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Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2012

PART
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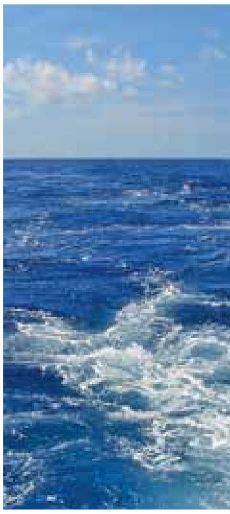

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Cover photographs

Front cover, blue grenadier, ocean perch, flathead and orange roughy.

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 2012.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2012

Part 1: Tier 1 assessments

G.N. Tuck
June 2013
Report 2010/0818

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2012 Part 1

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1. Non-Technical Summary

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2012

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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 2012 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 2012 were examined, to allow RAG judgement of whether as assessment may be warranted. Of the species considered, 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; this species was judged not to have broken out. However, silver warehou only had one CPUE indicator series, and this had unambiguously broken out for the past two years.

Management strategy evaluation testing of between Tier risk equivalence: the discount factor

The output of fishery harvest control rules (HCRs) used to determine management actions, such as setting a catch quota, should include a consideration of the uncertainty regarding resource status. In the SESSF a tier system of HCRs is used in the recommendation of Total Allowable Catches for target species, with the choice of which HCR to apply for a particular species dependent on the quantity and quality of information available. Accounting for increased uncertainty among tier levels in the SESSF is currently achieved by applying a discount factor (alternatively referred to as a risk premium or buffer) to the recommended catch level obtained from the HCRs. However, it is unclear whether the current magnitudes of the discount factor, which are the same for all species at a particular tier level, achieve the necessary precaution in the tier framework, and whether alternative methods might work better.

We used Management Strategy Evaluation (MSE) with three SESSF target species to determine the discount factors needed for two data-poor HCRs to obtain the same level of risk as when managed in a data-rich setting. We also compared the performance of alternative methods of implementing precaution, including: a) adjusting target reference points, b) accounting for assessment uncertainty, and c) the use of stable catch rates as a rationale for not applying a discount factor.

The discount factors required to obtain equivalent risk to the data-rich case varied with species and stock status, and were different from the values currently used by management. The alternative methods tested had similar performance (e.g. with respect to stock biomass levels, catch quota, and quota variability) as applying a discount factor when adjusted to the same level of risk. Using alternative reference points may be more attractive to stakeholders than using explicit discount factors. However, using stability in catch rates as an indicator for when not to apply a discount factor was unsatisfactory, as either the same or higher discount factors were then required to maintain risk at given levels.

The analyses required data-rich stocks on which to make the comparisons among HCRs. Additional uncertainties not addressed in the data-rich assessments, such as a non-linear relationship between exploitable biomass and catch rates, could increase the need for precautionary measures when setting catch quotas for some species.

Additional catch and catch rate analyses

During the Resource Assessment Group process each year, across a wide range of species, questions can be asked that require rapid separate investigation and reporting. Such additional analyses generally involve specific issues or questions relating to individual fisheries or species and they are *ad hoc* as they are unexpected and stem from how the discussions in the RAG develop. Some of these investigations can take a number of days of effort to resolve so to avoid the need to repeat such work these additional information requests are recorded here.

Analyses have been conducted to answer questions with respect to:

1. The effect of opening part of the deep water closure on Tasmania's north west on the catches and catch rates of the deep water shark species.
2. Detailed examination of catches of the four main shark species, Gummy Shark, School shark, elephant fish, and saw sharks, reported in different fisheries and by different methods, with the distribution of those catches schematically mapped for discussion by workshops and Shark RAG;
3. The influence of different mesh sizes on the Royal Red Prawn fishery was examined in detail again and these results were included in the final report.
4. A number of extra Tier 4 analyses were conducted and presented to the RAGs, these included consideration of the effect of discards and of an alternative target for certain non-primary target species. The species included in these analyses were: Inshore Ocean Perch included discards and with targets of 48% and 40% B_0, Offshore Ocean Perch with and without discards and with the two alternative targets. John Dory and Ribaldo were examined with the targets of 40% and 48%B_0, and finally redfish were considered with and without discards. None of the analyses using 40%B_0 as the target were used to produce management advice.

Catch rate standardisations

Catch-per-unit-effort (CPUE) data are 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 standardised 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 due to any of these other factors.

Catch rates, generally as kilograms per hour fished (though sometimes as catch per shot *e.g.* school whiting, or non-trawl methods), were natural log-transformed to normalise the data and stabilise the variance before standardisation. A General Linear Model was used rather than using a Generalised Linear Model with a log-link. This relatively simple analytical approach means that the exact same methods can be applied to all species in a robust manner. The statistical models were variants on the form: LnCE = Year + Vessel + Month + Depth_Category + Zone + Day_night. For some fisheries week_number or gear type was also included. In addition, there were interaction terms which could sometimes be fitted, such as Month:Zone or Month:Depth_Category. 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 stock and to reduce the number of empty categories within the statistical models.

The commercial catch and effort data for 19 scalefish species, distributed across 47 combinations of areas and fisheries, were standardised ready for inclusion in the annual round of stock assessments. These species were 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, offshore and inshore ocean perch, John dory, mirror dory, ribaldo, and ocean jackets.

In addition to the scalefish above, formal catch rate standardizations and other descriptions of the fisheries were produced for gummy sharks, elephant fish, and saw sharks. In the deepwater fishery, standardizations were also produced for smooth oreos, treating inside and outside the Cascade fishery separately, for mixed oreos (a basket species group), and for eastern and western deepwater sharks (again basket species groups). In addition, data for Alfonsino were considered although could not be standardized because there were too many large gaps in the time series.

Catch rate standardisation updates using data to October 2012

In order that the most recent catch rate data might influence the TAC setting procedures, the most up-to-data catch and effort data for each fishery were standardised (data to the end of October 2012) and the ratio of the 2012 and 2011 indices were compared and used as the basis for calculating the TAC multiplier for each fishery.

A total of 24 standardisations were conducted which related to 16 TACs. Of those 16 there were 12 fisheries for which the TAC multiplier was less than one, indicating an implied decrease in allocated TAC; only two of these were less than 0.9 indicating more than an implied 10% reduction; these were blue grenadier and royal red prawn, while the others all exhibited less than a 10% change. Only four fisheries had TAC multipliers greater than one, indicating an implied increase in the TAC, however, none of these implied an increase of greater than 10%. These species were school whiting, jackass morwong, flathead, and offshore ocean perch.

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 SESSF. Yield estimates were made using a yield-per-recruit model with the following inputs: selectivity-at-age, length-at-age, weight-at-age, age-at-maturity, stock-recruitment steepness, 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 age-at-length and length frequency data 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 determine the Recommended Biological Catch (RBC) for next year. An average length procedure has been developed and tested for species with only length data and no age samples. The average length method was applied for discussion and evaluation.

There were no current Tier 3 species without age samples to 2011. While average length results are comparable to age-based catch curves, the performance of Tier 3 using age based catch curves was shown to result in less catch variability. As age data are available, there is currently no need to use the average length procedure for Tier 3 species in the SESSF. Consequently, RBC calculations are only shown here that used the age-based catch curve procedure.

At the SESSFRAG meeting in early 2012 it was agreed to allow the investigation of an M-based threshold to limit the size of the RBC multiplier produced by Tier 3 analyses. In the results presented Fcur has been limited to a lowest possible value of M/10. Alfonsino, John dory and mirror dory all reached this threshold, so have had the RBC limited by this rule. RBC values for alfonsino, John dory mirror dory and redfish were all greater than reference average catches. Western gemfish, blue grenadier, pink ling, blue-eye trevalla and silver trevally were unable to be assessed using catch curves due to probable dome-shaped selectivity or high recruitment variability.

Tier 4 analyses 1986 - 2011

The Tier 4 harvest control rule is the default procedure applied to species for which only limited information is available; specifically no reliable information on either current biomass 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 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 doing so. The default procedure will now be to apply the discount factor unless RAGs advise 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 standardised or simple geometric mean catch rates. This year, only standardised catch rates were used. 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. The Tier 4 harvest control rule formulation essentially uses a ratio of current catch rates with respect to selected limit and target reference points to calculate a scaling factor. This scaling factor is applied to the target catch to generate an RBC.

This year the tier 4 analyses for the shelf and slope species as well as the deep water species were combined into one report, with the results for Tier 4 species and non-Tier4 species being kept in different sections. RBCs were only calculated for species that are assessed using the Tier 4 analysis, these are: Blue Eye, Blue Warehou, Inshore Ocean Perch, Offshore Ocean Perch, Redfish, Royal Red Prawns, and Silver Trevally.

Among the non-deep water scalefish a total of 18 species with 24 separate Tier 4 analyses were conducted, but these included a number of species for which spatial information was available (blue warehou and mirror dory) leading to analyses for east and west; with an alternative Royal Red Prawn analysis relating catch rates from different mesh sizes.

Two fisheries had zero RBCs: blue warehou and redfish.

Among the deep water species the Tier 4 control rule was used to calculate RBCs for the six deepwater fisheries. The target catches were obtained using the total catches reported outside of the closed areas deeper than 700m. Reported catches were relatively low in four fisheries so no change could be recommended to the RBC. For mixed oreos the RBC increased slightly from 120 – 132 t.

It should be noted that even the standardised catch rates may not reflect changes in stock sizes particularly well. Some of the apparent changes in catch rates exhibited by deep water species are so rapid and so large as to be implausible biologically. Such non-linearity between catch rates and stock size imply that any subsequent analyses that depend on the catch rates must remain uncertain. This means that the validity of the Tier 4 analyses for all these deepwater species is questionable.

1.3 Slope and Deepwater Species

Pink ling

An age-length structured population dynamics model was fitted to data for pink ling (*Genypterus blacodes*) separately for the eastern and western areas (stocks) of the SESSF. The data used for the assessment were updated from those on which the 2011 assessment was based to include 2011 data (catches, catch-rates, conditional age-at-length data and length-frequencies) and revisions to historical (pre-2011) data.

The estimated catch of pink ling during 2011 (1,262 t) was greater than the 2010 catch (1,162 t). The TAC for 2011/12 was 1,200 t and that for 2012/13 was 1,000 t (not split east-west).

A model similar to that on which the 2010 assessment was based was used as the base-case model. The current base-case model differs from the 2010 base-case model by allowing for time-varying growth, by the removal of a split in the catch-rate series for the eastern stock in 2000-01, and by allowing for a change in trawl selectivity in 2000-01. The current base-case model also includes data from the Kapala surveys.

Better fits to the data were obtained by not necessarily weighting the onboard and port length-frequencies equally. In addition, model fit diagnostics support time-varying growth (modelled as cohort-specific growth) and time-varying fishery selectivity for the trawl sector. The assessment was not based on splitting the catch-rate series for the eastern stock in 2000-01 owing to a lack of basis to support an approximate 30% decrease in catchability at that time.

An alternative model was considered in addition to the base-case as a next step towards the development of a model to account for lack of spatial homogeneity in population processes within the eastern and western stocks of pink ling. This alternative model treats the zone-based CPUE indices and the age- and length-compositions by zone as coming from different ‘fleets’. The results of this zone-based model are presented throughout this report for comparison with the base-case.

In the base-case model, the eastern stock is assessed to be $0.26B_0$ at the start of 2013 and the western stock to be $0.43B_0$ at this time (under the assumption that the TAC for 2012 of 1,000 t is taken). The Recommended Biological Catches (RBCs) arising from the base-case models are 223 t for the eastern stock and 490 t for the western stock; giving a total RBC of 713 t for the SESSF pink ling stocks. The long term RBC (for the year 2032) is 829 tonnes for the eastern stock and 548 tonnes for the western stock; giving a total long-term RBC of 1,377 t.

Stock status and RBC values are sensitive to data weighting and assumptions regarding pre-specified parameters. The eastern stock is assessed to be $0.22B_0$ at the start of 2013 and the western stock to be $0.34B_0$ at this time (under the assumption that the TAC for 2012 of 1,000t is taken) under the alternative model. The RBCs arising from this model are 6 t for the eastern stock and 247 t for the western stock; giving a total RBC of 253 t for the SESSF pink ling stocks

Silver warehou

A quantitative Tier 1 assessment of silver warehou (*Seriolella punctata*) in the SESSF was conducted using data up to 31 December 2011. The last full quantitative assessment was presented in 2009. The 2012 assessment updates all data inputs (catch, discard, length, ageing error, age and catch rate data) and is performed using the stock assessment package Stock Synthesis (SS-V3.24f).

Results show reasonably good fits to the catch rate data. However, when comparing the observed and expected catch rate data points for the last 2 years in the series, the model may be overly optimistic and the stock could break out again (requiring a further Tier 1 update if it is placed on a multi-year TAC) in a relatively short time period. Additional data will help identify if the initial signs of a possible strong recruitment are confirmed or not.

The increase in spawning biomass in the late 1980s is supported by the CPUE data and the age and length data and does not appear to be an artefact of the increase in CPUE when this fishery was initially exploited. While continued declines in catches and catch rates indicated some concern for this species, results suggest that it is still very close to the target biomass.

The primary base-case assessment estimates that the projected 2013 spawning stock biomass will be 46.6% of virgin stock biomass. The RBC from the base-case model for 2013 is 2,544t for the 20:35:48 harvest control rule, with a long-term yield of 2,618t. In comparison, the last assessment estimated the 2010 and 2013 depletions to both be 48%, with corresponding RBCs of 2,660t and 2,644t, with a long-term yield of 2,664t.

If recent recruitments (2008-2011), which are not currently estimated by the model, are assumed to be poor and at similar levels to recruitment during the period 2002-2005, then depletion in 2013 could fall below 40%. Under this scenario, setting a multi-year TAC could result in depletion levels falling below 30% by 2015. In contrast, if recruitment is average (which is what is assumed in most projections of stock dynamics), and if catches continue to fall below the TAC, then depletion should be above the target level by 2015.

1.4 Shelf Species

Jackass morwong

In 2012, the Shelf RAG agreed to not conduct a full jackass morwong (*Nemadactylus macropterus*) stock assessment. To calculate the 2013 RBC, the 2011 assessments for both eastern and western morwong have been projected for one more year, using actual catches from 2011, and estimated catches for 2012. 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.

The 2011 catches for each fleet 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 2011, and state catches were added. The estimated catch in 2012 was the amount of the 2012 calendar year actual Total Allowable Catch (TAC) that is expected to be caught, based on the proportion of TAC caught in 2011. The TACs are for a fishing year starting on 1 May, whereas the model uses calendar year catches. Thus the 2012 calendar year TAC is calculated as one-third of the 2011/2012 TAC plus two-thirds of the 2012/13 TAC. To arrive at the amount expected to be caught in 2012 this is then multiplied by the proportion of the calendar year TAC caught in 2011. This catch is then divided amongst fleets in the same proportions by fleet as caught in 2011.

Current spawning biomass in the eastern stock is projected to be 37.7% of 1988 spawning stock biomass, and the 2013 RBC under the 20:35:48 harvest control rule is 380 t. For the western stock, current spawning biomass is projected to be 66% of unexploited stock biomass, and the 2013 RBC is 275 t.

In recent years the catch in the east has exceeded the eastern RBC, although the total catch has been within the TAC as the addition of the western stock increases the combined RBC. The 2013 combined RBC is 655 t. The RBC for the east, at 380 t, is comparable to recent catches in the east.

1.5 Shark Species

School Shark

The current version of the school shark (*Galeorhinus galeus*) model predicts that catches of up to 250t allow recovery of the stock, but that 275t will not. Rebuilding to the limit reference point (B_{20}) cannot be achieved in a generation time plus time 10 years (32 years) given current levels of catch (176t). Rebuilding in three generation times (66 years) can be achieved with future catches of up to 225t. If the limit reference point is moved from B_{20} to half B_{MSY} (i.e. B_{25}), then rebuilding within 32 years would require catches of close to zero; future catches would need to be of the order of 200t in order to achieve rebuilding in 66 years.

Recovery times are only slightly lengthened by higher levels of auto-line fishing in South Australia (SA), however, this lowers B_{MSY} so the impact of an auto-line fishery would be felt when the school shark stock has recovered to levels where the overall catch can be increased to levels closer to B_{MSY}. If the auto-line fishery in SA is allowed to take a substantial portion of the catches in that state, the overall maximum sustainable catch for school shark will be lower than it would be if the auto-line fishery remained small relative to the gillnet fishery.

The results are valid for a fishery whose seasonality and regional distribution are similar to that of the 2011 school shark fishery. Substantial (or perhaps even subtle) deviations from this pattern could alter these findings by altering the size and sex composition of the commercial school shark catch.

Standardised catch rates for gummy shark

Catch rates for gummy shark (*Mustelus antarcticus*) were standardised for the three zones South Australian (1984 – 2011), Bass Strait (1976 – 2011), and Tasmania (1990 – 2011). To account for the occurrence of zero catches, the standardisations used a Delta method. This entails estimating the probabilities of obtaining a positive catch as a function of various factors, and combining these with the yearly indices from a log-linear statistical model that standardises those catch rates coming from shots with positive catches. Data selection for gummy sharks has previously been relatively complex. In these current analyses, data selection for all areas included the years chosen by the RAG, only effort by mesh nets of 6.0”, 6.5”, and 7.0” mesh were included, all records where total net length was < 1000m were removed, and all records with depths > 240m were removed. In addition, the base case analysis for each zone required each statistical reporting area included to have a total reported catch across the selected years of > 10t, and vessels were only included if their average annual catch was >2 t and they reported catches in the fishery in three or more years.

Reported catches of gummy sharks has 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 is real and is related to parallel declines in catches from South Australia and Bass Strait. Catches from South Australia decreased further in 2011 but recovered slightly in Bass Strait. These changes appear related to the introduction of gillnet fishery closures to protect Australian sea lions and dolphins in South Australian waters. At the same time the proportion of catches taken by gillnets declined over the period 2001 – 2011.

Standardized catch rates of gummy shark 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 slightly below the long term average, which again is thought to be related to the influence of the marine closures in South Australia.

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.

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.

Standardised catch rates for sawshark and elephant fish

Catch rates for sawshark (*Pristiophorus* sp.) were standardised for the years 1980 – 1991 and 1998 – 2011, while those for elephant fish (*Callorhinchus milii*) were standardised for the years 1980 – 2011. Both were treated as fisheries across their full ranges but, in addition, in an attempt to focus on the approximate details of the geographical range of the two species of sawsharks, these were also briefly considered as two populations split across eastern and western Bass Strait. To account for the occurrence of zero catches, the standardisations used a Delta method whereby the probability of obtaining a positive catch was estimated using a Generalised Linear Model with a binomial error structure (to describe the presence or absence of catches). This probability was combined with the yearly indices from a log-linear statistical model that standardises those catch rates coming from positive catches. Data selection for saw sharks was restricted to the years used (1980 – 1991 and 1998 – 2010), those statistical areas from which, across the 25 years, >10 t of sawshark were reported, those vessels that had an average annual catch >0.25 t, and from depths < 160 m. For elephant fish, data selection was a minimum catch by statistical area of 4 t, a minimum annual catch per vessel of 0.25 t, and depths < 200 m. For both species only the records pertaining to 6” mesh gear were used. The depth threshold for elephant fish (family *Callorhinchidae*) is designed to exclude catches of ghost sharks (family *Chimaeridae*), which are included in the quota allocation for elephant fish; when trunked these can be difficult to separate.

For sawsharks, taking into account the approximate 95% confidence intervals around the mean estimates for each year, the combined standardised catch rates were approximately flat from 1981 – 2011, although 1980 differed significantly from this and 1988 – 1990 appeared to be below the average while 1998 – 2000 appear to be above the long term average. The 2010 and 2011 values appear to be below the scaled average of 1.0. A declining trend to 2010 appears to have begun in 2008 but catch rates in 2011 were the same as in 2010. The combined standardization was robust to different data selection criteria and to splitting the data into eastern and western fisheries. The relatively flat combined catch rate arose because a declining catch rate for positive catches was counter-acted by an increase in the probability of obtaining a positive catch. The drop in 2010 resulted from a recent decline in the relative probability of a positive catch combined with a continuation of the decline in the catch rate of positive catches. Vessels accounted for most variation in the catch rates followed by year, area, and depth category. The Area x Month interaction term accounted for more than twice the variation accounted by Month indicating that seasonal patterns are expressed more by where fishing occurs than by when fishing occurs.

Trawl caught sawsharks exhibited a similar pattern of standardised catch rates to those seen in the GHT for the positive catches. The seasonality of sawshark availability is clearly apparent in the monthly catch rates.

For elephant fish, the standardised catch rates were more variable than those for sawsharks and there was a significant decline between 1984 and 1991. However, catch rates could not be distinguished from the average across the time series from 1992 – 2006. A significant rise from 2007 – 2009 has been reversed and the value for 2010 and 2011 have declined and are not significantly different from the mean of the complete time series. This recent decline is a result of a small decrease in the standardized catch rates for positive catches combined with a decrease in the relative probability of a positive shot. Most of the variation accounted for in the log-linear modelling was driven by Vessel followed by year. Area, month, and depth category were all minor contributors, although, like saw-sharks, the Area x Month interaction was important, suggesting that location of fishing changes with the season which emphasizes that spatial details in this fishery are as important as in the other shark fisheries.

Sawshark and elephant fish Tier 4 analyses

The stock assessments that feed into the management control rules that reflect the harvest strategy adopted in the SESSF are arranged in a tiered system ranging from fully quantified modelled stock assessments (Tier 1) down to empirical rules based only on catch and catch rates (Tier 4). For those species where biological and fisheries data are limited an examination of trends in catch rates is used to modify allowable catches with the objective of managing the particular fishery towards a target that represents a desirable state for the fishery that also acts as a proxy for the general Harvest Strategy Policy target of 48% B_0.

The Tier 4 control rule is used to calculate Recommended Biological Catches (RBCs) for sawsharks and elephant fish. Standardized catch rates for both species were used along with total catches of the respective species in a standard analysis. This year's analysis varied from previous analyses by comparing the outcome of treating the catch rate target as a proxy for 48% B_0 versus with a proxy for 40%B_0 as an alternative target for these non-target species. For sawsharks 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 sawsharks in 2011 barely differed from that in 2010 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 64% of the target catch. 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 sawsharks are standardized a different trend is apparent; the catches by trawl are almost at the same level as that taken by gill net.

The decline in catch rates in elephant fish seen in 2010 continued in 2011 and this implies a decrease in the RBC. However, these values relate to the target catch rate being a proxy for 48% of unfished biomass. Neither sawsharks or elephant fish are targeted in the fishery (when using any method) and so the analyses were repeated, except using a proxy target of 40% B_0 which, given the control rule, will always increase the RBC if it is above zero.

Incidental bycatch of shark when using longline and gillnet

The relative incidental bycatch ratios of school shark (*Galeorhinus galeus*) and gummy shark (*Mustelus antarcticus*) off South Australia were compared using automatic longlines and gillnets. Data on catches of school and gummy sharks collected during scientific fishing trials using automatic longlines across South Australia were compared with reported catches using gillnets during the same period and broad area from the Commonwealth logbook database. A variety of methods were used for averaging and calculating the ratio of school shark to gummy shark, including or excluding zero catches and discards. Overall, these results provide strong evidence in favour of the conclusion that the bycatch of school shark is not greater when using automatic longlines as compared with gillnets. However, sample sizes from the automatic longline trials are relatively small, seasonal coverage is lacking (being confined to just summer months) and deliberate avoidance of school shark during the trial may have been greater than that practiced by gillnet fishers not participating in the trial.

1.6 GAB Species

Deepwater Flathead

An update of the 2010 assessment of deepwater flathead (*Neoplatycephalus conatus*) was conducted, providing 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 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.

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. In addition to these five key species, quantitative assessments for several additional species were also conducted each year. Species for which such assessments have been conducted recently include school whiting, pink ling and spotted warehou. 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 Shark RAG is responsible for assessments of all chondrichthyan species, and the GAB RAG for those species in the Great Australian Bight.

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. Pink ling (*Genypterus blacodes*) stock assessment based on data up to 2011[1]

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5.1 Summary

An age-length 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 2011 assessment was based to include 2011 data (catches, catch-rates, conditional age-at-length data and length-frequencies) and revisions to historical (pre-2011) data.

The estimated catch of pink ling during 2011 (1,262 t) was greater than the 2010 catch (1,162 t). The TAC for 2011/12 was 1,200 t and that for 2012/13 was 1,000 t (not split east-west).

A model similar to that on which the 2010 assessment was based was used as the base-case model. The current base-case model differs from the 2010 base-case model by allowing for time-varying growth, by the removal of a split in the catch-rate series for the eastern stock in 2000-01, and by allowing for a change in trawl selectivity in 2000-01. The current base-case model also includes data from the Kapala surveys.

Better fits to the data were obtained by not necessarily weighting the onboard and port length-frequencies equally. In addition, model fit diagnostics support time-varying growth (modelled as cohort-specific growth) and time-varying fishery selectivity for the trawl sector. The assessment was not based on splitting the catch-rate series for the eastern stock in 2000-01 owing to a lack of basis to support an approximate 30% decrease in catchability at that time.

An alternative model was considered in addition to the base-case as a step towards the development of a model to account for lack of spatial homogeneity in population processes within the eastern and western stocks of pink ling. This alternative model treats the zone-based CPUE indices and the age- and length-compositions by zone as coming from different 'fleets'. The results of this zone-based model are presented throughout this report for comparison with the base-case.

Likelihood profiles for natural mortality (*M*) indicate that estimates of *M* are well-informed by the data, with age data being the primary source of information on *M*. Data for the eastern stock are very uninformative about steepness of the stock recruitment curve (*h*), and there is essentially no information about steepness in the data for the

[1] Paper presented to the Slope RAG November 2012.

western stock. This validates the decision not to estimate steepness in any of the assessment model configurations in this report. Likelihood profiles for recruitment at pre-exploitation equilibrium (R_0) indicate that R_0 is estimated with adequate precision for the eastern stock, and estimated precisely for the western stock. As such, the related estimates of long term yield are also at least adequate.

In the base-case model, the eastern stock is assessed to be $0.26B_0$ at the start of 2013 and the western stock to be $0.43B_0$ at this time (under the assumption that the TAC for 2012 of 1,000 t is taken). The Recommended Biological Catches (RBCs) arising from the base-case models are 223 t for the eastern stock and 490 t for the western stock; giving a total RBC of 713 t for the SESSF pink ling stocks. The long term RBC (for the year 2032) is 829 tonnes for the eastern stock and 548 tonnes for the western stock; giving a total long-term RBC of 1,377 t.

Stock status and RBC values are sensitive to data weighting and assumptions regarding pre-specified parameters. The eastern stock is assessed to be $0.22B_0$ at the start of 2013 and the western stock to be $0.34B_0$ at this time (under the assumption that the TAC for 2012 of 1,000t is taken) under the alternative model. The RBCs arising from this model are 6 t for the eastern stock and 247 t for the western stock; giving a total RBC of 253 t for the SESSF pink ling stocks.

5.2 Introduction

Pink ling (*Genypterus blacodes*) forms the basis for major fisheries off Australia and New Zealand, *Genypterus capensis* is exploited off the west and south coasts of South Africa, and *Genypterus chilensis* is exploited off South America. 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 147˚E (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 conducted for several “management stocks” of pink ling in New Zealand (Anon, 2010).

Pink ling has been assessed several times in the past. The first assessment (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) 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 (Punt, 2012; Punt and Taylor, 2012), but this assessment was not accepted for use in management.

The total catch during 2011 was 1,262 t of which 1,219 t counted against the 2011 TAC of 1,200 t. The total catch during 2011 was the fifth highest during the 10-year period 2002-11, and was 52% of the peak catch of pink ling which occurred during 1997. By sector, the 2011 catch by the trawl sector was the highest since 2004, and 43% of the peak catch. By contrast, the catch by the non-trawl sector during 2011 was 48% of the peak catch by this sector and the 2nd highest catch by this sector since 2008 (see Figure 5.2 and Section 5.3 for additional details).

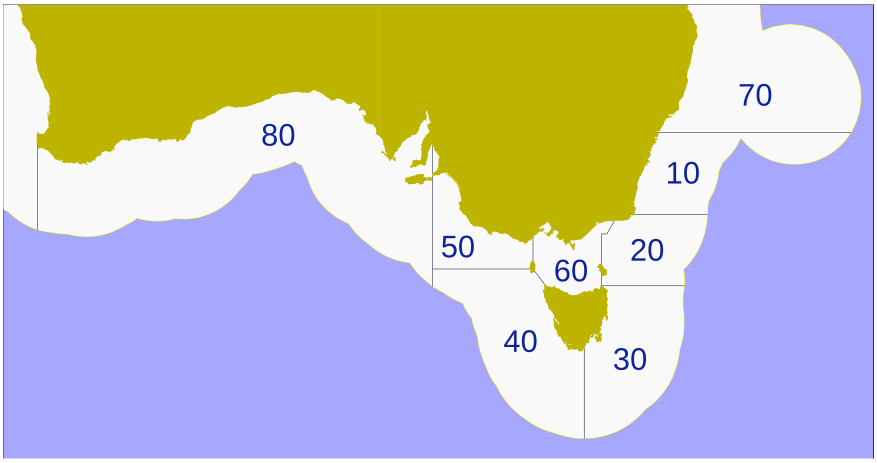

Figure 5.1. Map of the SESSF showing statistical zones used in stock assessments.

5.3 Data sources

5.3.1 Catch data

Catches of pink ling have been recorded since the 1970s when the South East Fishery began to move to waters of 200 m 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) and the catches allocated to each of five Zones (10, 20, 30 = East; 40, 50 = West).

5.3.2 State Catches

State catches are available for Victoria, Tasmania and New South Wales (Table 5.1). These catches are allocated to Zone as follows: East Victoria – Zone 20; West Victoria – Zone 50; East Tasmania – Zone 30; West Tasmania – Zone 40; New South Wales – Zone 10. More accurate assignments to Zone are likely to be possible following an additional data review. However, given the magnitude of the catches and when they were taken, this is unlikely to have a substantial impact on the outcomes of the assessment.

5.3.3 *Commonwealth Catches*

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. The logbook catches by Zone were raised to landings, discards added and allocated to Zone as follows:

- For years with validated landings, the catches by Zone are the total logbook catches scaled to the validated landings and pro-rated to Zone based on the logbook data. The scaling to validated catches include catches for the non-trawl sector and in Zones 10-60 for the trawl sector.
- For years without validated landings, the logbook catches are scaled by the ratio of the sum of the validated catches to the sum of the logbook catches for the first five years for which validated landings data are available (1997-2001 for the non-trawl sector – 1.161; 1998-2002 for the trawl sector in Zones 10-60 – 1.245, and 2001-2005 for the trawl sector in the GAB – 0.996). The scaled catches are then pro-rated to Zone based on the logbook catches.
- The catches in Zones 10-30 are obtained by pro-rating the total catch for the east area to Zone using the catches for Zones 10-30 (any catches reported outside of Zones 10-30; e.g. Zone 60) are ignored when pro-rating the total catches to Zones 10-30 (the total catch allocated to Zones 10-30 is still, however, the actual total catch for the east area).
- The catches in Zones 40-50 are obtained by pro-rating the total catch for Zones 40-50 to Zone using the catches for Zones 40-50. The catches in the GAB are assumed to have been taken in (an extended) Zone 50 [as recommended by the 31 July 2012 Pink Ling Workshop].
- The annual estimates of discard (Table 5.2; Neil Klaer, pers. com.) are allocated to sector (trawl / non-trawl) and Zone (10, 20, 30, 40, 50) in proportion to the landings by sector * Zone. Given the magnitude of the estimated discard, this simple approach to allocation is unlikely to be consequential for the assessment outcomes.

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.

5.3.4 *Overall catch Summary*

Table 5.3 lists the catches by Zone (10, 20, 30, 40, 50), stock (east, west) and sector (trawl, non-trawl). Figure 5.2 shows the annual catches by Zone and sector while Figure 5.3 compares the catch time-series on which the present assessment is based and that on which the 2011 assessment (Punt, 2012) was based. The differences in catches are minor for the trawl sector, but there are notable differences in non-trawl catches from

1995 to 2005. The changes from the 2011 match differences in catches from the 2011 assessment and that in Taylor (2011a,b).

5.4 Catch-rate data

5.4.1 *Trawl Sector*

Figure 5.4 (and Table 5.4) list standardized catch-rate indices which involve Zone*year interactions as well as standardized indices by Zone. The trends by Zone are broadly similar to those for the whole stock. However, there is variability among Zones for some years (e.g. in the early years for the east stock).

The lack of consistency in standardized catch-rates among Zones for some years is suggestive that either each Zone contains a different population with slightly different demographics or that the GLM standardization method is not fully capturing all factors influencing catch-rates (other than abundance). As a first approximation to handle this and as in Punt and Taylor (2012), each data point is not equally weighted, but rather the annual between-Zone variance in standardized catch-rates (after the series for each Zone is normalized to 1) is computed and smoothed based on the fit of a Generalized Additive Model with a spline in year. The predicted variances (Figure 5.5) are then rescaled so that the overall weight assigned to each catch-rate series is 0.1 (Table 5.4).

5.4.2 *Non-Trawl Sector*

The approach used to standardize the non-trawl catch rates follows that of Punt and Taylor (2012). Specifically, vessels are selected (2 years in the fishery, average annual catches of 5 tonnes) for the east and west, and data for years before 2002 (west) and 2003 (east), for closed areas (Horseshoe, Maria Island, Ling hole) and in waters shallower than 400m or deeper than 650m are excluded. The remaining records (3,369 for the present assessment) are analysed by fitting a linear model to log-catch-rates (kg / hook) with covariates callsign, block*year, region*month, region*depth category, and region*Blue-eye targeting. Region is defined as west/east, the blocks are half-degree blocks to the east and west of Tasmania, depth is a categorical variable based on 50m depth increments, and Blue-eye is a categorical variable with value 1 if the catch of blue-eye is larger than that of ling.
There are many empty cells / cells with small sample size (

Table 5.5). Missing values, and values where the number of records was 3 or less are filled in by fitting a linear model to the block*year factors from the analysis of the catch-effort data (with each factor weighted by the inverse of its variance) and using the predicted block*year factors in the calculation of standardized catch rates. The “horseshoe” block is larger than the remaining blocks so the catch-rate data for this block are upweighted by 3 (roughly the area of the horseshoe block relative to the other blocks) when combining catch-rates over blocks to construct a final catch-rate index. Separate indices were calculated for each Zone based on allocating blocks to Zone (the boundary between Zones 20 and 30 splits the block between 40.50S and 410S in the east so the area for this block is assumed to be half of that for the remaining blocks, and the block included when calculating a catch-rate index for both Zones 20 and 30).

The trends in catch-rates (Table 5.4, Figure 5.6) are nearly identical to those from the 2011 assessment. The trends in standardized catch-rate are very similar between Zones

20 and 30, and Zones 40 and 50 so the assessment is only based on the total catch-rate (assumed to pertain to Zones 30 and 40 respectively).

5.4.3 *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. Year-Zone combinations for which the sample size was not at least 100 were ignored when fitting the model. The length-frequency data for the Kapala surveys for 1977 and 1980 were also included in the assessment.

The ageing data are used to estimate an ageing-error matrix (Appendix A of Punt and Taylor, 2012). The age data were assembled into conditional age-at-length matrices and allocated to Zones. Year-Zone combinations for which the sample size was not at least 50 were ignored when fitting the model. Table 5.6 and Table 5.7 list the number of animals sampled for length and age by Zone over the years included in the base-case assessment.

This assessment (but not the 2011 assessment) includes age-composition data for fish that were not sexed. This decision was made because detailed investigation of the age data revealed that most of the fish that were aged during 2008-10 were not sexed which meant that these data (which potentially inform recruitment strength) would be omitted from the assessment if only sexed animals are included in the assessment.

5.5 Analytical assessment

The stock assessment is based on Stock Synthesis version 3.24f. Initial results (not shown here) confirmed that had this version of Stock Synthesis been used for the 2011 assessment, the results would have been identical.

5.6 Basic structure

The basic structure of the assessment follows that of the 2010 and 2011 assessments (Taylor 2011a, 2011b, Punt 2012, Punt and Taylor, 2012). There are consequently two base-case models (one each for the eastern and western stocks) and two alternative models for comparison:

- Base-case East – aggregated over Zone (5 fleets: trawl and non-trawl fleets for each of onboard and port sampling, and Kapala)
- Base-case West – aggregated over Zone (4 fleets: trawl and non-trawl fleets for each of onboard and port sampling).
- Zone-based East – disaggregated by Zone (13 fleets: trawl and non-trawl fleets in each of Zones 10, 20, and 30 for each of onboard and port sampling, and Kapala)
- Zone-based West – disaggregated by Zone (8 fleets: trawl and non-trawl fleets in each of Zones 40 and 50 for each of onboard and port sampling)

The catches in the GAB are included in those for the western area, but no other data for the GAB (catch-rate series, length-composition data, conditional age-length data) are included in the assessment for consistency with past assessments. In common with the 2011 assessment, and as recommended by the July 2012 workshop, the preliminary base-case models do not split the catch-rate series in 2000-01 (Appendix A).

As noted, above, the base-case and Zone-based models are based on a variety of assumptions; however, the two models differ in terms of assumptions regarding population structure and hence how the data relate to the underlying population:

(1) Zone-based model: the differences in trends in catch-rate and age-/length-composition among Zones can be attributable to differences in selectivity / availability among Zones within each stock.
(2) Base-case model: there are either no differences in trends in catch-rate and age-/length-composition among Zones or the relative number of records among Zones reflects the relative abundance of ling.
(3) Both models: the animals are assumed to be fully mixed within each Zone

5.7 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. The growth curve and the variation in length-at-age were specified based on fits to length-at-age data in some previous assessments (e.g. Thomson et al., 2001). However, this and most other previous assessments of pink ling have treated the parameters of the growth curve as estimable; separate growth curves are estimated for males and females because females are known to grow significantly faster and to a larger size than males. Allowance is made for time-varying growth (by addition of estimated cohort-specific growth deviation parameters for some cohorts; see Appendix B). 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 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).

5.8 Fishery parameters

In common with the 2011 assessment, 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 2001 and 2006 (Table 5.8).

5.9 Model selection

Table 5.8 lists the specifications for the base-case and zone-based models. The model configuration is similar, but not identical, for the western and eastern areas (in particular the years for which recruitment deviations are estimated differ owing to the range of years for which age- and size-composition data are available; Appendix B). The model configurations related to when selectivity changes are identical to those for the 2011 assessment while the years for which recruitment deviations are estimated were selected separately for each model. Appendix C summaries the data used in the assessment. The catch-rate series for Zone 10 was omitted from the east-zone model because the model was unable to replicate it and because very little catch now comes from this Zone.

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 (an average CV of 0.1) on the abundance indices, modifying the years for which recruitment and growth deviations are estimated, modifying the effective sample sizes for the age- and length data (generally using the approach of McAllister and Ianelli (1997)), and only once a base-case model is selected, adjusting (increasing) the CVs for the catch-rate data.

5.10 Base-case model

Figure 5.7 shows the fits of the base-case and zone-based models to the length-frequency data (see Figure 5.9 for the fits by year). Two sets of results (A=Onboard; B=Port) are shown for each fleet. With the possible exception of the fit to the Kapala length-frequency data for the east-zone model (Figure 5.7c), the fits are adequate (in particular the summed effective sample sizes are close to the summed input sample sizes). Table 5.9 andTable 5.10 list the amount by which the input sample sizes for the length-frequency and conditional age-at-length data are adjusted downwards so that the residual and input variances match, while Table 5.11 lists the amount by which the CVs for the abundance indices are increased.

Figure 5.8 shows the fits of the base-case and zone-based models to catch-rate series. As expected, the model fits intersect all but a very few of the 95% confidence intervals for the data, indicating that the adjustments to the CVs for the indices performed as expected. The base-case model generally captures the trends in standardized catch-rates.

The fits of the Zone-based model to the trawl catch-rate series for Zones 20 and 30 (Figure 5.8a) exhibit noticeable trends in the residuals for the early years, with the ultimate fit a balance between the trends in catch-rate by Zone. The Zone-based model is unable to mimic the increase in trawl catch-rate in Zone 40 since 2006, partially because a large increase in standardized catch-rate is not evident for Zone 50 nor for the non-trawl fleet (Figure 5.8d). The fit to the trawl catch-rate series for the east-base model (Figure 5.8a) is adequate, but the model is unable to mimic the increase in catch-rate evident for the west area in the west-base model (Figure 5.8b).

There are a considerable number of conditional age-at-length frequencies and the summary plots are profuse. 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 5.10 summarizes selectivity-at-length for the base-case and Zone-based models. Selectivity for the non-trawl fleets is assumed to be time-invariant whereas selectivity for the trawl fleet is assumed to change in 2001 and 2006 (that for Zone 30 only changes in 2001). The patterns of selectivity are similar, but not identical, among Zones within area. The change in selection away from smaller fish in 2001 and 2006 is quite noticeable. Figure 5.11 shows how the growth curves change over time for the four models. The “ridges” in Figure 5.11 reflect the impact of cohorts growing faster or slower than average.

Figure 5.12 shows estimated recruitment time series for each of the four models. The time-trajectories of recruitment are very similar for the two west models, but there are differences between the base-case and Zone-based models for the east area as late as the mid-1990s. Figure 5.13 shows the time-trajectories of spawning biomass and depletion for the four models. The time-trajectories of spawning biomass for the western stock are qualitatively and quantitatively very similar between the base-case and Zone-based models. In contrast, the base-case model for the eastern stock suggests a slight increase in biomass in the last part of the 1970s which is not inferred by the Zone-based model. The difference in trajectories of spawning biomass between the base-case and Zone-based models is not surprising given the differences in recruitment time-series.

5.11 Stock projections

An estimate of the catch for the 2012 calendar year is required to apply the SESSF Tier 1 Harvest Control Rule, and run the base-case model forward to estimate the 2013 spawning biomass and depletion (Figure 5.13 and Figure 5.14). Stock projections are made under the assumption that the full TAC for 2012 of 1,000t is taken, and that catches are split between eastern and western stocks and among fleets in the same manner as was reported for 2011.

In the base-case model, the eastern stock is assessed to be $0.26B_0$ at the start of 2013 and the western stock to be $0.43B_0$ at this time (under the assumption that the TAC for 2012 of 1,000 t is taken). The Recommended Biological Catches (RBCs) arising from the base-case models are 223 t for the eastern stock and 490 t for the western stock; giving a total RBC of 713 t for the SESSF pink ling stocks. The long term RBC (for the year 2032) is 829 t for the eastern stock and 548 t for the western stock; giving a total long-term RBC of 1,377 t. Stock status and RBC values are sensitive to data weighting and assumptions regarding pre-specified parameters.

For the zone-based comparison model, the eastern stock is assessed to be $0.22B_0$ at the start of 2013 and the western stock to be $0.34B_0$ at this time (under the assumption that the TAC for 2012 of 1,000 t is taken).The RBCs arising from the zone-based models are 6 t for the eastern stock and 247 t for the western stock; giving a total RBC of 253 t for the SESSF pink ling stocks.

Estimates of historic spawning biomass deletion and stock projections for the base-case models (Figure 5.14) show that both spawning stocks have declined on average since the end of the 1970s. Future projections, under the assumption that future catches follow the SESSF Harvest Control Rule, suggest that the spawning biomass for the eastern and western stocks will recover to their respective management targets over the coming decades. The eastern stock is expected to recover quickly, but take more time to reach the management target, being currently at just $0.26B_0$. The western stock is expected to recover to the management target gradually, but in less time, being currently at $0.43B_0$. Each of these 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. However, recruitment has frequently failed to reach levels expected from the stock-recruitment relationship over the past decade (Figure 5.12); thus, although catches have consistently followed recommended levels over the past ten years, spawning biomass has not recovered as expected, especially in the east. This trend could continue if recruitment fails to meet levels expected from the pre-specified stock-recruitment relationship over the coming years.

Additional projections of spawning biomass depletion with different levels of fishing for the next two years (catch levels between 1,000 t and 500 t for 2013/2014, see Figure 5.15) indicate that recovery times for both the eastern and western stocks should not be significantly different under the scenarios tested. Furthermore, spawning stock biomass depletion should not differ greatly between different catch scenarios and those which follow the SESSF Tier 1 Harvest Control rule (Figure 5.15).

5.12 Sensitivity tests

5.12.1 General parameter and data sensitivities

Table 5.12 summarises analyses to examine the sensitivity of some key model outputs (unfished spawning biomass, current (2013) spawning biomass, 2012 and 2013 depletion) to assumptions of the assessment. Sensitivity was examined to (a) changing assumptions about how growth and selectivity are handled, (b) changing the value of the pre-specified stock recruitment function steepness parameter, (c) inclusion/exclusion of particular sets of data (Kapala data, non-trawl CPUE series, and GAB catch data), (d) changing assumptions about the CPUE series (including input CVs and a possible targeted CPUE series), and (e) changing the weights assigned to the age- and size-composition data. Comparisons of the spawning biomass trajectories and spawning depletion estimates for the base case models and each of the sensitivity tests are shown in Figure 5.16.

While care needs to be taken in interpreting changes in the value of the objective function among model configurations owing to issues related to the formulation of the likelihood function, the results in Table 5.12 indicate that the fits to the data deteriorate markedly when growth and/or selectivity are assumed to be time-invariant. Ignoring time-varying growth leads to poor fits to all data types, while ignoring time-varying selectivity leads to poorer fits to the CPUE and size-composition data. The eastern stock is estimated to be less depleted when time-varying selectivity and growth are ignored, while ignoring these features has the opposite effect for the western stock. The fit of the model to the data is not impacted much by changes to the value for steepness. The estimates of depletion and biomass are sensitive to several of the specifications of the assessment including data weightings, suggesting that the index and composition data are in conflict to some extent. As expected, estimates of biomass in absolute terms are generally more sensitive to assumptions than depletion.

5.12.2 *Likelihood profiles*

Figure 5.17 summarises the likelihood profiles for natural mortality (M), stock-recruitment steepness (h), and virgin recruitment (R_0) for the two base-case models. Natural mortality is implied to be well-informed by the data (Figure 5.17.1 and Figure 5.17.2). As expected, the contribution of age-composition data to the negative log-likelihood changes the most as the assumed value for M is changed, implying that age data are the primary source of data to inform the estimate of M. The fit to the length-composition data is less impacted by changing the assumed value for M, although those data support a lower value for M than the age data for the eastern stock.

There is no essentially no information on steepness in the data for the western stock (Figure 5.17.4). The data for the eastern stock are also very uninformative about steepness (all values considered in Figure 5.17.3 fall within the 95% confidence interval for the best estimate), although the MLE occurs at the lowest value considered for steepness (0.65). Estimates of recruitment at pre-exploitation equilibrium (virgin recruitment, R_0) are adequately informed by the available data (Figure 5.17.5 and Figure 5.17.6); though R_0 is estimated more precisely for the western stock than for the eastern stock (as indicated by the scale of likelihood changes between models with different assumed values of R_0). There is conflict between the length data and CPUE index in determining a likely value for R_0 for the eastern stock, but the crossover point between the likelihood profiles for those datasets corresponds to the most likely estimate determined from the age data, and for the total maximum likelihood estimate. All data sources in the western stock inform very similar maximum likelihood estimates for virgin recruitment: the estimate of R_0 is implied to be well-informed by the data for this stock.

5.13 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 2011. The base-case model presented in this report is very similar to the most recently accepted base-case model for pink ling: the 2010 assessment model. The base-case model differs from the 2010 base-case model by allowing for time-varying growth, by the removal of a split in the trawl catch-rate series for the eastern stock in 2000-01, and by including a change in trawl selectivity in 2000-01. The removal of time-varying growth is demonstrated by sensitivity tests to make the model fit considerably poorer, and the removal of Kapala data is shown to have very little effect on model fit or model outputs.

Unlike the 2008, 2009, and 2010 assessments, this assessment does not split the catch-rate series in 2000-2001. The rationale for introducing a knife-edged change in catchability (but not selectivity) was based on changes in fishing practices in the eastern stock. Making this change led to slightly improved fits to the data, but the estimated reduction in catchability from 2000 to 2001 in the 2010 assessment of 30% was very large, and the results were not markedly different from those for the base-case model (Taylor, 2001b). As such, this assessment does not include a change in catchability in the base-case model for the eastern stock. Instead, this assessment assumes that selectivity for the trawl fleet is dome-shaped, with changes in the ascending limb of the selectivity pattern occurring in 2001 and 2006. An assumed change in trawl selectivity is directly supported by both length and age data, whereas there is no direct data to support a change in catchability (see Appendix A).

Stock projections are made under the assumption that recruitment levels will follow the assumed 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 over the past decade, poor recruitment may have contributed to continuing declines in the eastern stock. This trend could continue if recruitment fails to meet levels expected from the assumed stock recruitment relationship over the coming years. As such, some caution should be taken when considering expected recovery times for the eastern stock. Furthermore, work should be conducted 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.

Projections of spawning biomass depletion with various different levels of fishing for the next two years (catch levels between 1,000 t and 500 t for 2013/2014) indicate recovery times for the eastern and western stocks should not be significantly different from those if catches which follow the SESSF Tier 1 Harvest Control rule. These projections again rely on recruitment levels being the same, or close to, those expected from the assumed stock-recruitment relationship in the future.

Likelihood profile analyses for natural mortality (M) indicate that M is well-determined by the data, with the age data being the primary source of information on M. Data for the eastern stock are very uninformative about steepness of the stock recruitment curve (h), and there is essentially no information on steepness in the data for the western stock. This validates the decision not to estimate steepness in any of the models in this report. Likelihood profile analyses for recruitment at pre-exploitation equilibrium (R_0) indicate that R_0 is adequately estimated for the eastern stock and well estimated for the western stock. As such, the related estimates of long term yield are also at least adequate.

This report considered an alternative model in addition to the base-case; the Zone-based model is a useful next step towards a model that can satisfactory account for lack of spatial homogeneity in population processes within the eastern and western stocks of pink ling. This alternative model treats the Zone-based CPUE indices and the age- and length-compositions by zone as coming from different ‘fleets’. Analyses of this Zone-based model demonstrate that considerably different fits to data, and model outputs, are produced when data is considered to come from different ‘fleets’. The results of the Zone-based model should be considered as a guide towards suggested future research in developing models and methods to deal with spatially-explicit stock dynamics for pink ling.

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.

5.14 Future Work

1. Develop a spatially-structured model as an alternative to the base-case and Zone-based models. Ideally, this model would allow for limited (if any) movement of adults among spatial strata, and larval movement from a total recruitment. The indices of abundance and the size-compositions and conditional age-at-length data would be fitted by Zone (or another appropriate set of spatial strata).

2. Develop a spatially-aggregated model where the data are pooled spatially, weighting the abundance indices from the different Zones relative to expected average abundance and the catch size-compositions and conditional age-at-length data proportional to catch. Missing data and low sample sizes for some combinations of year and area may reduce the ability of spatially-aggregated models to describe observed trends; when conducting these analyses, problems with missing data and low sample sizes should be considered carefully.

3. Evaluate the impact of including Blue-eye as a covariate in the standardization of the non-trawl data.

4. Include the FIS data in the assessment as a ghost fleet to evaluate the consistency of the FIS data with the predictions of the model; once sufficient FIS data are available, those data could be used for parameter estimation.

5. Re-evaluate the selection of the size-composition data and conditional age-at-length data in the assessment, accounting for temporal coverage as well as sample size.

6. A study should be conducted to determine a maturity ogive (proportion mature as a function of length and age) and the fecundity ogive (number of eggs produced as a function of length and age) because the current assessment is based on an uncertain (and dated) estimate of size-at-50%-maturity only.

7. Future assessments should consider including the GAB as a separate Zone within the west area.

8. As is conventional, the control rule used to calculate the RBC is a function of spawning biomass. Depletion in terms of spawning biomass will not be the same as that in terms of exploitable biomass. However, exploitable biomass may be a better measure when determining biomass relative to economic objectives. Unfortunately "exploitable biomass" is not a uniquely-defined concept in fisheries stock assessment (it will change depending on fleet composition, time-varying growth, etc.) Future work should explore this issue further.

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5.16 Tables and Figures

Table 5.1. Catches (t) reported to the States (1977-2011), 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	14
2010	*	*	*	*	0	0	54
2011	*	*	*	*	0	0	25

* Essentially zero

Table 5.2. 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	1	0	558	116	0	0	
1987	0	0	542	218	0	1	
1988	0	0	465	100	0	16	
1989	0	0	481	187	0	7	
1990	0	0	503	152	0	6	
1991	0	0	453	206	0	2	
1992	9	1	399	104	0	1	
1993	0	1	607	281	0	1	
1994	1	1	628	259	0	1	
1995	0	1	766	432	0	1	
1996	2	1	761	454	0	2	
1997	98	144	847	583	0	8	
1998	47	142	818	567	0	11	41
1999	92	179	927	436	0	11	12
2000	112	121	749	521	0	2	11
2001	148	170	542	518	0	8	5
2002	190	285	409	445	0	0	7
2003	223	210	510	396	0	13	1
2004	322	345	420	323	51	32	1
2005	223	244	417	210	63	46	3
2006	173	129	400	214	123	30	3
2007	162	64	262	296	75	16	21
2008	231	40	379	227	102	2	16
2009	157	54	244	273	46	0	49
2010	140	94	298	282	86	5	58
2011	159	146	330	370	72	3	14

Table 5.3. Catches of pink ling (t) by Zone and sector. The catches for 2012 are based on the assumption that the catch for 2012 will equal the TAC for 2012 of 1,200t. The catches for Zone 50 include those for the GAB.

Year	East						West				East		West		Total		Total	
	Non-trawl			Trawl			Non-trawl		Trawl		Trawl	Non-trawl	Trawl	Non-Trawl	Trawl	Non-Trawl	East	West
Zone	10	20	30	10	20	30	40	50	40	50								
1977	0	0	0	95	0	0	0	0	0	0	95	0	0	0	95	0	95	0
1978	0	0	0	114	0	0	0	0	0	0	114	0	0	0	114	0	114	0
1979	0	0	0	136	1	0	0	0	0	3	138	0	3	0	140	0	138	3
1980	0	0	0	215	0	0	0	0	0	0	215	0	0	0	215	0	215	0
1981	0	0	0	299	0	0	0	0	0	0	299	0	0	0	299	0	299	0
1982	0	0	0	340	8	0	0	0	0	9	348	0	9	0	356	0	348	9
1983	0	0	0	419	8	0	0	0	0	0	427	0	0	0	427	0	427	0
1984	0	1	0	507	4	0	0	0	0	0	511	1	0	0	512	1	512	1
1985	0	5	9	429	174	1	9	2	32	40	605	14	72	11	677	26	619	84
1986	1	9	18	351	345	3	18	5	64	80	699	28	144	23	843	50	727	167
1987	0	18	4	280	405	4	4	0	199	75	688	22	274	4	962	26	710	278
1988	0	15	5	247	360	6	5	0	67	73	614	20	140	5	754	25	634	145
1989	0	22	7	206	417	11	7	2	173	66	634	29	239	8	873	37	662	248
1990	0	21	8	178	455	15	11	2	126	70	647	29	196	13	843	42	676	209
1991	0	26	11	153	396	39	5	2	125	133	588	37	258	6	846	43	625	264
1992	9	115	51	148	379	7	65	1	50	84	534	175	134	65	668	241	710	199
1993	0	178	130	259	539	27	257	2	162	198	825	307	360	259	1184	566	1132	619
1994	0	33	76	291	497	38	244	1	167	156	826	110	323	245	1149	354	936	568
1995	0	81	9	325	624	47	145	1	267	272	996	90	539	146	1535	236	1086	685
1996	0	104	92	285	653	53	302	3	299	269	990	196	568	306	1558	502	1187	873
1997	0	151	125	366	647	74	235	79	427	307	1087	277	734	314	1821	591	1364	1048
1998	0	42	11	409	620	35	85	68	441	273	1064	53	715	153	1779	206	1117	868
1999	0	79	13	442	710	61	100	79	310	249	1213	93	559	179	1772	272	1306	738
2000	0	87	35	275	640	47	54	77	435	223	962	122	658	131	1621	253	1084	789
2001	1	34	141	147	470	83	153	48	481	190	699	176	671	202	1371	377	875	873
2002	0	55	153	121	361	50	278	36	396	166	532	209	563	314	1095	522	741	876
2003	0	132	114	110	490	44	213	18	353	151	644	246	504	232	1148	478	890	736
2004	0	262	120	73	411	40	321	148	185	241	524	382	425	469	949	851	906	894
2005	0	219	52	96	371	58	173	200	144	159	525	271	303	373	829	644	796	677
2006	0	158	27	62	386	44	96	174	158	134	493	185	292	270	784	455	678	562
2007	0	140	42	50	246	42	67	89	276	100	338	182	376	157	714	339	521	533
2008	0	196	79	75	351	58	42	127	193	80	485	275	273	169	757	444	759	442
2009	0	110	72	49	244	21	52	64	259	77	314	182	336	116	651	298	497	452
2010	0	124	46	107	292	22	93	126	233	119	420	170	352	219	772	389	591	571
2011	0	99	82	75	296	33	156	92	299	129	405	181	428	248	833	430	586	676

Table 5.4. Standardized indices of abundance, and input CV values, for pink ling.

Year	East Trawl					West Trawl			
	Zone 10	Zone 20	Zone 30	Total	CV	Zone 40	Zone 50	Total	CV
1986	1.192	1.080	2.001	1.122	0.140	1.158	1.058	1.168	0.124
1987	1.150	1.473	1.020	1.205	0.133	1.734	1.022	1.343	0.116
1988	1.198	1.005	2.163	1.123	0.125	0.942	1.153	1.047	0.107
1989	0.877	1.077	1.360	0.966	0.116	1.000	1.179	1.084	0.100
1990	1.191	1.274	1.476	1.358	0.113	0.947	0.987	0.975	0.095
1991	1.501	1.044	0.961	1.368	0.120	0.881	1.126	1.033	0.096
1992	1.329	0.935	0.569	1.096	0.131	0.600	0.873	0.772	0.101
1993	1.164	0.896	0.956	1.031	0.136	0.901	1.159	1.047	0.105
1994	1.463	0.816	0.790	1.044	0.127	1.114	1.393	1.258	0.105
1995	1.581	1.240	1.032	1.324	0.104	1.101	1.556	1.290	0.100
1996	1.331	1.379	1.164	1.294	0.074	1.251	1.458	1.373	0.088
1997	1.471	1.298	1.096	1.315	0.055	1.366	1.507	1.446	0.073
1998	1.393	1.363	1.047	1.325	0.062	1.328	1.572	1.441	0.060
1999	1.366	1.203	1.004	1.229	0.071	0.996	1.262	1.126	0.052
2000	1.214	1.029	0.893	1.081	0.064	1.050	0.997	0.997	0.049
2001	0.900	0.799	0.768	0.834	0.033	0.944	0.842	0.891	0.044
2002	0.723	0.752	0.754	0.734	0.012	0.750	0.812	0.770	0.036
2003	0.669	0.825	0.711	0.749	0.065	0.774	0.780	0.774	0.036
2004	0.502	0.801	0.596	0.664	0.119	0.599	0.766	0.721	0.058
2005	0.448	0.740	0.835	0.627	0.158	0.596	0.585	0.599	0.093
2006	0.411	0.936	0.824	0.748	0.174	0.742	0.574	0.642	0.129
2007	0.466	0.787	1.001	0.737	0.164	0.882	0.585	0.711	0.159
2008	0.584	0.940	0.938	0.866	0.132	1.208	0.718	0.908	0.177
2009	0.514	0.664	0.555	0.625	0.090	1.148	0.647	0.891	0.180
2010	0.709	0.783	0.700	0.749	0.053	1.037	0.715	0.857	0.170
2011	0.651	0.860	0.787	0.785	0.031	0.952	0.675	0.836	0.149

Year	East Non-trawl				West Non-trawl			
	Zone 20	Zone 30	Total	CV	Zone 50	Zone 40	Total	CV
2002	-	-	-	0.100	1.503	1.745	1.715	0.100
2003	1.717	1.770	1.739	0.100	1.324	1.633	1.594	0.100
2004	1.173	1.291	1.223	0.100	1.269	1.191	1.201	0.100
2005	0.789	0.774	0.783	0.100	0.948	0.656	0.693	0.100
2006	0.931	0.505	0.750	0.100	0.527	0.579	0.573	0.100
2007	0.718	0.778	0.744	0.100	0.586	0.620	0.616	0.100
2008	0.921	0.793	0.866	0.100	0.839	0.883	0.878	0.100
2009	0.699	0.755	0.723	0.100	0.789	0.854	0.846	0.100
2010	0.715	0.697	0.707	0.100	1.393	0.788	0.865	0.100
2011	0.519	0.916	0.688	0.100	0.821	1.050	1.021	0.100

Table 5.5. Number of records by block and year selected for use in the standardization of the catch and effort data for the non-trawl sector.

	Year									
Block	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
East										
1381	-	2	4	10	13	16	16	12	22	6
1383	-	7	6	19	19	25	15	18	20	14
1391	-	0	0	12	12	14	19	13	10	6
1393	-	1	6	50	49	13	25	29	23	9
1401	-	8	14	13	26	16	16	25	15	8
1403	-	6	16	33	1	4	2	12	4	5
1411	-	44	44	49	55	88	76	54	48	64
1413	-	4	17	8	5	5	8	13	6	8
1421	-	7	6	2	1	2	3	2	4	1
1423	-	22	34	19	6	6	18	14	9	25
1431	-	1	5	3	10	5	15	19	6	4
1433	-	15	10	21	32	43	35	58	32	31
1441	-	13	7	5	7	5	9	10	8	9
West										
2391	2	2	67	38	5	3	0	0	4	4
2393	16	4	12	5	12	4	1	1	15	9
2401	2	0	40	6	5	0	0	0	1	0
2403	0	0	51	8	6	0	0	0	0	0
2411	0	7	91	33	22	5	0	0	3	6
2413	7	14	21	25	18	9	5	2	8	11
2421	27	17	26	31	21	23	9	4	7	8
2423	21	12	25	12	19	10	10	12	11	21
2431	10	15	13	8	4	2	5	9	15	14
2433	17	29	23	28	29	22	25	45	35	20
2441	4	7	27	13	6	10	9	18	6	11

Table 5.6. Number of fish sized by year, Zone and gear.

(A) EAST AREA

Year	Onboard samples						Port samples						
Zone	10	10	20	20	30	30	10	10	20	20	30	30	
Gear	Non-trawl	Trawl	Non-trawl	Trawl	Non-trawl	Trawl	Non-trawl	Trawl	Non-trawl	Trawl	Non-trawl	Trawl	Kapala
1977	0	0	0	0	0	0	0	0	0	0	0	0	1838
1986	0	0	0	0	0	0	0	2389	0	0	0	0	0
1987	0	0	0	0	0	0	0	3958	0	1483	0	0	0
1990	0	0	0	0	0	0	0	0	0	355	0	0	0
1991	0	0	0	0	0	0	0	0	101	100	0	0	0
1993	0	0	0	369	0	0	0	0	0	0	0	0	0
1994	0	0	0	1025	0	0	0	0	0	0	0	0	0
1995	0	0	0	703	0	0	0	0	0	248	0	0	0
1996	0	0	0	2109	0	0	0	0	0	0	0	0	0
1997	0	0	0	1097	0	114	0	0	0	102	0	0	3497
1998	0	3541	0	2649	0	728	0	1108	251	309	0	0	0
1999	0	4814	0	2260	0	488	0	1027	386	455	0	0	0
2000	0	2104	0	548	0	516	0	489	1445	0	114	0	0
2001	0	2723	810	2276	0	514	0	282	195	0	0	0	0
2002	0	1126	211	1402	3819	454	0	0	0	106	769	2674	0
2003	0	1119	2410	1528	1938	237	0	0	104	102	0	0	0
2004	0	749	3036	0	2211	0	0	113	241	0	0	0	0
2005	0	1039	842	1509	459	217	0	723	0	298	108	426	0
2006	0	716	230	2408	0	0	0	385	183	242	439	470	0
2007	0	110	275	0	0	0	0	170	0	904	0	0	0
2008	0	200	249	161	0	0	0	0	0	1524	0	174	0
2009	0	0	599	361	0	0	0	0	346	1862	0	0	0
2010	0	254	897	385	343	0	0	0	937	1765	0	112	0
2011	0	0	257	108	0	0	0	0	169	712	0	285	0
Total	**0**	**18495**	**9816**	**20898**	**8770**	**3268**	**0**	**10644**	**4358**	**10567**	**1430**	**4141**	**5335**

(B) WEST AREA

Year	Onboard samples				Port samples			
Zone	40	50	50	50	40	50	50	50
Gear	Non-trawl	Trawl	Non-trawl	Trawl	Non-trawl	Trawl	Non-trawl	Trawl
1992	0	140	0	0	0	118	0	281
1993	0	904	0	0	0	0	0	0
1994	0	332	0	904	0	0	0	0
1995	0	1652	0	2374	0	205	0	579
1996	0	0	0	1358	234	108	0	1072
1997	0	0	0	2580	0	1202	0	1138
1998	0	849	0	882	0	1024	0	287
1999	351	339	0	715	0	300	0	625
2000	0	0	0	744	0	141	0	1223
2001	3210	860	0	348	0	143	0	2225
2002	3459	159	410	519	0	103	0	1726
2003	2382	1021	0	932	0	0	0	1470
2004	4696	154	465	744	0	0	0	1871
2005	626	0	0	627	0	0	0	1248
2006	397	107	0	409	0	0	0	421
2007	727	0	0	0	0	828	0	0
2008	0	0	0	0	0	113	0	0
2010	212	311	0	180	0	0	0	0
2011	0	176	0	0	0	0	0	0
Total	16060	7004	875	13316	234	4285	0	14166

Table 5.7. Number of fish aged by year, Zone and gear.

(a) EAST AREA

Zone	10	10	20	20	30	30
Gear	Non-trawl	Trawl	Non-trawl	Trawl	Non-trawl	Trawl
1979	0	150	0	245	0	0
1983	0	0	0	0	0	147
1984	0	0	0	0	0	143
1985	0	0	0	0	0	143
1994	0	129	0	89	0	0
1995	0	138	0	203	0	0
1996	0	790	0	0	0	0
1997	0	588	0	0	0	0
1998	0	542	0	127	0	0
1999	0	405	134	134	0	0
2000	94	110	124	0	243	0
2001	0	295	0	112	0	0
2002	0	244	90	0	0	100
2003	0	78	258	0	0	0
2004	0	61	94	0	0	0
2005	0	102	51	65	0	59
2007	0	0	98	262	0	195
2008	0	0	585	325	0	0
2009	0	0	242	599	0	0
2010	0	158	333	545	0	0
2011	0	0	533	532	109	71
Total	94	3790	2542	3238	352	858

(b) WEST AREA

Zone	40	50	40	50
Gear	Non-trawl	Trawl	Non-trawl	Trawl
1987	0	0	0	547
1988	0	0	0	318
1989	0	0	0	189
1994	0	0	0	247
1995	0	0	0	322
1996	0	0	0	68
1997	0	0	0	553
1998	0	109	0	100
1999	0	331	155	165
2001	314	93	0	0
2002	99	99	0	99
2003	313	95	0	81
2004	0	144	0	333
2005	0	78	137	231
2006	125	50	248	423
2007	95	128	0	0
2010	0	95	0	0
Total	946	1222	540	3676

Table 5.8. Model specifications for the base-case (aggregated) model and the Zone-based comparison model.

Parameter	East		West	
	Base-case model	Zone-based model	**Base-case model**	Zone-based model
Age classes	Ages 0-20+			
Length classes	Lengths 20-120 cm+			
Natural mortality, *M*	Estimated			
Growth parameters	Female growth is estimated first, male growth parameters are estimated as exponential offsets to females			
κ	Estimated (by sex)			
Cohort-specific deviations	Estimated 1988-2008	Estimated 1982-2005	Estimated 1980-2007	Estimated 1982-2005
L (a=1)	Estimated (by sex)			
L (a=20)	Estimated (by sex)			
σ (a=1)	Estimated (by sex)			
σ (a=20)	Estimated (by sex)			
Length-weight regression				
A	0.00293			
B	3.139			
Maturity ogive				
Length-at-50%-maturity	72cm			
Maturity slope	-1			
Stock-recruitment				
Recruitment variance, σ_R	0.7			
Bias-correction	1963, 1976, 2012, 2013	1965, 1973, 2008, 2013	1966, 1983, 2004, 2018	1961, 1982, 2003, 2017
Steepness, *h*	0.75			
Estimated recruitment deviations	1973-2009	1970-2009	1978-2009	1981-2009
Selectivity				
Non-trawl	logistic, time-invariant	Zone 10 – logistic, time-invariant	logistic, time-invariant	Zone 40 – logistic, time-invariant
		Zone 20 – same as for Zone 10		Zone 50 – same as for Zone 40
		Zone 20 – logistic, time-invariant		

Trawl	dome-shaped (1970-2000; 2001-05; 2006+ blocks*)	Zone 10 – dome-shaped (1970-2000; 2001-05; 2006+ blocks*)	dome-shaped (1970-2000; 2001-05; 2006+ blocks*)	Zone 40 – dome-shaped (1970-2000; 2001-05; 2006+ blocks*)
		Zone 20 – dome-shaped (1970-2000; 2001-05; 2006+ blocks*)		Zone 50 – dome-shaped (1970-2000; 2001-05; 2006+ blocks*)
		Zone 30 – dome-shaped (1970-2000; 2001+ blocks*)		
	Kapala – dome-shape; time-invariant	Kapala – dome-shape; time-invariant		

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

Table 5.9. Factors by which input sample sizes for the length-frequency data are multiplied for the base-case and Zone-based models. 'N/A' denotes no multiplier (or a value equal to one).

East area		**West area**	
Base-case model	Zone-based model	**Base-case model**	Zone-based model
Onboard Non-trawl: 0.045 Trawl: 0.04 Port Non-trawl: 0.095 Trawl: 0.025 Kapala: 0.01	Onboard Non-trawl 10: N/A Non-trawl 20: 0.11 Non-trawl 30: 0.25 Trawl 10: 0.15 Trawl 20: 0.10 Trawl 30: 0.25 Port Non-trawl 10: N/A Non-trawl 20: 0.12 Non-trawl 30: 0.15 Trawl 10: 0.36 Trawl 20: 0.07 Trawl 30: 0.05 Kapala: 0.05	Onboard Non-trawl: 0.03 Trawl: 0.1 Port Non-trawl: 035 Trawl: 0.06	Onboard Non-trawl 40: 0.06 Non-trawl 50: 0.18 Trawl 40: 0.34 Trawl 50: 0.27 Port Non-trawl 40: 0.36 Non-trawl 50: N/A Trawl 40: 0.43 Trawl 50: 0.25

Table 5.10. Factors by which input sample sizes for the conditional age-length data are multiplied for the base-case and Zone-based models. 'N/A' denotes no multiplier (or a value equal to one).

East area		**West area**	
Base-case model	Zone-based model	**Base-case model**	Zone-based model
Non-trawl: 0.35 Trawl: 0.35 Kapala: N/A	Non-trawl 10: 0.9 Non-trawl 20: 0.7 Non-trawl 30: 0.50 Trawl 10: 0.66 Trawl 20: 0.80 Trawl 30: N/A Kapala: N/A	Non-trawl: 0.47 Trawl: 0.62	Non-trawl 40: 1 Non-trawl 50: N/A Trawl 40: 0.80 Trawl 50: 1

Table 5.11. Additional standard deviations added to the input CV for the indices for the base-case and Zone-based models. 'N/A' denotes no multiplier (or a value equal to one).

East area		**West area**	
Base-case model	Zone-based model	**Base-case model**	Zone-based model
Non-trawl: 0.08 Trawl: 0.01 Kapala: 0.14	Non-trawl 10: N/A Non-trawl 20: 0 Non-trawl 30: 0.14 Trawl 10: N/A Trawl 20: 0.06 Trawl 30: 0.16 Kapala: 0.18	Non-trawl: 0.13 Trawl: 0.05	Non-trawl 40: 0.1 Non-trawl 50: N/A Trawl 40: 0.22 Trawl 50: 0.05

Table 5.12. Summary of model results and sensitivity tests (biomass units in metric tonnes). Shaded rows represent results of base-case models or main comparison models for reference to sensitivity test results.

(a) EAST AREA – base-case model

	B_0	B_{Curr}	B_{2012}/B_0	B_{2013}/B_0	-LnL CPUE	-LnL Length	-LnL Age	-LnL Other	**-LnL Total**	**Difference**
2011 Model										
Original	5724	881	0.15	-	-	-	-	-	-	-
With corrected time-varying growth	5830	1256	0.22	-	-	-	-	-	-	-
2012 Model										
Aggregated model	**7296**	**1920**	**0.28**	**0.26**	**-59.91**	**251.38**	**1543.79**	**-1.40**	**1734**	**-**
No time-varying (cohort-specific) growth	7282	2321	0.35	0.32	-39.60	253.05	1622.66	-0.16	1836	102
No time-varying selectivity	7861	2679	0.36	0.34	-46.27	293.92	1542.67	-1.90	1788	54
No time-varying growth or selectivity	7782	3055	0.42	0.39	-18.11	279.14	1618.70	-0.78	1879	145
Steepness fixed at 0.6	7705	1937	0.26	0.25	-59.75	251.17	1543.36	-1.57	1733	-1
Steepness fixed at 0.9	7069	1929	0.29	0.27	-60.02	251.55	1544.06	-1.23	1734	0
No Kapala data	7786	2217	0.30	0.28	-	-	-	-	NA	-
No non-trawl CPUE	7274	1760	0.26	0.24	-	-	-	-	NA	-
Constant CV on Trawl CPUE (0.1)	6962	1678	0.26	0.24	-	-	-	-	NA	-
Targeted Trawl CPUE	7663	2288	0.32	0.30	-	-	-	-	NA	-
Reweight length/age data (λ = 1)	7301	2126	0.31	0.29	-	-	-	-	NA	-
Reweight length/age data (λ = 0.25)	7309	1922	0.27	0.26	-	-	-	-	NA	-

(b) EAST AREA – zone-based (disaggregated) model

	B_0	B_{Curr}	B_{2012}/B_0	B_{2013}/B_0	-LnL CPUE	-LnL Length	-LnL Age	-LnL Other	**-LnL Total**	**Diff.**
2011 Model										
Original	5724	881	0.15	-	-	-	-	-	-	-
With corrected time-varying growth	5830	1256	0.22	-	-	-	-	-	-	-
2012 Model										
Zone model	**5348**	**1196**	**0.25**	**0.22**	**-66.31**	**963.59**	**3651.27**	**-0.92**	**4548**	-
No time-varying growth or selectivity	6549	1582	0.27	0.24	-47.98	1146.04	3731.78	2.89	4833	285
Steepness fixed at 0.6	5604	1218	0.24	0.22	-65.99	973.35	3652.76	-1.32	4559	11
Steepness fixed at 0.9	5128	1189	0.23	0.23	-65.61	957.04	3647.57	-0.54	4538	-10
No Kapala data	5400	1324	0.27	0.25	-	-	-	-	NA	-
No Non-trawl CPUE	5390	1246	0.26	0.23	-	-	-	-	NA	-
Reweight length/age data (λ = 2)	5115	1181	0.26	0.23	-	-	-	-	NA	-
Reweight length/age data (λ = 0.5)	5420	1193	0.24	0.22	-	-	-	-	NA	-

(c) WEST AREA – base-case model

	B_0	B_{Curr}	B_{2012}/B_0	B_{2013}/B_0	-LnL CPUE	-LnL Length	-LnL Age	-LnL Other	**-LnL Total**	**Diff.**
2011 Model										
Original	5017	1771	0.35	-	-	-	-	-	-	-
With corrected time-varying growth	5017	1771	0.35	-	-	-	-	-	-	-
2012 Model										
Aggregated model	**4707**	**2027**	**0.45**	**0.43**	**-49.10**	**227.41**	**1729.30**	**-9.88**	**1898**	**-**
No time-varying (cohort-specific) growth	4630	1750	0.42	0.38	-45.10	247.95	1764.66	-10.07	1957	59
No time-varying selectivity	4759	1951	0.46	0.41	-39.88	245.41	1730.55	-8.62	1927	29
No time-varying growth or selectivity	4714	1744	0.42	0.37	-38.52	259.83	1762.61	-7.66	1976	78
Steepness fixed at 0.6	4815	2022	0.44	0.42	-48.99	227.08	1729.52	-9.71	1898	0
Steepness fixed at 0.9	4636	2040	0.45	0.44	-49.16	227.64	1729.16	-10.00	1898	0
No non-trawl CPUE	4814	2127	0.46	0.44	-	-	-	-	NA	-
No GAB catch data	4371	1867	0.45	0.43	-	-	-	-	NA	-
Constant CV on Trawl CPUE (0.1)	4754	2116	0.46	0.45	-	-	-	-	NA	-
Targeted Trawl CPUE	5001	2403	0.49	0.48	-	-	-	-	NA	-
Reweight length/age data (λ = 1)	4364	1789	0.44	0.41	-	-	-	-	NA	-
Reweight length/age data (λ = 0.25)	5036	2239	0.45	0.44	-	-	-	-	NA	-

(d) WEST AREA – zone-based (disaggregated) model

	B_0	B_{Curr}	B_{2012}/B_0	B_{2013}/B_0	-LnL CPUE	-LnL Length	-LnL Age	-LnL Other	**-LnL Total**	**Diff.**
2011 Model										
Original	5724	881	0.15	-	-	-	-	-	-	-
With corrected time-varying growth	5830	1256	0.22	-	-	-	-	-	-	-
2012 Model										
Zone model	**4649**	**1589**	**0.39**	**0.34**	**-68.08**	**742.89**	**3129.30**	**-1.03**	**3803**	**-**
No time-varying growth or selectivity	5365	1606	0.36	0.30	-53.50	913.98	3188.36	0.85	4050	247
Steepness fixed at 0.6	4737	1614	0.39	0.34	-67.90	742.60	3129.87	-1.00	3804	1
Steepness fixed at 0.9	4584	1577	0.39	0.34	-68.20	743.10	3128.89	-1.01	3803	0
No non-trawl CPUE	4691	1587	0.39	0.34	-	-	-	-	3814	11
Reweight length/age data (λ = 2)	4212	1226	0.35	0.29	-	-	-	-	NA	-
Reweight length/age data (λ = 0.5)	4984	1884	0.41	0.38	-	-	-	-	NA	-

Table 5.13. Summary of key parameter estimates for eastern and western pink ling stocks for the base-case and Zone-based models.

Parameter	**East**		**West**	
	Base-case model	Zone-based model	**Base-case model**	Zone-based model
Natural mortality, M	0.24	0.24	0.21	0.23
Growth				
κ / O_M (Male exp. offset)	0.19 / 0.41	0.16 / 0.42	0.19 / 0.17	0.18 / 0.16
L_F (a=1) / O_M	27.18 / -0.11	27.66 / -0.08	24.85 / -0.04	26.21 / -0.02
L_F (a=20) / O_M	109.61 / -0.19	111.02 / -0.20	104.20 / -0.11	104.70 / -0.11
σ_F (a=1) / O_M	0.17 / 0.09	0.16 / 0.04	0.15 / 0.14	0.14 / 0.15
σ_F (a=20) / O_M	-1.00 / -1.24	-0.92 / -1.12	-0.52 / -1.00	-0.44 / -1.00
Selectivity				
Non-trawl A	P1: 64.6, P2: 10.04		P1: 69.92, P2: 9.55	
Trawl (A for East, B for West)	1970-2000 P1: 52.6, P2: -14.0, P3: 3.9, P4: 5.3, P5: -6.5, P6: -1.8		1970-2000 P1: 66.4, P2: -11.0, P3: 4.9, P4:4.9 , P5: -15.7, P6: -0.14	
(Time block multipliers)	2001-05 P1: 0.01, P2: -14.0, P3: 3.9, P4: 5.3, P5: -6.5, P6: -1.8 2006+ P1: 52.6, P2: -14.0, P3: 3.9, P4: 5.3, P5: -6.5, P6: -1.8		2001-05 P1: 0.05, P2: 0, P3: 0.03, P4: 0, P5:0.13, P6:0 2006+ P1:0.14, P2:0, P3: 0.06, P4: 0, P5:0.06, P6:0	
Kapala	P1: 54.98, P2: -11.04, P3: 4.12, P4: 3.85, P5:-5.40, P6: -0.74			

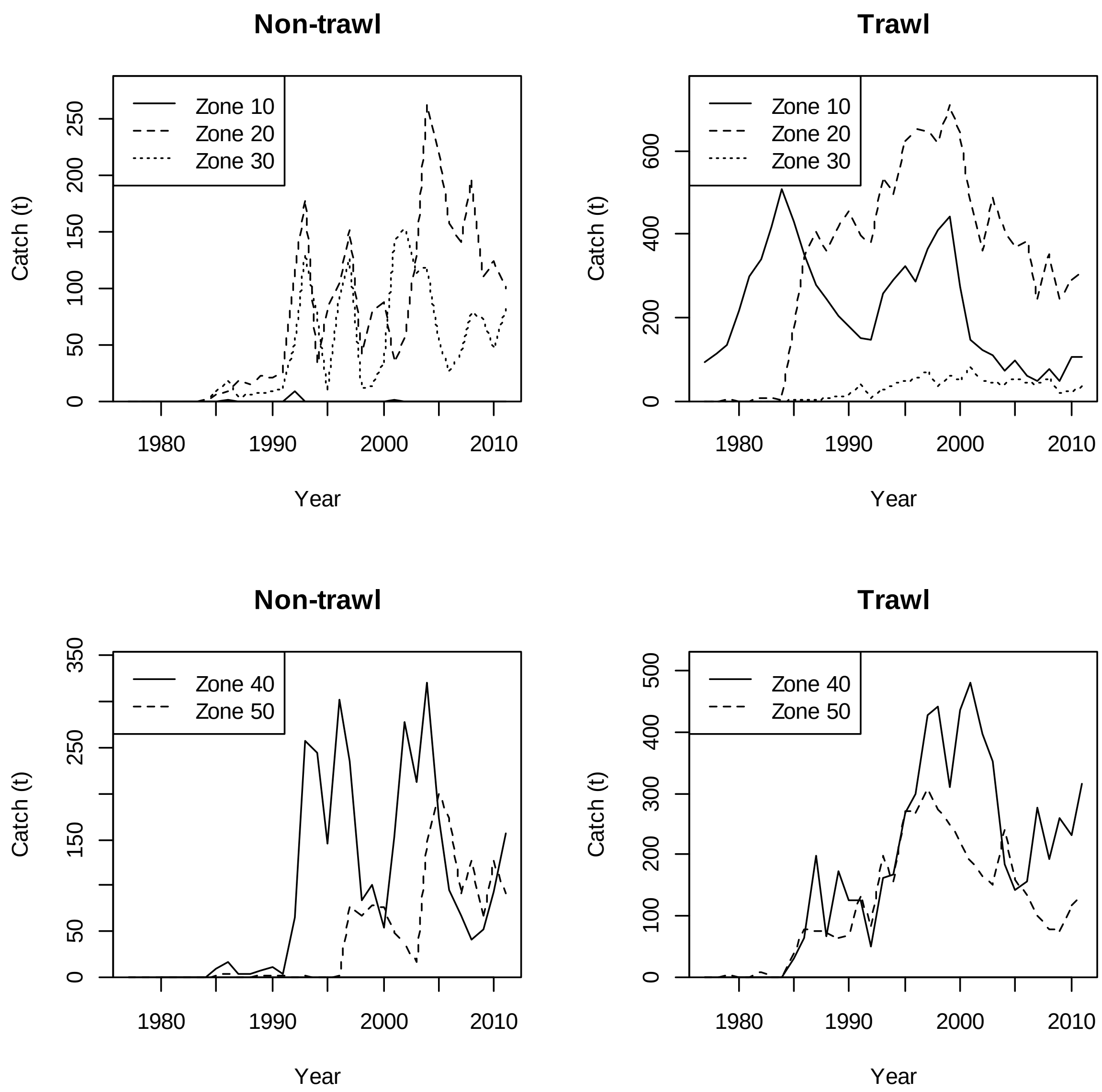


Figure 5.2 Catches (t) by Zone and by Sector.

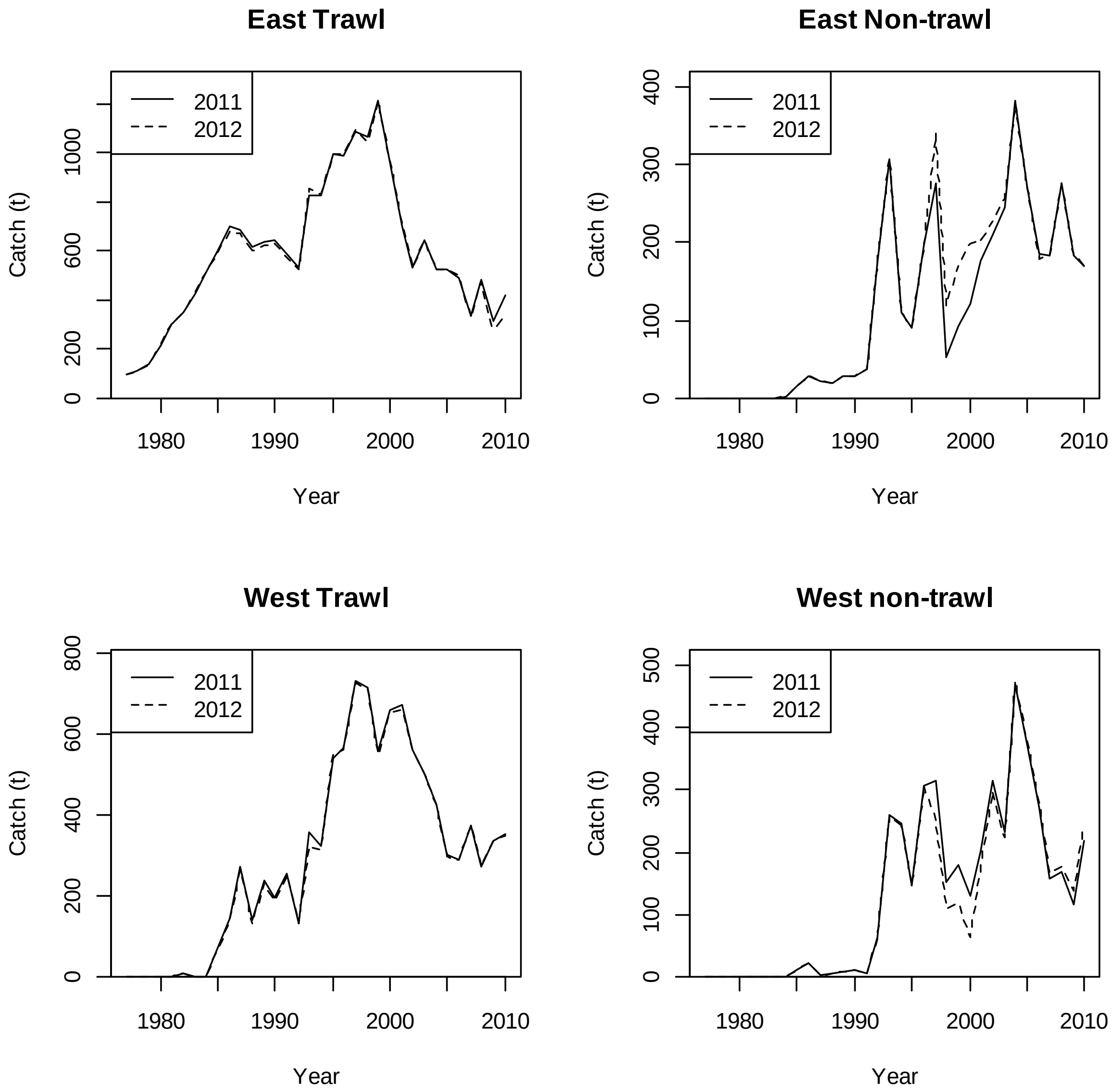


Figure 5.3. Comparison of the catches used in the current assessment ("2012") and those on which the 2011 assessment was based ("2011").

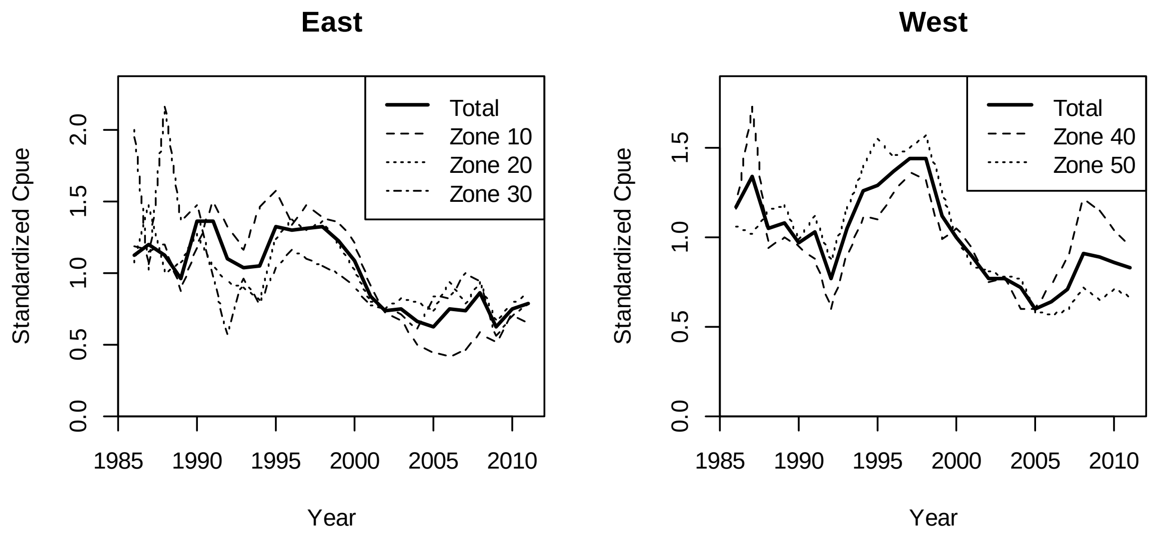


Figure 5.4. Standardized catch rate indices for the trawl sector.

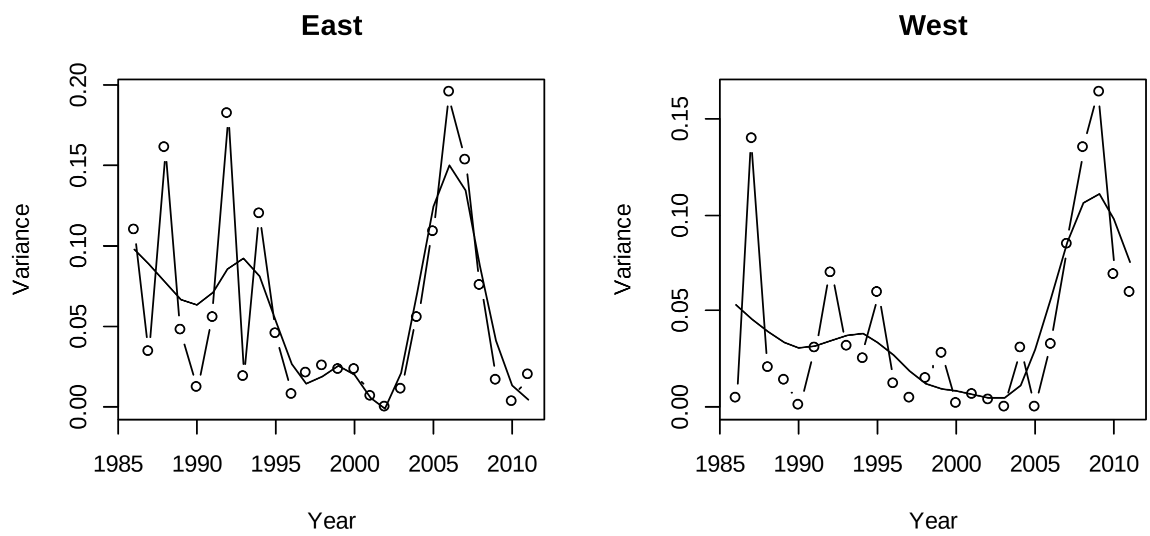


Figure 5.5. Spline fits (lines) to the between-Zone variances in catch-rates (dots).

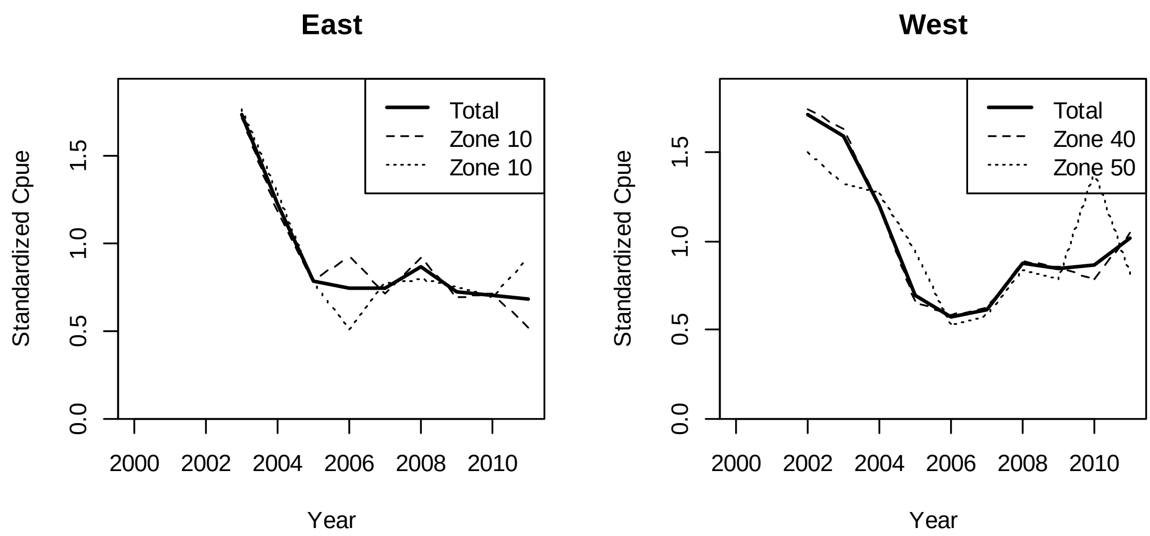


Figure 5.6. Standardized catch rate indices for the non-trawl sector.

(A) EAST AREA – BASE-CASE MODEL

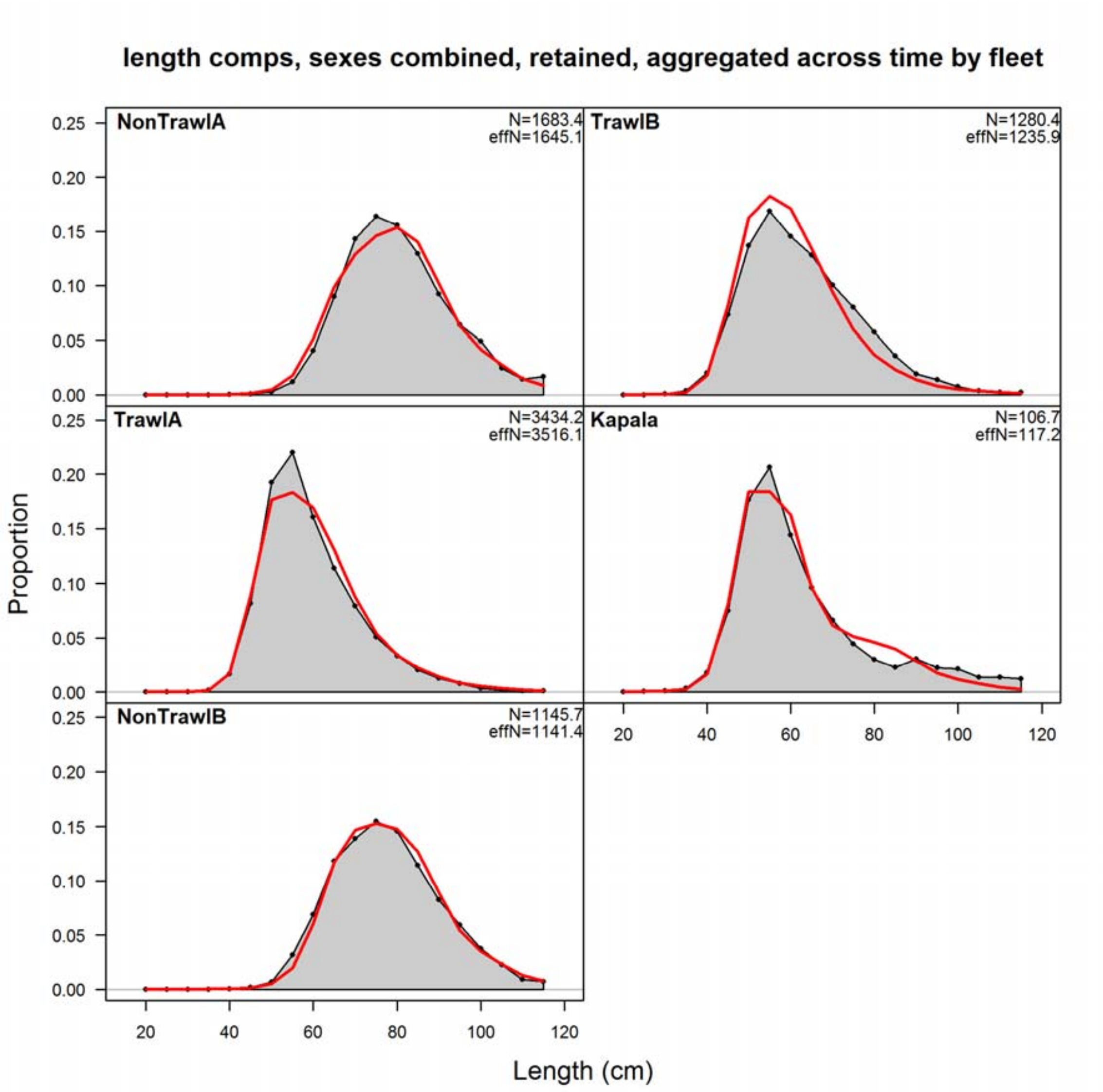


Figure 5.7. Fits to the aggregated length-frequency data ("A" denotes onboard and "B" denotes port).

(B) WEST AREA – BASE-CASE MODEL

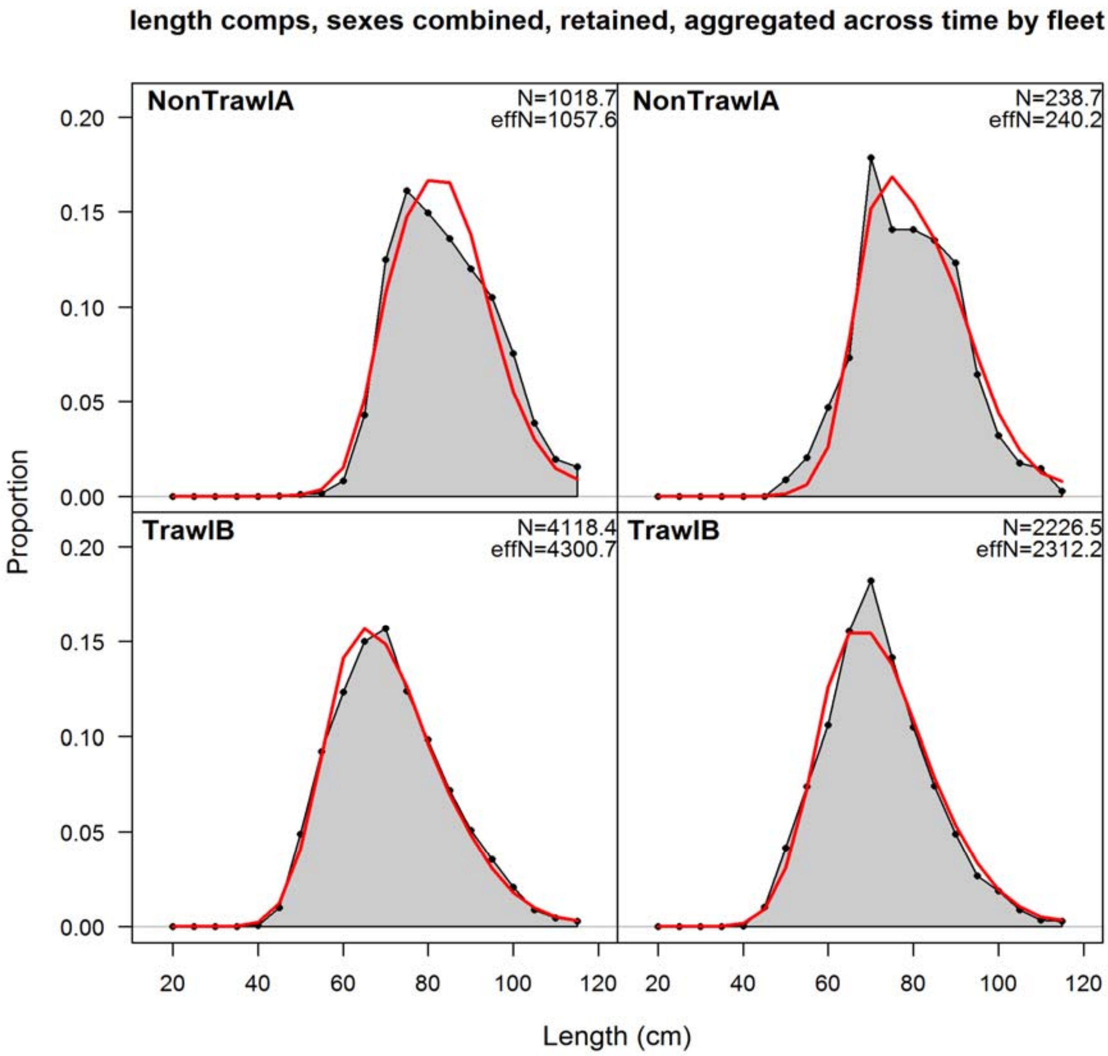


Figure 5.7 continued

(C) EAST AREA – ZONE MODEL

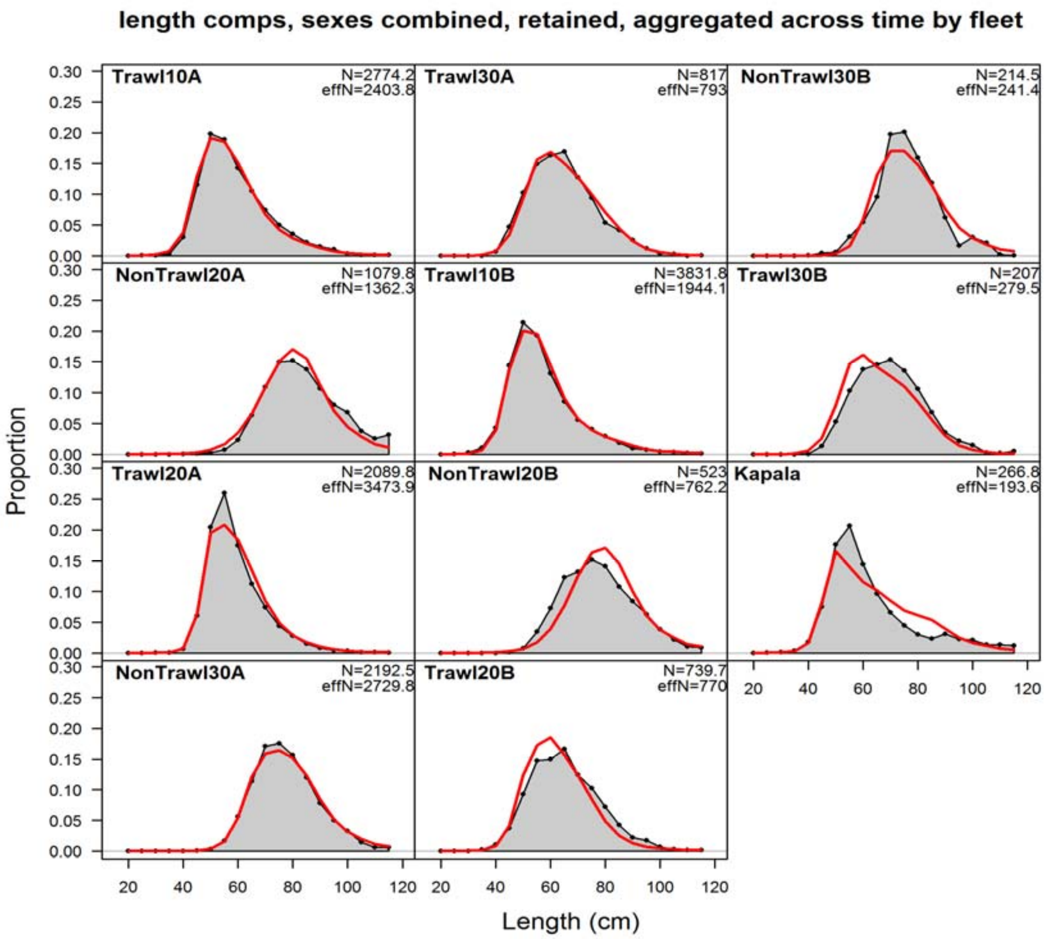


Figure 5.7 continued

(D) WEST AREA – ZONE MODEL

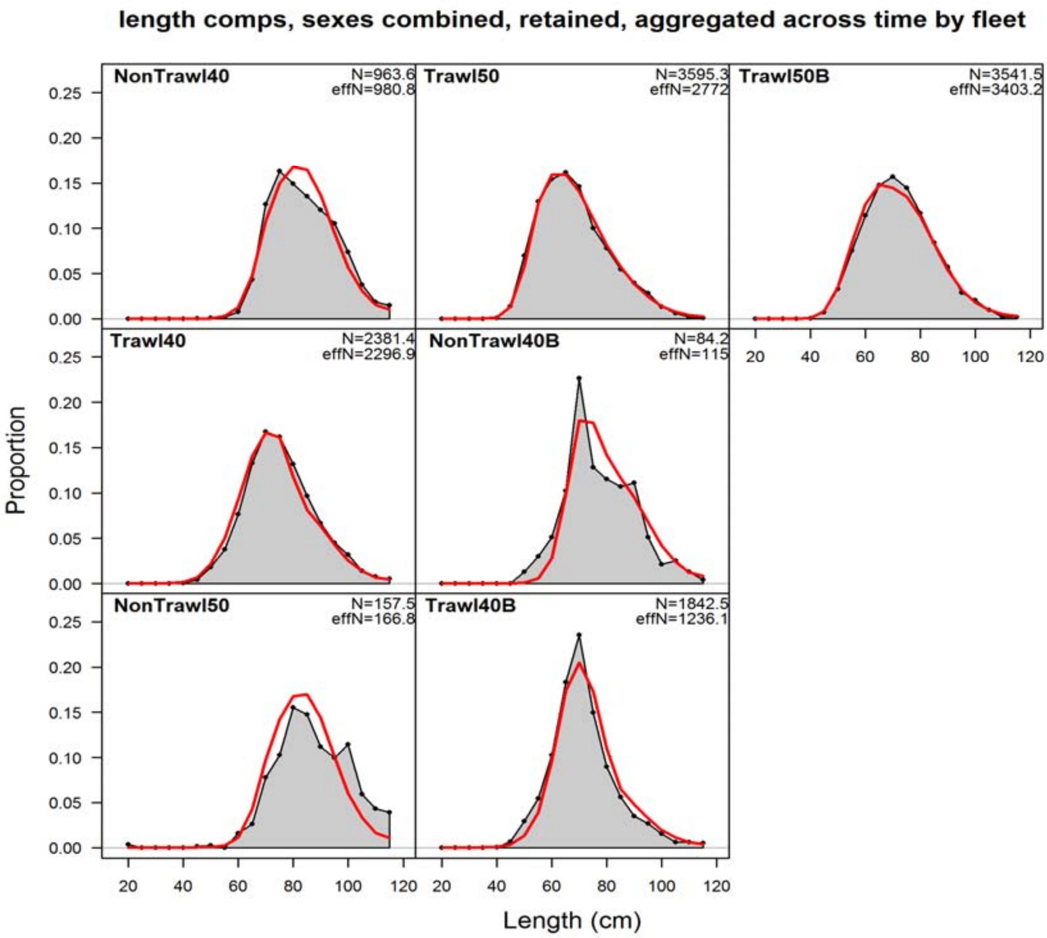


Figure 5.7 continued

(A) EAST AREA - BASE-CASE MODEL

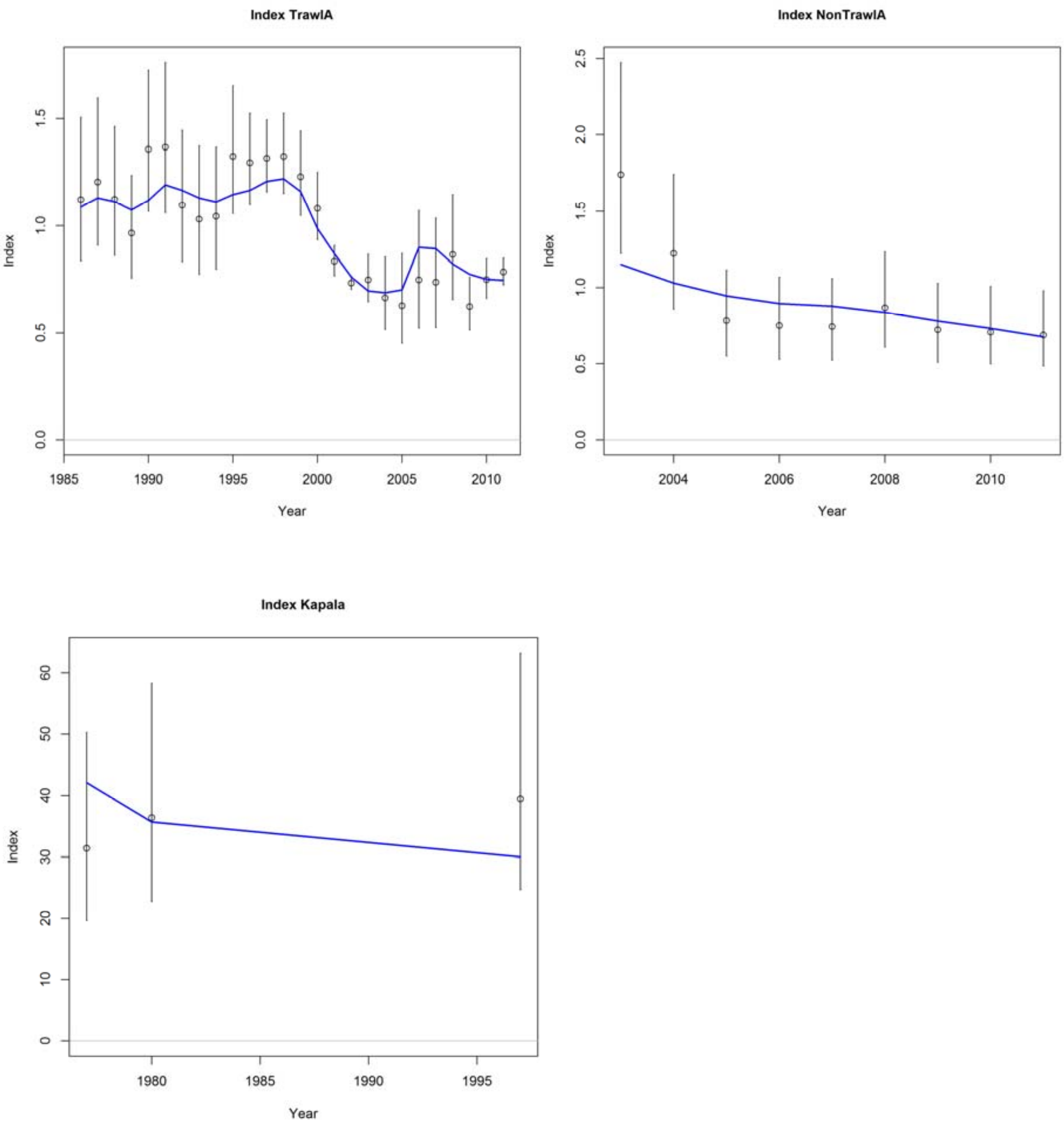


Figure 5.8. Base-case model fits to the standardized catch rate indices.

(B) WEST AREA - BASE-CASE MODEL

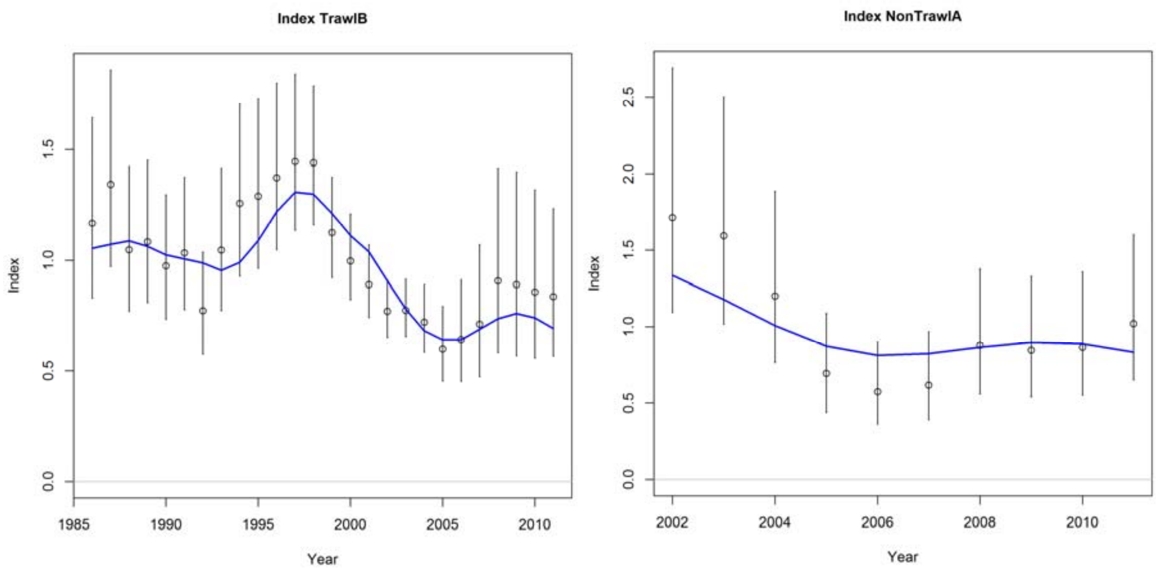
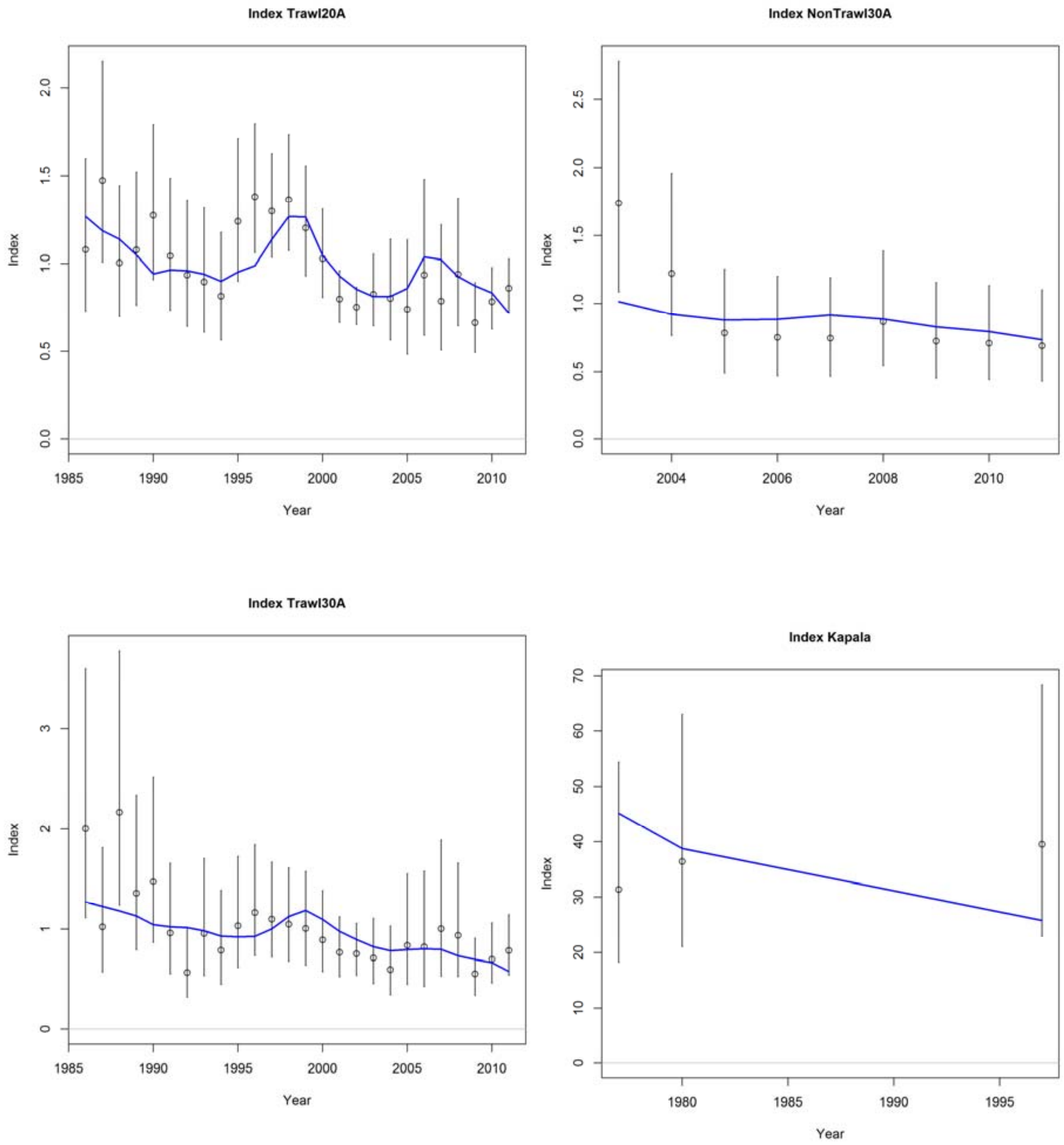


Figure 5.8 continued

(C) EAST AREA – ZONE MODEL



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(D) WEST AREA - ZONE MODEL

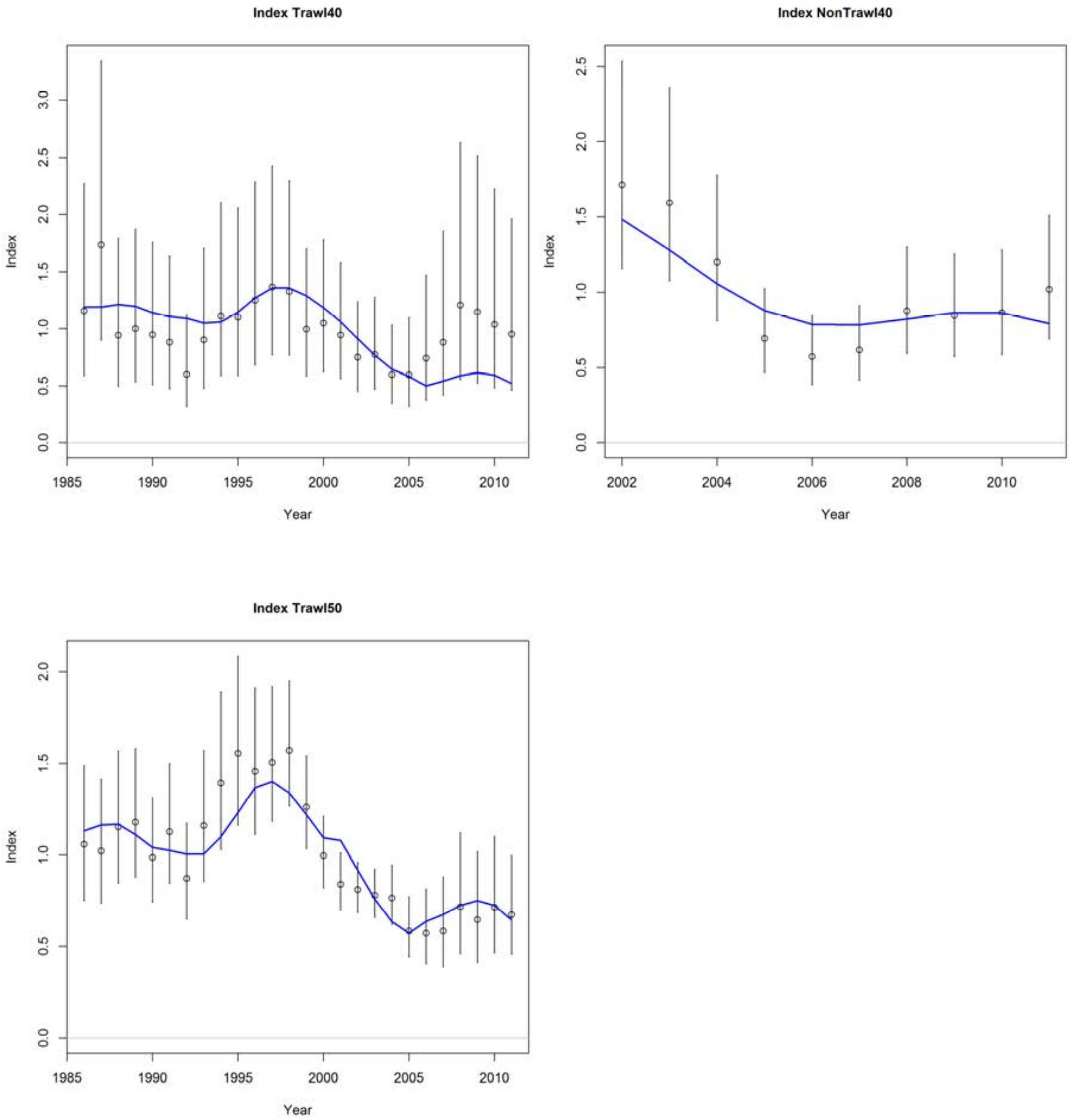


Figure 5.8 continued

(A) EAST AREA – BASE-CASE MODEL

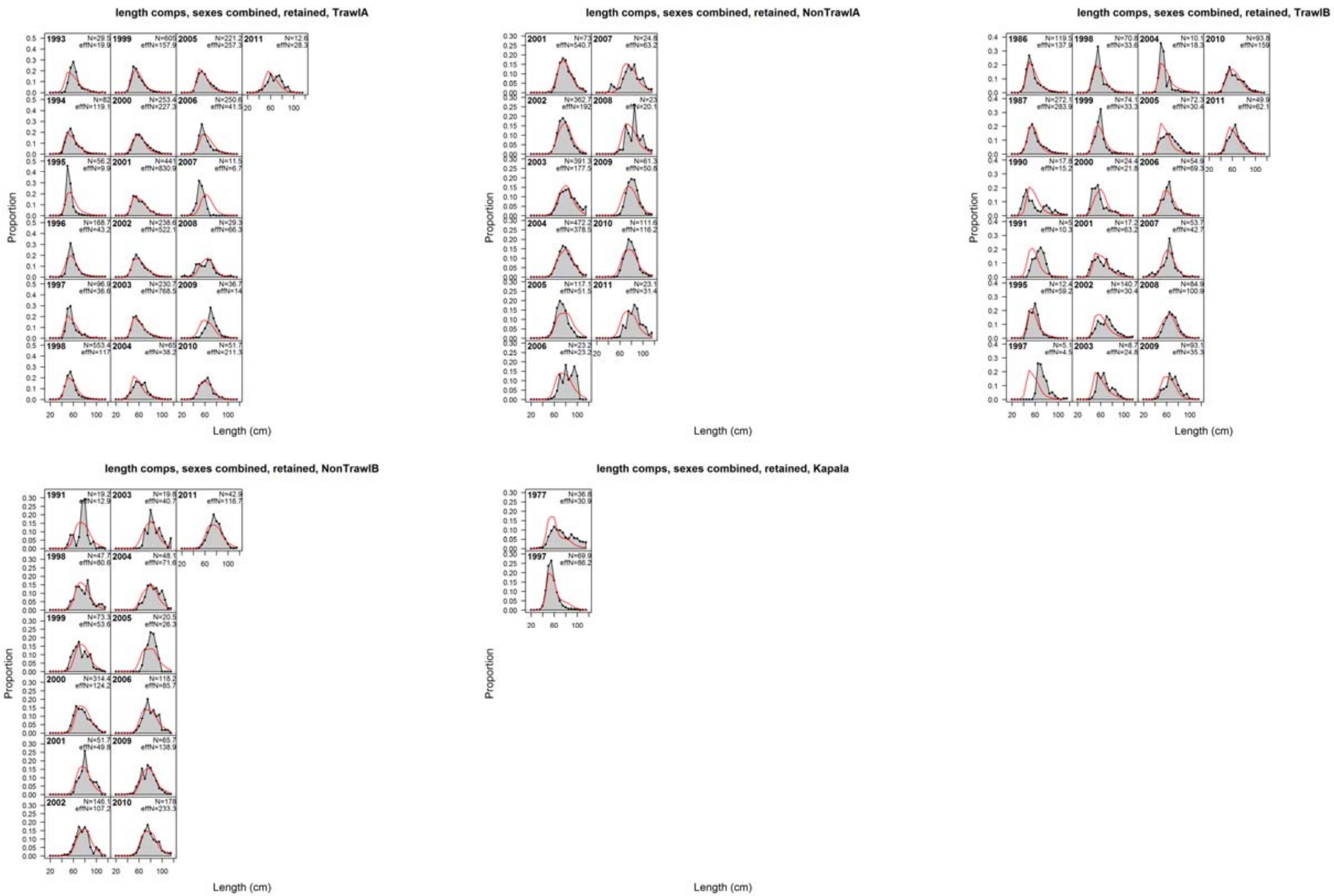
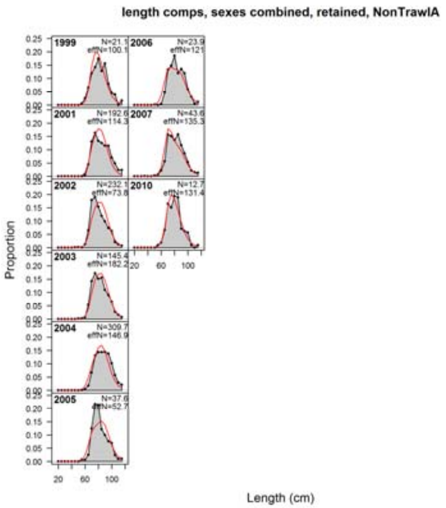
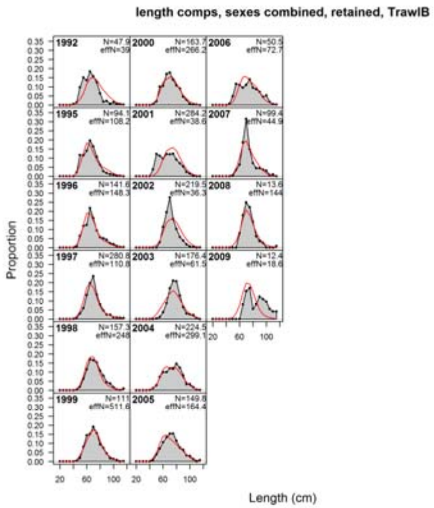
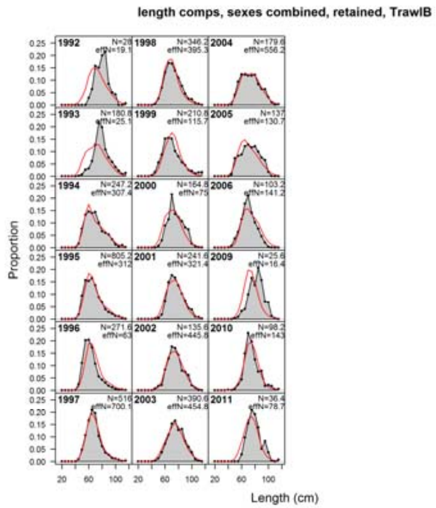


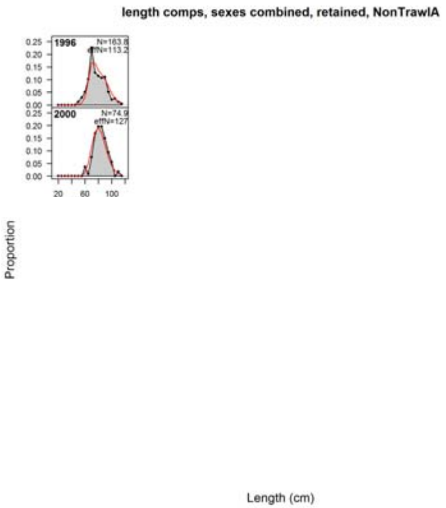
Figure 5.9. Fits of the base-case models to year-specific length-frequency data.

(B) WEST AREA – BASE-CASE MODEL









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(C) EAST AREA - ZONE MODEL

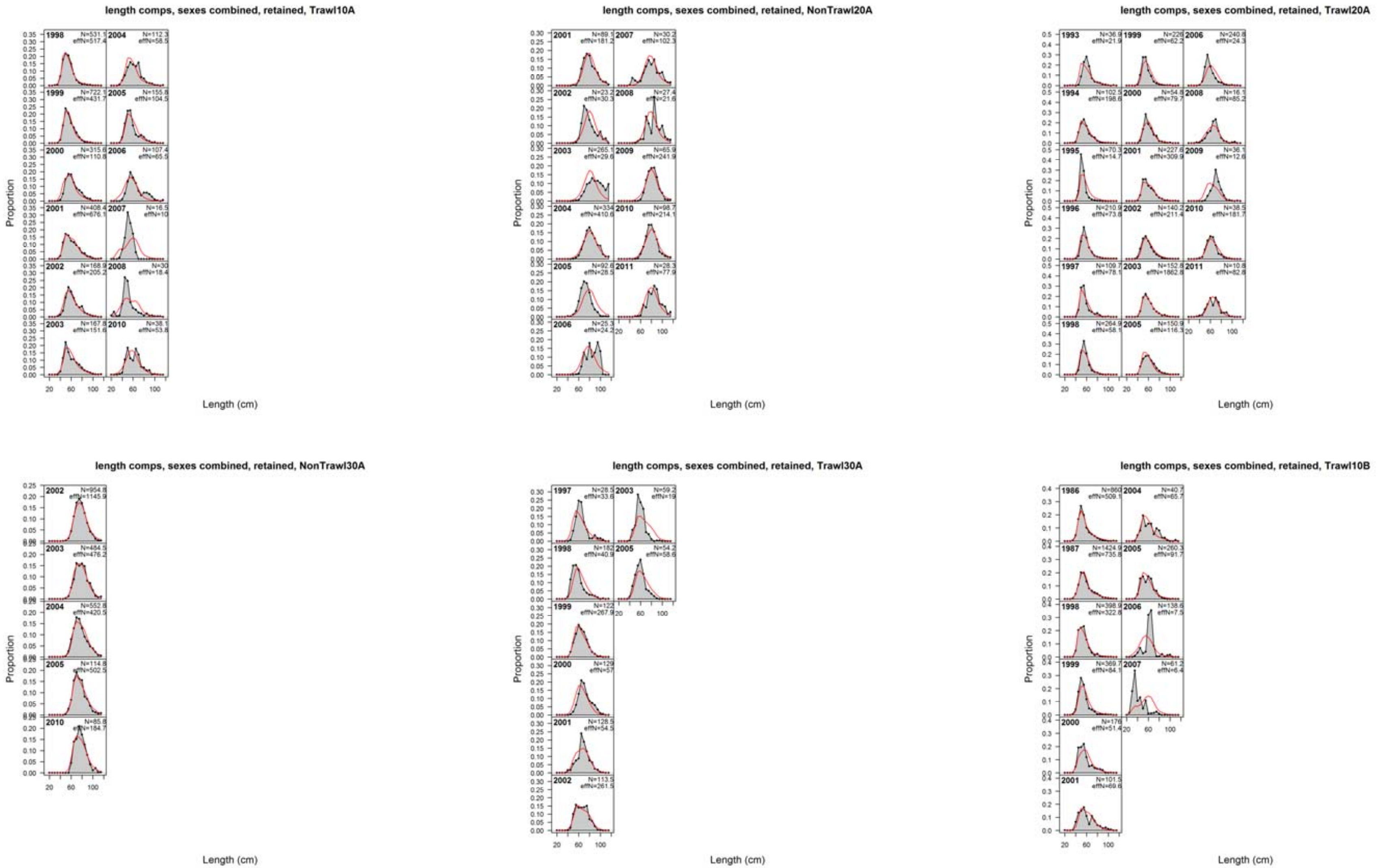


Figure 5.9 continued

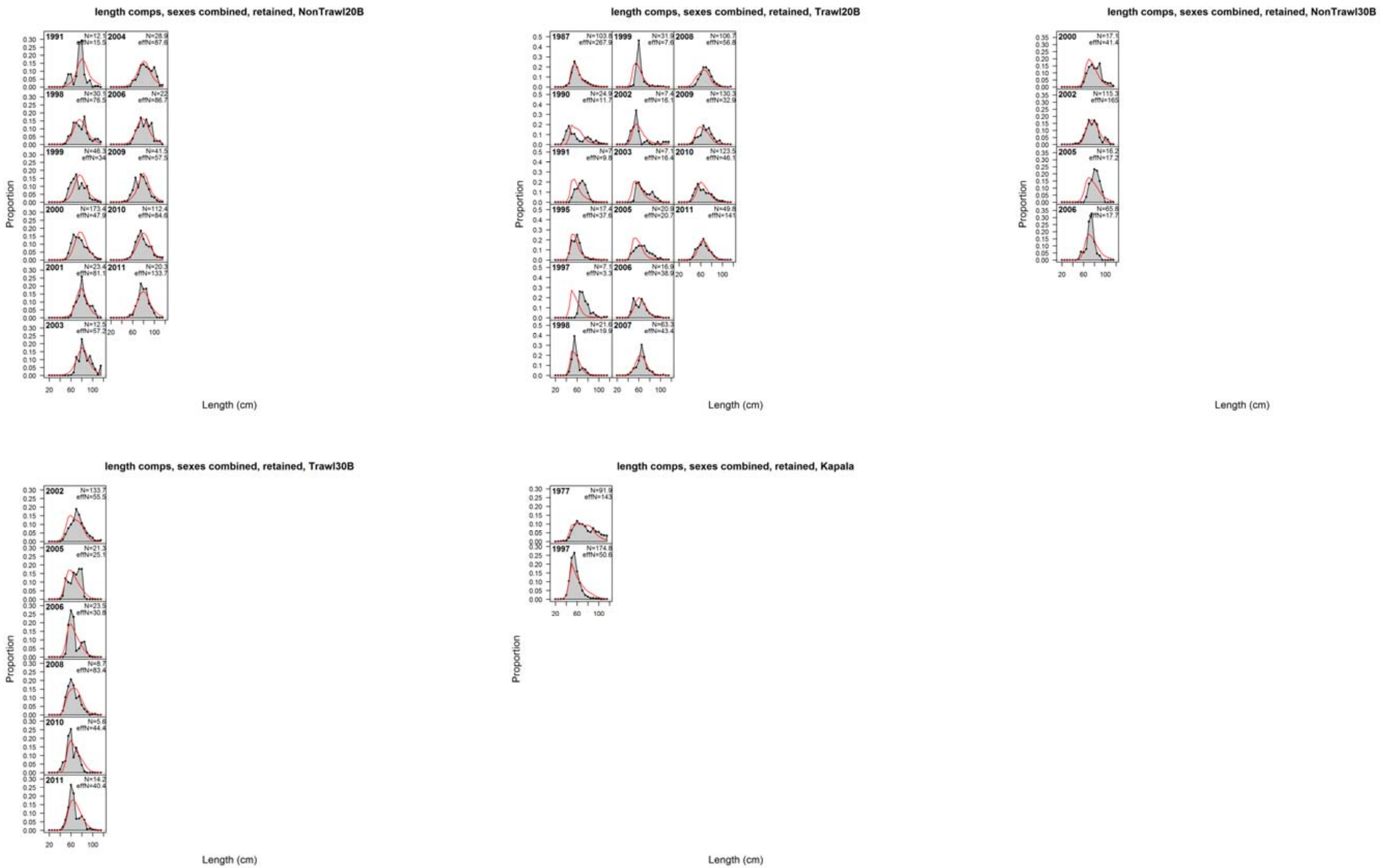


Figure 5.9 continued

(D) WEST AREA – ZONE MODEL

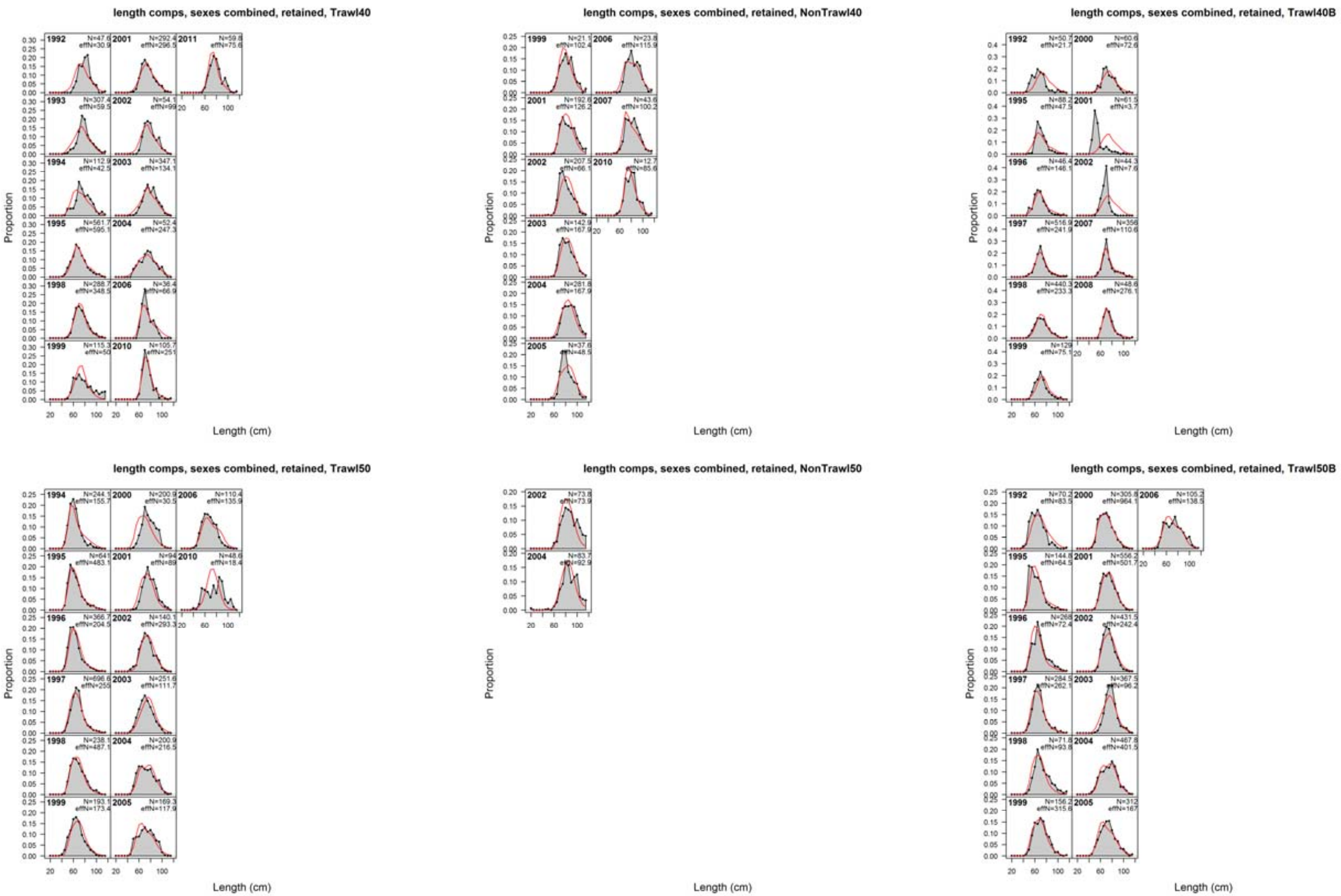


Figure 5.9 continued

(A) EAST AREA – BASE-CASE MODEL

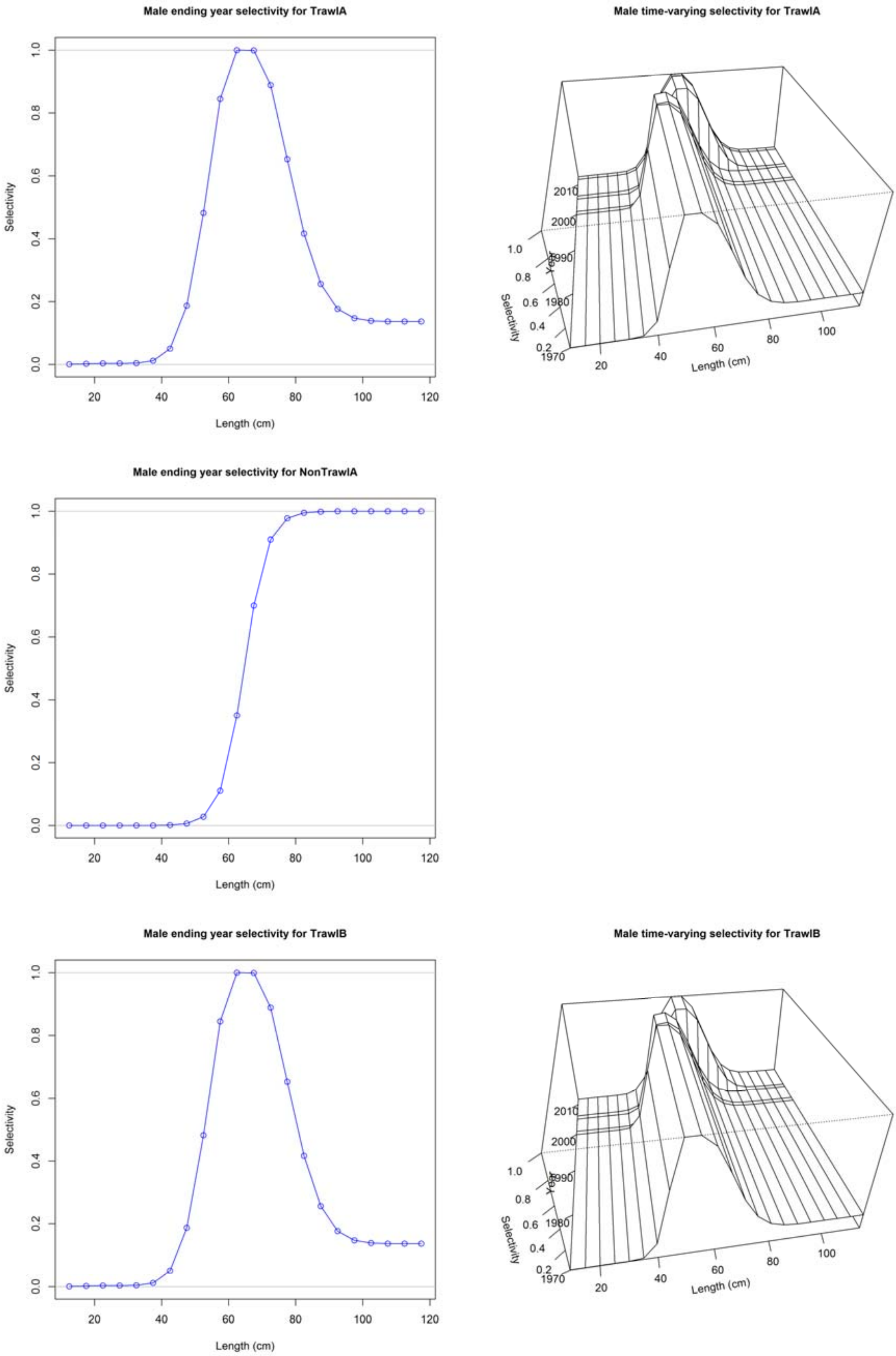
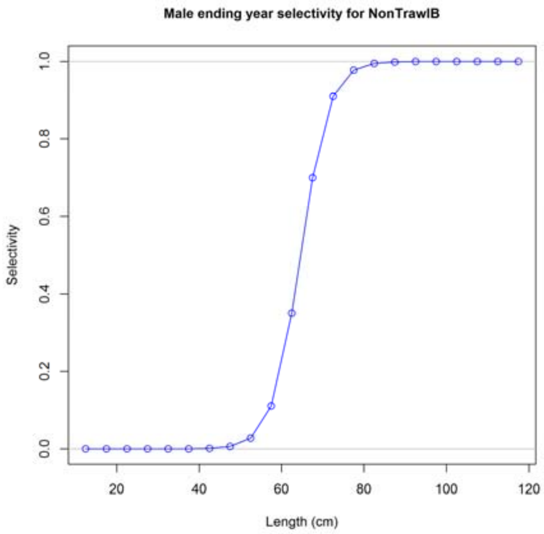


Figure 5.10. Predicted selectivity from base-case and zone-based models.



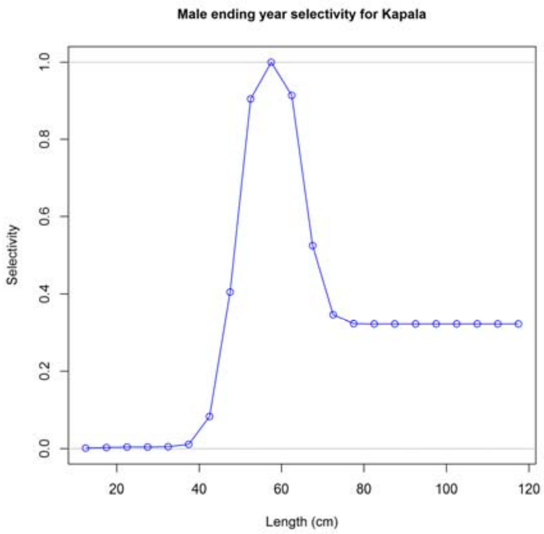


Figure 5.10 continued

(B) WEST AREA – BASE-CASE MODEL

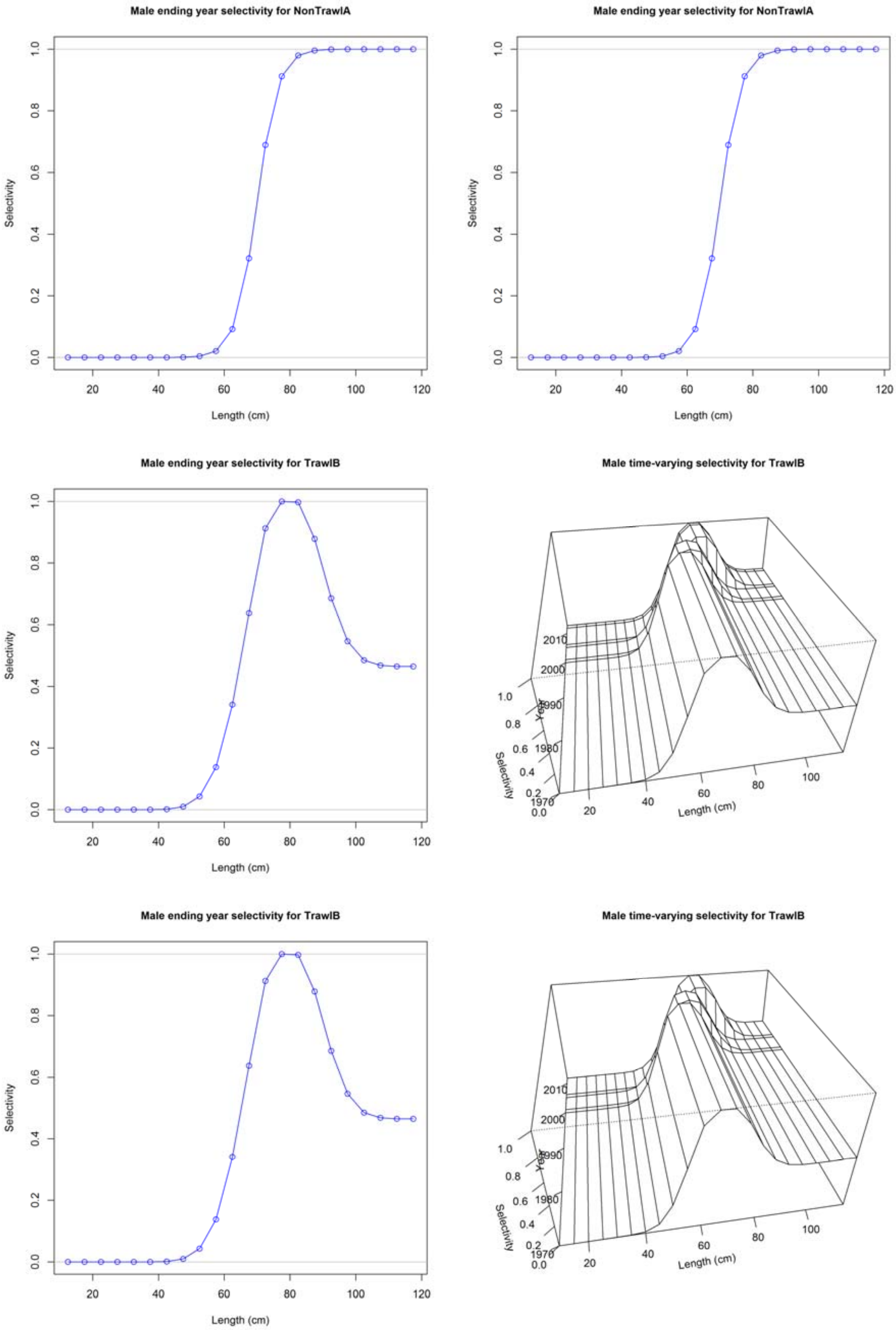
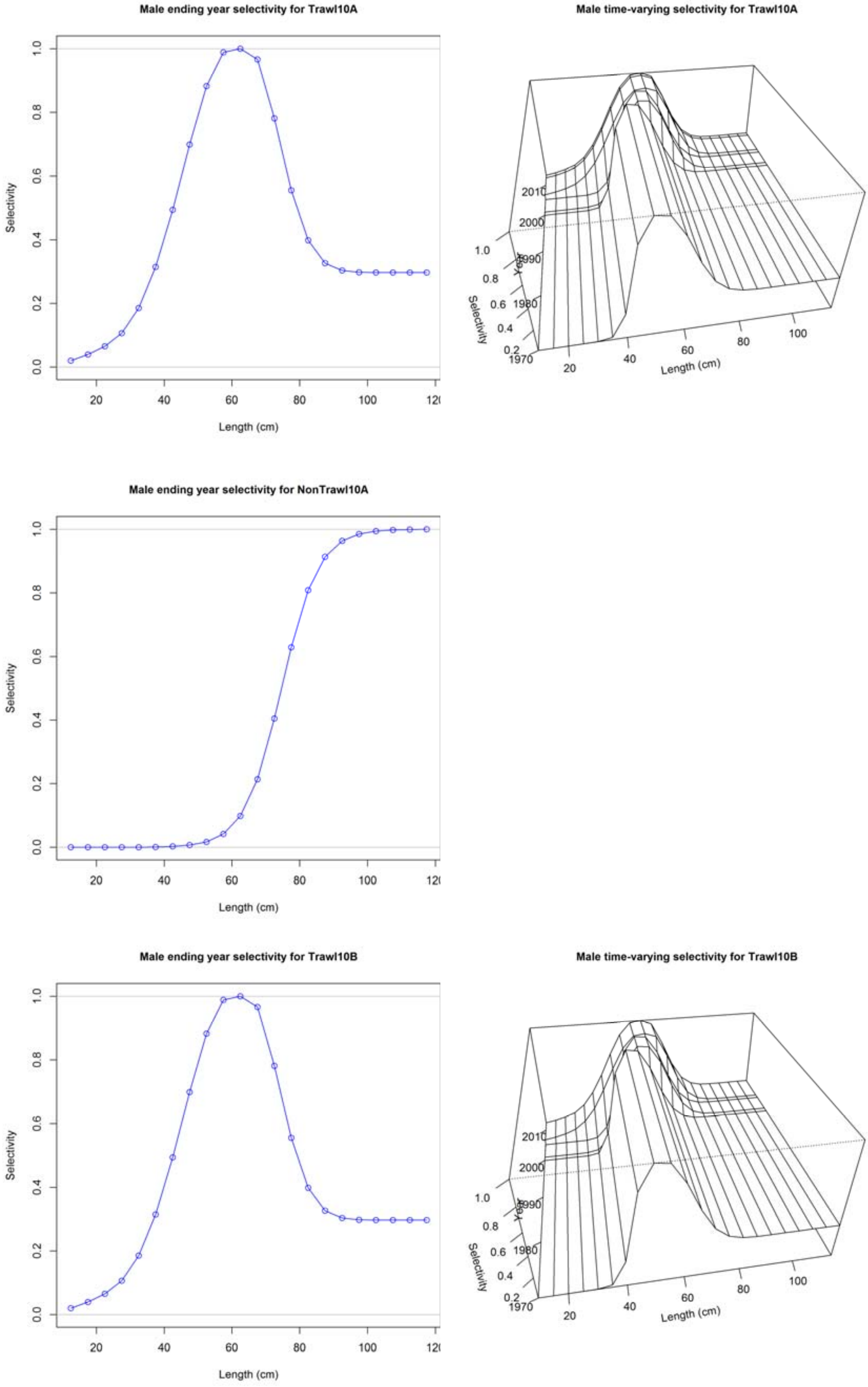


Figure 5.10 continued

(C) EAST AREA - ZONE MODEL



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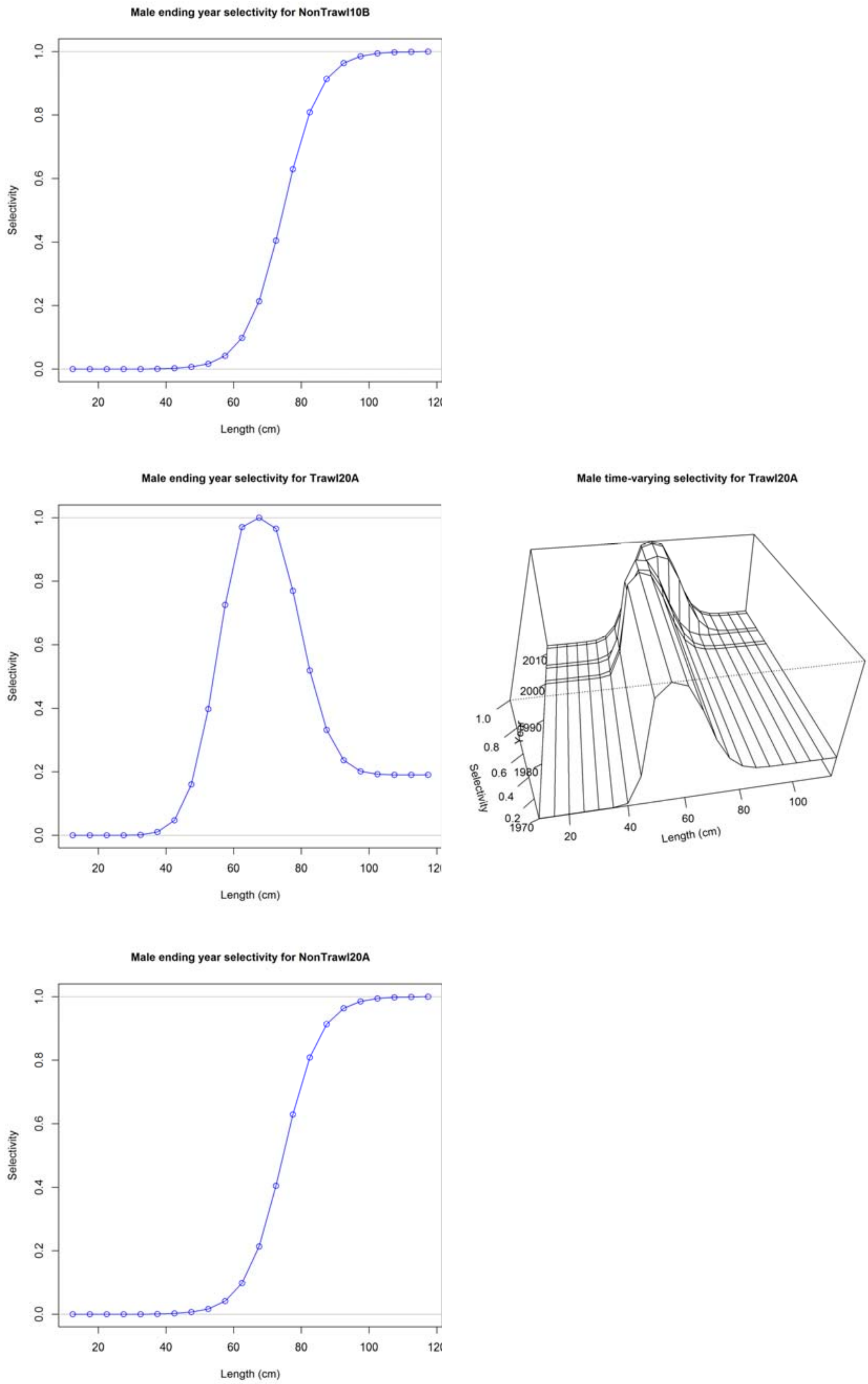

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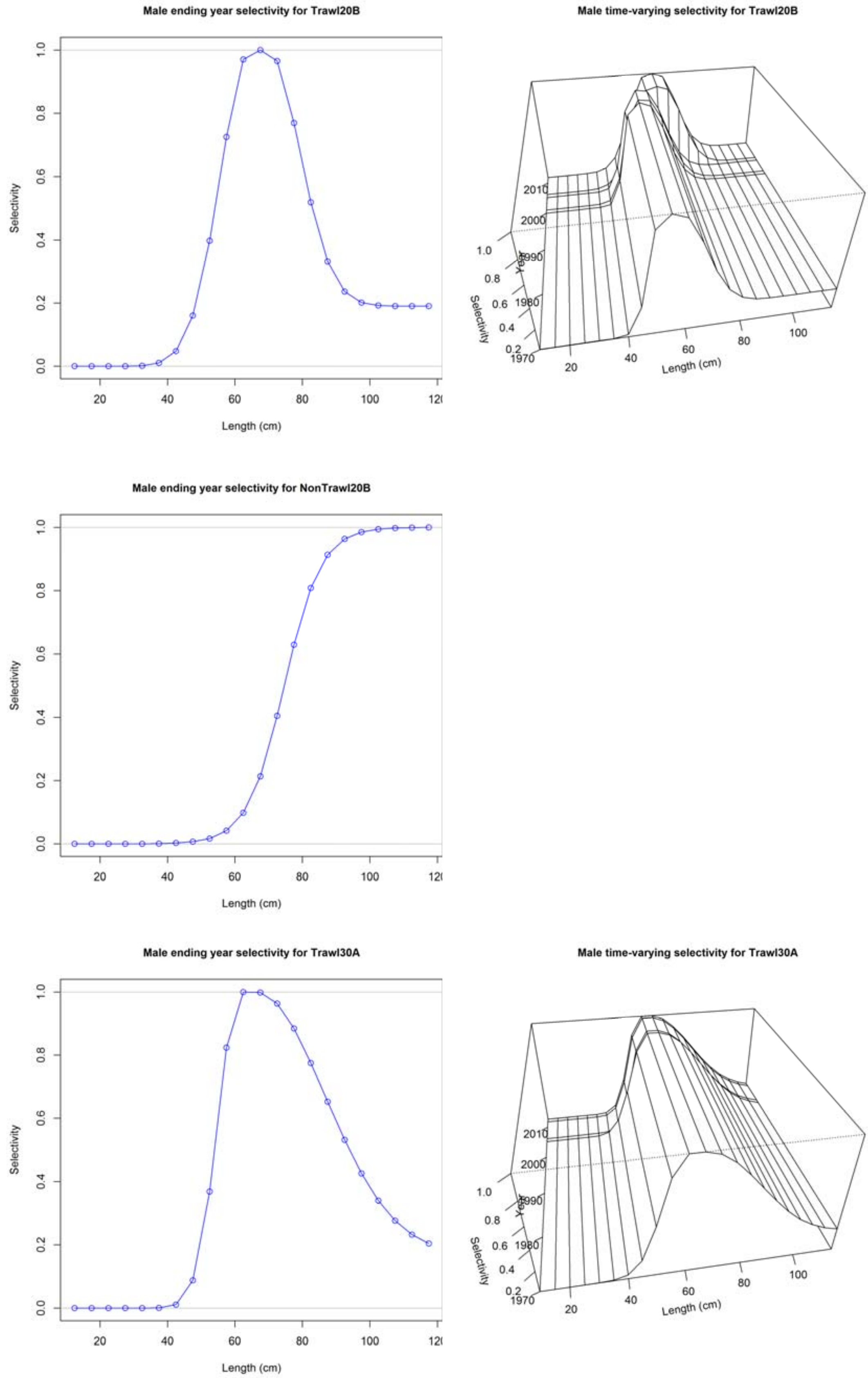

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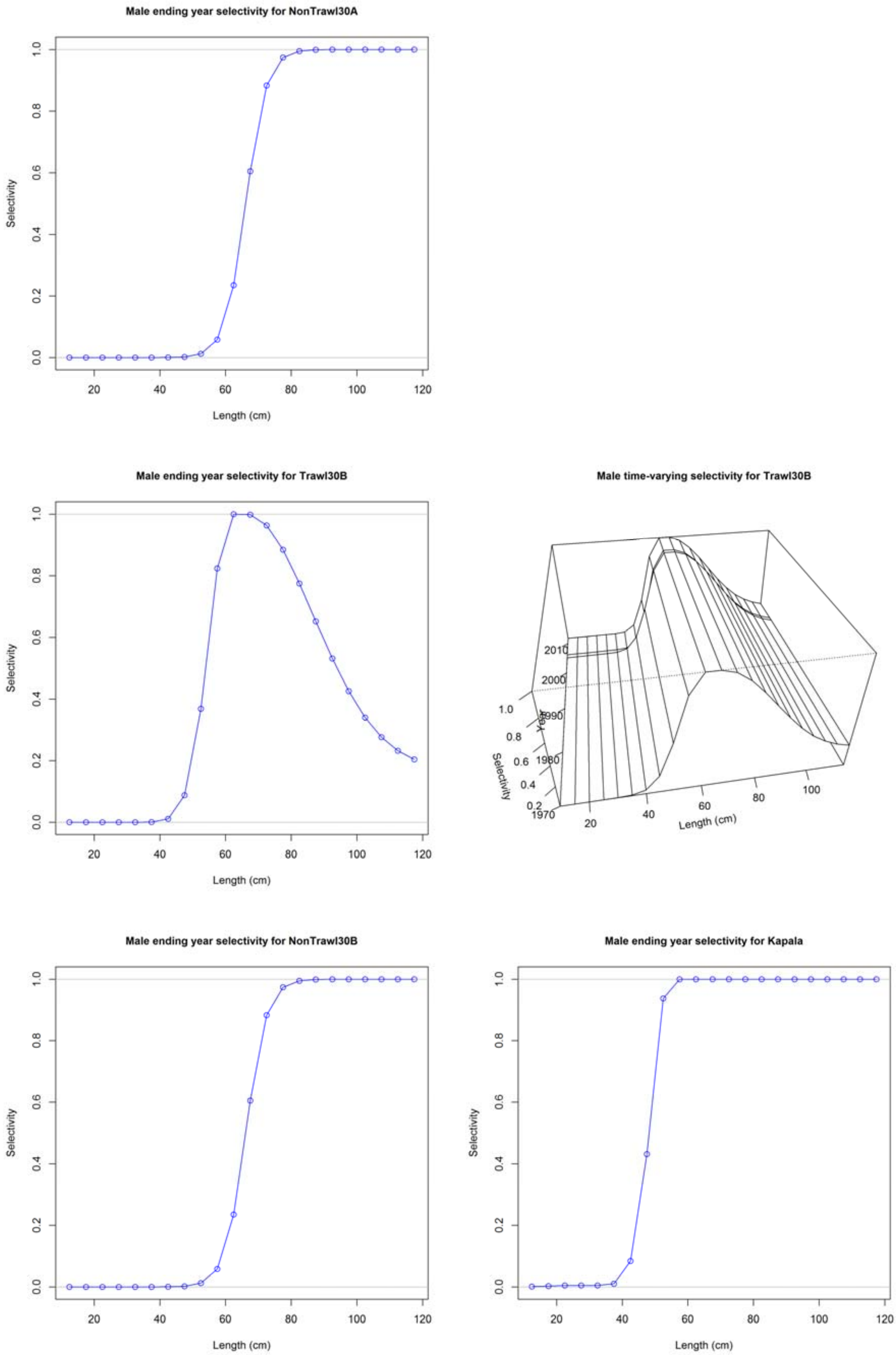


Figure 5.10 continued

(D) WEST AREA – ZONE MODEL

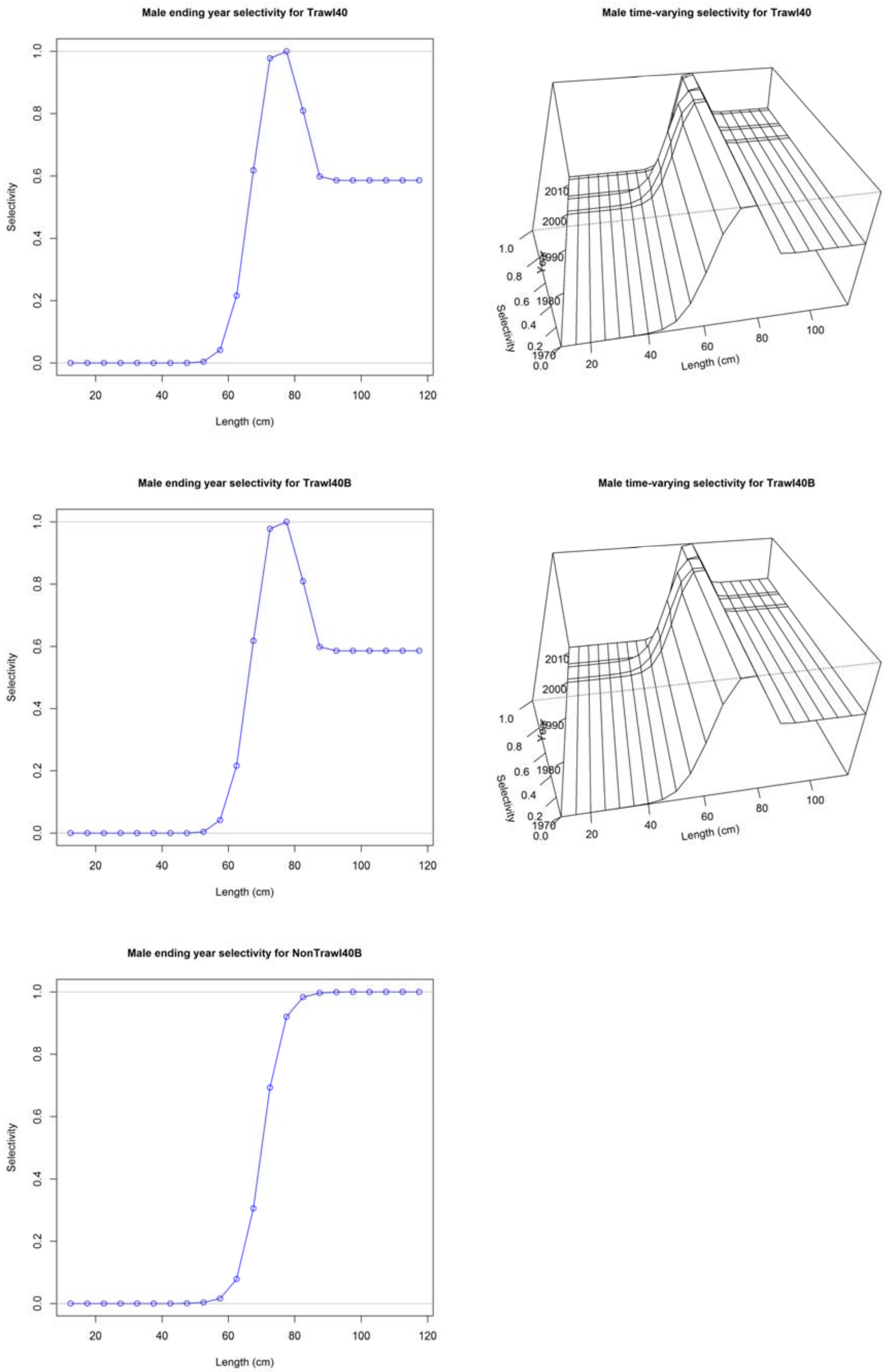


Figure 5.10 continued

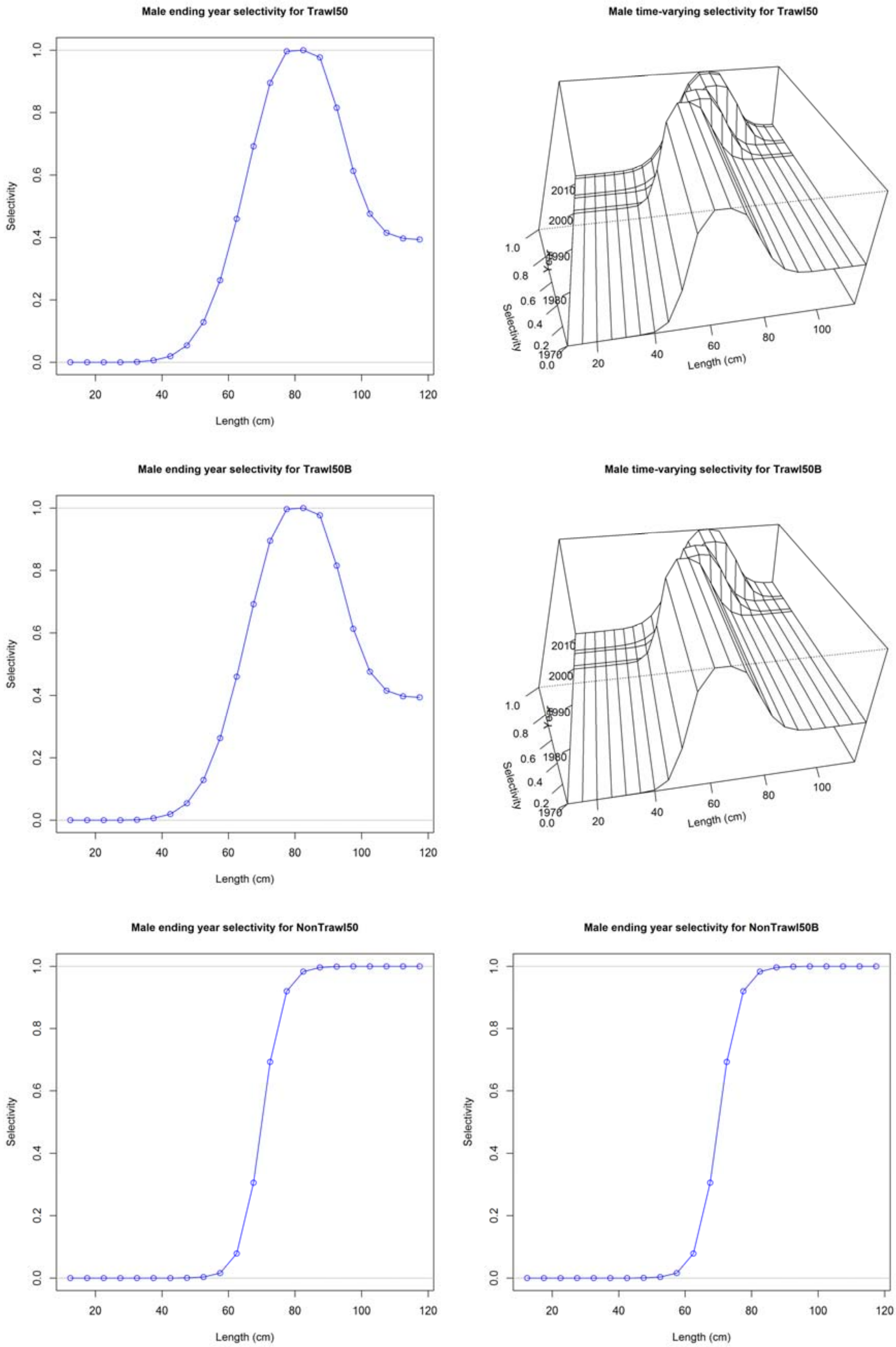
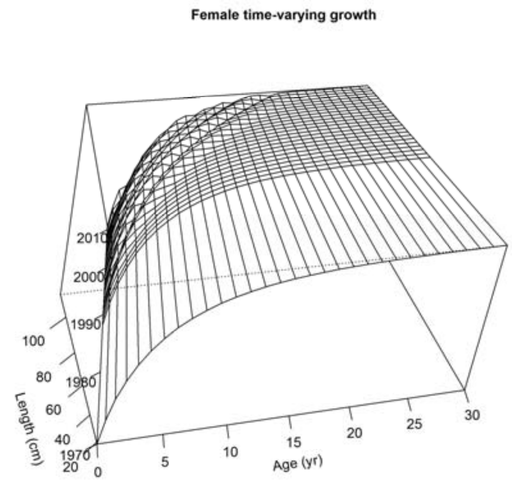
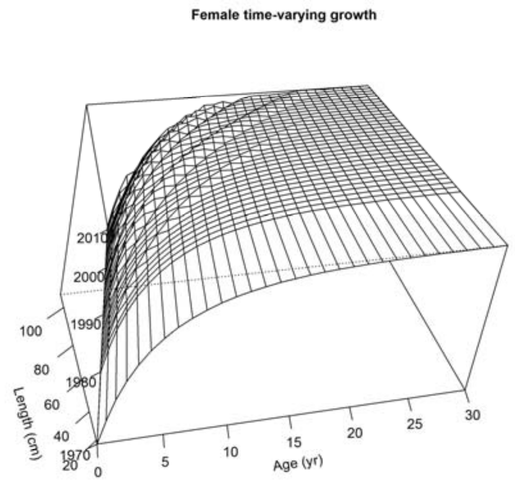


Figure 5.10 continued

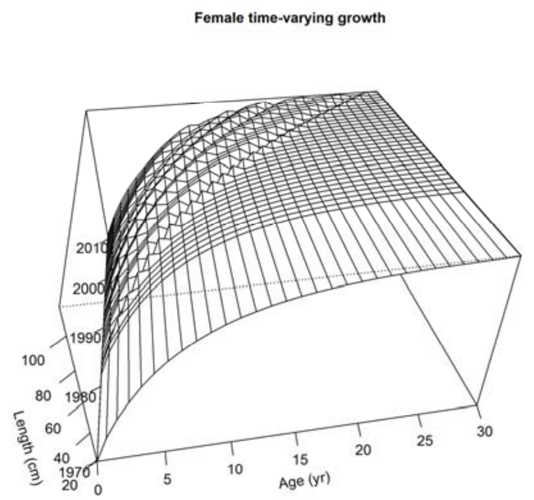
(A) EAST AREA – BASE-CASE MODEL



(B) WEST AREA – BASE-CASE MODEL



(C) EAST AREA - ZONE MODEL



(D) WEST AREA - ZONE MODEL

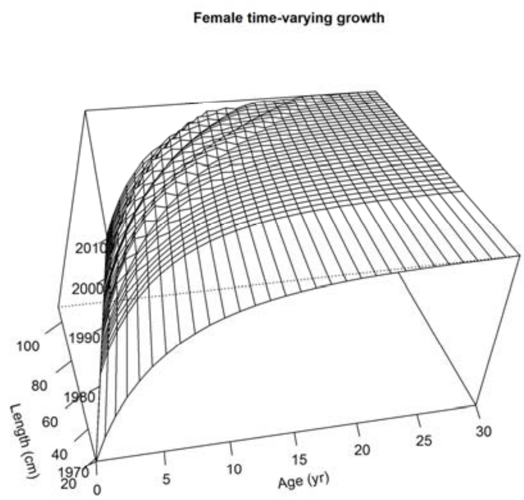


Figure 5.11. Estimated time-variable length-at-age series from base-case models.

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

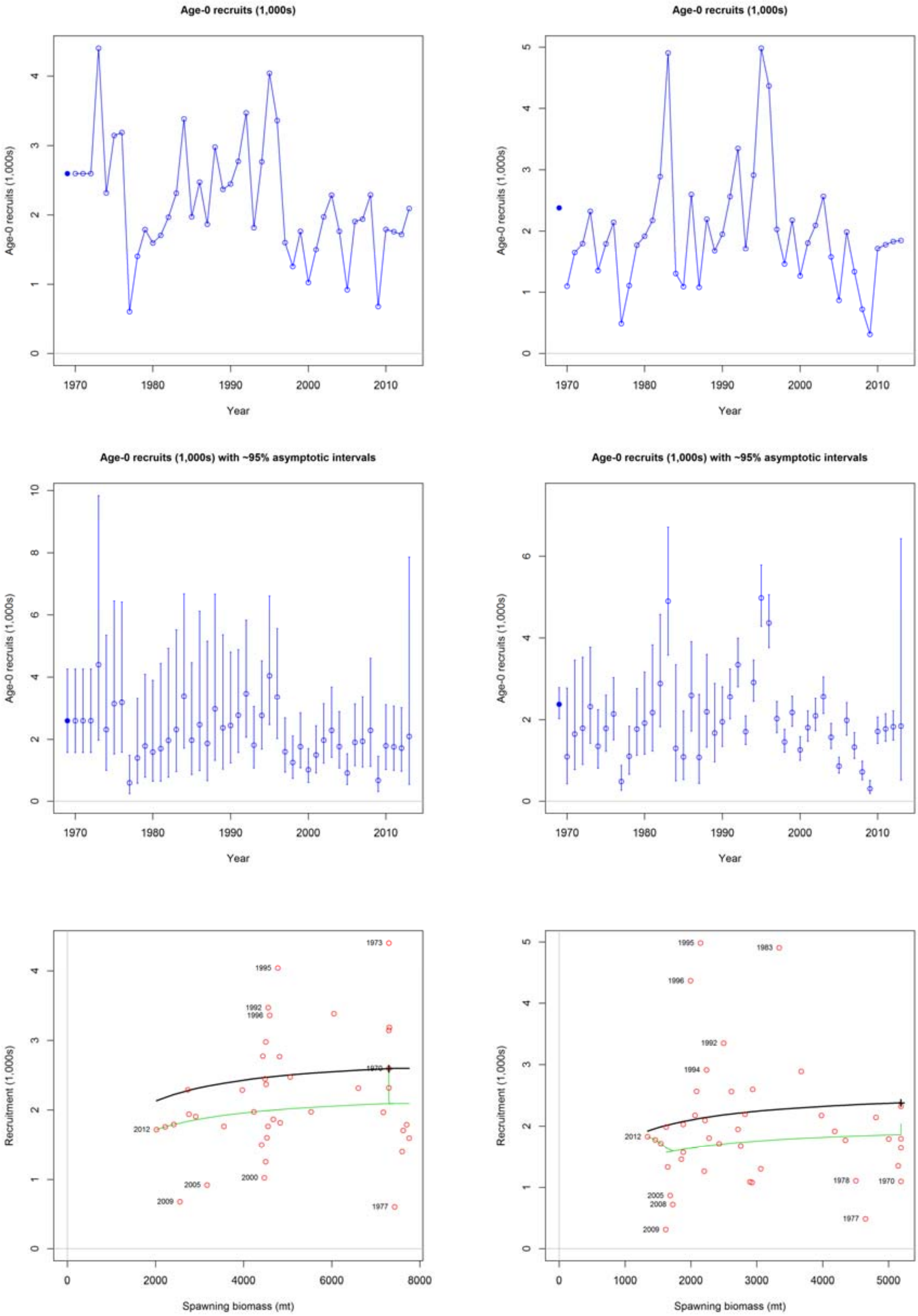


Figure 5.12. Recruitment estimates from base-case and zone-based models-.

(C) WEST AREA – BASE-CASE MODEL (D) WEST AREA – ZONE MODEL

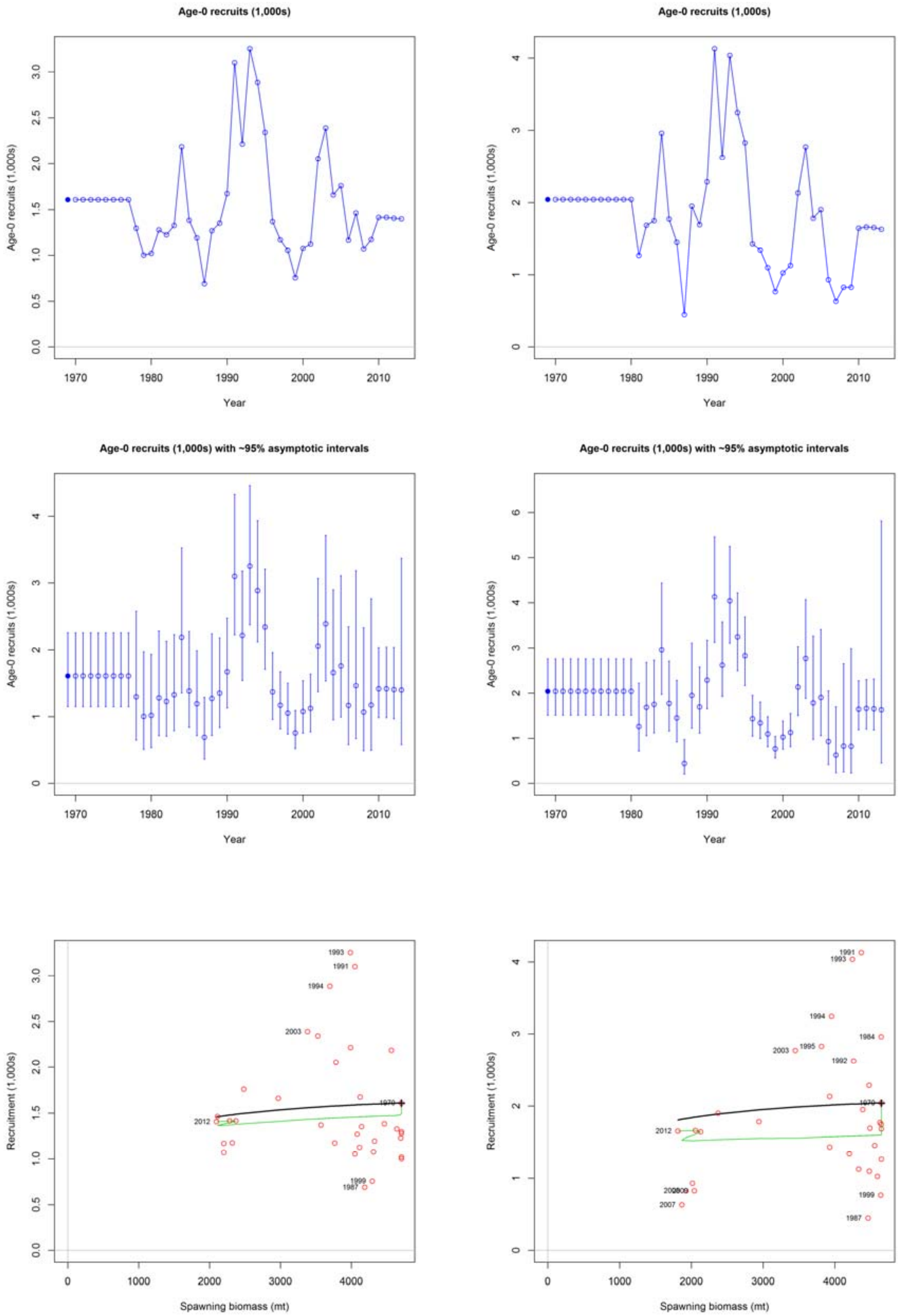


Figure 5.12 continued

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

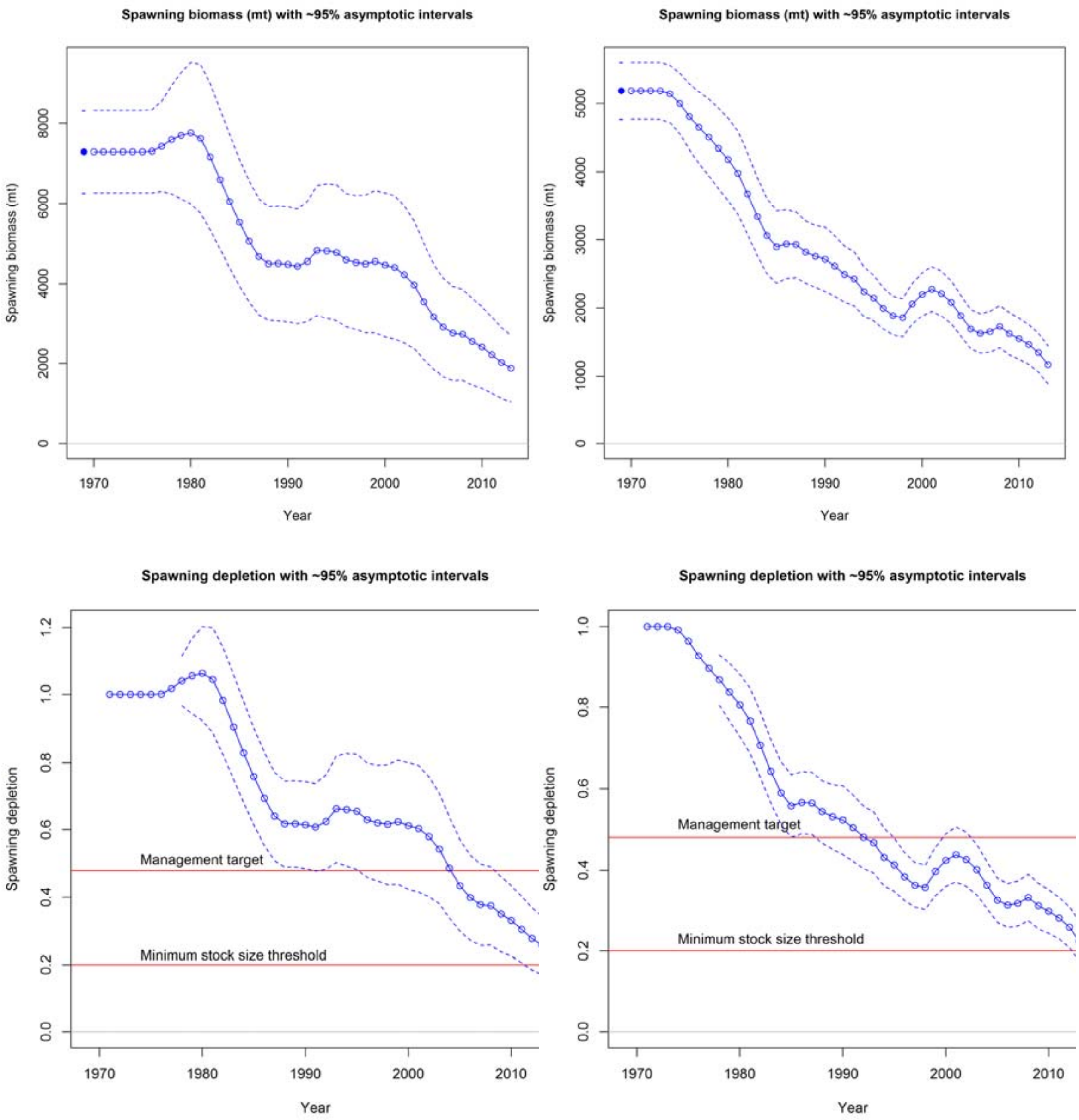


Figure 5.13.Time-trajectories of spawning biomass and depletion for the base-case and zone-based models

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

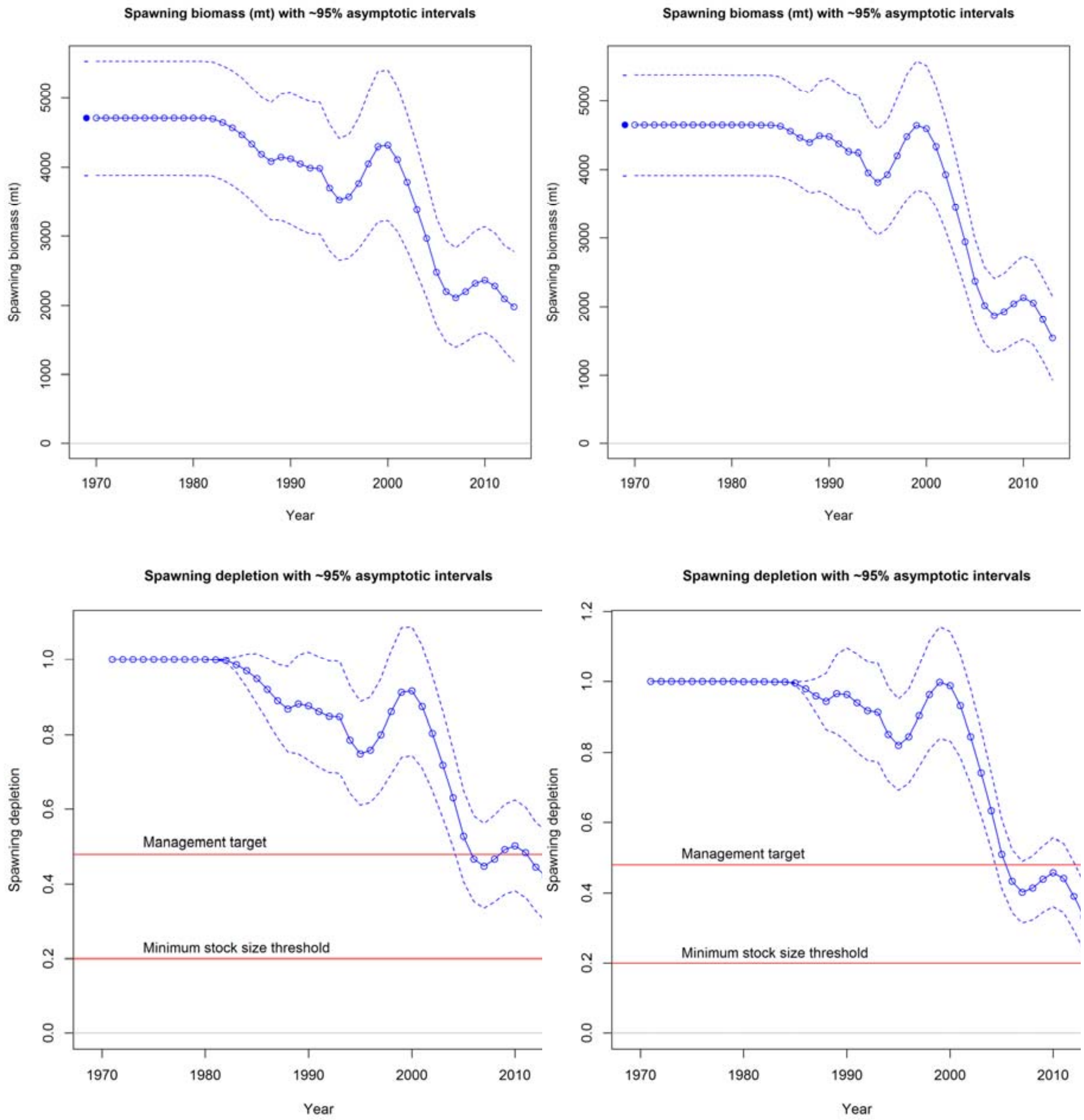
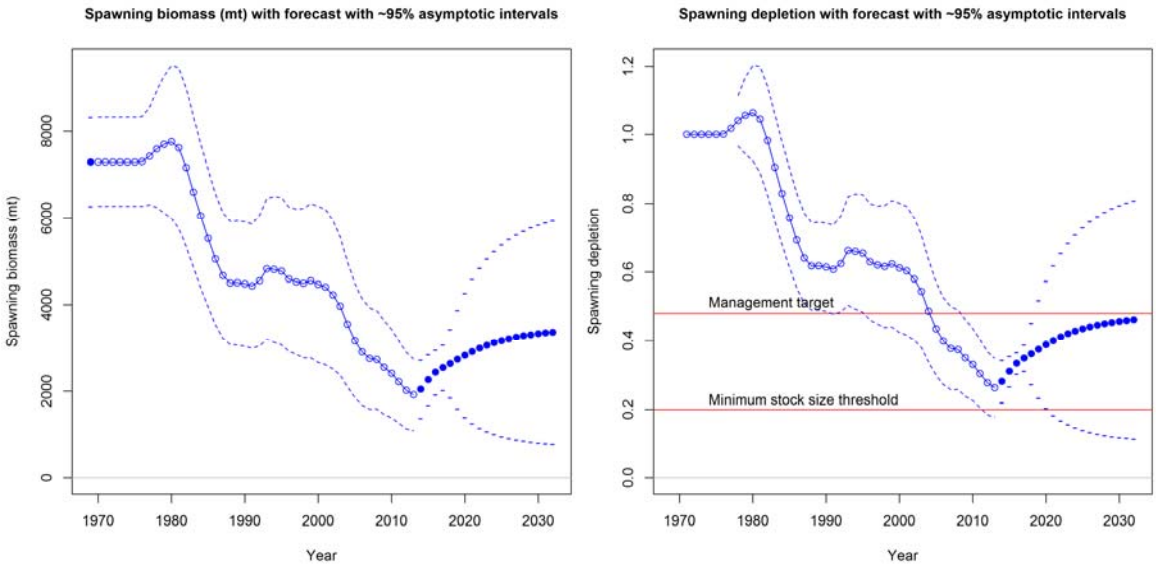
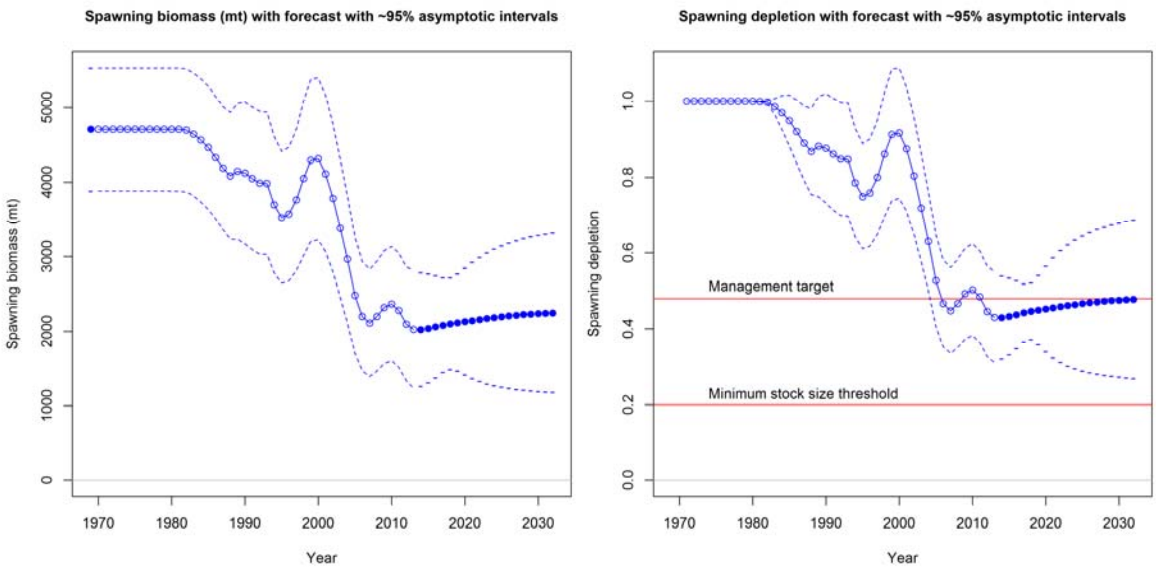


Figure 5.13 continued



(a) Eastern stock base-case projections



(b) Western stock base case projections

Figure 5.14. Stock projections of spawning biomass and spawning biomass depletion with forecast periods and 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 Tier 1 Harvest Control Rule.

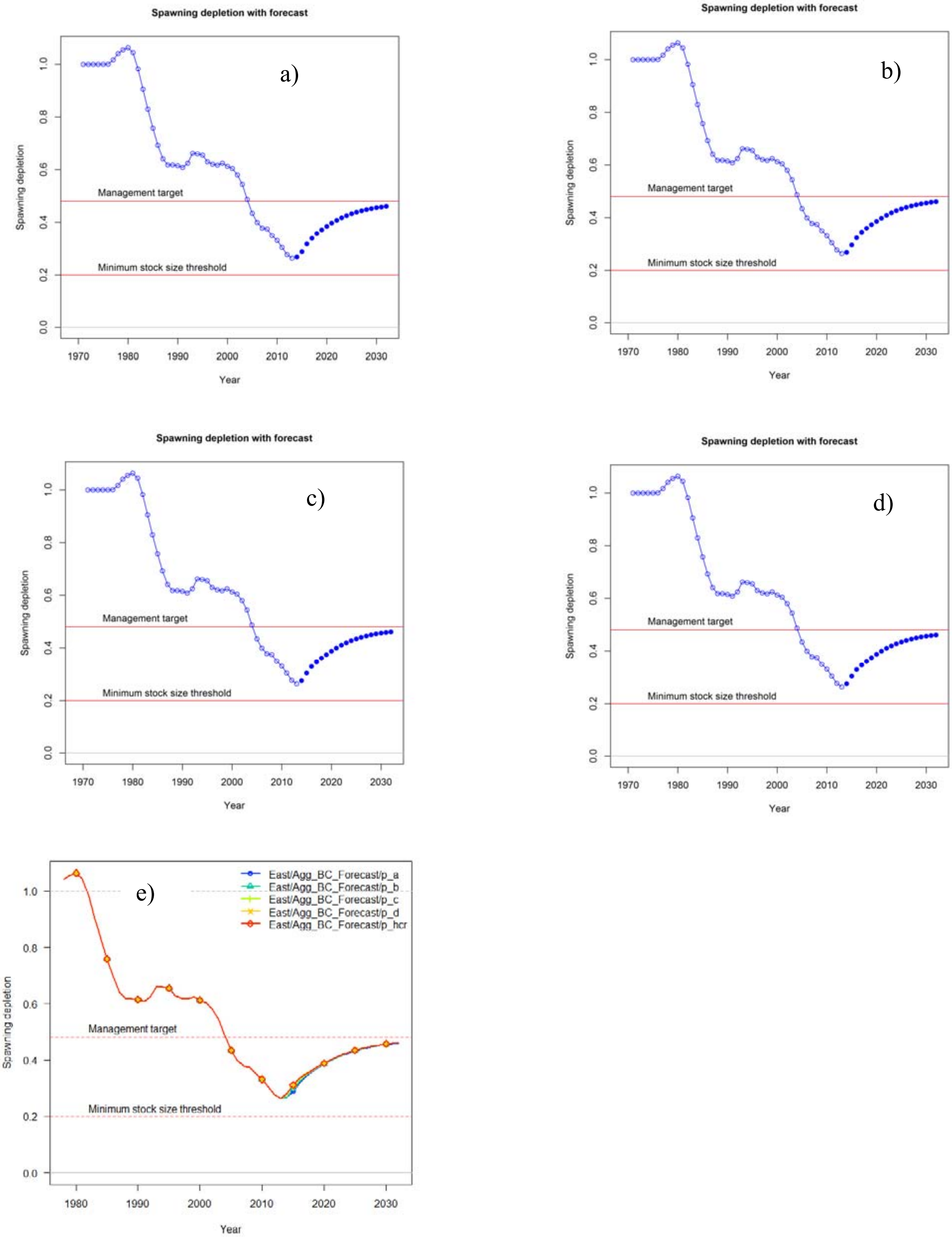
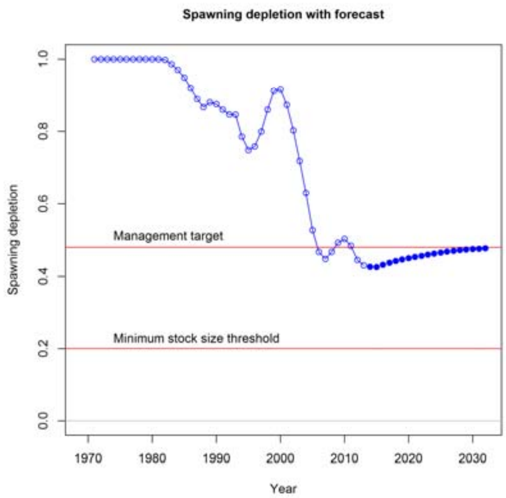
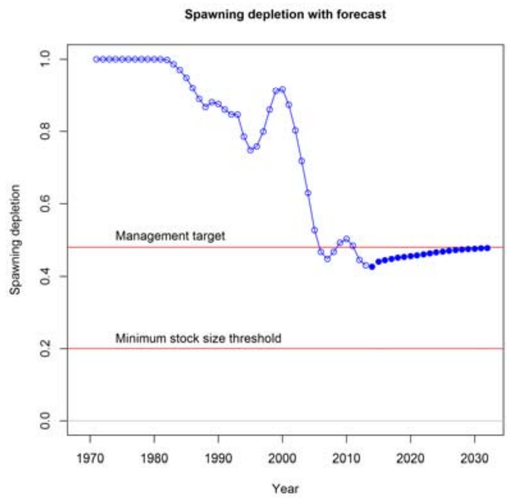


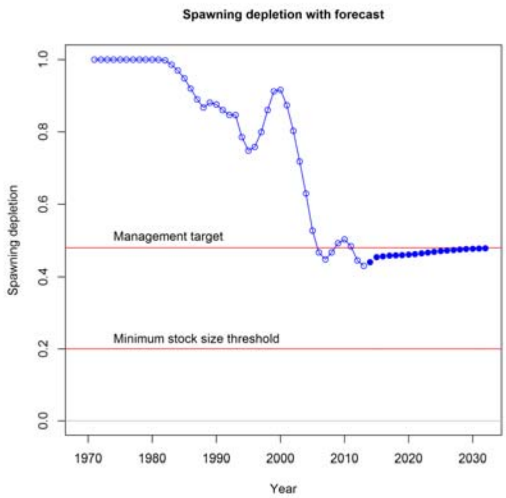
Figure 5.15.1 Additional stock projections of spawning biomass and spawning biomass depletion with forecast periods (with fixed input catches for two years) for the base-case models of the (1) eastern pink ling stock. Projection scenarios: (a) 1,000t per year for 2013 and 2014; (b) 1,000t for 2013, 700t for 2014; (c) 700t for 2013 and 2014; and (d) 700t for 2013, 500t for 2014. Plot (e) shows a comparison of stock projection scenarios versus projection following SESSF Tier 1 Harvest Control Rule.



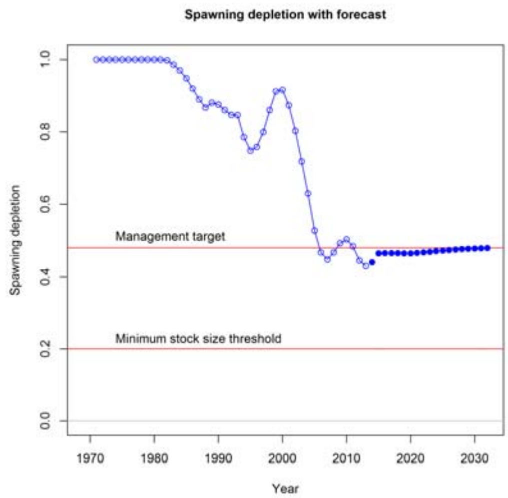
(a)



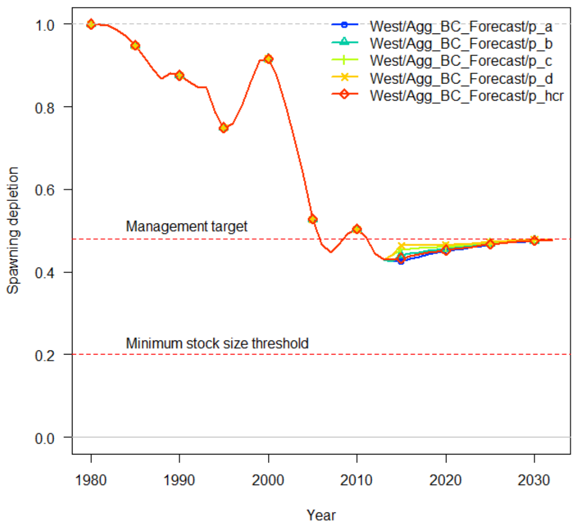
(b)



(c)



(d)



(e)

Figure 5.15.2 Additional stock projections of spawning biomass and spawning biomass depletion with forecast periods (with fixed input catches for two years) for the base-case models of the (2) western pink ling stock.

Projection scenarios: (a) 1,000t for 2013 and 2014; (b) 1000t for 2013, 700t for 2014; (c) 700t for 2013 and 2014; (d) 700t for 2013, 500t for 2014. Plot (e) shows a comparison of stock projection scenarios versus projection following SESSF Tier 1 Harvest Control Rule.

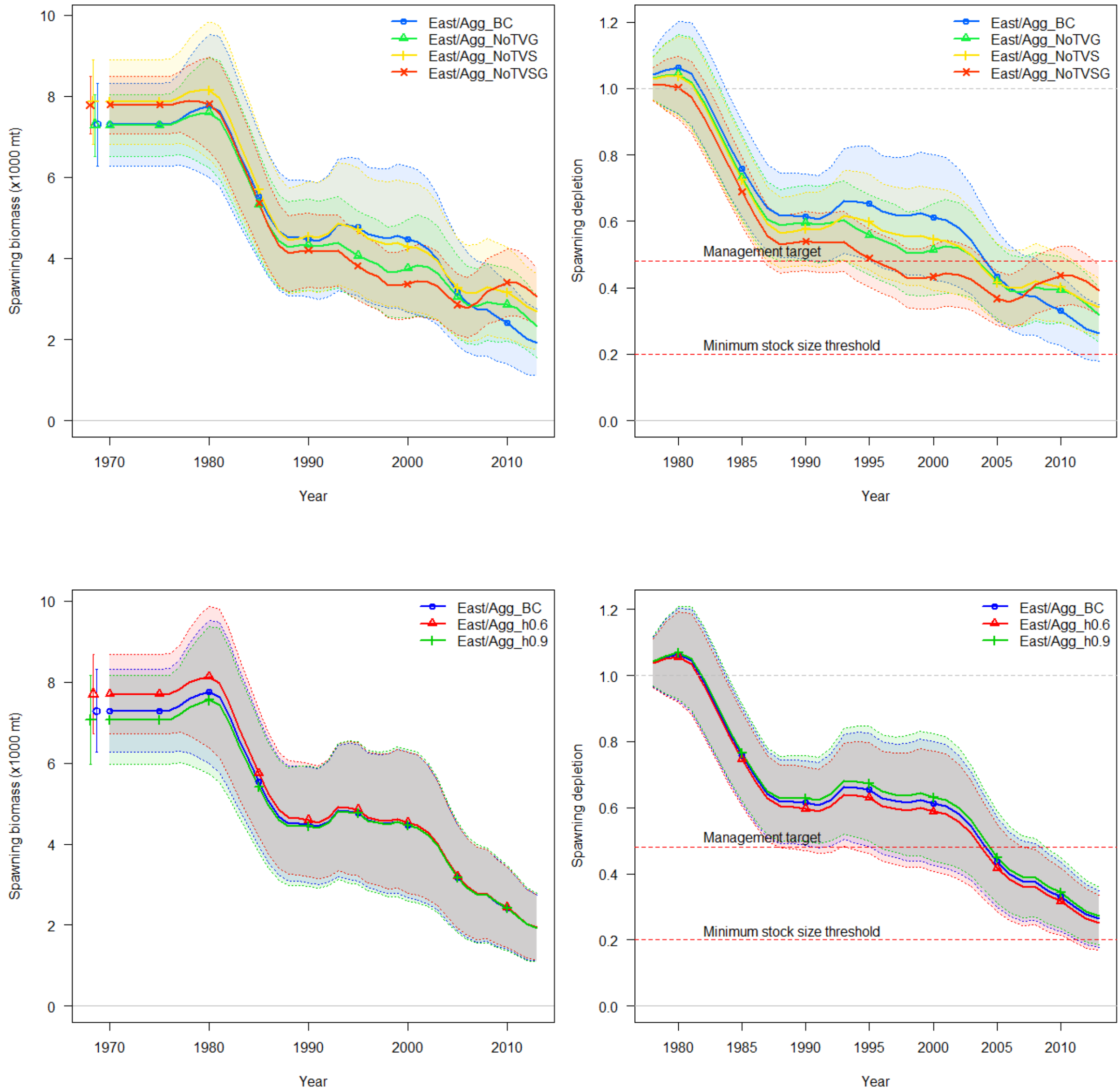


Figure 5.16. Time-trajectories of spawning biomass and depletion for sensitivities compared with base-case models. In plot legends: East = Eastern Stock, West = Western Stock, Agg = Base-case Model, Zone = Zone-based Model, BC = Base-case Model, NoTVG = No Time-varying Growth, NoTVS = No Time-varying Selectivity, NoTVSG = No Time-varying Selectivity or Growth, h = Steepness fixed at specified value, NoKap = No Kapala Data, NoNTrCPUE = No Non-trawl CPUE Series, NoGAB = No GAB Data, CCV = Constant CV on CPUE Series (CV = 0.1), TCPUE = Targetted CPUE Series, wla = Re-weighted Length and Age Data Components with specified lambda (weighting) values. Each series bounded by colour coded 95% confidence intervals and corresponding shading. Overlapping confidence intervals show mixed colours to indicate overlapping estimate bounds.

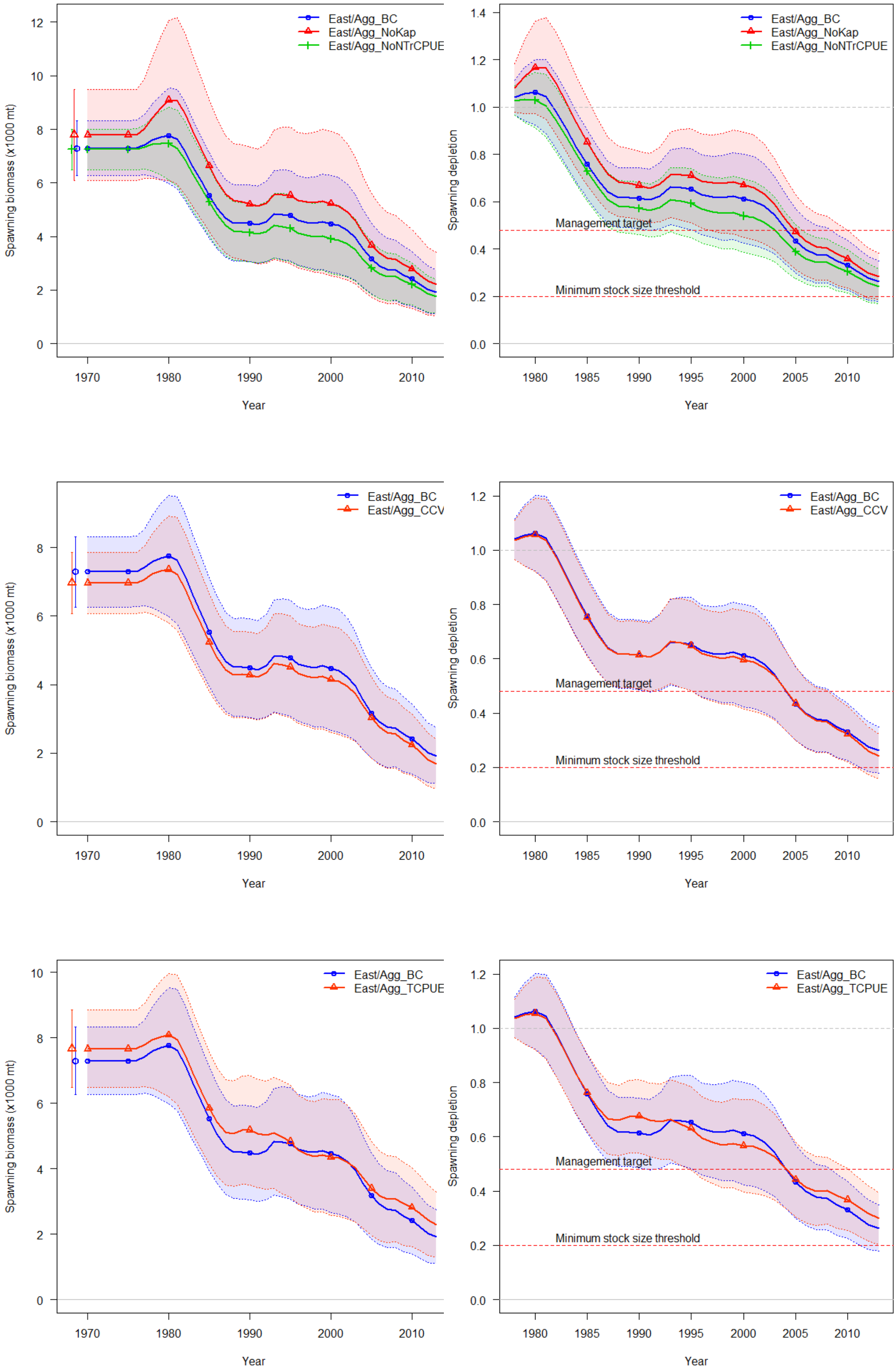


Figure 5.16 continued

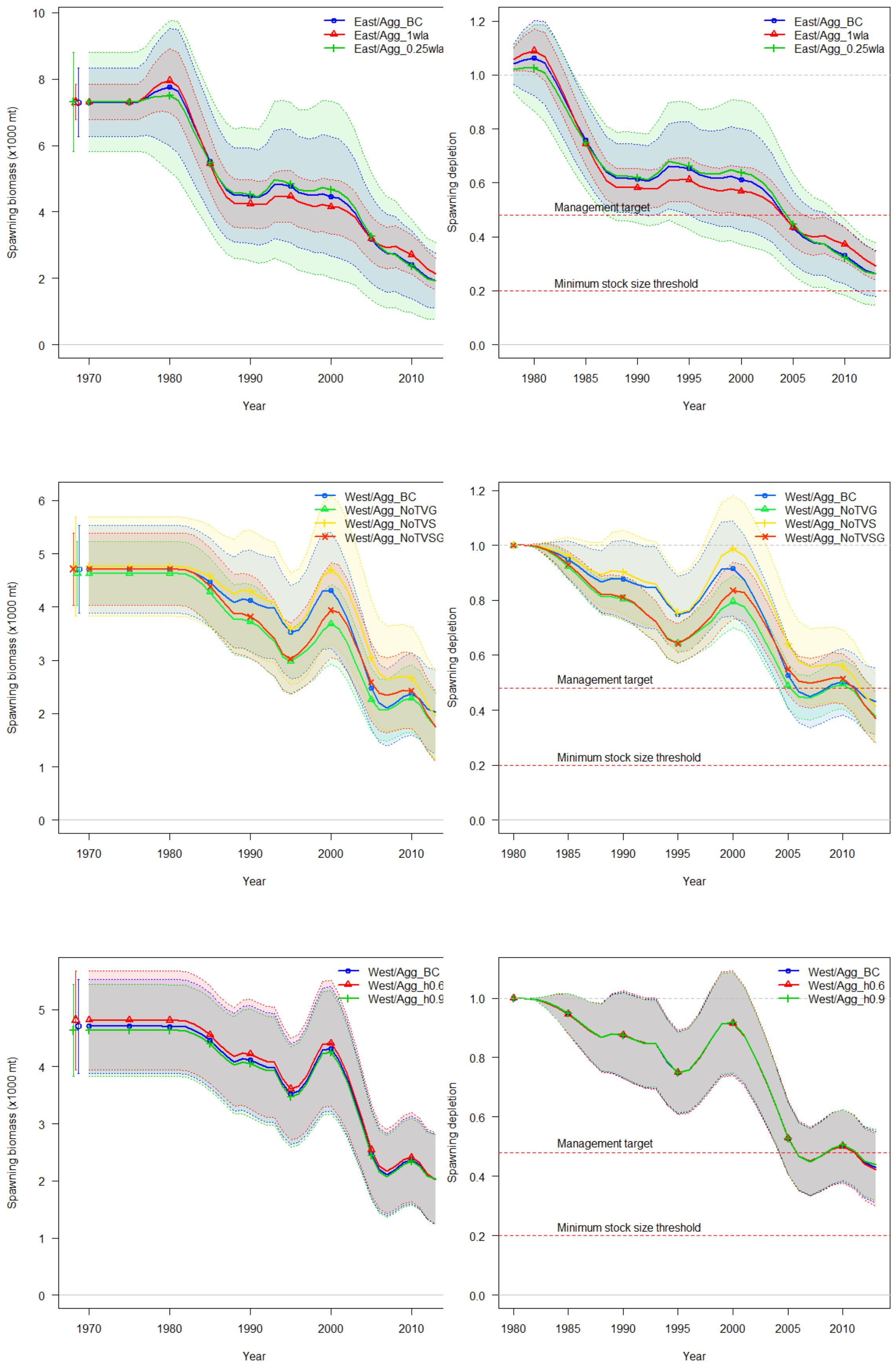


Figure 5.16 continued

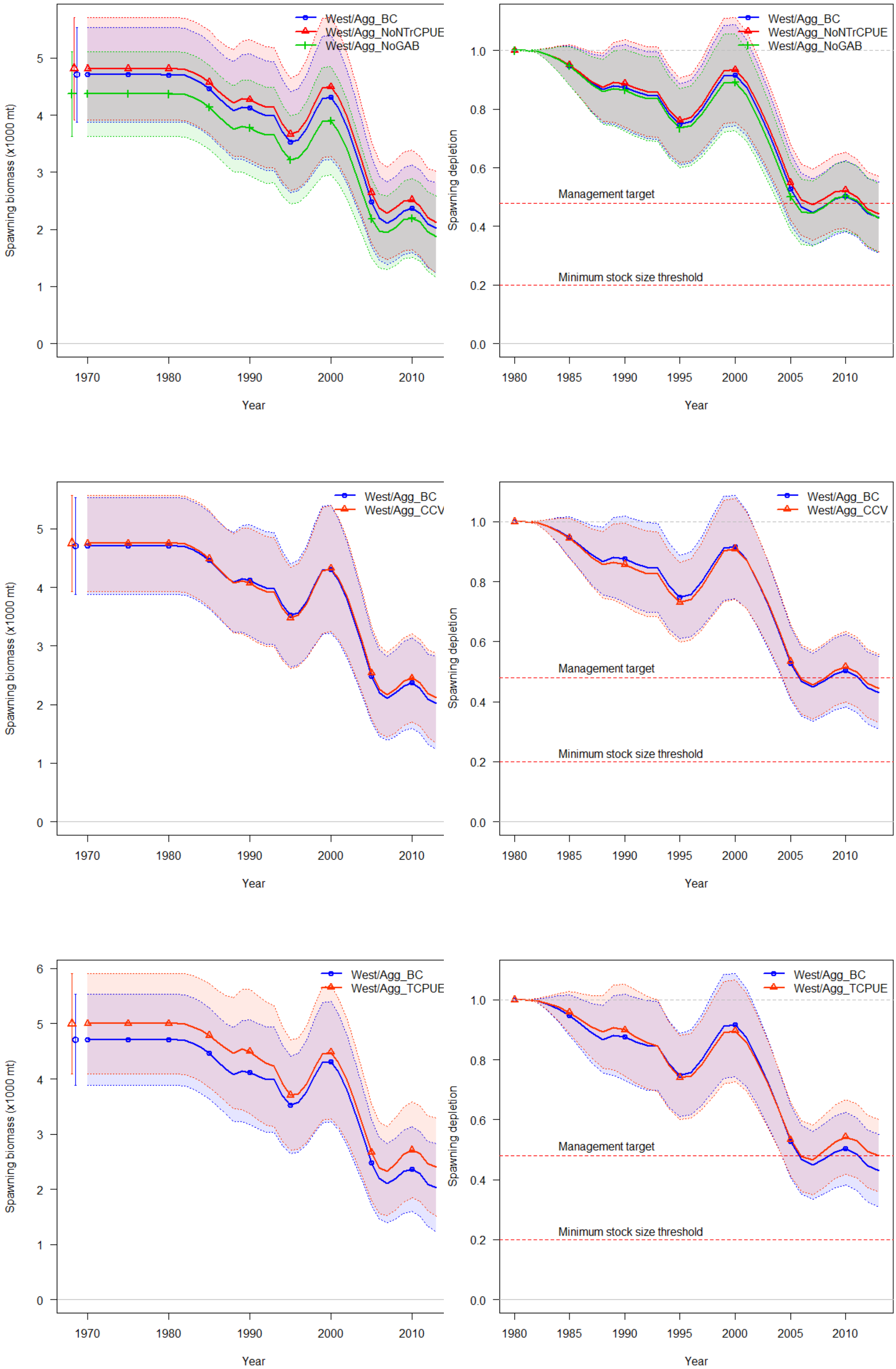


Figure 5.16 continued

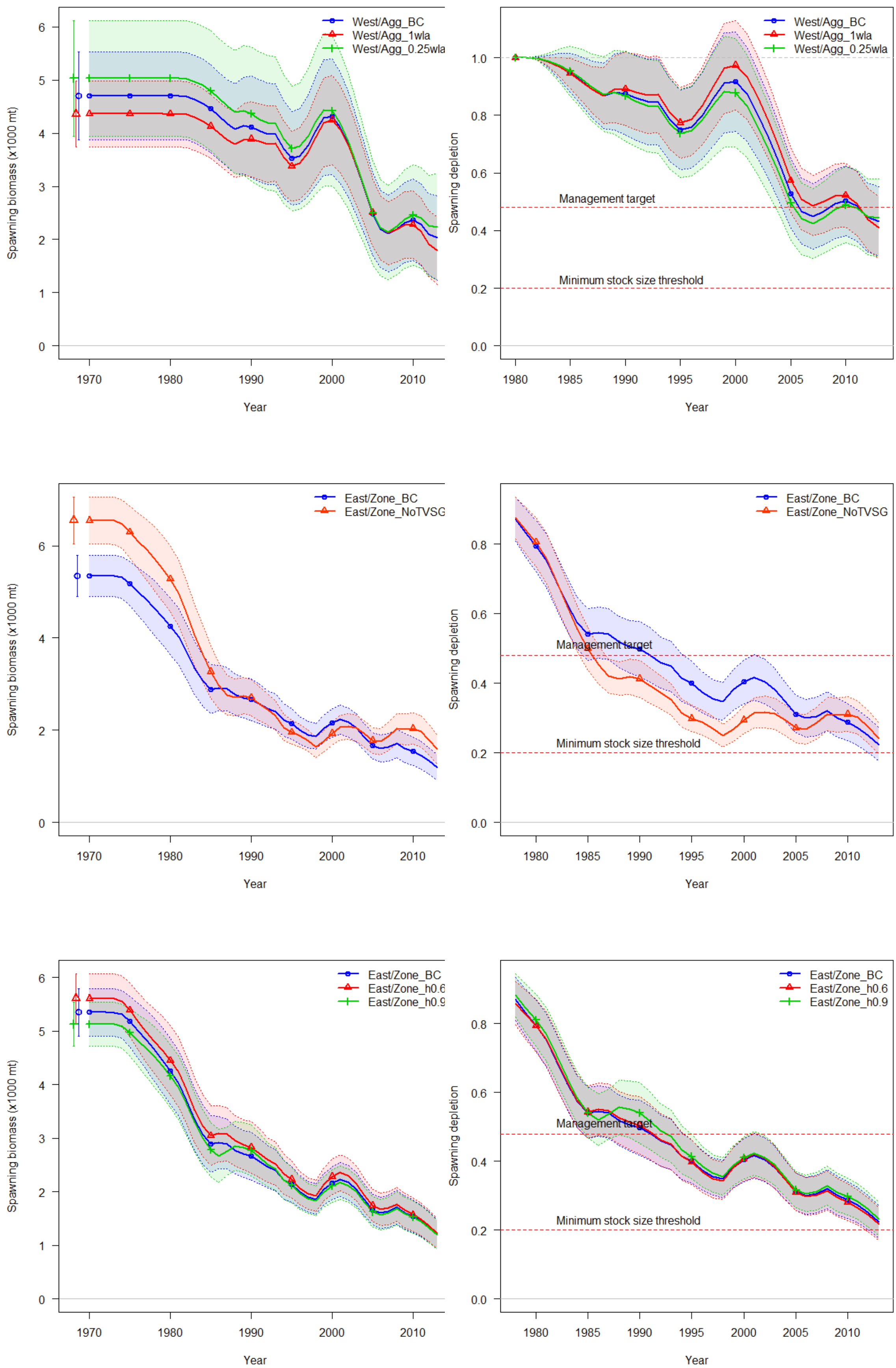


Figure 5.16 continued

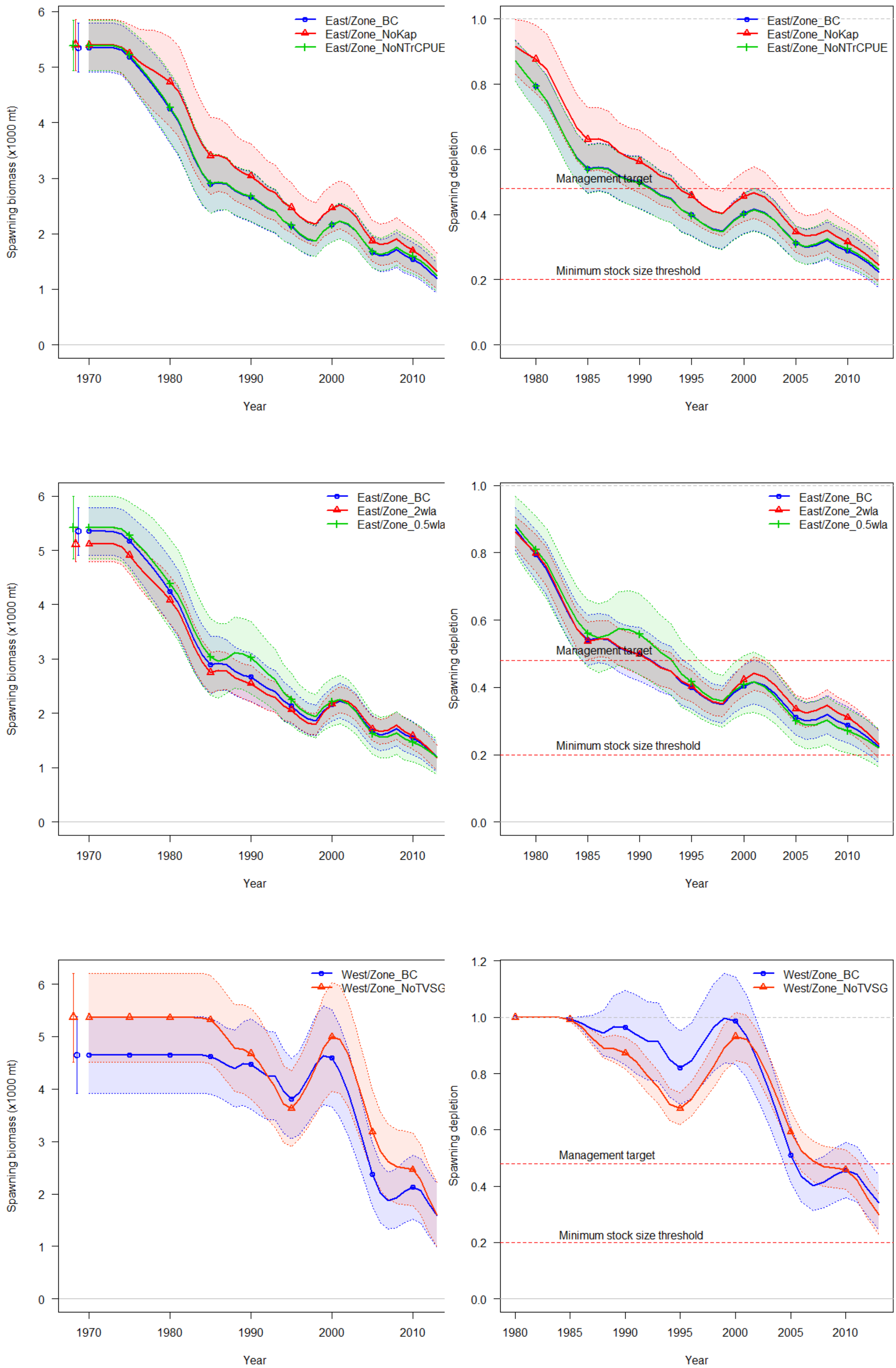


Figure 5.16 continued

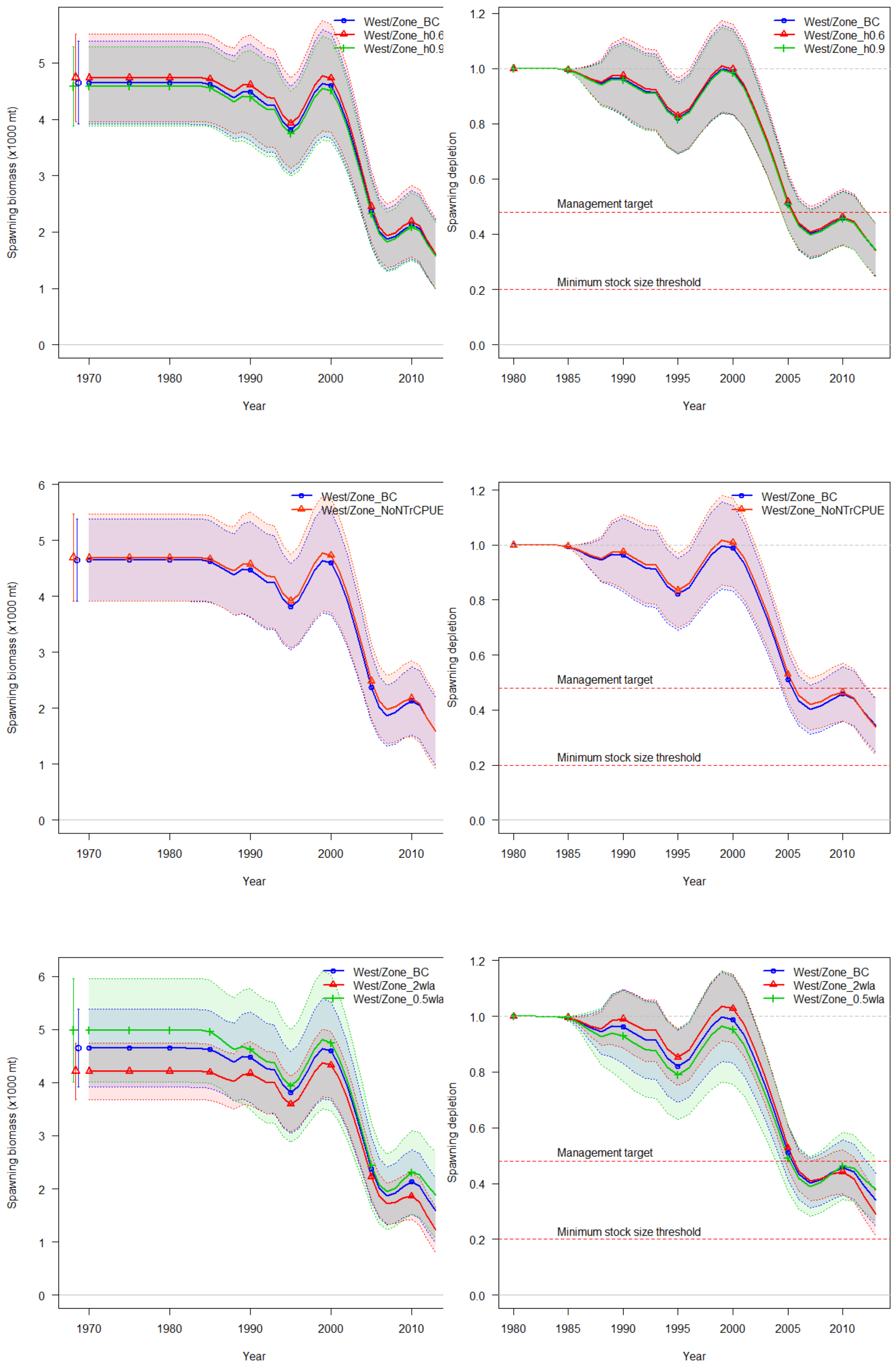
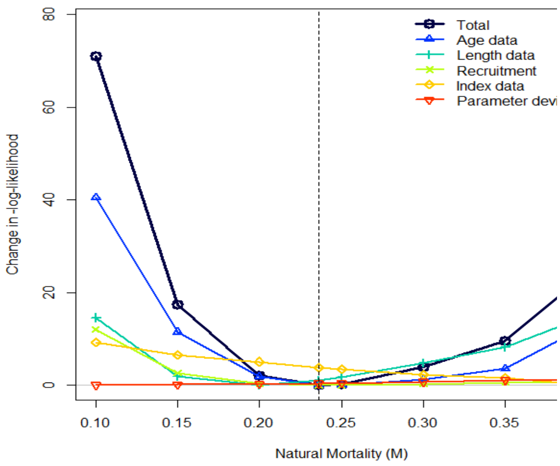
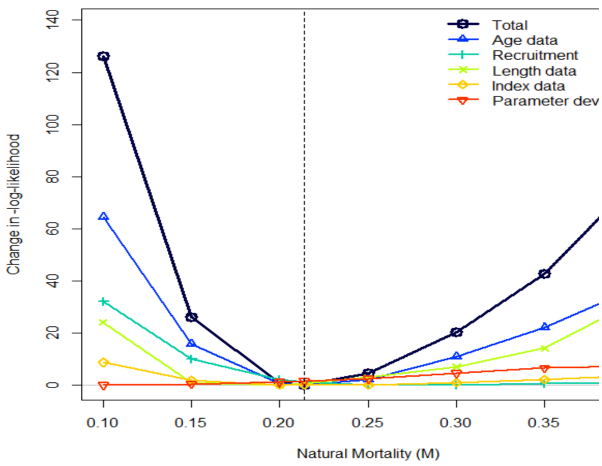


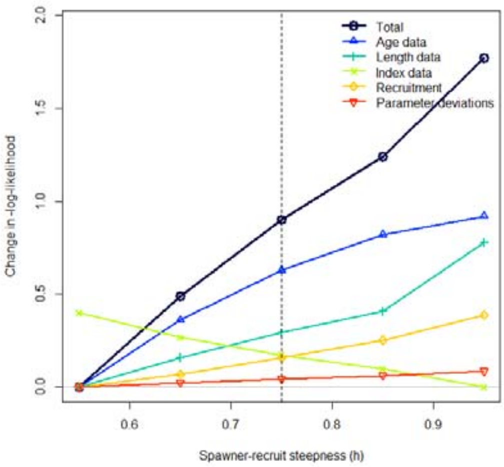
Figure 5.16 continued



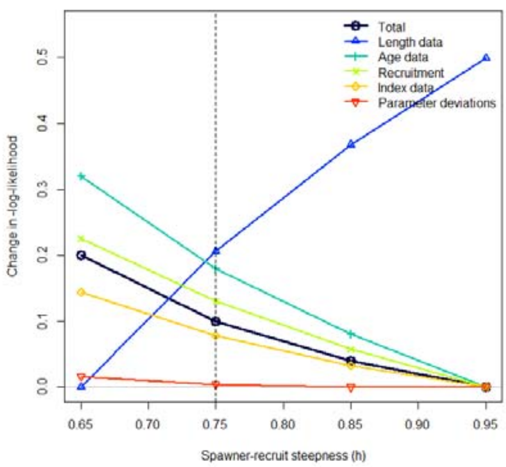
17.1 East base-case model – likelihood profile for *M*. Dashed vertical line shows maximum likelihood estimate *M*=0.24 yr^{-1}..



17.2 West base-case model – likelihood profile for *M*. Dashed vertical line shows maximum likelihood estimate *M*=0.21 yr^{-1}.

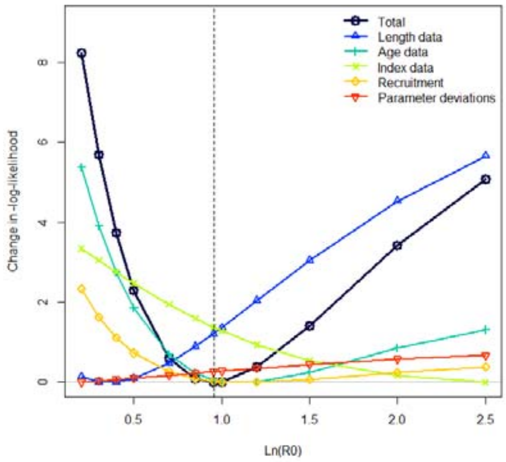


17.3 East base-case model – likelihood profile for *h*. Dashed line shows the assumed value *h*=0.75.

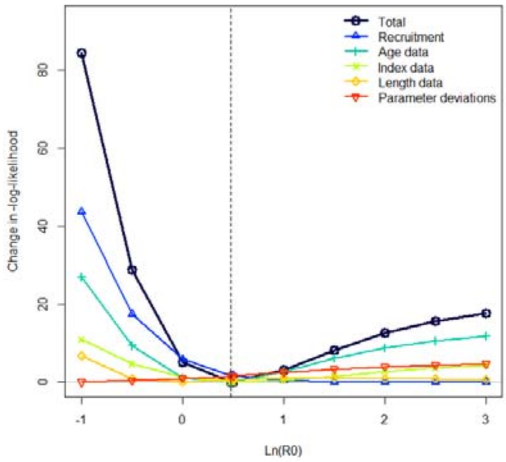


17.4 West base-case model – likelihood profile for h. Dashed line shows the assumed value *h*=0.75.

Figure 5.17. Likelihood profiles for natural mortally (*M*), spawner-recruit steepness (*h*) and recruitment (at pre-exploitation equilibrium) (R_0) for the base-case models.



17.5 East base-case model – likelihood profile for R_0. Dashed line shows the maximum likelihood estimate Ln(R_0)=0.95.



17.6 West base-case model – likelihood profile for R_0. Dashed line shows the maximum likelihood estimate Ln(R_0)=0.48.

Figure 5.17 continued

5.17 Appendix A: Evaluation of a possible change in catchability in 2000/2001

One of the key differences between the 2010 and 2011 assessments is that the 2010 assessment assumed that catchability for the trawl catch-rate series in the east changed between 2000and 2001. However, no direct evidence was available to support such a change, although considerable anecdotal information suggests that the change in catch-rate from 2000 to 2001 does not match observations. An evaluation is conducted in this section of several indirect sources of information regarding a possible change in catchability. The analyses cannot be definitive, but provide an indication of the support for a change. Three alternative approaches are considered:

- changes in catch composition over time;
- impacts of changed targeting as inferred from the value of the catch
- impacts of different trends in different depth-zones

A.1 Changes in catch composition

A Principal Components Analysis (PCA) was conducted on the catch composition data (1986-2010) by trawl vessels for Zones 10, 20 and 30. Vessels had to take at least 10t (at least 1t of ling) in a year to be included in the analysis. The selected data were aggregated over vessels and the species were grouped into blue grenadier (GRE), flathead (FLT), gemfish (GEM), Jackass morwong (MOW), pink ling (LIG), mirror dory (DOM), ocean perch (REG), red fish (RED), red royal prawn (PRR), silver warehou (TRE), and "others".

The PCAs for Zones 10, 20, and 30 respectively explained 69%, 59% and 54% of the variance. The biplots (Fig. App.A.1) highlight several patterns, particularly for Zones 10 and 20. Specifically, the late 1980s are periods where gemfish was a key component of the catch. More importantly for the analyses related to changes in targeting, the late-1990s – early-2000s, 2002-05 and 2006+ period clump for Zone 10 while the years 1993-1999 and 2000+ clump for Zone 20. This is indicative of a change in abundance or targeting.

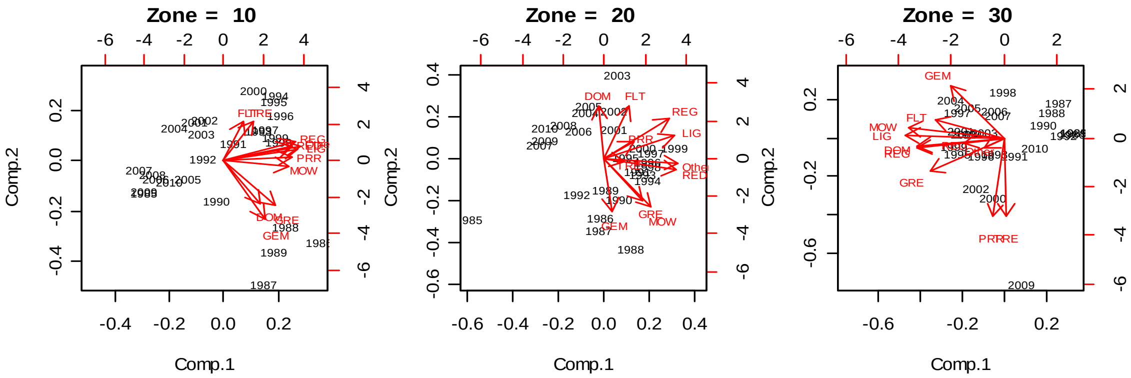


Figure App.A.1. Outputs of the Principal Components Analysis for Zones 10, 20 and 30

A.2 Including targeting

Klaer and Smith (2012) developed a method for identifying targeted shots. The data for shots made on the slope in Zones 10, 20 and 30 between 1986-2010 by vessels which took at least 10t (i.e. only vessel-year combinations with 10t of catch) were extracted. The mean proportion of the catch of ling which was ascribed by the Klaer-Smith method to targeted shots was computed for each year and the average proportion targeted was computed for 1995-98 and 2002-05 (before and after the possible change in catchability). Figure App.A.2 shows the ratio for the proportion of the catch which was targeted in 2002-05 relative to that for 1995-98 by vessel (only vessels which caught ling in two years within 1995-98 and 2002-05 are included in Figure App.A.2)

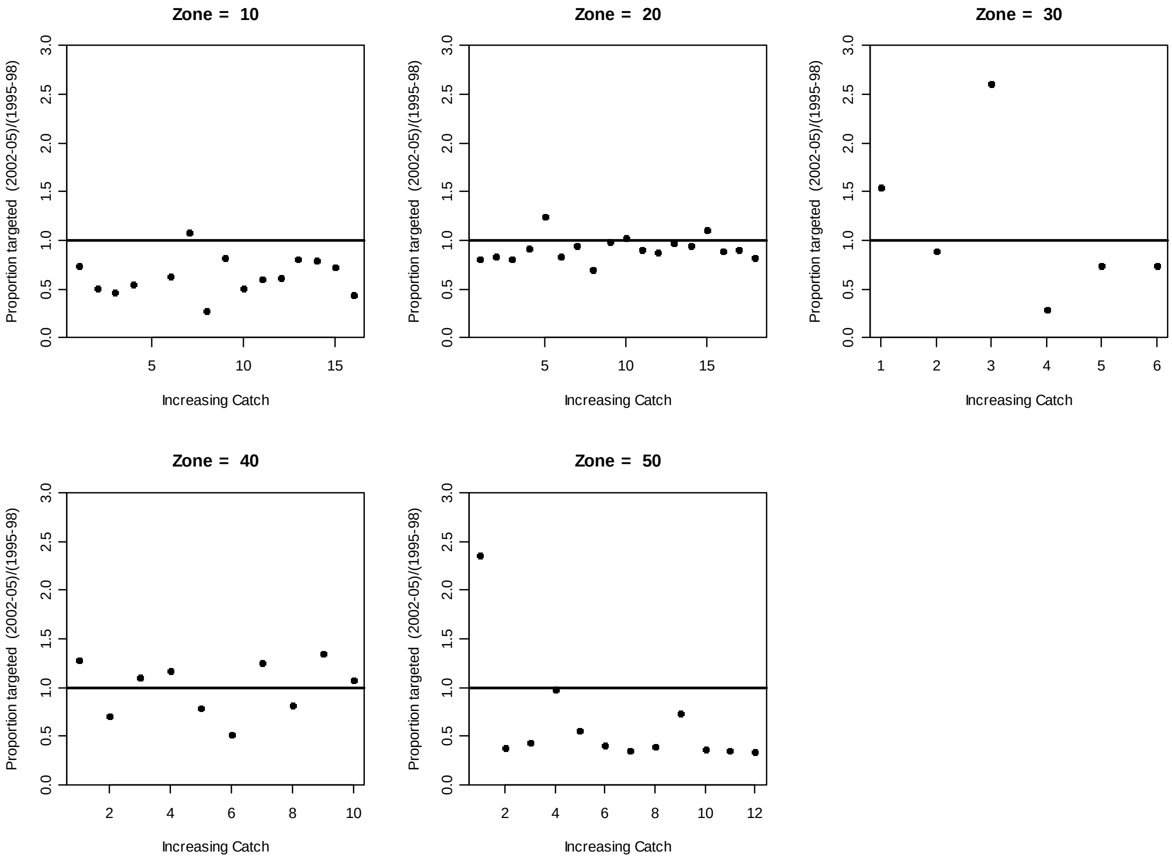


Figure App.A.2. Ratio of the average proportion of ling catch targeted during 1995-98 relative to that during 2002-05. The points are individual vessels, sorted by vessel catch.

The results App.A.2 suggest that targeting on ling has decreased in Zones 10 and 50m but is largely unchanged in Zones 20 and 40 (the data for Zone 30 are too sparse to draw conclusions). While this is again evidence for a change in targeting in at least two Zones, the process which defines whether a shot is targeted is based on catch so there is the potential for bias in this approach.

Figure App.A.3 shows the time-trajectories of standardized catch-rate for Zones 10, 20, and 30 and for these three Zones combined. The time-trajectories are qualitatively similar irrespective of whether targeted shots are used as the basis for the catch-effort standardization (except perhaps for Zone 30 for which the catch-rate series based on targeted shots varies to unrealistic extent). However, the standardized catch-rate series based on targeted shots is more stable, suggesting a lesser decline in abundance.

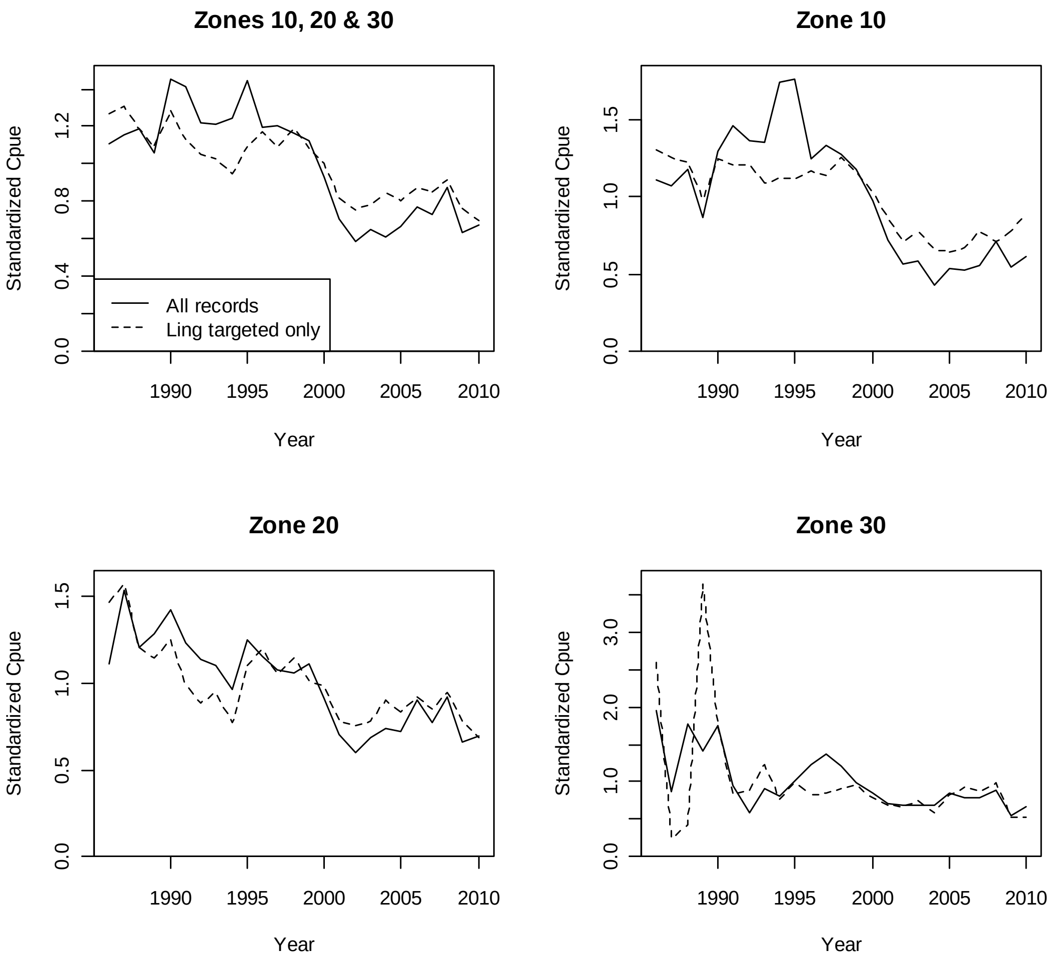


Figure App.A.3 Time-trajectories of standardized catch-rate by Zone (and for Zones 10, 20 and 30 combined) based on analyses which use all records and those which restrict the data to targeted shots (as defined using the Klaer-Smith method).

A.3 Interactions

Most catch-effort standardization for SESSF species ignore interactions with year because (a) the interpretation of the results of analyses with such interactions are difficult to interpret and (b) because they are often computationally challenging. However, the results in Figure App.A.3 suggest that year-Zone interactions are likely important. Exploratory analyses suggest that there are significant depth-year-Zone interaction. Figure App.A.4 shows time-trajectories of standardized catch-rate using (a) all records, (b) the records identified using the Klaer-Smith method as being targeted, and (c) records in water deeper than 200m. The trends in standardized catch-rate are more stable when the standardization is based on either records identified by the Klaer-Smith method as being targeted, or records in water deeper than 200m. The results for Zone 20 for the latter two approaches are remarkably similar, indicating that the method for identifying targeting identifies many of records < 200m as being non-targeted.

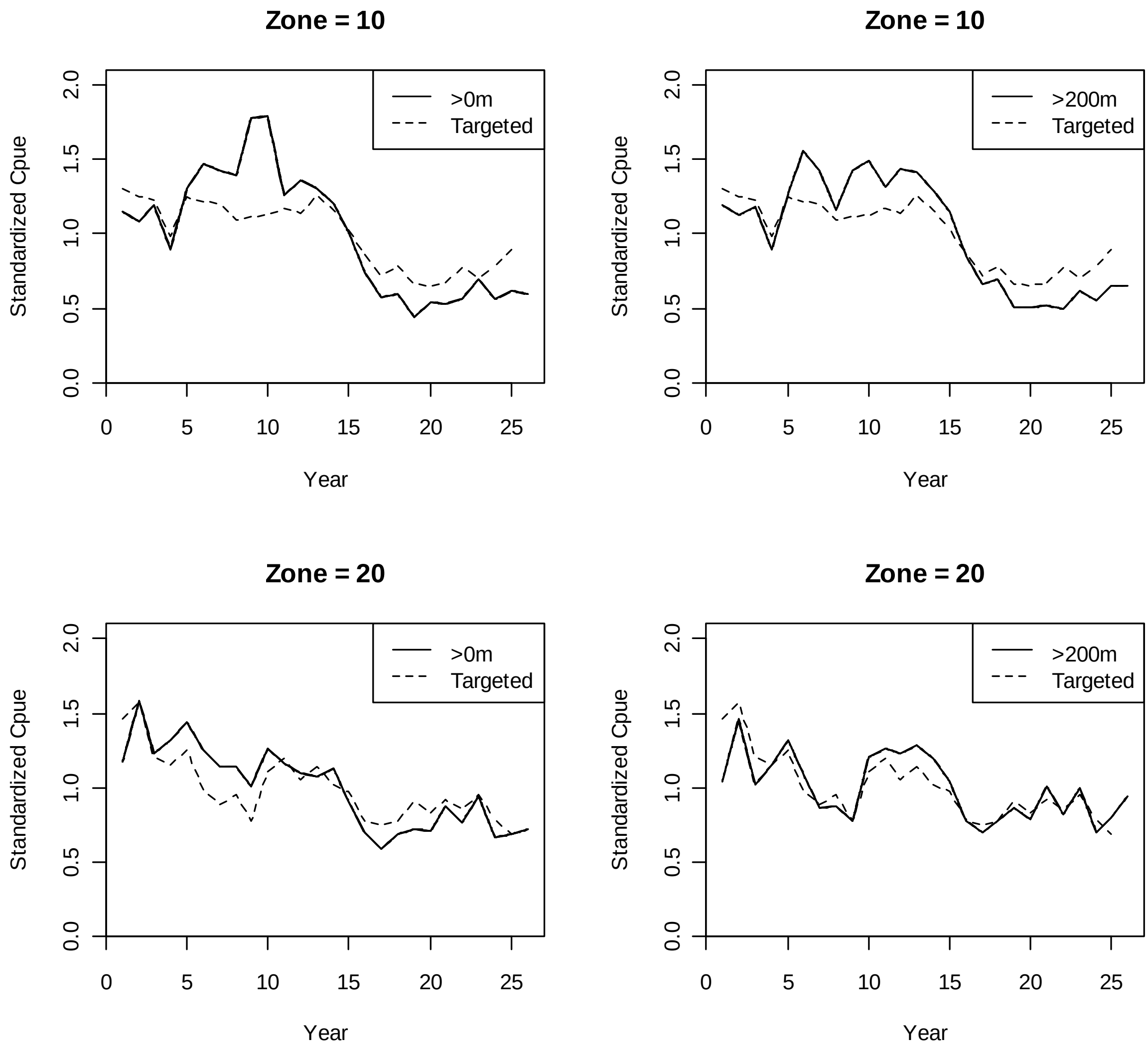


Figure App.A.4. Time-trajectories of standardized catch-rate for Zones 10 and 30. Results are shown for all records (“>0m”), for those records classified as targeted, and for all records deeper than 200m.

5.18 Appendix B: Evidence for time-varying growth

The 2011 assessment was the first for pink ling to allow for time-varying growth. The model was specified to account for cohort-specific growth for cohorts from 1982 to 2005 (inclusive) based on observed changes in age-length data and availability of data that would allow for accurate estimation of cohort-specific growth deviation parameters. An age-length data analysis for pink ling is presented here and utilises the same spatial structure assumptions as the main assessments.

B.1 Time-varying growth in the eastern pink ling stock

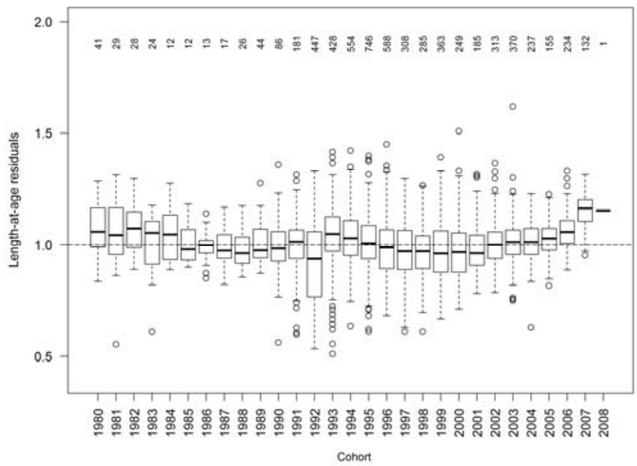


Figure App.B. 1. Cohort-specific length-at-age residuals for eastern pink ling. Boxplots show distributions of ratios of individual length-at-age observations compared to their group means. Numbers inside the plots represent the number of residual calculations per individual boxplot.

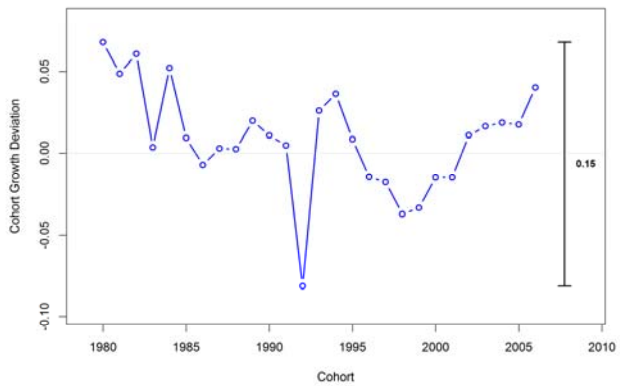


Figure App.B. 2. Cohort-specific growth deviation estimates (percent deviation from average growth) for the eastern stock of pink ling. The vertical black bar indicates the absolute percentage difference between the greatest and least cohort growth deviation estimates.

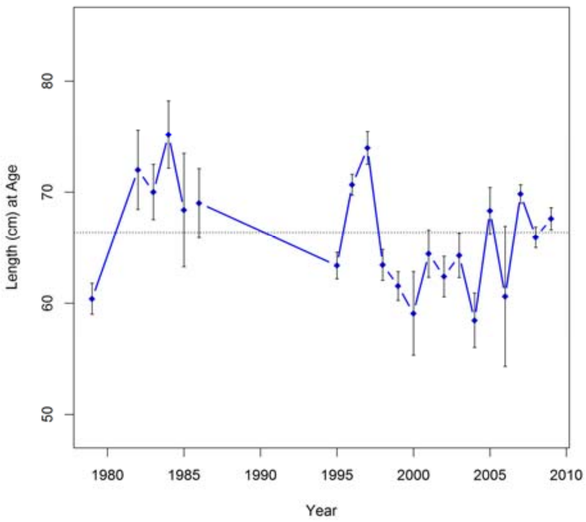


Figure App.B. 3. Year-specific estimated mean size of age-4 fish from the eastern stock of pink ling. Bars represent standard errors of the estimates.

B.2 Time-varying growth in the western pink ling stock

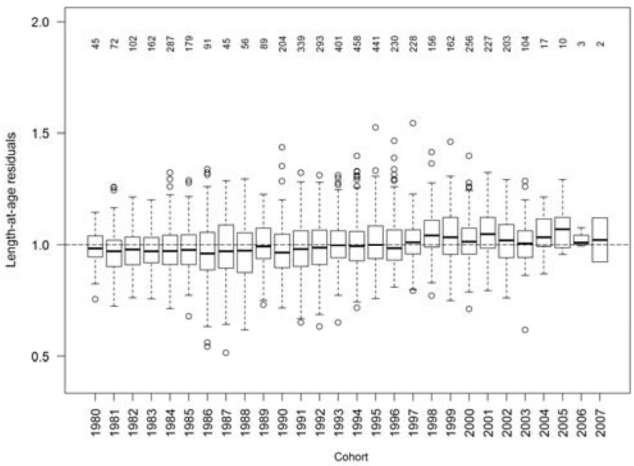


Figure App.B. 4. Cohort-specific length-at-age residuals for western pink ling. Boxplots show distributions of ratios of individual length-at-age observations compared to their group means. Numbers inside the plots represent the number of residual calculations per individual boxplot.

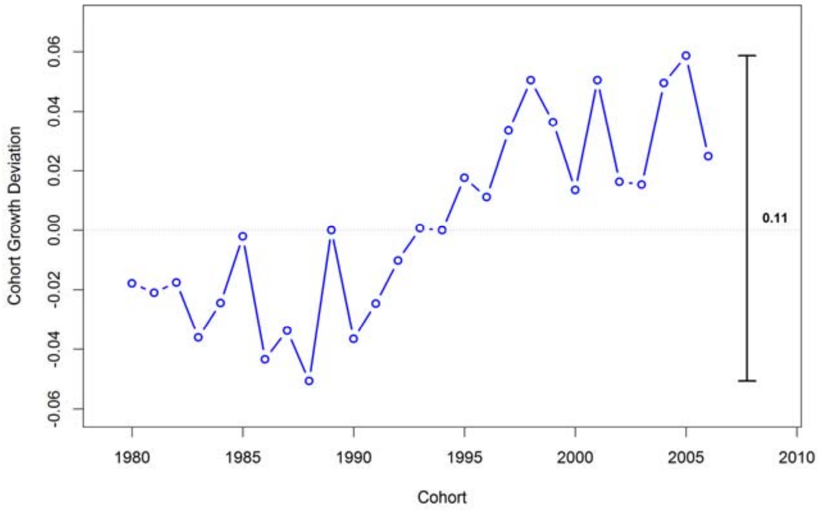


Figure App.B. 5. Cohort-specific growth deviation estimates (percent deviation from average growth) for the western stock of pink ling. The vertical black bar indicates the absolute percentage difference between the greatest and least cohort growth deviation estimates.

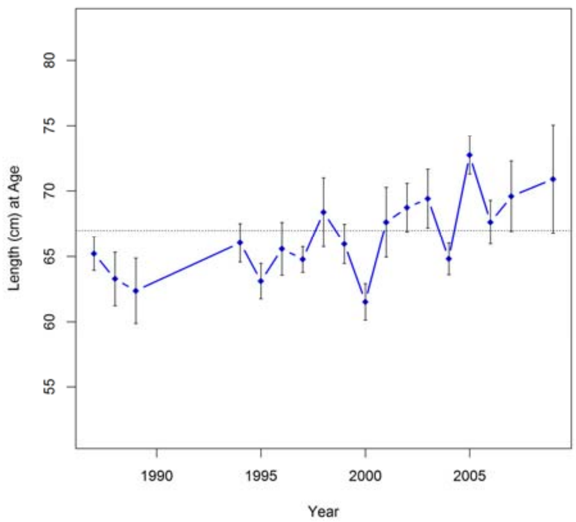


Figure App.B. 6. Year-specific estimated mean size of age-4 fish from the western stock of pink ling. Bars represent standard errors of the estimates.

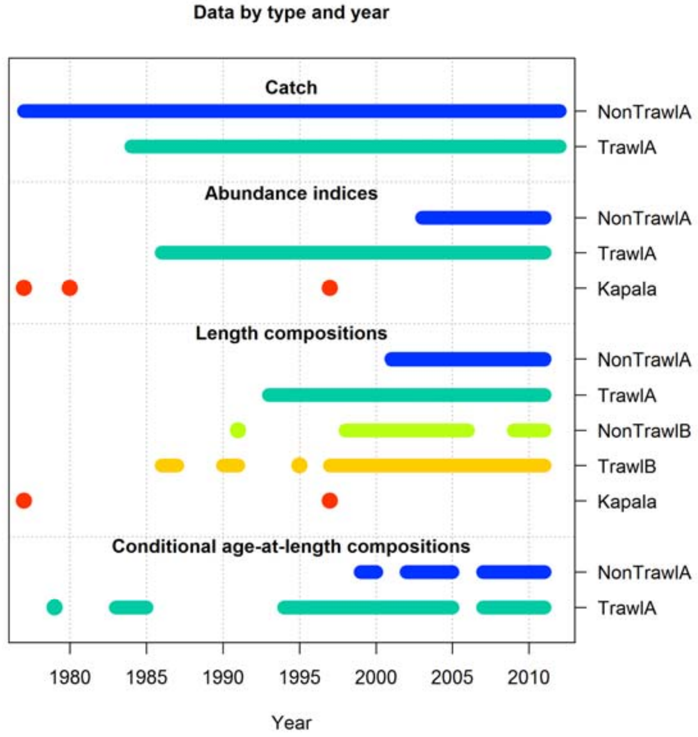
B.3 Results and summary

Time-varying growth appears to be a significant characteristic of both the eastern and western stocks of pink ling. The eastern stock exhibits cohort-specific growth with large fluctuations in mean size-at-age of particular cohorts (such as the 1992, 1994, and 1998 cohorts, (Figure App.B.2). There is also some evidence that the years 1995 and 1996 were particularly fast-growing years for fish of the eastern stock. The mean size-at-age of fish of a representative age for the fishery (age-4) has fluctuated around an average of about 66cm over the past 20 years (Figure App. B.3). The western stock shows both year- and cohort-specific variations to mean size-at-age. The years 1994 and 1996 appear to have been fast-growing years for the western stock, and unlike the eastern stock, the year 1995 appears to have been a slow growing year. There have been cohort-specific fluctuations in growth for the western stock, but the most noticeable feature of both Figures App.B.5 and App.B.6 is the trend towards faster growth (or larger sizes-at-age) over the past 20 years. The size of an age-4 fish has steadily increased from a mean of 63cm in 1998 to 70cm in 2008.

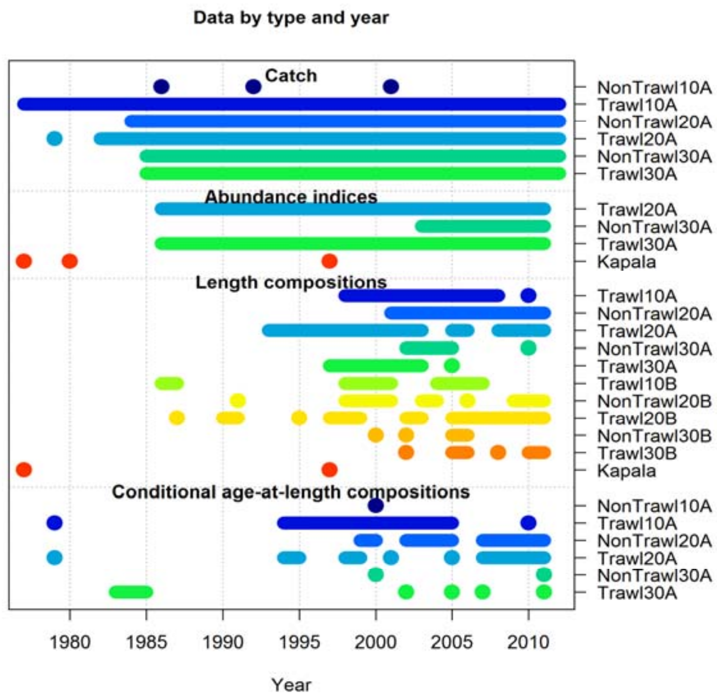
These results may reflect biological changes consistent across each of the managed stocks or the changing dynamics of fishing by Zones, among different operators, or with different gears. More analyses are required to determine whether apparent growth variation is due to biotic or abiotic influences. Base-case models in this report have been structured to estimate cohort-specific variability in growth and provided better fits to data than models with fixed or time-invariant growth.

5.19 Appendix C : Summary of data used in assessments

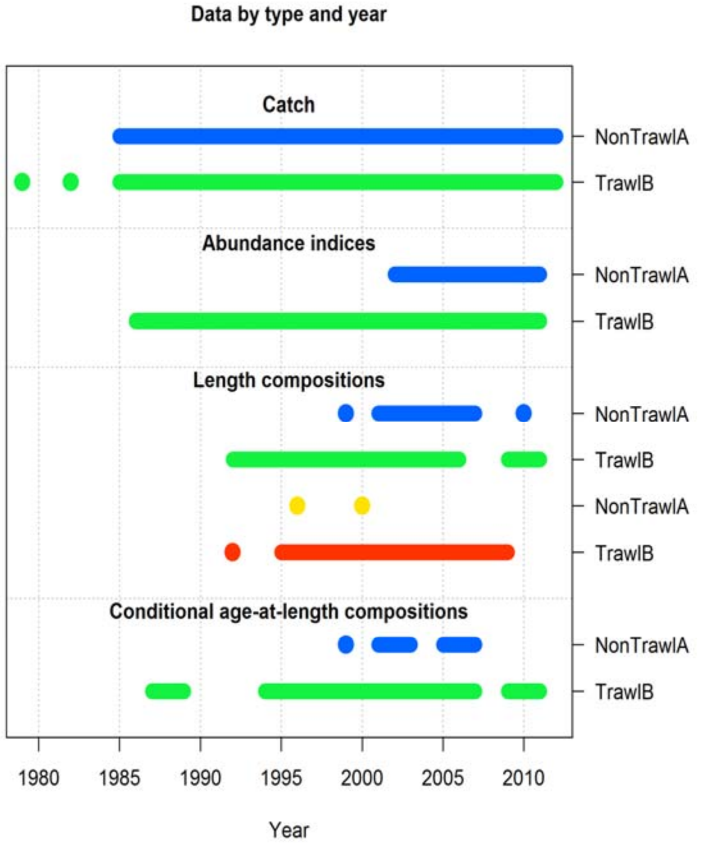
(A) EAST AREA – AGGREGATED MODEL



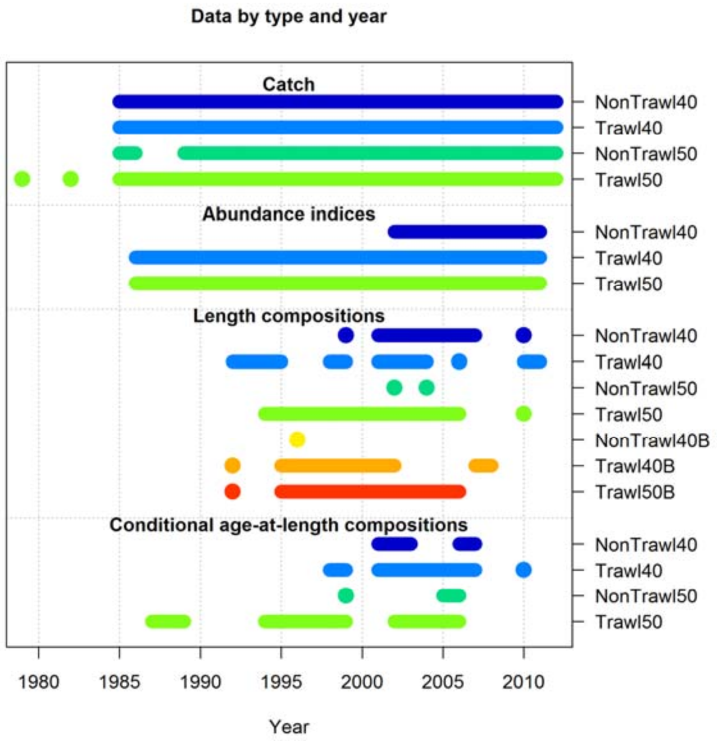
(B) EAST AREA – ZONE MODEL



(C) WEST AREA – AGGREGATED MODEL



(D) WEST AREA – ZONE MODEL



6. Silver Warehou (*Seriolella punctata*) stock assessment based on data up to 2011 – development of a preliminary base case[2]

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6.1 Summary

This document presents a suggested base case for an updated silver warehou assessment. The assessment has been updated by the inclusion of data up to the end of 2011, which entails an additional 3 years of catch, discard, CPUE, length and age data since the 2009 assessment. Improvements to the fits to the length frequency data are obtained by implementing cohort specific growth and by further down-weighting the age data, to balance the contributions of the length and age data to the overall likelihood. A number of alternatives are presented along with the associated fits to CPUE, length and age data and examination of recruitment estimates.

6.2 Comparison of 2009 assessment with 2012 assessment

6.2.1 *Bridging from 2009 to 2012 assessments*

The previous full quantitative assessment for silver warehou was performed in 2009 (Tuck and Fay, 2009) using Stock Synthesis (version SS-V3.03a, Methot May 2009). The 2012 assessment uses the current version of Stock Synthesis (version SS-V3.24f, Methot August 2012). There are only minor 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 2009 assessment was used in the new software (SS-V3.24f). This was followed by updating the data, 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 2009, 2010 and 2011. The last year of recruitment estimation was extended to 2007 (2004 in the 2009 assessment). Neither the use of this updated software nor the inclusion of additional data resulted in noticeable differences in the fits to CPUE, age or length data. In this case, due to the similarities in these model outputs, 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 not required.

Comparisons between fits to the CPUE and spawning biomass trajectories are shown for these two cases (Figure 6.1). The model with the updated data results in some minor

[2] Paper presented to the Slope RAG, October 2012

changes to estimates of the recruitment deviations at the beginning and the end of the series (Figure 6.2) which explain the differences in the spawning biomass trajectories.

The 2009 assessment (Tuck and Fay, 2009) provided a base case with a 2010 spawning stock biomass of 48% of virgin stock biomass. The 2012 assessment update also assumes silver warehou forms a single stock and is fished by a single fleet (otter trawl). Discards were added to the landings to account for variable discarding practices between years and natural mortality was fixed at 0.3. All of these model assumptions, which were agreed at previous RAG meetings, have been used for the 2012 assessment. In the 2009 assessment, it was noted that there was some conflict between the length and age data and that the length residuals behave differently before and after 2002, with patterns in these residuals indicating some possible issues with the fits to the length data. In addition, it was noted that there had been a recent decline in both the catch and the CPUE.

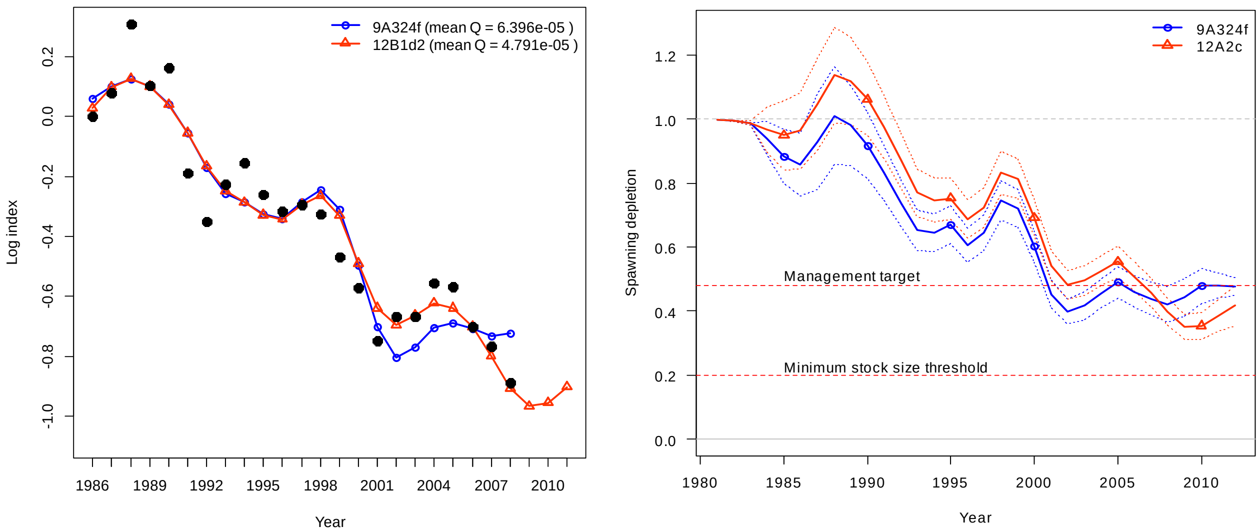


Figure 6.1. A comparison between the 2009 assessment (blue with circles) and a model with the same structure with the addition of data from 2009, 2010 and 2011 (red with triangles). Fits to CPUE (left), with observations from the 2009 assessment (black circles; observations from the 2012 CPUE update are not shown), and spawning depletion (right).

6.3 Recommended changes for the 2012 base case

The trends showing a decline in both catch and CPUE seen towards the end of the data used in the 2009 assessment largely continued with the new CPUE and catch data, which suggested some concern about the status of this stock and some closer examination of some of the assumptions and issues identified in the 2009 assessment.

In exploring alternative base cases for the 2012 assessment, a number of potential model sensitivities were considered, including estimating more recent recruitment deviations (beyond 2007) and estimating mortality. However, these scenarios were not considered strong candidates for the base-case (results to be discussed at the RAG).

Two issues were addressed differently when searching for a 2012 base case: the balance in contribution of the likelihood from the length and age data and the residual patterns in the fits to the length data. These will be discussed in more detail in the sections that follow.

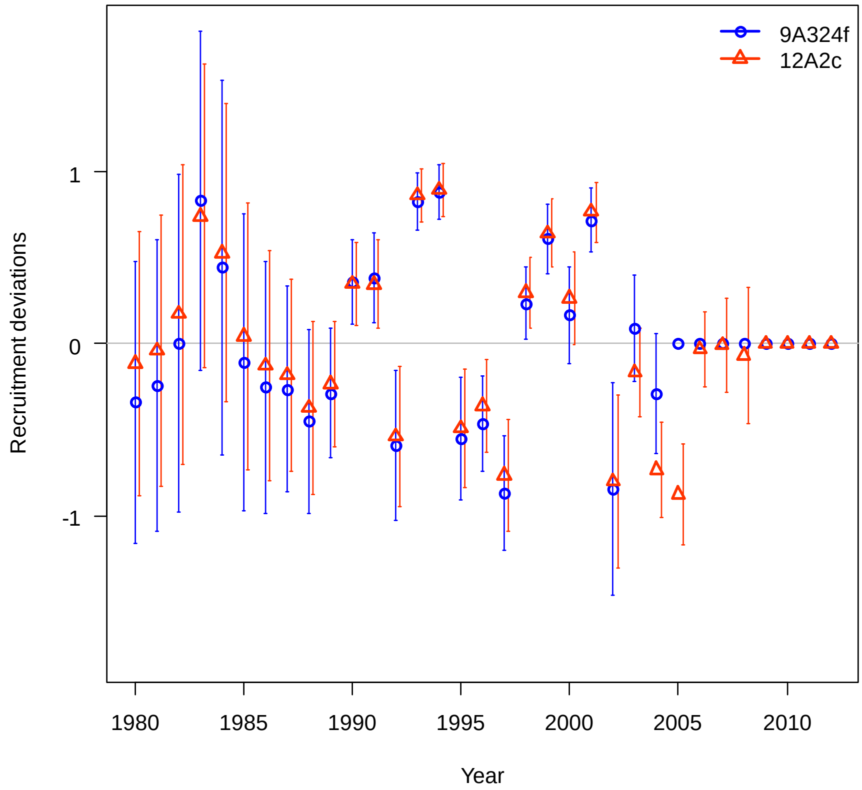


Figure 6.2 Recruitment deviations comparison between 2009 assessment (blue with circles) and a model with the same structure with the addition of data from 2009, 2010 and 2011 (red with triangles).

6.3.1 *Balance between length and age data*

Balancing the likelihood contribution from different data sources can present difficulties in integrated assessments, especially given differing forms of CPUE, length and age data and when there is conflict between different sources of data. Following current practice in tuning the fits for SESSF stock assessments, the length frequencies sample sizes are capped at 200 and then further tuned so that the mean of the effective sample sizes (calculated by the model) matches the mean of the input sample sizes. This typically requires down-weighting the length data. As the age data is used in the form of age-at-length data, capping the sample size at 200 is not practicable due to constraints on the number of samples at any given length. However, the mean effective sample size is tuned to match the mean input sample size, again by down-weighting these samples. In contrast, the CPUE data has a relatively low number of apparent data points, yet each annual standardised CPUE data point is derived from data from many individual shots over a year. While the age and length data is typically down-weighted, the weighting on the CPUE is not adjusted (however the input and output CV for CPUE are balanced in the final model).

The 2009 assessment showed some conflict between the age data and the CPUE and length data, resulting in a modification to the usual tuning practices. To balance the means of the effective and input sample sizes for the age data would require up-weighting the age data. Instead of up-weighting these sample sizes, they are left unadjusted in the tuned case (age λ =1.0). However, this resulted in a large component of the likelihood coming from the age data and poor fits to the length and CPUE data. To improve the overall fits, the 2009 base case down-weighted the age data (age λ =0.25).

In this assessment, we propose further down-weighting the age components (age λ =0.10) to give the likelihood component from the age a similar magnitude to the likelihood component of the lengths. This produces much better fits to the length composition data, although with some reduction to the fit in the CPUE data. We think the improvements to the fit to the length data justify this change.

6.3.2 *Cohort dependent growth*

The differences in the patterns of the length residuals before and after 2002 warranted further investigation. These patterns suggest that growth could be changing over time. There are a number of mechanisms which could result in changes to growth over time: a steady decrease in growth over time; spatial variability in growth rates and changes to the areas being fished over time; and cohort dependent growth.

Von Bertalanffy growth curves were fitted to the length and age data for each of the major SEF fishing zones fished for silver warehou (Figure 6.3). These indicate that there are some differences in growth between SEF zones, especially between Eastern Bass Strait (Zone 20) and Western Tasmania (Zone 40) and Western Bass Strait (zone 50) (zone definitions are listed in Figure 6.4) with growth appearing to be fastest in Western Tasmania in the first 5 or 6 years and slowest in Eastern Bass Strait for the same ages (Figure 6.3). These are the three major zones in which silver warehou are caught and the proportion of the catch spread between these three areas has varied over the course of the fishery. However, without a spatial component to the model, it is difficult to include this variation directly.

Previous assessments show that recruitment is quite variable, with periods showing a couple of years of above average recruitment followed by below average recruitment. This suggests that cohort dependent growth may be responsible for changes in growth over time. Cohort dependent growth was incorporated in the model and this resulted in improvements in the fits to the length data and an improvement to the patterns of residuals in the length frequencies. Further work could be done to examine other possible explanations, such as modelling a linear decline in growth over time. However implementing cohort specific growth is one reasonable option and results in better fits to the data than a constant growth function.

6.3.3 *Potential new base case: cohort dependent growth and age λ = 0.1*

Combining cohort dependent growth and λ = 0.1 on the ages gives improved fits to the length frequencies, removes the residual pattern and balances the contribution of the likelihood between the length and age data. In addition to this proposed base case, we ran a number of alternative models

1. Base case with λ = 0.25 on the ages
2. Base case with constant growth
3. Base case with λ = 0.25 on the ages and constant growth
4. Base case with an additional year of recruitment estimated (to 2008)

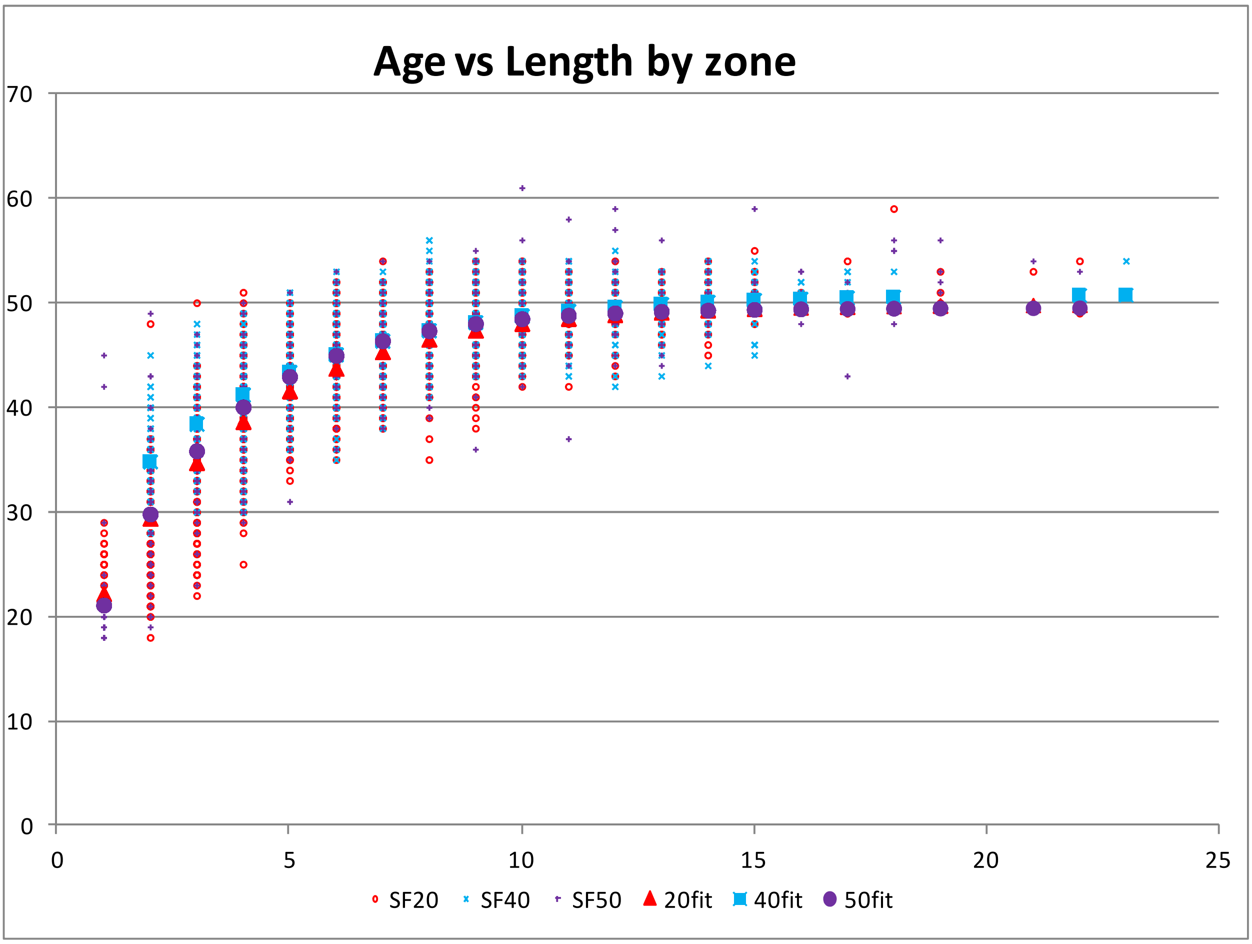


Figure 6.3. Raw data and fitted von Bertalanffy curves for zones 20 (red triangles), zone 40 (aqua squares) and zone 50 (purple circles). For fish aged less than 6 years old, the growth in zone 40 appears to be faster than the growth in zone 20, with a 40cm fish aged at around 4 years in zone 40 and 5 years in zone 20.

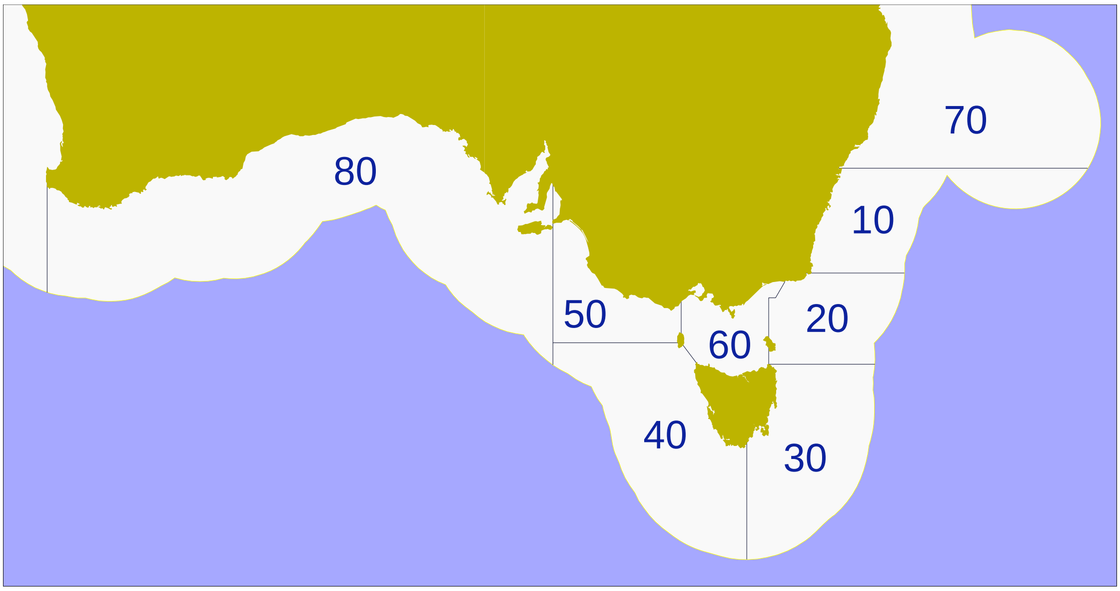


Figure 6.4. Map of the SESSF showing statistical zones used here.

Comparisons of the fits to the CPUE, the spawning depletion trajectory, recruitment, fits to age and length and residuals of the fits to length are shown in the appendix between the proposed base case model and the following models

1. The 2009 assessment (Figure 6.5, Figure 6.6, Figure 6.7)
2. Base case with $\lambda = 0.25$ on the ages (Figure 6.8, Figure 6.9, Figure 6.10)
3. Base case with constant growth (Figure 6.11, Figure 6.12, Figure 6.13)
4. Base case with $\lambda = 0.25$ on the ages and constant growth (Figure 6.14, Figure 6.15, Figure 6.16)
5. Base case with an additional year of recruitment estimated (to 2008)

6.4 References

Methot, R.D. 2009. User manual for Stock Synthesis. Model Version 3.03a. NOAA Fisheries Service, Seattle. 143 pp.

Methot, R.D. 2012. User manual for Stock Synthesis. Model Version 3.24f. NOAA Fisheries Service, Seattle. 150 pp.

Tuck, G.N and Fay, G. 2009. Silver warehou (*Seriolella punctata*) stock assessment based on data up to 2008. Unpublished report to Slope RAG. 28 pp.

6.5 Appendix A

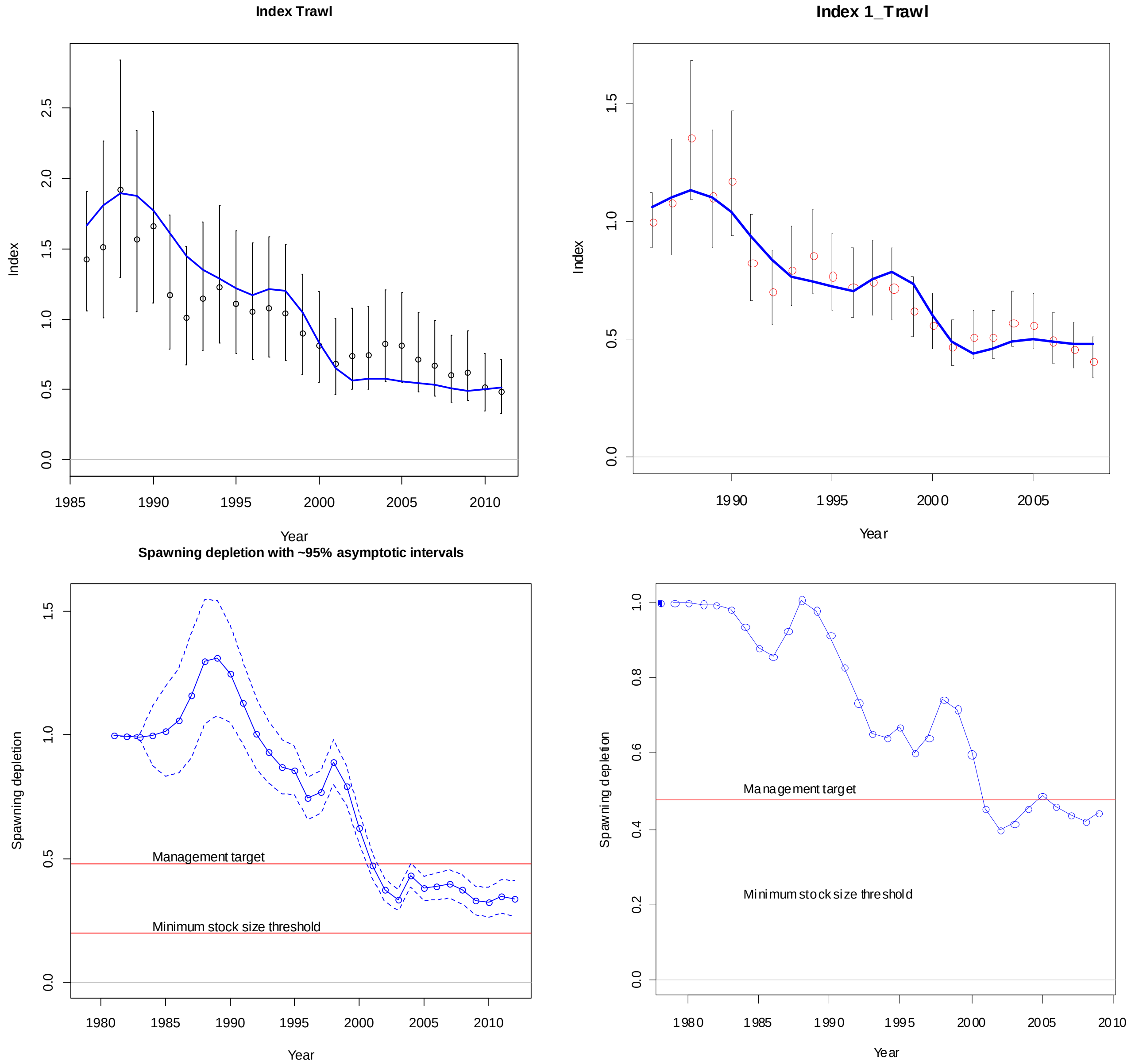


Figure 6.5. Top: observed (circles) and model-predicted (blue lines) catch-rates versus year. The vertical lines indicate approximate 95% confidence intervals for the data. Bottom: time-trajectory of spawning depletion for proposed base-case analysis (age λ = 0.1, cohort dependent growth; LHS) and 2009 assessment (RHS).

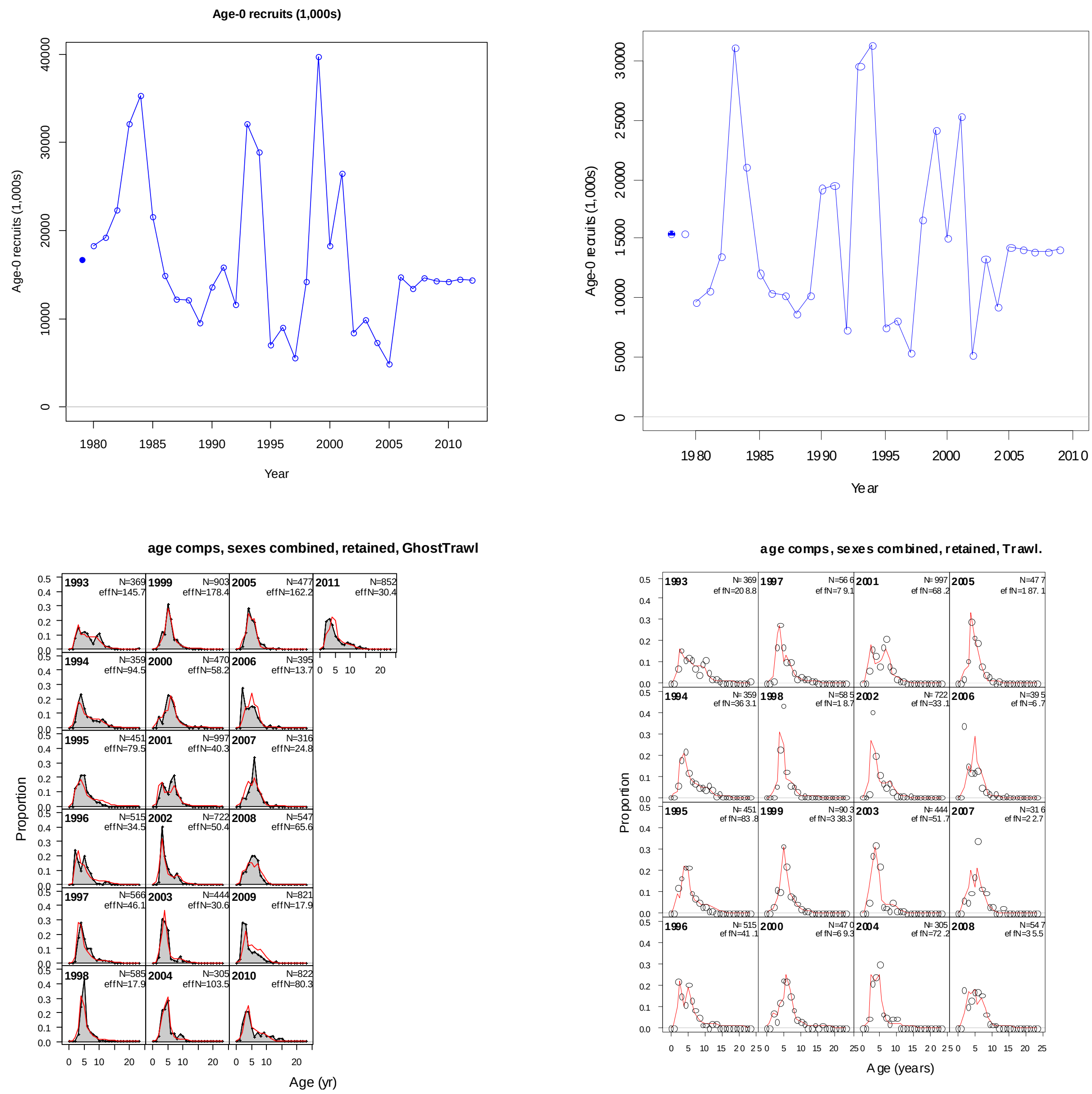


Figure 6.6. Top: The time-trajectory of recruitment. Bottom: observed and model-predicted fits to the age data for the proposed base-case analysis (age λ = 0.1, cohort dependent growth; LHS) and 2009 assessment (RHS).

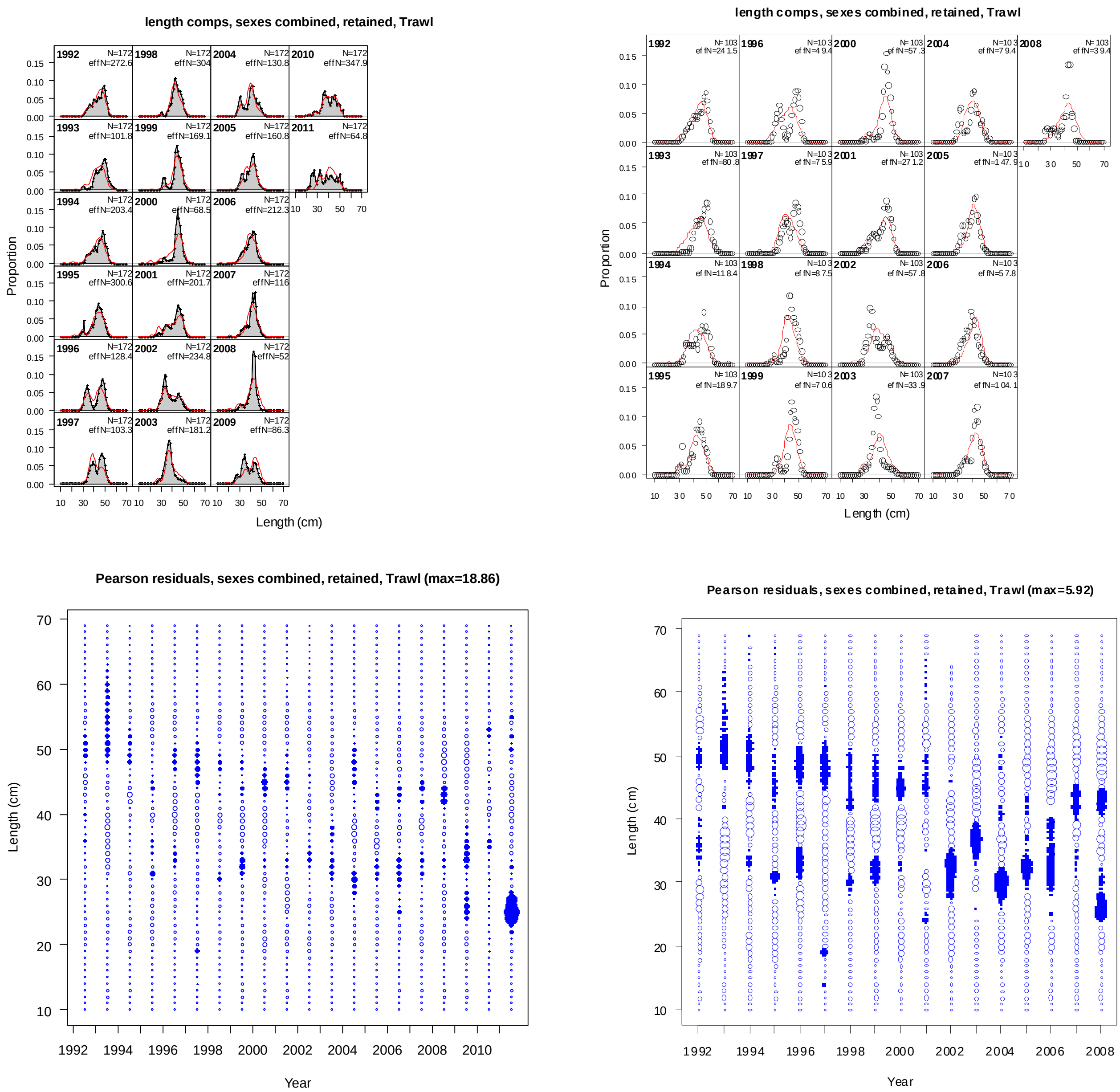


Figure 6.7. Top: observed and model-predicted fits to the length data. Bottom: residuals from the annual length compositions for the proposed base-case analysis (age λ = 0.1, cohort dependent growth; LHS) and 2009 assessment (RHS).

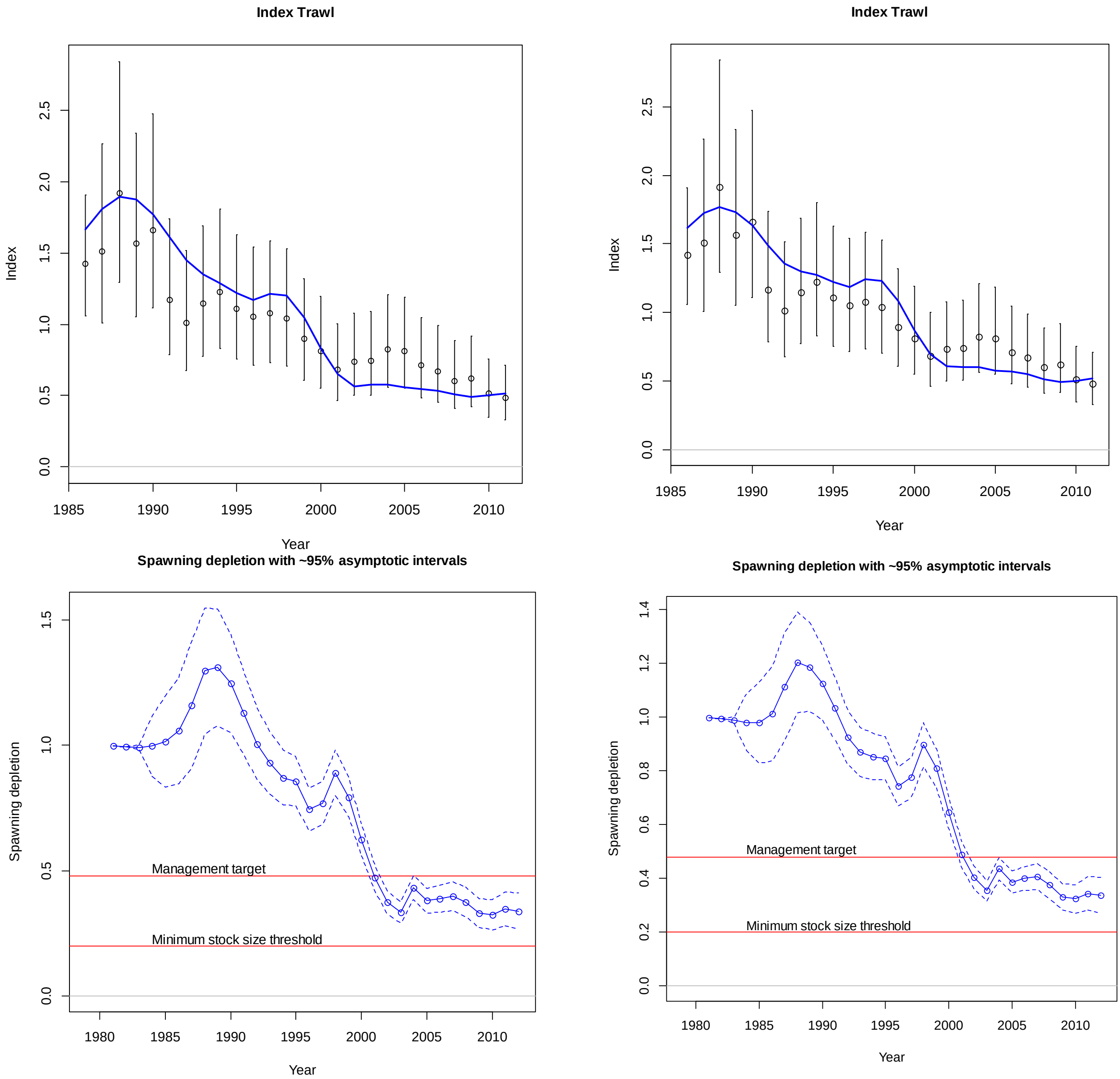


Figure 6.8. Top: observed (circles) and model-predicted (blue lines) catch-rates versus year. The vertical lines indicate approximate 95% confidence intervals for the data. Bottom: time-trajectory of spawning depletion for proposed base-case analysis (age λ= 0.1, cohort dependent growth; LHS) and alternative 1 (age λ = 0.25; RHS).

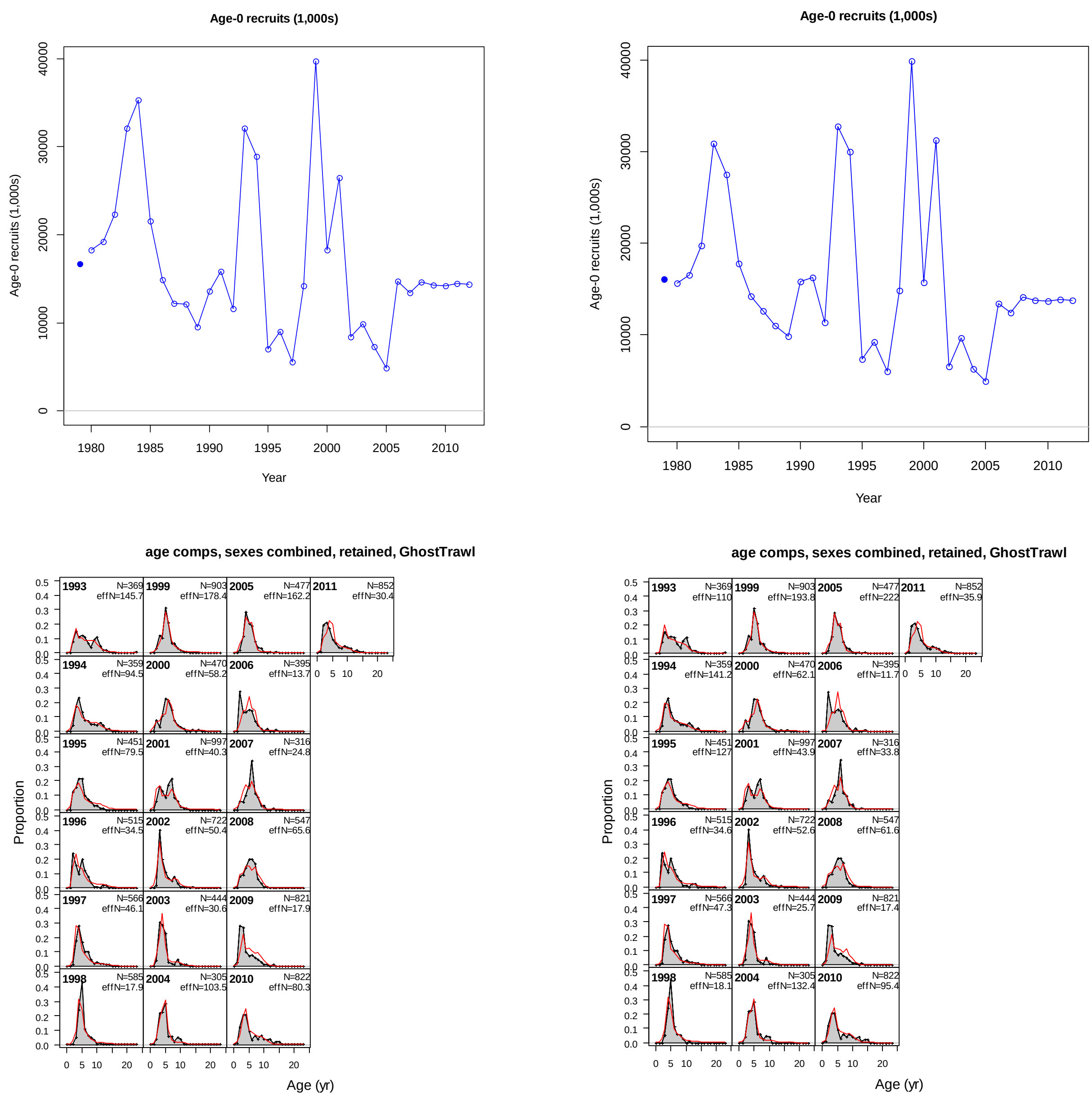


Figure 6.9. Top: The time-trajectory of recruitment. Bottom: observed and model-predicted fits to the age data for the proposed base-case analysis (age λ = 0.1, cohort dependent growth; LHS) and alternative 1 (age λ = 0.25; RHS).

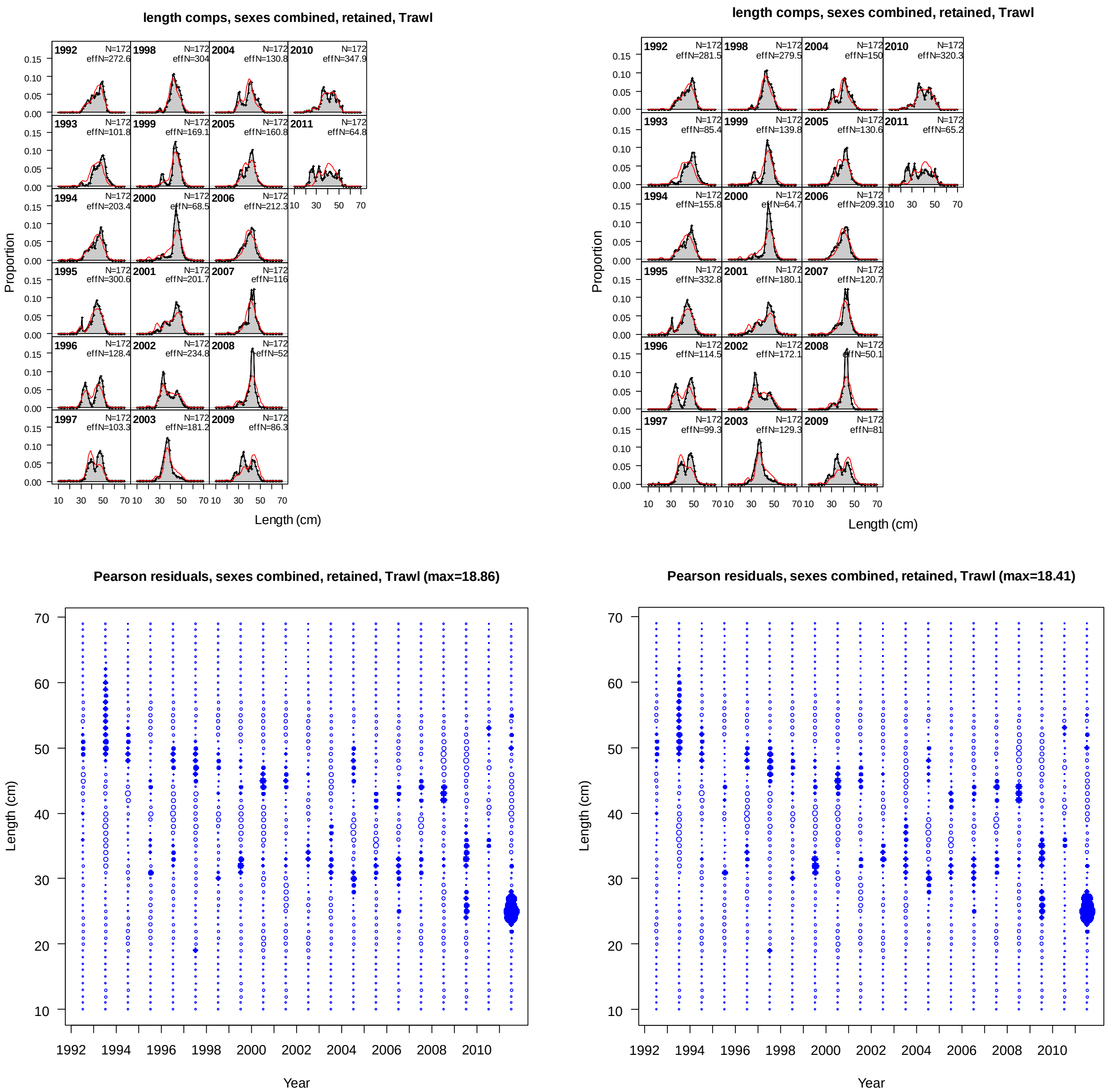


Figure 6.10. Top: observed and model-predicted fits to the length data. Bottom: residuals from the annual length compositions for the proposed base-case analysis (age λ = 0.1, cohort dependent growth; LHS) and alternative 1 (age λ = 0.25; RHS).

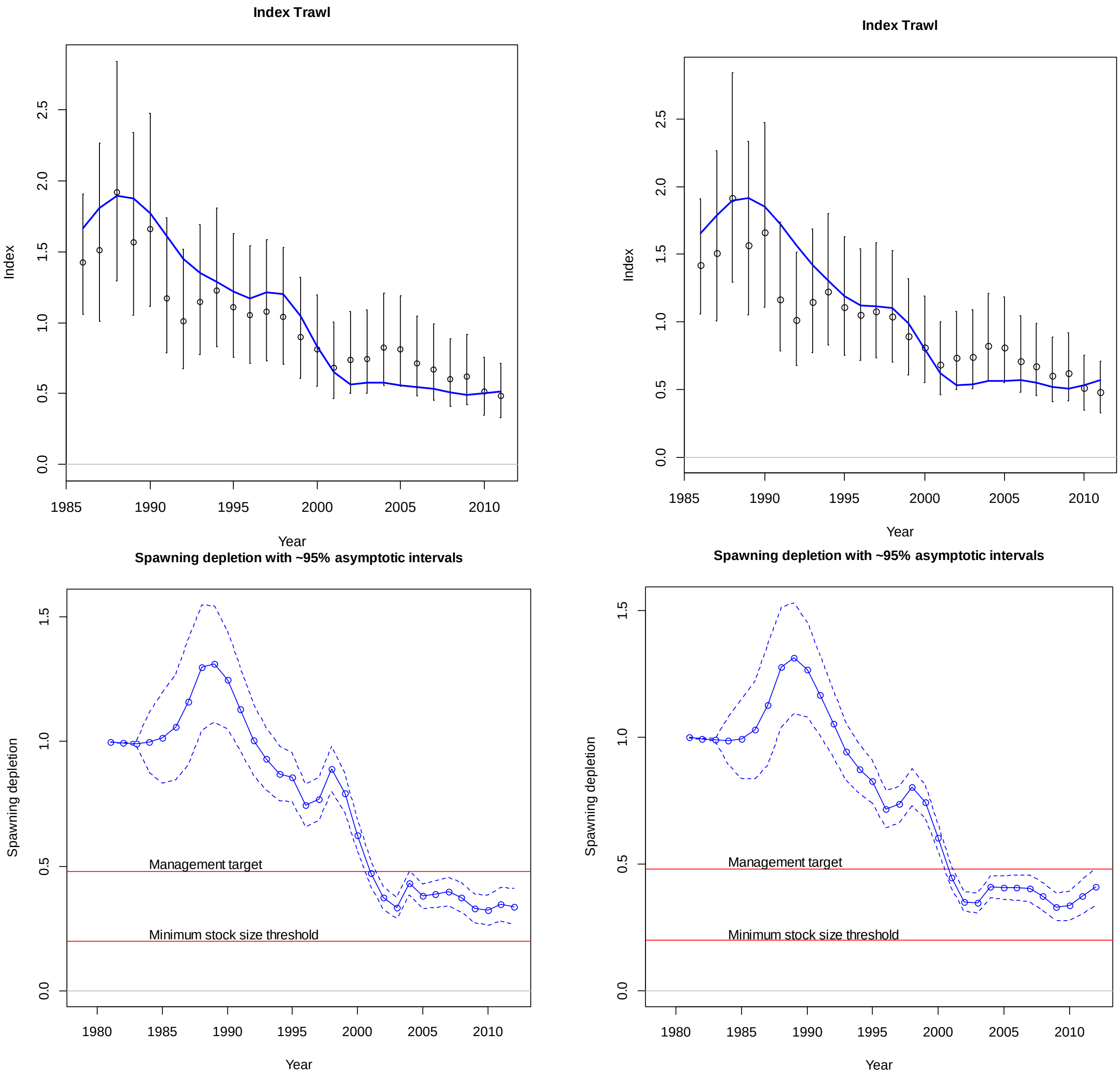


Figure 6.11. Top: observed (circles) and model-predicted (blue lines) catch-rates versus year. The vertical lines indicate approximate 95% confidence intervals for the data. Bottom: time-trajectory of spawning depletion for proposed base-case analysis (age λ= 0.1, cohort dependent growth; LHS) and alternative 2 (constant growth; RHS).

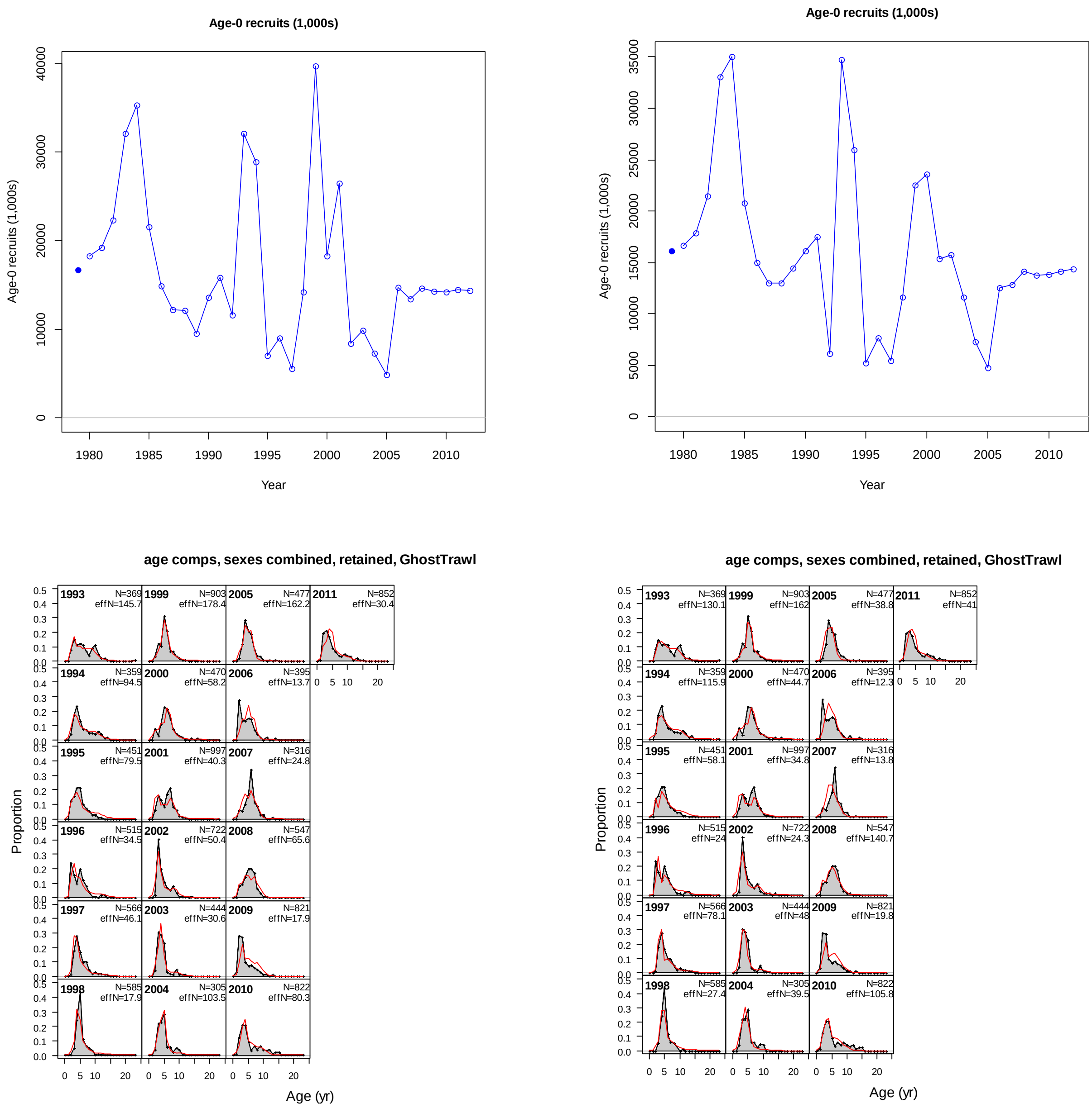


Figure 6.12. Top: The time-trajectory of recruitment. Bottom: observed and model-predicted fits to the age data for the proposed base-case analysis (age λ = 0.1, cohort dependent growth; LHS) and alternative 2 (constant growth; RHS).

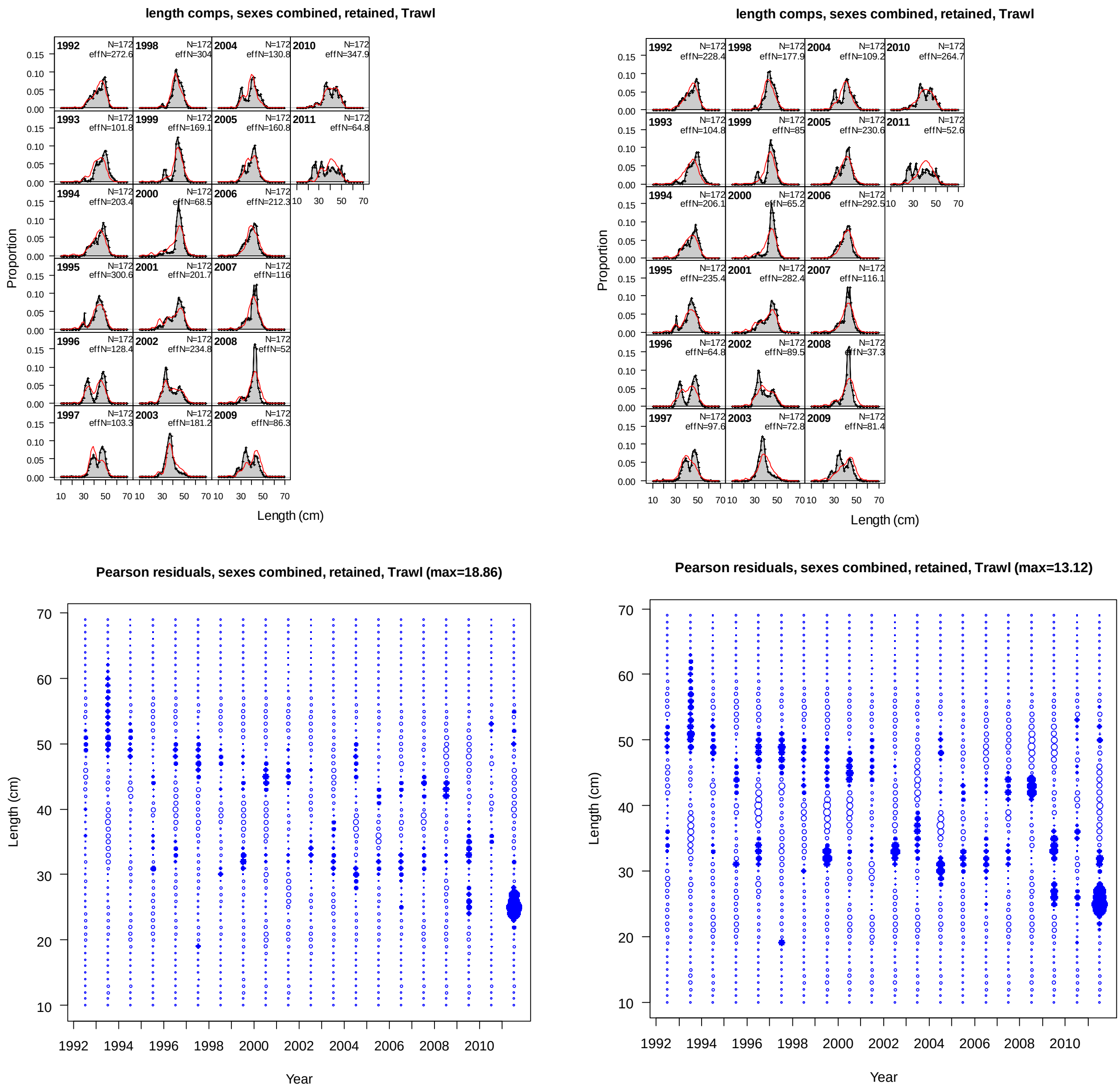


Figure 6.13. Top: observed and model-predicted fits to the length data. Bottom: residuals from the annual length compositions for the proposed base-case analysis (age λ = 0.1, cohort dependent growth; LHS) and alternative 2 (constant growth; RHS).

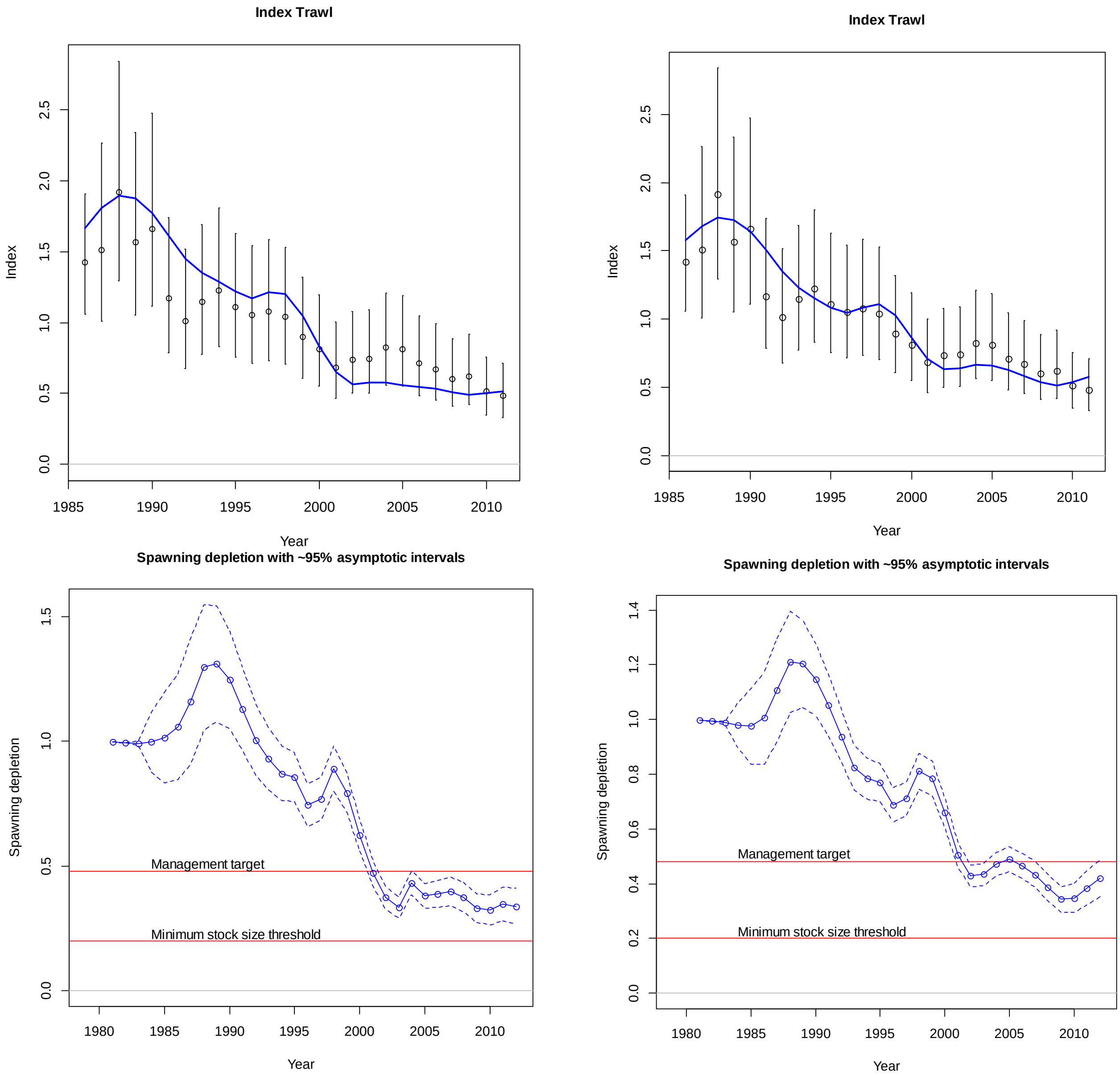


Figure 6.14. Top: observed (circles) and model-predicted (blue lines) catch-rates versus year. The vertical lines indicate approximate 95% confidence intervals for the data. Bottom: time-trajectory of spawning depletion for proposed base-case analysis (age λ= 0.1, cohort dependent growth; LHS) and alternative 3 (age λ = 0.25, constant growth; RHS).

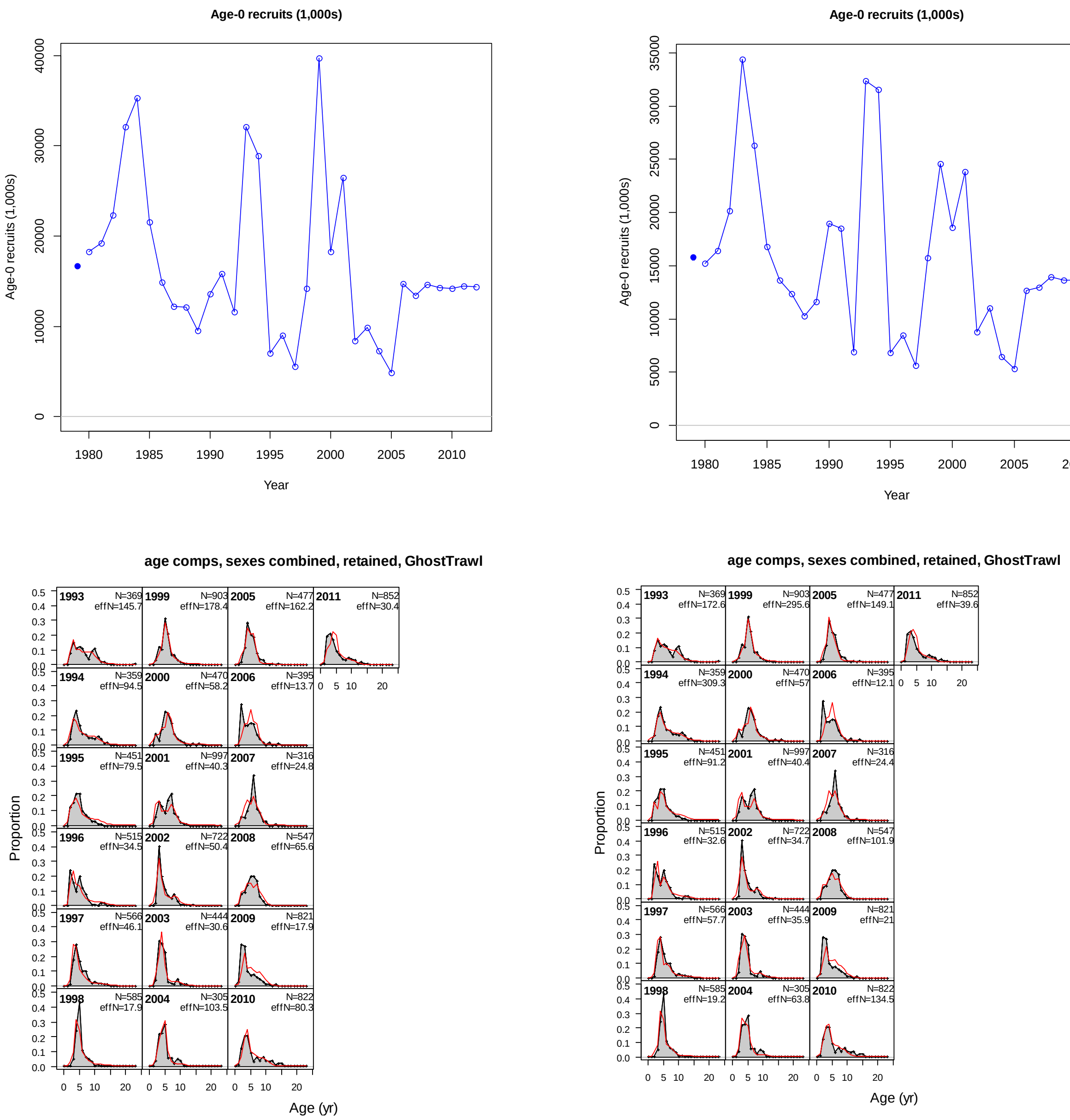
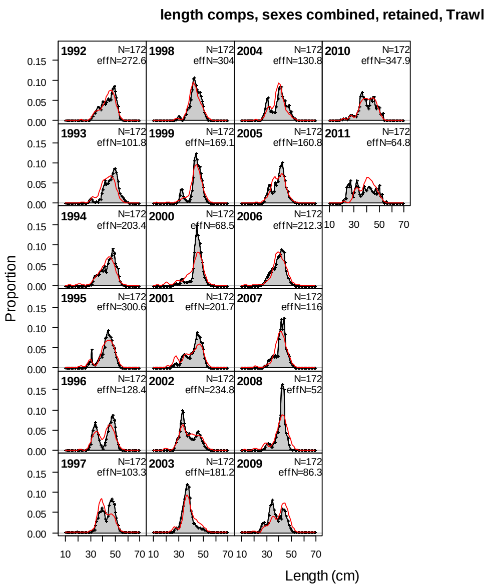
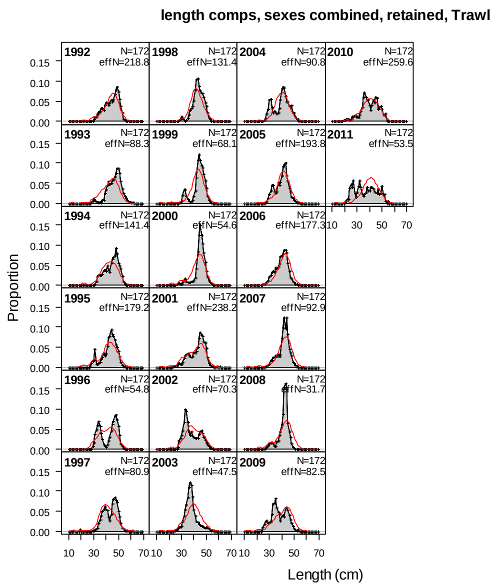
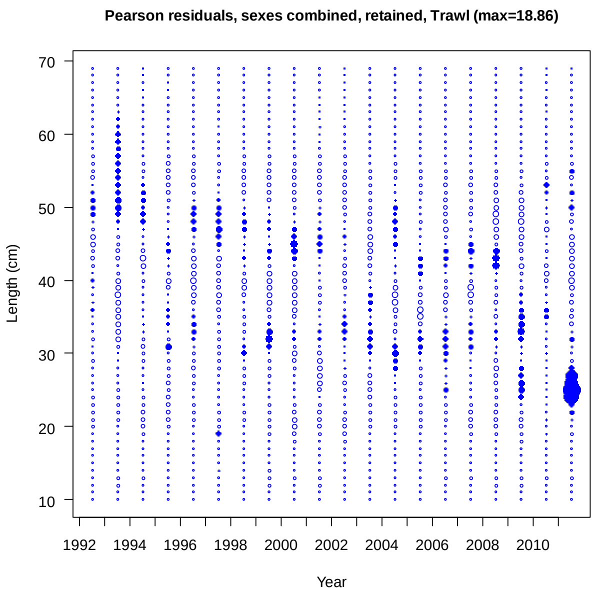


Figure 6.15. Top: The time-trajectory of recruitment. Bottom: observed and model-predicted fits to the age data for the proposed base-case analysis (age λ = 0.1, cohort dependent growth; LHS) and alternative 3 (age λ = 0.25, constant growth; RHS).







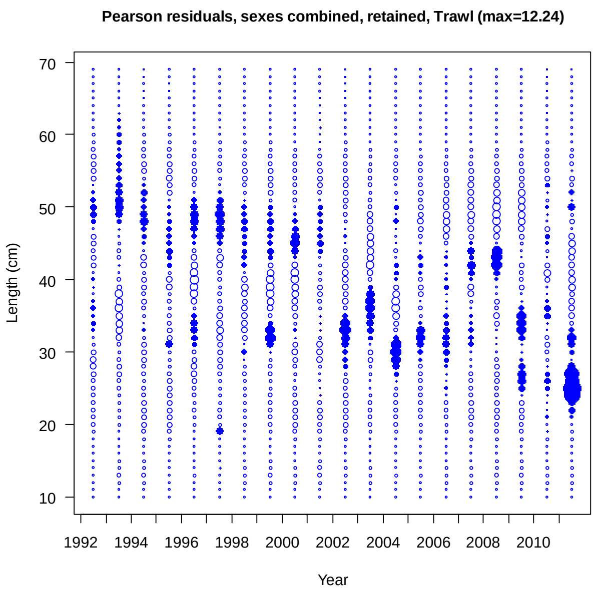


Figure 6.16. Top: observed and model-predicted fits to the length data. Bottom: residuals from the annual length compositions for the proposed base-case analysis (age λ = 0.1, cohort dependent growth; LHS) and alternative 3 (age λ = 0.25, constant growth; RHS).

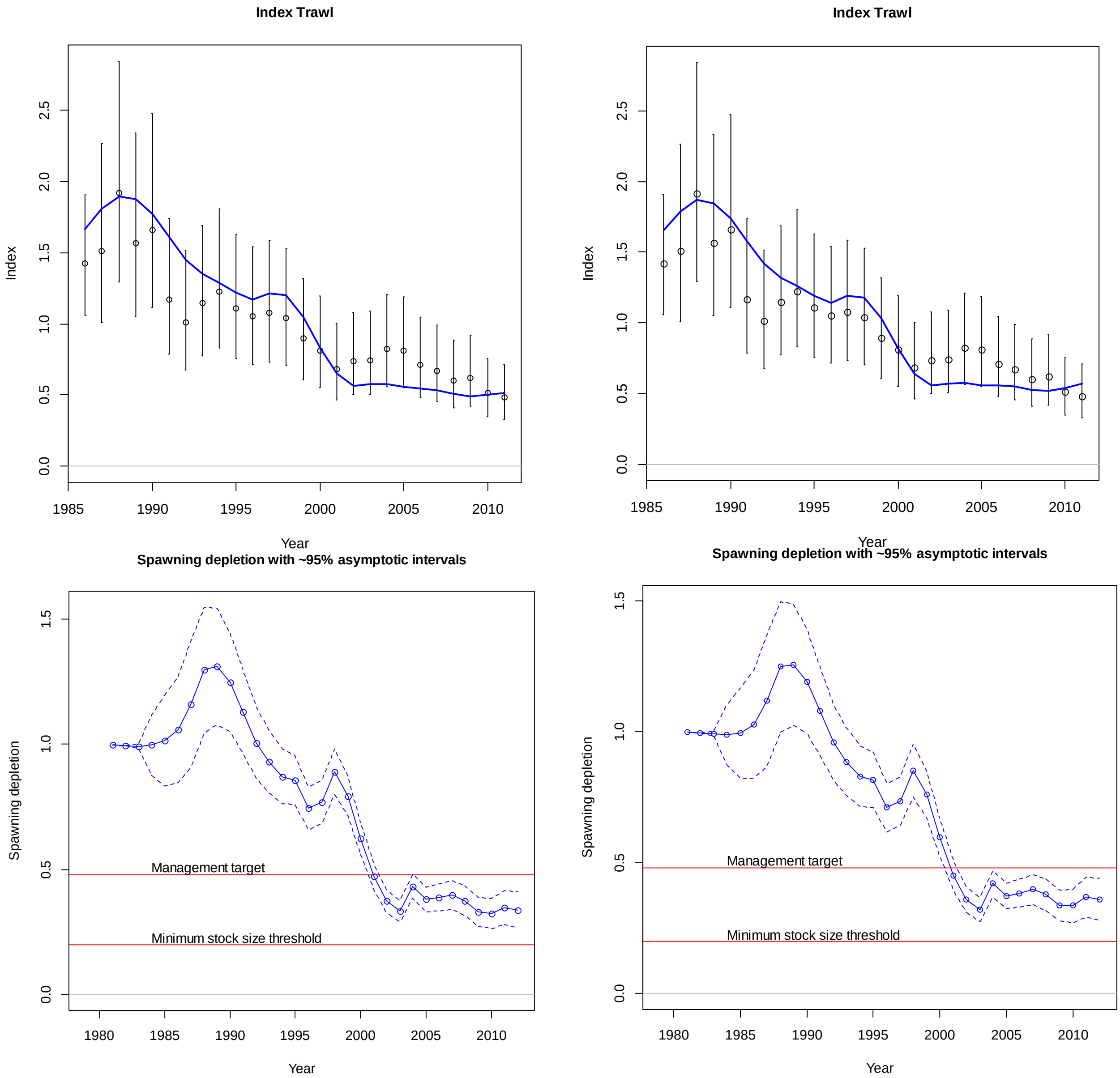


Figure 6.17. Top: observed (circles) and model-predicted (blue lines) catch-rates versus year. The vertical lines indicate approximate 95% confidence intervals for the data. Bottom: time-trajectory of spawning depletion for proposed base-case analysis (age λ= 0.1, cohort dependent growth; LHS) and alternative 4 (one extra recruitment; RHS).

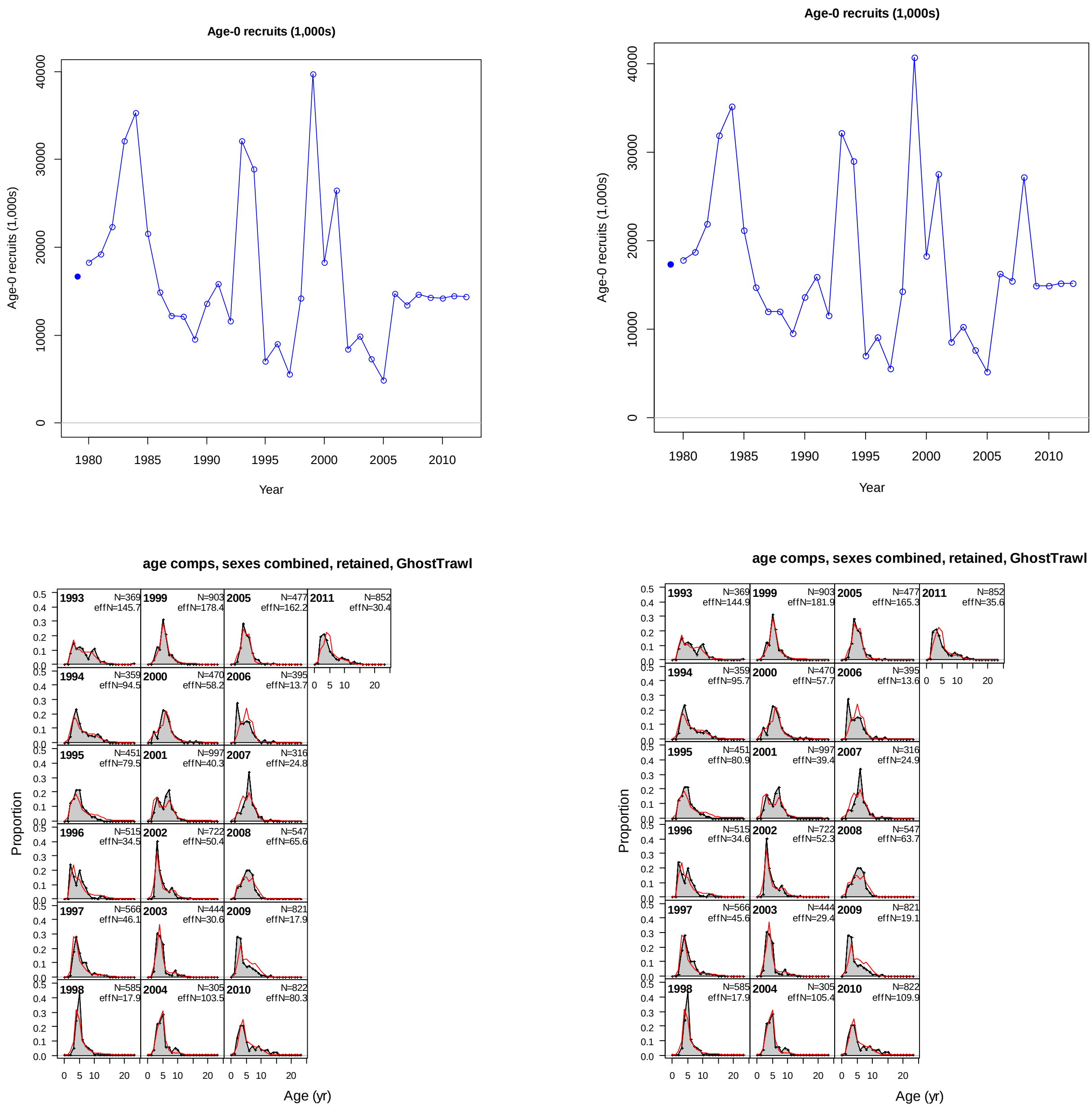


Figure 6.18. Top: The time-trajectory of recruitment. Bottom: observed and model-predicted fits to the age data for the proposed base-case analysis (age $\lambda = 0.1$, cohort dependent growth; LHS) and alternative 4 (one extra recruitment; RHS).

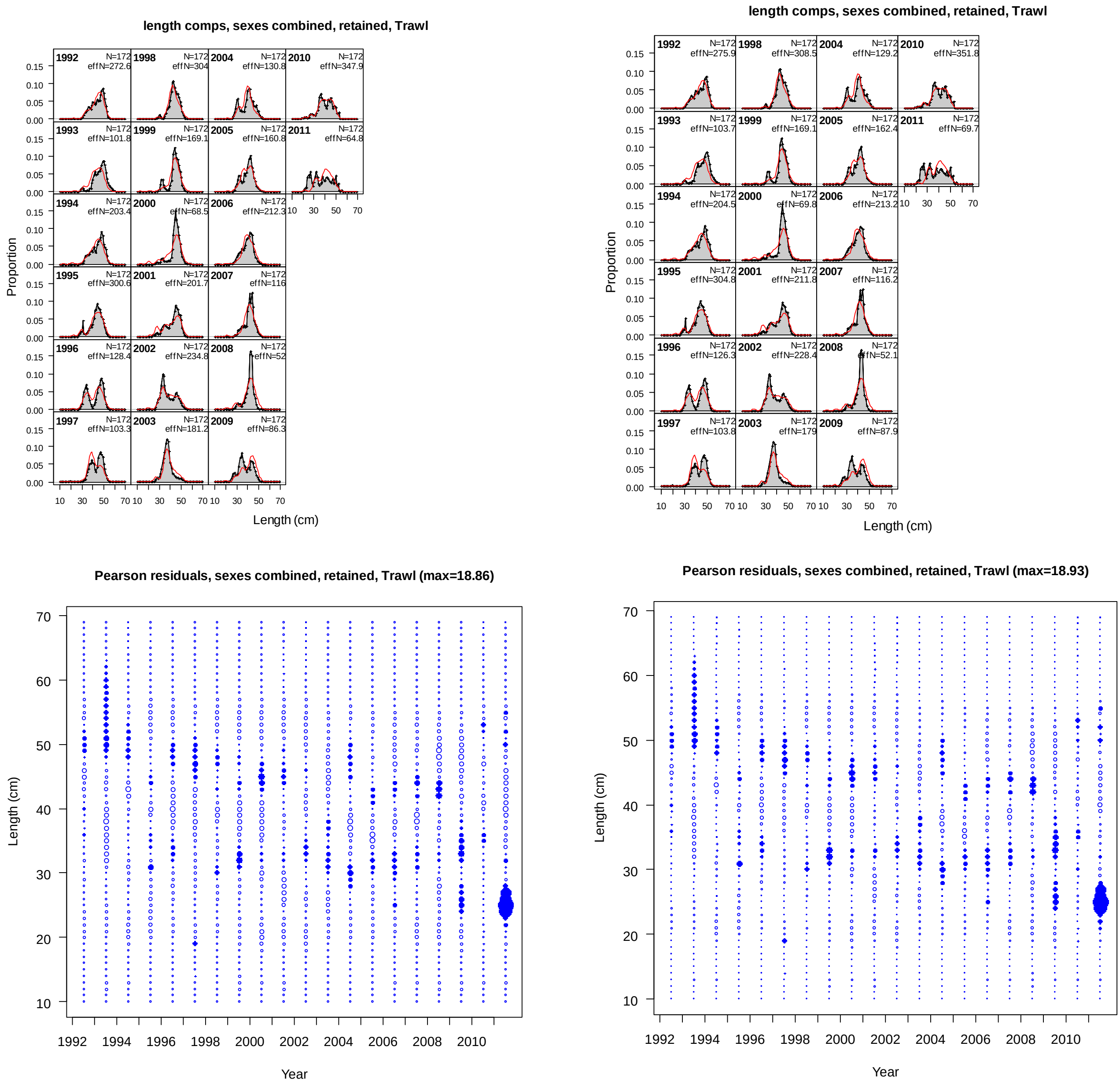


Figure 6.19. Top: observed and model-predicted fits to the length data. Bottom: residuals from the annual length compositions for the proposed base-case analysis (age $\lambda = 0.1$, cohort dependent growth; LHS) and alternative 4 (one extra recruitment; RHS).

7. Silver Warehou (*Seriolella punctata)* stock assessment based on data up to 2011[3]

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7.1 Summary

This chapter presents a quantitative Tier 1 assessment of silver warehou (*Seriolella punctata*) in the Southern and Eastern Scalefish and Shark Fishery (SESSF) using data up to 31 December 2011. The last full assessment was presented in Tuck and Fay (2009). The 2012 assessment updates all data inputs (catch, discard, length, ageing error, age and catch rate data) and is performed using the stock assessment package Stock Synthesis (SS-V3.24f).

Results show reasonably good fits to the catch rate data. However, when comparing the observed and expected catch rate data points for the last 2 years in the series, the model may be overly optimistic and the stock could break out again (requiring a further Tier 1 update if it is placed on a multi-year TAC) in a relatively short time period. Additional data will help identify if the initial signs of a possible strong recruitment are confirmed or not.

The increase in spawning biomass in the late 1980s is supported by the CPUE data and the age and length data and does not appear to be an artefact of the increase in CPUE when this fishery was initially exploited. While continued declines in catches and catch rates indicated some concern for this species, the results of the primary base-case model suggest that it is still very close to the target biomass.

The primary base-case assessment estimates that the projected 2013 spawning stock biomass will be 46.6% of virgin stock biomass. The RBC from the base-case model for 2013 is 2,544t for the 20:35:48 harvest control rule, with a long-term yield of 2,618t. In comparison, the last assessment estimated the 2010 and 2013 depletions to both be 48%, with corresponding RBCs of 2,660t and 2,644t, with a long-term yield of 2,664t.

If recent recruitments (2008-2011), which are not currently estimated by the model, are assumed to be poor and at similar levels to recruitment during the period 2002-2005, then depletion in 2013 could fall below 40%. Under this scenario, setting a multi-year TAC could result in depletion levels falling below 30% by 2015. In contrast, if recruitment is average (which is what is assumed in most projections of stock dynamics), and if catches continue to fall below the TAC, then depletion should be above the target level by 2015.

[3] Paper presented to the Slope RAG, November 2012

7.2 Introduction

7.2.1 ***The Fishery***

Silver warehou occur throughout the SESSF in depths to 500m. They are predominantly caught by trawl, although some non-trawl (gillnet) catches occur (Morison *et al*., 2007). Annual catches (landings and discards) of silver warehou by calendar year are shown in Table 7.1. Large catches of silver warehou were first taken in the 1970's (Smith, 1994) and catches increased to 4,400t in 2002. Catches have since declined to less than 2000t. Discard tonnage and length frequency are very variable and appear market driven. Silver warehou have also been captured off western Tasmania as bycatch of the winter spawning blue grenadier fishery in recent years.

Since 2010, the agreed TAC has been 2,566t. This agreed TAC was set following the last assessment in 2009 (Tuck and Fay, 2009) and applies to the 2012/2013 fishing year.

7.2.2 ***Stock structure***

A recent stock-structure study indicated that a single stock exists east and west of Bass Strait (Morison *et al*. 2007). A common stock had previously been assumed for management purposes and is assumed for the assessment presented here.

7.2.3 ***Previous Assessments***

The previous full quantitative assessment for silver warehou was performed in 2009 (Tuck and Fay, 2009) using Stock Synthesis (version SS-V3.03a, Methot, May 2009). The 2009 assessment indicated that the spawning stock biomass levels in 2010 were around 48% of virgin biomass.

Fits to the length, age, and catch-rate data were reasonable. The fit to the catch rate index was a substantial improvement compared to Tuck and Punt, (2007). Exploration of model sensitivity showed that the model outputs are sensitive to the value assumed for natural mortality, *M*.

Prior to the 2009 assessment, the previous full quantitative assessment for silver warehou was performed in 2007 (Tuck and Punt, 2007), and before that in 2004 (Taylor and Smith, 2004). The model of Tuck and Punt (2007) was an age-structured integrated assessment coded in SS2. It indicated that spawning stock biomass levels at 2006/07 were around 49% of virgin biomass.

7.2.4 ***Modifications to the previous assessments***

Only minor modifications have been made to the previous assessment, including updating data to 2011. The previous assessment (Tuck and Fay, 2009) used Stock Synthesis version SS-V3.03a (Methot, May 2009). The 2012 assessment uses the most recent version of Stock Synthesis (version SS-V3.24f, Methot, October 2012). There are relatively minor changes between these two versions of Stock Synthesis.

7.2.5 ***Data-related issues***

(a) The landings and discard mass (added into the landings) have been updated to the end of 2011.
(b) Port-based length-frequency data and age data have been updated to 2011.
(c) The catch-rate time series has been updated (Haddon, 2012).
(d) Age-reading error has been updated.

(e) Alternative weighting on the length frequency data has been considered at the request of the Slope RAG.

7.2.6 *Model-related issues*

(a) The assessment platform has been moved from SS-V3.03a to SS-V3.24f.
(b) Estimation of recruitment residuals has been limited to those cohorts for which length-composition data are available and estimated only until 2007, four years prior to the most recent data.
(c) Cohort dependent growth was fitted to improve the fits to the length frequency data (Day *et al.*, 2012), but these models were rejected by Slope RAG in October 2012 because of the poorer resulting fits to the CPUE data

Table 7.1. The discard rate, the proportion of factory vessels, the adjusted discard rate, the landed catch, the discard mass, the total catch (tonnes), the state catch and the standardised catch rate and c.v. (Haddon, 2012) and the agreed TAC for silver warehou based upon a calendar year (Klaer, 2009). Note that landed catch data include state catch.

Year	Discard rate (%)	Proportion factory vessels	Adjusted discard rate (%)	Landed (t)	Discard (t)	Total catch (t)	State catch (t)	Catch rate	Catch rate c.v.	Agreed TAC (t)
1979						0				
1980						67				
1981						135				
1982						202				
1983						269				
1984						337				
1985			10.85	360	44	404				
1986			10.85	1008	123	1131		1.4228	0.0000	
1987			10.85	749	91	840		1.5121	0.0563	
1988			10.85	1366	166	1532		1.9169	0.0510	
1989			10.85	920	112	1032		1.5678	0.0539	
1990			10.85	1126	137	1263		1.659	0.0544	
1991			10.85	1363	166	1529		1.1675	0.0532	
1992			10.85	1865	227	2092		1.0123	0.0558	2000
1993	1.33		1.33	1969	27	1996		1.1448	0.0487	2000
1994	2.02		2.02	2054	42	2097	188	1.2249	0.0477	2500
1995	23.67		23.67	2214	686	2900	149	1.1080	0.0470	2500
1996	22.19		22.19	2736	780	3516	181	1.0502	0.0462	2500
1997	10.87	0.01	10.76	2807	339	3146	38	1.0783	0.0469	2500
1998	9.28	0.02	9.09	2434	243	2677	24	1.0390	0.0478	3500
1999	1.36	0.11	1.21	3255	40	3295	2	0.8951	0.0474	4000
2000	3.20	0.23	2.46	3727	94	3821	0	0.8113	0.0464	4000
2001	17.42	0.18	14.28	3295	549	3845	0	0.6811	0.0462	4400
2002	11.87	0.34	7.83	4102	349	4451	0	0.7357	0.0456	4400
2003	20.10	0.21	15.88	3060	578	3638	1	0.7411	0.0461	4488
2004	26.30	0.04	25.25	3315	1120	4435	4	0.8231	0.0459	4039
2005	12.99	0.00	12.99	2913	435	3348	5	0.8088	0.0464	4400
2006	3.87	0.02	3.79	2374	94	2468	2	0.7116	0.0473	4400
2007	3.98	0.01	3.94	1987	82	2069	4	0.6722	0.0484	3088
2008	3.16	0.06	2.97	1523	47	1570	1	0.6018	0.0487	3227
2009	2.36	0.02	2.31	1379	33	1412	1	0.6203	0.0488	3000
2010	1.31	0.05	1.25	1289	16	1305	1	0.5126	0.0488	2566
2011	25.81	0.05	24.52	1229	399	1629	1	0.4816	0.0484	2566

7.3 Methods

7.3.1 ***The data and model inputs***

7.3.1.1 Biological parameters

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

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

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

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

7.3.1.2 Fleets

The assessment for silver warehou is based on a single trawl fleet, with time-invariant logistic selectivity. While there is some non-trawl catch, it is small and the results of previous assessments (e.g. Thomson, 2001) were insensitive to the inclusion of the non-trawl catches.

7.3.1.3 Landed catches

The model uses a calendar year for all catch data. Landings of silver warehou prior to the start of SEF1 record-keeping in 1985 are not considered to have been large. However, a linear increase in catch from 1979 to the first year of SEF1 catches was used as an estimate of pre-SEF1 catch, following Punt *et al*. (2005). Total landings data (including both Commonwealth and state landings) were reliably available from 1985-2011 (Klaer 2009, Upston and Klaer 2012). Annual landed catches used in this assessment are shown in Table 7.1 and Figure 7.1.

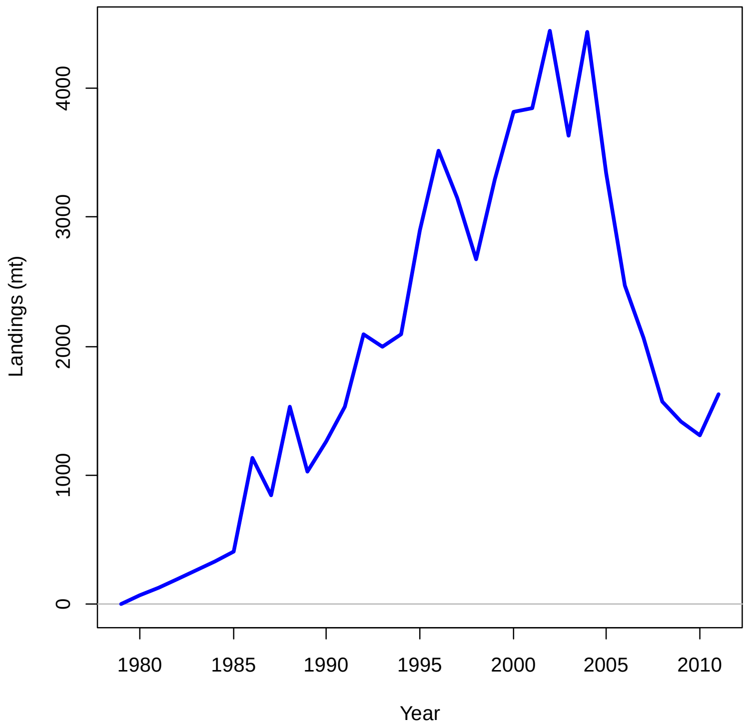

Figure 7.1. The total landed catch of silver warehou in the SESSF from 1979-2011 as used in this assessment.

7.3.1.4 Discarded catches

Information on the discard rate of silver warehou is available from the ISMP for 1993-2011. These data are summarised in Table 7.1 and Figure 7.2. Discard rates vary amongst years and have ranged between 20% and 30% for a number of periods (1995-6, 2003-4, 2011), less than 5% for other periods (1993-4, 1999-2000, 2006-10) and with values in between these extremes for the remaining years. Thomson (2002a) states that members of the fishing industry had indicated that discarding of silver warehou occurs when market prices are low and is therefore not related to the size of the fish caught. However, examination of the ISMP data on the length frequency of catches and discards (Figure 7.2) shows that there are times when discarding of silver warehou also appears to be size-related (Tuck and Fay, 2009). There is no clear pattern indicating when discarding will be market-driven and when it will be size-related. Consequently, the mass of fish that were estimated to have been discarded by the trawl fleet was added to the landed catch and not treated as a separate data source, so the discard length frequencies shown in Figure 7.2 are not used in the assessment. The average discard rate for 1993 to 2008 (10.85%) was assumed for the years from 1985 to 1993 to calculate the discard mass to add to the landings data, using the same period to calculate this average discard rate as used in the previous assessment (Tuck and Fay 2009). This choice of time period prevents any possible recent changes to discarding practices affecting the discard rate assumed in these earlier years.

In addition, a number of factory trawlers have operated since 1997 in the spawning fishery for blue grenadier. These trawlers have fishmeal plants which absorb all fish that might otherwise have been discarded. Thus, the factory vessels effectively have zero discard rates (Thomson, 2002b). ISMP sampling occurs aboard 'wet boats' only and not aboard factory trawlers. The discard rates therefore apply to the 'wet boats' only. The overall discard rate for the year is therefore computed by adjusting the 'wet boat' discard rates by the proportion of the catch not taken by factory vessels. This follows the same procedure for dealing with discards as used by Tuck and Fay (2009).

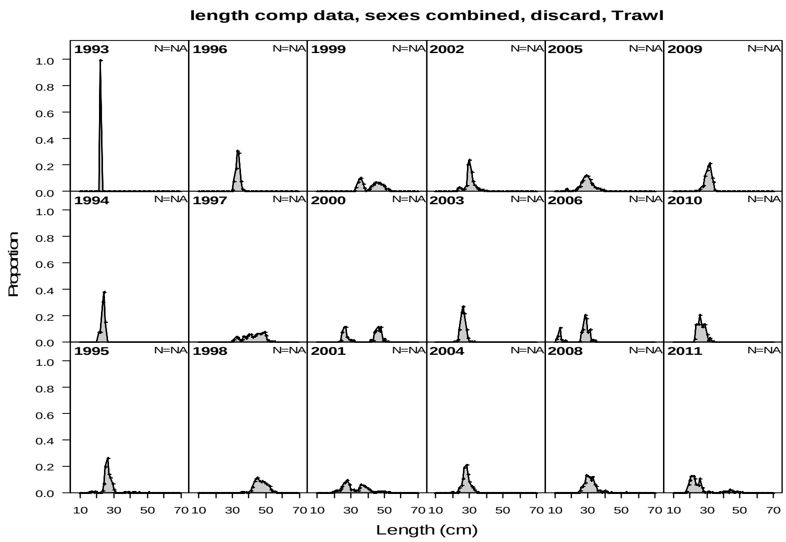

Figure 7.2. The discard length frequencies for silver warehou by year.

7.3.1.5 Catch rate indices

Catch and effort data from the SEF1 logbook database from the period 1986 to 2011 were standardised using GLMs to obtain indices of relative abundance (Haddon, 2012) with the results listed in Table 7.1 and illustrated in Figure 7.3. Data used in this standardisation were restricted to trawl shots in depths between 0 and 600m from zones 10 to 50.

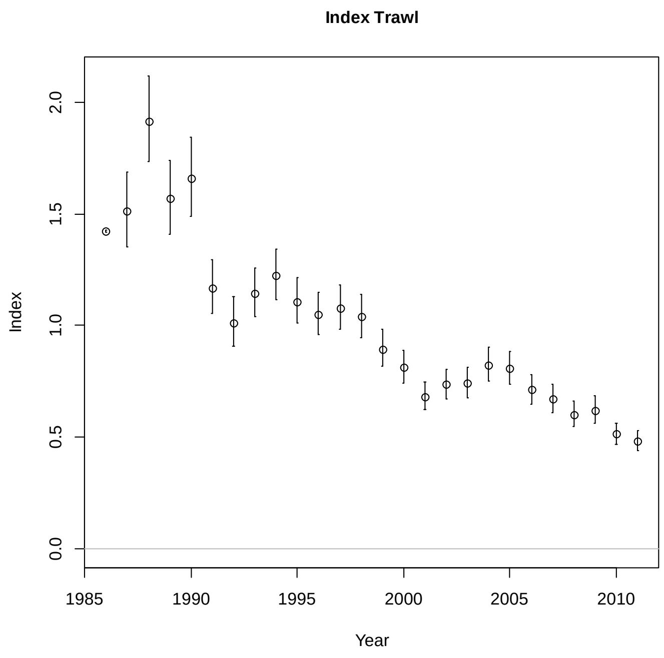

Figure 7.3. Standardised catch rates for silver warehou with error bars indicating the standard deviation.

7.3.1.6 Length composition data

In 2010 the RAGs decided to include both port and onboard retained length frequency data (for both historic and current years) in future assessments, whereas previously only port data have been used (Tuck and Fay, 2009). Length composition information for the retained component of the catch by the trawl fleet is available from port and onboard sampling for 1992-2011 (Table 7.2 and Figure 7.8).

Table 7.2. Number of samples in the length composition data used in the primary base case.

year	length samples
1992	3835
1993	4895
1994	4322
1995	8611
1996	10317
1997	14864
1998	22022
1999	19531
2000	19223
2001	21106
2002	28644
2003	15932
2004	13345
2005	20971
2006	14459
2007	1392
2008	1609
2009	3521
2010	4001
2011	2861

7.3.1.7 Age composition data

Age-at-length measurements, based on sectioned otoliths provided by the CAF, were available for the years 1993 to 2011 (Table 7.3 and Figure 7.10). An estimate of the standard deviation of age-reading error was calculated by André Punt (pers. comm., 2012) using data supplied by Kyne Krusic-Golub of Fish Ageing Services Pty Ltd and a variant of the method of Richards *et al.* (1992) (Table 7.4).

The implied age distributions are obtained by transforming length frequency data to age data by using the information contained in the conditional age-at-length data from each year.

Table 7.3. Number of samples in the conditional age-at-length data used in the primary base case.

year	age-at-length samples
1988	132
1993	334
1994	359
1995	451
1996	515
1997	566
1998	585
1999	782
2000	406
2001	997
2002	722
2003	444
2004	305
2005	477
2006	395
2007	306
2008	547
2009	821
2010	822
2011	852

Table 7.4. The standard deviation of age reading error.

Age	Std dev.
0	0.153649
1	0.153649
2	0.220276
3	0.289405
4	0.361129
5	0.435546
6	0.512757
7	0.592866
8	0.675983
9	0.762221
10	0.851697
11	0.944532
12	1.04085
13	1.14079
14	1.24448
15	1.35206
16	1.46368
17	1.57949
18	1.69965
19	1.82432
20	1.95367
21	2.08788
22	2.22713
23	2.37160

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7.3.1.8 Input data summary

The data used in this assessment is summarised in Figure 7.4, indicating which years the various data types were available.

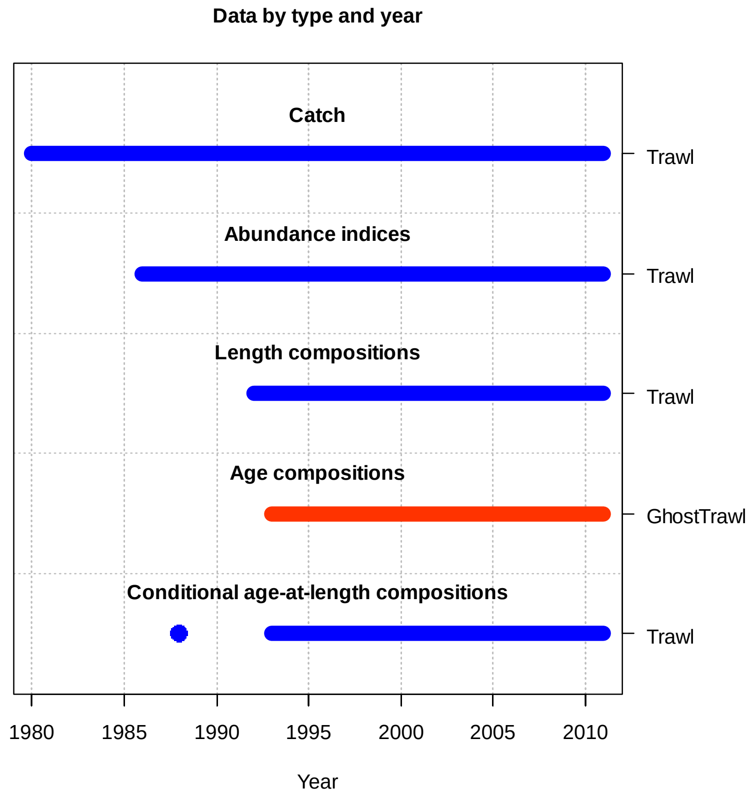


Figure 7.4. Summary of input data used for the silver warehou assessment.

7.3.2 ***Stock Assessment method***

7.3.2.1 Population dynamics model and parameter estimation

In 2009, a single-sex single-fleet stock assessment for silver warehou was conducted using the software package Stock Synthesis (version SS-V3.03a, Methot 2009). Stock Synthesis is a statistical age- and length-structured model which can allow for multiple fishing fleets, and can be fitted simultaneously to the types of information available for silver warehou. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, is outlined fully in the SS2 user manual (Methot, 2009, Methot, 2012) and is not reproduced here. This year, the model was translated to the latest version of Stock Synthesis (version SS-V3.24f, Methot 2012). A comparison of parameter estimates and population trajectories showed a very close match across the two versions of Stock Synthesis.

Some key features of the base case model are:

(a) Silver warehou constitute a single stock with in the area of the fishery.
(b) The population was at its unfished (virgin) biomass with the corresponding equilibrium (unfished) age-structure at the start of 1979.
(c) The CVs of the CPUE indices for the trawl fleet are tuned (by adding 0.05 to the CVs provided with the CPUE standardisation (Haddon 2012).

(d) Selectivity for the trawl fleet is length-specific, logistic and time-invariant. The two parameters of the selectivity function were estimated within the assessment.
(e) The rate of natural mortality, *M*, is assumed to be constant with age, and also time-invariant. The base-case value for *M* is 0.30 yr^{-1}
(f) Recruitment to the stock is assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at virgin spawning biomass, R_0, and the steepness parameter, *h*. Steepness for the base-case analysis is set to 0.75. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1980 to 2007. Deviations are not estimated prior to 1980 because there are insufficient data prior to 1980 to permit reliable estimation of recruitment residuals. Deviations are not estimated after 2007 as there would be insufficient numbers of fish recruited to the fishery to reliably estimate recruitments from 2008 (the age at which 50% of fish have been recruited to the trawl fishery is approximately 4). This final year for estimating recruitment deviations is confirmed by observing the increase in asymptotic standard error estimate of the recruitment deviation produced by Stock Synthesis.
(g) The value of the parameter determining the magnitude of the process error in annual recruitment, σ_r, is tuned (set equal to 0.52 prior to tuning) according to current agreed practice.
(h) A plus-group is modelled at age 23 years.
(i) All sample sizes for length frequency data greater than 200 were individually down-weighted to a maximum sample size of 200. This is because the appropriate sample size for length frequency data has a closer relation to the number of shots sampled, than the number of fish measured. The length frequency data would be given too much weight relative to other data sources if the raw numbers of fish measured were used. These capped sample sizes were then further tuned so that the input sample size was equal to the effective sample size calculated by the model.
(j) Growth of silver warehou is assumed to be time-invariant, in that there is no change over time in mean size-at-age, with the distribution of size-at-age being estimated along with the remaining growth parameters within the assessment. No differences in growth related to gender are modelled, because the stock is modelled as a single-sex.

This model is referred to as the primary base case model. Two additional possible base case models are also considered in this document.

7.3.2.2 Calculating the RBC

The SESSF Harvest Strategy Framework (HSF) was developed during 2005 (Smith *et al.* 2008) and has been used as a basis for providing advice on TACs in the SESSF quota management system for fishing years 2006-2012. The HSF uses harvest control rules to determine a recommended biological catch (RBC) for each stock in the SESSF quota management system. Each stock is assigned to one of four Tier levels depending on the quality and quantity of data for that stock. Silver warehou is assessed as a Tier 1 stock and it has an agreed quantitative stock assessment.

The Tier 1 harvest control rule specifies a target and a limit biomass reference point, as well as a target fishing mortality rate. Since 2005 various values have been used for the target and the breakpoint in the rule. For the 2013 TACs AFMA has directed that the 20:40:40 (B_{lim}:B_{msy}:F_{targ}) form of the rule will be used up to where fishing mortality reaches F_{48}. Once this point is reached, the fishing mortality is set at F_{48}. Day (2008) has determined that for most SESSF stocks where the proxy values of B_{40} and B_{48} are used for B_{MSY} and B_{MEY} this form of the rule is equivalent to a 20:35:48 strategy.

7.3.2.3 Sensitivity tests

A number of standard sensitivity tests are used to examine the sensitivity of the results of the 2012 primary base case to some of the assumptions and data inputs:
(a) M = 0.25 and 0.35 yr^{-1}.
(b) h = 0.65 and 0.85
(c) 50% maturity occurs at length 34 and 40cm.
(d) σ_R = 0.42 and 0.62.
(e) Recruitment deviations estimated to 2006 and 2008.
(f) Double and halve the weighting on the CPUE series.
(g) Double and halve the weighting on the length composition data.
(h) Double and halve the weighting on the age-at-length data.
(i) CPUE data deleted prior to 1992.

In addition to these sensitivities, the October 2012 Slope RAG meeting requested two additional alternative base cases be prepared, with the length frequency data down weighted compared to the primary base case using the length λ set to 0.25 and 0.1 and the model retuned in each case.

7.3.2.4 Summary statistics

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

(a) SB_0	the average unexploited spawning biomass,
(b) SB_{2013}	the spawning biomass at the start of 2013,
(c) SB_{2013}/SB_0	the depletion level at the start of 2013, i.e. the 2013 spawning biomass expressed as a percentage of the virgin spawning biomass
(d) $-lnL$	the negative of the logarithm of the likelihood function (this is the value minimised when fitting the model, thus a lower value implies a better fit to the data),
(e) 2013 RBC 20:35:48	the 2013 RBC calculated using the 20:35:48 harvest rule.
(f) *Long term RBC 20:35:48*	the long term RBC calculated using the 20:35:48 harvest rule.

7.4 The 2012 assessment of silver warehou

7.4.1 ***The primary base case***

7.4.1.1 Transition from the 2009 base-case to the 2012 base-case

The assessment models presented in Tuck and Fay (2009) used data up to 2008. The major changes in the 2012 assessment are: updating the version of Stock Synthesis; the addition of new data for 2009, 2010 and 2011 (including new catch, discard, CPUE, length frequency and age-at-length data); some revision of historical data, especially discards; and the inclusion of onboard data in the length frequency compositions. These revisions were considered by Day *et al.* (2012) and showed minimal changes to the general assessment outcomes and in the fits to CPUE, age and length data. The most notable changes came from minor changes to estimates of the recruitment deviations at the beginning and the end of the recruitment series which explain the differences in the spawning biomass trajectories. These differences are due to the increased freedom associated with additional data and the increase in the number of years for which recruitment is estimated. There is also additional information in the new length and age data to further inform the estimates of the 2003 and 2004 recruitment events.

The 2009 assessment (Tuck and Fay, 2009) provided a base case with a 2010 spawning stock biomass of 48% of virgin stock biomass. This assessment assumed silver warehou forms a single stock and is fished by a single fleet (otter trawl). Discards were added to the landings to account for variable discarding practices between years and natural mortality was fixed at 0.3. All of these model assumptions, which were agreed at previous RAG meetings, have also been used for the 2012 assessment.

In the 2009 assessment, it was noted that there was some conflict between the length and age data and that the length residuals behave differently before and after 2002, with patterns in these residuals indicating some possible issues with the fits to the length data. In addition, it was noted that there had been a recent decline in both the catch and the CPUE.

Day *et al.* (2012) demonstrated spatial variability in fits to the von Bertalanffy growth curves in silver warehou, with apparent differences in growth between fishing zones 20 (Eastern Bass Strait), 40 (Western Tasmania) and 50 (Western Bass Strait). Changes in the distribution of fishing effort between these regions over time may be responsible for the poor residual pattern seen in the fits to the length composition data. A number of approaches could be used to address this issue and to try and improve the fits to the length composition data, including using cohort specific growth, time variant growth or possibly a spatial model (which would only be feasible if the data could be separated spatially). Day *et al.* (2012) considered some alternative assumptions, including cohort specific growth and altering the weighting on the age composition data (further decreasing the parameter down-weighting the age data, the age λ, from 0.25 to 0.1) and proposed an alternative base case incorporating both of these changes. This alternative base case produced an improvement in the fits to the length composition data, but was rejected at the October 2012 Slope RAG meeting because the fit to the CPUE deteriorated as a result.

In addition to a proposed primary base case with the same model structure as the 2009 assessment (Tuck and Fay, 2009), the October 2012 Slope RAG meeting requested that two other alternatives be considered with the length data further down-weighted, by including two values for the length λ (for the length composition data) of 0.25 and 0.1.

7.4.1.2 Tuning the 2012 base-case assessment

The proposed primary base case model needed to be tuned, following the addition of new data and this tuning was done according the following procedure:

Start with a high weight on CPUE (use very low CVs on the CPUE estimates).

Cap length frequency sample size at 200, and omit sample sizes less than 100. This is because the appropriate sample size for length frequency data is more closely 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 is used.

Reset the bias adjustment fraction and ramps before and after recruitment is estimated

The sample sizes for length frequencies are tuned for each fleet so that the input sample size is on average approximately equal to the effective sample size calculated by the model.

In this case, tuning the age data according to the procedure outlined in (d) would have resulted in an increase in weighting in the age samples, due to a conflict between the age data and the rest of the fitted data (length and CPUE data), as was seen in the 2009 assessment (Tuck and Fay, 2009). As a result, the tuning of the age data was done by adjusting the age λ, the weight assigned to the total likelihood for these data. There are large numbers of observations (ages at a given length) with small sample sizes, so there is an additional advantage in using the age λ which avoids any risk of attempting to down weight sample sizes below one.

The value of the parameter determining the magnitude of the process error in annual recruitment, σ_R, is set such that the standard deviations of estimated recruitment about the stock-recruitment relationship equals the pre-specified value for σ_R.

The CVs of the CPUE indices for the trawl fleet are tuned to match the model-estimated standard errors (by adding an appropriate amount to the CVs provided with the CPUE standardisation of Haddon (2012)).

When re-tuning the silver warehou assessment, the data series showed a clear conflict between (i) the length and CPUE data, and (ii) the age data. If the weight on the age data remained fixed at a value that approximates that used in 2009 (age λ = 0.25) then fits to the length, catch rate and age data are very good. However, if greater weight is apportioned to the age data (age λ =1.0) as suggested by the standard tuning procedure, then fits to the length data and in particular the catch rate data deteriorate markedly without a clear improvement in the fits to the age data. The proposed base-case model maintains the data weighting on ages at the fixed value of age, λ = 0.25, as used by Tuck and Fay (2009).

7.4.1.3 Parameter estimates of the primary base case model

Figure 7.5 shows the estimated growth curve for silver warehou. All growth parameters are estimated. The estimates of the growth parameters are: (a) L_{min}=16.66cm, (b) L_{max}=50.41cm, (c) K=0.3080 yr^{-1}, and (d) cv of growth = 0.0841.

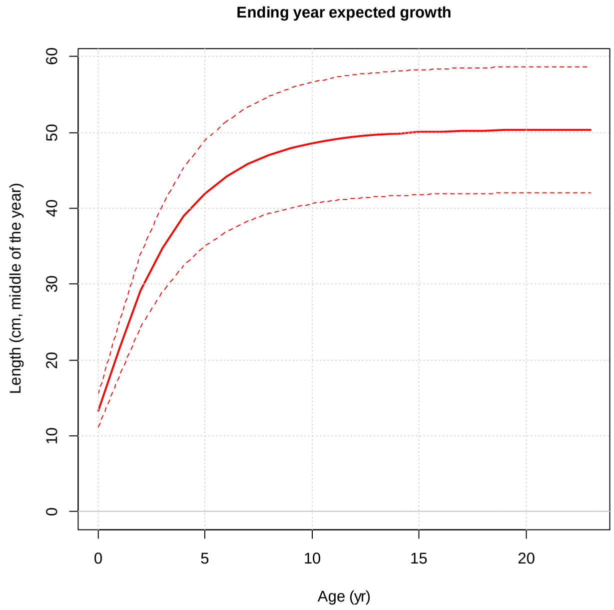


Figure 7.5. The model estimated growth function for silver warehou for the primary base case analysis.

Figure 7.6 shows the estimated selectivity curve for silver warehou, with the parameters that define this selectivity function including the length at 50% selection and the spread. The estimates of these parameters for the base-case analysis are 39.51cm and 11.69cm respectively. The estimate of the parameter that defines the initial numbers (and biomass), *ln(R0)*, is 9.668 for the primary base case.

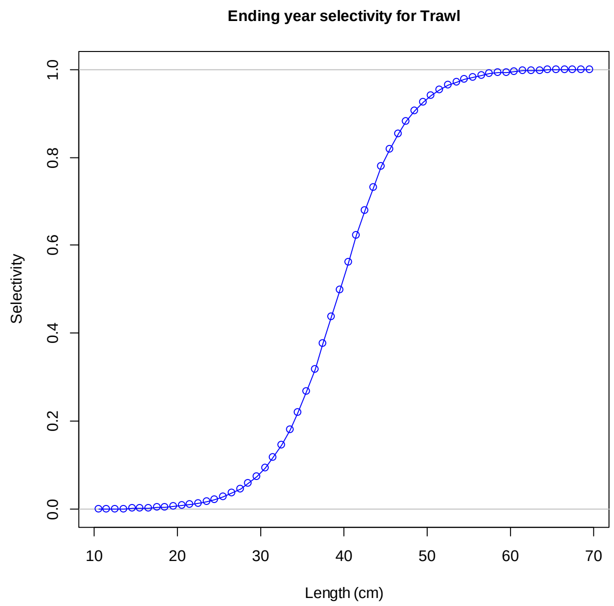


Figure 7.6. The model estimated selectivity for the otter trawl fleet for silver warehou for the primary base case analysis.

7.4.1.4 Fits to the data for the primary base case

The fits to the catch rate indices (Figure 7.7) for the primary base case are very good with an improvement to the fit from the previous assessment (Tuck and Fay, 2009), especially in the period from 2000 to 2008. However, the trends in the data and the fit for the last three data points, (2009, 2010 and 2011) suggest some conflict and the potential for this species to break out again in the near future. The data over this period suggests a downwards trend, and yet the model shows an increasing trend, with the model prediction very close to the upper 95% confidence bound. The 2009 assessment (Tuck and Fay, 2009) showed a similar contrast in trends between the data and the fit in the last three points of the CPUE time series (2006, 2007 and 2008), with the modelled value in 2008 close to the upper 95% confidence bound, leading to a breakout between the modelled predicted CPUE values and the observed CPUE values in the future.

The primary base-case analysis is able to fit the retained length-frequency distributions adequately (Figure 7.8), with similar fits to those obtained by Tuck and Fay (2009) and reproducing a similar poor residual pattern (Figure 7.9). The implied fits to the age-composition data are shown in Figure 7.10. It should be noted that these age-compositions are not fitted directly, but are essentially fits to the length distributions with the length data transformed to age using a conversion from length to age obtained through the conditional age-at-length data. The fits to the implied age-compositions provide a means of checking the adequacy of the model and the model fits the observed age data very well. Of the new age and length composition data, the fits to length and age are excellent for 2010, with poorer fits to both length and age in 2009 and length in 2011.

The 2011 length data has two peaks of small fish which may indicate a recruitment coming through or may be a result of unrepresentative sampling. The smallest peak appears to come from the port length frequency data and the next peak up from the onboard length frequencies (Klaer *et al*., 2012). The port length frequencies were largely sampled from Eastern Bass Strait (SESSF Zone 20) with no port length frequency samples collected from Western Tasmania and Western Bass Strait (SESSF Zones 40 and 50), where the majority of the catch was taken. Future length frequency data should confirm whether this data is indicative of a recruitment event, or if it is an artefact of the sampling regime.

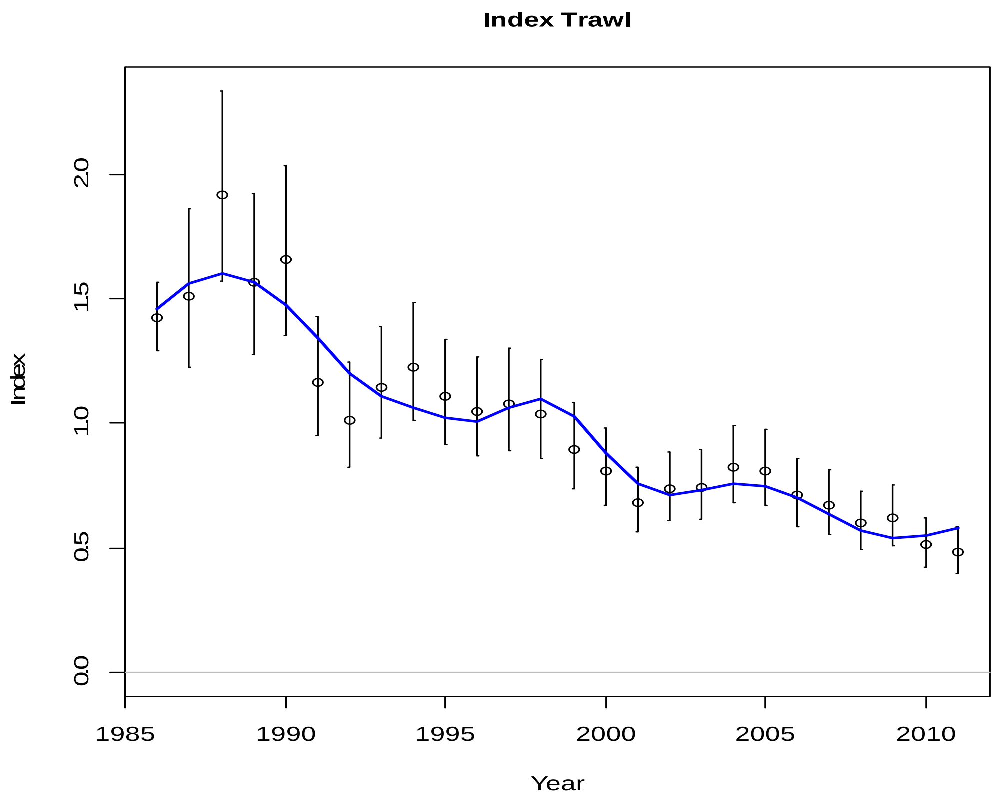


Figure 7.7. Observed (circles) and model-predicted (blue line) catch-rates for silver warehou for the otter trawl fleet versus year for the primary base case analysis. The vertical lines indicate approximate 95% confidence intervals for the data.

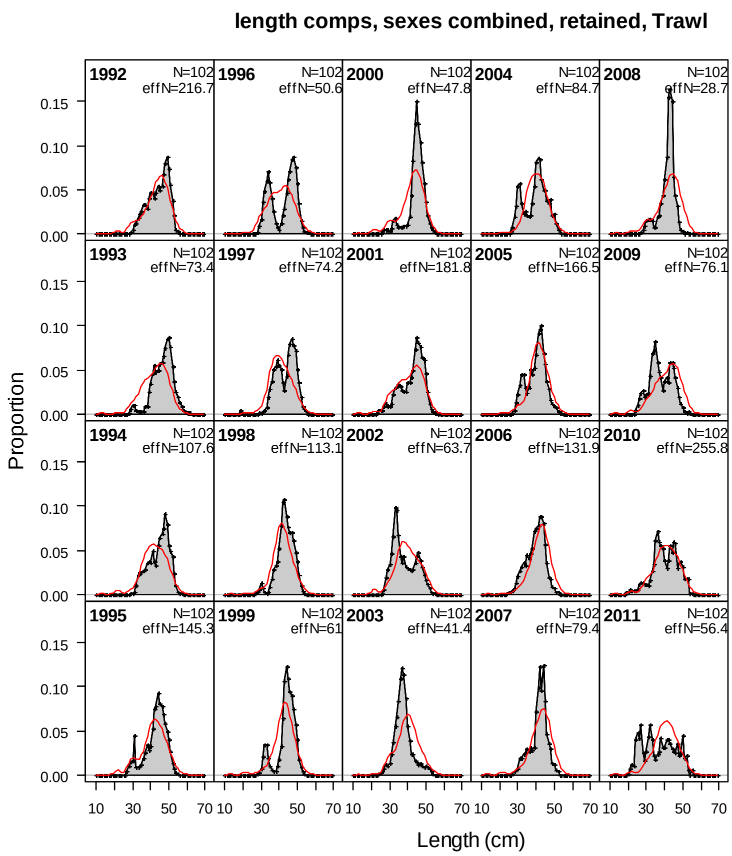


Figure 7.8. The observed (shaded) and model-predicted (red line) fits to the length composition data for silver warehou for the otter trawl fleet for the primary base case analysis.

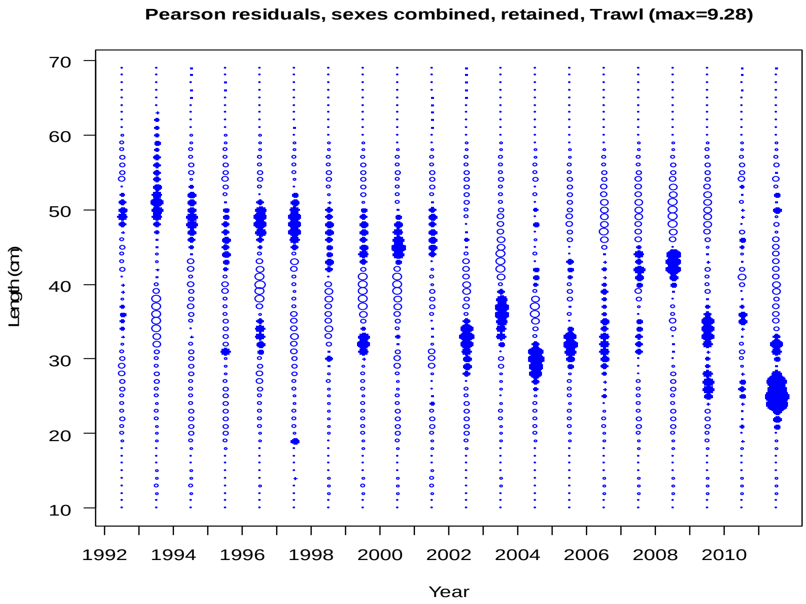


Figure 7.9. The residual pattern for the length composition data for silver warehou for the primary base case analysis.

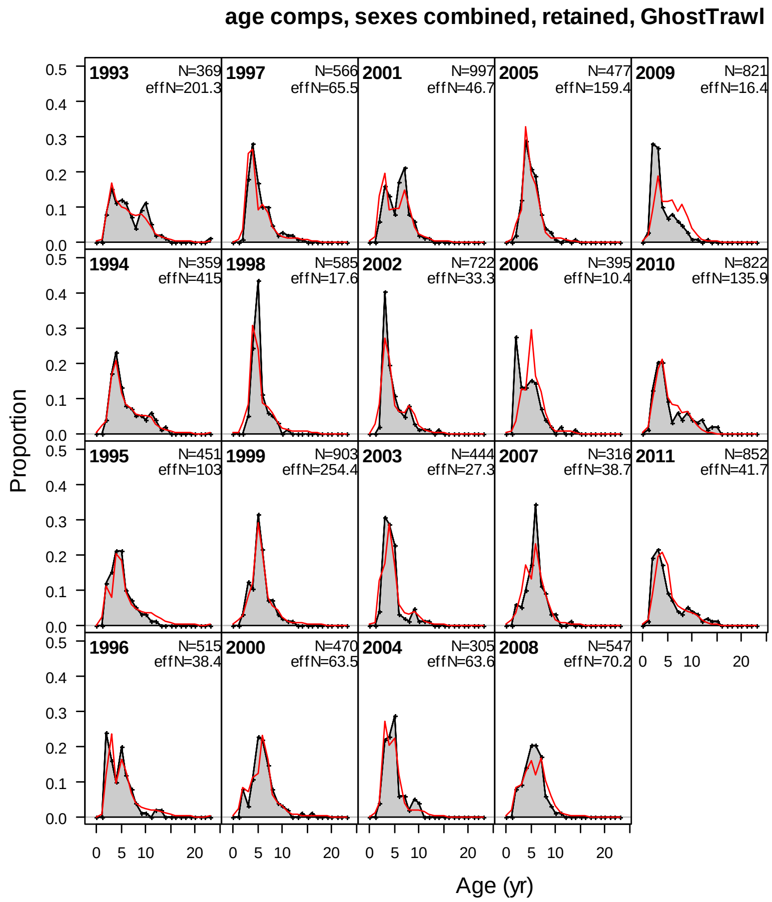


Figure 7.10. The observed (shaded) and model-predicted (red line) fits to the implied age composition data for silver warehou for the otter trawl fleet for the primary base case analysis.

7.4.1.5 Assessment outcomes for the primary base case

Figure 7.11 shows the relative spawning stock depletion with the limit and target reference points at 20% and 48% respectively. The increase in stock size in the late 1980s followed by a subsequent decline is a result of the large recruitment in 1983 with below average recruitment in the early and late 1980s. The stock size continues to fluctuate as recruitment varies between periods of good and poor recruitment and as the catch also varies. However there is clearly an overall decline in stock size since the late 1980s. The increase in stock size towards the end of the series should be treated with some caution as this may be a result of the model imposed average recruitment from 2008 onwards, when recruitment is unable to be estimated. As data becomes available to inform these recruitment events in future assessments, this increase in stock size from 2010 - 2012 may need to be revised.

The time-trajectories of recruitment and recruitment deviation are shown in Figure 7.12 and the bias adjustment and standard errors of recruitment deviation estimates are shown in Figure 7.13. The current (2013) spawning stock biomass is estimated to be 47% of unfished stock biomass (i.e. 2013 spawning biomass relative to unfished spawning biomass).

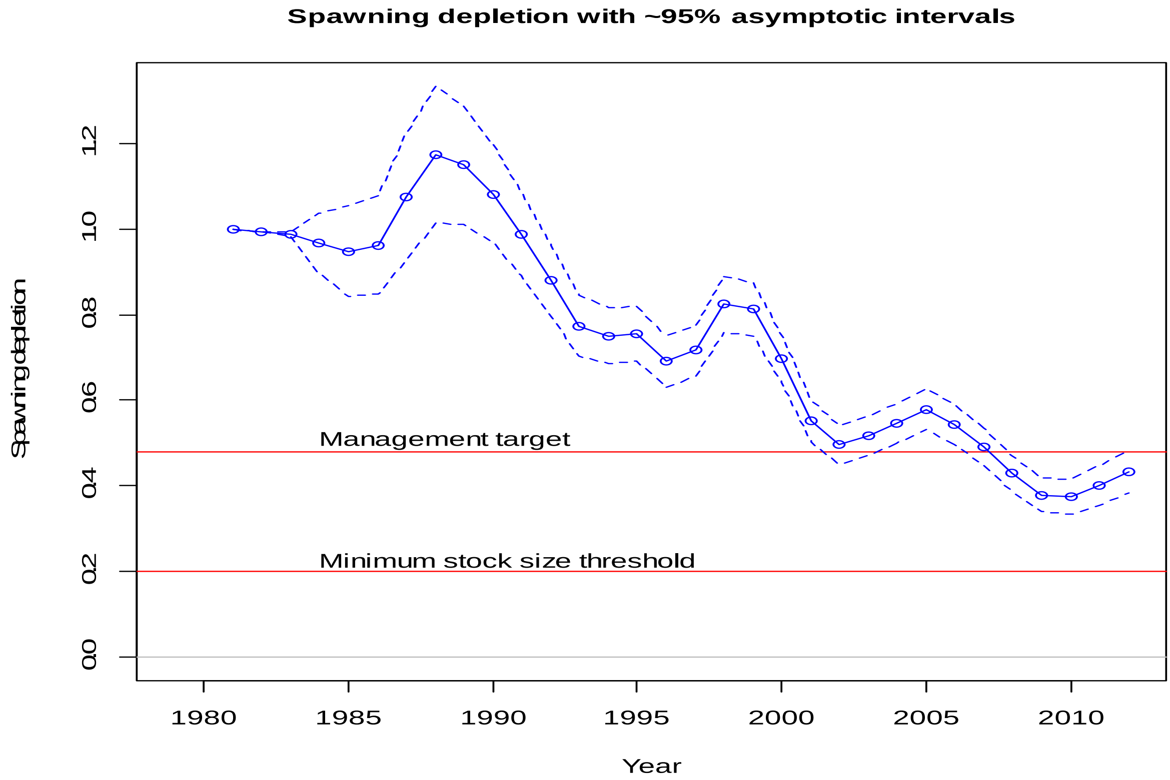


Figure 7.11. Time-trajectory of spawning biomass depletion (with 95% confidence intervals) corresponding to the MPD estimates for the primary base case for silver warehou.

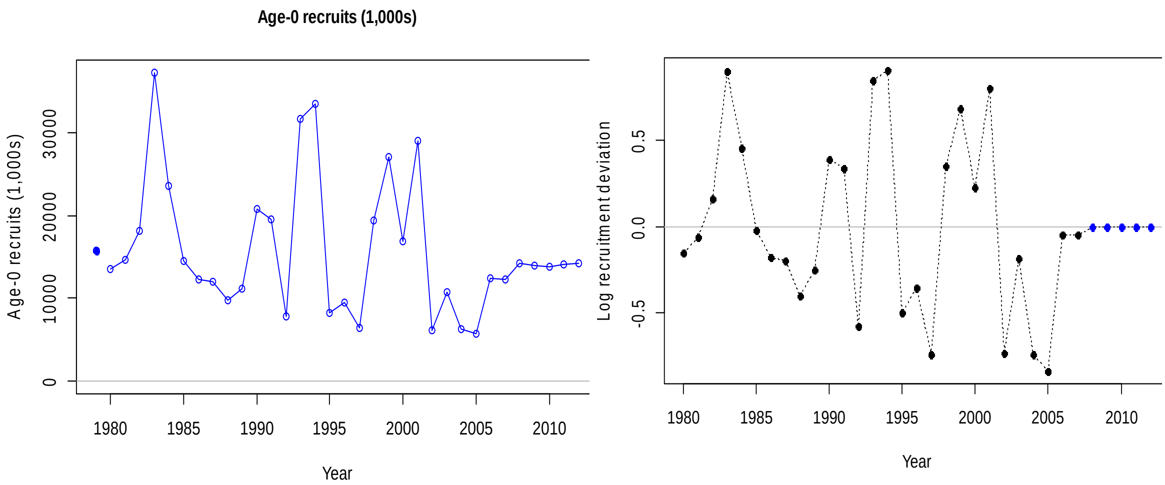


Figure 7.12. Recruitment estimates for the primary base case for silver warehou. Time trajectories of estimated recruitment numbers (left) and estimated log recruitment deviations (right).

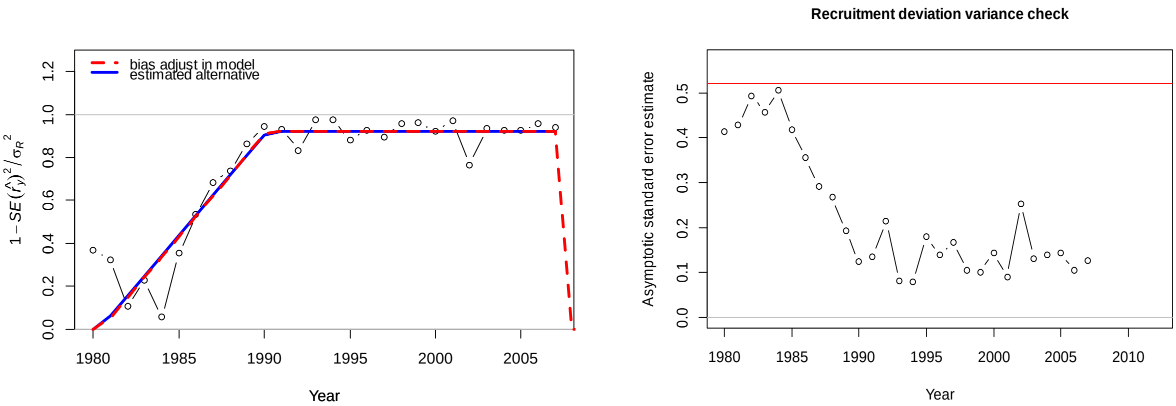


Figure 7.13. Bias adjustment (left) and standard errors of recruitment deviation estimates (right) for the primary base case for silver warehou.

Table 7.5. Summary of fixed and estimated parameters for the primary base case model

Feature	Details	
Natural mortality (*M*)	fixed	0.3
Steepness (*h*)	fixed	0.75
σ_R in	fixed	0.52
length-weight scale, *a*	fixed	0.0000065
length-weight power, *b*	fixed	3.27
length at 50% maturity (cm)	fixed	37
maturity slope	fixed	-6
Recruitment deviations	estimated	1980-2007, bias adjustment ramp 1980-1990
CV growth	estimated	0.0841
Growth *K*	estimated	Female 0.308
Growth l_{min}	estimated	Female age 2 16.66
Growth l_{max}	estimated	Female 50.41
length at 50% selectivity (cm)	estimated	39.51
selectivity spread (cm)	estimated	11.69
$ln(R_0)$	estimated	9.668

7.4.2 ***Fits to the data for the alternative base cases***

At the October 2012 Slope RAG meeting, it was suggested that the length composition data could be further down weighted with the expectation that this would give an improved fit to the CPUE series and potentially an alternative base case. This was achieved by applying values of 0.25 and 0.1 to the length λ (the length λ is set to 1 for the primary base case) and then tuning these two alternative models.

When these alternative base case models were constructed, the model produced worse fits to the length composition data, as expected, and better fits to the age composition data. However the fits to the CPUE data did not improve and instead deteriorated slightly (see Table 7.7). Given these alternative base cases were suggested in an effort to produce even better fits to the CPUE and this objective is not achieved, these (fully tuned) models are presented here as sensitivities rather than as genuine alternative base cases. The comparative fits to the length and age data between the primary base case and these alternatives are not presented here. Instead, the comparisons of the fit to the CPUE data are shown in Figure 7.14.

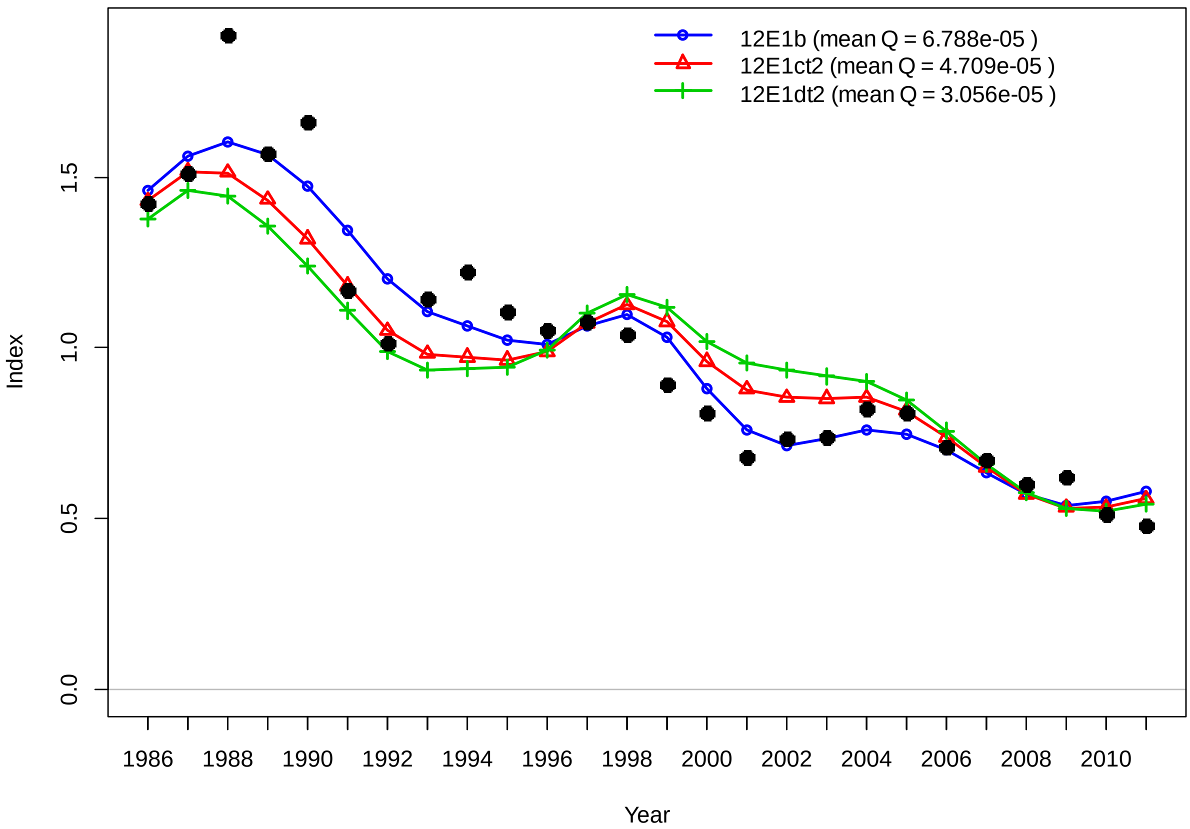


Figure 7.14. Fits to the CPUE data for the primary base case (blue) and the two alternative base cases with length λ=0.25 (red) and length λ=0.1 (green). The primary base case (blue) clearly has the best fit to the CPUE data out of these three alternative models.

7.4.3 *Sensitivities and alternative models*

Results of the sensitivity tests are shown in Table 7.6 and Table 7.7. The results are most sensitive to the assumed value for natural mortality (*M*). However, even with *M*=0.35, the improved fits to the age data give an improvement to the overall likelihood of only two units. The base-case value for *M* of 0.3 was previously agreed by the RAG (Tuck and Fay 2009), based on biological reasons relating to the maximum age of this species and previous likelihood profile analysis (Tuck and Punt, 2007). These results also show some sensitivity to the length at 50% maturity. However varying this parameter does not alter the overall likelihood. Changes to the other fixed parameters produce little change to the overall likelihood and only minor changes to the depletion estimates.

Changing the weighting on various data sources has only minor impacts on the depletion estimates. The likelihood cannot be compared directly in these cases, but Table 7.7 shows the relative differences between the different components of the total likelihood, attributable to these changes.

This also confirms the conflict between the CPUE and the age and length data as increasing the weight on the age or the length data results in poorer fits to the CPUE data and yet the standard tuning procedure suggests that the age data should receive more weighting.

7.4.3.1 CPUE from 1992 onwards

The CPUE data prior to 1992 was deleted to test the theory that the early increase in CPUE may be driving an increase in spawning biomass predicted by the model in the late 1980s. It was thought that this increase may be spurious and potentially driven by some poor CPUE data, given it was obtained at a time prior to quota and when there were potential issues separating blue warehou and silver warehou in some catch records. The resulting fit to this modified CPUE series (Figure 7.15) and spawning depletion trajectories (Figure 7.16) indicate that the length and age composition data support this increase in biomass in the 1980s, and support strong recruitment in the period from 1982-1984 followed by a few years of poor recruitment in the late 1980s. This recruitment pattern produces the length and age frequencies from 1993 to 1995 with a large proportion of old fish and few young fish, which also supports the fit to the CPUE data. This suggests that there is no reason to discard the CPUE data prior to 1992 as this increase in spawning biomass is supported by both the CPUE data and the age and length data.

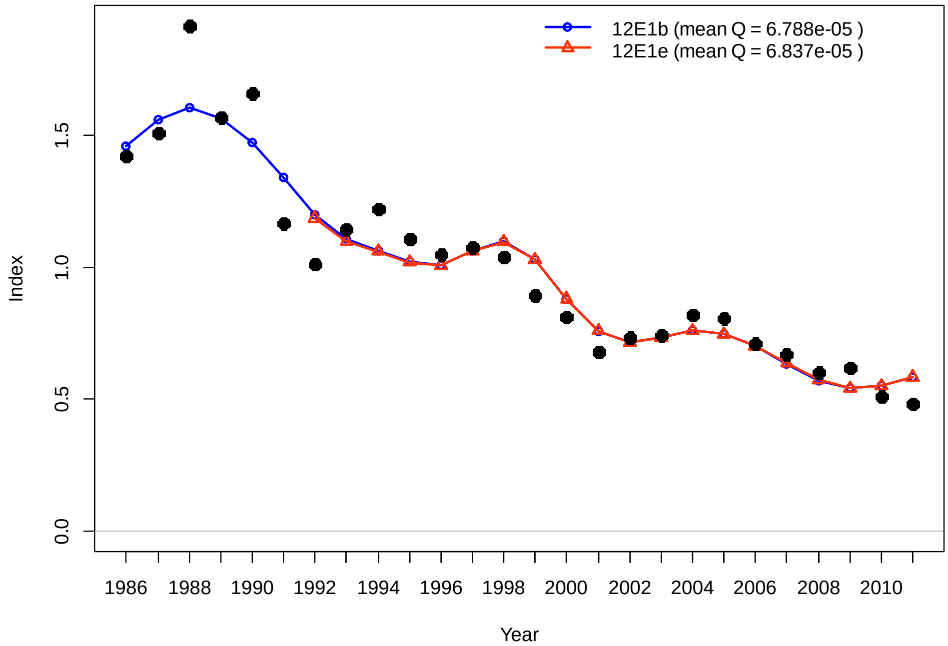


Figure 7.15. Fits to the CPUE data for the primary base case (blue) and the sensitivity excluding CPUE data prior to 1992 (red). From 1992 onwards, these fits are almost identical.

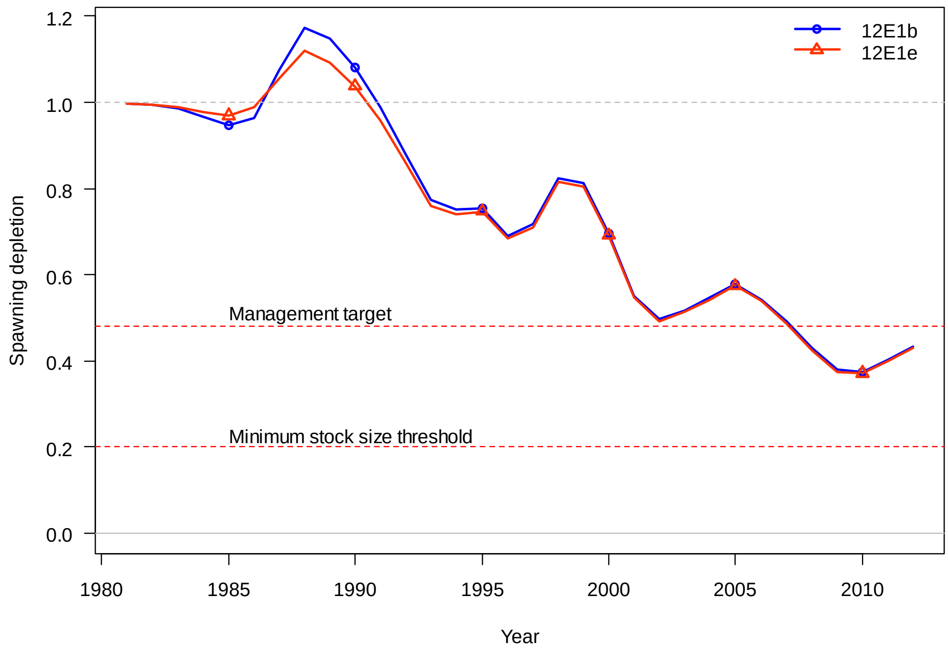


Figure 7.16. Spawning depletion trajectories for the primary base case (blue) and the sensitivity excluding CPUE data prior to 1992 (red). Both of these trajectories show an increase in spawning biomass in the late 1980s.

7.4.4 *Application of the harvest control rules in 2012*

An estimate of the catch for the 2012 calendar year is needed to run the model forward to calculate the 2013 spawning biomass and depletion. Given that recent TACs have been considerably under-caught, the catch in 2012 is assumed to equal that of 2011 (namely 1629t).

The depletion in 2013 under the base-case parameterisation is estimated to be 46.6%. An application of the Tier 1 harvest control rule with a target depletion of 48% leads to the 2013 and long-term RBCs of 2544t and 2618t (Table 7.6). An example of the time-series of RBCs and corresponding spawning biomass for the 20:35:48 harvest control rule is shown in
Figure 7.17. Table 7.8 shows the annual RBCs and depletion estimates under the 20:35:48 harvest control rule.

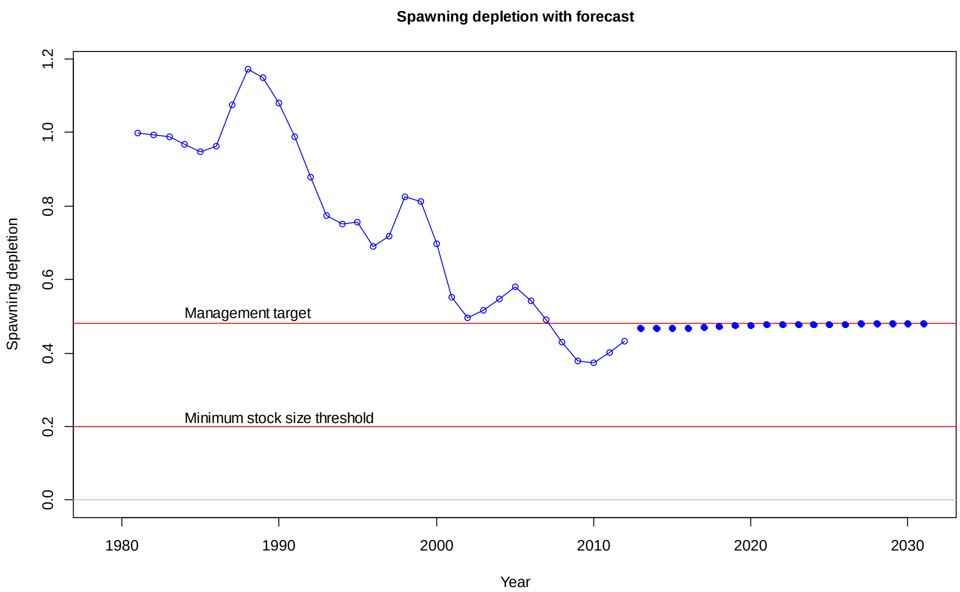


Figure 7.17. The projection of catch and RBCs (top) and the corresponding relative spawning biomass (bottom) under the 20:35:48 rule for silver warehou.

Table 7.6. Summary of results for the primary base-case analysis and sensitivity tests (log-likelihood (-ln L) values that are comparable are in bold face). Spawning stock biomass includes both male and female biomass in the total.

Model	-ln L	SB_0	SB_{2013}	SB_{2013}/SB_0	2013 RBC (t)	long term RBC (t)
primary base case	1438	**25570**	**11929**	**46.6**	**2544**	**2618**
M=0.25	1445	24504	9462	38.6		
M=0.35	1436	28552	15526	54.4		
h=0.65	1438	26088	11647	44.6		
h=0.85	1438	25200	12171	48.3		
50% maturity at 34cm	1438	28161	14145	50.2		
50% maturity at 40cm	1438	22228	9330	42.0		
σ_R = 0.42	1445	25016	11867	47.4		
σ_R = 0.62	1434	26375	12075	45.8		
est. recruitment to 2006	1439	25436	12423	48.8		
est. recruitment to 2008	1437	25710	11169	43.4		
double weight on CPUE	1449	25458	11705	46.0		
halve weight on CPUE	1431	25597	12063	47.1		
double weight on lengths	1819	25872	12128	46.9		
halve weight on lengths	1227	26260	12334	47.0		
double weight on age	2421	25481	12133	47.6		
halve weight on age	924	26400	12235	46.3		
length λ = 0.25 (tuned)	1081	29375	14112	48.0	2844	2847
length λ = 0.1 (tuned)	997	37782	19246	50.9	3652	3476
CPUE from 1992 onwards	1434	25747	11974	46.5		

Table 7.7. Summary of likelihood components for the primary base case and sensitivity tests. Likelihood components are unweighted and all cases below the primary base case are shown as differences from the base case. A negative value either in the total or individual components of likelihood indicates an improvement in fit compared to the primary base case. A positive value indicates deterioration in the fit.

Model	Likelihood TOTAL	Survey	Length	Age	Recruitment	parm_priors
primary base case	4456.28	12.41	405.47	4024.48	13.80	0.11
M=0.25	23.19	2.09	-1.20	22.13	0.16	0.01
M=0.35	-14.74	-1.12	2.45	-16.86	0.80	-0.01
h=0.65	-1.24	-0.24	1.39	-2.15	-0.24	0.00
h=0.85	1.08	0.20	-1.05	1.72	0.21	0.00
50% maturity at 34cm	0.16	0.00	-0.14	0.15	0.14	0.00
50% maturity at 40cm	-0.06	0.00	-0.04	0.18	-0.20	0.00
σ_R = 0.42	13.14	0.36	-0.46	7.82	5.42	0.00
σ_R = 0.62	-7.55	-0.11	0.18	-4.23	-3.39	0.00
est. recruitment to 2006	0.68	1.01	-0.20	-0.30	0.17	0.00
est. recruitment to 2008	0.56	-0.88	-0.50	2.02	-0.08	0.00
double weight on CPUE	4.05	-2.17	1.18	4.12	0.93	0.00
halve weight on CPUE	-1.61	1.98	-0.12	-2.87	-0.60	0.00
double weight on lengths	203.43	5.69	-45.41	243.49	-0.34	0.00
halve weight on lengths	-80.67	1.40	37.54	-121.23	1.62	-0.01
double weight on age	-101.27	5.78	46.14	-156.96	3.77	-0.01
halve weight on age	177.45	1.78	-38.17	215.54	-1.72	0.01
length λ = 0.25 (tuned)	-214.68	1.15	16.48	-232.68	0.39	-0.02
length λ = 0.1 (tuned)	-299.46	1.04	13.60	-314.34	0.23	0.01
CPUE from 1992 onwards	-4.85	-3.29	0.95	-1.62	-0.88	0.00

Table 7.8. Summary of the annual RBCs and corresponding depletion for the primary base-case analysis under the 20:35:48 harvest control rule.

Year	RBC(t)	Depletion
2012	1629	43.2
2013	2544	46.6
2014	2552	46.8
2015	2556	46.8
2016	2564	46.9
2017	2574	47.1
2018	2584	47.3
2019	2593	47.5
2020	2599	47.6
2021	2604	47.7
2022	2607	47.7
2023	2610	47.8
2024	2612	47.8
2025	2614	47.9
2026	2615	47.9
2027	2616	47.9
2028	2617	47.9
2029	2617	48.0
2030	2618	48.0
2031	2618	48.0

7.4.5 ***Scenarios with low recruitment for 2008-2011***

7.4.5.1 Poor recruitment scenario

To explore the potential impact of setting a multi-year TAC without updating this assessment, scenarios were run where the recruitment in the period from 2008-2011 was assumed to be poor. When the harvest control rules are applied and forward projections are made, recruitment deviations from 2008 onwards are set to zero, as there is insufficient information to estimate recruitment in this period. This essentially assumes average recruitment for the given level of spawning biomass for the period 2008-2011.

If recruitment from 2008-2011 was actually below average, then these forward projections produce RBCs that, if caught, could result in a lower spawning biomass than the target level. A scenario with poor recruitment was examined by fixing the recruit deviations to the mean of the log recruitment deviations from the period 2002-2005, a value of -0.62731. The period from 2002-2005 was chosen because it was a recent period of 4 years of poor recruitment, and given the historical recruitment deviation series (Figure 7.12), it seemed plausible that series of four years of poor recruitment could be repeated. The recruitment estimates for this poor recruitment scenario are shown in Figure 7.18.

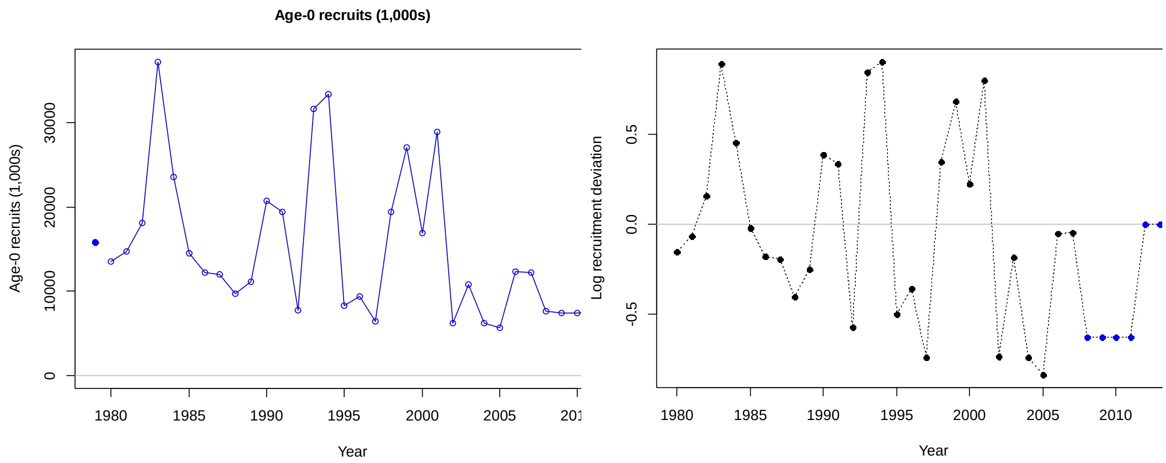
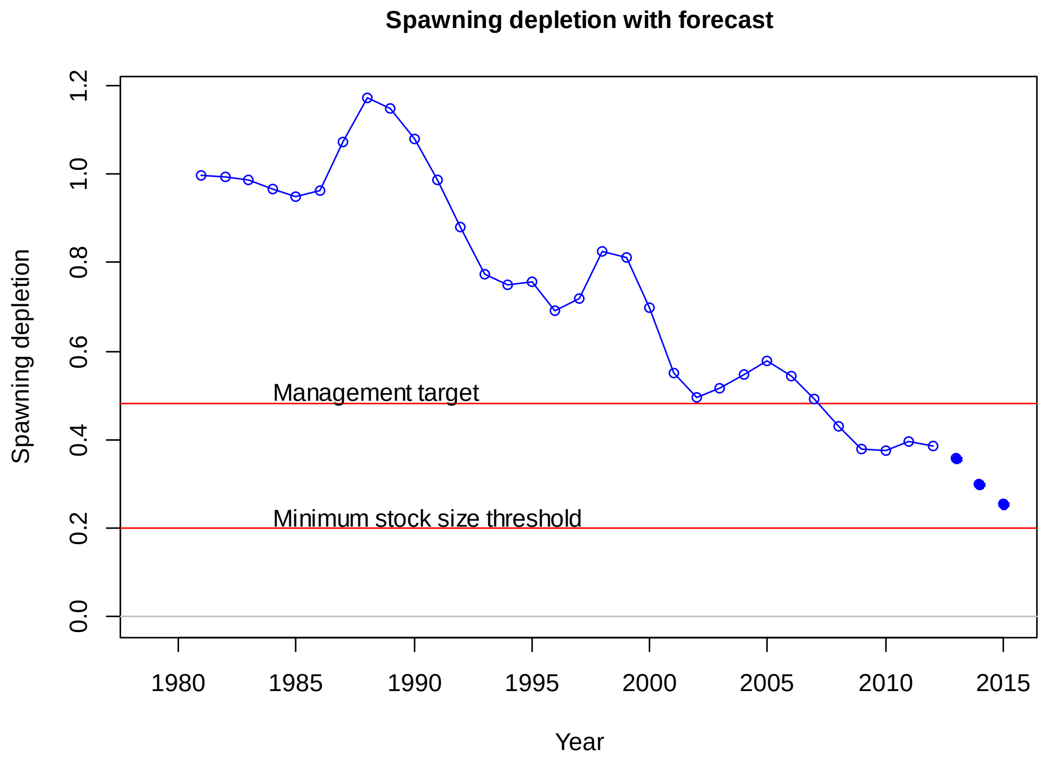


Figure 7.18. Recruitment estimates for the scenario with four years of poor recruitment (2008-2011). Time trajectories of estimated recruitment numbers (left) and estimated log recruitment deviations (right).

7.4.5.2 Fixed catch projection for three years 2013-2015

With this low recruitment assumption, the dynamics were projected forward for three additional years with two fixed catch levels examined. The first fixed catch scenario assumed that the catch was 2544t for each of the years 2013, 2014 and 2015, a catch equal to the 2013 RBC from the primary base case. The second fixed catch scenario assumed that the catch was 1629t, again for each of the years 2013, 2014 and 2015. This lower catch level, 1629t, is the 2011 total catch used in this assessment and is also the assumed catch projected forward for 2012, used to calculate the 2013 RBC. Spawning depletion scenarios and actual depletion levels are shown in Figure 7.19, Table 7.9 and Table 7.10.

The spawning biomass at the start of 2013 is 34.3% for the poor recruitment scenarios, compared to 46.6% for the average recruitment case. With both levels of fixed catch and poor recent recruitment, the spawning biomass continues to decline through until 2015. Given that the TAC has not been limiting catches recently, the fixed catch of 1629t is the more likely of these two scenarios, but even in this case, depletion could decline to below 30% by 2015 with poor recruitment in the years 2008-2011.



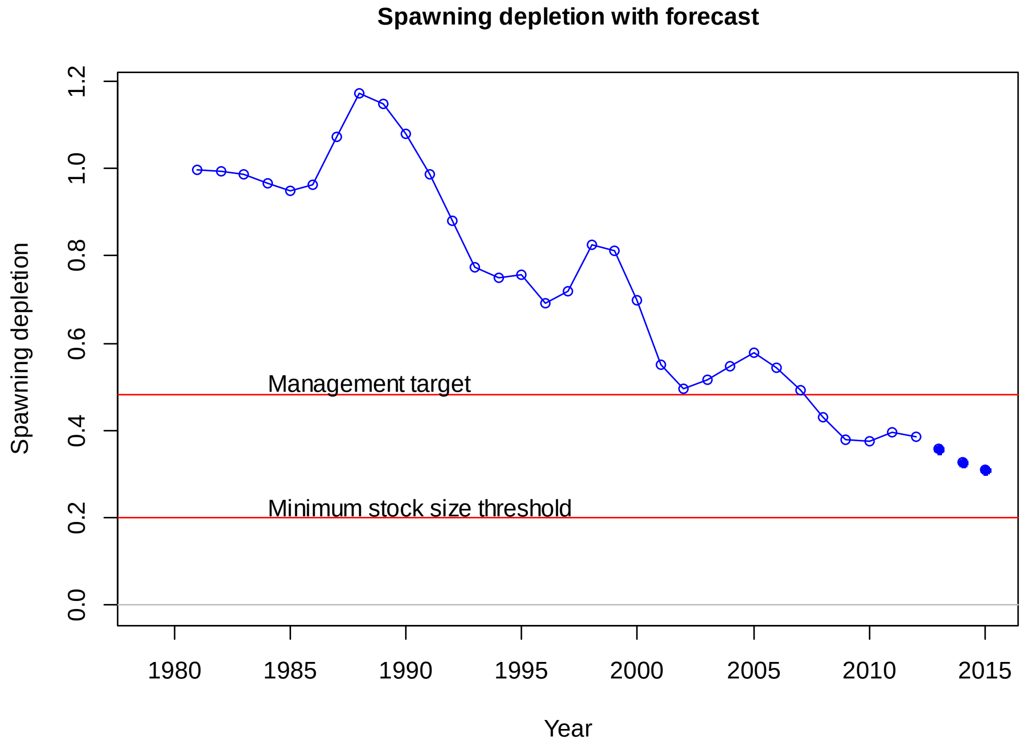


Figure 7.19. The poor recruitment scenario projections of relative spawning biomass with fixed catch of 2544t (2013 RBC) (top) and fixed catch of 1629t (2011 catch) (bottom).

Table 7.9. Depletion levels assuming poor recruitment from 2008-2011 and a fixed catch of 2544t.

Year	Catch	Depletion
2013	2544	34.3
2014	2544	27.9
2015	2544	23.0

Table 7.10. Depletion levels assuming poor recruitment from 2008-2011 and a fixed catch of 1629t.

Year	Catch	Depletion
2013	1629	34.3
2014	1629	30.7
2015	1629	28.2

7.4.5.3 Catch set to RBC for three years 2013-2015

An additional scenario was explored with the same low recruitment scenario, but with the catch set at the calculated RBC for each of the three years in the period 2013-2015. Under this scenario, the spawning biomass at the start of 2013 is still 34.3%, as in the scenarios listed in the previous section, but the catch declines, in response to the decline in spawning stock biomass. This decline in spawning stock biomass is a result of a combination of the level of the catches taken and the impact of a lower input of younger fish into the spawning stock as individuals mature from the low recruitment years 2008-2011.

RBCs and actual depletion levels for 2013, 2014 and 2015 are shown in Table 7.11. Note that both the catch (set to the RBC) and the depletion level continue to decline as the period of four years of poor recruitment gradually works its way into the spawning biomass.

Table 7.11. Depletion levels assuming poor recruitment from 2008-2011 with the yearly catch set to the calculated RBC.

Year	Catch	Depletion
2013	1706	34.3
2014	1177	30.5
2015	1098	29.4

7.5 Conclusion

This document presents an updated assessment of silver warehou (*Seriolella punctata*) in the SESSF using data up to 31 December 2011. A full stock assessment for silver warehou was last performed in 2009 by Tuck and Fay (2009) using the stock assessment package Stock Synthesis. Changes from the 2009 assessment include: (a) migration to the latest version of Stock Synthesis (SS-V3.24f), (b) updates of all catch, discard, length, age and catch rate data and the last year of estimation of recruitment (2007), four years prior to the last year of data (2008), (c) model tuning practices that are in-line with current agreed practice.

The fit of the last two CPUE data points suggest that the model may be overly optimistic at the end of the time series and that this stock could “break out” again in a relatively short time period. Breaking out occurs when the CPUE trends fall outside of the 95% confidence bounds projected from the stock assessment (Klaer, 2012). The 2011 data point is already very close to the lower 95% confidence bound from the stock assessment without any projection. Additional data will help identify if the initial signs of a possible strong recruitment are confirmed or not.

The increase in spawning biomass in the late 1980s is supported by the CPUE data and the age and length data and does not appear to be an artefact of the increase in CPUE when this fishery was initially exploited. While continued declines in catches and catch rates indicated some concern for this species, the results of this model suggest that it is still very close to the target biomass.

Alternative weightings to the length data did not result in improvements to the fit to the CPUE data. While the structure of this model closely reflects the structure adopted by Tuck and Fay (2009), there are still some causes for concern about the residual patterns in the fits to the length composition data and temporal and spatial differences in fishing effort and growth. The failure of the standard tuning methods to balance the length and age data remains an issue to be resolved.

Future development of the stock assessment for silver warehou could include a more in depth exploration of the raw data (e.g. spatial and temporal aspects of sampling), and potential changes in selectivity and growth. This may help resolve why the tuning process has a desire for greater weighting of the age data, and why there is a potential lack of fit to the length data before and after 2002. Despite these issues, the proposed base-case model in general shows good correspondence between observed and expected length, catch rate and age data.

The primary base-case assessment estimates that the projected 2013 spawning stock biomass will be 46.6% of virgin stock biomass. The RBC from the base-case model for 2013 is 2,544t for the 20:35:48 harvest control rule, with a long-term yield of 2,618t. In comparison, the last assessment estimated the 2010 and 2013 depletions to both be 48%, with corresponding RBCs of 2,660t and 2,644t, with a long-term yield of 2,664t.

If recent recruitment (2008-2011) turns out to be poor, at similar levels to recruitment during the period 2002-2005, then depletion in 2013 could fall below 40% and setting a multi-year TAC could result in depletion levels falling below 30% by 2015. In contrast, if recruitment is average, and if catches continue to fall below the TAC, then depletion is estimated to be above the target level by 2015.

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8. Jackass morwong (*Nemadactylus macropterus*) 2013 RBC calculation[4]

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8.1 Summary

In 2012, the Shelf RAG agreed to not conduct a full jackass morwong stock assessment. To calculate the 2013 RBC, the 2011 assessments for both eastern and western morwong have been projected for one more year, using actual catches from 2011, and estimated catches for 2012. 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 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 2011, and state catches were added. The estimated catch in 2012 was the amount of the 2012 calendar year actual Total Allowable Catch (TAC) that is expected to be caught, based on the proportion of TAC caught in 2011. The TACs are for a fishing year starting on 1 May, whereas the model uses calendar year catches. Thus the 2012 calendar year TAC is calculated as one-third of the 2011/2012 TAC plus two-thirds of the 2012/13 TAC. To arrive at the amount expected to be caught in 2012 this is then multiplied by the proportion of the calendar year TAC caught in 2011. This catch is then divided amongst fleets in the same proportions by fleet as caught in 2011.

Current spawning biomass in the eastern stock is projected to be 37.7% of 1988 spawning stock biomass, and the 2013 RBC under the 20:35:48 harvest control rule is 380 t. For the western stock, current spawning biomass is projected to be 66% of unexploited stock biomass, and the 2013 RBC is 275 t (Table 8.2).

In recent years the catch in the east has exceeded the eastern RBC, although the total catch has been within the TAC as the addition of the western stock increases the combined RBC. The 2013 combined RBC is 655 t. The RBC for the east, at 380 t, is comparable to recent catches in the east (Table 8.2).

[4] Paper presented to the Shelf RAG, 5-6 November 2012

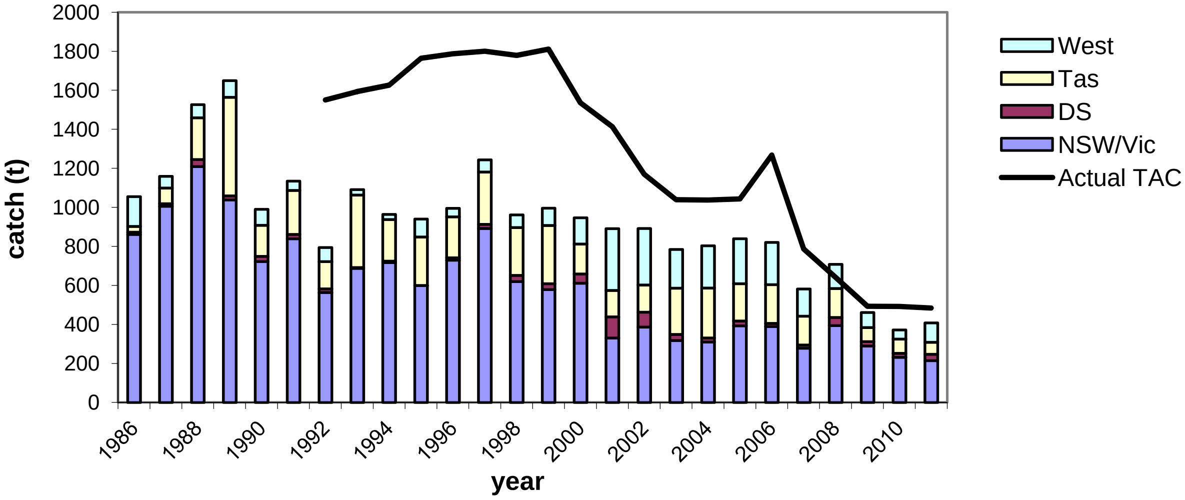

Figure 8.1. Actual TAC (by fishing year from 2008) and catches of jackass morwong by fleet (calendar year), for 1986 to 2011.

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 – 2011. The 2012 catches are 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 (est)	*239*	*66*	*37*	*111*

Table 8.2. Relative stock biomass estimates (%), RBCs, actual 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		67	282		640		565
2013	38	380		66	275		655		

* 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

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9. Deepwater flathead (*Neoplatycephalus conatus*) stock assessment based on data up to 2011/12 – development of a base case[5]

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9.1 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 chapter describes the process used to develop a preliminary base case for deepwater flathead (*Neoplatycephalus conatus*) for presentation at the first stock assessment meeting in 2012, and the subsequent development of a base case, given additional data prior to the second meeting. 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 37% of B_0.

9.2 Input data

9.2.1 *Catches*

Recent catches for deepwater flathead and Bight redfish were taken directly from CDR landings data for the GABTF maintained by AFMA. All values from 02/03 to 09/10 were checked to be the same as reported previously. New figures were added for 10/11 and 11/12. Total catch estimates for the period 1988/89 to 2009/10 are given in Table 9.1. A new Danish seine vessel operated in the 2011/12 financial year, taking 16% of the total deepwater flathead catch and 1% of the Bight redfish catch. Both state catches and discards are assumed to be negligible for deepwater flathead, and are not accounted for by the stock assessment.

9.3 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, 2006). It is anticipated that standardisations for deepwater flathead and Bight redfish will be added to the list of SESSF species processed in a standard manner. However, for the assessment this year the standardisation was carried out for GAB species in the same manner as in previous years (e.g. Klaer, 2006).

5 Paper presented to the GAB RAG November 2012

Table 9.1. 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

Only data that conformed to the following filtering criteria were examined:

- Boats included if median annual catch greater than 4t and have caught the species for 3 or more years;
- Depth<1000m;
- Non-zero species catch;
- Shot length >1.0 hr <10.0 hr.

The following factors were included for examination of their effects on catch rate:

- Year (Financial)
- Month
- Zone: int(Longitude/5.0)
- Depth: int(Depth/50)
- Vessel

The form of the model used in the R statistical package was:

sSP.glm<-
lm(datSP.CPUE~datSP.year+datSP.month+datSP.zone+datSP.depth+datSP.vessel, data= datSP)

where CPUE for each fishing operation is log(catch/hours trawled).

A comparison of LM model results with that presented in 2010 is shown in Figure 9.1.

Table 9.2. Year factor values from GAB log-linear model for deepwater flathead.

	Index
87/88	0.43
88/89	0.96
89/90	0.89
90/91	0.96
91/92	0.85
92/93	1.02
93/94	1.38
94/95	1.80
95/96	1.78
96/97	1.20
97/98	0.82
98/99	0.61
99/00	0.71
00/01	0.79
01/02	0.92
02/03	1.32
03/04	1.28
04/05	1.02
05/06	0.65
06/07	0.59
07/08	0.65
08/09	0.77
09/10	0.70
10/11	0.89
11/12	0.65

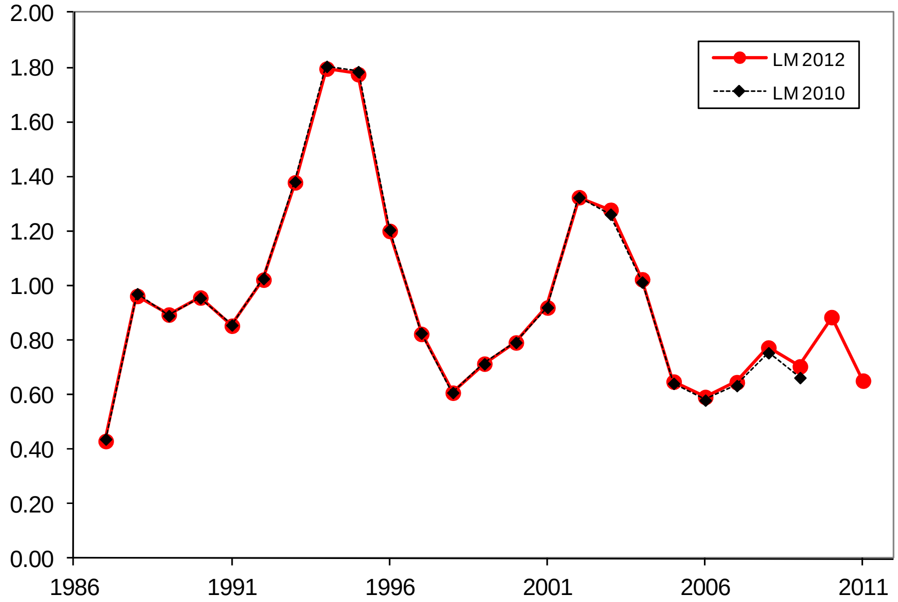

Figure 9.1. Deepwater flathead comparison of LM 2012 results with LM 2010.

9.4 Fishery-independent survey

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

Table 9.3. 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

9.5 Development of a preliminary base case

9.5.1 *Initial development of a preliminary base case presented to GABRAG October 2012*

Updated recent data were then added sequentially to the converted 2010 model to develop a preliminary base case for the 2012 assessment:

1. Upgrade to SS version 3.24f and rerun 2010 assessment (2012SS3.24f).

2. Change final assessment year to 2011, add catch and CPUE to 2011 (2012CatCPUE).

3. Add survey abundance estimates to 2010/11 (Surv200810).

4. Add age composition data to 2010 (none 2011) (Age2011).

5. Add length compositions from AFMA observers/port to 2011 (LenAFMA11).

6. Add length compositions from industry collections in 2011/12 (LenInd2011).

7. Set final estimable recruitment value to 2004.

8. Retune model. Start with low CV on CPUE and survey, set age comp lambda to 0.1 (0.25 previously), set 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.

Sequential effects of the above changes are shown in Figure 10.1.

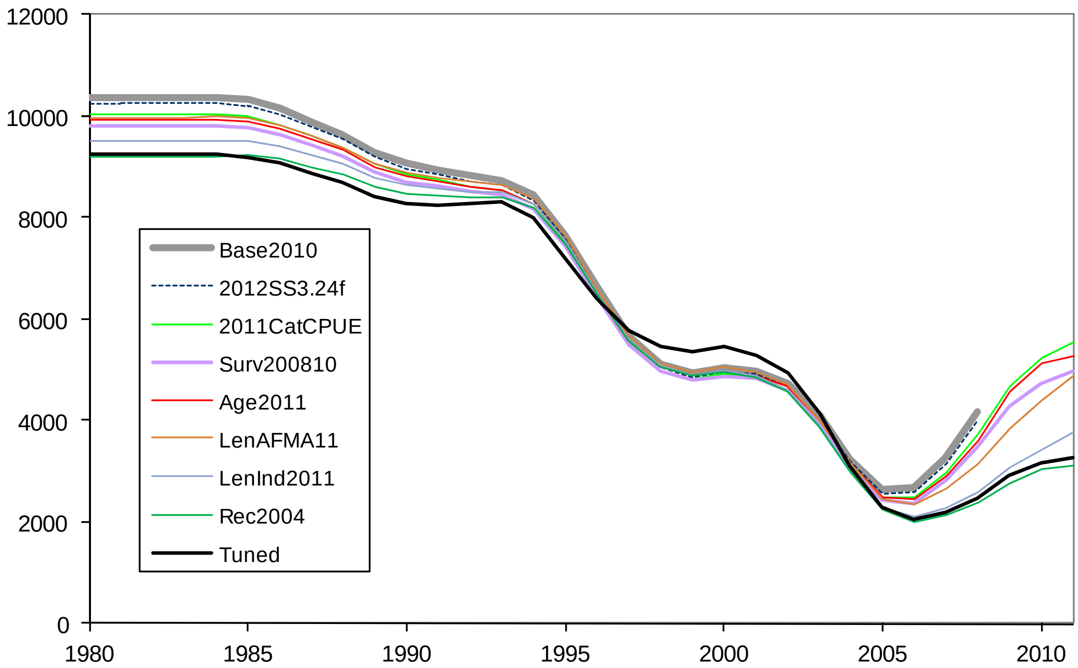

Figure 10.2. Effect on spawning biomass trends of sequential update with the most recent data, and preliminary model balancing.

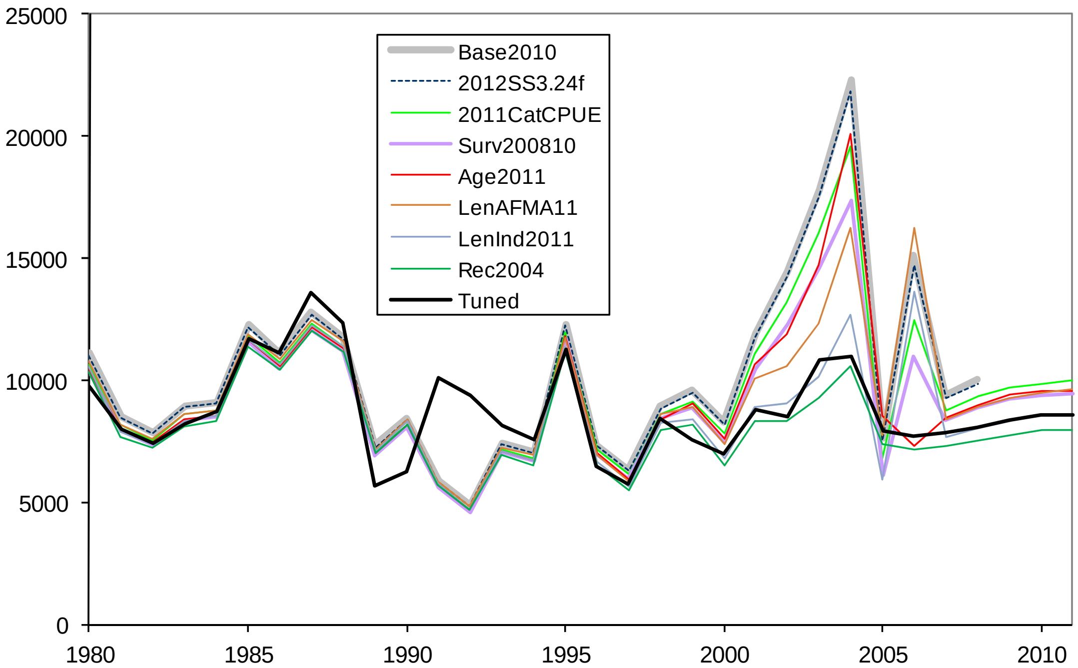

Figure 10.3. Effect on recruitment trends of sequential update with the most recent data, and preliminary model balancing.

9.6 *Subsequent development incorporating data collected to June 2012*

Some confusion was caused by the unknown status of length samples collected by the fishing industry during the 2009 to 2012 calendar years. A summary of the number of length samples available from AFMA by calendar year as port measurements and how many of those contained sample weights allowing processing is shown in Table 9.4. Although industry measurements are collected on board fishing vessels, at present those samples are most easily processed as samples collected in port. This is due to the increased requirement for supplementary data not collected by the industry that are required for onboard AFMA observer-collected samples.

Length samples included in the current deepwater flathead stock assessment are summarised in Table 9.5. This shows a lower number of available samples for 2010/11 than surrounding years – some of which would be attributable to missing information, particularly on sampled fraction of the catch. A small number (121) of industry-collected samples from early in 2012 were included as onboard samples. An additional 367 otolith age samples were made available for the 2011/12 financial year and also included in the stock assessment.

Table 9.4. Summary by calendar year of data held as port samples by AFMA.

Calendar year	Available	Inc sample wt
2009	8,042	6,670
2010	17,919	6,650
2011	31,053	3,771

Table 9.5. Summary by financial year of length samples included in the current stock assessment by source.

Financial year	Lengths	Source
2009/10	13,911	Port+onboard
2010/11	2,502	Port
2011/12	7,280	Port+onboard

Because of the additional age data available for 2011/12 a re-examination was required of the standard errors of recruitment residuals when residuals were estimated through to 2009 (Figure 9.2). This standard error for the 2005 estimate is considerably greater than for 2004, but the two subsequent estimates for 2006 and 2007 are within the same range as other recent estimates e.g. 1996 to 1998. Based on these standard errors, it was decided that the base case model could provide recruitment residual estimates to 2007.

The effect of inclusion of additional length measurements (Len2012) and age samples (Age2012) on the preliminary base case, estimating recruitment to 2007 (Rec2007) is shown in Figure 9.3 and Figure 9.4. In these plots, the tuned model from Figure and Figure was the starting point for comparison, and is labelled PreBase.

The SS2 versions of previous deepwater flathead assessments (to 2009) used a setting that set the maximum allowable F value in any year to 0.9. On conversion to SS3, the setting for maximum F was set to 1.0, although the meaning of this value differs depending on the F estimation method used. The current deepwater flathead assessment uses the recommended hybrid of Pope's approximation and instantaneous F calculations. Documentation also says that for this method, the maximum F setting should be a value of 4, which is assumed to not put any particular penalty on high annual F values. As this was the recommended procedure, a setting of 4 was implemented (FPen). This option allows F values in particular years to be higher than the previous assessment versions allowed – the highest now being a value of about 0.7 in 2005 when fishery catches were highest. While this value may seem intuitively high, there does not appear to be an objective reason or data that could be used to show that the value is implausible. To follow objective procedures therefore, the recommended value of 4 has now been used.

The FPen model was then tuned to create the base case (Base2012).

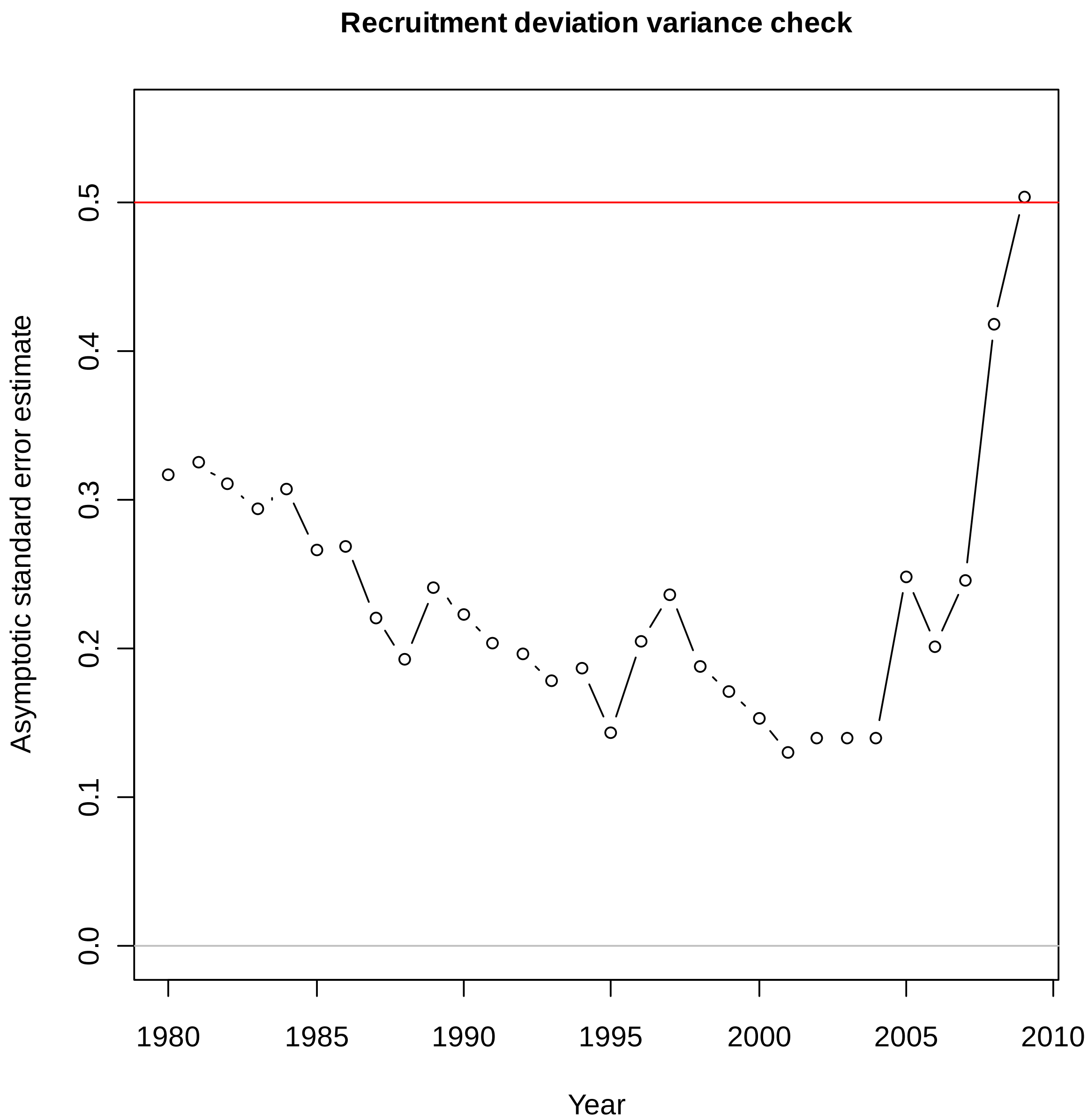

Figure 9.2. Standard errors of recruitment residual estimates for the Age2012 model with estimation of residuals to 2009.

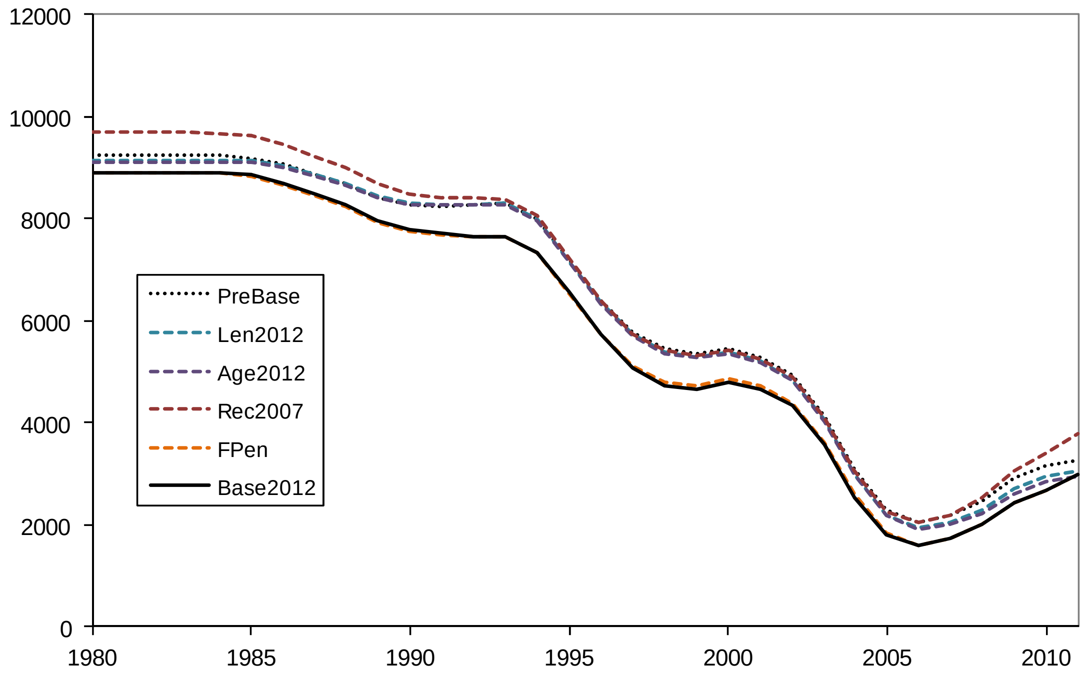

Figure 9.3. Effect on spawning biomass trends of sequential update with 2012 data, and final model balancing.

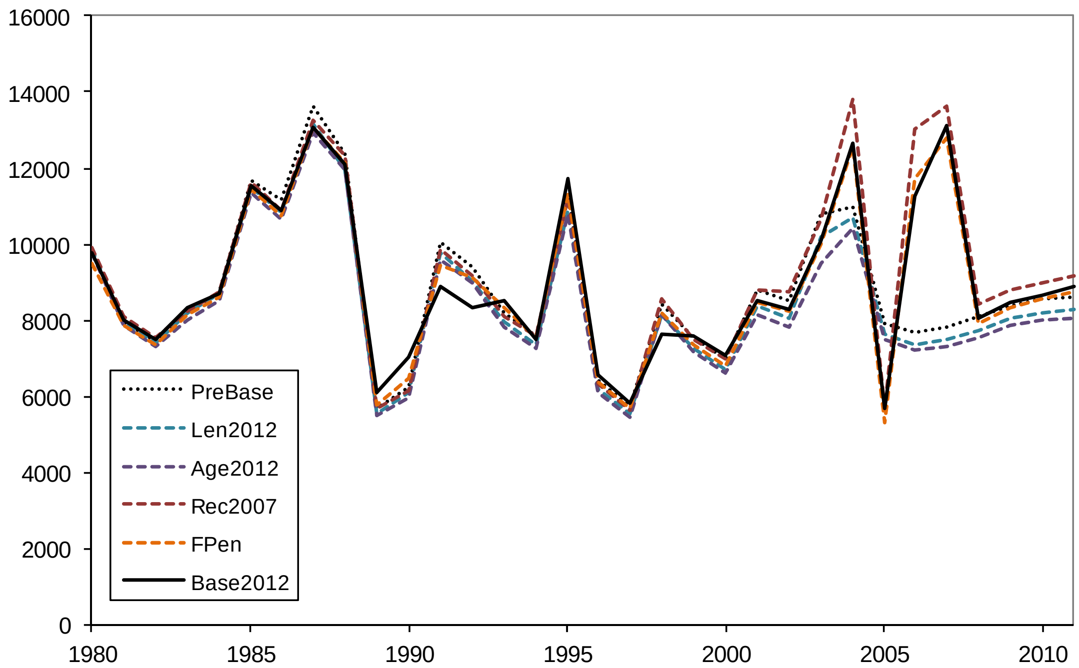

Figure 9.4. Effect on recruitment trends of sequential update with 2012 data, and final model balancing.

9.7 Further work

If Danish seine catches continue to be a significant proportion of the total, length samples should be collected from that vessel to investigate whether a different selectivity to otter trawl should be estimated for that fleet.

Industry-collected length data requires examination and most likely entry and storage on a database separate from both AFMA port and onboard data collections. Records that do not contain all necessary data fields should be flagged and reported to field collectors – particularly in future so that the collection of valid records is encouraged.

9.8 Characteristics of the base case

Biological parameters of the base case are given in Table 9.6. Diagnostic plots are provided in the Appendix.

Table 9.6. Deepwater flathead biological parameters.

	Source	Parameter	Female	Male
Years		y	1988-2011	
Recruitment		r	est 1980 - 2007	
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 (0.22) 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

9.9 References

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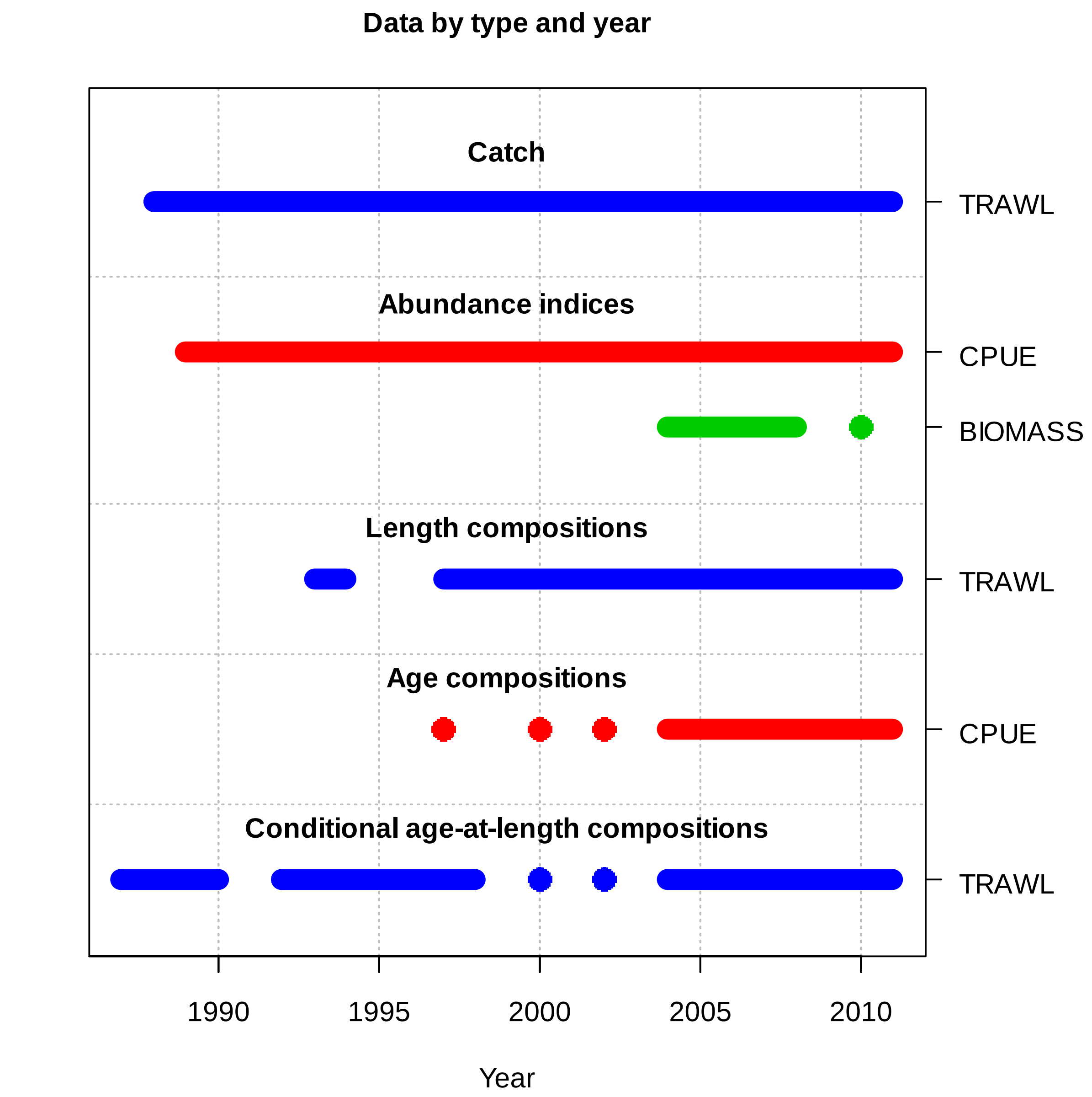
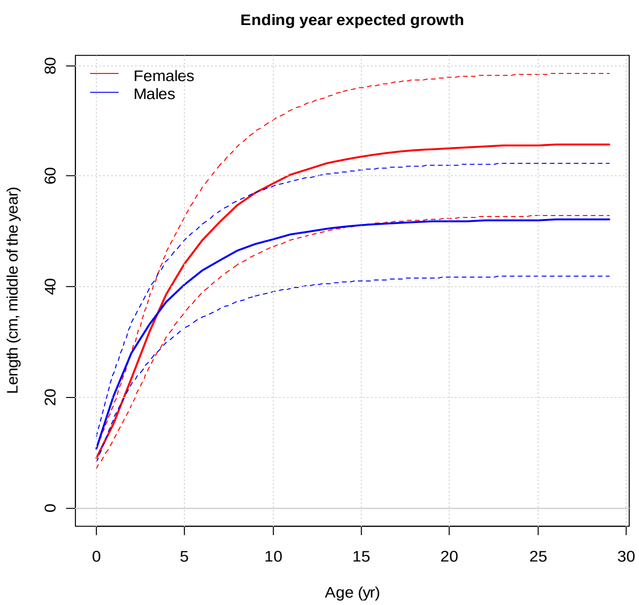
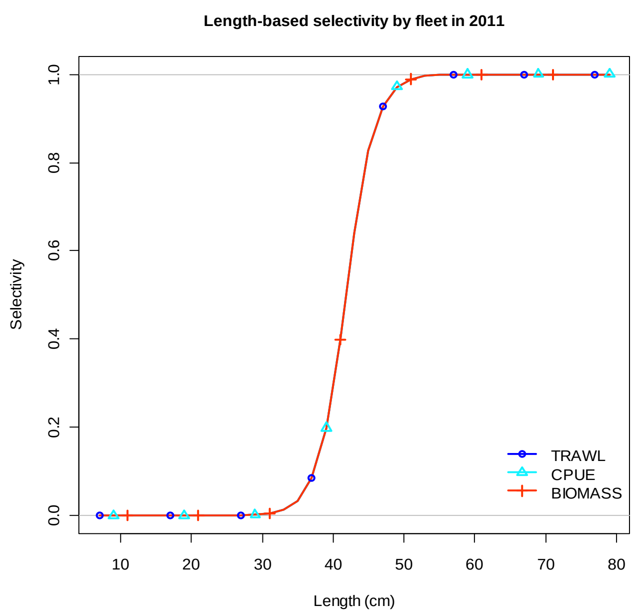
Klaer, N. 2007. Updated stock assessment for deepwater flathead (*Neoplatycephalus conatus*) and Bight redfish (*Centroberyx gerrardi*) in the Great Australian Bight trawl fishery using data to June 2007. Paper to GABRAG, October 2007.

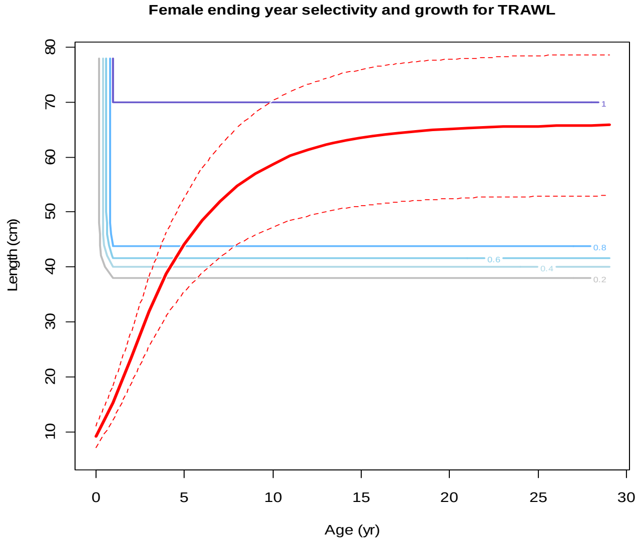
Knuckey, I., Koopman, M, Hudson, R. 2011. Resource Survey of the Great Australian Bight Trawl Sector 2011. Report to AFMA.

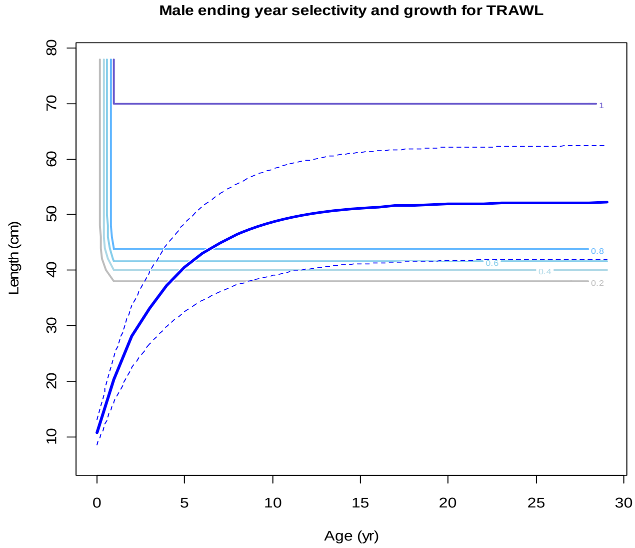
9.10 Appendix: base case diagnostics.

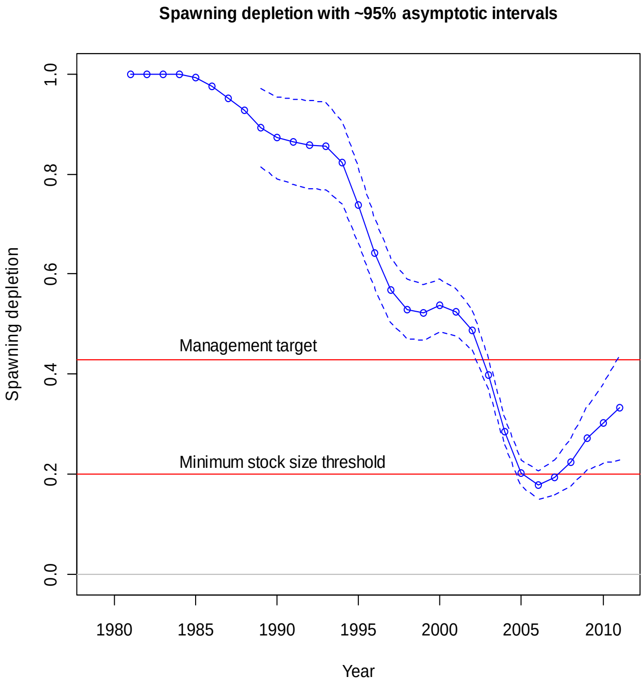


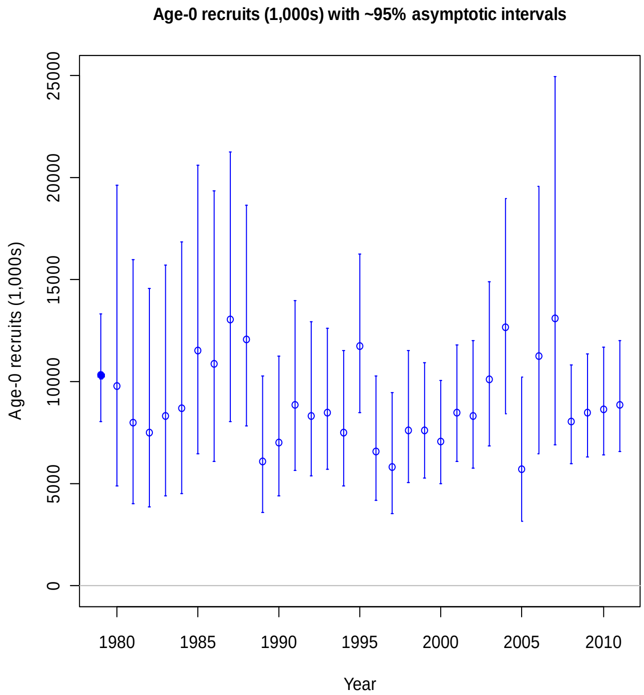


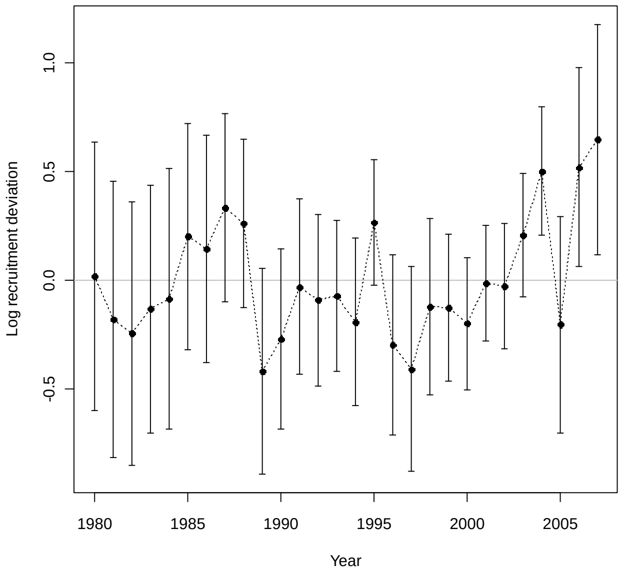


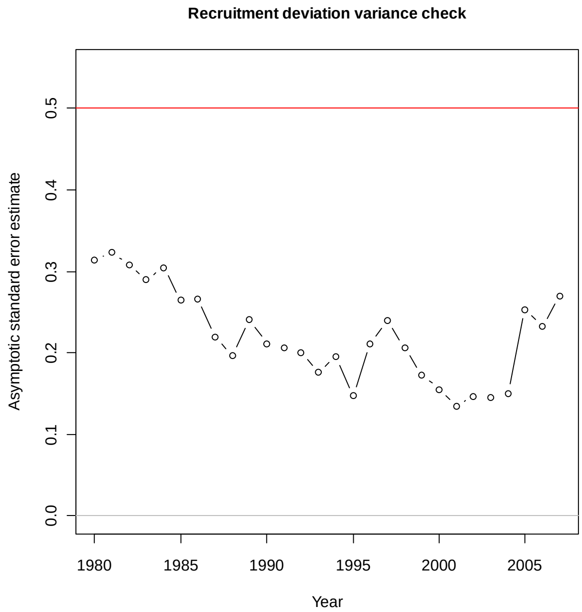

Female ending year selectivity and growth for TRAWL
Length (cm)
Age (yr)

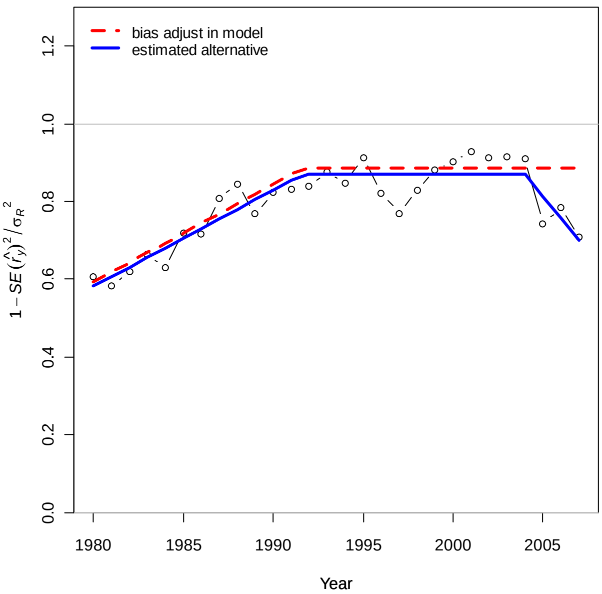

Male ending year selectivity and growth for TRAWL
Length (cm)
Age (yr)

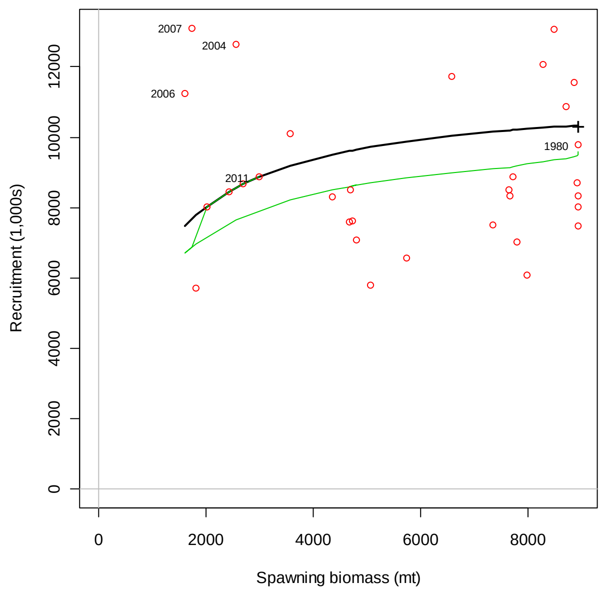

Spawning depletion with ~95% asymptotic intervals
Spawning depletion
Management target
Minimum stock size threshold
Year

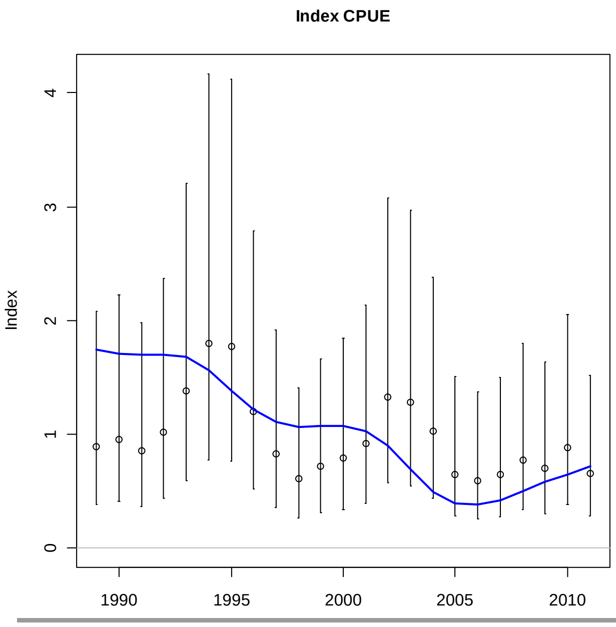

Age-0 recruits (1,000s) with ~95% asymptotic intervals
Age-0 recruits (1,000s)
Year

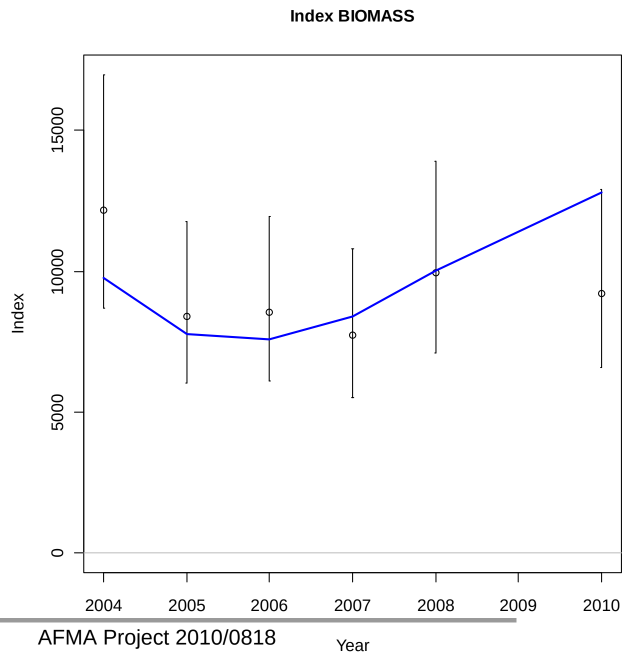

Log recruitment deviation
Year

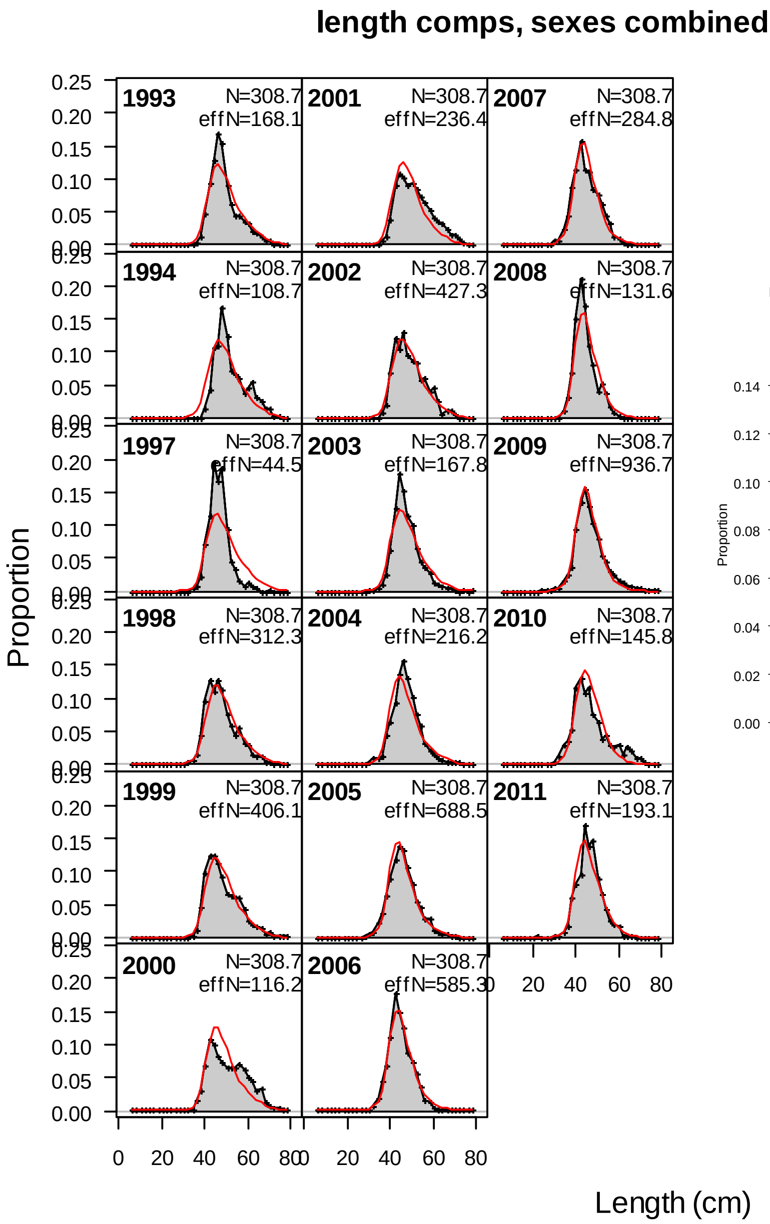

Recruitment deviation variance check
Asymptotic standard error estimate
Year

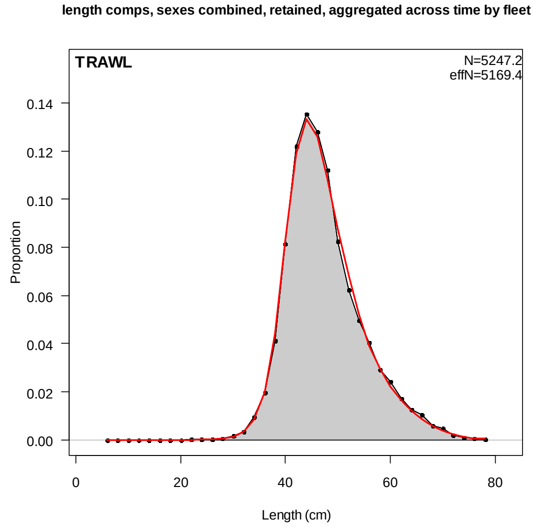

bias adjust in model
estimated alternative
$1 - SE(\hat{r}_y)^2 / \sigma_R^2$
Year

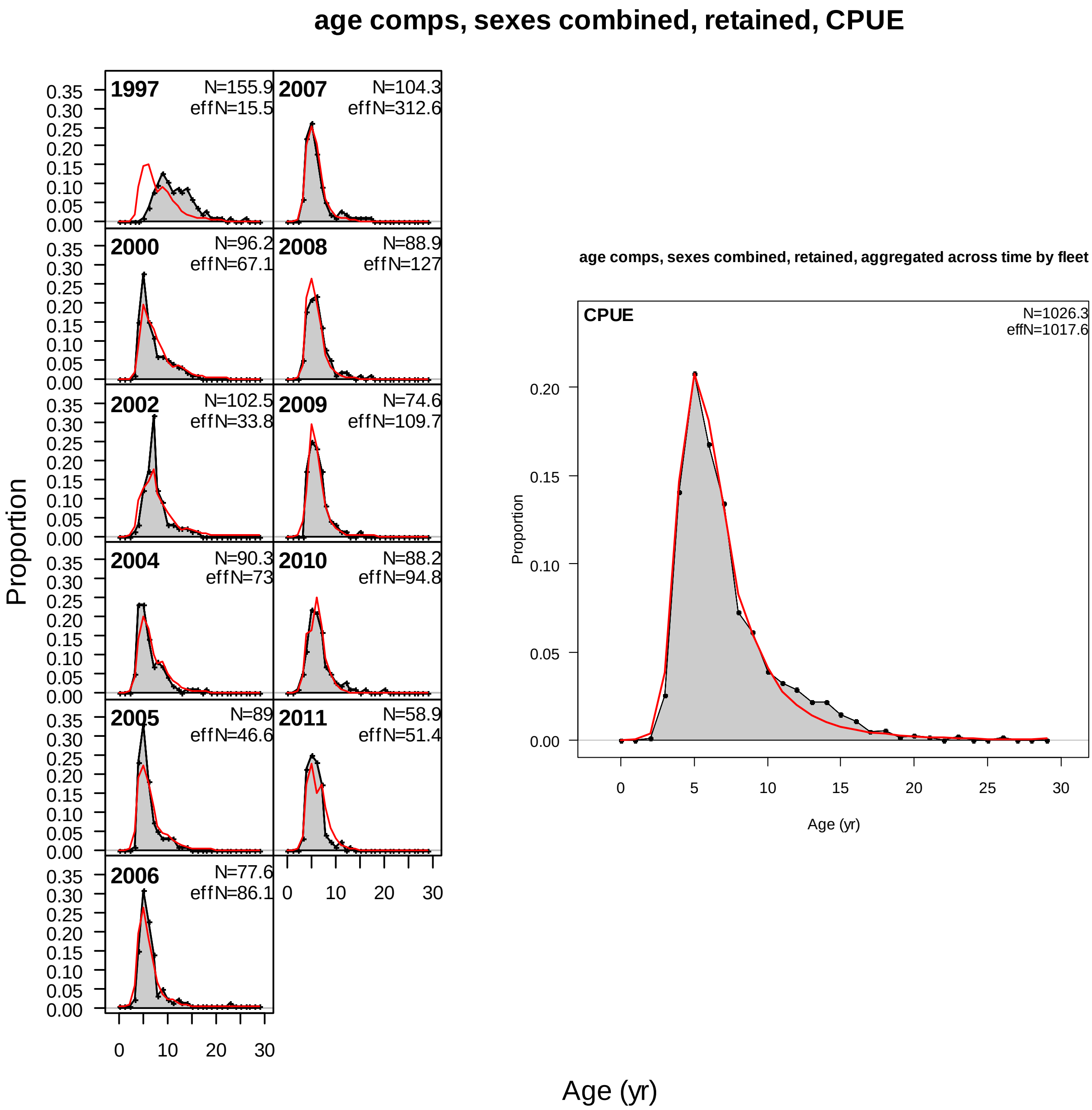

2007
2004
2006
2011
1980
Recruitment (1,000s)
Spawning biomass (mt)


Index CPUE
Index
Year


Index BIOMASS
Index
Year


length comps, sexes combined, retained, TRAWL
Proportion
Length (cm)
1993 N=308.7 effN=168.1
2001 N=308.7 effN=236.4
2007 N=308.7 effN=284.8
1994 N=308.7 effN=108.7
2002 N=308.7 effN=427.3
2008 N=308.7 effN=131.6
1997 N=308.7 effN=44.5
2003 N=308.7 effN=167.8
2009 N=308.7 effN=936.7
1998 N=308.7 effN=312.3
2004 N=308.7 effN=216.2
2010 N=308.7 effN=145.8
1999 N=308.7 effN=406.1
2005 N=308.7 effN=688.5
2011 N=308.7 effN=193.1
2000 N=308.7 effN=116.2
2006 N=308.7 effN=585.3


length comps, sexes combined, retained, aggregated across time by fleet
TRAWL
N=5247.2
effN=5169.4
Proportion
Length (cm)



age comps, sexes combined, retained, CPUE
1997 N=155.9 effN=15.5
2007 N=104.3 effN=312.6
2000 N=96.2 effN=67.1
2008 N=88.9 effN=127
2002 N=102.5 effN=33.8
2009 N=74.6 effN=109.7
2004 N=90.3 effN=73
2010 N=88.2 effN=94.8
2005 N=89 effN=46.6
2011 N=58.9 effN=51.4
2006 N=77.6 effN=86.1
Proportion
Age (yr)
age comps, sexes combined, retained, aggregated across time by fleet
CPUE N=1026.3 effN=1017.6
Proportion
Age (yr)

10. Deepwater flathead (*Neoplatycephalus conatus*) stock assessment based on data up to 2011/12[6]

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10.1 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.

10.2 Introduction

10.2.1 *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).

10.3 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.

[6] Paper presented at the GAB RAG meeting November 2012

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 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 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.

10.4 Modifications to the previous assessment

The development of the base case is detailed in Klaer (2012). Steps in the process were to convert the 2010 assessment to SS3 (version 3.24f), then to sequentially apply the following updates:

1. Change final assessment year to 2011, add catch and CPUE to 2011.
2. Add survey abundance estimates to 2010/11.
3. Add age composition data to 2010 (none 2011).
4. Add length compositions from AFMA observers/port to 2011.
5. Add length compositions from industry collections in 2011/12.
6. Set final estimable recruitment value to 2004.
7. Retune model. Start with low CV on CPUE and survey, set age comp lambda to 0.1 (0.25 previously), set maximum sample size for lengths 200 all.
8. Add additional 2011/12 length data.
9. Add age samples for 2011/12.
10. Re-examine recruitment deviation CVs and estimate recruitment to 2007.
11. Set no penalty on high annual F values.
12. Retune model.

10.5 Methods

10.5.1 The data and model inputs

10.5.1.1 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 0.233.

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 x 10^{-6}, b=3.332).

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

10.5.1.2 Landed catches

A landed catch history for deepwater flathead is available for the years from 1987/88 to 2011/12 (Figure 10.1, Table 10.1).

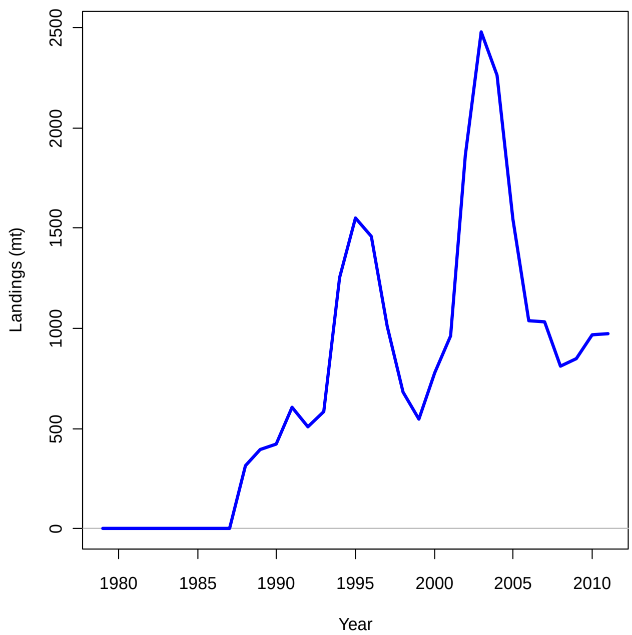

Figure 10.1 Total landed catch of deepwater flathead 1987/88-2011/12.

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 2013/14, it is necessary to estimate the financial year catch for 2012/13. As TACs have been substantially under-caught in recent years, the 2012/13 catch was assumed to be the same as the catch in 2011/12 - 973t (see Table 10.1).

Table 10.1. 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	*973,371	1,560

* 2012/13 catches are estimated as the same as 2011/12

10.5.1.3 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, 2006). It is anticipated that standardisations for deepwater flathead and Bight redfish will be added to the list of SESSF species processed in a standard manner. However, for the assessment this year the standardisation was carried out for GAB species in the same manner as in previous years (e.g. Klaer, 2006).

Only data that conformed to the following filtering criteria were examined:

- Boats included if median annual catch greater than 4t and have caught the species for 3 or more years;
- Depth<1000m;
- Non-zero species catch;
- Shot length >1.0 hr <10.0 hr.

The following factors were included for examination of their effects on catch rate:

- Year (Financial)
- Month
- Zone: int(Longitude/5.0)
- Depth: int(Depth/50)
- Vessel

The form of the model used in the R statistical package was:

sSP.glm<-
lm(datSP.CPUE~datSP.year+datSP.month+datSP.zone+datSP.depth+datSP.vessel,
data= datSP) where CPUE for each fishing operation is log(catch/hours trawled).

A comparison of LM model results with that presented in 2010 is shown in Figure 10.2.

Table 10.2. Year factor values from GAB log-linear model for deepwater flathead.

Financial year	Index
87/88	0.43
88/89	0.96
89/90	0.89
90/91	0.96
91/92	0.85
92/93	1.02
93/94	1.38
94/95	1.80
95/96	1.78
96/97	1.20
97/98	0.82
98/99	0.61
99/00	0.71
00/01	0.79
01/02	0.92
02/03	1.32
03/04	1.28
04/05	1.02
05/06	0.65
06/07	0.59
07/08	0.65
08/09	0.77
09/10	0.70
10/11	0.89
11/12	0.65

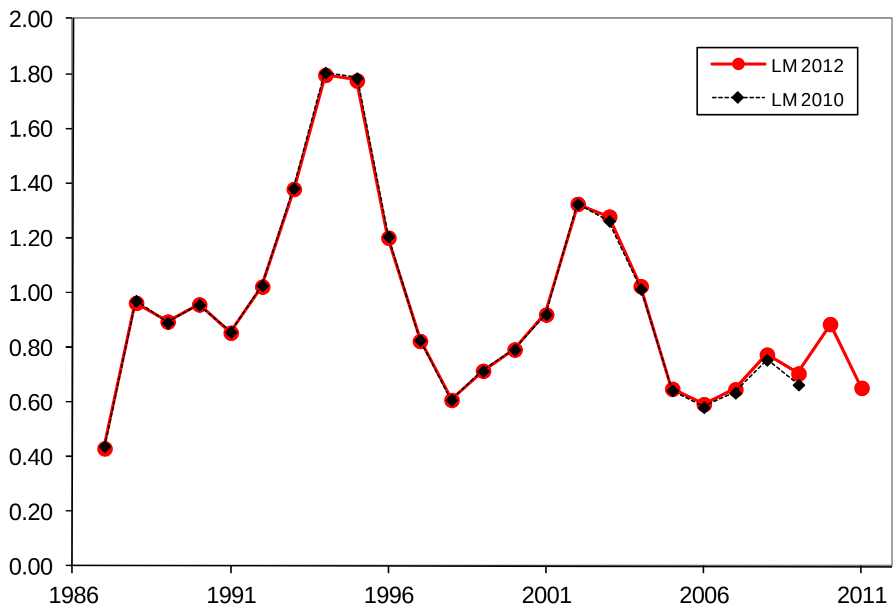

Figure 10.2. Deepwater flathead comparison of LM 2012 results with LM 2010.

10.5.1.4 Fishery-independent survey

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

Table 10.3. 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

10.5.1.5 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 Services (Table 10.4).

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, 2004/05-2011/12 Table 10.5). The minimum number of fish sampled in any financial year was 50.

Table 10.4 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 10.5 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	550
11/12	367

10.5.1.6 Length composition data

Length composition information for the retained component of the trawl fleet catch is available from 1993/94 to 2011/12 (Table 10.6). Following advice from GABRAG in 2009, all available length samples have been included in the assessment, collected from in port and on-board.

Table 10.6 Number of retained fish lengths included in the base case assessment by fleet 1993/94-2011/12.

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	13,911	Port+Onboard
10/11	2,502	Port
11/12	7,280	Port+Onboard

10.5.2 ***Stock Assessment method***

10.5.2.1 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 2007/08. 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 10.7 Summary of selected parameters of the base case model**.**

Description	Source	Parameter	Female	Male
Years		y	1988-2011	
Recruitment		*r*	est 1980 - 2007	
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 (0.233) 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

10.5.2.2 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 downweight 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 downweighted 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 5,500, with the age and length components making the greatest contributions (length about 270, age about 5,200) (Table 10.9). 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 800, and more balanced contributions of age and length data to the overall likelihood.

10.5.2.3 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

10.5.2.4 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 2012 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.

10.5.2.5 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 2004/05 only
- No FIS
- Lower maximum allowed annual F
- Default harvest control rule 20:35:48

10.6 Results and Discussion

10.6.1 *The base-case analysis*

10.6.1.1 Parameter estimates

Figure 10.3 shows the estimated growth curve for female and male deepwater flathead. All growth parameters are estimated by the model except for lmax (other parameter values are given in Table 10.7).

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 10.4 shows the fitted selectivity function for the trawl fleet.

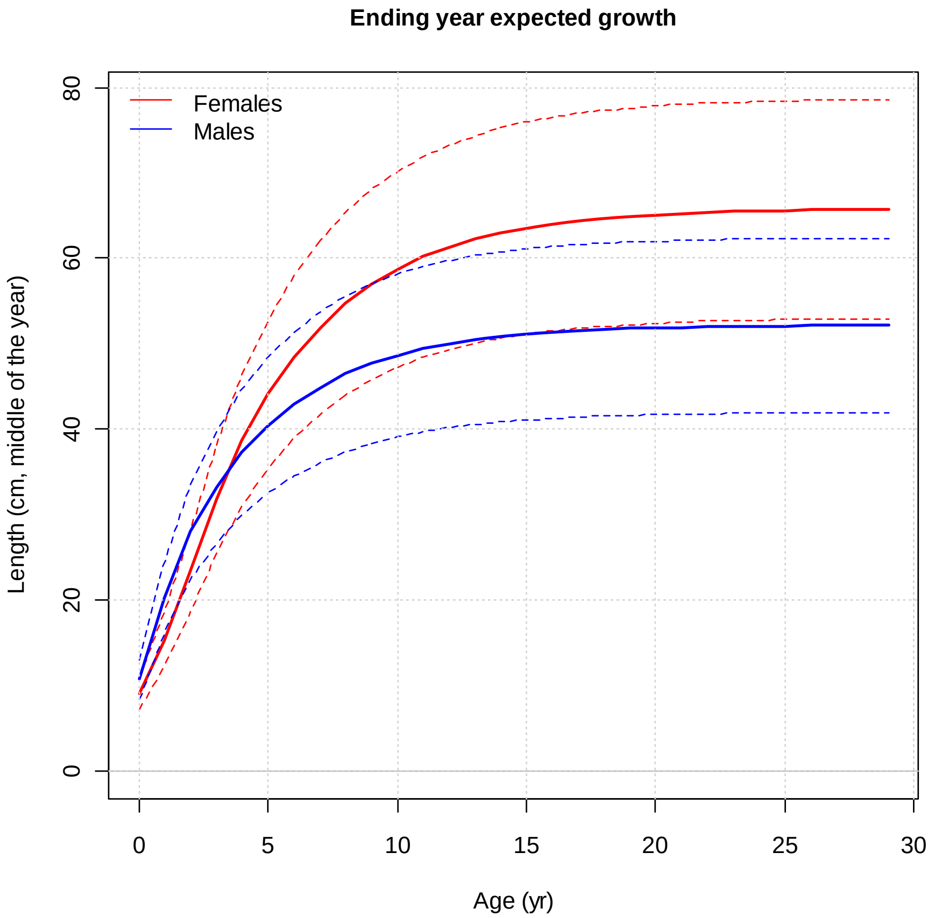

Figure 10.3 The model-estimated growth curves.

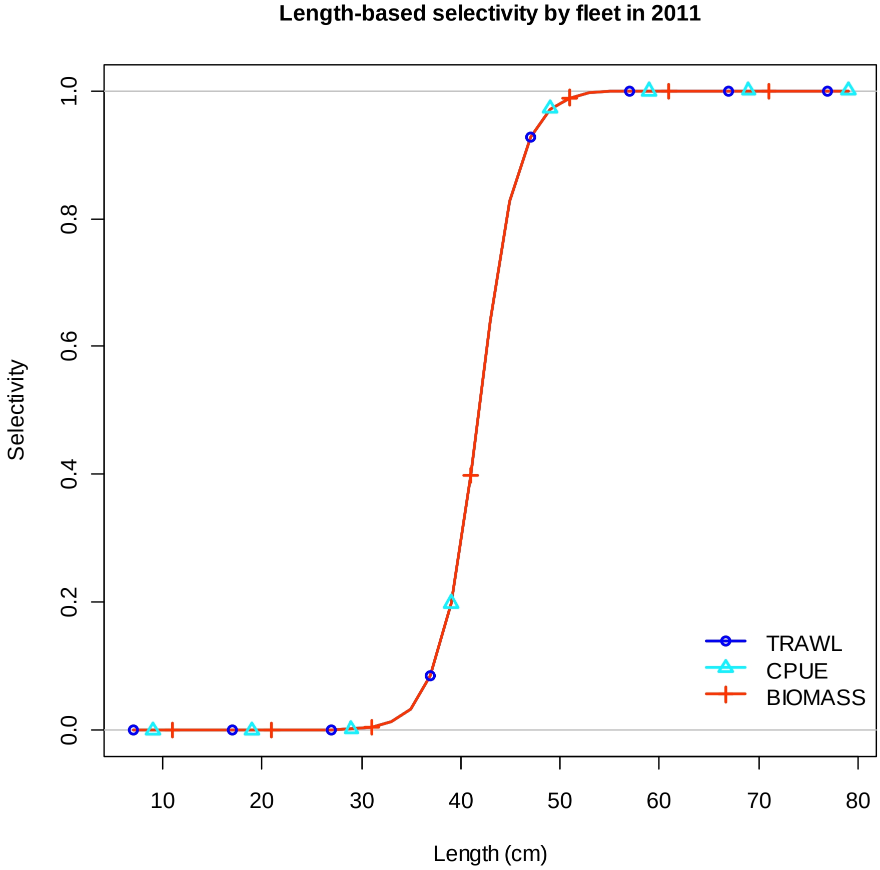

Figure 10.4 Selectivity at length for trawl.

10.6.2 *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.

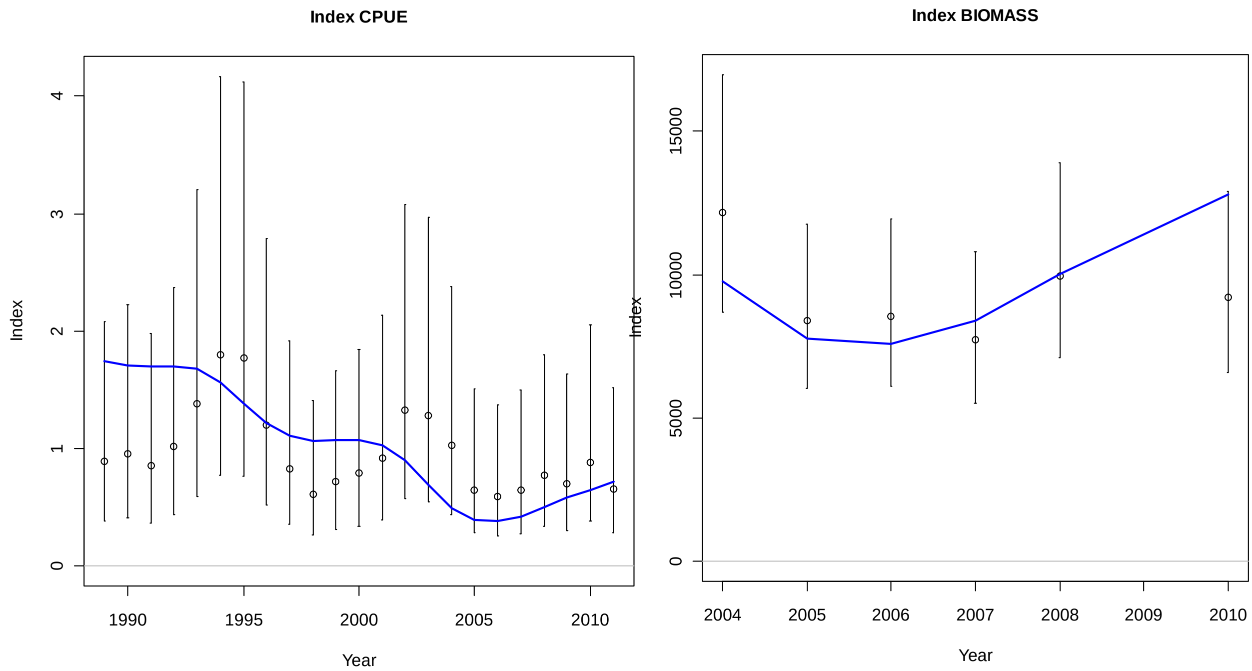

Figure 10.5 Observed (solid dots) and model-estimated (lines) of CPUE and biomass survey versus year. The vertical lines indicate approximate 95% confidence intervals for the data.

10.6.3 ***Assessment outcomes***

Figure 10.6 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 almost to the target currently. The recent increase was driven by favourable recruitments as shown in Figure 11.7.

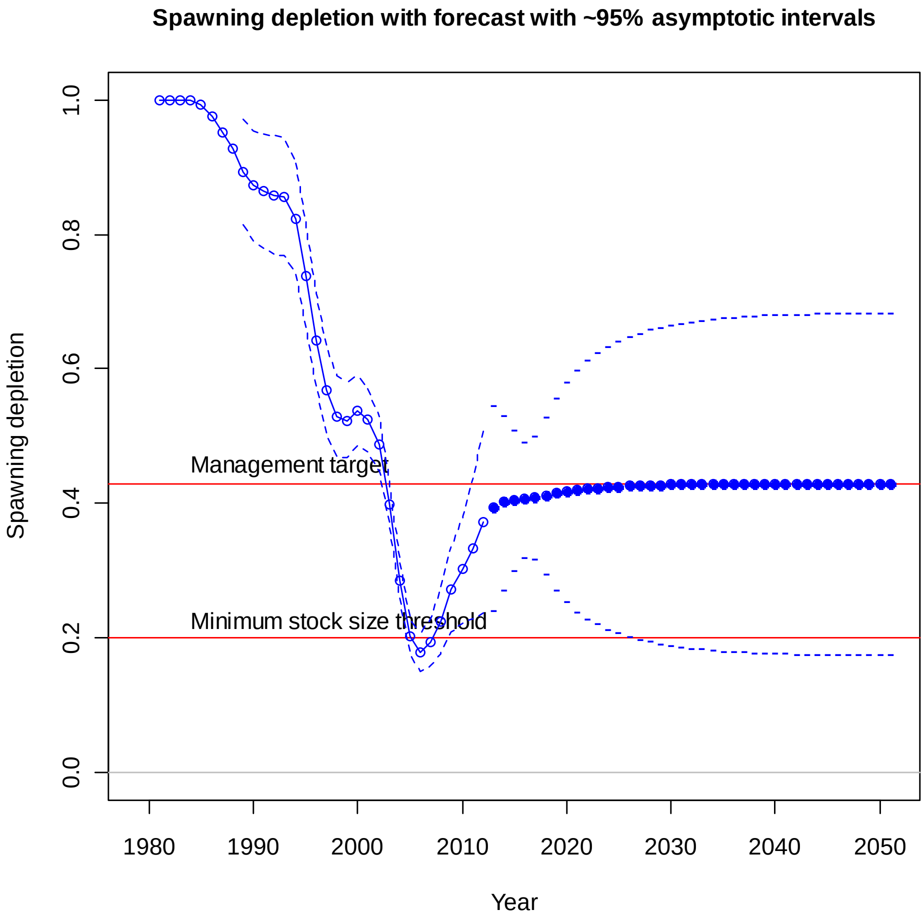

Figure 10.6 Time-trajectory of spawning biomass depletion (with 95% confidence intervals) corresponding to the MPD estimates for the base-case analysis. The first solid blue dot is 2014 depletion, and subsequent solid dots are forecast depletion under the 20:35:48 harvest control rule assuming average recruitment.

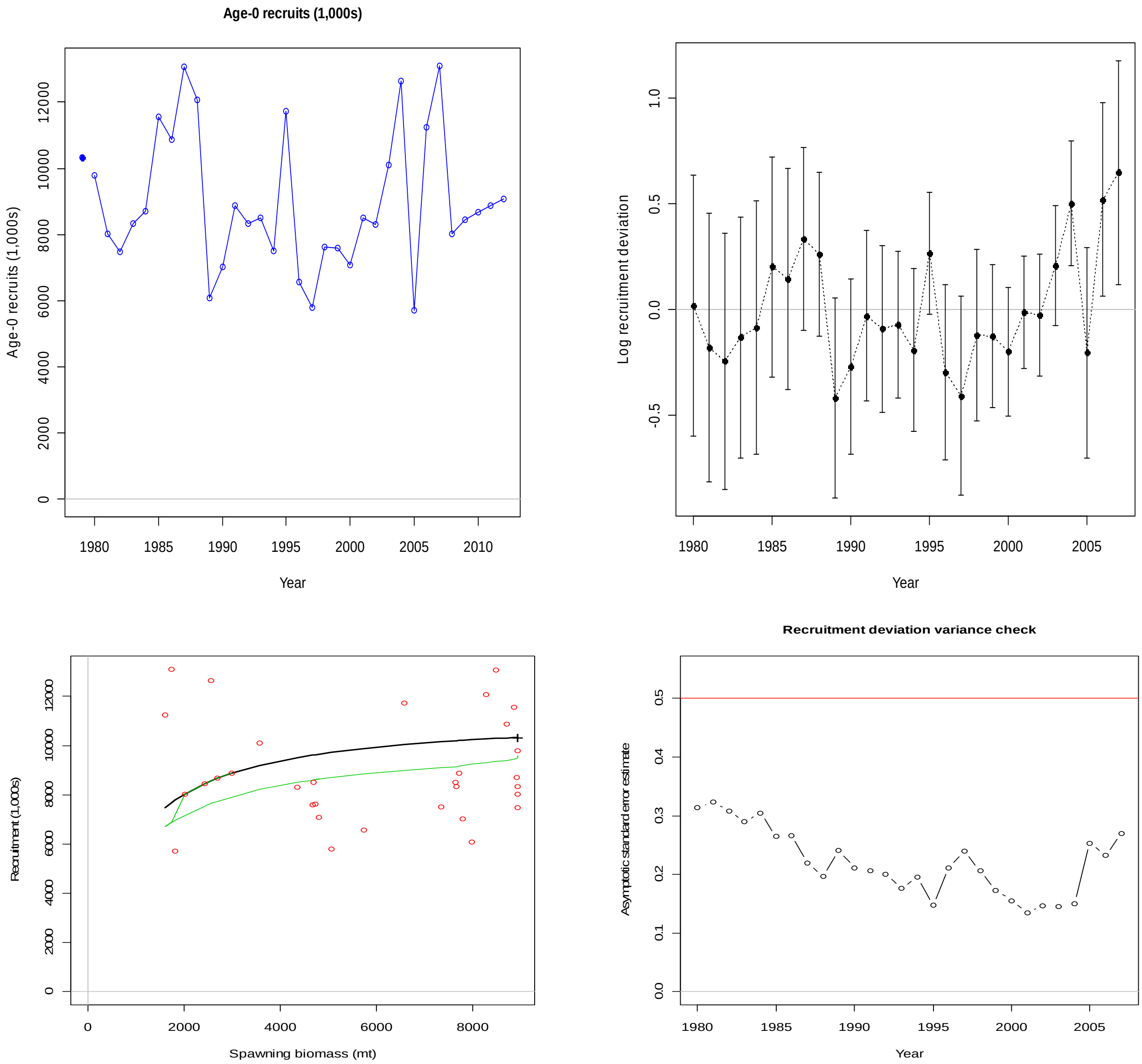

Figure 10.7 Recruitment estimation for the base case analysis. Top left : Time-trajectories of estimated recruitment numbers; top right : time trajectory of estimated recruitment deviations; bottom left : the stock-recruit curve and estimated recruitments; bottom right: recruitment deviation variance check.

The time-trajectories of recruitment and recruitment deviation are shown in Figure 11.7. Estimates of recruitments are made with reasonable precision until 2004/05. The last three recruitment points are less well estimated, and sensitivity analyses were included that dropped the estimation of the last three points. As two of the most recent 3 estimates are above average, dropping these points leads to a lower level of current depletion than the base case.

The current spawning stock biomass is estimated by the base-case model to be 39% of unexploited stock biomass at the start of 2013/14, and the 2013/14 recommended biological catch (RBC) under the 20:35:43 harvest control rule is 979t (Table 10.8). The longterm RBC (assuming average recruitment in the future) is 1,051t under the 20:35:43.

10.6.4 *Sensitivity tests and alternative models*

Results of the sensitivity tests are shown in Table 10.8. 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 0.4 up or down in the *M* value can change the current depletion from 25 to 52% of B_0, with comparable changes in the long-term catches. The current assessment estimates the value of *M*, and likelihood values in Table 10.9 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 not been depleted less.

The effect of removing estimates of recruitments in 2007/08, 2006/07 and 2005/06 is a more depleted stock.

Removal of both 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 year.

Table 10.8 Summary of results for the base-case and sensitivity tests.

Case		SSB0	SSB2013	SSB2013/SSB0	M	RBC2013	RBClongterm
0	base case 20:35:43 *h* 0.75 *M* est	8,921	3,516	0.39	0.2334	979	1,051
1	steepness *h* 0.65	9,214	3,346	0.36	0.2364		982
2	steepness *h* 0.85	8,704	3,672	0.42	0.2311		1,107
3	natural mortality *M* 0.19	8,884	2,264	0.25	0.1900		845
4	natural mortality *M* 0.27	9,270	4,792	0.52	0.2700		1,278
5	age comp weighting 0.5	8,744	3,281	0.38	0.2338		1,017
6	age comp weighting 2	8,847	3,633	0.41	0.2316		1,047
7	age comp weighting 4	8,855	3,986	0.45	0.2292		1,043
8	length comp weighting 0.5	8,632	2,990	0.35	0.2289		1,008
9	length comp weighting 2	8,923	4,051	0.45	0.2383		1,058
10	recruitment to 2004	8,408	2,399	0.29	0.2307		979
11	no FIS	9,618	5,553	0.58	0.2420		1,178
12	lower max *F*	9,809	4,616	0.47	0.2293		1,133
13	HCR 20:35:48	8,921	3,516	0.39	0.2334	832	983

Note: RBC values are only shown for fully tuned models.

Table 10.9 Summary of likelihood components for the base-case and sensitivity tests. Likelihood components are unweighted, and cases 1-13 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	5523.14	-15.17	274.78	5275.09	-11.78	0.22	0.00
1	steepness *h* 0.65	1.81	0.05	0.20	0.88	0.55	0.13	0.00
2	steepness *h* 0.85	-1.24	-0.01	-0.16	-0.60	-0.37	-0.10	0.00
3	natural mortality *M* 0.19	75.00	-0.81	4.14	71.28	0.39	0.00	0.00
4	natural mortality *M* 0.27	38.59	1.61	-1.13	37.18	0.92	0.02	0.00
5	age comp weighting 0.5	309.69	-0.50	-23.83	332.59	1.26	0.16	0.00
6	age comp weighting 2	-128.10	0.85	18.97	-148.59	0.71	-0.04	0.00
7	age comp weighting 4	-178.08	2.18	34.91	-217.69	2.57	-0.05	0.00
8	length comp weighting 0.5	-115.25	-0.81	20.56	-134.18	-0.78	-0.04	0.00
9	length comp weighting 2	341.91	1.27	-28.26	365.30	3.42	0.19	0.00
10	recruitment to 2004	6.31	-0.26	7.12	-0.48	-0.08	0.00	0.02
11	no FIS	-4.08	6.42	-2.08	-10.89	2.46	0.00	0.00
12	lower max *F*	57.41	-1.56	0.66	51.47	0.53	0.00	6.31
13	HCR 20:35:48	0.00	0.00	0.00	0.00	0.00	0.00	0.00

10.7 Acknowledgements

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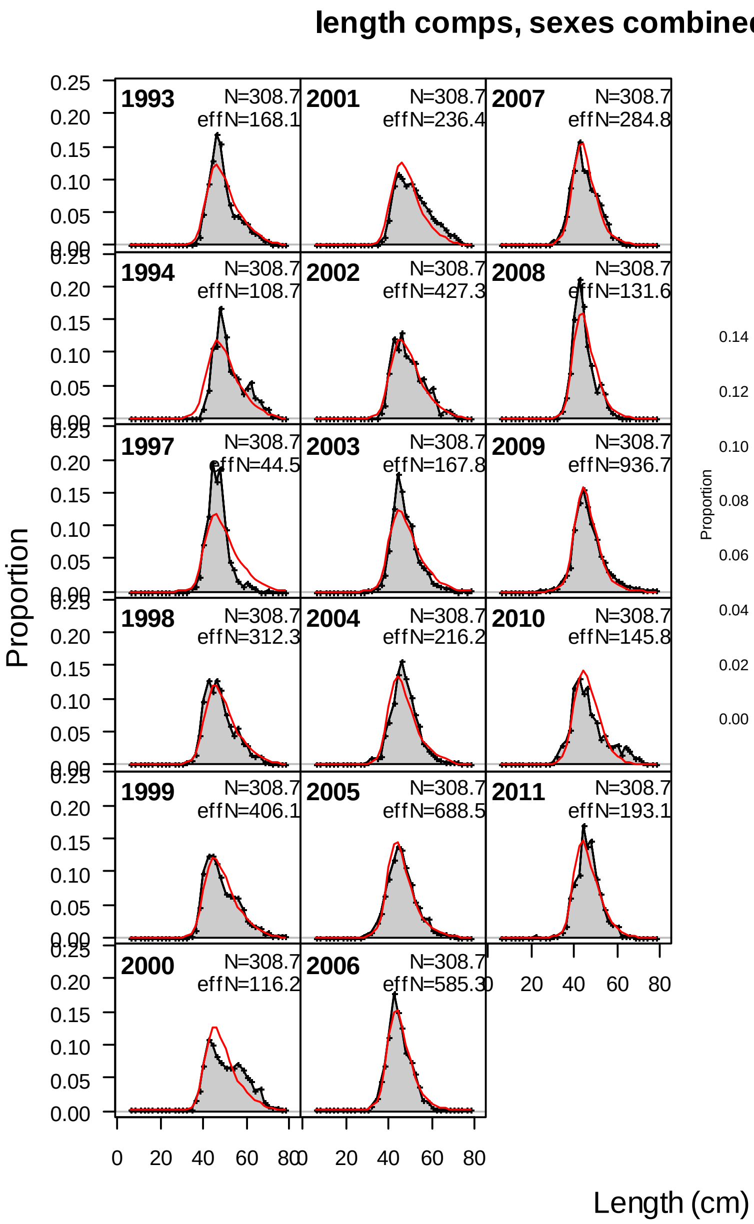
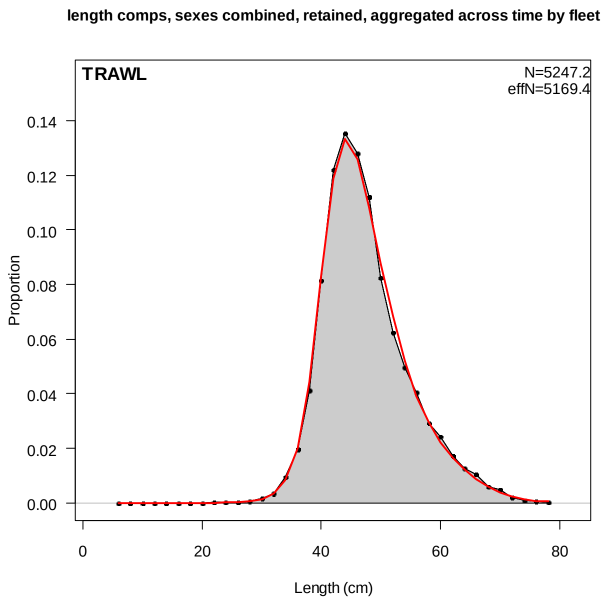
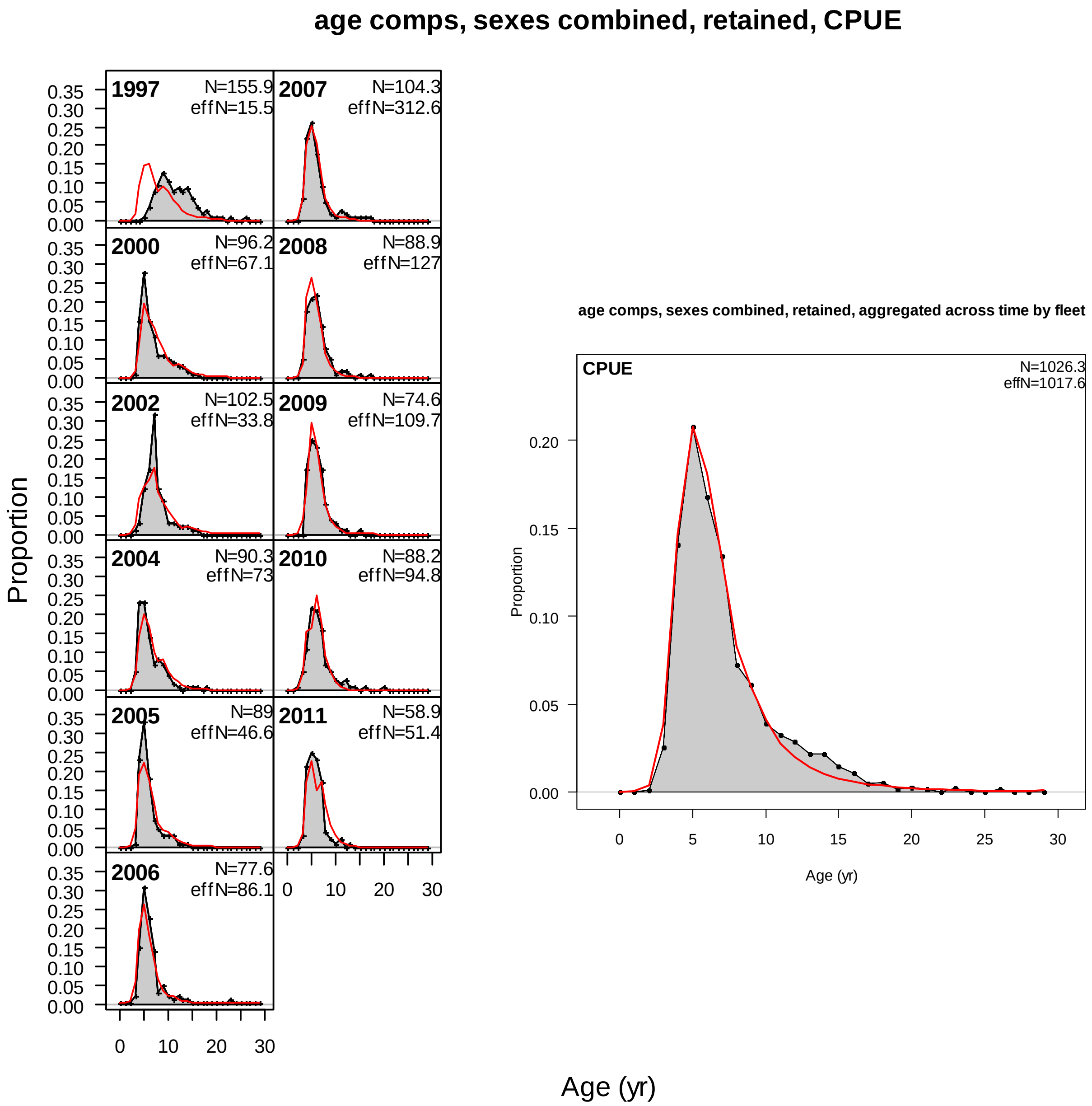
10.9 Appendix A: base-case fits to the length composition data





10.10 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.


age comps, sexes combined, retained, CPUE
1997
N=155.9
effN=15.5
2007
N=104.3
effN=312.6
2000
N=96.2
effN=67.1
2008
N=88.9
effN=127
2002
N=102.5
effN=33.8
2009
N=74.6
effN=109.7
2004
N=90.3
effN=73
2010
N=88.2
effN=94.8
2005
N=89
effN=46.6
2011
N=58.9
effN=51.4
2006
N=77.6
effN=86.1
Proportion
Age (yr)
age comps, sexes combined, retained, aggregated across time by fleet
CPUE
N=1026.3
effN=1017.6
Proportion
Age (yr)

11. Appendix: Project Staff

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