curve within the assessment using the age-at-length data. Differences in growth by gender are modelled.

10.3.2.2 Relative data weighting

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

Data series with a large number of individual measurements such as length or weight frequencies tend to swamp the combined likelihood value with poor fits to noisy data when fitting is highly partitioned by area, time or fishing method. These misfits to small samples mean that simple series such as a single CPUE might be almost completely ignored in the fitting process. This model behaviour is not optimal, because we know, for example, that the CPUE values are in fact derived from a very large number of observations. If there is reason to believe that the length and age data are noisy at the level fitted, it has been recommended in similar circumstances (e.g. see sablefish: Schirripa 2007, pacific sardine: Hill *et. al* 2005) that the length and age data be down weighted to allow the model to better fit other data sources.

All sample sizes for length frequency data greater than 200 are set to 200. This is because the appropriate sample size for length frequency data is probably related more closely to the number of shots sampled, rather than the number of fish measured. The length frequency data is given too much weight relative to other data sources if the number of fish measured is used. The sample sizes for the recent fleets are also individually tuned so that the input sample size is equal to the effective sample size calculated by the model.

The overall unadjusted likelihood value for the base-case assessment is in the order of 14,000, with the age and length components making the greatest contributions (length about 7,500, age-at-length about 6,000) (Table 10.14). Other likelihood components are very much smaller. Of all the SESSF quota species, tiger flathead has the greatest amount of length and age composition data, particularly in the number of years where large samples were available. To reduce the tendency of the length and age data to swamp the likelihood function, both the age and length components were reduced by a factor of 10 for the base-case, which produces an overall adjusted likelihood value near 1,500. This weighting procedure is identical to that used in the previous assessment (Klaer, 2010).

10.3.2.3 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 2006-2013. The HSF uses harvest control rules to determine a recommended biological catch (RBC) for each stock in the SESSF quota management system. Each stock is assigned to one of four Tier levels depending on the basis used for assessing stock status or exploitation level for that stock. Tiger flathead is classified as a Tier 1 stock as it has an agreed quantitative stock assessment.

The Tier 1 harvest control rule specifies a target and a limit biomass reference point, as well as a target fishing mortality rate. Since 2005 various values have been used for the target and the breakpoint in the rule. In 2009, AFMA directed that the 20:40:40 (B_{lim}: B_{MSY}: F_{targ}) form of the rule is used up to where fishing mortality reaches F_{48}. Once this point is reached, the fishing mortality is set at F_{48}. Day (2008) determined that for most SESSF stocks where the proxy values of B_{40} and B_{48} are used for B_{MSY} and B_{MEY} respectively, this form of the rule is equivalent to a 20:35:48 (B_{lim}: Inflection point: F_{targ}) strategy.

Previously, a preliminary economic analysis was used as a basis for using a 20:35:41 rule for tiger flathead (Klaer 2010). As steepness is an estimated parameter in the tiger flathead assessment, it is one of the few SESSF stocks where an MSY estimate may be taken from the base-case stock assessment. SESSFRAG in 2010 determined that a tiger flathead RBC may be calculated using a rule that incorporates application of the default 1.2 multiplier to the MSY depletion level to determine a minimum value for an MEY depletion level. It was also agreed at SESSFRAG that if this level was below 40% of B_0, that the 40% level be used to generate an RBC to maintain the biological precaution implicit in the 40% level. For the 2013 assessment, Shelf RAG agreed that the default RBC for tiger flathead is calculated under the 20:35:40 strategy.

10.3.2.4 Sensitivity tests and alternative models

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

1. $M = 0.2$ yr^{-1}.
2. $M = 0.35$ yr^{-1}.
3. 50% maturity at 27cm.
4. 50% maturity at 33 cm.
5. σ_R set to 0.3.

6. σ_R set to 0.4.
7. Double the weighting on the length composition data.
8. Halve the weighting on the length composition data.
9. Double the weighting on the age-at-length data.
10. Halve the weighting on the age-at-length data.
11. Double the weighting on the survey (CPUE) data.
12. Halve the weighting on the survey (CPUE) data.
13. Set age and length weighting to 1 rather than 0.1.
14. Derive the RBC using the 20:35:48 harvest control rule.
15. Fix steepness (h) at 0.75 and estimate natural mortality (M).
16. Include the summer fishery independent survey (FIS) abundance index
17. Estimate recruitment only until 2007 (exclude the 2008 and 2009 recruitment estimates).

The results of the sensitivity tests are summarized by the following quantities (Table 10.13):

1. SSB_0: the average unexploited female spawning biomass.
2. SSB_{2014}: the female spawning biomass at the start of 2014.
3. SSB_{2014}/SSB_0: the female spawning biomass depletion level at the start of 2014.
4. Steepness: the estimated steepness of the stock-recruitment relationship.
5. SSB_{MSY}/SSB_0: the female spawning biomass depletion level at maximum sustainable yield (MSY).
6. RBC_{2014}: the recommended biological catch (RBC) for 2014.
7. $\mathrm{RBC}_{2014\text{-}6}$: the mean RBC over the three years from 2014-2016.
8. $\mathrm{RBC}_{2014\text{-}8}$: the mean RBC over the five years from 2014-2018.
9. $\mathrm{RBC}_{\mathrm{longterm}}$: the longterm RBC.

The RBC values are calculated for tuned models only, which are the base case and the final sensitivity where recruitment is estimated until 2007 instead of 2009 (sensitivity 17). When recruitment is estimated to 2009, the last two recruitment events are estimated to be above average, with a particularly large recruitment estimated in 2008. While these most recent recruitment events seem to be well estimated, the estimated size of these recruitment events could be modified by additional data. The sensitivity with recruitment only estimated to 2007 assumes that recruitment in 2008 and 2009 is average.

To explore the impact of the last two above average estimated recruitment events on the base case (recruitments estimated in 2008 and 2009), sensitivity 17 was explored in more detail than the other sensitivities. In addition to tuning this sensitivity, the impacts of applying a multi-year RBCs (or TACs) derived from the base case on this lower recruitment scenario were explored, for both the 20:35:48 and the 20:35:40 Harvest Control Rules. Multi-year RBCs were calculated by averaging the projected RBC from the base case for three years (2014-2016) or for five years (2014-2018) for both of these harvest control rules. The impacts of these multi-year RBCs on the base case were also explored for the 4 combinations obtained by combining both the 3 and 5 year means with the two Harvest Control Rules. These averaged RBCs were applied for the five year period 2014-2018 and then the RBC reverts to the projected RBC for the particular Harvest Control Rule for projections beyond 2018.

10.4 Results and discussion

10.4.1 *The base-case analysis*

10.4.1.1 Parameter estimates

Figure 9.2 shows the estimated growth curve for female and male tiger flathead. All growth parameters are estimated by the model except for l_{max} (parameter values are listed in Table 10.12).

Selectivity is assumed to be logistic for all fleets. The parameters that define the selectivity function are the length at 50% selection and the spread (the difference between length at 50% and length at 95% selection). Figure 10.7 shows the selectivity and retention functions for each fleet.

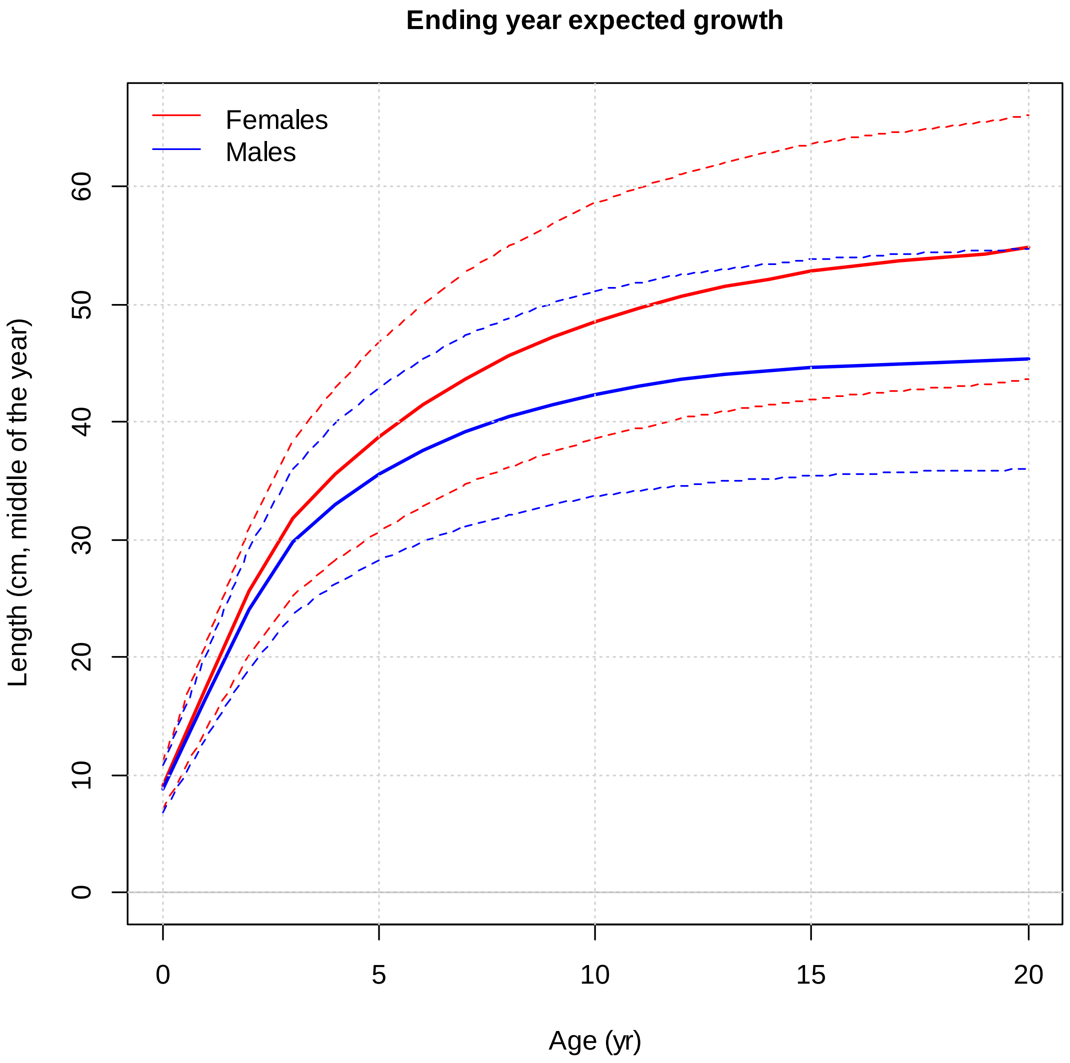

Figure 10.6. The model-estimated growth curves.

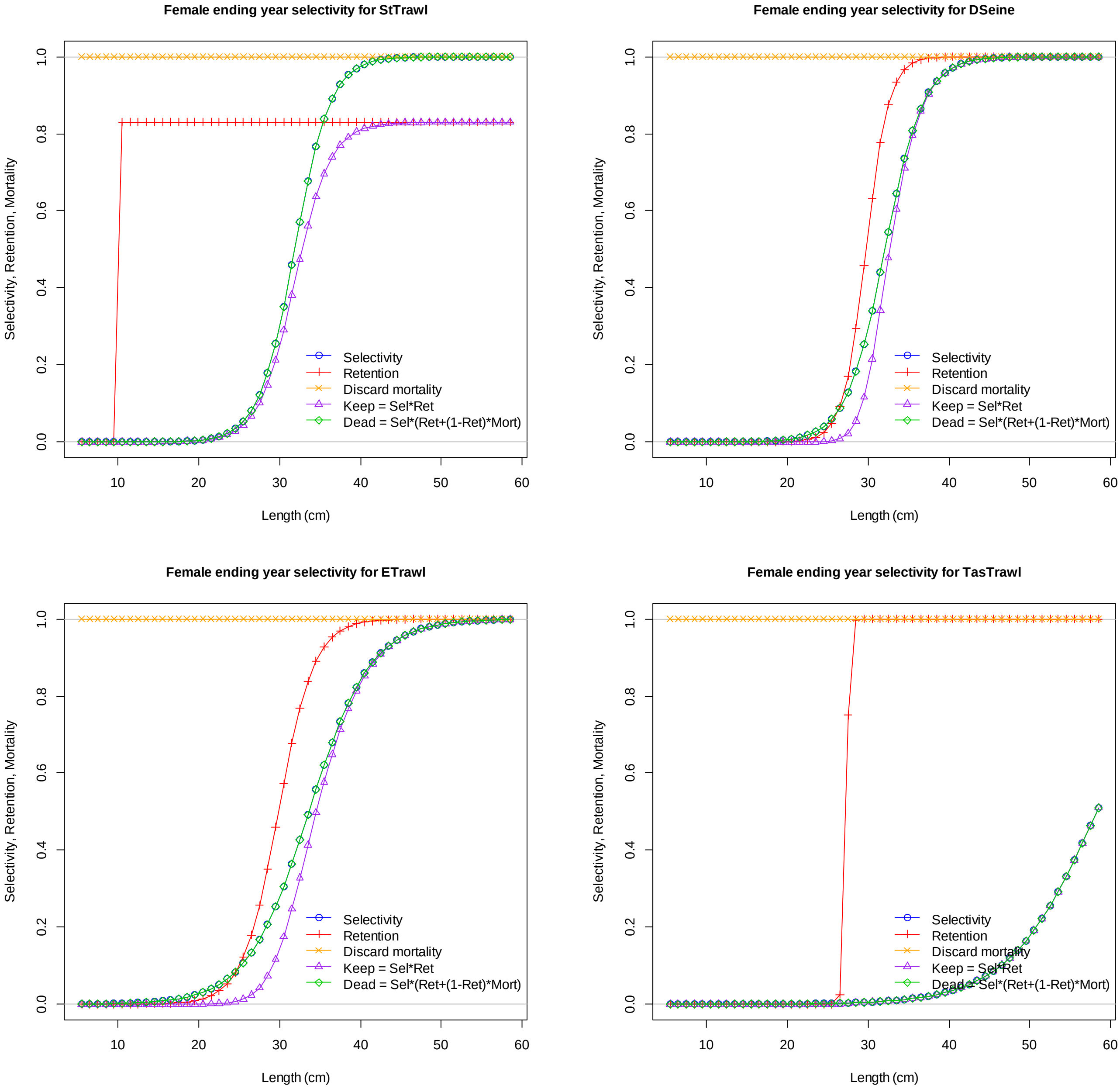

Figure 10.7. Selectivity (blue/green) and retention (red) functions for the four fleets.

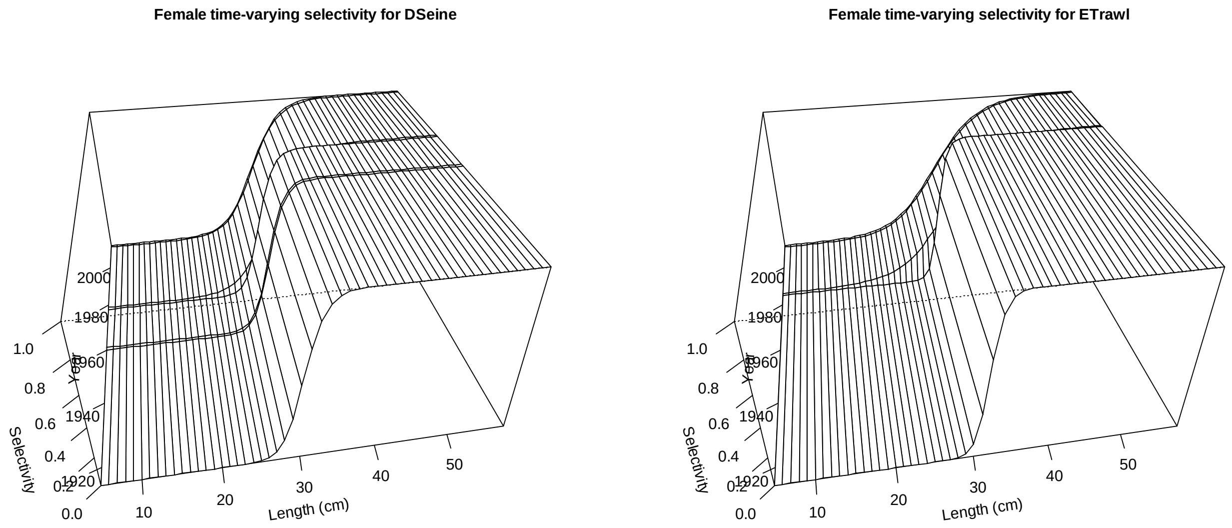

Figure 10.8. Time variation in selectivity for Danish seine and eastern diesel trawl.

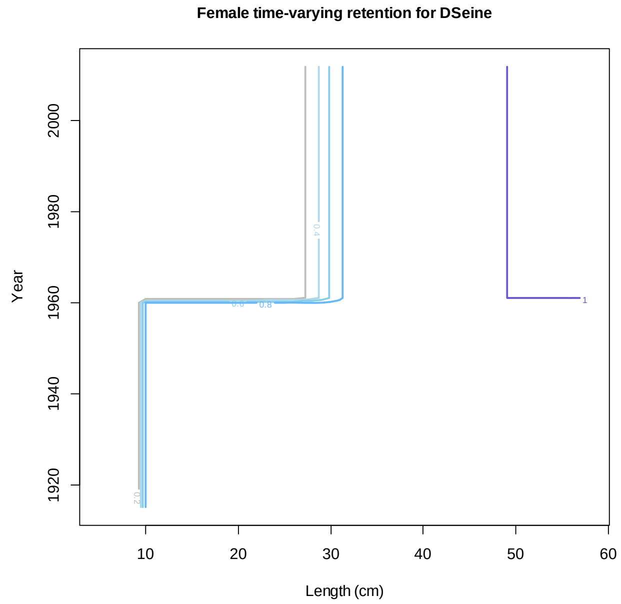

Figure 10.9. Time variation in retention for Danish seine.

10.4.1.2 Fits to the data

The fits to the catch rate indices (Figure 10.10) are variable in quality. The catch rate indices for the steam trawl fleet shows a considerable decline from 1915 to 1950, consistent with overexploitation during that time (see Fairbridge 1948, Klaer 2006b). The early Danish seine index from 1950 to 1978 was relatively flat or increasing over that period. Recent abundance indices from 1986 to present also show reasonably flat trends. The Tasmanian trawl fleet index is the worst fit for the recent indices, but the catch contribution by that fleet is also the smallest.

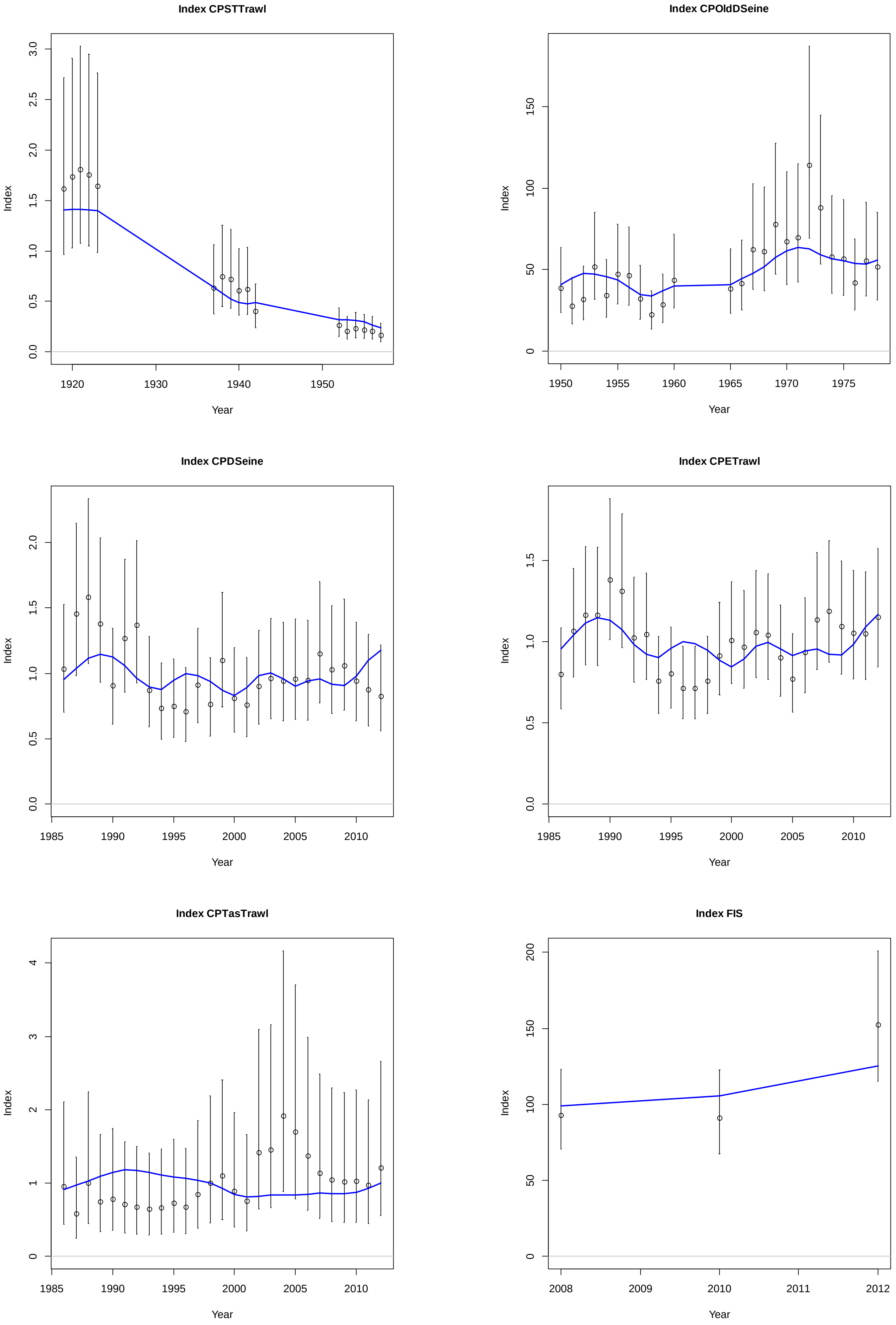

Figure 10.10. Observed (circles) and model-estimated (lines) catch rates vs year, with approx 95% asymptotic intervals.

The base-case model is able to mimic the retained length-frequency distributions adequately (Appendix A), with the exception of the Tasmanian trawl fleet, for which the actual sample sizes are relatively small. The fits to the historical steam trawl and early Danish seine fleets are better than those for the more recent data (except for steam trawl in 1957 and 1958). The number of fish measured for the historical data is generally very high, which leads to smoother observed distributions. The fits to the discarded length compositions are variable (Appendix A). This is not surprising, as the observed discard length frequencies are quite variable from year to year, and actual sample sizes are small in comparison to retained.

The implied fits to the age composition data are shown in Appendix B. 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 reasonably well for all three recent fleets.

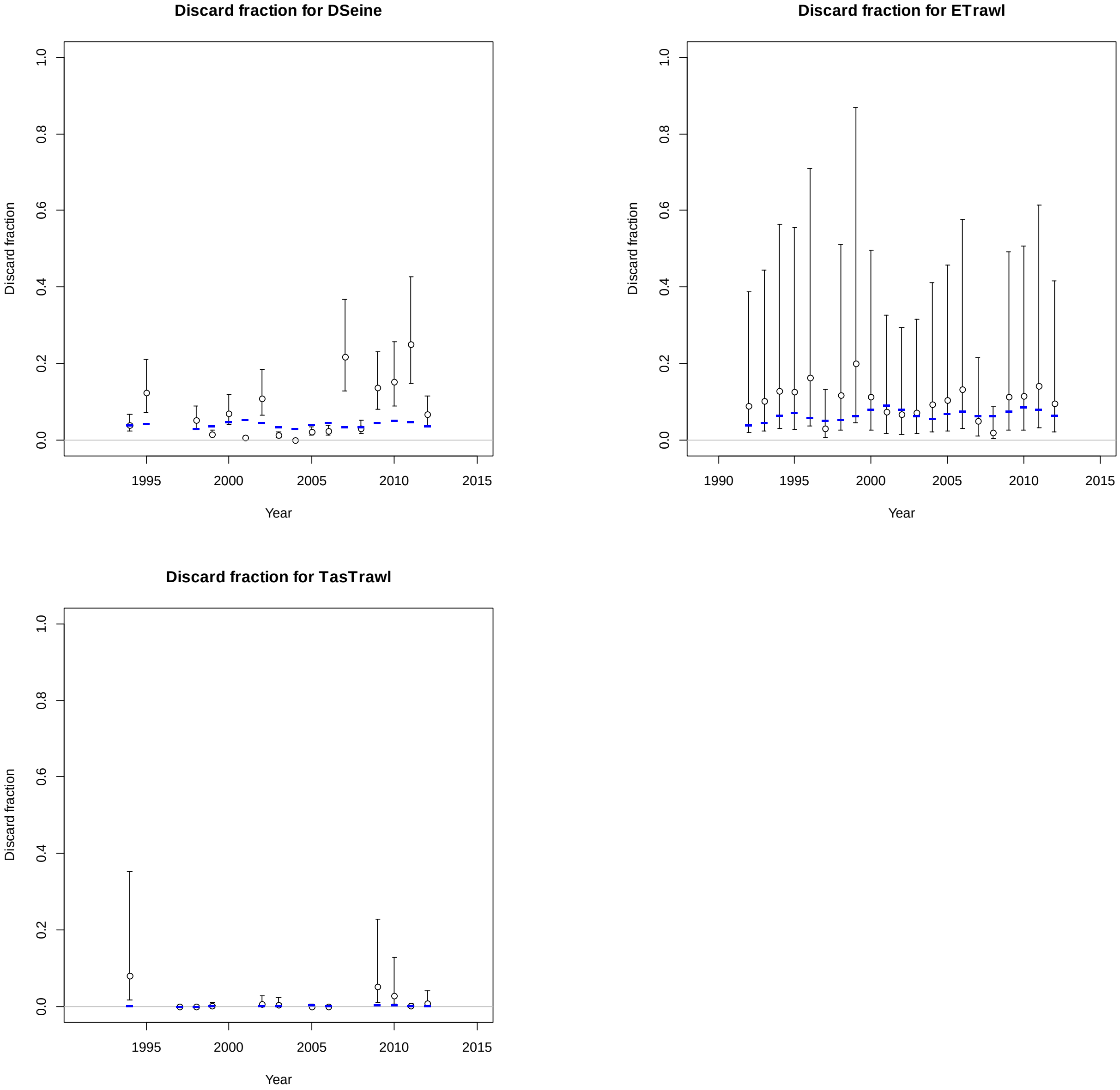

Figure 10.11. Observed (circles) and model-estimated (blue lines) discard estimates versus year, with approximate 95% asymptotic intervals.

The fits to the discard fractions (Figure 10.11) are reasonable given the variability in the data, with some very low data points (less than 1%) and others up to 20% for Danish seine and eastern trawl and up to 8% for Tasmanian trawl.

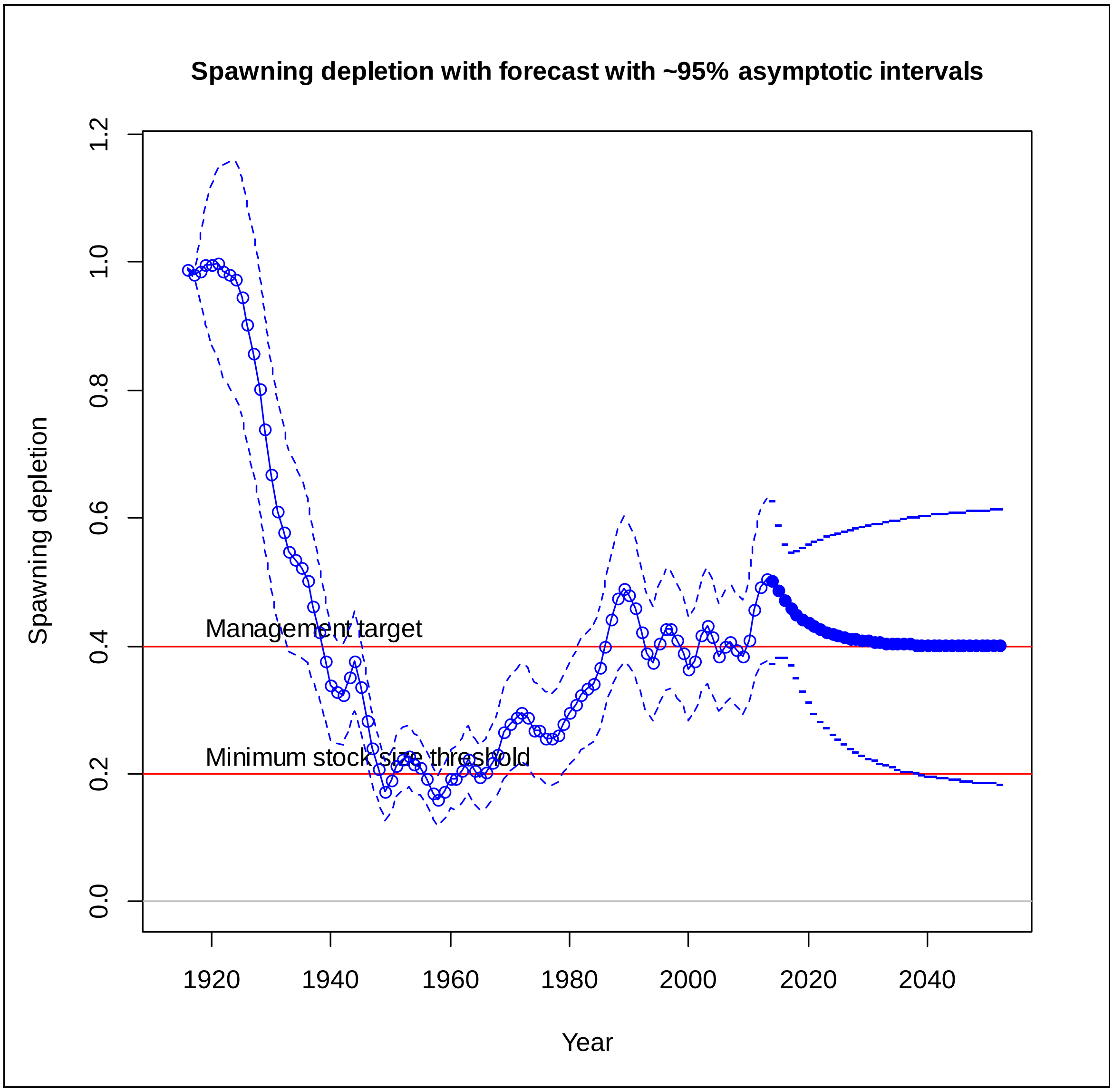

Figure 10.12. Time-trajectory of spawning biomass depletion (with approximate 95% asymptotic intervals) corresponding to the MPD estimates for the base-case analysis for tiger flathead. The first solid blue dot is 2014 depletion, and subsequent solid dots are forecast depletion under the 20:35:40 harvest control rule assuming that each year's catch is set to the forecast RBC for that year and assuming average recruitment.

10.4.1.3 Assessment outcomes

Figure 10.12 shows the trajectory of spawning stock depletion. The stock declines substantially from the beginning of the fishery in 1915 to 1950, fluctuates near the minimum threshold of 20% SSB0 during the 1950s and 1960s, before an increase to above 40% SSB0 by the 1980s. This increase in the 1980s was driven by a combination of favourable recruitments (Figure 10.13) and total landings of less than 2,000t in the late 1970s and early 1980s. The stock has fluctuated near or above 40% SSB0 since the late 1980s with a notable increase to around 50% SSB0 in the last couple of years.

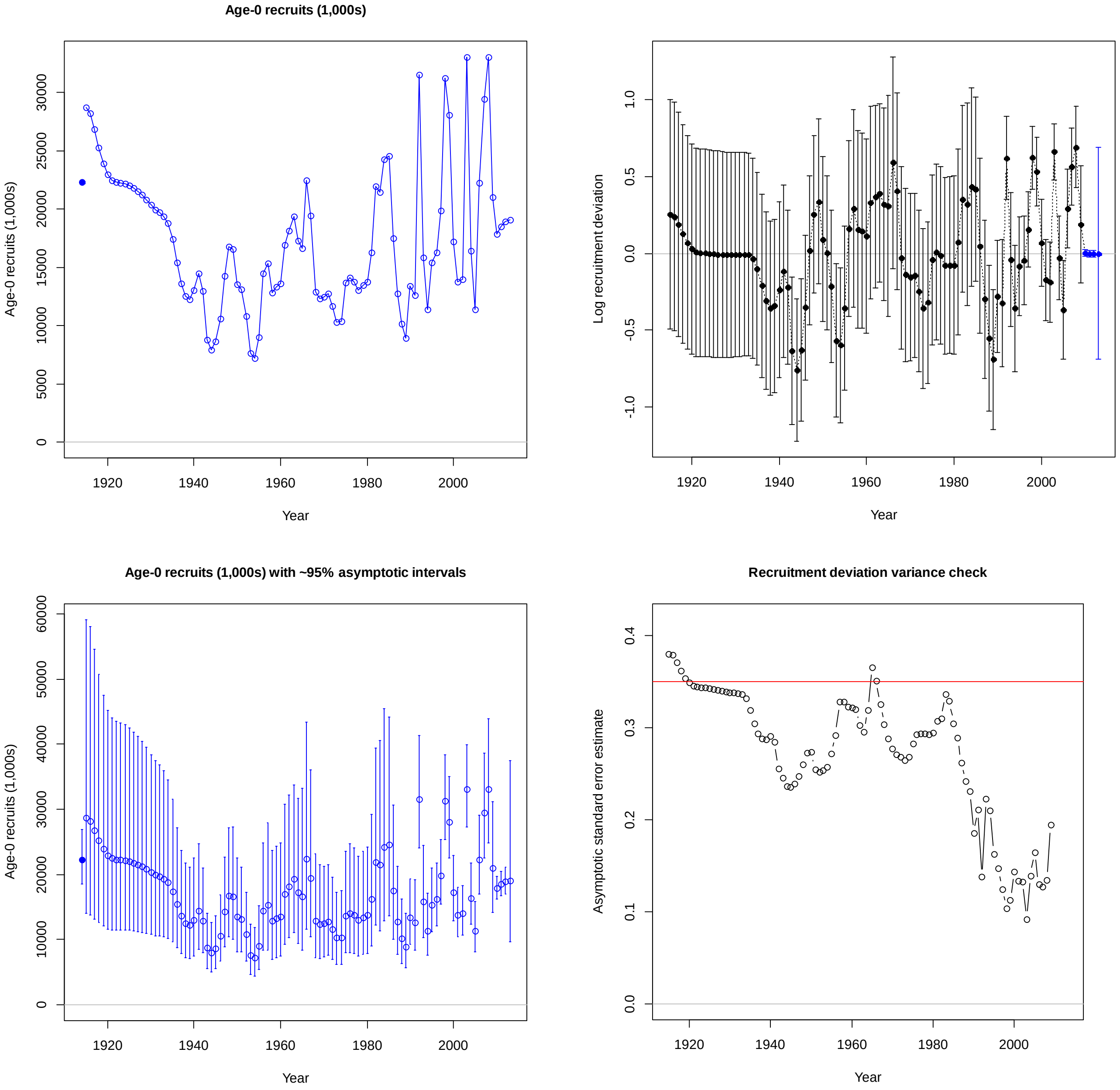

Figure 10.13. Recruitment estimation for the base case analysis. Top left : Time-trajectories of estimated recruitment numbers; top right : time trajectory of estimated recruitment deviations; bottom left : time-trajectories of estimated recruitment numbers with approximate 95% asymptotic intervals; bottom right: the standard errors of recruitment deviation estimates.

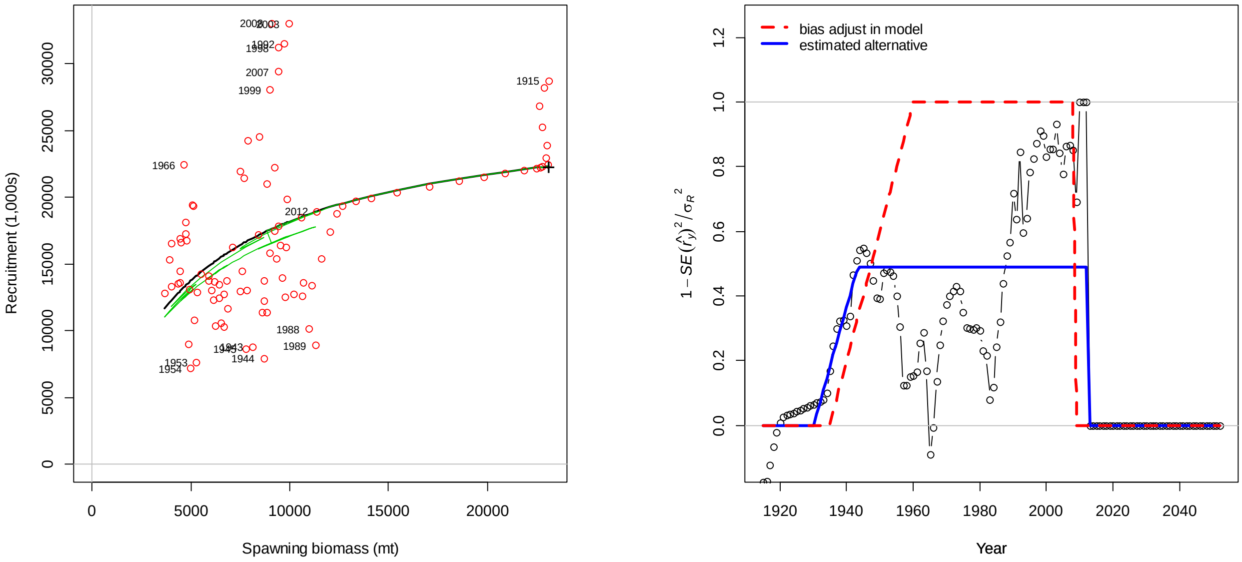

Figure 10.14. Recruitment estimation for the base case analysis. Left: the stock-recruit curve and estimated recruitments; right: bias adjustment.

The time-trajectories of recruitment and recruitment deviation are shown in Figure 10.13. Estimates of recruitments since about 1940 are generally variable, but periods of above and below average recruitment levels appear for periods of up to 12 years. Long-term regular cycles are not evident however. Recruitment in the past 15 years has been highly variable, but largely above average. The variability in estimated recent recruitment is likely to be a result of the model attempting to fit the increased quantity of data in recent years, particularly the age data.

The base-case assessment estimates that current spawning stock biomass is 50% of unexploited stock biomass (SSB_0). The 2014 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 2,683 t and the long term yield (assuming average recruitment in the future) is 2,560 t (Table 10.13). Averaging the RBC over the three year period 2014-2016, the average RBC is 2,683 t and over the five year period 2014-2018, the average RBC is 2,671 t (Table 10.16).

Under the 20:35:40 harvest control rule the 2014 RBC is 3,428 t and the long term yield is 2,753 t (Table 10.13). Using the 20:35:40 harvest control rule, averaging the RBC over the three year period 2014-2016, the average RBC is 3,334 t and over the five year period 2014-2018, the average RBC is 3,252 t (Table 10.16).

10.4.1.4 Discard estimates

Model estimates for discards for the period 2014-18 with the 20:35:40 Harvest Control Rule are listed in Table 10.17 for the base case, with a range of 212 to 217 t, and for the sensitivity where recruitment was not estimated in 2008 and 2009, with a range of152 to 155 t.

10.4.1.5 Sensitivity tests and alternative models

Results of the sensitivity tests are shown in Table 10.13. The results are very sensitive to the assumed value for natural mortality (*M*). Much of this variability is due to the estimated current depletion level, which can be as low as 36% SSB_0 when *M* is 0.2. The range of values used to explore the sensitivity to *M* is quite broad and future sensitivities could be conducted over a narrower range of values. The values used here are identical to those used in the 2010 assessment, when the range was deliberately broad due to changes to the base case value chosen for *M* in that assessment. With the assumed value of 0.27 for *M*, there is less need to explore such a broad range for this sensitivity in future. For all other standard sensitivities, there is much less variability in current depletion. The one exception to this result for a non-standard sensitivity is when recruitment is only estimated to 2007, and not estimated in 2008 and 2009.

The length and age composition data were down-weighted by a factor of 10 for the base case, primarily to allow the model to take account of the large number of samples in the CPUE index data. Not making that adjustment (age and length lambda 1) results in a current depletion level of 49% SSB_0, and a 2014 RBC of 3,212 t.

Unweighted likelihood components for the base case and differences for the sensitivities reveal several points (Table 10.14). The overall likelihood is improved for a smaller value of M, counter to the case examined in Klaer (2010). This emphasises that steepness and M are highly correlated, and it is normally not possible to estimate both of these parameters. The base-case is essentially uninformative about the value of M, which needs to be sourced independently of the stock assessment if steepness is estimated.

The overall fit is improved by increased weight on length frequencies. This is to be expected because of the disproportionately large number of samples inherent in that data component. Of more importance is the decrease to the fit to CPUE (and other non-composition components) for the model with lambda values of 1 for length and age data. For reasons outlined previously, it is important to allow the model to account for the large actual sample sizes associated with the CPUE index data.

In addition to the standard sensitivities, (cases 1-15 in Table 10.13), two additional sensitivities were investigated. Including the abundance index values from the summer fishery independent survey resulted in minor changes to the depletion estimate (48% SSB_0) which is not surprising given that the summer index monotonically decreases (Table 10.7). Given the number of abundance indices used in this assessment and the quantity of data it would be surprising if inclusion of these values made large differences.

The final sensitivity was examined to explore the effects of the large estimated recruitment in 2008. While this recruitment appears to be well estimated, future data may moderate the estimated size of this recruitment. A precautionary approach is to assume that the recruitments in 2008 and 2009 are average recruitments, which is equivalent to estimating recruitment only to 2007. With this assumption, there are larger changes to the depletion estimate (40% SSB_0) and the 2014 RBC (2,699 t) in comparison to the base case.

The impact of the last two above average estimated recruitment events on the base case is demonstrated in Table 10.15, with the impact of a three or five year averaged RBC examined and the impact of the 20:35:48 control rule compared to the 20:35:40 control rule.

The difference between using a three year averaged RBC and a five year averaged RBC on the depletion were minimal, with a slightly slower movement towards the target biomass for a five year average (Table 10.15) These minor differences are also highlighted in Figure 10.15 which shows the depletion trajectories through to 2040. In all cases, the depletion eventually tends towards the Harvest Control Rule Target (40% for the red and yellow lines and 48% for the blue and green lines). In all cases the differences between the three and five year means is minimal. The yellow and blue lines are almost coincident in Figure 10.14, as are the yellow and red lines.

For the base case (Figure 10.15, left), movement towards the target is monotonic, as expected. For the recruitment to 2007 sensitivity (Figure 10.15, right), application of the average RBC from the base case leads to movement away from the target for the first 5 years, with 2019 depletion dropping to 33% for the 20:35:40 Harvest Control Rule and dropping to 39% for the 20:35:48 Harvest Control Rule. Once the projected RBC is applied from 2019 onwards, the depletion trajectory moves back towards the target depletion level.

The differences between the base case and the sensitivity with recruitment estimated to 2007 are illustrated in Figure 10.16 and Figure 10.17. In both cases the catches from 2014 to 2018 are identical (set to the mean RBC for the period 2014-2018 for the appropriate Harvest Control Rule). For the base case, these RBC values are set appropriately, but for the sensitivity, these catches are set too high, resulting in the depletion either falling below or remaining below the target value in that period. The approximate 95% asymptotic intervals suggest that depletion is unlikely to go below 20% of B_0 by 2018 for any of the scenarios with catches fixed until 2018 at three or five year averages of the RBC, for either the base case or for sensitivity 17, with recruitment only estimated to 2007.

Exploration of model sensitivity showed a variation in spawning biomass from 36% to 66% of SSB_0 when natural mortality was fixed at values of 0.2 and 0.35 respectively. When recruitment is only estimated to 2007, excluding the above average recruitment estimates in 2008 and 2009, the spawning biomass was estimated to be 40% of SSB_0. For all other sensitivities explored, the variation in spawning biomass was much narrower, ranging between 47% and 52%.

For the base-case (20:35:40 Harvest Control Rule with recruitment estimated to 2009), SSB_{MSY} is estimated to be 32% of SSB_0. If the standard MEY proxy multiplier of 1.2 is applied to this MSY estimate, the SSB_{MEY} estimate for the base case is 38% of SSB_0. This proxy for SSB_{MEY} is rounded up to 40% of SSB_0 by agreement at SESSFRAG, with a 20:35:40 Harvest Control Rule used for tiger flathead.

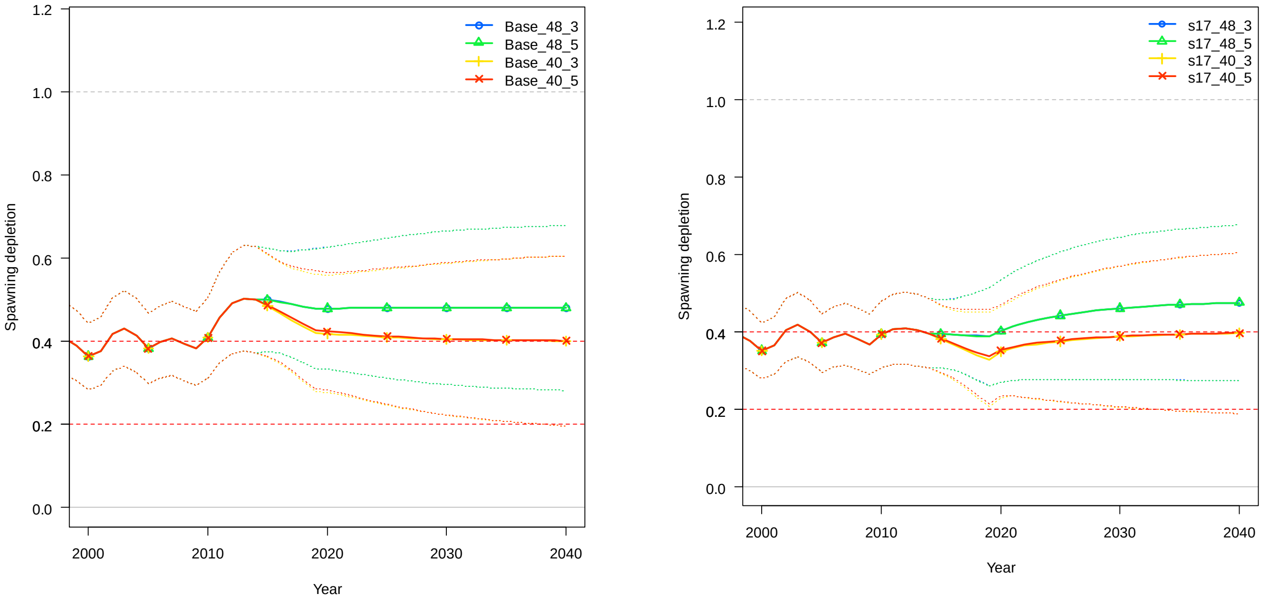

Figure 10.15. Spawning depletion with approximate 95% asymptotic intervals from 2000 to 2012 and then projected to 2040 using either three or five year average RBCs for the period 2014-2018 and either the 20:35:48 or 20:35:40 Harvest Control Rules. Left: the base case, recruitment estimated to 2009; right: sensitivity 17, recruitment estimated to 2007. For a given Harvest Control Rule, the three and five year averages lead to almost identical spawning depletion trajectories, as shown by the blue and green lines being almost coincident, as are the yellow and red lines.

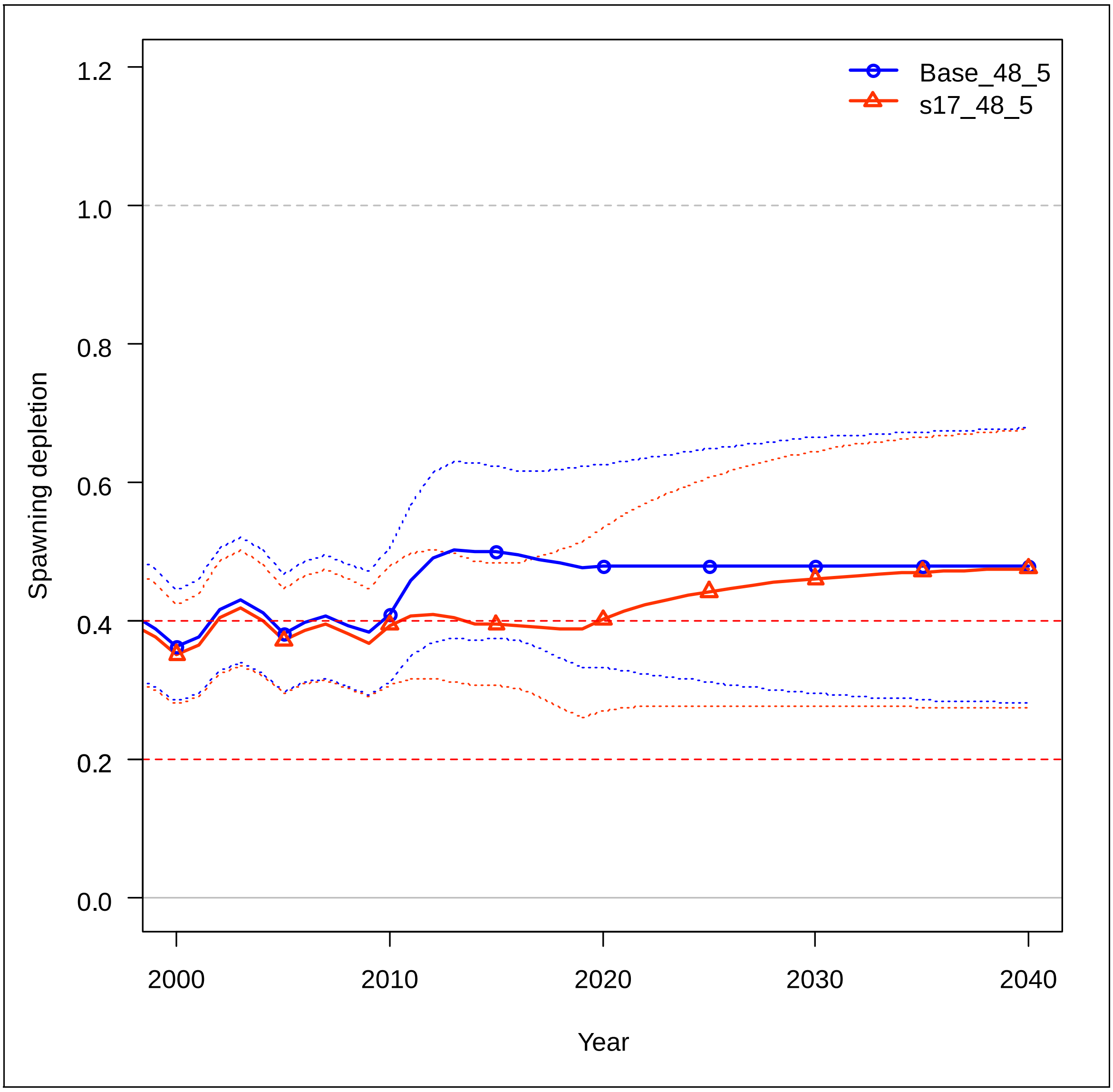

Figure 10.16. Spawning depletion with approximate 95% asymptotic intervals from 2000 to 2012 and then projected to 2040 using five year average RBCs for the period 2014-2018 and the 20:35:48 Harvest Control Rule. The base case trajectory is shown in blue and the recruitment to 2007 sensitivity is shown in red.

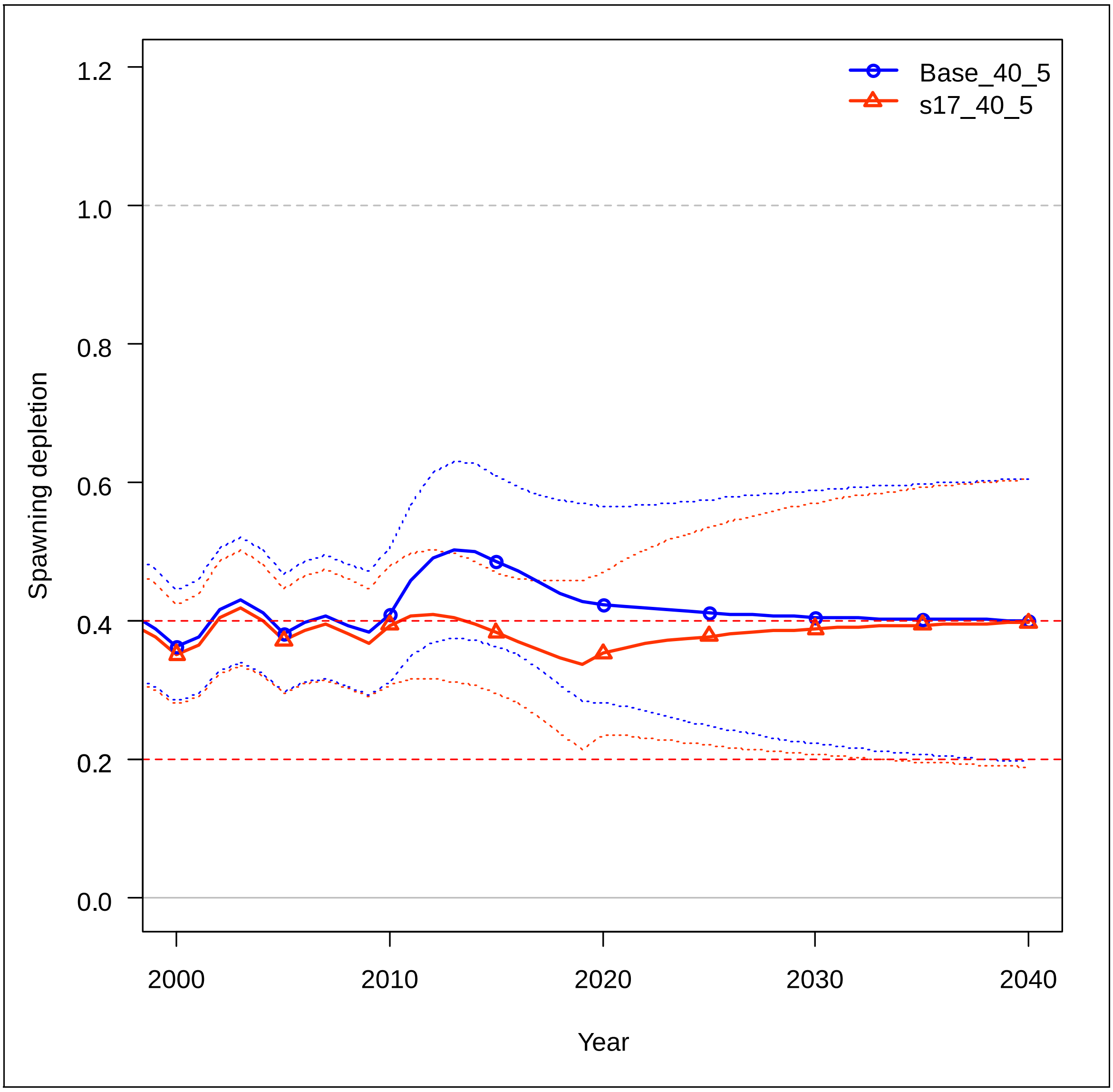

Figure 10.17. Spawning depletion with approximate 95% asymptotic intervals from 2000 to 2012 and then projected to 2040 using five year average RBCs for the period 2014-2018 and the 20:35:40 Harvest Control Rule. The base case trajectory is shown in blue and the recruitment to 2007 sensitivity is shown in red.

10.4.1.6 Further work

The 2001 Tasmanian trawl length frequency was excluded from the 2010 assessment due to a small number of operations to collect this length frequency composition data. The number of operations was not initially made available with the automatic data processing in 2013, so this length frequency was included. Future assessments should consider excluding this year of data (which is poorly fit by the model in any case) and possibly investigate other years of Tasmanian trawl length frequency data which may not have a sufficient number of hauls to get a representative length frequency distribution.

Future sensitivities on natural mortality should probably consider a narrower range of potential values for *M*.

Table 10.1. Total retained catches (tonnes) of tiger flathead per fleet for calendar years from 1915-2013.

Year	Fleet			
	St Trawl	D Seine	E Trawl	Tas Trawl
1915	371	0	0	0
1916	373	0	0	0
1917	432	0	0	0
1918	671	0	0	0
1919	1,151	0	0	0
1920	931	0	0	0
1921	1,297	0	0	0
1922	840	0	0	0
1923	796	0	0	0
1924	1,356	0	0	0
1925	1,969	0	0	0
1926	2,167	0	0	0
1927	2,735	0	0	0
1928	3,277	0	0	0
1929	3,768	102	0	0
1930	3,329	330	0	0
1931	2,932	4	0	0
1932	2,642	385	0	0
1933	2,456	44	0	0
1934	2,278	276	0	0
1935	2,514	270	0	0
1936	2,712	872	0	0
1937	2,912	637	0	0
1938	2,924	725	0	0
1939	2,185	1,035	0	0
1940	815	1,108	0	0
1941	403	1,255	0	0
1942	167	225	0	0
1943	223	317	0	0
1944	315	2,624	0	0
1945	953	2,168	0	0
1946	1,088	1,425	0	0
1947	884	1,193	0	0
1948	735	1,767	0	0
1949	330	804	0	0
1950	310	1,095	0	0
1951	583	1,625	0	0
1952	769	1,499	0	0
1953	517	2,235	0	0
1954	366	1,737	0	0
1955	211	1,932	0	0
1956	157	1,868	0	0
1957	139	1,459	0	0
1958	68	1,138	0	0
1959	32	1,467	0	0
1960	15	2,206	0	0
1961	9	1,974	0	0
1962	0	1,742	0	0
1963	0	3,745	0	0
1964	0	3,707	0	0
1965	0	3,322	0	0
1966	0	2,769	0	0
1967	0	2,912	0	0
1968	0	2,355	0	0
1969	0	3,289	0	0
1970	0	2,667	0	0
1971	0	1,793	286	0
1972	0	1,981	491	0
1973	0	2,397	490	0
1974	0	1,493	369	0
1975	0	1,367	827	0
1976	0	900	712	0
1977	0	977	522	0
1978	0	836	446	0
1979	0	928	520	0
1980	0	851	609	0
1981	0	418	877	0
1982	0	615	930	0
1983	0	889	950	0
1984	0	890	978	0
1985	0	890	978	30
1986	0	892	1,005	26
1987	0	1,358	1,109	6
1988	0	1,177	1,263	116
1989	0	1,189	1,318	128
1990	0	591	1,425	178
1991	0	746	1,461	166
1992	0	1,019	1,080	170
1993	0	516	962	194
1994	0	626	982	178
1995	0	564	1,189	139
1996	0	711	1,265	114
1997	0	1,023	1,542	175
1998	0	905	1,700	186
1999	0	1,873	1,520	248
2000	0	1,286	2,006	203
2001	0	1,170	1,710	113
2002	0	1,301	1,736	235
2003	0	1,440	1,962	269
2004	0	1,410	1,667	519
2005	0	1,291	1,534	471
2006	0	1,111	1,554	353
2007	0	1,442	1,394	216
2008	0	1,466	1,731	250
2009	0	1,340	1,424	161
2010	0	1,349	1,466	174
2011	0	1,284	1,450	212
2012	0	1,439	1,423	202
2013*	0	1,439	1,423	202

*2013 catches are estimated

Table 10.2. Total allowable catch (t) from 1992 to 2013/14.

Year	TAC Agreed
1992	3000
1993	3000
1994	3500
1995	3500
1996	3500
1997	3500
1998	3500
1999	3500
2000	3500
2001	3500
2002	3500
2003	3500
2004	3500
2005	3150
2006	3000
2007	3015
2008-09	2850
2009-10	2850
2010-11	2750
2011-12	2750
2012-13	2750
2013-14	2750

Table 10.3. Proportion of catch discarded by fleet, with sample sizes.

Year	Fleet					
	D Seine	n	E Trawl	n	Tas Trawl	n
1992			0.089098	11		
1993			0.101916	195		
1994	0.040237	78	0.129849	266	0.08138	18
1995	0.124329	43	0.127663	129		
1996			0.163244	189		
1997			0.030862	380	0.000956	10
1998	0.052878	23	0.117911	244	0.000245	27
1999	0.015417	34	0.19967	381	0.002363	48
2000	0.071091	27	0.114204	395		
2001	0.007126	41	0.074943	455		
2002	0.109788	29	0.067539	384	0.006729	8
2003	0.013427	112	0.072868	469	0.005699	10
2004	0.001229	39	0.09468	382		
2005	0.021173	59	0.105397	460	0.001489	16
2006	0.023399	125	0.132579	369	0.000582	59
2007	0.217173	23	0.049705	36		
2008	0.031104	32	0.020063	209		
2009	0.136464	32	0.113276	195	0.052681	8
2010	0.151784	75	0.116734	169	0.029486	20
2011	0.250837	123	0.141346	140	0.002074	22
2012	0.068640	69	0.095465	128	0.009509	27

Table 10.4. Standardised catch rates for the steam trawl fleet (Klaer 2004).

Year	Value	CV
1919	1.618	0.31
1920	1.732	0.31
1921	1.806	0.31
1922	1.758	0.31
1923	1.646	0.31
1937	0.635	0.31
1938	0.749	0.31
1939	0.723	0.31
1940	0.611	0.31
1941	0.618	0.31
1942	0.401	0.31
1952	0.262	0.31
1953	0.208	0.31
1954	0.232	0.31
1955	0.219	0.31
1956	0.208	0.31
1957	0.169	0.31

Table 10.5. Unstandardised catch rates for the early Danish seine fleet.

Year	Value	CV
1950	38.7	0.33
1951	27.6	0.33
1952	31.8	0.33
1953	52.0	0.33
1954	34.4	0.33
1955	47.4	0.33
1956	46.5	0.33
1957	32.1	0.33
1958	22.5	0.33
1959	28.7	0.33
1960	43.6	0.33
1965	38.2	0.33
1966	41.5	0.33
1967	62.5	0.33
1968	61.2	0.33
1969	77.8	0.33
1970	67.1	0.33
1971	69.9	0.33
1972	114.0	0.33
1973	88.0	0.33
1974	58.1	0.33
1975	56.6	0.33
1976	41.9	0.33
1977	55.5	0.33
1978	51.9	0.33

Table 10.6. Standardised catch rates for the Danish seine, Eastern and Tasmanian diesel trawl fleets from 1986-2012.

Year	Fleet					
	D Seine	CV	E Trawl	CV	Tas Trawl	CV
1986*	1.0351	0.0228	0.7988	0.0166	0.9552	0.1592
1987	1.4551	0.0228	1.0669	0.0160	0.5791	0.1897
1988	1.5850	0.0226	1.1668	0.0158	0.9973	0.1701
1989	1.3782	0.0229	1.1636	0.0159	0.7477	0.1625
1990	0.9073	0.0242	1.3835	0.0168	0.7835	0.1647
1991	1.2672	0.0243	1.3128	0.0168	0.7086	0.1608
1992	1.3677	0.0223	1.0246	0.0175	0.6741	0.1649
1993	0.8698	0.0230	1.0470	0.0166	0.6422	0.1563
1994	0.7325	0.0219	0.7592	0.0160	0.6649	0.1573
1995	0.7512	0.0233	0.8038	0.0159	0.7276	0.1576
1996	0.7098	0.0219	0.7163	0.0158	0.6716	0.1573
1997	0.9134	0.0215	0.7162	0.0162	0.8451	0.1562
1998	0.7634	0.0210	0.7588	0.0162	0.9967	0.1568
1999	1.0990	0.0215	0.9137	0.0160	1.0984	0.1570
2000	0.8110	0.0225	1.0085	0.0155	0.8899	0.1582
2001	0.7585	0.0226	0.9704	0.0157	0.7588	0.1552
2002	0.9012	0.0222	1.0586	0.0157	1.4192	0.1544
2003	0.9628	0.0220	1.0439	0.0155	1.4503	0.1538
2004	0.9410	0.0225	0.9029	0.0157	1.9138	0.1534
2005	0.9586	0.0229	0.7712	0.0162	1.6981	0.1540
2006	0.9493	0.0240	0.9342	0.0167	1.3685	0.1548
2007	1.1494	0.0239	1.1350	0.0184	1.1339	0.1563
2008	1.0271	0.0235	1.1909	0.0178	1.0469	0.1562
2009	1.0604	0.0239	1.0952	0.0185	1.0169	0.1577
2010	0.9420	0.0235	1.0558	0.0181	1.0297	0.1587
2011	0.8779	0.0230	1.0487	0.0182	0.9714	0.1578
2012	0.8261	0.0229	1.1529	0.0180	1.2106	0.1570

* CV values for 1986 were set to the average of all other years

Table 10.7. Abundance indices for the winter and summer fishery independent survey.

Year	FIS Season			
	winter	CV	summer	CV
2008	93.06	0.11	113.63	0.15
2010	91.06	0.12	101.01	0.14
2012	152.36	0.11	81.52	0.14

Table 10.8. Standard deviation of age reading error (A Punt pers. comm. 10 Sep 2013).

Age	sd
0.5	0.254784
1.5	0.280050
2.5	0.305635
3.5	0.331543
4.5	0.357778
5.5	0.384344
6.5	0.411246
7.5	0.438487
8.5	0.466072
9.5	0.494005
10.5	0.522290
11.5	0.550933
12.5	0.579937
13.5	0.609308
14.5	0.639049
15.5	0.669165
16.5	0.699662
17.5	0.730544
18.5	0.761815
19.5	0.793481
20.5	0.825547

Table 10.9. Number of age-length otolith samples included in the base case assessment by fleet 1998-2012.

Year	Fleet			
	D Seine	E Trawl	Tas Trawl	Total
1998	101	209		310
1999		165	46	211
2000	191	518	56	765
2001	30	180		210
2002	558	582	146	1286
2003	102			102
2004	174	152		326
2005	603	268	11	882
2006	311	64	141	516
2007	115	302		417
2008	363	258	52	673
2009	385	473		858
2010	259	304	75	638
2011	711	406		1117
2012	118	612	131	861

Table 10.10. Number of retained lengths included in the base case assessment by fleet 1945-2012.

Year	Fleet	(retained)			Year	Fleet			
	St Trawl	D Seine	E Trawl	Tas Trawl		St Trawl	D Seine	E Trawl	Tas Trawl
1945	5,076	21,735			1980			8,757	
1946	10,916	26,475			1981			6,184	
1947	15,488	20,287			1982			5,893	
1948	11,973	20,721			1983			5,140	
1949	10,863	23,316			1984			6,702	
1950	18,057	16,640			1985			2,633	
1951	25,843	21,423			1986			12,513	
1952	32,188	28,941			1987			8,154	
1953	14,880	16,264			1988			6,274	
1954	13,167	26,263			1989			3,999	
1955	2,313	9,966			1990			1,398	
1956	343	14,878			1991			4,040	
1957	150	15,283			1992		1,442	873	
1958	149	17,291			1993		356	871	
1959		20,354			1994		1,950	650	
1960		25,334			1995		2,129	1,747	
1961		18,623			1996		3,760	3,014	
1962		20,255			1997		11,857	8,716	
1963		15,988			1998		13,052	20,666	
1964		17,882			1999		6,844	31,518	3,585
1965		17,861	14,310		2000		4,273	28,384	854
1966		19,101	23,222		2001		5,928	33,039	383
1967		7,233	11,798		2002		3,901	23,437	5,678
1969			96		2003		6,054	22,873	1,048
1970			187		2004		7,875	22,083	2,082
1971			610		2005		8,895	31,780	2,461
1972			1,223		2006		14,577	25,166	5,911
1973			435		2007		2,098	4,267	
1974			5,590		2008		466	1,614	101
1975			11,684		2009		1,100	2,109	176
1976			14,881		2010		1,429	4,016	303
1977			20,153		2011		2,369	2,942	538
1978			16,335		2012		2,577	2,997	536
1979			12,189						

Table 10.11. Number of discarded lengths included in the base case assessment by fleet 1992-2012

Year	Fleet	(discards)
	D Seine	E Trawl
1992	0	131
1993	0	1,905
1994	0	0
1995	0	0
1996	0	0
1997	0	2,203
1998	126	2,155
1999	104	3,988
2000	110	2,890
2001	86	2,310
2002	235	2,834
2003	102	2,622
2004	0	3,098
2005	0	1,478
2006	119	2,116
2007	218	0
2008	0	99
2009	0	376
2010	0	175
2011	132	546
2012	212	388

Table 10.12. Summary of parameters of the base case model.

Feature	Details	
Fleets	Steam trawl	Fixed discard rate of 17%
	Danish seine	Fixed discard rate of 17% to 1960, fitted thereafter Selectivity change in 1978 from early to modern Danish seine
	East coast trawl	Selectivity change in 1985 from early to modern diesel trawl
	Tasmanian trawl	Diesel trawl in Zone 30
Natural mortality *M*	fixed	0.27
Steepness *h*	estimated	0.59
σ_R in	fixed	0.35
Recruitment devs	estimated	1915-2009, bias adjustment ramps 1935-60 and 2008-09
CV growth	estimated	0.10
Growth *K*	estimated	Female 0.169
Growth l_{min}	estimated	Female age 2 29.73
Growth l_{max}	fixed	Female 55.9

Table 10.13. Summary of results for the base-case and sensitivity tests. Recommended biological catches (RBCs) are only shown for tuned models (cases 0 & 17).

Case		SSB_0	SSB_{2014}	SSB_{2014}/SSB_0	Steepness	SSB_{MSY}/SSB_0	RBC_{2014}	RBC_{2014-6}	RBC_{2014-8}	$RBC_{longterm}$
0	base case 20:35:40 *M* 0.27	23,104	11,572	0.50	0.59	0.32	3,428	3,334	3,252	2,753
1	*M* 0.2	22,901	8,133	0.36	0.78	0.25				
2	*M* 0.35	28,649	18,796	0.66	0.41	0.38				
3	50% maturity at 27cm	24,309	12,422	0.51	0.58	0.32				
4	50% maturity at 33cm	21,451	10,427	0.49	0.61	0.30				
5	$\sigma_R = 0.3$	22,856	11,257	0.49	0.59	0.32				
6	$\sigma_R = 0.4$	23,392	11,817	0.51	0.60	0.31				
7	wt x 2 length comp	22,878	11,490	0.50	0.59	0.32				
8	wt x 0.5 length comp	22,943	11,736	0.51	0.60	0.31				
9	wt x 2 age comp	23,328	10,987	0.47	0.58	0.32				
10	wt x 0.5 age comp	22,806	11,856	0.52	0.60	0.31				
11	wt x 2 CPUE	23,556	11,968	0.51	0.59	0.32				
12	wt x 0.5 CPUE	22,159	10,723	0.48	0.61	0.31				
13	age + length lambda 1	23,586	11,603	0.49	0.61	0.32				
14	20:35:48 HCR	23,104	11,572	0.50	0.59	0.32				
15	estimate *M* (0.240), *h* 0.75	20,625	9,779	0.47	0.75	0.26				
16	add summer FIS	22,970	10,930	0.48	0.59	0.32				
17	no rec estimated 2008-9	23,264	9,227	0.40	0.58	0.32	2,699	2,706	2,709	2,708

Table 10.14. Summary of likelihood components for the base-case and sensitivity tests. Likelihood components are unweighted, and cases 1-17 are shown as differences from the base case. A negative value indicates a better fit, a positive value a worse fit.

Case		Likelihood TOTAL	CPUE	Discard	Length comp	Age comp	Recruitment
0	base case 20:35:40 *M* 0.27	13640.49	-118.33	196.27	7510.77	6075.37	-26.18
1	*M* 0.2	-16.35	4.51	0.39	-17.27	-4.70	0.77
2	*M* 0.35	10.44	-3.81	-0.49	8.31	3.55	1.97
3	50% maturity at 27cm	0.32	-0.16	0.00	0.64	-0.10	-0.11
4	50% maturity at 33cm	-0.36	0.20	0.00	-0.83	0.17	0.15
5	$\sigma_R = 0.3$	38.52	2.77	1.41	43.66	-3.90	-5.42
6	$\sigma_R = 0.4$	-27.56	-1.99	-1.00	-32.80	3.71	4.53
7	wt x 2 length comp	-176.11	8.49	11.45	-254.27	46.37	11.84
8	wt x 0.5 length comp	220.63	-3.43	-6.84	252.23	-14.77	-6.52
9	wt x 2 age comp	-37.74	1.41	7.61	34.06	-79.67	-1.16
10	wt x 0.5 age comp	75.77	-0.42	-5.65	-22.70	103.59	0.96
11	wt x 2 CPUE	73.02	-11.85	2.43	63.61	12.10	6.71
12	wt x 0.5 CPUE	-44.67	17.76	-2.10	-49.86	-5.69	-4.76
13	age + length lambda 1	-351.69	63.94	84.88	-493.74	-60.37	53.63
14	20:35:48 HCR	0.00	0.00	0.00	0.00	0.00	0.00
15	estimate *M* (0.240), *h* 0.75	0.76	1.96	0.02	-1.51	0.45	-0.01
16	add summer FIS	-10.02	-2.64	2.13	-2.38	-6.58	-0.69
17	no rec estimated 2008-9	-194.04	-0.64	9.69	-35.10	-168.35	0.26

Table 10.15. Yearly projected depletion estimates for the base case (columns 2-5, recruitment estimated up to 2009) and for sensitivity 17 (columns 6-9, no recruitment estimated for 2008-9) with either the 20:35:48 harvest control rule or the 20:35:40 harvest control rule. For each harvest control rule, the forecast catch is fixed for five years from 2014 onwards with the base case (recruitment estimated to 2009) using either the mean of three years of projected RBC values (2014-2016, 3 yr avg RBC) or the mean of five years of projected RBC values (2014-2018, 5 yr avg RBC). The first four columns (base case) see the depletion move towards the target. For the last four columns (sensitivity 17 where the recruitment is estimated to 2007), the average RBCs are set using values from the base case (assuming a 2014 depletion of 50%) yet the starting depletion in 2014 is actually 40%. This explores the impact of assuming good recruitment for 2008 and 2009 in setting the RBC when that good recruitment is replaced with average recruitment in 2008 and 2009.

Year	Rec2009 20:35:48 3 yr avg RBC	Rec2009 20:35:48 5 yr avg RBC	Rec2009 20:35:40 3 yr avg RBC	Rec2009 20:35:40 5 yr avg RBC	Rec2007 20:35:48 3 yr avg RBC	Rec2007 20:35:48 5 yr avg RBC	Rec2007 20:35:40 3 yr avg RBC	Rec2007 20:35:40 5 yr avg RBC
2014	0.50	0.50	0.50	0.50	0.40	0.40	0.40	0.40
2015	0.50	0.50	0.49	0.49	0.40	0.40	0.38	0.38
2016	0.49	0.49	0.47	0.47	0.39	0.39	0.37	0.37
2017	0.49	0.49	0.45	0.46	0.39	0.39	0.35	0.36
2018	0.48	0.48	0.43	0.44	0.39	0.39	0.34	0.35
2019	0.48	0.48	0.42	0.43	0.39	0.39	0.33	0.34

Table 10.16. Yearly projected RBCs (tonnes) under the 20:35:48 and 20:35:40 harvest control rules, assuming average recruitment from 2010 (columns 2 and 3 – base case, recruitment estimated up to 2009) and average recruitment from 2008 (columns 4 and 5 – sensitivity 17: no recruitment estimated for 2008-9).

Year	Rec 2009 20:35:48	Rec 2009 20:35:40	Rec 2007 20:35:48	Rec 2007 20:35:40
2014	2,683	3,428	2,117	2,699
2015	2,688	3,334	2,183	2,708
2016	2,677	3,241	2,236	2,712
2017	2,661	3,161	2,276	2,713
2018	2,645	3,095	2,308	2,712
2019	2,631	3,042	2,335	2,711
2020	2,619	2,998	2,359	2,710
2021	2,610	2,962	2,379	2,709
2022	2,602	2,931	2,398	2,708
2023	2,596	2,905	2,414	2,708
2024	2,591	2,883	2,429	2,708
2025	2,586	2,864	2,442	2,708
2026	2,582	2,848	2,453	2,708
2027	2,579	2,834	2,463	2,708
2028	2,576	2,823	2,471	2,708
2029	2,574	2,812	2,479	2,708
2030	2,572	2,804	2,485	2,708
2031	2,570	2,796	2,491	2,708
2032	2,569	2,790	2,496	2,708
2033	2,567	2,784	2,500	2,708
2034	2,566	2,780	2,503	2,708
2035	2,565	2,776	2,507	2,708
2036	2,565	2,772	2,509	2,708
2037	2,564	2,769	2,512	2,708
2038	2,563	2,767	2,514	2,708
2039	2,563	2,764	2,515	2,708
2040	2,563	2,763	2,517	2,708
2041	2,562	2,761	2,518	2,708
2042	2,562	2,760	2,519	2,708
2043	2,562	2,758	2,520	2,708
2044	2,561	2,757	2,521	2,708
2045	2,561	2,756	2,522	2,708
2046	2,561	2,756	2,523	2,708
2047	2,561	2,755	2,523	2,708
2048	2,561	2,754	2,524	2,708
2049	2,561	2,754	2,524	2,708
2050	2,561	2,753	2,524	2,708
2051	2,560	2,753	2,525	2,708
2052	2,560	2,753	2,525	2,708

Table 10.17. Yearly projected discards (tonnes) across all fleets under the 20:35:40 harvest control rules with catches set to the calculated RBC for each year from 2014 to 2018: assuming average recruitment from 2010 (base case, column 2); and for the sensitivity when recruitment is only estimated to 2007 (sensitivity 17, column 3), assuming average recruitment from 2008.

	Base	Sens 17
Year	Rec2009	Rec2007
2014	217	152
2015	215	154
2016	214	154
2017	213	154
2018	212	155

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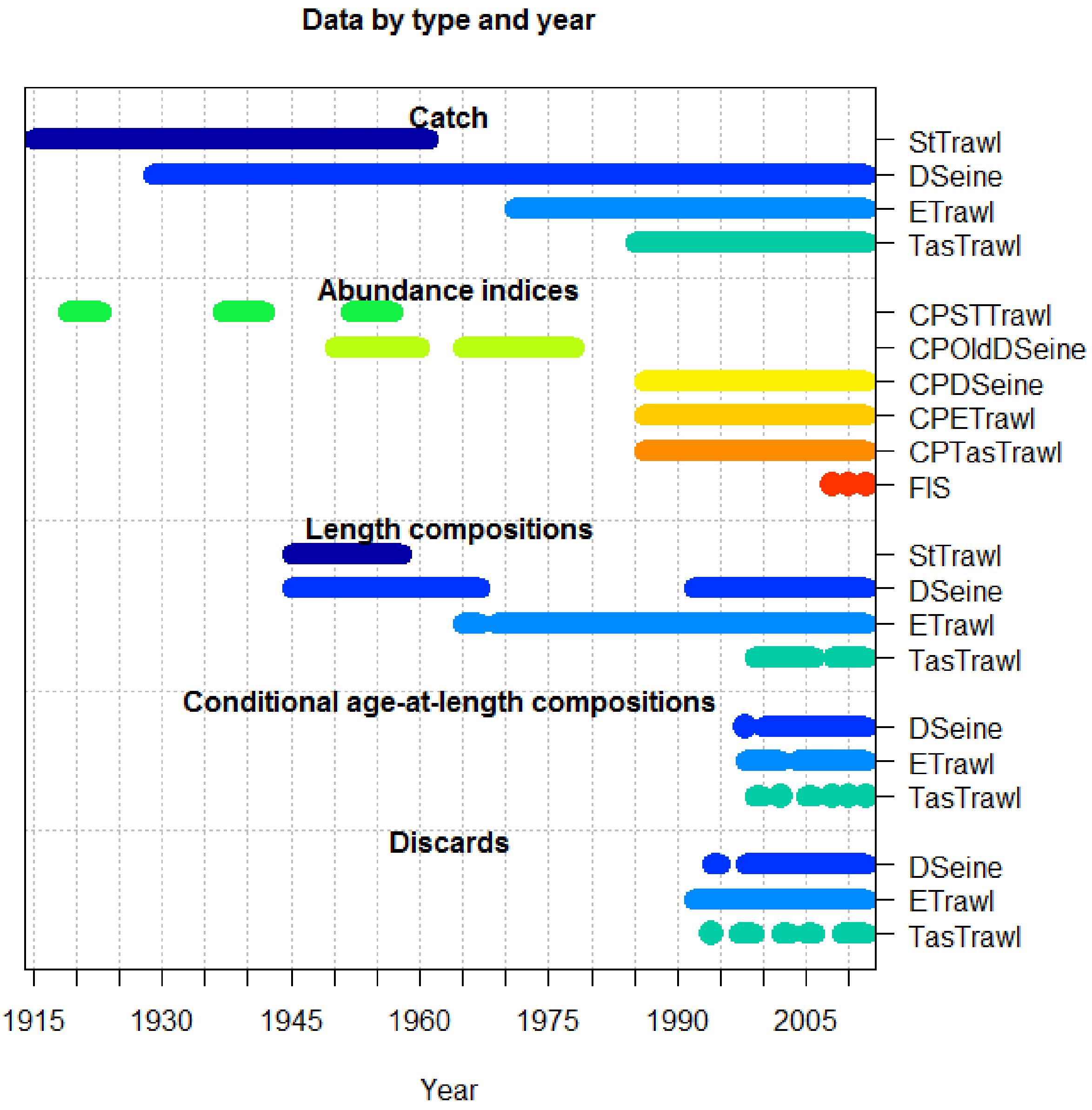
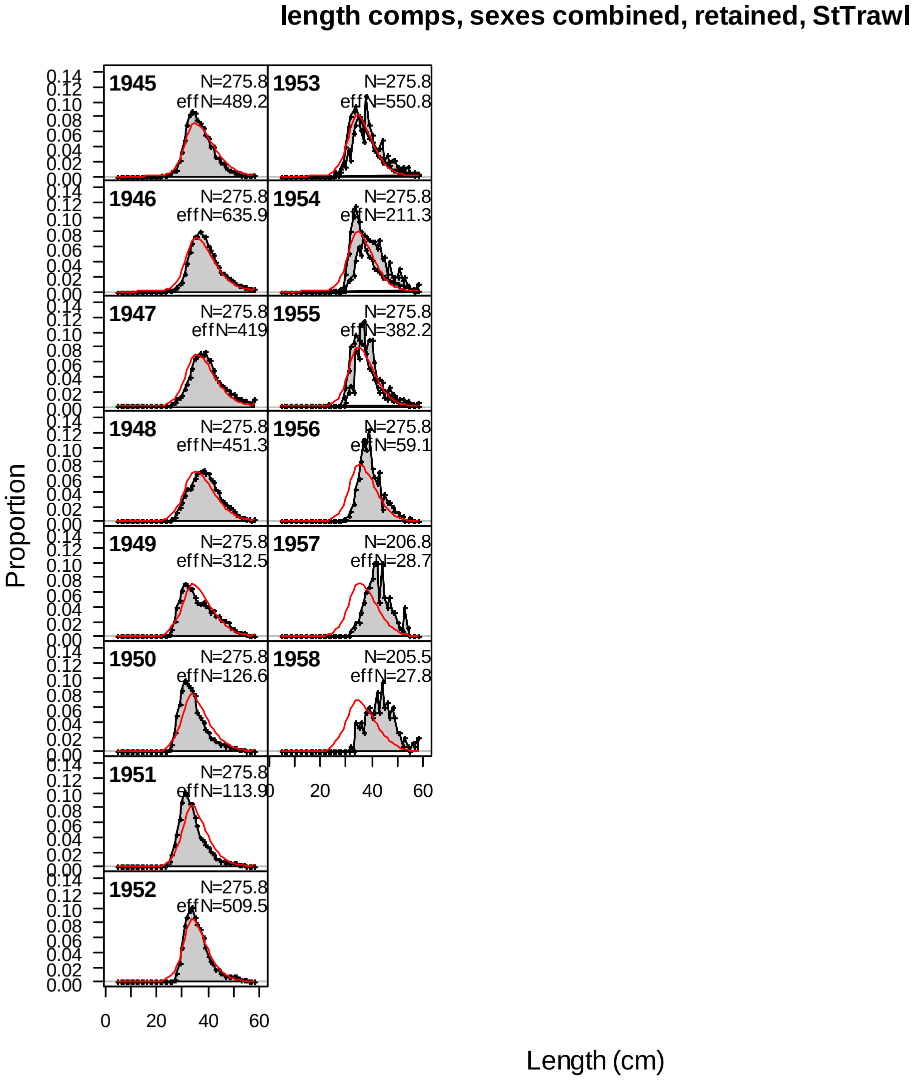
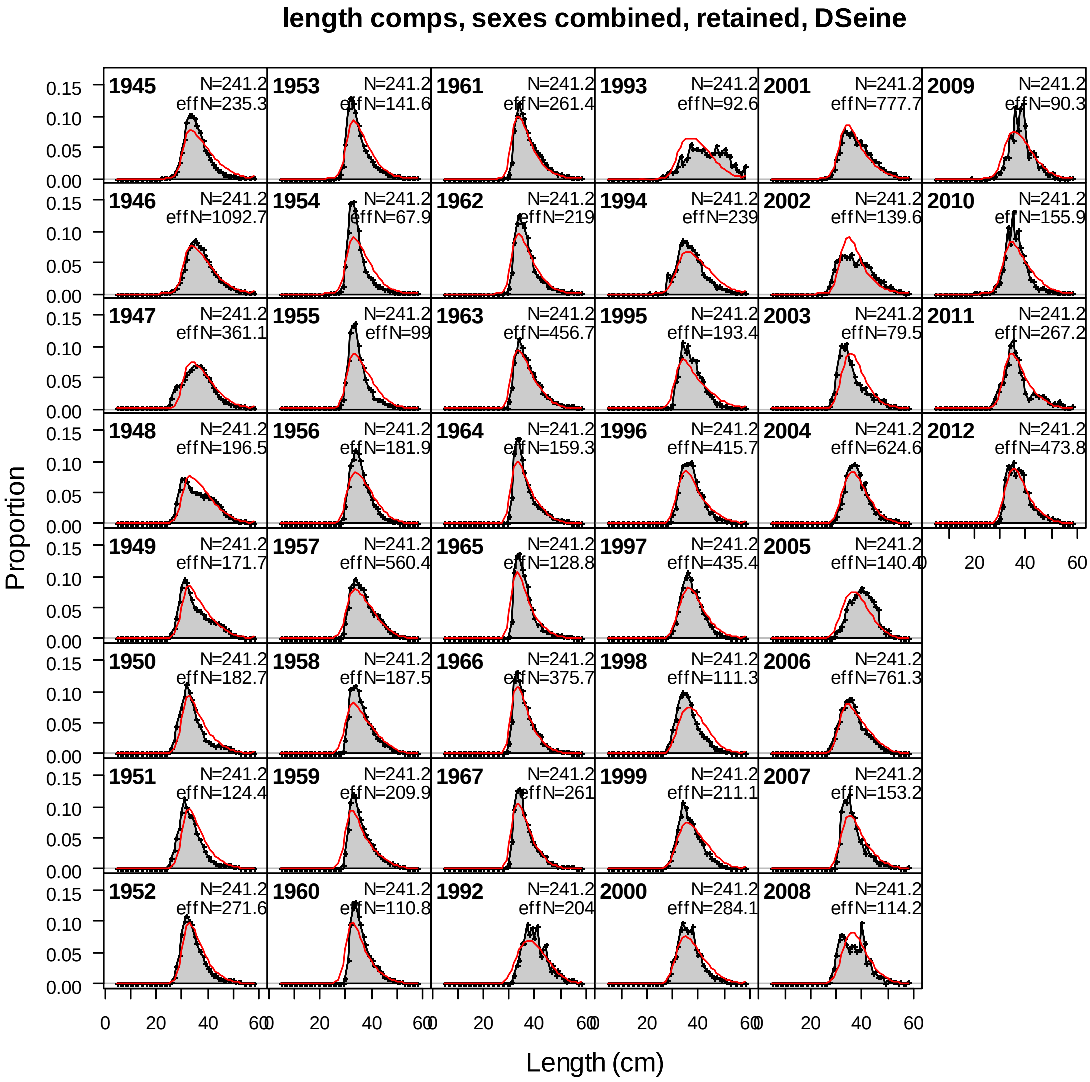
10.7 Appendix A: Data source summary and fits to length composition data



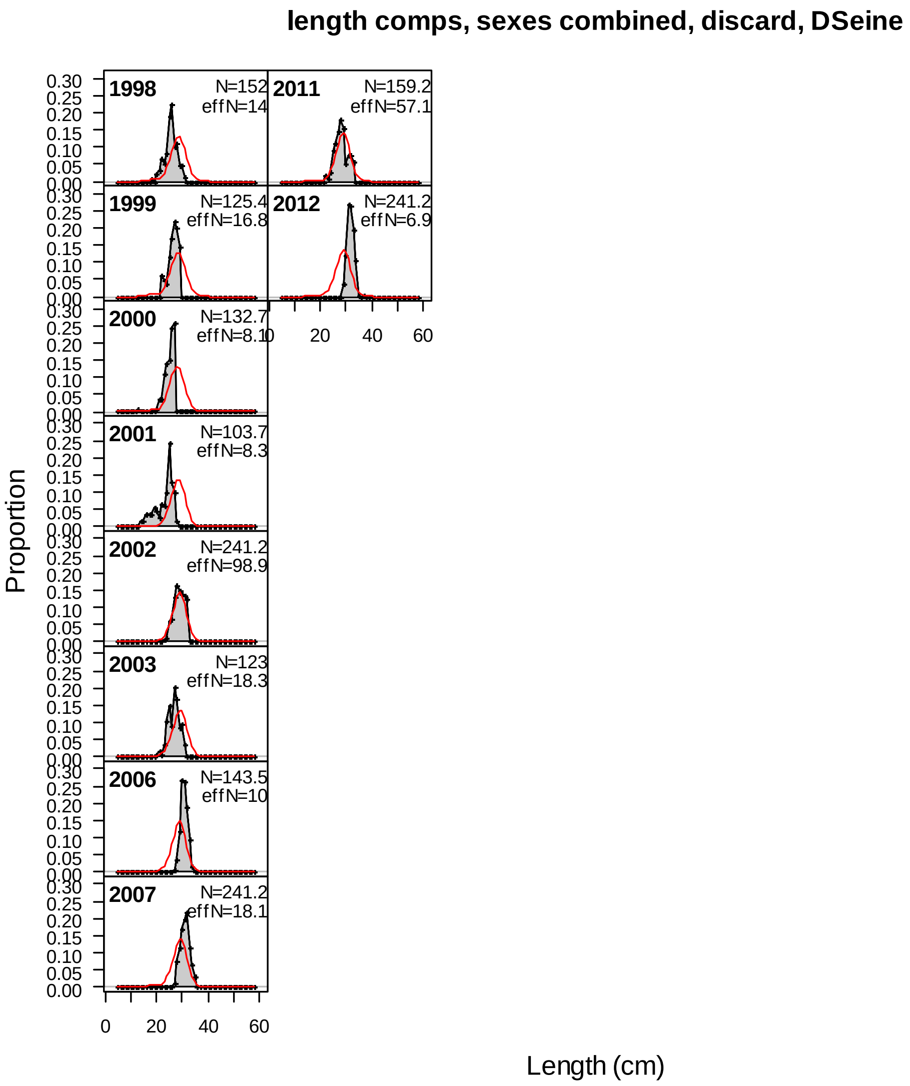
Apx Figure 10.1. Summary of data sources for tiger flathead stock assessment.



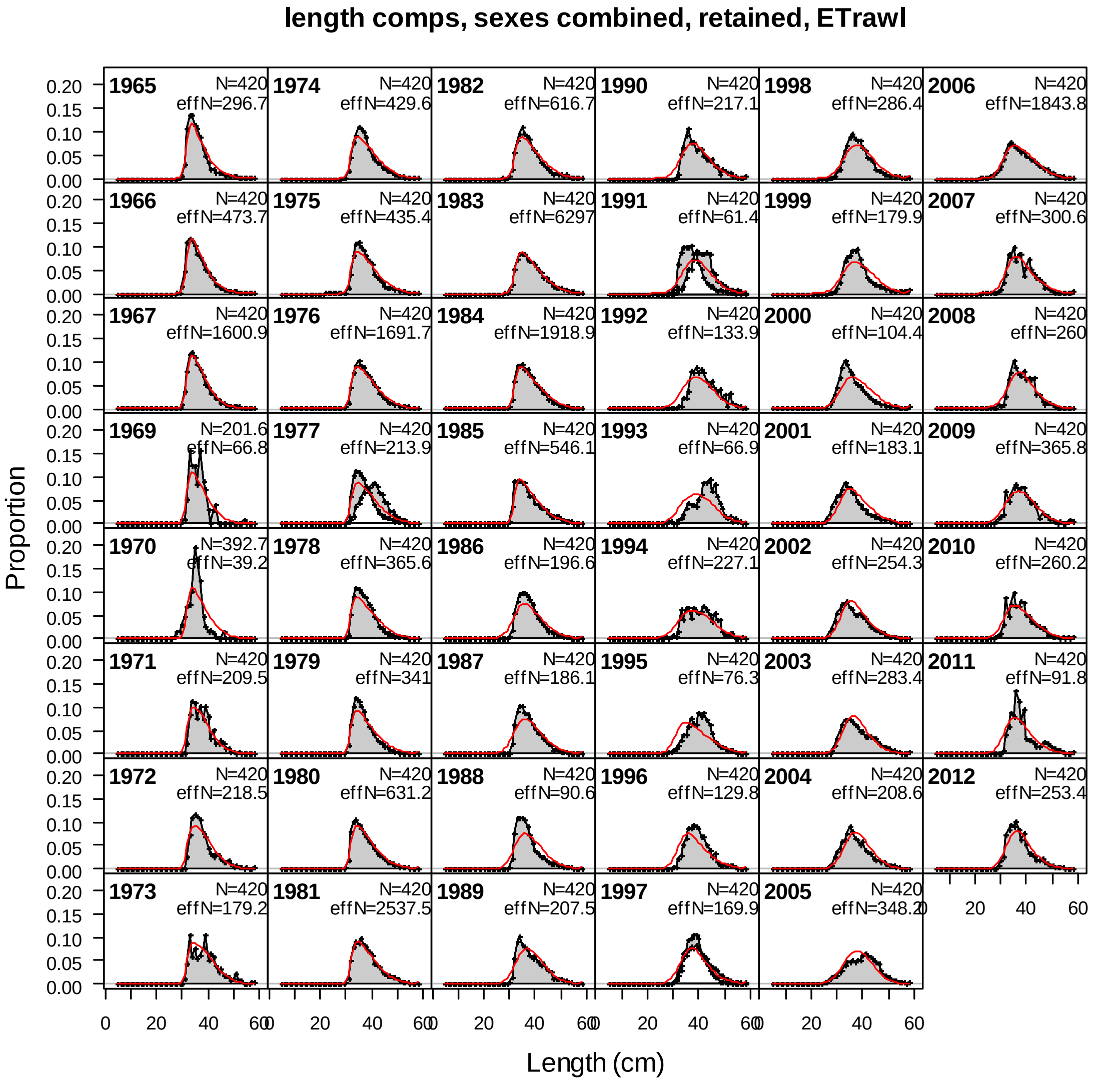
Apx Figure 10.2. Tiger flathead length composition fits: steam trawl retained.



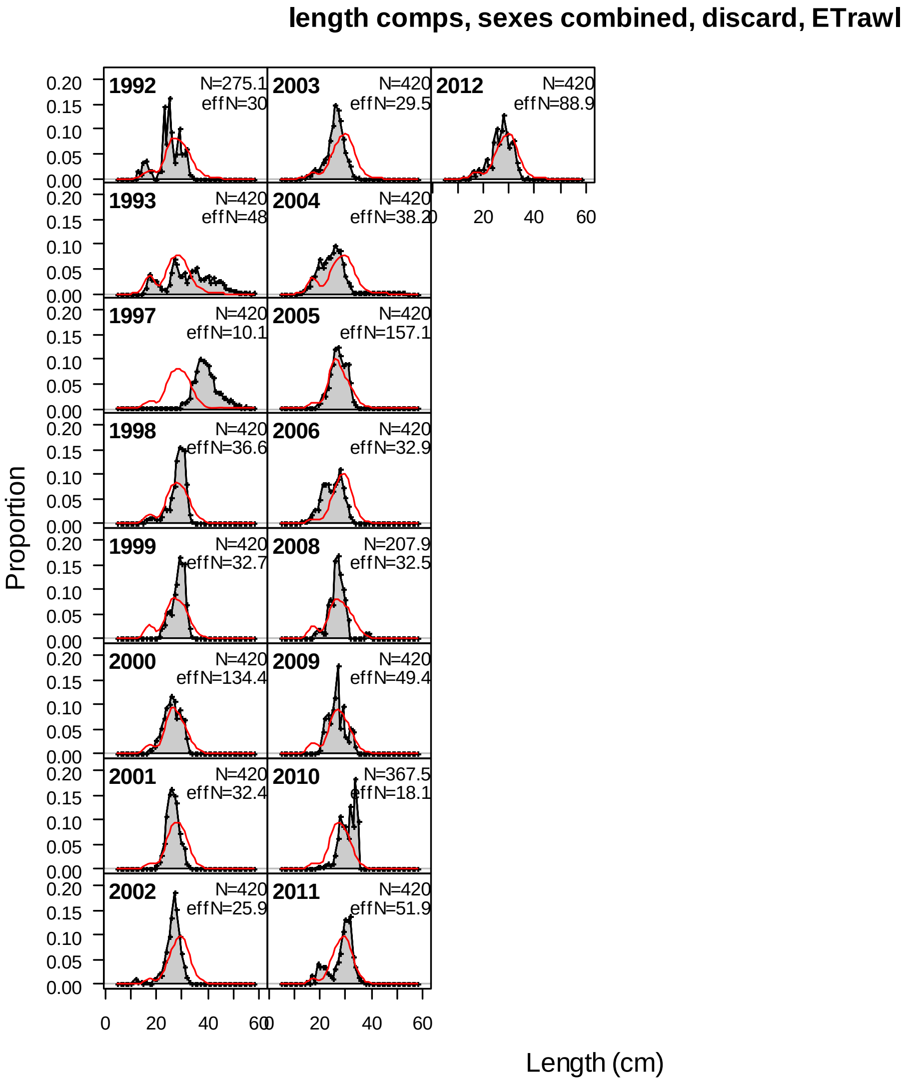
Apx Figure 10.3. Tiger flathead length composition fits: Danish seine retained.



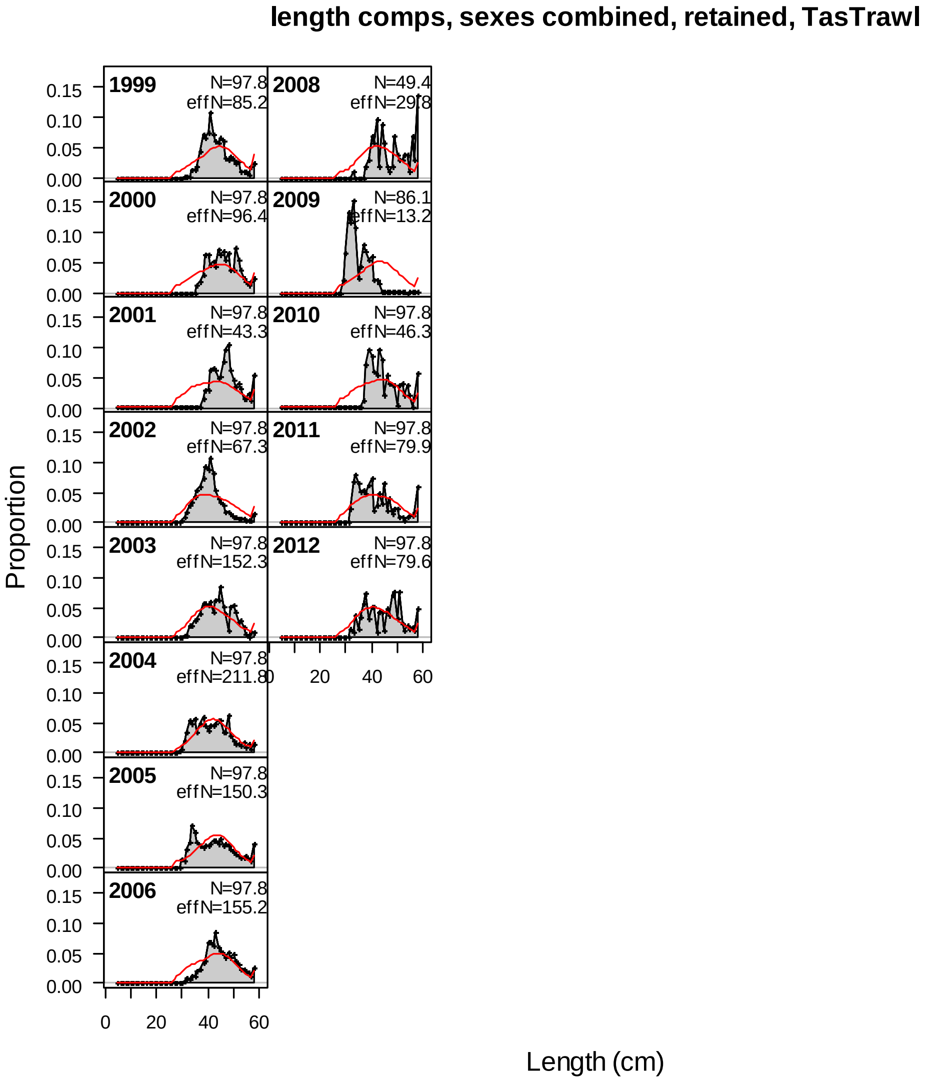
Apx Figure 10.4. Tiger flathead length composition fits: Danish seine discarded.



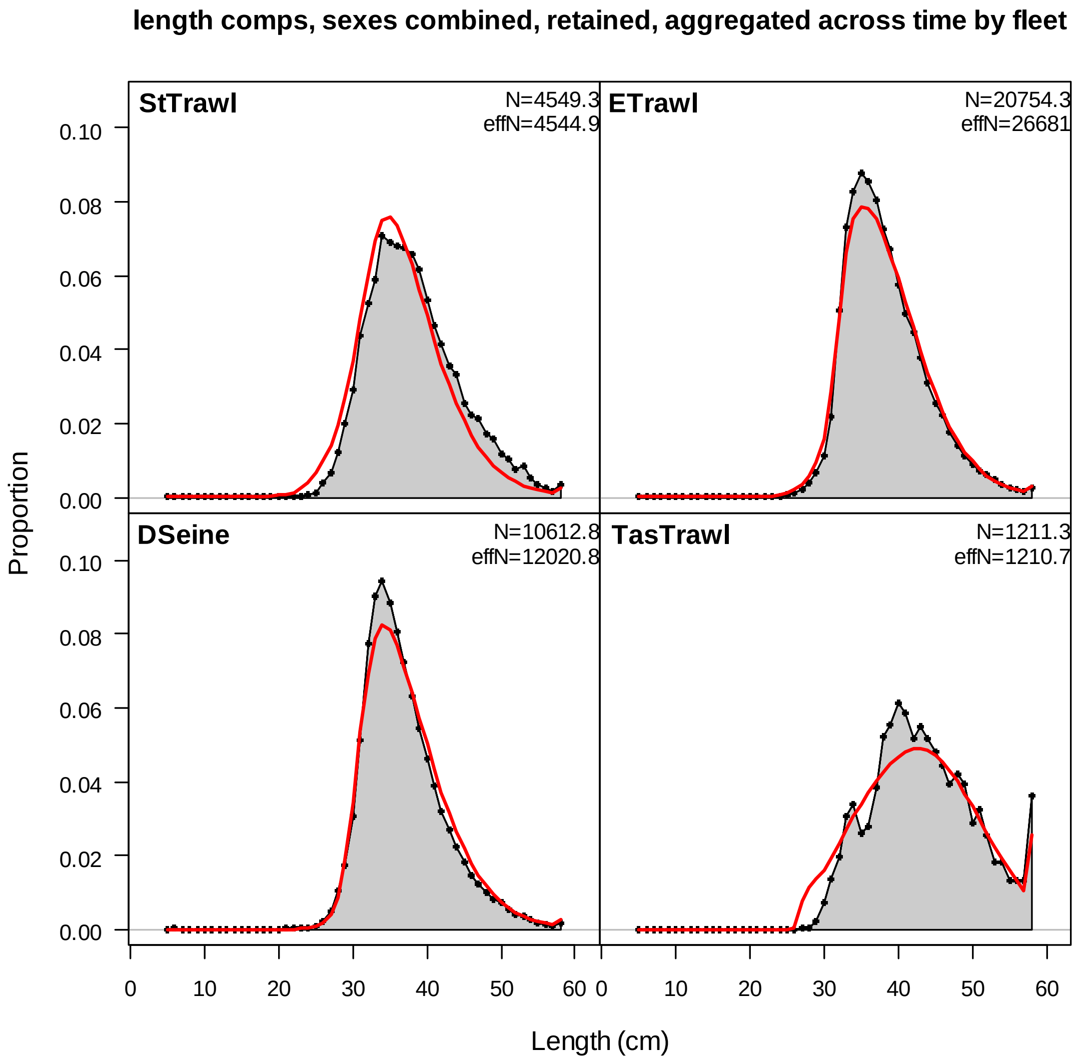
Apx Figure 10.5. Tiger flathead length composition fits: eastern trawl retained.



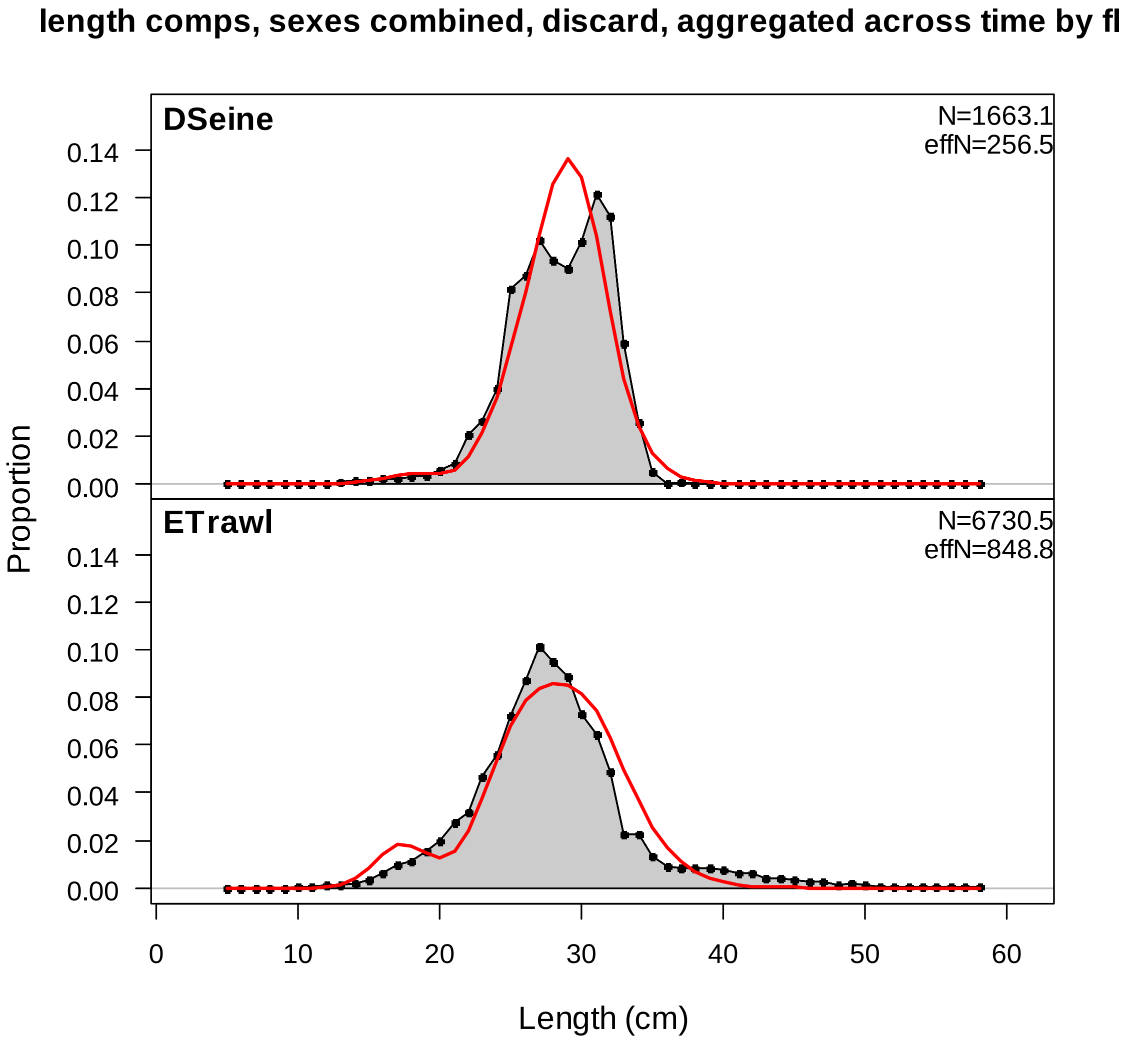
Apx Figure 10.6. Tiger flathead length composition fits: eastern trawl discarded.



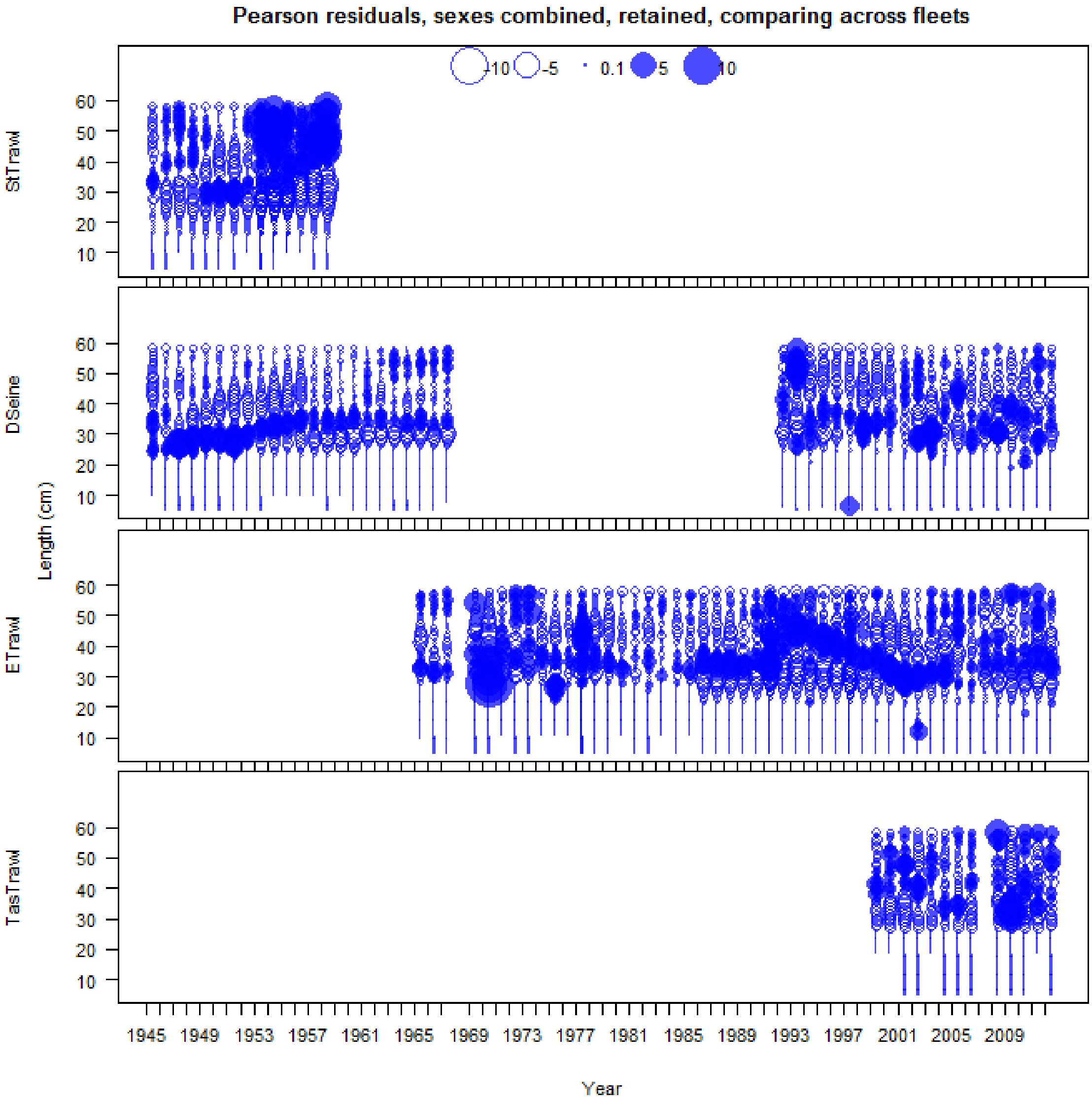
Apx Figure 10.7. Tiger flathead length composition fits: Tasmanian trawl retained.



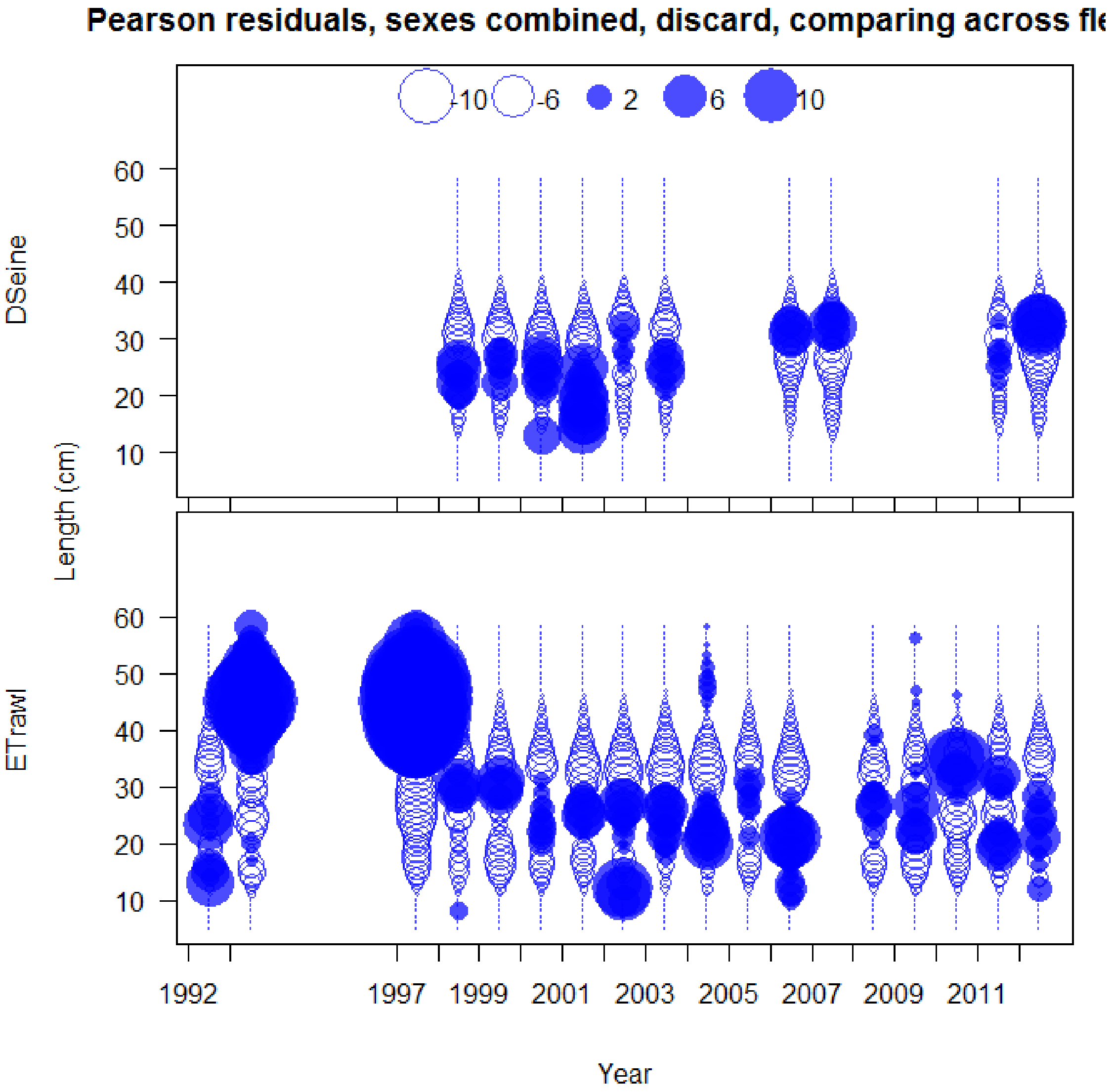
Apx Figure 10.8. Tiger flathead length composition fits (retained): all fleets aggregated across time.



Apx Figure 10.9. Tiger flathead length composition fits (discarded): all fleets aggregated across time.



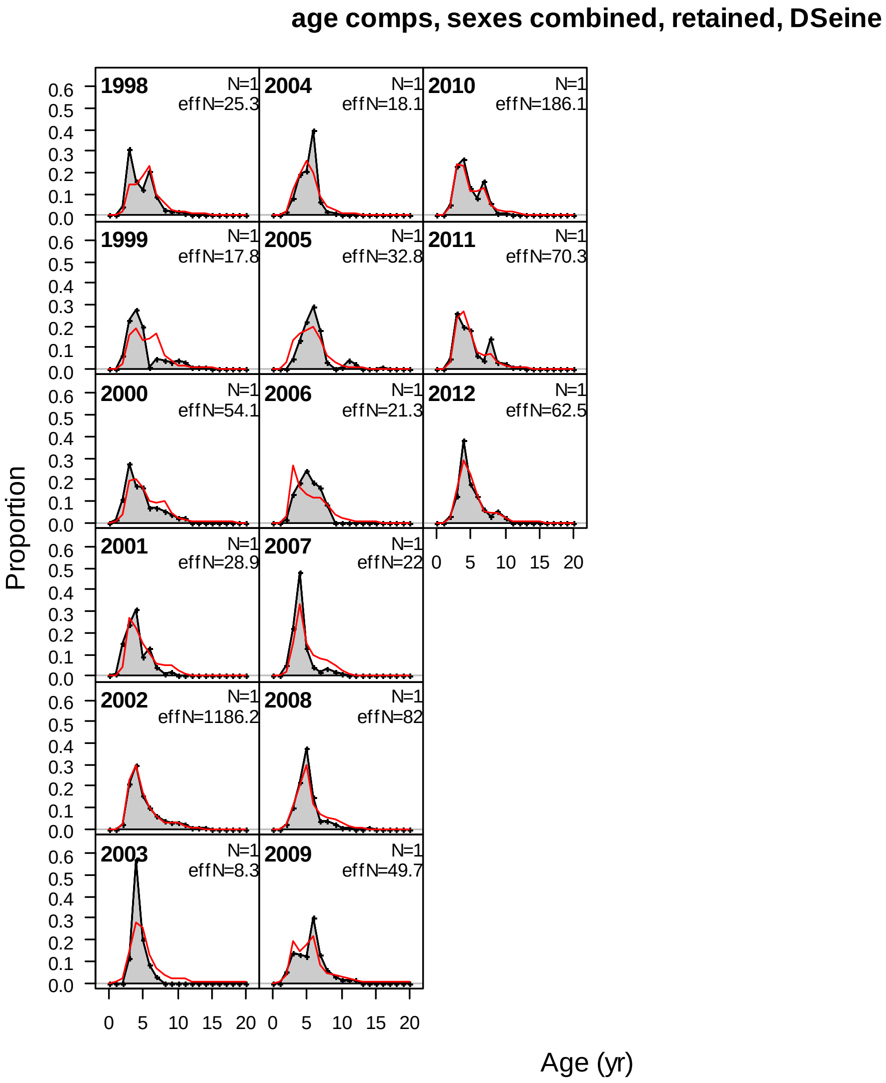
Apx Figure 10.10. Residuals from the annual length compositions (retained) for tiger flathead displayed by year and fleet.



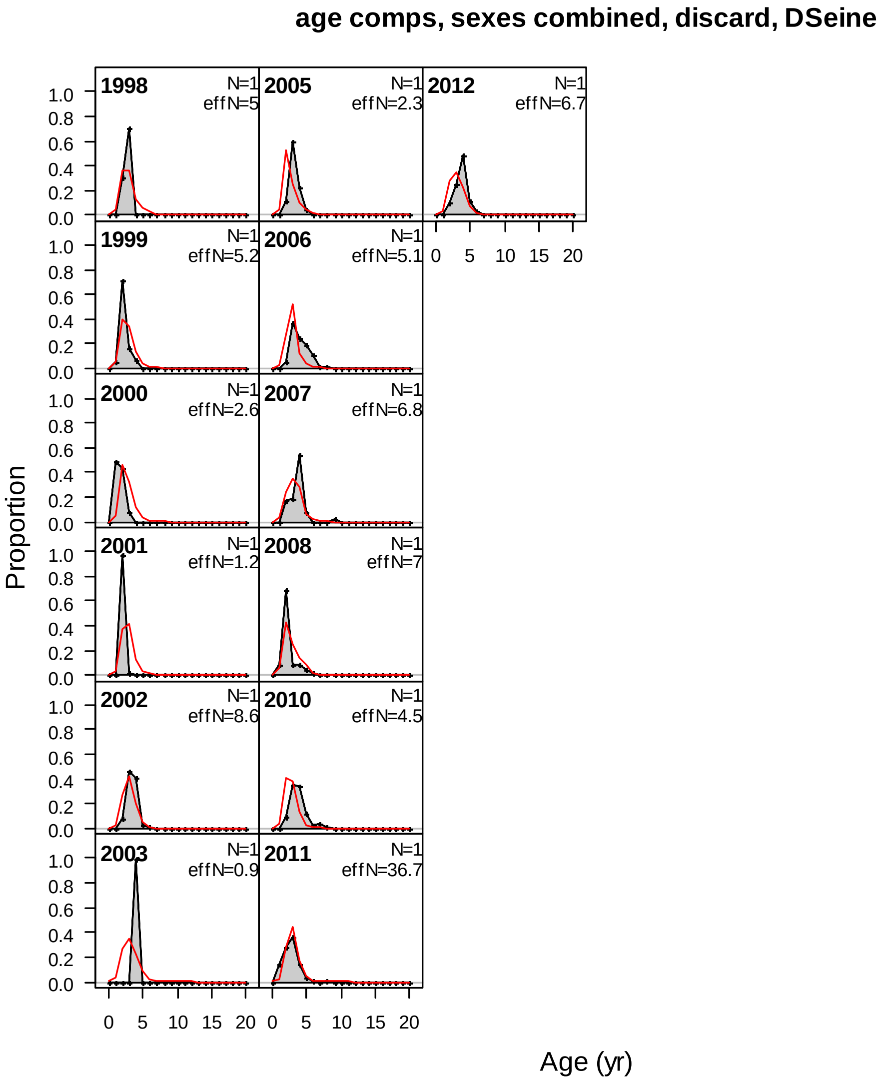
Apx Figure 10.11. Residuals from the annual length compositions (discarded) for tiger flathead displayed by year and fleet.

10.8 Appendix B: Implied fits to age composition data

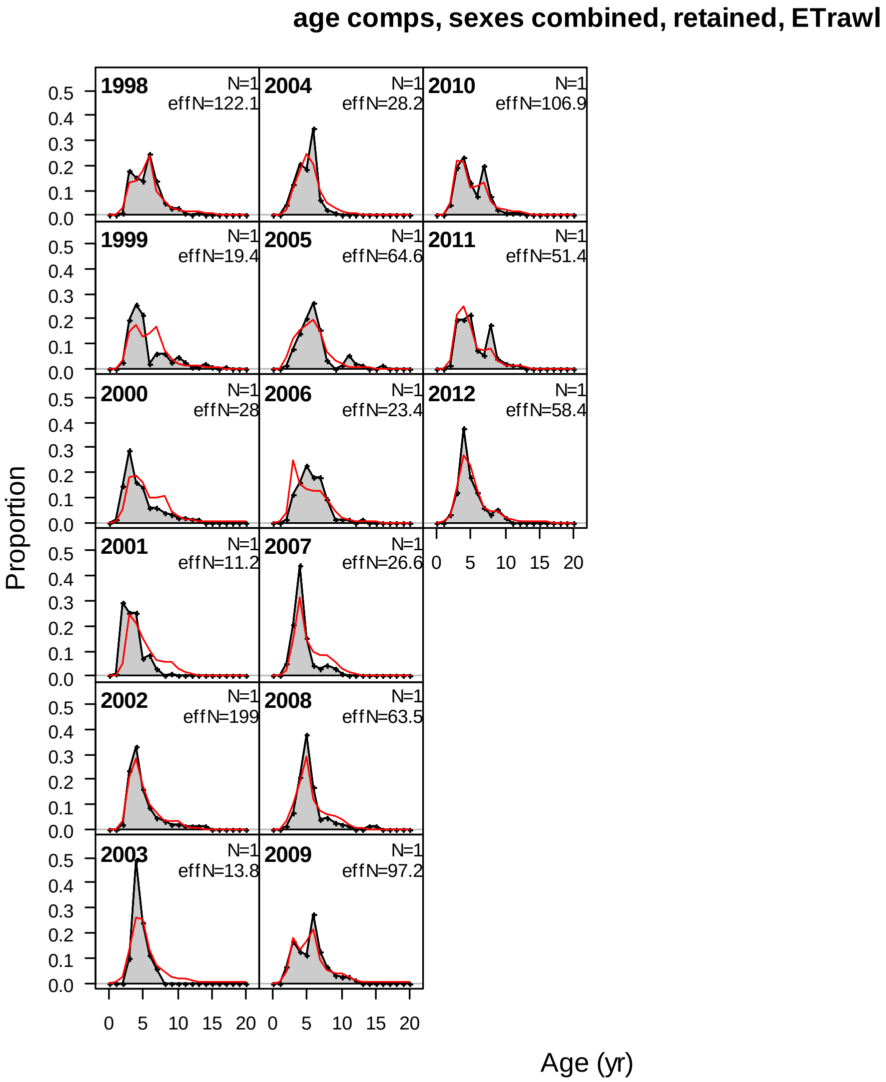
The age composition data is not directly fitted, so these are fits to the implied age composition calculated from the age-length relationship and the length frequencies. The observed values (black dots) for a particular fleet and year are calculated from the age-length key from all fish aged in that year (over all fleets) multiplied by the observed length frequency for that fleet. The fitted values (red lines) are the estimates of age frequency in that year from the model, multiplied by the selectivity for that fleet.



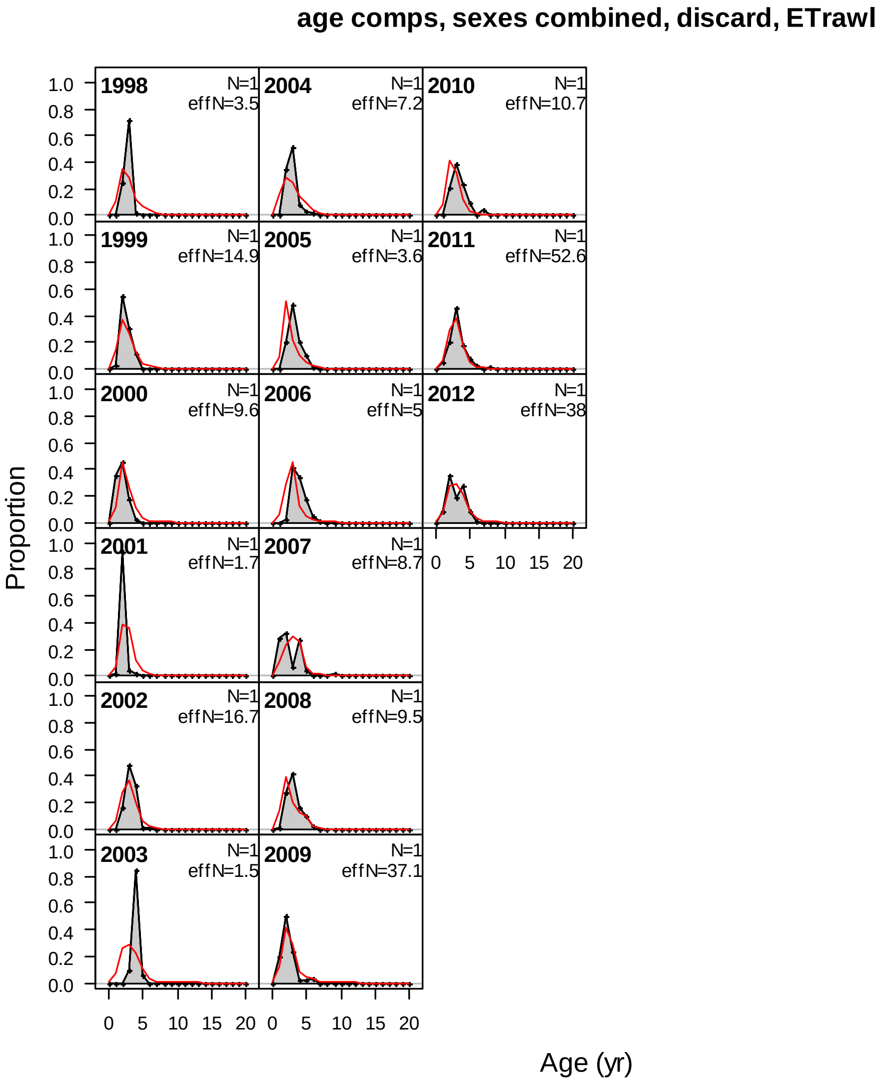
Apx Figure 10.12. Tiger flathead implied age composition fits: Danish seine retained.



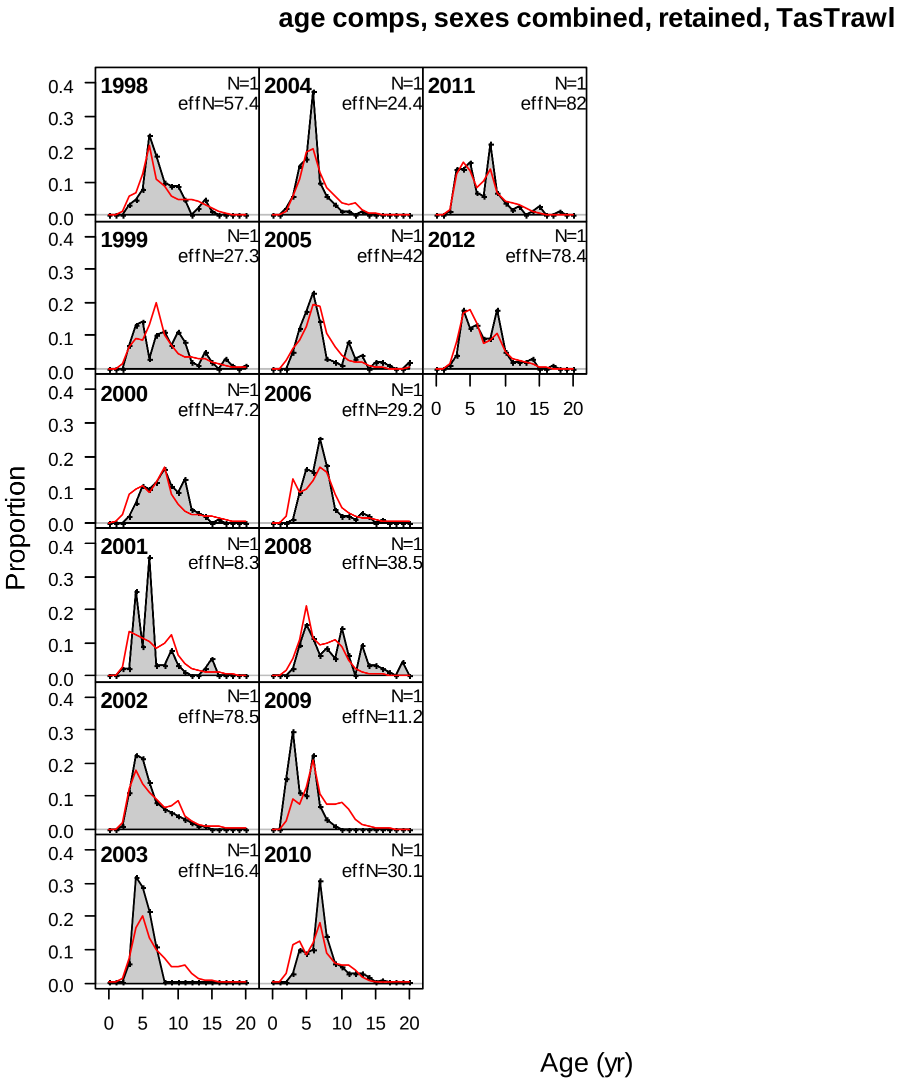
Apx Figure 10.13. Tiger flathead implied age composition fits: Danish seine discarded.



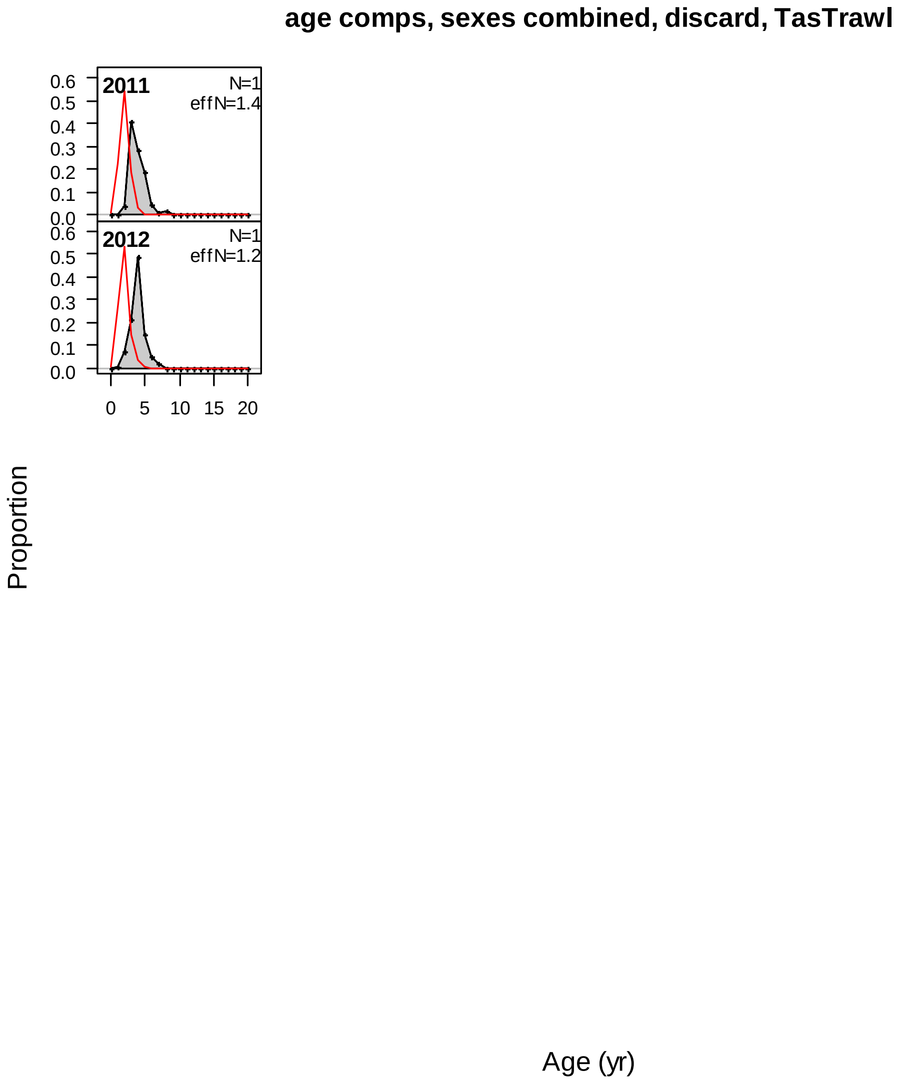
Apx Figure 10.14. Tiger flathead implied age composition fits: eastern trawl retained.



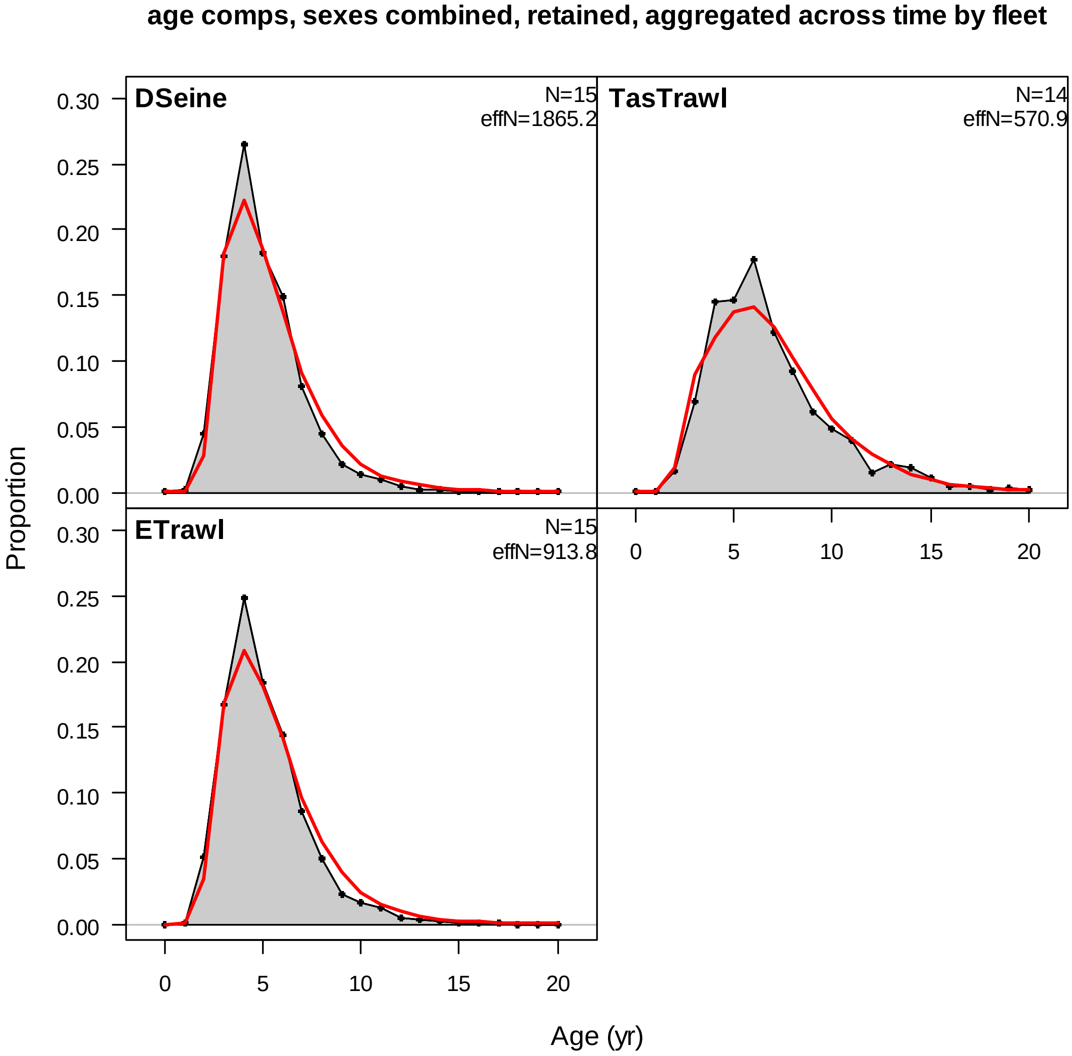
Apx Figure 10.15. Tiger flathead implied age composition fits: eastern trawl discarded.



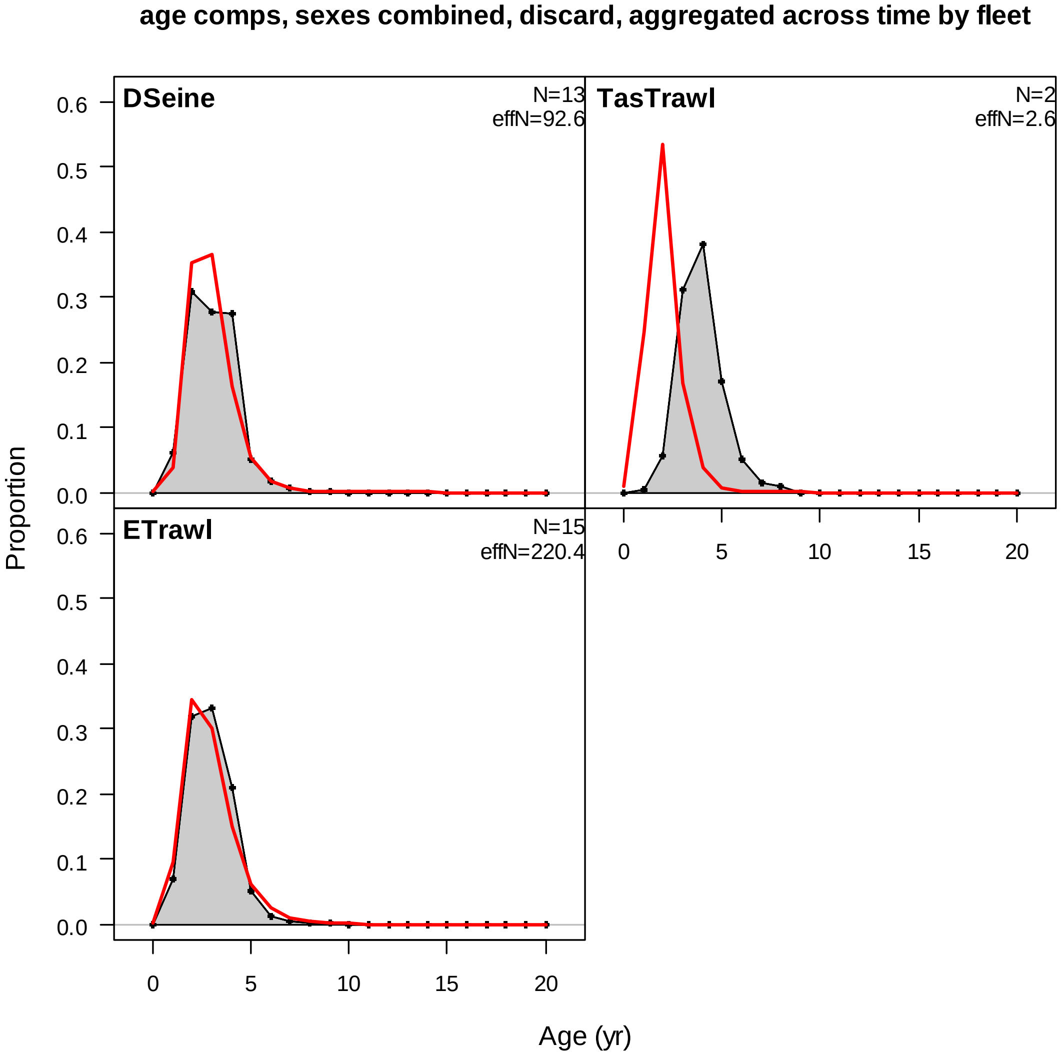
Apx Figure 10.16. Tiger flathead implied age composition fits: Tasmanian trawl retained.



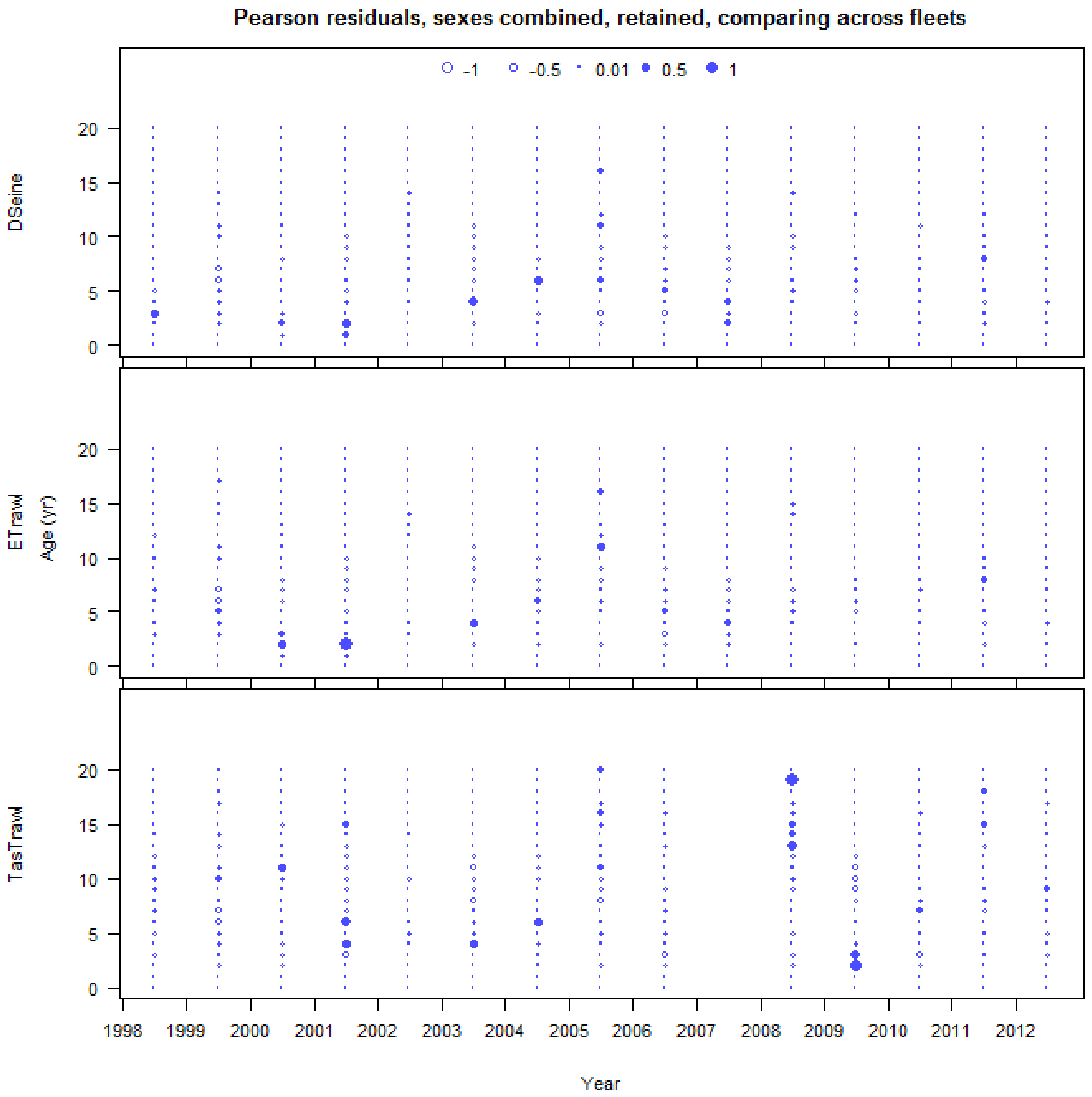
Apx Figure 10.17. Tiger flathead implied age composition fits: Tasmanian trawl discarded.



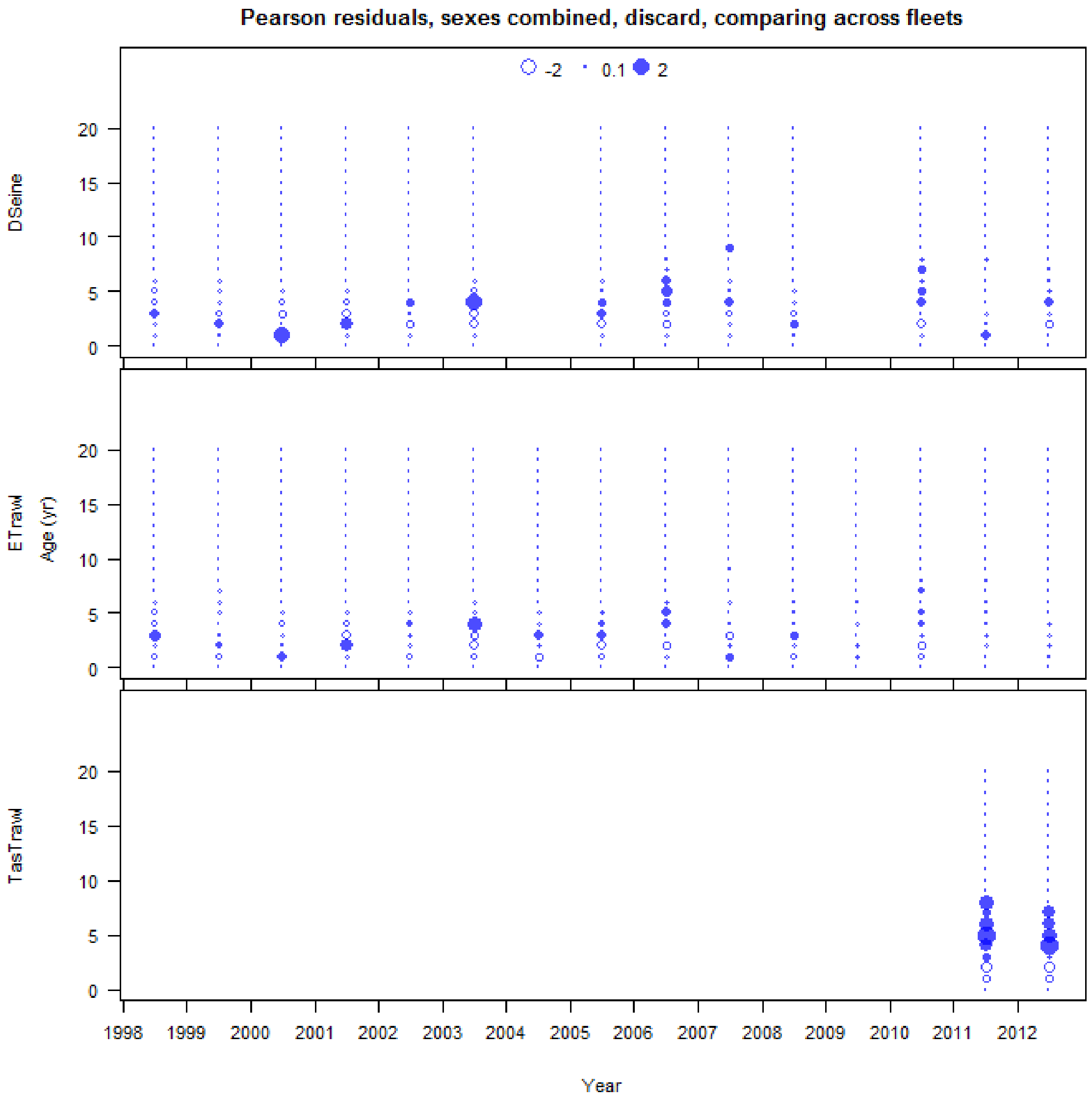
Apx Figure 10.18. Tiger flathead implied age composition fits (retained): all fleets aggregated across time.



Apx Figure 10.19. Tiger flathead implied age composition fits (discarded): all fleets aggregated across time.



Apx Figure 10.20. Residuals from the annual implied age compositions (retained) for tiger flathead displayed by year and fleet.



Apx Figure 10.21. Residuals from the annual implied age compositions (discarded) for tiger flathead displayed by year and fleet.

11. Deepwater flathead (*Neoplatycephalus conatus*) stock assessment based on data up to 2012/13 – development of a base case [7]

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11.1 Summary

In an assessment year, the current approach is to have two research assessment group (RAG) meetings to examine stock assessment results, with the first to decide on a base case stock assessment, and the second to provide recommended biological catch (RBC) values and sensitivity results for the basecase. This document describes the process used to develop a preliminary base case for deepwater flathead (*Neoplatycephalus conatus*) for presentation at the first stock assessment meeting in 2013. It details the sequential application of recent data to the stock assessment, tuning of the preliminary base model, and final development of the base case model. The base case presented here estimates depletion in 2012/13 at 47% of B_0.

11.2 Input data

11.2.1 *Catches*

Recent catches for deepwater flathead and Bight redfish were taken directly from CDR landings data for the GABTF maintained by AFMA. New figures were added for 12/13, while also checking that the figures for 2010/11 and 2011/12 were unchanged. Total catch estimates for the period 1988/89 to 2009/10 are given in Table 11.1. A new Danish seine vessel operated from the 2011/12 financial year. Both state catches and discards are assumed to be negligible for deepwater flathead, and are not accounted for by the stock assessment.

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[7] Paper presented at the GAB RAG meeting November 2013

Table 11.1. Financial year catch of deepwater flathead and Bight redfish.

	Catch (kg)	
	Deepwater flathead	Bight redfish
88/89	312,491	85,651
89/90	394,672	170,833
90/91	420,152	281,808
91/92	608,128	265,612
92/93	508,162	120,698
93/94	585,072	107,472
94/95	1,254,803	157,803
95/96	1,551,593	173,922
96/97	1,459,341	327,177
97/98	1,010,348	372,617
98/99	680,659	437,788
99/00	544,992	323,641
00/01	776,912	387,879
01/02	963,613	262,613
02/03	1,866,026	424,672
03/04	2,482,093	946,477
04/05	2,264,119	937,456
05/06	1,545,604	789,704
06/07	1,039,687	1,023,908
07/08	1,034,709	808,024
08/09	812,663	681,875
09/10	851,272	469,696
10/11	968.028	297,596
11/12	973,371	341,481
12/13	1,027,842	273,541

11.2.2 **Catch rates**

Catch rates were previously standardised using Generalised Additive Models (GAMs) (Hobsbawn et al. 2002a, 2002b) and a log-linear model (Klaer, 2006). Standardisations for a range of SESSF species are carried out each year by CSIRO (see Haddon, 2013). Standardisations commencing this year for deepwater flathead and Bight redfish have been added to the list of SESSF species processed in a standard manner. Standardised results produced by Haddon (2013) are given in Table 11.2.

Table 11.2. Deepwater flathead standardised CPUE per financial year (Haddon 2013)

	Index
87/88	0.47
88/89	1.03
89/90	1.03
90/91	1.04
91/92	0.90
92/93	1.07
93/94	1.44
94/95	1.85
95/96	1.81
96/97	1.23
97/98	0.86
98/99	0.65
99/00	0.76
00/01	0.84
01/02	1.00
02/03	1.41
03/04	1.35
04/05	1.09
05/06	0.68
06/07	0.62
07/08	0.68
08/09	0.81
09/10	0.75
10/11	0.95
11/12	0.70
12/13	0.86

A comparison of log-linear model results by Haddon (2013) with those from Klaer (2012) (Figure 11.1) shows that results from 1987/88 to 2011/12 are very similar, despite several differences in the model procedures used. A major difference is that time of day (whether the fishing was carried out during the day or night) is included in the new procedure.

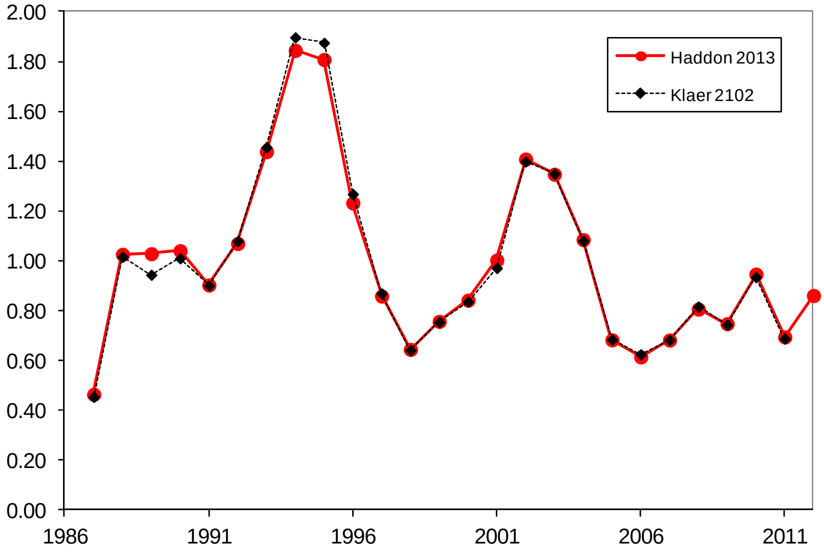


Figure 11.1. Deepwater flathead comparison of LM 2012 results with LM 2010.

11.2.3 ***Fishery-independent survey***

Biomass estimates have been taken from Knuckey *et al*. (2011).

Table 11.3. Estimated exploitable biomass (t) with coefficient of variation (cv) of major species.

	Estimated relative biomass											
Species	2005		2006		2007		2008		2009		2011	
	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.
Bight Redfish[A]	20,887	0.13	25,380	0.16	25,713	0.16	14,591	0.11	27,610	0.18	13,189	0.13
Deepwater Flathead	12,152	0.05	8,415	0.06	8,540	0.05	7,725	0.06	9,942	0.05	9,227	0.05
Ocean Jacket	7,163	0.14	9,111	0.26	6,701	0.37	7,709	0.29	21,374	0.21	27,712	0.2
Common Sawshark	298	0.16	138	0.23	462	0.24	231	0.14	530	0.21	788	0.11
Yellowspotted Boarfish	349	0.19	181	0.15	142	0.26	170	0.25	121	0.18	353	0.23
Gummy Shark	558	0.17	288	0.25	402	0.23	434	0.14	470	0.18	797	0.16
Jackass Morwong	1,025	0.34	1,037	0.23	1,236	0.31	916	0.3	783	0.23	441	0.24
Knifejaw	955	0.12	1,133	0.14	570	0.13	806	0.11	1,121	0.15	1,129	0.17
Latchet	9,401	0.13	6,135	0.25	7,040	0.21	3,688	0.17	12,997	0.15	8,690	0.17
Ornate Angelshark	3,078	0.09	1,887	0.1	2,770	0.11	1,742	0.1	2,107	0.07	2,305	0.08
Spikey Dogfish	834	0.24	867	0.3	1,006	0.23	508	0.33	607	0.17	1,799	0.16
Other species	11,693	0.13	14,405	0.14	22,990	0.14	17,558	0.12	23,666	0.12	15,272	0.09

[A] night hauls only

11.2.4 ***Composition data***

Table 11.4. Number of retained fish lengths included in the base case assessment by fleet 1993/94-2012/13.

Year	Length samples	Source
93/94	1,242	Port
94/95	584	Port
97/98	697	Port+Onboard
98/99	3,782	Port
99/00	5,368	Port
00/01	9,731	Port+Onboard
01/02	6,401	Onboard
02/03	2,478	Port+Onboard
03/04	6,761	Port+Onboard
04/05	12,852	Port+Onboard
05/06	10,773	Port+Onboard
06/07	2,098	Onboard
07/08	2,666	Onboard
08/09	1,849	Onboard
09/10	25,665	Port+Onboard
10/11	4,611	Port
11/12	11,368	Port
12/13	12,236	Port

Table 11.5 Number of age-length otolith samples included in the base case assessment 1987/88-2011/12.

Year	Age-length samples
87/88	61
88/89	290
89/90	214
90/91	96
92/93	50
93/94	407
94/95	178
95/96	430
96/97	287
97/98	972
98/99	1,162
00/01	600
02/03	639
04/05	563
05/06	555
06/07	484
07/08	650
08/09	554
09/10	465
10/11	552
11/12	367
12/13	787

11.3 Development of a preliminary base case

11.3.1 *Initial development of a preliminary base case*

Updated recent data were then added sequentially to the 2012 model to develop a preliminary base case for the 2013 assessment:

1. Change final assessment year to 2012/13, add catch and CPUE to 2012 (2013CatCPUE).
2. Add age composition data to 2012/13 (Age2012).
3. Update length compositions from 2009/10 to 2011/12 (Len2011).
4. Add length compositions from 2012/13 (Len2012).
5. Set final estimable recruitment value to 2008.
6. Retune model. Age comp lambda at 0.1 as previously, maximum sample size for lengths 200 all, tune input and output sample sizes for length and age comps, set bias adjustment, tune CV for CPUE and survey.

At step 5, recruitment was initially set to be estimated to 2011 and the variance of those estimates examined (Figure 11.2). The 2008 estimate had a variance comparable to estimates earliest in the series, so 2008 was chosen as the last year that could provide an estimated recruitment with acceptable variance.

Sequential effects of all of the above changes are shown in Figure 11.3 and Figure 11.4.

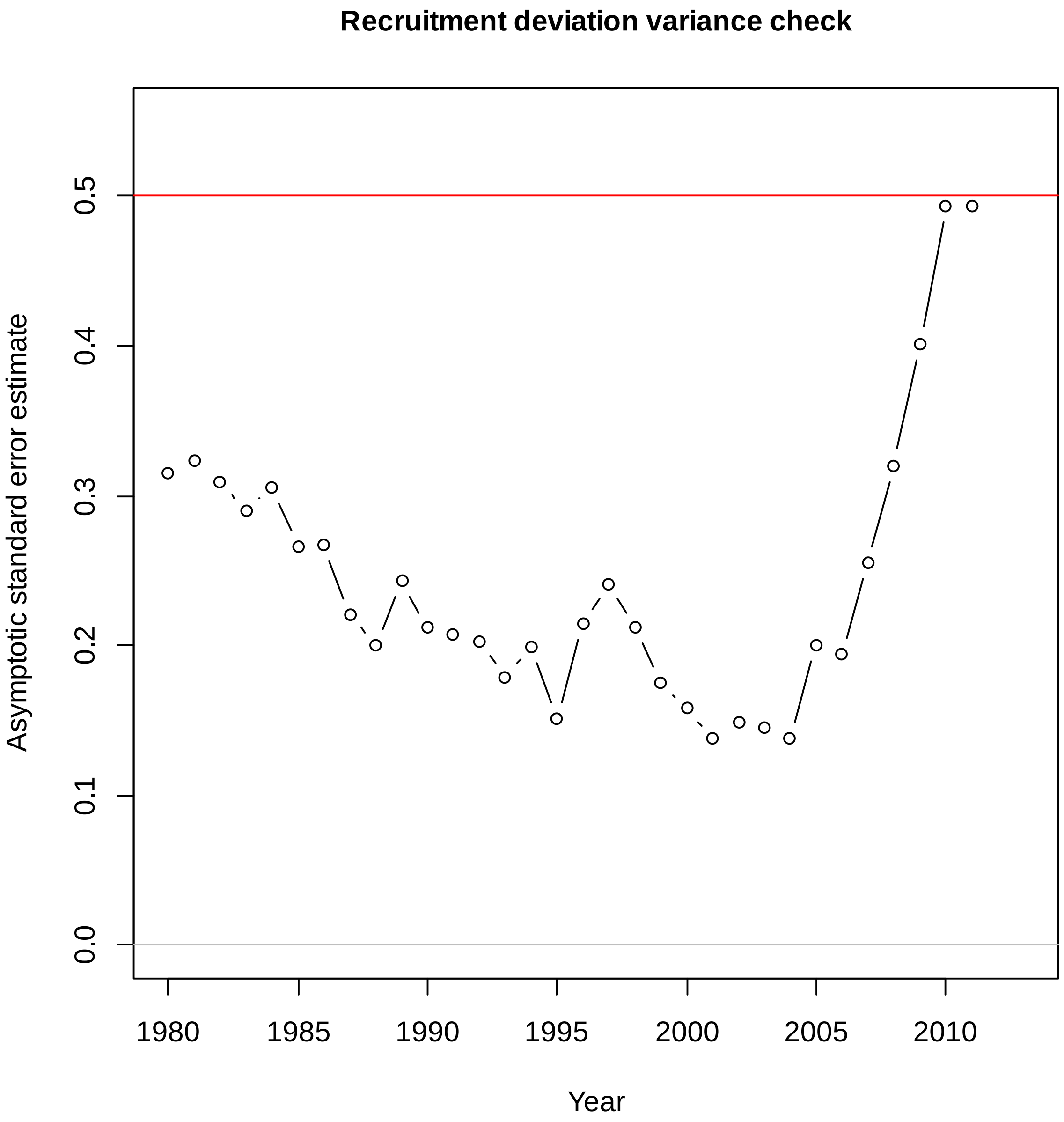


Figure 11.2. Variance of recruitment estimates when estimated to 2011.

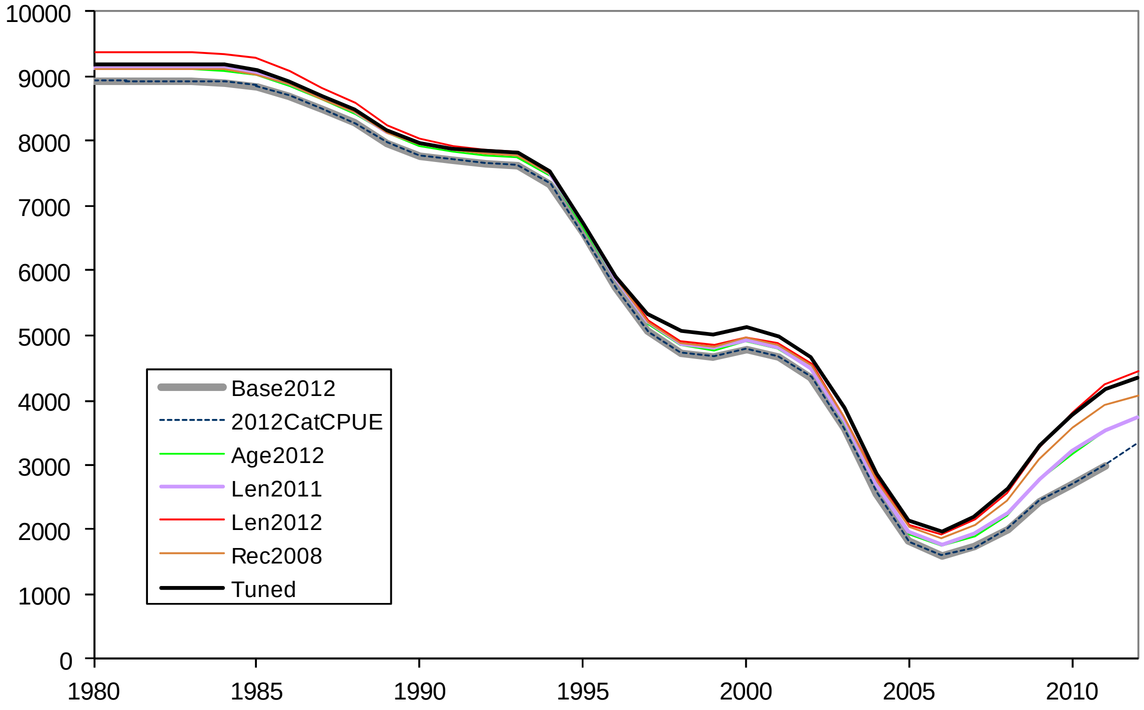


Figure 11.3. Effect on spawning biomass trends of sequential update with the most recent data, and preliminary model balancing.

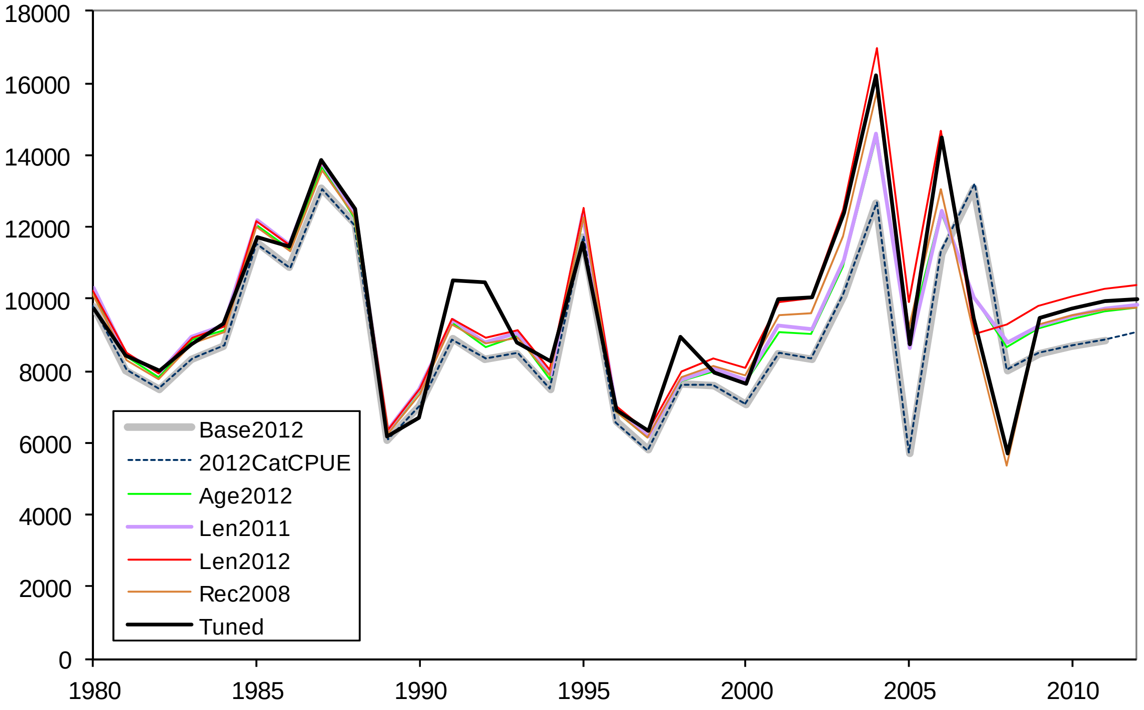


Figure 11.4. Effect on recruitment trends of sequential update with the most recent data, and preliminary model balancing.

11.3.2 ***Characteristics of the base case***

Biological parameters of the base case are given in Table 11.6. Diagnostic plots are provided in the Appendix.

Table 11.6. Deepwater flathead biological parameters.

	Source	Parameter		
			Female	Male
Years		y	1988-2012	
Recruitment		r	est 1980 - 2008	
Fleets			1 trawl only	
Discards			none significant, not included	
Age classes		a	0-30 years	
Sex ratio		p_s	0.5 (1:1)	
Natural mortality		M	fitted (0.24) per year	
Steepness		h	0.75	
Female maturity	1		40 cm (TL)	
Growth	2	Lmax	65.0258 cm (TL)	fitted
		K	fitted	fitted
		Lmin	fitted	fitted
		CV	fitted	
Length-weight	3	ϕ_1	0.002 cm (TL)/gm	0.002 cm (TL)/gm
		ϕ_2	3.332	3.339

11.4 References

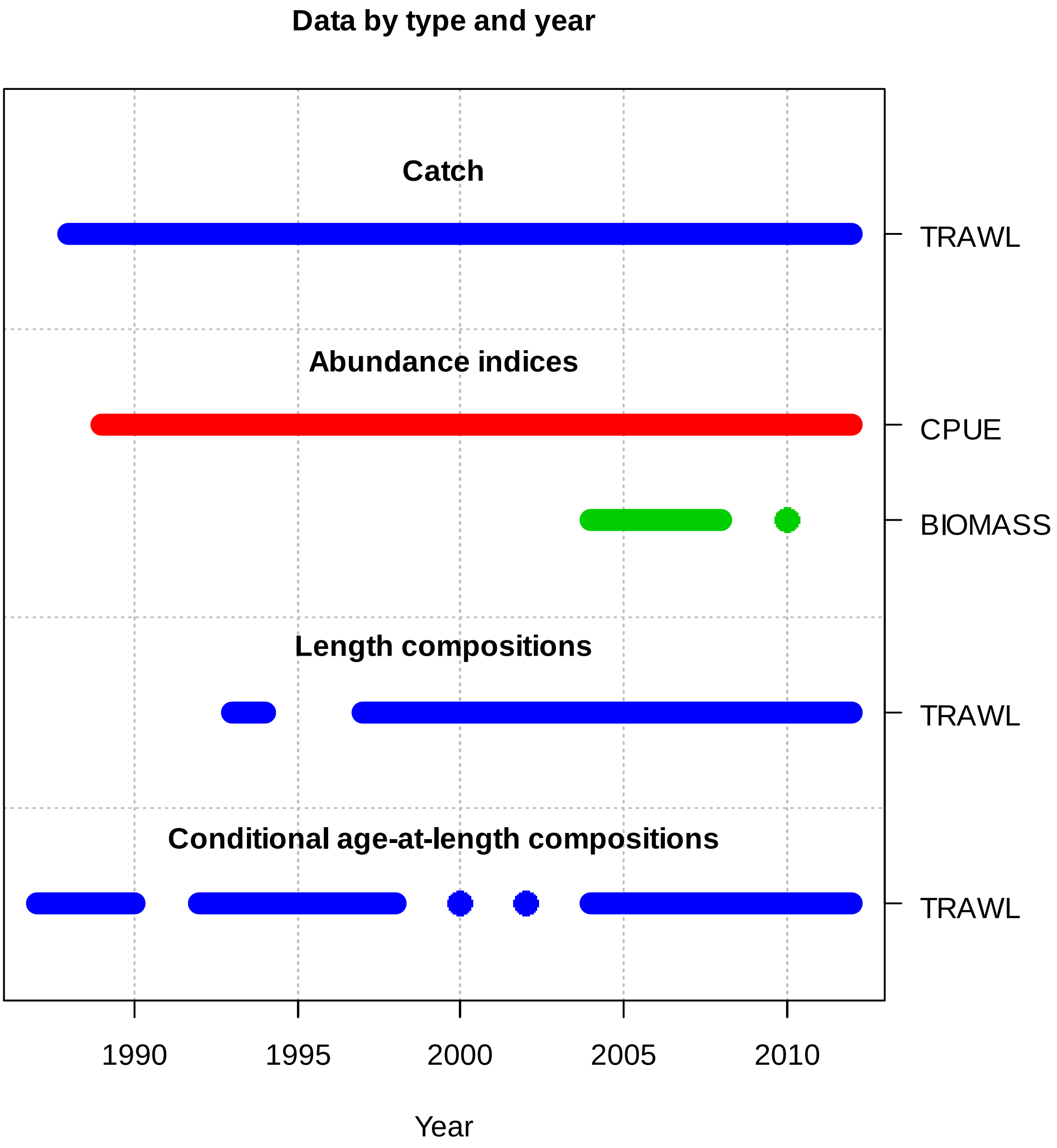
Haddon, M., 2013. Catch Rate Standardizations for Selected Species from the SESSF (data 1986 – 2012). Document prepared for SESSF RAGs 2013.

Klaer, N. 2007. Updated stock assessment for deepwater flathead (*Neoplatycephalus conatus*) and Bight redfish (*Centroberyx gerrardi*) in the Great Australian Bight trawl fishery using data to June 2007. Paper to GABRAG, October 2007.

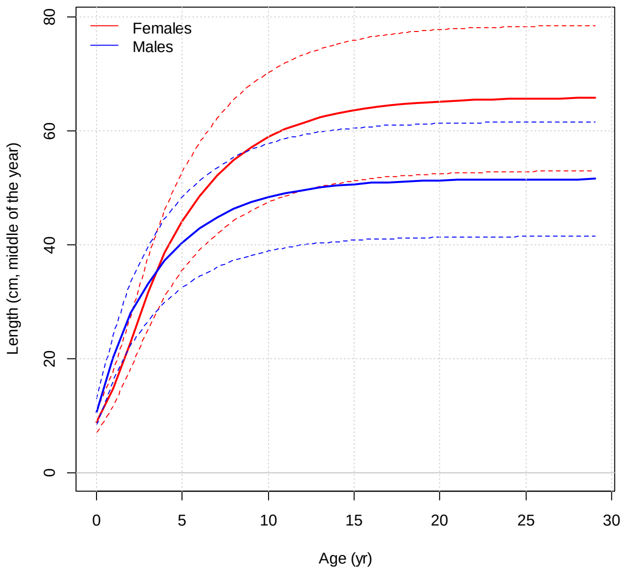
Klaer, N.L. 2012. Stock assessment for deepwater flathead (*Neoplatycephalus conatus*) in the Great Australian Bight trawl fishery using data to June 2012. Report to GABRAG 2012.

Knuckey, I., Koopman, M, Hudson, R. 2011. Resource Survey of the Great Australian Bight Trawl Sector 2011. Report to AFMA.

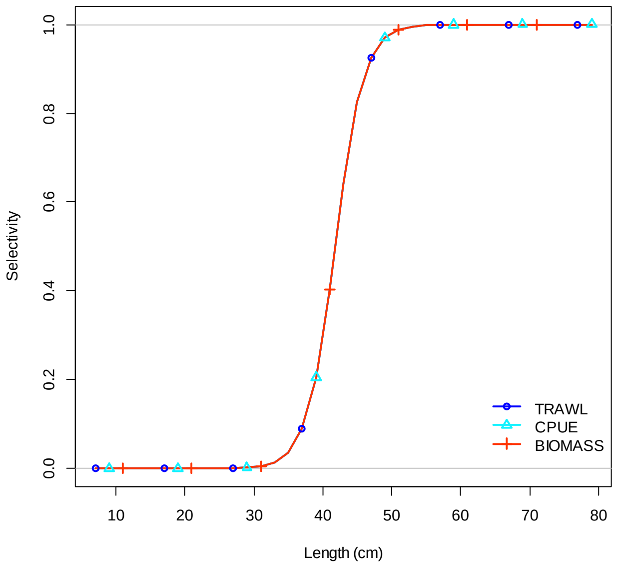
11.5 Appendix : base case diagnostics



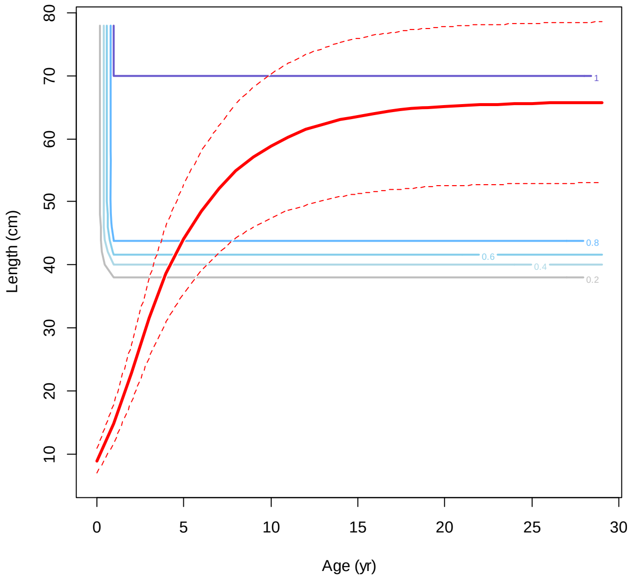
Ending year expected growth



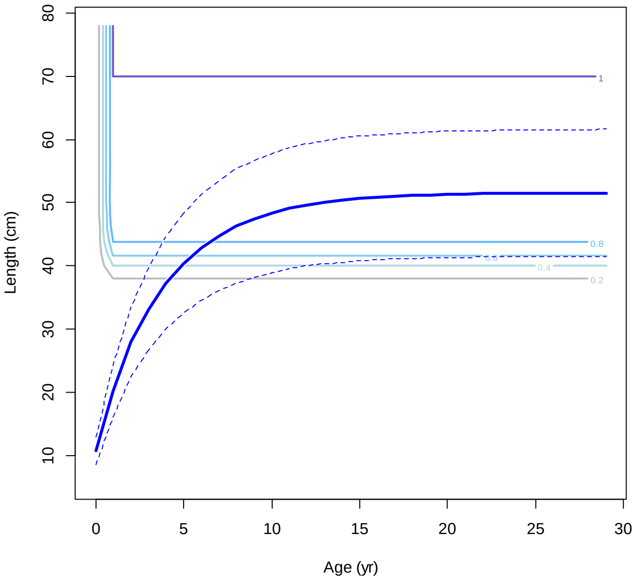
Length-based selectivity by fleet in 2012



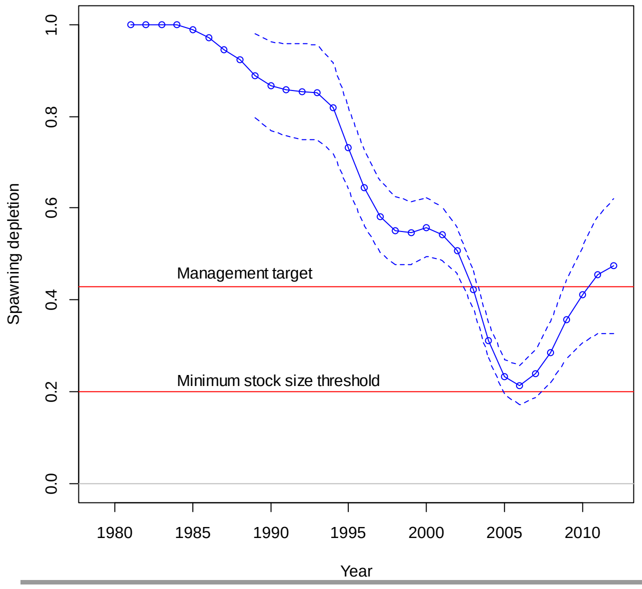
Female ending year selectivity and growth for TRAWL



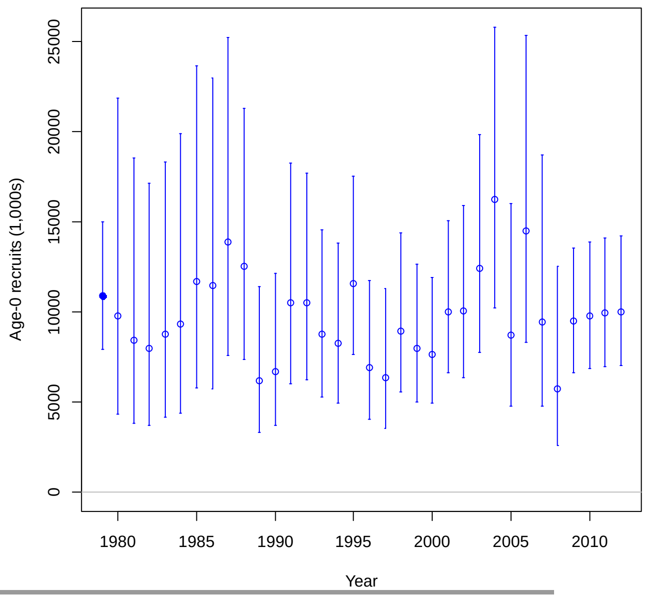
Male ending year selectivity and growth for TRAWL

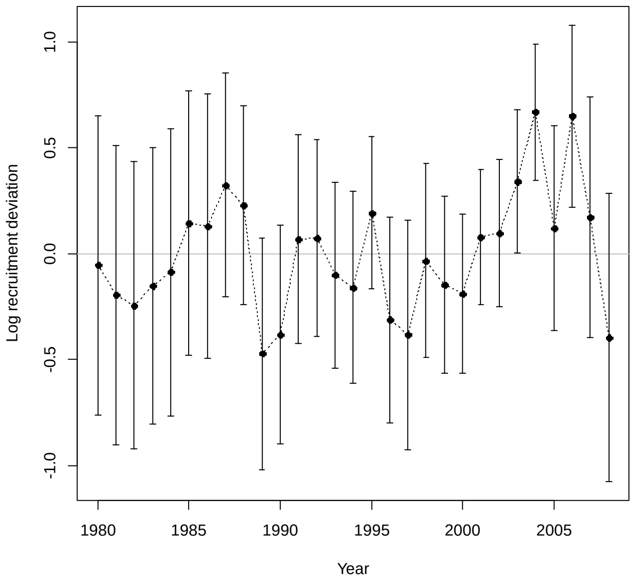


Spawning depletion with ~95% asymptotic intervals



Age-0 recruits (1,000s) with ~95% asymptotic intervals

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0.0
-0.5
-1.0
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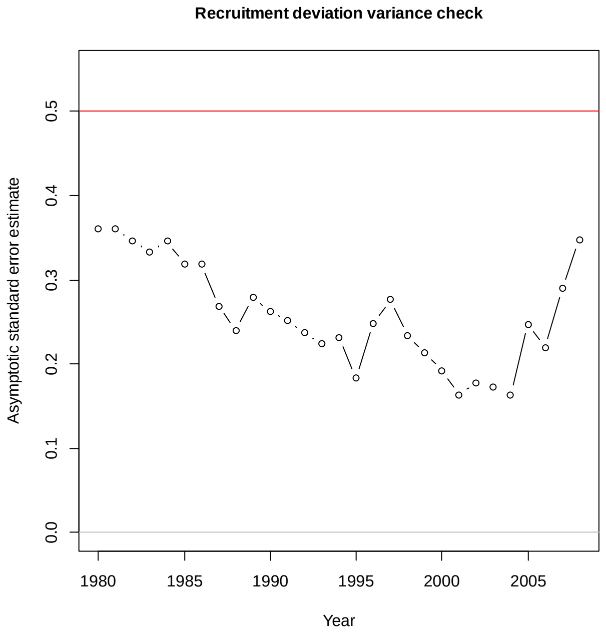
1985
1990
1995
2000
2005
Year


Recruitment deviation variance check
Asymptotic standard error estimate
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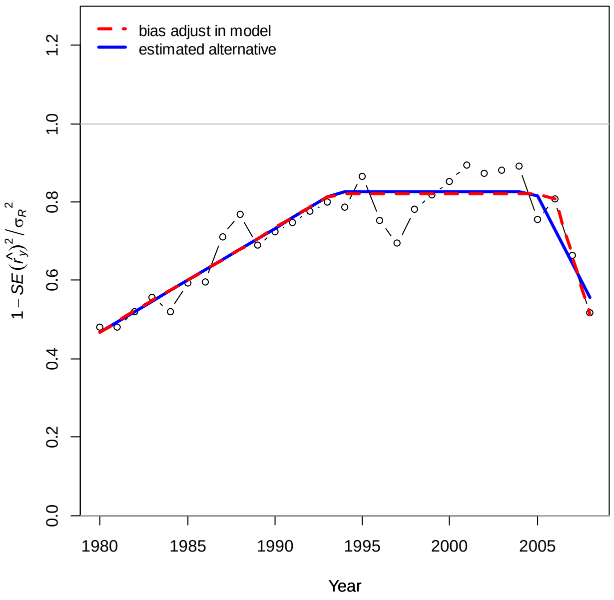
0.3
0.2
0.1
0.0
1980
1985
1990
1995
2000
2005
Year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estimated alternative
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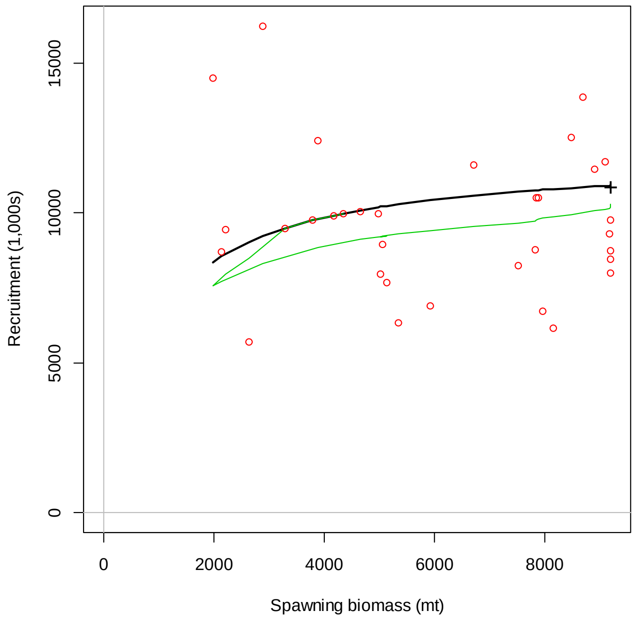
0.2
0.0
1980
1985
1990
1995
2000
2005
Year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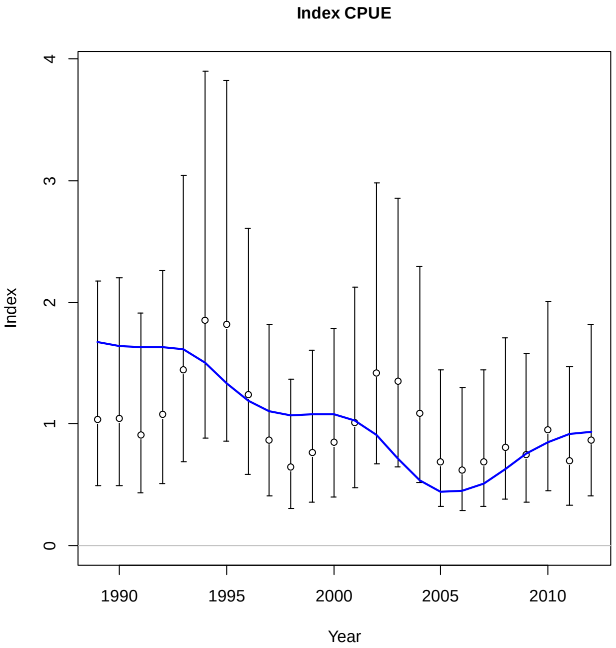
10000
5000
0
0
2000
4000
6000
8000
Spawning biomass (mt)


Index CPUE
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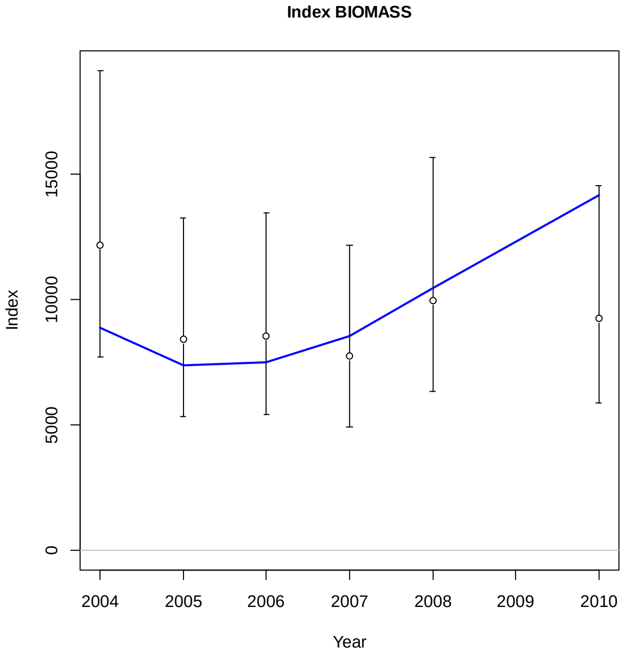
4
3
2
1
0
1990
1995
2000
2005
2010
Year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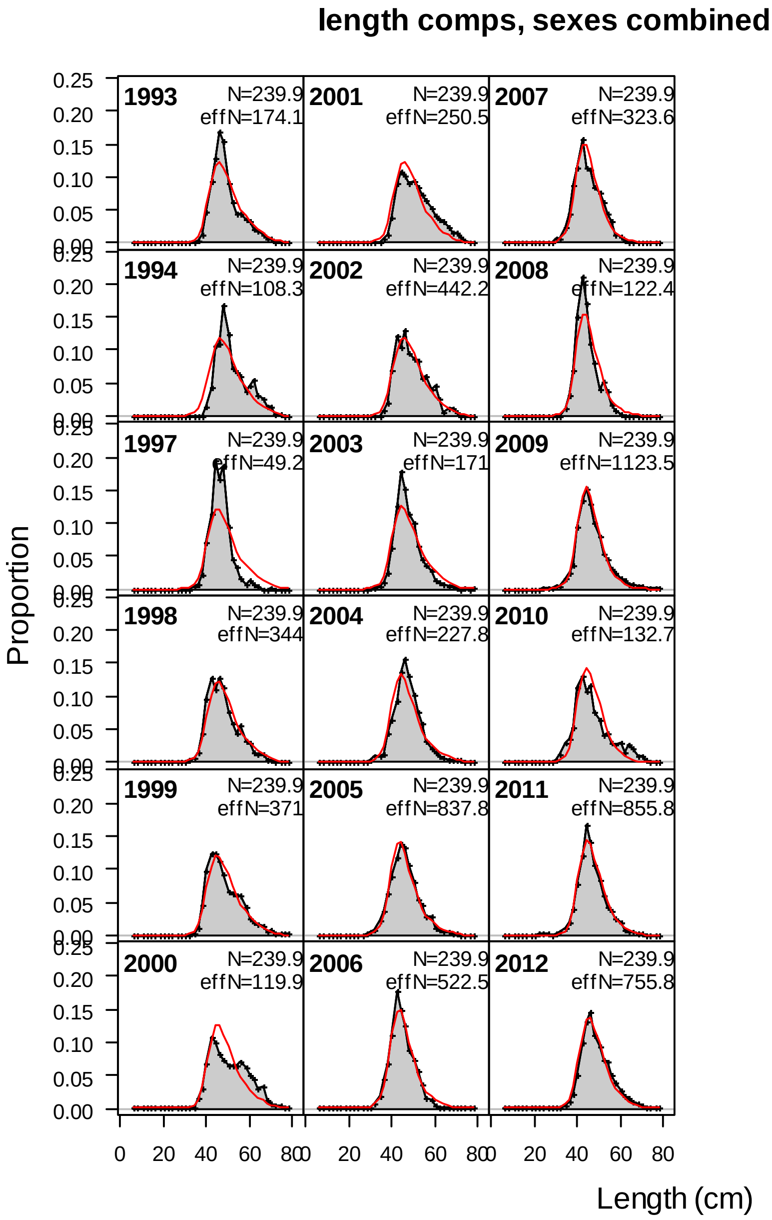
2004
2005
2006
2007
2008
2009
2010
Year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2008 N=239.9 effN=122.4
1997 N=239.9 effN=49.2
2003 N=239.9 effN=171
2009 N=239.9 effN=1123.5
1998 N=239.9 effN=344
2004 N=239.9 effN=227.8
2010 N=239.9 effN=132.7
1999 N=239.9 effN=371
2005 N=239.9 effN=837.8
2011 N=239.9 effN=855.8
2000 N=239.9 effN=119.9
2006 N=239.9 effN=522.5
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Proportion
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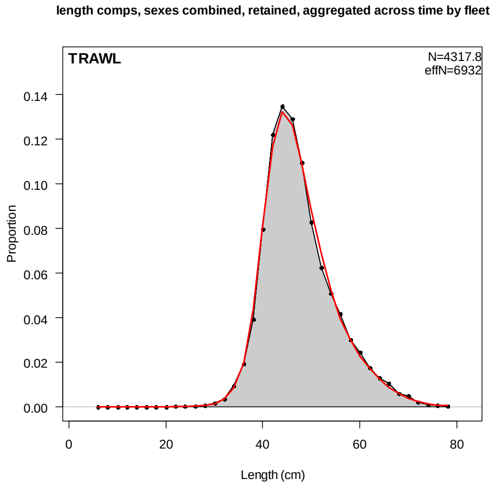
0 20 40 60 80
Length (cm)


length comps, sexes combined, retained, aggregated across time by fleet
TRAWL
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0 20 40 60 80
Length (cm)

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172 SizeSel_1P_2_TRAWL  6.0911700     3  0.01 60.00  5.0000     OK 0.24861700  Normal 15.000
    Pr_SD      Prior_Like Afterbound
111   0.8 0.0144234000000         OK
112  10.0 0.0276022000000         OK
114   0.8 0.0111989000000         OK
115   0.8 0.0000053440500         OK
118   0.8 0.0909267000000         OK
```

```
119   0.8 0.0441944000000         OK
120   0.8 0.0065506100000         OK
135  10.0 0.0000000331193         OK
171  99.0 0.0034249900000         OK
172  99.0 0.0040489400000         OK

$log_det_hessian
[1] 152.319

$maximum_gradient_component
[1] 0.00413821

$sigma_R_in
[1] 0.5

$rmse_table
      ERA  N     RMSE RMSE_over_sigmaR mean_BiasAdj
693  main 29 0.280494         0.314707     0.717379
694 early  0 0.000000         0.000000     0.000000

$index_variance_tuning_check
      Fleet           Q  N r.m.s.e. Input+VarAdj+extra New_VarAdj
767    CPUE 0.000143443 24  0.36823             0.3797    0.26823
768 BIOMASS     2.38373  6 0.234771             0.2312   0.134771

$Length_comp_Eff_N_tuning_check
    FleetName Fleet mean_effN mean(inputN*Adj) HarMean(effN) Mean(effN/inputN)
813     TRAWL     1   385.112           239.88       197.785           1.60544
    MeaneffN/MeaninputN Var_Adj HarEffN/MeanInputN
813             1.60544  1.1994          0.8245164

$Age_comp_Eff_N_tuning_check
     FleetName Fleet mean_effN mean(inputN*Adj) HarMean(effN) Mean(effN/inputN)
1545     TRAWL     1   11.1618          9.56269       2.73943           1.58988
     MeaneffN/MeaninputN Var_Adj HarEffN/MeanInputN
1545             1.16722   0.666          0.2864706

$SBzero
[1] 9193.67

$current_depletion
[1] 0.4738032

$last_years_SPR
[1] 0.516983

$SPRratioLabel
[1] "1-SPR"

$last_years_SPRratio
[1] 0.483017

$cormessage1
[1] Range of abs(parameter correlations) is 0.000182346 to 0.937311

$cormessage2
[1] No correlations above threshold (cormax=0.95)

$cormessage7
[1] No uncorrelated parameters below threshold (cormin=0.01)

completed SS_output
```

12. Deepwater flathead (*Neoplatycephalus conatus*) stock assessment based on data up to 2012/13[8]

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12.1 Summary

This document updates the 2012 assessment of deepwater flathead (*Neoplatycephalus conatus*) to provide estimates of stock status in the Great Australian Bight at the start of 2014/15. This assessment is performed using the stock assessment package SS v3.24f.

The base-case assessment estimates an unexploited spawning stock biomass (SSB_0) of 9,320t and a current depletion at the start of 2014/15 of 45% of SSB_0. The 2014/15 recommended biological catch (RBC) under the 20:35:43 harvest control rule is 1,146t and the long-term yield (assuming average recruitment in the future) is 1,105 t.

Exploration of model sensitivity showed a variation in depletion levels of between 32% and 54% of SSB_0.

12.2 Introduction

12.2.1 *The Fishery*

Deepwater flathead (*Neoplatycephalus conatus*) and Bight redfish (*Centroberyx gerrardi*) have been trawled 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 steadily increasing catches of both species. Deepwater flathead are 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). Bight redfish are also endemic to southern Australia, occurring from off Lancelin in WA to Bass Strait in depths from 10m to 500m (www.fishbase.org).

12.2.2 *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. At this time, the short history of the managed fishery precluded any stock assessment based on a time series of catch and effort data. Therefore, logbook data were examined on a shot-by-shot basis to make biomass estimates using an 'area-swept' approach. Catch per unit area (kg/km^2) was calculated for quarter-degree squares and then scaled up by the total area in which the species had been recorded. The approximate exploitable biomass estimates for deepwater flathead and Bight

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[8] Paper presented at the GAB RAG meeting December 2013

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. Using growth and mortality data together with these biomass estimates, sustainable yields were estimated to be 1,500-3,000t for deepwater flathead and 200-400t for Bight redfish.

Wise and Tilzey (2000) summarised the data for the GABTF focusing on deepwater flathead and Bight redfish, the two principle commercial species in shelf waters. They produced the first attempt to assess the status of these deepwater flathead and Bight redfish populations using age- and sex-structured stock assessment models. The virgin total biomass estimates for the base case model were 53,760t (95% confidence interval is 2,488-105,032t) for deepwater flathead and 9,095t (95% confidence interval is 4,924-13,266t) for Bight redfish. In 2002 an updated assessment was carried out including data up to 2001. The unexploited biomass estimates for the base case model were 12,876t (95%CI=11,928-13,824) and 9,563t (95%CI=8,368-10,759) for deepwater flathead and Bight redfish, respectively.

GABTF assessments in 2005 (Wise and Klaer, 2005; Klaer, 2005) continued to use a custom-designed integrated assessment model developed using the AD Model Builder software (Otter Research Ltd. 2000). 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*., 2005). Although it was recognized that the survey was designed to provide relative abundance estimates after several years of operation, at this early stage preliminary absolute abundance estimates were made using swept area methods from the survey data. The unexploited biomass levels estimated for the base case models were 20,418t and 13,932t for deepwater flathead and Bight redfish, respectively. Current depletion levels were estimated at over 100% for deepwater flathead due to recent large recruitments and 75% for Bight redfish. The absolute biomass estimate from the survey was consistent with other fishery data for deepwater flathead, but was much greater than the biomass modelled without the survey for Bight redfish.

The 2006 assessment (Klaer, 2006) 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, and 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. Unexploited female spawning biomass (SSB_0) was estimated as 8,836t and current depletion was 56%.

The 2010 assessment (Klaer 2010) included all port and onboard collected length data, rather that the source with the most annual samples as in previous assessments. Following agreement by the RAG, the 2010 assessment included the FIS as a relative index for the first time. Unexploited female spawning biomass was estimated as 10,366t and current depletion at 62% of B_0. The longterm RBC estimate was 1,137t. This assessment indicated that the stock was more depleted than expected in 2005/06, to near the 20% B_0 limit. Previous assessments had all indicated a stock in fish-down, but always above the target biomass.

The base-case 2012 assessment (Klaer 2012) estimated an unexploited spawning stock biomass of 8,921t and current depletion of 39% of SSB_0. The 2013/14 recommended biological catch (RBC) under the 20:35:43 harvest control rule was 979t and the long-term yield (assuming average recruitment in the future) was 1,051 t.

12.2.3 *Modifications to the previous assessment*

The development of the base case is detailed in Klaer (2013). Steps in the process were to convert the 2012 assessment to SS3 (version 3.24f), then to sequentially apply the following updates:

1. Change final assessment year to 2012/13, add catch and CPUE to 2012 (2013CatCPUE).
2. Add age composition data to 2012/13 (Age2012).
3. Update length compositions from 2009/10 to 2011/12 (Len2011).
4. Add length compositions from 2012/13 (Len2012).
5. Set final estimable recruitment value to 2008.
6. Retune model. Age comp lambda at 0.1 as previously, maximum sample size for lengths 200 all, tune input and output sample sizes for length and age comps, set bias adjustment, tune CV for CPUE and survey.

12.3 Methods

12.3.1 *The data and model inputs*

12.3.1.1 Biological parameters

As male and female deepwater flathead have different growth patterns (females are substantially larger), a two-sex model has been used.

The parameters of the von Bertalanffy growth equation are estimated within the model-fitting procedure from age-at-length data. This approach accounts for the impact of gear selectivity on the age-at-length data collected from the fishery and the impact of ageing error.

The rate of natural mortality, M, is estimated in the base-case model, with the estimated value being 0.237.

Female deepwater flathead become sexually mature at a length of 40 cm. Maturity is modelled as a logistic function, with 50% maturity at 40 cm. Fecundity-at-length is assumed to be proportional to weight-at-length.

The parameters of the length-weight relationship are the same as those used in previous assessments ($a=2.0 \times 10^{-6}$, $b=3.332$).

The assessment data for deepwater flathead comes from a single trawl fleet.

12.3.1.2 Landed catches

A landed catch history for deepwater flathead is available for the years from 1987/88 to 2013/14 (Figure 12.1, Table 12.1).

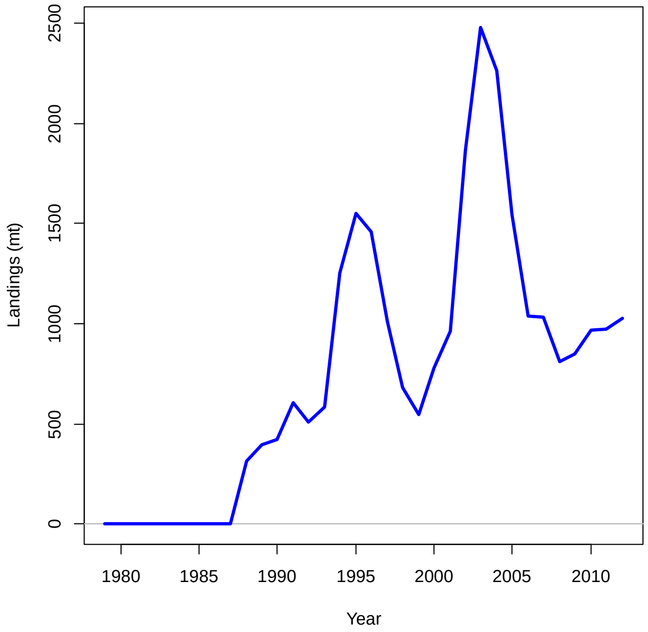

Figure 12.1. Total landed catch of deepwater flathead 1987/88-2012/13.

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 order to calculate the Recommended Biological Catch (RBC) for 2014/15, it is necessary to estimate the financial year catch for 2013/14. As TACs have been under-caught in recent years, the 2013/14 catch was assumed to be the same as the catch in 2012/13 – 1,027,842kg (see Table 12.1).

Table 12.1. Financial year catch of deepwater flathead and recent TAC values.

	Catch (kg)	
	Deepwater flathead	TAC
88/89	312,491	
89/90	394,672	
90/91	420,152	
91/92	608,128	
92/93	508,162	
93/94	585,072	
94/95	1,254,803	
95/96	1,551,593	
96/97	1,459,341	
97/98	1,010,348	
98/99	680,659	
99/00	544,992	
00/01	776,912	
01/02	963,613	
02/03	1,866,026	
03/04	2,482,093	
04/05	2,264,119	
05/06	1,545,604	
06/07	1,039,687	3,000
07/08	1,034,709	2,129
08/09	812,663	1,400
09/10	851,272	1,300
10/11	968.028	1,100
11/12	973,371	1,650
12/13	1,027,842	1,560
13/14*	1,027,842	1,150

* 2013/14 catches are estimated as the same as 2012/13

12.3.1.3 Catch rate indices

Catch rates were previously standardised using Generalised Additive Models (GAMs) (Hobsbawn et al. 2002a, 2002b) and a log-linear model (Klaer, 2006). Standardisations for a range of SESSF species are carried out each year by CSIRO (see Haddon, 2013). Standardisations commencing this year for deepwater flathead and Bight redfish have been added to the list of SESSF species processed in a standard manner. Standardised results produced by Haddon (2013) are given in Table 12.2.

Table 12.2. Year factor values from Haddon (2013) for deepwater flathead.

Financial year	Index
87/88	0.48
88/89	0.99
89/90	1.01
90/91	1.03
91/92	0.89
92/93	1.06
93/94	1.45
94/95	1.82
95/96	1.76
96/97	1.22
97/98	0.86
98/99	0.65
99/00	0.77
00/01	0.85
01/02	1.01
02/03	1.42
03/04	1.37
04/05	1.09
05/06	0.71
06/07	0.62
07/08	0.69
08/09	0.81
09/10	0.75
10/11	0.94
11/12	0.74
12/13	0.86

A comparison of log-linear model results by Haddon (2013) with those from Klaer (2012) (

Figure 12.2) shows that results from 1987/88 to 2011/12 are very similar, despite several differences in the model procedures used. The Haddon (2013) series was revised from the version given in Klaer (2013) because 2012/13 data from eLogs was not included in the previous series. This is the only change to the base case given in Klaer (2013).

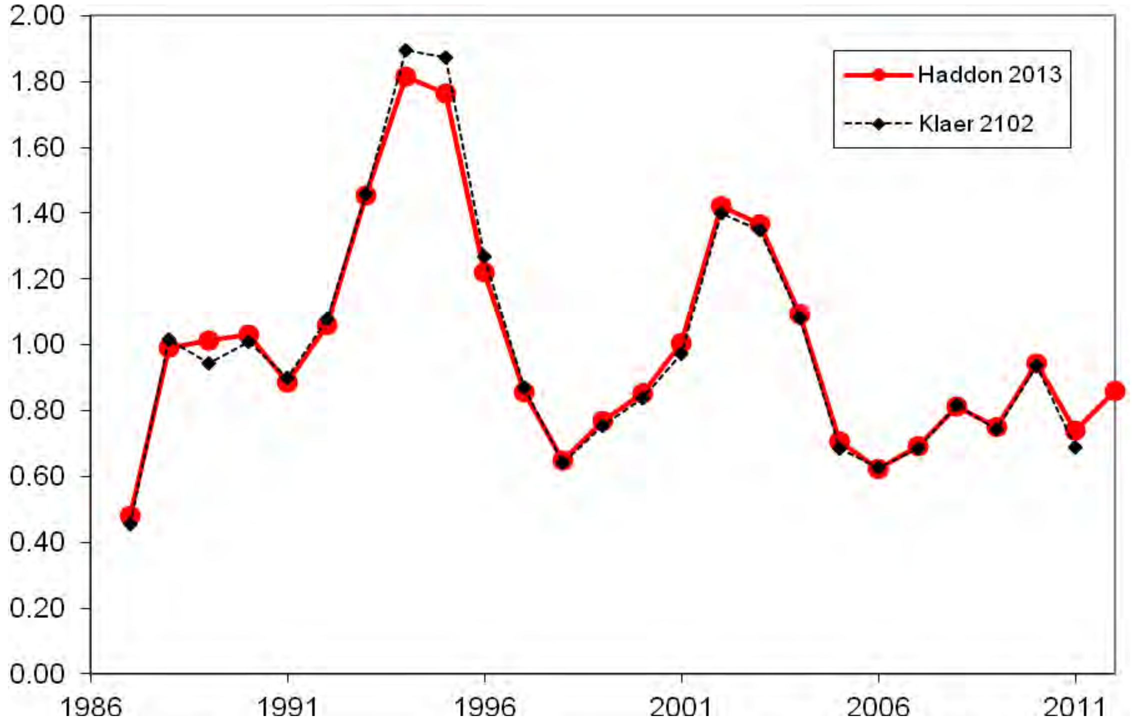

Figure 12.2. Deepwater flathead comparison of Haddon 2013 results with LM 2010.

12.3.1.4 Fishery-independent survey

Biomass estimates have been taken from Knuckey *et al*. (2011).

Table 12.3. Estimated exploitable biomass (t) with coefficient of variation (cv) of major species.

	Estimated relative biomass											
Species	2005		2006		2007		2008		2009		2011	
	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.
Bight Redfish[A]	20,887	0.13	25,380	0.16	25,713	0.16	14,591	0.11	27,610	0.18	13,189	0.13
Deepwater Flathead	12,152	0.05	8,415	0.06	8,540	0.05	7,725	0.06	9,942	0.05	9,227	0.05
Ocean Jacket	7,163	0.14	9,111	0.26	6,701	0.37	7,709	0.29	21,374	0.21	27,712	0.2
Common Sawshark	298	0.16	138	0.23	462	0.24	231	0.14	530	0.21	788	0.11
Yellowspotted Boarfish	349	0.19	181	0.15	142	0.26	170	0.25	121	0.18	353	0.23
Gummy Shark	558	0.17	288	0.25	402	0.23	434	0.14	470	0.18	797	0.16
Jackass Morwong	1,025	0.34	1,037	0.23	1,236	0.31	916	0.3	783	0.23	441	0.24
Knifejaw	955	0.12	1,133	0.14	570	0.13	806	0.11	1,121	0.15	1,129	0.17
Latchet	9,401	0.13	6,135	0.25	7,040	0.21	3,688	0.17	12,997	0.15	8,690	0.17
Ornate Angelshark	3,078	0.09	1,887	0.1	2,770	0.11	1,742	0.1	2,107	0.07	2,305	0.08
Spikey Dogfish	834	0.24	867	0.3	1,006	0.23	508	0.33	607	0.17	1,799	0.16
Other species	11,693	0.13	14,405	0.14	22,990	0.14	17,558	0.12	23,666	0.12	15,272	0.09

[A] night hauls only

12.3.1.5 Age composition data

An estimate of the standard deviation of age reading error was calculated by Andre Punt (pers. comm., 2009) from data supplied by Kyne Krusic Golub of Fish Ageing ServicesTable 12.4).

Age-at-length measurements, based on sectioned otoliths, provided by Fish Ageing Services, were available for the years 1987/88-1990/91, 1992/93-1998/99, 2000/01, 2002/03, 2004/05-2012/13 Table 12.5). The minimum number of fish sampled in any financial year was 50.

Table 12.4. Standard deviation of age reading error (A Punt pers. comm. 26.08.09).

Age	sd
0.5	0.201743
1.5	0.257037
2.5	0.306319
3.5	0.350243
4.5	0.389392
5.5	0.424284
6.5	0.455384
7.5	0.483102
8.5	0.507807
9.5	0.529826
10.5	0.549451
11.5	0.566942
12.5	0.582532
13.5	0.596427
14.5	0.608811
15.5	0.619849
16.5	0.629687
17.5	0.638455
18.5	0.646271
19.5	0.653236
20.5	0.659444
21.5	0.664977
22.5	0.669909
23.5	0.674305
24.5	0.678222
25.5	0.681714

Table 12.5. Number of age-length otolith samples included in the base case assessment 1987/88-2012/13.

Year	Age-length samples
87/88	61
88/89	290
89/90	214
90/91	96
92/93	50
93/94	407
94/95	178
95/96	430
96/97	287
97/98	972
98/99	1,162
00/01	600
02/03	639
04/05	563
05/06	555
06/07	484
07/08	650
08/09	554
09/10	465
10/11	552
11/12	367
12/13	787

12.3.1.6 Length composition data

Length composition information for the retained component of the trawl fleet catch is available from 1993/94 to 2012/13 (Table 12.6). Following advice from GABRAG in 2009, all available length samples have been included in the assessment, collected from in port and on-board. Additional efforts were made in 2013 to increase the number of industry measurements available to the stock assessment as port measurements from 2009/10 to 2012/13.

Table 12.6. Number of retained fish lengths included in the base case assessment by fleet 1993/94-2012/13.

Year	Length samples	Source
93/94	1,242	Port
94/95	584	Port
97/98	697	Port+Onboard
98/99	3,782	Port
99/00	5,368	Port
00/01	9,731	Port+Onboard
01/02	6,401	Onboard
02/03	2,478	Port+Onboard
03/04	6,761	Port+Onboard
04/05	12,852	Port+Onboard
05/06	10,773	Port+Onboard
06/07	2,098	Onboard
07/08	2,666	Onboard
08/09	1,849	Onboard
09/10	25,665	Port+Onboard
10/11	4,611	Port
11/12	11,368	Port
12/13	12,236	Port

12.3.2 Stock Assessment method

12.3.2.1 Population dynamics model and parameter estimation

A two-sex stock assessment for deepwater flathead was conducted using the software package Stock Synthesis (SS, version 3.24f; Methot 2009). SS 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 deepwater flathead. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, are given fully in the SS technical description (Methot, 2005) and are not reproduced here. Some key features of the population dynamics model underlying SS which are pertinent to this assessment are discussed below.

A single stock of deepwater flathead was assumed that occurs across the GAB. The stock was assumed to have been unexploited prior to 1988/89. The input CVs of the catch rate index and the biomass survey were set to fixed values which are arbitrary because of iterative reweighting. Within an index, the variation of all of the annual estimates is assumed to be equal.

The selectivity pattern for the trawl fleet was modelled as being time-invariant. The two parameters of the selectivity function were estimated within the assessment.

The rate of natural mortality, M, was assumed to be constant with age, and also time-invariant. 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 for 1979/80 to 2008/09. The value of the parameter determining the magnitude of the process error in annual recruitment, σ_R , was set equal to 0.5, which is greater than the amount of error estimated by the model.

A plus-group was modelled at age 30. Growth of deepwater flathead 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. Differences in growth by gender are modelled.

Table 12.7. Summary of selected parameters of the base case model.

Description	Source	Parameter	Female	Male
Years		y	1988-2012	
Recruitment		r	est 1980 - 2008	
Fleets			1 trawl only	
Discards			none significant, not included	
Age classes		a	0-30 years	
Sex ratio		p_s	0.5 (1:1)	
Natural mortality		M	fitted (0.237) per year	
Steepness		h	0.75	
Female maturity	1		40 cm (TL)	
Growth	2	L_{max}	65.0258 cm (TL)	fitted offset
		K	fitted	fitted offset
		L_{min}	fitted	fitted offset
		CV	fitted	
Length-weight	3	ϕ_1	0.002 cm (TL)/gm	
		ϕ_2	3.332	

Sources: (1) Analyses of biological samples collected during the 2004 GAB reproductive study, (2) length and age samples collected between 2000-2003 and (3) length samples collected during the 2001 FRDC project

12.3.2.2 Relative data weighting

Iterative reweighting of input and output CVs or input and effective sample sizes is an imperfect, but objective method for ensuring that the expected variation is comparable to what is input. This makes the model internally consistent, but some have trouble with this, particularly if it is believed that the input variance is well measured and potentially accurate. It isn't necessarily a good thing to down-weight a data series just because the model won't fit it, if in fact, that series is reliably measured. On the other hand, most of the indices we deal with in fisheries underestimate the true variance by only reporting measurement and not process error.

Data series with a large number of individual measurements such as length or weight frequencies tend to swamp the combined likelihood value with poor fits to noisy data when fitting is highly partitioned by area/time/fishing method etc. These misfits to small samples mean that simple series such as a single CPUE might be almost completely ignored in the fitting process. This model behaviour is not optimal, because we know, for example, that the CPUE values are in fact derived from a very large number of observations. If there is reason to believe that the length/age data are noisy at the level fitted, it has been recommended in similar circumstances (e.g. see sablefish: Schirripa 2007, pacific sardine: Hill et al. 2005) that the length/age data be down-weighted to allow the model to better fit other data sources.

It is generally the practice for SESSF species to set an upper limit of 200 on all length sample sizes, which for this species would set them all to this upper limit. However, many SESSF species have sample sizes ranging from tens of fish to many thousands. The sample sizes for deepwater flathead are less variable than for many SESSF species, so in previous assessments it was judged acceptable to leave the information on relative sample sizes within the assessment. However, to conform to standard practice used for other SESSF assessments all input annual length sample sizes were set to 200. In iterative reweighting, the annual sample sizes were tuned so that the input sample size was equal to the effective sample size calculated by the model.

Tuning followed the current SESSF standard tuning practice to start with low CV on CPUE and survey, set length or age composition lambda values, set maximum sample size for lengths, tune input and output sample sizes for length and age comps, set bias adjustment, and then tune the CV for CPUE and survey.

The overall unadjusted likelihood value for the base-case assessment is in the order of 3,500, with the age and length components making the greatest contributions (length about 210, age about 3,300) (Table 12.9). Other likelihood components are very much smaller. To reduce the tendency of the age data to swamp the likelihood function, the age component was reduced by a factor of 10 for the base-case, which produced an overall adjusted likelihood value of about 500, and more balanced contributions of age and length data to the overall likelihood.

12.3.2.3 Recruitment deviation bias adjustment

A bias adjustment is required for estimated recruitment deviations so that the distribution of exponentiated recruitment deviations has a mean value of 1.0. As annual recruitment deviations have differing data contributing to the estimate, and differing associated variances, it has been recognised that it is not appropriate to apply the same bias adjustment to all estimates. Typically, the recruitment deviations have little contributing data early in the series, informed estimates in the middle, and less informed at the end of the series. A method has been developed to account for differences in the variance of individual recruitment deviations and how that can be related to the amount of bias adjustment that should be applied (see Methot and Taylor, in review). That standardised approach is in early development and testing, but has been applied here (see Figure 12.7).

12.3.2.4 Calculating the RBC

The SESSF Harvest Strategy Framework (HSF) was developed during 2005 (Smith *et al*. 2008) and has been used as a basis for providing advice on TACs in the SESSF quota management system for fishing years 2006-2012. 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 basis used for assessing stock status or exploitation level for that stock. Deepwater flathead is assessed 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. For this 2013 assessment, the maximum economic yield (MEY) target value of 43% of B_0 reported in Kompas *et al*. (2011) has been used for the base case, therefore using a 20:35:43 harvest control rule. Results using the default 20:35:48 strategy are also reported.

Steepness is assumed to have the default value of 0.75 in the deepwater flathead assessment.

12.3.2.5 Sensitivity tests and alternative models

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

- Steepness 0.65
- Steepness 0.85
- M 0.19
- M 0.27
- Age composition wt x 0.5
- Age composition wt x 2
- Age composition wt x 4
- Length composition wt x 0.5
- Length composition wt x 2
- Estimate recruitment to 2007/08 only
- No FIS

12.4 Results and discussion

12.4.1 *The base-case analysis*

12.4.1.1 Parameter estimates

Figure 12.3 shows the estimated growth curve for female and male deepwater flathead. All growth parameters are estimated by the model except for L_{max} (other parameter values are given in Table 12.7.

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). Figure 12.4 shows the fitted selectivity function for the trawl fleet.

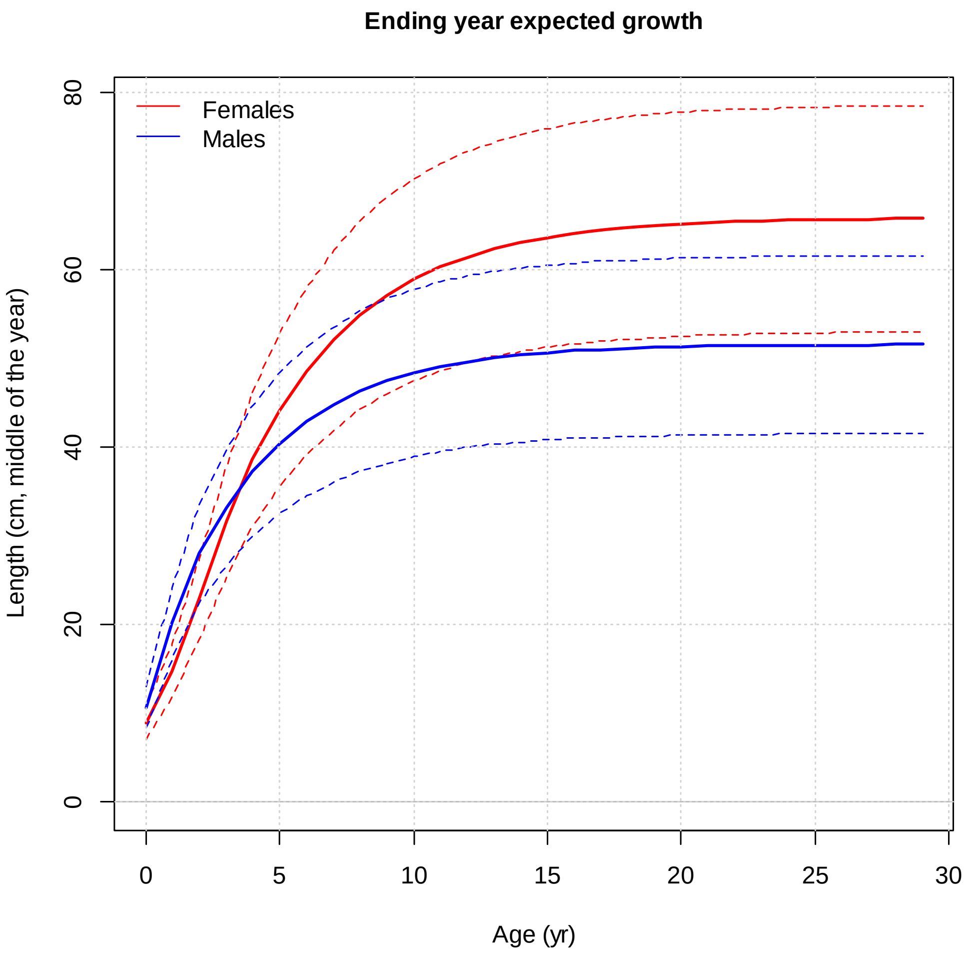

Figure 12.3. The model-estimated growth curves.

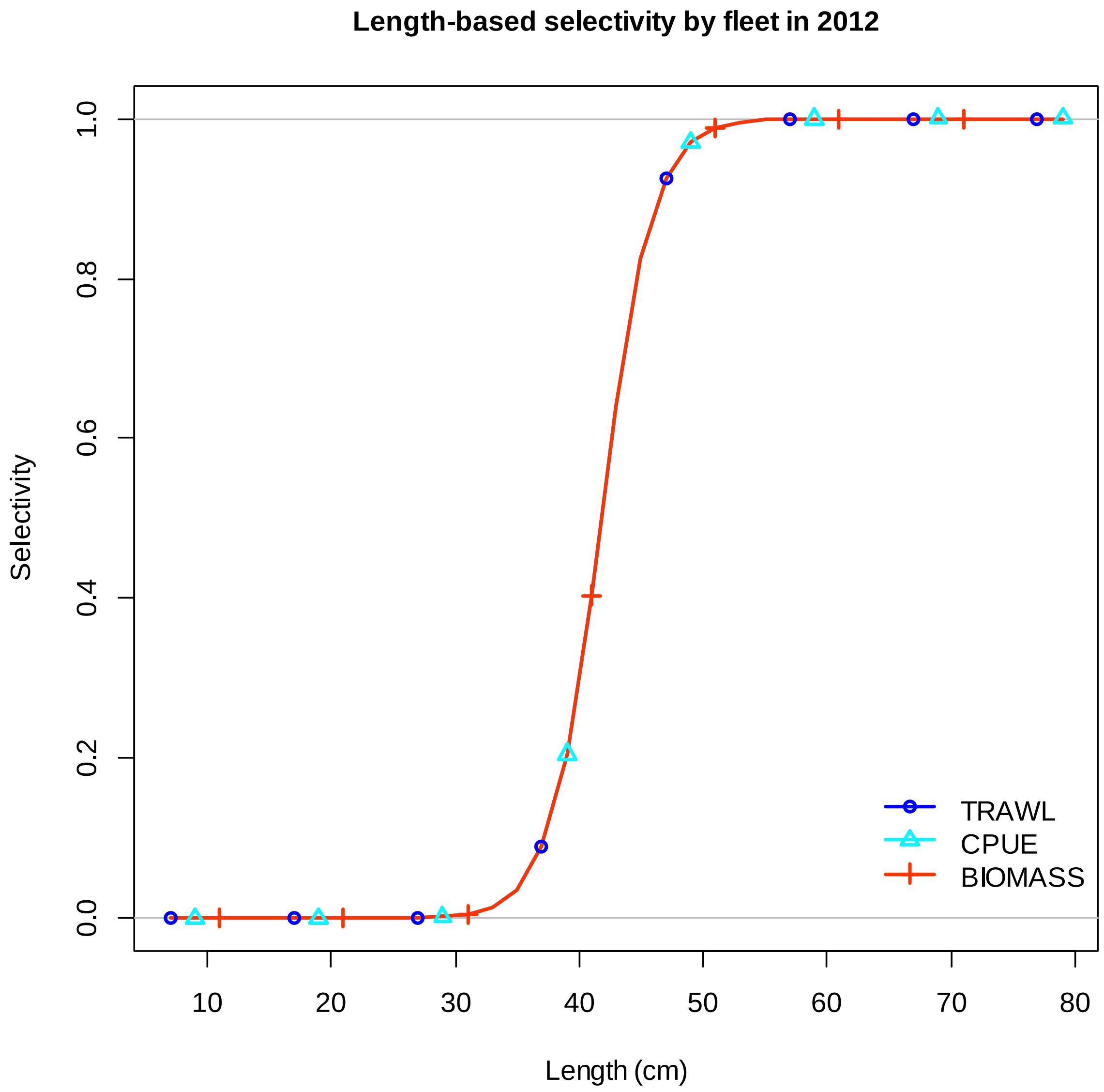

Figure 12.4. Selectivity at length for trawl.

12.4.1.2 Fits to the data

The catch rate index for the trawl fleet shows a cyclical pattern with two peaks in the period 1989/90 to 2011/12. The model was unable to fit the cycles, but fits the general decline over that same period. The decline is consistent with the fish-down of a developing fishery. Industry members of GABRAG have stated previously that deepwater flathead availability is cyclical in nature, and the cyclical residuals of the model trend are consistent with that hypothesis. The observed pattern in the fishery independent biomass survey is consistent with the fishery CPUE index over the comparable period, with a decline and then an increase. The assessment produces a smaller decline and larger increase in the period of the survey.

The base-case model is able to mimic the retained length-frequency distributions very well (Appendix A), with the exception of individual years, particularly 1997/98. The implied fits to the age composition data are shown in Appendix B. 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 reasonably well, except for 1997/98.

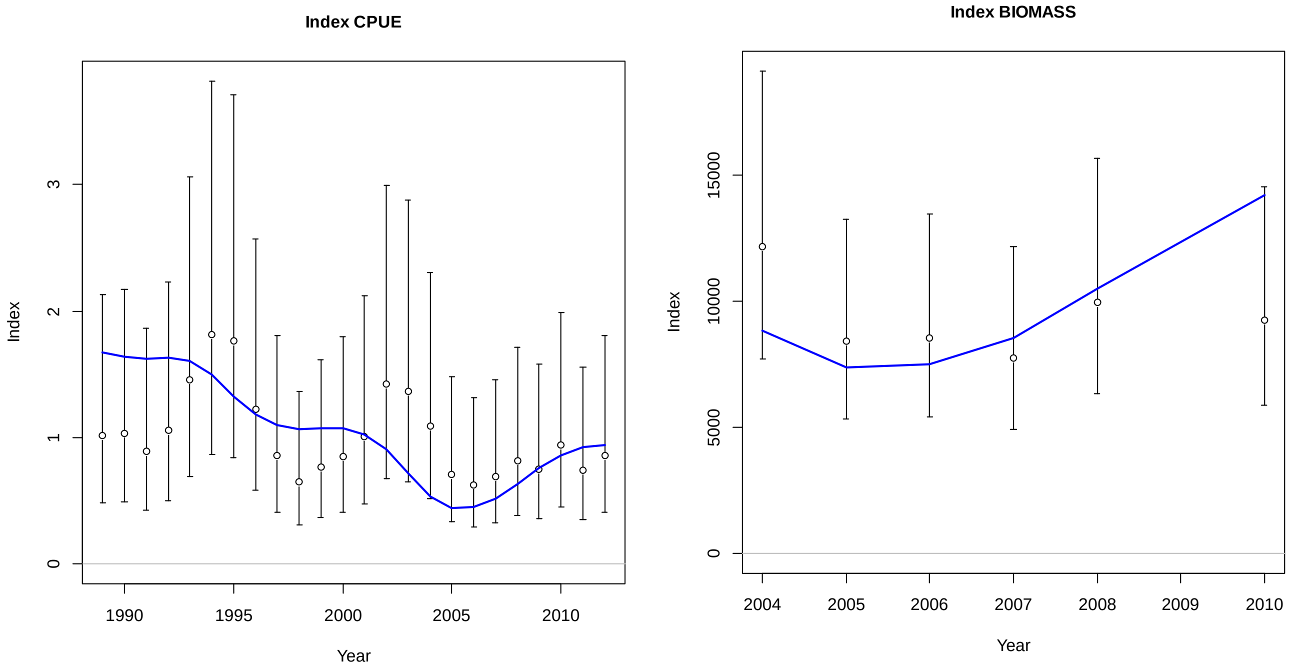

Figure 12.5. Observed (solid dots) and model-estimated (lines) of CPUE and biomass survey versus year. The vertical lines indicate approximate 95% confidence intervals for the data.

12.4.1.3 Assessment outcomes

Figure 12.6 shows the trajectory of spawning stock depletion. The stock declined past the target in about 2004/05 to near or below the lower limit 2006/07, followed by a steep recovery to above the target currently. The recent increase was driven by favourable recruitments as shown in Figure 12.7.

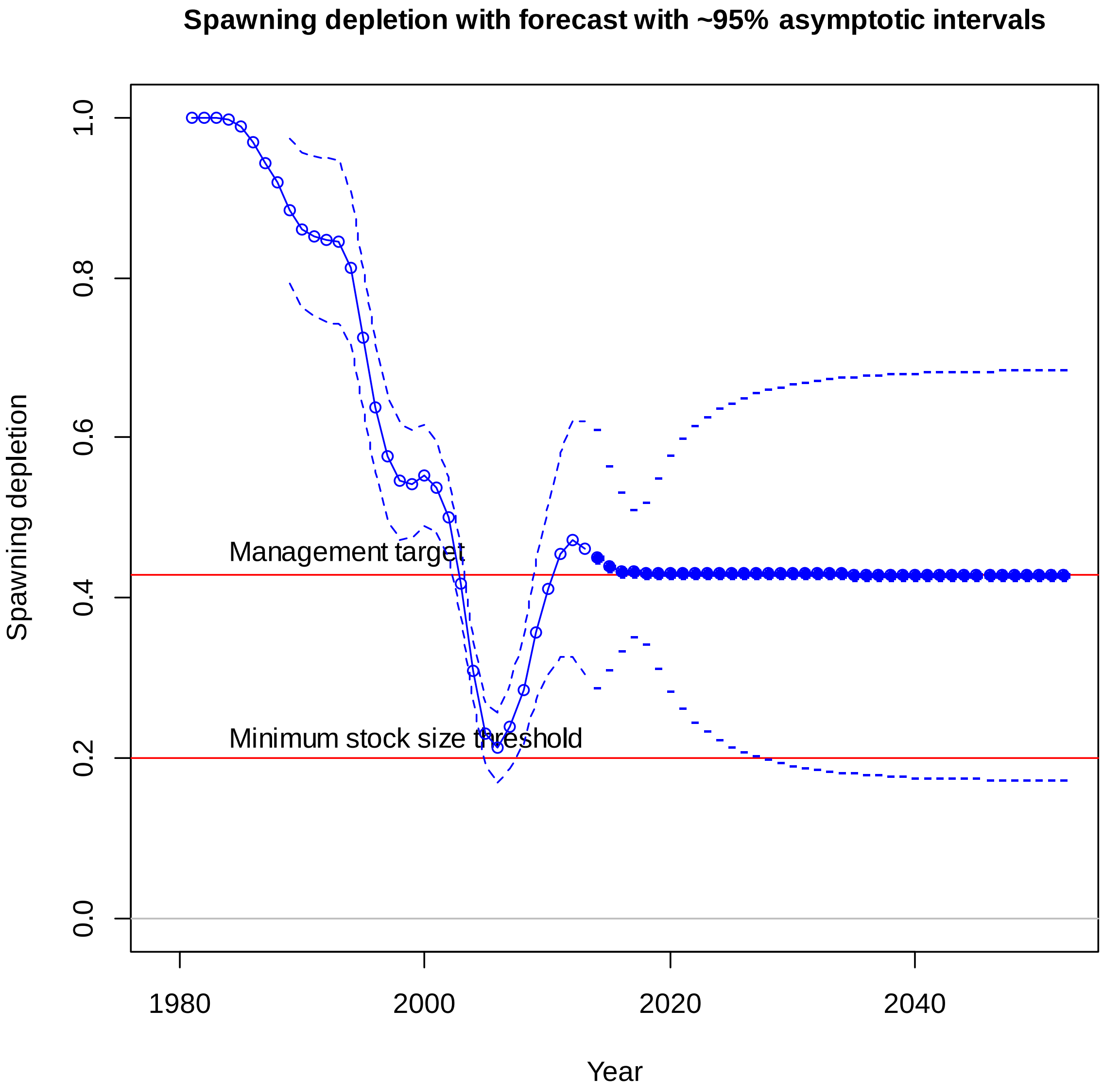

Figure 12.6. Time-trajectory of spawning biomass depletion (with 95% confidence intervals) corresponding to the MPD estimates for the base-case analysis. The first solid blue dot is 2014 depletion, and subsequent solid dots are forecast depletion under the 20:35:48 harvest control rule assuming average recruitment.

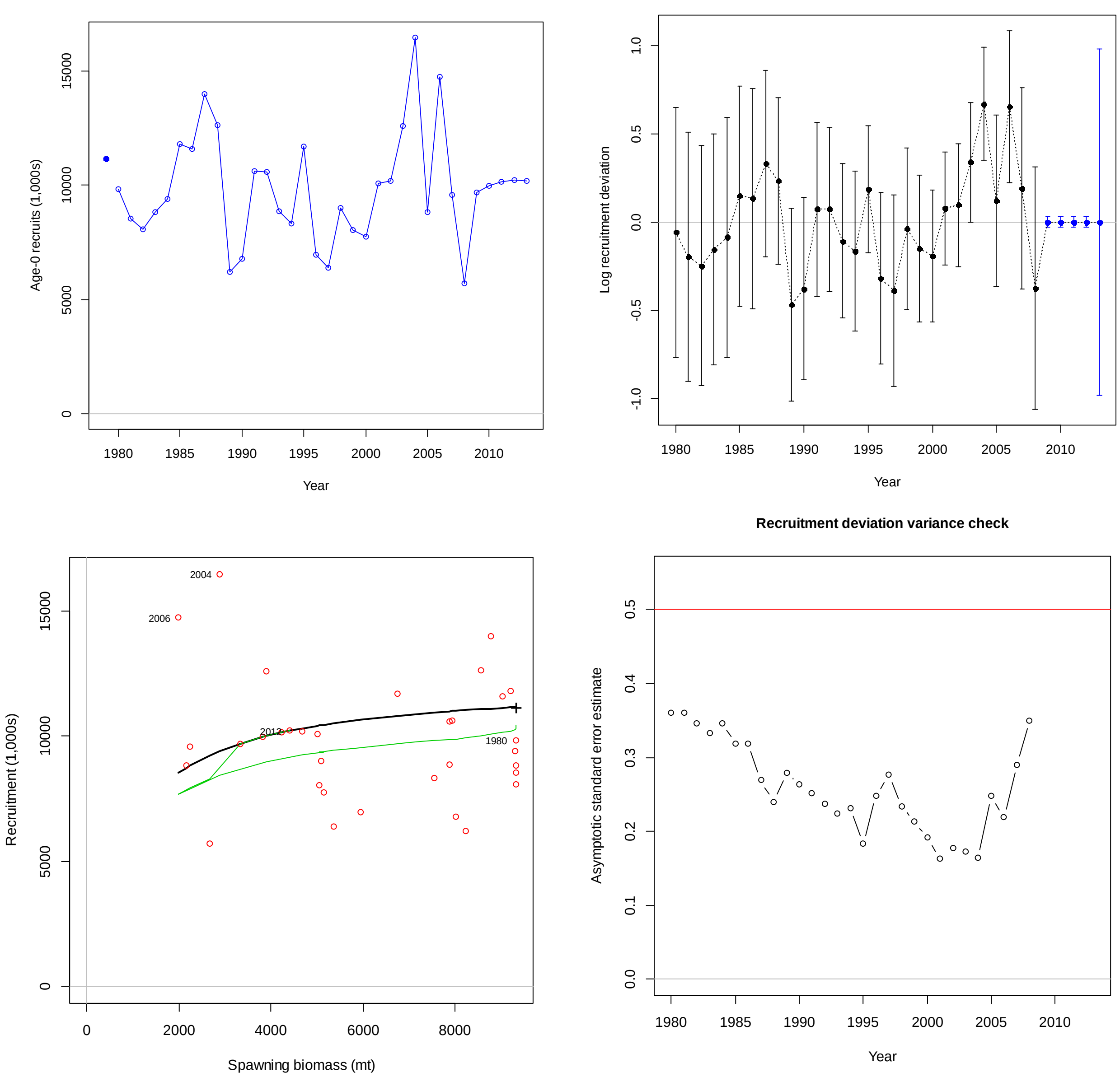

Figure 12.7. Recruitment estimation for the base case analysis. Top left : Time-trajectories of estimated recruitment numbers; top right : time trajectory of estimated recruitment deviations; bottom left : the stock-recruit curve and estimated recruitments; bottom right: recruitment deviation variance check.

The time-trajectories of recruitment and recruitment deviation are shown in Figure 12.7. Estimates of recruitments are made with reasonable precision until 2007/08. The 2008/09 recruitment points is less well estimated, and sensitivity analyses is included that drops the last estimated point. As the last point is below average, dropping that point leads to a higher current SSB than the base case.

The current spawning stock biomass is estimated by the base-case model to be 45% of unexploited stock biomass at the start of 2014/15, and the 2014/15 recommended biological catch (RBC) under the 20:35:43 harvest control rule is 1,106t Table 12.8). The longterm RBC (assuming average recruitment in the future) is 1,106t under the 20:35:43 rule (Table 12.8).

12.4.1.4 Sensitivity tests and alternative models

Results of the sensitivity tests are shown in Table 12.8. Variation in steepness does not greatly affect results because of the relatively high level of current versus unexploited biomass. As for most/all assessments, the results are however, sensitive to the value of *M*. A change of 0.04 up or down in the *M* value can change the current depletion from 32 to 54% of B_0, with comparable changes in the long-term catches. The current assessment estimates the value of *M*, and likelihood values in Table 12.9 show that the likelihood surface is not flat, and that the estimation of *M* is supported.

Less variability in current depletion and RBCs is caused by increasing or decreasing the weighting by a factor of two given to the length and/or age data. Although down-weighting of the age composition appears to be justified, and has been discussed above, making less adjustment results in a stock that has been less depleted.

The effect of removing the 2008/09 estimate of recruitment results in a less depleted stock. Removal of the fishery independent biomass survey produces a stock that is less depleted than the base case. This may be expected, because the estimated biomass is considerably higher than the observed index in the last survey year.

Table 12.8. Summary of results for the base-case and sensitivity tests.

Case		SSB0	SSB2014	SSB2014/SSB0	M	RBC2014	RBClongterm
0	base case 20:35:43 *h* 0.75 *M* est	9,321	4,200	0.45	0.2367	1,146	1,106
1	steepness *h* 0.65	9,625	4,051	0.42	0.2399		1,034
2	steepness *h* 0.85	9,097	4,334	0.48	0.2344		1,164
3	natural mortality *M* 0.19	9,243	2,919	0.32	0.1900		872
4	natural mortality *M* 0.27	9,659	5,235	0.54	0.2700		1,319
5	age comp weighting 0.5	8,963	3,865	0.43	0.2375		1,051
6	age comp weighting 2	9,311	4,366	0.47	0.2358		1,117
7	age comp weighting 4	9,331	4,718	0.51	0.2333		1,117
8	length comp weighting 0.5	9,132	3,816	0.42	0.2340		1,087
9	length comp weighting 2	9,016	4,490	0.50	0.2418		1,077
10	recruitment to 2007/08	9,507	4,685	0.49	0.2379		1,134
11	no FIS	9,699	5,210	0.54	0.2422		1,179

Note: the 2014 RBC value is only shown for fully tuned models.

Table 12.9. Summary of likelihood components for the base-case and sensitivity tests. Likelihood components are unweighted, and cases 1-11 are shown as difference to the base case.

Case		Likelihood						
		TOTAL	Survey+CPUE	Length comp	Age comp	Recruitment	Parm_priors	Other
0	base case 20:35:43 *h* 0.75 *M* est	3523.13	-17.40	214.85	3337.11	-11.69	0.26	0.00
1	steepness *h* 0.65	1.15	-0.01	0.22	0.32	0.49	0.13	0.00
2	steepness *h* 0.85	-0.80	0.03	-0.17	-0.22	-0.34	-0.10	0.00
3	natural mortality *M* 0.19	55.02	-0.83	2.39	52.19	1.28	-0.01	0.00
4	natural mortality *M* 0.27	18.69	1.04	-0.37	17.77	0.22	0.03	0.00
5	age comp weighting 0.5	218.11	-0.25	-19.01	235.15	2.02	0.20	0.00
6	age comp weighting 2	-113.41	0.71	17.48	-131.59	0.05	-0.07	0.00
7	age comp weighting 4	-158.29	1.95	31.91	-193.64	1.58	-0.10	0.00
8	length comp weighting 0.5	-102.75	-1.34	20.02	-120.08	-1.28	-0.07	0.00
9	length comp weighting 2	251.57	1.75	-23.94	269.02	4.52	0.23	0.00
10	recruitment to 2007/08	0.85	0.32	0.46	-0.29	0.35	0.01	0.00
11	no FIS	-1.23	5.85	-1.06	-6.96	0.94	0.00	0.00

12.5 Acknowledgements

The members of the SESSF stock assessment group at CMAR – Jemery Day, Rich Little, Geoff Tuck, Malcolm Haddon, and Judy Upston – are thanked for their generous advice and comments during the development of this assessment. Thanks also to the providers of data for this assessment – John Garvey (AFMA) for the provision of logbook and ISMP data, Mike Fuller for organising the CSIRO version of the GenLog and ISMP databases, and Kyne Krusic Golub (Fish Ageing Services) for the provision of ageing data. Thanks to all members of the GAB Resource Assessment Group for helpful discussions and advice on this assessment.

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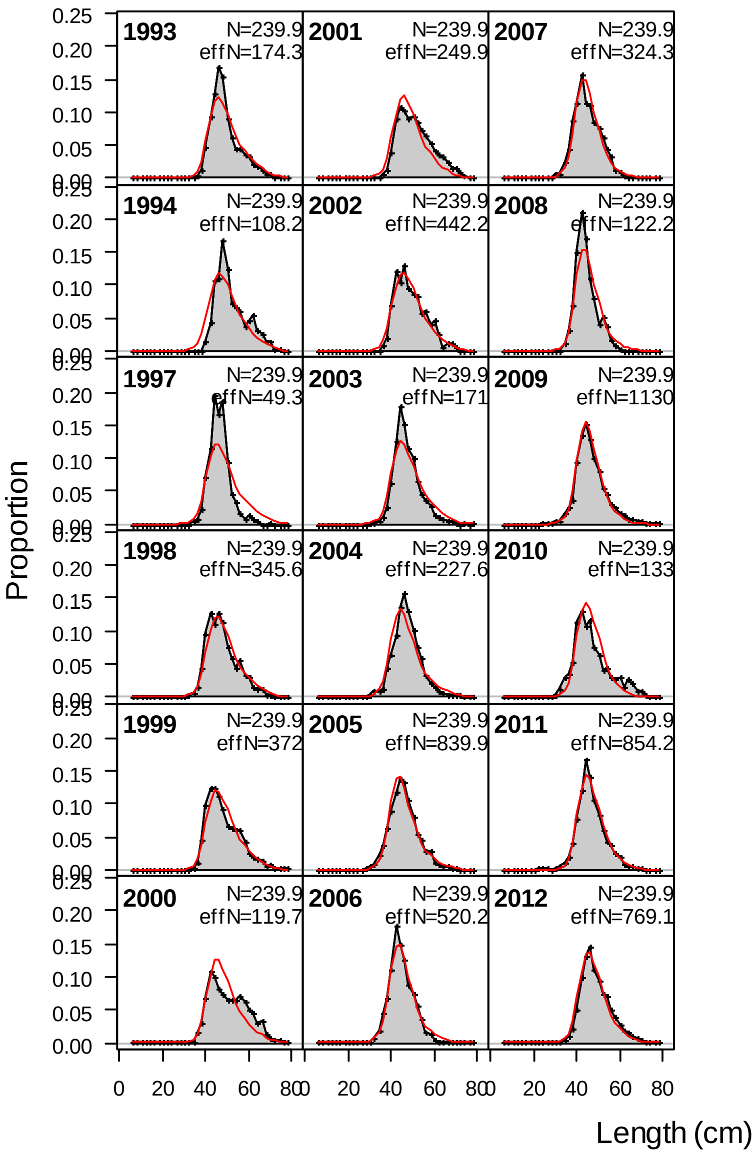
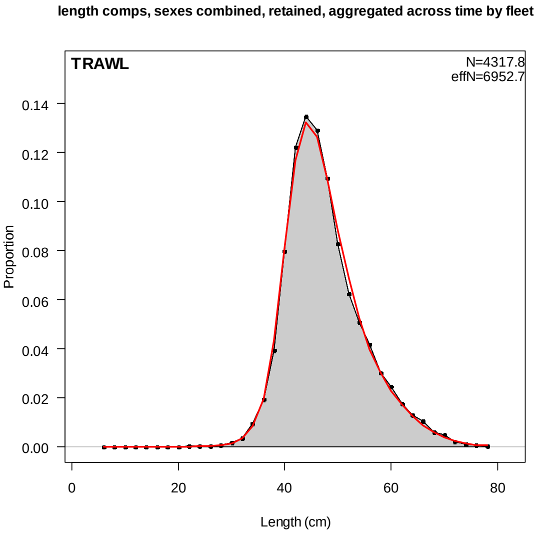
12.7 Appendix A: base-case fits to the length composition data

length comps, sexes combined, retained, TRAWL

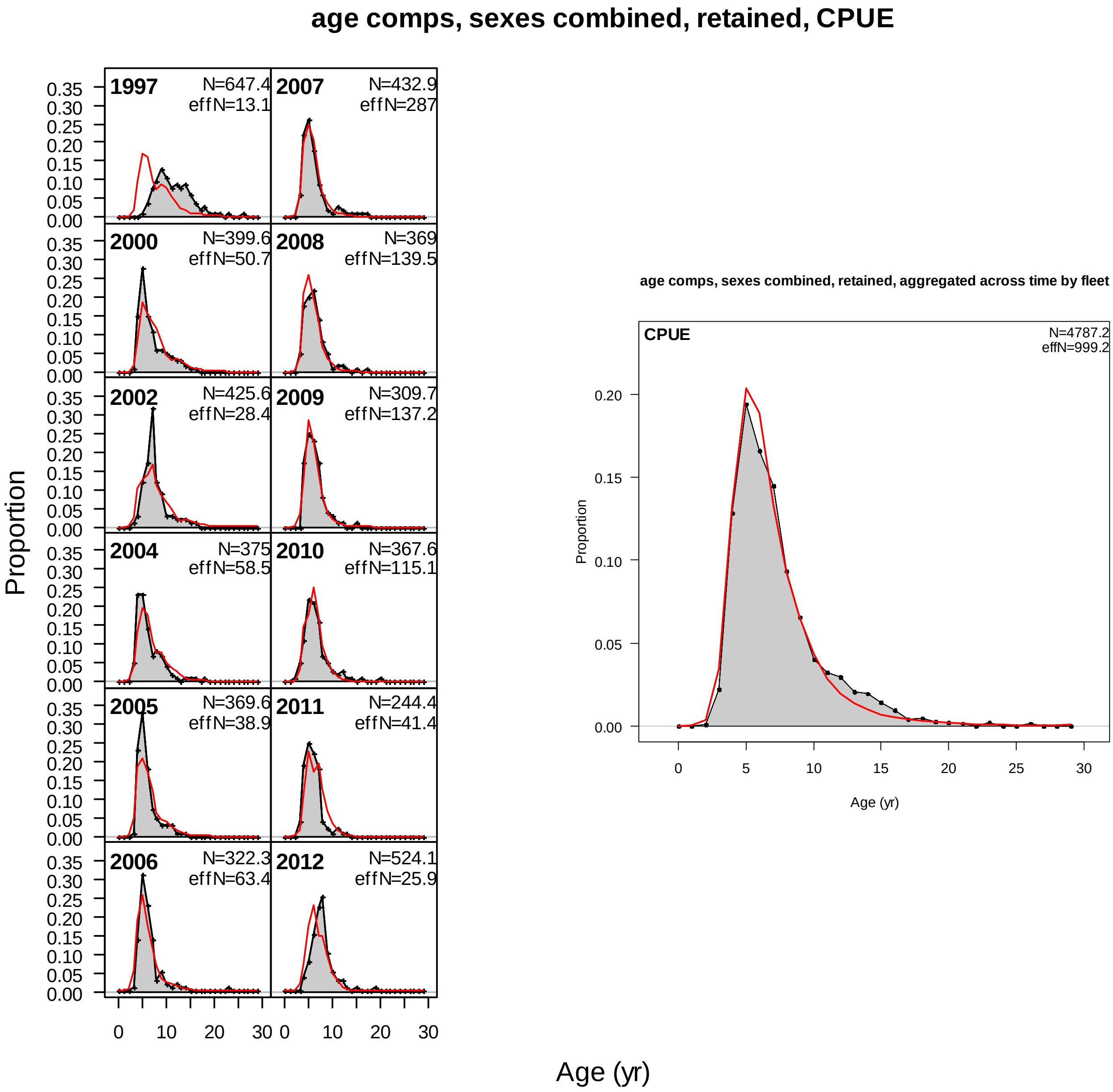


length comps, sexes combined, retained, aggregated across time by fleet

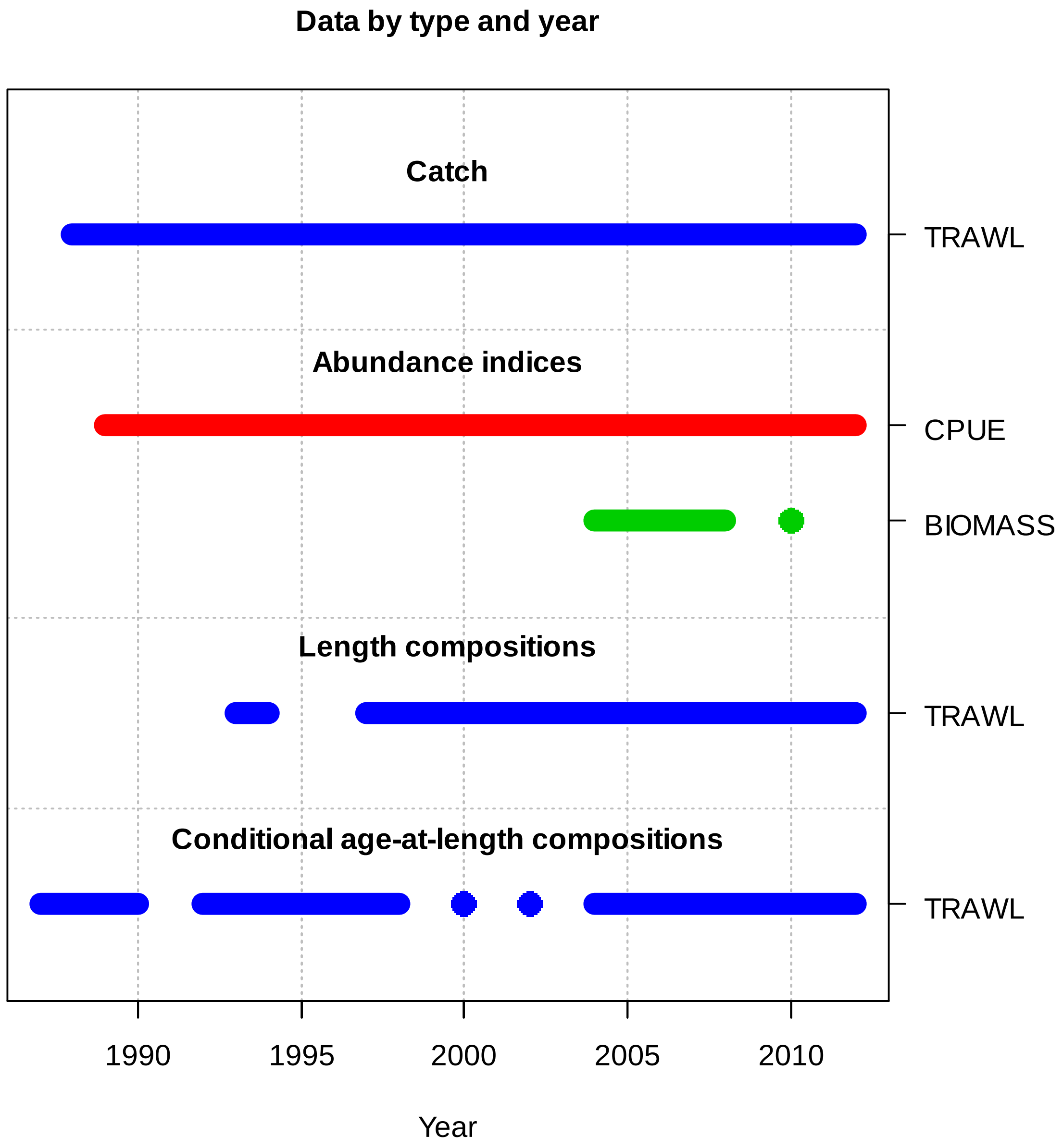


12.8 Appendix B: fits to the age composition data

The age composition data are not directly fitted, so these are fits to the implied age composition calculated from the age-length relationship and the length frequencies. The observed values (dots) in a year are calculated from the age-length key from all fish aged in that year multiplied by the observed length frequency. The fitted values (lines) are the model's estimates of age frequency in that year, multiplied by selectivity.



12.9 Appendix C: summary of data availability by year



13. Gummy shark assessment update for 2013, using data to the end of 2012 [9]

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13.1 Summary

The most recent gummy shark assessment model formulation (Punt & Thomson 2010) was updated using data from 2010-2012. The model recognises three separate populations (Bass Strait, South Australia and Tasmania), that share some parameter values. Closures of traditional fishing grounds in South Australia (SA), in order to protect Australian sea lions, began to take effect during 2010and have caused declines in catches and catch per unit effort (CPUE) in that state. CPUE in Bass Strait (BS) may have been impacted by the entry of South Australian fishers, inexperienced in fishing other grounds. Trial hook fishing for sharks has been permitted, under short term licences, in SA since 2011.

The length frequencies for 2008-2010 that were used by the 2010 assessment were recalculated, in particular, sharks whose fork length were sampled were included in the dataset now that a fork length to total length (LCF-TOT) conversion formula is available.

The sensitivity of the model results to the inclusion or exclusion of a range of data selections was considered. Not fitting the model to tag return data collected after 2005, when return rates appear to have been low, results in the estimation of larger population sizes.

The inclusion of recent CPUE leads to the estimation of a more depleted stock in BS and a less depleted stock in SA. While it is counter-intuitive that CPUE data that shows a fall in SA should lead to the estimation of a less depleted stock, it is reasonable to assume that the reduction in fishing effort in that region should lead to some increase in stock size. Similarly, effort has increased in BS due to the entrance of gillnet vessels that were excluded from traditional fishing grounds in SA.

For the base case gummy shark stock assessment for 2013 (data to 2012) we used CPUE to 2009 (the effects from closures began in 2010) in South Australia and to 2012 in Victoria and Tasmania. Recommended Biological Catches (RBCs) have been calculated for the base case model assuming a range of splits between hook and gillnet fishing in the future. Future hook fishing in SA alone, or in all states, is considered. Higher levels of hook fishing lead to lower RBCs.

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[9] Paper presented at the Shark RAG meeting December 2013

13.2 Introduction

Gummy shark are considered to be relatively sedentary and not to undertake spawning or feeding migrations. Any management region could therefore be thought of as a separate stock, however, to be useable, length frequency data that inform the model must contain at least 400 records so that if the stock is divided into a large number of small regions, none would provide useable length frequency data. Stock boundaries have been chosen to allow sufficient data for assessment, and to encompass possible differences in fishery and stock characteristics. The assessment model treats gummy shark as three separate stocks: South Australia (SA), Victoria (Vic) and Tasmania (Tas) (Figure 1). Due to data limitations for the SA and Tas stocks, some biological parameters are shared between the three stocks. Recent closures to gillnet fishing in South Australia to protect Australian sea lions and dolphins have altered the pattern of fishing in that state, and possibly in neighbouring Victoria. During 2012-13 an automatic long-line trial was conducted in South Australian waters to investigate the viability of allowing long-line fishing for shark species in South Australia. It collected catch and length information for, amongst other species, school and gummy shark.

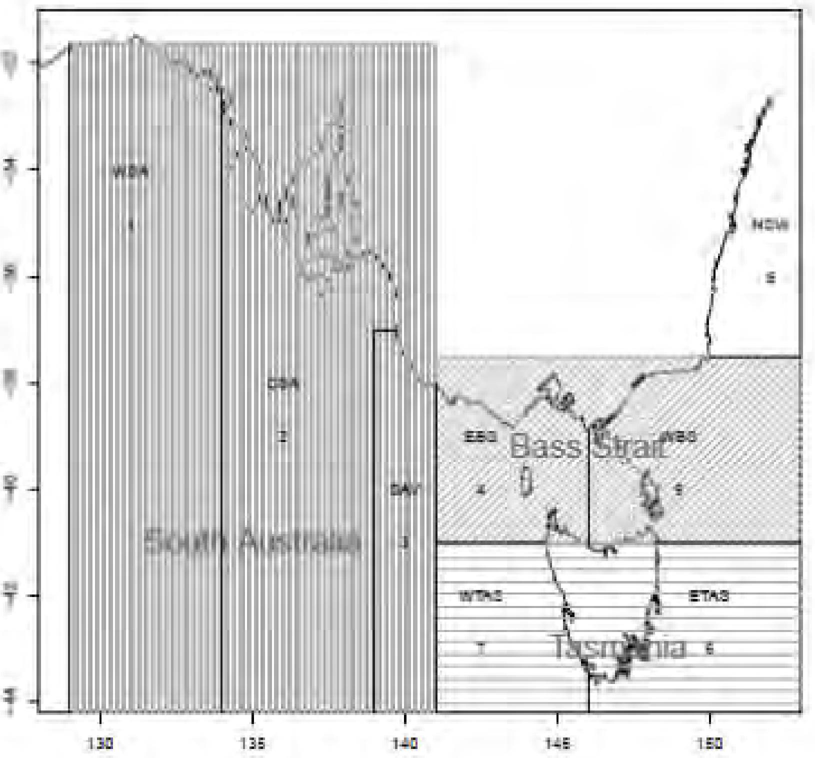


Figure 1. Three gummy shark management regions, each assigned to a separate stock (from Punt & Thomson 2010).

The most recent assessment update for gummy shark used data to 2009, and was presented to the September 2010 SharkRAG meeting (Punt & Thomson 2010). Unlike previous assessments, this one did not have a base case model. Instead, 10 models were constructed, of which four were discarded (three because they were computationally unstable and another to maintain balance). The quantities of interest (e.g. Recommended Biological Catch; RBC) calculated from the remaining six models were averaged to provide final results. Three of these six models produced unstable oscillations when projected into the future – an implausible result (Sporcic & Thomson 2012). For the 2013 assessment update it is recommended that the RAG return to using a base case model with sensitivities to that base case.

The stock assessment model was described by Punt et al. (2004) and Pribac et al. (2005). An update, using data to 2005, and extension to the Tasmanian stock, was presented by Punt et al. (2006). It was originally written in Fortran but was migrated to AD Model Builder (Otter Research, 2000), which involved some changes to the model structure. Work on a Stock Synthesis version of the gummy shark model is under discussion (SharkRAG 2013).

Here we present an update of the Punt & Thomson (2010) assessment:

i. landings data for 2010-2012 were included;
ii. landings for 2006-2009 for the unselective gear type (trawl and line) were found to be greater than those used by Punt & Thomson (2010). The reason for this is unknown and sensitivity to it was explored;
iii. length frequency information collected by the Observer Program (ISMP) were re-analysed and additional length frequencies have been added;
iv. length data from surveys were not used (although survey age data was retained); and
v. CPUE information for 2010 to 2012 was added.

Note: No new age information was available.

13.3 SharkRAG decisions Oct 2013

During the October 2013 meeting, SharkRAG discussed several aspects of the gummy shark stock assessment update for 2013. Questions (bold italic; underlined), background material, and SharkRAG/AFMA decisions (italics) are listed below.

What assumptions should be made regarding future line catches in South Australia and Bass Strait?

Sporcic & Thomson (2012) assumed that 0, 50% or 100% of current gillnet catches would be taken by hook and line gear (“line”) in the future. Is it possible to narrow down the range of plausible future options? Changes to fishing practices in Victoria were not considered by Sporcic & Thomson (2012); should changes in that state also be projected?

It was considered that a 50:50 split between line and gillnet vessels in SA is the most likely future scenario. A range of splits are considered (0%, 10%, 25%, 50%, 75% and 100% to line). It will take some time for the fishery in Victoria to ‘settle down’ before the effect of any changes there become apparent.

What model structure should we use?

The sensitivities presented in this report outline a range of options that need to be considered for the final assessment update for gummy shark. Which options should be included?

Truncate the likelihood for tag returns at 2005.Use the new length frequencies and existing survey age frequency data. Estimate effort saturation but also present results for no effort saturation case. Explore CPUE data in more detail looking at period of "peak saturation" when the number of vessels in the fishery is large. Use 'reference case" as the base case.

Should we include discarding in the stock assessment model?

The re-designed Observer Program is now able to provide discard estimates for gillnet caught species. For gummy shark, estimates of roughly 1% for 2008 and 6% for 2011 have been calculated (Klaer *et al*. 2013). Discard length frequencies are also available from the Observer Program. Although there are insufficient samples to form annual length frequencies by gender, pooling over years yields enough samples to form a length frequency for males and another for females. We do not have historical discard estimates for this fishery. Recent estimates would have to be applied back to 1927, or likely historical discard rates will have to be discussed by SharkRAG.

Discard rates are low, and past rates are unknown. Discards will not be used in the assessment model.

Should we move the assessment into Stock Synthesis?

The stock assessment package Stock Synthesis (SS) now includes an new, mortality based, stock-recruitment function designed for assessing species, such as sharks, that have a strong relationship between number of mature females and number of pups. Moving gummy shark into this framework would bring it into line with ShelfRAG, SlopeRAG and GABRAG which exclusively use SS for assessments. This would standardize the communication of results, reduce user error and allow for succession. Currently, there is a steep learning curve for anyone taking over the gummy shark assessment. Moving to an SS framework, however, would mean that only a single density dependent formulation is available, as opposed to the suite of alternatives used in the 2010 assessment. The formulation available in SS will be different from any of those used in the past.

Although there was support for building an SS model for gummy shark, SharkRAG were anxious not to replace the existing assessment with a new one without careful consideration. The problem of the cost of the SS work was also discussed.

***Should we go back to using a single base case model*?**

The 2010 gummy shark assessment was the first to use a suite of alternative models, each implementing density dependence in a different way. This was done because we have no information on the form that density dependence takes for the gummy population. This assumption has a strong influence on results (Punt & Thomson 2010). Results from these alternative models were combined by giving each equal weight, even though some gave much lower likelihoods than others when fitted to the data. The most common approach adopted in the SESSF is to select a base case model and use that, running other possible model configurations as sensitivities. By integrating over a range of possible models, the gummy shark stock assessment has been more difficult to report on than most (e.g. by ABARES). If we move to an SS framework, we once again will have just one base case model.

Go back to using a single base case model and sensitivity tests as a means of dealing with uncertainty.

How should we standardize catch rate?

Two alternative series exist – that using the historical method, which selects a set of vessels to use for the assessment, and whose applicability to the current fishery needs to be investigated; and another that uses all the data. Both are likely to suffer from the difficulty of identifying true zero catches (Haddon, 2013).

It would be beneficial to closely examine the existing method (Punt & Gason 2006) to fully understandit, as well as the reasons for its selection. Catch rates from past surveys could also be re-examined and included in the assessment. This process would take time, and would benefit from presentation to and discussion by SharkRAG. The historical data (commencing with 1970, contained in the CANDE file) have been reconstructed from a variety of data sources and do not have the quality of the current shot-by-shot logbook dataset. A cut off date of 1997 should be used and the historical series standardized up to that date and not beyond. Logbook data should be standardized separately. This decision is relevant to all four shark quota species. The Tier 4 method is not designed to cope with such a split, however, both of the Tier 4 shark species use data from only 1997 onwards.

Should we use the recent catch rates from South Australia (and Bass Strait)?

With the closure of historical fishing grounds to gillnets in South Australia, catch rates in that state are unlikely to be comparable with historical catch rates. There may be a spill over effect in Bass Strait due to operators moving into those waters. Voluntary closures around sea lion colonies were put into place in late 2010, and formal arrangements made in 2011.

The 2010-12 data in SA are affected by the closure of traditional fishing grounds in SA and by a spill-over of effort into Victoria. Their use in the assessment is therefore not justified.

What catch rates will we use in South Australia (and Bass Strait) into the future?

It is likely that after a period of transition, the fishery will settle into a new pattern in both SA and BS. If this new pattern includes a larger line sector, a catch rate series from that sector will become available. Catch rates from the "settling" period for both gillnet and line sectors are unlikely to be reliable indices of abundance so that there is likely to be a gap of several years in the catch rate series, and the new "post-settlement" series will not be comparable with the old.

The relative stability and longevity of the gummy shark population suggests that provided catches do not change greatly during this time of upheaval, the population ought not to be greatly affected. Once the fishery has settled down, catch rates from the fishery will again become useable, providing information to future stock assessments. Once it has been in place for a few years, catch rates from the new line fishery should be useful.

Should we raise logbook catches to landed catches (as is standard for other SESSF assessments)?

The assessment uses skipper's estimates of catch weight as recorded in logbooks. However, total landed catches recorded in the CDR database are consistently greater than those from the logbooks - typically 1.1 to 1.3 times greater each year. CDR records don't have the spatial resolution of the logbooks so the standard approach is to use logbook data to estimate catch by region and then inflate these by the ratio of the total CDR to total logbook catch for the year. This step has not been taken for gummy shark catches in previous (or this) assessment. CDR records are available back to 2001, the assessment uses catches back to 1927, the earliest non-zero catches being from Bass Strait in 1965. An average ratio of logbook to CDR catches for years 2001-2013 could be applied to catch prior to 2001, but how far back would that ratio be applicable? Were the earlier catches equivalent to the logbook catches of today?

The average ratio over 2001-2013 is 1.06 for non-trawl gears and 1.22 for trawl gears. As the vast majority of catches are made by gillnets, and the accuracy of these figures seems to be very good, inflation factors should not be used.

13.4 Data

13.4.1 *Catches and Effort*

Historical catch and effort data (between 1927 to 2005) were compiled, and 'cleaned', using rules discussed by past SharkRAG meetings. This work has been outlined in past SharkFAG and SharkRAG documents and some of it is implemented in FORTRAN code developed by A. Punt. The AFMA logbook database was used to update the landings time series (for 2006-2012). These data were also used to update the catch and effort file (CANDE12.dat) which was used to obtain standardized catch rate series.

The shark fishery predominantly used line gear but moved to gillnets during the 1960s. The larger 7 and 8 inch gillnets that targeted large female school shark have been replaced by smaller mesh sizes targeting gummy shark. In Bass Strait and Tasmania 6 inch gillnets predominate, and in South Australia 6.5 inch nets are also used (Figure 2).

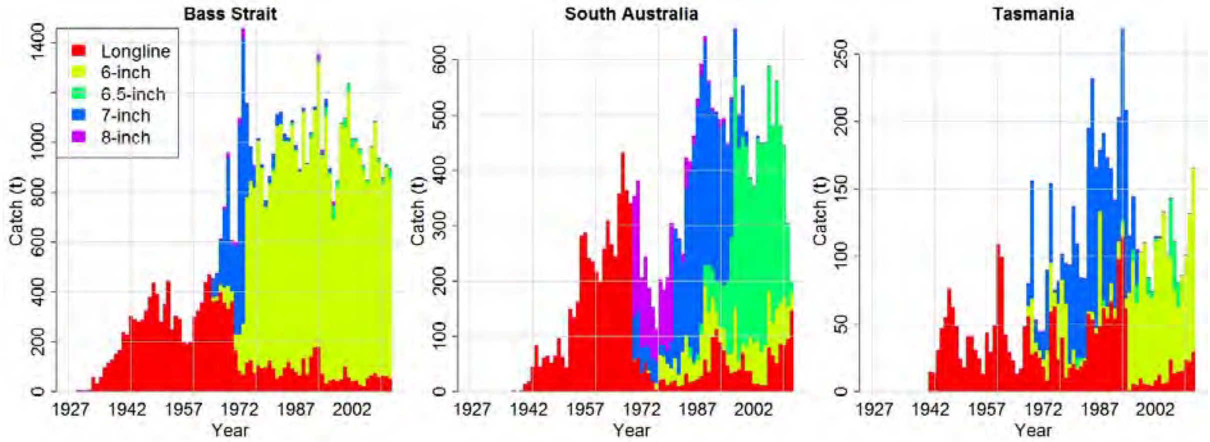


Figure 2. Gummy shark catches (tonnes) by gear type for three management regions (Bass Strait, South Australia and Tasmania) between 1927- 2012.

A method of CPUE standardization for gummy shark was first outlined by Punt *et al*. (2000) and evolved during a subsequent application (Punt, 2004). The method currently used is summarised by Punt & Gason (2006). The selection of data to be included in the standardization amounts to identifying fishers who target school and gummy shark, rather than those who catch them incidentally while targeting other species. Tables 1 and 2 detail the selection criteria used. A number of ‘fixes’ have also been applied to the data; these are listed in Table 3. This analysis has been repeated, using computer code developed by Andre Punt, using catch and effort data to 2012.

We used the original dataset developed by Punt & Gason (2006) (i.e., CANDE05.dat), which covers the 1997-2005 period. Data from 2006 to 2012 were obtained from the GENLOG database and merged with CANDE05.dat to obtain CANDE12.dat. A description of how these two data sets were combined is given in Thomson (2009). Resulting CPUE series for Bass Strait, South Australia and Tasmania are shown, along with model estimated CPUE (Figures 5, 6).

An alternative CPUE standardization for gummy shark, using data for all operators was developed using CANDE12.dat (Haddon (2013)). However, this was not available in time for use in sensitivity tests shown here. Therefore, only the series derived using the Punt & Gason (2006) method was used. More detailed investigation of CPUE methodology appropriate for application to recent (post 1997) CPUE data for gummy shark is planned for 2014.

Table 1. Criteria used to select ‘indicative’ shark fishers (adapted from Punt and Gason 2006).

Criterion No.	Criterion	Gummy shark
1	Years included:	
	South Australia	1984–present
	Bass Strait	1976– present
	Tasmania	1990– present
2	Minimum median annual catches	
	Total (school and gummy) shark	10 t
	School shark	N/A
	Gummy shark	5 t
3	Minimum years with data:	5
4	Minimum percentage gummy shark:	
	South Australia	0
	Bass Strait	60%
	Tasmania	60%
5	Maximum -percentage (%) of gummy toschool catches	
	South Australia	25%
	Bass Strait	99%
	Tasmania	25%
6	Minimum usable monthly records per vessel *	20

* after excluding records for the reasons outlined in Table 2.

Table 2. Criteria used to select records for use in the catch effort standardization.

Criterion No.	Criterion	Gummy shark
1	Years included:	
	South Australia	1984–present
	Bass Strait	1976–present
	Tasmania	1990–present
2	Gear types:	6, 6.5, 7inch mesh
3	Must have a depth:	
	Bass Strait	Yes
	South Australia	No
	Tasmania	Yes
4	Use records with depth between 20 and 40 m where corresponding school shark catch is zero	Yes
5	Minimum effort (gillnet metre-lifts):	1000 m

Table 3. ‘Fixes’ applied to the catch and effort data for school and gummy shark, implemented in Fortran computer code as part of the Punt and Gason (2006) CPUE standardization method.

Fix No.	Fix
1	Attribute catch and effort for ‘unknown mesh’ to 6 inch mesh in Bass Strait and to 7 inch mesh elsewhere.
2	Where statistical cell conflicts with region information, reset the region to match the cell.
3	Where gear type is given as =0 (a code that is not meant to appear in the dataset) reset to =1 (unknown gear type).
4	Divide catches reported as “combined school and gummy” according to school to gummy catch ratios available elsewhere in the dataset. A cascading hierarchy of rules is applied in selecting where this ratio will come from.
5	A list of “potentially acceptable” vessels is used, in addition to the criteria outlined in Tables 1 and 2.
6	Catches that have no region specified are attributed to region using the proportion of the catch for each gear type known to have been taken within each region in each year. Catches within each statistical cell of that region are scaled up to match the new total catch. However, these catches are stored separately from those that were not adjusted and had no adjustment to the effort associated with them – they are not used in the CPUE standardization.

13.4.2 *Length frequency data*

Gummy shark length data from commercial catches were collected by MAFRI until 2006 and used in the 2006 assessment (Punt *et al.*, 2006) as well as in the current update. Responsibility for collection of commercial length data has now moved to the AFMA Observer Program, which has yielded length frequency information from 2008 to 2012.

The Observer Program collects length information onboard vessels (mostly as total length (TOT) but also significant amounts as fork length (LCF) or in port (all partial length (PAR)). Detail on sample sizes is given in Appendix A. Samples sizes are greatest for the onboard data, and the validity of the historical conversion formula for PAR to TOT is in doubt (i.e., TOT(cm) = 2.65 + 1.61PAR (cm), Walker *et al.* 2009). This doubt arises from converting partial lengths to total length and then comparing the converted length frequencies with the whole length frequencies. It has been recommended that the Observer Program collect dual TOT and PAR measurements from gummy and school shark in order to calculate new conversion factors (Thomson & Sporcic 2013).

Port-based length data were not used because:

1. all measurements are partial lengths and the conversion formula is in doubt;
2. 52% of all port-based samples were collected in Lakes Entrance; and in 2011 and 2012 no collections were made outside of Lakes Entrance; this sampling regime may not yield data that is representative of the whole stock and
3. area of capture was not reported by shark zone until 2009 (prior to that SET zones were reported).

Criteria for including length measurements made on board vessels were:

1. samples must be from a mesh net;
2. length code must be TOT or LCF (converted to TOT using newly available conversion formulae, see Thomson & Sporcic 2013);
3. at least 400 animals of a given gender and and region (Bass Strait, South Australia or Tasmania) must have been measured and
4. measurements which were tagged as “discarded” were ignored.

Punt & Thomson (2010) used the observer data to derive length frequencies for 2009, and used survey data for 2007 and 2008, but not observer data from 2008.

Length frequencies (lfs) used here (Table 4) differ from those of Punt & Thomson (2010) in that:

1. survey data (which might not reflect commercial fishing patterns) are not used, this eliminates:
   a. a single lf for Tasmania for male sharks caught in 2007 and
   b. four lfs for 2008 for male and females sharks in Bass Strait and South Australia
2. any animals whose length is reported as partial length are excluded (since PAR to TOT conversion is not used). This eliminates:
   a. 75 animals in 2008,
   b. 356 animals in 2009,
   c. 20 animals in 2010,
   d. 34 animals in 2011,
   e. 8 animals in 2012,
3. a newly calculated LCF to TOT conversion is used, adding
   a. 172 animals in 2008,
   b. 1517 animals in 2009,
   c. 2145 animals in 2010,
   d. 898 animals in 2011,
   e. 143 animals in 2012,
4. samples are catch weighted by region before summation (something that Punt & Thomson (2010), recommended were unable to do),
5. length-based data collected in CSA during 2009 are used in the assessment, despite the presence of some small animals (it may be that catch weighting has reduced the influence of that sub-sample).

Table 4. Length frequency sample sizes (for those >400) used here, by management region and gender for 2008 to 2012 (Observer Program data). Note: samples in (i) 2008data replace survey data (used by Punt & Thomson 2010);(ii) 2009 data for Bass Strait are similar to those used by Punt & Thomson (2010) and (iii) 2009 data for South Australia were also available but were not used by Punt & Thomson (2010).

Year	Bass Strait		South Australia		Tasmania	
	Females	Males	Females	Males	Females	Males
2008	762	1794	412	581	-	-
2009	2193	1465	687	-	-	-
2010	1526	2736	1304	-	-	436
2011	5049	8720	1978	956	-	-
2012	5691	11803	1082	443	560	995

The size of gillnet was not recorded for these data so the mesh size was assumed to be that which led to the largest catch in the region from which the data were collected (i.e., 6 inch in Bass Strait and Tasmania and 6.5 inch in South Australia. Overall, catch weighting did not noticeably alter length frequencies, suggesting that it is valid to combine samples across SharkRAG zones/regions.

The Observer Program also gathered length information on discarded gummy shark (Figure 3). Sample sizes are currently too small for length frequencies to be used in the assessment model if they are split by gender, region and year, but they appear to be consistent across years (with the possible exception of 2010) and regions. This suggests that the sample could be split by gender only and applied to all regions and to at least recent years. Currently, the sample for females is too small (i.e., 301), while that for males (i.e., 420) exceeds the minimum requirement (i.e., 400 animals).

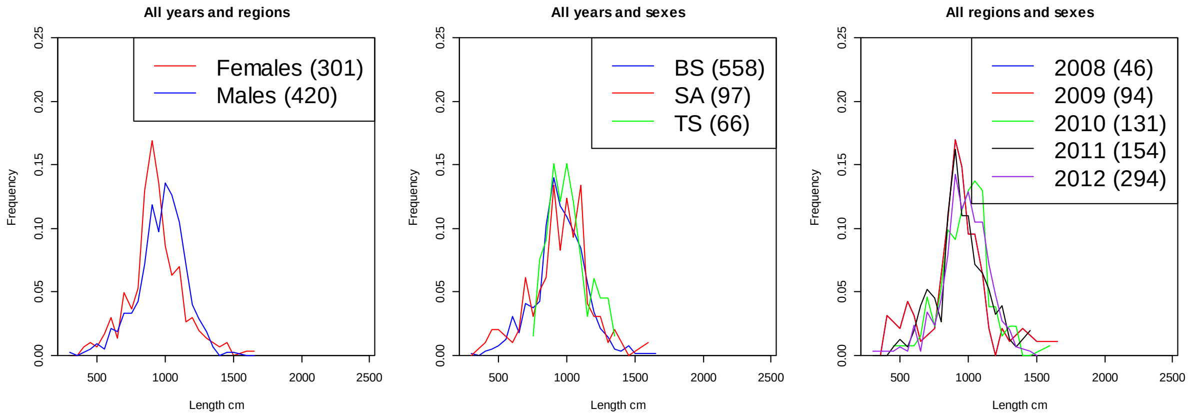


Figure 3. Length frequencies for 721 discarded gummy sharks (Observer Program data) by (left plot) gender (across all years and regions; left); (middle plot) region (across all years and genders) and (right plot) by year (across all regions and genders). Sample sizes are shown in parentheses.

13.4.3 *Age data*

Age data used by Punt & Thomson (2010) were used for this assessment update, even though they were derived from 2007 and 2008 surveys, not from commercial fishing. It should be assessed whether this data be excluded from analyses once additional age data become available (as it will from the Observer Program). Sample sizes for Bass Strait were 81 (5 in 2007 and 76 in 2008), South Australia, 178 (124 in 2007 and 54 in 2008), and Tasmania, 18 (17 in 2007 and 1 in 2008). In line with Punt & Thomson (2010), we included age data only when at least 10 animals of a particular gender were aged within a year. This criterion eliminated data from Bass Strait from 2007, and all Tasmanian data. Data were aggregated to ages 1 – 10+ for consistency with the previous assessment.

13.4.4 *Tag-recapture data*

It is not known whether any new tag-recaptures have been reported since 2008. Reporting rates have probably decreased in recent years and are probably effectively close to zero from 2009 onwards. Sensitivity of the model to assuming zero tag return rates in recent years was considered.

13.5 Methods

This assessment employed the model presented by Punt & Thomson (2010). Data to 2012 were incorporated, and parameter estimates were updated. Some catch and length frequency data were replaced. The impact of adding new data, and of different model formulations, is examined using the ‘reference case’ assessment i.e., model “b” of Punt & Thomson (2010). The reference case assumes that (i) density-dependence is a function of total (1+) biomass, (ii) density-dependence impacts the rate of natural mortality for animals aged 0-30 years, and (iii) gear competition is modelled using Equation 1a of Punt and Thomson (2010):

$$U_y^a = q^a \, B_y^{e,a} \, \tfrac{1}{1+\gamma^a E_y^a} \, e^{\varepsilon_y^a} \,, \qquad (1a).$$

where U_y^a is the catch-rate for region *a* (Bass Strait, South Australia, or Tasmania) and year *y*, q^a is the catchability coefficient for region *a*, $B_y^{e,a}$ is the exploitable biomass for region *a* and year *y*, E_y^a is the nominal effort for region *a* and year *y*, γ^a is the parameter which determines the extent of effort saturation / gear competition for region *a* (no gear competition if γ^a=0, with increasing amounts of gear competition as γ^a is increased), and ε_y^a is the observation error for region *a* and year *y* (assumed for consistency with past assessments to be normal with mean 0 and standard deviation 0.15).

A bridging analysis was performed to examine the effect of changes to the model. First, the 2010 reference model was run with no changes (reproducing the results given in Punt & Thomson 2010) and then new data were added, or structural adjustments made, sequentially. The parameter values were estimated after each small change to understand the effect of that change. These model sensitivities (or steps in a bridging analysis), each differing slightly from the previous one, were given unique numbers and are described in Table 5. Non sequential (i.e., missing) numbers resulted from the exclusion from the table of tests that showed no notable differences:

The bridging analysis was presented to SharkRAG at its first meeting for the year (27-28 October 2013, Melbourne) (Thomson 2013). The group chose a base case model (the years to be included for the CPUE were subsequently chosen by AFMA as that choice had been left unclear by SharkRAG). This model was used to examine sensitivity to the choice made for density dependence. The alternative forms for density dependence that were explored by Punt & Thomson (2010) were used; these are listed in Table 5.

Table 5. Twenty-two model sensitivity tests performed.

Sensitivity No (#)	Sensitivity attribute
1	Punt & Thomson (2010) reference case (model b) from the 2010 assessment update, model ends 2009.
2	SN 1 with catches for 2006-2009 replaced (giving higher line&trawl catches), model ends 2009.
3	SN 2 extended to 2012 (uses catches 2010-2012), no extra recruitments are estimated.

4	SN 3 with tagging truncated at 2000.
5	SN 3 with tagging truncated at 2005.
6	SN 5 with 2008&9 BS female lfs replaced with new lfs.
7	SN 6 with 2008&9 BS male lfs replaced with new lfs.
8	SN 7 with 2008 SA female lfs replaced with the new lfs.
9	SN 8 with 2008 SA male lfs replaced with the new lfs.
10	SN 9 with new 2009 SA female lfs added.
11	SN 10 without 2007 survey lfs.
12	SN 11 with new BS lfs for 2010-12.
13	SN 12 with new SA lfs for 2010-12.
14	SN 13 with new TS lfs for 2010-12.
17	SN 14 with 3 more recruitment residuals estimated (for all but the last 5 years, consistent with the 2010 reference case).
18	SN 17 with Punt CPUE standardization method applied to data to 2009.
19	SN 17 with Punt CPUE standardization method applied to data to 2010.
20	SN 17 with Punt CPUE standardization method applied to data to 2011.
21	SN 17 with Punt CPUE standardization method applied to data to 2012.
24	SN 18 (CPUE series ends 2009) with effort saturation/gear competition eliminated.
27	SN 21 (CPUE series ends 2012) with effort saturation/gear competition eliminated.
28	**Base case model for 2013: SI 21 with CPUE in SA truncated at 2009 (CPUE for Vic and Tas ends 2012).**
29	Base case with density dependence (dd) on M for ages 0-15 based on 1+ biomass (B1+) [model d, Punt & Thomson, 2010]
30	Base case with density dependence (dd) on M for ages 0-4 (B1+) [model e]

31	Base case with density dependence (dd) on M for ages 0-30 based on mature biomass (Bmat) [model f]
32	Base case with density dependence (dd) on M for ages 0-15 (Bmat) [model g]
33	Base case with density dependence (dd) on M for ages 0-4 (Bmat) [model h]
34	Base case with density dependence (dd) on M for ages 0-2 (B1+) [model i]
35	Base case with density dependence (dd) on M for ages 0-2 (Bmat) [model j]
36	Base case with density dependence (dd) on fecundity (B1+) [model k]
37	Base case with density dependence (dd) on fecundity (Bmat) [model l]

Table 6. Estimates from bridging analysis "#" listed in Table 5, showing adult natural mortality rate "M_a", pup production in year 'X' compared with pristine "PembryoX" (%), effort saturation parameter value for each population "effort sat'n", negative log likelihood "-LnL" and its constituent components. A brief description of each sensitivity is provided in last column. Numbers (italics) under "Pembryo12" refer to depletion in 2009 not 2012.

#	M_a	B_0			MSYR			Pembryo73			Pembryo12			Effort sat'n			-LnL	-LnL components					Brief description of sensitivity
		BS	SA	TS	BS	SA	TS	BS	SA	TS	BS	SA	TS	BS	SA	TS		CPUE	Len	Age	Tag	Prior	
1	0.18	9854	5441	2181	0.22	0.24	0.22	64	70	90	*61*	*70*	*84*	1.03	7.3	0	970	77	408	149	299	37	2010 "Ref case"
2	0.18	9905	5501	2187	0.22	0.24	0.22	64	70	90	*60*	*68*	*83*	1.07	7.74	0	972	78	408	150	299	37	'06-'09 line cat
3	0.19	9868	5487	2173	0.22	0.24	0.22	64	70	90	61	68	81	1.08	7.82	0	973	78	408	150	299	37	Run to 2012
4	0.18	9944	5598	2229	0.22	0.24	0.22	65	70	90	60	69	81	1.14	6.3	0	933	78	407	148	264	37	Tagging to 2000
5	0.18	9961	5515	2215	0.22	0.24	0.22	65	70	90	62	69	82	1.13	7.79	0	964	78	408	149	292	37	Tagging to 2005
6	0.18	10000	5519	2222	0.22	0.24	0.22	65	70	90	61	69	82	1.61	7.98	0	968	78	411	149	293	36	'08-09 lfs: BS f
7	0.18	9995	5517	2224	0.22	0.24	0.22	65	70	90	60	69	82	2.17	8.17	0	968	79	410	149	294	36	'08-09 lfs: BS m
8	0.18	9991	5510	2221	0.22	0.24	0.22	65	70	90	60	69	82	2.17	8.48	0	969	79	411	150	294	36	'08 lfs: SA f
9	0.18	9982	5482	2212	0.22	0.24	0.22	65	70	90	60	69	82	2.17	9.17	0	973	78	415	151	293	36	'08 lfs: SA m
10	0.18	9925	5454	2197	0.23	1	0.23	65	70	90	61	68	82	2.17	10.55	0	977	78	418	151	293	35	2009 lf in SA
11	0.18	9927	5455	2190	0.23	0.25	0.23	65	70	90	61	68	82	2.17	10.57	0	976	78	418	152	293	35	No 07 survey lf
12	0.18	9996	5595	2264	0.22	0.24	0.22	65	71	91	57	69	82	6.34	9.46	0	1002	82	437	150	296	36	'10-'12 lfs: BS
13	0.18	9826	5500	2222	0.22	0.24	0.22	65	70	90	58	68	82	6.19	13.87	0	1014	83	449	151	296	36	'10-'12 lfs: SA
14	0.18	9821	5504	2268	0.22	0.24	0.22	65	70	91	57	68	83	6.28	13.69	0	1026	82	460	150	297	36	'10-'12 lfs: TS
17	0.18	9954	5522	2212	0.22	0.24	0.22	65	70	90	62	68	82	1.07	8.07	0	964	78	408	149	292	37	3 more Recs'
18	0.18	9898	5503	2266	0.23	0.25	0.23	65	71	91	59	69	83	19.01	8.89	0	1026^a	83	458	151	297	36	CPUE, ends '09
19	0.18	9915	5513	2261	0.23	0.25	0.23	66	71	91	59	69	83	21.46	10.29	0	1027	83	458	152	297	37	CPUE, ends '10
20	0.17	10229	5667	2332	0.22	0.24	0.22	66	71	91	58	70	83	22.36	3.01	0	1034	88	460	150	298	37	CPUE, ends '11
21	0.16	11009	5988	2563	0.2	0.21	0.2	67	71	91	56	73	83	32.77	1.13	0	1061^b	107	465	148	302	40	CPUE, ends '12
24	0.17	10868	6214	2419	0.19	0.21	0.19	65	72	90	57	73	81	0	0	0	1067^a	100	472	154	293	48	CPUE, ends '09
27	0.16	11466	6383	2594	0.19	0.2	0.19	67	72	91	58	75	82	0	0	0	1090^b	116	476	154	297	47	CPUE, ends '12
28	0.18	9949	5541	2271	0.22	1	0.22	65	71	91	59	69	83	225.50	8.56	0	1028	85	458	151	297	37	**Base case**

^{a} and ^{b} indicate comparable likelihoods.

Table 7. Estimates from base case and sensitivity tests “#” listed in Table 5, showing adult natural mortality rate “M_a”, pup production in year ‘X’ compared with pristine “PembryoX” (%), effort saturation parameter value for each population “effort sat’n”, negative log likelihood “-LnL” and its constituent components. A brief description of each sensitivity is provided in last column. Numbers (italics) under “Pembryo12” refer to depletion in 2009 not 2012*.

#	M_a	B_0			MSYR			Pembryo73			Pembryo12			Effort sat’n			-LnL	-LnL components					Brief description of sensitivity
		BS	SA	TS	BS	SA	TS	BS	SA	TS	BS	SA	TS	BS	SA	TS		CPUE	Len	Age	Tag	Prior	
28	0.18	9949	5541	2272	0.22	0.24	0.22	65	71	91	59	69	83	25.5	8.56	0	1028	85	458	151	297	37	**Base case**
29	0.18	10001	5544	2292	0.24	0.26	0.24	62	67	89	51	65	79	25.32	11.29	0	1029	86	460	151	296	37	M 0-15, B1+
30	0.14	10888	6069	2672	0.23	0.25	0.23	55	59	87	36	55	73	50	14.97	0	1024	83	457	147	306	31	M 0-4, B1+
31	0.23	7037	4298	1642	0.25	1	0.25	67	78	92	64	82	80	8.19	1.18	0	1008	75	462	154	284	32	M0-30, Bmat
32	0.24	6870	4218	1578	0.24	0.26	0.24	64	76	91	59	79	77	6.08	1.07	0	1007	75	465	155	280	33	M 0-15, Bmat
33	0.16	8273	4456	2121	0.17	0.19	0.17	43	83	89	40	89	79	50	1.58	0	1013	72	461	143	304	31	M 0-4, Bmat
34	0.14	11099	6186	2580	0.21	0.23	0.21	52	58	86	31	54	69	50	10.33	0	1015	83	448	148	304	32	M 0-2, B1+
35	0.17	6960	3860	1756	0.18	0.2	0.18	32	83	86	35	87	76	50	1.79	0	998	73	448	146	301	31	M 0-2, Bmat

*All models in this table have comparable likelihoods.

13.6 Results and discussion

13.6.1 Bridging analysis

Selected model outputs for each of the steps in the bridging analysis listed under in Table 5 are shown in Table 6. Hereafter these steps are referred to as “sensitivities”.

Altering catches for the line and trawl fleet for 2006-09 and adding catches to 2012 had little effect on results (sensitivities 1-3, Table 6). Ending the tagging time series earlier resulted in the appearance of somewhat larger population sizes (sensitivities 4&5, Table 6).This suggests that tag return rates may have continued to decline after 2005 and those tag returns should not be used.

Various substitutions, additions and deletions of length frequencies had no great effect on the model outputs (sensitivities 6-14, Table 6). This suggests that these length frequencies do not contradict any of the other data sources or the earlier length frequencies. Despite the stability of the population sizes, natural mortality rate, and depletion estimates, there are, however, a wide range of effort saturation parameter estimates suggesting that this parameter is not well estimated, but also that it is, strangely, not particularly influential.

The estimated MSYR for sensitivity 10 in South Australia is a concern, suggesting that the model has not converged on a correct solution.

The estimation of additional recruitments allowed the model to greatly improve the fit to the CPUE series (sensitivity 17, Table 6, -LnL component: CPUE). The Bass Strait stock shows less depletion due to larger estimates of recruitment in recent years (Figure 4).

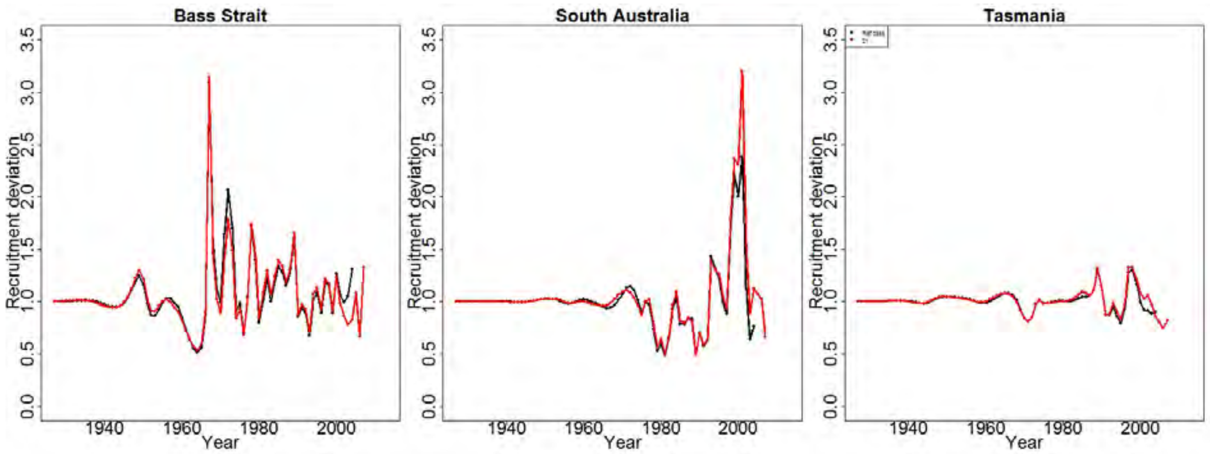


Figure 4. Estimated recruitment deviations for each region for the reference case (“Ref case”, black line) and the sensitivity (21) that uses all new data (red line).

The inclusion of the new CPUE series, truncated at 2009, leads to a much larger estimate of the effort saturation parameter in BS and a slightly larger one in SA. The fit to the CPUE series is worsened (sensitivity 18, Table 6, -LnL component: CPUE). However, The results are qualitatively similar (Figure 5). Fitting to additional years of the standardized CPUE series results in greater values for the effort saturation parameter in BS but smaller values in SA (sensitivity 18-21, Table 6). Counter-intuitively, the BS stock appears more depleted with the addition of each year’s data and the SA stock less depleted. Fits to CPUE are similar, only the final year showing sensitivity (Figure 6) – this is likely due to uncertainty regarding the most recent estimates of recruitment. Removing effort saturation and using CPUE to 2009 (sensitivity 24, Table 6) produced similar results compared to allowing effort saturation and using CPUE to 2012. With no effort saturation and CPUE to 2012 (sensitivity 27, Table 6) depletion in BS is similar to that estimated when effort saturation is used, but the SA stock is less depleted than it is for any other sensitivity.

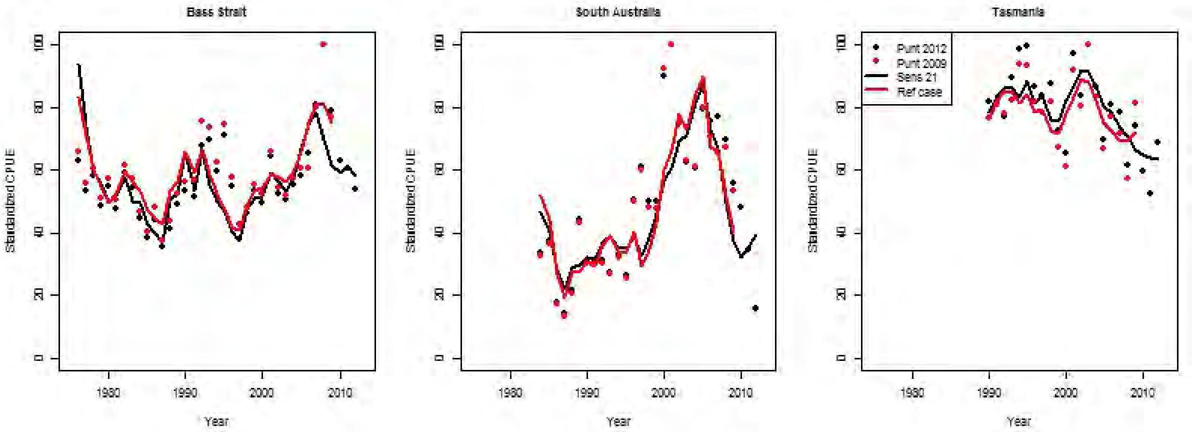


Figure 5. Observed (dots) and estimated (lines) standardized CPUE for the three regions. Results are shown for the CPUE standardization used by Punt & Thomson (2010) – “Punt 2009” and the one that uses data to 2012 “Punt 2012”. The reference case “Ref case” uses the 2009 series and the sensitivity that uses all new data (“Sens 21”) uses the 2012 series.

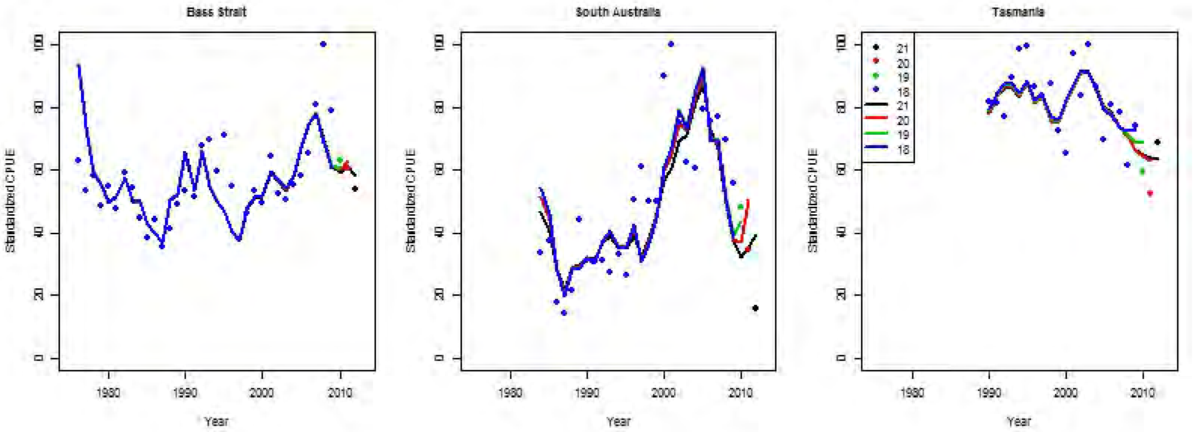


Figure 6. Observed (dots) and estimated (lines) standardized CPUE for the three regions for sensitivities 18 to 21, which truncate the CPUE series at 2009 (blue), 2010 (green), 2011 (red) or 2012 (black). The earlier observed points overlie one another so that the blue dots are relevant to all four sensitivities.

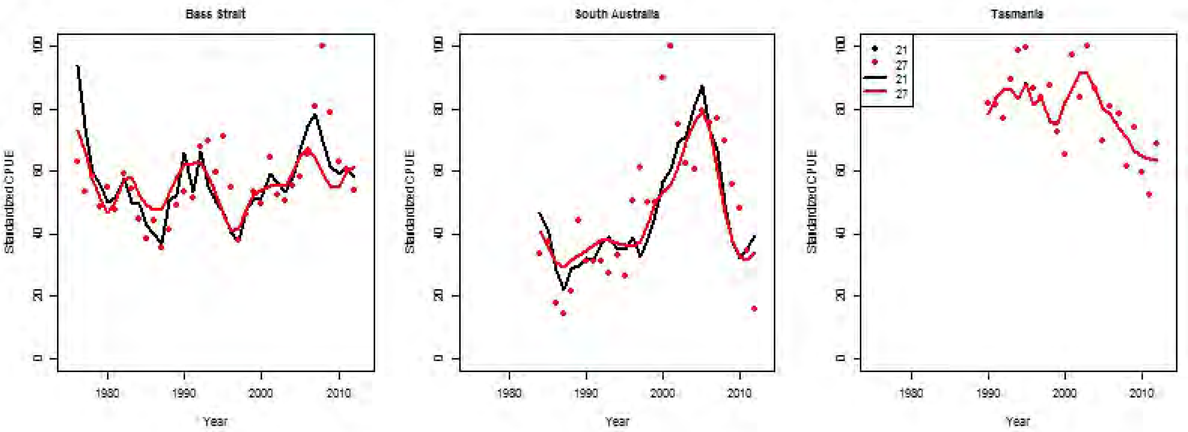


Figure 7. Observed (dots) and estimated (lines) standardized CPUE for the three regions for the sensitivity 21, which estimates gear saturation, and sensitivity 27, which does not allow gear saturation. (For these plots, the red dots obscure the black dots because the data are the same).

The effort saturation formula was included in model because of non-linearity in the relationship between catch rate and abundance for gummy shark (Equation 1a, Punt & Thomson 2010). A power parameter (γ) is calculated for each population; setting this parameter to zero forces the model to assume the more usual linear relationship. Removing these three parameters from the fitting procedure causes the negative log likelihood to increase by 29 (from 1061 to 1090; sensitivities 21 and 27). Using a likelihood ratio test, the inclusion of these three parameters is highly significant (P<1e-6). However, there was little effect on the model fit to CPUE and no effect in Tasmania because the estimated value for γ in that region is zero (Figure 7). It is difficult to say why the parameter would vary so much from population to population with Tasmania showing a linear relationship, and Bass Strait a highly non-linear relationship (Table 6). These parameters are highly sensitive to some of the changes made in these sensitivity tests. However, the parameter value does not have a linear relationship with its effect on CPUE, rather, this is a log relationship so that very large values have little more effect than moderately large values.

13.6.2 *Base case and sensitivities*

The base case model for the 2013 stock assessment update is sensitivity 28 (Tables 6 & 7). CPUE data to 2012 are used for Victoria and Tasmania but only to 2010 for South Australia. Tag return data are truncated at 2005. Compared with the 2010 reference case, the new base case shows the same trend but larger population sizes in all regions, most likely due to the exclusion of tag returns after 2005 (Figure 8). Fits to length frequencies for sensitivity 28 are good for most years (Figure 9).

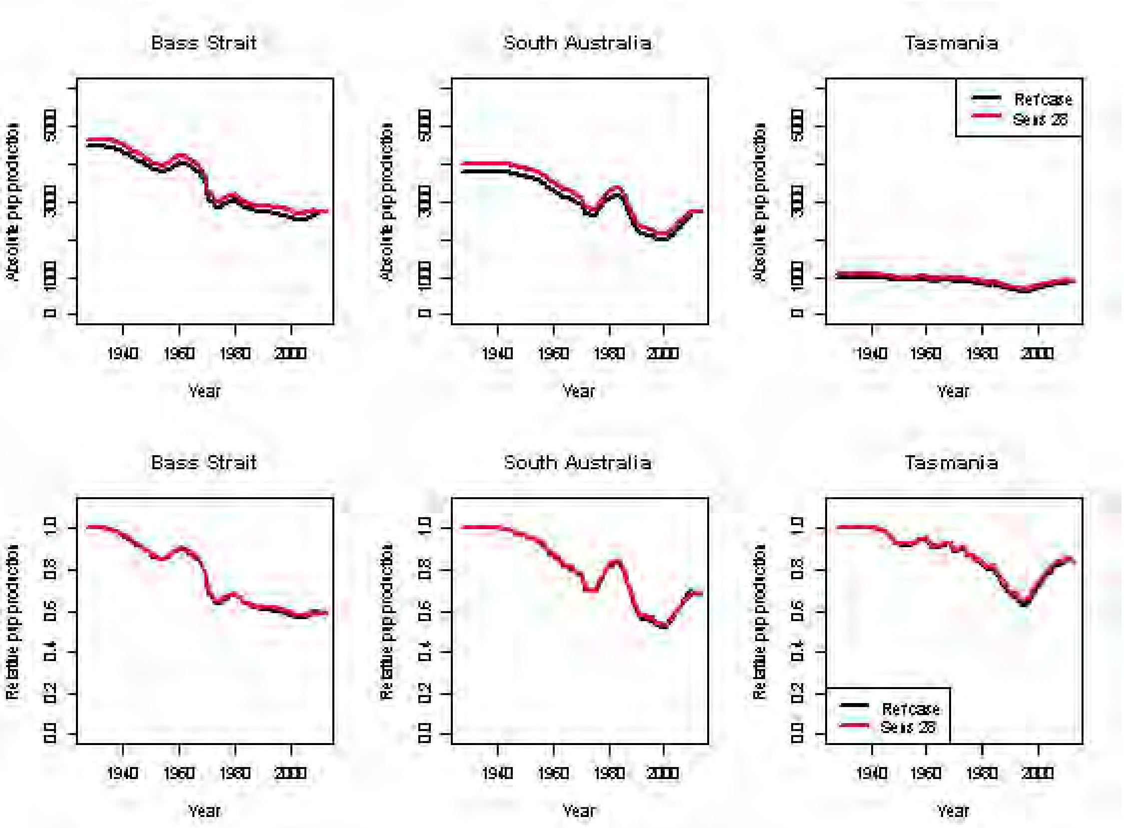


Figure 8. Pup production in thousands of pups (top panel) and pup production relative to 1927 (bottom panel) for the three gummy shark regions and two scenarios (Reference case and sensitivity 28).

The model shows great sensitivity to the assumption made for density dependence. The two models that allowed fecundity to be a function of density (SN 37 and SN 38), proved problematic in terms of achieving convergence – as was found by Punt & Thomson (2010). There are therefore excluded from the discussion.

Four out of seven sensitivities indicate that the Bass Strait population is below 48% of pristine (31-40%). The South Australian and Tasmanian stocks above the 48% target for all sensitivities (SA: 54-89%; Tas: 69-80%). The average depletion across all the base case and all seven sensitivities (i.e. using the method of Punt & Thomson 2010) is 47% for Bass Strait, 73% for South Australia, and 77% for Tasmania. However, not all sensitivities fit the data equally well. For South Australia, the four sensitivities that return the least depleted results (SN 31, 32, 33, 35) (79-89%) are also the four models that fit the data best. The four that fit the data worst (SN 28, 29, 30, 34) return the lowest depletions for South Australia (54-69%). These are also the four sensitivities that allow density dependence to affect only the youngest animals (0-2 or 0-4 year olds) instead of a wider age range (0-15 or 0-30). For Bass Strait and Tasmania there is no clear relationship between estimated depletion and likelihood.

13.6.3 *Recommended Biological Catches*

Recommended Biological Catches (RBCs) for the three gummy shark regions were estimated using the 20:35:48 Tier 1 harvest control rule of the SESSF Harvest Strategy Framework. RBC calculations are influenced by the type of fishing selectivity patterns assumed into the future. In this case, with the proportion of the catch likely to be taken by line gear uncertain, a range of assumptions were made, i.e., a future line sector will take 0, 10, 25, 50, 75 or 100% of the catch each year (Table 7). The assumption is made that the availability function *does* apply to line gear. Evidence in favour of the application of availability to line catches comes from examination of length-based data collected during the automatic long-line study (Knuckey *et al*. 2013). The estimation of line selectivity using collected length information and known gillnet gear selectivity is presented in Appendix B.

Table 7. Recommended Biological Catches (RBCs; tonnes) for Bass Strait “BS”, South Australian SA and Tasmanian TS populations. Calculations were done assuming that 0%, 10%, 25%, 75%, or 100% of the catch is taken by line gear Line (%). Totals are presented for situations where line gear is used in all regions ALL, or in South Australia alone SA only. RBCs are shown for 2014 “2014 RBCs” and for populations that are stable at 48% of pristine “Long term RBCs”.

2014 RBCs							Long term RBCs					
Line (%)	Population			Total			Line (%)	Population			Sum	
	BS	SA	TS	All	SA only			BS	SA	TS	All	SA only
0	1234	745	253	2232	2232		0	1149	676	272	2097	2097
10	1080	617	242	1939	2104		10	1095	635	250	1980	2056
25	1049	599	233	1881	2086		25	1067	622	244	1933	2043
50	1013	582	225	1820	2069		50	1028	602	235	1865	2023
75	988	567	219	1774	2054		75	1003	589	229	1821	2010
100	972	557	215	1744	2044		100	986	580	225	1791	2001

13.7 Conclusions

The stock assessment estimated that very large recruitments occurred in South Australia during the early 2000s, when the spawning biomass (potential pup production) was estimated to be very low. These recruits entered the fishery, which primarily takes a narrow age range of juvenile fish, passed through the lengths at which they were most available to gillnet gear, and then entered the spawning stock. The estimated CPUE in recent years has fallen due to the reduced availability of these large cohorts to gillnet gear. However, the estimated spawning biomass (and corresponding pup productivity) during the same period has increased. Evidence for the existence of these large cohorts is not compelling to the eye when examining the length frequency plots i.e. large modes are not apparent (Figure 9). Also, poor fits between model and observed length frequencies, which would suggest that the model has ‘invented’ large recruitment events that did not occur, are also not apparent. The relatively slow somatic growth of gummy shark compared with teleost fishes is the likely explanation for the absence of clear recruitment modes. The model does not have strong age information and mature sharks are largely not sampled by the fishery. Evidence for or against these large cohorts is therefore not strong. In the future, if a viable line sector is established in South Australia and is well sampled by the ISMP, then data on relative sizes of mature cohorts will start to become available.

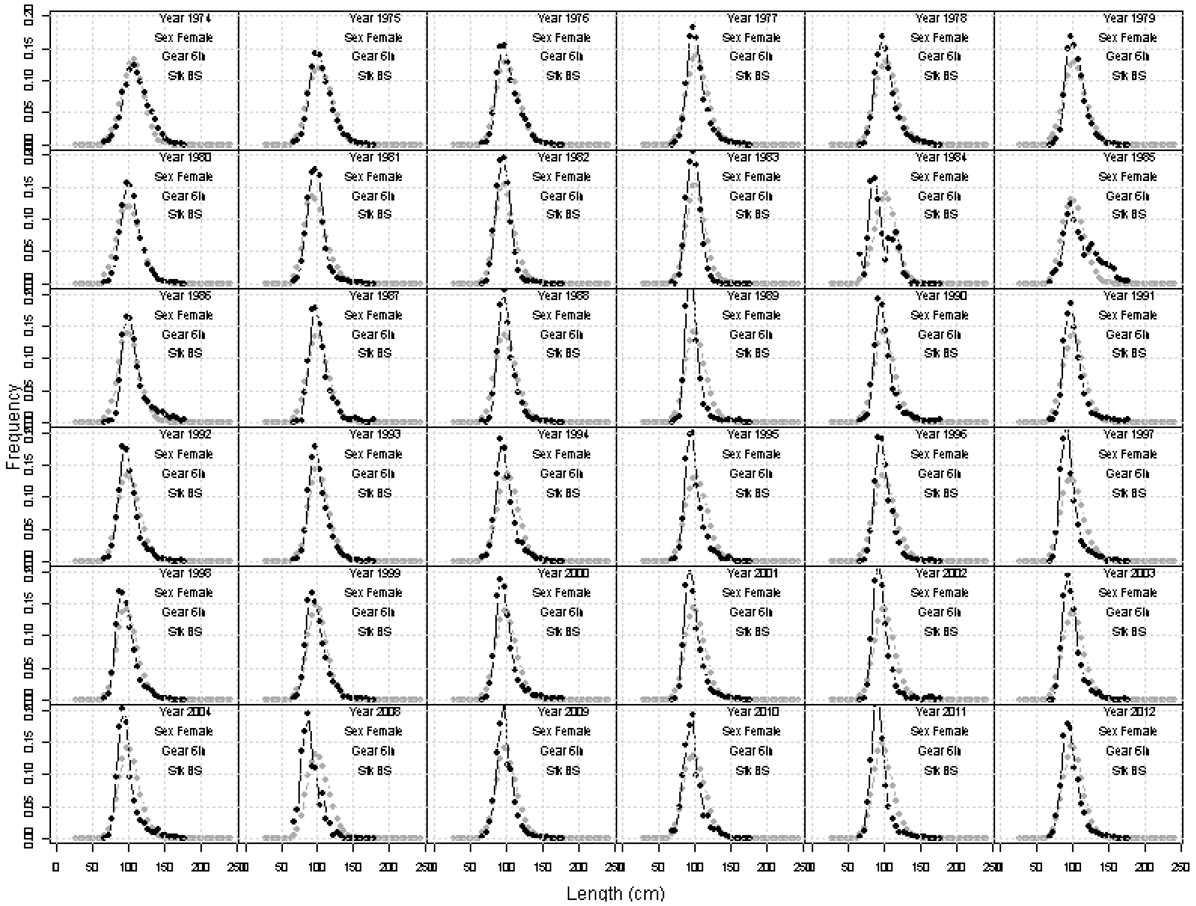
The base case model indicates that all three gummy shark populations have pup production above 48% of pristine. None of the sensitivity tests examined as part of the bridging analysis resulted in pup production estimates below 48%. However, some of the sensitivities that implement density dependence in different ways result in depletions as low as 31% for Bass Strait. No sensitivities found the South Australian or Tasmanian stocks to be below 48%. The depletions estimated for Bass Strait are somewhat lower than those estimated during 2010, where the lowest were 35 and 43% as opposed to the 31 and 35% found here (Punt & Thomson 2010). The average depletions (across the base case and the 7 sensitivities) are close to above the 48% target (BS: 47%, SA:73%, Tas: 77%).

RBCs (for the base case) for 2014 range from 2044t (whole catch taken by line gear) to 2232t (whole catch taken by gillnets) with more line fishing resulting in lower RBCs. Note that the assessment model makes the assumption that larger fish are less available to the gillnet fishery due to aspects of gummy shark behaviour. This assumption was extended to the line fishery due to evidence collected by the line trials (Knuckey *et al*. 2013). This is the less conservative choice (i.e., availability not applied to line gear), so RBCs would have been lower than those presented here for the scenarios where line gear takes more of the catch. The scenario where line gear take 0% of the catch would be unaffected.

Present catches of gummy shark have been held at approximately 1800 t in order to limit catches of school shark. If line fishing does not occur outside of South Australia, catches of roughly 1800t would not exceed the RBCs for gummy shark even if the South Australian line sector is dominant. However, if line fishing dominates in all regions of the fishery and takes 50% of the catch, the RBC for gummy shark will be lower than 1800t.

13.8 Future work

1. State catches are not included in the assessment model. Recent state catches in South Australia have been large and inclusion in the assessment model ought to be considered in the future.
2. Evidence for competition between fishing vessels, which depresses catch rates during periods when larger numbers of vessels are operating in the fishery, should be investigated.
3. CPUE standardization for data up to and including 1996 should use the method of Punt *et al*. (2000) but data from 1997 onwards should be standardized separately and sourced directly from the Commonwealth logbook database GENLOG (not from the MAFFRI derived CANDE file). An optimal method for standardizing recent data should also be investigated.
4. Development of a gummy shark model in SS should be undertaken.


Year 1974 Sex Female Gear 6h Stk BS
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Year 2010 Sex Female Gear 6h Stk BS
Year 2011 Sex Female Gear 6h Stk BS
Year 2012 Sex Female Gear 6h Stk BS
Frequency
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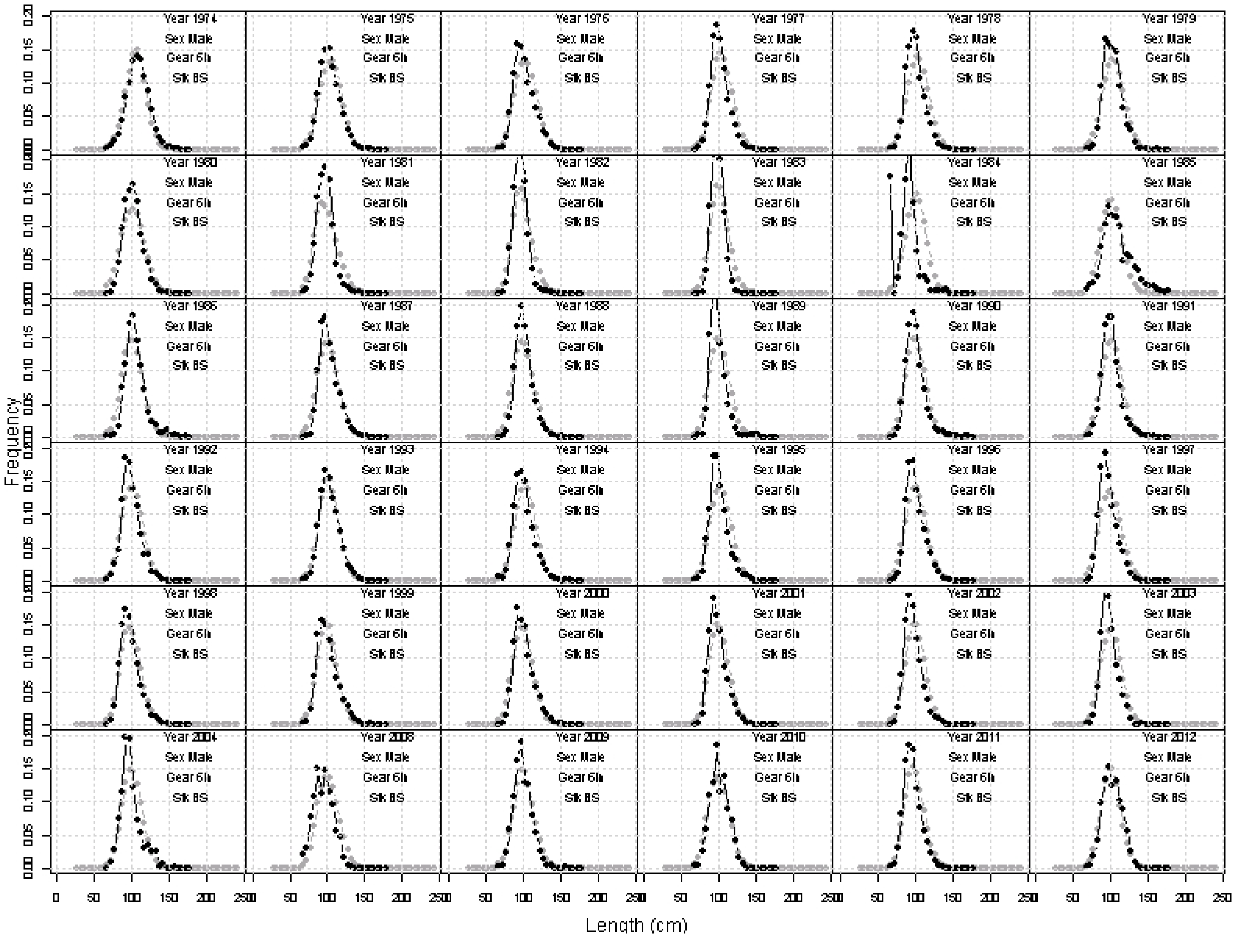
0 50 100 150 200 250
Length (cm)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Year 2010 Sex Male Gear 6h Stk BS
Year 2011 Sex Male Gear 6h Stk BS
Year 2012 Sex Male Gear 6h Stk BS
Frequency
0.00 0.05 0.10 0.15 0.20
0 50 100 150 200 250
Length (cm)

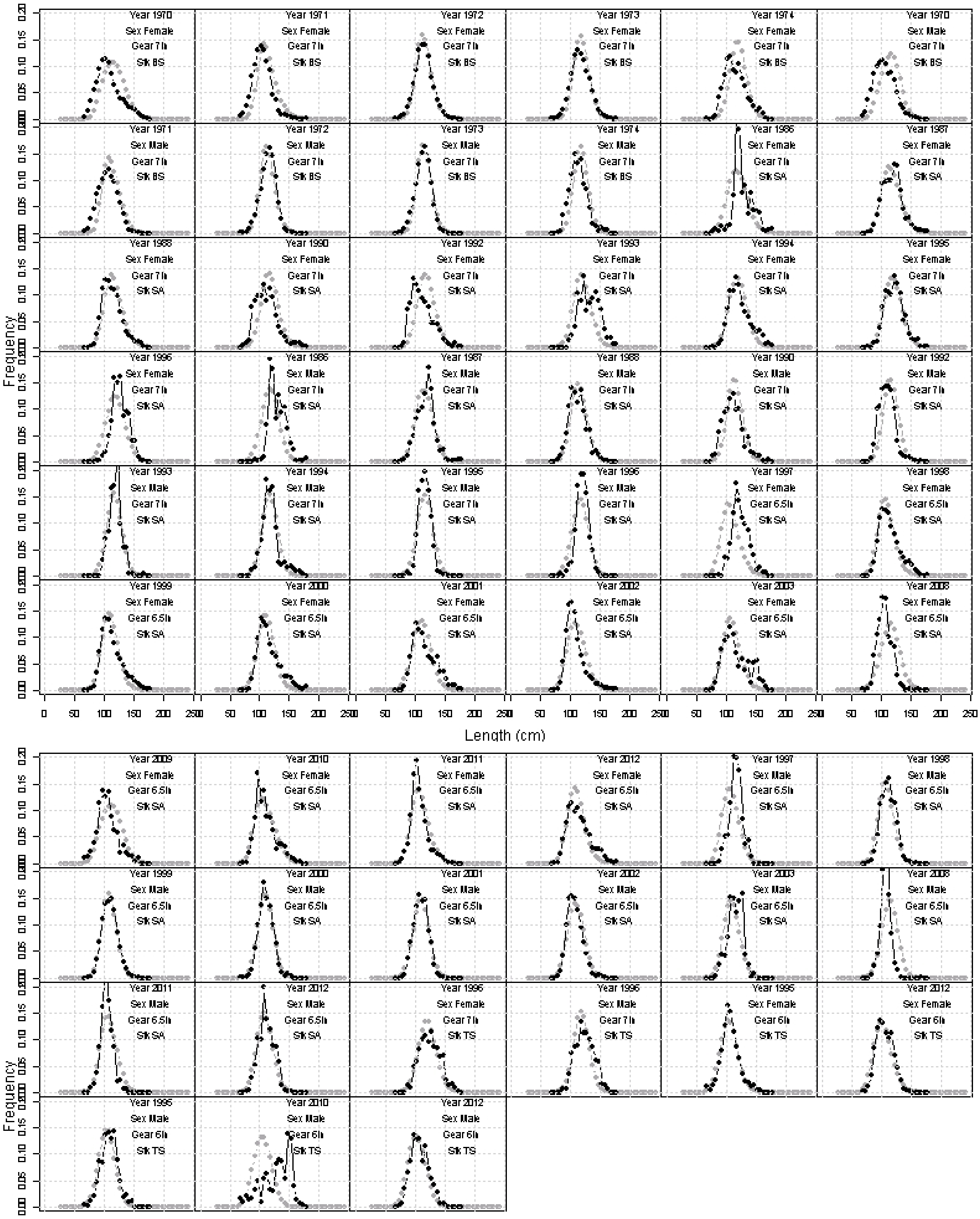

Figure 9. Observed (black) and expected (grey) length frequencies for sensitivity 28 by year, gender, fleet (6, 6.5 and 7 inch mesh) and region (Bass Strait – BS; South Australia – SA and Tasmania –TS).

13.9 Acknowledgments

Thanks go to Mike Fuller for providing the GENLOG data and interpretations and to Neil Klaer for providing Observer Program data. Thanks to Malcolm Haddon for useful discussions and for performing the CPUE standardizations. Andre Punt provided helpful comments on an earlier version of this report.

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13.11 Appendix A: Observer Program length data

13.11.1 *Port lengths*

The Observer Program has collected gummy shark length information at ports from 1998 onwards. Sample sizes are shown for partial (PAR) and total (TOT) length measurements combined (Table A.1).

The monthly spread of samples is good in Eastern Bass Strait (EBS) but tends to be sporadic in other areas, Eastern Tasmania being worst (Figure A.1).

Table A.1. Number of port lengths measured by the Observer Program (PAR or TOT) in each zone: Central South Australia (CSA), Eastern Bass Strait (EBS), Eastern South Australia (ESA), Eastern Tasmania (ET) and Western South Australia (WSA). Sample sizes greater than 400 can be included in the assessment. The female sample size is shown followed by the male sample size (F/M). A blank indicates that no samples were taken

			South Australia			Victoria			Tasmania	
Year	Unk	WA	WSA	CSA	ESA	SAV	WBS	EBS	WT	ET
1998	3887									
1999	5790									
2000	4912									
2001	4542									
2002	2293									
2003	944									
2004	2533									
2005	6161									
2006	415									
2007	1671									
2008	4060			/981			134	741		
2009	50		257/427	287/1957	/539			1572		
2010	2039	206		772/736	823		241	1622		
2011	15						235	2326		
2012	37						96	1224		
2013										

Note: Lakes Entrance was the source of 72% of the useable samples (ie mesh net, measured as TOT or PAR and known shark region). In 2011 and 2012 100% of samples were collected in Lakes Entrance.

The spread across months is reasonably good, apart from the 2008 sample which was entirely collected in December.

13.11.2 . ***Onboard lengths***

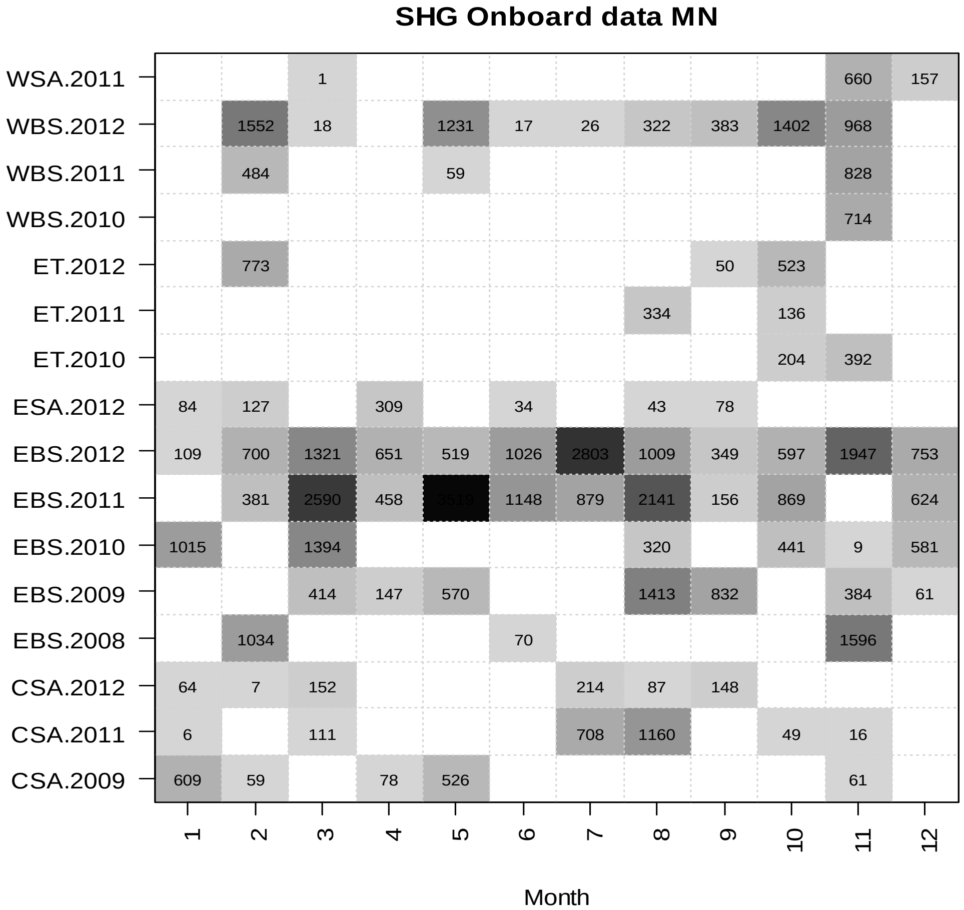
Measurements (PAR or TOT) made by onboard observers are shown in Table A.2, and fork length (LCF) measurements in Table A.3.

Table A.2. Number of onboard lengths (PAR or TOT) measured by the Observer Program in each zone and year. Sample sizes greater than 400 can be included in the assessment. A * indicates that data were included in the 2010 assessment.

			South Australia			Victoria			Tasmania	
Year	Unk	WA	WSA	CSA	ESA	SAV	WBS	EBS	WT	ET
2007				44						
2008				356				2691		
2009	112			566				2543*		
2010	5		234	13	93		714	975		596
2011	7		818	1338	120	8	1367	11782	105	470
2012	77	12	228	660	673	297	5868	11755	282	1280
2013								284		

Table A.3. Number of onboard LCF lengths measured by the Observer Program in each zone and year. Sample sizes greater than 400 can be included in the assessment.

		South Australia				Victoria			Tasmania	
Year	Unk	WA	WSA	CSA	ESA	SAV	WBS	EBS	WT	ET
2007			266				2			
2008			654				8			
2009		345	762				1274			345
2010		203	1303				2784			203
2011			712			4	981			
2012			12	2	1	48	27		66	



	1	2	3	4	5	6	7	8	9	10	11	12
WSA.2011			1								660	157
WBS.2012		1552	18		1231	17	26	322	383	1402	968	
WBS.2011		484			59						828	
WBS.2010											714	
ET.2012		773							50	523		
ET.2011								334		136		
ET.2010										204	392	
ESA.2012	84	127		309		34		43	78			
EBS.2012	109	700	1321	651	519	1026	2803	1009	349	597	1947	753
EBS.2011		381	2590	458	3519	1148	879	2141	156	869		624
EBS.2010	1015		1394					320		441	9	581
EBS.2009			414	147	570			1413	832		384	61
EBS.2008		1034				70					1596	
CSA.2012	64	7	152				214	87	148			
CSA.2011	6		111				708	1160		49	16	
CSA.2009	609	59		78	526						61	

Figure A.1. Monthly spread of samples (sample size shown as numerals an represented by colour density) taken onboard by the Observer Program between 2009 and 2011 in Central South Australia (CSA), Eastern Bass Strait (EBS), Eastern South Australia (ESA), Eastern Tasmania (ET) and Western South Australia (WSA).

13.12 Appendix B: Calculating hook selectivity

13.12.1 *Introduction*

Length frequency data were collected during an autolongline fishing trial conducted in South Australia (Knuckey *et al.* 2013), and during subsequent monitoring of commercial hook fishing (I. Knuckey, Fishwell Consulting; pers comm.). Length frequency data from commercial gillnet fishing is has been routinely collected by the AFMA Observer Program since 2007. These data, along with known gillnet selectivity functions (Kirkwood & Walker, 1986), can be used to calculate the selectivity of the hook fishing gear. Calculations were performed using data for for gummy sharks, resulting in an estimate of hook selectivity for gummy shark.

The Tier 1 stock assessment model for gummy shark assumes that both hook and trawl fishing gear have uniform selectivity for sharks of ages 2 and above (Pribac *et al.* 2005). This relates to an average total length of 76 cm or more. The model uses gear selectivity functions for 6, 6.5, 7 and 8 inch meshes as calculated by Kirkwood & Walker (1986). In addition to the gear selectivity functions, which are fixed (not estimated) the model also estimates an availability function that recognises that sharks become less available to the fishery as they grow older (Pribac *et al.* 2005). This is thought to be due to behaviour of gummy shark. The availability function is applied to all gears included in the model: hook, trawl and gillnets. It is likely that there was little data available on hook fishing when this model was constructed, so that the assumption of uniform selectivity over 76 cm for hook gear, and that the availability function applies to hook fishing, need to be re-examined in the context of new data collected during the recent hook fishing trial and hook fishery monitoring.

13.12.2 *Methods*

We used gummy shark length data, collected by the Observer Program onboard gillnet fishing vessels working in South Australia, to construct a length frequency (Figure B.1, upper left; repeated in Figure B.2, upper left). All gillnet data were pooled as information on monitored gillnet mesh sizes was not available to the authors. Length frequencies were constructed for all shark measured regardless of whether some were discarded, and for only those sharks recorded as having been retained.

Length frequency data for hook fishing were available from an experimental trial, during which investigators directed the skippers of participating commercial fishing vessels to fish in specified locations. The bycatch of school sharks from this trial was much lower than that from subsequent monitoring of hook fishing in which investigators allowed skippers to freely choose fishing locations. The average size of gummy shark from the trial is noticeably greater than that from the Observer Program. This is likely to be the result of the sampling regime conducted during the trial. Given this discrepancy, we did not combine data from these two sources (Figure B.1, upper left; repeated in Figure B.2, upper left). During commercial hook fishery monitoring, three vessels were monitored – one onboard and the other two at port. Discarded fish were therefore measured for only one out of the three vessels.

We estimated the discards of the two vessels that were measured in port by inflating the numbers of discarded sharks measured onboard just one vessel to match the total observed catch for all vessels.

We used the gummy shark gear selectivity functions for gillnets of 6 and 6.5 inch meshes as used in the Tier 1 gummy assessment model (Pribac *et al.* 2005) (Figure B.1, upper right; repeated in Figure B.2, upper right). Because size of the gillnets monitored by the Observer Program is unknown, we calculated a new ‘joint’ gear selectivity from a weighted sum of the selectivities for 6 and 6.5 inch gillnets. During the Observer Program sampling period (2007-2012) 38% of gummy shark landings from South Australia were taken using 6 inch mesh nets, and the remainder using 6.5 inch mesh nets. No other mesh sizes were used in South Australia during that time. The ‘joint’ net selectivity G_l^j for gummy sharks belonging to length class l was calculated as a normalised, weighted sum of the gear selectivities for 6 inch G_l^6 and 6.5 inch $G_l^{6.5}$ gillnets as:

$$G_l^j = \frac{0.38\, G_l^6 (1-0.38)\, G_l^{6.5}}{\sum_l \left[0.38\, G_l^6 (1-0.38)\, G_l^{6.5}\right]} \qquad \text{(A.1).}$$

Because the actual proportion of 6 to 6.5 inch catches in the Observer Program sample is unknown, we repeated our calculations assuming that the whole sample was taken using 6 inch mesh nets, or alternatively 6.5 inch mesh nets.

Given a length frequency from hook fishing, a length frequency from gillnet fishing, and known gillnet gear selectivity, hook selectivity can be calculated. The number of sharks in length class l that are caught during gillnet fishing $\tilde{C}_l^g$ is given by

$$\tilde{C}_l^g = G_l^g A_l N_l q \qquad \text{(A.2)}$$

where G_l^g is the gear selectivity assumed for gillnets (G_l^6 or $G_l^{6.5}$); A_l is the relative availability of sharks in length class l to the fishery; N_l is the number of sharks in length class l in the population and q is a constant representing ‘catchability’.

The calculations that follow use length frequencies C_l^g instead of absolute numbers of fish caught and therefore the constant q can be ignored. Similarly, the relative number of sharks from length class l taken by hook fishing C_l^h can be described by:

$$C_l^h = G_l^h A_l N_l \qquad \text{(A.3a)}$$

if availability applies to hook fishing and by:

$$C_l^h = G_l^h N_l \qquad \text{(A.3b)}$$

if it does not.

Equations B.2 and B.3a can be combined by making N_l the subject of both formulae, and then setting the resulting quantities equal to each other and solving for G_l^h, the hook (gear) selectivity. Hook selectivity is consequently found to be given by:

$$G_l^h = \frac{C_l^h}{C_l^g} G_l^g \tag{A.4a}$$

or by:

$$G_l^h = \frac{C_l^h}{C_l^g} G_l^g A_l , \tag{A.4b}$$

if equation B.3b is used instead of equation B.3a.

Calculations were based on a range of choices for the length frequency from the catch: C_l^g and C_l^h. Because discards were measured on only one of three vessels during commercial hook fishing so that discards for the remaining vessels had to be estimated, we examined the sensitivity of our results to these estimates. This was done by using only retained catch data for both gillnet and hook gears, or using the retained and discarded data (or estimates) for both gillnet and hook gears. Each of the three available selectivity patterns for gillnet gear were used. We allowed availability to apply or not to apply to hook gear (i.e. we used both Equations B.4a and B.4b).

A 50mm length class interval was chosen, which aligns with that used in the stock assessment model and seemed to be supported by the length frequency data.

13.12.3 *Results*

Gillnets select very few fish smaller than 80 cm and larger than 150 cm. Therefore results for those length classes (i.e., at the tails of the selectivity function) were very unreliable and have not been presented.

Selectivity estimates for hook gear are quite irregular (bumpy) reflecting some of the irregularity in the length frequencies, particularly for the commercial hook monitoring. The hook trial data show more sharks less than 110 cm than the commercial hook data, leading to much higher selectivity corresponding to the trial data for the smaller size classes (Figures B.1 and B.2). Results show greater selectivity by hooks compared with gillnets for sharks larger than 130 cm.

When the availability function is applied to both gear types (as it is in the stock assessment model), the discrepancy between the results that use the hook trial data and the commercial data is less severe in the 6.5 gillnet case (lower right plots on Figures B.1 and B.2). This, together with “mixed gillnet” selectivity is likely to be more realistic than the results that assumed 6 inch gillnet selectivity because most gillnet fishing in South Australia does use 6.5 inch gillnets.

13.12.4 *Discussion*

Given the level of variability in the data, the selectivity results cannot be given great credence, however, these results indicate that the assumption used in the stock assessment model, of uniform gear selectivity for sharks greater than 76 cm, cannot be dismissed for sharks of 80-150 cm in length. No results are available from this work for sharks outside that size range.

These results give very little indication of whether or not the assumption that availability applies to hook gear as well as to gillnet gear is reasonable. It is thought that this phenomenon results from shark behaviour, presumably due to larger fish moving into deeper waters than those typically exploited by gillnet operators. At present, hook fishing is occurring in similar depths so it seems reasonable to retain this assumption but continue to monitor the situation.

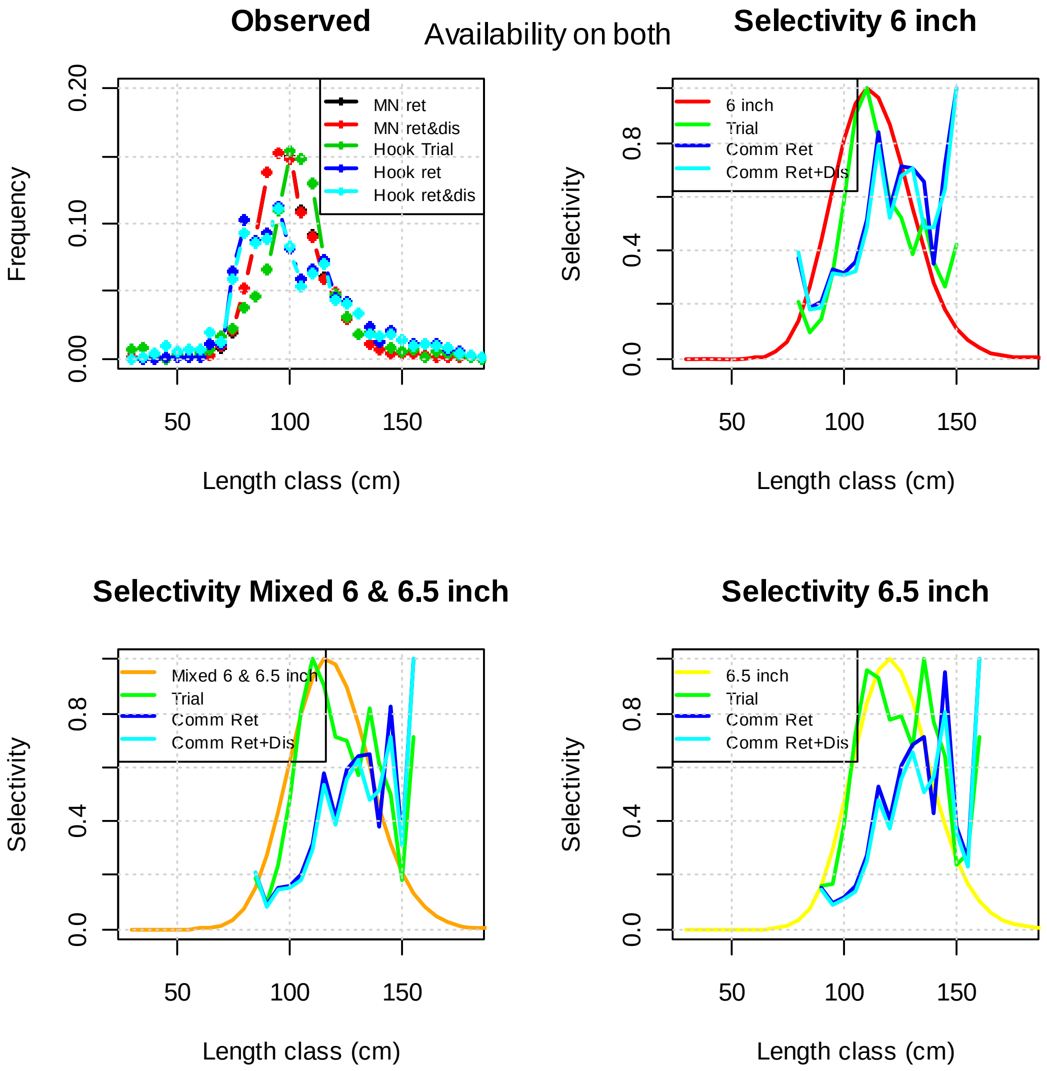


Figure B.1. Availability is applied to gillnets and hooks. *Upper left*: Observed length frequencies for gummy sharks captured during commercial gillnet fishing and measured by the Observer Program for only those sharks retained ‘MN ret’, or for both retained and discarded ‘MN ret & dis’ animals; and shark measured during a hook trial ‘Hook trial’ and those measured during monitoring of commercial hook fishing showing only those retained ‘Hook ret’ or an estimate of the full retained and discarded catch ‘Hook ret & dis”. Gear selectivity for 6 inch (*upper right*), mixed gillnet (*lower left*) or 6.5 inch (lower right) nets along with estimated gear selectivity for hook gear calculated using trial length frequencies ‘Trial’ or those from commercial hook fishing using either only the retained ‘Comm Ret’ or estimated retained and discarded catches ‘Comm Ret + Dis’.

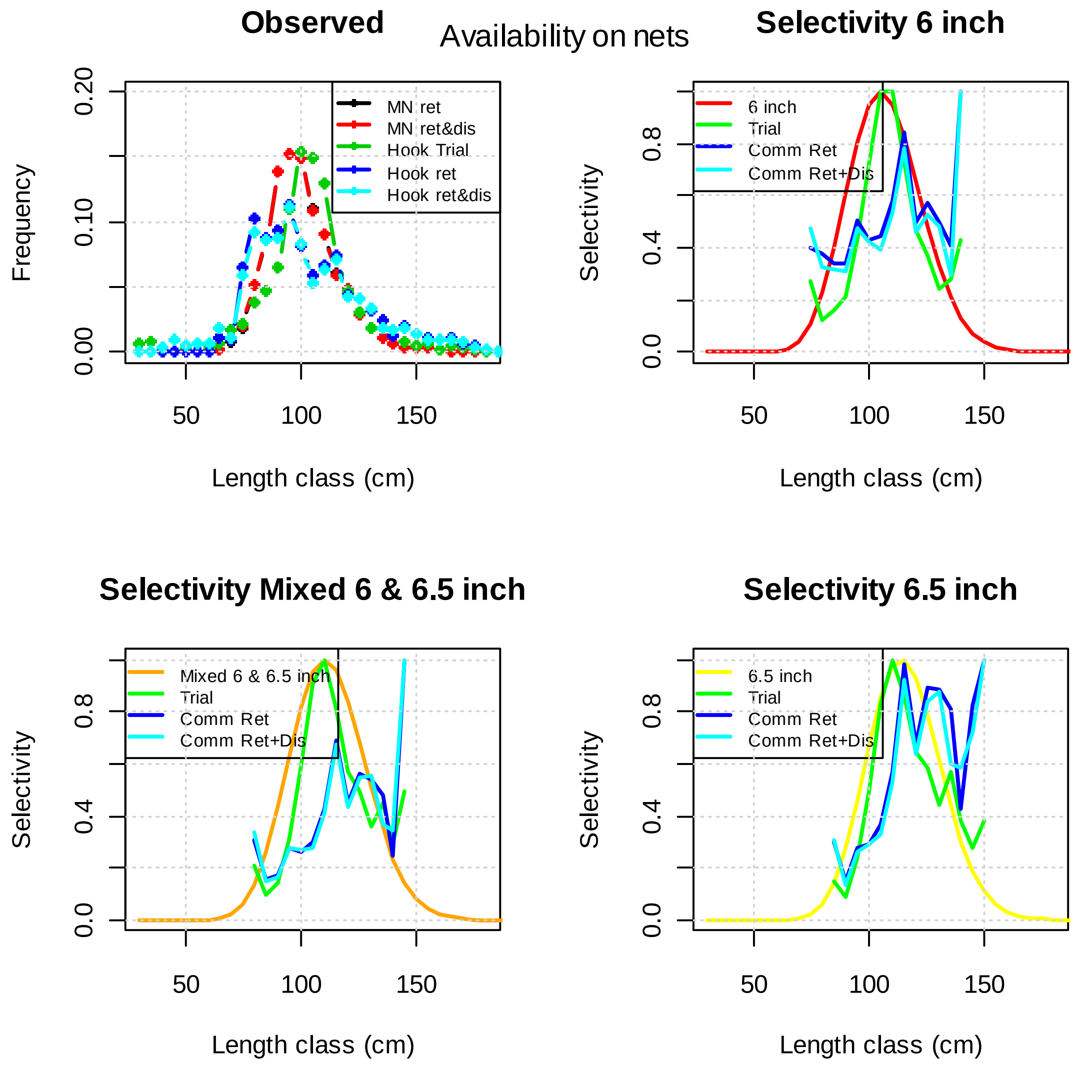


Figure B.2. Availability is applied to nets and not to hooks. *Upper left*: Observed length frequencies for gummy sharks captured during commercial gillnet fishing and measured by the Observer Program for only those sharks retained ‘MN ret’, or for both retained and discarded ‘MN ret & dis’ animals; and shark measured during a hook trial ‘Hook trial’ and those measured during monitoring of commercial hook fishing showing only those retained ‘Hook ret’ or an estimate of the full retained and discarded catch ‘Hook ret & dis”. Gear selectivity for 6 inch (*upper right*), mixed gillnet (*lower left*) or 6.5 inch (lower right) nets along with estimated gear selectivity for hook gear calculated using trial length frequencies ‘Trial’ or those from commercial hook fishing using either only the retained ‘Comm Ret’ or estimated retained and discarded catches ‘Comm Ret + Dis’.

14. Appendix: Project Staff

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