



Fisheries New Zealand

Tini a Tangaroa

Characterisation and CPUE analyses for the gemfish fishery in SKI 3 and SKI 7 to 2020

New Zealand Fisheries Assessment Report 2024/39

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Plain language summary

Gemfish (southern kingfish) are found throughout New Zealand waters and are generally caught by trawl fisheries in depths from 150 to 500 metres. There are two New Zealand stocks of gemfish, with the southern stock caught around the South Island and a northern stock caught off both coasts of the North Island.

The trawl fisheries taking gemfish around the South Island were described for the period 1989–90 to 2019–20, using commercial catch and effort and observer data. Eleven standardised catch-per-unit-effort (CPUE) analyses were investigated as potential abundance series. South Island gemfish are thought to mainly live in the waters south of Stewart Island during the spring and summer and to migrate in the winter to the west coast of the South Island to spawn. Gemfish on the east coast of the South Island appear to be less abundant than on the west and south coasts of the South Island and their spawning migration patterns are not well understood.

Catches of southern gemfish were high in the 1980s and their abundance dropped by the early 1990s. Catch limits were curtailed, and commercial catches dropped to low levels from the late 1990s to the early 2010s. From the mid-2010s gemfish were increasingly caught in fisheries targeting hoki and squid.

All the analysed data sets indicated that the relative abundance of South Island gemfish had substantially increased, beginning in the mid-2010s. However, the size of increase was not consistent among the various indices and areas, and a CPUE based management reference point was not established.

EXECUTIVE SUMMARY

Starr, P.J.¹; Tornquist, M.G.²; Middleton, D.A.J.³; Neubauer, P.²; Langley, A.D.¹ (2024). Characterisation and CPUE analyses for the gemfish fishery in SKI 3 and SKI 7 to 2020.

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South Island gemfish (*Rexea solandri*, SKI), found in Quota Management Areas (QMAs) 3 and 7 (Figure 1), are considered to be a single stock. South Island gemfish were heavily fished, beginning in the late 1970s and extending into the early 1990s, with catch rates and catches rapidly diminishing from a peak in 1986 to low levels after 1991. This report presents detailed data from 1990 up to the end of the 2020 fishing year⁴ and characterises the fisheries which capture gemfish in SKI 3 and SKI 7, including gemfish landings by capture method, gemfish catch locations and depth range of capture, plus associated captured species.

This report presents detailed analyses of all available catch-effort data for SKI 3 and SKI 7 from 1990 up to the end of the 2020 fishing year, extending a preliminary catch-per-unit-effort (CPUE) analysis which included data to 2018. Three southern gemfish fisheries were identified: (1) SKI 7 target hoki; (2) SKI 3 Stewart-Snares shelf; (3) SKI 3 East coast South Island. Four CPUE series, based on different data sources (commercial tow-by-tow, daily processing, observer, and commercial daily “rollup”), were analysed for each fishery, except for the SKI 3 East coast South Island fishery where there were insufficient observer data to generate a series.

The Deepwater Working Group (DWWG) accepted that all eleven series indicated that there had been a considerable increase in apparent relative biomass in the late 2010s compared with the low levels of gemfish observed during the period 1990 to the mid-2010s. The DWWG preferred the daily processing series because these series would have been less affected by the limitations of the species reporting requirements of the TCEPR forms during the period of low abundance and that these series covered more years than the observer CPUE series. The DWWG also accepted the SKI 7 target hoki (*Macruronus novaezelandiae*, HOK) daily processing series as the primary abundance indicator for southern gemfish because it operates during the spawning period in the location where this stock is presumed to spawn. The SKI 3 Stewart-Snares shelf series was viewed as a corroborative series which operates in the feeding and migratory region for this stock. The DWWG noted that the gemfish index from the 2018 *Tangaroa* survey showed an increase that was consistent with the SKI 7 target HOK series. This observation corroborated the SKI 7 target HOK CPUE series, despite the short period covered by the west coast South Island *Tangaroa* survey series, given that this survey is likely to be indexing recruited gemfish.

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⁴where 2020 indicates the fishing year from 1 October 2019 to 30 September 2020

1. INTRODUCTION

This document describes work conducted under Specific Objectives 1 and 2 of Fisheries New Zealand contract SKI2020-01.

Overall Objective:

1. To update the characterisation and CPUE indices for gemfish (*Rexea solandri*) in SKI 3 and SKI 7.

Specific Objectives:

1. To undertake a descriptive analysis of gemfish in SKI 3 & 7 with data up to and including the 2020 fishing year.
2. To examine relevant CPUE indices.

South Island gemfish (*Rexea solandri*), found in Quota Management Areas (QMAs) 3 and 7 (Figure 1), are considered to be a single stock. South Island gemfish were heavily fished, beginning in the late 1970s and extending into the early 1990s, with catch rates and catches rapidly diminishing from a peak in 1986 to low levels after 1991. When South Island gemfish were introduced into the Quota Management System (QMS) in 1 October 1986, the combined Total Allowable Commercial Catch (TACC) was just over 5000 t and the peak combined catch in the year previous (1986) was 6900 t. However, the catches decreased to less than 1000 t/year for the combined fishery by 1991 and to less than 100 t in 1998 when the combined TACC was reduced to 600 t, where it remained until 1 October 2019. The combined TACC was increased for the 2020 fishing year⁵ to 1198 t (Table B.1 in Appendix B). This pattern of decreasing abundance in the presence of heavy fishing was mirrored in the North Island gemfish population (SKI 1 and SKI 2) (Middleton et al. 2023) and the Australian gemfish population (Liggins 2021). Recently, catches and catch rates have greatly improved in both SKI 3 & 7 (Langley 2020) and SKI 1 & 2 (Middleton et al. 2023), with the SKI 3 and SKI 7 TACCs being exceeded from 2017. The 2020 TACC increase accommodated the increasing catch in SKI 3, but catches in SKI 7 have continued to grow and considerably exceeded the new TACC in 2020.

A comprehensive review of SKI 3 and SKI 7 was completed in 2019 (Langley 2020), which indicated that catch-per-unit-effort (CPUE) and trawl survey indices had greatly increased in both QMAs since 2015. This project has added another two years to the Langley (2020) CPUE time series, extending it to the end of the 2020 fishing year. This project has also included observer data from the west coast South Island (WCSI) hoki fishery and southern South Island squid fishery to generate independent CPUE series for gemfish which were used as a check on the SKI 7 and SKI 3 statutory commercial fishery CPUE series. Trawl survey data additional to the Langley (2020) analysis were obtained from the 2019 WCSI *Kaharoa* trawl survey, which only partially monitors SKI 7, and from the 2016 and 2018 east coast South Island *Kaharoa* trawl surveys. The 2018 WCSI *Tangaroa* trawl survey index was available for the 2019 (Langley 2020) review.

An exploratory stock assessment model was fitted to the SKI 7 CPUE and four sets of trawl survey indices (WCSI *Tangaroa* and *Kaharoa*, Southland *Tangaroa* and *Shinkai Maru*) by Langley (2020). Biological data used in this model included length frequencies from the Southland and WCSI commercial fisheries, age frequencies from the Southland *Tangaroa* trawl survey and length frequencies from the WCSI *Tangaroa* and *Kaharoa* trawl surveys. This model predictably estimated a very strong recruitment event to account for the apparent increase in biomass indicated by the considerable upturn in the CPUE and trawl survey indices. Unfortunately, model fits to the recent length frequency data were poor which reduced the credibility of the model. The Deepwater Working

⁵where 2020 indicates the fishing year from 1 October 2019 to 30 September 2020

Group (DWWG) reviewed this model in March 2019, but did not accept its conclusions regarding stock status, citing uncertainty in the size of the recruitment pulse and concern that it was influenced by recent changes in the operation of the hoki fishery. This stock assessment model was not extended as part of this project because there were insufficient additional data to materially alter the previous DWWG conclusions, which could only be credibly modified with age frequency data that were currently unavailable. Because the rebuild of this stock is entirely dependent on one (or possibly more) recruitment events, age data are needed to corroborate the apparent increase in abundance.

2. INFORMATION ABOUT THE STOCK/FISHERY

2.1 Catches

Historical annual landings reported to the Quota Management Report (QMR)/Monthly Harvest Return (MHR) and TACCs for SKI 3 and SKI 7 up to 2020 are provided in Table B.1. The TACCs and allowances that comprise the Total Allowable Catch (TAC) for the two SKI QMAs as of 1 October 2023 are presented in Table 1.

2.1.1 SKI 3

The TACC for gemfish in SKI 3 was initially set at 2843 t when this Fishstock was first put into the QMS in 1986, but was increased by 17% through the process of quota appeals to more than 3300 t by 1992 (1992, Figure 2; Table B.1). Although this initial TACC was aligned with catches before 1986, catch in SKI 3 rapidly dropped to less than 100 t/y by the early 1990s (Figure 2). The TACC was brought down to 300 t/y for 1998, but catches in SKI 3 remained near to or below 100 t/y until they started climbing again in 2017. Catches exceeded the TACC of 300 t in 2018 and 2019 but did not exceed the higher TACC of 599 t that was set for 2020 (Figure 2; Table B.1).

2.1.2 SKI 7

The TACC for gemfish in SKI 7 was initially set at 1491 t when this Fishstock was first put into the QMS in 1986, but was increased by 11% through the process of quota appeals to more than 1650 t by 1991 (1991, Figure 2; Table B.1). Although this initial TACC was aligned with catches before 1986, catches in SKI 7 dropped to around 100 t/y by the early 1990s (Figure 2). The TACC was brought down to 300 t/y for 1998, and catches in SKI 7 remained below the TACC except for a brief resurgence in 2004 and 2005, before they started climbing again in 2017. Catches exceeded the TACC of 300 t from 2017 to 2019 and continued to exceed the higher TACC of 599 t that was set for 2020 (Figure 2; Table B.1).

2.1.3 Recreational catches

Recreational catches in New Zealand are poorly known (compared with commercial catches), and SKI 3/SKI 7 are no exception. However, it is thought that gemfish play an unimportant role in the New Zealand recreational fishery. Two large-scale population-based diary/interview surveys were conducted under contract for MPI from 1 October 2011 to 30 September 2012 (Wynne-Jones et al. 2014) and from 1 October 2017 to 30 September 2018 (Wynne-Jones et al. 2019). The primary objective for both surveys was to estimate Fishery Management Area (FMA)-specific annual catches for all major finfish and non-fish species. Both surveys estimated the New Zealand-wide recreational gemfish catch to be small, with only 2900 gemfish caught in 2012 (CV=0.39) and 8500 caught in 2018 (CV=0.39) in all of New Zealand. These estimates were based on 12 diarists reporting from 17 events in 2012 and 28 diarists from 37 events in 2018. Recreational catch estimates were not provided by SKI QMA, so the location of these catches is not known. However, the precision of the estimates is likely to be very poor at the level of the two South Island QMAs.

2.2 Regulations Affecting the Fishery

There are no specific regulations which affect the South Island gemfish fishery apart from the general regulations which affect the capture of deepwater finfish species. Some of these regulations include the exclusion of large (>43 m in overall length) from waters within 25 nm from the coast and the requirement to have annual catch entitlement to offset the catch of gemfish.

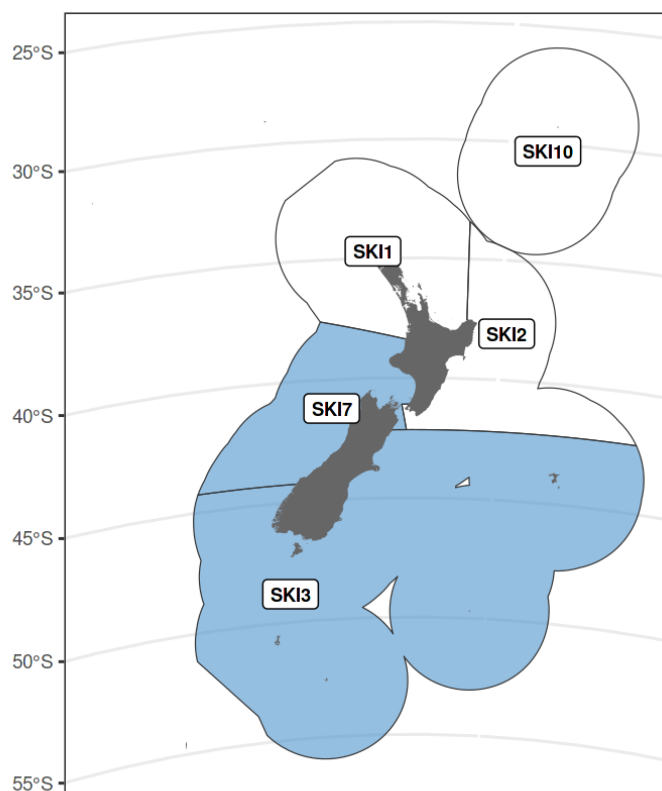


Figure 1: Quota Management Areas for gemfish with SKI 3 and SKI 7 highlighted.

Table 1: Total Allowable Catch (TAC), Total Allowable Commercial Catch (TACC), and allowances (all tonnes) for SKI 3 and SKI 7, as at 1 October 2023.

Stock	TAC	TACC	Allowances		
			Customary	Recreational	Other mortality
SKI 3	1 103	1 091	1	0	11
SKI 7	1 103	1 091	1	0	11

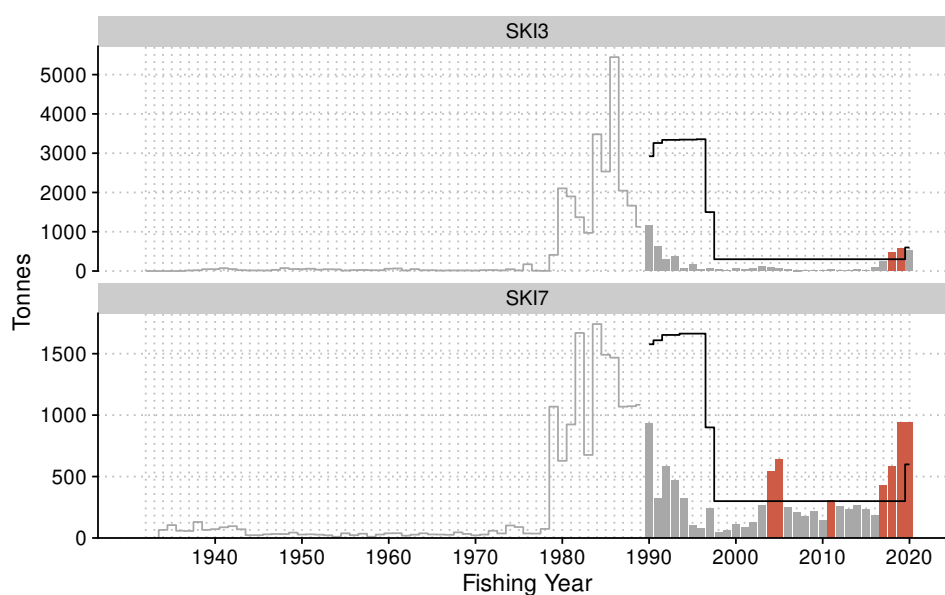


Figure 2: Total Allowable Commercial Catch (TACC; black line) and Monthly Harvest Return/Quota Management Report totals (bars) for SKI 3 and SKI 7 from 1990 to 2020. Years where the TACC was exceeded are highlighted in red. Catches prior to 1990 are shown by the grey line using the information compiled in the Fisheries Assessment Plenary Report (Fisheries New Zealand 2022). Tabulated data are provided in Table B.1.

3. METHODS

Extracts (report logs 13159, 15575) of statutory commercial catch, effort, and landings data were provided by Fisheries New Zealand and processed using standardised grooming routines (Appendix A).

All years in this report refer to the normal New Zealand fishing year which runs from 1 October to 30 September. Fishing years are labelled using the later calendar year; thus, for example, 1990 refers to the fishing year 1 October 1989 to 30 September 1990.

For a full list of acronyms used in this report, please refer to Appendix E.

3.1 Terminology

In this report we use the term **catches** to refer to the catch of legally retainable fish. Catches include any legally retainable fish that are optionally returned to the sea (for example, schedule 6 returns) but exclude those fish that *must* be returned to the sea, such as fish below the minimum legal size (MLS). Catches include declared accidental losses of fish but do not include fish that escape capture, for example by escaping through the mesh of a trawl.

For species managed under the Quota Management System (QMS) we use the term **removals** to refer to the known mortality of fish; the legally retainable catches without those fish that are optionally returned to the sea and considered likely to survive. Any mortality suffered by these returned fish is not included in removals. However, in the case of non-QMS species we include returned fish as part of the removals.

3.2 Data sources

There are three types of statutory commercial data relevant to assessing catches and removals:

- Monthly Harvest Returns (MHRs) and their forerunner, Quota Management Reports (QMRs), which we refer to as the **MHR/QMR** data;
- landings and disposals, referred to as **landings** data; and
- the **estimated catches** recorded by fishers for individual fishing events.

MHR/QMR data are the key information used in the balancing of commercial catch against the Total Allowable Commercial Catch (TACC); however, they provide information at a relatively coarse resolution of client, stock, and month. QMRs provided a record of the total monthly catch of each QMS fishstock for each quota holder, by month from December 1986 to September 2001. MHRs replaced QMRs from October 2001 and record data on harvest of both QMS and non-QMS species.

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.

Landings and disposals provide data on the catches of all stocks, generally at the fishing trip resolution, with quantities verified (where practicable; e.g., when landed) by weighing. Under the Electronic Reporting regime introduced by the Fisheries (Reporting) Regulations 2017, these data provide a comprehensive record of catches per trip, with the fate of those catches indicated by a destination code (Table 2). However, the set of available destinations has become more comprehensive as reporting regulations have evolved and the possibility that the landings data were less complete in the past must be considered.

In some cases, landings from a trip are first recorded to an interim destination. Because these fish should subsequently be reported to a final destination, the data for the initial, non-final landings are dropped from the landings dataset used in this report, together with any landings data for categories of fish that are not legally retainable.

The **catches** and **removals** used in the remainder of this report comprise the landings for final, legally retainable destinations (Table 2).

3.3 Allocation of catches to fishing events

As noted above, the landings data that define the catches and removals for a stock are generally reported at the resolution of the fishing trip. In some fisheries, trips are lengthy (exceeding a month) and carry out fishing over a wide area; as a result, catches are most usefully *allocated* to individual fishing events. Two allocation approaches are available: *trip-based allocation* and *annual scaling*. In this report, trip-based allocation was used for all stocks and methods.

The trip-based approach allocates the catches of SKI from a trip to the fishing event records from the trip using the hierarchical method of Starr (2007). If gemfish were included in the estimated catch for at least one of the fishing event records on the trip, then catches were allocated in proportion to the estimated catch for each record (**Est. catch** allocation). If no estimated catch of gemfish was recorded on the trip, but a single fishing method was used on the trip, then catches were allocated in proportion to the number of fishing events per record (**Effort no.** allocation). If neither of the previous approaches applied for a trip then catches were allocated equally across fishing effort records (**Equal** allocation).

3.4 Conversion factors

Catches and removals in this report are reported as greenweight. However, actual weighing of the catch may take place after processing, in which case the greenweight is derived by applying a conversion factor to the measured processed weight. The conversion factors used in the statutory commercial reporting are specified by Fisheries New Zealand, by species and processed state.

The regulated conversion factors may be updated at times; occasionally this is because the nature of processing a particular species or state has changed, but usually it is because sufficient data have been collected to provide a more reliable estimate of the appropriate conversion factor. In this report, we adjust historical landings data to the current conversion factor for the species and processed state:

$$gwt_{adj} = gwt_{rep} \frac{CF_{cur}}{CF_{rep}} \quad (1)$$

where gwt_{adj} is the adjusted greenweight, gwt_{rep} is the greenweight originally reported, CF_{cur} is the current conversion factor, and CF_{rep} is the conversion factor used when the data were reported.

Table 2: Destination codes used in reporting of landings and disposals, with introduction date for codes that were not defined in the original Fisheries (Reporting) Regulations 1990. The inclusion of the landing/disposal in subsequent MHR returns is indicated in circulars issued under the Fisheries (Reporting) Regulations 2017. Only categories that are legally retainable, and considered final, are included in the catches and removals for a stock. LFR = Licensed Fish Receiver.

Code	Description	Date		Final	Retainable	Included in		
		Introduced	Revoked			MHR	Catches	Removals
A	Accidental losses			Y	Y	Y	Y	Y
B	Retained for use as bait			Y	Y	Y	Y	Y
E	Catch eaten on board			Y	Y	Y	Y	Y
EOY	End of year landings	2017-10-01		Y	Y	Y	Y	Y
H	Losses from holding receptacles		2018-06-30	Y	Y	Y	Y	Y
HL	Losses from holding receptacles on land	2018-07-01		Y	Y	Y	Y	Y
HW	Losses from holding receptacles in the water	2018-07-01		Y	Y	Y	Y	Y
J	Observer or Fishery Officer authorised returns	2013-10-01		Y	Y	Y	Y	Y
L	Landings to an LFR			Y	Y	Y	Y	Y
LFL	Fish landed after being held live on land	2019-01-10		Y	Y	Y	Y	Y
LP	Final landing of fish from holding receptacles at sea	2018-07-01	2019-01-09	Y	Y	Y	Y	Y
LR	Final landing of retained fish	2017-10-01		Y	Y	Y	Y	Y
M	Sixth schedule returns (spiny dogfish)	2004-10-01		Y	Y	Y	Y	Y
O	Catch transported outside the EEZ			Y	Y	Y	Y	Y
PF	Predated fish	2018-07-01		Y	Y	Y	Y	Y
QL	Landings to an LFR after storing in a holding receptacle on land	2018-07-01		Y	Y	Y	Y	Y
S	Catch taken by a Fishery Officer or observer			Y	Y	Y	Y	Y
T	Transhipments		2018-06-30	Y	Y	Y	Y	Y
TL	Transhipments, reported as landed by the catching vessel	2018-07-01		Y	Y	Y	Y	Y
U	Used as bait			Y	Y	Y	Y	Y
W	Wharf sales			Y	Y	Y	Y	Y
Z	Returns to the sea (certain sharks, dead or near-dead)	2014-10-01		Y	Y	Y	Y	Y
BS	Biotoxin samples	2019-11-26		Y	Y	N	Y	Y
CS	Customary catch	2017-10-01	2019-11-25	Y	Y	N	Y	Y
D	Non-QMS returns			Y	Y	N	Y	Y
F	Landings as recreational entitlement	2002-07-11		Y	Y	N	Y	Y
I	Returns for safety of protected species	2022-11-01		Y	Y	N	Y	Y
V	Observer samples	2017-10-01		Y	Y	N	Y	Y
X	Permitted returns	2006-10-01		Y	Y	N	Y	N
C	Disposal to the Crown		2001-09-30	Y	Y		Y	Y
G	Returns above legal size	2018-07-01		Y	N	N	N	N
K	Lobster required returns (not sub-MLS)	2018-07-01		Y	N	N	N	N
Y	Sub-MLS returns	2017-10-01		Y	N	N	N	N
LF	Live fish held on land	2019-01-10		N	Y	N	N	N
N	Removals from holding receptacles at sea	2018-07-01		N	Y	N	N	N
P	Placed into a holding receptacle at sea			N	Y	N	N	N
Q	Placed into a holding receptacle on land		2018-06-30	N	Y	N	N	N
R	Landings retained on board			N	Y	N	N	N
TT	Transhipments, reported as landed by the receiving vessel	2017-10-01		N	Y	N	N	N

3.5 Characterisation dataset

A fishery characterisation dataset was prepared by identifying all trips with landings or estimated catches from SKI 3 and SKI 7 and extracting the associated catch and effort data for fishing events within the SKI 3 and SKI 7 Quota Management Areas (Figure 1). Fishing events were selected based on start position (where available) or statistical area (Figure 3). The earlier QMS-era catch and effort data were reported at the resolution of statistical areas, and some statistical areas cannot be uniquely assigned to a single fishstock (Figure 3).

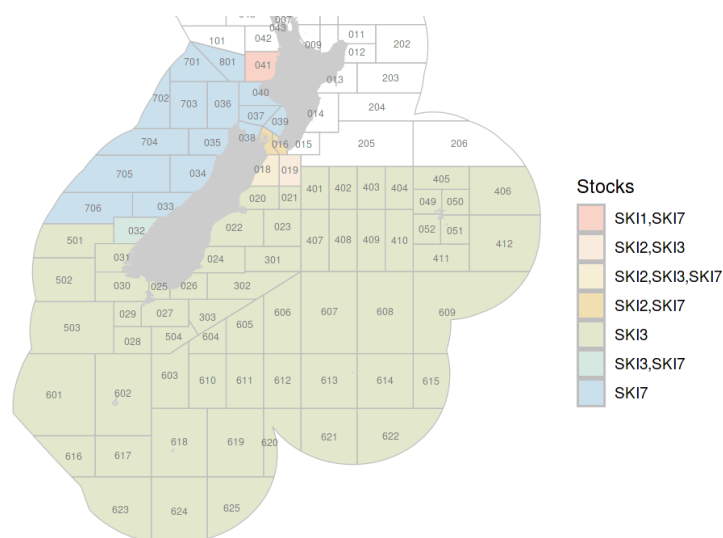


Figure 3: Statistical Areas that intersect the SKI 3 and SKI 7 Quota Management Areas.

3.6 CPUE methods

Fishing events for catch-per-unit-effort (CPUE) modelling were selected by a combination of some or all of:

- reporting form;
- fishing method;
- target species;
- area; and
- time period.

All fishing events matching the series definition were extracted, whether or not SKI were caught. Datasets for CPUE modelling were prepared at differing resolutions:

fishing event level where records represented individual fishing events such as trawls or longline sets;

daily (pseudo-CELR) resolution where finer scale records were aggregated to vessel-day resolution to provide data that mimic the resolution provided by the Catch, Effort and Landing Return (CELR), following the approach suggested by Langley (2014); or

trip level where each record was for a complete fishing trip with aggregated statistics summarising the fishing effort from the trip.

For the fishing event and daily resolution data, catches were allocated to fishing events following the approach of Starr (2007) as summarised above. For the fishing event resolution data, the catch allocation process was applied after restricting estimated catches to the top five species (a1lockg_top5; matching the resolution of the TCEPR form), the top eight species (a1lockg_top8; matching the resolution of

the TCER, NCELR, LCER, and LTCER forms), or without restricting estimated catches (alllockg, or scaledkg in cases where annual rather than trip level scaling was applied).

For the daily resolution data, catches were allocated after first restricting the estimated catches to include only the top five species estimated caught on the day, to match the resolution of the CELR data (alllockg). For the daily resolution data, processed catch totals were also included (prockg); these included the summed greenweight of any processed catch records for the date of the fishing activity.

Trip resolution CPUE datasets included the aggregate, trip-level catches directly, without any allocation to fishing events (1andkg) and sums, mean, and/or modal values of the effort variables for the trip.

The gemfish CPUE models were offered SeasonDay as an explanatory variable. This was defined as days since the start of the October fishing year; thus, for example, SeasonDay 306 is 1 August 2020 in the 2019–20 fishing year.

4. FISHERY CHARACTERISATION

4.1 Destination codes in the SKI 3 & 7 landings data

Landings data for gemfish were provided for every trip which landed SKI 3 or SKI 7 at least once, with one record for every reported SKI landing from the trip. Each of these records contained a reported green weight (in kilograms), a code indicating the processed state of the landing, along with other auxiliary information such as the conversion factor used, the number of containers involved and the average weight of the containers. Every landing record also contained a “destination code” (Table B.4, Table B.5, Figure 4), which indicated the category under which the landing occurred. The majority of landings were made using destination code “L” (landed to a Licensed Fish Receiver (LFR); Table B.4, Table B.5). However, other codes (e.g., A, C, O or W; Table B.4, Table B.5) also described potentially valid landings and were included in this analysis. These codes usually tended to be of minor importance, but codes O and T, which were prevalent in the early 1990s, were needed to approximate the total QMR catch for the years 1990 to 1996 in SKI 3 and to 1998 in SKI 7 (Figure 4). Code O (conveyed outside New Zealand) should be included in the catch total but code T (transferred to another vessel) is usually omitted because it represents an intermediate code for catch which is expected to be landed later under the L category. Other codes (Q, P and R) represent intermediate landings which are expected to be reported at a later date under the “L” destination category. These categories are usually omitted from the annual totals because of the potential for double counting catch. However, the early T landings codes were most likely miscoded O landings, which represented transshipments at sea that were then conveyed outside New Zealand waters and consequently needed to be included in the annual totals shown in Figure 4. This behaviour by the deepwater fleet was common in the early days of the QMS.

4.2 State codes in the SKI landings data

Most gemfish in SKI 3 and SKI 7 were landed in the “dressed” processed state (DRE) (Figure 5, Table B.6, Table B.7), except for 1990 where the “head, gut and tail-off” (HGT) processed state predominated in both QMAs (Figure 5). Other processed states of importance for gemfish included “green” (GRE), “head and gutted” (HGU) and “meal” (MEA) (Figure 5). There have been no changes in the conversion factors for any of the state codes of importance to gemfish in SKI 3 or SKI 7 (Figure 6, Table B.8).

4.3 Allocation of landings

Figure 7 indicates that, for both SKI 3 and SKI 7, almost all landings had associated effort information. Only SKI 3 in 1990 showed an approximate 20% shortfall between the actual landings and the landings with associated effort information. This was likely due to the large size of transhipped landings (destination code T) in that year (Figure 4). There was a drop in the proportion of T destination landings after 1990 which likely resulted in a smaller proportion of unallocated landings in SKI 3 (compare Figure 4 with Figure 7). There was a much smaller proportion of unallocated landings in SKI 7, even in the years 1990 to 1994, when there were reasonably large amounts of T destination codes landed in those years (compare Figure 4 with Figure 7).

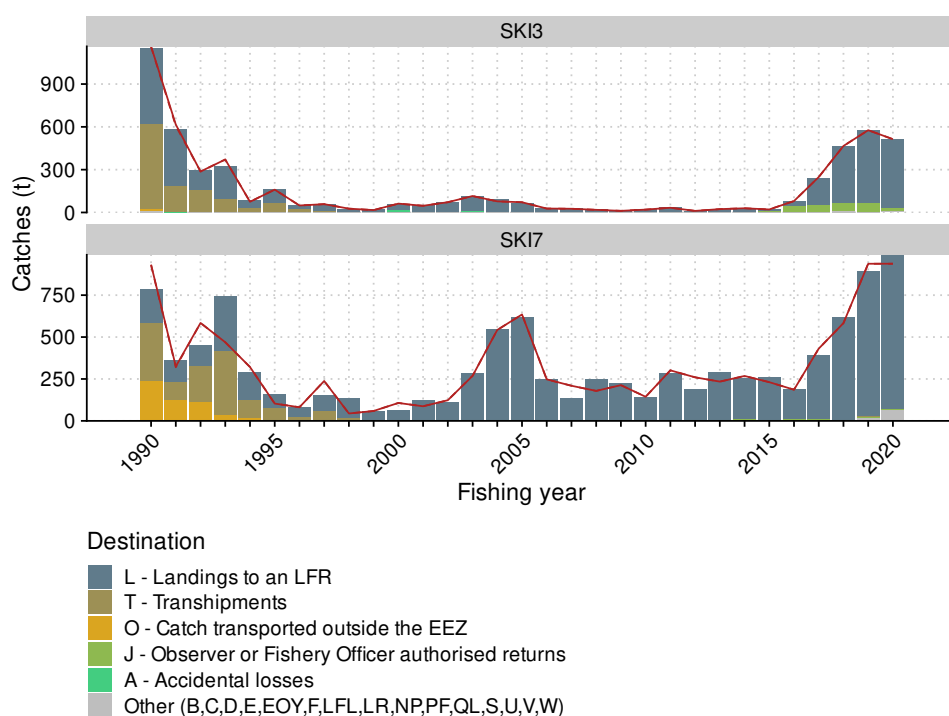


Figure 4: Catches of gemfish by destination (bars), compared with Monthly Harvest Return / Quota Management Report (MHR/QMR) totals (line), for Quota Management Areas SKI 3 and SKI 7. Destination codes are defined in Table 2 and tabulated catches are in Appendix B.

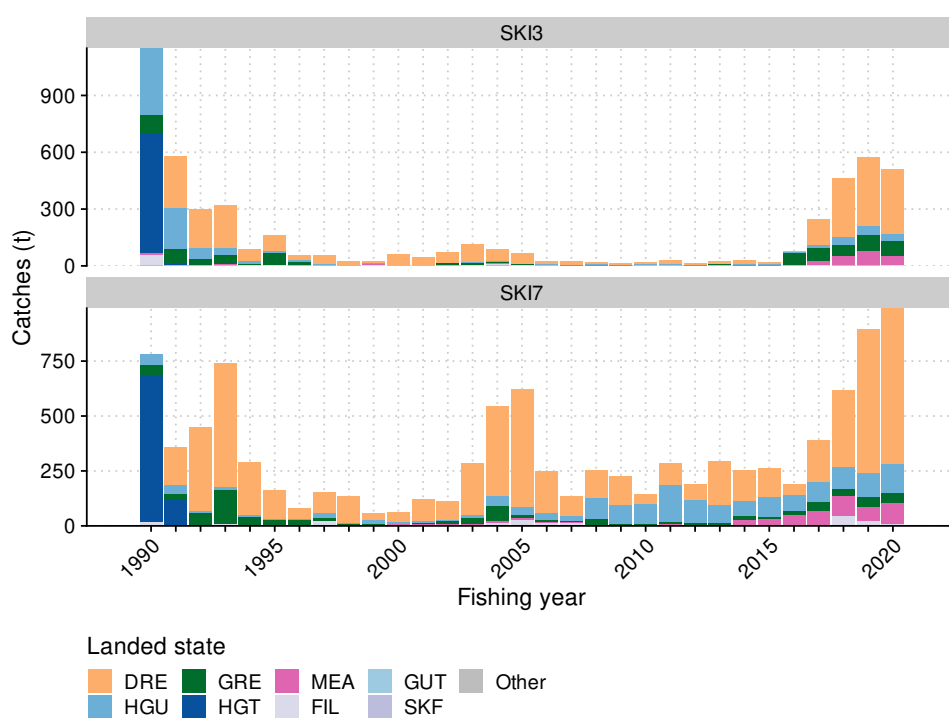


Figure 5: Landed state of gemfish from Quota Management Areas SKI 3 and SKI 7. Catches are tabulated in Appendix B, and landed state codes are defined in the glossary Table E.1.

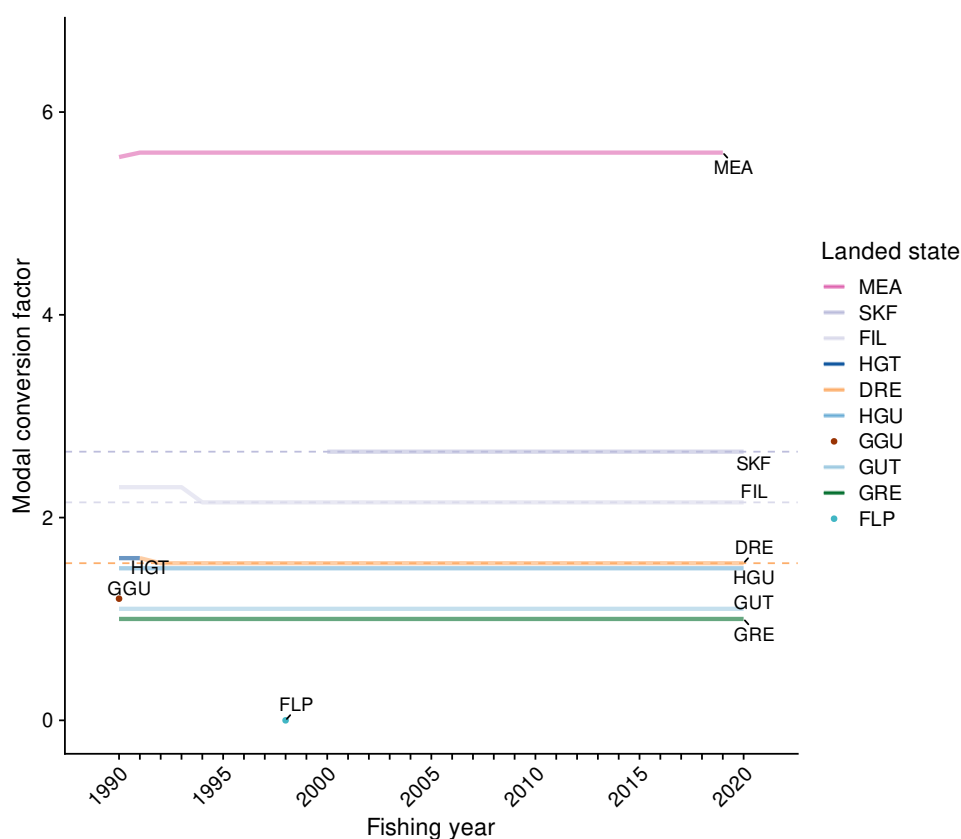


Figure 6: The modal annual conversion factor reported for the product states used in SKI 3 and SKI 7 catches. The current statutory conversion factor is indicated by a dashed line for states where a species-specific value is defined. Tabulated results are provided in Table B.8, and landed state codes are defined in the glossary Table E.1.

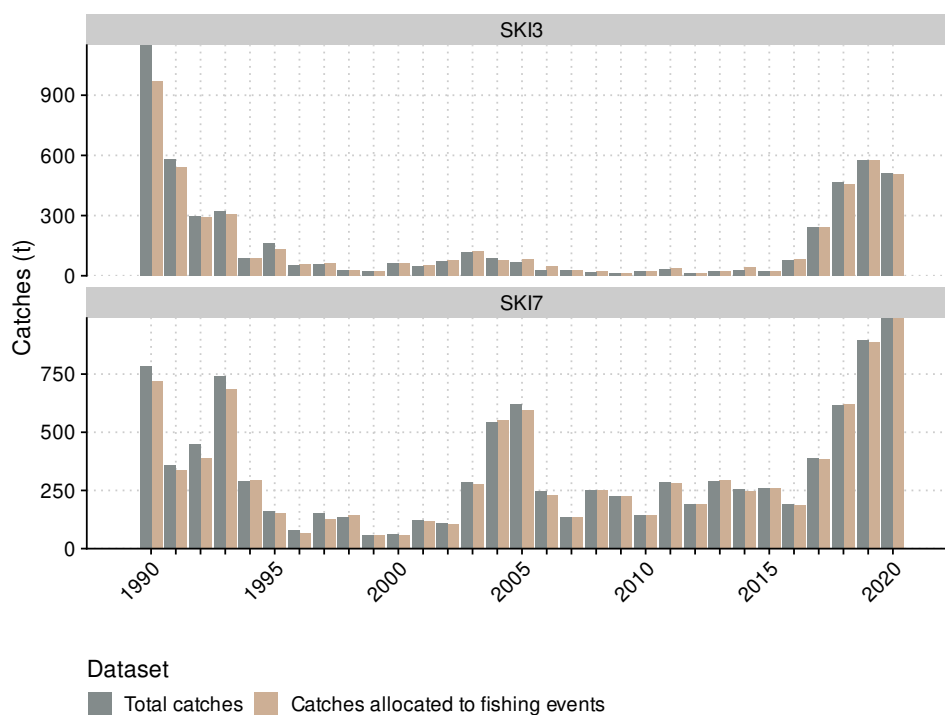


Figure 7: Total catches (t) of gemfish from SKI 3 and SKI 7 in comparison with catches allocated to fishing events in the characterisation dataset.

4.4 The SKI 3 Quota Management Area

4.4.1 Allocation of estimated catches to landings

Figure 8 shows the results of the application of the allocation procedures described in Section 3.3 to the SKI 3 catch and effort data. Panel (a) shows that the sums of both the estimated and processed SKI 3 catches were less than the declared landings in the same year. It also shows that the majority of landings (by weight) were associated with effort information. Panel (b) plots this same information as a ratio. In general, the ratio of estimated catch to landings declined as catches diminished, probably because gemfish would not be included in the top five species for any event when the abundance was low. However, even with higher catches (before 1995 and after 2016), this ratio never rose much higher than 0.75. Panel (c) shows that the median number of tows with positive SKI catch was near zero from 1990 to 1994 even though the reported estimated catches in each of those years totalled to about 75% of the landings. The mean number of tows with positive catch (solid line) was closer to 20% in 1990 (but declined to less than 10% by 1994). Note that the median for positive tows was greater in 2019 and 2020 while the mean for those years was close to the 20% observed in 1990. This was likely because of the reporting change from the top five species in 1990 compared with the more comprehensive species reporting requirements under Electronic Reporting System (ERS) in 2019 and 2020.

4.4.2 Form types used in the SKI 3 landings and effort data

The majority of SKI 3 landings were reported on the deepwater TCEPR forms until the introduction of the replacement electronic reporting system (ERS) in 2018 (Figure 9, Table B.9). A relatively small amount (near 30%) of gemfish catch was reported on the daily inshore CELR forms in the early 1990s.

4.4.3 Distribution of landings by method of capture

The distribution of landings by fishing method in SKI 3 was heavily weighted towards bottom trawl, with 88% of all landings attributed to this capture method averaged over the 31 years of catch history (Figure 10, Table B.11). About 4% of the catch of this species over the period 1990 to 1994 was captured by midwater trawl. The percentage of the midwater catch increased to 15% for the five years from 2016 to 2020 as gemfish abundance increased.

4.4.4 Distribution of landings by target species

Most of the recent (2016 to 2020) SKI 3 bottom trawl landings came from tows targeting squid and to a lesser extent hoki (63% for SQU and 7% for HOK; Figure 11). The early (1990 to 1994) large catches of SKI 3 were targeted at a wider range of species, including barracouta, gemfish, silver warehou and ling. Squid target fishing made up only 20% of catch during this period. About 50% of 2016 to 2020 midwater landings were from effort targeting squid.

4.4.5 Species rank by form type and target species

Gemfish were not at the top of the species catch rank even in the early 1990s when the catch of gemfish was greater than 500 t/y (Figure 12). Most of the catch was reported on the TCEPR forms which only required the top five species for any event. The mean species rank ranged between three and four for both BT and MW and there does not seem to be any systematic difference in the relative rank among the plotted target species. There was better reporting of gemfish with the change to ERS reporting with gemfish showing mean ranks greater than five (which would have been omitted under the previous TCEPR forms).

4.4.6 Number of fishing events by day and form type

Figure 13 shows that there had been a gradual decline in the mean number of fishing events per day for bottom trawl and possibly for midwater trawl vessels, with the bottom trawl mean dropping from about three events per day to close to 2.5 events per day by 2020. The mean number of events per day returned by the ERS data was very close to values returned by the previous inshore TCER forms, while the deepwater bottom trawl vessels using the TCEPR forms had a mean number of events per day that was slightly lower than that returned by the vessels using the TCER forms and the ERS data.

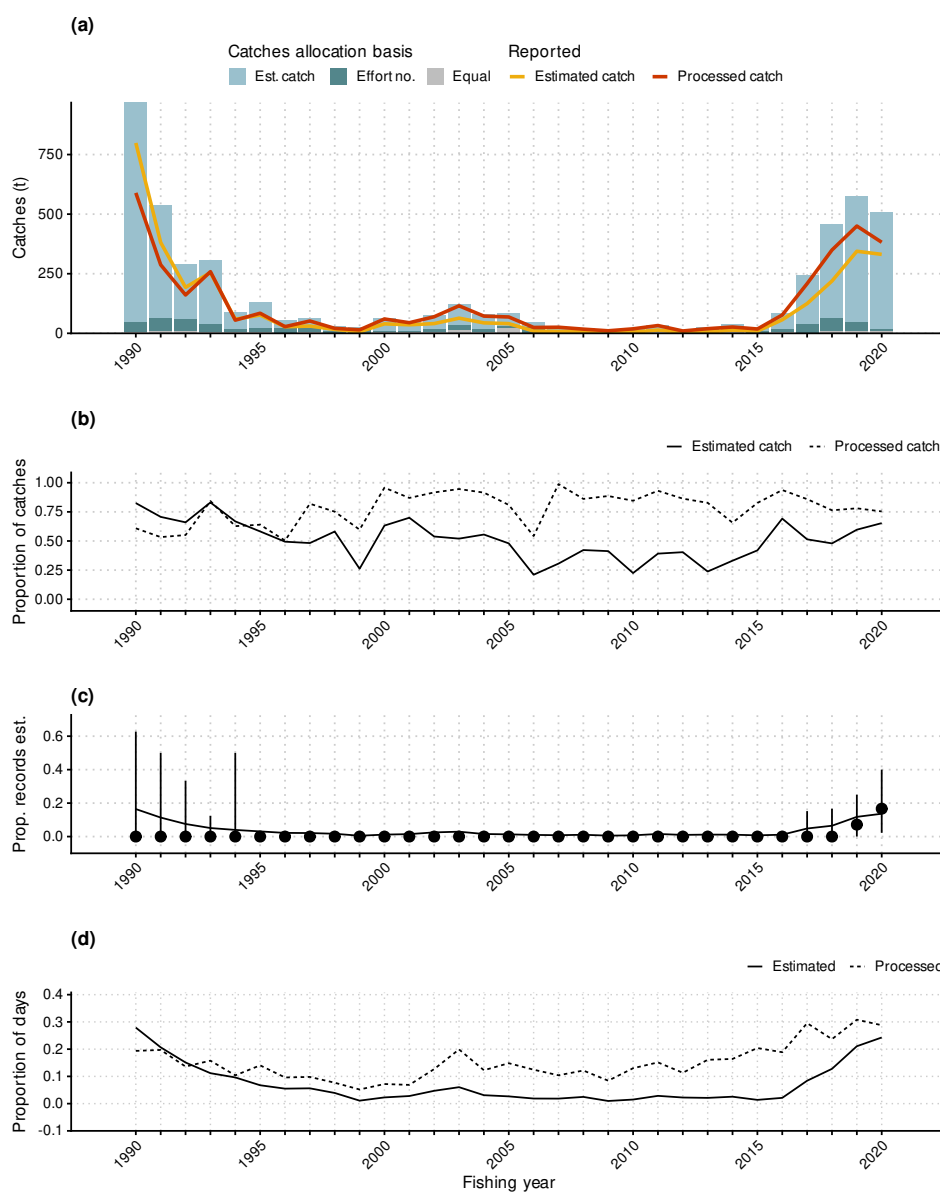


Figure 8: (a) bars: gemfish catches allocated to fishing events in the SKI 3 QMA with allocation method indicated by fill colour (see Section 3.3); lines: total estimated and processed catch of SKI; (b) the proportion of SKI 3 catches included in estimated and processed catch data; (c) the proportion of fishing event records with an estimated catch of SKI, with the line showing the overall proportion and the distributions illustrating the median and inter-quartile range by trip; (d) the proportion of vessel-days fished with a reported catch of SKI.

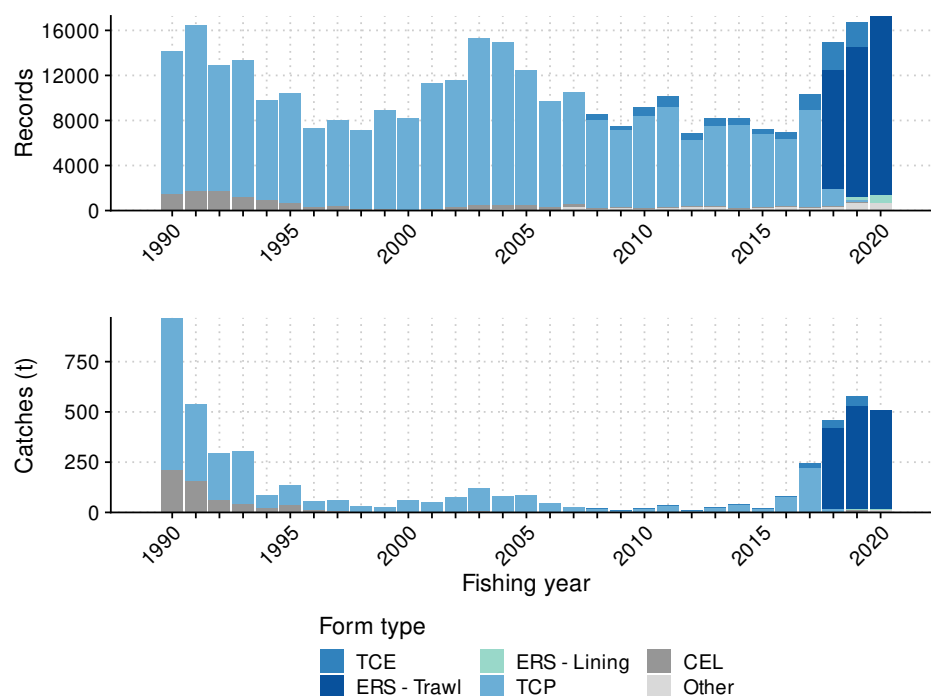


Figure 9: Reporting forms used on trips catching gemfish within the SKI 3 Quota Management Area, in terms of fishing event records and catches. Tabulated results are available in Appendix B. Form types grouped as Other include: ERS - Netting, ERS - Potting, ERS - Seining, LCE, LTC, NCE, SJC. A list of the main form type codes is included in the glossary Table E.2.

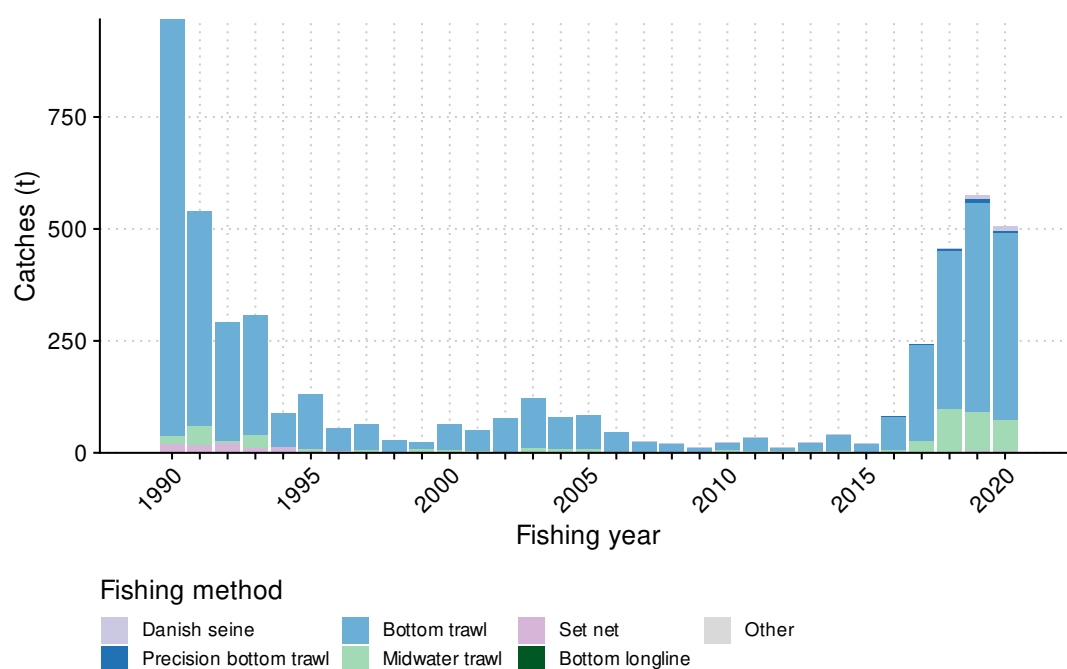


Figure 10: Catches of gemfish by fishing method, for events within the SKI 3 Quota Management Area. Methods grouped as Other include: BPT, CP, DL, FP, HL, PL, PRM, PSH, RLP, RN, SJ, T, TL. Tabulated results are provided in Appendix B, and a list of the main fishing method code types is included in the glossary Table E.3.

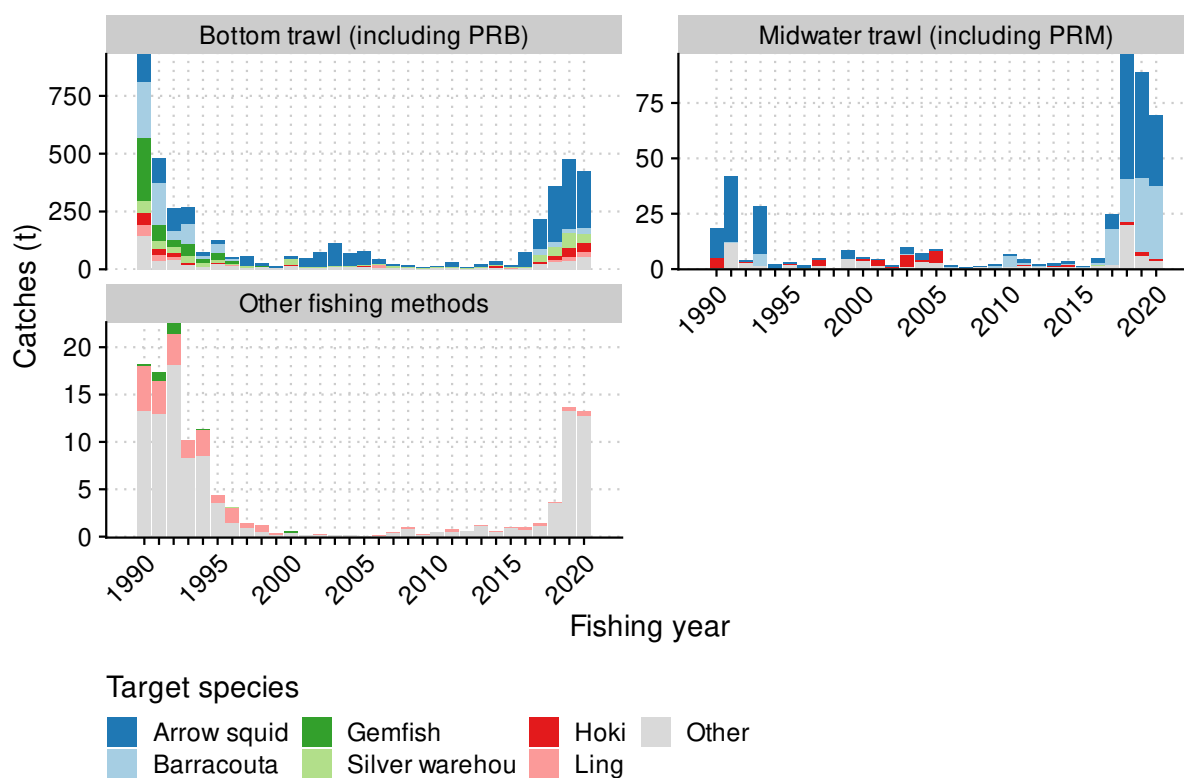


Figure 11: Catches of gemfish by fishing method and declared target species, for events within the SKI 3 Quota Management Area. Fishing Methods grouped as Other include: BLL, BPT, CP, DL, DS, FP, HL, PL, PSH, RLP, RN, SJ, SN, T, TL. Species grouped as Other include target species with less than 20% of the gemfish catch within the SKI 3 Quota Management Area in a fishing year.

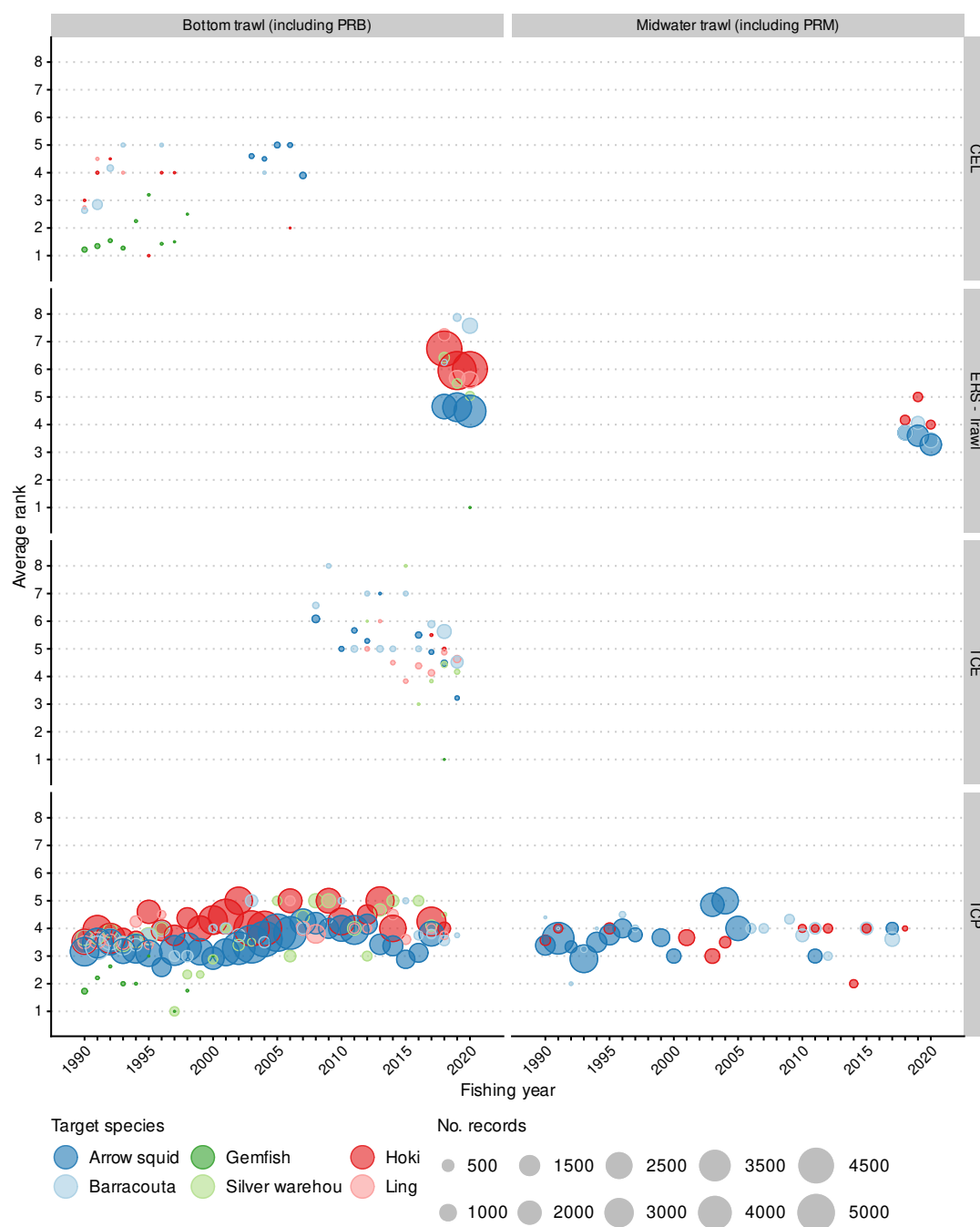


Figure 12: Average rank of gemfish in the estimated catch, by fishing method, form type and declared target species, for events with estimated catches within the SKI 3 Quota Management Area. The area of the circles scales with the number of records.

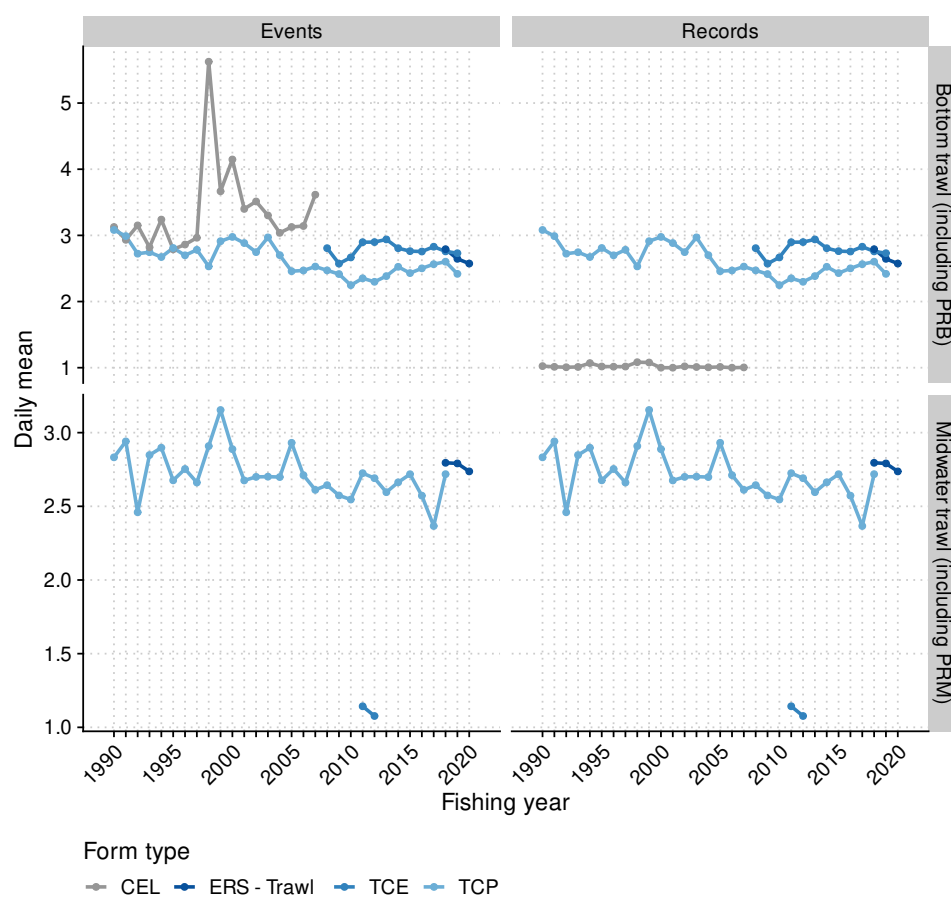


Figure 13: The mean number of fishing events and data records per vessel-day, by fishing method and reporting form, for effort within the SKI 3 QMA on trips landing catch from SKI 3. Data are included for years where a form was used on at least five vessel-days.

4.5 The SKI 7 Quota Management Area

4.5.1 Allocation of estimated catches to landings

Figure 14 shows the results of the application of the allocation procedures described in Section 3.3 to the SKI 7 catch and effort data. As seen in the equivalent figure for SKI 3 (Figure 8), panel (a) showed that the sums of both the estimated and processed SKI catches were always less than the declared landings in the same year. It also showed that the majority of the landings (by weight) were associated with effort information. Panel (b) plotted this same information as a ratio. These ratios appeared to be greater than the equivalent SKI 3 ratios in Figure 8, with less attenuation of the ratio of estimated catch to landings as catches diminished. However, unlike in SKI 3, the estimated/landed ratio continued to decrease with increased catches after 2015. As noted for SKI 3, panel (c) showed that the median number of tows with positive SKI catch was near zero right up to the mid-2000s. However, by 2008, the median and mean numbers of tows with positive catch (solid line) were very close, reflecting a larger proportion of tows where gemfish was among the top ranked species catch.

4.5.2 Form types used in the SKI 7 landings and effort data

Figure 15 provides an explanation for the matching of the mean and median proportions of positive tows beginning in 2008 noted in panel (c) of Figure 14. Unlike in SKI 3, a relatively large proportion of the SKI 7 records which captured gemfish were reported on the inshore TCER forms from 2008 onwards (Table B.10). When these forms were introduced in 2008, the number of species reported increased from five species per day (CELR) to eight species per tow, which is the most likely reason for the upturn in the median number of positive tows beginning in that year, even though gemfish catches did not increase at that time.

4.5.3 Distribution of landings by method of capture

The distribution of landings by fishing method in SKI 7 was also (as for SKI 3) weighted towards bottom trawl, with 76% of all landings attributed to this capture method averaged over the 31 years of catch history (Figure 16, Table B.12). Most (21%) of the remaining SKI 7 landings were by midwater trawl over the same period. However, there is a trend in the allocation of catch between capture methods, with 19% of the catch taken by midwater trawl in the first five years (1990 to 1994), which increased to 29% in the final five years (2016 to 2020; Table B.12).

4.5.4 Distribution of landings by target species

Beginning in the early 2000s, the majority of SKI 7 catches were taken when targeting for hoki by both bottom and midwater trawl (Figure 17). There was also a large bycatch of gemfish in the 2020 ling target fishery, accounting for 18% of the total 2020 catch. The early bottom trawl catches of SKI 7 were targeted at a wide range of species, including barracouta, gemfish, jack mackerel, hoki, silver warehou and ling. The midwater trawl fishery taking SKI 7 fish has always been targeted at hoki, with over 90% of the SKI 7 catch taken when hoki was the target species in nearly every fishing year from 1990 to 2020.

4.5.5 Species rank by form type and target species

As seen in SKI 3, gemfish were not at the top of the species catch rank, even in the early 1990s when the catch of SKI was greater than 500 t/y (Figure 18). Most of the catch was reported on the TCEPR forms which only requested the top five species for any event. The mean species rank ranged between three and four for both BT and MW and there did not seem to be any systematic difference in the relative rank among the plotted target species. The advent of the inshore TCER forms in 2008 revealed that the majority of the BT catch of gemfish were taken while targeting tarakihi, but the mean species rank was near five in most years. The change to ERS improved the reporting of gemfish in the estimated catch, allowing mean ranks greater than five (which would have been omitted under the previous TCEPR forms) (Figure 18).

4.5.6 Number of fishing events by day and form type

Figure 19 shows a stronger decline in the mean number of tows per day in the bottom trawl fishery than seen in SKI 3, declining from around three tows/day at the beginning of the series to less than two tows per day by 2015. However, the trend then reversed, climbing to a mean value of almost three tows/day in the bottom trawl fishery by 2020. There appeared to be no trend in the mean number of tows per day in the midwater trawl fishery. The mean number of tows per day reported by the ERS from the bottom trawl fishery lay midway between the previous TCEPR and TCER mean estimates, while the equivalent estimates from the midwater trawl fishery lay well above the means from either previous form type (Figure 19).

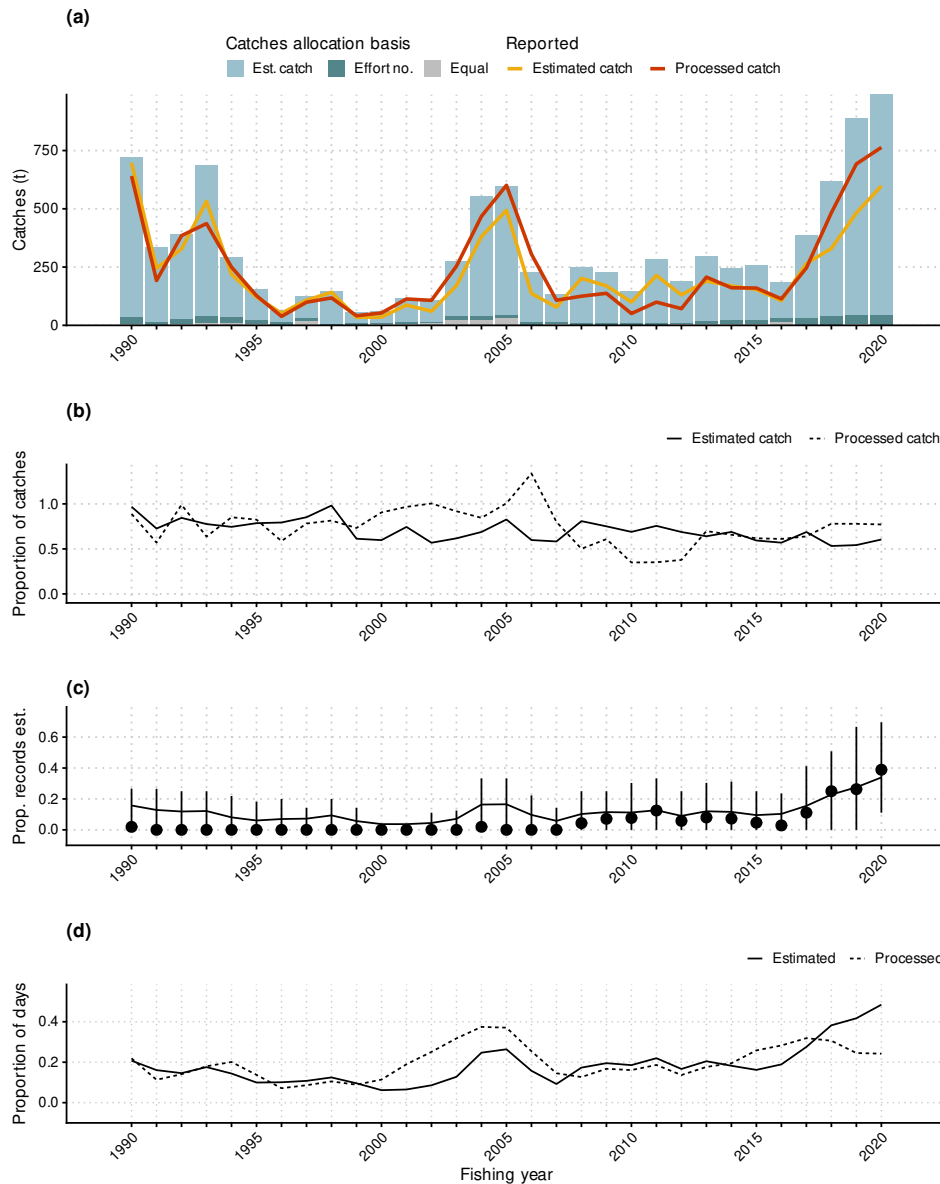


Figure 14: (a) bars: gemfish catches allocated to fishing events in the SKI 7 QMA with allocation method indicated by fill colour (see Section 3.3); lines: total estimated and processed catch of SKI; (b) the proportion of SKI 7 catches included in estimated and processed catch data; (c) the proportion of fishing event records with an estimated catch of SKI, with the line showing the overall proportion and the distributions illustrating the median and inter-quartile range by trip; (d) the proportion of vessel-days fished with a reported catch of SKI.

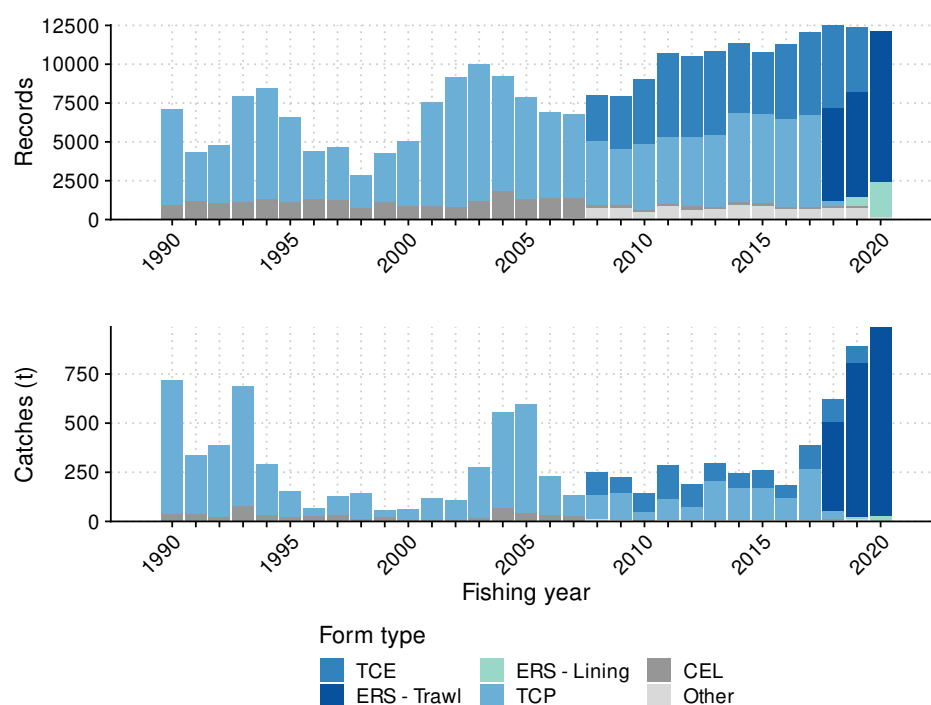


Figure 15: Reporting forms used on trips catching gemfish within the SKI 7 Quota Management Area, in terms of fishing event records and catches. Tabulated results are available in Appendix B. Form types grouped as Other include: ERS - Netting, ERS - Other Lining, HCE, HLC, HTC, LCE, LTC, NCE, TUN. A list of the main form type codes is included in the glossary Table E.2.

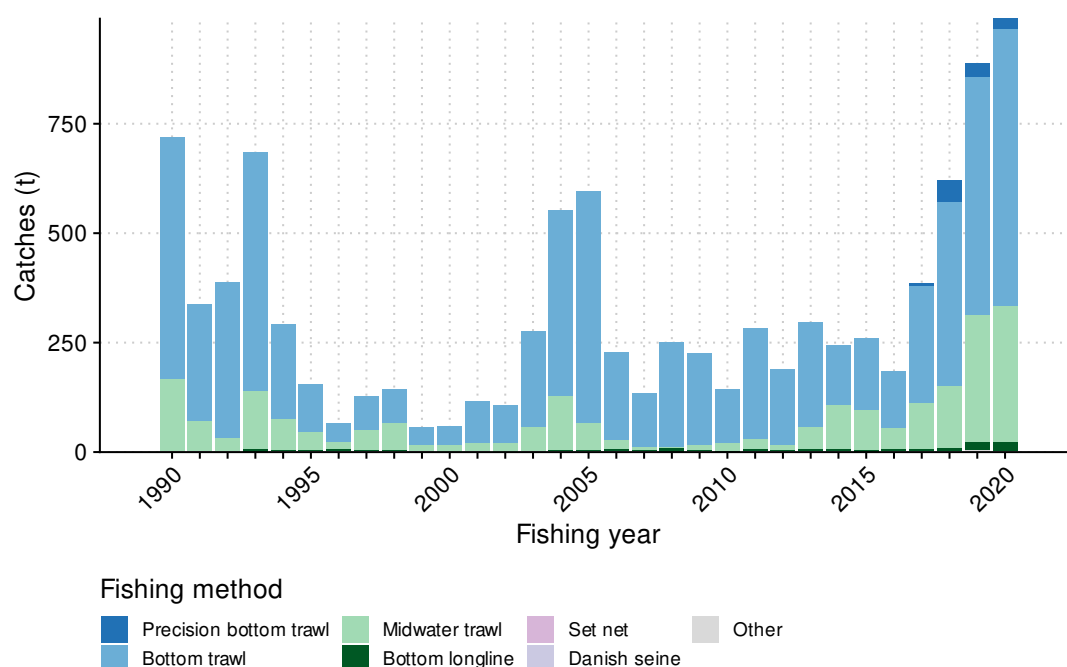


Figure 16: Catches of gemfish by fishing method, for events within the SKI 7 Quota Management Area. Methods grouped as Other include: CP, DL, FP, HL, MPT, PL, PRM, PS, SLL, T, TL. Tabulated results are provided in Appendix B, and a list of the main fishing method code types is included in the glossary Table E.3.

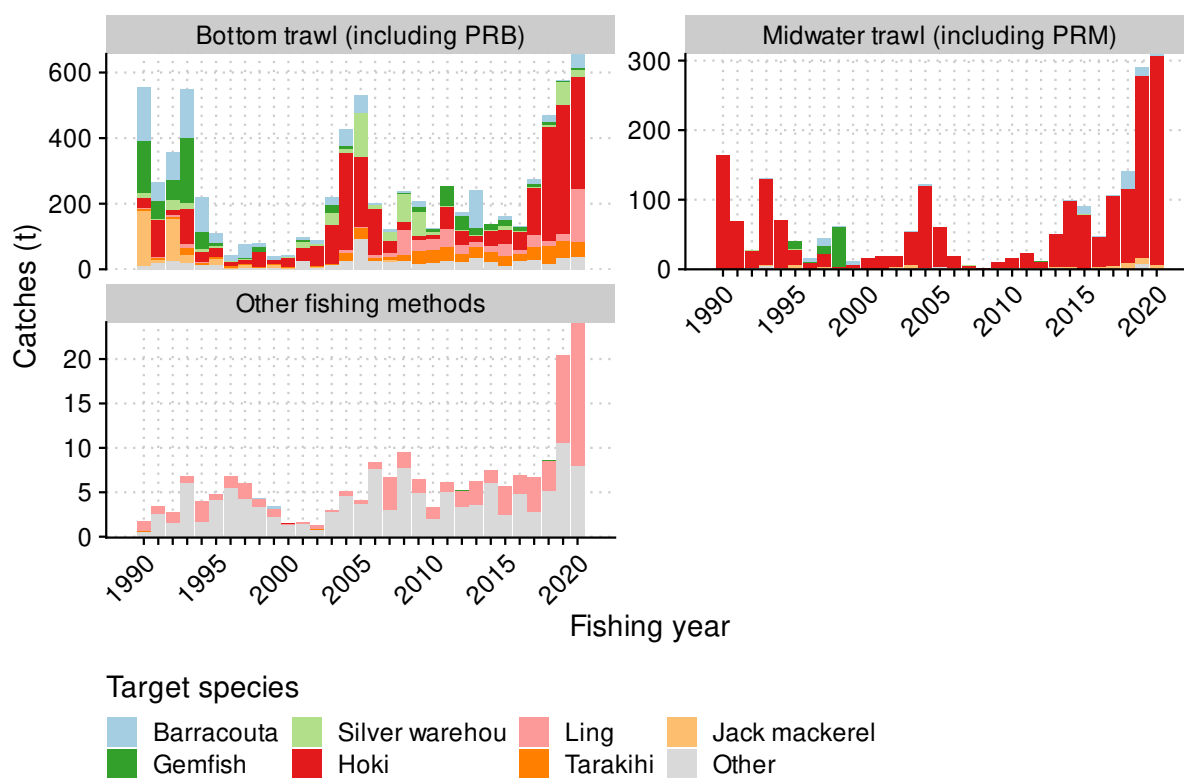


Figure 17: Catches of gemfish by fishing method and declared target species, for events within the SKI 7 Quota Management Area. Fishing Methods grouped as Other include: BLL, CP, DL, FP, HL, MPT, PL, PS, SLL, SN, T, TL. Species grouped as Other include target species with less than 20% of the gemfish catch within the SKI 7 Quota Management Area in a fishing year.

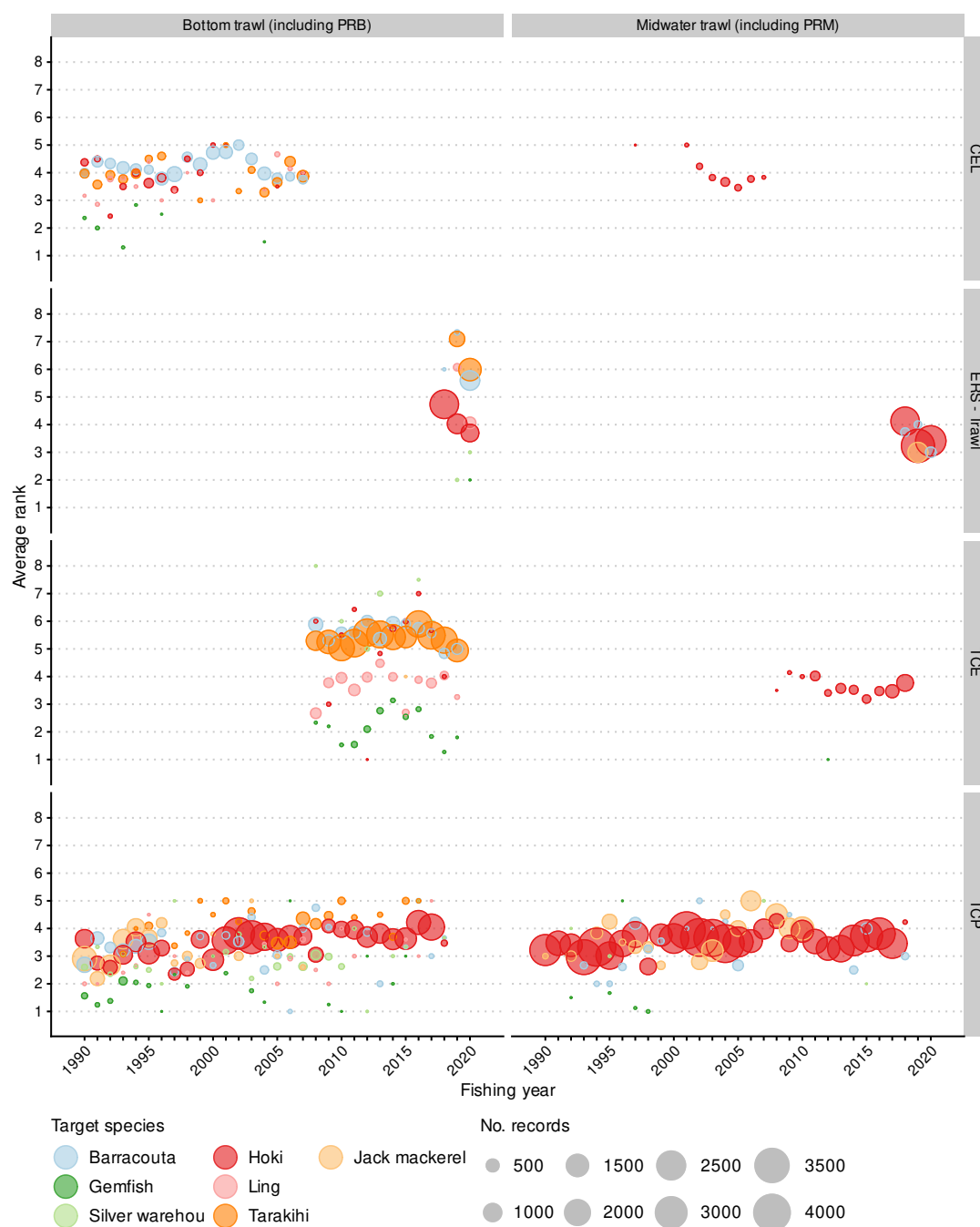


Figure 18: Average rank of gemfish in the estimated catch, by fishing method, form type and declared target species, for events with estimated catches within the SKI 7 Quota Management Area. The area of the circles scales with the number of records.

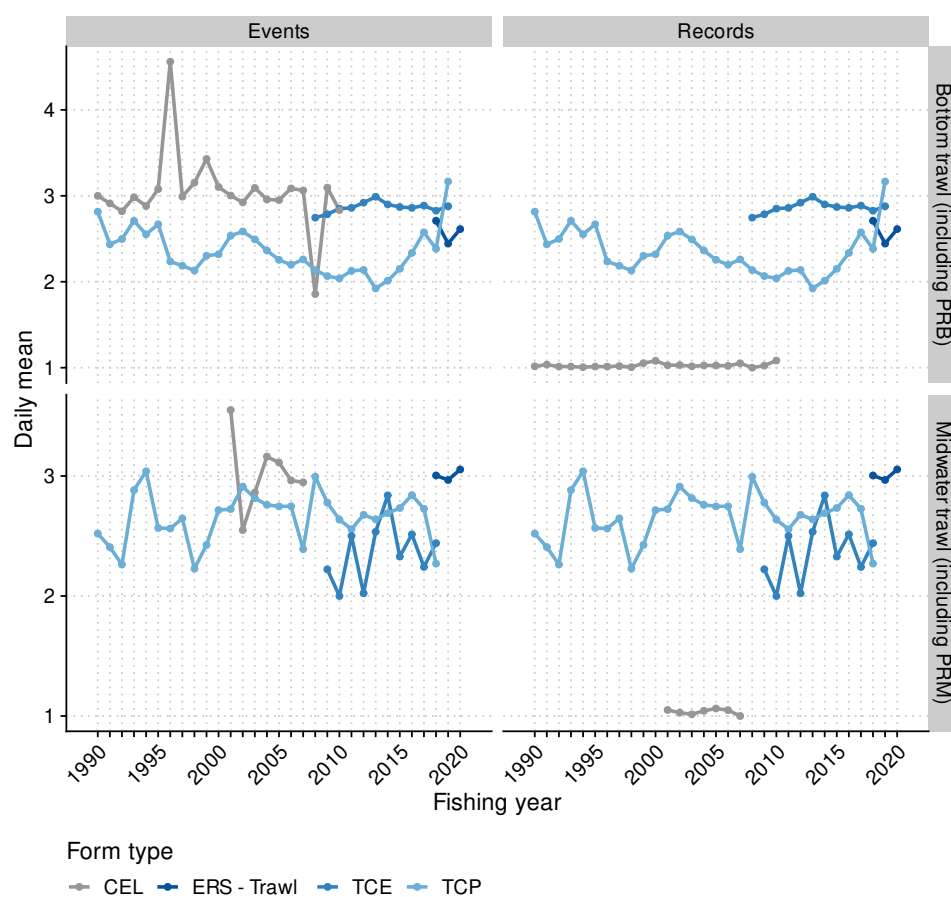


Figure 19: The mean number of fishing events and data records per vessel-day, by fishing method and reporting form, for effort within the SKI 7 QMA on trips landing catch from SKI 7. Data are included for years where a form was used on at least five vessel-days.

4.6 The bottom trawl (including PRB) fishery

4.6.1 Spatial catch information

The proportion of bottom trawl tows reporting position information exceeded 75% in SKI 3 in all years before 2008 while the same proportion occasionally dipped to near 50% in some years before 2008 for SKI 7 (Figure 20). The level of spatial reporting after 2008 included nearly 100% of the fleet beginning in 2008. This high level of spatial reporting gives confidence that the available spatial information will provide a reliable snapshot of the spatial distribution of this fishery, including how it may have evolved over time.

Gemfish were captured by the bottom trawl fishery off the west coast of the South Island along the 400 m depth contour, off the east coast of the South Island north and south of Banks Peninsula and along the Stewart-Snares shelf drop-off at the southern end of the South Island (Figure 21, Figure 22). Gemfish were also taken by BT around Puysegur Bank. Figure 21 provides the spatial distribution of BT catch in five-year blocks, showing the extent of the fishery at the beginning of the data (1990 to 1994), in middle years (200 to 2007) and in the final five years (2016 to 2020). Although the spatial distribution of the catch was similar in the first and last five-year blocks, there was a diminution of catch in the middle five-year block, with the loss of most of the east and south coast South Island BT catches of gemfish (Figure 21, Figure 22). A somewhat different picture emerges when BT CPUE is plotted spatially in the same five-year blocks (Figure 22): BT CPUE was more concentrated and greater in the 1990 to 1994 block, both on the WCSI and on the Stewart-Snares shelf, while BT CPUE in the 2016 to 2020 block was more widely distributed and less intense. When the BT spatial catches were disaggregated by the primary BT target species, the east and south coast South Island catches were made when targeting squid (Figure 23) while the west coast South Island catches were made while targeting hoki (Figure 24). The observation of reduced spatial extent for the BT gemfish catches in the middle period (200 to 2007) was corroborated in Figure 25, with fewer than 50 of the 0.2° grid cells accounting for 90% of the 200 to 2007 BT catch while 90% of the catch in both the 1990–1994 and 2016–2020 periods required just under 100 grid cells to account for 90% of the BT gemfish catch. Only a few statistical areas contributed the majority of the gemfish BT catch (Figure 26; see Figure 3 for the location of the statistical areas). These included Statistical Areas 034 and 035 on the WCSI, Statistical Areas 020 and 022 on the ECSI, and Statistical Areas 026 to 030 on the southern end of the South Island. Note that most of these areas are inshore statistical areas, indicating that gemfish tend to be captured relatively close to shore, primarily by the inshore BT fishery.

4.6.2 Seasonal catch information by target species

Gemfish bycatches by bottom trawl were mainly taken while target fishing for hoki in SKI 7 and for squid in SKI 3 (Figure 27). Other target fisheries taking gemfish as a bycatch included barracouta in both SKI 3 and SKI 7, silver warehou in both SKI 3 and SKI 7, and hoki in SKI 3 (Figure 27). There was some BT target fishing for gemfish in SKI 3 and SKI 7 in the early 1990s when the TACC was still at a high level (Figure 27; Table B.1).

The seasonal distribution of gemfish BT catches reflected the seasonality of the respective target species fisheries in both SKI 3 and SKI 7 (Figure 28). For instance, the gemfish bycatch in the target SKI 7 BT hoki fishery was taken during the winter months when the hoki target fishery was active while the SKI 3 BT catches in the Southland target squid fishery were taken between January and May when that fishery was active (Figure 28). The seasonality of the SKI 3 BT catches in the target barracouta fishery extended between November and April and may be linked to the Southland squid fishery, with both fisheries having similar spatial and temporal configurations (Figure 28; see Large (in prep.)). On the other hand, SKI 7 BT catches when target fishing for barracouta were taken much later in the fishing year compared with the equivalent fishery in SKI 3 (August and September, see Figure 28). It seems likely that gemfish are available year-round off both South Island coasts, given the year-round presence of BT gemfish catches in all months across the range of target fisheries plotted in Figure 28. While the seasonal distribution

of gemfish bycatch reflected the seasonal distribution of the target species, there is also an abundance component to the bycatch. This can be seen when comparing the seasonal distribution of bycatch in the winter SKI 7 hoki fishery, with high catches of gemfish extending from May to September in many years (Figure 28). When the gemfish CPUE in the same hoki target fishery is plotted for the same years and months as in Figure 28, only September has high gemfish catch rates (Figure 29), which is a month when the target hoki fishery is winding down.

4.6.3 Depth distribution information by target species

In most cases, the depth distribution of all tows in a target fishery and that of the tows which caught gemfish were reasonably similar, as can be seen for tarakihi in both QMA, squid in SKI 3, and ling in SKI 7 (Figure 30). There were also some notable differences, such as for ling and silver warehou target catches in SKI 3 and hoki target catches in SKI 7, where there are departures from the overall [grey] distribution by the positive [green] catch distribution at the top and bottom ends of the distributions (Figure 30). Important depth bins where gemfish were taken as bycatch were the 400–500 m depth bin for the SKI 7 BT hoki target fishery, the 200–300 m depth bin for the SKI 3 squid target fishery and the 100–200 m depth bin for the SKI 3 barracouta target fishery (Figure 31).

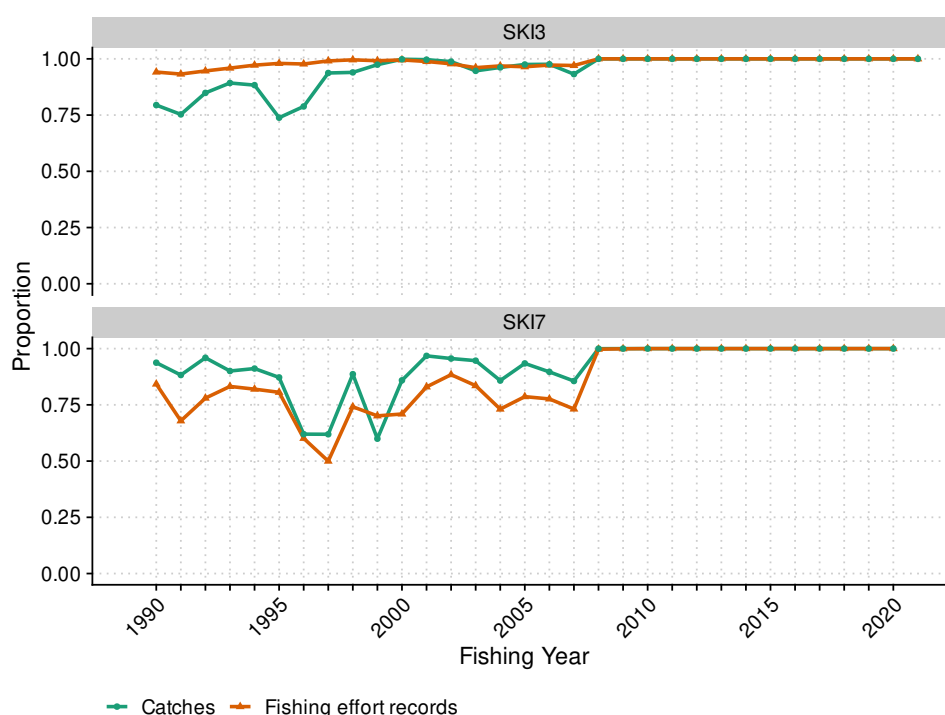


Figure 20: The proportion of records and catches reported with a latitude/longitude for the SKI 3 and SKI 7 bottom trawl (including PRB) fishery.

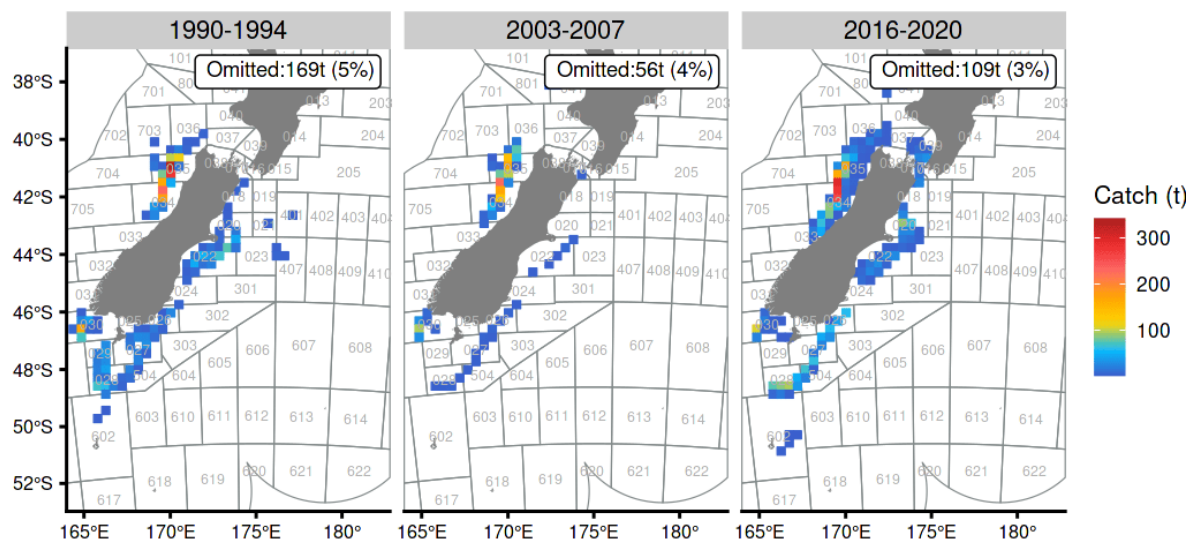


Figure 21: Catches (t) for the SKI 3 and SKI 7 bottom trawl (including PRB) fishery, for 5-year periods within the era during which at least 80% of catch was reported with spatial information. These plots use a 32 km grid and include records where catches were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

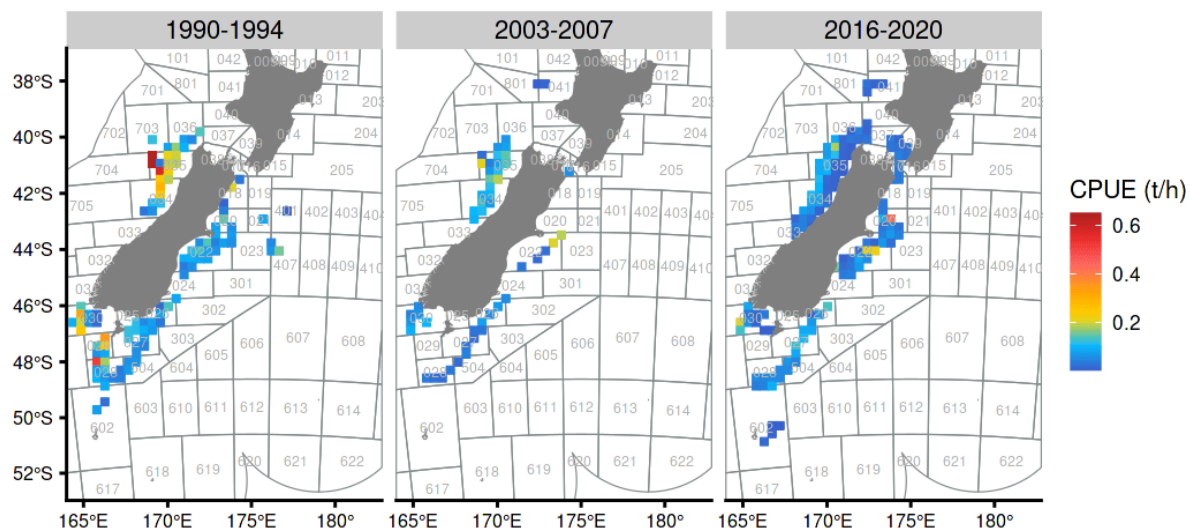


Figure 22: Raw aggregate CPUE (t/h) for the SKI 3 and SKI 7 bottom trawl (including PRB) fishery, for 5-year periods within the era during which at least 80% of catch was reported with spatial information. These plots use a 32 km grid and include records where catches were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted.

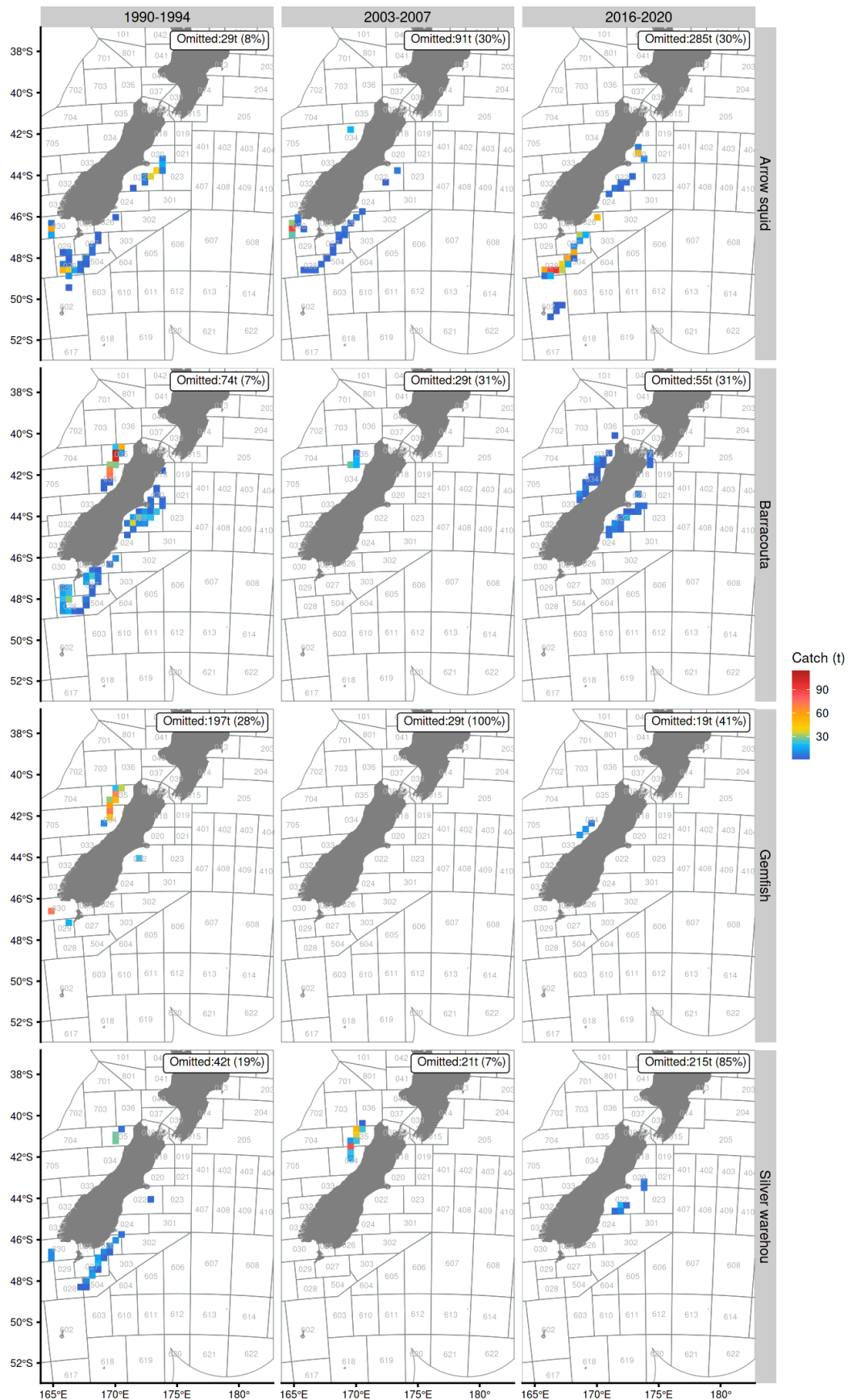


Figure 23: Catches of gemfish from the bottom trawl (including PRB) fishery by key target species. These plots use a 32 km grid and include records where landings were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

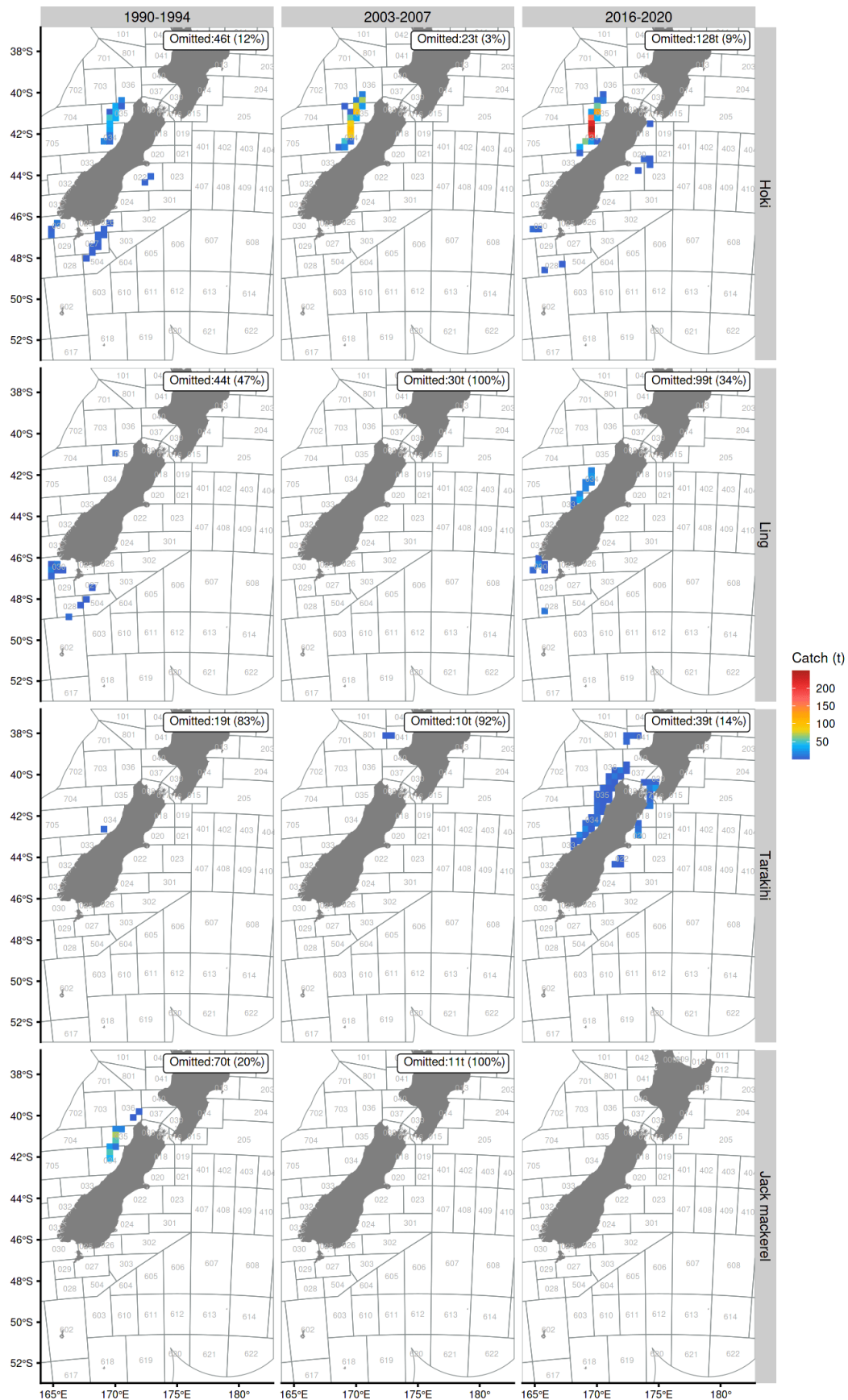


Figure 24: Catches of gemfish from the bottom trawl (including PRB) fishery by key target species. These plots use a 32 km grid and include records where landings were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

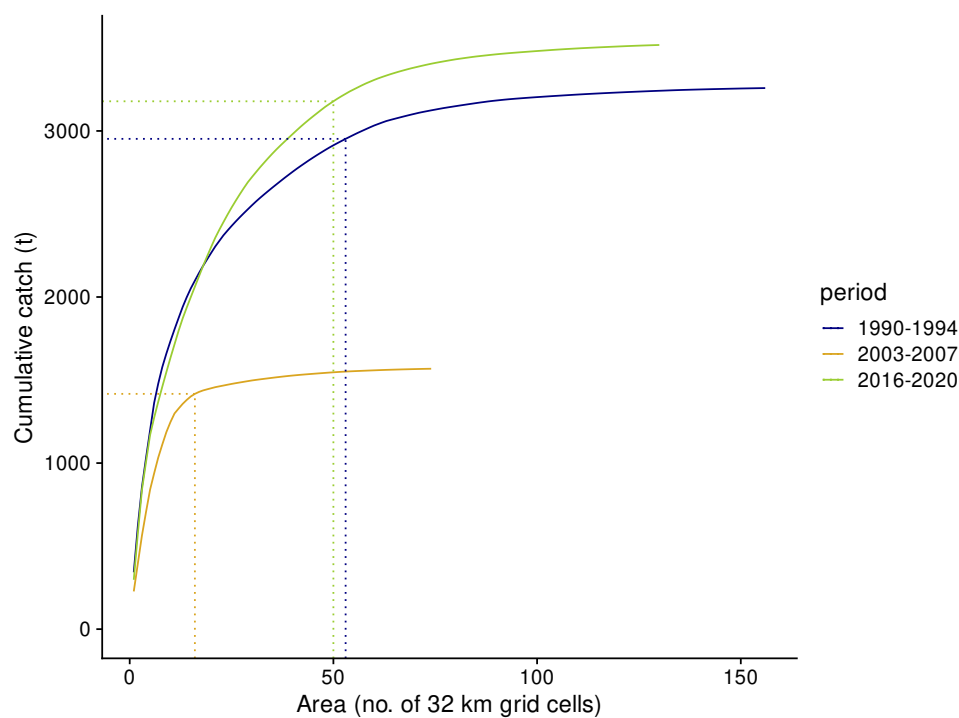


Figure 25: Cumulative SKI 3 and SKI 7 catch by area (grid cells) for the bottom trawl (including PRB) fishery, aggregated for the first, middle, and last 5-year period of reporting. Dotted lines indicate the 90th percentile for the first, middle, and last 5-year period of reporting.

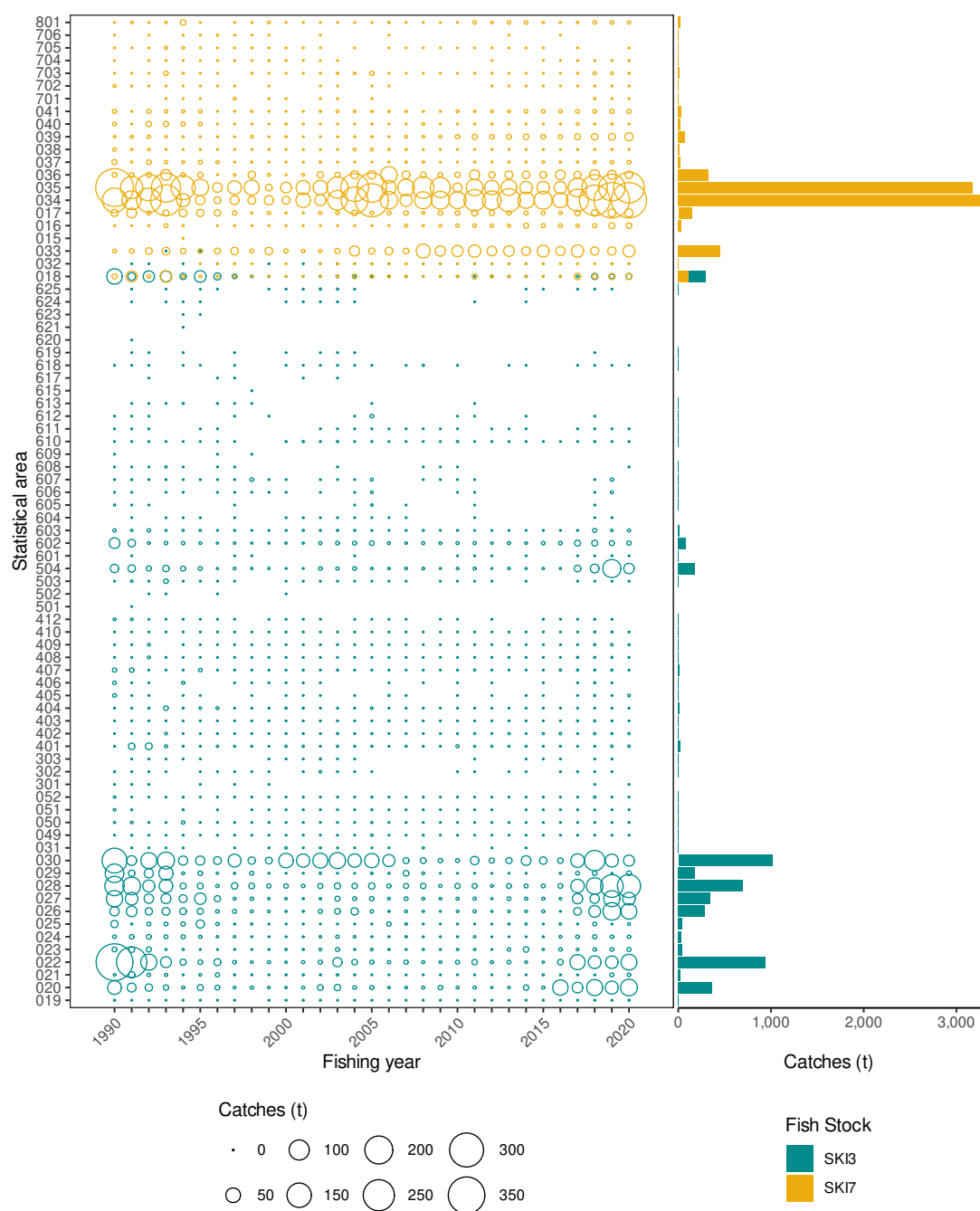


Figure 26: Annual SKI 3 and SKI 7 catches (t) by statistical area for the bottom trawl (including PRB) fishery. The circle size scales with the catches by statistical area. The bar plot (right) shows the total catches of SKI 3 and SKI 7 for each statistical area.

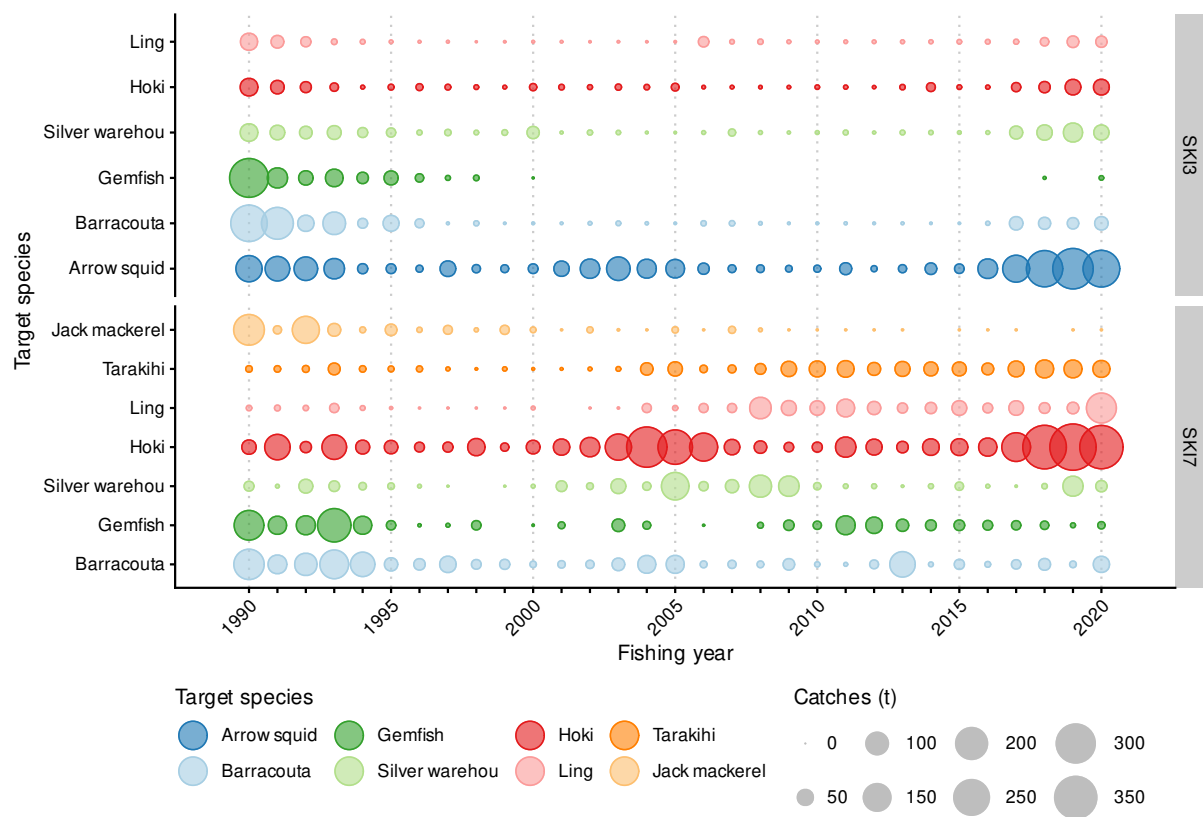


Figure 27: Gemfish catches by fishing year and target species for the bottom trawl (including PRB) fishery. The area of the circle scales with the yearly catches.

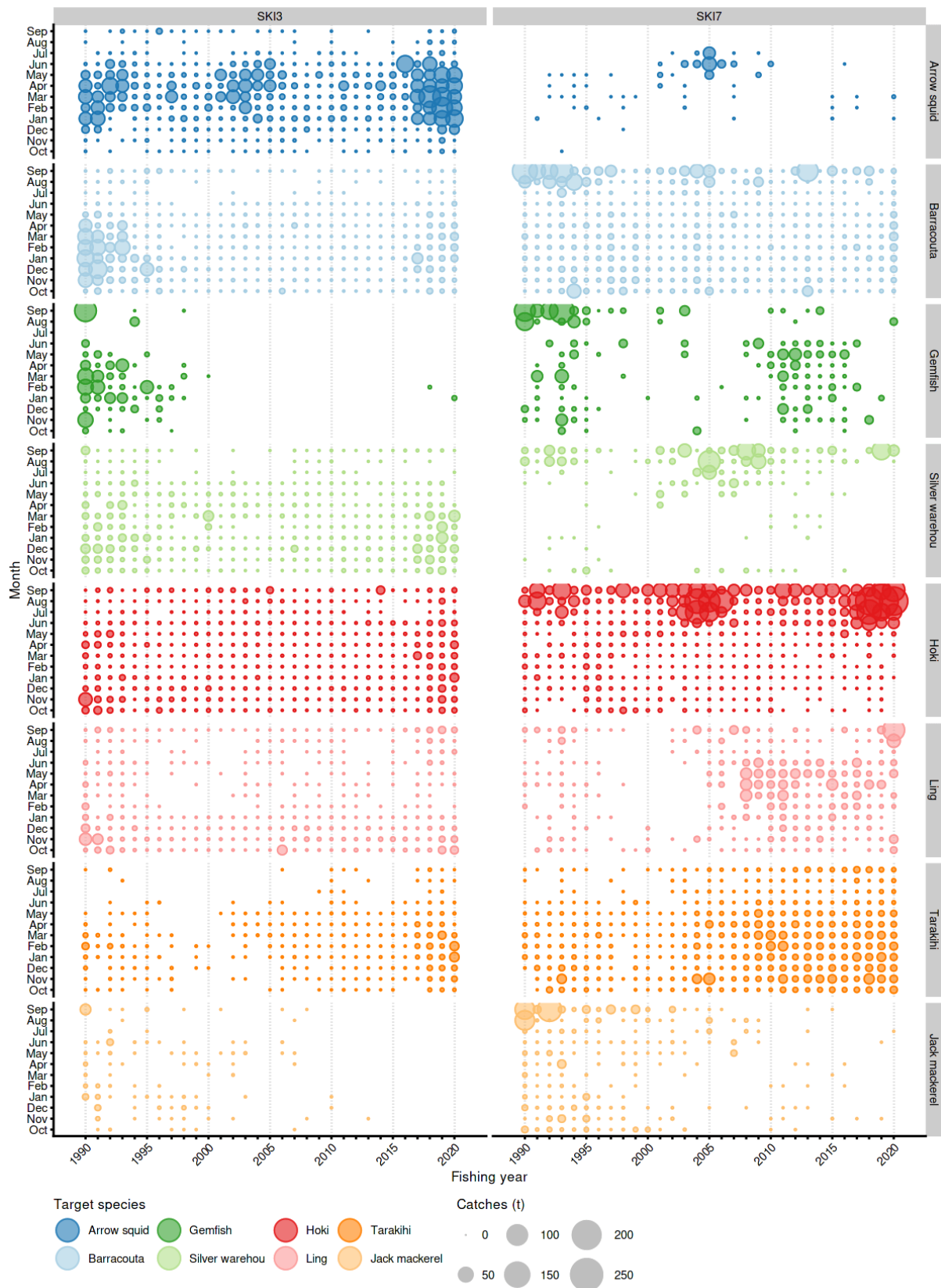


Figure 28: Seasonal distribution of SKI 3 and SKI 7 catches by month and fishing year for the bottom trawl (including PRB) target fisheries. The area of the circle scales with the monthly catches.

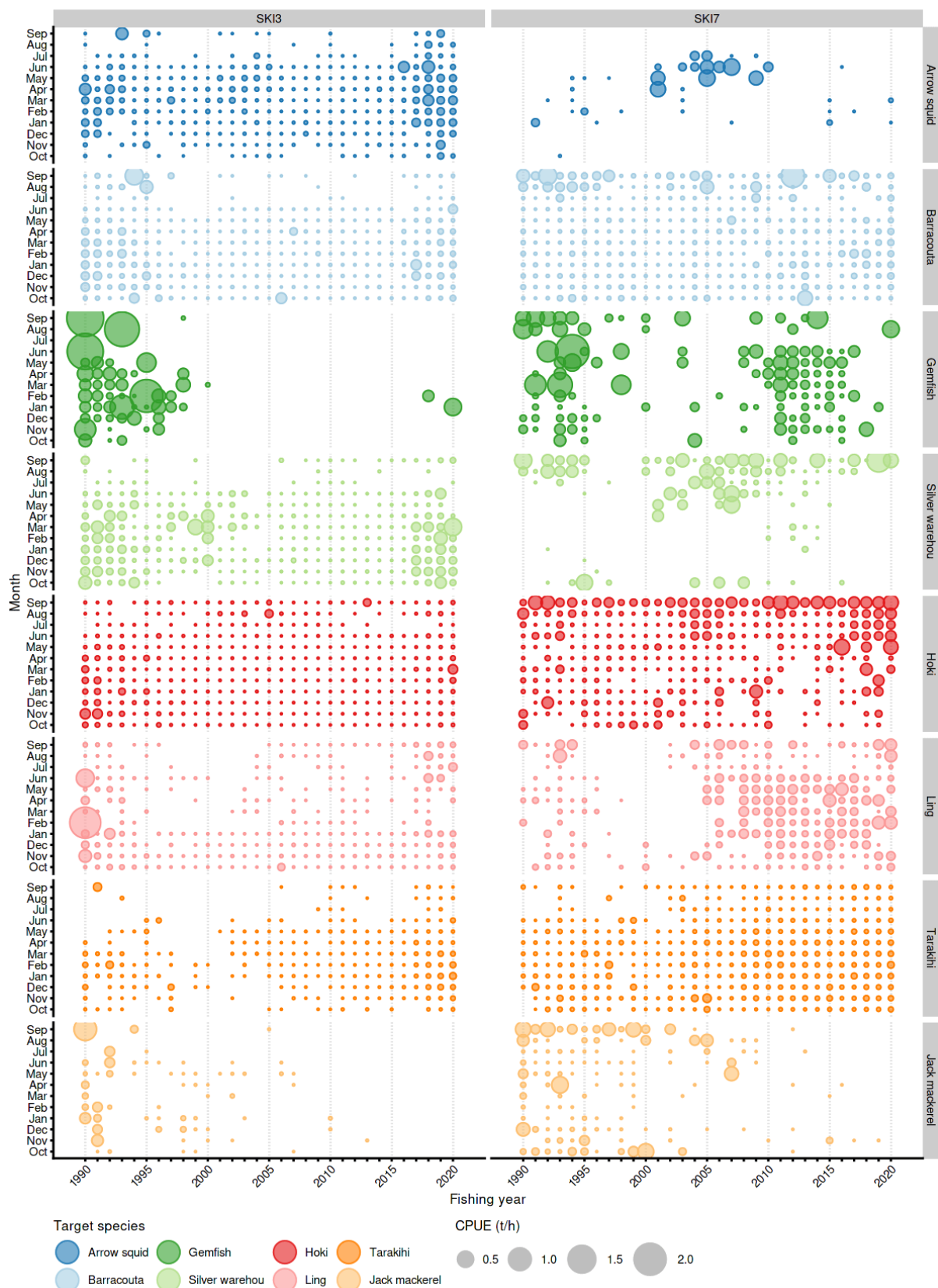


Figure 29: Seasonal distribution of SKI 3 and SKI 7 raw aggregate CPUE (t/h) by month and fishing year for the bottom trawl (including PRB) target fisheries. The area of the circle scales with the monthly raw aggregate CPUE (t/h).

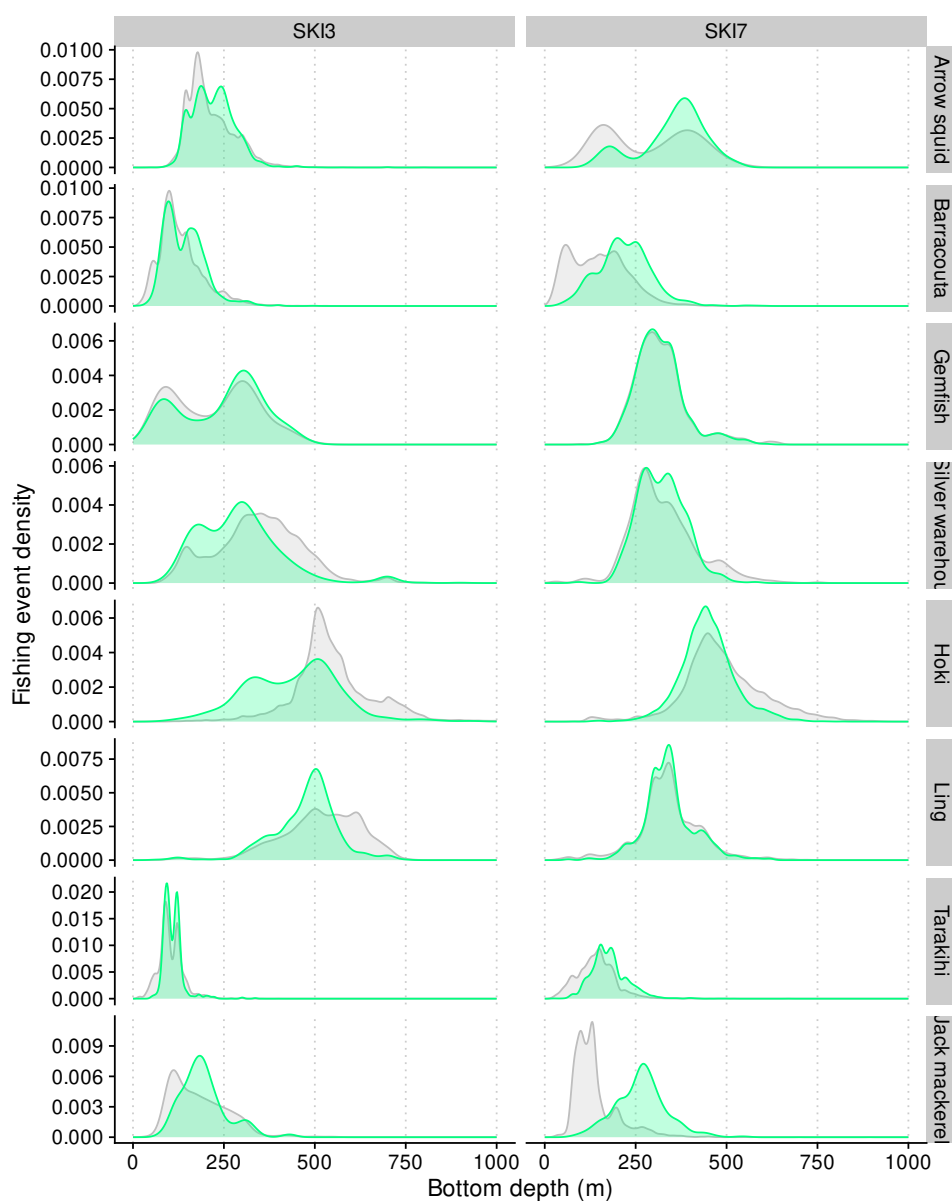


Figure 30: Effort depth distribution by target species for trips landing SKI 3 and SKI 7 from the bottom trawl (including PRB) fishery. Target species are included if they are represented in at least 30 events. Grey fill = total effort, Green fill = positive effort (i.e., estimated catch > 0).

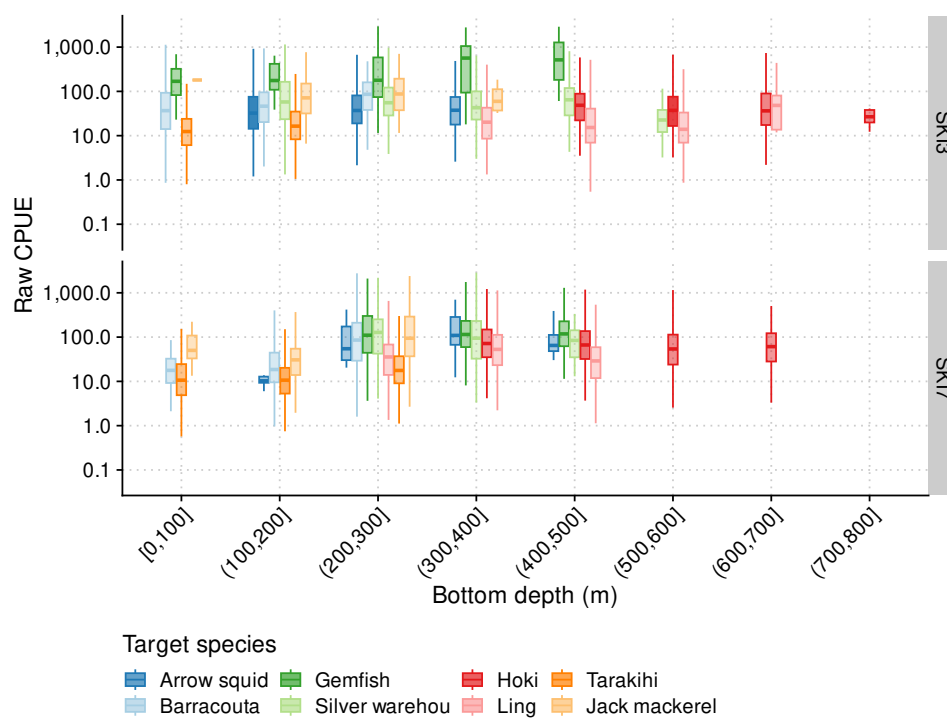


Figure 31: Raw CPUE (t/h) by depth bin and target species for events catching gemfish from the bottom trawl (including PRB) target fisheries in SKI 3 and SKI 7. Boxplots are included for depth bins that include at least 5% of the events in the dataset for a particular target species, and events with a raw CPUE greater than the 99.9th percentile have been removed. The box indicates the median and quartiles, while the whiskers extend to the largest and smallest values no more than 1.5 times the inter-quartile range from the hinge.

4.7 The midwater trawl (including PRM) fishery

4.7.1 Spatial catch information

The proportion of midwater trawl tows reporting position information was near 100% for both SKI 3 and SKI 7 in all years from 1990 to 2020 (Figure 32). This high level of reporting gives confidence that the available position information will provide a reliable snapshot of the spatial distribution of this fishery, including how it may have evolved over time.

Midwater trawl catches of gemfish have been confined to the west coast of the South Island and the farthest extension of the Stewart-Snares shelf in Statistical Area 028 (Figure 33). This was true for all three five-year time blocks (1990 to 1994, 2003 to 2007 and 2016 to 2020) except that the Snares shelf catches mostly disappeared for the 2003 to 2007 time block. Unlike the equivalent BT spatial plots, the MW CPUE spatial distribution did not widen in the final five-year block (2016 to 2020) compared with the first five-year block (1990 to 1994), reflecting the distribution of the hoki midwater fishery (Figure 34). The disaggregation of these catches by the primary MW target species confirmed that the Stewart-Snares shelf catches were made when targeting squid while the WCSI catches were made while targeting hoki (Figure 35). Target MW catches directed at barracouta did not register on this plot. The spatial extent of the MW gemfish fishery, when plotted as cumulative catch in 0.2° grid cells, showed differences among the three time blocks. Less than 10 grid cells were needed to account for 90% of the MW catch in 2003 to 2007 while less than 15 grid cells were needed for the 1990 to 1994 and 2016 to 2020 time blocks to get to 90% cumulative landings (Figure 36). Even fewer statistical areas contributed the majority of the gemfish MW catch than seen for the equivalent BT catch (Figure 37; see Figure 3 for the location of the statistical areas; compare with Figure 26 which gives the equivalent sums for gemfish BT catch). There were only three statistical areas of importance: Statistical Areas 034 and 035 on the WCSI and Statistical Area 028 on the Stewart-Snares shelf (Figure 37).

4.7.2 Seasonal catch information by target species

The bycatch of gemfish by midwater trawl was mainly taken while target fishing for hoki in SKI 7 and squid in SKI 3, with the gemfish bycatch in the hoki fishery predominating overall (Figure 38). The MW gemfish bycatch when fishing for other target species was low. The seasonal distribution of gemfish MW bycatch reflected the seasonality of the two main fisheries, with the SKI 7 MW bycatch by the target MW hoki fishery taken during the winter months while the SKI 3 MW bycatch by the target MW squid fishery taken between January and April (Figure 39). The seasonality of the SKI 3 MW bycatch by the target barracouta fishery was also taken between January and April and appeared to be closely linked to the Southland squid fishery, with both fisheries having similar spatial and temporal configurations (Figure 39 and see Large (in prep.)). The seasonal distribution of gemfish bycatch MW CPUE differs from the equivalent seasonal bycatch distribution for both the SKI 3 MW target squid fishery and the SKI 7 MW target hoki fishery. For instance, the CPUE associated with the bycatch of gemfish in the SKI 3 target MW squid fishery in February for 2018, 2019 and 2020 was low (Figure 40) while the bycatch of gemfish in those same months was high. Similarly, the bycatch of gemfish in the SKI 7 target hoki fishery was very high from June to August in 2018, 2019 and 2020 while the MW gemfish CPUE in those months was lower than the May CPUE in the same fishing years (Figure 40).

4.7.3 Depth distribution information by target species

Most (>80%) of the midwater trawl tows which reported gemfish catch, regardless of declared target species, were made within five metres of the bottom, based on the declared bottom depth of the tow (Figure 41). There was a near perfect overlap between the distribution of all tows and those that reported a catch of gemfish in the SKI 3 MW target squid fishery while the equivalent distribution from the WCSI target hoki fishery showed that the deepest tows did not report gemfish bycatch (Figure 42). The target barracouta fishery distribution for all tows and those that reported a catch of gemfish differed between the two coasts, with the west coast fishery occurring at more shallow depths that did not take gemfish while the overlap between all tows and positive gemfish tows is nearly perfect for SKI 3 (Figure 42). Important depth bins where gemfish was taken as bycatch were the 400–500 m depth bin for the SKI 7 MW hoki target fishery and the 100–200 m depth bin for SKI 3 squid target fishery (Figure 43).

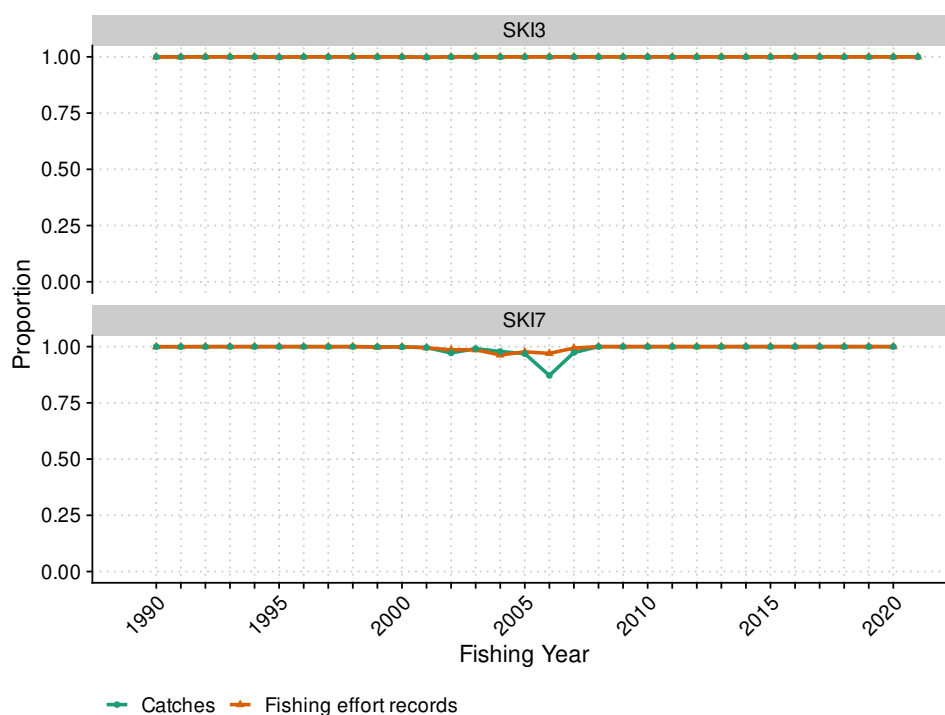


Figure 32: The proportion of records and catches reported with a latitude/longitude for the SKI 3 and SKI 7 midwater trawl (including PRM) fishery.

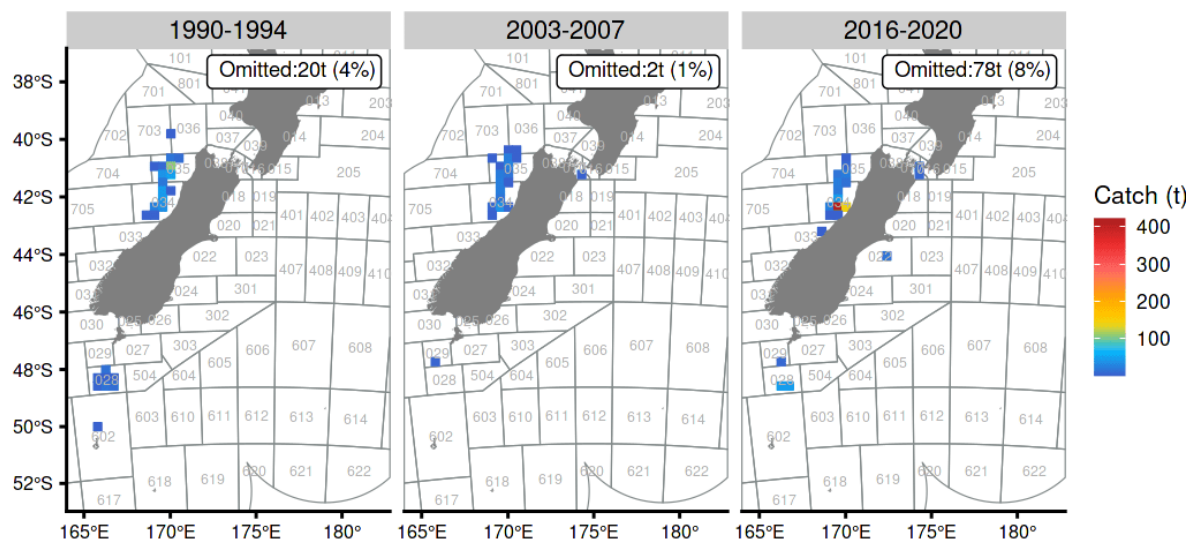


Figure 33: Catches (t) for the SKI 3 and SKI 7 midwater trawl (including PRM) fishery, for 5-year periods within the era during which at least 80% of catch was reported with spatial information. These plots use a 32 km grid and include records where catches were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

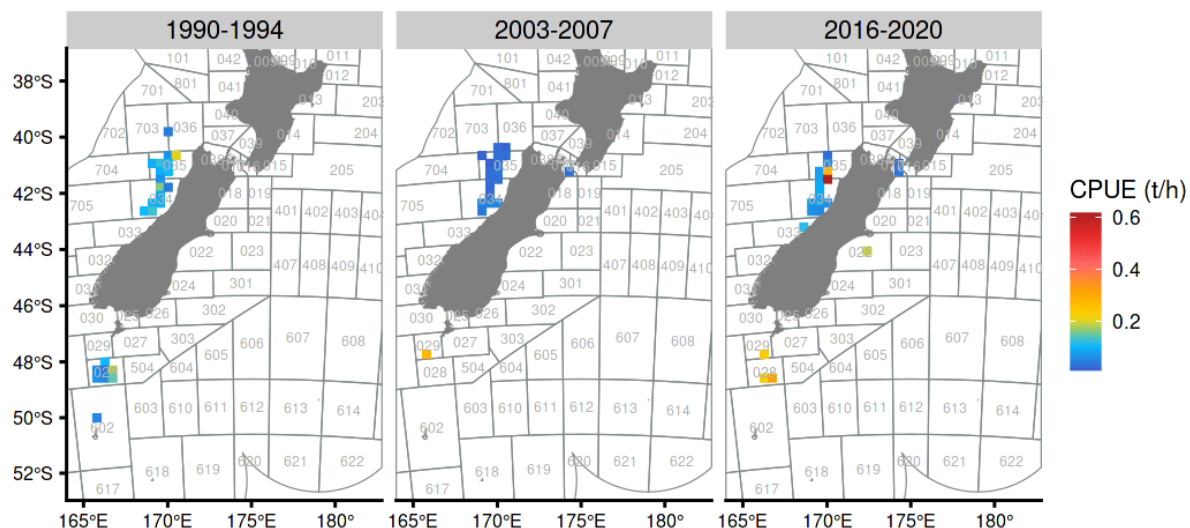


Figure 34: Raw aggregate CPUE (t/h) for the SKI 3 and SKI 7 midwater trawl (including PRM) fishery, for 5-year periods within the era during which at least 80% of catch was reported with spatial information. These plots use a 32 km grid and include records where catches were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted.

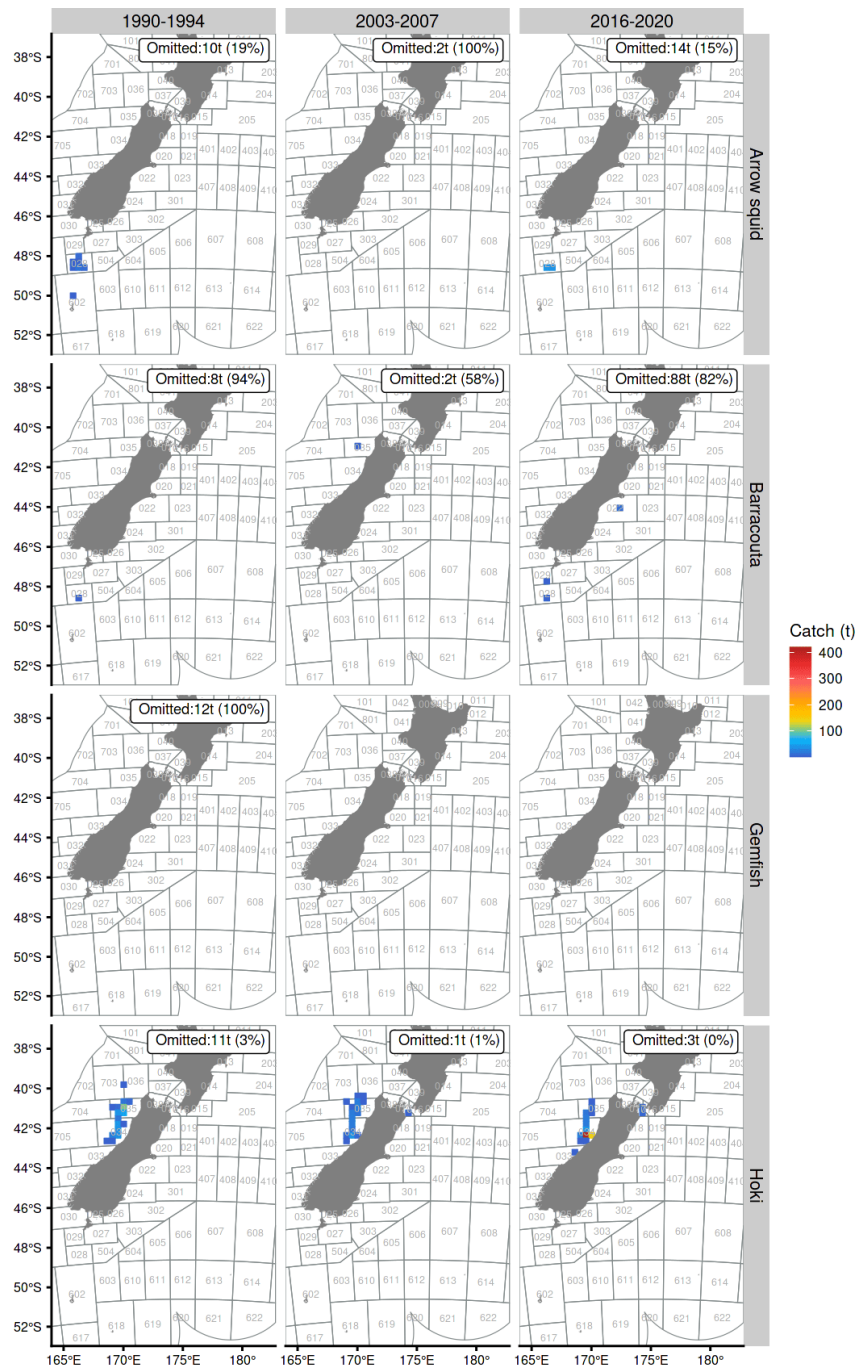


Figure 35: Catches of gemfish from the midwater trawl (including PRM) fishery by key target species. These plots use a 32 km grid and include records where landings were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

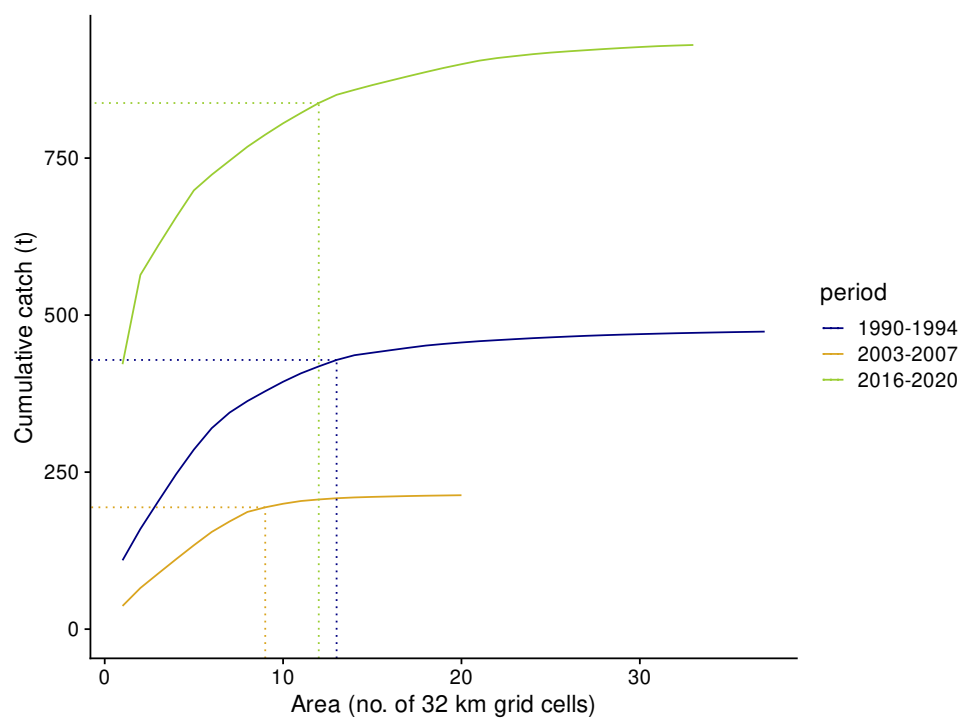


Figure 36: Cumulative SKI 3 and SKI 7 catch by area (grid cells) for the midwater trawl (including PRM) fishery, aggregated for the first, middle, and last 5-year period of reporting. Dotted lines indicate the 90th percentile for the first, middle, and last 5-year period of reporting.

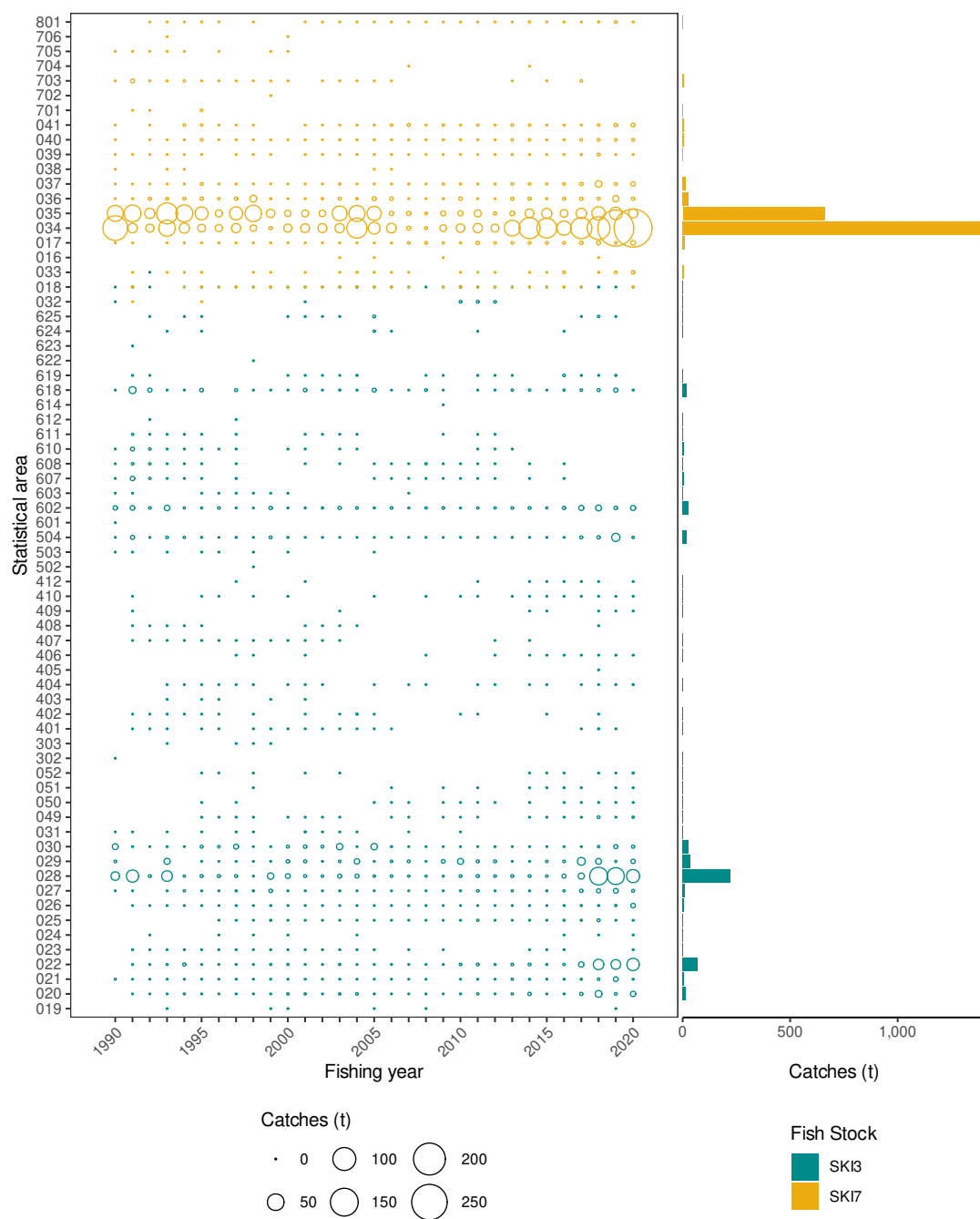


Figure 37: Annual SKI 3 and SKI 7 catches (t) by statistical area for the midwater trawl (including PRM) fishery. The circle size scales with the catches by statistical area. The bar plot (right) shows the total catches of SKI 3 and SKI 7 for each statistical area.



Figure 38: Gemfish catches by fishing year and target species for the midwater trawl (including PRM) fishery. The area of the circle scales with the yearly catches.



Figure 39: Seasonal distribution of SKI 3 and SKI 7 catches by month and fishing year for the midwater trawl (including PRM) target fisheries. The area of the circle scales with the monthly catches.

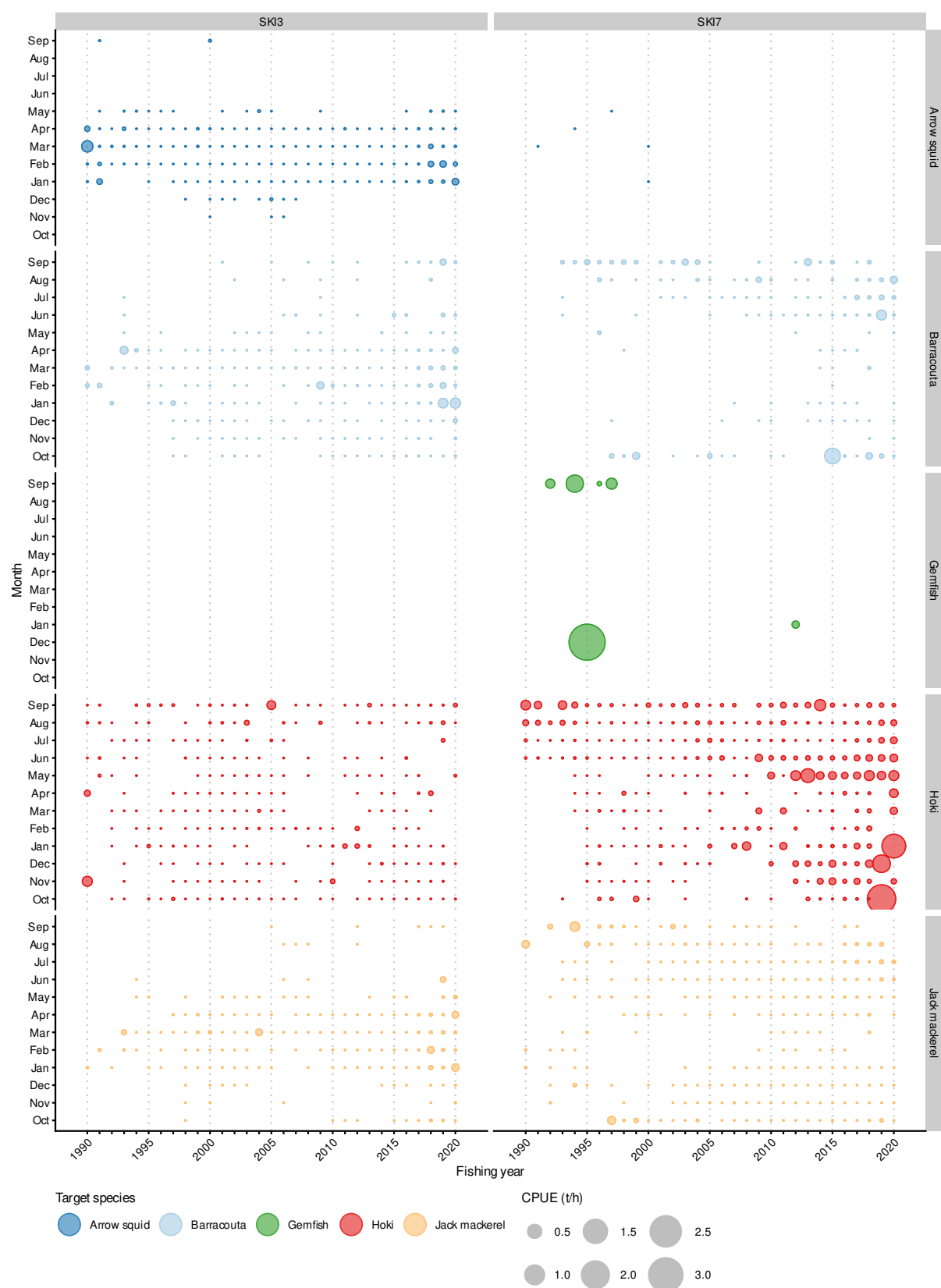


Figure 40: Seasonal distribution of SKI 3 and SKI 7 raw aggregate CPUE (t/h) by month and fishing year for the midwater trawl (including PRM) target fisheries. The area of the circle scales with the monthly raw aggregate CPUE (t/h).

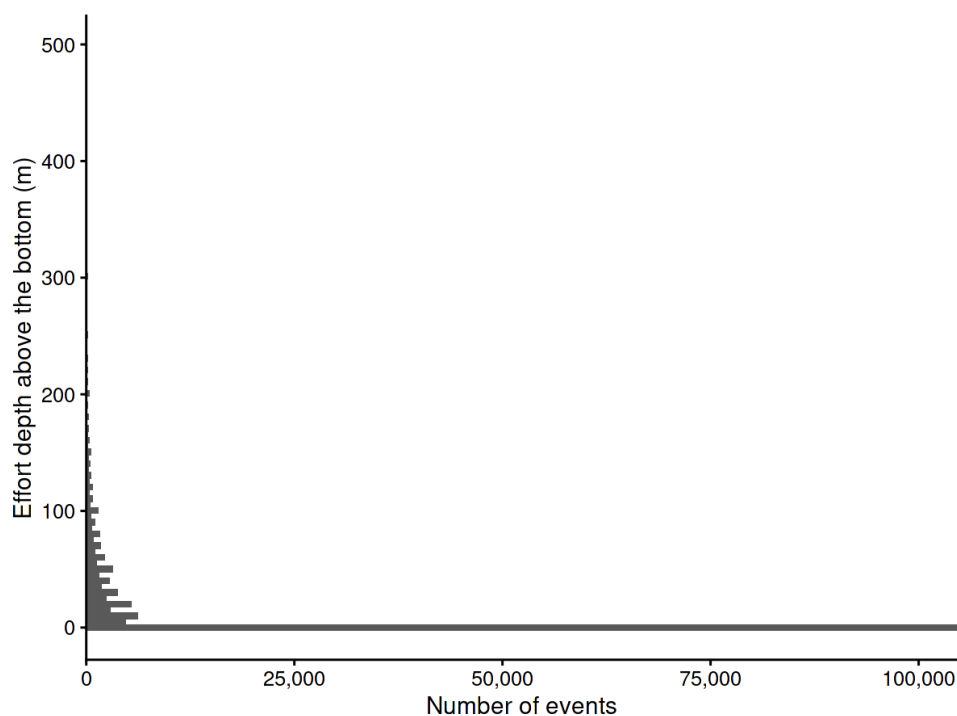


Figure 41: Distribution of the distance of fishing effort from the bottom for trips landing SKI 3 and SKI 7 from the midwater trawl (including PRM) fishery.

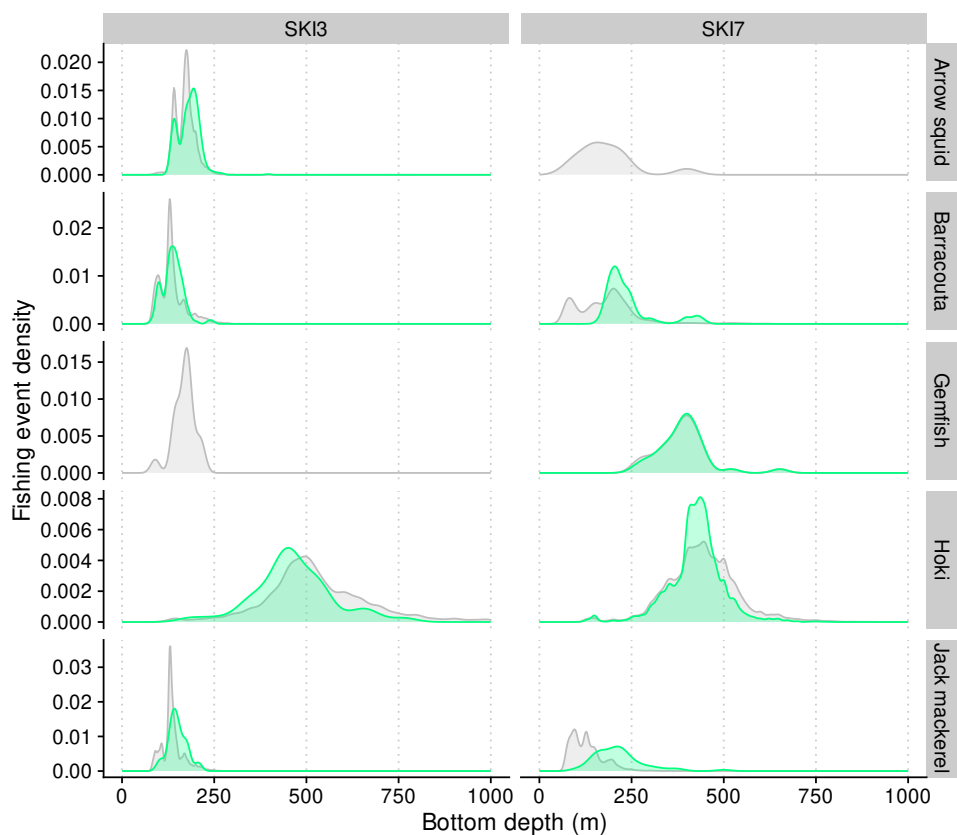


Figure 42: Effort depth distribution by target species for trips landing SKI 3 and SKI 7 from the midwater trawl (including PRM) fishery. Target species are included if they are represented in at least 30 events. Grey fill = total effort, Green fill = positive effort (i.e., estimated catch > 0).

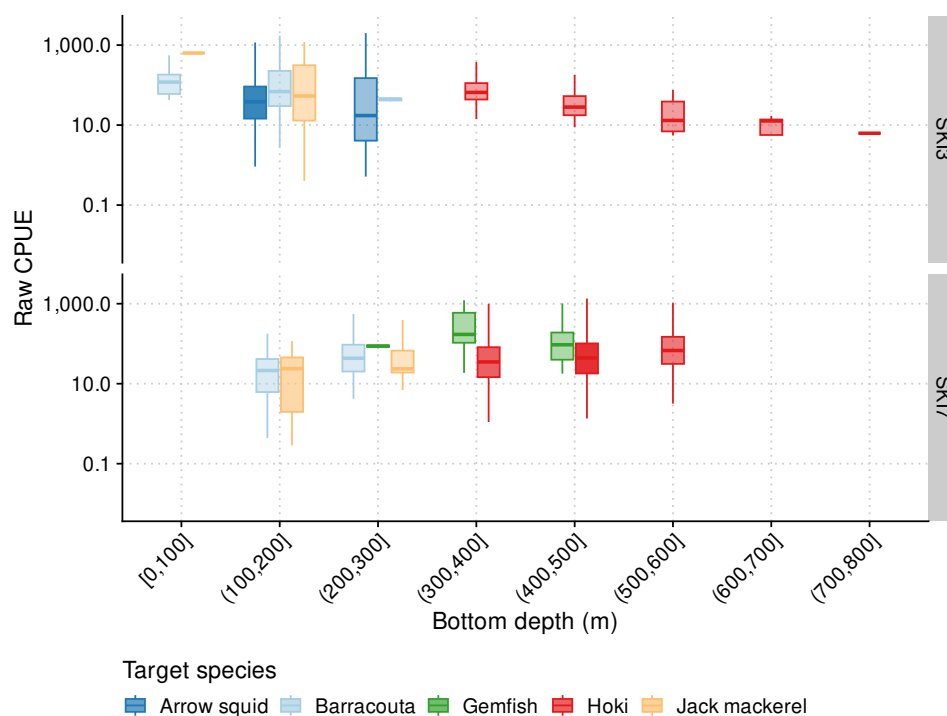


Figure 43: Raw CPUE (t/h) by depth bin and target species for events catching gemfish from the midwater trawl (including PRM) target fisheries in SKI 3 and SKI 7. Boxplots are included for depth bins that include at least 5% of the events in the dataset for a particular target species, and events with a raw CPUE greater than the 99.9th percentile have been removed. The box indicates the median and quartiles, while the whiskers extend to the largest and smallest values no more than 1.5 times the inter-quartile range from the hinge.

5. CATCH-PER-UNIT-EFFORT

5.1 Introduction

Eleven fisheries (Table 3) were considered for CPUE analysis for possible inclusion as biomass index series for gemfish off the South Island of New Zealand. Datasets were defined from the catch and effort data available from the three major trawl fishing areas which take South Island gemfish: WCSI, Stewart-Snares shelf (SShelf) and the east coast South Island (ECSI) (see Sections 4.4, 4.5, 4.6 and 4.7 for detailed descriptions of these fisheries). Three data sources (statutory commercial catch and effort data, daily processing data and observer records) were considered, with the statutory commercial catch and effort data stratified at two levels: tow-by-tow and summarised by day (pseudo-CELR). Although four datasets in three areas result in 12 potential CPUE analysis datasets, this number was reduced to 11 because the amount of observer data available from the ECSI trawl fishery was insufficient to undertake a CPUE analysis. The tow-by-tow (event-based) WCSI trawl fishery analysis was an extension of the CPUE analysis done in 2019 (Langley 2020), while the remaining ten analyses are new to this report. Data preparation procedures and analysis methodology are presented in Section 3 and Appendix A. Descriptions of the six primary CPUE analyses, along with diagnostic plots and tables, can be found in the sections below. Five supporting analyses can be found in ‘Appendix D - Additional CPUE analyses’. Full diagnostics are presented for these latter analyses, without supporting descriptive text.

Table 3: Summary of models constructed for CPUE standardisation. The primary models are highlighted in darker grey and supporting diagnostics are included below. Diagnostics for secondary models, highlighted in lighter grey, are included in Appendix D.

Series name	Data resolution	Response variable	Explanatory variable selection process	Core fleet years	Core fleet trips	Assumed error distribution
SKI7 BT+MW HOK event	event	allockg_top5	Stepwise	5	1	lognormal
SKI7 BT+MW process daily	daily	prockg	Stepwise	4	1	lognormal
SKI7 BT+MW observer	observer	obskg	Stepwise	5	1	lognormal
SKI7 BT+MW HOK daily rollout	daily	allockg	Stepwise	4	1	lognormal
SKI3 BT+MW SShelf event	event	allockg_top5	Stepwise	5	1	lognormal
SKI3 BT+MW SShelf process daily	daily	prockg	Stepwise	3	1	lognormal
SKI3 BT+MW SShelf observer	observer	obskg	Stepwise	5	1	lognormal
SKI3 BT+MW SShelf daily rollout	daily	allockg	Stepwise	3	1	lognormal
SKI3 BT+MW east coast event	event	allockg_top5	Stepwise	3	1	lognormal
SKI3 BT+MW east coast process daily	daily	prockg	Stepwise	2	1	lognormal
SKI3 BT+MW east coast daily rollout	daily	allockg	Stepwise	2	1	lognormal

5.2 SKI7 BT+MW HOK event

This series was based on the tow-by-tow bycatch of gemfish in the WCSI BT/MW winter target hoki (HOK) fishery. The analysis was constrained to Statistical Area 034 (Greymouth) and Statistical Area 035 (Westport) where the majority of the target hoki fishery takes place (Table 4). The MW component of the analysis was constrained to midwater gear fished within 10 m of the bottom. The core fleet was defined by having fished at least once in each of five years, retaining 92% of the catch and reducing the fleet from over 150 vessels to 91 vessels (Figure 44). A substantial number of the core fleet vessels were present in the defined fishery for 20 years or more (Figure 45) and these vessels showed good overlap over the 31 years of data, with the final groomed dataset representing 24% (1990) to 100% (2007, 2008) of the annual catch (Table 5). The bycatch of gemfish in the defined fishery was generally less than 100 t/y up to the 2017 fishing year, except for a short period from 2003 to 2005 and in 2014 when the gemfish bycatch exceeded 100 t/y (Table 6). Beginning in 2017, the bycatch of gemfish started to rise and peaked at 500 t in 2019 and 442 t in 2020. Most catches in the dataset were derived from landings allocated to each tow based on estimated catches (Figure 46).

The binomial (occurrence) model only accepted one predictive variable after fishing year (vessel), with the total model explaining just over 16% of the deviance (Table 7). The unstandardised series showed a gradually increasing trend and there was almost no standardisation effect relative to the unstandardised series (Figure 47, Figure 48). The vessel coefficient-distribution-influence (CDI; Bentley et al. 2012) plot showed no systematic change in the vessel covariate that explained the gradual upward trend in the occurrence series (Figure 49).

The lognormal model accepted two predictive variables after fishing year (vessel and day of season), with the total model explaining 67% of the deviance (Table 8). Residuals to the lognormal model showed some concentration in the centre of the distribution along with contraction at the distribution sides, but with little deviation at the tails of the distribution (Figure 50). Neither the Weibull nor the gamma distributions resulted in better fits to the positive catch data (Figure 51) than seen for the lognormal distribution. The lognormal model was characterised by two early indices at a relatively high level, followed by a long period of very low indices and then an abrupt increasing trend from 2017 to 2020 (Figure 52). The standardisation effect was confined to the final four years of the series where the standardised model was lifted upward from the unstandardised series (Figure 52). Almost all this standardisation effect occurred with the addition of the vessel covariate (Figure 53) which may be evidence of a systematic effort on the part of the fleet to avoid gemfish in the final years of the series (Figure 54). On the other hand, there was no systematic shift in the day of the year (Figure 55), which was likely driven by access to hoki rather than by gemfish availability. Implied residual plots of gemfish annual CPUE showed no difference between the two statistical areas (Figure 56) or the two capture methods (Figure 57).

The multiplicative effect of the combined model exaggerates the increasing trend in both the binomial and lognormal components, resulting in a very strong increasing trend (Figure 58, Figure 59, Table 9).

Table 4: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SKI7 BT+MW HOK event CPUE series.

Series	SKI7 BT+MW HOK event
QMS stock	SKI7
Reporting forms	TCE, TCP, ERS - Trawl
Fishing methods	BT, MW
Target species	HOK
Statistical Areas	034, 035
Period	1989-10-01, 2020-09-30
Resolution	Fishing event
Core fleet years	5
Core fleet trips	1
Default model	allockg_top5 ~ fyear + vessel_key + stat_area + primary_method + ns(log(fishing_duration), 3) + bs(start_latitude, 3) + bs(effort_width, 3) + bs(effort_height, 3) + bs(bottom_depth, 3) + bs(effort_speed, 3) + bs(start_hour, 3) + bs(SeasonDay, 3)
Stepwise selection	Yes
Positive catch distribution	Lognormal

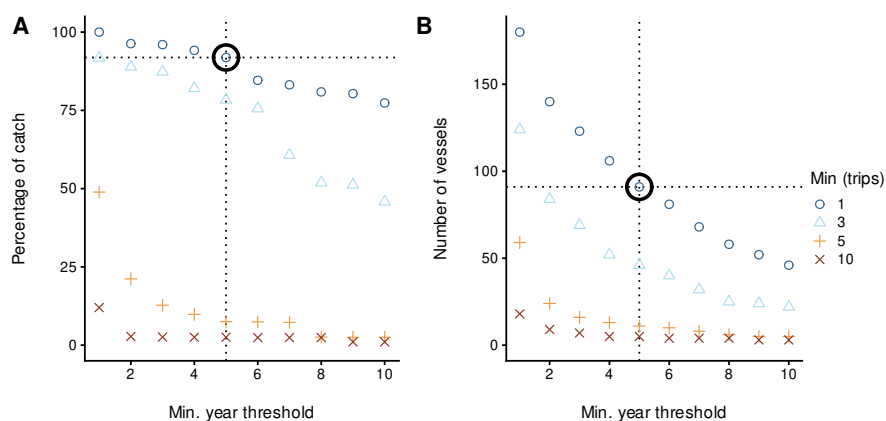


Figure 44: Percentage of catch and number of vessels for different core vessel selection criteria for the SKI7 BT+MW HOK event CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

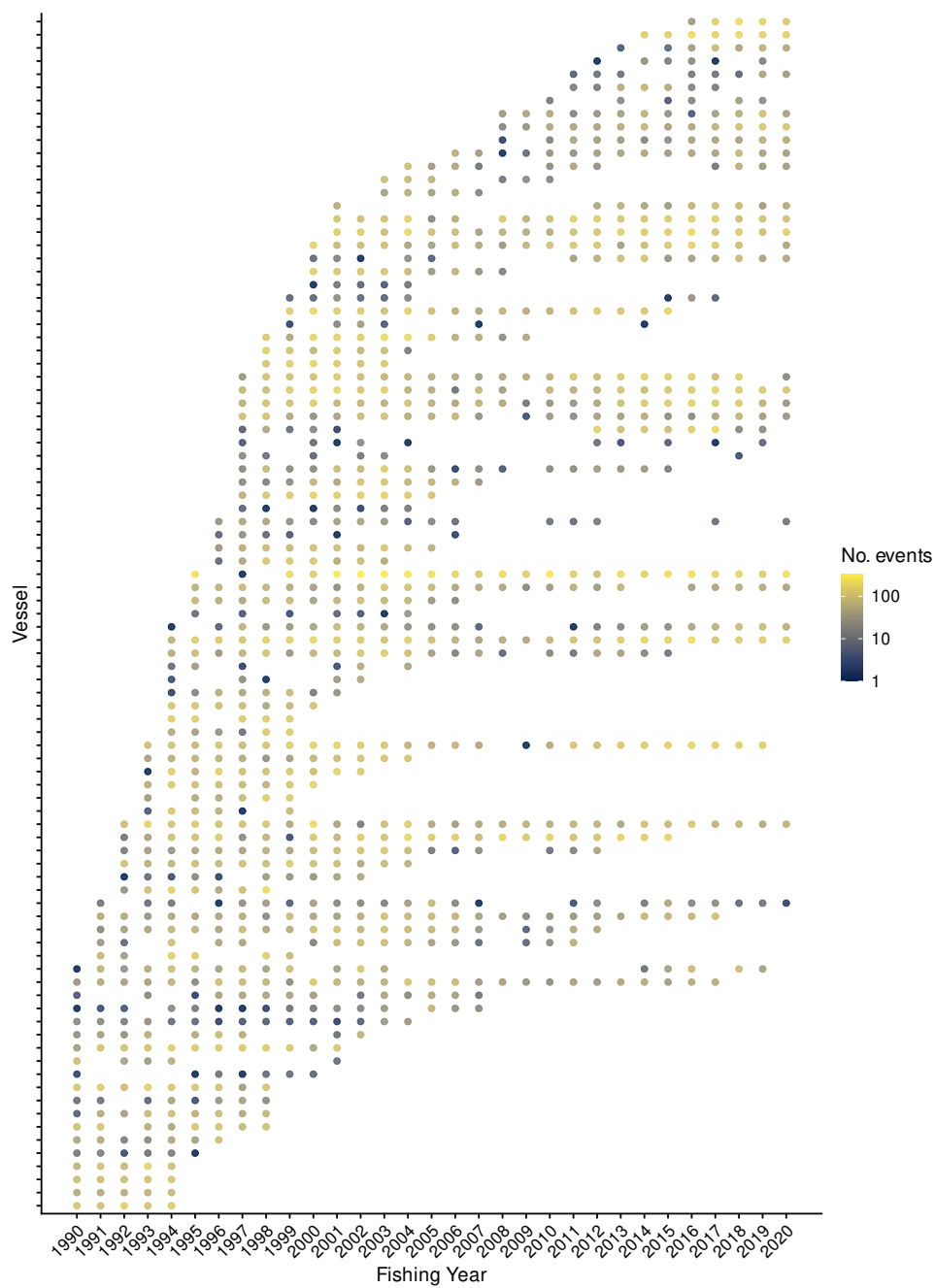


Figure 45: Number of events by fishing year for core vessels. The colour of the points is proportional to the number of events undertaken by a vessel in a fishing year.

Table 5: Summary of the SKI7 BT+MW HOK event dataset total catch (tonnes) and number of records (n), by fishing year after the application of various filters. The first row gives the catch and number of records before filters were applied (ungroomed data). Subsequent rows display the remaining catch (and percent of catch), and the number of records, after the specified filter was applied. (Continued on next page)

Filter	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ungroomed data	256 (100%) n: 8150	116 (100%) n: 8239	73 (100%) n: 6072	163 (100%) n: 6425	126 (100%) n: 8916	21 (100%) n: 8162	12 (100%) n: 7158	66 (100%) n: 8422	12 (100%) n: 8066
Fishing duration is not NA	256 (100%) n: 8150	116 (100%) n: 8239	73 (100%) n: 6072	163 (100%) n: 6425	126 (100%) n: 8916	21 (100%) n: 8162	12 (100%) n: 7158	66 (100%) n: 8422	12 (100%) n: 8066
Positive fishing duration	256 (100%) n: 8149	116 (100%) n: 8239	73 (100%) n: 6071	163 (100%) n: 6423	126 (100%) n: 8913	21 (100%) n: 8160	12 (100%) n: 7154	66 (100%) n: 8415	12 (100%) n: 8061
Bottom depth >=250	253 (100%) n: 8116	116 (100%) n: 8182	69 (94%) n: 6031	136 (83%) n: 6318	124 (100%) n: 8674	21 (100%) n: 7961	12 (100%) n: 6996	66 (100%) n: 8007	12 (100%) n: 7961
Bottom depth <=600	245 (100%) n: 5647	114 (100%) n: 6025	68 (93%) n: 5042	132 (81%) n: 5324	121 (100%) n: 7699	18 (89%) n: 7247	11 (92%) n: 6113	65 (100%) n: 7134	12 (100%) n: 7043
Season start day >215	243 (100%) n: 5639	114 (100%) n: 6022	68 (93%) n: 5037	132 (81%) n: 5318	121 (100%) n: 7683	18 (89%) n: 7222	9.6 (81%) n: 6077	64 (100%) n: 7113	7.8 (67%) n: 7010
Midwater effort depth <=10 m from bottom	165 (65%) n: 3276	94 (80%) n: 3791	61 (84%) n: 2881	104 (64%) n: 3694	91 (72%) n: 5206	16 (76%) n: 4719	5 (43%) n: 3631	59 (89%) n: 4325	7.8 (66%) n: 4759
Core fleet selection	60 (24%) n: 874	59 (50%) n: 1285	53 (72%) n: 1229	98 (60%) n: 1947	71 (56%) n: 3238	7.7 (37%) n: 2921	4.5 (38%) n: 2615	53 (80%) n: 2996	7.8 (66%) n: 4276

Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	13 (100%) n: 7039	78 (100%) n: 7182	36 (100%) n: 8219	80 (100%) n: 7428	174 (100%) n: 6807	373 (100%) n: 5861	246 (100%) n: 3442	98 (100%) n: 2886	49 (100%) n: 1808
Fishing duration is not NA	13 (100%) n: 7039	78 (100%) n: 7182	36 (100%) n: 8219	80 (100%) n: 7428	174 (100%) n: 6807	373 (100%) n: 5861	246 (100%) n: 3442	98 (100%) n: 2886	49 (100%) n: 1808
Positive fishing duration	13 (100%) n: 7038	78 (100%) n: 7180	36 (100%) n: 8214	80 (100%) n: 7423	174 (100%) n: 6805	373 (100%) n: 5859	246 (100%) n: 3442	98 (100%) n: 2886	49 (100%) n: 1808
Bottom depth >=250	13 (100%) n: 6733	78 (100%) n: 7166	35 (100%) n: 7904	79 (100%) n: 7204	173 (100%) n: 6774	370 (100%) n: 5799	240 (100%) n: 3405	95 (100%) n: 2834	49 (100%) n: 1799
Bottom depth <=600	13 (100%) n: 5760	77 (100%) n: 6414	35 (100%) n: 6976	77 (100%) n: 6141	168 (100%) n: 6147	364 (100%) n: 5399	240 (100%) n: 3204	94 (100%) n: 2532	48 (100%) n: 1617
Season start day >215	11 (82%) n: 5696	77 (100%) n: 6392	33 (92%) n: 6933	77 (100%) n: 6136	168 (100%) n: 6138	364 (100%) n: 5398	239 (100%) n: 3183	94 (100%) n: 2532	48 (100%) n: 1617
Midwater effort depth <=10 m from bottom	9.7 (73%) n: 4059	71 (92%) n: 4244	31 (85%) n: 4767	71 (89%) n: 4462	156 (90%) n: 4510	337 (90%) n: 4058	230 (94%) n: 2503	86 (88%) n: 1876	47 (100%) n: 1202
Core fleet selection	9.7 (73%) n: 3813	71 (92%) n: 4220	30 (84%) n: 4316	70 (88%) n: 4219	155 (90%) n: 4290	334 (89%) n: 3850	230 (93%) n: 2421	85 (87%) n: 1854	47 (100%) n: 1187
Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	9.9 (100%) n: 1361	14 (100%) n: 1138	26 (100%) n: 1966	106 (100%) n: 2769	32 (100%) n: 3196	67 (100%) n: 3314	160 (100%) n: 4103	99 (100%) n: 4558	95 (100%) n: 4908
Fishing duration is not NA	9.9 (100%) n: 1361	14 (100%) n: 1138	26 (100%) n: 1966	106 (100%) n: 2769	32 (100%) n: 3196	67 (100%) n: 3314	160 (100%) n: 4103	99 (100%) n: 4558	95 (100%) n: 4908
Positive fishing duration	9.9 (100%) n: 1360	14 (100%) n: 1138	26 (100%) n: 1966	106 (100%) n: 2768	32 (100%) n: 3195	67 (100%) n: 3313	160 (100%) n: 4102	99 (100%) n: 4558	95 (100%) n: 4907
Bottom depth >=250	9.9 (100%) n: 1358	14 (100%) n: 1138	26 (100%) n: 1965	106 (100%) n: 2766	32 (100%) n: 3194	67 (100%) n: 3310	160 (100%) n: 4097	99 (100%) n: 4557	95 (100%) n: 4889
Bottom depth <=600	9.9 (100%) n: 1334	14 (100%) n: 1089	25 (100%) n: 1938	106 (100%) n: 2689	32 (100%) n: 3054	64 (100%) n: 3175	159 (100%) n: 3910	97 (100%) n: 4344	92 (100%) n: 4688
Season start day >215	9.7 (100%) n: 1331	14 (100%) n: 1087	24 (100%) n: 1932	106 (100%) n: 2689	32 (100%) n: 3054	64 (100%) n: 3175	159 (100%) n: 3910	96 (100%) n: 4338	92 (100%) n: 4684
Midwater effort depth <=10 m from bottom	9.6 (100%) n: 1200	12 (85%) n: 959	23 (90%) n: 1567	98 (92%) n: 1853	25 (79%) n: 2145	48 (71%) n: 2358	125 (78%) n: 2675	64 (64%) n: 2688	70 (74%) n: 2954
Core fleet selection	9.6 (100%) n: 1185	12 (85%) n: 959	23 (90%) n: 1564	98 (92%) n: 1852	25 (79%) n: 2081	48 (71%) n: 2337	125 (78%) n: 2652	64 (64%) n: 2653	70 (74%) n: 2951

Filter	2017	2018	2019	2020
Ungroomed data	257 (100%) n: 4904	384 (100%) n: 4919	650 (100%) n: 3898	597 (100%) n: 3218
Fishing duration is not NA	257 (100%) n: 4904	384 (100%) n: 4919	650 (100%) n: 3898	597 (100%) n: 3218
Positive fishing duration	257 (100%) n: 4902	384 (100%) n: 4918	650 (100%) n: 3896	597 (100%) n: 3218
Bottom depth >=250	255 (100%) n: 4894	384 (100%) n: 4917	650 (100%) n: 3886	597 (100%) n: 3213
Bottom depth <=600	246 (100%) n: 4517	360 (94%) n: 4316	629 (100%) n: 3669	583 (100%) n: 3081
Season start day >215	246 (100%) n: 4516	360 (94%) n: 4314	629 (100%) n: 3669	583 (100%) n: 3081
Midwater effort depth <=10 m from bottom	201 (78%) n: 2954	321 (84%) n: 3002	521 (80%) n: 2253	474 (79%) n: 2086
Core fleet selection	183 (71%) n: 2757	286 (75%) n: 2751	498 (77%) n: 2140	443 (74%) n: 1923

Table 6: Summary of the SKI7 BT+MW HOK event dataset after core fleet selection. ‘Records’ indicates the number of rows (events) in the dataset, and ‘Records caught’ indicates the percentage of events with catches of gemfish.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
1990	19	46	874	3 912.45	60.38	11.21
1991	21	51	1 285	5 208.00	58.51	17.98
1992	25	55	1 229	4 860.98	52.66	18.31
1993	32	72	1 947	7 269.90	97.59	29.48
1994	41	148	3 238	11 908.84	71.16	27.42
1995	40	96	2 921	11 555.40	7.66	14.17
1996	41	91	2 615	10 693.45	4.53	8.72
1997	55	152	2 996	12 739.70	52.61	25.20
1998	53	140	4 276	18 594.08	7.75	8.68
1999	51	139	3 813	14 592.93	9.74	23.11
2000	50	175	4 220	15 567.37	71.29	38.03
2001	56	180	4 316	16 831.35	29.98	52.25
2002	52	192	4 219	15 920.08	70.39	47.07
2003	47	136	4 290	20 267.80	155.39	37.53
2004	45	117	3 850	18 824.48	333.65	44.42
2005	36	82	2 421	11 738.81	229.63	46.92
2006	34	75	1 854	9 127.00	85.47	29.83
2007	31	64	1 187	5 422.63	46.84	51.47
2008	23	59	1 185	3 948.12	9.63	43.71
2009	22	60	959	3 417.03	11.90	47.03
2010	29	96	1 564	4 907.67	22.87	42.14
2011	32	131	1 852	6 506.57	97.64	38.12
2012	35	138	2 081	6 854.52	25.33	63.48
2013	31	155	2 337	7 406.77	47.56	64.70
2014	31	165	2 652	9 269.65	125.26	71.00
2015	34	175	2 653	9 428.87	63.63	62.65
2016	32	201	2 951	9 442.33	69.92	54.90
2017	33	215	2 757	10 864.28	182.81	45.41
2018	29	218	2 751	11 288.51	286.19	46.64
2019	28	206	2 140	8 962.80	497.67	55.09
2020	25	201	1 923	6 289.80	443.49	68.23

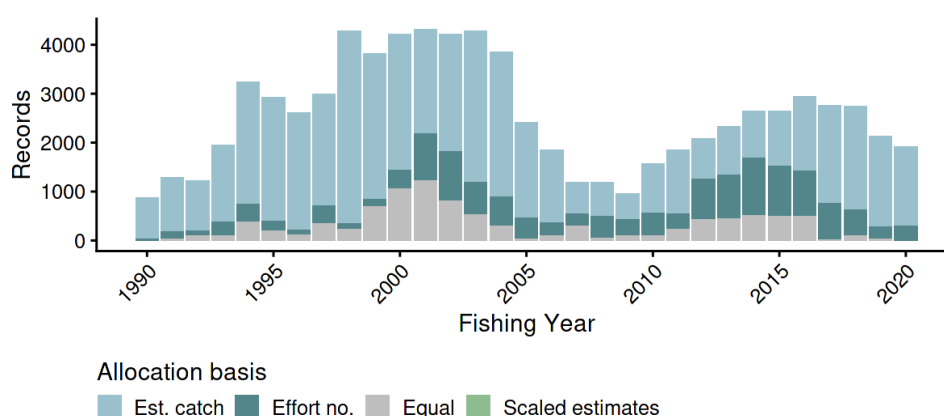


Figure 46: Allocation basis for attributing landings to records in the SKI7 BT+MW HOK event catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table 7: Summary of stepwise selection for occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	29.00	95 833	10.20	10.20	*
+ vessel_key	90.00	89 306	16.50	6.30	*
+ bs(SeasonDay, 3)	3.00	88 934	16.80	0.40	
+ stat_area	1.00	88 756	17.00	0.20	
+ bs(bottom_depth, 3)	3.00	88 622	17.10	0.10	
+ ns(log(fishing_duration), 3)	3.00	88 494	17.20	0.10	
+ bs(start_hour, 3)	3.00	88 389	17.30	0.10	
+ bs(start_latitude, 3)	3.00	88 296	17.40	0.10	
+ bs(effort_speed, 3)	3.00	88 247	17.50	0.10	
+ bs(effort_height, 3)	3.00	88 209	17.50	0.00	
+ primary_method	1.00	88 206	17.50	0.00	

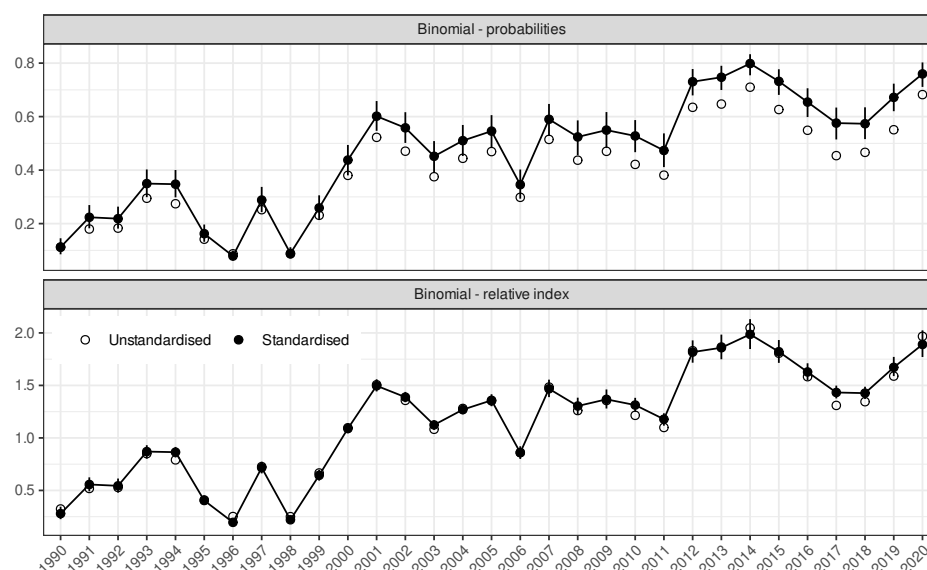


Figure 47: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SKI7 BT+MW HOK event dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

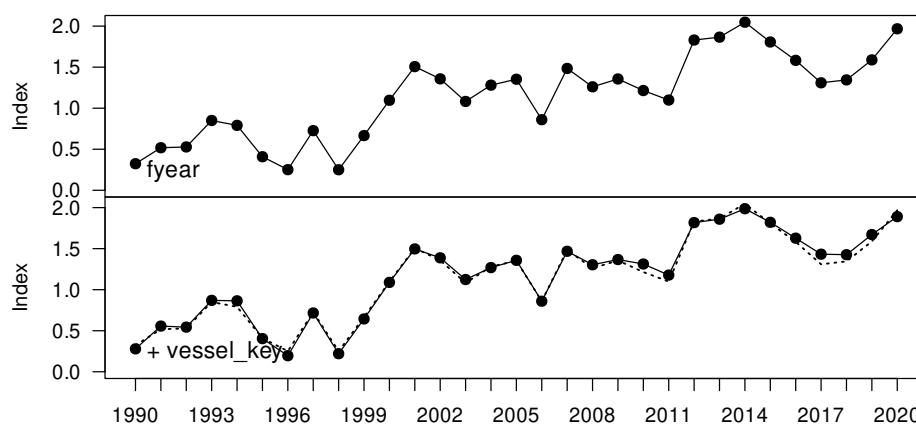


Figure 48: Step plot for occurrence of catch in the SKI7 BT+MW HOK event dataset.

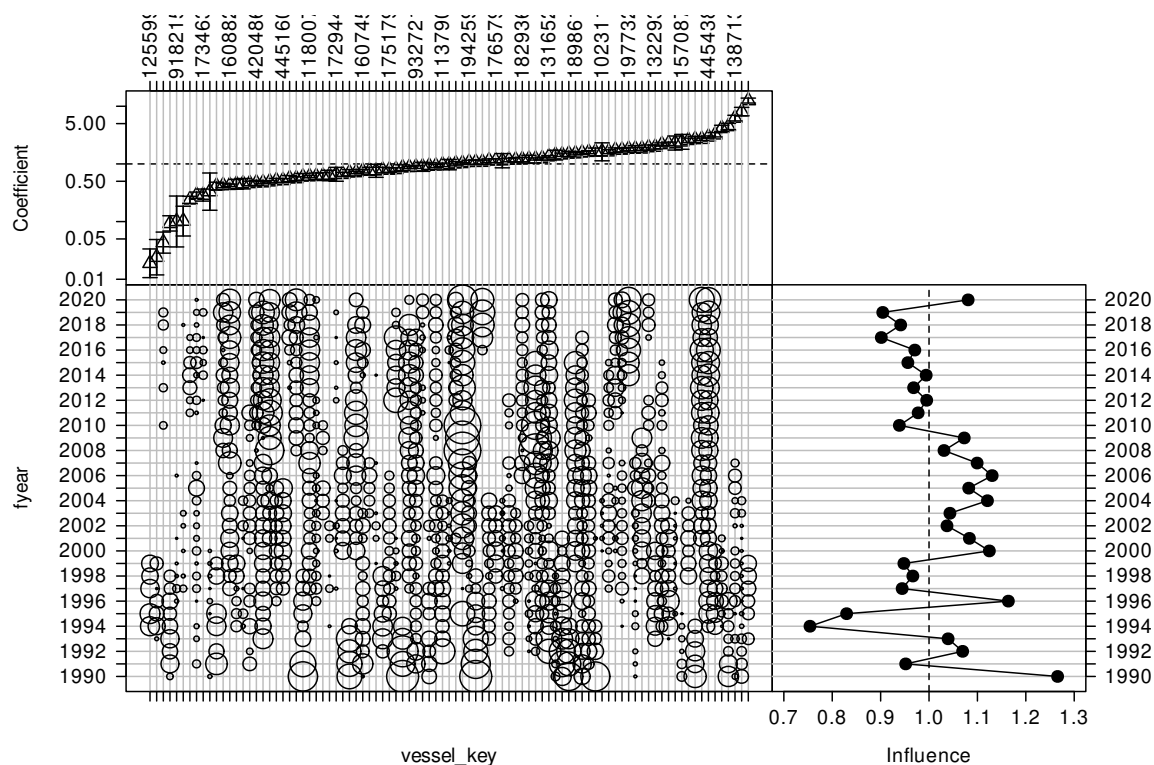


Figure 49: CDI plot for vessel key for the occurrence of positive catch SKI7 BT+MW HOK event catch-per-unit-effort dataset.

Table 8: Summary of stepwise selection for the lognormal model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	29	132 377	39.6	39.6	*
+ vessel key	90	122 066	56.7	17.1	*
+ bs(SeasonDay, 3)	3	113 638	66.9	10.2	*
+ bs(bottom depth, 3)	3	112 928	67.6	0.7	
+ bs(start latitude, 3)	3	112 530	68.0	0.4	
+ bs(effort height, 3)	3	112 297	68.3	0.2	
+ bs(effort width, 3)	3	112 193	68.4	0.1	
+ bs(start hour, 3)	3	112 109	68.5	0.1	
+ ns(log(fishing duration), 3)	3	111 987	68.6	0.1	
+ bs(effort speed, 3)	3	111 945	68.7	0.0	
+ primary method	1	111 918	68.7	0.0	
+ stat area	1	111 908	68.7	0.0	

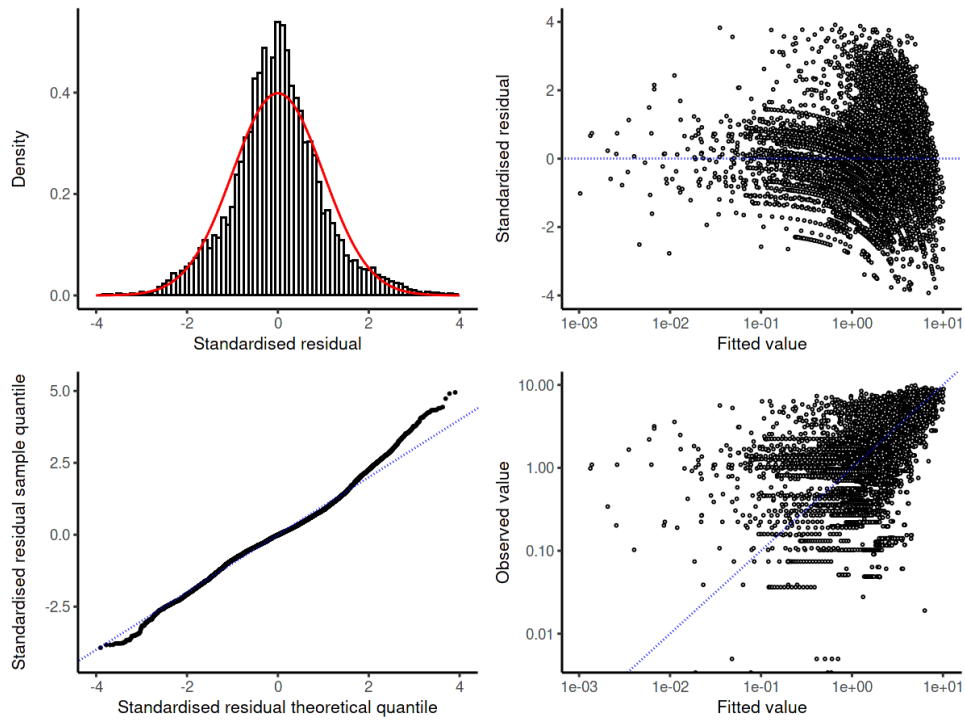


Figure 50: Diagnostic plots for the lognormal model for the SKI7 BT+MW HOK event dataset.

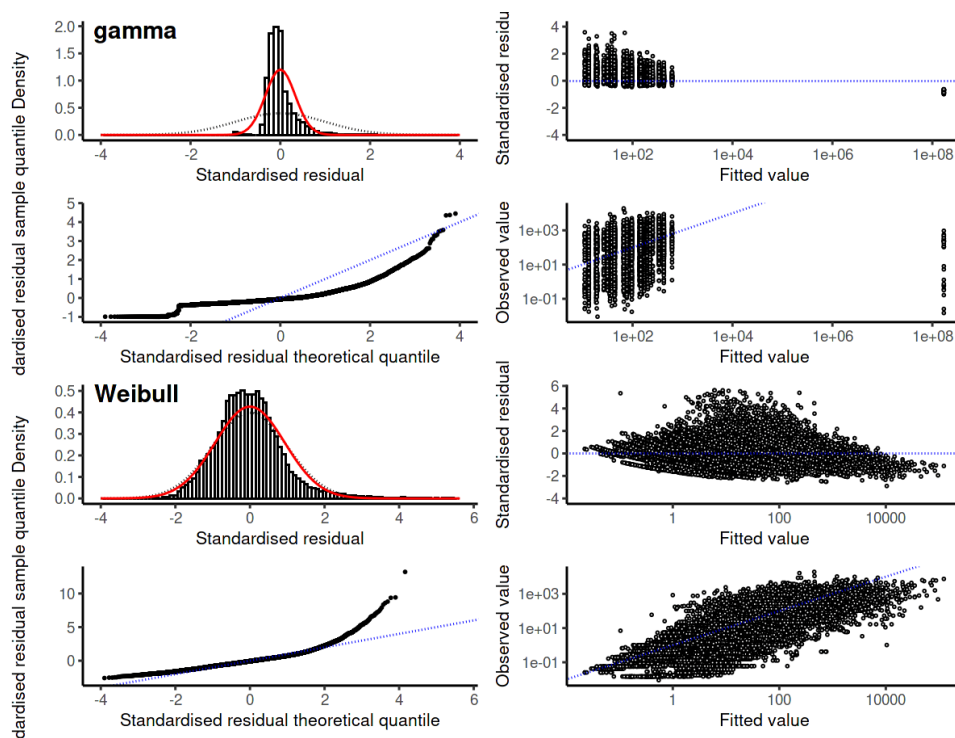


Figure 51: Diagnostic plots for the gamma and Weibull model for the SKI7 BT+MW HOK event dataset.

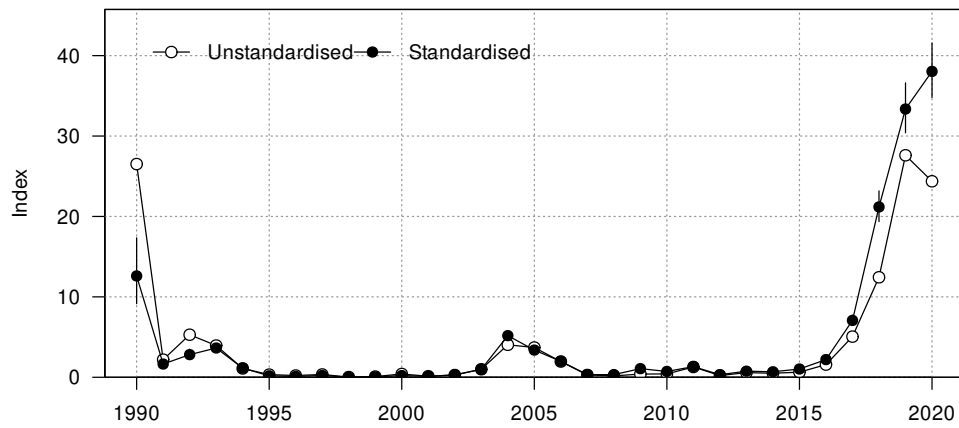


Figure 52: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SKI7 BT+MW HOK event dataset.

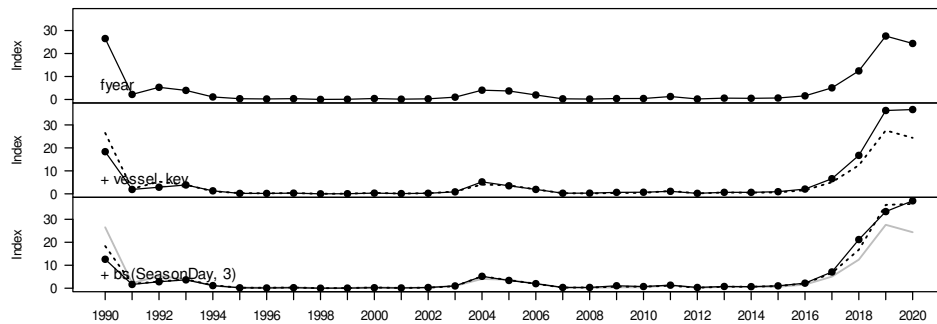


Figure 53: Changes to the SKI7 BT+MW HOK event positive catch index as terms are successively entered into the model.

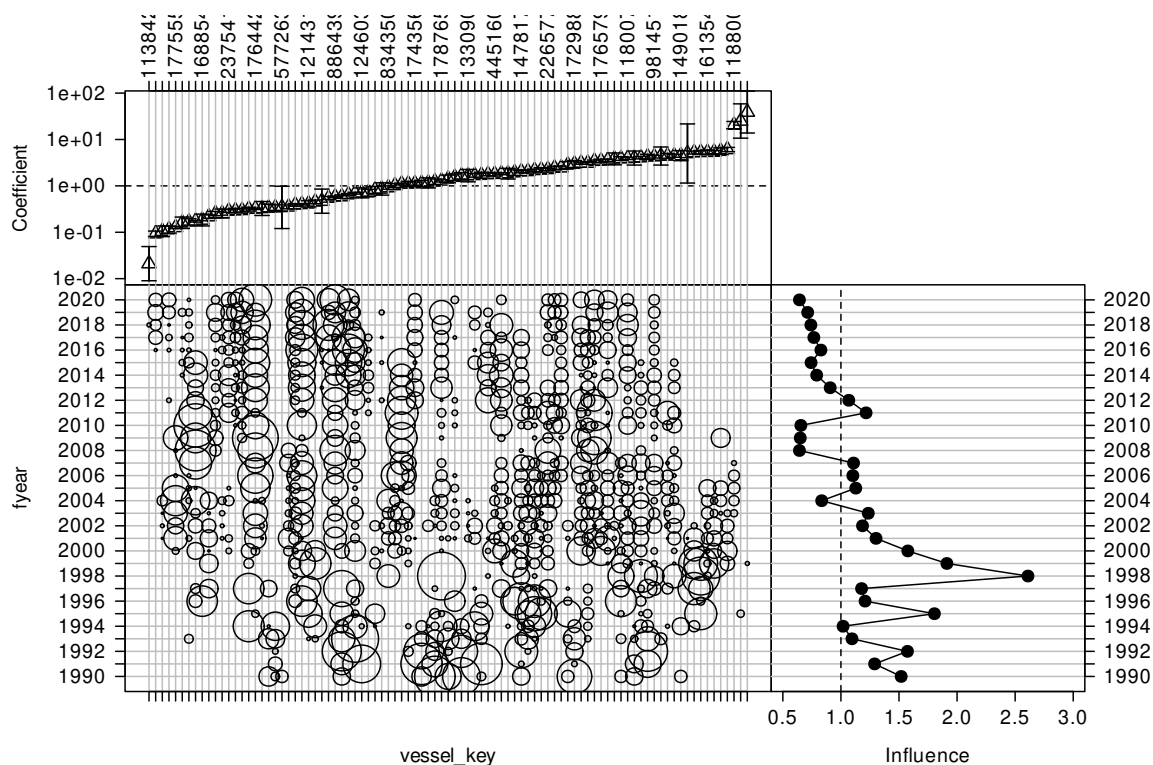


Figure 54: CDI plot for vessel key for the positive catch SKI7 BT+MW HOK event catch-per-unit-effort dataset.

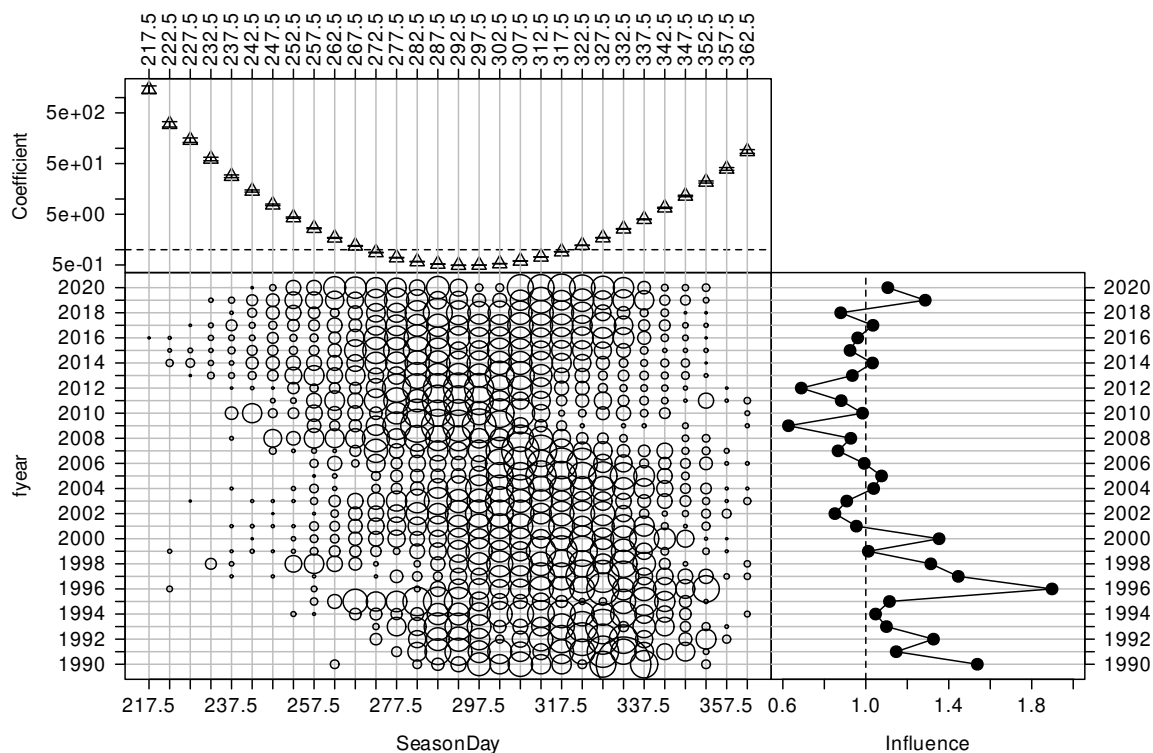


Figure 55: CDI plot for SeasonDay for the positive catch SKI7 BT+MW HOK event catch-per-unit-effort dataset.

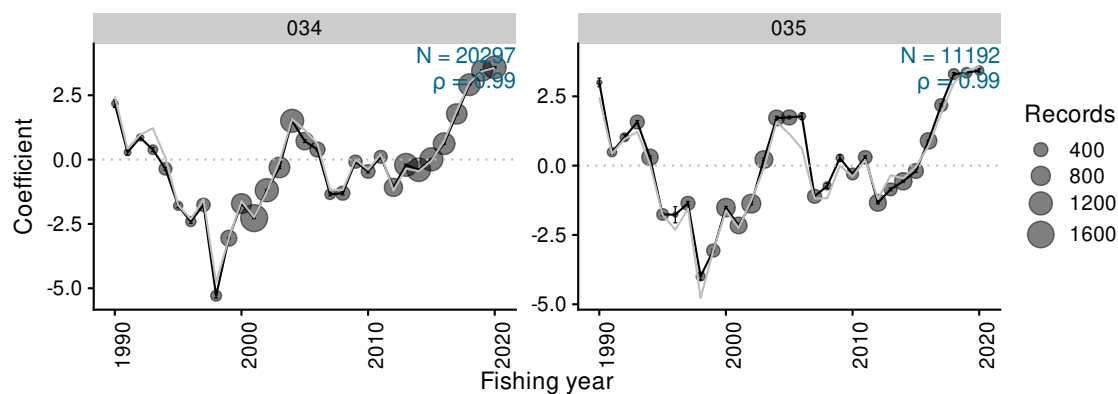


Figure 56: Residual implied coefficients for area-year in the lognormal positive catch model for the SKI7 BT+MW HOK event dataset.

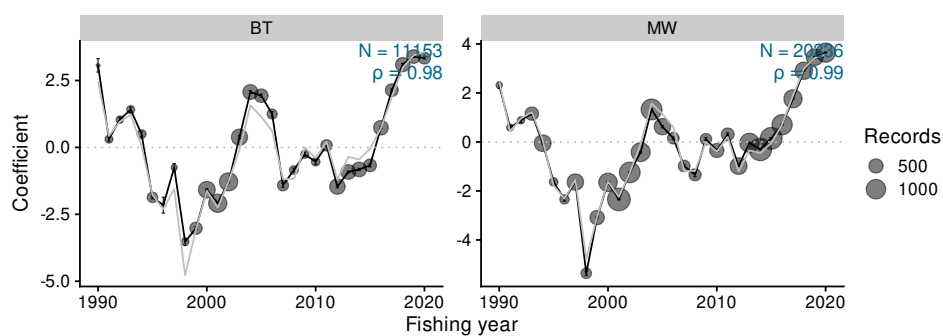


Figure 57: Residual implied coefficients for primary method-year in the lognormal positive catch model for the SKI7 BT+MW HOK event dataset.

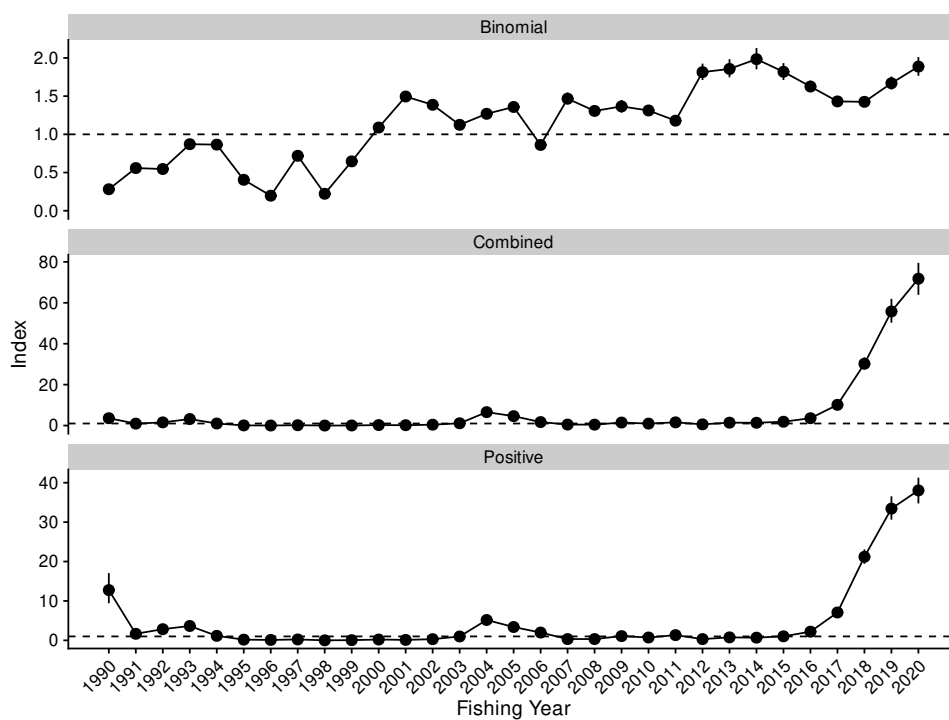


Figure 58: Standardised indices and 95% confidence intervals for the SKI7 BT+MW HOK event dataset.

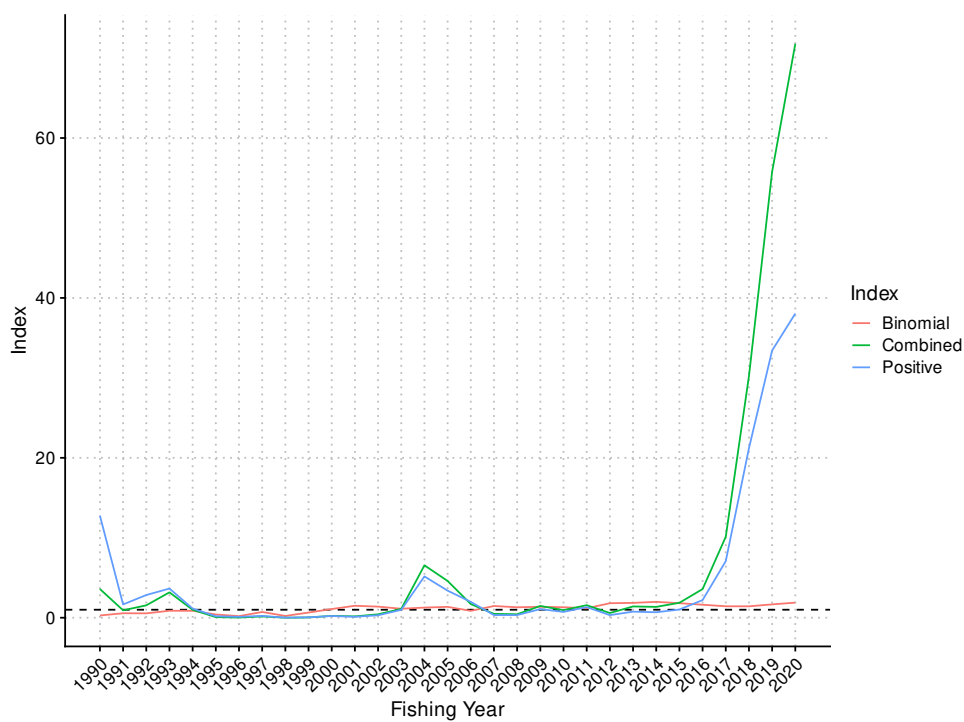


Figure 59: Standardised indices for the SKI7 BT+MW HOK event dataset.

Table 9: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SKI7 BT+MW HOK event.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.281	0.030	0.226	0.344	3.593	0.675	2.452	5.098	12.759	1.949	9.422	17.062
1991	0.558	0.035	0.489	0.627	0.928	0.132	0.698	1.216	1.660	0.214	1.272	2.112
1992	0.546	0.034	0.485	0.618	1.551	0.191	1.213	1.962	2.840	0.314	2.303	3.535
1993	0.871	0.031	0.811	0.931	3.175	0.246	2.703	3.666	3.645	0.253	3.177	4.169
1994	0.865	0.026	0.814	0.917	0.992	0.066	0.869	1.126	1.146	0.067	1.021	1.285
1995	0.405	0.024	0.361	0.456	0.074	0.007	0.061	0.090	0.183	0.015	0.156	0.213
1996	0.197	0.015	0.169	0.229	0.021	0.003	0.016	0.027	0.107	0.011	0.088	0.130
1997	0.719	0.028	0.666	0.778	0.165	0.011	0.144	0.188	0.229	0.014	0.204	0.258
1998	0.222	0.016	0.192	0.254	0.002	0.000	0.002	0.002	0.009	0.001	0.008	0.011
1999	0.646	0.026	0.597	0.700	0.033	0.002	0.029	0.038	0.051	0.003	0.045	0.057
2000	1.089	0.022	1.045	1.130	0.232	0.011	0.211	0.254	0.213	0.009	0.195	0.232
2001	1.495	0.029	1.442	1.555	0.171	0.007	0.157	0.184	0.114	0.004	0.106	0.121
2002	1.387	0.025	1.340	1.439	0.423	0.018	0.388	0.458	0.305	0.011	0.283	0.328
2003	1.124	0.023	1.079	1.168	1.111	0.049	1.014	1.207	0.988	0.040	0.909	1.068
2004	1.269	0.022	1.226	1.314	6.556	0.283	5.991	7.102	5.167	0.203	4.759	5.554
2005	1.358	0.029	1.303	1.416	4.599	0.247	4.131	5.098	3.386	0.166	3.063	3.714
2006	0.861	0.031	0.803	0.925	1.708	0.118	1.483	1.947	1.983	0.122	1.747	2.225
2007	1.467	0.039	1.394	1.548	0.482	0.032	0.424	0.547	0.329	0.019	0.294	0.368
2008	1.307	0.037	1.237	1.383	0.432	0.031	0.376	0.497	0.331	0.021	0.293	0.377
2009	1.365	0.042	1.285	1.450	1.473	0.114	1.259	1.704	1.079	0.078	0.934	1.240
2010	1.312	0.034	1.252	1.383	0.953	0.059	0.838	1.069	0.726	0.041	0.646	0.807
2011	1.179	0.032	1.119	1.243	1.567	0.097	1.390	1.769	1.329	0.073	1.195	1.480
2012	1.814	0.055	1.711	1.926	0.587	0.031	0.530	0.650	0.323	0.014	0.298	0.351
2013	1.856	0.060	1.747	1.984	1.410	0.074	1.276	1.566	0.760	0.031	0.698	0.818
2014	1.984	0.071	1.851	2.130	1.356	0.070	1.227	1.500	0.683	0.025	0.636	0.734
2015	1.819	0.057	1.711	1.932	1.867	0.094	1.691	2.061	1.026	0.040	0.950	1.108
2016	1.626	0.038	1.553	1.704	3.583	0.166	3.271	3.923	2.204	0.085	2.041	2.376
2017	1.431	0.030	1.375	1.493	10.126	0.529	9.114	11.189	7.076	0.317	6.468	7.710
2018	1.426	0.030	1.367	1.484	30.221	1.496	27.499	33.365	21.200	0.933	19.428	23.087
2019	1.669	0.043	1.587	1.757	55.781	2.982	50.266	61.955	33.424	1.507	30.638	36.547
2020	1.887	0.062	1.767	2.011	71.785	3.987	63.901	79.532	38.048	1.666	34.748	41.279

5.3 SKI7 BT+MW process daily

This series was also based on the bycatch of gemfish in the WCSI BT/MW winter target hoki (HOK) fishery, except it was based on the daily processing data instead of the catch by tow. As for the tow-by-tow CPUE analysis, this analysis was constrained to Statistical Area 034 (Greymouth) and Statistical Area 035 (Westport) where the majority of the target hoki fishery takes place (Table 10). The MW component of the analysis was constrained to midwater gear fished within 10 m of the bottom. 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 120 vessels to 74 vessels (Figure 60). A substantial number of the core fleet vessels were present in the defined fishery for 20 years or more (Figure 61) and these vessels show good overlap over the 31 years of data. On an annual basis, the groomed dataset represented 21% (1990) to 100% (2007, 2008) of the annual catch (Table 11). The pattern of gemfish bycatch in this dataset is similar to that shown for the SKI7-BT+MW HOK event CPUE analysis: less than 100 t/y up to the 2017 fishing year, except for a short period from 2003 to 2005 when the gemfish bycatch exceeded 100 t/y (Table 12), with the bycatch of gemfish rising in 2017 and peaking at 341 t in 2019 and 264 t in 2020. All catches in the dataset were derived from landings allocated to each day of fishing based on the daily processed catches (Figure 62).

The binomial (occurrence) model accepted three predictive variables after fishing year (day of season, vessel and bottom depth), with the total model explaining 41% of the deviance (Table 13). The occurrence of gemfish in a day of processing showed a similar pattern as the event-based series but was more extreme, with the early part of the series going much lower and the latter part of the series higher, again resulting in a gradually increasing trend in the daily processing series (Figure 63). There was only a minor standardisation effect on the final years in the series, but if we look at the stepwise addition of covariates to the model, we see that the addition of the day of season variable raised the final six years of the series, a rise which was negated when the vessel covariate was added to the model (Figure 64). These effects can be seen in the respective CDI plots (day of season: Figure 65; vessel: Figure 66; bottom depth: Figure 67), which indicate that while each series has a trend over time, the overall effect is small.

The lognormal model accepted four predictive variables after fishing year (day of season, vessel, capture method and bottom depth), with the total model explaining 55% of the deviance (Table 14). Residuals to the lognormal model showed a good fit to the lognormal distribution, except for some minor deviations along the lower tail of the distribution (Figure 68). Both the Weibull and the gamma distributions resulted in reasonable fits to the positive catch data except that the deviations from the distributions occurred at the upper tail of the residual distribution (Figure 69) rather than in the lower tail as was seen in the lognormal distribution. The lognormal model was characterised by a period of variable indices with an overall declining trend to about 2007, followed by a period of very low indices and then, as in the event-based series, an abrupt increasing trend from 2017 to 2020 (Figure 70). The standardisation effect of the model was mixed, with the most notable effect being the raising of the final year (2020) CPUE, which was declining in the unstandardised series but rose in the full model (Figure 52). The other notable standardisation effect was the dropping of the 1997 and 1998 indices. Each successive covariate raised the final year index relative to the previous covariate while the drops in 1997 and 1998 can be attributed to the day of season covariate (Figure 71). The day of season CDI plot showed that the data for this variable were quite different in 1997 and 1998 compared with other years (Figure 72). This may indicate that there was a problem with the data in those years and that these years should possibly be discounted while the rest of the data have no impact on the series. The effect of the vessel covariate was mainly in the first few years of the series when there were a few vessels with high gemfish catch rates which subsequently dropped out of the fishery (Figure 73). The other two covariates (capture method: Figure 74 and bottom depth: Figure 75) were responsible for the uptick in CPUE in the final year, with an increase in the midwater tows in 2020 (which have a lower catch rate) and a move to deeper bottom depths (which also have lower catch rates) which in turn caused the increase in the standardised CPUE. As for the event-based series, the implied residual plots of annual gemfish CPUE showed no difference between the two statistical areas (Figure 76) or the two capture methods (Figure 77).

As with the event-based series, the multiplicative effect of the combined model exaggerated the increasing trend in both the binomial and lognormal components, resulting in a very strong increasing trend (Figure 78, Figure 79, Table 15).

Table 10: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SKI7 BT+MW process daily CPUE series.

Series	SKI7 BT+MW process daily
QMS stock	SKI7
Reporting forms	TCE, TCP, ERS - Trawl
Fishing methods	BT, MW
Target species	HOK
Statistical Areas	034, 035
Period	1989-10-01, 2020-09-30
Resolution	Day
Core fleet years	4
Core fleet trips	1
Default model	prockg ~ fyear + vessel_key + stat_area + primary_method + ns(log(fishing_duration), 3) + bs(SeasonDay, 3) + bs(bottom_depth, 3)
Stepwise selection	Yes
Positive catch distribution	Lognormal

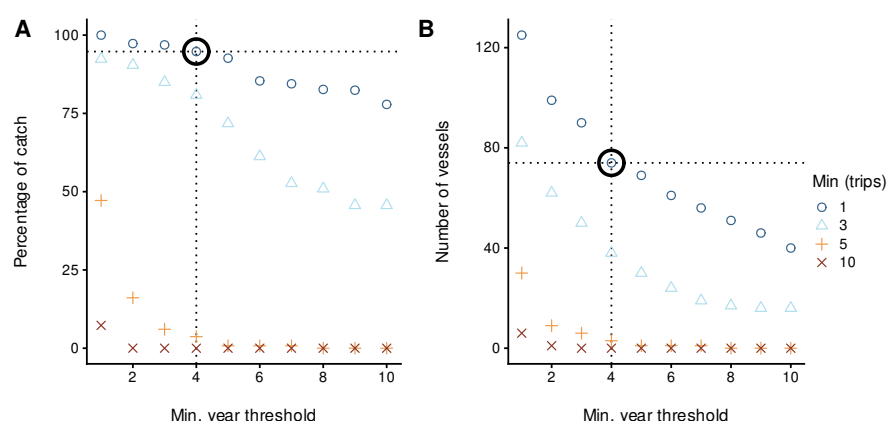


Figure 60: Percentage of catch and number of vessels for different core vessel selection criteria for the SKI7 BT+MW process daily CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

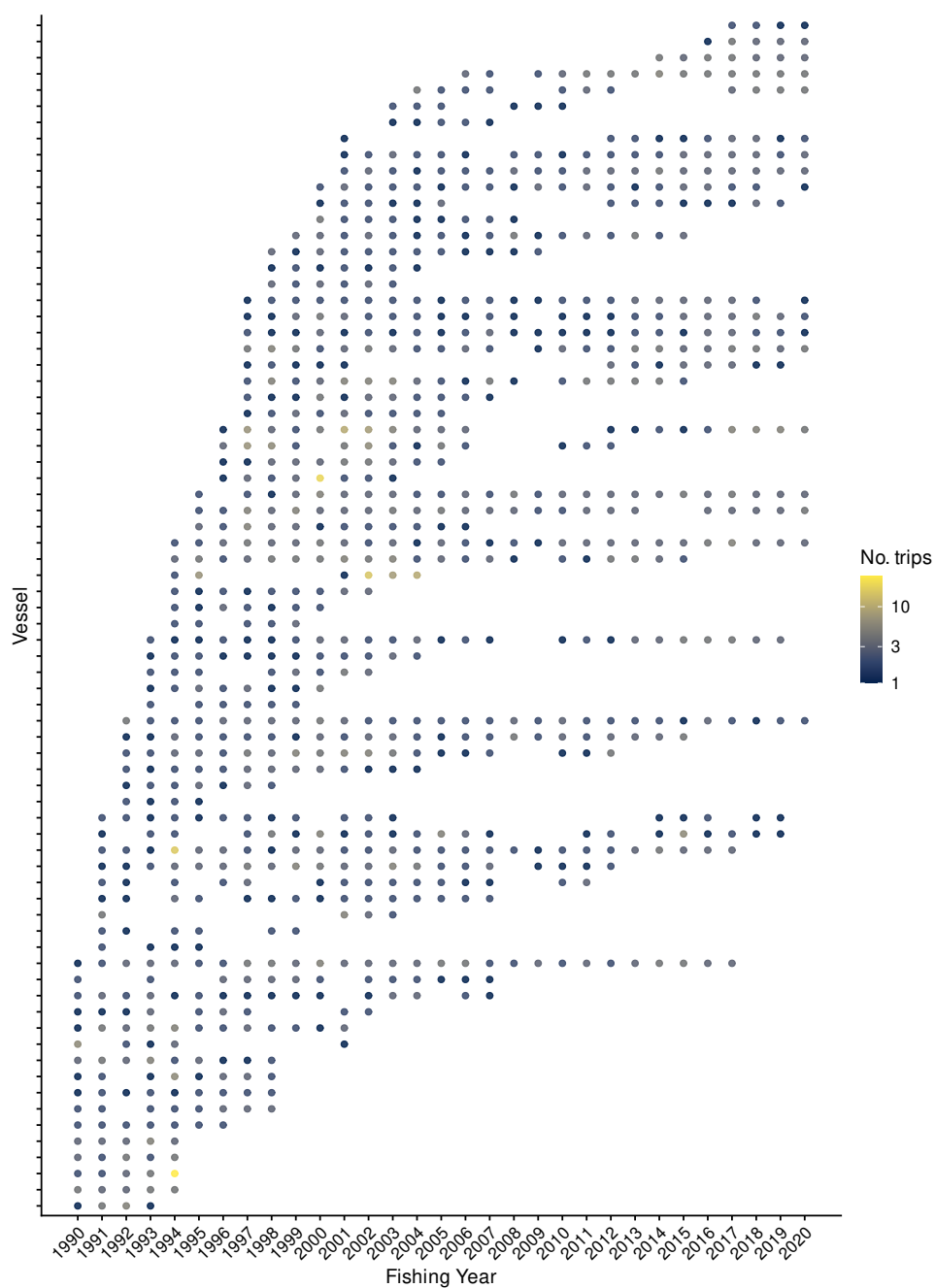


Figure 61: Number of trips by fishing year for core vessels. The colour of the points is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 11: Summary of the SKI7 BT+MW process daily dataset total catch (tonnes) and number of records (n), by fishing year after the application of various filters. The first row gives the catch and number of records before filters were applied (ungroomed data). Subsequent rows display the remaining catch (and percent of catch), and the number of records, after the specified filter was applied. (Continued on next page)

Filter	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ungroomed data	199 (100%) n: 1895	128 (100%) n: 1876	81 (100%) n: 1313	125 (100%) n: 1412	127 (100%) n: 2157	20 (100%) n: 2056	13 (100%) n: 1685	35 (100%) n: 2208	11 (100%) n: 2364
Fishing duration is not NA	199 (100%) n: 1895	128 (100%) n: 1876	81 (100%) n: 1313	125 (100%) n: 1412	127 (100%) n: 2157	20 (100%) n: 2056	13 (100%) n: 1685	35 (100%) n: 2208	11 (100%) n: 2364
Positive fishing duration	199 (100%) n: 1894	128 (100%) n: 1876	81 (100%) n: 1313	125 (100%) n: 1412	127 (100%) n: 2157	20 (100%) n: 2056	13 (100%) n: 1685	35 (100%) n: 2208	11 (100%) n: 2364
Bottom depth >=250	199 (100%) n: 1892	128 (100%) n: 1874	81 (100%) n: 1312	125 (100%) n: 1392	127 (100%) n: 2143	20 (100%) n: 2042	13 (100%) n: 1679	35 (100%) n: 2127	11 (100%) n: 2349
Bottom depth <=600	190 (100%) n: 1355	127 (100%) n: 1472	81 (100%) n: 1158	124 (100%) n: 1201	124 (100%) n: 1954	17 (86%) n: 1892	13 (100%) n: 1513	35 (100%) n: 1945	11 (100%) n: 2144
Season start day >215	190 (100%) n: 1353	127 (100%) n: 1472	81 (100%) n: 1158	124 (100%) n: 1199	124 (100%) n: 1952	17 (85%) n: 1887	12 (89%) n: 1501	34 (100%) n: 1938	8.8 (77%) n: 2133
Midwater effort depth <=10 m from bottom	84 (42%) n: 547	93 (72%) n: 730	69 (85%) n: 509	97 (78%) n: 700	66 (52%) n: 1000	14 (70%) n: 988	4.8 (36%) n: 601	29 (84%) n: 793	8.8 (77%) n: 1181
Core fleet selection	42 (21%) n: 242	59 (46%) n: 428	58 (72%) n: 390	92 (73%) n: 576	50 (40%) n: 763	5.8 (29%) n: 728	4.7 (35%) n: 545	29 (84%) n: 720	8.8 (77%) n: 1175

Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	7.8 (100%) n: 1855	56 (100%) n: 1996	29 (100%) n: 2050	56 (100%) n: 1826	149 (100%) n: 1917	307 (100%) n: 1655	250 (100%) n: 1101	92 (100%) n: 850	41 (100%) n: 575
Fishing duration is not NA	7.8 (100%) n: 1855	56 (100%) n: 1996	29 (100%) n: 2050	56 (100%) n: 1826	149 (100%) n: 1917	307 (100%) n: 1655	250 (100%) n: 1101	92 (100%) n: 850	41 (100%) n: 575
Positive fishing duration	7.8 (100%) n: 1854	56 (100%) n: 1996	29 (100%) n: 2050	56 (100%) n: 1826	149 (100%) n: 1917	307 (100%) n: 1655	250 (100%) n: 1101	92 (100%) n: 850	41 (100%) n: 575
Bottom depth >=250	7.8 (100%) n: 1798	56 (100%) n: 1995	29 (100%) n: 2008	56 (100%) n: 1792	149 (100%) n: 1917	307 (100%) n: 1653	248 (100%) n: 1093	90 (100%) n: 834	41 (100%) n: 572
Bottom depth <=600	7.3 (94%) n: 1510	56 (100%) n: 1785	29 (100%) n: 1805	55 (100%) n: 1513	145 (100%) n: 1783	302 (100%) n: 1574	246 (100%) n: 1056	88 (100%) n: 770	41 (100%) n: 518
Season start day >215	5.2 (66%) n: 1484	55 (100%) n: 1777	27 (92%) n: 1791	54 (100%) n: 1510	145 (100%) n: 1779	302 (100%) n: 1574	245 (100%) n: 1046	88 (100%) n: 770	41 (100%) n: 518
Midwater effort depth <=10 m from bottom	3.5 (45%) n: 782	53 (95%) n: 957	25 (86%) n: 1057	50 (90%) n: 999	132 (89%) n: 1197	269 (88%) n: 1143	233 (94%) n: 737	81 (88%) n: 536	40 (100%) n: 354
Core fleet selection	3.5 (45%) n: 782	53 (95%) n: 957	25 (86%) n: 1057	50 (90%) n: 999	132 (89%) n: 1197	269 (88%) n: 1140	233 (94%) n: 737	81 (88%) n: 536	40 (100%) n: 354
Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	11 (100%) n: 375	12 (100%) n: 296	21 (100%) n: 526	51 (100%) n: 724	19 (100%) n: 712	60 (100%) n: 673	126 (100%) n: 881	68 (100%) n: 944	73 (100%) n: 956
Fishing duration is not NA	11 (100%) n: 375	12 (100%) n: 296	21 (100%) n: 526	51 (100%) n: 724	19 (100%) n: 712	60 (100%) n: 673	126 (100%) n: 881	68 (100%) n: 944	73 (100%) n: 956
Positive fishing duration	11 (100%) n: 375	12 (100%) n: 296	21 (100%) n: 526	51 (100%) n: 724	19 (100%) n: 712	60 (100%) n: 673	126 (100%) n: 881	68 (100%) n: 944	73 (100%) n: 956
Bottom depth >=250	11 (100%) n: 375	12 (100%) n: 296	21 (100%) n: 526	51 (100%) n: 724	19 (100%) n: 712	60 (100%) n: 673	126 (100%) n: 881	68 (100%) n: 944	73 (100%) n: 954
Bottom depth <=600	11 (100%) n: 374	12 (100%) n: 291	21 (100%) n: 521	51 (100%) n: 710	19 (100%) n: 691	59 (100%) n: 643	126 (100%) n: 833	67 (100%) n: 915	72 (100%) n: 918
Season start day >215	11 (100%) n: 374	12 (100%) n: 291	21 (100%) n: 517	51 (100%) n: 710	19 (100%) n: 691	59 (100%) n: 643	126 (100%) n: 833	67 (100%) n: 915	71 (100%) n: 916
Midwater effort depth <=10 m from bottom	11 (100%) n: 321	9.6 (78%) n: 232	18 (86%) n: 406	45 (89%) n: 510	11 (58%) n: 479	34 (56%) n: 461	86 (68%) n: 519	36 (53%) n: 506	43 (58%) n: 539
Core fleet selection	11 (100%) n: 321	9.6 (78%) n: 232	18 (86%) n: 406	45 (89%) n: 510	11 (58%) n: 479	34 (56%) n: 461	86 (68%) n: 519	36 (53%) n: 506	43 (58%) n: 539

Filter	2017	2018	2019	2020
Ungroomed data	187 (100%) n: 1050	301 (100%) n: 1196	485 (100%) n: 919	412 (100%) n: 731
Fishing duration is not NA	187 (100%) n: 1050	301 (100%) n: 1196	485 (100%) n: 919	412 (100%) n: 731
Positive fishing duration	187 (100%) n: 1050	301 (100%) n: 1196	485 (100%) n: 919	412 (100%) n: 731
Bottom depth >=250	186 (100%) n: 1049	301 (100%) n: 1196	485 (100%) n: 919	412 (100%) n: 731
Bottom depth <=600	176 (94%) n: 969	281 (93%) n: 1087	465 (100%) n: 887	403 (100%) n: 709
Season start day >215	176 (94%) n: 969	281 (93%) n: 1086	465 (100%) n: 887	403 (100%) n: 709
Midwater effort depth <=10 m from bottom	132 (71%) n: 575	230 (76%) n: 706	342 (71%) n: 526	282 (68%) n: 453
Core fleet selection	132 (71%) n: 575	227 (75%) n: 683	340 (70%) n: 512	264 (64%) n: 420

Table 12: Summary of the SKI7 BT+MW process daily dataset after core fleet selection. ‘Records’ indicates the number of rows (days) in the dataset, and ‘Records caught’ indicates the percentage of days with catches of gemfish.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
1990	16	35	242	3 032.33	42.15	34.71
1991	23	53	428	4 639.02	59.01	14.95
1992	25	55	390	4 006.50	58.44	18.21
1993	32	68	576	6 787.88	91.90	25.17
1994	37	126	763	9 148.85	50.44	27.92
1995	35	77	728	9 212.20	5.79	3.98
1996	33	69	545	7 406.90	4.65	4.22
1997	44	114	720	8 837.83	29.48	5.56
1998	47	110	1 175	14 858.05	8.75	3.32
1999	43	105	782	9 489.03	3.52	3.84
2000	42	133	957	11 356.50	53.44	15.15
2001	47	125	1 057	13 391.41	24.93	19.02
2002	45	134	999	12 680.45	50.02	37.84
2003	44	114	1 197	17 446.89	132.35	57.31
2004	41	91	1 140	16 314.50	269.00	83.86
2005	36	75	737	9 677.58	233.44	86.84
2006	34	67	536	7 624.35	81.35	66.04
2007	30	57	354	4 407.80	40.02	33.05
2008	19	38	321	3 624.24	11.25	42.37
2009	18	30	232	2 870.35	9.60	62.07
2010	25	48	406	3 955.27	18.50	52.46
2011	25	57	510	5 021.93	45.41	62.55
2012	28	66	479	4 920.85	11.08	36.95
2013	23	63	461	4 689.08	34.11	50.54
2014	25	67	519	5 650.00	85.89	47.40
2015	25	69	506	6 160.35	35.77	73.12
2016	23	64	539	6 078.40	42.57	85.53
2017	24	76	575	7 778.26	132.17	92.52
2018	23	63	683	10 253.12	227.06	87.85
2019	21	53	512	6 760.27	340.50	88.87
2020	18	48	420	4 988.40	263.52	90.00

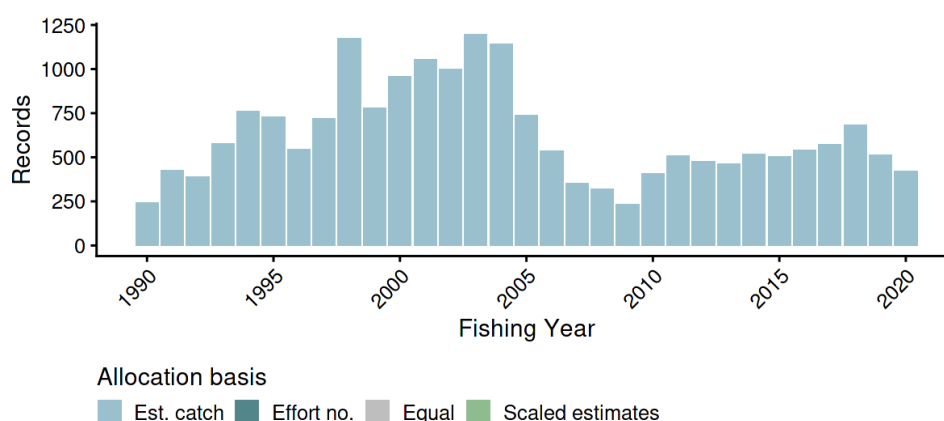


Figure 62: Allocation basis for attributing landings to records in the SKI7 BT+MW process daily catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table 13: Summary of stepwise selection for occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	29.00	17 965	32.90	32.90	*
+ bs(SeasonDay, 3)	3.00	16 971	36.70	3.70	*
+ vessel_key	73.00	16 150	40.30	3.60	*
+ bs(bottom_depth, 3)	3.00	15 866	41.40	1.10	*
+ primary_method	1.00	15 640	42.20	0.90	
+ ns(log(fishing_duration), 3)	3.00	15 527	42.70	0.40	
+ stat_area	1.00	15 507	42.80	0.10	

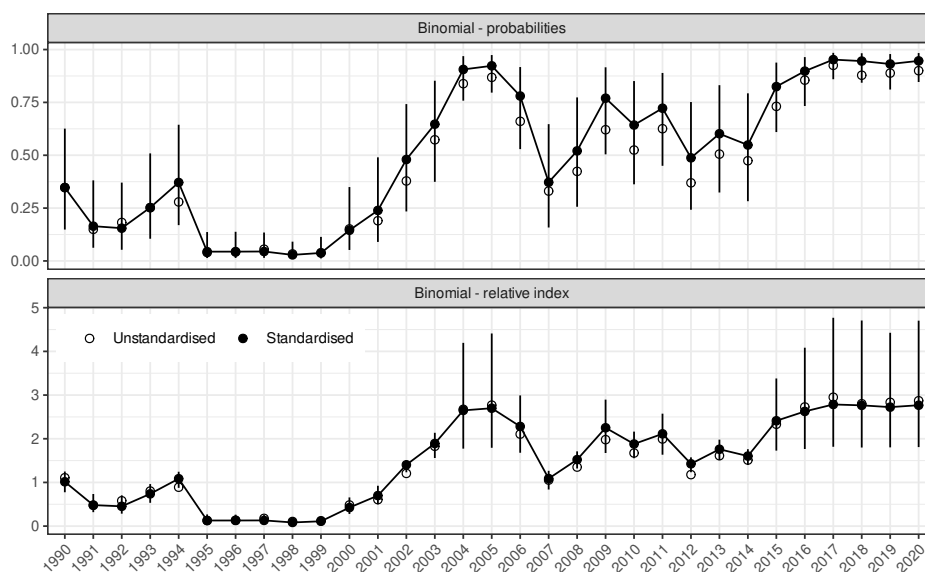


Figure 63: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SKI7 BT+MW process daily dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

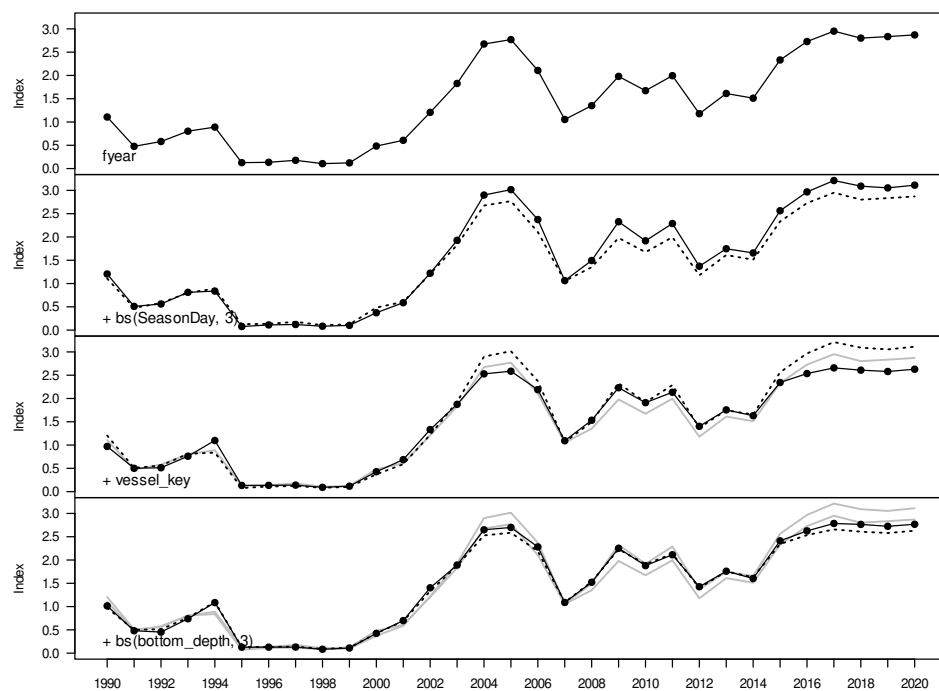


Figure 64: Step plot for occurrence of catch in the SKI7 BT+MW process daily dataset.

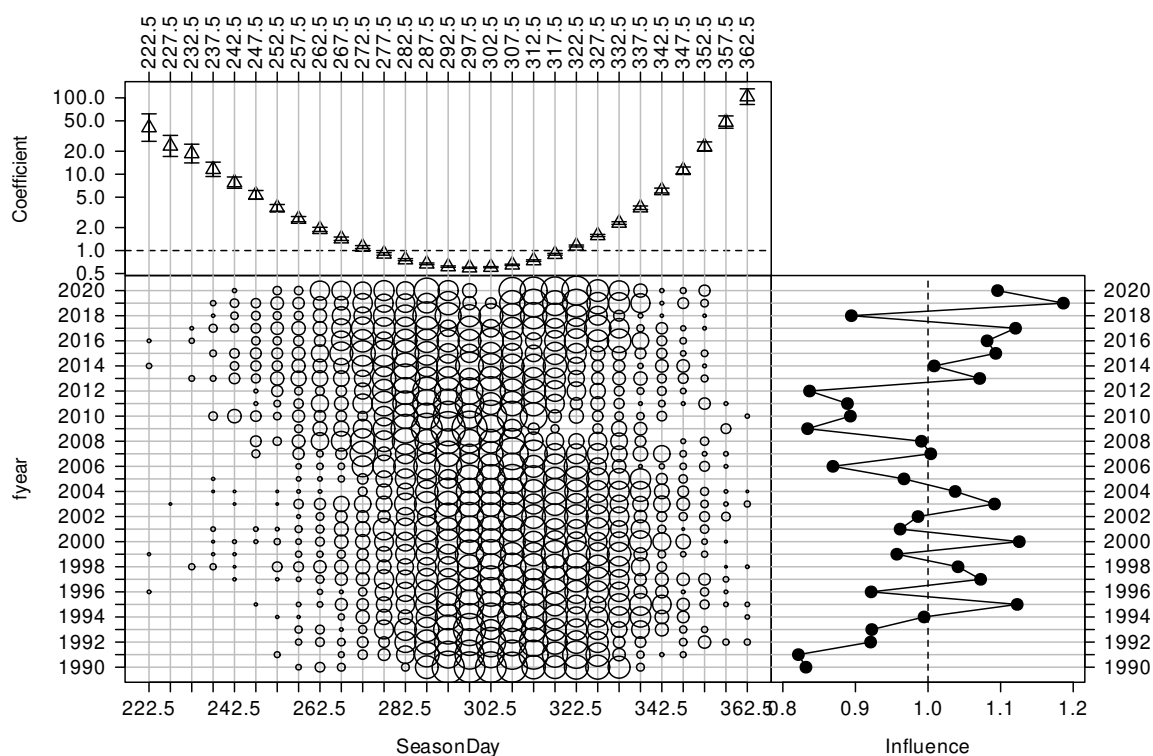


Figure 65: CDI plot for SeasonDay for the occurrence of positive catch SKI7 BT+MW process daily catch-per-unit-effort dataset.

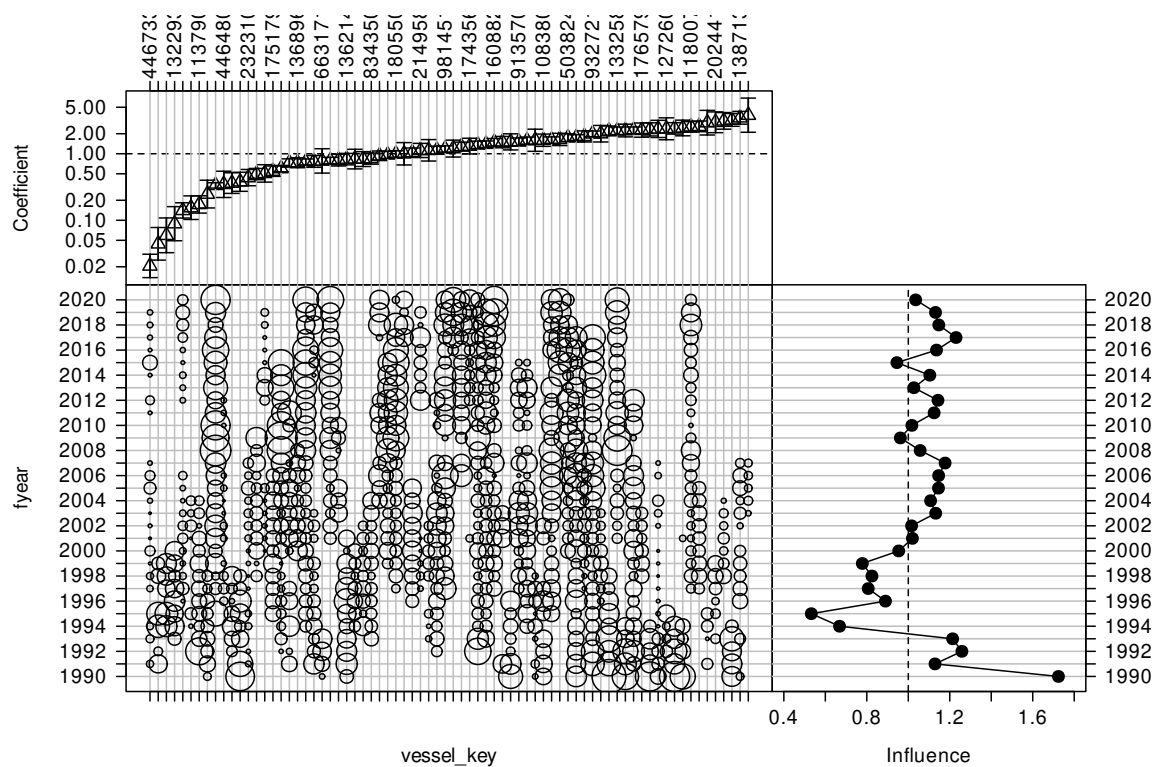


Figure 66: CDI plot for vessel key for the occurrence of positive catch SKI7 BT+MW process daily catch-per-unit-effort dataset.

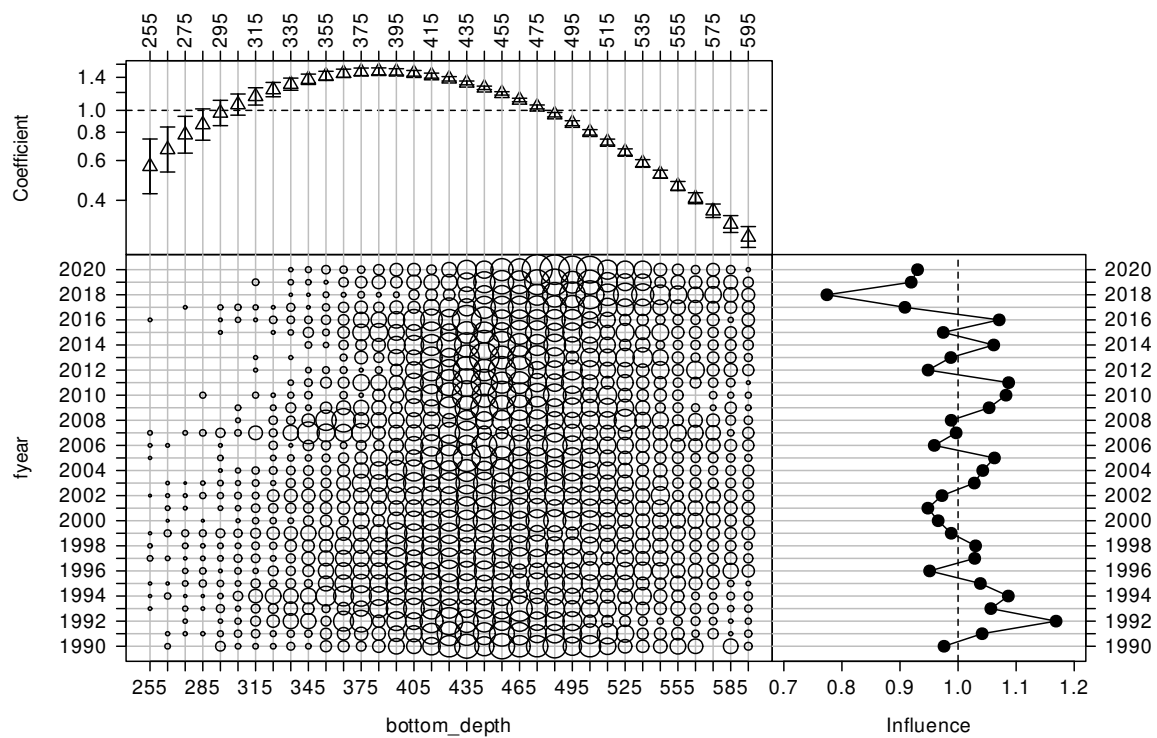


Figure 67: CDI plot for bottom depth (m) for the occurrence of positive catch SKI7 BT+MW process daily catch-per-unit-effort dataset.

Table 14: Summary of stepwise selection for the lognormal model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	29	29 899	30.6	30.6	*
+ bs(SeasonDay, 3)	3	28 203	43.2	12.6	*
+ vessel key	73	27 048	51.3	8.1	*
+ primary method	1	26 685	53.3	2.1	*
+ bs(bottom depth, 3)	3	26 415	54.8	1.5	*
+ ns(log(fishing duration), 3)	3	26 349	55.2	0.4	

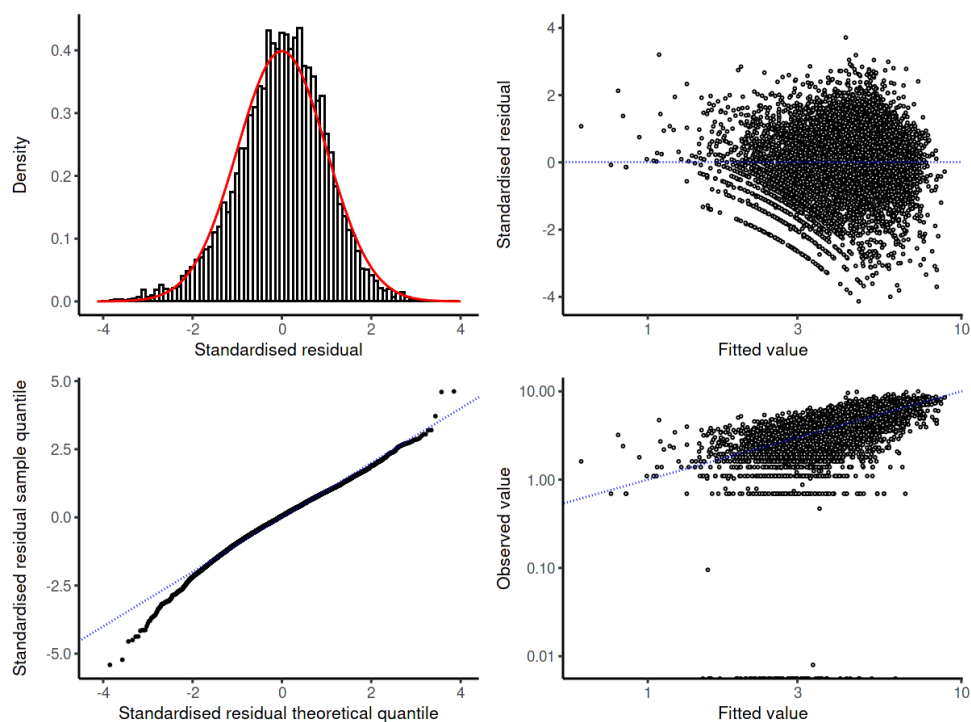


Figure 68: Diagnostic plots for the lognormal model for the SKI7 BT+MW process daily dataset.

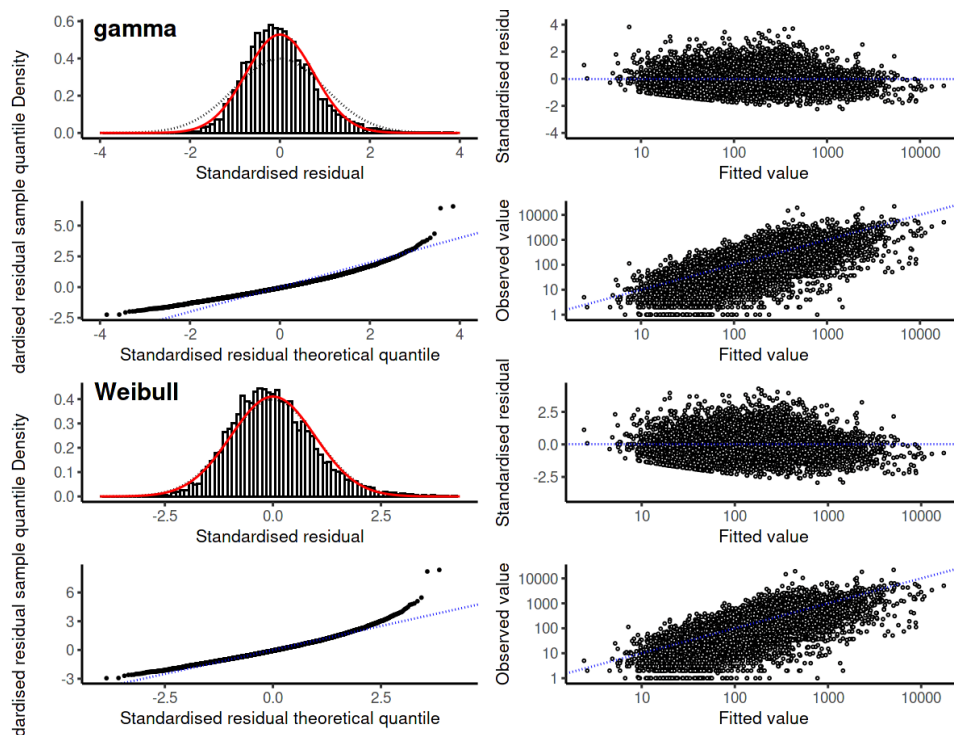


Figure 69: Diagnostic plots for the gamma and Weibull model for the SKI7 BT+MW process daily dataset.

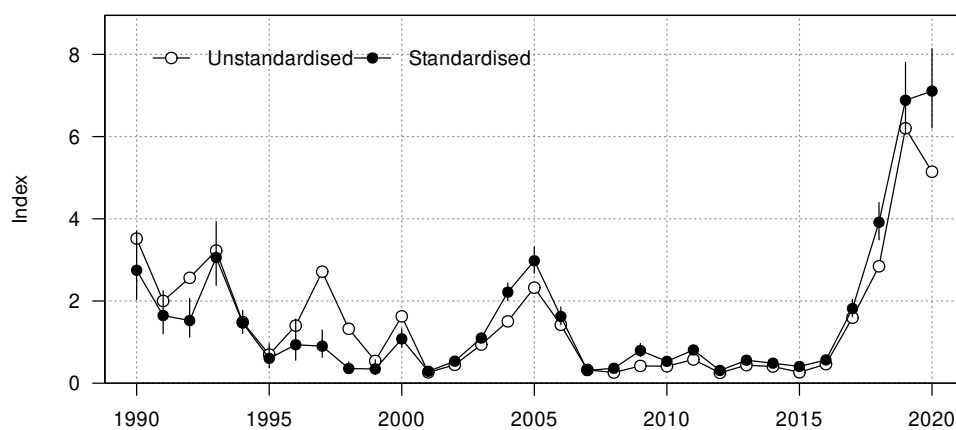


Figure 70: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SKI7 BT+MW process daily dataset.

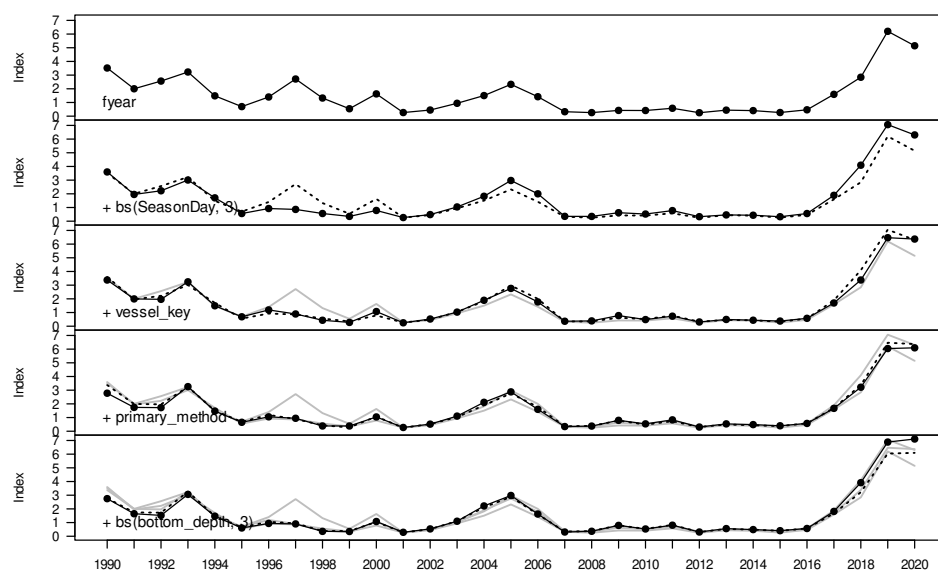


Figure 71: Changes to the SKI7 BT+MW process daily positive catch index as terms are successively entered into the model.

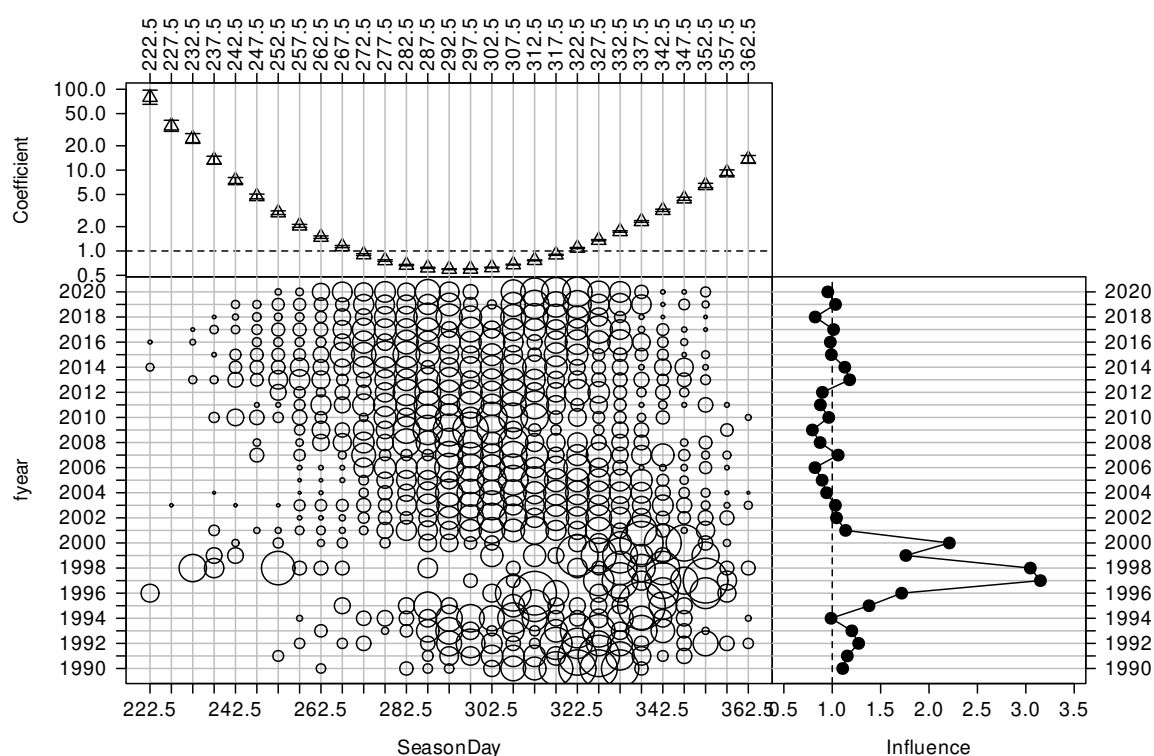


Figure 72: CDI plot for SeasonDay for the positive catch SKI7 BT+MW process daily catch-per-unit-effort dataset.

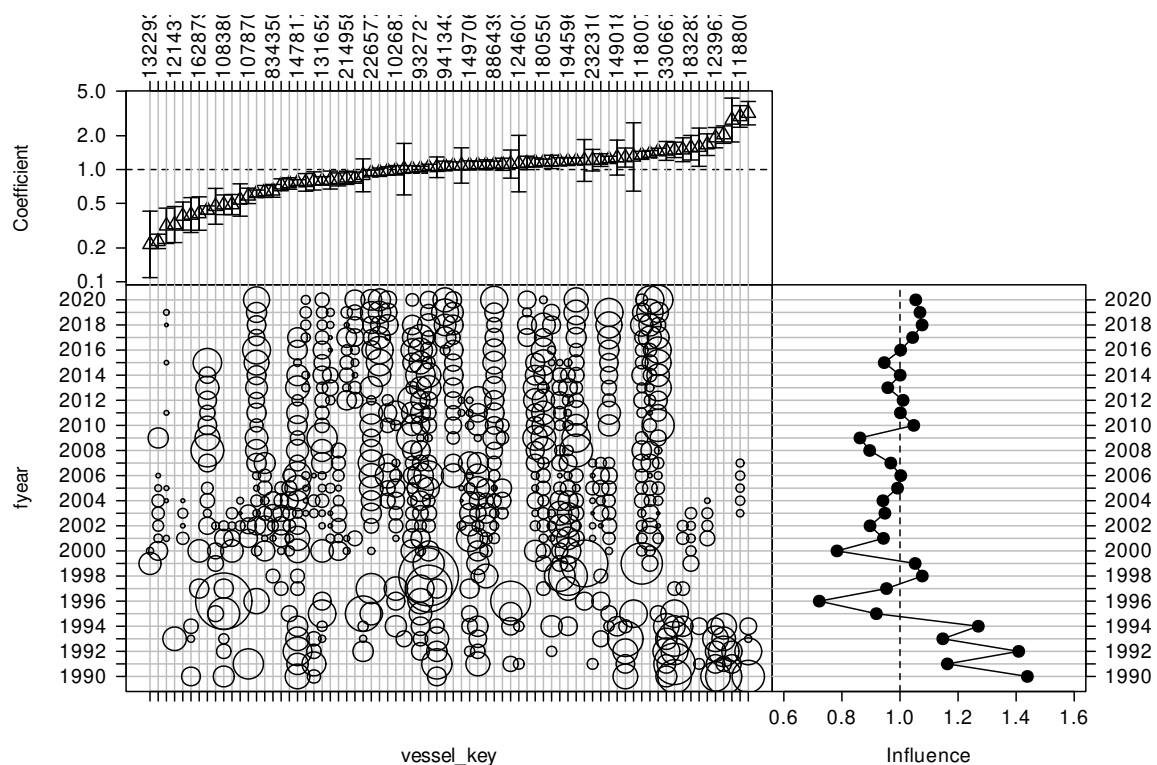


Figure 73: CDI plot for vessel key for the positive catch SKI7 BT+MW process daily catch-per-unit-effort dataset.

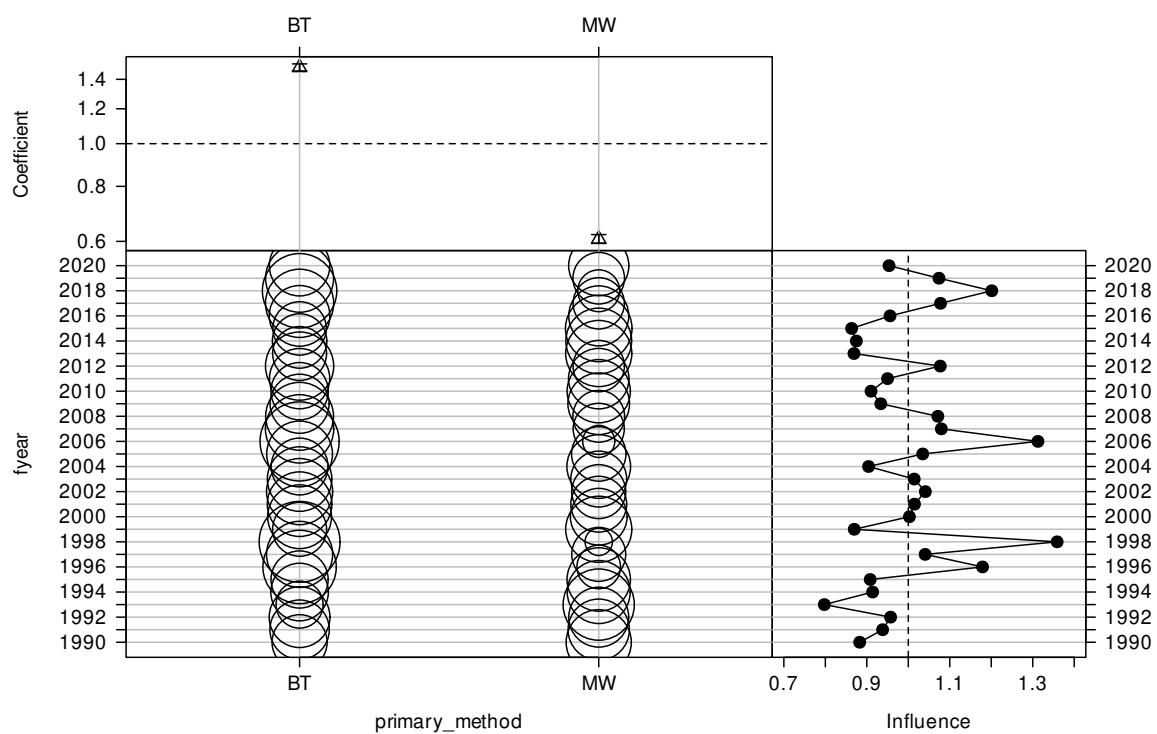


Figure 74: CDI plot for primary method for the positive catch SKI7 BT+MW process daily catch-per-unit-effort dataset.

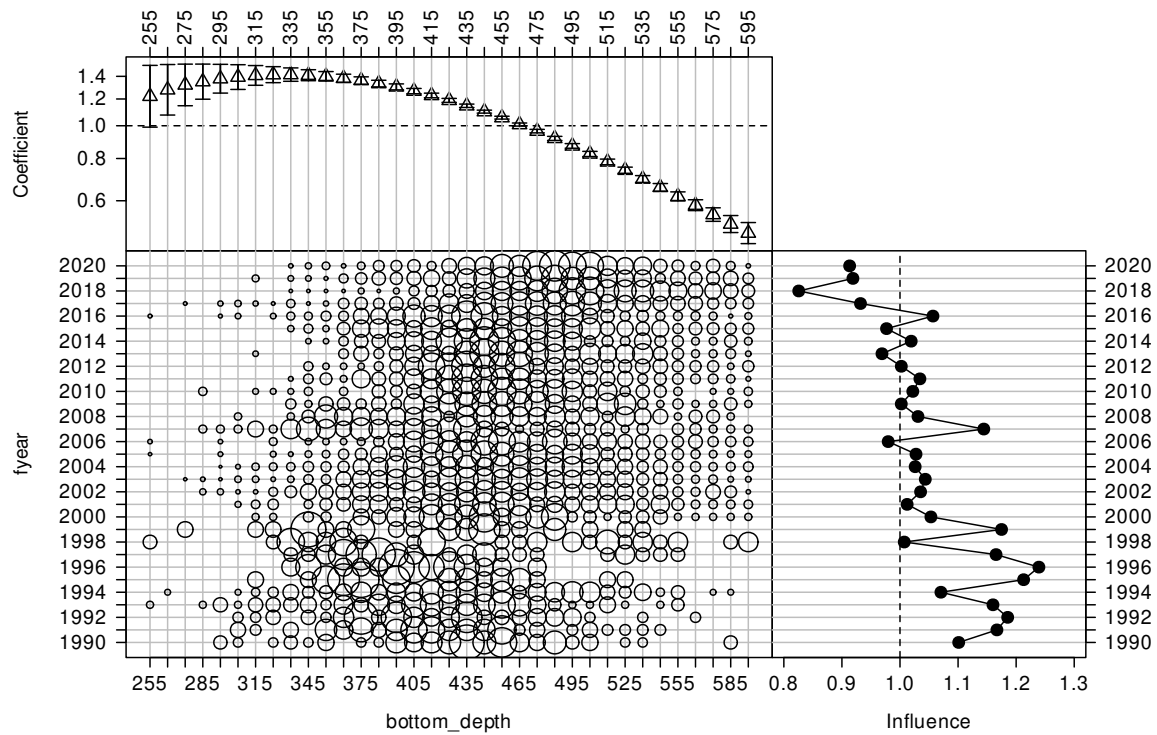


Figure 75: CDI plot for bottom depth (m) for the positive catch SKI7 BT+MW process daily catch-per-unit-effort dataset.

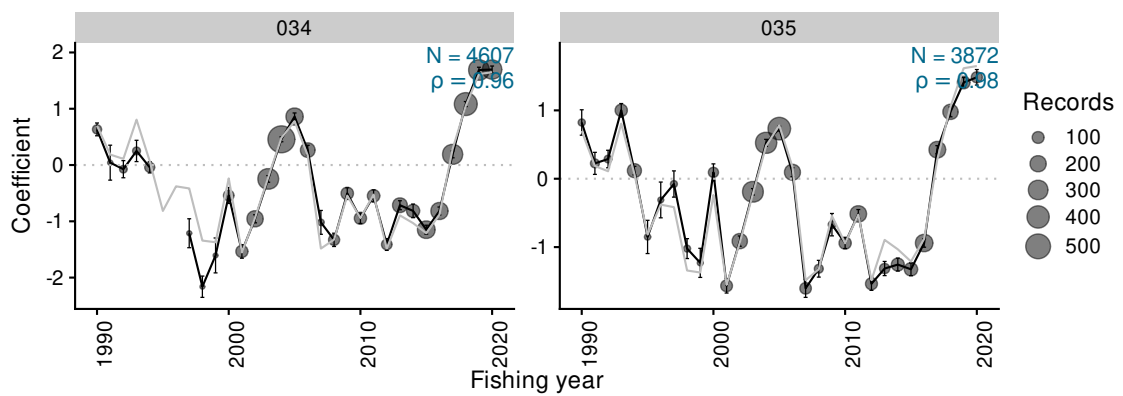


Figure 76: Residual implied coefficients for area-year in the lognormal positive catch model for the SKI7 BT+MW process daily dataset.

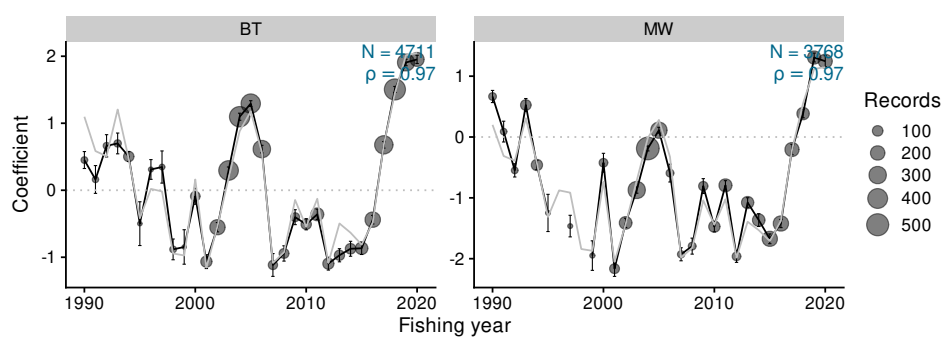


Figure 77: Residual implied coefficients for primary method-year in the lognormal positive catch model for the SKI7 BT+MW process daily dataset.

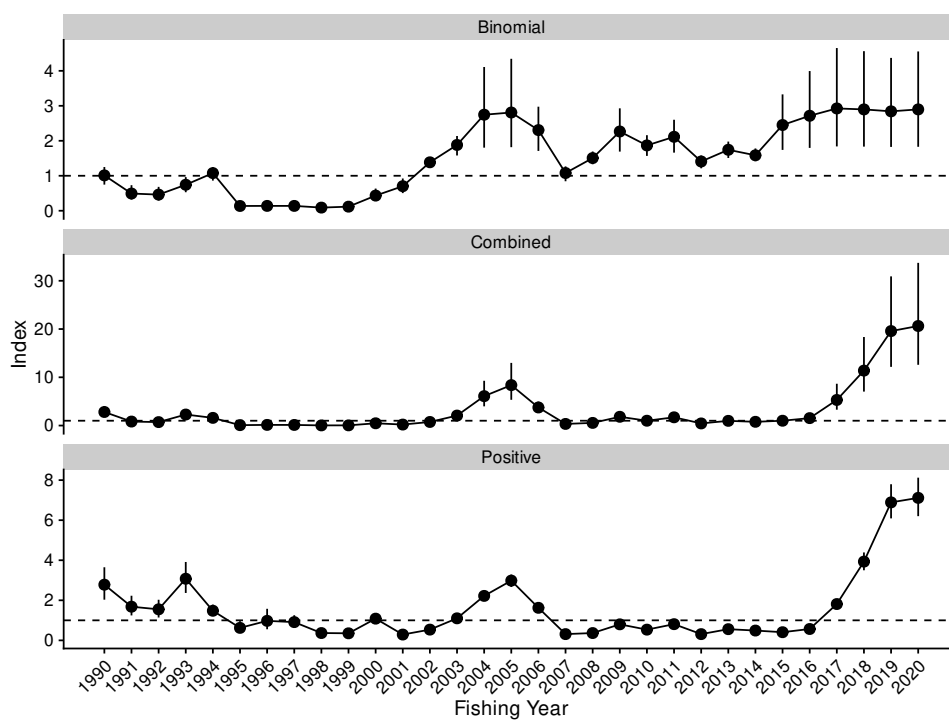


Figure 78: Standardised indices and 95% confidence intervals for the SKI7 BT+MW process daily dataset.

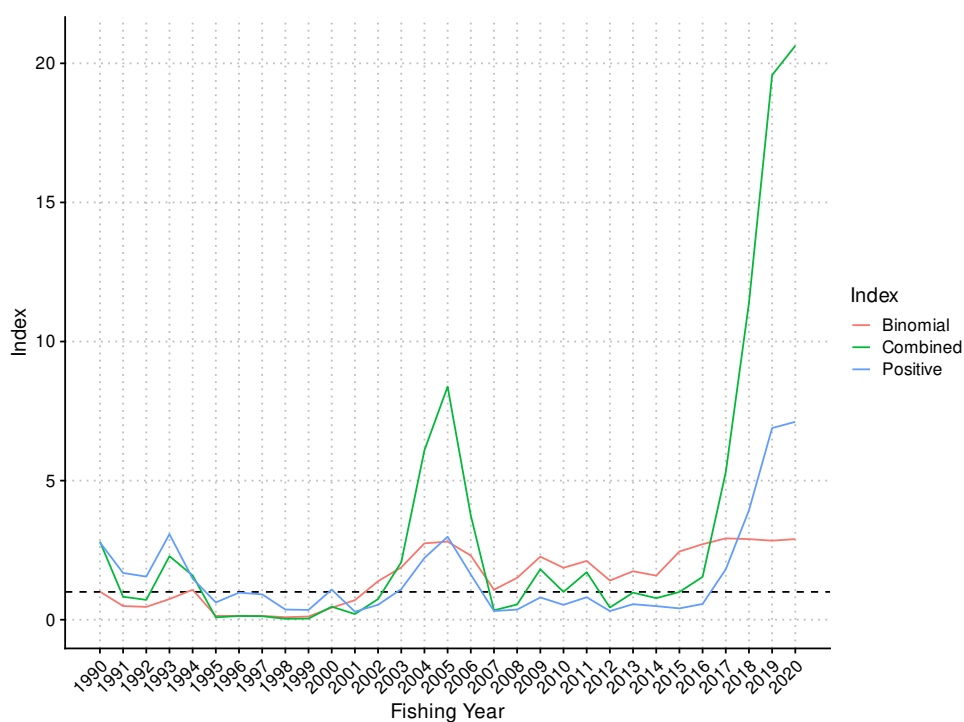


Figure 79: Standardised indices for the SKI7 BT+MW process daily dataset.

Table 15: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SKI7 BT+MW process daily.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	1.011	0.128	0.747	1.250	2.809	0.563	1.845	4.053	2.779	0.413	2.031	3.649
1991	0.492	0.105	0.318	0.730	0.826	0.223	0.473	1.346	1.681	0.251	1.244	2.228
1992	0.461	0.100	0.289	0.682	0.714	0.191	0.384	1.131	1.549	0.226	1.140	2.028
1993	0.743	0.110	0.529	0.961	2.284	0.443	1.477	3.214	3.076	0.395	2.366	3.914
1994	1.076	0.098	0.861	1.247	1.590	0.211	1.184	2.013	1.478	0.147	1.209	1.784
1995	0.136	0.048	0.069	0.256	0.085	0.031	0.037	0.160	0.623	0.145	0.388	0.957
1996	0.138	0.047	0.070	0.256	0.134	0.057	0.056	0.281	0.973	0.261	0.554	1.576
1997	0.138	0.043	0.075	0.243	0.126	0.048	0.059	0.247	0.911	0.158	0.636	1.255
1998	0.090	0.027	0.049	0.157	0.033	0.012	0.016	0.063	0.366	0.068	0.252	0.518
1999	0.116	0.038	0.062	0.212	0.041	0.018	0.018	0.087	0.352	0.091	0.206	0.563
2000	0.433	0.091	0.277	0.634	0.469	0.113	0.285	0.729	1.084	0.108	0.886	1.309
2001	0.702	0.107	0.504	0.922	0.203	0.037	0.139	0.282	0.290	0.024	0.246	0.340
2002	1.385	0.069	1.242	1.513	0.743	0.060	0.631	0.864	0.536	0.036	0.469	0.612
2003	1.881	0.142	1.580	2.137	2.069	0.190	1.693	2.436	1.100	0.061	0.987	1.225
2004	2.746	0.588	1.804	4.109	6.092	1.352	3.978	9.277	2.220	0.106	2.016	2.430
2005	2.809	0.645	1.817	4.344	8.376	1.951	5.336	12.984	2.982	0.159	2.664	3.287
2006	2.306	0.323	1.710	2.975	3.747	0.585	2.682	4.976	1.625	0.100	1.434	1.828
2007	1.079	0.108	0.843	1.268	0.337	0.051	0.242	0.442	0.312	0.033	0.254	0.385
2008	1.506	0.093	1.329	1.694	0.550	0.064	0.433	0.686	0.365	0.036	0.300	0.440
2009	2.266	0.316	1.691	2.928	1.813	0.309	1.246	2.459	0.800	0.081	0.656	0.972
2010	1.867	0.151	1.568	2.160	0.999	0.115	0.780	1.231	0.535	0.043	0.452	0.621
2011	2.114	0.240	1.661	2.601	1.708	0.221	1.283	2.150	0.808	0.057	0.702	0.925
2012	1.408	0.093	1.213	1.580	0.439	0.050	0.348	0.542	0.312	0.028	0.261	0.371
2013	1.743	0.120	1.509	1.977	0.973	0.101	0.786	1.181	0.559	0.044	0.474	0.648
2014	1.585	0.093	1.416	1.781	0.775	0.074	0.639	0.931	0.489	0.038	0.418	0.566
2015	2.451	0.405	1.739	3.327	0.998	0.180	0.688	1.395	0.407	0.025	0.360	0.458
2016	2.715	0.561	1.796	3.994	1.540	0.346	0.995	2.350	0.567	0.035	0.501	0.638
2017	2.925	0.718	1.839	4.652	5.303	1.372	3.285	8.662	1.813	0.100	1.623	2.013
2018	2.897	0.696	1.833	4.562	11.385	2.885	7.036	18.347	3.932	0.227	3.499	4.390
2019	2.842	0.649	1.825	4.370	19.577	4.783	12.163	30.912	6.889	0.435	6.089	7.794
2020	2.898	0.695	1.828	4.554	20.630	5.389	12.590	33.715	7.114	0.490	6.201	8.122

5.4 SKI3 BT+MW SShelf event

This series was based on the tow-by-tow bycatch of gemfish in the mixed target species Southland BT/MW fishery. The analysis included seven statistical areas at the southern end of the South Island, encompassing the Stewart-Snares shelf, Foveaux Strait and the waters around Stewart Island (Table 16). The MW component of the analysis was constrained to midwater gear fished within 10 m of the bottom and the target species suite included squid (SQU), barracouta (BAR), hoki (HOK), silver warehou (SWA), ling (LIN) and gemfish (SKI). The core fleet was defined by having fished at least once in each of five years (Figure 80), retaining 81% of the catch and reducing the fleet from over 150 vessels to 79 vessels. Some of the core fleet vessels had been present in the defined fishery for 20 years or more, but there were also vessels which had been in the fishery for relatively few years (Figure 81) compared with the SKI 7 core fleet. The final groomed dataset represented 43% (1992) to 100% (2007, 2008, 2009, 2010, 2013, 2014, 2017) of the annual catch (Table 17). The bycatch of gemfish in the defined fishery was less than 100 t/y from 1994 to 2016 (Table 18). Between 2016 and 2017, the bycatch of gemfish rose from 9 t to 142 t, and then peaked at 374 t in 2019 and 258 t in 2020. Most catches in the dataset were derived from landings allocated to each tow based on estimated catches (Figure 82).

The binomial (occurrence) model only accepted one predictive variable after fishing year (vessel), with the total model explaining under 17% of the deviance (Table 19). The unstandardised series showed a gradually increasing trend from 1992 to 2016, followed by a decline to the end of the series with almost no standardisation effect relative to the unstandardised series (Figure 83, Figure 84). Although there was a net positive corrective effect from the vessel covariate after 2002, the actual amount of the correction was small (compare Figure 85 with Figure 84).

The lognormal model accepted three predictive variables after fishing year (vessel, statistical area, bottom depth), with the total model explaining 59% of the deviance (Table 20). Residuals to the lognormal model show some skewness in the distribution residuals, but there was good conformity to the lognormal assumption over most of the distribution except for the upper tail of the distribution (Figure 86). Neither the Weibull nor the gamma distributions resulted in better fits to the positive catch data (Figure 87) than seen for the lognormal distribution. The lognormal model was characterised by two early indices at a relatively high level, followed by a long period of very low indices and then an abrupt increasing trend from 2017 to 2019 and a drop from 2019 to 2020, with the standardisation effect mainly raising the series in the final four years (Figure 88). Almost all this standardisation effect occurred with the addition of the vessel covariate, followed by the statistical area covariate (Figure 89). This effect from the addition of the vessel covariate may indicate (as with the SKI 7 HOK event series) that there may have been systematic effort on the part of the fleet to avoid gemfish in the final years of the series (Figure 90). The statistical area covariate had a similar effect, with a concentration of gemfish catch in Statistical Areas 026 and 028 off the west and east coasts of Stewart Island and in Statistical Area 504 (Stewart-Snares shelf) where the gemfish CPUE tended to be lower (Figure 91). Finally, the bottom depth covariate showed a move in the mid-2000s to a more shallow fishery at less than 200 m where SKI CPUE tended to be lower (Figure 92). Implied residual plots of gemfish annual CPUE showed good conformity with the overall annual CPUE trend across five of the six target species (there were too few SKI observations in the dataset; Figure 93), the seven statistical areas (Figure 94) and the two capture methods (Figure 95).

The multiplicative effect of the combined model exaggerated the increasing trend in both the binomial and lognormal components, resulting in a very strong increasing trend (Figure 96, Figure 97, Table 21).

Table 16: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SKI3 BT+MW SShelf event CPUE series.

Series	SKI3 BT+MW SShelf event
QMS stock	SKI3
Reporting forms	TCE, TCP, ERS - Trawl, CEL
Fishing methods	BT, MW
Target species	SQU, BAR, HOK, SWA, SKI, LIN
Statistical Areas	025, 026, 027, 028, 029, 030, 504
Period	1989-10-01, 2020-09-30
Resolution	Fishing event
Core fleet years	5
Core fleet trips	1
Default model	allockg_top5 ~ fyear + vessel_key + stat_area + target_species + primary_method + ns(log(fishing_duration), 3) + bs(start_latitude, 3) + bs(effort_width, 3) + bs(effort_height, 3) + bs(bottom_depth, 3) + bs(effort_speed, 3) + bs(start_hour, 3) + bs(SeasonDay, 3)
Stepwise selection	Yes
Positive catch distribution	Lognormal

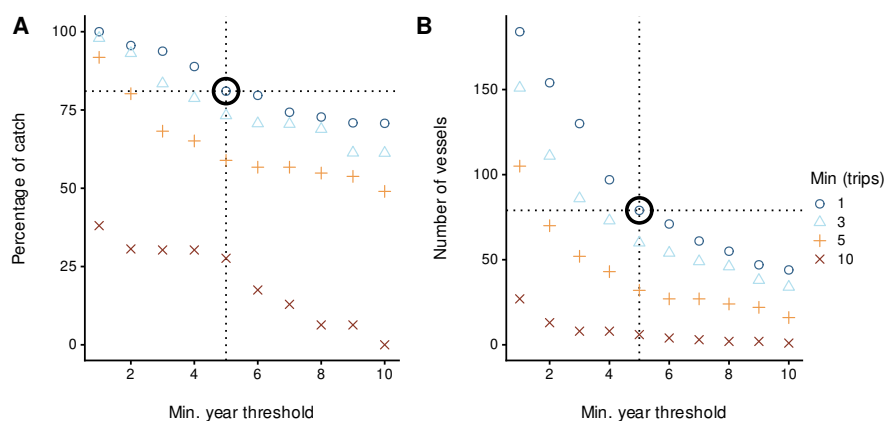


Figure 80: Percentage of catch and number of vessels for different core vessel selection criteria for the SKI3 BT+MW SShelf event CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

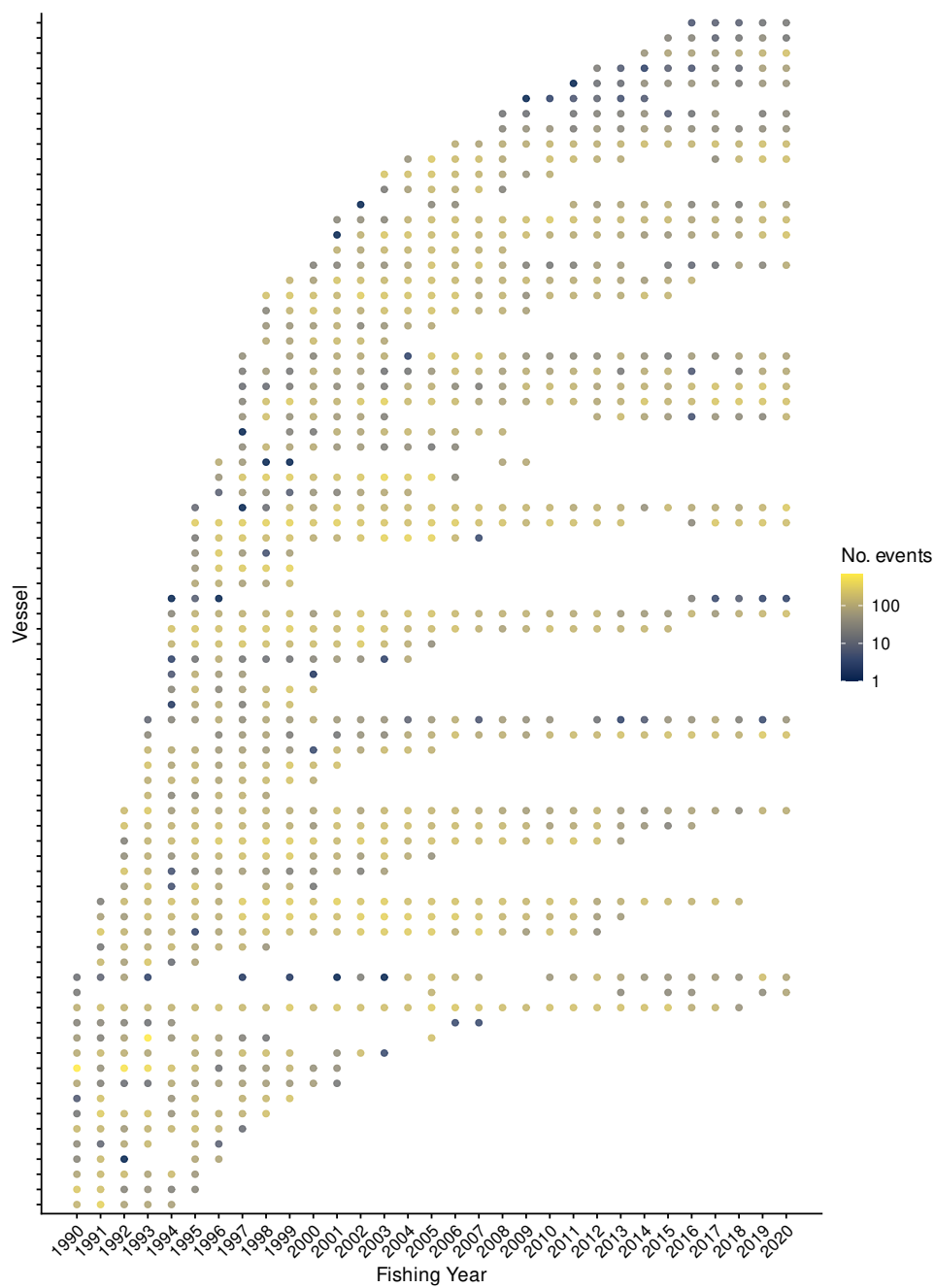


Figure 81: Number of events by fishing year for core vessels. The colour of the points is proportional to the number of events undertaken by a vessel in a fishing year.

Table 17: Summary of the SKI3 BT+MW SShelf event dataset total catch (tonnes) and number of records (n), by fishing year after the application of various filters. The first row gives the catch and number of records before filters were applied (ungroomed data). Subsequent rows display the remaining catch (and percent of catch), and the number of records, after the specified filter was applied. (Continued on next page)

Filter	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ungroomed data	435 (100%) n: 5985	201 (100%) n: 11062	131 (100%) n: 10029	231 (100%) n: 11333	38 (100%) n: 5817	64 (100%) n: 8378	13 (100%) n: 7632	50 (100%) n: 8606	16 (100%) n: 8554
Fishing duration is not NA	435 (100%) n: 5985	201 (100%) n: 11062	131 (100%) n: 10029	231 (100%) n: 11333	38 (100%) n: 5817	64 (100%) n: 8378	13 (100%) n: 7632	50 (100%) n: 8606	16 (100%) n: 8554
Positive fishing duration	435 (100%) n: 5985	201 (100%) n: 11060	131 (100%) n: 10029	231 (100%) n: 11332	38 (100%) n: 5816	64 (100%) n: 8378	13 (100%) n: 7629	50 (100%) n: 8603	16 (100%) n: 8552
Bottom depth >=50	435 (100%) n: 5974	201 (100%) n: 11051	131 (100%) n: 10027	231 (100%) n: 11313	38 (100%) n: 5808	64 (100%) n: 8355	13 (100%) n: 7615	50 (100%) n: 8575	16 (100%) n: 8536
Bottom depth <=600	434 (100%) n: 5279	200 (100%) n: 10061	131 (100%) n: 8146	231 (100%) n: 9557	38 (100%) n: 4982	64 (100%) n: 7326	12 (94%) n: 6722	48 (100%) n: 7321	15 (92%) n: 7515
Midwater effort depth <=10 m from bottom	429 (100%) n: 4958	199 (100%) n: 9666	131 (100%) n: 7921	231 (100%) n: 9193	37 (100%) n: 4726	63 (100%) n: 7017	12 (92%) n: 6347	47 (100%) n: 6907	15 (92%) n: 7425
Core fleet selection	303 (70%) n: 1867	86 (43%) n: 2535	67 (51%) n: 2908	142 (61%) n: 4488	35 (91%) n: 2891	54 (84%) n: 4619	9.6 (73%) n: 4625	46 (92%) n: 5129	14 (86%) n: 6234

Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	15 (100%) n: 8844	43 (100%) n: 6023	41 (100%) n: 7246	61 (100%) n: 6751	86 (100%) n: 7007	60 (100%) n: 6182	64 (100%) n: 7742	39 (100%) n: 6408	18 (100%) n: 5196
Fishing duration is not NA	15 (100%) n: 8844	43 (100%) n: 6023	41 (100%) n: 7246	61 (100%) n: 6751	86 (100%) n: 7007	60 (100%) n: 6182	64 (100%) n: 7742	39 (100%) n: 6408	18 (100%) n: 5196
Positive fishing duration	15 (100%) n: 8842	43 (100%) n: 6021	41 (100%) n: 7245	61 (100%) n: 6751	86 (100%) n: 7006	60 (100%) n: 6179	64 (100%) n: 7739	39 (100%) n: 6407	18 (100%) n: 5196
Bottom depth >=50	15 (100%) n: 8815	43 (100%) n: 5997	41 (100%) n: 7221	61 (100%) n: 6728	86 (100%) n: 6964	60 (100%) n: 6141	64 (100%) n: 7684	37 (100%) n: 6232	17 (100%) n: 5068
Bottom depth <=600	12 (77%) n: 7908	18 (41%) n: 4653	39 (100%) n: 5829	59 (100%) n: 5777	85 (100%) n: 6409	60 (100%) n: 5843	62 (100%) n: 7455	37 (100%) n: 5949	17 (100%) n: 4747
Midwater effort depth <=10 m from bottom	12 (76%) n: 7575	17 (39%) n: 4427	38 (94%) n: 5352	59 (100%) n: 5594	82 (100%) n: 6207	60 (100%) n: 5736	61 (95%) n: 7089	37 (100%) n: 5792	17 (100%) n: 4585
Core fleet selection	12 (76%) n: 7000	17 (39%) n: 4322	38 (94%) n: 5243	57 (93%) n: 5488	81 (94%) n: 6059	60 (100%) n: 5687	61 (95%) n: 6734	36 (95%) n: 5389	17 (100%) n: 4301

Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	11 (100%) n: 4110	5.5 (100%) n: 3200	13 (100%) n: 3931	23 (100%) n: 3833	6.5 (100%) n: 3668	13 (100%) n: 3300	24 (100%) n: 2903	15 (100%) n: 3101	9.9 (100%) n: 2474
Fishing duration is not NA	11 (100%) n: 4110	5.5 (100%) n: 3200	13 (100%) n: 3931	23 (100%) n: 3833	6.5 (100%) n: 3668	13 (100%) n: 3300	24 (100%) n: 2903	15 (100%) n: 3101	9.9 (100%) n: 2474
Positive fishing duration	11 (100%) n: 4109	5.5 (100%) n: 3197	13 (100%) n: 3930	23 (100%) n: 3832	6.5 (100%) n: 3667	13 (100%) n: 3297	24 (100%) n: 2900	15 (100%) n: 3100	9.9 (100%) n: 2472
Bottom depth >=50	11 (100%) n: 4102	5.5 (100%) n: 3195	13 (100%) n: 3929	23 (100%) n: 3823	6.5 (100%) n: 3661	13 (100%) n: 3294	24 (100%) n: 2894	15 (100%) n: 3095	9.9 (100%) n: 2469
Bottom depth <=600	10 (100%) n: 3762	5.5 (100%) n: 2953	13 (100%) n: 3607	23 (100%) n: 3523	6.4 (100%) n: 3341	13 (100%) n: 2879	24 (100%) n: 2530	15 (100%) n: 2630	9.8 (100%) n: 2256
Midwater effort depth <=10 m from bottom	10 (100%) n: 3620	5.5 (100%) n: 2886	12 (100%) n: 3578	23 (100%) n: 3495	6.4 (100%) n: 3293	13 (100%) n: 2868	24 (100%) n: 2519	15 (100%) n: 2584	9.8 (100%) n: 2230
Core fleet selection	10 (100%) n: 3616	5.5 (100%) n: 2883	12 (100%) n: 3497	21 (94%) n: 3316	6.1 (93%) n: 3229	12 (100%) n: 2796	23 (100%) n: 2464	13 (89%) n: 2540	8.9 (90%) n: 2108

Filter	2017	2018	2019	2020
Ungroomed data	145 (100%) n: 3010	284 (100%) n: 2694	438 (100%) n: 3973	307 (100%) n: 4290
Fishing duration is not NA	145 (100%) n: 3010	284 (100%) n: 2691	438 (100%) n: 3972	307 (100%) n: 4290
Positive fishing duration	145 (100%) n: 3010	284 (100%) n: 2688	438 (100%) n: 3972	307 (100%) n: 4290
Bottom depth >=50	145 (100%) n: 2996	284 (100%) n: 2686	438 (100%) n: 3966	307 (100%) n: 4277
Bottom depth <=600	145 (100%) n: 2671	284 (100%) n: 2486	436 (100%) n: 3888	306 (100%) n: 4224
Midwater effort depth <=10 m from bottom	144 (100%) n: 2628	283 (100%) n: 2451	431 (100%) n: 3768	305 (100%) n: 4109
Core fleet selection	143 (100%) n: 2446	266 (94%) n: 2166	374 (86%) n: 3121	260 (85%) n: 3305

Table 18: Summary of the SKI3 BT+MW SShelf event dataset after core fleet selection. ‘Records’ indicates the number of rows (events) in the dataset, and ‘Records caught’ indicates the percentage of events with catches of gemfish.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
1990	16	59	1 867	6 864.63	302.98	30.85
1991	20	103	2 535	9 384.75	86.48	24.58
1992	25	89	2 908	10 636.82	67.41	13.03
1993	30	160	4 488	16 127.78	142.00	20.79
1994	35	137	2 891	12 496.83	34.67	17.43
1995	42	173	4 619	18 469.40	54.09	22.54
1996	41	203	4 625	18 877.41	9.58	18.27
1997	47	191	5 129	20 452.48	46.20	21.68
1998	47	190	6 234	26 375.42	14.17	19.12
1999	47	219	7 000	30 691.77	11.50	35.43
2000	40	170	4 322	19 515.77	16.89	30.19
2001	42	188	5 243	22 632.73	38.47	40.09
2002	40	193	5 488	23 836.52	57.10	42.51
2003	41	189	6 059	26 012.80	80.53	37.93
2004	38	200	5 687	23 359.32	60.06	56.29
2005	39	204	6 734	31 911.20	60.67	45.86
2006	35	178	5 371	28 013.21	36.44	45.78
2007	32	166	4 301	23 372.17	17.28	55.66
2008	32	160	3 616	19 672.61	10.17	46.71
2009	29	158	2 883	14 899.89	5.49	62.71
2010	28	150	3 497	20 875.05	12.44	68.03
2011	29	153	3 316	18 372.42	21.45	69.03
2012	32	183	3 229	17 169.53	6.08	60.92
2013	32	146	2 796	15 186.08	12.38	75.86
2014	27	171	2 464	12 823.05	23.12	59.78
2015	29	157	2 540	13 071.42	13.43	61.50
2016	30	161	2 108	9 593.38	8.87	64.71
2017	27	156	2 440	12 541.73	142.75	48.28
2018	27	148	2 106	10 406.23	265.33	44.68
2019	27	175	3 072	15 653.10	373.48	45.80
2020	27	179	3 244	15 822.12	258.46	42.60

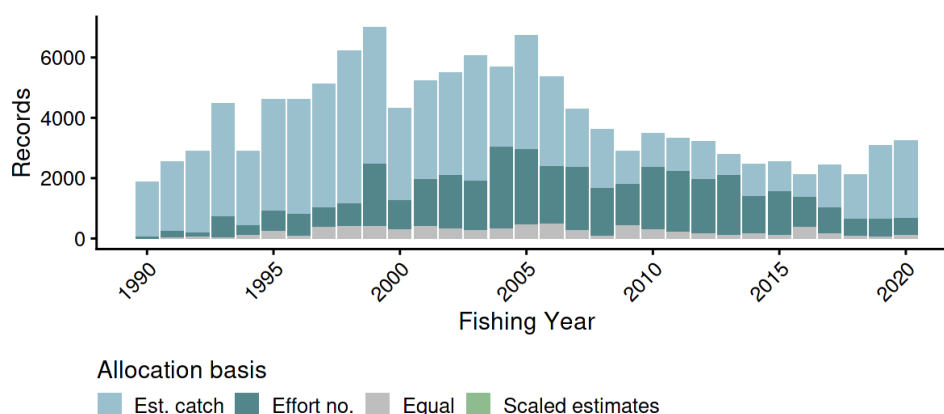


Figure 82: Allocation basis for attributing landings to records in the SKI3 BT+MW SShelf event catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table 19: Summary of stepwise selection for occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	29.00	152 226	8.70	8.70	*
+ vessel_key	80.00	139 152	16.60	7.90	*
+ bs(SeasonDay, 3)	3.00	138 444	17.00	0.40	
+ stat_area	6.00	137 809	17.40	0.40	
+ target_species	5.00	137 425	17.70	0.20	
+ bs(bottom_depth, 3)	3.00	137 241	17.80	0.10	
+ ns(log(fishing_duration), 3)	3.00	137 169	17.80	0.00	
+ primary_method	1.00	137 150	17.80	0.00	
+ bs(effort_height, 3)	3.00	137 090	17.90	0.00	
+ bs(effort_speed, 3)	3.00	137 073	17.90	0.00	
+ bs(start_hour, 3)	3.00	137 063	17.90	0.00	

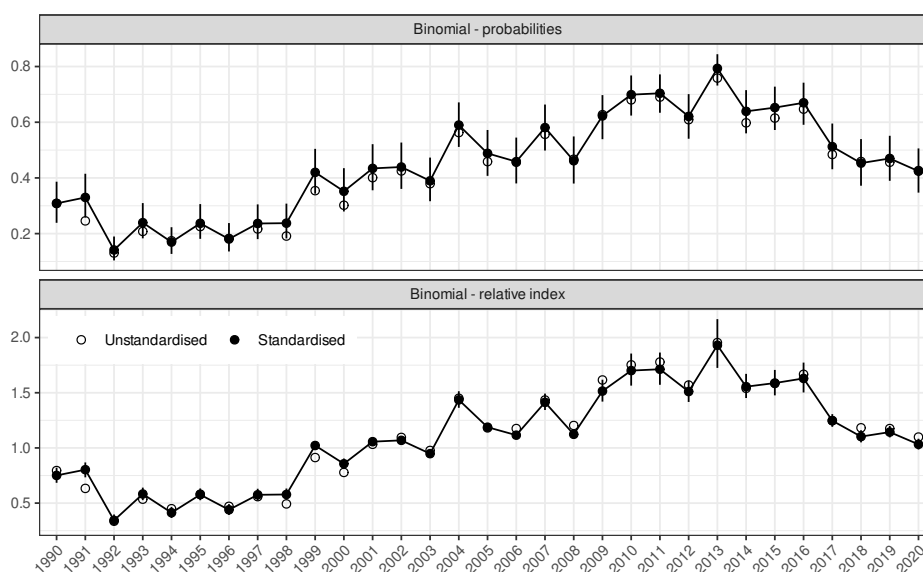


Figure 83: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SKI3 BT+MW SShelf event dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

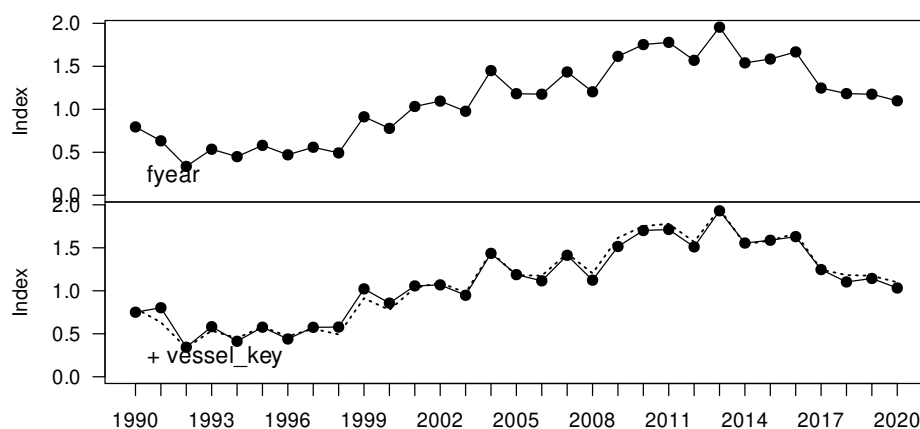


Figure 84: Step plot for occurrence of catch in the SKI3 BT+MW SShelf event dataset.

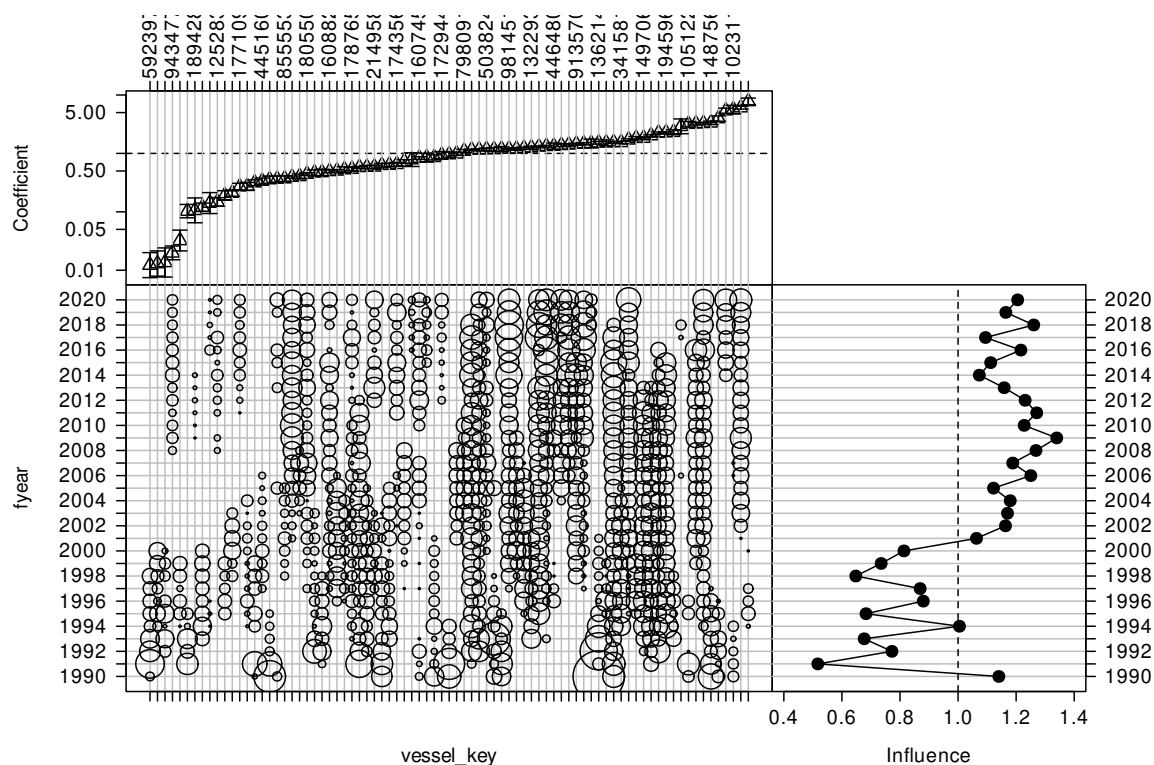


Figure 85: CDI plot for vessel key for the occurrence of positive catch SKI3 BT+MW SShelf event catch-per-unit-effort dataset.

Table 20: Summary of stepwise selection for the lognormal model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	29	210376	32.2	32.2	*
+ vessel key	80	194889	50.3	18.1	*
+ stat area	6	187591	57.0	6.7	*
+ bs(bottom depth, 3)	3	185041	59.1	2.1	*
+ bs(SeasonDay, 3)	3	184296	59.7	0.6	
+ target species	5	183864	60.0	0.4	
+ bs(start latitude, 3)	3	183721	60.2	0.1	
+ primary method	1	183661	60.2	0.0	
+ bs(effort width, 3)	3	183580	60.3	0.1	
+ ns(log(fishing duration), 3)	3	183554	60.3	0.0	
+ bs(start hour, 3)	3	183531	60.3	0.0	
+ bs(effort height, 3)	3	183511	60.3	0.0	

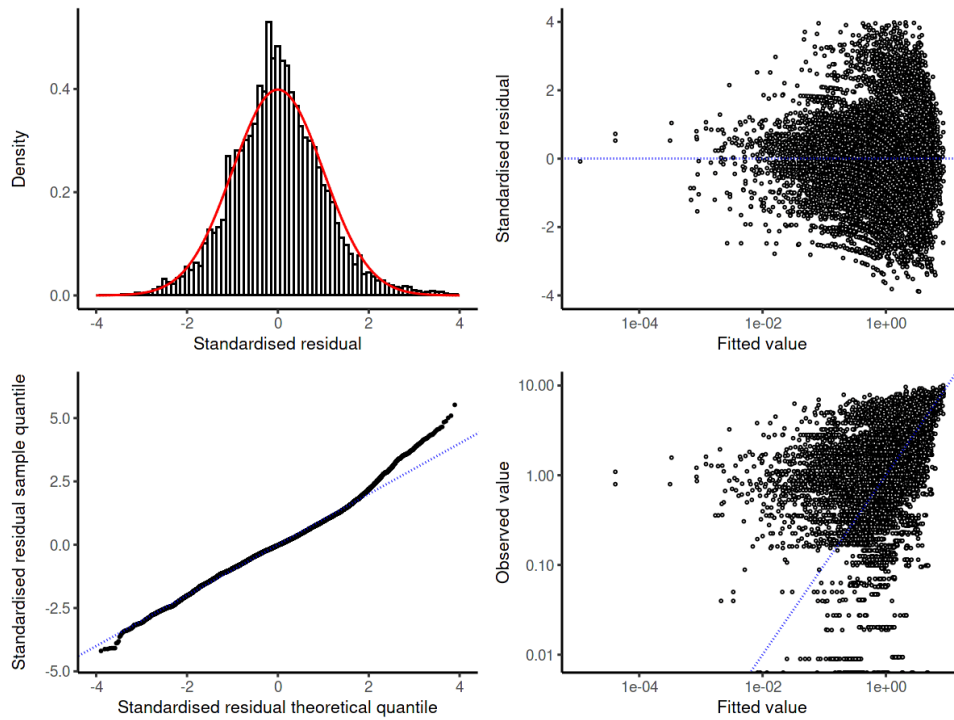


Figure 86: Diagnostic plots for the lognormal model for the SKI3 BT+MW SShelf event dataset.

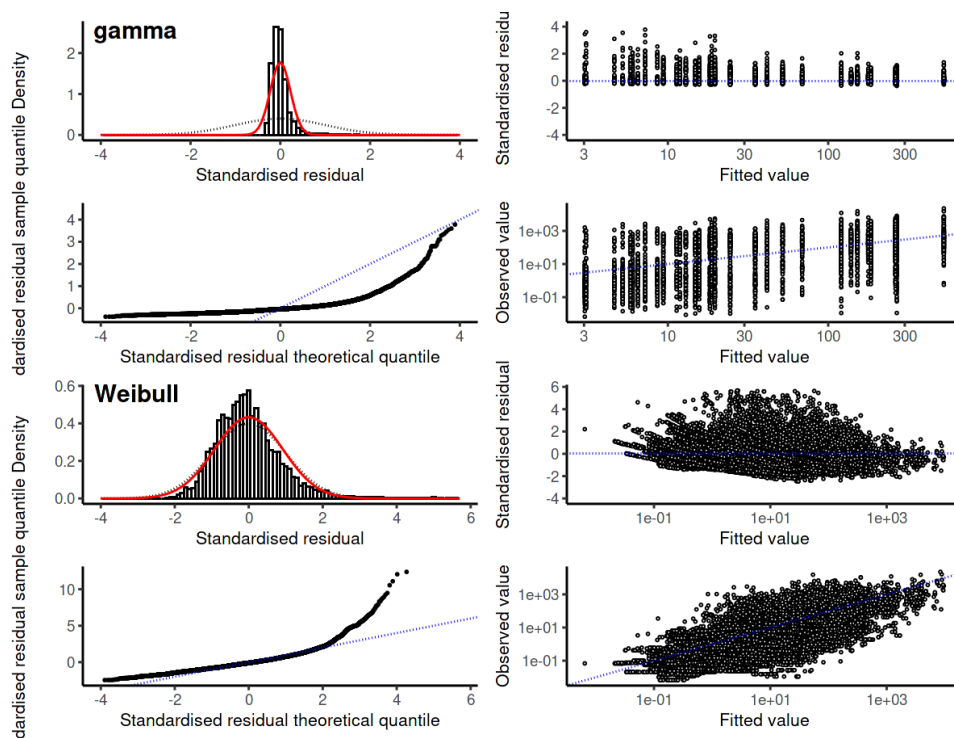


Figure 87: Diagnostic plots for the gamma and Weibull model for the SKI3 BT+MW SShelf event dataset.

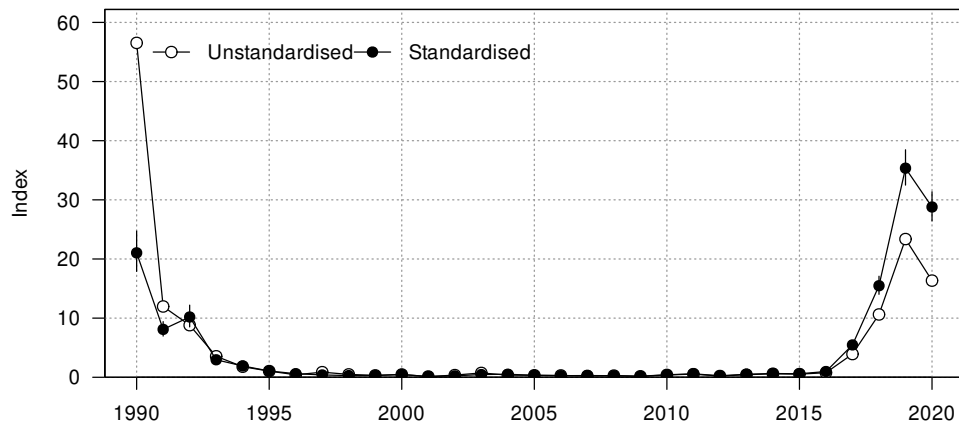


Figure 88: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SKI3 BT+MW SShelf event dataset.

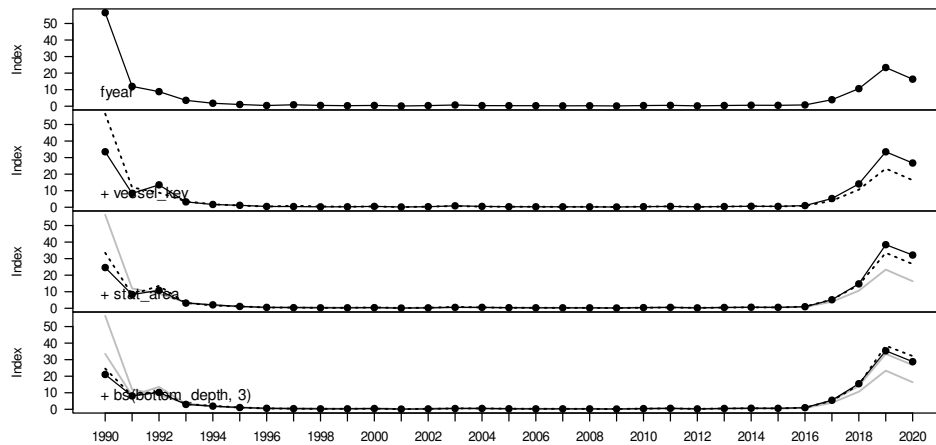


Figure 89: Changes to the SKI3 BT+MW SShelf event positive catch index as terms are successively entered into the model.

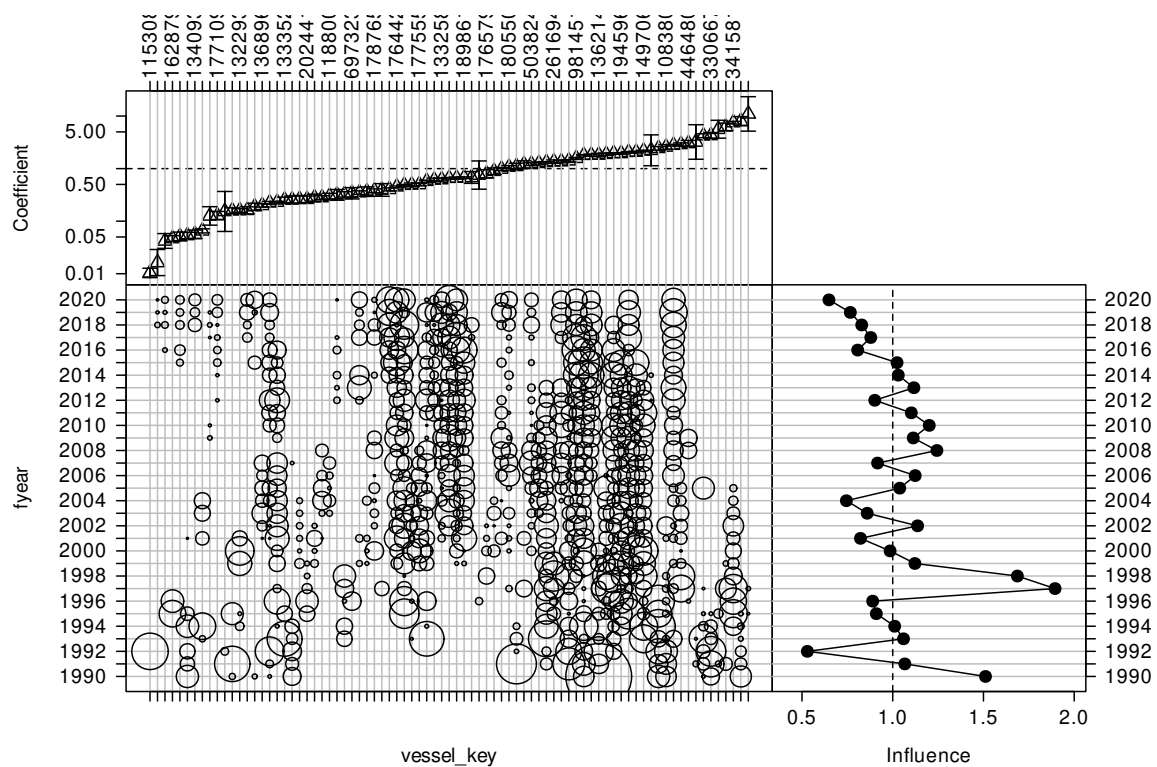


Figure 90: CDI plot for vessel key for the positive catch SKI3 BT+MW SShelf event catch-per-unit-effort dataset.

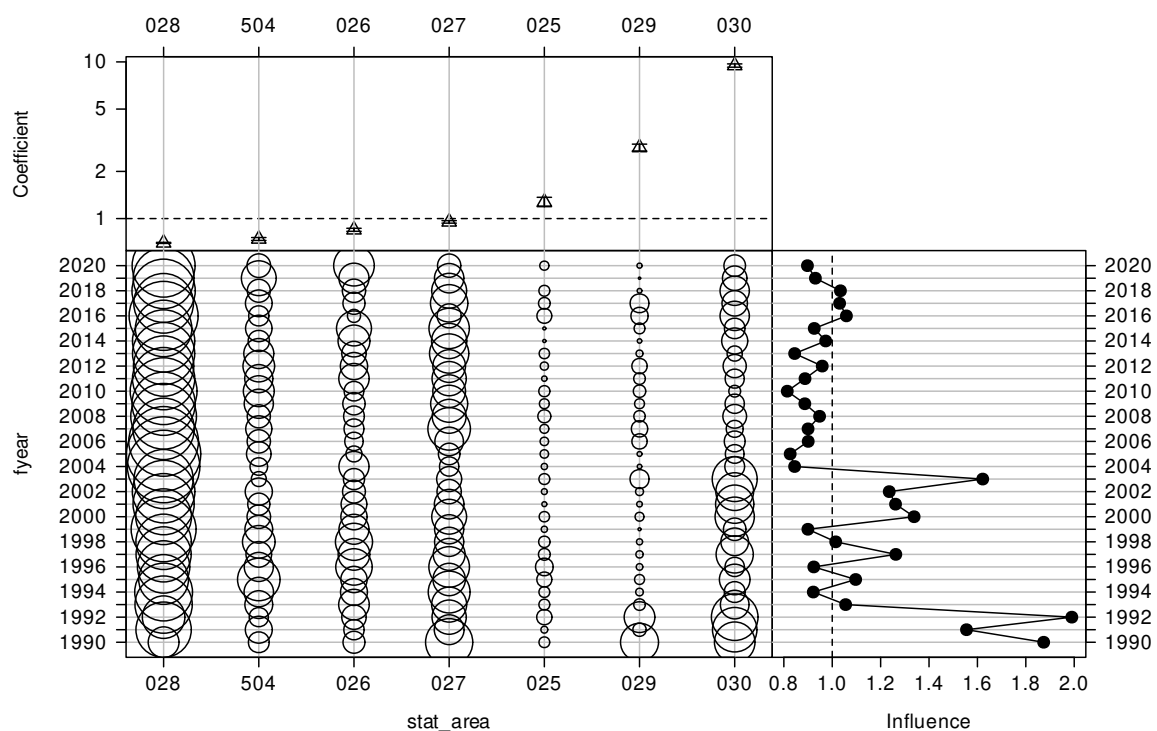


Figure 91: CDI plot for statistical area for the positive catch SKI3 BT+MW SShelf event catch-per-unit-effort dataset.

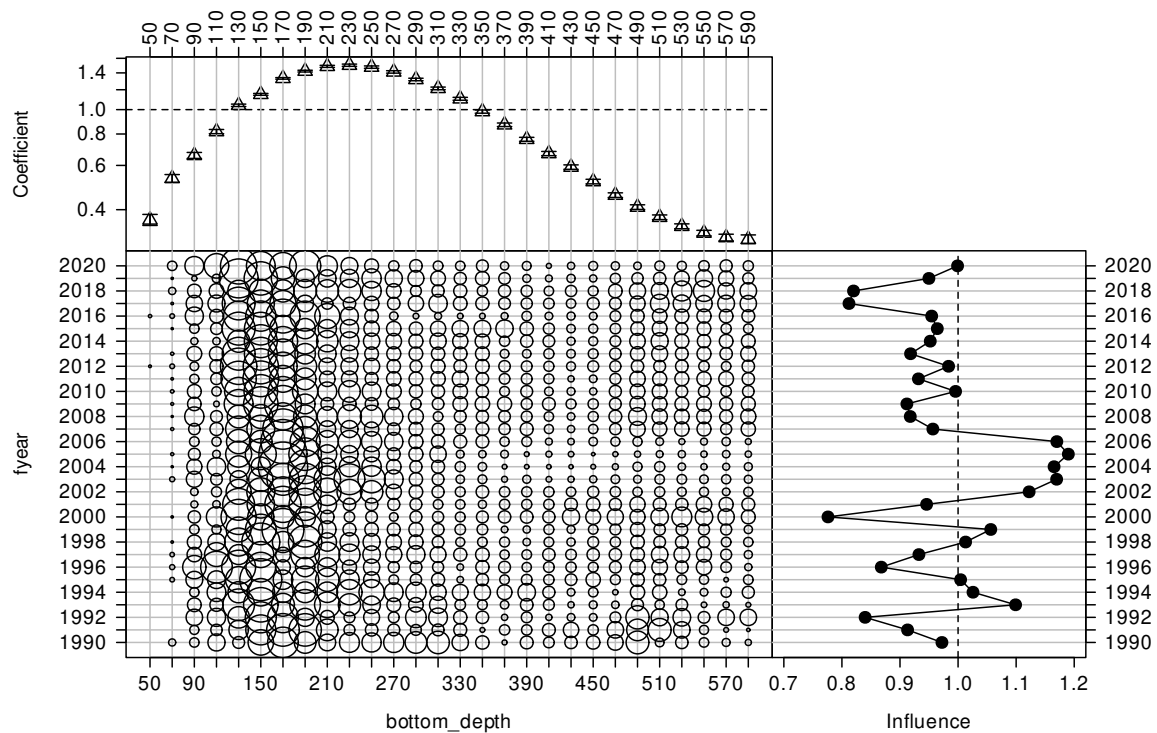


Figure 92: CDI plot for bottom depth (m) for the positive catch SKI3 BT+MW SShelf event catch-per-unit-effort dataset.

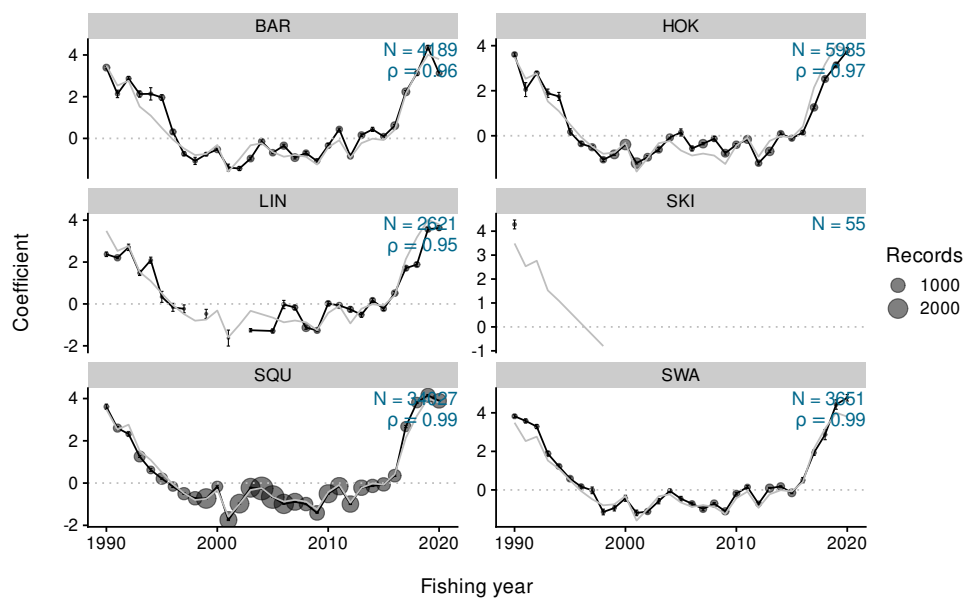


Figure 93: Residual implied coefficients for target-year in the lognormal positive catch model for the SKI3 BT+MW SShelf event dataset.

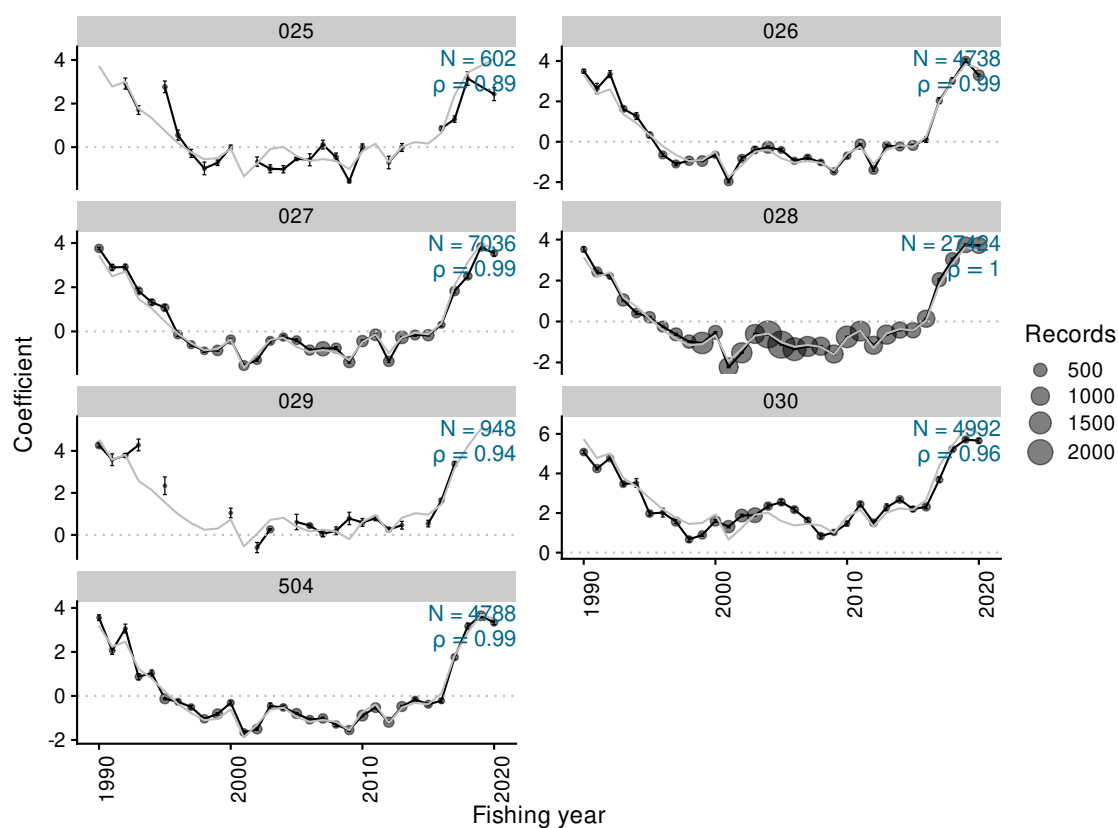


Figure 94: Residual implied coefficients for area-year in the lognormal positive catch model for the SKI3 BT+MW SShelf event dataset.

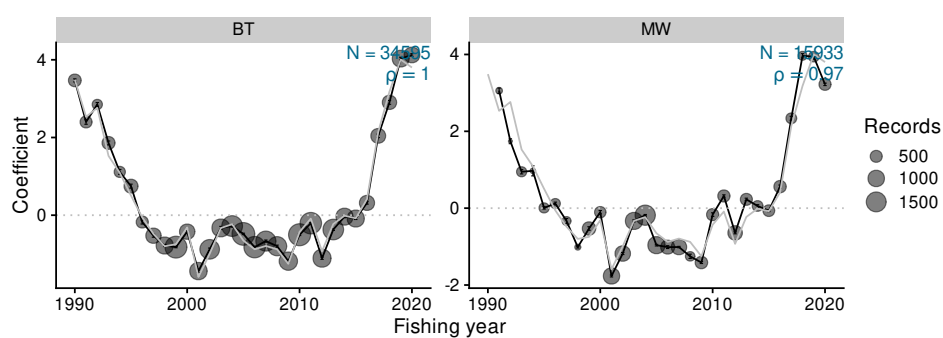


Figure 95: Residual implied coefficients for primary method-year in the lognormal positive catch model for the SKI3 BT+MW SShelf event dataset.

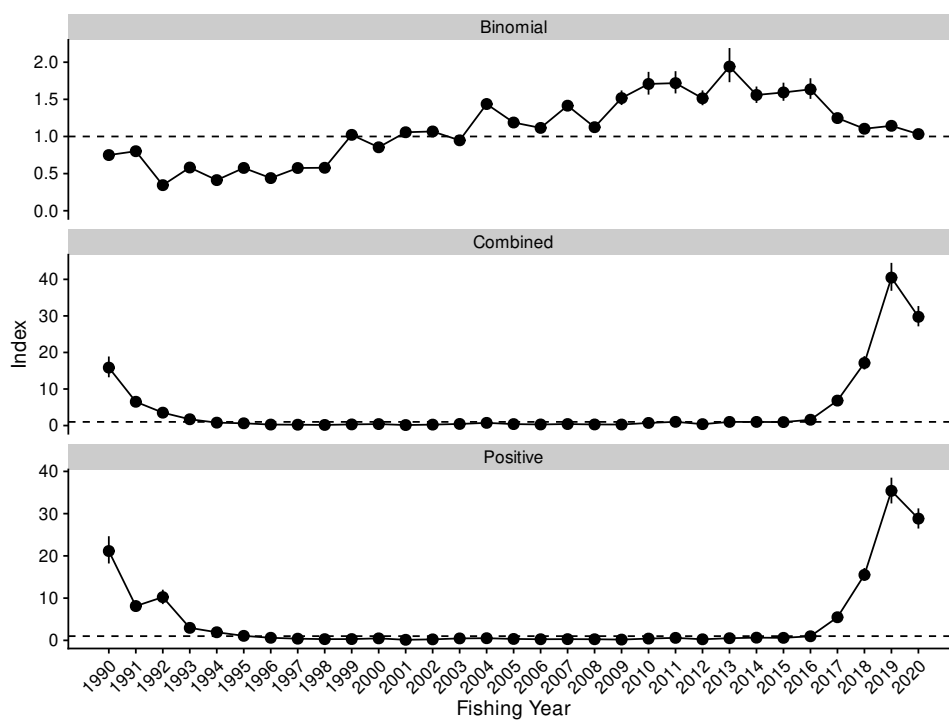


Figure 96: Standardised indices and 95% confidence intervals for the SKI3 BT+MW SShelf event dataset.

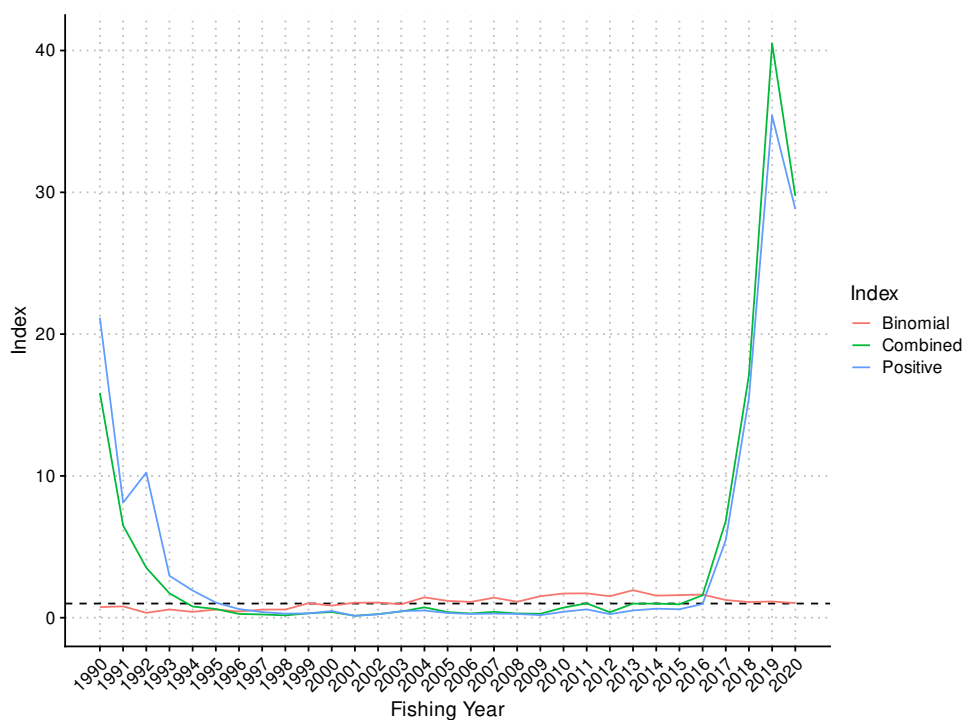


Figure 97: Standardised indices for the SKI3 BT+MW SShelf event dataset.

Table 21: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SKI3 BT+MW SShelf event.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.750	0.036	0.675	0.818	15.854	1.451	13.206	18.895	21.147	1.647	18.199	24.654
1991	0.802	0.035	0.731	0.867	6.506	0.580	5.413	7.687	8.116	0.641	6.931	9.442
1992	0.345	0.025	0.298	0.395	3.526	0.378	2.821	4.303	10.236	0.871	8.585	11.998
1993	0.582	0.027	0.529	0.637	1.721	0.125	1.489	1.979	2.957	0.164	2.657	3.299
1994	0.412	0.027	0.360	0.467	0.791	0.075	0.652	0.947	1.918	0.128	1.669	2.171
1995	0.576	0.028	0.521	0.631	0.615	0.045	0.531	0.709	1.067	0.053	0.966	1.174
1996	0.440	0.025	0.391	0.488	0.268	0.022	0.227	0.312	0.610	0.032	0.548	0.675
1997	0.575	0.026	0.526	0.627	0.229	0.015	0.200	0.260	0.398	0.019	0.361	0.436
1998	0.578	0.025	0.530	0.629	0.167	0.011	0.147	0.190	0.289	0.014	0.264	0.318
1999	1.022	0.017	0.988	1.057	0.312	0.011	0.290	0.335	0.305	0.011	0.285	0.326
2000	0.854	0.025	0.805	0.903	0.402	0.021	0.362	0.446	0.470	0.021	0.432	0.514
2001	1.057	0.019	1.019	1.092	0.139	0.005	0.128	0.150	0.131	0.005	0.122	0.141
2002	1.068	0.018	1.030	1.102	0.255	0.009	0.236	0.273	0.239	0.007	0.224	0.253
2003	0.948	0.019	0.912	0.986	0.438	0.018	0.405	0.474	0.462	0.016	0.433	0.496
2004	1.437	0.038	1.365	1.515	0.733	0.029	0.677	0.792	0.510	0.015	0.482	0.541
2005	1.188	0.018	1.154	1.223	0.398	0.013	0.372	0.425	0.335	0.010	0.316	0.356
2006	1.115	0.018	1.082	1.152	0.299	0.010	0.279	0.320	0.268	0.008	0.251	0.284
2007	1.415	0.037	1.346	1.491	0.412	0.017	0.379	0.446	0.292	0.009	0.273	0.310
2008	1.125	0.022	1.082	1.168	0.300	0.013	0.274	0.325	0.267	0.010	0.247	0.288
2009	1.517	0.050	1.423	1.620	0.279	0.014	0.254	0.310	0.184	0.007	0.171	0.199
2010	1.707	0.078	1.564	1.870	0.714	0.040	0.640	0.798	0.418	0.014	0.392	0.447
2011	1.718	0.076	1.580	1.879	1.014	0.059	0.907	1.138	0.590	0.018	0.556	0.629
2012	1.514	0.051	1.421	1.621	0.385	0.019	0.348	0.422	0.254	0.009	0.236	0.272
2013	1.941	0.117	1.731	2.191	0.994	0.071	0.865	1.144	0.512	0.017	0.480	0.548
2014	1.559	0.056	1.451	1.673	0.993	0.052	0.894	1.099	0.637	0.025	0.589	0.686
2015	1.593	0.062	1.480	1.724	0.947	0.051	0.848	1.049	0.595	0.024	0.550	0.644
2016	1.635	0.071	1.506	1.784	1.586	0.093	1.406	1.771	0.970	0.039	0.896	1.049
2017	1.248	0.029	1.191	1.307	6.828	0.352	6.175	7.555	5.472	0.252	4.999	5.988
2018	1.104	0.026	1.051	1.154	17.123	0.933	15.338	18.995	15.508	0.765	14.125	17.125
2019	1.143	0.024	1.097	1.191	40.475	1.951	36.865	44.513	35.398	1.556	32.414	38.515
2020	1.032	0.025	0.983	1.080	29.746	1.418	27.142	32.699	28.820	1.217	26.473	31.244

5.5 SKI3 BT+MW SShelf process daily

This series was also based on the bycatch of gemfish in the mixed target species Southland BT/MW fishery, except it was based on the daily processing data instead of the catch by tow. This analysis used the same seven statistical areas at the southern end of the South Island, encompassing the Stewart-Snares shelf, Foveaux Strait and the waters around Stewart Island (Table 22). The MW component of the analysis was constrained to midwater gear fished within 10 m of the bottom and the target species suite included the same six species: squid (SQU), barracouta (BAR), hoki (HOK), silver warehou (SWA), ling (LIN) and gemfish (SKI). The core fleet was defined by having fished at least once in each of three years, retaining 95% of the catch and reducing the fleet from over 100 vessels to 79 vessels (Figure 98). As with the event-based series, some of the core fleet vessels had been present in the defined fishery for 20 years or more, but there were also vessels which had been in the fishery for relatively few years (Figure 99) compared with the SKI 7 core fleet. The final groomed dataset represented 63% (2000) to 100% (1992, 1993 to 1995, 1997, 1998, 2001 to 2005, 2007 to 2015, 2017, 2019) of the annual catch (Table 23). The bycatch of gemfish in the defined fishery was less than 100 t/y from 1994 to 2016 (Table 24). Between 2016 to 2017, the bycatch of gemfish rose from 10 t to 148 t, and then peaked at 318 t in 2019 and 217 t in 2020. All catches in the dataset were derived from landings allocated to each day of fishing based on the daily processed catches (Figure 100).

The binomial (occurrence) model accepted four predictive variables after fishing year (vessel, statistical area, day of season and bottom depth), with the total model explaining 28% of the deviance (Table 25). The unstandardised series showed a decline from 1990 to 2000, followed by a slowly increasing trend to 2016 and then a step up to a new level from 2017 to 2020 (Figure 101, Figure 102). The main standardisation effect was to lift the 2017 to 2020 indices from three or less to greater than three. The respective CDI plots show little standardisation effect from the addition of the vessel covariate, in spite of having the greatest explanatory power from this covariate (Figure 103). However, the covariates for statistical area (Figure 104), day of season (Figure 105) and bottom depth (Figure 106) all contributed to raising the indices in the final four years of the series, with the greatest effect coming from the day of season covariate (Figure 102).

The lognormal model accepted three predictive variables after fishing year (statistical area, vessel, bottom depth), with the total model explaining 46% of the deviance (Table 26). Residuals to the lognormal model show good conformity to the lognormal assumption with little evidence of skewness over all of the distribution (Figure 107). The Weibull and gamma distributions show much poorer fits to the positive catch data than seen for the lognormal distribution (Figure 108). The series showed a steep decline during the 1990s and early 2000s, followed by a period of very low indices from 2006 to 2016 and then a sharp rise in 2017 and 2018 after which the index remained stable (Figure 109). The standardisation effect raised the series in the final three years to a level comparable to that seen in the first few years of the series (Figure 109). This standardisation effect occurred with the successive addition of the statistical area covariate and then the vessel covariate (Figure 110). The statistical area covariate showed a shift to Statistical Areas 026 and 028 off the west and east coasts of Stewart Island and in Statistical Area 504 (Stewart-Snares shelf) where the gemfish CPUE tended to be lower (Figure 111). Similarly, there may be evidence of avoidance behaviour, with vessels having lower coefficients predominating in the final four years of the series (Figure 112). Finally, the bottom depth covariate showed a move in the final three years of the series to a more shallow fishery at less than 200 m where SKI CPUE tended to be lower (Figure 113). Implied residual plots of gemfish annual CPUE showed good conformity with the overall annual CPUE trend across five of the six target species (there were too few SKI observations in the dataset; Figure 114), the seven statistical areas (Figure 115) and the two capture methods (Figure 116).

The multiplicative effect of the combined model exaggerated the increasing trend in both the binomial and lognormal components, resulting in a very strong increasing trend (Figure 117, Figure 118, Table 27).

Table 22: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SKI3 BT+MW SShelf process daily CPUE series.

Series	SKI3 BT+MW SShelf process daily
QMS stock	SKI3
Reporting forms	TCE, TCP, ERS - Trawl
Fishing methods	BT, MW
Target species	SQU, BAR, HOK, SWA, SKI, LIN
Statistical Areas	025, 026, 027, 028, 029, 030, 504
Period	1989-10-01, 2020-09-30
Resolution	Day
Core fleet years	3
Core fleet trips	1
Default model	prockg ~ fyear + vessel_key + stat_area + target_species + primary_method + ns(log(fishing_duration), 3) + bs(SeasonDay, 3)+ bs(bottom_depth, 3)
Stepwise selection	Yes
Positive catch distribution	Lognormal

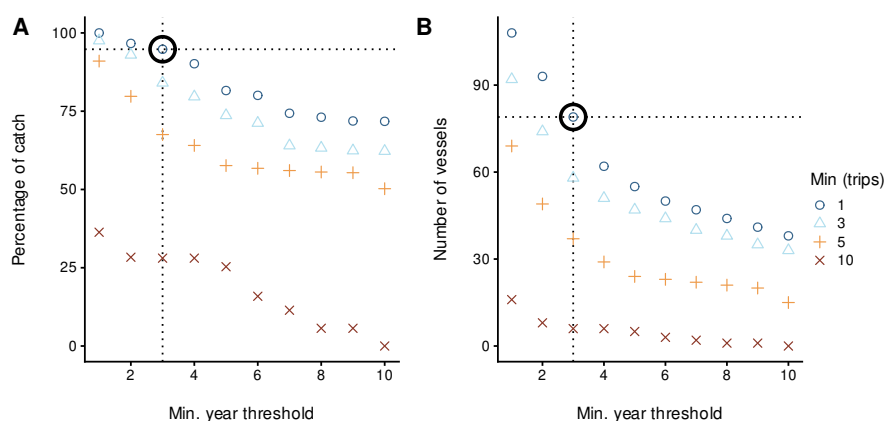


Figure 98: Percentage of catch and number of vessels for different core vessel selection criteria for the SKI3 BT+MW SShelf process daily CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

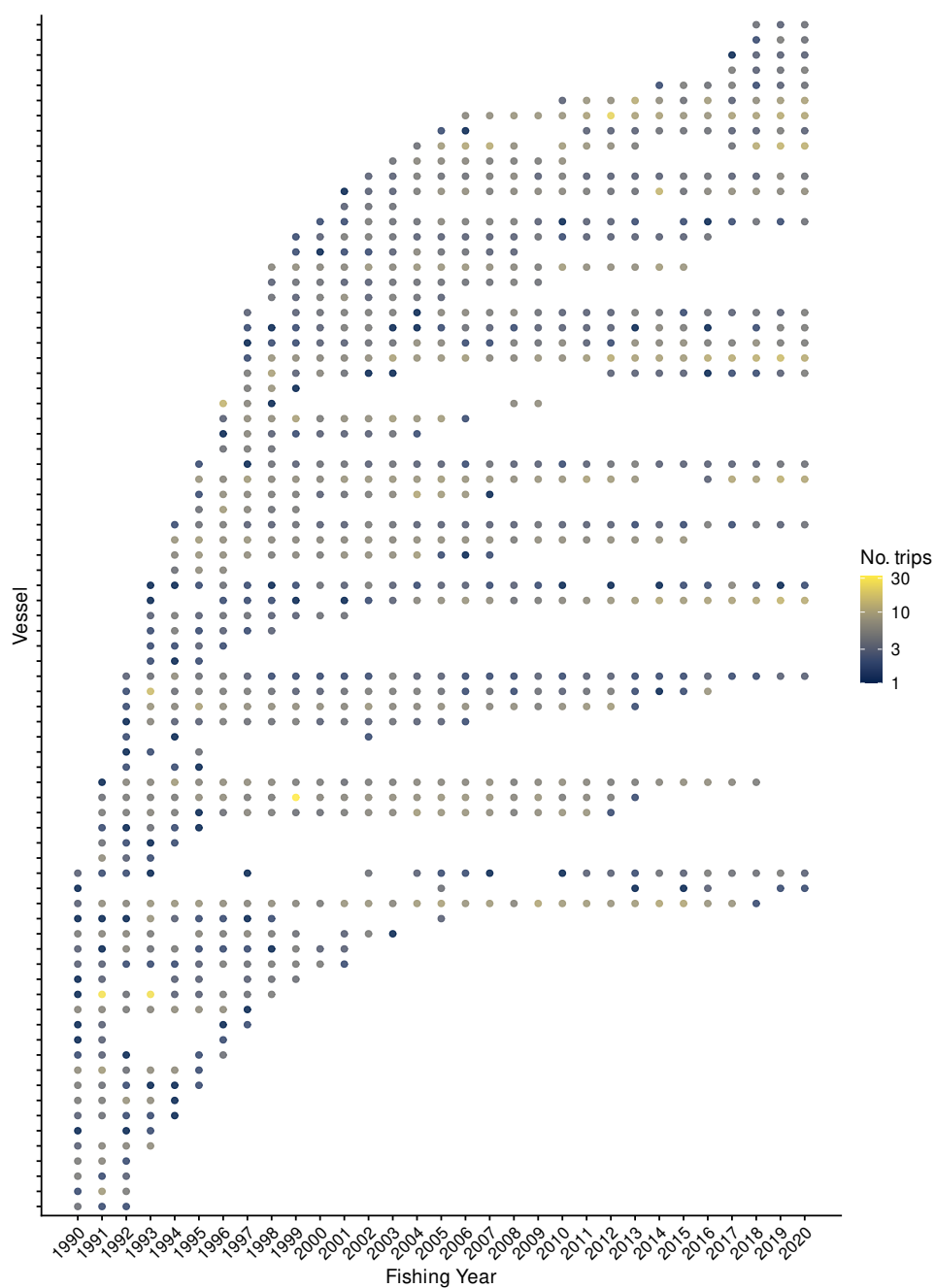


Figure 99: Number of trips by fishing year for core vessels. The colour of the points is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 23: Summary of the SKI3 BT+MW SShelf process daily dataset total catch (tonnes) and number of records (n), by fishing year after the application of various filters. The first row gives the catch and number of records before filters were applied (ungroomed data). Subsequent rows display the remaining catch (and percent of catch), and the number of records, after the specified filter was applied. (Continued on next page)

Filter	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ungroomed data	326 (100%) n: 1257	212 (100%) n: 2229	126 (100%) n: 1684	246 (100%) n: 2113	43 (100%) n: 1192	65 (100%) n: 1634	18 (100%) n: 1545	49 (100%) n: 2038	19 (100%) n: 2502
Fishing duration is not NA	326 (100%) n: 1257	212 (100%) n: 2229	126 (100%) n: 1684	246 (100%) n: 2113	43 (100%) n: 1192	65 (100%) n: 1634	18 (100%) n: 1545	49 (100%) n: 2038	19 (100%) n: 2502
Positive fishing duration	326 (100%) n: 1257	212 (100%) n: 2229	126 (100%) n: 1684	246 (100%) n: 2113	43 (100%) n: 1192	65 (100%) n: 1634	18 (100%) n: 1545	49 (100%) n: 2038	19 (100%) n: 2502
Bottom depth >=50	326 (100%) n: 1257	212 (100%) n: 2229	126 (100%) n: 1684	246 (100%) n: 2113	43 (100%) n: 1192	65 (100%) n: 1630	18 (100%) n: 1544	49 (100%) n: 2038	19 (100%) n: 2501
Bottom depth <=600	324 (100%) n: 1177	212 (100%) n: 2183	126 (100%) n: 1622	246 (100%) n: 2032	42 (100%) n: 1106	65 (100%) n: 1565	17 (94%) n: 1468	49 (100%) n: 1885	19 (100%) n: 2349
Midwater effort depth <=10 m from bottom	324 (100%) n: 1116	210 (100%) n: 2091	126 (100%) n: 1579	245 (100%) n: 1924	42 (100%) n: 1070	64 (100%) n: 1478	17 (94%) n: 1398	49 (100%) n: 1806	19 (100%) n: 2314
Core fleet selection	275 (84%) n: 750	144 (68%) n: 1358	122 (100%) n: 1336	236 (100%) n: 1685	42 (100%) n: 1041	64 (100%) n: 1478	17 (94%) n: 1398	48 (100%) n: 1733	18 (100%) n: 2254

Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	13 (100%) n: 2290	44 (100%) n: 1706	39 (100%) n: 2249	59 (100%) n: 2201	91 (100%) n: 2294	61 (100%) n: 2157	63 (100%) n: 2780	22 (100%) n: 2535	17 (100%) n: 1979
Fishing duration is not NA	13 (100%) n: 2290	44 (100%) n: 1706	39 (100%) n: 2249	59 (100%) n: 2201	91 (100%) n: 2294	61 (100%) n: 2157	63 (100%) n: 2780	22 (100%) n: 2535	17 (100%) n: 1979
Positive fishing duration	13 (100%) n: 2290	44 (100%) n: 1706	39 (100%) n: 2249	59 (100%) n: 2201	91 (100%) n: 2294	61 (100%) n: 2157	63 (100%) n: 2780	22 (100%) n: 2535	17 (100%) n: 1979
Bottom depth >=50	13 (100%) n: 2289	44 (100%) n: 1701	39 (100%) n: 2246	59 (100%) n: 2199	91 (100%) n: 2293	61 (100%) n: 2157	63 (100%) n: 2775	20 (94%) n: 2448	17 (100%) n: 1921
Bottom depth <=600	10 (78%) n: 2136	28 (64%) n: 1424	38 (100%) n: 1940	58 (100%) n: 2035	91 (100%) n: 2164	61 (100%) n: 2085	63 (100%) n: 2716	20 (94%) n: 2354	17 (100%) n: 1837
Midwater effort depth <=10 m from bottom	10 (78%) n: 2010	28 (63%) n: 1337	38 (100%) n: 1765	58 (100%) n: 1977	91 (100%) n: 2096	61 (100%) n: 2040	63 (100%) n: 2571	20 (94%) n: 2306	17 (100%) n: 1781
Core fleet selection	10 (78%) n: 2010	28 (63%) n: 1337	38 (100%) n: 1765	58 (100%) n: 1977	91 (100%) n: 2096	61 (100%) n: 2040	63 (100%) n: 2571	20 (91%) n: 2179	17 (100%) n: 1781

Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	12 (100%) n: 1694	6.4 (100%) n: 1343	11 (100%) n: 1758	23 (100%) n: 1623	7.6 (100%) n: 1515	13 (100%) n: 1473	24 (100%) n: 1232	16 (100%) n: 1240	11 (100%) n: 927
Fishing duration is not NA	12 (100%) n: 1694	6.4 (100%) n: 1343	11 (100%) n: 1758	23 (100%) n: 1623	7.6 (100%) n: 1515	13 (100%) n: 1473	24 (100%) n: 1232	16 (100%) n: 1240	11 (100%) n: 927
Positive fishing duration	12 (100%) n: 1694	6.4 (100%) n: 1343	11 (100%) n: 1758	23 (100%) n: 1623	7.6 (100%) n: 1515	13 (100%) n: 1473	24 (100%) n: 1232	16 (100%) n: 1240	11 (100%) n: 926
Bottom depth >=50	12 (100%) n: 1694	6.4 (100%) n: 1343	11 (100%) n: 1758	23 (100%) n: 1622	7.6 (100%) n: 1515	13 (100%) n: 1473	24 (100%) n: 1232	16 (100%) n: 1240	11 (100%) n: 926
Bottom depth <=600	12 (100%) n: 1614	6.4 (100%) n: 1282	11 (100%) n: 1676	23 (100%) n: 1542	7.5 (100%) n: 1423	13 (100%) n: 1355	23 (100%) n: 1125	16 (100%) n: 1116	11 (100%) n: 862
Midwater effort depth <=10 m from bottom	12 (100%) n: 1530	6.3 (100%) n: 1243	11 (100%) n: 1655	23 (100%) n: 1512	7.5 (100%) n: 1395	13 (100%) n: 1333	23 (100%) n: 1097	16 (100%) n: 1064	10 (92%) n: 845
Core fleet selection	12 (100%) n: 1530	6.3 (100%) n: 1243	11 (100%) n: 1655	22 (100%) n: 1485	7.5 (100%) n: 1395	13 (100%) n: 1333	23 (100%) n: 1097	16 (100%) n: 1064	10 (92%) n: 845

Filter	2017	2018	2019	2020
Ungroomed data	151 (100%) n: 1223	226 (100%) n: 1053	328 (100%) n: 1499	234 (100%) n: 1456
Fishing duration is not NA	151 (100%) n: 1223	226 (100%) n: 1053	328 (100%) n: 1499	234 (100%) n: 1456
Positive fishing duration	151 (100%) n: 1223	226 (100%) n: 1052	328 (100%) n: 1499	234 (100%) n: 1456
Bottom depth >=50	151 (100%) n: 1223	226 (100%) n: 1052	328 (100%) n: 1499	234 (100%) n: 1456
Bottom depth <=600	151 (100%) n: 1142	225 (100%) n: 997	327 (100%) n: 1476	231 (100%) n: 1440
Midwater effort depth <=10 m from bottom	148 (100%) n: 1111	209 (92%) n: 942	318 (100%) n: 1414	217 (93%) n: 1375
Core fleet selection	148 (100%) n: 1111	209 (92%) n: 942	318 (100%) n: 1414	217 (93%) n: 1375

Table 24: Summary of the SKI3 BT+MW SShelf process daily dataset after core fleet selection. ‘Records’ indicates the number of rows (days) in the dataset, and ‘Records caught’ indicates the percentage of days with catches of gemfish.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
1990	23	71	750	8 394.85	274.91	43.33
1991	27	136	1 358	15 156.57	143.50	41.38
1992	32	103	1 336	13 928.40	122.21	26.72
1993	31	158	1 685	17 626.05	236.38	24.57
1994	31	121	1 041	12 326.80	42.26	29.49
1995	34	138	1 478	17 324.22	64.45	27.00
1996	33	164	1 398	16 473.76	16.79	12.09
1997	38	159	1 733	19 520.57	48.16	12.06
1998	37	161	2 254	25 539.08	18.26	7.85
1999	35	172	2 010	24 573.32	10.23	5.77
2000	31	129	1 337	16 248.12	27.63	9.80
2001	35	149	1 765	19 805.55	38.22	10.03
2002	35	165	1 977	21 755.85	58.08	18.77
2003	34	160	2 096	24 315.68	90.68	35.83
2004	33	176	2 040	21 717.15	60.59	24.36
2005	35	188	2 571	30 017.95	62.56	20.50
2006	33	167	2 179	26 795.25	19.72	16.25
2007	30	150	1 781	22 992.85	16.76	14.15
2008	28	137	1 530	18 781.45	11.74	17.84
2009	26	137	1 243	15 089.99	6.34	13.11
2010	27	138	1 655	21 232.57	10.53	17.82
2011	26	144	1 485	18 345.00	21.66	25.99
2012	28	155	1 395	16 854.08	7.47	15.05
2013	27	131	1 333	15 166.08	13.34	25.13
2014	23	131	1 097	12 802.74	23.38	31.45
2015	25	118	1 064	13 031.85	16.24	37.78
2016	24	120	845	8 952.17	10.05	33.25
2017	23	117	1 111	13 012.35	147.95	68.95
2018	26	131	942	11 291.22	208.64	56.90
2019	25	149	1 414	16 795.30	318.13	69.59
2020	25	145	1 375	16 613.95	217.28	65.45

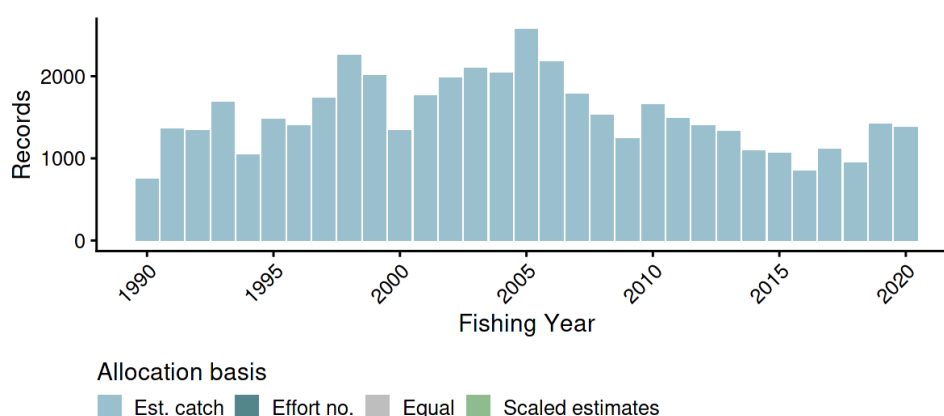


Figure 100: Allocation basis for attributing landings to records in the SKI3 BT+MW SShelf process daily catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table 25: Summary of stepwise selection for occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	29.00	47 057	12.20	12.20	*
+ vessel_key	78.00	44 380	17.50	5.30	*
+ stat_area	6.00	41 986	22.00	4.50	*
+ bs(SeasonDay, 3)	3.00	39 792	26.10	4.10	*
+ bs(bottom_depth, 3)	3.00	38 837	27.90	1.80	*
+ ns(log(fishing_duration), 3)	3.00	38 482	28.50	0.70	
+ target_species	5.00	38 222	29.00	0.50	
+ primary_method	1.00	38 101	29.30	0.20	

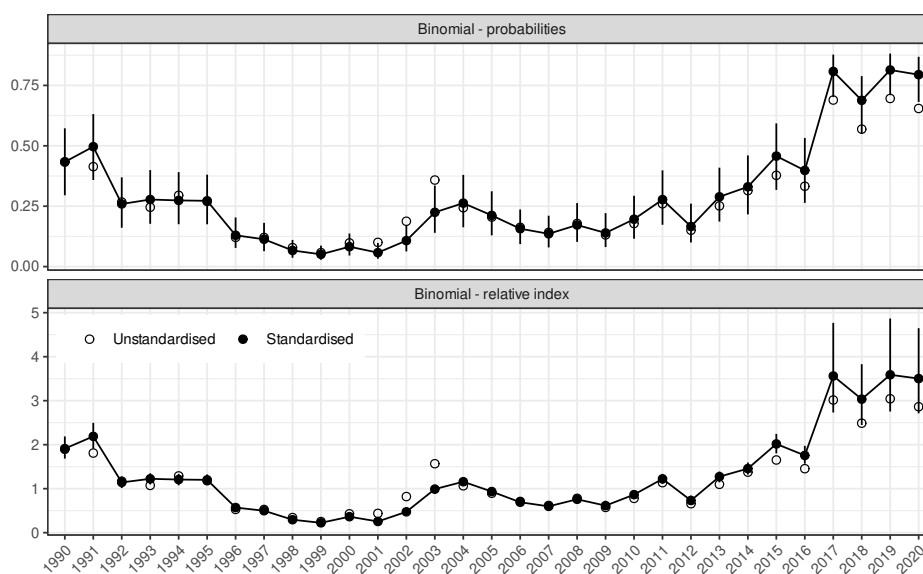


Figure 101: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SKI3 BT+MW SShelf process daily dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

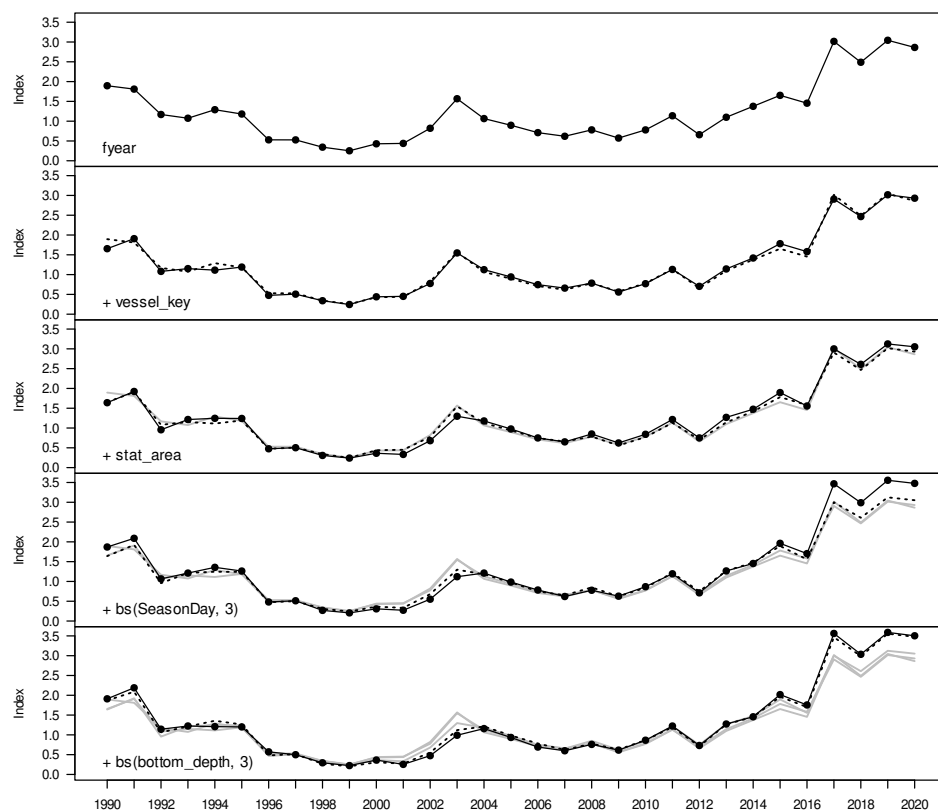


Figure 102: Step plot for occurrence of catch in the SKI3 BT+MW SShelf process daily dataset.

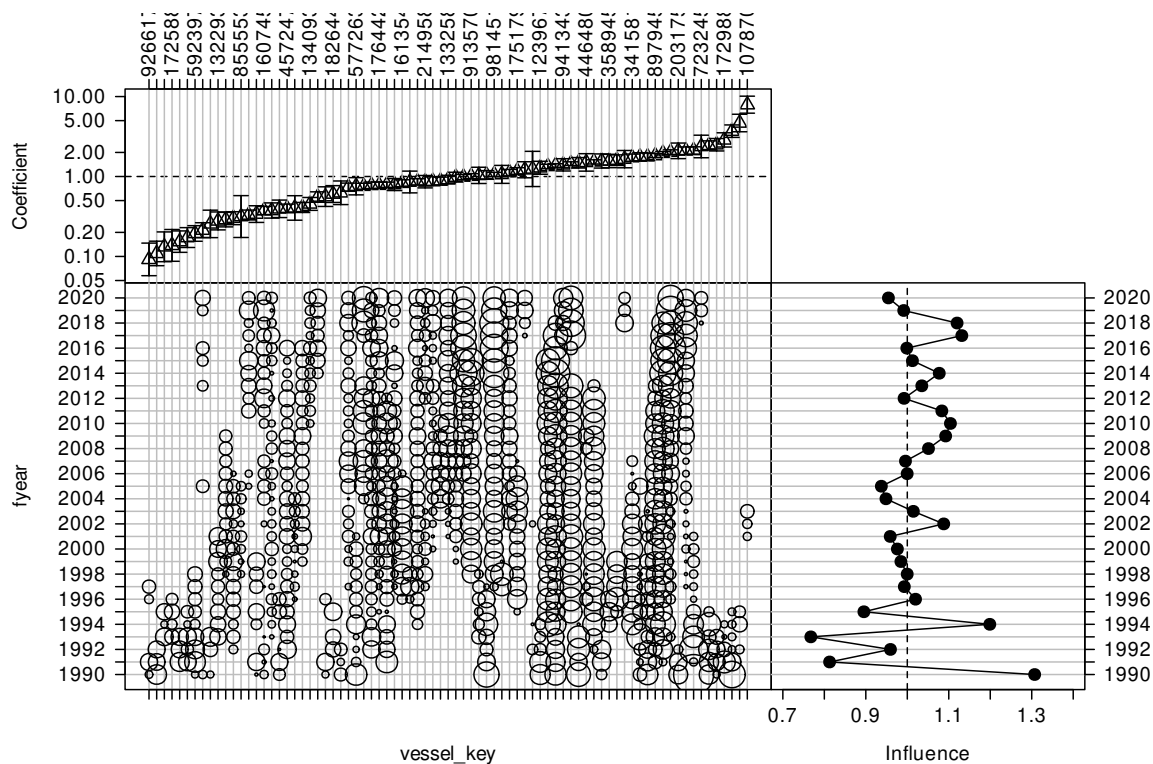


Figure 103: CDI plot for vessel key for the occurrence of positive catch SKI3 BT+MW SShelf process daily catch-per-unit-effort dataset.

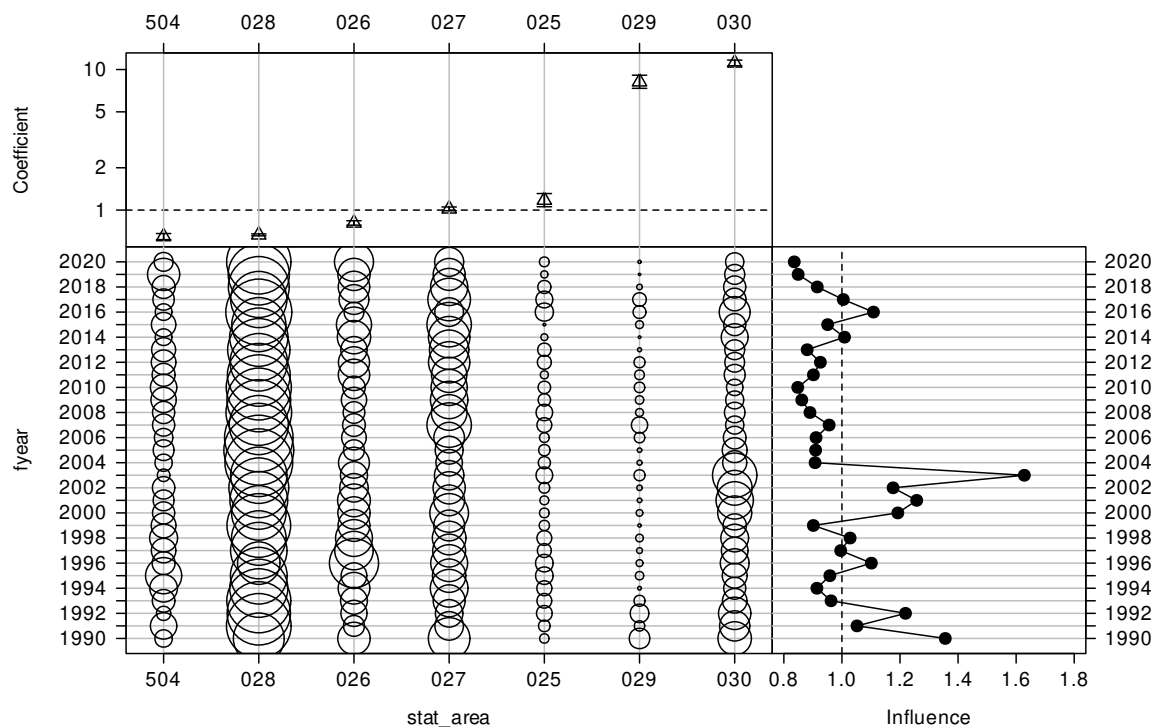


Figure 104: CDI plot for statistical area for the occurrence of positive catch SKI3 BT+MW SShelf process daily catch-per-unit-effort dataset.

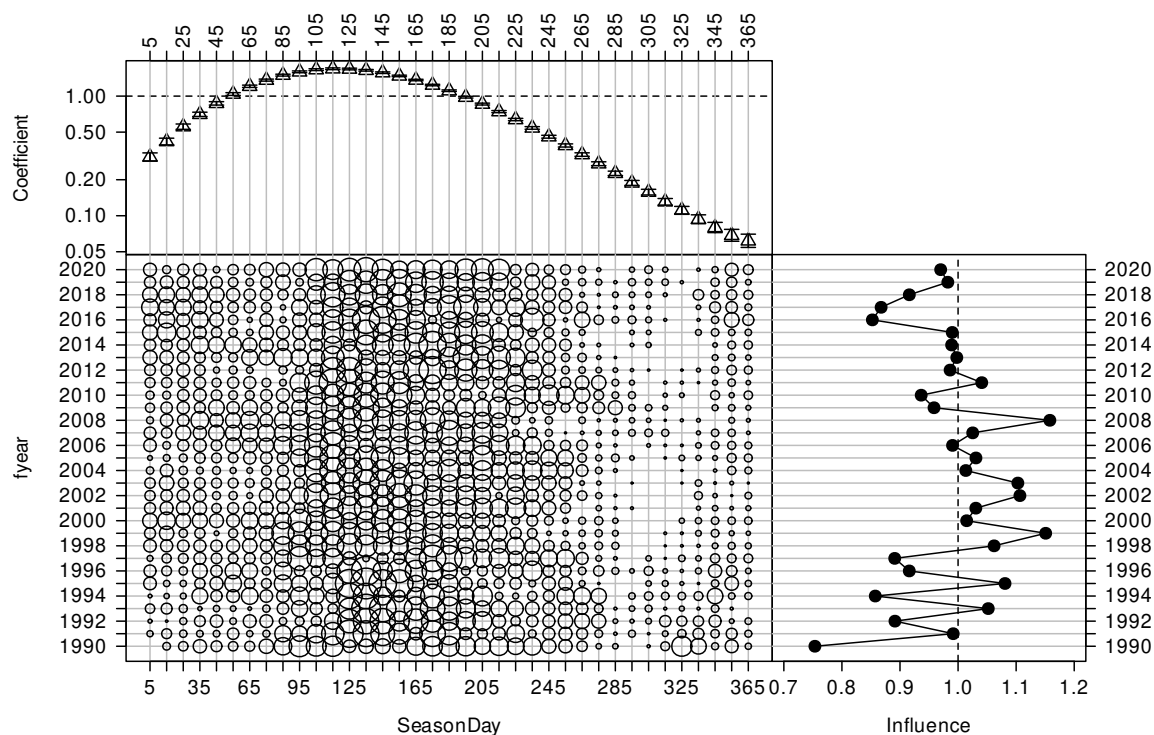


Figure 105: CDI plot for SeasonDay for the occurrence of positive catch SKI3 BT+MW SShelf process daily catch-per-unit-effort dataset.

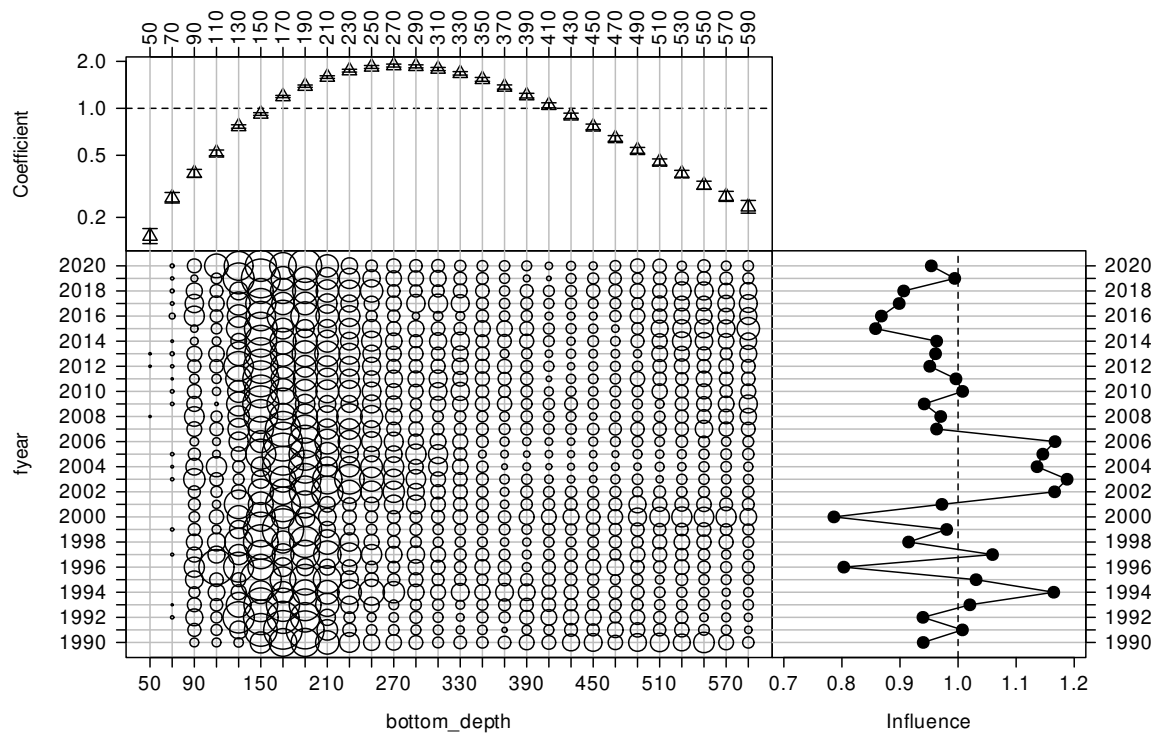


Figure 106: CDI plot for bottom depth (m) for the occurrence of positive catch SKI3 BT+MW SShelf process daily catch-per-unit-effort dataset.

Table 26: Summary of stepwise selection for the lognormal model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	29	41 901	28.6	28.6	*
+ stat area	6	40 176	38.3	9.6	*
+ vessel key	78	39 272	43.5	5.2	*
+ bs(bottom depth, 3)	3	38 682	46.2	2.7	*
+ bs(SeasonDay, 3)	3	38 508	47.0	0.8	
+ target species	5	38 402	47.5	0.5	
+ ns(log(fishing duration), 3)	3	38 322	47.9	0.4	

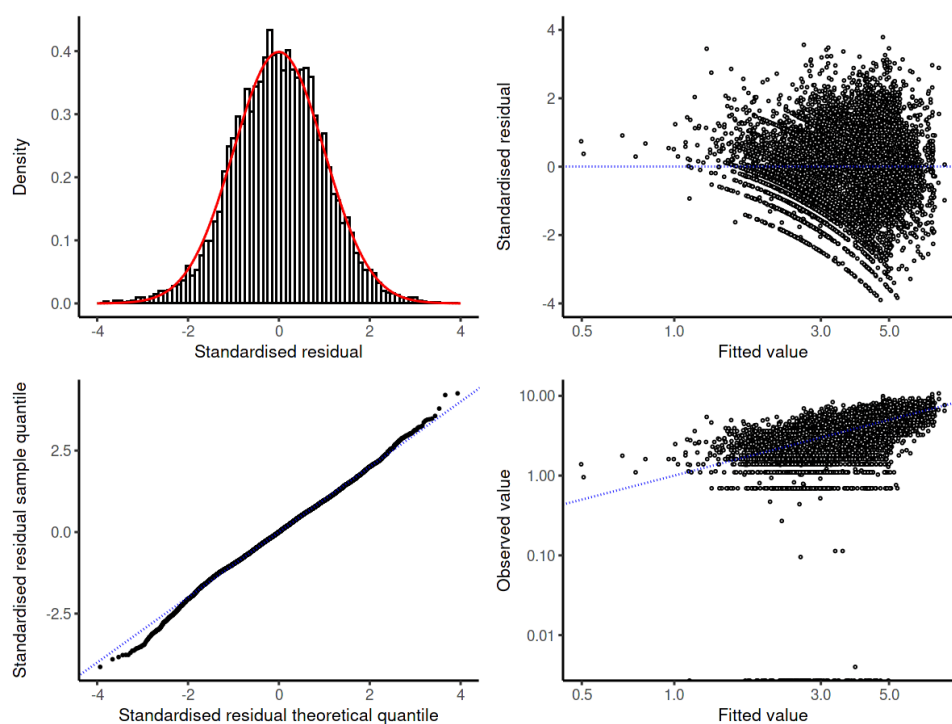


Figure 107: Diagnostic plots for the lognormal model for the SKI3 BT+MW SShelf process daily dataset.

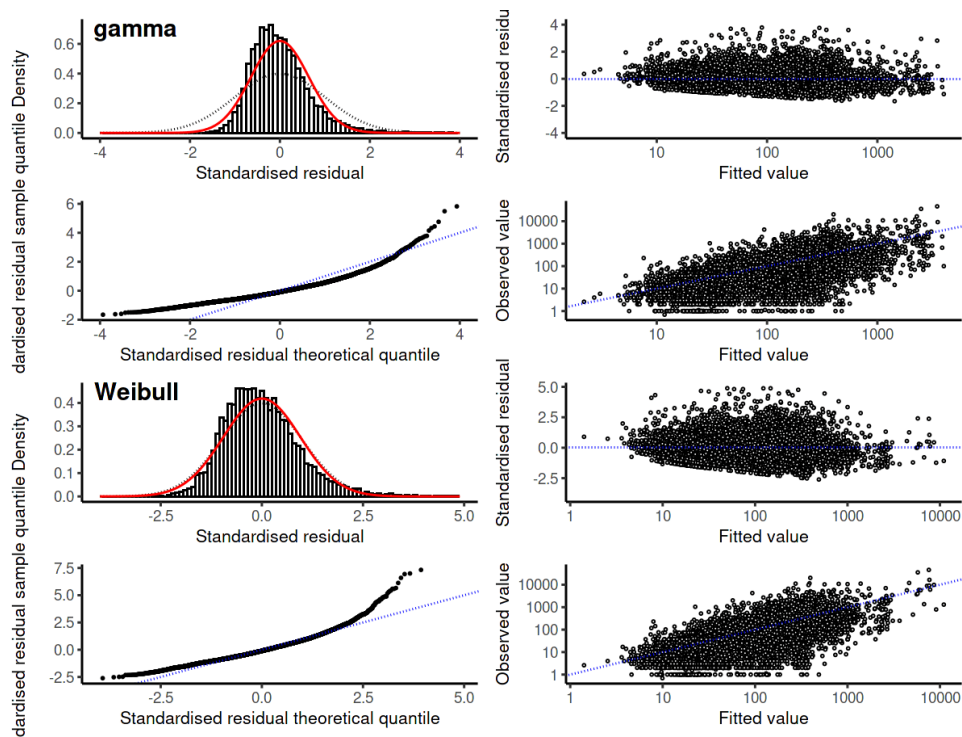


Figure 108: Diagnostic plots for the gamma and Weibull model for the SKI3 BT+MW SShelf process daily dataset.

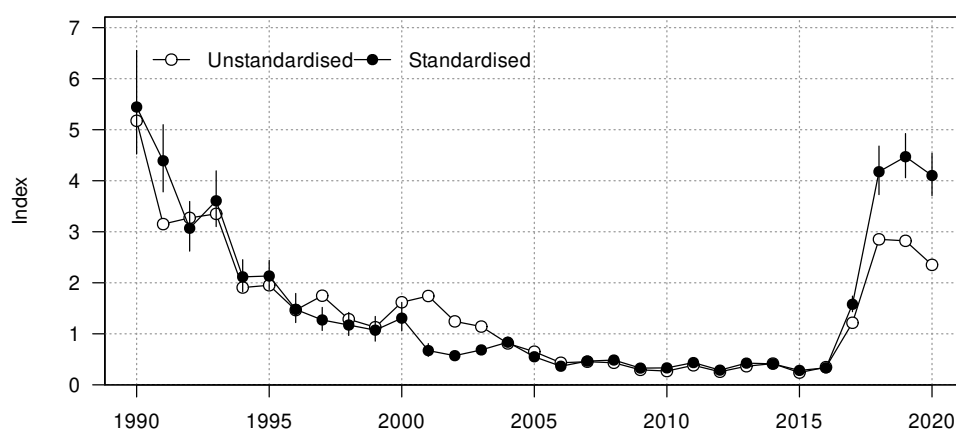


Figure 109: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SKI3 BT+MW SShelf process daily dataset.

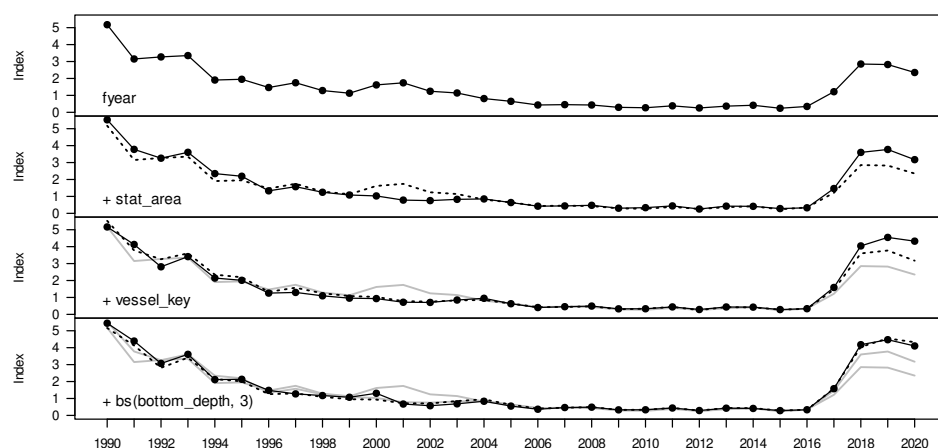


Figure 110: Changes to the SKI3 BT+MW SShelf process daily positive catch index as terms are successively entered into the model.

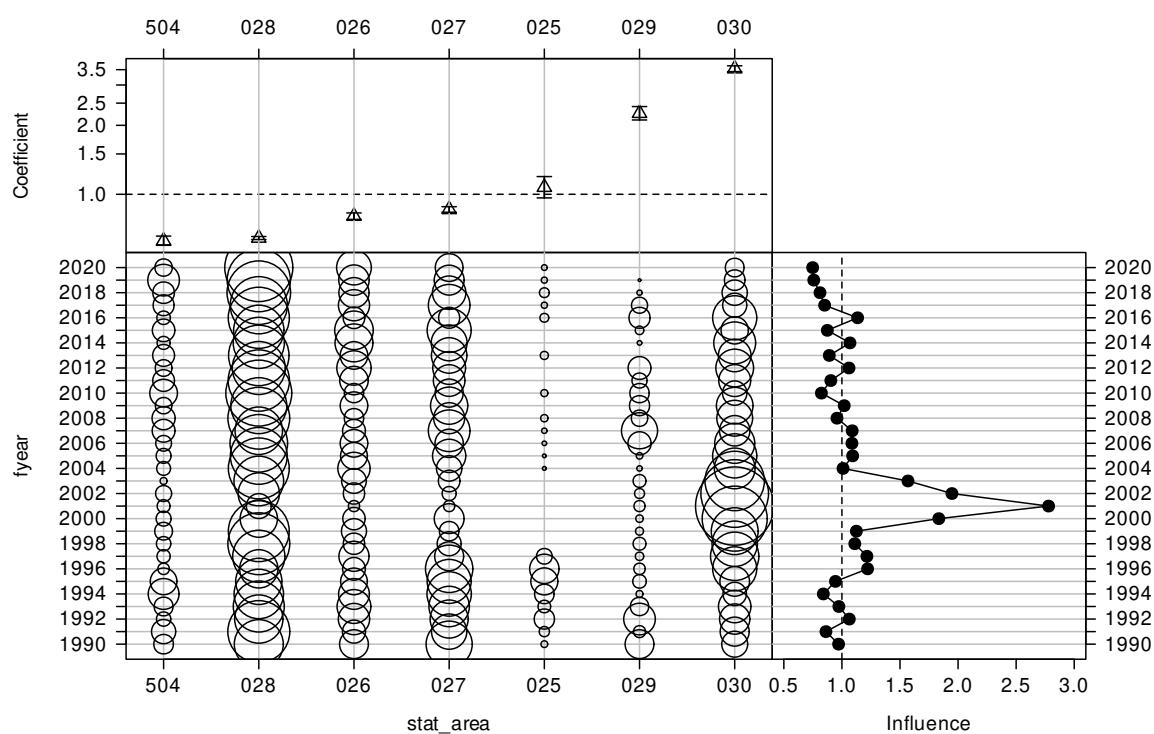


Figure 111: CDI plot for statistical area for the positive catch SKI3 BT+MW SShelf process daily catch-per-unit-effort dataset.

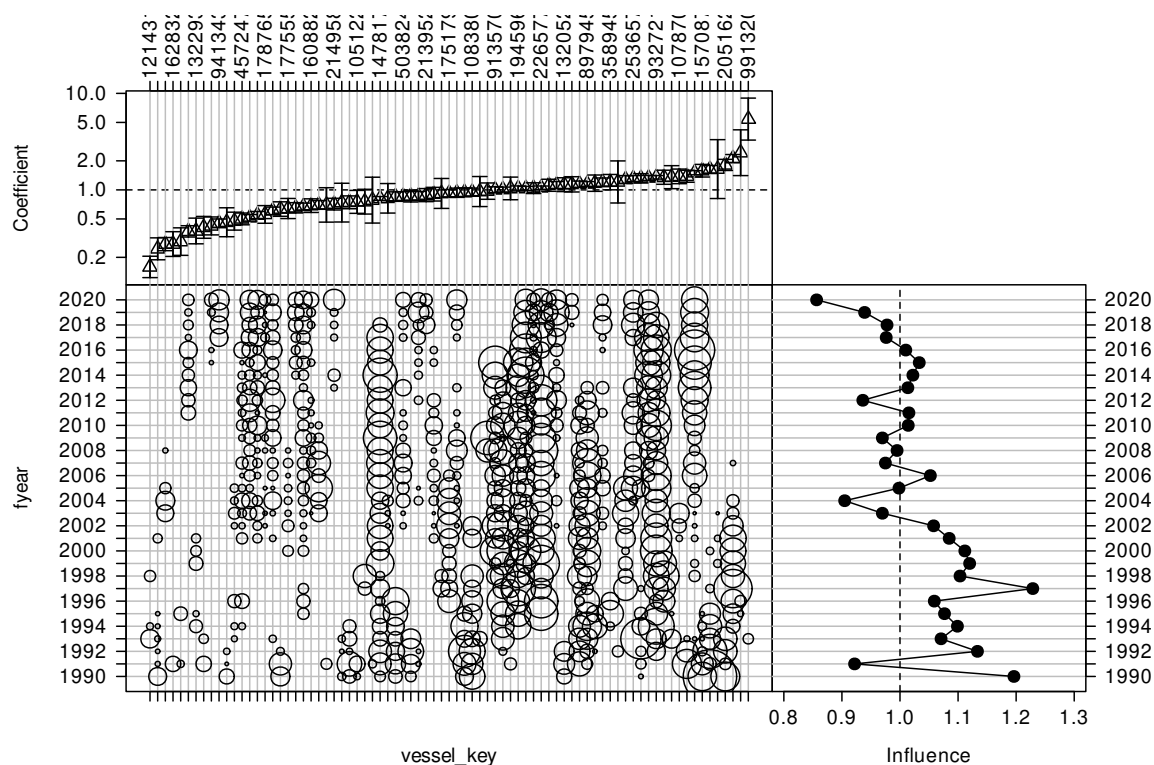


Figure 112: CDI plot for vessel key for the positive catch SKI3 BT+MW SShelf process daily catch-per-unit-effort dataset.

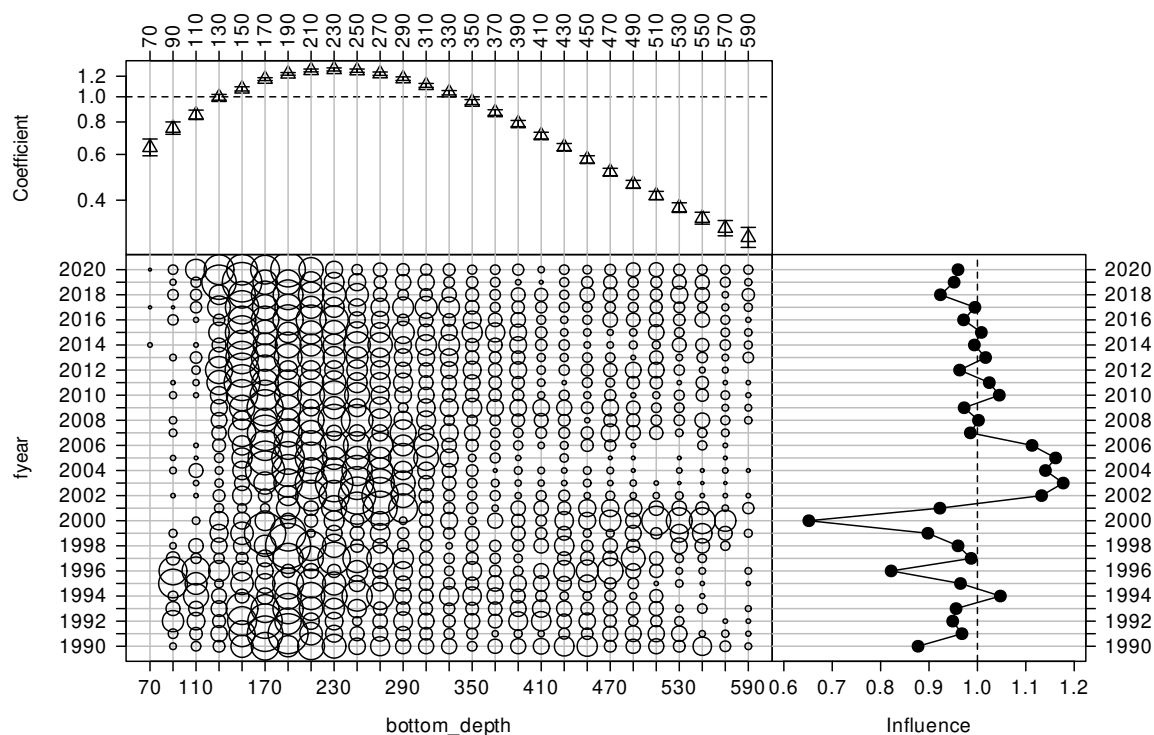


Figure 113: CDI plot for bottom depth (m) for the positive catch SKI3 BT+MW SShelf process daily catch-per-unit-effort dataset.

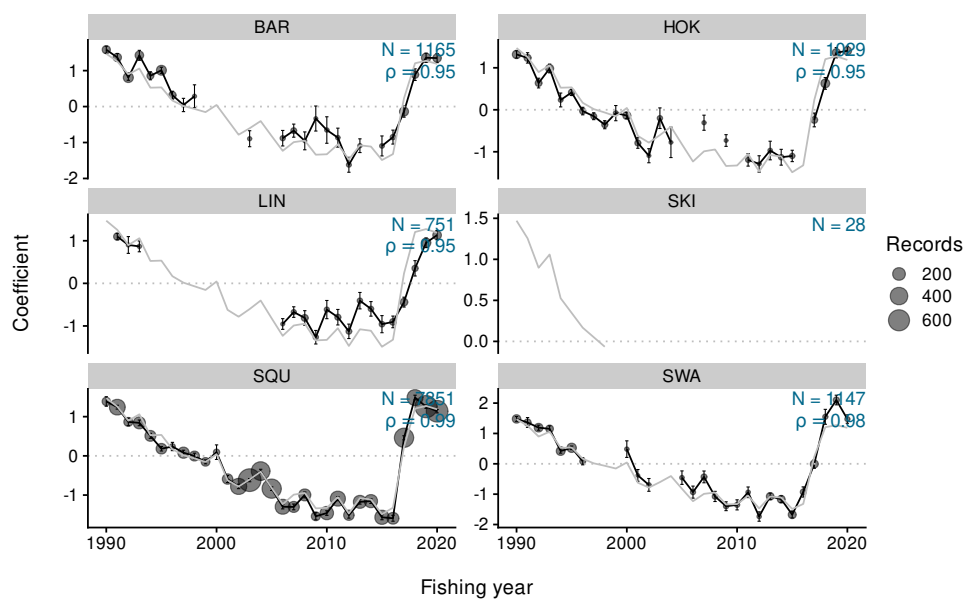


Figure 114: Residual implied coefficients for target-year in the lognormal positive catch model for the SKI3 BT+MW SShelf process daily dataset.

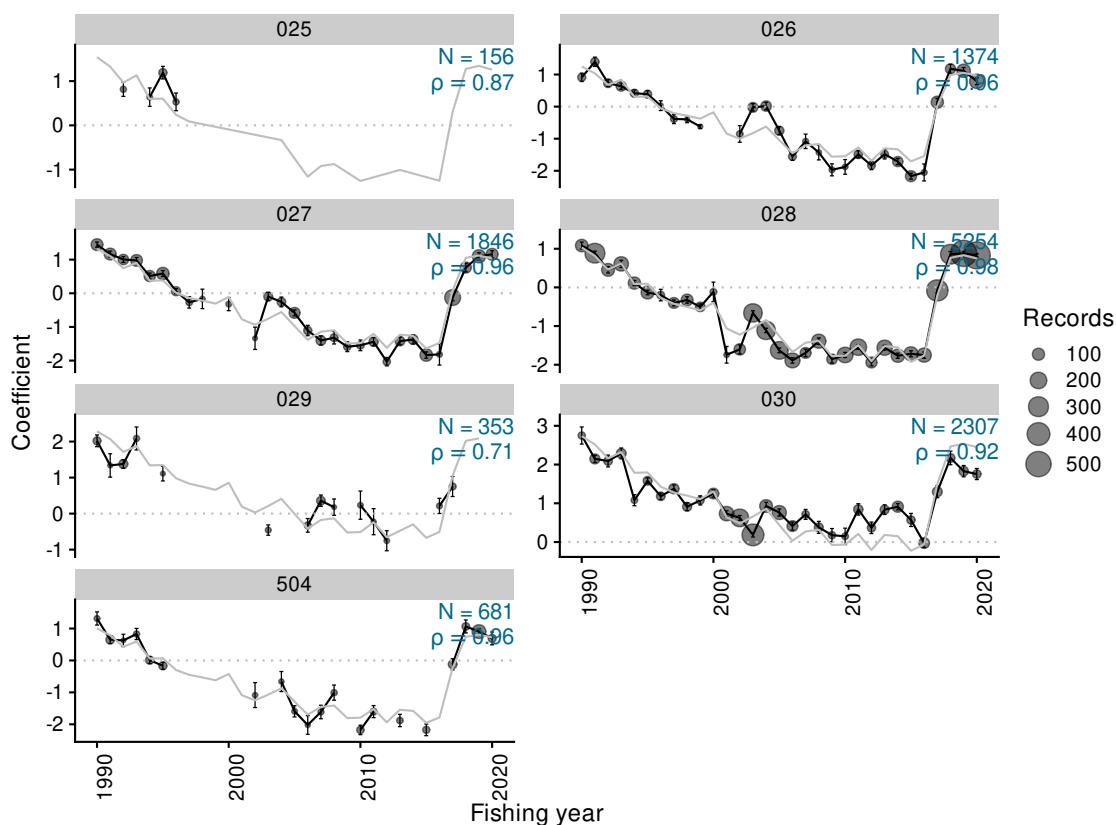


Figure 115: Residual implied coefficients for area-year in the lognormal positive catch model for the SKI3 BT+MW SShelf process daily dataset.

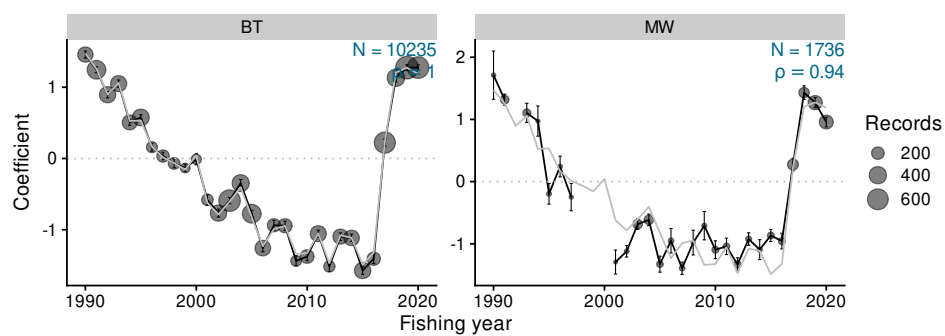


Figure 116: Residual implied coefficients for primary method-year in the lognormal positive catch model for the SKI3 BT+MW SShelf process daily dataset.

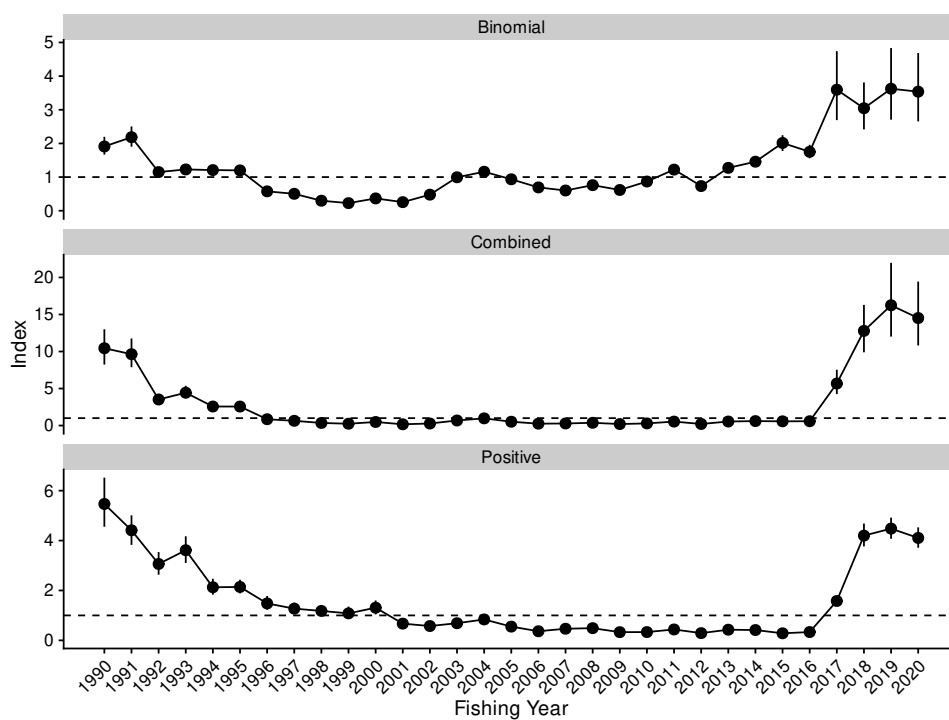


Figure 117: Standardised indices and 95% confidence intervals for the SKI3 BT+MW SShelf process daily dataset.

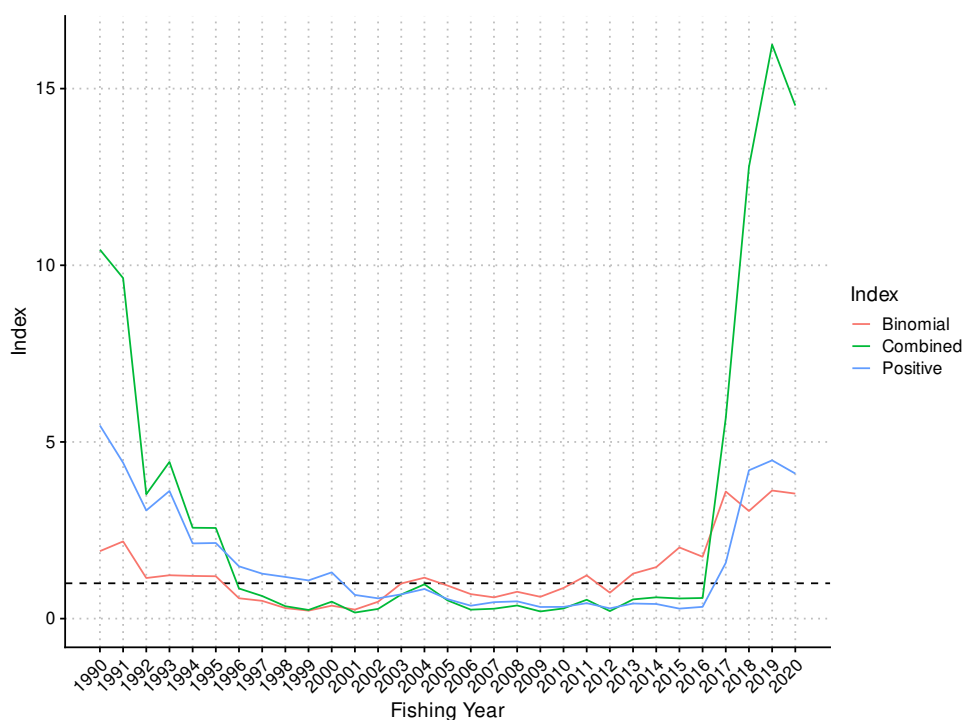


Figure 118: Standardised indices for the SKI3 BT+MW SShelf process daily dataset.

Table 27: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SKI3 BT+MW SShelf process daily.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	1.910	0.135	1.667	2.197	10.443	1.216	8.237	13.002	5.467	0.502	4.553	6.521
1991	2.185	0.154	1.902	2.504	9.638	0.990	7.880	11.761	4.411	0.302	3.827	5.011
1992	1.149	0.069	1.014	1.286	3.520	0.352	2.896	4.276	3.062	0.231	2.632	3.539
1993	1.227	0.063	1.103	1.350	4.434	0.428	3.687	5.365	3.612	0.273	3.102	4.171
1994	1.208	0.068	1.078	1.346	2.571	0.233	2.154	3.067	2.128	0.163	1.831	2.468
1995	1.199	0.060	1.080	1.317	2.565	0.201	2.180	2.967	2.140	0.140	1.881	2.430
1996	0.576	0.053	0.477	0.683	0.853	0.113	0.652	1.096	1.480	0.141	1.225	1.778
1997	0.503	0.047	0.418	0.601	0.640	0.086	0.495	0.831	1.272	0.114	1.061	1.509
1998	0.298	0.029	0.245	0.360	0.351	0.049	0.262	0.455	1.179	0.112	0.971	1.409
1999	0.226	0.026	0.181	0.283	0.245	0.039	0.179	0.333	1.081	0.123	0.870	1.354
2000	0.366	0.041	0.292	0.451	0.480	0.074	0.351	0.641	1.309	0.142	1.040	1.598
2001	0.255	0.027	0.205	0.312	0.171	0.025	0.127	0.223	0.671	0.065	0.550	0.806
2002	0.478	0.039	0.406	0.560	0.274	0.028	0.221	0.333	0.574	0.036	0.509	0.651
2003	0.994	0.051	0.892	1.091	0.683	0.050	0.592	0.788	0.687	0.034	0.625	0.759
2004	1.158	0.050	1.062	1.257	0.971	0.070	0.839	1.113	0.838	0.047	0.750	0.936
2005	0.935	0.047	0.844	1.028	0.515	0.040	0.439	0.596	0.551	0.031	0.496	0.616
2006	0.693	0.046	0.609	0.788	0.253	0.024	0.211	0.305	0.366	0.024	0.321	0.415
2007	0.601	0.049	0.504	0.697	0.280	0.030	0.226	0.343	0.466	0.035	0.399	0.537
2008	0.760	0.047	0.669	0.854	0.372	0.036	0.305	0.445	0.489	0.035	0.421	0.557
2009	0.617	0.056	0.512	0.730	0.203	0.027	0.156	0.263	0.329	0.033	0.268	0.397
2010	0.868	0.051	0.766	0.965	0.288	0.026	0.241	0.341	0.332	0.023	0.290	0.379
2011	1.223	0.059	1.106	1.338	0.534	0.041	0.454	0.615	0.437	0.027	0.384	0.490
2012	0.733	0.053	0.630	0.837	0.213	0.024	0.168	0.263	0.290	0.025	0.246	0.344
2013	1.273	0.064	1.150	1.400	0.544	0.047	0.456	0.638	0.427	0.028	0.374	0.483
2014	1.457	0.070	1.330	1.607	0.603	0.048	0.513	0.702	0.414	0.028	0.362	0.473
2015	2.014	0.120	1.774	2.245	0.570	0.047	0.479	0.664	0.283	0.017	0.252	0.318
2016	1.751	0.102	1.558	1.960	0.584	0.055	0.485	0.699	0.333	0.025	0.288	0.384
2017	3.596	0.523	2.692	4.741	5.676	0.838	4.252	7.535	1.578	0.077	1.439	1.742
2018	3.045	0.356	2.417	3.811	12.784	1.633	9.893	16.294	4.197	0.233	3.768	4.681
2019	3.625	0.543	2.706	4.834	16.243	2.541	12.013	21.972	4.479	0.216	4.072	4.918
2020	3.538	0.518	2.655	4.686	14.520	2.201	10.813	19.442	4.105	0.208	3.713	4.528

5.6 SKI3 BT+MW east coast event

This series was based on the tow-by-tow bycatch of gemfish in the east coast South Island mixed target species BT/MW fishery. The analysis included the two primary east coast statistical areas: Statistical Area 020 (Pegasus Bay) and Statistical Area 022 (Canterbury Bight) (Table 28). The MW component of the analysis was constrained to midwater gear fished within 10 m of the bottom and the target species suite included squid (SQU), barracouta (BAR), hoki (HOK), red cod (RCO) and tarakihi (TAR). The core fleet was defined by having fished at least once in each of three years, retaining 97% of the catch and reducing the fleet from over 100 vessels to 94 vessels (Figure 119). The majority of vessels in this fishery appeared to be characterised by their continuity in this fishery, with many vessels being present for 20 years or more (Figure 120). The final groomed dataset represented 28% (1996) to 100% (2004, 2010, 2012, 2016 to 2019) of the annual catch (Table 29). The bycatch of gemfish in the defined fishery was less than 10 t/y in every year from 1996 to 2015, except for 2003 when it was nearly 20 t (Table 30). This model was started in 1996 because the gemfish bycatch prior to this year was negligible. However, beginning in 2016, the bycatch of gemfish rose to greater than 60 t/y and peaked at 109 t in 2020. Most catches in the dataset were derived from landings allocated to each tow based on estimated catches (Figure 121).

The binomial (occurrence) model accepted three predictive variables after fishing year (vessel, bottom depth and day of season), with the total model explaining 21% of the deviance (Table 31). The unstandardised series showed a gradually increasing trend from 1996 to 2018, followed by a decline to the end of the series with the standardisation steepening the series relative to the unstandardised series (Figure 122). Almost all the standardisation occurred with the addition of the vessel covariate (Figure 123) because vessels with low gemfish CPUE predominated after 2008 (Figure 124). The bottom depth covariate showed a similar corrective pattern, with shallow tows (which have lower gemfish CPUE) predominating after 2008, but there also remained a lot of deeper tows probably representing target hoki fishing (Figure 125). However, there was little standardisation effect with the addition of this covariate (Figure 123). Although day of season entered the occurrence model, the standardisation effect from this variable was small (Figure 126, Figure 123).

The lognormal model accepted two predictive variables after fishing year (vessel, bottom depth), with the total model explaining 50% of the deviance (Table 32). Residuals to the lognormal model showed some skewness in the distribution residuals, but overall there was reasonable conformity to the lognormal assumption over most of the distribution except for the upper tail of the distribution (Figure 127). The gamma distribution showed a very poor fit to the positive catch data while the Weibull model residuals had a similar fit to the data compared with the lognormal model (Figure 128). The lognormal model was characterised by a long period of very low indices from the beginning of the model in 1996 to 2015, followed by a strong increasing trend from 2016 to 2020, with almost no standardisation effect over the entire series (Figure 129, Figure 130). While the CDI plots for vessel (Figure 131) and bottom depth (Figure 132) indicate that there should have been some standardisation resulting from the application of these variables, the net effect appeared to be small (Figure 130). Implied residual plots of gemfish annual CPUE showed good conformity with the overall annual CPUE trend across all five target species (Figure 133), the two statistical areas (Figure 134) and the two capture methods (Figure 135).

The multiplicative effect of the combined model negated the flat trend in the binomial model and favoured the strong increasing trend in the lognormal model (Figure 136, Figure 137, Table 33).

Table 28: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SKI3 BT+MW east coast event CPUE series.

Series	SKI3 BT+MW east coast event
QMS stock	SKI3
Reporting forms	TCE, TCP, ERS - Trawl, CEL
Fishing methods	BT, MW
Target species	SQU, BAR, HOK, RCO, TAR
Statistical Areas	020, 022
Period	1995-10-01, 2020-09-30
Resolution	Fishing event
Core fleet years	3
Core fleet trips	1
Default model	allockg_top5 ~ fyear + vessel_key + stat_area + target_species + primary_method + ns(log(fishing_duration), 3) + bs(start_latitude, 3) + bs(effort_width, 3) + bs(effort_height, 3) + bs(bottom_depth, 3) + bs(effort_speed, 3) + bs(start_hour, 3) + bs(SeasonDay, 3)
Stepwise selection	Yes
Positive catch distribution	Lognormal

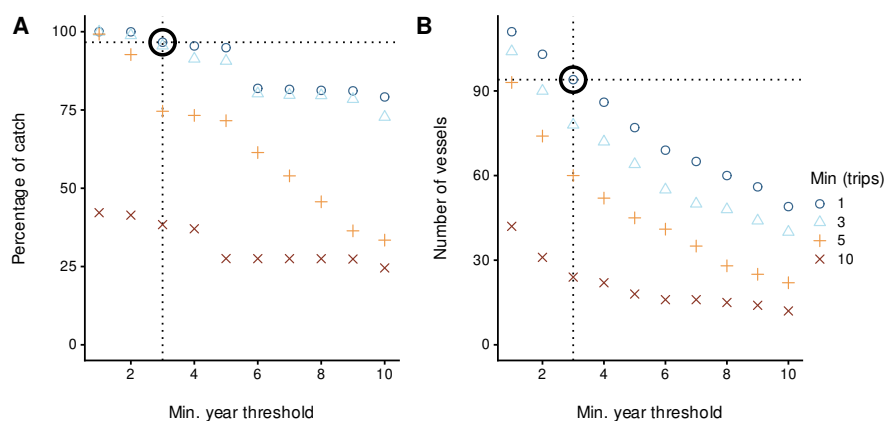


Figure 119: Percentage of catch and number of vessels for different core vessel selection criteria for the SKI3 BT+MW east coast event CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

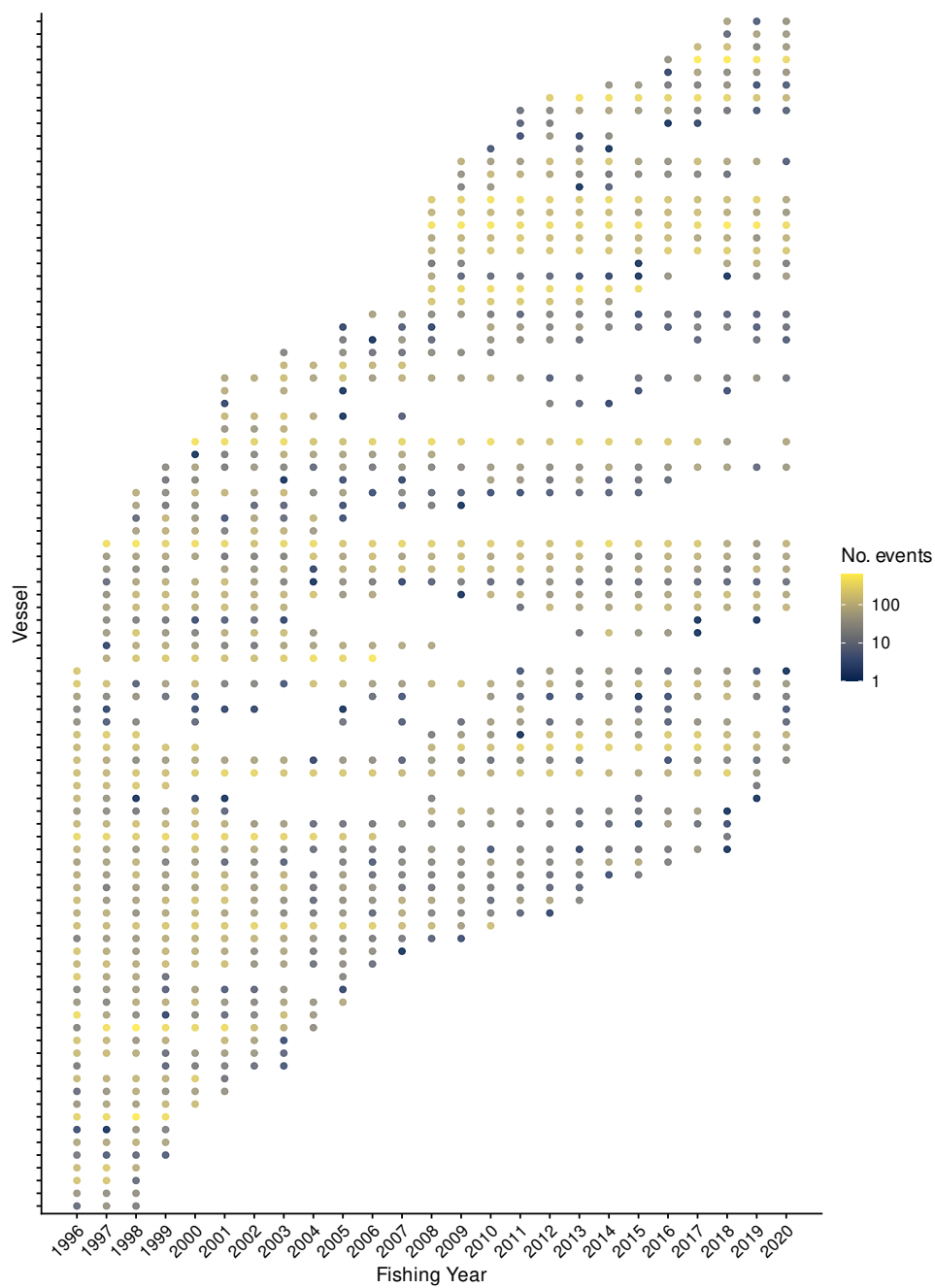


Figure 120: Number of events by fishing year for core vessels. The colour of the points is proportional to the number of events undertaken by a vessel in a fishing year.

Table 29: Summary of the SKI3 BT+MW east coast event dataset total catch (tonnes) and number of records (n), by fishing year after the application of various filters. The first row gives the catch and number of records before filters were applied (ungroomed data). Subsequent rows display the remaining catch (and percent of catch), and the number of records, after the specified filter was applied. (Continued on next page)

Filter	1996	1997	1998	1999	2000	2001	2002	2003	2004
Ungroomed data	7.7 (100%) n: 11059	2.3 (100%) n: 10558	1.8 (100%) n: 12076	1.1 (100%) n: 8778	1.7 (100%) n: 8980	1.7 (100%) n: 8044	8.2 (100%) n: 6066	24 (100%) n: 7404	6.4 (100%) n: 5821
Fishing duration is not NA	7.7 (100%) n: 11038	2.3 (100%) n: 10515	1.8 (100%) n: 12034	1.1 (100%) n: 8749	1.7 (100%) n: 8964	1.7 (100%) n: 8043	8.2 (100%) n: 6066	24 (100%) n: 7404	6.4 (100%) n: 5820
Positive fishing duration	7.7 (100%) n: 11032	2.3 (100%) n: 10509	1.8 (100%) n: 12026	1.1 (100%) n: 8748	1.7 (100%) n: 8963	1.7 (100%) n: 8043	8.2 (100%) n: 6063	24 (100%) n: 7402	6.4 (100%) n: 5818
Bottom depth >=50	7 (92%) n: 7557	1.7 (75%) n: 6910	0.81 (45%) n: 8049	1 (89%) n: 5802	1.7 (100%) n: 6453	1.6 (93%) n: 5309	7.5 (91%) n: 4139	20 (84%) n: 5066	4.2 (66%) n: 3665
Bottom depth <=600	7 (92%) n: 7311	1.7 (74%) n: 6453	0.8 (44%) n: 7627	0.98 (87%) n: 5537	1.5 (88%) n: 6050	1.5 (90%) n: 4983	7.4 (90%) n: 3871	20 (83%) n: 4761	4.2 (65%) n: 3364
Midwater effort depth <=10 m from bottom	7 (92%) n: 7203	1.6 (73%) n: 6291	0.79 (44%) n: 7489	0.97 (86%) n: 5453	1.3 (78%) n: 5939	1.5 (89%) n: 4911	7.3 (89%) n: 3766	19 (82%) n: 4582	4.2 (65%) n: 3339
Core fleet selection	2.1 (28%) n: 5145	1.5 (67%) n: 5131	0.73 (41%) n: 6059	0.92 (82%) n: 5048	1.3 (78%) n: 5535	1.1 (65%) n: 4730	7.3 (89%) n: 3697	19 (82%) n: 4452	4 (63%) n: 3144

Filter	2005	2006	2007	2008	2009	2010	2011	2012	2013
Ungroomed data	4.4 (100%) n: 5623	1.6 (100%) n: 5094	2.9 (100%) n: 4180	1.2 (100%) n: 5031	3.4 (100%) n: 5642	2.8 (100%) n: 6070	5 (100%) n: 5464	1.1 (100%) n: 4838	7.7 (100%) n: 5300
Fishing duration is not NA	4.4 (100%) n: 5623	1.6 (100%) n: 5094	2.9 (100%) n: 4180	1.2 (100%) n: 5031	3.4 (100%) n: 5642	2.8 (100%) n: 6070	5 (100%) n: 5464	1.1 (100%) n: 4838	7.7 (100%) n: 5300
Positive fishing duration	4.4 (100%) n: 5621	1.6 (100%) n: 5094	2.9 (100%) n: 4179	1.2 (100%) n: 5028	3.4 (100%) n: 5642	2.8 (100%) n: 6069	5 (100%) n: 5464	1.1 (100%) n: 4838	7.4 (100%) n: 5297
Bottom depth >=50	2.9 (65%) n: 3180	0.81 (50%) n: 2903	1.4 (50%) n: 2389	1.2 (100%) n: 3998	3.4 (100%) n: 4480	2.8 (100%) n: 5060	4.9 (100%) n: 4814	1.1 (100%) n: 4493	7.4 (100%) n: 4712
Bottom depth <=600	2.8 (64%) n: 3021	0.8 (50%) n: 2829	1.4 (49%) n: 2298	1.2 (94%) n: 3806	3.4 (100%) n: 4264	2.7 (100%) n: 4840	4.9 (100%) n: 4667	1.1 (100%) n: 4334	7.3 (100%) n: 4576
Midwater effort depth <=10 m from bottom	2.8 (64%) n: 2976	0.8 (50%) n: 2805	1.4 (49%) n: 2289	1.2 (94%) n: 3782	3.4 (100%) n: 4251	2.7 (100%) n: 4811	4.9 (100%) n: 4622	1.1 (100%) n: 4251	6.9 (90%) n: 4426
Core fleet selection	2.8 (63%) n: 2905	0.77 (48%) n: 2698	1.3 (45%) n: 2128	1.2 (94%) n: 3566	3.4 (100%) n: 3956	2.7 (100%) n: 4473	3.7 (74%) n: 4179	1.1 (100%) n: 4159	6.9 (90%) n: 4267

Filter	2014	2015	2016	2017	2018	2019	2020
Ungroomed data	1.2 (100%) n: 5446	1.3 (100%) n: 4197	61 (100%) n: 4203	63 (100%) n: 5456	93 (100%) n: 4719	66 (100%) n: 3582	121 (100%) n: 3393
Fishing duration is not NA	1.2 (100%) n: 5446	1.3 (100%) n: 4197	61 (100%) n: 4203	63 (100%) n: 5456	93 (100%) n: 4717	66 (100%) n: 3581	121 (100%) n: 3393
Positive fishing duration	1.2 (100%) n: 5446	1.3 (100%) n: 4197	61 (100%) n: 4202	63 (100%) n: 5456	93 (100%) n: 4717	66 (100%) n: 3579	121 (100%) n: 3392
Bottom depth >=50	1.2 (100%) n: 4739	1.3 (100%) n: 3741	61 (100%) n: 3797	63 (100%) n: 4878	92 (100%) n: 4355	66 (100%) n: 3236	121 (100%) n: 2962
Bottom depth <=600	1.2 (100%) n: 4617	1 (82%) n: 3586	61 (100%) n: 3591	63 (100%) n: 4661	92 (100%) n: 4228	65 (100%) n: 3177	119 (100%) n: 2806
Midwater effort depth <=10 m from bottom	1.1 (92%) n: 4510	1 (81%) n: 3487	61 (100%) n: 3506	63 (100%) n: 4568	91 (100%) n: 4123	64 (100%) n: 3107	119 (100%) n: 2660
Core fleet selection	1.1 (92%) n: 4395	1 (81%) n: 3420	60 (100%) n: 3264	63 (100%) n: 4528	91 (100%) n: 4103	64 (100%) n: 3034	108 (90%) n: 2467

Table 30: Summary of the SKI3 BT+MW east coast event dataset after core fleet selection. ‘Records’ indicates the number of rows (events) in the dataset, and ‘Records caught’ indicates the percentage of events with catches of gemfish.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
1996	43	483	5 145	18 214.53	2.12	11.74
1997	51	495	5 131	18 751.28	1.51	15.38
1998	54	567	6 059	23 390.98	0.73	12.23
1999	50	467	5 048	19 660.85	0.92	20.31
2000	47	432	5 535	22 050.60	1.34	15.16
2001	48	356	4 730	21 036.17	1.12	28.67
2002	43	344	3 697	14 936.50	7.27	30.29
2003	46	365	4 452	18 885.78	19.50	44.50
2004	34	278	3 144	13 664.48	4.04	30.50
2005	41	254	2 905	13 196.80	2.76	34.25
2006	32	225	2 698	11 881.20	0.77	41.07
2007	33	187	2 128	9 716.48	1.29	43.89
2008	40	594	3 566	15 423.17	1.16	23.33
2009	40	677	3 956	16 986.42	3.36	19.69
2010	42	741	4 473	19 215.55	2.70	31.39
2011	44	696	4 179	17 855.10	3.70	27.16
2012	45	786	4 159	15 967.47	1.08	18.56
2013	46	788	4 267	15 889.55	6.92	23.95
2014	42	692	4 395	18 681.35	1.15	19.84
2015	42	586	3 420	15 283.23	1.04	18.65
2016	40	536	3 264	13 183.52	60.45	22.86
2017	39	724	4 528	18 210.72	62.65	32.42
2018	41	672	4 103	17 195.80	91.20	50.30
2019	37	563	3 034	12 796.37	64.37	44.26
2020	36	424	2 467	10 735.48	108.39	41.55

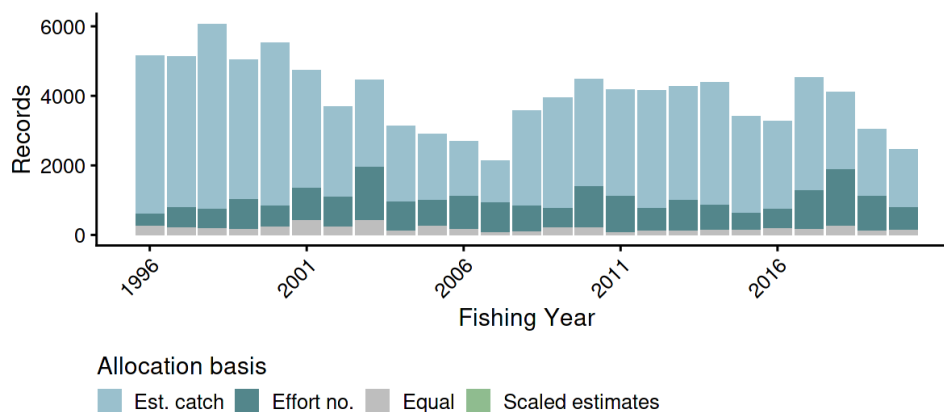


Figure 121: Allocation basis for attributing landings to records in the SKI3 BT+MW east coast catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table 31: Summary of stepwise selection for occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	23.00	110 007	5.20	5.20	*
+ vessel_key	93.00	96 204	17.30	12.10	*
+ bs(bottom_depth, 3)	3.00	93 742	19.40	2.10	*
+ bs(SeasonDay, 3)	3.00	92 367	20.60	1.20	*
+ bs(effort_height, 3)	3.00	92 339	20.60	0.00	
+ primary_method	1.00	92 257	20.70	0.10	
+ bs(effort_width, 3)	3.00	92 217	20.80	0.00	
+ target_species	4.00	92 184	20.80	0.00	
+ ns(log(fishing_duration), 3)	3.00	92 172	20.80	0.00	
+ bs(effort_speed, 3)	3.00	92 168	20.80	0.00	

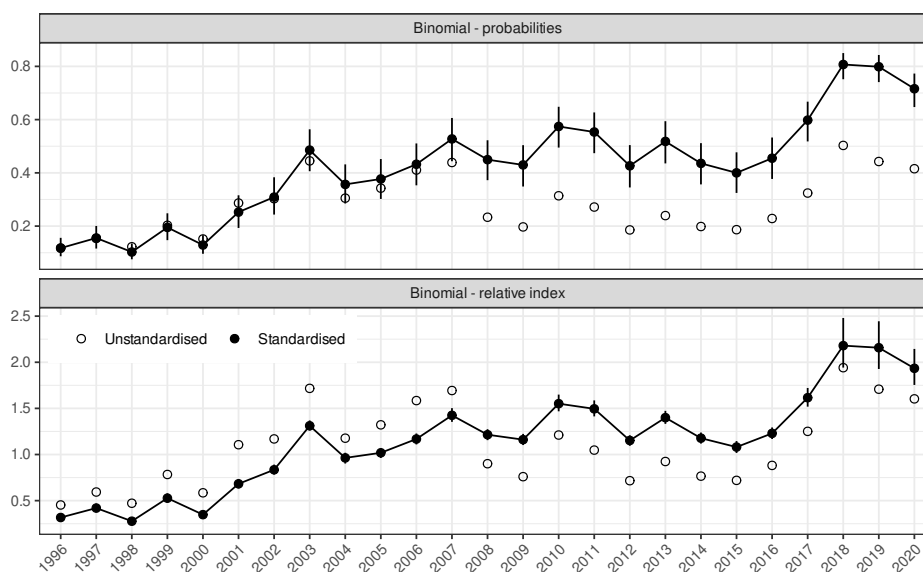


Figure 122: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SKI3 BT+MW east coast event dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

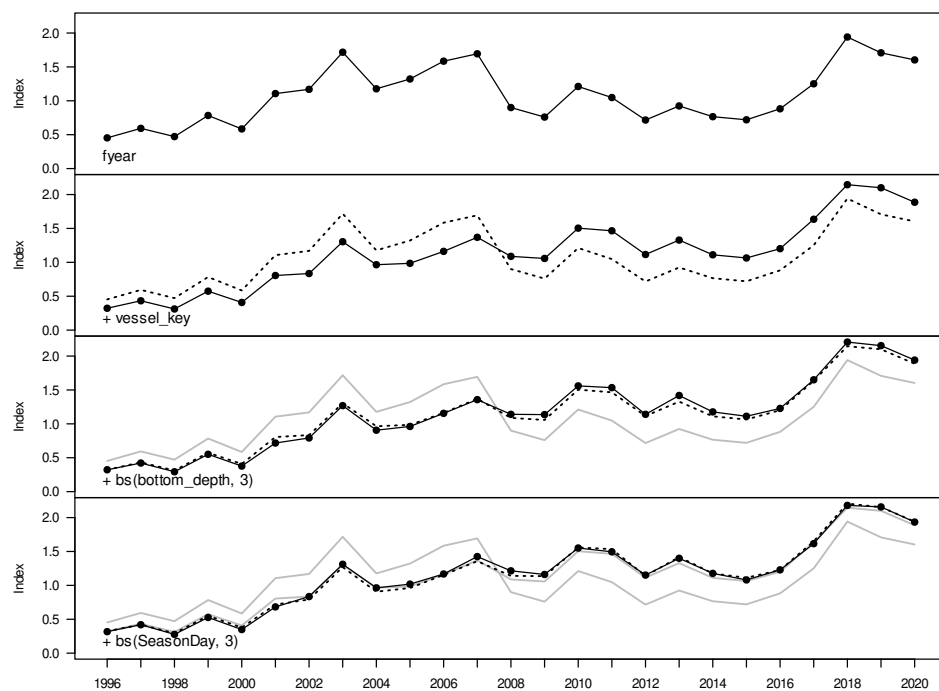


Figure 123: Step plot for occurrence of catch in the SKI3 BT+MW east coast event dataset.

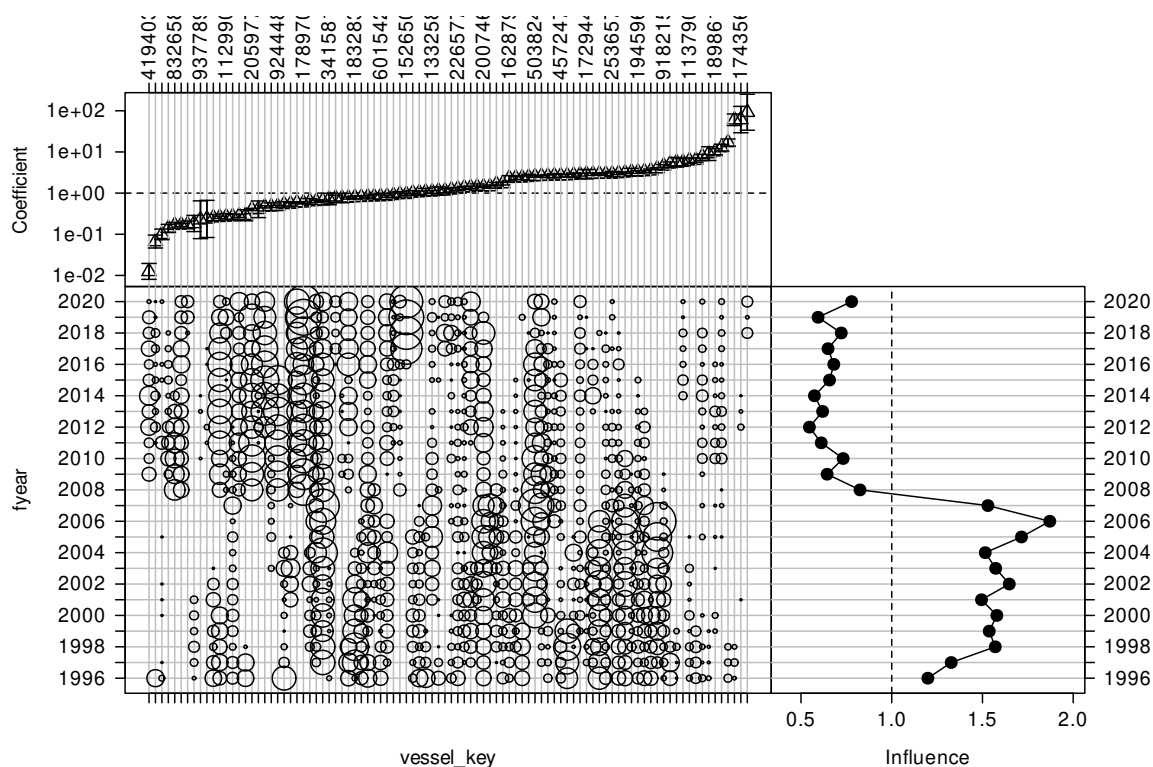


Figure 124: CDI plot for vessel key for the occurrence of positive catch SKI3 BT+MW east coast event catch-per-unit-effort dataset.

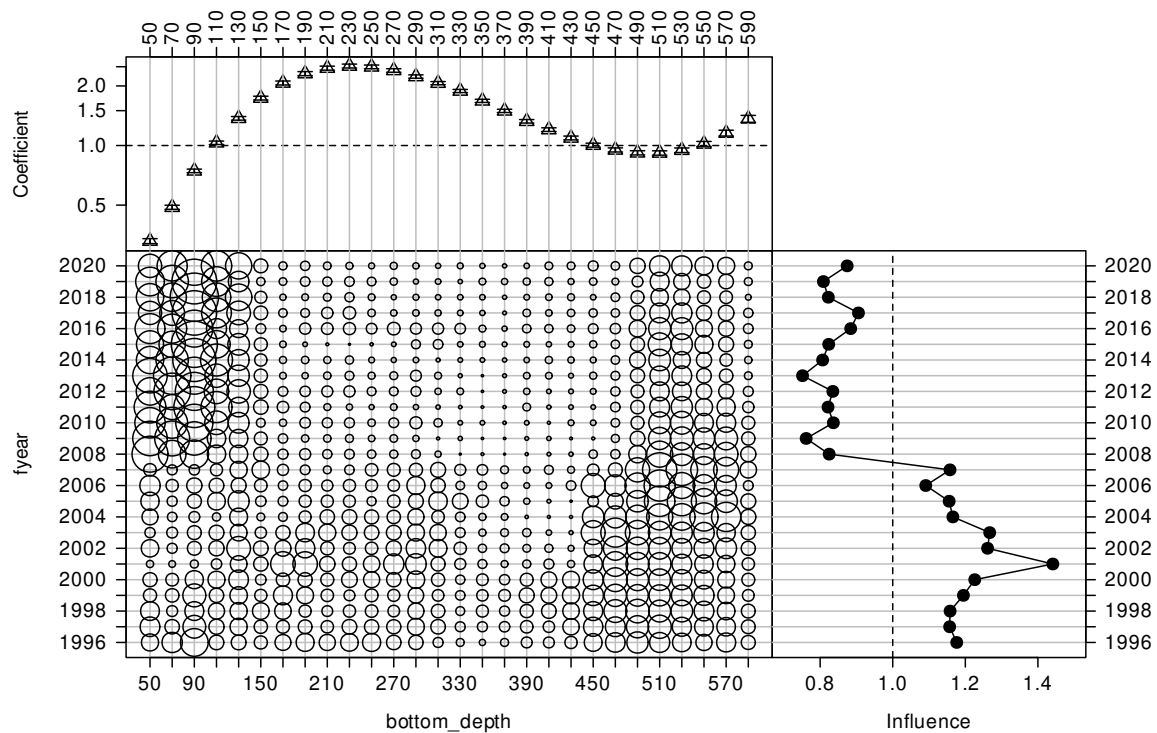


Figure 125: CDI plot for bottom depth (m) for the occurrence of positive catch SKI3 BT+MW east coast event catch-per-unit-effort dataset.

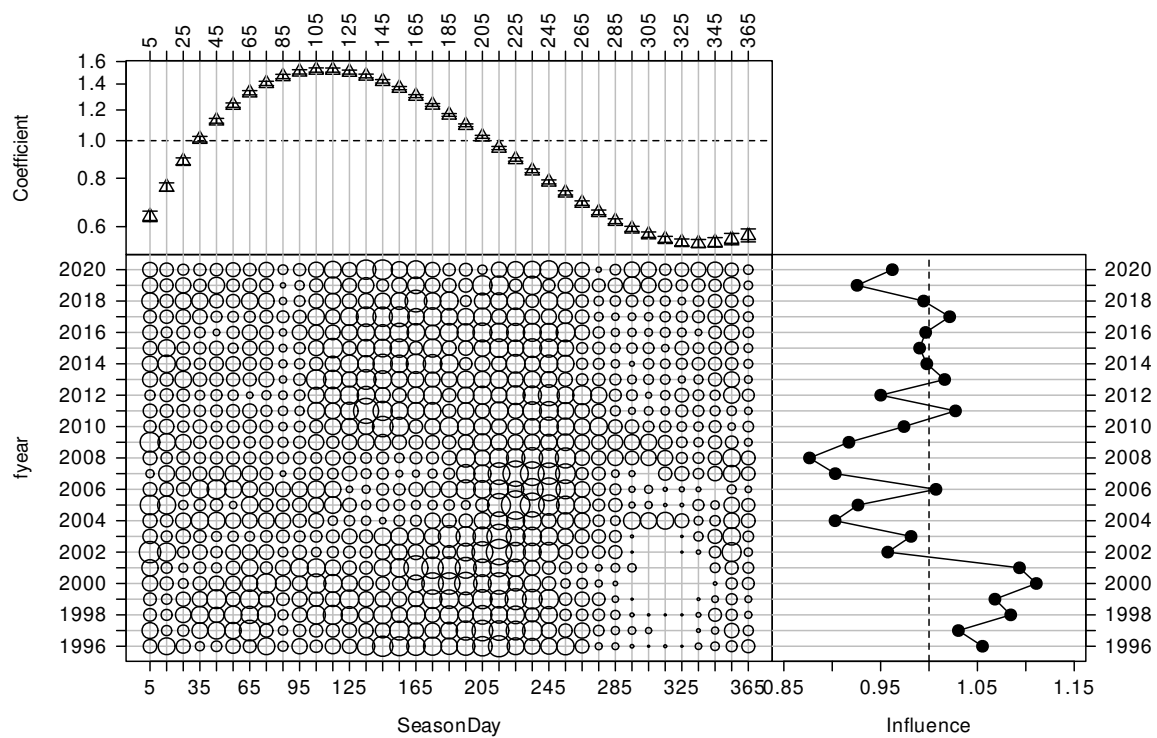


Figure 126: CDI plot for SeasonDay for the occurrence of positive catch SKI3 BT+MW east coast event catch-per-unit-effort dataset.

Table 32: Summary of stepwise selection for the lognormal model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	23	108 305	24.1	24.1	*
+ vessel key	93	98 130	48.6	24.5	*
+ bs(bottom depth, 3)	3	97 422	50.0	1.4	*
+ bs(SeasonDay, 3)	3	97 119	50.5	0.6	
+ stat area	1	96 991	50.8	0.2	
+ target species	4	96 964	50.9	0.1	
+ bs(start latitude, 3)	3	96 949	50.9	0.0	
+ bs(effort height, 3)	3	96 948	50.9	0.0	

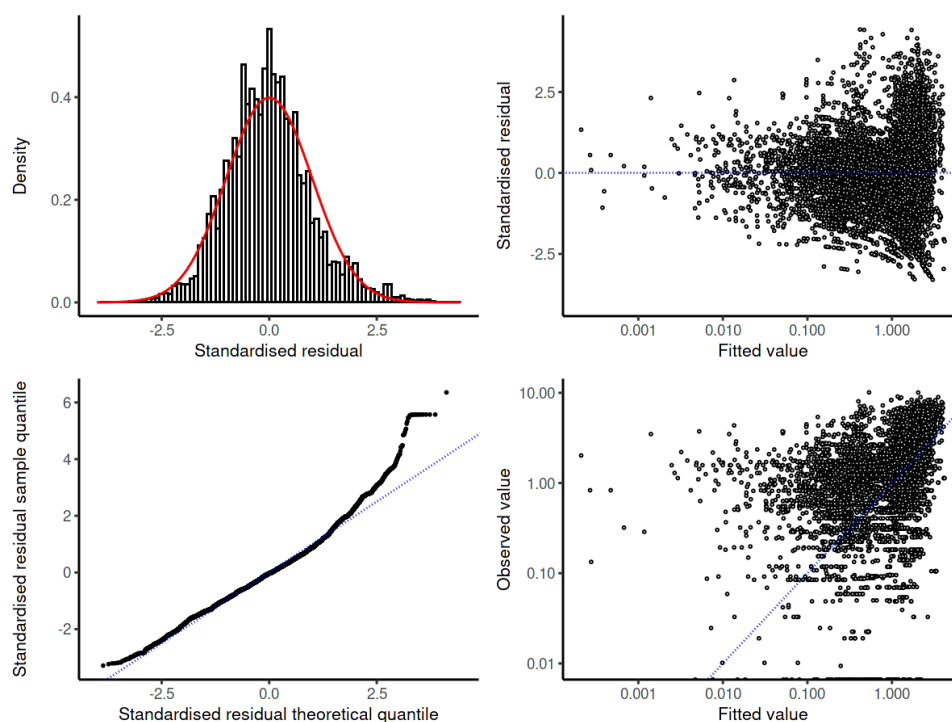


Figure 127: Diagnostic plots for the lognormal model for the SKI3 BT+MW east coast event dataset.

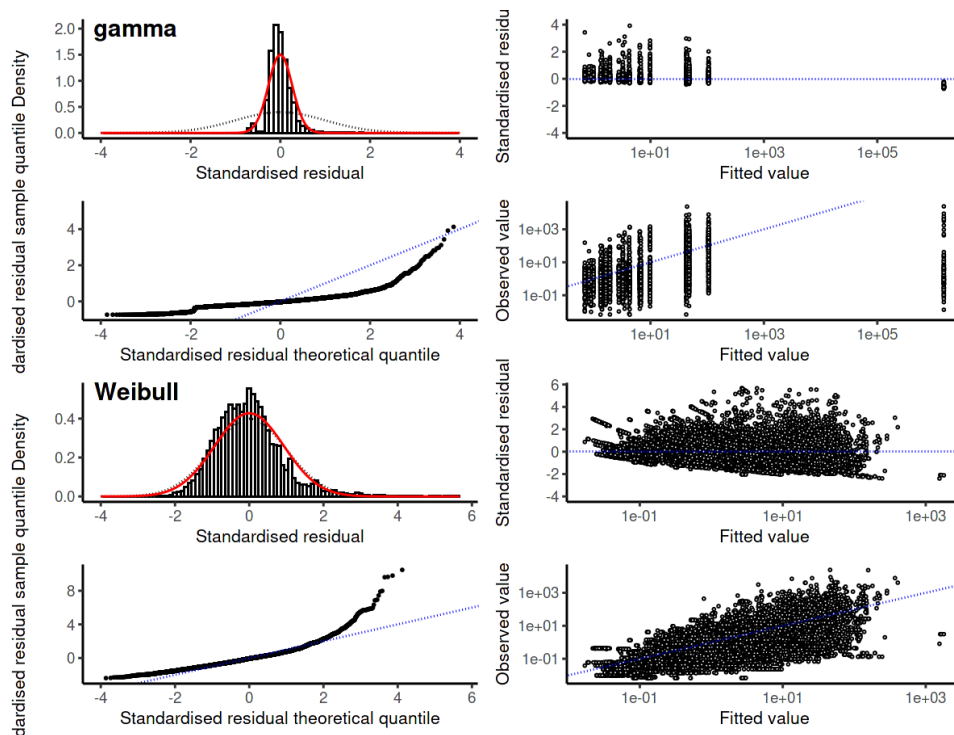


Figure 128: Diagnostic plots for the gamma and Weibull model for the SKI3 BT+MW east coast event dataset.

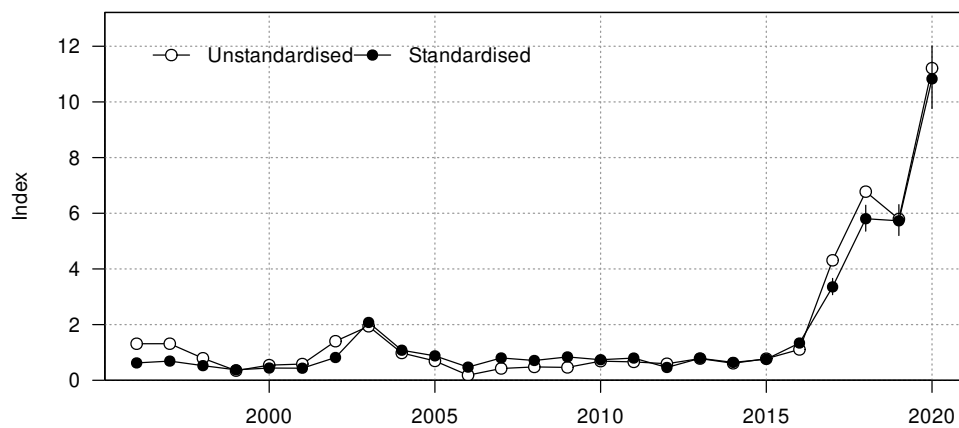


Figure 129: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SKI3 BT+MW east coast event dataset.

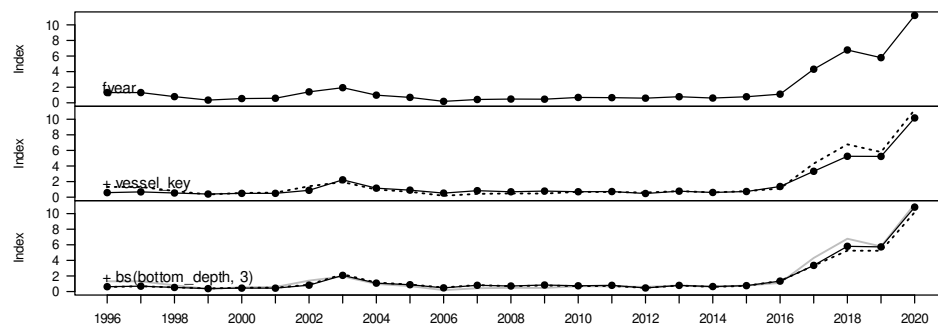


Figure 130: Changes to the SKI3 BT+MW east coast event positive catch index as terms are successively entered into the model.

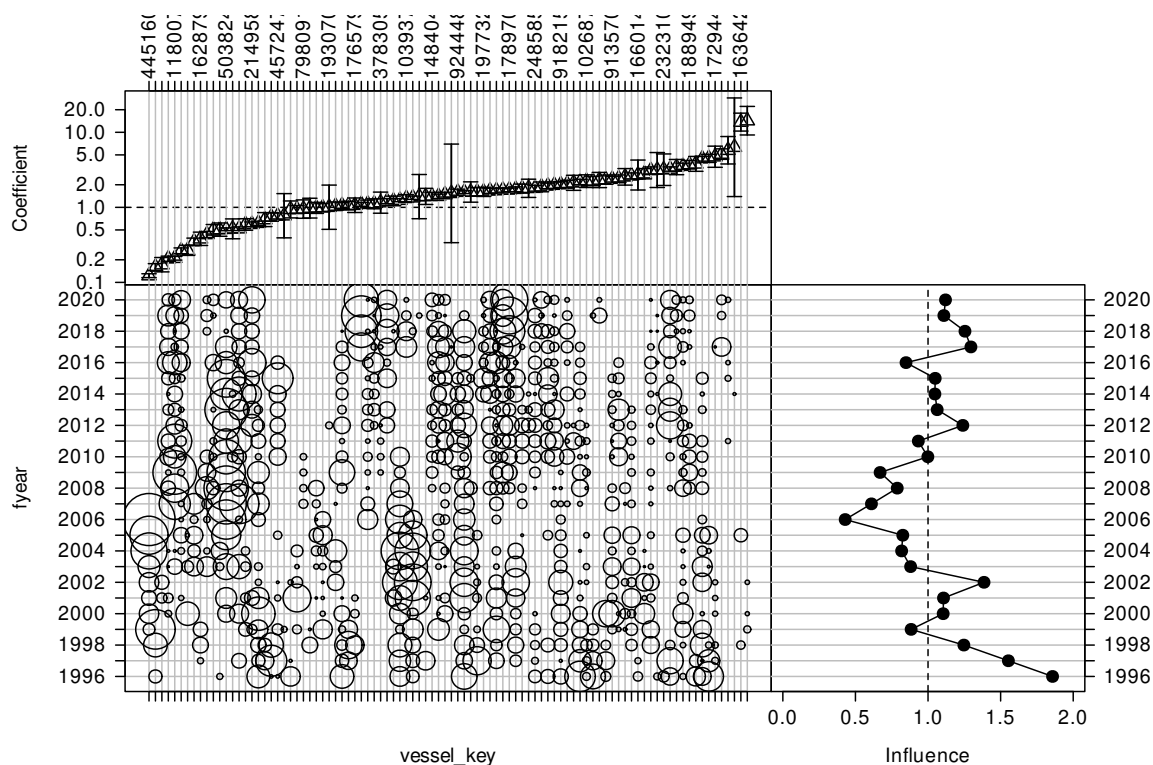


Figure 131: CDI plot for vessel key for the positive catch SKI3 BT+MW east coast event catch-per-unit-effort dataset.

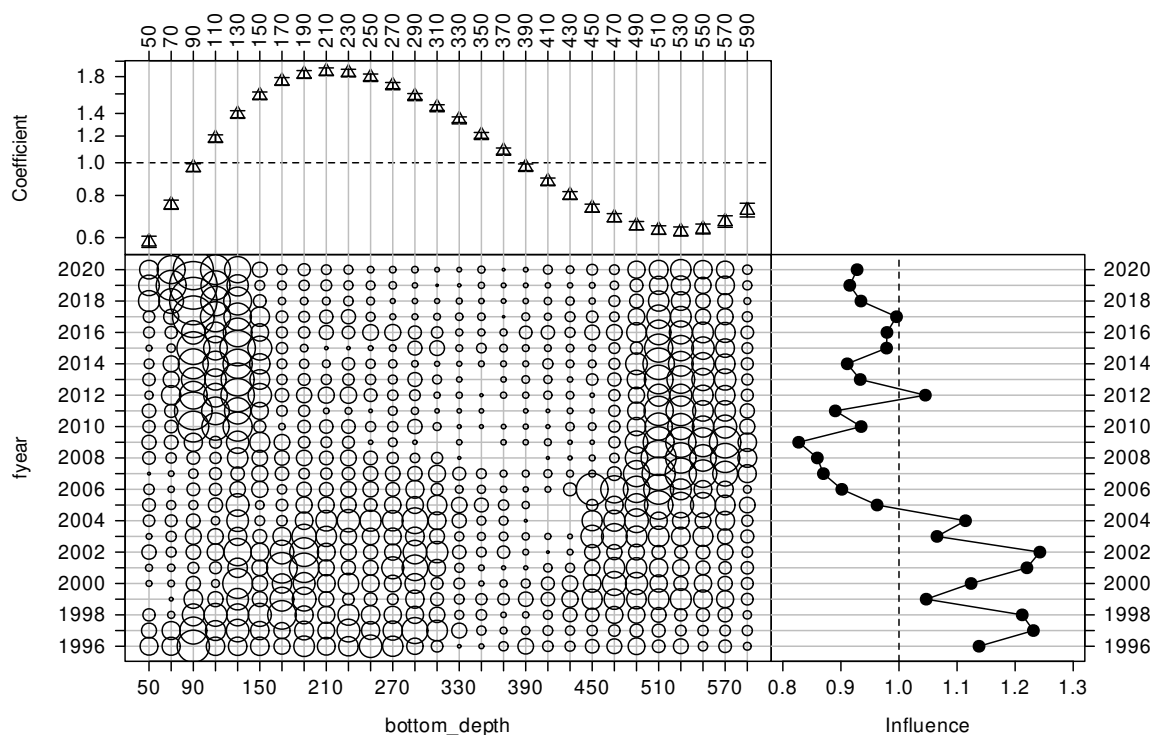


Figure 132: CDI plot for bottom depth (m) for the positive catch SKI3 BT+MW east coast event catch-per-unit-effort dataset.

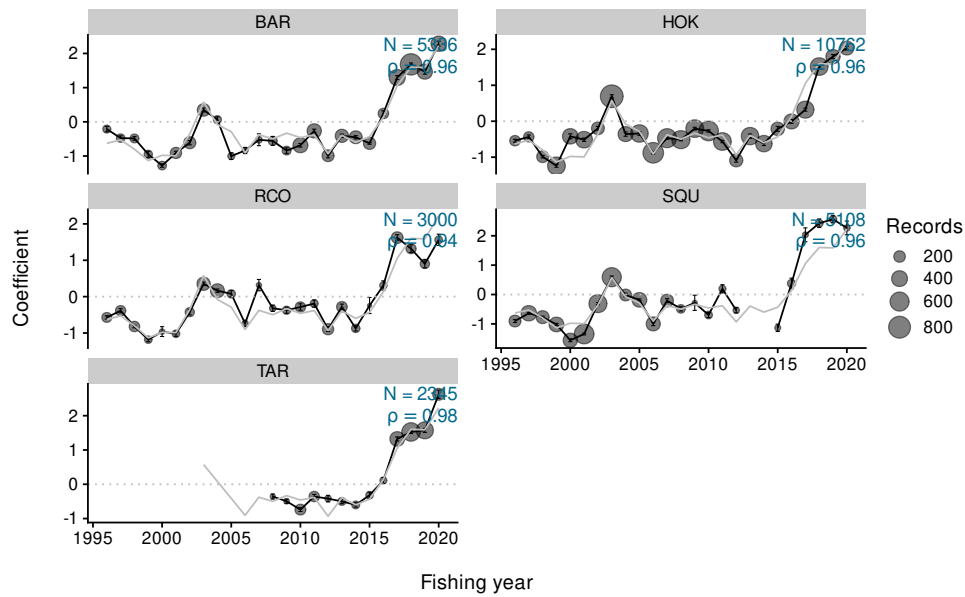


Figure 133: Residual implied coefficients for target-year in the lognormal positive catch model for the SKI3 BT+MW east coast event dataset.

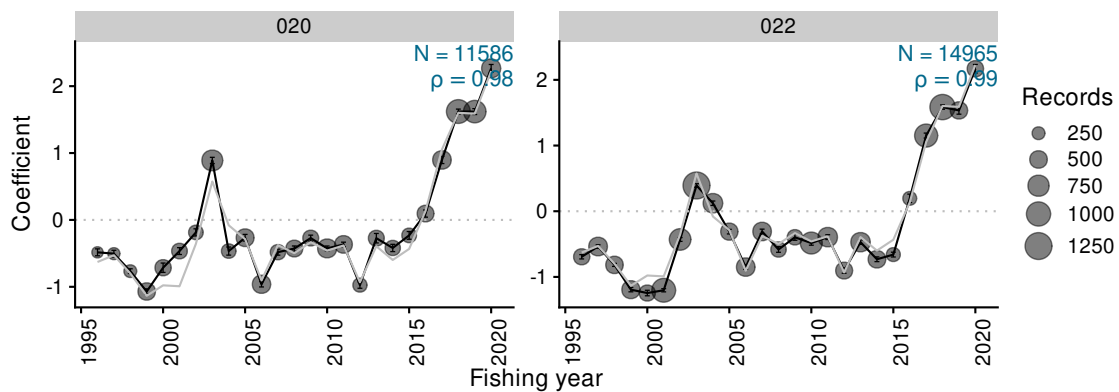


Figure 134: Residual implied coefficients for area-year in the lognormal positive catch model for the SKI3 BT+MW east coast event dataset.

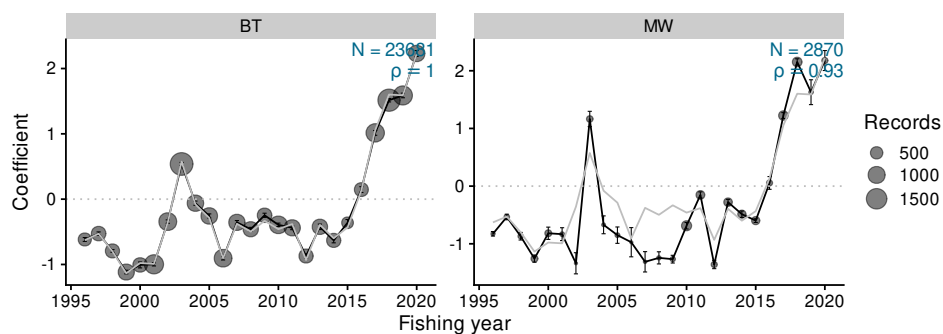


Figure 135: Residual implied coefficients for primary method-year in the lognormal positive catch model for the SKI3 BT+MW east coast event dataset.

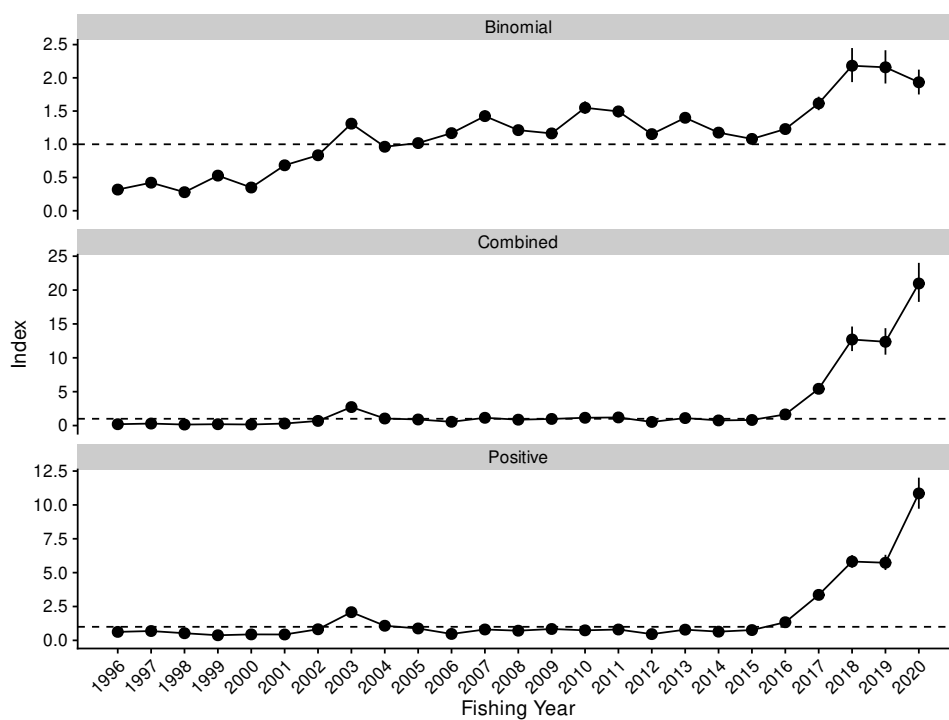


Figure 136: Standardised indices and 95% confidence intervals for the SKI3 BT+MW east coast event dataset.

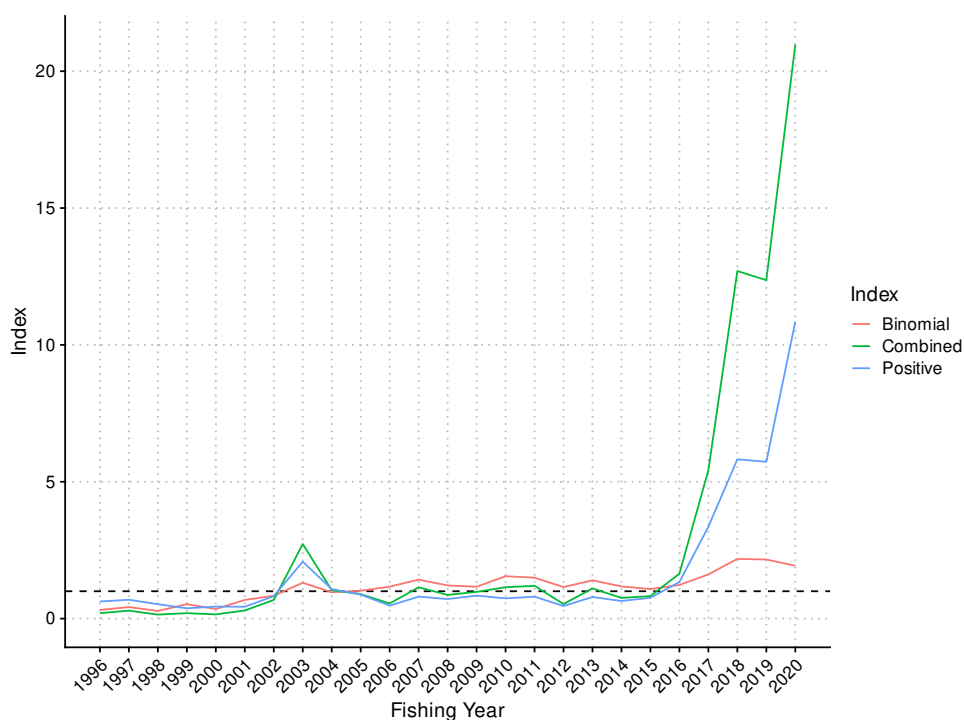


Figure 137: Standardised indices for the SKI3 BT+MW east coast event dataset.

Table 33: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SKI3 BT+MW east coast event.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1996	0.318	0.021	0.279	0.363	0.199	0.019	0.165	0.242	0.626	0.042	0.549	0.714
1997	0.422	0.025	0.374	0.474	0.291	0.026	0.245	0.345	0.689	0.044	0.604	0.776
1998	0.279	0.019	0.246	0.321	0.147	0.013	0.123	0.176	0.527	0.035	0.463	0.600
1999	0.529	0.026	0.479	0.582	0.200	0.015	0.172	0.229	0.377	0.020	0.339	0.418
2000	0.349	0.019	0.314	0.389	0.154	0.012	0.131	0.177	0.440	0.025	0.390	0.490
2001	0.684	0.027	0.632	0.737	0.297	0.019	0.262	0.335	0.434	0.021	0.393	0.474
2002	0.835	0.028	0.782	0.891	0.683	0.039	0.612	0.764	0.819	0.042	0.742	0.906
2003	1.310	0.028	1.258	1.367	2.726	0.109	2.518	2.947	2.081	0.075	1.941	2.236
2004	0.963	0.029	0.906	1.019	1.039	0.064	0.914	1.164	1.079	0.059	0.969	1.199
2005	1.018	0.027	0.964	1.069	0.895	0.052	0.797	0.999	0.879	0.044	0.800	0.972
2006	1.168	0.029	1.111	1.226	0.552	0.031	0.492	0.615	0.473	0.024	0.428	0.523
2007	1.424	0.040	1.352	1.509	1.144	0.073	1.011	1.296	0.803	0.043	0.726	0.896
2008	1.213	0.030	1.155	1.274	0.866	0.051	0.769	0.969	0.714	0.036	0.644	0.785
2009	1.163	0.031	1.100	1.222	0.977	0.057	0.875	1.097	0.839	0.045	0.755	0.930
2010	1.550	0.047	1.459	1.645	1.147	0.060	1.034	1.268	0.740	0.032	0.679	0.804
2011	1.494	0.044	1.405	1.577	1.198	0.066	1.077	1.337	0.802	0.038	0.727	0.876
2012	1.153	0.030	1.096	1.214	0.532	0.033	0.471	0.600	0.461	0.026	0.411	0.513
2013	1.399	0.036	1.327	1.468	1.104	0.058	0.997	1.227	0.789	0.038	0.718	0.868
2014	1.176	0.029	1.120	1.233	0.756	0.042	0.676	0.842	0.644	0.033	0.580	0.708
2015	1.081	0.032	1.017	1.144	0.822	0.056	0.721	0.940	0.760	0.048	0.670	0.859
2016	1.229	0.033	1.165	1.296	1.644	0.105	1.447	1.858	1.338	0.077	1.194	1.496
2017	1.615	0.052	1.513	1.716	5.424	0.287	4.877	6.000	3.358	0.148	3.076	3.656
2018	2.182	0.131	1.936	2.448	12.699	0.924	10.994	14.616	5.820	0.237	5.362	6.290
2019	2.158	0.128	1.914	2.415	12.366	0.997	10.462	14.371	5.729	0.286	5.194	6.317
2020	1.933	0.095	1.749	2.124	20.969	1.470	18.255	24.016	10.848	0.585	9.719	12.012

5.7 SKI3 BT+MW east coast process daily

This series was also based on the bycatch of gemfish in the east coast South Island mixed target species BT/MW fishery, except it used on the daily processing data instead of the catch by tow. The area definition for this analysis was the same as the event-based analysis which used the two primary east coast statistical areas: Statistical Area 020 (Pegasus Bay) and Statistical Area 022 (Canterbury Bight) (Table 34). The MW component of the analysis was constrained to midwater gear fished within 10 m of the bottom and the target species suite included squid (SQU), barracouta (BAR), hoki (HOK), red cod (RCO) and tarakihi (TAR). The core fleet was defined by having fished at least once in each of two years, only dropping 100% of the catch and dropping no vessels (Figure 138). This was done so as to retain as much catch as possible and to include all vessels, given the small size of this dataset. It can be seen from Figure 139 that a majority of vessels in this analysis participated in the fishery in all modelled years, ensuring reasonable continuity in the vessel covariate. Table 35 indicated that the only catch dropped from the model occurred when the catch in a processing day failed to meet the bottom depth (less than 600 m) or MW trawl (within 10 m of the bottom) model criteria. The bycatch of gemfish in the defined fishery was small (at less than 10 t/y and often less than 1 t/y) from 2001 to 2015, except for 2003 when it was nearly 20 t (Table 36). This model was started in 2001 because the gemfish bycatch prior to this year was negligible. However, as seen in the tow-by-tow model in the same area, catches rose to 61 t in 2016 and remained above 15 t in a year up to 2020. All catches in the dataset were derived from landings allocated to each day of fishing based on the daily processed catches (Figure 140).

The binomial (occurrence) model accepted three predictive variables after fishing year (vessel, target species and day of season), with the total model explaining 31% of the deviance (Table 37). Both the unstandardised and standardised series showed little or no trend from 2001 to 2015, followed by a substantial increase from 2016 to 2018 and then a levelling off to the end of the series in 2020 (Figure 141). Unlike other series in this analysis where the standardisation process raised the model CPUE in the last four or five years in the series, this analysis lowered the final four years relative to the unstandardised series while raising the four years from 2013 to 2016 (Figure 141). Although the vessel covariate had the greatest explanatory power in the model after fishing year, the standardisation effect attributed to this variable was small (Figure 142, Figure 143). Target species was accepted into this model in third place rather than bottom depth as in the equivalent event-based model, showing a strong standardisation effect with the addition of this variable (Figure 142). This effect reflected a switch to hoki targeting (which has lower gemfish CPUE) and away from red cod and squid (Figure 144). Although day of season entered the occurrence model, the standardisation effect from this variable was small (Figure 142), possibly because there was little contrast in this variable in this dataset (Figure 145).

The lognormal model accepted two predictive variables after fishing year (day of season, vessel), with the total model explaining 32% of the deviance (Table 38). Residuals to the lognormal model showed some skewness in the distribution residuals, but overall there was good conformity to the lognormal assumption over most of the distribution without much deviation in the upper tail of the distribution (Figure 146). Neither the gamma distribution nor the Weibull distribution fitted the positive catch data as well as the lognormal distribution (Figure 147). The lognormal model was characterised by a short period of higher indices at the beginning of the model in 2002 and 2003, followed by a period of low indices from 2004 to 2015 (Figure 148). Beginning in 2016, there was a strong increase in CPUE which was present in both the unstandardised and standardised series. The increase in the unstandardised series tapered off after 2018 while the standardised series continued to increase in 2019 and 2020, an effect that was attributable to the addition of the vessel covariate (Figure 149). The day of season variable entered the model second with a low AIC attributable to the three degrees of freedom associated with this variable (Table 38). However, there was little standardisation effect from this variable (Figure 149), possibly due to the inconsistent between year distribution of the data (Figure 150). On the other hand, the vessel covariate had greater explanatory power than the day of season variable (Table 38) and the addition of this variable resulted in continuing the increasing trend in the series (Figure 149). This effect is attributable to the predominance of vessels with lower gemfish catch rates in the last three years of the series (Figure 151). Implied residual plots of gemfish annual CPUE showed conformity with the overall

annual CPUE trend across three of the target species (BAR and HOK after 2015 and SQU in 2001 to 2006; Figure 152), the two statistical areas (Figure 153) and the two capture methods (Figure 154).

The multiplicative effect of the combined model resulted in a much stronger increasing trend in the combined model than in either the binomial or the lognormal models, with the combined model showing a small drop in 2020 (Figure 155, Figure 156, Table 39).

Table 34: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SKI3 BT+MW east coast process daily CPUE series.

Series	SKI3 BT+MW east coast process daily
QMS stock	SKI3
Reporting forms	TCE, TCP, ERS - Trawl
Fishing methods	BT, MW
Target species	SQU, BAR, HOK, RCO, TAR
Statistical Areas	020, 022
Period	2000-10-01, 2020-09-30
Resolution	Day
Core fleet years	2
Core fleet trips	1
Default model	$\text{prockg} \sim \text{fyear} + \text{vessel_key} + \text{stat_area} + \text{target_species} + \text{primary_method} + \text{ns}(\log(\text{fishing_duration}), 3) + \text{bs}(\text{SeasonDay}, 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

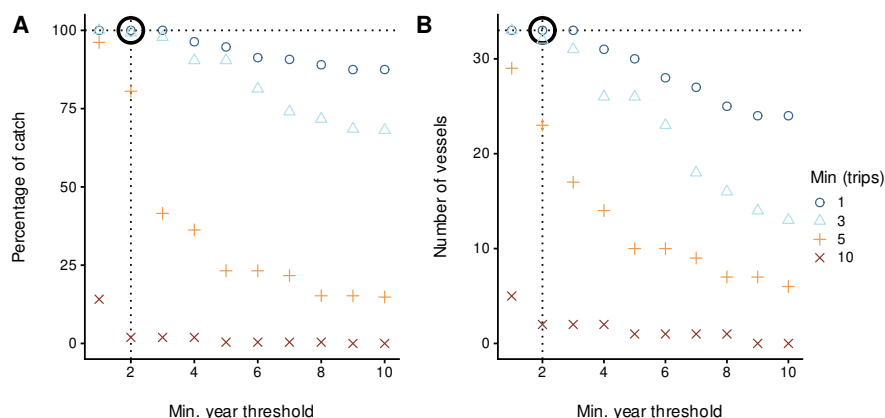


Figure 138: Percentage of catch and number of vessels for different core vessel selection criteria for the SKI3 BT+MW east coast process daily CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

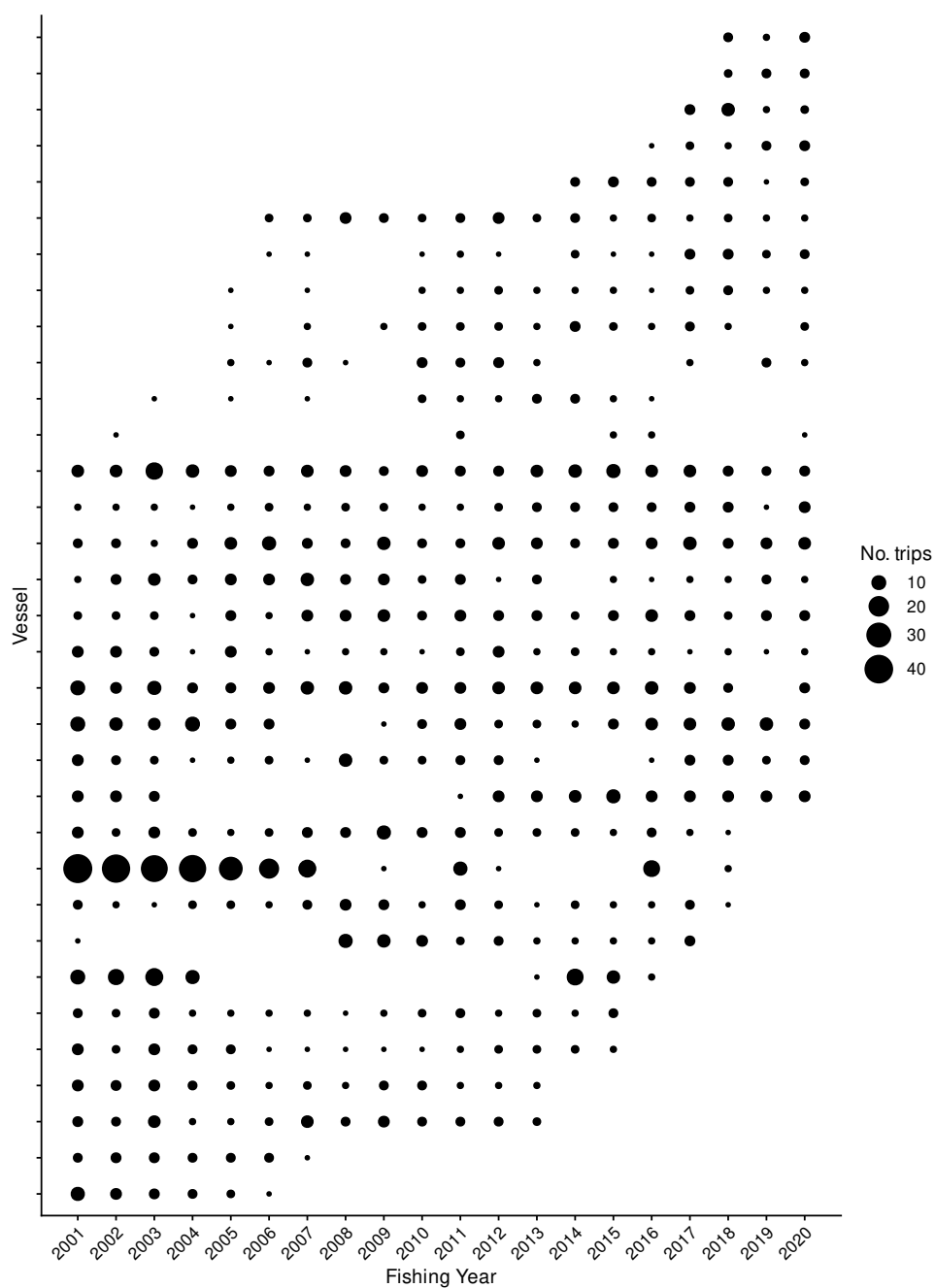


Figure 139: Number of trips by fishing year for core vessels. The area of the circles is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 35: Summary of the SKI3 BT+MW east coast process daily dataset total catch (tonnes) and number of records (n), by fishing year after the application of various filters. The first row gives the catch and number of records before filters were applied (ungroomed data). Subsequent rows display the remaining catch (and percent of catch), and the number of records, after the specified filter was applied. (Continued on next page)

Filter	2001	2002	2003	2004	2005	2006	2007	2008	2009
Ungroomed data	0.41 (100%) n: 1099	7.3 (100%) n: 734	20 (100%) n: 873	1.5 (100%) n: 593	2 (100%) n: 548	0.45 (100%) n: 509	7 (100%) n: 524	0.83 (100%) n: 531	2.5 (100%) n: 551
Fishing duration is not NA	0.41 (100%) n: 1099	7.3 (100%) n: 734	20 (100%) n: 873	1.5 (100%) n: 593	2 (100%) n: 548	0.45 (100%) n: 509	7 (100%) n: 524	0.83 (100%) n: 531	2.5 (100%) n: 551
Positive fishing duration	0.41 (100%) n: 1099	7.3 (100%) n: 734	20 (100%) n: 873	1.5 (100%) n: 593	2 (100%) n: 548	0.45 (100%) n: 509	7 (100%) n: 524	0.83 (100%) n: 531	2.5 (100%) n: 551
Bottom depth >=50	0.41 (100%) n: 1089	7.3 (100%) n: 731	20 (100%) n: 849	1.5 (100%) n: 575	2 (100%) n: 538	0.45 (100%) n: 498	7 (100%) n: 519	0.83 (100%) n: 531	2.5 (100%) n: 551
Bottom depth <=600	0.41 (100%) n: 1036	7.3 (100%) n: 701	20 (100%) n: 825	1.5 (100%) n: 536	1.7 (88%) n: 532	0.45 (100%) n: 490	4 (57%) n: 508	0.83 (100%) n: 506	2.5 (100%) n: 492
Midwater effort depth <=10 m from bottom	0.41 (100%) n: 1024	7.3 (100%) n: 684	20 (100%) n: 802	1.5 (100%) n: 536	1.7 (88%) n: 530	0.45 (100%) n: 490	4 (57%) n: 505	0.83 (100%) n: 501	2.5 (100%) n: 487
Core fleet selection	0.41 (100%) n: 1024	7.3 (100%) n: 684	20 (100%) n: 802	1.5 (100%) n: 536	1.7 (88%) n: 530	0.45 (100%) n: 490	4 (57%) n: 505	0.83 (100%) n: 501	2.5 (100%) n: 487

Filter	2010	2011	2012	2013	2014	2015	2016	2017	2018
Ungroomed data	0.91 (100%) n: 579	5.3 (100%) n: 588	0.16 (100%) n: 445	1.2 (100%) n: 480	1.6 (100%) n: 495	0.28 (100%) n: 394	61 (100%) n: 464	35 (100%) n: 564	38 (100%) n: 445
Fishing duration is not NA	0.91 (100%) n: 579	5.3 (100%) n: 588	0.16 (100%) n: 445	1.2 (100%) n: 480	1.6 (100%) n: 495	0.28 (100%) n: 394	61 (100%) n: 464	35 (100%) n: 564	38 (100%) n: 445
Positive fishing duration	0.91 (100%) n: 579	5.3 (100%) n: 588	0.16 (100%) n: 445	1.2 (100%) n: 480	1.6 (100%) n: 495	0.28 (100%) n: 394	61 (100%) n: 464	35 (100%) n: 564	38 (100%) n: 445
Bottom depth >=50	0.91 (100%) n: 579	5.3 (100%) n: 588	0.16 (100%) n: 445	1.2 (100%) n: 480	1.6 (100%) n: 495	0.28 (100%) n: 394	61 (100%) n: 461	35 (100%) n: 564	38 (100%) n: 443
Bottom depth <=600	0.91 (100%) n: 538	5.3 (100%) n: 560	0.16 (100%) n: 416	1.2 (100%) n: 452	1.6 (100%) n: 465	0.28 (100%) n: 353	61 (100%) n: 429	33 (100%) n: 507	38 (100%) n: 403
Midwater effort depth <=10 m from bottom	0.91 (100%) n: 537	2.7 (51%) n: 548	0.14 (86%) n: 396	0.84 (70%) n: 375	0.72 (44%) n: 427	0.2 (72%) n: 314	61 (100%) n: 398	33 (94%) n: 475	30 (80%) n: 351
Core fleet selection	0.91 (100%) n: 537	2.7 (51%) n: 548	0.14 (86%) n: 396	0.84 (70%) n: 375	0.72 (44%) n: 427	0.2 (72%) n: 314	61 (100%) n: 398	33 (94%) n: 475	30 (80%) n: 351

Filter	2019	2020
Ungroomed data	15 (100%) n: 241	19 (100%) n: 381
Fishing duration is not NA	15 (100%) n: 241	19 (100%) n: 381
Positive fishing duration	15 (100%) n: 241	19 (100%) n: 381
Bottom depth >=50	15 (100%) n: 241	19 (100%) n: 381
Bottom depth <=600	15 (100%) n: 229	18 (94%) n: 350
Midwater effort depth <=10 m from bottom	15 (100%) n: 220	17 (93%) n: 306
Core fleet selection	15 (100%) n: 220	17 (93%) n: 306

Table 36: Summary of the SKI3 BT+MW east coast process daily dataset after core fleet selection. ‘Records’ indicates the number of rows (days) in the dataset, and ‘Records caught’ indicates the percentage of days with catches of gemfish.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
2001	21	152	1 024	13 858.37	0.41	1.95
2002	21	134	684	8 948.03	7.28	10.23
2003	21	148	802	11 738.90	19.78	17.71
2004	19	107	536	7 518.53	1.47	4.48
2005	22	99	530	6 912.43	1.72	10.75
2006	21	83	490	6 931.92	0.45	5.71
2007	22	88	505	7 273.52	4.01	8.32
2008	17	77	501	6 790.07	0.83	6.59
2009	19	81	487	6 772.95	2.54	4.93
2010	22	75	537	8 319.37	0.91	11.36
2011	25	96	548	7 771.23	2.70	15.51
2012	24	89	396	5 045.33	0.14	4.29
2013	23	76	375	5 384.75	0.84	9.60
2014	20	86	427	5 983.55	0.72	7.49
2015	22	85	314	4 602.37	0.20	7.64
2016	23	87	398	5 647.90	60.51	15.83
2017	21	91	475	6 520.97	32.75	34.95
2018	22	84	351	4 793.72	30.26	51.57
2019	18	62	220	2 555.55	15.12	42.27
2020	21	81	306	3 749.88	17.40	47.39

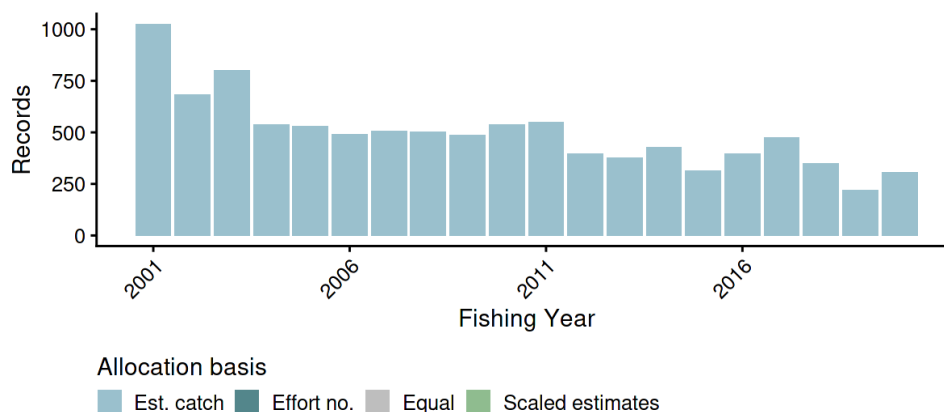


Figure 140: Allocation basis for attributing landings to records in the SKI3 BT+MW east coast process daily catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table 37: Summary of stepwise selection for occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	18.00	6 733	14.90	14.90	*
+ vessel_key	32.00	5 908	26.20	11.30	*
+ target_species	4.00	5 679	29.20	3.00	*
+ bs(SeasonDay, 3)	3.00	5 566	30.70	1.50	*
+ primary_method	1.00	5 554	30.90	0.20	
+ ns(log(fishing_duration), 3)	3.00	5 549	31.00	0.10	
+ stat_area	1.00	5 544	31.10	0.10	

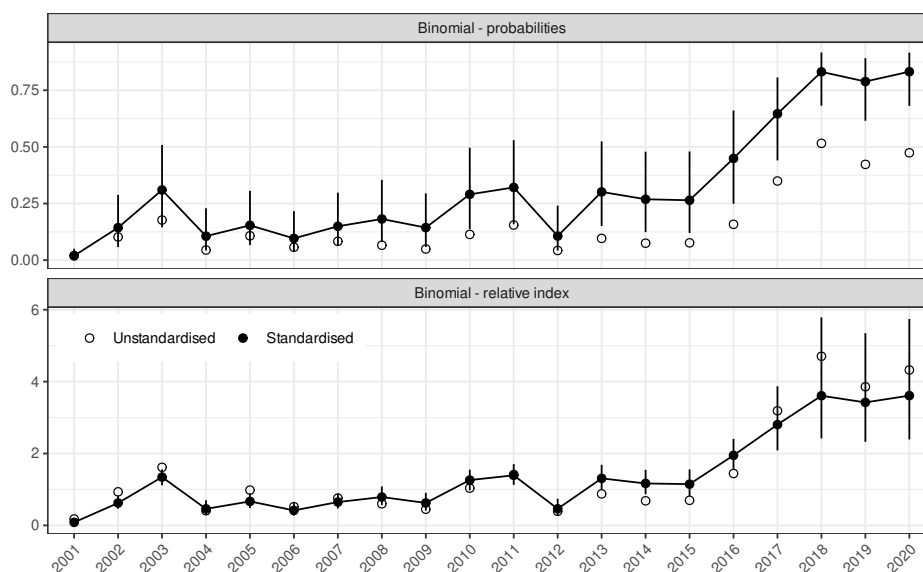


Figure 141: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SKI3 BT+MW east coast process daily dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

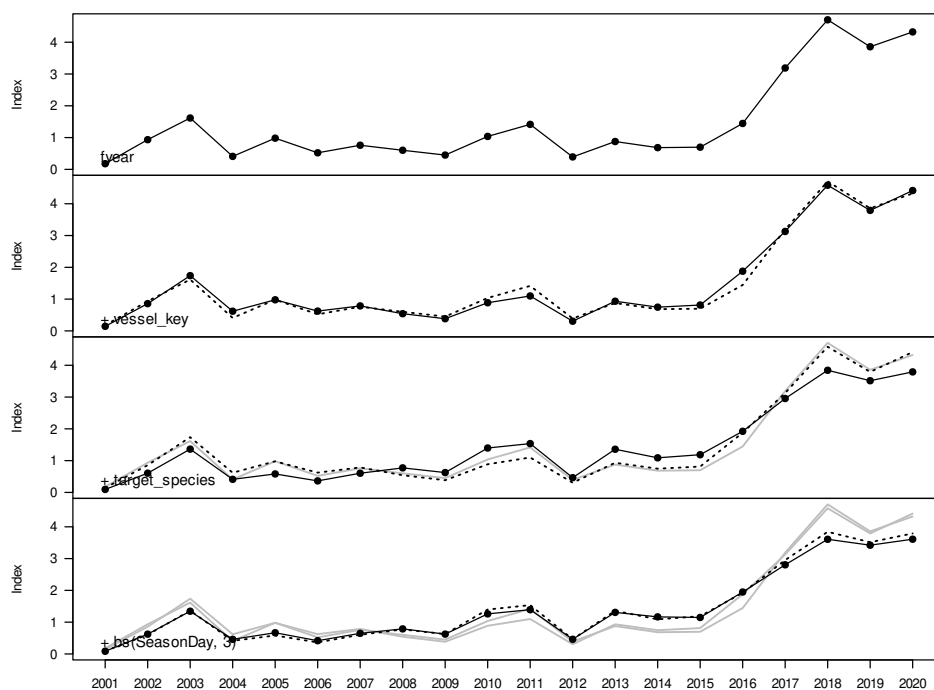


Figure 142: Step plot for occurrence of catch in the SKI3 BT+MW east coast process daily dataset.

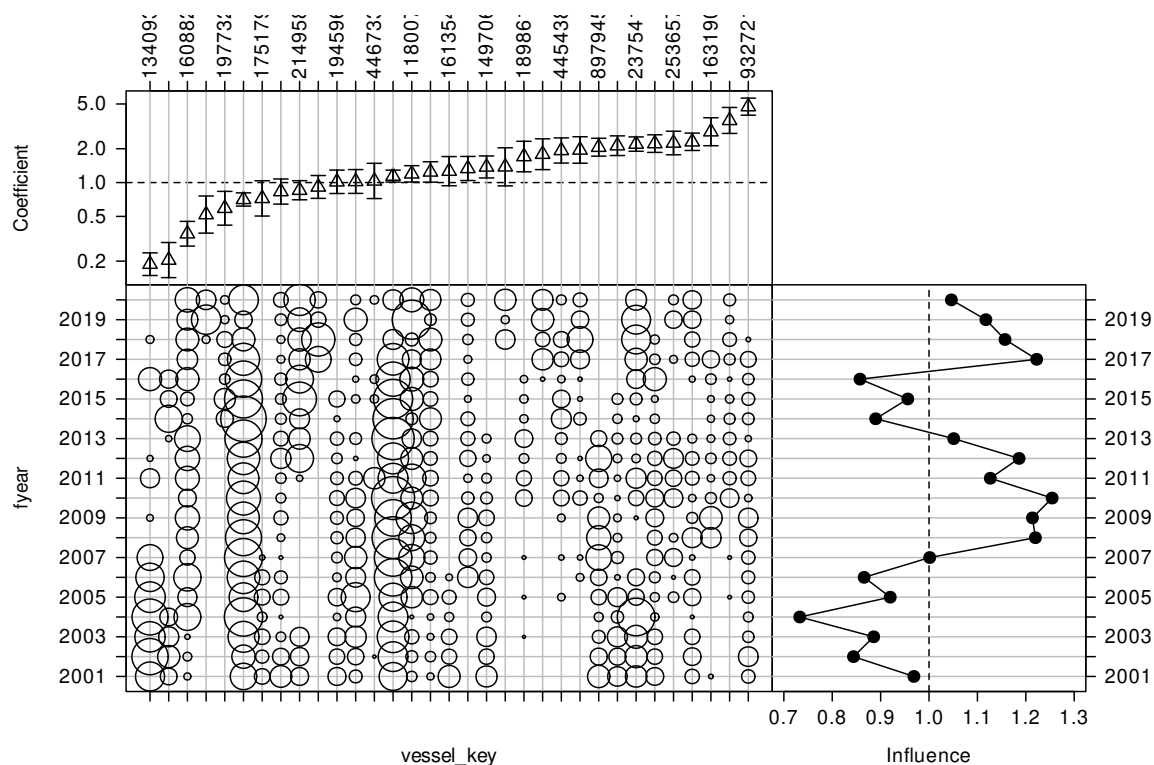


Figure 143: CDI plot for vessel key for the occurrence of positive catch SKI3 BT+MW east coast process daily catch-per-unit-effort dataset.

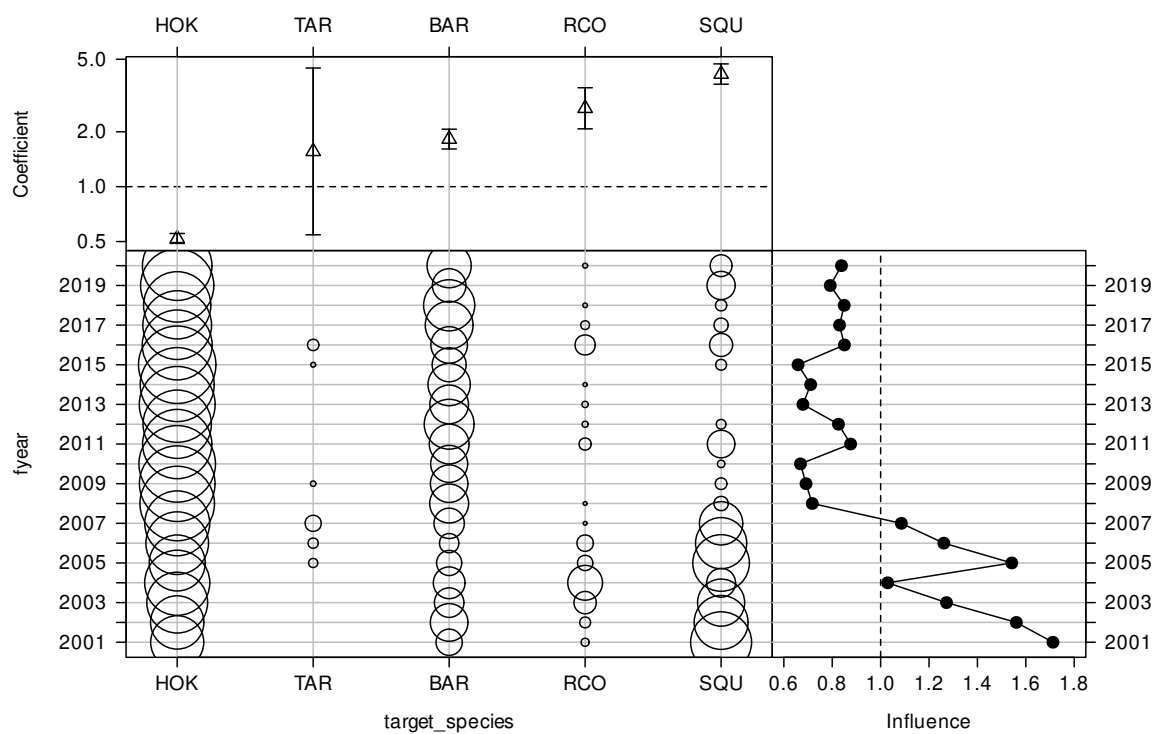


Figure 144: CDI plot for target species for the occurrence of positive catch SKI3 BT+MW east coast process daily catch-per-unit-effort dataset.

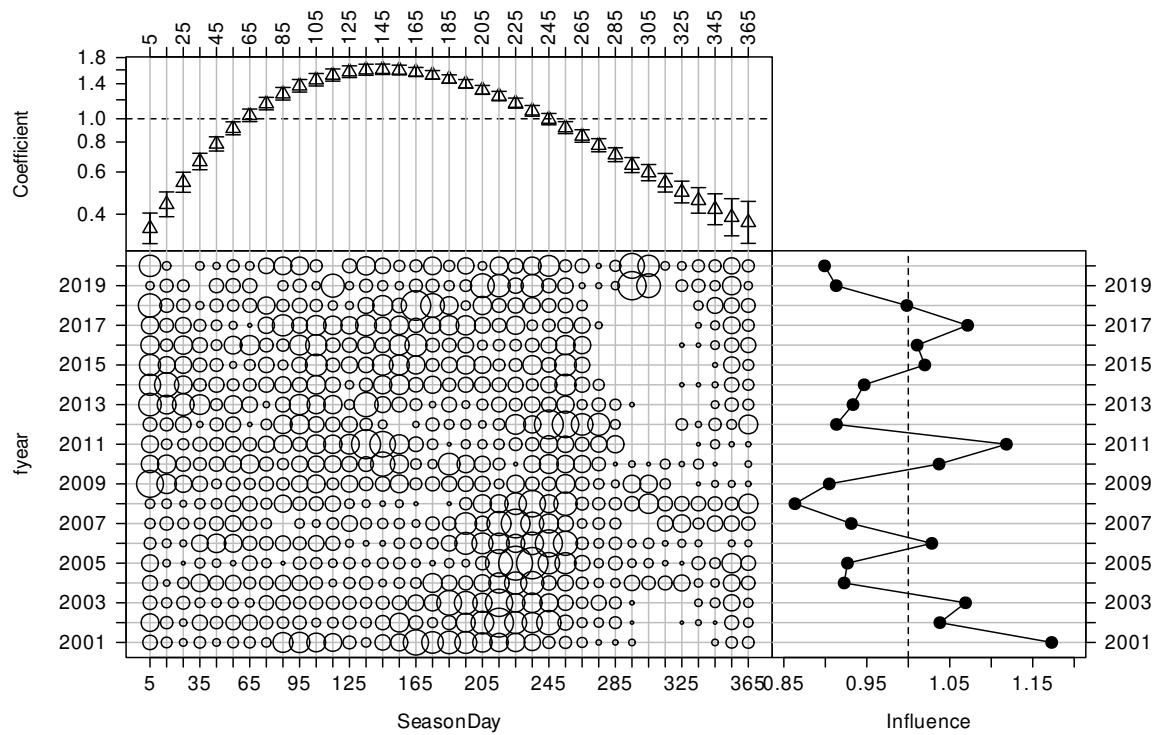


Figure 145: CDI plot for SeasonDay for the occurrence of positive catch SKI3 BT+MW east coast process daily catch-per-unit-effort dataset.

Table 38: Summary of stepwise selection for the lognormal model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	18	4876	20.5	20.5	*
+ bs(SeasonDay, 3)	3	4805	25.0	4.5	*
+ vessel key	32	4737	32.0	7.0	*
+ stat area	1	4722	32.8	0.9	
+ target species	4	4718	33.4	0.6	

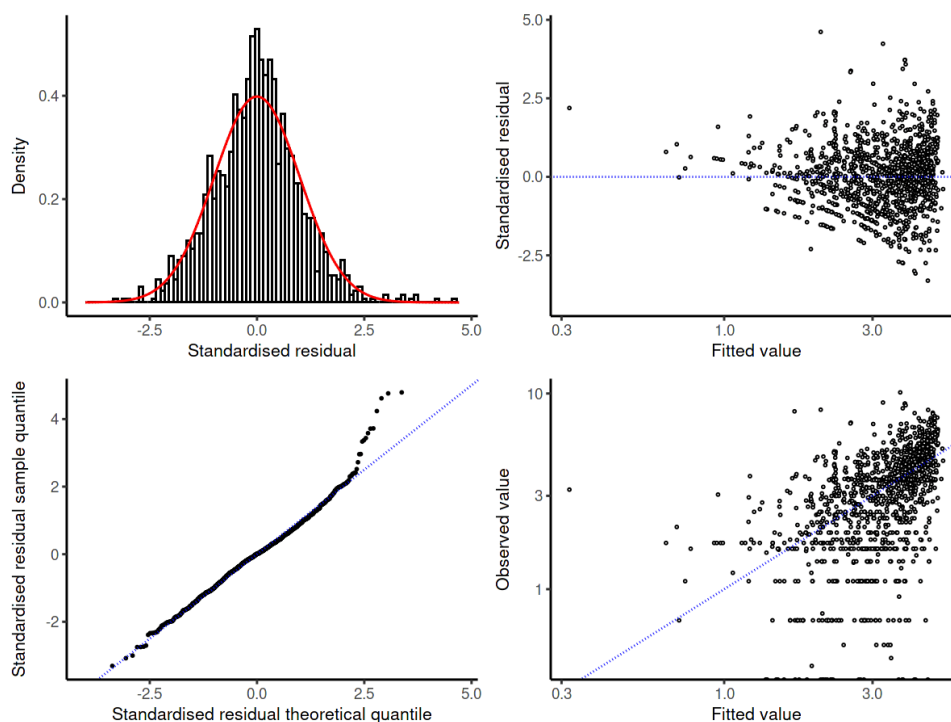


Figure 146: Diagnostic plots for the lognormal model for the SKI3 BT+MW east coast process daily dataset.

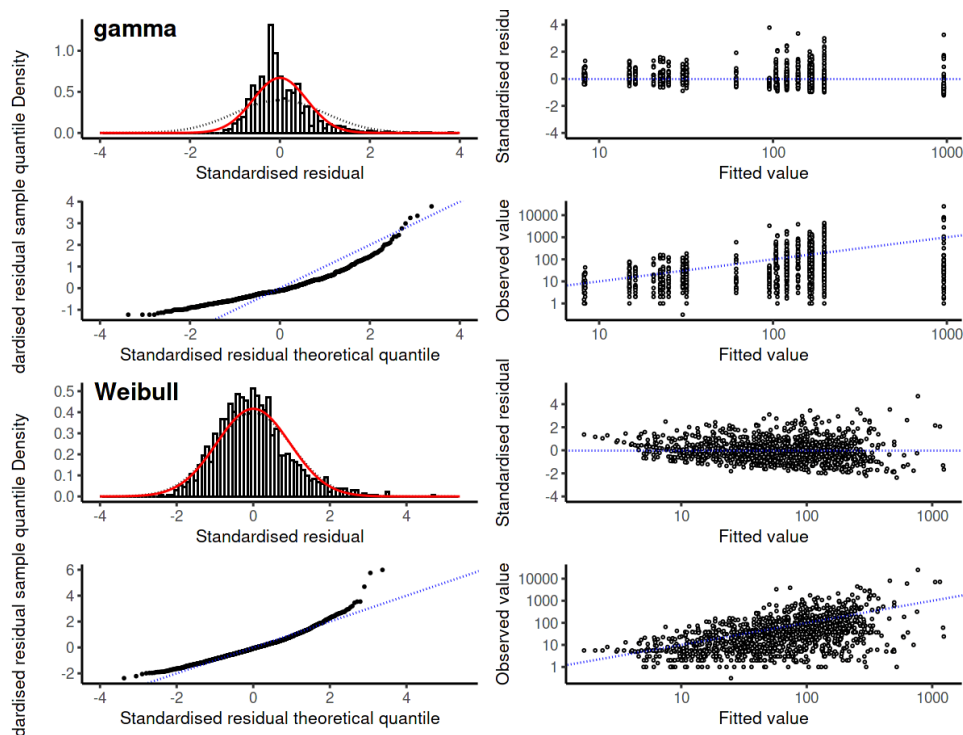


Figure 147: Diagnostic plots for the gamma and Weibull model for the SKI3 BT+MW east coast process daily dataset.

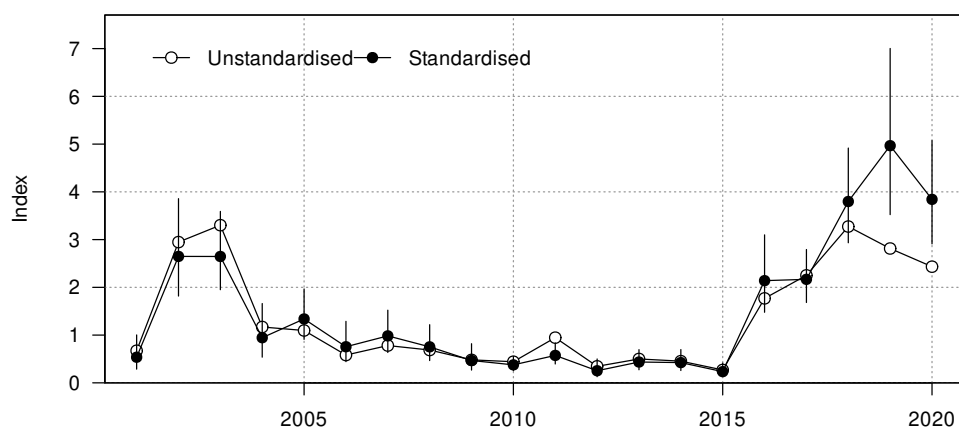


Figure 148: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SKI3 BT+MW east coast process daily dataset.

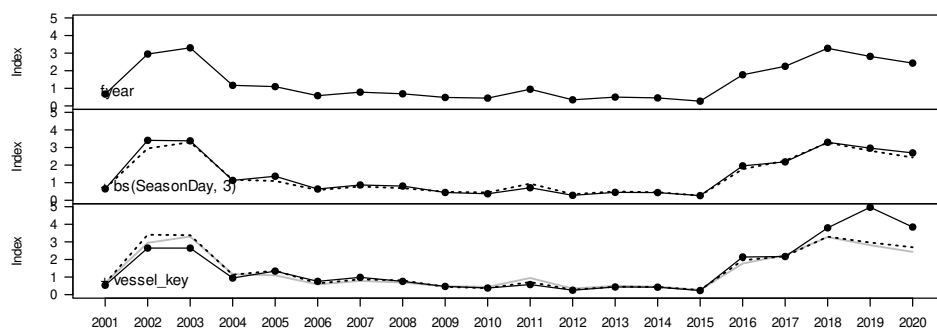


Figure 149: Changes to the SKI3 BT+MW east coast process daily positive catch index as terms are successively entered into the model.

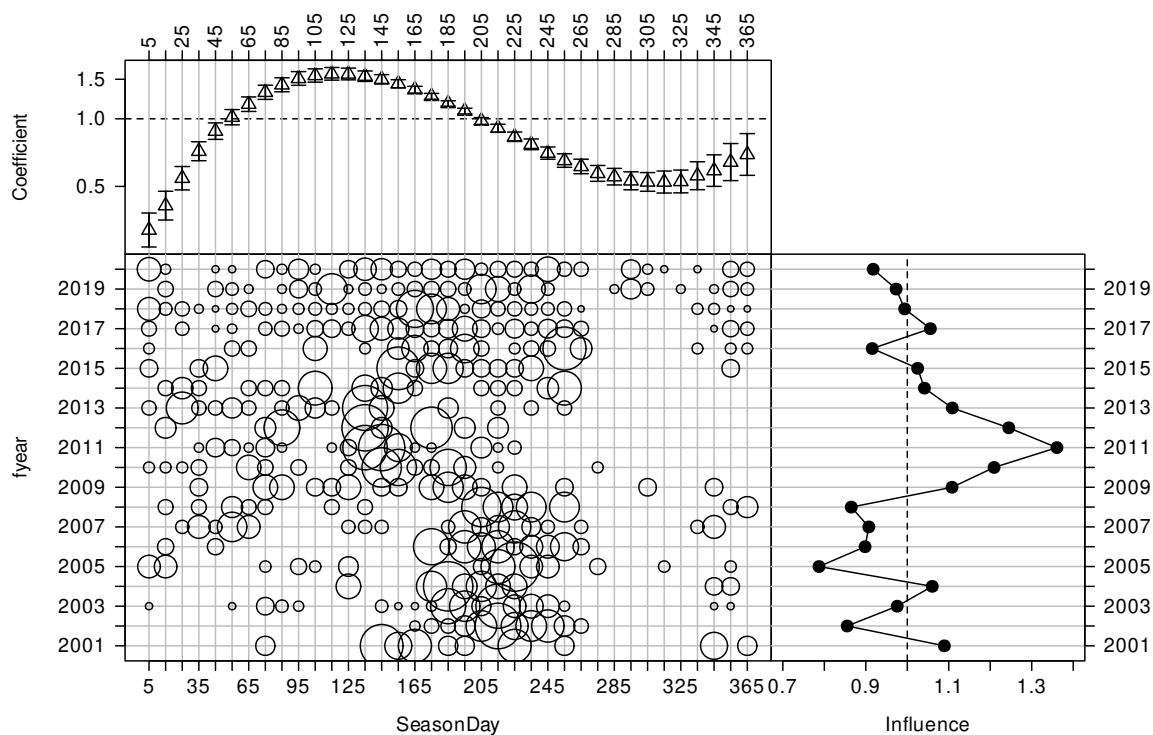


Figure 150: CDI plot for SeasonDay for the positive catch SKI3 BT+MW east coast process daily catch-per-unit-effort dataset.

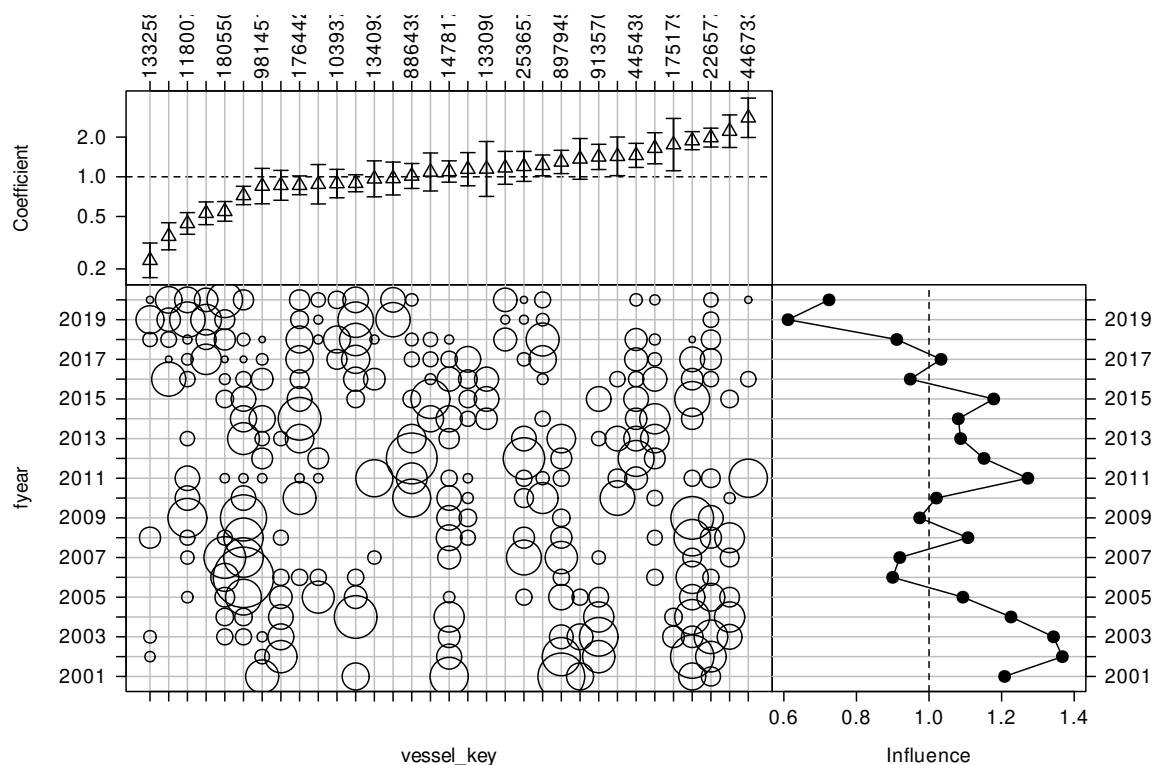


Figure 151: CDI plot for vessel key for the positive catch SKI3 BT+MW east coast process daily catch-per-unit-effort dataset.

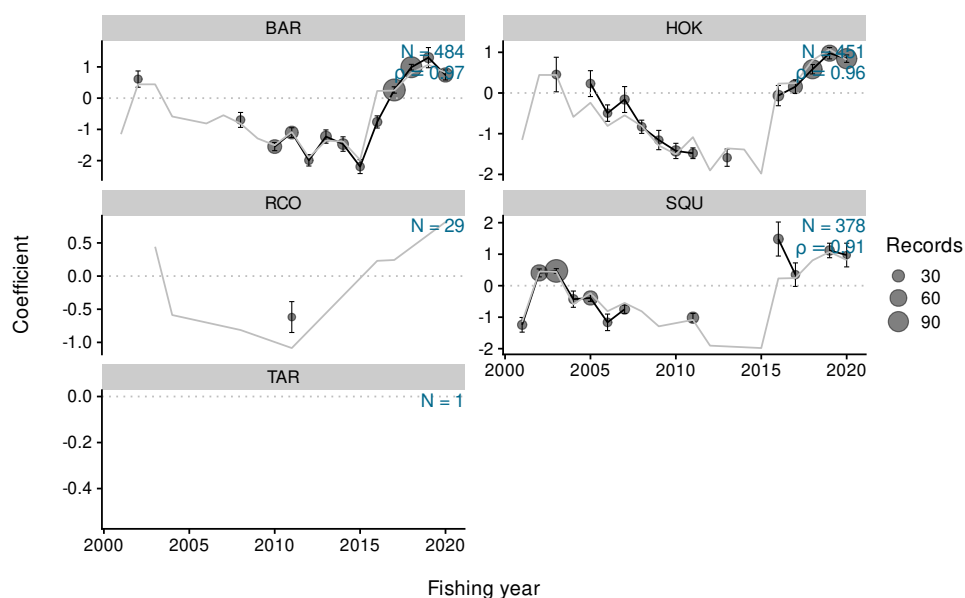


Figure 152: Residual implied coefficients for target-year in the lognormal positive catch model for the SKI3 BT+MW east coast process daily dataset.

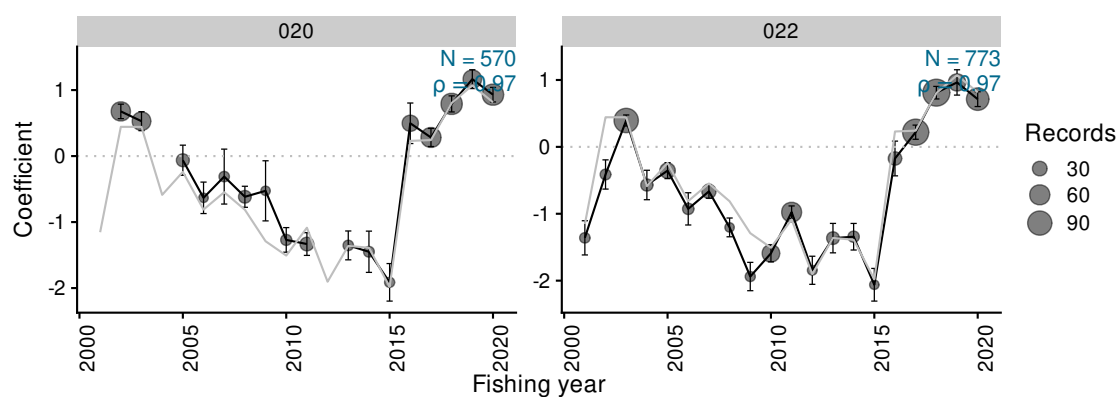


Figure 153: Residual implied coefficients for area-year in the lognormal positive catch model for the SKI3 BT+MW east coast process daily dataset.

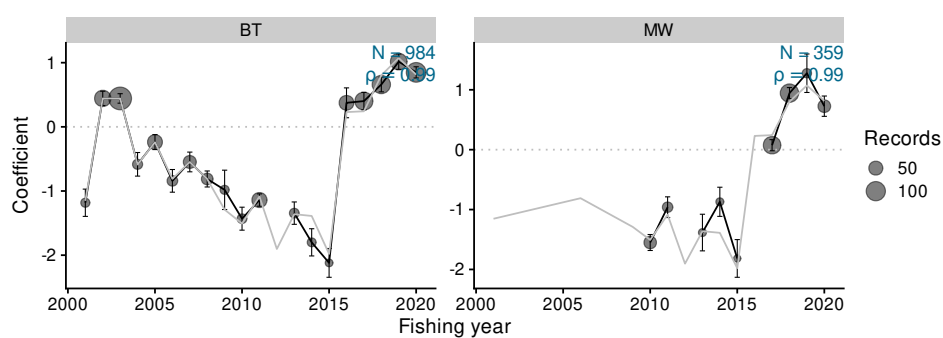


Figure 154: Residual implied coefficients for primary method-year in the lognormal positive catch model for the SKI3 BT+MW east coast process daily dataset.

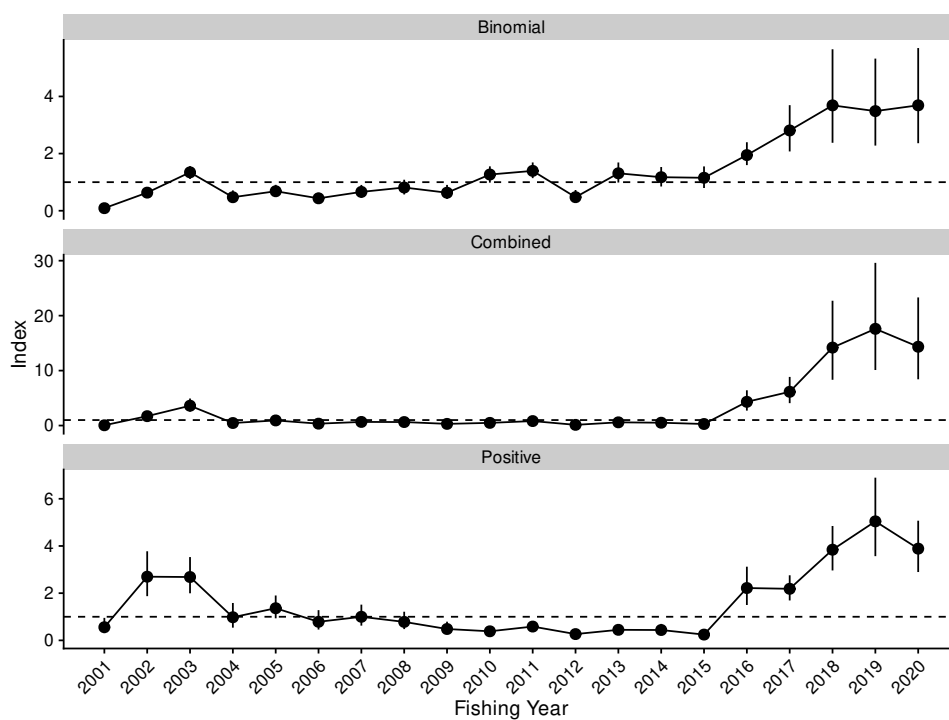


Figure 155: Standardised indices and 95% confidence intervals for the SKI3 BT+MW east coast process daily dataset.

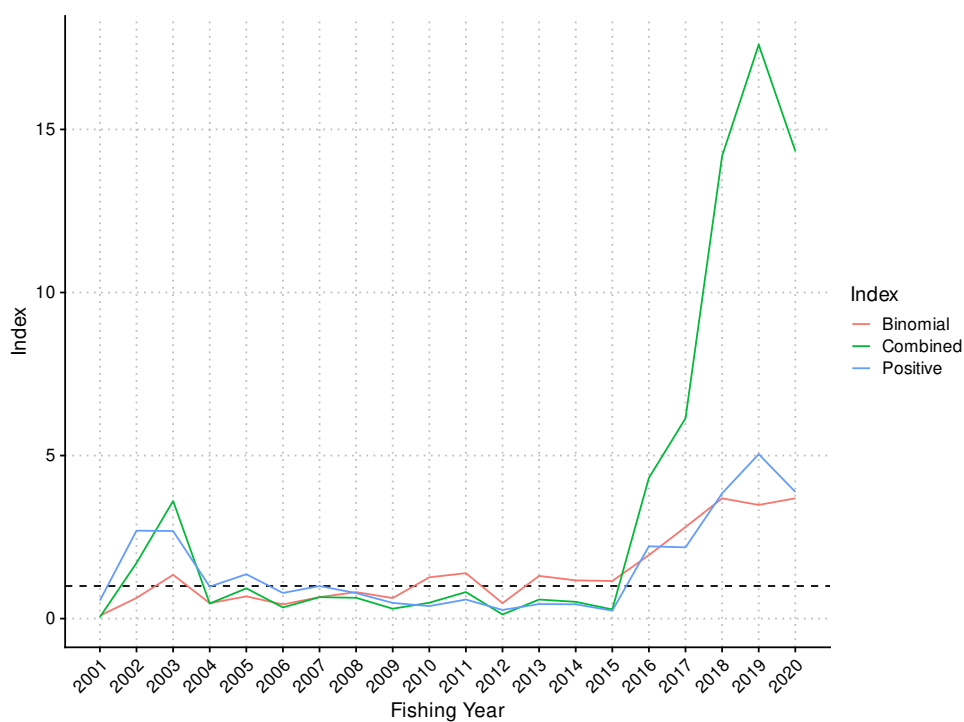


Figure 156: Standardised indices for the SKI3 BT+MW east coast process daily dataset.

Table 39: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SKI3 BT+MW east coast process daily.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
2001	0.090	0.025	0.049	0.148	0.050	0.020	0.020	0.100	0.557	0.165	0.307	0.953
2002	0.634	0.094	0.458	0.827	1.707	0.404	1.046	2.629	2.698	0.485	1.873	3.776
2003	1.344	0.115	1.113	1.562	3.608	0.610	2.525	4.918	2.685	0.392	1.995	3.530
2004	0.473	0.107	0.294	0.712	0.463	0.174	0.213	0.897	0.980	0.267	0.538	1.584
2005	0.682	0.109	0.480	0.906	0.929	0.226	0.547	1.433	1.361	0.247	0.934	1.901
2006	0.435	0.091	0.273	0.631	0.343	0.123	0.163	0.646	0.787	0.210	0.458	1.280
2007	0.659	0.115	0.452	0.902	0.658	0.178	0.374	1.073	0.999	0.227	0.624	1.514
2008	0.813	0.131	0.570	1.085	0.638	0.194	0.341	1.100	0.783	0.188	0.478	1.213
2009	0.630	0.125	0.413	0.904	0.304	0.109	0.145	0.572	0.481	0.132	0.275	0.791
2010	1.267	0.145	0.984	1.553	0.487	0.110	0.304	0.736	0.384	0.075	0.256	0.549
2011	1.395	0.140	1.141	1.690	0.815	0.163	0.537	1.176	0.585	0.103	0.405	0.809
2012	0.474	0.113	0.283	0.726	0.126	0.052	0.053	0.257	0.266	0.089	0.135	0.484
2013	1.310	0.179	0.987	1.689	0.585	0.163	0.341	0.980	0.447	0.102	0.284	0.683
2014	1.173	0.174	0.848	1.530	0.515	0.143	0.283	0.846	0.439	0.112	0.259	0.697
2015	1.153	0.192	0.796	1.550	0.281	0.092	0.138	0.501	0.245	0.072	0.136	0.419
2016	1.947	0.204	1.597	2.397	4.317	0.943	2.720	6.416	2.218	0.414	1.500	3.122
2017	2.809	0.413	2.075	3.694	6.142	1.218	4.076	8.849	2.185	0.272	1.691	2.758
2018	3.687	0.835	2.378	5.650	14.186	3.669	8.330	22.712	3.842	0.481	2.963	4.847
2019	3.486	0.776	2.280	5.324	17.599	4.974	10.107	29.606	5.043	0.849	3.569	6.895
2020	3.689	0.850	2.363	5.693	14.339	3.800	8.418	23.313	3.887	0.555	2.896	5.071

6. DISCUSSION

This report has presented detailed analyses of all available catch-effort data for SKI 3 and SKI 7 up to the end of the 2020 fishing year, extending a preliminary CPUE analysis conducted by Langley (2020). The following three southern gemfish fisheries have been identified:

- SKI 7 target HOK: a target HOK fishery operating in the winter (May–September) off the west coast of the South Island (Statistical Areas 034 and 035) based on bottom trawl (BT) gear or midwater gear fished within 10 m of the bottom;
- SKI 3 Stewart-Snares shelf: a mixed target (SQU, BAR, HOK, SWA, SKI, LIN) fishery operating year round on the Stewart-Snares shelf and Pukaki Rise (Statistical Areas 025–030 and 504) based on bottom trawl (BT) gear or midwater gear fished within 10 m of the bottom;
- SKI 3 East coast: a mixed target (SQU, BAR, HOK, RCO, TAR) fishery operating year round off the east coast South Island (Statistical Areas 020 and 022) based on bottom trawl (BT) gear or midwater gear fished within 10 m of the bottom.

For each of these fisheries, four data sets were identified:

- event: tow-by-tow event-based data, based on TCEPR, TCER, and ERS-trawl forms, with estimated catches scaled to landings and constrained to report only the top five species caught in each tow (to conform to the requirements of the TCEPR form);
- daily processing: based on processing data from large factory trawlers, where the processed catch for the day was assumed to have been caught on that day; effort was the sum of the hours fished on that day, depth was the mean depth fished, and the modal statistical area and target species for the day was used;
- observer: tow-by-tow observer data; there was no concern about missing SKI in each tow with the assumption that the observer would find gemfish if it was present in the tow;
- daily rollup: the catch for the day was summed, along with the hours fished; the modal statistical area and target species for the day was used and the catch was constrained to be the top five species caught for the day; this ‘rollup’ was meant to emulate the CELR form requirements and was intended to include inshore vessels into the analysis; all MW catch and effort were included because depth is not a valid CELR field.

Although the event and daily rollup data sets will have considerable data overlap, the catch data in the daily processing data set should be relatively independent from the event data set and the observer data set. This latter data set is based on many of the same events, but the data are usually recorded independently from the statutory commercial catch and effort logs. The amount of data available for the SKI 3 East coast fisheries was considerably less than for the other two fisheries and thus the observer analysis was dropped. The remaining eleven CPUE analyses are presented in detail in this report, with six primary event and daily processing analyses presented in the main body of this report (Section 5) and the remaining five secondary observer and daily rollup analyses presented in Appendix D (Additional CPUE series).

The Deepwater Working Group (DWWG) accepted that all eleven series indicated that there had been a considerable increase in apparent relative biomass in the late 2010s compared with the low levels of gemfish observed during the period 1990 to the mid-2010s. This was true for all three evaluated fisheries: SKI 7 target HOK (Figure 157), the SKI 3 Stewart-Snares shelf (Figure 158), and the SKI 3 East coast (Figure 159).

The proportional size of the increase in the late 2010s varied among fisheries and data sources. For instance, the event series in the SKI 7 target HOK (Figure 157) had a much larger relative increase compared with the other three series in that fishery, with these latter series each having similar proportional increases (Figure 157). The proportionate increase observed in the daily processed data series in the SKI 3 Stewart-Snares shelf fishery was more modest than for the other three series, with the event-based observer and tow-by-tow series having about the same level of increase while the daily rollup series had an even larger proportionate increase (Figure 158). It is of note that only the daily rollup series in the SKI 3 SShelf fishery did not show a decrease in the 2020 fishing year. Finally, the proportionate increase in the SKI 3 East coast daily rollup series was so large that it flattened the other two series. The daily rollup series in this instance seemed unreliable, given that this series estimated a 90-fold increase for the 2020 gemfish abundance index stemming from an increase in the proportion of gemfish in the daily records, rising from less than 1% of the days before 2017 to >10% of the days in 2020 (see Table D.27). Consequently, the daily rollup series has been omitted from the series comparison plot in Figure 159. The analyses for the west coast SKI 7 target HOK fishery developed for this report show much stronger increases compared with the event-based target HOK series developed by Langley (2020) (Figure 160). The Langley (2020) analysis only went to the end of 2018, which is two years less than for this report, thus missing much of the recent increase and was likely affected by the range of variation in the proportionate size of the increase observed across the eleven analyses.

The DWWG preferred the three daily processing series because these series would have been less affected by the limitations of the species reporting requirements of the TCEPR forms during the period of low abundance and that these series covered more years than the observer CPUE series. All three daily processing series are presented in Figure 161, with all three series showing increases ranging from over ten times the series average (SKI 7 target HOK) to nearly twenty times the series average (SKI 3 Stewart-Snares shelf). The DWWG accepted the SKI 7 target HOK daily processing series as the primary abundance indicator for southern gemfish because it operates during the spawning period in the location where this stock is presumed to spawn (see the discussion in Appendix C and the cumulative frequency distributions in Figure C.3). The SKI 3 Stewart-Snares shelf series were viewed as corroborative series which operate in the feeding and migratory region for this stock (Appendix C).

The DWWG noted that the gemfish index from the 2018 *Tangaroa* WCSI survey showed an increase that was consistent with several of the SKI 7 target HOK series (Figure 162). This observation corroborated the SKI 7 target HOK CPUE series, despite the short period covered by the WCSI survey series, given that this survey is likely to be indexing recruited gemfish. The DWWG also noted that the correspondence between the SKI 7 target HOK series with the *Kaharoa* WCSI survey was poor (Figure 163), but this was understandable because this survey primarily indexes gemfish recruitment and not gemfish adults.

6.1 Stock Status

The 2021 Plenary meeting did not make an evaluation of the status of southern gemfish relative to a reference point. However, the Plenary meeting evaluated this stock as Unlikely (<40% probability) to be driven below the Hard Limit (10% B_0) at current catch levels, but made no other evaluations. The plot of the catch against the CPUE and the resulting relative exploitation rate provides a basis for concluding that the current stock status is relatively secure, given the low exploitation rates estimated for the period 2017 to 2020 in both primary South Island gemfish fisheries (Figure 164).

As noted in the Introduction (Section 1.0), the preliminary stock assessment model developed by Langley (2020) was not extended as part of this project because there were insufficient additional data to materially alter the previous conclusions. Given the wide range of proportionate increases observed among these eleven CPUE series, estimating the relative magnitude of the abundance increase would require age frequency data in a stock assessment model. Even if such data were available, it is likely that there would remain considerable uncertainty. Age frequency samples were collected in 2021 from the SKI 7

target HOK fishery and from the 2021 *Tangaroa* WCSI survey. These data will be available when this stock is next assessed.

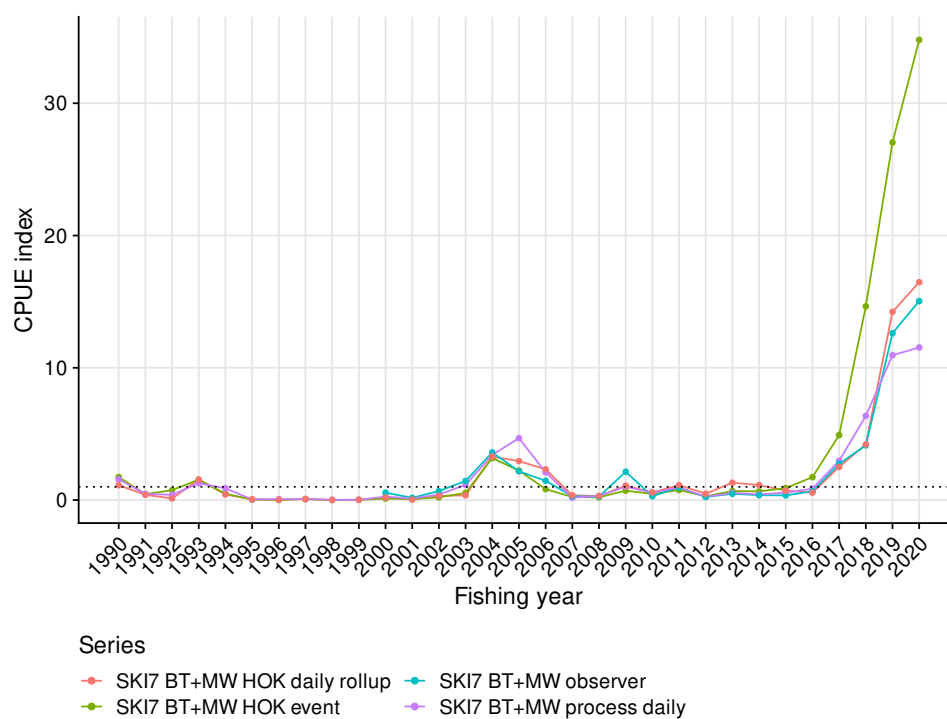


Figure 157: Comparing the four SKI 7 target HOK CPUE series (combined models).

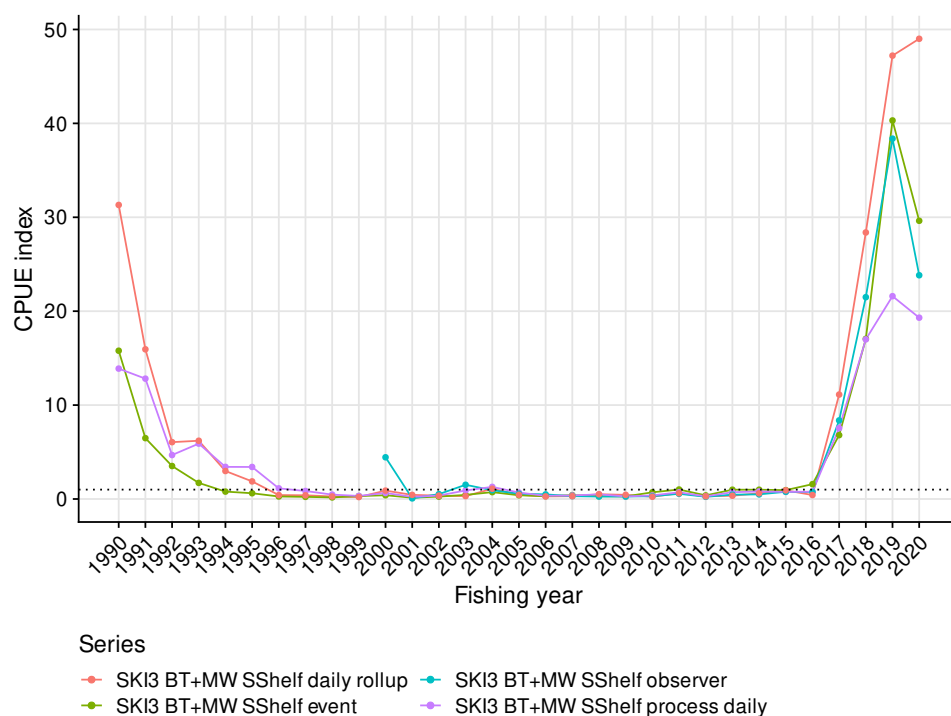


Figure 158: Comparing the four SKI 3 Stewart-Snares shelf CPUE series (combined models).

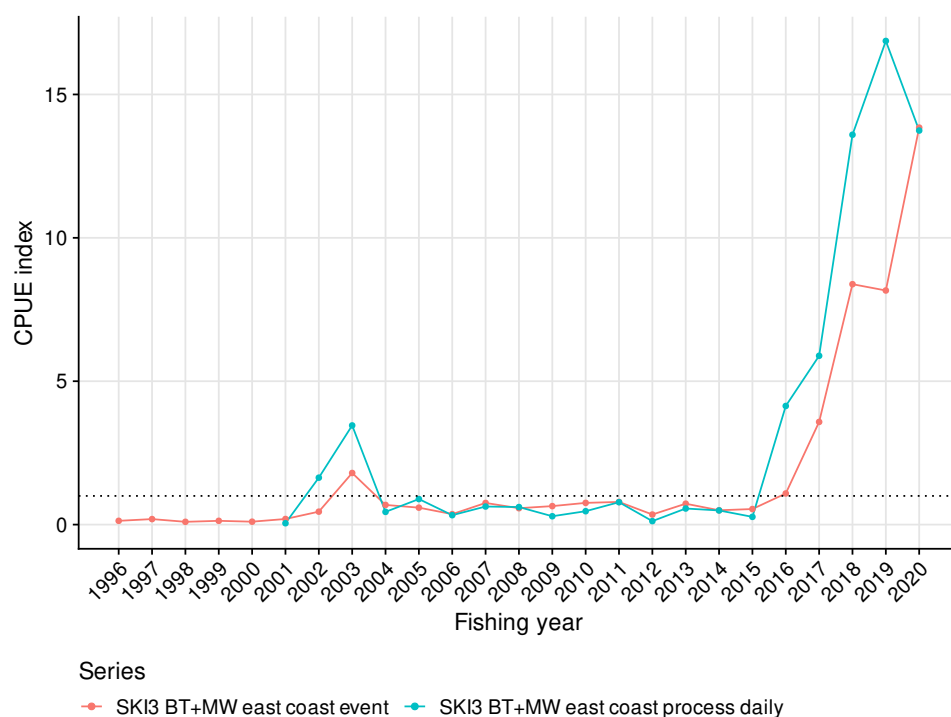


Figure 159: Comparing two SKI 3 East coast CPUE series (combined models). The daily rollup and observer series from this fishery have been omitted for reasons given in the text.

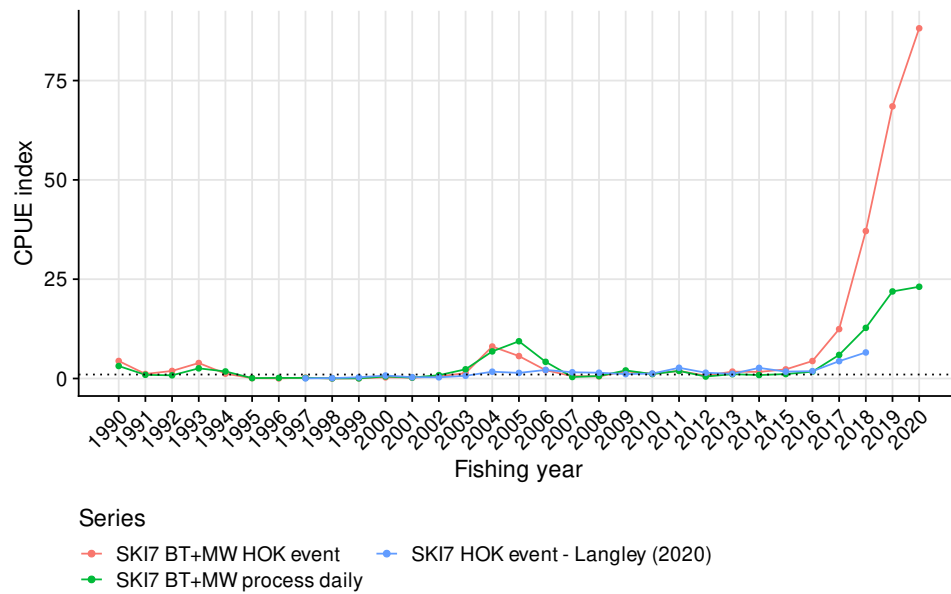


Figure 160: Comparison of the SKI 7 BT+MW HOK event and the SKI 7 BT+MW daily process series with the Langley (2020) series. Each series is scaled to a geometric mean of one for the years in common.

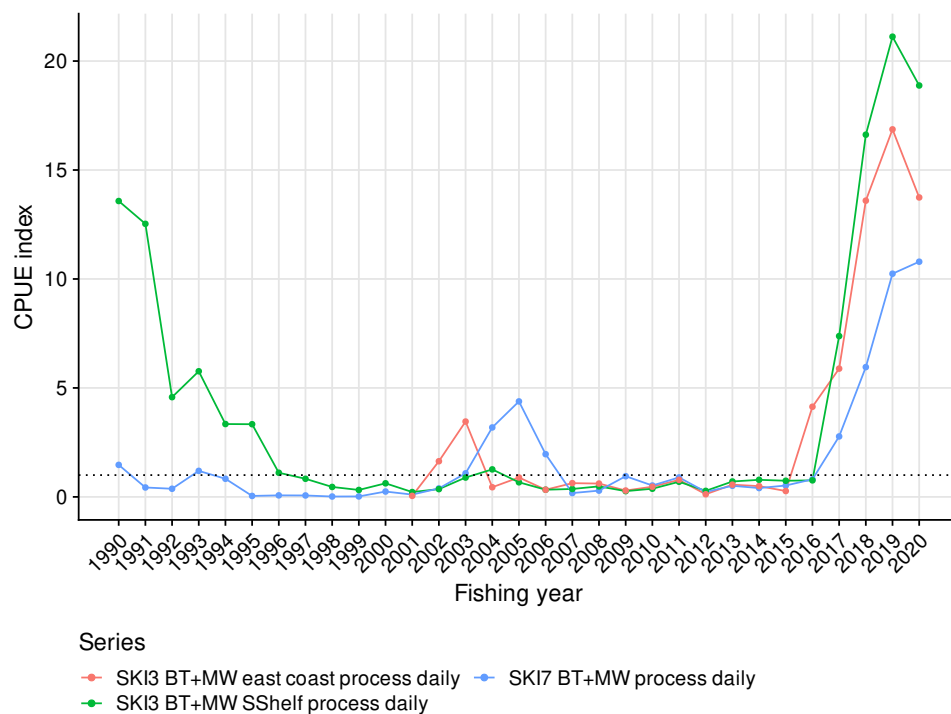


Figure 161: Comparing the daily processed CPUE series across the three SKI 3 and SKI 7 fisheries (combined models).

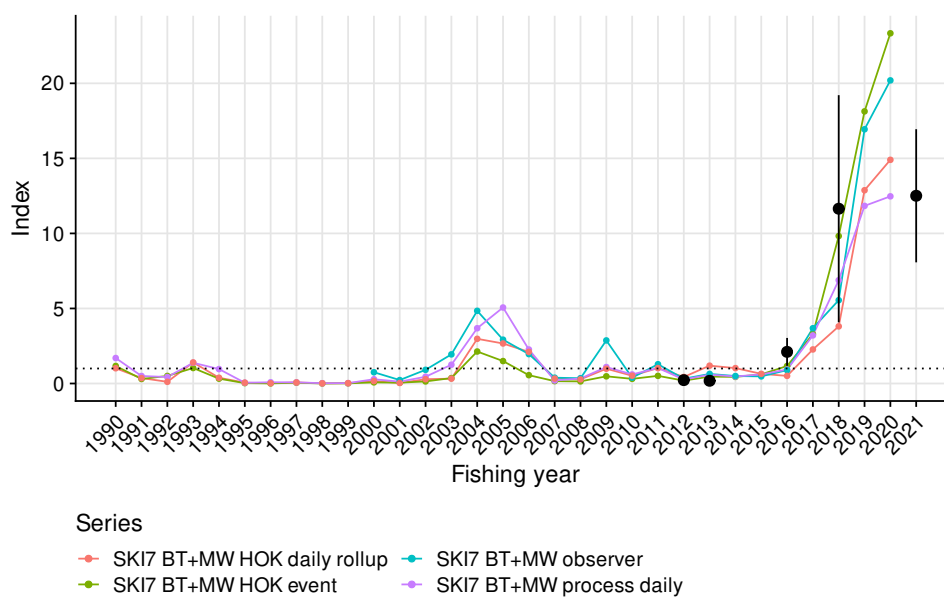


Figure 162: Comparison of the four SKI 7 series (combined models) with the *Tangaroa* WCSI trawl survey series (black points and 95% confidence intervals). Each series is scaled to a geometric mean of one for the years in common.

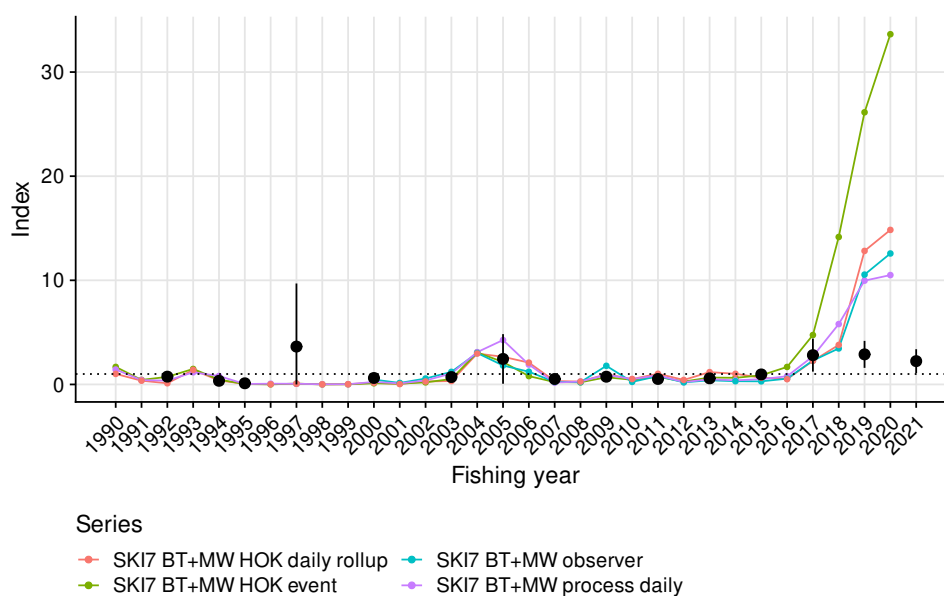


Figure 163: Comparison of the four SKI 7 series (combined models) with the *Kaharoa* WCSI trawl survey series (black points and 95% confidence intervals). Each series is scaled to a geometric mean of one for the years in common.

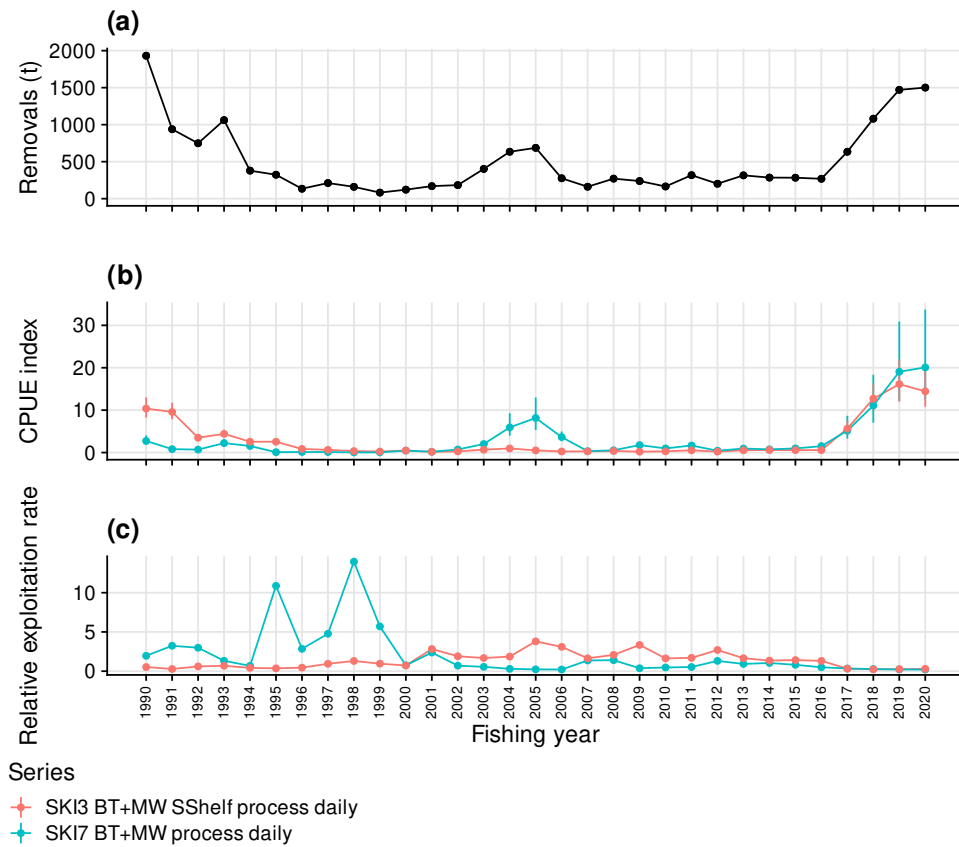


Figure 164: Removals, CPUE (daily process series combined models) and calculated relative exploitation rates for the SKI 3 BT+MW SShelf and SKI 7 BT+MW fisheries.

7. ACKNOWLEDGEMENTS

This work was funded by Fisheries New Zealand (Project SKI2020-01). Data were provided by Fisheries New Zealand. We extend our thanks for help and discussion when creating this report to the Deepwater Working Group, the Kahawai Collective and to Trophica, Dragonfly Data Science and Pisces Research.

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APPENDIX A: DATA GROOMING

Grooming of the statutory commercial catch, effort and landings data followed the approach of Starr (2007), with a set of rules defined for each of the different types of data (Bentley 2012).

A.1 Landings

Table A.1: Grooming rules applied to landings data.

Rule	Effect	Description
FLKIN	Fix	Update landed species to SUR when KIN is landed from trips with diving events and no MHR support
LADAM	Flag	Landings where the landing date is missing
LADAF	Flag	Landings where the landing date is in the future
LADTI	Flag	Invalid landing destination
LAFLA	Fix	Correct landings using a flatfish species code to FLA
LAHPB	Fix	Correct landings using a groper species code to HPB
LASQU	Fix	Recode SQU1J and SQU1T landings to SQU1
LATUN	Fix	Correct stock code for non-QMS tunas
LASEC	Fix	Landings to Crown or experimental stock codes
LAQMS	Fix	Replace pre-QMS pseudo-stock with the post-QMS stock code
LADMR	Drop	Mandatory returns (e.g. sub-MLS)
LADTH	Drop	Retained (non-final) landings
LADTT	Flag	Vessel received transshipments
LASCF	Fix	Correct some state codes
LASCI	Flag	Landings to invalid state code
LASCD	Drop	Drop landings of secondary product states
LADUP	Drop	Duplicate landings
LACFM	Fix	Replace missing conversion factors with the median over all years
LAGWI	Fix	Estimate missing greenweights
LAGWM	Drop	Missing greenweights that cannot be estimated
LAGWO	Fix	Identify and fix order of magnitude errors in landings

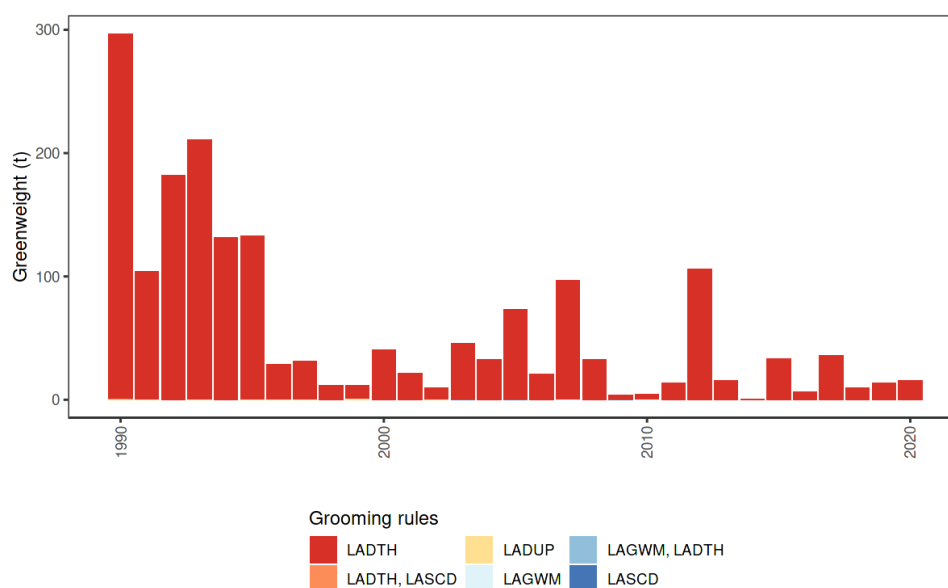


Figure A.1: The quantity of landings dropped, with the relevant grooming rules indicated.

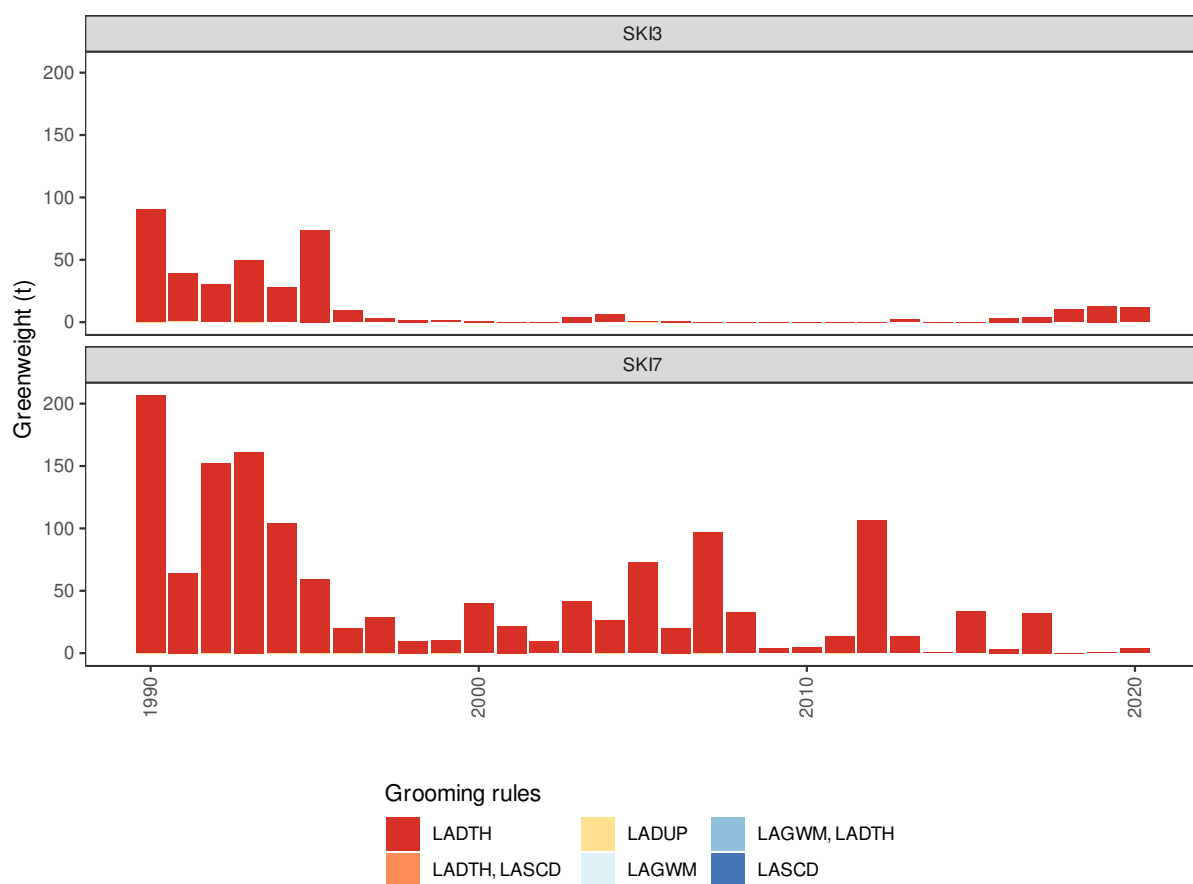


Figure A.2: The quantity of landings dropped, with the relevant grooming rules indicated, by QMA.

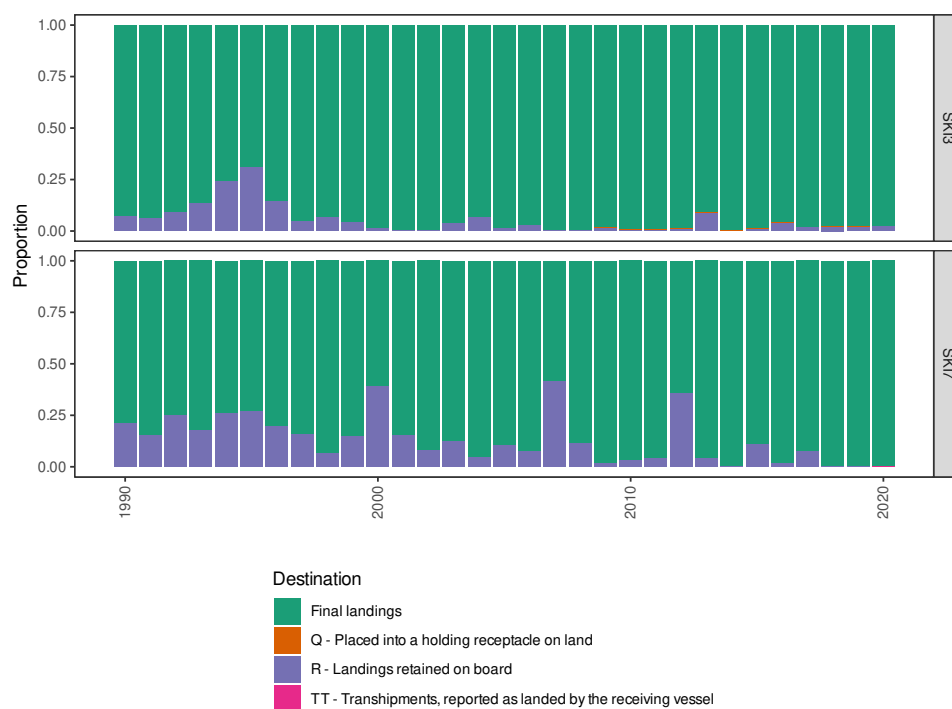


Figure A.3: The proportion of total (final and non-final) landings that are initially to non-final destinations, by stock and fishing year.

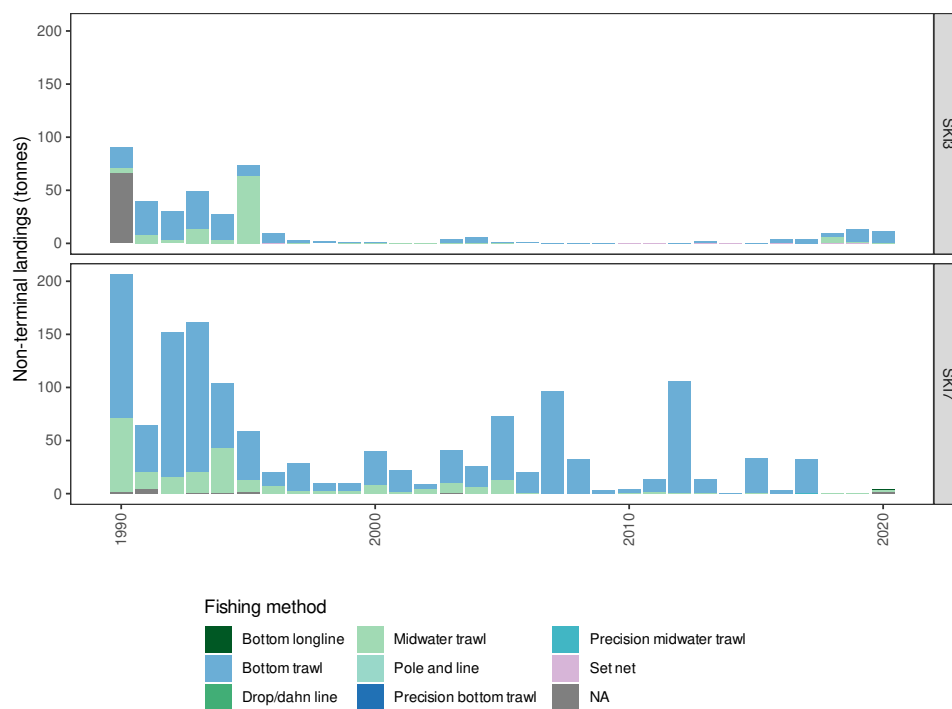


Figure A.4: The quantity of non-final landings, by stock, fishing year, and the modal fishing method used on the trip.

Table A.2: Annual number of trips, and affected greenweight quantity, where the LAGWO rule indicated an order of magnitude error in the landing weight and this was adjusted.

QMA	Fishing year	Trips	Greenweight (kg)	
			Original	Adjusted
SKI3	1990	2	64 547	645.470
SKI3	2020	1	3 587	3.587
SKI7	1994	1	53 475	534.750

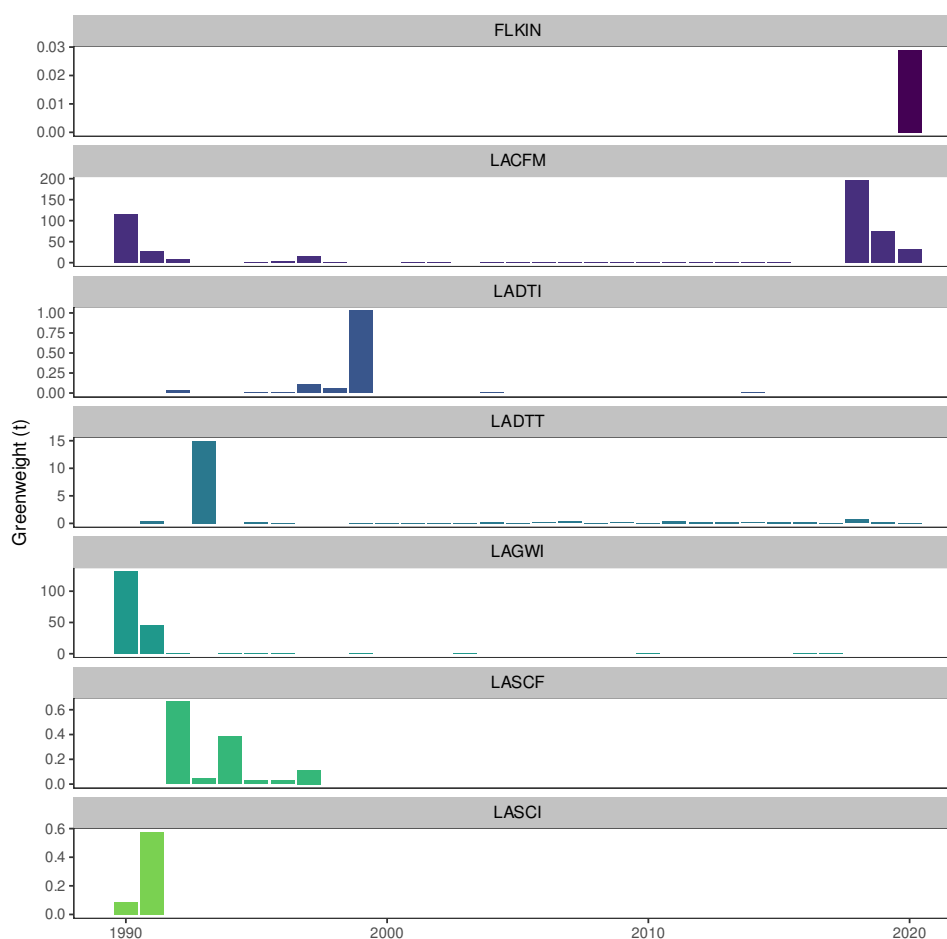


Figure A.5: The quantity of landings flagged by the grooming rules, or where fixes were applied to fields other than the landed greenweight. Note that some landing events may be affected by multiple rules.

A.2 Effort

Table A.3: Grooming rules applied to effort data.

Rule	Effect	Description
FLKIN	Fix	Update target species to SUR when KIN is reported from diving events with no MHR support
FEMDV	Fix	Update historical diving method codes to DV
FEPMN	Fix	Add PSH as a method code for certain vessels if method is null
FEPMI	Fix	Replace missing methods if there is only one method used on the trip (by form type)
FEPMM	Flag	Flag trips if any events have a missing method
FESAI	Fix	Substitute the modal statistical area from a trip for missing areas
FESAM	Flag	Flag events with missing statistical areas
FESAS	Fix	For BCO4 only correct RL statistical areas to general areas
FESAF	Flag	Flag non RLP events using RL statistical area codes
FESDF	Flag	Flag events in the future
FESDM	Flag	Flag events with missing start date/time
FETSE	Fix	Set target species to group code for HPB and FLA species
FETSW	Fix	Flag and set target species to null if target species is not a valid species code
FETSI	Fix	Replace missing target species with the modal value for a trip
FEETN	Fix	Flag and fix some CP effort errors
FEEHN	Fix	Fix transposed effort numbers for lining methods on CELR forms
FEEMU	Fix	Fix SN mesh sizes recorded in inches
FEFMA	Flag	Mark trips which landed to more than one fishstock for straddling statistical areas
FEMEM	Flag	Flag events where the primary effort measure is missing
FEHDE	Flag	Flag records where the maximum daily effort is out of range
FEDBE	Fix	Transpose bottom and effort depths if reported effort depth > bottom depth

Table A.4: Grooming rules applied to estimated catch data.

Rule	Effect	Description
FLKIN	Fix	Update estimated catch species to SUR when KIN is reported from diving events with no MHR support
ESTGT	Fix	Create estimated catch records for events with a total catch weight only
ESCWN	Fix	Correct cases where estimated catch is recorded in weight but number of fish is expected

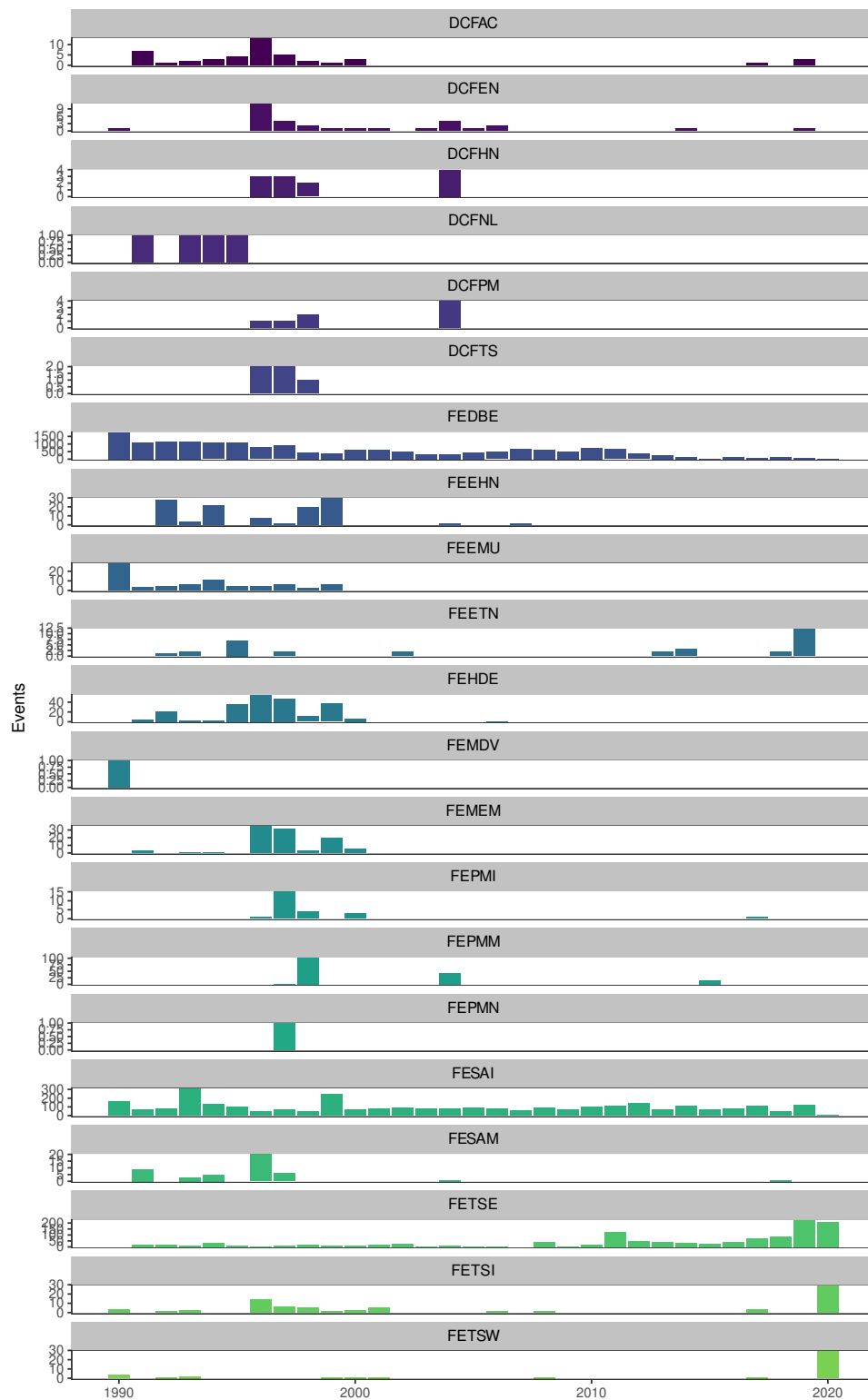


Figure A.6: The number of fishing events flagged or fixed by the grooming rules. Note that some events may be affected by multiple rules.

APPENDIX B: TABULATED FISHERIES CHARACTERISATION DATA

Table B.1: Annual Total Allowable Commercial Catch (TACC; t) and Monthly Harvest Return/Quota Management Report totals (t) for SKI 3 and SKI 7 from 1990 to 2020.

Fishing year	SKI3		SKI7	
	TACC	MHR/QMR	TACC	MHR/QMR
1990	2921.80	1163.71	1576.80	931.87
1991	3259.20	616.06	1609.00	324.66
1992	3338.70	286.89	1652.50	584.16
1993	3338.70	371.17	1652.50	469.04
1994	3345.40	74.90	1663.30	321.31
1995	3345.40	160.01	1663.30	103.20
1996	3355.40	48.81	1663.30	81.22
1997	1500.00	58.22	900.00	238.02
1998	300.00	26.72	300.00	44.08
1999	300.00	16.52	300.00	59.02
2000	300.00	62.00	300.00	106.91
2001	300.00	46.80	300.00	87.04
2002	300.39	71.86	300.00	123.16
2003	300.39	115.15	300.00	268.40
2004	300.39	77.80	300.00	542.26
2005	300.39	71.57	300.00	634.83
2006	300.39	27.48	300.00	247.64
2007	300.39	25.91	300.00	209.49
2008	300.39	18.44	300.00	178.87
2009	300.39	11.34	300.00	213.04
2010	300.39	19.99	300.00	143.67
2011	300.39	33.09	300.00	301.33
2012	300.39	10.95	300.00	259.84
2013	300.39	23.39	300.00	234.15
2014	300.39	29.34	300.00	267.92
2015	300.39	21.05	300.00	230.88
2016	300.39	80.02	300.00	185.99
2017	300.39	248.17	300.00	431.03
2018	300.39	466.00	300.00	583.19
2019	300.39	576.59	300.00	937.28
2020	599.00	513.58	599.00	937.52

Table B.2: Annual SKI 3 catches (t) from the different sources of data used in the fishery characterisation. QMR = Quota Management Reports; MHR = Monthly Harvest Returns. Catches represent groomed (Appendix A) landings/discards data summed by stock (see Table 2 for destination codes included). Allocated catch represents catches allocated to fishing events in the characterisation dataset, with the percentage taken by key fishing methods indicated. Target catch is the allocated catch taken on fishing events where gemfish was targeted. – : no observations.

Fishing year	QMR/MHR (t)	Catches (t)	Allocated catches			Target catches	
			Total (t)	BT-PRB (%)	MW-PRM (%)	tonnes	%
1990	1 163.71	1 149.00	967.74	96.21	1.91	275.24	28.44
1991	616.06	580.10	538.85	89.02	7.76	69.78	12.95
1992	286.89	297.98	291.88	90.98	1.30	34.02	11.65
1993	371.17	319.88	306.90	87.47	9.21	51.08	16.64
1994	74.90	86.82	87.80	84.65	2.45	19.65	22.38
1995	160.01	163.84	131.72	94.23	2.45	31.26	23.73
1996	48.81	53.98	55.34	91.37	3.06	9.41	17.01
1997	58.22	58.99	63.00	89.89	7.80	2.55	4.04
1998	26.72	25.78	27.74	94.43	1.35	3.49	12.59
1999	16.52	24.52	24.32	62.30	36.22	-	-
2000	62.00	60.13	62.76	90.55	8.50	0.22	0.36
2001	46.80	48.00	51.14	91.38	8.28	-	-
2002	71.86	72.00	75.75	97.75	1.92	-	-
2003	115.15	115.89	121.97	92.01	7.87	-	-
2004	77.80	88.93	78.80	90.88	8.98	-	-
2005	71.57	66.47	84.62	89.42	10.51	-	-
2006	27.48	27.00	45.27	96.40	3.43	-	-
2007	25.91	26.19	25.83	94.36	4.01	-	-
2008	18.44	18.78	20.32	87.75	7.26	-	-
2009	11.34	11.32	11.94	80.43	17.87	-	-
2010	19.99	20.29	22.22	68.21	29.82	-	-
2011	33.09	33.18	34.99	85.86	11.94	-	-
2012	10.95	10.86	11.38	75.00	20.51	-	-
2013	23.39	23.34	23.51	83.34	11.67	-	-
2014	29.34	29.30	40.28	90.46	8.06	-	-
2015	21.05	21.06	21.90	88.99	6.30	-	-
2016	80.02	79.71	82.03	92.80	5.98	-	-
2017	248.17	244.25	242.50	89.19	10.23	-	-
2018	466.00	463.88	457.77	78.01	21.19	0.51	0.11
2019	576.59	575.07	576.72	82.21	15.43	-	-
2020	513.58	510.53	506.83	83.73	13.67	2.00	0.40

Table B.3: Annual SKI 7 catches (t) from the different sources of data used in the fishery characterisation. QMR = Quota Management Reports; MHR = Monthly Harvest Returns. Catches represent groomed (Appendix A) landings/discards data summed by stock (see Table 2 for destination codes included). Allocated catch represents catches allocated to fishing events in the characterisation dataset, with the percentage taken by key fishing methods indicated. Target catch is the allocated catch taken on fishing events where gemfish was targeted. – : no observations.

Fishing year	QMR/MHR (t)	Catches (t)	Allocated catches			Target catches	
			Total (t)	BT-PRB (%)	MW-PRM (%)	tonnes	%
1990	931.87	782.50	720.30	77.02	22.74	156.90	21.78
1991	324.66	358.36	337.24	78.69	20.30	55.13	16.35
1992	584.16	450.66	388.84	92.13	7.16	62.00	15.94
1993	469.04	741.34	685.65	79.91	19.10	200.98	29.31
1994	321.31	291.93	293.31	74.51	24.14	54.36	18.53
1995	103.20	159.63	154.34	70.65	26.25	23.73	15.38
1996	81.22	80.36	65.28	66.56	23.01	0.80	1.22
1997	238.02	152.47	126.65	60.08	35.17	11.71	9.25
1998	44.09	134.47	144.47	54.69	42.37	68.67	47.53
1999	59.02	57.62	56.03	72.35	21.51	-	-
2000	106.91	61.66	58.58	70.98	26.50	0.18	0.30
2001	87.04	121.59	116.95	82.75	15.90	5.83	4.98
2002	123.16	111.20	106.64	81.32	17.49	-	-
2003	268.40	286.18	276.42	79.46	19.48	24.49	8.86
2004	542.26	545.13	553.71	77.12	21.95	8.07	1.46
2005	634.83	620.48	596.99	89.10	10.21	-	-
2006	247.64	248.76	228.20	88.00	8.31	0.11	0.05
2007	209.49	135.05	134.42	91.31	3.74	-	-
2008	178.87	251.97	249.49	95.46	0.72	3.99	1.60
2009	213.04	227.06	225.71	92.60	4.57	15.79	7.00
2010	143.67	144.77	144.95	86.65	11.06	9.18	6.33
2011	301.33	284.57	283.14	89.89	7.94	60.14	21.24
2012	259.84	190.86	189.49	91.50	5.78	44.49	23.48
2013	234.15	291.94	296.48	80.99	16.92	23.00	7.76
2014	267.92	255.60	245.15	56.43	40.51	17.15	6.99
2015	230.88	262.12	258.81	62.89	34.93	16.55	6.39
2016	185.99	189.22	185.87	71.11	25.17	13.53	7.28
2017	431.03	389.78	385.55	70.77	27.48	12.04	3.12
2018	583.19	616.70	619.70	75.80	22.83	9.55	1.54
2019	937.28	895.43	889.55	64.95	32.75	2.47	0.28
2020	937.52	990.45	989.84	66.31	31.26	6.77	0.68

Table B.4: Annual gemfish catches (t) by destination code for the SKI 3 Quota Management Area. A = Accidental losses, J = Observer or Fishery Officer authorised returns, L = Landings to an LFR, O = Catch transported outside the EEZ, T = Transshipments. A complete list of destination codes is provided in Table 2. – : no observations.

Fishing year	L	T	O	A	J	Other	Total
1990	531.41	596.90	9.23	-	-	11.47	1 149.00
1991	395.36	183.47	1.19	0.08	-	0.01	580.10
1992	143.67	150.82	3.25	0.04	-	0.19	297.98
1993	224.29	94.44	0.50	0.02	-	0.64	319.88
1994	57.20	29.13	0.12	-	-	0.36	86.82
1995	99.98	63.02	0.52	-	-	0.32	163.84
1996	33.30	18.49	0.72	-	-	1.47	53.98
1997	52.87	5.36	-	-	-	0.77	58.99
1998	25.12	0.37	-	-	-	0.29	25.78
1999	24.06	-	-	0.03	-	0.43	24.52
2000	46.77	-	-	12.24	-	1.12	60.13
2001	46.69	-	0.15	0.07	-	1.09	48.00
2002	67.76	-	-	2.04	-	2.20	72.00
2003	111.40	-	0.10	0.03	-	4.36	115.89
2004	85.98	-	0.42	0.02	-	2.51	88.93
2005	63.60	-	-	0.13	-	2.74	66.47
2006	24.51	-	-	-	-	2.49	27.00
2007	24.58	-	-	0.01	-	1.60	26.19
2008	16.84	-	-	0.08	-	1.86	18.78
2009	9.69	-	-	0.01	-	1.63	11.32
2010	17.89	-	-	0.02	-	2.37	20.29
2011	30.52	-	-	0.11	-	2.55	33.18
2012	9.22	-	-	0.06	-	1.59	10.86
2013	20.37	-	-	0.29	-	2.67	23.34
2014	26.12	-	-	0.18	0.22	2.78	29.30
2015	17.24	-	-	0.01	0.92	2.90	21.06
2016	37.67	-	-	0.01	40.51	1.52	79.71
2017	195.92	-	-	-	44.83	3.50	244.25
2018	400.70	-	-	0.03	55.47	7.68	463.88
2019	513.40	-	-	0.03	58.62	3.02	575.07
2020	479.18	-	-	0.35	24.32	6.68	510.53

Table B.5: Annual gemfish catches (t) by destination code for the SKI 7 Quota Management Area. A = Accidental losses, J = Observer or Fishery Officer authorised returns, L = Landings to an LFR, O = Catch transported outside the EEZ, T = Transshipments. A complete list of destination codes is provided in Table 2. – : no observations.

Fishing year	L	T	O	A	J	Other	Total
1990	200.31	345.46	236.72	-	-	0.00	782.50
1991	126.42	108.31	123.41	0.20	-	0.02	358.36
1992	128.56	208.80	112.62	0.01	-	0.66	450.66
1993	322.44	381.36	35.81	0.01	-	1.72	741.34
1994	171.24	103.35	15.88	0.01	-	1.46	291.93
1995	84.28	68.94	5.03	0.01	-	1.37	159.63
1996	61.16	18.45	0.45	0.02	-	0.29	80.36
1997	96.05	55.19	0.20	0.17	-	0.86	152.47
1998	117.50	16.70	-	-	-	0.27	134.47
1999	55.92	0.17	-	0.16	-	1.37	57.62
2000	60.26	0.24	0.22	0.03	-	0.91	61.66
2001	120.46	0.05	-	-	-	1.08	121.59
2002	108.80	0.36	-	0.02	-	2.02	111.20
2003	284.16	-	-	0.00	-	2.02	286.18
2004	541.97	0.03	0.07	0.01	-	3.05	545.13
2005	618.05	0.01	-	-	-	2.41	620.48
2006	246.38	0.04	-	0.04	-	2.31	248.76
2007	133.51	0.03	-	0.02	-	1.49	135.05
2008	250.48	0.01	-	0.10	-	1.37	251.97
2009	225.32	0.05	-	0.01	-	1.68	227.06
2010	142.42	0.04	-	0.04	-	2.27	144.77
2011	281.81	0.01	-	-	-	2.75	284.57
2012	189.35	0.03	-	0.02	-	1.46	190.86
2013	288.24	0.09	-	0.30	-	3.31	291.94
2014	248.25	0.04	-	0.62	3.91	2.78	255.60
2015	257.86	0.01	-	-	1.68	2.57	262.12
2016	178.29	-	-	0.05	7.74	3.14	189.22
2017	381.29	0.01	-	0.01	5.94	2.54	389.78
2018	609.97	0.00	-	0.33	3.60	2.81	616.70
2019	869.52	0.06	-	0.15	11.60	14.10	895.43
2020	921.80	-	-	0.16	4.77	63.72	990.45

Table B.6: Annual catches by landed state of gemfish from the SKI 3 Quota Management Area. DRE = Dressed, FIL = Fillets: skin-on, GRE = Green (or whole), GUT = Gutted, HGT = Headed, gutted, and tailed, HGU = Headed and gutted, MEA = Fish meal, SKF = Fillets: skin-off. A complete list of state codes is provided in Table E.1. – : no observations. Records where the landed state was missing were excluded.

Fishing year	DRE	HGU	GRE	HGT	MEA	FIL	GUT	SKF	Other	Total
1990	-	355.74	95.15	630.68	11.63	55.45	0.26	-	-	1 148.92
1991	273.66	219.74	70.56	14.17	0.92	0.09	0.38	-	-	579.53
1992	207.39	53.78	36.52	-	0.15	0.05	0.08	-	-	297.98
1993	229.44	33.96	48.77	-	7.49	-	0.16	0.06	0.01	319.88
1994	61.02	16.68	7.90	-	0.95	0.26	0.00	-	-	86.82
1995	88.59	6.58	67.71	-	0.84	0.10	0.01	-	-	163.84
1996	27.38	5.41	20.54	-	0.54	0.01	0.02	-	0.04	53.95
1997	50.89	2.41	5.27	-	0.20	-	0.05	-	0.17	58.99
1998	22.83	1.16	1.63	-	0.13	-	0.00	-	0.02	25.78
1999	14.19	0.55	1.75	-	7.87	0.15	-	-	0.01	24.52
2000	56.62	0.40	1.85	0.19	0.69	-	0.39	-	-	60.13
2001	44.61	1.06	1.67	-	0.39	0.03	0.01	0.23	-	48.00
2002	56.58	2.57	11.20	-	0.95	0.65	0.00	-	0.05	72.00
2003	94.81	6.52	9.11	-	4.07	1.38	-	-	-	115.89
2004	65.75	4.87	4.76	-	3.29	10.23	0.03	-	-	88.93
2005	55.38	2.35	5.07	-	2.49	1.17	0.01	-	-	66.47
2006	20.96	1.32	3.40	-	1.30	-	0.02	-	-	27.00
2007	20.56	2.91	2.02	-	0.70	-	0.00	-	-	26.19
2008	13.34	1.49	3.61	-	0.34	-	-	-	-	18.78
2009	7.36	0.78	2.92	-	0.26	-	0.00	-	-	11.32
2010	14.15	2.25	2.66	-	1.14	-	0.09	-	-	20.29
2011	25.92	2.51	3.23	-	1.46	-	0.06	-	-	33.18
2012	6.99	1.53	1.97	-	0.35	-	0.01	-	-	10.86
2013	13.50	2.95	3.13	-	3.29	0.44	0.03	-	-	23.34
2014	22.81	1.84	3.47	-	1.17	-	0.01	-	-	29.30
2015	12.55	3.07	4.24	-	1.20	-	0.00	-	-	21.06
2016	7.72	4.02	65.38	-	2.53	-	0.03	0.04	-	79.71
2017	135.50	18.04	66.32	-	22.57	1.81	-	-	-	244.25
2018	314.40	37.60	62.45	-	44.62	4.79	0.02	-	-	463.88
2019	365.01	50.21	81.23	-	76.77	1.26	0.58	-	-	575.07
2020	342.77	38.36	79.92	-	49.25	0.21	0.01	0.01	-	510.53

Table B.7: Annual catches by landed state of gemfish from the SKI 7 Quota Management Area. DRE = Dressed, FIL = Fillets: skin-on, GRE = Green (or whole), GUT = Guttled, HGT = Headed, gutted, and tailed, HGU = Headed and gutted, MEA = Fish meal, SKF = Fillets: skin-off. A complete list of state codes is provided in Table E.1. – : no observations. Records where the landed state was missing were excluded.

Fishing year	DRE	HGU	GRE	HGT	MEA	FIL	SKF	GUT	Other	Total
1990	-	48.81	49.20	667.19	0.46	16.09	-	0.74	0.01	782.50
1991	173.42	40.63	22.58	120.96	0.70	0.04	-	0.03	-	358.36
1992	385.49	8.25	56.79	-	0.06	-	-	0.07	-	450.66
1993	567.20	11.05	153.57	-	4.53	4.96	-	0.03	-	741.34
1994	245.60	9.50	32.84	-	2.25	1.72	-	0.01	-	291.93
1995	127.65	7.05	23.27	-	0.52	0.49	-	0.66	-	159.63
1996	48.09	6.63	23.77	-	1.04	0.83	-	-	-	80.36
1997	93.87	25.19	12.16	-	2.36	18.74	-	0.00	-	152.33
1998	119.83	8.82	4.86	-	0.03	-	-	-	-	133.54
1999	33.42	16.84	6.86	-	0.49	-	-	-	0.01	57.62
2000	46.88	5.79	2.47	-	3.45	2.33	0.72	-	0.02	61.66
2001	99.88	10.71	4.61	-	5.67	-	0.72	-	-	121.59
2002	86.59	4.75	12.22	-	7.59	-	-	-	0.05	111.20
2003	236.93	15.26	24.48	0.10	7.41	0.04	-	-	1.96	286.18
2004	411.43	45.91	65.30	-	10.86	11.14	0.47	0.01	0.01	545.13
2005	535.79	37.71	14.97	-	5.96	24.85	-	0.06	1.13	620.48
2006	189.88	31.06	13.13	-	2.39	12.22	-	0.09	-	248.76
2007	91.36	22.02	6.53	-	1.77	13.27	-	0.09	-	135.05
2008	124.55	95.55	30.79	-	1.01	0.06	-	0.01	-	251.97
2009	135.06	82.72	7.02	-	2.25	0.00	-	-	-	227.06
2010	46.05	90.64	6.25	-	1.77	-	-	0.07	-	144.77
2011	98.82	167.95	11.62	-	2.93	3.26	-	-	-	284.57
2012	72.37	106.66	10.01	-	1.82	-	0.01	-	-	190.86
2013	196.30	83.37	8.43	-	3.37	0.45	-	-	-	291.93
2014	140.98	72.15	14.55	-	26.73	0.36	-	0.84	-	255.60
2015	133.05	89.42	10.18	-	28.17	0.11	1.11	0.07	-	262.12
2016	50.38	73.12	16.71	-	46.89	1.46	0.60	0.06	-	189.22
2017	191.79	87.95	44.90	-	60.86	4.26	-	0.02	-	389.78
2018	352.97	95.91	31.29	-	94.31	42.13	-	0.10	-	616.70
2019	657.36	107.33	48.26	-	64.08	18.27	-	0.13	-	895.43
2020	709.85	133.47	43.76	-	97.98	5.39	-	0.00	-	990.45

Table B.8: Annual modal conversion factor reported for product state codes of gemfish from the SKI 3 and SKI 7 Quota Management Areas. DRE = Dressed, FIL = Fillets: skin-on, FLP = Flaps, GGU = Gilled and gutted, GRE = Green (or whole), GUT = Gutted, HGT = Headed, gutted, and tailed, HGU = Headed and gutted, MEA = Fish meal, SKF = Fillets: skin-off. – : no observations.

Fishing year	FIL	GGU	GRE	GUT	HGT	HGU	MEA	DRE	FLP	SKF
1990	2.30	1.20	1.00	1.10	1.60	1.50	5.56	-	-	-
1991	2.30	-	1.00	1.10	1.60	1.50	5.60	1.60	-	-
1992	2.30	-	1.00	1.10	-	1.50	5.60	1.55	-	-
1993	2.30	-	1.00	1.10	-	1.50	5.60	1.55	-	-
1994	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
1995	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
1996	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
1997	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
1998	-	-	1.00	1.10	-	1.50	5.60	1.55	0.00	-
1999	2.15	-	1.00	-	-	1.50	5.60	1.55	-	-
2000	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	2.65
2001	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	2.65
2002	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2003	2.15	-	1.00	-	-	1.50	5.60	1.55	-	-
2004	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	2.65
2005	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2006	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2007	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2008	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2009	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2010	-	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2011	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2012	-	-	1.00	1.10	-	1.50	5.60	1.55	-	2.65
2013	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2014	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2015	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	2.65
2016	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	2.65
2017	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2018	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2019	2.15	-	1.00	1.10	-	1.50	5.60	1.55	-	-
2020	2.15	-	1.00	1.10	-	1.50	-	1.55	-	2.65

Table B.9: Reporting forms used for effort on trips landing gemfish from the SKI 3 Quota Management Area in terms of data records and their allocated catches. A complete list of form type codes is provided in Table E.2. – : no observations.

Fishing year	Records (N)							Allocated catches (t)						
	TCP	CEL	Other	TCE	ERS - Trawl	ERS - Lining	Total	TCP	CEL	Other	TCE	ERS - Trawl	ERS - Lining	Total
1990	12 637	1 472	-	-	-	-	14 109	758.28	209.46	-	-	-	-	967.74
1991	14 785	1 692	-	-	-	-	16 477	381.25	157.60	-	-	-	-	538.85
1992	11 156	1 757	-	-	-	-	12 913	228.88	63.00	-	-	-	-	291.88
1993	12 162	1 198	-	-	-	-	13 360	267.02	39.88	-	-	-	-	306.90
1994	8 842	941	8	-	-	-	9 791	67.78	20.02	0.01	-	-	-	87.80
1995	9 689	672	8	-	-	-	10 369	94.54	37.14	0.04	-	-	-	131.72
1996	6 930	316	1	-	-	-	7 247	41.40	13.94	0.00	-	-	-	55.34
1997	7 661	357	5	-	-	-	8 023	57.99	4.93	0.08	-	-	-	63.00
1998	7 002	159	-	-	-	-	7 161	24.99	2.75	-	-	-	-	27.74
1999	8 789	104	-	-	-	-	8 893	23.56	0.75	-	-	-	-	24.32
2000	8 101	63	-	-	-	-	8 164	62.07	0.70	-	-	-	-	62.76
2001	11 179	176	-	-	-	-	11 355	50.79	0.35	-	-	-	-	51.14
2002	11 300	282	-	-	-	-	11 582	74.59	1.16	-	-	-	-	75.75
2003	14 744	514	-	-	-	-	15 258	115.78	6.19	-	-	-	-	121.97
2004	14 400	392	109	-	-	-	14 901	75.95	2.85	0.00	-	-	-	78.80
2005	12 024	360	62	-	-	-	12 446	82.63	1.99	0.00	-	-	-	84.62
2006	9 432	245	60	-	-	-	9 737	44.15	1.12	0.01	-	-	-	45.27
2007	9 886	270	300	-	-	-	10 456	23.75	1.86	0.22	-	-	-	25.83
2008	7 829	9	172	508	-	-	8 518	18.61	0.07	0.94	0.69	-	-	20.32
2009	6 949	21	239	301	-	-	7 510	11.26	0.06	0.15	0.48	-	-	11.94
2010	8 320	25	128	723	-	-	9 196	20.19	0.24	0.20	1.59	-	-	22.22
2011	8 966	46	233	955	-	-	10 200	32.14	0.22	0.33	2.30	-	-	34.99
2012	5 929	63	324	585	-	-	6 901	9.48	0.41	0.10	1.39	-	-	11.38
2013	7 187	70	283	676	-	-	8 216	20.64	0.96	0.21	1.69	-	-	23.51
2014	7 411	59	160	564	-	-	8 194	38.66	0.31	0.28	1.03	-	-	40.28
2015	6 568	19	257	359	-	-	7 203	19.69	0.15	0.88	1.18	-	-	21.90
2016	5 956	41	349	587	-	-	6 933	80.07	0.17	0.83	0.96	-	-	82.03
2017	8 732	59	214	1 335	-	-	10 340	217.99	0.74	0.66	23.12	-	-	242.50
2018	1 494	103	290	2 543	10 547	-	14 977	15.99	3.21	0.44	38.06	400.07	-	457.77
2019	237	90	637	2 209	13 324	204	16 701	1.70	10.85	2.48	46.18	515.22	0.29	576.72
2020	-	-	633	-	15 905	741	17 279	-	-	11.49	-	493.66	1.69	506.83

Table B.10: Reporting forms used for effort on trips landing gemfish from the SKI 7 Quota Management Area in terms of data records and their allocated catches. A complete list of form type codes is provided in Table E.2. – : no observations.

Fishing year	Records (N)							Allocated catches (t)						
	TCP	CEL	Other	TCE	ERS - Trawl	ERS - Lining	Total	TCP	CEL	Other	TCE	ERS - Trawl	ERS - Lining	Total
1990	6 128	944	-	-	-	-	7 072	683.82	36.48	-	-	-	-	720.30
1991	3 123	1 182	-	-	-	-	4 305	299.73	37.52	-	-	-	-	337.24
1992	3 676	1 075	-	-	-	-	4 751	367.03	21.81	-	-	-	-	388.84
1993	6 865	1 107	-	-	-	-	7 972	608.50	77.15	-	-	-	-	685.65
1994	7 175	1 293	-	-	-	-	8 468	258.93	34.38	-	-	-	-	293.31
1995	5 504	1 099	-	-	-	-	6 603	133.63	20.71	-	-	-	-	154.34
1996	3 115	1 298	-	-	-	-	4 413	39.40	25.88	-	-	-	-	65.28
1997	3 364	1 256	-	-	-	-	4 620	96.39	30.26	-	-	-	-	126.65
1998	2 106	736	-	-	-	-	2 842	131.24	13.22	-	-	-	-	144.47
1999	3 135	1 132	-	-	-	-	4 267	35.28	20.75	-	-	-	-	56.03
2000	4 154	876	-	-	-	-	5 030	51.23	7.35	-	-	-	-	58.58
2001	6 739	838	-	-	-	-	7 577	112.15	4.81	-	-	-	-	116.95
2002	8 331	771	33	-	-	-	9 135	100.99	5.61	0.03	-	-	-	106.64
2003	8 850	1 160	3	-	-	-	10 013	261.25	15.17	0.00	-	-	-	276.42
2004	7 405	1 806	1	-	-	-	9 212	485.31	68.38	0.03	-	-	-	553.71
2005	6 525	1 334	5	-	-	-	7 864	555.94	41.05	0.00	-	-	-	596.99
2006	5 518	1 370	20	-	-	-	6 908	196.49	31.68	0.02	-	-	-	228.20
2007	5 387	1 330	71	-	-	-	6 788	109.76	24.38	0.27	-	-	-	134.42
2008	4 122	154	766	2 939	-	-	7 981	123.64	0.22	9.39	116.23	-	-	249.49
2009	3 613	188	739	3 379	-	-	7 919	141.05	0.54	5.90	78.21	-	-	225.71
2010	4 283	103	494	4 166	-	-	9 046	48.88	0.25	3.10	92.73	-	-	144.95
2011	4 321	109	874	5 391	-	-	10 695	106.98	0.27	5.90	169.99	-	-	283.14
2012	4 518	207	631	5 158	-	-	10 514	71.88	0.56	4.60	112.45	-	-	189.49
2013	4 604	164	655	5 389	-	-	10 812	198.97	0.77	5.44	91.31	-	-	296.48
2014	5 799	152	940	4 500	-	-	11 391	164.25	0.68	6.83	73.39	-	-	245.15
2015	5 757	161	881	3 947	-	-	10 746	164.40	0.53	5.11	88.78	-	-	258.81
2016	5 728	110	679	4 786	-	-	11 303	112.97	0.20	6.70	66.00	-	-	185.87
2017	5 929	108	695	5 281	-	-	12 013	259.69	0.24	6.48	119.14	-	-	385.55
2018	314	158	718	5 370	5 967	-	12 527	46.55	0.37	8.16	115.13	449.49	-	619.70
2019	19	175	727	4 188	6 762	523	12 394	0.31	0.94	13.34	81.82	787.02	6.12	889.55
2020	-	4	180	-	9 667	2 251	12 102	-	0.00	1.38	-	965.79	22.66	989.84

Table B.11: Allocated catches (t) of gemfish in SKI 3 by method of capture and fishing year. A complete list of fishing method codes is provided in Table E.3. – : no observations.

Fishing year	BLL	BT	MW	SN	DS	PRB	Other	Total
1990	0.19	931.08	18.49	17.93	-	-	0.04	967.74
1991	0.03	479.68	41.84	17.01	-	-	0.30	538.85
1992	0.18	265.56	3.79	22.17	-	-	0.19	291.88
1993	0.54	268.44	28.26	9.62	-	-	0.05	306.90
1994	0.06	74.33	2.15	11.25	-	-	0.01	87.80
1995	0.07	124.12	3.23	4.15	-	-	0.15	131.72
1996	1.46	50.57	1.69	1.61	-	-	0.01	55.34
1997	0.05	56.63	4.92	1.30	-	-	0.10	63.00
1998	0.03	26.20	0.37	1.14	-	-	0.00	27.74
1999	0.18	15.15	8.81	0.18	-	-	-	24.32
2000	0.41	56.83	5.34	0.19	-	-	-	62.76
2001	0.08	46.73	4.24	0.09	-	-	0.00	51.14
2002	0.07	74.05	1.45	0.18	-	-	0.00	75.75
2003	0.04	112.22	9.60	0.11	-	-	0.00	121.97
2004	0.02	71.61	7.07	0.09	-	-	-	78.80
2005	0.02	75.67	8.90	0.04	-	-	-	84.62
2006	0.03	43.64	1.55	0.04	-	-	0.01	45.27
2007	0.05	24.38	1.04	0.21	0.15	-	0.01	25.83
2008	0.87	17.83	1.48	0.08	0.06	-	0.00	20.32
2009	0.01	9.60	2.13	0.18	0.02	-	0.00	11.94
2010	0.12	15.15	6.62	0.08	0.24	-	-	22.22
2011	0.10	30.04	4.18	0.26	0.18	-	0.22	34.99
2012	0.04	8.53	2.33	0.10	0.36	-	0.01	11.38
2013	0.12	19.59	2.74	0.11	0.91	-	0.03	23.51
2014	0.14	36.44	3.25	0.14	0.31	-	0.01	40.28
2015	0.72	19.49	1.38	0.17	0.15	-	0.00	21.90
2016	0.64	76.02	4.91	0.19	0.16	0.11	0.01	82.03
2017	0.59	216.26	24.80	0.06	0.74	0.03	0.01	242.50
2018	0.33	354.49	96.64	0.11	3.20	2.62	0.38	457.77
2019	2.35	465.86	88.97	0.12	11.15	8.28	0.00	576.72
2020	1.67	420.10	69.27	0.33	11.15	4.26	0.03	506.83

Table B.12: Allocated catches (t) of gemfish in SKI 7 by method of capture and fishing year. A complete list of fishing method codes is provided in Table E.3. – : no observations.

Fishing year	BLL	BT	DS	MW	SN	PRB	Other	Total
1990	1.23	554.78	0.00	163.76	0.11	-	0.41	720.30
1991	3.16	265.37	-	68.46	0.03	-	0.22	337.24
1992	2.25	358.23	-	27.86	0.07	-	0.43	388.84
1993	6.71	547.93	-	130.93	0.02	-	0.05	685.65
1994	3.51	218.54	-	70.80	0.15	-	0.31	293.31
1995	4.00	109.04	-	40.51	0.15	-	0.64	154.34
1996	5.31	43.45	-	15.02	1.16	-	0.34	65.28
1997	3.88	76.10	-	44.55	2.03	-	0.09	126.65
1998	3.17	79.02	-	61.20	0.04	-	1.04	144.47
1999	3.11	40.54	-	12.05	0.10	-	0.23	56.03
2000	1.39	41.58	-	15.52	-	-	0.08	58.58
2001	1.31	96.78	-	18.60	0.04	-	0.22	116.95
2002	1.12	86.72	-	18.65	0.03	-	0.12	106.64
2003	2.32	219.64	-	53.84	0.46	-	0.17	276.42
2004	4.56	427.03	-	121.55	0.04	-	0.53	553.71
2005	3.53	531.90	-	60.96	0.16	-	0.44	596.99
2006	8.22	200.83	-	18.95	0.08	-	0.13	228.20
2007	6.21	122.74	-	5.03	0.27	-	0.17	134.42
2008	9.40	238.16	-	1.80	0.01	-	0.12	249.49
2009	5.97	208.99	-	10.31	0.02	-	0.42	225.71
2010	3.21	125.59	-	16.03	0.01	-	0.10	144.95
2011	5.89	254.50	-	22.47	0.05	-	0.23	283.14
2012	4.76	173.38	-	10.95	0.06	-	0.34	189.49
2013	5.80	240.12	-	50.16	0.04	-	0.36	296.48
2014	6.94	138.34	-	99.31	0.17	-	0.40	245.15
2015	5.50	162.78	-	90.40	0.01	-	0.13	258.81
2016	6.64	132.18	-	46.36	0.20	-	0.48	185.87
2017	6.66	268.18	-	104.98	0.00	4.69	1.04	385.55
2018	8.34	420.83	-	140.73	0.00	48.89	0.92	619.70
2019	20.13	546.48	-	288.77	0.08	31.31	2.78	889.55
2020	23.92	633.38	-	308.79	0.05	23.01	0.67	989.84

APPENDIX C: COMPOSITION DATA

C.1 Introduction

There exists a reasonably large dataset of observer length frequencies for both SKI 3 and SKI 7, collected almost entirely from either the midwater or bottom trawl fisheries in both QMA's (Table C.1). The largest number of tows sampled was in the SKI 7 MW trawl fishery (CHA), followed by the BT fishery on the SKI 3 Stewart-Snares shelf (SOU) (Table C.1). There does not appear to be a great deal of sexual dimorphism for southern gemfish, with males and females having similar length frequency distributions, both in the size range and relative proportions (Figure C.2). There is also variation in the size of gemfish captured by area, with the largest gemfish coming from the SKI 7 west coast (CHA) and the smallest from SKI 3 east coast (SEC) (Figure C.3). The SEC samples should be viewed with caution because the number of sampled tows was low, while both the CHA and SOU had a reasonable number of samples (Table C.1). Note that for the latter two areas (CHA, SOU), there was not much difference in the empirical cumulative frequencies by method of capture (BT or MW), indicating that these two fisheries are probably operating on the same population with a similar selectivity (Figure C.3). Figure C.3 also indicated that the CHA gemfish tended to be larger than the SOU gemfish, lending support to the contention that the CHA is where larger gemfish go to spawn while the SOU is more of a feeding ground for all gemfish, including immatures.

The representativeness of all MW observer samples by month (Figure C.6, Figure C.7) or latitude (Figure C.8, Figure C.9) was poor for most years. However, the MW sample coverage appeared to have improved in recent years (2019 and 2020), possibly as abundance increased. The BT fishery representativeness across all fisheries was poor both by month (Figure C.13, Figure C.14) and latitude (Figure C.15, Figure C.16) and did not show any improvement in recent years.

The available observer length frequency data for SKI 3 and SKI 7 showed clear length mode progressions in all observer regions where southern gemfish occurred for both midwater trawl (Figure C.10) and bottom trawl (Figure C.17). These progressions were most evident in the CHA (WCSI) observer region where there was much better observer coverage. Both capture methods in the CHA region showed a broadening of the length frequency distributions in 2019 and particularly in 2020, with fish smaller than 30 cm entering the fishery, possibly indicating that new recruitment has entered these fisheries.

C.2 Observer length-frequency data

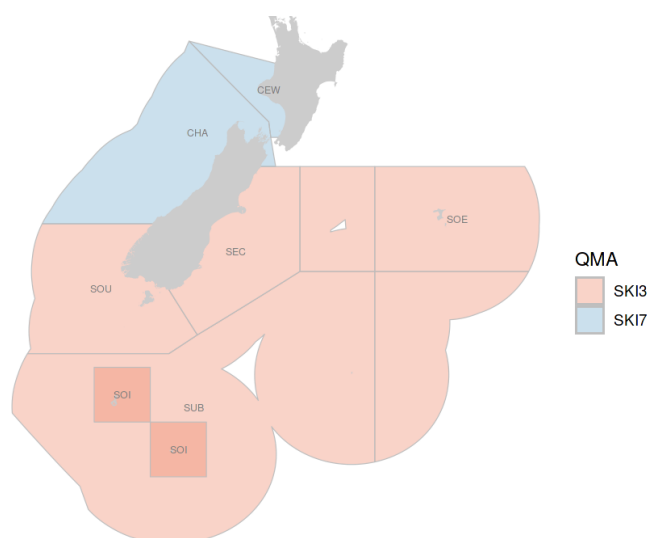


Figure C.1: Observer Fisheries Management Areas in relation to the Quota Management Areas (QMA) for gemfish.

Table C.1: Length-frequency samples of gemfish by area and method, sampled by the Observer Programme from fishing years 1990 to 2020. Observer Fisheries Management Area (FMA) codes and method codes are defined in the glossary.

QMA	Observer FMA	Method	Sampled events	Number of fish
SKI3	SEC	B	1	6
SKI3	SEC	BT	154	2022
SKI3	SEC	MW	66	933
SKI3	SEC	PRB	2	45
SKI3	SOE	BT	2	5
SKI3	SOI	BT	2	3
SKI3	SOI	BT	2	3
SKI3	SOI	MW	1	3
SKI3	SOI	MW	1	3
SKI3	SOU	BLL	7	7
SKI3	SOU	BT	868	9044
SKI3	SOU	MW	501	2728
SKI3	SUB	BT	2	3
SKI7	CEW	BT	9	32
SKI7	CEW	MW	42	149
SKI7	CHA	BLL	15	87
SKI7	CHA	BT	563	7819
SKI7	CHA	MPT	1	2
SKI7	CHA	MW	1568	12421
SKI7	CHA	PRB	1	25

C.2.1 Length composition by area and method

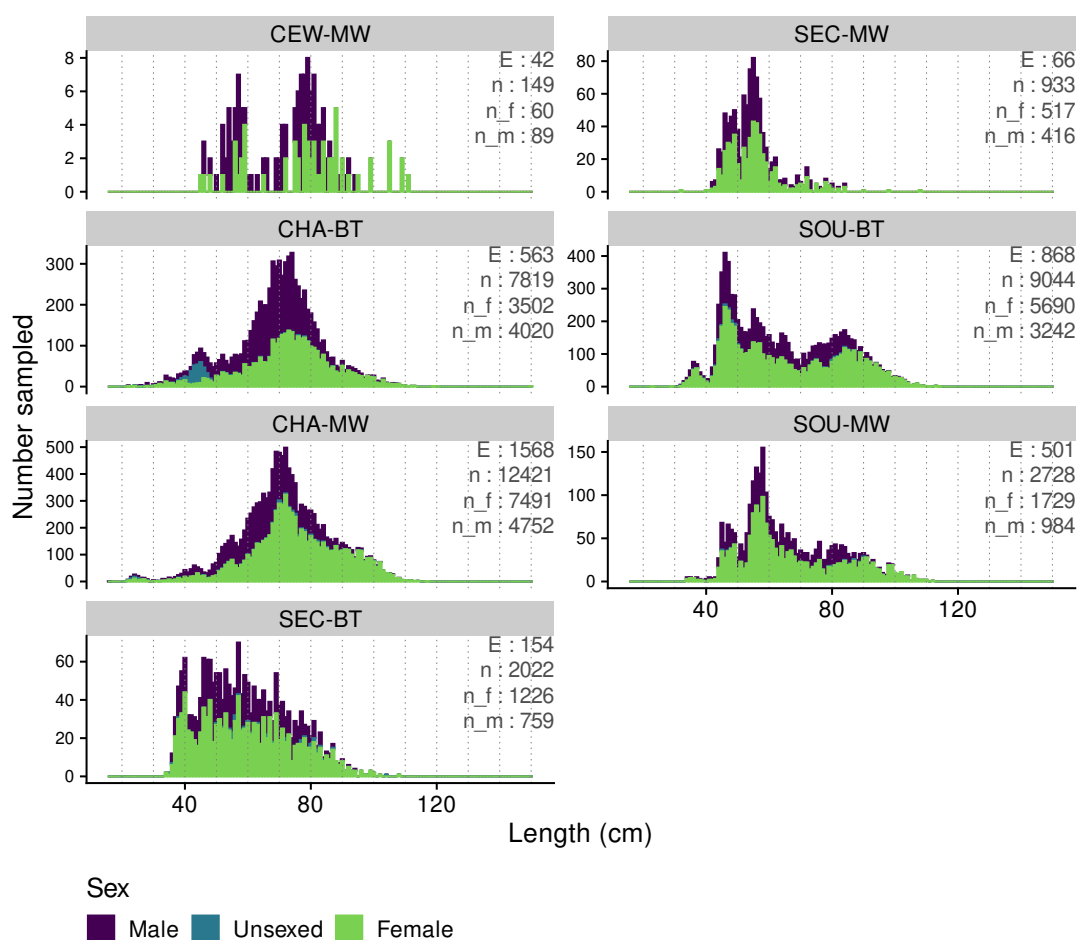


Figure C.2: Length-frequency distributions of gemfish for the CEW, CHA, SEC, SOU areas by fishing method. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area-method. Only area-methods with at least 100 fish measurements are included. The observer area codes are defined in the glossary.

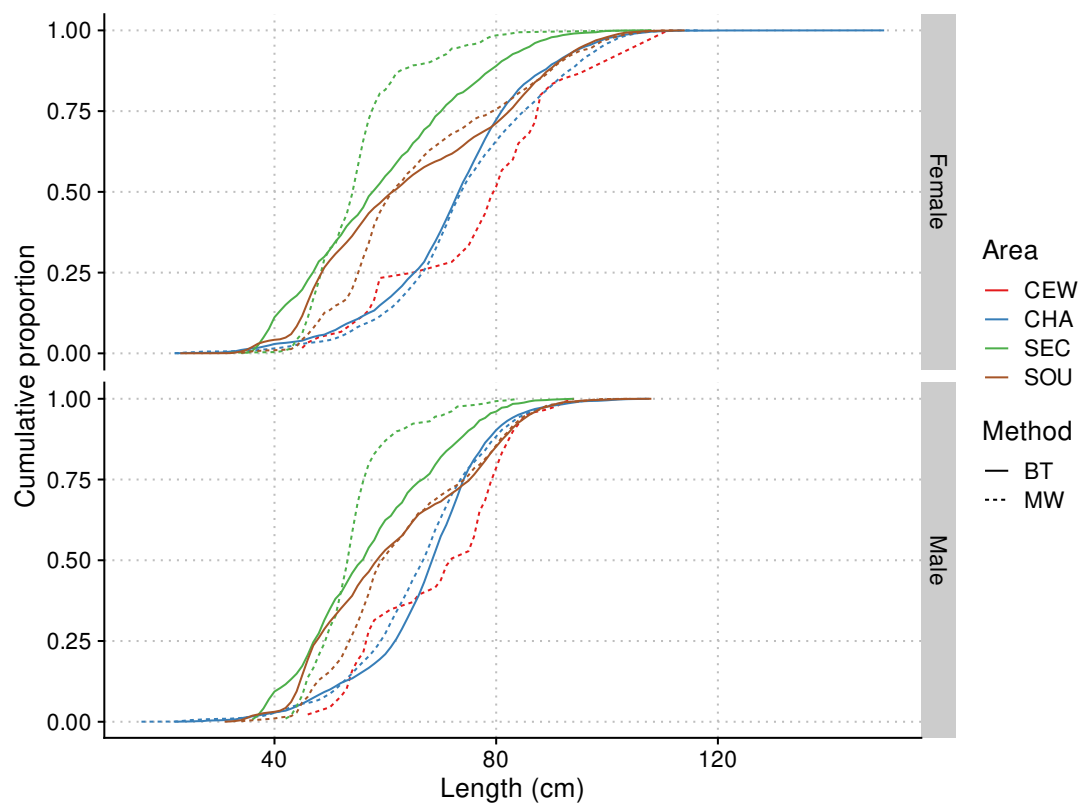


Figure C.3: Cumulative length-frequency distributions of gemfish for the CEW, CHA, SEC, SOU area by fishing method, using raw, unscaled observer samples.

C.2.2 The midwater trawl fishery

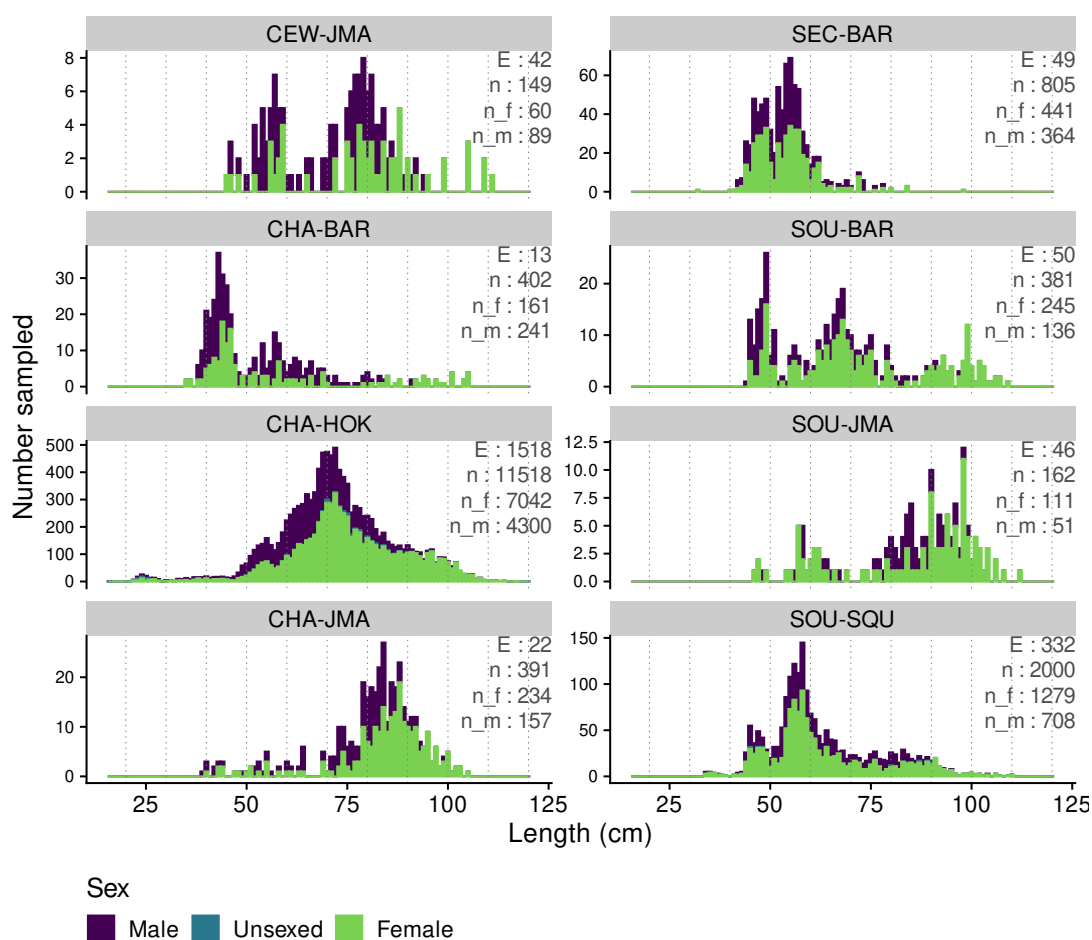


Figure C.4: Length-frequency distributions for gemfish caught in the midwater trawl fishery, by area, target species, and sex. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area-target and sex. Only area-targets at least 100 fish measurements are included. Observer area codes are defined in the glossary.

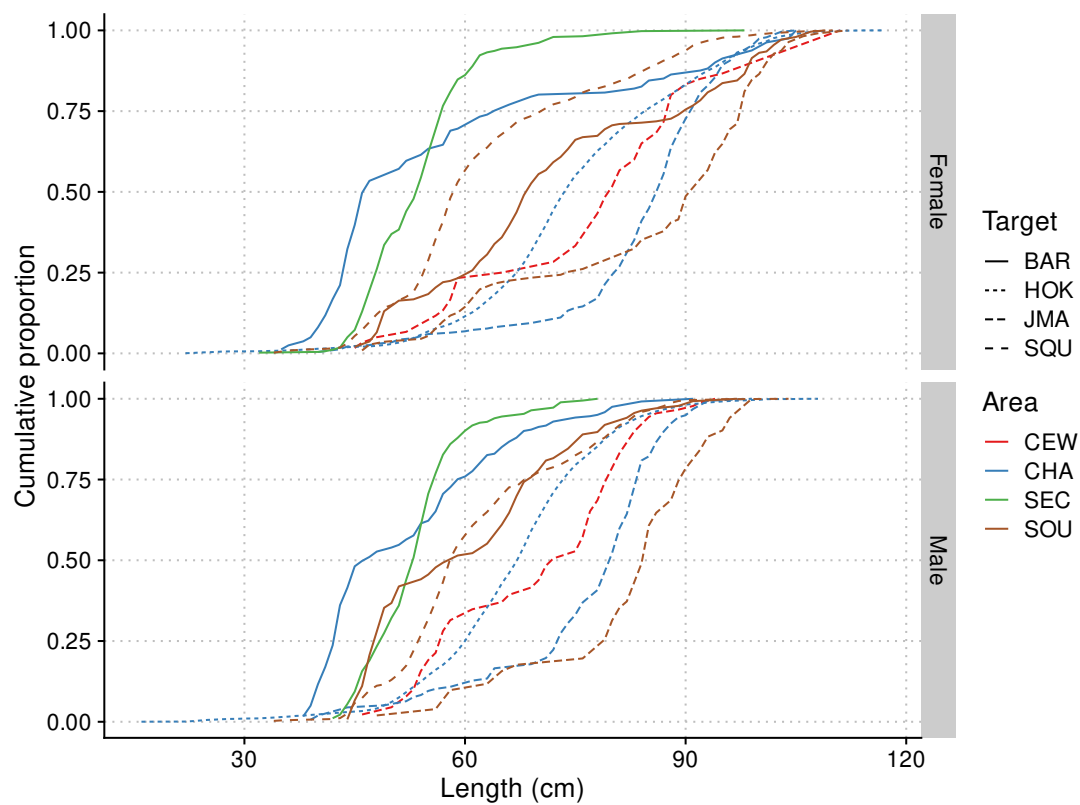


Figure C.5: Cumulative length-frequency distributions for gemfish caught in the midwater trawl fishery, by area and target species. Only area-targets at least 100 fish measurements are included. Observer area codes are defined in the glossary.

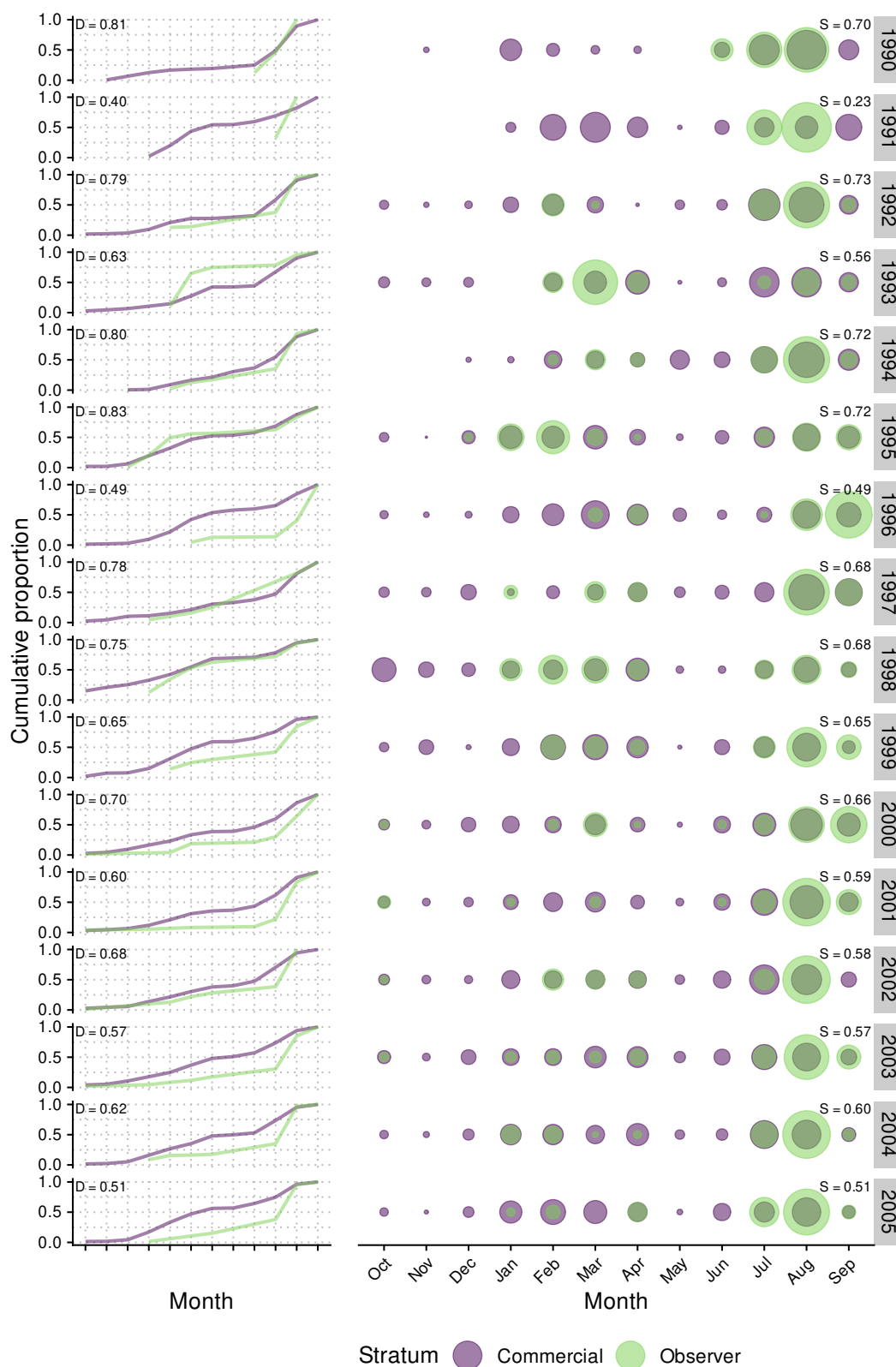


Figure C.6: Representativeness of observer sampling coverage of midwater trawl fishing events that caught gemfish in 1990 to 2005 by fishing year and month. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a month, with proportions summing to one within each fishing year. D: Kolmogorov-Smirnov maximum absolute difference; S: Manhattan block distance.

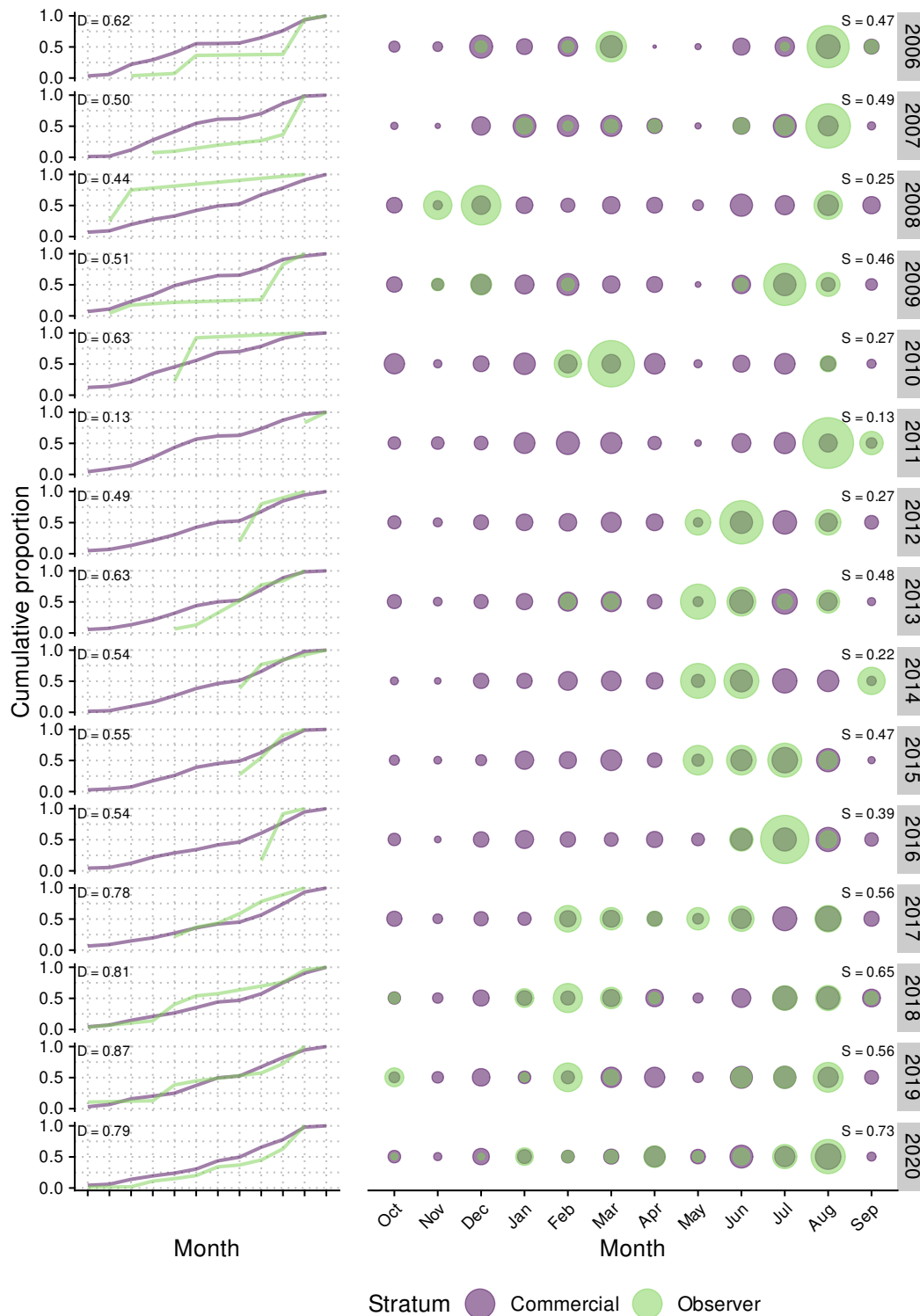


Figure C.7: Representativeness of observer sampling coverage of midwater trawl fishing events that caught gemfish in 2006 to 2020 by fishing year and month. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a month, with proportions summing to one within each fishing year. D: Kolmogorov-Smirnov maximum absolute difference; S: Manhattan block distance.

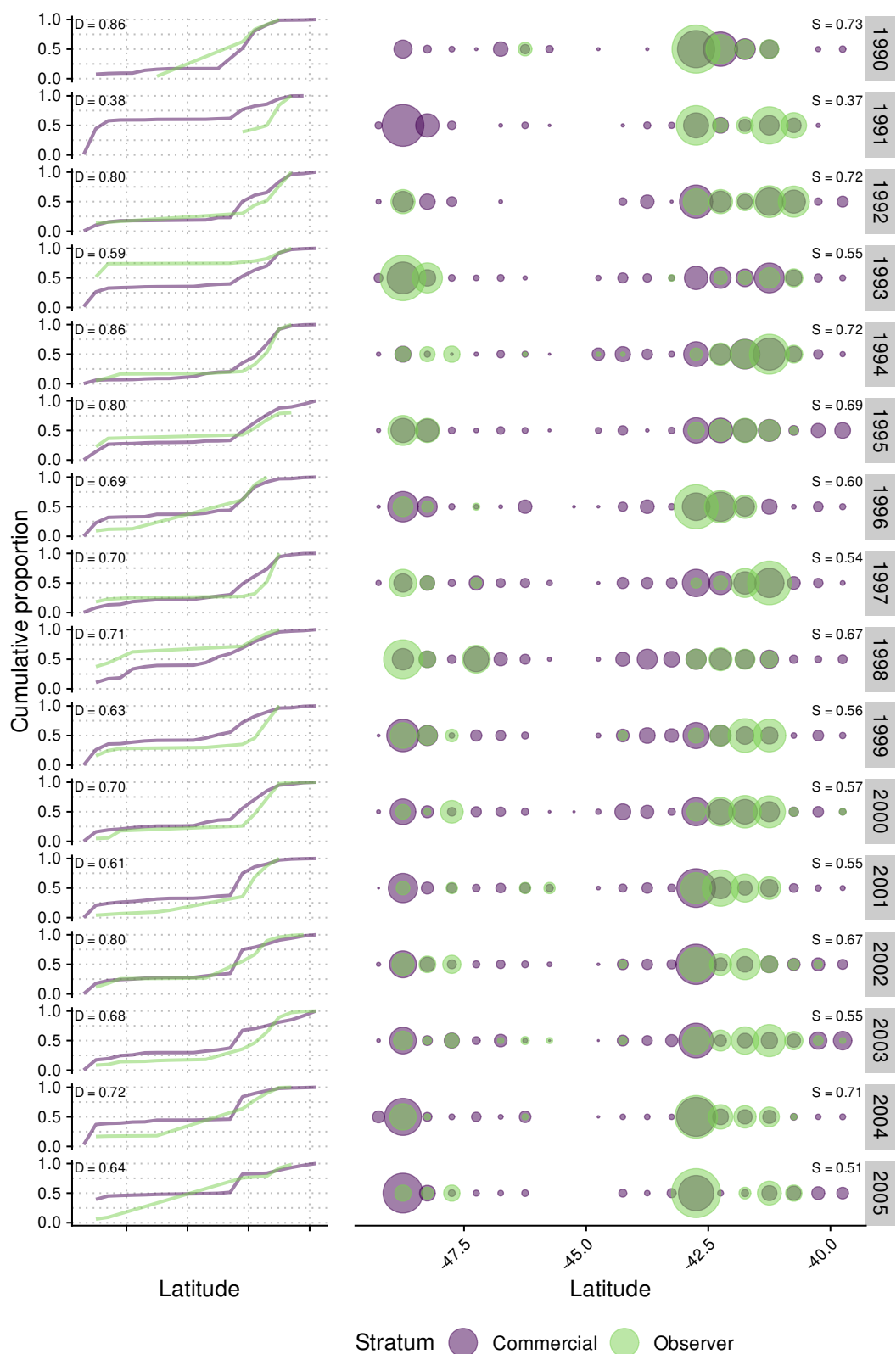


Figure C.8: Representativeness of observer sampling coverage of midwater trawl fishing events that caught gemfish in 1990 to 2005 by fishing year and latitude. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a latitude bin, with proportions summing to one within each fishing year.

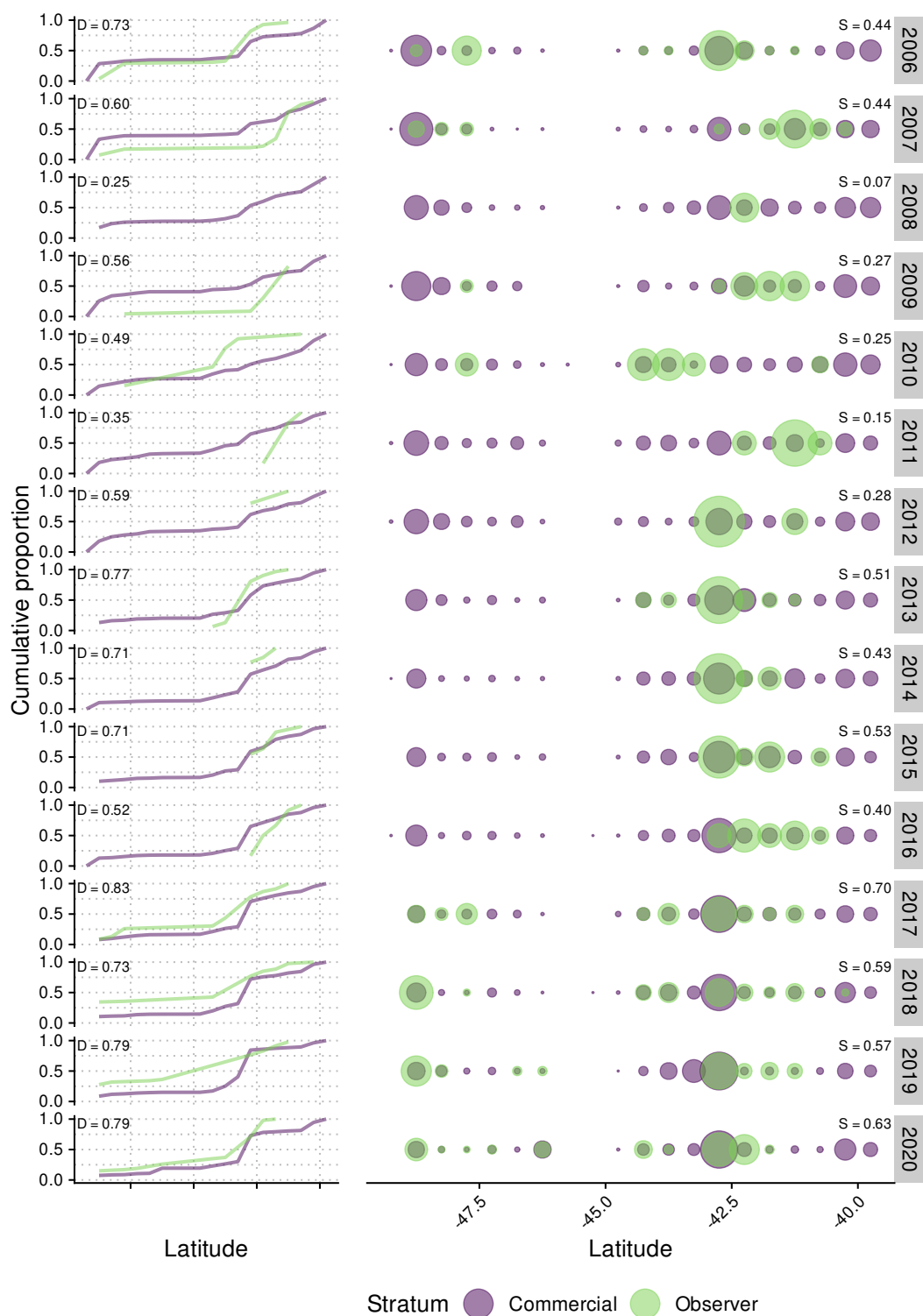


Figure C.9: Representativeness of observer sampling coverage of midwater trawl fishing events that caught gemfish in 2006 to 2020 by fishing year and latitude. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a latitude bin, with proportions summing to one within each fishing year.

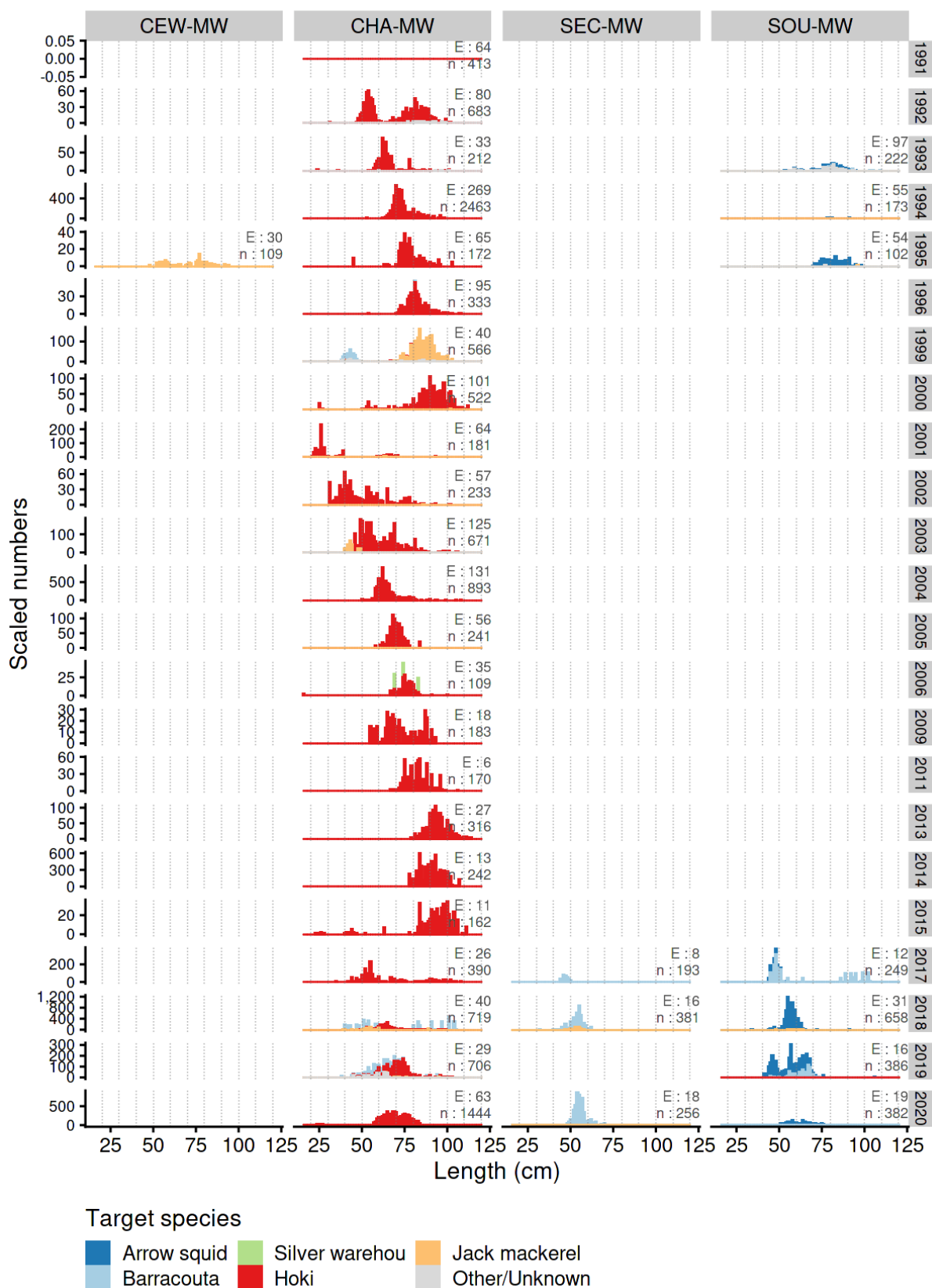


Figure C.10: Length-frequency distributions for gemfish caught in the midwater trawl fishery, by area, fishing year, and target species. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area, target and year. Sampled numbers are scaled to the catch weight in each sampled event. Observer area codes are defined in the glossary. The Other grouping includes both minor target species and events where the target species was not recorded.

C.2.3 The bottom trawl fishery

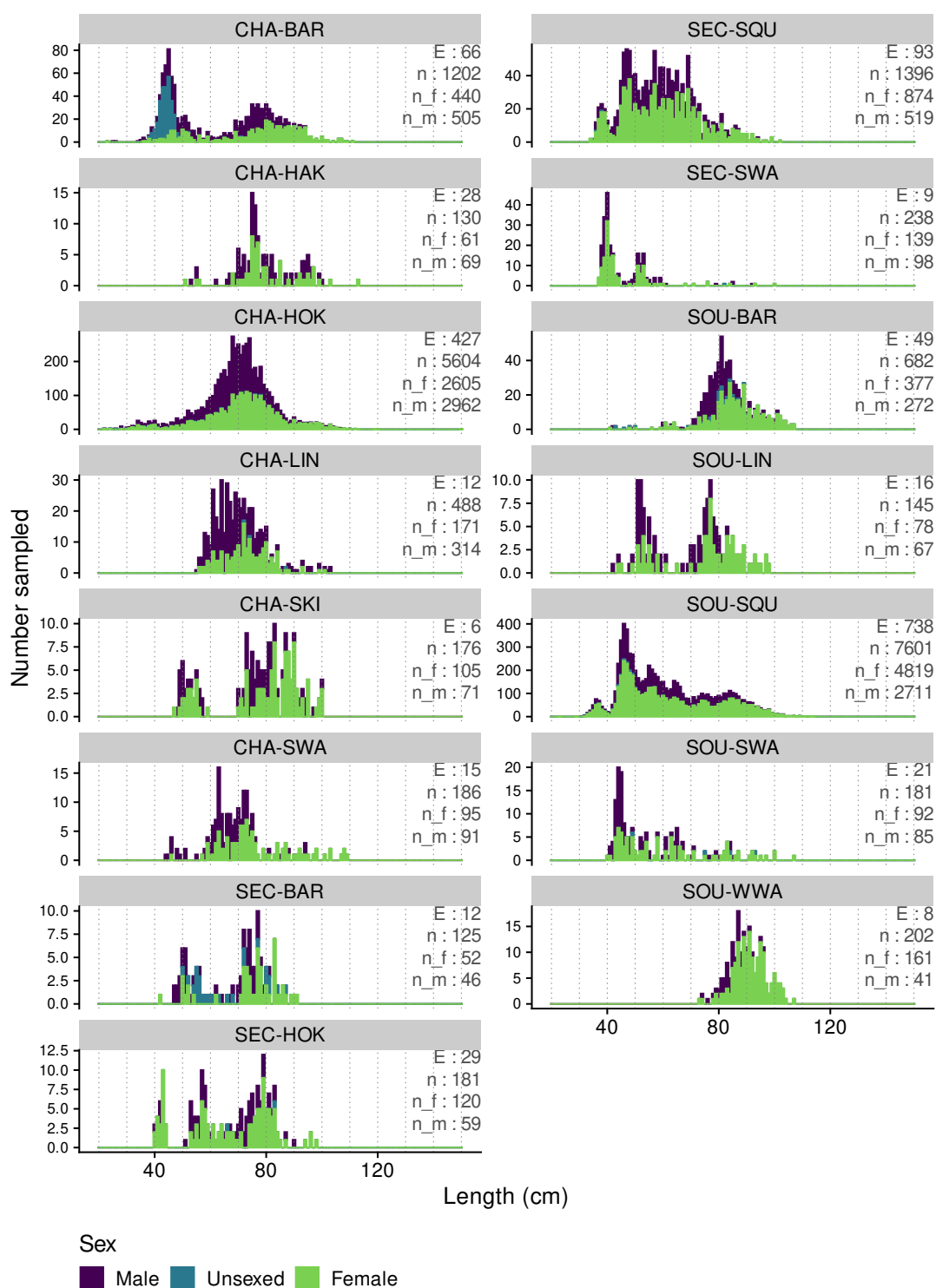


Figure C.11: Length-frequency distributions for gemfish caught in the bottom trawl fishery, by area, target species, and sex. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area-target and sex. Only area-targets at least 100 fish measurements are included. Observer area codes are defined in the glossary.

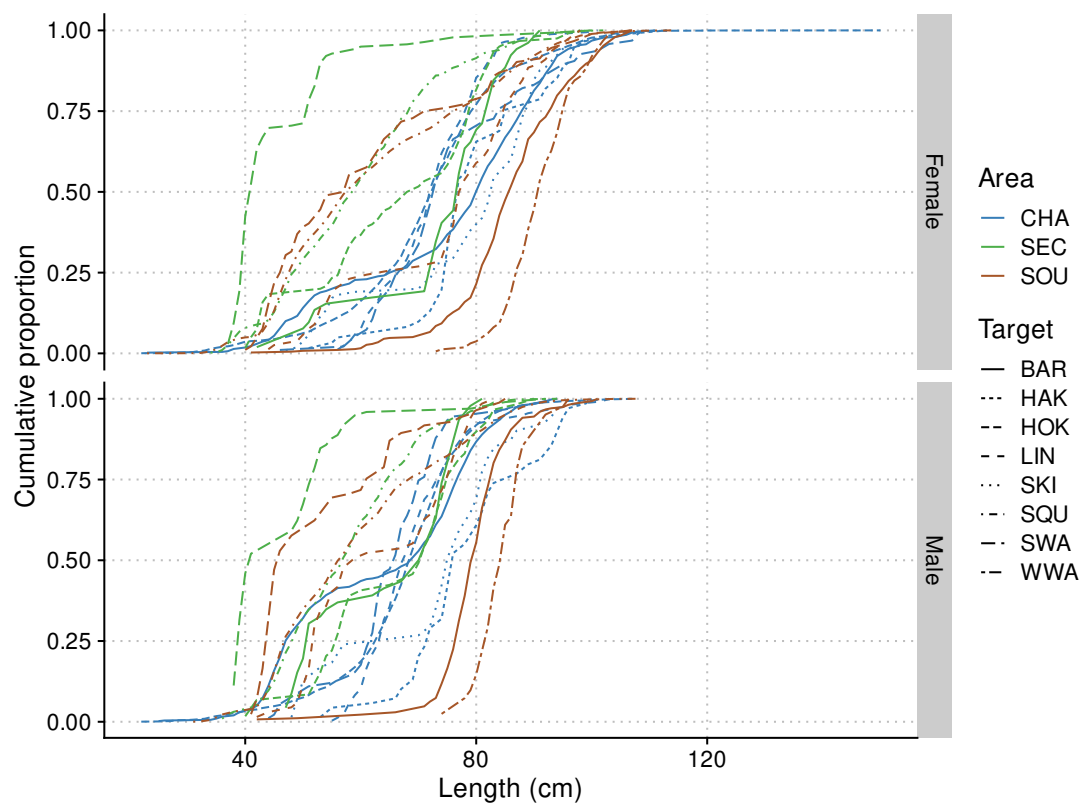


Figure C.12: Cumulative length-frequency distributions for gemfish caught in the bottom trawl fishery, by area and target species. Only area-targets at least 100 fish measurements are included. Observer area codes are defined in the glossary.

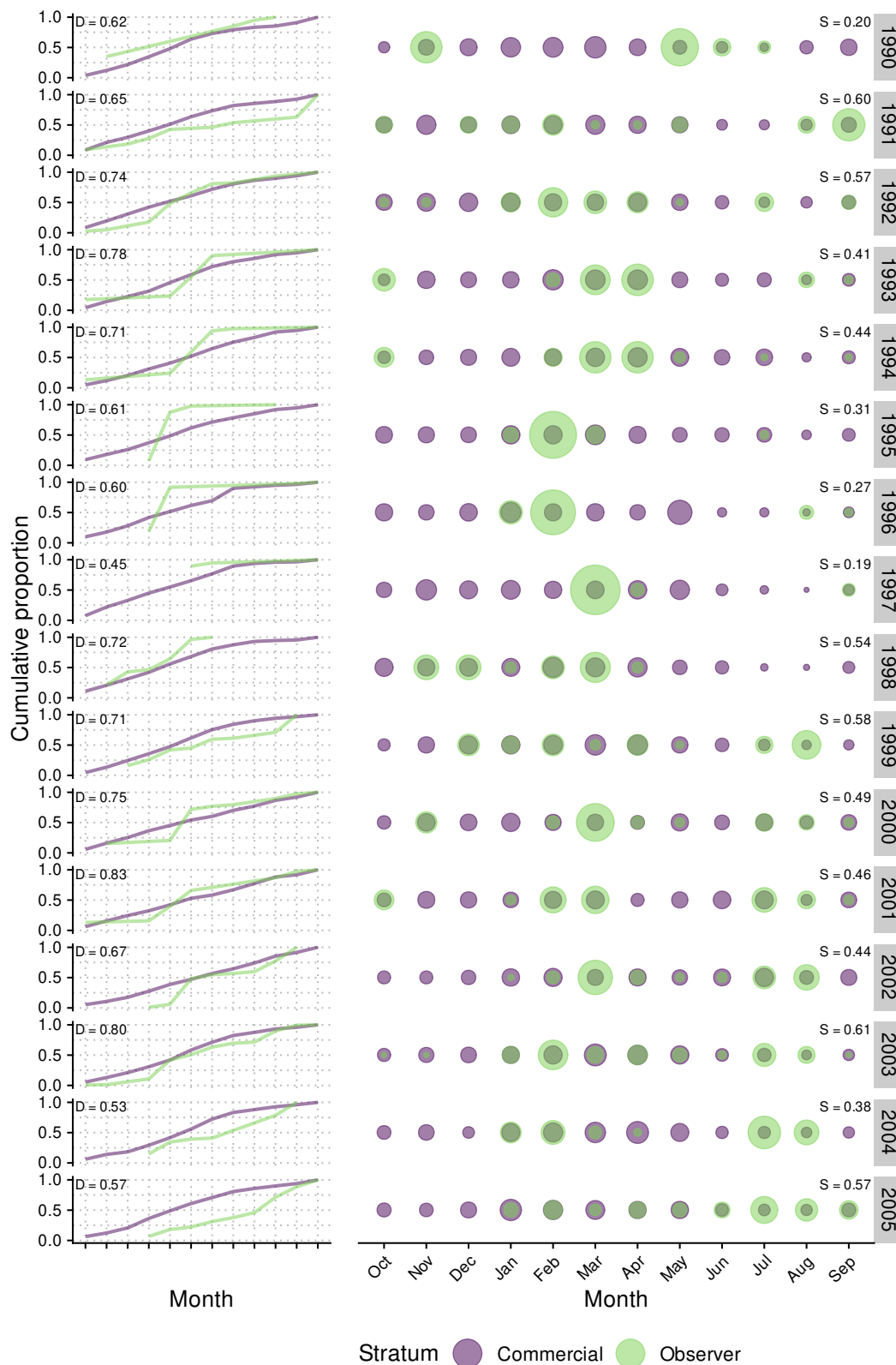


Figure C.13: Representativeness of observer sampling coverage of bottom trawl fishing events that caught gemfish in 1990 to 2005 by fishing year and month. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a month, with proportions summing to one within each fishing year. D: Kolmogorov-Smirnov maximum absolute difference; S: Manhattan block distance.

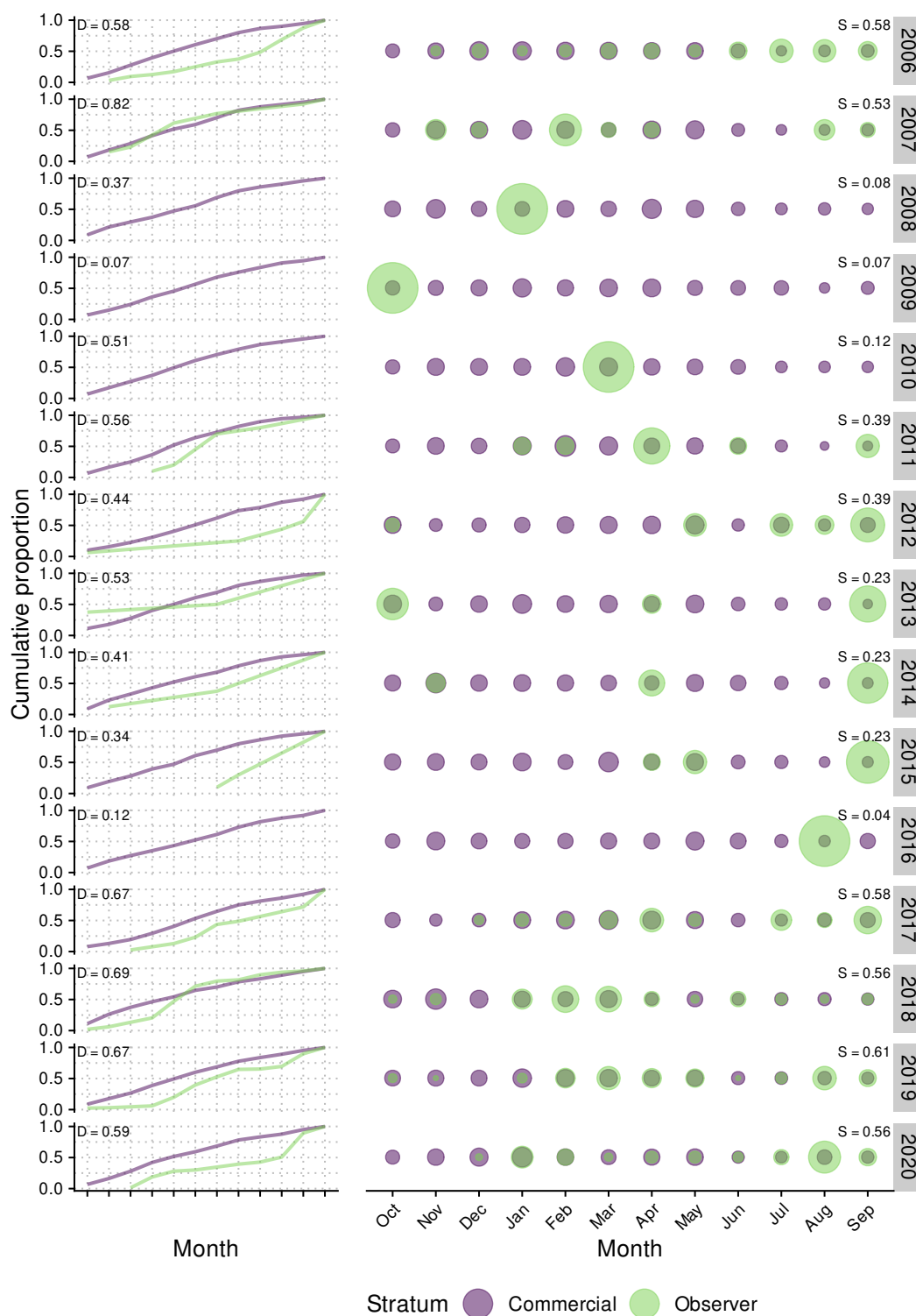


Figure C.14: Representativeness of observer sampling coverage of bottom trawl fishing events that caught gemfish in 2006 to 2020 by fishing year and month. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a month, with proportions summing to one within each fishing year. D: Kolmogorov-Smirnov maximum absolute difference; S: Manhattan block distance.

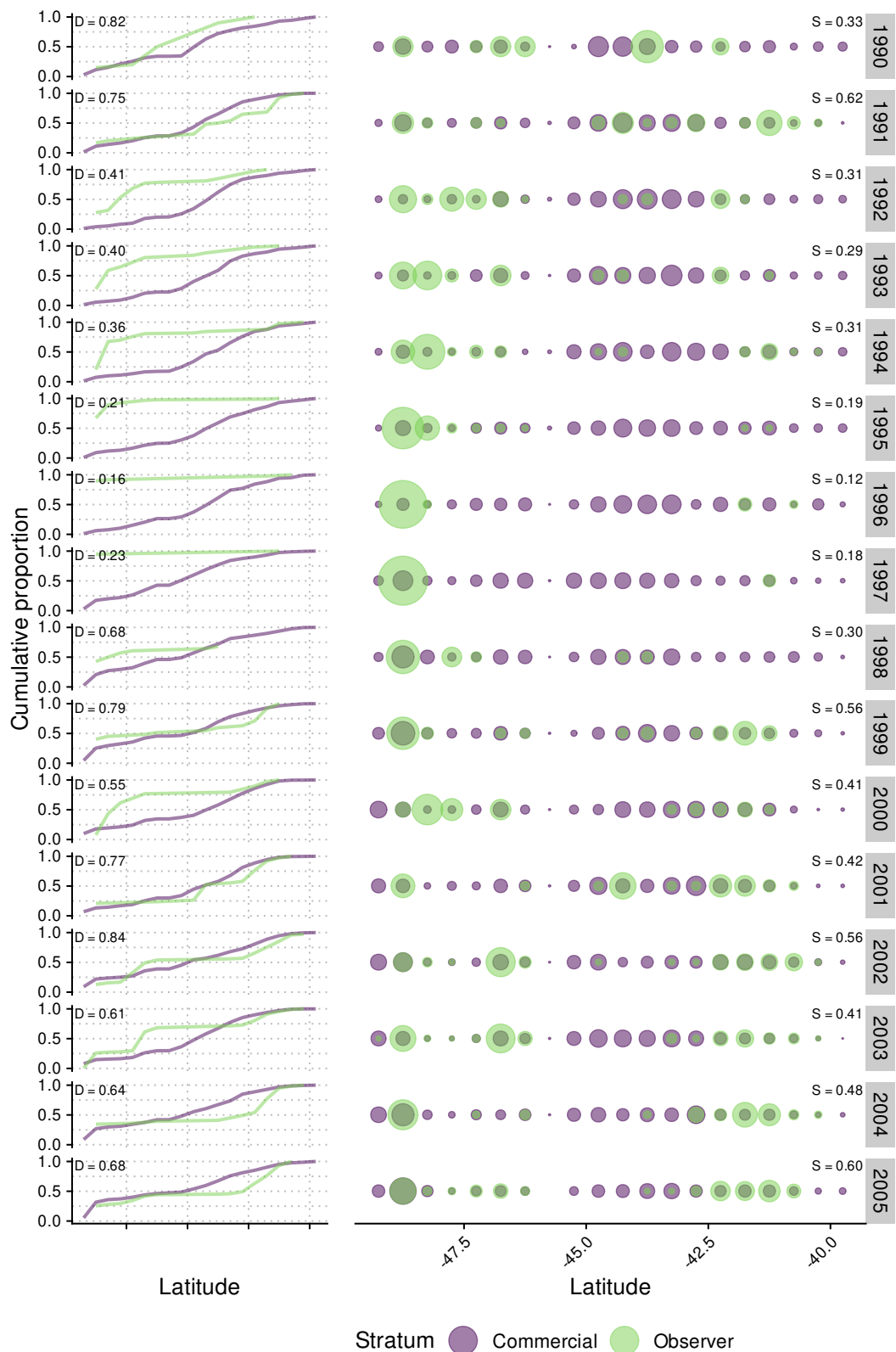


Figure C.15: Representativeness of observer sampling coverage of bottom trawl fishing events that caught gemfish in 1990 to 2005 by fishing year and latitude. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a latitude bin, with proportions summing to one within each fishing year.

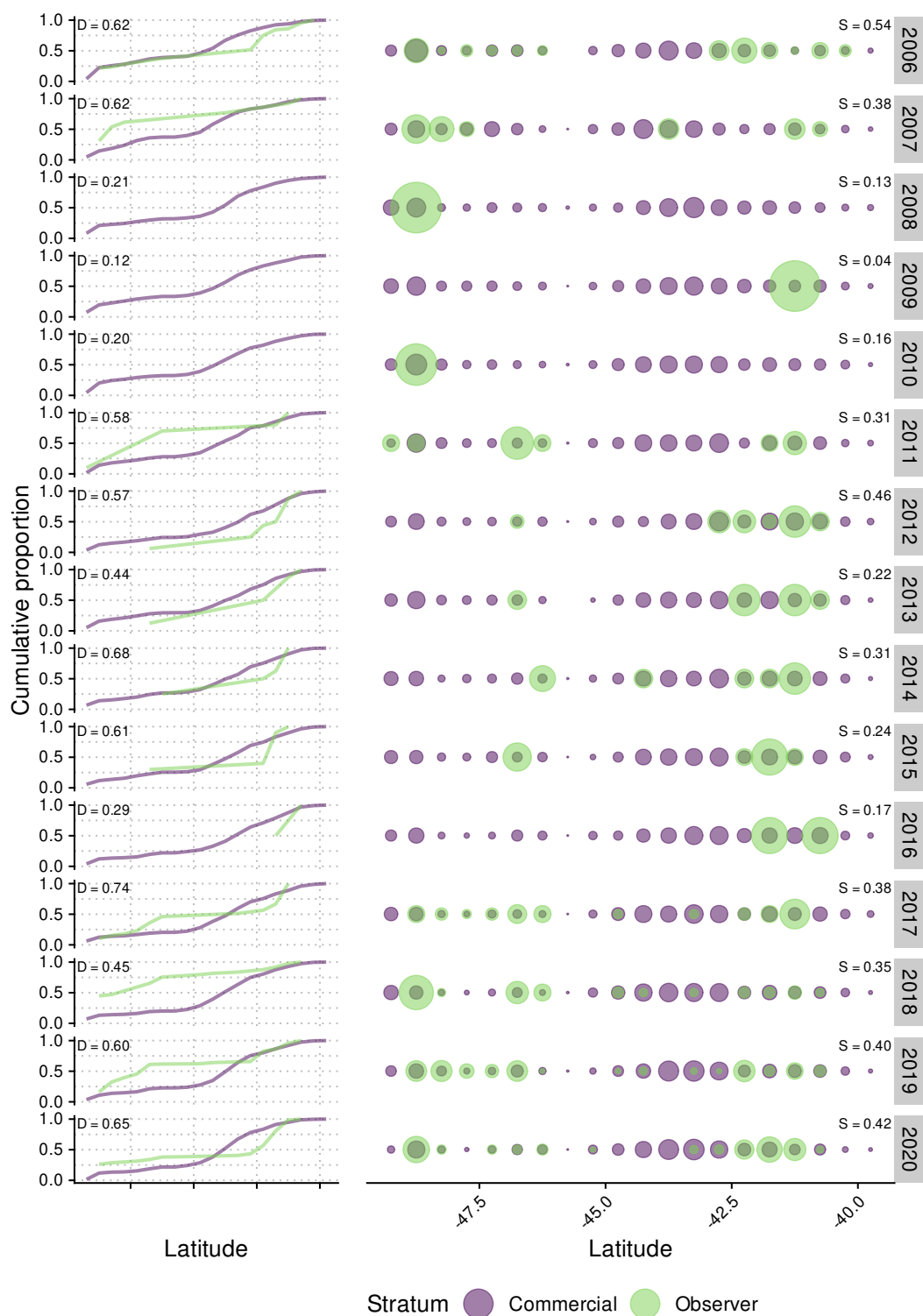


Figure C.16: Representativeness of observer sampling coverage of bottom trawl fishing events that caught gemfish in 2006 to 2020 by fishing year and latitude. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a latitude bin, with proportions summing to one within each fishing year.

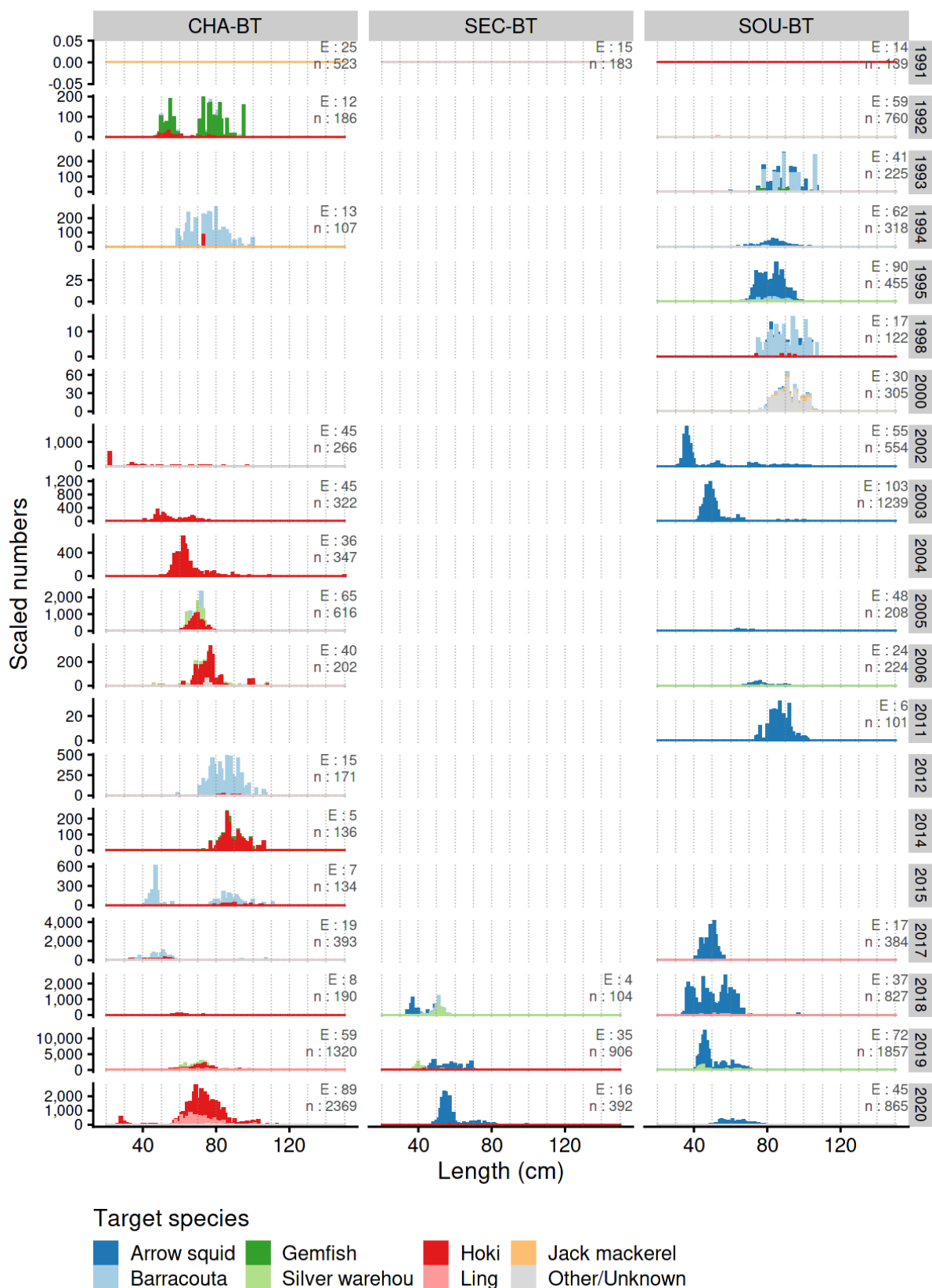


Figure C.17: Length-frequency distributions for gemfish caught in the bottom trawl fishery, by area, fishing year, and target species. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area, target and year. Sampled numbers are scaled to the catch weight in each sampled event. Observer area codes are defined in the glossary. The Other grouping includes both minor target species and events where the target species was not recorded.

APPENDIX D: ADDITIONAL CPUE SERIES

D.1 SKI7 BT+MW observer

Table D.1: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SKI7 BT+MW observer CPUE series.

Series	SKI7 BT+MW observer
QMS stock	SKI7
Reporting forms	
Fishing methods	BT, MW
Target species	HOK
Statistical Areas	034, 035
Period	1999-10-01, 2020-09-30
Resolution	Observed event
Core fleet years	5
Core fleet trips	1
Default model	obskg ~ fyear + vessel_key + stat_area + primary_method + ns(log(fishing_duration), 3) + bs(start_latitude, 3) + bs(start_seabed_depth, 3) + bs(start_hour, 3)+ bs(SeasonDay, 3)
Stepwise selection	Yes
Positive catch distribution	Lognormal

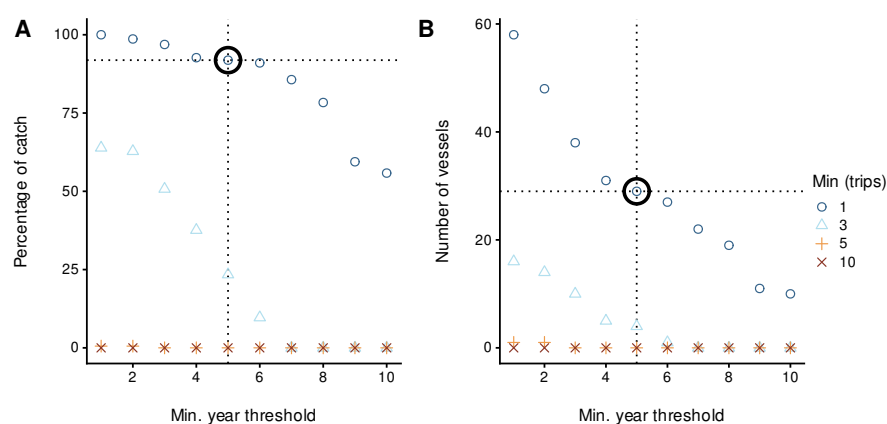


Figure D.1: Percentage of catch and number of vessels for different core vessel selection criteria for the SKI7 BT+MW observer CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel was observed in the fishery and the number of observed trips per year.



Figure D.2: Number of events by fishing year for core vessels. The area of the circles is proportional to the number of events undertaken by a vessel in a fishing year.

Table D.2: Summary of the SKI7 BT+MW observer dataset total catch (tonnes) and number of records (n), by fishing year after the application of various filters. The first row gives the catch and number of records before filters were applied (ungroomed data). Subsequent rows display the remaining catch (and percent of catch), and the number of records, after the specified filter was applied. (Continued on next page)

Filter	2000	2001	2002	2003	2004	2005	2006	2007	2008
Ungroomed data	12 (100%) n: 1151	3.2 (100%) n: 1072	9.3 (100%) n: 1285	23 (100%) n: 864	88 (100%) n: 1276	48 (100%) n: 962	24 (100%) n: 744	2.6 (100%) n: 511	1.2 (100%) n: 457
Fishing duration is not NA	12 (100%) n: 1151	3.2 (100%) n: 1072	9.3 (100%) n: 1285	23 (100%) n: 864	88 (100%) n: 1276	48 (100%) n: 962	24 (100%) n: 744	2.6 (100%) n: 511	1.2 (100%) n: 457
Positive fishing duration	12 (100%) n: 1138	3.2 (100%) n: 1072	9.3 (100%) n: 1283	23 (100%) n: 864	88 (100%) n: 1273	48 (100%) n: 962	24 (100%) n: 743	2.6 (100%) n: 509	1.2 (100%) n: 454
Bottom depth >=250	12 (100%) n: 1136	3.2 (100%) n: 1062	9.2 (100%) n: 1279	23 (100%) n: 862	86 (100%) n: 1255	48 (100%) n: 961	24 (100%) n: 742	2.6 (100%) n: 508	1.2 (100%) n: 437
Bottom depth <=600	12 (100%) n: 1013	3.1 (100%) n: 1001	8.4 (91%) n: 992	22 (100%) n: 782	85 (100%) n: 1180	47 (100%) n: 930	24 (100%) n: 651	2.6 (100%) n: 482	1.2 (100%) n: 426
Season start day >215	12 (100%) n: 1013	3.1 (100%) n: 1001	8.4 (91%) n: 992	22 (100%) n: 782	85 (100%) n: 1180	47 (100%) n: 930	24 (100%) n: 651	2.6 (100%) n: 482	1.2 (100%) n: 426
Midwater effort depth <=10 m from bottom	10 (84%) n: 634	2.8 (88%) n: 663	7.5 (81%) n: 769	19 (83%) n: 558	73 (83%) n: 891	47 (100%) n: 786	22 (94%) n: 480	2.4 (90%) n: 361	1.1 (89%) n: 270
Core fleet selection	8 (65%) n: 347	2.3 (70%) n: 541	6.5 (70%) n: 685	7.8 (34%) n: 177	56 (63%) n: 741	42 (89%) n: 778	22 (91%) n: 478	2.1 (82%) n: 326	0.93 (77%) n: 254

Filter	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ungroomed data	8.5 (100%) n: 493	3.9 (100%) n: 619	27 (100%) n: 583	6.3 (100%) n: 978	35 (100%) n: 1827	104 (100%) n: 1817	53 (100%) n: 2011	51 (100%) n: 1852	102 (100%) n: 1571
Fishing duration is not NA	8.5 (100%) n: 493	3.9 (100%) n: 619	27 (100%) n: 583	6.3 (100%) n: 978	35 (100%) n: 1827	104 (100%) n: 1817	53 (100%) n: 2011	51 (100%) n: 1852	102 (100%) n: 1571
Positive fishing duration	8.5 (100%) n: 493	3.9 (100%) n: 619	27 (100%) n: 583	6.3 (100%) n: 976	35 (100%) n: 1825	104 (100%) n: 1816	53 (100%) n: 2009	50 (100%) n: 1848	102 (100%) n: 1571
Bottom depth >=250	8.4 (100%) n: 480	3 (75%) n: 425	26 (100%) n: 506	6.2 (100%) n: 934	35 (100%) n: 1677	76 (74%) n: 1616	51 (100%) n: 1810	50 (100%) n: 1798	98 (100%) n: 1418
Bottom depth <=600	8.3 (100%) n: 466	3 (75%) n: 420	26 (100%) n: 473	6.2 (100%) n: 903	33 (93%) n: 1559	76 (73%) n: 1476	50 (95%) n: 1731	49 (100%) n: 1744	97 (100%) n: 1327
Season start day >215	8.3 (100%) n: 466	2.9 (73%) n: 417	26 (100%) n: 473	6.2 (100%) n: 903	33 (93%) n: 1559	76 (73%) n: 1476	50 (95%) n: 1731	49 (100%) n: 1740	97 (100%) n: 1326
Midwater effort depth <=10 m from bottom	5.8 (69%) n: 207	2.6 (65%) n: 269	22 (81%) n: 285	3.6 (57%) n: 614	25 (71%) n: 949	43 (42%) n: 927	34 (65%) n: 1113	33 (65%) n: 1195	80 (79%) n: 922
Core fleet selection	5.8 (69%) n: 201	2.6 (65%) n: 263	20 (75%) n: 265	2.5 (39%) n: 571	25 (71%) n: 949	43 (42%) n: 923	34 (65%) n: 1111	33 (65%) n: 1195	69 (68%) n: 806
Filter	2018	2019	2020						
Ungroomed data	127 (100%) n: 2203	277 (100%) n: 1655	371 (100%) n: 1741						
Fishing duration is not NA	127 (100%) n: 2203	277 (100%) n: 1655	371 (100%) n: 1741						
Positive fishing duration	127 (100%) n: 2201	277 (100%) n: 1651	371 (100%) n: 1739						
Bottom depth >=250	126 (100%) n: 2176	268 (100%) n: 1593	367 (100%) n: 1708						
Bottom depth <=600	122 (100%) n: 1898	257 (93%) n: 1489	357 (100%) n: 1612						
Season start day >215	122 (100%) n: 1896	257 (93%) n: 1489	357 (100%) n: 1612						
Midwater effort depth <=10 m from bottom	113 (90%) n: 1495	215 (78%) n: 866	305 (82%) n: 1090						
Core fleet selection	109 (86%) n: 1297	194 (70%) n: 771	295 (80%) n: 986						

Table D.3: Summary of the SKI7 BT+MW observer dataset after core fleet selection. ‘Records’ indicates the number of rows (events) in the dataset, and ‘Records caught’ indicates the percentage of events with catches of gemfish.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
2000	8	9	347	894.70	7.98	21.04
2001	14	15	541	2 032.80	2.26	19.78
2002	11	12	685	2 622.92	6.54	31.24
2003	6	6	177	937.78	7.82	65.54
2004	10	10	741	2 971.78	55.52	66.80
2005	12	13	778	2 637.22	42.29	52.70
2006	12	14	478	1 853.98	21.57	50.63
2007	12	12	326	1 117.82	2.15	30.06
2008	10	12	254	676.40	0.93	27.17
2009	9	11	201	685.15	5.81	59.70
2010	12	13	263	737.38	2.57	27.76
2011	9	11	265	775.82	20.14	44.91
2012	13	19	571	1 671.82	2.49	18.56
2013	17	50	949	3 625.87	24.93	34.77
2014	16	41	923	3 654.12	43.42	28.82
2015	19	43	1 111	4 468.82	34.44	41.22
2016	16	34	1 195	4 298.77	32.71	57.07
2017	17	27	806	3 651.12	69.21	69.23
2018	18	33	1 297	6 416.40	108.77	76.56
2019	15	28	771	4 171.25	194.18	81.58
2020	17	30	986	3 558.85	295.48	88.64

Table D.4: Summary of stepwise selection for occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	19.00	16 202	14.60	14.60	*
+ bs(SeasonDay, 3)	3.00	15 692	17.40	2.70	*
+ bs(start_latitude, 3)	3.00	15 072	20.70	3.30	*
+ bs(start_hour, 3)	3.00	14 800	22.10	1.50	*
+ bs(start_seabed_depth, 3)	3.00	14 560	23.40	1.30	*
+ vessel_key	28.00	14 397	24.60	1.20	*
+ ns(log(fishing_duration), 3)	3.00	14 348	24.90	0.30	
+ primary_method	1.00	14 315	25.10	0.20	
+ stat_area	1.00	14 314	25.10	0.00	

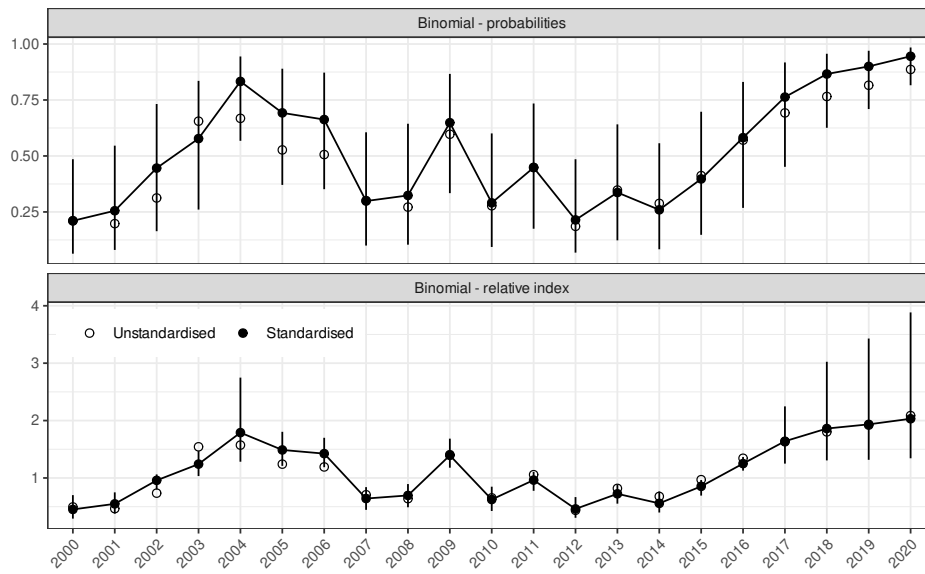


Figure D.3: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SKI7 BT+MW observer dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

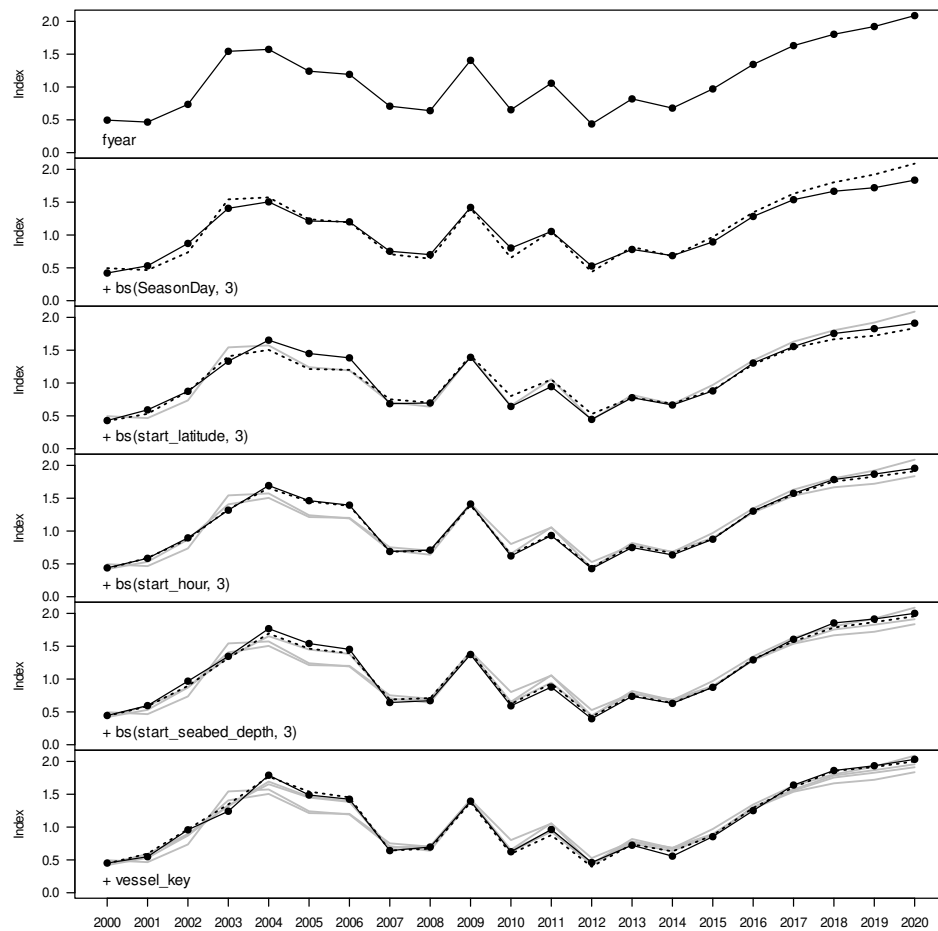


Figure D.4: Step plot for occurrence of catch in the SKI7 BT+MW observer dataset.

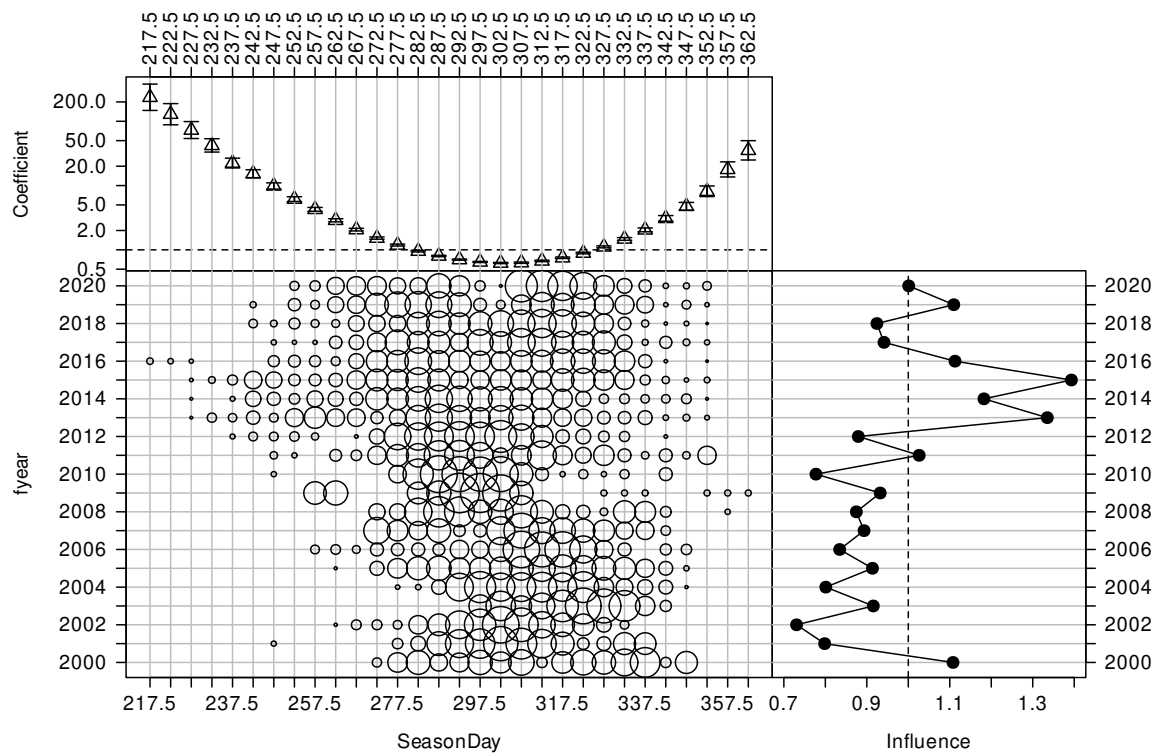


Figure D.5: CDI plot for SeasonDay for the occurrence of positive catch SKI7 BT+MW observer catch-per-unit-effort dataset.

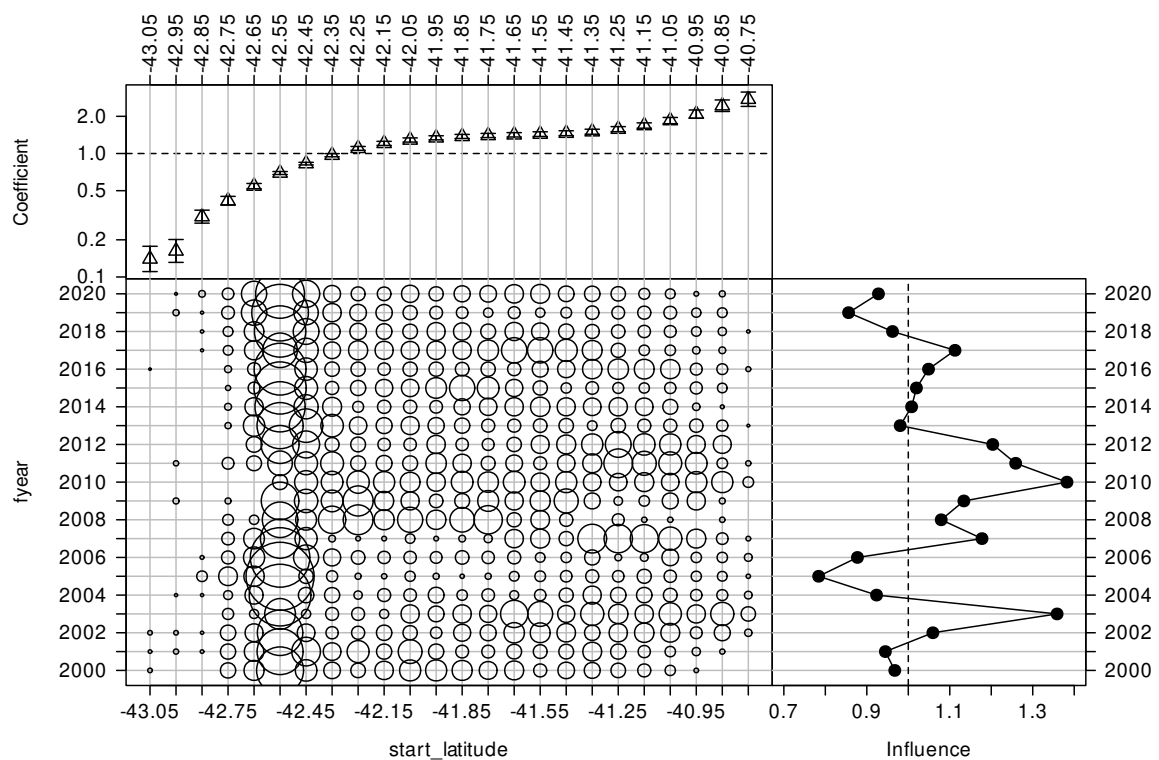


Figure D.6: CDI plot for start latitude for the occurrence of positive catch SKI7 BT+MW observer catch-per-unit-effort dataset.

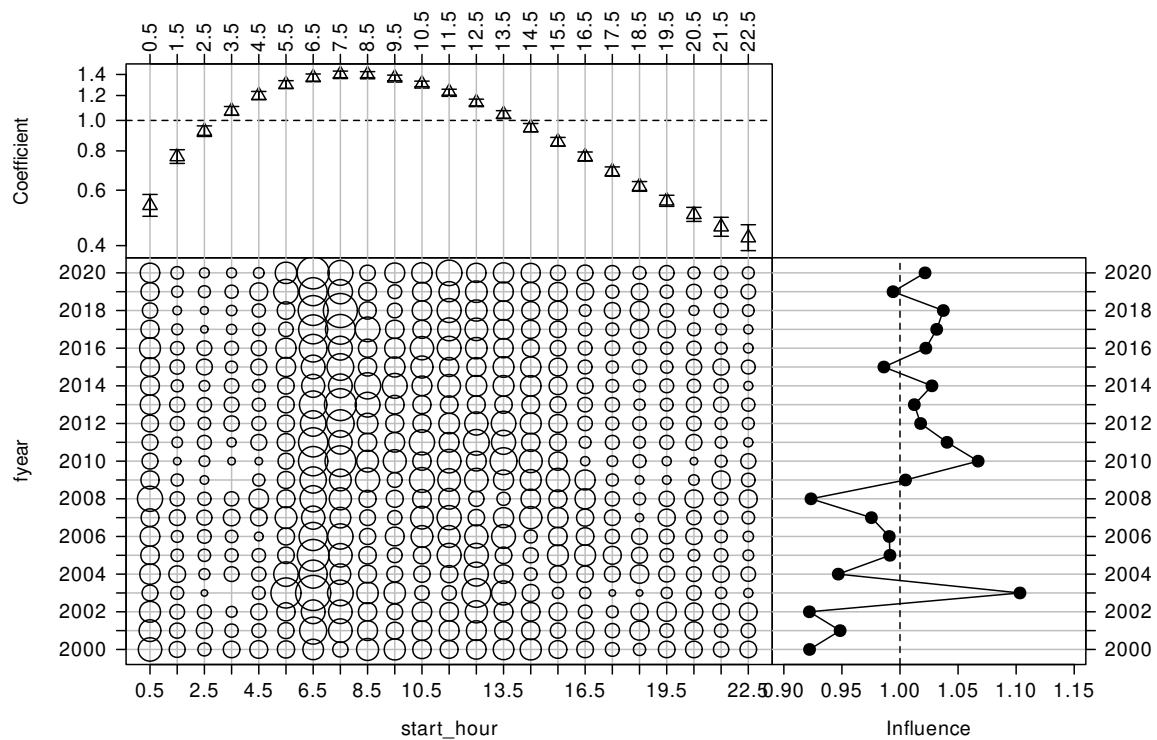


Figure D.7: CDI plot for start hour for the occurrence of positive catch SKI7 BT+MW observer catch-per-unit-effort dataset.

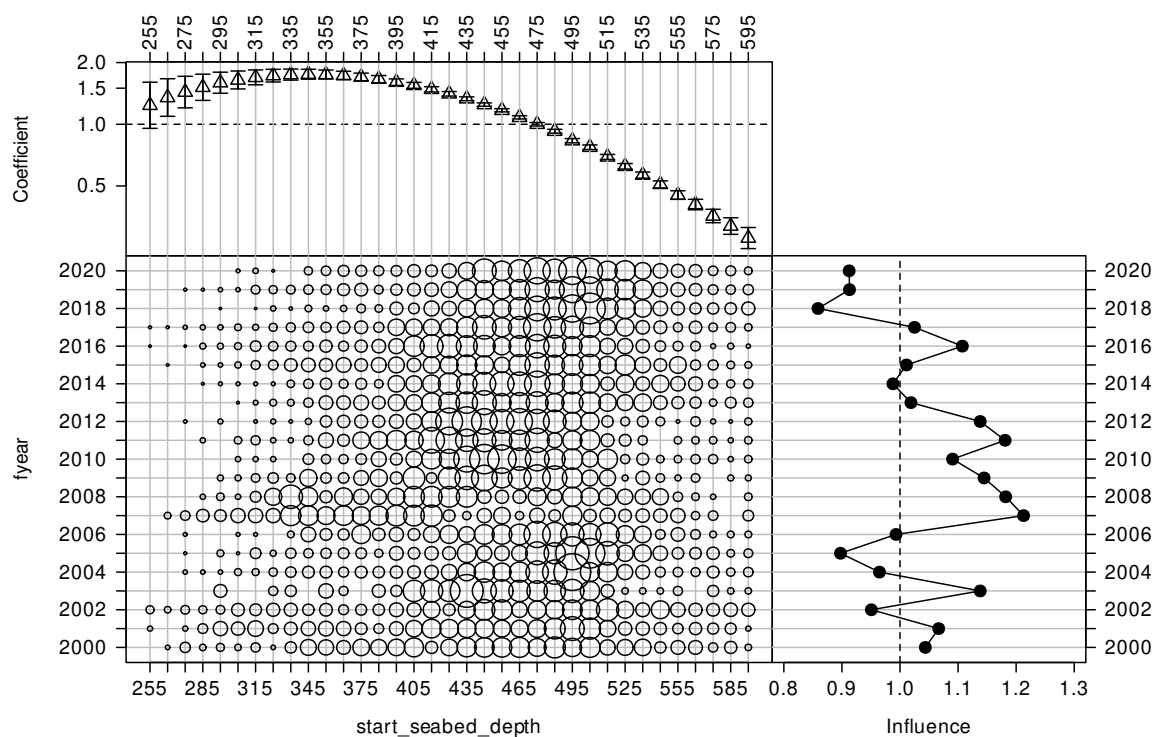


Figure D.8: CDI plot for start seabed depth (m) for the occurrence of positive catch SKI7 BT+MW observer catch-per-unit-effort dataset.

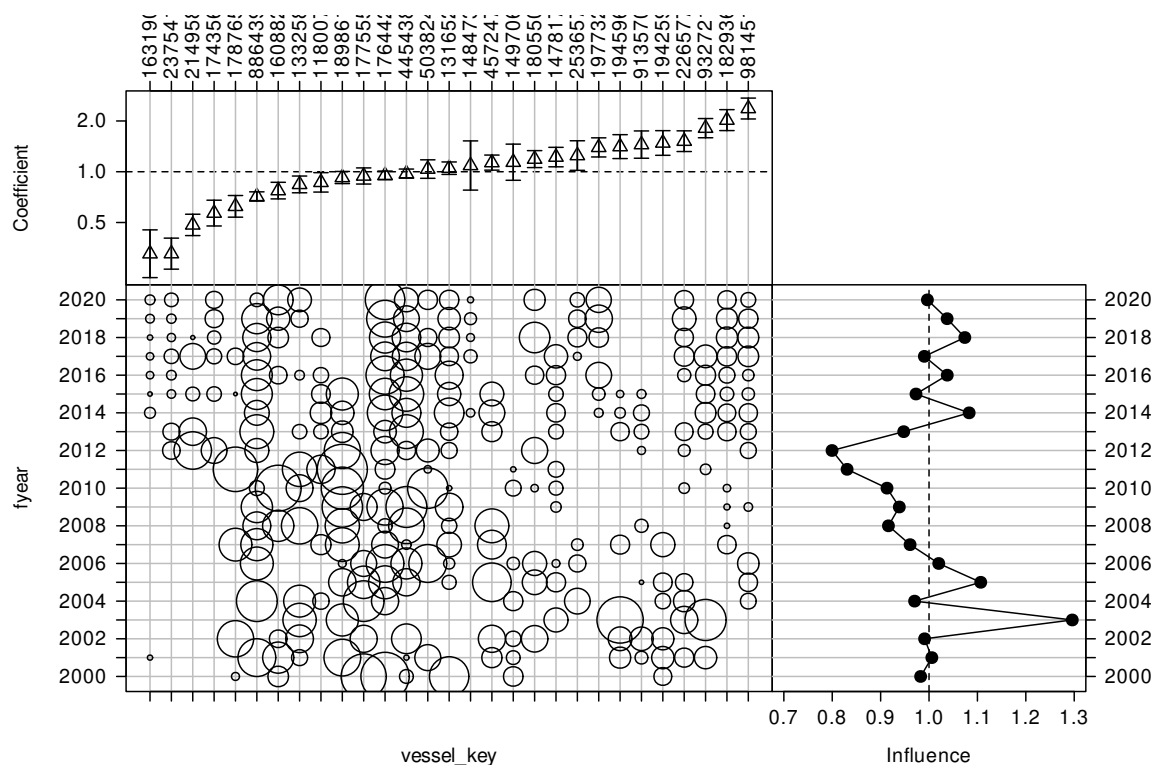


Figure D.9: CDI plot for vessel key for the occurrence of positive catch SKI7 BT+MW observer catch-per-unit-effort dataset.

Table D.5: Summary of stepwise selection for the lognormal model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	19	25 239	26.9	26.9	*
+ vessel key	28	23 577	42.7	15.8	*
+ bs(SeasonDay, 3)	3	22 472	51.1	8.4	*
+ bs(start seabed depth, 3)	3	22 291	52.4	1.3	*
+ bs(start hour, 3)	3	22 094	53.8	1.4	*
+ ns(log(fishing duration), 3)	3	21 972	54.6	0.8	
+ primary method	1	21 880	55.2	0.6	
+ bs(start latitude, 3)	3	21 847	55.4	0.2	

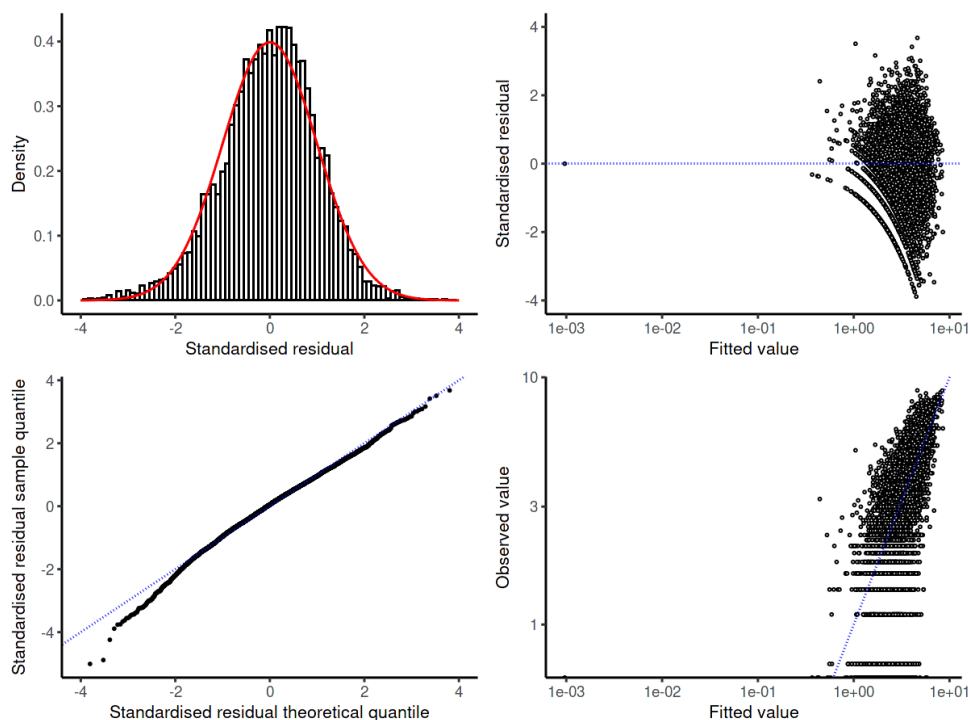


Figure D.10: Diagnostic plots for the lognormal model for the SKI7 BT+MW observer dataset.

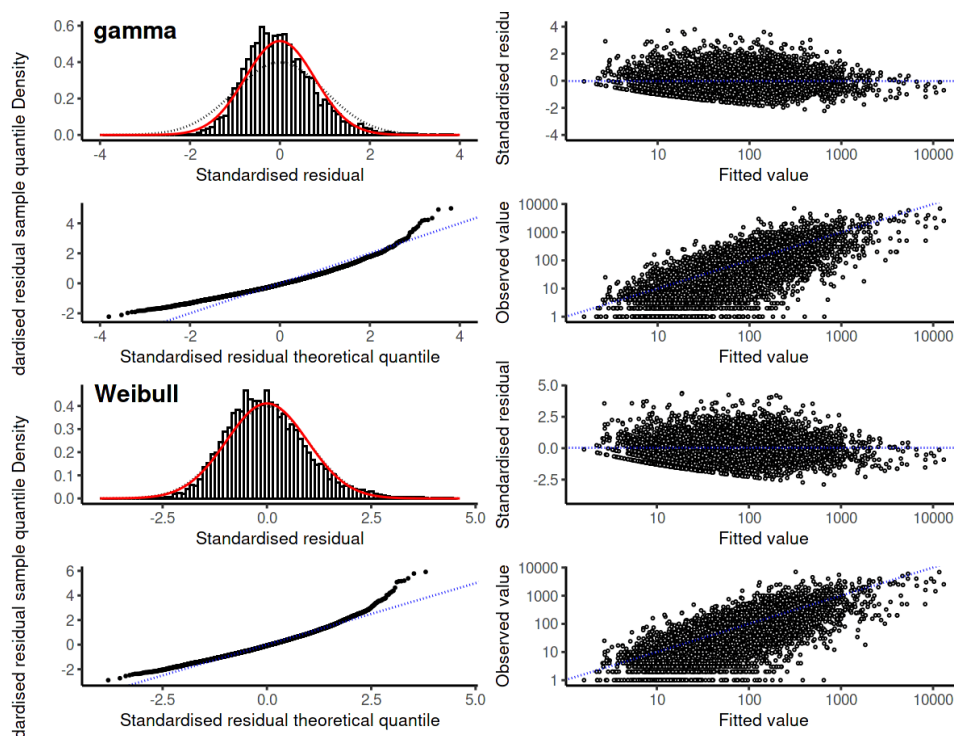


Figure D.11: Diagnostic plots for the gamma and Weibull model for the SKI7 BT+MW observer dataset.

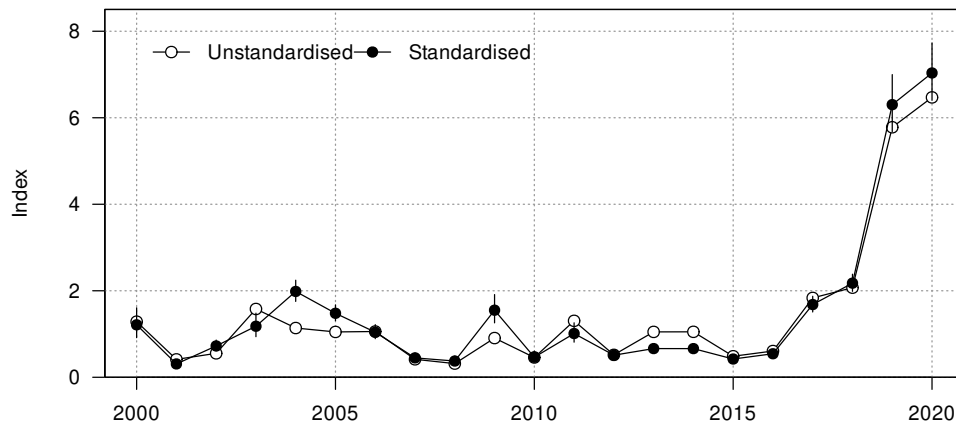


Figure D.12: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SKI7 BT+MW observer dataset.

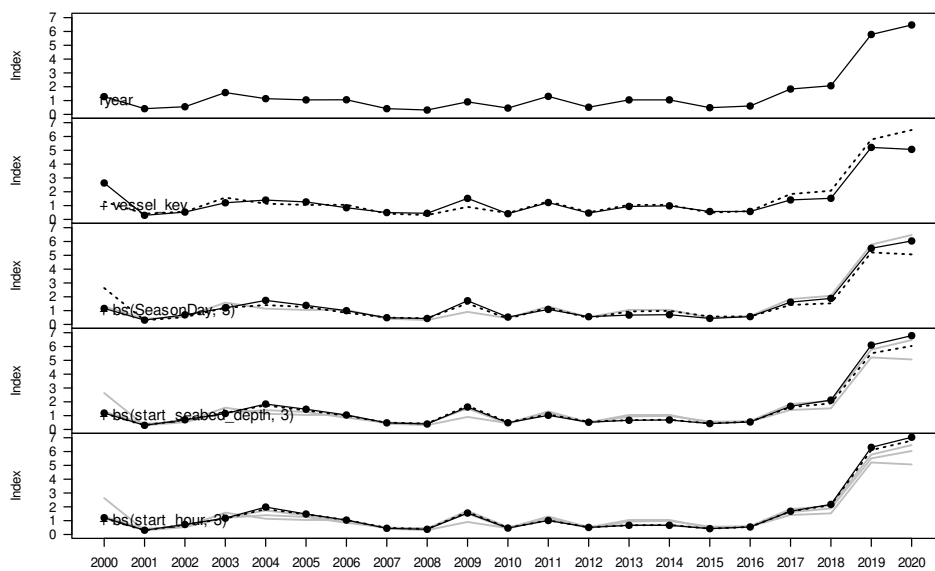


Figure D.13: Changes to the SKI7 BT+MW observer positive catch index as terms are successively entered into the model.

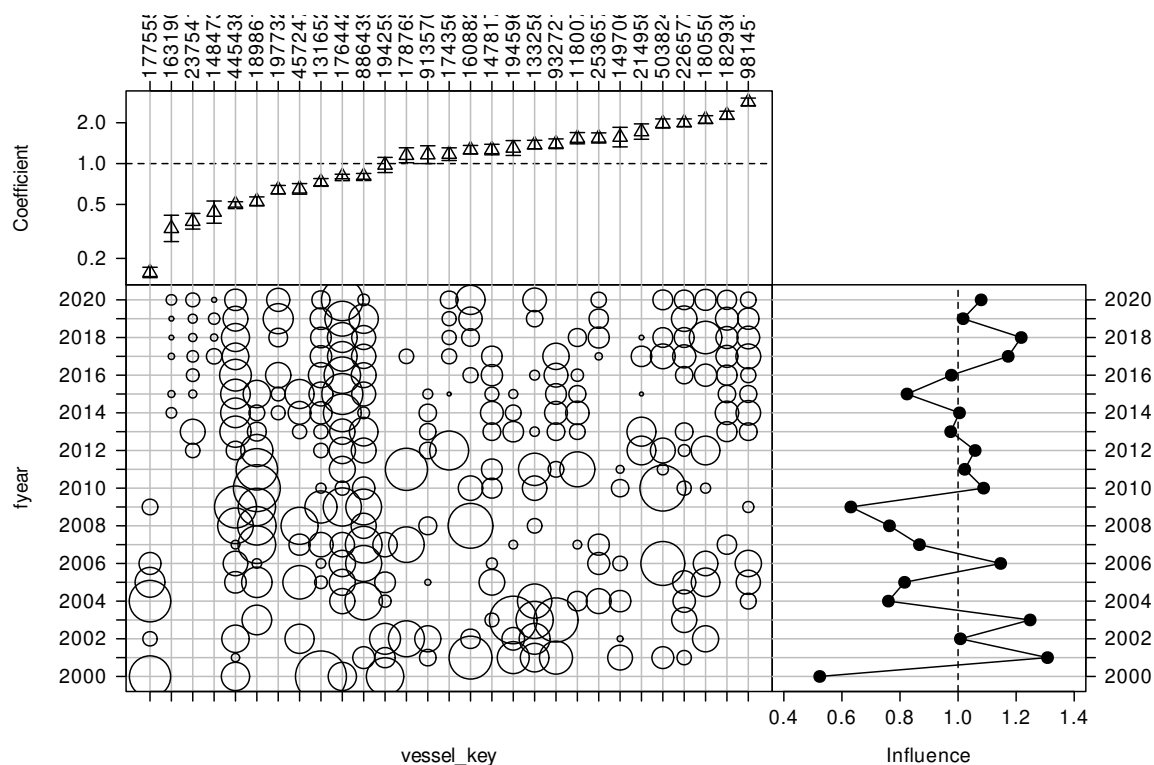


Figure D.14: CDI plot for vessel key for the positive catch SKI7 BT+MW observer catch-per-unit-effort dataset.

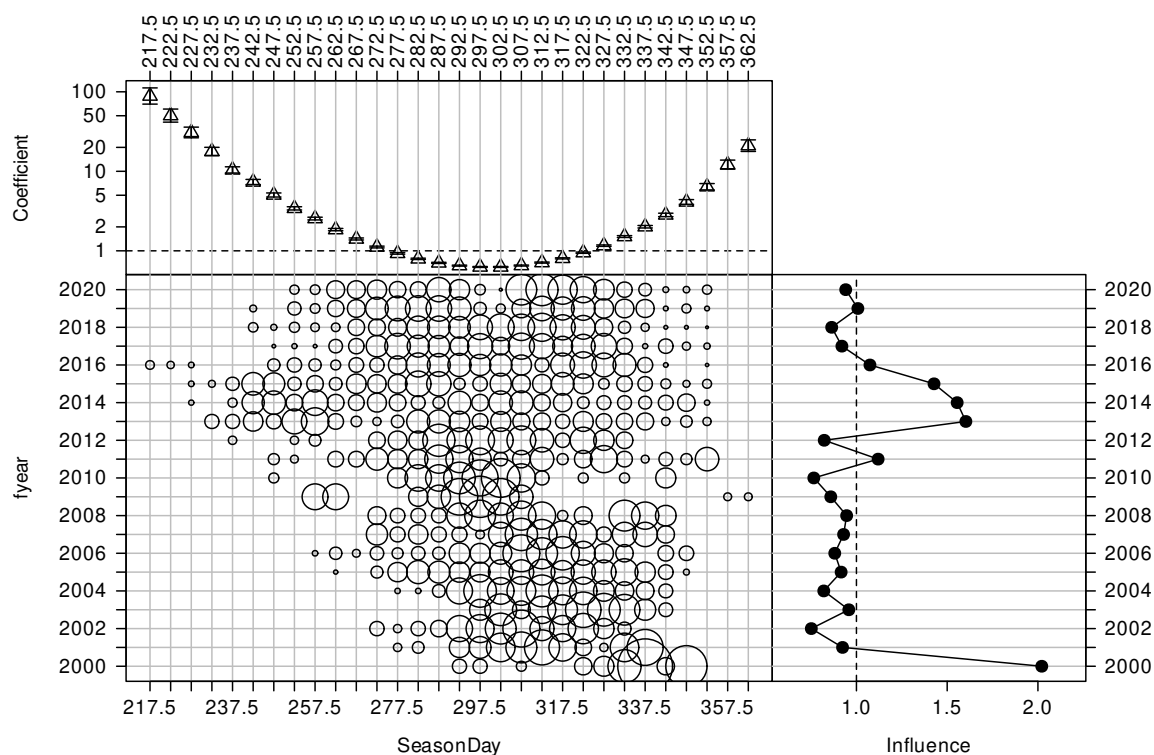


Figure D.15: CDI plot for SeasonDay for the positive catch SKI7 BT+MW observer catch-per-unit-effort dataset.

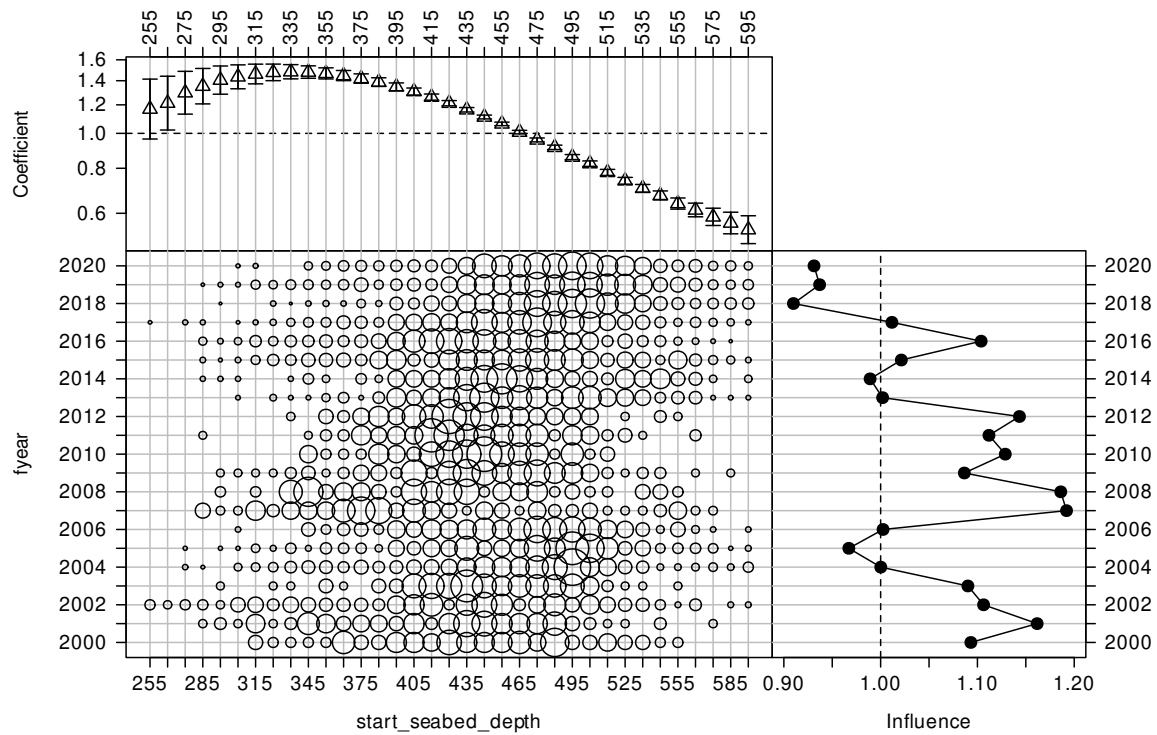


Figure D.16: CDI plot for start seabed depth (m) for the positive catch SKI7 BT+MW observer catch-per-unit-effort dataset.

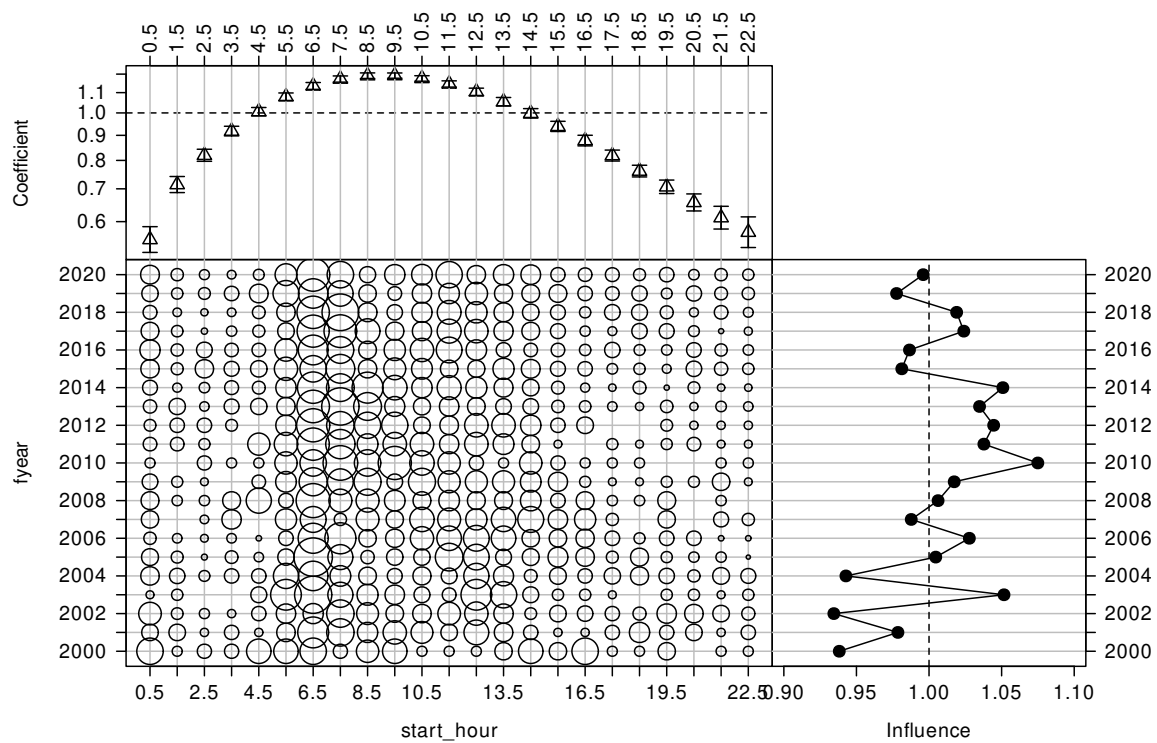


Figure D.17: CDI plot for start hour for the positive catch SKI7 BT+MW observer catch-per-unit-effort dataset.

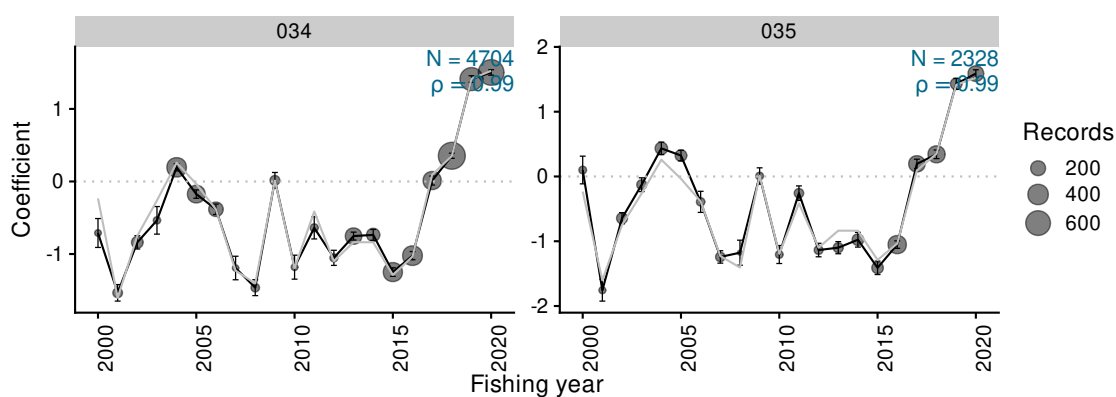


Figure D.18: Residual implied coefficients for area-year in the lognormal positive catch model for the SKI7 BT+MW observer dataset.

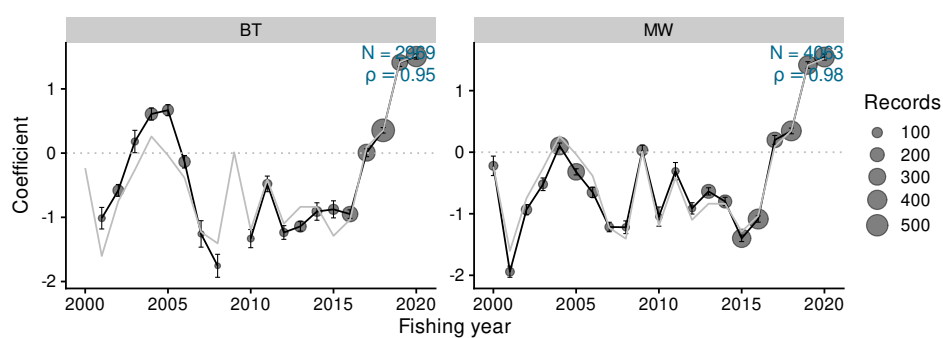


Figure D.19: Residual implied coefficients for primary method-year in the lognormal positive catch model for the SKI7 BT+MW observer dataset.

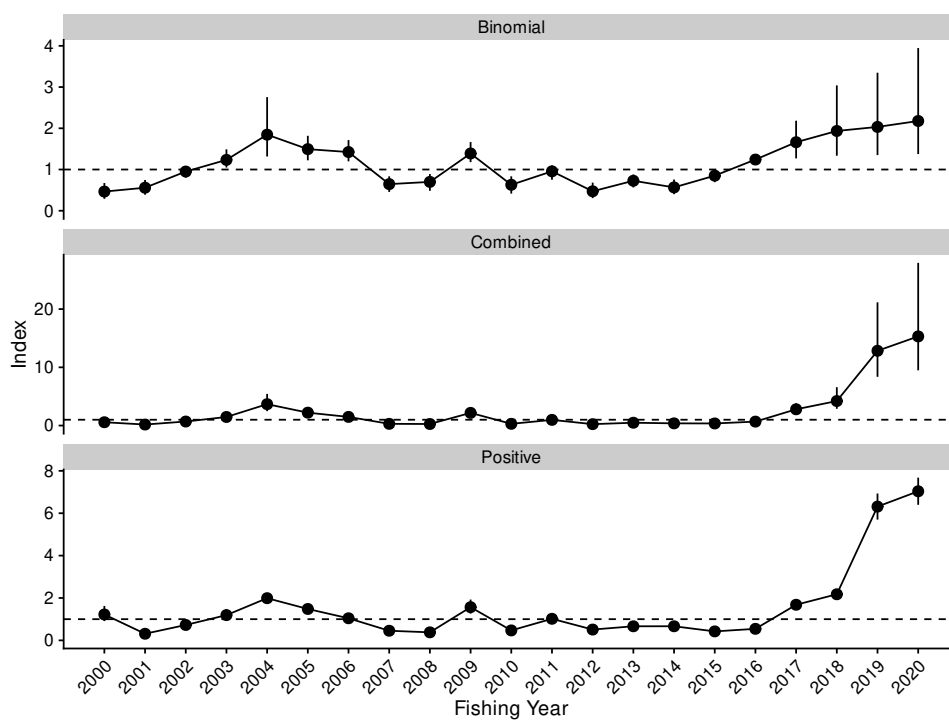


Figure D.20: Standardised indices and 95% confidence intervals for the SKI7 BT+MW observer dataset.

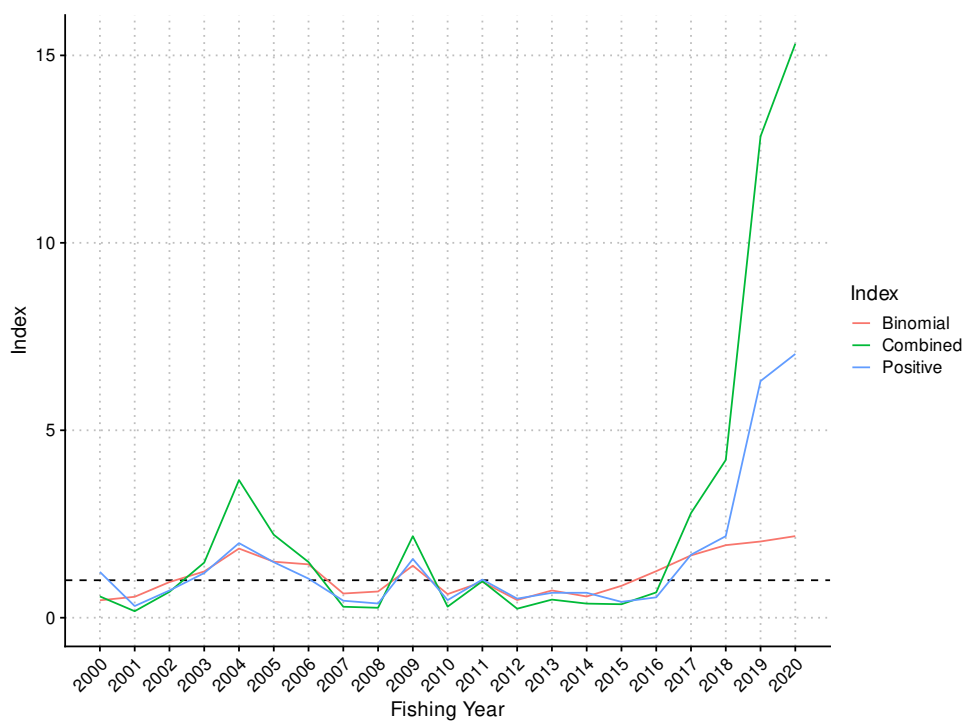


Figure D.21: Standardised indices for the SKI7 BT+MW observer dataset.

Table D.6: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SKI7 BT+MW observer.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
2000	0.465	0.098	0.289	0.673	0.568	0.150	0.319	0.909	1.222	0.182	0.912	1.624
2001	0.558	0.091	0.389	0.746	0.174	0.036	0.111	0.251	0.312	0.035	0.248	0.385
2002	0.951	0.065	0.802	1.057	0.691	0.081	0.541	0.857	0.726	0.066	0.598	0.859
2003	1.234	0.112	1.048	1.489	1.471	0.217	1.088	1.938	1.192	0.138	0.930	1.473
2004	1.845	0.368	1.315	2.756	3.671	0.757	2.469	5.435	1.990	0.120	1.771	2.242
2005	1.494	0.152	1.223	1.818	2.213	0.272	1.726	2.791	1.481	0.090	1.319	1.670
2006	1.424	0.131	1.198	1.714	1.485	0.184	1.166	1.885	1.042	0.082	0.893	1.215
2007	0.646	0.097	0.456	0.835	0.293	0.059	0.189	0.421	0.454	0.055	0.356	0.570
2008	0.699	0.104	0.484	0.890	0.265	0.057	0.172	0.396	0.379	0.053	0.284	0.493
2009	1.389	0.124	1.178	1.666	2.176	0.317	1.652	2.897	1.566	0.169	1.262	1.925
2010	0.629	0.107	0.415	0.835	0.295	0.065	0.176	0.430	0.469	0.067	0.357	0.618
2011	0.956	0.088	0.752	1.098	0.974	0.141	0.703	1.256	1.018	0.111	0.825	1.259
2012	0.472	0.096	0.306	0.681	0.240	0.056	0.145	0.366	0.509	0.058	0.408	0.635
2013	0.727	0.080	0.565	0.879	0.483	0.065	0.357	0.610	0.664	0.047	0.576	0.758
2014	0.566	0.091	0.402	0.757	0.377	0.067	0.256	0.520	0.665	0.052	0.570	0.773
2015	0.851	0.070	0.693	0.968	0.360	0.038	0.285	0.433	0.423	0.025	0.376	0.474
2016	1.241	0.060	1.135	1.371	0.675	0.044	0.592	0.765	0.544	0.027	0.492	0.598
2017	1.662	0.233	1.270	2.184	2.792	0.443	2.082	3.817	1.680	0.090	1.510	1.865
2018	1.935	0.435	1.335	3.040	4.207	0.946	2.875	6.585	2.176	0.102	1.984	2.383
2019	2.033	0.510	1.350	3.348	12.840	3.263	8.370	21.161	6.313	0.314	5.699	6.929
2020	2.177	0.656	1.374	3.947	15.309	4.708	9.486	27.940	7.036	0.327	6.397	7.678

D.2 SKI7 BT+MW HOK daily rollup

Table D.7: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SKI7 BT+MW HOK daily rollup CPUE series.

Series	SKI7 BT+MW HOK daily rollup
QMS stock	SKI7
Reporting forms	TCE, TCP, ERS - Trawl, CEL
Fishing methods	BT, MW
Target species	HOK
Statistical Areas	034, 035
Period	1989-10-01, 2020-09-30
Resolution	Day
Core fleet years	4
Core fleet trips	1
Default model	$\text{allockg} \sim \text{fyear} + \text{vessel_key} + \text{stat_area} + \text{primary_method} + \text{ns}(\log(\text{fishing_duration}), 3) + \text{bs}(\text{SeasonDay}, 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

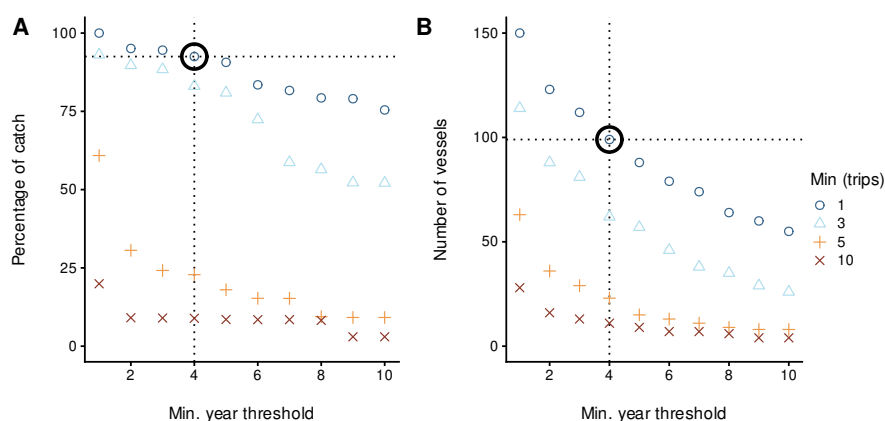


Figure D.22: Percentage of catch and number of vessels for different core vessel selection criteria for the SKI7 BT+MW HOK daily rollup CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

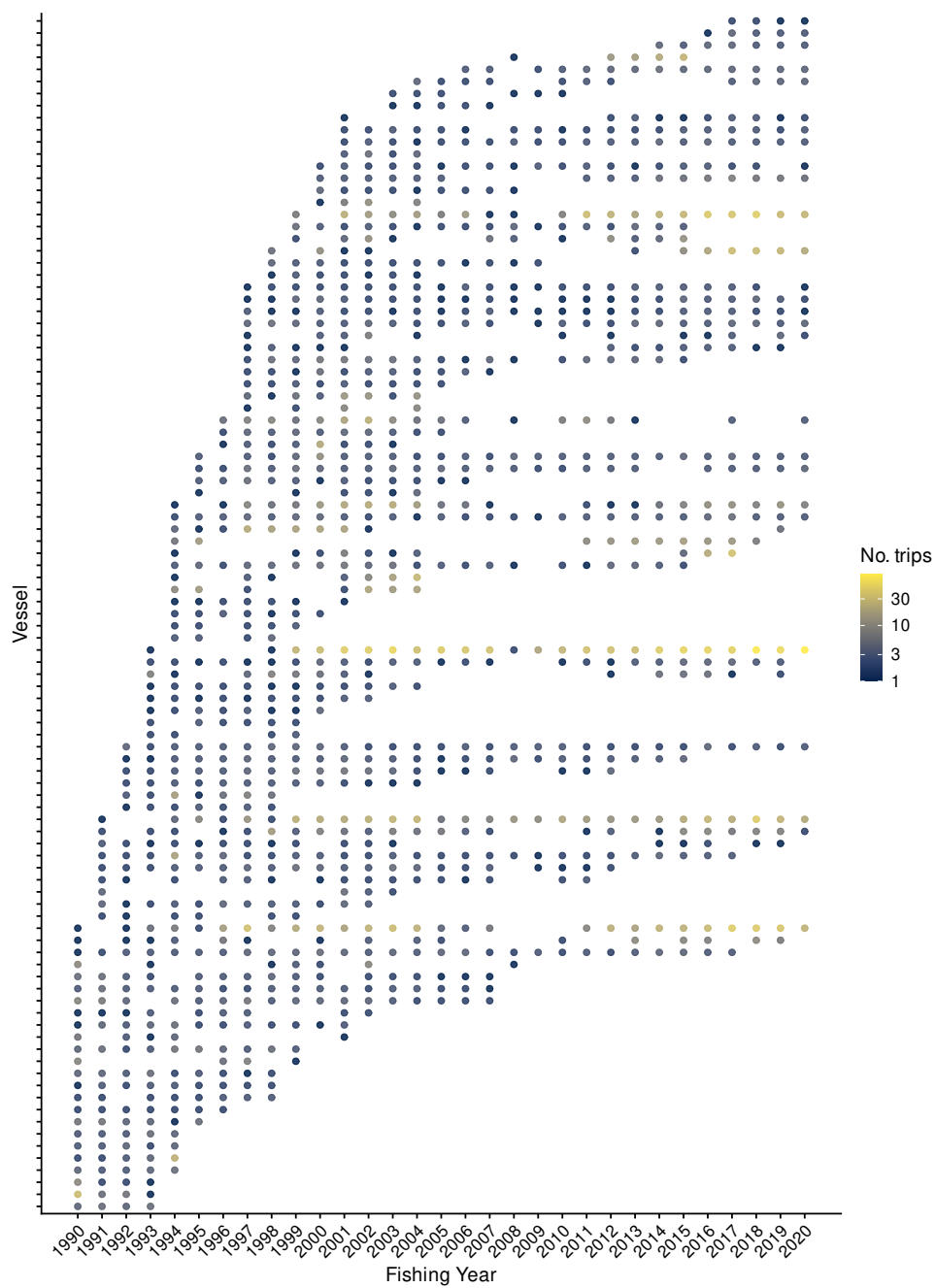


Figure D.23: Number of trips by fishing year for core vessels. The colour of the points is proportional to the number of trips undertaken by a vessel in a fishing year.

Table D.8: Summary of the SKI7 BT+MW HOK daily rollup dataset total catch (tonnes) and number of records (n), by fishing year after the application of various filters. The first row gives the catch and number of records before filters were applied (ungroomed data). Subsequent rows display the remaining catch (and percent of catch), and the number of records, after the specified filter was applied. (Continued on next page)

Filter	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ungroomed data	204 (100%) n: 2820	108 (100%) n: 2887	61 (100%) n: 2151	136 (100%) n: 2028	76 (100%) n: 2754	13 (100%) n: 2707	6.8 (100%) n: 2298	34 (100%) n: 2946	11 (100%) n: 2886
Fishing duration is not NA	204 (100%) n: 2820	108 (100%) n: 2887	61 (100%) n: 2151	136 (100%) n: 2028	76 (100%) n: 2754	13 (100%) n: 2707	6.8 (100%) n: 2298	34 (100%) n: 2944	11 (100%) n: 2885
Positive fishing duration	204 (100%) n: 2819	108 (100%) n: 2887	61 (100%) n: 2151	136 (100%) n: 2028	76 (100%) n: 2754	13 (100%) n: 2707	6.8 (100%) n: 2298	34 (100%) n: 2944	11 (100%) n: 2885
Season start day >215	203 (100%) n: 2813	108 (100%) n: 2886	61 (100%) n: 2146	136 (100%) n: 2025	76 (100%) n: 2747	13 (100%) n: 2698	5.2 (77%) n: 2271	33 (100%) n: 2936	7.3 (67%) n: 2863
Core fleet selection	72 (35%) n: 937	73 (68%) n: 1107	47 (77%) n: 956	131 (100%) n: 1213	64 (84%) n: 1828	5.1 (41%) n: 1731	5.1 (75%) n: 1655	30 (90%) n: 2270	7.3 (67%) n: 2461
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	5.4 (100%) n: 2305	46 (100%) n: 2261	19 (100%) n: 2456	52 (100%) n: 2174	94 (100%) n: 2184	259 (100%) n: 2007	187 (100%) n: 1206	68 (100%) n: 974	34 (100%) n: 653
Fishing duration is not NA	5.4 (100%) n: 2302	46 (100%) n: 2261	19 (100%) n: 2456	52 (100%) n: 2174	94 (100%) n: 2184	259 (100%) n: 2007	187 (100%) n: 1206	68 (100%) n: 974	34 (100%) n: 653
Positive fishing duration	5.4 (100%) n: 2301	46 (100%) n: 2261	19 (100%) n: 2456	52 (100%) n: 2174	94 (100%) n: 2184	259 (100%) n: 2007	187 (100%) n: 1206	68 (100%) n: 974	34 (100%) n: 653
Season start day >215	3.6 (66%) n: 2268	46 (100%) n: 2247	18 (95%) n: 2433	52 (100%) n: 2168	94 (100%) n: 2174	259 (100%) n: 2006	187 (100%) n: 1192	68 (100%) n: 970	34 (100%) n: 653
Core fleet selection	3.6 (66%) n: 2036	46 (100%) n: 2142	18 (94%) n: 2333	52 (100%) n: 2121	94 (100%) n: 2143	258 (100%) n: 1921	187 (100%) n: 1192	68 (100%) n: 949	34 (100%) n: 653

Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	9.5 (100%) n: 416	6.2 (100%) n: 346	17 (100%) n: 623	44 (100%) n: 894	16 (100%) n: 916	44 (100%) n: 886	119 (100%) n: 1119	56 (100%) n: 1258	47 (100%) n: 1324
Fishing duration is not NA	9.5 (100%) n: 416	6.2 (100%) n: 346	17 (100%) n: 623	44 (100%) n: 894	16 (100%) n: 916	44 (100%) n: 886	119 (100%) n: 1119	56 (100%) n: 1258	47 (100%) n: 1324
Positive fishing duration	9.5 (100%) n: 416	6.2 (100%) n: 346	17 (100%) n: 623	44 (100%) n: 894	16 (100%) n: 916	44 (100%) n: 886	119 (100%) n: 1119	56 (100%) n: 1258	47 (100%) n: 1324
Season start day >215	9.5 (100%) n: 416	5.9 (95%) n: 345	16 (94%) n: 619	44 (100%) n: 894	16 (100%) n: 916	44 (100%) n: 886	119 (100%) n: 1119	56 (100%) n: 1255	47 (100%) n: 1322
Core fleet selection	9.5 (100%) n: 416	5.9 (95%) n: 345	16 (94%) n: 618	44 (100%) n: 894	16 (100%) n: 916	44 (100%) n: 886	119 (100%) n: 1113	56 (100%) n: 1251	47 (100%) n: 1320

Filter	2017	2018	2019	2020
Ungroomed data	146 (100%) n: 1437	206 (100%) n: 1561	524 (100%) n: 1308	436 (100%) n: 1012
Fishing duration is not NA	146 (100%) n: 1437	206 (100%) n: 1561	524 (100%) n: 1308	436 (100%) n: 1012
Positive fishing duration	146 (100%) n: 1437	206 (100%) n: 1561	524 (100%) n: 1308	436 (100%) n: 1012
Season start day >215	146 (100%) n: 1437	206 (100%) n: 1559	524 (100%) n: 1308	436 (100%) n: 1012
Core fleet selection	146 (100%) n: 1433	205 (100%) n: 1515	519 (100%) n: 1257	418 (100%) n: 934

Table D.9: Summary of the SKI7 BT+MW HOK daily rollup dataset after core fleet selection. ‘Records’ indicates the number of rows (days) in the dataset, and ‘Records caught’ indicates the percentage of days with catches of gemfish.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
1990	24	125	937	12 215.40	72.23	6.83
1991	28	91	1 107	13 877.42	73.03	4.34
1992	33	82	956	10 856.30	47.35	2.09
1993	41	102	1 213	14 530.01	131.42	10.72
1994	49	197	1 828	21 004.09	63.92	5.20
1995	43	138	1 731	21 032.63	5.14	1.10
1996	43	131	1 655	20 722.92	5.08	0.60
1997	59	244	2 270	27 518.40	30.43	1.15
1998	60	197	2 461	29 626.60	7.25	0.77
1999	58	257	2 036	22 752.37	3.58	0.44
2000	54	303	2 142	22 071.98	45.74	2.61
2001	64	352	2 333	25 333.58	17.85	1.29
2002	61	357	2 121	23 263.00	51.71	4.76
2003	53	304	2 143	26 652.49	94.42	9.05
2004	54	294	1 921	23 621.87	257.70	27.28
2005	42	144	1 192	13 964.45	186.93	37.92
2006	38	140	949	12 112.43	67.71	16.97
2007	36	119	653	7 355.33	34.00	3.98
2008	26	60	416	4 312.99	9.52	1.44
2009	20	61	345	3 746.13	5.85	3.77
2010	31	112	618	5 534.92	15.70	7.61
2011	32	173	894	7 128.55	44.20	12.86
2012	37	207	916	7 569.72	15.80	4.48
2013	33	195	886	7 459.92	43.93	12.08
2014	33	231	1 113	10 411.08	119.17	10.33
2015	37	298	1 251	11 363.98	55.54	7.51
2016	33	309	1 320	10 982.18	47.45	8.33
2017	34	340	1 433	13 769.42	146.03	20.80
2018	30	341	1 515	16 583.45	204.54	28.65
2019	30	275	1 257	13 136.13	519.49	54.18
2020	27	244	934	8 301.27	417.67	58.46

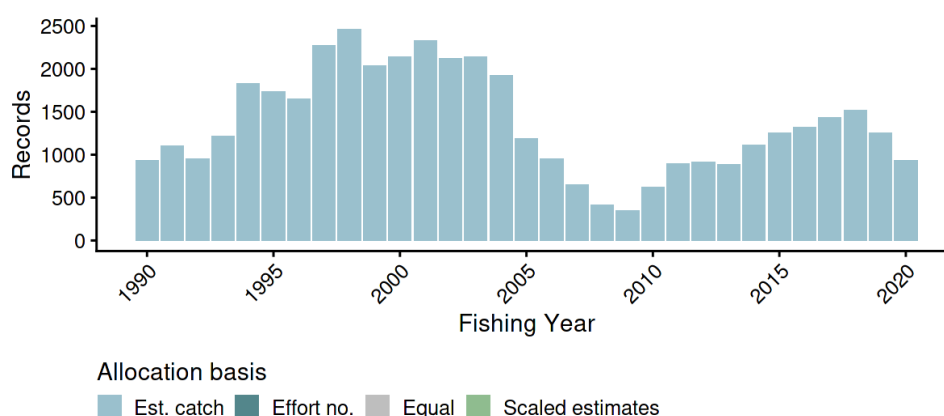


Figure D.24: Allocation basis for attributing landings to records in the SKI7 BT+MW HOK daily rollup catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table D.10: Summary of stepwise selection for occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	29.00	22 141	24.20	24.20	*
+ vessel_key	98.00	20 172	31.60	7.40	*
+ bs(SeasonDay, 3)	3.00	18 357	37.80	6.30	*
+ stat_area	1.00	18 126	38.70	0.80	
+ ns(log(fishing_duration), 3)	3.00	18 064	38.90	0.20	
+ primary_method	1.00	18 048	38.90	0.10	

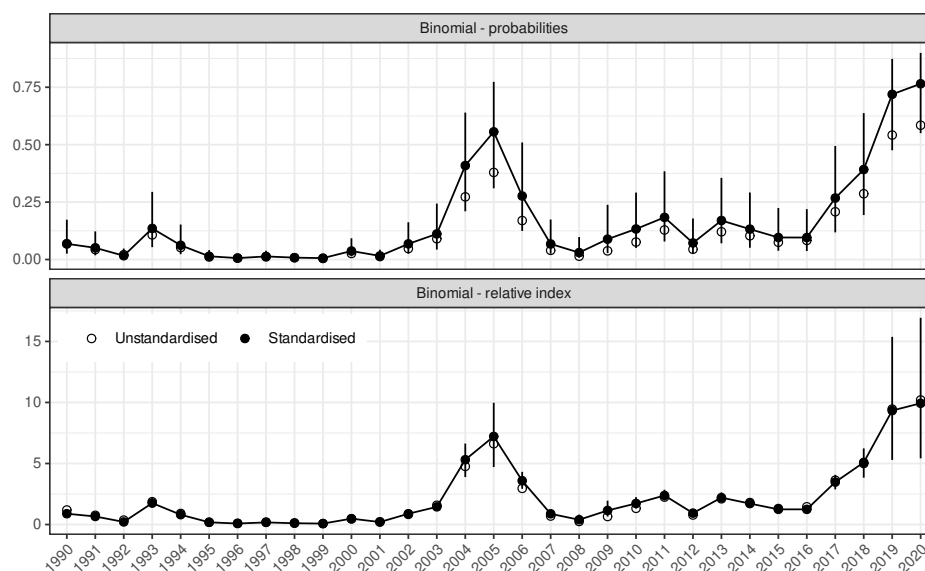


Figure D.25: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SKI7 BT+MW HOK daily rollup dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

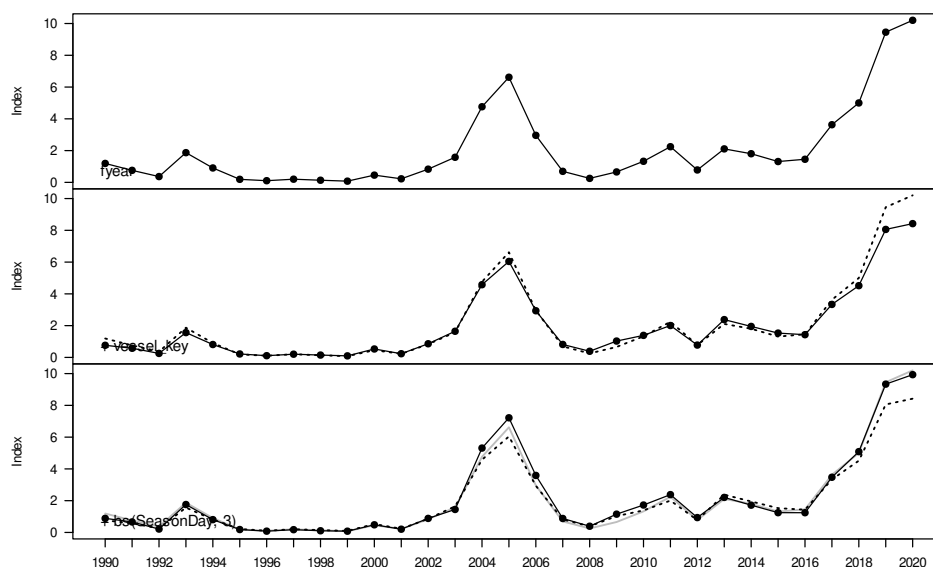


Figure D.26: Step plot for occurrence of catch in the SKI7 BT+MW HOK daily rollup dataset.

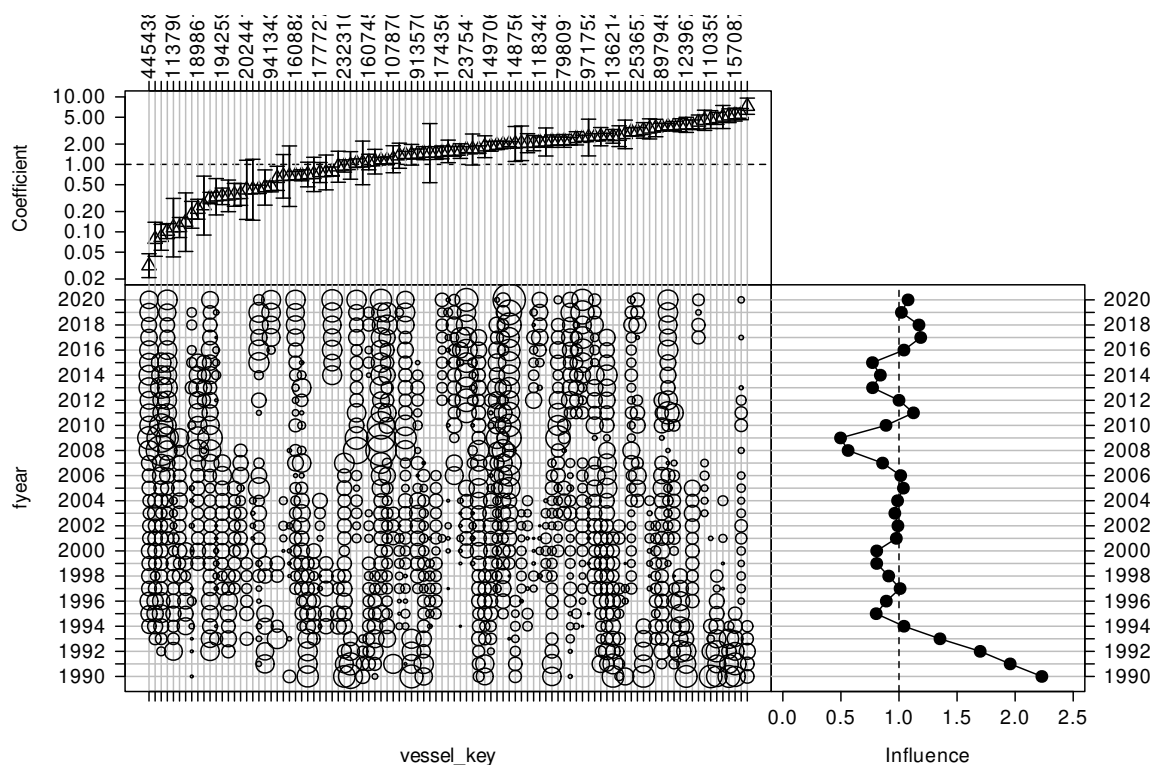


Figure D.27: CDI plot for vessel key for the occurrence of positive catch SKI7 BT+MW HOK daily rollout catch-per-unit-effort dataset.

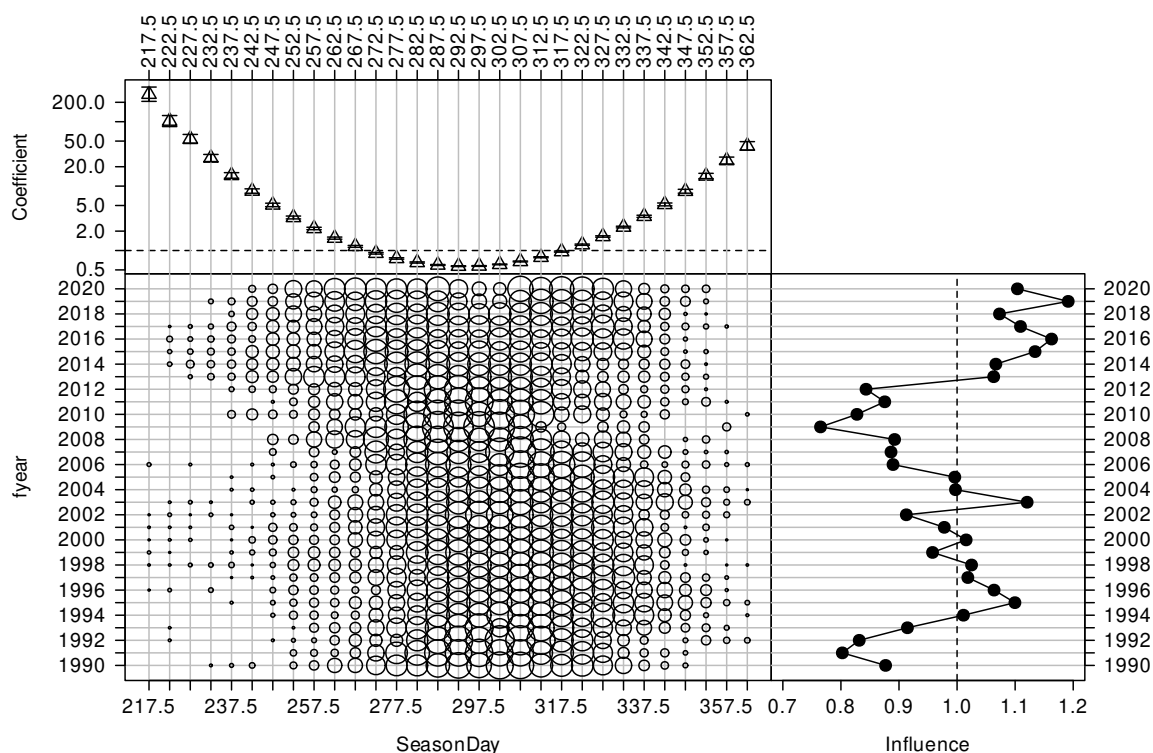


Figure D.28: CDI plot for SeasonDay for the occurrence of positive catch SKI7 BT+MW HOK daily rollout catch-per-unit-effort dataset.

Table D.11: Summary of stepwise selection for the lognormal model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	29	16 908	7.5	7.5	*
+ vessel key	98	13 859	54.4	46.9	*
+ bs(SeasonDay, 3)	3	13 133	61.1	6.7	*
+ primary method	1	12 882	63.2	2.1	*
+ ns(log(fishing duration), 3)	3	12 680	64.8	1.6	*

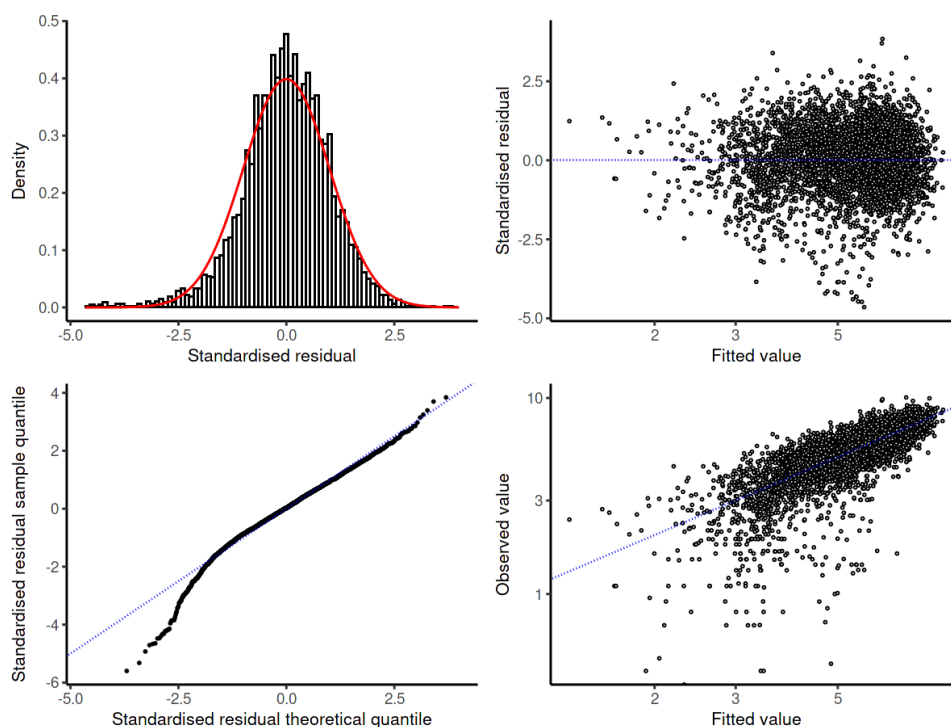


Figure D.29: Diagnostic plots for the lognormal model for the SKI7 BT+MW HOK daily rollup dataset.

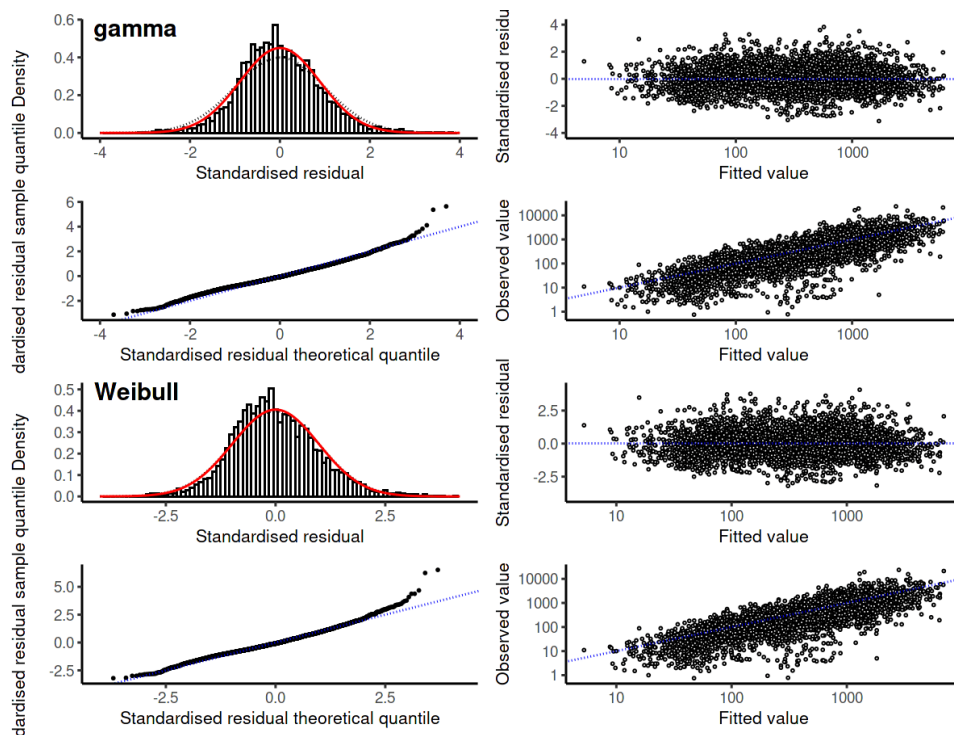


Figure D.30: Diagnostic plots for the gamma and Weibull model for the SKI7 BT+MW HOK daily rollup dataset.

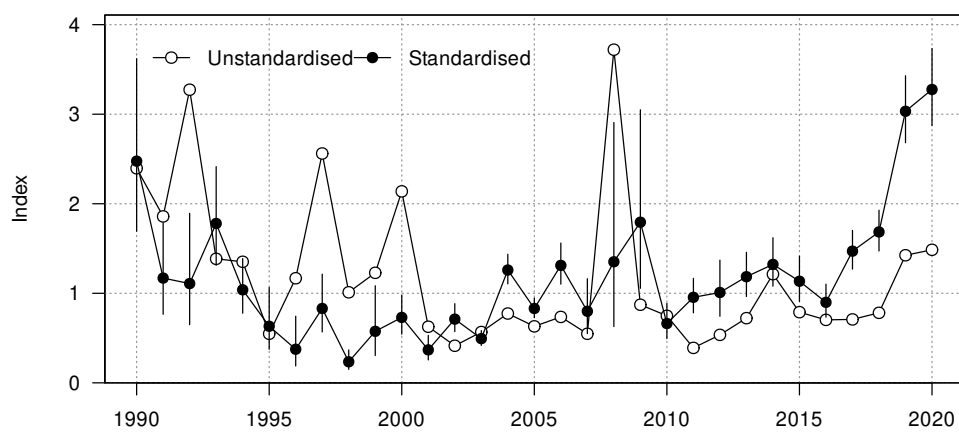


Figure D.31: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SKI7 BT+MW HOK daily rollup dataset.

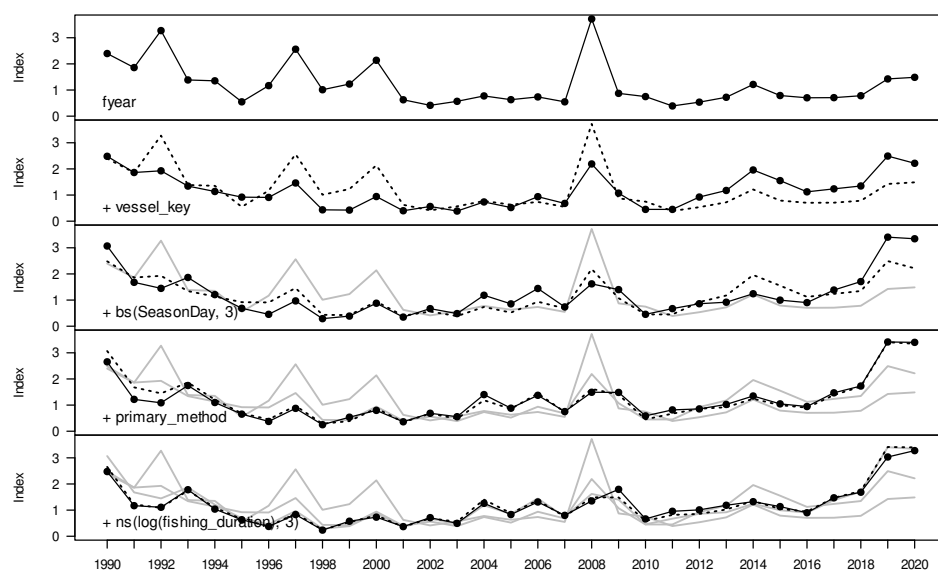


Figure D.32: Changes to the SKI7 BT+MW HOK daily rollup positive catch index as terms are successively entered into the model.

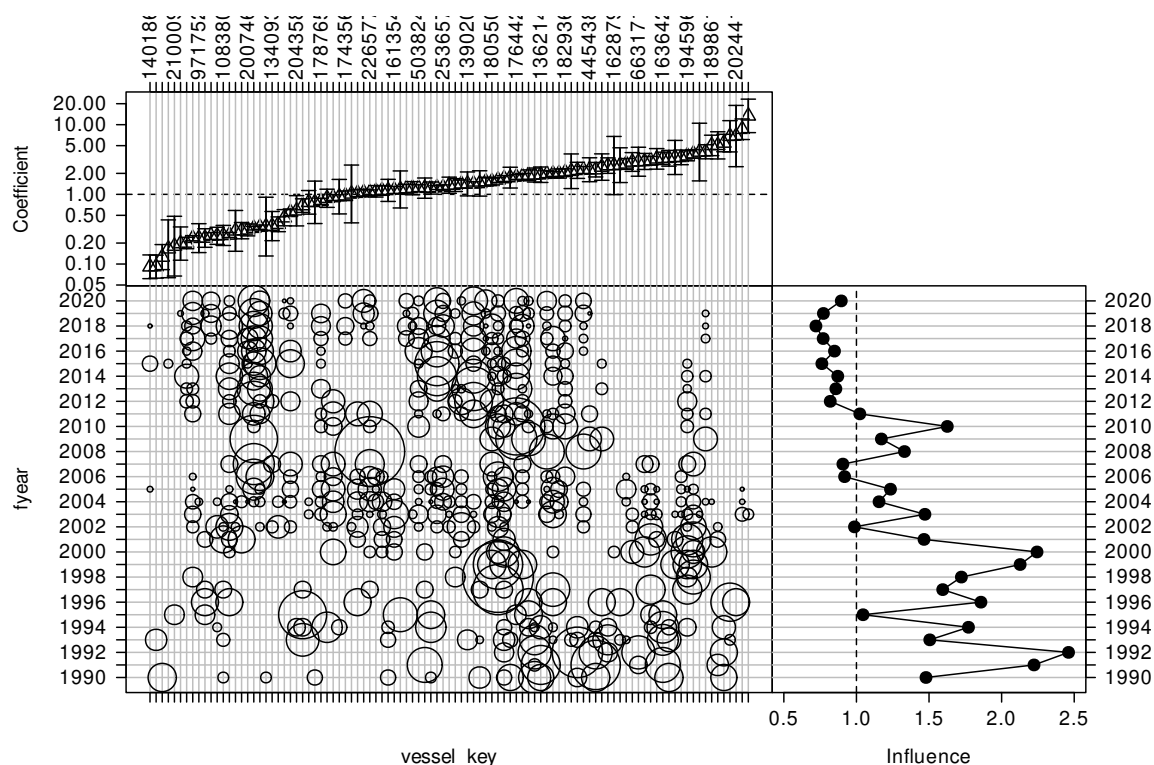


Figure D.33: CDI plot for vessel key for the positive catch SKI7 BT+MW HOK daily rollup catch-per-unit-effort dataset.

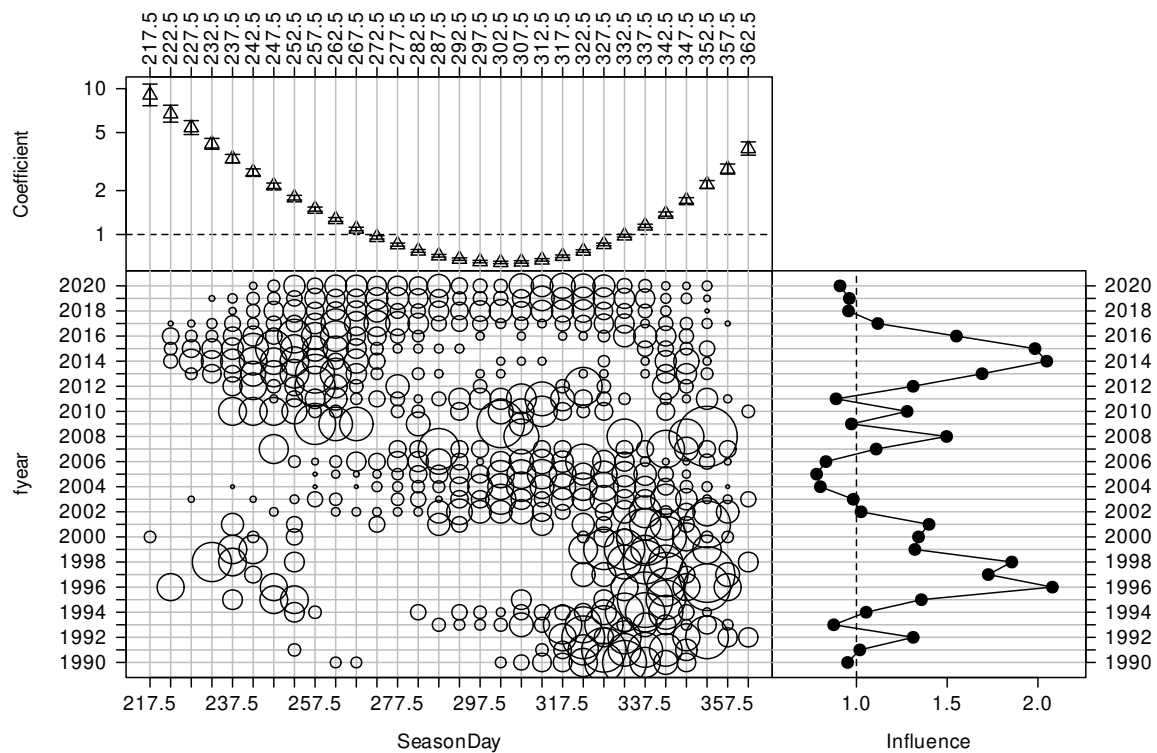


Figure D.34: CDI plot for SeasonDay for the positive catch SKI7 BT+MW HOK daily rollup catch-per-unit-effort dataset.

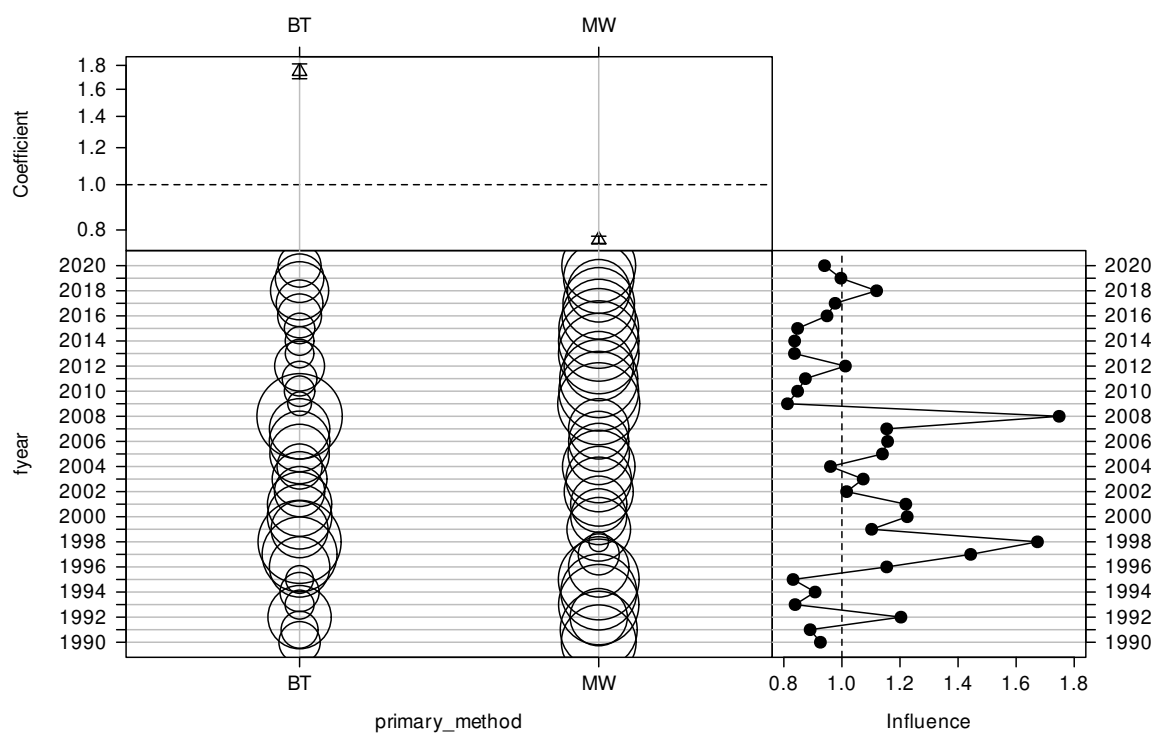


Figure D.35: CDI plot for primary method for the positive catch SKI7 BT+MW HOK daily rollup catch-per-unit-effort dataset.

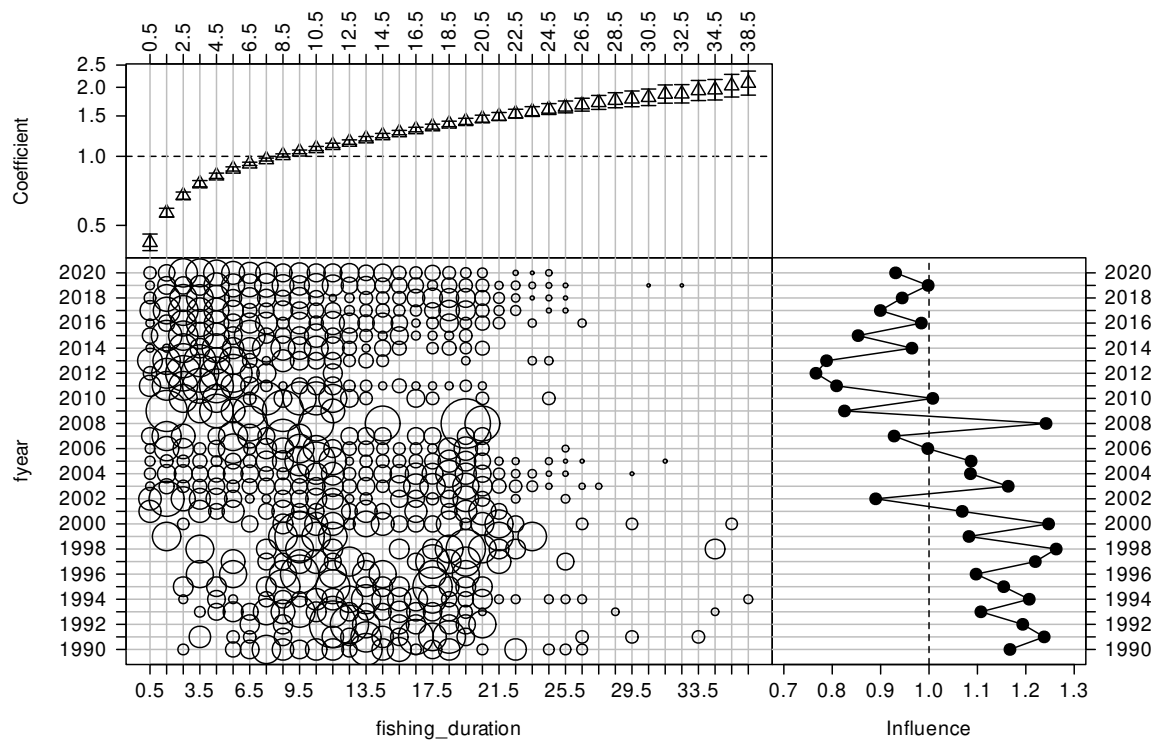


Figure D.36: CDI plot for fishing duration (h) for the positive catch SKI7 BT+MW HOK daily rollup catch-per-unit-effort dataset.

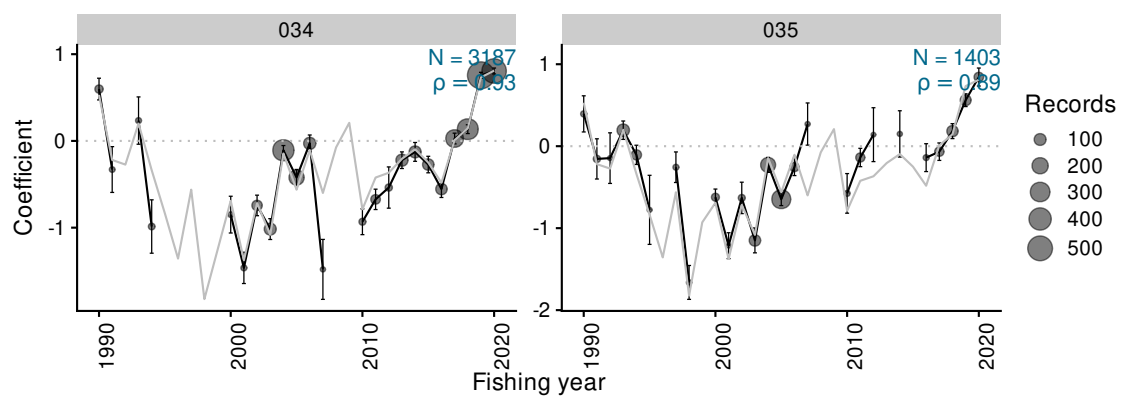


Figure D.37: Residual implied coefficients for area-year in the lognormal positive catch model for the SKI7 BT+MW HOK daily rollup dataset.

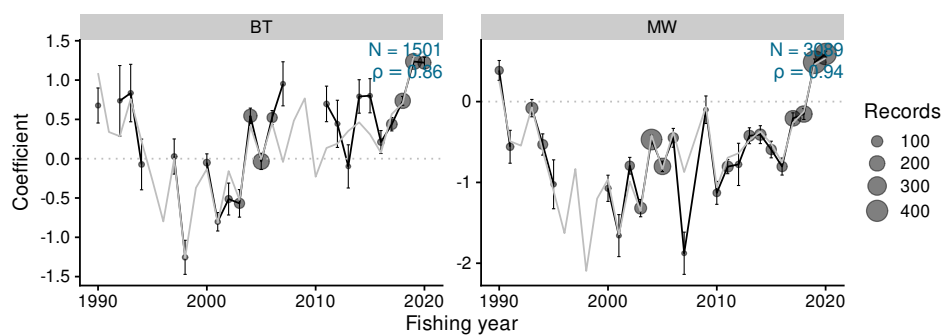


Figure D.38: Residual implied coefficients for primary method-year in the lognormal positive catch model for the SKI7 BT+MW HOK daily rollup dataset.

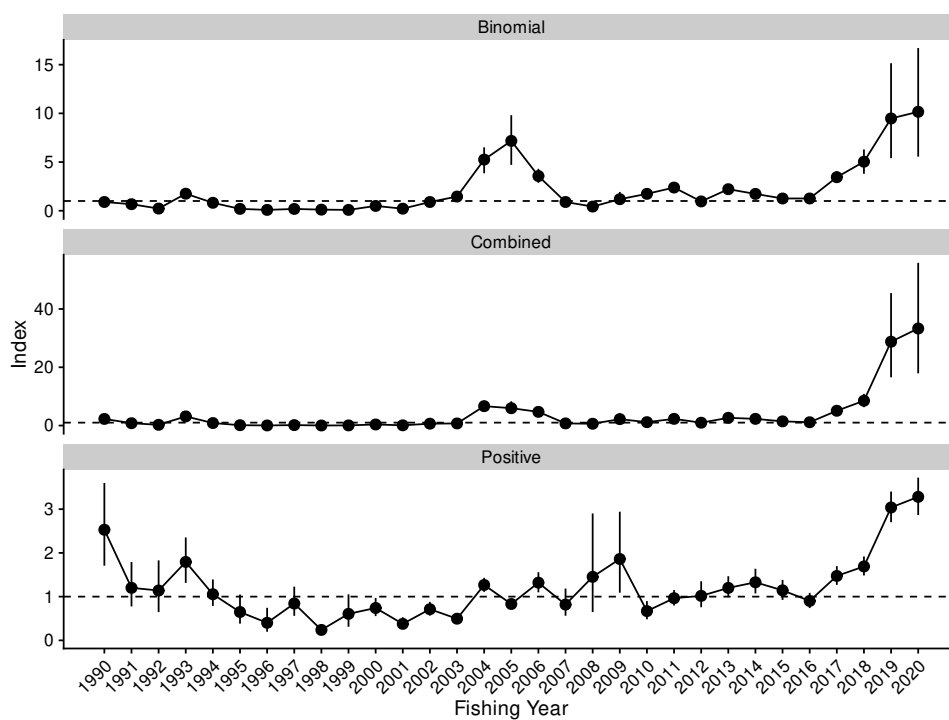


Figure D.39: Standardised indices and 95% confidence intervals for the SKI7 BT+MW HOK daily rollup dataset.

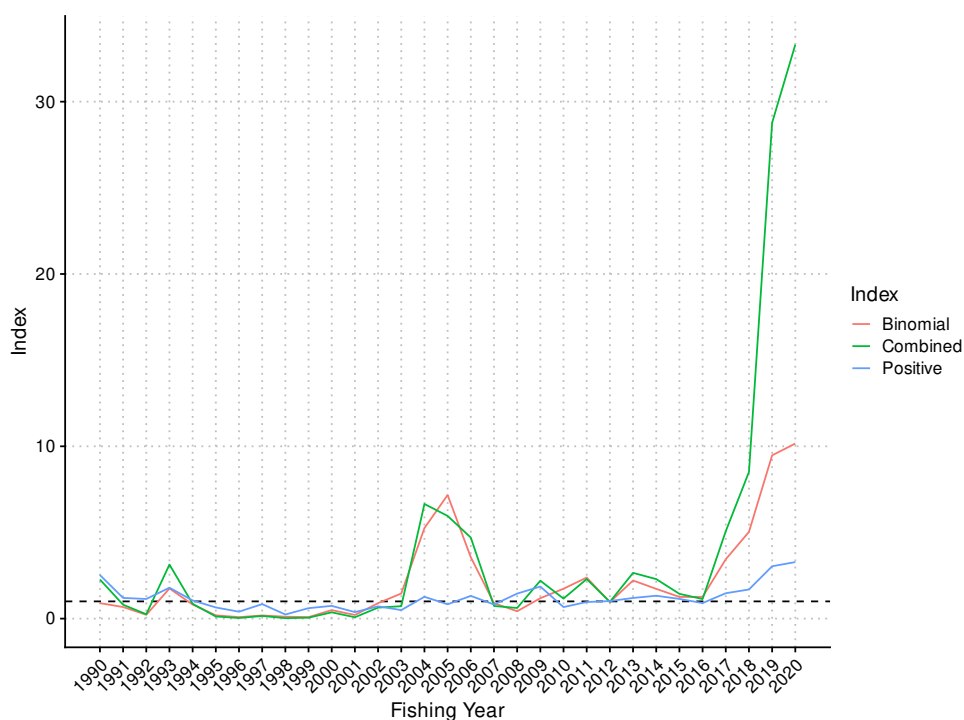


Figure D.40: Standardised indices for the SKI7 BT+MW HOK daily rollup dataset.

Table D.12: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SKI7 BT+MW HOK daily rollup.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.898	0.150	0.638	1.227	2.270	0.558	1.321	3.509	2.529	0.482	1.708	3.598
1991	0.672	0.122	0.468	0.945	0.806	0.221	0.456	1.322	1.201	0.259	0.776	1.791
1992	0.222	0.059	0.131	0.360	0.253	0.095	0.114	0.485	1.140	0.302	0.646	1.829
1993	1.750	0.198	1.379	2.157	3.137	0.602	2.128	4.488	1.793	0.265	1.314	2.352
1994	0.815	0.109	0.615	1.041	0.859	0.167	0.569	1.225	1.055	0.154	0.788	1.393
1995	0.191	0.047	0.119	0.302	0.124	0.045	0.062	0.239	0.648	0.169	0.383	1.047
1996	0.086	0.029	0.043	0.156	0.035	0.018	0.012	0.081	0.401	0.140	0.197	0.745
1997	0.184	0.039	0.119	0.270	0.155	0.044	0.084	0.257	0.842	0.170	0.561	1.228
1998	0.112	0.029	0.068	0.180	0.027	0.009	0.013	0.049	0.239	0.051	0.152	0.353
1999	0.087	0.032	0.040	0.164	0.053	0.027	0.019	0.123	0.606	0.189	0.311	1.053
2000	0.493	0.073	0.366	0.652	0.365	0.075	0.239	0.533	0.740	0.106	0.555	0.969
2001	0.211	0.041	0.143	0.305	0.080	0.021	0.046	0.127	0.377	0.067	0.263	0.527
2002	0.896	0.107	0.699	1.119	0.639	0.105	0.455	0.866	0.713	0.080	0.565	0.880
2003	1.457	0.126	1.224	1.719	0.721	0.087	0.564	0.907	0.495	0.043	0.422	0.589
2004	5.253	0.680	3.844	6.508	6.652	0.927	4.899	8.534	1.267	0.081	1.110	1.430
2005	7.173	1.303	4.707	9.813	5.960	1.120	3.943	8.332	0.832	0.051	0.738	0.939
2006	3.565	0.366	2.867	4.303	4.703	0.615	3.608	6.020	1.319	0.117	1.099	1.558
2007	0.897	0.179	0.593	1.294	0.734	0.195	0.421	1.187	0.819	0.158	0.564	1.184
2008	0.428	0.172	0.171	0.847	0.617	0.351	0.178	1.553	1.452	0.575	0.647	2.902
2009	1.186	0.328	0.644	1.929	2.201	0.818	0.987	4.194	1.861	0.473	1.090	2.942
2010	1.734	0.239	1.312	2.249	1.161	0.247	0.752	1.720	0.669	0.106	0.482	0.898
2011	2.382	0.226	1.958	2.845	2.297	0.311	1.752	2.970	0.964	0.090	0.796	1.149
2012	0.956	0.148	0.691	1.270	0.973	0.213	0.617	1.451	1.017	0.151	0.758	1.351
2013	2.213	0.229	1.788	2.686	2.655	0.403	1.963	3.542	1.200	0.122	0.987	1.466
2014	1.727	0.171	1.414	2.083	2.294	0.329	1.703	2.993	1.328	0.144	1.073	1.637
2015	1.258	0.149	0.982	1.565	1.438	0.227	1.032	1.922	1.144	0.117	0.925	1.383
2016	1.260	0.135	1.001	1.531	1.136	0.168	0.834	1.492	0.902	0.089	0.738	1.086
2017	3.444	0.310	2.862	4.079	5.072	0.575	4.018	6.274	1.473	0.109	1.269	1.696
2018	5.035	0.636	3.796	6.290	8.508	1.166	6.299	10.868	1.690	0.111	1.485	1.919
2019	9.476	2.487	5.401	15.149	28.778	7.369	16.559	45.447	3.038	0.179	2.702	3.403
2020	10.161	2.845	5.554	16.708	33.307	9.671	17.920	55.830	3.281	0.218	2.865	3.720

D.3 SKI3 BT+MW SShelf observer

Table D.13: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SKI3 BT+MW SShelf observer CPUE series.

Series	SKI3 BT+MW SShelf observer
QMS stock	SKI3
Reporting forms	
Fishing methods	BT, MW
Target species	SQU, BAR, HOK, SWA, SKI, LIN
Statistical Areas	025, 026, 027, 028, 029, 030, 504
Period	1999-10-01, 2020-09-30
Resolution	Observed event
Core fleet years	5
Core fleet trips	1
Default model	obskg ~ fyear + vessel_key + bs(SeasonDay, 3) + stat_area + target_species + ns(log(fishing_duration), 3) + bs(start_latitude, 3) + bs(start_seabed_depth, 3) + bs(start_hour, 3)
Stepwise selection	Yes
Positive catch distribution	Lognormal

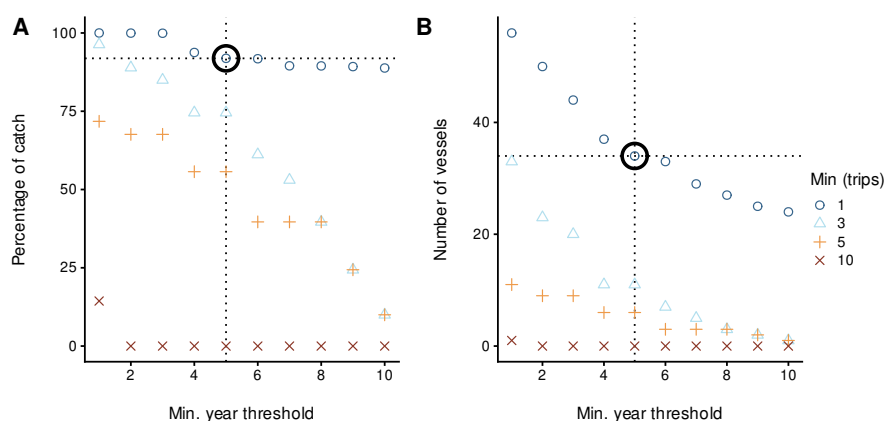


Figure D.41: Percentage of catch and number of vessels for different core vessel selection criteria for the SKI3 BT+MW SShelf observer CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel was observed in the fishery and the number of observed trips per year.

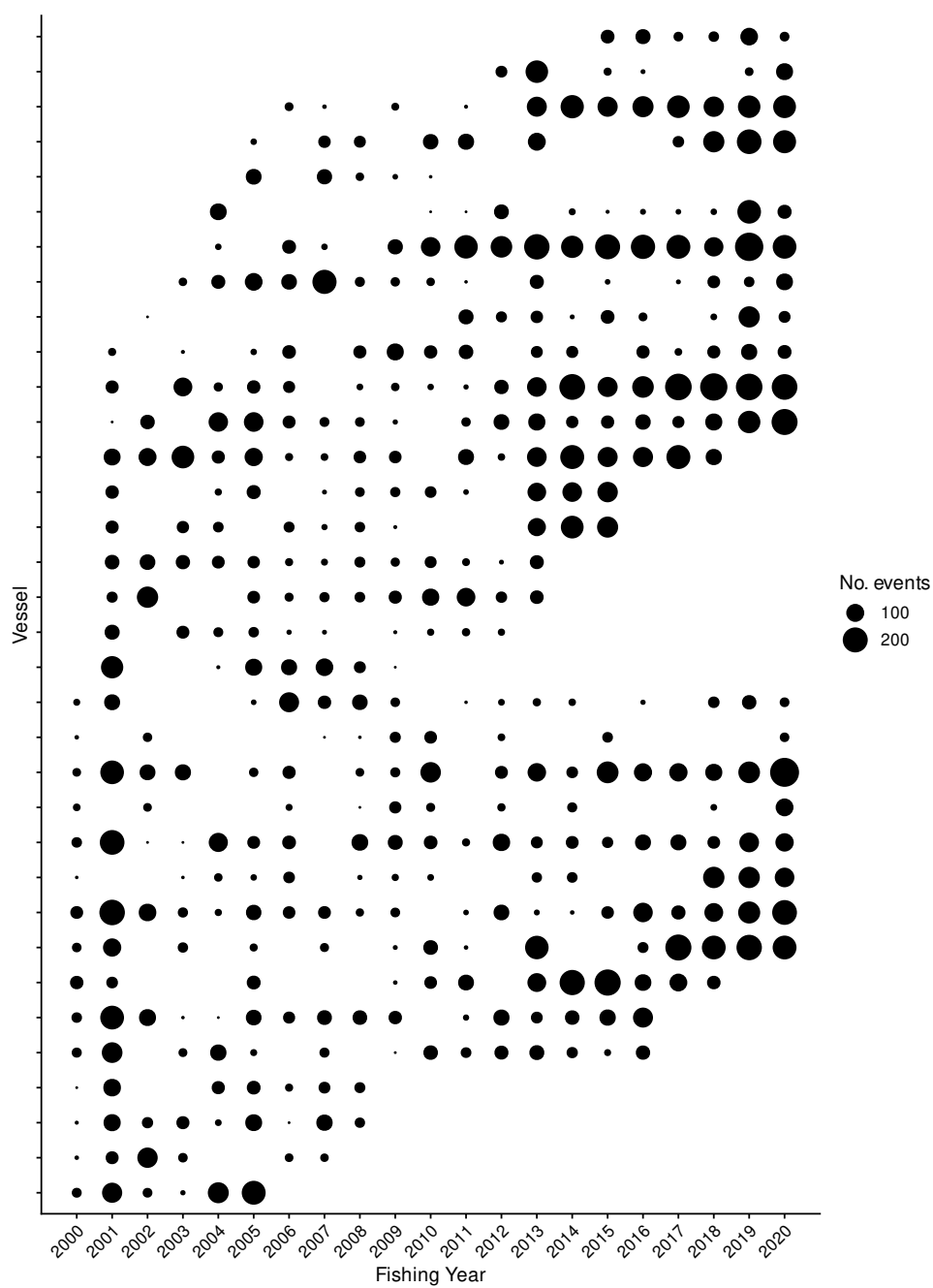


Figure D.42: Number of events by fishing year for core vessels. The area of the circles is proportional to the number of events undertaken by a vessel in a fishing year.

Table D.14: Summary of the SKI3 BT+MW SShelf observer dataset total catch (tonnes) and number of records (n), by fishing year after the application of various filters. The first row gives the catch and number of records before filters were applied (ungroomed data). Subsequent rows display the remaining catch (and percent of catch), and the number of records, after the specified filter was applied. (Continued on next page)

Filter	2000	2001	2002	2003	2004	2005	2006	2007	2008
Ungroomed data	1.9 (100%) n: 710	0.37 (100%) n: 2779	20 (100%) n: 1097	34 (100%) n: 1170	2 (100%) n: 1063	10 (100%) n: 1777	3.5 (100%) n: 1130	1.1 (100%) n: 1064	1.1 (100%) n: 1194
Fishing duration is not NA	1.9 (100%) n: 710	0.37 (100%) n: 2779	20 (100%) n: 1097	34 (100%) n: 1170	2 (100%) n: 1063	10 (100%) n: 1777	3.5 (100%) n: 1130	1.1 (100%) n: 1064	1.1 (100%) n: 1194
Positive fishing duration	1.9 (100%) n: 710	0.37 (100%) n: 2776	20 (100%) n: 1097	34 (100%) n: 1170	2 (100%) n: 1063	10 (100%) n: 1777	3.5 (100%) n: 1130	1.1 (100%) n: 1064	1.1 (100%) n: 1192
Bottom depth >=50	1.9 (100%) n: 708	0.37 (100%) n: 2773	20 (100%) n: 1097	34 (100%) n: 1170	2 (100%) n: 1062	10 (100%) n: 1775	3.5 (100%) n: 1130	1.1 (100%) n: 1064	0.9 (82%) n: 1022
Bottom depth <=600	1.9 (100%) n: 511	0.36 (100%) n: 2577	20 (100%) n: 1033	34 (100%) n: 1064	2 (100%) n: 1024	10 (100%) n: 1762	3.5 (100%) n: 1080	1.1 (100%) n: 996	0.9 (81%) n: 869
Midwater effort depth <=10 m from bottom	1.9 (100%) n: 499	0.3 (80%) n: 2515	20 (100%) n: 1002	34 (100%) n: 1029	2 (100%) n: 999	10 (100%) n: 1615	3.5 (100%) n: 992	1.1 (100%) n: 990	0.9 (81%) n: 738
Core fleet selection	1.9 (100%) n: 304	0.25 (68%) n: 2058	18 (87%) n: 877	27 (80%) n: 694	1.9 (94%) n: 897	7.6 (73%) n: 1385	3.4 (100%) n: 881	0.92 (86%) n: 871	0.9 (81%) n: 718

Filter	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ungroomed data	1.2 (100%) n: 869	1.5 (100%) n: 1086	8 (100%) n: 1056	1.4 (100%) n: 1143	8.4 (100%) n: 2410	19 (100%) n: 1860	17 (100%) n: 1891	11 (100%) n: 1606	140 (100%) n: 1710
Fishing duration is not NA	1.2 (100%) n: 869	1.5 (100%) n: 1086	8 (100%) n: 1056	1.4 (100%) n: 1143	8.4 (100%) n: 2410	19 (100%) n: 1860	17 (100%) n: 1891	11 (100%) n: 1606	140 (100%) n: 1710
Positive fishing duration	1.2 (100%) n: 869	1.5 (100%) n: 1086	8 (100%) n: 1056	1.4 (100%) n: 1142	8.3 (100%) n: 2405	19 (100%) n: 1860	17 (100%) n: 1890	11 (100%) n: 1606	140 (100%) n: 1706
Bottom depth >=50	1.2 (100%) n: 803	1.4 (95%) n: 963	7.4 (93%) n: 916	1.4 (100%) n: 1091	7.9 (93%) n: 2260	18 (100%) n: 1761	16 (100%) n: 1750	11 (100%) n: 1576	133 (95%) n: 1627
Bottom depth <=600	1.2 (100%) n: 758	1.4 (95%) n: 923	7.4 (93%) n: 859	1.4 (100%) n: 1029	7.8 (92%) n: 2118	18 (100%) n: 1698	16 (100%) n: 1680	11 (100%) n: 1538	133 (95%) n: 1612
Midwater effort depth <=10 m from bottom	1.1 (95%) n: 687	1.4 (93%) n: 901	7.4 (93%) n: 811	1.1 (79%) n: 899	7.7 (92%) n: 1987	18 (95%) n: 1580	16 (100%) n: 1618	11 (100%) n: 1481	130 (93%) n: 1509
Core fleet selection	1.1 (95%) n: 687	1.4 (93%) n: 901	7.4 (92%) n: 794	1.1 (79%) n: 892	7.7 (92%) n: 1987	18 (95%) n: 1580	16 (100%) n: 1618	11 (100%) n: 1435	130 (93%) n: 1445

Filter	2018	2019	2020
Ungroomed data	240 (100%) n: 2139	370 (100%) n: 3032	226 (100%) n: 3112
Fishing duration is not NA	240 (100%) n: 2139	370 (100%) n: 3032	226 (100%) n: 3112
Positive fishing duration	240 (100%) n: 2139	370 (100%) n: 3032	226 (100%) n: 3109
Bottom depth >=50	239 (100%) n: 2097	361 (100%) n: 2976	215 (100%) n: 3034
Bottom depth <=600	238 (100%) n: 2014	360 (100%) n: 2940	215 (100%) n: 3004
Midwater effort depth <=10 m from bottom	224 (93%) n: 1915	354 (100%) n: 2802	214 (95%) n: 2902
Core fleet selection	210 (87%) n: 1619	325 (88%) n: 2381	184 (82%) n: 2319

Table D.15: Summary of the SKI3 BT+MW SShelf observer dataset after core fleet selection. ‘Records’ indicates the number of rows (events) in the dataset, and ‘Records caught’ indicates the percentage of events with catches of gemfish.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
2000	15	15	304	1 149.52	1.88	7.57
2001	22	37	2 058	7 793.15	0.25	1.46
2002	14	22	877	3 176.60	17.75	24.97
2003	17	20	694	2 937.88	27.24	52.88
2004	19	26	897	3 216.18	1.86	19.84
2005	24	31	1 385	6 198.70	7.63	15.74
2006	22	24	881	4 041.28	3.40	16.69
2007	22	29	871	4 395.63	0.92	9.18
2008	22	31	718	3 688.03	0.90	8.22
2009	25	31	687	3 237.23	1.12	5.53
2010	19	32	901	4 827.58	1.39	11.88
2011	21	36	794	4 518.90	7.41	20.15
2012	18	39	892	4 105.17	1.11	7.85
2013	23	87	1 987	11 222.13	7.75	17.31
2014	19	77	1 580	8 908.50	17.74	21.27
2015	19	71	1 618	9 252.80	16.12	27.94
2016	18	63	1 435	6 850.18	10.87	26.34
2017	15	65	1 445	7 599.37	129.68	67.13
2018	19	70	1 619	8 180.60	209.83	68.87
2019	17	76	2 381	12 454.15	325.41	78.83
2020	19	63	2 319	11 509.58	184.24	67.36

Table D.16: Summary of stepwise selection for occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	19.00	24 803	26.00	26.00	*
+ bs(start_seabed_depth, 3)	3.00	22 732	32.20	6.20	*
+ stat_area	6.00	21 706	35.30	3.10	*
+ vessel_key	33.00	20 936	37.80	2.50	*
+ ns(log(fishing_duration), 3)	3.00	20 592	38.90	1.00	*
+ bs(SeasonDay, 3)	3.00	20 458	39.30	0.40	
+ target_species	4.00	20 326	39.70	0.40	
+ bs(start_hour, 3)	3.00	20 193	40.10	0.40	
+ bs(start_latitude, 3)	3.00	20 139	40.30	0.20	

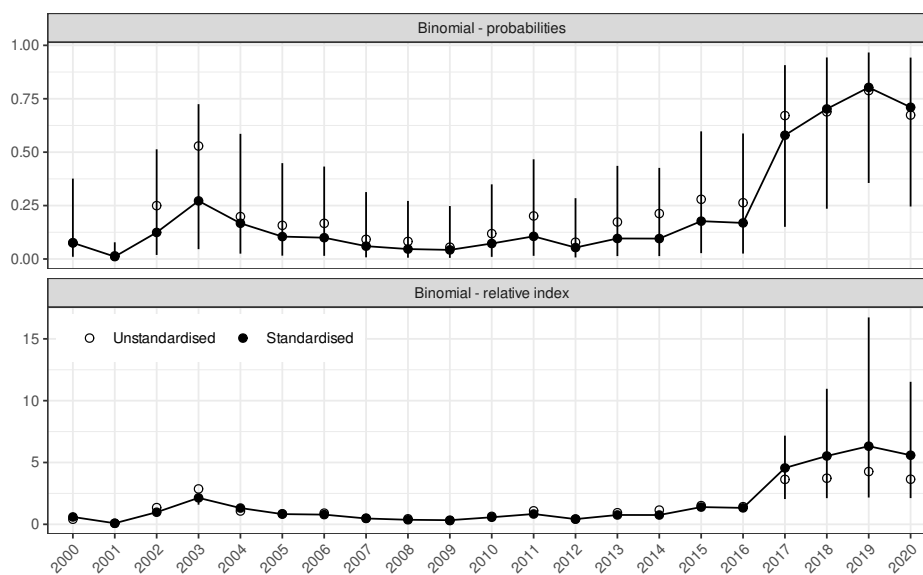


Figure D.43: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SKI3 BT+MW SShelf observer dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

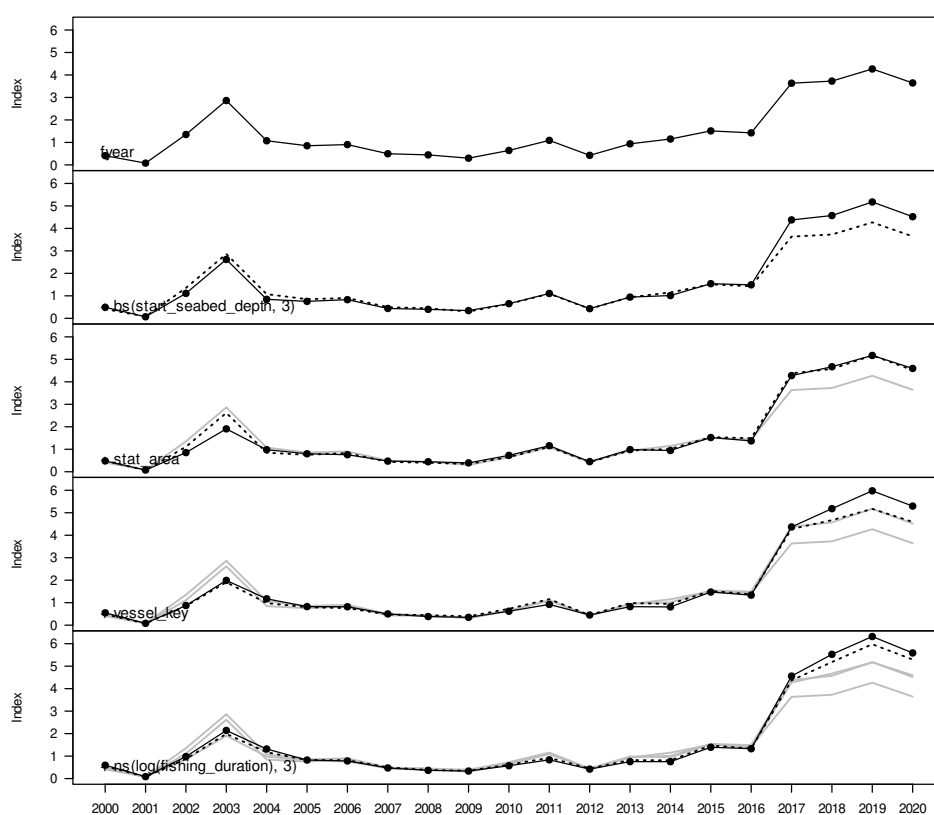


Figure D.44: Step plot for occurrence of catch in the SKI3 BT+MW SShelf observer dataset.

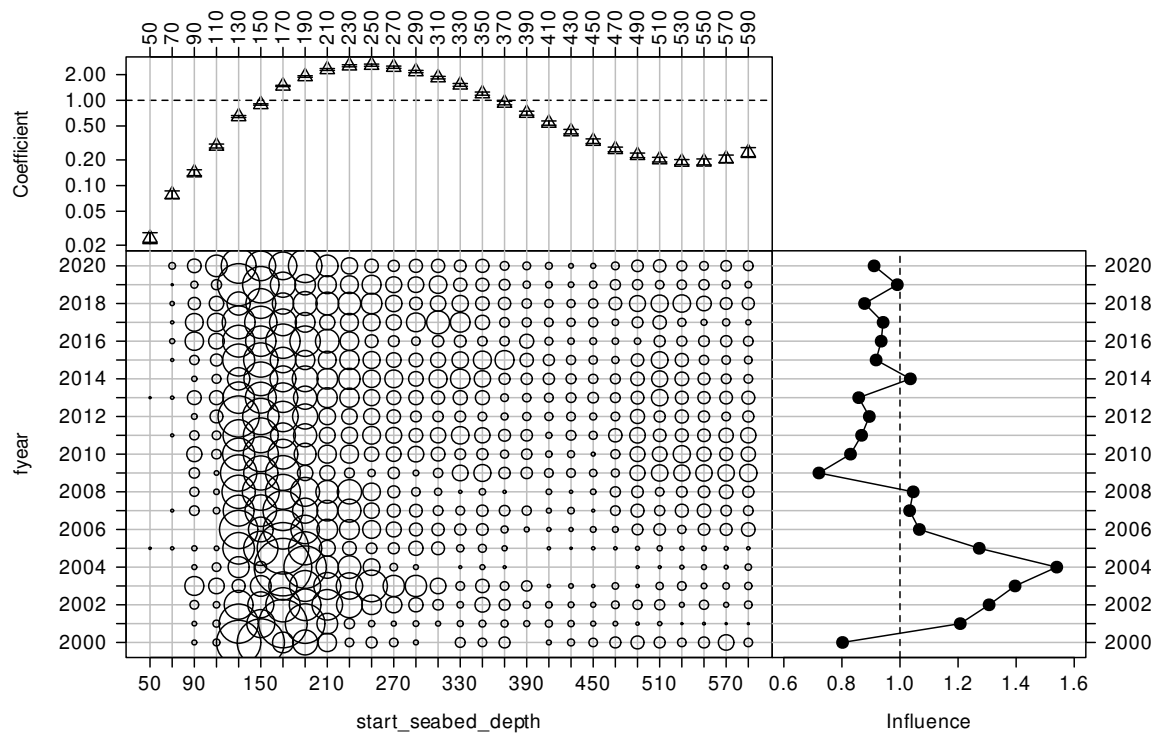


Figure D.45: CDI plot for start seabed depth (m) for the occurrence of positive catch SKI3 BT+MW SShelf observer catch-per-unit-effort dataset.

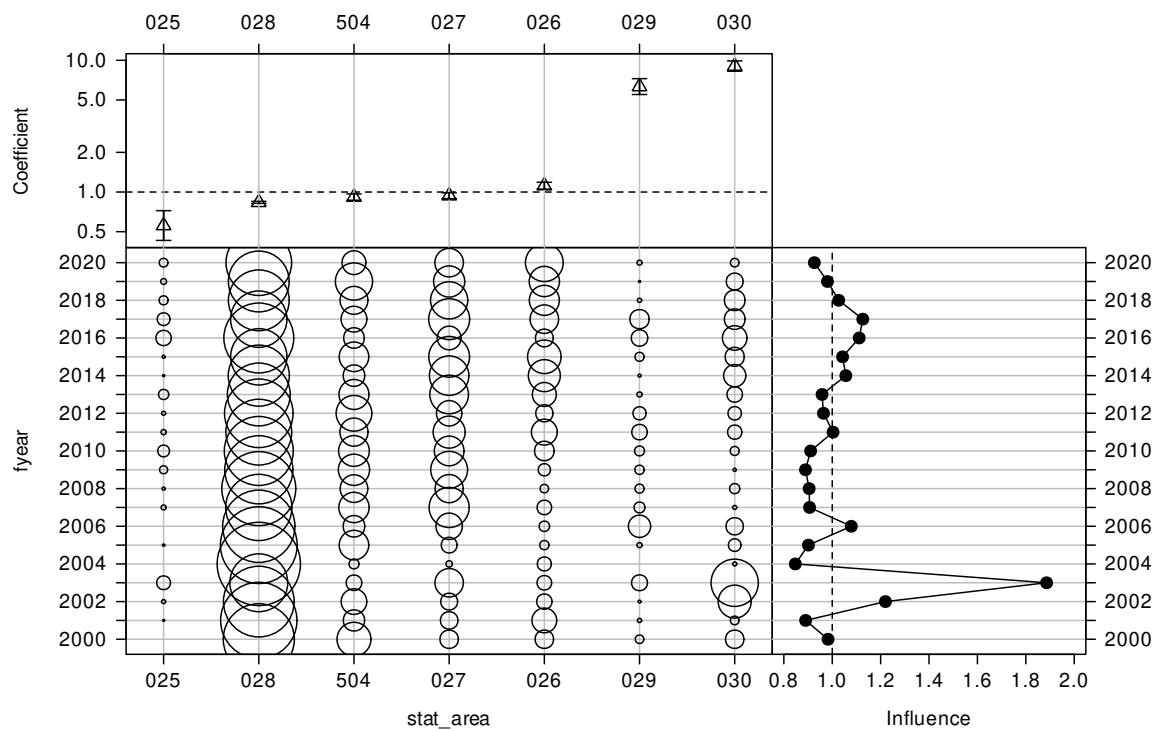


Figure D.46: CDI plot for statistical area for the occurrence of positive catch SKI3 BT+MW SShelf observer catch-per-unit-effort dataset.

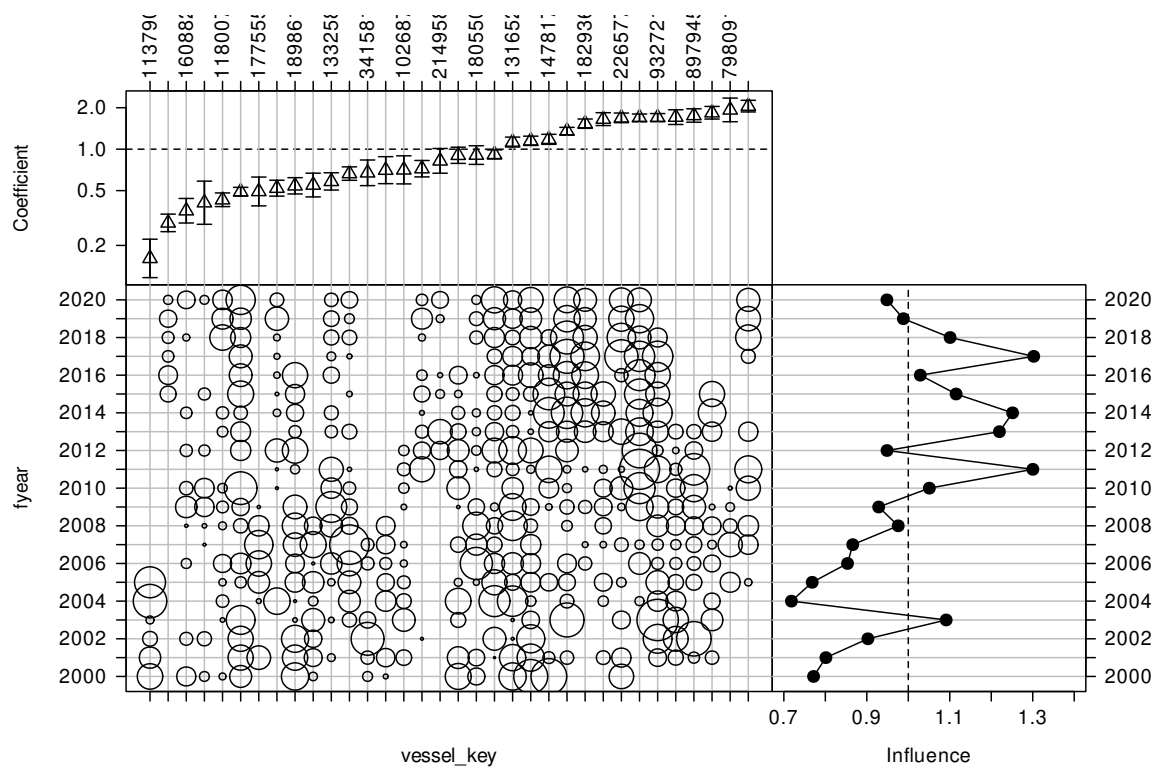


Figure D.47: CDI plot for vessel key for the occurrence of positive catch SKI3 BT+MW SShelf observer catch-per-unit-effort dataset.

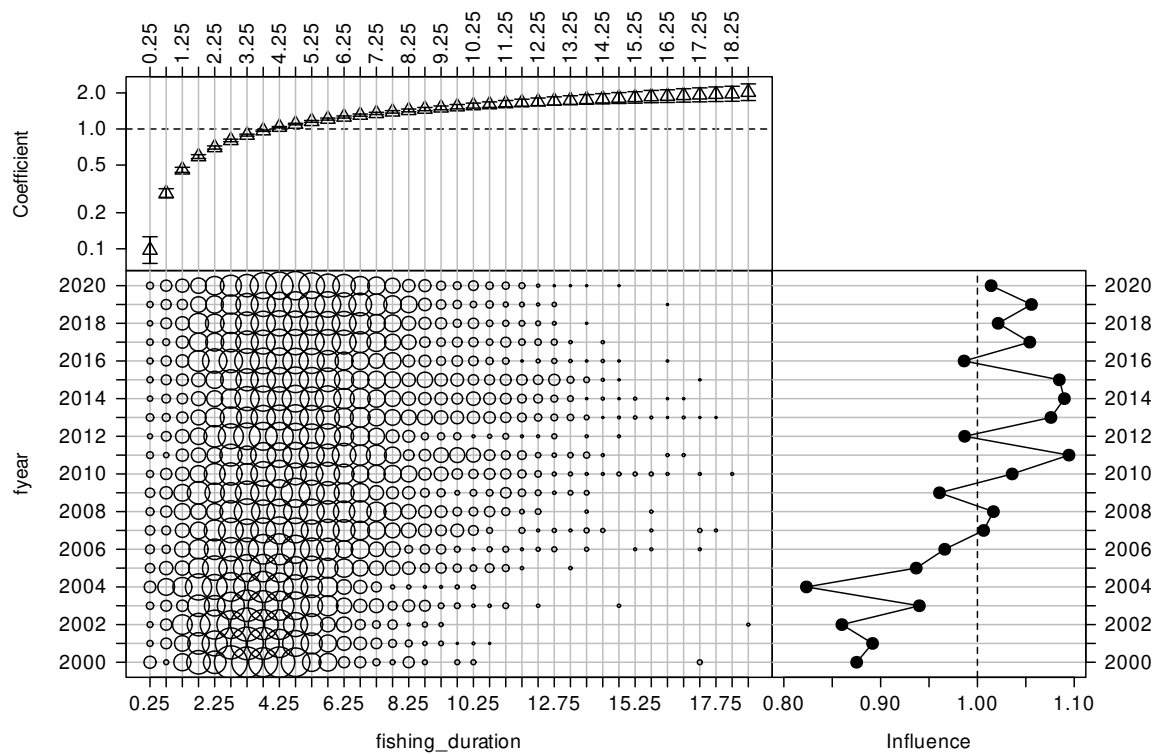


Figure D.48: CDI plot for fishing duration (h) for the occurrence of positive catch SKI3 BT+MW SShelf observer catch-per-unit-effort dataset.

Table D.17: Summary of stepwise selection for the lognormal model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	19	31 633	20.3	20.3	*
+ stat area	6	30 578	29.5	9.2	*
+ bs(start seabed depth, 3)	3	29 712	36.2	6.7	*
+ vessel key	33	29 217	40.2	4.0	*
+ bs(SeasonDay, 3)	3	28 960	42.0	1.8	*
+ ns(log(fishing duration), 3)	3	28 766	43.3	1.3	*
+ bs(start latitude, 3)	3	28 739	43.5	0.2	
+ bs(start hour, 3)	3	28 723	43.6	0.1	
+ target species	4	28 714	43.7	0.1	

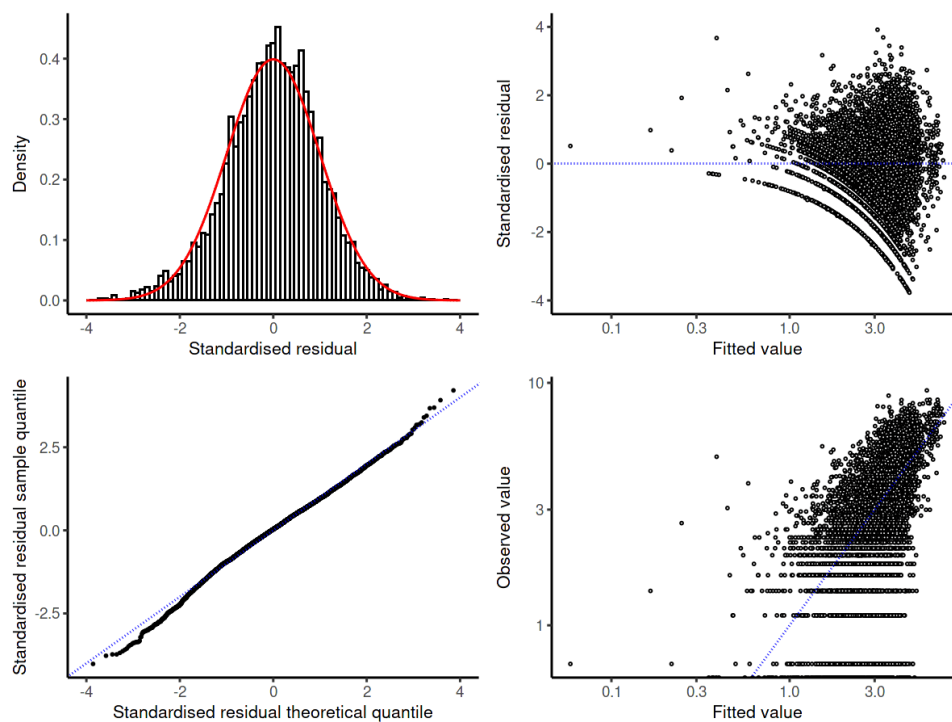


Figure D.49: Diagnostic plots for the lognormal model for the SKI3 BT+MW SShelf observer dataset.

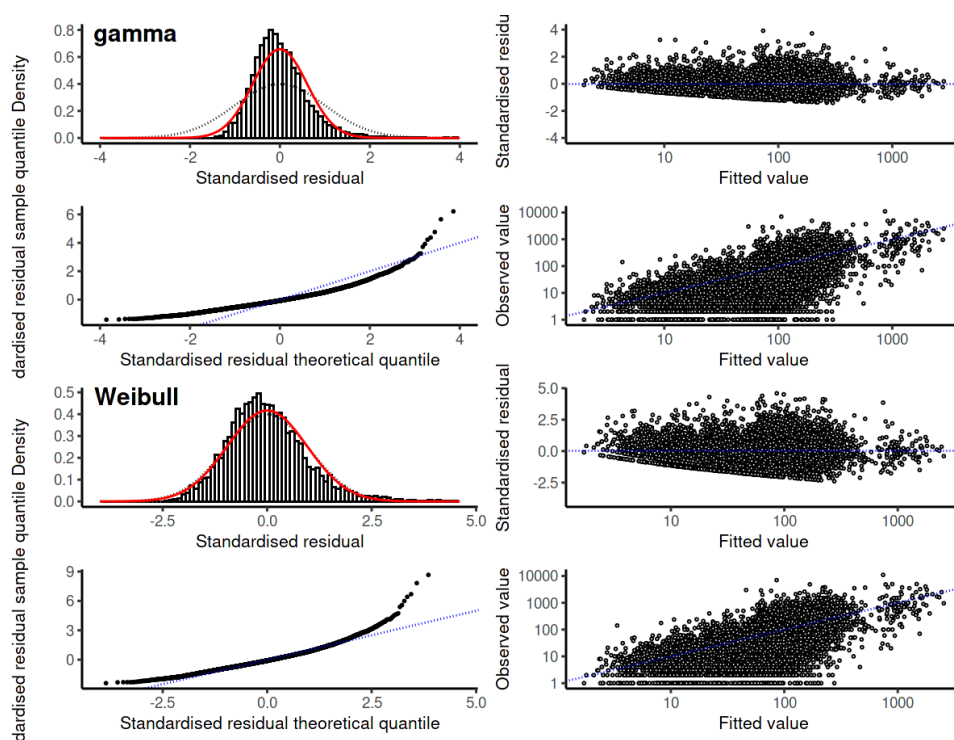


Figure D.50: Diagnostic plots for the gamma and Weibull model for the SKI3 BT+MW SShelf observer dataset.

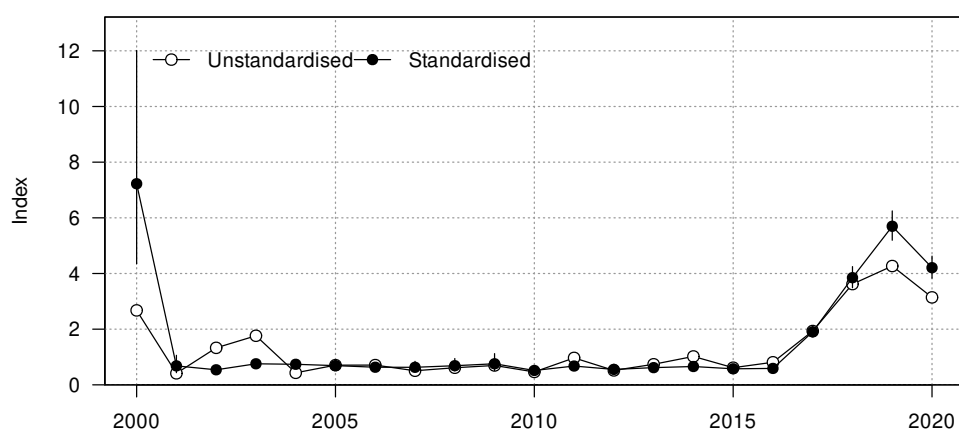


Figure D.51: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SKI3 BT+MW SShelf observer dataset.

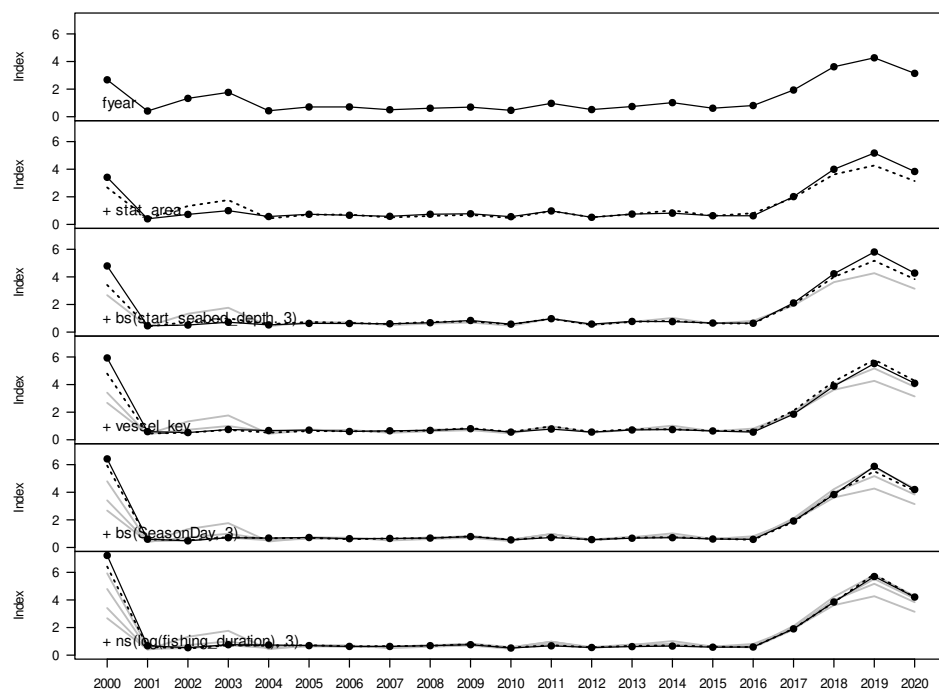


Figure D.52: Changes to the SKI3 BT+MW SShelf observer positive catch index as terms are successively entered into the model.

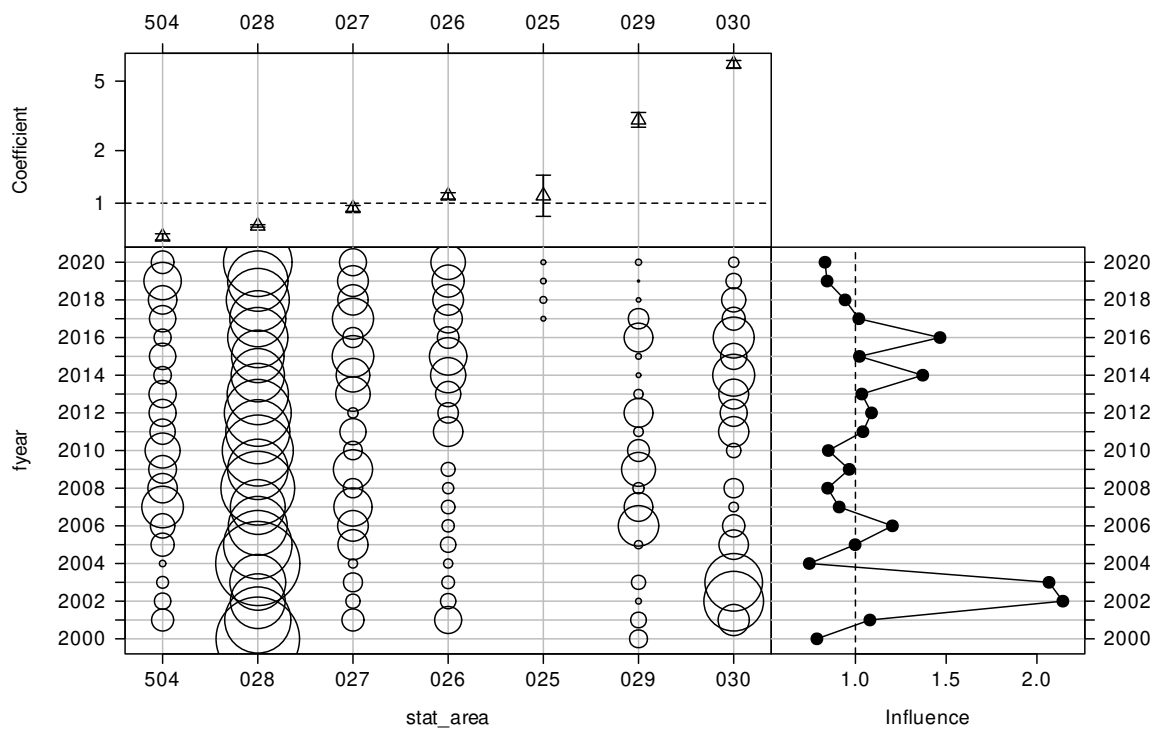


Figure D.53: CDI plot for statistical area for the positive catch SKI3 BT+MW SShelf observer catch-per-unit-effort dataset.

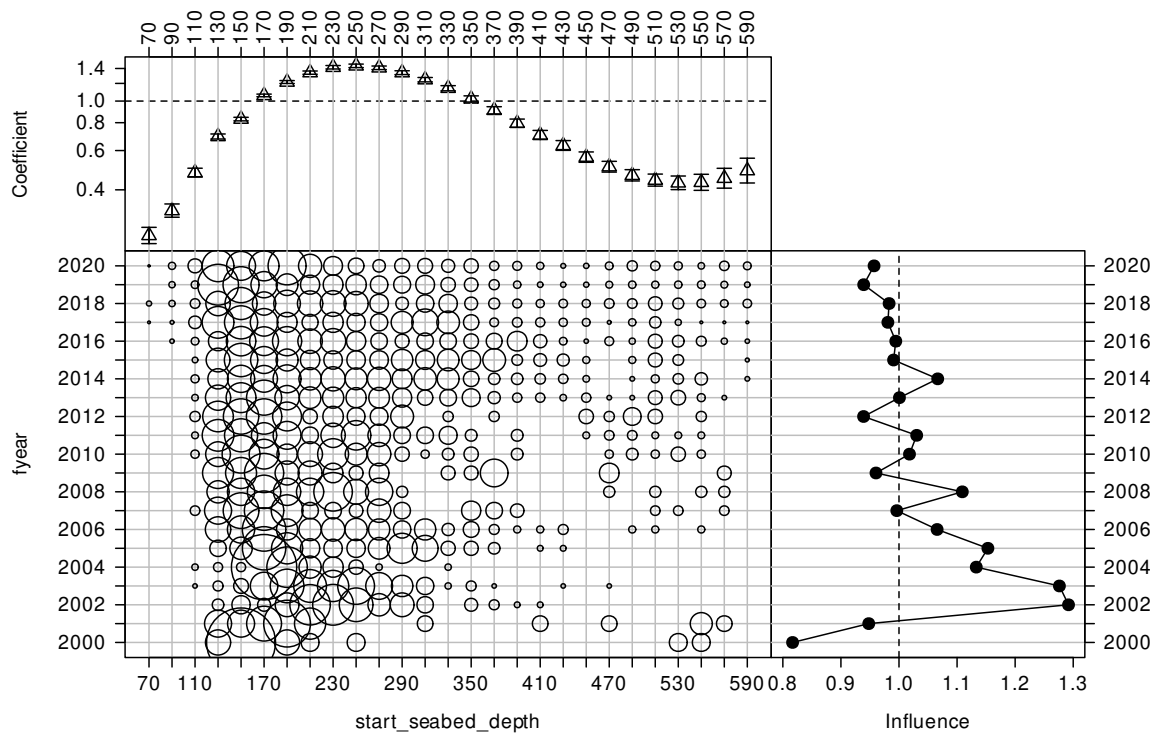


Figure D.54: CDI plot for start seabed depth (m) for the positive catch SKI3 BT+MW SShelf observer catch-per-unit-effort dataset.

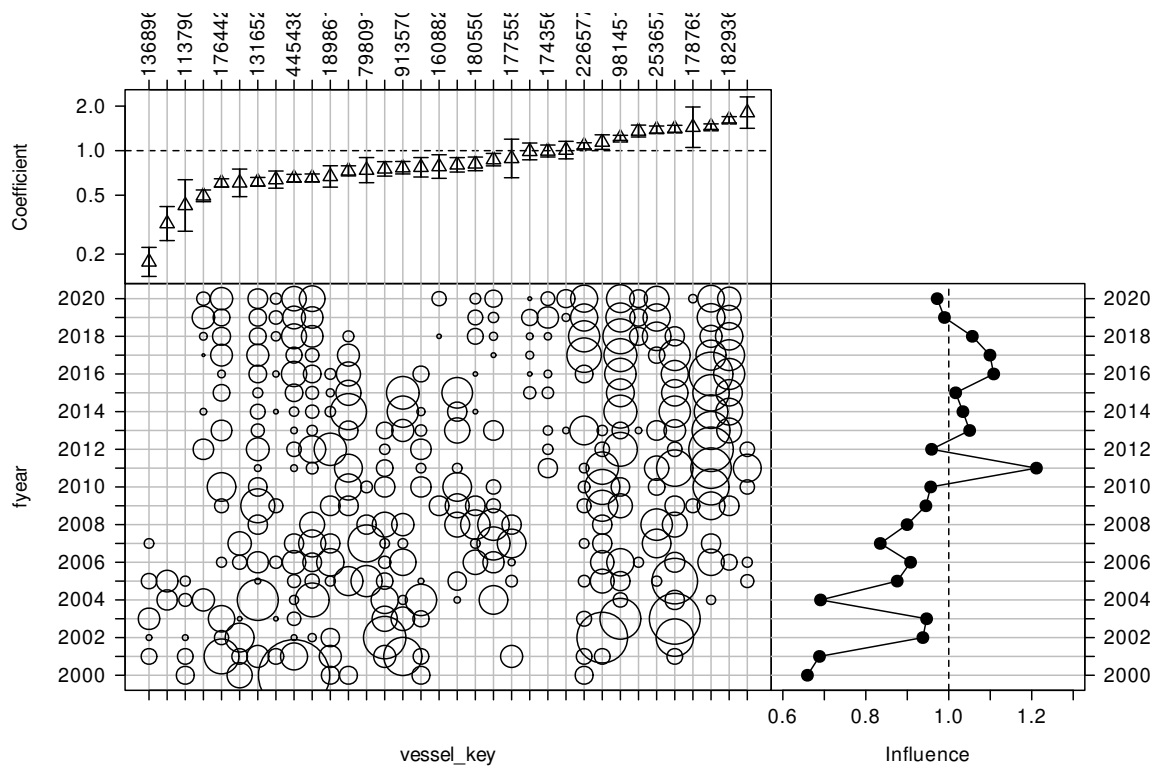


Figure D.55: CDI plot for vessel key for the positive catch SKI3 BT+MW SShelf observer catch-per-unit-effort dataset.

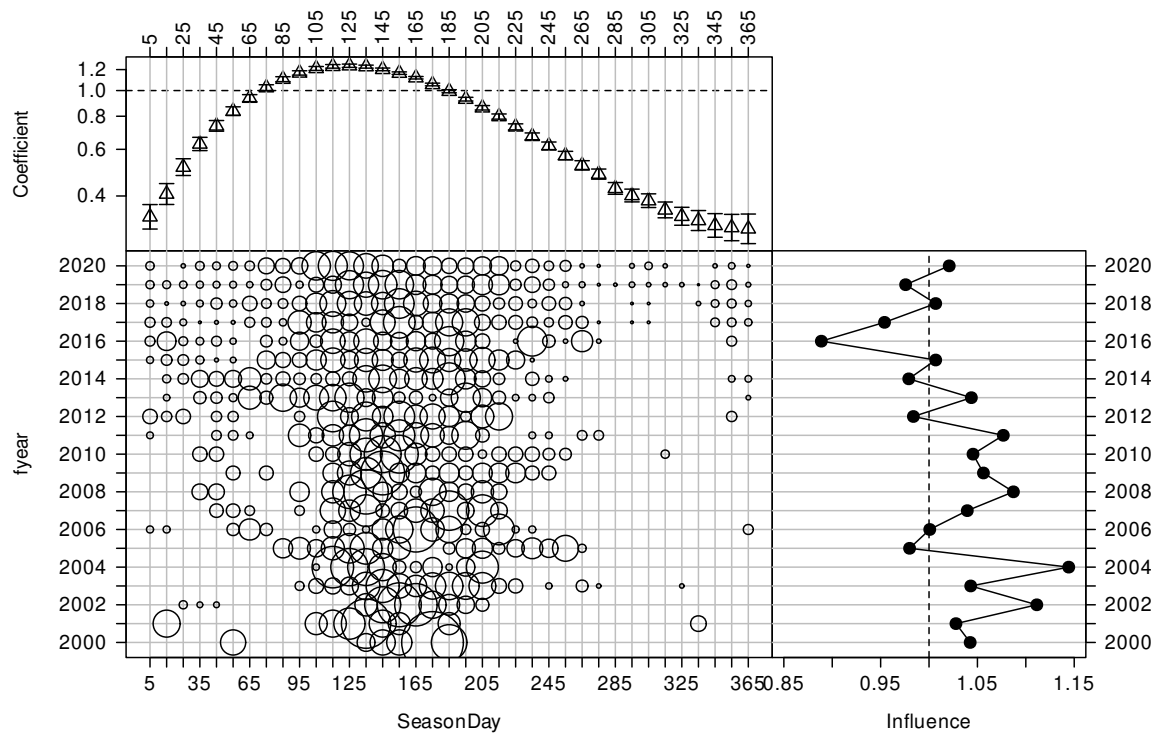


Figure D.56: CDI plot for SeasonDay for the positive catch SKI3 BT+MW SShelf observer catch-per-unit-effort dataset.

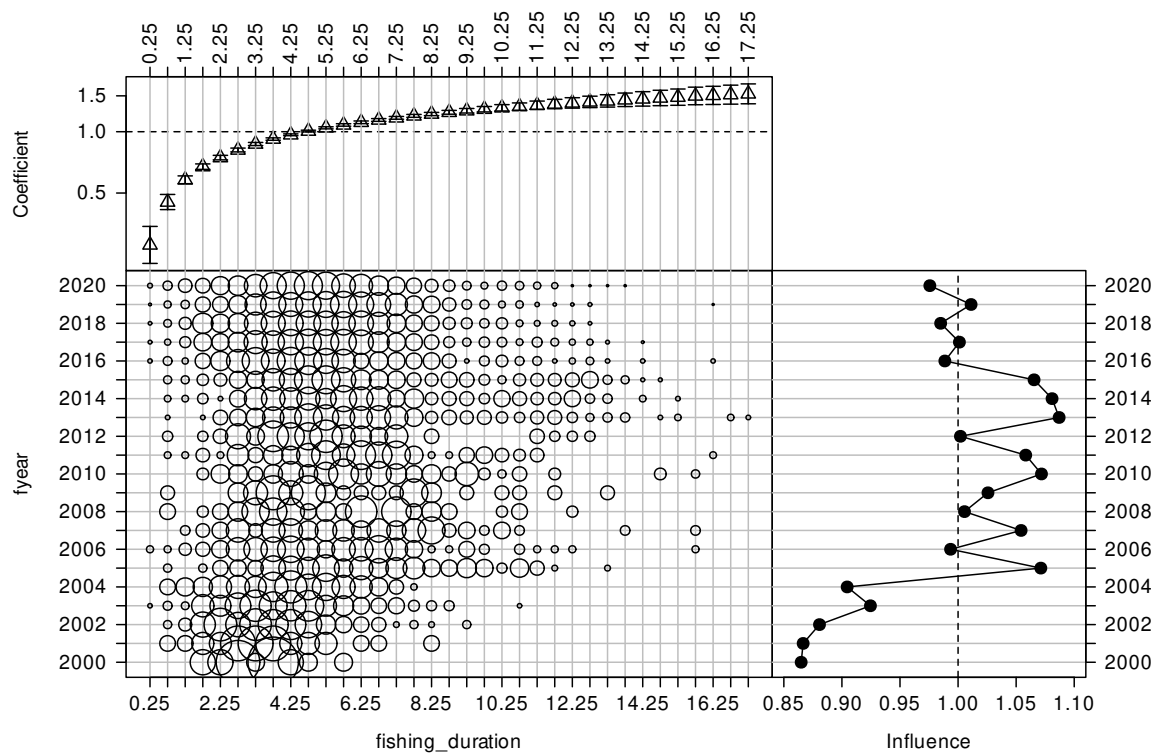


Figure D.57: CDI plot for fishing duration (h) for the positive catch SKI3 BT+MW SShelf observer catch-per-unit-effort dataset.

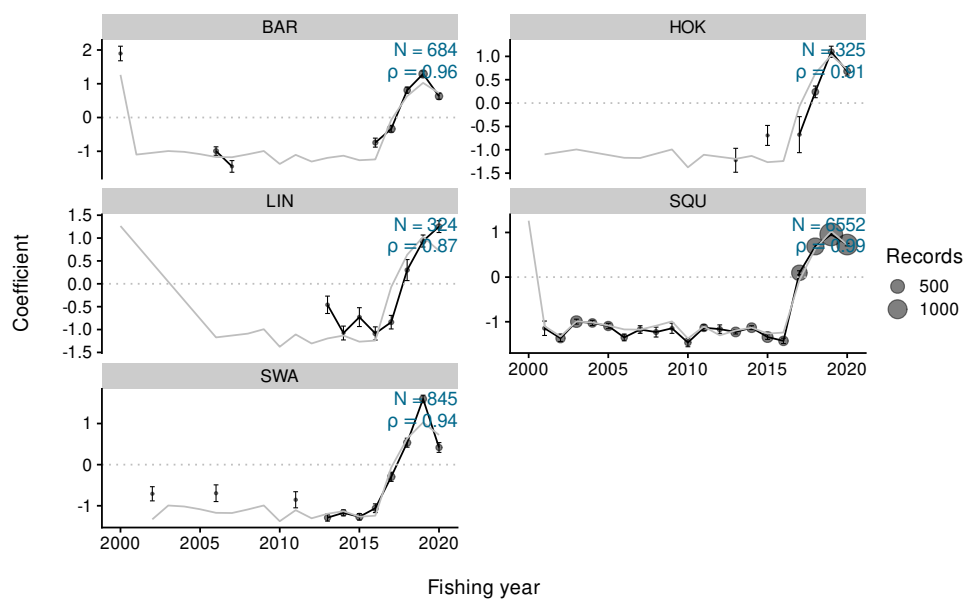


Figure D.58: Residual implied coefficients for target-year in the lognormal positive catch model for the SKI3 BT+MW SShelf observer dataset.

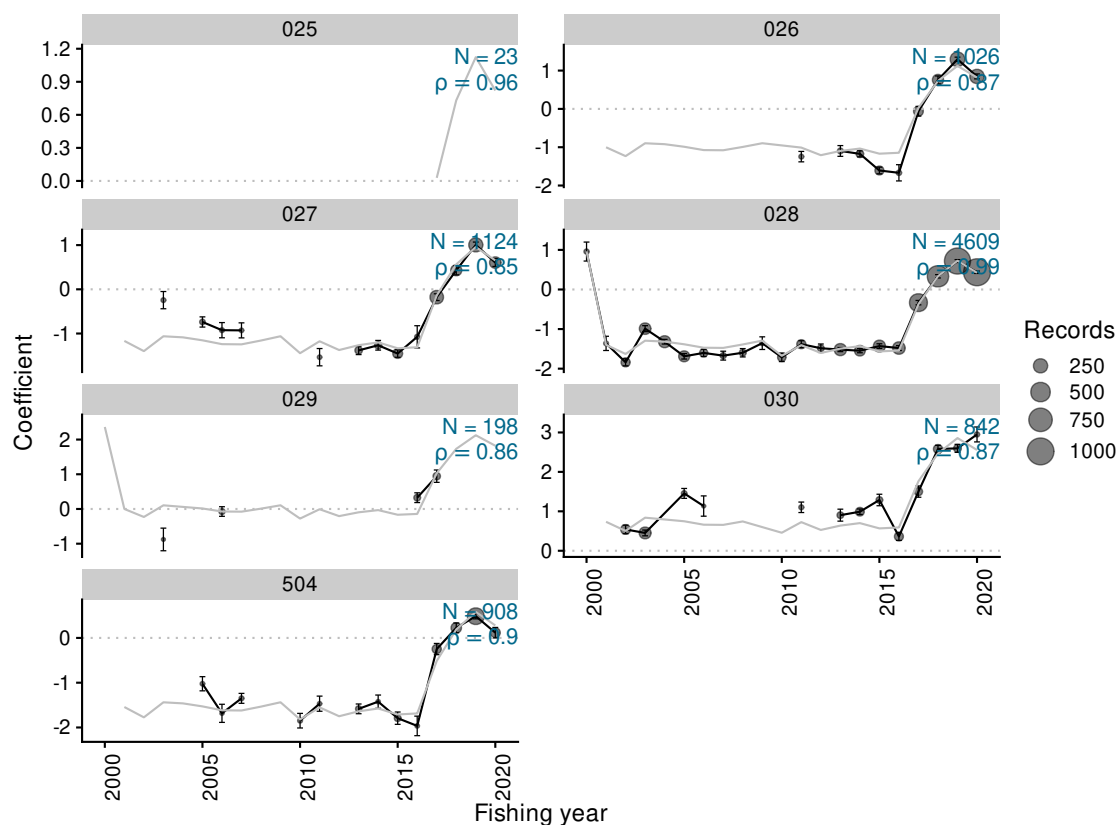


Figure D.59: Residual implied coefficients for area-year in the lognormal positive catch model for the SKI3 BT+MW SShelf observer dataset.

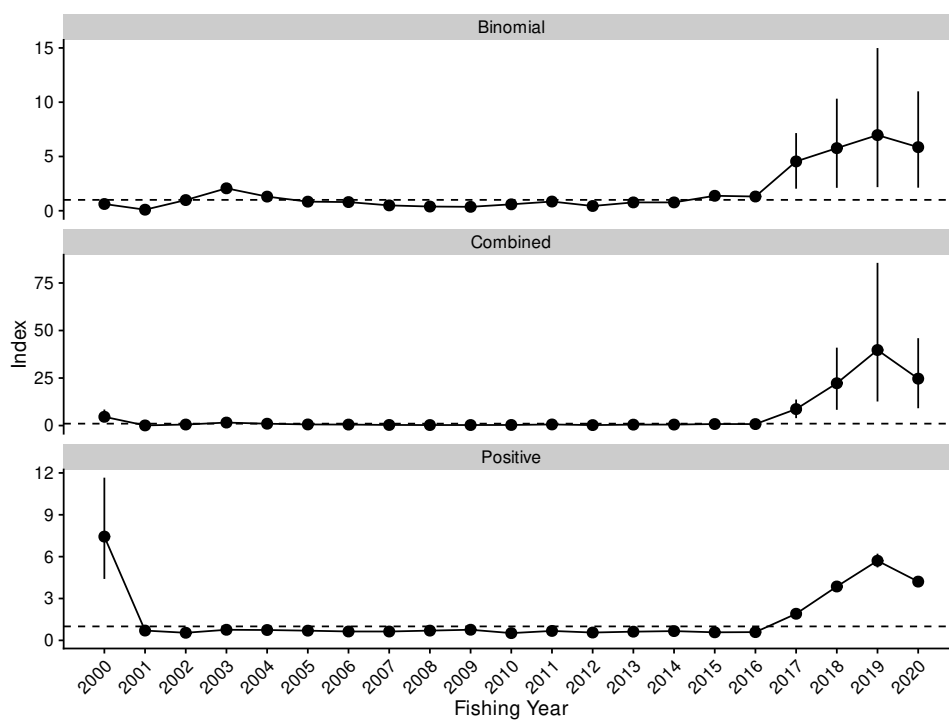


Figure D.60: Standardised indices and 95% confidence intervals for the SKI3 BT+MW SShelf observer dataset.

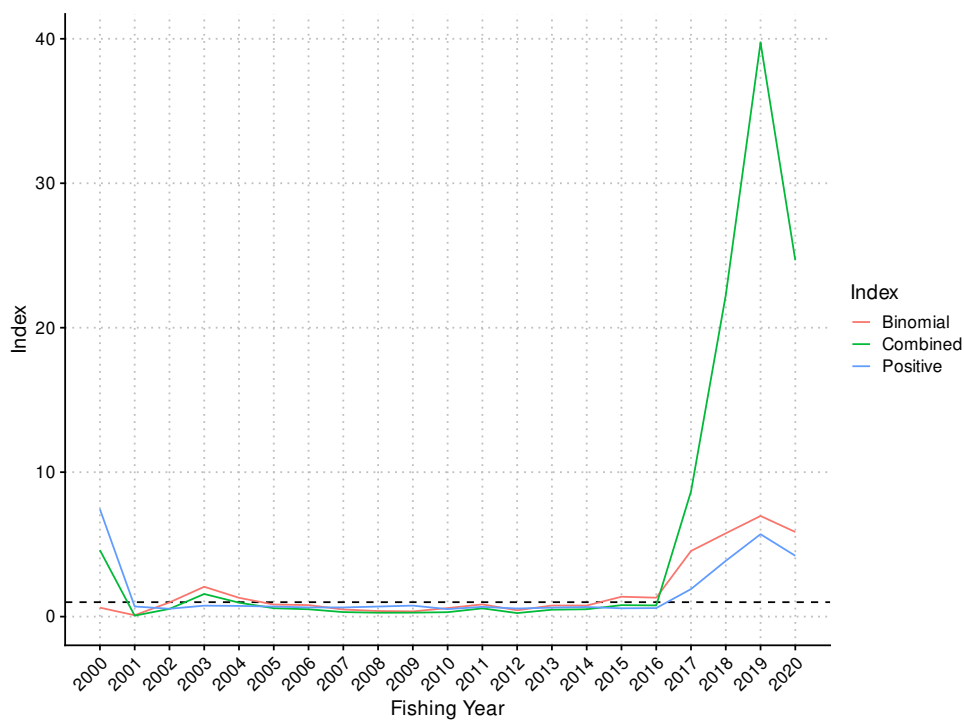


Figure D.61: Standardised indices for the SKI3 BT+MW SShelf observer dataset.

Table D.18: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SKI3 BT+MW SShelf observer.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
2000	0.621	0.148	0.376	0.955	4.598	1.574	2.255	8.425	7.437	1.851	4.403	11.660
2001	0.096	0.029	0.056	0.170	0.067	0.026	0.032	0.133	0.702	0.153	0.457	1.057
2002	0.983	0.108	0.772	1.195	0.535	0.080	0.388	0.702	0.543	0.055	0.442	0.659
2003	2.066	0.215	1.624	2.466	1.567	0.204	1.187	1.987	0.758	0.058	0.650	0.878
2004	1.302	0.106	1.089	1.506	0.966	0.130	0.741	1.250	0.742	0.074	0.603	0.893
2005	0.837	0.095	0.665	1.037	0.581	0.082	0.433	0.754	0.695	0.065	0.576	0.830
2006	0.798	0.107	0.605	1.024	0.508	0.089	0.357	0.706	0.636	0.069	0.514	0.784
2007	0.493	0.095	0.344	0.716	0.313	0.081	0.191	0.508	0.635	0.092	0.467	0.828
2008	0.387	0.083	0.268	0.591	0.270	0.072	0.166	0.447	0.698	0.109	0.507	0.933
2009	0.360	0.087	0.230	0.571	0.274	0.085	0.148	0.482	0.761	0.147	0.515	1.092
2010	0.590	0.096	0.426	0.801	0.306	0.062	0.202	0.445	0.520	0.064	0.407	0.658
2011	0.846	0.103	0.658	1.061	0.572	0.095	0.408	0.780	0.676	0.068	0.558	0.824
2012	0.437	0.090	0.301	0.652	0.245	0.060	0.150	0.385	0.561	0.085	0.409	0.743
2013	0.767	0.092	0.614	0.975	0.478	0.068	0.364	0.629	0.623	0.044	0.540	0.714
2014	0.767	0.093	0.607	0.972	0.510	0.075	0.388	0.681	0.664	0.051	0.571	0.769
2015	1.377	0.087	1.207	1.546	0.794	0.073	0.660	0.945	0.577	0.039	0.506	0.659
2016	1.310	0.087	1.138	1.478	0.774	0.073	0.636	0.922	0.591	0.042	0.516	0.682
2017	4.544	1.307	2.031	7.155	8.664	2.498	3.892	13.685	1.906	0.092	1.731	2.090
2018	5.767	2.095	2.111	10.325	22.253	8.341	8.280	40.976	3.860	0.183	3.503	4.220
2019	6.969	3.269	2.174	14.990	39.730	18.606	12.652	85.588	5.704	0.252	5.225	6.213
2020	5.858	2.264	2.125	11.001	24.669	9.402	9.103	45.959	4.211	0.194	3.851	4.610

D.4 SKI3 BT+MW SShelf daily rollup

Table D.19: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SKI3 BT+MW SShelf daily rollup CPUE series.

Series	SKI3 BT+MW SShelf daily rollup
QMS stock	SKI3
Reporting forms	TCE, TCP, ERS - Trawl, CEL
Fishing methods	BT, MW
Target species	SQU, BAR, HOK, SWA, SKI, LIN
Statistical Areas	025, 026, 027, 028, 029, 030, 504
Period	1989-10-01, 2020-09-30
Resolution	Day
Core fleet years	3
Core fleet trips	1
Default model	$\text{allockg} \sim \text{fyear} + \text{vessel_key} + \text{stat_area} + \text{target_species} + \text{primary_method} + \text{ns}(\log(\text{fishing_duration}), 3) + \text{bs}(\text{SeasonDay}, 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

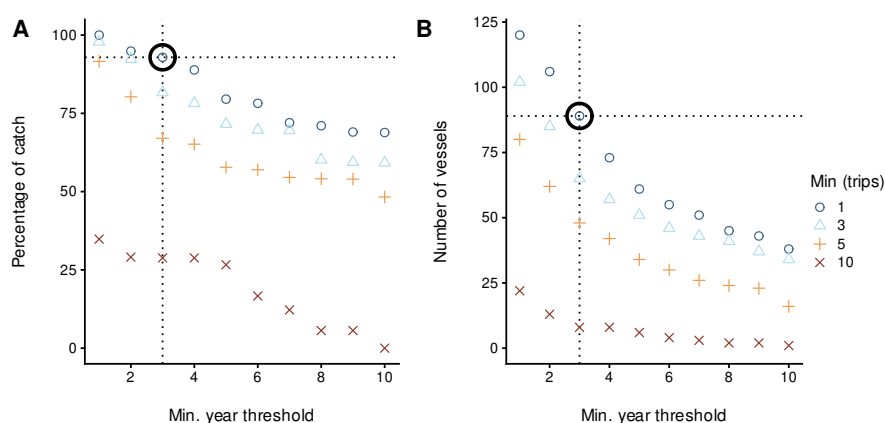


Figure D.62: Percentage of catch and number of vessels for different core vessel selection criteria for the SKI3 BT+MW SShelf daily rollup CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

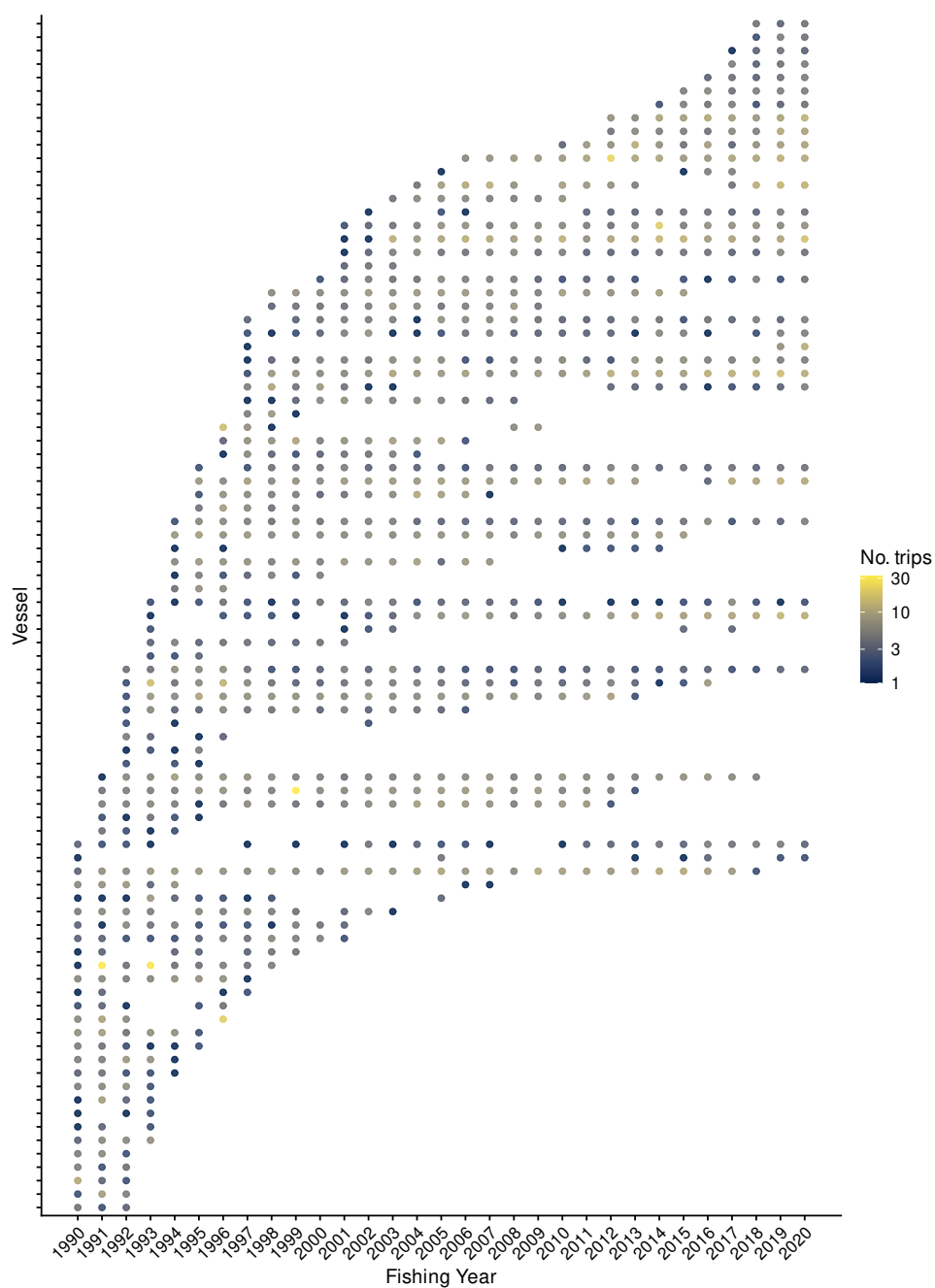


Figure D.63: Number of trips by fishing year for core vessels. The colour of the points is proportional to the number of trips undertaken by a vessel in a fishing year.

Table D.20: Summary of the SKI3 BT+MW SShelf daily rollup dataset total catch (tonnes) and number of records (n), by fishing year after the application of various filters. The first row gives the catch and number of records before filters were applied (ungroomed data). Subsequent rows display the remaining catch (and percent of catch), and the number of records, after the specified filter was applied. (Continued on next page)

Filter	1990	1991	1992	1993	1994	1995	1996	1997	1998
Ungroomed data	408 (100%) n: 1972	164 (100%) n: 3575	110 (100%) n: 3422	195 (100%) n: 3677	27 (100%) n: 2040	49 (100%) n: 2886	6.5 (100%) n: 2618	33 (100%) n: 2961	11 (100%) n: 3183
Fishing duration is not NA	408 (100%) n: 1972	164 (100%) n: 3575	110 (100%) n: 3422	195 (100%) n: 3677	27 (100%) n: 2040	49 (100%) n: 2886	6.5 (100%) n: 2618	33 (100%) n: 2961	11 (100%) n: 3183
Positive fishing duration	408 (100%) n: 1972	164 (100%) n: 3575	110 (100%) n: 3422	195 (100%) n: 3677	27 (100%) n: 2040	49 (100%) n: 2886	6.5 (100%) n: 2618	33 (100%) n: 2961	11 (100%) n: 3183
Core fleet selection	314 (77%) n: 893	113 (69%) n: 1474	108 (100%) n: 1511	188 (100%) n: 1780	27 (100%) n: 1164	49 (100%) n: 1636	6.5 (100%) n: 1529	32 (100%) n: 1882	10 (100%) n: 2368
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	7.8 (100%) n: 3144	36 (100%) n: 2118	36 (100%) n: 2622	45 (100%) n: 2482	60 (100%) n: 2561	47 (100%) n: 2448	42 (100%) n: 3069	11 (100%) n: 2746	7.7 (100%) n: 2243
Fishing duration is not NA	7.8 (100%) n: 3144	36 (100%) n: 2118	36 (100%) n: 2622	45 (100%) n: 2482	60 (100%) n: 2561	47 (100%) n: 2448	42 (100%) n: 3069	11 (100%) n: 2746	7.7 (100%) n: 2243
Positive fishing duration	7.8 (100%) n: 3144	36 (100%) n: 2118	36 (100%) n: 2622	45 (100%) n: 2482	60 (100%) n: 2561	47 (100%) n: 2448	42 (100%) n: 3069	11 (100%) n: 2746	7.7 (100%) n: 2243
Core fleet selection	7.8 (100%) n: 2300	36 (100%) n: 1709	36 (100%) n: 2102	45 (100%) n: 2119	60 (100%) n: 2229	47 (100%) n: 2075	42 (100%) n: 2705	11 (100%) n: 2375	7.7 (100%) n: 1953
Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	4.4 (100%) n: 1783	3 (100%) n: 1367	4.4 (100%) n: 1806	14 (100%) n: 1685	3.9 (100%) n: 1596	4.3 (100%) n: 1531	17 (100%) n: 1338	7.6 (100%) n: 1335	1.2 (100%) n: 1051
Fishing duration is not NA	4.4 (100%) n: 1783	3 (100%) n: 1367	4.4 (100%) n: 1806	14 (100%) n: 1685	3.9 (100%) n: 1596	4.3 (100%) n: 1531	17 (100%) n: 1338	7.6 (100%) n: 1335	1.2 (100%) n: 1051
Positive fishing duration	4.4 (100%) n: 1783	3 (100%) n: 1367	4.4 (100%) n: 1806	14 (100%) n: 1685	3.9 (100%) n: 1596	4.3 (100%) n: 1531	17 (100%) n: 1338	7.6 (100%) n: 1335	1.2 (100%) n: 1050
Core fleet selection	4.4 (100%) n: 1658	3 (100%) n: 1307	4.4 (100%) n: 1745	13 (100%) n: 1576	3.9 (100%) n: 1526	4.3 (100%) n: 1486	17 (100%) n: 1288	7.6 (100%) n: 1293	1.2 (100%) n: 976

Filter	2017	2018	2019	2020
Ungroomed data	104 (100%) n: 1349	205 (100%) n: 1131	295 (100%) n: 1645	215 (100%) n: 1651
Fishing duration is not NA	104 (100%) n: 1349	205 (100%) n: 1131	295 (100%) n: 1645	215 (100%) n: 1651
Positive fishing duration	104 (100%) n: 1349	205 (100%) n: 1130	295 (100%) n: 1645	215 (100%) n: 1651
Core fleet selection	104 (100%) n: 1314	205 (100%) n: 1111	295 (100%) n: 1627	215 (100%) n: 1611

Table D.21: Summary of the SKI3 BT+MW SShelf daily rollup dataset after core fleet selection. ‘Records’ indicates the number of rows (days) in the dataset, and ‘Records caught’ indicates the percentage of days with catches of gemfish.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
1990	28	100	893	9 924.20	313.91	24.08
1991	31	167	1 474	16 204.73	113.49	15.74
1992	37	135	1 511	15 537.45	108.44	9.00
1993	34	169	1 780	18 622.33	188.34	6.69
1994	33	126	1 164	13 526.30	27.17	4.30
1995	34	147	1 636	18 896.12	49.11	4.40
1996	33	194	1 529	17 691.11	6.51	1.31
1997	39	163	1 882	21 383.52	32.17	2.18
1998	36	159	2 368	27 092.42	10.30	1.27
1999	35	179	2 300	28 021.54	7.82	0.35
2000	30	138	1 709	21 230.98	35.81	1.40
2001	37	160	2 102	24 039.00	35.80	3.57
2002	36	171	2 119	23 868.45	44.83	5.62
2003	35	183	2 229	25 942.40	59.64	8.84
2004	32	181	2 075	21 999.33	47.01	4.48
2005	35	196	2 705	31 535.45	42.38	2.51
2006	34	186	2 375	29 402.43	10.73	1.47
2007	31	170	1 953	25 248.34	7.69	0.67
2008	28	147	1 658	20 699.41	4.37	1.15
2009	26	143	1 307	15 933.83	3.00	0.31
2010	28	152	1 745	22 275.12	4.39	0.17
2011	27	151	1 576	19 530.60	13.05	1.84
2012	31	177	1 526	18 485.61	3.91	0.72
2013	31	155	1 486	17 186.33	4.29	1.08
2014	26	166	1 288	14 955.54	17.22	3.26
2015	30	156	1 293	15 703.05	7.56	0.70
2016	29	157	976	10 310.72	1.19	0.82
2017	30	159	1 314	15 382.28	103.78	6.24
2018	31	162	1 111	13 214.17	205.14	12.15
2019	31	197	1 627	19 087.83	295.40	23.91
2020	31	209	1 611	19 055.57	214.96	23.77

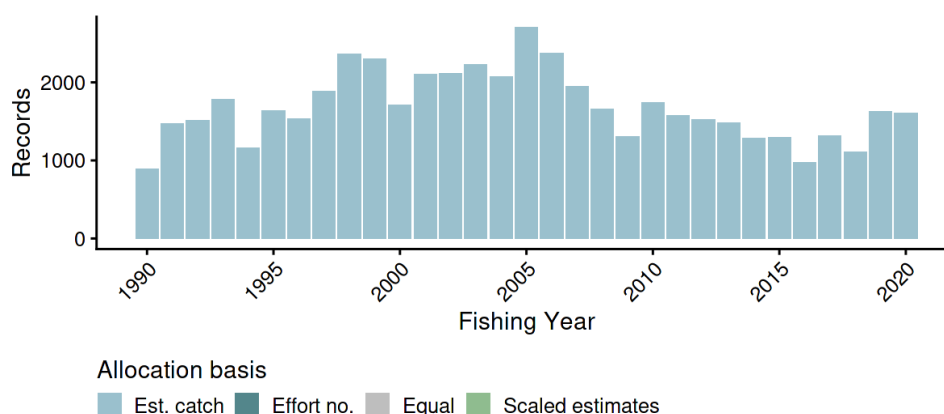


Figure D.64: Allocation basis for attributing landings to records in the SKI3 BT+MW SShelf daily rollup catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table D.22: Summary of stepwise selection for occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	29.00	17 688	16.60	16.60	*
+ vessel_key	88.00	16 299	24.00	7.40	*
+ stat_area	6.00	14 909	30.60	6.60	*
+ bs(SeasonDay, 3)	3.00	13 421	37.70	7.10	*
+ target_species	5.00	12 904	40.20	2.50	*
+ ns(log(fishing_duration), 3)	3.00	12 867	40.40	0.20	
+ primary_method	1.00	12 852	40.50	0.10	

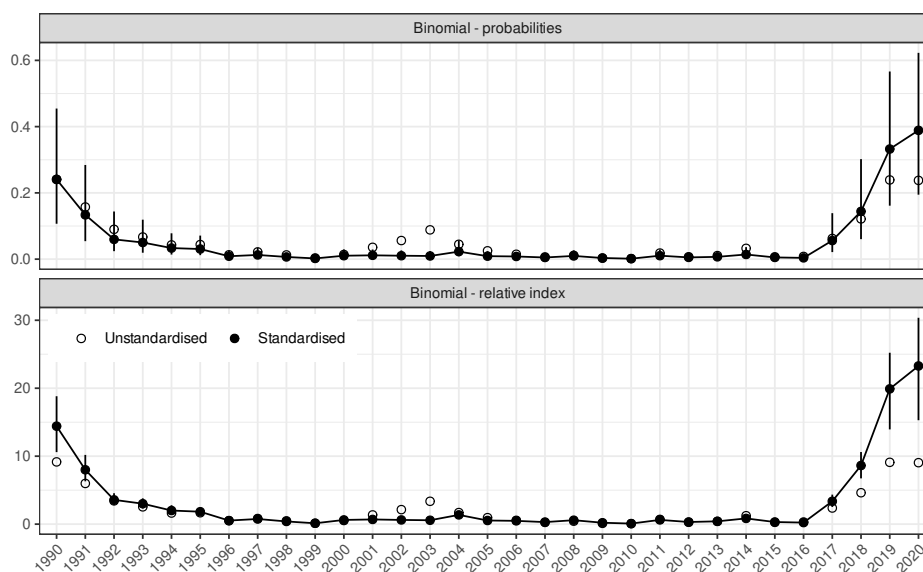


Figure D.65: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SKI3 BT+MW SShelf daily rollup dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

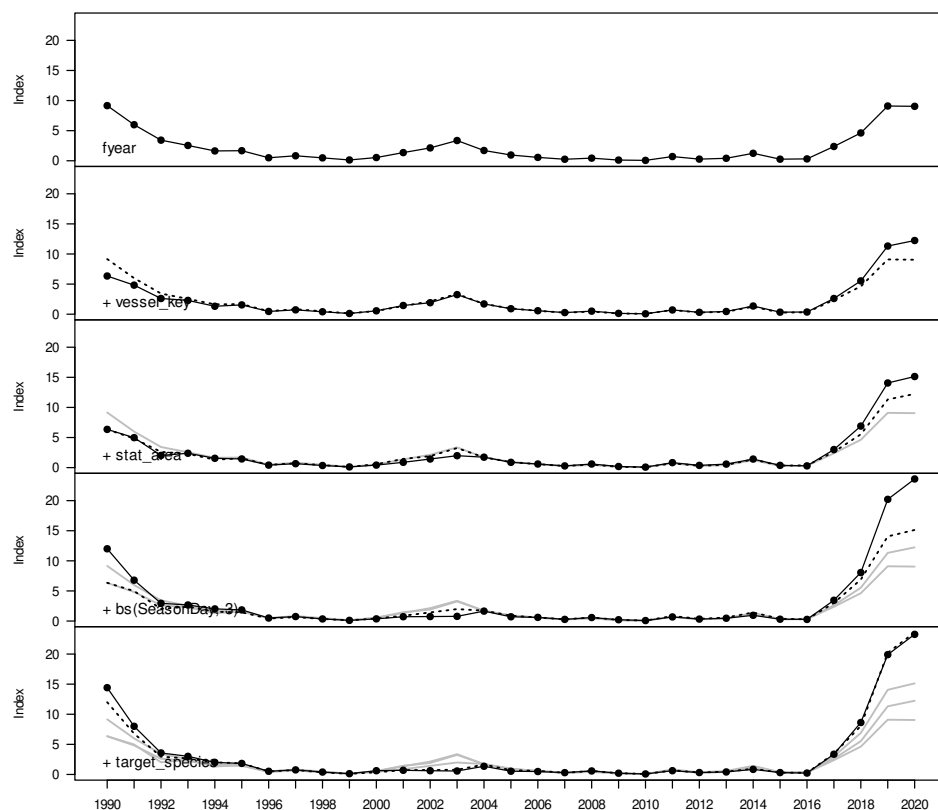


Figure D.66: Step plot for occurrence of catch in the SKI3 BT+MW SShelf daily rollout dataset.

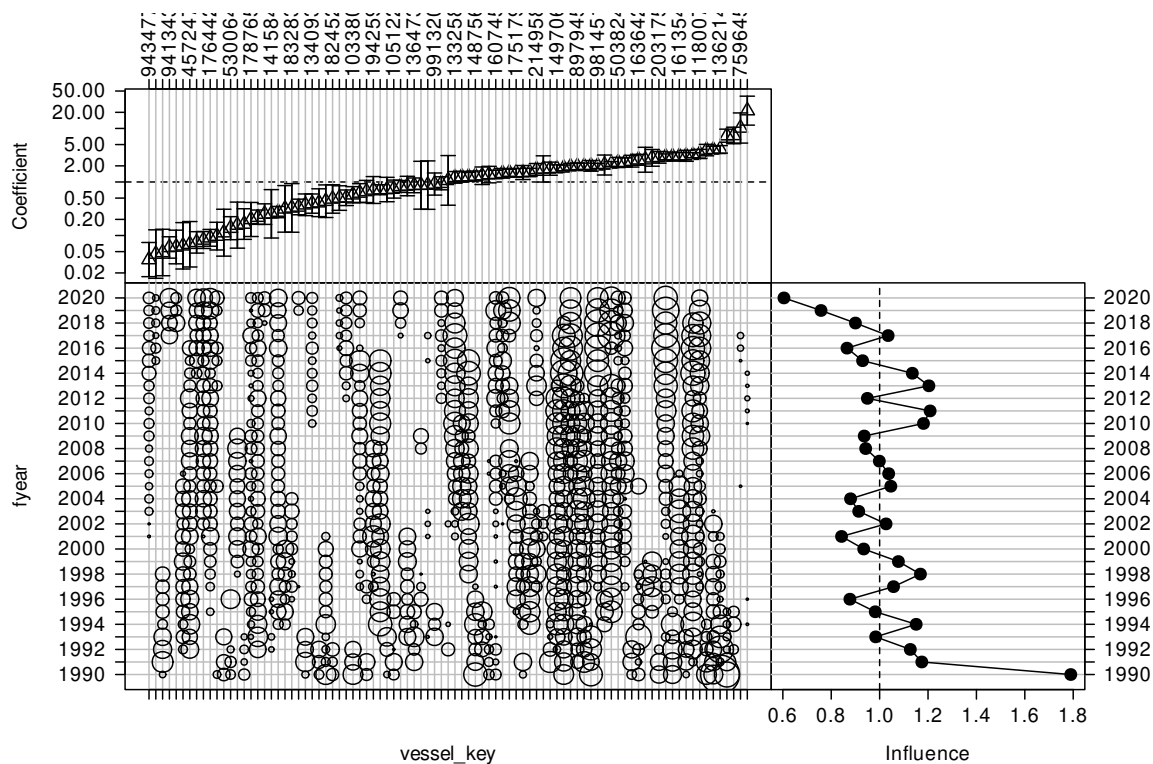


Figure D.67: CDI plot for vessel key for the occurrence of positive catch SKI3 BT+MW SShelf daily rollout catch-per-unit-effort dataset.

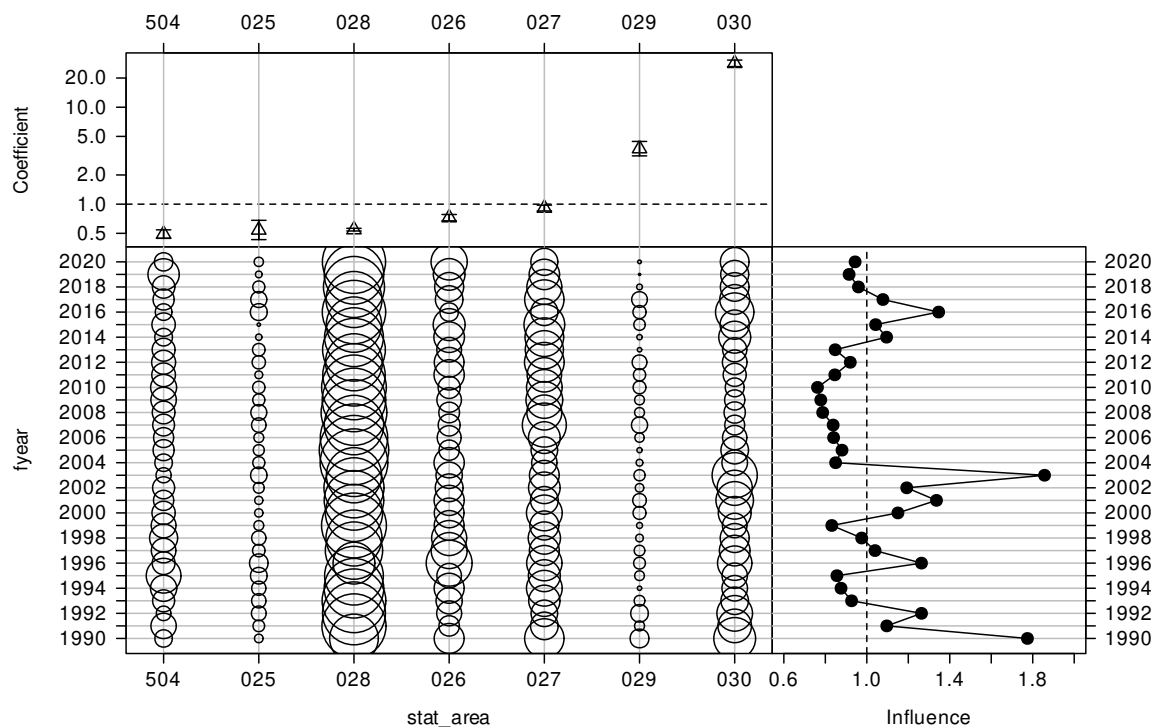


Figure D.68: CDI plot for statistical area for the occurrence of positive catch SKI3 BT+MW SShelf daily rollup catch-per-unit-effort dataset.

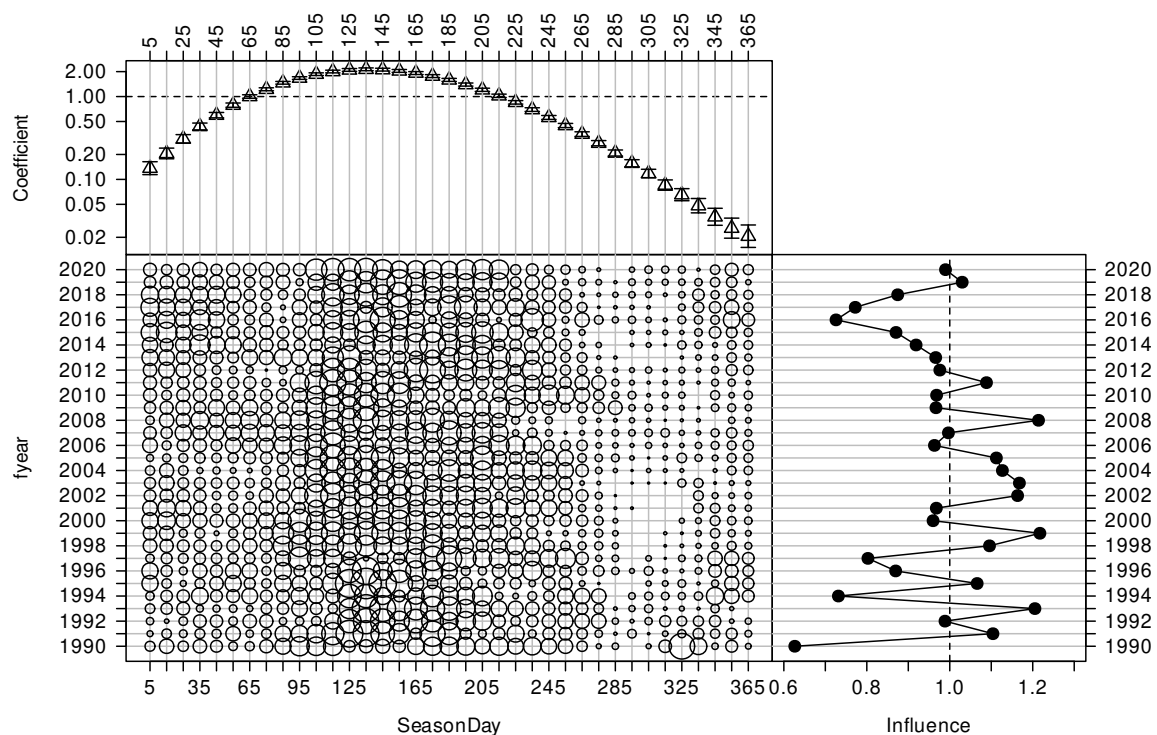


Figure D.69: CDI plot for SeasonDay for the occurrence of positive catch SKI3 BT+MW SShelf daily rollup catch-per-unit-effort dataset.

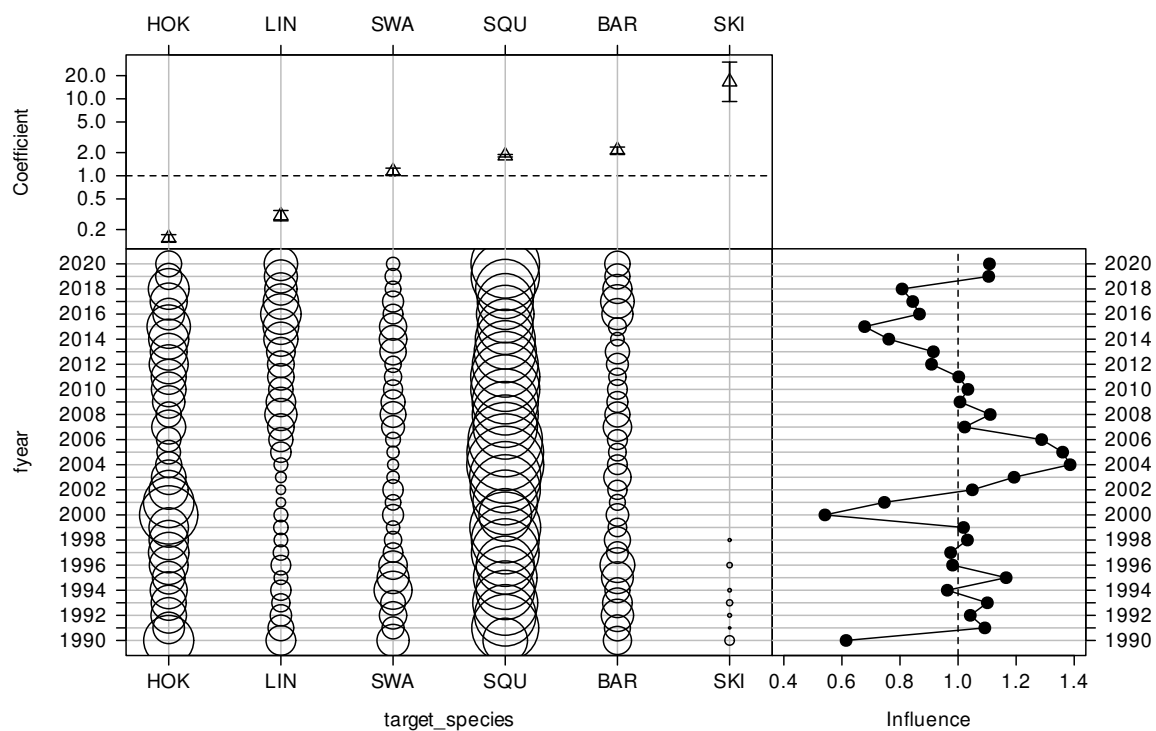


Figure D.70: CDI plot for target species for the occurrence of positive catch SKI3 BT+MW SShelf daily rollup catch-per-unit-effort dataset.

Table D.23: Summary of stepwise selection for the lognormal model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	29	8 759	9.9	9.9	*
+ vessel key	88	8 120	33.5	23.6	*
+ stat area	6	7 970	37.4	3.9	*
+ ns(log(fishing duration), 3)	3	7 851	40.3	2.8	*
+ target species	5	7 770	42.3	2.0	*
+ bs(SeasonDay, 3)	3	7 751	42.8	0.5	
+ primary method	1	7 750	42.9	0.1	

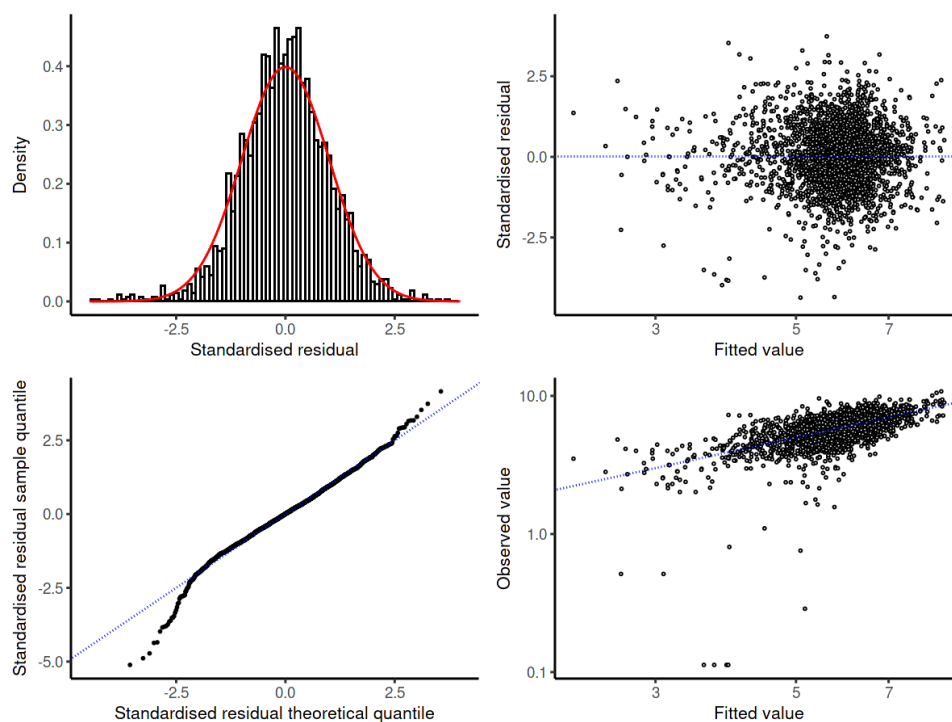


Figure D.71: Diagnostic plots for the lognormal model for the SKI3 BT+MW SShelf daily rollup dataset.

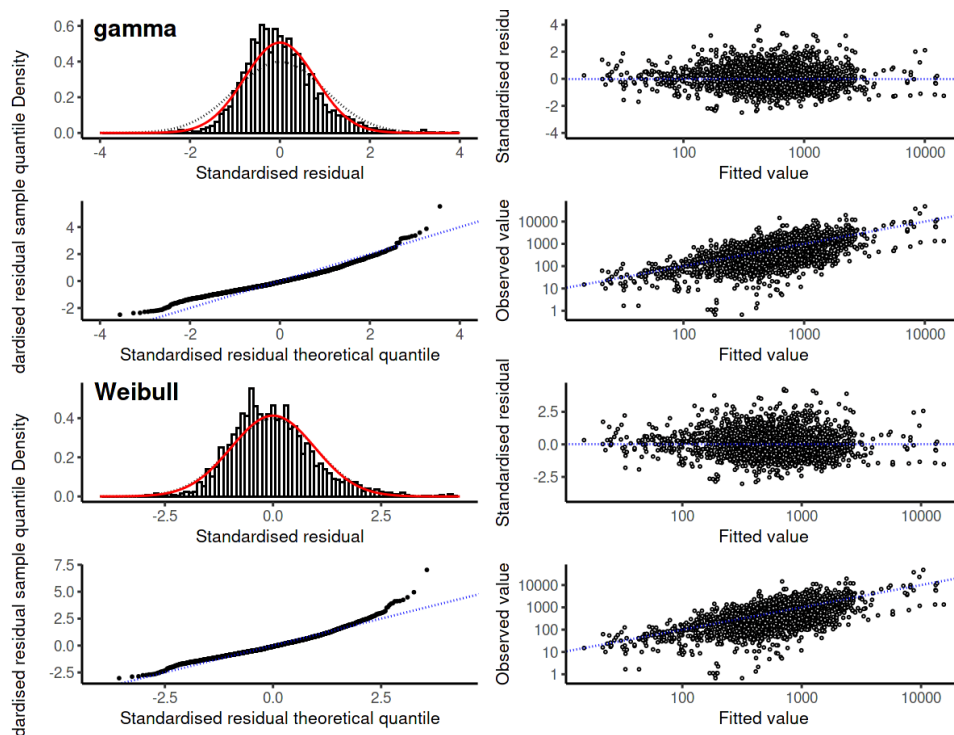


Figure D.72: Diagnostic plots for the gamma and Weibull model for the SKI3 BT+MW SShelf daily rollup dataset.

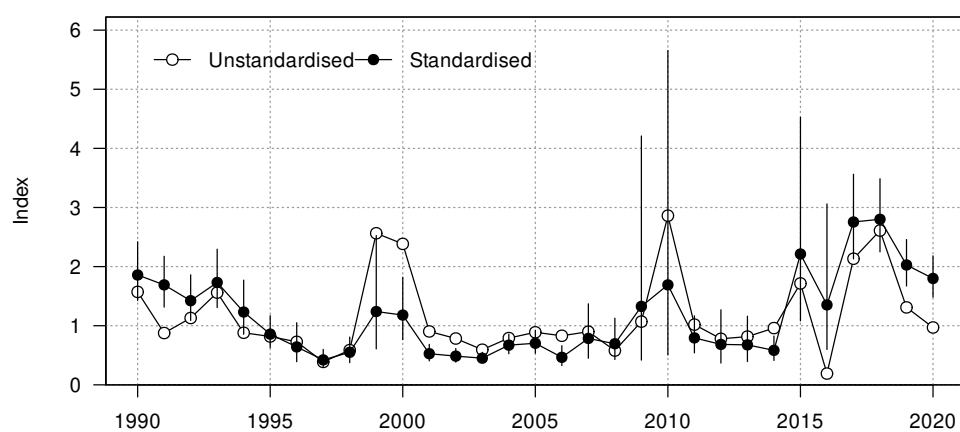


Figure D.73: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SKI3 BT+MW SShelf daily rollup dataset.

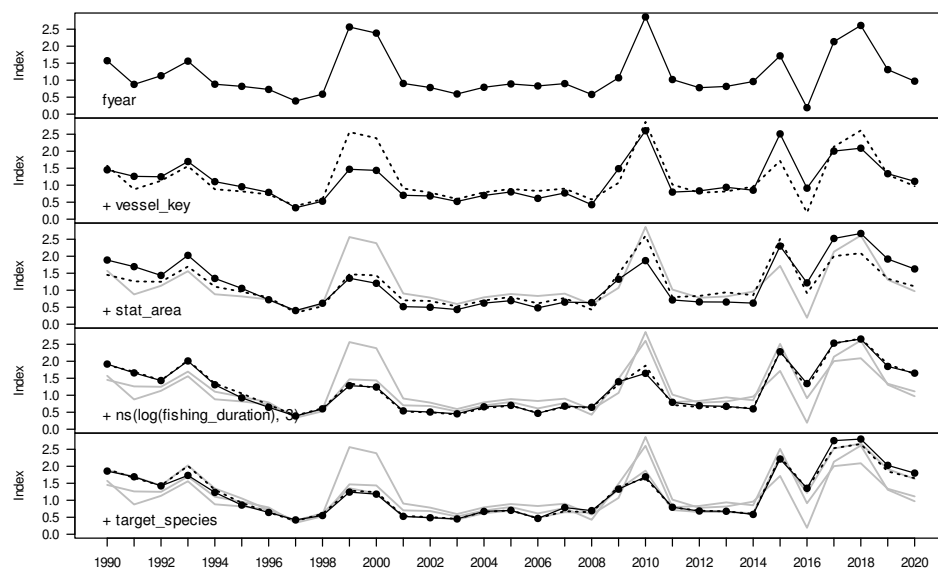


Figure D.74: Changes to the SKI3 BT+MW SShelf daily rollup positive catch index as terms are successively entered into the model.

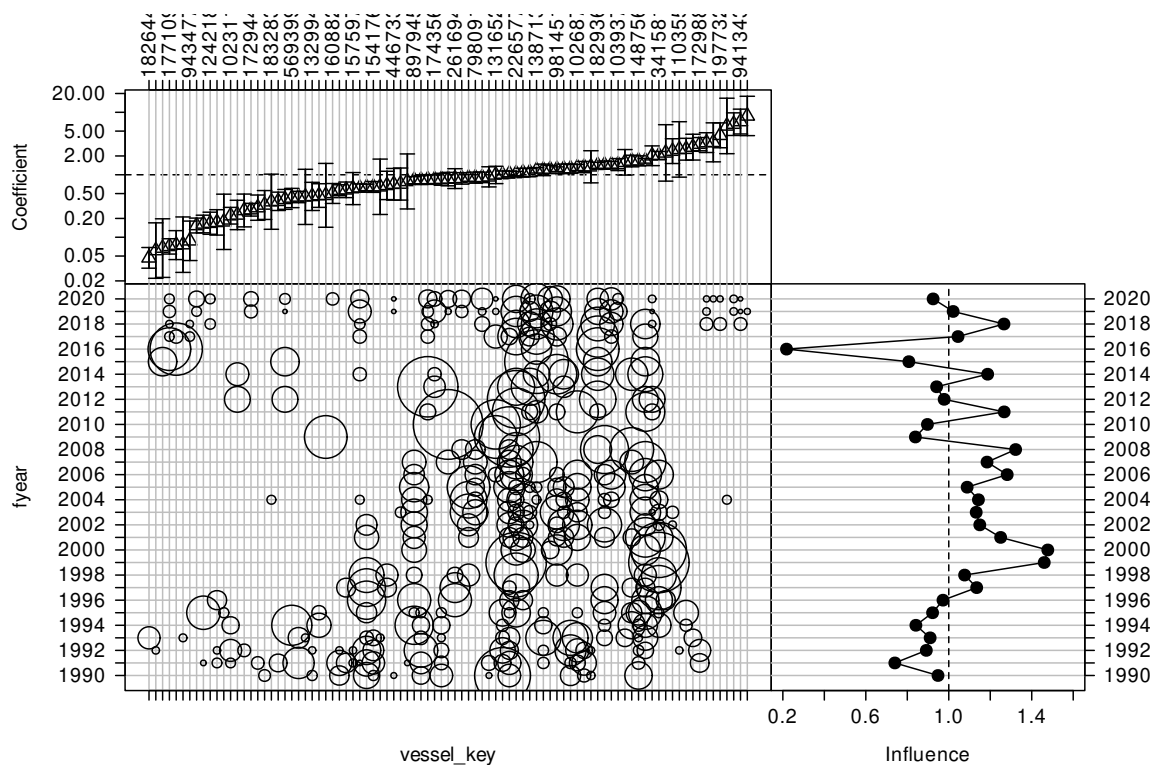


Figure D.75: CDI plot for vessel key for the positive catch SKI3 BT+MW SShelf daily rollup catch-per-unit-effort dataset.

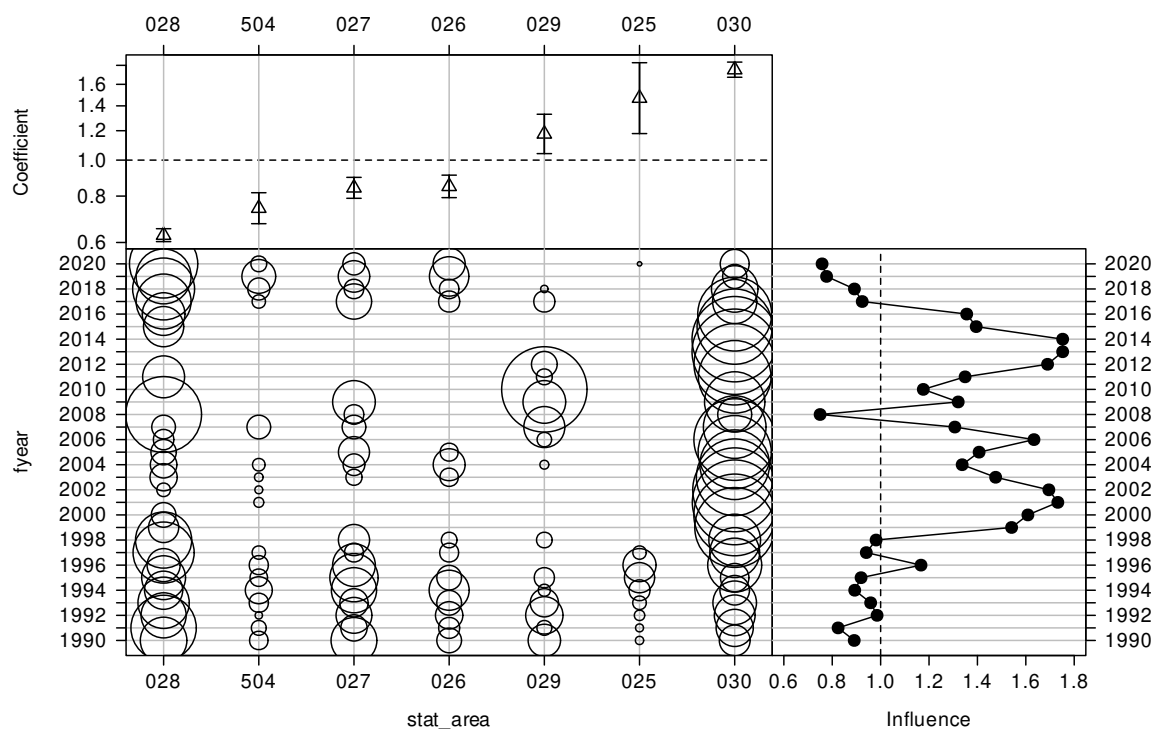


Figure D.76: CDI plot for statistical area for the positive catch SKI3 BT+MW SSshelf daily rollup catch-per-unit-effort dataset.

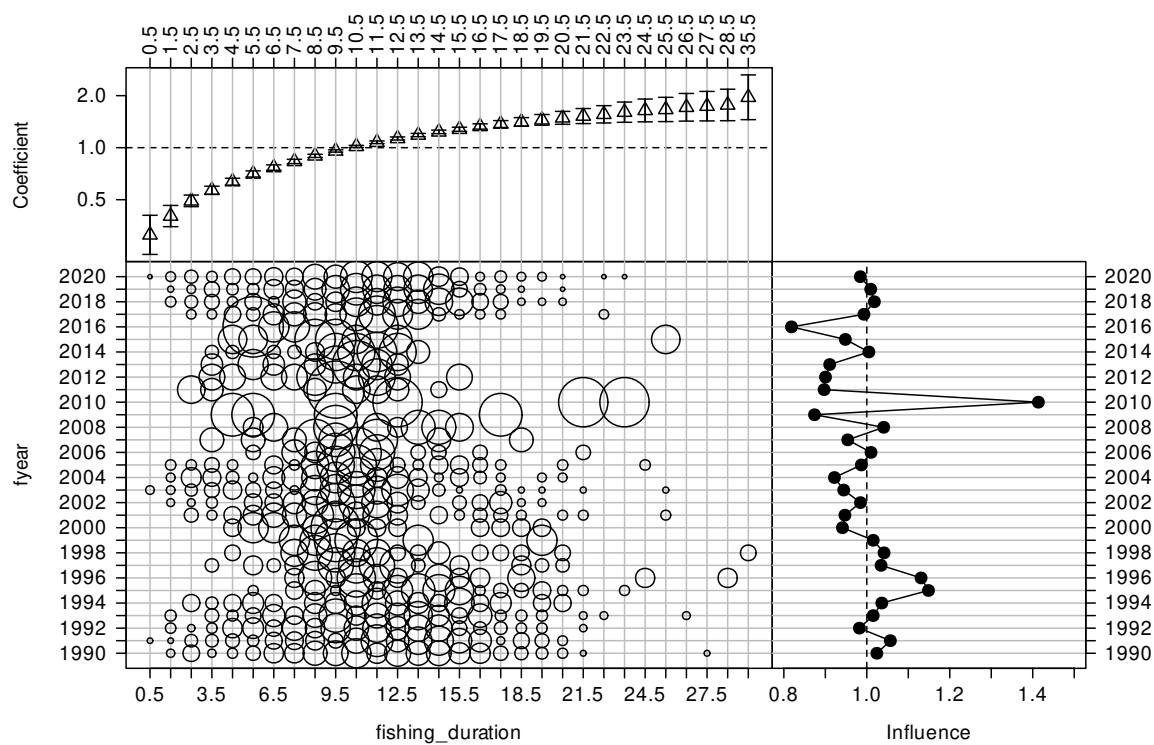


Figure D.77: CDI plot for fishing duration (h) for the positive catch SKI3 BT+MW SSshelf daily rollup catch-per-unit-effort dataset.

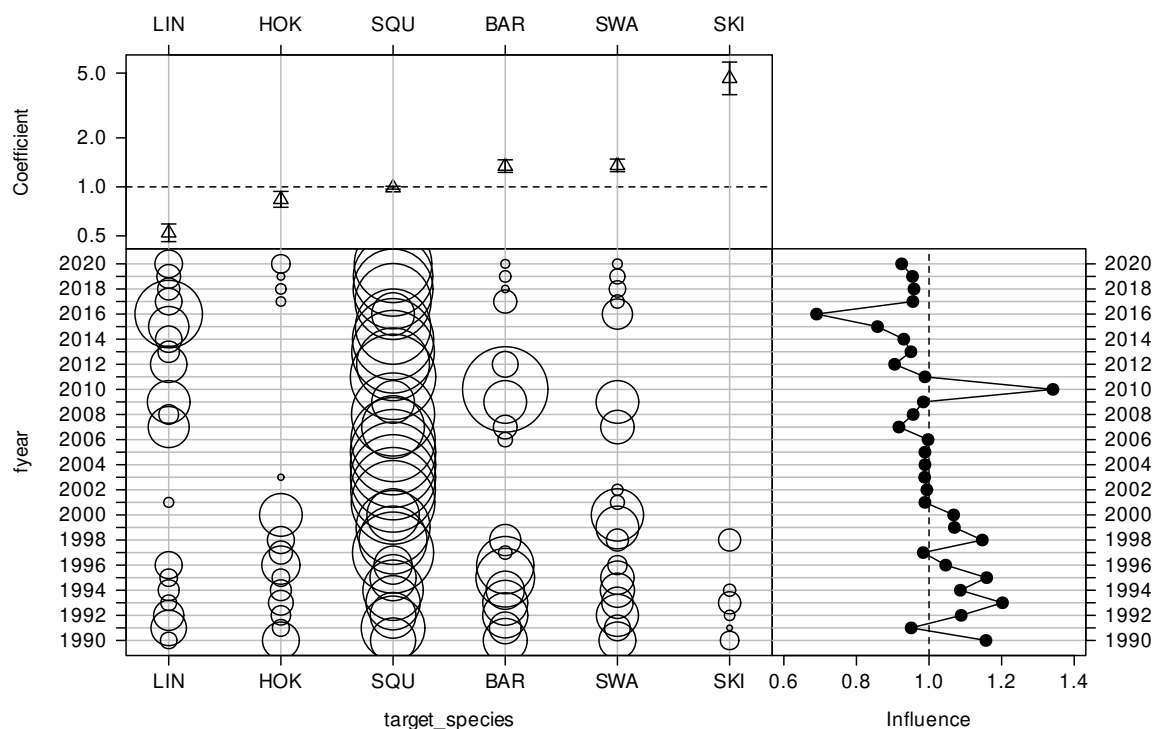


Figure D.78: CDI plot for target species for the positive catch SKI3 BT+MW SShelf daily rollup catch-per-unit-effort dataset.

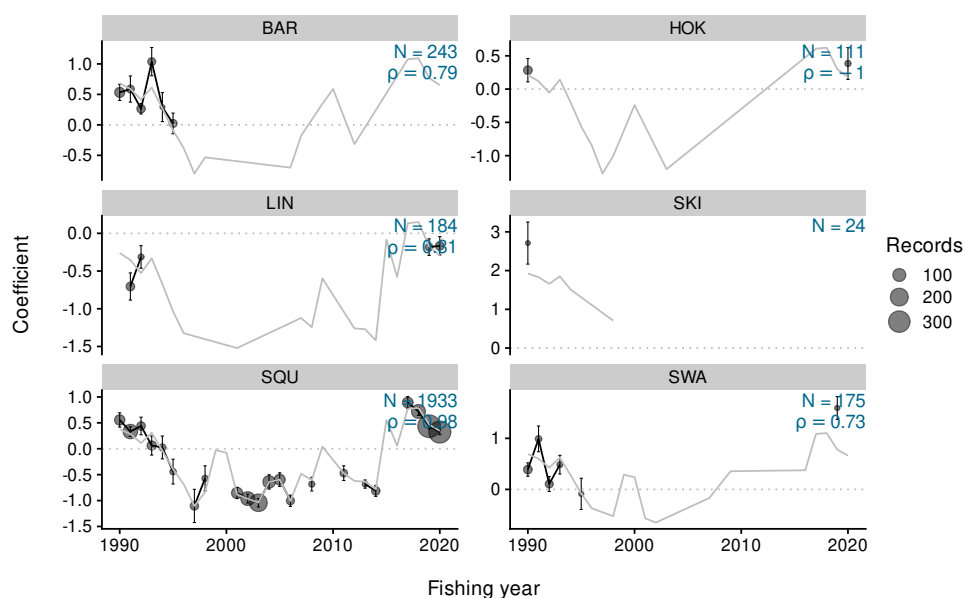


Figure D.79: Residual implied coefficients for target-year in the lognormal positive catch model for the SKI3 BT+MW SShelf daily rollup dataset.

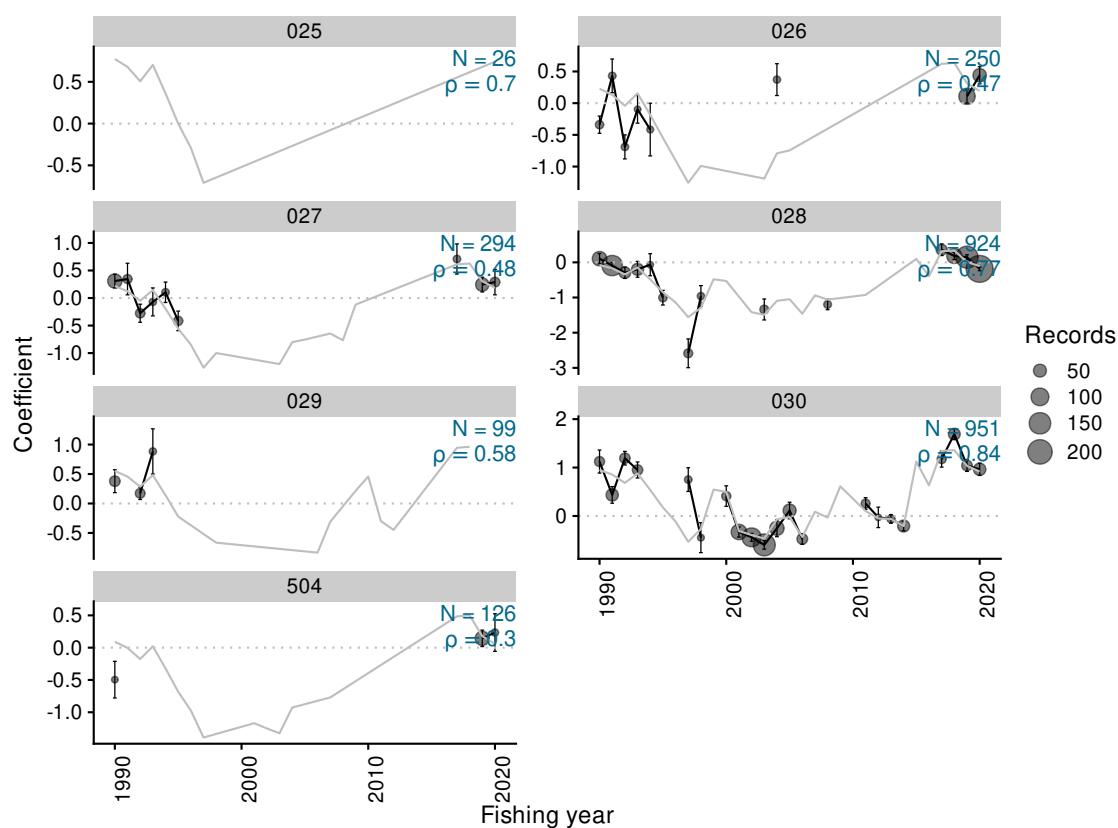


Figure D.80: Residual implied coefficients for area-year in the lognormal positive catch model for the SKI3 BT+MW SShelf daily rollup dataset.

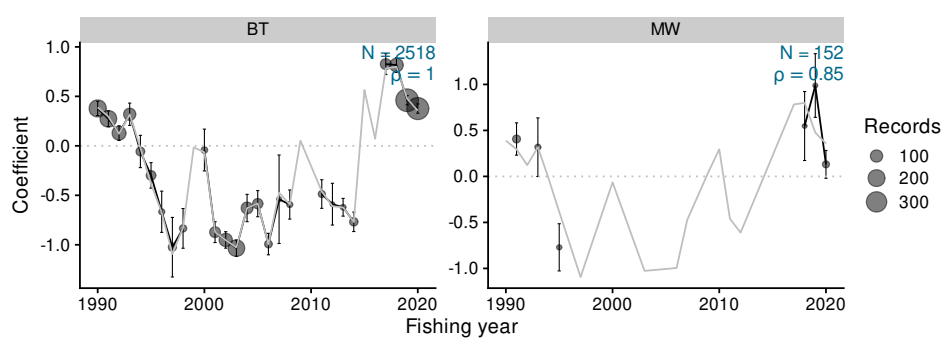


Figure D.81: Residual implied coefficients for primary method-year in the lognormal positive catch model for the SKI3 BT+MW SShelf daily rollup dataset.

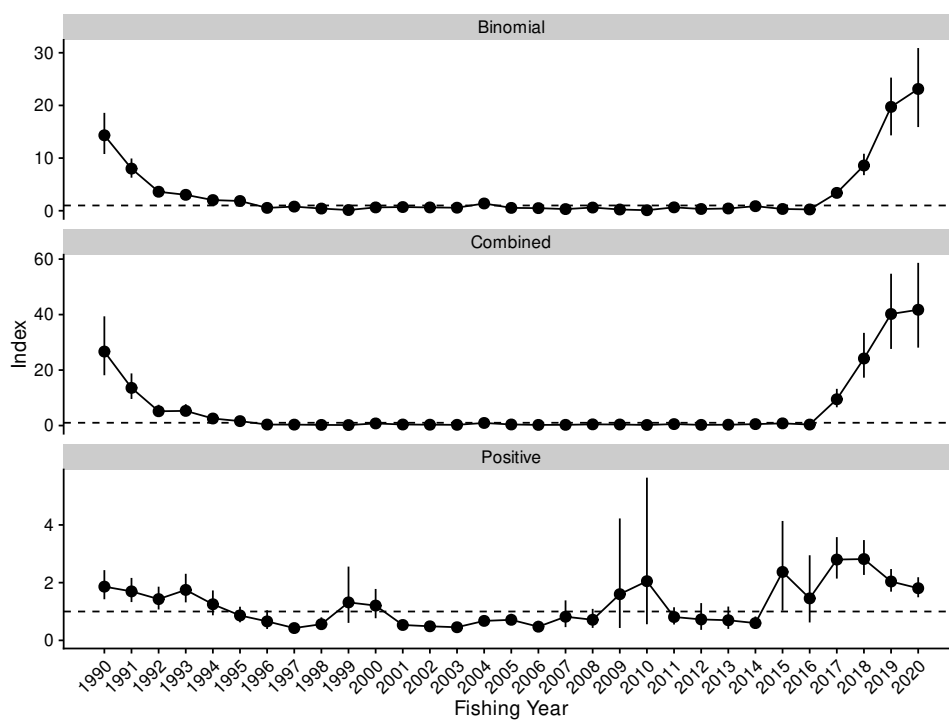


Figure D.82: Standardised indices and 95% confidence intervals for the SKI3 BT+MW SShelf daily rollup dataset.

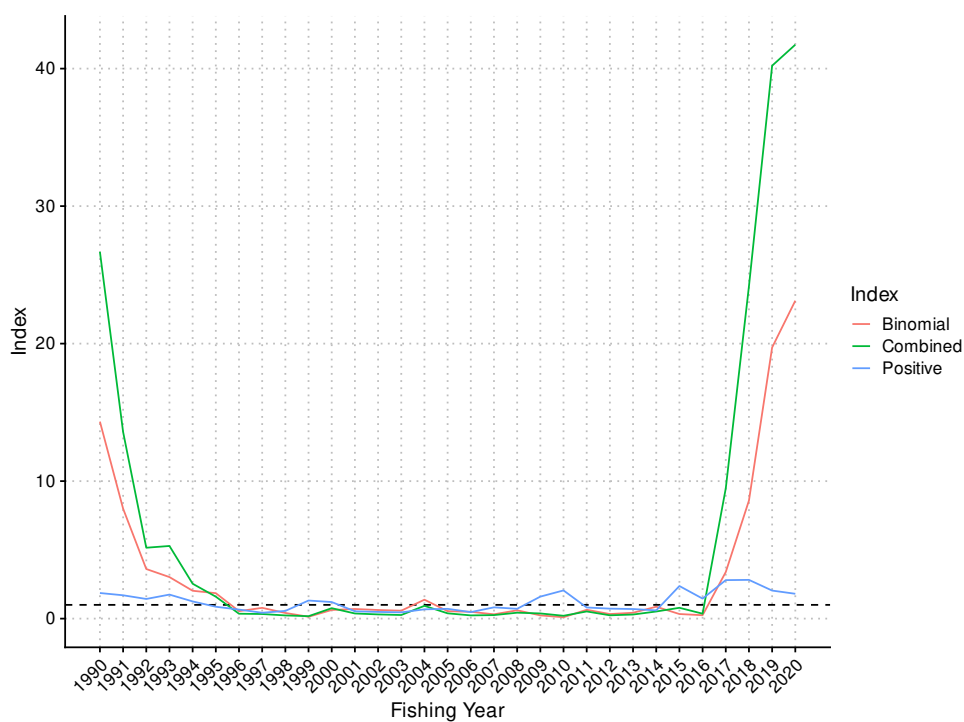


Figure D.83: Standardised indices for the SKI3 BT+MW SShelf daily rollup dataset.

Table D.24: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SKI3 BT+MW SShelf daily rollup.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	14.327	1.994	10.772	18.588	26.670	5.418	18.136	39.374	1.862	0.257	1.425	2.433
1991	7.999	0.931	6.275	9.923	13.577	2.348	9.587	18.792	1.697	0.213	1.327	2.163
1992	3.607	0.466	2.771	4.598	5.155	1.014	3.519	7.493	1.430	0.201	1.070	1.860
1993	3.021	0.381	2.341	3.835	5.283	1.050	3.584	7.699	1.748	0.253	1.317	2.307
1994	2.026	0.319	1.450	2.700	2.538	0.630	1.524	3.995	1.251	0.220	0.869	1.730
1995	1.850	0.251	1.401	2.386	1.596	0.326	1.053	2.332	0.864	0.138	0.625	1.166
1996	0.542	0.129	0.326	0.830	0.356	0.124	0.174	0.658	0.657	0.166	0.393	1.043
1997	0.784	0.137	0.545	1.084	0.334	0.081	0.199	0.518	0.426	0.076	0.302	0.602
1998	0.412	0.086	0.271	0.607	0.231	0.065	0.131	0.386	0.560	0.105	0.385	0.798
1999	0.135	0.044	0.065	0.240	0.176	0.084	0.062	0.391	1.316	0.498	0.606	2.556
2000	0.630	0.141	0.401	0.954	0.759	0.242	0.398	1.347	1.205	0.259	0.766	1.781
2001	0.700	0.097	0.527	0.907	0.373	0.073	0.250	0.536	0.533	0.069	0.407	0.678
2002	0.627	0.076	0.488	0.787	0.306	0.053	0.211	0.420	0.487	0.057	0.383	0.607
2003	0.577	0.068	0.457	0.724	0.262	0.040	0.191	0.348	0.455	0.043	0.380	0.550
2004	1.377	0.174	1.065	1.748	0.929	0.164	0.650	1.293	0.675	0.080	0.527	0.843
2005	0.541	0.080	0.411	0.725	0.385	0.073	0.260	0.546	0.712	0.096	0.543	0.920
2006	0.495	0.089	0.340	0.687	0.235	0.061	0.139	0.378	0.474	0.087	0.336	0.677
2007	0.313	0.091	0.164	0.521	0.256	0.109	0.109	0.535	0.819	0.236	0.458	1.385
2008	0.604	0.148	0.369	0.949	0.430	0.149	0.216	0.800	0.714	0.168	0.432	1.091
2009	0.236	0.121	0.080	0.552	0.377	0.313	0.063	1.288	1.600	0.968	0.429	4.225
2010	0.100	0.061	0.029	0.267	0.207	0.183	0.031	0.747	2.050	1.296	0.559	5.638
2011	0.642	0.128	0.430	0.930	0.520	0.143	0.298	0.860	0.810	0.152	0.549	1.146
2012	0.333	0.107	0.169	0.589	0.241	0.107	0.094	0.512	0.726	0.237	0.364	1.291
2013	0.425	0.113	0.245	0.688	0.297	0.116	0.130	0.585	0.697	0.197	0.398	1.171
2014	0.865	0.175	0.573	1.258	0.518	0.134	0.298	0.823	0.598	0.104	0.421	0.827
2015	0.334	0.118	0.158	0.619	0.787	0.378	0.263	1.746	2.371	0.793	1.031	4.138
2016	0.247	0.089	0.111	0.461	0.359	0.209	0.109	0.928	1.455	0.594	0.620	2.949
2017	3.389	0.453	2.607	4.381	9.471	1.697	6.583	13.234	2.800	0.367	2.141	3.578
2018	8.586	1.037	6.757	10.823	24.174	4.121	17.255	33.411	2.817	0.308	2.267	3.475
2019	19.719	2.798	14.313	25.280	40.211	6.915	27.622	54.729	2.040	0.200	1.688	2.471
2020	23.123	3.828	15.890	30.896	41.740	7.796	28.089	58.648	1.807	0.177	1.493	2.187

D.5 SKI3 BT+MW east coast daily rollup

Table D.25: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SKI3 BT+MW east coast daily rollup CPUE series.

Series	SKI3 BT+MW east coast daily rollup
QMS stock	SKI3
Reporting forms	TCE, TCP, ERS - Trawl, CEL
Fishing methods	BT, MW
Target species	SQU, BAR, HOK, RCO, TAR
Statistical Areas	020, 022
Period	2001-10-01, 2020-09-30
Resolution	Day
Core fleet years	2
Core fleet trips	1
Default model	$\text{allockg} \sim \text{fyear} + \text{vessel_key} + \text{stat_area} + \text{target_species} + \text{primary_method} + \text{ns}(\log(\text{fishing_duration}), 3) + \text{bs}(\text{SeasonDay}, 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

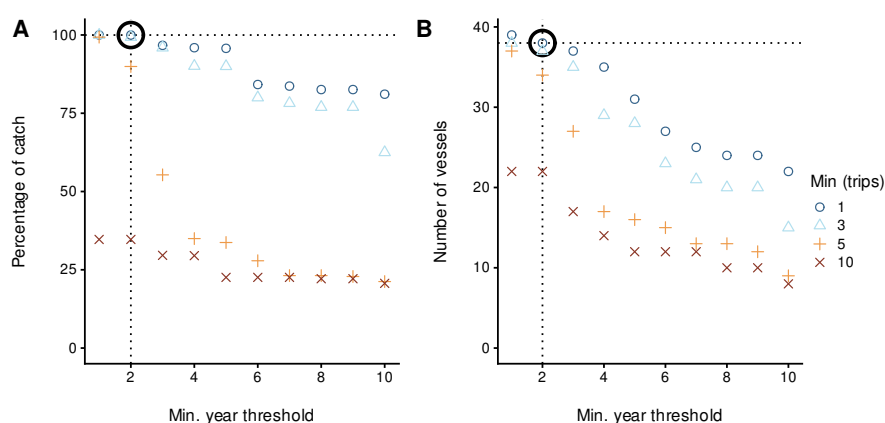


Figure D.84: Percentage of catch and number of vessels for different core vessel selection criteria for the SKI3 BT+MW east coast daily rollup CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

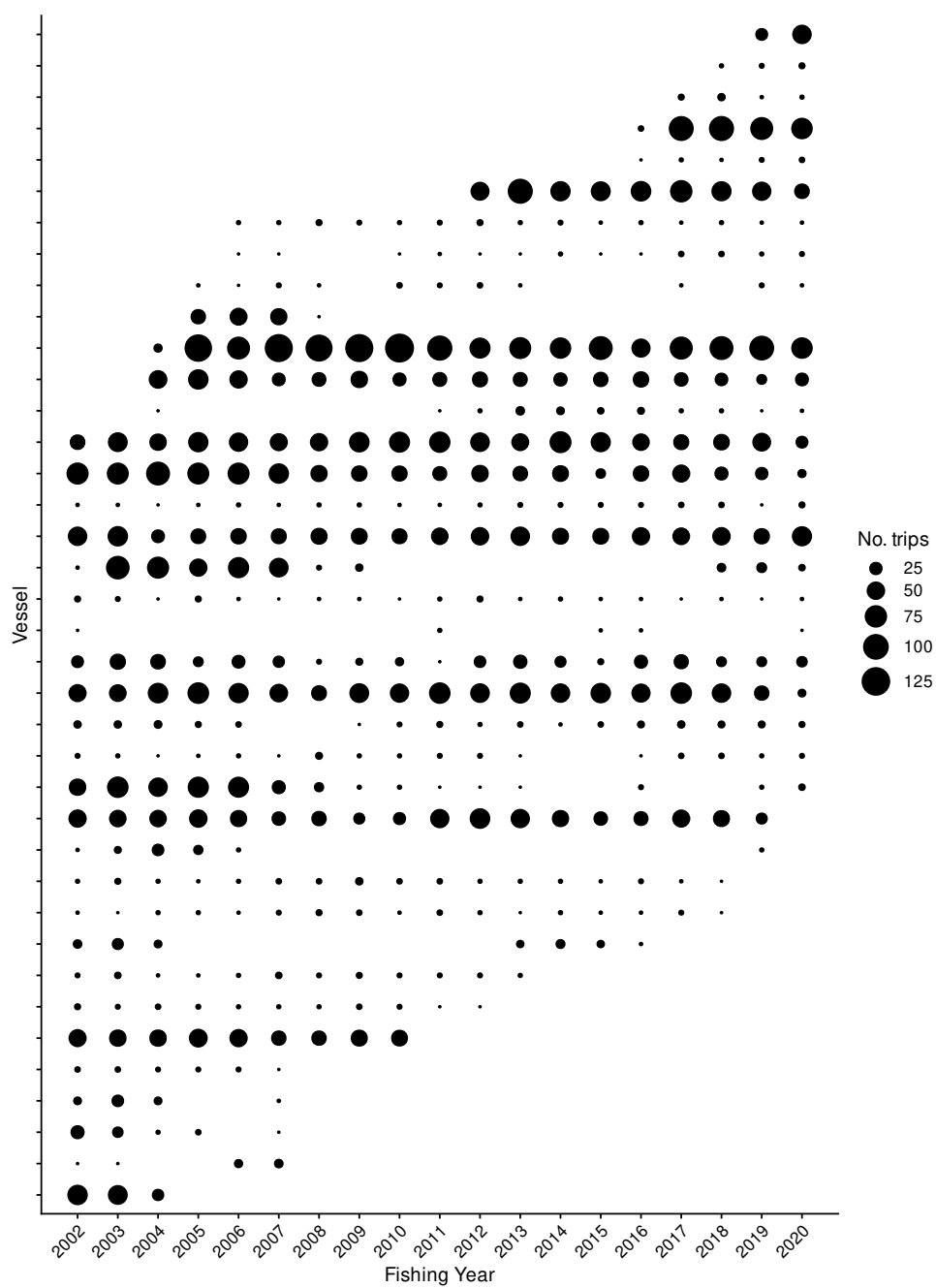


Figure D.85: Number of trips by fishing year for core vessels. The area of the circles is proportional to the number of trips undertaken by a vessel in a fishing year.

Table D.26: Summary of the SKI3 BT+MW east coast daily rollup dataset total catch (tonnes) and number of records (n), by fishing year after the application of various filters. The first row gives the catch and number of records before filters were applied (ungroomed data). Subsequent rows display the remaining catch (and percent of catch), and the number of records, after the specified filter was applied. (Continued on next page)

Filter	2002	2003	2004	2005	2006	2007	2008	2009	2010
Ungroomed data	1.4 (100%) n: 3181	5.9 (100%) n: 3759	0.63 (100%) n: 3226	0.17 (100%) n: 3431	0.057 (100%) n: 3090	0.57 (100%) n: 2534	0 (100%) n: 1890	2.7 (100%) n: 2097	0.4 (100%) n: 2169
Fishing duration is not NA	1.4 (100%) n: 3181	5.9 (100%) n: 3759	0.63 (100%) n: 3225	0.17 (100%) n: 3431	0.057 (100%) n: 3090	0.57 (100%) n: 2534	0 n: 1890	2.7 (100%) n: 2097	0.4 (100%) n: 2169
Positive fishing duration	1.4 (100%) n: 3181	5.9 (100%) n: 3759	0.63 (100%) n: 3225	0.17 (100%) n: 3431	0.057 (100%) n: 3090	0.57 (100%) n: 2534	0 n: 1890	2.7 (100%) n: 2097	0.4 (100%) n: 2169
Core fleet selection	1.4 (100%) n: 1438	5.9 (100%) n: 1660	0.63 (100%) n: 1426	0.17 (100%) n: 1697	0.057 (100%) n: 1588	0.57 (100%) n: 1413	0 n: 948	2.7 (100%) n: 1062	0.4 (100%) n: 981
Filter	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ungroomed data	1.5 (100%) n: 2009	0.039 (100%) n: 1808	0.44 (100%) n: 1927	0.054 (100%) n: 1945	0 (100%) n: 1532	58 (100%) n: 1494	34 (100%) n: 2008	55 (100%) n: 1759	43 (100%) n: 1331
Fishing duration is not NA	1.5 (100%) n: 2009	0.039 (100%) n: 1808	0.44 (100%) n: 1927	0.054 (100%) n: 1945	0 n: 1532	58 (100%) n: 1494	34 (100%) n: 2008	55 (100%) n: 1758	43 (100%) n: 1331
Positive fishing duration	1.5 (100%) n: 2009	0.039 (100%) n: 1808	0.44 (100%) n: 1927	0.054 (100%) n: 1945	0 n: 1532	58 (100%) n: 1494	34 (100%) n: 2008	55 (100%) n: 1758	43 (100%) n: 1331
Core fleet selection	1.5 (100%) n: 1006	0.039 (100%) n: 1001	0.44 (100%) n: 1038	0.054 (100%) n: 1056	0 n: 868	58 (100%) n: 987	34 (100%) n: 1397	55 (100%) n: 1384	43 (100%) n: 1126
Filter	2020								
Ungroomed data	86 (100%) n: 1300								
Fishing duration is not NA	86 (100%) n: 1300								
Positive fishing duration	86 (100%) n: 1300								
Core fleet selection	86 (100%) n: 1046								

Table D.27: Summary of the SKI3 BT+MW east coast daily rollup dataset after core fleet selection. ‘Records’ indicates the number of rows (days) in the dataset, and ‘Records caught’ indicates the percentage of days with catches of gemfish.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
2002	25	535	1438	15477.07	1.39	0.56
2003	24	686	1660	18316.63	5.93	0.72
2004	26	632	1426	13705.63	0.63	0.63
2005	24	736	1697	17538.82	0.17	0.24
2006	26	701	1588	16745.78	0.06	0.25
2007	26	605	1413	16151.52	0.57	0.64
2008	21	442	948	10017.43	0.00	0.00
2009	20	485	1062	11411.58	2.67	0.28
2010	21	465	981	11030.76	0.40	0.71
2011	22	443	1006	11056.03	1.55	1.19
2012	22	492	1001	8962.68	0.04	0.40
2013	22	534	1038	9250.23	0.44	0.39
2014	18	477	1056	11362.87	0.05	0.09
2015	19	429	868	9455.18	0.00	0.00
2016	23	450	987	10048.65	58.41	0.81
2017	22	607	1397	14600.07	33.74	4.22
2018	23	558	1384	15875.05	54.92	3.11
2019	25	507	1126	12359.75	43.34	7.46
2020	24	435	1046	10911.00	85.82	10.71

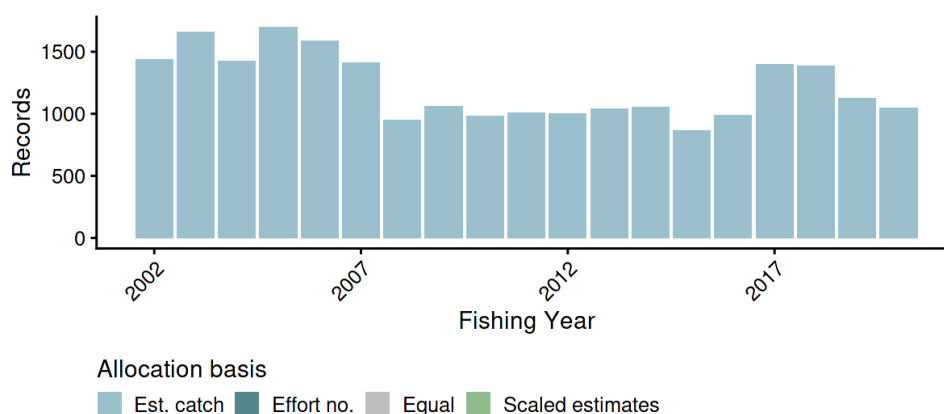


Figure D.86: Allocation basis for attributing landings to records in the SKI3 BT+MW east coast daily rollup catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table D.28: Summary of stepwise selection for occurrence of positive catch. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	17.00	3155	16.80	16.80	*
+ target_species	4.00	2939	22.80	6.00	*
+ bs(SeasonDay, 3)	3.00	2767	27.60	4.80	*
+ vessel_key	36.00	2667	32.20	4.60	*
+ stat_area	1.00	2661	32.40	0.20	
+ primary_method	1.00	2658	32.50	0.10	

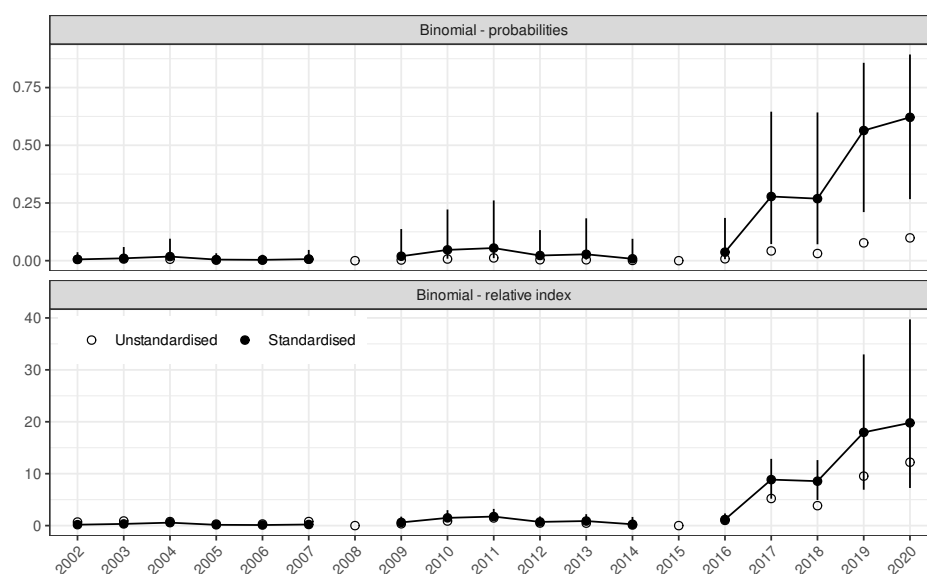


Figure D.87: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SKI3 BT+MW east coast daily rollup dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

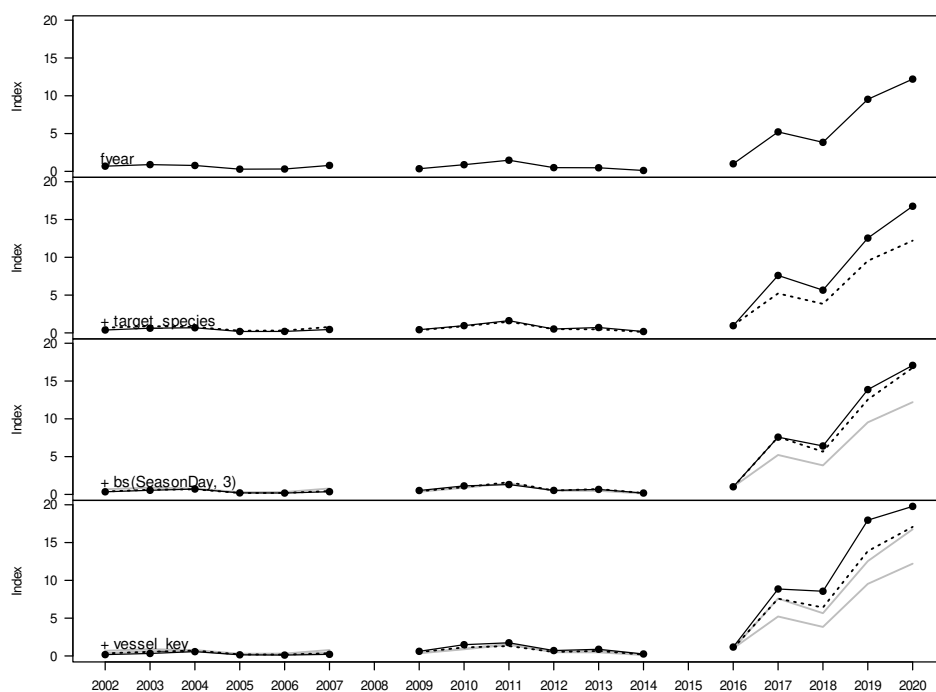


Figure D.88: Step plot for occurrence of catch in the SKI3 BT+MW east coast daily rollup dataset.

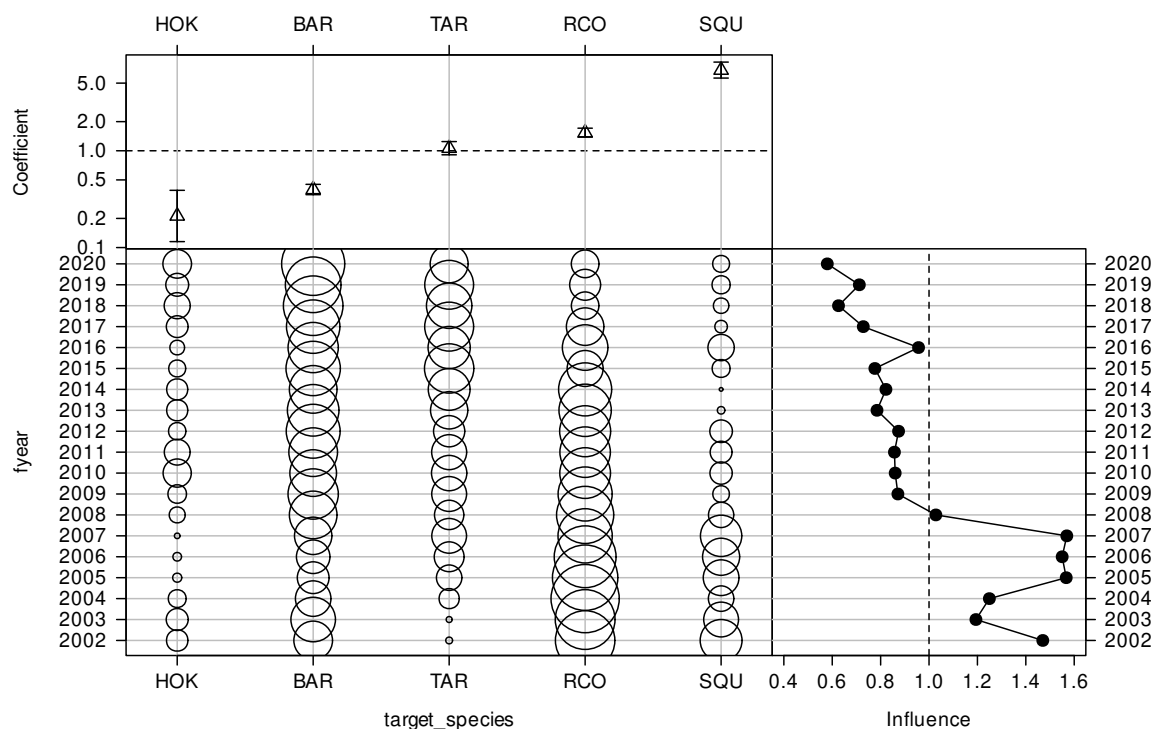


Figure D.89: CDI plot for target species for the occurrence of positive catch SKI3 BT+MW east coast daily rollup catch-per-unit-effort dataset.

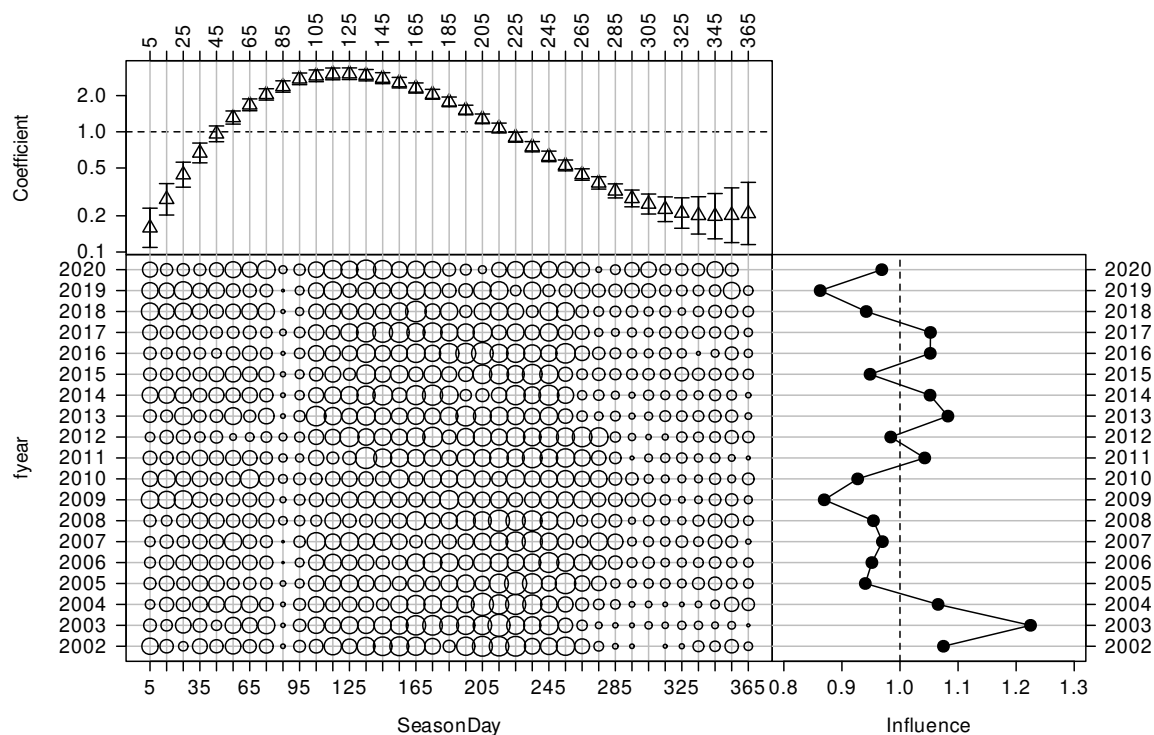


Figure D.90: CDI plot for SeasonDay for the occurrence of positive catch SKI3 BT+MW east coast daily rollup catch-per-unit-effort dataset.

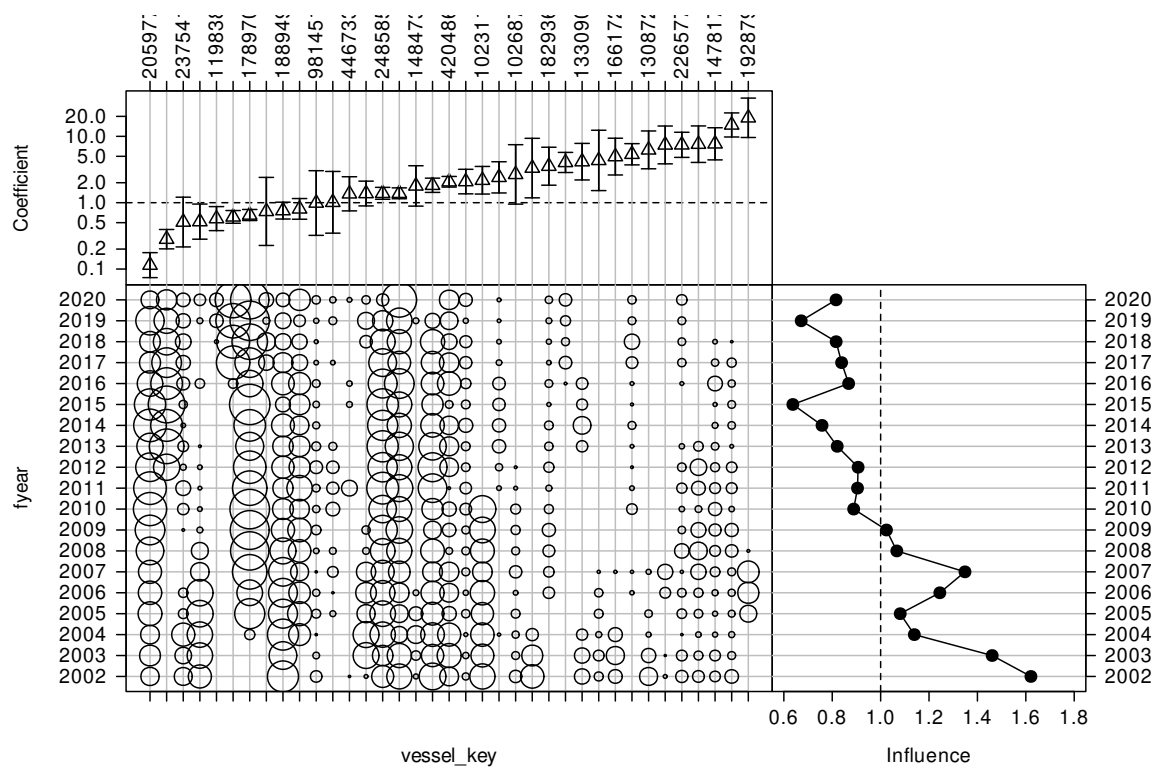


Figure D.91: CDI plot for vessel key for the occurrence of positive catch SKI3 BT+MW east coast daily rollup catch-per-unit-effort dataset.

Table D.29: Summary of stepwise selection for the lognormal model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	addl. % deviance	Included
fyear	15	1 209	40.0	40.0	*
+ vessel key	36	1 057	67.5	27.5	*
+ ns(log(fishing duration), 3)	3	1 009	72.0	4.5	*
+ bs(SeasonDay, 3)	3	994	73.5	1.6	*
+ primary method	1	989	74.0	0.5	

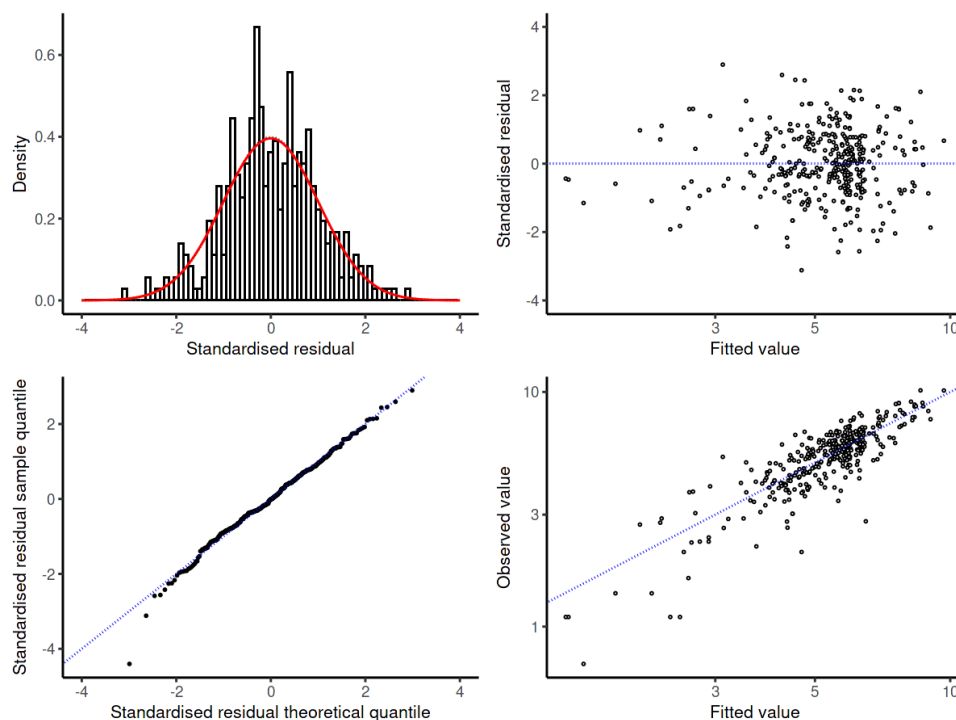


Figure D.92: Diagnostic plots for the lognormal model for the SKI3 BT+MW east coast daily rollup dataset.

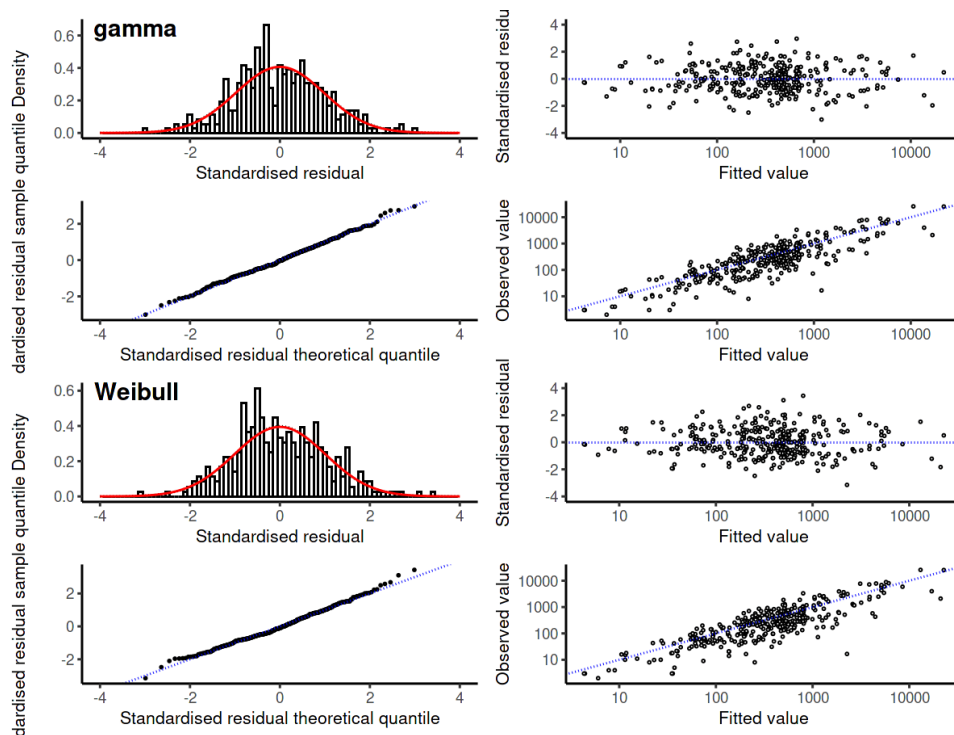


Figure D.93: Diagnostic plots for the gamma and Weibull model for the SKI3 BT+MW east coast daily rollup dataset.

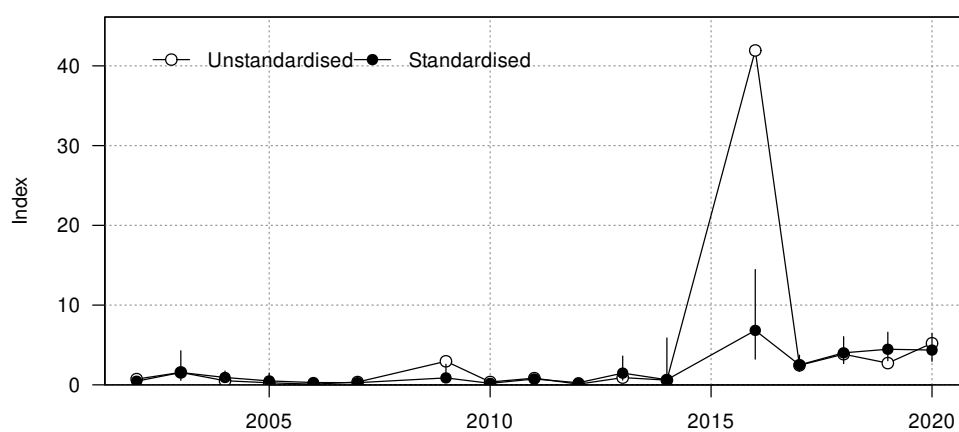


Figure D.94: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SKI3 BT+MW east coast daily rollup dataset.

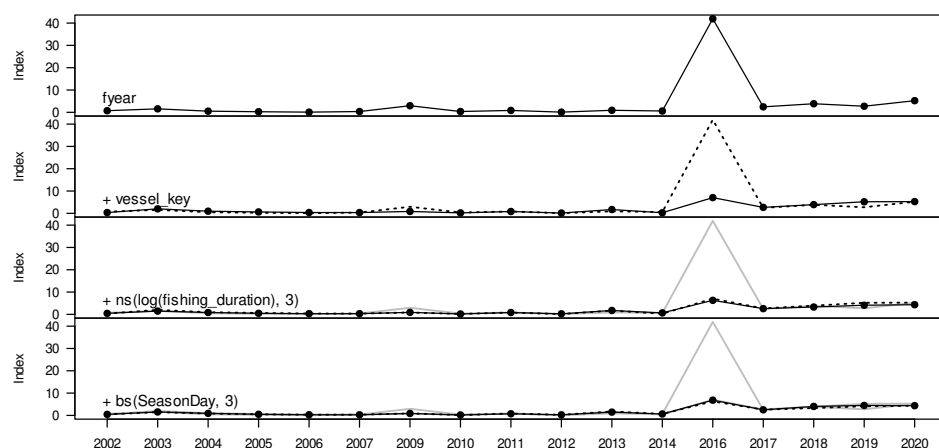


Figure D.95: Changes to the SKI3 BT+MW east coast daily rollup positive catch index as terms are successively entered into the model.

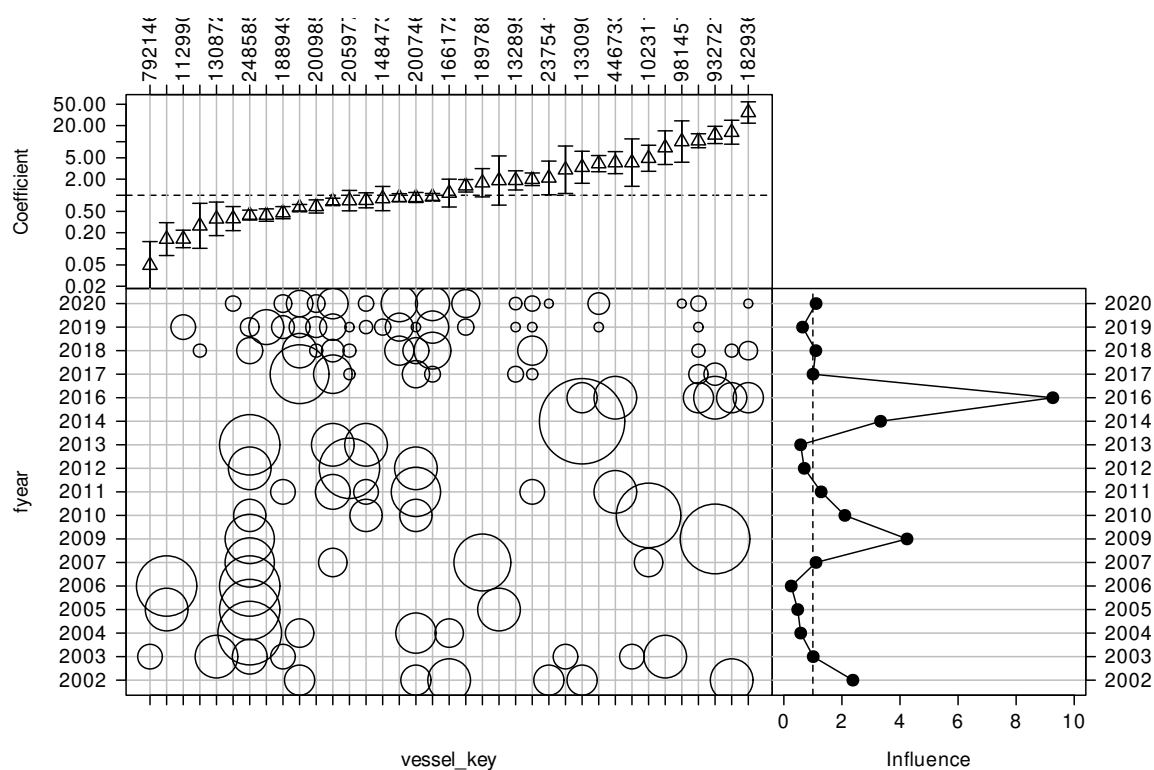


Figure D.96: CDI plot for vessel key for the positive catch SKI3 BT+MW east coast daily rollup catch-per-unit-effort dataset.

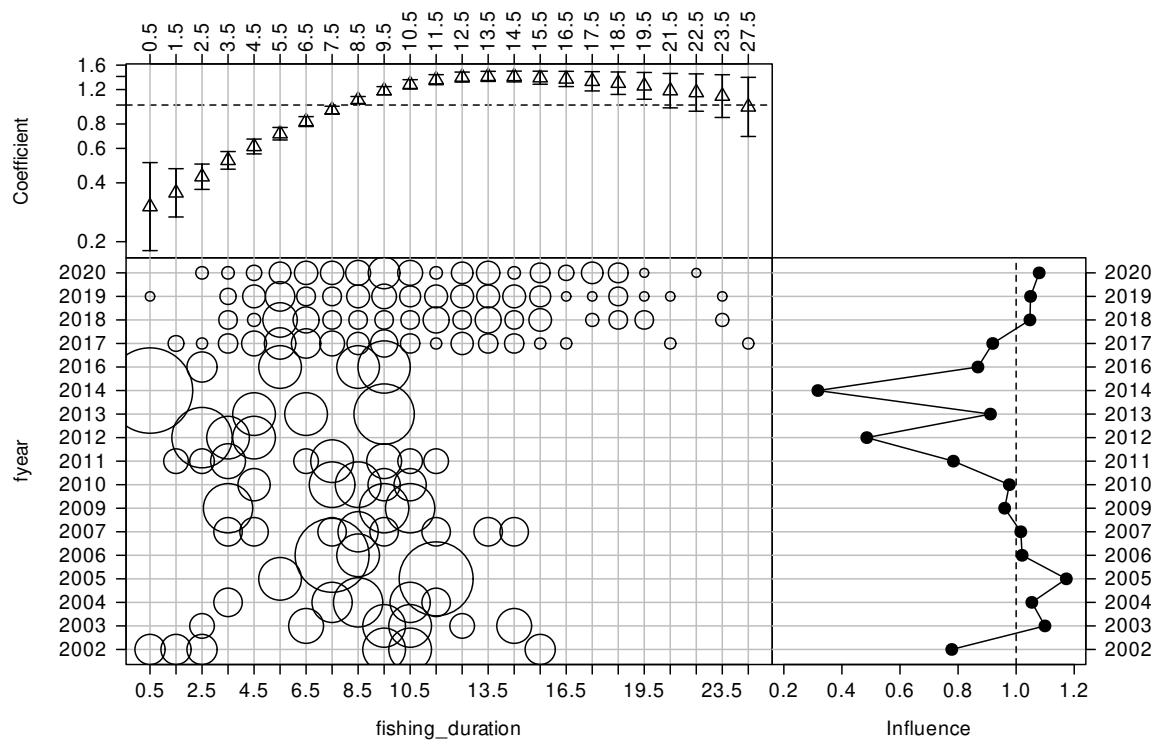


Figure D.97: CDI plot for fishing duration (h) for the positive catch SKI3 BT+MW east coast daily rollup catch-per-unit-effort dataset.

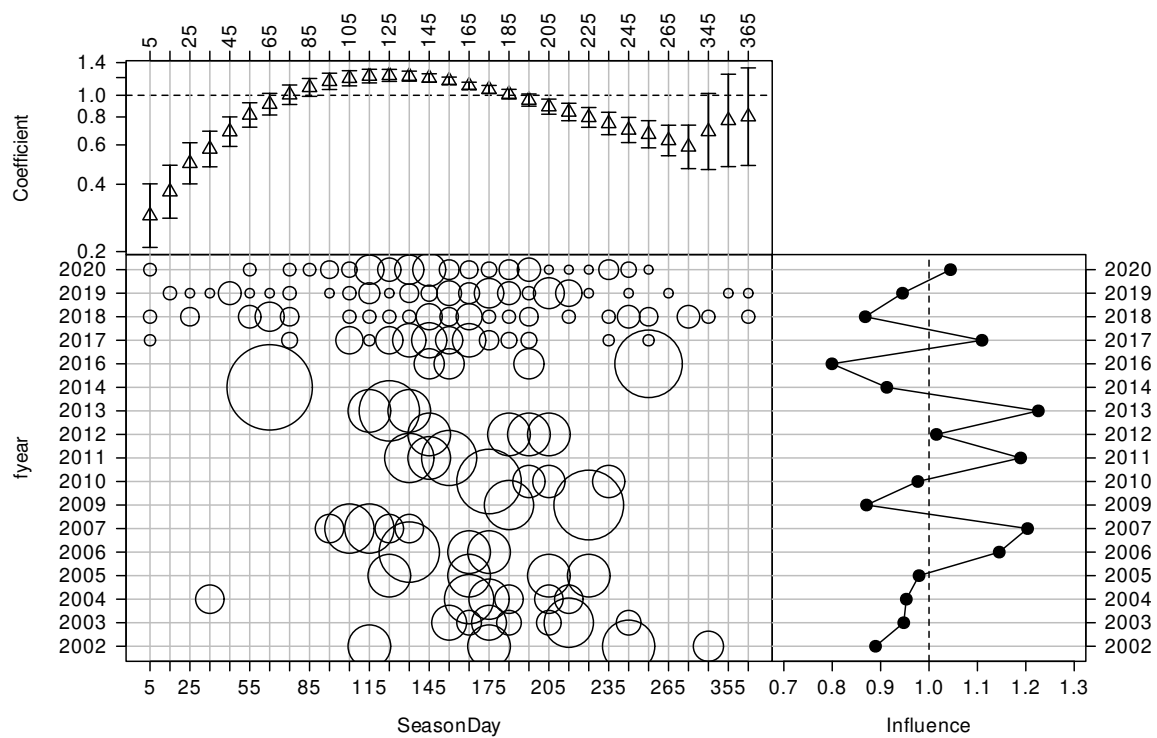


Figure D.98: CDI plot for SeasonDay for the positive catch SKI3 BT+MW east coast daily rollup catch-per-unit-effort dataset.

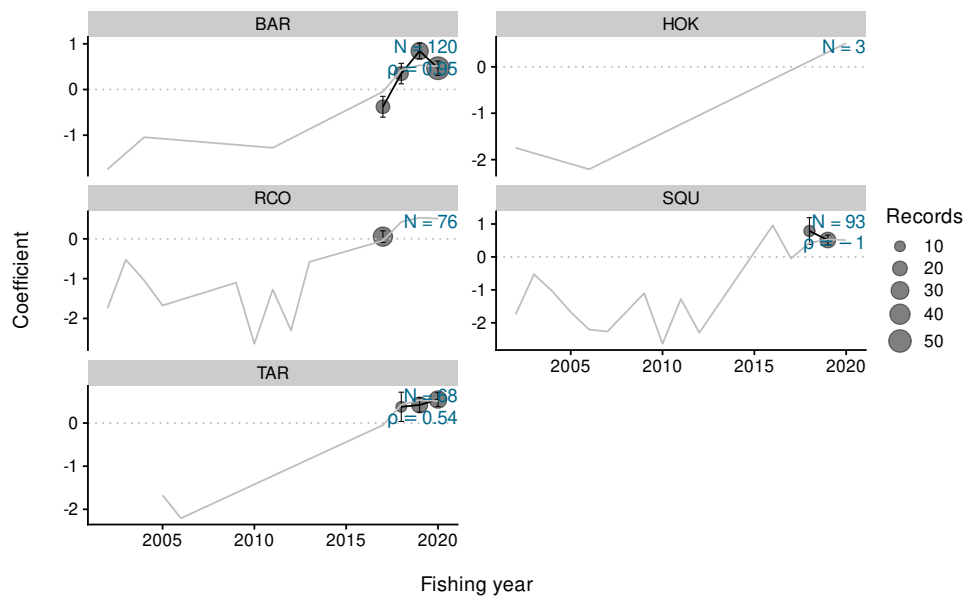


Figure D.99: Residual implied coefficients for target-year in the lognormal positive catch model for the SKI3 BT+MW east coast daily rollup dataset.

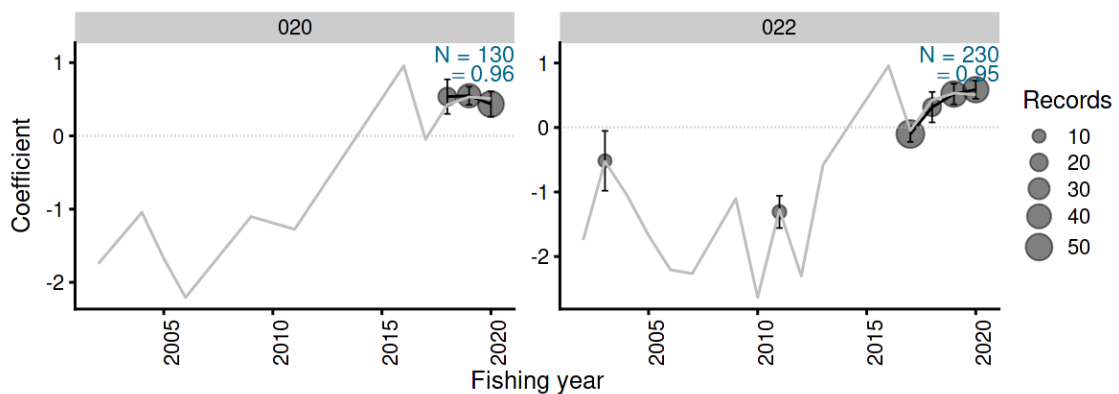


Figure D.100: Residual implied coefficients for area-year in the lognormal positive catch model for the SKI3 BT+MW east coast daily rollup dataset.

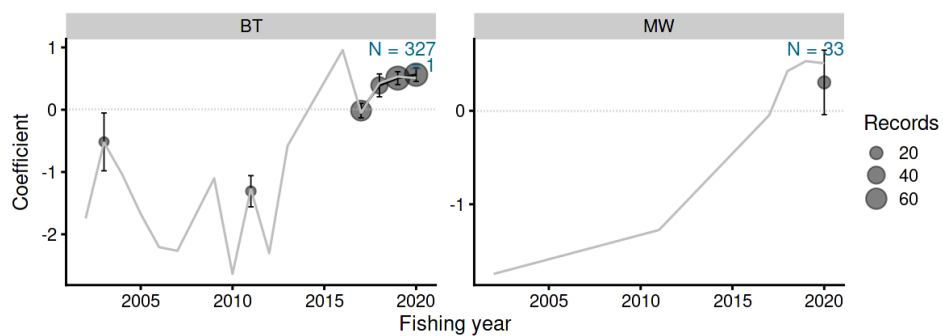


Figure D.101: Residual implied coefficients for primary method-year in the lognormal positive catch model for the SKI3 BT+MW east coast daily rollup dataset.

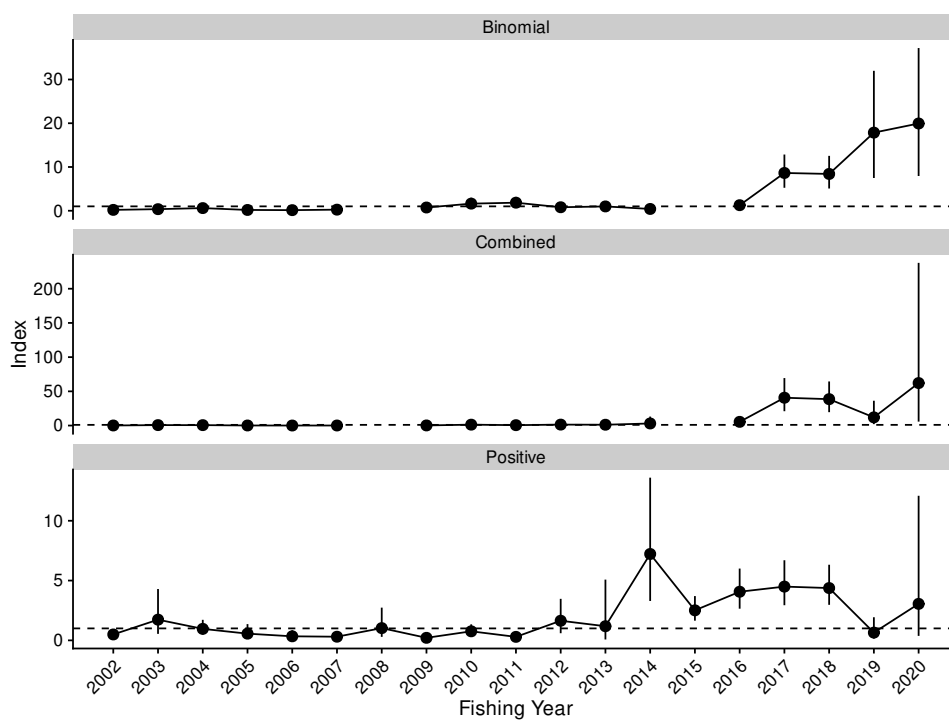


Figure D.102: Standardised indices and 95% confidence intervals for the SKI3 BT+MW east coast daily rollup dataset.

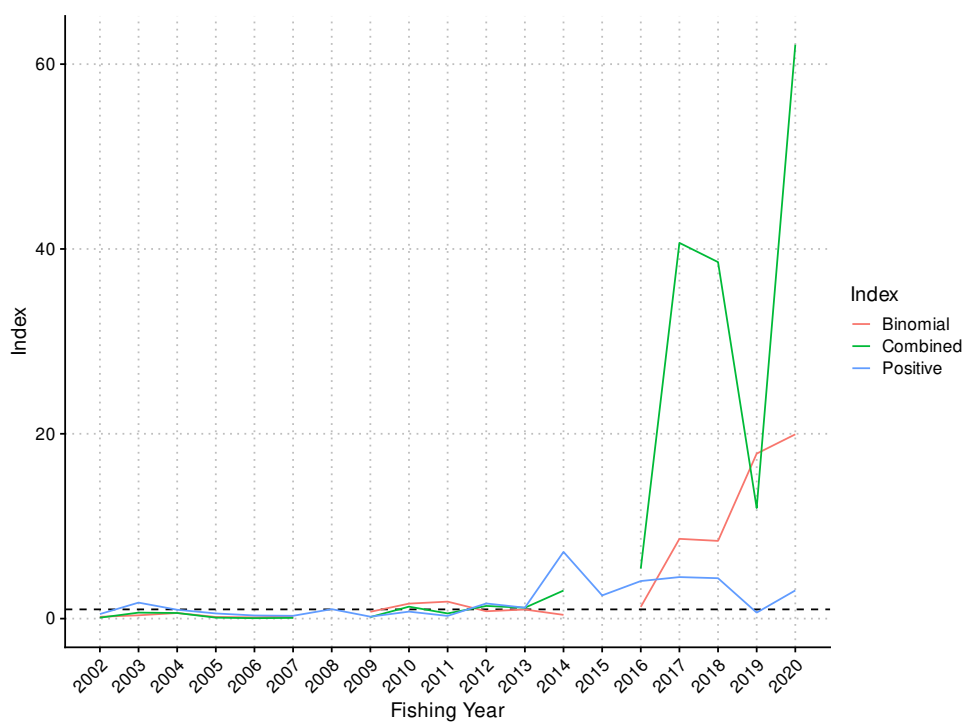


Figure D.103: Standardised indices for the SKI3 BT+MW east coast daily rollup dataset.

Table D.30: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SKI3 BT+MW east coast daily rollup.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
2002	0.197	0.084	0.078	0.405	0.102	0.061	0.029	0.267	0.494	0.173	0.239	0.916
2003	0.359	0.122	0.173	0.651	0.648	0.440	0.156	1.879	1.731	0.956	0.544	4.292
2004	0.605	0.223	0.292	1.165	0.607	0.297	0.222	1.385	0.961	0.318	0.472	1.717
2005	0.178	0.094	0.056	0.425	0.105	0.089	0.018	0.365	0.561	0.307	0.154	1.358
2006	0.136	0.077	0.043	0.345	0.048	0.038	0.009	0.156	0.338	0.189	0.104	0.846
2007	0.247	0.108	0.100	0.522	0.079	0.054	0.018	0.230	0.305	0.142	0.111	0.666
2008	-	-	-	-	-	-	-	-	1.024	0.623	0.292	2.736
2009	0.738	0.411	0.194	1.804	0.166	0.132	0.027	0.542	0.212	0.097	0.071	0.450
2010	1.622	0.577	0.720	2.983	1.294	0.625	0.422	2.872	0.756	0.237	0.411	1.340
2011	1.839	0.578	0.904	3.170	0.561	0.341	0.147	1.482	0.292	0.144	0.095	0.658
2012	0.799	0.399	0.283	1.848	1.372	0.980	0.277	4.118	1.640	0.734	0.596	3.472
2013	0.985	0.465	0.340	2.163	1.177	1.399	0.053	5.537	1.182	1.277	0.073	5.079
2014	0.406	0.416	0.038	1.669	3.038	3.287	0.227	13.112	7.221	2.630	3.293	13.603
2015	-	-	-	-	-	-	-	-	2.511	0.524	1.646	3.702
2016	1.268	0.430	0.562	2.250	5.412	2.194	2.134	10.734	4.065	0.856	2.649	6.003
2017	8.633	1.939	5.247	12.849	40.660	12.360	20.947	69.398	4.494	0.959	2.938	6.698
2018	8.411	1.904	5.081	12.545	38.579	11.455	19.553	64.454	4.373	0.855	2.971	6.323
2019	17.853	6.249	7.486	31.984	11.966	8.718	2.079	36.254	0.648	0.457	0.142	1.932
2020	19.942	7.461	7.942	37.189	62.105	59.202	5.735	237.809	3.051	2.988	0.374	12.089

APPENDIX E: GLOSSARY

Table E.1: Product state codes used in this report.

Code	Description
DRE	Dressed
FIL	Fillets: skin-on
FLP	Flaps
GGU	Gilled and gutted
GRE	Green (or whole)
GUT	Gutted
HGT	Headed, gutted, and tailed
HGU	Headed and gutted
MEA	Fish meal
SKF	Fillets: skin-off

Table E.2: Form type codes used in this report.

Code	Description
CEL	Catch, Effort and Landing Return (CELR)
ERS - Trawl	Electronic Reporting System - Trawl
ERS - Netting	Electronic Reporting System - Netting
ERS - Lining	Electronic Reporting System - Lining
ERS - Potting	Electronic Reporting System - Potting
ERS - Diving	Electronic Reporting System - Diving
ERS - Seining	Electronic Reporting System - Seining
LCE	Lining Catch Effort Return (LCER)
NCE	Netting Catch, Effort and Landing Return (NCELR)
SJC	Squid Jigging Catch and Effort Return (SJCER)
TCE	Trawl Catch Effort Return (TCER)
TCP	Trawl Catch, Effort and Processing Return (TCEPR)
TUN	Tuna Longlinging Catch Effort Return (TLCER)
LTC	Lining Trip Catch Effort Return (LTCER)
HCE	High Seas Catch, Effort and Landing Return (HS CELR)
HTC	High Seas Trawl Catch Effort Return (HS TCER)
HTU	High Seas Tuna Longlinging Catch Effort Return (HS TLCER)
HLC	High Seas Lining Catch Effort Return (HS LCER)

Table E.3: Fishing method codes used in this report.

Code	Description
BLL	Bottom longline
BT	Bottom trawl
DS	Danish seine
MW	Midwater trawl
PRB	Precision bottom trawl
PRM	Precision midwater trawl
SN	Set net

Table E.4: Species codes used in this report.

Code	Common name	Scientific name
BAR	Barracouta	<i>Thyrsites atun</i>
HOK	Hoki	<i>Macruronus novaezelandiae</i>
JMA	Jack mackerel	<i>Trachurus declivis</i> , <i>Trachurus murphyi</i> , <i>Trachurus novaezelandiae</i>
LIN	Ling	<i>Genypterus blacodes</i>
SKI	Gemfish	<i>Rexea</i> spp.
SQU	Arrow squid	<i>Nototodarus sloanii</i> , <i>Nototodarus gouldi</i>
SWA	Silver warehou	<i>Seriolella punctata</i>
TAR	Tarakihi	<i>Nemadactylus macropterus</i> , <i>Nemadactylus</i> sp. (King tarakihi)

Table E.5: Area codes for Observer data used in this report.

Code	Description
CEW	Central (Egmont) (FMA 8)
CHA	Challenger/Central (Plateau) (FMA 7)
SEC	South-East (Coast) (FMA 3)
SOE	South-East (Chatham Rise) (FMA 4)
SOI	Southern Ocean Islands (Auckland Islands and Campbell Island)
SOU	Southland (FMA 5)
SUB	Sub-Antarctic (FMA 6)