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A joint Commonwealth and NSW assessment of Silver Trevally (*Pseudocaranx georgianus*)

ENVIRONMENT

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Executive Summary

Silver Trevally (*Pseudocaranx georgianus*), formerly known as *P. dentex*, inhabit estuarine and coastal waters to depths of up to 200m. They have a relatively contiguous distribution from northern New South Wales (NSW) to Western Australia. Silver Trevally are predominately caught by trawl in the Commonwealth Southern and Eastern Scalefish and Shark Fishery (SESSF), by a variety of gears in State jurisdictions, predominately NSW and the recreational sector.

While catches of Silver Trevally have declined substantially since the 1990s, the trends in standardized catch per unit effort (CPUE) have been more variable. Despite similar trends in Commonwealth and NSW CPUE for 2017–2021, the most recent Commonwealth Tier 4 assessment was above the limit reference point (LRP) of 20% of unfished biomass while the most recent NSW assessment using an ensemble of data limited assessment methods indicated that the stock was below the LRP. Given the difference in stock status estimates between the Commonwealth and NSW assessments, a collaboration between CSIRO and NSW DPI Fisheries ensued to evaluate the Commonwealth and NSW data and progress the development of a joint assessment of this stock.

This report reviews previous assessments of the stock, provides a summary of the available data sources, and develops a Tier 1 assessment of Silver Trevally for the areas off the NSW and Victorian coasts i.e. the Commonwealth Trawl Sector (CTS) zones 10, 20 and 60. The base case assessment includes commercial and recreational catch and discard estimates for 1955–2022, length data for the NSW trawl, trap, line and estuary fisheries, Commonwealth trawl sector, recreational sector and the Kapala survey, age data for 1998, standardized CPUE for NSW trawl, NSW trap and Commonwealth trawl, and biological (life history) parameters from previous studies.

CPUE for the NSW trawl and trap fisheries and Commonwealth trawl sector has increased over 2019–2022. Model fits to NSW trap and pre-2007 NSW trawl CPUE are good, while fits to the Commonwealth trawl and 2010–2022 NSW trawl series are poor, with inconsistency between the trends of these two CPUE series has prevented the model to fit well to all three CPUE series simultaneously. The model fits well to the NSW trap, NSW estuary, Commonwealth trawl and recreational lengths and reasonably well to the NSW trawl lengths prior to the NSW introduction of a minimum legal length (MLL) in 2007, however, the NSW line and Kapala length data show bimodality which the model cannot replicate.

Silver Trevally shows evidence of below average recruitment over much of the last 30 years and SERAG specified that the base case model be projected assuming below average recruitment. The base case assessment estimates unfished female spawning biomass (SSB_0) at 5,091t and current spawning biomass (SSB_{2024}) at 1,360t with current stock status (SSB_{2024}/SSB_0) estimated to be 26.7%. If average recruitment is assumed, then current stock status is estimated to be 32.8%. The assessment is very sensitive to the assumed value of natural mortality, with the base case assuming M=0.18yr^{-1}. Current stock status estimates from models with plausible natural mortality values of M=0.11–0.18yr^{-1} are 12.8–26.7%. For catches of 50–150t per annum, stock status in 2027 is estimated to increase to 30.3–32.9% for the base case and 22.3–24.5% for a low recruitment scenario with M=0.14yr^{-1}.

More details of the assessment and its sensitivity to data sources, model assumptions and biological parameters are provided in the following six-page Extended Summary.

Extended Summary

This assessment was developed as a collaboration between CSIRO and NSW DPI Fisheries, building on earlier work (Burch et al., 2023c) that reviewed the available data for Silver Trevally and developed two provisional Tier 1 assessments, one of which was presented to SESSFRAG in April 2023. As this is a new assessment for which there is no accepted base case, intersessional review of the assessment was undertaken by SESSFRAG and the Silver Trevally Steering Committee comprising Paul McShane (SERAG Chair), Andrew Penney (SERAG Independent Scientist), Mark Grubert (AFMA) and Ian Stockton (NSW DPI Fisheries Manager). A summary of the development and review of this assessment is provided in Appendix A.

Key assessment features and results

The base case assessment estimates stock status in 2024 to be 26.7% of its unfished level (Table 1, Figure 1). At the behest of SERAG, the base case model assumes below average recruitment (the average of estimated recruitments for 2010–2019) from 2020 onwards (Figure 2). If recruitment is assumed to be at the long-term average, then the stock status at the beginning of 2024 is estimated to be 32.8%. Spawning biomass estimates gradually declined from unfished levels in the 1950s to ~75% of unfished spawning biomass by the mid-1980s (Figure 1). A period of rapid decline in biomass followed, with the stock dropping below the target reference point (TRP) in the mid-1990s, then below the limit reference point (LRP) in the early 2000s. This was associated with extremely high fishing mortality, which increased from $F\approx1$ in the early 1980s to $F\approx2$ by 1990 and exceeded $F=4$ in the mid-2000s (Figure 3). Fishing mortality then rapidly and consistently declined so that by 2019–2022, $F<0.5$. CPUE and spawning biomass both increased in 2019–2022, which may indicate that recent exploitation has declined to a level that permits some recovery of the stock.

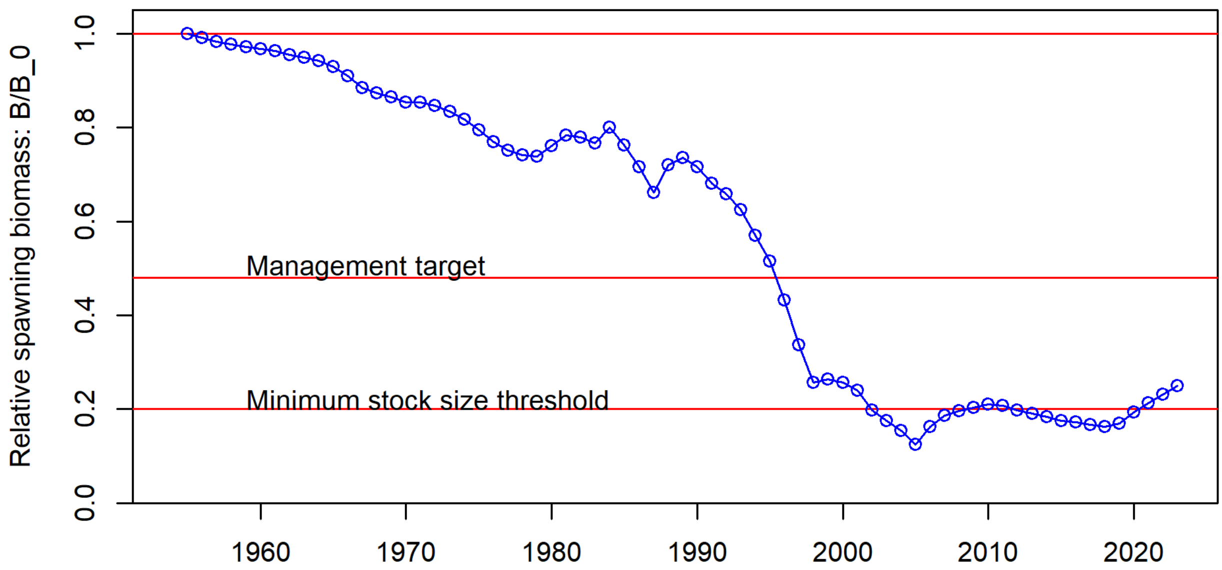

Figure 1 The estimated time-series of relative spawning biomass for the 2023 base case Silver Trevally assessment.

Natural mortality is the primary driver of uncertainty in current stock status estimates within the assessment: the base case assumes $M=0.18yr^{-1}$, however, stock status estimates range between 12.8–26.7% of unfished spawning biomass for plausible values of natural mortality (M=0.11–

0.18yr^{-1}, Table 1). The key uncertainties within the assessment and a comparison of this assessment with previous NSW and Commonwealth assessments of this stock are discussed briefly below.

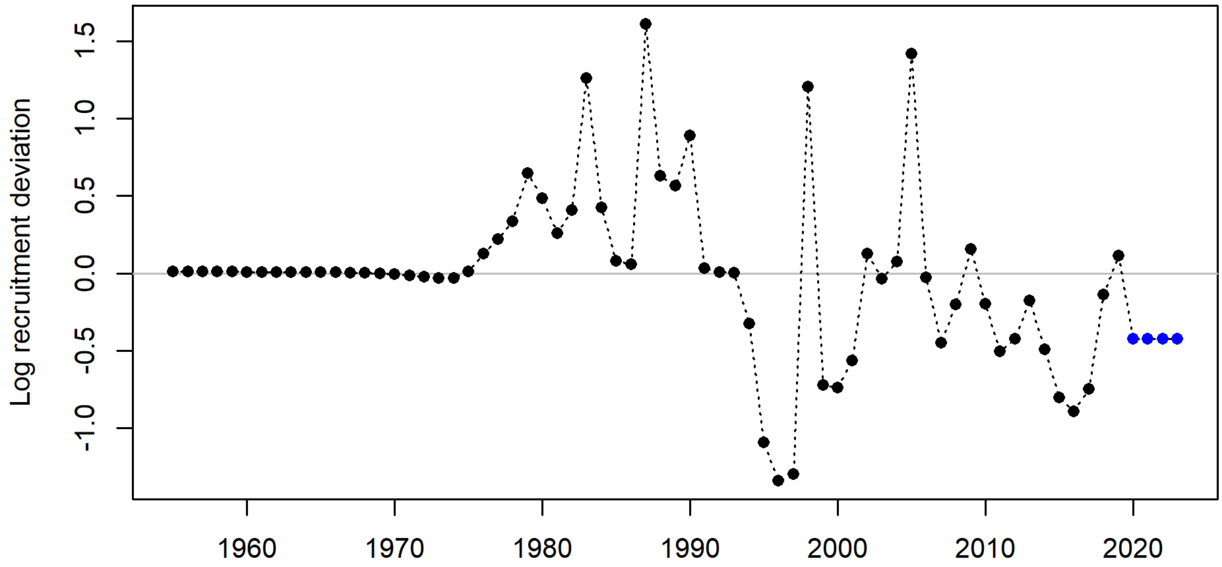

Figure 2 Estimated logarithm of recruitment deviations (black circles) and projected years where below average recruitment is assumed (blue circles) for the 2023 base case Silver Trevally assessment.

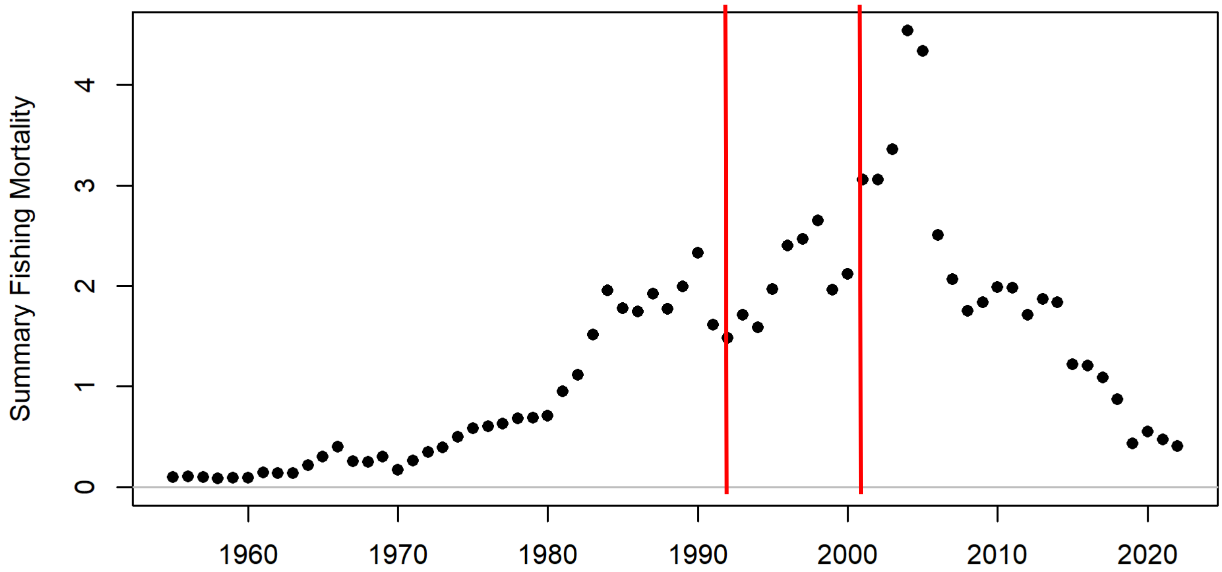

Figure 3 Estimated annual instantaneous fishing mortality for the 2023 base case Silver Trevally assessment. The red vertical lines show the reference period for the Commonwealth Tier 4 assessment (1992–2001).

Stock structure and data

The assessment assumes a single stock of Silver Trevally in NSW and Victorian state waters and in the adjacent Commonwealth waters (CTS zones 10, 20 and 60). This region provides more than 95% of the catches and all of the available biological data (lengths, ages, biological parameters). The assessment is unlikely to be sensitive to the inclusion of South Australian or Tasmanian catches, however, this can be explored with sensitivity analyses in future assessments.

The assessment is implemented in Stock Synthesis version 3.30.31 using the following data and model specifications:

- Commercial and recreational landed catch estimates from NSW, Victoria and Commonwealth CTS zones 10, 20 and 60 (the areas off NSW and Victoria) from 1955–2022.
- Seven catch fleets: NSW trawl, NSW trap, NSW line, NSW estuary, Commonwealth trawl, the NSW and Victorian recreational sector and Victorian commercial.
- Length data for six of the catch fleets and the Kapala survey, with selectivity estimated for all fleets except NSW trawl (fixed at values estimated from an earlier model due to difficulties implementing the retention function) and Victorian commercial (mirrored to Commonwealth trawl).
- Estimated discards for the NSW trawl fleet after the introduction of the minimum legal length (MLL) in 2007. Other NSW fleets do not select fish below the MLL.
- Age-at-length data for 1998 from NSW trawl, NSW trap, NSW line and NSW estuary fisheries.
- Standardised CPUE for the NSW trawl, NSW trap and Commonwealth trawl fisheries.
- Biological parameters from earlier studies and estimated from the available data externally to the assessment.

Standard techniques for specifying SESSF Tier 1 assessments were applied, principally the application of the Francis data weighting method[1]. The impacts of the alternative data and model assumptions are explored using sensitivity analyses.

Evidence for below average recruitment

Several SESSF stocks have shown evidence of below average recruitment over the last two decades, including eastern Jackass Morwong, eastern Redfish, eastern Gemfish, Blue Warehou and Silver Warehou. For Silver Trevally, the estimated recruitment deviations provide a reasonable level of evidence that this stock has experienced below average recruitment over much of the last 30 years (Figure 2). To accommodate this apparent below average recruitment within its management advice, SERAG directed that the base case assessment be projected assuming future recruitment remains below the long-term average. Future recruitment was set to the average of the most recent 10 years of estimated recruitments (2010–2019).

Natural mortality

Estimates of natural mortality for Silver Trevally from life history studies in south-eastern Australia are M=0.12–0.19yr^{-1}, while the estimate from New Zealand is M=0.10 yr^{-1}. The New Zealand estimate is based on a maximum age of 45 years, which is almost double the maximum age of 25 years observed in Silver Trevally from south-eastern Australia. Additionally, New Zealand Silver

[1] Re-weighting methods objectively assign a higher or lower weighting to different data sources within a model to accommodate conflicts in the data. The Francis method, widely used in Australia, New Zealand and the United States, down weights the age and length composition data compared with the indices of abundance (i.e. CPUE, acoustic surveys).

Trevally also mature at 32–37cm, much larger than the 19–23cm for Silver Trevally in south-eastern Australia. Finally, the growth rates of Silver Trevally in south-eastern Australia and New Zealand are substantially different (Figure 4). Based on these differences, natural mortality for the 2023 base case Silver Trevally assessment was pre-specified at the estimate of M=0.18yr^{-1} derived from life history correlates[2] in the most recent NSW assessment (Fowler et al. 2023).

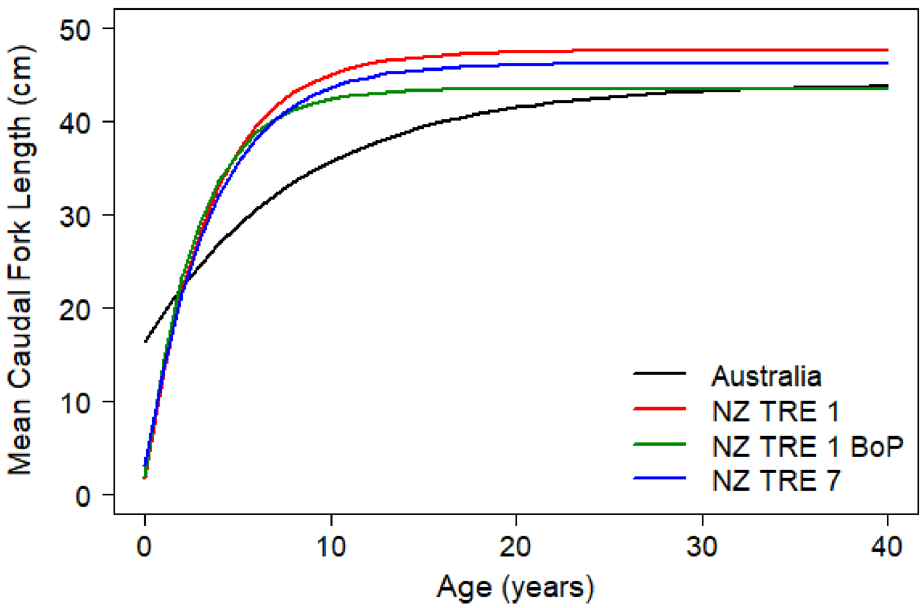

Figure 4 Estimated von Bertalanffy growth model for the 2023 base case Silver Trevally assessment (black line), New Zealand trevally zone 1 (red line), New Zealand Bay of Plenty (green line) and New Zealand trevally zone 7 (blue line).

Selected sensitivities

Natural mortality is the primary driver of uncertainty in current stock status estimates within the Silver Trevally assessment, with the base case assuming M=0.18yr^{-1}. A likelihood profile undertaken after the base case value of M had been chosen suggests plausible values of M within the range of M=0.11–0.18yr^{-1}, with a preferred value of M=0.14yr^{-1}. Assuming future recruitments are below average (the base case assumption) the estimated current stock status for M=0.11–0.18yr^{-1} is 12.8–26.7% of unfished spawning biomass. The estimated current stock status from a (low recruitment) sensitivity assuming M=0.14yr^{-1} is 18.6%. If average recruitment were to be assumed, then the current stock status would be 21.4% of the unfished level.

In addition to natural mortality, the assessment is also somewhat sensitive to the steepness of the stock recruitment relationship (h)[3] and the CPUE data inclusions and weightings, with estimated stock status 2–4% lower than the base case when h=0.6, the NSW trap CPUE is removed, the Commonwealth CPUE time series is restricted to 1992–2022, or the weighting of the CPUE in the likelihood is halved. Conversely, when h=0.8 or the weighting on the CPUE in the likelihood is doubled, current stock status is 2–4% higher than the base case. Including the 1997 age data or the

[2] The oldest age observed for Silver Trevally in south-eastern Australia is 25 years from a 1997–1999 study. A conservative maximum age of 30 years was used to estimate natural mortality to account for exploitation prior to the collection of age data.

[3] The steepness parameter (h) of the stock recruitment relationship determines the stock status at which recruitment drops below its average unfished level; when h=1 there is no relationship between spawning biomass and recruitment, for lower values of h the current stock status has an increasingly more negative impact on recruitment.

1945–1954 catches, varying the length at maturity or the recruitment variability, or changing the likelihood weighting of the age and length composition data resulted in <1% change in the estimates of current stock status, compared with the base case.

Table 1. Selected sensitivity scenarios to the 2023 base case Silver Trevally model. Estimates of current stock status and the difference between the current stock status from the base case and the sensitivity (Δ Stock Status). All models assume below average recruitment during the projection period (2020 onwards), with the exception of the 2023 base case with average recruitment. † Denotes models that have had their Francis weighting recalculated, while the other models retain the base case Francis weighting.

Sensitivity Scenario	Current Stock Status (%)	Δ Stock Status (%)
†2023 base case (*M*=0.18yr^{-1})	**26.7**	**-**
†2023 base case (*M*=0.18yr^{-1}) assuming average recruitment	**32.8**	**6.1**
†Low natural mortality (*M*=0.14yr^{-1})	**18.6**	**-8.1**
Very low natural mortality (*M*=0.11yr^{-1})	**12.8**	**-13.9**
Low steepness (*h*=0.6)	22.7	-4.0
High steepness (*h*=0.8)	30.3	3.6
†Remove NSW trap CPUE	23.8	-2.9
Commonwealth CPUE 1992–2022	23.3	-3.4
Halve the weighting on the CPUE data	24.4	-2.4
Double the weighting on the CPUE data	29.0	2.2

Comparison with previous assessments

This report was initiated because of discrepancies between the NSW and Commonwealth Tier 4 assessments, with the NSW assessment that concluded that the stock was below the LRP, while the Commonwealth assessment was above the LRP.

The most recent NSW assessment of Silver Trevally used a weight of evidence approach comprising a surplus production model fitted to catch and standardized CPUE, a length-based population dynamics model fitted to 1987–2007 trawl data and a consideration of the proportion of large fish in recent NSW trawl catches relative to that in the last model year (2007 when NSW introduced the MLL). The results from this assessment are reasonably consistent with the NSW surplus production model, with both assessments having similar biomass trends. While the current stock status estimates of this assessment are above the LRP for the base case model, lower assumed values of natural mortality put the stock below the LRP, well within the range of uncertainty of the NSW base case surplus production model and the numerous sensitivity scenarios undertaken thereof. The NSW length-based assessment estimates 2007 exploitable biomass to be between 1.9–5.1% of unfished levels. The conclusion that is then drawn about current biomass rests on the absence of large fish in NSW trawl catches after 2007, suggesting no improvement of size structure following the model period. However, during the development of the current assessment, it was identified that larger fish were present after 2007, albeit in small numbers, in the catches from other fleets. This suggests that the lack of large fish in the NSW trawl catch may be due to lack of availability to this fleet, for example, as a result of changes in fishing location. As such, the estimation of no improvement in stock status after 2007, based on NSW trawl length data, may be invalid.

The Commonwealth Tier 4 assessment method is an empirical harvest control rule that compares a four-year average of the most recent catch and CPUE to the catch and CPUE during a reference period of relative stability, where the stock is assumed to be at a TRP of 48% unfished biomass. The Tier 4 method relies on the assumption that the stock is around the TRP during the reference period. In the case of Silver Trevally, this assessment estimated that the stock declined from 65.7% to 23.9% of unfished spawning biomass during the 1992–2001 reference period (Figure 1) with fishing mortality increasing from $F \approx 1.5$ to $F \approx 3$ (Figure 3). This suggests that the assumption of the stock being around the TRP during the reference period of 1992-2001 is likely incorrect, and hence the inference that stock is above the Tier 4 LRP may be invalid.

Fixed catch projections

The implementation of the SESSF Tier 1 harvest control rule within Stock Synthesis does not work correctly for low recruitment projections, as it projects future catches assuming recruitment is at the long-term average. To explore the sensitivity of the assessment and subsequent management advice to the pre-specified value of *M*, fixed catch projections of 50, 75, 100, 125 and 150t were undertaken using the base case and the lower natural mortality (M=0.14yr^{-1}) scenario, both of which include low recruitment (Table 2). For catches of 50–150t per annum, stock status in 2027 is estimated to increase to 30.3–32.9% for the base case and 22.3–24.5% for the low recruitment scenario. While current stock status estimates are sensitive to the pre-specified value of natural mortality, in the medium to long term the stock status is reasonably insensitive to the value of *M* for catches of 50–150t per annum. This is due to the recent recruitment estimates for the base case being lower than the low natural mortality scenario. Fixed catch projections using the sensitivity that assumes a very low natural mortality (M=0.11yr^{-1}), were also attempted, however, it wasn't possible to achieve a converged model with Francis weighting in the available time. While this model was not suitable to inform management advice, it would be expected that the stock status estimates for the sensitivity with M=0.11yr^{-1}) would remain below the LRP of 20% of unfished biomass in the short term for catches of 50–150t per annum.

Table 2. Stock status estimates for fixed catch projections of 50, 75, 100, 125 and 150t using the base case (M=0.18yr^{-1}) and a (low recruitment) sensitivity with a lower natural mortality (Low nat. mort.) of M=0.14yr^{-1}.

	50t yr^{-1}		75t yr^{-1}		100t yr^{-1}		125t yr^{-1}		150t yr^{-1}	
Year	Low nat. mort.	Base case	Low nat. mort.	Base case	Low nat. mort.	Base case	Low nat. mort.	Base case	Low nat. mort.	Base case
2024	18.6	26.7	18.6	26.7	18.6	26.7	18.6	26.7	18.6	26.7
2027	24.5	32.9	24.0	32.3	23.4	31.6	22.9	31.0	22.3	30.3
2032	34.4	41.3	32.9	39.8	31.5	38.3	30.1	36.8	28.6	35.3
2042	49.2	51.0	46.8	48.7	44.3	46.3	41.8	43.9	39.2	41.5
2052	57.0	54.7	54.3	52.2	51.6	49.7	48.7	47.1	45.8	44.3

Future needs

The assessment is currently dependent on length data to inform the estimation of recent recruitment. With the stock near the LRP, monitoring future recruitment is critical to provide managers with robust estimates of current stock status to inform the management of this stock over the medium term. While length data provides information on recruitment while fish are growing rapidly, once growth plateaus it is usually not possible to distinguish between cohorts. Recent age data is likely biased due to the truncation of the length distribution at the MLL. Consequently, to support the estimation of recruitment, it is essential to obtain unbiased age data, either from fishery independent sources in NSW or from the Commonwealth trawl fleet. Unbiased recent age data could also be utilised to estimate growth, to determine whether growth rates may have changed.

Introduction

Background

Biology

Silver Trevally (*Pseudocaranx georgianus*), formerly known as *P. dentex*, inhabit estuarine and coastal waters to depths of up to 200m and are moderately long lived with a maximum observed age of 25 years (Rowling and Raines 2000). They have a relatively contiguous distribution from northern NSW to Western Australia, south of 25˚S latitude (Bearham et al. 2020). The bulk of the catches have been taken off NSW, suggesting that stock abundance is greatest in that region.

While Silver Trevally have a continuous distribution on the east coast of Australia, stock structure is poorly understood. Their continuous distribution, the dominance of the East Australian Current, and a recent genetic study, suggest Silver Trevally are likely genetically homogenous on Australia's east coast (Bearham et al. 2020). Tagging studies in Australia and New Zealand suggest that movement after settlement is limited, so there is potential for fine-scale population structure within the east coast population (Fowler et al. 2018).

Fishery

The Commonwealth fishery for Silver Trevally operates over most of south-eastern Australia, however, more than 99% of the catch is taken by demersal trawl, with the majority of that taken by vessels operating off the NSW coast (Burch et al. 2021). Silver Trevally are also caught commercially off New South Wales (NSW), South Australia, Tasmania and Victoria, with the majority of catches taken off NSW. While catch estimates are available for South Australia, Tasmania and Victoria (Steer et al. 2018, Krueck et al. 2020, Conran et al. 2020, Burch et al. 2023a), these are relatively small compared to Commonwealth and NSW catches. In NSW, Silver Trevally are caught by four commercial fisheries: Ocean Trawl Fishery (OTF), Ocean Trap and Line Fishery (OTLF), Estuary General Fishery (EGF) and Ocean Hauling Fishery (OH). The OTF is separated into northern and southern components at Barrenjoey Point (Sydney). The Ocean Trawl — Fish Northern zone (OTFN) operates partially into Commonwealth waters under an offshore constitutional settlement arrangement with the Commonwealth. The Southern Fish Trawl (SFT) operates to the 3 nm limit of NSW State waters. South of Barrenjoey Point (Sydney), Silver Trevally are also harvested in Commonwealth waters by trawlers managed as part of the SESSF, many of which hold dual endorsements in the SFT.

Silver Trevally are also harvested by recreational fishers across south-eastern Australia where they are managed using a combination of gear, size, bag, and possession limits that differ among jurisdictions. Estimates of recreational harvest are available from periodic offsite surveys that are undertaken either nationally (e.g. Henry and Lyle 2003) or by individual jurisdictions (e.g. Ghosn et al. 2010, Lyle et al. 2014, West et al. 2015, Murphy et al. 2022).

Management

The Commonwealth fishery for Silver Trevally commenced in 1985 after the establishment of the Australian Fishing Zone in the early 1980s. Prior to this, fishing for Silver Trevally outside of State waters was regulated by the jurisdiction where the vessel was based or where the catch was landed. As the majority of the catches and biological data have been collected off the NSW coast, we focus on this region. There have been several management changes over the history of the fishery in NSW, many of which complicate the assessment of the stock. Prior to 1984, catches were reported monthly but no information on fisher, vessels or effort is available, and catch could only be assigned to individual methods if a single method was used by a fisher in any given month. There were further changes in how catch and effort were reported from 1984–1997, 1998–2009 and from 2010 to the present in NSW (e.g., changes from monthly to daily reporting). From a stock assessment perspective, the main implication of these changes is that they complicate the creation of a consistent time-series of catch per unit effort (CPUE) for each fleet; however, this has been accommodated within the assessment by time-blocking the NSW trawl and trap CPUE (estimating a separate catchability (q) parameter before and after 2007). In 2007 a minimum legal length (MLL) of 30cm total length, equivalent to ~25cm caudal fork length (CFL) was introduced, and some previously fished areas were closed to commercial fishing due to the establishment of marine parks.

Rationale for joint assessment

While catches of Silver Trevally have declined substantially since their peak in the late 1980s and early 1990s, standardized Commonwealth CPUE has been more variable. Commonwealth CPUE increased rapidly from 1986–1990, before declining to roughly the 1986 level in 1992. From 1993–2016, Commonwealth CPUE gradually declined, then increased while staying above the limit reference point, before declining sharply in 2018 (Figure 5). Commonwealth standardized CPUE declined over 2017–2019, with 2019 CPUE being below the Tier 4 limit reference point (LRP). However, the 2020 and 2021 CPUE points, as well as the two most recent four-year averages of standardized CPUE, used in the Tier 4 harvest control rule, have remained above the LRP (Sporcic 2021, 2022a). Recent Tier 4 assessments of the stock have remained above the Tier 4 limit reference point of 50% of the CPUE during the reference period (1992–2001). While the Commonwealth Tier 4 assessment estimated the stock to be above the LRP, the Recommended Biological Catches (RBCs) have declined from 445.0 t in 2017 to 117.4 t in 2022 (Haddon and Sporcic 2017, Sporcic 2022a). Recent NSW assessments, undertaken with similar data in 2020, 2021 and 2022, using an ensemble of data-poor assessment methods, estimate the stock to be depleted below the 20% limit reference point (Fowler and Chick, 2020; Fowler et al. 2021, 2023).

Based on the discrepancy in stock status estimates between the most recent Commonwealth and NSW assessments (i.e. being above and below the limit reference point, respectively), AFMA funded CSIRO to collaborate with NSW DPI Fisheries to evaluate the Commonwealth and NSW data, and progress the development of a joint Commonwealth-NSW assessment of Silver Trevally.

Recent NSW assessment

The most recent NSW assessment of Silver Trevally (Fowler et al. 2023) used a weight of evidence approach that comprised a JABBA surplus production model (Winker et al. 2018) fitted to catch and standardized CPUE, a length-based age-structured population dynamics model, LIME (Rudd and Thorson 2018) for 1987–2007 (when the NSW MLL was introduced) and a consideration of the proportion of large fish in recent NSW trawl catches relative to that in the last model year (2007). The assessment estimated current biomass to be less than 20% of unfished levels from most scenarios of the JABBA production model, the stock to have been at or below 5% of unfished biomass from 1999–2007 from the length-based assessment, and no increase in the proportion of large fish in NSW trawl catches in 2008–2022. Previous NSW assessments have also included catch-only assessment methods that estimated stock status below 20% of unfished biomass (Fowler and Chick, 2020; Fowler et al. 2021). The most recent NSW assessment subsequently concluded that Silver Trevally was depleted below 20% of unfished biomass.

Most recent Commonwealth Tier 4 assessment

Commonwealth assessments of Silver Trevally have been undertaken using a Tier 4 assessment based on reported catch from the Commonwealth, NSW, Victoria, South Australia and Tasmania, estimated discards and standardized Commonwealth trawl CPUE for CTS zones 10 and 20, excluding the Bateman's Bay Marine Park (Sporcic 2022a, b). This assessment showed that standardized CPUE declined from 2017–2019 to below the Tier 4 reference limit, then increased towards the long-term average in 2020 and 2021 (Figure 5). The four-year average of recent CPUE was above the limit reference point and the assessment provided an RBC of 117.4 t for the 2023 fishing season, a 61.5 t decline from the 2022 RBC of 178.9 t.

The Tier 4 assessment method used in the SESSF is an empirical harvest control rule that compares a four-year average of the most recent catch and CPUE to the catch and CPUE during a reference period where catch and CPUE show relative stability (Little et al. 2011). Tier 4 assessments assume that CPUE is directly related to biomass and is consistent over time, the stock is at the target reference point of 48% unfished spawning biomass during the reference period and the catch history is accurate (Sporcic 2022a). The reference period for Silver Trevally (1992–2001) differs from that used for most other shelf species (i.e., 1986–1995; AFMA 2009). The later reference period for Silver Trevally was selected by Shelf RAG because of the large increase in catch and CPUE in 1988–1991 that '*most likely resulted from about four NSW trawl vessels that used increased engine power and high trawl speeds to particularly target silver trevally during this period*' (AFMA 2009) and hence was not thought to be representative of stock status.

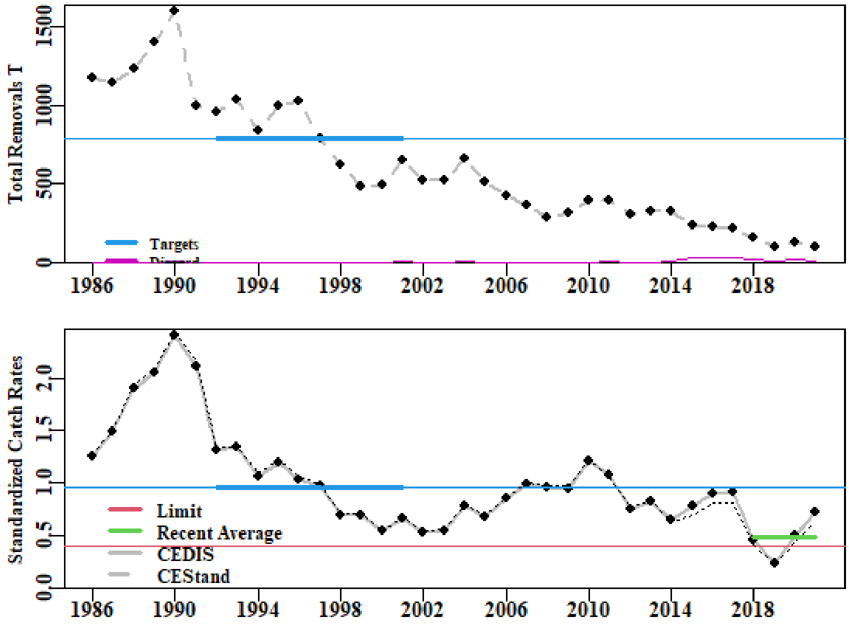

Figure 5 Standardized CPUE, target CPUE (blue line) and reference period (bold blue line) from the 2022 Commonwealth Tier 4 assessment. Reproduced from Sporcic (2022a).

While the 2022 Commonwealth Tier 4 assessment shows that the stock declined below the limit reference point in 2019, because it uses a four-year average of recent CPUE, the stock has not been assessed as overfished. The consistent and large decline in catch and standardized CPUE during the reference period (1992–2001) would appear to be inconsistent with the requirement for the reference period that catch and CPUE are relatively stable (Little et al. 2011). Recent NSW assessments and this assessment would also suggest that the stock was well below the target reference point of 48% unfished spawning biomass during the reference period (Fowler et al. 2021, 2023).

Summary of previous joint assessment

While Silver Trevally is currently assessed using a Tier 4 assessment method, integrated assessments were undertaken in 2005 and 2006 (Day et al. 2005, 2006). The 2005 assessment was implemented using the package Coleraine (Hilborn et al. 2001) and subsequently moved to version 2 of Stock Synthesis (Methot 2006) for the 2006 assessment. The focus below is on the 2006 assessment by Day et al. (2006).

The 2006 assessment included catches from 1945–2005, CPUE from the Commonwealth trawl fishery, length data from NSW trawl, trap and line and Commonwealth trawl fisheries, one year of age data from NSW fisheries and assumed a natural mortality value of M=0.10yr^{-1}. Two fleet structures were explored: a one fleet model with dome-shaped selectivity and a four fleet model, where the line and trap fleet assumed dome-shaped selectivity, while the other three fleets had logistic selectivity. Both models were unstable, being sensitive to the inclusion of length data, growth estimates and the years for which recruitment deviations were estimated, leading ShelfRAG to reject the assessment and instead adopt the Tier 4 assessment method (AFMA 2009).

Methods

Stock structure and key assumptions

With the exception of catches from other State jurisdictions, all of the available biological and fishery data comes from NSW and the Commonwealth. Consequently, biological data were restricted to samples from NSW State waters and Commonwealth CTS zones 10, 20 and 60. Calendar years were used for the assessment, which differs from the previous NSW assessment which was based on financial years (Fowler et al. 2023). The choice of calendar year was based on new recruitment entering the fishery in winter (Rowling and Raines 2000) and it being desirable that annual recruitment not be split between two 'model years'. Changes in NSW management arrangements, in particular, the introduction of a MLL of 30cm total length in 2007 and the move from monthly to daily reporting of catch and effort in 2009 led to the NSW trawl and trap CPUE being time blocked so that separate catchability (*q*) parameters are estimated before and after 2007.

It was agreed that catches and discards from the NSW and Victorian commercial and recreational sectors and the Commonwealth commercial sector in CTS zones 10, 20 and 60 (Figure 6) would be used. Catches of Silver Trevally outside of CTS zones 10, 20 and 60, including South Australian and Tasmanian catches, are relatively small and previous work by NSW using production models has shown the assessment outcomes to be insensitive to their inclusion (results not shown).

There is considerable uncertainty in catches, due to the potential double reporting of some catches to both the Commonwealth and NSW during 1986–2000 and imputed catches for some sectors, particularly the recreational sector. The methods used to impute catches are described below. Biological parameters were taken from Rowling and Raines (2000) or estimated from the available data.

Data sources

The data sources included in the 2023 base-case Silver Trevally assessment are:

- Commercial and recreational landed catch estimates from NSW, Victoria and the Commonwealth zones 10, 20 and 60 (the areas off NSW and Victoria) from 1955–2022. A sensitivity for adding catches for 1945–1955 is undertaken.
- Estimated discards by the NSW trawl fleet after the introduction of the MLL in 2007.
- Three standardized CPUE indices from NSW trawl, trap and Commonwealth trawl fisheries.
- Length data from NSW trawl, trap, line, estuary, Commonwealth trawl and recreational fisheries, and from the (fishery independent) RV Kapala surveys.
- Age-at-length data for 1998 from NSW trawl, trap, line and estuary fisheries. The sensitivity to including the 1997 age data is undertaken.
- Biological parameters are taken from Rowling and Raines (2000) or are estimated from the available data externally to the assessment.

Details of these data sources and how the data were prepared for the base-case assessment and additional sensitivities are provided below.

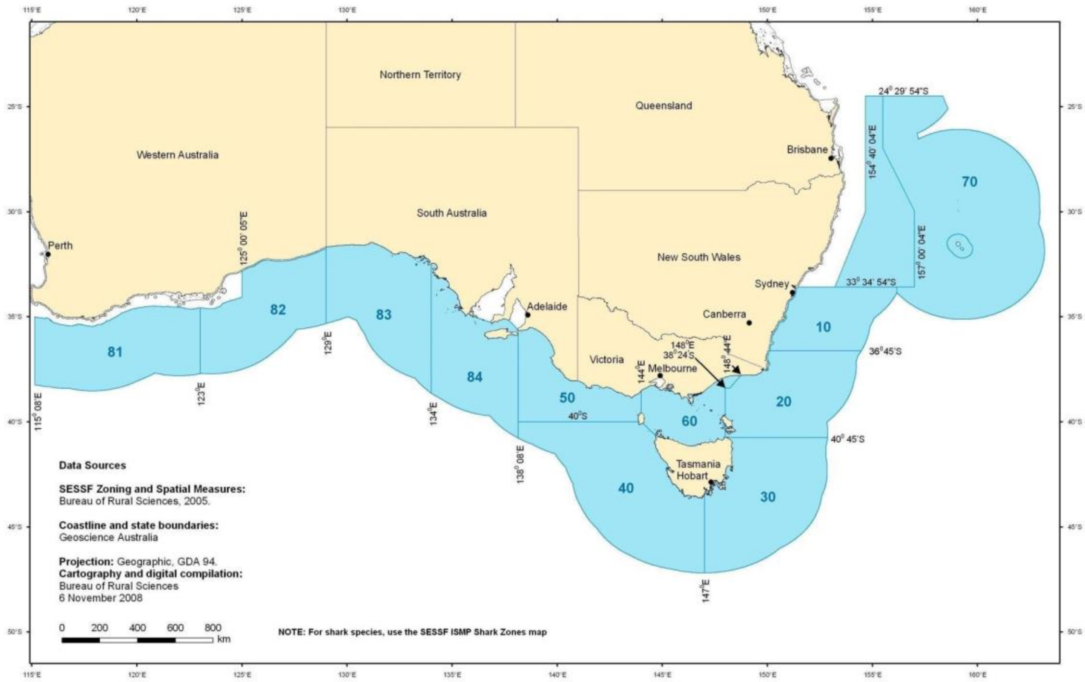

Figure 6 Map of southern Australia overlaid with the Commonwealth Trawl Sector (CTS) zones.

Catches and discards

Catch estimates for the base case are provided in Tables 3–4 and Figure 7. They comprise the best estimate of total catch taken off the NSW and Victorian coasts back to 1945. This includes all commercial catch reported to NSW and Victoria along with Commonwealth catches in CTS zones 10, 20 and 60 (the areas off NSW and Victoria). The base case also includes recreational catch estimates from NSW and Victoria that were imputed using the method described below. The Commonwealth fishery was established in 1985, with catches reported to State jurisdictions prior to that time. Commonwealth catches in 1985 were considered unreliable as this was the first year of the transition to the new fishery, so Commonwealth catches from 1986–2022 are used. NSW commercial catches are available for 1945–2022, however, they are not separated by gear type prior to 1955 so catches from 1955–2022 are used in the base case. A sensitivity that includes catches from 1945–2022 is also presented. Victorian commercial landings for 1979–2022 were taken from Conran et al. (2020) and Burch et al. (2023a), however, the Victorian fishery operated prior to this time, so catches for 1955–1978 were imputed by taking the mean ratio of Victorian to NSW catches for 1979–1985 (28.4%). Commonwealth discards are estimated by Deng and Burch (2023) using the method of Bergh et al. (2009), with discard estimates projected backwards to 1986 from the earliest valid discard estimate. These imputed discards were then added to the landed catches of the Commonwealth trawl fleet. The NSW trawl discard rate after the introduction of the 30cm MLL in 2007 was estimated from onboard observer surveys to be 27% (Fowler et al. 2023). Discards for the NSW trawl fleet are estimated within the assessment using a retention function for 2008 onwards. The other NSW commercial fleets (trap, line and estuary) and the recreational fleet do not select fish below the MLL. Additionally, should these fleets catch fish below the MLL, the presence of an anatomical structure in Silver Trevally allowing rapid ascent without barotrauma is likely to minimise discard mortality (Hughes et al. 2016).

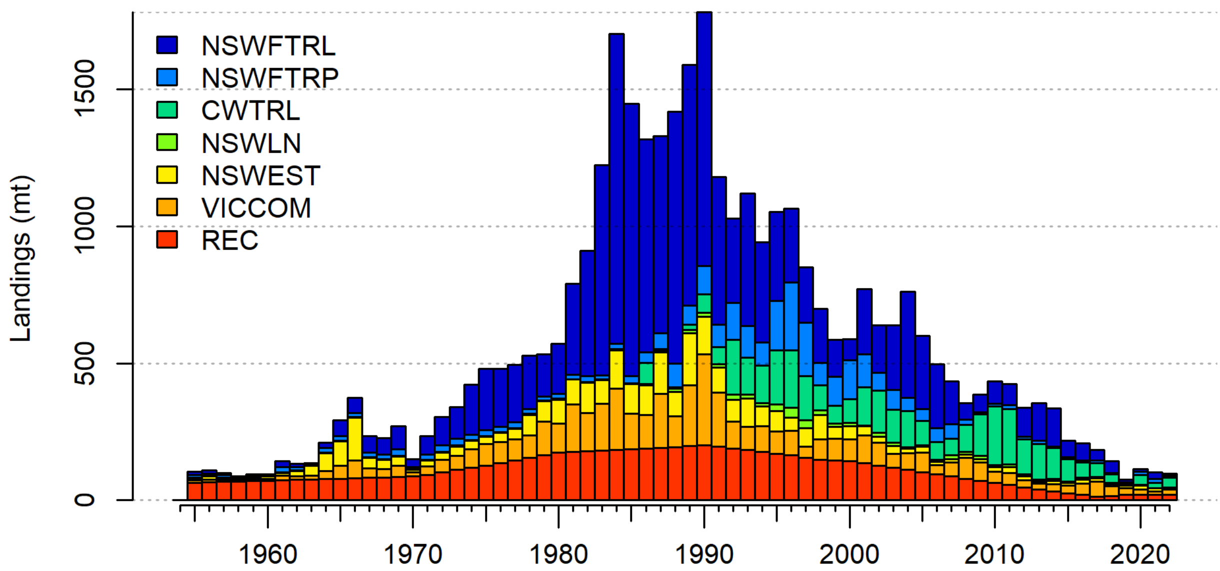

Figure 7 Landed catch and estimated discards for the 2023 base case Silver Trevally assessment. Note that the catches for the NSW and Victorian recreational (REC) and Victorian commercial (VICCOM) fleets have been imputed.

NSW recreational catches were imputed based on linear interpolation between the four available recreational catch estimates since 2000, and, prior to 2000, were back-scaled based on relative changes in estimates of total recreational catch, largely inferred from coastal population size (Fowler et al. 2023). NSW and Victorian recreational catches for 1945–1949 were assumed identical to the 1950 estimate. Victorian recreational catches were imputed based on the ratio of Victorian to NSW recreational catch estimates from the 2000 national survey (Henry and Lyle 2003), which estimated Victoria recreational catch of Silver Trevally to be 42.9% of NSW recreational catch.

Table 3. Catches of Silver Trevally (tonnes) reported to NSW and Victoria for 1945–1985. † Note catches for 1945–1954 were not used in the 2023 base case Silver Trevally assessment and instead are included in a sensitivity analysis.

	NSW Commercial				Victorian	NSW & Vic.	
Year	Trawl	Trap	Line	Estuary	Commercial	Recreational	Total
1945†	41.6	36.4	5.2	7.5	25.8	52.2	168.7
1946†	27.2	23.8	3.4	7.5	17.6	52.2	131.6
1947†	24.6	21.5	3.1	7.5	16.1	52.2	125.0
1948†	24.5	21.4	3.1	7.5	16.0	52.2	124.6
1949†	21.4	18.7	2.7	7.5	14.3	52.2	116.7
1950†	18.1	15.9	2.3	7.5	12.4	52.2	108.4
1951†	8.9	7.8	1.1	7.5	7.2	58.9	91.3
1952†	3.6	3.2	0.4	7.5	4.2	60.2	79.1
1953†	6.3	5.5	0.8	7.5	5.7	61.6	87.3
1954†	13.5	11.8	1.7	7.5	9.8	62.9	107.3
1955	11.3	9.9	1.4	7.9	8.7	64.2	103.4
1956	10.1	8.8	1.3	12.5	9.3	65.9	107.9
1957	8.7	7.7	1.1	7.7	7.2	67.3	99.6
1958	5.5	4.8	0.7	3.9	4.3	68.6	87.8
1959	6.6	5.8	0.8	5.6	5.5	69.9	94.2
1960	4.1	3.6	0.5	9.5	5.2	71.3	94.1
1961	22.1	19.3	2.8	11.0	15.8	72.6	143.6
1962	13.9	12.1	1.7	19.0	13.3	73.9	134.0
1963	5.2	4.6	0.6	36.3	13.3	75.3	135.3
1964	18.8	16.4	2.3	65.2	29.3	77.0	209.0
1965	56.9	16.6	2.4	90.1	47.3	78.3	291.6
1966	54.5	15.9	2.3	156.0	65.3	79.6	373.6
1967	59.6	17.4	2.5	39.4	34.0	81.3	234.1
1968	58.2	17.0	2.4	33.6	31.6	83.0	225.8
1969	84.4	24.6	3.5	32.4	41.3	84.7	270.9
1970	29.3	8.6	1.2	11.0	14.3	86.3	150.7
1971	65.5	19.1	2.7	21.8	31.0	92.7	232.9
1972	103.3	22.6	3.2	27.2	44.4	102.4	303.1
1973	115.9	25.4	3.6	34.4	51.3	110.4	341.0
1974	184.6	18.0	2.6	31.5	67.2	118.5	422.3
1975	223.5	21.7	3.1	25.9	77.9	126.8	479.0
1976	211.0	20.5	2.9	33.7	76.2	135.2	479.5
1977	209.5	20.4	2.9	39.2	77.3	144.6	493.9
1978	194.8	18.9	2.7	75.5	83.1	153.6	528.6
1979	152.5	14.8	2.1	74.3	124.9	163.3	531.9
1980	182.7	17.8	2.5	88.6	106.1	173.0	570.6
1981	332.9	15.3	2.2	91.1	173.2	175.7	790.4
1982	458.7	21.1	3.0	111.5	139.2	178.0	911.5
1983	767.7	13.7	2.0	88.5	170.7	180.4	1222.9
1984	1132.4	20.2	2.9	140.9	224.3	183.0	1703.7
1985	996.1	25.3	3.6	108.5	129.9	185.4	1448.8

Table 4. Catches of Silver Trevally (tonnes) reported to NSW, Victoria and Commonwealth trawl zones 10, 20 and 60 for 1986–2022 and used in the 2023 base case Silver Trevally assessment. † Note Silver Trevally catches for 2023 are assumed to be the same as those from 2022.

	NSW Commercial				Victorian	NSW & Vic.	Commonwealth	
Year	Trawl	Trap	Line	Estuary	Commercial	Recreational	Trawl	Total
1986	777.5	38.6	5.5	108.2	122.4	187.7	77.0	1316.9
1987	720.5	57.2	8.2	150.9	197.7	190.7	5.6	1330.8
1988	920.5	86.4	12.3	88.7	113.4	193.7	4.7	1419.7
1989	879.1	71.2	10.2	192.2	221.7	196.8	19.1	1590.2
1990	927.6	103.3	14.7	136.3	333.9	199.8	66.4	1782.0
1991	540.1	81.0	11.5	91.6	198.5	194.4	64.1	1181.3
1992	309.3	133.2	19.0	79.5	99.0	188.1	200.8	1028.9
1993	483.9	115.7	16.5	101.6	85.8	183.0	133.5	1120.0
1994	366.9	84.4	12.0	73.3	92.4	177.0	136.5	942.5
1995	324.0	180.9	25.8	74.5	79.9	170.0	197.2	1052.3
1996	271.5	247.8	35.3	50.0	88.6	164.0	208.4	1065.6
1997	202.5	194.5	27.7	68.5	39.7	155.3	162.0	850.1
1998	198.4	80.3	15.7	89.7	74.9	146.6	93.4	698.9
1999	135.2	106.4	13.7	41.2	80.6	144.9	64.7	586.7
2000	78.8	141.2	11.4	47.0	79.9	142.9	88.0	589.1
2001	239.6	120.3	3.4	32.6	102.5	134.9	138.6	771.7
2002	172.4	65.6	14.8	23.2	82.2	126.8	152.9	637.9
2003	236.0	72.7	12.2	28.3	51.1	118.8	119.2	638.3
2004	389.7	48.3	4.4	18.1	60.0	110.8	131.4	762.6
2005	267.6	42.2	6.5	20.5	71.5	102.8	88.8	599.7
2006	234.6	50.0	6.2	11.7	34.3	94.7	65.8	497.2
2007	155.3	53.1	13.5	12.1	50.7	86.7	61.9	433.3
2008	59.1	19.4	9.3	11.6	76.5	78.7	99.7	354.4
2009	63.5	8.6	10.6	12.5	66.9	70.7	152.1	384.9
2010	82.6	9.4	6.5	17.1	41.9	62.6	213.9	434.1
2011	76.8	14.8	9.2	23.3	43.6	54.6	201.7	424.0
2012	107.4	9.6	7.2	13.7	25.7	46.6	128.2	338.5
2013	136.8	11.3	6.2	7.7	22.5	38.6	131.2	354.4
2014	138.4	5.5	6.1	13.0	25.7	31.9	113.9	334.6
2015	59.6	7.5	6.0	9.1	28.6	25.3	80.1	216.1
2016	62.4	7.4	8.2	12.5	43.0	18.7	55.9	208.1
2017	38.6	9.7	5.3	12.3	55.2	12.0	51.2	184.3
2018	43.2	5.2	5.1	5.7	36.2	15.6	31.9	142.9
2019	10.7	6.2	3.3	9.9	24.8	19.2	2.2	76.1
2020	10.9	10.1	3.6	13.2	20.8	19.1	36.0	113.8
2021	23.7	15.1	2.0	12.0	11.5	19.1	18.9	102.4
2022	8.6	6.3	2.3	5.6	19.8	19.1	35.7	97.5
2023†	8.6	6.3	2.3	5.6	19.8	19.1	35.7	97.5

There was potential double reporting of some catches to both the Commonwealth and NSW during 1992–2000. Two sensitivity scenarios were explored to account for potential double reporting during 1992–2000: the 'NSW low' scenario assumes all catch reported to Commonwealth was also reported to NSW (Table 5), the 'NSW high' assumes there was no double reporting (Table 6), while the base case catches are the mean of the 'NSW low' and 'NSW high' scenarios (effectively assumes that 50% of the catch reported to the Commonwealth was double-reported to NSW). The recent provisional assessment (Burch et al. 2023c) also adjusted NSW catches from 1986–1991 using the same method, however, on further examination it was identified that the agreed Commonwealth catch series was substantially lower than the catches in the AFMA database, suggesting that a modification to the agreed Commonwealth catches had already been made for earlier assessments (e.g. Day et al. 2006). Therefore, the scenarios that adjust for vessels potentially reporting to both the Commonwealth and NSW were restricted to 1992–2000.

Total removals of Silver Trevally used in the 2023 base case and sensitivity analyses remain uncertain due to the potential double reporting described above, uncertainty in recreational catch estimates and the interpolation of recreational and Victorian commercial catches.

Table 5. Alternative "low" catch scenario to account for potential double reporting of Commonwealth and NSW catches during 1992–2000.

	NSW Commercial				Victorian	NSW & Vic.	Comm.	"low"	Base case
Year	Trawl	Trap	Line	Estuary	Comm.	Rec.	Trawl	Total	Total
1992	208.9	133.2	19.0	79.5	99.0	188.1	200.8	928.5	1028.9
1993	417.1	115.7	16.5	101.6	85.8	183.0	133.5	1053.3	1120.0
1994	298.6	84.4	12.0	73.3	92.4	177.0	136.5	874.2	942.5
1995	225.5	180.9	25.8	74.5	79.9	170.0	197.2	953.7	1052.3
1996	167.3	247.8	35.3	50.0	88.6	164.0	208.4	961.4	1065.6
1997	121.5	194.5	27.7	68.5	39.7	155.3	162.0	769.1	850.1
1998	151.7	80.3	15.7	89.7	74.9	146.6	93.4	652.2	698.9
1999	102.8	106.4	13.7	41.2	80.6	144.9	64.7	554.4	586.7
2000	34.8	141.2	11.4	47.0	79.9	142.9	88.0	545.1	589.1

Table 6. Alternative "high" catch scenario to account for potential double reporting of Commonwealth and NSW catches during 1992–2000.

	NSW Commercial				Victorian	NSW &Vic.	Comm.	"high"	Base case
Year	Trawl	Trap	Line	Estuary	Comm.	Rec.	Trawl	Total	Total
1992	409.7	133.2	19.0	79.5	99.0	188.1	200.8	1129.2	1028.9
1993	550.6	115.7	16.5	101.6	85.8	183.0	133.5	1186.8	1120.0
1994	435.1	84.4	12.0	73.3	92.4	177.0	136.5	1010.7	942.5
1995	422.6	180.9	25.8	74.5	79.9	170.0	197.2	1150.9	1052.3
1996	375.7	247.8	35.3	50.0	88.6	164.0	208.4	1169.8	1065.6
1997	283.5	194.5	27.7	68.5	39.7	155.3	162.0	931.1	850.1
1998	245.1	80.3	15.7	89.7	74.9	146.6	93.4	745.6	698.9
1999	167.5	106.4	13.7	41.2	80.6	144.9	64.7	619.1	586.7
2000	122.8	141.2	11.4	47.0	79.9	142.9	88.0	633.1	589.1

Length data

Length data have been collected from both onboard and port-based sampling for the NSW trawl, trap, line and estuary fleets, the Commonwealth trawl fleet, the recreational sector and the Kapala survey. The Commonwealth length data have been restricted to onboard sampling off the NSW and Victorian coasts (CTS zones 10, 20 and 60). Commonwealth port data were excluded because of the difficulty associating samples with the zone of capture. All length measurements used in the assessment have been converted to CFL, consistent with both NSW and Commonwealth protocol for Silver Trevally. The MLL of 30cm introduced by NSW in 2007 was specified as total fish length, and corresponds with approximately 25cm CFL.

The number of length measurements by fleet and year used in the base case assessment is provided in Table 7. The standard practice for Commonwealth Tier 1 assessments is to exclude length data from fleets for years where there are fewer than 100 onboard measurements and to use the number of shots or trips (i.e. the number of sampling events), rather than the number of fish measured as the effective sample size in the assessment. These protocols were applied to this assessment. In addition, a minimum of five sampling events was required for inclusion in the model. Initial effective sample sizes for the data were set to the number of shots or trips that were sampled, these were then adjusted using the Francis method described below.

Table 7. Number of length measurements and number of samples or trips in parentheses by year of capture and fleet for the 2023 base case Silver Trevally assessment.

	NSW				NSW & Vic	Commonwealth	Kapala
Year	Trawl	Trap	Line	Estuary	Rec.	Trawl	Survey
1987	590 (5)						
1989	875 (7)						
1993	5498 (90)					711 (12)	2672 (36)
1994	1190 (72)				3333 (35)		2225 (36)
1995	4344 (35)					493 (7)	
1996						1164 (13)	
1997	853 (6)					1514 (12)	
1998	6678 (52)					956 (15)	
1999	9728 (67)					3737 (41)	
2000						2666 (28)	
2001						5925 (59)	
2002						3129 (30)	
2003						5608 (62)	
2004						9152 (77)	
2005	930 (8)	297 (5)				9389 (77)	
2006	2248 (20)	1074 (17)	1335 (15)			6756 (54)	
2007		1449 (19)					
2008	657 (5)	981 (12)	408 (5)			1133 (16)	
2009	710 (7)	494 (7)				1213 (16)	
2010	887 (10)		702 (9)			2036 (30)	
2011	386 (7)		608 (11)			474 (14)	
2012		588 (7)				1128 (17)	
2013						575 (10)	
2014						640 (9)	
2015						734 (19)	
2016		412 (12)	713 (14)				
2018	754 (10)	283 (6)	201 (5)				
2019	912 (15)	1055 (40)	1089 (31)	372 (6)			
2020	1019 (14)	1474 (42)	1294 (34)	1739 (28)			
2021	932 (13)	913 (22)	397 (12)	611 (13)			
2022	713 (10)	787 (19)		305 (5)		1420 (13)	

Age-at-length data

Age-at-length data are available from NSW fleets for 1997–1999 and 2019–2021 (Table 8). The data for 1997–1999 was collected as part of FRDC project 97/125 (Rowling and Raines 2000). While there are no age estimates of Silver Trevally from the Commonwealth fishery at present, approximately 300 otoliths were collected from 1995–2020 and could potentially be aged (pers. comm. Kyne Krusic-Golub, Fish Ageing Services).

An update on the progress of this assessment, presented to the September 2023 SERAG meeting identified that the age-at-length of some samples collected in 1999 included older fish that were unusually small. The model did not fit to the group of smaller fish with CFL 30–40cm that were estimated to be 10–20 years old. To address this idiosyncrasy, the unusual 1999 age samples were re-aged and, while the uncertainty in the age estimates was high, there was no evidence of bias in the original age estimates. Further exploration of the data identified that 1997 and 1999 data was collected from four and three samples respectively (Figure 8). As Silver Trevally are thought to exhibit some spatial heterogeneity in growth rates, the 1997 and 1999 data were subsequently excluded due to the concern they may not be representative of the population. The implications of removing the 1997 and 1999 age data were investigated in the model bridging that was presented to the 19 October 2023 Silver Trevally Steering Committee meeting and are summarised in Appendix A. A sensitivity which includes the 1997 age data is also undertaken.

The 2019–2021 data were similarly collected from fewer than five samples and, in addition to having inherent sampling variability, are also likely biased, because market based sampling does not have access to fish below the MLL. This is particularly a concern for the NSW trawl fishery which selects for fish below the current MLL that are then discarded.

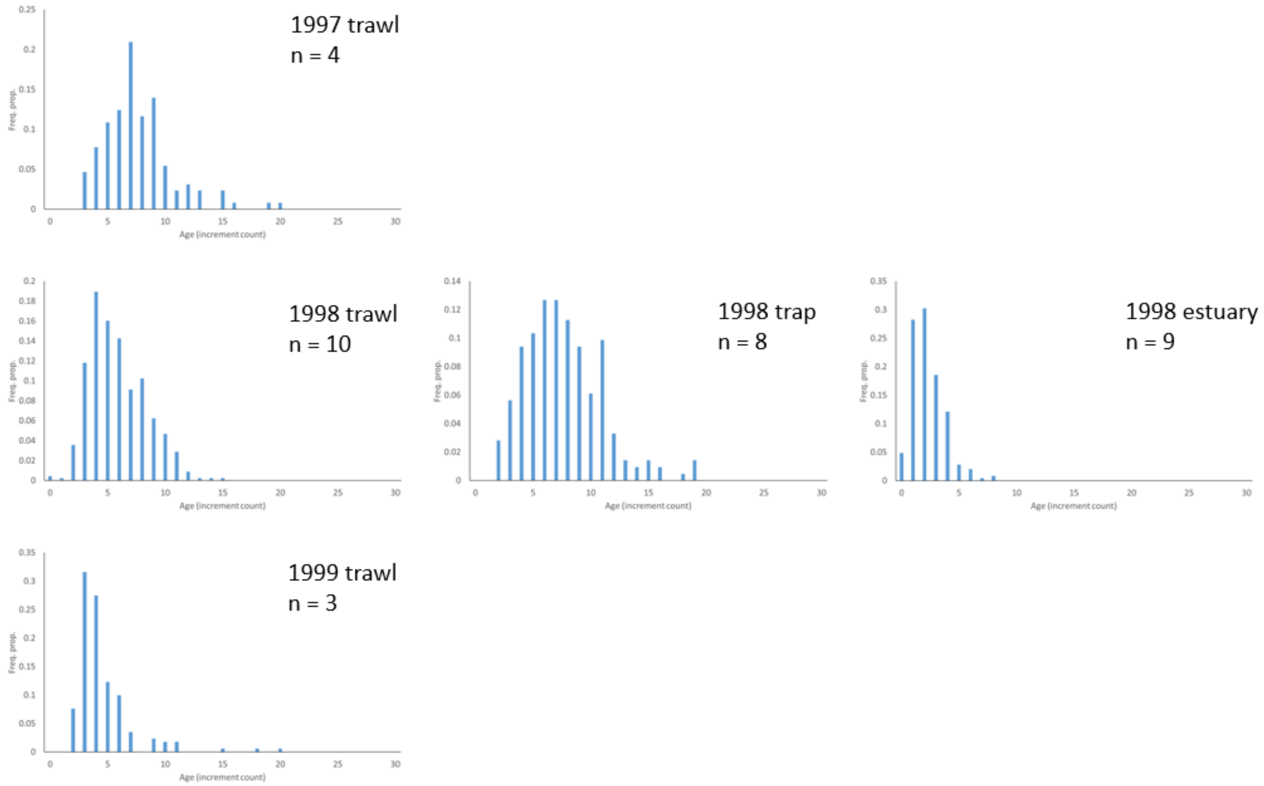

Figure 8 Age frequency data and the number of samples for NSW trawl, NSW trap and NSW estuary fleets for 1997, 1998 and 1999.

Table 8. Number of age-at-length measurements by year of capture and gear type of Silver Trevally for NSW fleets. † Only the 1998 data have been included in the 2023 base case assessment. * A sensitivity is undertaken that also includes the 1997 age data.

Year	Trawl	Trap	Line	Estuary	Haulnet
1997*	129				
1998†	449	213	42	240	
1999	171				
2019		123	613	96	118
2020	369	484	161	160	99
2021	77	446			

Ageing error

Investigation of the ageing error estimates used in model 2 of the provisional assessment (Burch et al. 2023c) identified that the ageing error model had failed to converge. The high level of uncertainty in Silver Trevally age estimates necessitated the use of an ageing error model that assumed the standard deviation of age reading error is a linear function of age (Punt et al. 2008). The data were restricted to samples from 1998 (consistent with the base case). This model converged (final gradient <1e-4), with only a few outliers outside of the 95% confidence intervals. Estimated standard deviations of age reading error (by age class) are provided in Table 9.

Table 9. The standard deviation (StDev) of age reading error by age for the 2023 base case Silver Trevally assessment.

Age (year)	StDev	Age (year)	StDev	Age (year)	StDev
0	0.7880	13	0.9176	26	1.0580
1	0.7880	14	0.9284	27	1.0688
2	0.7988	15	0.9392	28	1.0796
3	0.8096	16	0.9500	29	1.0904
4	0.8204	17	0.9608	30	1.1012
5	0.8312	18	0.9716	31	1.1120
6	0.8420	19	0.9824	32	1.1228
7	0.8528	20	0.9932	33	1.1336
8	0.8636	21	1.0040	34	1.1444
9	0.8744	22	1.0148	35	1.1552
10	0.8852	23	1.0256	36	1.1660
11	0.8960	24	1.0364		
12	0.9068	25	1.0472		

Standardized CPUE series

For the three fleets with CPUE indices included in the base case model, CPUE was standardized using generalised linear models (Table 10, Figure 9). The standardization approach for the Commonwealth trawl CPUE is described in Sporcic (2023a), while the approach for NSW CPUE is described in Fowler et al. (2023) and follows a similar approach to Sporcic (2023a). NSW CPUE was standardized by calendar year for this assessment; in Burch et al. (2023c), it had been standardised by financial year. Coefficients of variation (CVs) associated with each CPUE series were estimated using a Loess smoother (Sporcic, 2023b), per the standard practice for SESSF Tier 1 assessments. The catchability parameter (q) for the NSW trawl and NSW trap fleets is time blocked to account for the changes in the reporting of catch and effort and the introduction of the MLL in 2007. A sensitivity analysis using the alternative Commonwealth CPUE series from 1992–2022 (Sporcic, 2023a) is also undertaken to test the impact of the large increase in catch and CPUE from 1988–1991 that may have resulted from vessels fishing differently.

Table 10. Standardized CPUE and CV for the NSW trawl, NSW trap and Commonwealth trawl fleets for the 2023 base case Silver Trevally assessment. † Alternative Commonwealth trawl standardised CPUE series for 1992–2022 used for a sensitivity analysis.

	NSW Trawl		NSW Trap		Commonwealth Trawl			
Year	Index	CV	Index	CV	Index	CV	Alt. Index†	CV†
1986	-	-	-	-	1.279	0.263	-	-
1987	-	-	-	-	1.524	0.263	-	-
1988	-	-	-	-	1.959	0.263	-	-
1989	-	-	-	-	2.106	0.263	-	-
1990	-	-	-	-	2.465	0.263	-	-
1991	-	-	-	-	2.175	0.263	-	-
1992	-	-	-	-	1.342	0.263	1.759	0.161
1993	-	-	-	-	1.375	0.263	1.759	0.161
1994	-	-	-	-	1.095	0.263	1.437	0.161
1995	-	-	-	-	1.229	0.263	1.585	0.161
1996	-	-	-	-	1.066	0.263	1.373	0.161
1997	-	-	-	-	0.998	0.263	1.276	0.161
1998	-	-	-	-	0.709	0.263	0.919	0.161
1999	1.157	0.381	1.195	0.103	0.718	0.263	0.912	0.161
2000	1.184	0.381	1.402	0.103	0.554	0.263	0.718	0.161
2001	0.649	0.381	1.565	0.103	0.680	0.263	0.889	0.161
2002	1.581	0.381	1.535	0.103	0.548	0.263	0.705	0.161
2003	0.907	0.381	0.891	0.103	0.560	0.263	0.721	0.161
2004	0.977	0.381	0.695	0.103	0.803	0.263	1.022	0.161
2005	0.880	0.381	0.542	0.103	0.693	0.263	0.867	0.161
2006	0.977	0.381	0.542	0.103	0.880	0.263	1.078	0.161
2007	0.688	0.381	0.634	0.103	1.015	0.263	1.169	0.161
2008	-	-	-	-	0.984	0.263	1.160	0.161
2009	-	-	-	-	0.977	0.263	1.165	0.161
2010	1.127	0.172	0.858	0.104	1.243	0.263	1.467	0.161
2011	1.250	0.172	1.113	0.104	1.070	0.263	1.271	0.161
2012	1.457	0.172	1.049	0.104	0.770	0.263	0.908	0.161
2013	1.420	0.172	0.995	0.104	0.845	0.263	0.971	0.161
2014	1.319	0.172	0.873	0.104	0.637	0.263	0.762	0.161
2015	0.995	0.172	0.944	0.104	0.703	0.263	0.808	0.161
2016	1.223	0.172	0.872	0.104	0.811	0.263	0.847	0.161
2017	1.137	0.172	1.016	0.104	0.817	0.263	0.898	0.161
2018	0.677	0.172	0.925	0.104	0.408	0.263	0.465	0.161
2019	0.321	0.172	0.830	0.104	0.210	0.263	0.238	0.161
2020	0.633	0.172	1.054	0.104	0.443	0.263	0.437	0.161
2021	0.696	0.172	1.231	0.104	0.515	0.263	0.575	0.161
2022	0.745	0.172	1.241	0.104	0.799	0.263	0.842	0.161

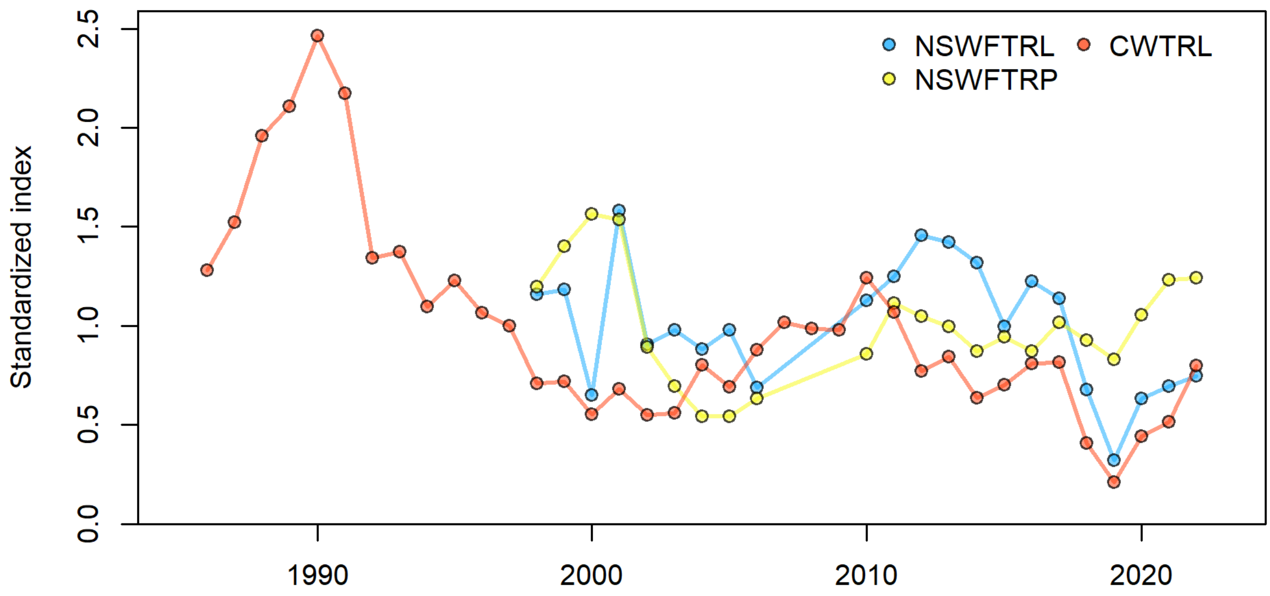

Figure 9 Standardized CPUE series for the NSW trawl, NSW trap and Commonwealth trawl fleets in the 2023 base case Silver Trevally assessment (each index is rescaled to have mean observation = 1.0).

Biological and fishery parameters

The pre-specified biological parameters used in the base case assessment and their sources are provided in Table 11. Male and female Silver Trevally are assumed to have the same biological parameters, including natural mortality, growth and length-weight relationship.

Growth

The growth estimates used in the base case assessment derive from the 1997–1999 data (Rowling and Raines 2000). Estimating growth using the recent 2019–2022 age-at-length data provides quite different estimates. While this may be due to a change in growth rates over time, it is more likely due to the absence of fish below the MLL in fishery dependent samples. Lack of small fish in age-at-length samples can lead to bias in the estimation of growth rates (Andre Punt pers. comm.), so age-at-length data from an alternative source is required to re-estimate Silver Trevally growth rates.

Stock recruitment relationship

There was no information to inform the value of the steepness of the Beverton-Holt stock recruitment relationship so a value of h=0.7 was chosen for the base case, similar to the pre-specified values of h used by the Commonwealth where there is insufficient information to estimate h. Sensitivities to h=0.6 and h=0.8 are undertaken.

Table 11. The values of the pre-specified parameters used in the 2023 base case assessment of Silver Trevally, their plausible range, whether model sensitivities are warranted, and whether they are both uncertain and influential on assessment outcomes and their source.

Parameter	Value	Plausible range	Sensitivities recommended	Uncertain and influential	Source / Rationale
Natural mortality M (yr^{-1})	0.18	0.1–0.25	Yes and likelihood profile undertaken.	Yes	Fowler et al. (2023). Upper end of the range of life history estimates from Bax and Knuckey (2004). Higher than estimate of M=0.1yr^{-1} (Day 2006), which derives from a New Zealand study (Fisheries New Zealand 2023) .
Beverton Holt Steepness (h)	0.7	0.6–0.8	Yes	No	The selected value of h=0.7 is a standard default for SESSF Tier 1 assessments.
Recruitment variability (σ_R)	0.7	0.6–0.8	Yes	No	The selected value of σ_R=0.7 is a standard default for SESSF Tier 1 assessments.
Growth parameters[4]					
Von Bertalanffy K (yr^{-1})	0.12			Yes	
Length (cm) t_0	-3.89			Yes	Fowler et al. (2023).
Asymptotic length L_∞ (cm)	43.97			Yes	
Growth CV	0.17, 0.17				Appropriate default value (Jason Cope, pers. comm.).
Length-weight parameters					
Scalar a	0.0000443			No	Rowling and Raines (2000).
Power b	2.7864			No	
Maturity					
Length 50% (m_1)	19			No	Rowling and Raines (2000).
Length 95% (m_2)	22.5			No	
Plus group age	37			No	Larger than the highest observed age in the data (Burch et al. 2023).

[4] Stock Synthesis uses the Schnute parameterisation of the von Bertalanffy growth model, the standard parameterisation is presented here for consistency with Table 1, however, the equivalent Schnute parameterisation has been used in the 2023 base case Silver Trevally assessment.

Natural mortality

Estimates of natural mortality for Silver Trevally are available from life history studies in Australia and New Zealand. The provisional assessment (Burch et al. 2023c) pre-specified at M=0.15yr^{-1} based on the estimates of M=0.12–0.19yr^{-1} from Bax and Knuckey (2004) who used the methods of Pauly (1980) and Hoenig (1983). Fowler et al. (2023) who obtained estimates of M=0.18–0.19yr^{-1} using two empirical approaches - the inverse relationship based on maximum age (assuming 30 years) and empirical K based on the growth coefficient (Hamel and Cope 2022). While Smith and Wayte (2002) provide estimates of M=0.05–0.15 yr^{-1}, these appear to have come from Rowling and Raines (2000), who in turn cite a New Zealand study.

Further investigation after the September 2023 SERAG meeting identified that New Zealand Silver Trevally assessments assume a natural mortality value of M=0.10 yr^{-1} (Fisheries New Zealand 2023). This estimate was obtained by applying the method of Hoenig (1983) to a maximum age of 45 years, which is almost double the maximum age of 25 years observed in Silver Trevally from south-eastern Australia. Additionally, New Zealand Silver Trevally also mature at 32–37cm CFL, much larger than the 19–23cm CFL of Australian Silver Trevally and growth rates are quite different (Table 12, Figure 4).

The differences in the biology of Silver Trevally in south-eastern Australia and New Zealand and the relatively low maximum observed age of 25 led to the increase of the assumed natural mortality rate from M=0.15yr^{-1} in the provisional assessment (Burch et al. 2023) to M=0.18yr^{-1} for the 2023 base case Silver Trevally assessment. This value is more consistent with life history correlates calculated from the data for south-eastern Australia being the estimate from Fowler et al. (2023) and within the range from Bax and Knuckey (2004).

Table 12. Estimated von Bertalanffy growth rates of Silver Trevally in south-eastern Australia and three locations in New Zealand. Growth estimates for south-eastern Australia derive from Rowling and Raines (2000) while those from New Zealand are sourced from Walsh et al. (1999) and McKenzie (in prep) cited in Fisheries New Zealand (2023).

Location	L_∞	K	t_0
New Zealand TRE 1	47.55	0.29	-0.13
New Zealand TRE 1 Bay of Plenty	43.50	0.36	-0.13
New Zealand TRE 7	46.21	0.28	-0.25
South-eastern Australia	43.97	0.12	-3.89

Assessment method

Fitting procedure

Assessment was undertaken using Stock Synthesis 3.30.21 (Methot and Wetzel 2013). Convergence was assessed by checking that the final gradient was < 1e^{-4} (the default in Stock Synthesis) and that the Hessian is positive definite. Model outputs were summarised and plotted using R and the R package r4ss (Taylor et al. 2014).

Base case model

The base case model was developed from the provisional assessment (Burch et al. 2023c) with advice from SERAG and the Silver Trevally Steering Committee. A summary of these discussions is provided in Appendix A. The 2023 base case model was specified as:

- A single stock comprising catches from NSW, Victoria and Commonwealth CTS zones 10, 20 and 60 (the area off the NSW and Victorian coasts) for 1955–2022.
- Seven catch fleets: NSW trawl, NSW trap, NSW line, NSW estuary, the NSW and Victorian recreational sector, Victorian commercial and Commonwealth trawl.
- Length data for six of the catch fleets and the RV Kapala survey, with selectivity estimated for all fleets except NSW trawl (fixed to values estimated from an earlier model) and Victorian commercial (mirrored to Commonwealth trawl).
- Age-at-length data for 1998 from NSW trawl, NSW trap, NSW line and NSW estuary fleets.
- Ageing error estimated from the 1998 age data using the method of Punt et al. (2008).
- Pre-specified biological parameters described in Table 11.
- Estimated recruitment deviations from 1955–2019.
- Francis weighting was applied to fleets where there were sufficient length composition data (there were insufficient years of data to apply Francis weighting to the age compositions).
- Bias ramp was poorly estimated and pre-specified within the base case. The base case was insensitive to alternate specifications of the bias ramp (results not shown).

The data sources used in the 2023 Silver Trevally base case assessment are shown in Figure 10.

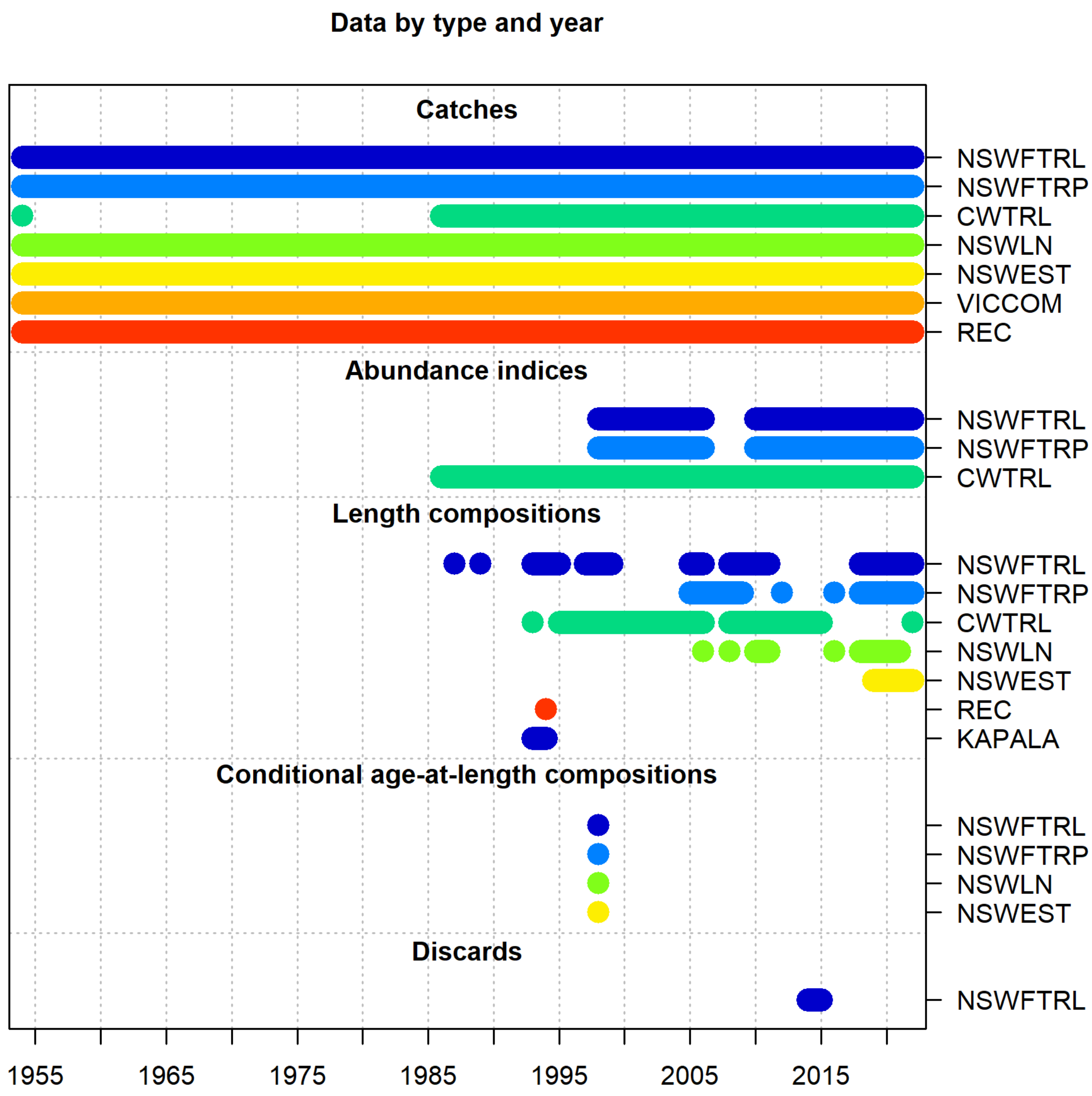

Figure 10 A summary of the input data for the 2023 base case Silver Trevally assessment.

Data weighting – Francis 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 what is input (Pacific Fishery Management Council, 2020). This makes the model internally consistent, although some argue against this approach (e.g. Lee et al. 2014), 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 consisting of 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 series 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 by numbers of fish measured, and by adopting the Francis weighting method (Francis, 2011) for age and length composition data and the approach of Punt (2017) for conditional age-at-length data. These measures prevent the issue of length data overwhelming CPUE 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 inferred trips was capped at 100 and the number of inferred shots capped at 200. For each fleet, years with fewer than 100 fish measured or fewer than five samples 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 as follows:

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. This additional variance was only applied to the NSW trawl fleet, because the model was able to fit adequately to the NSW trap and Commonwealth trawl CPUE.

An automated iterative tuning procedure was used for and length composition data:

2. The initial samples sizes for the length composition data were multiplied by the sample size multipliers using the 'Francis method' (Francis, 2011), with this process repeated until all are converged and stable (proposed changes < 1%).

It was not possible to apply Francis weighting to the composition data sources that have relatively few years of data. This included the NSW estuary, recreational and Kapala length data and all of the age-at-length data. Instead, we applied Francis weighting to only those composition data with sufficient sample sizes and applied a variance input factor of 1 to those with relatively few years of data. We then undertook a sensitivity to halving the weight given to the data sources with small sample sizes (Andre Punt pers. comm.; Appendix A Figure 42), which showed that down weighting the composition data that has insufficient sample sizes to apply Francis weighting had minimal impact on the assessment outcomes (i.e. spawning biomass trends).

Harvest Strategy / Biological Reference Points

Commonwealth fisheries harvest strategies are generally based on target and limit reference points with the target reference point for key commercial fish stocks being the spawning stock biomass (*SSB*) that produces maximum economic yield (B_{MEY}) from the fishery while keeping the biomass greater than the limit reference point biomass (B_{LIM}) at least 90 per cent of the time (ABARES 2018). In most cases B_{MEY} and B_{LIM} are not estimated so proxies of B_{MEY} = 0.48 and B_{LIM} = 0.2 of the unfished spawning stock biomass (SSB_0) are used. Silver Trevally in NSW are not currently managed using a formal harvest control rule; however, the Commonwealth reference points are consistent with the NSW Harvest Strategy Policy (DPI Fisheries 2020).

For a joint assessment to be used to provide management advice for the shared stock in both NSW and the Commonwealth, ideally agreed biological reference points and harvest strategies would be identified. In the meantime, in this report we present stock status relative to the Commonwealth SESSF target and limit reference points of 0.48 and 0.2 SSB_0 respectively (Smith et al. 2008).

Low recruitment base case

Silver Trevally shows evidence of below average recruitment over much of the last 30 years (Burch et al. 2023c), similar to some other SESSF stocks (e.g. Bessell-Browne and Day 2021). Based on a presentation of preliminary results from this assessment, SERAG 1 decided to select a low recruitment base case with the Silver Trevally Steering Committee selecting the year range from which the projected low recruitment was determined (Appendix A). Low recruitment scenarios were implemented by projecting the estimated parameters from the base case model with recruitment deviations of -0.4252 (the mean of the ten most recent recruitment estimates, 2010–2019).

Likelihood profiles

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

We undertook a likelihood profile on *M* to provide guidance to SERAG on providing catch advice. Due to time constraints, there was no opportunity for the likelihood profile to inform the value of *M* used in the 2023 base case assessment, however, it was used to inform the sensitivity analyses.

Sensitivity analyses

The following analyses are undertaken to examine the sensitivity of the results of the 2023 base case to alternative assumptions or data inputs:

- Assume average recruitment during the projection period.
- Use Commonwealth CPUE for 1992–2022 (Table 10) to test the hypothesis that the large increase in catch and CPUE for 1988–1991 may have resulted from vessels fishing differently.

- Assume low (h=0.6) or high (h=0.8) steepness of the Beverton-Holt stock recruitment relationship.
- Assume low (σ_R = 0.6) or high (σ_R = 0.8) recruitment variability.
- Assume very low (M=0.11yr^{-1}) or high (M=0.22yr^{-1}) natural mortality.
- Assume low (m_1=17cm) or high (m_1=21cm) length at 50% maturity
- Halve or double the weights assigned to the age and length composition data in the likelihood.
- Halve or double the weights assigned to the CPUE indices in the likelihood.
- Allow low or high catch scenarios during 1992–2000, the period of double reporting of trawl catches to the Commonwealth and NSW (see Tables 5 and 6).

In addition to the sensitivities above, to which the base case Francis weighting was used, the following sensitivities were undertaken with their Francis weighting recalculated:

- Low (M=0.14yr^{-1}) natural mortality.
- Include the 1997 age data because earlier models appeared to fit well to this data even though the sample size is small (see Appendix A).
- Include catches for 1945–1954 assigned to fleets using the ratio of catch by fleet in 1955 (Table 3), these catches were omitted from the base case because only total NSW catch was available during this period.
- Remove the NSW trap CPUE to test the hypothesis that the CPUE from this fleet, which has relatively low catches, is influential in the assessment outcomes.

For consistency, the same mean low recruitment estimate from the base case (-0.4252) was used for all the sensitivity analyses with the exception of the model with a low natural mortality of M=0.14yr^{-1} for which an estimate of -0.3428 was obtained (Table 13, Figure 11).

The results of the sensitivity analyses are summarized by considering the following performance measures:

1. SSB_0: the average unexploited female spawning biomass.
2. SSB_{2024}: the female spawning biomass at the start of 2024.
3. SSB_{2024}/SSB_0: the stock status at the start of 2024.
4. $\Delta SSB_{2024}/SSB_0$: the difference in the stock status at the start of 2024 between the base case model and the sensitivity.

RBC advice

At the September 2023 SERAG meeting it was agreed that a low recruitment base case would be used to provide management advice. The implementation of the SESSF Tier 1 harvest control rule within Stock Synthesis does not work correctly for low recruitment projections, as it projects future catches assuming recruitment is at the long-term average. Consequently, to quantify the risk to the stock, we undertook fixed catch projections of 50, 75, 100, 125 and 150t, projecting 30 years into the future, using the base case and a (low recruitment) sensitivity using lower natural mortality of M=0.14yr^{-1}. Fixed catch projections using the sensitivity with a very low natural mortality (M=0.11yr^{-1}), were also attempted, however, it wasn't possible to achieve a converged model with Francis weighting in the available time.

Results

Base-case assessment

The base-case model converged with final gradient <1e^{-4} and a positive definite Hessian. The base case model was projected using the average recruitment deviations for 2010–2019, the period of below average recruitment selected by the Steering Committee (see Appendix A), from 2020 onwards (Table 13, Figure 11).

Table 13. Estimated recruitment deviations for 2010–2019 and their average from the 2023 base case Silver Trevally assessment and a (low recruitment) sensitivity with lower natural mortality of *M*=0.14yr^{-1}.

Year	Base case	*M*=0.14
2019	0.1133	-0.0846
2018	-0.1361	-0.3977
2017	-0.7453	-0.3045
2016	-0.8930	-0.0593
2015	-0.8010	-0.4388
2014	-0.4924	-0.7589
2013	-0.1750	-0.8337
2012	-0.4217	-0.6649
2011	-0.5030	-0.0547
2010	-0.1978	0.1694
Average	**-0.4252**	**-0.3428**

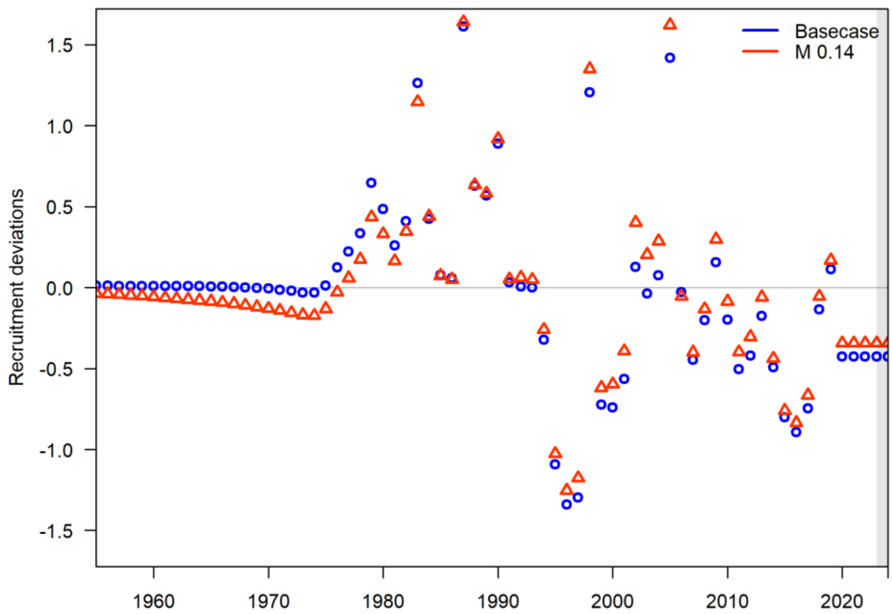

Figure 11 Estimated recruitment deviations for 1955–2019 and the projected recruitment deviations for the 2023 base case Silver Trevally assessment and a (low recruitment) sensitivity with lower natural mortality of *M*=0.14yr^{-1}.

Parameter estimates and derived quantities

Using the base case model, the estimate of unfished female spawning biomass (SSB_0) was 5,091t and the current 2024 spawning biomass (SSB_{2024}) was estimated to be 1,360t with current stock status (SSB_{2024}/SSB_0) estimated to be 26.7% (Table 14). Spawning biomass estimates gradually declined from unfished levels in the 1950s to ~75% of unfished spawning biomass by the mid-1980s (Figure 12). A period of rapid decline in biomass followed with the stock dropping below the target reference point (TRP) in the mid-1990s, then below the limit reference point (LRP) in the early 2000s (Figure 12). The spawning biomass was then estimated to have increased to just above the LRP in 2009–2011 before again dropping below the LRP. Spawning biomass was estimated to have increased above the LRP in 2021, corresponding with a period of lower fishing mortality in 2019–2022 (Figure 3).

Table 14. Estimated log of unfished recruitment (lnR_0), spawning biomass at the beginning of 2023 and 2024 and stock status at the beginning of 2023 and 2024 for the 2023 low recruitment base case Silver Trevally assessment.

Quantity	Estimate
ln(R_0)	8.128
SSB_0 *(t)*	5,091
SSB_{2023} *(t)*	1,269
SSB_{2024} *(t)*	1,360
SSB_{2023}/SSB_0	24.9%
SSB_{2024}/SSB_0	26.7%

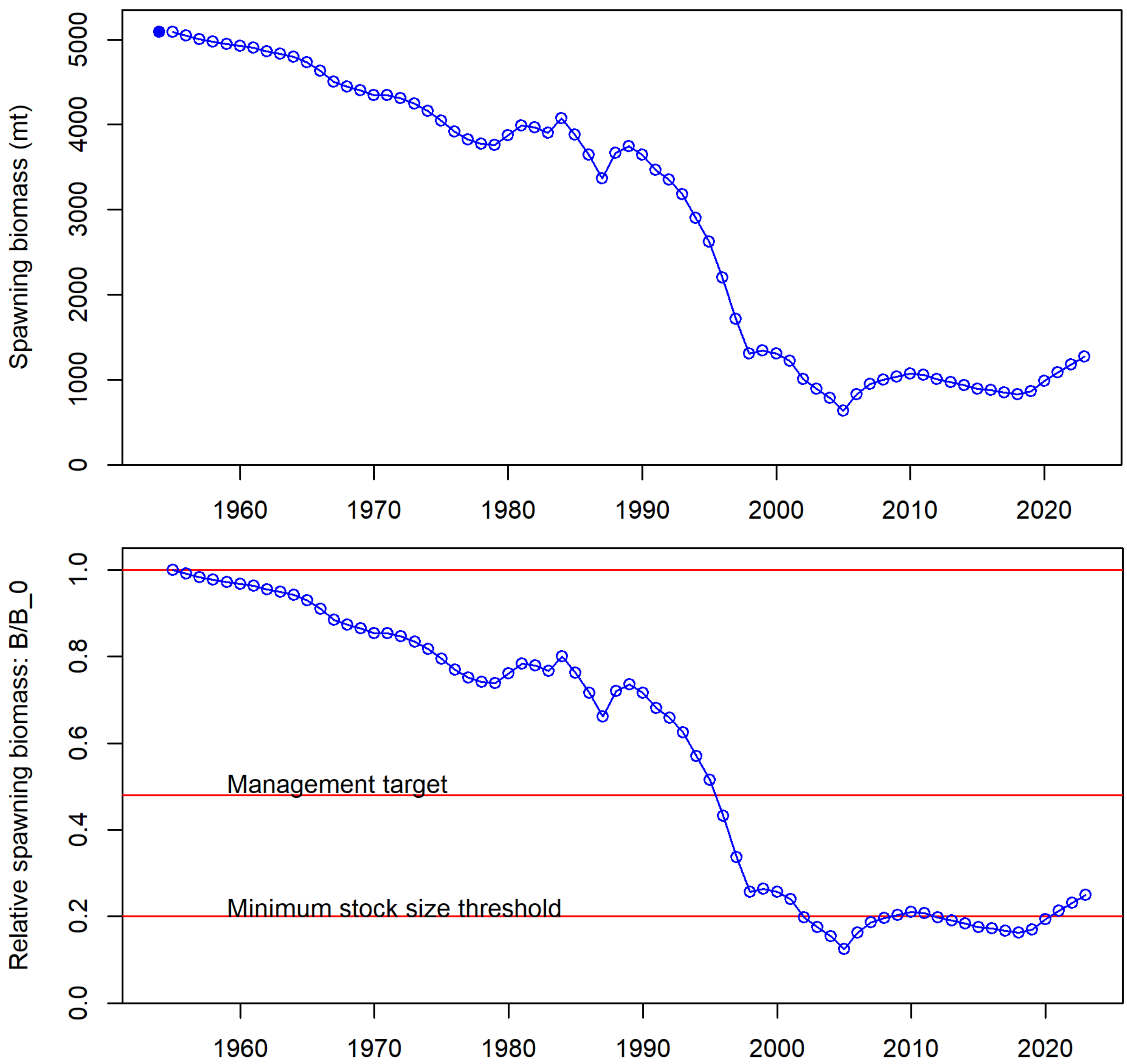

Figure 12 Time-series of absolute (top) and relative (bottom) spawning biomass estimates for the 2023 base case Silver Trevally assessment.

The pre-specified growth curve is shown in Figure 13. The selectivity functions for the seven fleets and one survey are shown in Figure 14. Selectivity is estimated for all fleets and the survey, except for NSW trawl and Victorian commercial. NSW trawl selectivity was estimated prior to the modification of the retention function (see model C, Appendix A) and it is pre-specified at the estimated values from the previous model (model B, Appendix A). The retention function is shown in Figure 15. As there was no length data available for the Victorian commercial fleet, its selectivity was mirrored to Commonwealth trawl which was selected because it is not subject to the MLL. Estimates of catchability, selectivity and retention parameters are provided in Table 18 of Appendix B.

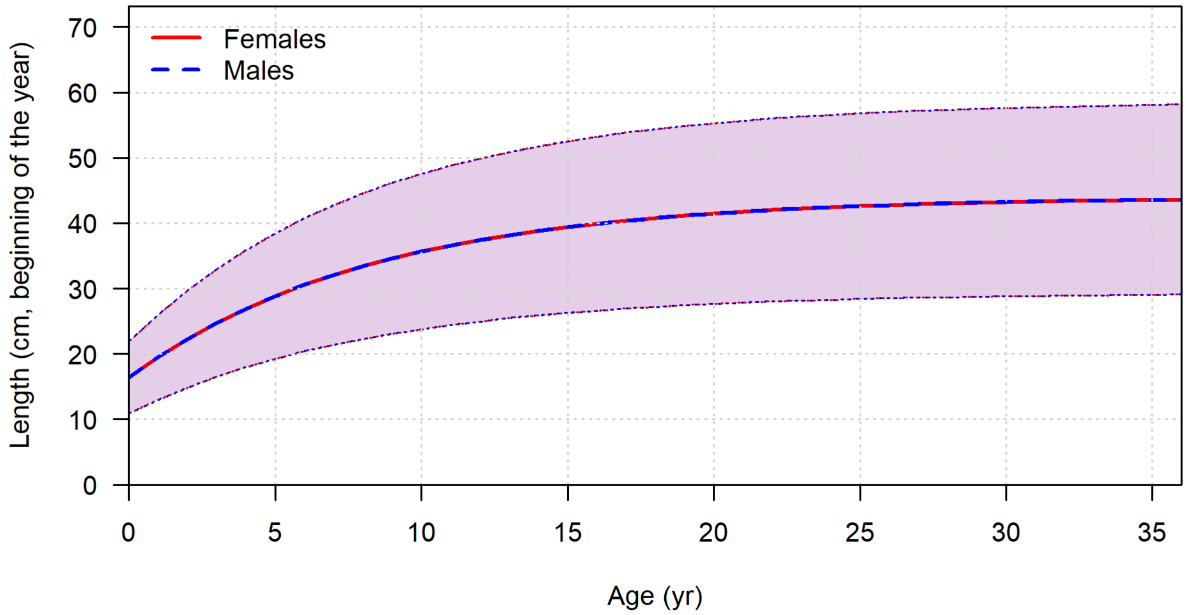

Figure 13 Pre-specified growth curve for the 2023 base case Silver Trevally assessment.

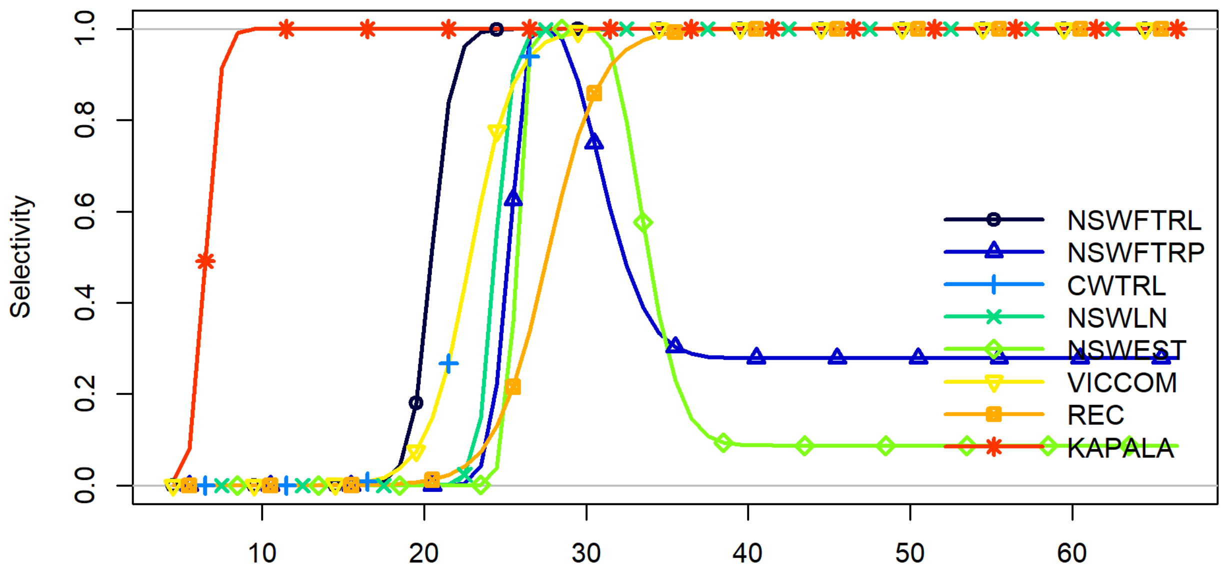

Figure 14 Length based selectivity estimates by fleet for the 2023 base case Silver Trevally assessment.

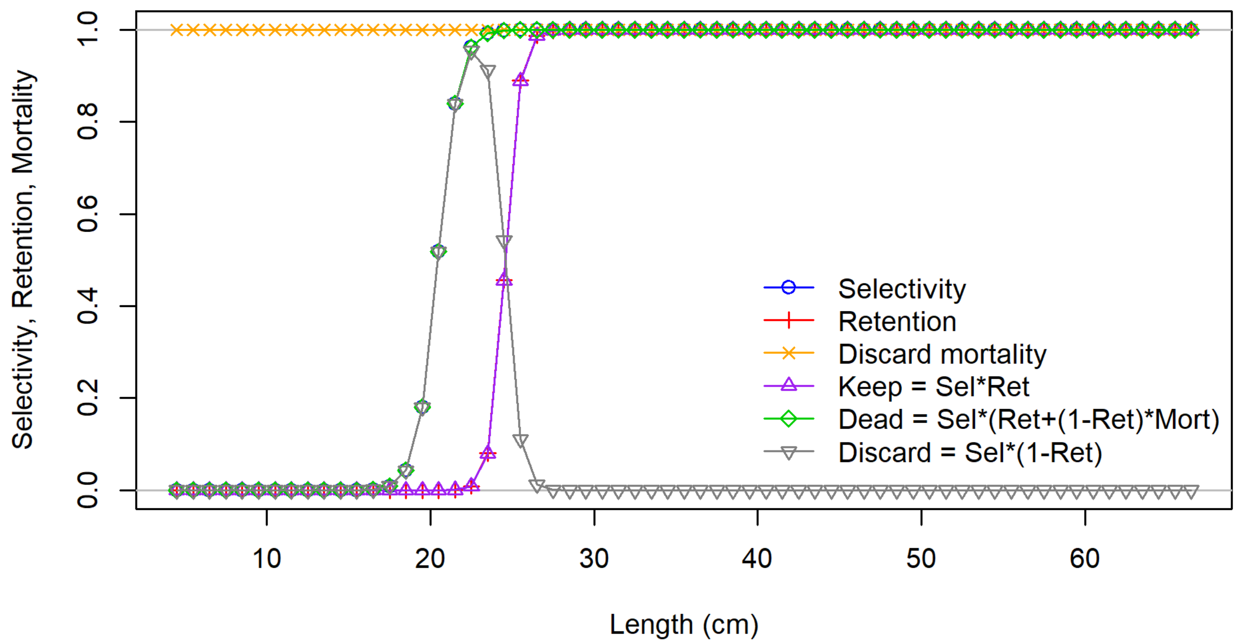

Figure 15 The pre-specified retention and selectivity functions for the NSW trawl fleet that are used to accommodate the introduction of the MLL in 2007 in the 2023 base case Silver Trevally assessment. Note the MLL is applied to a total length of 30cm which corresponds to a caudal fork length of ~25cm used in the assessment.

Model fits

Fits to the three CPUE series are provided in Figure 16. The base case model fits reasonably well to the NSW trawl CPUE in the early period (1998–2006), but poorly in the later period, underestimating the CPUE from 2010–2017 and overestimating it from 2018–2022. While the model fits the trend in the NSW trap CPUE for 1998–2006, it underestimates the CPUE in 1998–2001, then overestimates it from 2002–2006. The fits to the 2010–2022 NSW trap CPUE are good. Commonwealth trawl CPUE is poorly fit by the model, with CPUE mostly overestimated in 1986–2002, underestimated from 2003–2017 then overestimated for 2018–2021. CPUE for these three index fleets are inconsistent, so the model is not able to fit to all series simultaneously. The CPUE for all three index fleets has increased over 2019–2022, corresponding with reduced fishing mortality ($F<0.5$) over this period (Figure 3).

Fits to the discard estimates for the NSW trawl fleet and the estimated discard tonnages after the introduction of the MLL are shown in Figure 17. The model estimates that discarding in 2014 and 2015 is ~15%, lower than estimate of 27% from onboard observers during this period.

Fits to the combined length data are good for the NSW trap and estuary, Commonwealth trawl and recreational fleets (Figure 18), and reasonable to the NSW trawl fleet. Length data from the NSW line and Kapala fleets show evidence of bimodality. For the annual NSW trawl length data, the model underestimates the lengths before 1995 but fits well to most years in 1995–2006 (Figure 19). The retention function fits well to the left hand side of the length distribution after the introduction of the MLL in 2007; however, the absence of fish >30cm CFL, which are present in NSW trap and Commonwealth trawl, suggests there may have been a change in selectivity. Fits to the annual NSW trap length data are generally good (Figure 20), while the fits to the Commonwealth trawl lengths are more variable, but good in most years (Figure 21). The fits to the NSW line length data are reasonable in 2006, 2011 and 2018–2021 with other years fitting poorly, with some evidence of bimodality (Figure 22). The NSW estuary data are fitted well, as are the recreational data, however, only a single year is available for the latter fleet (Figure 23). The Kapala length data are poorly fitted and shows evidence of bimodality (Figure 23).

Fits to the 1998 age-at-length data were good for the NSW trawl, line and estuary fleets (Figure 24). The age data for NSW trap fleet contains some 35–40cm fish, with estimated ages of 10–20, which the model ignores (Figure 24).

The model estimates recruitment to be above average for the 1980s and early 1990s, but generally below average after the mid-1990s (Figure 2, Appendix B Figure 43). The stock recruitment curve is provided in Appendix B Figure 44. The recruitment deviation asymptotic standard error shows that the recent recruitment deviations are well estimated to 2019 (Figure 25). A Kobe plot of the time series of spawning biomass plotted against spawning potential ratio is provided in Appendix B Figure 45.

The pre-specified bias ramp is shown in Figure 26.

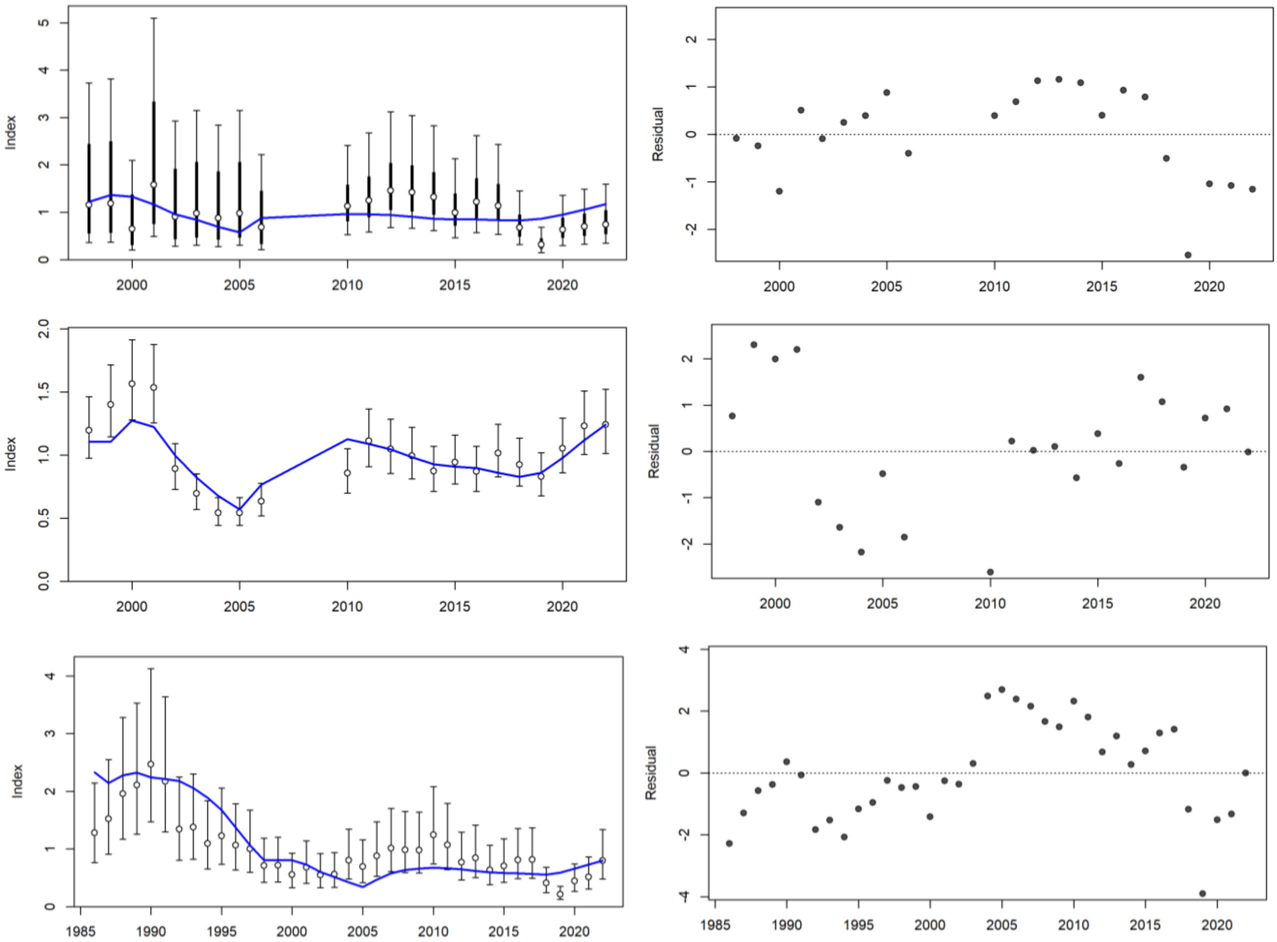

Figure 16 Fits (left) and residuals (right) of standardized CPUE series for NSW trawl (top), NSW trap (middle) and Commonwealth trawl (bottom) for the 2023 base case Silver Trevally assessment.

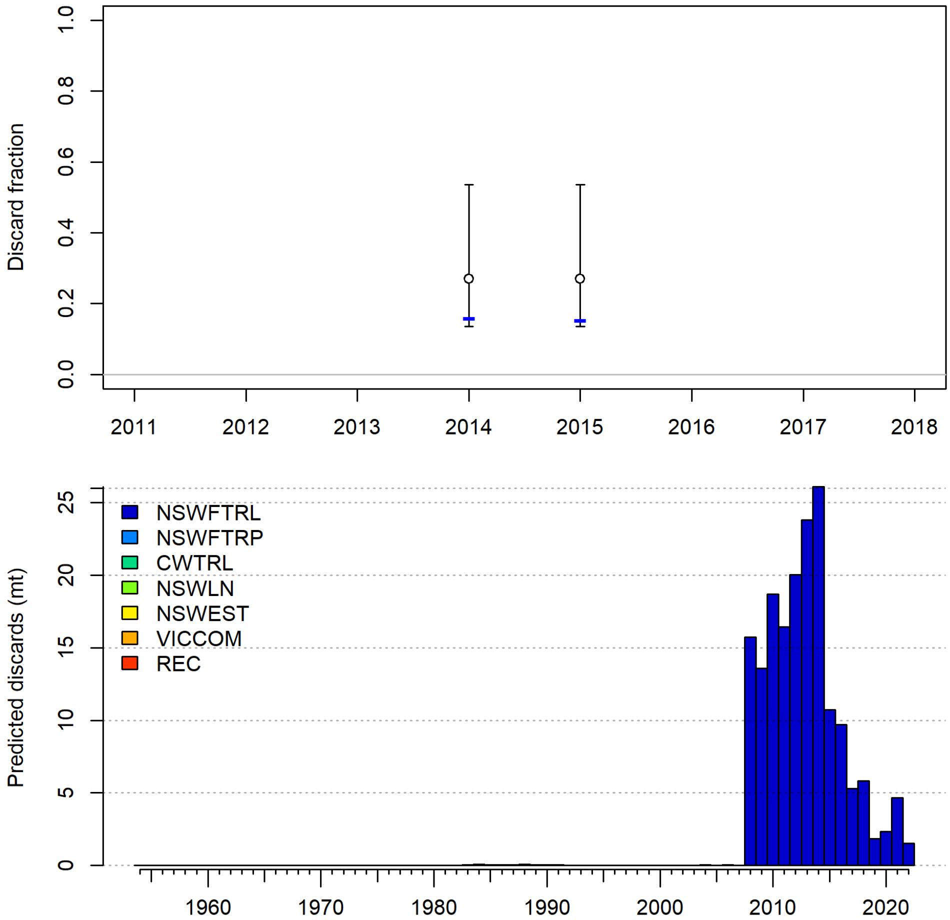

Figure 17 Fits to estimated discard proportions (top) and estimated discard tonnage (bottom) for the NSW trawl fleet after the introduction of the MLL in 2007 for the 2023 base case Silver Trevally assessment.

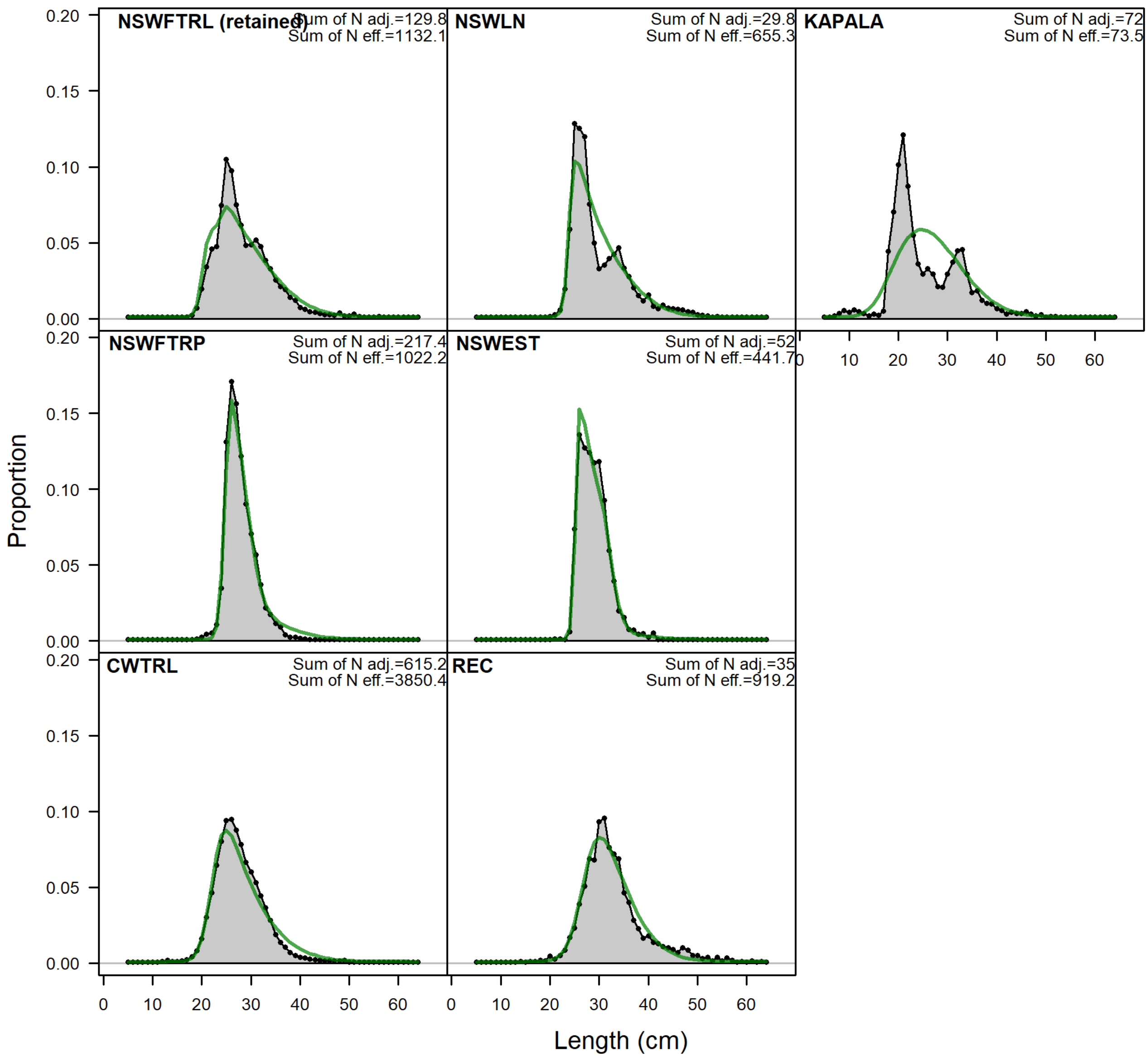

Figure 18 Fits to the combined length frequency data for all fleets that include length data for the 2023 base case Silver Trevally assessment.

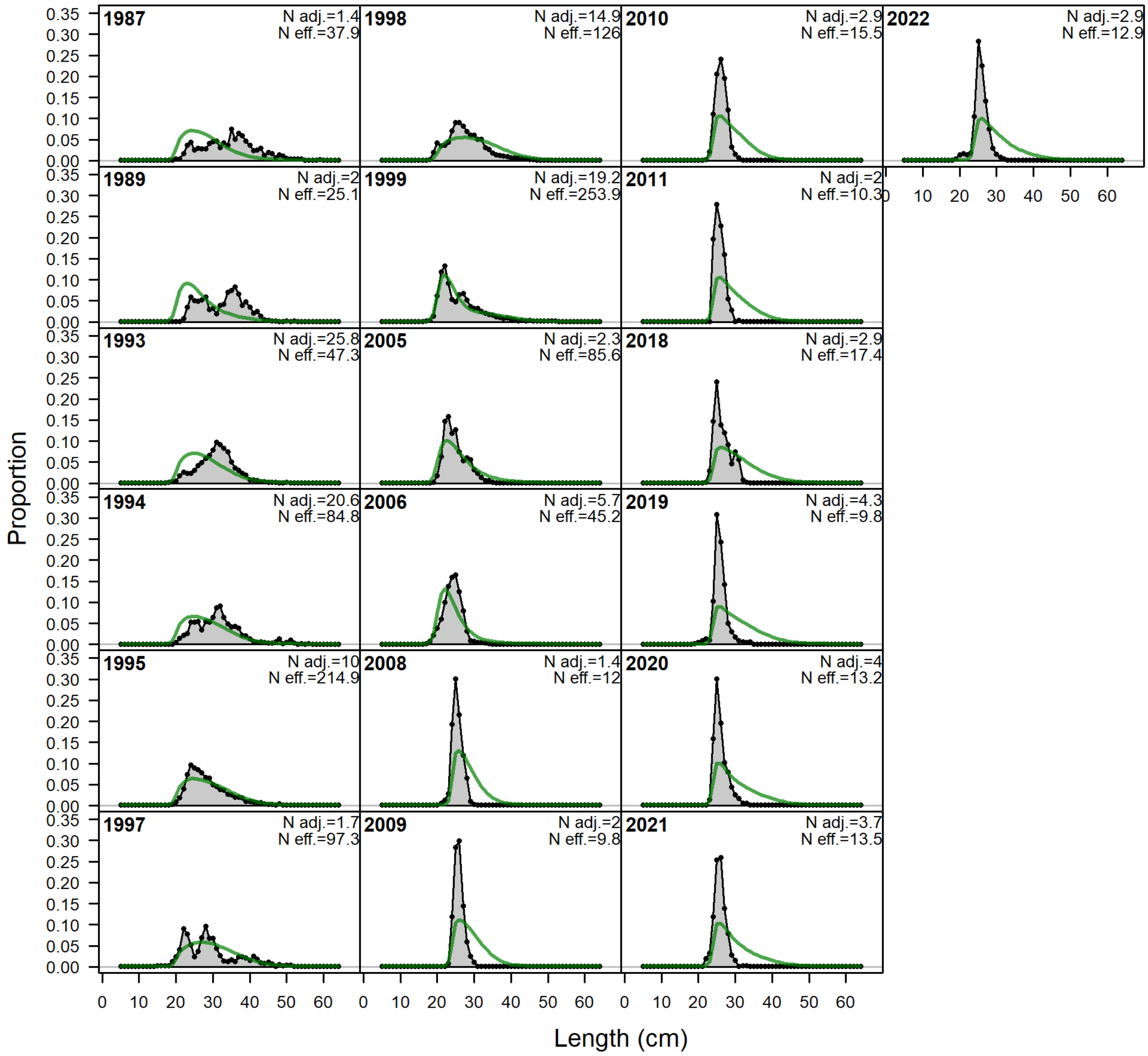

Figure 19 Fits to the annual NSW trawl retained length frequency data for the 2023 base case Silver Trevally assessment.

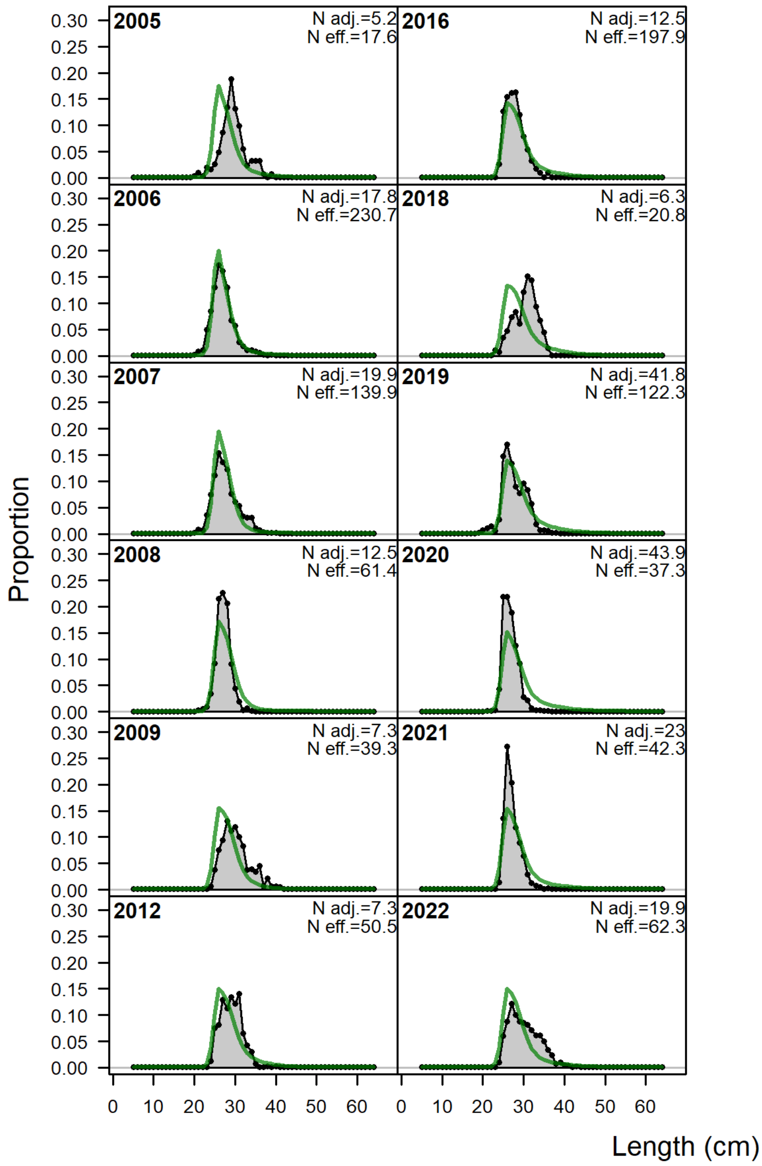

Figure 20 Fits to the annual NSW trap whole length frequency data for the 2023 base case Silver Trevally assessment.

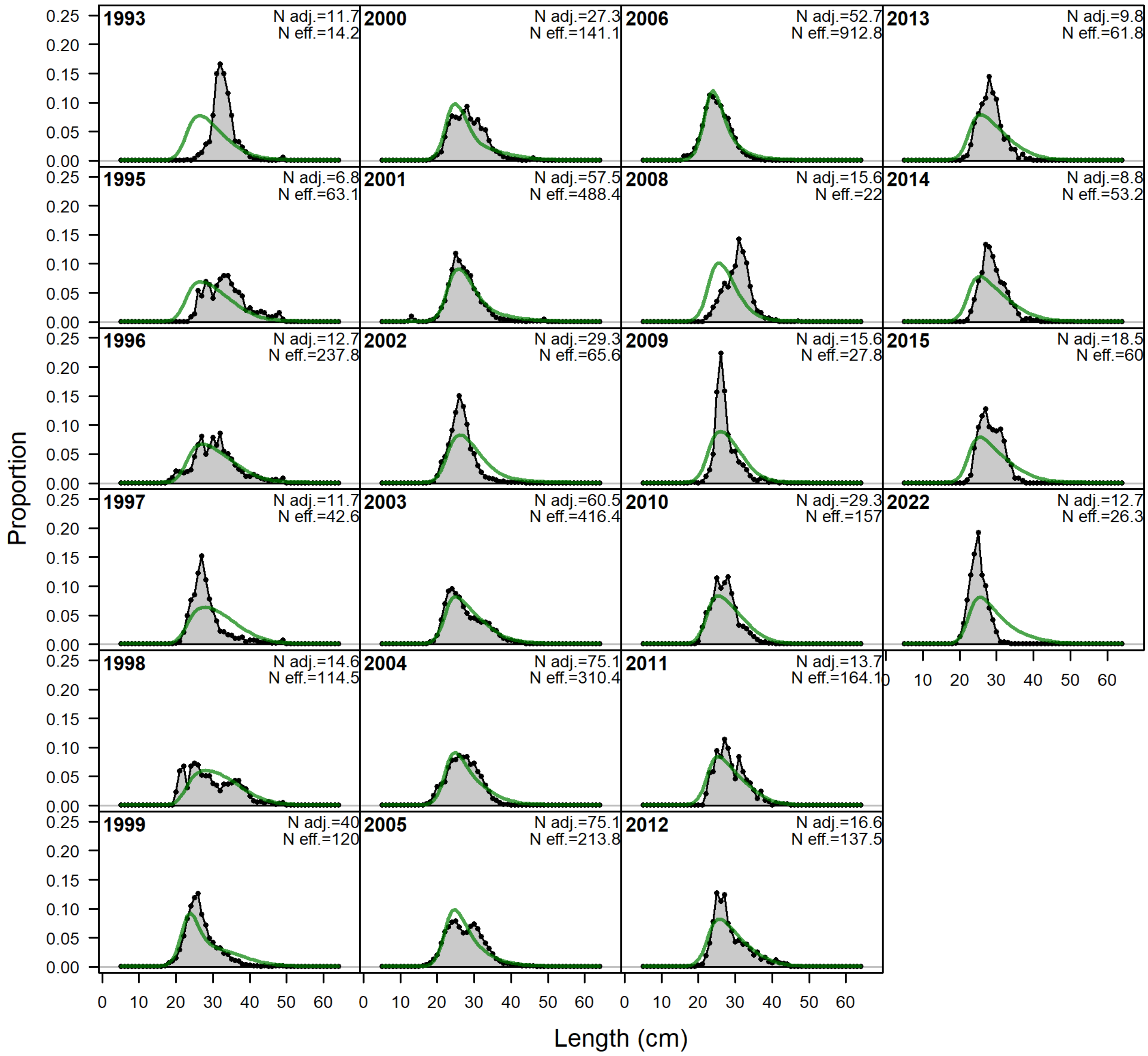

Figure 21 Fits to the annual Commonwealth trawl whole length frequency data for the 2023 base case Silver Trevally assessment.

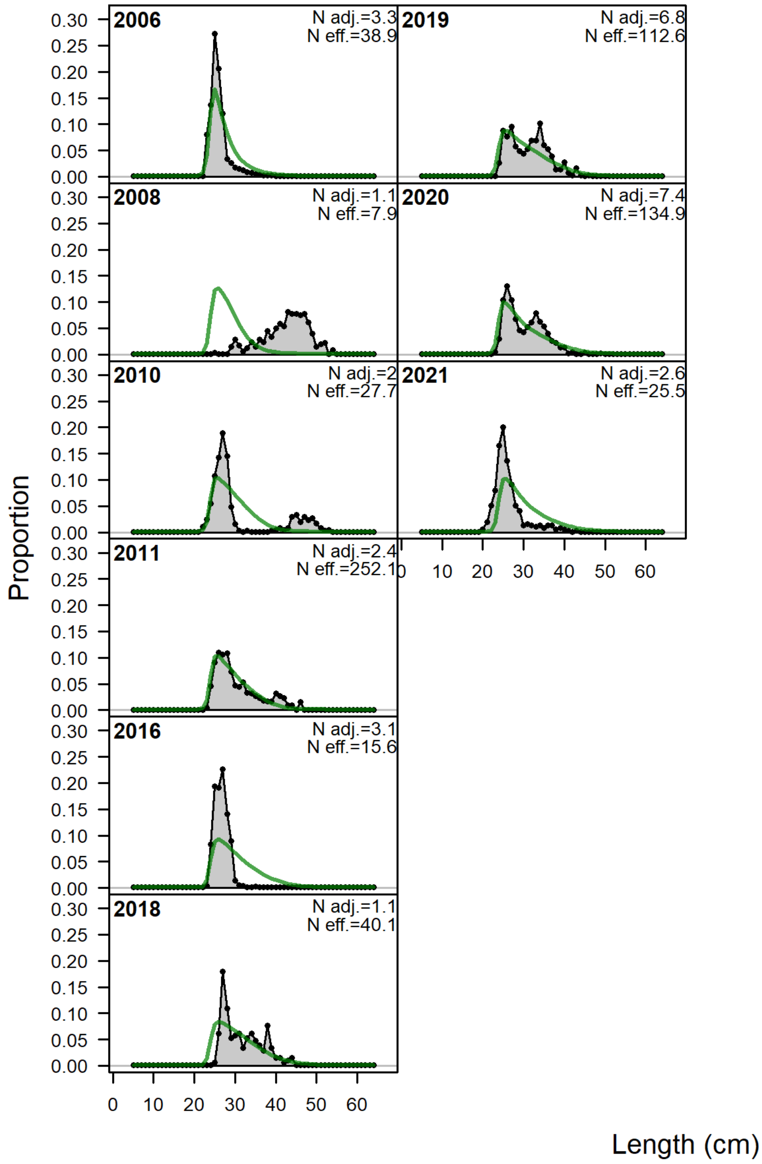

Figure 22 Fits to the annual NSW line whole length frequency data for the 2023 base case Silver Trevally assessment.

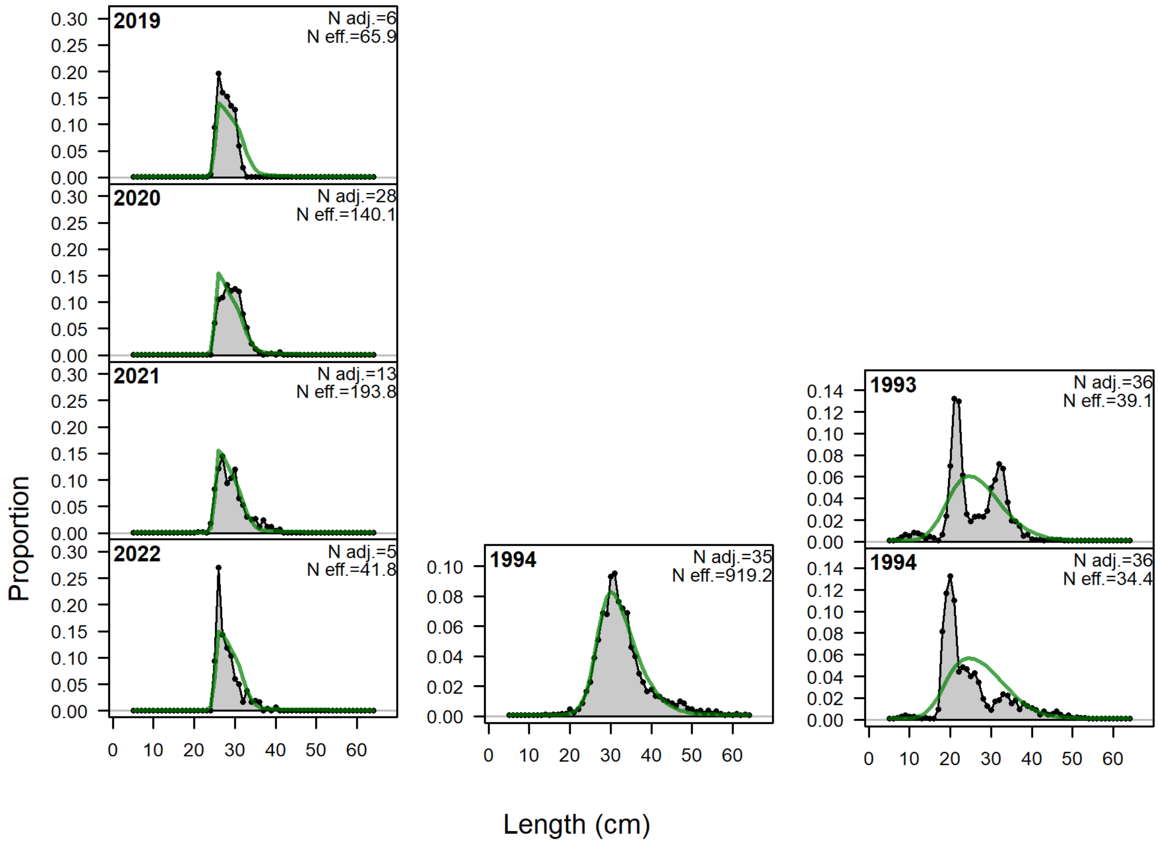

Figure 23 Fits to the annual NSW estuary (left), recreational (middle) and Kapala (right) whole length frequency data for the 2023 base case Silver Trevally assessment.

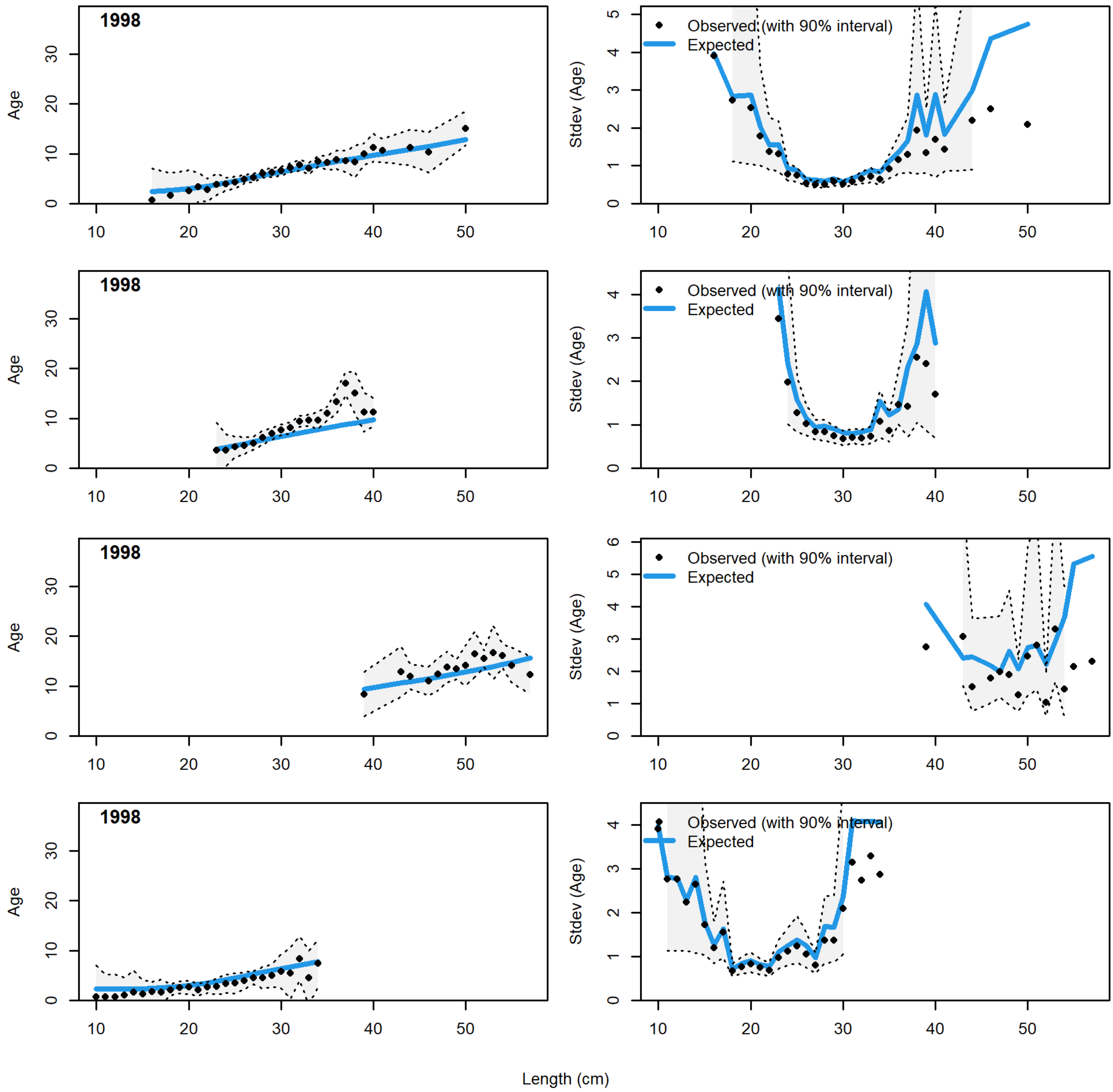

Figure 24 Fits to the mean (left) and standard deviation (right) of age-at-length data for the NSW trawl (top), NSW trap (upper middle), NSW line (lower middle) and NSW estuary (bottom) fleets for the 2023 base case Silver Trevally assessment.

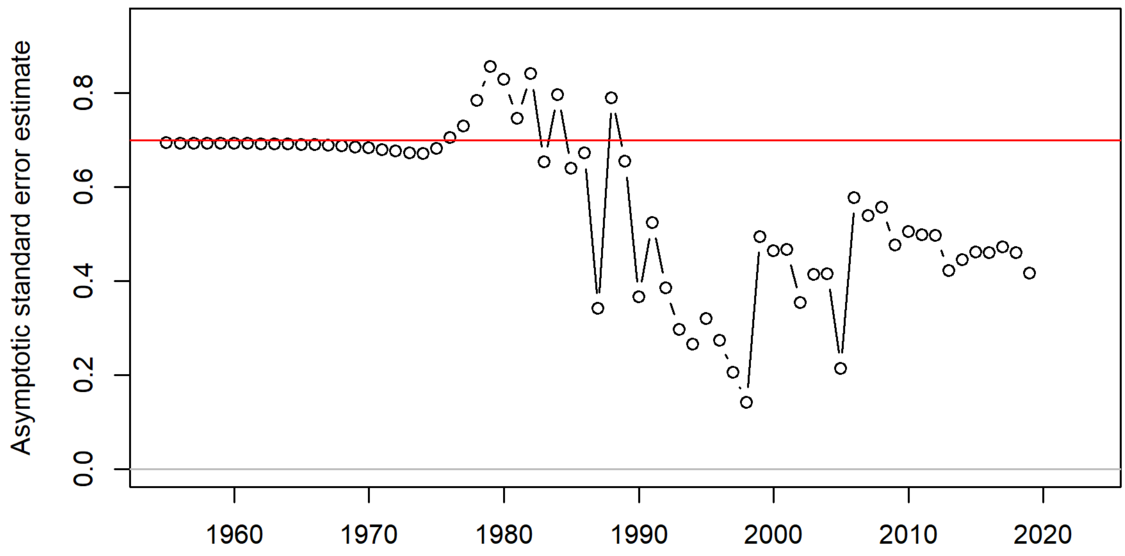

Figure 25 Recruitment deviation asymptotic standard error for the 2023 base case Silver Trevally assessment.

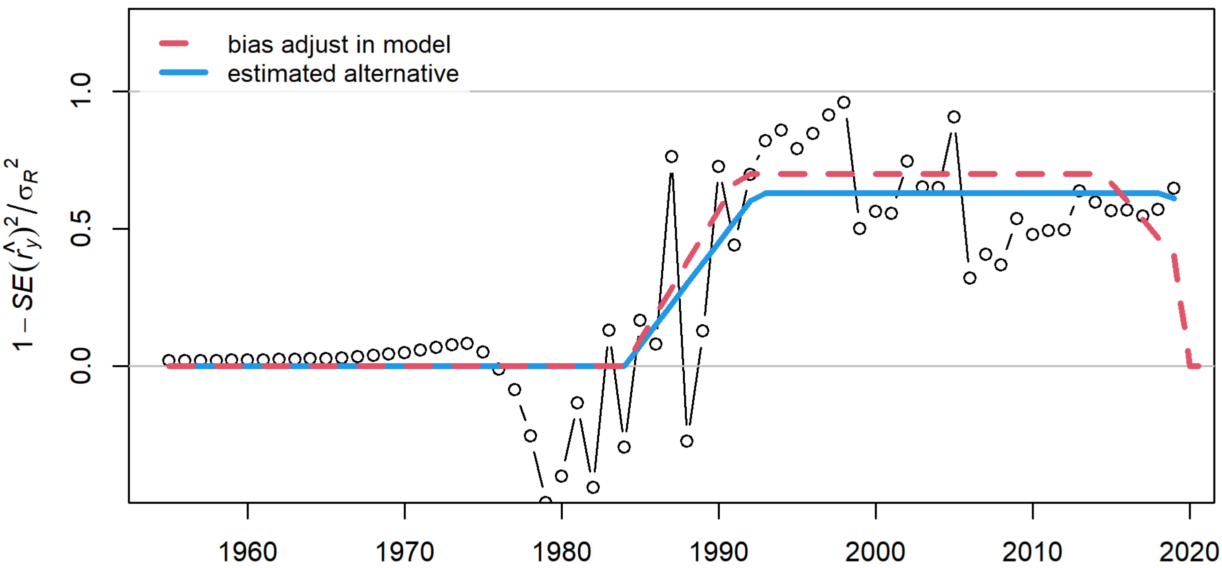

Figure 26 Pre-specified bias ramp for the 2023 base case Silver Trevally assessment.

Likelihood Profile on natural mortality

The likelihood profile for the base case model shows that the data supports a value for *M* between 0.11yr^{-1} and just below 0.18yr^{-1} (Table 15, Figure 27). While the change in log-likelihood of 1.935 for *M*=0.18yr^{-1} is technically above the value of 1.92 used in the 95% confidence interval, the difference is negligible, with *M*=0.18yr^{-1} effectively representing the upper bound on the 95% confidence interval on *M*.

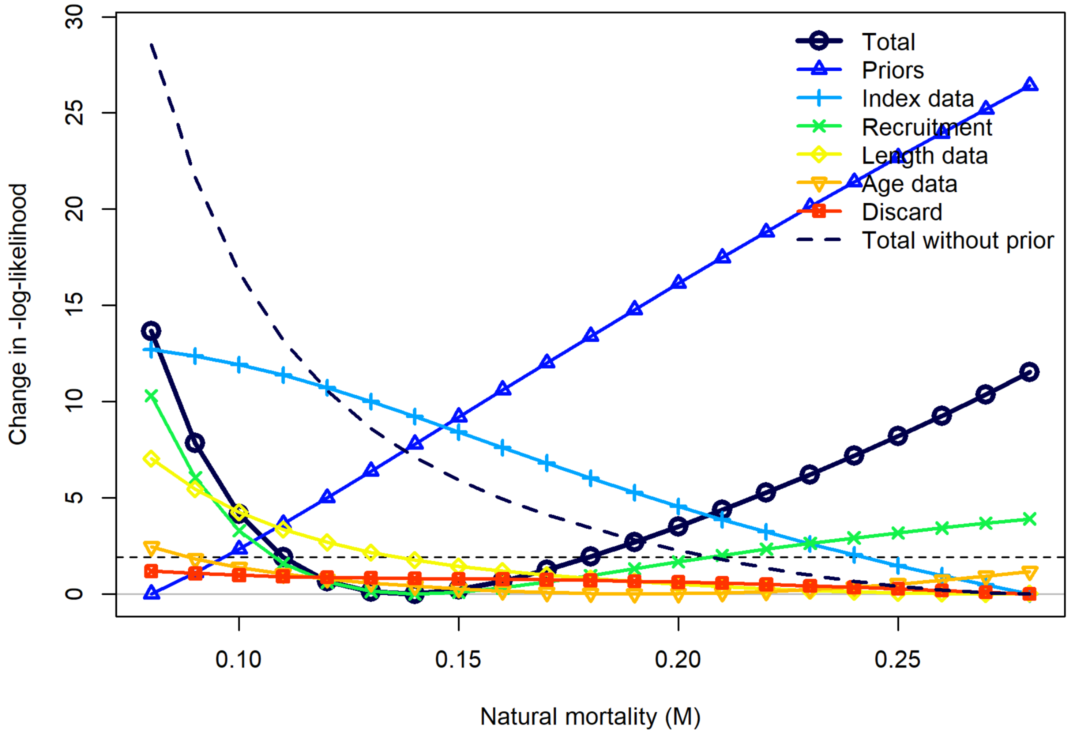

Figure 27 Likelihood profile on natural mortality (*M*). The pre-specified value of natural mortality in the 2023 base case Silver Trevally assessment is *M*=0.18yr^{-1}.

Table 15. Changes in total log-likelihood (Total) and the contributions from the CPUE indices, length (Length) and age (Age) composition data, discards (Discard) and estimated recruitment (Recruit) for a likelihood profile on natural mortality. Minimum values for each component (Total, CPUE, Length, Age, Discard and Recruit) are shown in bold. The pre-specified value of natural mortality used in the 2023 base case Silver Trevally assessment is *M*=0.18yr^{-1}.

M	Total	CPUE	Length	Age	Discard	Recruit
0.08	13.659	12.688	7.023	2.445	1.178	10.299
0.09	7.854	12.372	5.438	1.807	1.062	6.046
0.10	4.160	11.928	4.250	1.361	0.970	3.294
0.11	1.916	11.368	3.355	1.034	0.904	1.588
0.12	0.667	10.714	2.676	0.781	0.858	0.610
0.13	0.100	9.991	2.156	0.577	0.826	0.135
0.14	**0.000**	9.219	1.753	0.408	0.802	**0.000**
0.15	0.221	8.420	1.437	0.269	0.781	0.087
0.16	0.659	7.612	1.184	0.158	0.759	0.311
0.17	1.246	6.811	0.978	0.076	0.733	0.613
0.18	1.935	6.028	0.806	0.023	0.701	0.953
0.19	2.697	5.273	0.659	**0.000**	0.660	1.304
0.2	3.505	4.555	0.493	0.010	0.612	1.672
0.21	4.362	3.868	0.373	0.050	0.555	2.008
0.22	5.259	3.217	0.268	0.120	0.490	2.326
0.23	6.195	2.603	0.177	0.221	0.418	2.627
0.24	7.171	2.023	0.103	0.352	0.341	2.910
0.25	8.190	1.475	0.046	0.513	0.259	3.177
0.26	9.252	0.957	0.011	0.701	0.174	3.431
0.27	10.362	0.466	**0.000**	0.917	0.088	3.671
0.28	11.520	**0.000**	0.017	1.158	**0.000**	3.901

Sensitivities

Results from sensitivities to the data and assumptions used in the 2023 base case model are provided in Table 16. The base case assessment, which assumes below average recruitment from 2020 onwards, estimates the current (2024) stock status to be 26.7%. If average recruitment is assumed, then current stock status is estimated to be 32.8%. The assessment is very sensitive to the pre-specified value of natural mortality. The base case assumes a value of M=0.18yr^{-1}. A likelihood profile suggests plausible values of M within the range of M=0.11–0.18yr^{-1}, with a preferred value of M=0.14yr^{-1}. The estimated stock status from a (low recruitment) sensitivity assuming M=0.14yr^{-1} is 18.6% in 2024. If average recruitment is assumed, then the current stock status is 21.4% (results not shown). The current stock status from the very low recruitment sensitivity assuming M=0.11yr^{-1} is 12.8%.

Table 16. Sensitivities to the 2023 base case Silver Trevally model, showing estimates of unfished (SSB_0) and current (SSB_{2024}) spawning biomass, current stock status (SSB_{2024}/SSB_0) and the difference between the current stock status of the base case and the sensitivity (SSB_{2024}/SSB_0). All models use the low recruitment deviation of -0.4252 in the projection period (2020 onwards), with the exception of the 2023 base case with average recruitment and the model with lower natural mortality of M=0.14yr^{-1} (which uses low recruitment deviation of -0.3428). † Denotes models that have been Francis weighted.

Scenario	SSB_0	SSB_{2024}	SSB_{2024}/SSB_0(%)	$\Delta SSB_{2024}/SSB_0$
†2023 base-case	5,091	1,360	26.7	0
†2023 base case with average recruitment	5,091	1,671	32.8	6.1
†Add 1997 age data	5,143	1,375	26.7	<0.1
†Add 1945-1954 catch	5,105	1,360	26.6	-0.1
†Remove NSW trap CPUE	4,927	1,172	23.8	-2.9
Commonwealth CPUE 1992–2022	5,030	1,171	23.3	-3.4
Low steepness (h=0.6)	5,763	1,309	22.7	-4.0
High steepness (h=0.8)	4,641	1,407	30.3	3.6
Low recruitment variability (σ_R=0.6)	5,095	1,376	27.0	0.3
High recruitment variability (σ_R=0.8)	5,125	1,353	26.4	-0.3
Very low natural mortality (M=0.11yr^{-1})	7,839	1,001	12.8	-13.9
†Low natural mortality (M=0.14yr^{-1})	6,291	1,134	18.6	-8.1
High natural mortality (M=0.22yr^{-1})	4,525	1,642	36.3	9.6
Low (m_1=17cm) length at 50% maturity	5,122	1,400	27.3	0.6
High (m_1=21cm) length at 50% maturity	5,007	1,291	25.8	-0.9
Halve the weighting on the composition data	5,283	1,424	27.0	0.2
Double the weighting on the composition data	4,831	1,265	26.2	-0.5
Halve the weighting on the CPUE data	5,245	1,278	24.4	-2.4
Double the weighting on the CPUE data	4,915	1,424	29.0	2.2
"Low" catch scenario (Table 4)	4,985	1,304	26.2	-0.5
"High" catch scenario (Table 5)	5,196	1,417	27.3	0.6

The assessment is also somewhat sensitive to the steepness of the stock recruitment relationship (h) and the CPUE data inclusions and weightings, with estimated stock status 2–4% lower than the base case when h=0.6, when the NSW trap CPUE is removed, when the Commonwealth CPUE time series is restricted to 1992–2022, or when the weighting of the CPUE in the likelihood is halved.

Conversely, when *h*=0.8 or the weighting on the CPUE in the likelihood is doubled, current stock status is 2–4% higher than the base case. Including the 1997 age data, or the 1945–1954 catches, the "low" and "high" catch scenarios, varying the length at maturity or the recruitment variability or changing the likelihood weighting of the age and length composition data resulted in less than 1% change to the estimates of current stock status, relative to the base case.

RBC advice

Fixed catch projections

The implementation of the SESSF Tier 1 harvest control rule within Stock Synthesis does not work correctly for low recruitment projections – it projects future catches assuming recruitment is at the long-term average. Fixed catch projections of 50, 75, 100, 125 and 150t were undertaken using the base case and the lower natural mortality (M=0.14yr^{-1}) scenario, both of which include low recruitment (Table 17). For catches of 50–150t per annum, stock status in 2027 is estimated to increase to 30.3–32.9% for the base case and 22.3–24.5% for the low M scenario. While current stock status estimates are sensitive to the pre-specified value of natural mortality, in the medium to long term the stock status is reasonably insensitive to the value of M for catches of 50–150t per annum (Table 17, Figure 28). This is due to the recent recruitment estimates for the base case being lower than for the low natural mortality scenario (Table 13, Figure 11). Fixed catch projections using the sensitivity that assumes very low natural mortality (M=0.11yr^{-1}), were also attempted, however, it wasn't possible to achieve a converged model with the Francis weighting recalculated in the available time. While this model was not suitable to inform management advice, it would be expected that the stock status estimates for the M=0.11yr^{-1} sensitivity) would remain below the LRP of 20% of unfished biomass for catches of 50–150t per annum in the short term.

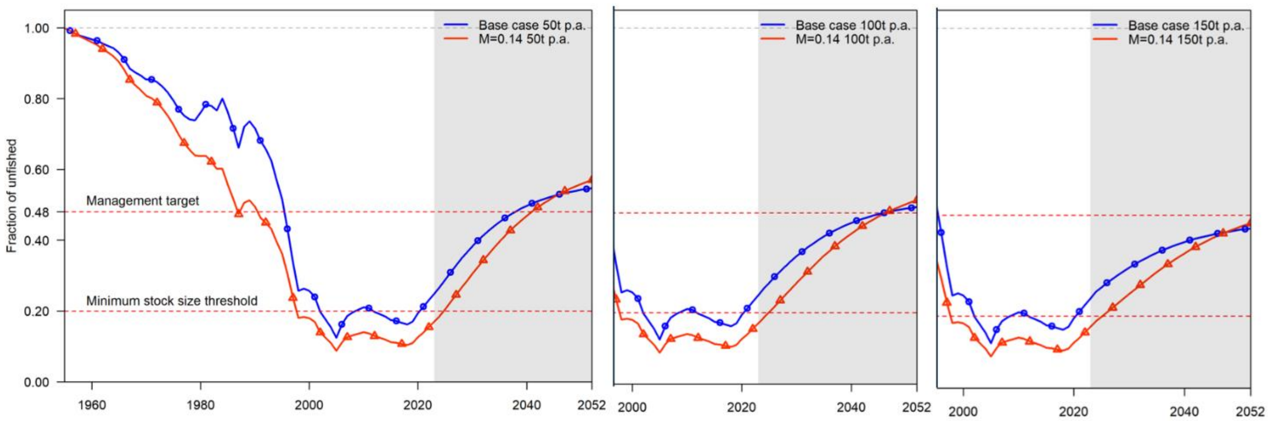

Figure 28 Comparison of time series of estimated stock status for the 2023 base case (M=0.18yr^{-1}) Silver Trevally assessment and a sensitivity assuming M=0.14yr^{-1}, both of which are projected assuming low recruitment.

Table 17. Stock status estimates for fixed catch projections of 50, 75, 100, 125 and 150t using the base case (M=0.18yr^{-1}) and a sensitivity assuming M=0.14yr^{-1}, both of which are projected assuming low recruitment. † Stock status estimates for 2023 are also provided as they represent the last estimation year within the assessment.

	50t yr^{-1}		75t yr^{-1}		100t yr^{-1}		125t yr^{-1}		150t yr^{-1}	
Year	Low nat. mort.	Base case	Low nat. mort.	Base case	Low nat. mort.	Base case	Low nat. mort.	Base case	Low nat. mort.	Base case
2023†	17.0	24.9	17.0	24.9	17.0	24.9	17.0	24.9	17.0	24.9
2024	18.6	26.7	18.6	26.7	18.6	26.7	18.6	26.7	18.6	26.7
2025	20.5	28.9	20.3	28.6	20.2	28.4	20.0	28.2	19.8	28.0
2026	22.5	30.9	22.2	30.5	21.8	30.1	21.4	29.6	21.1	29.2
2027	24.5	32.9	24.0	32.3	23.4	31.6	22.9	31.0	22.3	30.3
2028	26.6	34.8	25.8	34.0	25.1	33.1	24.3	32.3	23.6	31.4
2029	28.6	36.6	27.6	35.6	26.7	34.5	25.8	33.5	24.9	32.5
2030	30.5	38.3	29.4	37.1	28.3	35.9	27.2	34.7	26.1	33.5
2031	32.5	39.9	31.2	38.5	29.9	37.1	28.7	35.8	27.4	34.4
2032	34.4	41.3	32.9	39.8	31.5	38.3	30.1	36.8	28.6	35.3
2037	42.8	47.2	40.7	45.2	38.6	43.1	36.5	41.0	34.4	38.9
2042	49.2	51.0	46.8	48.7	44.3	46.3	41.8	43.9	39.2	41.5
2047	53.9	53.3	51.3	50.9	48.6	48.4	45.8	45.8	43.0	43.2
2052	57.0	54.7	54.3	52.2	51.6	49.7	48.7	47.1	45.8	44.3

Discussion

Assessment summary

This report has reviewed the data available and developed a Tier 1 integrated assessment for Silver Trevally to inform management advice for the stock in 2024. Similar to several other SESSF stocks, Silver Trevally shows evidence of below average recruitment over much of the last 30 years, leading SERAG to direct that the base case model be projected with below average recruitment. The base case assessment estimates unfished female spawning biomass (SSB_0) at 5,091t and current spawning biomass (SSB_{2024}) at 1,360t with current stock status (SSB_{2024}/SSB_0) estimated to be 26.7%. If average recruitment is assumed, then current stock status is estimated to be 32.8%.

The assessment is very sensitive to the assumed value of natural mortality: current stock status estimates from models with plausible natural mortality values of M=0.11–0.18yr^{-1} are 12.8–26.7% (the base case assumes M=0.18yr^{-1}). While estimates of current stock status are sensitive to the pre-specified value of natural mortality, in the medium to long term the stock status is reasonably insensitive to the value of M for catches of 50–150t per annum because the model with lower M has higher average recruitment than the base case. The assessment is also somewhat sensitive to the steepness of the stock recruitment relationship (h) and to CPUE data inclusions and weightings, with stock status varying ±2–4% relative to the base case. The other sensitivities considered had minimal (<1%) impact on estimates of current stock status.

CPUE and spawning biomass have both increased in 2019–2022 and while recruitment has been below the long term average for most of the last 30 years, the most recent two recruitments are around the long term average. Under catches of 50–150t per annum stock status is projected to increase for models with M=0.14–0.18yr^{-1}. Given the uncertainty around the estimates of current stock status, primarily associated with uncertainty in natural mortality, monitoring future recruitment is critical to provide managers with robust information to manage set sustainable catch limits in the short term.

Comparison with previous assessments

This report was initiated because of discrepancies between the NSW and Commonwealth Tier 4 assessments with the NSW assessment concluding the stock was below the LRP, while the Commonwealth assessment was above the LRP.

The most recent NSW assessment of Silver Trevally used a weight of evidence approach comprising a JABBA surplus production model (Winker et al. 2018) fitted to catch and standardized CPUE, a LIME length-based population dynamics model (Rudd and Thorson 2018) fitted to 1987–2007 trawl data and a consideration of the proportion of large fish in recent NSW trawl catches relative to that in the last model year (2007 when NSW introduced the MLL). The results from this assessment are reasonably consistent with the NSW surplus production model, with both assessments having similar biomass trends. While the current stock status estimates of this assessment are above the LRP for the base case model, lower assumed values of natural mortality put the stock below the LRP, well within the range of uncertainty of the NSW base case surplus production model and the numerous sensitivity scenarios undertaken thereof. The conclusions of the NSW length-based assessment on current stock status rest on: 1) a similar biomass trajectory to the production model;

2) an estimate of depletion at the end of the modelling period (2007) of 1.9% of unfished biomass, 3) a maximum of 5.1% across all sensitivity scenarios, and 4) the absence of large fish in NSW trawl catches after 2007, suggesting no improvement of size structure following the model period. However, during the development of the current assessment, it was identified that larger fish were present after 2007, albeit in small numbers, in NSW trap, line and estuary catches and in Commonwealth trawl catches. This suggests that the lack of large fish in the NSW trawl catch may be more due to lack of availability to this fleet, for example, as a result of changes in fishing location. As such, the estimation of no improvement in stock status after 2007, based on NSW trawl length data, may be invalid.

For the Commonwealth Tier 4 assessment, the assumed reference period is during a time of substantial exploitation for the stock. This assessment estimates that the unfished spawning biomass declined from 65.7% to 23.9% during the Tier 4 assessment reference period (1992–2001), with fishing mortality increasing from $F≈1.5$ to $F≈3$. This suggests that the stock was well below the TRP during the reference period, and hence the inference that stock is above the Tier 4 LRP may be invalid.

Assessment development

This assessment builds an earlier collaboration between CSIRO and NSW DPI Fisheries that reviewed the available data for Silver Trevally and developed two provisional Tier 1 assessments (Burch et al. 2023c). Much of the further model development identified by Burch et al. 2023c has been achieved in this assessment, including:

- Associating catches with the fleets that caught them and estimating selectivity ogives for most of those fleets.
- Incorporating multiple CPUE series for NSW fleets through time-blocked catchability, rather than the use of additional survey fleets.
- Including discarding in the NSW trawl fleet after the 2007 introduction of the MLL by using a retention function, and estimating discarded catches from 2008 onwards.
- Including the length data from the early fishery-independent trawl survey undertaken by the RV Kapala.
- Separating the early NSW length and age data, which had been aggregated among years, into the years it was sampled.
- Establishing minimum criteria (i.e., number of samples, fisher measured) for the inclusion of annual length and age data for each fleet.
- Re-estimating the NSW CPUE series by calendar year so that all data inputs are based on calendar year.
- Evaluating the sensitivity of the assessment to the 1988–1991 Commonwealth CPUE that may be biased due to NSW based trawl vessels that potentially used increased engine power and high trawl speeds to particularly target Silver Trevally during this period.
- Reweighting the data sources using the version of Francis weighting applied in the SESSF (Punt 2017).
- Reviewing the age data and the estimates of growth.
- Reviewing and re-estimating the ageing error.

Key uncertainties and future needs

The assessment is sensitive to the pre-specified value of natural mortality. Ideally, to reduce the subjectivity in choosing the value of natural mortality, *M* would be estimated, potentially using a weakly informative prior (Hamel 2015, Hamel and Cope 2022).

The assessment is currently dependent on length data to inform the estimation of recent recruitment and with the stock near the LRP, monitoring future recruitment is critical to provide managers with robust estimates of current stock status. While length data provides information on recruitment when fish are growing rapidly, once growth plateaus it is usually not possible to distinguish individual cohorts. The recent NSW age data for 2019–2022 are likely biased due to the truncation of the length distribution at the MLL, and it is not clear whether these data can be incorporated into future assessments. Consequently, to support the estimation of recruitment, there is the need to obtain unbiased age data, either from fishery independent sources in NSW, or from the Commonwealth trawl fleet. Unbiased recent age data could also be utilised to estimate growth to determine whether growth rates may have changed since the late 1990s (Rowling and Raines 2000).

The assessment also assumes that selectivity has not changed over time. The lack of large fish (>30cm CFL) in NSW trawl catches after 2007 suggests that the selectivity of the NSW trawl fleet may have changed. A comparison of the spatial patterns of fishing / sampling before and after 2007 would be useful; however, spatial resolution for NSW catches is coarse. If selectivity has changed, then this can be accommodated by time blocking it within the assessment, as has been done with the catchability of the NSW trawl and NSW trap CPUE.

Finally, the total removals of Silver Trevally are uncertain. While the sensitivity analyses found minimal impact from the inclusion of 1945–1954 catches, or the “low” and “high” scenarios that account for potential double reporting of trawl catches during 1992–2000, the effect of the uncertainty in recreational catch estimates and the interpolation of recreational and Victorian commercial catches has not been evaluated.

Appendix A – Assessment development and review

This assessment was developed as part of a collaboration between CSRIO and NSW Fisheries that builds on earlier work (Burch et al. 2023c) that reviewed the available data for Silver Trevally and developed two provisional Tier 1 assessments. Preliminary results were presented to the September 2023 SERAG meeting and intersessional review was provided by the Silver Trevally Steering Committee (STSC) comprising Paul McShane (SERAG Chair), Andrew Penney (SERAG Independent Scientist), Mark Grubert (AFMA) and Ian Stockton (NSW DPI Fisheries Manager). A summary of development and review of this assessment is provided below.

Steering Committee July 2023

The STSC met on 25th July 2023 to review the progress towards a joint assessment for Silver Trevally made between CSIRO and NSW DPI Fisheries (Burch et al. 2023c) and provide advice on the development of a Tier 1 assessment for Silver Trevally to be presented to SERAG in 2023.

Stock Structure

The assessment team proposed a stock structure for base case comprising NSW, Victorian and the adjacent Commonwealth waters (CTS zones 10, 20 and 60). This accounts for >95% of the catches and all of the available biological data (lengths, ages, biological parameters). The STSC discussed the potential contamination of the length data due to misidentification of related species trevally inhabiting northern NSW. The assessment team confirmed that this was not the case as the data collection locations are further south than the known range of the related species.

Silver trevally off eastern Tasmania are genetically homogeneous to those off Victoria and NSW. The STSC felt that it would be useful to include Tasmanian catches, however, this is challenging because Tasmania catch estimates are not currently available before the mid-1990s. Tasmanian catches are small, ~1% total catch in the 1990s, increasing to 3–5% total catch in recent years. South Australian catches are of a similar magnitude to Tasmanian catches.

The STSC agreed that whether or not Tasmanian and South Australian catches are included in the assessment was unlikely to have a material impact on the results and that the proposed stock structure (CTS zones 10, 20 and 60) was agreed for the 2023 assessment. Should Tasmanian catches before the 1990s become available they could be included in a future Silver Trevally assessment.

Fleet structure and selectivity

The two provisional assessments presented in Burch et al. (2023) were developed in a step-wise manner using SS-DL (Cope 2023), beginning with simple model and progressively adding data. A consequence of this was the catches were assigned to a single fleet with pre-specified selectivity, while the NSW trawl, NSW trap and Commonwealth trawl fleets were treated as surveys (i.e. they had length and index data but no catches). The STSC discussed the benefits of estimating selectivity, including:

- Aligning catches with fleets that caught them would help account for differences in the size structure of catches due to gear differences and where and when fishing occurs.

- It permits the mirroring of selectivity for fleets where insufficient length data is available, or selectivity is poorly estimated.
- It may be possible to include the NSW line and NSW estuary catches as fleets, even those they don't have CPUE indices. This would be important if these gear types catch different sized fish.
- The length data from the RV Kapala could be included as a survey fleet to test the hypothesis that specialised gear and high tow speeds are required to target large Silver Trevally (the RV Kapala was towing slowly, using generalist gear).

The STSC agreed that selectivity should be estimated where it could be and otherwise fixed to appropriate values or mirrored to a fleet where catches would be expected to have a similar size composition.

The STSC then discussed the 2007 introduction of a MLL in NSW and the impacts of selectivity and the need to account for the associated discarding and that implementing a retention function within Stock Synthesis, particularly for NSW trawl where discarding due to the MLL has been observed (Fowler et al. 2023). The STSC agreed that using a retention function was the preferable way to account for discarding due to the NSW MLL and that if this was not successful then the estimated discards should be added to landed catches.

Catches

The available catch series for Silver Trevally commences in 1945 (Table 3). The STSC discussed the potential for substantial catches to have occurred prior to this time and recommended that the work of Neil Klaer be reviewed to identify whether Silver Trevally were a substantial component of Steam Trawler catches prior to 1945. Following the STSC meeting Klaer (2006) was reviewed and Silver Trevally were not identified as a species that was caught by Steam Trawlers, hence any catches prior to 1945 were assumed to be negligible.

Biological and fishery parameters

Biological parameters for Silver Trevally are sourced from Rowling and Raines (2000), estimated from the available data or pre-specified to sensible default values.

Growth

There are two potential sources of data to estimate growth for the 2023 Silver Trevally assessment, the 1997–1999 age-at-length data (Table 8; Rowling and Raines 2000) and the 2019–2021 age-at-length data (Table 8). The STSC discussed the merits of estimating of growth within the assessment, compared with estimating growth externally and pre-specifying it. Estimating growth within the assessment is dependent on the quality of the conditional age-at-length data and there may be issues with the recent data due to the NSW MLL. Ideally the estimates of growth within the assessment and those externally would be similar.

Noting the need to provide certainty for the assessment, the STSC recommended that growth be estimated externally and pre-specified within the assessment and the sensitivity of the assessment to different growth estimates be addressed using sensitivity analyses.

Stock recruitment relationship

It is usually not possible to estimate the steepness (*h*) of the Beverton-Holt stock recruitment relationship so *h* is typically pre-specified at some sensible default value. The STSC supported the use of a default steepness of *h*=0.7 and requested that a sensitivity be undertaken with *h*=0.6. The STSC also recommended that undertaking a likelihood profile on *h* was not worthwhile, as this rarely provided useful information on steepness.

Natural mortality

The assessment team proposed a pre-specified natural mortality of M=0.18yr^{-1}, an increase from the value of M=0.15yr^{-1} that was used for the provisional assessment scenarios (Burch et al. 2023c). This increase was based on the estimates of M=0.18–019yr^{-1} from life history correlates from Fowler et al. (2023) and the apparent biological differences between Silver Trevally in south-eastern Australia and New Zealand. The STSC agreed with the selection of M=0.18yr^{-1} for the base case, however, given the importance of this parameter within the assessment, requested that the reasoning for the choice of natural mortality be fully documented within the assessment report.

Review of early Commonwealth trawl CPUE

There is uncertainty about whether the Commonwealth trawl CPUE for 1986–1991 is representative due to claims that some vessels were targeting Silver Trevally using modified gear and higher trawl speeds during this period. To address this issue the annual Commonwealth catch by vessel for 1986–1991 was examined and while there were some high catching vessels, they were not consistent between years. This provided no evidence for the above claim above and it was not clear whether any further investigation would be able to definitely answer this question. The STSC agreed and suggested testing the impact of the Commonwealth trawl CPUE for 1986–1991 on the assessment with a sensitivity analysis.

SERAG September 2023

An update on progress of the 2023 joint Silver Trevally assessment was presented to SERAG on 26th September 2023 that include the recommendations from the STSC on stock structure, fleet structure, selectivity and the biological parameters.

SERAG reviewed the progress and supported proceeding with the Silver Trevally Tier 1 assessment. SERAG noted the evidence for Silver Trevally experiencing below average recruitment over much of the past 30 years and directed that the final base case assume low recruitment would continue into the projection period. As there was still the need to select a final base case, the year to stop the estimation of recruitment and specify the years from which to calculate the average “low” recruitment, SERAG directed that STSC be convened prior to the second SERAG meeting to advise on these aspects of the assessment.

SERAG directed that the following be presented to the STSC:

- Complete the Francis weighting and the bias ramp specification.
- Check to see if the model can estimate more recent recruitment estimates (beyond 2017).

- Attempt to incorporate the recent NSW age data to provide more information on recent recruitments – noting there is potential bias due to the NSW MLL.

The STSC would then select the base case model, the years to estimate recruitment for and the years to estimate low recruitment for the projections. The selected low recruitment base case and the following:

- A likelihood profile on natural mortality (currently M=0.18yr^{-1})
- Adjusting the retention function for NSW trawl (after the 2007 MLL) to better fit the data.
- Exploring the impacts of the higher ageing error.
- Investigating the different length-age relationship apparent in older fish from 1999.

The low recruitment base case and the agreed sensitivity analyses would then be presented to SERAG 2 to inform the management of Silver Trevally.

Steering Committee October 2023

The STSC met on 19th October 2023 to review the progress on the Silver Trevally assessment since the September 2023 SERAG meeting.

Alternate Francis weighting

It was not possible to apply Francis weighting to the composition data sources that have relatively few years of data. This included the NSW estuary, recreational and Kapala length data and all of the age-at-length data. Instead, we applied Francis weighting to those composition data with sufficient samples and applied unit weighting to the other data sources. We also undertook a sensitivity with half the weight on the data sources with small sample sizes (Andre Punt pers. comm.).

It was also not possible to obtain a consistent fit the bias ramp, with the model fluctuating between two alternate states. This was likely due to the lack of recent age data in the model. Instead the bias ramp was pre-specified at sensible values.

Bridging Analysis

The STSC reviewed a bridging analysis from the model presented to SERAG 1 (model A) though four subsequent bridging steps that incorporated the Action Items from SERAG 1 and corrected some minor errors. The five models in the bridging analysis were;

- Model A: The model presented to the September 2023 SERAG meeting. Note this model was not Francis weighted and had a slightly different bias ramp specification than models B–E.
- Model B: Incorporated Francis weighting, a pre-specified bias ramp and estimated recruitment deviations to 2021 (so that the final year of estimated recruitment could be assessed).
- Model C: Modified the retention function for NSW trawl (which accounts for discarding after the 2007 introduction of a minimum legal length), which improved the fit to the left hand side of the length distribution.

- Model D: Estimated additional selectivity parameters, including releasing the requirement for the right hand side of the NSW estuary and trap fleets' dome shaped selectivity to return to zero (i.e., double normal plateau selectivity), resulting in better fits to the length data, particularly for NSW trap.
- Model E: Removed the 1997 and 1999 age data after identifying that the data in these years came from <5 samples and that the spatial coverage was poor.

The fits to the NSW trawl CPUE were almost identical among models A–E (Figure 29). Model E provided a better fit to the early NSW trap CPUE than models A–D (Figure 30). The fits to Commonwealth trawl CPUE are very similar, except for model C which fits more poorly to the early part of the series (Figure 31). Fits to the combined length data were very similar (Figure 32), with model C (and subsequent models) providing better fits to the left hand side of the NSW trawl lengths (Figure 33), while model E provides better fits to the Commonwealth trawl lengths (Figure 34). Models D and E provided a better fit to the right-hand side of the NSW trap lengths than Models B or C (Figure 34). The selectivity by fleet and the retention function for NSW trawl that accommodates discarding due to the 2007 MLL are shown in Figures 35 and 36.

Estimated recruitment asymptotic standard error suggests that models B and C would not estimate the most recent three recruitments, while models D and E would not estimate the most recent two recruitments (Figure 37). The pre-specified bias ramp was very similar amongst models B–E, with model E fitting slightly better in the early 1980s (Figure 38). Recruitment estimates were similar among the four models, with recent recruitments (2019 and 2020) around the long-term average (Figure 39). The strong negative deviation in recruitment estimated during the late 1990s in models B, C, and D is not evident in model E (Figure 39). The trends in estimates of absolute relative spawning biomass were very similar among the models (Figures 40 and 41). All models, which assume average recruitment to 2023, estimate current spawning biomass above the limit reference point with Model D the highest and Model C the lowest. The alternative tuning had minimal impact on the trends or estimates of spawning biomass so the STSC recommended using the standard tuning (Figure 42).

Base case model

The STSC reviewed the bridging analysis and selected model E (the model incorporating all of the improvements) as it provided the best fits to the CPUE and length data. The STSC decided to cease estimating recruitment deviations from 2020 onwards (i.e. 2019 is the last estimated recruitment; Figure 37). The STSC then recommended to project the base case using the average from the last ten estimated recruitments (2010-2019; Figure 2).

Additional sensitivities

In addition to the sensitivities agreed at SERAG 1 the following sensitivities were requested by the STSC:

- That the low steepness sensitivity use a steepness value of h=0.6.
- Removal of the NSW trap CPUE, as the model fits poorly to recent NSW trawl and Commonwealth trawl CPUE.

- The inclusion of catch estimates for 1945–1954. These catches were omitted from the base case due to the need to assign catches to fleets, and fleet specific catches are not available prior to 1955.
- The inclusion of the 1997 age data, as this appears to be well fitted by the model, even though the sample size is small.

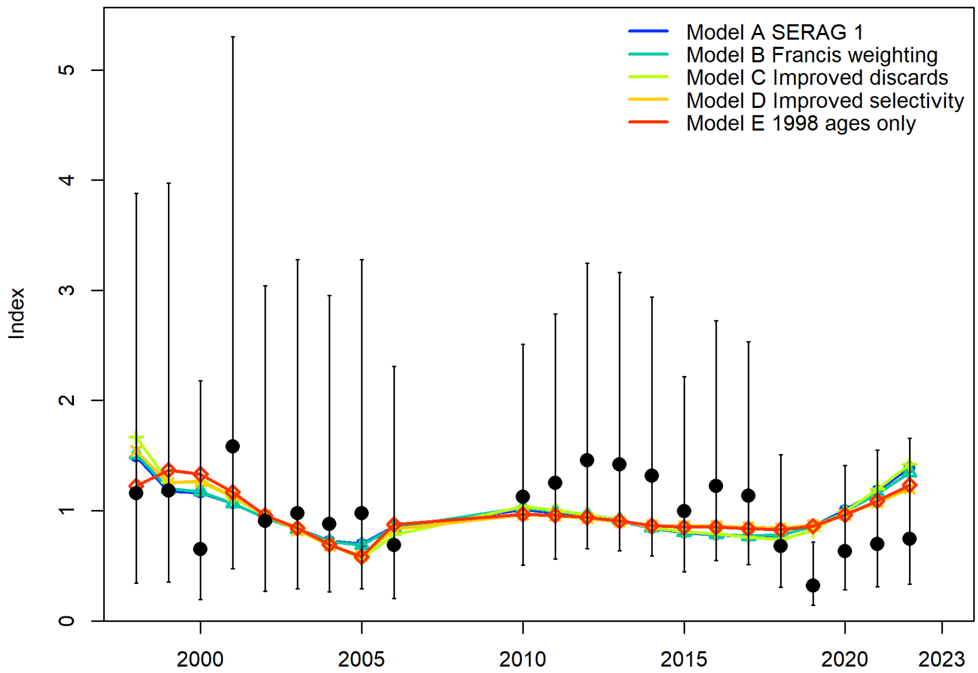

Figure 29 Combined CPUE fits for the NSW trawl fleet. The black dots represent the CPUE index data, the bars the uncertainty, the lines are coloured shapes are the fits for Silver Trevally models A–E.

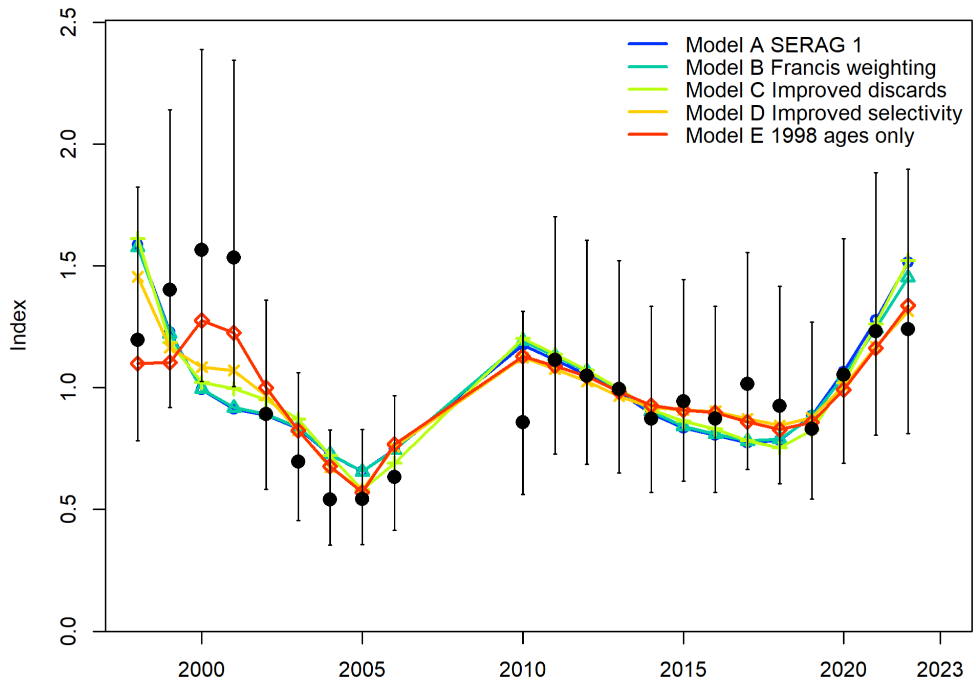

Figure 30 Combined CPUE fits for the NSW trap fleet. The black dots represent the CPUE index data, the bars the uncertainty, the lines are coloured shapes are the fits for Silver Trevally models A–E.

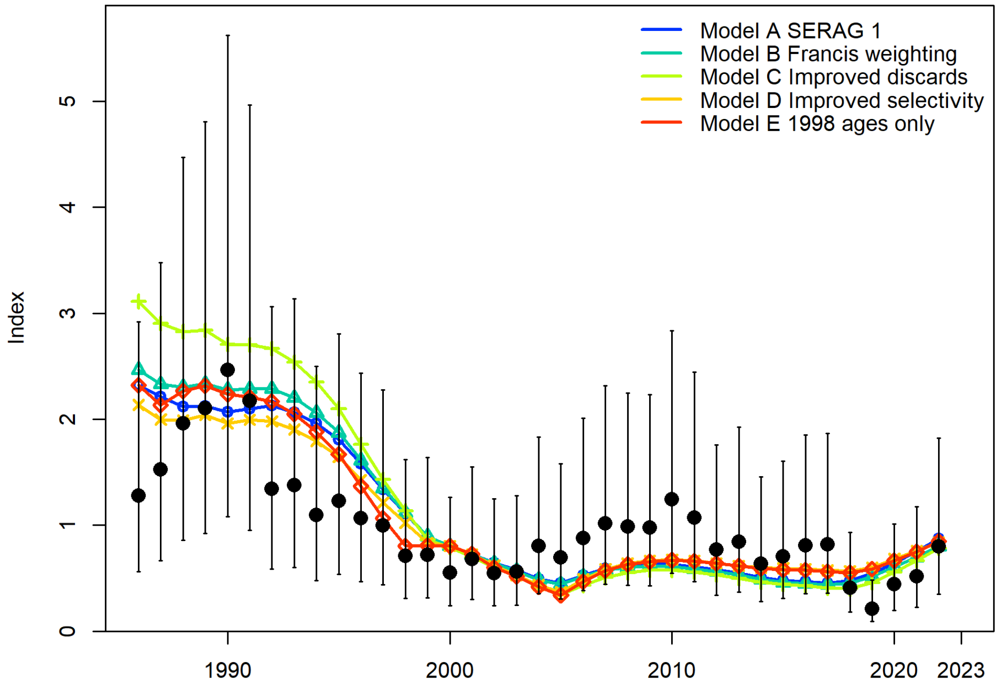

Figure 31 Combined CPUE fits for the Commonwealth trawl fleet. The black dots represent the CPUE index data, the bars the uncertainty, the lines are coloured shapes are the fits for Silver Trevally models A–E.

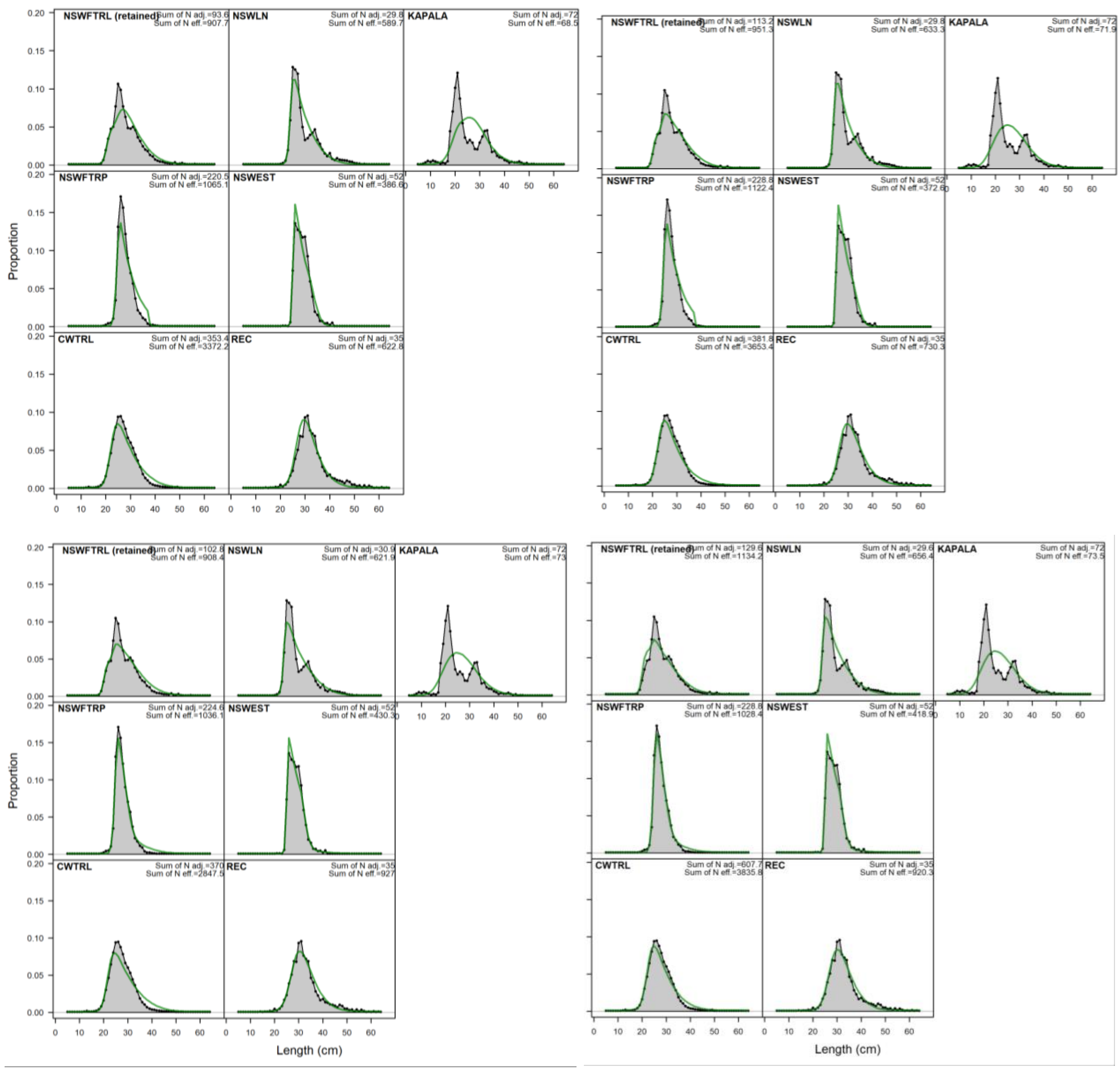

Figure 32 Length composition aggregated across time by fleet for Silver Trevally models B (top left), C (top right), D (bottom left) and E (bottom right).

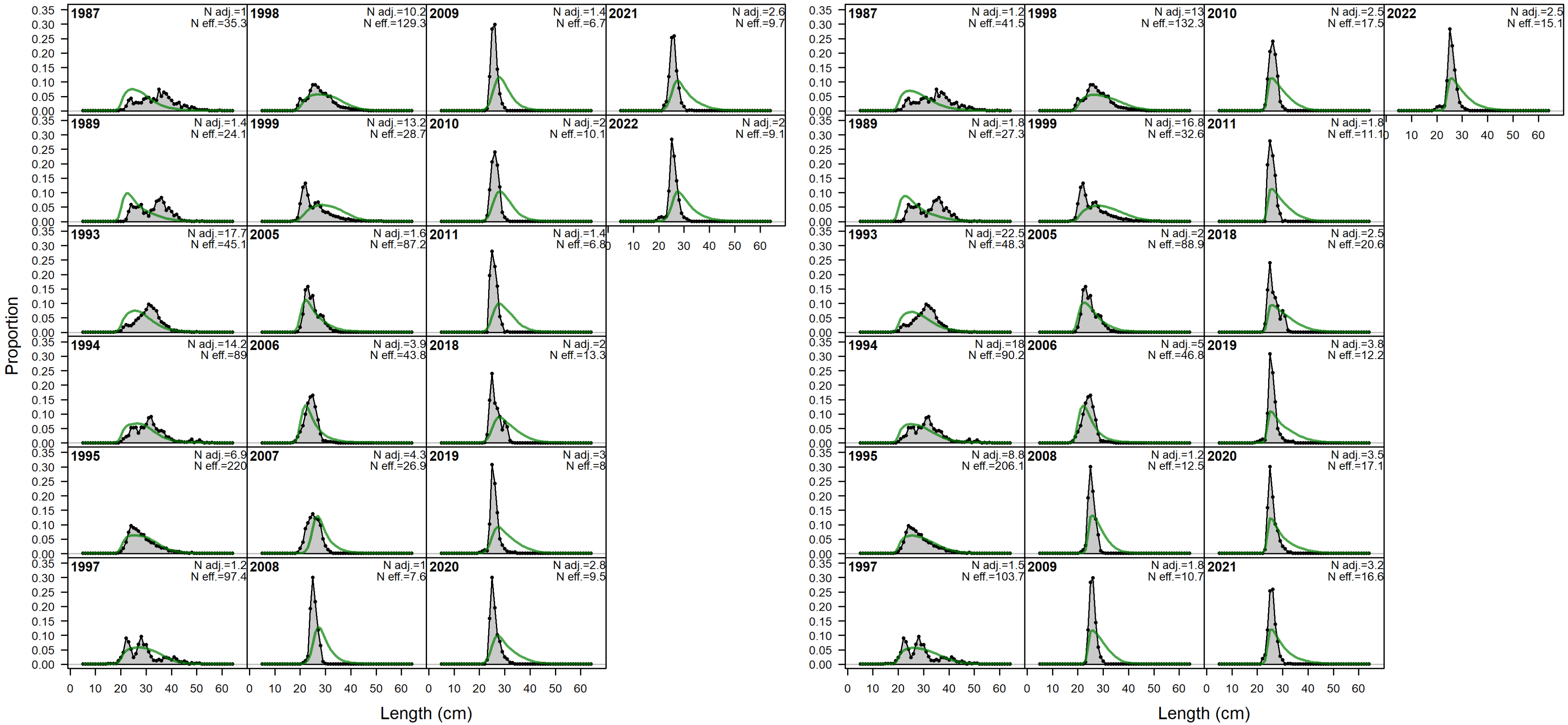

Figure 33 Retained length compositions by year for the NSW trawl fleet for Silver Trevally models B (left) and C (right). This figure shows effect of adjusting the retention function to better match the minimum legal length.

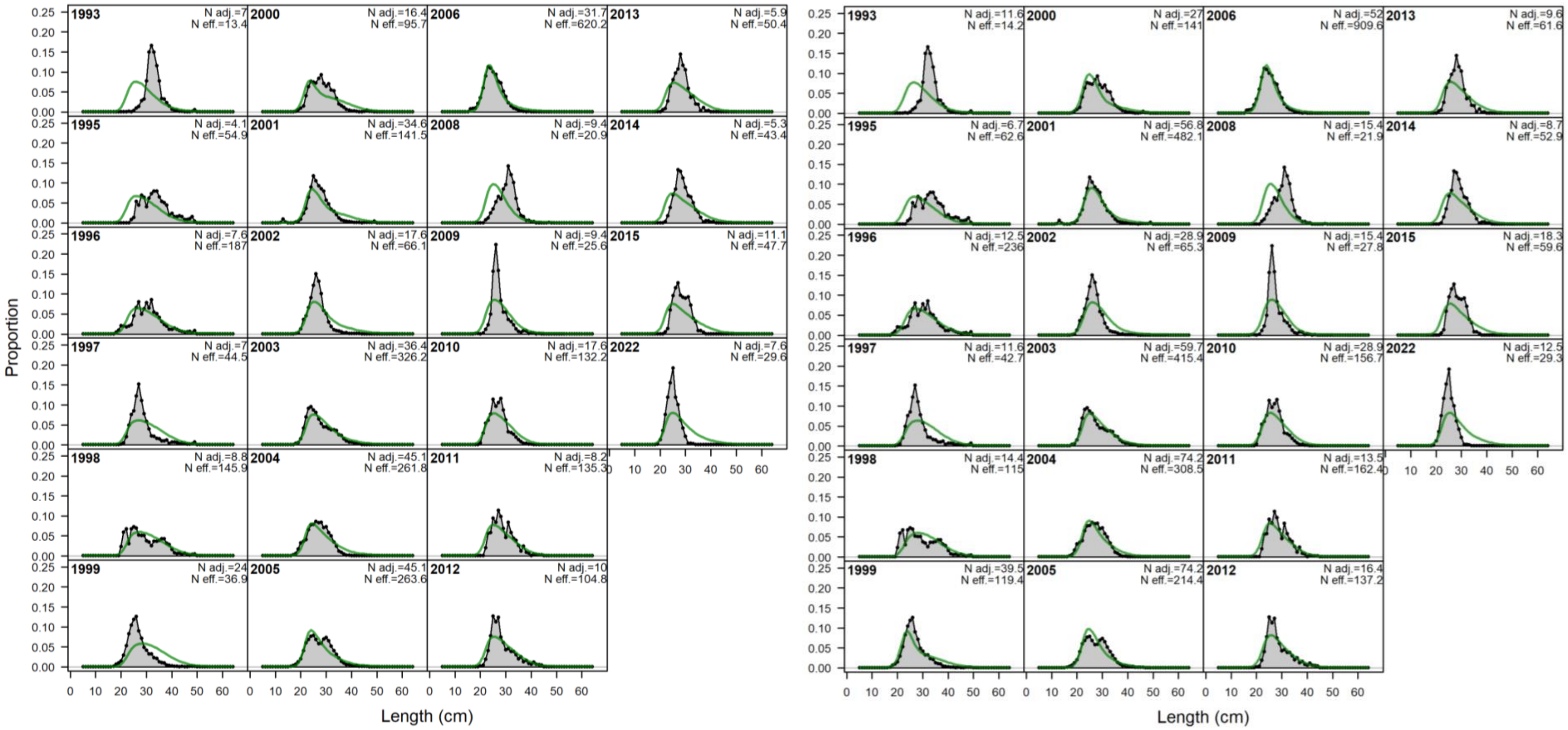

Figure 34 Combined compositions by year for the Commonwealth trawl fleet for Silver Trevally models D (left) and E (right).

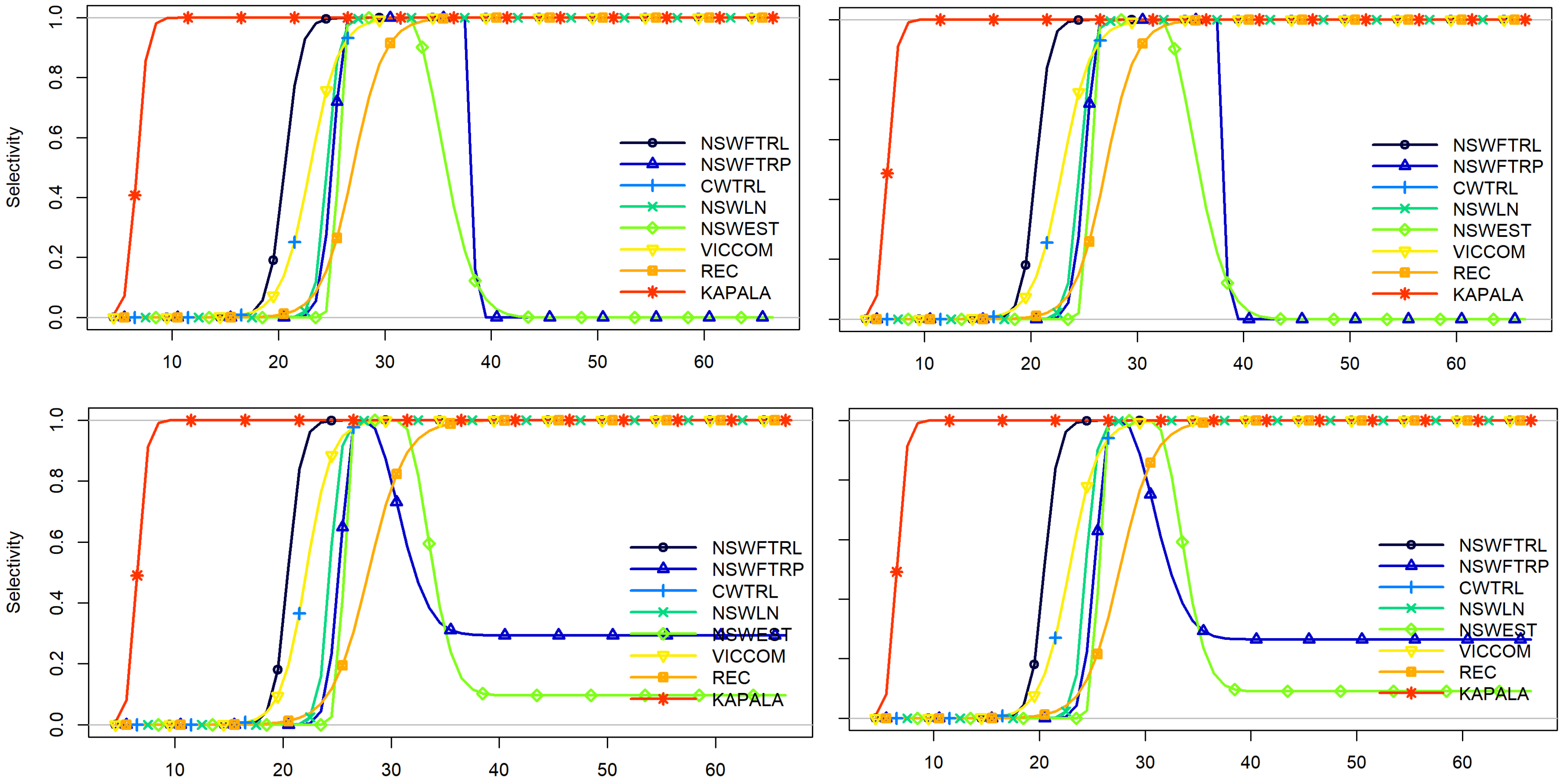

Figure 35 The selectivities by fleet for Silver Trevally models B (top left), C (top right), D (bottom left) and E (bottom right).

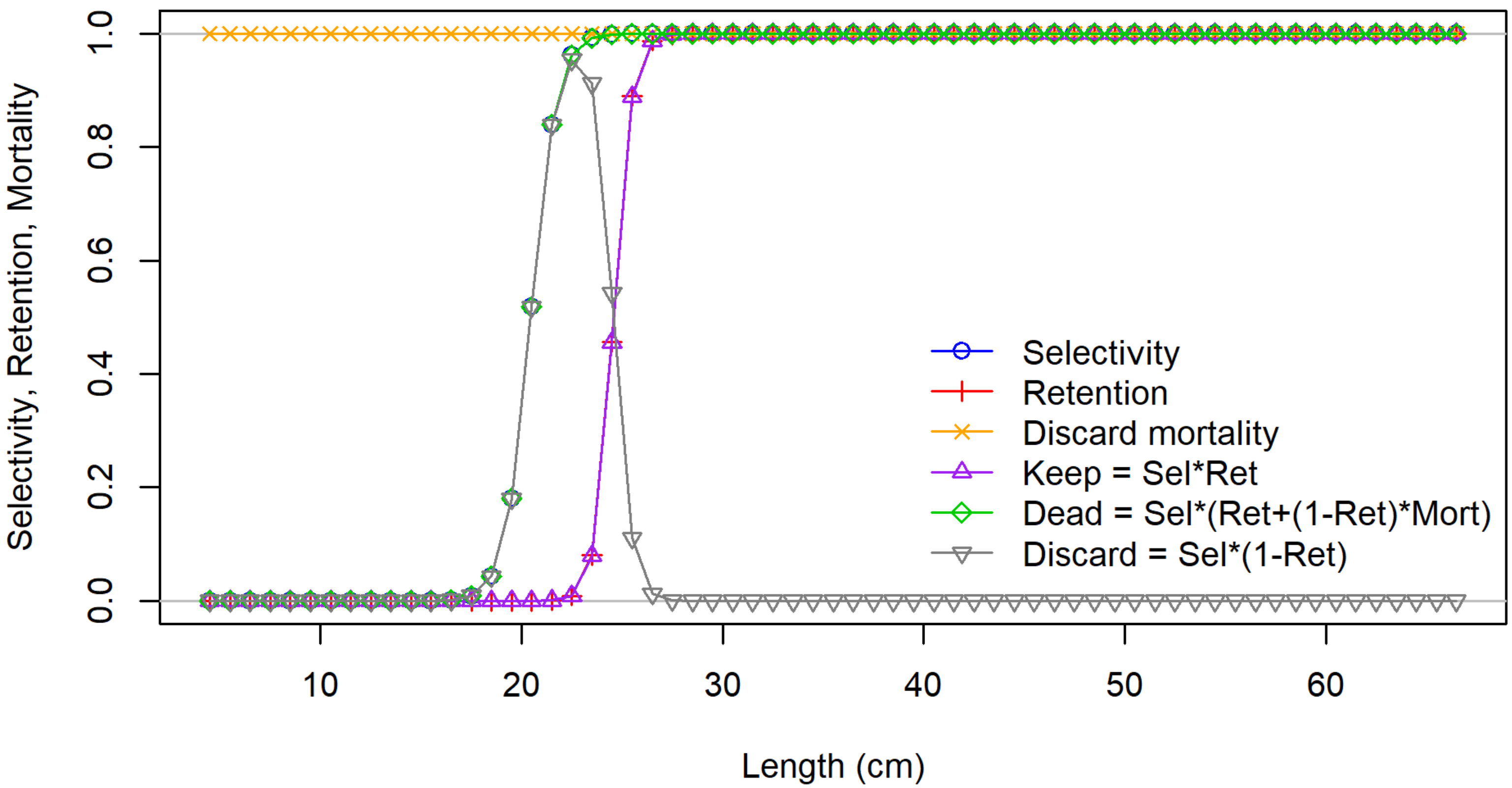

Figure 36 The selectivities by fleet for Silver Trevally models B (top left), C (top right), D (bottom left) and E (bottom right).

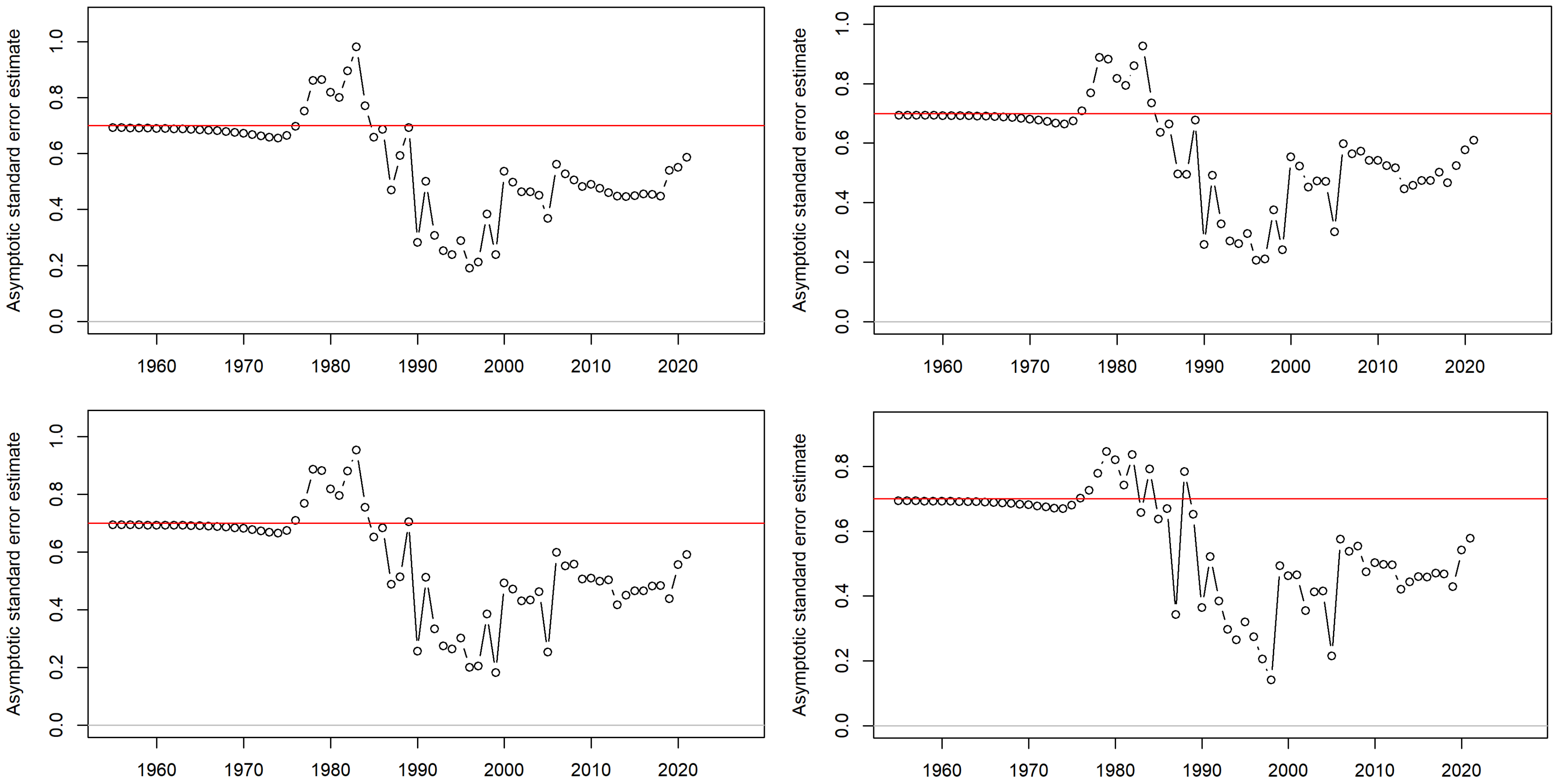

Figure 37 Estimated recruitment asymptotic standard error for Silver Trevally models B (top left), C (top right), D (bottom left) and E (bottom right).

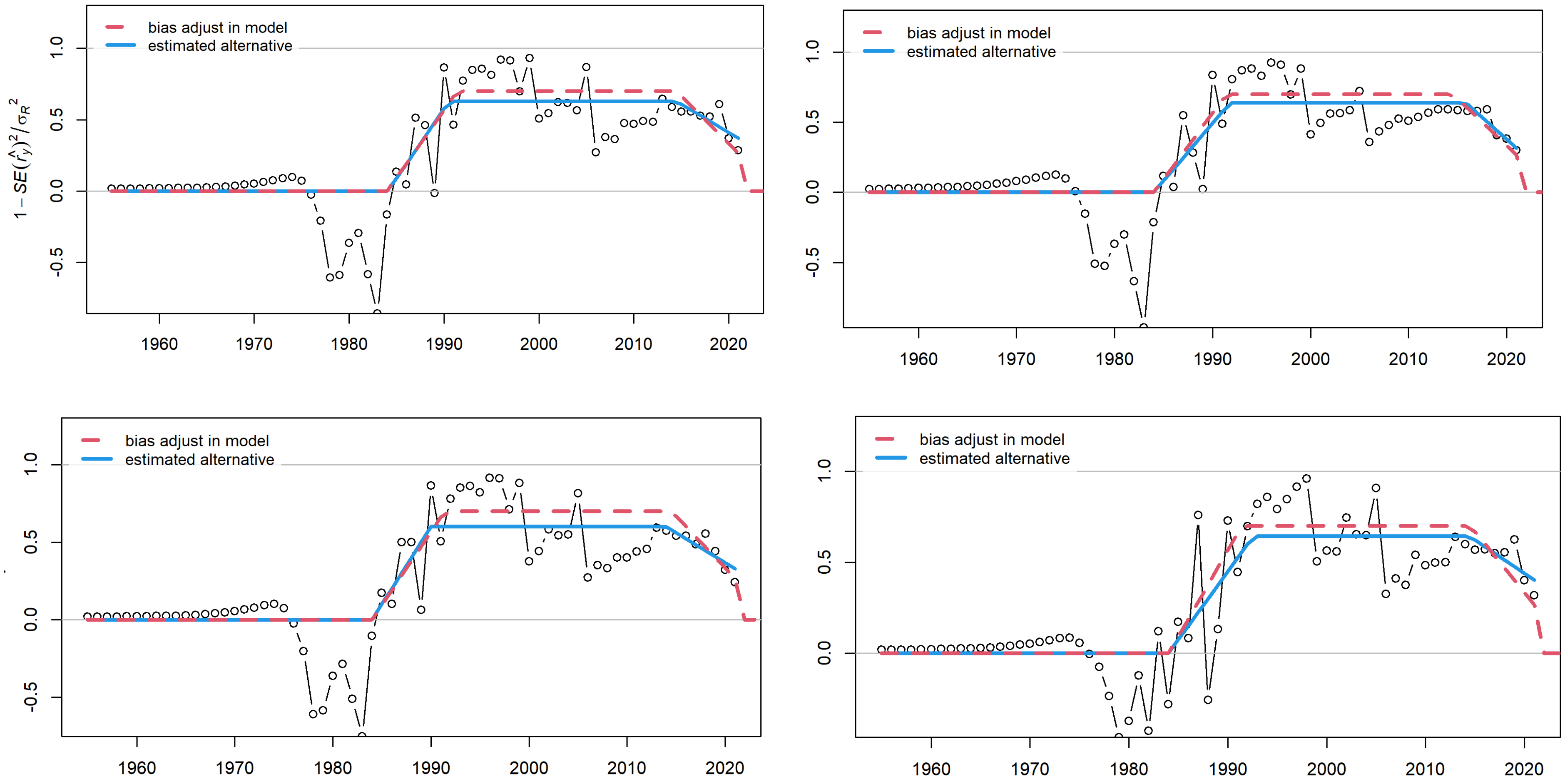

Figure 38 Pre-specified bias ramp for Silver Trevally models B (top left), C (top right), D (bottom left) and E (bottom right).

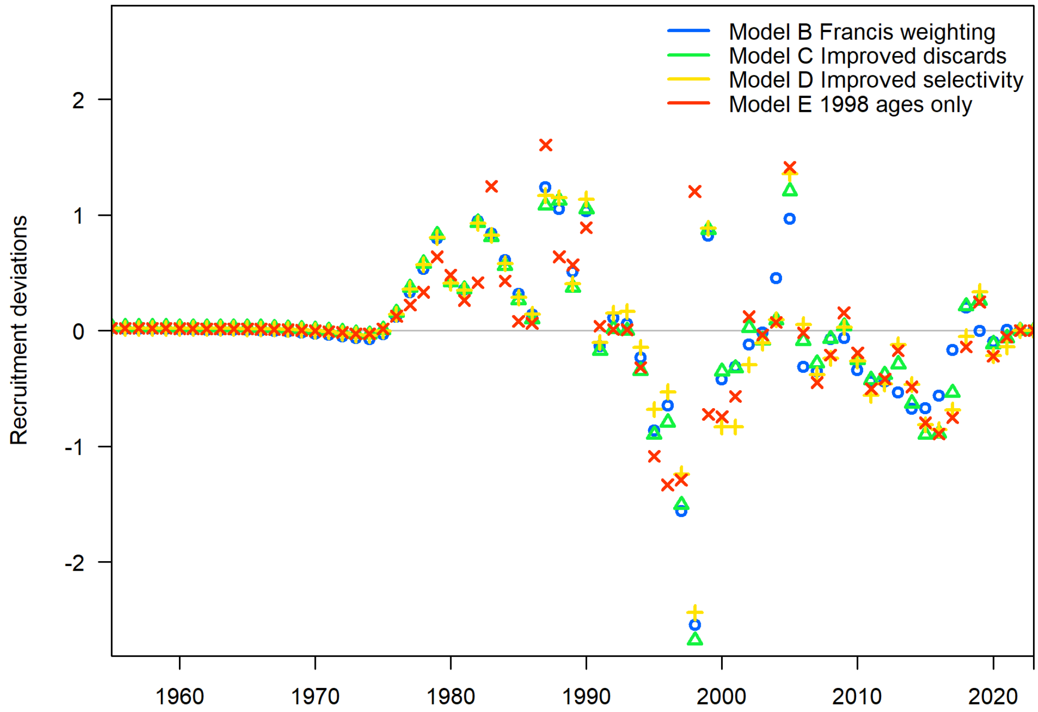

Figure 39 Recruitment deviation estimates for Silver Trevally models B–E.

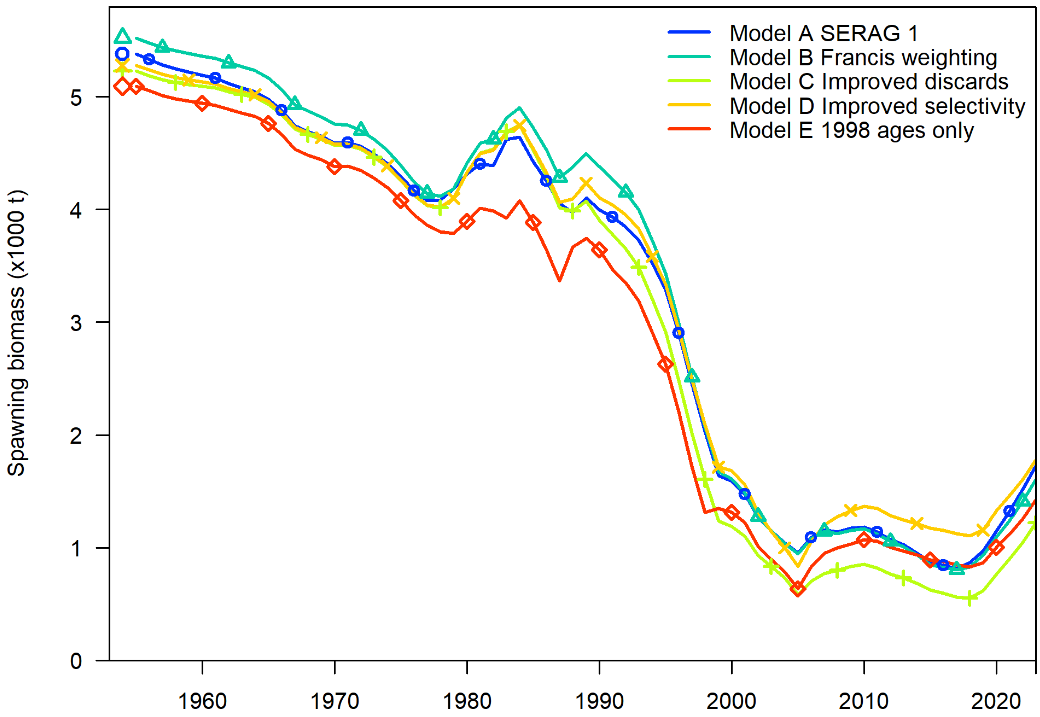

Figure 40 Absolute spawning biomass estimates for Silver Trevally models A–E.

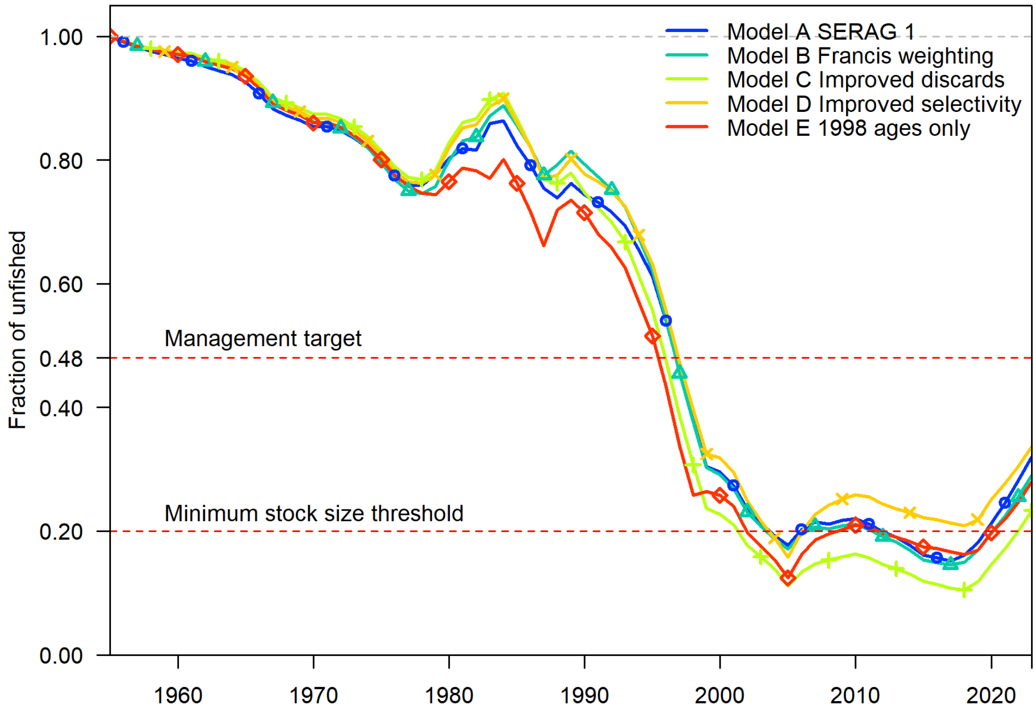

Figure 41 Relative spawning biomass estimates for Silver Trevally models A–E.

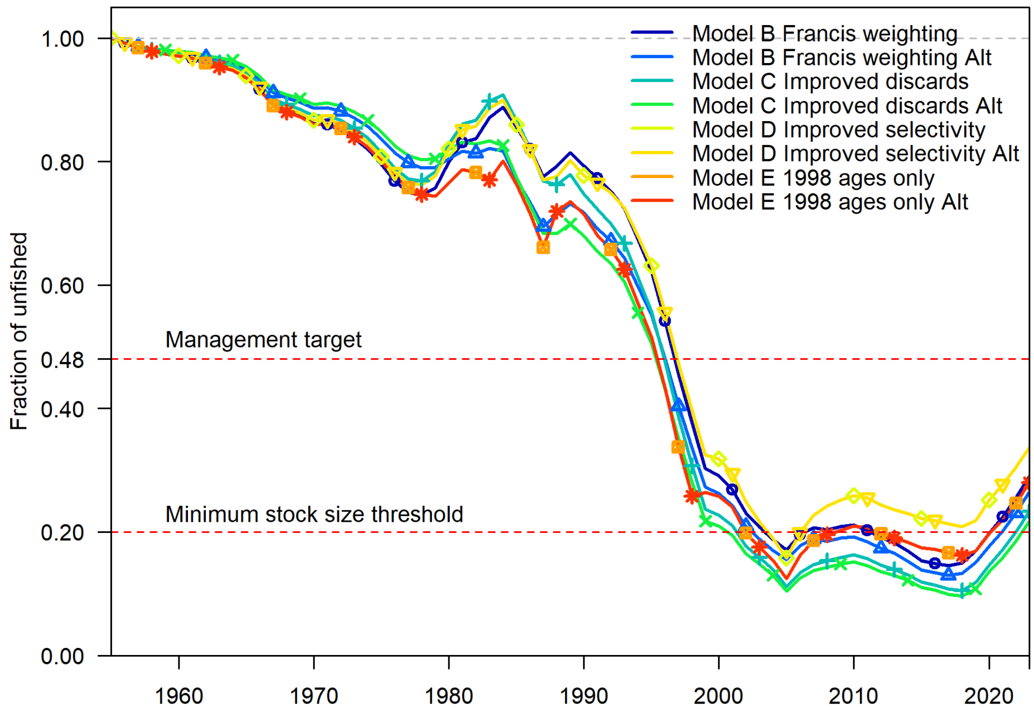

Figure 42 Relative spawning biomass estimates for Silver Trevally models A–E with both standard Francis weighting and the alternate scenario where the age and length composition down from fleets with <5 years of samples was down weighted by 50%.

Appendix B – Additional Tables and Figures

Table 18. Catchability, selectivity and retention parameters for the fleets and survey in the 2023 base case Silver Trevally assessment. The retention function for the NSW trawl fleet is pre-specified at the MLL. † Selectivity for the NSW trawl fleet is pre-specified at values estimated by an earlier model (model B Appendix A).

Parameter	Units	Value
NSW trawl catchability 1955–2007	ln(Q)	-7.510
NSW trawl catchability 2008 onwards	ln(Q)	-7.433
NSW trap catchability 1955–2007	ln(Q)	-6.781
NSW trap catchability 2008 onwards	ln(Q)	-6.791
Commonwealth trawl catchability	ln(Q)	-7.885
NSW trawl selectivity size inflection 1955–2007	cm	20.454
NSW trawl selectivity size 95% width 1955–2007	cm	1.857
NSW trawl selectivity size inflection 2008 onwards	cm	24.578
NSW trawl selectivity size 95% width 1955–2007	cm	0.442
NSW trawl retention inflection 2008 onwards	cm	10.452
NSW trawl retention width 2008 onwards	cm	1.423
NSW trap selectivity size peak	cm	26.755
NSW trap selectivity size top (logit)	cm	-10.578
NSW trap selectivity size ascending (SE)	cm	1.213
NSW trap selectivity descending (SE)	cm	2.871
NSW trap selectivity size end (logit)	cm	-0.950
Commonwealth trawl selectivity size inflection	cm	22.841
Commonwealth trawl selectivity size 95% width	cm	3.925
NSW line selectivity size inflection	cm	24.380
NSW line selectivity size 95% width	cm	1.485
NSW estuary selectivity size peak	cm	26.774
NSW estuary selectivity size top (logit)	cm	-2.470
NSW estuary selectivity size ascending (SE)	cm	0.462
NSW estuary selectivity descending (SE)	cm	2.500
NSW estuary selectivity size end (logit)	cm	-2.347
Recreational size inflection	cm	27.583
Recreational size 95% width	cm	4.759
Kapala survey size inflection	cm	6.514
Kapala survey size 95% width	cm	1.227

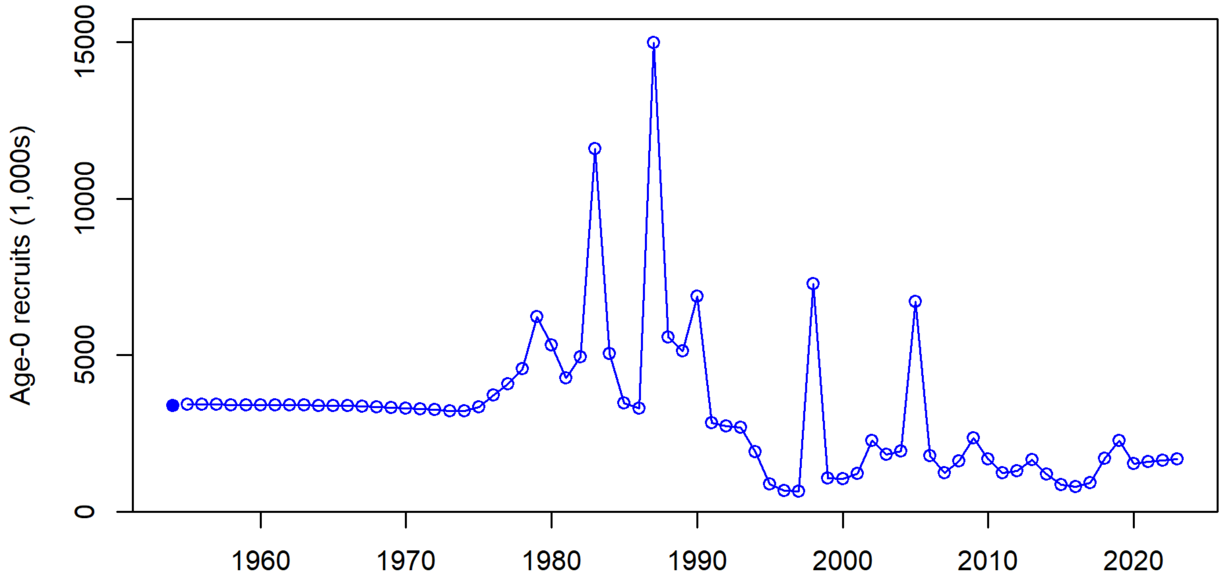

Figure 43 Absolute recruitment estimates for the 2023 base case Silver Trevally assessment.

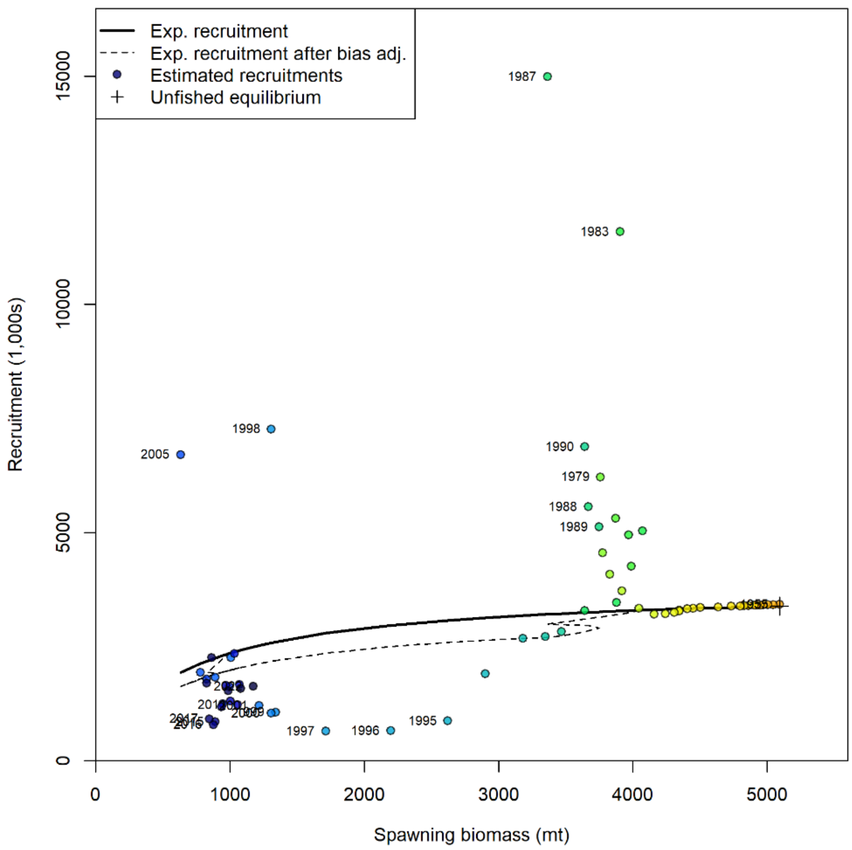

Figure 44 Stock recruitment curve for the 2023 base case Silver Trevally assessment.

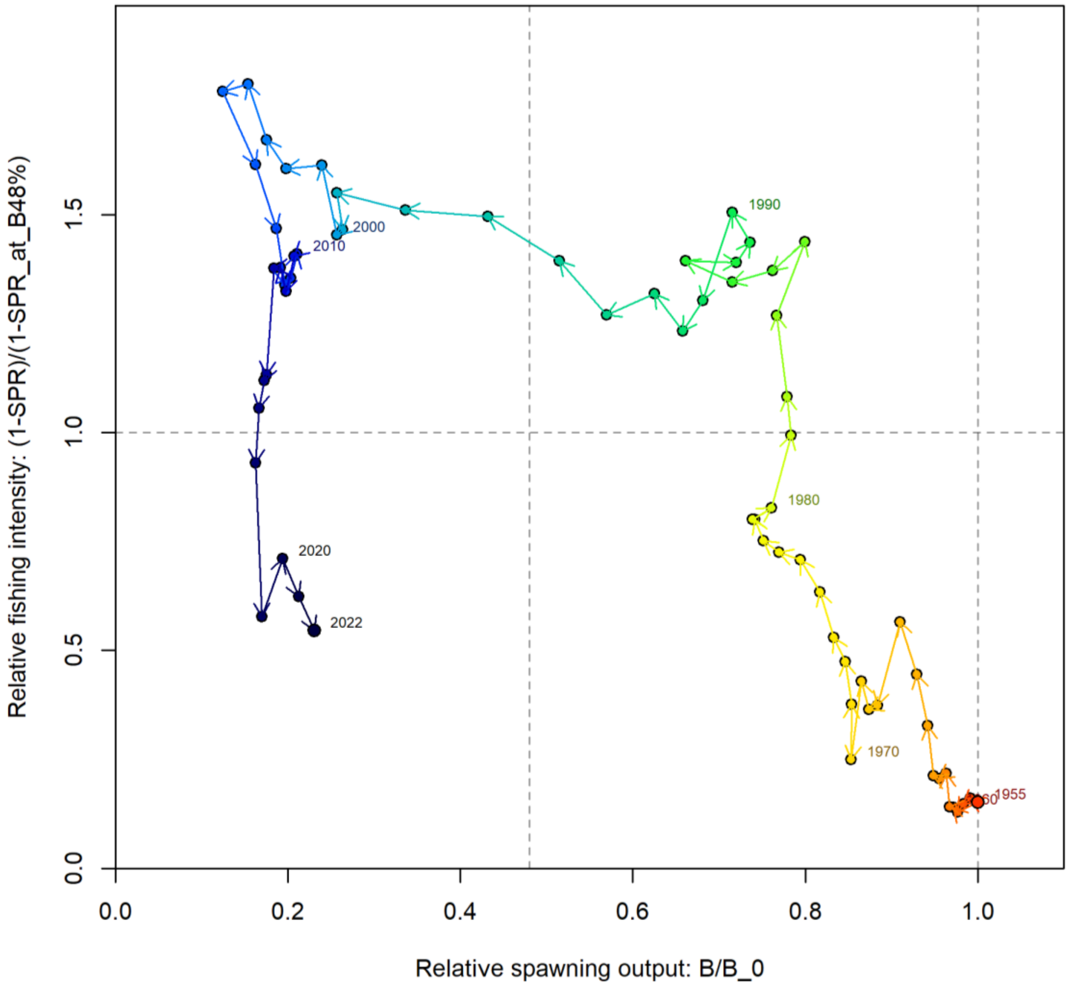

Figure 45 Kobe plot of biomass vs SPR ratio for the 2023 base case Silver Trevally assessment. The grey, horizontal dashed line represent the target fishing mortality, while the two vertical dashed lines represent the target and unfished spawning biomass respectively from left to right.

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