Australian Government
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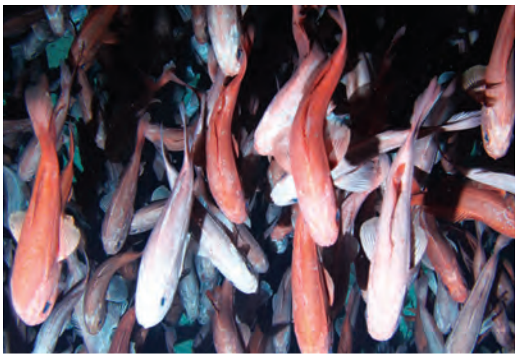
2019/0800 May 2022

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2020 and 2021

PART 1

2021



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Cover photographs

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

Report structure

Part 1 of this report describes the Tier 1 assessments of 2021. Part 2 describes the Tier 4 and Tier 5 assessments, catch rate standardisations and other work contributing to the assessment and management of SESSF stocks in 2021.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2020 and 2021

Part 1: 2021

G.N. Tuck
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Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2021

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1. Non-Technical Summary

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery 2020 and 2021

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OBJECTIVES:

- Provide quantitative and qualitative species assessments in support of the four SESSFRAG assessment groups, including RBC calculations within the SESSF harvest strategy framework
- 2020: Provide Tier 1 assessments for Gummy Shark, Eastern Redfish and School Whiting; Tier 4 assessments for John Dory, Mirror Dory, Ocean Perch, OreoBasket, Ribaldo, Royal Red Prawn, Sawshark and Silver Trevally; and Tier 5 for Blue-eye Trevalla
- 2021: Provide Tier 1 assessments for Eastern Orange Roughy, Blue Grenadier, Eastern Jackass Morwong and Silver Warehou; Tier 4 for Mirror Dory and Tier 5 for E/W Deepwater Shark

Outcomes Achieved - 2021

The 2021 assessments of stock status of the key Southern and Eastern Scalefish and Shark fishery (SESSF) species are based on the methods presented in this report. Documented are the latest quantitative assessments for the SESSF quota species. Typical assessment results provide indications of current stock status, in addition to an application of the recently introduced Commonwealth fishery harvest control rules that determine a Recommended Biological Catch (RBC). These assessment outputs are a critical component of the management and Total Allowable Catch (TAC) setting process for these fisheries. The results from these studies are being used by SESSFRAG, industry and management to help manage the fishery in accordance with agreed sustainability objectives.

1.1 South East RAG Species

Blue Grenadier

This chapter updates the agreed base case for a Tier 1 assessment of Blue Grenadier (*Macruronus novaezelandiae*). The last full assessment was conducted in 2018. The 2018 assessment was updated by the inclusion of data up to the end of 2020, which entails an additional three years of catch, discard, CPUE, length and age data and ageing error updates. The agreed base case now includes estimation of both female and male natural mortality, and no longer includes the FIS survey results.

Results of the base case show reasonably good fits to the length-composition data, conditional age at length, egg and acoustic surveys and discard mass. As has been noted in previous Blue Grenadier assessments, the fit to the standardized non-spawning catch-rate index is generally poor; the model is unable to fit to the high early catch rates and over-estimates catch rates during the early 2000s. More recent catch rates fit reasonably well, including the recent marked increase in catch rate in 2019 and 2020.

The estimated time series of recruitment under the base-case parameter set shows the typical episodic nature of Blue Grenadier recruitment, with strong year-classes in 1979, the mid-1980s, 1994, and 2003, with very little recruitment between these years. However, recent recruitments are more stable, as was first observed in the 2018 assessment. The trajectories of spawning biomass show increases and decreases in spawning biomass as strong cohorts move into and out of the spawning population. For the base case model, the estimated virgin female spawning biomass (SSB_0) is 37,445 tonnes and the projected 2022 spawning stock biomass will be 155% of SSB_0 (projected assuming 2020 catches in 2021). The 2022 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 23,777 t, with 245 t estimated discards (23,532 t retained). The long-term RBC is 7,100 t, with 183 t discards.

Eastern Jackass Morwong

This chapter updates the 2018 Tier 1 assessment of eastern Jackass Morwong (*Nemadactylus macropterus*) to provide estimates of stock status in the SESSF at the start of 2022. The 2018 stock assessment has been updated with the inclusion of data up to the end of 2020, comprising an additional three years of catch, discard, CPUE, length and age data and ageing error updates, including revisions to historical catch series, length frequencies and discard rates. A range of sensitivities were explored.

The base-case assessment estimates that the projected 2022 spawning stock biomass will be 15% of unexploited spawning stock biomass (SSB_0), with recruitment from 2016 onwards projected using a low recruitment scenario, using the average of the ten most recently estimated recruitment deviations, from 2006-2015. Under the agreed 20:35:48 harvest control rule, the 2022 recommended biological catch (RBC) is 0 t, with the long-term yield (assuming low recruitment in the future) of 91 t. The average RBC over the three-year period 2022-2024 is 0 t and over the five-year period 2022-2026, the average RBC is 1 t. If recruitment from 2016 onwards is assumed to be average, the projected 2022 spawning stock biomass would be 22% of SSB_0.

The updated assessment produces markedly different results from the 2018 assessment, under both the average and the low recruitment scenarios. This is due to downward revisions to the 13 of most recent 15 years of recruitment estimates from the 2018 assessment (for the period 1998-2012), poor recruitment estimates for the three new years of recruitment estimated in the 2021 assessment (for the years 2013-2015), a continuing decline in recent catches, a continuing decline in the recent CPUE indices and an improved fit to the most recent CPUE data points, partly due to the implementation of a low recruitment scenario.

Eastern Orange Roughy

This chapter updates the 2017 eastern zone Orange Roughy (*Hoplostethus atlanticus*) stock assessment to include revised modelling assumptions and new data for 2020. The objective of the 2021 assessment is to account for the uncertainty in *M* by estimating it within the assessment using an informative prior developed from New Zealand Orange Roughy assessments.

The 2021 base-case assessment updates the 2017 assessment with recent catch, relative estimates of female spawning biomass from the 2019 acoustic towed surveys at St Helens Hill and St Patricks Head, and new age composition data from the 2019 acoustic survey. Two major changes were made to the previous assessment: natural mortality is now estimated within the assessment and the plus-group are increased from 80 to 120 years.

The median estimate of unfished female spawning biomass from the MCMC analysis was 38,924 t, slightly lower than the MPD estimate of 40,479 t. The current 2022 female spawning biomass is estimated to be 11,644 t from the MCMC and 13,126 t from the MPD. Relative spawning biomass in 2022 is estimated at 30% of unfished levels from the MCMC and 32.4% of unfished levels from the MPD. Natural mortality was successfully estimated within the assessment. The median estimate of natural mortality from the MCMC analysis is M=0.0393 yr^{-1}, which is slightly higher than the MPD estimate of M=0.0386 yr^{-1}. The recommended biological catch (RBC) for 2022 from the MCMC analysis is 681 t, lower than the MPD estimate for 2022 of 944 t. The average RBC over the next three years (2022-2024) is 737 t from the MCMC analysis and 1,025 t from the MPD. There is a high level of uncertainty in the estimated RBC, with the 75% and 95% credible intervals from the MCMC analysis for the 2022 RBC being 287–1,316 t and 119–1,645 t respectively.

Further MCMC analysis was undertaken to evaluate scenarios of fixed catch projections of 550, 650, 737, 850 and 950 t yr^{-1} and a catch scenario proposed by industry of 1,166 t in 2022, 1,055 t in 2023 and 950 t yr^{-1} thereafter. The projections show that female spawning biomass is estimated to increase under all the fixed catch scenarios considered with the probability of the stock being below the limit reference point of 20% unfished spawning biomass in both 2024 and 2031 being less than 0.5%. Under the lowest constant catch scenario of 550 t yr^{-1}, stock status is estimated to be 0.317 and 0.348 in 2024 and 2031 respectively. Under the highest constant catch scenario of 950 t yr^{-1}, stock status is estimated to be 0.312 and 0.323 in 2024 and 2031 respectively. Under the industry proposed scenario stock status estimated to be 0.309 and 0.321 in 2024 and 2031 respectively. When the SESSF harvest control rule is used to set RBCs, the stock status is estimated to be 0.316 and 0.330 in 2024 and 2031 respectively.

School Whiting

This chapter presents School Whiting (*Sillago flindersi*) RBC projections from the 2020 stock assessment using a modified target MEY reference proxy of 40% instead of 48%. The 2020 School Whiting stock assessment estimates that current spawning stock biomass (at the beginning of 2021) is 41% of unexploited spawning stock biomass (SSB_0). Under the agreed 20:35:48 harvest control rule, the 2021 recommended biological catch (RBC) is 2,140 t. The RBC averaged over the three-year period of 2021-2023 is 2,237 t.

If the default (proxy) target reference point (48%) used in the SESSF harvest control rule, and specifically as used by AFMA for School Whiting, is reduced to 40%, a modified 20:35:40 harvest control rule can be applied. This lower target allows the stock to be fished to a lower target biomass (40% of unfished spawning stock biomass (SSB_0)). Under a revised 40% target, the 2021 recommended biological catch (RBC) would be 2,753 t. The RBC, calculated under a 20:35:40 harvest control rule, averaged over the three-year period of 2021-2023 is 2,730 t.

Silver Warehou

This chapter presents a quantitative Tier 1 assessment of Silver Warehou (*Seriolella punctata*) to provide stock status estimates at the start of 2022 and describes the base case. The 2018 base case has been updated with the inclusion of data up to the end of 2020, which entails an additional three years of catch, discard, CPUE, length and age data, along with ageing error updates, revisions to historical catch series, length frequencies and discard rates.

The assessment estimates that the projected 2022 stock status will be 29% of unfished spawning stock biomass (SSB_0) , projected assuming 2020 catches in 2021, with recruitment from 2016 onwards assumed to be below average, fixed at the average of 2011-2015 levels. The assessment suggests that stock status was as low as 21% of SSB_0 in 2016. Under the 20:35:48 harvest control rule, the 2022 recommended biological catch (RBC) is 587 t, while the long-term yield (assuming continuation of low recruitment) is 591 t. The average RBC over the three-year period 2022-2024 is 581 t.

This assessment has seen a continuation of below average recruitment noted in the last three assessments with the last 12 years of estimated recruitment all below average. This continuation of below average recruitment resulted in the base case for this assessment moving to low recruitments projected forward from 2016. This change reduced the severity of retrospective patterns observed in previous assessments.

Tiger Flathead

This chapter presents results of fixed catch projections for Tiger Flathead (*Neoplatycephalus richardsoni*) to provide information on possible projected stock status in light of changes to both catches and CPUE following the 2019 Tiger Flathead stock assessment.

Updated data used from the 2019 assessment, including preliminary catch (combined Commonwealth and state catch) for 2019-2020, estimated 2021 catch and updated CPUE series to the end of 2020 were included in this analysis. Updates to age and length composition data were not available and were not included. These updates to catch and CPUE alone resulted in a revision downwards to the 2020 stock status, from 34% in the last stock assessment to 32% in this analysis. These changes are due to revisions to the catches (2017-2021) and to the revised CPUE series, which has a downturn at the end of the time series (2019-2020) for the Danish seine CPUE. The eastern trawl and Tasmanian trawl CPUE series do not show the same downturn at the end of the CPUE series as Danish seine, with both trawl CPUE relatively flat in the period 2019-2020. Projecting forward to 2022 takes the stock status to 35% at the start of 2022, and this is expected to recover to 37% at the start of 2025, assuming that the RBC is caught in 2023 and 2024 and there is average recruitment from 2017 onwards. Changes to the projected stock status when the 2019 base case is updated are a consistent 1% reduction in stock status in the period 2020-2025, assuming the RBC is caught each year.

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

2. Background

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

Management of the SESSF is based on a mixture of input and output controls, with over 20 commercial species or species groups currently under quota management. For the previous South East Fishery (SEF), there were 17 species or species groups managed using TACs. Five of these species had their own species assessment groups (SAGs) – Orange Roughy (ORAG), Eastern Gemfish (EGAG), Blue Grenadier (BGAG), Blue Warehou (BWAG), and Redfish (RAG). The assessment groups comprise scientists, fishers, managers and (sometimes) conservation members, meeting several times in a year, and producing an annual stock assessment report based on quantitative species assessments. The previous Southern Shark Fishery (SSF), with its own assessment group (SharkRAG), harvested two main species (Gummy and School Shark), but with significant catches of Saw Shark and Elephantfish.

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

- SESSFRAG (an umbrella assessment group for the whole SESSF)
- South East Resource Assessment Group (slope, shelf and deep water species)
- Shark Resource Assessment Group (shark species)
- Great Australian Bight Resource Assessment Group (GAB species)

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

The quantitative assessments produced annually by the Resource Assessment Groups are a key component of the TAC setting process for the SESSF. For assessment purposes, stocks of the SESSF currently fall under a Tier system whereby those with better quality data and more robust assessments fall under Tier 1, while those with less reliable available information are in Tiers 4 and 5. To support the assessment work of the four Resource Assessment Groups, the aims of the work conducted in this report were to develop new assessments if necessary (under all Tier levels), and update and improve existing ones for priority species in the SESSF.

3. Need

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

4. Objectives

These Objectives include a description of the SESSFRAG agreed changes to the assessment schedule and may differ from the objectives in the original contract:

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

- 2020: Provide Tier 1 assessments for Gummy Shark, Eastern Redfish and School Whiting; Tier 4 assessments for John Dory, Mirror Dory, Ocean Perch, OreoBasket, Ribaldo, Royal Red Prawn, Sawshark and Silver Trevally; and Tier 5 for Blue-eye Trevalla

- 2021: Provide Tier 1 assessments for Eastern Orange Roughy, Blue Grenadier, Eastern Jackass Morwong and Silver Warehou; Tier 4 for Mirror Dory and Tier 5 for E/W Deepwater Shark

12. Silver Warehou (*Seriolella punctata*) stock assessment based on data up to 2020 – development of a preliminary base case

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12.1 Executive Summary

This document presents a base case for an updated quantitative Tier 1 assessment of Silver Warehou (*Seriolella punctata*) for presentation at the first SERAG meeting in 2021. The last full assessment was presented in 2018 (Burch et al., 2018b). The preliminary base case has been updated with the inclusion of data up to the end of 2020, which entails an additional three years of catch, discard, CPUE, length and age data and ageing error updates since the 2018 assessment. This document describes the process used to develop a preliminary base case for Silver Warehou through the sequential updating of recent data to the stock assessment, using the stock assessment package Stock Synthesis (SS-V3.30, Methot and Wetzel (2013)), referred to hereon as base case 2.

In addition to the standard Bridge 1, which updates the assessment to the most recent version of Stock Synthesis, ensures correct settings are used and updates the historical catch series, Bridge 2, which sequentially incorporates updated data, a third bridging step (Bridge 3) is presented here. This third bridging step adds an additional time block on retention of the east trawl fleet from 2018 onwards. This allows the model to fit the large increase in discarding observed between 2018 and 2020. It also only adds one additional recruitment deviation rather than the usual three to account for a residual pattern that estimates above average recruitment deviations at the end of the series which are revised downwards when additional data is included in the assessment. This updated preliminary base case is referred to as base case 3 throughout this document and is proposed as the base case for the 2021 assessment.

The results from base case 3 show reasonably good fits to the conditional age-at-length data and standardised catch rates. The fits to the standardised catch rates in the east trawl fleet have improved from the previous assessment, while fits to the west trawl fleet remain similar. Fits to both discard data and standardised catch rates improved in base case 3 compared to those in base case 2. Fits to the length data have remained poor, as has been observed in previous assessments, with length frequency inputs highly variable, often showing multiple modes in the distributions that are not consistent from one year to the next. The estimated length frequencies are also not able to fit the small fish that were observed across both fleets over the past five years.

Base case 3 estimates that the projected 2021 spawning stock biomass will be 35.43% of virgin stock biomass (projected assuming 2020 catches in 2021), compared to 26.04% at the start of 2018 from the last assessment (Burch et al., 2018b). This assessment suggests that spawning stock biomass was as low as 21.11% in 2016. The increase in estimated stock status since the 2018 assessment is likely due to slight increases in standardised catch rates and increasing recruitment combined with low catches.

12.2 Introduction

12.2.1 *2021 Silver Warehou assessment base case*

The 2021 preliminary base case assessment of Silver Warehou uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Version 3.30.17.00, Methot et al. (2021)). The methods utilised in SS are based on the integrated analysis paradigm. SS can allow for multiple seasons, areas and fleets, but most applications are based on a single season and area. Recruitment is governed by a stochastic Beverton-Holt stock-recruitment relationship, parameterized in terms of the steepness of the stock-recruitment function (h), the expected average recruitment in an unfished population (R_0), and the degree of variability about the stock-recruitment relationship (σ_r). SS allows the user to choose among a large number of age- and length-specific selectivity patterns. The values for the parameters of SS are estimated by fitting to data on catches, catch-rates, discard rates, discard and retained catch length-frequencies, and conditional age-at-length data. The population dynamics model and the statistical approach used in fitting the model to the various data types are given in the SS technical documentation (Methot, 2005).

The base case model includes the following key features:

A single region, single stock model is considered with two fleets, one in the east including SESSF zones 10, 20 and 30 (east trawl), and one in the west including SESSF zones 40 and 50 (west trawl). Selectivity is modelled separately for each fleet, with both selectivity patterns assumed to be length-specific and logistic. The parameters of the selectivity function for each fleet were estimated within the assessment.

The model does not account for males and females separately and fits one growth curve across both sexes.

The initial and final years are 1980 and 2020.

The CVs of the CPUE indices were initially set at a value equal to the standard error from a loess fit (0.174; Sporcic (2021)), before being re-tuned to the model-estimated standard errors within SS.

Discard tonnage was estimated through the assignment of a retention function. This was defined as a logistic function of length, and the inflection and slope of this function were estimated where discard information was available. In the 2018 assessment two retention functions were estimated, one for each 'block' period: namely 1980–2001 and 2002–2020. The first block allows the model to fit discarding across all length classes due to limited markets, while the second block allows the model to fit to size based discarding once markets for the species were established. The proposed updated preliminary base case includes an additional retention function between 2018 and 2020 for the east trawl fleet to account for increased discarding observed in these years.

The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The value for M is assumed to be 0.3 y^{-1}.

Recruitment to the stock is assumed to follow a Beverton-Holt stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, h. Steepness for the base case analysis is set to 0.75.

The initial value of the parameter determining the magnitude of the process error in annual recruitment, σ_R, is set to 0.7.

The population plus-group is modelled at age 23 years.

Growth is assumed to follow a von Bertalanffy length-at-age relationship, with the parameters of the growth function estimated together for females and males inside the assessment model.

Retained and discarded onboard length sample sizes were capped at 200, with greater than 100 fish sampled annually required for inclusion in the model. For port samples, numbers of trips were used as the sampling unit, with a cap of 100 (which was not reached). The sample size is reduced because the appropriate sample size for length frequency data is probably more closely related to the number of shots (onboard) or trips (port) sampled, rather than the number of fish measured.

The values assumed for some of the (non-estimated) parameters of the base case models are shown in Table 12.1.

Table 12.1. Parameter values assumed for some of the non-estimated parameters of the base-case model.

Parameter	Description	Value
M	Natural mortality	0.3
h	steepness' of the Beverton-Holt stock-recruit curve	0.75
x	age observation plus group	23 years
a	allometric length-weight equations	0.0000065 g-1 cm
b	allometric length-weight equations	3.27
l_m	Female length at 50% maturity	37 cm

12.3 Bridging methodology

The previous full quantitative assessment for Silver Warehou was performed in 2018 by Burch et al. (2018b) using Stock Synthesis (version SS-V3.30.12.00, Methot et al. (2018)). The 2021 assessment uses the current version of Stock Synthesis (version SS-V3.30.17.00, Methot et al. (2021)).

As a first step in the process of bridging to a new model, the data used in the 2018 assessment was used in the new software (SS-V3.30.17.00). Once this translation was complete, improved features unavailable in SS-V3.12.00 were incorporated into the SS-V3.30.17 assessment. The catch series was then updated to include any amended estimates for the historical period from 1980 to 2018 since the 2018 assessment. Following this step, the model was re-tuned using the most recent tuning protocols (Pacific Fishery Management Council, 2018), thus allowing the examination of changes to both assessment practices and the tuning procedure on the previous model structure. These changes to software and tuning practices may lead to changes to key model outputs, such as the estimates of stock status and the trajectory of spawning biomass. This initial bridging phase (Bridge 1) highlights changes that have occurred since 2018 simply through changes to software and assessment practices.

The subsequent bridging exercise (Bridge 2) then sequentially updates the model with new data through to 2020. These additional data included new catch, discard estimates, CPUE, length composition data, conditional age-at-length data and an updated ageing error matrix. The last year of recruitment estimation was extended to 2017 (from 2014 in Burch et al. (2018b)). The final step is to re-tune the model.

A third bridging step (Bridge 3) has also been included. This bridging step has expanded on the preliminary base case (results of Bridge 2) by incorporating an additional time block on retention to allow the model to fit the increased discard estimated for the east trawl fleet between 2018 and 2020. In addition, this bridging step has also fixed rather than estimated the 2016 and 2017 recruitment deviations. These deviations were estimated to be above average in Bridge 2 and previous assessments have observed a retrospective pattern in their estimation, with future assessments generally observing a downward shift in their estimation when additional years of data are included in the assessment.

12.4 Bridge 1

The 2018 Silver Warehou assessment was converted to the most recent version of the software, Stock Synthesis version SS-V3.30.17.00. This resulted in no changes to the stock status estimates throughout the timeseries (Figure 12.1).

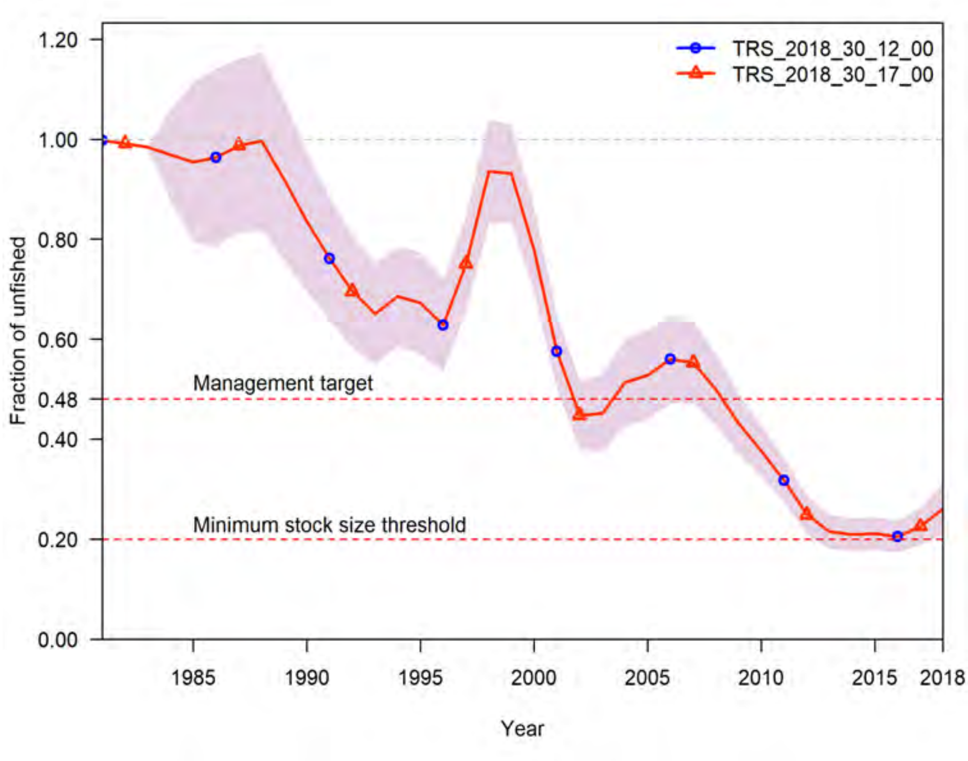

Figure 12.1. Comparison of the relative spawning biomass time series for the 2018 assessment (SS3-30.12) and a model converted to SS-V3.30.17.

New features available in the latest versions of Stock Synthesis, such as allowing smaller lower bounds on minimum sample sizes and estimating additional standard deviation to abundance indices were then incorporated (labelled 'New'). This step resulted in minor changes to the estimated depletion trajectory, with slight differences apparent between 1994 and 2003 (Figure 12.2). There were no other discernible changes that resulted from alteration of these settings.

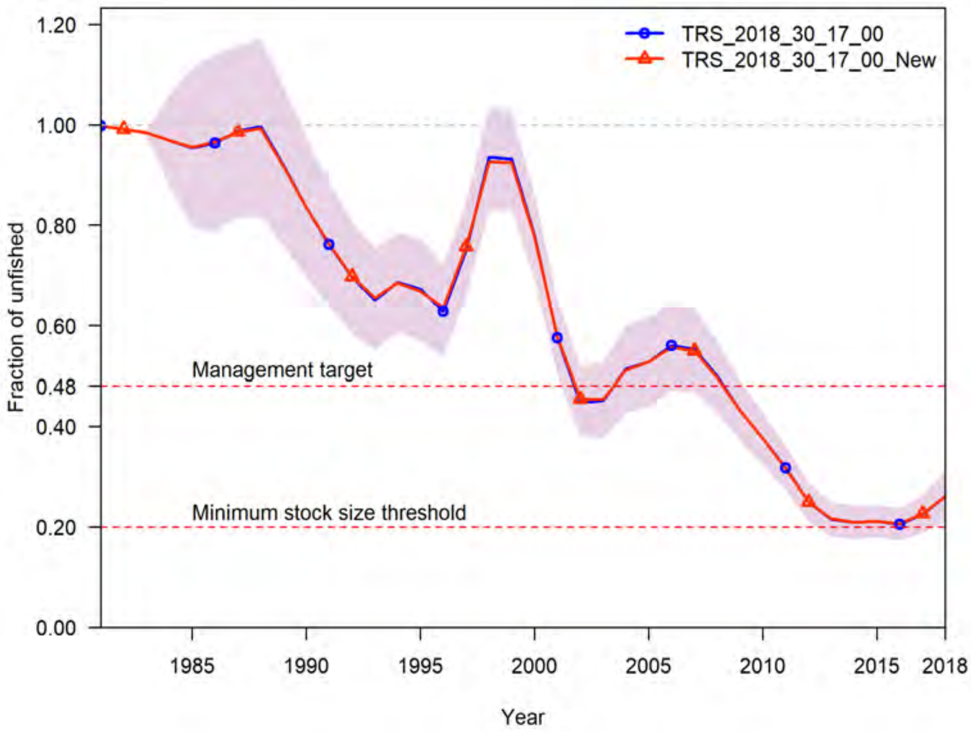

Figure 12.2. Comparison of the relative spawning biomass time series for the 2018 assessment updated to the latest Stock Synthesis version (SS-V3.30.17), with new settings applied to the model (New).

Incorporating amended historical catches resulted in minor changes to depletion estimates, which are only just evident (Figure 12.3). This change also resulted in minor upward revision of recruitment deviations between 1991 and 1993 (Figure 12.4).

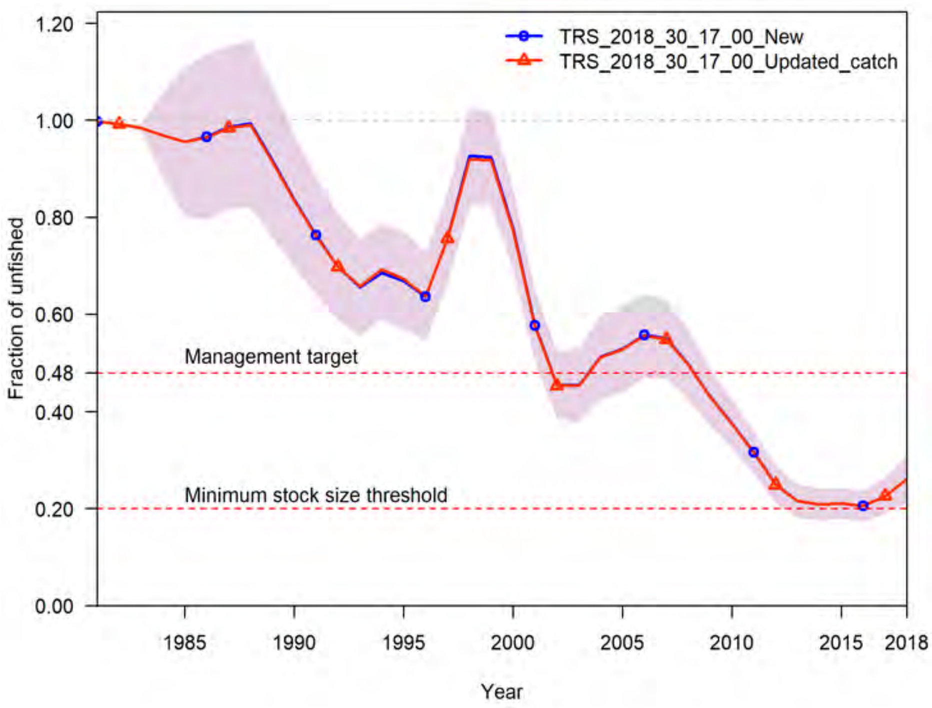

Figure 12.3. Comparison of the relative spawning biomass time series for the 2018 assessment with updated settings (New) with the 2018 assessment with both updated settings and amended historical catch series (Updated catch).

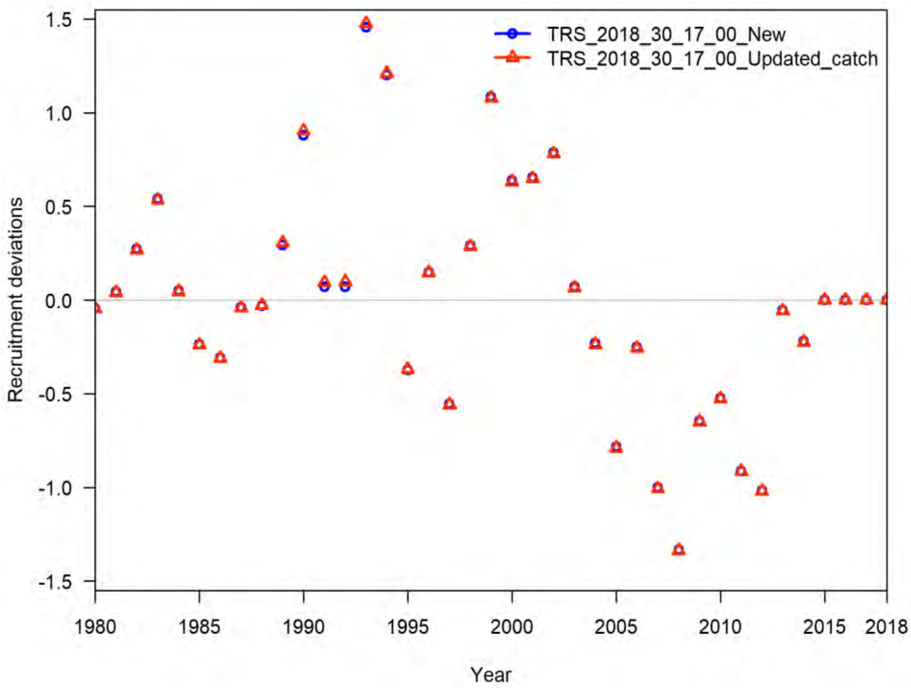

Figure 12.4. Comparison of the estimated recruitment deviations for the 2018 assessment with updated settings (New) with the 2018 assessment with both updated settings and amended historical catch series (Updated catch).

The assessment was then tuned using the latest tuning protocol (labelled 'Tuned') (Figure 12.5, Figure 12.6). This process demonstrates the outcomes that could theoretically have been achieved with the last assessment if we had the latest software, tuning protocols and corrected data available in 2018. This initial bridging step, Bridge 1, does not incorporate any data after 2017 or any structural changes to the assessment.

When these series are plotted together, there are minor changes resulting from transitioning to the new version of Stock Synthesis and incorporating new features (Figure 12.5, Figure 12.6). The new tuning procedures result in no change to the stock status estimates or estimated recruitment deviations (Figure 12.5, Figure 12.6, orange and red lines).

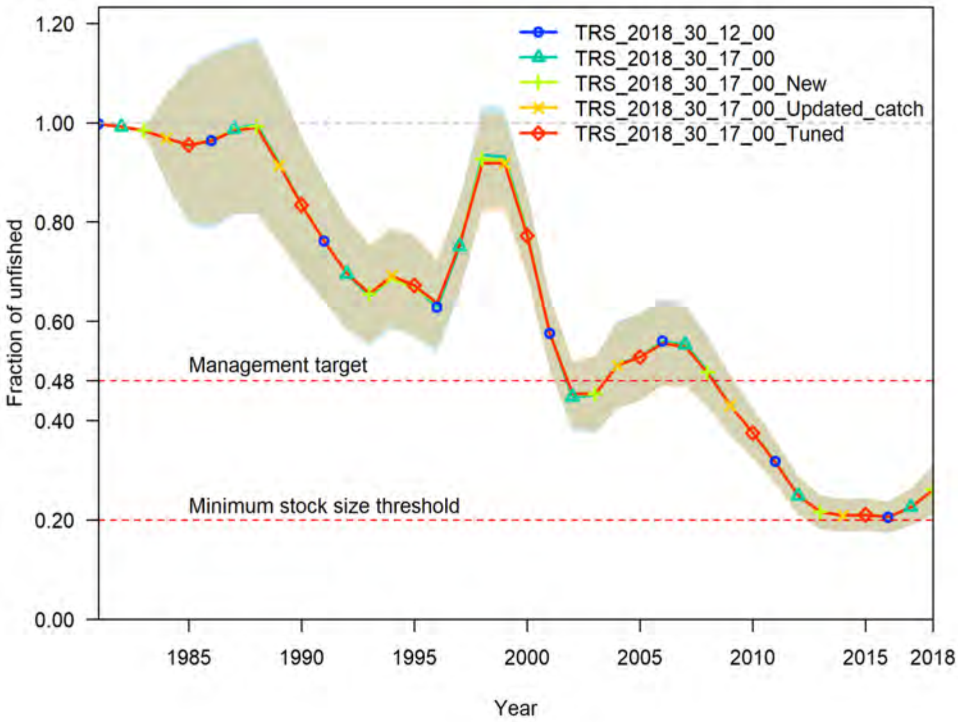

Figure 12.5. Comparison of the relative spawning biomass time series for the four steps included in the first bridging.

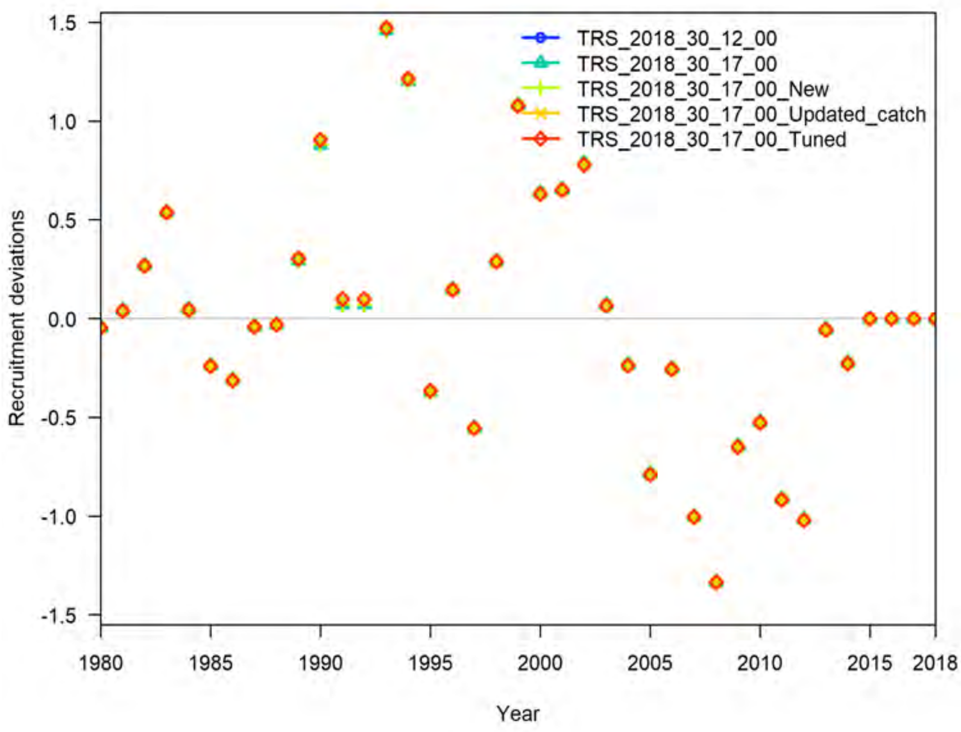

Figure 12.6. Comparison of the estimate recruitment deviations for the four steps included in the first bridging.

12.5 Bridge 2

12.5.1 *Inclusion of new data*

The data inputs to the assessment comes from multiple sources, including: length and conditional age-at-length data from the trawl fishery, updated standardized CPUE series (Sporcic, 2021), the annual total mass landed, discard rates, and age-reading error. Data were formulated by calendar year (i.e. 1 Jan to 31 Dec) and were split into two fleets: east trawl (SESSF zones 10, 20, 30) and west trawl (SESSF zones 40 and 50).

Starting from the converted 2018 base case model (labelled TRS_2018_Updated) additional and updated data to 2020 were added sequentially to develop a preliminary base case for the 2021 assessment, these steps included:

1. Change final assessment year to 2020, add catch to 2020 (addCatch2020).
2. Add CPUE to 2020 (from Sporcic (2021)) (addCPUE2020).
3. Add updated discard fraction estimates to 2020 (add_Discards2020).
4. Update length frequency data, including both port and onboard length frequencies (addLengths2020).
5. Add updated age error matrix and age-at-length data to 2020 (addAge2020).
6. Change the final year for which recruitments are estimated from 2014 to 2017 (extendRec2017).

7. Retune using latest tuning protocols, including Francis weighting on length-compositions and conditional age-at-length data (Tuned).

12.5.2 *Results – base case 2*

Inclusion of the new data resulted in a series of changes to the outputs of the model. The addition of catch data made no difference to the estimated spawning biomass (Figure 12.7). The addition of updated CPUE series resulted in decreased spawning biomass from 1980 to 1990, had no influence on spawning biomass between 1991 and 2015 and reduced estimated spawning biomass from 2015 onwards (Figure 12.7). The addition of updated discard estimates further reduced initial estimates of spawning biomass, however increased estimates between 1985 and 1996 (Figure 12.7). There were minimal changes resulting from the addition of discard data between 1997 and 2015, however, from 2018 the addition of new discard data reduced estimates of absolute spawning biomass (Figure 12.7). The addition of length and age data generally increased estimates of spawning biomass between 1980 and 2010, while there was little impact between 2010 and 2020 (Figure 12.7). Extending recruitment deviations and then tuning resulted in slight downward revisions throughout the series (Figure 12.7). The impacts on relative spawning biomass from the addition of each of the updated and extended data sets was similar as those observed in absolute spawning biomass (Figure 12.7, Figure 12.8).

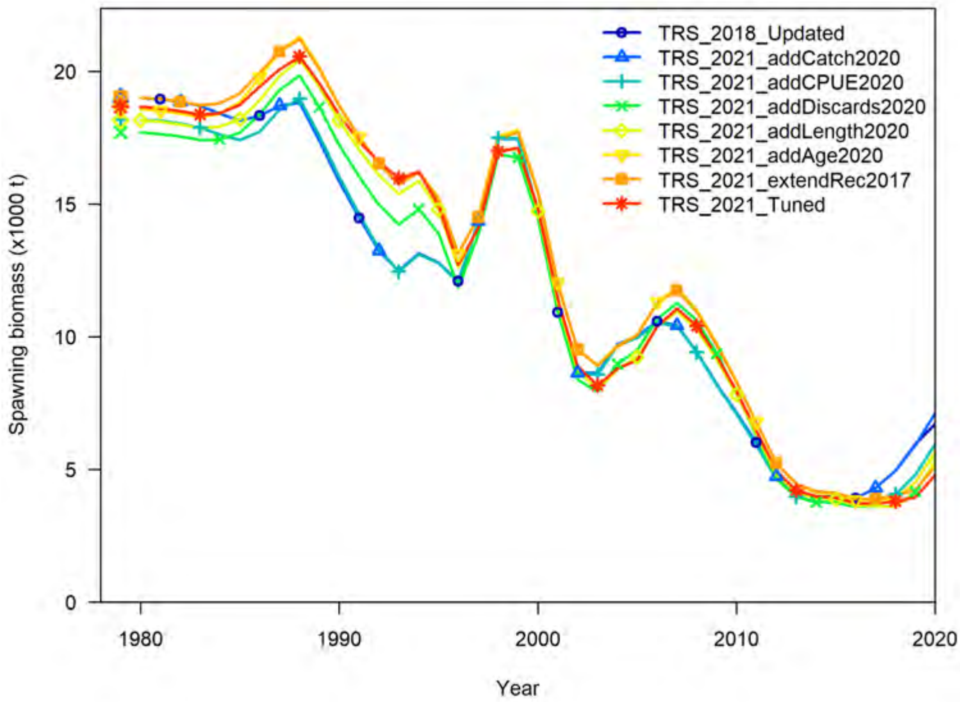

Figure 12.7. Comparison of the absolute spawning biomass for the updated 2018 assessment converted to SS-V3.30.17 (TRS_2018_Updated - blue) with various bridging models leading to the 2021 base case 2 (TRS_2021_Tuned - red)

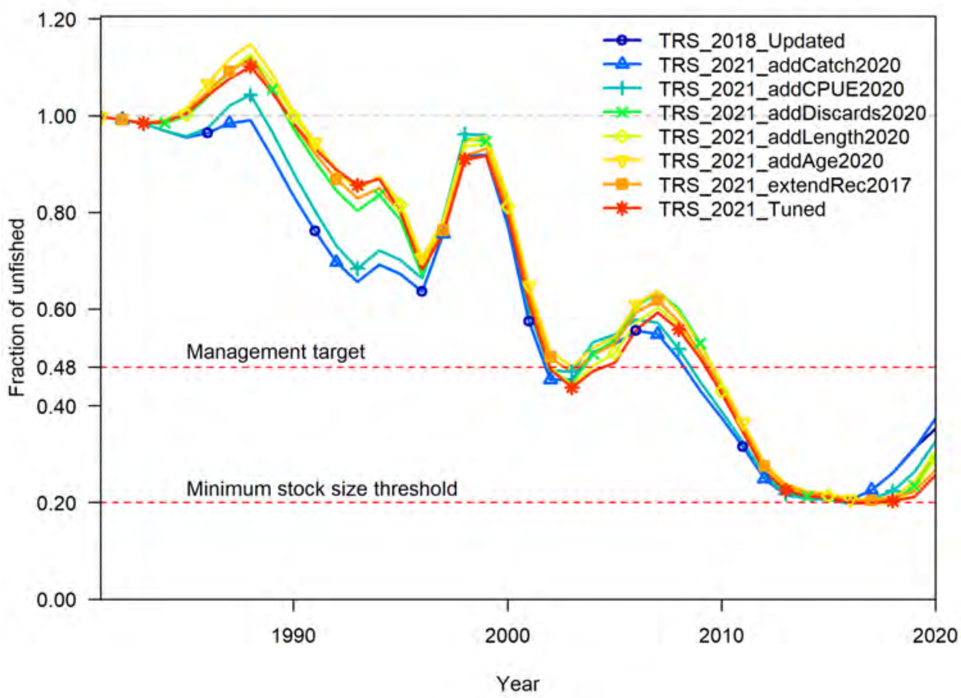

Figure 12.8. Comparison of the fit to the relative spawning biomass for the updated 2018 assessment model converted to SS-V3.30.17 (TRS_2018_Updated - blue) with various bridging models leading to the 2021 base case 2 (TRS_2021_Tuned - red)

The sequential addition of data resulted in increased recruitment estimates between 1980 and 1990, with this also apparent in the recruitment deviations (Figure 12.9, Figure 12.10). In 1991 and 1992 the addition of discard data considerably reduced recruitment estimates, while also increasing estimates in 1993 (Figure 12.9). This is also apparent in the recruitment deviations, where in 1991, deviations were just above average until discard data were included, resulting in downward revision to well below average (Figure 12.10). Recruitment estimates were again revised upwards in 2001 with the addition of discard data (Figure 12.9, Figure 12.10). In 2007 and 2008, the addition of discard data resulted in downward revision of recruitment and recruitment deviations (Figure 12.9, Figure 12.10). The three last recruitment deviation estimates from the previous assessment (2012 to 2014) were also revised downwards with the inclusion of new data (Figure 12.9, Figure 12.10), with this consistent with a pattern observed in previous assessments (Burch et al., 2018a). The new 2015 recruitment deviation was estimated below average, however estimates in 2017 and 2018 were above average, again following a retrospective pattern observed in previous assessments. The impact of these recruitment deviations is explored further below.

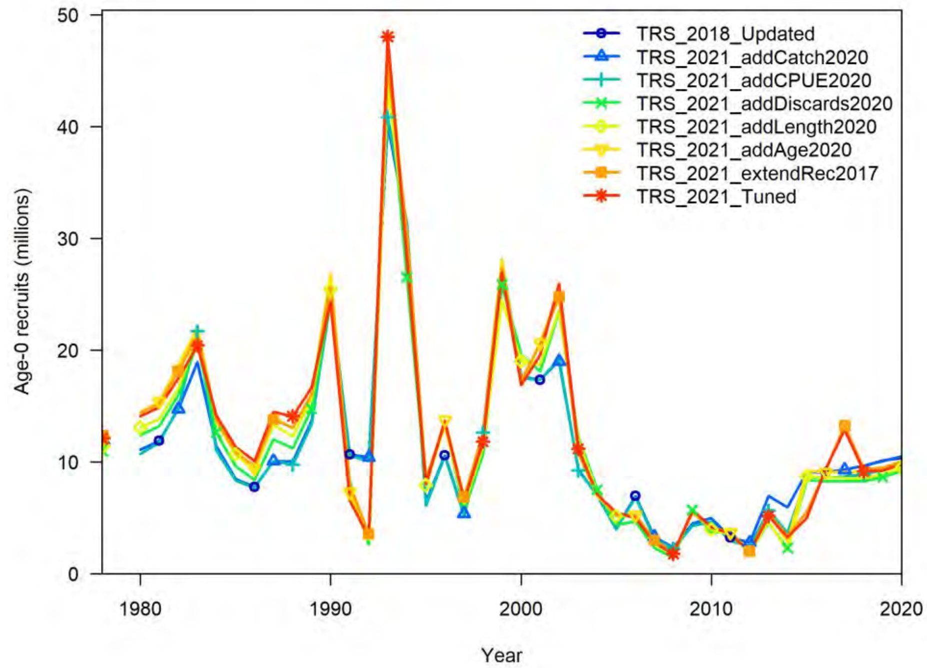

Figure 12.9. Comparison of the estimated absolute recruitments for the updated 2018 assessment model converted to SS-V3.30.17 (TRS_2018_Updated - blue) with various bridging models leading to the 2021 base case 2 (TRS_2021_Tuned - red)

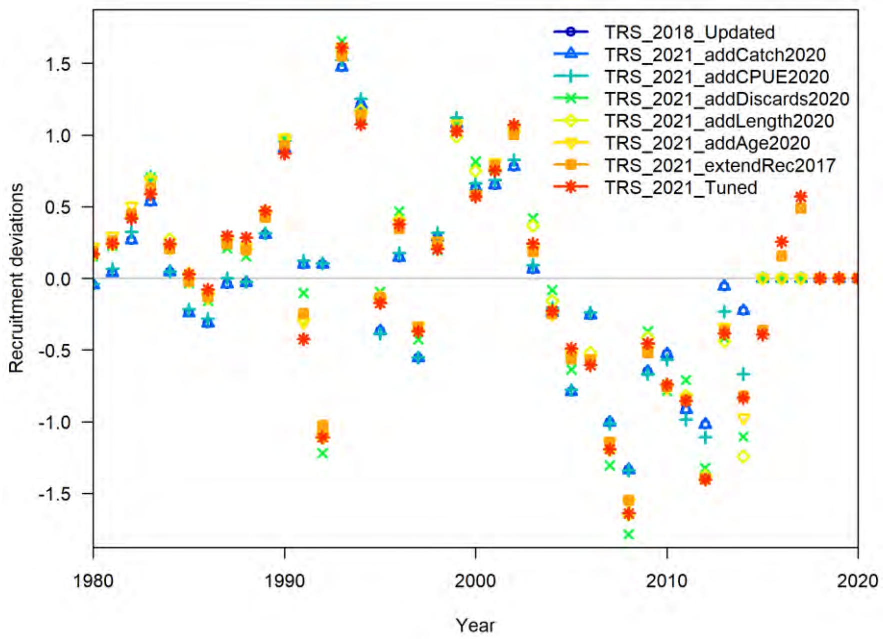

Figure 12.10. Comparison of the estimated recruitment deviations for the updated 2018 assessment model converted to SS-V3.30.17 (TRS_2018_Updated - blue) with various bridging steps leading to the 2021 base case 2 (TRS_2021_Tuned - red)

The impacts of inclusion of new data on fits to CPUE series were generally small. Fits to the east trawl fleet CPUE series were improved between 1985 and 1995, where estimates were higher and closer to the estimated inputs, although this resulted in worse fits to the west trawl CPUE over this period (Figure 12.11, Figure 12.12). Fits between 1995 and 2015 were similar for the east trawl fleet, however from 2015 estimates were lower than in the previous assessment fitting more closely to the inputs (Figure 12.12). Again, fits to the west trawl input data were similar between 1996 and 2017, with the addition of data resulting in sequential improvement to fits between 2018 and 2020 (Figure 12.12).

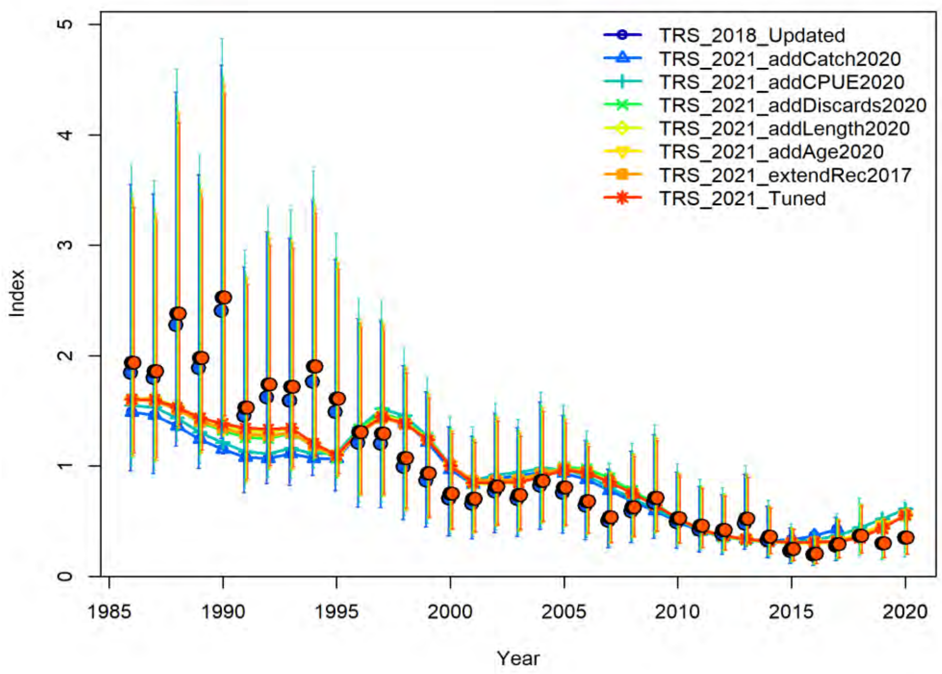

Figure 12.11. Comparison of the fit to the east trawl CPUE index for the updated 2018 assessment model converted to SS-V3.30.17 (TRS_2018_Updated - blue) with various bridging models leading to the 2021 preliminary base case (TRS_2021_Tuned - red)

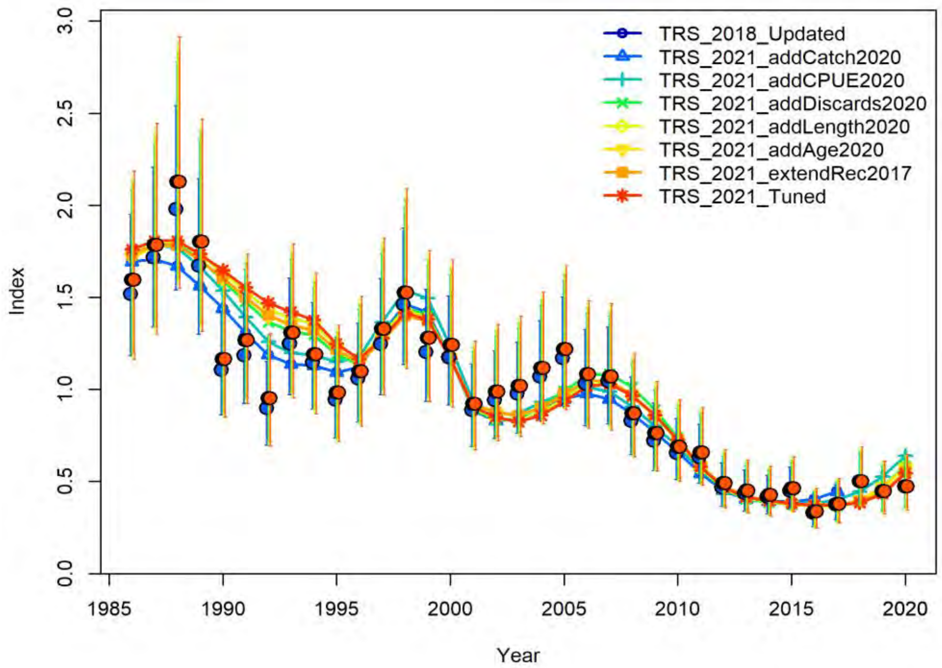

Figure 12.12. Comparison of the fit to the west trawl CPUE index for the updated 2018 assessment model converted to SS-V3.30.17 (TRS_2018_Updated - blue) with various bridging models leading to the 2021 preliminary base case (TRS_2021_Tuned - red).

12.5.3 *Recruitment deviations*

Previous assessments have noted a tendency for the model to estimate higher than average recruitment deviations at the end of the assessment series when investigating retrospecive patterns (Burch et al., 2018b). In subsequent assessments these recruitments are generally revised downwards. The estimation of above average recruitment deviations in 2016 and 2017 follows this same pattern, suggesting that they will likely be revised down to below average in future assessments.

The addition of the extra three recruitment deviations at the end of the series resulted in minor revisions of stock status downwards between 1980 and 2000 and this change was mostly associated with the addition of the last recruitment deviation in 2017 (Figure 12.13).

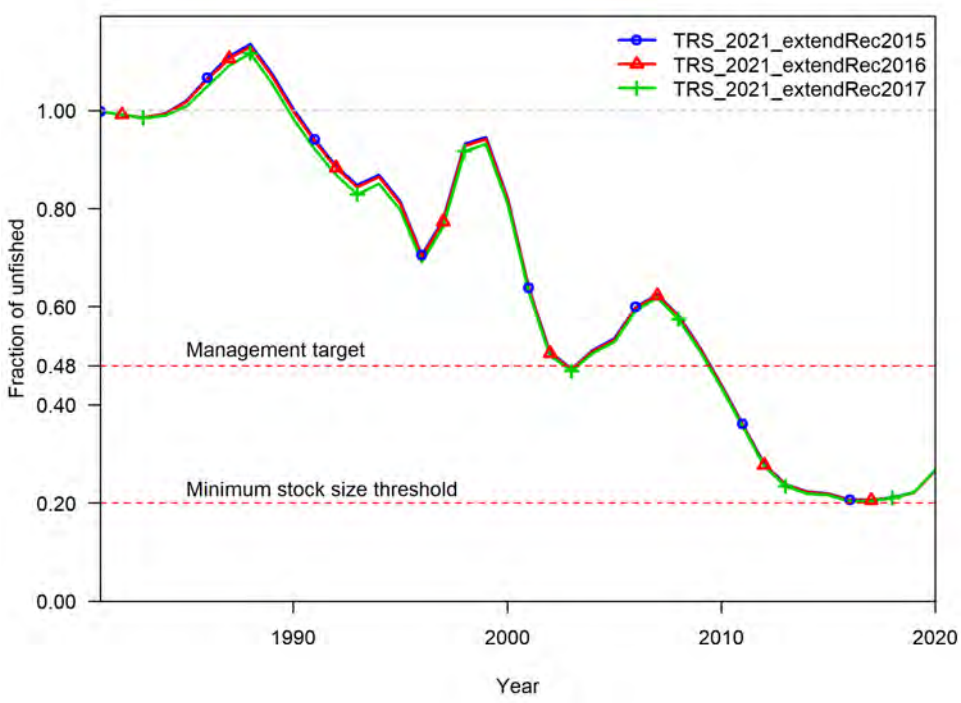

Figure 12.13. Comparison of the relative spawning biomass estimates when extending recruitment deviations to 2015, 2016 and 2017 (blue, red and green respectively)

There is no noticeable difference in the estimated number of recruits with the addition of the three extra recruitment deviations at the end of the series, although the addition of the 2017 deviation resulted in an increase in the estimate (Figure 12.14). Recruitment deviations were revised slightly downwards between 1980 and 2012 with the addition of the 2017 deviation (Figure 12.14). The recruitment deviation in 2016 was revised upwards with addition of the 2016 and 2017 deviations, while the 2017 recruitment was revised upwards with inclusion of the 2017 assessment (Figure 12.14).

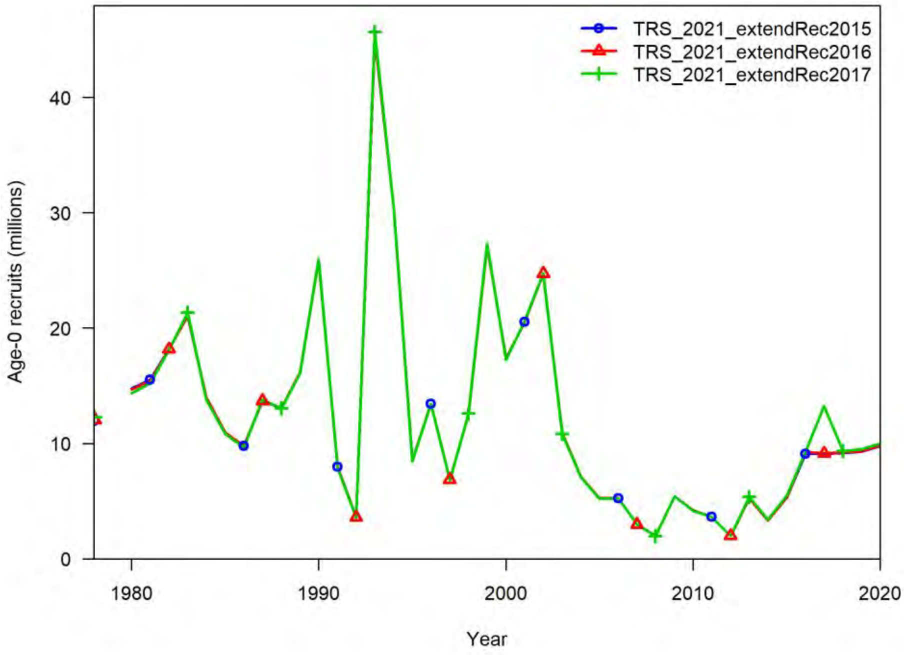

Figure 12.14. Comparison of the estimated recruitment when extending the year of estimation to 2015, 2016 and 2017 (blue, red and green respectively)

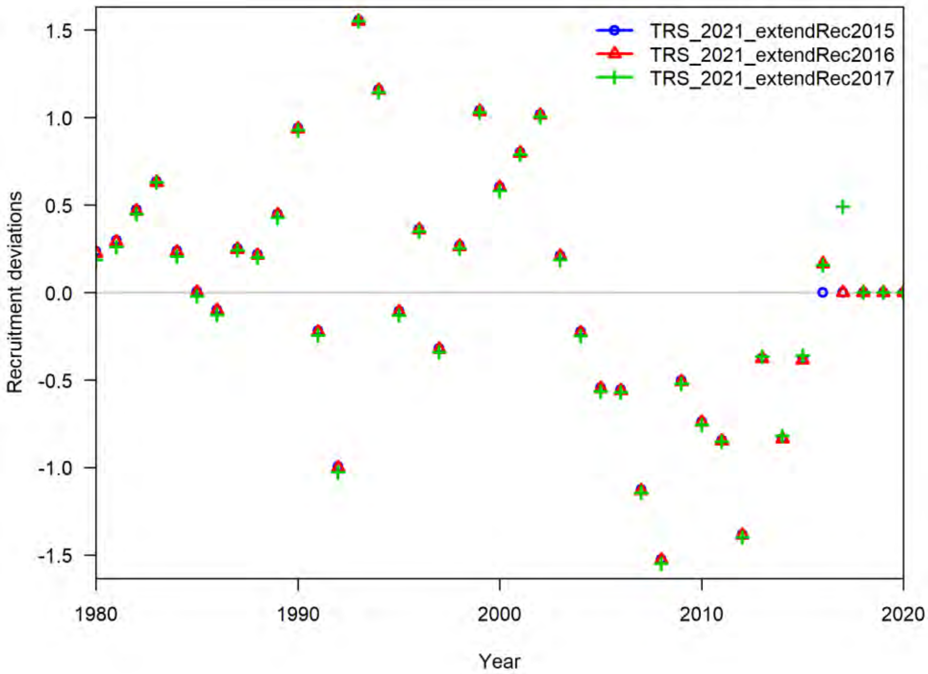

Figure 12.15. Comparison of the estimated recruitment deviations when extending the year of estimation to 2015, 2016 and 2017 (blue, red and green respectively)

12.5.4 *Fits to data – base case 2*

Estimated outputs and fits to data base case 2 are presented in Figure 12.16-Figure 12.23. While most fits are comparable to those in the previous assessment (see Burch et al. (2018b)), the fits to the last three discard estimates for the east trawl fleet are poor (Figure 12.21). This appears to be due to a change in discarding practices over the past 3 years, with substantial increases in discarding. In order to improve fits to these data, an additional retention time block is required, and this is explored further in section Bridge 3.

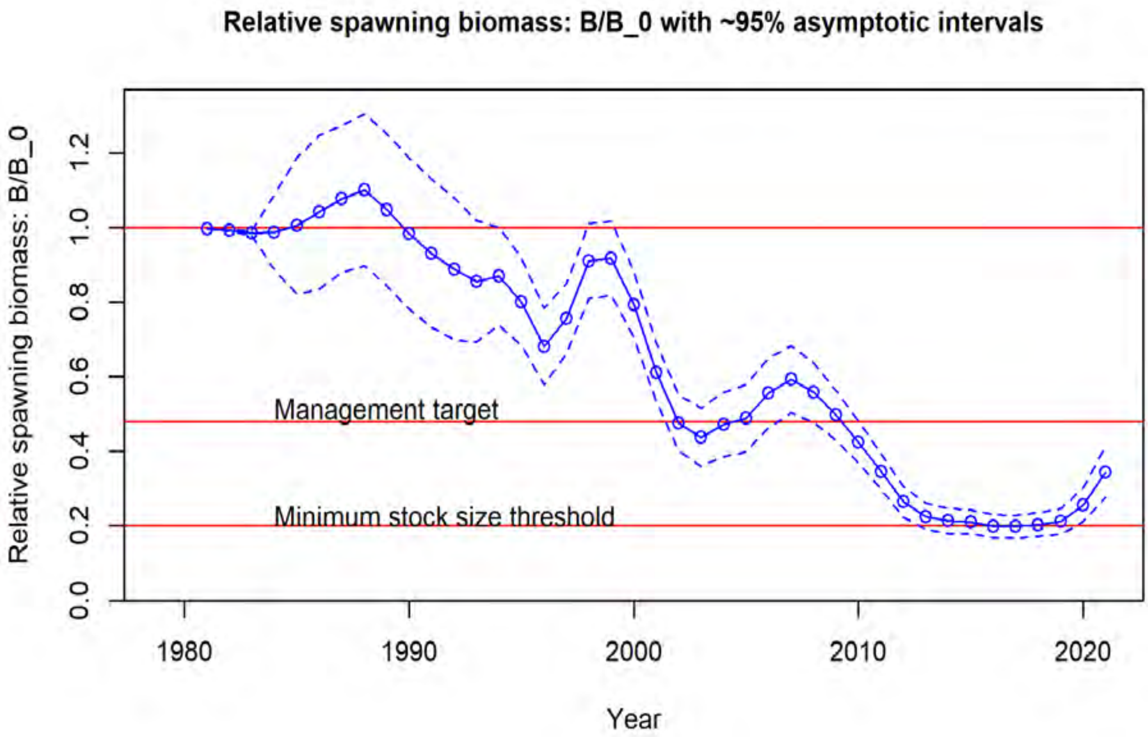

Figure 12.16. The estimated time-series of relative spawning biomass for the 2021 preliminary base case assessment

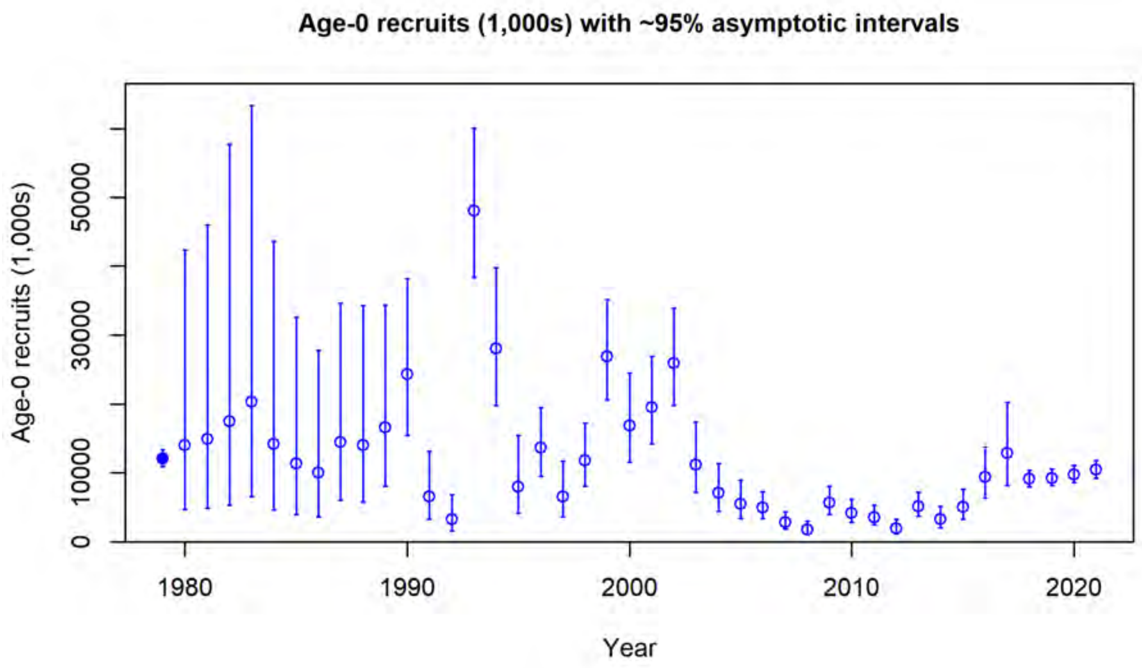

Figure 12.17. The estimated time-series of recruitment for the 2021 preliminary base case assessment

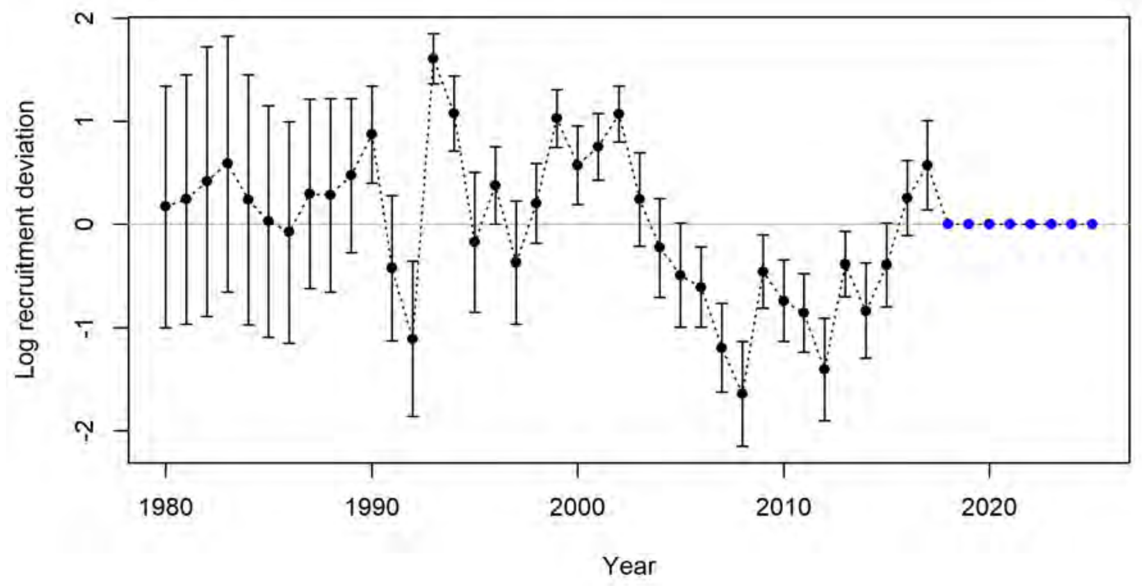

Figure 12.18. The estimated time-series of recruitment deviations for the 2021 preliminary base case assessment

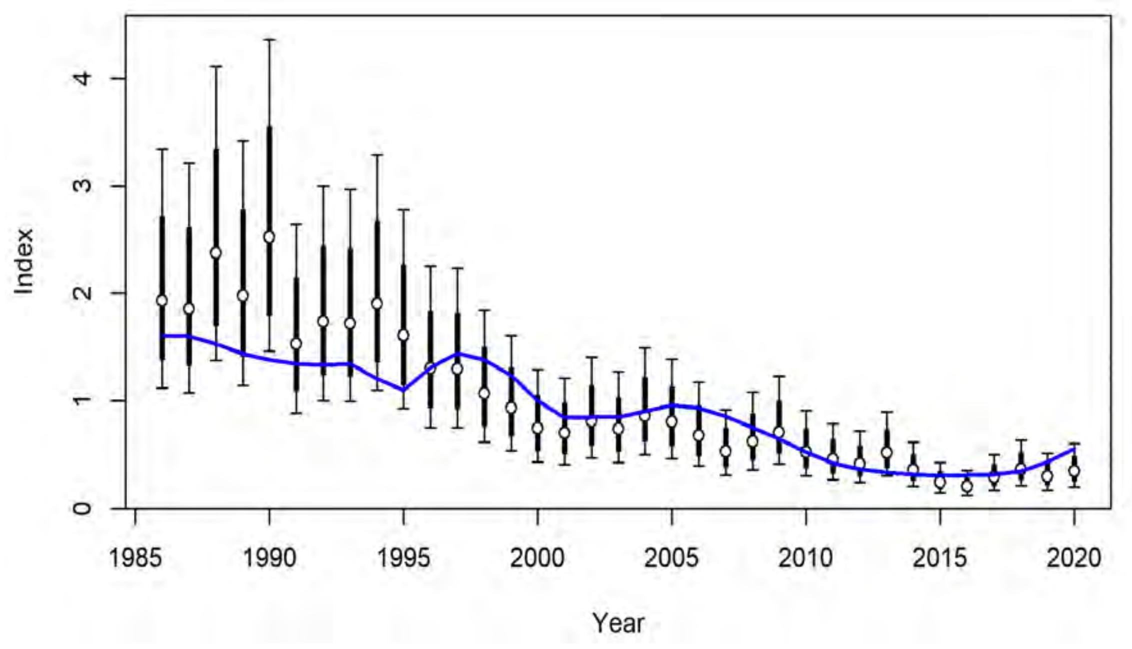

Figure 12.19. Fits to the east trawl CPUE for the 2021 preliminary base case assessment

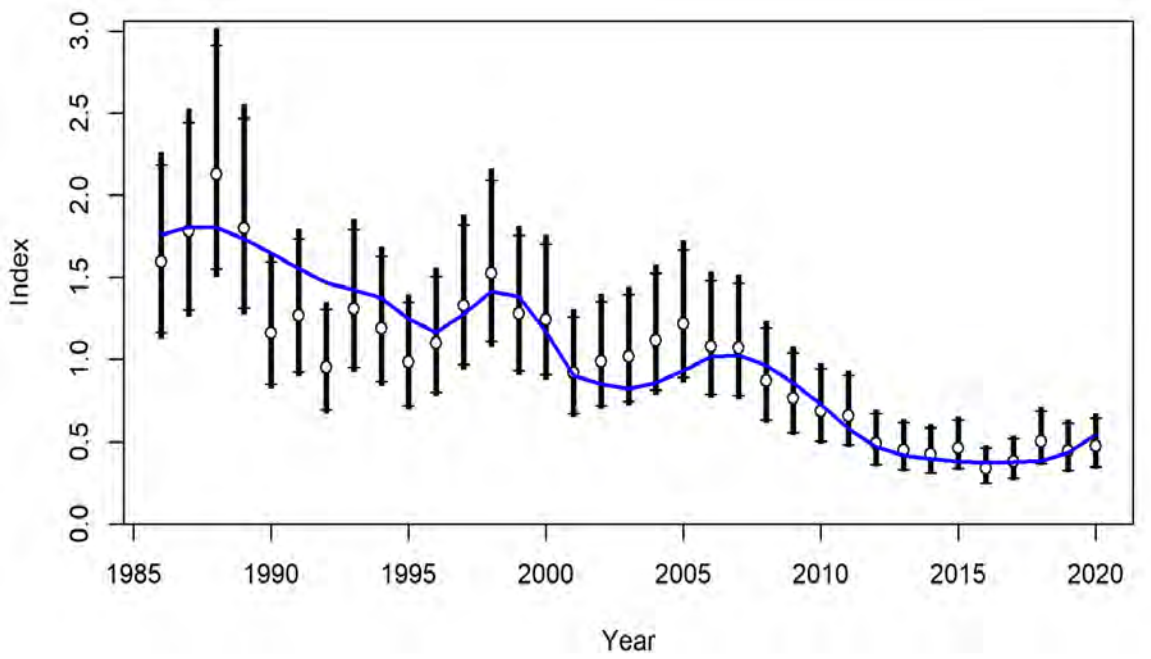

Figure 12.20. Fits to the west trawl CPUE for the 2021 preliminary base case assessment

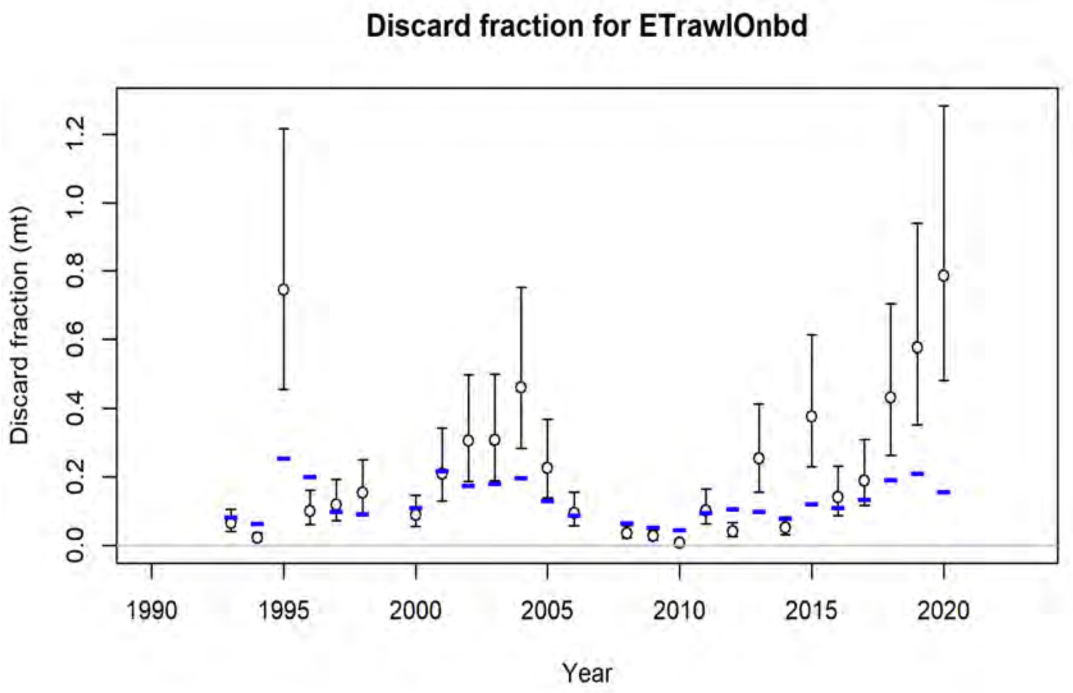

Figure 12.21. Fits to the east trawl discards for the 2021 preliminary base case assessment

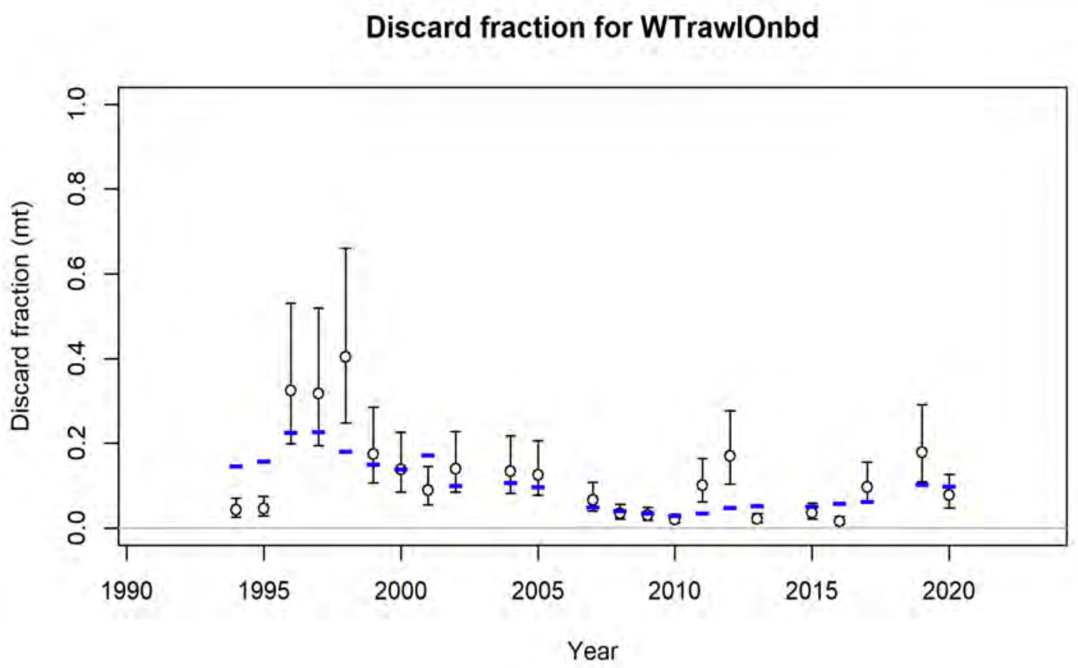

Figure 12.22. Fits to the west trawl discards for the 2021 preliminary base case assessment

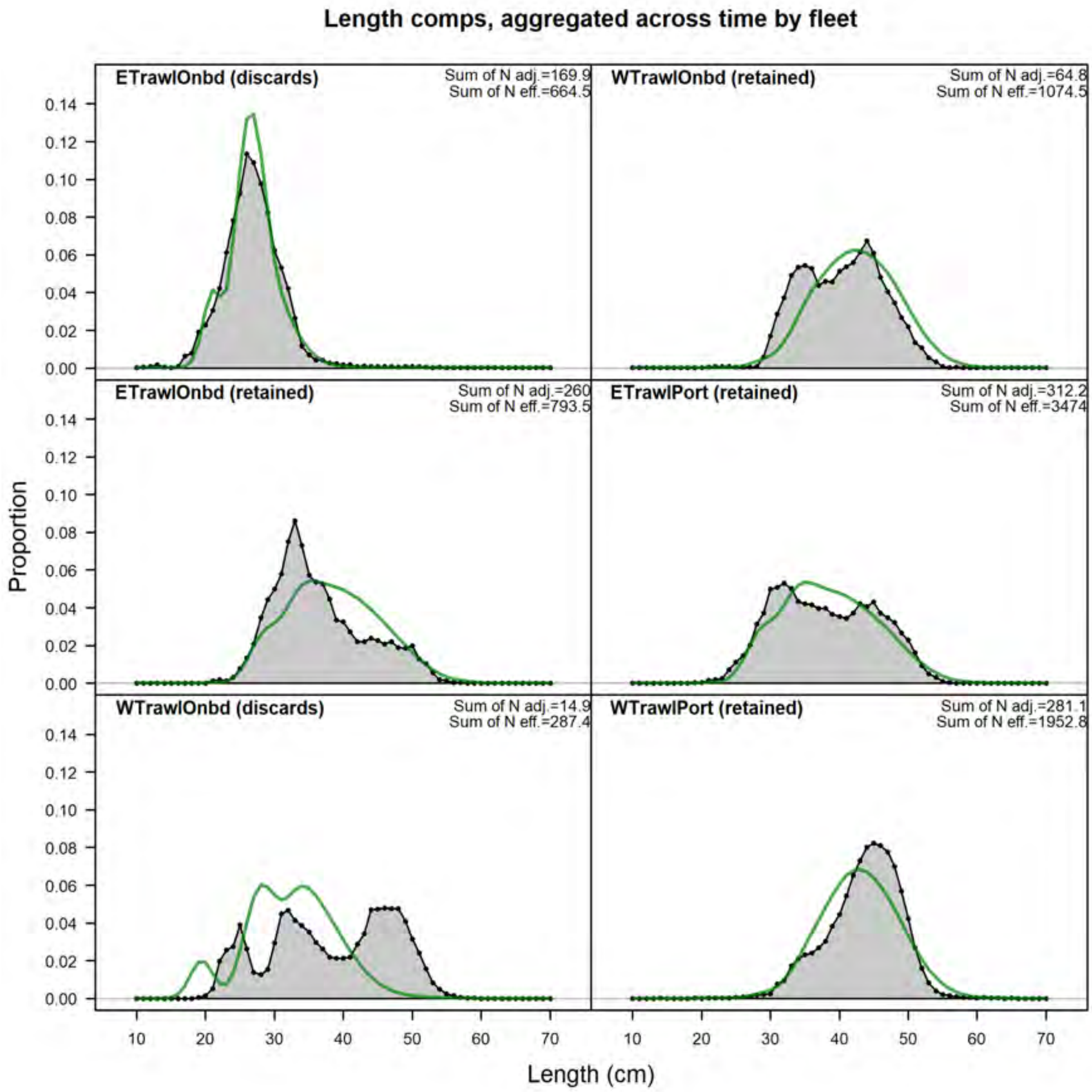

Figure 12.23. Fits to the aggregated length data for the 2021 preliminary base case assessment

12.6 Bridge 3

12.6.1 *Including an additional retention time block and removing recruitment deviations – base case 3*

The model diagnostics and comparisons for base case 2 show poor fits to the discard data for the east trawl fleet (see Bridge 2). There appears to have been a change in discarding practices in this fleet between 2018 and 2020 with increased discard estimates observed over these three years, reaching 79% of the total catch in 2020. In order to adequately fit these increased discard estimates an additional time block on retention for the east trawl fleet from 2018 onwards is required. As part of this last bridging step this retention time block has been included and results are compared with those from base case 2.

In addition to including the extra time block on retention for the east trawl fleet, the last two recruitment deviations have been removed as previous assessments have found these to fit a retrospective pattern which revises recent recruitments downwards with the inclusion of additional years of data (see Burch et al. (2018b)). For a more detailed description and investigation of these trends see Burch et al. (2018b) and Bridge 2. This model with the extra retention time block and removed recruitment deviations is referred to as base case 3.

Including the extra retention time block resulted in little change to both the stock status and absolute spawning biomass estimates, while there was almost no impact on these when removing the last two recruitment deviations (Figure 12.24). Stock status was slightly higher than in base case 2 (TRS_2021_Tuned) between 1985 and 1995 and again at the end of the time series from 2015 when including the extra retention time block (TRS_2021_exra_ret_Tuned), with very little difference observed when removing the last two recruitment deviations (TRS_2021_extra_ret_remove_dev_Tuned, Figure 12.24). Spawning biomass estimates were slightly higher throughout the majority of the timeseries in both models with the extra time block and the removed recruitment deviations (Figure 12.25).

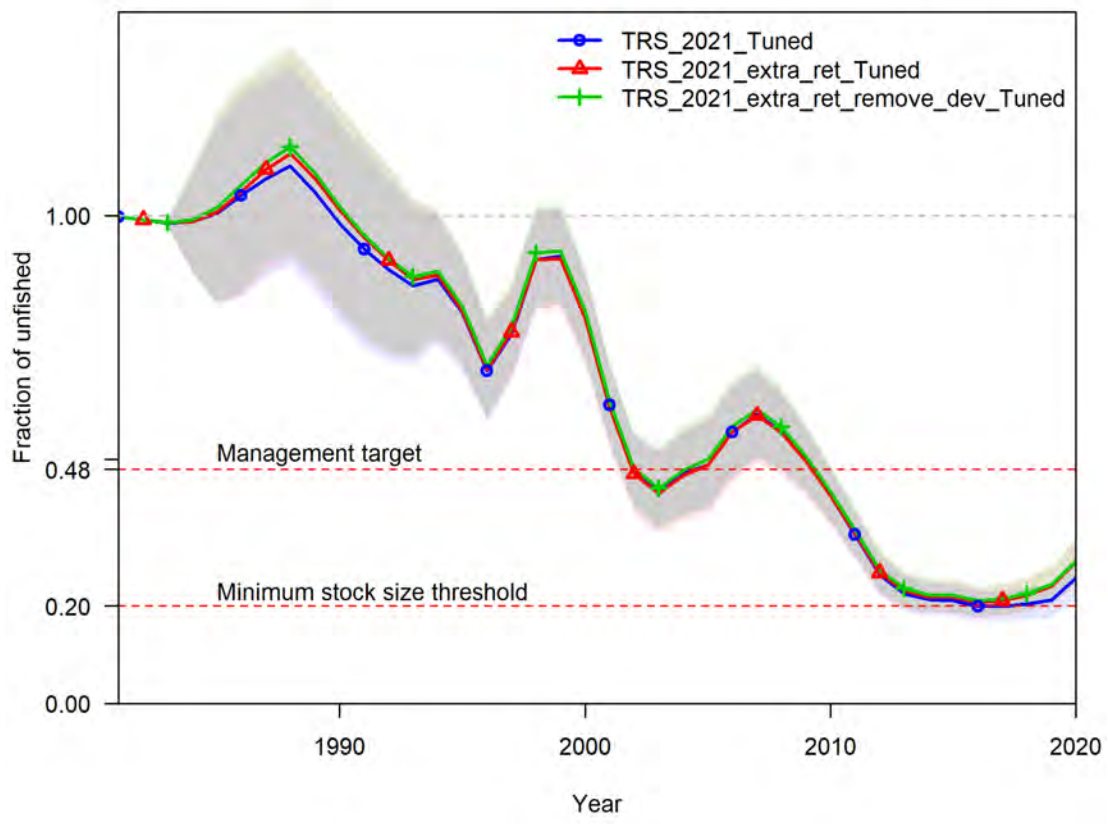

Figure 12.24. Comparison of relative spawning biomass from base case 2 (TRS_2020_Tuned - blue) with the model including an additional retention time block (TRS_2021_extra_ret_Tuned - red) and that with the last two recruitment deviations removed (base case 3, TRS_2021_extra_ret_remove_dev_Tuned - green)

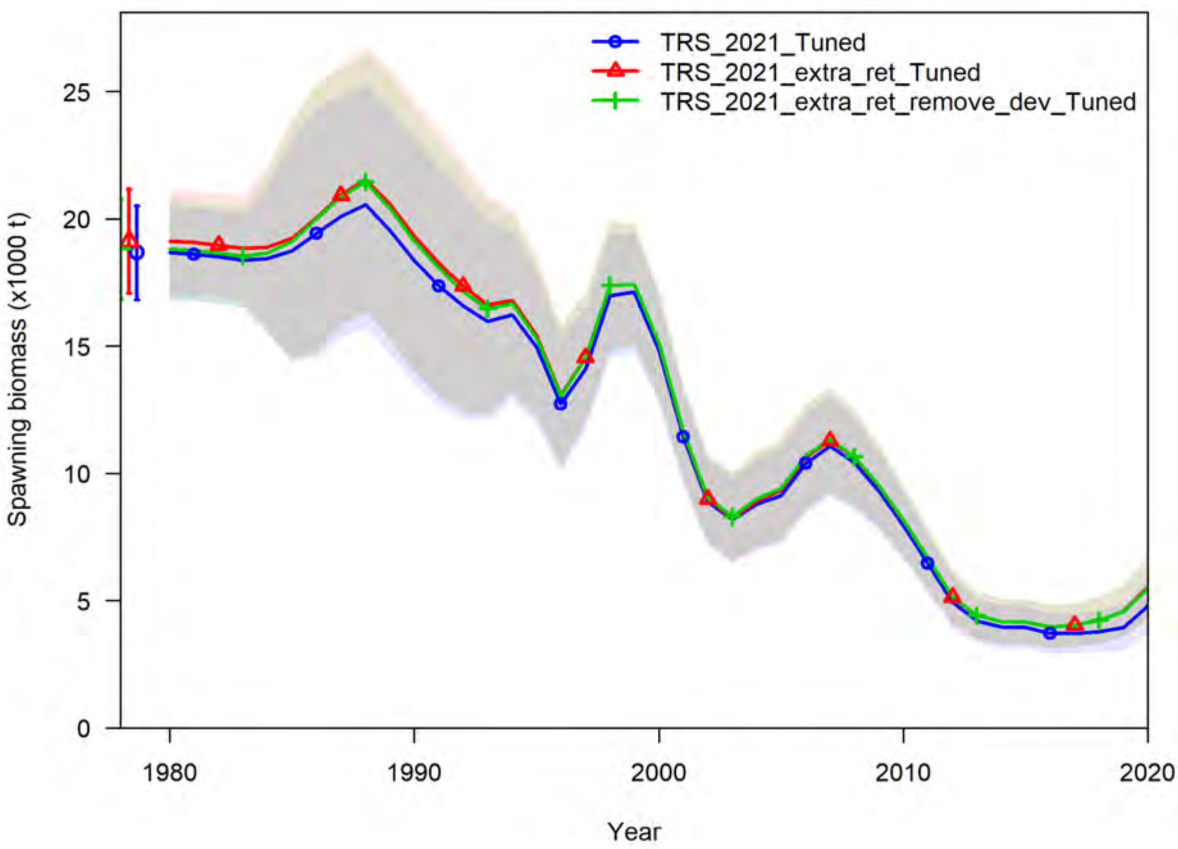

Figure 12.25. Comparison of absolute spawning biomass from base case 2 (TRS_2020_Tuned - blue) with the model including an additional retention time block (TRS_2021_extra_ret_Tuned - red) and that with the last two recruitment deviations removed (base case 3, TRS_2021_extra_ret_remove_dev_Tuned - green)

There were minor differences in the recruit estimates throughout the series, shifting estimates both above and below previous estimates (Figure 12.26). This result was also evident in the recruitment deviation estimates (Figure 12.27). When removing the recruitment deviations from the model with the additional time block there was almost no change in estimated recruitment, besides the removal of the spike in 2017 (Figure 12.26).

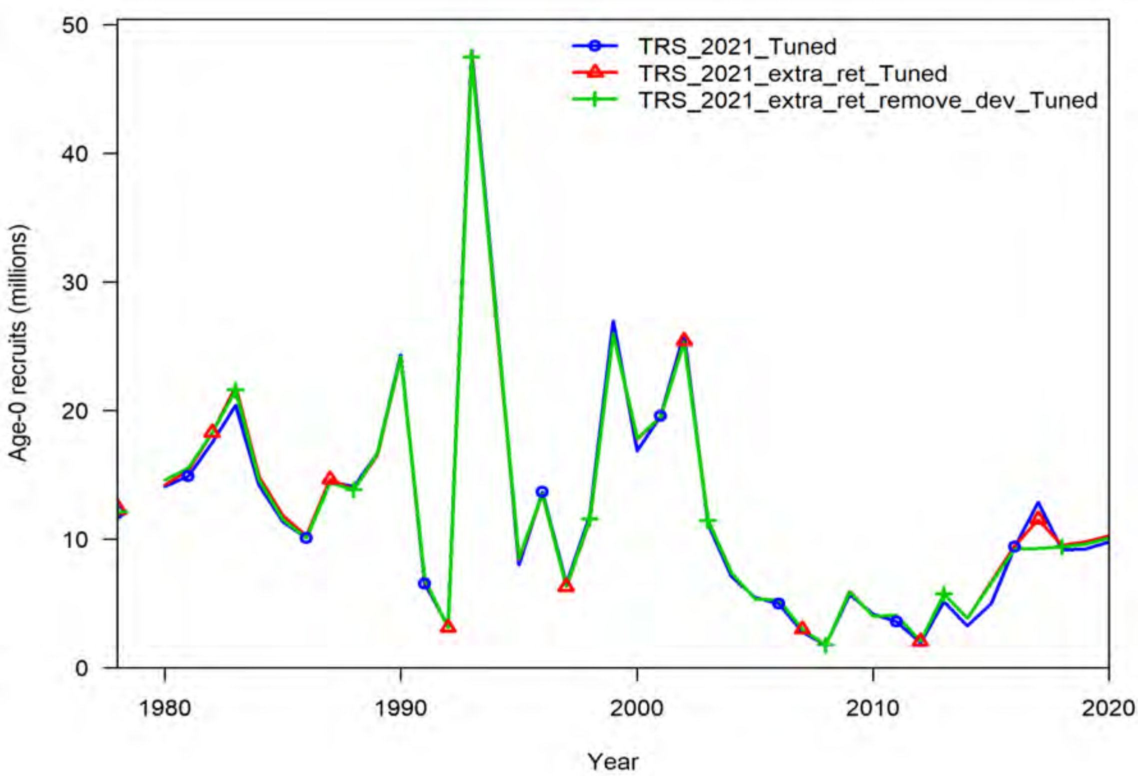

Figure 12.26. Comparison of estimated recruitments for the 2021 base case 2 (TRS_2020_Tuned - blue) with the model including an additional retention time block (TRS_2021_extra_ret_Tuned - red) and that with the last two recruitment deviations removed (base case 3, TRS_2021_extra_ret_remove_dev_Tuned - green)

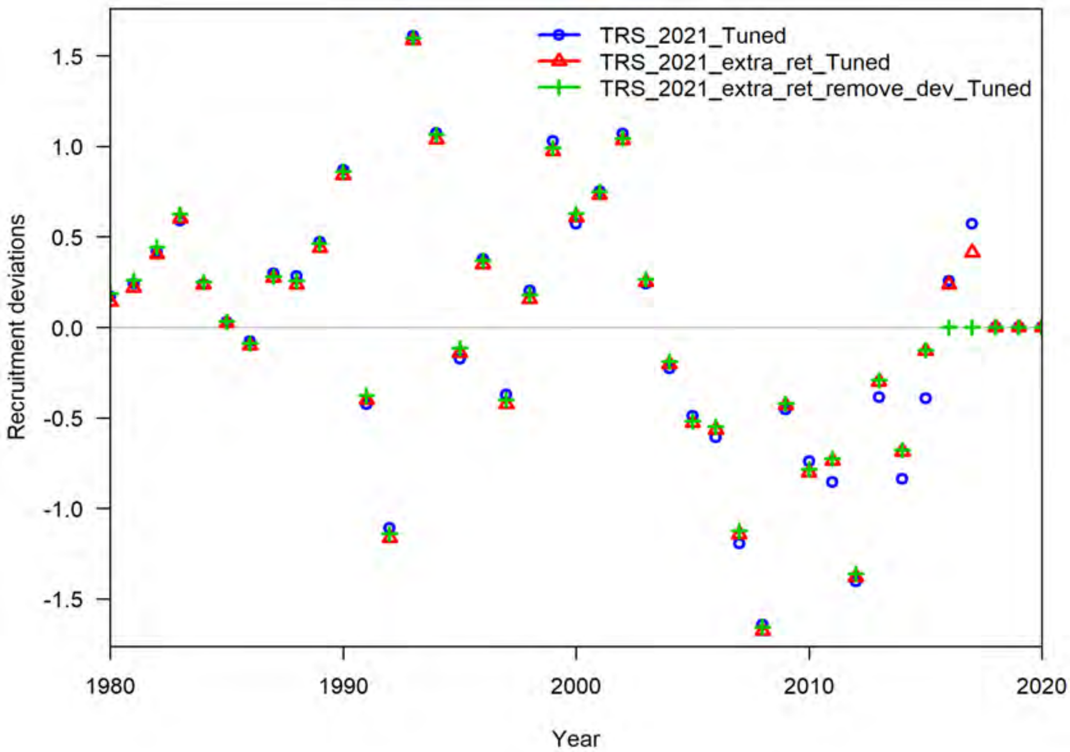

Figure 12.27. Comparison of the estimated recruitment for the 2021 base case 2 (TRS_2020_Tuned - blue) with the model including an additional retention time block (TRS_2021_extra_ret_Tuned - red) and that with the last two recruitment deviations removed (base case 3, TRS_2021_extra_ret_remove_dev_Tuned - green)

From 2017 base case 3 showed improved fits to the CPUE series (Figure 12.28). Fits to the west trawl CPUE series were similar for the majority of the timeseries, however, fits to the last three years slightly worse than in base case 2 (Figure 12.29). There was no discernible difference when moving to the model with the recruitment deviation series shortened (Figure 12.28, Figure 12.29).

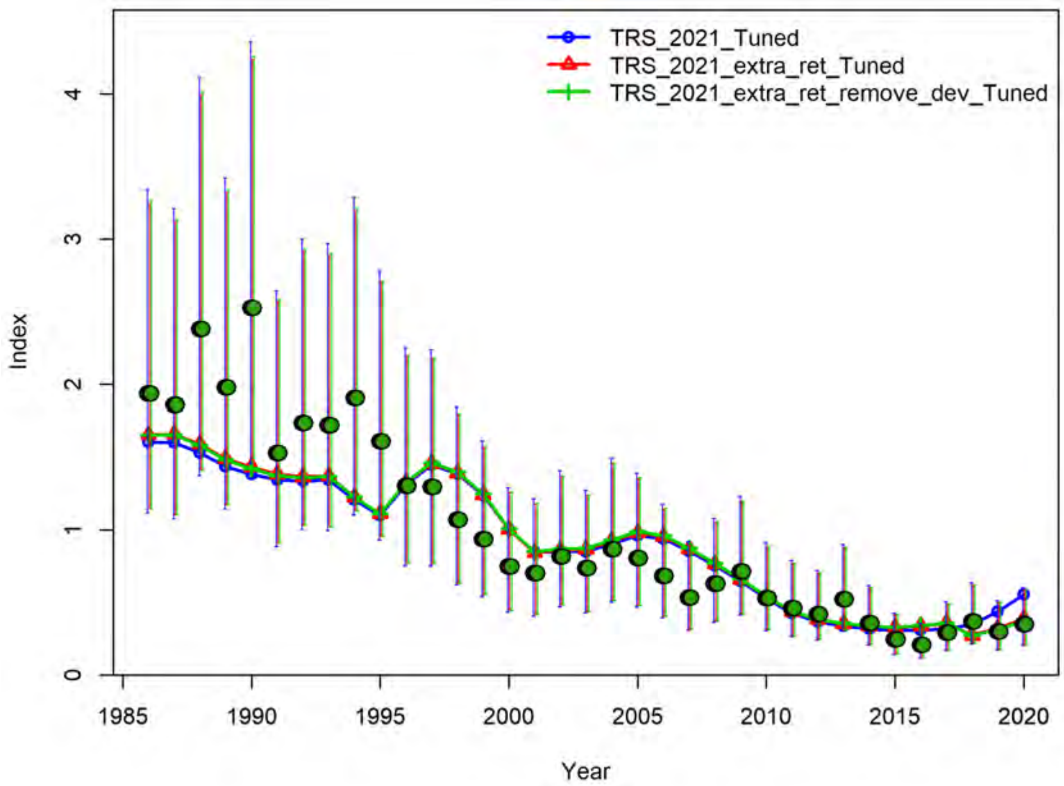

Figure 12.28. Comparison of the fit to CPUE for the east trawl fleet for the 2021 base case 2 (TRS_2020_Tuned - blue) with the model including an additional retention time block (TRS_2021_extra_ret_Tuned - red) and that with the last two recruitment deviations removed (base case 3, TRS_2021_extra_ret_remove_dev_Tuned - green)

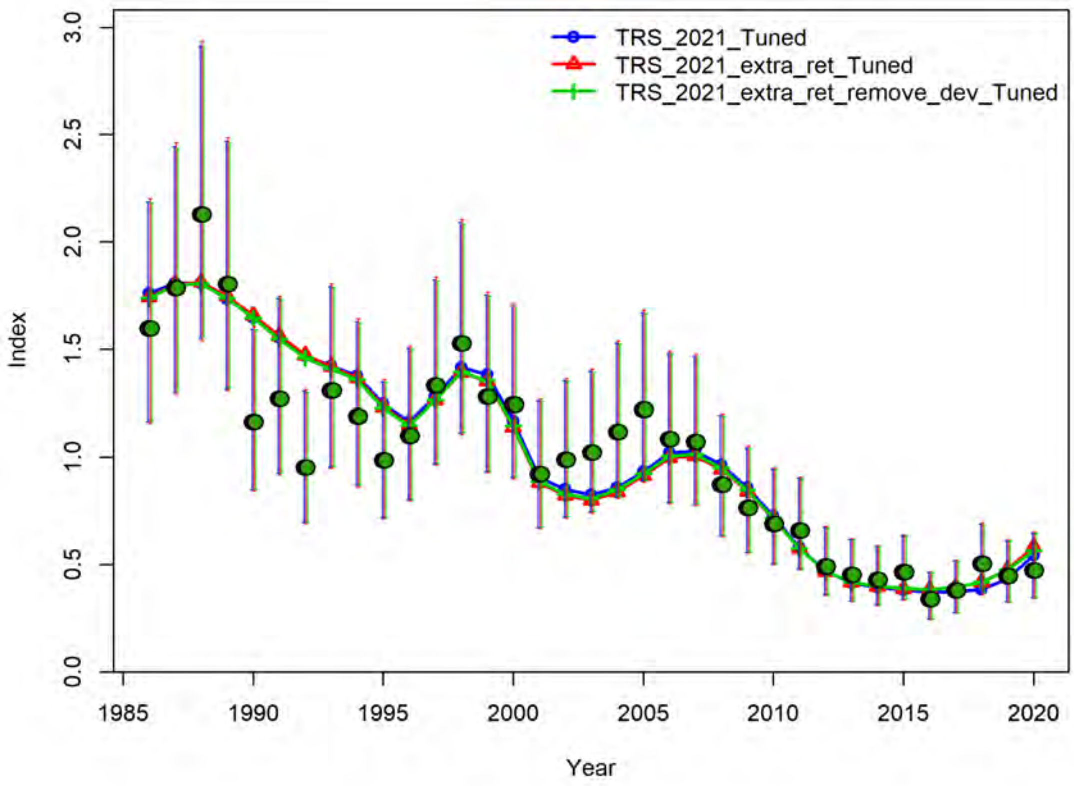

Figure 12.29. Comparison of the fit to CPUE for the west trawl fleet for the 2021 base case 2 (TRS_2020_Tuned - blue) with the model including an additional retention time block (TRS_2021_extra_ret_Tuned - red) and that with the last two recruitment deviations removed (base case 3, TRS_2021_extra_ret_remove_dev_Tuned - green)

12.6.2 *Fits to data – base case 3*

The base case specifications agreed by SERAG in 2018 are maintained into base case 2 presented in Bridge 2. Two changes to this model have been made, including the addition of a retention time block to the east trawl fleet to allow the model to fit the increased discarding, which has changed since the previous assessment and removing estimation of recruitment deviations in 2016 and 2017 due to a retrospective pattern in these recruitments which is revised down with the inclusion of additional years of data. Both of these changes have had minimal impacts on estimated stock status and have improved fits to the data input to the model. This update is referred to as ‘base case 3.

The results from this model show good fits to CPUE abundance indices for both fleets. Fits to the conditional age at length data are also good. Discard data in the east is fit more closely than before, although it is still not fitting the highest estimate in 2020. Fits to discard data in the west are similar as in the previous model specification. As with previous models, fits to the length data are poor. Model diagnostics are presented in Figure 12.30-Figure 12.83.

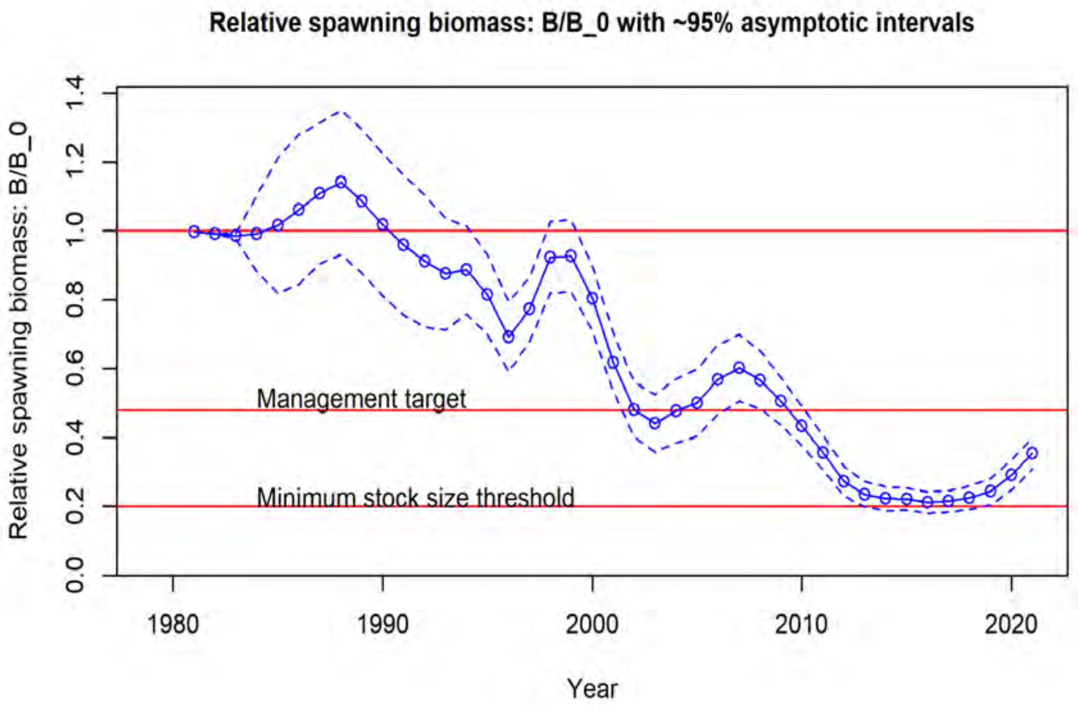

Figure 12.30. The estimated time-series of relative spawning biomass for the 2021 base case 3

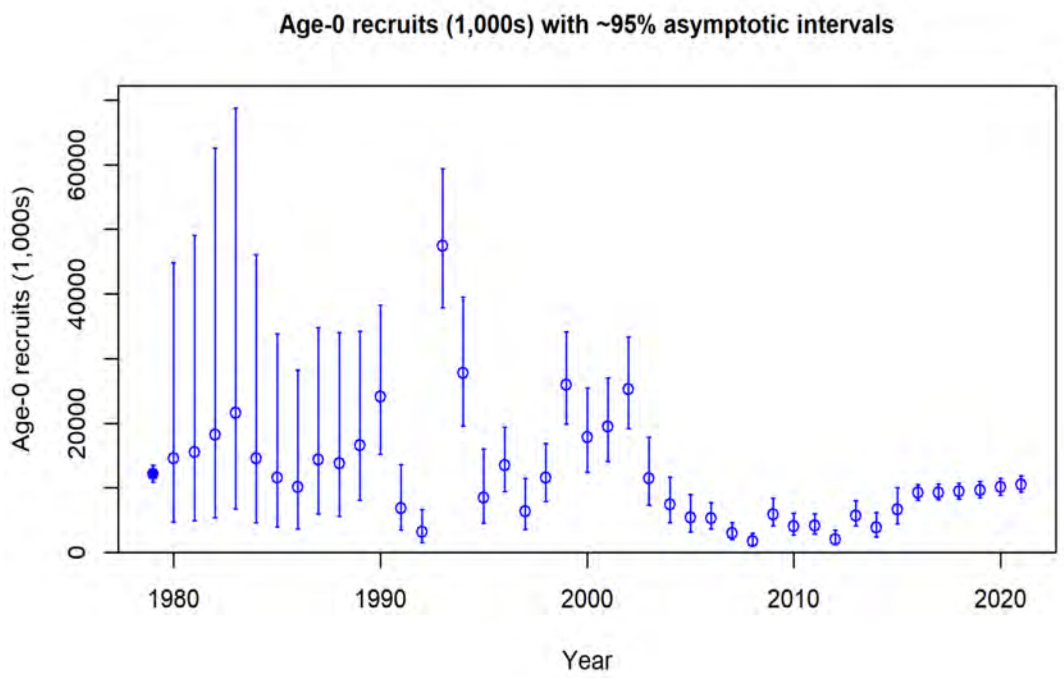

Figure 12.31. The estimated time-series of recruitment for the 2021 base case 3

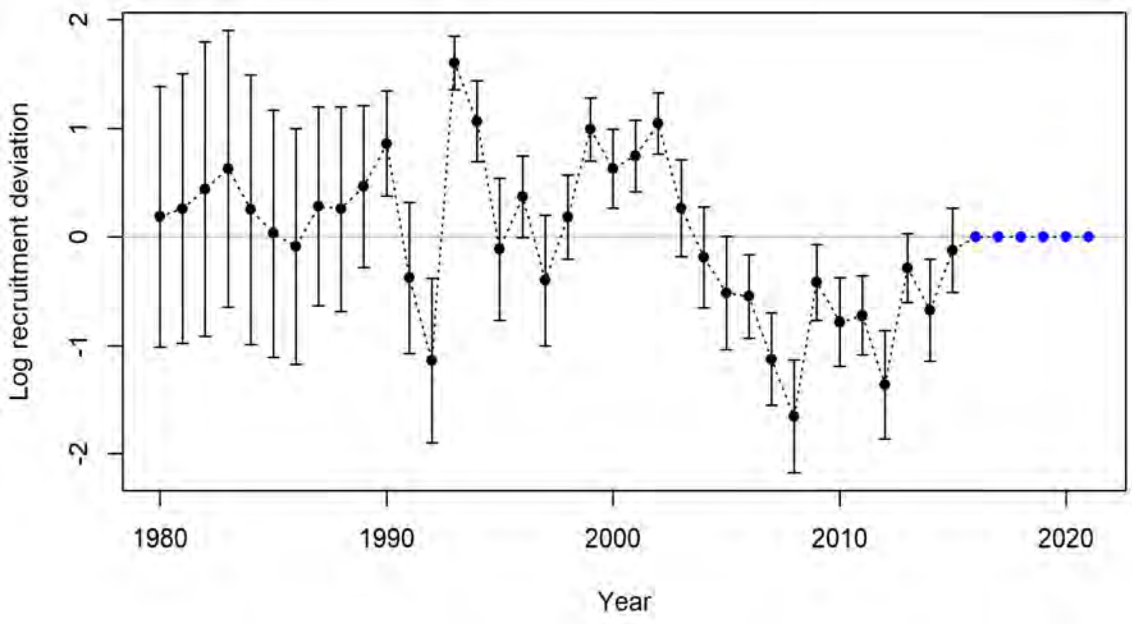

Figure 12.32. The estimated time-series of recruitment deviations for the 2021 base case 3

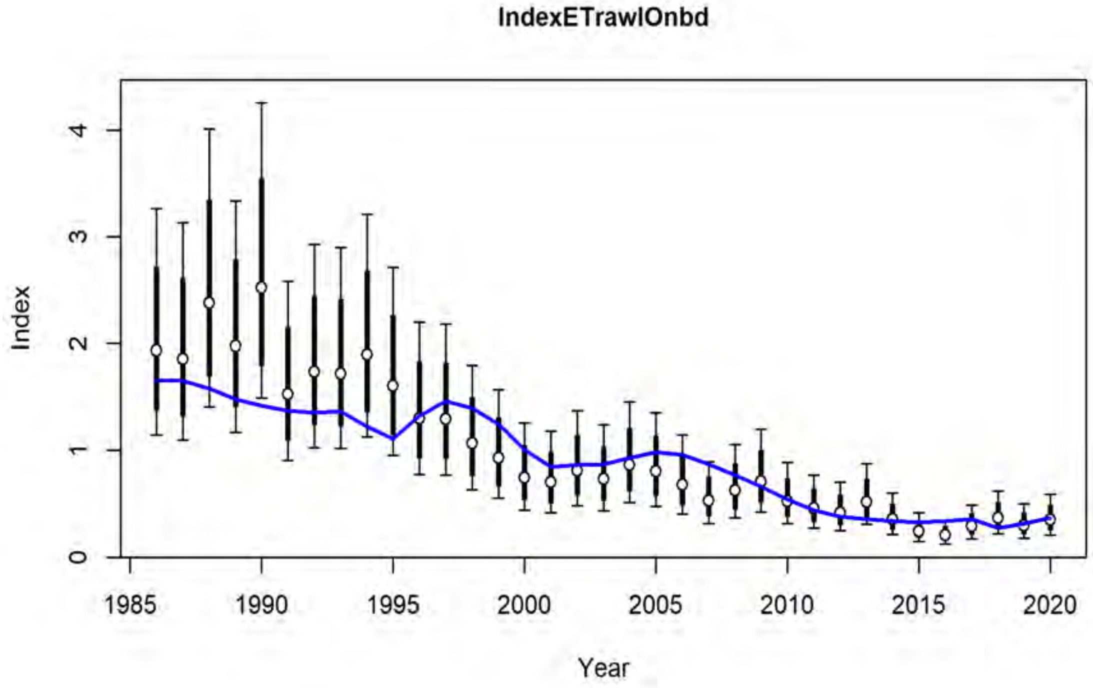

Figure 12.33. Fits to the east trawl CPUE for the 2021 base case 3

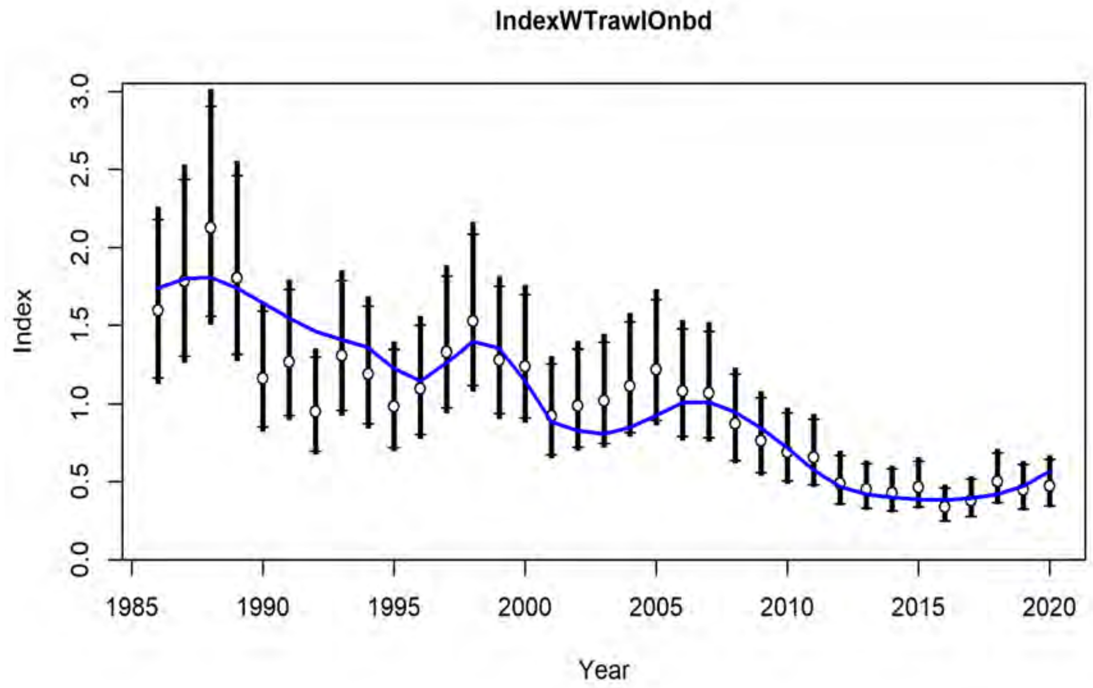

Figure 12.34. Fits to the west trawl CPUE for the 2021 base case 3

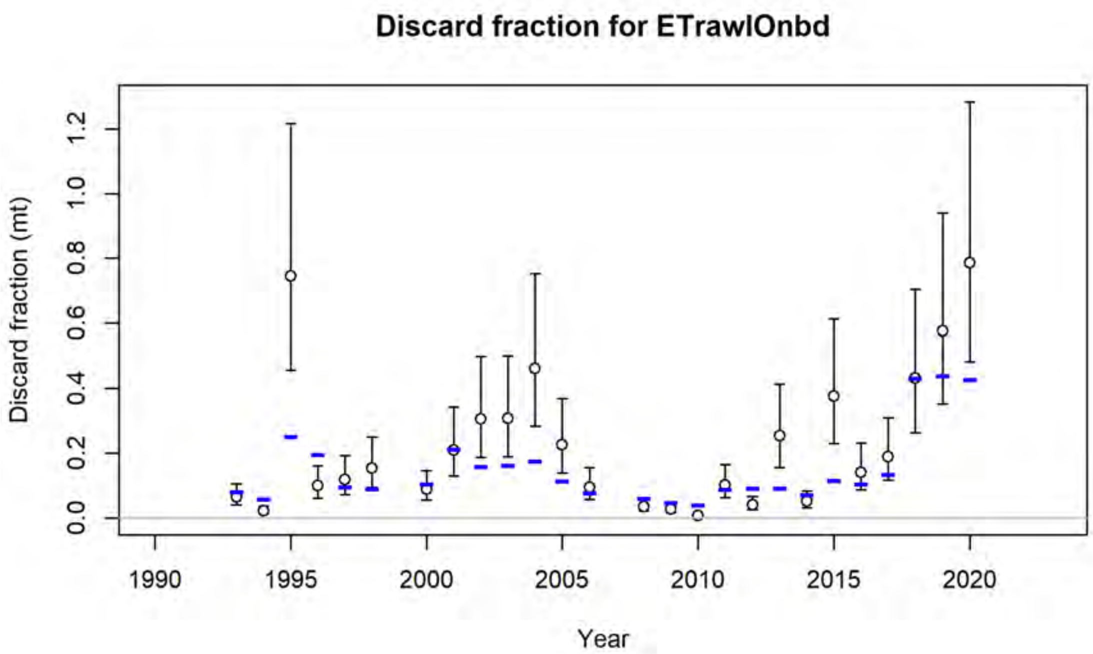

Figure 12.35. Fits to the east trawl discards for the 2021 base case 3

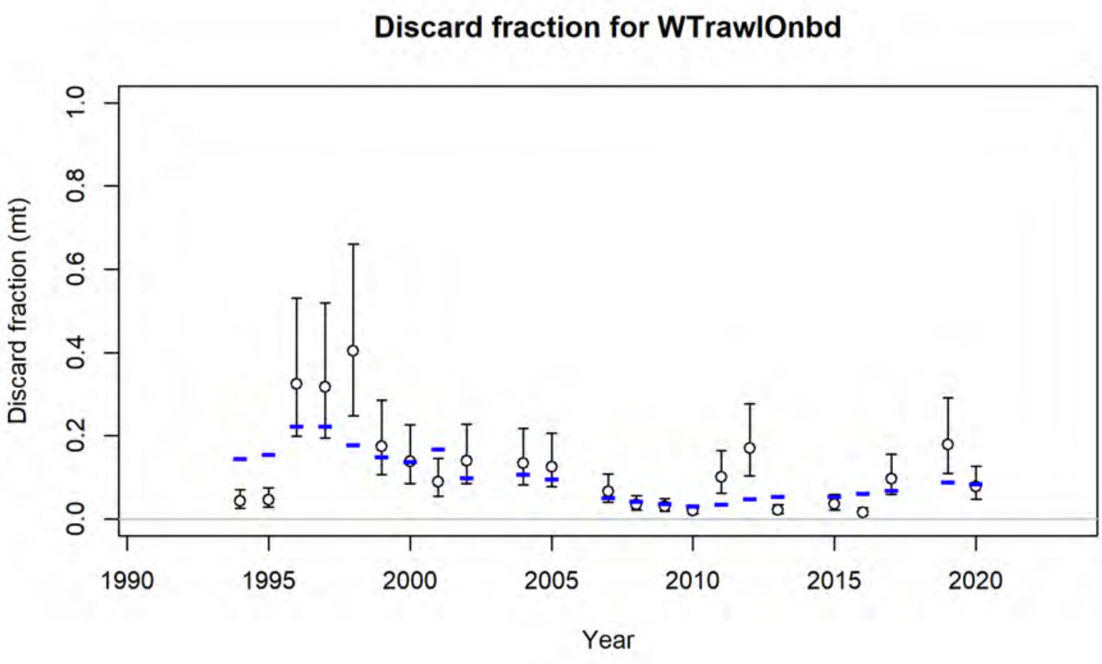

Figure 12.36. Fits to the west trawl discards for the 2021 base case 3

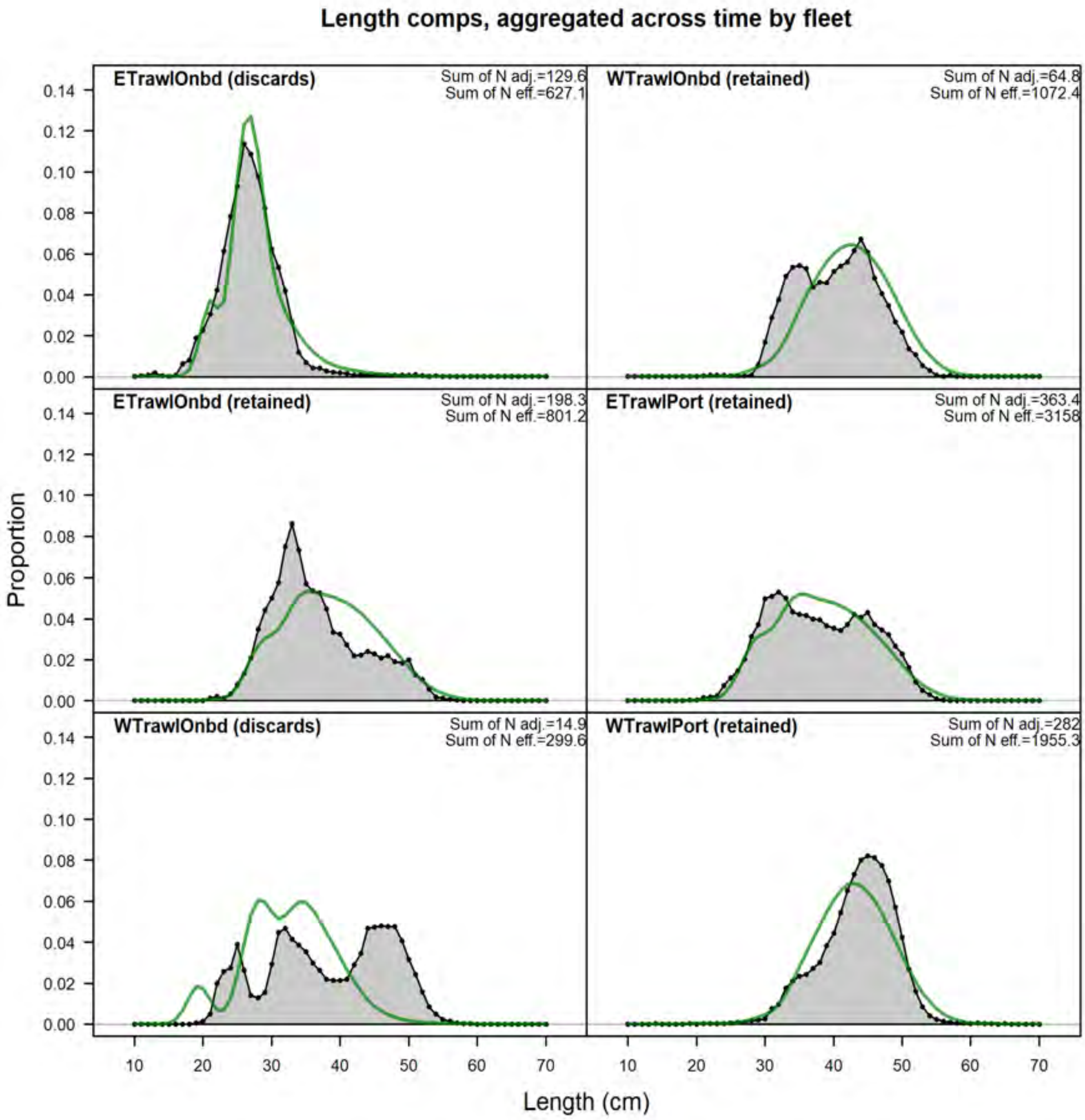

Figure 12.37. Fits to the aggregated length data for the 2021 base case 3

12.7 Acknowledgements

Age data were provided by Kyne Krusic-Golub (Fish Ageing Services), ISMP and AFMA logbook and CDR data were provided by John Garvey (AFMA). Mike Fuller, Paul Burch, Robin Thomson, Roy Deng, Franzis Althaus, Toni Cannard and Caroline Sutton (CSIRO) pre-processed the data. Miriana Sporcic provided standardised CPUE. Malcolm Haddon provided useful code for auto-balancing, Athol Whitten provided useful R code for organising plots. Paul Burch provided an updated ageing error matrix. Geoff Tuck, Jemery Day, Robin Thomson and Paul Burch (CSIRO) provided valuable review and discussion of this work. Ian Taylor, Chantel Wetzel, Kathryn Doering and Kelli Johnson (NOAA) are thanked for helpful reccomendations and fixes in relation to the the r4ss package. The r4ss package maintained by Ian Taylor (https://github.com/r4ss/r4ss) was critical for producing multiple diagnostic plots, and tuning models. Geoffrey Liggins is thanked for discussions on the catch history.

12.8 References

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12.9 Appendix

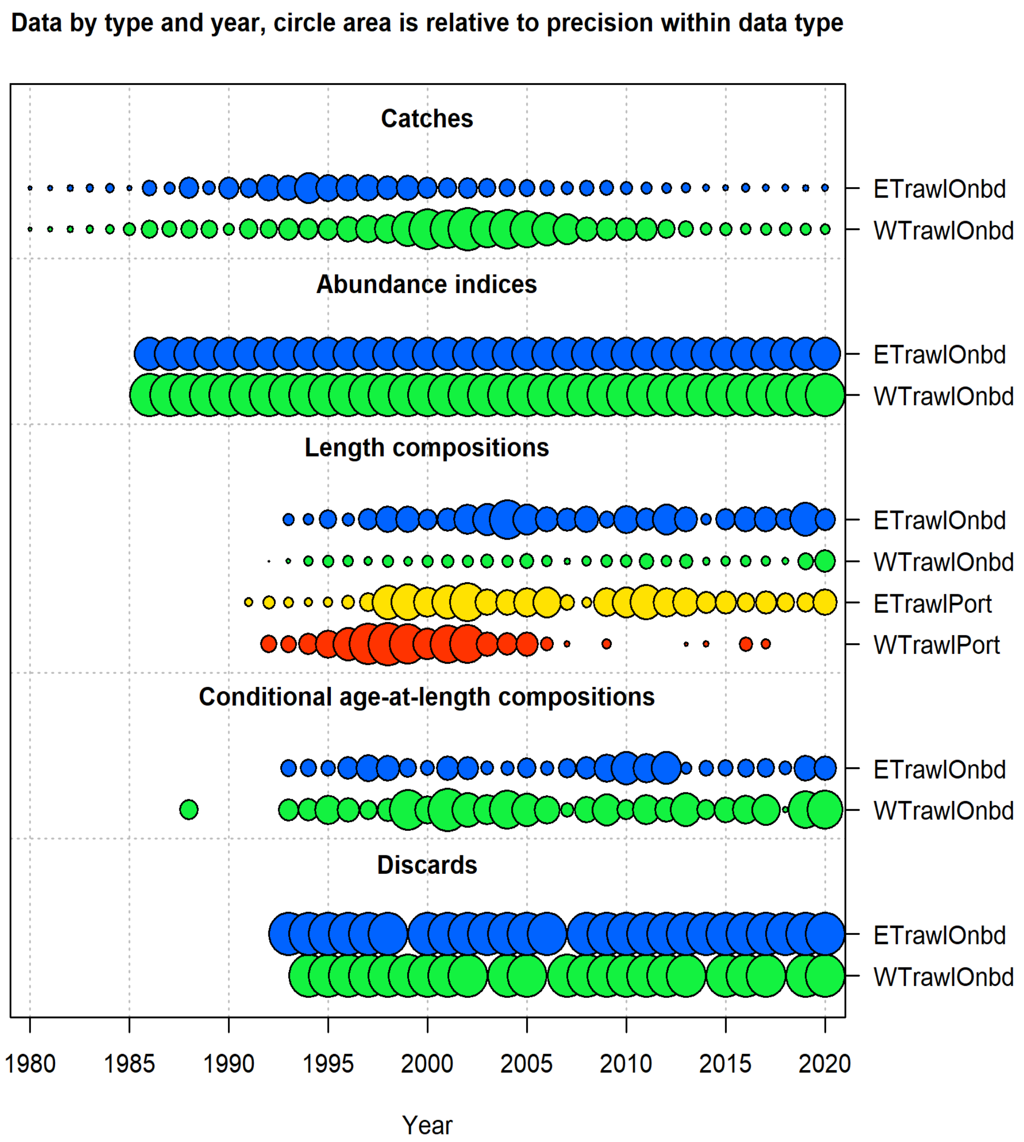

Figure 12.38. Summary of Silver Warehou data sources

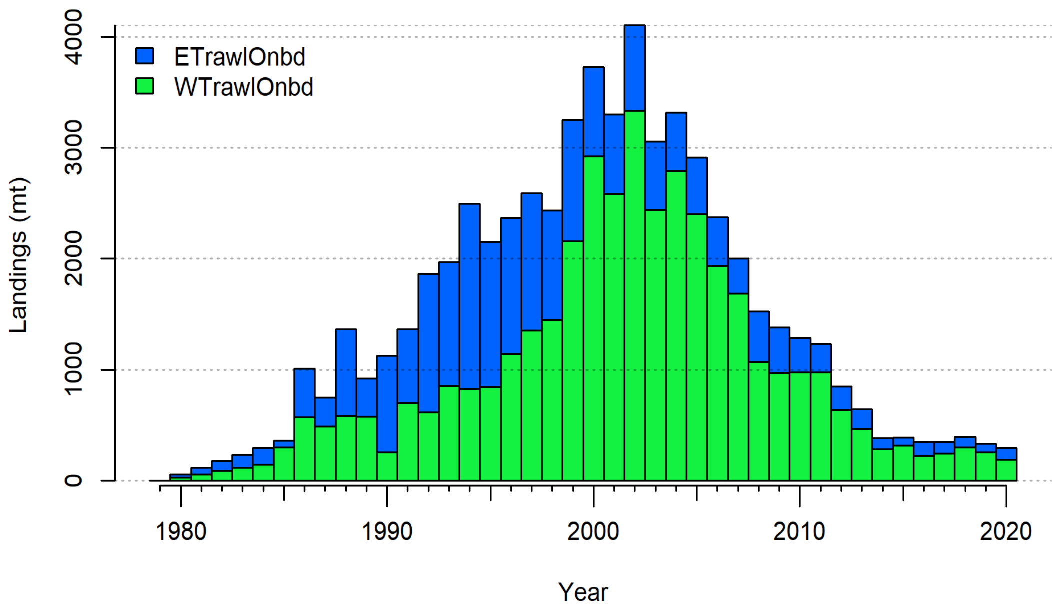

Figure 12.39. Summary of catch by fleet

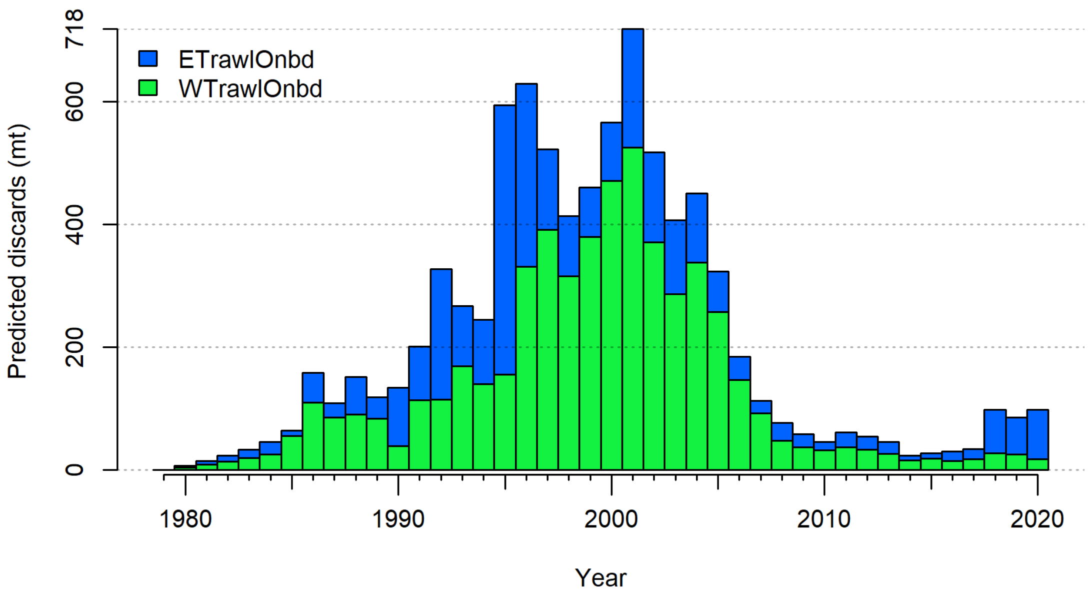

Figure 12.40. Summary of total discards by fleet

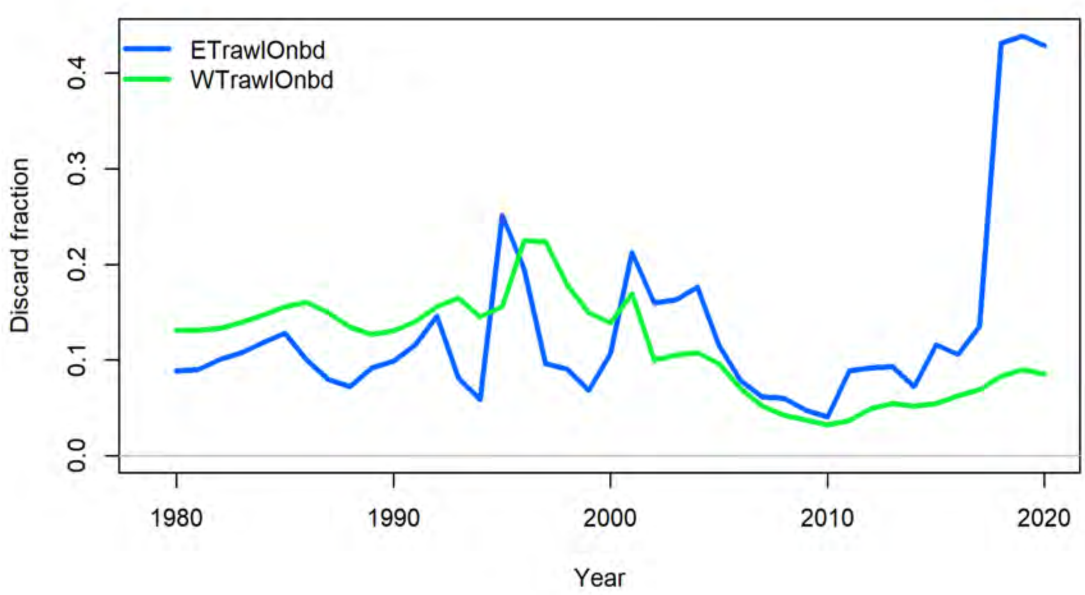

Figure 12.41. Summary of proportional discards by fleet

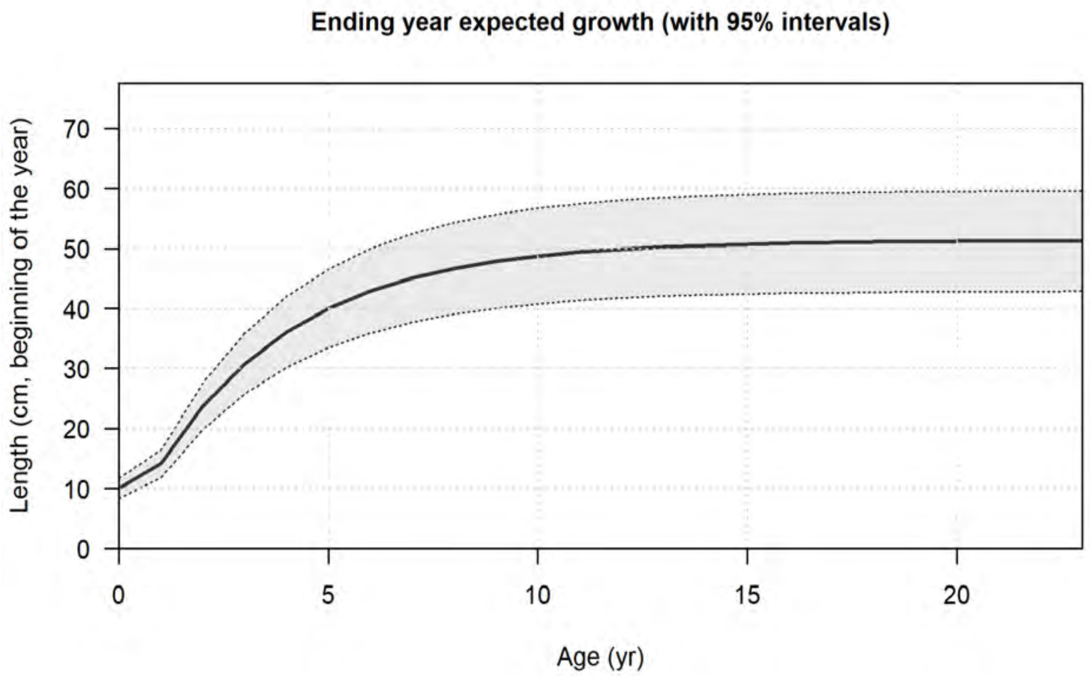

Figure 12.42. Estimated growth curve for base case 3

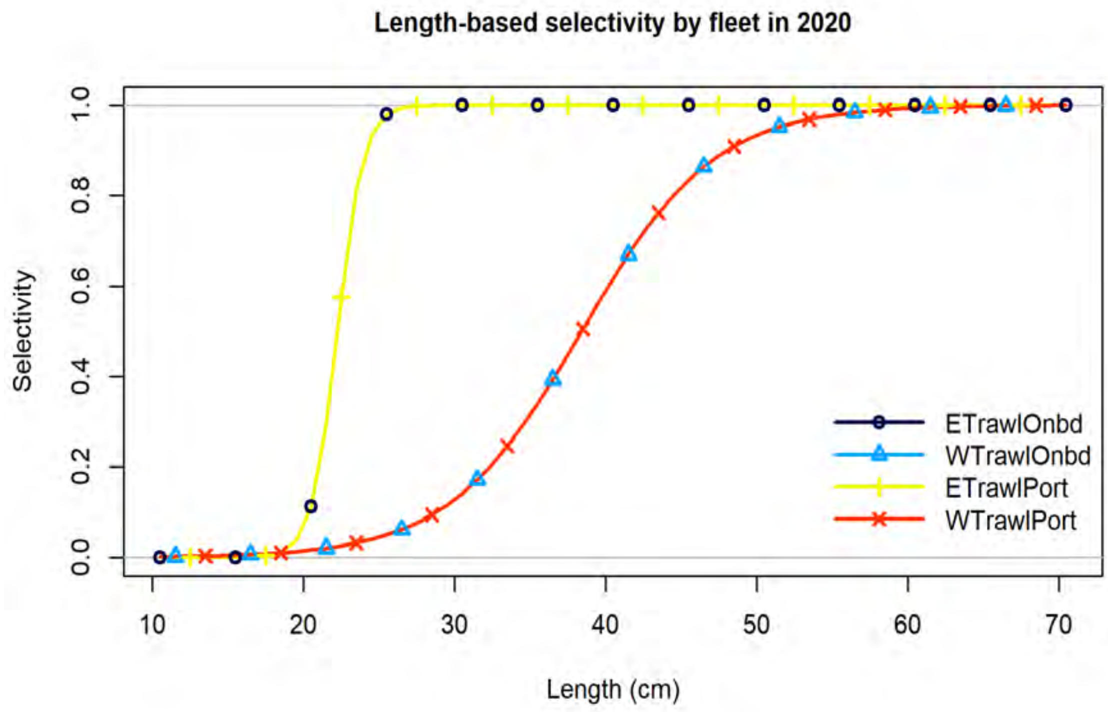

Figure 12.43. Estimated selectivity by fleet for base case 3

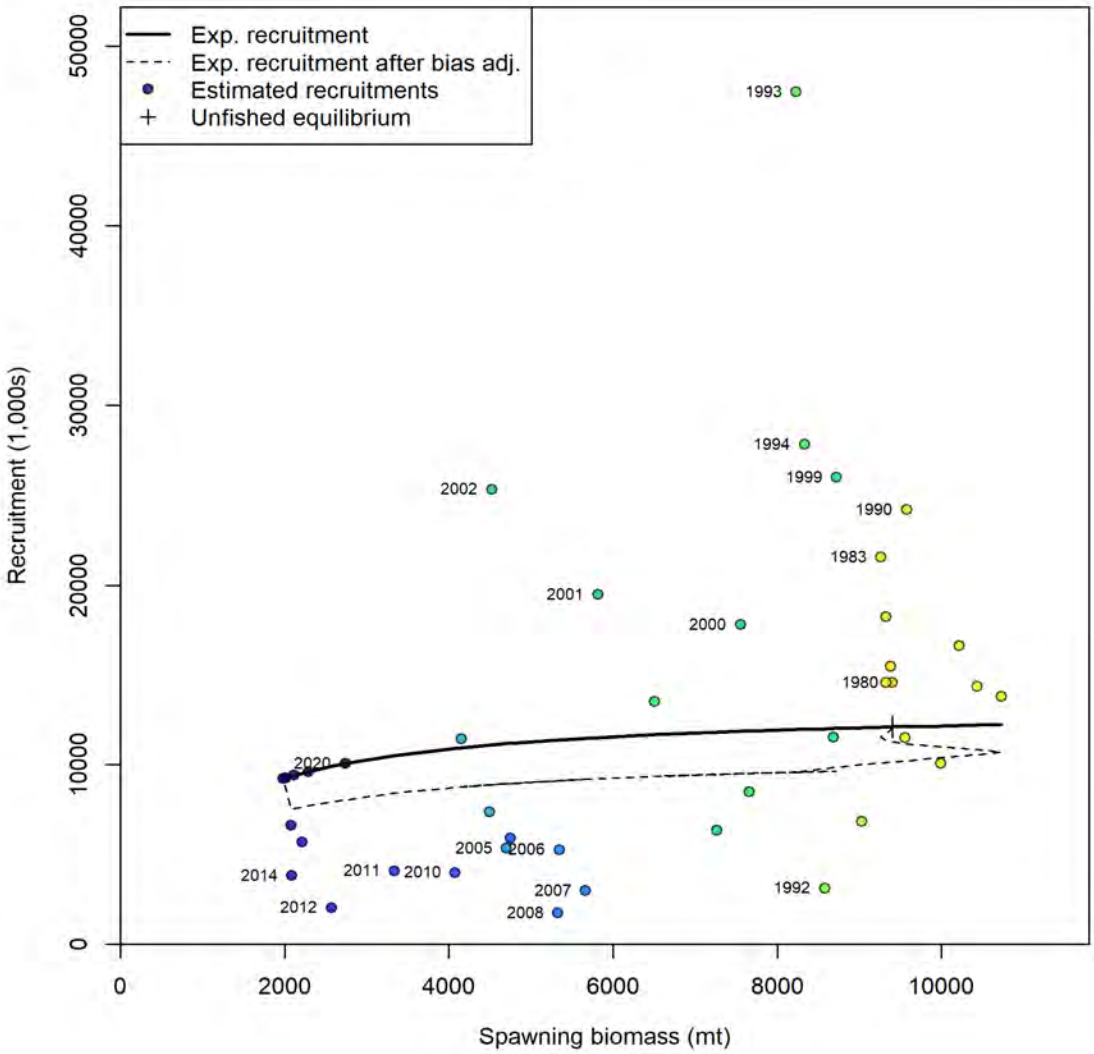

Figure 12.44. Time series showing stock recruitment curve for base case 3

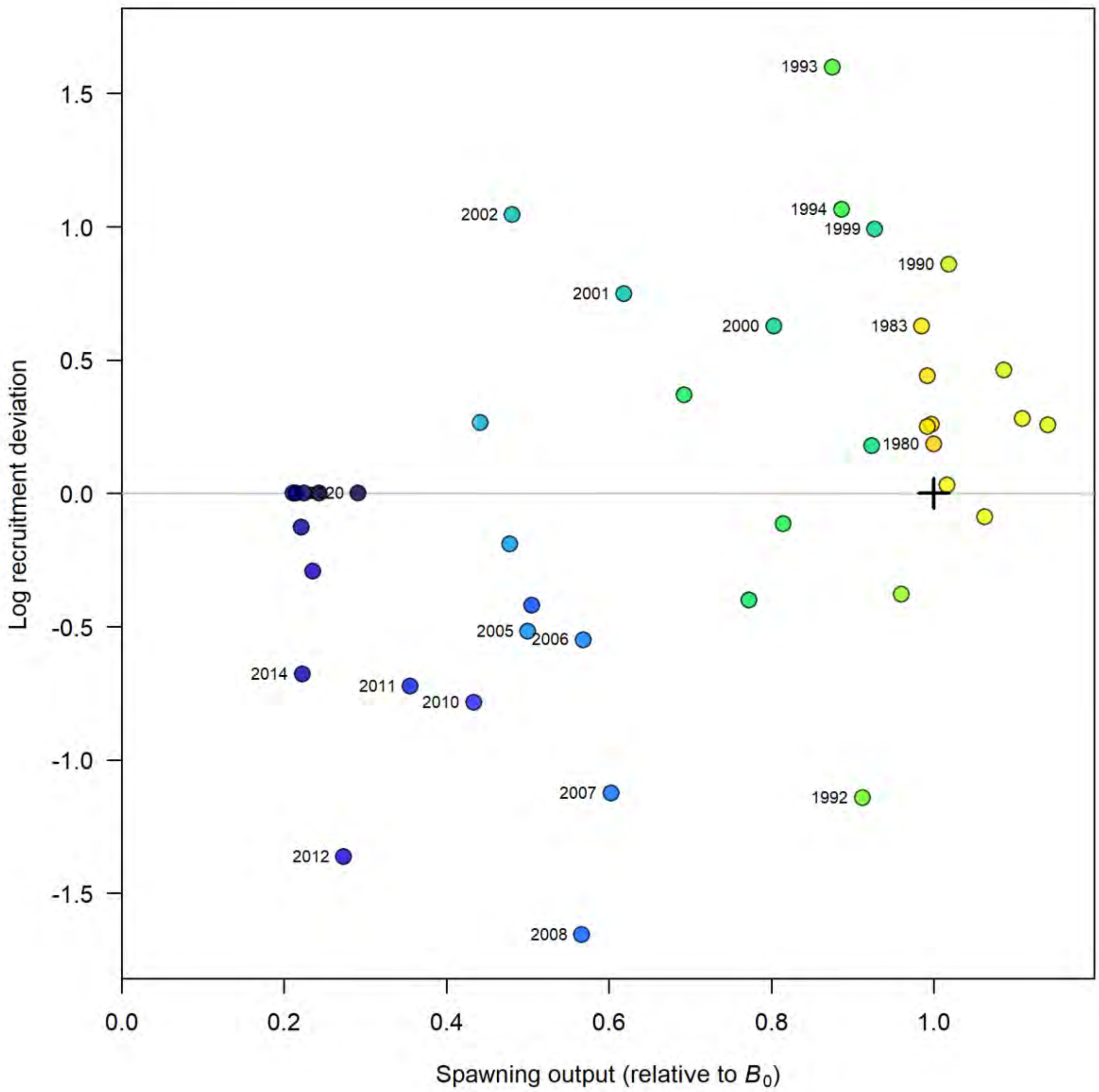

Figure 12.45. Time series showing stock recruitment deviations for base case 3

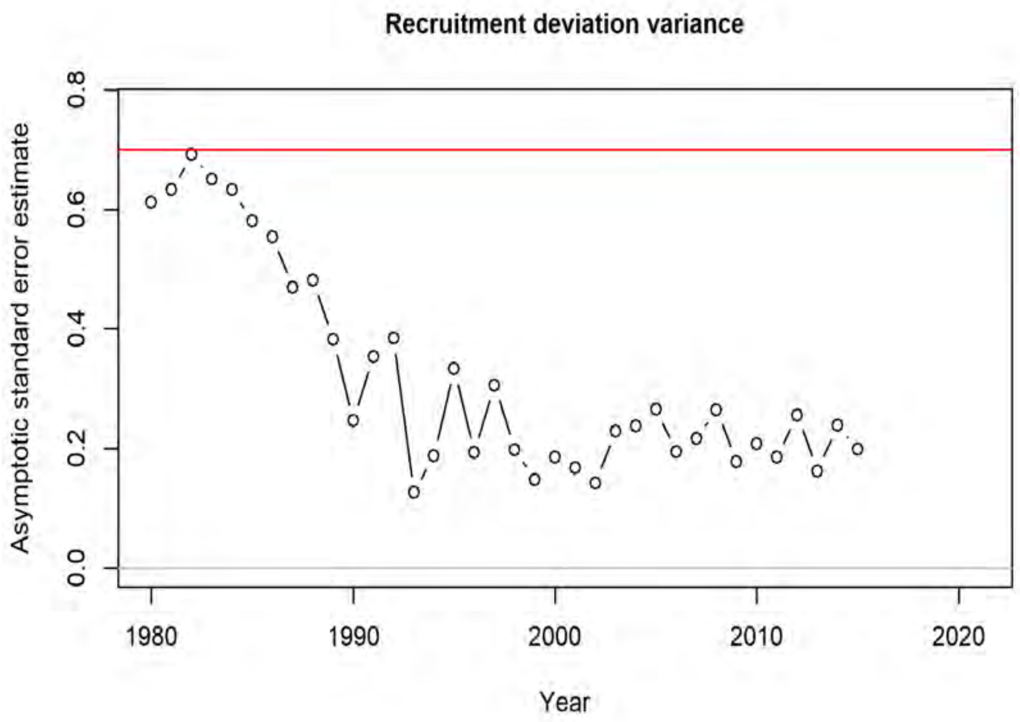

Figure 12.46. Recruitment deviation variance check for base case 3

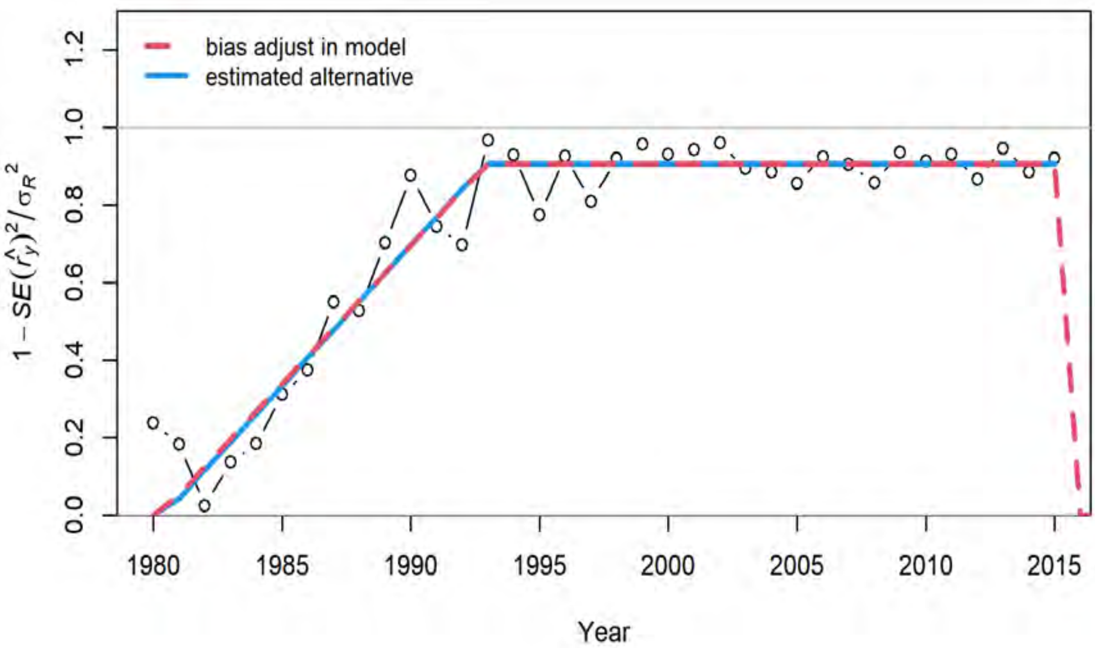

Figure 12.47. Recruitment deviation bias ramp adjustment for base case 3

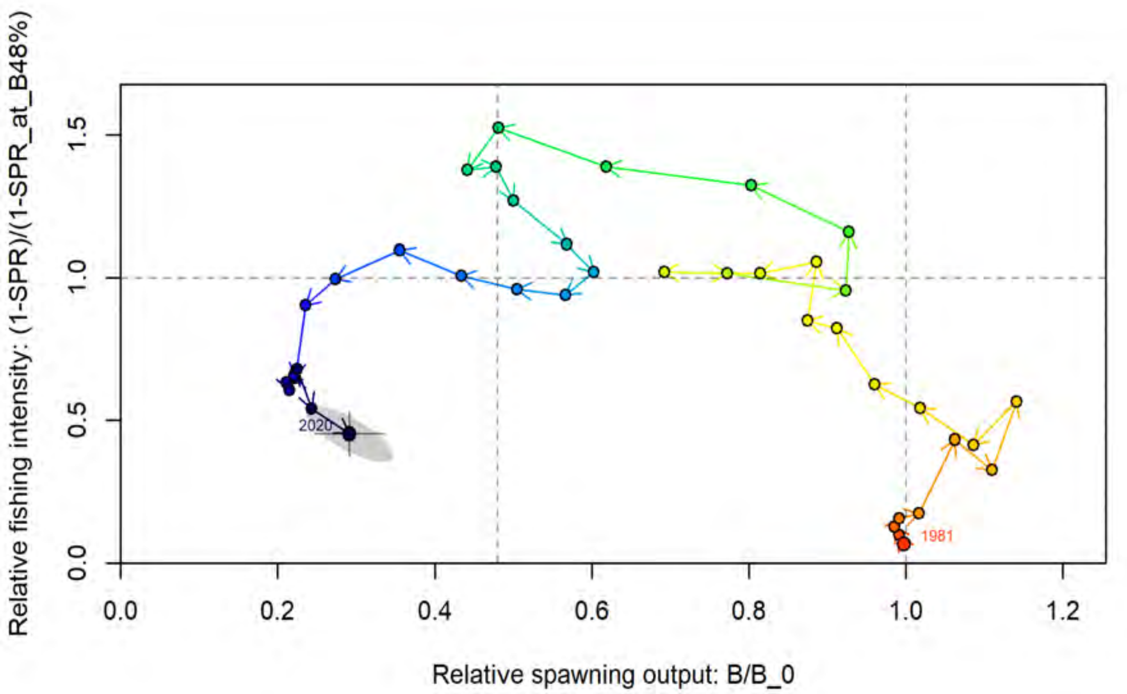

Figure 12.48. Phase plot of biomass vs SPR ratio for base case 3

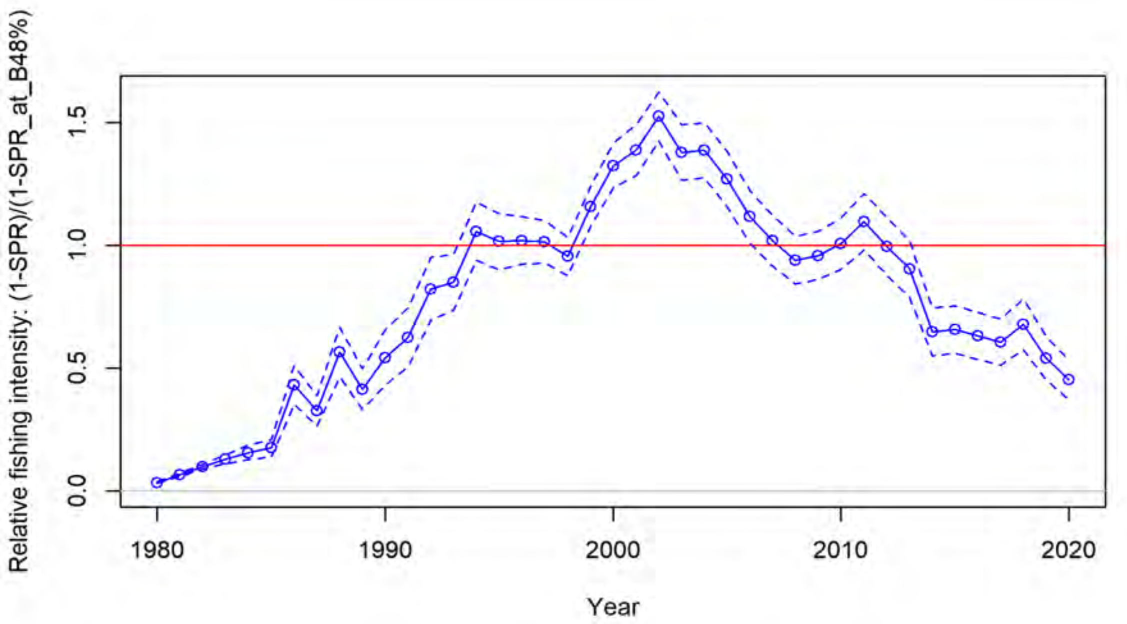

Figure 12.49. SPR ratio through time, the red line represents the target fishing mortality and each point is a year in the model, starting on the left hand side of the figure

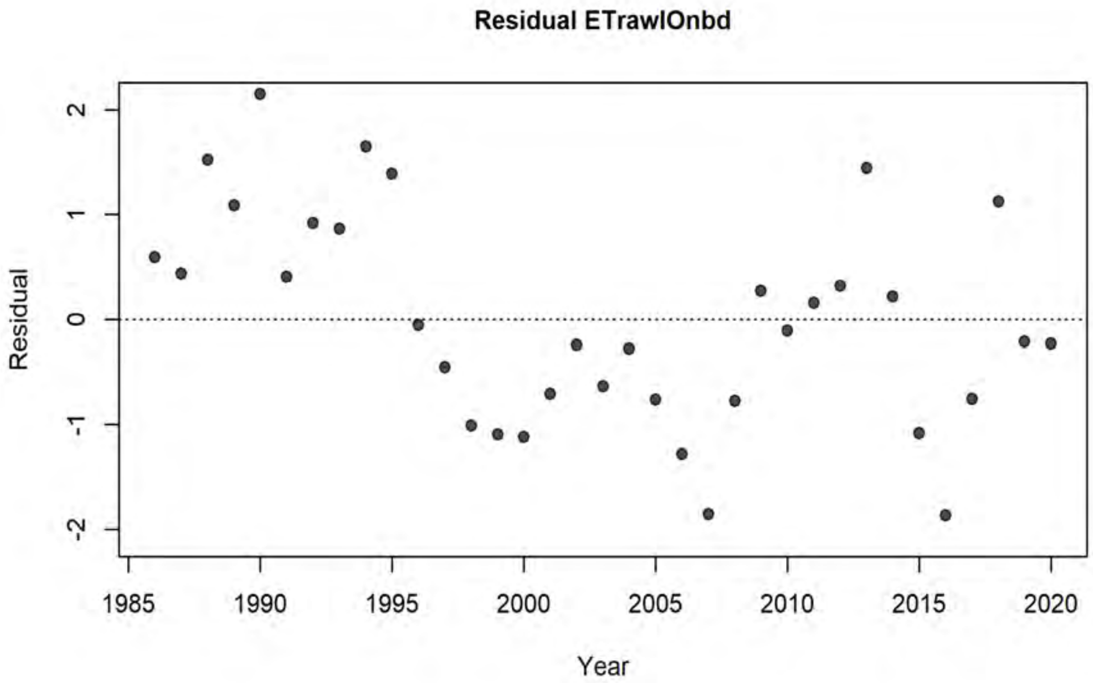

Figure 12.50. Residuals for fits to CPUE for the east trawl fleet for base case 3

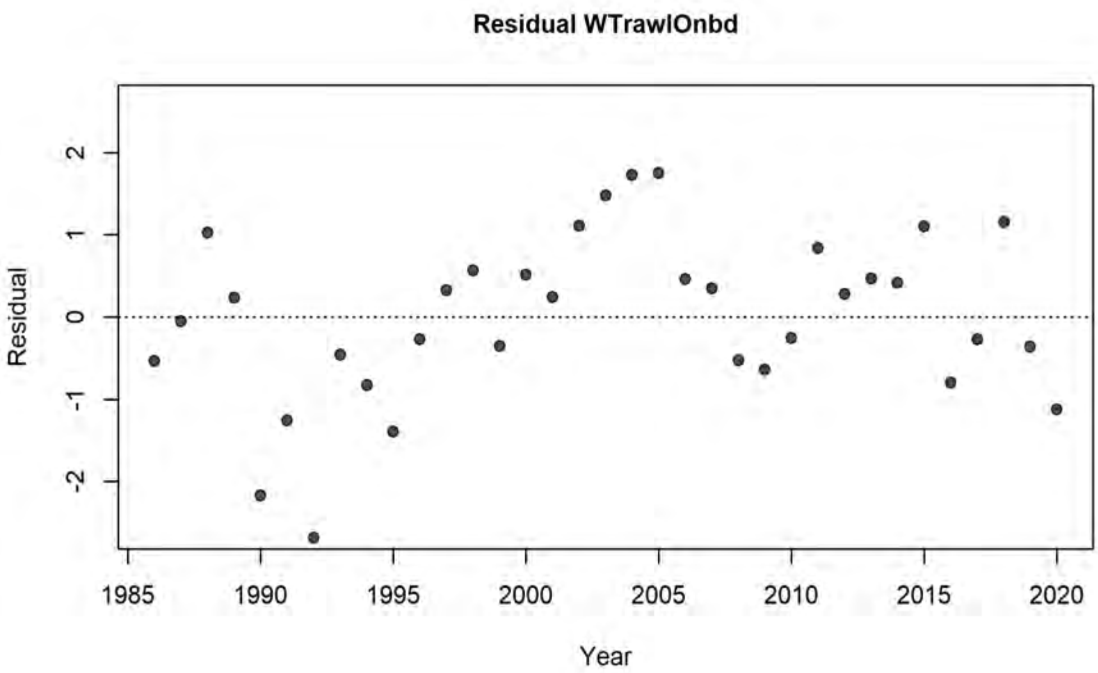

Figure 12.51. Residuals for fits to CPUE for the west trawl fleet for base case 3

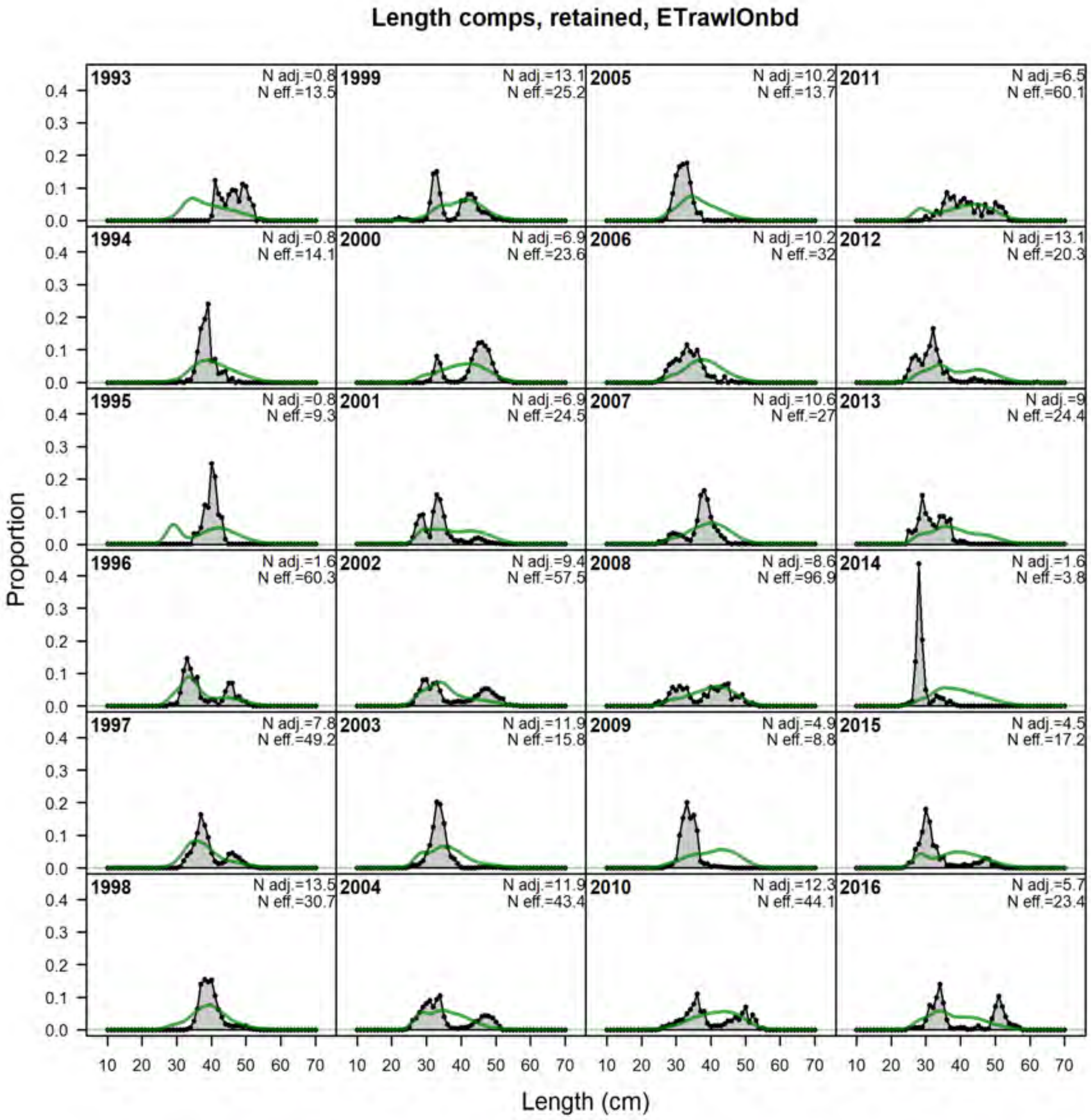

Figure 12.52. Fits to onboard retained length compositions for the east trawl fleet for base case 3

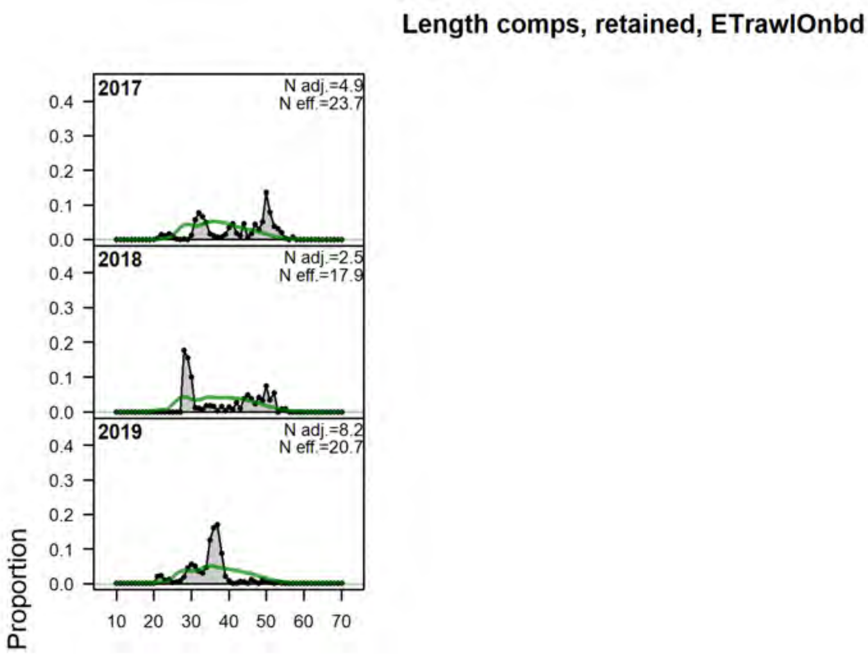

Figure 12.53. Fits to onboard retained length compositions for the east trawl fleet for base case 3

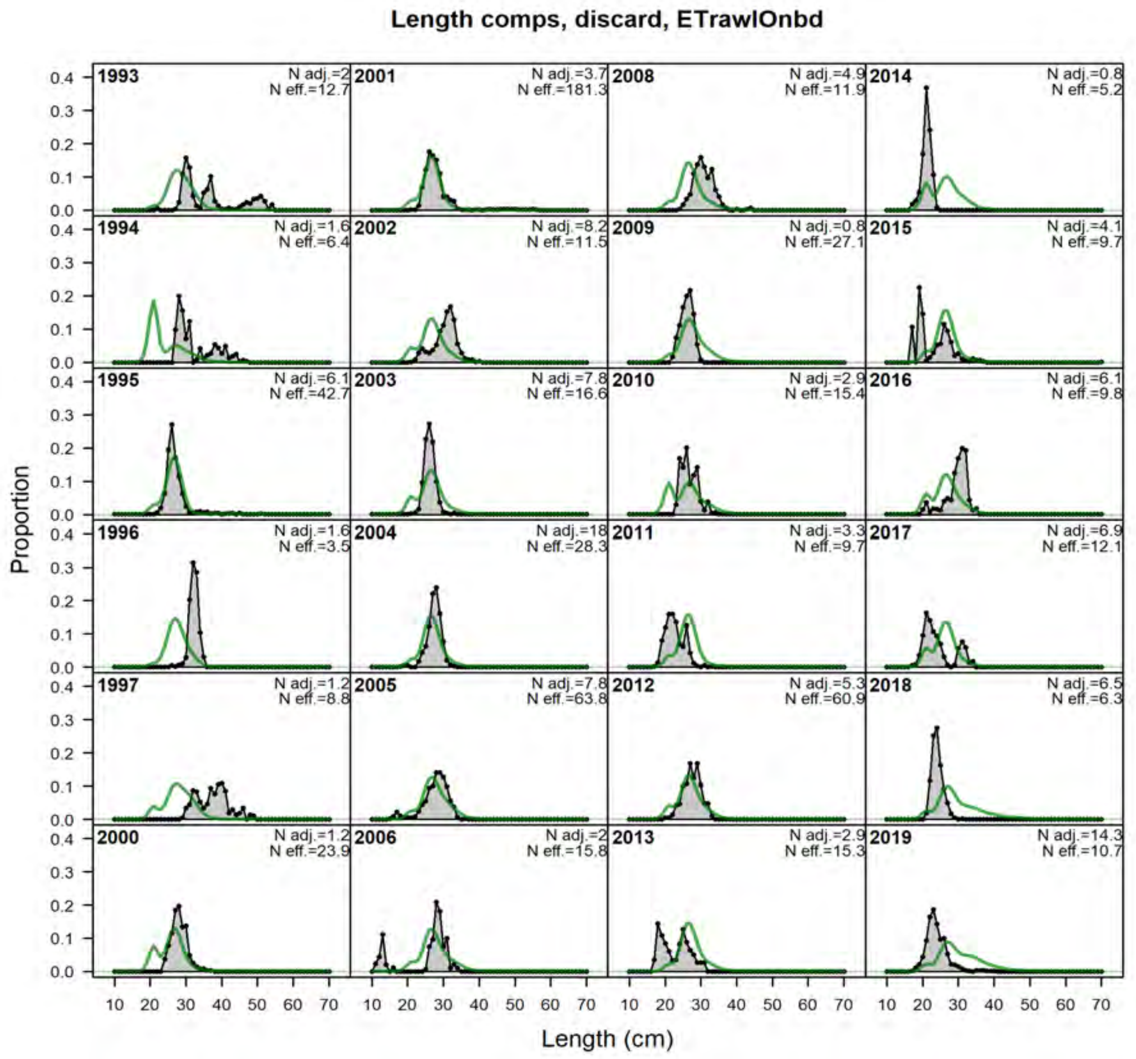

Figure 12.54. Fits to onboard discarded length compositions for the east trawl fleet for base case 3

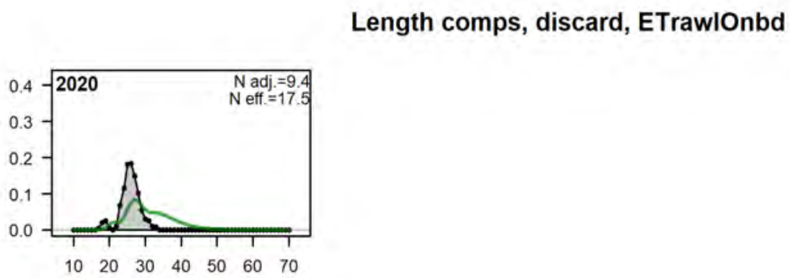

Figure 12.55. Fits to onboard discarded length compositions for the east trawl fleet for base case 3 continued

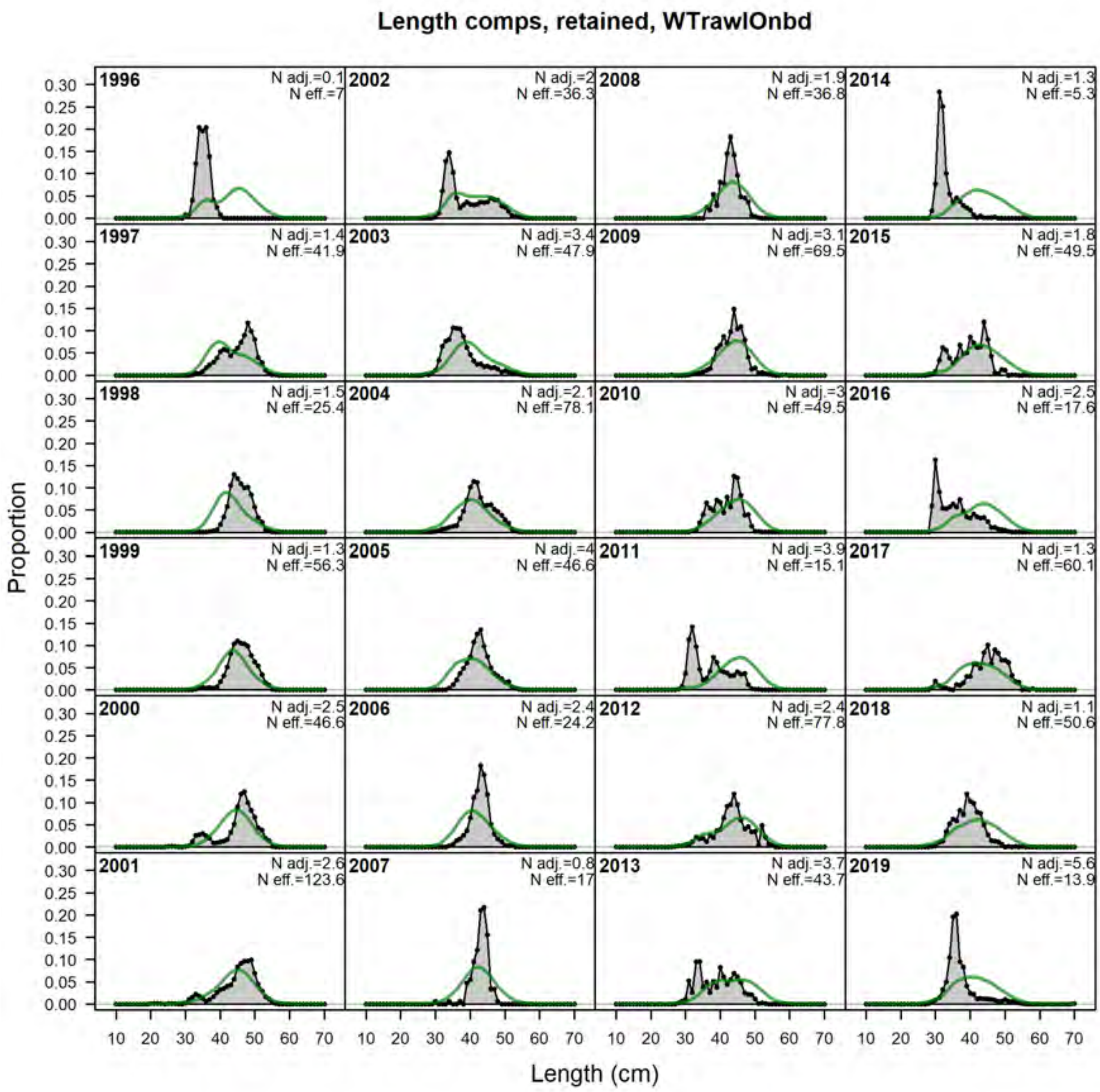

Figure 12.56. Fits to onboard retained length compositions for the west trawl fleet for base case 3

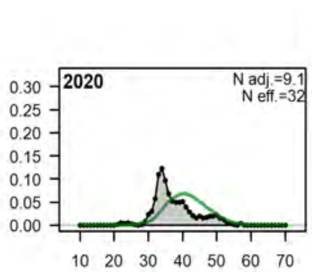

Figure 12.57. Fits to onboard retained length compositions for the west trawl fleet for base case 3 continued

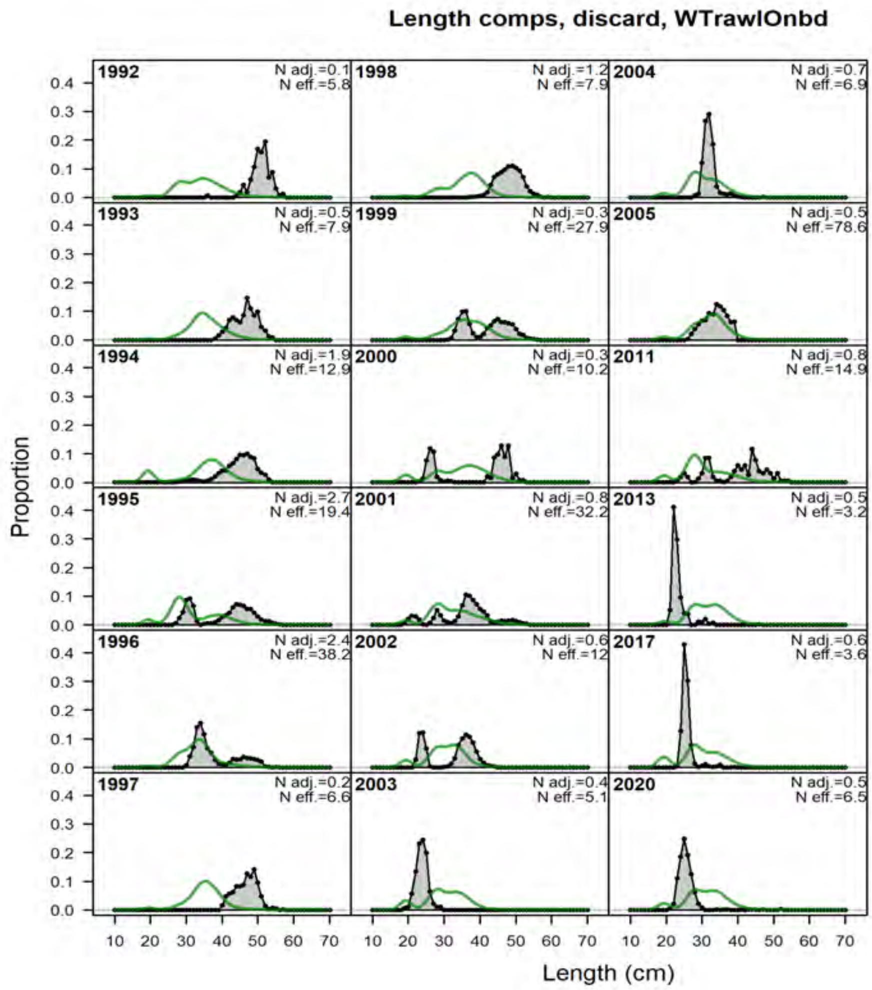

Figure 12.58. Fits to onboard discarded length compositions for the west trawl fleet for base case 3

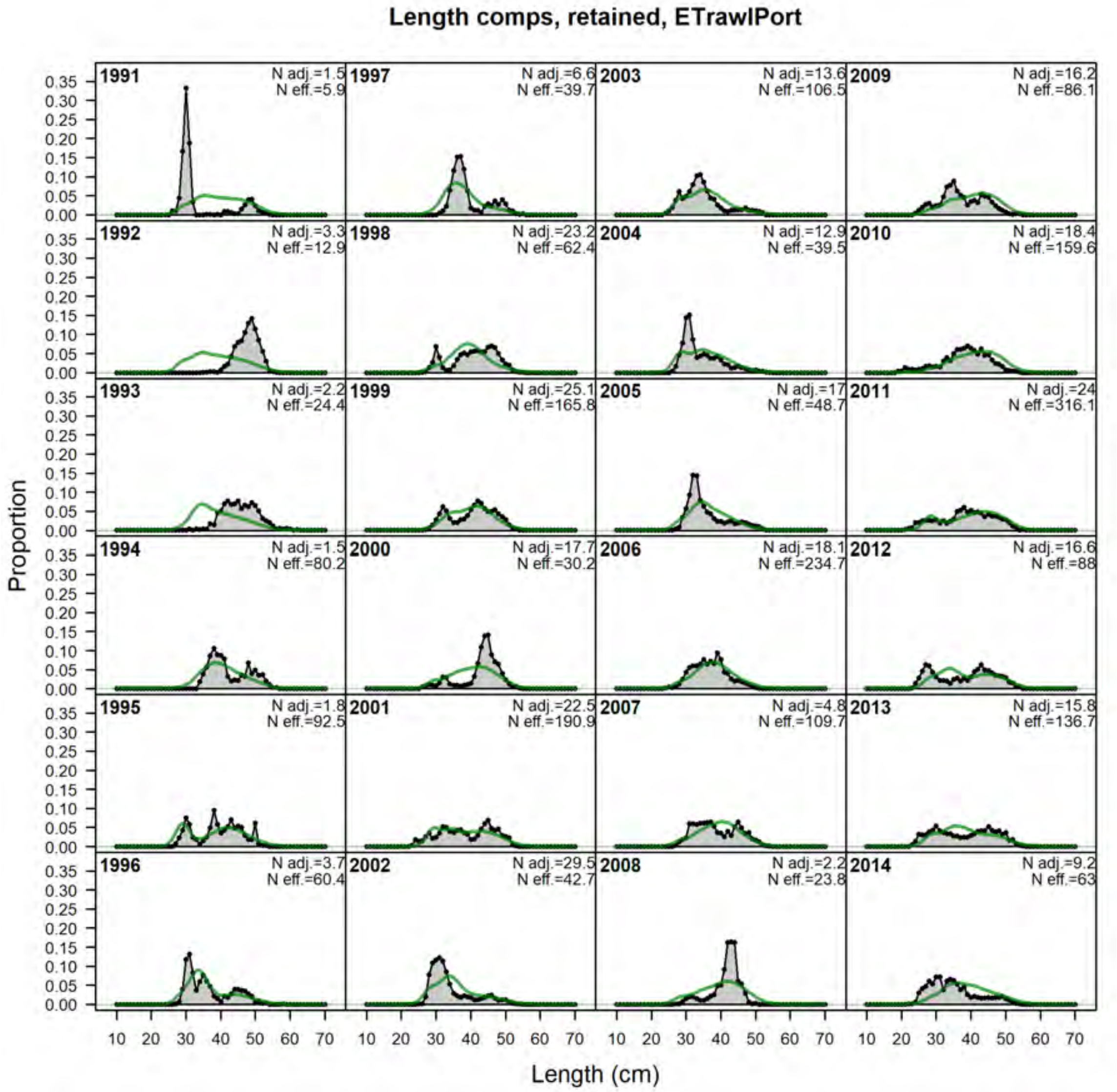

Figure 12.59. Fits to port length compositions for the east trawl fleet for base case 3

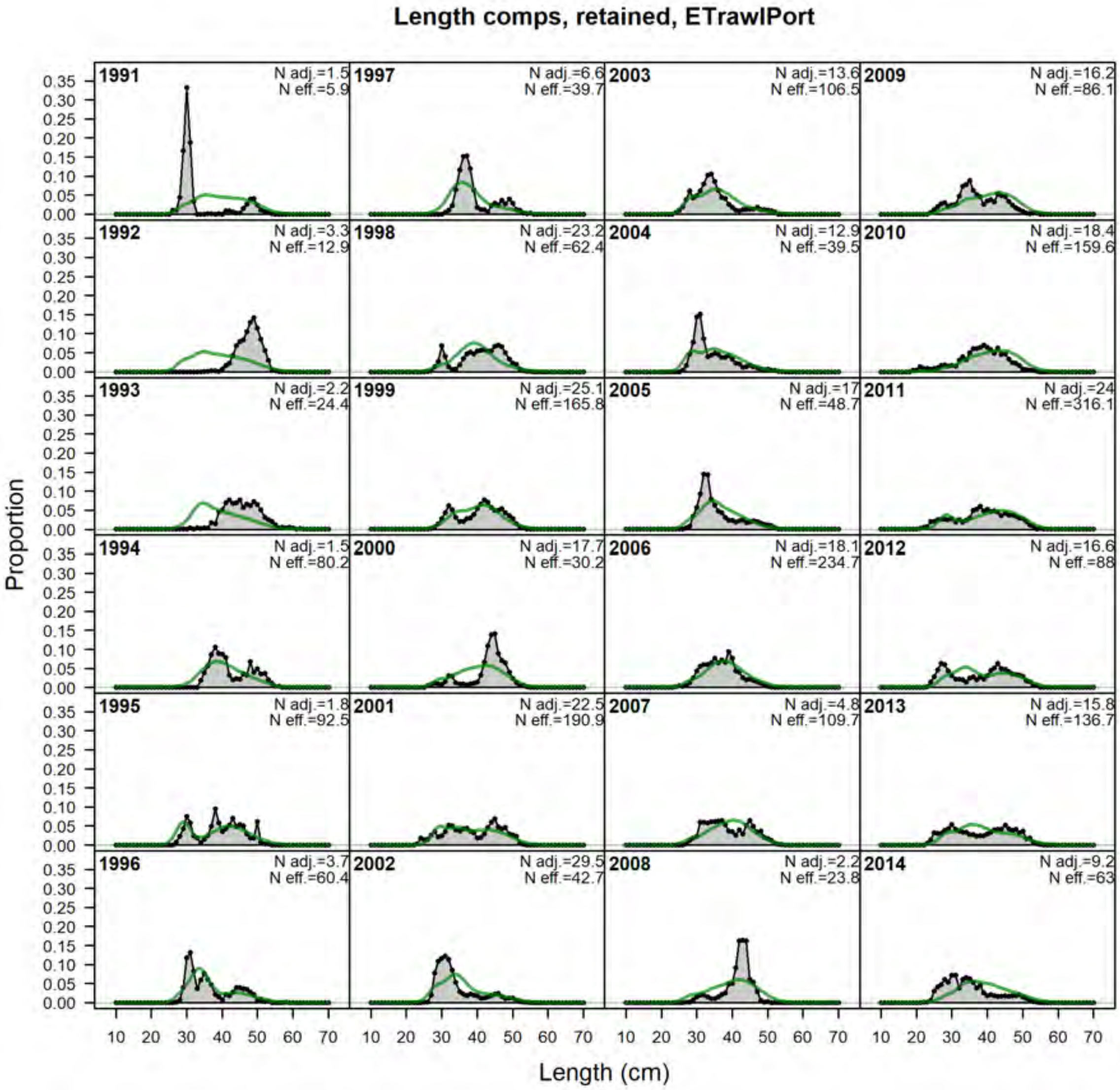

Figure 12.60. Fits to port length compositions for the east trawl fleet for base case 3 continued

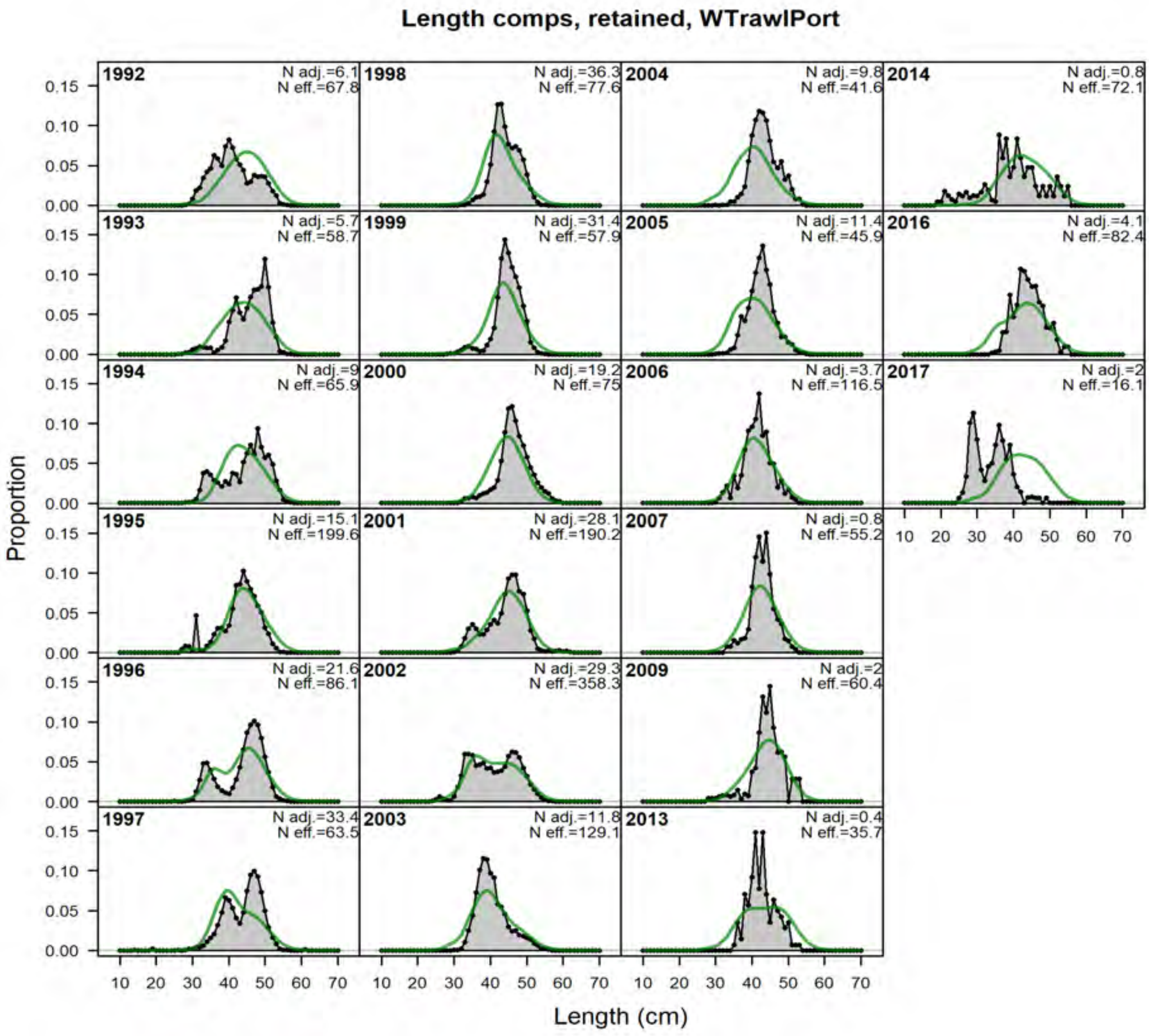

Figure 12.61. Fits to port length compositions for the west trawl fleet for base case 3

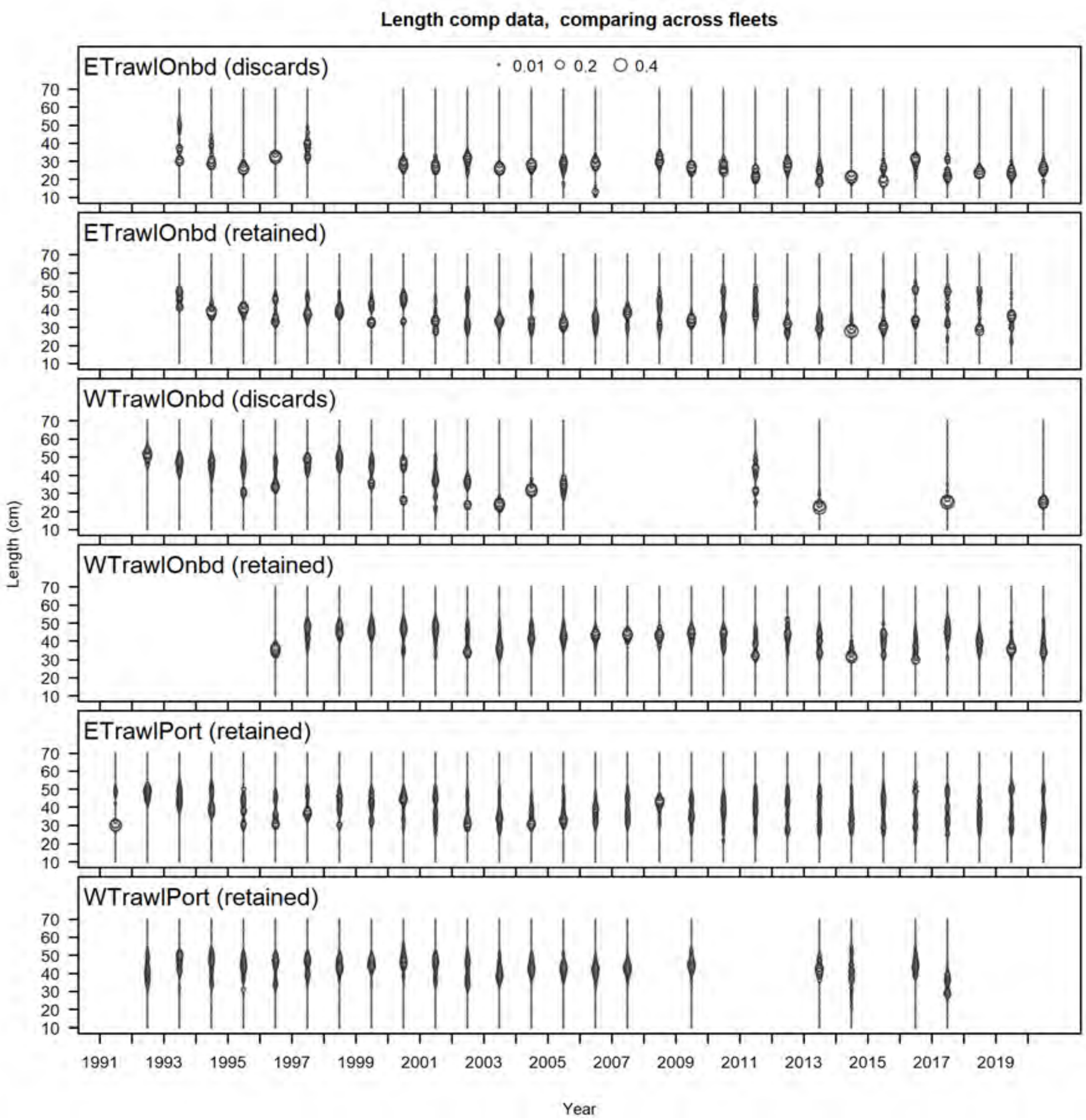

Figure 12.62. Residuals from the annual length compositions for both the east the west trawl fleets for base case 3

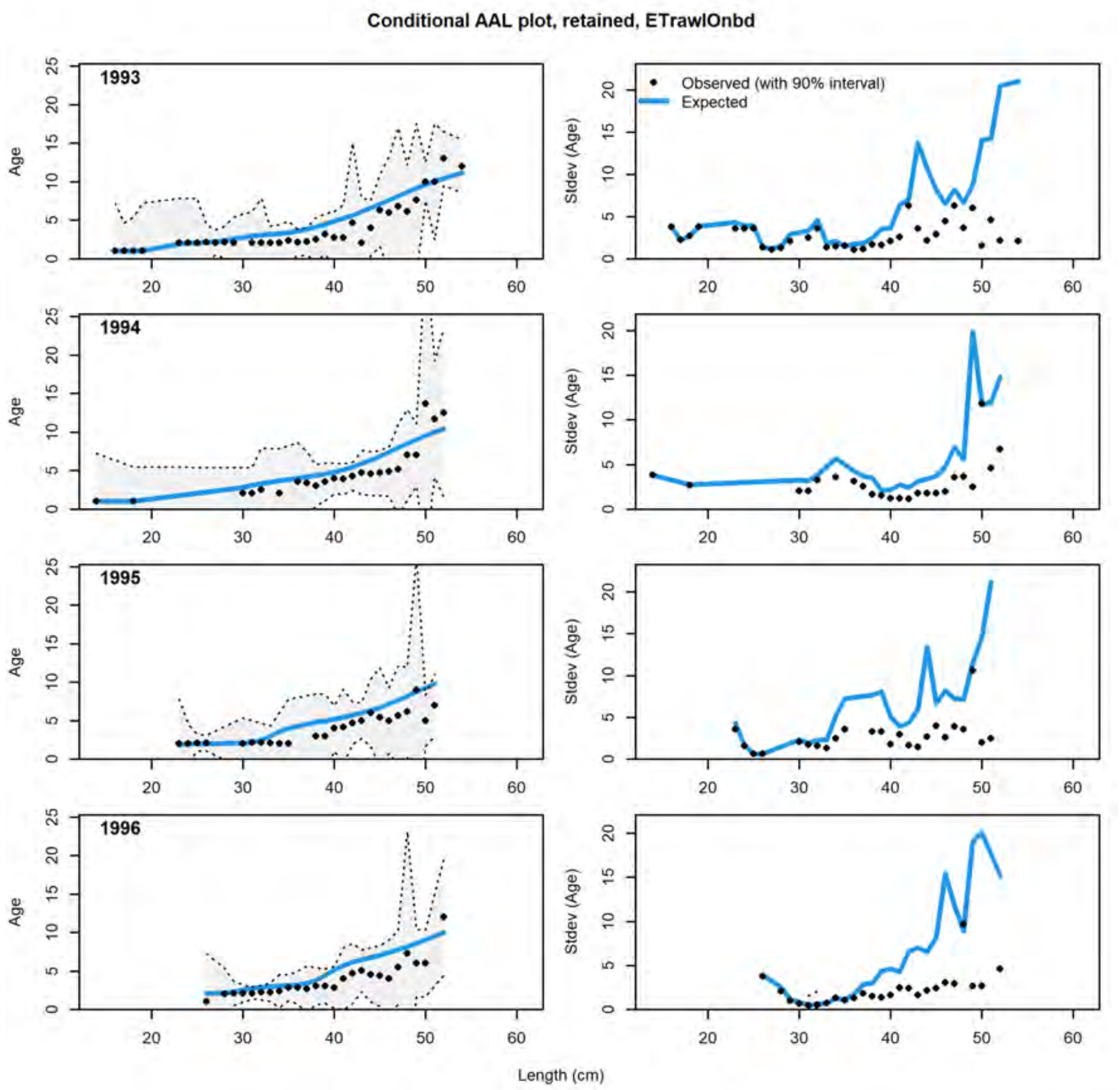

Figure 12.63. Fits to conditional age at length data for the east trawl fleet for base case 3

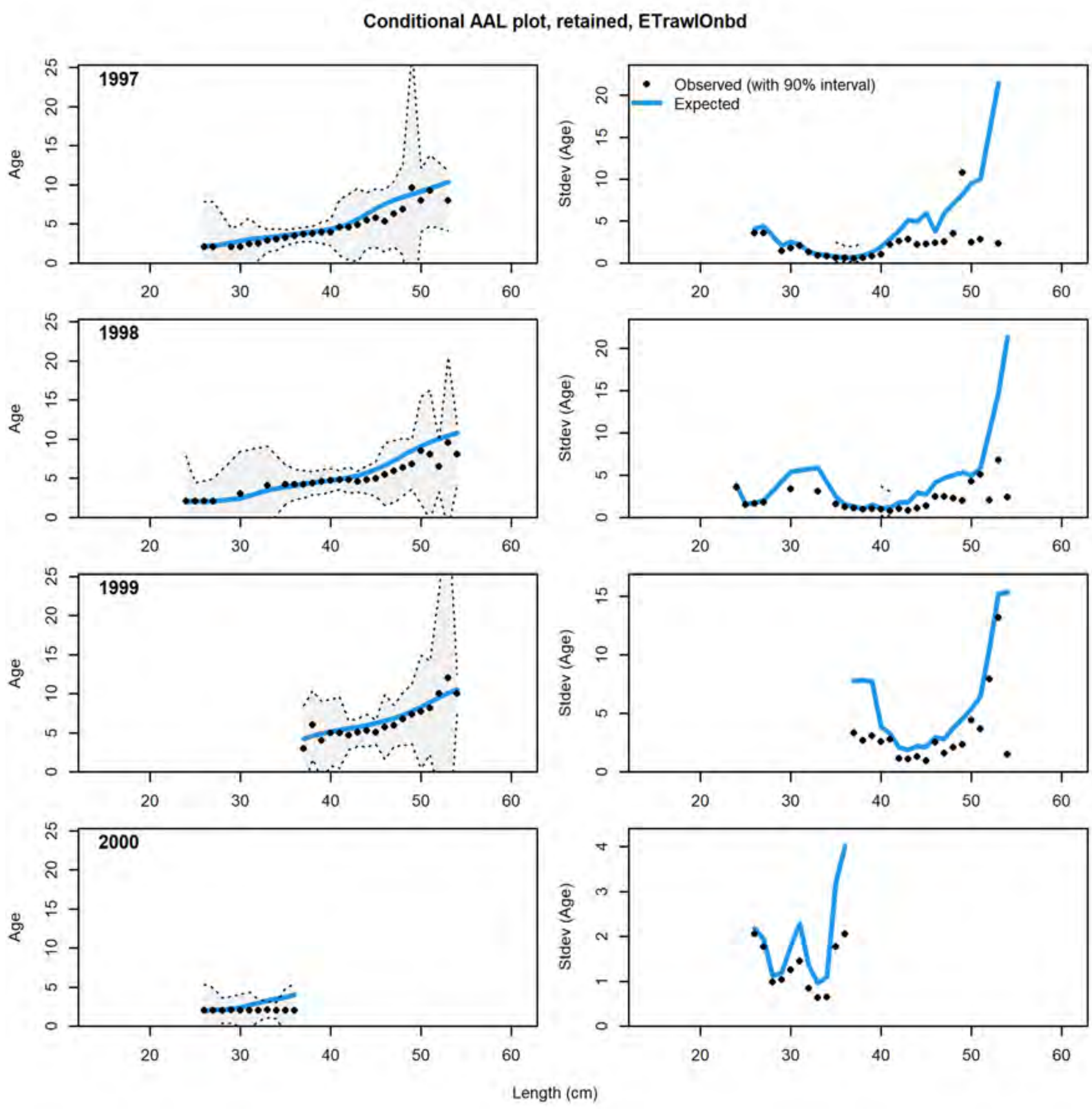

Figure 12.64. Fits to conditional age at length data for the east trawl fleet for base case 3

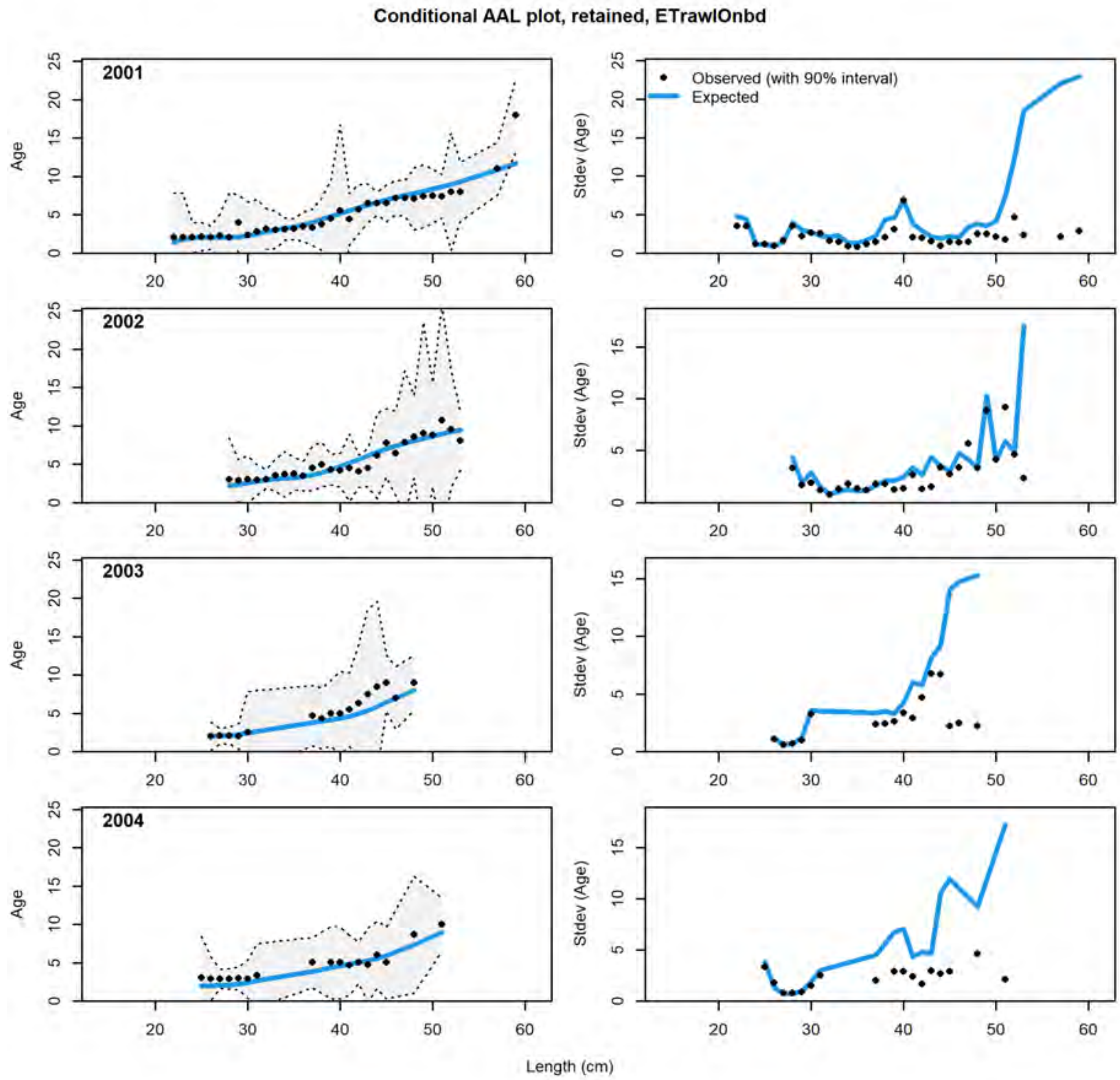

Figure 12.65. Fits to conditional age at length data for the east trawl fleet for base case 3

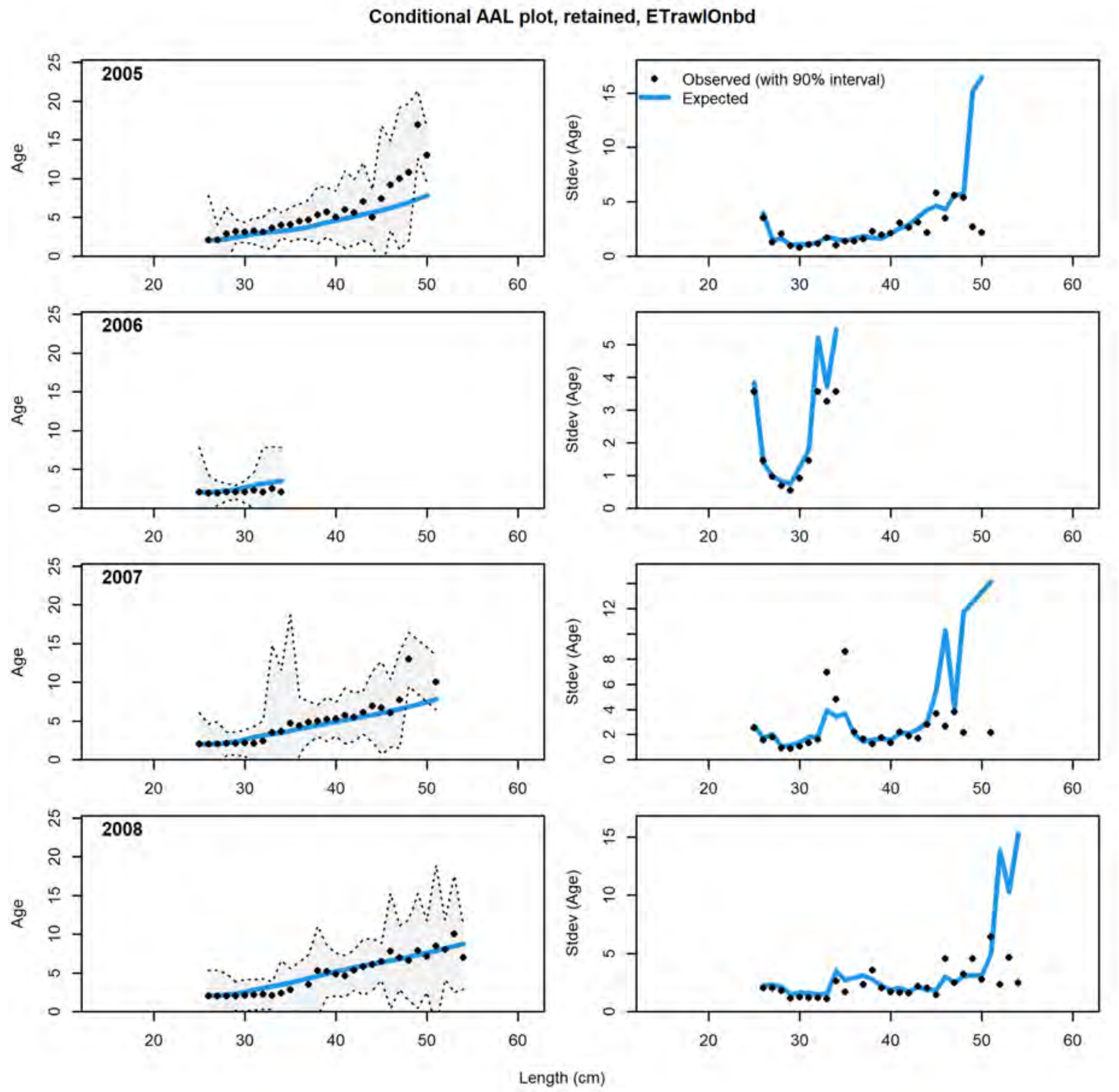

Figure 12.66. Fits to conditional age at length data for the east trawl fleet for base case 3

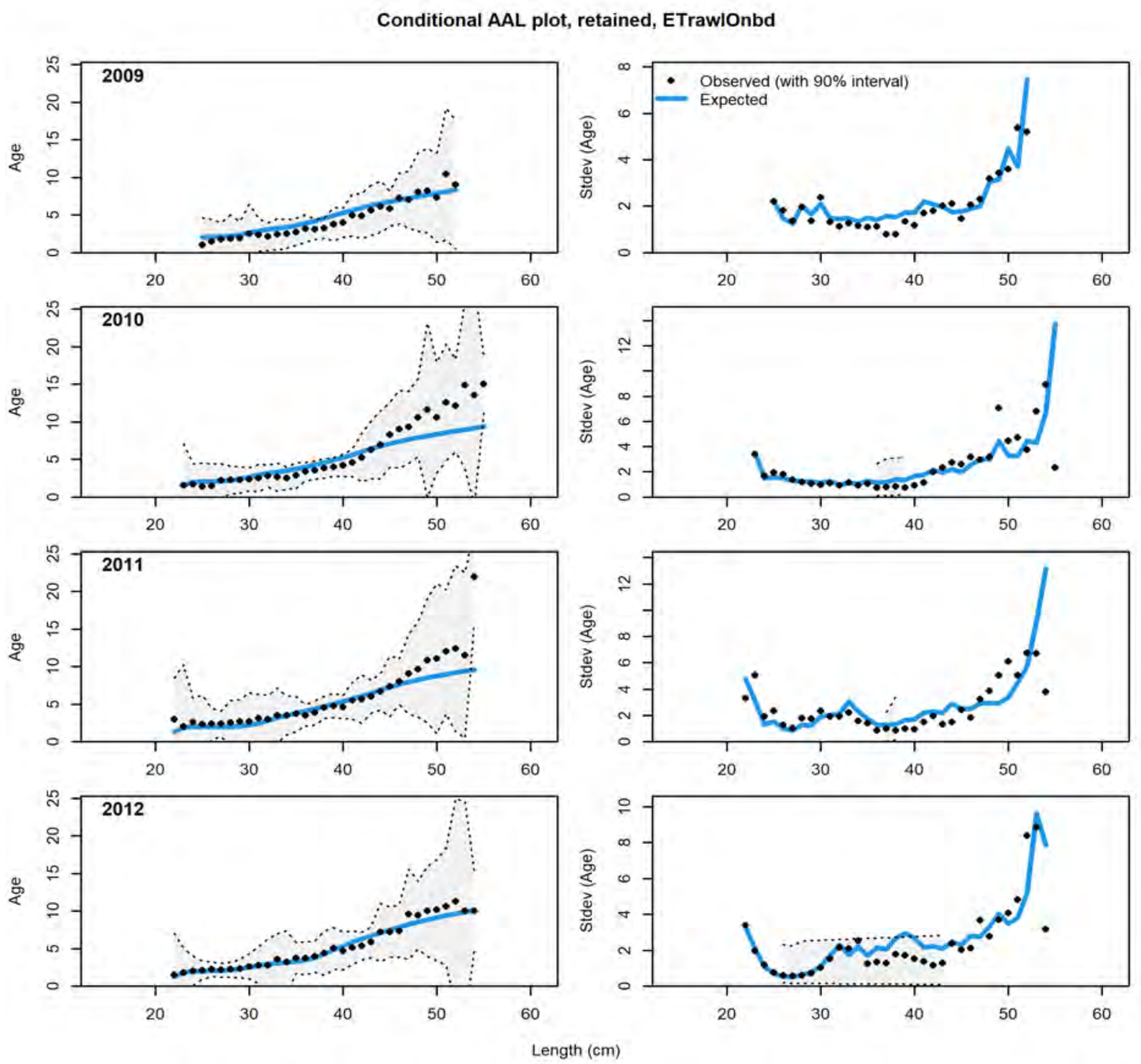

Figure 12.67. Fits to conditional age at length data for the east trawl fleet for base case 3

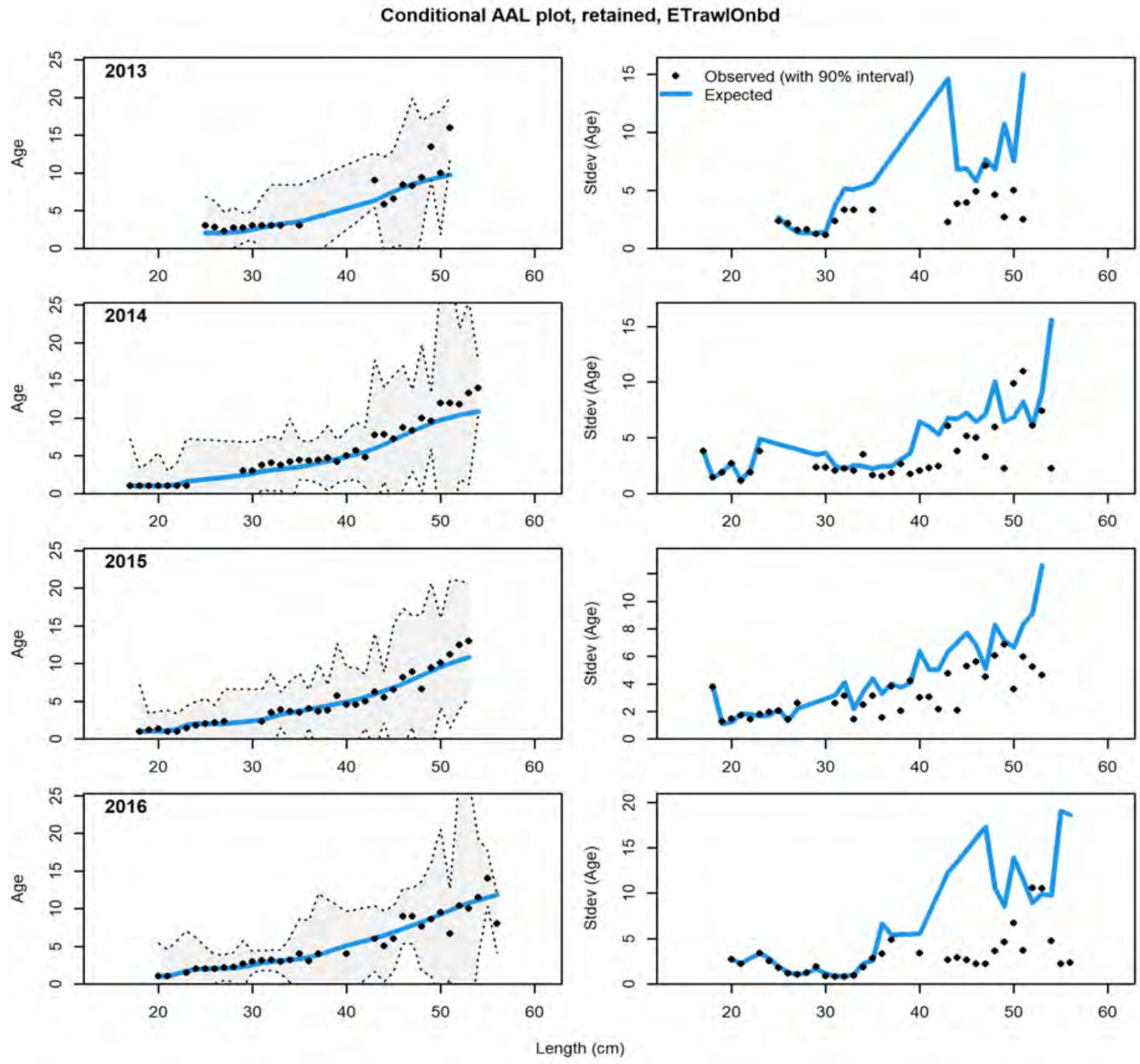

Figure 12.68. Fits to conditional age at length data for the east trawl fleet for base case 3

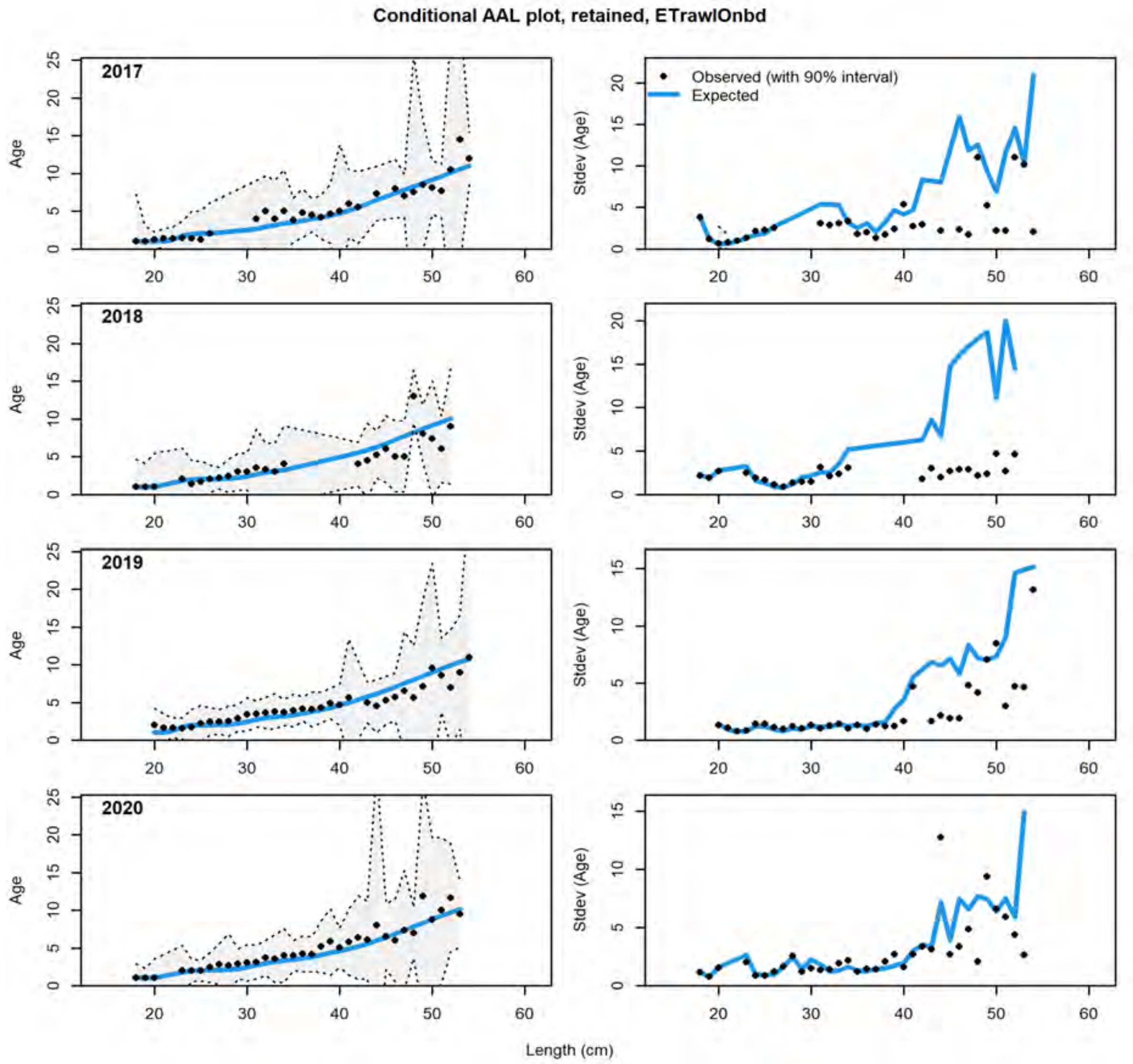

Figure 12.69. Fits to conditional age at length data for the east trawl fleet for base case 3

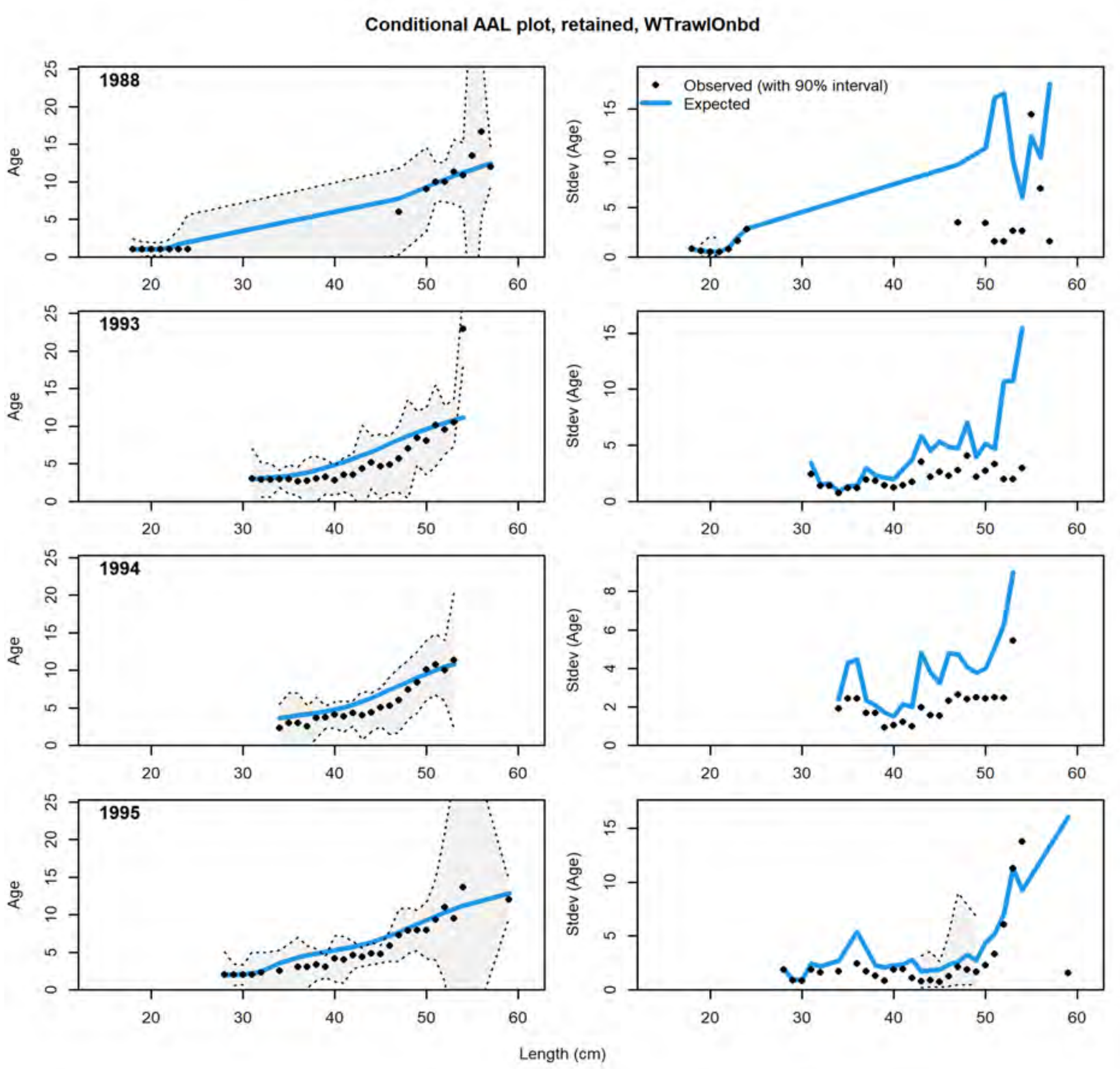

Figure 12.70. Fits to conditional age at length data for the west trawl fleet for base case 3

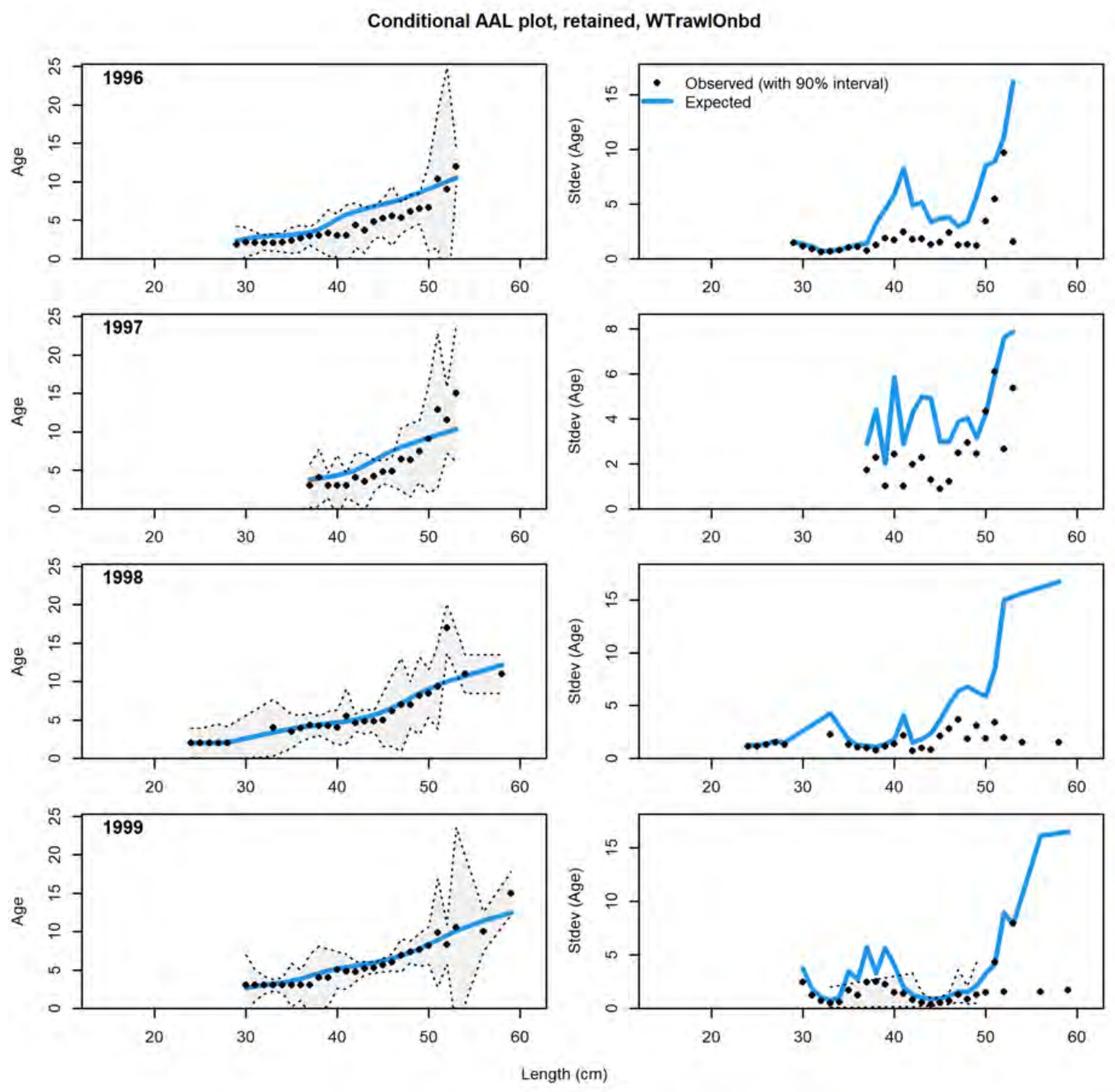

Figure 12.71. Fits to conditional age at length data for the west trawl fleet for base case 3

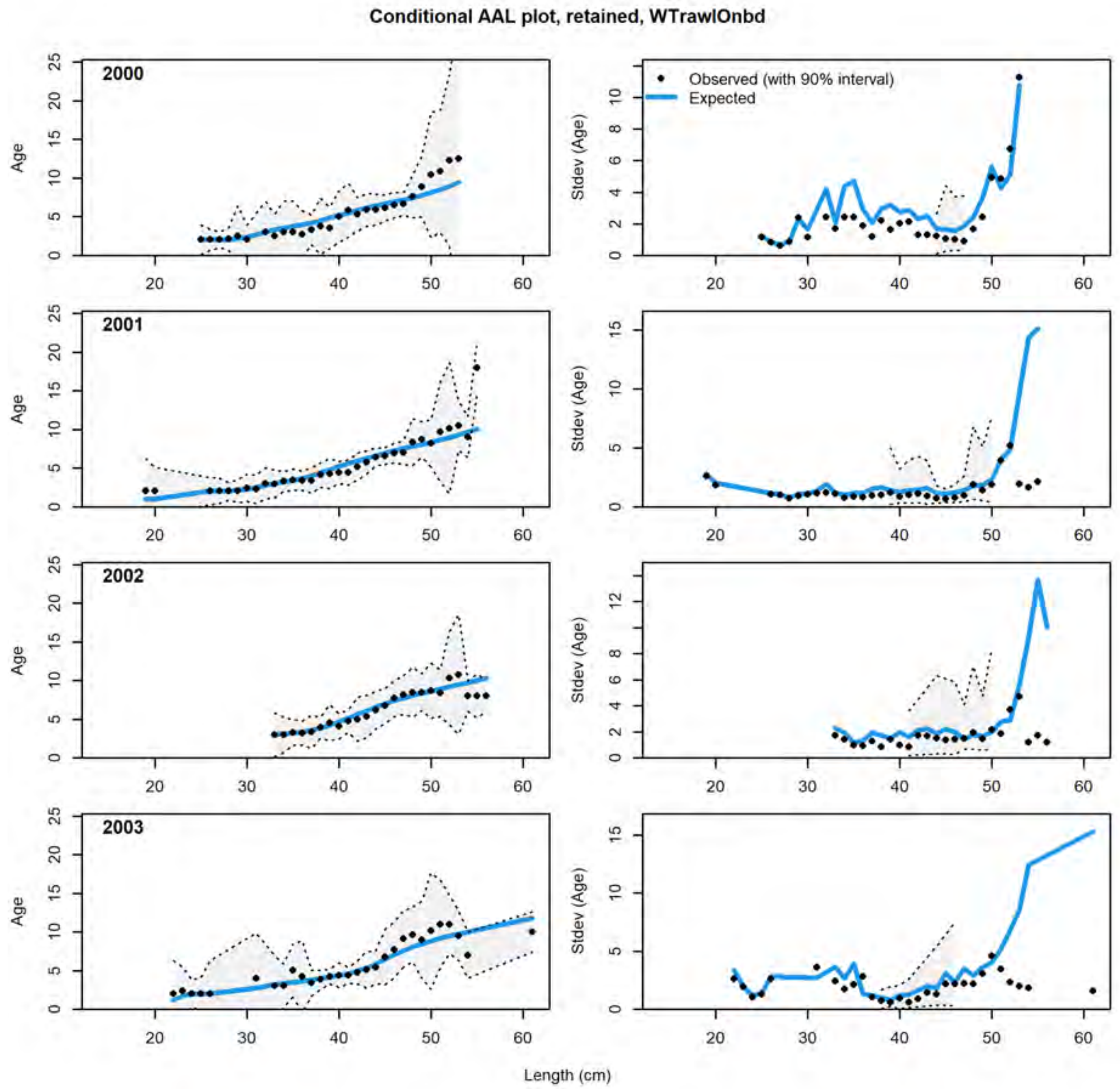

Figure 12.72. Fits to conditional age at length data for the west trawl fleet for base case 3

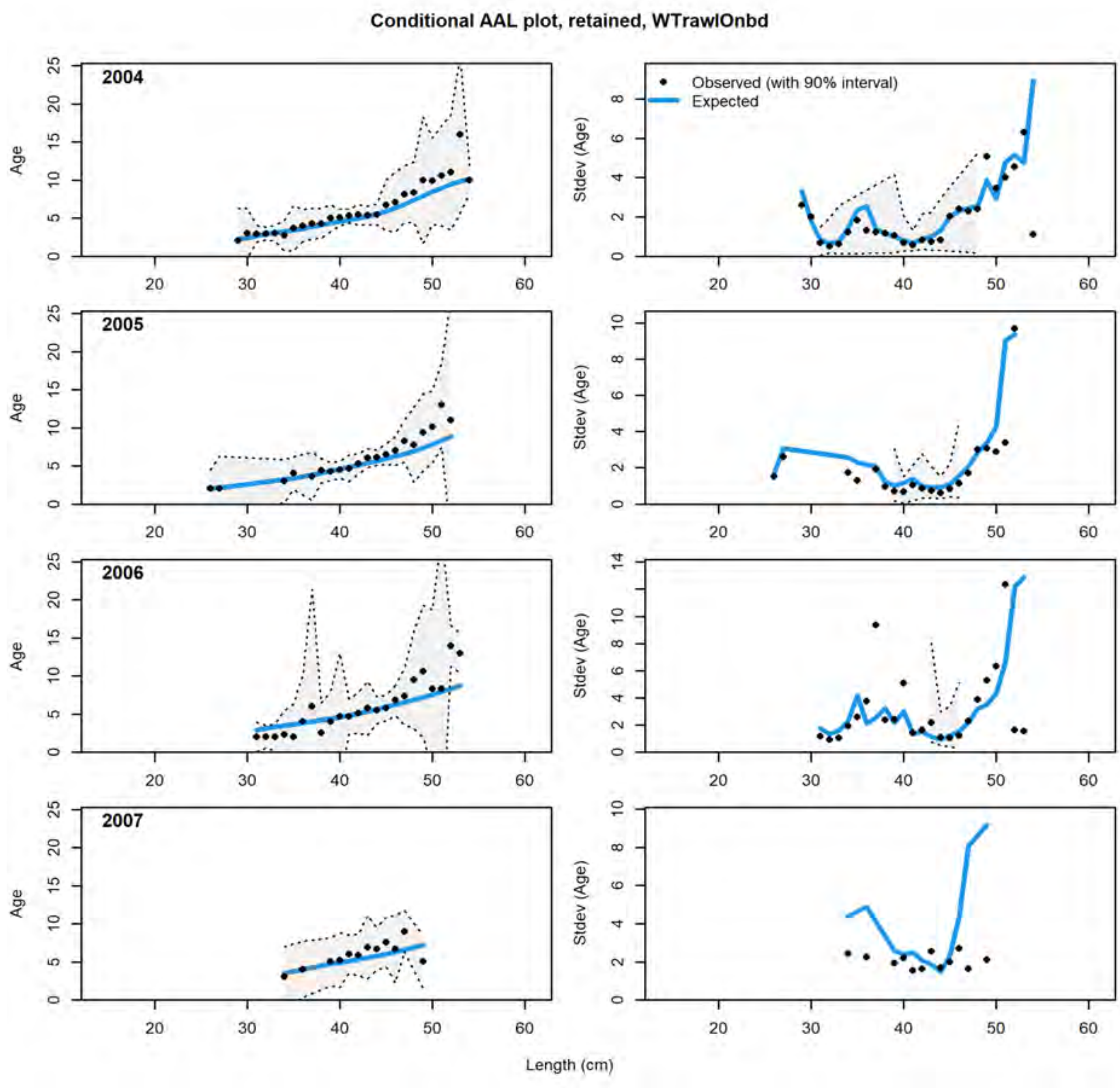

Figure 12.73. Fits to conditional age at length data for the west trawl fleet for base case 3

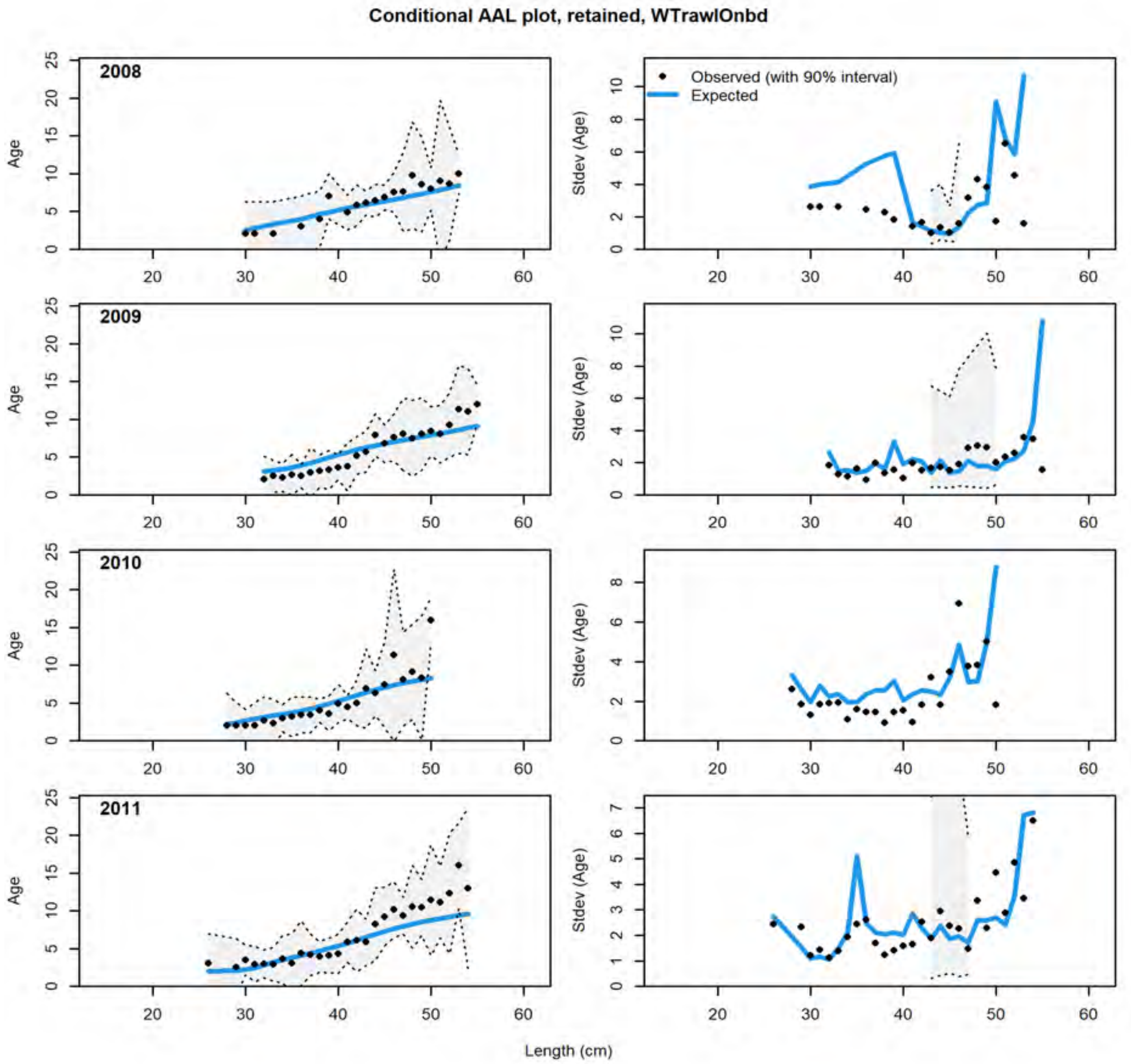

Figure 12.74. Fits to conditional age at length data for the west trawl fleet for base case 3

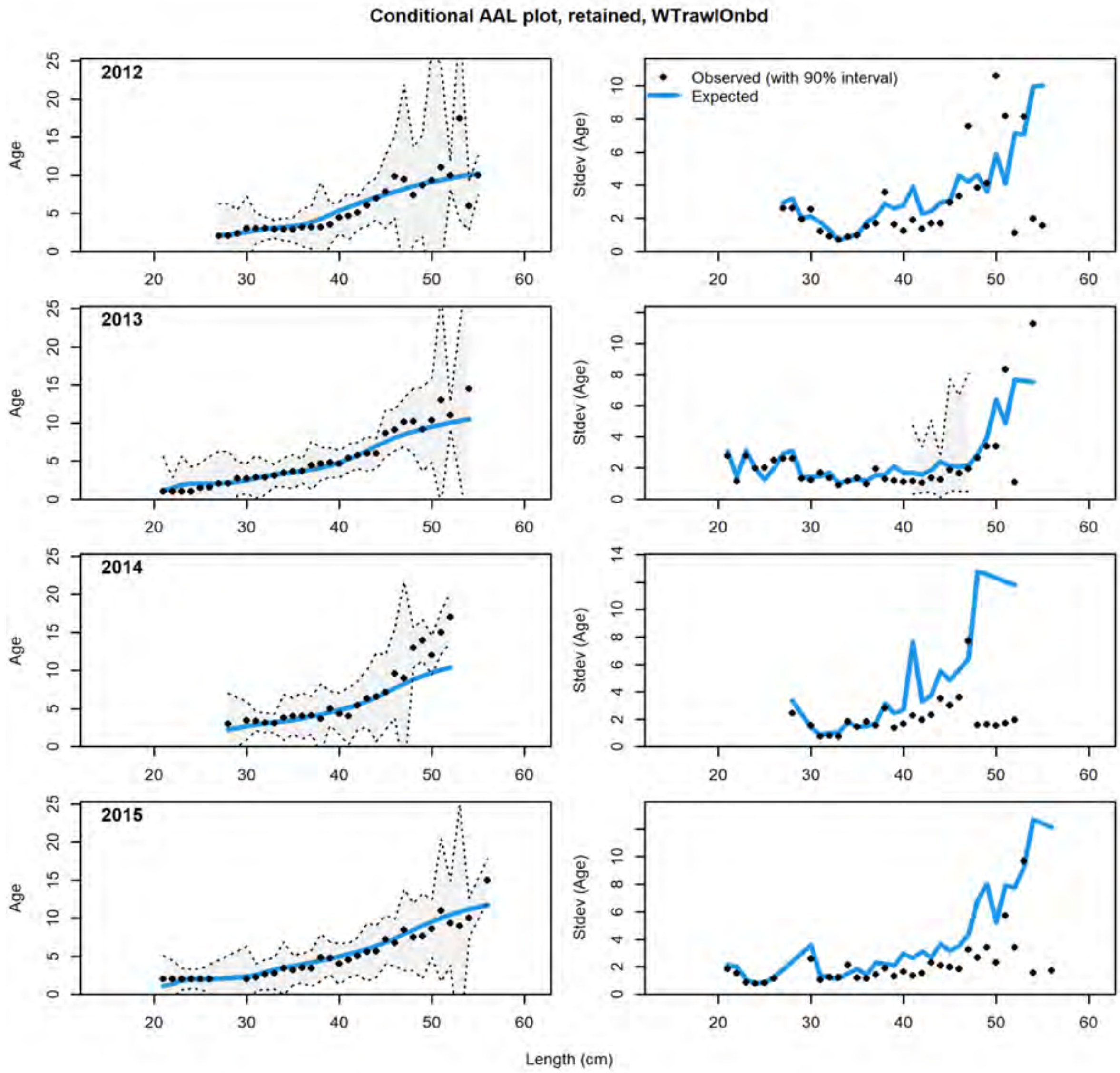

Figure 12.75. Fits to conditional age at length data for the west trawl fleet for base case 3

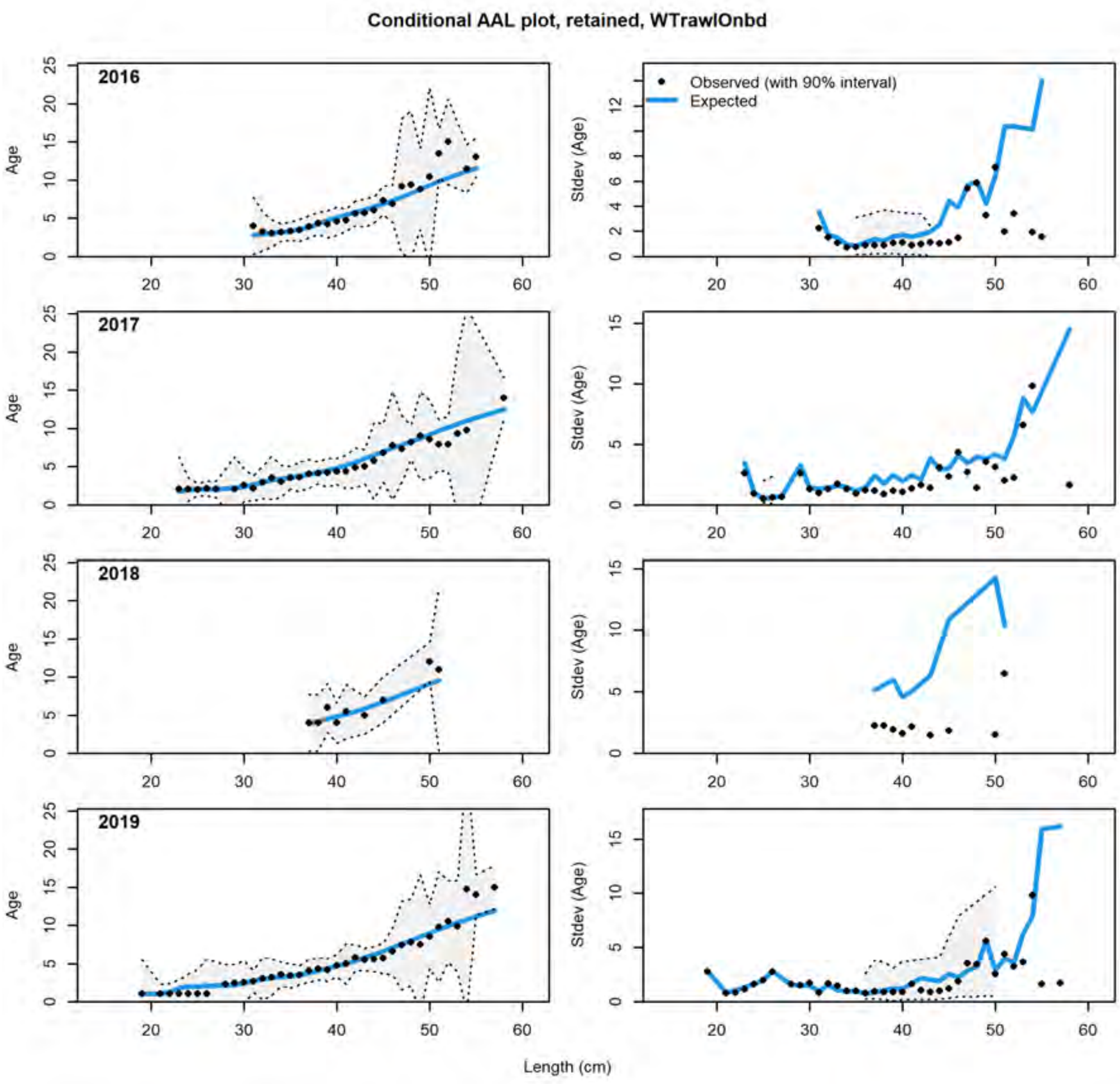

Figure 12.76. Fits to conditional age at length data for the west trawl fleet for base case 3

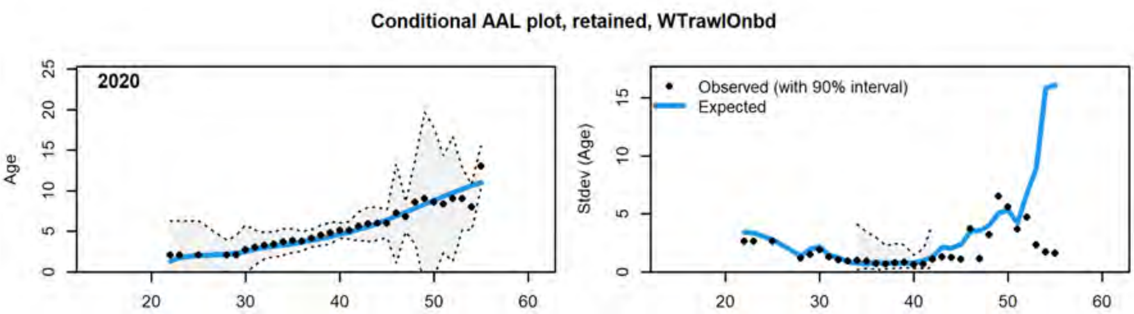

Figure 12.77. Fits to conditional age at length data for the west trawl fleet for base case 3

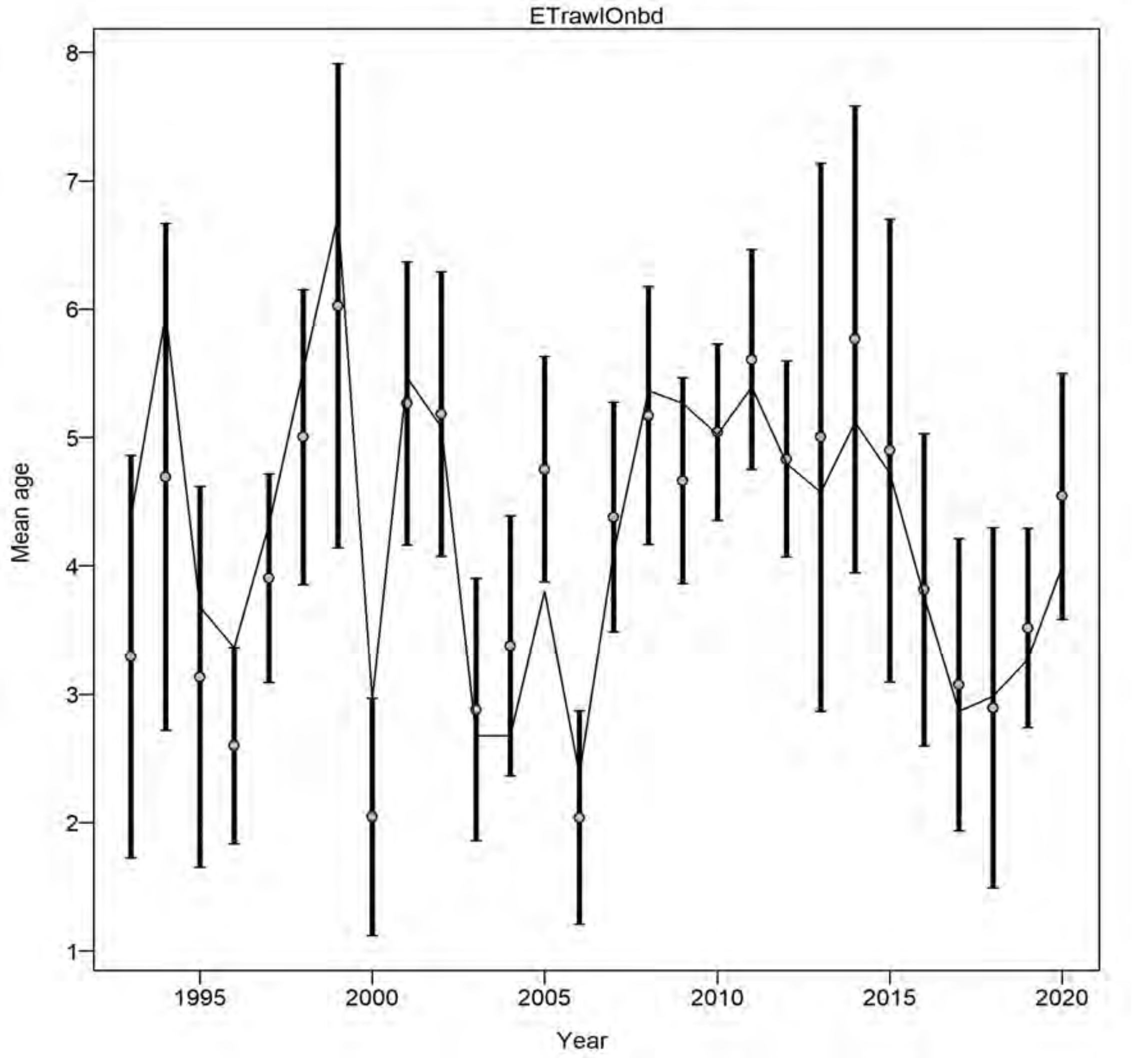

Figure 12.78. Data weighting of conditional age at length data for the east trawl fleet for base case 3

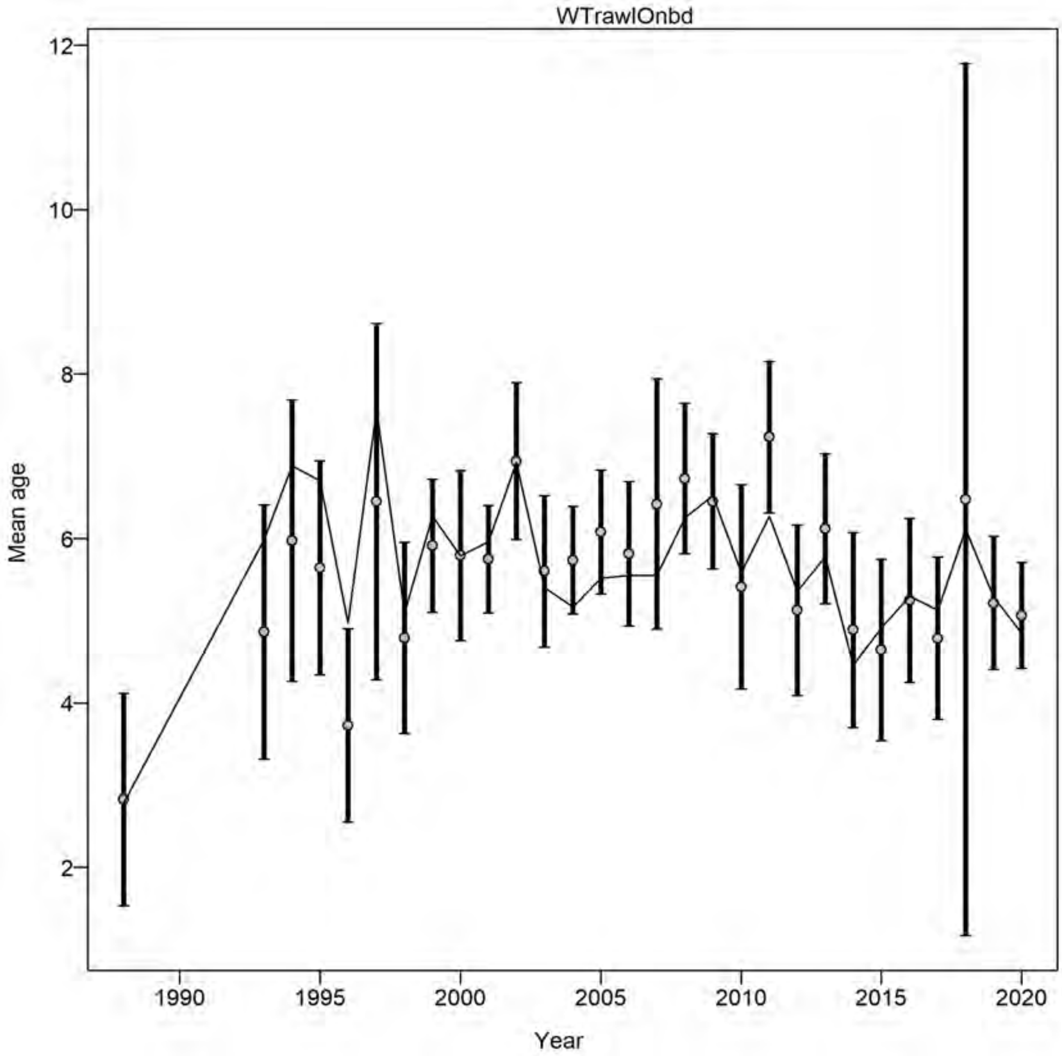

Figure 12.79. Data weighting of conditional age at length data for the west trawl fleet for base case 3

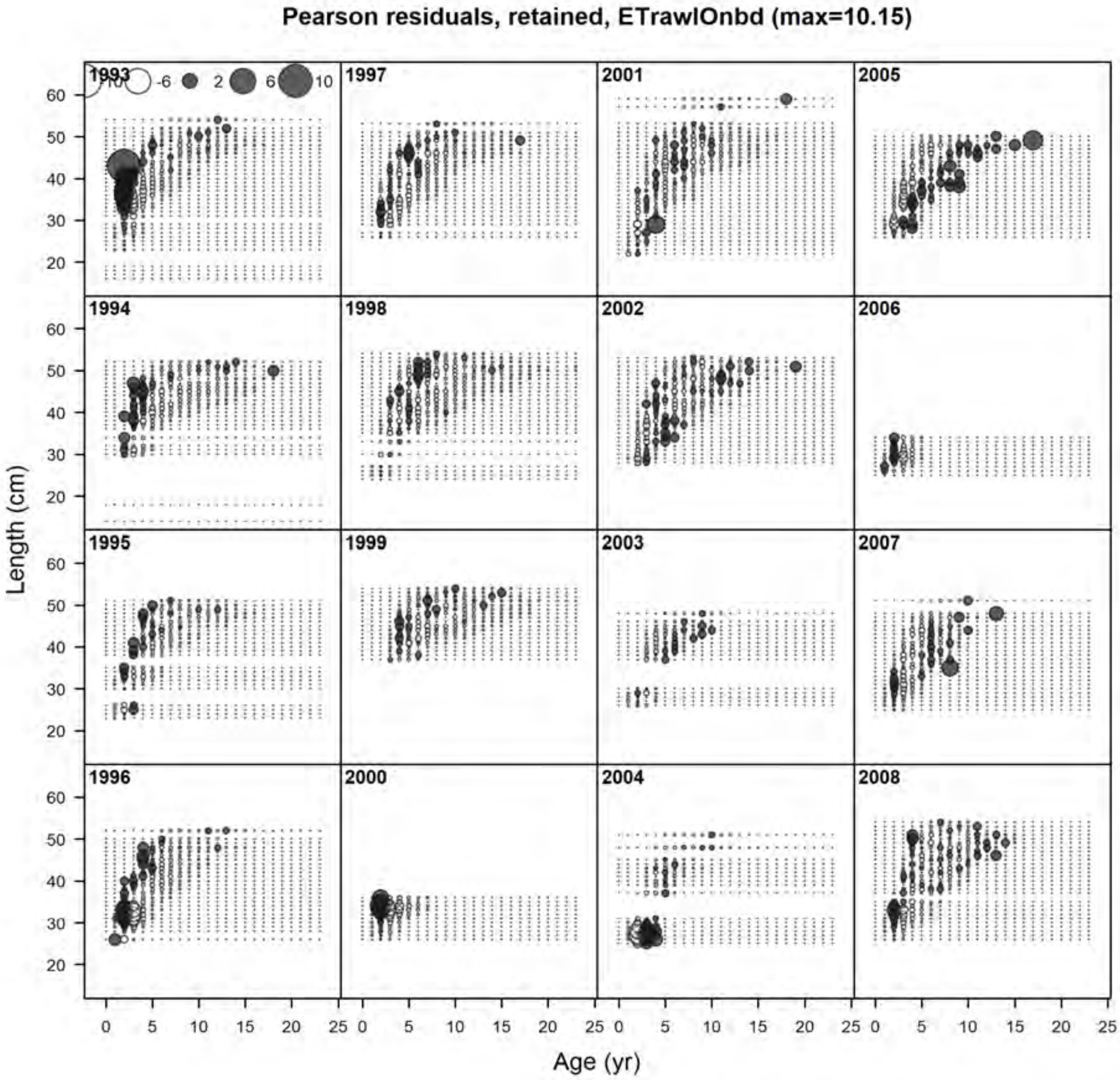

Figure 12.80. Pearson residuals of conditional age at length data for the east trawl fleet for base case 3

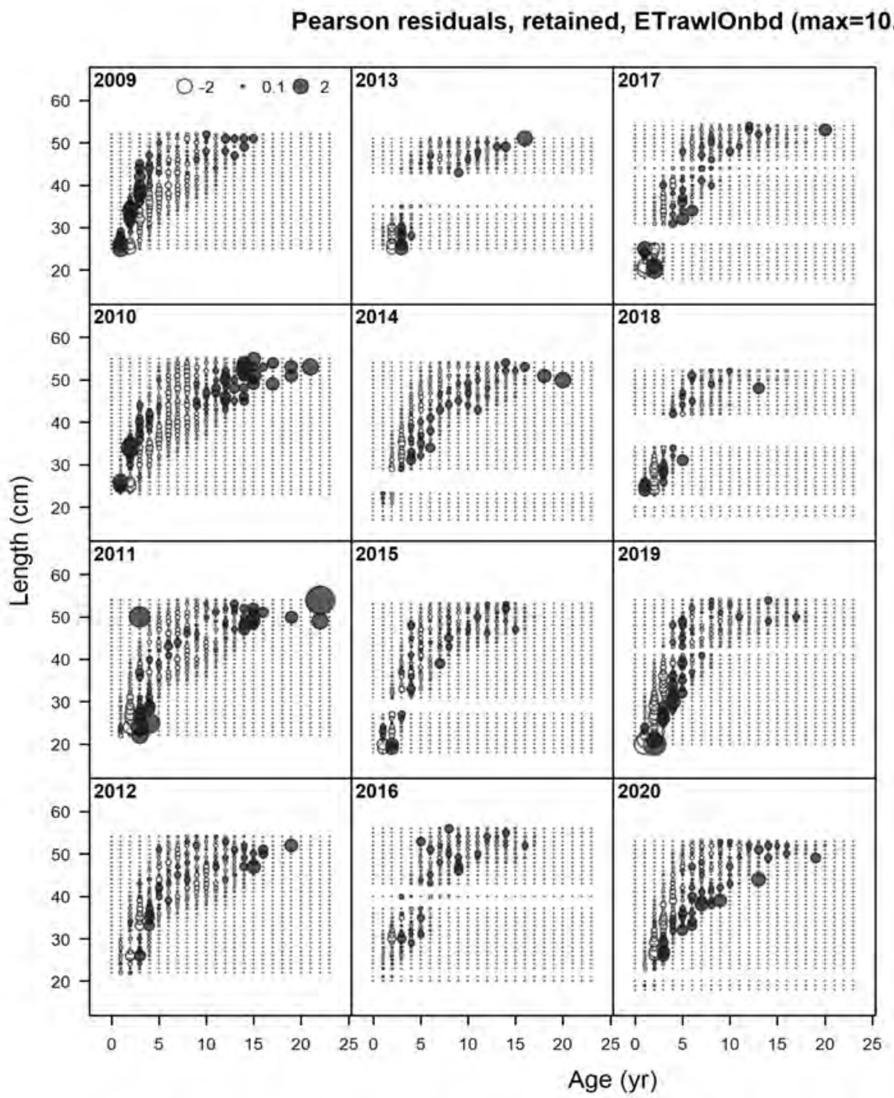

Figure 12.81. Pearson residuals of conditional age at length data for the east trawl fleet for base case 3 continued

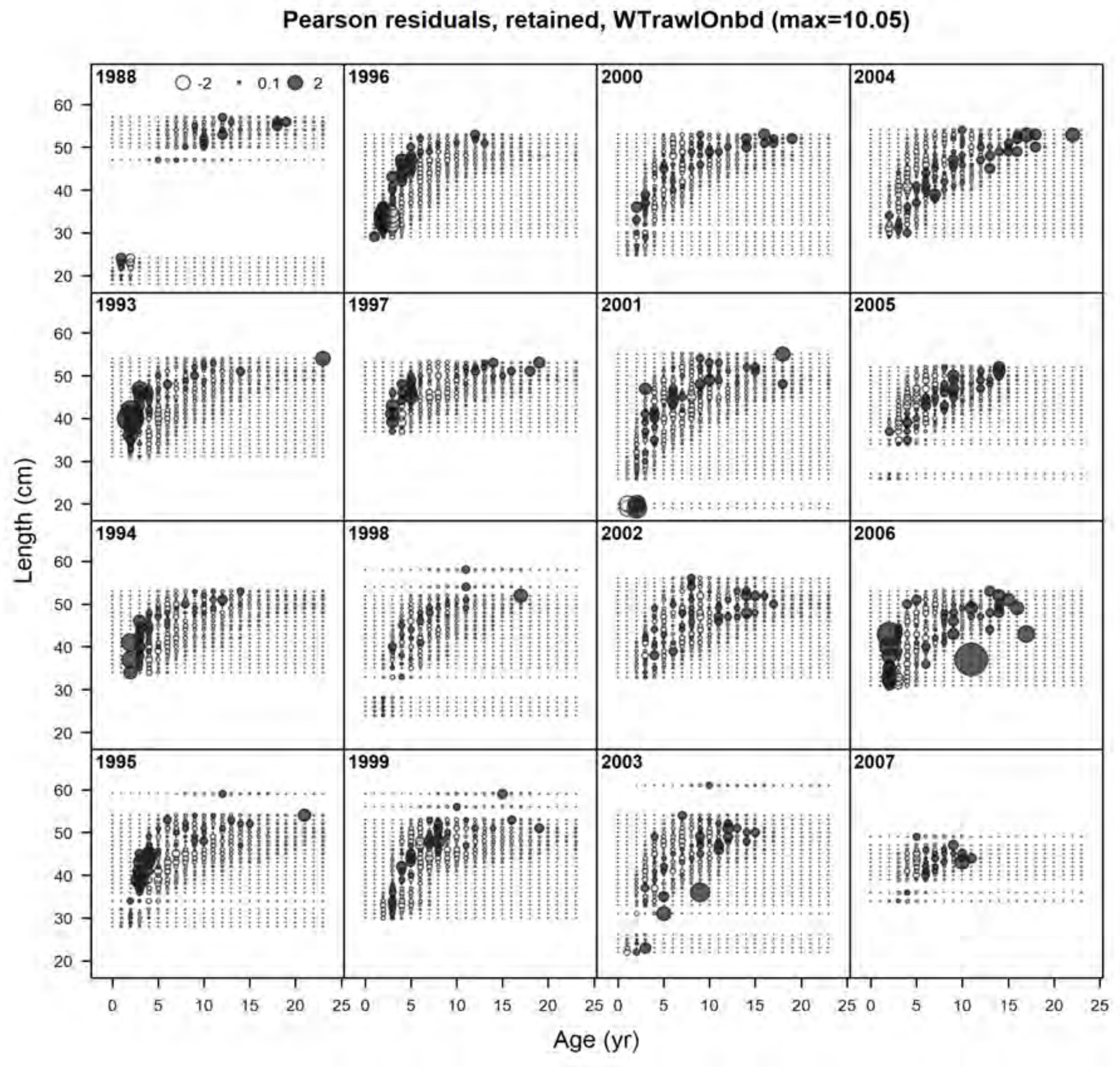

Figure 12.82. Pearson residuals of conditional age at length data for the west trawl fleet for base case 3

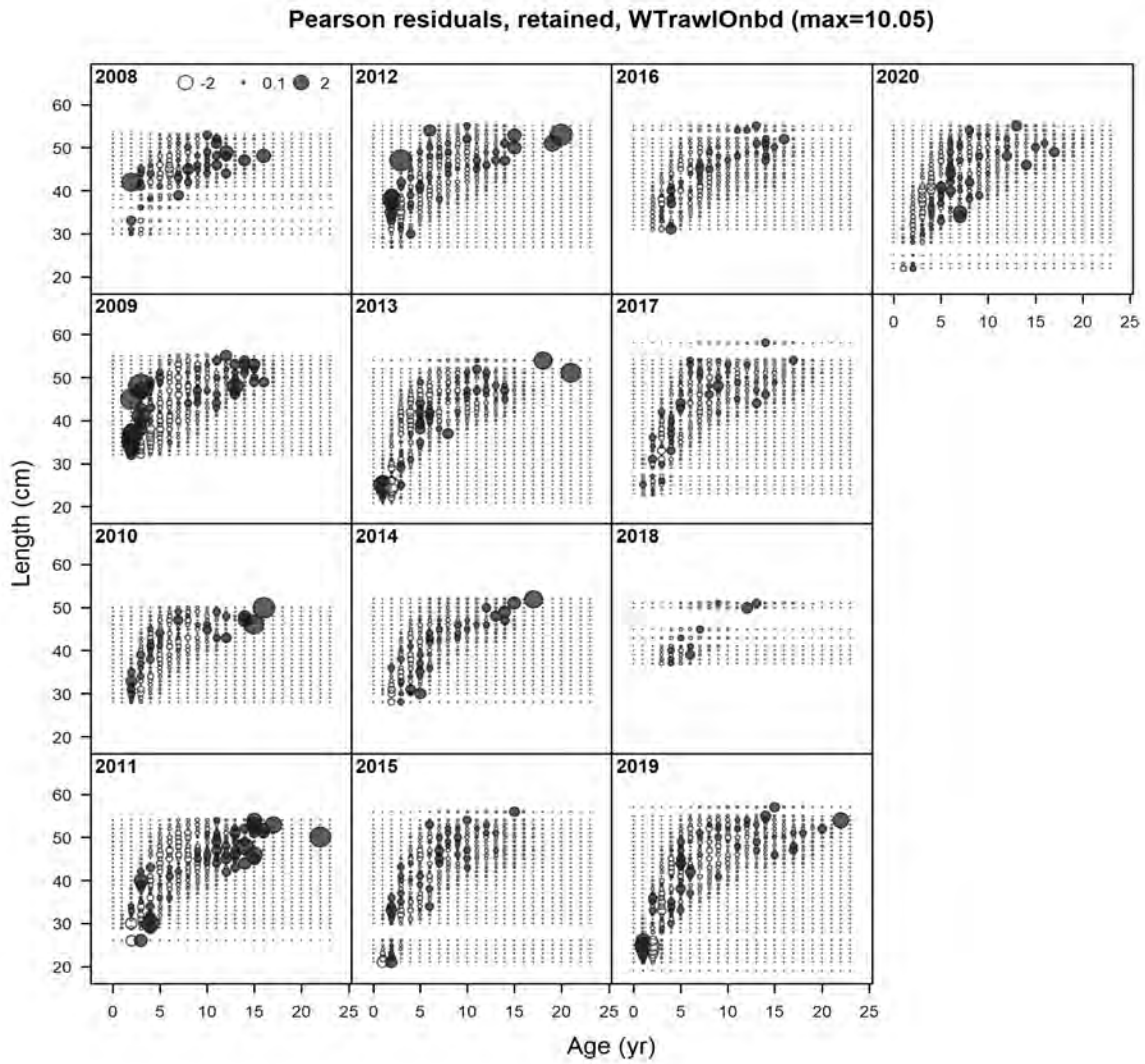

Figure 12.83. Pearson residuals of conditional age at length data for the west trawl fleet for base case 3 continued

13. Silver Warehou (*Seriolella punctata*) stock assessment based on data up to 2020

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13.1 Executive Summary

This document presents a quantitative Tier 1 assessment of Silver Warehou (*Seriolella punctata*) to provide stock status estimates at the start of 2022 and describes the base case. The assessment was performed using the stock assessment package Stock Synthesis (SS3.30.17). The 2018 base case has been updated with the inclusion of data up to the end of 2020, which entails an additional three years of catch, discard, CPUE, length and age data, along with ageing error updates, revisions to historical catch series, length frequencies and discard rates.

The assessment estimates that the projected 2022 stock status will be 29% of unfished spawning stock biomass (SSB_0), projected assuming 2020 catches in 2021, with recruitment from 2016 onwards assumed to be below average, fixed at the average of 2011-2015 levels. The assessment suggests that stock status was as low as 21% of SSB_0 in 2016. Under the 20:35:48 harvest control rule, the 2022 recommended biological catch (RBC) is 587 t, while the long-term yield (assuming continuation of low recruitment) is 591 t. The average RBC over the three-year period 2022-2024 is 581 t and over the five-year period 2022-2026, the average RBC is also 581 t. If recruitment from 2016 onwards is assumed to be average, the projected 2022 spawning stock biomass would be 42% of SSB_0. It is important to note that these RBCs do not result in an increase in stock status towards the target level of 48% SSB_0 due to reduced productivity under sustained low recruitment projections, which break the assumption of projected average recruitment in the HCR.

This assessment has seen a continuation of below average recruitment noted in the last three assessments with the last 12 years of estimated recruitment all below average. This continuation of below average recruitment resulted in the base case for this assessment moving to low recruitments projected forward from 2016. This change reduced the severity of retrospective patterns observed in previous assessments. Previous assessments have generally predicted sharp increases in stock status at the end of the assessment, which have not been realised in subsequent assessments. This trend of overly optimistic recent biomass is reduced when projecting forward with below average recruitment. This low recruitment projection has also reduced the productivity potential of the stock, with recovery to 100% of SSB_0 no longer possible, with the population now only able to reach 49% of SSB_0 if fishing mortality was to cease.

The 2018 assessment predicted that 2019 stock status would be 31% of SSB_0, with a long-term yield of 1,772 t. The stock status and the long-term yield have been revised downwards in the current assessment. This was mainly due to including low recruitment projections in the base case, but also continued low catches and improved fits to the low values at the end of the CPUE series have also contributed to the reduced estimate of stock status.

Likelihood profiles on various parameters have demonstrated clear conflicts in data inputs and between the two fleets for individual data components. These conflicts between fleets suggest that splitting the assessment between the east and the west in the future may help to alleviate this and may also further improve retrospective patterns and fits to length frequencies.

13.2 Introduction

13.2.1 *The Fishery*

Silver Warehou occur in waters of southern Australia and New Zealand, and are possibly found off South America (Tilzey, 1998). In Australia, they are found in waters of the south-east including New South Wales, Victoria, Tasmania and South Australia. Adults are generally found on the continental shelf and upper slope, while juveniles are initially pelagic and subadults are often found in large estuaries and bays during the summer and autumn (Tilzey, 1998). In the SESSF they are found in depths to 600 m and are predominantly caught by demersal trawl (Bessell-Browne et al., 2021; Morison et al., 2007; Sporcic et al., 2015). Silver Warehou have also been captured off western Tasmania as bycatch of the winter spawning Blue Grenadier (*Macruronus novaezelandiae*) fishery. In addition to demersal trawl, there have also been some gillnet catches (Morison et al., 2007) and catches by the small pelagic fishery (SPF) using mid-water trawl.

Large catches of Silver Warehou were first taken in the 1970's (Smith, 2007) and landed catches increased to around 2,000 t in the early 1990's peaking at 4,100 t in 2002. Catches declined to less than 2,000 t from 2007 onwards, with further declines to less than 1,000 t since 2012. Catches have remained relatively stable since 2014 at between 350 t and 400 t.

For 2019, 2020 and 2021 the agreed total allowable catches (TACs) were all 450 t. These TACs were set following the last assessment in 2018 assuming a low recruitment scenario (Burch et al., 2018).

13.2.2 *Stock Structure*

Prior to 2015, Silver Warehou was assessed as a single population using a single trawl fleet in SESSF zones 10–50 (Day et al., 2012). However, differences in standardised catch rates, length and age distribution east and west of longitude 147°E were identified by Sporcic et al. (2015). This led to the development of a preliminary assessment which split the data into two fleets, an eastern fleet (SESSF zones 10, 20 and 30) and a western fleet (SESSF zones 40 and 50) (Thomson et al., 2015). This fleet structure was adopted as the base case for the 2015 assessment (Day et al., 2015), 2018 assessment (Burch et al., 2018) and has been retained as the base case for the current assessment.

13.2.3 *Previous Assessments*

The previous full quantitative assessment for Silver Warehou was performed in 2018 (Burch et al., 2018) using Stock Synthesis (SS-V3.30.12.00, Methot et al. (2018)). The 2018 assessment indicated that the spawning stock biomass levels in 2019 were 31% of unfished biomass, however, recruitment for the last 11 years years was estimated to be below average and the TACs for 2019–2021 were set assuming below average future recruitment from fixed catch projections.

The 2015 assessment (Day et al., 2015) used Stock Synthesis (SS-V3.24U, Methot (2015)). The 2015 assessment indicated that the spawning stock biomass levels in 2016 were 40% of unfished biomass, however, recruitment for nine out of the ten most recent years was estimated to be below average and the TACs for 2016-2018 were set assuming below average future recruitment.

The 2015 assessment was the first to split the assessment between east trawl (SESSF zones 10–30) and west trawl fleets (SESSF zones 40–50). This change was implemented following investigations by Sporcic et al. (2015) and Thomson et al. (2015). Sporcic et al. (2015) highlighted differences in standardised catch rates, along with age and length distributions in the east and west. Thomson et al. (2015) investigated the relationship between depth and length frequencies and concluded there was a strong relationship with larger fish caught in deeper water in the west, and smaller fish caught in the east and in shallow waters. These investigations led to the development of a preliminary base case assessment which split the single trawl fleet into eastern and western fleets (Thomson et al., 2015).

Thomson et al. (2015) also identified evidence of changing discarding practices within the fishery with both size and market-based discarding occurring up until 2001 and only size-based discarding from 2002 onwards. This permitted discard rates to be estimated within the 2015 assessment using separate retention functions pre and post 2002 (Day et al., 2015). The changes to the fleet structure and fitting to discard rates led to improvements in the fits to the length and age composition data compared with previous assessments (Day et al., 2012; Tuck and Fay, 2009).

The 2012 assessment (Day et al., 2012) used Stock Synthesis (SS-V3.23b, Methot (2012)). This assessment modelled the stock using a single trawl fleet in SESSF zones 10–50, which continued the fleet structure from previous assessments (Tuck and Fay, 2009). This assessment suggested the 2013 spawning stock biomass was 47% of unfished levels.

Prior to 2012, an assessment for Silver Warehou was performed in 2009 (Tuck and Fay, 2009) using Stock Synthesis (version SS-V3.03a, Methot (2009)) and this assessment indicated that the spawning stock biomass levels in 2010 were around 48% of unfished biomass.

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

13.2.4 *Modifications to the previous assessment*

The base case specifications agreed by SERAG in 2018 are maintained into the assessment presented here, with three changes. Firstly, an additional time block on retention for the east trawl fleet has been included to allow the model to fit the increased recent discarding, which has occurred since the previous assessment. Secondly the assessment has only estimated one additional recruitment deviation rather than the usual three due to a retrospective pattern which revises down recruitment with the inclusion of additional years of data. Lastly the base case assessment now includes low recruitment projections rather than an assumed return to average recruitment levels post 2015. These changes have improved fits to the data inputs and reduced retrospective patterns within the assessment. These changes are described in further detail in Bessell-Browne (2021).

The 2018 assessment (Burch et al., 2018) made a number of changes to the structure of the assessment, these included:

1. Catches from the Gillnet, Hook and Trap sector (GHAT) and the SPF are included in the assessment;
2. Estimated annual discard rates that are fitted to by the assessment have been split into eastern and western components;

3. Factory trawlers are now included in the estimation of annual discard rates when there is observer coverage;
4. FIS abundance indices for east and west fleets are removed from the base case assessment and are instead considered as a sensitivity.

The usual process of bridging to a new model by adding new data piecewise and analysing which components of the data could be contributing to changes in the assessment outcome was conducted by Bessell-Browne (2021).

13.3 Methods

13.3.1 *Model Structure*

The 2021 base case assessment of Silver Warehou uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Version 3.30.17.00, Methot et al. (2021)). The methods utilised in SS are based on the integrated analysis paradigm. SS can allow for multiple seasons, areas and fleets, but most applications are based on a single season and area. Recruitment is governed by a stochastic Beverton-Holt stock-recruitment relationship, parameterised in terms of the steepness of the stock-recruitment function (h), the expected average recruitment in an unfished population (R_0), and the degree of variability about the stock-recruitment relationship (σ_R). SS allows the user to choose among a large number of age- and length-specific selectivity patterns. The values for the parameters of SS are estimated by fitting to data on catches, catch-rates, discard rates, discard and retained catch length-frequencies, and conditional age-at-length data. The population dynamics model and the statistical approach used in fitting the model to the various data types are given in the SS technical documentation (Methot, 2005).

The base case model includes the following key features:

A single region, single stock model is considered with two fleets, one in the east including SESSF zones 10, 20 and 30 (east trawl), and one in the west including SESSF zones 40 and 50 (west trawl). Selectivity is modelled separately for each fleet, with both selectivity patterns assumed to be length-specific and logistic. The parameters of the selectivity function for each fleet were estimated within the assessment. The model does not account for males and females separately and fits one growth curve across both sexes. The initial and final years are 1980 and 2020.

13.3.1.1 Biological parameters and stock structure assumptions

The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The value for M is assumed to be 0.3 y^{-1}.

Recruitment to the stock is assumed to follow a Beverton-Holt stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, R_0, and the steepness parameter, h. Steepness for the base case analysis is fixed at 0.75.

The initial value of the parameter determining the magnitude of the process error in annual recruitment, σ_R, is set to 0.7.

The population plus-group is modelled at age 23 years.

Growth is assumed to follow a von Bertalanffy length-at-age relationship, with the parameters of the growth function estimated together for females and males inside the assessment model.

Silver Warehou become sexually mature at around 42 cm length, when they are around five years old. Maturity is modelled as a logistic function, with 50% maturity fixed at 37 cm in the assessment. Fecundity-at-length is assumed to be proportional to weight-at-length. The parameters of the length-weight relationship are obtained from Taylor and Smith (2004).

The values assumed for some of the (non-estimated) parameters of the base case models are shown in Table 13.1.

Table 13.1. Parameter values assumed for some of the non-estimated parameters of the base-case model

Parameter	Description	Value
M	Natural mortality	0.3
h	steepness' of the Beverton-Holt stock-recruit curve	0.75
x	age observation plus group	23 years
a	allometric length-weight equations	0.0000065 g^{-1} cm
b	allometric length-weight equations	3.27
l_m	Female length at 50% maturity	37 cm

13.3.2 *Data*

A summary of the data available in the assessment is presented in Figure 13.1.

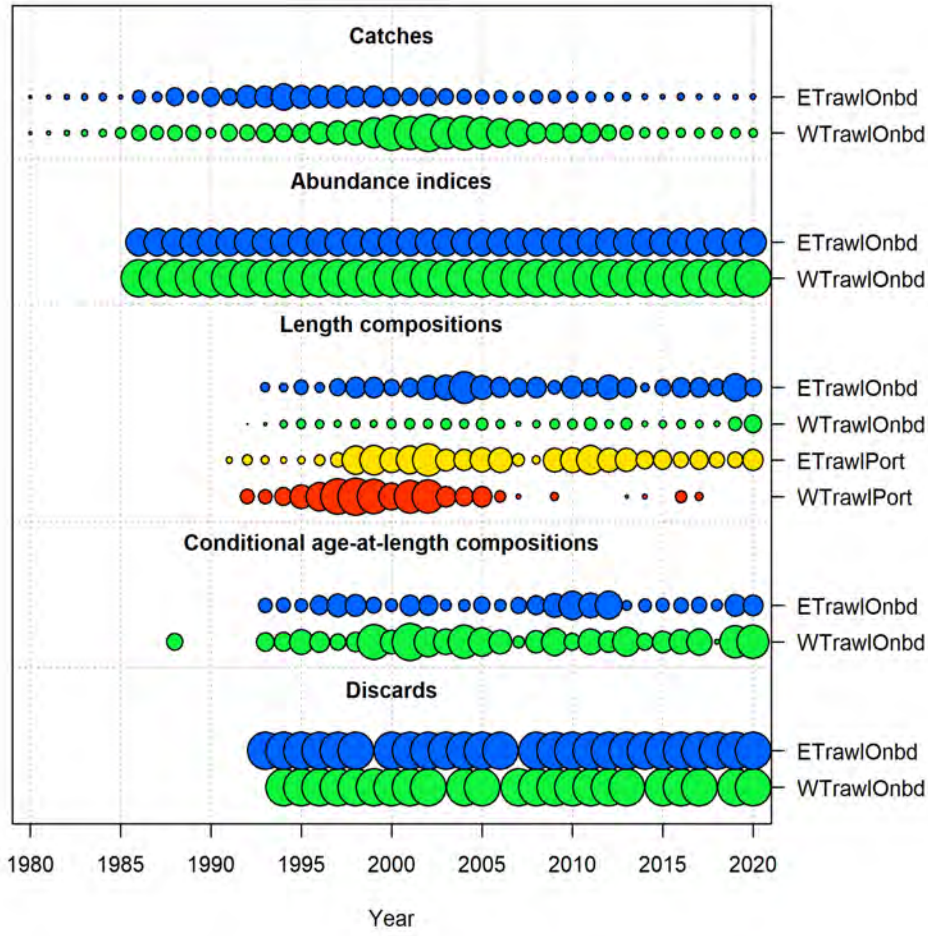

Figure 13.1. Summary of Silver Warehou data sources

13.3.2.1 Catch data

The model uses a calendar year for all catch data. The first model year is 1980, however, SEF1 record-keeping did not begin until 1985. Landings of Silver Warehou prior to 1985 are not considered to have been large and a linear increase in catch from 1980 to 1985 was assumed, following Punt et al. (2005). Silver Warehou are closely related to Blue Warehou (*Seriolella brama*) and historically catches have often been reported mixed, or with all Warehou species combined and referred to as Tassie Trevally (Sporcic et al., 2015). This practice was most prevalent in the late 1980s with it unclear which species was caught and recorded in Commonwealth logbooks. For this reason, catches prior to 1994 have not been revised and are instead taken from Table 13.11 of Sporcic et al. (2015) and shown in the first column of Table 13.2, although separated into east trawl and west trawl fleets.

The catch history of Silver Warehou from 1994 onwards has been revised in the current assessment to account for updates to the database made by AFMA (Althaus et al., 2021).

As was done in the 2018 assessment, catches of Silver Warehou from both the small pelagic fishery (SPF) and the gillnet hook and trap sector (GHT) were included with Commonwealth trawl (CTS) catches when compiling the catch series (Burch et al., 2018). Catches recorded within the SESSF, those taken by state jurisdictions, total catches prepared for the assessment and historical TACs are detailed in Table 13.2, with catches used in the assessment presented in Figure 13.2.

To calculate the RBC for 2022, it is necessary to estimate the catch for 2021. Without any other information, the 2021 catch is assumed to be identical to the 2020 catch.

The percentage of the TAC that has been caught through time has been variable, ranging from a high of 104% in 1997 to a low of 16% in 2014 and 2015 (Table 13.2). From 2018 to 2020 between 66% and 74% of the TAC has been caught (Table 13.2).

Table 13.2. Catch summary including the agreed historical catch series between 1980 and 1993 (Total East and Total West), and catches compiled for the current assessment (1994-2020). Catches are split between the fleets and presented by total SESSF catches (SESSF East and SESSF West), total state catches (State East and State West), along with the total catch (Total East, Total West), and also summarised to represent all Silver Warehou catches (Total Catch). The catch series included in the assessment are presented in the *Total East* and *Total West* columns. Agreed TACs are also included. * denotes catches that are assumed to be the same as the previous year.

YEAR	SESSF EAST	SESSF WEST	STATE EAST	STATE WEST	TOTAL EAST	TOTAL WEST	TOTAL CATCH	TAC
1980	-	-	-	-	29.5	29.5	59.0	-
1981	-	-	-	-	59.0	59.0	118.0	-
1982	-	-	-	-	88.6	88.6	177.2	-
1983	-	-	-	-	118.1	118.1	236.2	-
1984	-	-	-	-	147.6	147.6	295.2	-
1985	-	-	-	-	58.4	301.6	360.0	-
1986	-	-	-	-	433.3	574.7	1,008.0	-
1987	-	-	-	-	261.0	487.8	748.8	-
1988	-	-	-	-	781.6	584.0	1,365.6	-
1989	-	-	-	-	342.8	577.6	920.4	-
1990	-	-	-	-	866.8	258.7	1,125.5	-
1991	-	-	-	-	664.3	698.9	1,363.2	-
1992	-	-	-	-	1,246.0	618.8	1,864.8	2000
1993	-	-	-	-	1,115.7	853.5	1,969.2	2000
1994	1,545.8	763.5	126.0	62.2	1,671.8	825.7	2,497.5	2500
1995	1,213.0	788.9	94.0	54.8	1,307.0	843.7	2,150.7	2500
1996	1,128.5	1,057.6	93.7	87.8	1,222.1	1145.4	2,367.6	2500
1997	1,213.2	1,339.7	22.9	15.1	1,236.1	1,354.8	2,590.9	2500
1998	964.8	1,445.0	22.7	1.4	987.5	1,446.4	2,434.0	3500
1999	1,089.4	2,158.7	1.8	0.0	1,091.1	2,158.7	3,249.8	4000
2000	802.5	2,923.6	0.5	0.0	803.0	2,923.7	3,726.6	4000
2001	713.0	2,583.2	0.3	0.1	713.4	2,583.3	3,296.6	4400
2002	770.8	3,330.6	0.4	0.1	771.3	3,330.7	4,101.9	4400
2003	618.0	2,439.1	0.9	0.2	618.8	2,439.3	3,058.1	4488
2004	524.5	2,786.8	3.7	0.7	528.2	2,787.5	3,315.6	4039
2005	507.2	2,400.6	4.1	0.0	511.3	2,400.6	2,911.9	4400
2006	440.4	1,933.2	2.5	0.0	442.9	1,933.2	2,376.1	4400
2007	309.6	1,688.8	4.4	0.0	313.9	1,688.9	2,002.8	3088
2008	449.8	1,073.1	0.7	0.5	450.5	1,073.6	1,524.1	3227
2009	409.3	968.9	3.8	0.0	413.1	968.9	1,382.1	3000
2010	312.0	976.4	0.2	0.6	312.2	977.0	1,289.2	2566
2011	252.5	976.4	0.0	0.0	252.5	976.4	1,228.9	2566
2012	209.3	638.4	0.0	0.0	209.3	638.4	847.7	2566
2013	181.2	464.4	0.0	0.0	181.3	464.4	645.7	2329
2014	95.9	285.7	0.0	0.0	95.9	285.7	381.5	2329
2015	71.3	315.3	0.1	0.0	71.4	315.3	386.8	2417
2016	128.3	222.3	0.0	0.0	128.3	222.3	350.5	1209
2017	105.8	242.4	0.1	0.0	105.8	242.4	348.2	605
2018	94.3	299.0	0.2	0.0	94.5	299	393.4	600
2019	77.5	256.1	0.0	0.0	77.5	256.1	333.6	450
2020	106.6	190.7	0.0	0.0	106.6	190.7	297.3	450
2021	106.6*	190.7*	0.0*	0.0*	106.6*	190.7*	297.3*	450

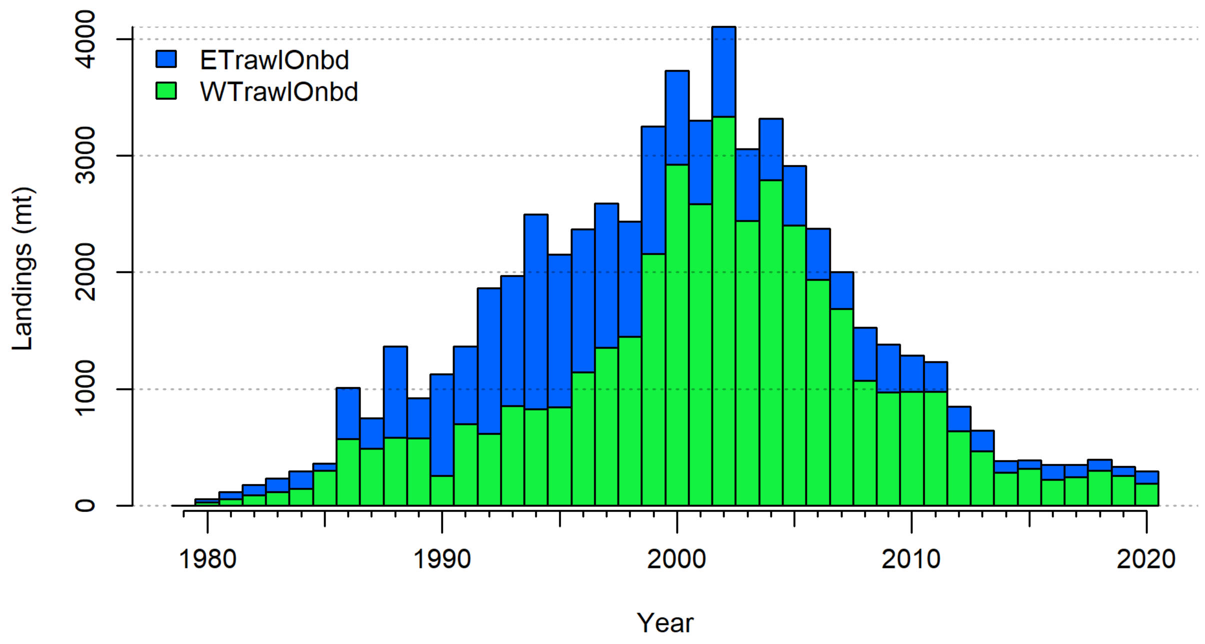

Figure 13.2. Total landed catch by fleet

13.3.2.2 Discard rates

Information on the discarded catches of Silver Warehou are available from the integrated scientific monitoring program (ISMP) for 1993-2020. This program was run by PIRVic from 1992-2006 and by AFMA from 2007 onwards.

Discard tonnage was estimated through the assignment of a retention function. This was defined as a logistic function of length, and the inflection and slope of this function were estimated where discard information was available. In the 2018 assessment two retention functions were estimated, one for each 'block' period: namely 1980–2001 and 2002–2020. The first block allows the model to fit discarding across all length classes due to limited markets, while the second block allows the model to fit to size based discarding once markets for the species were established. For the east trawl fleet an additional retention time block was included between 2018 and 2020 to account for an increase in discard estimates over this period. Discarding periods are detailed below:

1980–2001: Market driven discarding

- Discards across all size ranges due to limited markets

2002–2020: Sized based discarding

- Markets for Silver Warehou have been established
- Discarding is mainly of small fish
- Occasional discarding of larger fish due to low market prices

2018–2020: Increased discarding (East trawl fleet only)

- Large increase in discarding in the east trawl fleet (not observed in the west)
- These discards are mainly small fish

Estimated discard fractions in the east were variable with highs of 74% in 1995, 46% in 2004, 38% in 2015 and 43%, 58% and 79% in 2018, 2019 and 2020 respectively (Table 13.3, Figure 13.3). The remainder of estimates in the east trawl fleet were generally below 15% (Table 13.3). In the west estimated discard fractions were generally lower than those in the east with only the 1996-1998 estimates being above 20% (Table 13.3, Figure 13.3). The discarded weights for 1980 to 2020 are displayed in Figure 13.4.

Table 13.3. Discard proportions for east trawl and west trawl fleets from 1993 to 2020 (prop) with sample sizes for each data point (n). Entries in the 'used' columns indicate data that are either used (y) or not used (n) either due to small sample size (less than 10 samples) or because the value is too close to zero (0.01 or less)

YEAR	East trawl PROP	East trawl n	East trawl USED	West trawl PROP	West trawl n	West trawl USED
1992	0.00	6	n	0.00	7	n
1993	0.06	182	y	0.00	52	n
1994	0.02	199	y	0.04	109	y
1995	0.74	123	y	0.05	127	y
1996	0.10	173	y	0.33	120	y
1997	0.12	285	y	0.32	90	y
1998	0.15	174	y	0.40	120	y
1999	0.01	155	n	0.17	121	y
2000	0.09	135	y	0.14	94	y
2001	0.21	228	y	0.09	161	y
2002	0.31	209	y	0.14	184	y
2003	0.31	262	y	0.00	129	n
2004	0.46	343	y	0.13	123	y
2005	0.23	299	y	0.13	263	y
2006	0.09	271	y	0.00	125	n
2007	0.01	53	n	0.06	71	y
2008	0.03	155	y	0.03	143	y
2009	0.03	108	y	0.03	159	y
2010	0.01	106	y	0.02	233	y
2011	0.10	108	y	0.10	229	y
2012	0.04	76	y	0.17	165	y
2013	0.25	70	y	0.02	161	y
2014	0.05	42	y	0.02	57	n
2015	0.37	89	y	0.01	77	y
2016	0.24	121	y	0.02	54	y
2017	0.19	99	y	0.10	78	y
2018	0.43	98	y	0.00	71	n
2019	0.58	149	y	0.18	213	y
2020	0.79	71	y	0.08	416	y

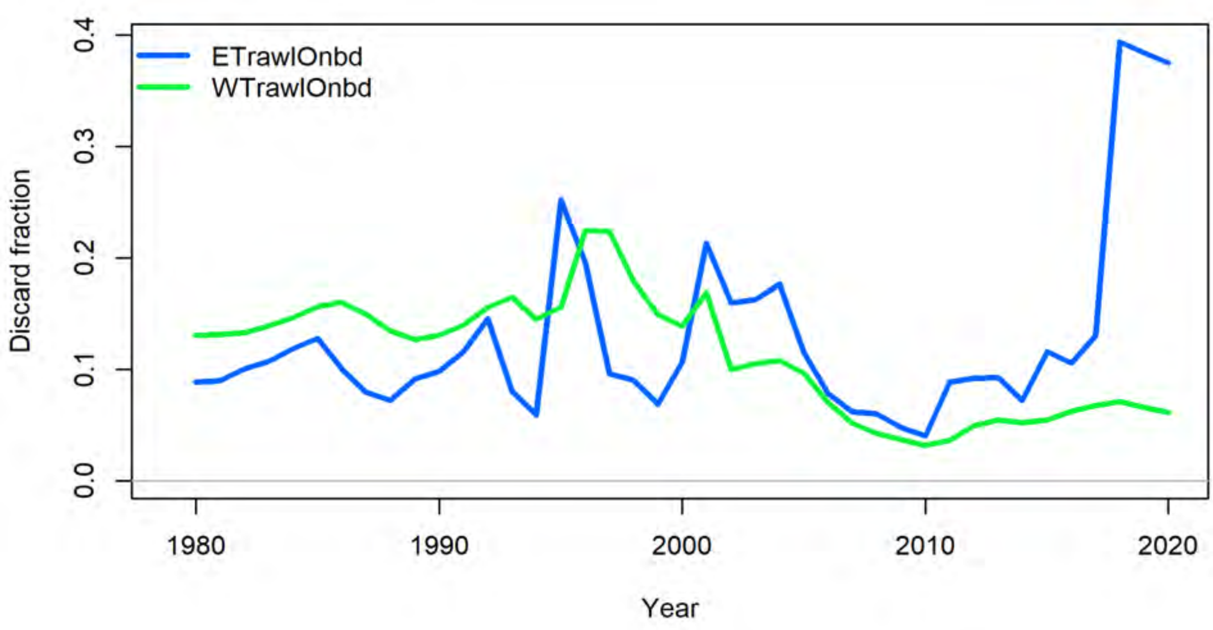

Figure 13.3. Model estimated discards as a proportion of catch by fleet

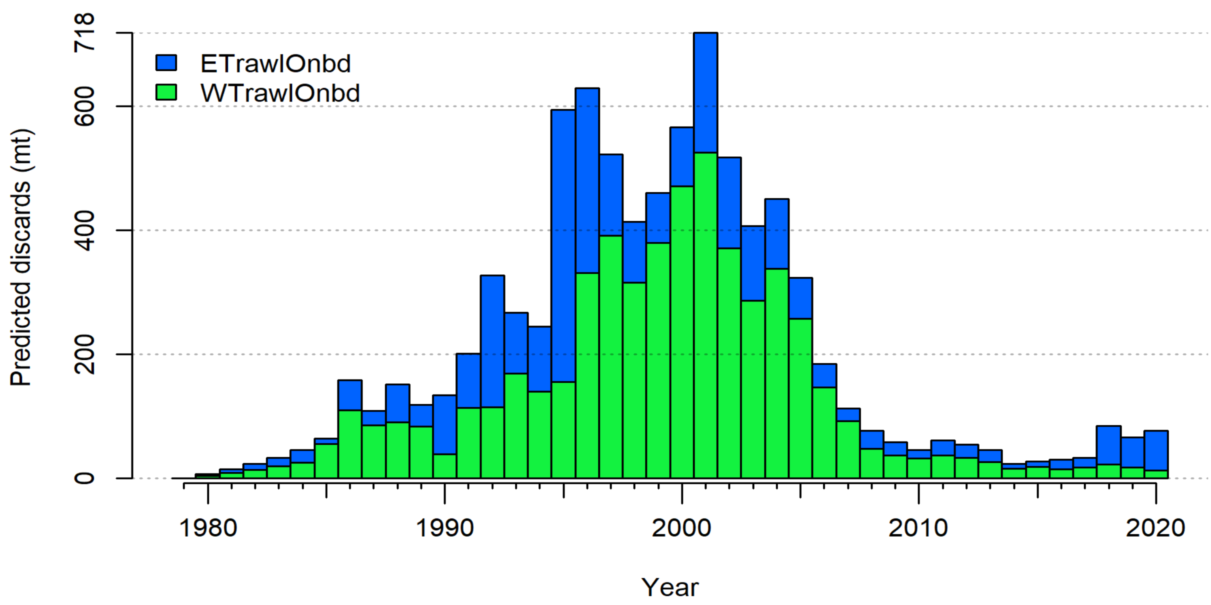

Figure 13.4. Total model estimated discards as weight by fleet

13.3.2.3 Standardised catch rates

Catch and effort data from the SEF1 logbook database from the period 1986 to 2020 were standardised using GLMs to obtain indices of relative abundance (Figure 13.5) (Sporcic 2021). Data used in this standardisation were restricted to trawl shots between 0 and 600 m depth from zones 10, 20 and 30 for the eastern trawl fleet and zones 40 and 50 for the western trawl fleet. The CVs of the CPUE indices were initially set at a value equal to the standard error from a loess fit (east trawl = 0.174, west trawl = 0.178; Sporcic (2021)), before being re-tuned to the model-estimated standard errors within SS.

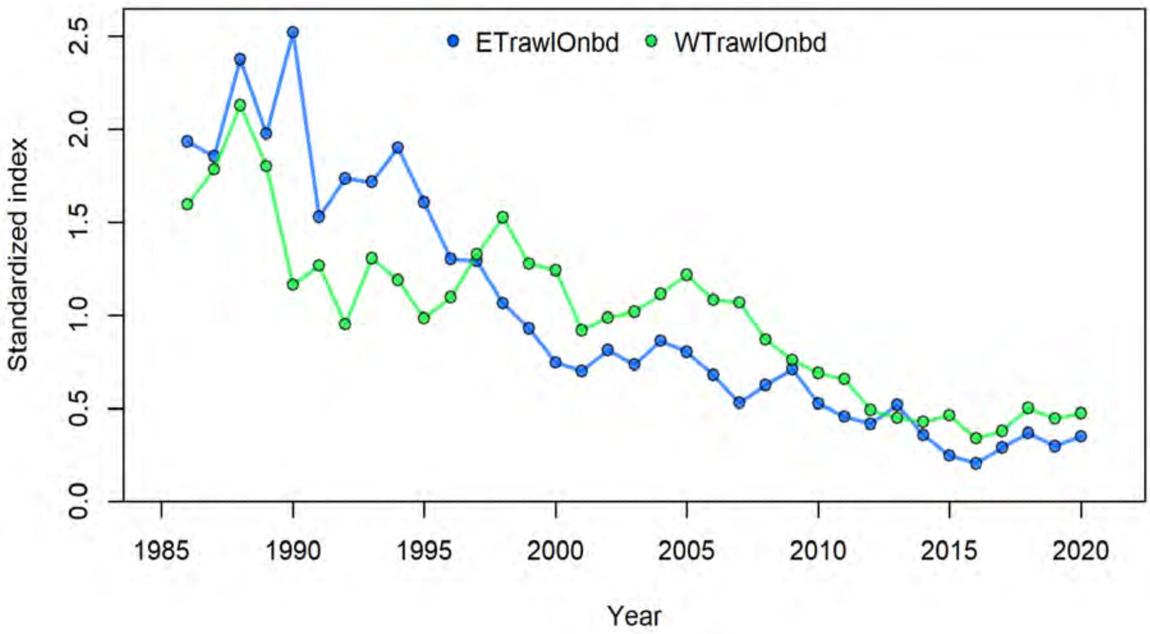

Figure 13.5. Input standardised catch rates for the east and west trawl fleets

13.3.2.4 Length frequencies

Both onboard and port length frequency data was included in the assessment, consistent with previous assessments. These data sources are included separately, with the gear selectivity estimated jointly from both data sets from each fleet (east trawl and west trawl), as is the standard practice in SESSF stock assessments. Onboard data includes length frequencies from both retained and discarded fish, while port length frequencies only contain retained samples.

For onboard data, the number of shots is used as the initial sample size before the length frequency data are re-weighted in the tuning process. This is considered more representative of the true sample size than the number of fish measured (Francis, 2011). For port data, the number of shots is not available, but the number of trips is used instead. Data was excluded for years with less than 100 individual fish measured per fleet, as small samples are potentially unrepresentative.

Length composition data from onboard samples is available from 1993-2019 for retained east trawl samples, 1993-2020 for discarded east trawl samples, 1996-2020 for retained west trawl samples and 1992-2020 for discarded west trawl samples (Table 13.4, Table 13.5). Port samples were available between 1991-2020 for the east trawl fleet and 1992-2017 for the west trawl fleet (Table 13.4, Table 13.5).

Sample sizes for retained length frequencies, including both the number of individuals measured and numbers of shots or trips, are listed in Table 13.4 for the east trawl fleet and Table 13.5 for the west trawl fleet.

Table 13.4. Number of retained lengths, shots and trips included in the base case assessment for the east trawl fleet. Samples with less than 100 fish measured were not included in the assessment and are denoted with a *.

YEAR	ONBOARD DISCARD: LENGTHS	ONBOARD DISCARD: SHOTS	ONBOARD RETAINED: LENGTHS	ONBOARD RETAINED: SHOTS	PORT: LENGTHS	PORT: TRIPS
1991	0*	0	0*	0	273	4
1992	0*	0	0*	0	1,648	9
1993	290	5	225	2	1,087	6
1994	136	4	172	2	215	4
1995	706	15	142	2	500	5
1996	382	4	293	4	1,014	10
1997	234	3	1,585	19	1,762	18
1998	79*	1	3,060	33	6,386	63
1999	10*	1	2,449	32	6,347	68
2000	210	3	1,642	17	8,239	48
2001	888	9	1,446	17	7,958	61
2002	1,805	20	2,554	23	12,978	80
2003	1,597	19	2,050	29	5,431	37
2004	3,319	44	2,749	29	4,980	35
2005	1,332	19	2,028	25	10,147	46
2006	140	5	1,923	25	7,994	49
2007	0*	0	727	26	2,206	13
2008	298	12	584	21	971	6
2009	127	2	397	12	2,650	44
2010	174	7	1,419	30	1,714	50
2011	159	8	371	16	2,038	65
2012	471	13	848	32	1,748	45
2013	109	7	731	22	1,919	43
2014	163	2	142	4	1,391	25
2015	337	10	282	11	1,844	28
2016	518	16	452	14	1,516	20
2017	465	17	404	12	1,861	28
2018	593	16	321	6	1,229	20
2019	1,378	35	541	20	1,044	20
2020	634	23	5*	1	1,702	36

Table 13.5. Number of retained lengths, shots and trips included in the base case assessment for the west trawl fleet. Samples with less than 100 fish measured were not included in the assessment and are denoted with a *.

YEAR	ONBOARD DISCARD: LENGTHS	ONBOARD DISCARD: SHOTS	ONBOARD RETAINED: LENGTHS	ONBOARD RETAINED: SHOTS	PORT: LENGTHS	PORT: TRIPS
1991	0*	0	0*	0	51*	1
1992	158	1	0*	0	1,769	15
1993	243	6	0*	0	1,742	14
1994	2,401	25	0*	0	1,802	22
1995	4,082	35	0*	0	4,651	37
1996	3,766	31	122	1	6,023	53
1997	232	2	1,883	18	8,874	82
1998	1,998	16	2,671	20	9,704	89
1999	477	4	1,952	17	7,849	77
2000	283	4	3,698	33	5,424	47
2001	1,371	11	4,743	34	6,978	69
2002	1,257	8	4,047	26	9,064	72
2003	193	5	5,174	45	3,455	29
2004	1,111	9	3,788	27	2,760	24
2005	658	7	6,617	52	3,319	28
2006	0*	0	3,763	32	855	9
2007	0*	0	147	11	491	2
2008	36*	3	808	25	0*	0
2009	95*	2	1,021	41	333	5
2010	89*	3	1,341	39	47*	1
2011	152	10	1,242	51	0*	0
2012	6*	1	991	31	0*	0
2013	189	6	1,696	48	141	1
2014	0*		900	17	152	2
2015	66	4	934	24	0*	0
2016	2*	2	656	33	240	10
2017	723	8	549	17	226	5
2018	0*	0	1,094	15	69*	1
2019	86*	5	1,905	74	0*	0
2020	276	7	2,704	119	0*	0

13.3.2.5 Conditional age at length

Age-at-length measurements, based on sectioned otoliths, were available for 1993-2020 for the east trawl fleet and 1988, 1993-2020 for the west trawl fleet, with the number of aged otoliths available for the assessment presented in Table 13.6.

Table 13.6. Number of conditional age-at-length samples in the base case assessment

YEAR	EAST	WEST	TOTAL
1988	0	132	132
1993	172	163	335
1994	186	173	359
1995	157	294	451
1996	317	198	515
1997	443	123	566
1998	404	181	585
1999	220	562	782
2000	139	267	406
2001	366	631	997
2002	327	395	722
2003	122	302	424
2004	126	512	638
2005	250	375	625
2006	132	261	393
2007	237	69	306
2008	313	234	547
2009	493	345	838
2010	687	135	822
2011	543	309	852
2012	659	214	873
2013	89	383	472
2014	153	139	292
2015	165	218	383
2016	206	273	479
2017	220	316	536
2018	118	13	131
2019	414	475	889
2020	371	510	881

13.3.2.6 Age-reading error

An estimate of the standard deviation of age-reading error for the entire fishery (east and west combined) was calculated by Paul Burch (pers. comm. 2021) using data supplied by Kyne Krusic-Golub of Fish Ageing Services Pty Ltd using a variant of the method of Richards et al. (1992) (Table 13.7).

Table 13.7. Standard deviation (SD) of age reading error

AGE	SD
0	0.170607
1	0.170607
2	0.229462
3	0.290210
4	0.352911
5	0.417629
6	0.484427
7	0.553373
8	0.624537
9	0.697988
10	0.773802
11	0.852053
12	0.932821
13	1.016190
14	1.102230
15	1.191040
16	1.282710
17	1.377330
18	1.474980
19	1.575780
20	1.679820
21	1.787210
22	1.898040
23	2.012440

13.3.3 *Tuning method*

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

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

Length compositions were initially weighted using trip and shot numbers, where available, instead of numbers of fish measured and by adopting the Francis weighting method (Francis, 2011) for length composition data and the approach of Punt (2017) for conditional age-at-length data.

Shot or trip number is not available for all data, especially for some of the early length frequency data. In these cases, the number of trips was inferred from the number of fish measured using the average number of fish per trip for the relevant gear type for years where both data sources were available. The number of trips were also capped at 100 and the number of shots capped at 200. Samples with less than 100 fish measured per fleet, retained status and year were excluded.

In iterative reweighting, the effective annual sample sizes are tuned/adjusted so that the input sample size is equal to the effective sample size calculated by the model. In SS-V3.30 it is possible to estimate an additional standard deviation parameter to add to the input CVs for the abundance indices (CPUE). This is done by:

1. Set the standard error for the log of relative abundance indices (CPUE) to the standard deviation of a loess curve fitted to the original data, which will provide a more realistic estimate to that obtained from the original statistical analysis. SS-V3.30 then allows an estimate to be made for an additional adjustment to the relative abundance variances appropriately.
2. The initial value of the parameter determining the magnitude of the process error in annual recruitment, σ_R, is set to 0.7, reflecting the variation in recruitment for Silver Warehou. The magnitude of bias-correction depends on the precision of the estimate of recruitment and time-dependent bias-correction factors were estimated following the approach of Methot and Taylor (2011).

An automated iterative tuning procedure was used for the remaining adjustments. For the conditional age-at-length and length composition data:

3. Multiply the stage-1 (initial) sample sizes for the conditional age-at-length data by the sample size multipliers using the approach of Punt (2017).
4. Similarly multiply the initial samples sizes by the sample size multipliers for the length composition data using the ‘Francis method’ (Francis, 2011).
5. Repeat steps 3–4, until all are converged and stable (proposed changes < 1%).

This procedure constitutes current best practice for tuning assessments, however, it may be amended in the future.

13.3.4 *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 total allowable catches (TACs) in the SESSF quota management system from 2006 onwards. The HSF uses harvest control rules (HCRs) to determine a recommended biological catch (RBC) for each stock in the SESSF quota management system. Each stock is assigned to a Tier level depending on the quality and quantity of data for that stock. Silver Warehou is assessed as a Tier 1 stock as it has an agreed quantitative stock assessment.

The Tier 1 HCR specifies a target and a limit biomass reference point, as well as a target fishing mortality rate. In 2009, AFMA directed that the 20:35:48 (B_{lim}: B_{break}: F_{targ}) form of the rule is used, assuming a F_{targ} of F_{48}, the default economic target for B_{MEY} in the SESSF.

13.3.5 *Low recruitment scenario*

Estimates of recruitment strength for Silver Warehou have been below average since the early 2000s, potentially as a consequence of directional environmental change. If this below average recruitment trend continues into the future, assuming a return to average recruitment would result in overly optimistic biomass and stock status estimates. Due to these concerns the base case for this assessment incorporates low, rather than average, recruitment projected into the future. The projected value is based on the average recruitment deviations between 2011 and 2015 (average = -0.64).

13.3.6 *Retrospective analyses*

A retrospective analysis (Cadrin and Vaughan, 1997; Mohn, 1999) has been undertaken to identify whether below average recruitment and declining stock size would have been identified by previous assessments using the same assumptions, data and tuning as this assessment.

The retrospective analysis was undertaken using the following procedure:

1. One year of data was removed sequentially from the 2021 base case assessment;
2. Time dependent model parameters (e.g. last year of recruitment) were changed to be one year earlier;
3. The model was run to determine stock status estimates when less data is available;
4. Steps 1–3 were repeated for five subsequent years.

Trends in spawning biomass and estimated recruitment are then examined to help understand how reliable the most recent few years of estimated recruitments and spawning biomass are in the current assessment. The severity of retrospective patterns can be quantified using a statistic called Mohn’s rho, which is defined as the average of the relative differences between an estimate from an assessment with a truncated time series and an estimate of the same quantity from an assessment using the full time series (Hurtado-Ferro et al., 2015). Mohn’s rho values are calculated for a range of effects, including SSB, recruitment, F and stock status. As a general rule of thumb values of Mohn’s rho higher than 0.20 or lower than −0.15 are cause for concern in an assessment (Hurtado-Ferro et al., 2015).

13.3.7 *Likelihood profiles*

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

13.3.8 *Jitter analyses*

Jitter analysis is a technique used to test the optimality, robustness and stability of the maximum likelihood estimate obtained for a particular model. This involves randomly changing the starting values used for all estimated parameters and re-running the model, to test what alternative solutions may be found by the optimisation algorithm from different initial locations, which is sometimes referred to as sensitivity to initial conditions. Two diagnostics are of interest with a jitter analysis, initially a check on whether a better "optimal solution" may be found, with a higher likelihood value, and also to see how frequently the optimal solution is found. As all estimated parameters are randomly modified, or "jittered," simultaneously, this can sometimes result in a model either failing to converge or finding a local maximum in a different (suboptimal) part of the multi-dimensional parameter space. A jitter analysis was conducted with 25 replications, modifying initial values by 0.1.

13.3.9 *Sensitivity tests*

A number of standard sensitivity tests are used to examine the sensitivity of the results of the 2021 base case to some of the assumptions and data inputs:

a) M = 0.25 and 0.35 yr^{-1}.

b) h = 0.65, 0.85 and estimated.

c) 50% maturity occurs at length 34 and 40 cm.

d) σ_R = 0.6 and 0.8.

e) Double and halve the weighting on the CPUE series.

f) Double and halve the weighting on the length composition data.

g) Double and halve the weighting on the age-at-length data.

h) The assessment with average recruitment projections.

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

1. SSB_0: the average unexploited female spawning biomass.
2. SSB_{2022}: the female spawning biomass at the start of 2022.
3. SSB_{2022}/SSB_0: the female spawning biomass depletion level at the start of 2022.

13.4 Results

13.4.1 *The base case assessment model*

The development of a preliminary base case, and a bridging analysis from the 2018 assessment (Burch et al., 2018), was presented at the September 2021 SERAG 1 meeting (Bessell-Browne, 2021), including updating the version of Stock Synthesis and sequentially updating data. This bridging analysis is not repeated in this report.

13.4.1.1 Parameter estimates

Figure 13.6 shows the estimated growth curve for Silver Warehou. L_∞ or the average maximum length was estimated to be 51.3 cm, with the upper confidence interval estimated at around 60 cm, while the lower interval was around 42 cm (Figure 13.6). The length at a_{min} was estimated at 14.1 cm for one year olds (Figure 13.6). The κ parameter of the von Bertalanffy growth equation is estimated to be 0.30.

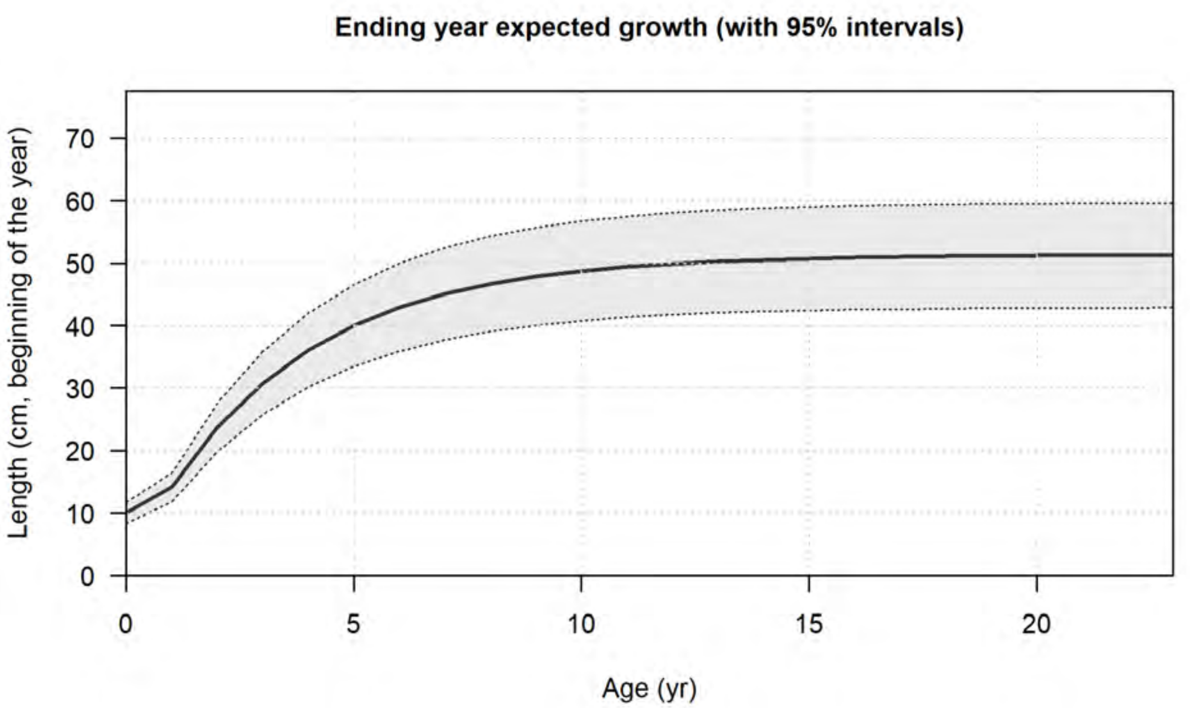

Figure 13.6. The model estimated growth curve, with 95% confidence intervals

Selectivity is assumed to be logistic and to differ between the two fleets. The parameters that define the selectivity function are the length at 50% selection and the spread (the difference between length at 50% and length at 95% selection). The selectivity curve estimated by the model is displayed in Figure 13.7, with parameter estimates specified in Table 13.8. Separate retention functions were estimated for each fleet to allow for different discarding practices. The two estimated retention functions are displayed in Figure 13.8 and Figure 13.9.

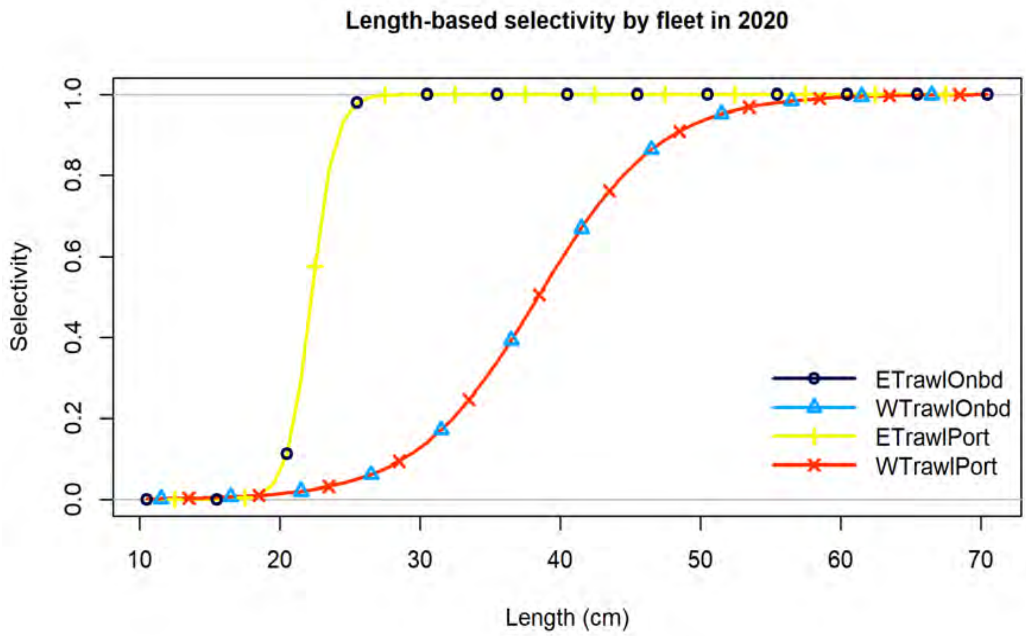

Figure 13.7. Estimated selectivity curves

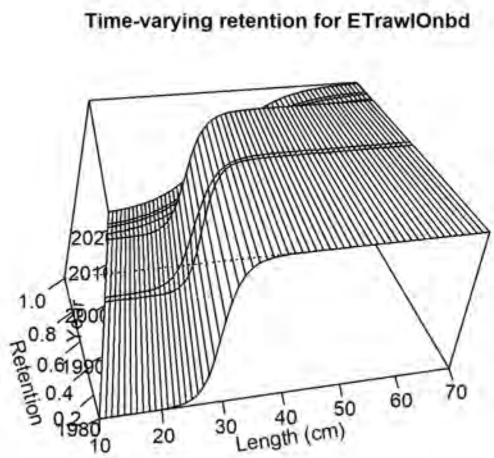

Figure 13.8. Estimated retention for the east trawl fleet

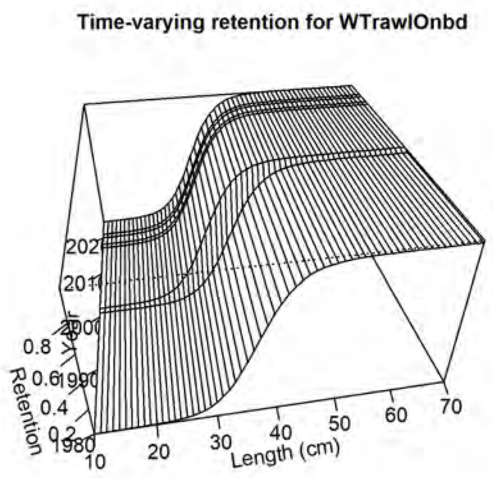

Figure 13.9. Estimated retention for the west trawl fleet

Parameters estimated within the model are presented in Table 13.8.

Table 13.8. Parameter values estimated by the base-case model

Parameter	Value
L_at_amin	14.12
L_at_amax	51.30
VonBert_K	0.30
CV_young	0.08
Q_EastTrawl	9.40
Q_WestTrawl	-0.02
Size inflection Etrawl	22.24
Size 95% width Etrawl	2.50
Size inflection Wtrawl	38.40
Size 95% width Wtrawl	12.91

13.4.1.2 Fits to data

The results from this model show good fits to CPUE abundance indices for both fleets (Figure 13.10, Figure 13.11). These fits are similar to those observed in the 2018 assessment, however, fits to the start of the west trawl series have improved. The model estimates an additional standard error on top of that input for the east trawl fleet, suggesting higher variability associated with this series than the standardisation suggested (Figure 13.10). The opposite trend is observed for the west trawl fleet, where a smaller standard deviation was estimated than that of the loess fit (Figure 13.11).

The model is also unable to fit the high east trawl CPUE estimates between 1985 and 1995, which suggest there was a larger decline in abundance in the early 1990s and 2000s than the model suggests (Figure 13.10). Residuals of the fits to CPUE for the east trawl fleet show potential problems, with all residuals above zero prior to 1995, residuals between 1996 and 2008 are then all below zero and a mix of points above and below zero are only observed from 2010 (Figure 13.12). In contrast the residuals of the fit to the west trawl CPUE are well mixed above and below zero suggesting good fits to the data (Figure 13.13). This discrepancy between residual fits between the two fleets is not unexpected as the model is fitting to the two series simultaneously and this appears to be the best compromise under this constraint.

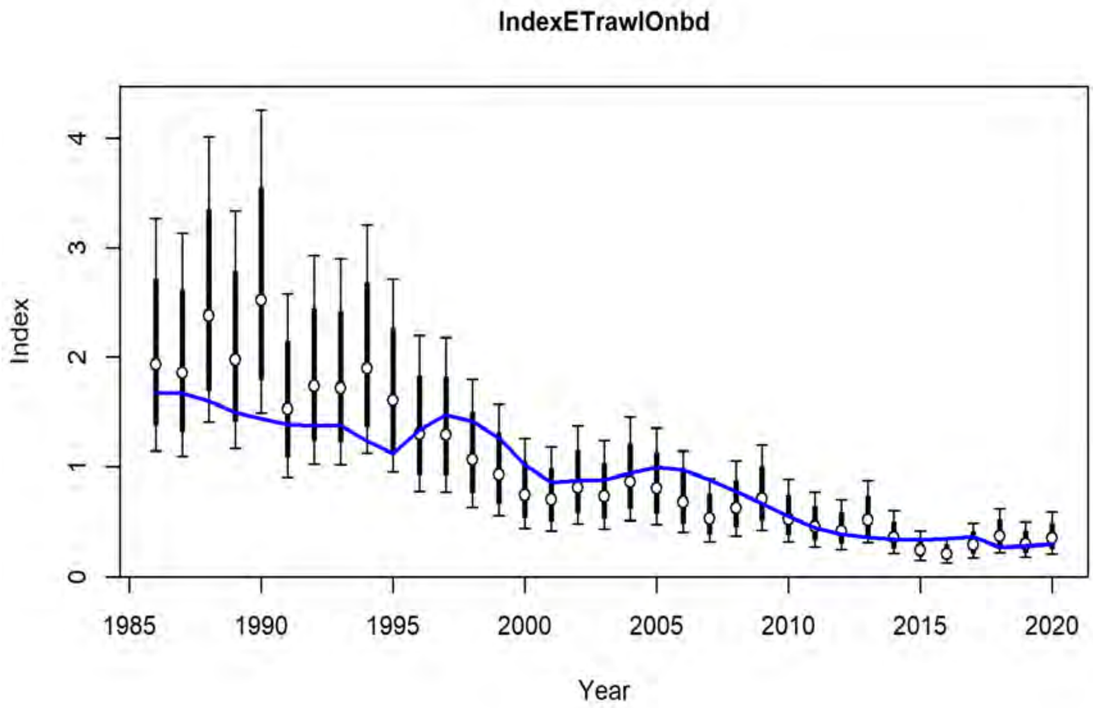

Figure 13.10. Fits to the east trawl CPUE

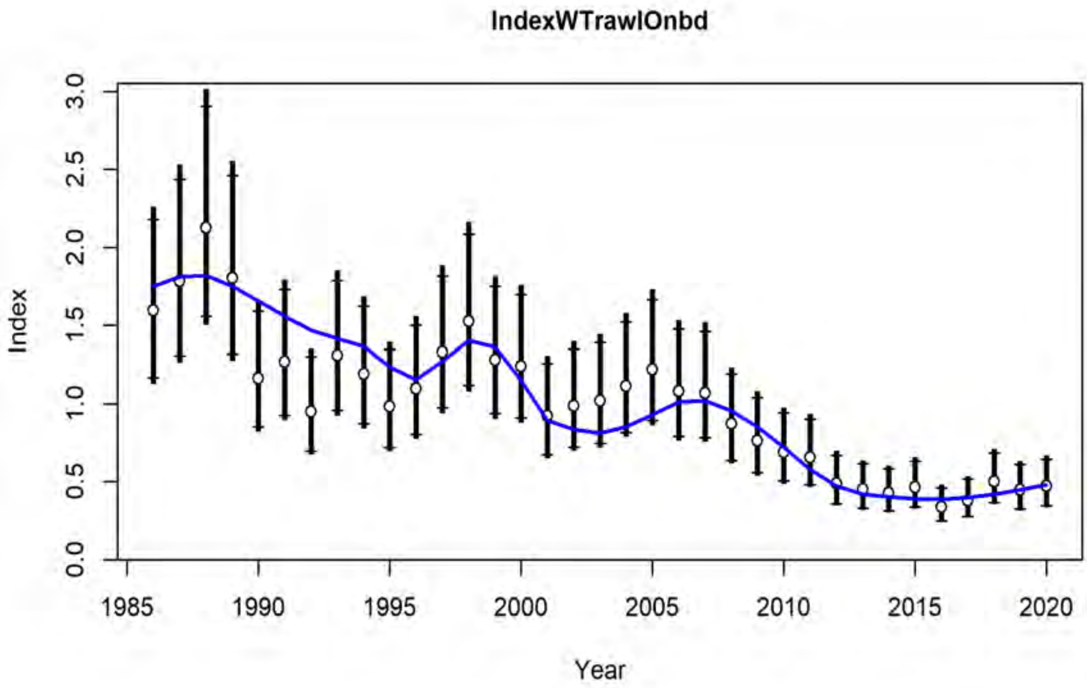

Figure 13.11. Fits to the west trawl CPUE

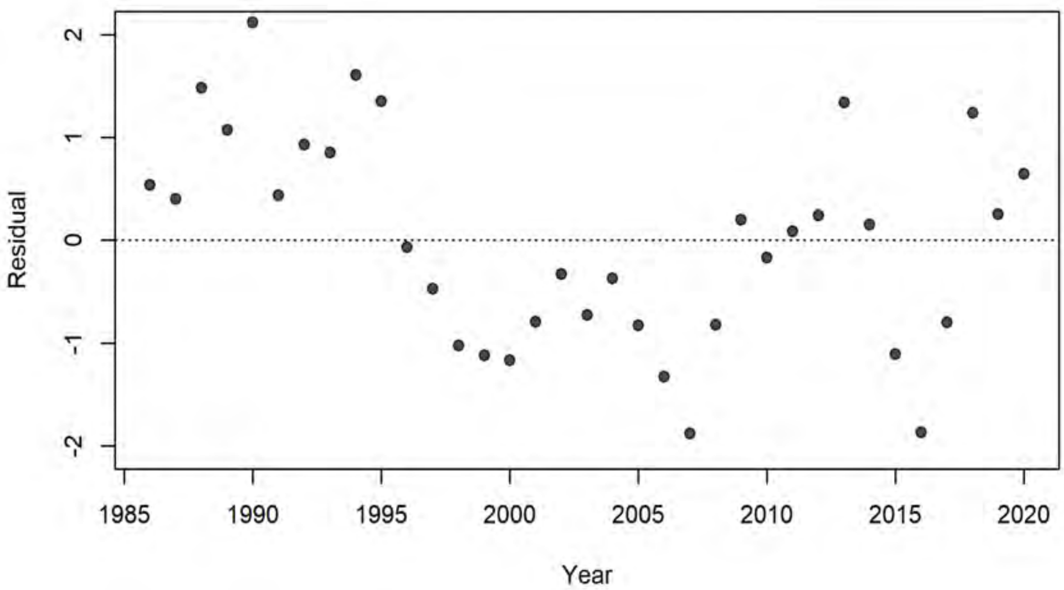

Figure 13.12. Residuals for fits to CPUE for the east trawl fleet

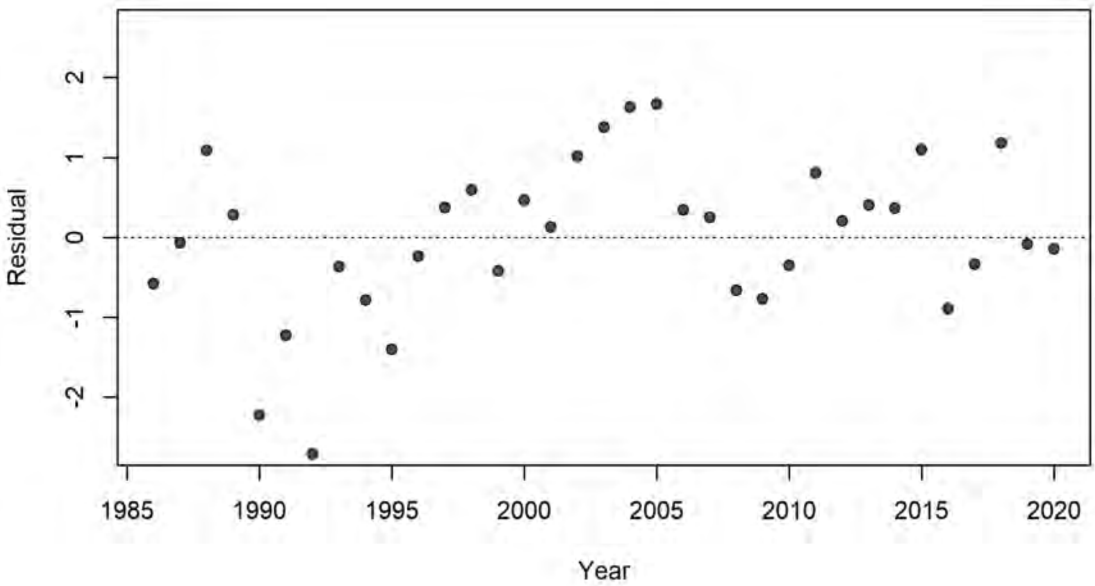

Figure 13.13. Residuals for fits to CPUE for the west trawl fleet

The fits to the discard rate data are reasonable given the variability in the data. Discard data in the east trawl fleet fit more closely than observed in previous assessments, although it is still not fitting the highest east trawl estimates in 1995 and 2020 (Figure 13.14). Fits to discard data in the west are similar to those observed in previous assessments and fit the data reasonably well (Figure 13.15). Generally discarding in the west trawl fleet has been lower and less variable than that observed in the east trawl fleet (Figure 13.14-Figure 13.15).

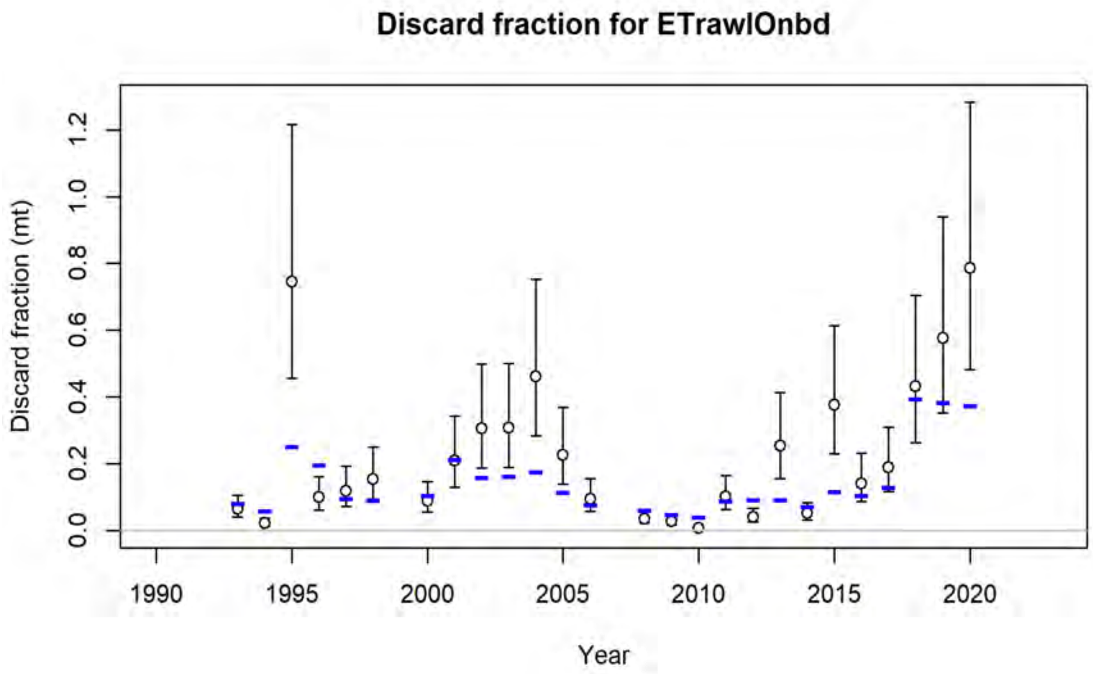

Figure 13.14. Fits to the east trawl discards

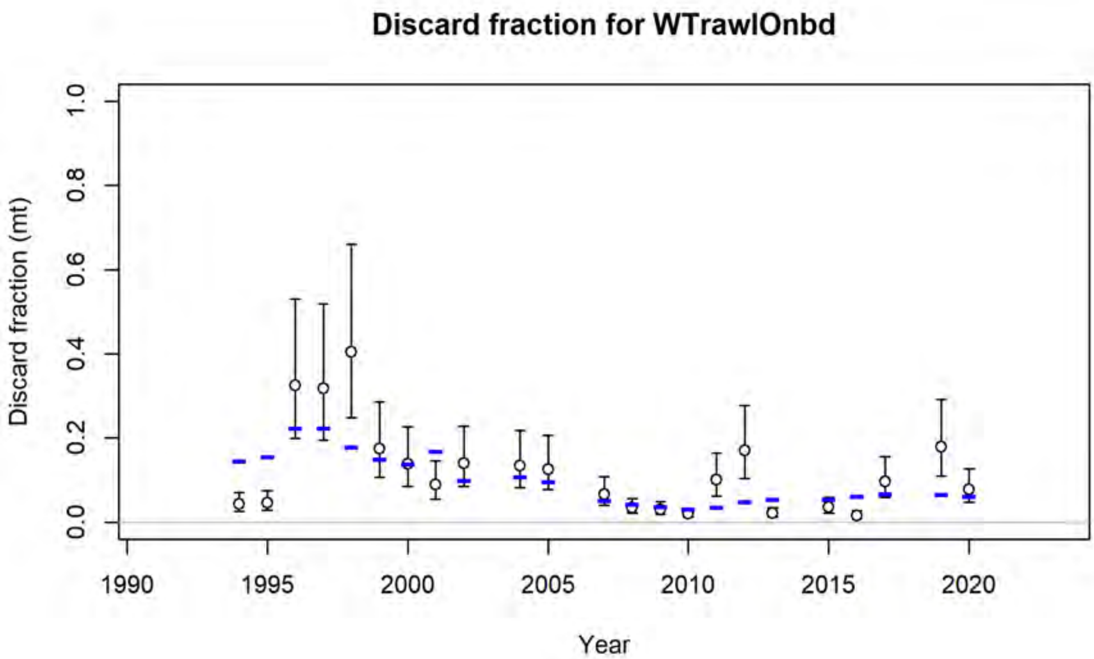

Figure 13.15. Fits to the west trawl discards

As with previous models, fits to the aggregated length frequencies are poor across both fleets (Figure 13.16). These poor fits are driven by highly variable length frequencies, often showing multiple modes in the distributions that are not consistent from one year to the next (Figure 13.16). This is most likely due to unrepresentative spatial and temporal sampling of this schooling species. The estimated length frequencies are also not able to fit the small fish that were observed across both fleets over the past five years. Fits to individual years of length frequency data by fleet and sampling type are presented in Figure 13.49–Figure 13.54, while residual patterns are presented in Figure 13.55.

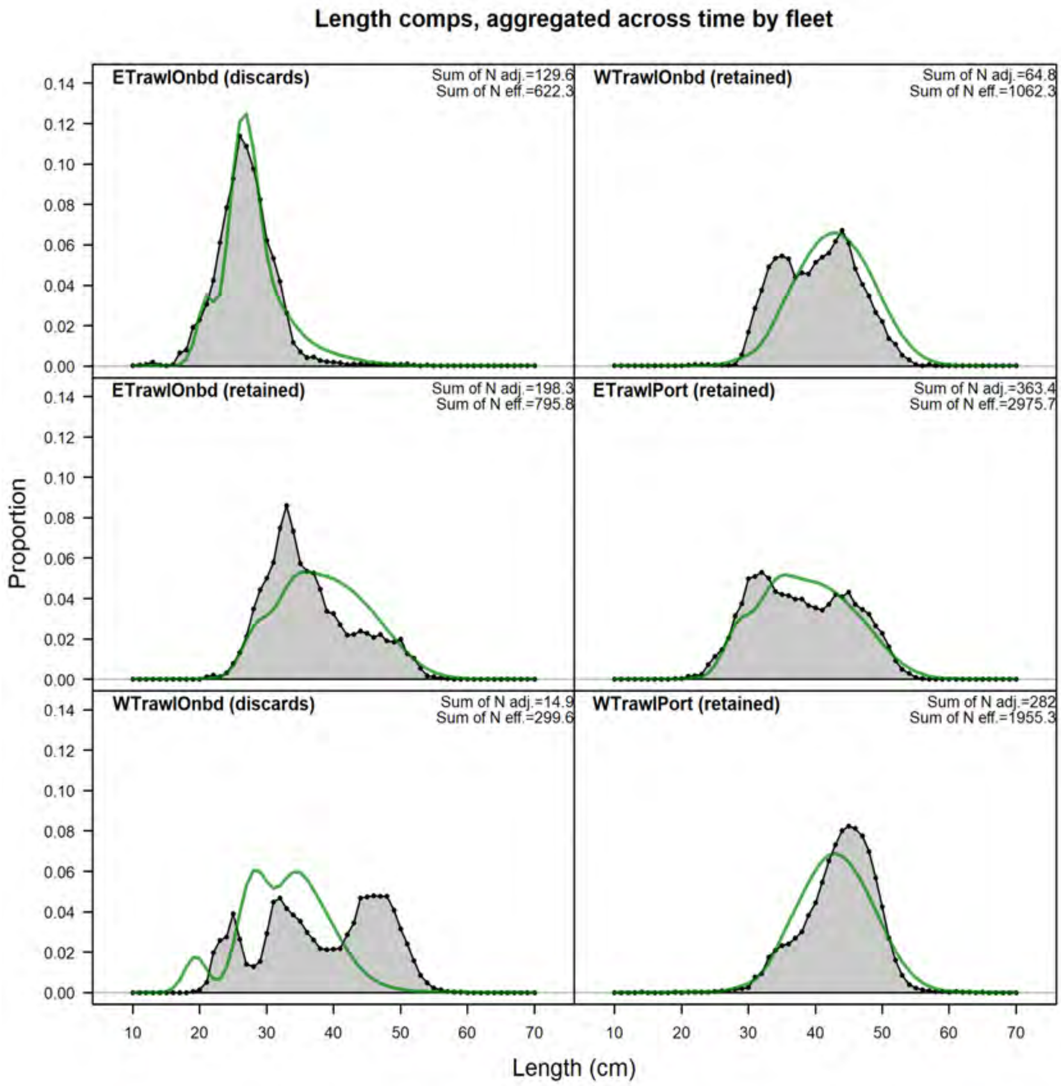

Figure 13.16. Fits to the aggregated length data

Fits to the conditional age at length data are good, with fits for individual years presented in Figure 13.56–Figure 13.67. The mean age varies between two and six years for east trawl fish and three and six for west trawl fish, however since 1993 this range has been between four and six (Figure 13.68–Figure 13.69). Residuals for these fits and mean age for each year are shown in Figure 13.70–Figure 13.73.

13.4.1.3 Likelihood components

The contributions to the total negative log likelihood by fleet and data source is shown in Table 13.9. This gives an indication of the contribution to the total negative log likelihood from different data components. These likelihood components decrease as the fit improves yet increase as the number of data points used for this fit increases, so a direct comparison is not always useful. Both east trawl and west trawl CPUE series have the same number of data points so comparisons are available, with the west trawl showing a lower negative log likelihood and therefore a better fit to the data than the east trawl fleet (Table 13.9). For the discard data, different numbers of data points are available for each fleet so comparisons are not directly available. For the length data there is clearly much poorer fits to the east trawl onboard data than observed for the east trawl port data and also west trawl onboard and port data (Table 13.9). For the age data, the east trawl fleets shows improved fits when compared to the west trawl fleet (Table 13.9).

Table 13.9. Negative log likelihood contributions by fleet and data source

Fleet	CPUE	Discard	Length	Age
East trawl (onboard)	-27.4	65.1	172.5	124.5
East trawl (port)			66.6	
West trawl (onboard)	-49.6	59.5	46.7	199.4
West trawl (port)			46.3	

13.4.1.4 Assessment outcomes

This assessment estimates that the projected 2022 spawning stock biomass will be 29% of SSB_0 (projected assuming 2020 catches in 2021; Figure 13.17), compared to 31% at the start of 2019 from the 2018 assessment (Burch et al., 2018). Moving to the model with low recruitment projections as the base case for this assessment has been the main driver of this downward revision of stock status.

Between 2013 and 2018 estimated biomass was close to the limit reference point and only in the past three years has stock status increased towards the target reference point, with this particularly concerning when error around estimates is considered (Figure 13.17). It is likely that this increase in stock status has been driven by decreases in catch below TAC levels.

The base case assessment estimated the unexploited spawning stock biomass, SSB_0, to be 18,806 t (Figure 13.18). This decreases to 5,374 t by 2022 (Figure 13.18).

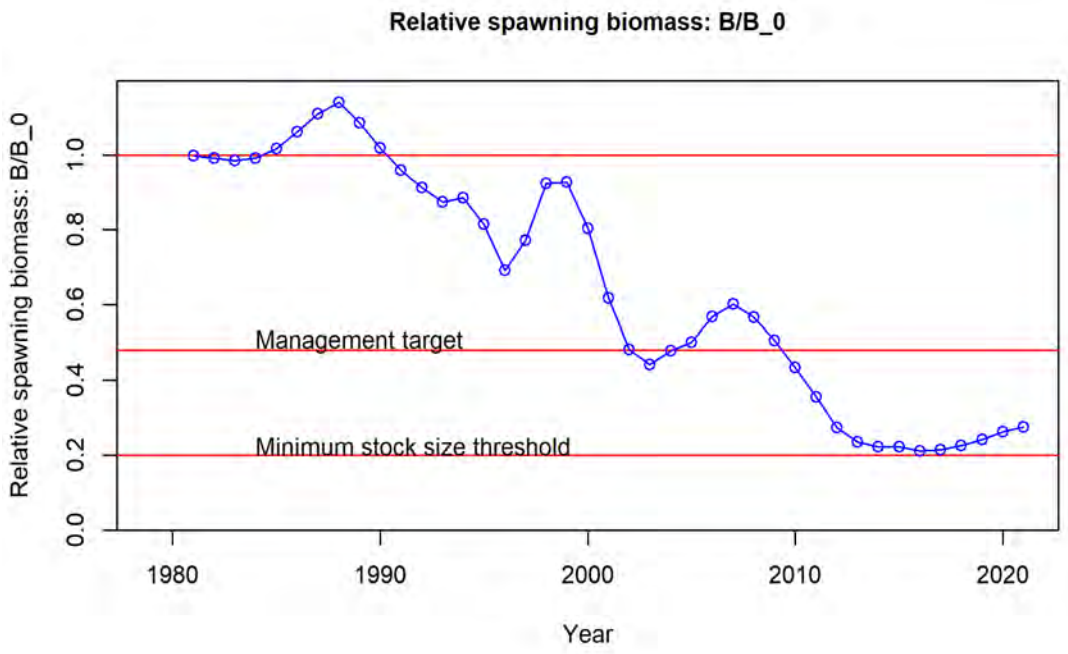

Figure 13.17. The estimated time-series of relative spawning biomass

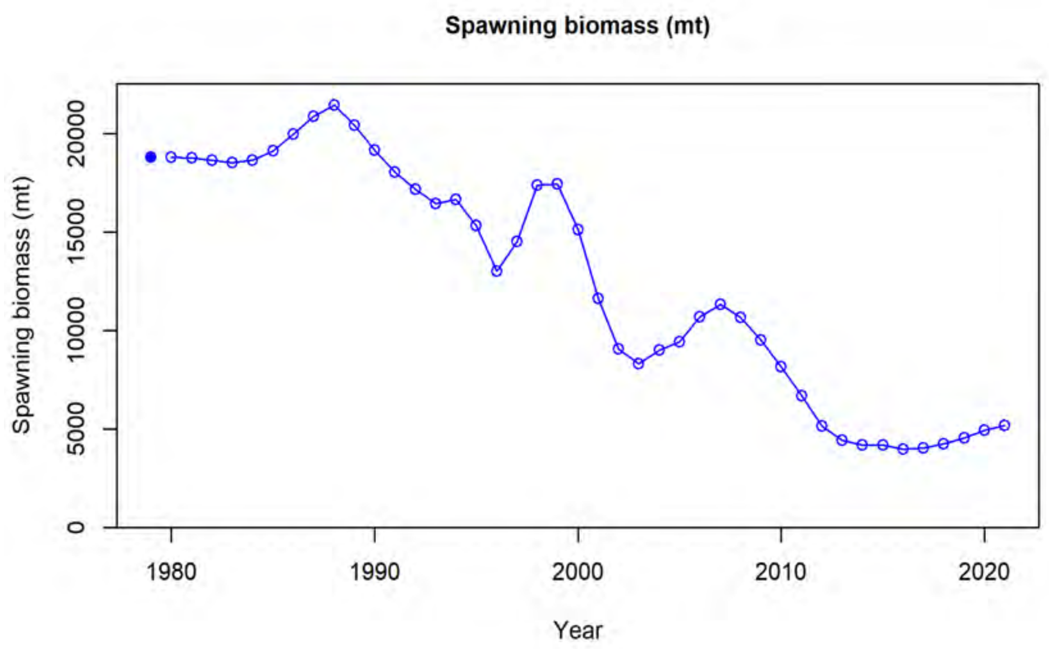

Figure 13.18. The estimated time-series of absolute spawning biomass

Recruitments show a fluctuating pattern, with a recent period of poor, below average, recruitment from 2004 to the last estimated recruitment in 2015. The 2015 and 2013 recruitments are closer to the average, however, previous assessment have highlighted that recruitment deviations at the end of the series are often revised downwards with the inclusion of additional years of data so these should be interpreted with caution (Figure 13.19, Figure 13.20).

The estimated stock recruitment curve demonstrates the relationship between the size of the population and the number of recruits produced in a year. The relationship shows that at the start of the time series, between 1975 and 1980, the spawning biomass was large and many recruits were produced (Figure 13.21). This was followed by a period of reduced spawning biomass but high recruitment between 1990 and 2000 (Figure 13.21). Since 2000, both spawning biomass and recruitment have been low (Figure 13.21).

The variance associated with estimation of recruitment deviations is shown in Figure 13.23. Between 1970 and 1990 there is a gradual decline in variance as more data is available to the model to inform estimation (Figure 13.23). The variance between 1990 and 2015 at the end of the recruitment deviation time series is relatively stable, suggesting that the model has sufficient information to inform the estimation of these deviations (Figure 13.23).

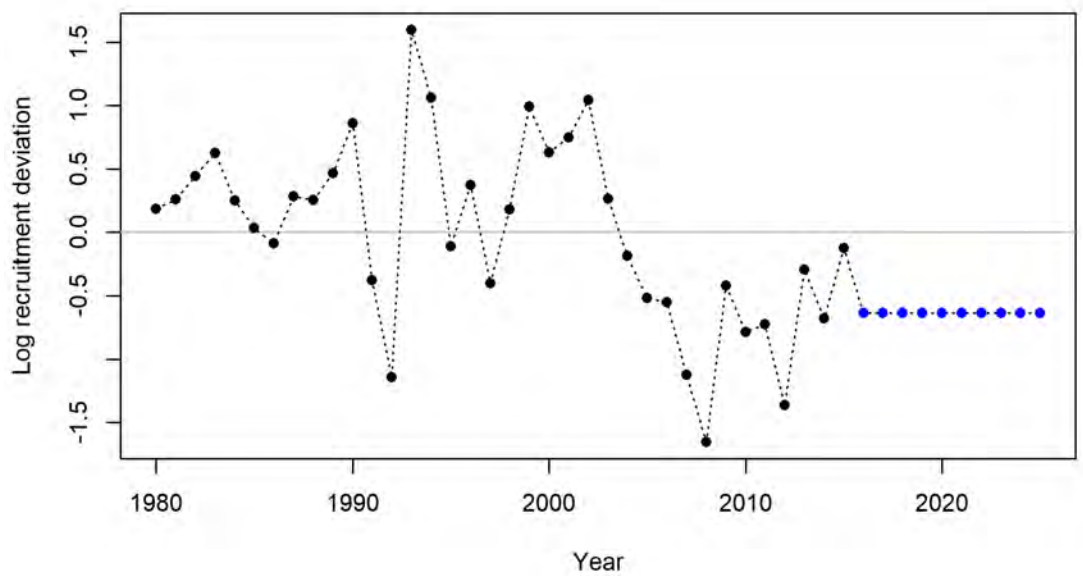

Figure 13.19. Estimated recruitment deviations

Figure 13.20. Absolute recruitment estimates

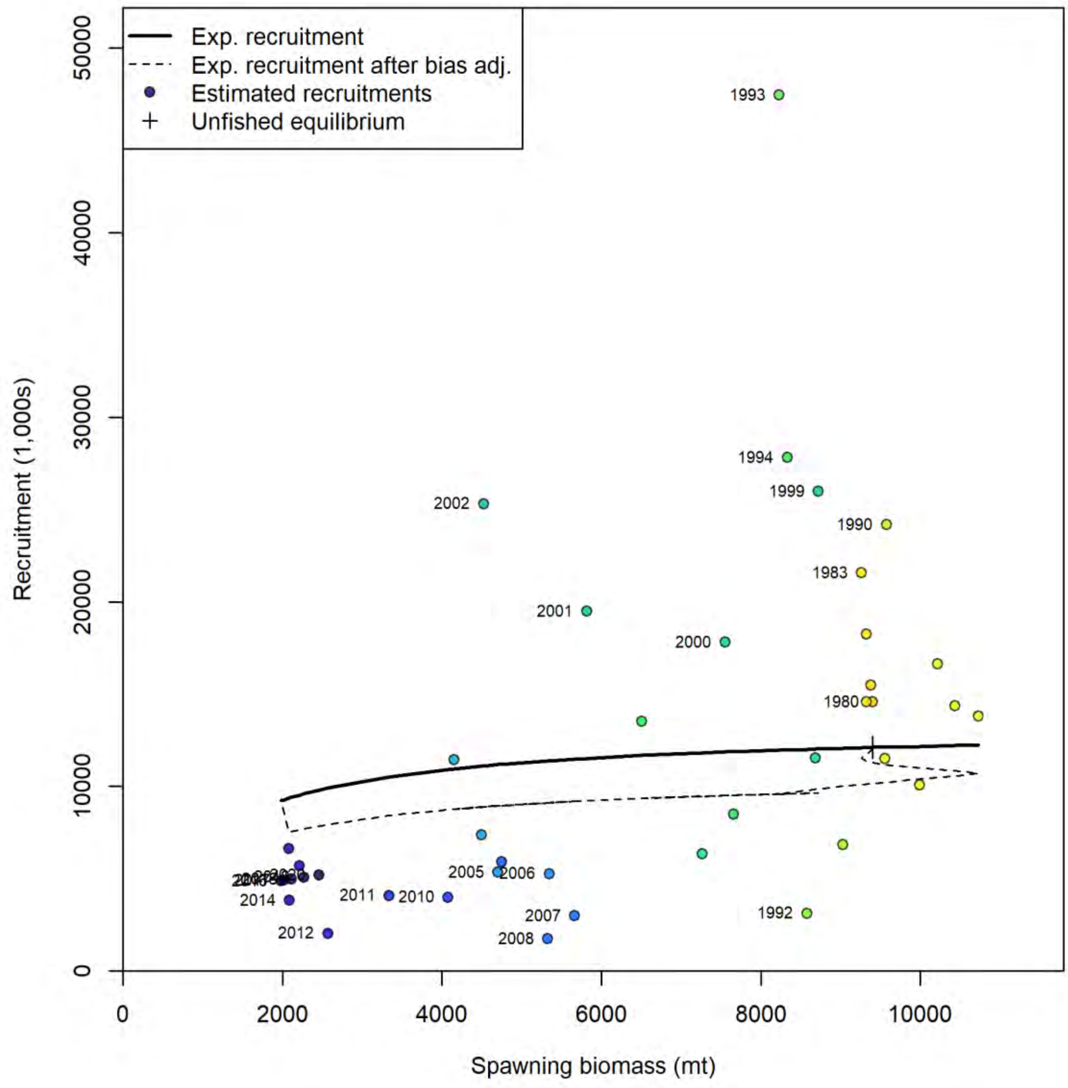

Figure 13.21. Stock recruitment curve

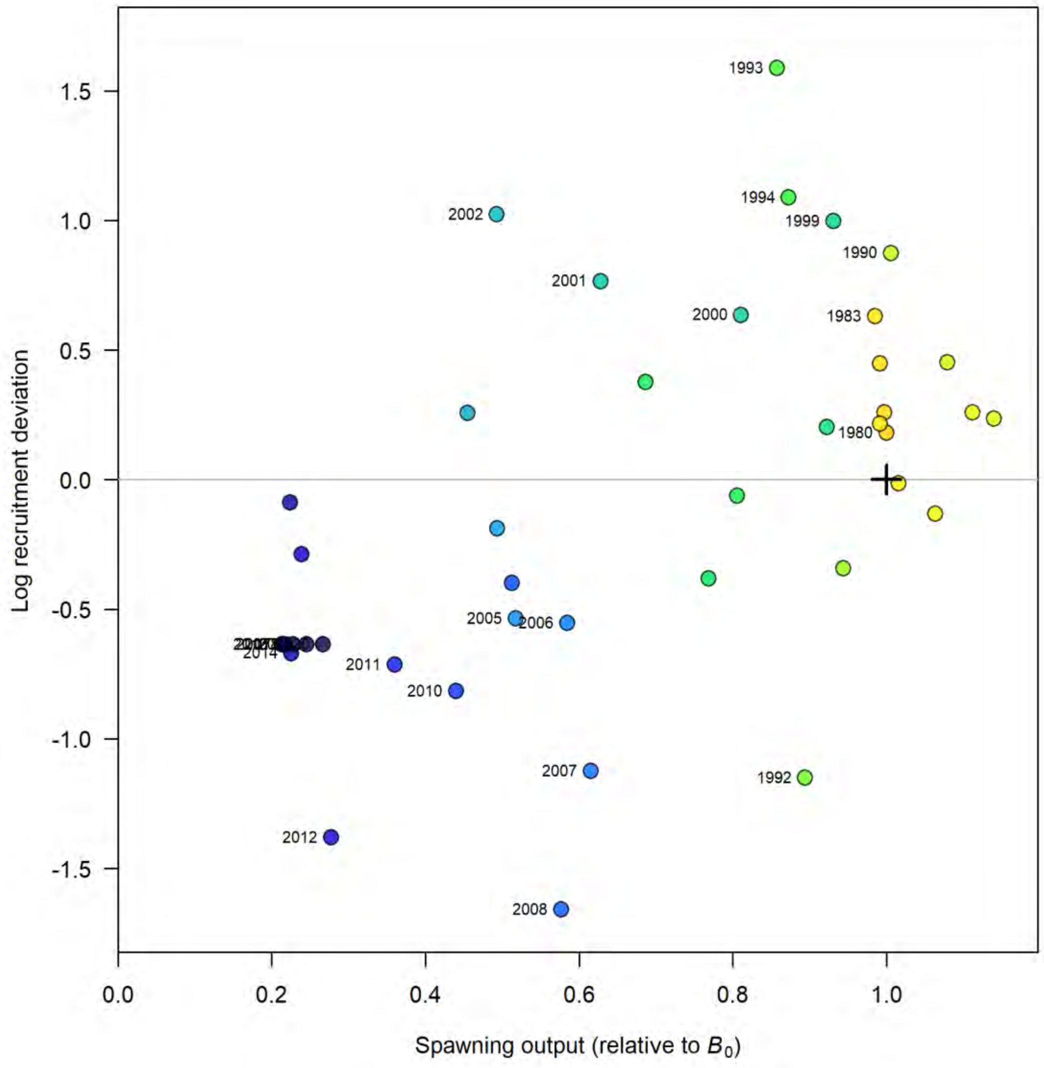

Figure 13.22. Residuals from the stock recruitment curve

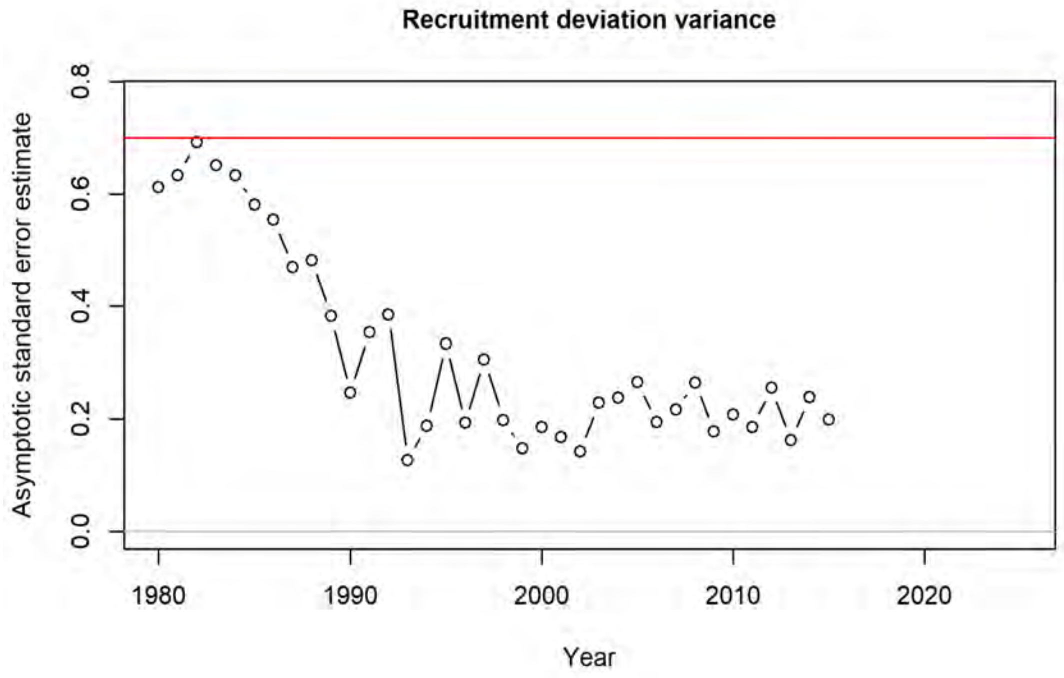

Figure 13.23. Recruitment deviation variance check

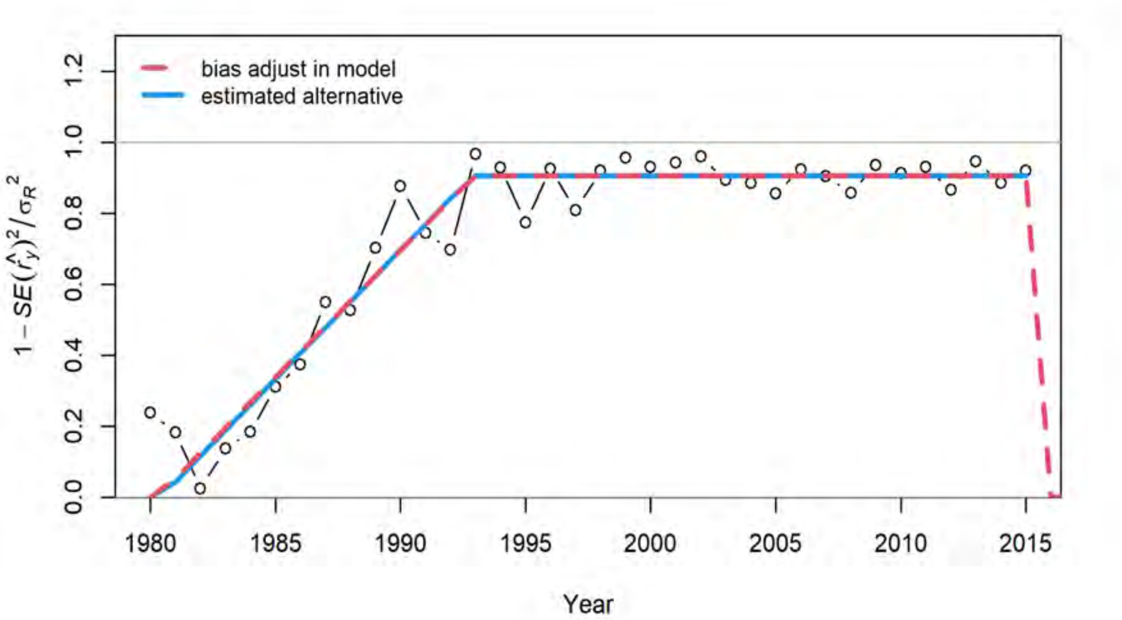

Figure 13.24. Recruitment deviation bias ramp adjustment

Figure 13.25 shows a Kobe plot for the base case analysis. This plot shows a time series of spawning biomass plotted against spawning potential ratio, which provides a measure of overall fishing mortality, and shows the stepwise movement in this space from the start of the fishery. The assessment starts in the bottom right corner, when there was low fishing mortality and high biomass, fishing pressure then increased to around target levels, resulting in a decline in biomass, before fishing pressures dropped for a period before stabilising around the target and then falling to below the target with a small increase in biomass in the last few years (Figure 13.25).

The relationship between fishing pressure and time is presented in Figure 13.26, demonstrating that fishing pressure has been above the target from the late 1990s to the late 2000s. For the past eight years fishing pressure has dropped below the target level (Figure 13.26).

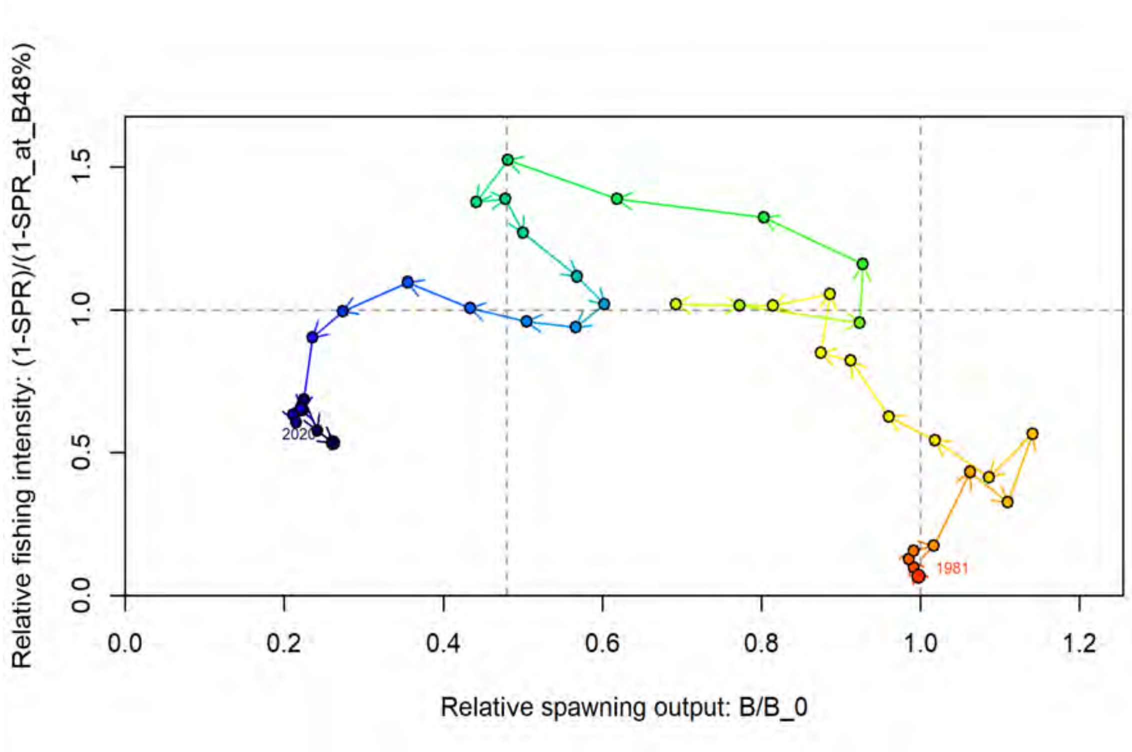

Figure 13.25. Kobe plot of biomass vs SPR ratio, the grey, horizontal dashed line represents the target fishing mortality, while the two vertical dashed lines represent the target and unfished spawning biomass respectively from left to right

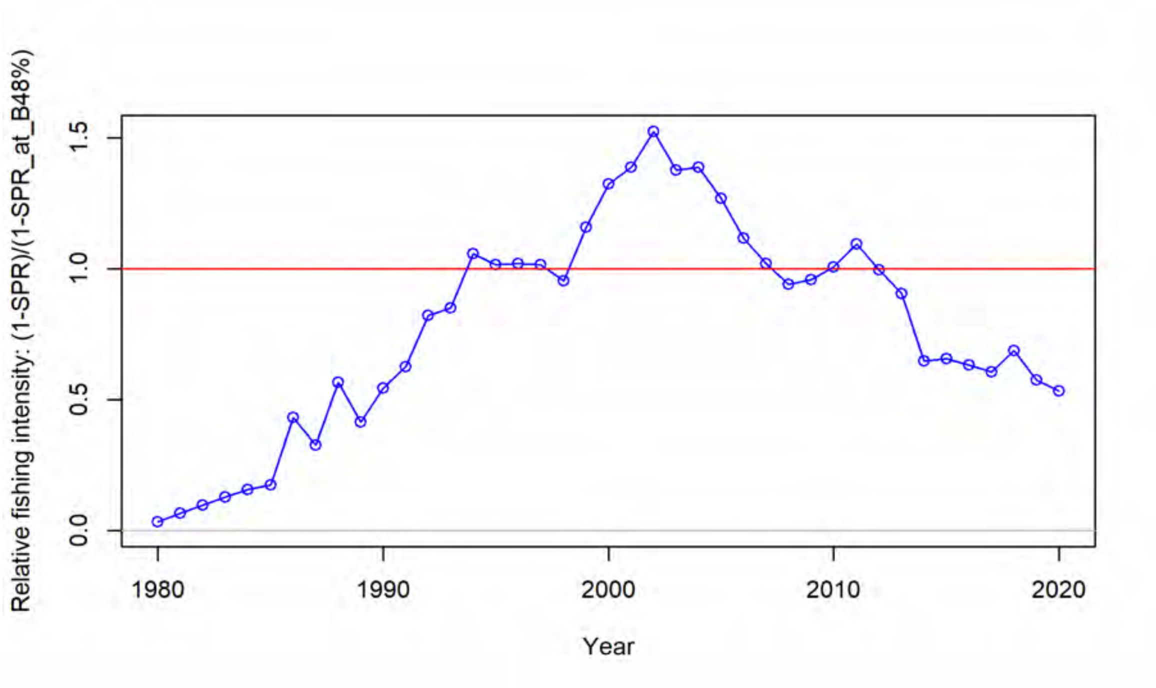

Figure 13.26. SPR ratio through time, the red line represents the target fishing mortality and each point is a year in the model, starting on the left hand side of the figure at 1980

13.4.2 *Application of the HCR*

An estimate of the catch for the 2021 calendar year is needed to run the model forward to calculate the 2022 spawning biomass and estimated stock status. We assume the same catch in 2021 as was caught in 2020, which was 375 t. The assessment estimates the 2022 stock status to be 29% of SSB_0 (Figure 13.27). Stock status was below 23% between 2015 and 2018, and was as low as 21% in 2016, close to the limit reference point of 20% of SSB_0 (Figure 13.27).

Figure 13.27 demonstrates that the application of the current HCR does not increase the stock size to the target reference point of 48% SSB_0. This is because the current HCR assumes that future recruitment will be at average levels, whereas the accepted base case for this assessment projects forward below average recruitment.

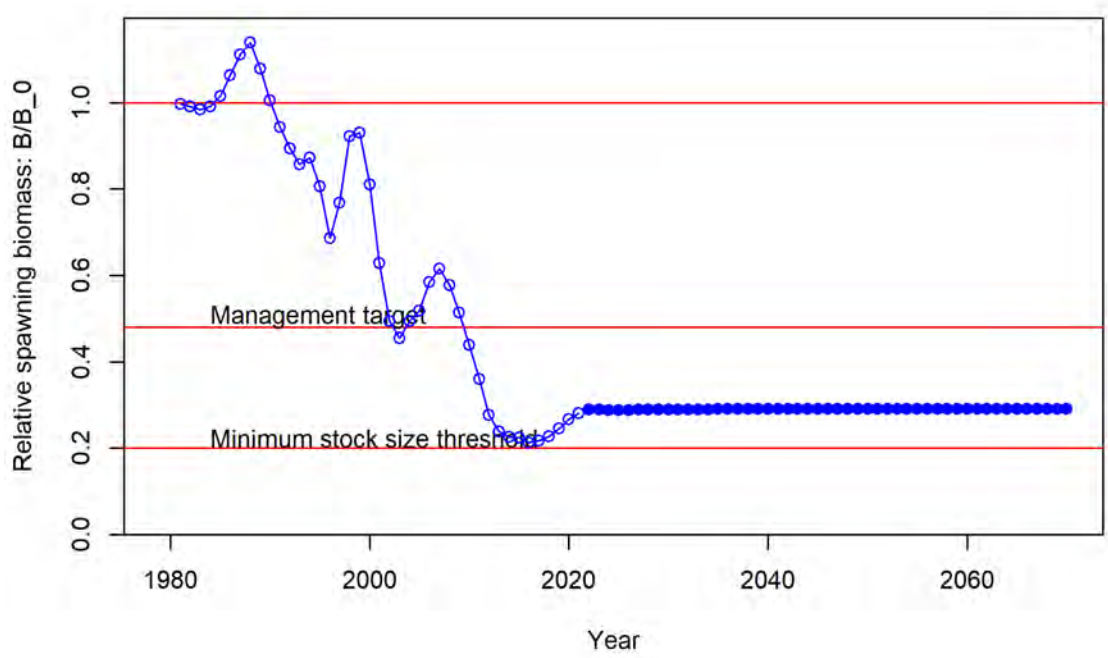

Figure 13.27. The estimated time-series of relative spawning biomass with projections applying the HCR to 2070

The predicted RBCs resulting from the application of the HCR, along with stock status estimates and retained catch and discards are presented in Table 13.10 from 2022 to 2025, with estimates of stock status, retained catch and discard estimates provided for 2018 to 2025.

Table 13.10. Summary of estimated stock status, RBCs and estimated discard mass for the base case assuming low recruitment projections under the 20:35:48 harvest control rule.

Year	Stock status (%)	RBC (t)	Retained catch (t)	Estimated discard (t)
2018	23	-	393	89
2019	25	-	334	70
2020	27	-	297	80
2021	29	-	297	78
2022	28	587	467	120
2023	29	580	461	119
2024	29	575	457	118
2025	29	575	457	118

13.4.3 *Fixed catch, low recruitment projections*

Estimates of recruitment strength for Silver Warehou have been below average since the early 2000s (Figure 13.19), with this potentially a consequence of directional environmental change. If this below average recruitment trend continues into the future, assuming a return to average recruitment would result in overly optimistic biomass and stock status estimates. Due to these concerns, the base case for this assessment incorporates low, rather than average, recruitment projected into the future. The projected value is based on the average recruitment deviations between 2011 and 2015 (average = -0.64). Constant annual catches have been projected with this low recruitment level to explore biomass trajectories into the future. The recruitment deviation series with projections is presented in Figure 13.19.

As the low recruitment scenario markedly reduces stock productivity, the population is no longer able to recover to unfished levels, with this apparent in the 0 t catch projection scenario, where the population only recovers to 49% of SSB_0 (Figure 13.28, blue line).When various fixed catches are projected into the future (250 t, 350 t, 450 t and the RBC), the recovery of the population declines to a different stable level for each fixed catch scenario (Figure 13.28). The RBC is calculated from the base case assessment with low recruitment projections. Any catches above 450 t limit further recovery of stock status towards the target reference point (Figure 13.28).

Table 13.11 provides annual stock status, retained catches and estimated discards for the low recruitment scenarios with zero catch (0 t), 250 t, 350 t and 450 t catches and applying the standard SESSF harvest control rule (HCR, 587 t catch in 2022), with catches and discards summed across both the east trawl and west trawl fleets.

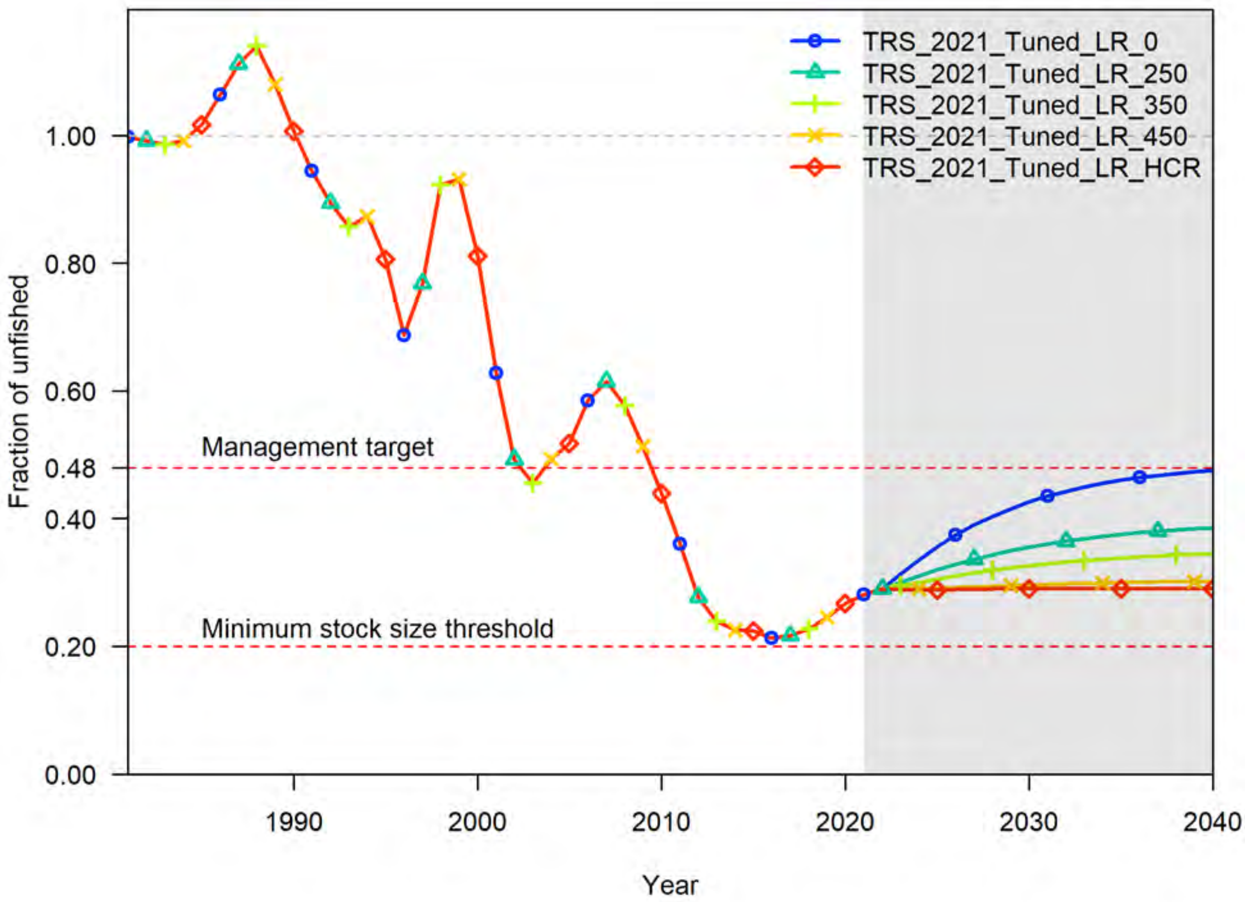

Figure 13.28. Relative spawning biomass time-series for the RBC calculated by the SESSF harvest control rule (red, HCR), and four alternative constant catch scenarios 0 t, 250 t, 350 t, 450 t. All scenarios assume low recruitment for the entire forecast period

Table 13.11. Stock status (SS), retained catch (RET, t) and estimated discards (DIS, t) corresponding to the low recruitment, fixed catch projection scenarios with the zero catch (0 t), 250 t constant catch, 350 t constant catch, 450 t constant catch and applying the HCR (587 t in 2022)

YEAR	0 t			250 t			350 t			450 t			HCR		
	SS	RET	DIS	SS	RET	DIS	SS	RET	DIS	SS	RET	DIS	SS	RET	DIS
2022	0.29	0	0	0.29	250	61	0.29	350	86	0.29	450	110	0.29	587	120
2023	0.31	0	0	0.30	250	60	0.30	350	85	0.29	450	110	0.29	580	119
2024	0.34	0	0	0.31	250	59	0.30	350	85	0.29	450	110	0.29	575	118
2025	0.36	0	0	0.32	250	59	0.31	350	84	0.29	450	110	0.29	575	118
2026	0.37	0	0	0.33	250	58	0.31	350	84	0.29	450	110	0.29	580	119
2027	0.39	0	0	0.34	250	58	0.31	350	83	0.29	450	110	0.29	585	120
2028	0.40	0	0	0.34	250	57	0.32	350	83	0.29	450	110	0.29	588	121
2029	0.42	0	0	0.35	250	57	0.32	350	83	0.30	450	110	0.29	590	121
2030	0.43	0	0	0.36	250	56	0.33	350	82	0.30	450	110	0.29	590	121
2031	0.44	0	0	0.36	250	56	0.33	350	82	0.30	450	110	0.29	591	121
2032	0.44	0	0	0.36	250	56	0.33	350	82	0.30	450	110	0.29	591	121
2033	0.45	0	0	0.37	250	56	0.33	350	81	0.30	450	109	0.29	591	122
2034	0.46	0	0	0.37	250	55	0.34	350	81	0.30	450	109	0.29	591	122
2035	0.46	0	0	0.38	250	55	0.34	350	81	0.30	450	109	0.29	591	122
2036	0.46	0	0	0.38	250	55	0.34	350	81	0.30	450	109	0.29	591	122
2037	0.47	0	0	0.38	250	55	0.34	350	81	0.30	450	109	0.29	591	122
2038	0.47	0	0	0.38	250	55	0.34	350	81	0.30	450	109	0.29	591	122
2039	0.47	0	0	0.38	250	55	0.34	350	81	0.30	450	109	0.29	591	122
2040	0.48	0	0	0.39	250	55	0.35	350	80	0.30	450	109	0.29	591	122

13.4.4 *Retrospective analysis*

The retrospecives analyses were conduced on the base case with low rectuitment projections and retrospecives with average recruitment projections are also presented for comparison. A retrospective analysis for absolute spawning biomass is shown in Figure 13.29, with the data after 2020 removed initially (shown in light blue), then successive years of data removed back to 2015 (shown in red). The same analysis is plotted in terms of relative stock in Figure 13.31. In both cases there is downward revision when additional years of data are included, with this particuarily evident between 2016 and 2017 and again to a lesser extent between 2018 and 2019 (Figure 13.29, Figure 13.31). These retrospective patters are much smaller than those observed for the model without low recruitment projections (Figure 13.30, Figure 13.32).

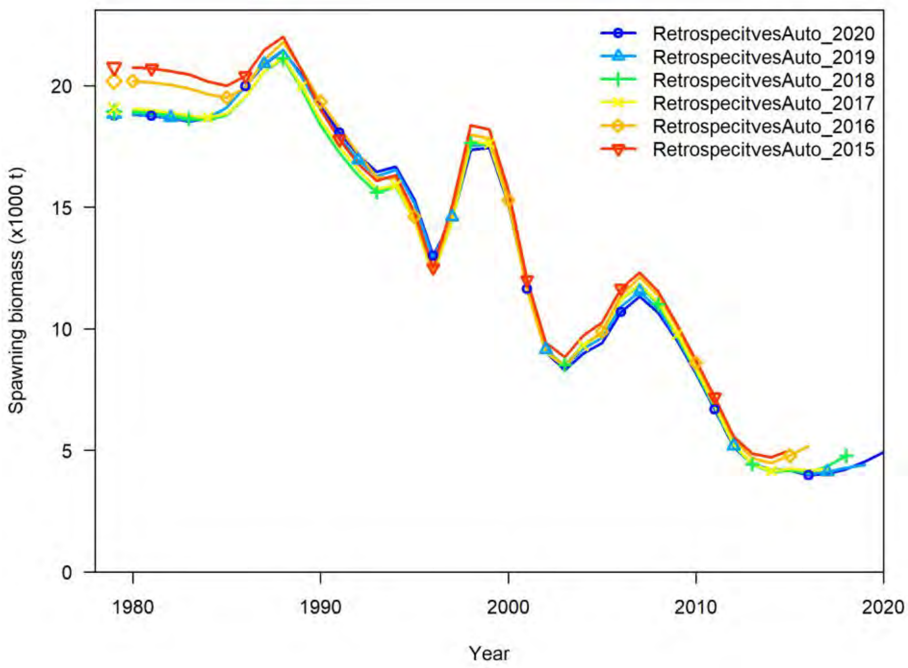

Figure 13.29. Retrospectives for absolute spawning biomass for the base case assessment with low recruitment projections, with data included to 2020 (blue) and then successive years removed back to 2015 (red)

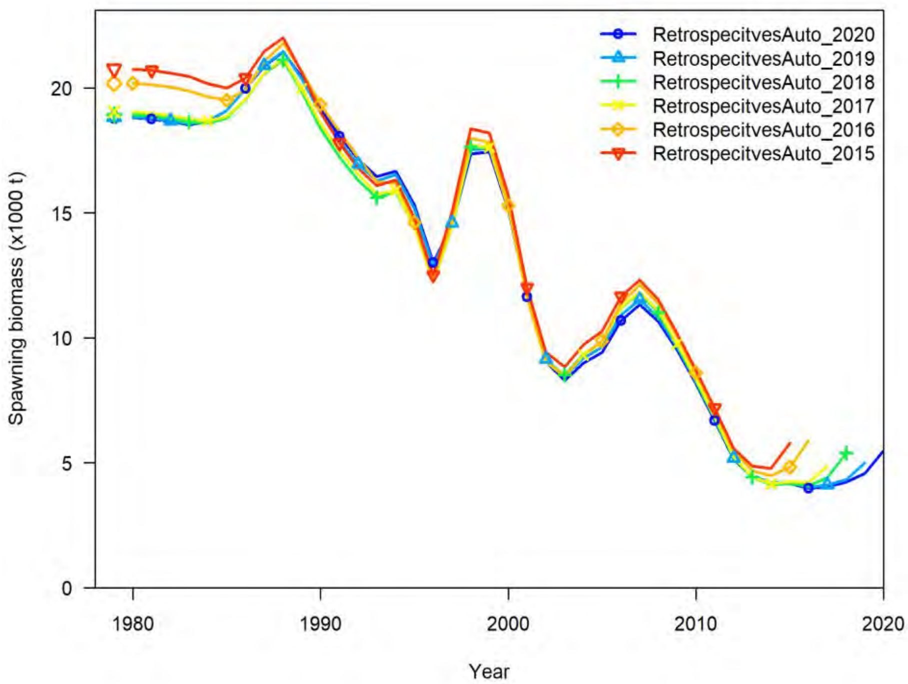

Figure 13.30. Retrospectives for absolute spawning biomass for the model with average recruitment projections, with data included to 2020 (blue) and then successive years removed back to 2015 (red)

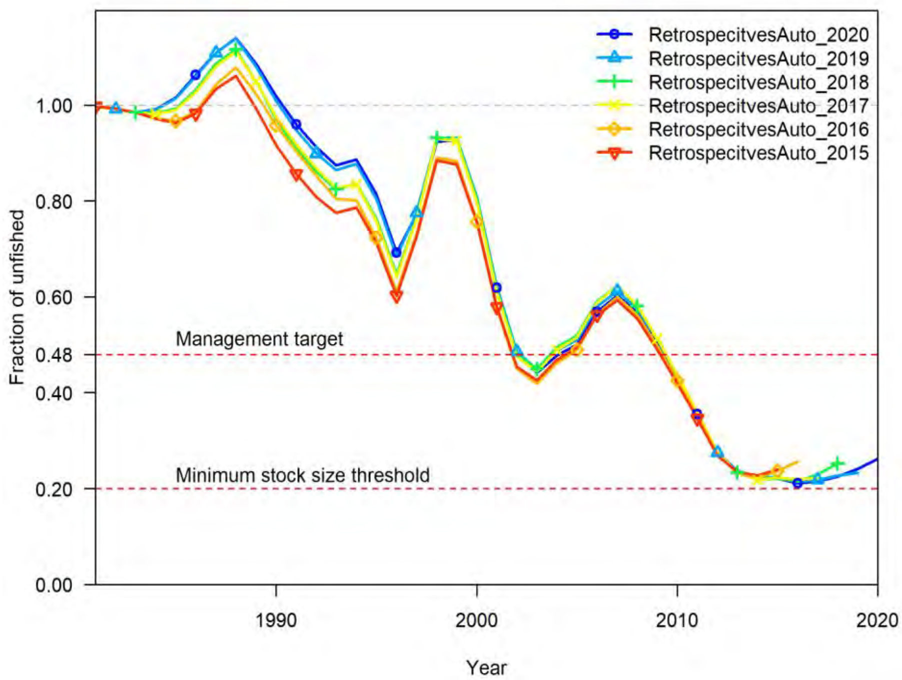

Figure 13.31. Retrospectives for relative stock status for the base case assessment with low recruitment projections, with data included to 2020 (blue) and then successive years removed back to 2015 (red)

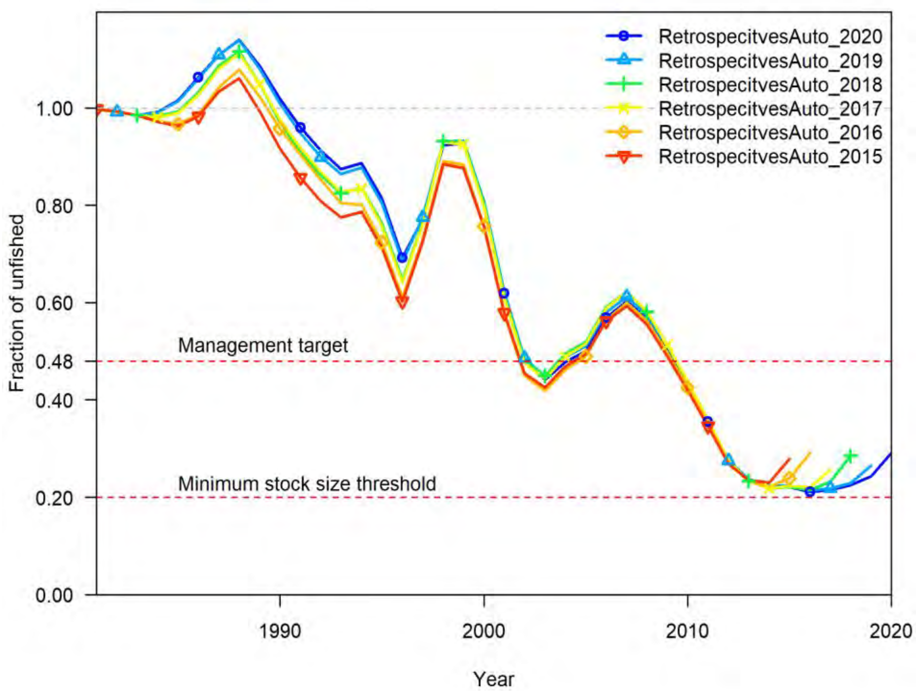

Figure 13.32. Retrospectives for relative stock status for the model with average recruitment projections, with data included to 2020 (blue) and then successive years removed back to 2015 (red)

When this retrospective analysis is applied to the recruitment time series (Figure 13.33), inclusion of data in 2017 results in a downward revision to the recruitment estimate in 2011 and 2012, while addition of 2018 data resulted in upward revision of the 2013 recruitment estimate (Figure 13.33). Recruitment from 2014 onwards has small revisions both up and down with the inclusion of data from 2018 Figure 13.33). Similar trends are observed in the recruitment deviations as were observed in absolute recruitment (Figure 13.35). Retrospective patterns in recruitment are much worse when not using low recruitment projections, with all estimates being revised downwards with the inclusion of additional years of data (Figure 13.34, Figure 13.36).

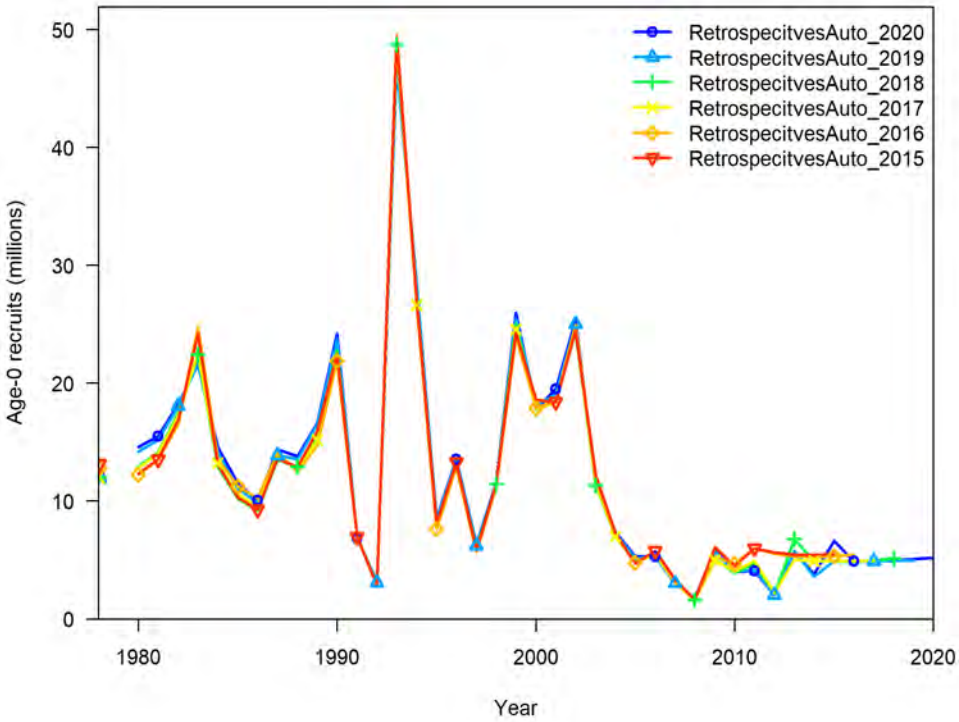

Figure 13.33. Retrospectives for the absolute number of recruits for the base case assessment with low recruitment projections, with data included to 2020 (blue) and then successive years removed back to 2015 (red)

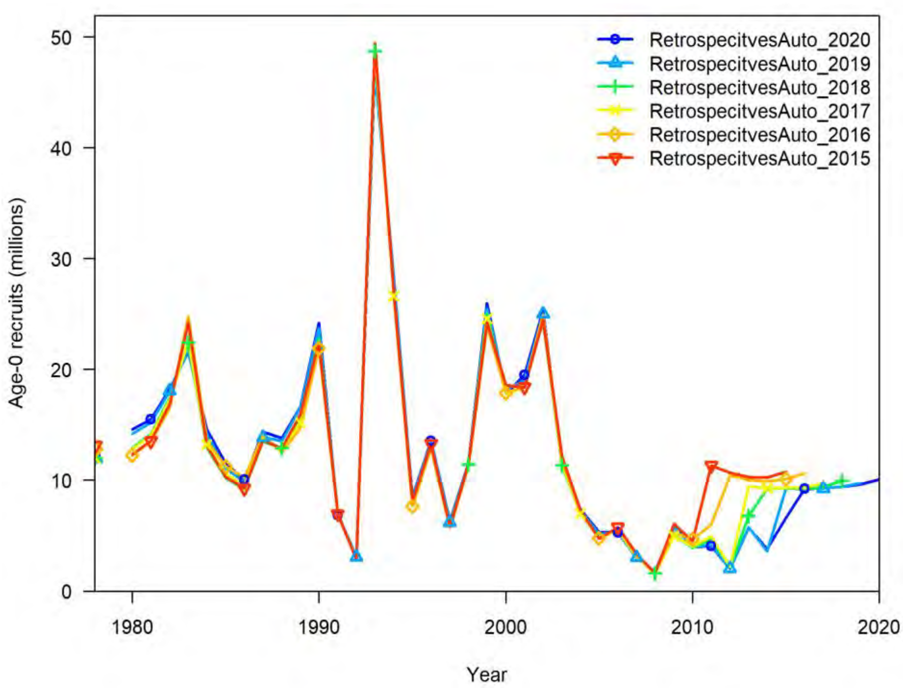

Figure 13.34. Retrospectives for the absolute number of recruits for the model with average recruitment projections, with data included to 2020 (blue) and then successive years removed back to 2015 (red)

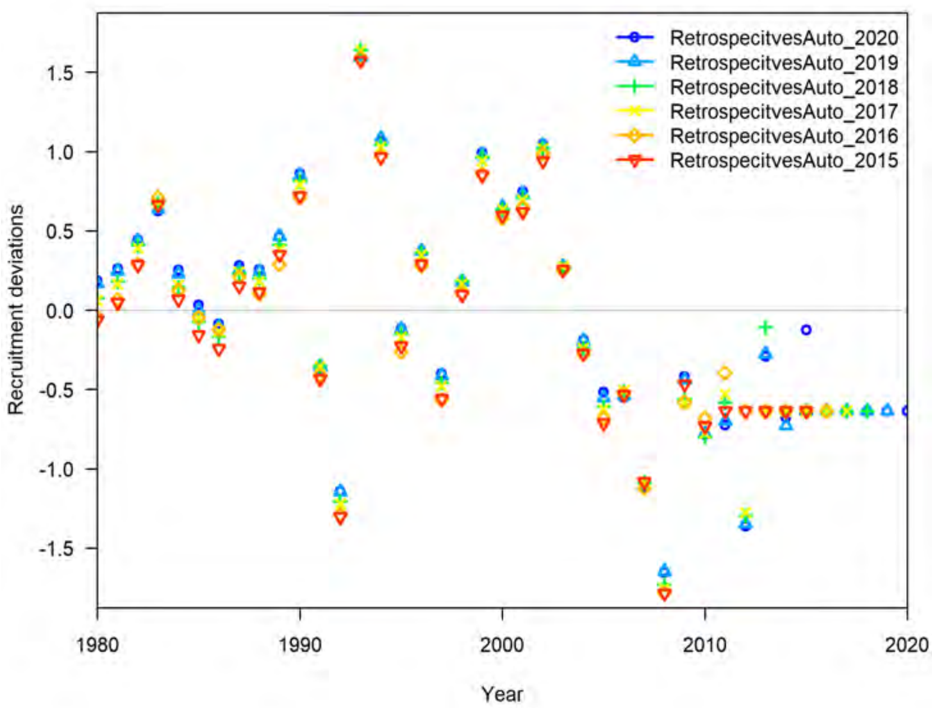

Figure 13.35. Retrospectives for recruitment deviations for the base case assessment with low recruitment projections, with data included to 2020 (blue) and then successive years removed back to 2015 (red)

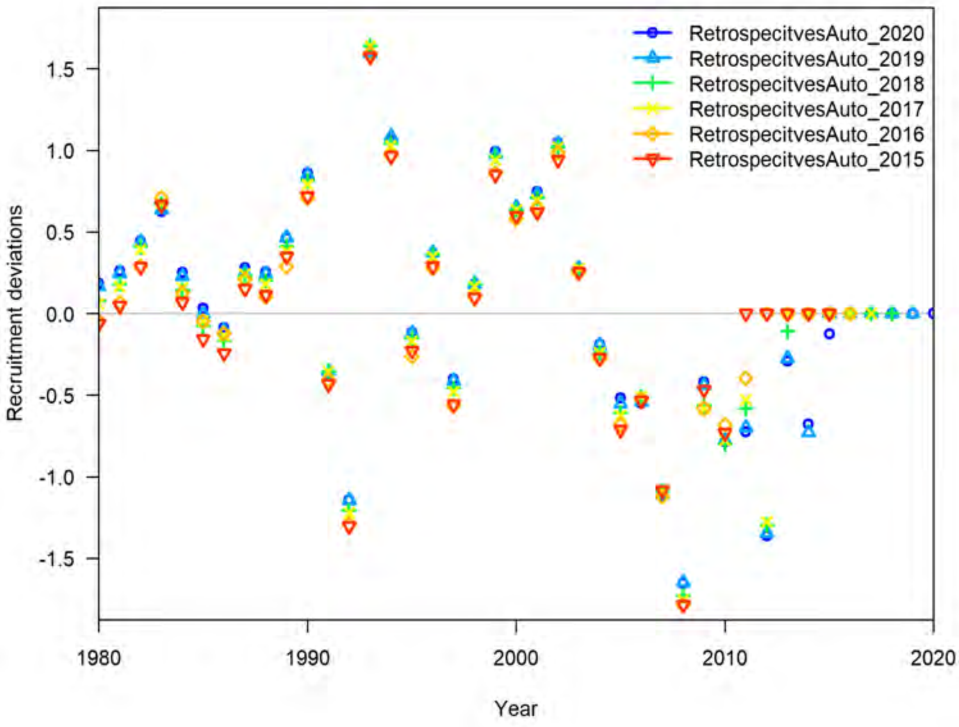

Figure 13.36. Retrospectives for recruitment deviations for the model with average recruitment projections, with data included to 2020 (blue) and then successive years removed back to 2015 (red)

An alternative presentation of the retrospective analysis applied to the recruitment time series is shown in a "squid plot" (Figure 13.37). Squid plots follow changes in the recruitment deviations for particular cohorts as the last five years of data is successively removed. Each coloured string corresponding to a cohort only includes a maximum of six points, one for the base case model using data up to 2020 and then one more point for each of the five different retrospectives. Each string can be followed from right to left as successive years of data are removed. The changes to the estimates of recruitment deviation, as each year of data is removed, are measured by changes in the y-axis, with a negative value indicting a revision upwards and a positive value indicating a revision downwards, relative to the most recent estimate. Large changes on the y-axis indicate large revisions, and if all the changes have the same sign (positive or negative) this indicates a series of changes in the same direction, which may provide evidence of bias rather than random revisions to parameter estimates.

The squid plot for the base case assessment with low recruitment projections shows a mix of deviations both above and below zero, suggesting that there is no pathological retrospective pattern in recruitment deviation estimates (Figure 13.37). This result contrasts with the squid plot for the model with average recruitment projected into the future, where all cohort lines from 2010 to 2015 are positive, suggesting that these recruitment deviations have all been revised downwards (Figure 13.38). This pattern is typical of a pathological pattern and suggest misspecification in this model.

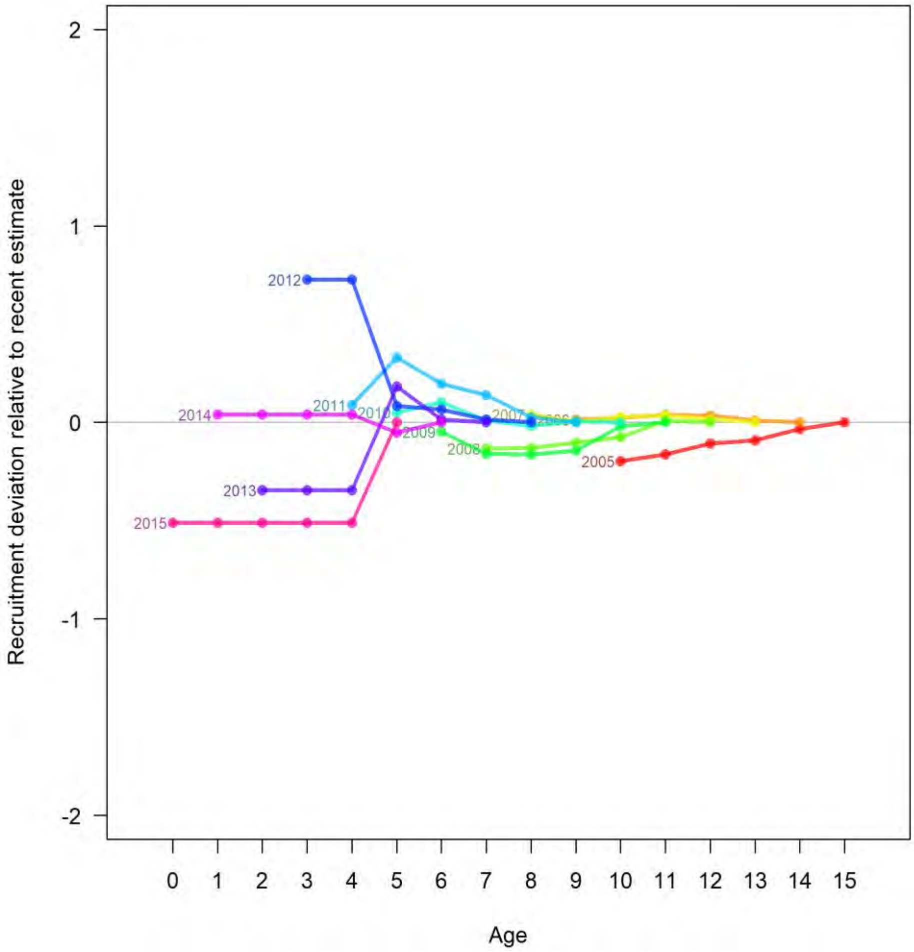

Figure 13.37. Retrospective analysis of recruitment deviations (squid plot), for the base case assessment with low recruitment projections, with data removed in successive years back to 2015

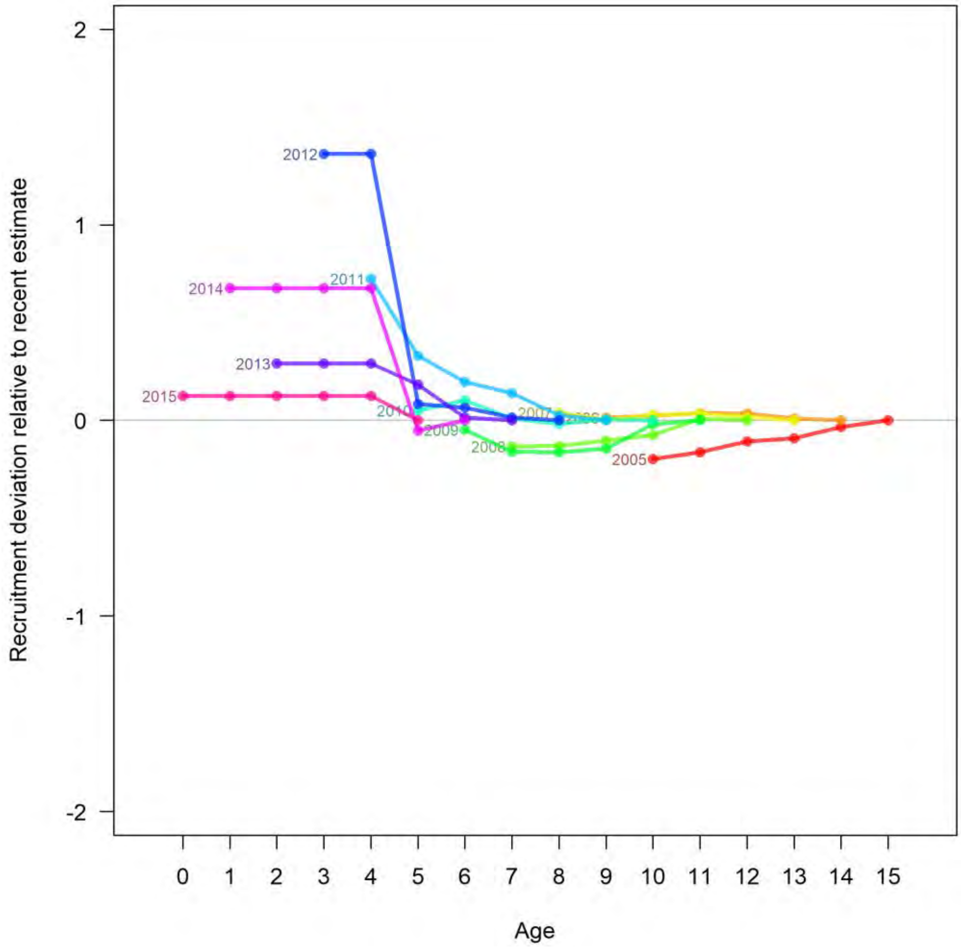

Figure 13.38. Retrospective analysis of recruitment deviations (squid plot), for the base case assessment with low recruitment projections, with data removed in successive years back to 2015

Mohn's Rho estimates for SSB, recruitment, F and stock status were 0.13, -0.008, -0.15 and 0.08 respectively, with SSB, recruitment and stock status estimates within the range of acceptable values, whereas the F estimate is on the edge of acceptability. To compare, when conducting retrospectives on the model without low recruitment projections, these values were 0.29, 0.18, -0.33 and 0.24 for SSB, recruitment, F and stock status respectively, with SSB, F and stock status failing acceptability criteria. These results demonstrate the improvement in reducing model misspecification when using the low recruitment projections compared to the assessment assuming average recruitment into the future.

13.4.5 *Likelihood profiles*

The likelihood profile for M suggests that this parameter could range from 0.375 and 0.475 year^{-1}, with these bounds higher than the fixed value in the model of 0.3 year^{-1} (Figure 13.39). This high estimate of M is driven by both the length and index data, and to a lesser extent the age data (Figure 13.39). There is little information on M in the discard data (Figure 13.39). This high estimate of M is unrealistic compared to the biology of the species, with a plus group age of 23, and as a result M will remain fixed at 0.3 in the assessment, as has been done in previous assessments.

The fleet contribution to each of the likelihood components are presented in Figure 13.40. For survey or index likelihoods the high M estimates are driven by the west trawl fleet, with little information apparent in the east trawl fleet (Figure 13.40). For the discard component of the likelihood, higher values of M are suggested by the east trawl fleet, while lower values are preferred by the west trawl fleet (Figure 13.40). Higher values of M in the length component of the likelihood are driven by the east trawl onboard, west trawl onboard and west trawl port data, conflicting trends from east trawl port data (Figure 13.40). Age composition data suggests a value of M around 0.4 from the west trawl fleet, while there is very little data to inform M in the east trawl age data (Figure 13.40). Overall, there is considerable conflicting data informing the value of M in the assessment and the suggested preference for higher values of M above those considered biologically sensible for this species are unrealistic.

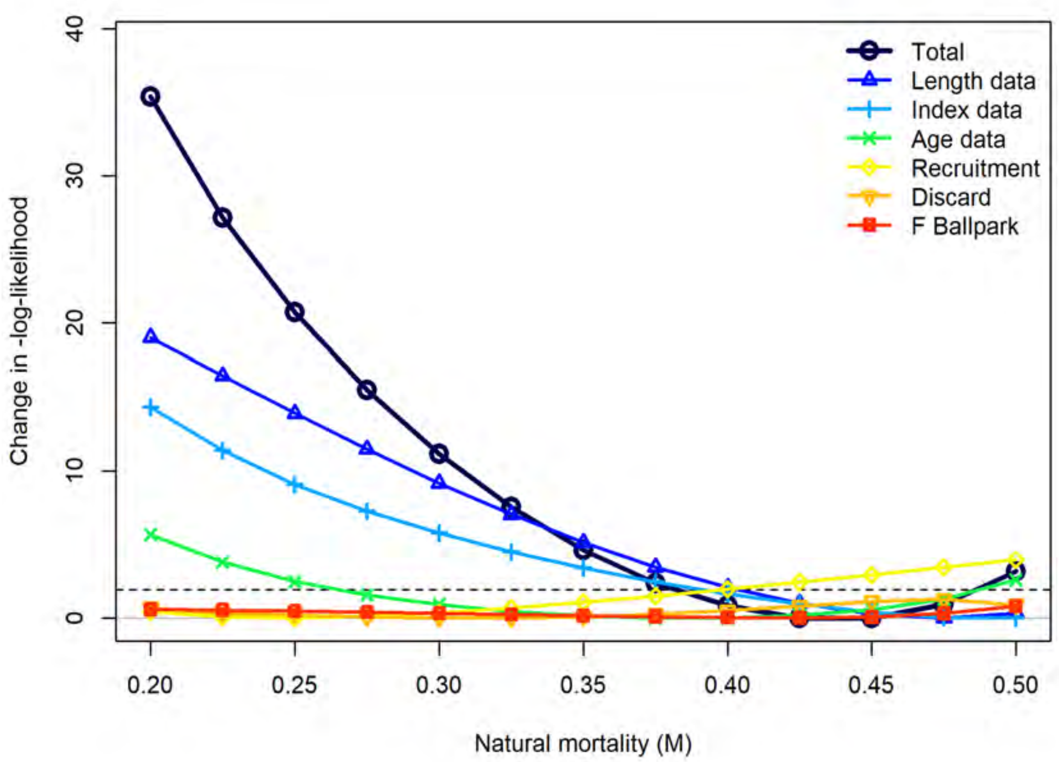

Figure 13.39. The likelihood profile for natural morality ($\boldsymbol{M}$). $\boldsymbol{M}$ is fixed in the base case at 0.3 year^{-1}

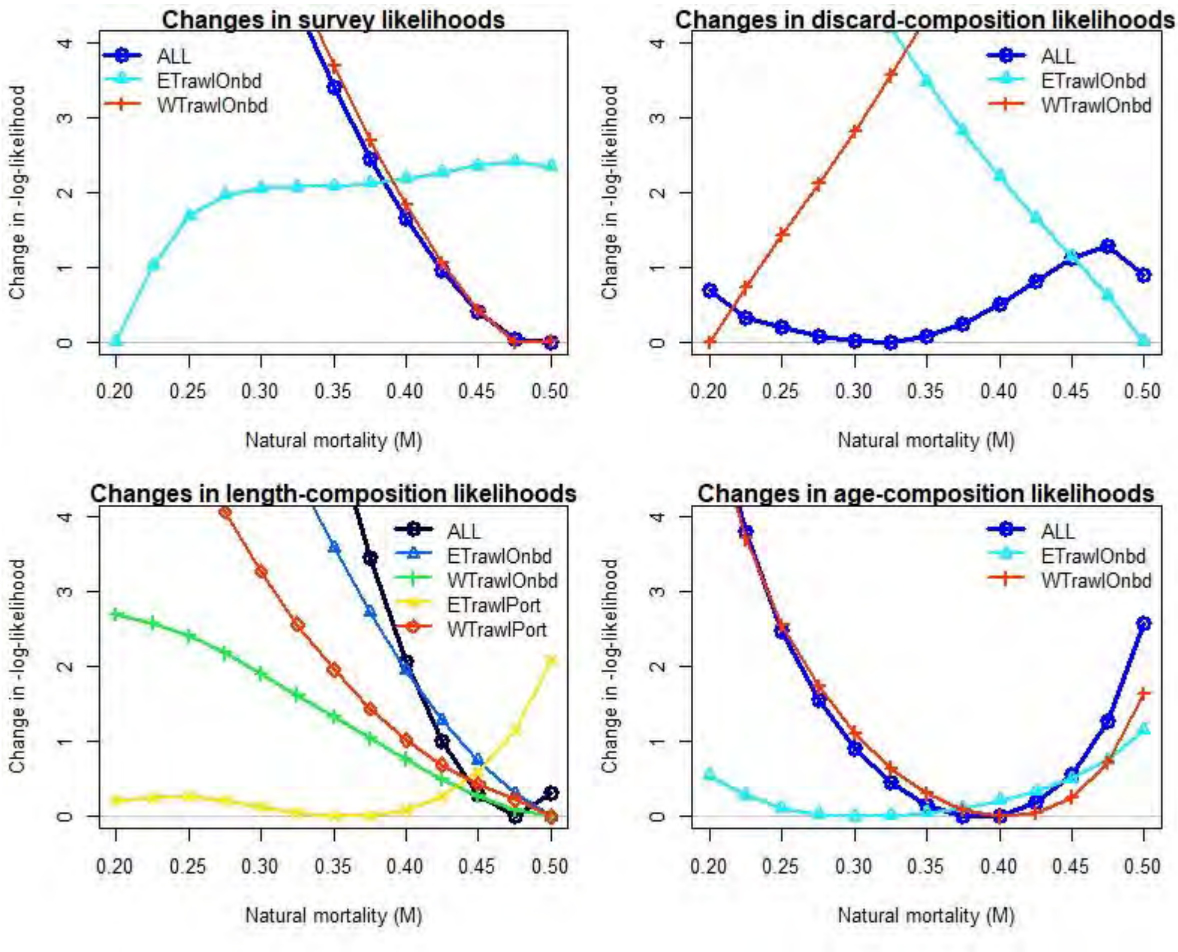

Figure 13.40. Piner plot for likelihood profile on ***M***

The likelihood profile on h suggests there is little information in the model that can inform estimation of this parameter (fixed at 0.75 in the model, Figure 13.41). The model suggests that h could range between 0.56 to well above 0.85, demonstrating a large range of plausible values (Figure 13.41). There is conflict in the data inputs, with discard and length data suggesting a higher value of h is preferable, while recruitment penalties, age and index data suggest lower values are more appropriate (Figure 13.41).

For survey or index likelihoods, the west trawl fleet is driving the profile towards a lower estimate of h, while there is no information in the east trawl fleet (Figure 13.42). From the discard likelihood, both the east and west trawl fleet data suggests that higher estimates of h are preferable (Figure 13.42). For the length component of the likelihood, the east trawl onboard data and to a lesser extent the west trawl onboard data suggests higher estimates of h are preferable, while there is no information on estimates in the east and west trawl port length data (Figure 13.42). For both east trawl and west trawl age composition data suggest lower estimates of h are preferred (Figure 13.42).

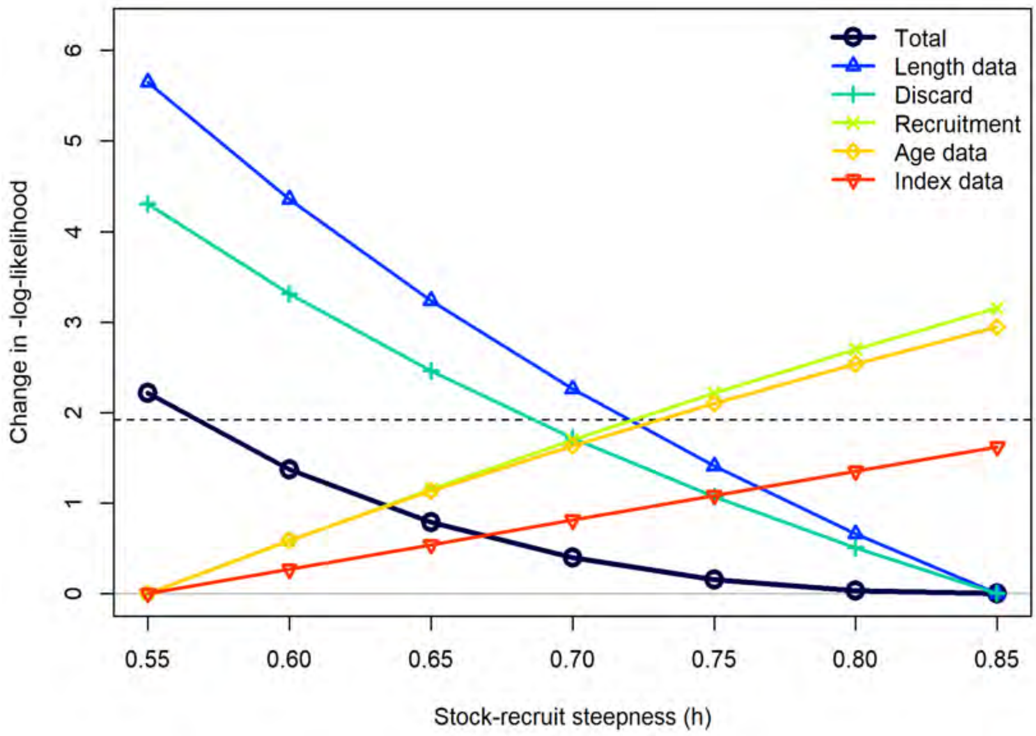

Figure 13.41. The likelihood profile for stock-recruitment steepness (***h***), ***h*** is fixed in the base case at 0.75

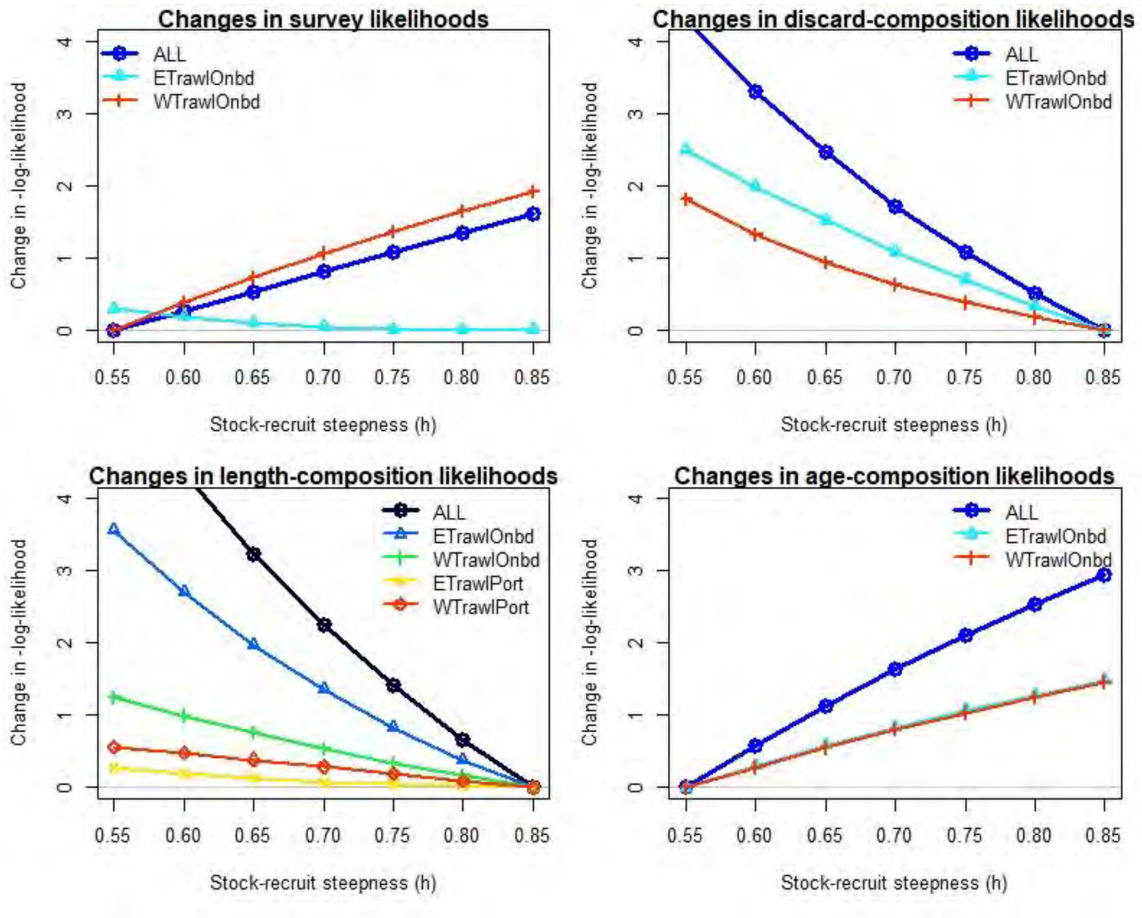

Figure 13.42. Piner plot for likelihood profile on ***h***

The stock status likelihood profile suggests that estimates in 2020 were between 25% and 34% (Figure 13.43). Index data is driving this estimate suggesting a stock status of 30%, while length data suggests lower estimates, there is little information in discard or recruitment penalties on this estimate (Figure 13.43).

The survey component of the likelihood is being mainly informed by the west trawl fleet, with the east trawl fleet suggesting lower estimates of stock status are more appropriate (Figure 13.44). For the discard component, east trawl data suggests higher stock status estimates, while the west trawl fleet suggests lower estimates (Figure 13.44). For the length composition likelihood component, east trawl onboard data strongly suggests lower stock status estimates, while west trawl port data suggests higher estimates, there is little information in east trawl port or west trawl onboard data (Figure 13.44). For the age composition component, both east trawl and west trawl data suggests higher estimates of stock status are most appropriate (Figure 13.44).

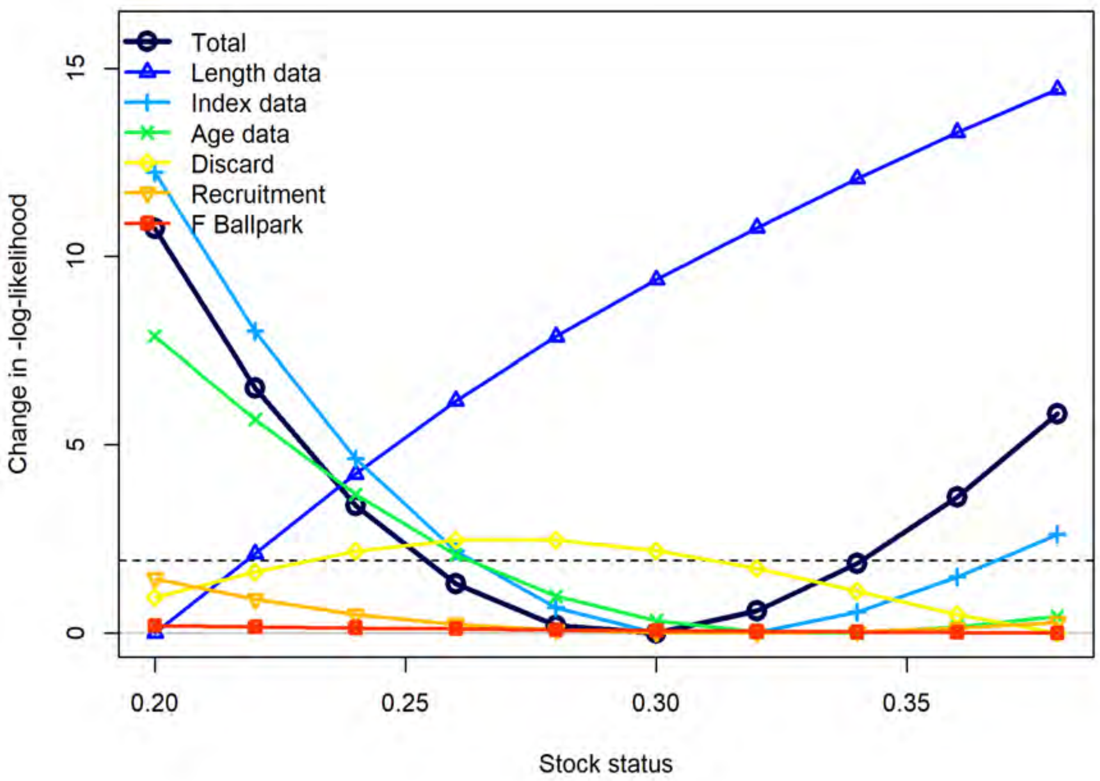

Figure 13.43. The likelihood profile for stock status in 2020, the base case without low recruitment projections estimates 2020 depletion to be 0.29 or 29%

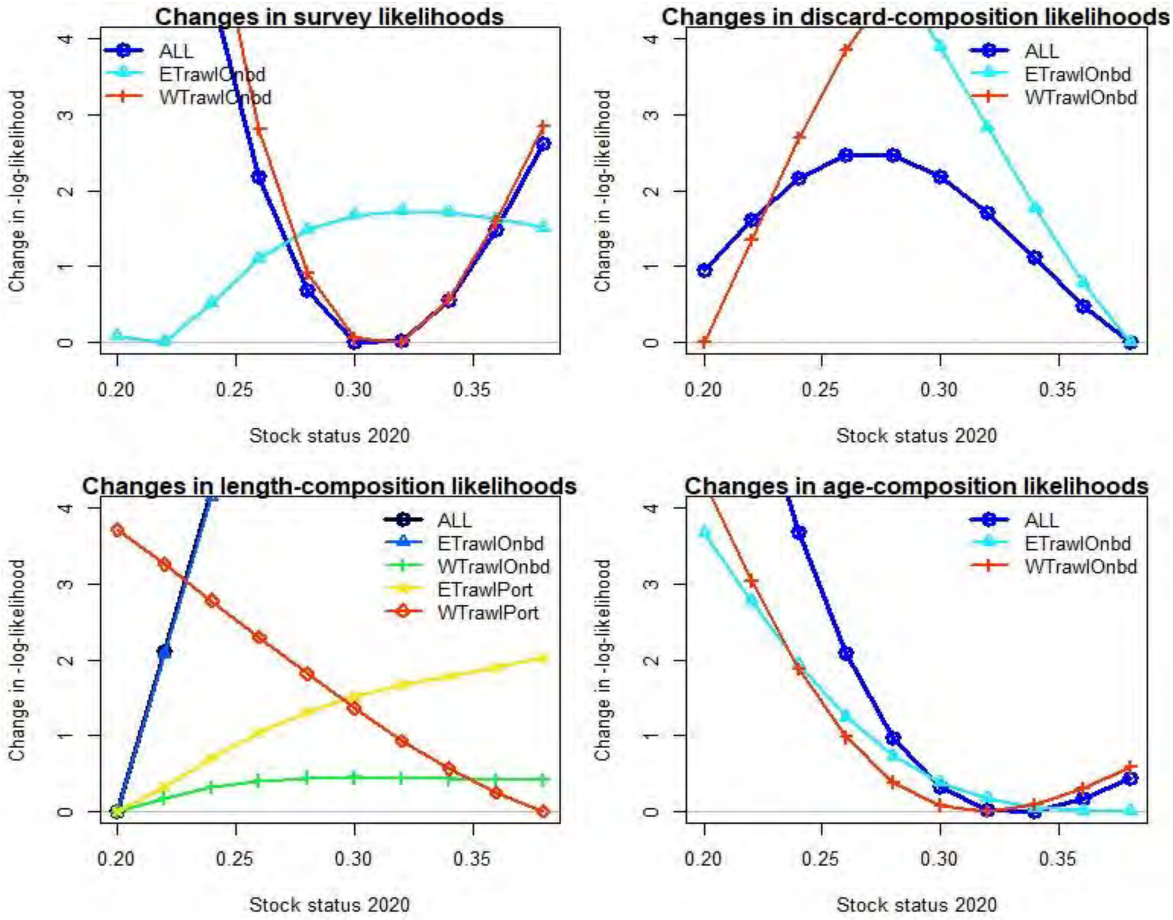

Figure 13.44. Piner plot for likelihood profile on 2020 stock status

The likelihood profile on SSB_0 suggests that estimates range between 17,000 t and 21,000 t (Figure 13.45). There is conflict in the data sources with recruitment penalties and to a lesser extent age data suggesting higher estimates of SSB_0, while discard data suggests lower estimates (Figure 13.45). There is no information in length and index data to inform estimation of SSB_0 (Figure 13.45).

There is conflict between data for the east trawl and west trawl fleet index data informing the profiles, with the east trawl index suggesting higher SSB_0, while west trawl index suggests lower estimates (Figure 13.46). For the discard component of the likelihood, east trawl data strongly suggests lower estimates are preferable, while west trawl data suggest higher estimates (Figure 13.46). There are no strong drivers in the length data, although west trawl onboard and west trawl port data suggests higher estimates of SSB_0, while east trawl onboard and west trawl port data suggests lower estimates (Figure 13.46). There is no information in east trawl age data to inform estimation of SSB_0, however, west trawl data suggests higher estimates are preferable (Figure 13.46).

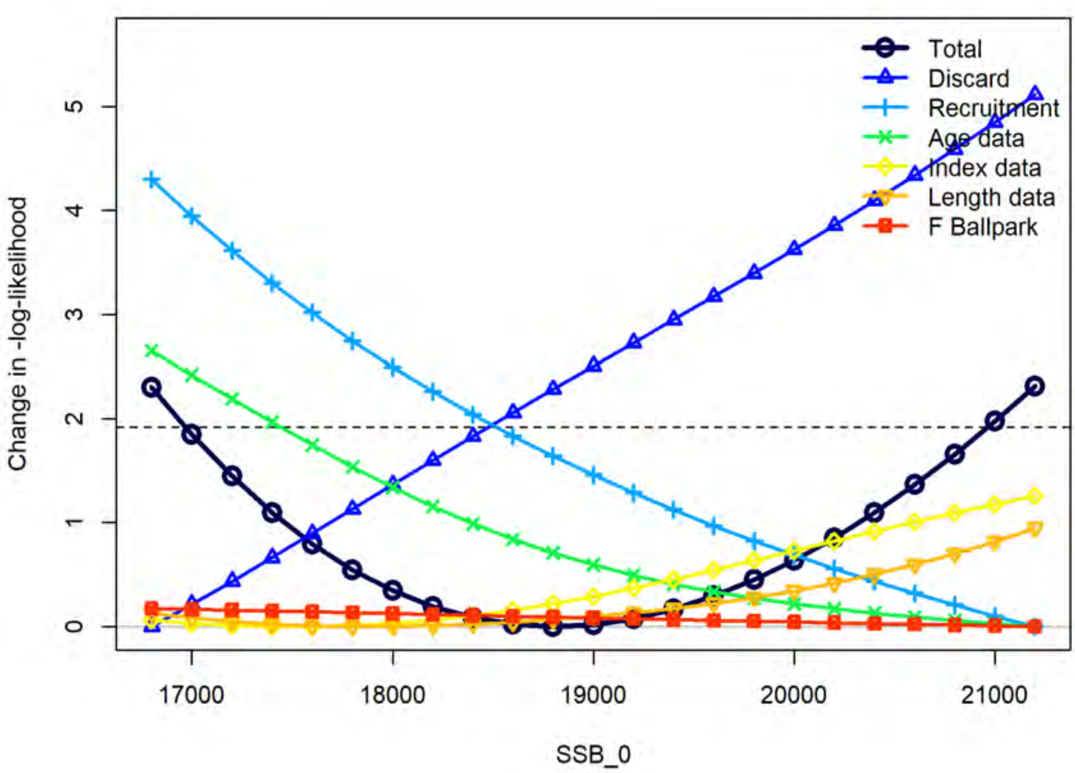

Figure 13.45. The likelihood profile for unfished spawning stock biomass, the base case estimate of SSB_0 is 18,806 t

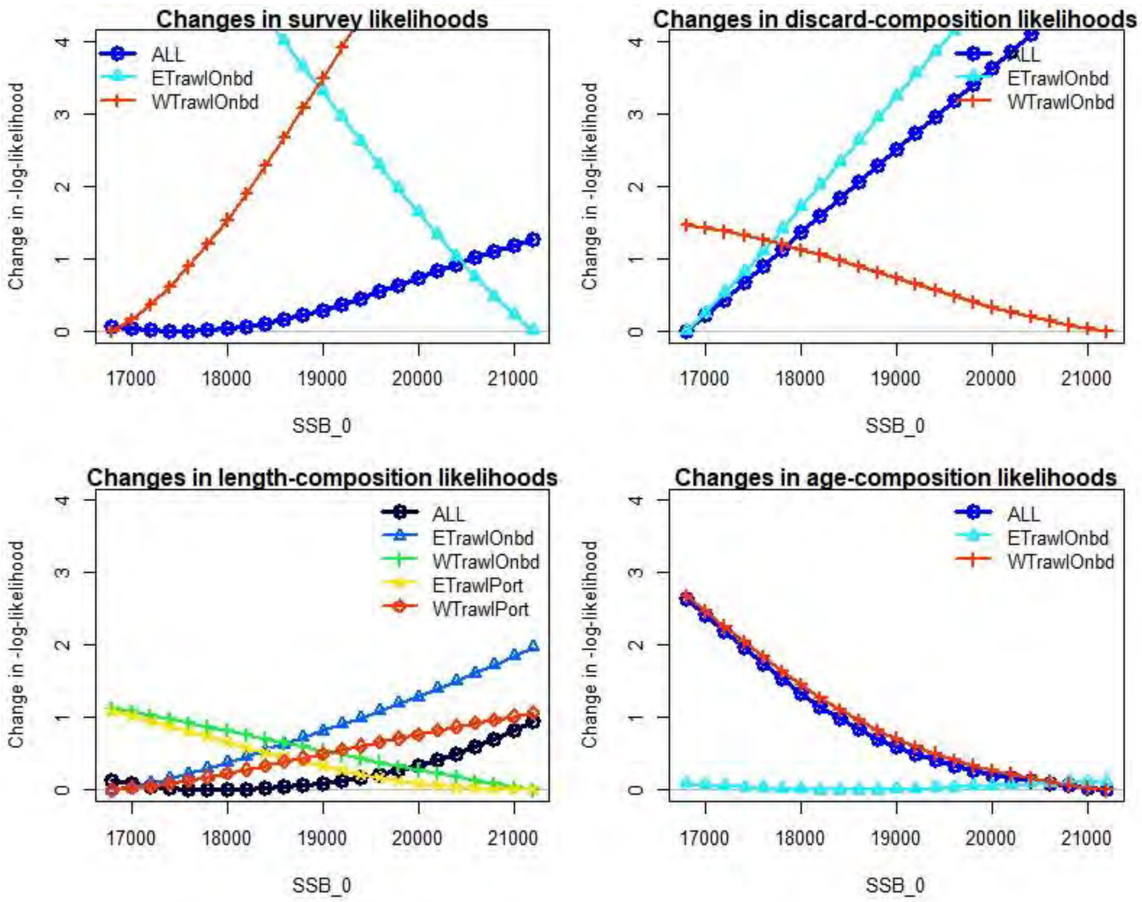

Figure 13.46. Piner plot for likelihood profile on $\boldsymbol{SSB_0}$

The likelihood profile over SSB in 2020 (SSB_{2020}) suggests that estimates range between 4,600 t and 6,700 t (Figure 13.47). Again, there is conflict in the data inputs associated with this profile, with age data and to a lesser extent recruitment data suggesting higher estimates are better, while length and discard data prefer lower estimates (Figure 13.47). There is limited information to inform estimates in the index data (Figure 13.47).

For survey or index likelihoods, the west trawl fleet is driving the profile towards lower estimates around 5,000 t, while the east trawl fleet prefers higher estimates (Figure 13.48). From the discard likelihood, both the east and west trawl fleet data suggests that lower estimates are preferable (Figure 13.48). For the length component of the likelihood, the east trawl onboard data suggests lower estimates of SSB_{2020} are preferable, while there is little information in the other fleets to inform estimation (Figure 13.48). For both east trawl and west trawl age composition data suggest higher estimates of SSB_{2020} are preferred (Figure 13.48).

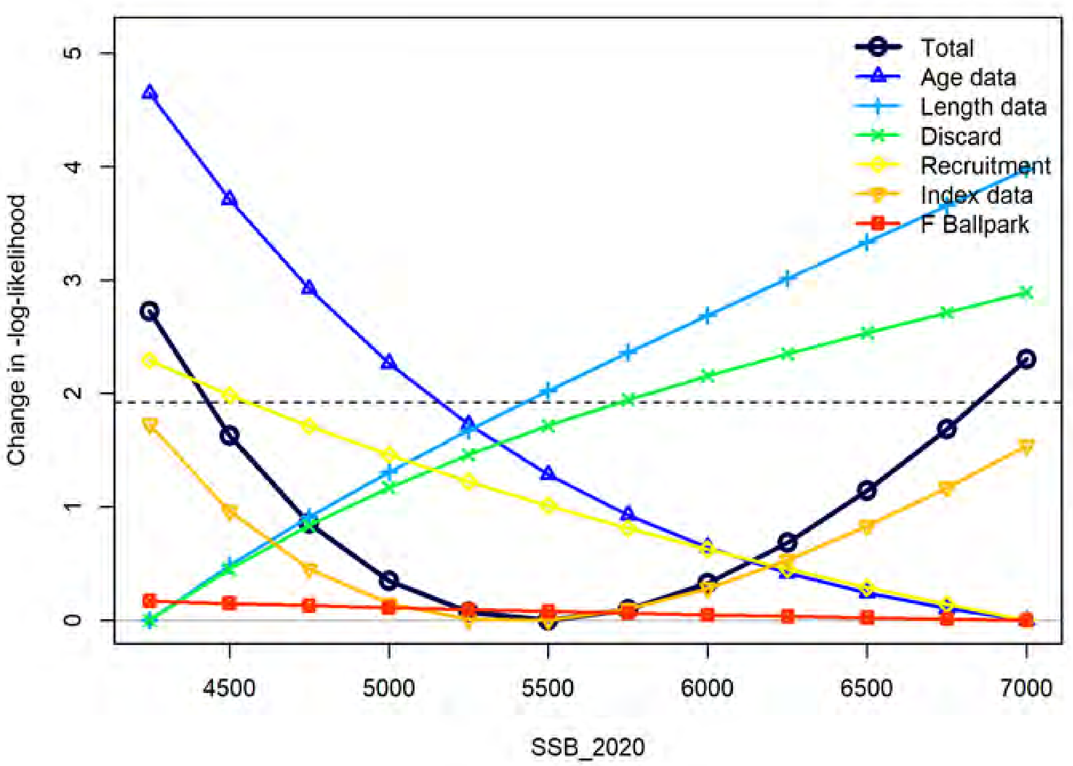

Figure 13.47. The likelihood profile for 2020 spawning stock biomass, the base case estimate of $\boldsymbol{SSB_{2020}}$ is 5,480 t

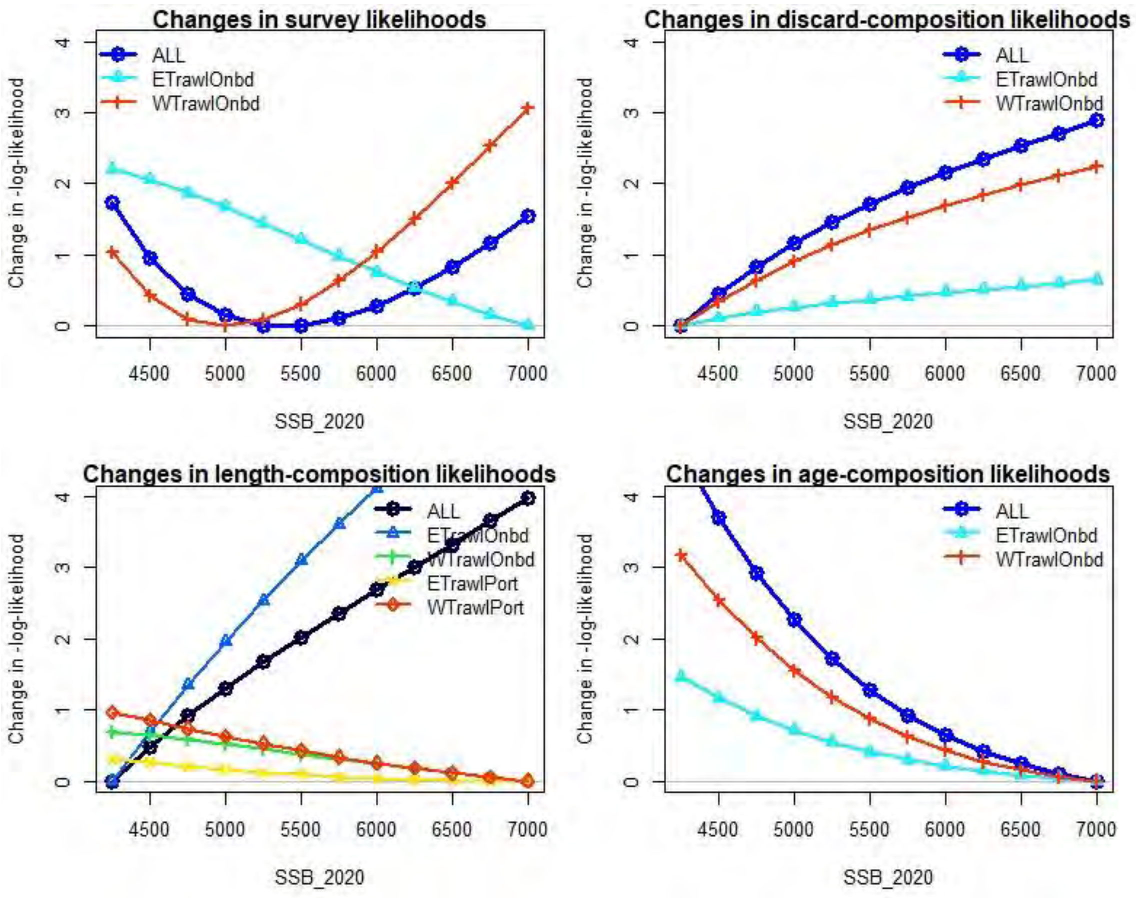

Figure 13.48. Piner plot for likelihood profile on $\boldsymbol{SSB_{2020}}$

13.4.6 *Jitter analysis*

For the base case, 22 of the 25 jitter replicates found the same optimal solution, with negative log likelihood of 720.387. The remaining three replicates found different (worse) "optimal" solutions, with a negative log likelihood of 720.578 for two replicates and 731.222 for the last replicate.

13.4.7 *Sensitivities to the base case model*

Standard sensitivities to alternative natural mortality values (M = 0.25, 0.35), steepness (h = 0.65, 0.85, and h estimated), length at maturity (34 and 40 cm), variation in recruitment (σ_R = 0.6 and 0.8), variation in data weighting and a model with average recrutiment projections were considered (Table 13.12 and Table 13.13). The base-case model and sensitivities all have stock status' that were between the target and limit reference points, ranging between 24% and 33% for models with low recruitment and up to 42% with average recruitment (Table 13.12).

Interestingly changing the weighting of the length data had the largest impact on the negative log likelihood of the models, with doubling the likelihood weighting on length data resulting in a considerable improvement to the likelihood (improved by 47 units), while having the weighting resulted in a much poorer likelihood (increased by 122, Table 13.12). However, these changes in length weighting only resulted in relatively small changes in stock status with estimates ranging between 26% and 30% (Table 13.12).

The high variability in the length data the model means the model is unable to fit the length compositions well, with this most likely resulting in the high sensitivity to the length data weighting in the likelihoods (Table 13.13). Other sensitivity scenarios had little impact on the likelihoods (Table 13.13).

Table 13.12. Summary of results for the base case and sensitivity tests. Spawning stock biomass includes both male and female biomass in the total.

MODEL	NLL	NLL CHANGE	SSB_0	SSB_{2022}	SSB_{2022} / SSB_0
base case (*M* = 0.3, *h* = 0.75, 50% mat = 37)	745.33	-	18,806	5,374	0.29
***M* = 0.25**	756.45	11.6	19,076	4,490	0.24
***M* = 0.35**	737.21	-7.96	20,551	6,867	0.33
***h* = 0.65**	747.52	2.52	19,535	5,102	0.26
***h* = 0.85**	743.18	-1.82	18,306	5,651	0.31
estimate *h*	743.26	-1.74	18,328	5,636	0.31
50% maturity at 34cm	744.74	-0.26	20,565	6,120	0.30
50% maturity at 40cm	745.21	0.2	16,508	4,474	0.27
σ_R= 0.6	752.85	4.12	18,122	5,359	0.30
σ_R = 0.8	740.14	-2.44	19,727	5,435	0.28
wt x 2 CPUE	748.39	3.06	18,740	5,394	0.29
wt x 0.5 CPUE	747.03	1.7	18,938	5,398	0.29
wt x 2 length comp	698.01	-47.32	18,634	4,811	0.26
wt x 0.5 length comp	867.82	122.49	18,897	5,645	0.30
wt x 2 age comp	752.00	6.25	19,525	5,866	0.30
wt x 0.5 age comp	752.74	7.41	18,546	5,137	0.28
Average recruitment	730.71	-14.62	18,806	7,824	0.42

Table 13.13. Summary of likelihood components for the base case and sensitivity tests. Likelihood components are unweighted and all cases below the primary base case are shown as differences from the base case. A negative value either in the total or individual components of likelihood indicates an improvement in fit compared to the primary base case. A positive value indicates deterioration in the fit.

MODEL	TOTAL	SURVEY	DISCARD	LENGTH	AGE	RECRUITMENT
base case (*M* = 0.3, *h* = 0.75, 50% mat = 37)	745.33	-75.87	126.25	362.84	311.62	9.83
***M* = 0.25**	11.60	3.31	0.70	5.86	1.93	-0.35
***M* = 0.35**	-7.95	-2.17	-0.30	-4.98	-1.07	0.72
***h* = 0.65**	2.52	-0.17	1.86	2.57	-0.67	-1.06
***h* = 0.85**	-1.82	0.16	-1.52	-2.00	0.60	0.94
estimate *h*	-1.74	0.16	-1.45	-1.91	0.57	0.90
50% maturity at 34cm	-0.26	-0.01	-0.11	-0.17	0.00	0.03
50% maturity at 40cm	0.20	0.05	0.05	0.15	0.05	-0.09
σ_R= 0.6	4.12	0.09	3.10	0.32	-1.20	1.81
σ_R = 0.8	-2.44	0.03	-2.45	-0.50	1.04	-0.57
wt x 2 CPUE	3.06	-8.82	9.62	5.63	-4.41	1.38
wt x 0.5 CPUE	1.70	6.29	-5.19	-3.69	4.96	-0.34
wt x 2 length comp	-47.32	4.56	22.70	-79.63	5.69	-0.31
wt x 0.5 length comp	122.49	-1.42	-11.09	135.98	-1.34	0.70
wt x 2 age comp	6.25	-5.34	24.37	8.06	-18.71	-1.80
wt x 0.5 age comp	7.41	6.30	-17.92	-5.97	23.55	1.78
Average recruitment	-14.62	0.35	-7.12	-10.93	3.09	0.00

13.5 Discussion

This document presents an updated assessment of Silver Warehou (*Seriolella punctata*) in the SESSF using data up to 31 December 2020. A full stock assessment for Silver Warehou was last performed in 2018 by Burch et al. (2018) using the stock assessment package Stock Synthesis version SS-V3.30.12.00 (Methot et al., 2018). Changes from the 2018 assessment include:

a) migration to the latest version of Stock Synthesis (SS-V3.30.17, Methot et al. (2021));
b) updates of all catch, CPUE, discard, length, age and ageing error data;
c) extending the last year of recruitment estimation (2015);
d) including an additional time block on retention for the east trawl fleet between 2018 and 2020 and
e) using low recruitment projections in the base case.

Results show reasonable fits to the CPUE abundance index for the western trawl fleet, however, fits to the eastern trawl fleet are poor prior to 1996, although these have improved from the 2018 assessment. Fits to the discard data are reasonable, although the model still struggles to fit the high estimates in the east trawl fleet in 2020, even when including an additional time block. The fits to the length data for both fleets and both onboard and port samples were poor. The length frequency data is highly variable from year to year, which has resulted in these poor fits. The assessment is also sensitive to weighting of the length frequency data. The overall fits to the conditional age-at-length data are good.

The assessment shows retrospective patterns, which is consistent with previous assessments. These patterns have been substantially improved through inclusion of the low recruitment projections and are within acceptability criteria. Generally, the increase in SSB and relative stock status is revised downwards at the end of the series with the inclusion of additional years of data, resulting in overoptimistic estimates of stock status at the end of the series. These patterns suggest there is some misspecification in the model.

Likelihood profiles have demonstrated there are considerable conflicts in different data sources. This is particularly concerning where conflicts in individual components are apparent between the two fleets in the assessment. Given these conflicts, future assessments should consider splitting the assessment between the east and the west to investigate whether this results in a more stable assessment with less evidence of model misspecification and conflict between data sources.

Previous assessments in 2015 and 2018 have observed downward revisions in stock status towards the limit reference point from 2015 to 2017, however, this downward revision appears to have stabilised in the current assessment and no further revisions below the limit reference point were observed. There does appear to have been some recovery above the limit reference point in the last 3 years due to low catches below the TAC, however projections suggest this recovery will not continue at current catch levels and while recruitment remains below average.

In this new low productivity state, with below average recruitment, the population is no longer able to recover to unfished levels observed in the 1980s, as projections with zero catch suggest the population is now only capable of recovering to 49% of unfished levels by 2040.

This assessment estimates that the projected 2022 spawning stock biomass will be 29% of unfished SSB. The RBC from the base case model for 2022 is 587 t for the 20:35:48 harvest control rule, however, as the base case has violated the assumptions of the HCR, catches of this magnitude result in no increase in projected stock status. In comparison, the 2018 assessment estimated stock status to be 31% of unfished levels in 2019, while the 2015 assessment estimated the 2016 percentage of the unfished spawning biomass to be 40%. However, both the 2015 and 2018 assessments assumed recruitment will return to average levels, while the current assessment assumes recruitment will remain low into the future.

The current SESSF HCR assumes that there is average recruitment into the future and therefore applying the HCR with low recruitment projections does not result in recovery of stocks towards the target reference point if the calculated RBCs are caught. Further work is required to develop and test an HCR that could be used in such scenarios, as recent and continued poor recruitment appears to be occurring more commonly across multiple species the SESSF.

13.6 Acknowledgements

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13.8 Appendix

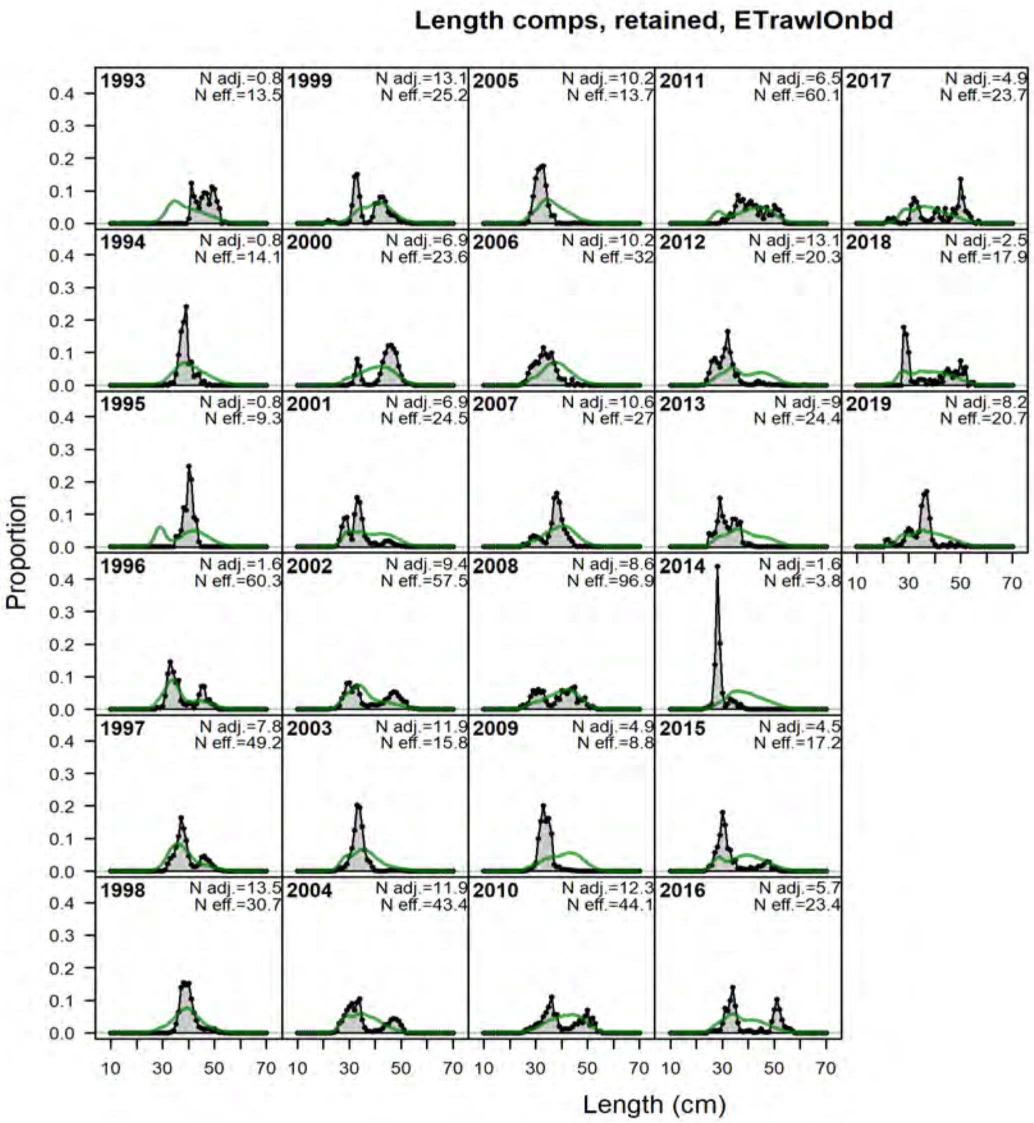


Figure 13.49. Fits to onboard retained length compositions for the east trawl fleet

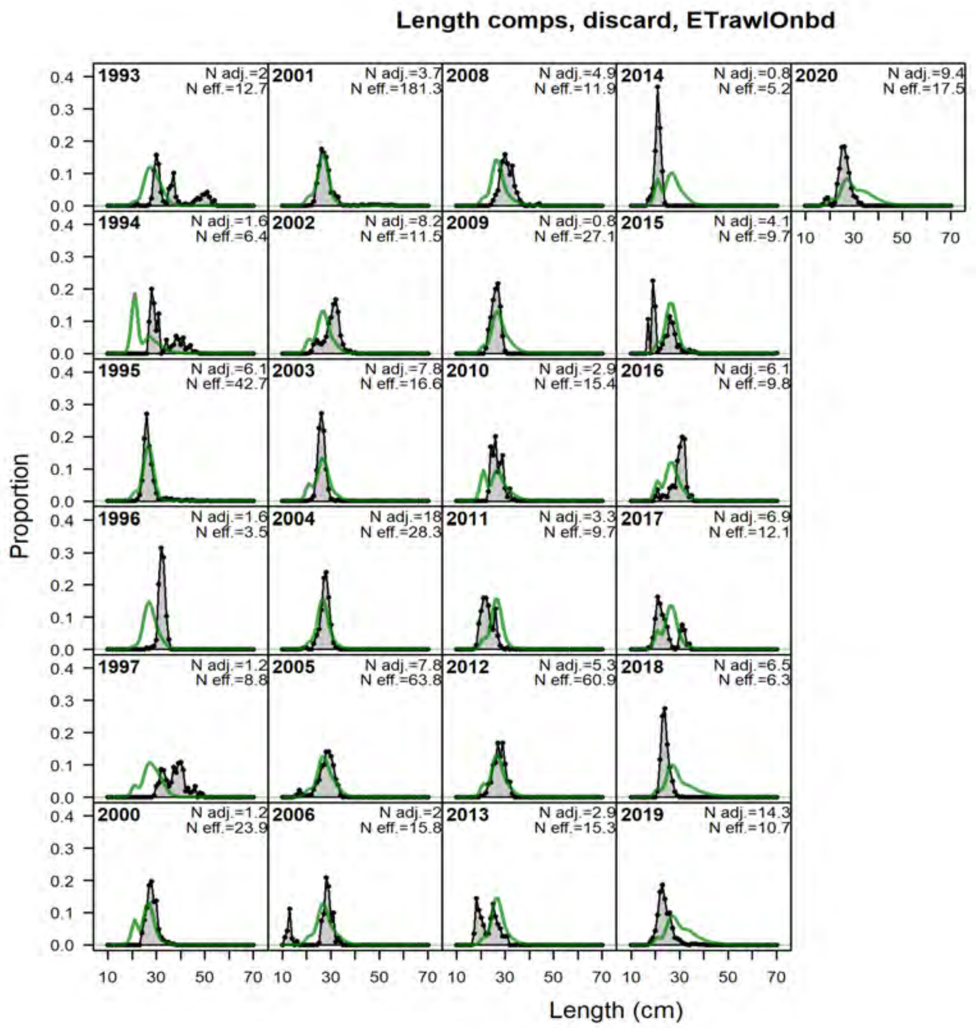


Figure 13.50. Fits to onboard discarded length compositions for the east trawl fleet

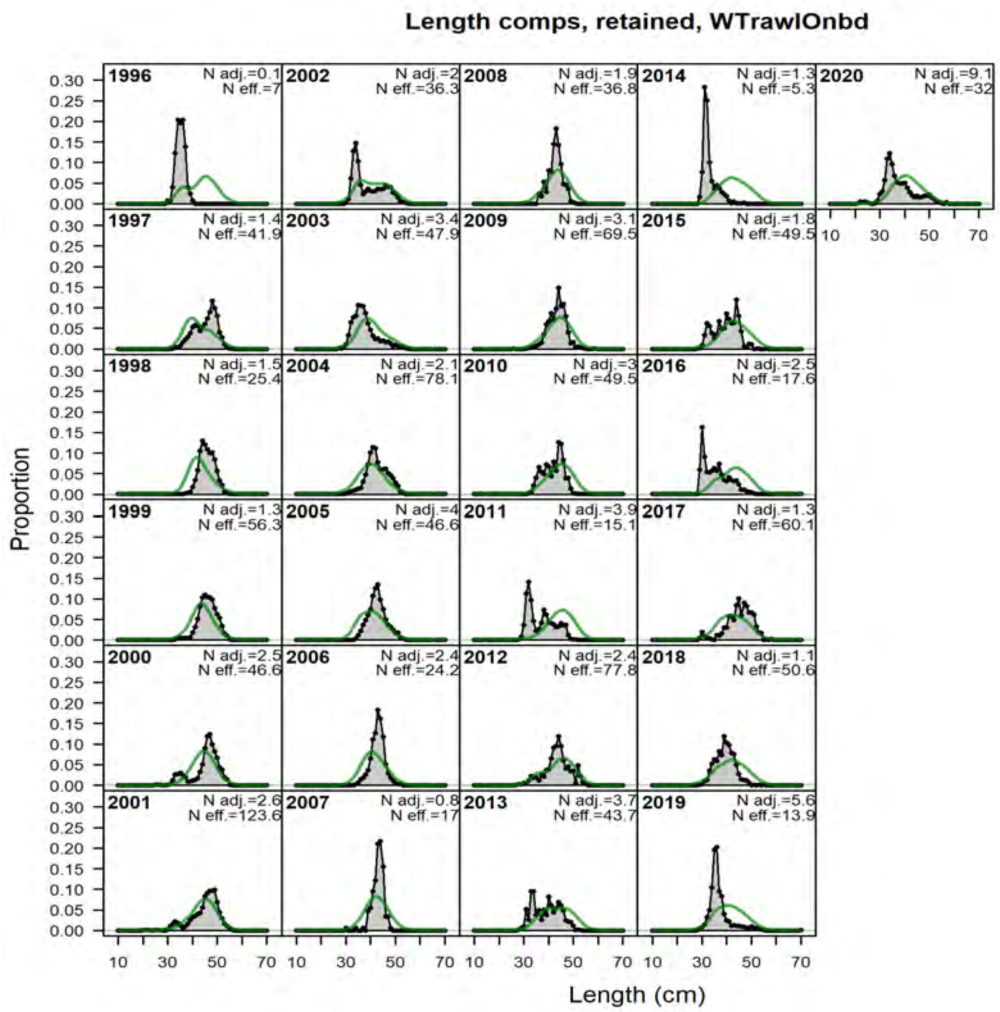


Figure 13.51. Fits to onboard retained length compositions for the west trawl fleet

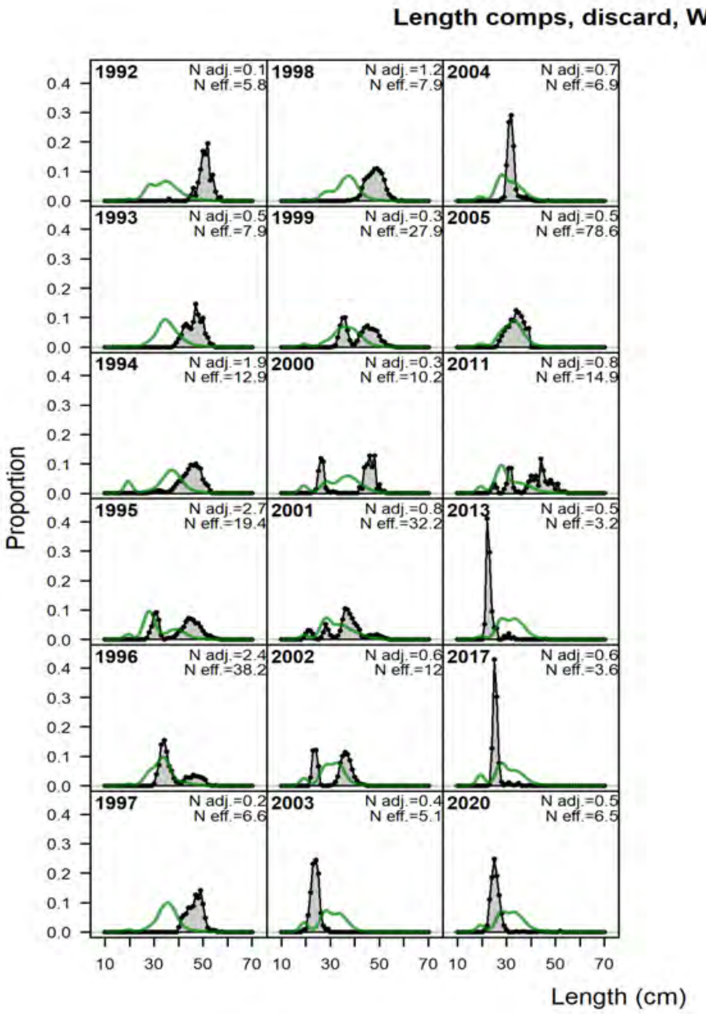


Figure 13.52. Fits to onboard discarded length compositions for the west trawl fleet

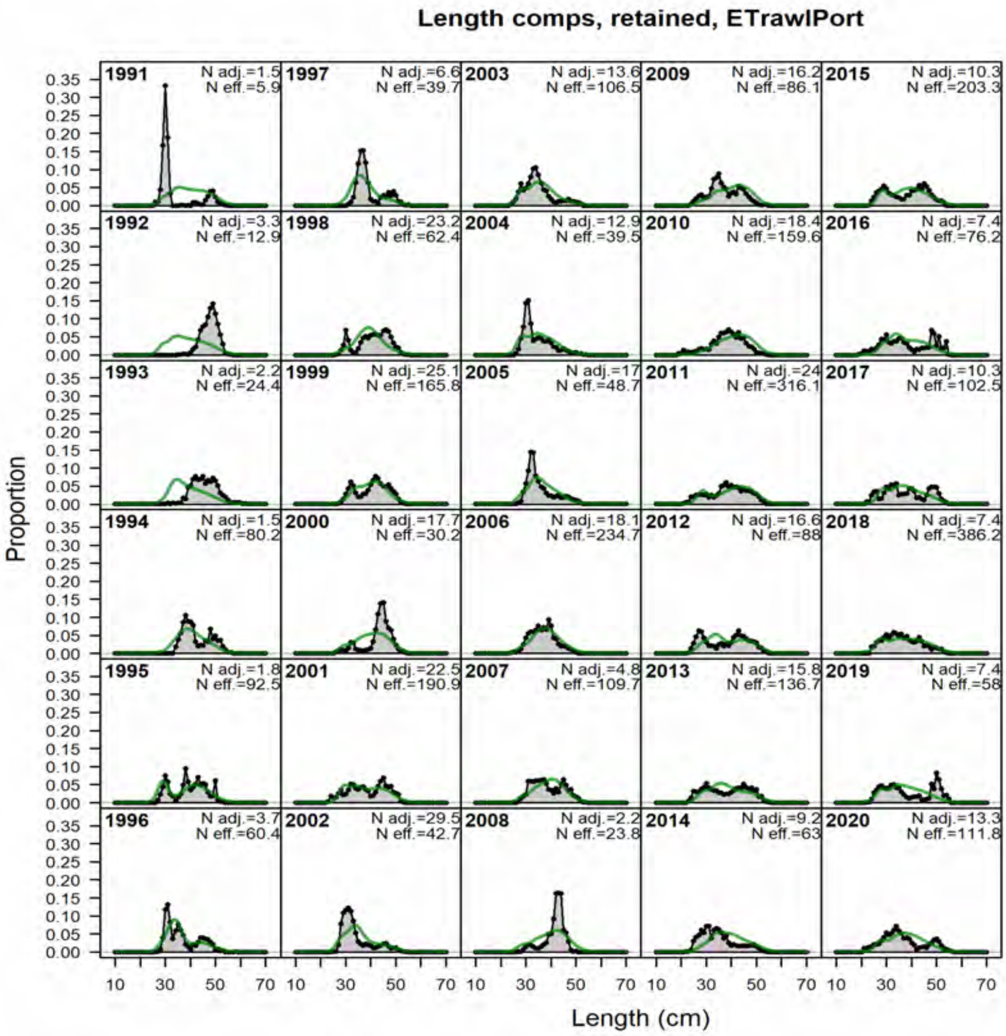


Figure 13.53. Fits to port length compositions for the east trawl fleet

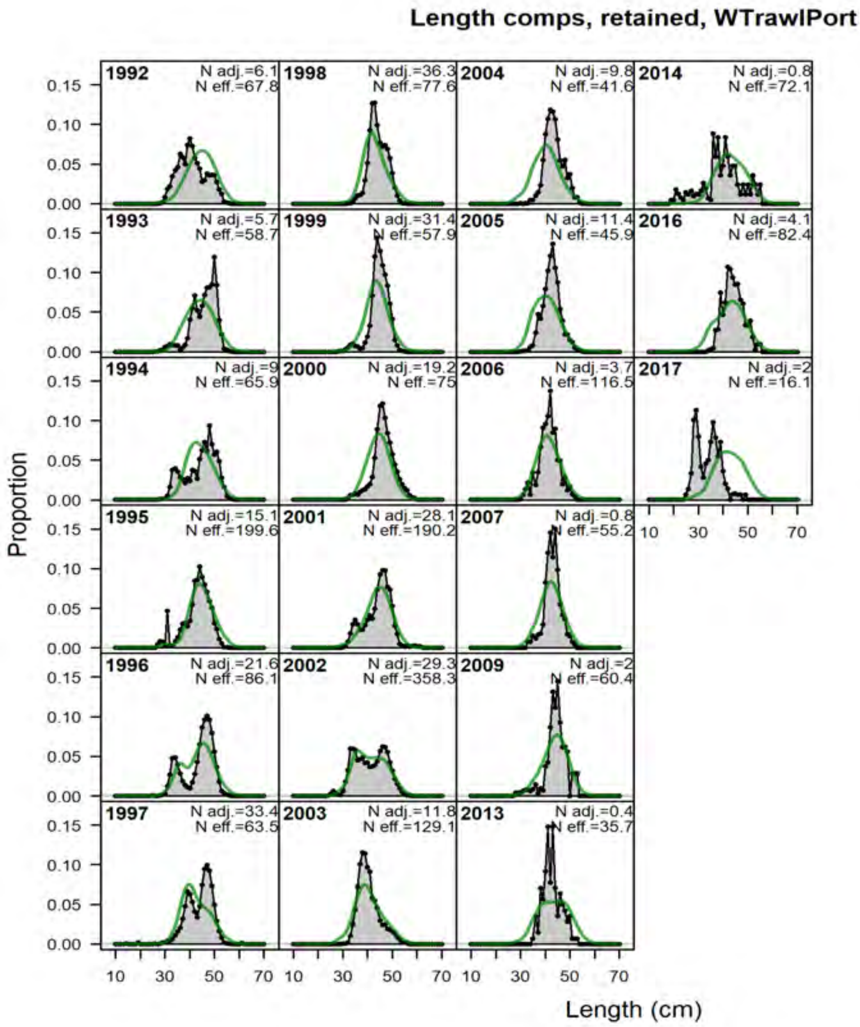


Figure 13.54. Fits to port length compositions for the west trawl fleet

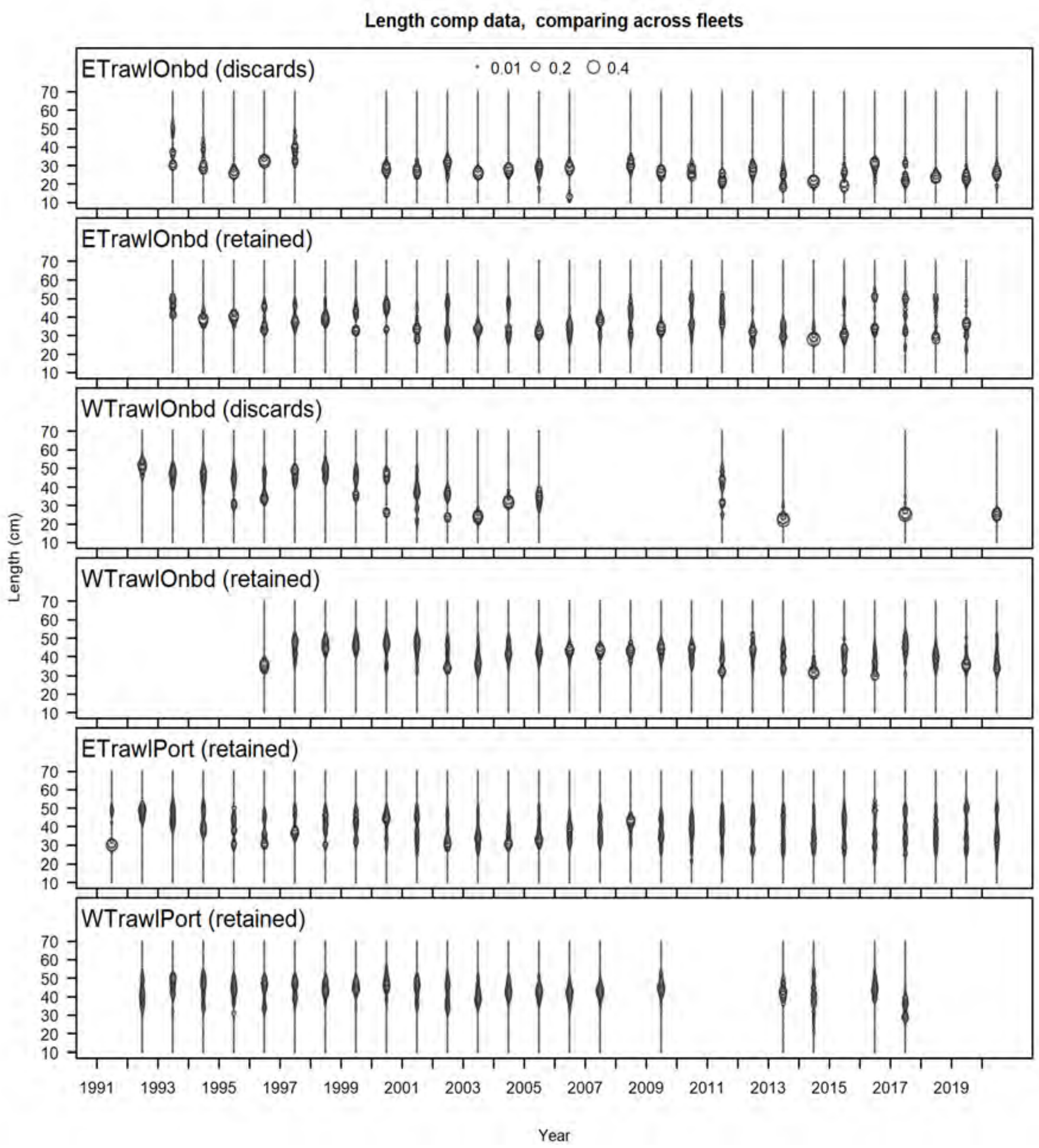


Figure 13.55. Residuals from the annual length compositions for both the east the west trawl fleet

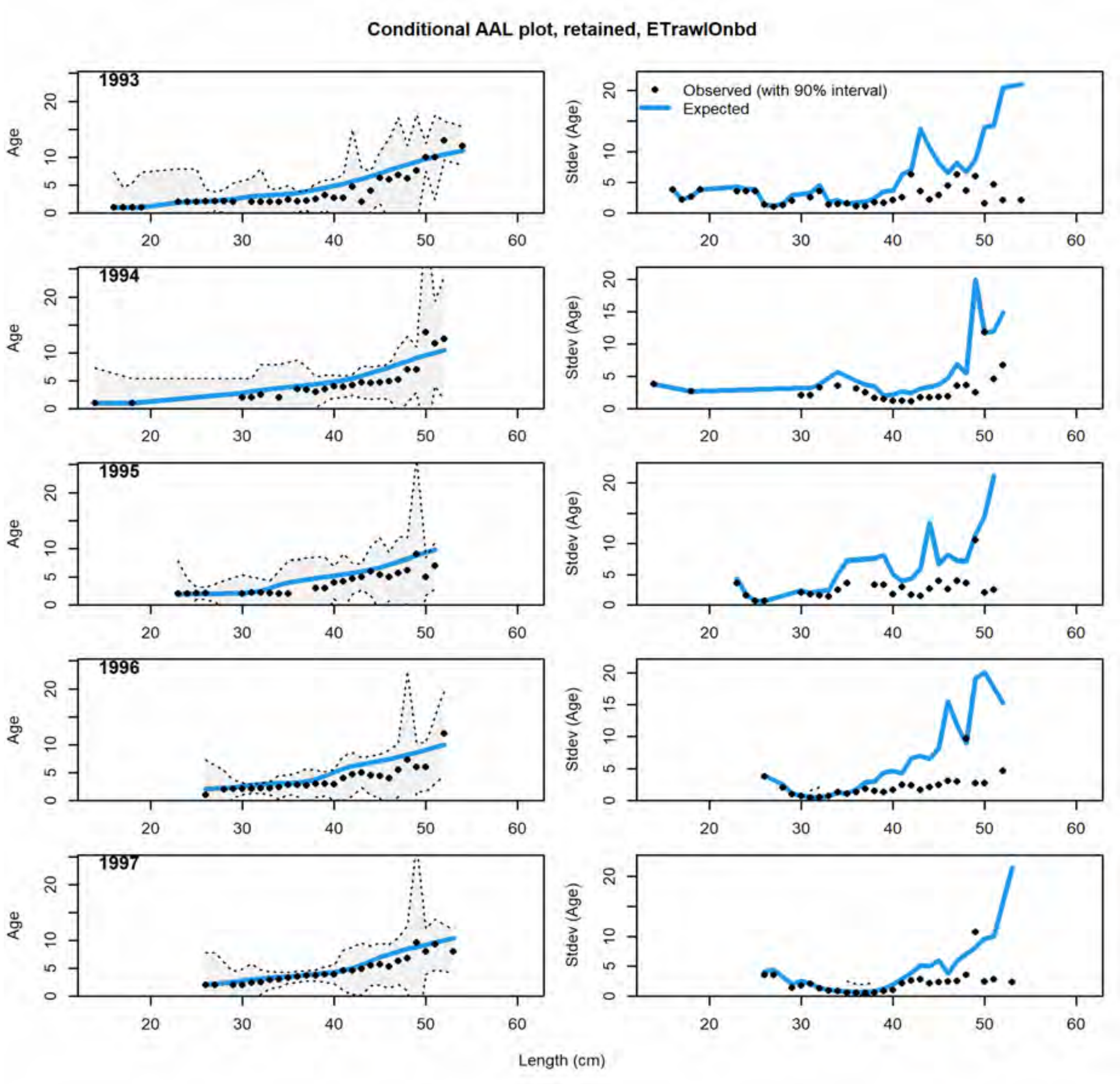


Figure 13.56. Fits to conditional age at length data for the east trawl fleet

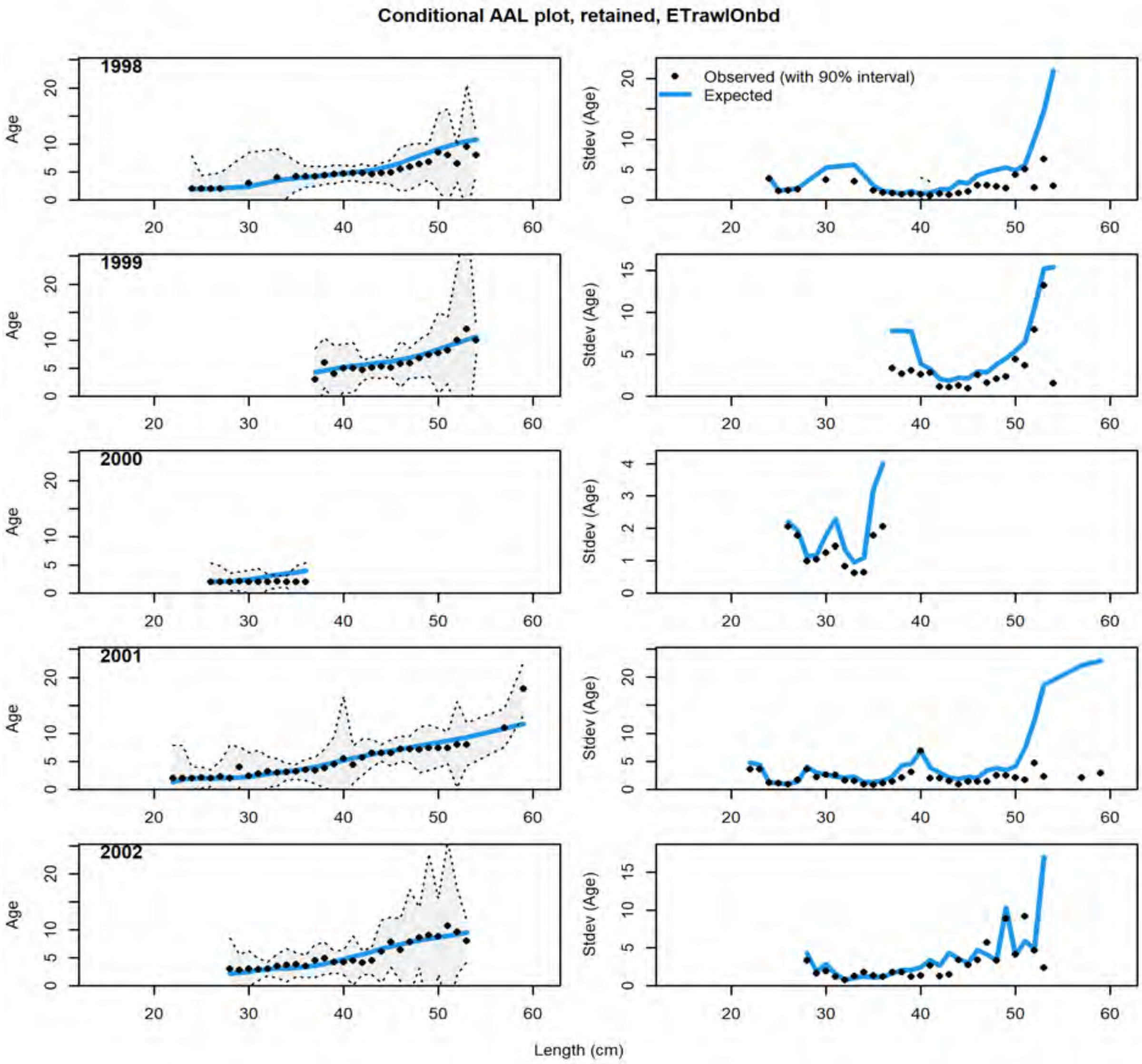
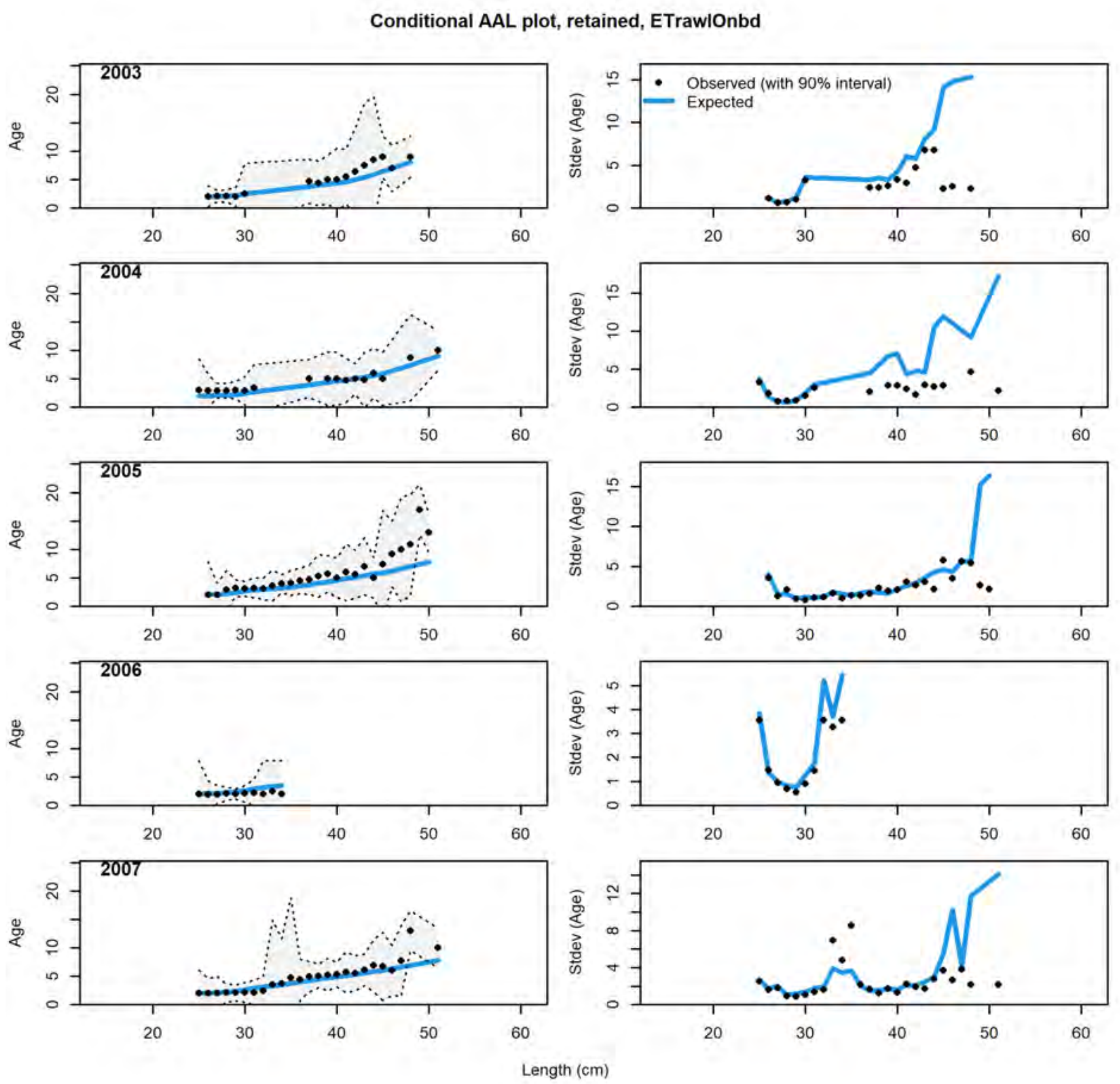


Figure 13.57. Fits to conditional age at length data for the east trawl fleet



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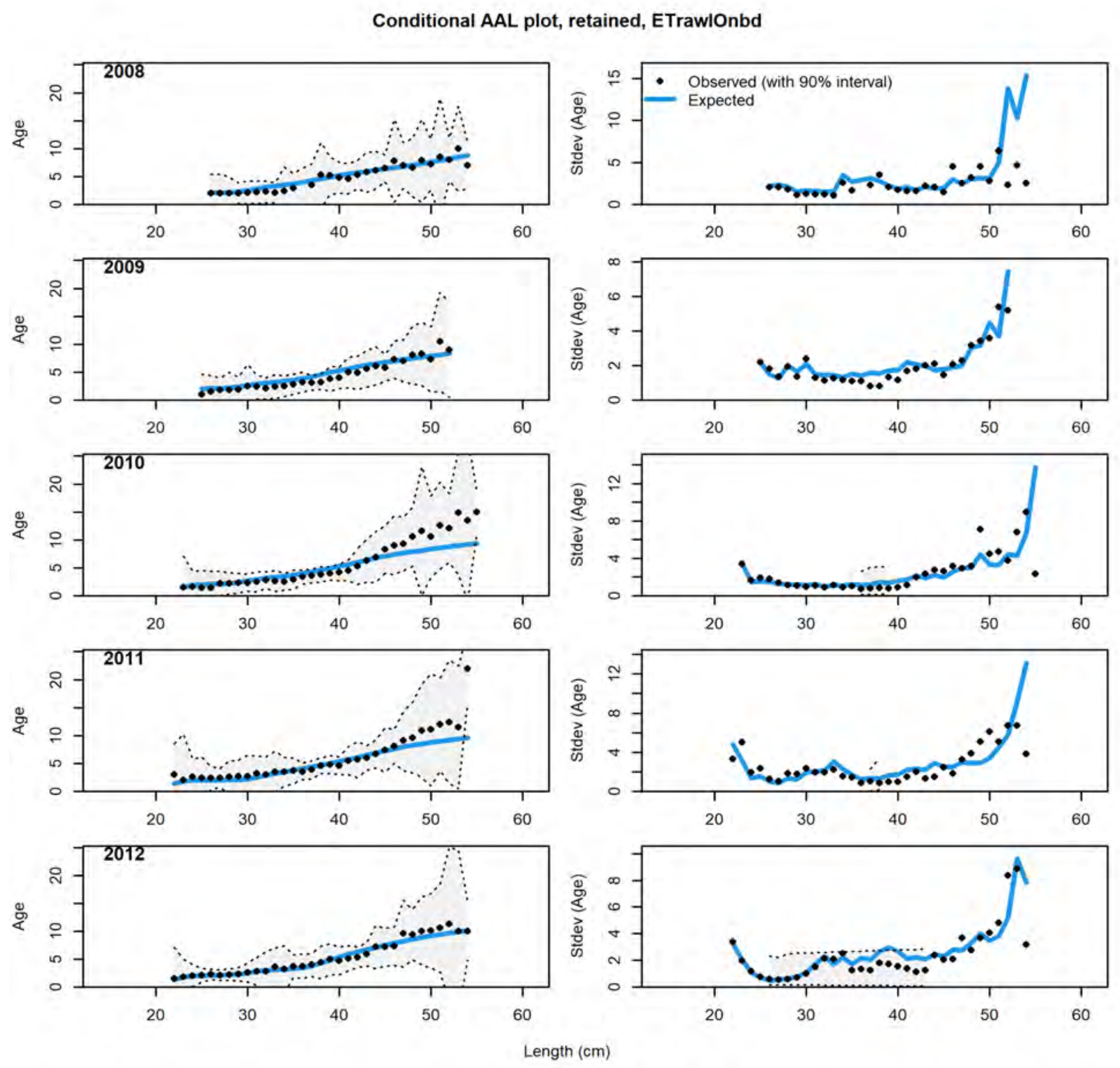

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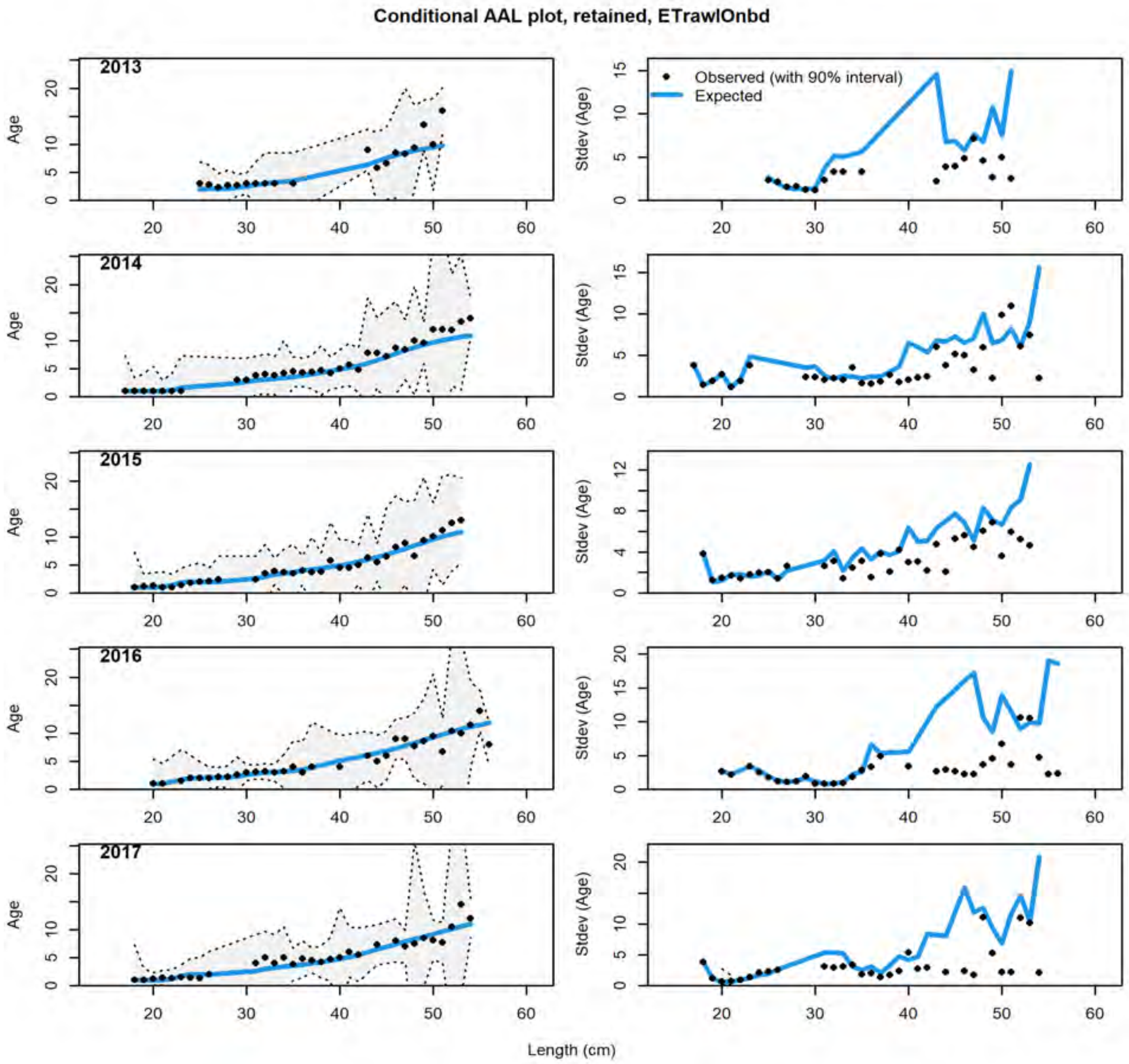


Figure 13.60. Fits to conditional age at length data for the east trawl fleet

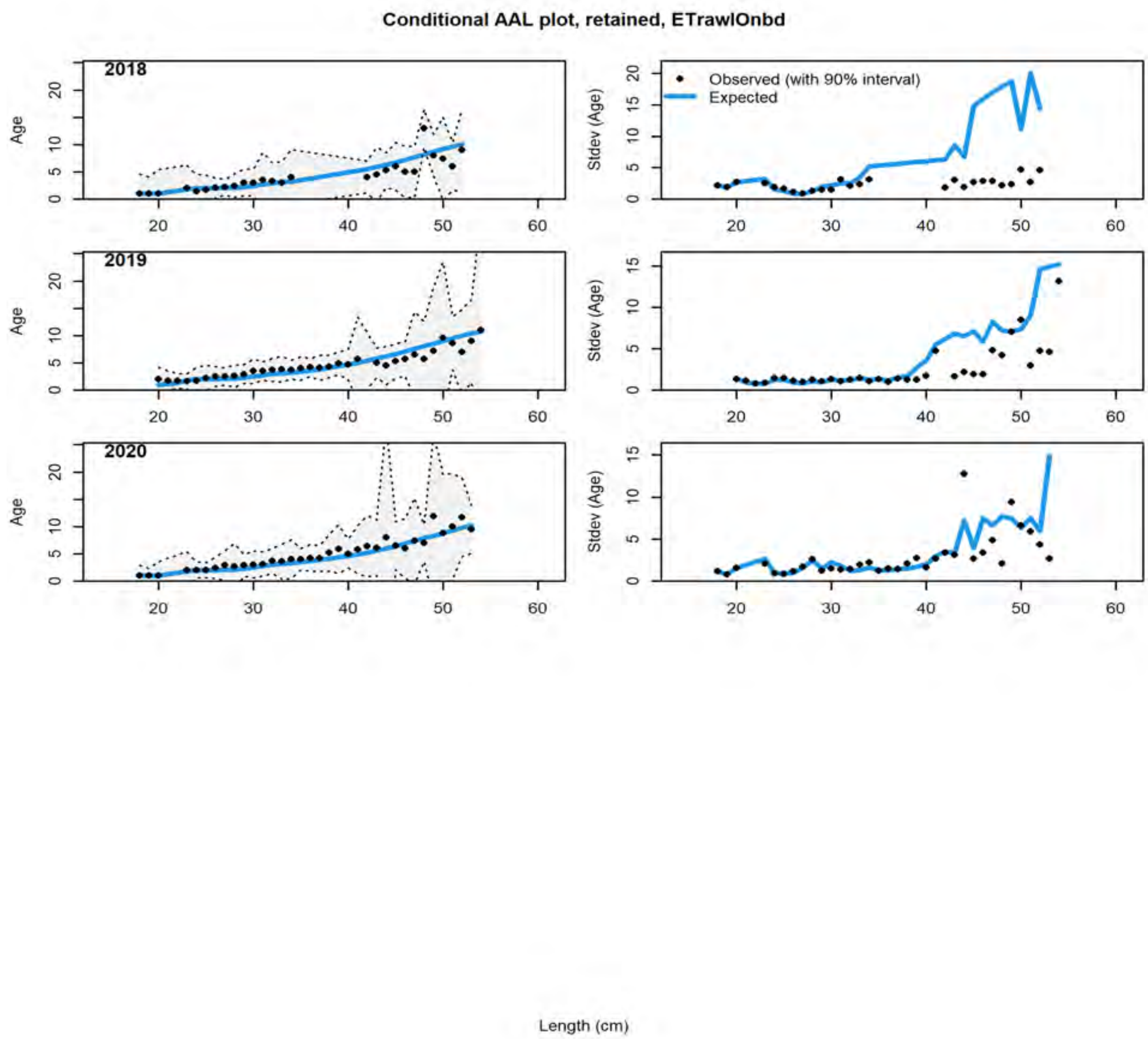


Figure 13.61. Fits to conditional age at length data for the east trawl fleet

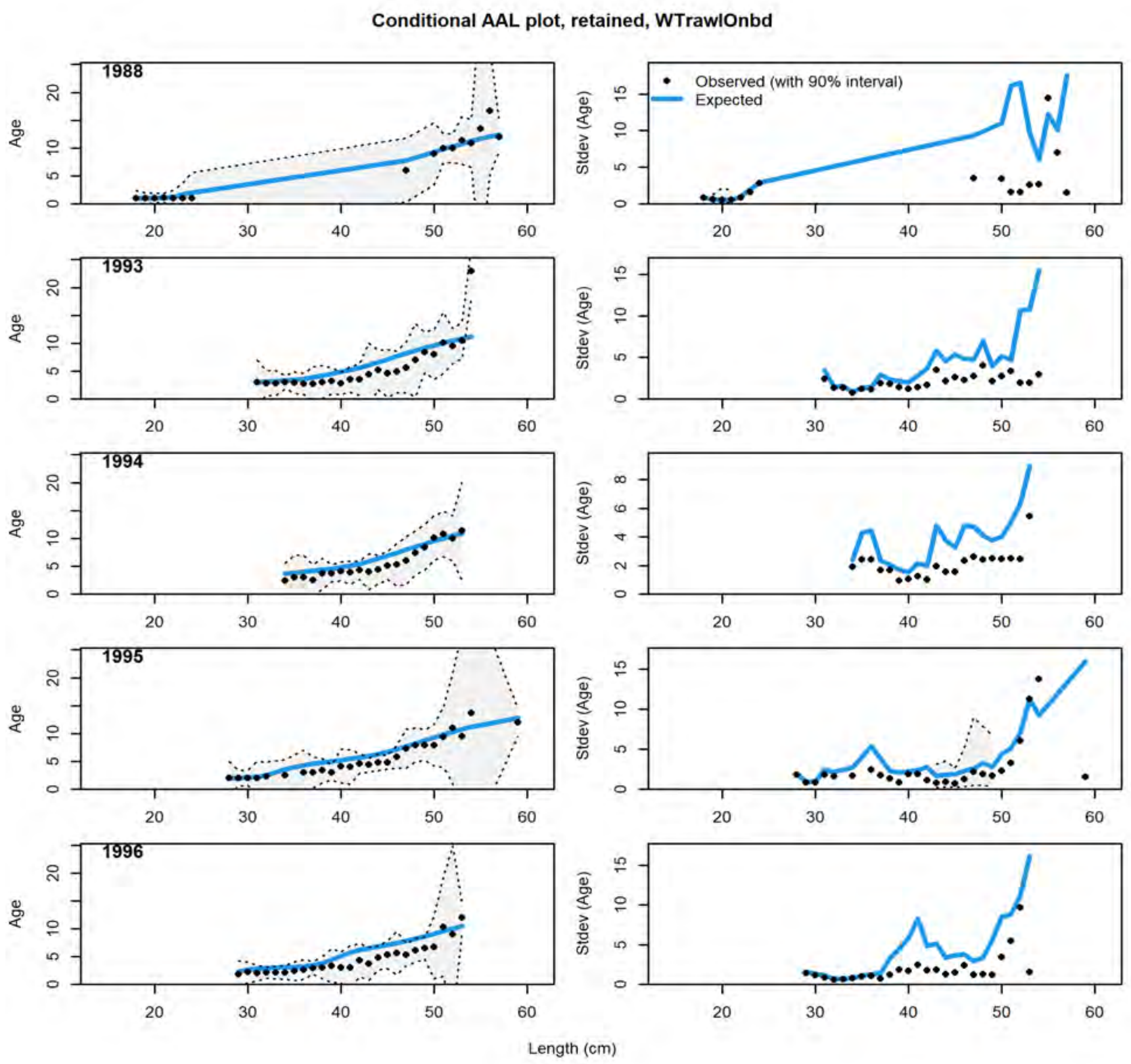
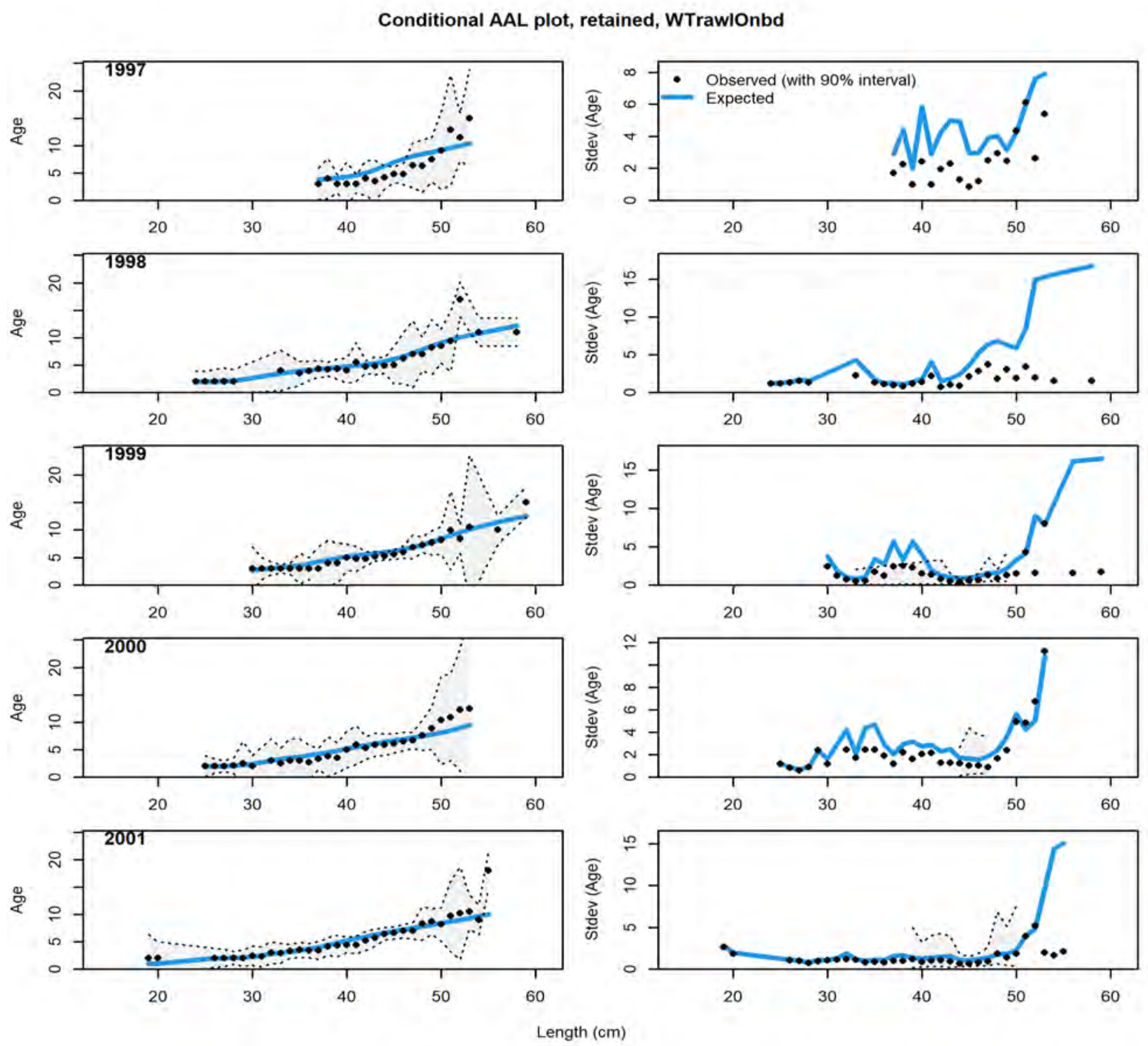


Figure 13.62. Fits to conditional age at length data for the west trawl fleet



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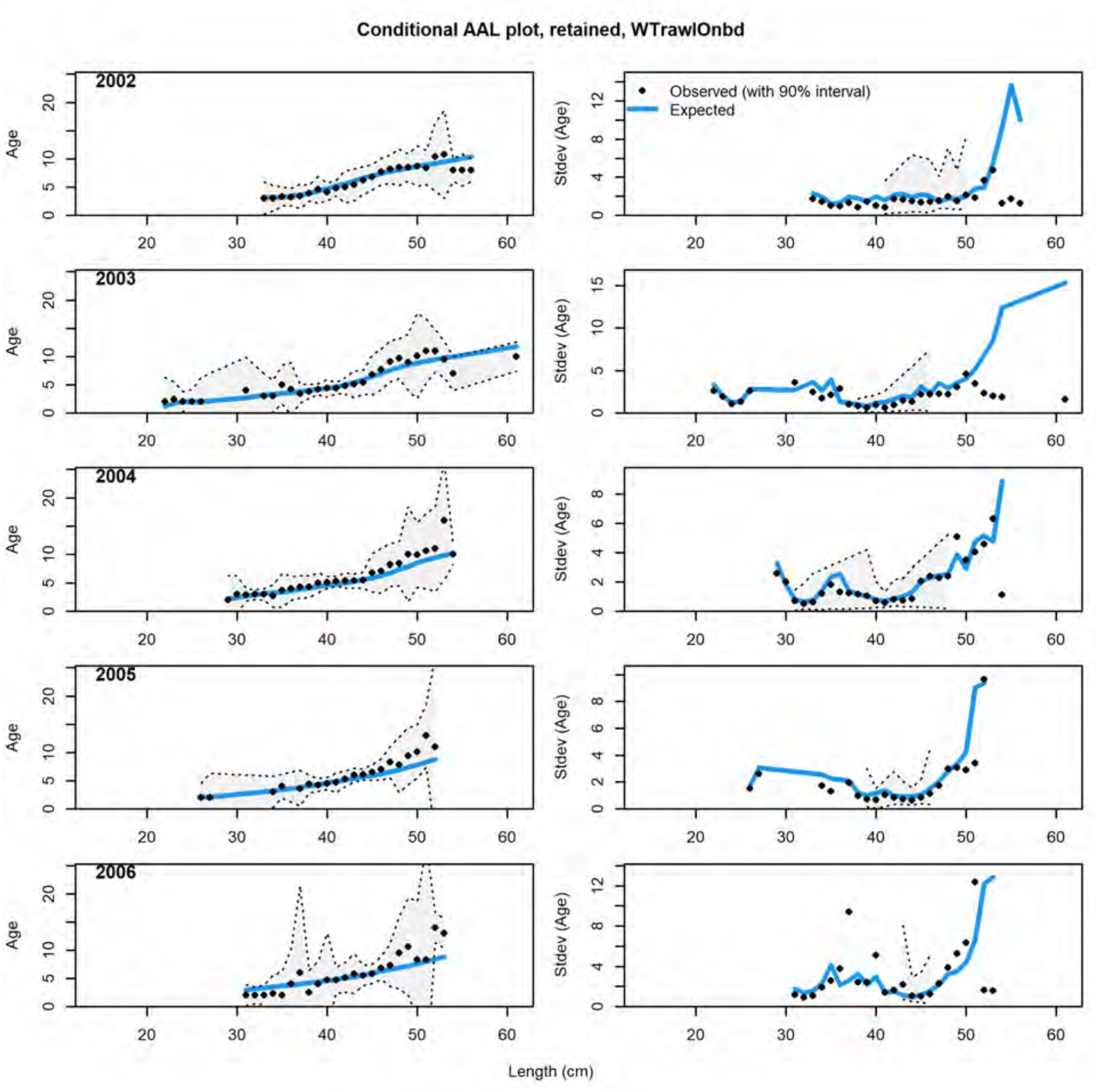

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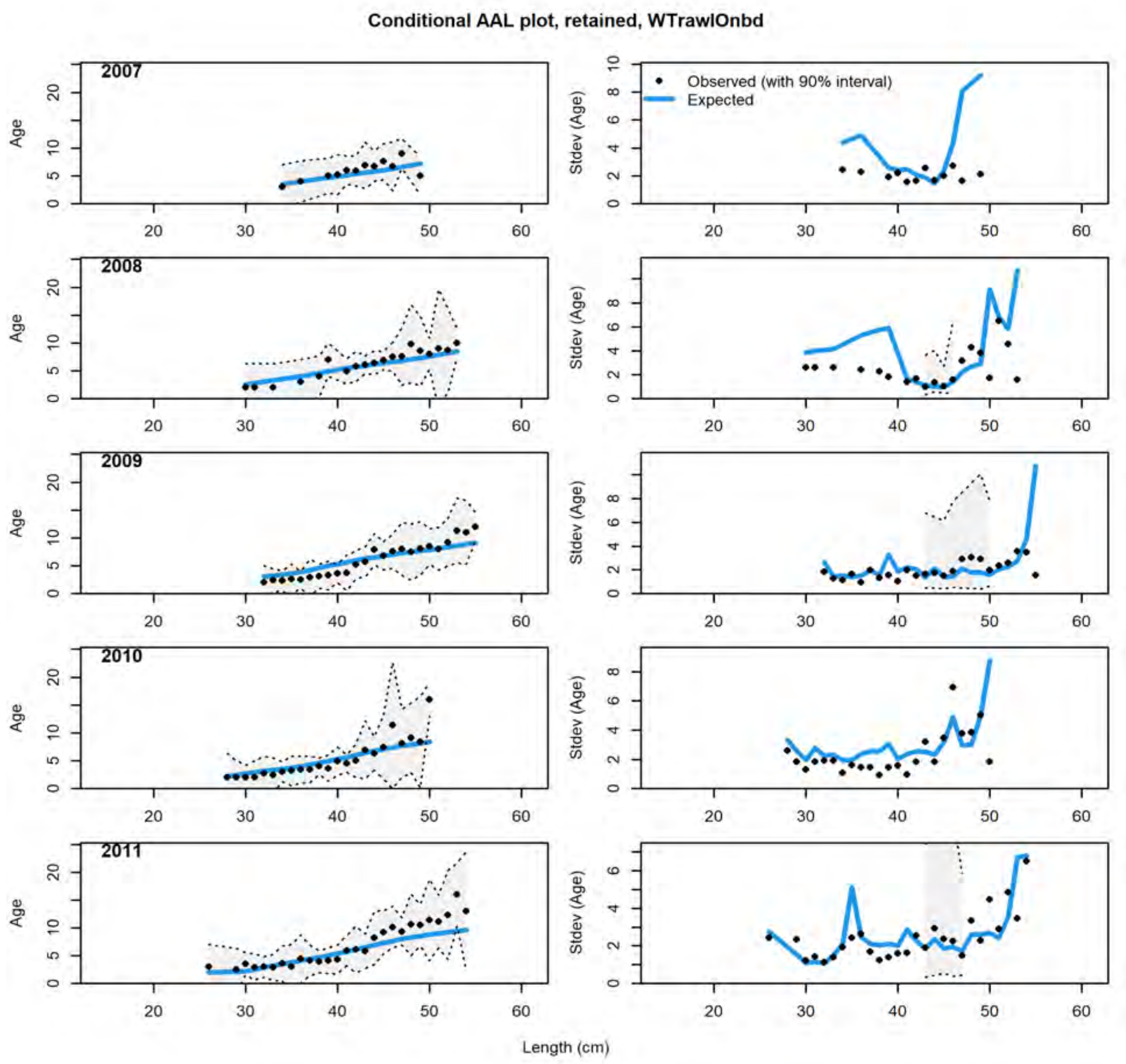

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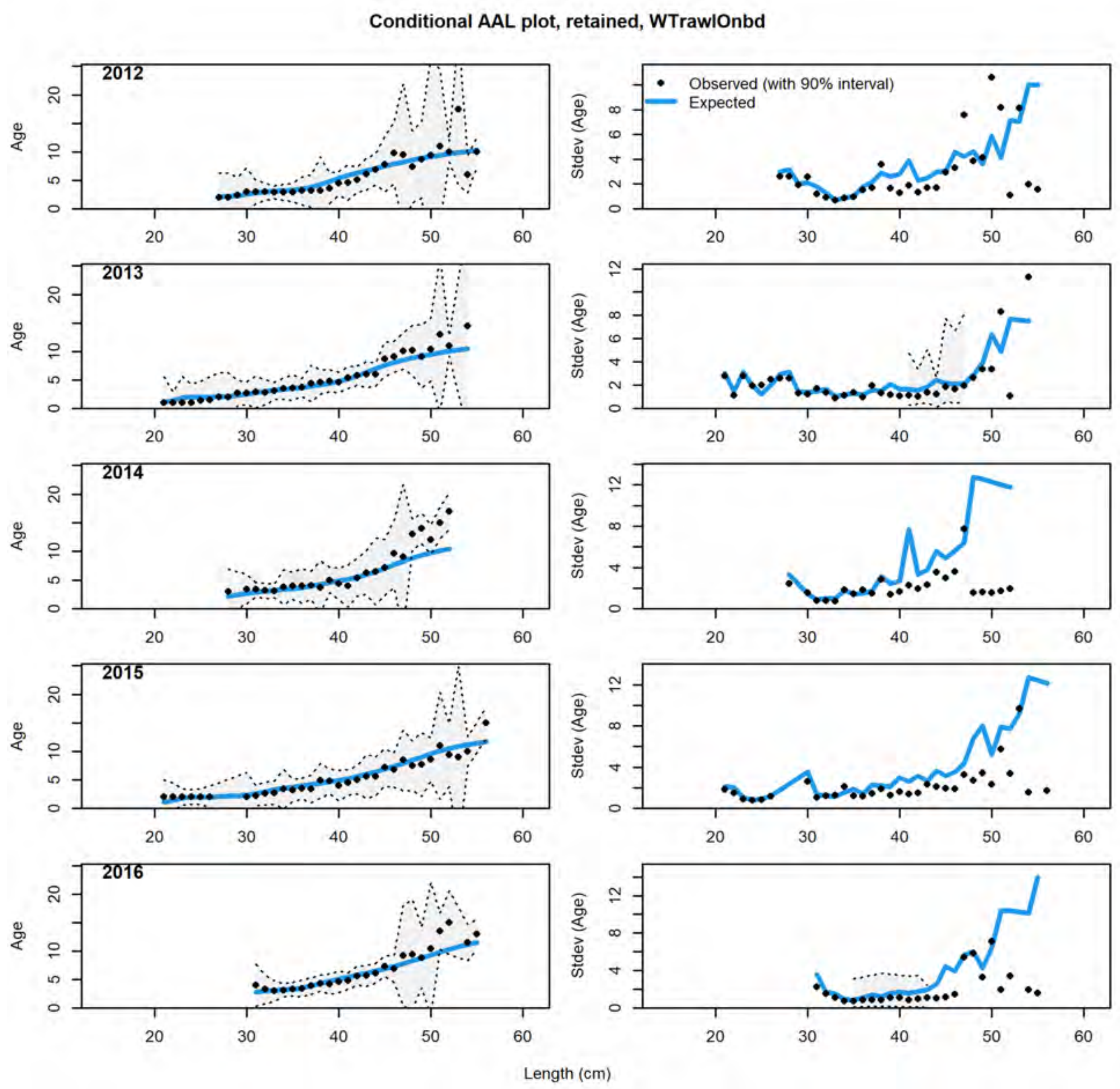

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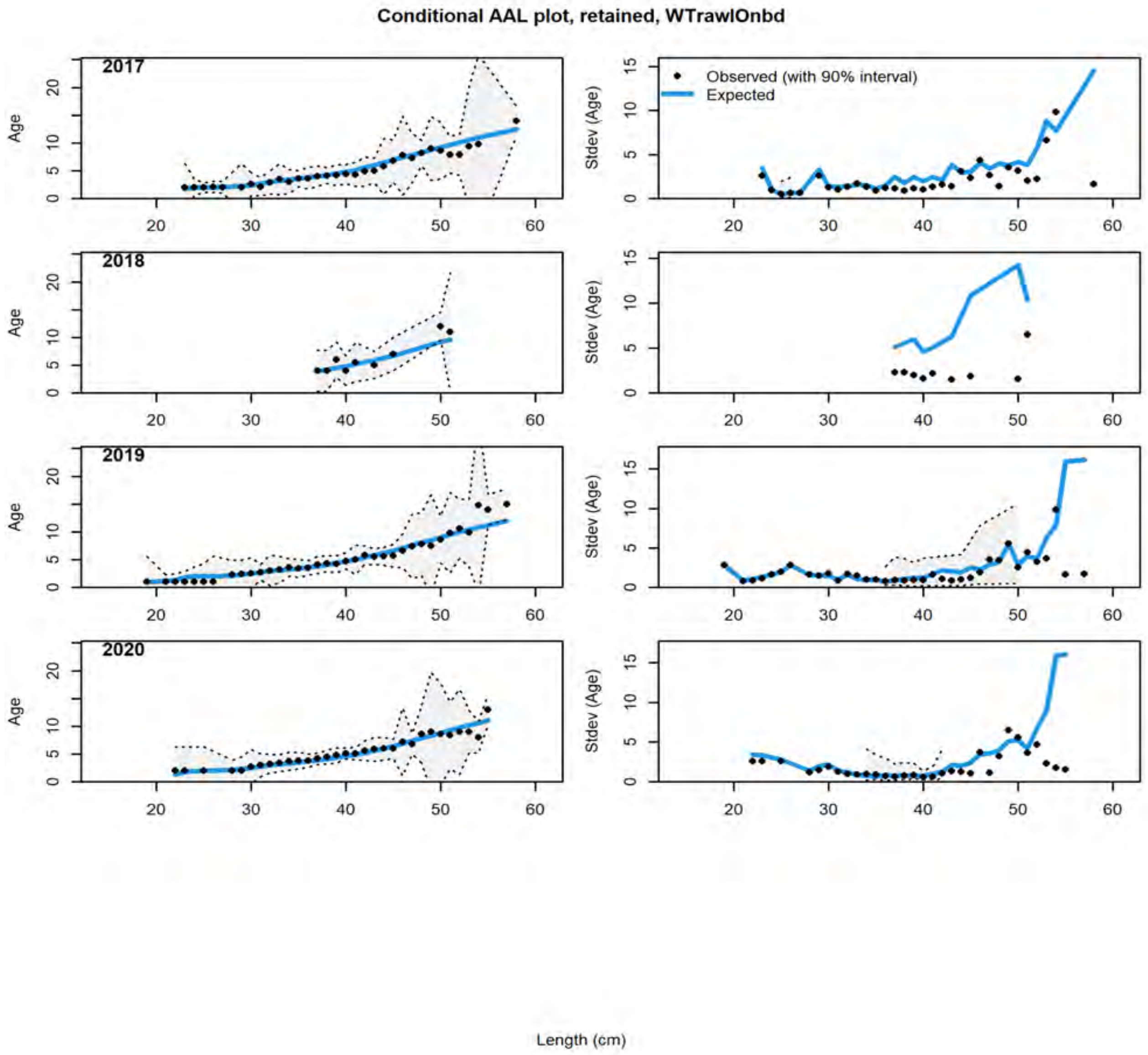

Figure 13.67. Fits to conditional age at length data for the west trawl fleet

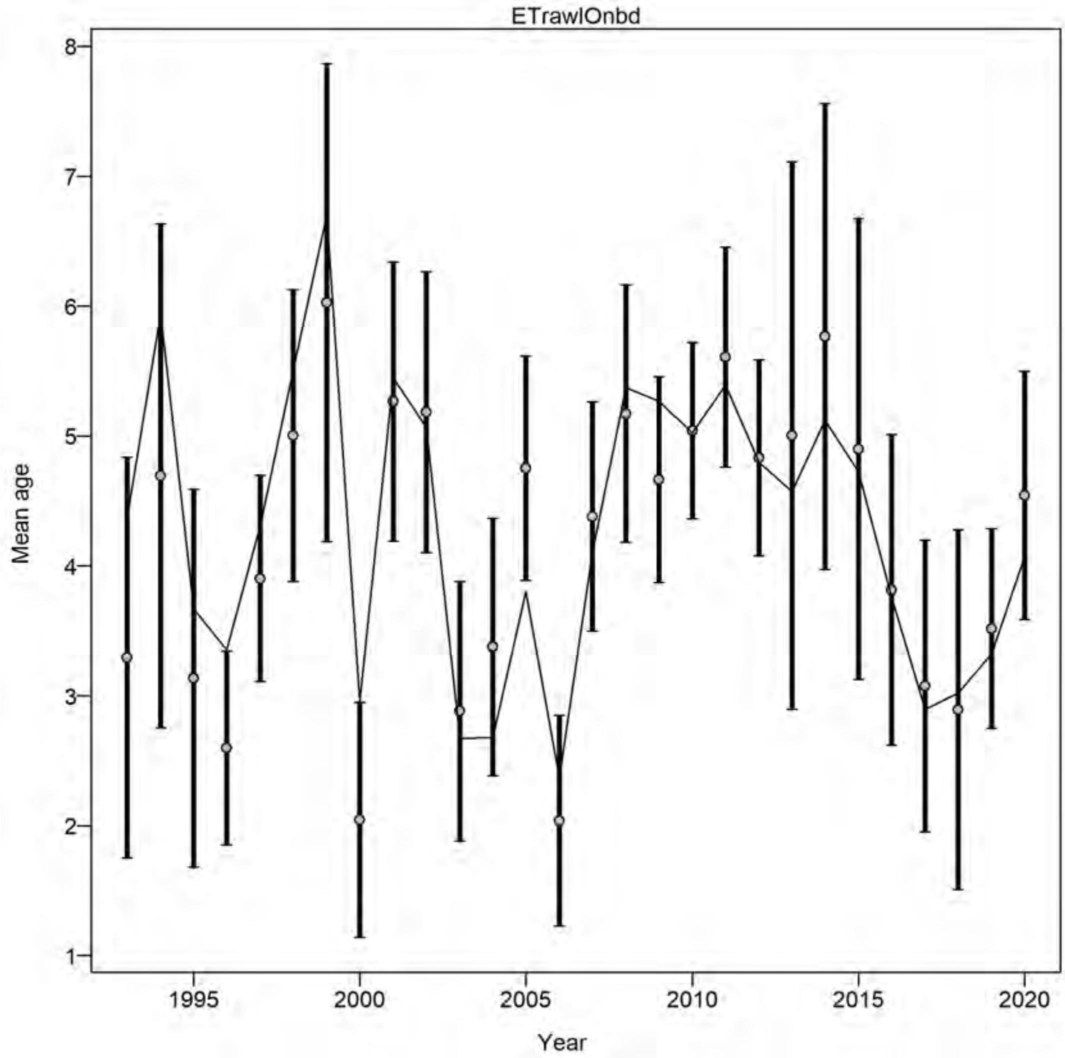

Figure 13.68. Data weighting of conditional age at length data for the east trawl fleet

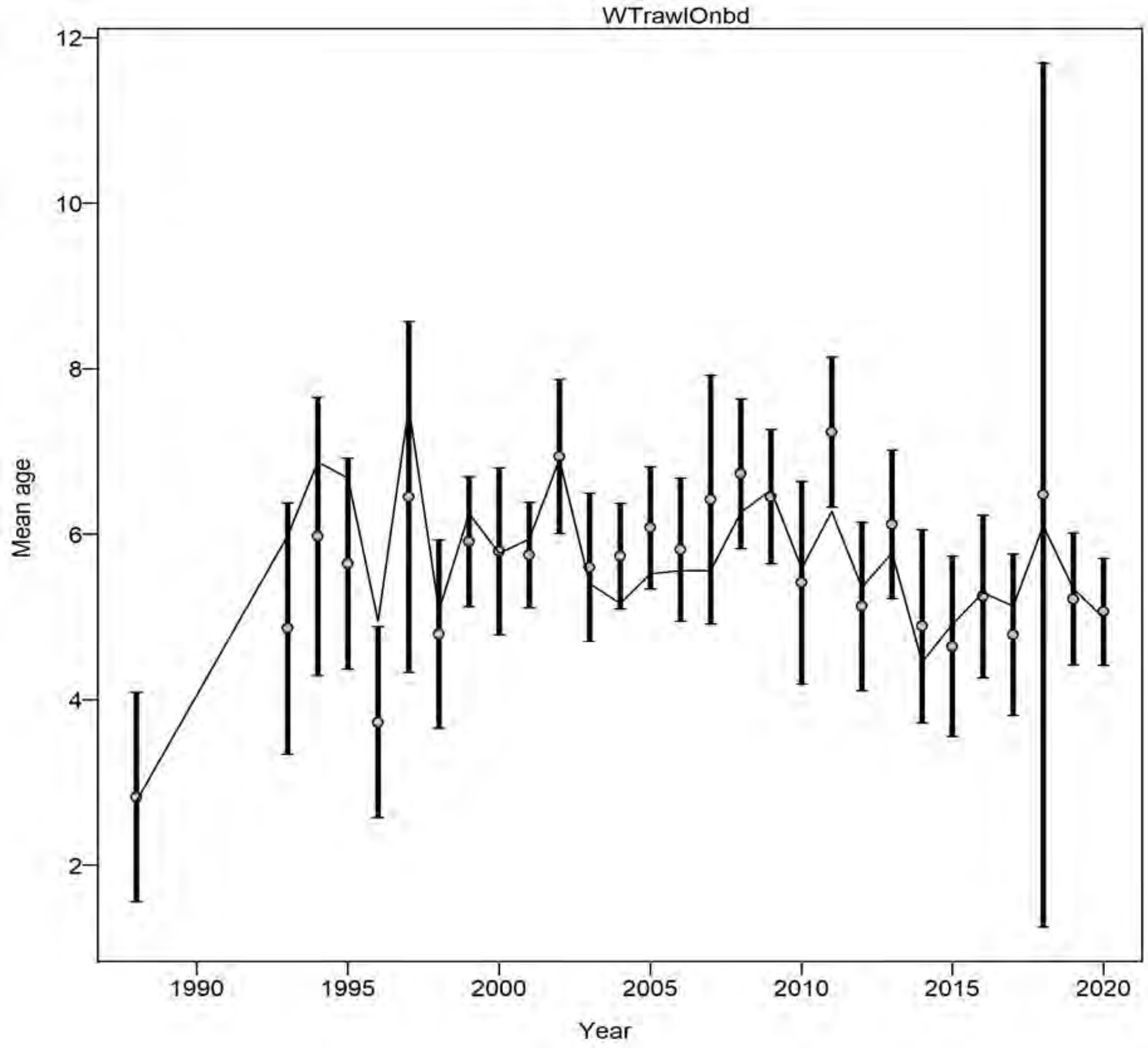

Figure 13.69. Data weighting of conditional age at length data for the west trawl fleet

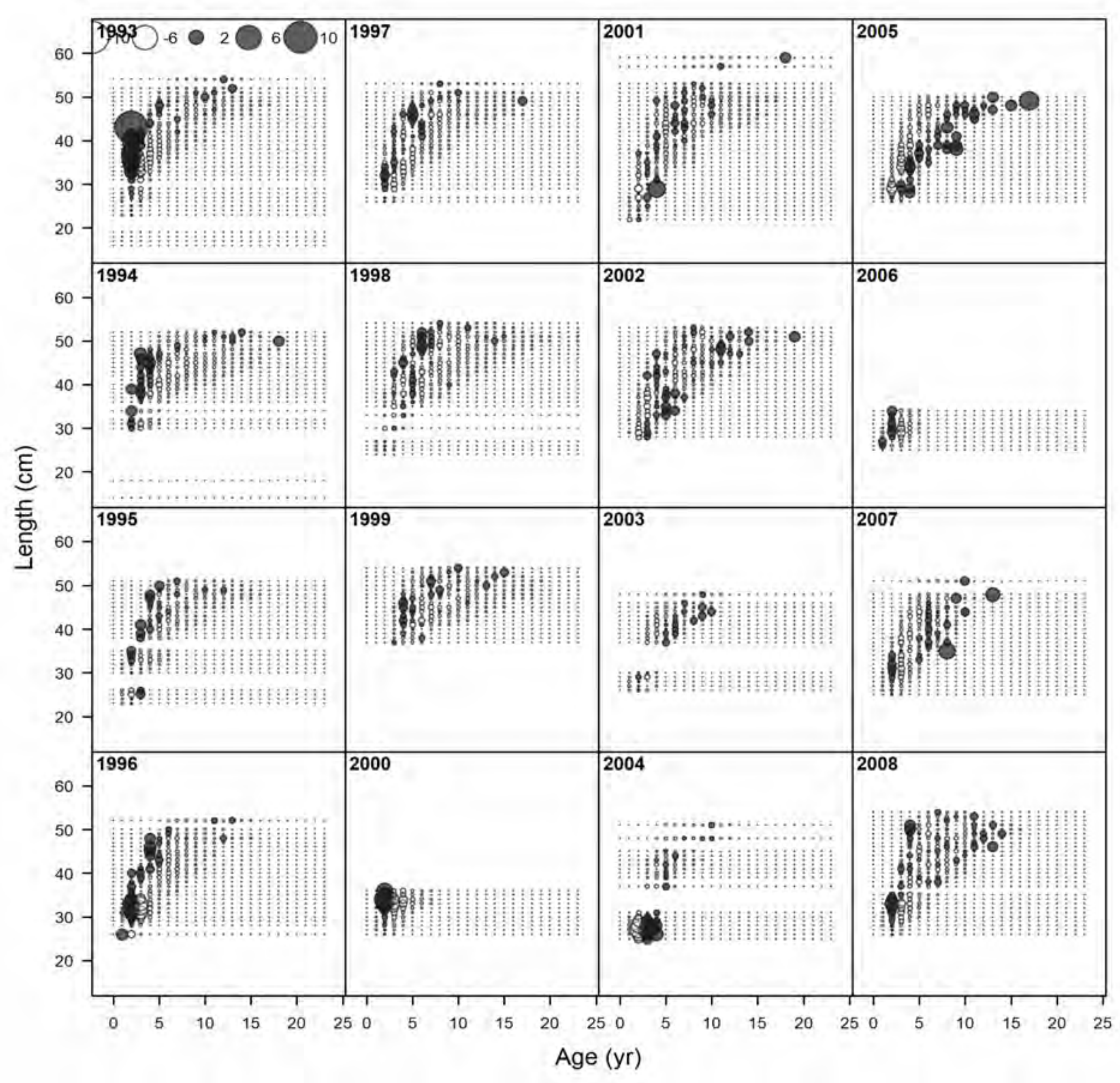

Figure 13.70. Pearson residuals of conditional age at length data for the east trawl fleet

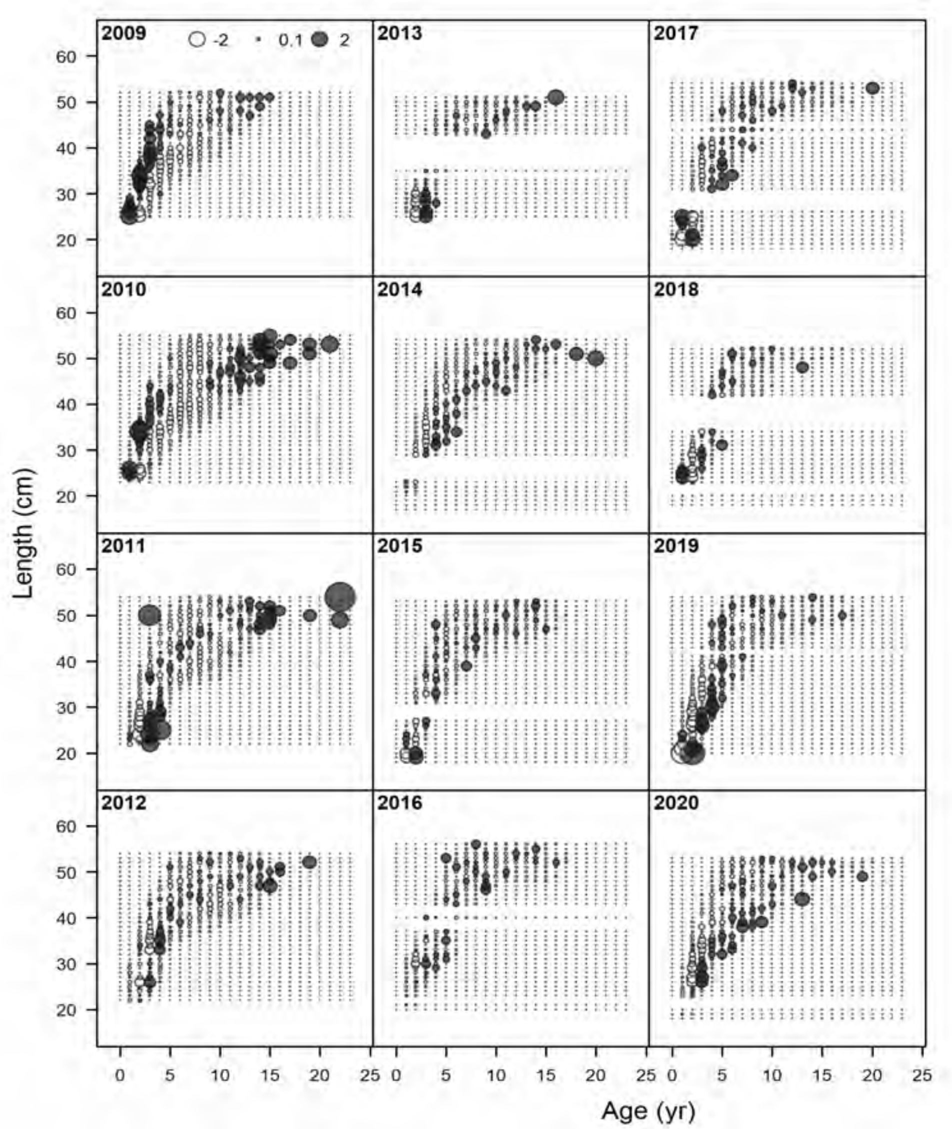

Figure 13.71. Pearson residuals of conditional age at length data for the east trawl fleet

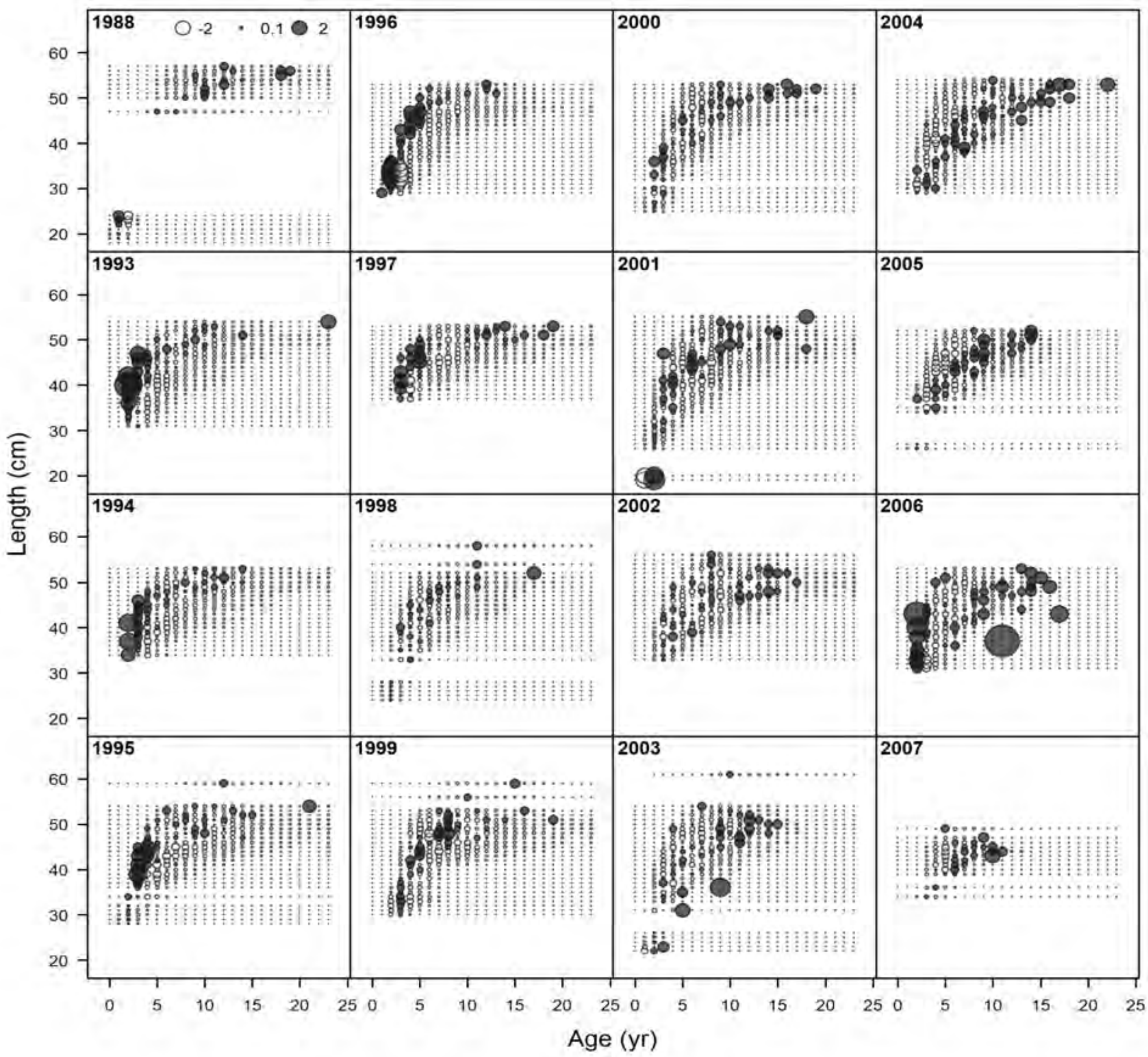

Figure 13.72. Pearson residuals of conditional age at length data for the west trawl fleet

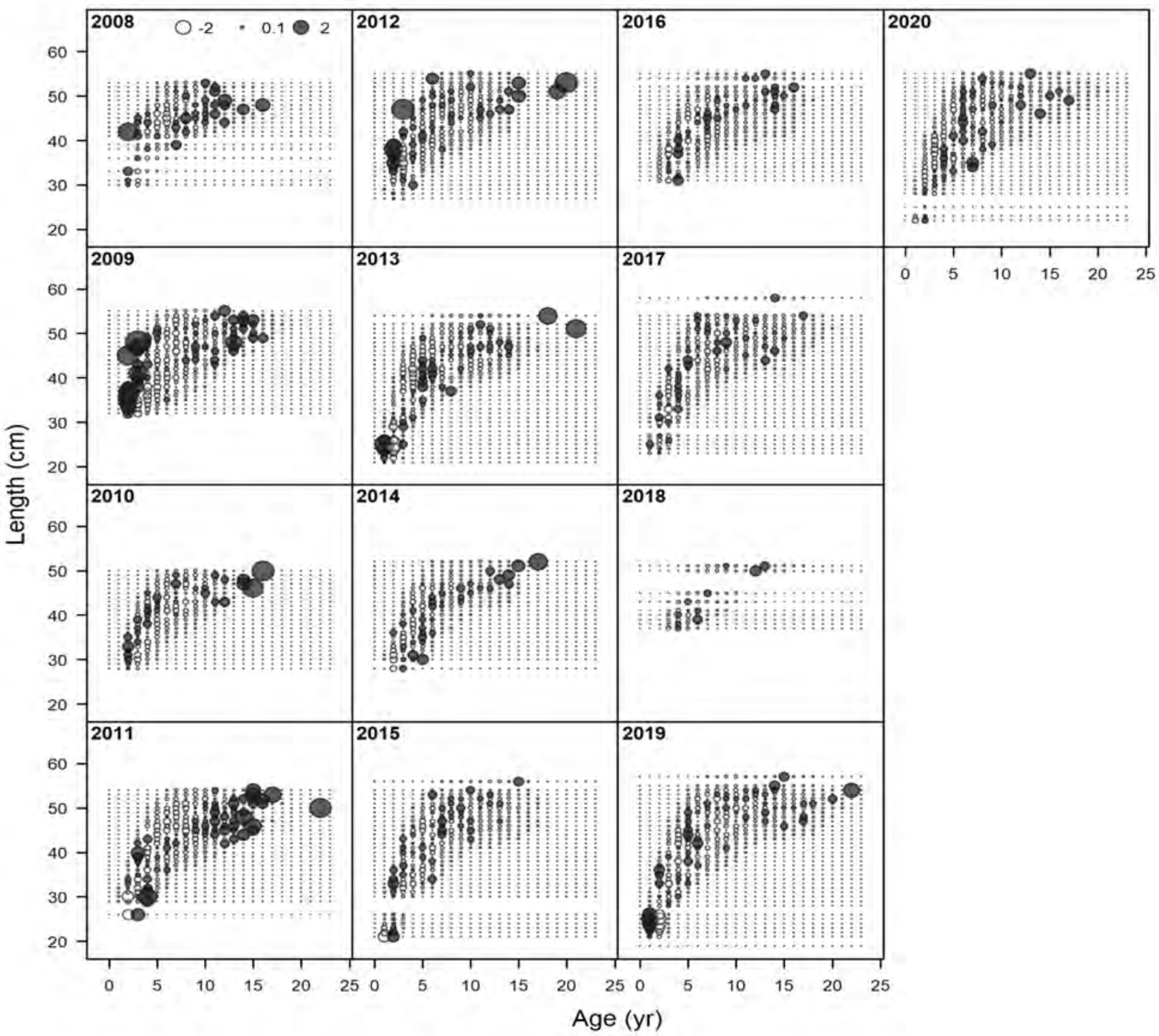

Figure 13.73. Pearson residuals of conditional age at length data for the west trawl fleet

15. Benefits

The results of this project have had a direct bearing on the management of the Southern and Eastern Scalefish and Shark Fishery. Direct benefits to the commercial fishing industry in the SESSF have arisen from improvements to, or the development of, assessments under the various Tier Rules of the Commonwealth Harvest Strategy Policy for selected quota and non-quota species. Information from the stock assessments has fed directly into the TAC setting process for SESSF quota species. As specific and agreed harvest strategies are being developed for SESSF species (a process required by and agreed to under EPBC approval for the fishery), improvements in the assessments developed under this project have had direct and immediate impacts on quota levels or other fishery management measures (in the case of non-quota species).

Participation by the project's staff on the SESSF Resource Assessment Groups has enabled the production of critical assessment reports and clear communication of the reports' results to a wide audience (including managers, industry). Project staff's scientific advice on quantitative and qualitative matters is also clearly valued.

The stock assessments presented in this report have provided managers and industry greater confidence when making key commercial and sustainability decisions for species in the SESSF. These assessments have provided the most up-to-date information, in terms of data and methods, to facilitate the management of the Southern and Eastern Scalefish and Shark Fishery.

16. Conclusion

The 2021 assessment of the stock status of key Southern and Eastern Scalefish and Shark fishery species is based on the methods presented in this report. Documented are the latest quantitative assessments (Tier 1) for key quota species (Blue Grenadier, Silver Warehou, Eastern Jackass Morwong and Eastern Zone Orange Roughy), projection updates for School Whiting and Tiger Flathead, as well as CPUE standardisations for shelf, slope, deepwater and shark species, Tier 4 and Tier 5 analyses. Typical assessment outputs provided indications of current stock status and an application of the Commonwealth Harvest Strategy framework. This framework is based on a set of assessment methods and associated harvest control rules, with the decision to apply a particular combination dependent on the type and quality of information available to determine stock status (Tiers 1 to 5).

The assessment outputs from this project are a critical component of the management and 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.

Stock status and Recommended Biological Catch (RBC) conclusions (Tier 1):

For Blue Grenadier, the estimated virgin female spawning biomass (SSB_0) is 37,445 tonnes and the projected 2022 spawning stock biomass will be 155% of SSB_0 (projected assuming 2020 catches in 2021). The 2022 recommended biological catch (RBC) under the 20:35:48 harvest control rule is 23,777 t, with 245 t estimated discards (23,532 t retained). The long-term RBC is 7,100 t, with 183 t discards.

For Eastern Jackass Morwong, the base-case assessment estimates that the projected 2022 spawning stock biomass will be 15% of SSB_0, with recruitment from 2016 onwards projected using a low recruitment scenario, using the average of the ten most recently estimated recruitment deviations, from 2006-2015. Under the agreed 20:35:48 harvest control rule, the 2022 RBC is 0 t, with the long-term yield (assuming low recruitment in the future) of 91 t.

For Eastern Orange Roughy, the median estimate of $SSB_0$from the MCMC analysis was 38,924 t, slightly lower than the MPD estimate of 40,479 t. The current 2022 female spawning biomass is estimated to be 11,644 t from the MCMC and 13,126 t from the MPD. Relative spawning biomass in 2022 is estimated at 30.0% of unfished levels from the MCMC and 32.4% of unfished levels from the MPD. The RBC for 2022 from the MCMC analysis is 681 t, lower than the MPD estimate for 2022 of 944 t. The average RBC over the next three years (2022-2024) is 737 t from the MCMC analysis and 1,025 t from the MPD.

For Silver Warehou, the assessment estimates that the projected 2022 stock status will be 29% ofSSB_0, projected assuming 2020 catches in 2021, with recruitment from 2016 onwards assumed to be below average, fixed at the average of 2011-2015 levels. The assessment suggests that stock status was as low as 21% of SSB_0 in 2016. Under the 20:35:48 harvest control rule, the 2022 RBC is 587 t, while the long-term yield (assuming continuation of low recruitment) is 591 t.

For School Whiting, if the default (proxy) target reference point (48%) used in the SESSF harvest control rule, and specifically as used by AFMA for School Whiting, is reduced to 40%, a modified 20:35:40 harvest control rule can be applied. This lower target allows the stock to be fished to a lower target biomass (40% of SSB_0). Under a revised 40% target, the 2021 RBC would be 2,753 t.

For Tiger Flathead, updates to catch and CPUE resulted in a revision downwards to the 2020 stock status, from 34% in the last stock assessment to 32% in this analysis. These changes are due to revisions to the catches (2017-2021) and to the revised CPUE series, which has a downturn at the end of the time series (2019-2020) for the Danish seine CPUE. The eastern trawl and Tasmanian trawl CPUE series do not show the same downturn at the end of the CPUE series as Danish seine, with both trawl CPUE relatively flat in the period 2019-2020. Projecting forward to 2022 takes the stock status to 35% at the start of 2022, and this is expected to recover to 37% at the start of 2025, assuming that the RBC is caught in 2023 and 2024 and there is average recruitment from 2017 onwards

17. Appendix: Intellectual Property

No intellectual property has arisen from the project that is likely to lead to significant commercial benefits, patents or licenses.

18. Appendix: Project Staff

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