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2025 stock assessment of gemfish (*Rexea solandri*) in SKI 3 and SKI 7

New Zealand Fisheries Assessment Report 2026/39

J. R. McKenzie
I. Doonan
R. Bian

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Fisheries Science Editor
Fisheries New Zealand
Ministry for Primary Industries
PO Box 2526
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NEW ZEALAND

Email: Fisheries-Science.Editor@mpi.govt.nz
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PLAIN LANGUAGE SUMMARY

An assessment of the southern gemfish (SKI 3 & SKI 7) stock complex was undertaken in 2025. The assessment included characterising commercial fisheries, updating the catch-per-unit effort (CPUE) indices, and carrying out a stock assessment using an age-structured model.

The recent increase in SKI 3 and 7 commercial catches has continued with catches in 2023–24 being some of the highest on record. Because gemfish are mainly taken as bycatch in the SKI 3 & 7 fisheries, rising catches are likely to be due to increased gemfish abundance.

The recent increase in commercial CPUE was considered biologically implausible. The stock assessment modelling was unable to fit to adequately represent these CPUE indices and performed better when only the abundance information from research trawl surveys was used.

The assessment modelling suggested that the increase in the SKI 3 & 7 gemfish stock since 2017 was driven by recent above-average recruitment. There is some evidence to suggest that the recent period of above-average recruitment is due to ocean warming. If the current productivity of the SKI 3 & 7 gemfish stock is higher than the long-term average recruitment, then B_0-reference sustainability measures would not be appropriate stock management.

The 2025 stock assessment Plenary recommended the use of an annual fixed proportional removal target as an alternative sustainability measure. The modelling suggests annual proportional removals of 18% or less of the standing biomass are sustainable, and current catches are below this level.

Stock biomass is expected to continue to increase for at least the next 2–3 years as the strong 2021, 2022, and 2023 year-classes grow through the fishery.

EXECUTIVE SUMMARY

McKenzie[1], J.R.; Doonan, I.; Bian, R. (2026) 2025 stock assessment of gemfish (*Rexea solandri*) in SKI 3 and SKI 7. *New Zealand Fisheries Assessment Report 2026/39.* 132 p.

An assessment of the SKI 3 & SKI 7 stock complex was undertaken in 2025. The assessment included characterising the SKI 3 & 7 commercial fisheries and updating the 2020 SKI 3 & 7 trawl CPUE indices up to and including the 2023–24 fishing year. The second project objective was to further develop the previous total catch history age-structured assessment model and then to update the gemfish assessment through to the end of 2025 including observational data collected post-2020.

The recent increase in SKI 3 & 7 commercial catches has continued with 2023–24 catches being some of the highest on record. Because gemfish are mainly taken as bycatch in SKI 3 & 7, rising catches are likely to be due to increased gemfish abundance. Increasing abundance in SKI 3 has also resulted in gemfish being a more prevalent bycatch species in other QMA 3 trawl fisheries principally those targeting barracouta, ling, and silver warehou. The SKI 3 & 7 bycatch fisheries largely operate at different times of the year: the SKI 7 hoki target fishery occurs largely during winter; the SKI 3 mixed trawl fisheries largely during summer and autumn.

The latest updates of the SKI 3 & 7 commercial trawl CPUE indices show a continuation of the upward trend that began in 2017. However, the magnitude of increase in these indices between the lowest and highest values are biologically implausible; it is therefore likely that the commercial CPUE is over-representing the "true" magnitude of increase in stock abundance.

The revised and updated stock assessment model struggled to fit the increase inferred by the CPUE indices. Models fitting these indices predicted the stock must have declined to less than 1% of virgin biomass (B_0) during the late 1990s, this again being biologically implausible. More "plausible" stock assessment outcomes were achieved by fitting the models only to the trawl survey abundance observations.

Model fits to recent length and age data from surveys and the commercial fisheries suggest that the post-2017 abundance increase in the SKI 3 & 7 gemfish stock was largely driven by above-average recruitment. There is some evidence to suggest that the recent period of above-average recruitment is due to ocean warming. If the current productivity of the SKI 3 & 7 gemfish stock is higher than the long-term average recruitment then B_0-reference sustainability measures would not be appropriate for stock management. In line with this supposition, the 2025 Plenary recommended exploitation ($U_{40\%B0}$) reference measures be adopted for assessing the SKI 3 & 7 gemfish stock. The deterministic $U_{40\%B0}$ estimate from the base model was 0.18. The current (2025) exploitation rate predictions from the base model and model sensitivity on natural mortality (M) and steepness (h) MPD runs were all well below $U_{40\%B0}$.

Stock biomass is expected to continue to increase for at least the next 2–3 years as the strong 2021, 2022 and 2023 year-classes grow through the fishery.

The model fitting process revealed a high degree of likelihood conflict in observational data series in respect to average productivity (B_0) and SSB estimation. Likely due to model misspecification and data conflict issues, the base model failed to achieve statistically acceptable MCMC convergence, so the assessment was unable to provide uncertainty measures on model predictive outcomes.

[1] All authors Earth Sciences New Zealand

1 INTRODUCTION

Although there are likely to be more than one species of gemfish of the genus *Rexea* in the New Zealand EEZ, New Zealand commercial gemfish fisheries are thought to largely comprise just one species, *Rexea solandri* (Middleton et al. 2023).

Gemfish were introduced into the Quota Management System (QMS) in 1986 with the establishment of Total Allowable Commercial Catch (TACC) limits relative to four Quota Management Areas (QMAs) or stocks (SKI 1, 2, 3, & 7; Figure 1). For assessment purposes New Zealand gemfish is believed to comprise two biological stocks: SKI 1 & 2 belong to the northern stock; and SKI 3 & 7 comprise the west and east coast South Island southern stock (Fisheries New Zealand 2024).

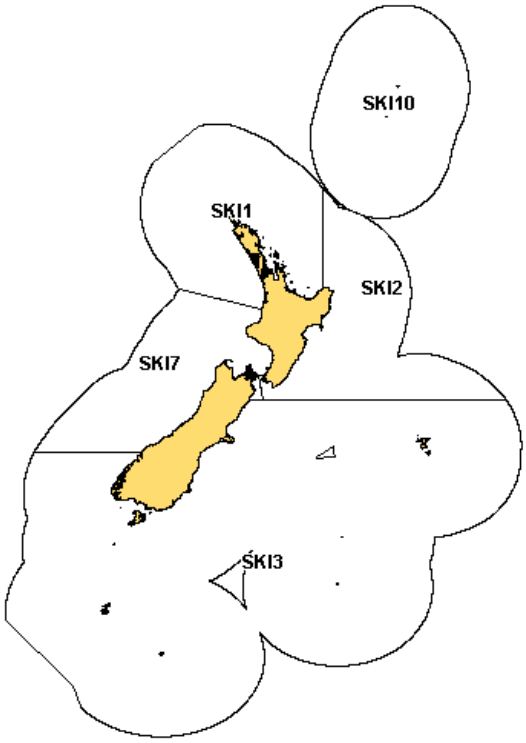


Figure 1: New Zealand gemfish stock Quota Management Area boundaries.

Very little of the commercial SKI 3 & 7 gemfish catch is targeted, most is taken as bycatch from west coast hoki and east coast squid commercial trawl fisheries (Starr et al. 2024). Commercial SKI 3 & 7 catch histories date back to the late 1970s when NZ deepwater fisheries were in a period of expansion after the establishment of the NZ EEZ in 1975.

Commercial SKI 3 & 7 catch histories both follow a similar pattern, with initially high catches in the early 1980s followed by a marked decline down to negligible annual removal levels by 1994. A similar trend of progressively increasing commercial catches is seen in both SKI 3 & 7 after 2015. SKI 7 fisheries also experienced a marked increase in catch between 2000 and 2005 followed by a five-year period of decline, this pattern, although evident in the SKI 3 catch history, is not as pronounced. Differences between SKI 3 & 7 historical catch trends may reflect differences in gemfish depth availability to the hoki (SKI 7; 400–600 m) and squid (SKI 3; 250–300 m) fisheries (Langley 2020). Seasonal differences in gemfish availability to the SKI 3 & 7 fisheries are likely to relate to spawning seasonal migration of the adult stock (Hurst & Bagley 1998).

Declining and increasing catches in SKI 3 & 7 correspond strongly to episodic patterns of strong recruitment which appear to occur on 10-to-15-year intervals (Langley 2020).

The bycatch nature of the SKI 3 & 7 fisheries means that annual gemfish catches are relatively "passive" to these recruitment events. Australian gemfish assessments have also hypothesised highly episodic recruitment, which for the east stock has been low since the fishery started, and as a result the fishery is now depleted (Liggins 2023).

1.1 2020 age-based modelling assessment

Langley (2020) undertook a preliminary assessment of the SKI 3 & 7 stock complex in 2019 using age-based total catch history assessment modelling. The 2020 model commenced in 1975, prior to the period of peak catches, the assumption being that the stock was in a relatively unexploited state in 1975. The final year in the model was the 2018–19 fishing year. Langley (2020) increased the reported catches between 1975 and 1986 by 20% to account for assumed under-reporting; catches post 1986 were increased by 10% to account for supposed lower levels of under-reporting. Recreational/customary catches were not accounted for in the model as these catch sources were assumed negligible.

Stock abundance and age/length composition are thought to be indexed by various trawl surveys conducted in the SKI 3 & 7 since 1985. The trawl survey series used in the 2020 model were:

1. Southland region (SKI 3) *Shinkai Maru* (1981–1983) and *Tangaroa* (1993–1996);
2. West coast region (SKI 7) *Kaharoa* (1992–2018) and *Tangaroa* (2012–2018).

Langley (2020) assumed the Southland region early *Shinkai Maru* and *Tangaroa* surveys were indexing the same portion of the stock and were thus fitted in the model as a single index. (i.e. each index had the same catchability (q) and selectivity).

Length compositions from the Southland region surveys suggested that these surveys were predominantly indexing adult gemfish. The west coast South Island (WCSI) *Kaharoa* survey length compositions suggest that this series was indexing primarily juvenile gemfish, whereas the recent WCSI *Tangaroa* survey length compositions suggest both adult and juvenile gemfish are indexed. To account for these observed compositional differences the WCSI *Kaharoa* and *Tangaroa* survey series were fitted as separate indices with different selectivities in the 2020 model.

Commercial length compositional data collected by observers from SKI 7 (principally hoki) and SKI 3 (principally squid) were also fitted in the 2020 model. Differences in length composition between these two data sets suggested that the commercial selectivity characteristics for these regions differed. To account for this, the model estimated and applied separate selectivities for the SKI 7 and 3 fisheries catch histories.

The 2020 model was also fitted to a single CPUE index derived from the SKI 7 hoki trawl target fishery.

Despite having relatively comprehensive series of commercial and survey length frequency observations, the 2020 model (being age-based) was hampered by a paucity of at-age observational data. The only age observations fitted in the 2020 model came from the 1993–1996 Southland *Tangaroa* series; all other fitted compositional series in the model were length-based. Fitting length compositional series in age-based assessment models can be problematic, as to do this the model first has to convert its population at-age vectors to population at-length via a Von Bertalanffy (VB) growth function. Inaccuracies and biases could arise if model assumed growth rates are inaccurate, imprecise, or if true growth was time-varying. The Langley (2020) model fits to the length compositional series were inconsistent. The overall conclusion of the 2019 Deepwater Working Group was that assessment modelling should be deferred pending the collection of more recent at-age data from the commercial fisheries. Langley (2020) used basic sex specific VB growth models parameterised with the published growth estimates from Horn & Hurst (1999) but did not explore model sensitivity to alternative growth parameterisations. Another growth-related weakness in the 2020 model was in not fitting to separate

male and female length compositional series despite these being available, although this would have required estimating separate male and female gear-method selectivities in the model.

Other productivity parameters fixed in the 2020 model were: length-weight (Hurst & Bagley 1998); natural mortality (0.25, Horn & Hurst 1999); steepness (0.85, assumed). Again, due to the preliminary nature of the 2020 assessment, sensitivities to these assumed values were not explored. Parameters estimated in the 2020 model included virgin biomass (B_0); five survey/fishery selectivity ogives (as double normal or logistic); and recruitment deviates for 1975 to 2016. The model was able to account for the recent increase in abundance by predicting recent strong recruitments. The overall conclusion from the 2019 Deepwater Working Group was that the model was not sufficiently reliable to provide estimates of current biomass and stock status.

The Langley (2020) assessment model prediction of episodic and variable recruitment of increasing magnitude indicated that the southern gemfish stock has been subject to dynamic productivity shifts over the course of its exploitation history. Renwick et al. (1998) were able to show that episodic recruitment patterns in New Zealand gemfish are strongly related to the frequency of occurrence of south-westerly wind flow over New Zealand and to sea surface temperature variations during the winter spawning period. The southern gemfish stock now seems to be entering a period dominated by atypically strong recruitments and high productivity. The Renwick et al. (1998) finding would suggest that the recent sequence of high recruitment in the SKI 3 & 7 gemfish stock may be due to climate change. Under this dynamic, the use of B_0-ref equilibrium reference sustainability measures is questionable. It may be more reasonable for the focus of future assessments to be on estimating current biomass rather than current productivity. In line with this, assessment modelling will need to provide estimates of the optimal (target) harvest rate (F-ref) for the stock pursuant to its current exploitation (fishery) characteristics. Derivation of target (F-ref) harvest rate, in combination with estimates of current biomass, should enable managers to assess the "appropriateness" of current catches and the TACC.

1.2 2021 CPUE Assessment

Starr et al. (2024) conducted relative abundance analyses for the period 1989–90 through to the end of the 2020–21 fishing year using all available SKI 3 & 7 catch effort data. They identified the following three southern gemfish fisheries as having abundance monitoring utility:

1. Winter SKI 7 trawl target hoki fishery off the west cost of the South Island;
2. SKI 3 Stewart-Snares shelf mixed target trawl fishery (SQU, BAR, HOK, SWA, SKI, LIN);
3. SKI 3 east coast South Island mixed target trawl fishery (SQU, BAR, HOK, RCO, TAR).

Starr et al. (2024) derived various standardised abundance indices for each regional fishery comparing event level and daily rollup level data series. A substantive increase in CPUE after the 2014–15 fishing year was evident in all the Starr et al. (2024) derived indices. The Deepwater Working Group preferred daily rollup level series pro-rated by the daily processing records over the event-level series as this series was less prone to limitations of the top-five species reporting requirements of the TCEPR forms used during the period of low abundance. The Deepwater Working Group accepted the SKI 7 target hoki series as the primary abundance indicator for southern gemfish because it operated during the spawning period in the location where this stock is presumed to spawn. The Deepwater Working Group also accepted the SKI 3 Stewart-Snares shelf series as a corroborative index because it operates in the feeding and migratory region for this stock (Starr et al. 2024).

1.3 Report objectives

The analyses presented in this report were undertaken specifically to update the stock assessment of the SKI 3 & 7 stock complex through to the 2023–24 fishing year. This work, commissioned by Fisheries New Zealand under research project SKI2024-01, had the following specific objectives:

1. To update the descriptive analysis of gemfish in SKI 3 & 7 with data up to and including the 2023–24 fishing-year;

2. To update and complete relevant CPUE indices and continue to develop the preliminary stock assessment model using ageing information available from Fisheries New Zealand project MID2021-01 as appropriate.

2 DESCRIPTIVE ANALYSIS OF SKI 3 & 7 COMMERCIAL FISHERIES

2.1 Data sources

Commercial catch and effort data for the SKI 3 and SKI 7 fisheries (Figure 2) were sourced from the Fisheries New Zealand combined *Warehou* and Electronic Data Warehouse (EDW) databases. Data extract, report log 16382, provided by Fisheries New Zealand included the catch and effort data for gemfish from SKI 3 and SKI 7 fishstocks in the period 1 October 1989 to 30 September 2024, i.e., fishing years 1989–90 to 2023–24. The extracted data were composed of all trips landing SKI 3 and SKI 7 quotas between 1 October 1989 and 30 September 2024 in the statistical areas valid for SKI 3 and SKI 7 (Figure 2).

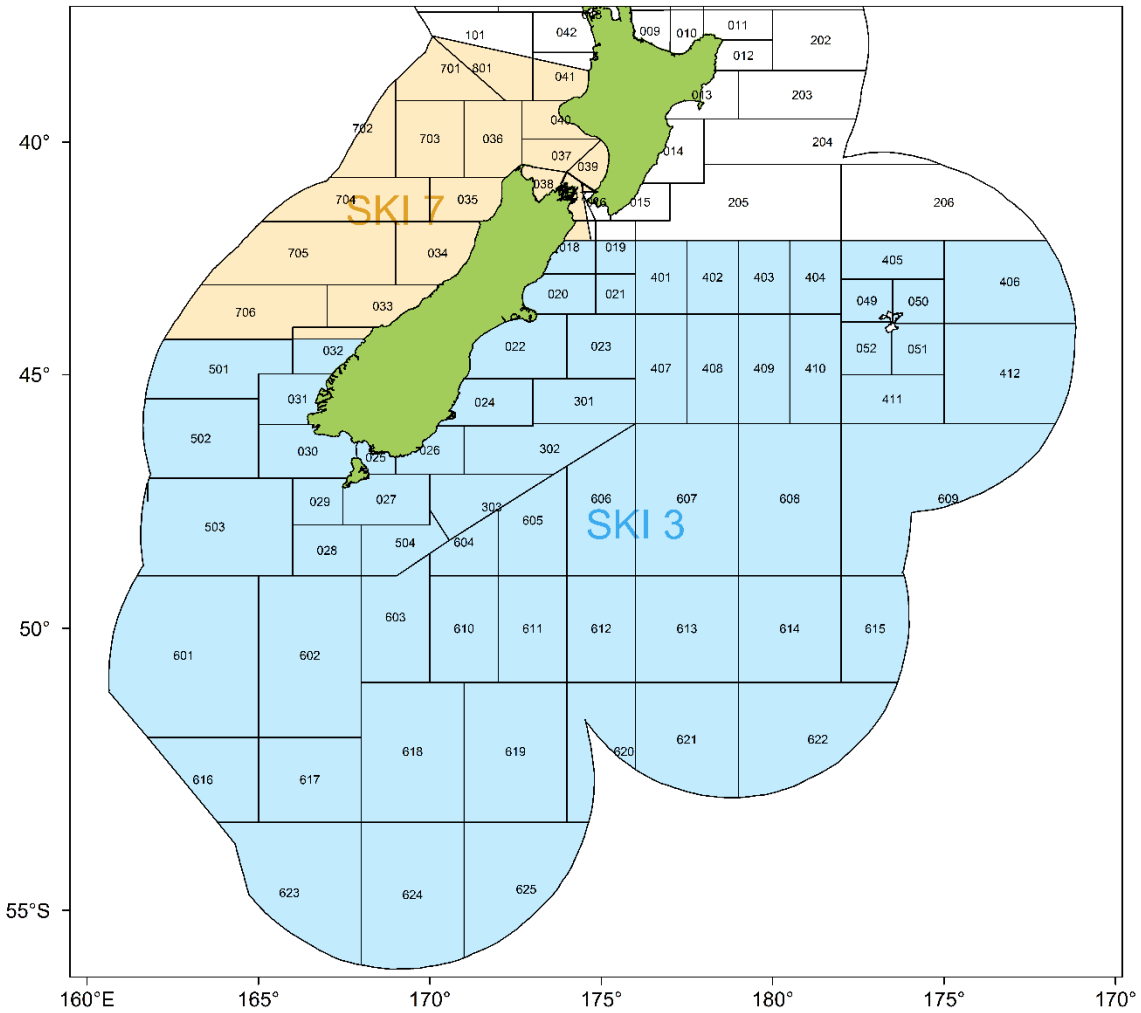


Figure 2: Southern gemfish (SKI 3 and SKI 7) Quota Management Areas (QMAs) and associated catch-effort statistical reporting areas relevant to data commercial data extracts.

Extracted data comprised four types of commercial data relevant to assessing catches and removals:

1. Monthly Harvest Returns (MHRs) and their forerunner, Quota Management Reports (QMRs), which we refer to as the MHR/QMR data with month resolution;
2. landings and disposals, data on the catches of all stocks, generally at the fishing trip resolution;

3. estimated catches recorded by fishers for individual fishing events;
4. daily processed catch totals from large factory trawlers (See Section 3.2).

Total annual catches of SKI 3 and SKI 7 under the Quota Management System (QMS) were compiled from Monthly Harvest Returns (MHR) submitted by fishing permit holders (Fisheries New Zealand 2024).

Landings and disposals records are typically at the trip resolution with weights derived by weighing at time of unloading. These data should provide a comprehensive record of catches per trip, with the fate of those catches indicated by a destination code. Trip catches recorded to an interim or not legally retainable destination code have been excluded from the trip landed catch totals in this report.

The finest-scale catch information is provided by estimated catches, which are reported per species per fishing event. However, estimated catch data are not necessarily comprehensive or accurate; this is because not all species caught are required to be reported for each event, and the quantities reported are estimated rather than weighed.

SKI 3 & SKI 7 estimated annual catch totals were consistently lower than MHR and landing totals, whereas annual landing totals mostly matched the MHR annual catch totals (Figure 3 and Figure 4).

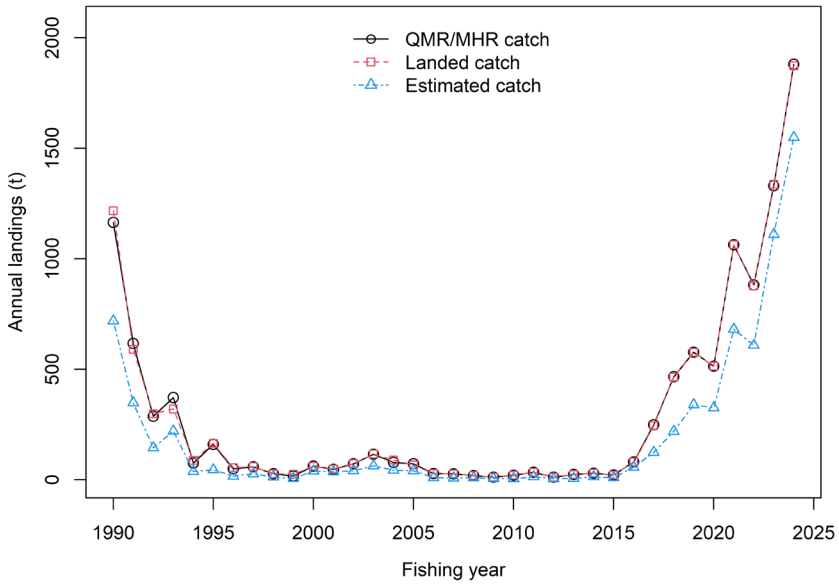


Figure 3: A comparison of the total annual SKI 3 landed and estimated catches (t) by fishing year from the groomed catch and effort data to the MHR/QMR catches for fishing years 1989–90 to 2023–24.

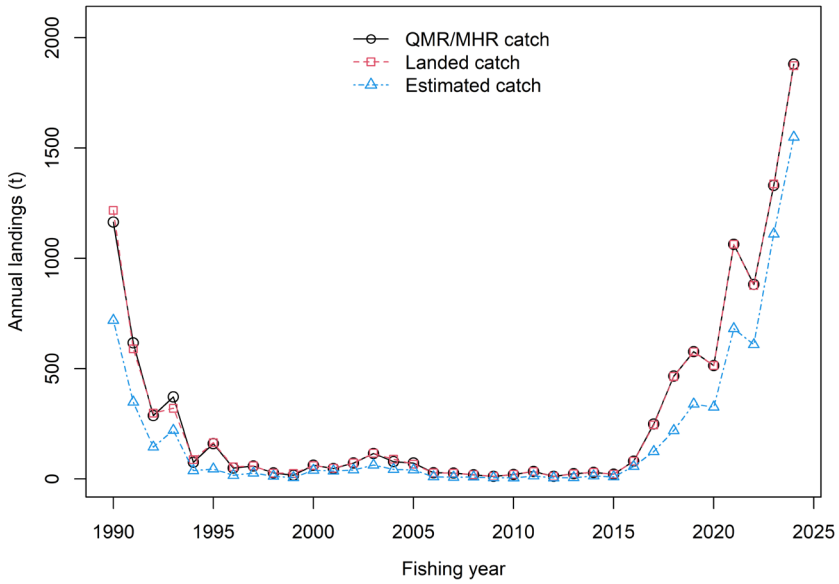


Figure 4: A comparison of the total annual SKI 3 landed and estimated catches (t) by fishing year from the groomed catch and effort data to the MHR/QMR catches for fishing years 1989–90 to 2023–24.

The current Electronic Reporting System (ERS) was introduced for the SKI 3 and SKI 7 deepwater trawl fleet in 2017–18 and the inshore fleet in 2019–20 (Figure 5). Prior to the ERS, SKI 3 and SKI 7 commercial catches had been primarily reported via the CELR and TCER from the inshore fleets and via the TCEPR from the deepwater trawl fleet (Figure 5).

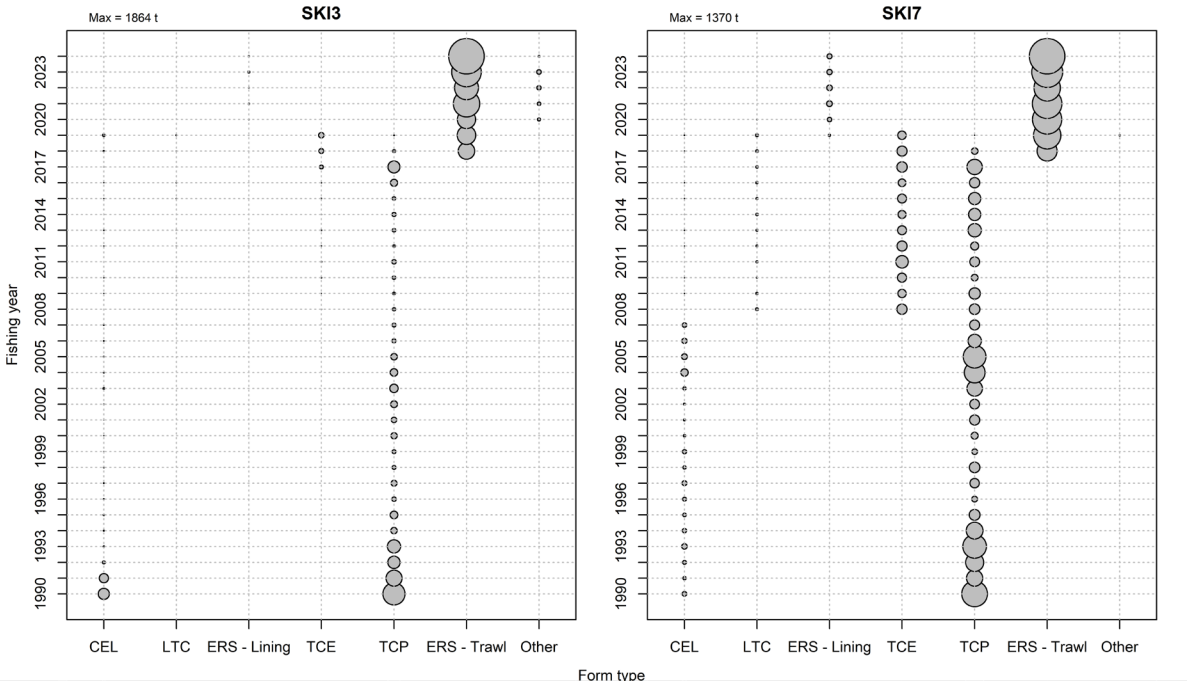


Figure 5: Annual catches of gemfish from SKI 3 (left panel) and SKI 7 (right panel) by reporting form type (TCE, Trawl Catch Effort Return; CEL, Catch Effort Landing Return; TCP, Trawl Catch Effort Processing Return; ERS, Electronic Reporting System).

2.2 Data grooming and processing

The landing catch and fishing effort data were groomed using Earth Sciences NZ's R package *CEgroom*. In the grooming process landings were distinguished as landed and non-landed based on destination codes, landed catches and the processed catches were allocated to fishing events using the method of

Dunn & Bian (2018). If there were estimated gemfish catches for at least one of the fishing events on a trip, then the trip's catch was allocated in proportion to the estimated catch in each fishing event. If no estimated catch of gemfish was recorded on a trip, the catch was allocated in proportion to the highest estimated catch in each fishing event. SKI 3 & 7 fishing events were determined based on start statistical. Where statistical areas crossed QMA boundaries (e.g., 016, 017, 018, 032 Figure 2) effort was assigned based on start longitudes and latitudes.

2.3 Fishery Characterisation

SKI 3 & 7 annual catches declined during the 1990s leading to TACC reductions in 1997 and 1998 (Figure 6). Despite these TACC reductions, SKI 3 & 7 annual catches remained mostly below the TACC until 2017 (Figure 6). Annual SKI 3 & 7 catches exceeded the TACC in 2017 and steadily increased after that. These increases prompted a series of TACC increases in both QMAs after 2020 (Figure 6).

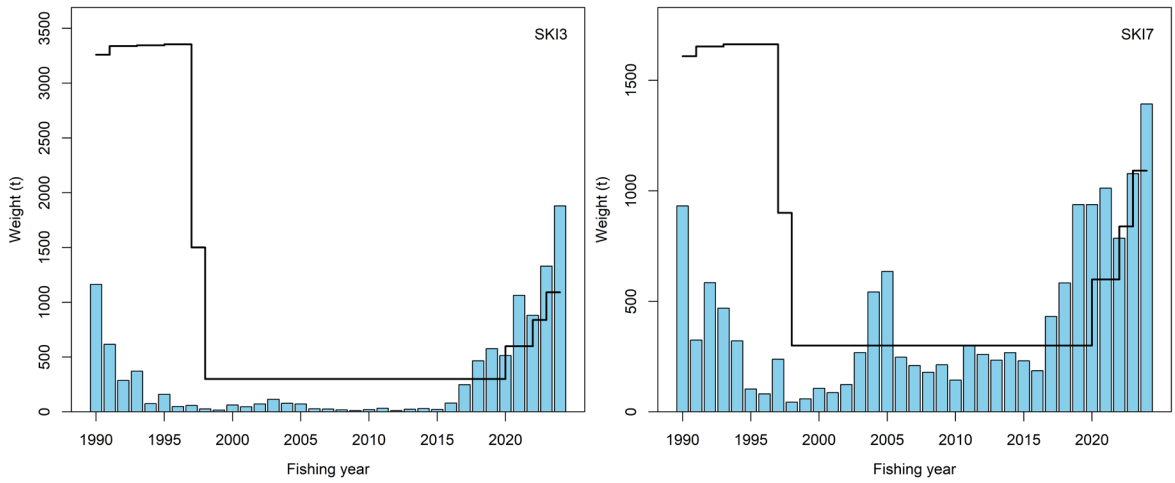


Figure 6: Total Allowable Commercial Catch (TACC; black line) and Monthly Harvest Return/Quota Management Report totals (MHR/QMR; bars) for SKI 3 (left panel) and SKI 7 (right panel) from fishing years 1989–90 to 2023–24.

Since 1989–90, the primary SKI 3 and SKI 7 fishing methods have been bottom trawl and midwater trawl (Figure 7). A relatively small proportion of the annual SKI 7 catch has been taken by longline since 1989–90 (Figure 7). Use of the precision bottom trawl method (PRB) in SKI 7 commenced in 2017–18, peaked a year later, and then declined (Figure 7).

Most of the annual SKI 3 and SKI 7 catch was processed at-sea, predominantly either as dressed or headed-and-gutted (Figure 8).

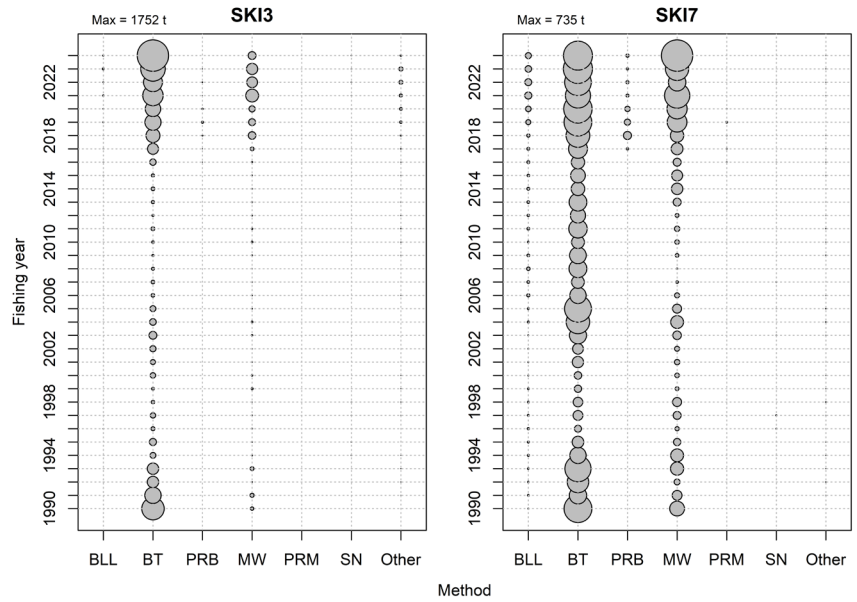


Figure 7: Annual landed catch of gemfish from SKI 3 (left panel) and SKI 7 (right panel) by fishing method (BLL, Bottom longline; BT, Bottom trawl; PRB, Precision bottom trawl; MW, Midwater trawl; PRM, Precision midwater trawl; SN, Setnet).

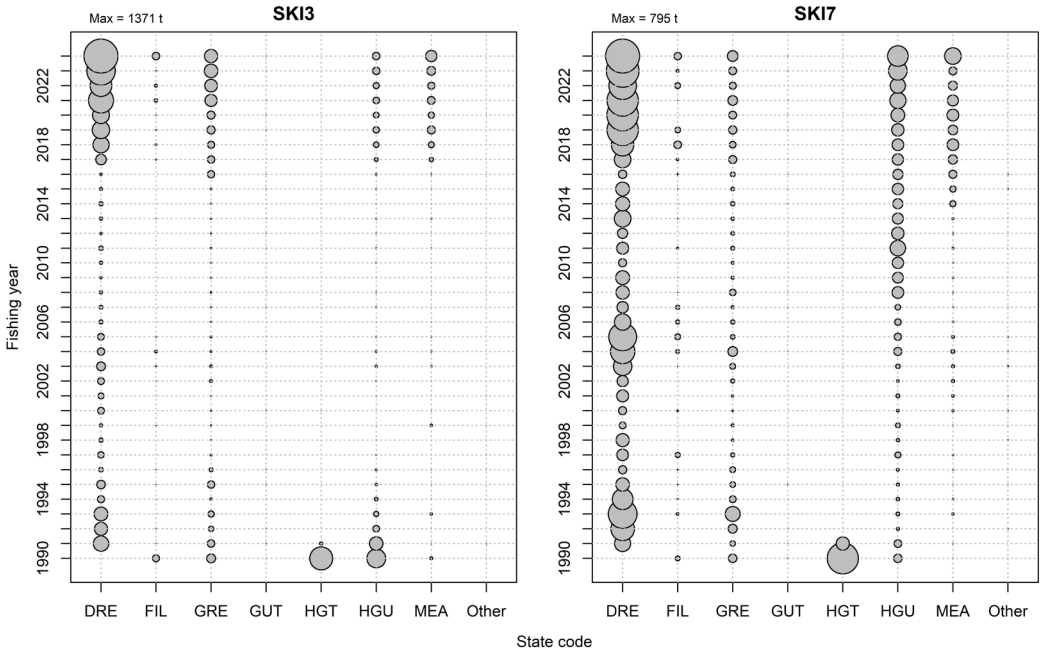


Figure 8: Landed state of gemfish from SKI 3 and SKI 7 (DRE, Dressed; FIL, Fillets: skin-on; GRE, Green or whole; GUT, Gutted; HGT, Headed, gutted and tailed; HGU, Headed and gutted; MEA, Fish meal).

2.4 SKI 3 & 7 Bottom trawl fisheries

Most of the annual SKI 3 bottom trawl catch was taken as bycatch to other regional target fisheries, predominately by the southern arrow squid fishery (Figure 9). The bycatch nature of the SKI 3 commercial catches implies that increased annual catches post 2017 most likely reflect increasing stock abundance and not increased targeting. As SKI 3 abundance increased after 2017, gemfish became more prevalent in other east coast South Island trawl target fisheries notably ling, silver warehou, and barracouta fisheries (Figure 9).

Similarly, most of the annual SKI 7 was taken as bycatch in the west coast South Island hoki and ling fisheries (Figure 10). Gemfish has also been a regular component of the west coast South Island tarakihi target fishery since 2005 (Figure 10).

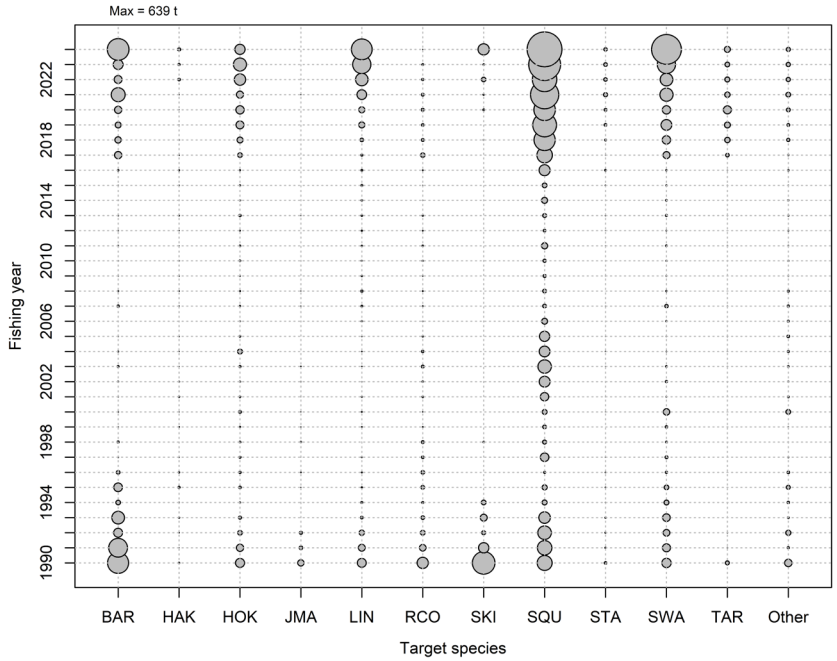


Figure 9: Annual SKI 3 catches (t) by target species for the bottom trawl fishery. The circle size scales with the catches by fishing year and target species (BAR, Barracouta; HAK, Hake; HOK, Hoki; JMA, Jack mackerel; LIN, Ling; RCO, Red cod; SKI, Gemfish; SQU, Arrow squid; STA, Giant stargazer; SWA, Silver warehou; TAR, Tarakihi).

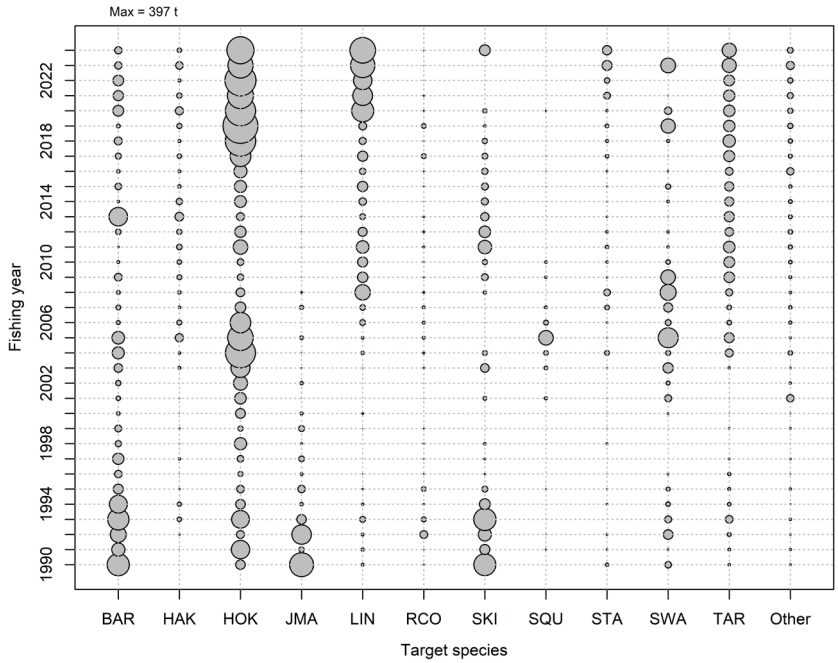


Figure 10: Annual SKI 7 catches (t) by target species for the bottom trawl fishery. The circle size scales with the catches by fishing year and target species (BAR, Barracouta; HAK, Hake; HOK, Hoki; JMA, Jack mackerel; LIN, Ling; RCO, Red cod; SKI, Gemfish; SQU, Arrow squid; STA, Giant stargazer; SWA, Silver warehou; TAR, Tarakihi).

In SKI 3 gemfish catches have been lower over the winter months reflecting the seasonal patterns of the related target fisheries (Figure 11). Similarly, in SKI 7 the high catching months of August and September reflect the seasonality of the west coast South Island hoki fishery (Figure 12).

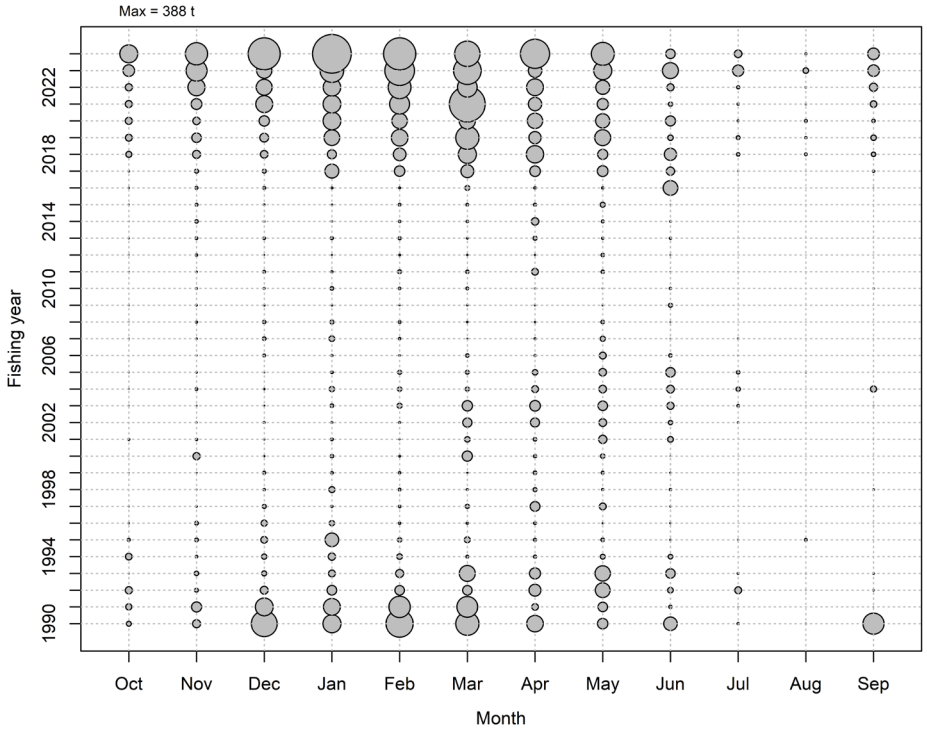


Figure 11: Annual SKI 3 catches (t) by month for the bottom trawl fishery. The circle size scales with the catches by fishing year and month.

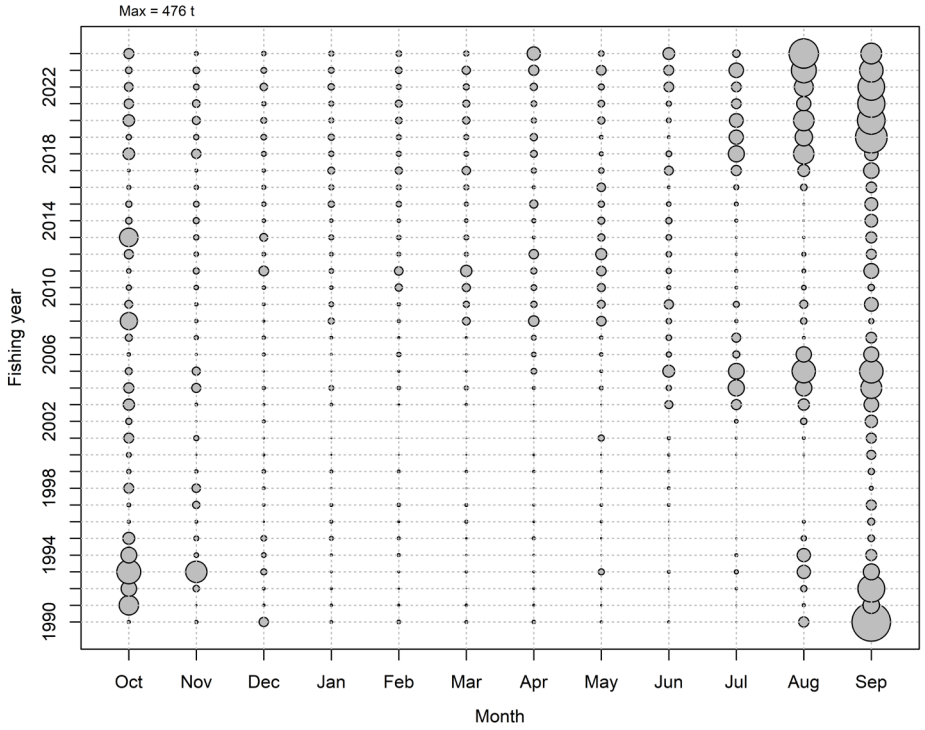


Figure 12: Annual SKI 7 catches (t) by month for the bottom trawl fishery. The circle size scales with the catches by fishing year and month.

As with seasonality, the spatial distribution of annual SKI 3 & 7 catches reflect those of the main associated target fisheries. In SKI 3 gemfish was more commonly taken from Statistical Areas 026 – 030 (Snares Shelf region) which matches the distribution pattern of the southern arrow squid fishery (Figure 13).

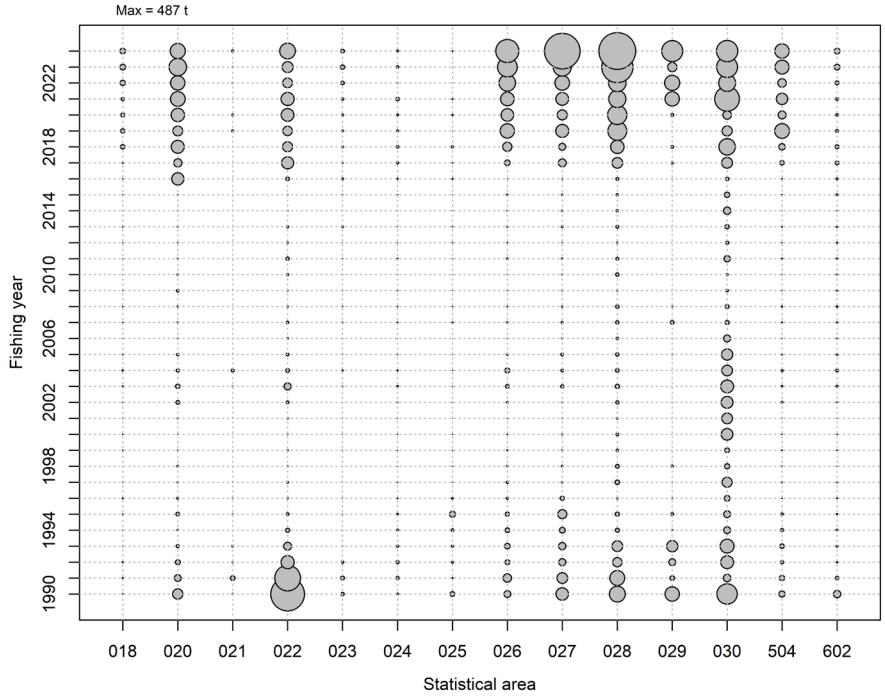


Figure 13: Annual SKI 3 catches (t) by statistical area for the bottom trawl fishery. The circle size scales with the catches by fishing year and statistical area.

The SKI 7 predominant catch in Statistical Areas 034 and 035 matches the west coast North Island hoki and ling fisheries (Figure 14).

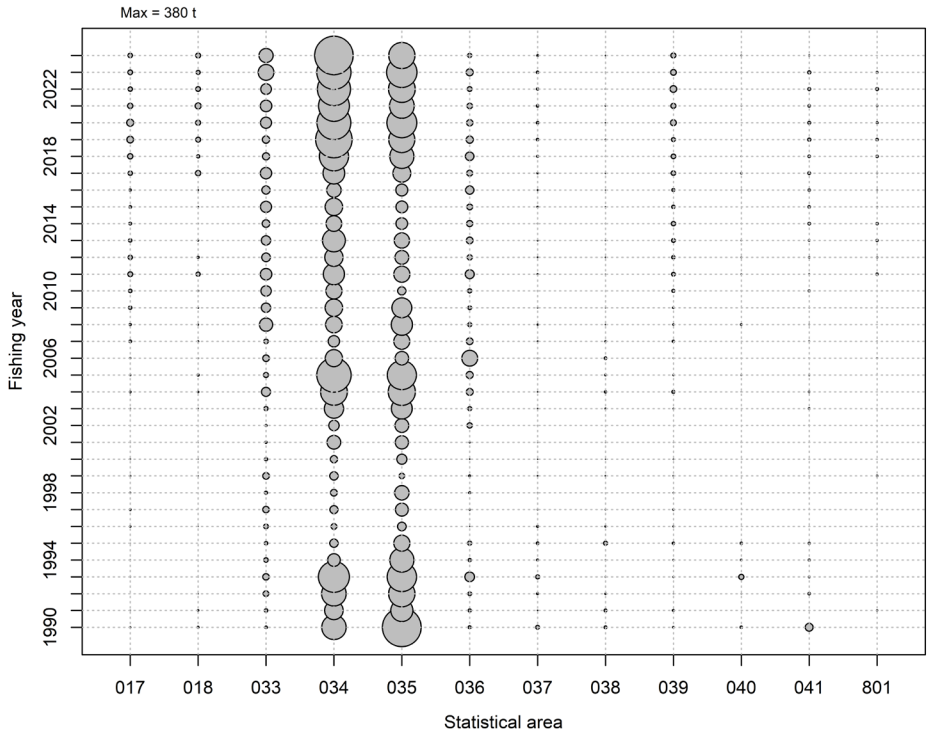


Figure 14: Annual SKI 7 catches (t) by statistical area for the bottom trawl fishery. The circle size scales with the catches by fishing year and statistical area.

Statistical Areas 020 and 022 (Banks Peninsula) were relatively high catch areas in the early 1990s (Figure 13; Appendix Figure 1); the associated target fisheries principally being barracouta and silver warehou. Gemfish had relatively low catches in the Banks Peninsula region over the years of low abundance, followed by a return to high catch rates in the region after 2017; this might reflect range contraction and expansion in the stock (Figure 13; Appendix Figure 1).

The depth ranges of SKI 3 & 7 catches again reflect those of the associated target fisheries. The barracouta, jack mackerel, and tarakihi fisheries operate in relatively shallow waters, generally below 300 m (Figure 15). The SKI 3 squid fisheries are also primarily in shallow waters but can reach depths of up to 500 m. The SKI 7 hoki and ling fishery typically operate in deeper waters between 300 and 800 m. The hake fishery tends to operate in deeper waters, starting at around 400 m and reaching depths of 800 m (Figure 15).

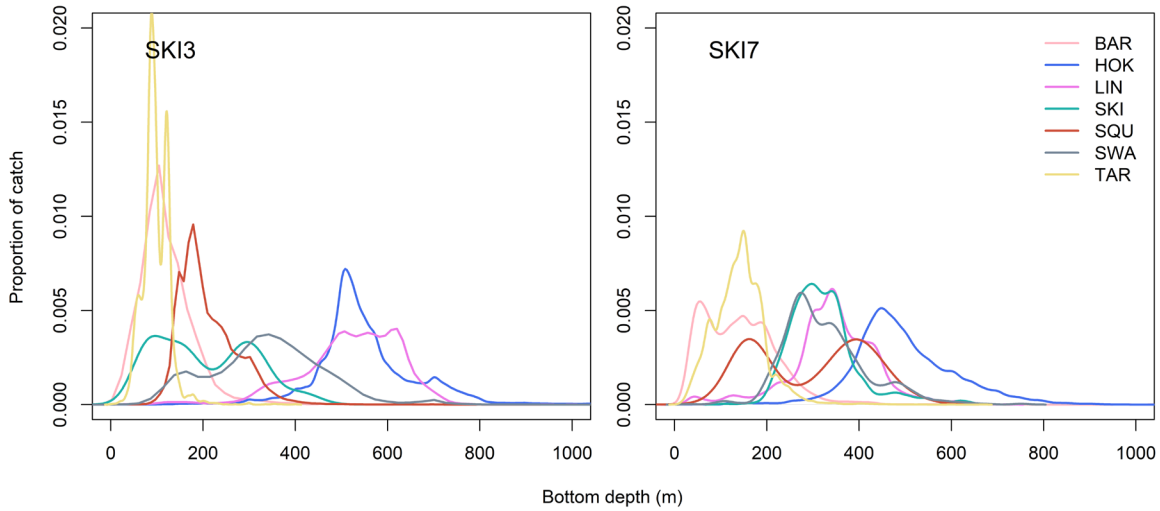


Figure 15: Bottom depth distribution of gemfish catch from SKI 3 (left panel) and SKI 7 (right panel) by target species for bottom trawl fishery for fishing years 1989–90 to 2023–24 (BAR, Barracouta; HOK, Hoki; LIN, Ling; SKI, Gemfish; SQU, Arrow squid; SWA, Silver warehou; TAR, Tarakihi).

2.5 SKI 3 & 7 midwater trawl fisheries

Gemfish in SKI 3 were taken predominantly as bycatch in the barracouta, squid, and to a lesser degree, jack mackerel mid-water trawl fisheries (Figure 16). In SKI 7, hoki was the only mid-water fishery that took significant gemfish bycatch (Figure 16).

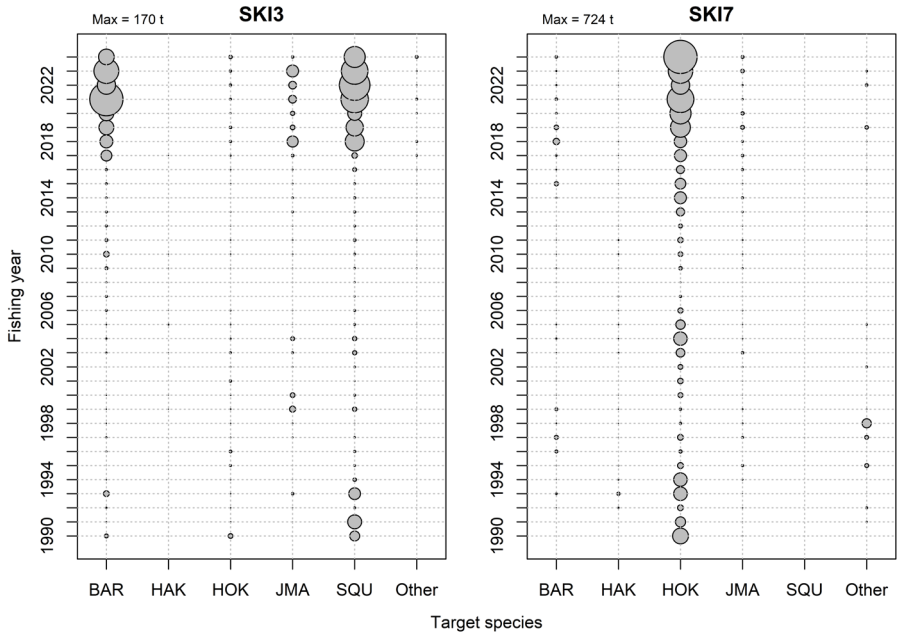


Figure 16: Annual gemfish catches (t) in SKI 3 and SKI 7 by target species for the midwater trawl fishery. The circle size scales with the catches by fishing year and target species (BAR, Barracouta; HAK, Hake; HOK, Hoki; JMA, Jack mackerel; SQU, Arrow squid).

As expected, seasonality and spatial distribution patterns in the SKI 3 and SKI 7 catches reflects that of the associated target fisheries (Figures 17–20).

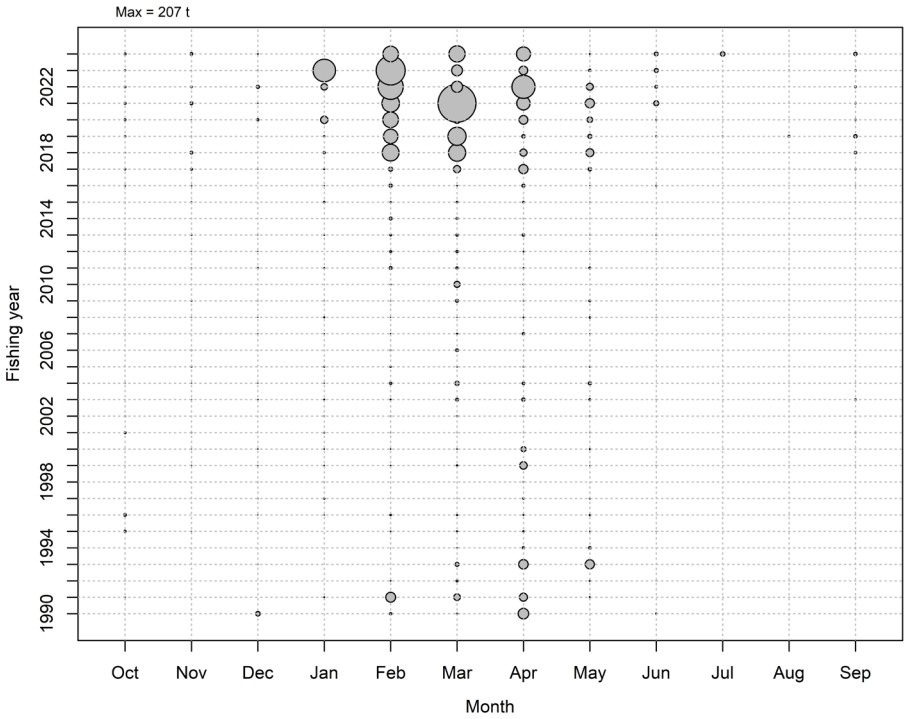


Figure 17: Annual SKI 3 catches (t) by month for the midwater trawl fishery. The circle size scales with the catches by fishing year and month.

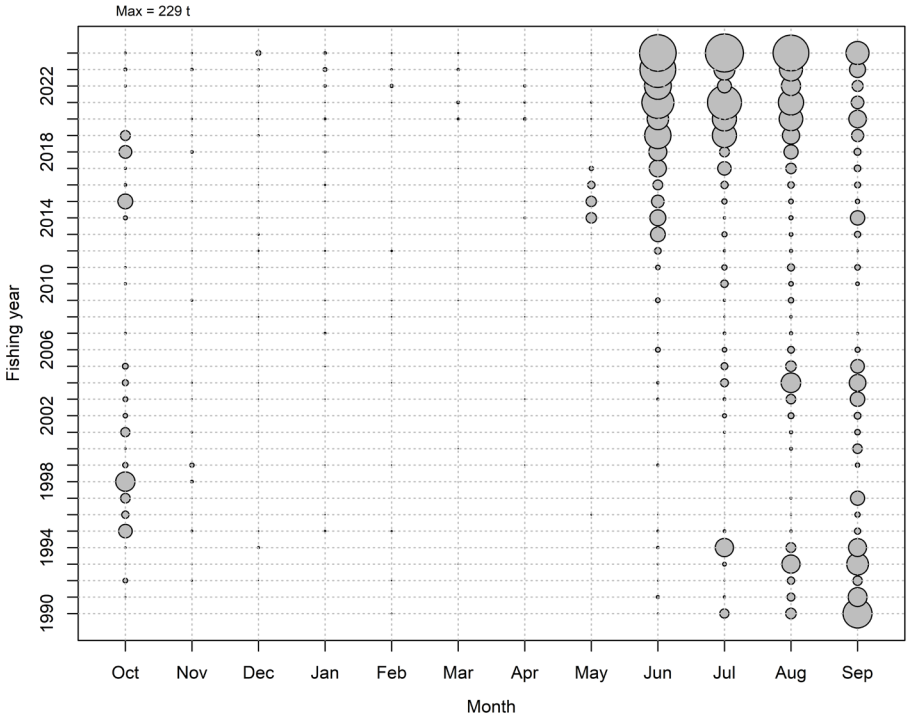


Figure 18: Annual SKI 7 catches (t) by month for the midwater trawl fishery. The circle size scales with the catches by fishing year and month.

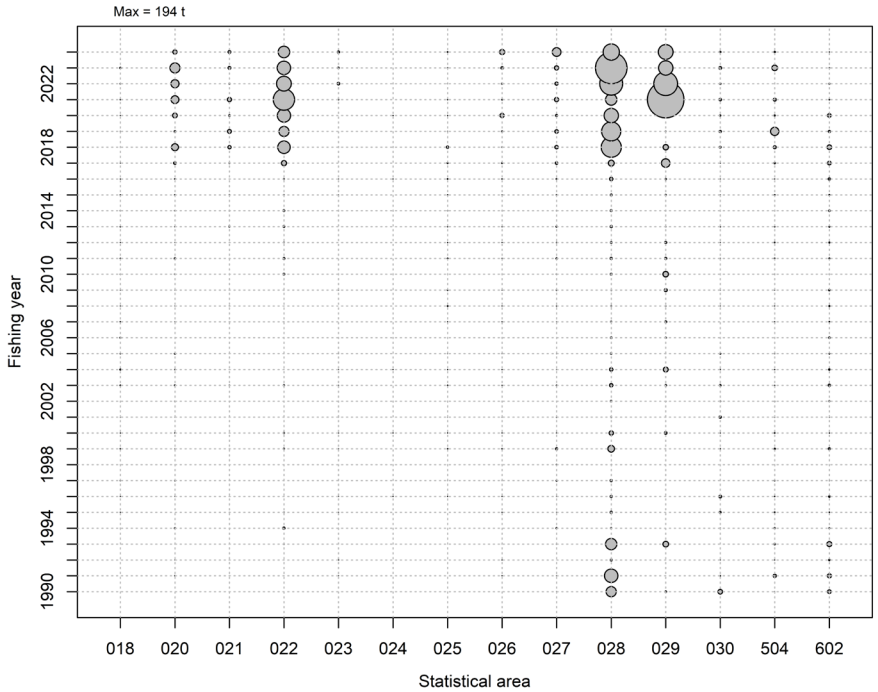


Figure 19: Annual SKI 3 catches (t) by statistical area for the midwater trawl fishery. The circle size scales with the catches by fishing year and statistical area.

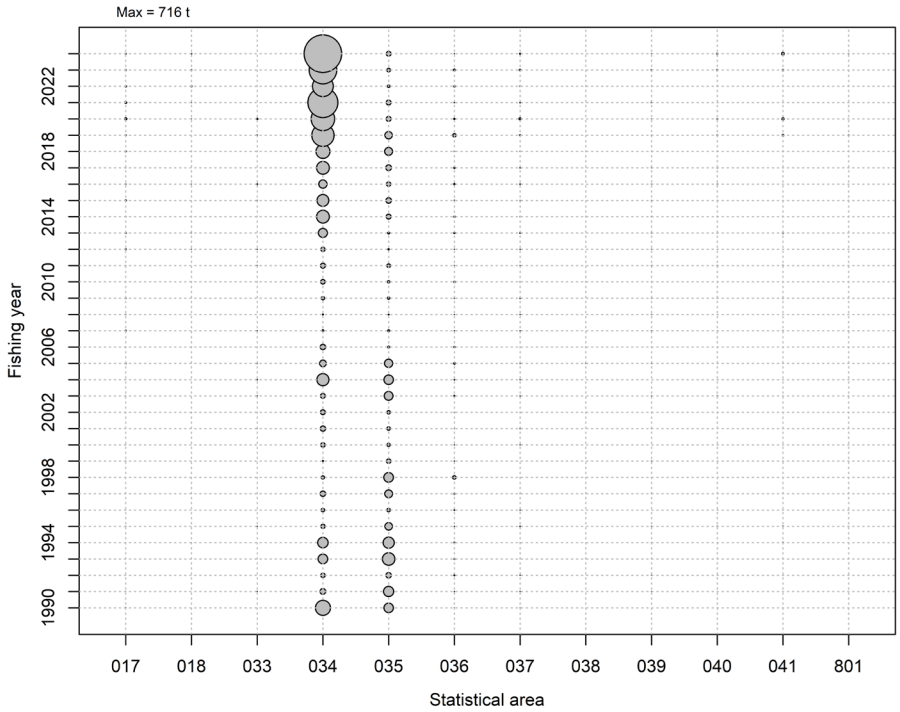


Figure 20: Annual SKI 7 catches (t) by statistical area for the midwater trawl fishery. The circle size scales with the catches by fishing year and statistical area.

The depth ranges of SKI 3 & 7 again reflected those of the associated target fisheries (Figure 21).

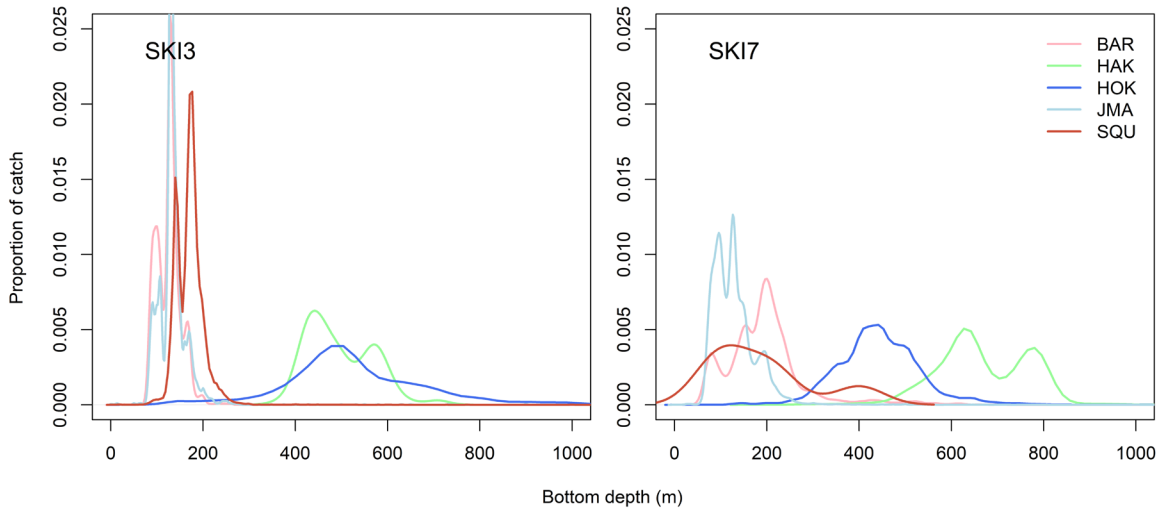


Figure 21: Bottom depth distribution of gemfish catch from SKI 3 (left panel) and SKI 7 (right panel) by target species for midwater trawl fishery for fishing years 1989–90 to 2023–24 (BAR, Barracouta; HOK, Hoki; HAK, Hake; JMA, Jack mackerel; SQU, Arrow squid).

3 DERIVATION OF SKI 3 & 7 COMMERCIAL CPUE INDICES THROUGH TO THE END OF THE 2023–24 FISHING YEAR

3.1 Analysis overview

As discussed in Section 1.2, Starr et al. (2024) conducted relative abundance analyses for the period 1989–90 through to the end of the 2020–21 fishing year using all available SKI 3 & 7 catch effort data. In line with working group recommendations (see Section 1.2) the following CPUE indices were updated in this report:

1. Winter SKI 7 trawl target hoki fishery off the west cost of the South Island;
2. SKI 3 Stewart-Snares shelf mixed target trawl fishery (SQU, BAR, HOK, SWA, SKI, LIN).

The Working Group preferred Starr et al.'s (2024) daily rollup series pro-rated by daily processing records over other data aggregation options (see Section 1.2), so this was the data aggregation approach used in this report.

3.2 Methods

CPUE analyses were undertaken using Fisheries New Zealand Electronic Data Warehouse extract requests:

> Extract 1: all trips landing SKI 3 and SKI 7 quotas between 1 October 1989 and 30 September 2024.
>
> Extract 2: all trips in which any events used method BT, PRB, MW or PRM in the Statistical Areas valid for SKI 3 and SKI 7, 016 –041, 049–052, 301–303, 401–412, 501–504, 601–625, 701–706 and 801, between 1 October 1989 and 30 September 2024.

The purpose of the second extract was to obtain effort data from trips which had been undertaken in areas where gemfish could have been caught but were not (i.e., addition of legitimate zero catch trips).

The use of daily processing data in the CPUE analyses restricted the analytical data series to large factory vessels. A required assumption in the use of the daily processing catch data was that only fishing effort on the days gemfish was processed caught gemfish; effort from all other days on the trip correspond to zero gemfish catches. Because daily processing analyses made no use of estimated catch data, these analyses were unaffected by changes in the number of species recorded for each fishing event throughout the series.

Processed catch records were linked to day-level aggregated effort data by trip-number and date. Processed catch weights were converted to greenweights by application of a conversion factor. Starr et al. (2024) note that the Fisheries New Zealand published conversion factor for gemfish had changed since 1989–90, requiring the current conversion factor to be retrospectively applied back across the whole processed catch data series to ensure consistency in the derived greenweight totals.

The analytical datasets were restricted to vessels with established fishing history.

Variables offered as covariate terms in the CPUE standardisations were: Fishing year; Vessel ID; Statistical area; Primary method (BT or MW); Target (SKI 3 analysis only), Duration (daily total); Depth (daily average); Fishing-year day (i.e. 1–365 commencing 1 October). The mechanism used to assign statistical area and target to the daily aggregate record followed that described in Dunn & Bian (2018).

Missing or extreme continuous variables were imputed to the vessel median recorded value.

Generalised Linear Modelling (GLM) was used to derived standardised CPUE indices. The high proportion of zero daily catches in the data sets required the use of the delta analytical approach to

combine the independently derived positive catch (log-normal) and proportion-zero (binomial) GLM indices. A stepwise fitting procedure was implemented for each GLM model in which variables in addition to fishing-year were sequentially included in the models until the improvement in the model R^2 was less than 1%.

3.3 SKI 3 CPUE abundance

This SKI 3 analysis was based on gemfish catch and effort data from the mixed target BT/MW fisheries at the southern end of the South Island, encompassing the Stewart-Snares shelf, Foveaux Strait and the waters around Stewart Island (Figure 2). The target species were squid (SQU), barracouta (BAR), hoki (HOK), silver warehou (SWA), ling (LIN), and gemfish (SKI).

3.3.1 Core vessel selection

Core vessel selection was based on positive catch trip data only. The core fleet was defined by having fished at least once in each of three or more years, these criteria retained 95% of the catch and reduced the fleet from over 150 vessels to 73 vessels (Figure 22, Figure 23). The core vessel proportion of the total annual gemfish catch did not drop below 65% in any fishing year (Figure 24).

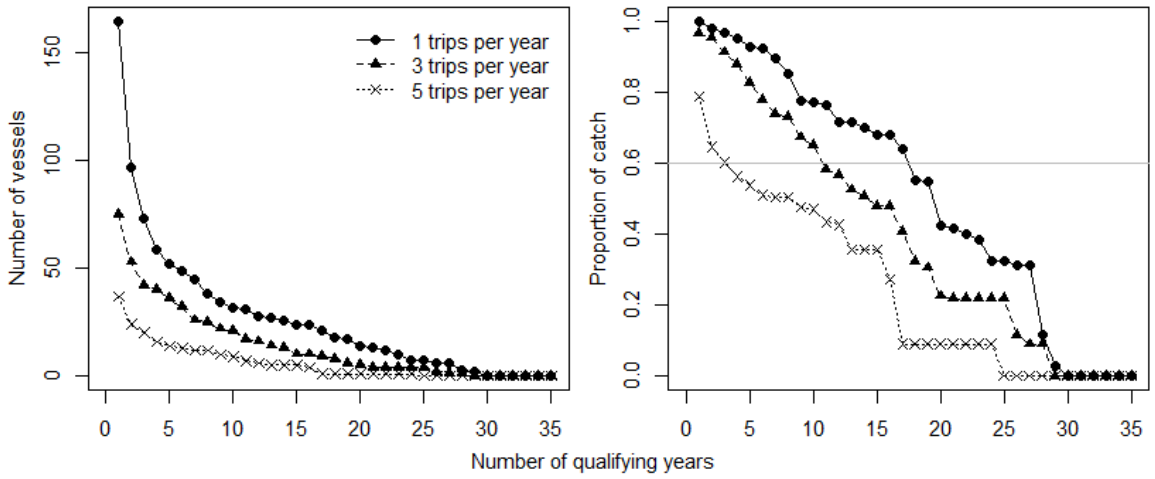


Figure 22: SKI 3 Stewart-Snares vessel selection: number of qualifying years versus the number of vessels (left panel), and proportion of total gemfish catch retained (right panel), for a minimum of 1, 3 or 5 trips per year. The grey line indicates a 60% retention of the catch in the core vessel dataset. The criteria for selection of core vessels were a minimum of 3 qualifying years and 1 trip per year.

The core vessel final data set shows a high proportion of zero trips and zero effort days across the series (Figure 25) justifying the delta log-normal analytical approach.

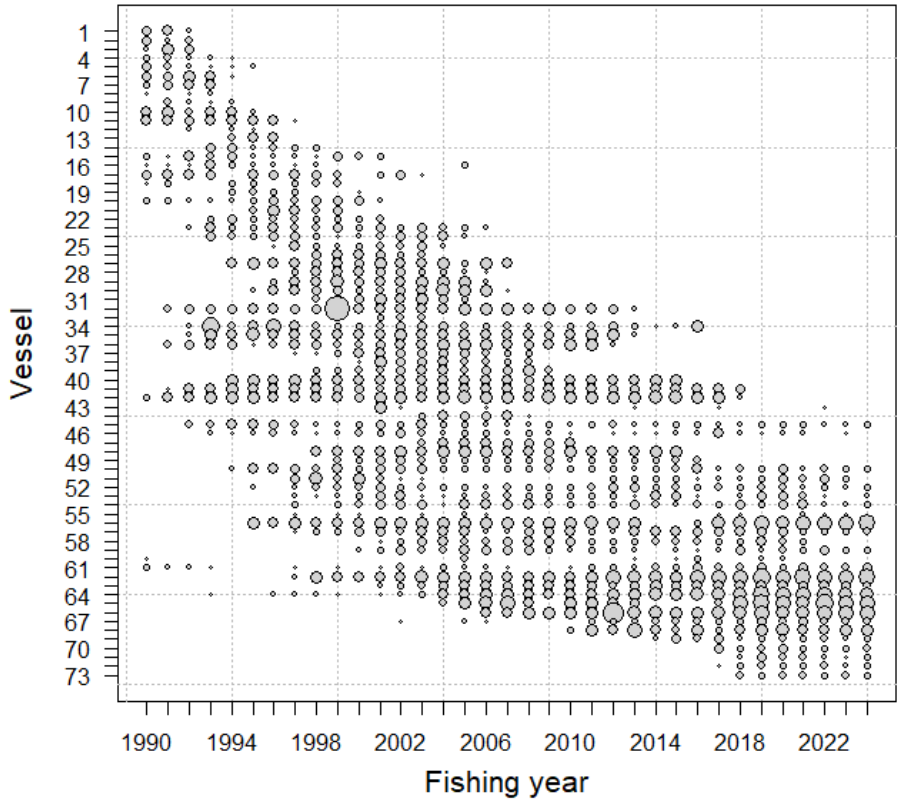


Figure 23: SKI 3 Stewart-Snares vessel core vessel relative number of fishing events from 1989–90 to 2023–24. N= 73 vessels.

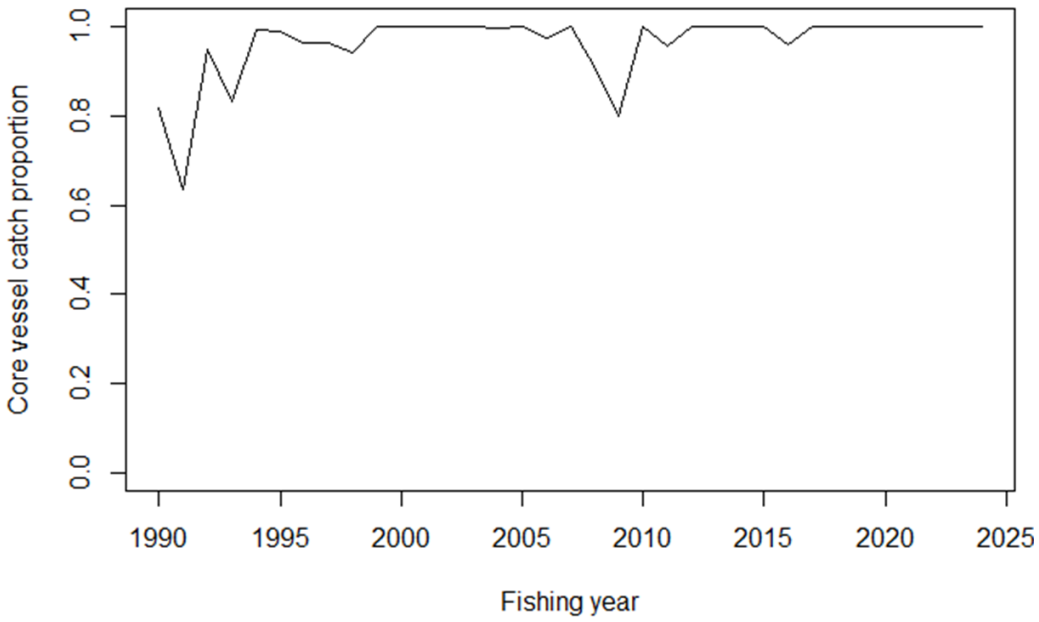


Figure 24: SKI 3 Stewart-Snares proportion of gemfish catch retained in the core vessel analyses dataset each year from 1989–90 to 2023–24, where core vessels were restricted to a minimum of 3 qualifying years and 1 trip per year.

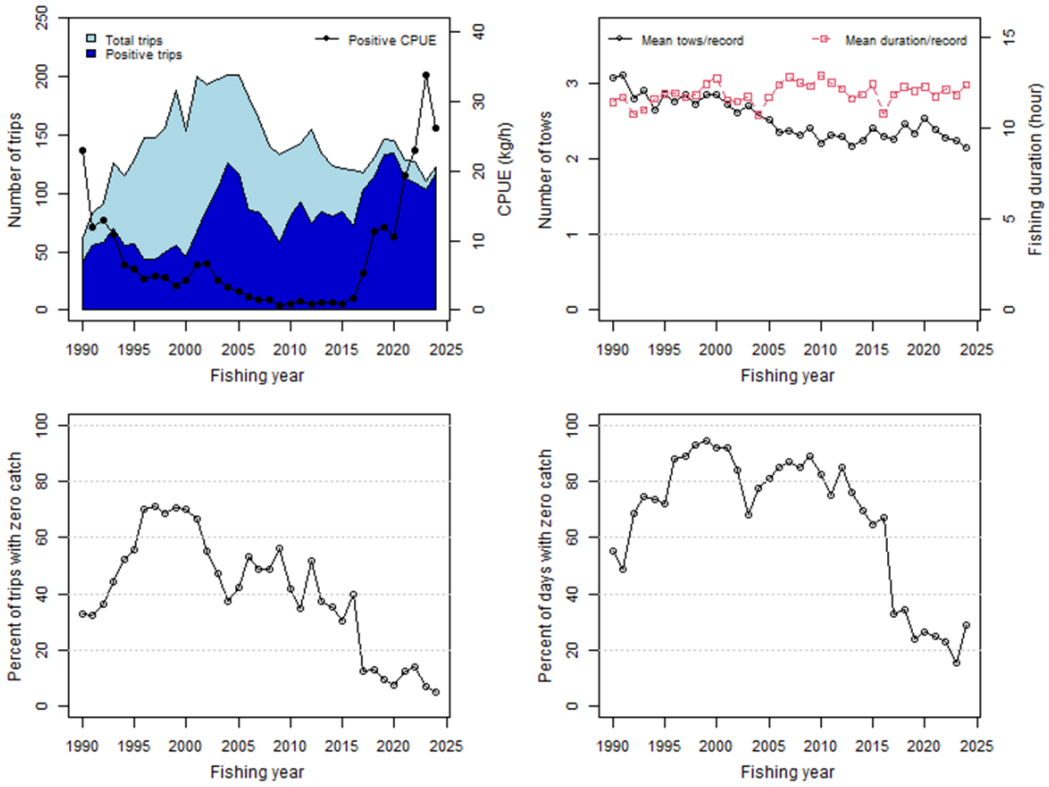


Figure 25: SKI 3 Stewart-Snares core vessel trip metrics from 1989–90 to 2023–24. Total number of trips with positive catch, and raw CPUE (top left). Percentage of trips with zero catch (bottom left), mean number of tows and mean duration per trip (top right), and mean days fished per trip (bottom right).

3.3.2 Lognormal (positive catch)

Response and covariate terms offered to the lognormal GLM standardisation models are given in Table 1.

Table 1: Model response and covariate terms offered in the SKI 3 Stewart-Snares log-normal GLM models.

Variable	Fitted as	Description
Catch (response)	Numeric	lognormal model: positive catch, log transformed binomial model: proportion zero catch ratio
Fishing year	Categorical	Fishing year (Oct-Sept)
Vessel	Categorical	Unique vessel identifier
Target	Categorical	Target species: SQU, BAR, HOK, SWA, SKI, LIN
Statistical area	Categorical	025, 026, 027, 028, 029, 030, 504
Primary method	Categorical	BT and MW
Duration	Natural spine	Fishing duration, (log transformed in log-normal model)
Depth	Basic spine	Bottom depth
Fishing-year day (i.e. 1 October = 1)	Basic spine	1–365

Preliminary diagnostics of the response and covariate model terms suggest that the data complies with the normality and other requirements of the log-normal GLM analyses (Appendix 2).

The final lognormal model accepted four predictive variables after fishing year (statistical area, vessel, fishing year day and bottom depth), with the total model explaining 50% of the variation in the response variable (R^2) (Table 2).

Table 2: Predictor variables accepted in the standardised log-normal CPUE model, the degrees of freedom (Df) and the proportion of variance in the model explained by addition of each variable (R^2).

Predictors	Df	R^2
Fishing year	34	0.33
Statistical area	6	0.4
Vessel	72	0.45
Fishing year day	3	0.48
Depth	3	0.5

The standardised canonical index from the model shows a progressive decline during the 1990s and early 2000s, followed by a period of very low abundance from 2006 to 2016 and then a sharp rise after 2017 (Figure 26). The index equated to an eighteen-fold difference between the lowest (2012) and highest points (2023) (Figure 26), the biomass difference between 1990 and 2023 was four-fold (Figure 26).

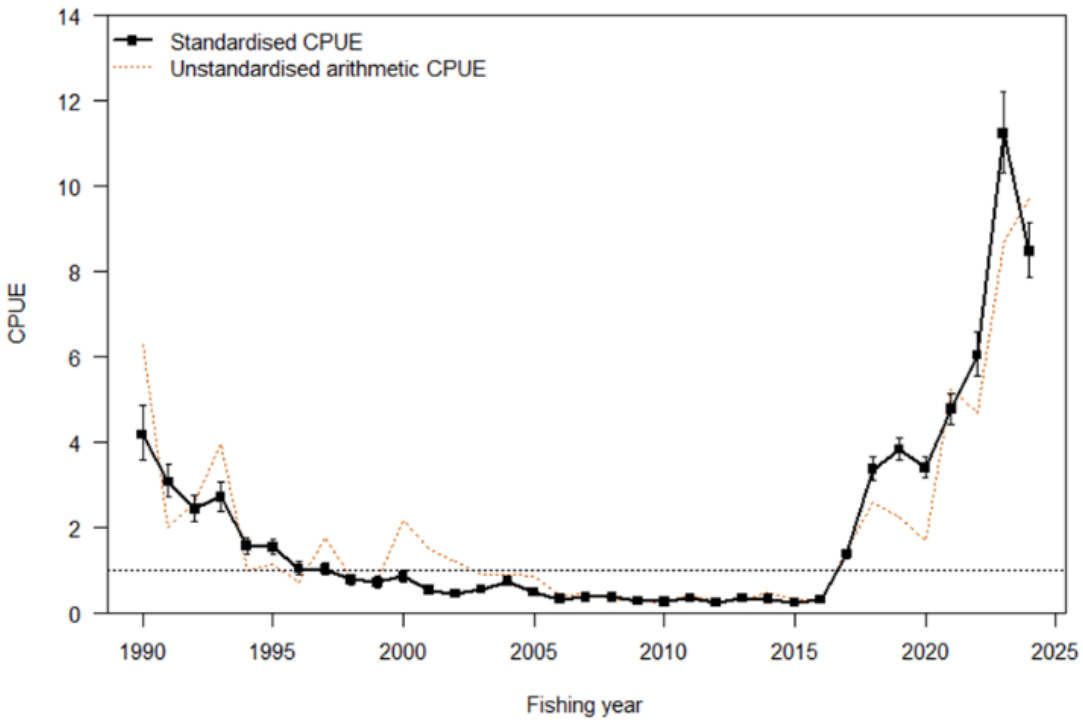


Figure 26: SKI 3 Stewart-Snares standardised log-normal canonical CPUE indices for core vessels from 1989–90 to 2023–24. The arithmetic unstandardised index for core vessels is also shown. Error bars are 95% confidence intervals. Indices are scaled to have a mean of 1.0.

The standardised canonical index from the model closely matched the 2020 Starr et al. (2024) index over the common series years (Figure 27).

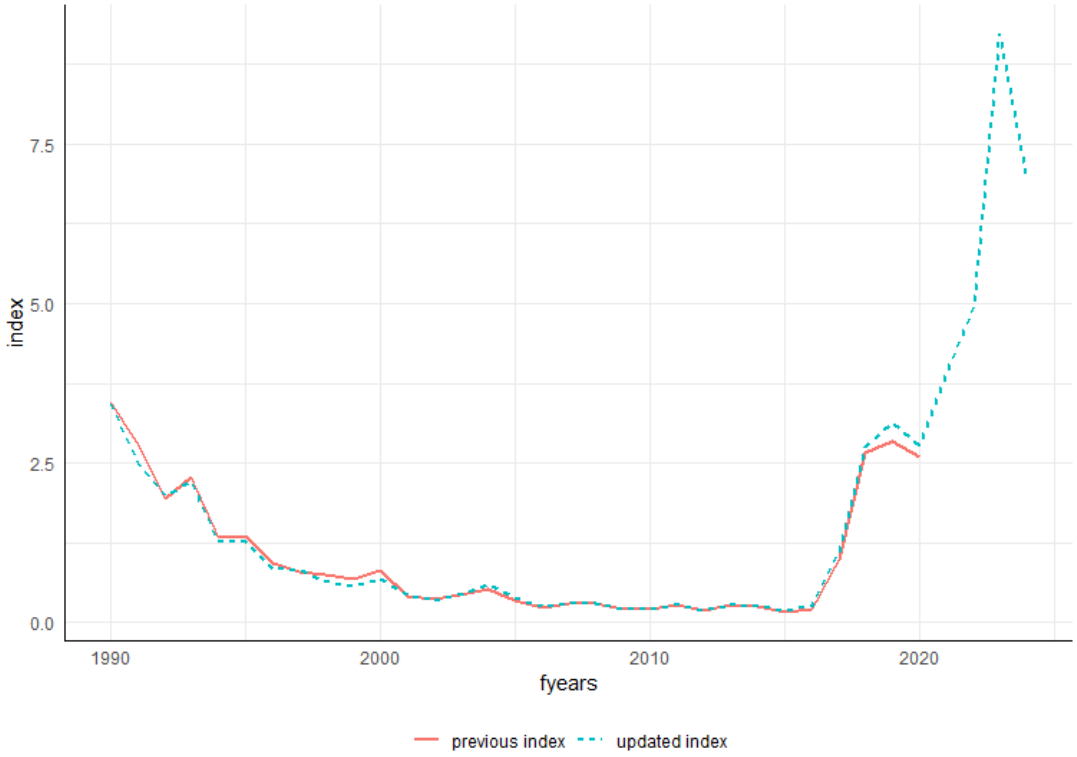


Figure 27: Starr et al. (2024) and updated SKI 3 Stewart-Snares standardised log-normal canonical CPUE index comparison. Indices are scaled to have a mean of 1.0.

The lognormal model residuals on the response variable (log-catch) predictions show good conformity to normality assumption over the 95% range of the data (Appendix 3). Similarly, there were no obvious model predictive issues in the model residuals across the range of the continuous variables (fishing-year-day and depth; Appendix 3). However, the residual diagnostics in respect to the model categorical terms (fishing year, vessel, statistical area) were less than ideal with apparent failures of the between group homogeneity-of-variance assumption and or the within-group uniformity assumption (Appendix 3).

As seen in Figure 26, the log-normal model did not have a strong standardisation effect on the predicted index with each successive term added to the model (Appendix 5).

3.3.3 Binomial (proportion-zero)

Response and covariate terms offered to the binomial GLM standardisation models are given in Table 1.

The final binomial model had accepted four predictive variables after fishing year (statistical area, vessel, fishing year day and bottom depth), with the total model explaining 35% of the variation in the response variable (R^2) (Table 3).

Table 3: Predictor variables accepted in the standardised binomial CPUE model, the degrees of freedom (Df) and the proportion of variance in the model explained by addition of each variable (R^2).

Predictors	Df	R^2
Fishing Year	34	0.20
Vessel	72	0.25
Statistical Area	6	0.29
Fishing Year Day	3	0.33
Depth	3	0.35

The predicted binomial predicted proportion positive catch index shows a pronounced rise after 2017 in line with increasing catch trends (Figure 28).

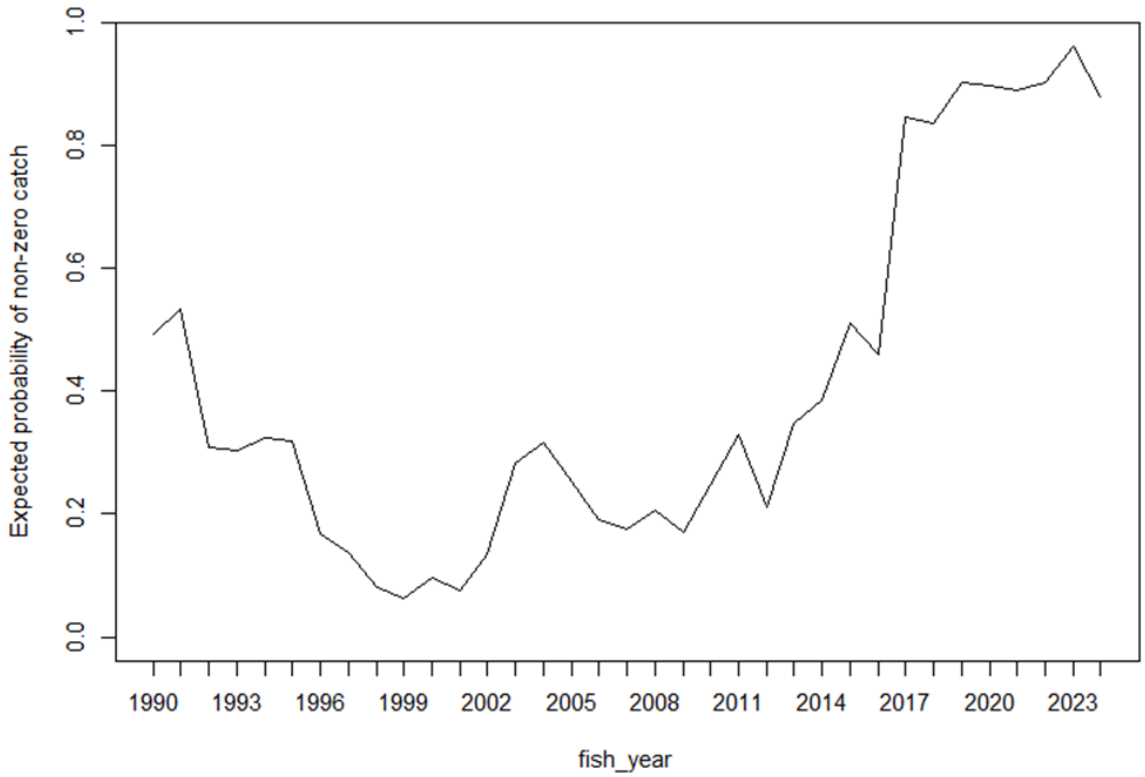


Figure 28: SKI 3 Stewart-Snares standardised binomial index on the expected non-zero catch proportion.

The binomial index from the model closely matched the 2020 Starr et al. (2024) index over the common series years (Figure 29).

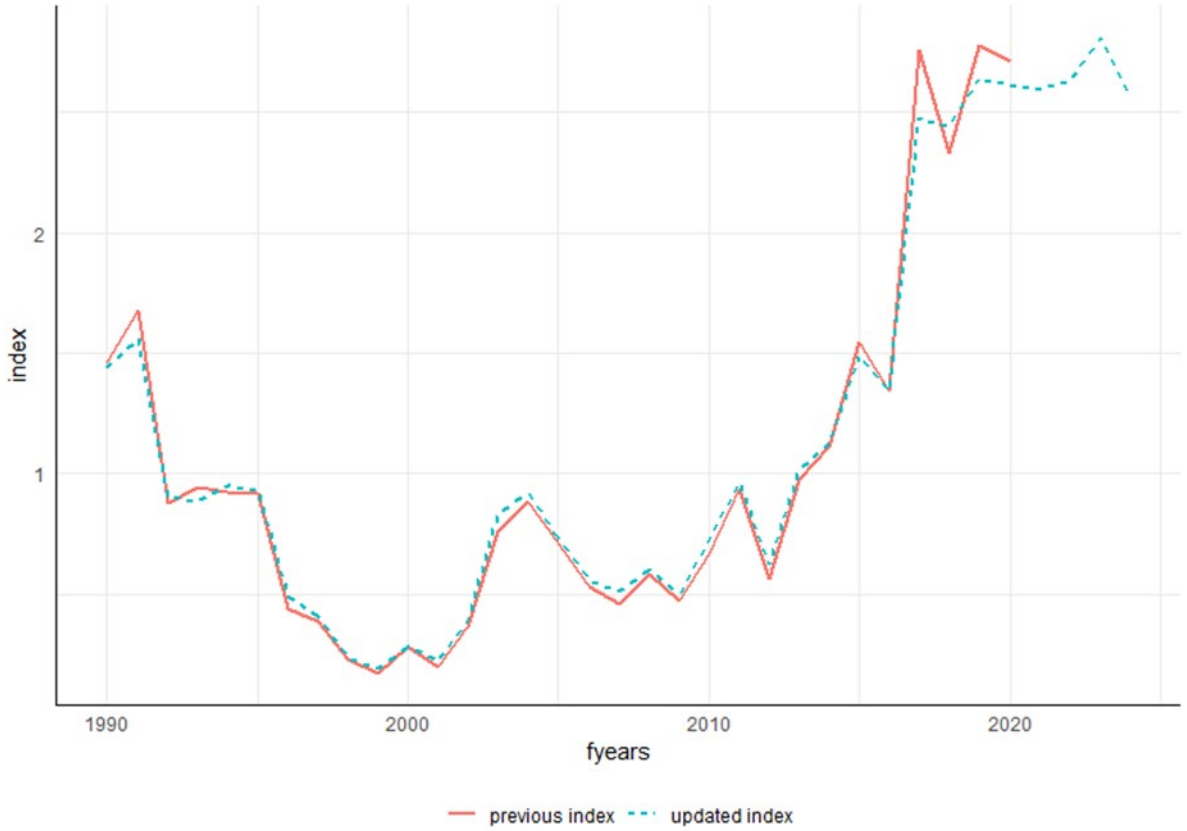


Figure 29: Starr et al. (2024) and updated SKI 3 Stewart-Snares standardised binomial index comparison. Indices are scaled to have a mean of 1.0.

The binomial model residuals on the response variable (proportion positive catch) predictions show good conformity to normality assumption over the 95% range of the data (Appendix 6). Similarly, there were no obvious model predictive issues in the model residuals across the range of the continuous variables (fishing-year-day and depth; Appendix 6). The DHARMa residual diagnostics in respect to the model categorical terms (fishing year, vessel, statistical area) were not ideal but better than for the log-normal model in that there was no failure of the within-group uniformity tests (Appendix 6).

As with the log-normal model, the binomial model did not have a strong standardisation effect on the predicted index with each successive term added to the model (Appendix 7).

3.3.4 Combined index

The effect of the binomial index on the combined index was to elevate the rise in predicted biomass over the recent years (Figure 30). The combined index equates to 270-fold difference between the lowest (2012) and highest points (2023) (Figure 30; Appendix 8), and fifteen-fold biomass difference between 1990 and 2023 (Figure 30; Appendix 8).

The combined index again closely matched the 2020 Starr et al. (2024) combined index over the common series years (Figure 31).

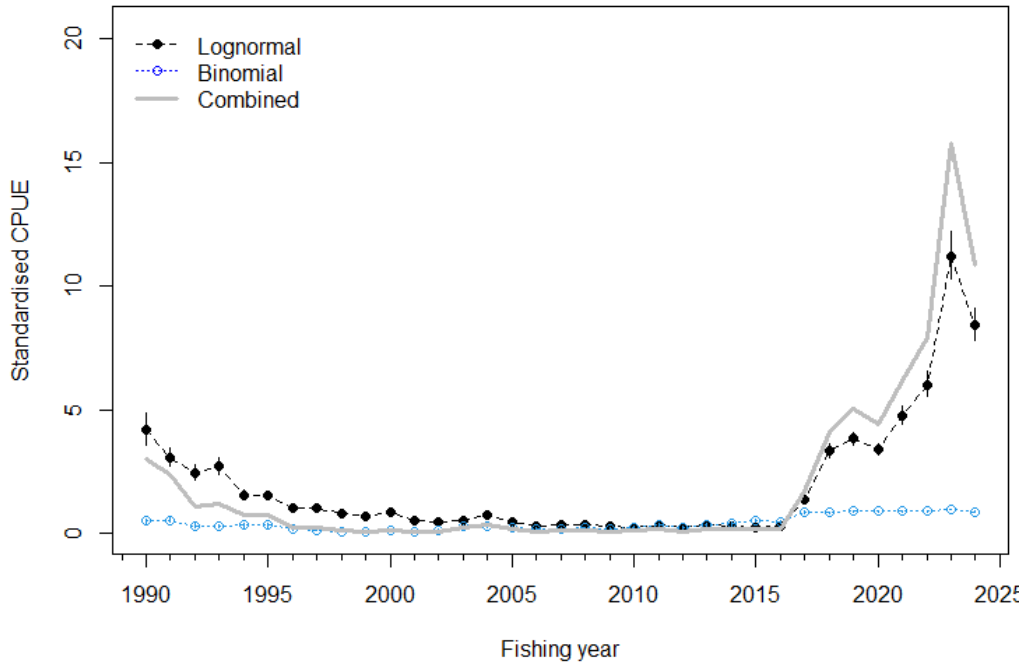


Figure 30: SKI 3 Stewart-Snares combined log-normal and binomial indices.

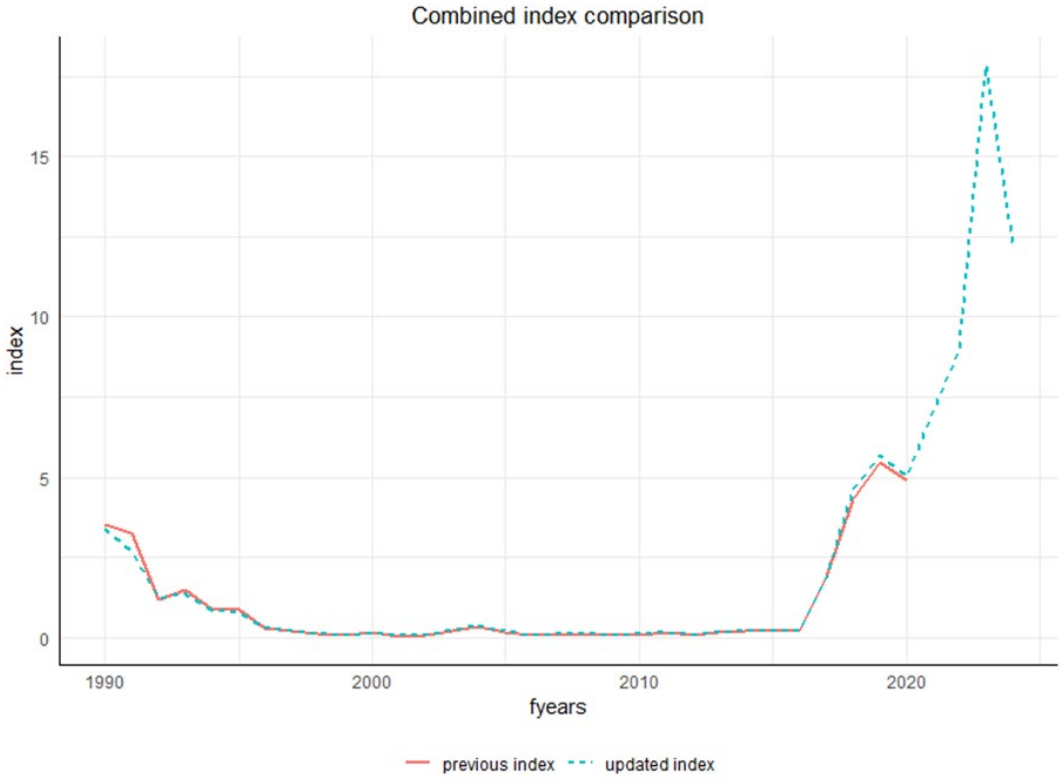


Figure 31: Starr et al. (2024) and updated SKI 3 Stewart-Snares combined index comparison. Indices are scaled to have a mean of 1.0.

3.4 SKI 7 CPUE abundance

This SKI 7 analysis was based on the BT and MW catch and effort data in the west coast South Island (WCSI) winter target hoki fishery. The analysis was constrained to Statistical Area 034 (Greymouth) and Statistical Area 035 (Westport) where most of the target hoki fishery takes place (Figure 2).

3.4.1 Core vessel selection

Core vessel selection was based on positive catch trip data only. The core fleet was defined by having fished at least once in each of four years, retaining 95% of the catch and reducing the fleet from over 150 vessels to 72 vessels (Figure 32, Figure 33). The core vessel proportion of the total annual gemfish catch only dropped below 60% in the 1990 fishing year (Figure 34).

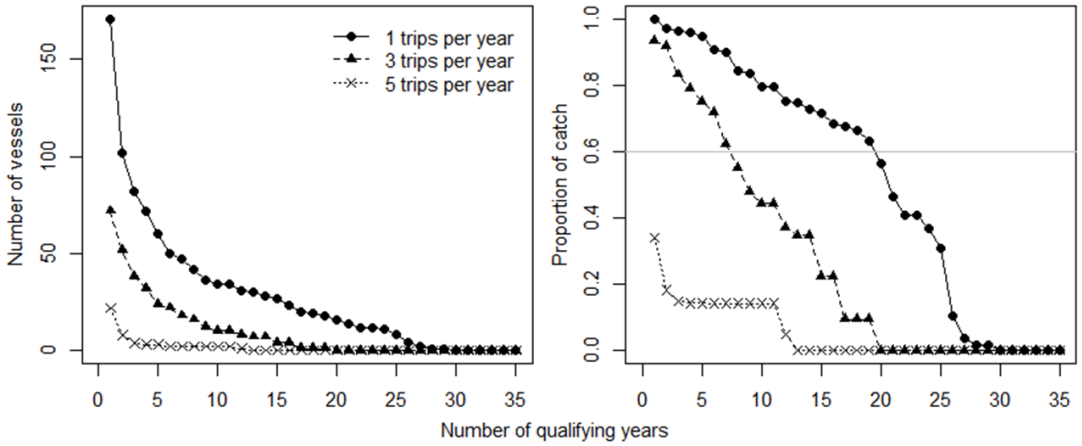


Figure 32: SKI 7 WCSI vessel selection: number of qualifying years versus the number of vessels (left panel), and proportion of total gemfish catch retained (right panel), for a minimum of 1, 3 or 5 trips per year. The grey line indicates a 60% retention of the catch in the core vessel dataset. The criteria for selection of core vessels were a minimum of 4 qualifying years and 1 trip per year.

The core vessel final data set shows a high proportion of zero trips and zero effort days across the series (Figure 35).

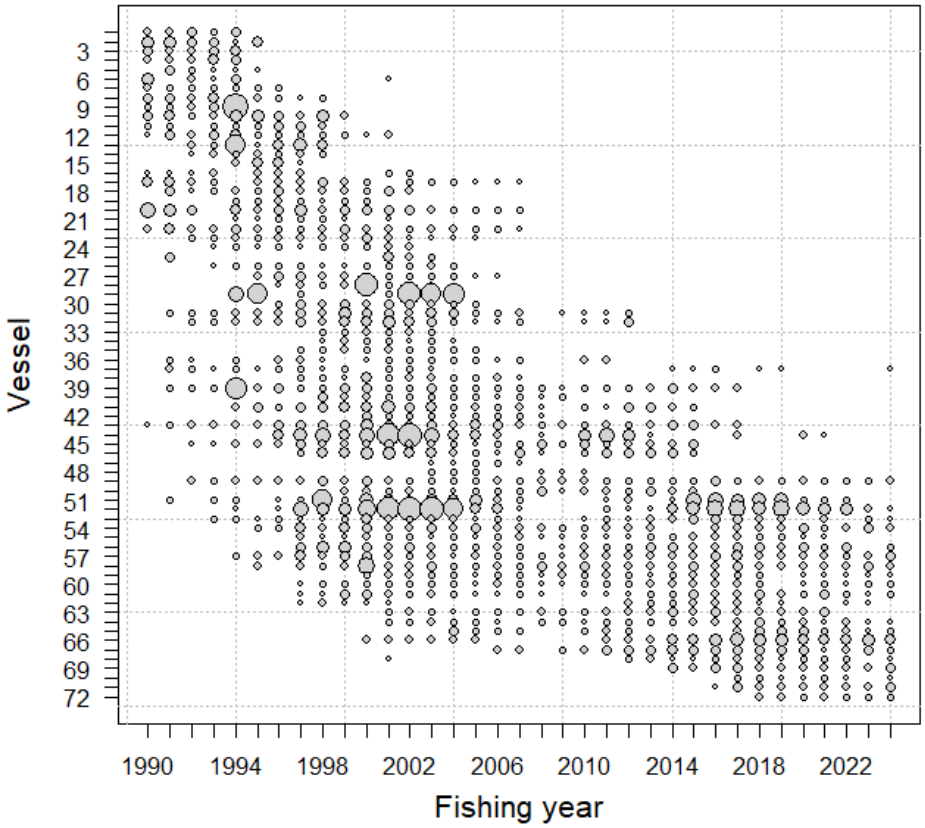


Figure 33: SKI 7 WCSI vessel core vessel relative number of fishing events from 1989–90 to 2023–24. N = 72 vessels.

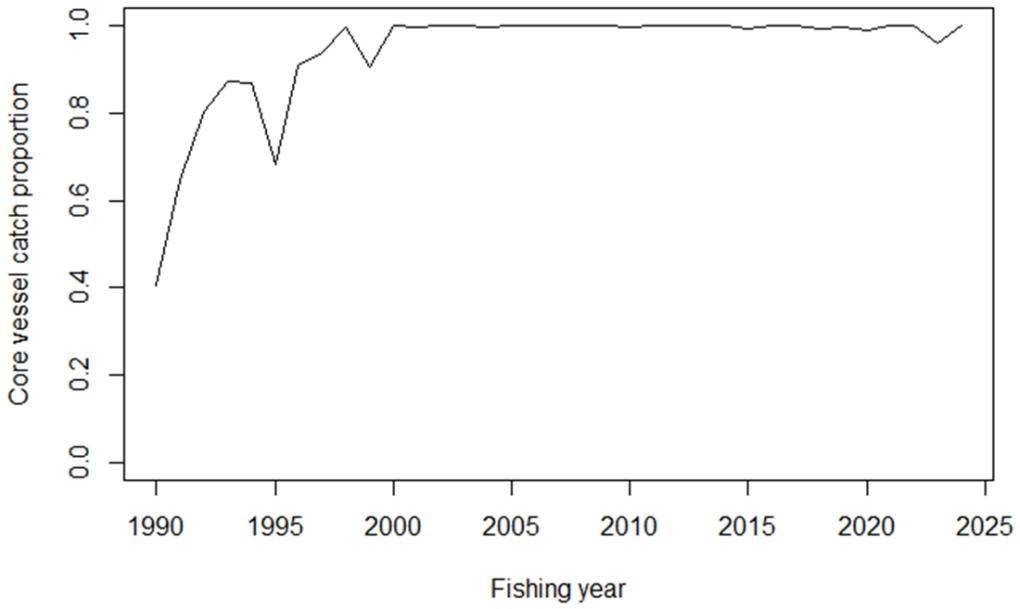


Figure 34: SKI 7 WCSI proportion of gemfish catch retained in the core vessel analyses dataset each year from 1989–90 to 2023–24, where core vessels were restricted to a minimum of 4 qualifying years and 1 trip per year.

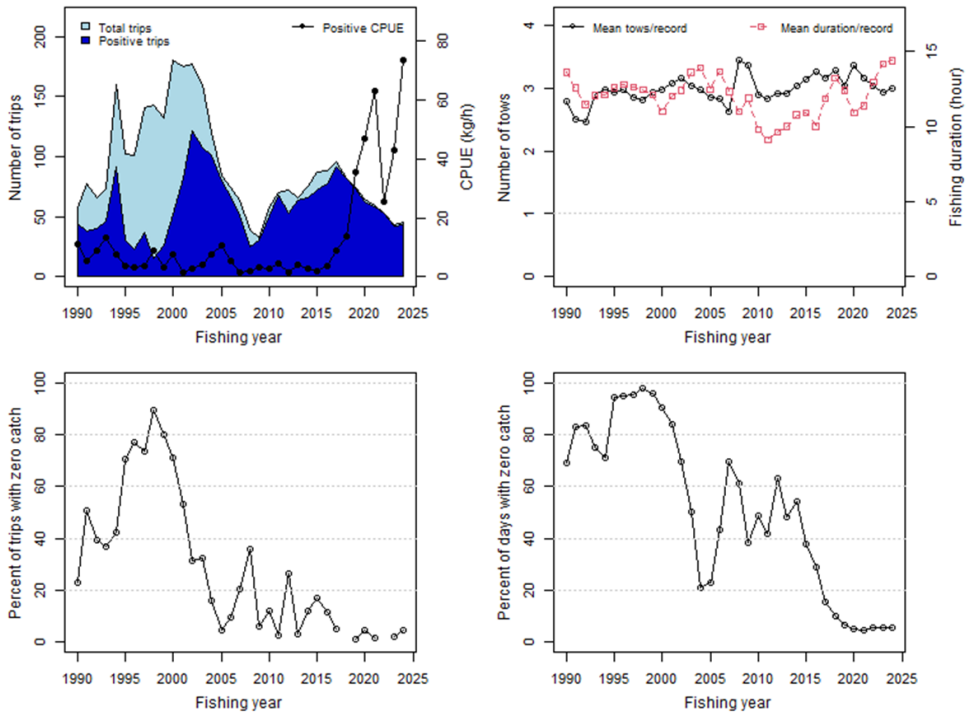


Figure 35: SKI 7 WCSI core vessel trip metrics from 1989–90 to 2023–24. Total number of trips with positive catch, and raw CPUE (top left). Percentage of trips with zero catch (bottom left), mean number of tows and mean duration per trip (top right), and mean days fished per trip (bottom right).

3.4.2 Lognormal (positive catch)

Response and covariate terms offered to the lognormal GLM standardisation models are given in Table 4.

Table 4: Model response and covariate terms offered in the SKI 7 WCSI log-normal GLM models

Variable	Fitted as	Description
Catch	Numeric	lognormal model: positive catch, log transformed binomial model: proportion zero catch ratio
Fishing year	Categorical	Fishing year (Oct-Sept)
Vessel	Categorical	Unique vessel identifier
Statistical area	Categorical	034, 035
Primary method	Categorical	BT and MW
Duration	Natural spine	Fishing duration, log transformed
Depth	Basic spine	Bottom depth
Fishing-year day (i.e. 1 October = 1)	Basic spine	1–365

Preliminary diagnostics of the response and covariate model terms suggest that the data comply with the normality and other requirements of the log-normal GLM analyses (Appendix 9).

The final lognormal model accepted four predictive variables after fishing year (fishing year day, vessel, bottom depth, and method), with the total model explaining 57% of the variation in the response variable (R^2).

Table 5: Predictor variables accepted in the standardised log-normal CPUE model, the degrees of freedom (Df) and the proportion of variance in the model explained by addition of each variable (R^2).

Predictors	Df	R^2
Fishing year	34	0.35
Fishing year day	3	0.46
Vessel	71	0.54
Depth	3	0.55
Primary method	1	0.57

The standardised canonical index from the model shows a progressive decline during the 1990s and early 2000s. After 2001, abundance increased to a peak in 2005 after which declined, remaining low through to the beginning of the current rise in 2017 (Figure 36). The index equated to a 74-fold difference between the lowest (2001) and highest points (2024) (Figure 36) and nine-fold biomass difference between 1990 and 2024 (Figure 36).

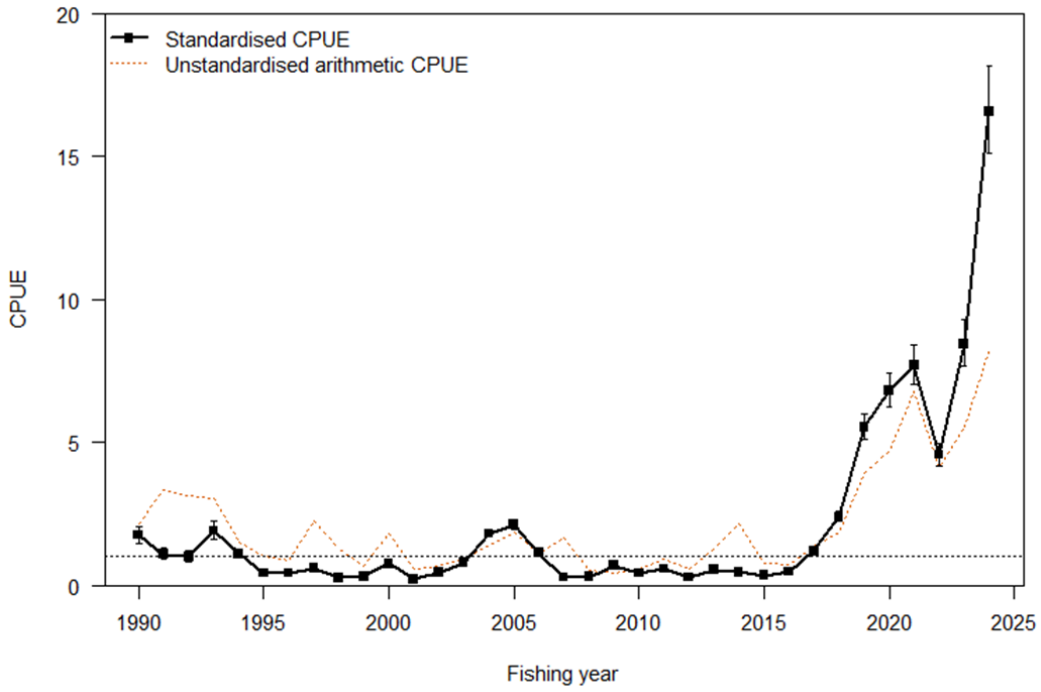


Figure 36: SKI 7 WCSI standardised log-normal canonical CPUE indices for core vessels from 1989–90 to 2023–24. The arithmetic unstandardised index for core vessels is also shown. Error bars are 95% confidence intervals. Indices are scaled to have a mean of 1.0.

The standardised canonical index from the model closely matched the 2020 Starr et al. (2024) index over the common series years (Figure 37).

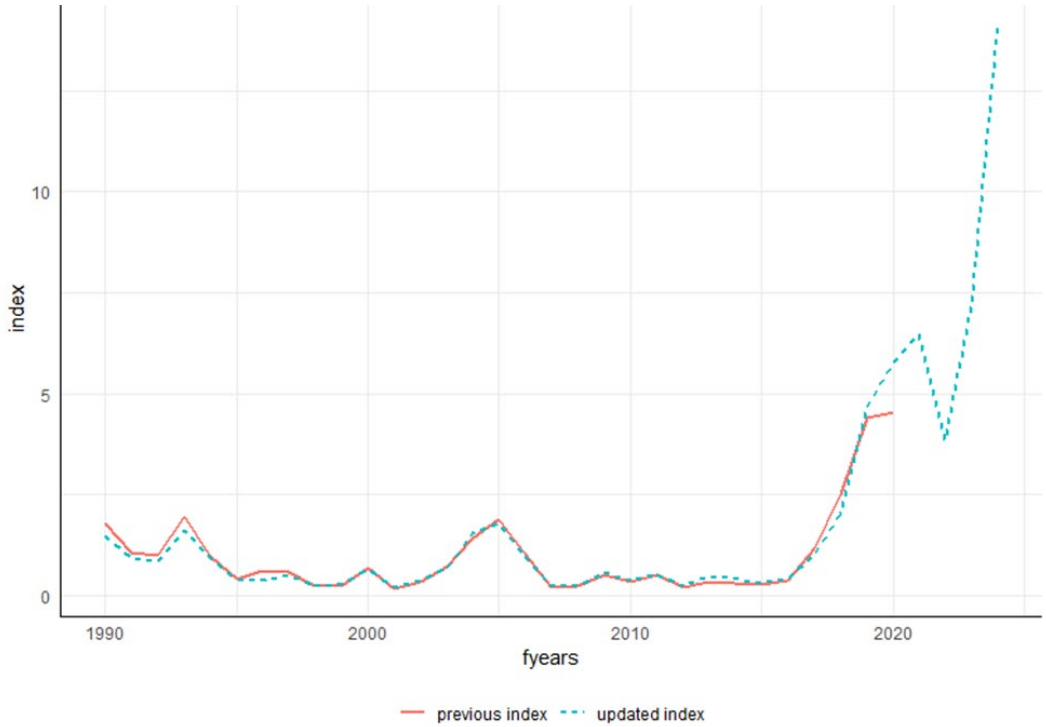


Figure 37: Starr et al. (2024) and updated SKI 7 WCNI standardised log-normal canonical CPUE index comparison. Indices are scaled to have a mean of 1.0.

The lognormal model residuals on the response variable (log-catch) predictions show good conformity to normality assumption over the 95% range of the data (Appendix 9). Similarly, there were no obvious predictive issues in the model residuals across the range of the continuous variables (fishing year day and depth; Appendix 10). However, the residual diagnostics in respect to the model categorical terms (fishing year, vessel, method) were less than ideal with apparent failures of the between group homogeneity-of-variance assumption and or the within-group uniformity assumption (Appendix 10).

As seen in Figure 36 the log-normal model did not have a strong standardisation effect on the predicted index with each successive term added to the model (Appendix 11).

3.4.3 Binomial (proportion-zero)

Response and covariate terms offered to the binomial GLM standardisation models are given in Table 1.

The final binomial model accepted four predictive variables after fishing year (vessel, fishing year day and bottom depth), with the total model explaining 45% of the variation in the response variable (R^2) (Table 6).

Table 6: Predictor variables accepted in the standardised binomial CPUE model, the degrees of freedom (Df) and the proportion of variance in the model explained by addition of each variable (R^2).

Predictors	Df	R^2
Fishing year	34	0.37
Vessel	71	0.40
Fishing year day	3	0.43
Depth	3	0.45

The predicted binomial predicted proportion positive catch index shows a pronounced rise until 2005 followed by a decline before the 2017 rise in catch (Figure 38).

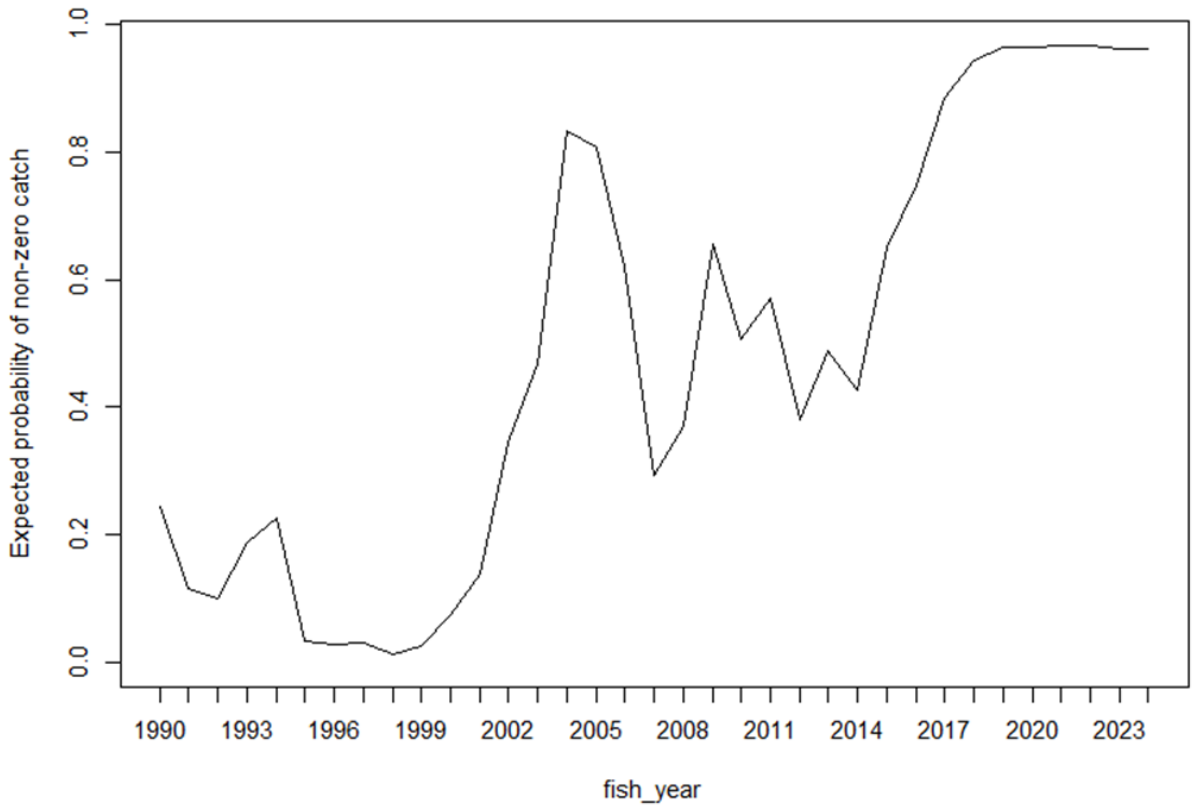


Figure 38: SKI 7 WCSI standardised binomial index on the expected non-zero catch proportion.

The binomial index from the model closely matched the comparable 2020 Starr et al. (2024) index over the common series years (Figure 29).

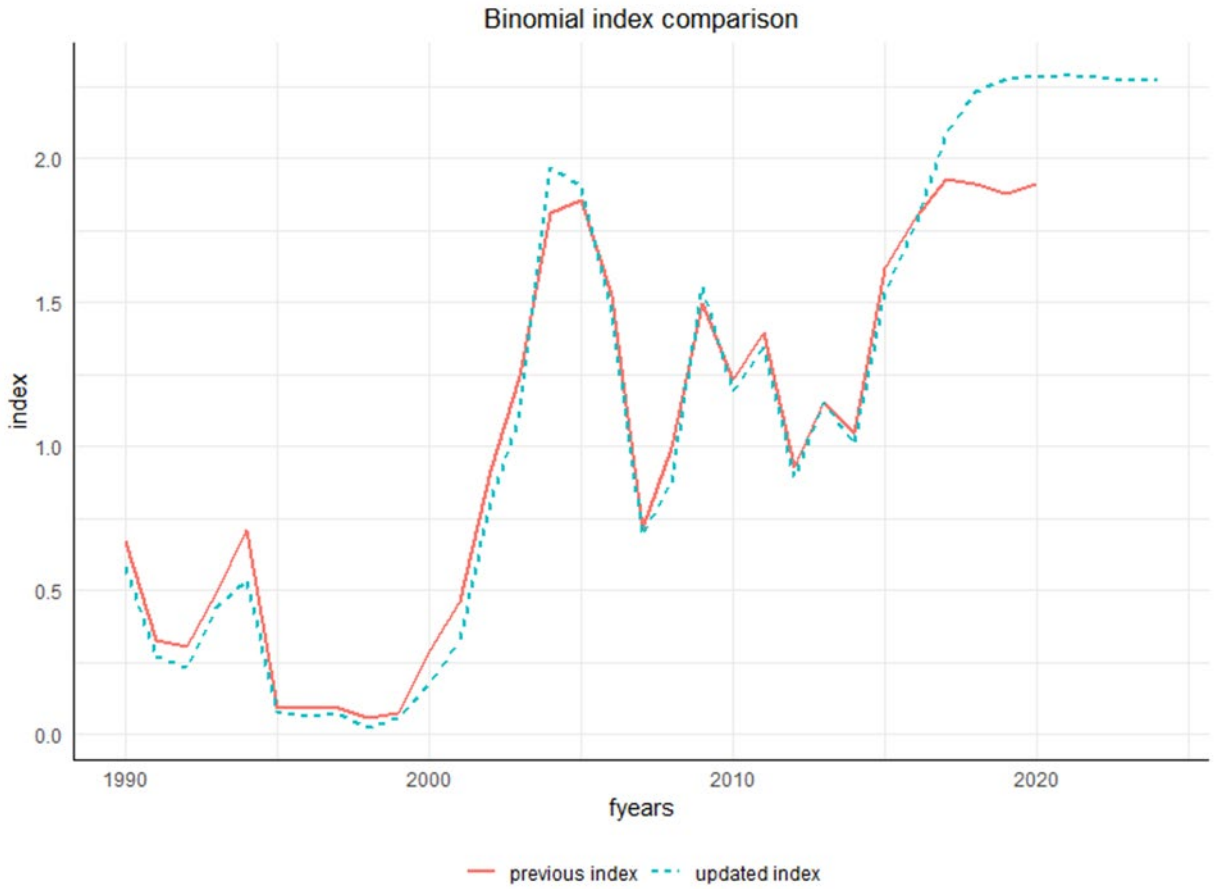


Figure 39: Starr et al. (2024) and updated SKI 7 WCSI standardised binomial index comparison. Indices are scaled to have a mean of 1.0.

The binomial model residuals on the response variable (proportion positive catch) predictions show good conformity to normality assumption over the 95% range of the data (Appendix 12). Similarly, there were no obvious model predictive issues in the model residuals across the range of the continuous variables (fishing year day and depth; Appendix 12). The DHARMa residual diagnostics in respect to the model categorical terms (fishing year, vessel) were not ideal but better than for the log-normal model (Appendix 12).

As with the log-normal model, the binomial model did not have a strong standardisation effect on the predicted index with each successive term added to the model (Appendix 13).

3.4.4 Combined index

The effect of the binomial index on the combined index was to elevate the rise in predicted biomass over the recent years (Figure 40). The combined index equates to a biologically impossible 5500-fold difference between the lowest (1998) and highest points (2024) (Figure 40; Appendix 14), and nineteen-fold biomass difference between 1990 and 2024 (Figure 40; Appendix 14).

The combined index closely matched the comparable 2020 Starr et al. (2024) combined index over the common series years (Figure 31).

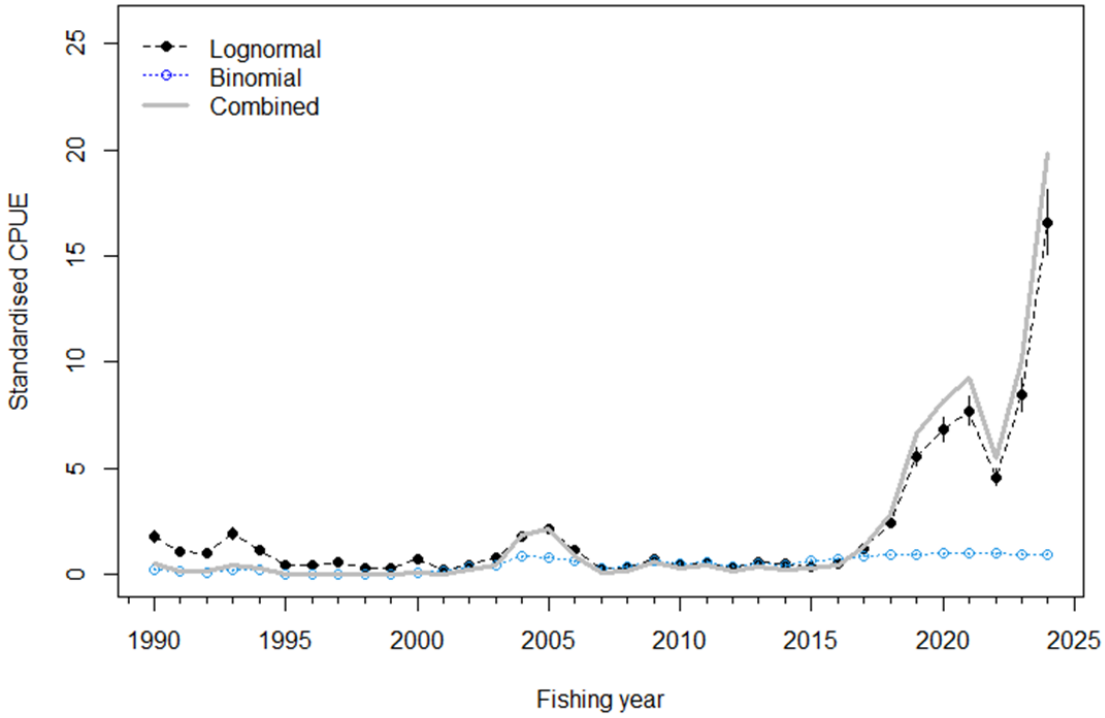


Figure 40: SKI 7 WCSI combined log-normal and binomial indices.

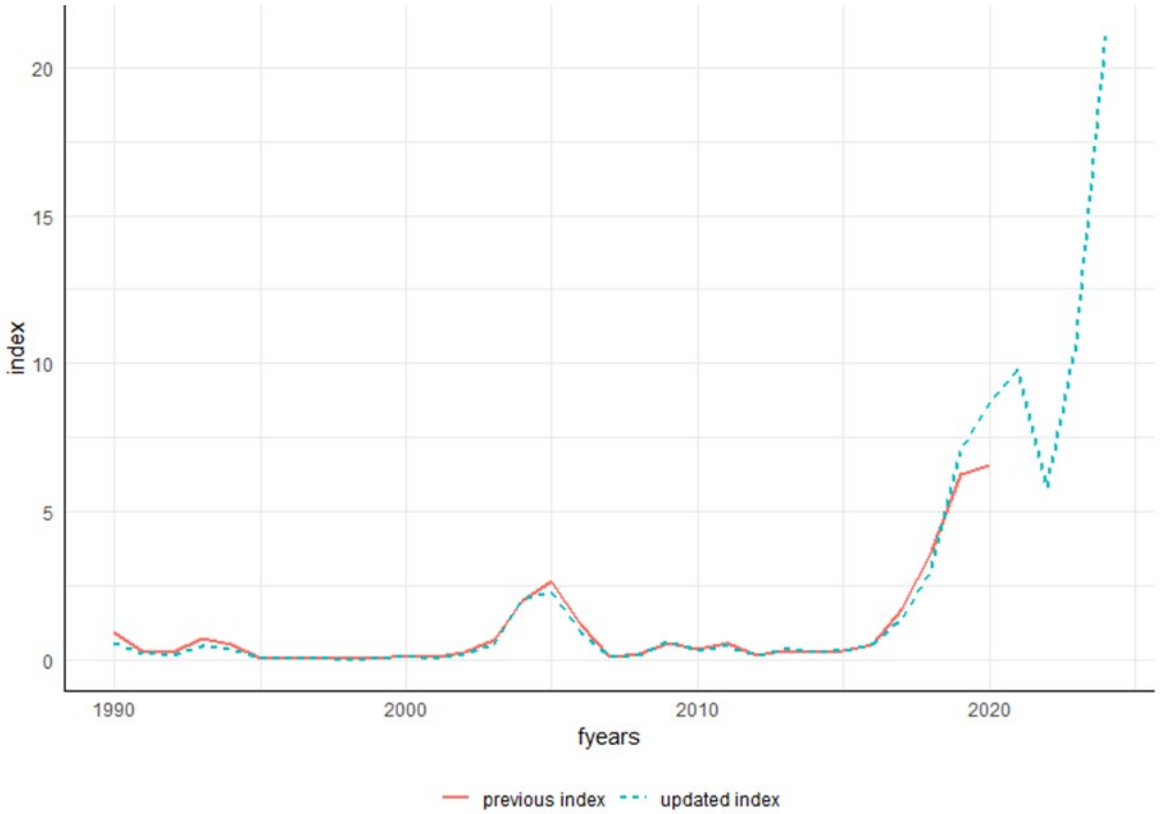


Figure 41: Starr et al. (2024) and updated SKI 7 WCSI combined index comparison. Indices are scaled to have a mean of 1.0.

4 AGE-STRUCTURED STOCK MODELLING ASSESSMENT OF THE SOUTHERN GEMFISH STOCK (SKI 3 & 7)

4.1 Model overview

Like the Langley (2020) model, the revised model was an age-structured total catch-history model. Recruitment (R_{year}) into the model occurred at age-1, with 15 explicit age classes represented in the model, the last being a plus-group (15+). The model age structure was further disaggregated by sex (male and female) and so the model was explicitly able to account for observed sex-related differences in growth and selectivity. The model assumed the SKI 3 & 7 stock complex was homogeneously distributed across the combined SKI 3 & 7 spatial extent (Figure 1) and homogeneously distributed within each annual time-interval (i.e. the model had only one annual timestep). Spatio-temporal age/length compositional differences seen in the survey and commercial fishery observational data series were accommodated in the model by applying different selectivity ogives to these data series. The model process sequence order was: recruitment (relative to start-of-year spawning-biomass); growth (annual); 50% annual fishing mortality; 100% natural mortality; remaining 50% annual fishing mortality. The model catch-history period covered the fishing-year interval 1975–76 through to the "current" fishing year (i.e. the 2024–25 fishing year), the SKI 3 & 7 gemfish stock was assumed to have been in a relatively unexploited (virgin) state in 1974–75, i.e. $B_{1975} \approx B_0$. Fishing years were defined as the 12-month interval between 1 October 1 and 30 September 30 of the following calendar year. Unless otherwise stated, the convention in this report is to denote a fishing year by the greater of the two calendar years, e.g. 1974–75 fishing year is denoted as 1975.

The model was constructed using Fisheries New Zealand's generic stock assessment modelling package Casal2 (Casal2 Development Team 2022).

4.2 Catch History

Langley (2020) compiled SKI 3 and SKI 7 commercial catch histories for the period 1974–75 to 2018–19. These were used in the revised assessment model. Model commercial catch histories for the period 2019–20 to current (2023–24) were derived from Fisheries New Zealand provided catch data. Commercial catches in the final model year (2024–25) were assigned as the average of the most recent five fishing years. As per Langley (2020), the published catch totals were inflated by 20% prior to the introduction of the QMS in 1986 and 10% for all years after this date to account for illegal or unreported catch. The final model commercial catch history is given in Appendix 15. In line with the fishery characterisation findings in Section 2, the SKI 3 & 7 commercial catch removals were modelled specific to one bottom trawl fishery operating in each QMA i.e. modelled as two commercial trawl fisheries (SKI 3 & 7).

Consistent with Langley (2020), annual recreational and customary catches were assumed to be effectively zero in the revised assessment model.

4.3 Observational data

4.3.1 Trawl Surveys

Survey data were extracted from the Fisheries New Zealand research database. Survey stratified random abundance estimates were derived from these data using the ESNZ's survey analysis package *SurvCalc* (Francis & Fu 2012). Survey length frequency compositions were derived using the Earth Sciences NZ *CALA* (Francis & Bian 2011) analytical package.

4.3.1.1 Southern Ocean (SKI 3) *Shinkai Maru* surveys

The Japanese research vessel *Shinkai Maru* conducted several trawl surveys within the Campbell and Bounty Plateau regions of the NZ EEZ between February 1981 and July 1986. Gemfish were caught in

nine of these surveys but only the Feb 1981; Mar-Apr 1982; Mar-Apr 1983 surveys are considered comparable for the purpose assessing gemfish abundance (Table 7).

Table 7: Southern Ocean *Shinkai Maru* survey gemfish catch totals. Only the shaded surveys had comparable timing, stratification, and gear configuration parameters.

Trip code	Year	Month(s)	Catch (kg)
SHI8101	1981	Feb	5 325.5
SHI8102	1981	Oct-Nov	5 354.0
SHI8201	1982	Mar-Apr	2 155.8
SHI8301	1983	Mar	160.9
SHI8302	1983	Mar-Apr	4 911.5
SHI8303	1983	Oct-Nov	330.5
SHI8304	1983	Nov-Dec	22.5
SHI8601	1986	Jun	2 822.7
SHI8602	1986	July	3.8

4.3.1.2 *Tangaroa* Snares Shelf (SKI 3) surveys

The fisheries research vessel *Tangaroa* conducted four trawl surveys within the Stewart-Snares Shelf region between February 1993 and February 1996 (Table 8).

Table 8: Snares Shelf *Tangaroa* survey gemfish catch totals. All surveys had comparable timing stratification and gear configuration parameters.

Trip code	Year	Month(s)	Catch (kg)
TAN9301	1993	Feb-Mar	1 153.0
TAN9402	1994	Feb-Mar	565.3
TAN9502	1995	Feb-Mar	995.0
TAN9604	1996	Feb-Mar	568.0

4.3.1.3 Comparability of *Shinkai Maru* and *Tangaroa* Snares Shelf survey series

The Snares Shelf strata from the *Shinkai Maru* surveys covered approximately the same area and depths as the *Tangaroa* Snares Shelf survey series strata (Appendix 16). To combine these series allowance must first be made in the *Tangaroa* series data for the exclusion of waters within twelve nautical miles from the coast by the *Shinkai Maru* surveys (Appendix 16). However, even adjusting for spatial coverage differences between each survey series, the validity of combining the series is questionable as uncertainty exists as to the validity of the same-survey-catchability (q) assumption due to known survey differences in gear configuration (e.g. door spread, head-line height, etc) and vessel-power (Hurst & Schofield 1990; Jack Fenaughty pers. comm.). These two surveys were fitted in the updated stock assessment models with separate catchability (q) terms.

4.3.1.4 WCSI (SKI 7) *Kaharoa* survey

Gemfish is taken by the west coast South Island (WCSI) *Kaharoa* trawl survey programme. This survey series commenced in autumn 1990 and, with few exceptions, has been repeated biennially, at the same time of year (Mar-Apr). At the time of the current assessment there had been 17 surveys, the most recent being in 2023 (Appendix 17). The gemfish catch data from the WCSI *Kaharoa* series was reanalysed up to and including the 2023 survey for this assessment with allowances made for differences in survey stratum areas between recent and earlier surveys (Appendix 17).

4.3.1.5 WCSI (SKI 7) *Tangaroa* survey

Gemfish is taken by the west coast South Island (WCSI) winter *Tangaroa* trawl survey programme. This survey series commenced in August 2012 and, with a few exceptions, has been repeated triennially, at the same time of year (Jul-Aug). As at the current assessment there had been six surveys, the most recent being in 2024 (Appendix 18). The gemfish catch data from the WCSI *Tangaroa* series was reanalysed up to and including the 2024 survey for this assessment with allowances made for differences in survey stratum areas between recent and earlier surveys (Appendix 18).

4.3.2 Abundance data

4.3.2.1 CPUE

Separate SKI 7 & 3 bottom trawl CPUE indices were fitted in the revised assessment models as given in Section 3. These indices covered the model fishing year period 1989–90 to 2023–24.

4.3.2.2 Survey abundance

The revised trawl survey gemfish abundance indices used in the assessment modelling are given in Table 9. An earlier *Tangaroa* WCSI survey in 2000 was not used because that survey did not extend inshore of 300 m depth.

Table 9: Revised gemfish biomass indices (t) and coefficients of variation (CV) from trawl surveys (assuming area availability, vertical availability, and vulnerability = 1).

Fishstock	Vessel	Trip code	Date	Biomass (t)	% CV
SKI 3	*Shinkai Maru*	SHI8102	Feb 1981	4 170	19
		SHI8201	Mar–Apr 1982	3 635	32
		SHI8303	Apr 1983	6 056	33
SKI 3	*Tangaroa*	TAN9301	Feb–Mar 1993	901	19
		TAN9402	Feb–Mar 1994	327	22
		TAN9502	Feb–Mar 1995	508	25
		TAN9604	Feb–Mar 1996	454	27
SKI 7	*Kaharoa*	KAH9204	Mar–Apr 1992	144	18
		KAH9404	Mar–Apr 1994	67	29
		KAH9504	Mar–Apr 1995	21	55
		KAH9701	Mar–Apr 1997	704	83
		KAH0004	Mar–Apr 2000	120	30
		KAH0304	Mar–Apr 2003	137	23
		KAH0503	Mar–Apr 2005	474	49
		KAH0704	Mar–Apr 2007	101	19
		KAH0904	Mar–Apr 2009	143	29
		KAH1104	Mar–Apr 2011	101	34
		KAH1305	Mar–Apr 2013	113	28
		KAH1503	Mar–Apr 2015	186	17
		KAH1703	Mar–Apr 2017	545	28
		KAH1902	Mar–Apr 2019	559	22
		KAH2103	Mar–Apr 2021	433	26
		KAH2303	Mar–Apr 2023	758	26
SKI 7	*Tangaroa*	TAN1210	Jul–Aug 2012	14	32
		TAN1308	Aug 2013	11	43
		TAN1609	Aug 2016	127	23
		TAN1807	Jul–Aug 2018	702	33
		TAN2107	Jul–Aug 2021	754	18
		TAN2407	Jul–Aug 2024	755	21

4.3.3 Compositional data

4.3.3.1 Commercial catch sampling

At-sea observer sampling of the SKI 3 & 7 trawl fisheries commenced in 1989–90, with the most recent sampled fishing year going into the assessment modelling being 2023–24. Although observer sampling occurred in all the intervening fishing years, the level of sampling, both in terms of fishery spatial

coverage and numbers of fish measured, in some years was poor. Length frequency data collected in fishing years where the number of observer sampling events were fewer than 20 and/or the total number of fish measured were fewer than 500 were not fitted in the revised assessment models because of lack of spatial coverage concerns (see Appendix 19 and Appendix 20).

The lack of age information from the SKI 3 & 7 trawl fisheries was identified as a limitation in the Langley (2020) assessment. In recognition of this, Fisheries New Zealand contracted collection of otolith data from the SKI 3 & 7 trawl fisheries during the 2021–22, 2022–23, and 2023–24 fishing years for the purpose of creating age-length keys (Table 10). Age composition estimates for the SKI 3 & 7 trawl fisheries were derived by Devine et al. (2023, 2024, 2025) by application of the otolith ageing data to the observer length frequency data. Fisheries New Zealand observer otolith collections were insufficient in each of the three sampling years to derive QMA-level gemfish age-length keys (Table 10). The age-length keys applied to SKI 3 & 7 fisheries were therefore an amalgamation of age data collected from both QMAs (Table 10).

Table 10: Number of age samples collected from SKI 3 & 7 bottom trawl catches.

Fishing year	SKI 3	SKI 7	Total
2021–22	276	152	428
2022–23	193	31	224
2023–24	93	196	289

Although length composition observations were also derived from the SKI 3 & 7 observer data from 2021–22 to 2023–24, the assessment models were only fitted to the age composition observations from those years.

Uncertainty on the commercial length and age observational data series were provided to the models as multinomial error values.

4.3.3.2 Survey compositional data

Gemfish length composition observations are available from all SKI 3 & 7 survey series except for the 1981 and 1982 *Shinkai Maru* surveys (Table 11). Age information is only available from the SKI 3 *Tangaroa* surveys conducted in the 1990s (Table 11).

Uncertainty on the survey length and age observational data series were provided to the models as multinomial error values.

Table 11: Compositional data types fitted in the assessment modelling. (N/A = not available).

Fishstock	Vessel	Trip code	Date	Fitted data type
SKI 3	*Shinkai Maru*	SHI8102	Feb-81	N/A
		SHI8201	Mar–Apr 1982	N/A
		SHI8303	Apr-83	length
SKI 3	*Tangaroa*	TAN9301	Feb–Mar 1993	age
		TAN9402	Feb–Mar 1994	age
		TAN9502	Feb–Mar 1995	age
		TAN9604	Feb–Mar 1996	age
SKI 7	*Kaharoa*	KAH9204	Mar–Apr 1992	length
		KAH9404	Mar–Apr 1994	length
		KAH9504	Mar–Apr 1995	length
		KAH9701	Mar–Apr 1997	length
		KAH0004	Mar–Apr 2000	length
		KAH0304	Mar–Apr 2003	length
		KAH0503	Mar–Apr 2005	length
		KAH0704	Mar–Apr 2007	length

Fishstock	Vessel	Trip code	Date	Fitted data type
		KAH0904	Mar–Apr 2009	length
		KAH1104	Mar–Apr 2011	length
		KAH1305	Mar–Apr 2013	length
		KAH1503	Mar–Apr 2015	length
		KAH1703	Mar–Apr 2017	length
		KAH1902	Mar–Apr 2019	length
		KAH2103	Mar–Apr 2021	length
		KAH2303	Mar–Apr 2023	length
SKI 7	*Tangaroa*	TAN1210	Jul–Aug 2012	length
		TAN1308	Aug-13	length
		TAN1609	Aug-16	length
		TAN1807	Jul–Aug 2018	length
		TAN2107	Jul–Aug 2021	length
		TAN2407	Jul–Aug 2024	length

4.4 Model productivity dynamics

4.4.1 Growth

Growth estimates (Von Bertalanffy) for the southern gemfish stock came from Horn & Hurst (1999) (see Table 13 below) as derived from the age data collected during the early 1990s SKI 3 *Tangaroa* survey series (Table 11).

Marked progressions of length frequency modes were evident in SKI 3 & 7 length compositional series (Appendix 21). Independent growth estimates were derived from these data series to both assess the power the assessment models had to estimate growth and identify YCS modes (Appendix 21).

Male and female gemfish VB growth parameter estimates were derived from the SKI 3 & 7 observer data series using Electronic LEngth-Frequency ANalysis (ELEFAN) algorithm methods first developed by Pauly & David (1981). The ELEFAN analyses were conducted using the FAO R package TropFishR (Sparre & Venema 1998; 1999). The ELEFAN model used a genetic algorithm fitting approach for parameter estimation (Appendix 21).

The SKI 3 & 7 ELEFAN male and female growth parameter estimates are consistent with the Horn & Hurst (1999) growth estimates (Table 12). The closeness of the ELEFAN observer growth prediction results to the Horn & Hurst (1999) known-age analytical results lends weight to the assumption that the 'discernible' mode progressions in the observer length frequency series reflect individual year class modes (Appendix Figure 35 and Appendix Figure 36).

Table 12: Male and female Horn & Hurst (1999) southern gemfish stock growth estimates compared to ELEFAN observer data estimates (see Appendix 21).

Sex	Fishstock	Source	*Linf*	*K*	*t0*
Female	SKI 3	Horn & Hurst (1999)	104.2	0.178	-0.86
	SKI 3	ELEFAN observer estimates	108.23	0.134	0.873
	SKI 7	ELEFAN observer estimates	103.94	0.159	0.334
Male	SKI 3	Horn & Hurst (1999)	88.5	0.242	-0.68
	SKI 3	ELEFAN observer estimates	100.09	0.134	0.251
	SKI 7	ELEFAN observer estimates	94.17	0.174	0.361

4.4.2 Natural mortality (*M*)

The natural mortality estimate of Horn & Hurst (1999) (M = 0.25; Table 13) was assumed in the base model assessment and applied to both sexes. However, base-model sensitivity runs at M values of 0.2 and 0.3 were also undertaken.

4.4.3 Steepness (*h*)

Langley (2020) used an assumed value of 0.85 for the Beverton & Holt steepness (h) parameter. This value was again assumed for the base-case assessment model; however, sensitivity runs at h values of 0.75 and 0.95 were also undertaken.

4.4.4 Maturity

The maturity at-age ogive used in the assessment model was based on Hurst & Bagley (1998) trawl survey age and maturity observations. Hurst & Bagley found some male and female gemfish were mature as young as age two and ascertained that the age of 50% maturity is likely to be around three years of age. Although uncertainty exists as to the proportion mature at age, the Hurst & Bagley observations indicate that nearly 100% of gemfish older than 5 years are mature.

4.5 Model structure

4.5.1 Fixed parameters

Model fixed parameters (Table 13) were assumed to be time invariant which in the case of growth is a strong assumption. Uncertainty relating to time-varying growth was not explored in the current assessment.

Table 13: Fixed productivity parameter values.

Natural mortality	0.25 y^{-1}
Stock-recruit steepness	0.85
Proportion mature (both sexes)	(0.1,0.4,0.8,1.0) for ages 1 - 5
Length-weight [mean weight (tonnes) = a (length (cm))^b]	
Male	$a = 1.2 \times 10^{-9}$, $b = 3.41$
Female	$a = 9.5 \times 10^{-10}$, $b = 3.47$
Growth (VB)	
Male	$Linf = 88.5$, $K = 0.242$, $t0 = -0.68$
Female	$Linf = 104.2$, $K = 0.178$, $t0 = -0.86$

4.5.2 Estimated parameters

B_0 was an estimated parameter in all assessment model variants and pertained to the unfished (virgin) mature stock mean biomass (Table 14).

Despite the addition of recent catch at-age observations from the SKI 3 & 7 trawl fisheries, the assessment models were still challenged by the lack of historical age compositional data from which to estimate recruitment variation (i.e., Year Class Strength YCS). As with the Langley (2020) assessment model, the updated assessment models were largely informed of pre-2010 YCSs by the observer length frequency data series. Model YCS predictions therefore depended on their ability to discern individual YCS modes in the annual length frequency observations. The earliest compositional series (length/age) comes from the 1981 *Shinkai Maru* survey which, given the expected age range of gemfish available to this survey, provided YCS information back to 1975. The full compositional series covered YCS period 1975 through 2023 (i.e. 49 estimable YCS; Table 14). The sex ratio of the age-one derived annual recruitments entering the model was 50:50.

As discussed in Section 4.4.1, the length compositional series, in some years, contains discernible YCS length modes of sufficient resolution to estimate growth. The current assessment models are strongly dependent on the growth parameter values because of the need to fit to the predominately length-based observational data series. The model VB growth and associated coefficient of variation (CV) curves are used to predict mean length at-age and the expected length distribution around it. The model uses the VB predicted length at-age distributions to project its predicted numbers at-age to expected numbers at-length. As model selectivity is specified as age-based the model first had to apply this selectivity to the population at-age vector before performing the growth transition to length. Model fits to specific area-method length data are made to the growth-projected length frequency predictions. Given the power in the length compositions to estimate growth (Section 4.4.1) the male and female model *Linf, K, cv first_age, cv last_age* VB growth parameters were estimated in the assessment modelling (Table 14).

There were six compositional series (four survey and two fishery series) fitted in the models and each had observations for male and female gemfish. The models therefore required 12 selectivity ogives to fit to these compositional series. All model selectivity ogives were specified as age-based. The SKI 3 & 7 trawl fishery selectivities were specified as logistic under the assumption that these fisheries were fully selective of the older population age classes (Table 14). All the survey selectivity ogives were specified as double-normal to give the models the freedom to predict domed selectivities for these series (Table 14). The *alpha* (proportional maximum selectivity at-age) parameter terms were fixed at 1.0 for on all male selectivity ogives. To allow the models the freedom to account for male and female proportional differences in the compositional data series, all the female selectivity model *alpha* parameter terms were estimated (Table 14).

Catchability parameters (q's) on all the abundance series fitted in the models were estimated as nuisance parameters meaning that the prior penalties associated with these parameters were not accounted for in the model maximum likelihood totals (Casal2 Development Team 2022). This is somewhat computationally equivalent to fitting the q's as free parameters assuming uniform priors, in that the estimated q values from both approaches are typically similar.

Table 14: Assessment models estimated parameters.

Type	Description	No. of parameters	Prior
B_0	Mean unfished Spawning Stock (mature) Biomass	1	uniform_log
YCS	Year-class strengths by year and stock	49[1]	lognormal[2]
Growth (mean length at-age)			
male *(vB) Linf, K, cv first_age, cv last_age*		4	uniform
female(vB) *Linf, K*		2[3]	uniform
Selectivity (all age-based)			
SKI 3 *Shinkai Maru* (double-normal) male *mu*, σ_L, σ_R		3	uniform
SKI 3 *Shinkai Maru* (double-normal) female *mu*, σ_L, σ_R, *alpha*		4	uniform
SKI 3 *Tangaroa* (double-normal) male *mu*, σ_L, σ_R		3	uniform
SKI 3 *Tangaroa* (double-normal) female *mu*, σ_L, σ_R, *alpha*		4	uniform
SKI 7 *Tangaroa* (double-normal) male *mu*, σ_L, σ_R		3	uniform
SKI 7 *Tangaroa* (double-normal) female *mu*, σ_L, σ_R, *alpha*		4	uniform
SKI 7 *Kaharoa* (double-normal) male *mu*, σ_L, σ_R		3	uniform
SKI 7 *Kaharoa* (double-normal) female *mu*, σ_L, σ_R, *alpha*		4	uniform
SKI 3 Observer (logistic) male *a50, ato95*		2	uniform
SKI 3 Observer (logistic) female *a50, ato95, alpha*		3	uniform
SKI 7 Observer (logistic) male *a50, ato95*		2	uniform
SKI 7 Observer (logistic) female *a50, ato95, alpha*		3	uniform
q's survey abundance and CPUE		4–6[4] / 98–100	as nuisance

[1]YCSs were estimated for years 1975–2023
[2]Sigma_r =1.8
[3]*female cv first_age = male, female cv last_age =male*
[4]model dependant

Additional penalties imposed on the likelihood terms were a penalty multiplier if the fisheries catch history could not be taken in any model year (i.e. exceeded the model U_{max} of 0.99), and a penalty imposed when the model estimated YCSs do not average to 1.0. The likelihood penalty on the catch history was 100 (strong penalty). Whereas the penalty term on the YCS average was 1.0 (effectivity no constraint) for reasons given in the Discussion (Section 5).

4.5.3 Model fitting

All model evaluations were undertaken based on Medium Posterior Density (MPD) fitting results from the Casal2 auto-differentiation minimiser ADOL_C (https://projects.coin-or.org/).

The survey abundance likelihoods were fitted in the models pursuant to the derived survey CVs with an additional process error of 0.1. The SKI 3 and SKI 7 CPUE indices (Section 3) were fitted using an assumed CV of 0.1.

Error on the compositional likelihoods were specified as multinomial initial values being those derived from the CALA analyses. The Francis TA1.8 reweighting process was used to down-weight the individual compositional likelihoods relative to assumed error on the abundance likelihoods (Francis & Bian 2011).

Ageing error was assumed by the models to be normally distributed with a low CV of 0.03.

Uncertainty on the base-model prediction outcomes was determined based on 95% credibility intervals derived from Bayesian MCMC sample posteriors.

4.6 MPD base-model selection

Model fitting issues to the compositional length observational data series (not shown in this report) during early model exploration runs were reduced after aggregating the length compositional data into 5-cm length bins.

Three candidate models were evaluated:

1. Full or all-abundance likelihood model;
2. CPUE abundance only likelihood model;
3. Survey abundance only likelihood model.

Note: growth was initially not estimated in the model evaluation comparisons.

All candidate base-case models estimated the stock to have been well above carrying capacity (B_0) in 2025, with 2025 annual fishery removals relative to biomass (U_{2025}) being in the order of only 3% or lower (Table 15).

Table 15: Model B_0 and stock status MPD predicted values

Model	B_0	% $B_{0\ 2025}$	U_{2025}
All-abundance	82 958	197%	0.016
CPUE-abundance	86 101	173%	0.017
Survey-abundance	48 720	174%	0.030

Issues with the All-abundance and CPUE-abundance are evident in the model stock-status and Spawning Stock Biomass (SSB) trajectory plots (Figure 42), these models predicted the stock to have been implausibly low relative to B_0 in 2000 (All-abundance 1.7%; CPUE-abundance 0.4%). In contrast the lowest stock status predicted by the Survey-abundance model was, a more plausible 14.7% in 2000 (Figure 42). Both the All-abundance and CPUE-abundance models needed to account for the extreme increase in the SKI 3 & 7 CPUE abundance indices after 2015 (Appendix Figure 37 & Appendix Figure 45), to do so, both models needed to reduce the stock down to extreme low levels prior to 2015. Both models did this by estimating a combination of higher initial B_0 values (Table 15) and stronger pre 1985 YCS deviates (Figure 43).

The working group rejected the two CPUE models, deeming the level of stock increase in the CPUE indices was “implausibly high” thus the survey-abundance model was accepted as the base-case.

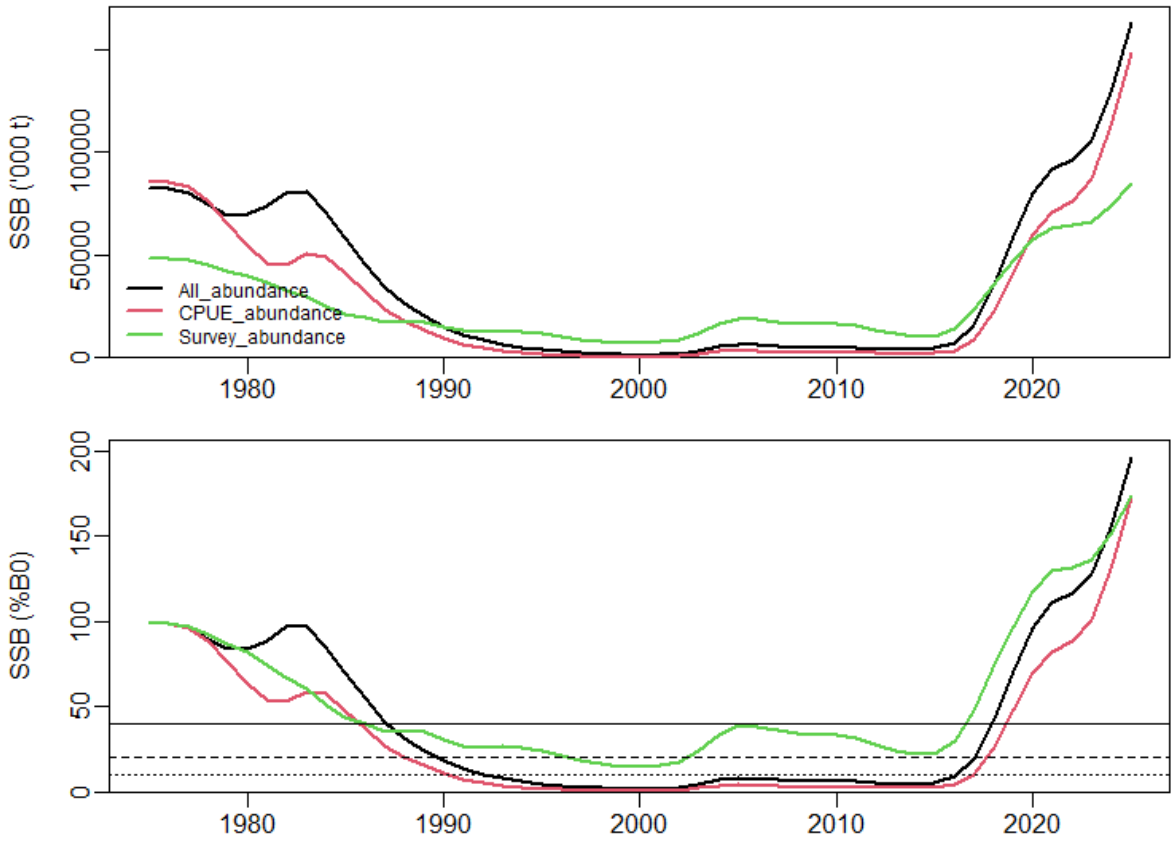


Figure 42: Model % B_0 and SSB predicted catch history trajectories.

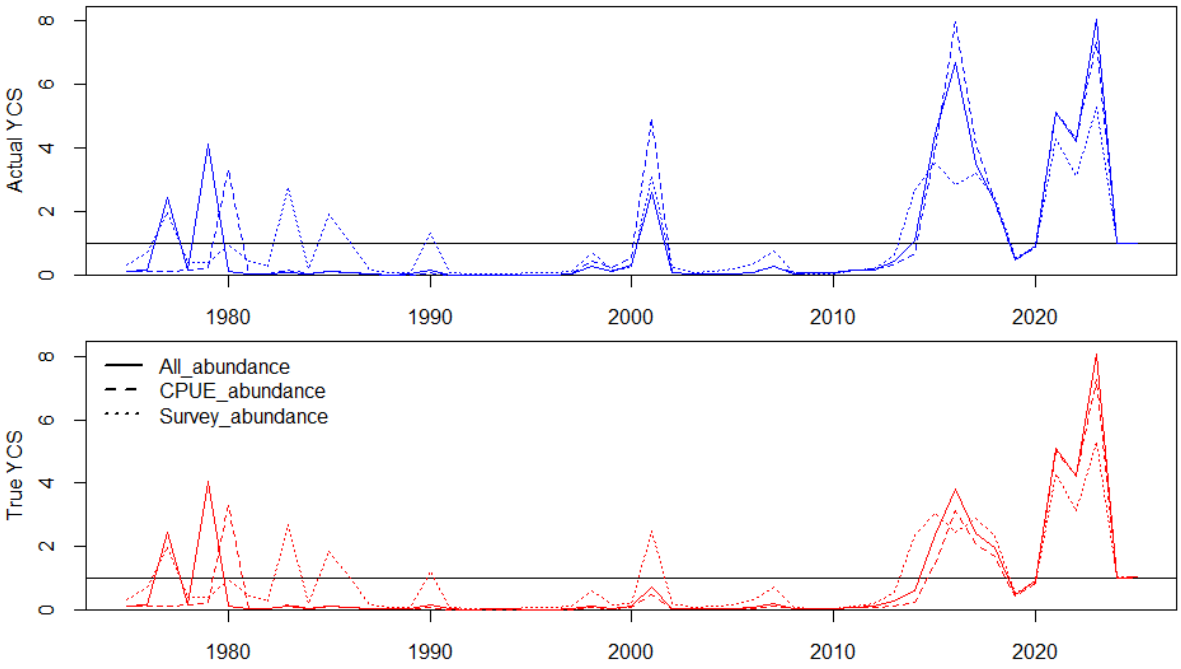


Figure 43: Model actual (raw) and true (steepness adjusted) predicted YCSs.

4.6.1 Base case growth estimation model AIC comparative fits

Estimating growth in the Survey-abundance model, although adding more free parameters (Table 14), resulted in an overall MPD likelihood reduction. The addition of the growth parameters resulted in reduction in model likelihood AIC (Table 16) validating the inclusion of growth estimation in the model. Most of the improved fit occurred in the compositional likelihoods, the abundance likelihood fits being slightly degraded (Figure 44).

Table 16: Overall MPD likelihood improvement on survey-abundance model with growth estimation

Model	B_0	Total likelihood	Free parameters	AIC
Survey-abundance	48 720	295.65	88	767.3
Survey-abundance_growth	39 394	281.27	94	750.54

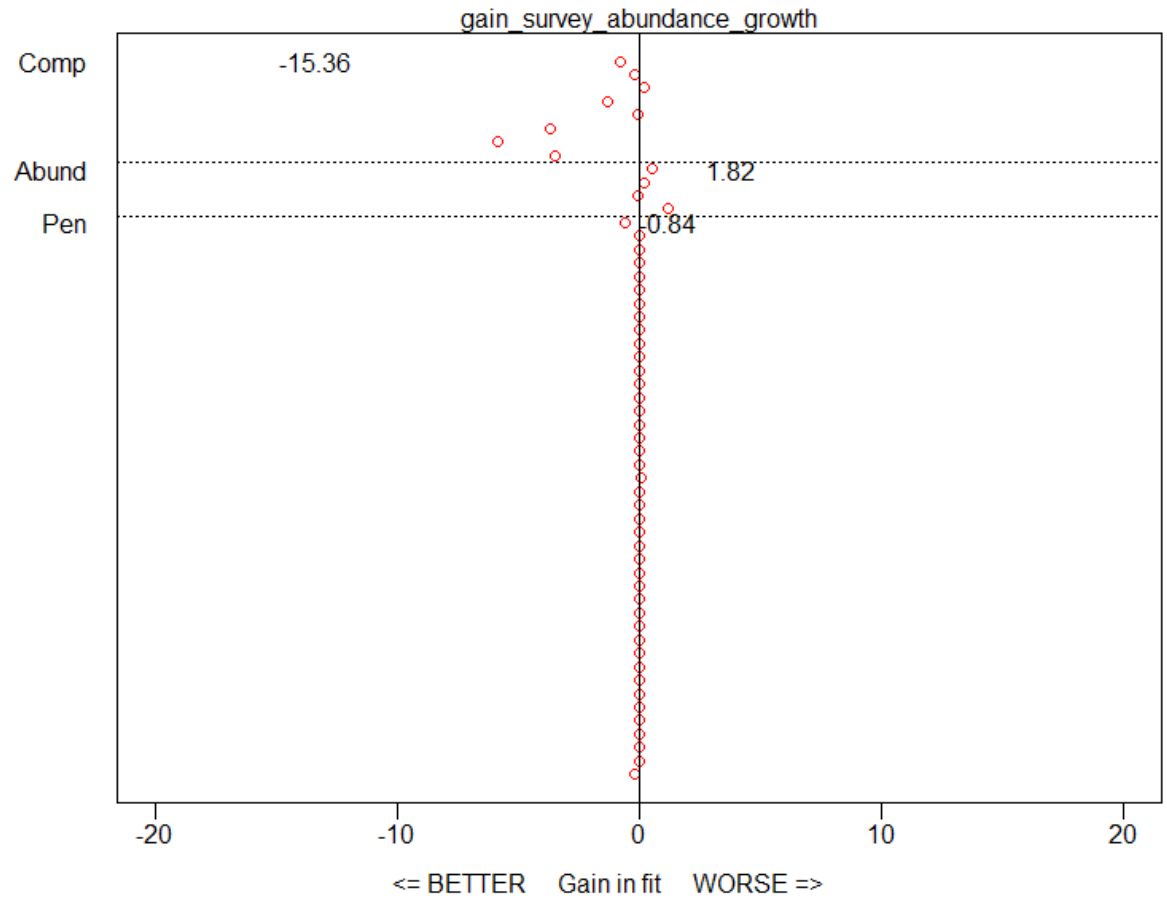


Figure 44: Likelihood gains and losses in the Survey-abundance growth estimation model relative to the fixed growth model by observational data class.

The Survey-abundance growth model biggest change on growth was to constrain the distribution of length about mean-age (i.e. *cv_first* and *cv_last* parameter reductions) which had the effect of reducing the length ranges the model numbers at-age could be projected across (darker shaded areas in Figure 45).

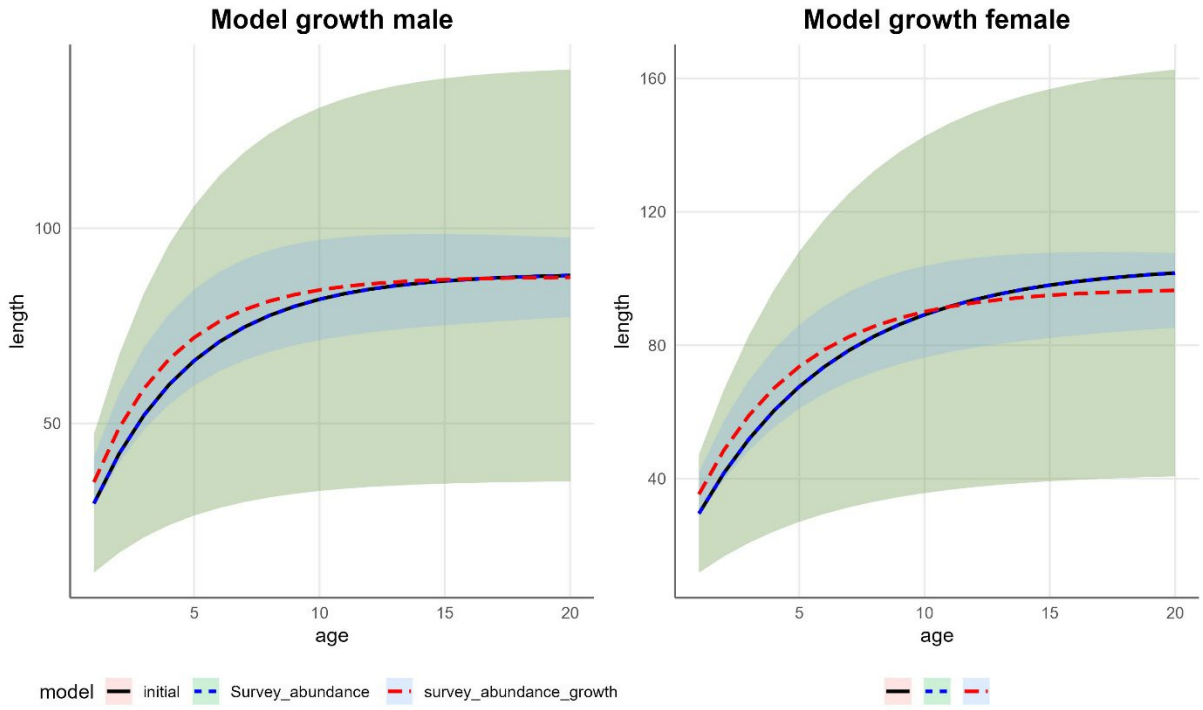


Figure 45: Change in male and female growth curves and model predicted distribution of length about mean-age (shaded areas) in the Survey-abundance growth model vs the fixed growth Survey-abundance model.

The Working Group accepted the Survey-abundance growth model as the base model.

4.7 Base-case MPD estimates and stock status predictions

The survey-abundance growth estimation model (henceforth termed the base-model) was iteratively reweighted, fits to the observational data series are given in Appendix 25. The reweighted base model B_0 estimate was 41 103 tonnes. The predicted stock status in 2025 was 176% B_0, the stock's lowest level status was 13.5% B_0 in 2000 (Figure 46).

The base-model predicts the stock to have experienced protracted periods of low recruitment (effectively zero) between 1990 and 2013 and a sustained period of above-average recruitment commencing after 2013 (Figure 47). Renwick et al. (1998) found YCS in southern gemfish to be significantly linked with the frequency of south-westerly airflows and with sea surface temperature (SST) anomalies, averaged over the winter half of the year. They found strong year classes to be associated with infrequent southwesterlies and with positive SST anomalies. It is therefore highly likely the recent period of above average recruitment in the southern gemfish stock is due climate-change induced ocean warming.

The likelihood of a climate-induced productivity shift in the southern gemfish stock has strong implications for management. Under this scenario, the base model B_0 estimate, which is highly determined on model predicted average recruitment since 1975, is likely to underestimate current "true" stock productivity potential (i.e., B_0 current). Under a regime-shift scenario, B_0 reference sustainability measures, as derived from the base-model, are less appropriate for management than exploitation-rate reference sustainability measures (F-ref) (Marsh et al. 2024).

The $U_{B040\%}$[2] reference rate from the base-model (as derived from projecting the base-model to attain $B_0$40% equilibrium) was 0.18 (Appendix Figure 65). $U_{B040\%}$ is a per-recruit reference measure meaning that it is relatively insensitive to the "true" B_0 value i.e. changing B_0. However, the utility of $U_{B040\%}$ for management is predicated on model predictions of SSB. Under a $U_{B040\%}$ sustainability measure

[2] The annual proportional removal rate (U) that produces 40% B_0 under deterministic model projection.

uncertainty in the assessment shifts from uncertainty on model B_0 estimation to uncertainty on model SSB estimation. The base-model predictions of annual fishing pressure (U) show the stock as having been well below $U_{B040\%}$ since the early 1990s (Figure 48), U_{2025} was 0.036 (20% $U_{B040\%}$).

Differences seen between base-model area-method selectivity ogives are more likely to be a proxy for spatio-temporal differences in the southern gemfish stock than true selectivities in the strict sense (Figure 49).

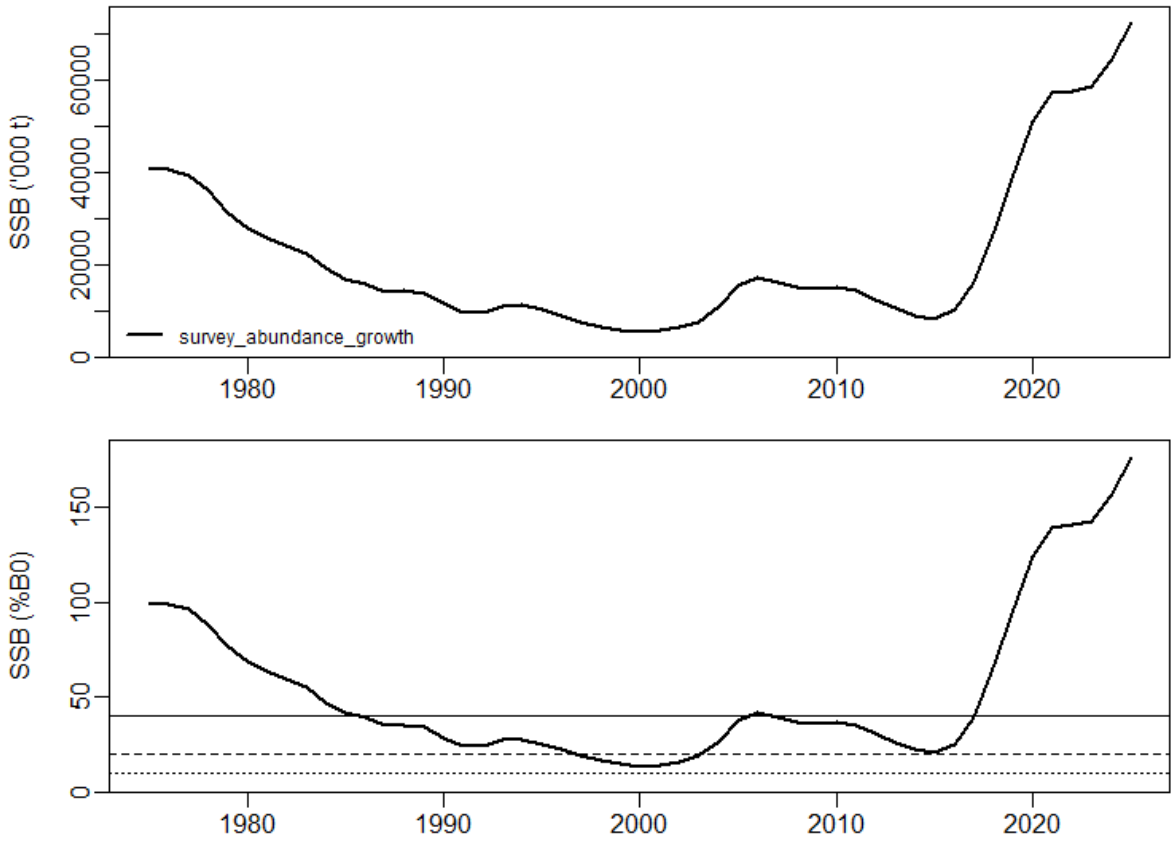


Figure 46: Base model % B_0 and SSB predicted catch history trajectories.

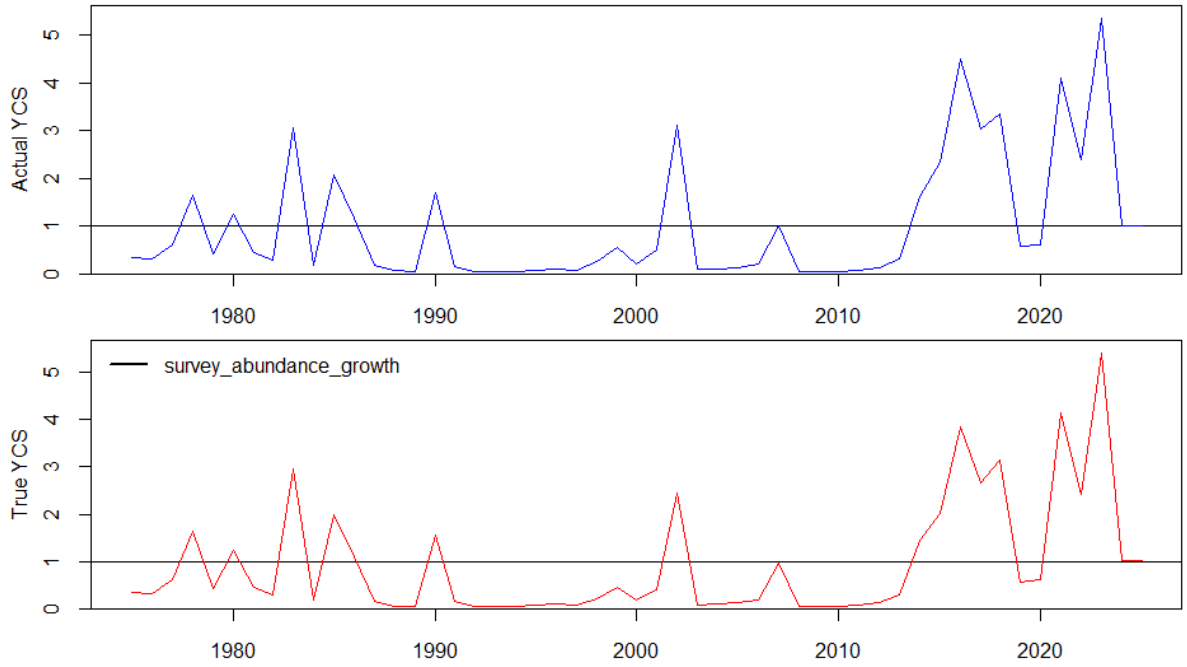


Figure 47: Base model actual (raw) and true (steepness adjusted) predicted YCSs.

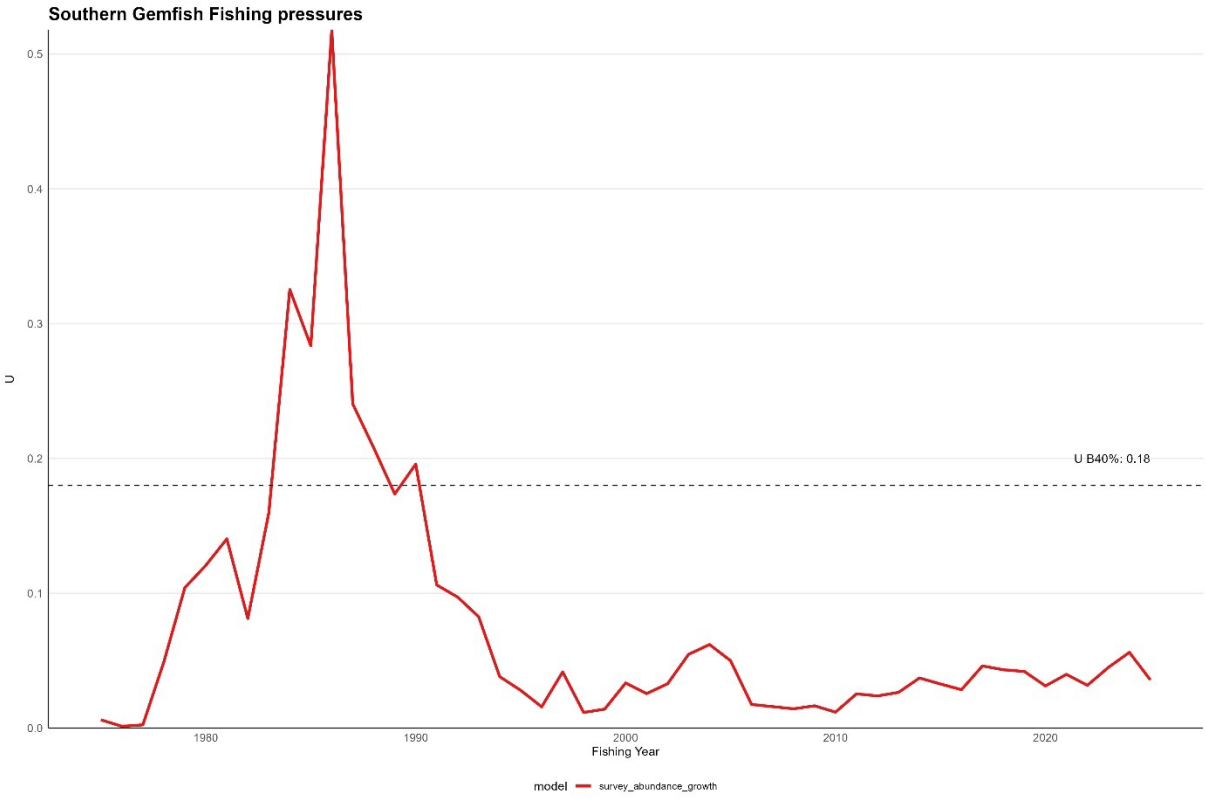


Figure 48: Base model fishing pressure (*U*) trajectory relative to $U_{B040\%}$.

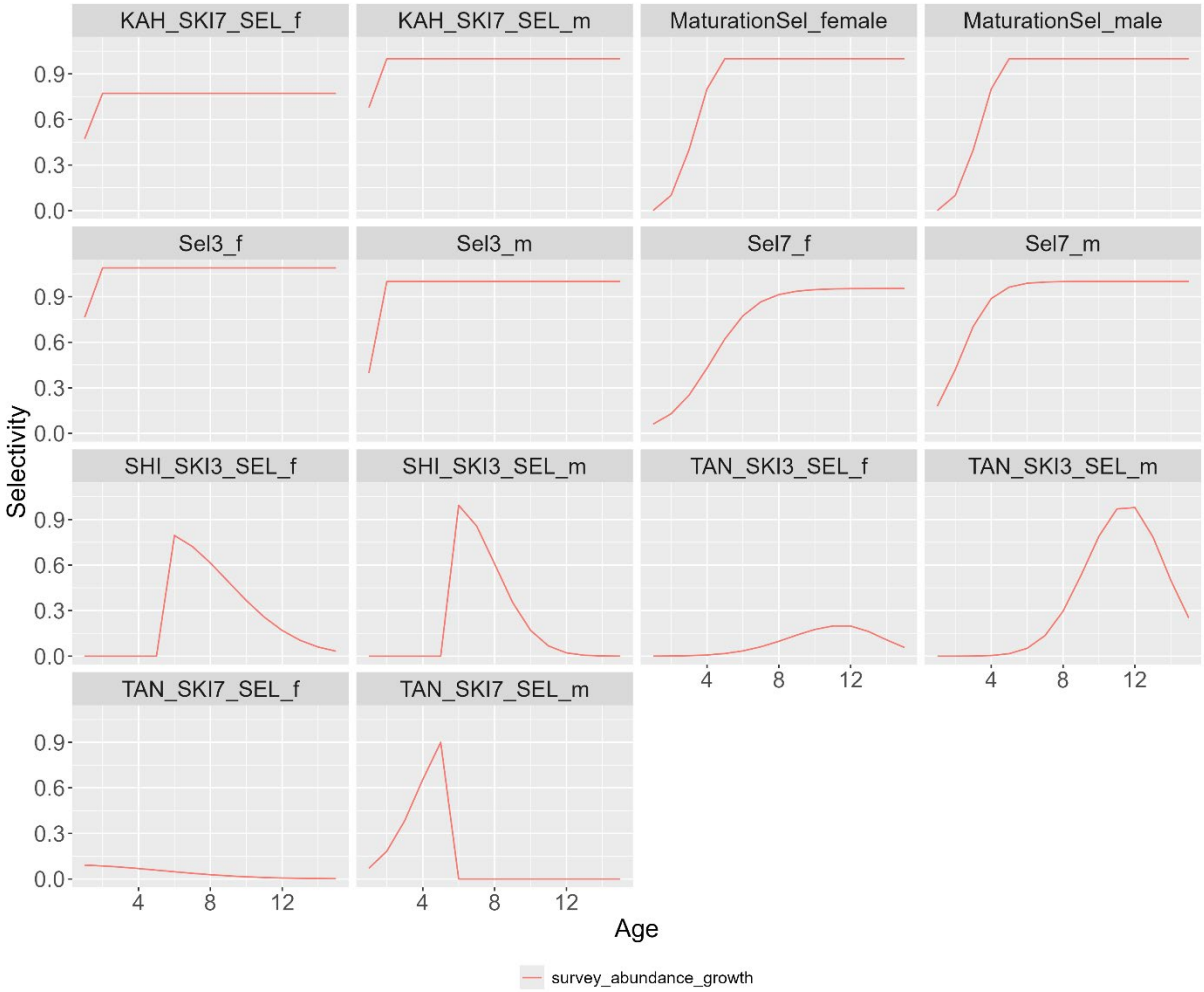


Figure 49: Base-model estimated selectivity ogives.

4.8 Base model MPD likelihood profiles

4.8.1 B_0 profiles

Base model B_0 likelihood profiles for the abundance and compositional likelihoods show a high degree of conflict meaning that B_0 was not well determined by these series (Figure 50). For example, the SKI 3 observer length frequency likelihood (ObserverLF3; Figure 50) favours a high B_0 which was at odds with the SKI 7 observer length frequency likelihood (ObserverLF7; Figure 50). Except for the SKI 7 *Tangaroa* survey series (TAN_SKI7_abundance), all the other survey abundance series predicted implausibly low B_0 values (Figure 50). The model is also being strongly influenced by the YCS priors (Figure 50), as higher B_0 (implied higher R_0) the effect being to reduce the amount of YCS variation required by the model to account for the observed catches.

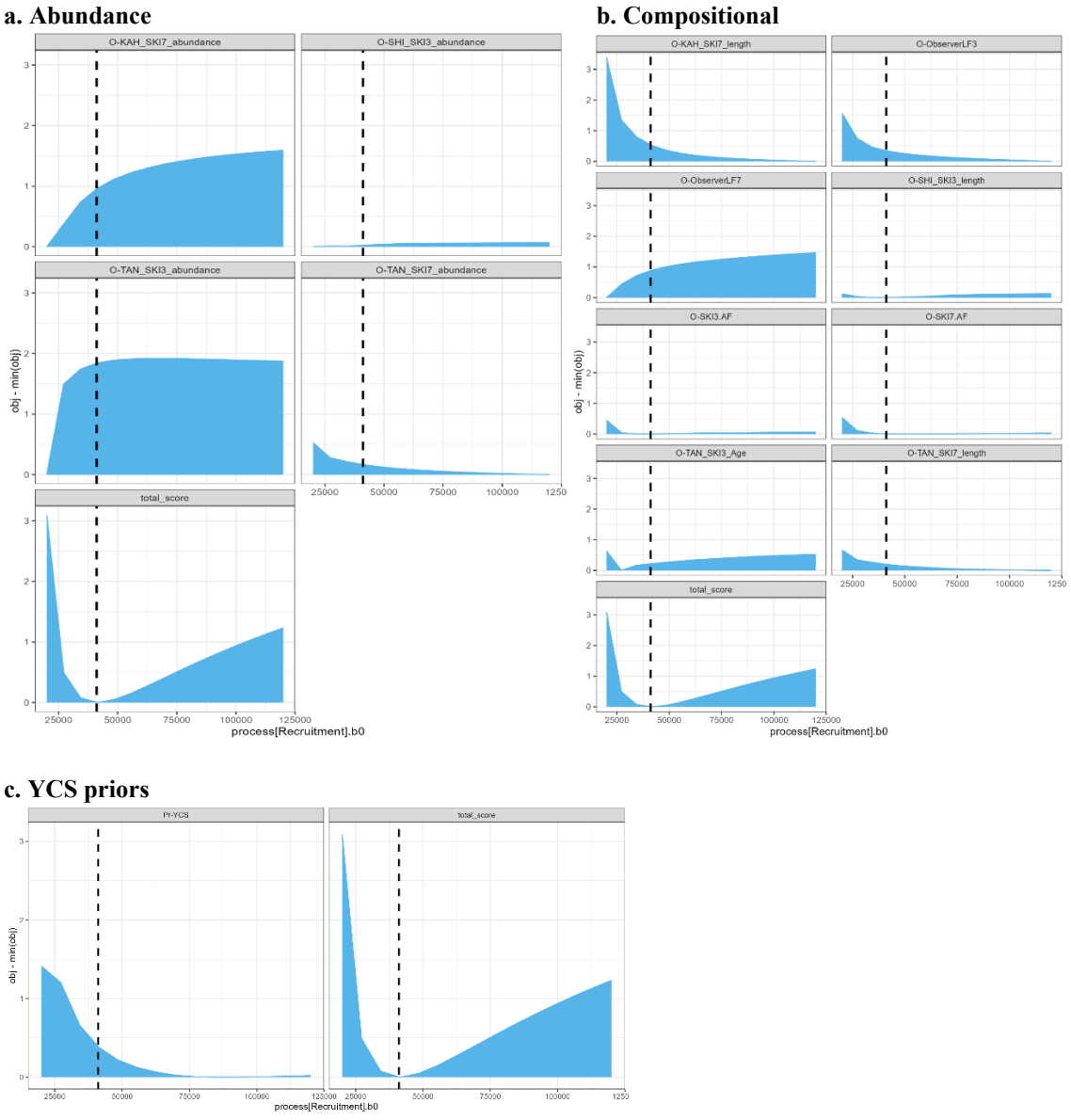


Figure 50: Base model B_0 likelihood profiles.

4.8.2 Survey catchability (*q*) profiles

Base model likelihood profiles on the four survey catchability coefficients (*q*s) also show a high degree of conflict as the model struggles to balance conflicting information on the historical SSB trajectory (Appendix 26). Smaller *q* values have a larger scaling effect on model SSB predictions which is likely to be the reason why the YCS priors consistently favoured smaller survey *q*s to reduce the amount of YCS variation required by the model to account for the observed catches.

4.9 Base model MPD sensitivities on natural mortality and steepness

Base model MPD sensitivity runs were conducted for lower and higher assumed values of natural mortality (*M* 0.2; 0.30) and steepness (*h* 0.75; 0.95). All sensitivity runs predicted the stock to be at or above B_0 and current exploitation (U_{2025}) to be well below the $U_{B040\%}$ exploitation reference (Table 17). The base model B_0 and SSB trajectory predictions were not greatly sensitive to the steepness assumption (Figure 51 & Table 17). The base model assessment was sensitive to the natural mortality assumption (Figure 51 & Table 17)

Table 17: Base and sensitivity model MPD stock status estimates.

Model	B_0	$\%B0_{2025}$	$U_{B040\%}$	U_{2025}	$U_{2025}/U_{B040\%}$
Base	41 103	176%	0.18	0.036	0.200
baseH75	39 852	155%	0.17	0.042	0.221
baseH95	42 110	191%	0.19	0.032	0.168
baseM20	30 930	103%	0.15	0.081	0.540
baseM30	50 898	212%	0.22	0.024	0.109

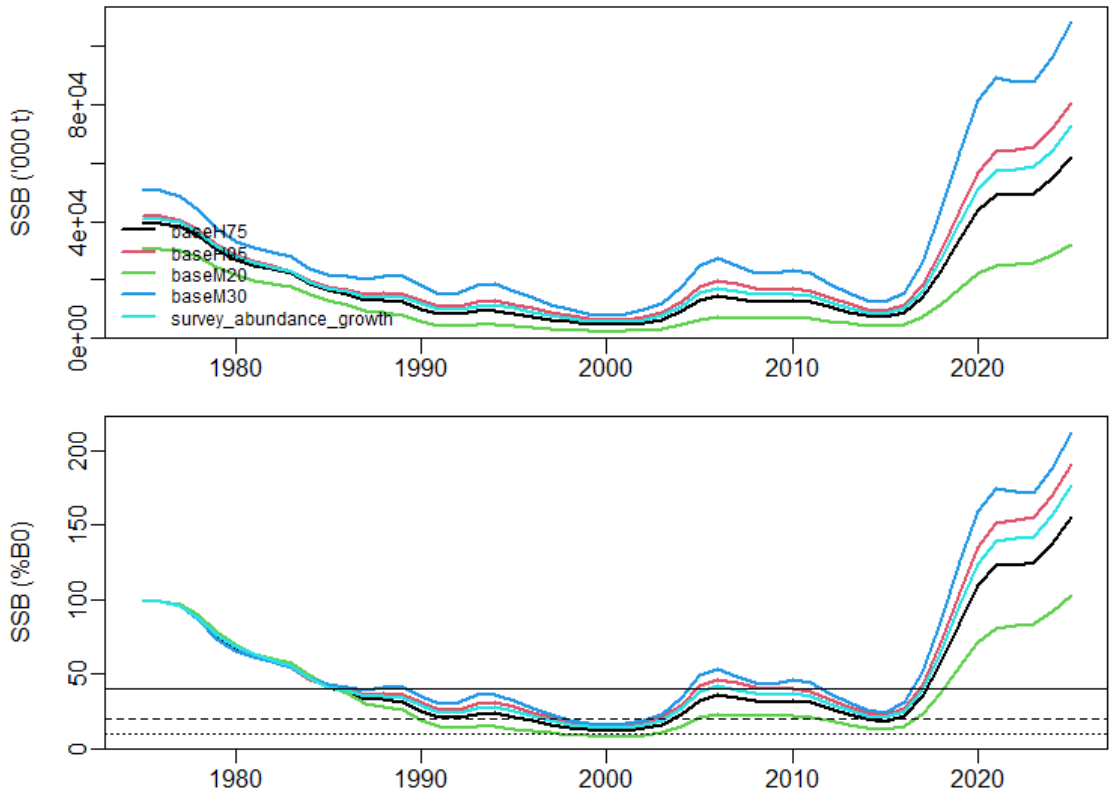


Figure 51: Base and sensitivity model $\%B_0$ and SSB predicted catch history trajectories.

4.10 Base model MCMC posterior predictions

Several attempts were made to generate statistically acceptable MCMC posteriors from the base model; all were unsuccessful. Future modelling work should explore fixing more of the selectivity parameters as well as running longer chains. Chain lengths of 2 000 000 sampling every 1000 were investigated, at least an order of magnitude increase in chain length and sampling frequency would likely be required to reduce auto-correlation in posterior generation.

5 DISCUSSION

The bycatch nature of the SKI 3 & 7 fisheries means that the increased gemfish catches since 2017 are likely to be a response to increased gemfish abundance. Increasing abundance in SKI 3 has also resulted in gemfish being a more prevalent bycatch species in other QMA 3 trawl fisheries principally those targeting barracouta, ling, and silver warehou. The SKI 3 & 7 bycatch fisheries operate at different times of the year, the SKI 7 hoki target fishery occurs largely during winter, the SKI 3 mixed trawl fisheries largely occurs in summer and autumn. Although SKI 3 & 7 are likely to be part of the same stock complex, differences in timing between the main fisheries relative to stock migration patterns means these fisheries are potentially catching different age components of the southern gemfish stock.

Updates of the Starr et al. (2024) SKI 3 & 7 commercial trawl CPUE indices show a continuation of the upward trend in abundance that began in 2017. The updated CPUE indices largely mirrored the trend in the commercial catches, the standardisation effect of the GLM modelling being minimal. There is little doubt that both catches and CPUE reflect a "true" increase in relative abundance of the SKI 3 & 7 gemfish stock complex. It can be inferred also from the CPUE that current abundance is likely to be greater than at any time in the history of the fishery. However, the magnitude of increase seen in the SKI 3 & 7 CPUE indices between the lowest and highest values were biologically implausible; it is therefore likely that the commercial CPUE was over-representing the "true" magnitude of increase in stock abundance. A possible explanation is that gemfish catchability by the commercial fisheries has not been constant over the fishing history, e.g., as might be expected under range contraction/expansion in the stock relative to, spatially-static, non-target fisheries. The stock assessment modelling struggled to fit the magnitude increase implied by the CPUE indices. Models fitting these indices predicted that the stock must have got down to less than 1% of virgin biomass (B_0) during the late 1990s, which is again considered to be biologically implausible.

Renwick et al. (1998) showed YCS in southern gemfish to be significantly linked with the frequency of south-westerly airflows and with SST anomalies, averaged over the winter half of the year. Recent compositional data from surveys and the commercial fisheries in conjunction with the stock assessment modelling suggest that the post-2017 abundance increase in the SKI 3 & 7 gemfish stock was being driven by above-average recruitment. Based on Renwick et al. (1998), it is likely that the recent period of above average recruitment in the SKI 3 & 7 gemfish stock is due to climate-change induced ocean warming. If the SKI 3 & 7 gemfish stock is now entering a period of higher productivity (i.e., higher B_0) long-term average recruitment is unlikely to be a good indicator of current productivity. The 2025 Plenary recommended exploitation ($U_{40\%B0}$) reference measures be adopted for assessing the SKI 3 & 7 gemfish stock. The deterministic $U_{40\%B0}$ estimate from the base model was 0.18. The current (2025) exploitation rate predictions from the base model and model sensitivity on natural mortality (M) and steepness (h) MPD runs were all well below $U_{40\%B0}$.

Stock biomass is expected to continue to increase for at least the next 2–3 years as the strong 2021, 2022, and 2023 year-classes continue to grow through the fishery. If the commercial SKI 3 & 7 fisheries continue to remain passive to changing abundance, is it unlikely that commercial exploitation rates will exceed $U_{40\%B0}$ in the next five years. However, there is a potential sustainability risk posed to the stock by a shift to active targeting.

To allow for spatial heterogeneity in length and age structure, the models estimated separate selectivities for each of the various survey and fishery data series (fleets as areas). The models generally achieved "acceptable" fits to the survey compositional data, meaning that there was little evidence of inconsistent spatial representativeness in these series. Lack-of-representativeness issues were evident in the SKI 3 & 7 observer length frequency series. An example being the model fits to the SKI 7 hoki fishery gemfish length compositional series (Appendix Figure 60). The model predicted that the strong 1990 year-class (Appendix Figure 60) should be seen by the hoki fishery in 1991 given that this fishery could see a similar strong pulse of sub-30 cm fish in 1999 (Appendix Figure 60) however very few sub-30 cm fish were seen in the 1991 hoki fishery. The inconsistency suggests that either the selectivity of the hoki fishery for gemfish changed between years or the sampling representativeness did. Either way the model was not structurally capable of representing the 1991 length data.

Despite some obvious inconsistences in the observer length frequency series, there seems to be power in these series to track individual year class modes and to estimate growth.

The MPD model fitting process revealed a high degree of likelihood conflict in observational data series in respect to average productivity (B_0) and SSB estimation. The modelling was incapable of explicitly accounting for dynamic productivity changes over the history of the fishery (i.e., dynamic B_0), which was a weakness of this assessment. Marsh et al. (2024) showed that, when fitted to regime shift simulated data, "traditional" constant B_0 assessment models provide less biased SSB trajectory estimates when the average-to-one YCS penalty is relaxed. This is why the average-to-one YCS penalty was set low in the current assessment modelling.

Probably because of model misspecification and data conflict issues, the base model failed to achieve statistically acceptable MCMC convergence, so the assessment was unable to provide uncertainty measures on model predictive outcomes.

6 FUTURE RESEARCH RECOMMENDATIONS

Monitoring

- Explore the representativeness of the available survey and observer data series in relation to gemfish monitoring requirements with the aim of:
  1. Removing non-spatially representative or biased observational data from the historical series;
  2. Providing specifications for a spatially representative Fisheries New Zealand Observer monitoring programme.

- Because the SKI 3 & 7 gemfish stock complex is highly recruitment driven, regular catch at-age monitoring is recommended.

- A limitation of the recent fishery catch at-age data was the necessary application of a combined-area annual age-length key to the area-specific length data; in future it would be preferable to develop separate age-length keys for each QMA.

Assessment

- Given the apparent changes in recent recruitment dynamics, the use of non-equilibrium productivity models for future SKI 3 & 7 gemfish assessments should be investigated.

- The current SKI 3 & 7 GLM CPUE indices appear to be over-estimating the magnitude of the recent increase in the SKI 3 & 7 gemfish stock and there seems to be little utility in updating them. As an alternative, we recommend investigating other spatio-temporal modelling approaches, e.g., spatial GAMs, VAST, to better understand stock structure.

- Conduct further independent growth analyses to better account for growth in the assessment models. This would include investigating the use of alternative growth models.

Environmental recruitment predictors

- Further investigate the potential relationship between SKI 3 & 7 gemfish recruitment success and changing oceanographic conditions.

7 ACKNOWLEDGEMENTS

The authors acknowledge Fisheries New Zealand for funding the SKI 3 & 7 gemfish assessment project (SKI2024-01). The authors also thank Gretchen Skea for guiding this project through the Working Group process and for review of the final report, and Marianne Vignaux for final editorial review.

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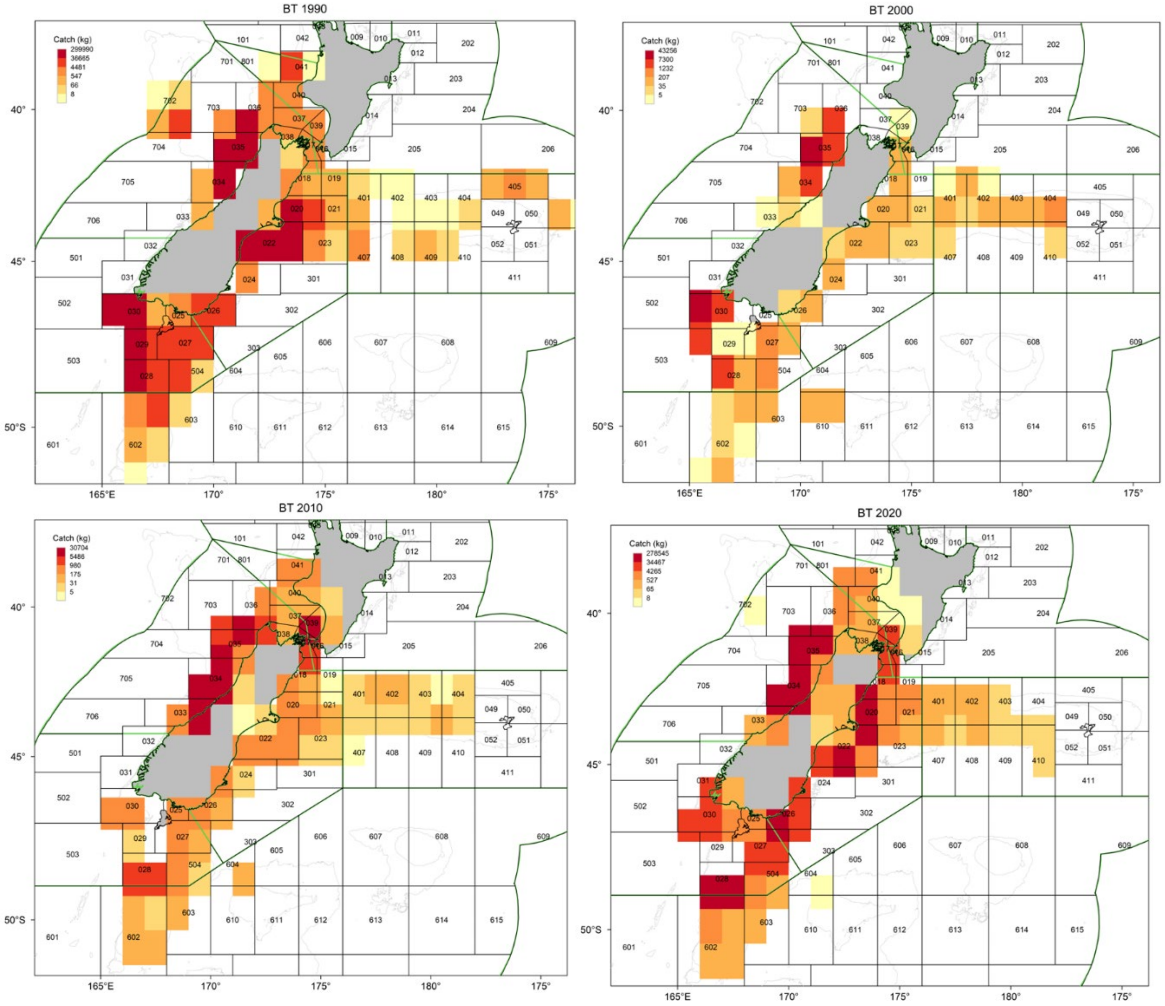
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9 APPENDICES

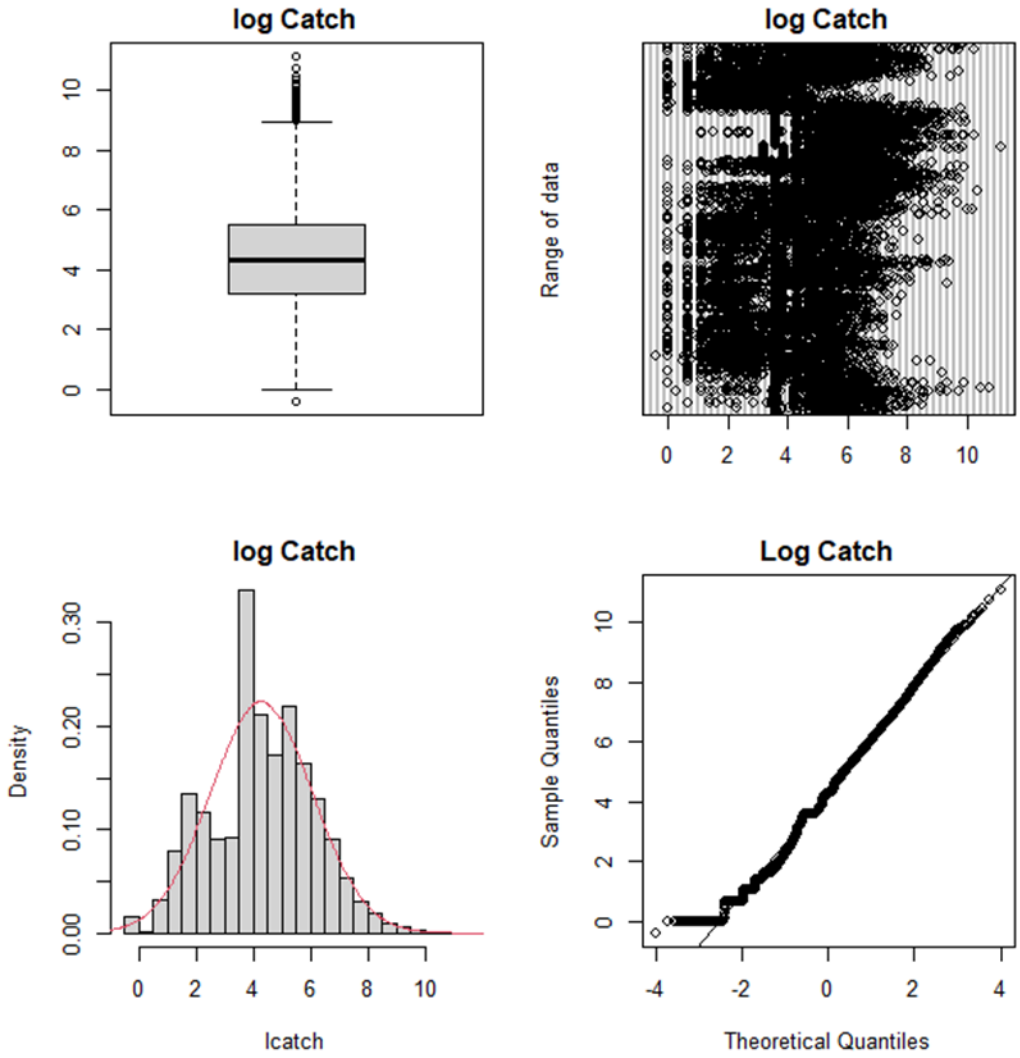
Appendix 1: SKI 3 & 7 changing spatial catch patterns 1990–2020



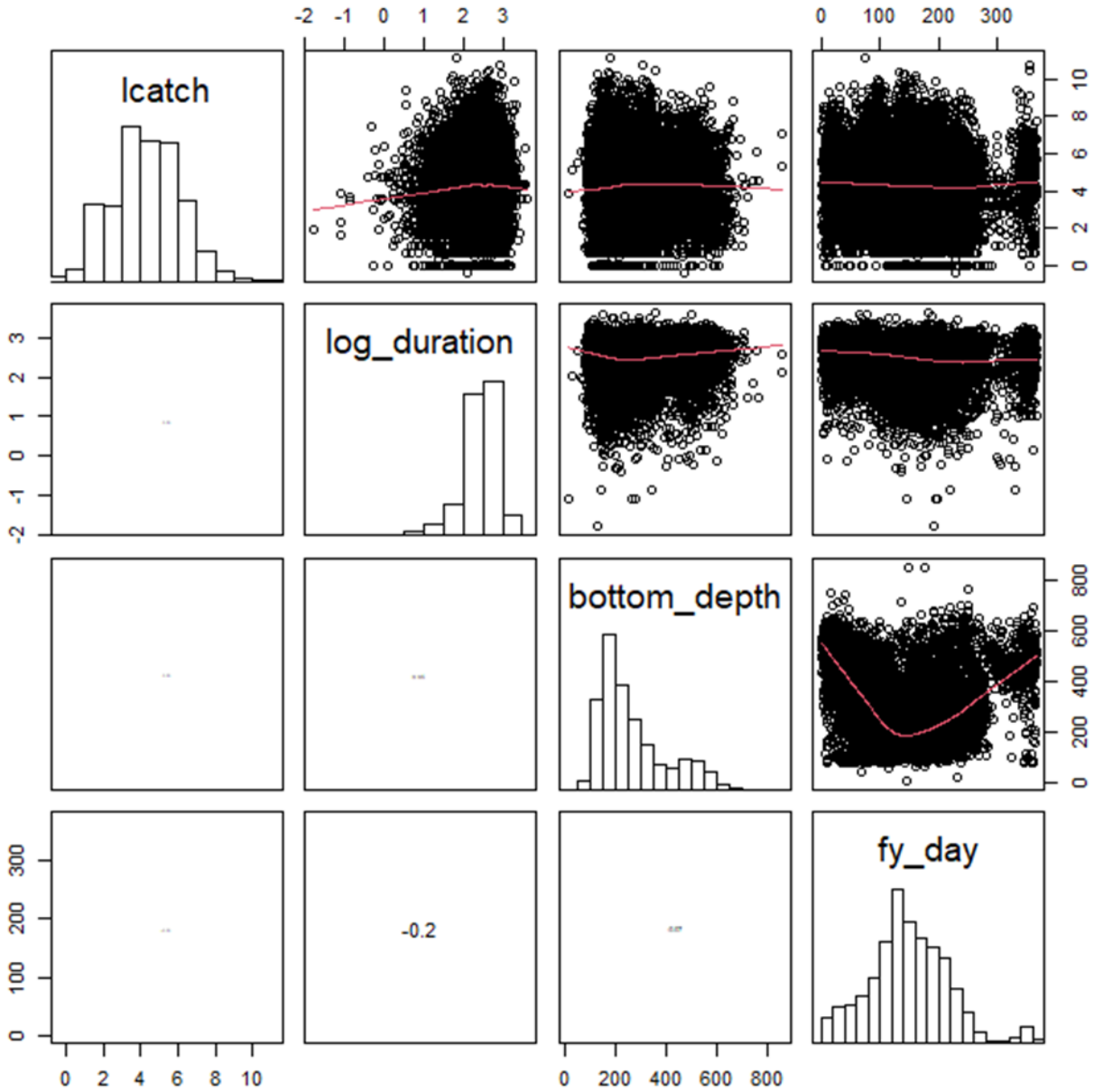
Appendix Figure 1: Catches of gemfish from the bottom trawl fishery for fishing years 1989–90, 1999–2000, 2009–2010, and 2019–2020. The plots comprise one degree of latitude and longitude grid and include allocated landing catches in the analysis data. Cells with data from less than three vessels or permit holders are omitted.

Appendix 2: SKI 3 Snares Shelf log-normal CPUE standardisation model input data issue tests

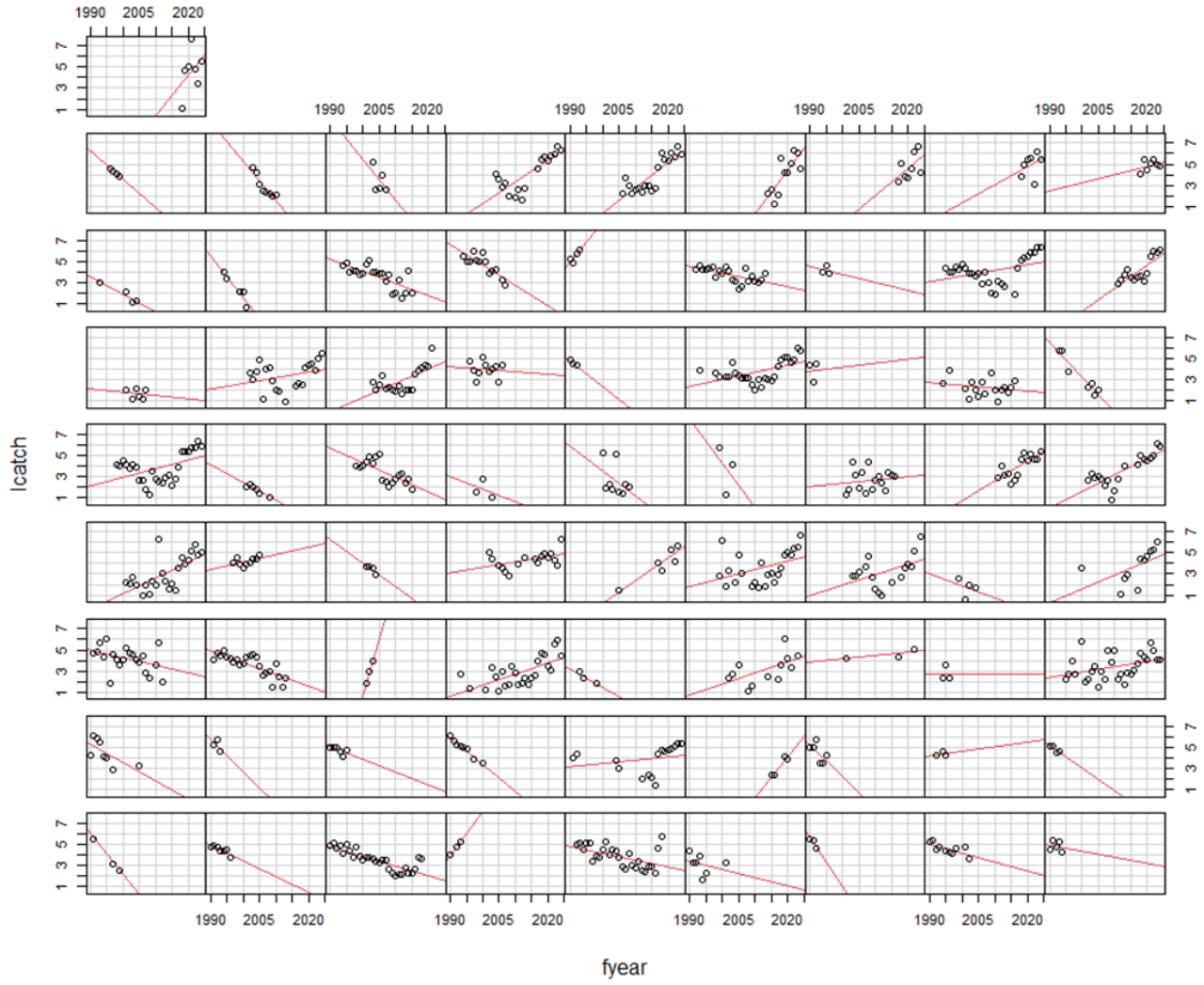
1. Test for normality in the model response variable PASSED



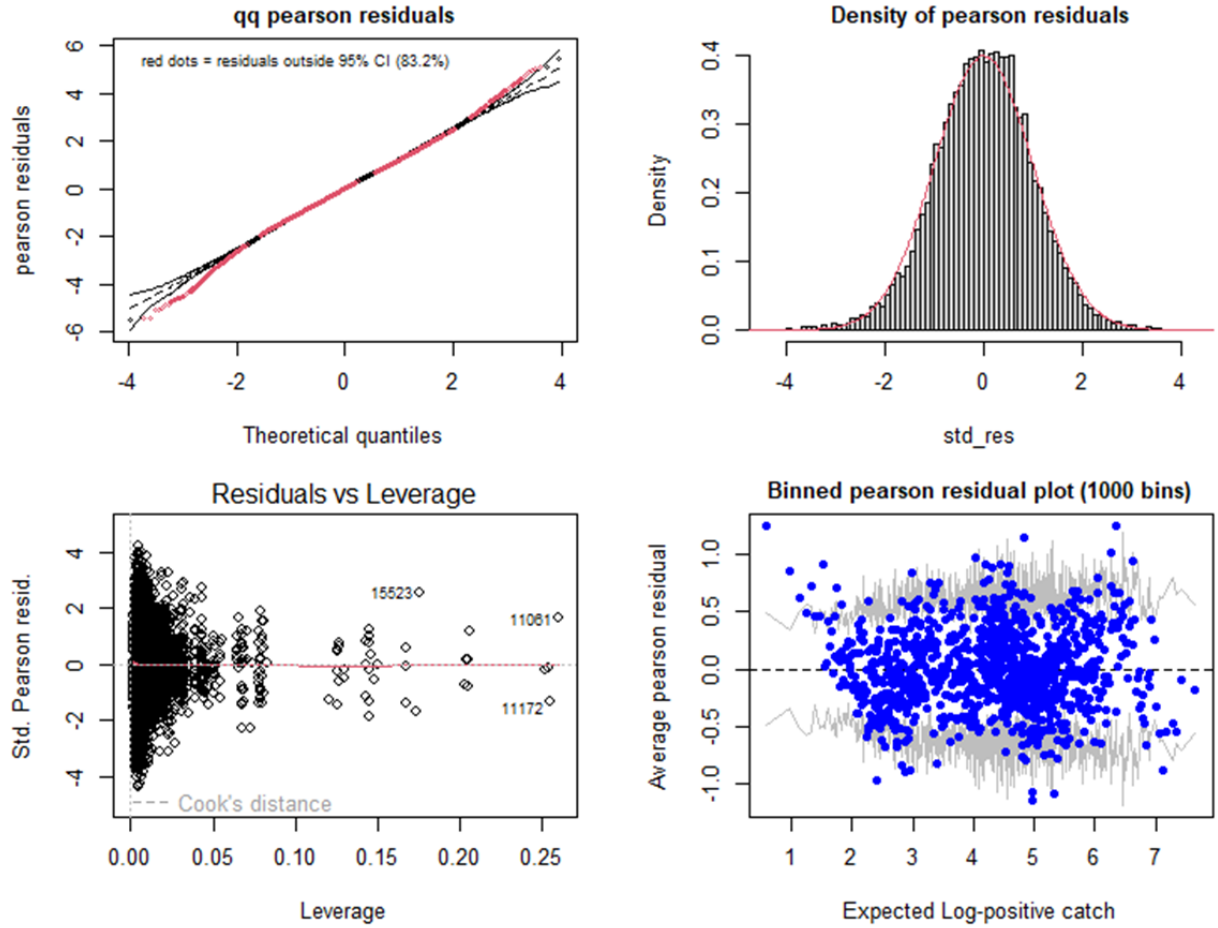
2. Test for high collinearity (Pearson correlation) issues between model continuous variables: PASSED



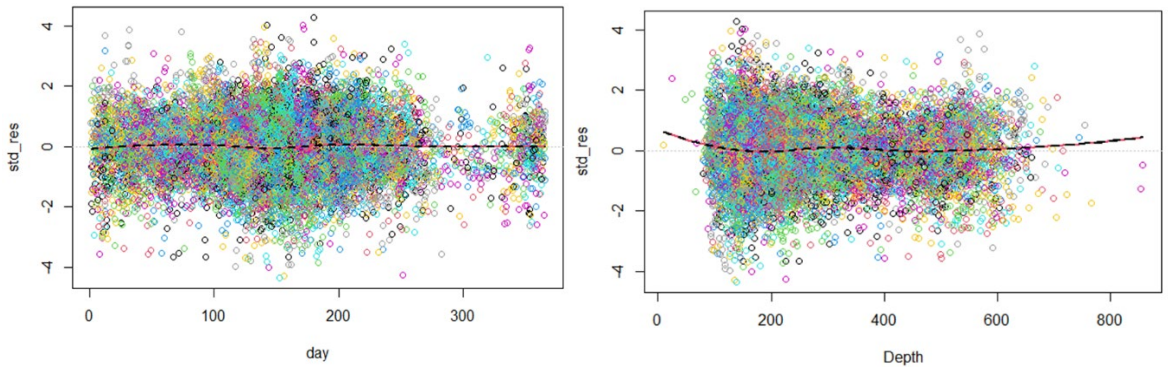
3. Test for marked discontinuities in individual vessel annual catches across fishing years: No obvious discontinuities.



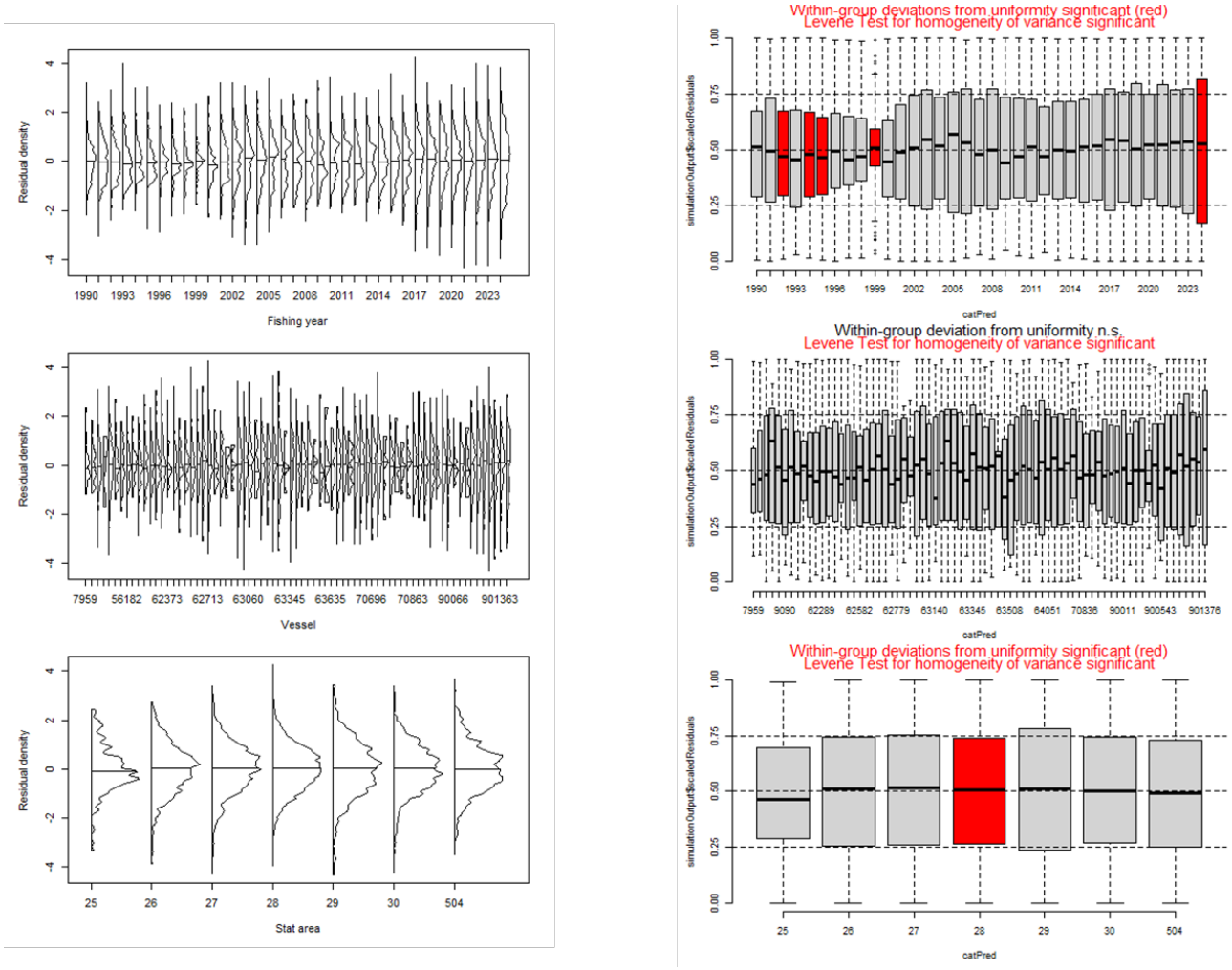
Appendix 3: SKI 3 Snares Shelf log-normal CPUE standardisation model residual diagnostics



Appendix Figure 2: **Residual diagnostics on the log-normal model log-catch (response) predictions**

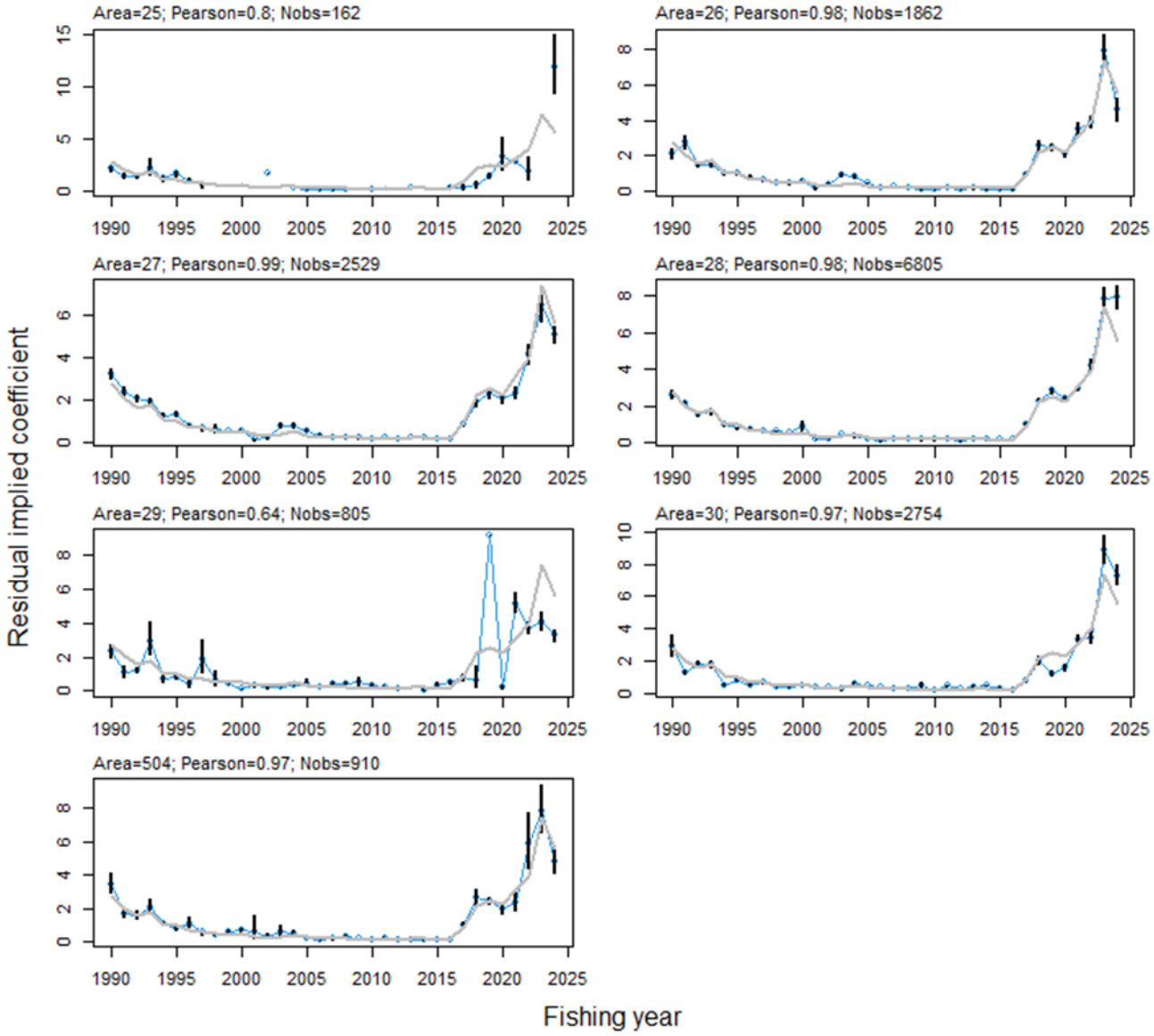


Appendix Figure 3: **Log-normal model residuals across the range of model fishing-year-day and depth parameter values. Loess spline (dotted lines) departure away from zero horizontal equate to poor predictive performance. Colours are the residuals for the different fishing years**

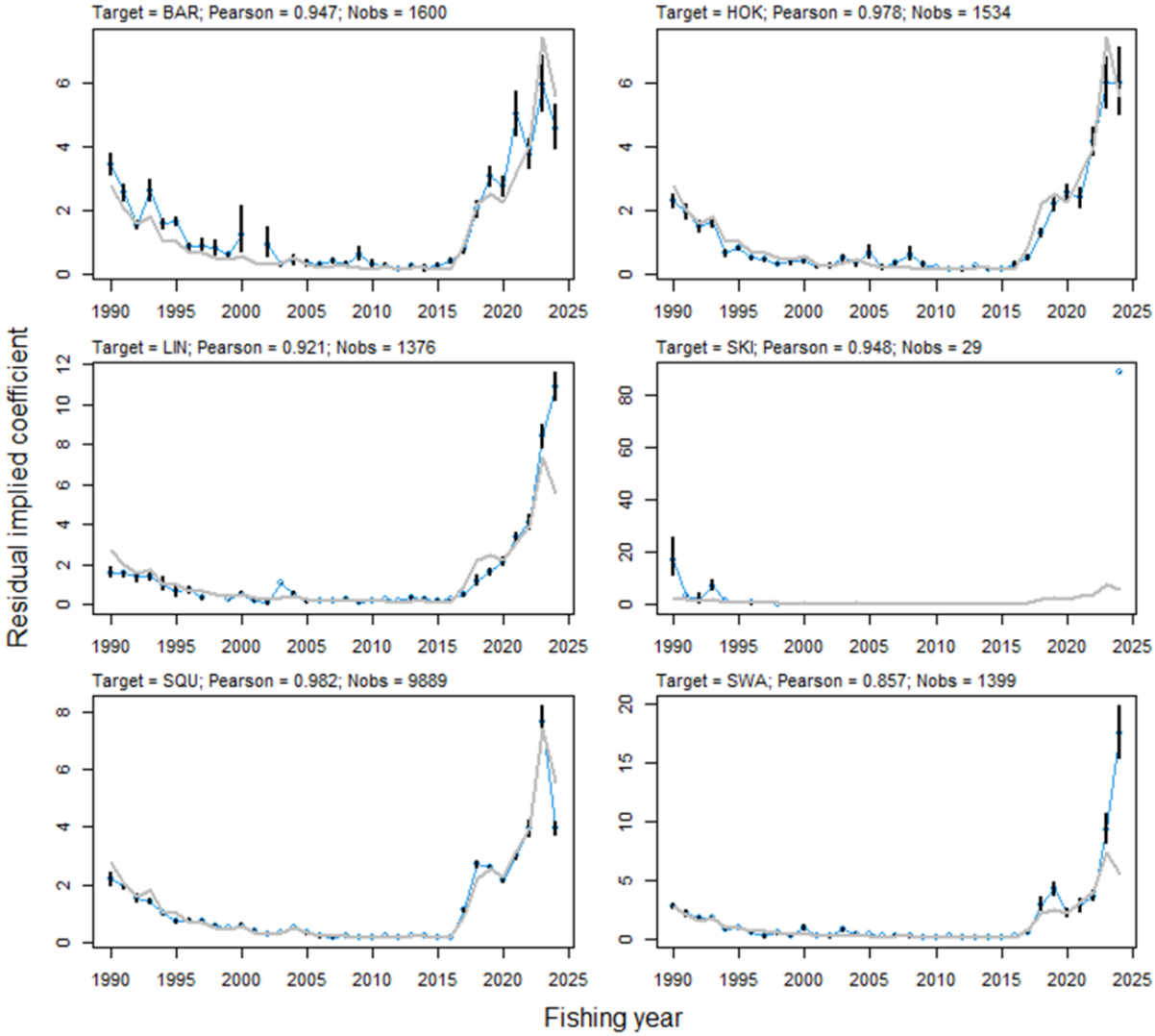


Appendix Figure 4: **Log-normal model categorical term residual distributional plots (left graphs) and associated DHARMa nonparametric goodness-of-fit test plots (right graphs). DHARMA plots show failure of the between-group homogeneity of variance assumptions and the within group uniformity assumptions (red groups in plots).**

Appendix 4: SKI 3 Snares Shelf log-normal CPUE standardisation model implied residual plots

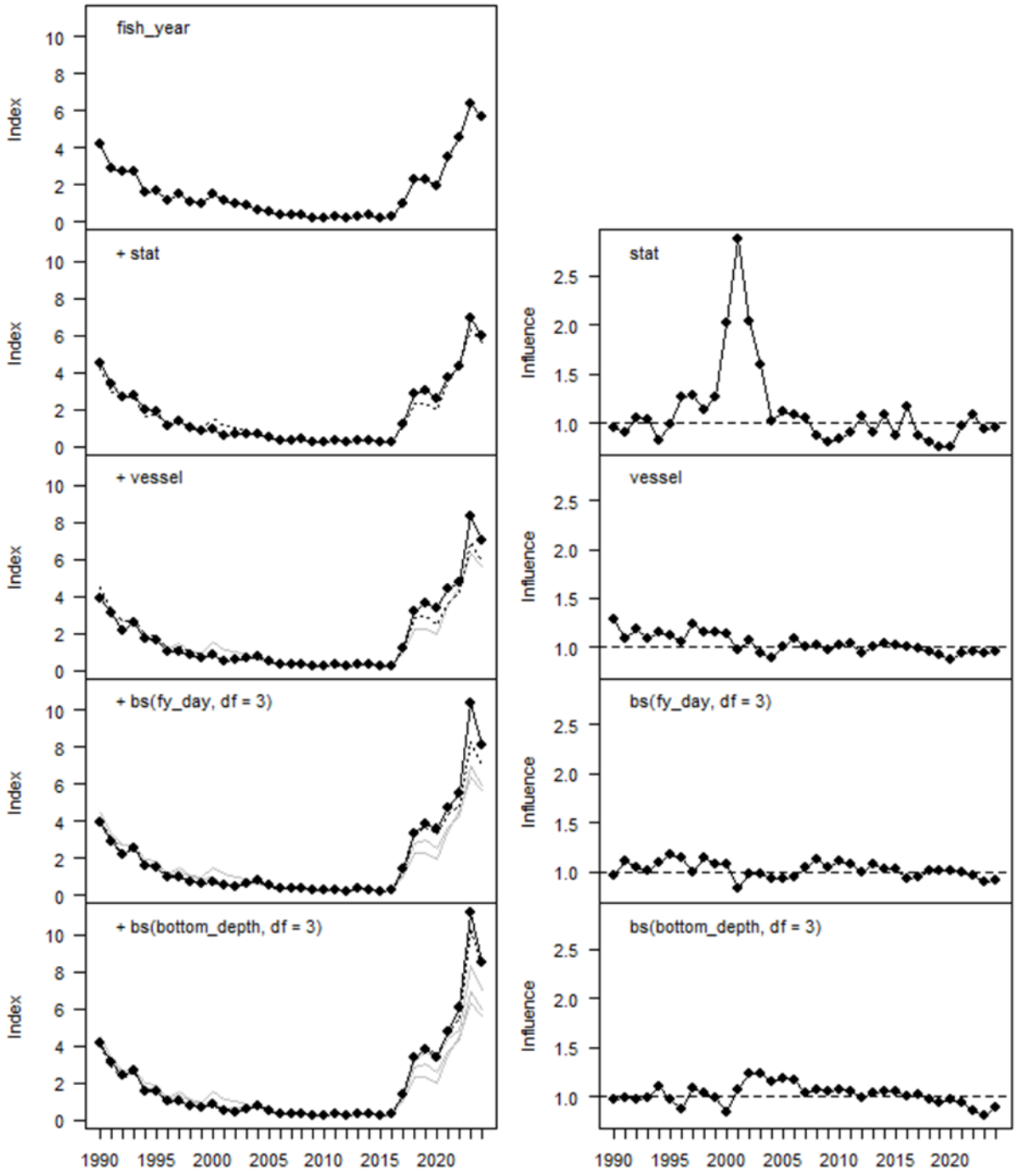


Appendix Figure 5: Statistical area implied residual plots.

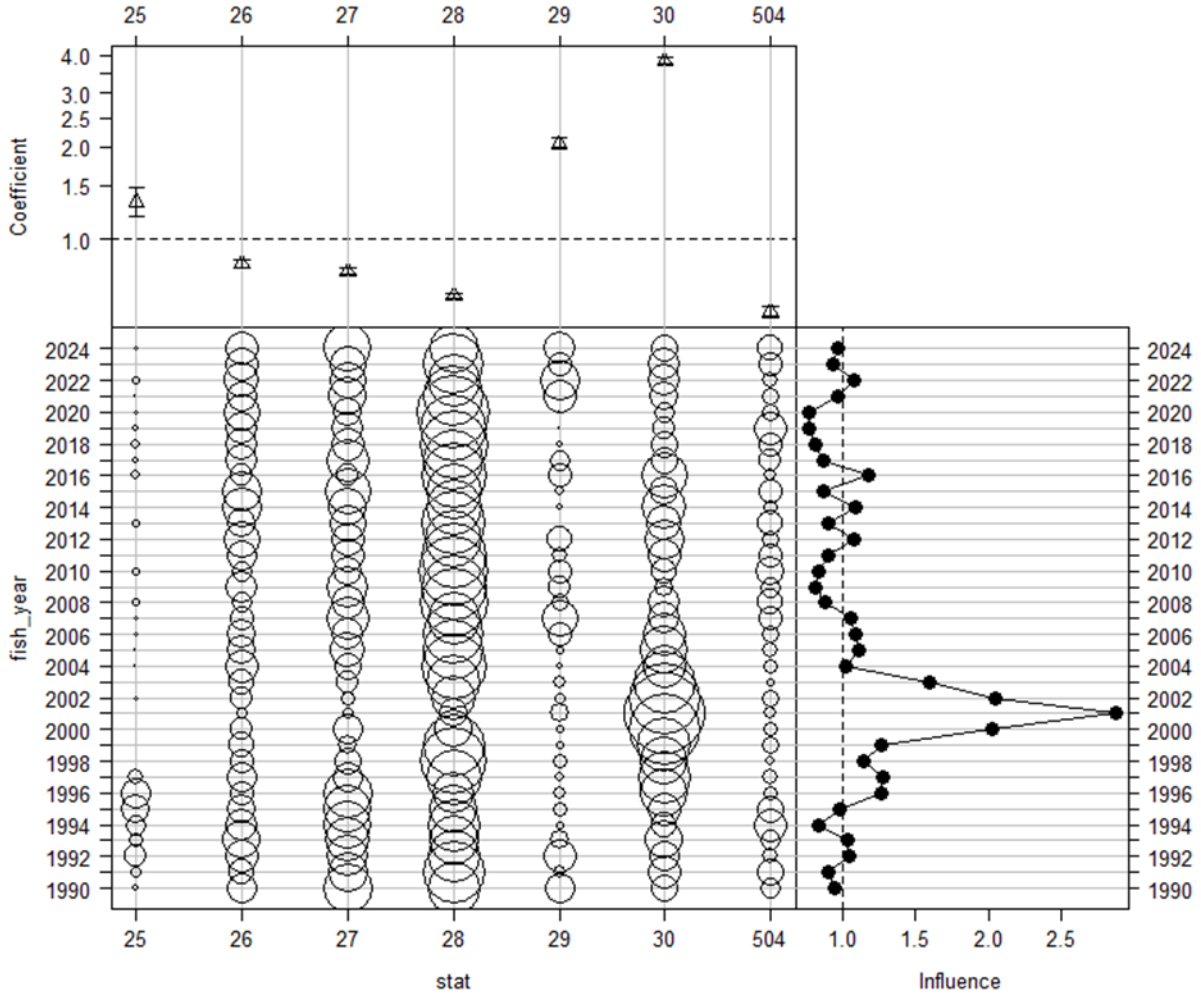


Appendix Figure 6: **Target species implied residual plots.**

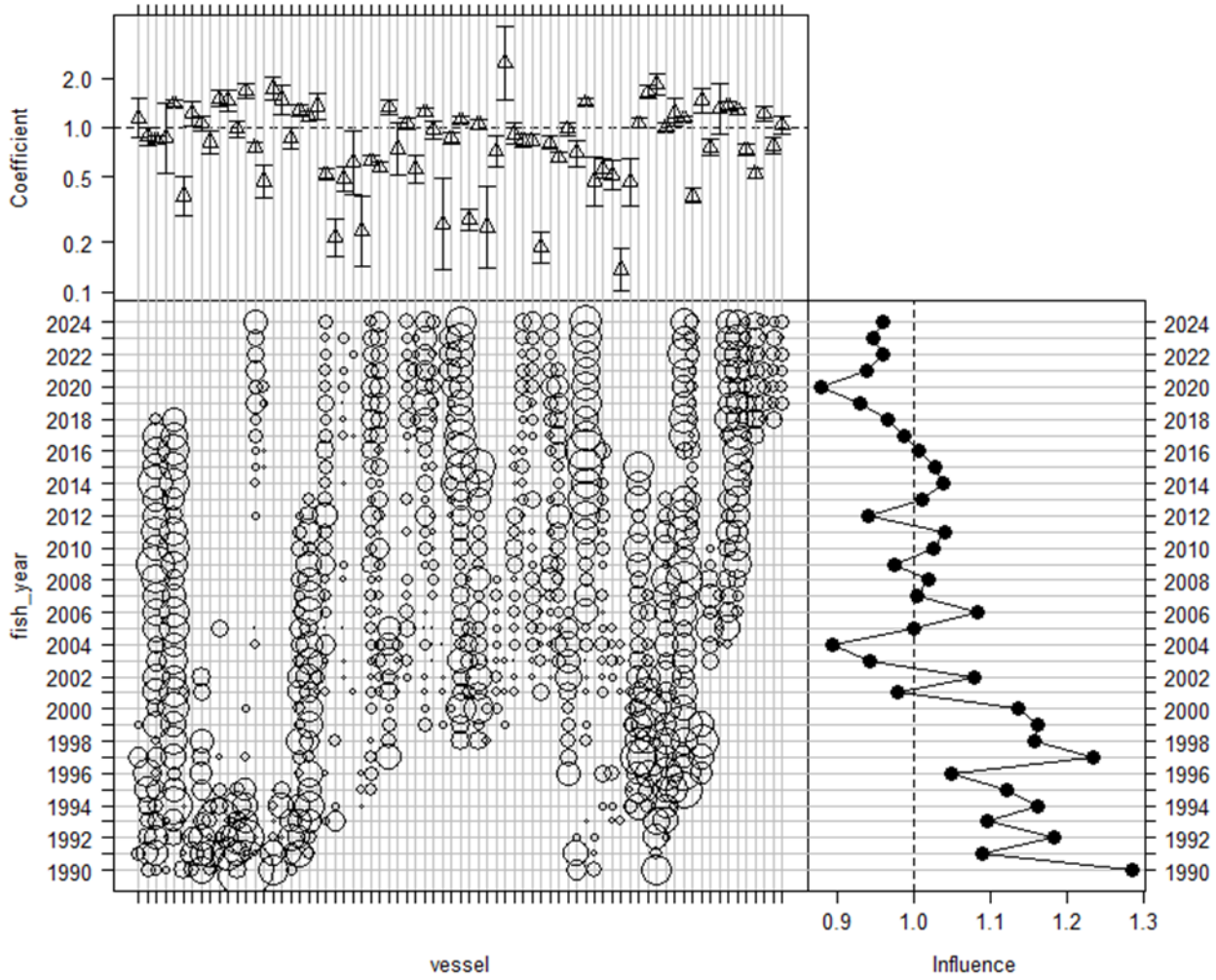
Appendix 5: SKI 3 Snares Shelf log-normal CPUE standardisation model influence and step plots



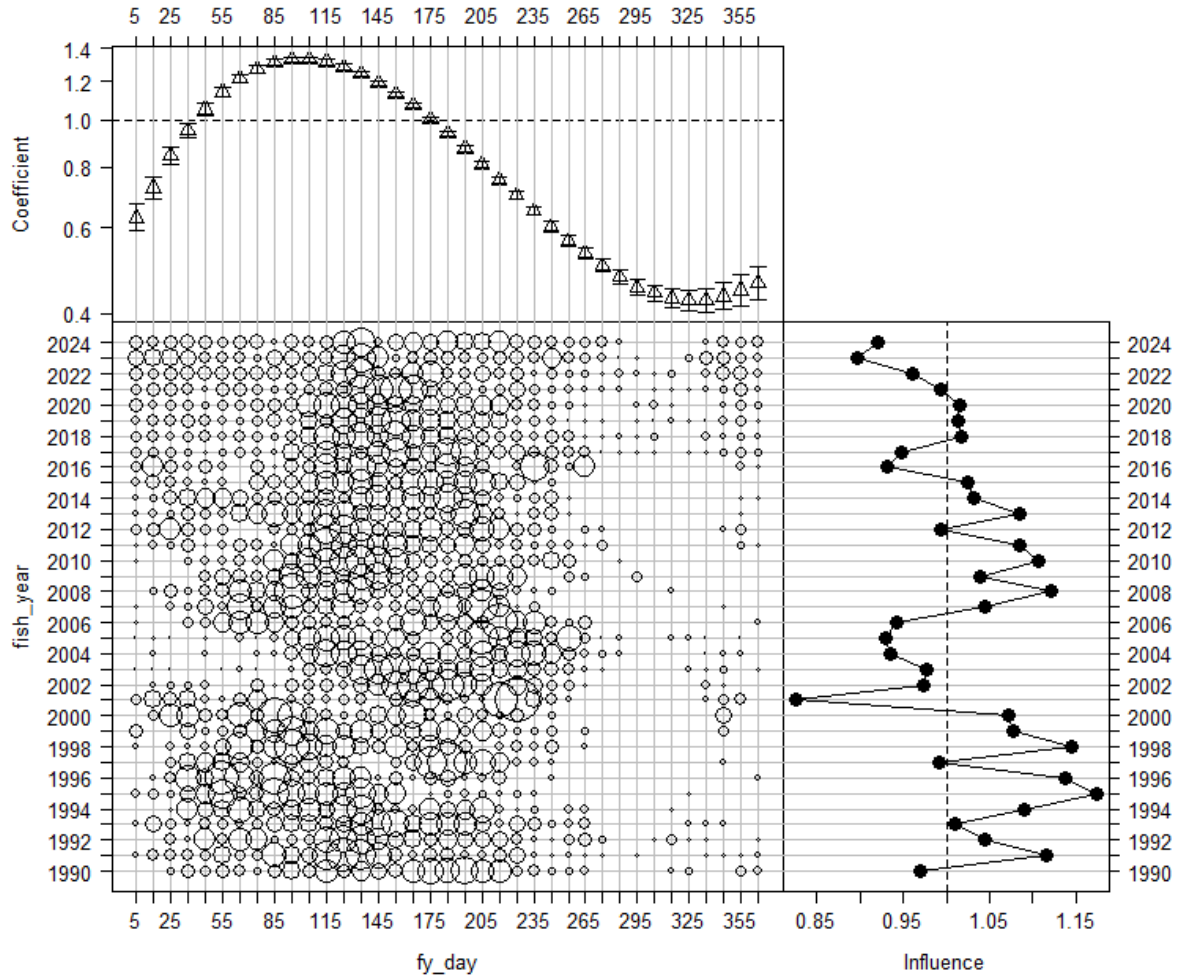
Appendix Figure 7: **SKI 3 Snares Shelf standardised CPUE indices step plots (left) and influence plots for core vessels from 1989–90 to 2023–24. The step plots show how the indices change with the addition of predictor variables into the model. The influence plots show where the predictor variable influence the indices.**



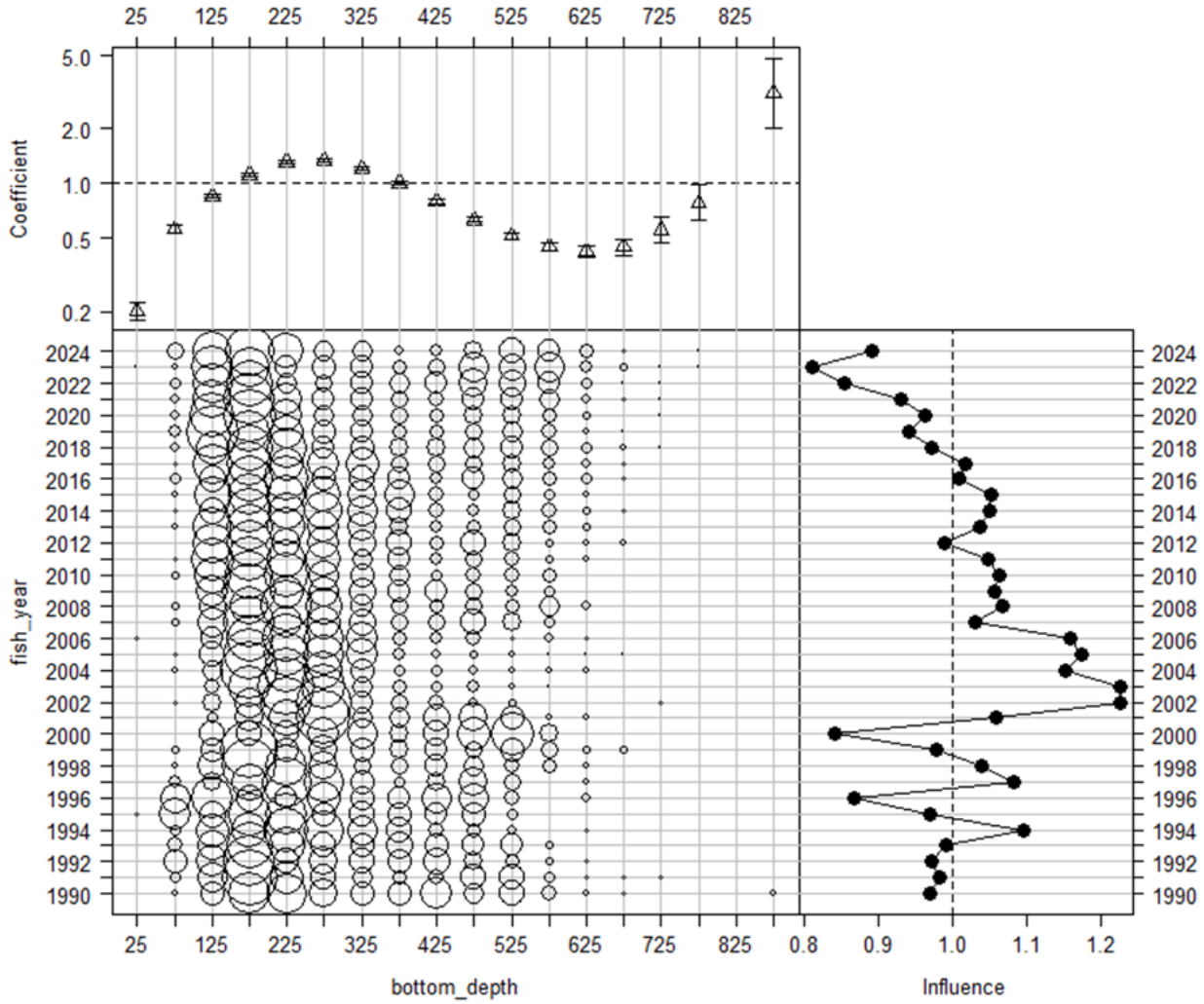
Appendix Figure 8: **SKI 3 Snares Shelf standardised CPUE analyses coefficient-distribution-influence plots (CDI) for statistical area from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**



Appendix Figure 9: **SKI 3 Snares Shelf standardised CPUE analyses coefficient-distribution-influence plots (CDI) for vessel from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**

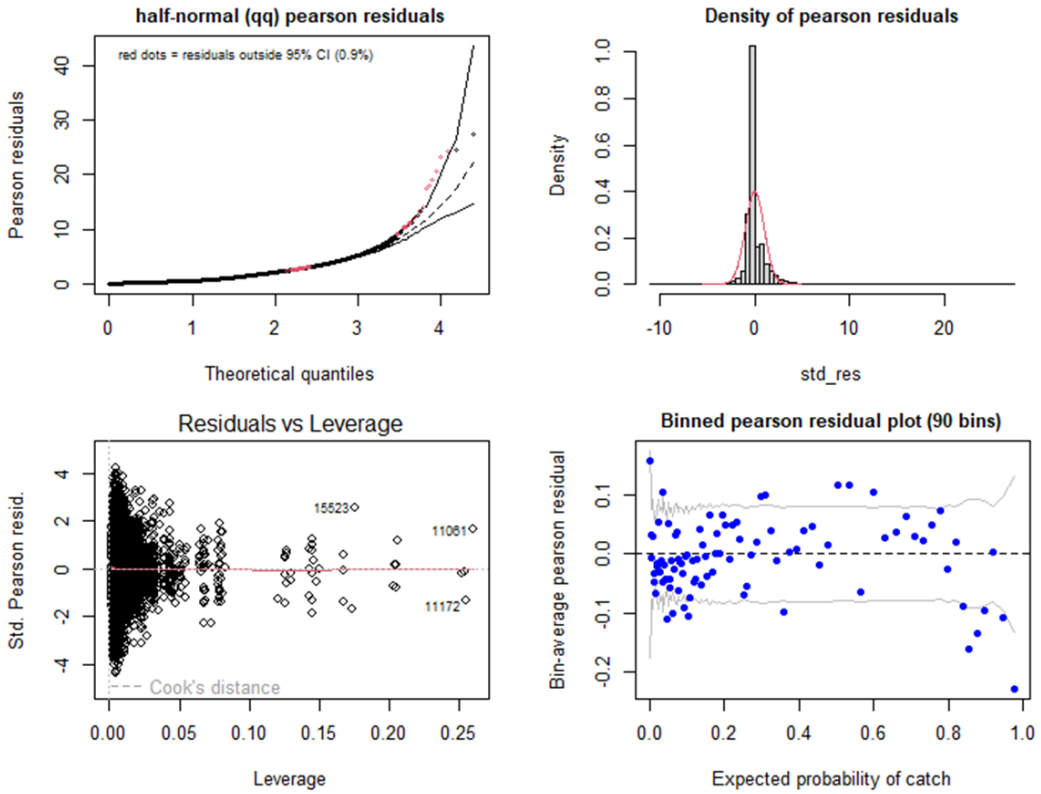


Appendix Figure 10: **SKI 3 Snares Shelf standardised CPUE analyses coefficient-distribution-influence plots (CDI) for fishing year day from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**

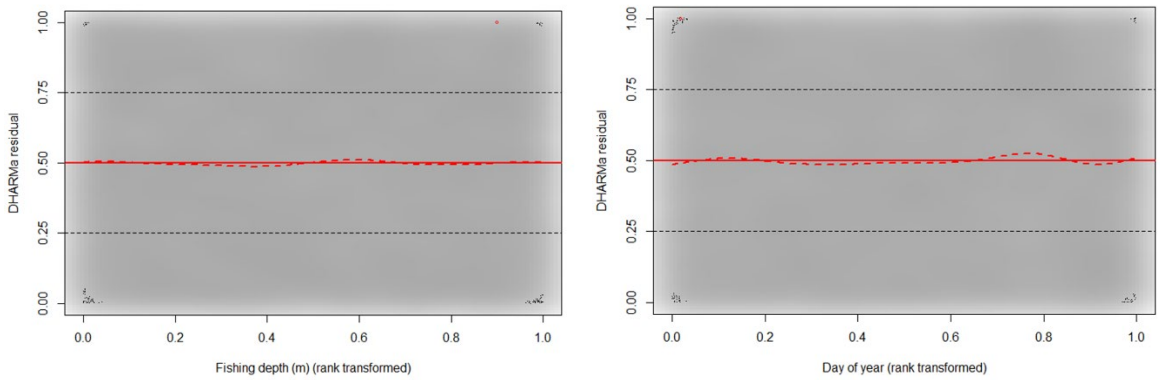


Appendix Figure 11: **SKI 3 Snares Shelf standardised CPUE analyses coefficient-distribution-influence plots (CDI) for bottom depth from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**

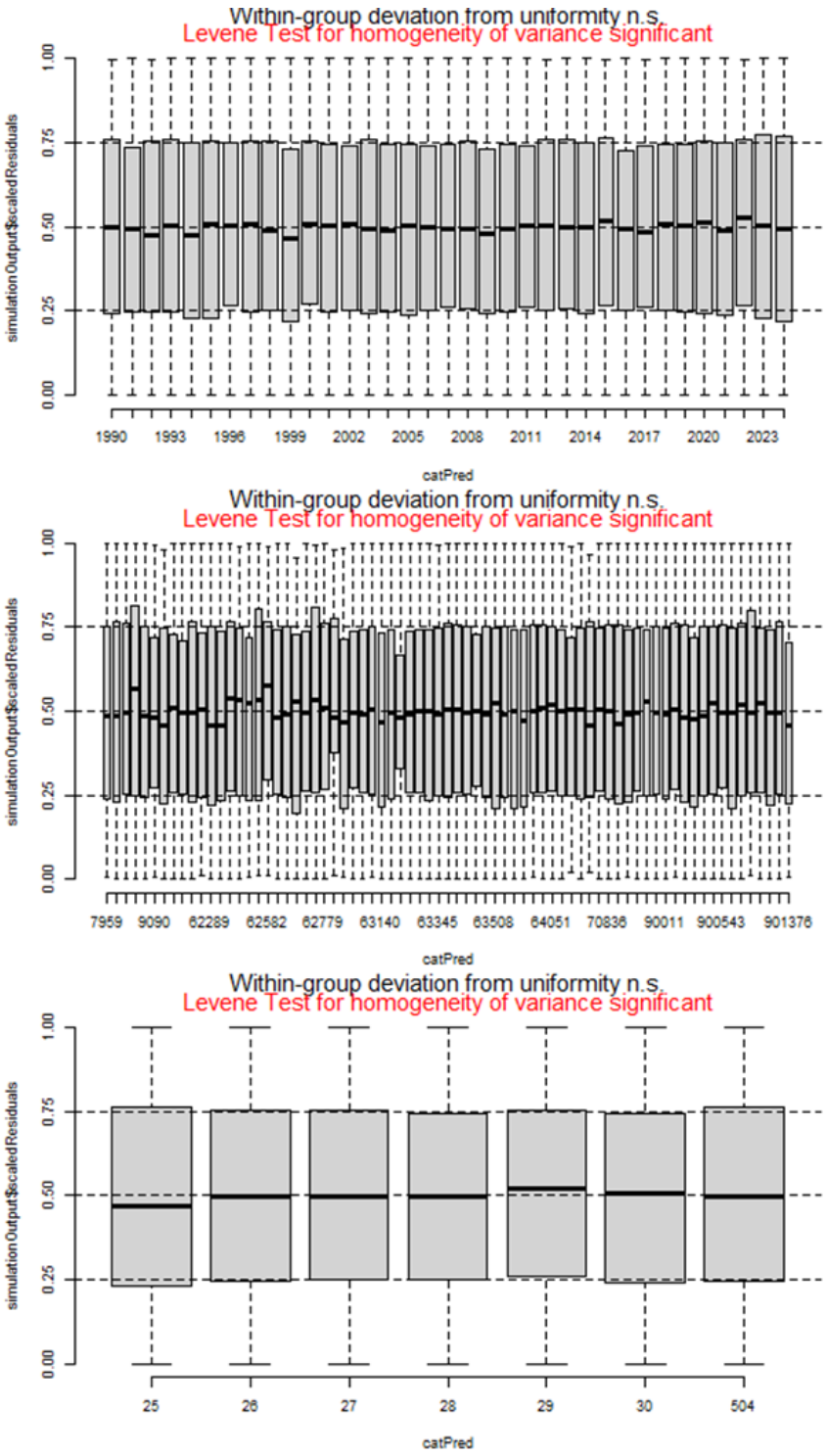
Appendix 6: SKI 3 Snares Shelf binomial proportion-zero standardisation model residual diagnostics



Appendix Figure 12: **Residual diagnostics on the binomial model proportion-zero (response) predictions.**

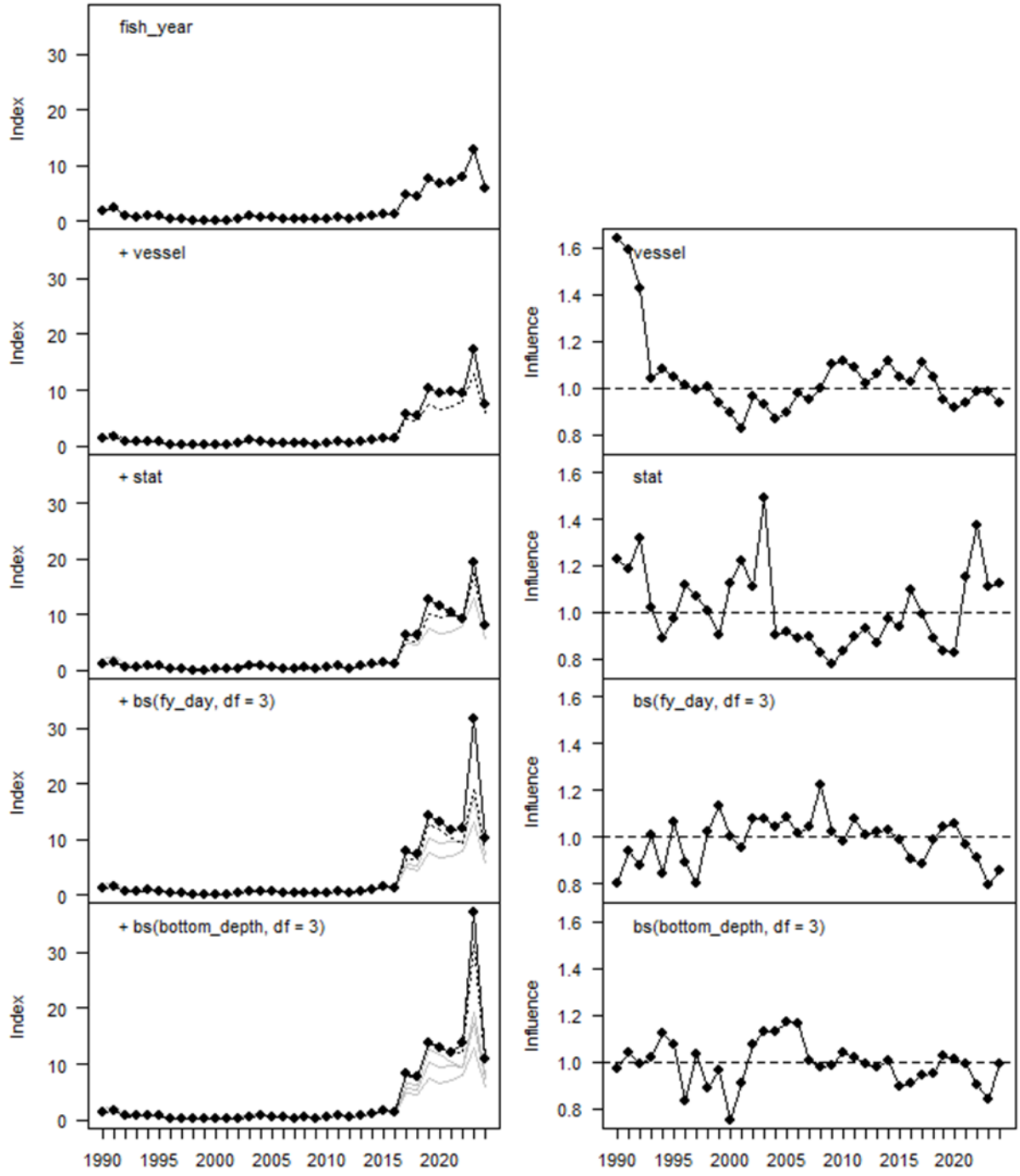


Appendix Figure 13: **DHARMa nonparametric goodness-of-fit test plots across the range of model fishing year day and depth parameter values. Loess spline (dotted lines) departure away from zero horizontal equate to poor predictive performance.**

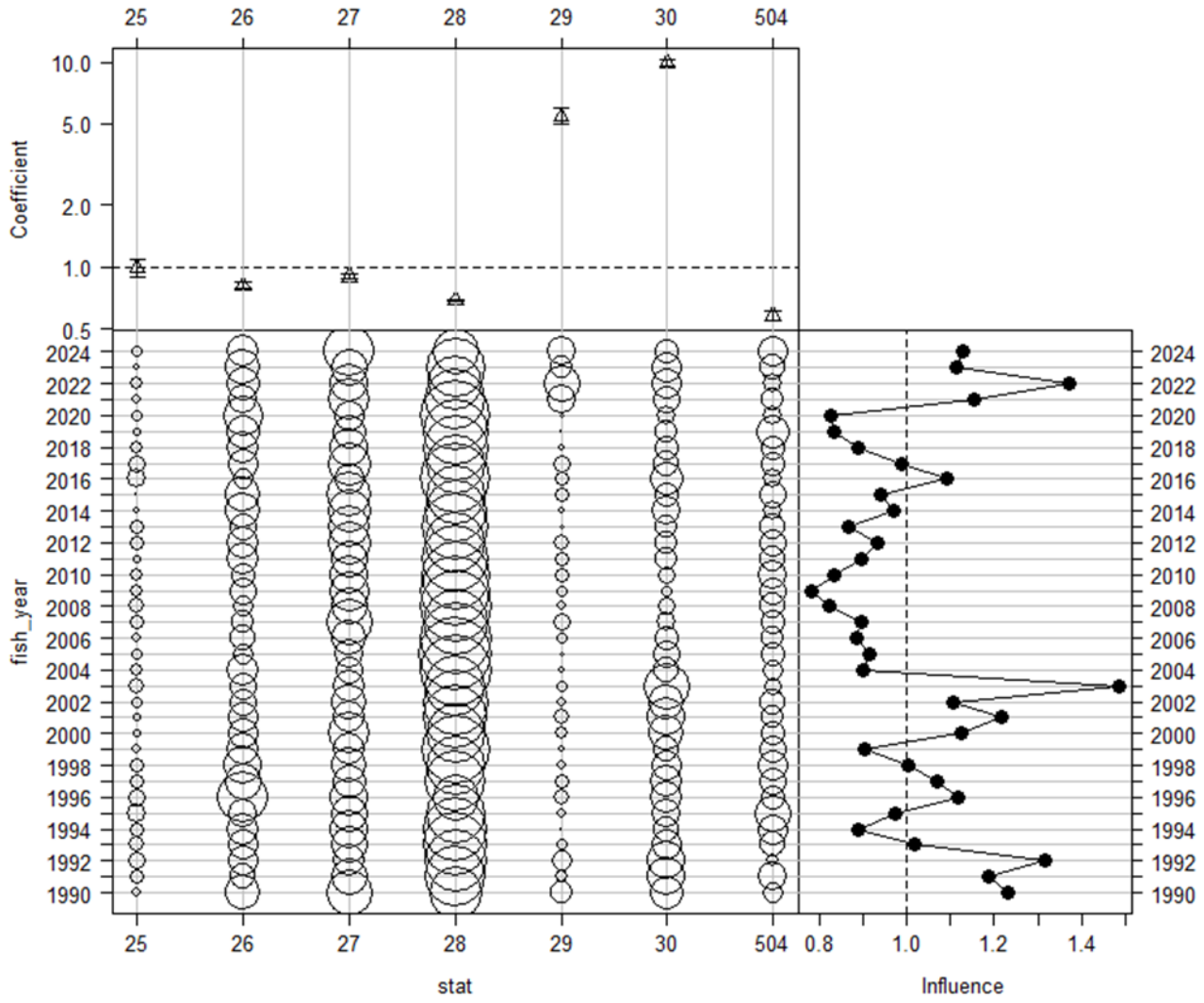


Appendix Figure 14: DHARMa plots showing within group deviation from uniformity assumptions (a red group would show that there was significant deviation using a Levene Test).

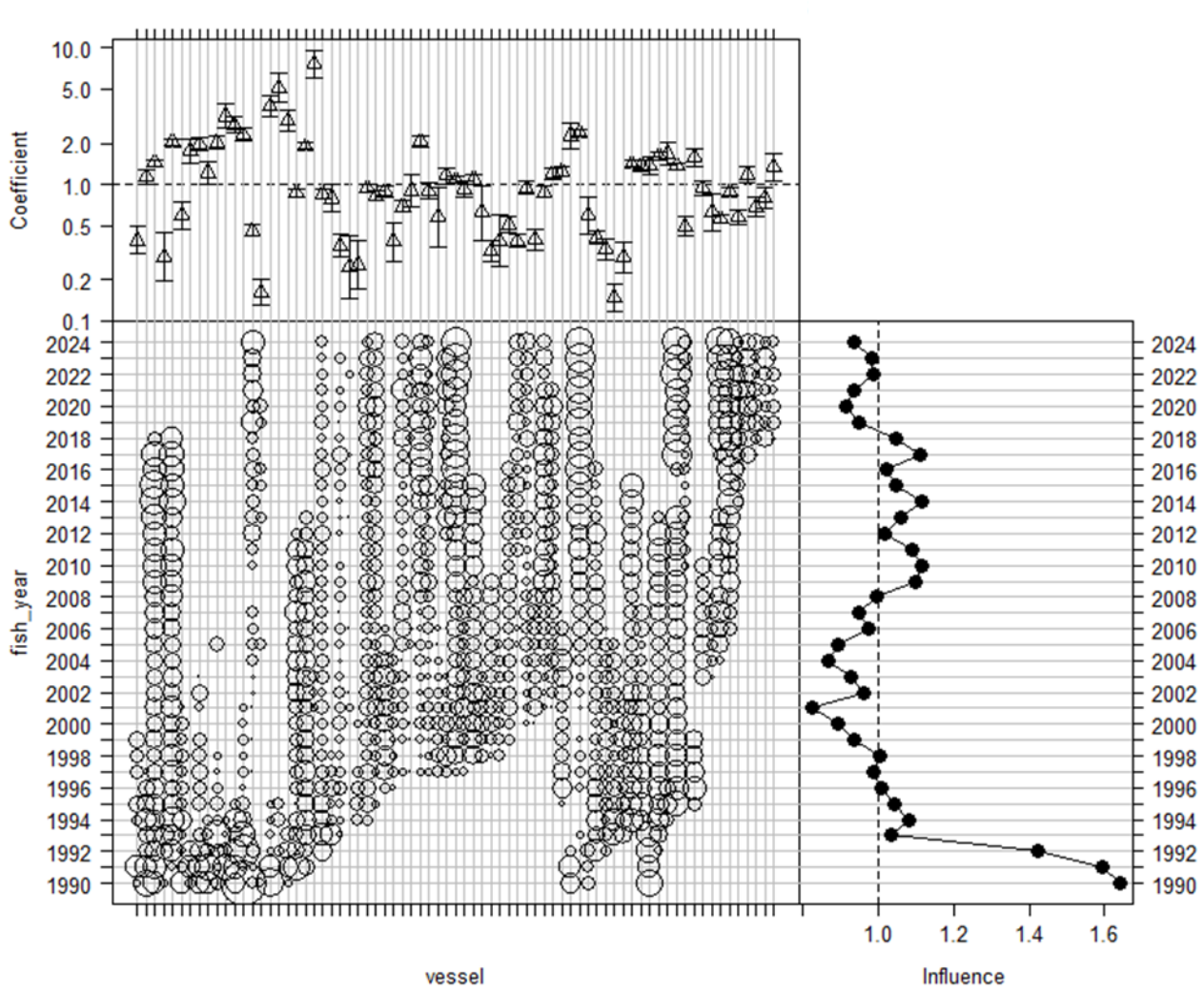
Appendix 7: SKI 3 Snares Shelf binomial proportion-zero standardisation model influence and step plots.



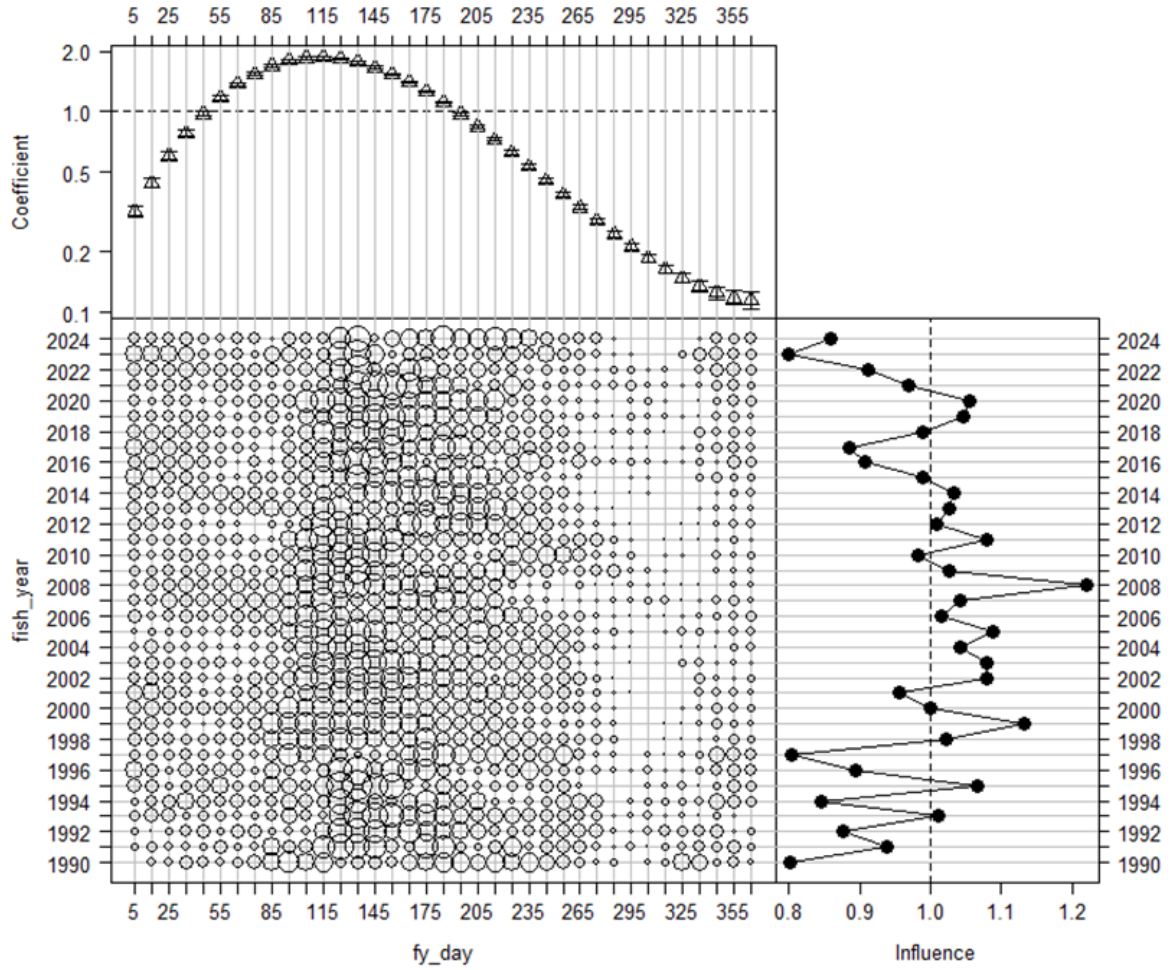
Appendix Figure 15: **SKI 3 Snares Shelf binomial proportion-zero model step plots (left) and influence plots for core vessels from 1989–90 to 2023–24. The step plots show how the indices change with the addition of predictor variables into the model. The influence plots show where the predictor variable influence the indices.**



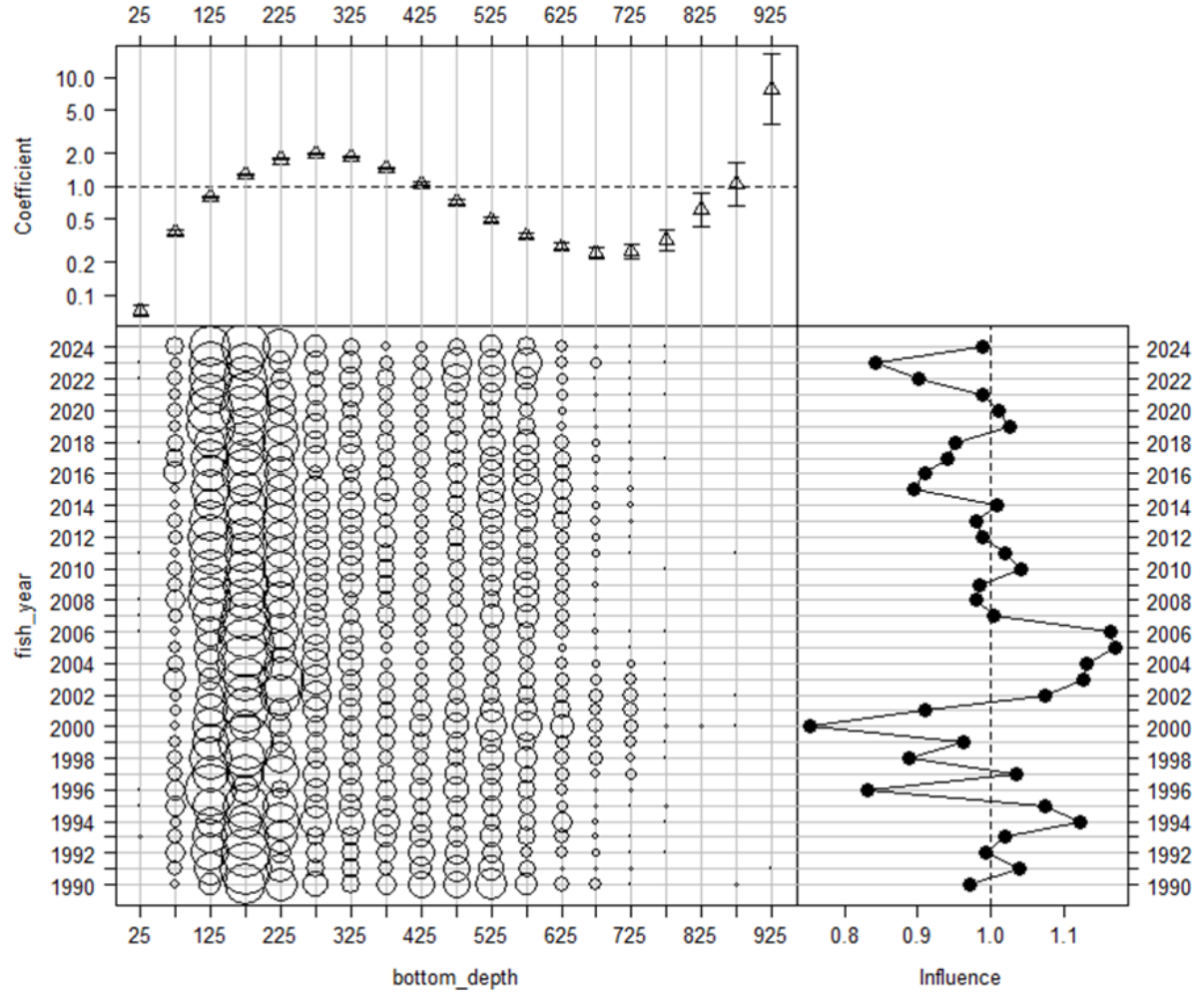
Appendix Figure 16: **SKI 3 Snares Shelf binomial proportion-zero model coefficient-distribution-influence plots (CDI) for statistical area from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**



Appendix Figure 17: SKI 3 Snares Shelf binomial proportion-zero model coefficient-distribution-influence plots (CDI) for vessel from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).



Appendix Figure 18: **SKI 3 Snares Shelf binomial proportion-zero model coefficient-distribution-influence plots (CDI) for fishing-year-day from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**



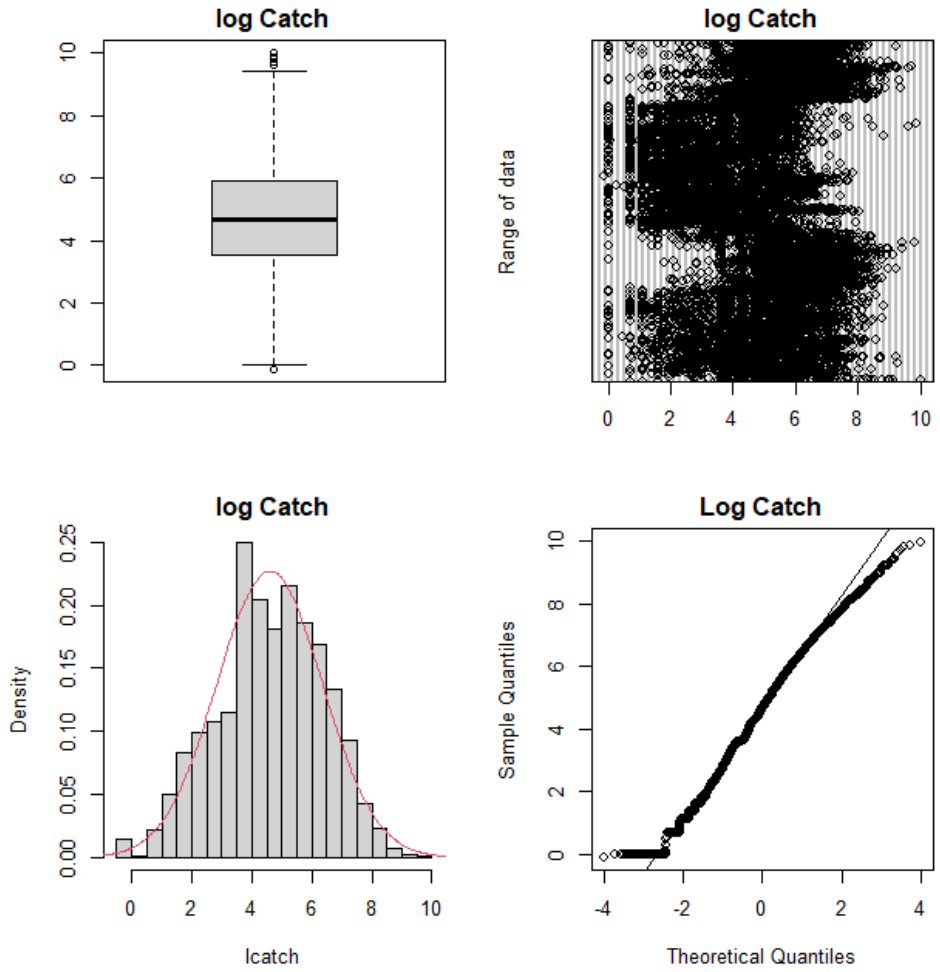
Appendix Figure 19: **SKI 3 Snares Shelf binomial proportion-zero model coefficient-distribution-influence plots (CDI) for bottom depth from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**

Appendix 8: SKI 3 Snares Shelf log-normal, binomial and combined CPUE indices

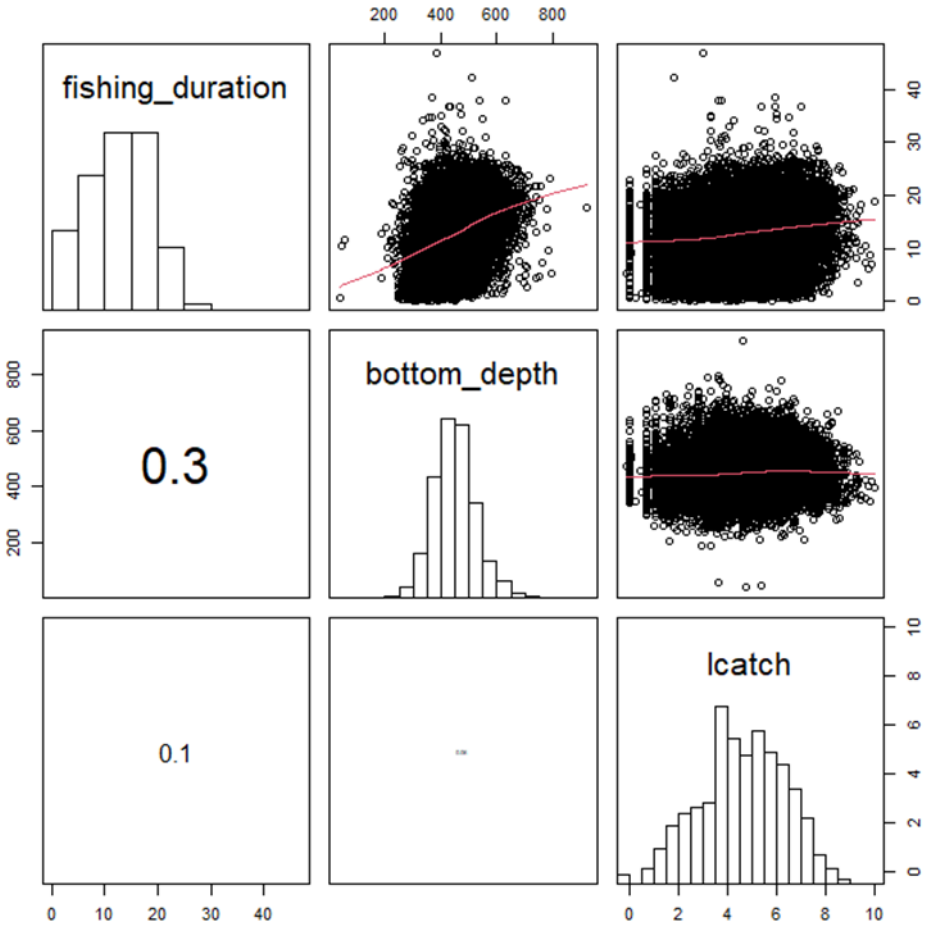
Fishing year	log-normal	SE log-normal	Binomial	Combined
1990	4.161	0.077	0.492	2.995
1991	3.059	0.063	0.535	2.391
1992	2.423	0.065	0.310	1.098
1993	2.699	0.062	0.302	1.193
1994	1.550	0.061	0.325	0.736
1995	1.533	0.056	0.319	0.714
1996	1.032	0.078	0.167	0.252
1997	1.008	0.073	0.139	0.204
1998	0.769	0.080	0.081	0.091
1999	0.706	0.088	0.064	0.066
2000	0.837	0.083	0.096	0.117
2001	0.521	0.072	0.077	0.059
2002	0.435	0.054	0.135	0.086
2003	0.536	0.041	0.284	0.223
2004	0.728	0.046	0.316	0.336
2005	0.480	0.045	0.251	0.176
2006	0.313	0.052	0.191	0.087
2007	0.358	0.061	0.175	0.092
2008	0.358	0.062	0.207	0.108
2009	0.265	0.083	0.170	0.066
2010	0.251	0.057	0.248	0.091
2011	0.336	0.051	0.330	0.162
2012	0.239	0.067	0.213	0.074
2013	0.331	0.054	0.346	0.167
2014	0.315	0.054	0.385	0.177
2015	0.234	0.050	0.510	0.174
2016	0.300	0.059	0.461	0.202
2017	1.365	0.038	0.847	1.690
2018	3.351	0.041	0.837	4.098
2019	3.822	0.035	0.903	5.046
2020	3.388	0.036	0.896	4.435
2021	4.759	0.039	0.889	6.184
2022	6.021	0.043	0.902	7.937
2023	11.216	0.043	0.962	15.763
2024	8.450	0.038	0.879	10.859

Appendix 9: SKI 7 WCSI log-normal CPUE standardisation model input data issue tests

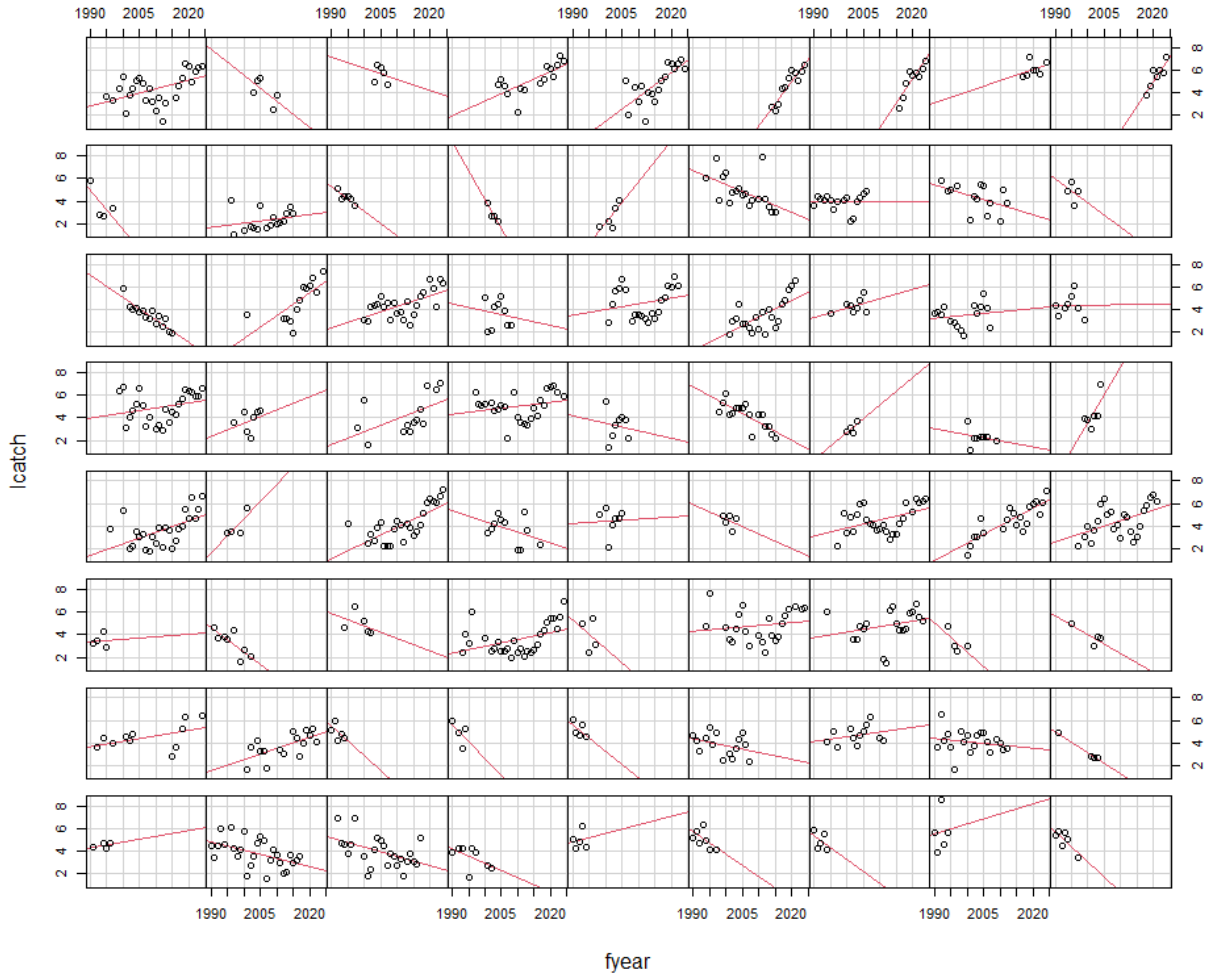
1. Test for normality in the model response variable PASSED



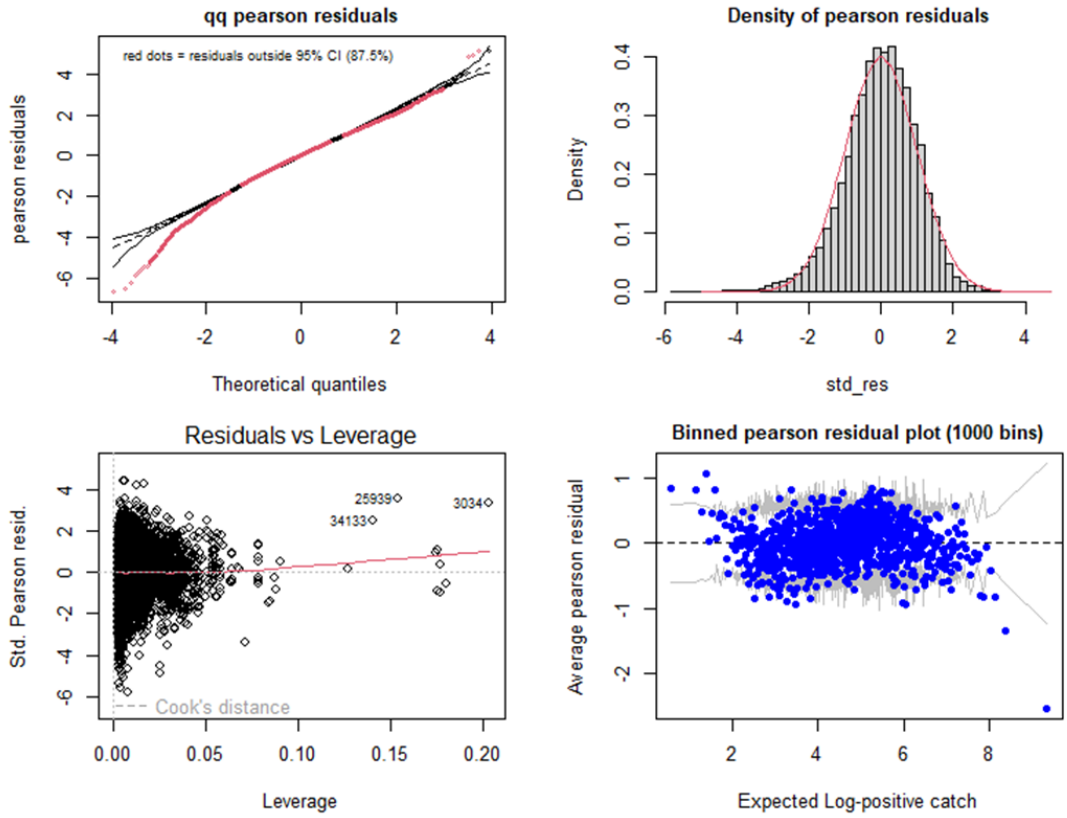
2. Test for high collinearity (Pearson correlation) issues between model continuous variables: PASSED



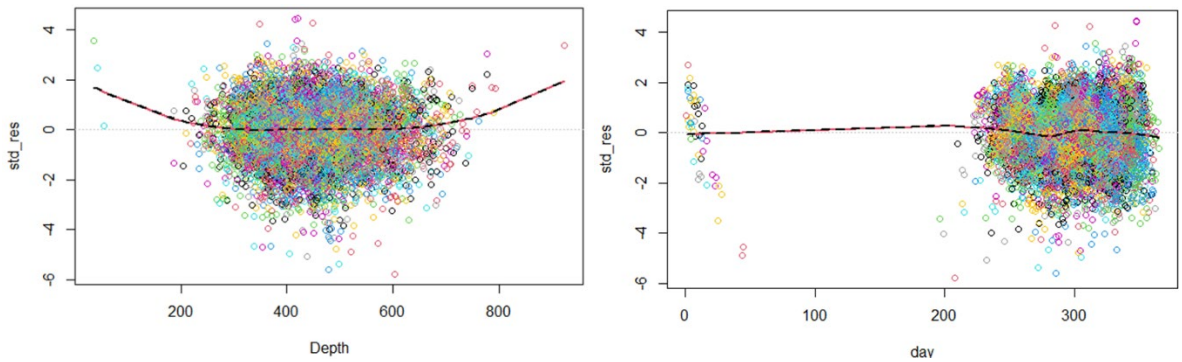
3. Test for marked discontinuities in individual vessel annual catches across fishing years: No obvious discontinuities.



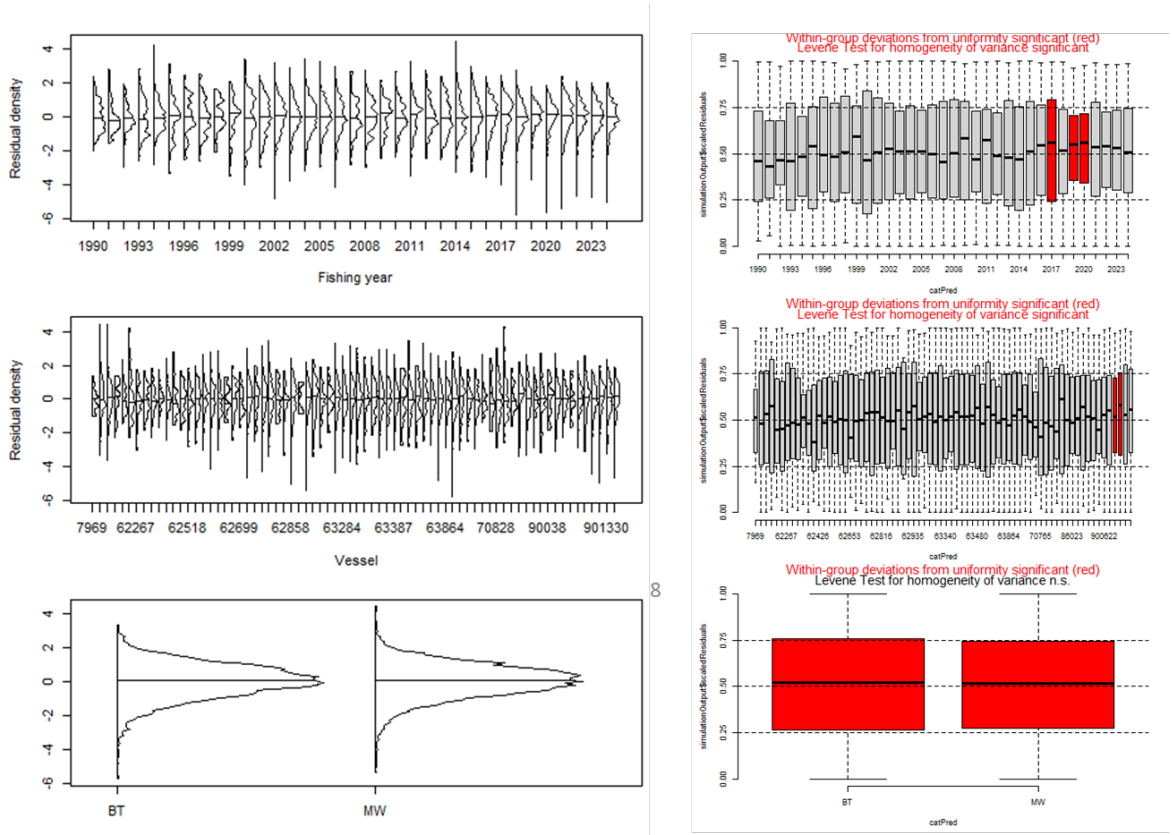
Appendix 10: SKI 7 WCSI log-normal CPUE standardisation model residual diagnostics



Appendix Figure 20: Residual diagnostics on the log-normal model log-catch (response) predictions

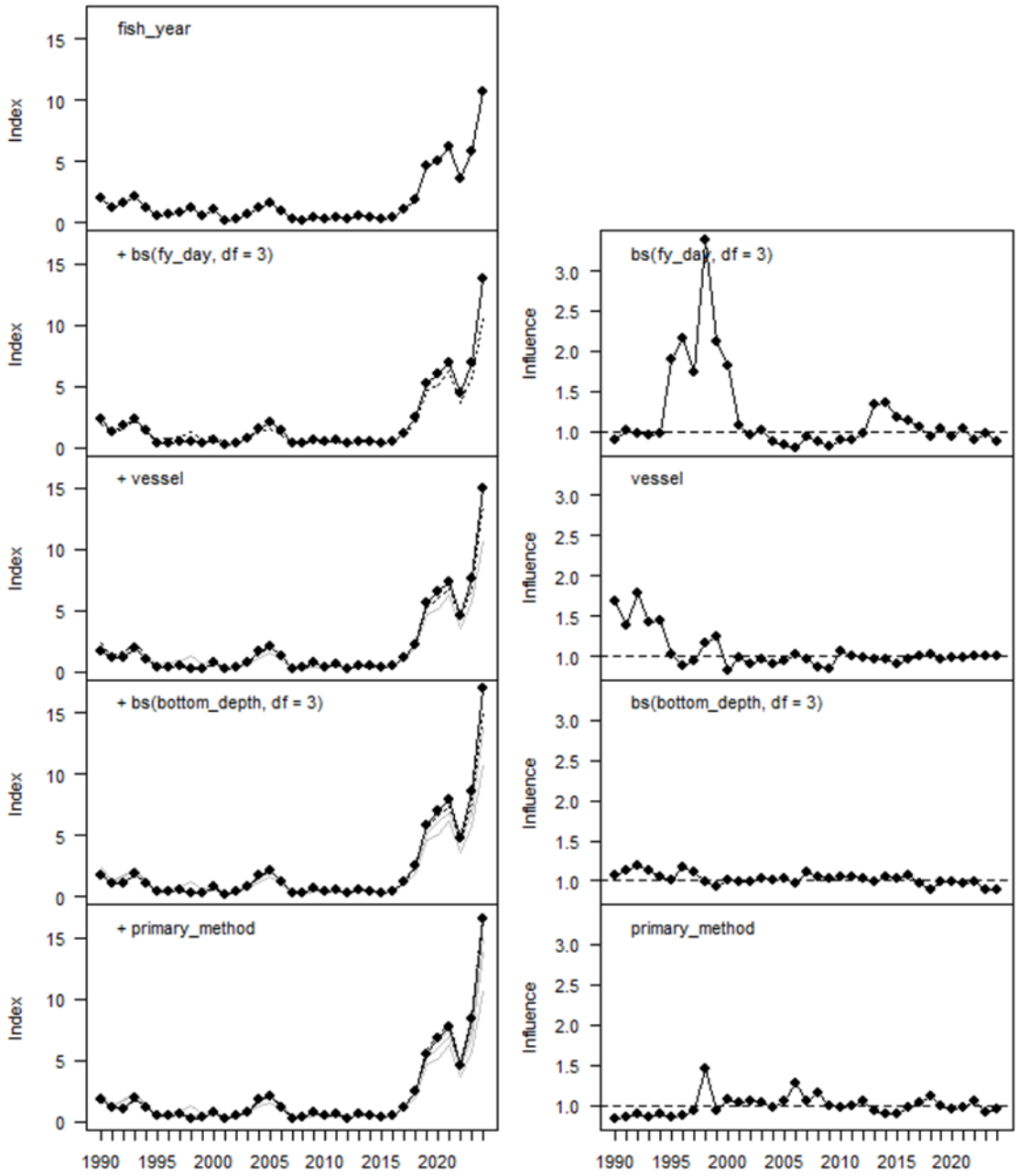


Appendix Figure 21: Log-normal model residuals across the range of model fishing year day and depth parameter values. Loess spline (dotted lines) departure away from zero horizontal equate to poor predictive performance. Colours are the residuals for the different fishing years.

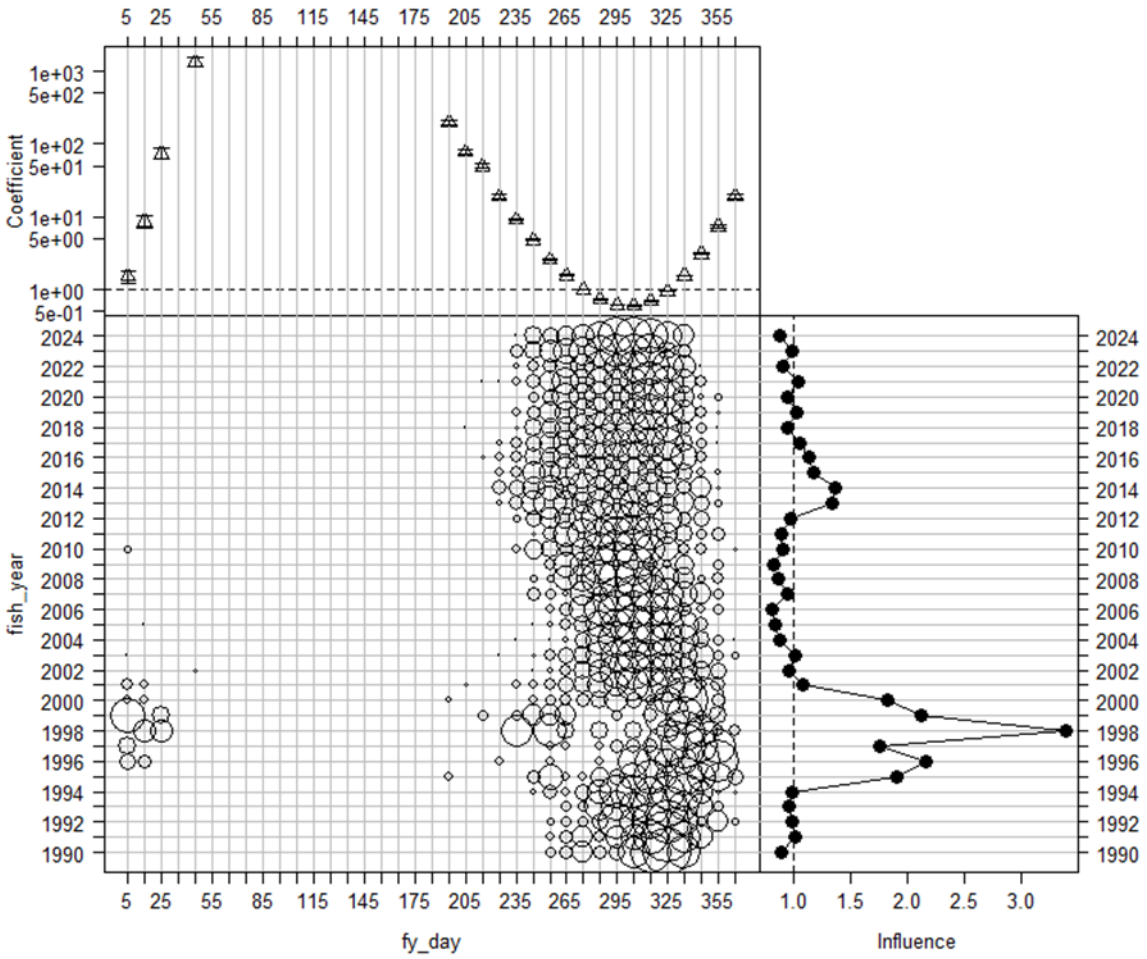


Appendix Figure 22: Log-normal model categorical term residual distributional plots (left graphs) and associated DHARMa nonparametric goodness-of-fit test plots (right graphs). DHARMa plots show failure of the between-group homogeneity of variance assumptions and the within group uniformity assumptions (red groups in plots).

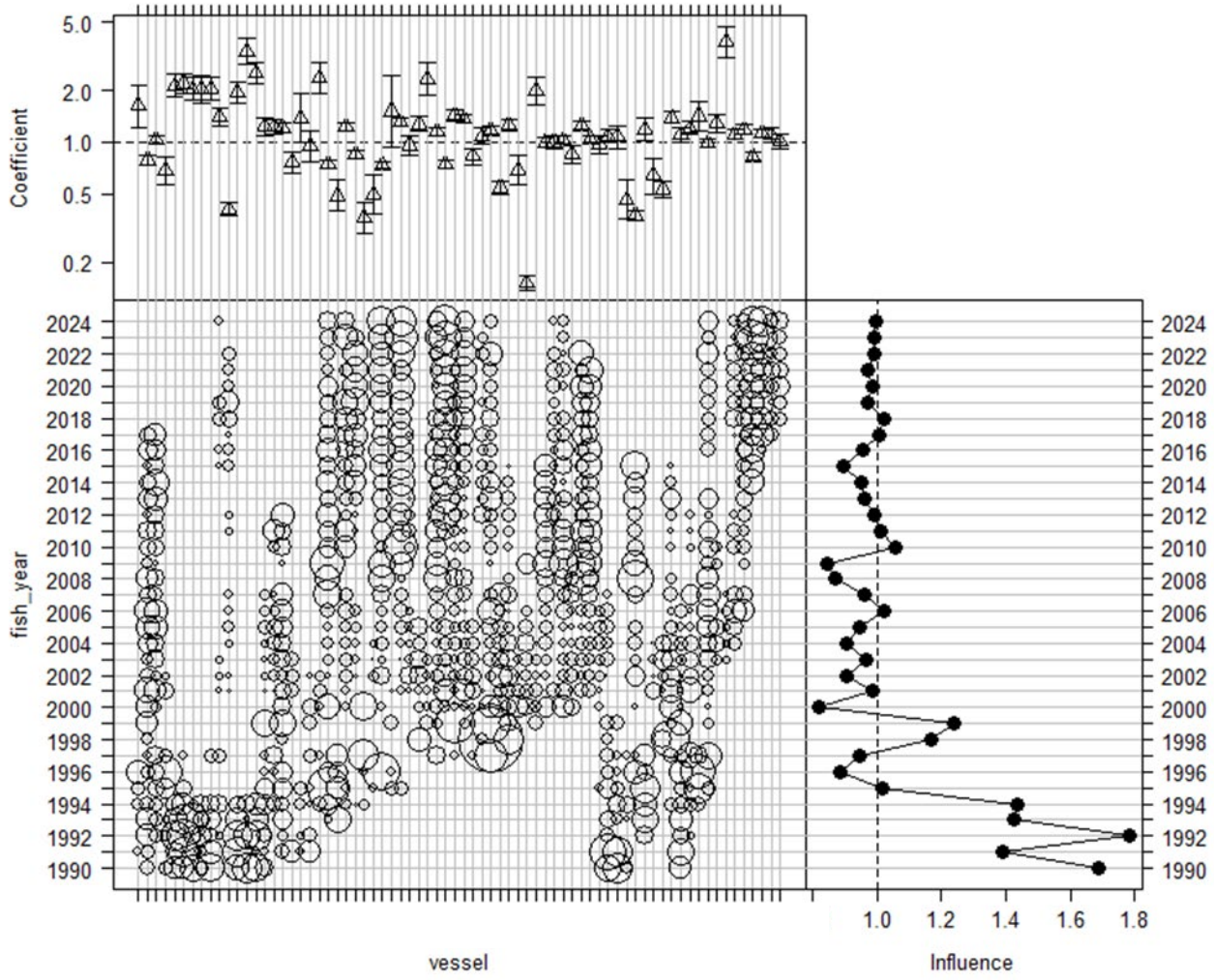
Appendix 11: SKI 7 WCSI log-normal CPUE standardisation model influence and step plots



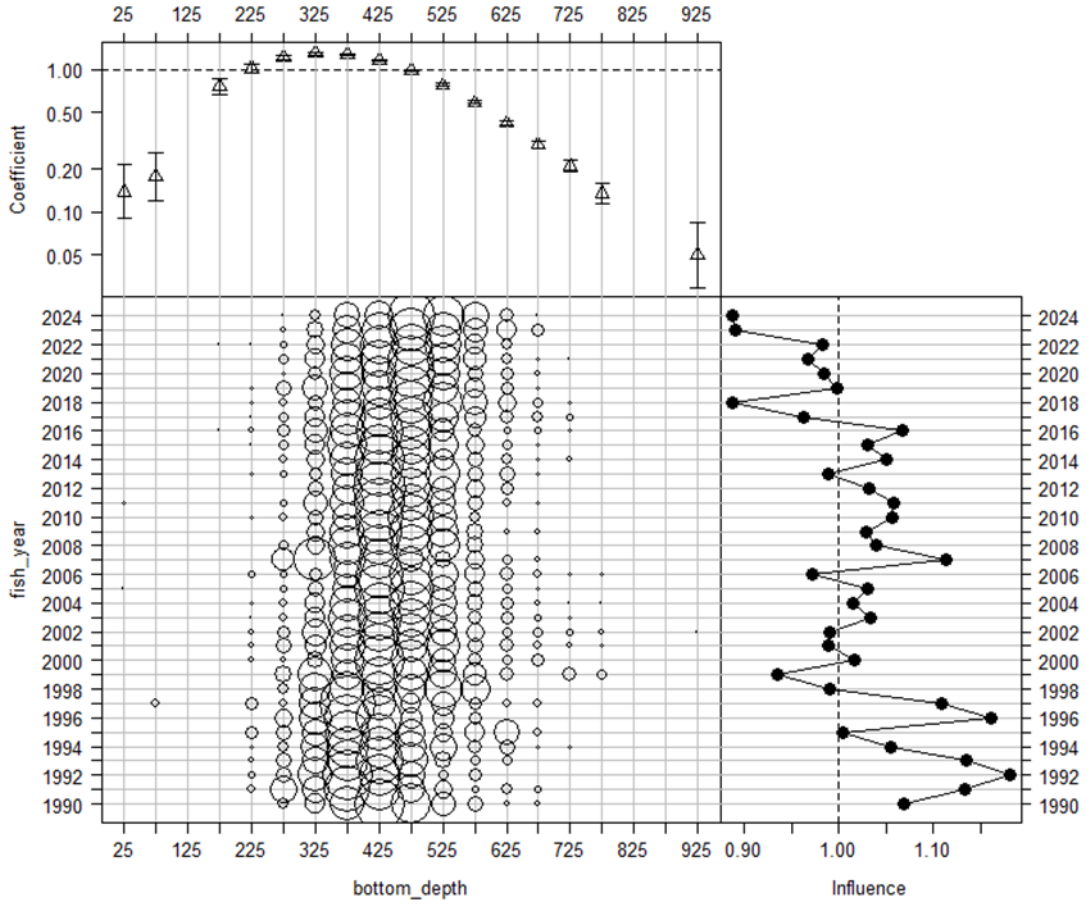
Appendix Figure 23: SKI 7 WCSI standardised CPUE indices step plots (left) and influence plots for core vessels from 1989–90 to 2023–24. The step plots show how the indices change with the addition of predictor variables into the model. The influence plots show where the predictor variable influence the indices.



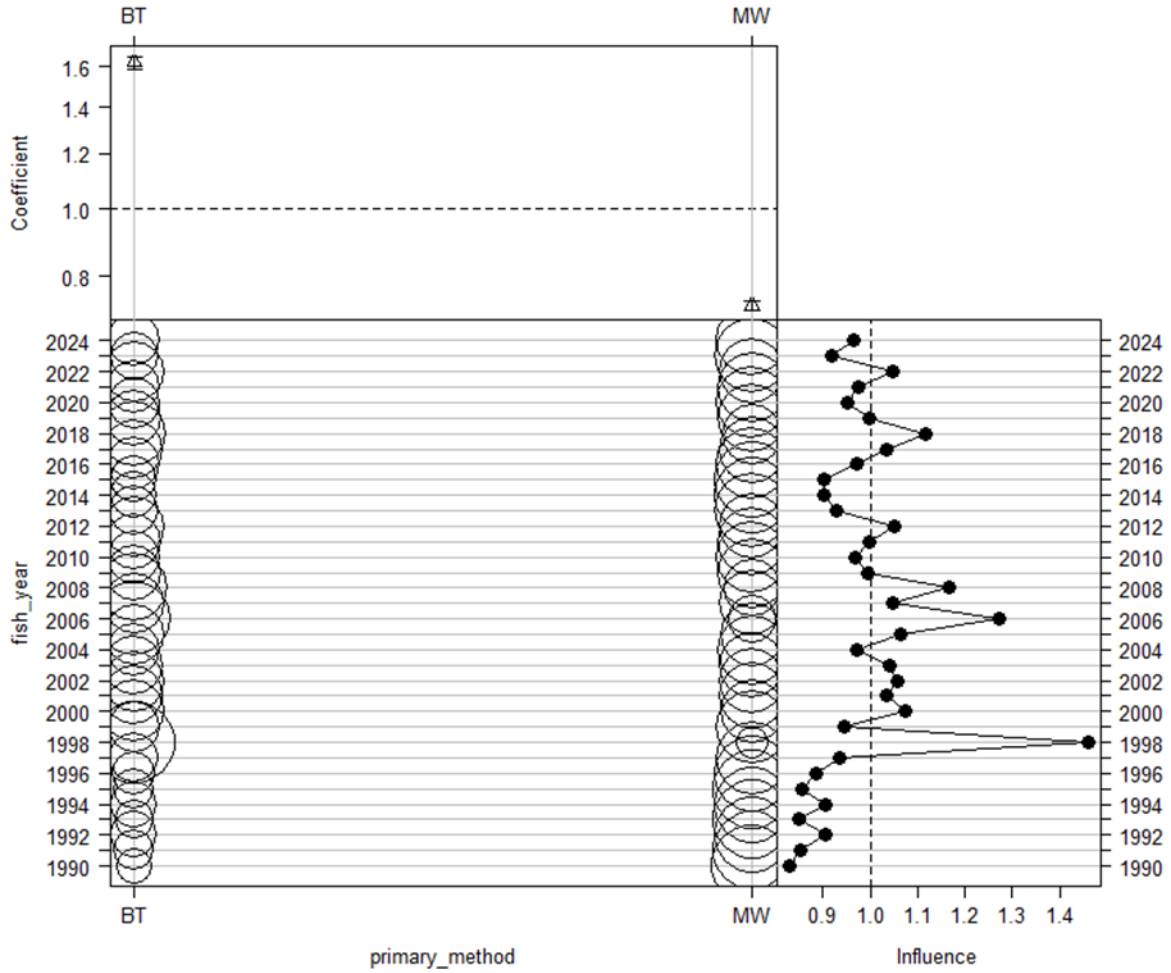
Appendix Figure 24: SKI 7 WCSI standardised CPUE analyses coefficient-distribution-influence plots (CDI) for fishing-year-day from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).



Appendix Figure 25: **SKI 7 WCSI standardised CPUE analyses coefficient-distribution-influence plots (CDI) for vessel from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**

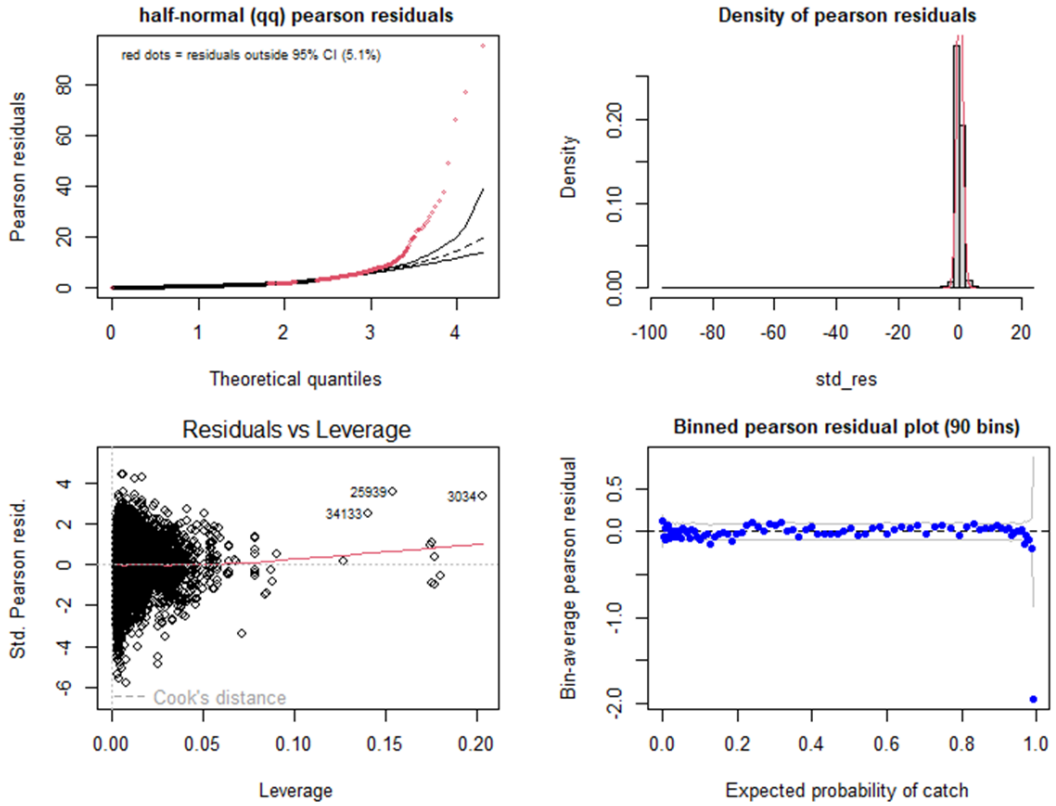


Appendix Figure 26: **SKI 7 WCSI standardised CPUE analyses coefficient-distribution-influence plots (CDI) for bottom depth from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**

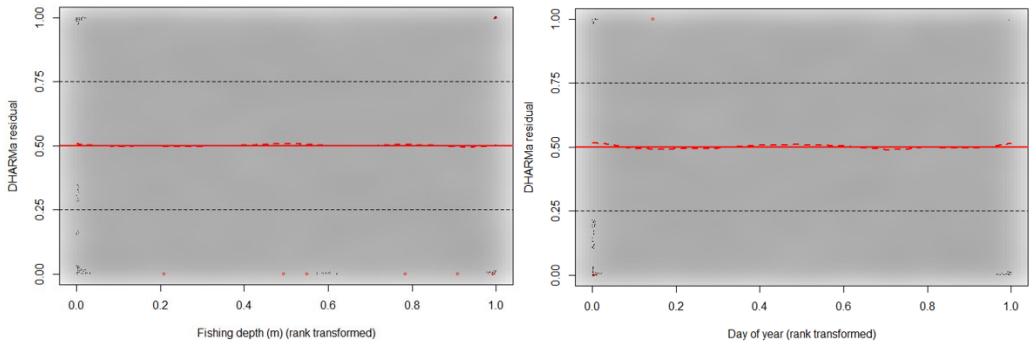


Appendix Figure 27: **SKI 7 WCSI standardised CPUE analyses coefficient-distribution-influence plots (CDI) for method from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**

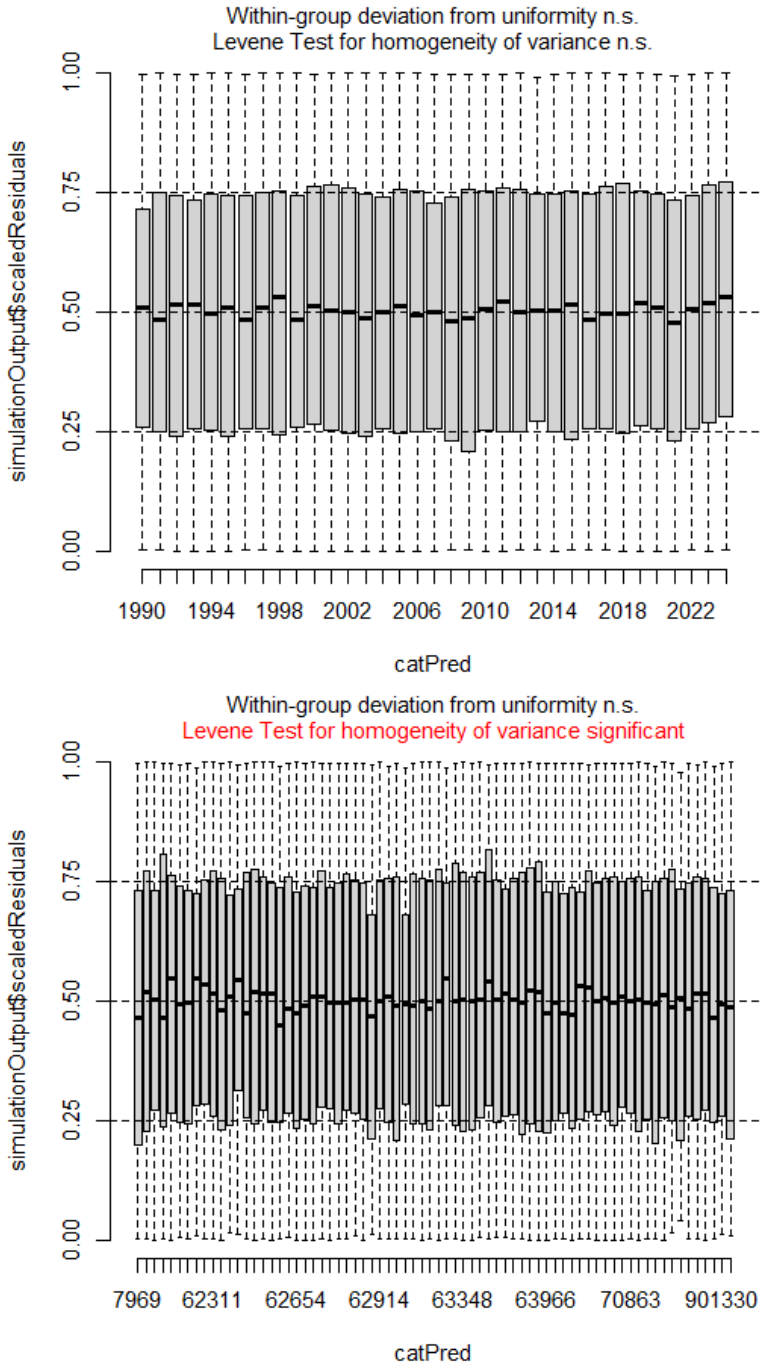
Appendix 12: SKI 7 WCSI binomial proportion-zero standardisation model residual diagnostics



Appendix Figure 28: Residual diagnostics on the binomial model proportion-zero (response) predictions

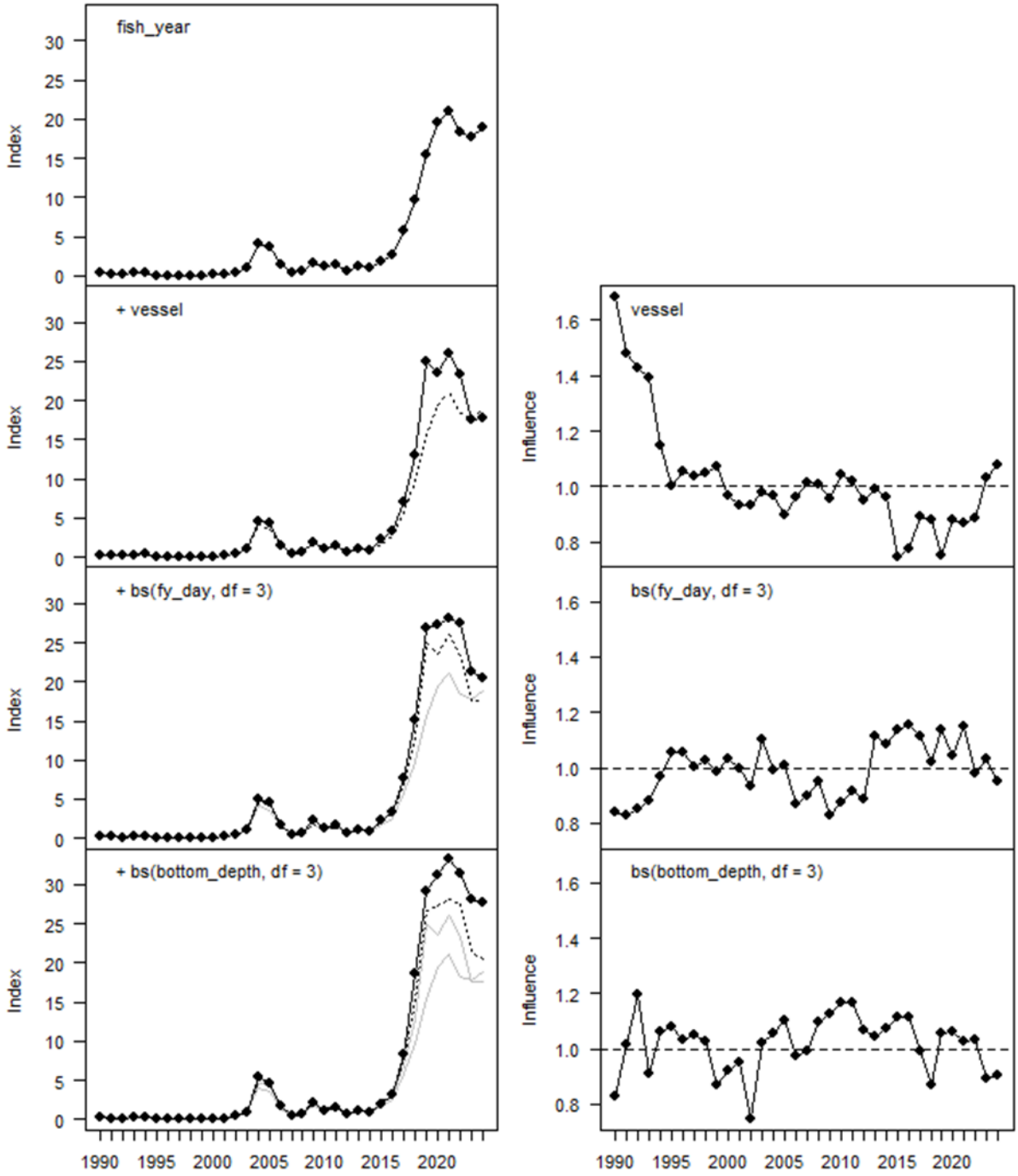


Appendix Figure 29: DHARMa nonparametric goodness-of-fit test plots across the range of model fishing-year-day and depth parameter values. Loess spline (dotted lines) departure away from zero horizontal equate to poor predictive performance.

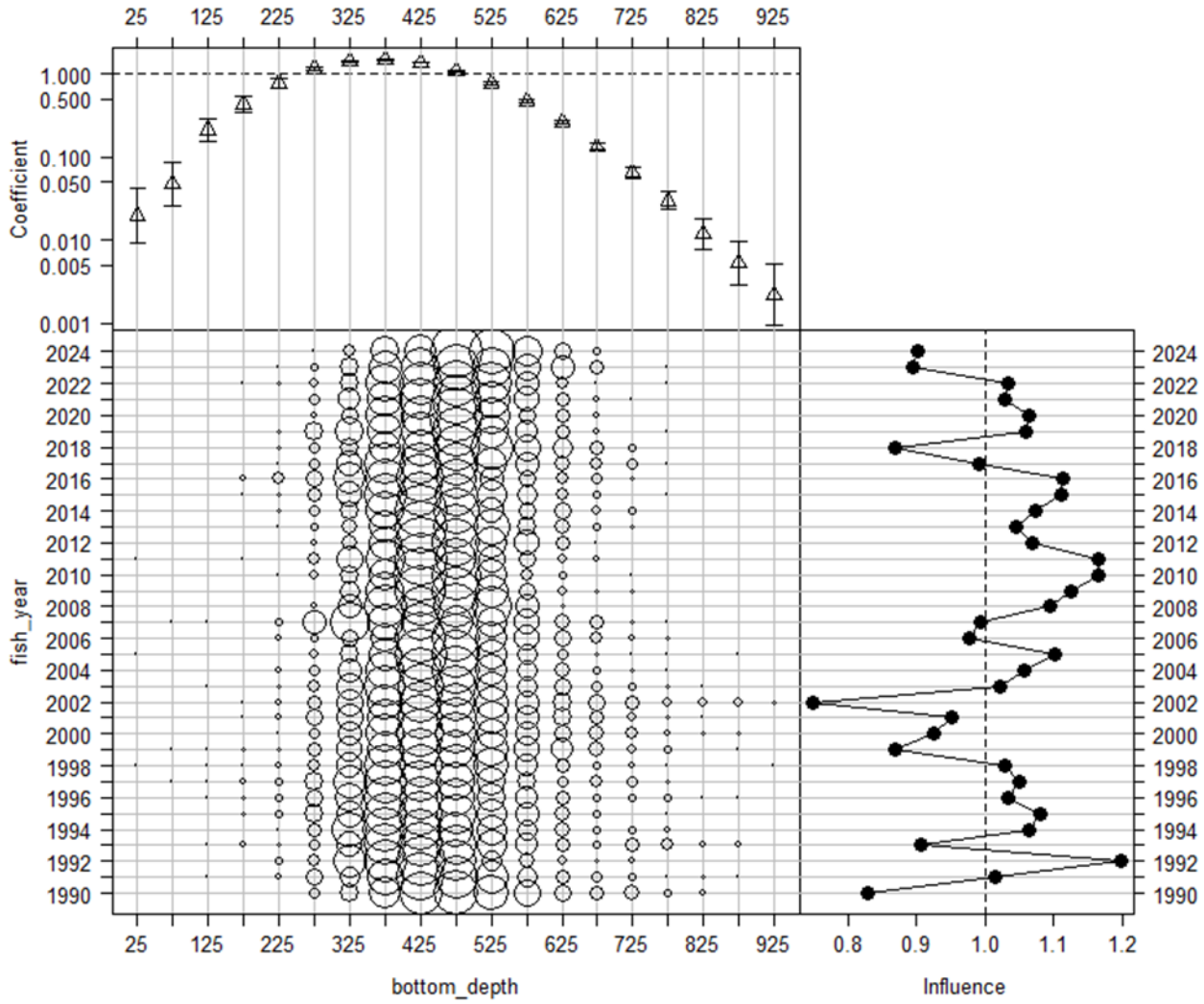


Appendix Figure 30: **DHARMa plots showing within group deviation from uniformity assumptions (a red group would show that there was significant deviation using a Levene Test).**

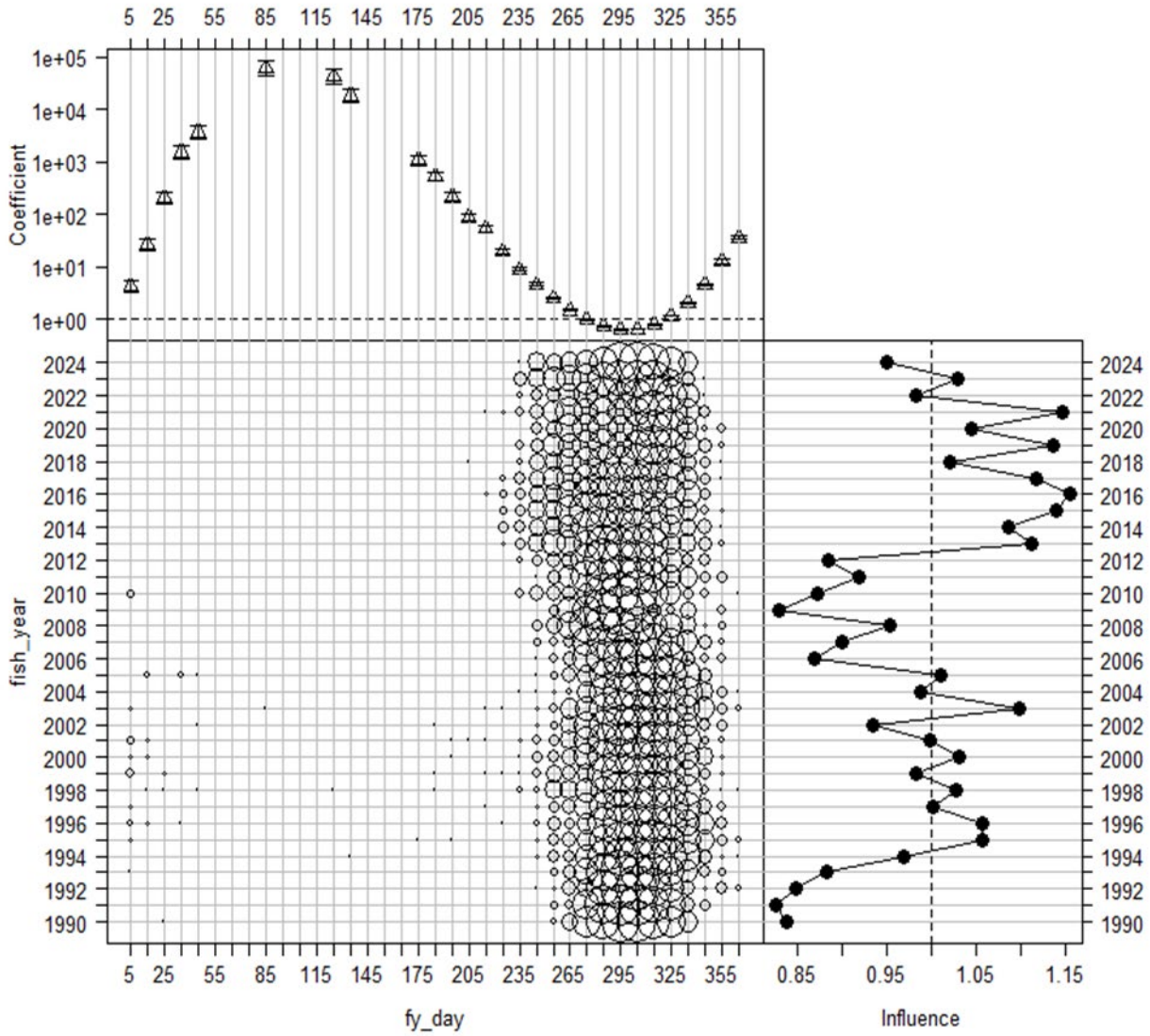
Appendix 13: SKI 7 WCSI binomial proportion-zero standardisation model influence and step plots



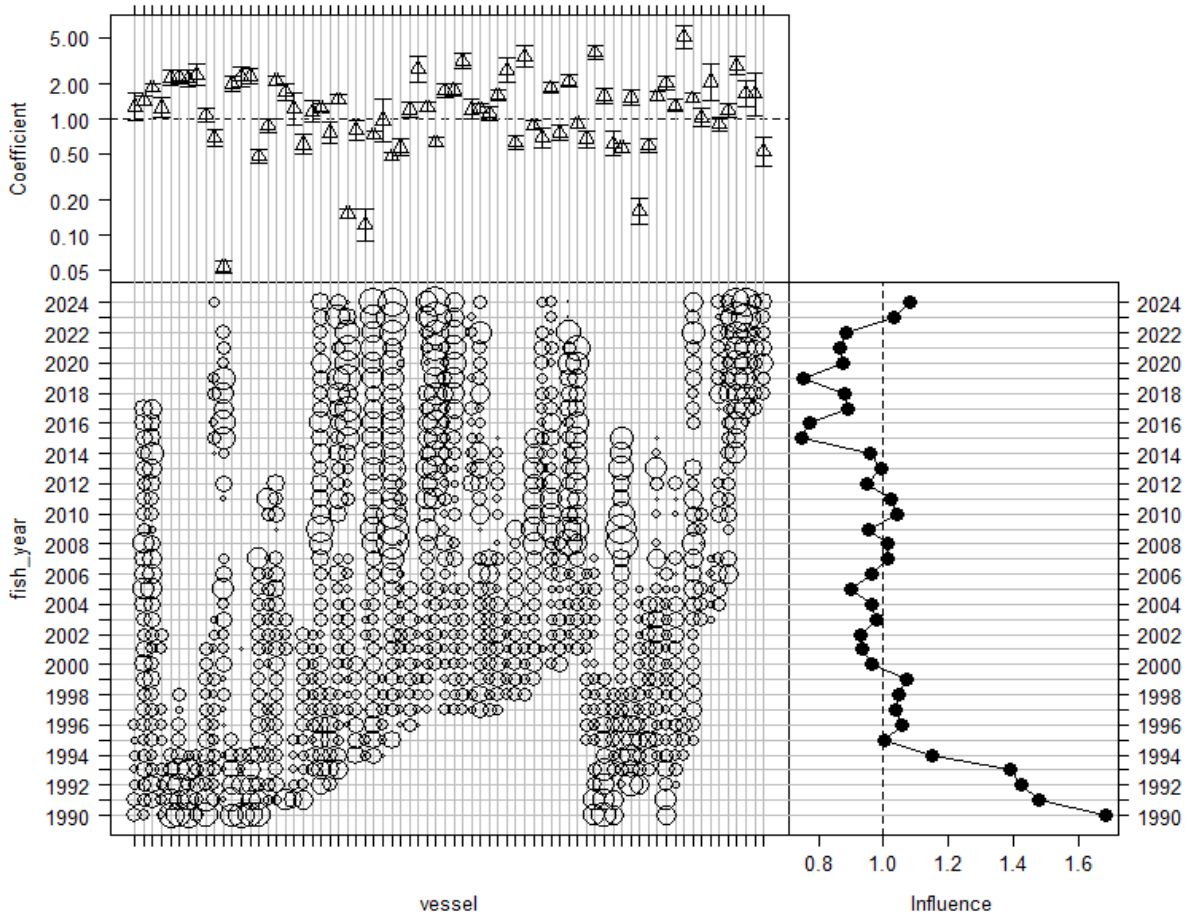
Appendix Figure 31: **SKI 7 WCSI binomial proportion-zero model step plots (left) and influence plots for core vessels from 1989–90 to 2023–24. The step plots show how the indices change with the addition of predictor variables into the model. The influence plots show where the predictor variable influence the indices.**



Appendix Figure 32: **SKI 7 WCSI binomial proportion-zero model coefficient-distribution-influence plots (CDI) for bottom depth from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**



Appendix Figure 33: **SKI 7 WCSI binomial proportion-zero model coefficient-distribution-influence plots (CDI) for fishing-year-day from 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**



Appendix Figure 34: **SKI 7 WCSI binomial proportion-zero model coefficient-distribution-influence plots (CDI) for vessel 1989–90 to 2023–24. Plots are shown for each predictor variable included in the model. Effect by level of variable (top), distribution of variable by fishing year (bottom left), and cumulative effect of variable each year (right).**

Appendix 14: SKI 7 WCSI log-normal, binomial and combined CPUE indices

Fishing year	log-normal	SE log-normal	Binomial	Combined
1990	1.757	0.083	0.244	0.534
1991	1.083	0.091	0.114	0.154
1992	1.001	0.098	0.098	0.123
1993	1.907	0.080	0.187	0.443
1994	1.109	0.059	0.226	0.311
1995	0.437	0.113	0.032	0.017
1996	0.440	0.119	0.027	0.015
1997	0.602	0.108	0.029	0.022
1998	0.261	0.148	0.011	0.004
1999	0.317	0.129	0.025	0.010
2000	0.751	0.077	0.075	0.070
2001	0.223	0.058	0.139	0.038
2002	0.453	0.046	0.344	0.194
2003	0.797	0.037	0.468	0.464
2004	1.815	0.033	0.834	1.882
2005	2.116	0.038	0.806	2.122
2006	1.144	0.048	0.619	0.880
2007	0.281	0.076	0.293	0.102
2008	0.296	0.083	0.371	0.136
2009	0.699	0.075	0.656	0.571
2010	0.432	0.062	0.505	0.271
2011	0.585	0.051	0.570	0.415
2012	0.282	0.063	0.380	0.133
2013	0.546	0.055	0.487	0.331
2014	0.469	0.052	0.427	0.249
2015	0.355	0.044	0.650	0.287
2016	0.485	0.041	0.749	0.452
2017	1.201	0.038	0.884	1.320
2018	2.405	0.036	0.945	2.826
2019	5.536	0.039	0.964	6.635
2020	6.809	0.043	0.966	8.180
2021	7.688	0.045	0.968	9.256
2022	4.564	0.043	0.966	5.485
2023	8.436	0.048	0.963	10.098
2024	16.556	0.046	0.962	19.808

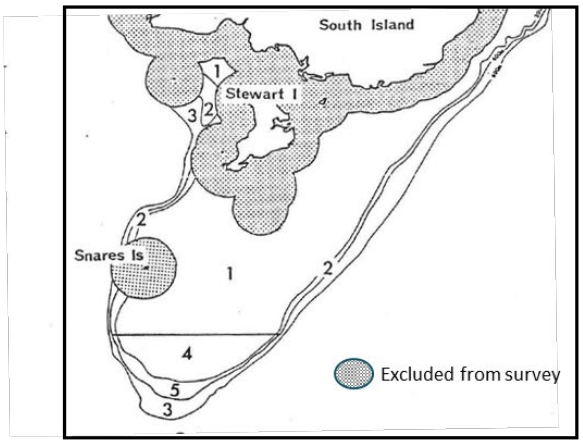
Appendix 15: SKI 3 & 7 catch history (tonnes) assumed in the 2025 assessment modelling

Fishing year	SKI 3	SKI 7	Fishing year	SKI 3	SKI 7
1975	206	44	2001	52	96
1976	10	43	2002	79	135
1977	5	89	2003	127	295
1978	492	1 284	2004	86	596
1979	2 524	754	2005	79	699
1980	2 279	1 109	2006	30	273
1981	1 643	2 003	2007	29	230
1982	1 166	810	2008	20	197
1983	2 400	1 200	2009	12	234
1984	4 177	2 089	2010	22	158
1985	3 040	1 789	2011	36	331
1986	6 535	1 762	2012	12	286
1987	2 250	1 176	2013	25	257
1988	1 830	1 180	2014	43	295
1989	1 239	1 191	2015	23	254
1990	1 280	1 025	2016	88	205
1991	678	358	2017	273	474
1992	316	642	2018	512	641
1993	408	516	2019	634.7	1 030.7
1994	83	353	2020	565.4	1 031.8
1995	176	113	2021	1 169.3	1 113.2
1996	54	89	2022	969.1	864.6
1997	64	262	2023	1 449.8	1 185.8
1998	30	48	2024	2 068.0	1 532.0
1999	19	65	2025	1 414*	1 173*
2000	68	118			

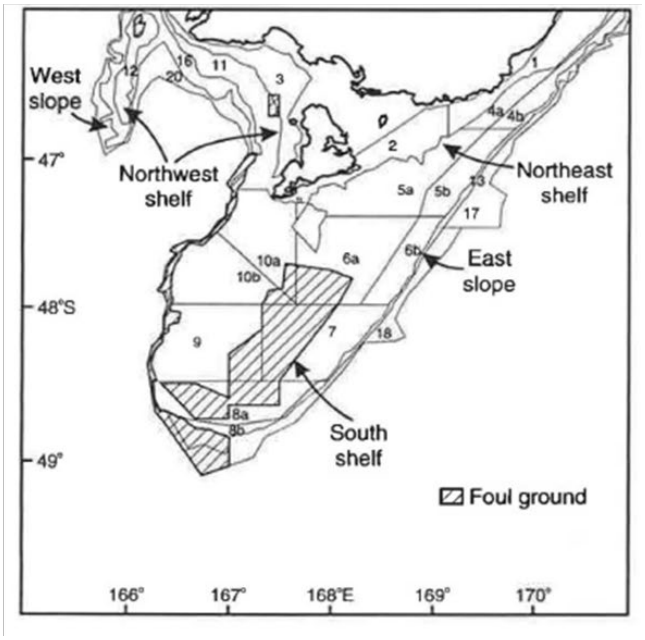
* Derived as average of most recent five years

Appendix 16: Snares Shelf (SKI 3) *Shinkai Maru* (1981–1983) and *Tangaroa* (1993–1996) comparable stratification

Shinkai Maru survey strata



Tangaroa survey strata



Shinkai Maru		*Tangaroa*	
Stratum id	Area km^2	Stratum id	Area km^2
1	22 020	4	2 056
2	1 762	5	5 249
3	5 432	6	5 551
	3 331	7	4 009
5	1 037	8	3 448
Total	33 582	9	4 071
		10	5 967
		12	1 003
		13	876
		17	1 820
		18	1 750
		Total	35 800

Appendix 17: WCSI *Kaharoa* survey stratum included in the gemfish reanalysis. Yellow highlighted strata were excluded from the analysis as these strata were not sampled in all years. Numbers are the stratum areas (km^2) in each survey year as recorded in the Fisheries New Zealand research database. Note: minor differences in stratum area definitions through time on the analytical conclusions can be assumed to be minimal.

	Survey year																
	1990	1992	1994	1995	1997	2000	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021	2023
1	1344.66	1344.66	1344.66	1342.93	1342.93	1342.93	1342.93	1342.93	1342.93	1342.93	1342.93	1342.93	1343	1343	1343	1343	1343
2	4301.99	4302	4302	4302	4302	4302	4302	4302	4302	4302	4302	4302	4302	4302	4302	4302	4302
3																	
4																	
5	1224.07	1224.07	1224.07	1224.07	1224.7	1224.07	1136.17	1136.17	1136.17	1136.17	1136.17	1224.07	1224	1224	1224	1224	1224
6	3232.66	3232.66	3232.66	3232.66	3232.66	3232.66	3232.66	3232.66	3232.66	3232.66	3232.66	3232.66	3233	3233	3233	3233	3233
7	926.97	926.97	926.97	926.97	926.97	926.97	926.97	926.97	926.97	926.97	926.97	926.97	927	927	927	927	927
8	2354.34	2354.34	2354.34	2354.34	2354.33	2354.34	2354.36	2354.36	2354.36	2354.36	2354.36	2354.34	2354	2354	2354	2354	2354
9	1506.93	1876.79	1876.79	1876.79	1876.78	1876.79	1876.79	1876.79	1876.79	1876.79	1876.79	1876.79	1877	1877	1877	1877	1877
10																	
11	1385.5	1438.18	1438.18	1438.18	1438.18	1438.18	1438.18	1438.18	1438.18	1438.18	1438.18	1438.18	1438	1438	1438	1438	1438
12	1947.57	1948.37	1948.37	2053.94	2053.94	2053.94	2053.94	2053.94	2053.94	2053.94	2053.94	2053.94	2054	2054	2054	2054	2054
13	662.89	1206.28	1206.28	1100.8	1100.8	1100.8	1100.8	1100.8	1100.8	1100.8	1100.8	1100.8	1101	1101	1101	1101	1101
14	1273.89	850.52	850.52	850.52	850.51	850.52	850.52	850.52	850.52	850.52	850.52	850.52	851	851	851	851	851
15	1178.94	904.93	904.93	881.24	881.71	882.84	882.84	882.84	882.84	882.84	882.84	882.84	881	881	881	881	881
16	582.54	295.18	295.18	318.6	318.6	318.6	318.6	318.6	318.6	318.6	318.6	318.6	319	319	319	319	319
17	307.44	307.44	307.44	307.44	307.44	307.44	307.44	307.44	307.44	307.44	307.44	307.44	307	307	307	307	307
18	1039.83	948.53	948.53	946.76	946.76	946.76	946.76	946.76	946.86	946.76	946.76	946.76	947	947	947	947	947
19	2339.5	2430.8	2430.8	2436.32	2436.21	2436.21	2436.21	2436.21	2436.21	2436.21	2436.21	2436.21	2436	2436	2436	2436	2436
20																	
21																	
Total	25609.72	25591.72	25591.72	25593.56	25594.52	25595.05	25507.17	25507.17	25507.27	25507.17	25507.17	25595.05	25594	25594	25594	25594	25594

Appendix 18: WCSI *Tangaroa* survey stratum included in the gemfish reanalysis. Yellow highlighted strata were excluded from the analysis as these strata were not sampled in all years. Numbers are the stratum areas (km^2) in each survey year as recorded in the Fisheries New Zealand research database.

	Survey year					
Stratum	2012	2013	2016	2018	2021	2024
0004						
0006						
0007						
0012						
004A	786	786	786	786	786	786
004B	592	592	592	592	592	592
004C	1455	1455	1455	1455	1455	1455
004D	1655	1655	1655	1655	1655	1655
004E						
004F						
004G						
004S	1600	1600	1600	1600	1600	1600
005A						
005B						
012A	1214	1214	1214	1214	1214	1214
012B	1028	1028	1028	1028	1028	1028
012C	3148	3148	3148	3148	3148	3148
012D						
012S	1450	1450	1450	1450	1450	1450
Total	12928	12928	12928	12928	12928	12928

Appendix 19: SKI 3 trawl fishery at-sea Observer length frequency sample numbers. '*' denotes sample year data fitted in the assessment modelling (i.e. > 20 events and > 500 fish sampled)

Fishing year	Events	Males	Females	All	Fitted
1990	19	44	61	107	
1991	30	111	206	328	
1992	78	294	427	805	*
1993	143	168	294	464	
1994	127	184	397	584	*
1995	147	222	342	564	*
1996	58	28	71	100	
1997	29	27	51	78	
1998	39	41	114	155	
1999	55	33	41	74	
2000	59	81	299	380	
2001	30	20	63	86	
2002	79	188	451	647	*
2003	141	390	1 010	1 400	*
2004	54	48	93	141	
2005	67	95	217	312	
2006	42	75	206	281	
2007	17	13	17	30	
2008	1	0	3	3	
2009	1	0	1	1	
2010	15	7	25	32	
2011	7	8	94	102	
2012	1	12	2	14	
2013	5	5	18	23	
2014	3	2	10	12	
2015	3	2	58	60	
2016	0	0	0	0	
2017	40	307	388	713	*
2018	88	631	890	1521	*
2019	126	1 064	1 569	2 634	*
2020	98	635	797	1 433	*
2021	96	837	1 169	2 013	*
2022	76	680	825	1 505	*
2023	63	785	1 128	1 915	*
2024	97	1 100	1 435	2 560	*

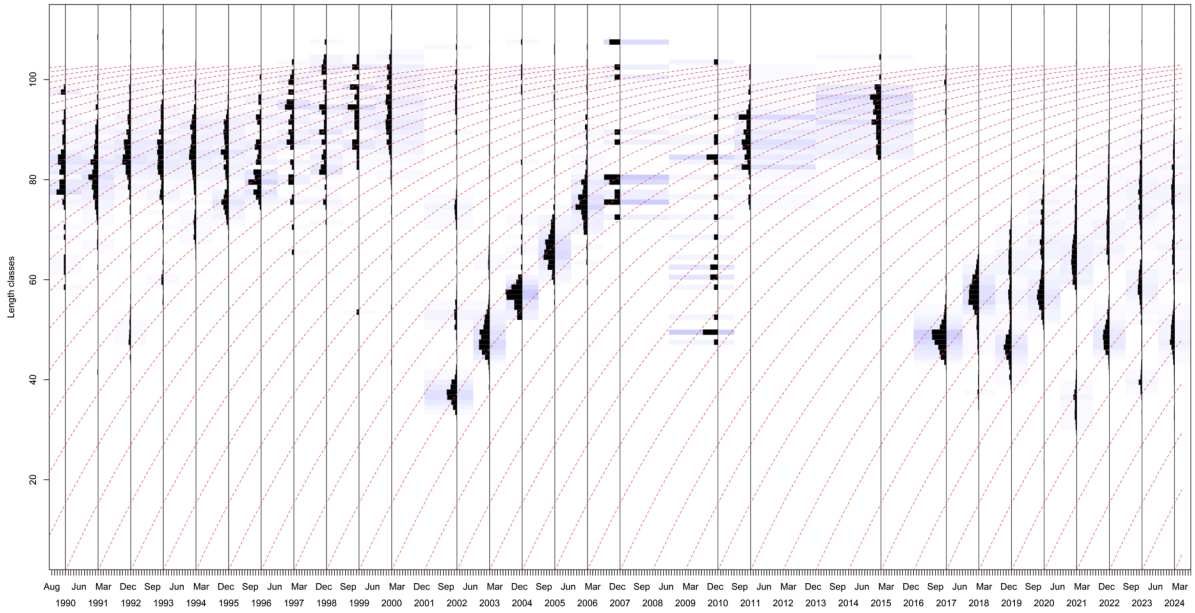
Appendix 20: SKI 7 trawl fishery at-sea Observer length frequency sample numbers. '*' denotes sample year data fitted in the assessment modelling (i.e. > 20 events and > 500 fish sampled)

Fishing year	Events	Male	Female	All	Fitted
1990	25	15	42	77	
1991	89	332	300	936	*
1992	92	354	497	869	*
1993	39	140	134	274	
1994	281	834	1 701	2 567	*
1995	94	135	129	281	
1996	99	150	269	420	
1997	34	34	73	107	
1998	18	20	15	35	
1999	64	300	310	612	*
2000	109	90	442	533	*
2001	81	127	111	259	
2002	102	229	263	499	
2003	171	512	481	994	*
2004	167	636	592	1 240	*
2005	121	474	383	857	*
2006	77	173	131	315	
2007	38	21	60	81	
2008	4	2	4	6	
2009	23	80	97	177	
2010	2	1	4	5	
2011	9	21	140	161	
2012	21	63	179	242	
2013	34	52	268	320	
2014	18	58	241	299	
2015	19	80	200	285	
2016	14	49	45	97	
2017	50	325	353	681	*
2018	55	364	384	749	*
2019	89	876	750	1 632	*
2020	160	1 579	1 518	3 107	*
2021	82	726	807	1 560	*
2022	48	406	608	1 015	*
2023	62	779	1 053	1 835	*
2024	68	671	851	1 528	*

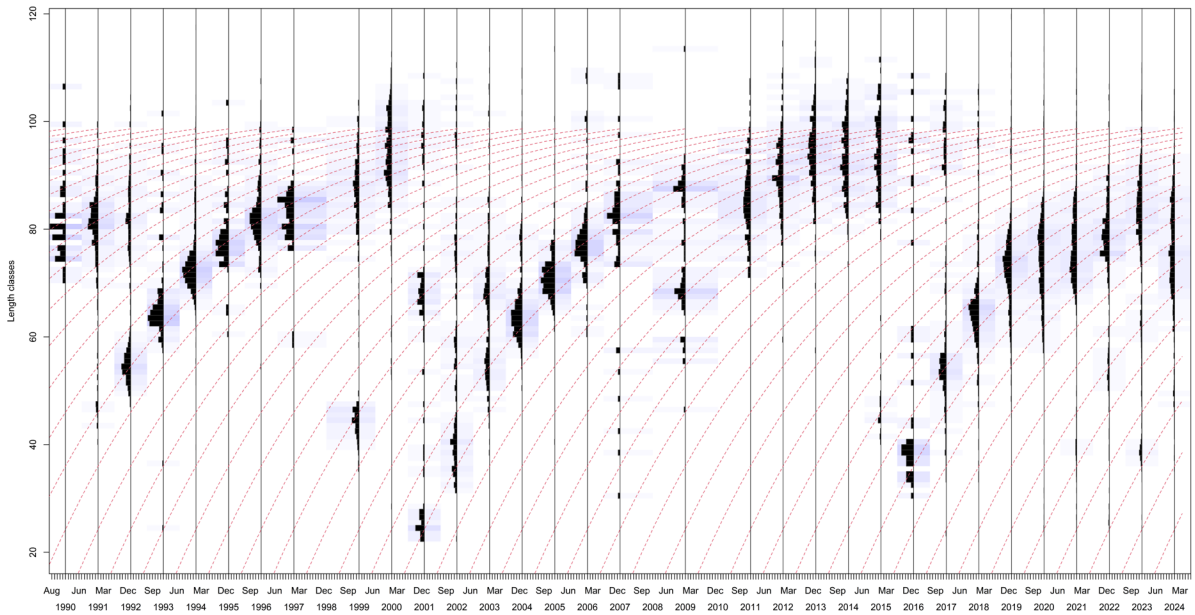
Appendix 21: SKI 3 & 7 observer data ELEFAN growth estimation

Male and Female gemfish VB growth parameter estimates were derived from the SKI 3 & 7 observer data series using Electronic Length-Frequency ANalysis (ELEFAN) algorithm methods first developed by Pauly & David (1981). The ELEFAN analyses were conducted using the FAO R package TropFishR (Sparre & Venema 1998, 1999). The ELEFAN model used a genetic algorithm (GA) fitting approach for parameter estimation.

a.

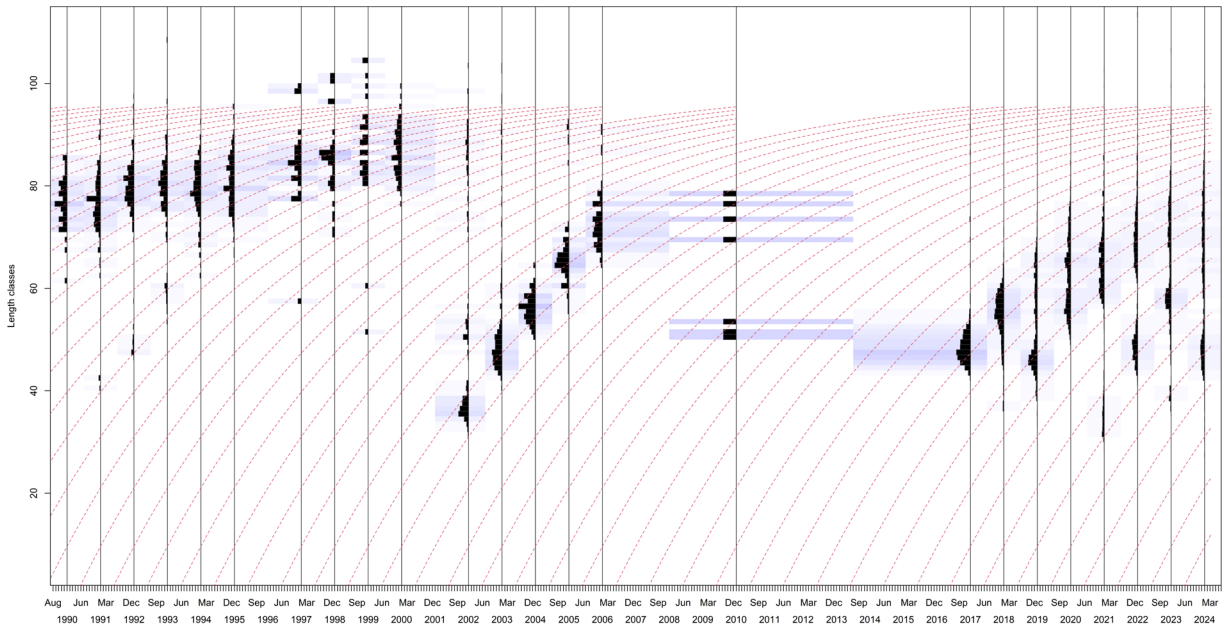


b.

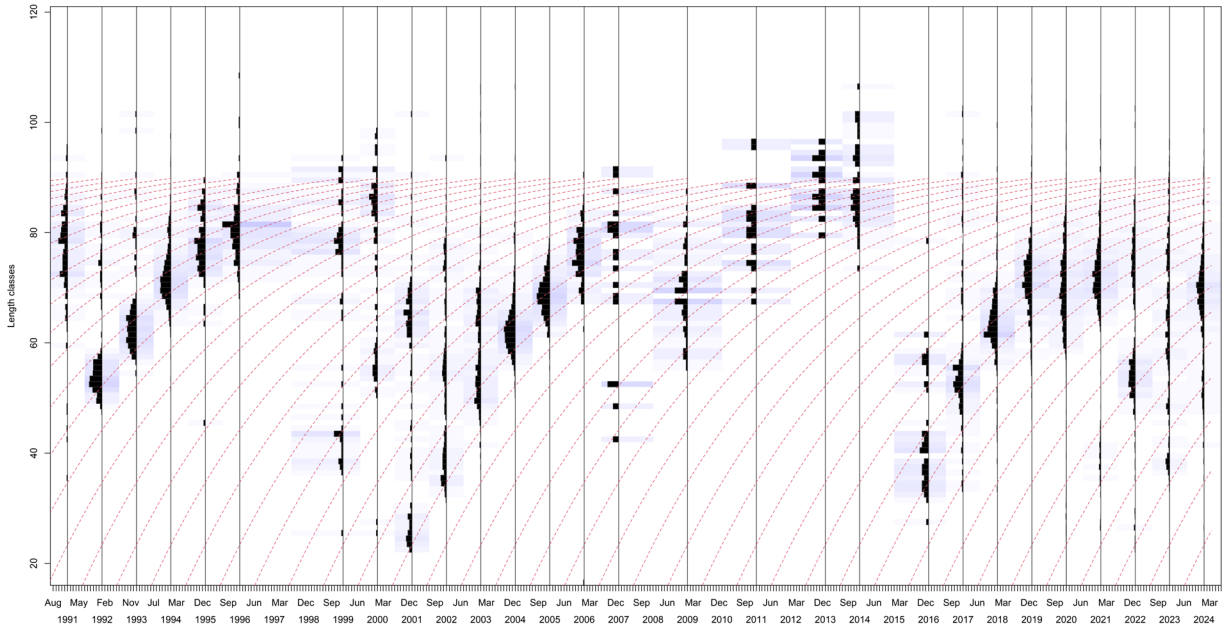


Appendix Figure 35: ELEFAN growth estimation for female SKI 3 & 7 observer length frequency data series: a. SKI 3 *Linf* = 108.23, *K* = 0.134, *t0* = 0.873; b. SKI 7 *Linf* = 103.94, *K* = 0.159, *t0* = 0.334.

a.



b.



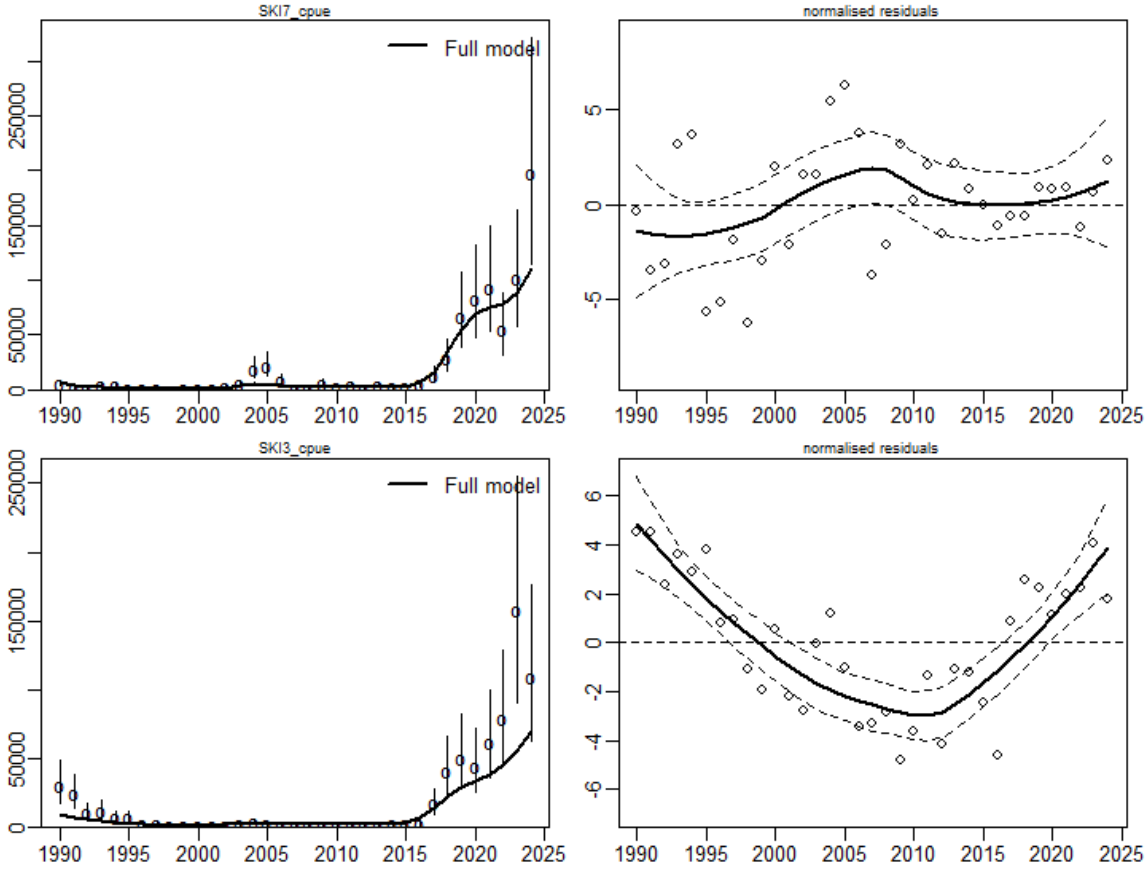
Appendix Figure 36: ELEFAN growth estimation for male SKI 3 & 7 observer length frequency data series: a. SKI 3 *Linf* = 100.09, *K* = 0.134, *t0* = 0.251; b. SKI 7 *Linf* = 94.17, *K* = 0.174, *t0* = 0.361.

Appendix 22: All-abundance likelihood model fits and diagnostics

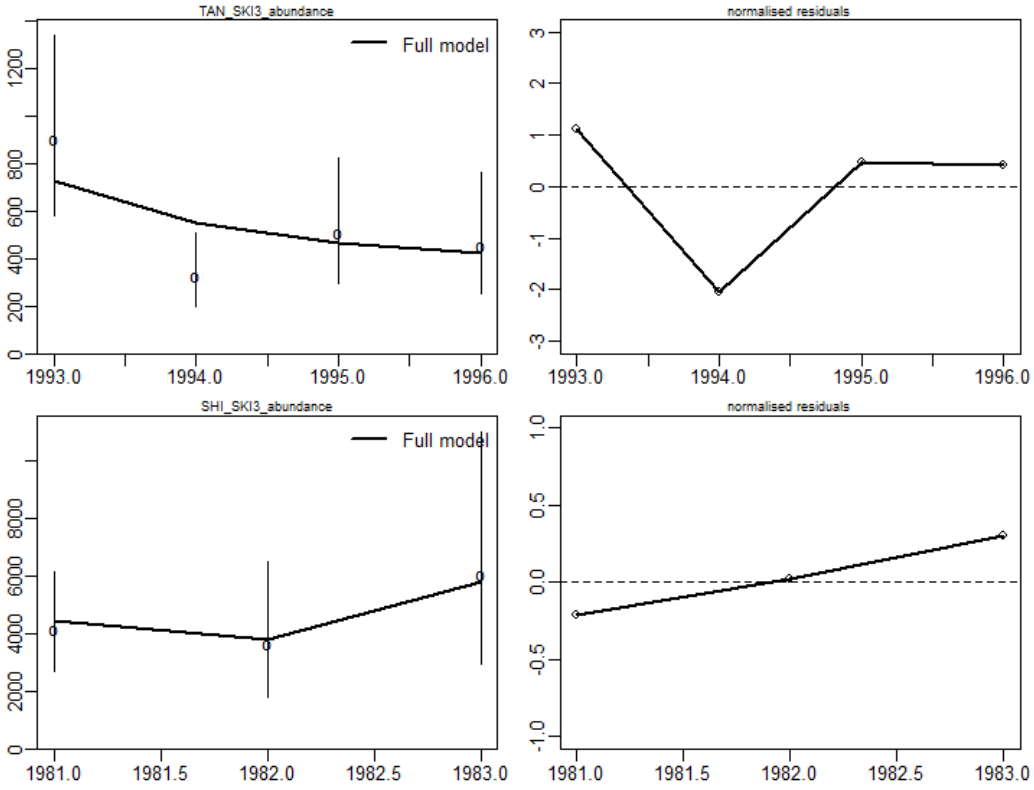
The All-Abundance model was unable to capture the recent increases in the SKI 3 & 7 commercial CPUE indices (Appendix Figure 37). Although the model achieved "acceptable" fits to the early SKI 3 trawl survey abundance series (Appendix Figure 38) it markedly over-estimated the recent abundance increase seen in the SKI 7 *Kaharoa* survey series (KAH_SKI7 Appendix Figure 39).

Although the model was able to capture the broad pattern of model progressions seen in the SKI 3 & 7 Observer length frequency data (Appendix Figure 40) it was unable to fully match the length frequency modal structure in some years, notable examples being the larger fish modes seen in SKI 7 1999 and 2000 data (Appendix Figure 40). The model preformed markedly better fitting the SKI 3 & 7 trawl survey length compositional series (Appendix Figure 41 & Appendix Figure 42).

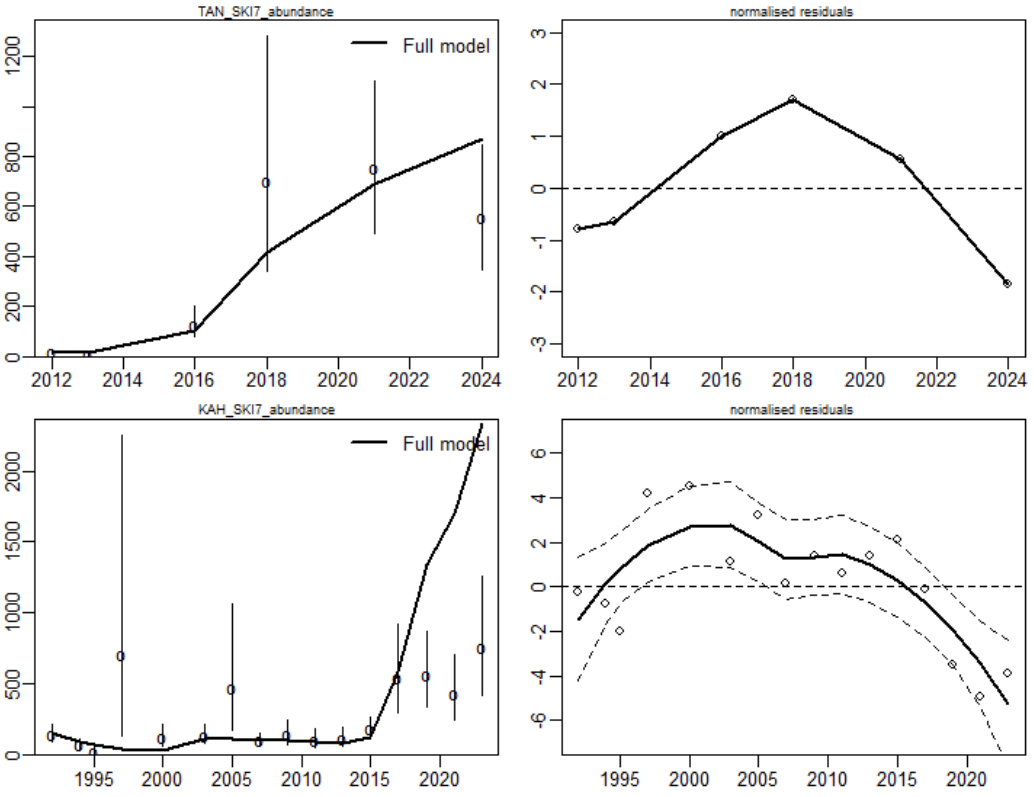
The model was again able to capture the broad patterns in the recent Observer age data series but was still unable to fully match the male/female proportional age-frequency model structure (Appendix Figure 43). In contrast, the model was able to achieve good fits to the early SKI 3 *Tangaroa* age compositional series (Appendix Figure 44).



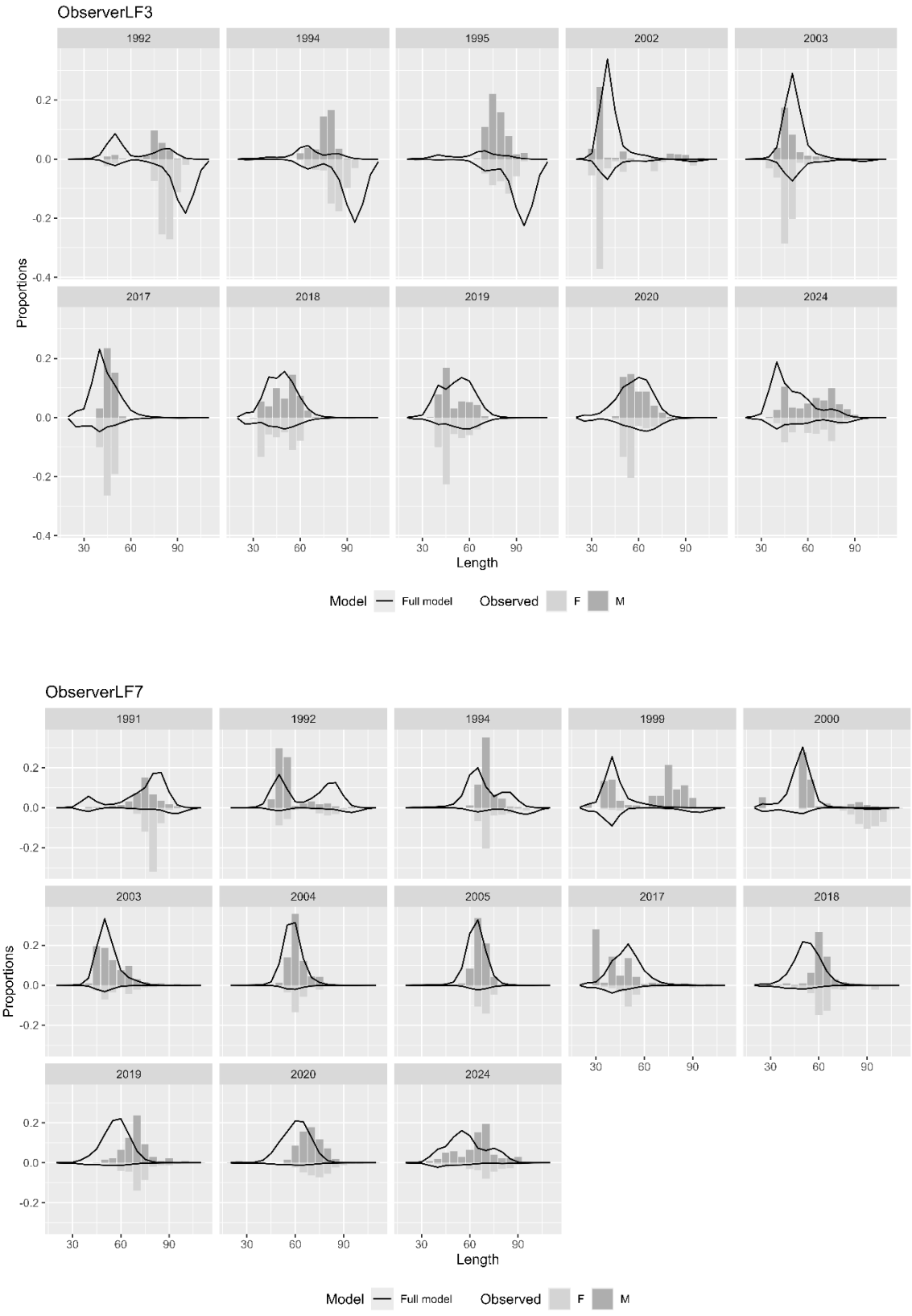
Appendix Figure 37: All-abundance model fits to SKI 3 & 7 trawl CPUE indices.



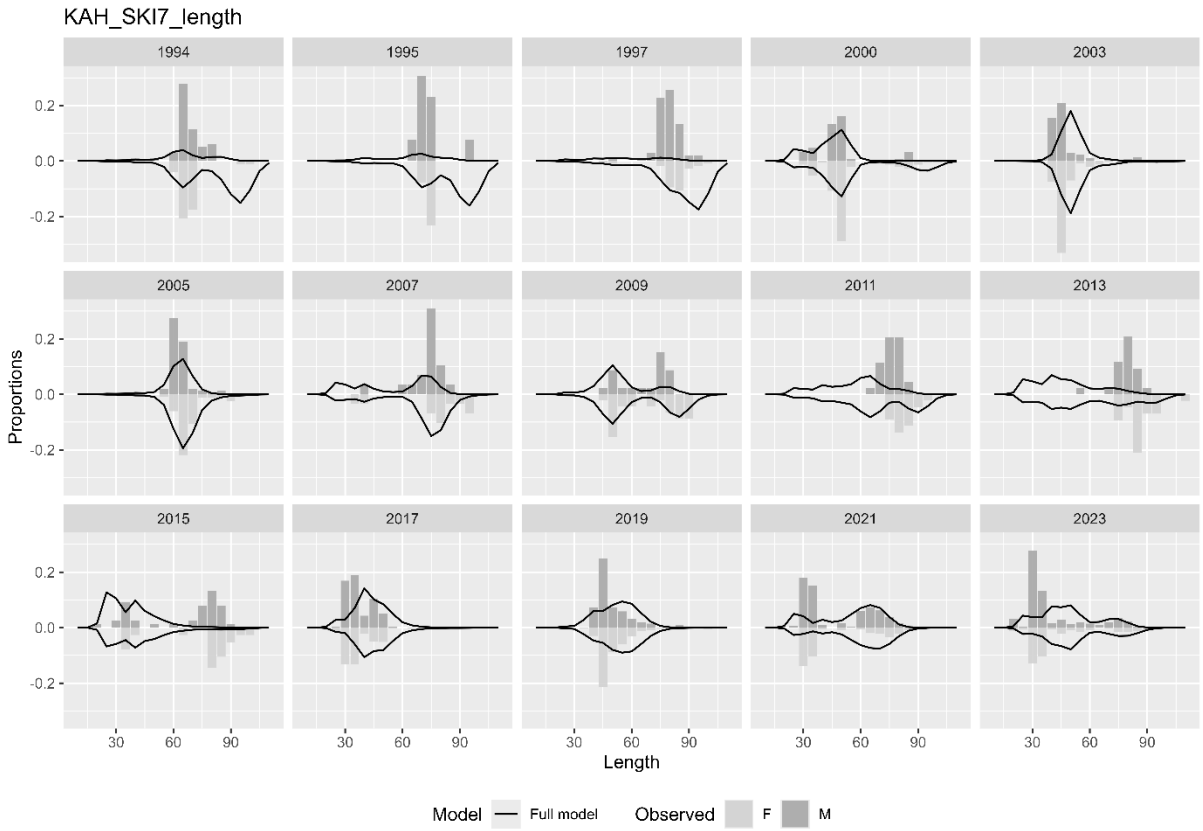
Appendix Figure 38: All-abundance model fits to SKI 3 trawl survey abundance series.

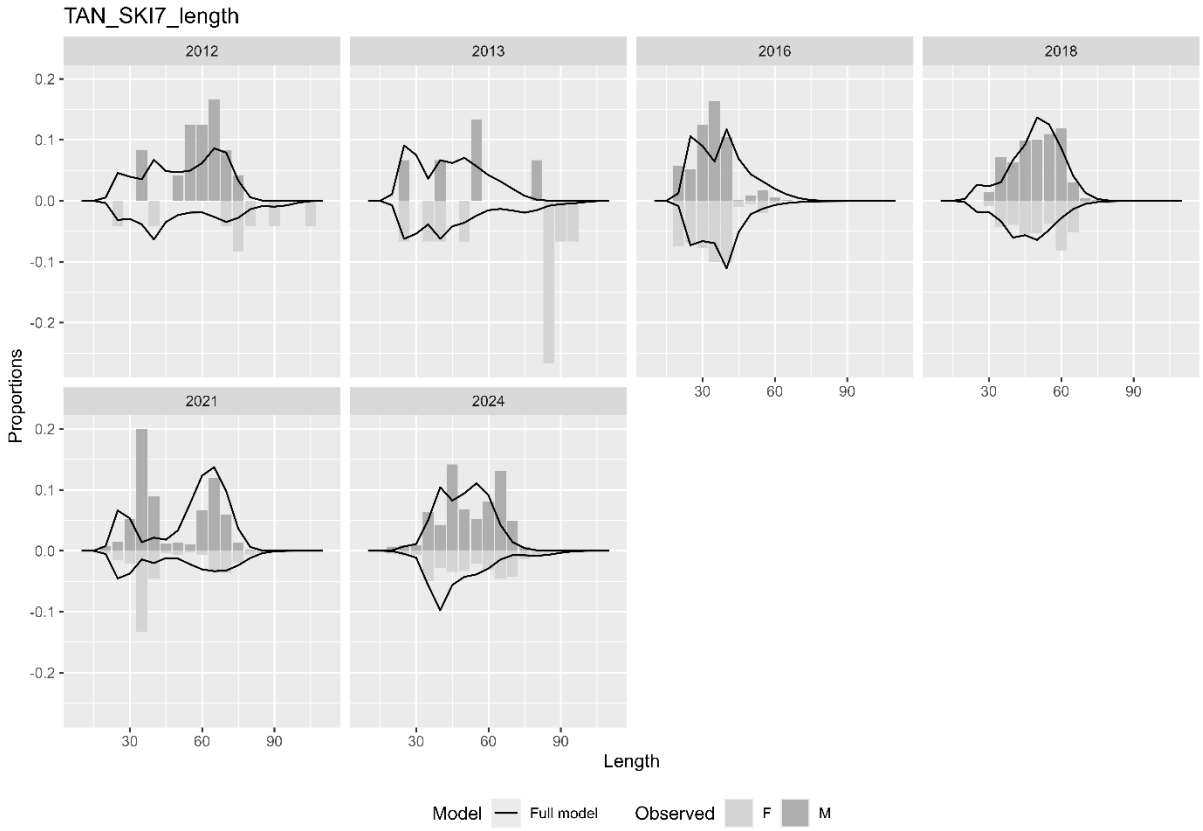


Appendix Figure 39: All-abundance model fits to SKI 7 trawl survey abundance series.

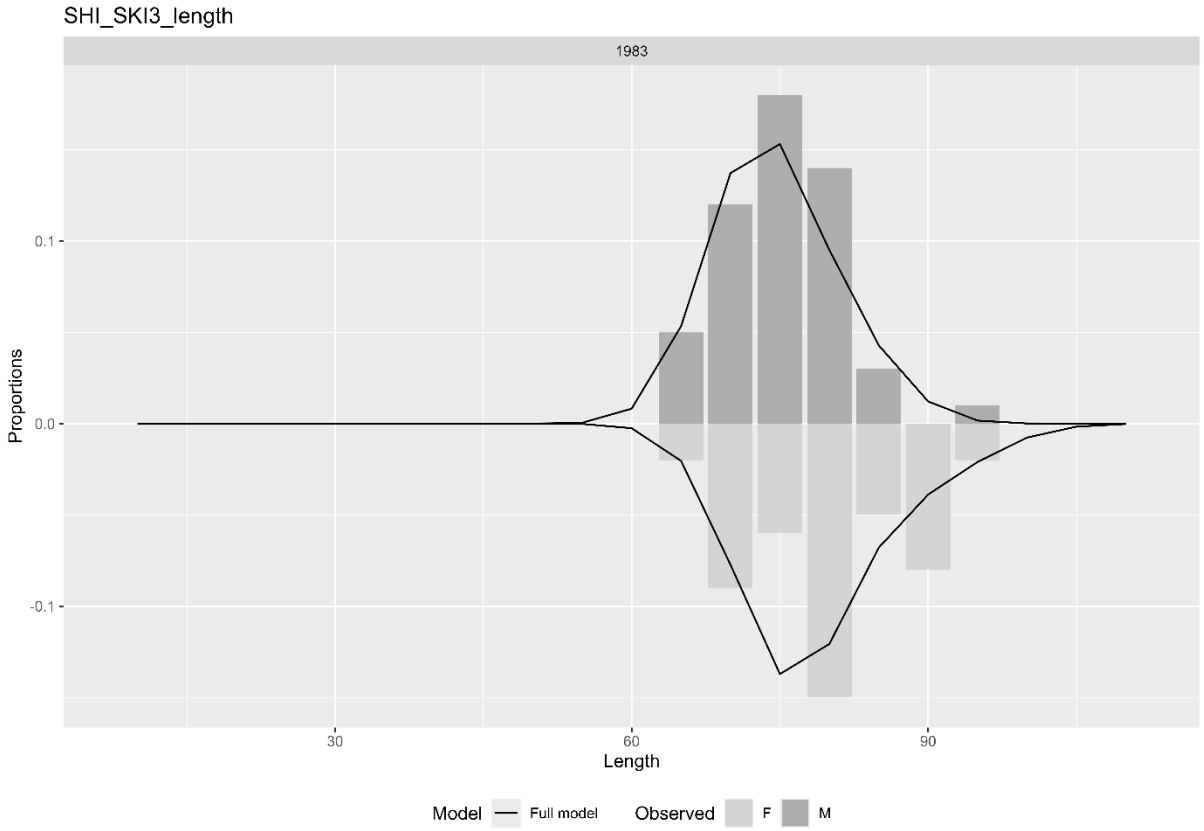


Appendix Figure 40: All-abundance model fits to SKI 3 & 7 Observer length frequency data series.

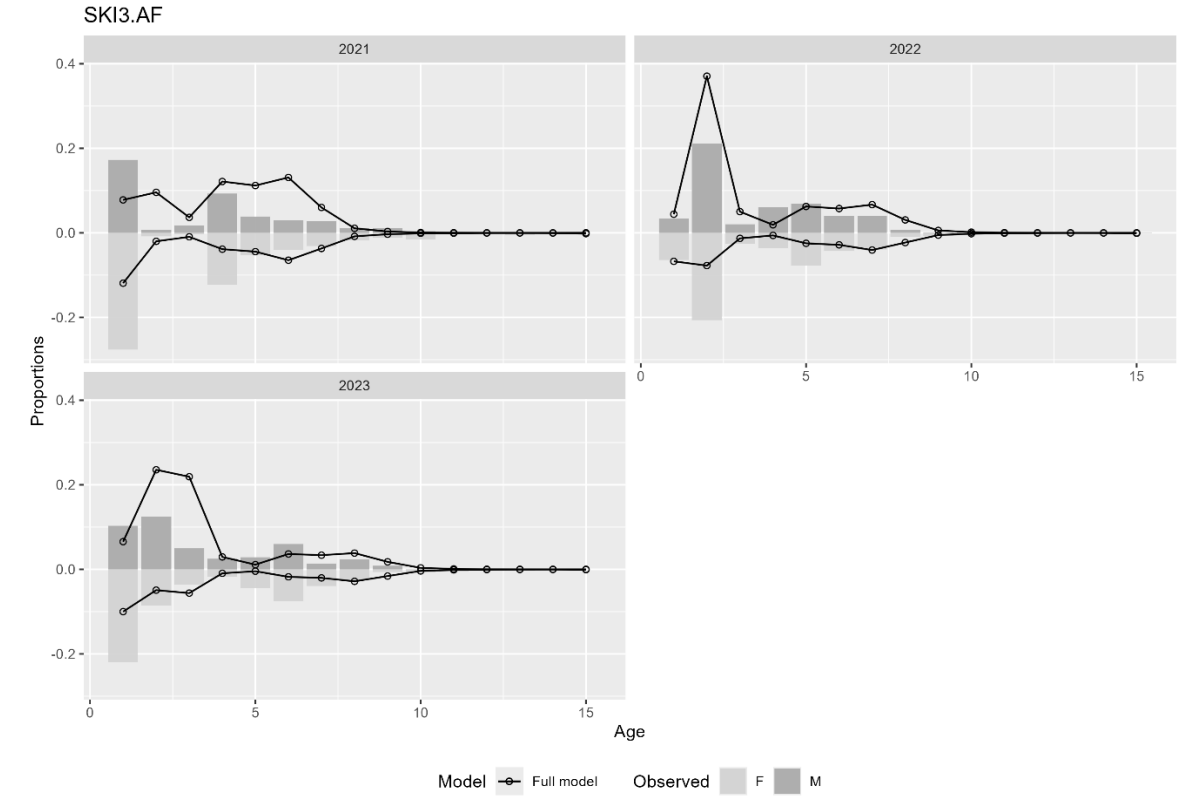


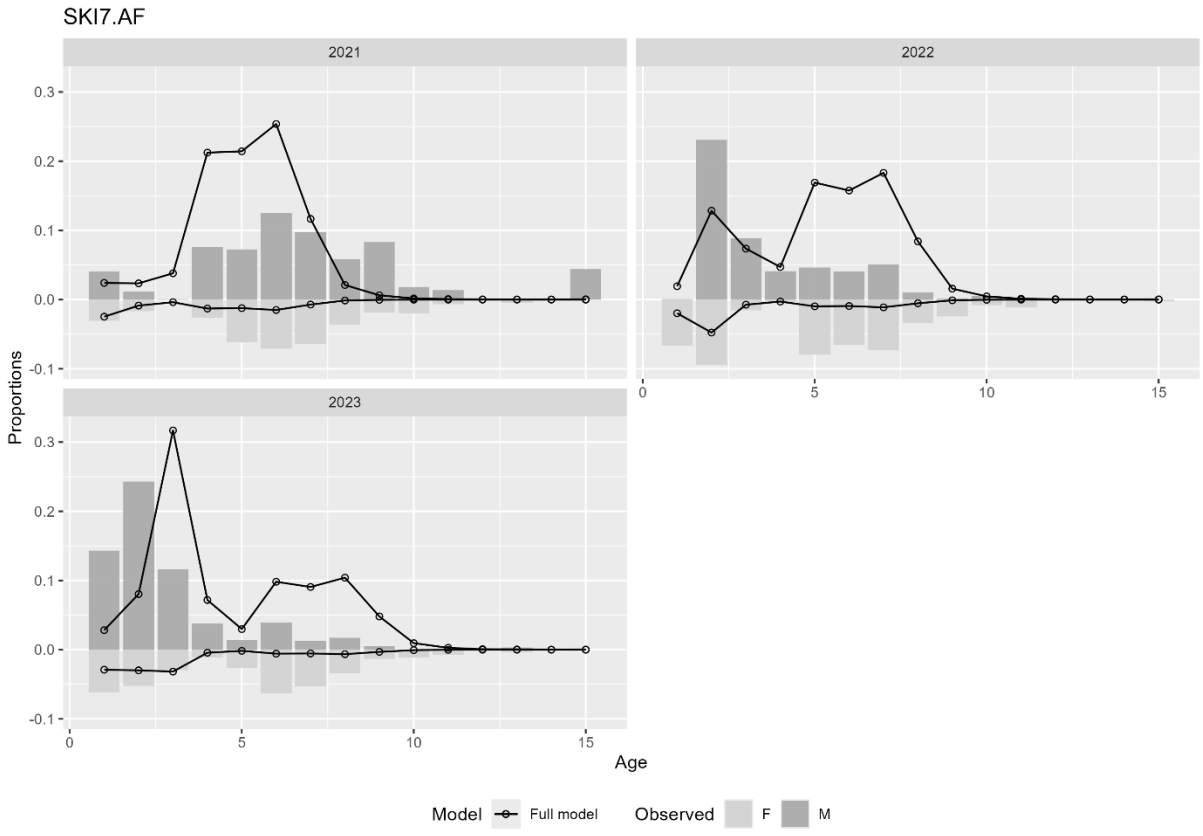


Appendix Figure 41: All-abundance model fits to SKI 7 survey length frequency data series.

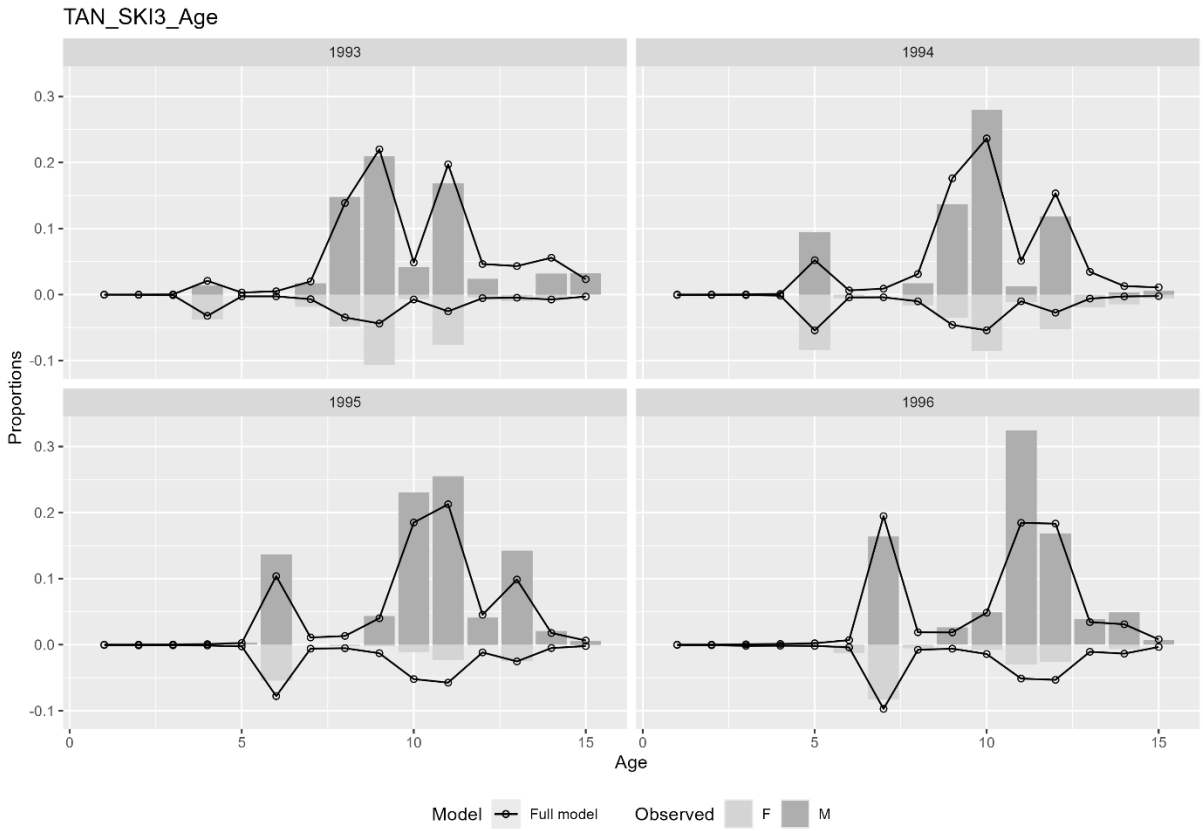


Appendix Figure 42: All-abundance model fits to SKI 3 1983 *Shinkai Maru* length frequency data.





Appendix Figure 43: All-abundance model fits to SKI 3 & 7 Observer age frequency data series.



Appendix Figure 44: All-abundance model fits to SKI 3 *Tangaroa* survey age frequency data.

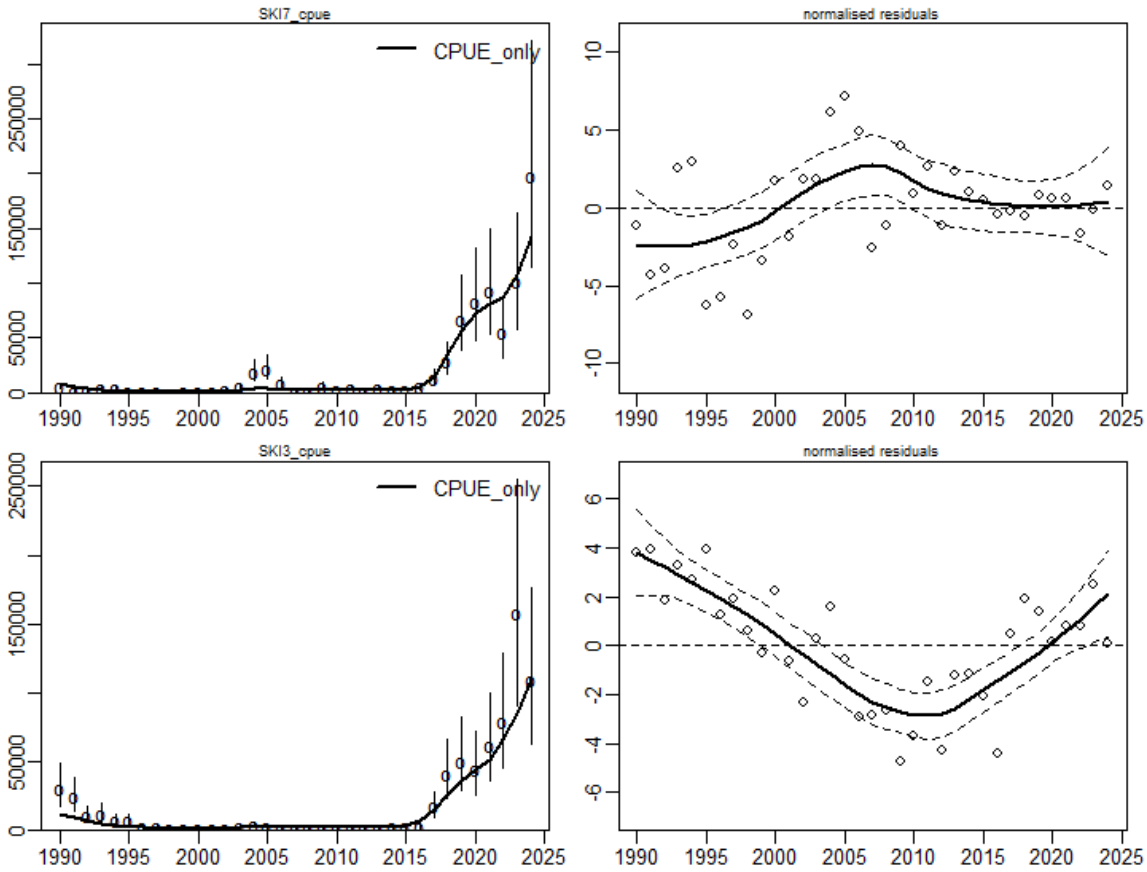
Appendix 23: CPUE abundance likelihood model fits and diagnostics

Understandably, the CPUE-Abundance model achieved a better fit to the recent increases in the SKI 3 & 7 commercial CPUE indices than the All-Abundance model (compare Appendix Figure 37 and Appendix Figure 45).

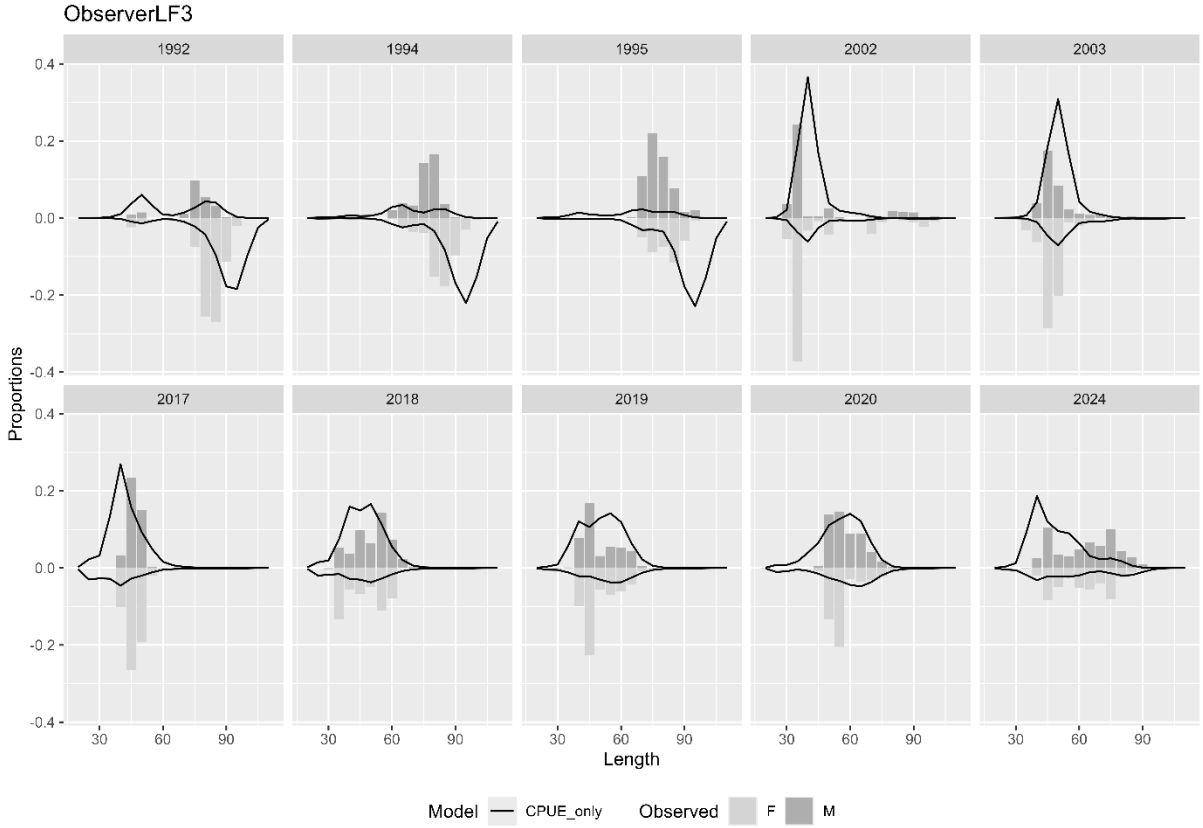
Model fits to the length compositional data series (Appendix Figure 46, Appendix Figure 47, and Appendix Figure 48) were comparable to those of the All-abundance model and the same descriptions apply (Appendix 22).

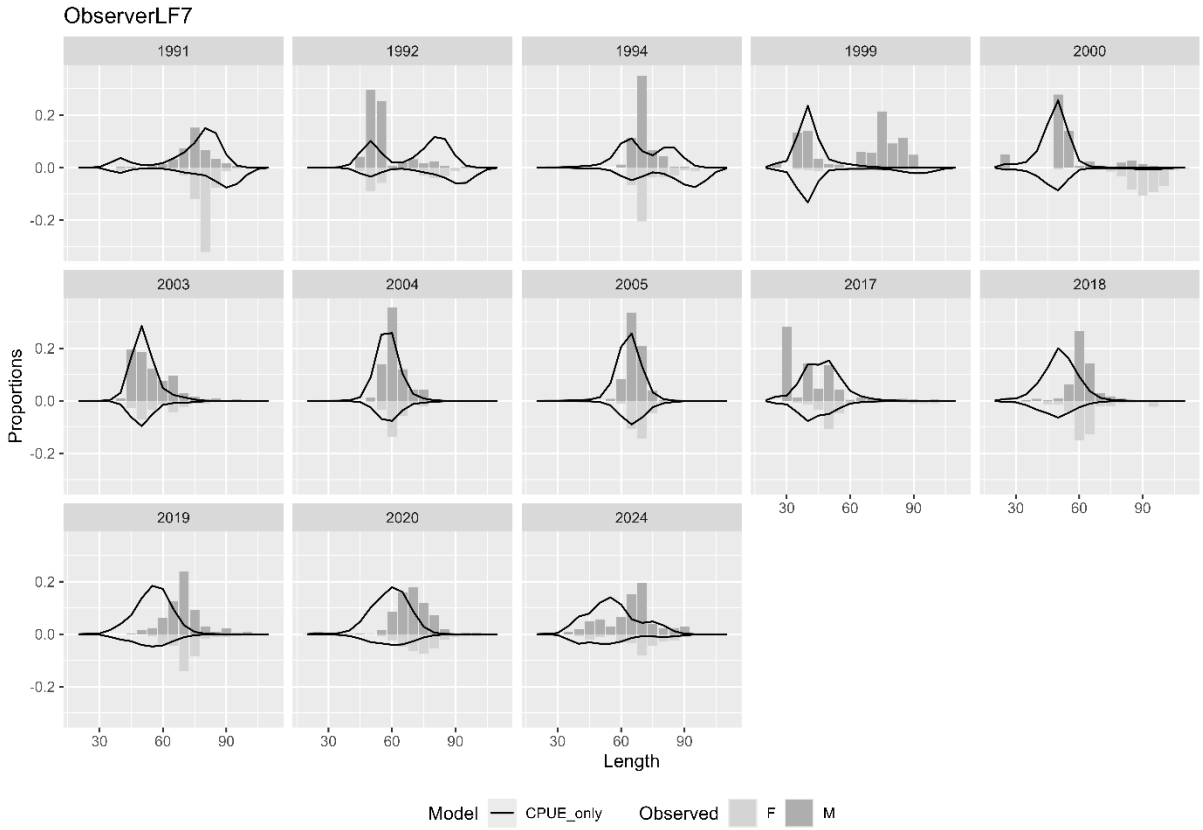
The CPUE-Abundance model fits to the recent SKI 3 & 7 Observer age compositional data series were much improved over the All-Abundance model fits to these series (compare Appendix Figure 43 and Appendix Figure 49).

Model fits to the SKI 3 *Tangaroa* age data, as with the All-Abundance model, were good (Appendix Figure 46).

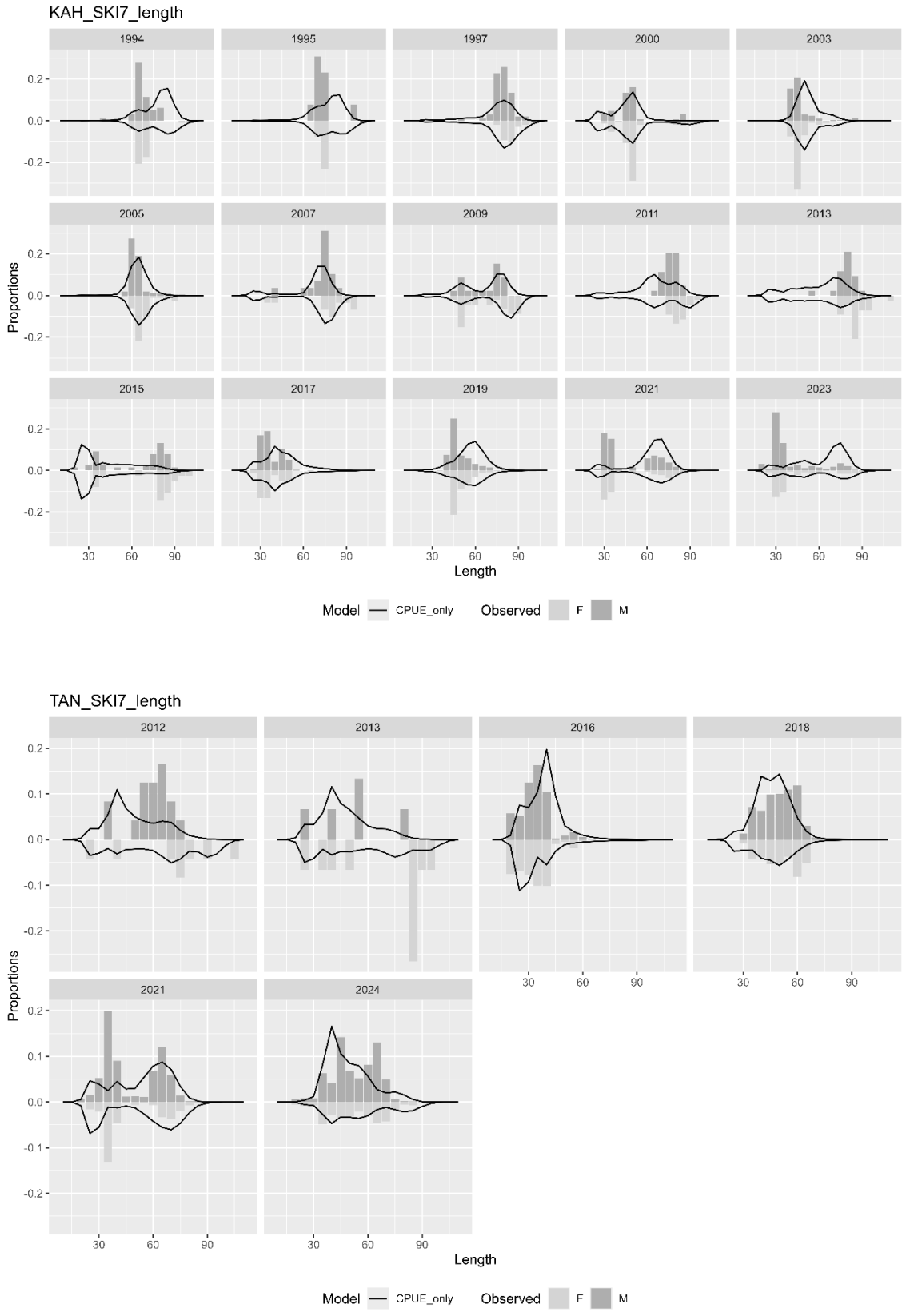


Appendix Figure 45: CPUE-abundance model fit to SKI 3 & 7 trawl CPUE indices.

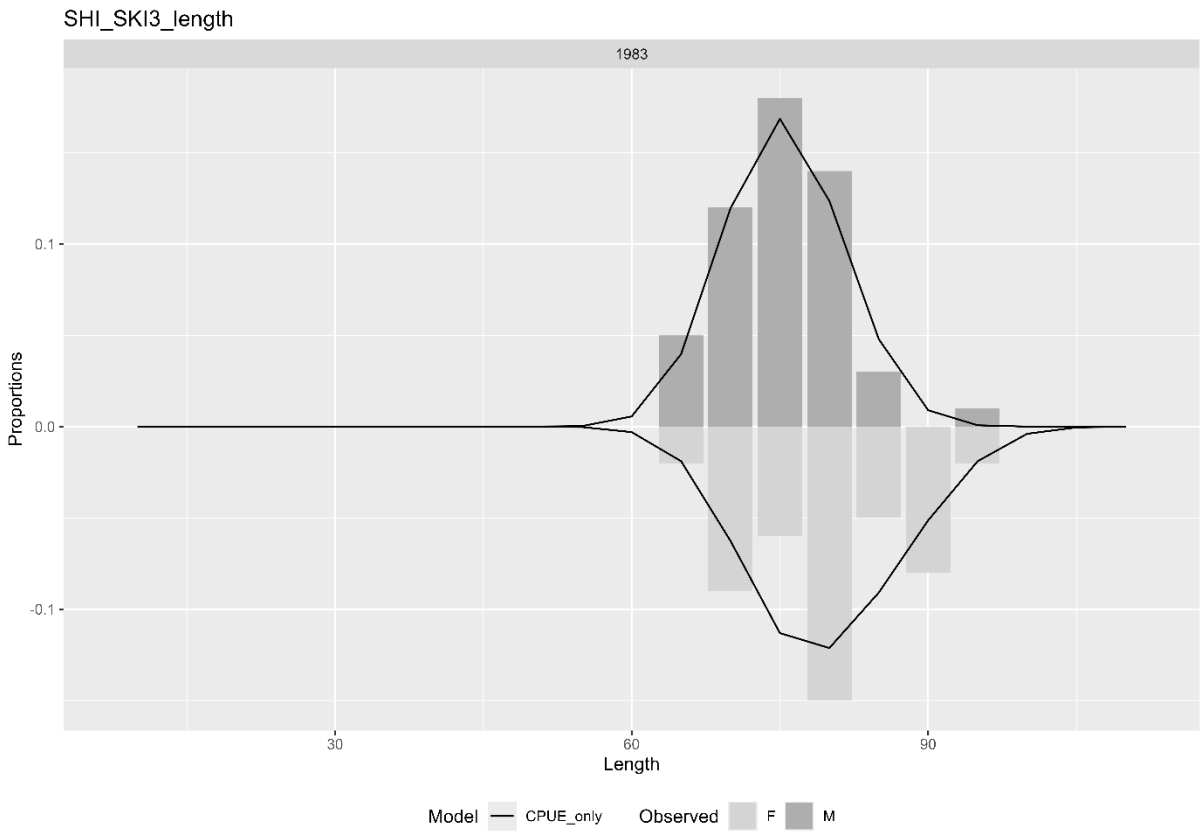




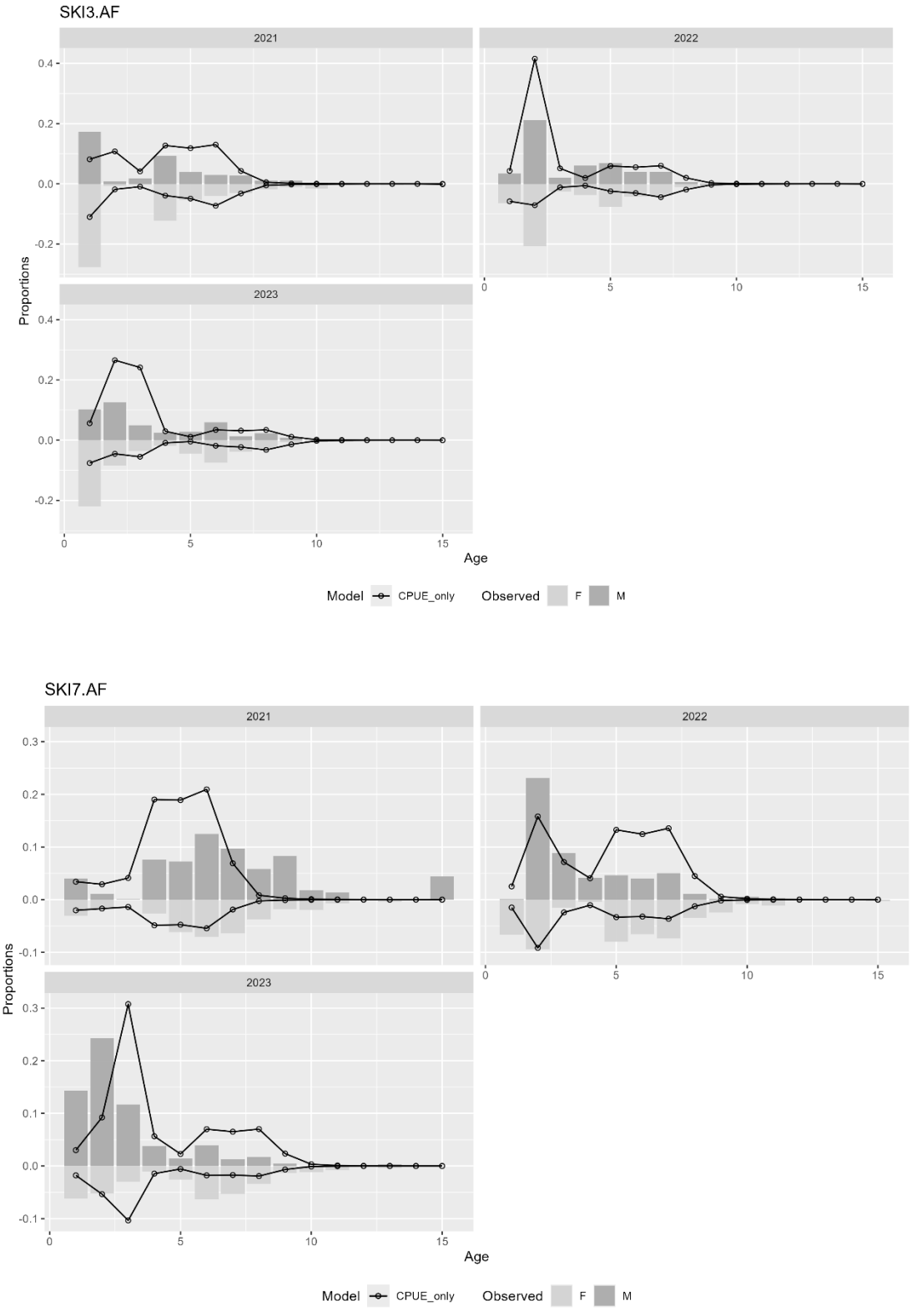
Appendix Figure 46: CPUE-abundance model fit to SKI 3 & 7 Observer length frequency data series.



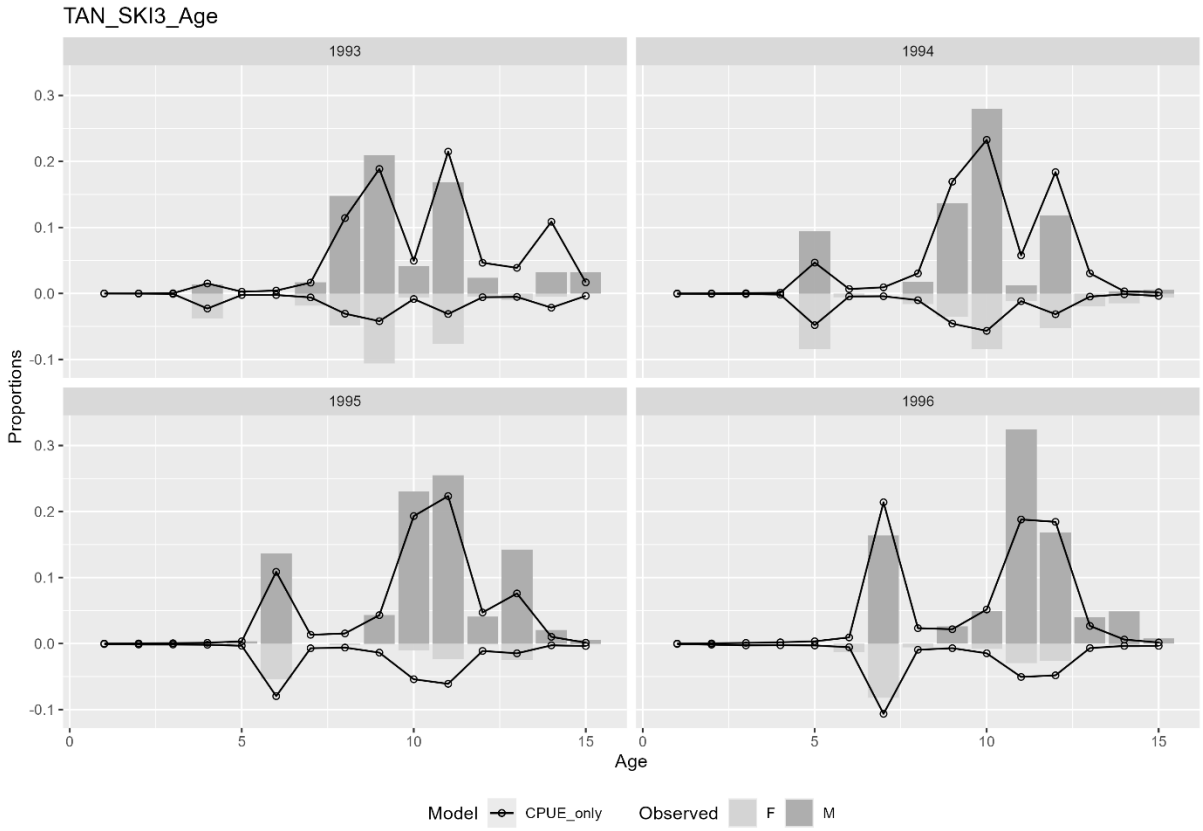
Appendix Figure 47: CPUE-abundance model fit to SKI 7 survey length frequency data series.



Appendix Figure 48: CPUE-abundance model fit to SKI 3 1983 *Shinka Maru* length frequency data.



Appendix Figure 49: CPUE-abundance model fit to SKI 3 & 7 Observer age frequency data series.



Appendix Figure 50: CPUE-abundance model fit to SKI 3 *Tangaroa* survey age frequency data.

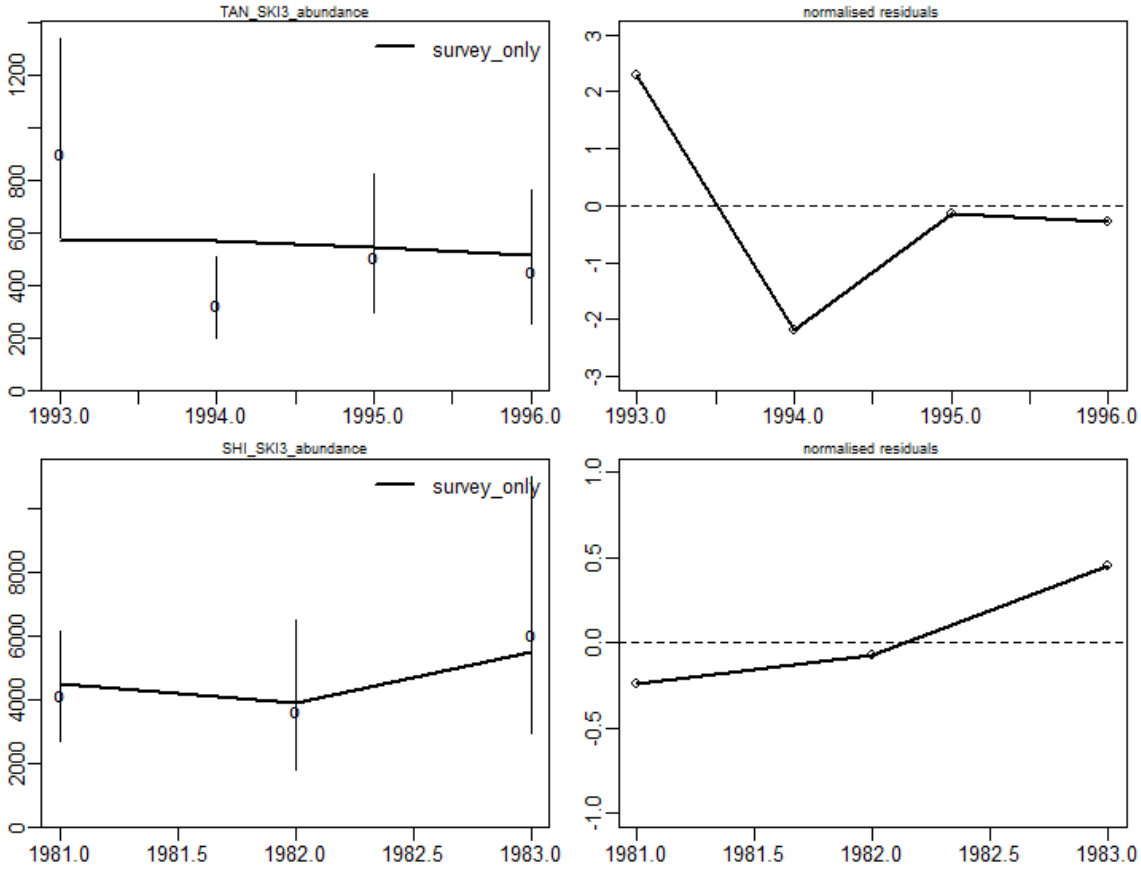
Appendix 24: Survey abundance likelihood model fits and diagnostics

Whereas, the Survey-abundance model fits to the SKI 3 trawl survey abundance series were similar to those of the All-abundance model (Appendix Figure 51 cf Appendix Figure 38), the Survey-abundance model fits to the SKI 7 trawl survey abundance series were improved (Appendix Figure 52 cf Appendix Figure 39).

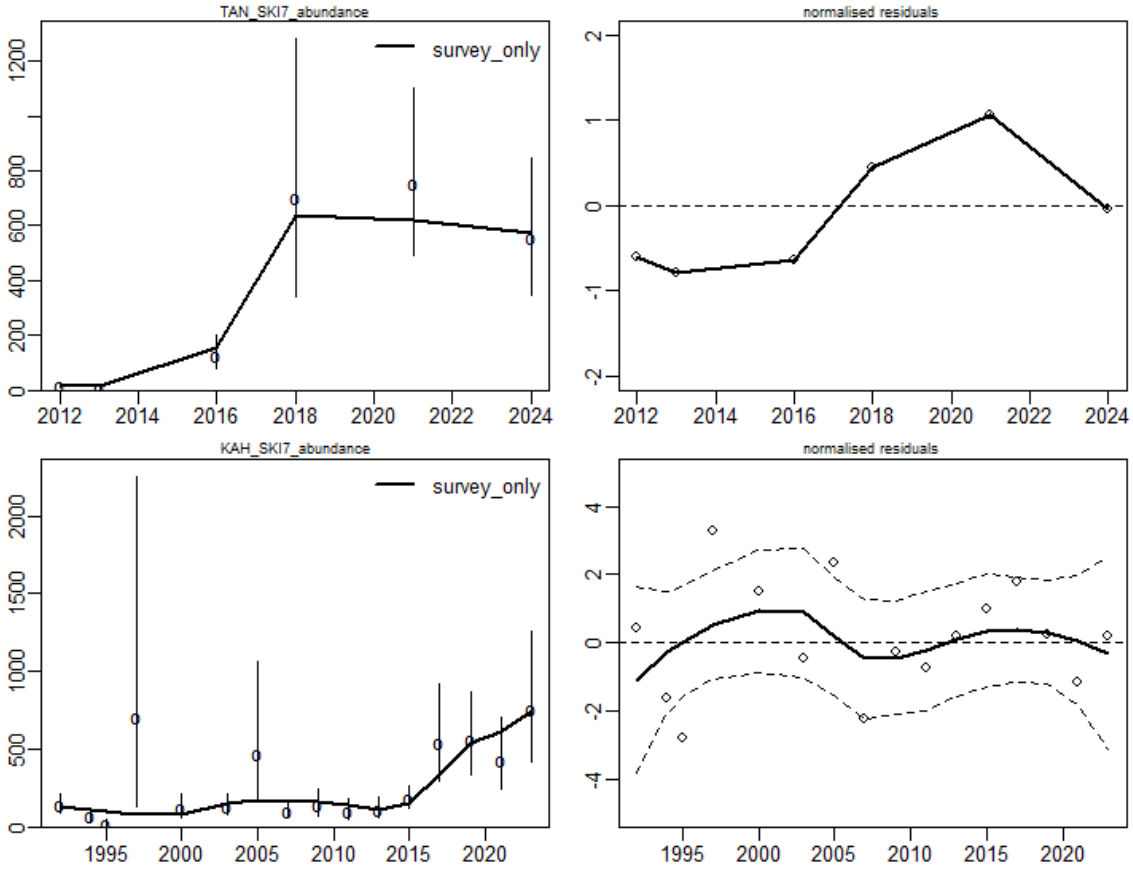
Model fits to the length compositional data series (Appendix Figure 53, Appendix Figure 54, and Appendix Figure 55) were comparable to those of the All-abundance and CPUE-abundance models and the same descriptions apply (Appendix 22 and Appendix 23).

The survey-Abundance model fits to the recent SKI 3 & 7 Observer age compositional data series were better than the All-abundance and CPUE-abundance models (Appendix Figure 56).

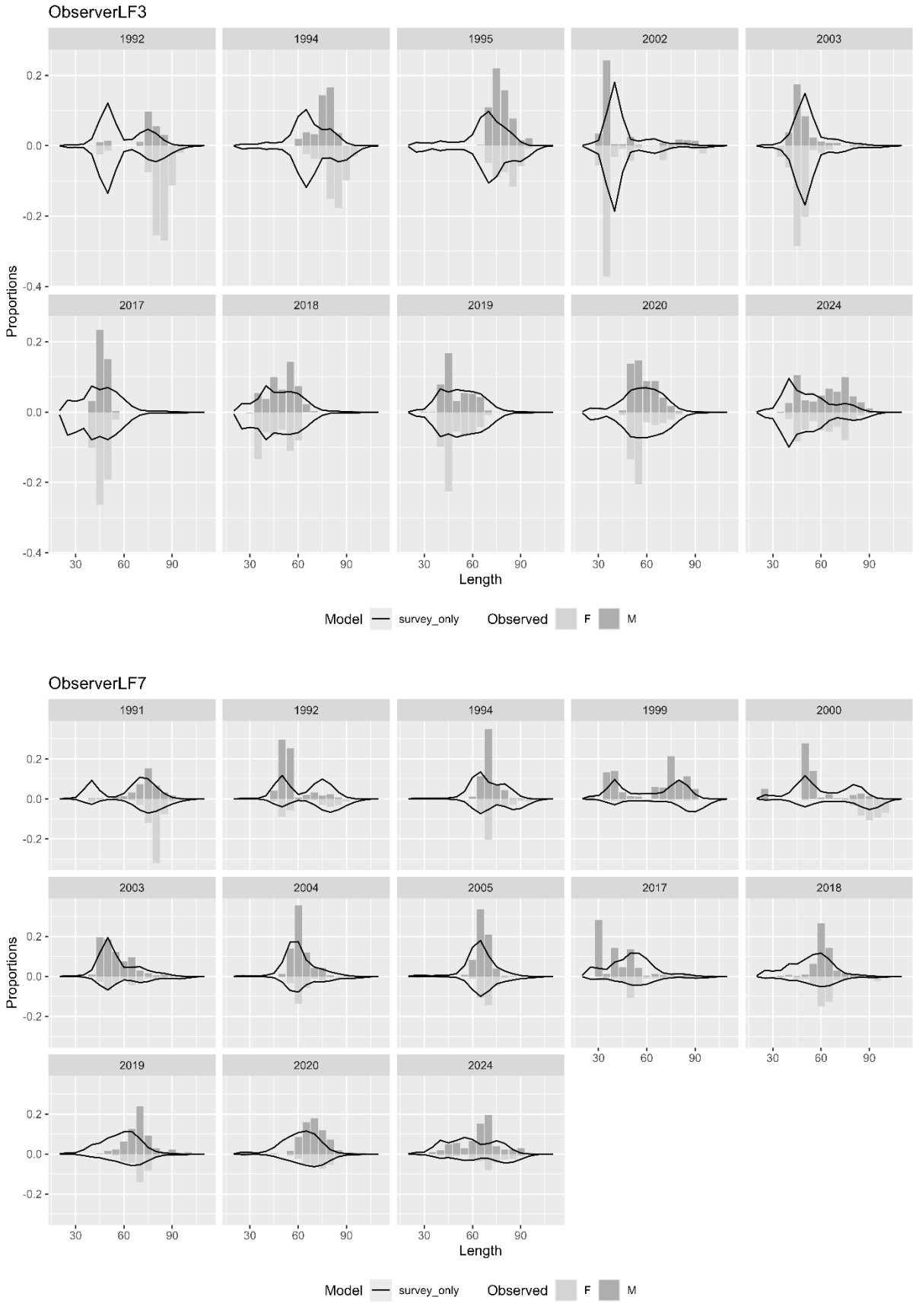
Model fits to the SKI 3 *Tangaroa* age data, as with the All-Abundance and CPUE-abundance models, were good (Appendix Figure 57).



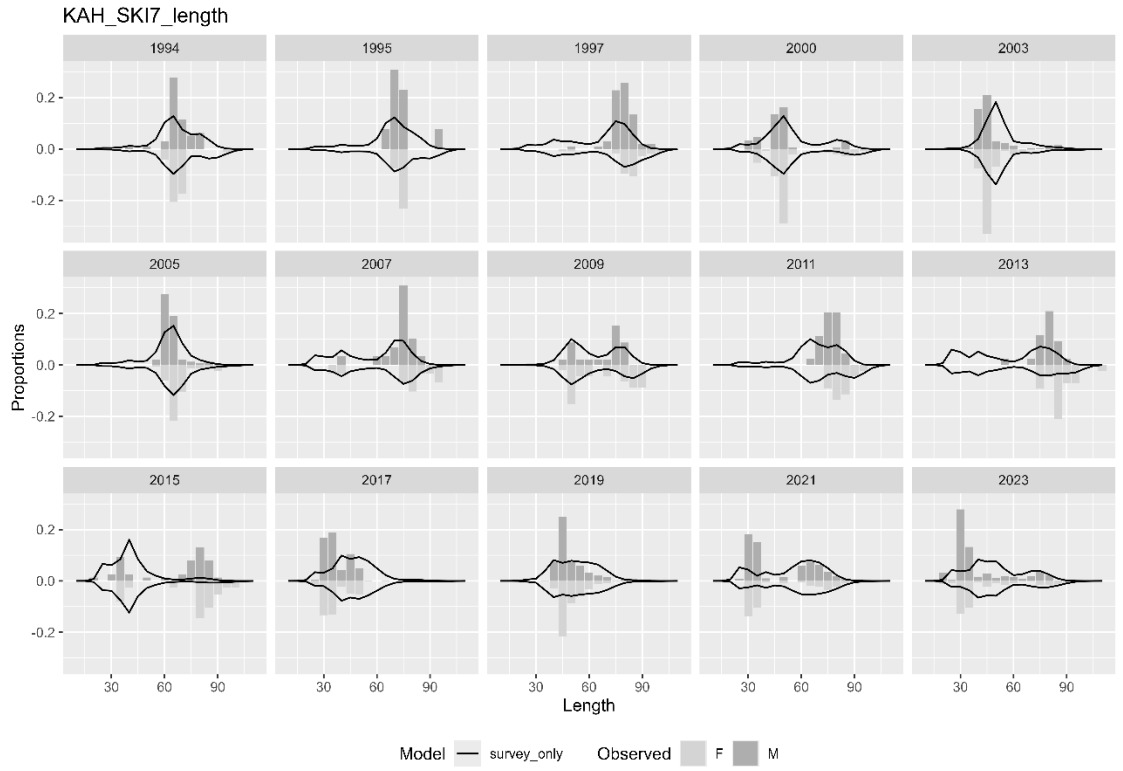
Appendix Figure 51: Survey-abundance model fit to SKI 3 trawl survey abundance series.

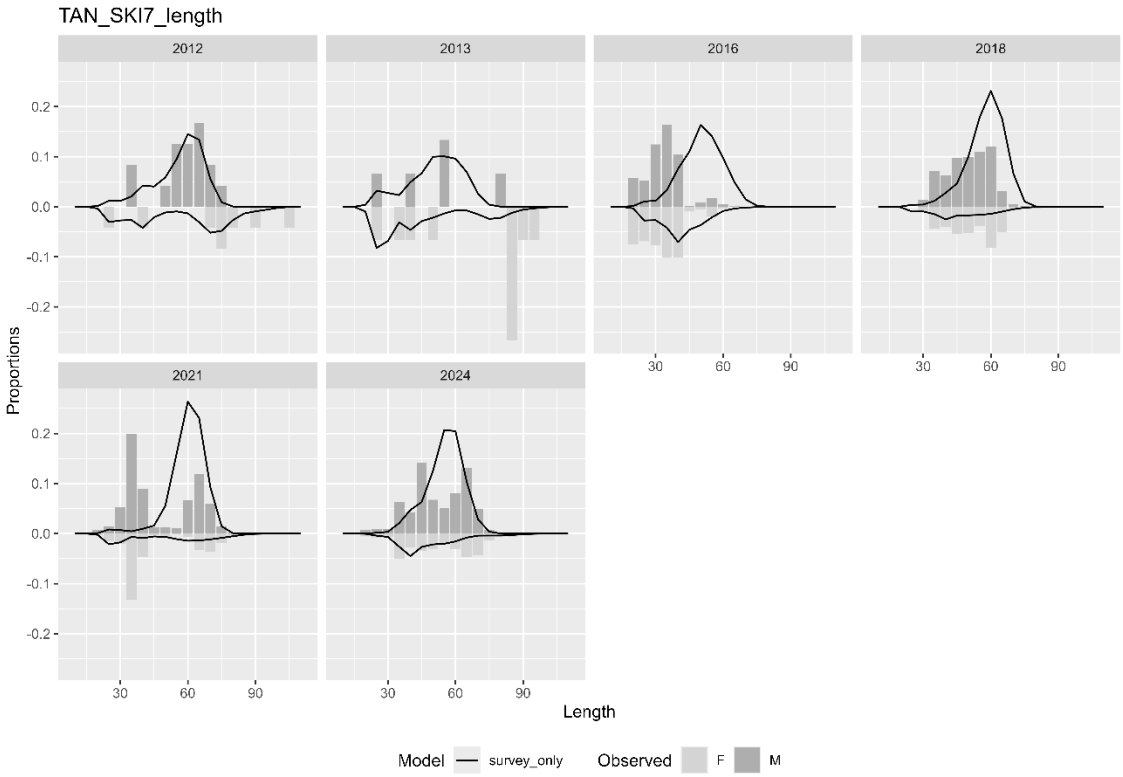


Appendix Figure 52: Survey-abundance model fit to SKI 7 trawl survey abundance series.

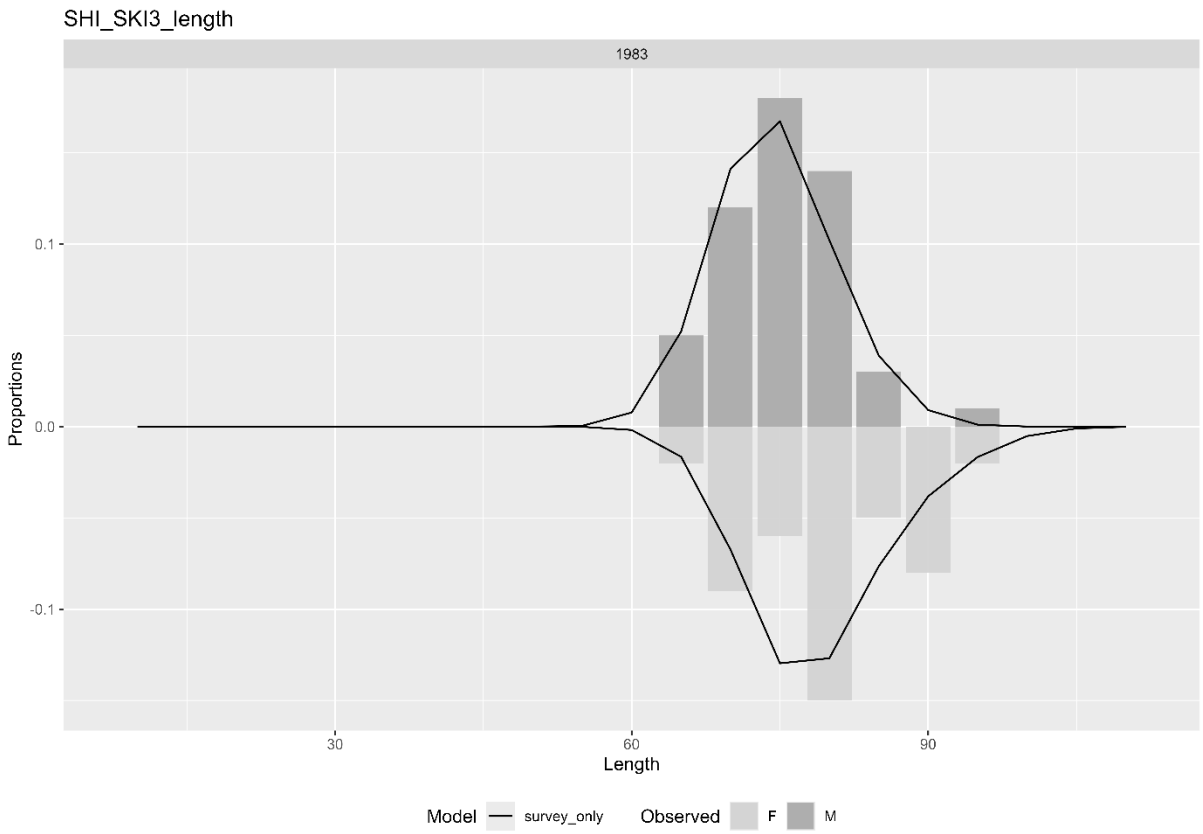


Appendix Figure 53: Survey-abundance model fit to SKI 3 & 7 Observer length frequency data series.

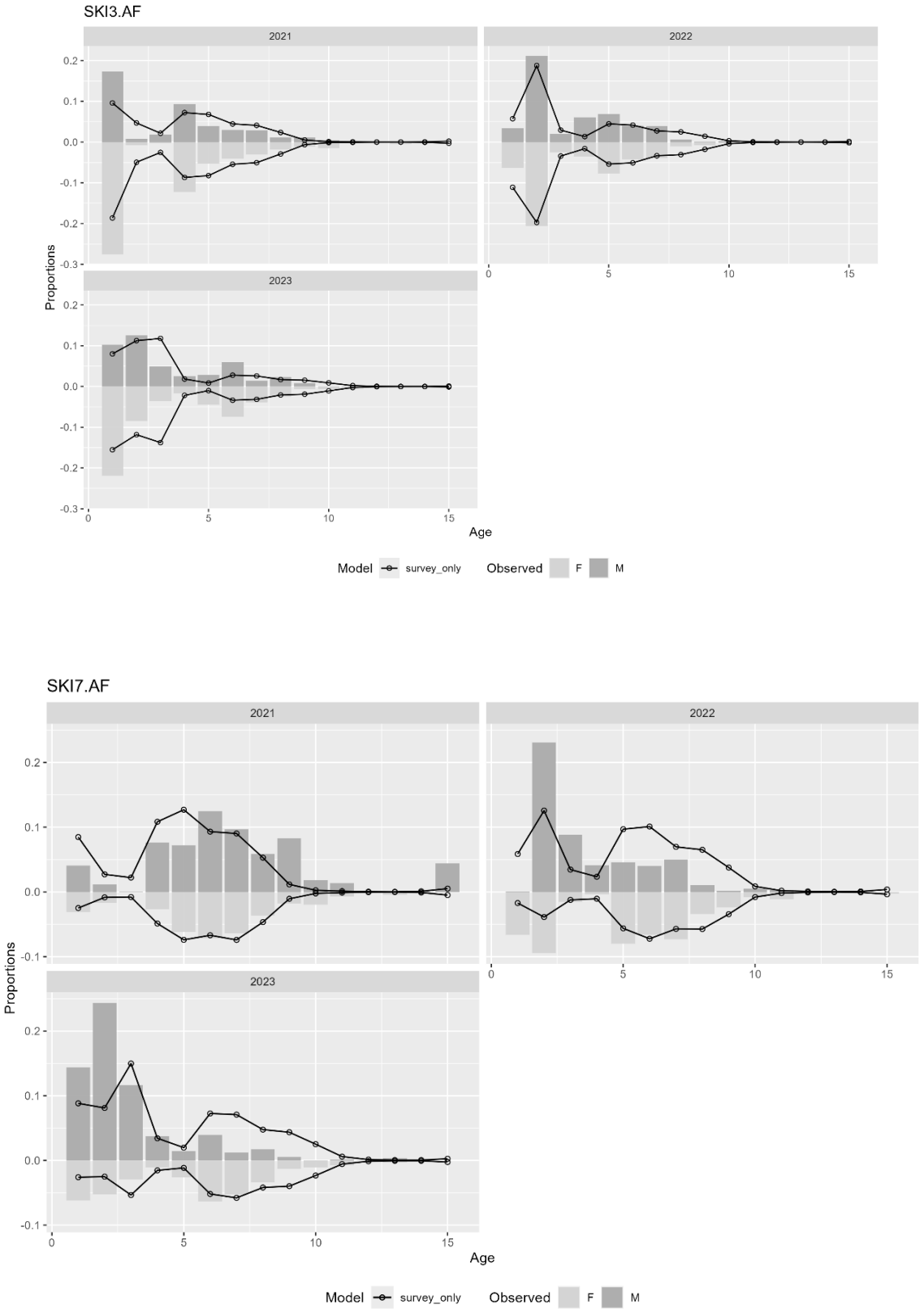




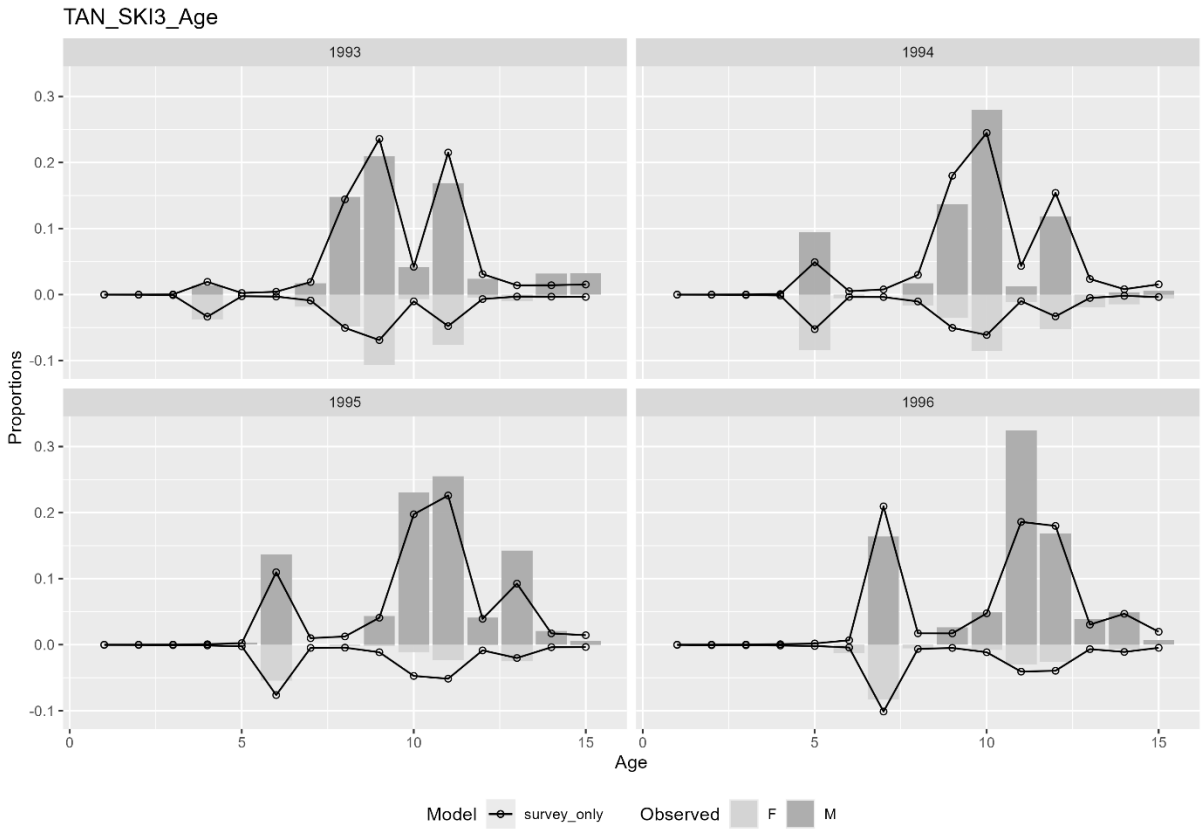
Appendix Figure 54: Survey-abundance model fit to SKI 7 survey length frequency data series.



Appendix Figure 55: Survey-abundance model fit to SKI 3 1983 *Shinkai Maru* length frequency data.



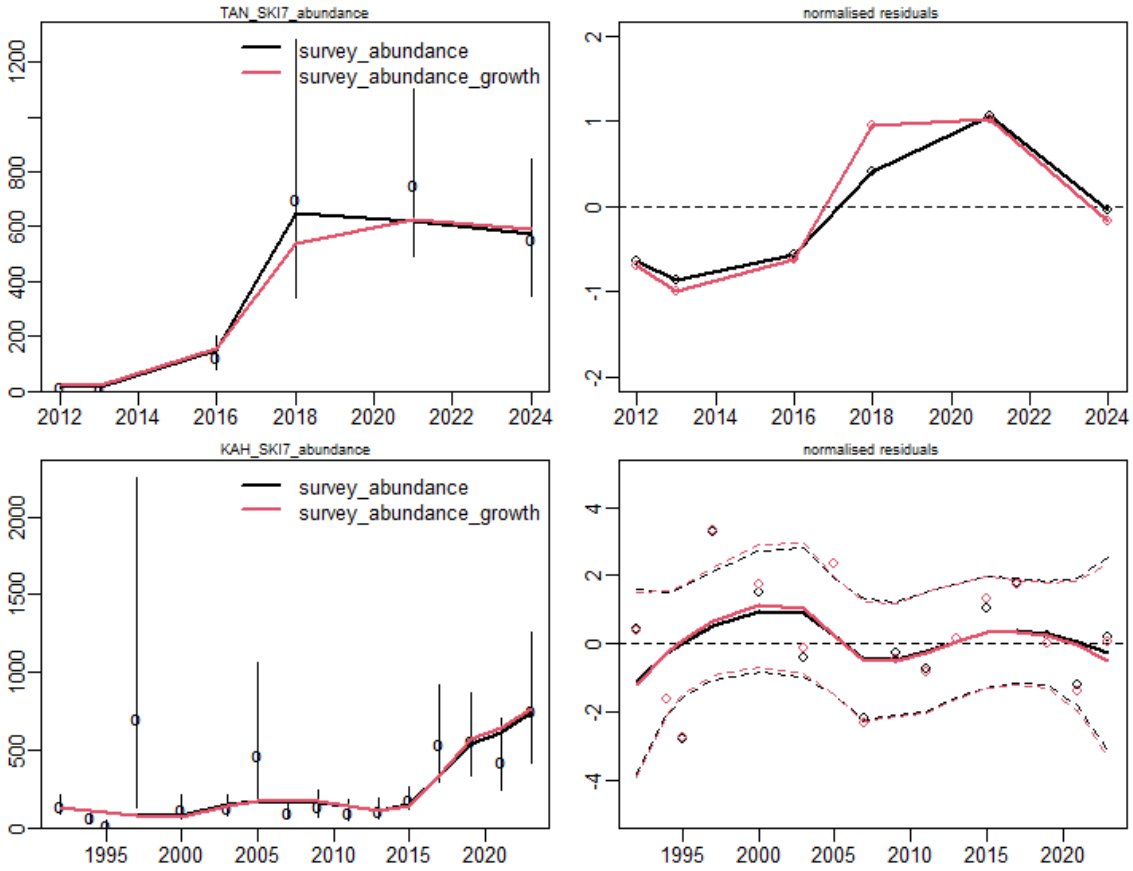
Appendix Figure 56: Survey-abundance model fit to SKI 3 & 7 Observer age frequency data series.



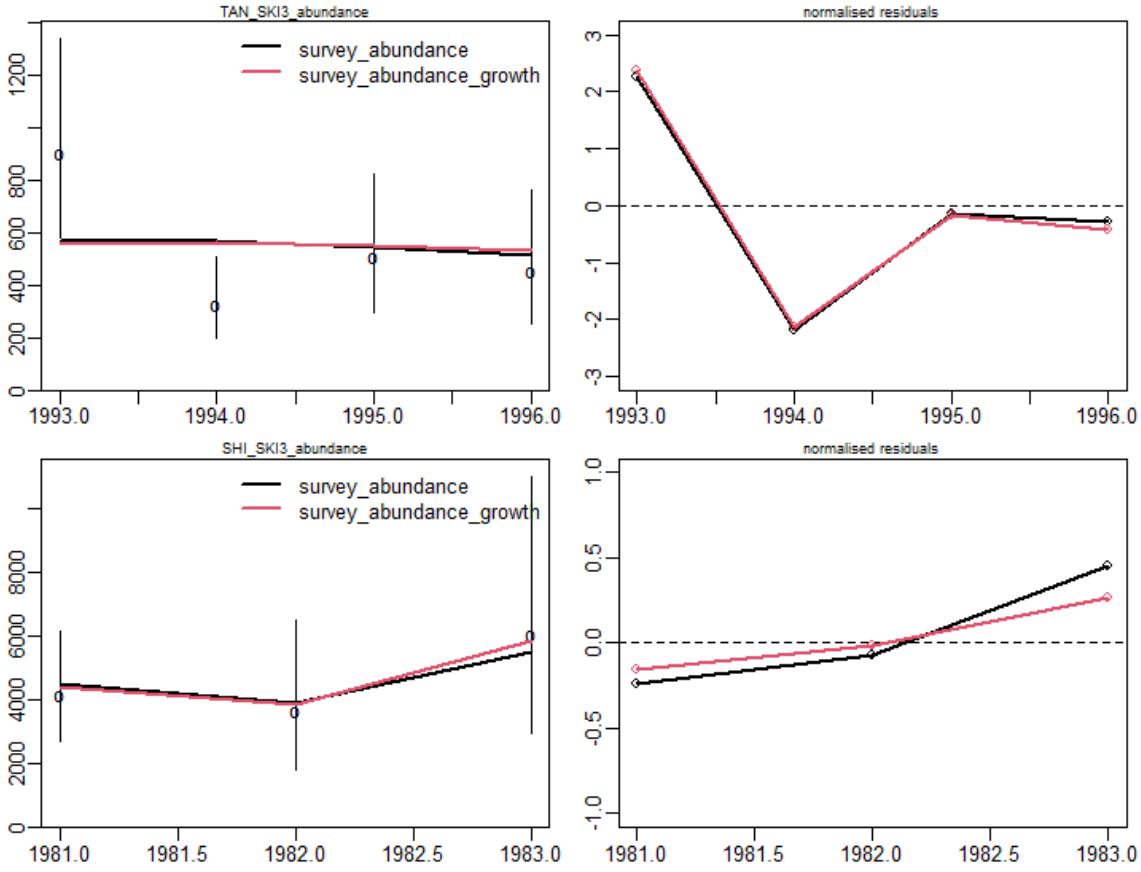
Appendix Figure 57: Survey-abundance model fit to SKI 3 *Tangaroa* survey age frequency data.

Appendix 25: Base-case fits and diagnostics

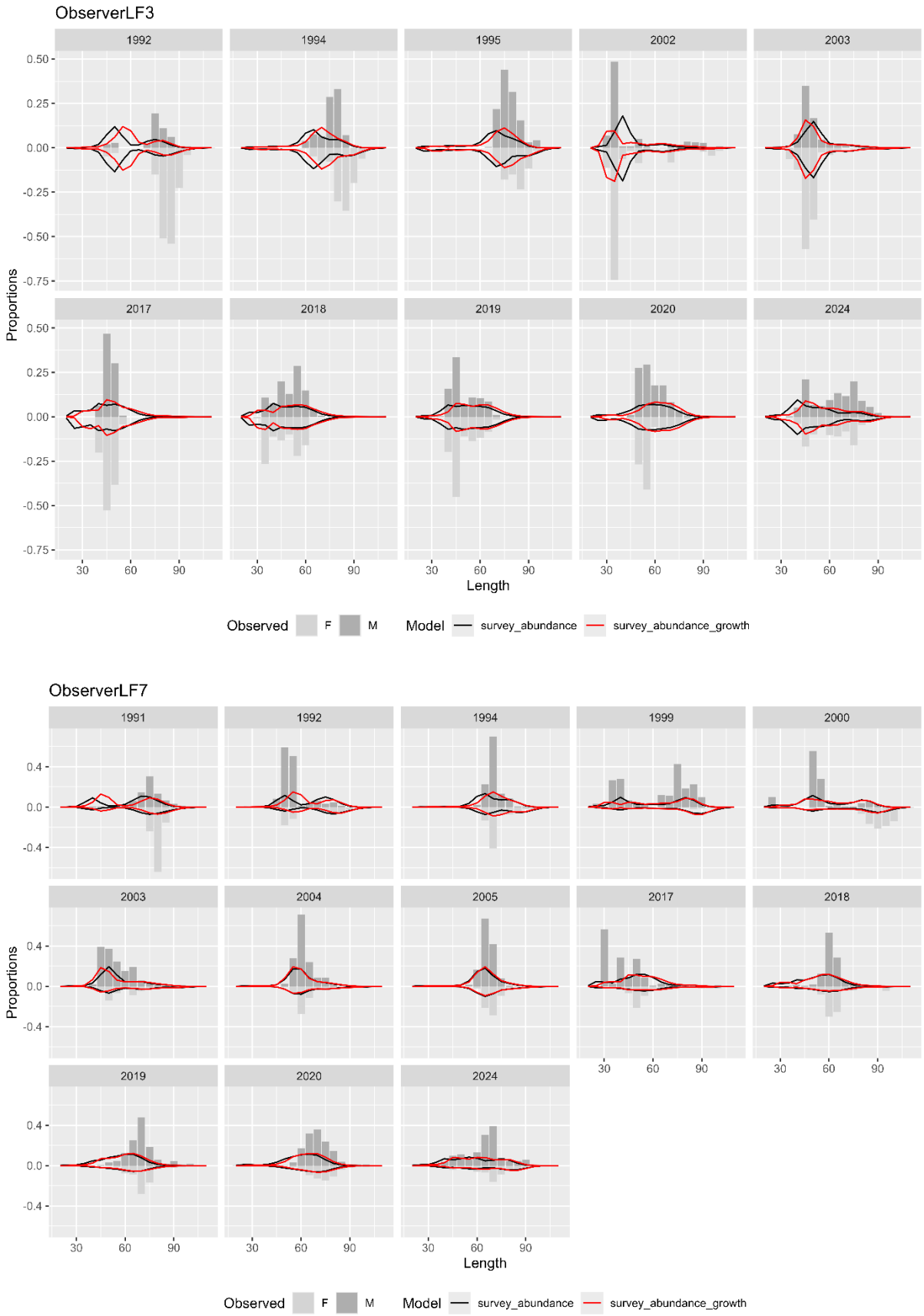
Improved fits to the length compositional data series by the survey-abundance growth estimation model are evident in Appendix Figure 60 and Appendix Figure 61. Fits to the survey abundance series (Appendix Figure 58 and Appendix Figure 59) and other compositional data series (Appendix Figure 62, Appendix Figure 63, and Appendix Figure 64) were similar to the survey-abundance fixed growth model.



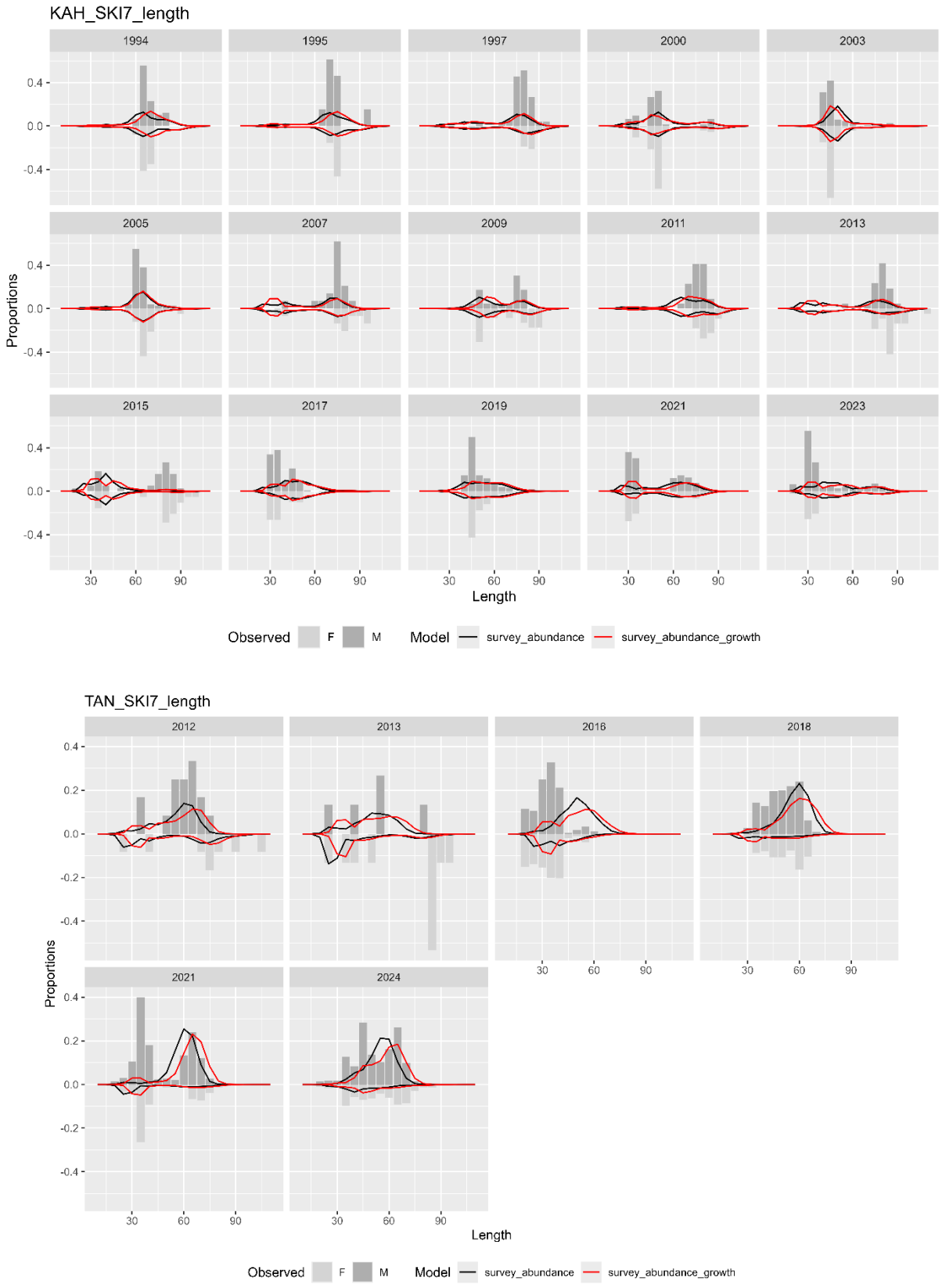
Appendix Figure 58: Base-case model fit to SKI 3 trawl survey abundance series.



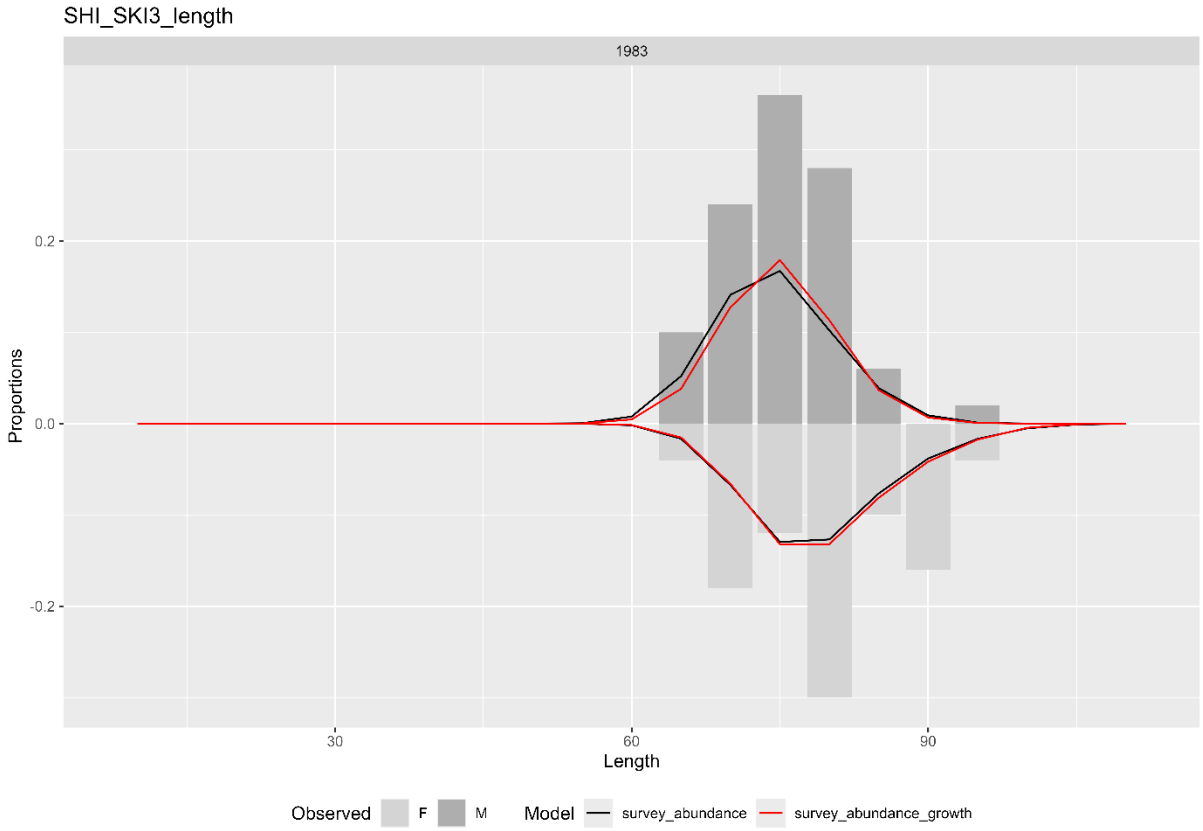
Appendix Figure 59: Base-case model fit to SKI 7 trawl survey abundance series.



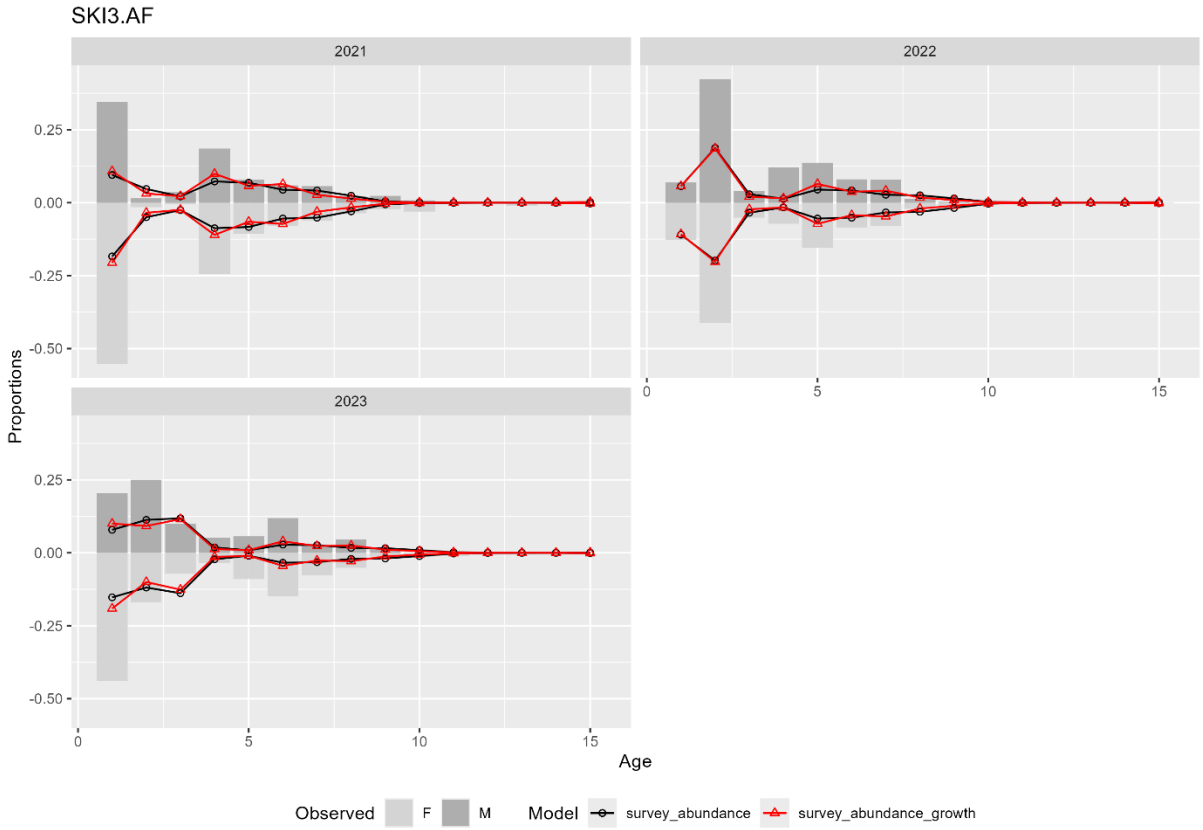
Appendix Figure 60: Base-case model fit to SKI 3 & 7 Observer length frequency data series.

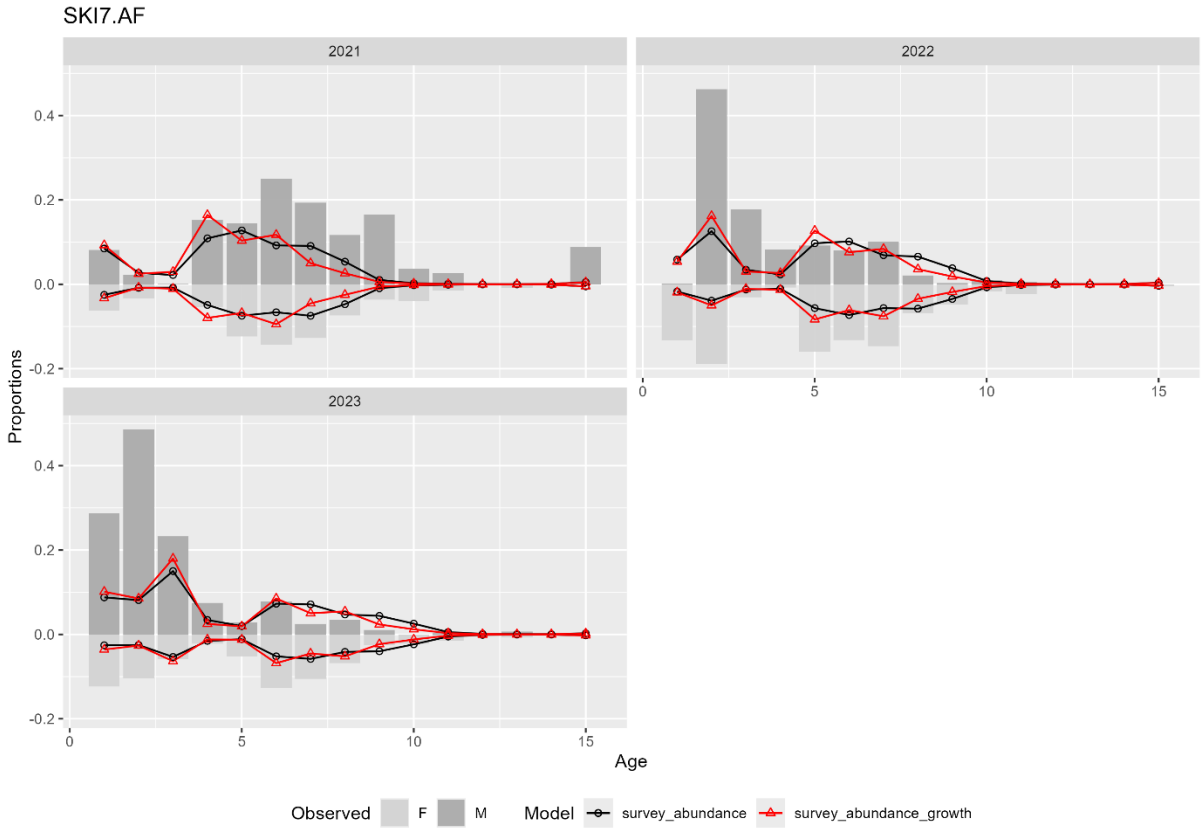


Appendix Figure 61: Base-case model fit to SKI 7 survey length frequency data series.

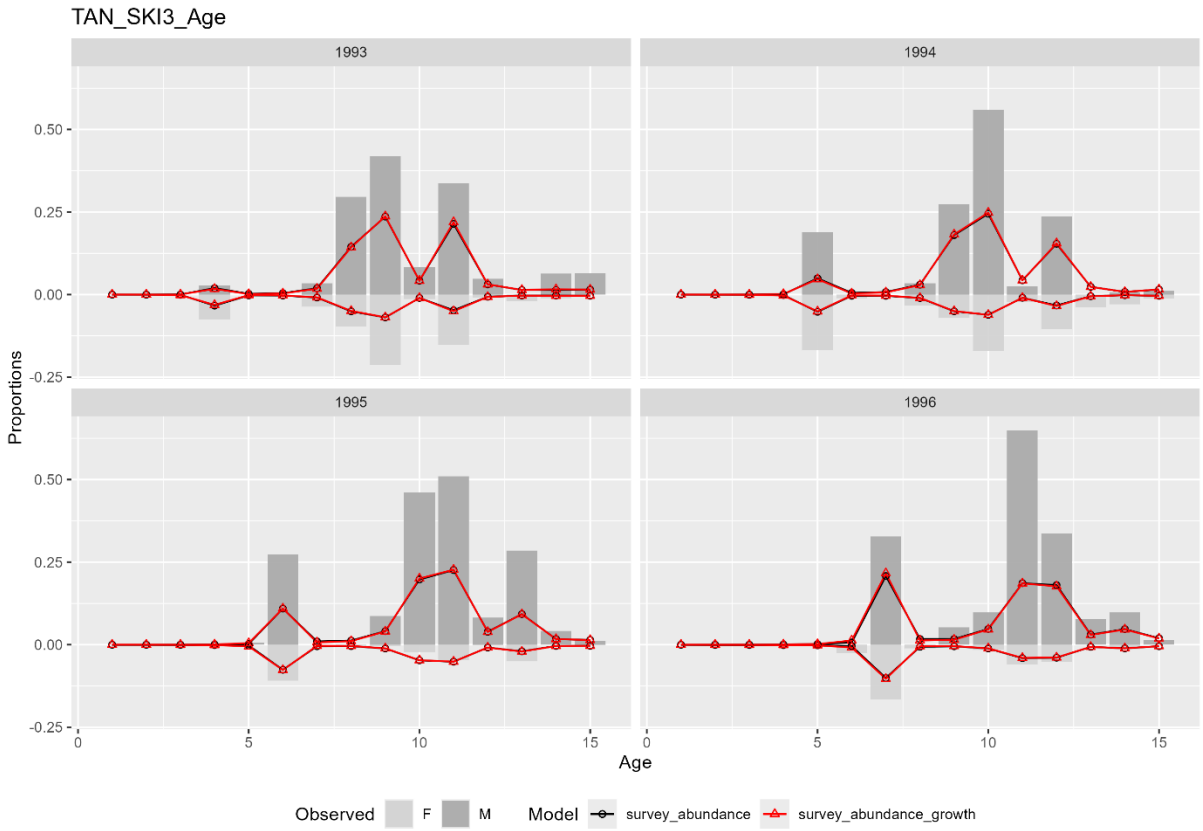


Appendix Figure 62: Base-case model fit to SKI 3 1983 *Shinkai Maru* length frequency data.

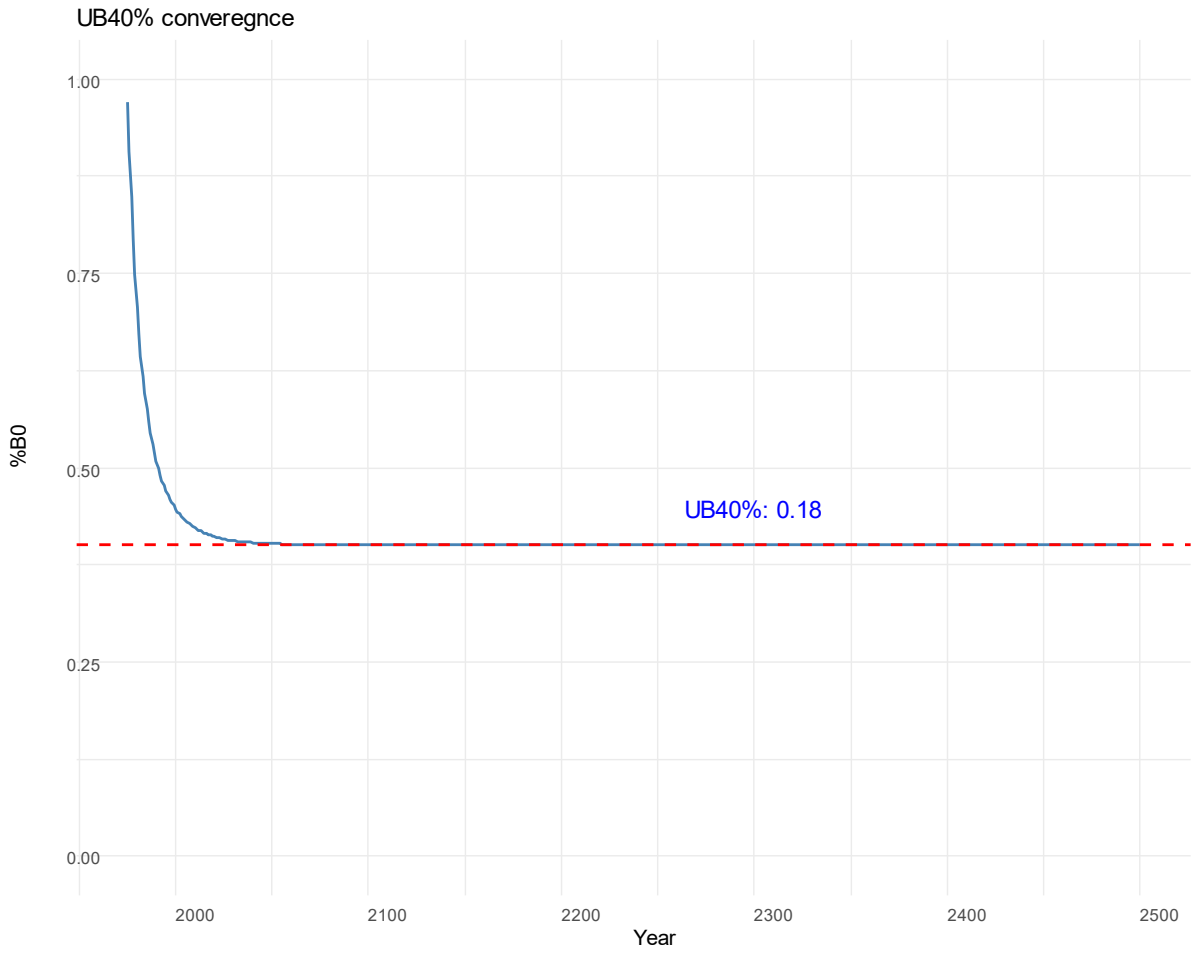




Appendix Figure 63: Base-case model fit to SKI 3 & 7 Observer age frequency data series.



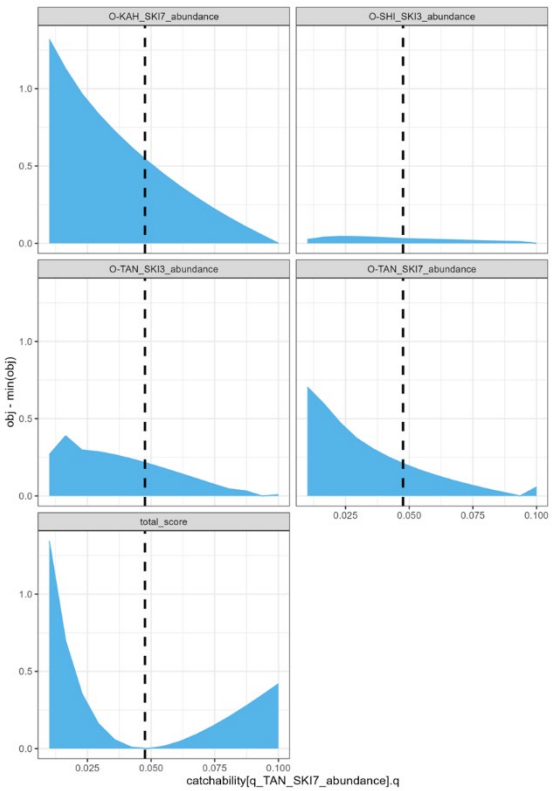
Appendix Figure 64: Base-case model fit to SKI 3 *Tangaroa* survey age frequency data.



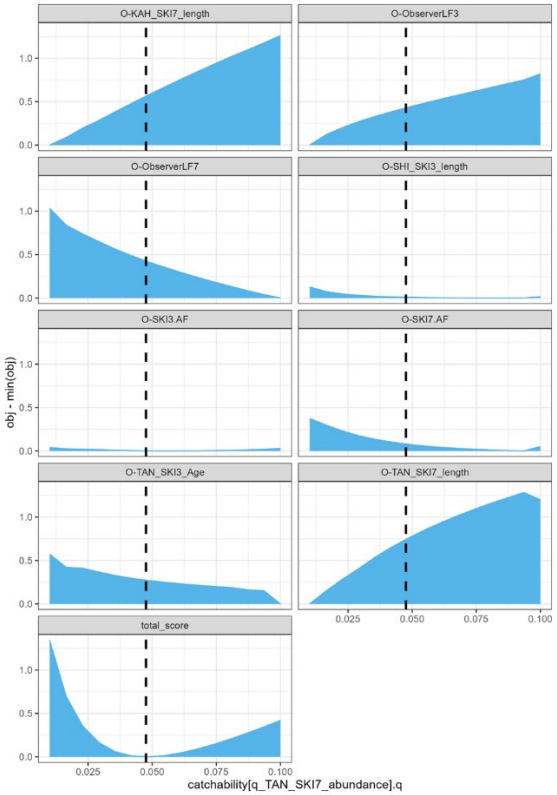
Appendix Figure 65: Base-case model deterministic $U_{B040\%}$ as derived from equilibrium projection.

Appendix 26: Base-case survey abundance catchability (*q*) profiles

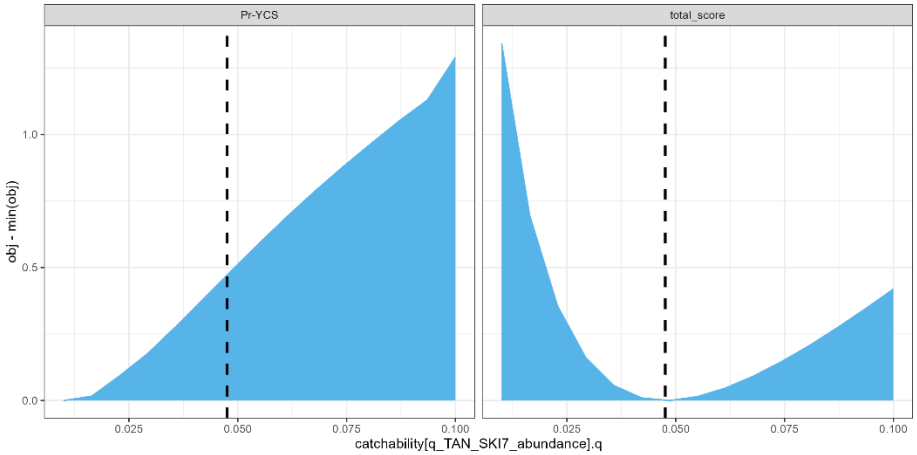
a. abundance likelihoods



b. compositional likelihoods

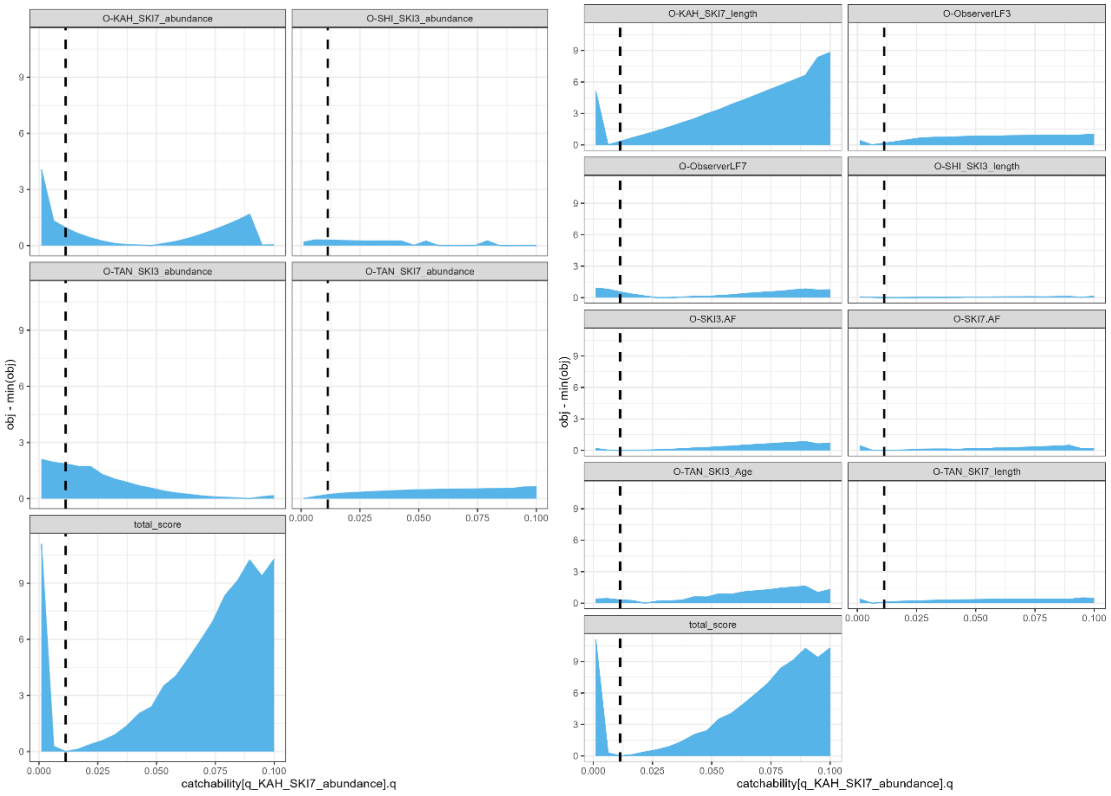


c. YCS priors

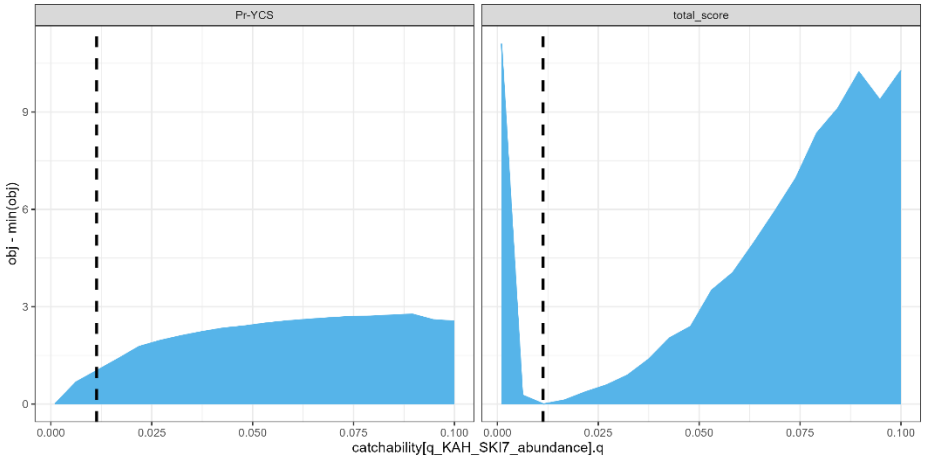


Appendix Figure 66: SKI 7 *Tangaroa* survey q profile.

a. abundance likelihoods **b. compositional likelihoods**

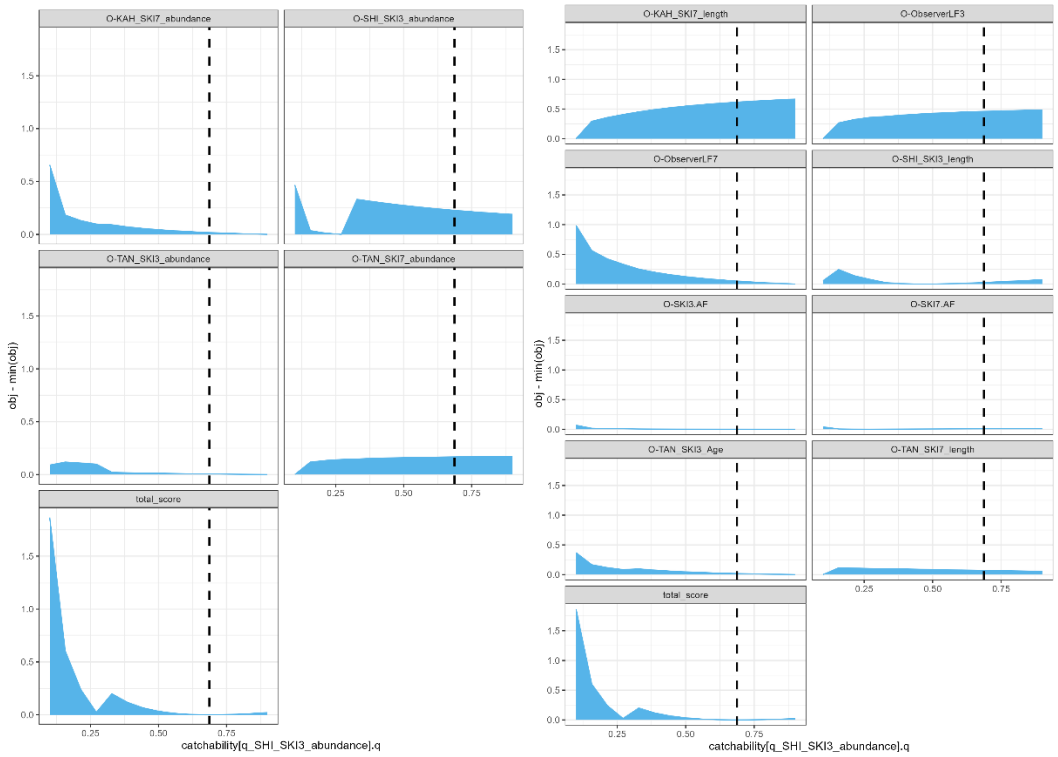


c. YCS priors

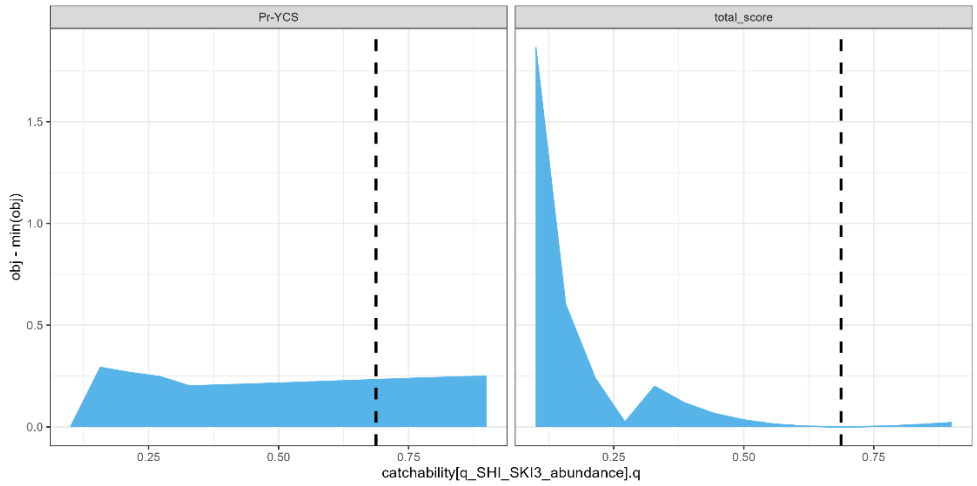


Appendix Figure 67: SKI 7 *Kaharoa* survey q profile.

a. abundance likelihoods **b. compositional likelihoods**

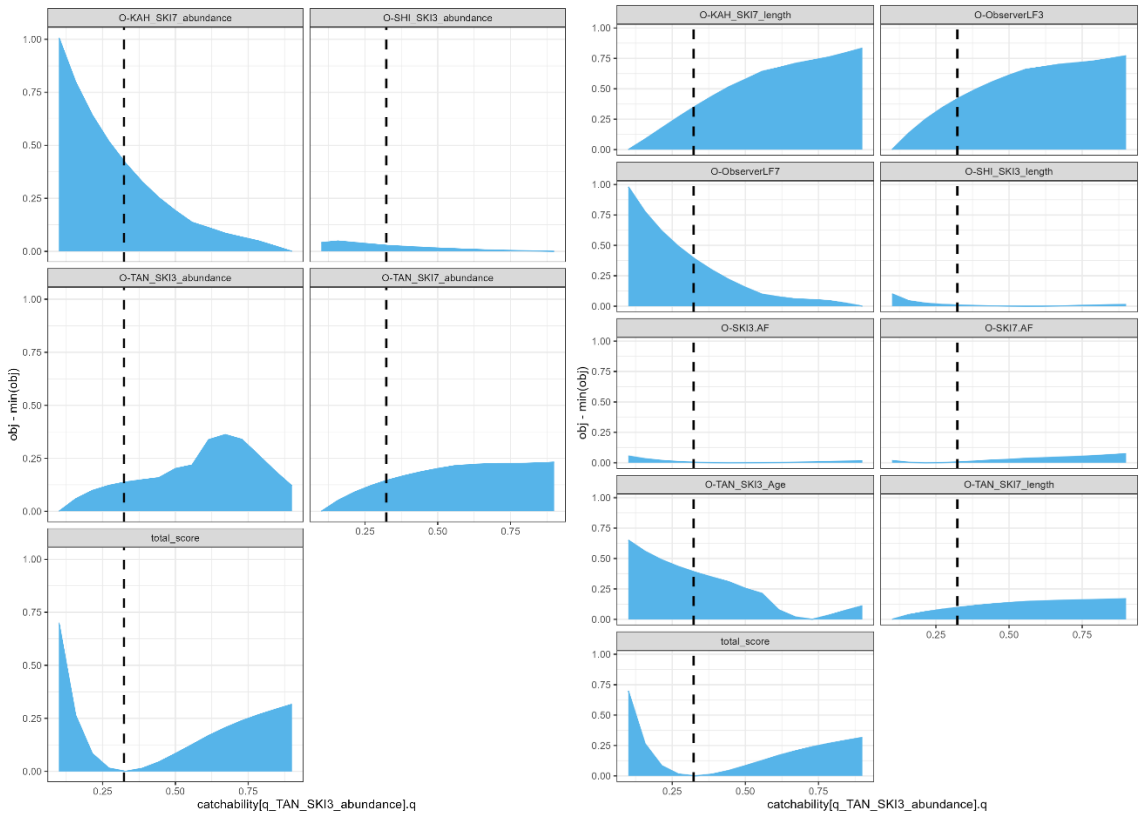


c. YCS priors

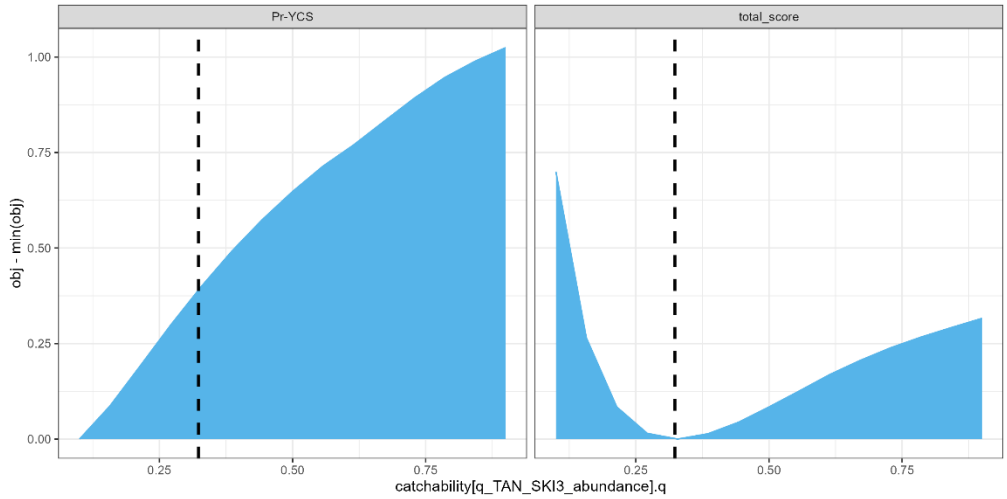


Appendix Figure 68: SKI 3 *Shinkai Maru* survey q profile.

a. abundance likelihoods **b. compositional likelihoods**



c. YCS priors



Appendix Figure 69: SKI 3 *Tangaroa* survey q profile.