



Characterisation and CPUE analyses for the SPO 1, SPO 2, SPO 3, SPO 7, and SPO 8 fisheries to 2020–21

New Zealand Fisheries Assessment Report 2024/40

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Plain language summary

Rig (lemonfish) is a coastal shark species caught in fisheries around New Zealand. Commercial fishers target rig (coded as SPO) in set nets, bottom trawl, and Danish seine nets. It is the most common shark species caught by recreational fishers.

As part of its management within the Quota Management System, rig abundance in five areas is monitored using catch-per-unit-effort (CPUE) from bottom trawl and set net fisheries and, in this report, this information is given for 1990 to 2021. Off the South Island, rig is also monitored by trawl surveys.

Around the north of the North Island, rig abundance targets have not been established, but trends can be monitored. In the Firth of Thames, rig abundance increased during 2013 to 2019, then decreased, but remained above average. On the west coast of the North Island abundance was stable or increasing in the various areas assessed.

Off the central and southern east coast of the North Island, rig abundance has increased since 2009 and in 2021 was 2.5 times the target abundance.

Rig abundance off the South Island east coast appeared to have increased between 2017 and 2021, but the 2021 trawl survey index was imprecise and the stock was assessed as being at or about its target level. Abundance off the South Island south coast was also found to have increased, and this stock was also assessed as being at or about its target level in 2021.

For the South Island west coast, and the southern Taranaki Bight, recent CPUE indices increased while the trawl survey showed an increase from the mid-2010s then a decrease. The stock was considered to be at the target level in 2021.

EXECUTIVE SUMMARY

Starr, P.J.¹; Tornquist, M.G.²; Large, K.²; Middleton, D.A.J.³; Neubauer, P.² (2024). Characterisation and CPUE analyses for the SPO 1, SPO 2, SPO 3, SPO 7, and SPO 8 fisheries to 2020–21.

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The fisheries taking rig (*Mustelus lenticulatus*) around the New Zealand North Island and South Island are described from 1989–90 to 2020–21, based on compulsory reported commercial catch and effort data held by Fisheries New Zealand. A number of set net (SN) and bottom trawl (BT) fisheries take rig around New Zealand. The set net fisheries tend to be fisheries targeted at rig or, less frequently, at school shark. Smaller rig (usually less than 1 m long) are taken incidentally in mixed target species bottom trawl fisheries off the North and South islands. Detailed characteristics of the landings data associated with these fisheries, as well as the spatial, temporal, target species and depth distributions relative to the catch of rig in these fisheries are presented for all of New Zealand, separated into five SPO Quota Management Areas (QMA). Annual performance of the landings in each SPO QMA relative to the respective Total Allowable Commercial Catches and some regulatory information are also presented.

Commercial catch-per-unit-effort (CPUE) analyses for six set net (SN) and five bottom trawl (BT) fisheries were evaluated as biomass indices to track population trends in these QMAs. These analyses were also based on the compulsory reported commercial catch and effort data that are collected by Fisheries New Zealand. Seven of the eleven fisheries were extensions of the same analyses that had been done in 2019 when rig were last reviewed. The other four fisheries (two SN and two BT) were created when wider BT and SN fisheries covering the combined east and south coasts of the South Island were split into regions representing separate east and south coast fisheries. This step was taken by the Inshore Working Group (INSWG) because the implied residuals from the component statistical areas pointed to spatial heterogeneity in both regions, particularly for the set net fishery. The CPUE series for the five BT fisheries (SPO 1W BT, SPO 2 BT, SPO 3 BT East Coast, SPO 3 BT Foveaux Strait, SPO 7 BT) and three of the six SN fisheries (SPO 3 SN East Coast, SPO 3 SN Foveaux Strait, SPO 7(038) SN) were deemed to be of High Quality (Research Ranking=1) and consequently could be used for monitoring rig abundance. The CPUE series from the remaining three SN fisheries (SPO 1E(007) SN, SPO 1W(043) SN, SPO 1W(044) SN) were given a Research Ranking of 2 (Medium or Mixed Quality). These CPUE series were downgraded because of concern that the spatial coverage in these fisheries was too restricted to monitor the full area, but the INSWG concluded they could still be used, with caution, for monitoring rig. Because the five BT fisheries were analysed at the trip level due to the large number of trips which landed rig but failed to declare rig in the estimated catches, three of the BT analyses (SPO 1W BT, SPO 2 BT, SPO 7 BT) were repeated at the level of an individual tow. The combined east and south coast analysis (SPO 3 BT) was also evaluated in this way. These additional analyses were done by using data from the tow-by-tow forms which were adopted in 2007–08 so that the longer trip-based series could be evaluated for possible bias relative to the more detailed event-based analyses over the overlapping years. The resulting series acceptably matched all four of the longer trip-based series.

Four of the five BT fisheries show similar strong increasing trends in recent years, with only the SPO 1W BT(trip) series remaining steady, but above the series mean, from the early 2010s. The SN fisheries have a mixed response, with the SPO 1W(043) SN and SPO 7(038) SN fisheries showing strong recent increases while the SPO 1E(007) SN and SPO 3 SN East Coast fisheries showed a strong increase in 2020 but fell back to just above the series mean in 2021. The remaining two SN fisheries (SPO 3 SN Foveaux Strait and SPO 1W(044) SN) show a more complex response over the most recent three years,

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with the Foveaux Strait SN series holding steady or possibly increasing at a level above the series mean while the (044) SN series has dropped to a level near the series mean. The increasing trends in the BT fisheries are interpreted as indicating good recruitment, an observation that seems to be corroborated by the east coast South Island survey but not by the two west coast surveys. Although the SN fisheries give a mixed signal, none show signs of long-term population decline. These contradictory signals are difficult to reconcile and suggest that the fisheries that capture this species need to be closely monitored.

Length analyses indicate that the available monitoring tools (CPUE and trawl survey) sample different parts of the rig population, with the two trawl surveys dominated by small rig that are less than 70 cm in total length, the BT fisheries taking somewhat larger rig which are generally less than 1 m in total length, and the set net fisheries capturing much larger rig (particularly females) up to 1.3 m.

1. INTRODUCTION

This document describes work conducted under Specific Objectives 1 and 2 of Fisheries New Zealand contract SPO2021–01.

Overall Objective:

1. To characterise all rig (*Mustelus lenticulatus*) fisheries and undertake CPUE analyses in SPO 1, 2, 3, 7, and 8.

Specific Objectives:

1. To characterise the SPO 1, 2, 3, 7, and 8 fisheries.
2. To analyse existing commercial catch and effort data to the end of 2020–21 fishing year and undertake CPUE standardisations for each stock.

This report summarises fishery and landings characterisations for SPO 1, SPO 2, SPO 3, SPO 7, and SPO 8, as well as presenting catch-per-unit-effort (CPUE) standardisations derived from trawl and set net data originating from each of the above Quota Management Areas (QMA). This work is part of the Fisheries New Zealand schedule for Group 5 stocks: chondrichthyan stocks that are monitored using indices of relative abundance. Abbreviations and definitions of terms used in this report are presented in Appendix A. A map showing the rig QMAs is presented in Figure 1.

There have been three previous national rig characterisations and CPUE standardisations: Starr & Kendrick (2016) (to 2011–12), Starr & Kendrick (2017) (to 2014–15), and Starr & Kendrick (2020) (to 2017–18). This project updates the national rig characterisation and CPUE standardisation to the 2020–21 fishing year. This project also summarises the available Fisheries New Zealand observer data from all observed fisheries capturing rig as well as summarising rig biological data collected by industry sponsored Adaptive Management Programmes (AMP).

2. INFORMATION ABOUT THE STOCK/FISHERY

2.1 Catches

Historical annual landings reported to the QMR/MHR and Total Allowable Commercial Catches (TACCs) by SPO QMA up to 2020–21 are provided in Table B.1. The TACCs and allowances that comprise the Total Allowable Catch (TAC) for each SPO QMA as of 1 October 2023 are presented in Table 1.

2.1.1 SPO 1

The TACC for rig in SPO 1 was set at 540 t when this Fishstock was first put in the Quota Management System (QMS) in 1985–86, but increased through the process of quota appeals to 688 t by 1990–91 (Figure 2; Table B.1; Table B.2). Note that, unlike for the other SPO QMAs, this TACC was set near the level of the 1973–1982 average catch (=562 t; Figure 2). The TACC was increased to 829 t in 1991–92 under the provisions of the Adaptive Management Programme (AMP) (Table B.1). The TACC was reduced to 692 t in 1997–98 when SPO 1 was removed from the AMP and has since remained at that level. Catch levels declined after 1991–92 to below 300 t/year in 2007–08, after which catches remained steady at levels slightly above 300 t/year up to 2017–18, when they dropped to below 250 t/year for the three years to 2020–21 (Figure 2; Table B.1).

2.1.2 SPO 2

The TACC for rig in SPO 2 was set at 64 t when this Fishstock was first put in the QMS in 1985–86 but it then increased in each successive year to 71 t in 1990–91 due to quota appeals (Figure 2; Table B.1; Table B.3). The original TACC of 64 t was considerably lower than the 1973–1982 average catch, consistent with a policy of reducing the pre-QMS exploitation on the commercially harvested shark species (=213 t; Figure 2). It was increased to 86 t in 1991–92 under the provisions of the AMP (Figure 2; Table B.1). Catch levels began to exceed the TACC in the early 1990s and remained above the TACC in every year from 1991–92 to 2012–13 (Figure 2; Table B.1). The TACC was reduced in 1997–98 to 72 t when SPO 2 was removed from the AMP but was raised back to 86 t in 2004–05, raised again to 108 t in 2011–12 and raised once more to 119 t in 2020–21. Landings exceeded the SPO 2 TACC by between 8% and 32% from 2001–02 to 2014–15, except for 2012–13 when the TACC was undercaught by 2% (Table B.1). Landings then dropped below the TACC for the next four years from 2015–16 to 2018–19. They rose to 117 t in 2019–20 but fell to 109 t in 2020–21, in spite of the increase in TACC in that year (Table B.1).

2.1.3 SPO 3

The TACC for SPO 3 was increased from 364 t (established in 1985–86) to 430 t for the 1991–92 fishing year when it was increased under the provisions of the AMP (Figure 2; Table B.1; Table B.4). The initial TACC of 364 t was considerably lower than the 1973–1982 average catch, consistent with a policy of reducing the pre-QMS exploitation on the commercially harvested shark species (=859 t; Figure 2). Landings increased but did not approach the new TACC until 1994–95. The TACC was increased under the AMP to 600 t/year in 2000–01 but did not reach this level until 2014–15, when 557 t were landed. The TACC was raised to 660 t in 2020–21 (Table B.1). Landings varied between 350 and 450 t/year from the mid-1990s to 2008–09, which had the lowest annual catch after 1993–94 (Figure 2; Table B.1). Landings then increased steadily to over 600 t/year in 2017–18, peaking at 651 t in 2019–20 (Table B.1). Landings fell to 632 t in 2020–21 in spite of the increase in TACC in that year.

2.1.4 SPO 7

The TACC for SPO 7 was increased from 294 t (established in 1985–86) to 350 t for the 1991–92 fishing year under the provisions of the AMP (Figure 2; Table B.1; Table B.5). The initial TACC of 294 t was lower than the 1973–1982 average catch, consistent with a policy of reducing the pre-QMS exploitation on the commercially harvested shark species (=429 t; Figure 2). Landings increased but did not exceed the higher TACC until 1995–96 and 1996–97. Catches dropped below the TACC after 1997–98 and subsequently dropped to below 300 t per year after the 2001–02 fishing year (Figure 2; Table B.1). The TACC was lowered to 221 t for the 2006–07 fishing year in response to a stock assessment that was based on the west coast South Island trawl survey indices and two CPUE series, one from the Statistical Area 038 (Tasman Bay/Golden Bay) and the other from the west coast of the South Island. Landings exceeded the new, lower, TACC in each year to 2014–15, by 20% in 2006–07 and then by 3% to 6% from 2007–08 to 2014–15. The TACC was raised to 246 t in 2015–16, again to 271 t in 2018–19 and then to 298 t in 2020–21 (Table B.1). Landings followed these TACC increases, but were lower than the TACC after 2017–18.

2.1.5 SPO 8

The TACC for SPO 8 increased gradually from 240 t (established in 1985–86) to 310 t through quota appeals between 1986–87 and 1990–91 (Figure 2; Table B.1; Table B.6). The initial TACC of 240 t was only slightly lower than the 1973–1982 average catch, which was inconsistent with the policy of reducing the pre-QMS exploitation on the commercially harvested shark species (=285 t; Figure 2) than was seen in SPO 2, SPO 3 and SPO 7 but similar to SPO 1. The TACC was increased to 370 t for the 1991–92 fishing year under the provisions of the AMP. Catches more than doubled by 1995–96, but never reached the new, higher, TACC. The TACC was reduced back to 310 t in 1997–98 when SPO 8 was removed from the AMP. Catches dropped to 174 t in 2000–01 and then fluctuated around 200 t/year up to 2016–17, ranging from 163 t in 2005–06 and a maximum of 246 t in 2009–10 (than in SPO 2, SPO 3 and SPO 7). An exception to this was the low annual catch in 2012–13 (120 t), which coincided with the introduction of severe restrictions to the North Taranaki Bight set net fishery in response to low population numbers in the endemic Māui dolphin. SPO 8 landings then recovered to near 200 t/year up to 2016–17, but then declined precipitously, dropping to 47 t by 2020–21. This decline in catch, particularly in 2021, coincided with the imposition of even more severe set net restrictions. It is likely that the primary cause of this decline was the restrictions that have been made to set net fishing in the North Taranaki Bight for the protection of Maui dolphins and the consequent loss of fishers participating in the fishery (see Appendix D).

2.1.6 Recreational catches

Recreational catches in New Zealand are poorly known (compared with commercial catches), and catches of rig in these QMAs are no exception. However, it is thought that rig are relatively unimportant in the New Zealand recreational fishery. Two large-scale population-based diary/interview surveys were conducted under contract for Fisheries New Zealand 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-specific annual catches for all major finfish and non-finfish species. Both surveys estimated the New Zealand-wide recreational rig catch to be low, with 52 t of rig caught in 2011–12 (CV=0.14) and 56 t of rig caught in 2017–18 (CV=0.15).

2.2 Regulations Affecting the Fishery

Rig are usually processed at sea shortly after they have been captured by removing the head and tail and then eviscerated. This processing procedure, termed ‘headed and gutted’ or HGU, had been industry practice for well over twenty years and there has been no known systematic change in processing procedure over that period (P. Dawson, Independent Fisheries, pers. comm.). What has changed is the ‘conversion factor’ used to translate the processed HGU (and DRE or ‘dressed’) weight back into greenweight (GRE). The conversion factor in use for these landing states, from at least 1960 to the 1991–92 fishing year, was 2.0 (Table B.17). The HGU and DRE conversion factors were dropped to 1.75 from 1992–93 to 1999–2000, and then to 1.55 until the present (Table B.17). This means that landings of rig are not directly comparable across years unless a correction is made for the changes in conversion factor.

Beginning in the early 2000s, a suite of regulations intended to protect Māui and Hector’s dolphins was implemented for all of New Zealand by the Minister of Fisheries. Further regulations were implemented off the west coast of the North Island on 1 October 2012 to additionally protect the small population of Māui dolphins. These regulation changes are listed by gear type and location in Appendix D. Many of these new regulations, particularly those which restrict access by set nets to inshore areas, have changed the catchability in the CPUE analyses derived from the fisheries affected by these regulation changes. On 1 October 2020, the Minister of Fisheries implemented additional set net closures on the west coast of the North Island. These included 4 nm closures from Cape Reinga at the top of the North Island to Wellington at the bottom. These closures were extended to 12 nm from Maunganui Bluff (between

Hokianga Harbour and Kaipara Harbour) all the way to New Plymouth and then scaled back to 7 nm to Hawera on the north coast of the South Taranaki Bight. These closures have effectively ended the outside (of harbours) set net fishery in SPO 8 and parts of SPO 1 outside on the west coast of the North Island. At the same time, the trawl fishery was excluded by 4 nm from Maunganui Bluff to New Plymouth.

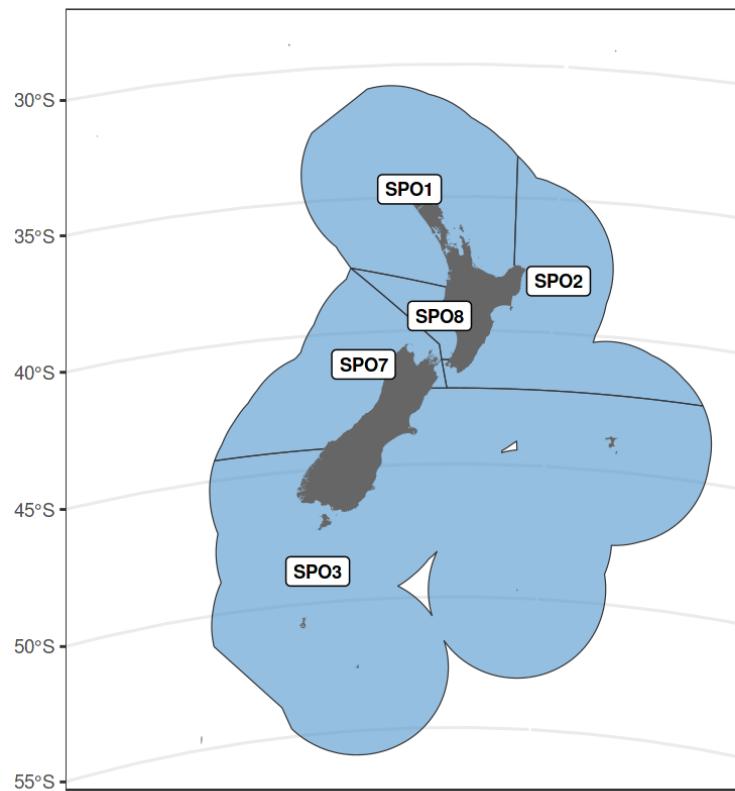


Figure 1: Quota Management Areas for rig with SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 highlighted.

Table 1: Total Allowable Catch (TAC), Total Allowable Commercial Catch (TACC), and allowances (all tonnes) for SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8, as at 1 October 2023.

Stock	TAC	TACC	Allowances		
			Customary	Recreational	Other mortality
SPO 1	752.064	692.064	20	25	15
SPO 2	146.000	119.000	5	10	12
SPO 3	766.000	660.000	20	20	66
SPO 7	373.000	298.000	15	33	27
SPO 8	401.000	310.000	31	60	0

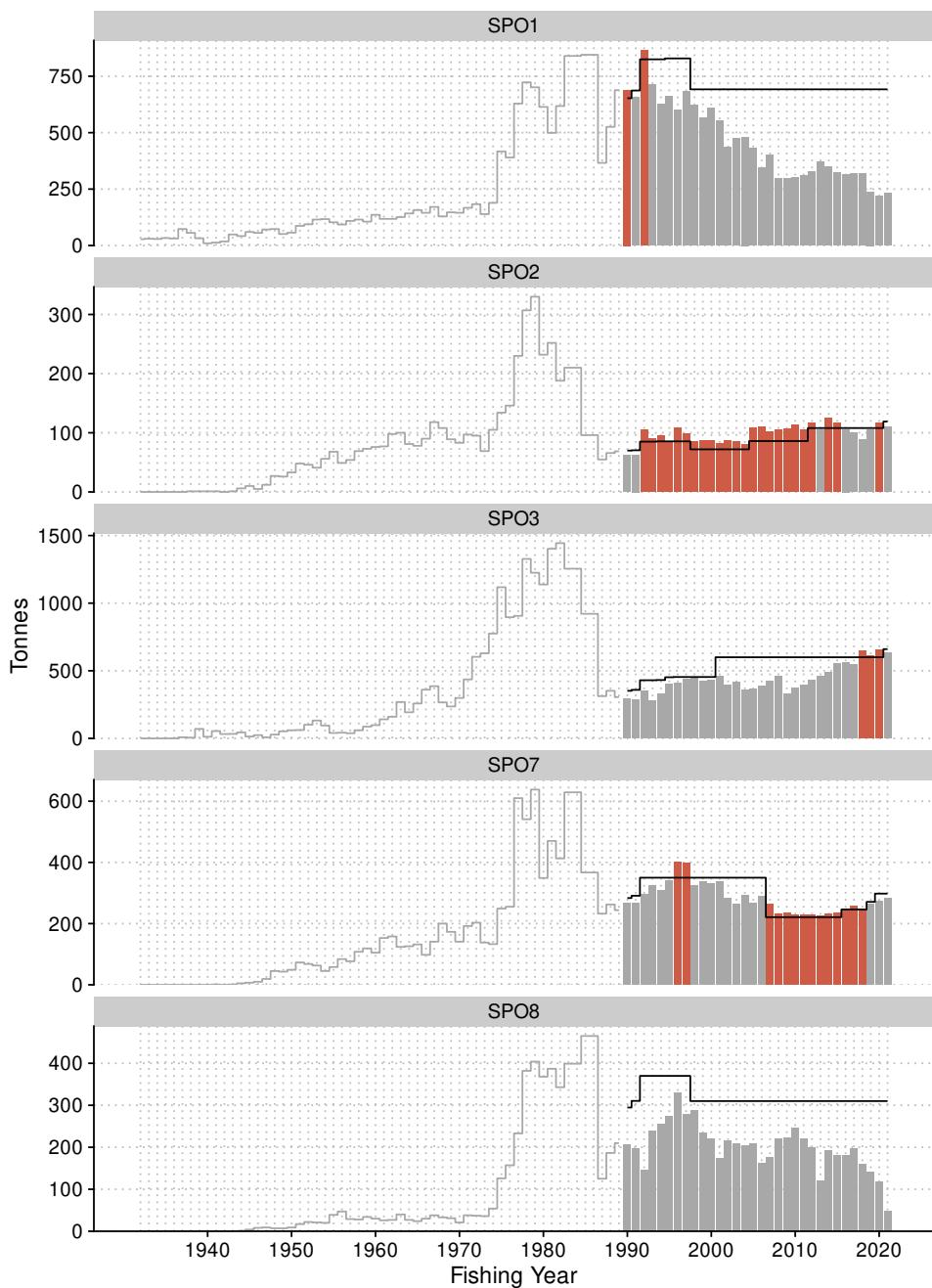


Figure 2: Total Allowable Commercial Catch (TACC; black line) and Monthly Harvest Return/Quota Management Report totals (bars) for SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 from 1990 to 2021. Years where the TACC was exceeded are highlighted in red. Catches prior to 1990 are shown by the grey line using the 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*.

The trip-based approach allocates the catches of SPO from a trip to the fishing event records from the trip using the hierarchical method of Starr (2007). If rig 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 rig 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).

However, in fisheries where there is significant use of intermediate destinations, the trip-based approach breaks down because catches may no longer be recorded in the same trip as the fishing effort that gave rise to those catches. In these cases, we instead calculate the annual ratio of summed catches to summed estimated catch for each vessel and species, and scale the estimated catch of the species for each fishing event within the year by this ratio. In this report, we employed this approach for trips in SPO 1 where the modal fishing method was SN .

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			Included in			
		Introduced	Revoked	Final	Retainable	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	N	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 SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 and extracting the associated catch and effort data for fishing events within the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 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).

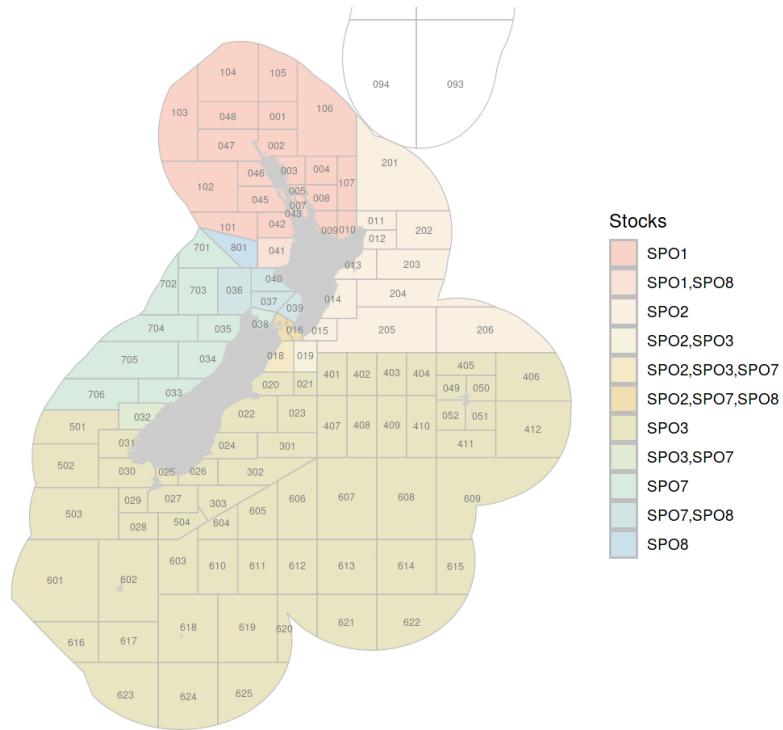


Figure 3: Statistical Areas that intersect the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 Quota Management Areas.

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 SPO 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 (`allockg_top5`; matching the resolution of the TCEPR form), the top eight species (`allockg_top8`; matching the resolution of the TCER, NCELR, LCER, and LTCER forms), or without restricting estimated catches (`allockg`, 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 (`allockg`). 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 (`landkg`) and sums, mean, and/or modal values of the effort variables for the trip.

4. FISHERY CHARACTERISATION

4.1 Destination codes in the SPO landings data

Landings data for rig were provided for every trip that landed SPO 1, SPO 2, SPO 3, SPO 7, and SPO 8 at least once, with one record for every reported SPO landing from the trip. Each of these records contained a reported greenweight (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.7, Table B.8, Table B.9, Table B.10, Table B.11, Figure 4), which indicated the category under which the landing occurred. The majority of the landings were made using destination code ‘L’ (landed to a Licensed Fish Receiver, LFR). However, other codes (e.g., ‘A’, ‘C’, or ‘W’; Table 2) also potentially described valid terminal landings and were included in this analysis but these are all minor compared to code ‘L’. A number of other codes (notably ‘Q’, ‘R’ and ‘T’) were not included because it was felt that these landings would be reported at a later date under the ‘L’ destination category. Two other codes (‘D’ and ‘NULL’) represented errors that could not be reconciled without making unwarranted assumptions and these were not included in the landings dataset.

Some of the destination codes (notably ‘T’, ‘Q’, and ‘R’) represent intermediate holding states that have the potential to invalidate the method of Starr (2007), which assumes that the reported landings for a trip have been taken using the effort reported for the trip. However, because these intermediate landing destination codes are dropped (due to the potential for double counting), it is quite possible that ‘L’ landings reported for a trip may have been taken by another trip where the landings were declared by an intermediate code. This issue cannot be resolved within the current Fisheries New Zealand catch reporting system because historically there was no requirement to maintain the integrity of catches from a trip. Consequently, in these situations, the linking method of Starr (2007) may result in biased estimates of CPUE, with landings associated with an incorrect measure of effort. The use of intermediate landings has been common in the rock lobster fishery, where catches have been left in holding pots (destination code ‘P’) beginning in the early 2000s (Starr 2007). Kendrick & Bentley (2012) noted that this was a particular problem in the SPO 1 set net fishery (Figure A.4), where an increasing proportion of landings (Figure A.3) used the intermediate code ‘Q’ because operators in this QMA held landings in freezers before taking them to an LFR, mostly likely due to economic reasons. For instance, the LFRs may limit the amount of landings permitted in a time period or the operators may wait for a more favourable beach price. Destination codes for the other SPO QMAs were examined, and, apart from a minor increase in the quantity of destination code ‘Q’ in SPO 3, beginning around 2009–10 (Figure A.3), there seemed to be little evidence of this type of behaviour in the other SPO QMAs.

Because it is essential to correct estimated rig catches to reflect the landed catch for catch/effort analyses (see above), the Kendrick & Bentley (2012) procedure to analyse SPO 1 CPUE was adopted. A similar solution has also been adopted for adjusting estimated catches put into holding pots for rock lobster CPUE (Starr 2007). This approach involves estimating, for every vessel participating in the fishery in a year, the ratio of landed to estimated catch. This ratio is then used to correct all estimated catch records without regard to the landed destination code on the form. A description of this algorithm is provided in Appendix H of Starr & Kendrick (2020).

4.2 State codes in the SPO landings data

Almost all of the valid landings data for SPO 1, SPO 2, SPO 3, SPO 7, and SPO 8 were reported using state code DRE or HGU, with the majority of the remaining landings using the state code GRE (Figure 5). The few remaining landings were spread out among GUT, HGT, MEA, and FIN codes. Apart from SPO 1, all landings report the DRE from the early 2000s, while the HGU code is still in use in SPO 1.

There have been substantial changes in the conversion factors for the two primary state codes (DRE and HGU) used for processing SPO (Figure 6, Table B.17). These changes occurred twice in the first 12 years of data and lead to important changes in how the landings data are interpreted for this species. Consequently, all landings have been converted to a consistent conversion factor, representing the conversion factors that have been in place from 2000–01 onward. These changes have implications for the historical catch, with the reported catches in the years before 2000–01 overestimated compared to the more recent years. Annual catch totals based on a consistent conversion factor are plotted with a dashed line in Figure 4.

A convention adopted in previous versions of this analysis was to drop the landings for state codes FIN, FLP (flaps), SHF (shark fins), and ROE when there was greater than one landing in a trip (Starr 2007). The latter three state codes are considered ‘secondary’ and thus should not enter into the calculation of landed greenweight, but these were all dropped to avoid potential double counting.

4.3 Allocation of landings

Figure 7 indicates that, for all SPO QMAs, almost all landings have been allocated successfully using some measure of associated effort information. Only in a few years before 2000 do the allocated landings fall below the QMR catch totals. The specific methods used in each SPO QMA to allocate the landings can be found below in the characterisation section associated with that QMA.

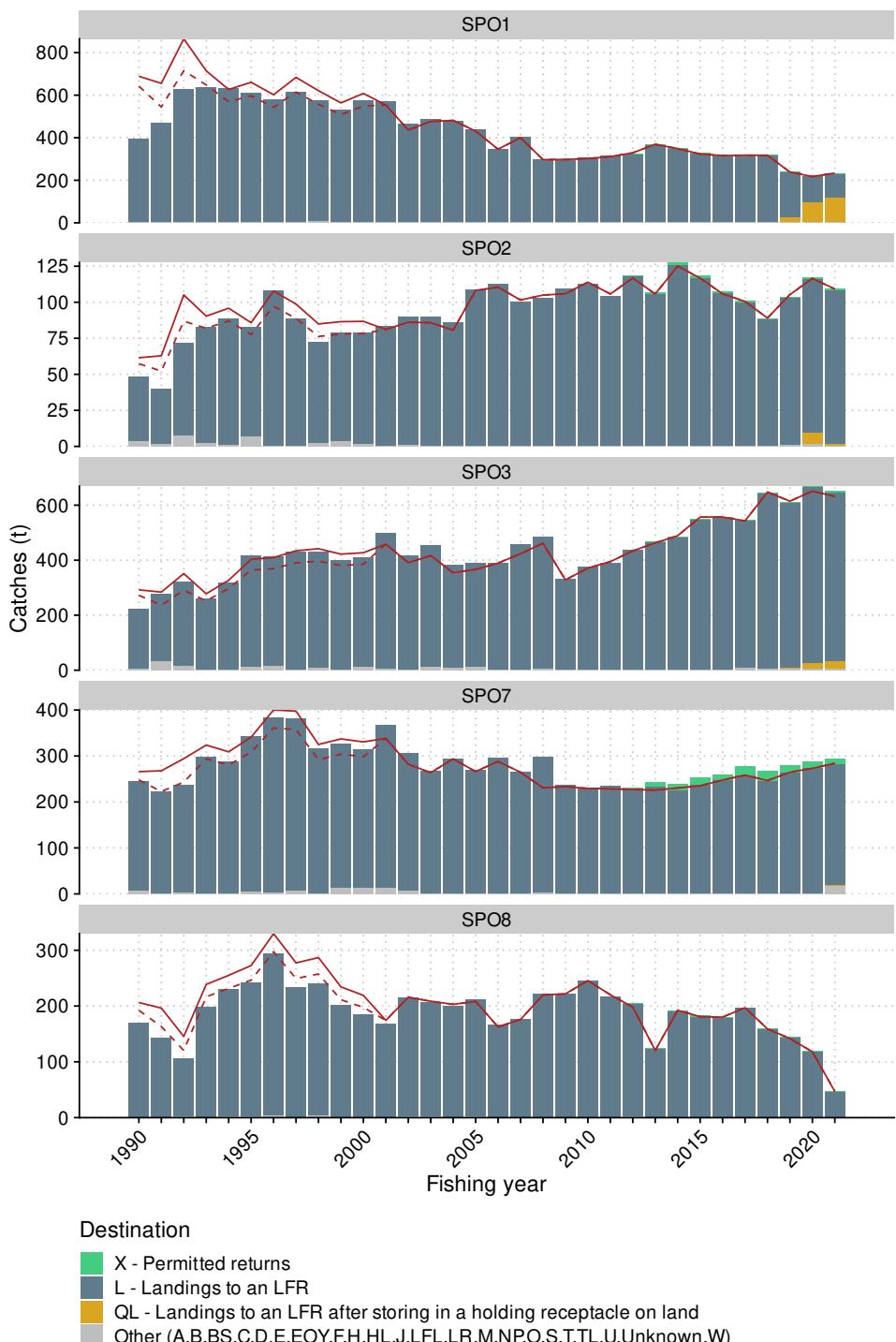


Figure 4: Catches of rig by destination (bars), compared with Monthly Harvest Return / Quota Management Report (MHR/QMR) totals (line), for Quota Management Areas SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8. The dashed line illustrates the MHR/QMR totals adjusted by the annual ratio between the originally reported landings and the landings adjusted to the current conversion factor. Destination codes are defined in Table 2 and tabulated catches are in Appendix B.

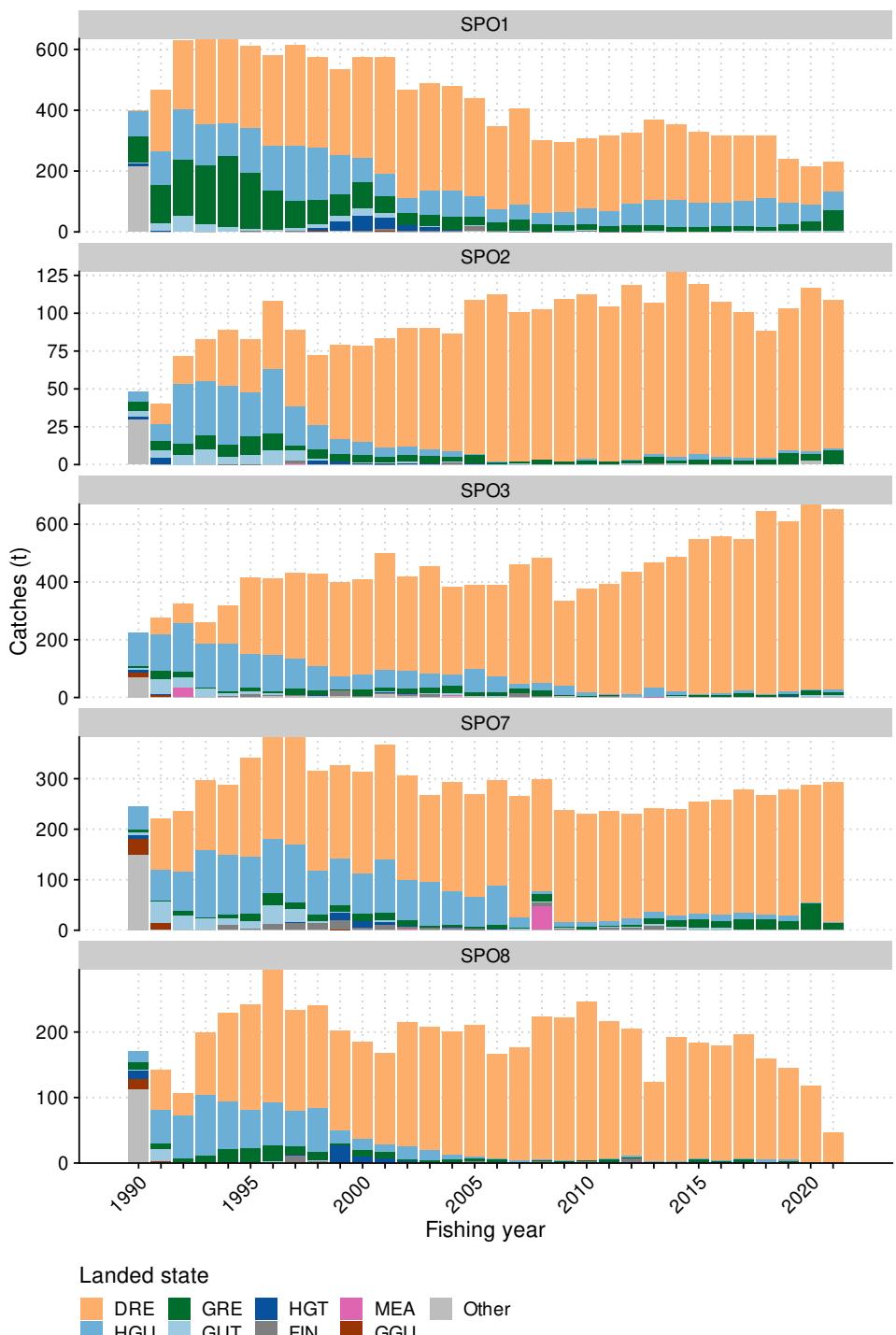


Figure 5: Landed state of rig from Quota Management Areas SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8.
Catches are tabulated in Appendix B, and landed state codes are defined in the glossary Table E.1.

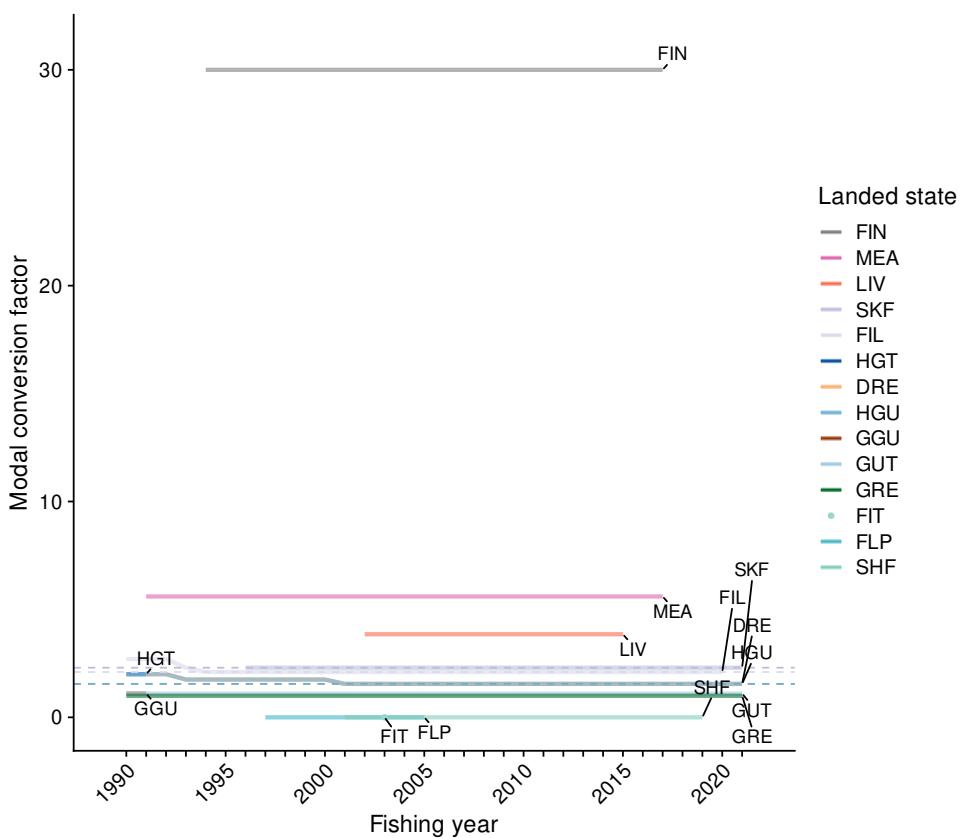


Figure 6: The modal annual conversion factor reported for the product states used in SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 catches. The current statutory conversion factor is indicated by a dashed line for states where a species-specific value is defined. Tabulated results are provided in Table B.17, and landed state codes are defined in the glossary Table E.1.

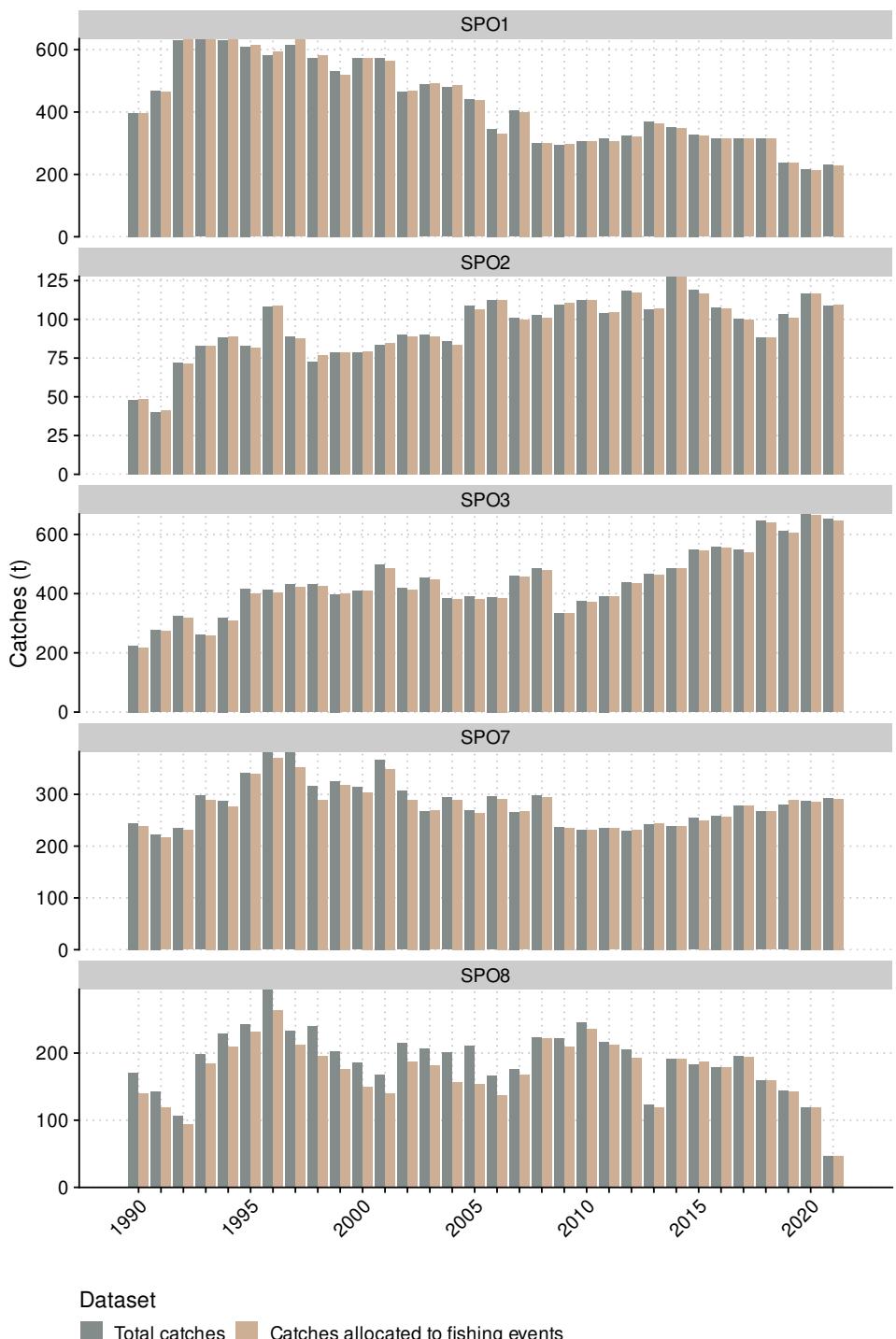


Figure 7: Total catches (t) of rig from SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 in comparison with catches allocated to fishing events in the characterisation dataset.

4.4 The SPO 1 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 2.3 to the SPO 1 catch/effort data. Panel (a) shows that the sum of the estimated SPO 1 catches was less than the declared landings in the same year. This is not surprising, given that rig are usually processed at sea to avoid urea contamination and fishers will often report processed weight instead of greenweight. It also shows that the majority of landings (by weight) were associated with effort information. In the case of SPO 1, the large majority of catch has been expanded using the scaled landings method of Kendrick & Bentley (2012) (green bars in Figure 8). Panel (b) plots this same information as a ratio, showing that the estimated catches represent about 0.75 of the annual landings expressed in terms of weight without an apparent temporal trend. Panel (c) shows that the proportion of events with positive SPO estimated catch expressed in terms of the number records hovered near 0.4 for most of the time period with an apparent increase to near 0.5 after 2017. The pattern in panel (d) (proportion of days fishing with SPO estimated catch) is similar to that in panel (c). Note that panels (c) and (d) will include effort by bottom trawl and bottom longline which catch rig in the top five or top eight estimated catch categories less frequently than by set net.

4.4.2 Form types used in the SPO 1 landing and effort data

The majority of SPO 1 landings were reported on the inshore CELR or the set net NCELR forms until the introduction of the replacement electronic reporting system (ERS) in 2020 (Figure 9, Table B.18). The use of the CELR form persisted in this QMA after the 2007 introduction of the NCELR form because a lot of the rig landings occurred in the large west coast Kaipara and Manukau harbours or in the Firth of Thames estuary where small set net vessels under 6 m in length were exempt from using the NCELR form.

4.4.3 Distribution of landings by method of capture

The distribution of landings by fishing method in SPO 1 was heavily weighted towards set net followed by bottom trawl, with 75 % of all landings attributed to this capture method averaged over the 32 years of catch history, followed by 16% for bottom trawl (Figure 10, Table B.23). While there has been a downward trend in the total SPO 1 landings over the period 1990 to 2021, the percentage of the catch returned by the set net fishery has remained relatively high, dropping to near 60% in 2019 to 2021 (Table B.23).

4.4.4 Distribution of landings by target species

Target fishing for rig dominated the set net landings where the majority of fishing for this species occurred in the two west coast harbours and the Firth of Thames (Figure 11). Bottom trawl landings of rig were more eclectic, with rig landed while fishing for snapper, trevally, red gurnard and tarakihi (Figure 11). There appeared to be no target fishing for rig using bottom trawl.

4.4.5 Species rank by form type and target species

As would be expected, rig was the top estimated catch species by rank when targeted by set net when using the CELR, the NCELR or the ERS-netting forms(Figure 12). Rig dropped to a lower estimated catch reporting rank in set net landings when targeted at other species such as tarakihi or trevally. The median estimated catch ranking of rig in the bottom trawl fishery varied between third and fourth, depending on the target species (Figure 12).

4.4.6 Number of fishing events by day and form type

The mean number of records per day of fishing for set net fishing using the CELR form was one, right up to 2021, indicating that these small boat harbour fisheries reported on a daily basis (Figure 13). This was also true of the bottom trawl vessels using the CELR form. These vessels averaged about three to four tows per day when they moved to an event based form (Figure 13).

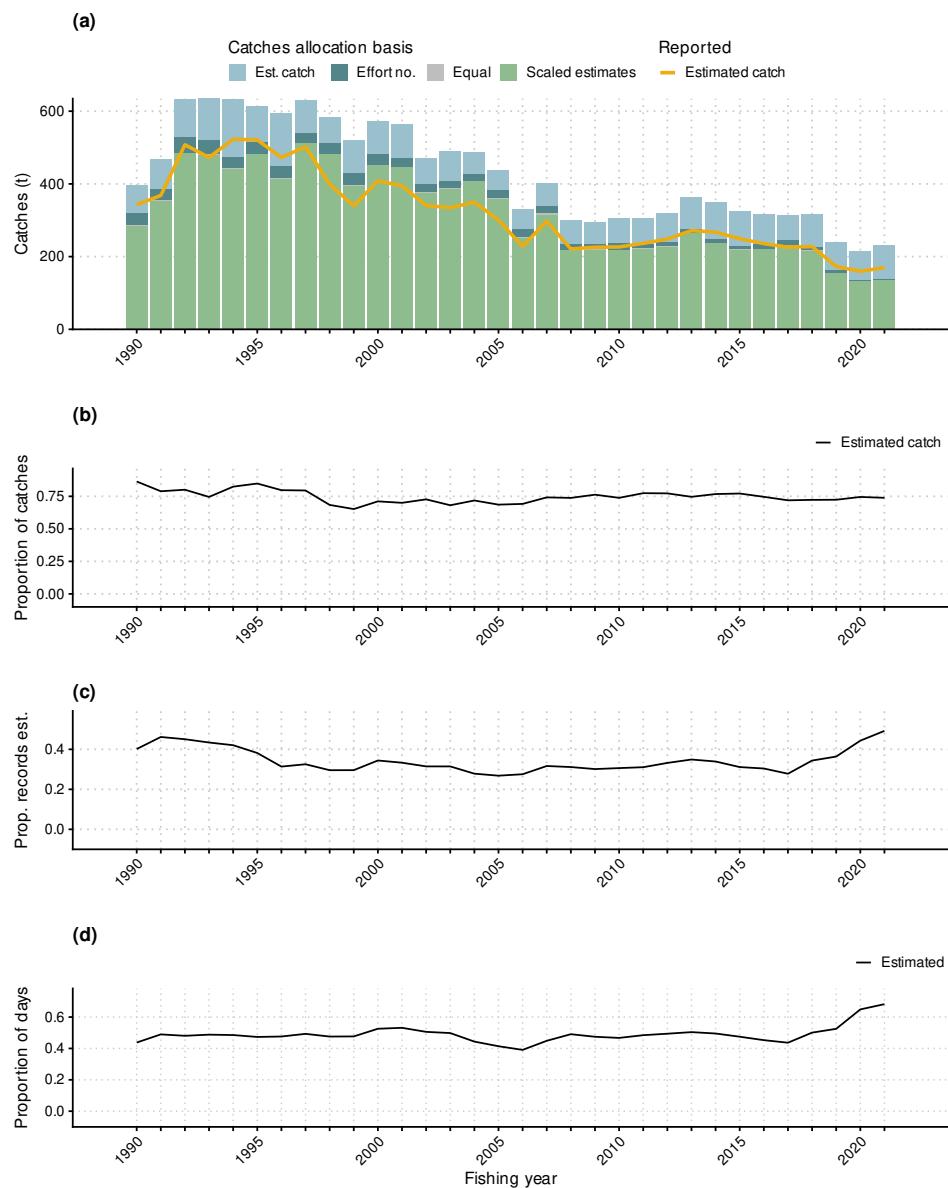


Figure 8: (a) bars: rig catches allocated to fishing events in the SPO 1 QMA with allocation method indicated by fill colour (see Section 3.3); line: total estimated catch of SPO; (b) the proportion of SPO 1 catches included in estimated catch data; (c) the proportion of fishing event records with an estimated catch of SPO; (d) the proportion of vessel-days fished with a reported catch of SPO.

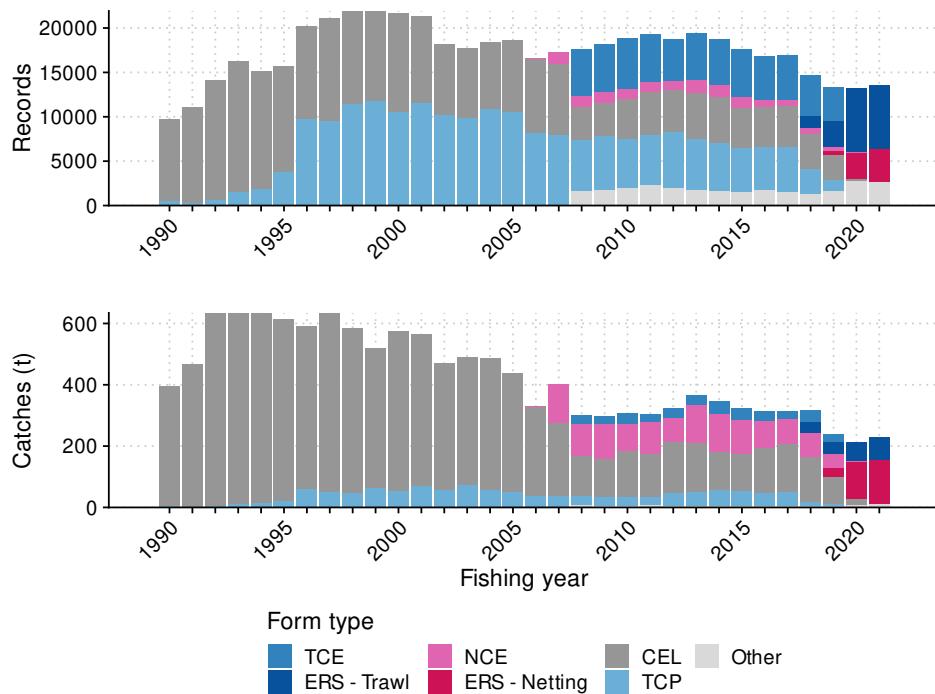


Figure 9: Reporting forms used on trips catching rig within the SPO 1 Quota Management Area, in terms of fishing event records and catches. Tabulated results are available in Appendix B. Form types grouped as Other include: ERS - Lining, ERS - Other Lining, ERS - Potting, ERS - Seining, HTC, LCE, LTC, TUN. A list of the main form type codes is included in the glossary Table E.2.

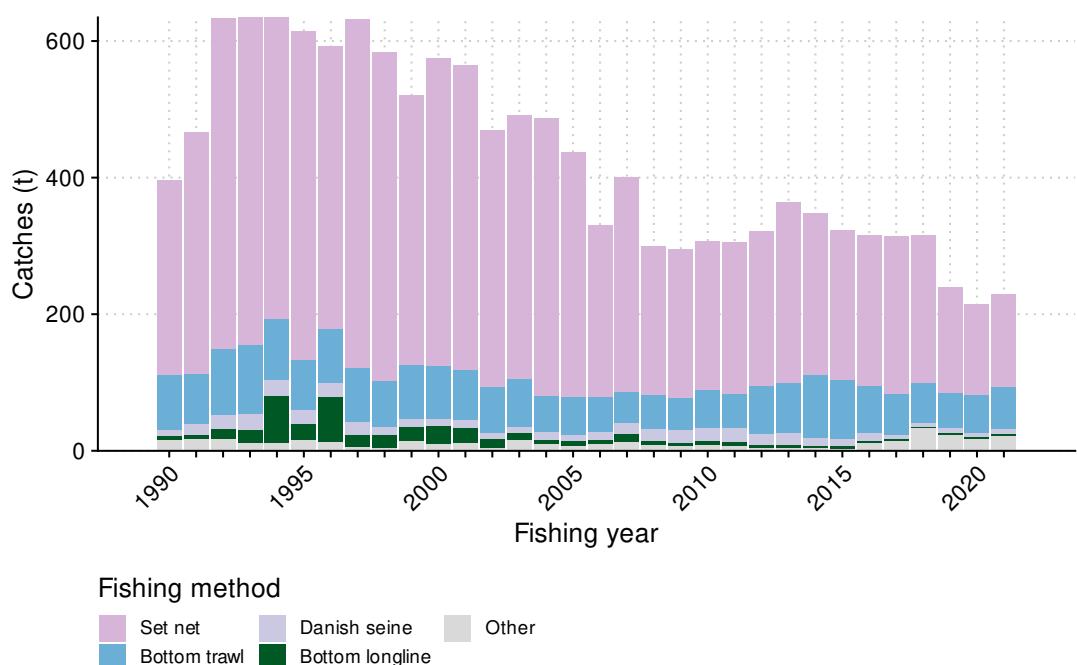


Figure 10: Catches of rig by fishing method, for events within the SPO 1 Quota Management Area. Methods grouped as Other include: BPT, BS, CP, CRP, D, DL, DN, DPS, DV, FN, FP, H, HL, L, MW, PL, POT, PRB, PS, PSH, PSN, RLP, RN, SCN, SLL, T, TL. Tabulated results are provided in Appendix B, and a list of the main fishing method code types is included in the glossary Table E.3.

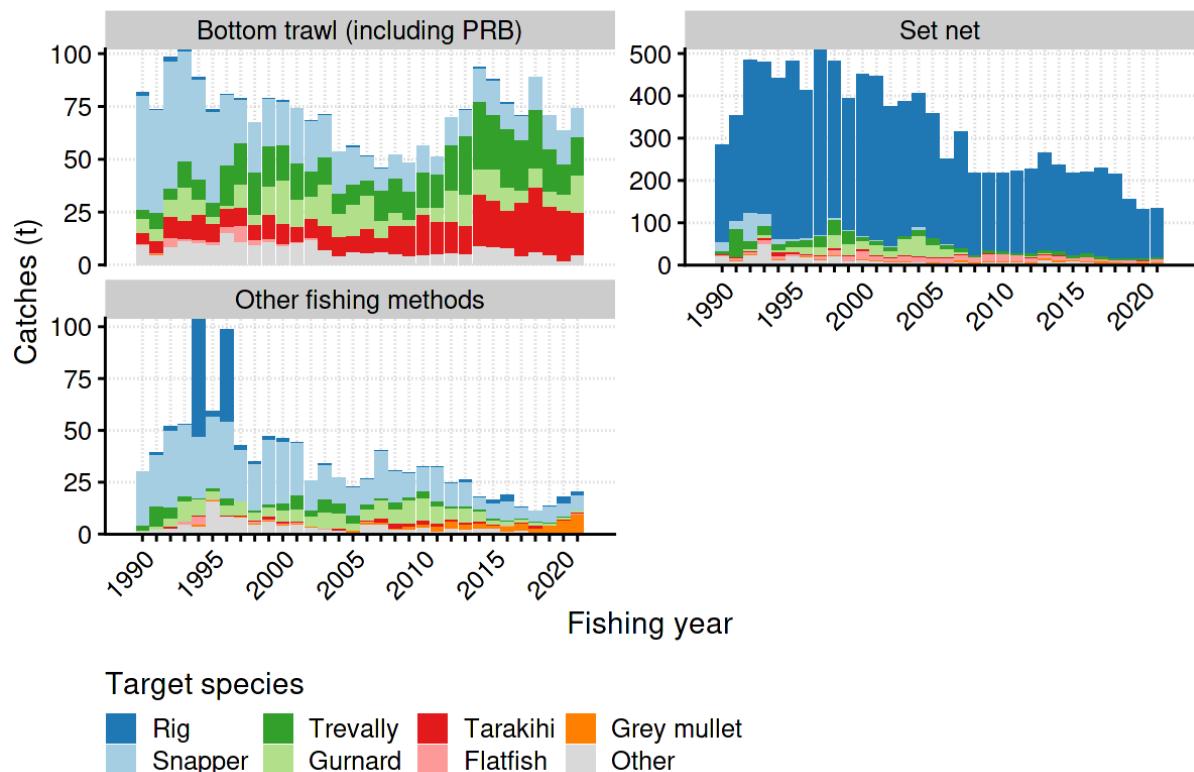


Figure 11: Catches of rig by fishing method and declared target species, for events within the SPO 1 Quota Management Area. Fishing Methods grouped as Other include: BLL, BPT, BS, CP, CRP, D, DL, DN, DPS, DS, DV, FN, FP, H, HL, L, MW-PRM, PL, POT, PS, PSH, PSN, RLP, RN, SCN, SLL, T, TL. Species grouped as Other include target species with less than 4% of the rig catch within the SPO 1 Quota Management Area in a fishing year.

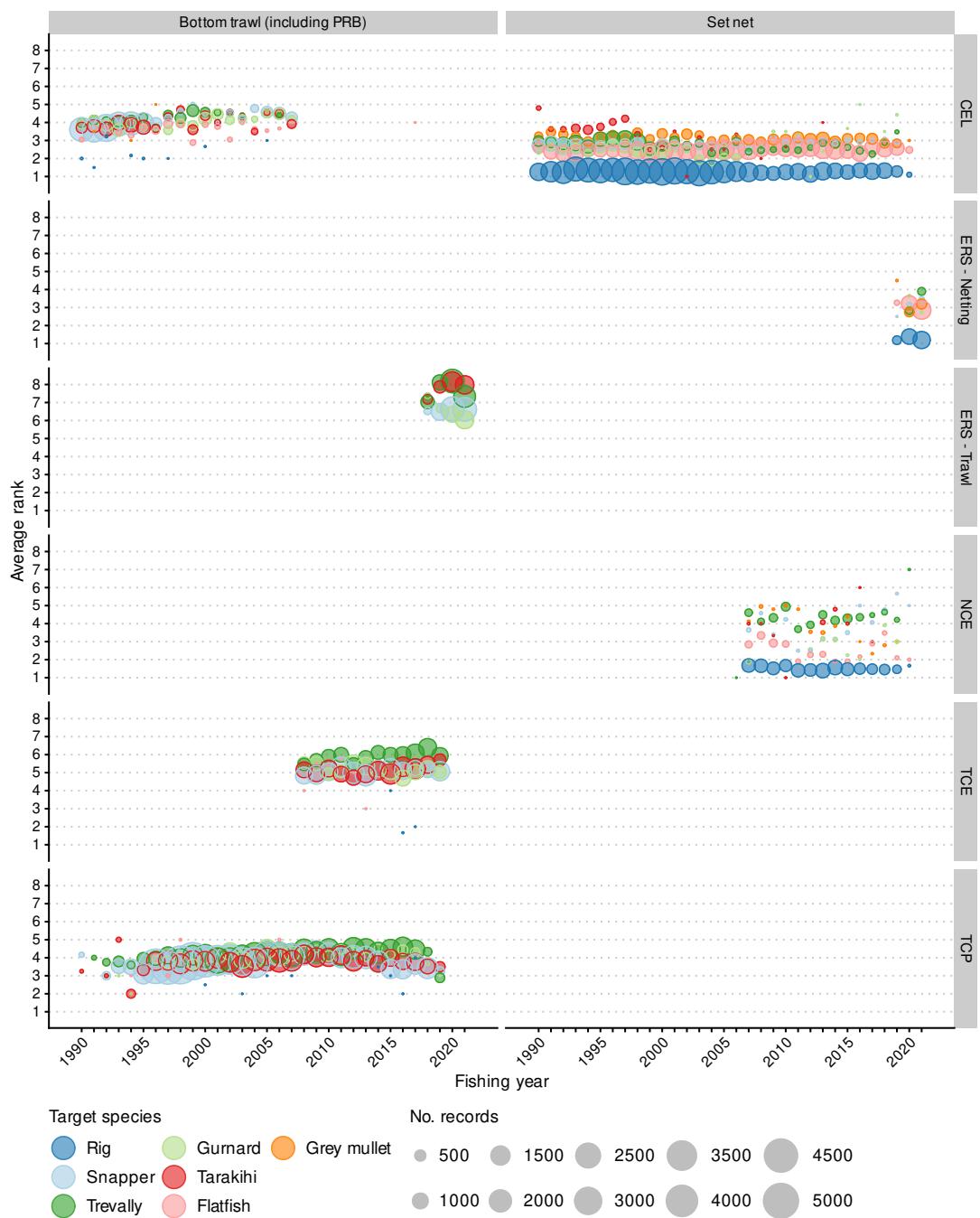


Figure 12: Average rank of rig in the estimated catch, by fishing method, form type and declared target species, for events with estimated catches within the SPO 1 Quota Management Area. The area of the circles scales with the number of records.

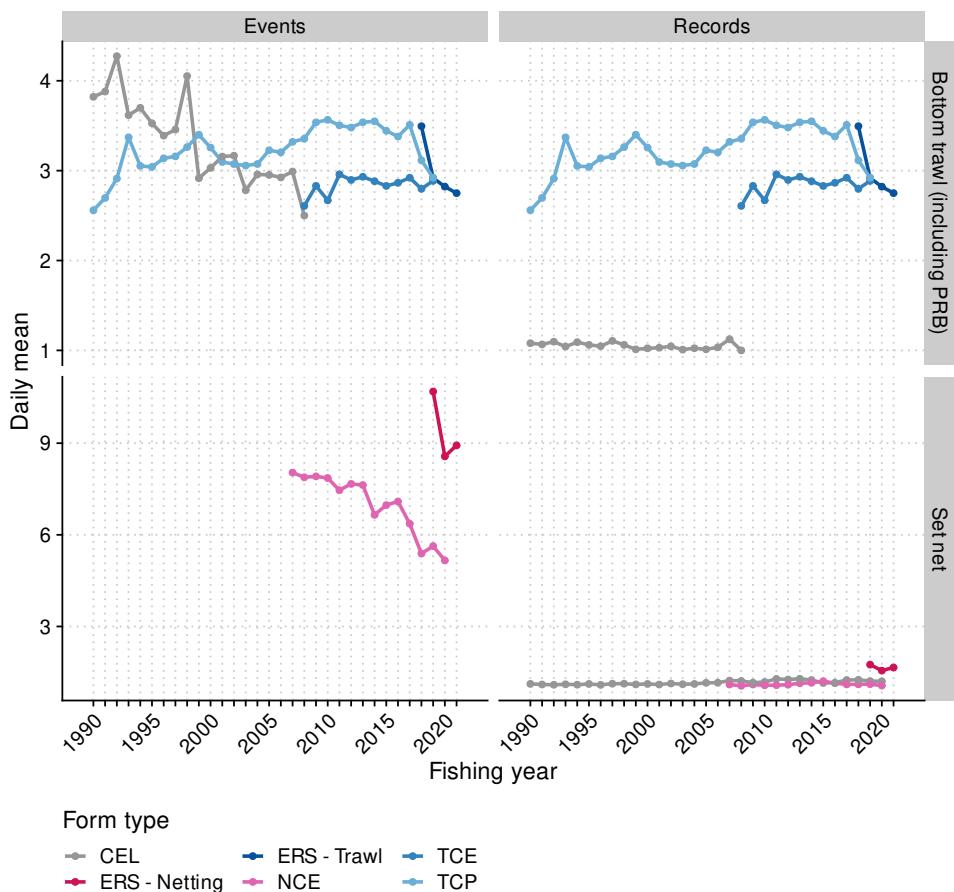


Figure 13: The mean number of fishing events and data records per vessel-day, by fishing method and reporting form, for effort within the SPO 1 QMA on trips landing catch from SPO 1. Data are included for years where a form was used on at least five vessel-days. CELR form types are undefined in set net events.

4.5 The SPO 2 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 2.3 to the SPO 2 catch/effort data. Panel (a) shows that the sum of the estimated SPO 2 catches was considerably less than the declared landings in the same year. This is probably due to the low rig catches in this QMA, resulting in rig being a minor species that is frequently not reported because it is not one of the top five species in the estimated catch. It also shows that the majority of landings (by weight) were associated with effort information although a relatively large proportion of the landings before 2000 were allocated by effort, which happens when rig are present at the landing but none of trip records recorded an estimated catch of rig. Panel (b) plots this information as a ratio, showing that the estimated catches represented about 0.5 of the annual landings by weight, rising to 0.75 by the end of the series. Panel (c) shows that the proportion of events with positive SPO estimated catch when calculated in terms of the number of records hovered near 0.2 at the beginning of the series, increasing to 0.6 by 2020. The pattern in panel (d) (proportion of days fishing with SPO estimated catch) is similar to that in panel (c). Note that panels (c) and (d) will include effort by bottom trawl and bottom longline which catch rig in the top five or top eight estimated catch categories less frequently than by set net.

4.5.2 Form types used in the SPO 2 landing and effort data

The majority of SPO 2 landings were reported on the inshore CELR forms and then switching to the TCER forms until the introduction of the replacement electronic reporting system (ERS) in 2020 (Figure 15, Table B.19). The use of the NCELR form is relatively low in this QMA because the majority of rig are landed by bottom trawl (Figure 16). There was some reporting of rig landings on the deepwater TCEPR form, but the use of this form tapered off with the introduction of the event-based TCER form in 2008 (Figure 15).

4.5.3 Distribution of landings by method of capture

The distribution of landings by fishing method in SPO 2 was primarily bottom trawl, with 73% of all landings attributed to this capture method averaged over the 32 years of catch history, followed by 24% for set net (Figure 16, Table B.24). The annual distribution of landings between bottom trawl and set net is variable but there is no apparent trend across the years (Table B.24).

4.5.4 Distribution of landings by target species

Bottom trawl landings of rig were primarily made while fishing for red gurnard or tarakihi (Figure 17). Set net landings of rig were made when targeting rig, common warehou or moki.

4.5.5 Species rank by form type and target species

The mean rank for estimated catch of rig when bottom trawling tended to be four or five, and moved up to seven on the ERS-trawl form, indicating that the incidence of rig was relatively low in this QMA when trawling (Figure 18). For set net, the mean rank for estimated catch of rig varied from one for target rig fishing to three to four when fishing for other target species such as blue moki (Figure 18).

4.5.6 Number of fishing events by day and form type

The mean number of records per day of fishing for set net effort using the CELR form was one right up to 2007, after which that form was little used, having been replaced by the NCELR form (Figure 19). However, the mean number of records per day stayed near one until the ERS-Netting form replaced the NCELR, when two to three records per day of fishing were observed. Bottom trawl vessels using the CELR form also recorded only a single record per day of fishing (Figure 19). After the CELR form was phased out in 2007, these vessels averaged two to three tows per day when they moved to an event based form and this was continued under the ERS-Trawl form (Figure 19).

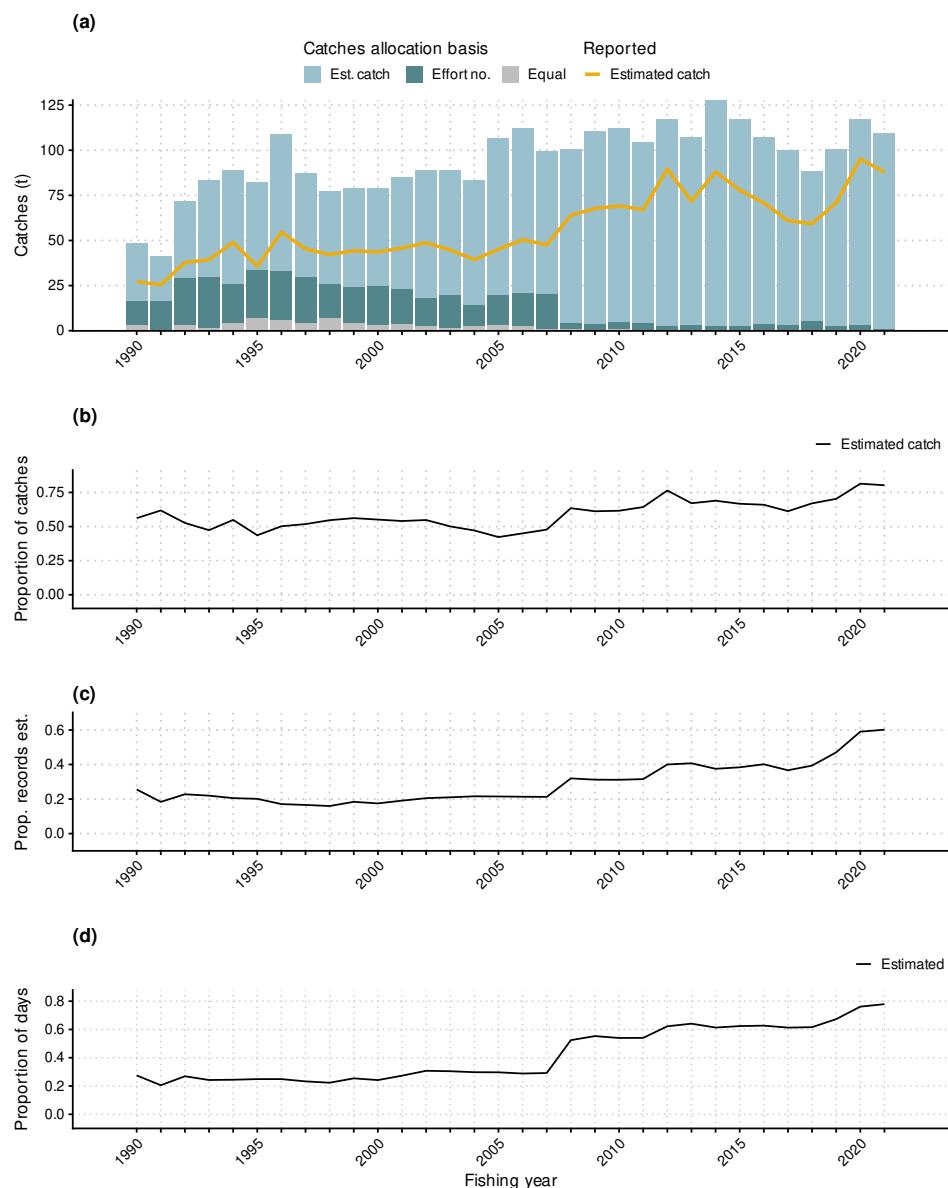


Figure 14: (a) bars: rig catches allocated to fishing events in the SPO 2 QMA with allocation method indicated by fill colour (see Section 3.3); line: total estimated catch of SPO; (b) the proportion of SPO 2 catches included in estimated catch data; (c) the proportion of fishing event records with an estimated catch of SPO; (d) the proportion of vessel-days fished with a reported catch of SPO.

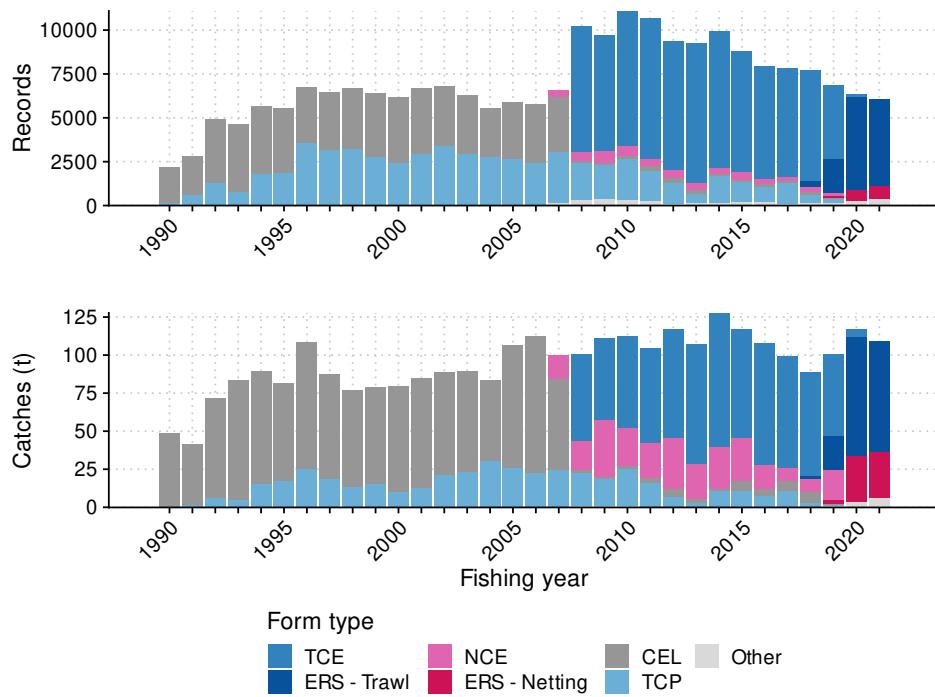


Figure 15: Reporting forms used on trips catching rig within the SPO 2 Quota Management Area, in terms of fishing event records and catches. Tabulated results are available in Appendix B. Form types grouped as Other include: ERS - Lining, ERS - Other Lining, ERS - Potting, ERS - Seining, LCE, LTC, TUN.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

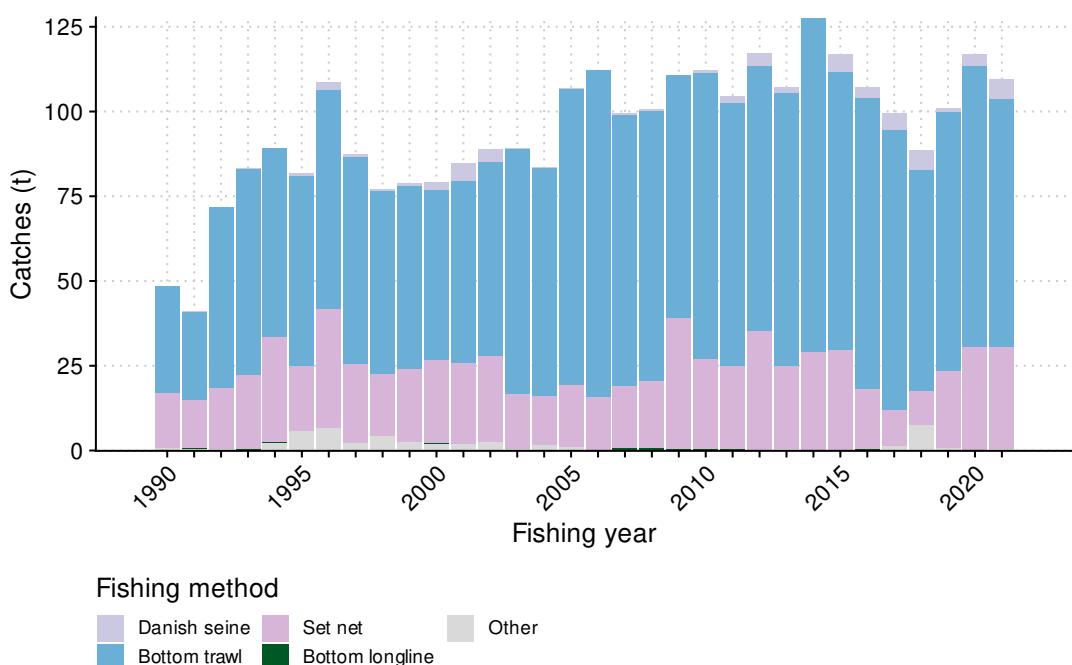


Figure 16: Catches of rig by fishing method, for events within the SPO 2 Quota Management Area. Methods grouped as Other include: BPT, BS, CP, CRP, DL, DV, FN, FP, HL, MW, PL, PRB, PS, PSH, RLP, SLL, T, TL. Tabulated results are provided in Appendix B, and a list of the main fishing method code types is included in the glossary Table E.3.

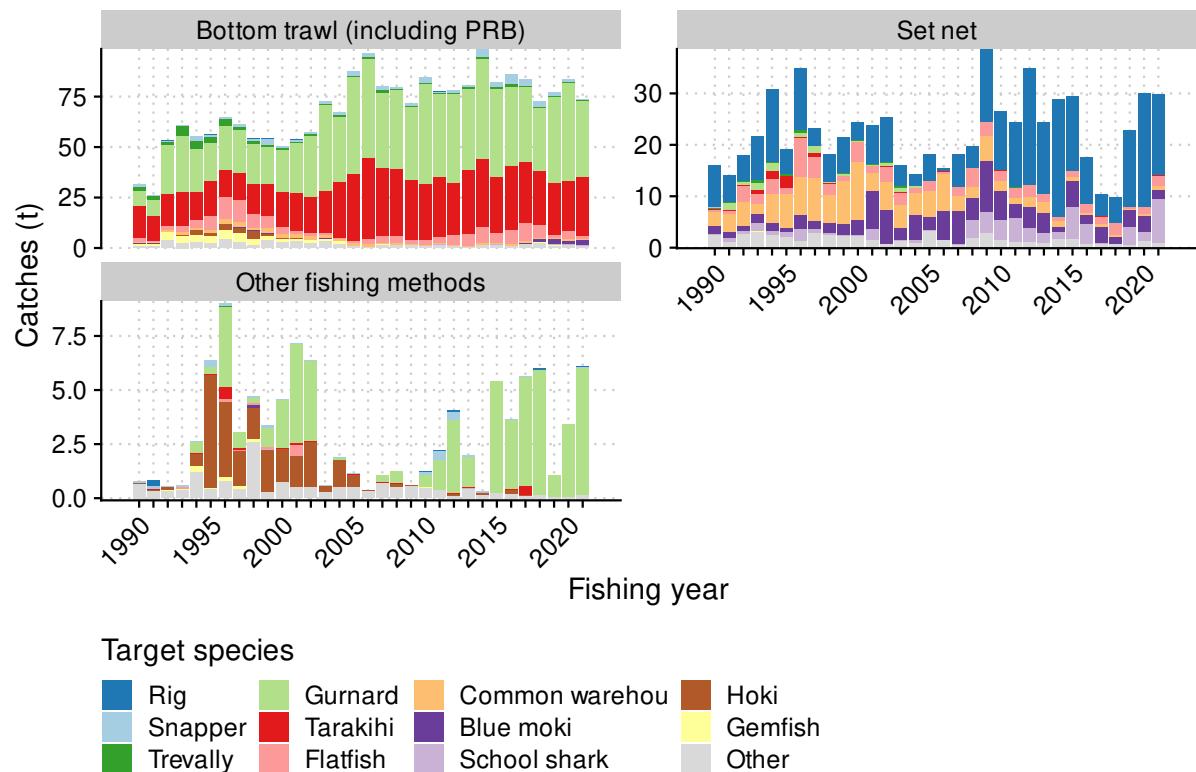


Figure 17: Catches of rig by fishing method and declared target species, for events within the SPO 2 Quota Management Area. Fishing Methods grouped as Other include: BLL, BPT, BS, CP, CRP, DL, DS, DV, FN, FP, HL, MW-PRM, PL, PS, PSH, RLP, SLL, T, TL. Species grouped as Other include target species with less than 4% of the rig catch within the SPO 2 Quota Management Area in a fishing year.

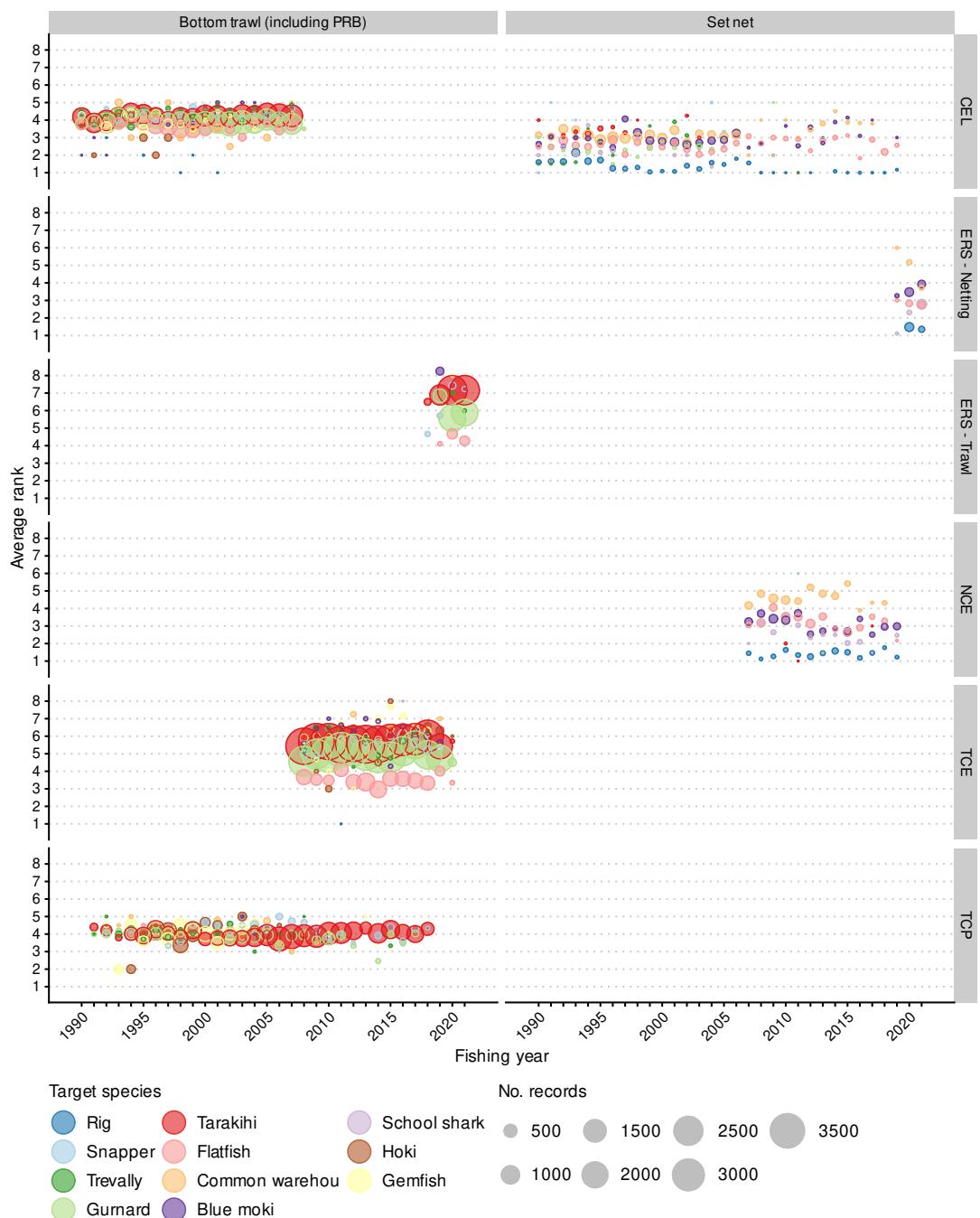


Figure 18: Average rank of rig in the estimated catch, by fishing method, form type and declared target species, for events with estimated catches within the SPO 2 Quota Management Area. The area of the circles scales with the number of records.

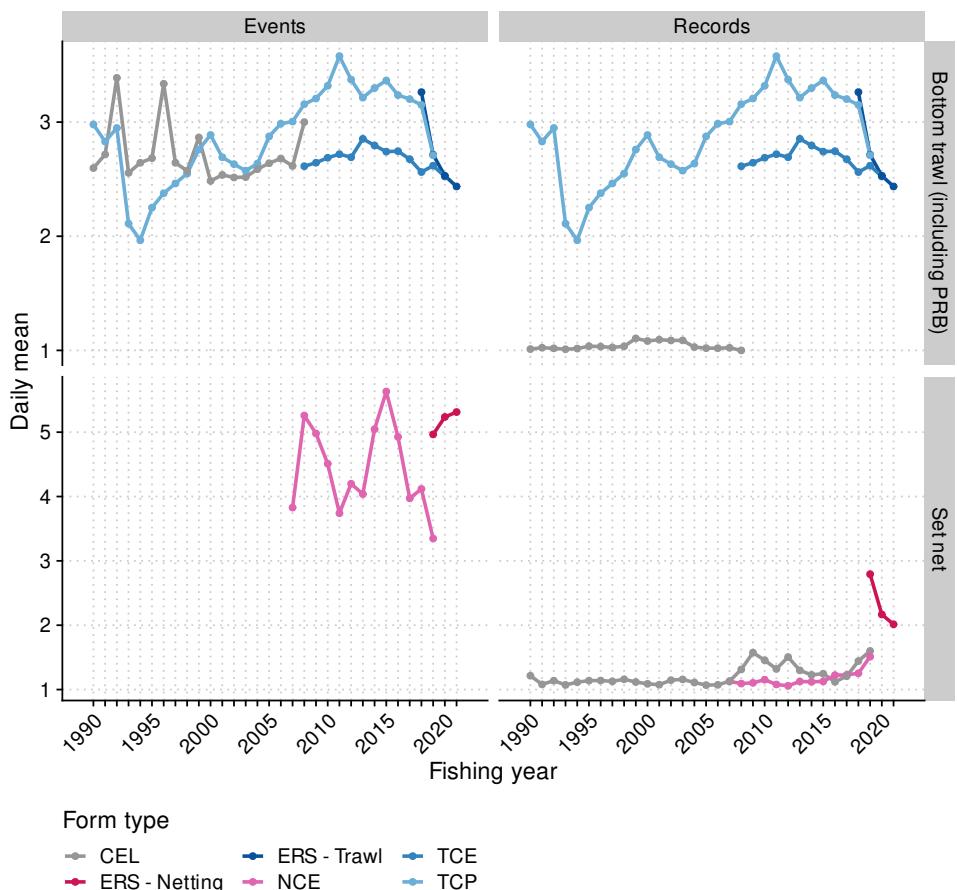


Figure 19: The mean number of fishing events and data records per vessel-day, by fishing method and reporting form, for effort within the SPO 2 QMA on trips landing catch from SPO 2. Data are included for years where a form was used on at least five vessel-days. CELR form types are undefined in set net events.

4.6 The SPO 3 Quota Management Area

4.6.1 Allocation of estimated catches to landings

Figure 20 shows the results of the application of the allocation procedures described in Section 2.3 to the SPO 3 catch/effort data. Panel (a) shows that the sum of the estimated SPO 3 catches was close to the declared landings in the same year. This is due to the well developed set net rig fishery in this QMA, accounting for a large proportion of the rig catch. It also shows that the majority of landings (by weight) were associated with effort information indicating that they were in the top five or eight estimated catch records for the fishing event with relatively few of the landings (mainly confined to the period before 2000) where catches were allocated in proportion to every effort record. Panel (b) plots this information as an annual ratio, showing that the estimated catches represented about 0.9 of the annual landings by weight, rising even higher by the end of the series after the introduction of ERS. Panel (c) shows that the proportion of events with positive SPO estimated catch when calculated in terms of the number of records hovered near 0.3 at the beginning of the series, increasing to 0.4 by 2020. The pattern in panel (d) (proportion of days fishing with SPO estimated catch) is similar to that in panel (c). Note that panels (c) and (d) include effort by bottom trawl and bottom longline gear where estimated rig catches in the top five or top eight rank were less frequent than for set net.

4.6.2 Form types used in the SPO 3 landing and effort data

Before 2008, the majority of SPO 3 landings were reported on the inshore CELR forms which switched to the event-based NCELR forms in 2008 until the introduction of the electronic reporting system (ERS) in 2020 (Figure 21, Table B.20). The use of the NCELR and ERS-Netting forms is high in this QMA because the majority of rig are landed by set net (Figure 22).

4.6.3 Distribution of landings by method of capture

The distribution of landings by fishing method in SPO 3 was primarily set net, with 65% of all landings attributed to this capture method averaged over the 32 years of catch history, followed by 28% for bottom trawl (Figure 22, Table B.25). Seven percent of the landings were attributed to Danish seine, a fishing method that developed in this QMA around 2009 or 2010 (Table B.25). There has been a trend of increasing bottom trawl catch of rig with a corresponding decrease in the importance of set net catches (Table B.25) with set net catches accounting for 50–60% of the catch after 2010. This may be due in part to the regulations imposed on the set net fishery for the protection of Hector’s dolphins.

4.6.4 Distribution of landings by target species

Set net landings of rig were made when targeting rig or school shark (Figure 23). Bottom trawl landings of rig were primarily made while fishing for red gurnard, flatfish or elephant fish. However, target fishing for rig when using bottom trawl has increased since around 2010. Danish seine landings were primarily targeted at rig or red cod.

4.6.5 Species rank by form type and target species

The mean rank for estimated catch of rig when bottom trawling tended to be four or five when targeting flatfish on both the TCER form or the ERS-trawl form, without much indication of change over time (Figure 25). The mean rank for estimated catch of rig when targeting other species with bottom trawl could be as high as eight when targeting barracouta. The mean rank for estimated catch of rig in the set net fishery varied from one when target rig fishing to two or three when targeting school shark (Figure 24). The mean rank for estimated catch of rig when Danish seining lay between three and four or five when targeting species such as tarakihi or red cod, which the mean rank for rig target fishing was near two (Figure 26).

4.6.6 Number of fishing events by day and form type

The mean number of records per day of fishing for set net, bottom trawl and Danish seine effort when using the CELR form was one up to 2021 (Figure 27). This number rose to about 1.5 records per day with the introduction of the NCELR form and rose again to above two when using the ERS-Netting form (Figure 27). Bottom trawl vessels using the event-based TCER form tended to average just below three records per day. This average dropped a bit under the ERS-Trawl form to about 2.5 records per day (Figure 27).

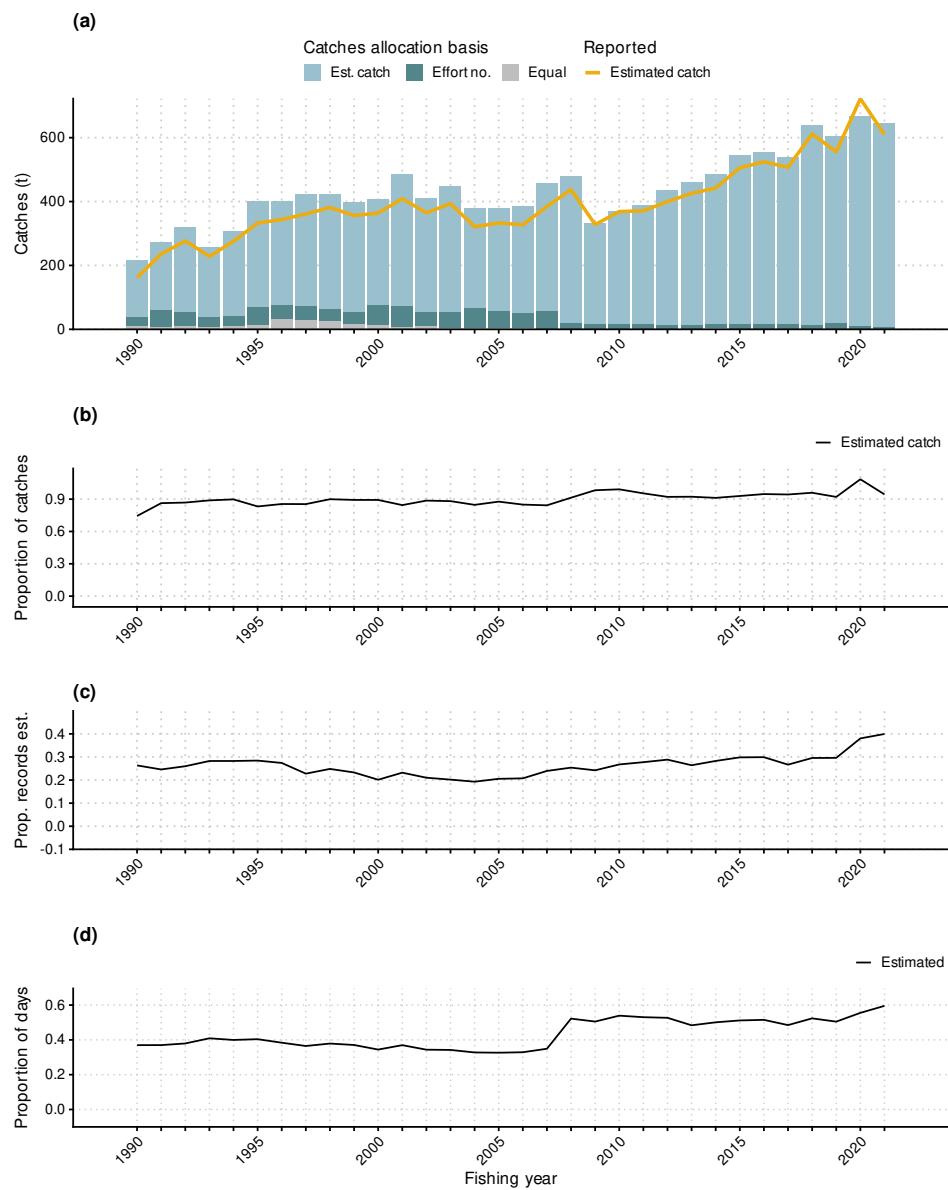


Figure 20: (a) bars: rig catches allocated to fishing events in the SPO 3 QMA with allocation method indicated by fill colour (see Section 3.3); line: total estimated catch of SPO; (b) the proportion of SPO 3 catches included in estimated catch data; (c) the proportion of fishing event records with an estimated catch of SPO; (d) the proportion of vessel-days fished with a reported catch of SPO.

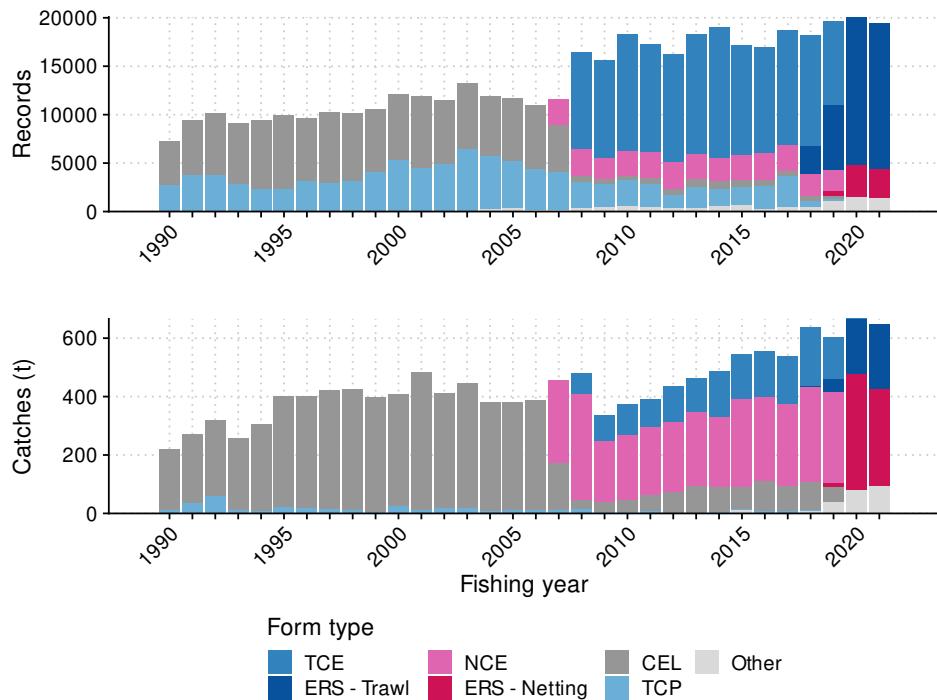


Figure 21: Reporting forms used on trips catching rig within the SPO 3 Quota Management Area, in terms of fishing event records and catches. Tabulated results are available in Appendix B. Form types grouped as Other include: ERS - Dredge, ERS - Lining, ERS - Other Lining, ERS - Potting, ERS - Seining, LCE, LTC, SJC. A list of the main form type codes is included in the glossary Table E.2.

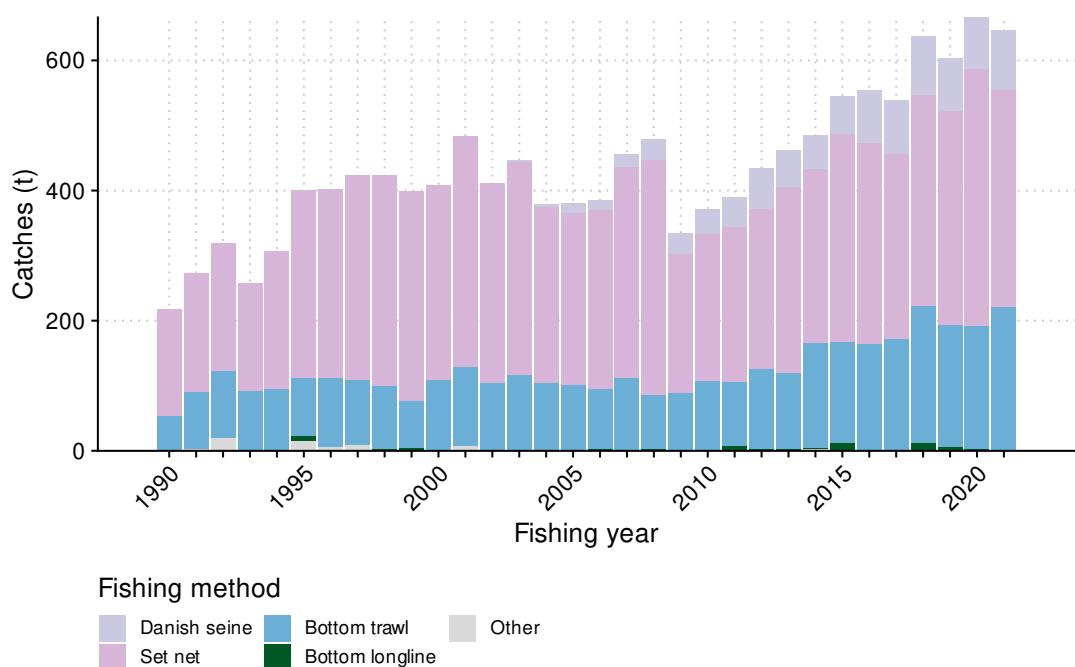


Figure 22: Catches of rig by fishing method, for events within the SPO 3 Quota Management Area. Methods grouped as Other include: BPT, BS, CP, CRP, D, DL, DN, DV, FN, FP, HL, L, MW, PL, POT, PRB, PRM, PS, RLP, RN, SCN, SJ, T, TL. Tabulated results are provided in Appendix B, and a list of the main fishing method code types is included in the glossary Table E.3.

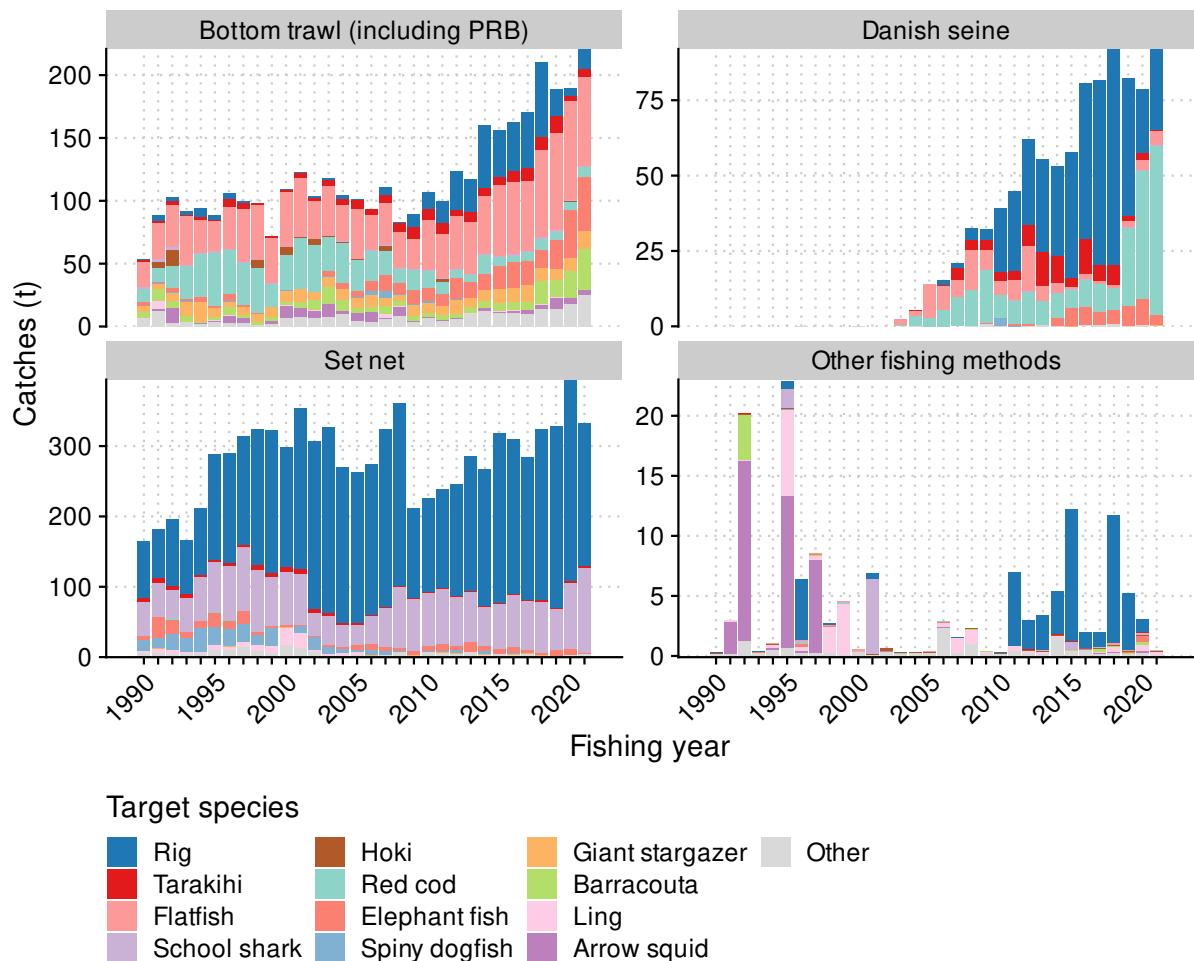


Figure 23: Catches of rig by fishing method and declared target species, for events within the SPO 3 Quota Management Area. Fishing Methods grouped as Other include: BLL, BPT, BS, CP, CRP, D, DL, DN, DV, FN, FP, HL, L, MW-PRM, PL, POT, PS, RLP, RN, SCN, SJ, T, TL. Species grouped as Other include target species with less than 4% of the rig catch within the SPO 3 Quota Management Area in a fishing year.



Figure 24: Average rank of rig in the estimated catch, by fishing method, form type and declared target species, for SN events with estimated catches within the SPO 3 Quota Management Area. The circle size scales with the number of records.

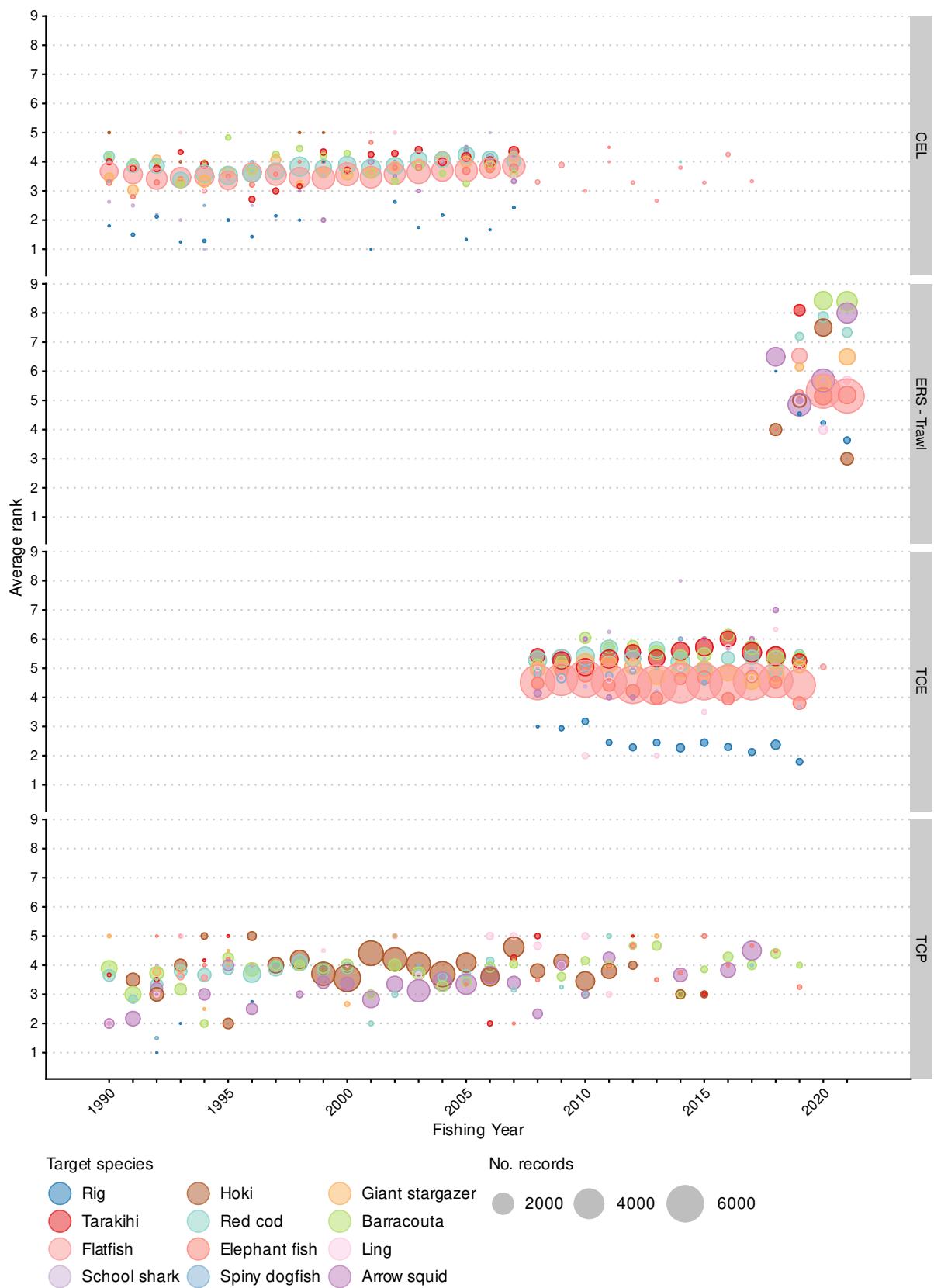


Figure 25: Average rank of rig in the estimated catch, by fishing method, form type and declared target species, for BT-PRB events with estimated catches within the SPO 3 Quota Management Area. The circle size scales with the number of records.

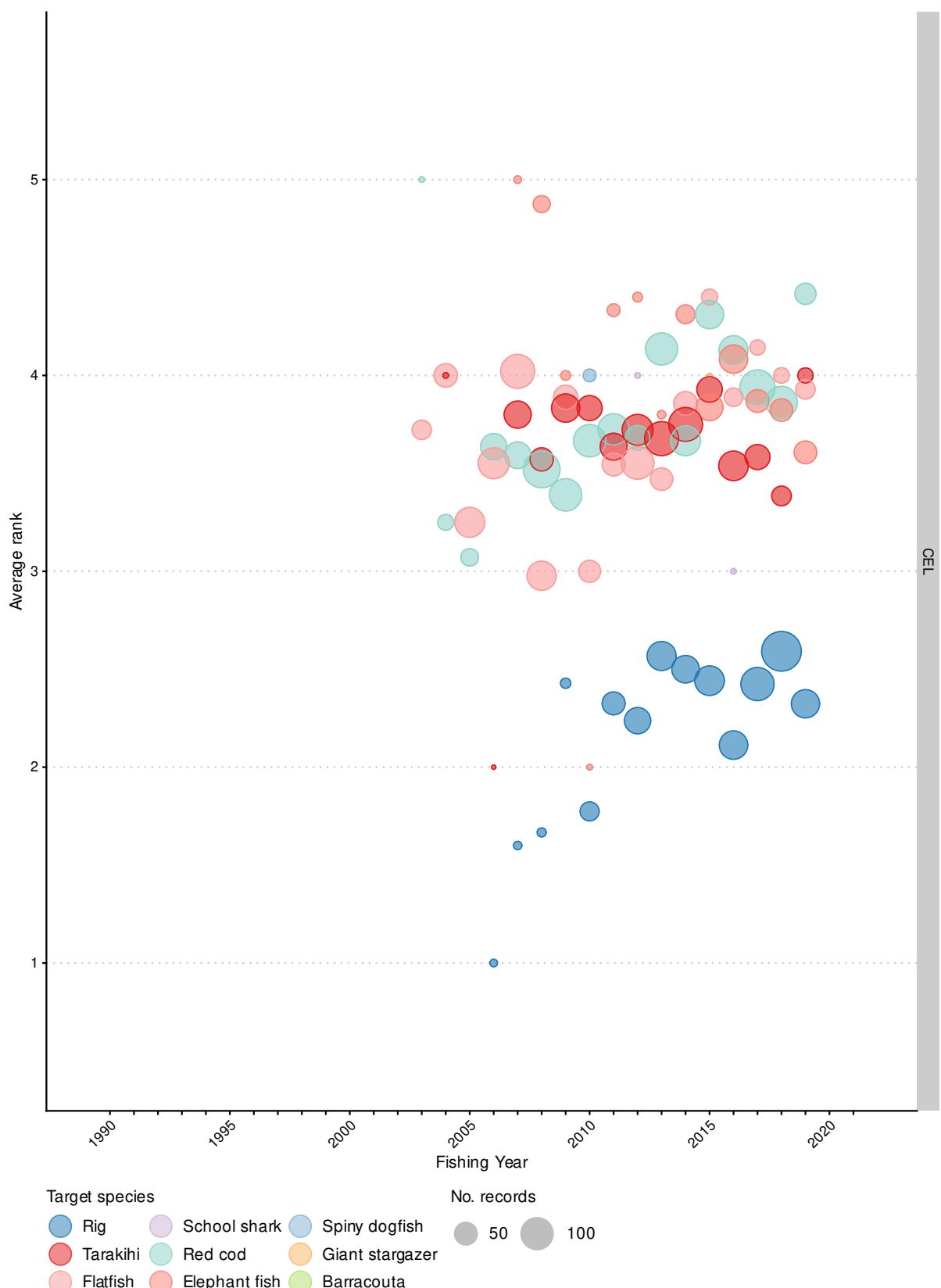


Figure 26: Average rank of rig in the estimated catch, by fishing method, form type and declared target species, for DS events with estimated catches within the SPO 3 Quota Management Area. The circle size scales with the number of records.

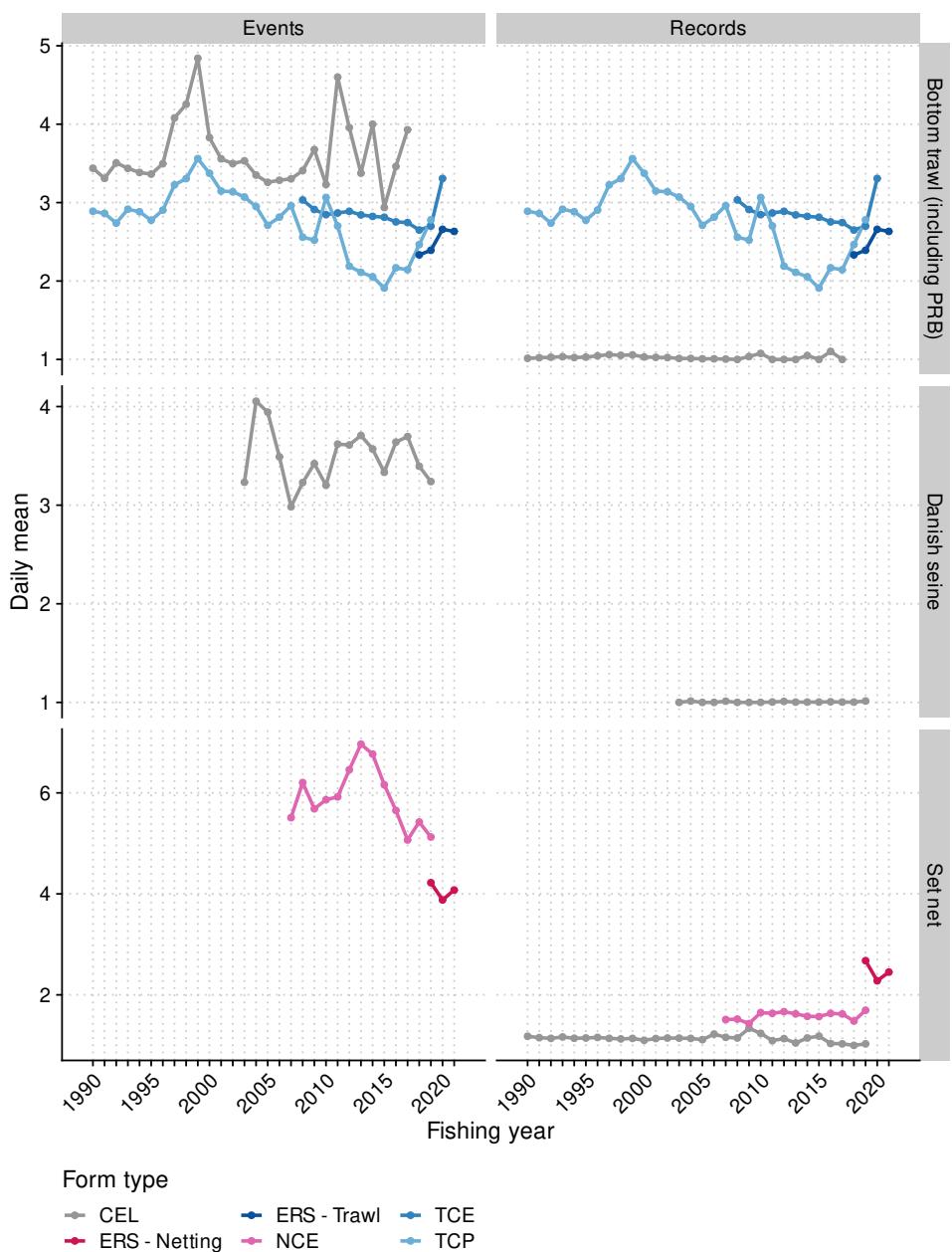


Figure 27: The mean number of fishing events and data records per vessel-day, by fishing method and reporting form, for effort within the SPO 3 QMA on trips landing catch from SPO 3. Data are included for years where a form was used on at least five vessel-days. CELR form types are undefined in set net events.

4.7 The SPO 7 Quota Management Area

4.7.1 Allocation of estimated catches to landings

Figure 28 shows the results of the application of the allocation procedures described in Section 2.3 to the SPO 7 catch/effort data. Panel (a) shows that the sum of the estimated SPO 7 catches was notably below the declared landings in the same year. This made SPO 7 more like SPO 1 and SPO 2 and less like SPO 3, with the estimated catches not required if they are in sixth rank or less by weight of the summed catch in an event or day's fishing. Panel (b) plots this information as an annual ratio, showing that the estimated catches represented about 0.75 of the annual landings, without any temporal trend over the 32 years of data. Panel (c) shows that when the proportion with estimated catch is calculated in terms of the number of records rather than by weight, there is an increasing trend rising from about 0.25 to 0.5 by 2021. The pattern in panel (d) (proportion of days fishing with SPO estimated catch) has a noticeable step up in the mid-2000s, but it is unclear what causes this as the TCER and NCELNR forms were introduced a bit later in 2008. Note that panels (c) and (d) include effort by bottom trawl where estimated rig catches in the top five or top eight rank were less frequent than for set net.

4.7.2 Form types used in the SPO 7 landing and effort data

Before 2008, nearly all of SPO 7 landings were reported on the inshore CELR forms which switched to the event-based TCER and NCELNR forms in 2008 until the introduction of the electronic reporting system (ERS) in 2020 (Figure 29, Table B.21). The distribution of NCELNR and TCER forms was nearly equal because rig were reported by both fishing methods (Figure 30). There is a noticeable trend towards bottom trawl reporting of rig by the end of the series.

4.7.3 Distribution of landings by method of capture

The distribution of landings by fishing method has been distributed equally in SPO 7 between set net and bottom trawl, with 50% of all landings attributed to set net when averaged over the 32 years of catch history, followed by 48% for bottom trawl (Figure 30, Table B.26). There has been a strong trend over time of an increase in the relative proportion of rig bottom trawl catch with a corresponding decrease in the importance of set net catches, with only 24% of the SPO 7 landings attributed to the set net method during the five year period 2017 to 2021 (Table B.26). The percentage of rig landed by set net dropped to 5% in 2021 with the imposition of severe restrictions to fishing on the west coasts of the North Island and South Island which were applied to set nets in Tasman Bay and Golden Bay.

4.7.4 Distribution of landings by target species

Set net landings of rig were made when almost exclusively targeting rig (Figure 31). Bottom trawl landings of rig were primarily made while fishing for flatfish or more recently (after 2010), red gurnard. The bycatch of rig in the target tarakihi BT fishery has also increased after 2010.

4.7.5 Species rank by form type and target species

The mean rank for estimated catch of rig in the set net fishery was centred at one when target rig fishing and to between three and four when targeting school shark (Figure 32). The mean rank for estimated catch of rig when bottom trawling tended to be four or five when targeting flatfish on both the TCER form or the ERS-trawl form, without much indication of change over time (Figure 32). The mean rank for estimated catch of rig when targeting other species with bottom trawl was near seven, including when targeting tarakihi and reporting on the ERS-Trawl form.

4.7.6 Number of fishing events by day and form type

The mean number of records per day of fishing by set net when using the CELR form was one up to 2020, and near one when using either NCELR or the ERS-Netting form from 2008 to 2021 (Figure 33). The mean number of records per day of fishing by bottom trawl when using the CELR form was one up to 2007 when the form was no longer used for this QMA. Bottom trawl vessels using the event-based TCER form tended to average just below three records per day and this average continued under the ERS-Trawl form (Figure 33).

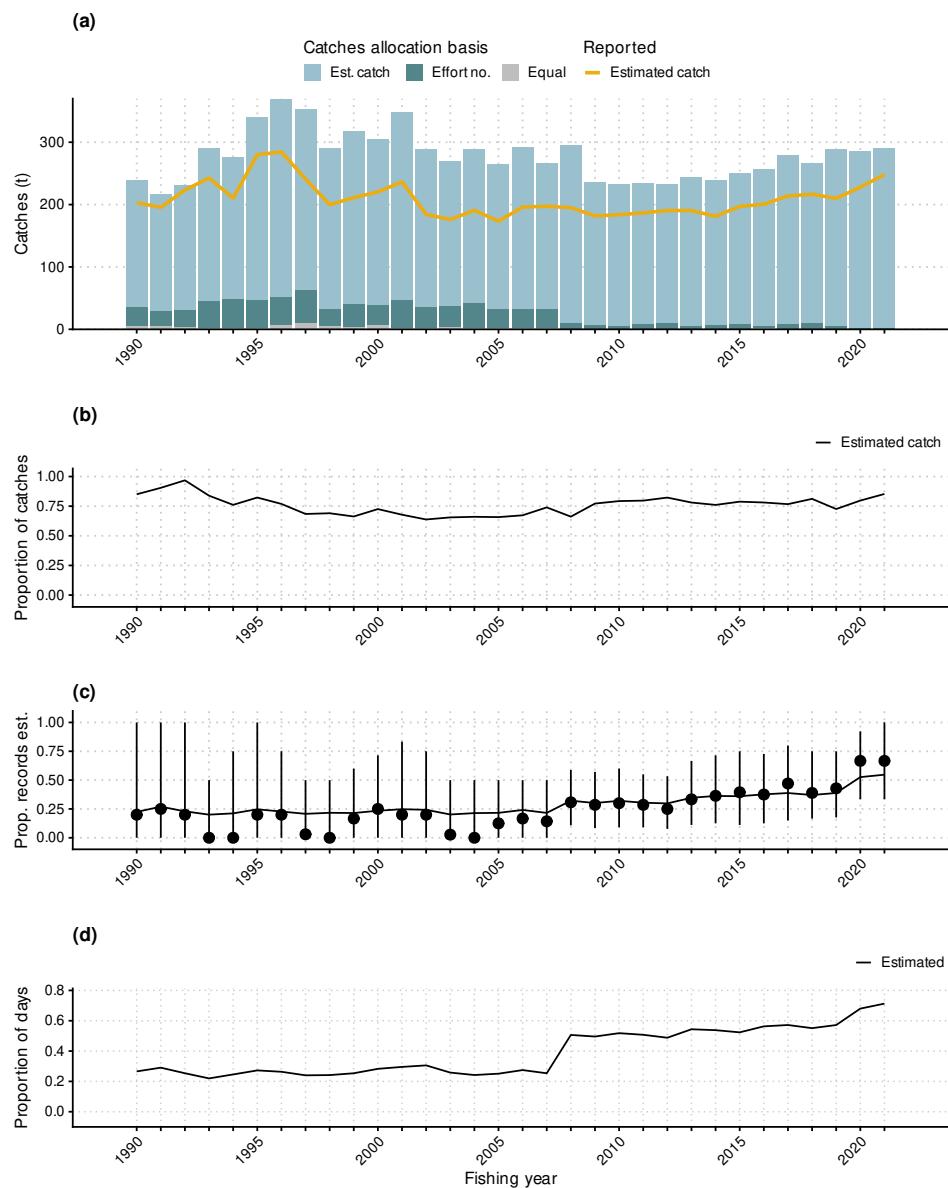


Figure 28: (a) bars: rig catches allocated to fishing events in the SPO 7 QMA with allocation method indicated by fill colour (see Section 3.3); line: total estimated catch of SPO; (b) the proportion of SPO 7 catches included in estimated catch data; (c) the proportion of fishing event records with an estimated catch of SPO, 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 SPO.

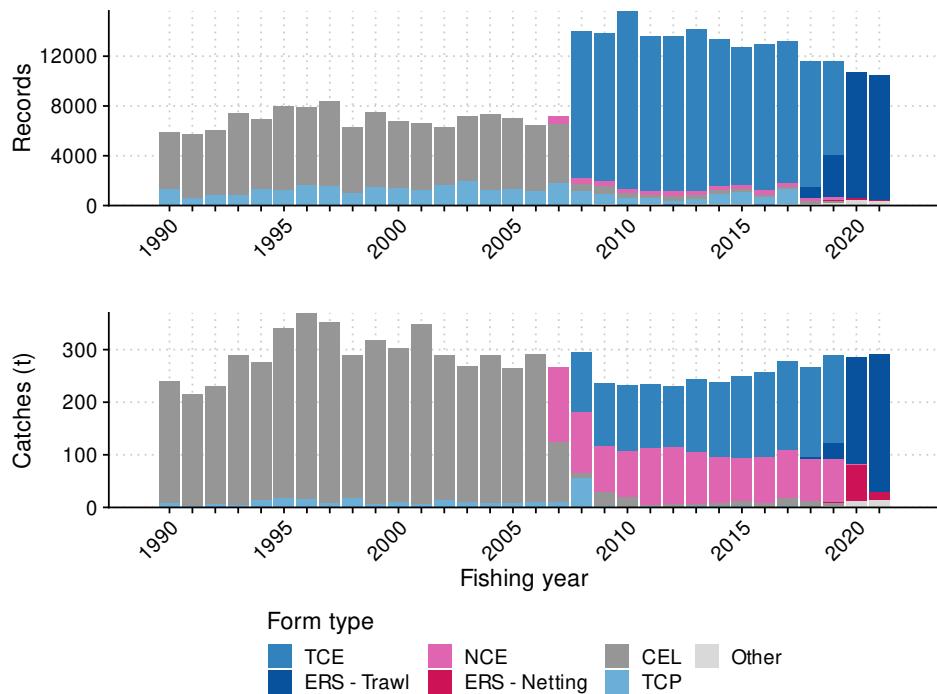


Figure 29: Reporting forms used on trips catching rig within the SPO 7 Quota Management Area, in terms of fishing event records and catches. Tabulated results are available in Appendix B. Form types grouped as Other include: ERS - Diving, ERS - Lining, ERS - Other Lining, ERS - Seining, LCE, LTC. A list of the main form type codes is included in the glossary Table E.2.

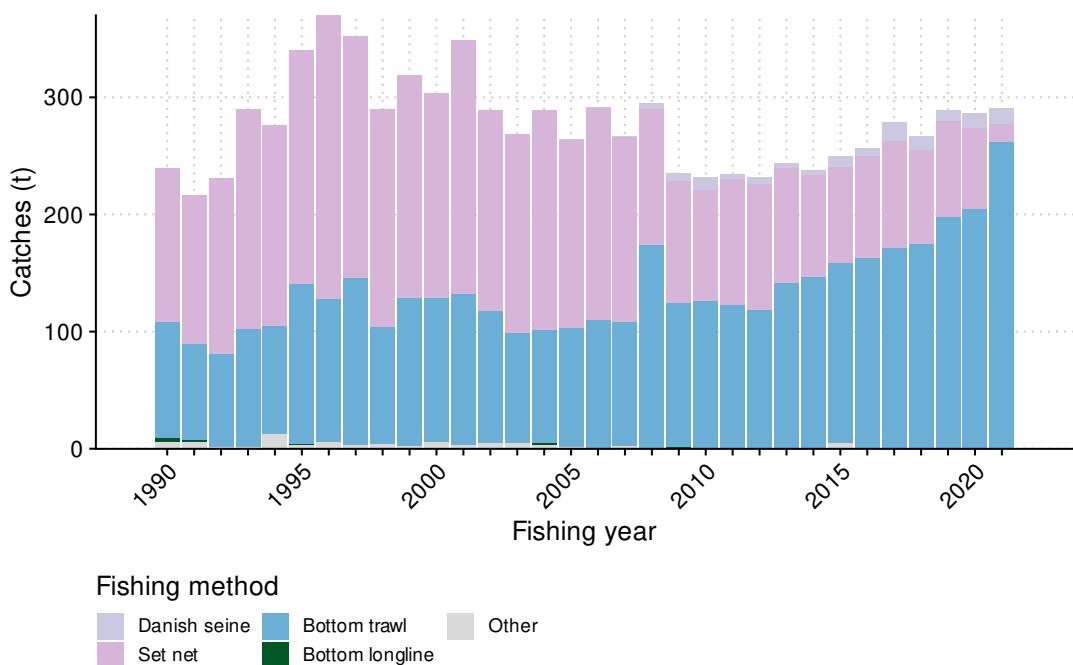


Figure 30: Catches of rig by fishing method, for events within the SPO 7 Quota Management Area. Methods grouped as Other include: BPT, BS, CP, CRP, D, DL, DN, DPS, DV, FN, FP, H, HL, L, MW, OCP, PL, PRB, PS, PSH, RLP, SLL, T, TL. Tabulated results are provided in Appendix B, and a list of the main fishing method code types is included in the glossary Table E.3.

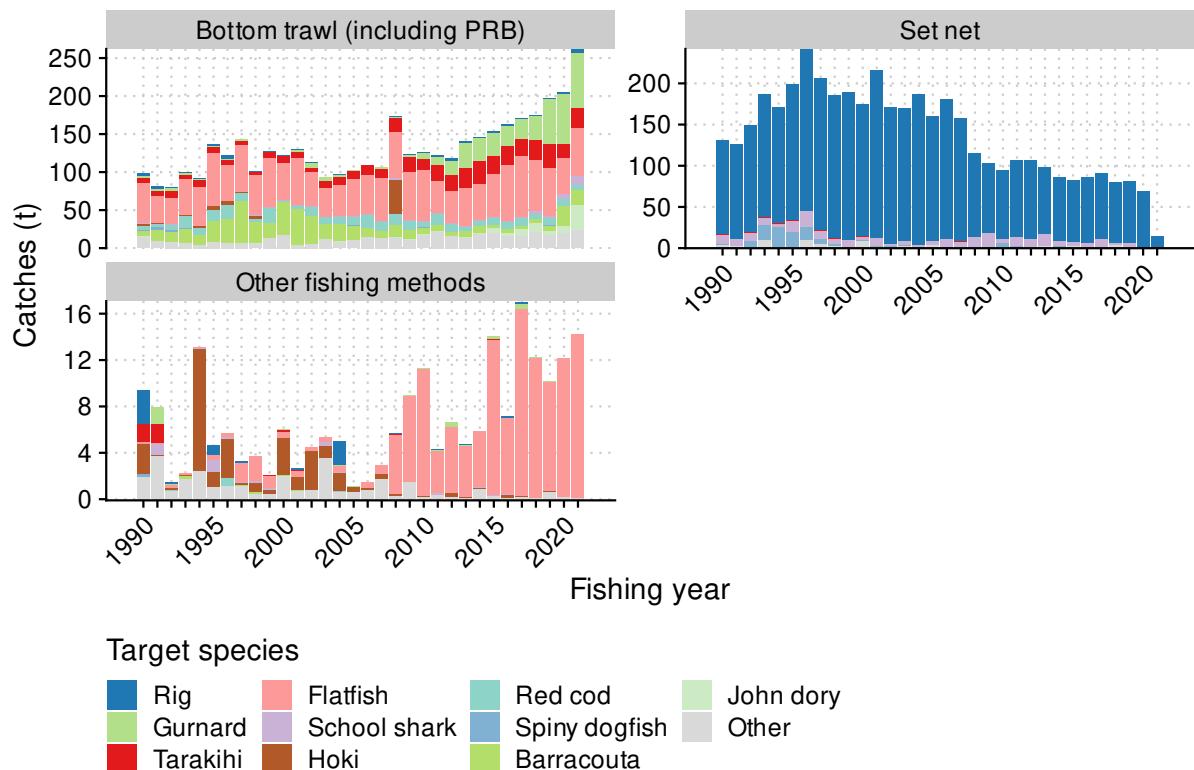


Figure 31: Catches of rig by fishing method and declared target species, for events within the SPO 7 Quota Management Area. Fishing Methods grouped as Other include: BLL, BPT, BS, CP, CRP, D, DL, DN, DPS, DS, DV, FN, FP, H, HL, L, MW-PRM, OCP, PL, PS, PSH, RLP, SLL, T, TL. Species grouped as Other include target species with less than 4% of the rig catch within the SPO 7 Quota Management Area in a fishing year.

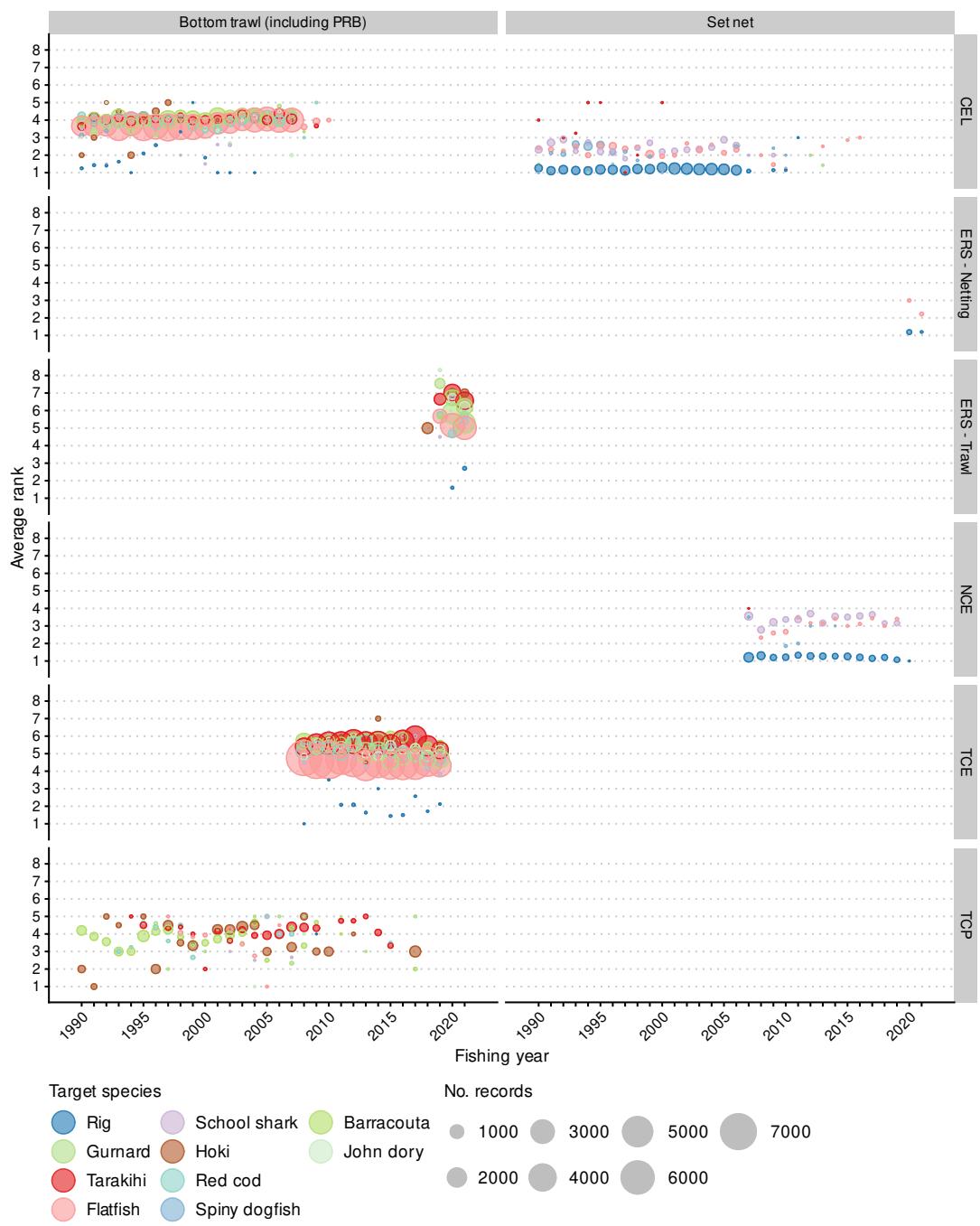


Figure 32: Average rank of rig in the estimated catch, by fishing method, form type and declared target species, for events with estimated catches within the SPO 7 Quota Management Area. The area of the circles scales with the number of records.

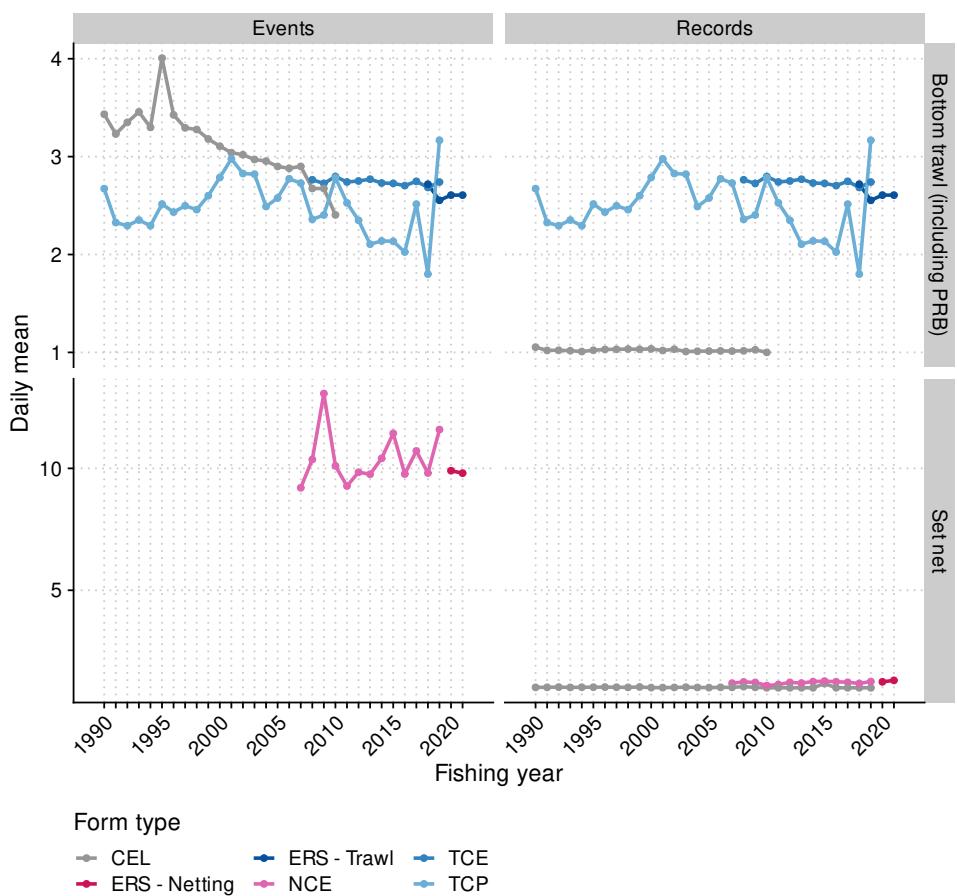


Figure 33: The mean number of fishing events and data records per vessel-day, by fishing method and reporting form, for effort within the SPO 7 QMA on trips landing catch from SPO 7. Data are included for years where a form was used on at least five vessel-days. CELR form types are undefined in set net events.

4.8 The SPO 8 Quota Management Area

4.8.1 Allocation of estimated catches to landings

Figure 34 shows the results of the application of the allocation procedures described in Section 2.3 to the SPO 8 catch/effort data. Panel (a) shows that the sum of the estimated SPO 8 catches was below the declared landings in the same year throughout most of the time period, but seemed to gradually improve over time. Almost all the landings could be attributed to estimated catch records, with very little of the landings attributed using the other procedures described in Section 2.3. Panel (b) plots this information as an annual ratio, showing that the estimated catches represented over 0.75 of the annual landings in most years, with this ratio increasing over time. Panel (c) shows that when the proportion with estimated catch is calculated in terms of the number of records rather than by weight, there was a decreasing trend from around 0.6 to 0.3 in the mid-2000s which then reversed, rising back to 0.6 by 2021. The pattern in panel (d) (proportion of days fishing with SPO estimated catch) has a similar trend as in panel (c). Both series have a noticeable step up in the mid-2000s. Note that panels (c) and (d) include effort by bottom trawl and bottom longline where estimated rig catches in the top five or top eight rank were less frequent than for set net.

4.8.2 Form types used in the SPO 8 landing and effort data

Before 2008, nearly all of SPO 8 rig landings were reported on the inshore CELR forms which switched to the event-based NCELR form in 2008 until the introduction of the electronic reporting system (ERS) in 2020 (Figure 35, Table B.22). There was almost no reporting of rig landings on any other form type until 2021 when rig landings dropped to less than 50 t and were predominantly reported on the ERS-Trawl form.

4.8.3 Distribution of landings by method of capture

The distribution of landings by fishing method was heavily weighted in SPO 8 to the set net method, with 84% of all landings attributed to set net when averaged over the 32 years of catch history, followed by 14% for bottom trawl (Figure 36, Table B.27). While the importance of rig bottom trawl landings increased in the 2010–2020 decade, this has largely been due to a decrease in the set net catch of rig rather than a large increase in rig bottom trawl landings, with 78% of the rig landings from 2016–2020 made by the set net method (Table B.27). However, as in SPO 7, the percentage of rig landed by set net dropped to 11 % in 2021 with the imposition of the severe restrictions on set net fishing on the west coasts of the North Island and South Island which were implemented to protect Hector's and Maui dolphins.

4.8.4 Distribution of landings by target species

Set net landings of rig were made when almost exclusively targeting rig (Figure 37). Bottom trawl landings of rig were made while fishing for a range of target species, including trevally, tarakihi, school shark and red gurnard.

4.8.5 Species rank by form type and target species

The mean rank for estimated catch of rig when bottom trawling tended to be at least four to five, regardless of the target species, being primarily constrained by the reporting requirements of each form type (Figure 38). This can be seen from the increase in the mean rank for estimated catch of rig when moving to form types which allow more species to be reported per event (e.g., the TCER and the ERS-Trawl form types). The mean rank for estimated catch of rig in the set net fishery was centred at one when target fishing for rig when using any of the three main form types (Figure 39).

4.8.6 Number of fishing events by day and form type

The mean number of records per day of fishing by set net when using the CELR form was one up to 2007, and one when using the NCELR form after 2007 (Figure 40). This value increased to near two when using the ERS-Netting form. The mean number of records per day of fishing by bottom trawl when using the CELR form was one up to 2007 when the form was no longer used for this QMA. Bottom trawl vessels using the event-based TCER form tended to average near three records per day and this average continued under the ERS-Trawl form (Figure 40).

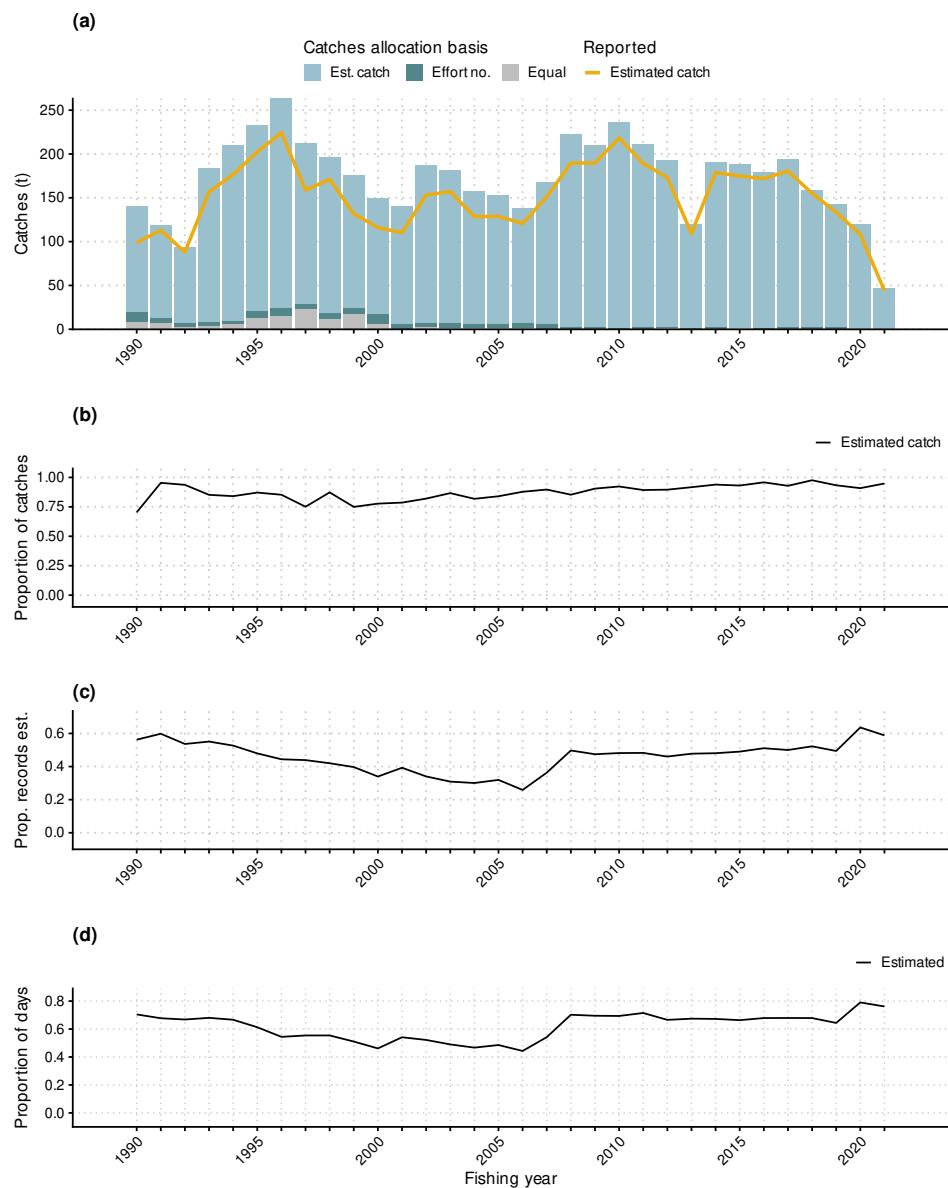


Figure 34: (a) bars: rig catches allocated to fishing events in the SPO 8 QMA with allocation method indicated by fill colour (see Section 3.3); line: total estimated catch of SPO; (b) the proportion of SPO 8 catches included in estimated catch data; (c) the proportion of fishing event records with an estimated catch of SPO; (d) the proportion of vessel-days fished with a reported catch of SPO.

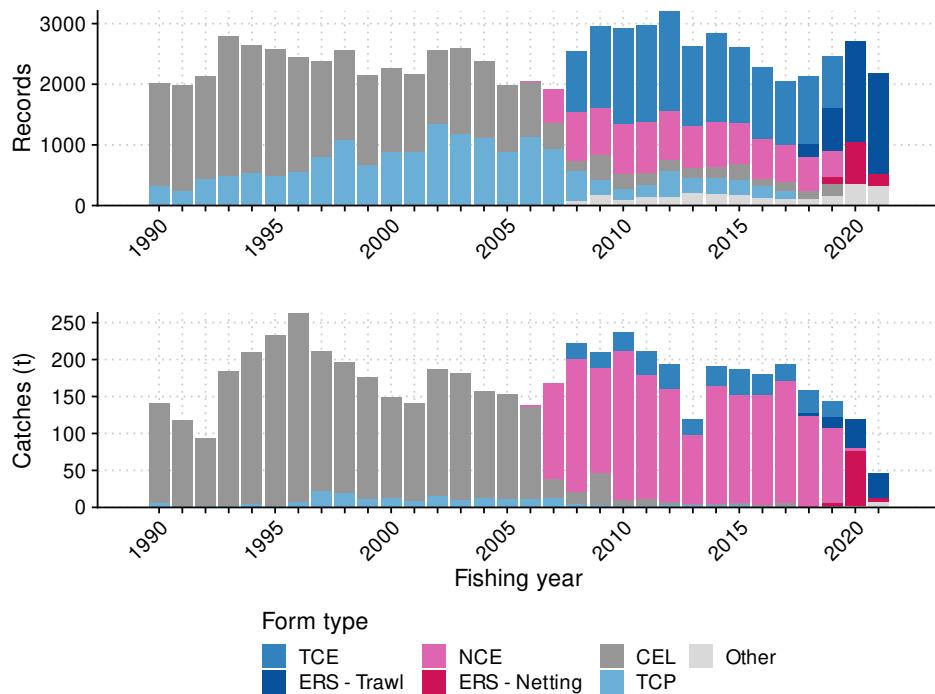


Figure 35: Reporting forms used on trips catching rig within the SPO 8 Quota Management Area, in terms of fishing event records and catches. Tabulated results are available in Appendix B. Form types grouped as Other include: ERS - Lining, ERS - Other Lining, LCE, LTC, TUN. A list of the main form type codes is included in the glossary Table E.2.

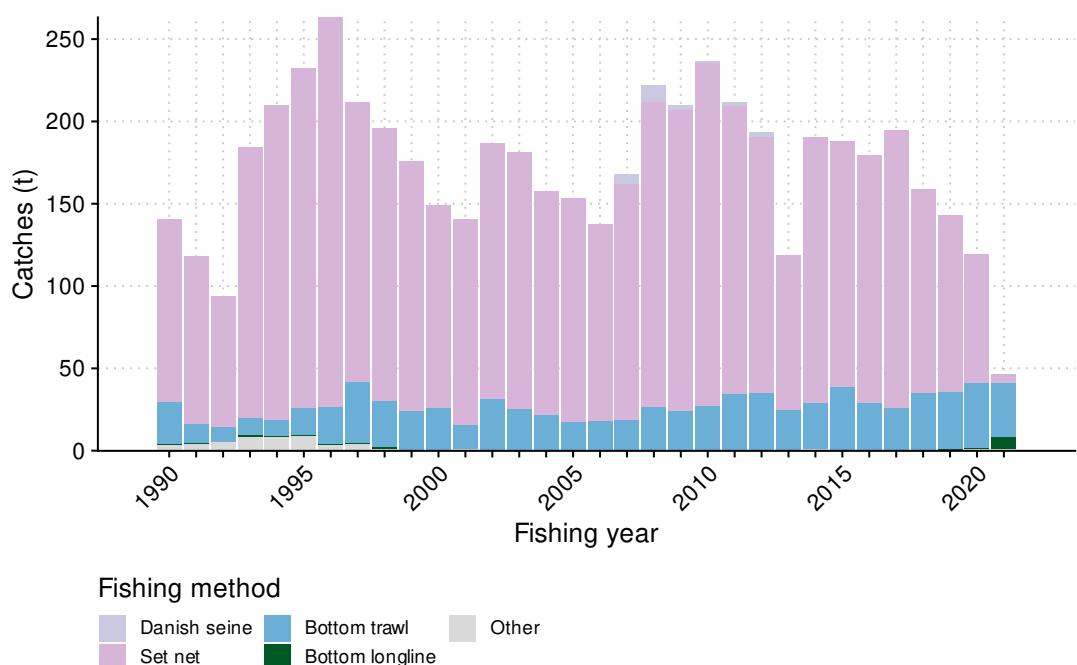


Figure 36: Catches of rig by fishing method, for events within the SPO 8 Quota Management Area. Methods grouped as Other include: BPT, CP, CRP, DL, DN, FP, HL, MW, PL, PRB, PS, RLP, SLL, T, TL. Tabulated results are provided in Appendix B, and a list of the main fishing method code types is included in the glossary Table E.3.

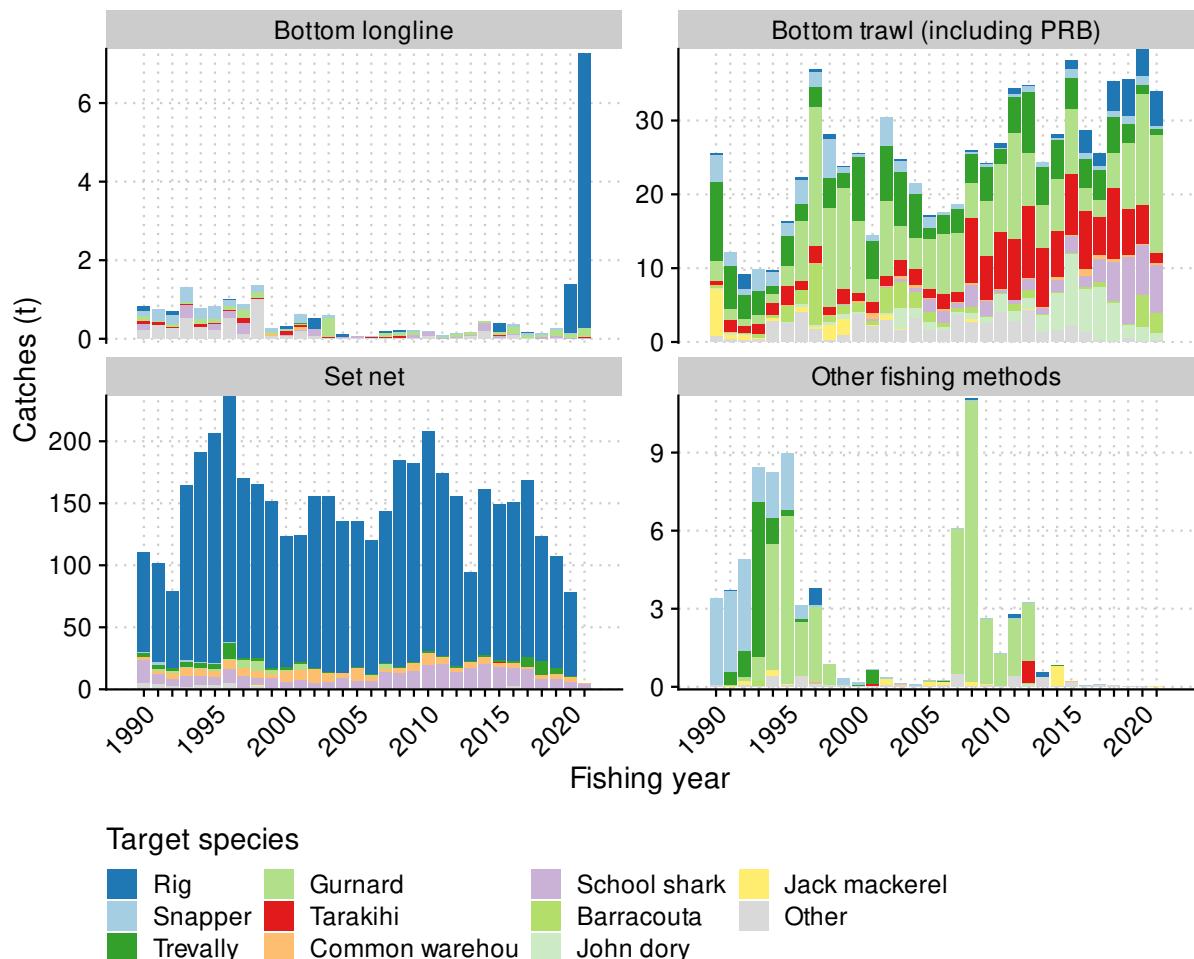


Figure 37: Catches of rig by fishing method and declared target species, for events within the SPO 8 Quota Management Area. Fishing Methods grouped as Other include: BPT, CP, CRP, DL, DN, DS, FP, HL, MW-PRM, PL, PS, RLP, SLL, T, TL. Species grouped as Other include target species with less than 4% of the rig catch within the SPO 8 Quota Management Area in a fishing year.

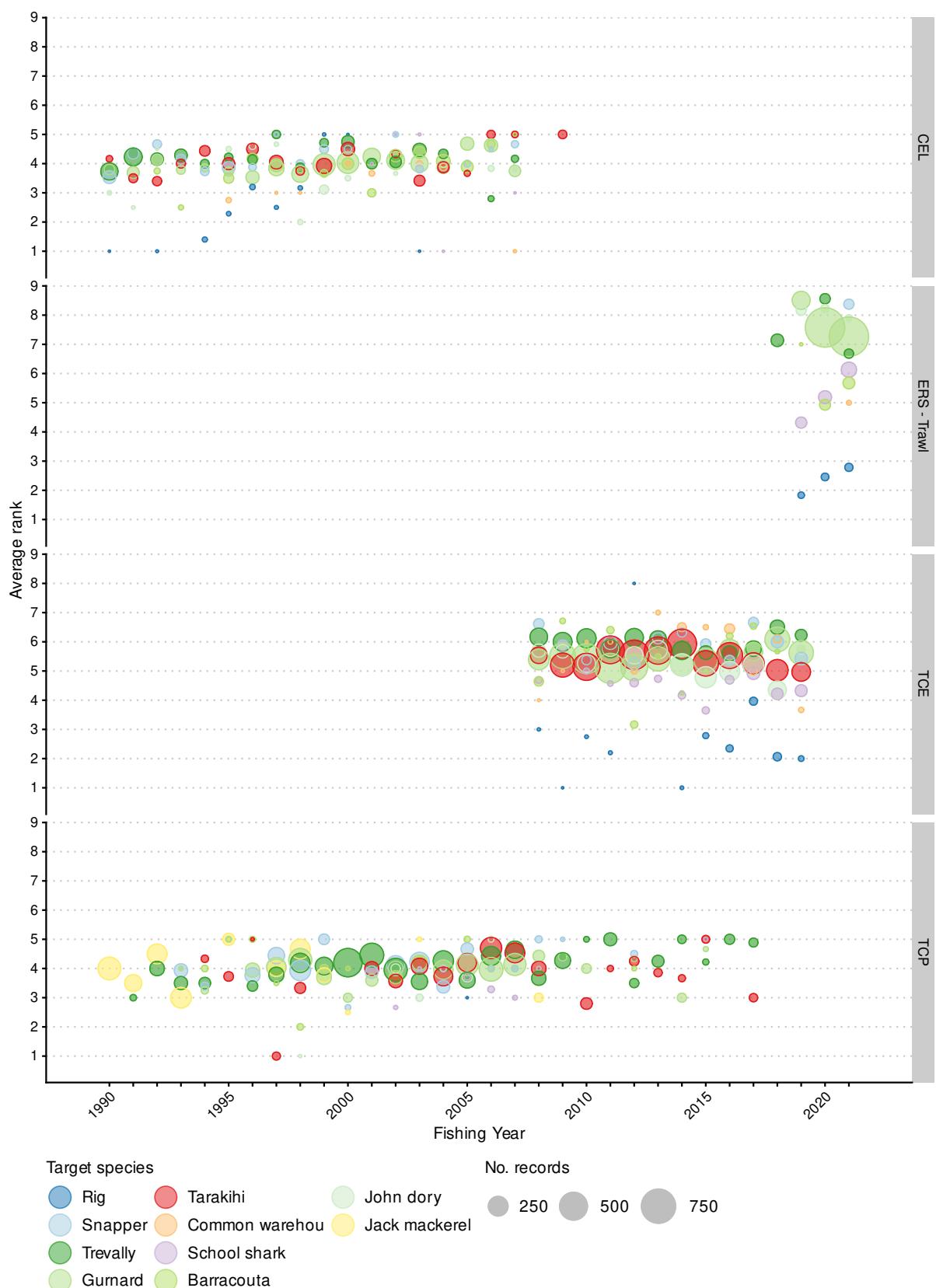


Figure 38: Average rank of rig in the estimated catch, by fishing method, form type and declared target species, for BT-PRB events with estimated catches within the SPO 8 Quota Management Area. The circle size scales with the number of records.

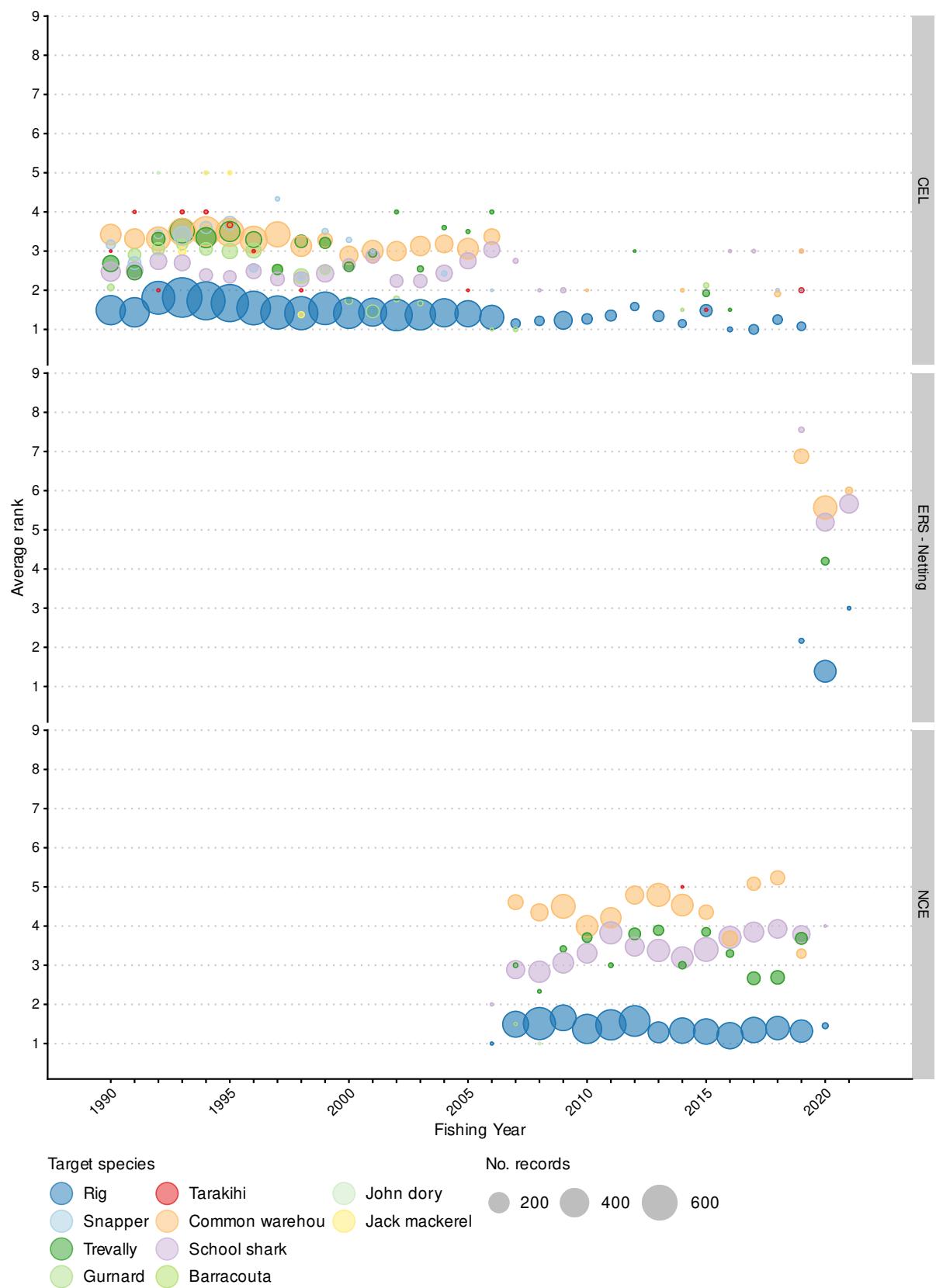


Figure 39: Average rank of rig in the estimated catch, by fishing method, form type and declared target species, for SN events with estimated catches within the SPO 8 Quota Management Area. The circle size scales with the number of records.

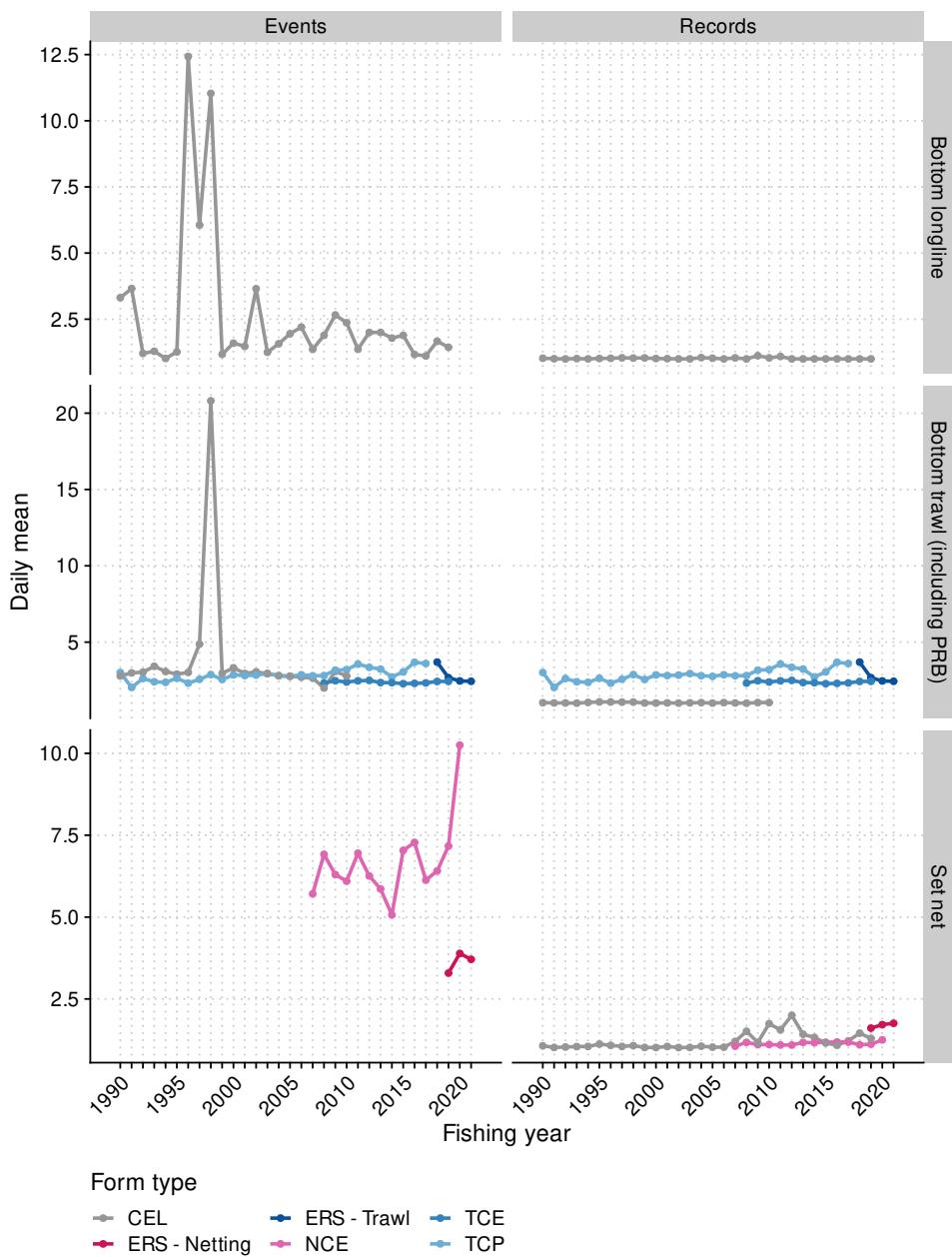


Figure 40: The mean number of fishing events and data records per vessel-day, by fishing method and reporting form, for effort within the SPO 8 QMA on trips landing catch from SPO 8. Data are included for years where a form was used on at least five vessel-days. CELR form types are undefined in set net events.

4.9 The set net fishery

4.9.1 Spatial catch information

Spatial catch information for SPO set net catches was not available on a New Zealand-wide basis until the introduction of the NCELNR form on 1 October 2006 (Figure 41). This reporting change ensured that almost all rig set net effort was associated with fine-scale spatial information with the notable exception of SPO 1, where nearly 50% of the rig catch took place in west coast harbours (e.g., Manukau and Kaipara) or in the Firth of Thames. The Ministry of Fisheries, when the NCELNR form was introduced, exempted vessels less than 6 m in length from using the new form and allowed these vessels to continue using the old CELR form which recorded daily catch at the level of a statistical area without specifying fine-scale spatial information. This effect can be seen in the lower panel of Figure 9 where about half of the SPO 1 post-2006 landings were still reported on the CELR form. This situation changed in 2019–20 for the set net fleet with the shift to electronic reporting, requiring all vessels (including those less than 6 m in length) to report fine-scale spatial information along with the catch and effort. The benefit from this change can be seen in Section 4.9.4 below.

Rig were caught ubiquitously by set net all around the North Island and South Island at relatively low but consistent levels throughout the fifteen year period with good spatial coverage (Figure 42). The notable exception to this generalisation is the west coast of the South Island where rig catches effectively disappeared by the mid-2010s (Figure 42). This shift was noted by Starr & Kendrick (2020) and was attributed to the effect of the management measures introduced to curb the bycatch of Hector's dolphins. Rig continued to be present in this section of the coast in good numbers because they are consistently taken in the west coast South Island trawl survey and by the bottom trawl fishery (see Section 4.10.1) The spatial CPUE plots did not show many 'hot spots' for rig abundance, emphasizing the ubiquitous nature of the catch distribution (Figure 43). However, a few recurring catch 'hot spots' can be seen in Figure 42, including Tasman/Golden bays, South Taranaki Bight near Wanganui, top of Banks Peninsula, near Dunedin, and central Foveaux Strait. When the SN spatial catches were disaggregated by the primary SN target species, target fishing for rig was ubiquitous at low levels around both islands while the remaining target species bycatches of rig reflected the distribution of each target species (Figure 44, Figure 45). An exception to this generalisation was the bycatch of rig when targeting for school shark, where the spatial distribution for rig bycatch when targeting SCH was similar to that seen when targeting for rig, reflecting the ubiquitous distribution of both commercial shark species around New Zealand (note that rig bycatch was relatively high in Foveaux Strait where SCH is principally targeted; Figure 46). The spatial extent for the SN rig catches is approximately the same for all three time periods in Figure 47, with a slight reduction by the 2014–2016 and 2019–2021 time blocks in the number of 32 x 32 km grid cells needed to reach the 90th percentile. Quite a few statistical areas contributed the catch of rig by SN, with at least 12 statistical areas contributing a significant amount of catch (Figure 48; see Figure 3 for the location of the statistical areas). The areas with the highest accumulated catch of rig included Statistical Areas 038 (Tasman/Golden bays), 007 (Firth of Thames), 022 (Canterbury Bight) and 040 (North Taranaki Bight).

4.9.2 Seasonal catch information by target species

The set net catch of rig is mainly made when targeting for rig, with the exception of the SN school shark fishery which takes rig in good amounts in SPO 3 (Figure 49). This fishery actually takes place in Foveaux Strait where there is an important SCH fishery (Tremblay-Boyer 2021).

The seasonal distribution of rig SN catches reflected the seasonality of the respective target species fisheries in all five SPO QMAs (SPO 1: Figure 50, SPO 2: Figure 51, SPO 3: Figure 52, SPO 7: Figure 53, SPO 8: Figure 54). Target SN fishing for rig appears to be a spring, early summer fishery in most QMAs, with the highest catches occurring in October to January or February, depending on the QMA. September catches in SPO 1 are also high while the SPO 2 catches were more variable, possibly because of the low incidence of rig target fishing in this QMA. The SN target fishery for school shark in SPO 3 appeared to

have a similar seasonal distribution to that of the SN rig target fishery in the 1990s and the early 2000s, but shifted to a more year-round fishery after the mid-2000s (Figure 52).

4.9.3 Depth distribution information by target species

Depth information is not available from the commercial SN fishery because the NCEL R form did not include a requirement to record the depth of each event and the ERS has continued the practice of not requiring the bottom depth of the event.

4.9.4 Fine-scale distributions of set net effort

With the introduction of Electronic Reporting (starting in 2019 for the inshore vessels fishing for rig, and becoming comprehensive from 2020), it is now possible to examine the fine-scale distribution of set net effort for rig throughout New Zealand, including in the SPO 1 harbour fisheries. Reported netting locations by declared target species during 2020 and 2021 are provided for Statistical Area 007 (Firth of Thames and Hauraki Gulf: Figure 55), Statistical Area 043 (Manukau Harbour: Figure 56), and Statistical Area 044 (Kaipara Harbour: Figure 57).

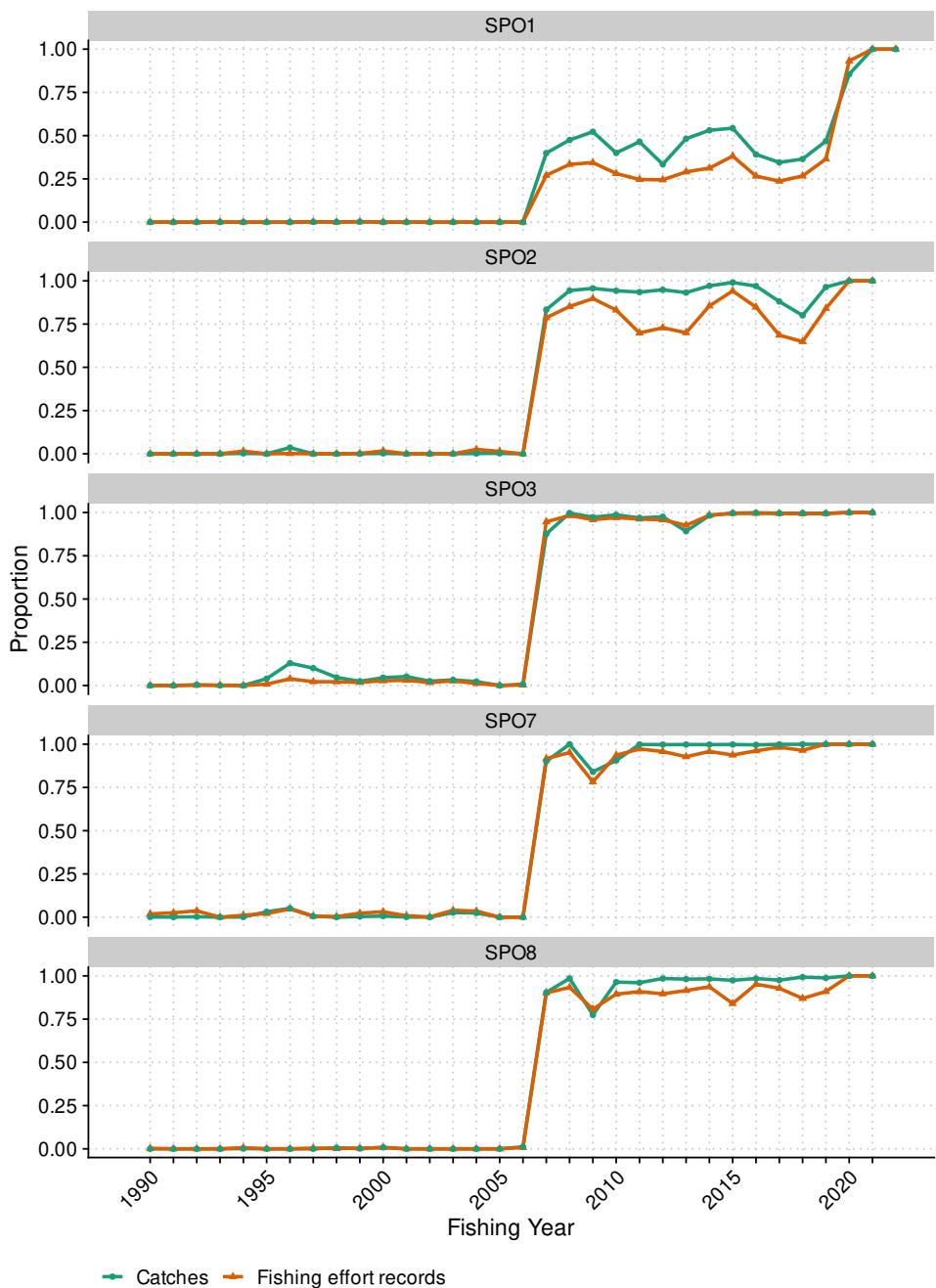


Figure 41: The proportion of records and catches reported with a latitude/longitude for the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 set net fishery.

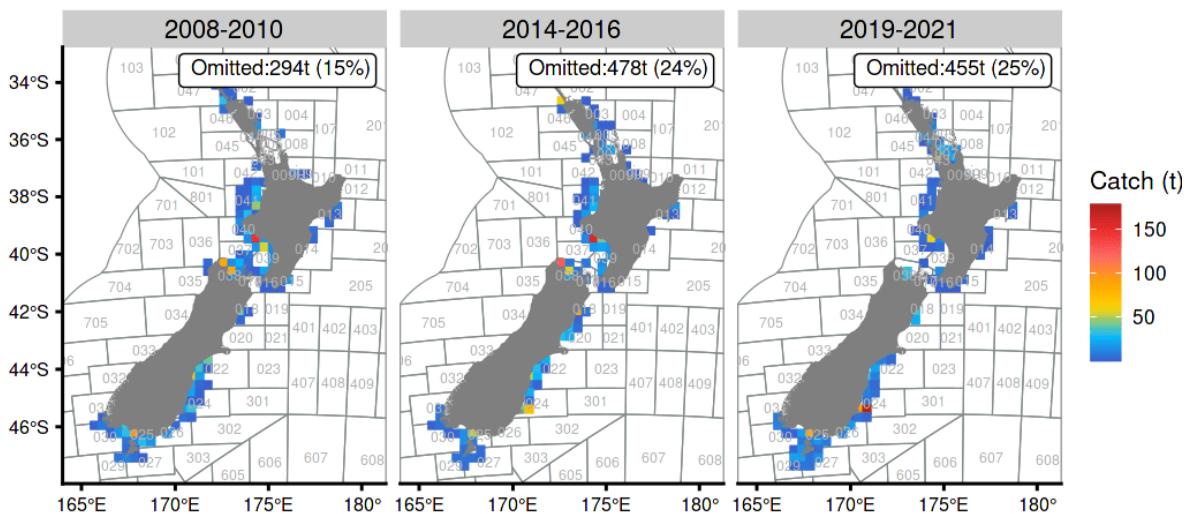


Figure 42: Catches (t) for the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 set net fishery, for 3-year periods within the era during which at least 80% of catch was reported with spatial information. These plots use a 32 km grid and include records where catches were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

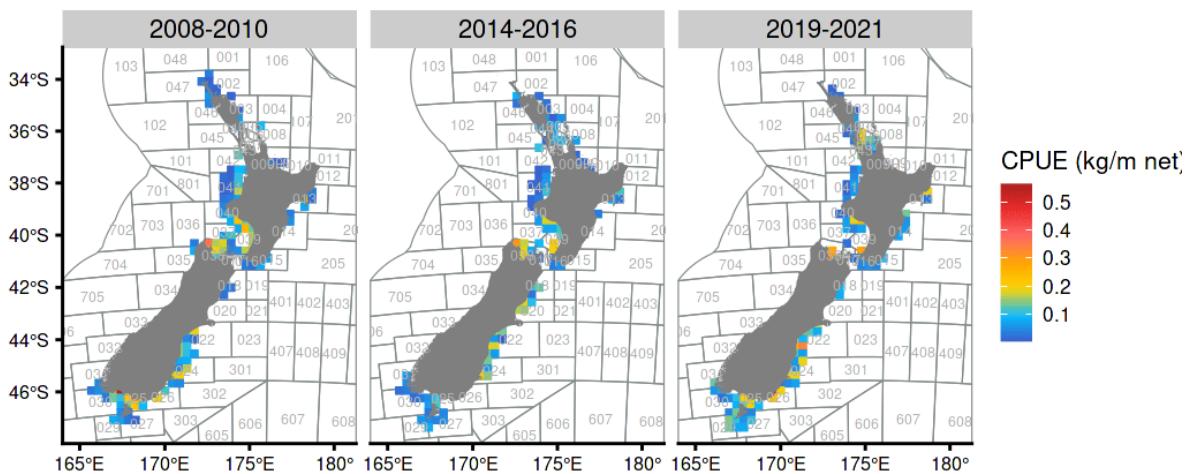


Figure 43: Raw aggregate CPUE (kg/m net) for the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 set net fishery, for 3-year periods within the era during which at least 80% of catch was reported with spatial information. These plots use a 32 km grid and include records where catches were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted.

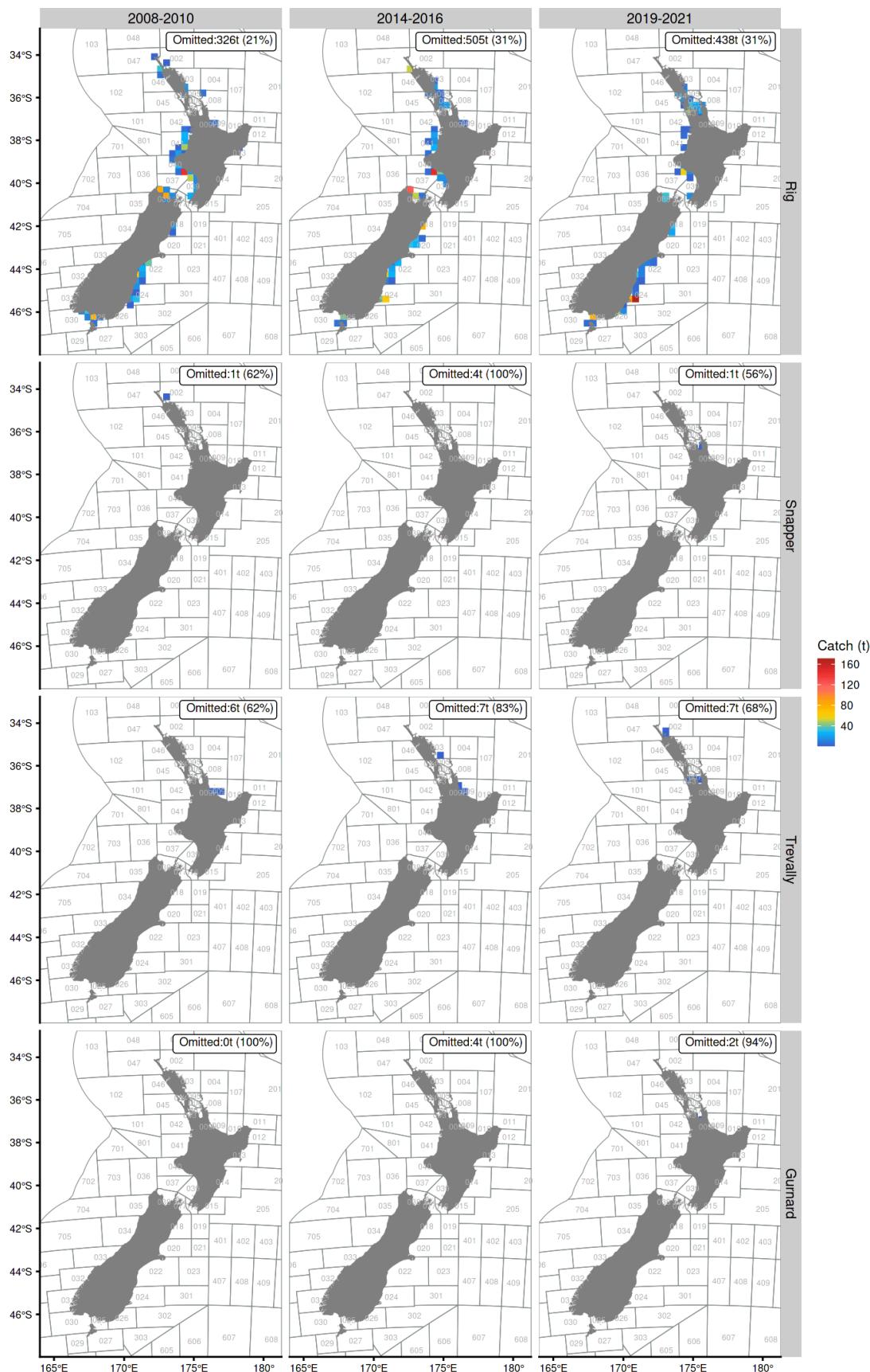


Figure 44: Catches of rig from the set net fishery by key target species. These plots use a 32 km grid and include records where landings were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

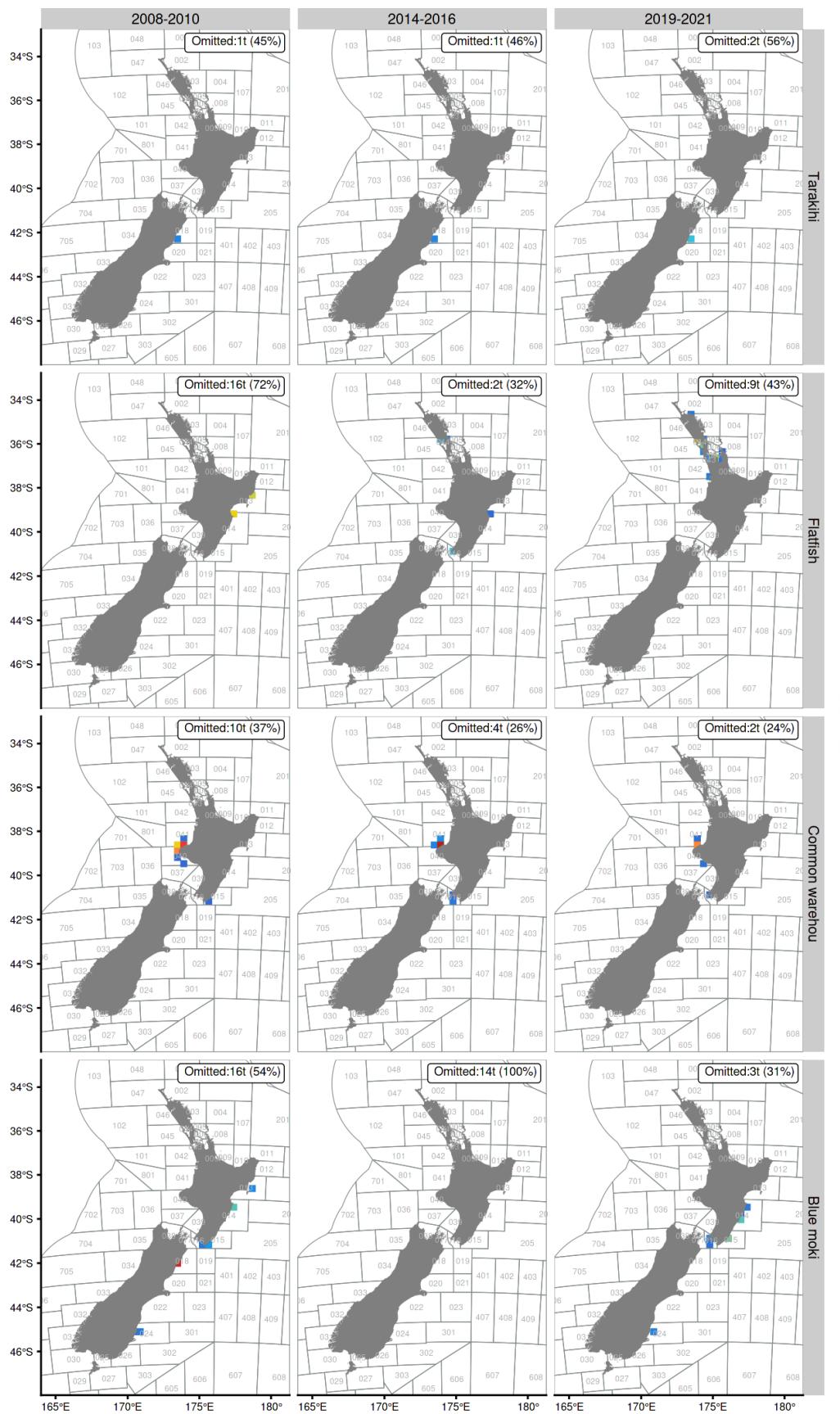


Figure 45: Catches of rig from the set net fishery by key target species. These plots use a 32 km grid and include records where landings were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

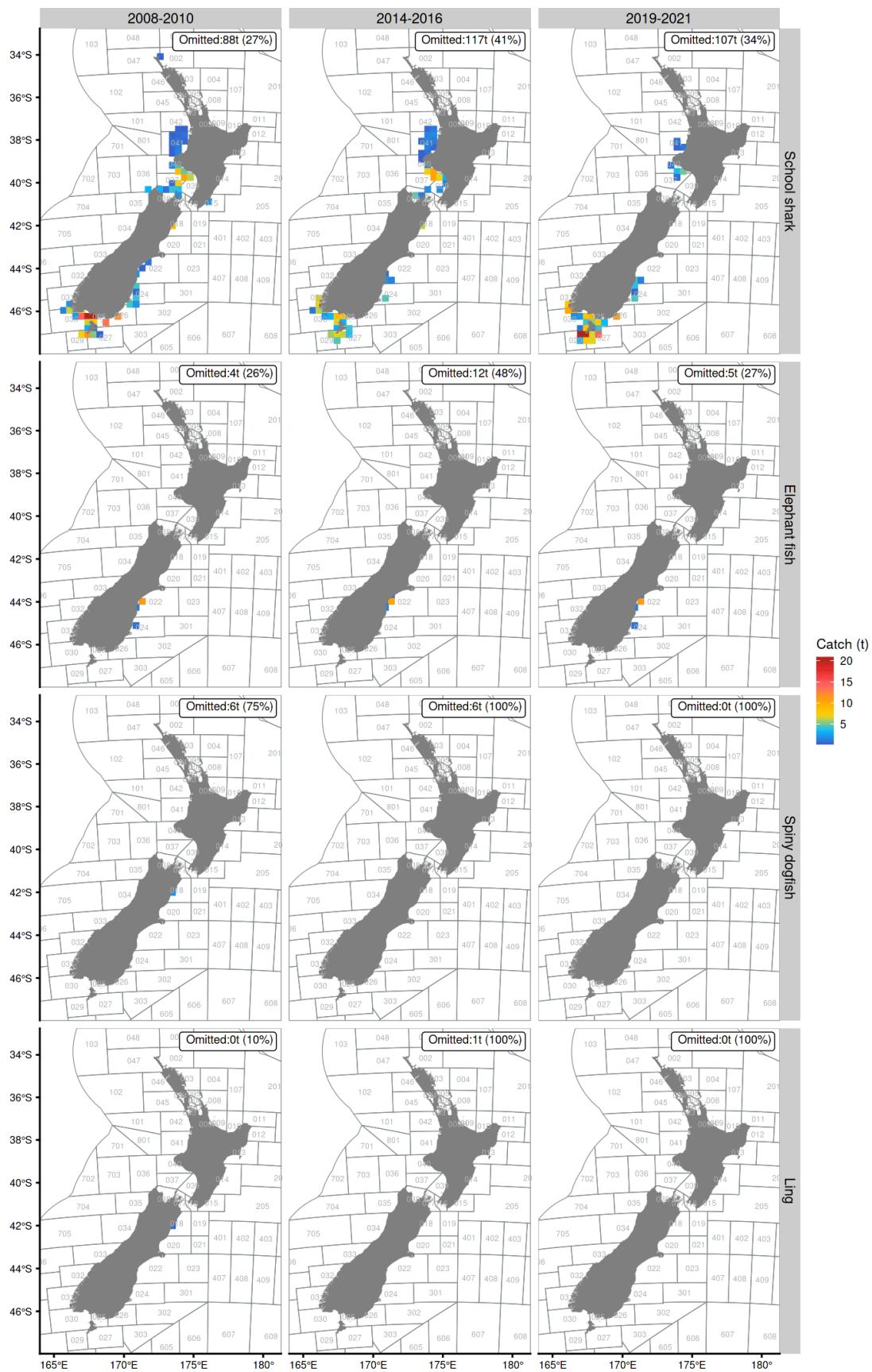


Figure 46: Catches of rig from the set net fishery by key target species. These plots use a 32 km grid and include records where landings were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

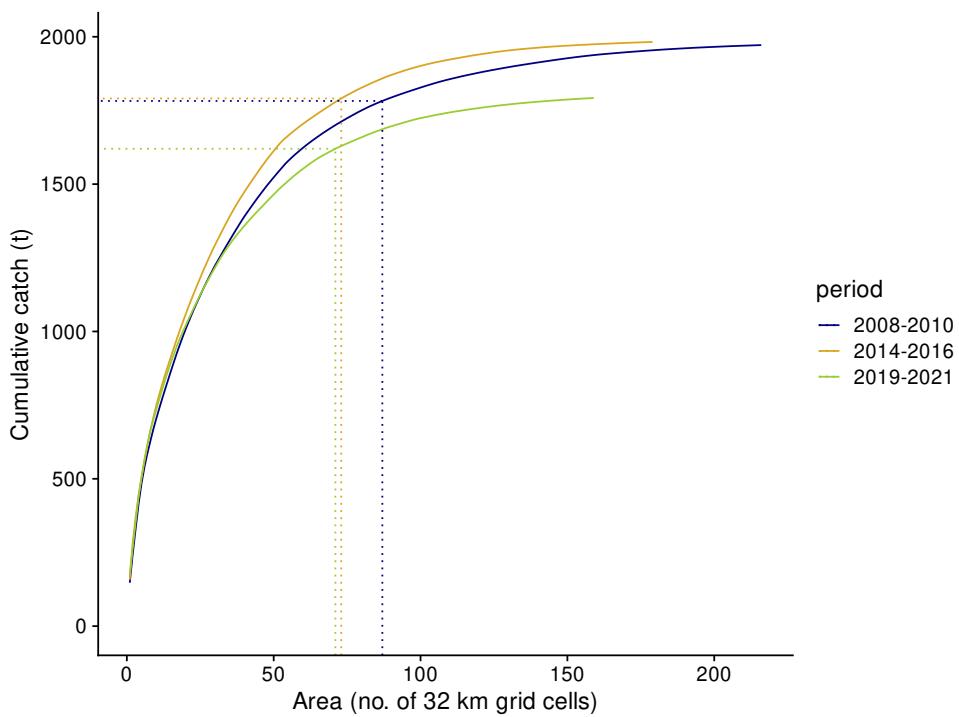


Figure 47: Cumulative SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 catch by area (grid cells) for the set net fishery, aggregated for the first, middle, and last 3-year period of reporting. Dotted lines indicate the 90th percentile for the first, middle, and last 3-year period of reporting.

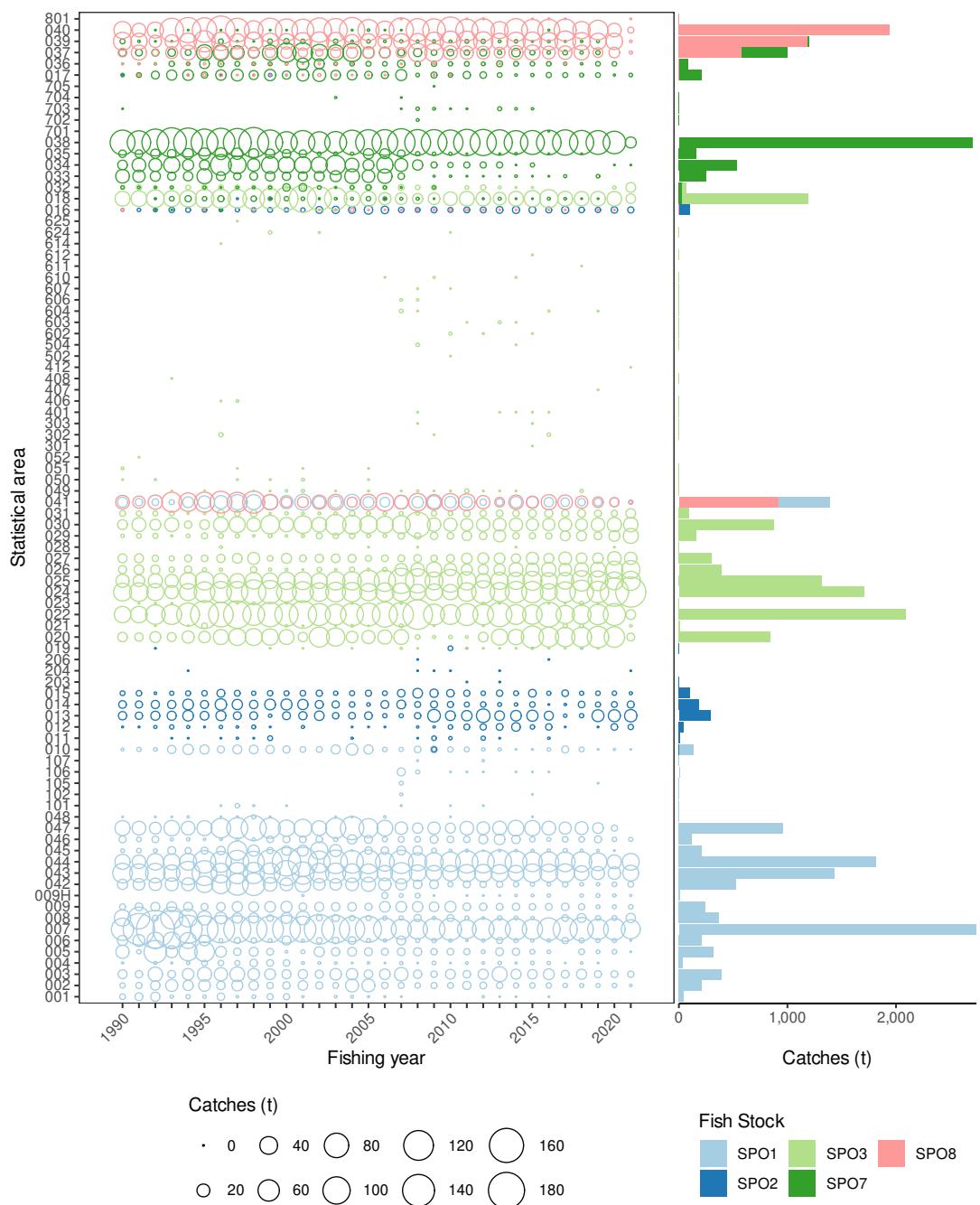


Figure 48: Annual SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 catches (t) by statistical area for the set net fishery. The circle size scales with the catches by statistical area. The bar plot (right) shows the total catches of SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 for each statistical area.

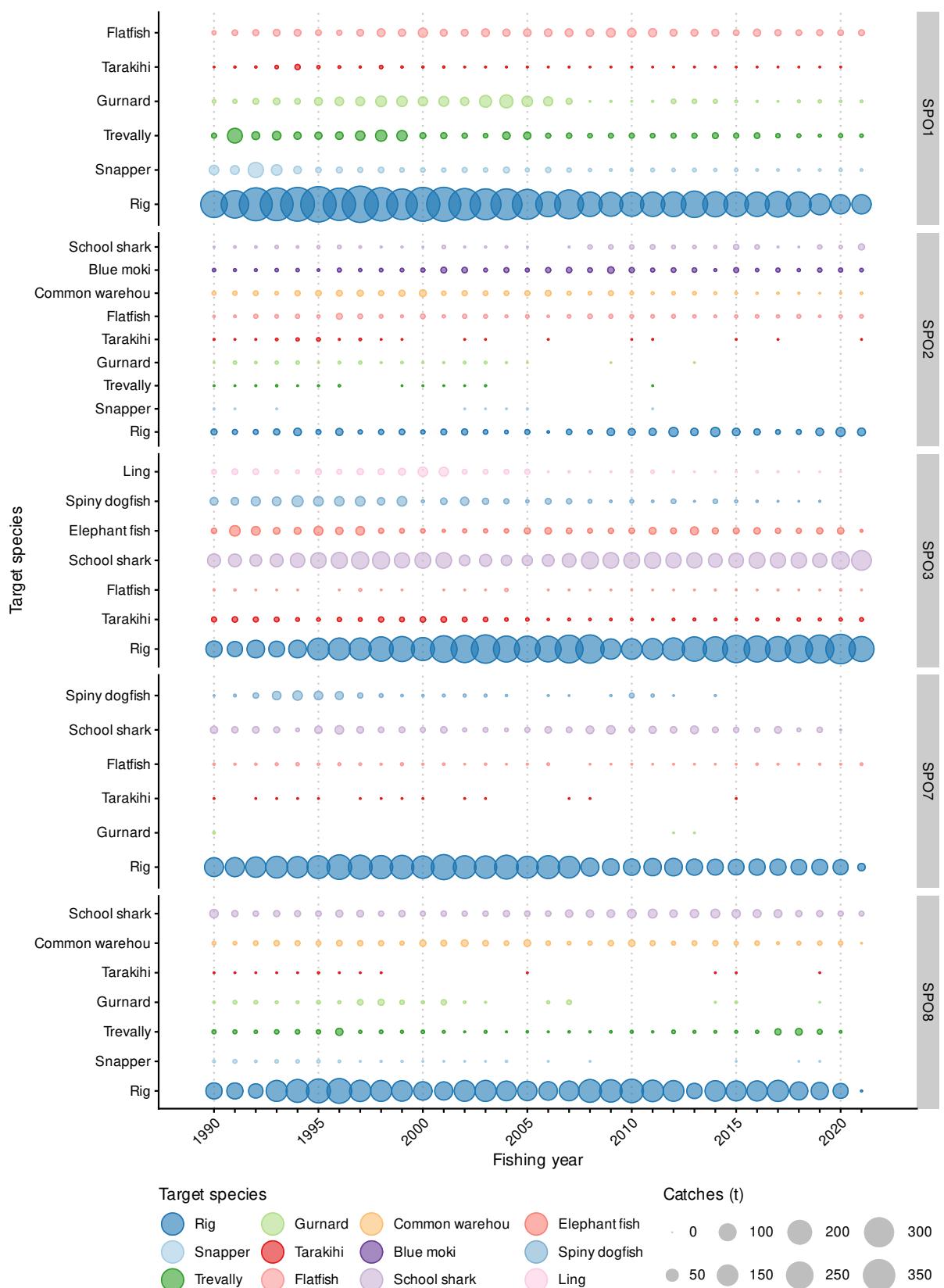


Figure 49: Rig catches by fishing year and target species for the set net fishery. The area of the circle scales with the yearly catches.

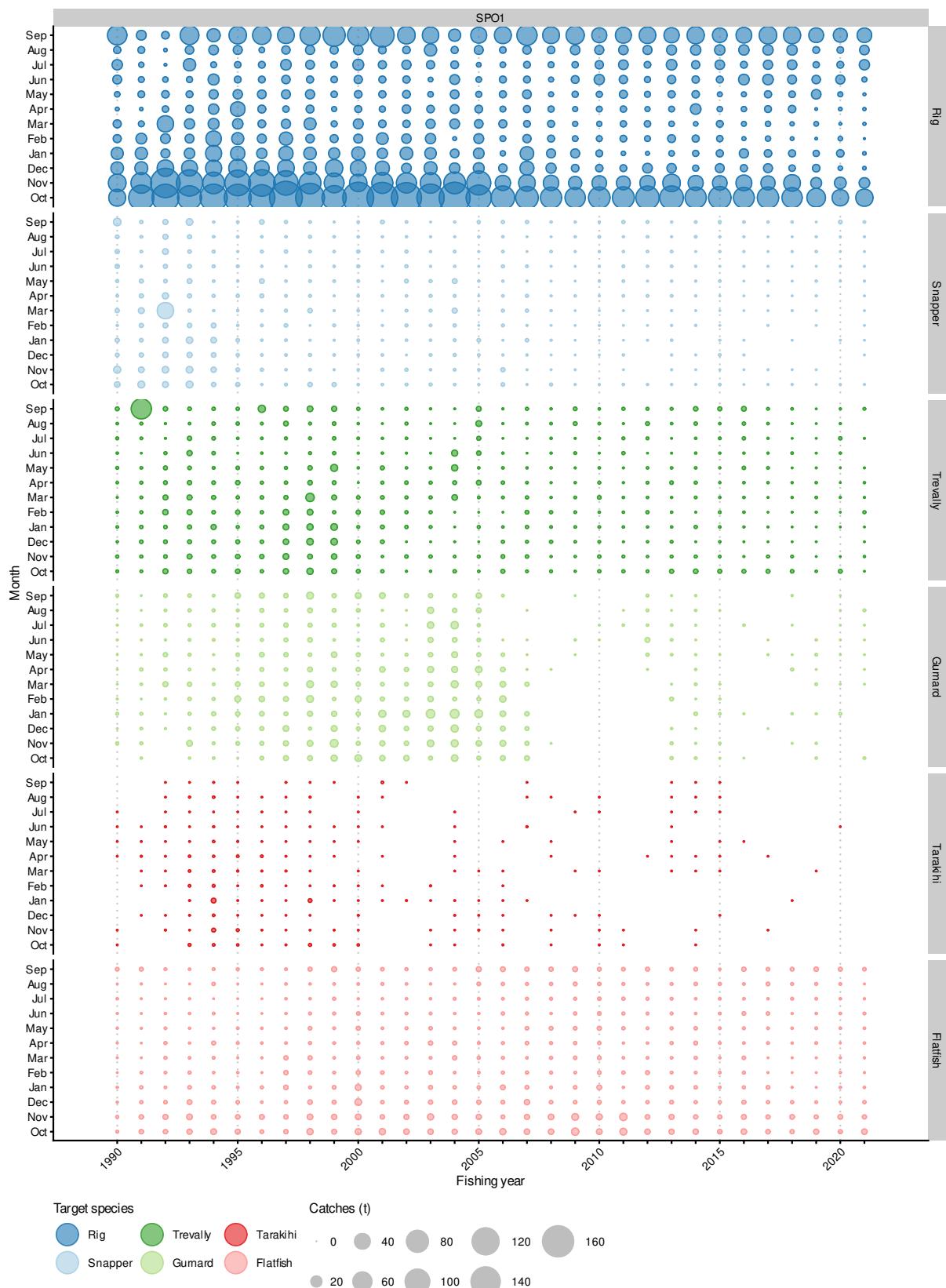


Figure 50: Seasonal distribution of SPO 1 catches by month and fishing year for the set net SPO 1 target fisheries. The area of the circle scales with the monthly catches.

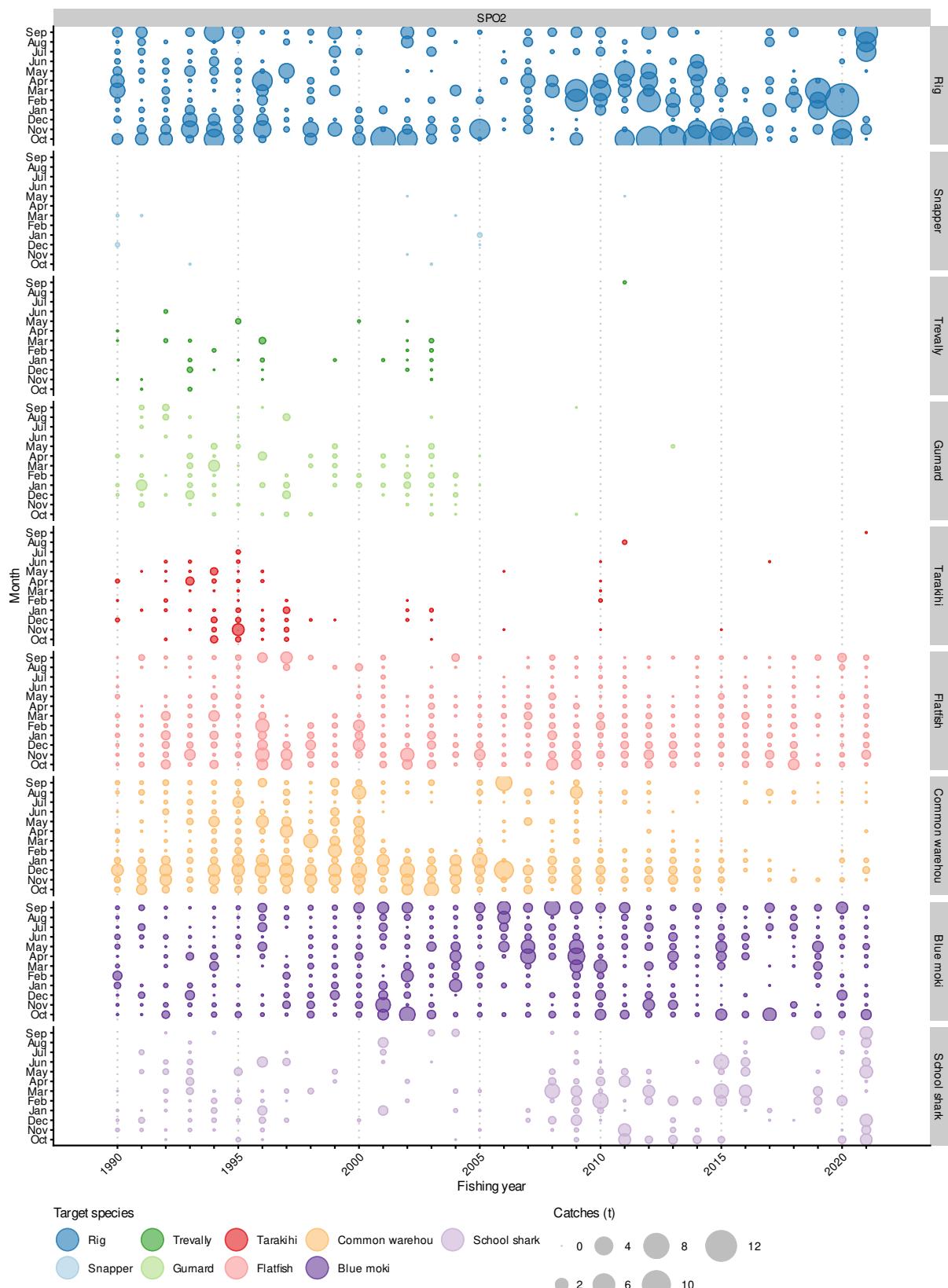


Figure 51: Seasonal distribution of SPO 2 catches by month and fishing year for the set net SPO 2 target fisheries. The area of the circle scales with the monthly catches.

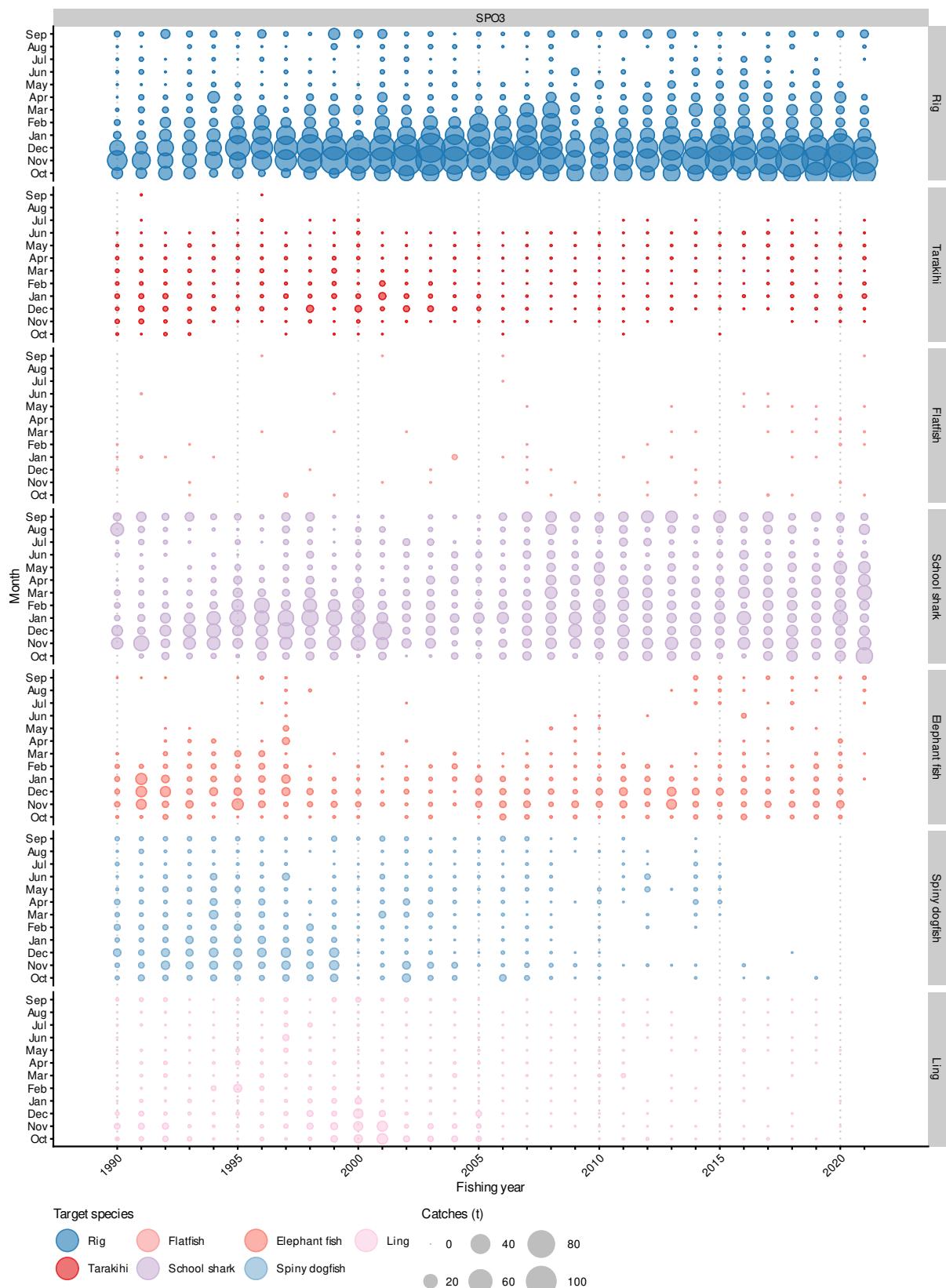


Figure 52: Seasonal distribution of SPO 3 catches by month and fishing year for the set net SPO 3 target fisheries. The area of the circle scales with the monthly catches.

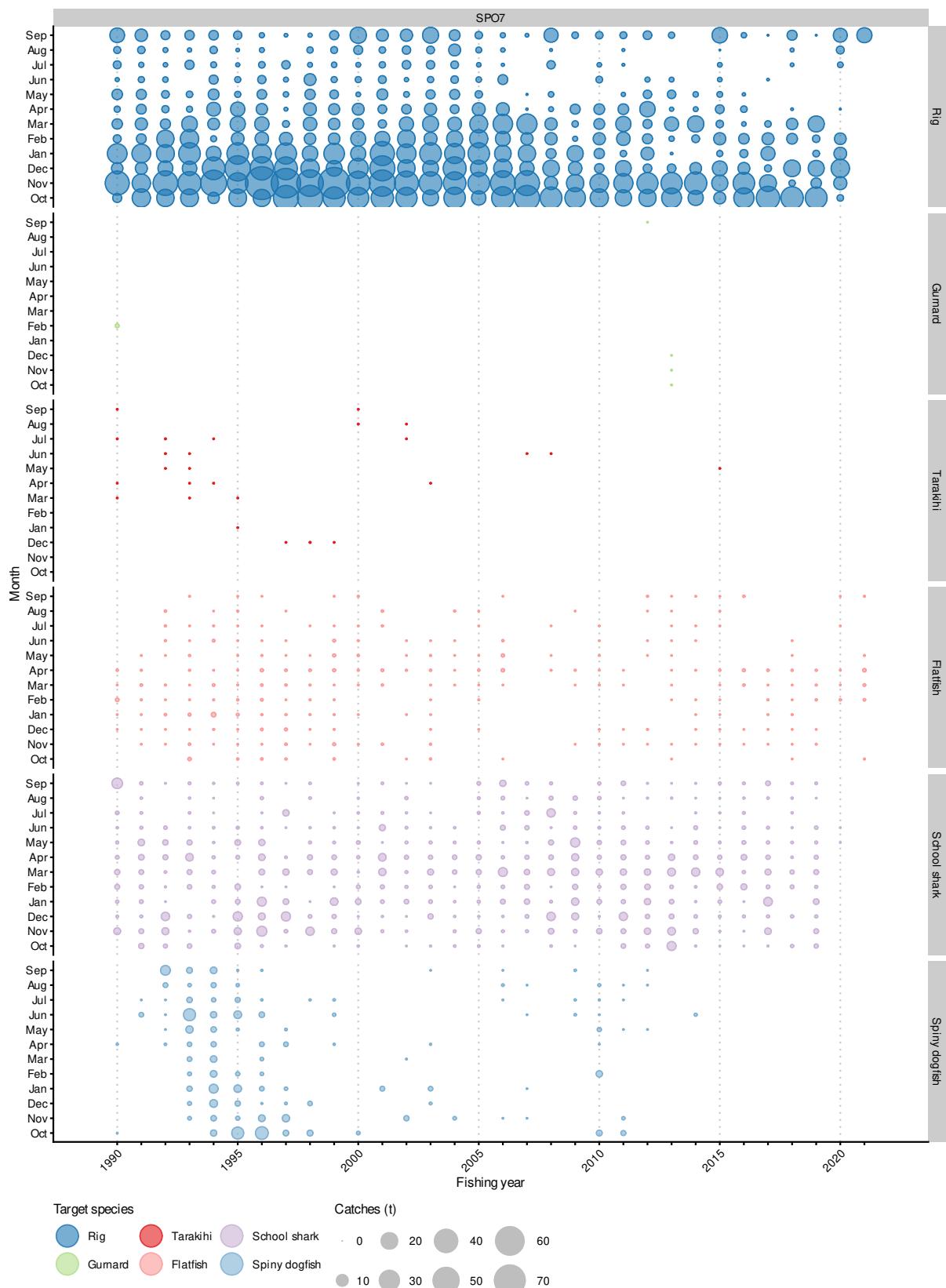


Figure 53: Seasonal distribution of SPO 7 catches by month and fishing year for the set net SPO 7 target fisheries. The area of the circle scales with the monthly catches.

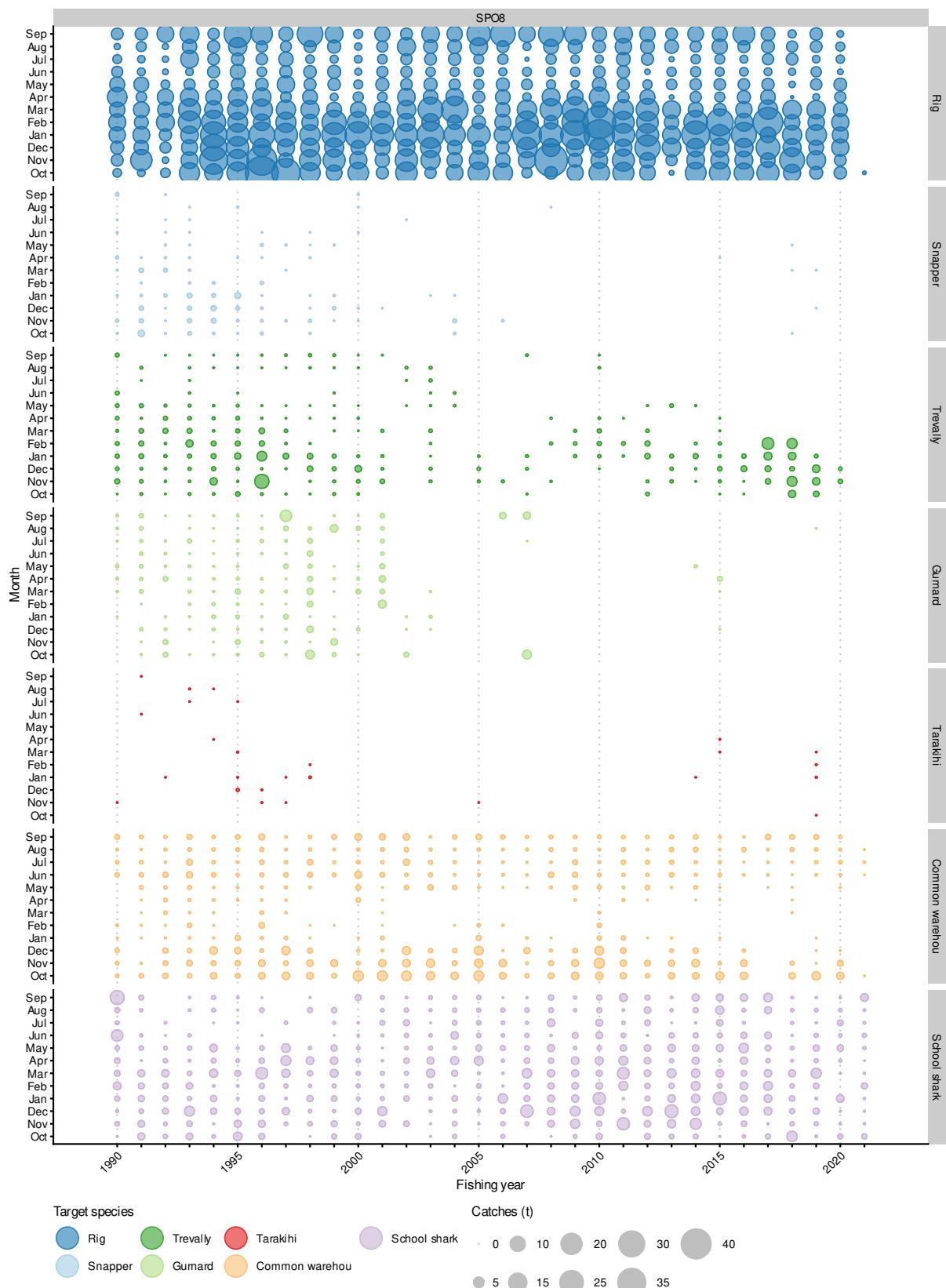


Figure 54: Seasonal distribution of SPO 8 catches by month and fishing year for the set net SPO 8 target fisheries. The area of the circle scales with the monthly catches.

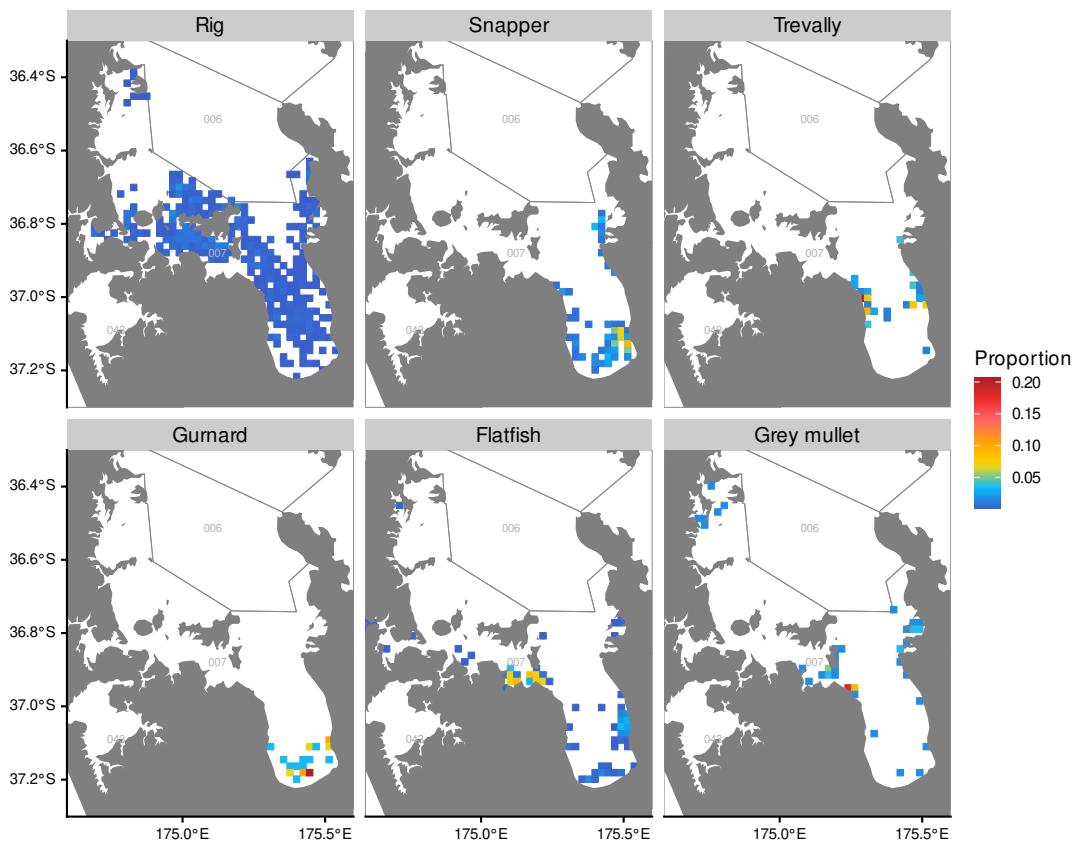


Figure 55: Proportions of fishing events by target species and 2km cell for events reported using the ERS - Netting format in Statistical Area 007 in 2020 and 2021. Target species shown were targeted by three or more vessels and fishers within the Statistical Area.

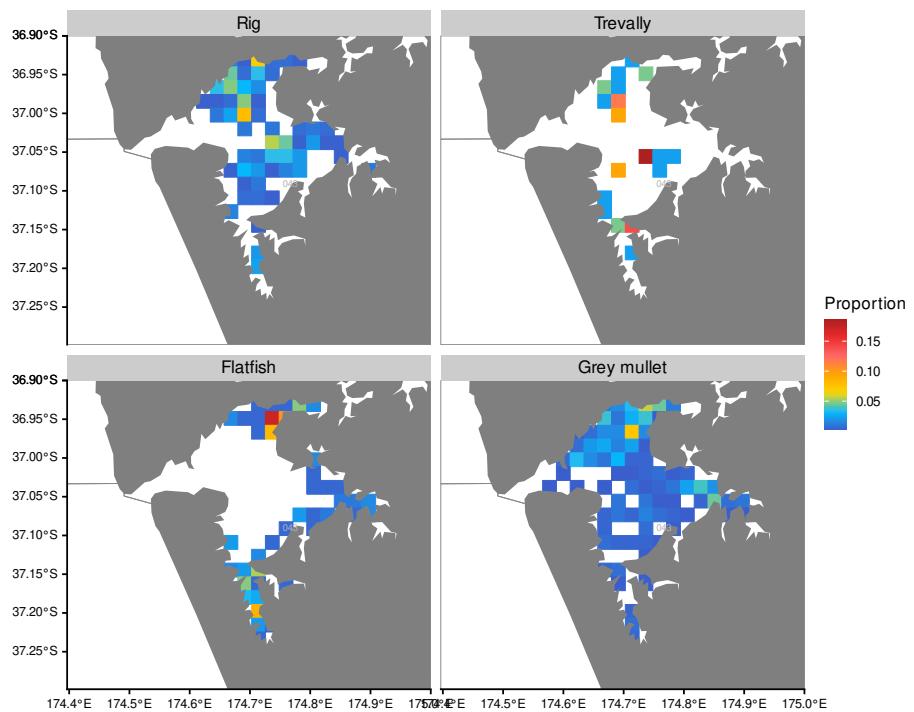


Figure 56: Proportions of fishing events by target species and 2km cell for events reported using the ERS - Netting format in Statistical Area 043 in 2020 and 2021. Target species shown were targeted by three or more vessels and fishers within the Statistical Area.

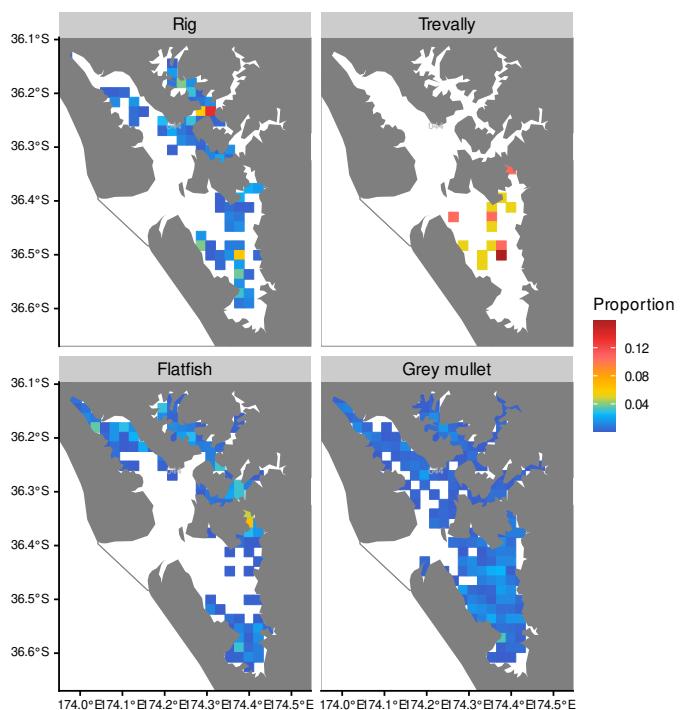


Figure 57: Proportions of fishing events by target species and 2km cell for events reported using the ERS - Netting format in Statistical Area 044 in 2020 and 2021. Target species shown were targeted by three or more vessels and fishers within the Statistical Area.

4.10 The bottom trawl (including PRB) fishery

4.10.1 Spatial catch information

Spatial catch information for most SPO bottom trawl catches was not available on a New Zealand-wide basis from the inshore fleet until the introduction of the TCER form on 1 October 2007 (Figure 58), although fine-scale reporting was implemented in the bottom trawl fleet fishing for snapper in the upper North Island in the mid-1990s. These early inshore spatial records were supplied on the deepwater TCEPR form and are responsible for the higher proportions of rig catch associated with spatial information observed in SPO 1, SPO 2 and SPO 8 (Figure 58).

As seen for set net, rig were caught ubiquitously by bottom trawl all around the North Island and South Island at relatively low but consistent levels throughout the fifteen year period with good spatial coverage (Figure 59). There were catch ‘hot spots’ where the bottom trawl fleet consistently took greater amounts of rig, including Hawke’s Bay, Canterbury Bight, Foveaux Strait, and Tasman/Golden bays (Figure 59). However, the spatial CPUE plots did not show corresponding ‘hot spots’ for rig abundance, indicating a wide distribution of rig at what appears to be relatively low and consistent levels of abundance (Figure 60). Unlike for set net, target fishing for rig using bottom trawl was mainly confined to both sides of the South Island while the distribution of rig bycatch for other BT target species tended to reflect the distribution of the target species (Figure 61). For instance, rig bycatch in the BT snapper target fishery was confined to the North Island and to Tasman/Golden bays where the snapper fishery was most active, rig bycatch in the trevally BT target fishery was also confined to the North Island, while rig bycatch in the red gurnard BT fishery took place around both islands given the wide distribution of that fishery (Figure 61). Figure 62 shows that rig BT bycatch was New Zealand-wide when targeting tarakihi, but was confined to the east coast of the North Island when targeting blue moki. Similar observations can be made for red cod (Figure 63), giant stargazer and elephant fish (Figure 64). That rig are primarily distributed in the near inshore of New Zealand can be seen by the small amount of rig bycatch coming from the fisheries targeting deepwater species like hoki and gemfish, which only have a low incidence of rig bycatch due to the offshore nature of the associated bottom trawl fleets (Figure 63). The spatial extent of BT rig catches showed almost no change across the three time periods (because the 90th percentile has the same grid number for all three time blocks), but there was an increase in the amount of rig catch in each successive time period (Figure 65). Quite a few Statistical Areas contributed to the BT catch of rig, with Statistical Area 022 (Canterbury Bight) accounting for the greatest summed catch over the 32 years of the data set (Figure 66; see Figure 3 for the location of the statistical areas). Other statistical areas with large amounts of accumulated catch included Statistical Areas 038 (Tasman/Golden bays), 034 (Westport), 013 (Hawke’s Bay) and 030 (Foveaux Strait).

4.10.2 Seasonal catch information by target species

A wide range of target species accounted for rig bottom trawl catch in the various SPO QMAs (Figure 67). Trevally, snapper and tarakihi target fishing predominated in SPO 1 while tarakihi and gurnard target fishing had the largest rig bycatch in SPO 2. Elephant fish, barracouta, and flatfish produced the most rig bycatch in SPO 3, while tarakihi, barracouta, and flatfish predominated in SPO 7. Although the level of rig bycatch in SPO 8 was lower than in the other QMAs, the important target species were tarakihi and gurnard. The only QMA where target fishing for rig was important was SPO 3 and that was only for just over a decade (from about 2009) while most of the target species with high levels of rig bycatch extended over the full period of available data (from 1990), indicating that rig bycatch in these fisheries has been persistent (Figure 67).

The seasonal distribution of rig BT catches reflected the seasonality of the respective species target fisheries in all five SPO QMAs (SPO 1: Figure 68, SPO 2: Figure 69, SPO 3: Figure 70, SPO 7: Figure 71, SPO 8: Figure 72). Some of the target species responsible for rig bycatch were primarily year-round fisheries such as tarakihi, gurnard and snapper while elephant fish was seasonal in SPO 3 (Figure 70).

4.10.3 Depth distribution information by target species

Rig appeared to be taken between from 5–10 m to 200 m, although most rig were taken at depths of less than 100 m (Figure 73). In most instances, the depth range reported reflected the depth range of the target species, with rig taken at most reported depths less than 200 m.

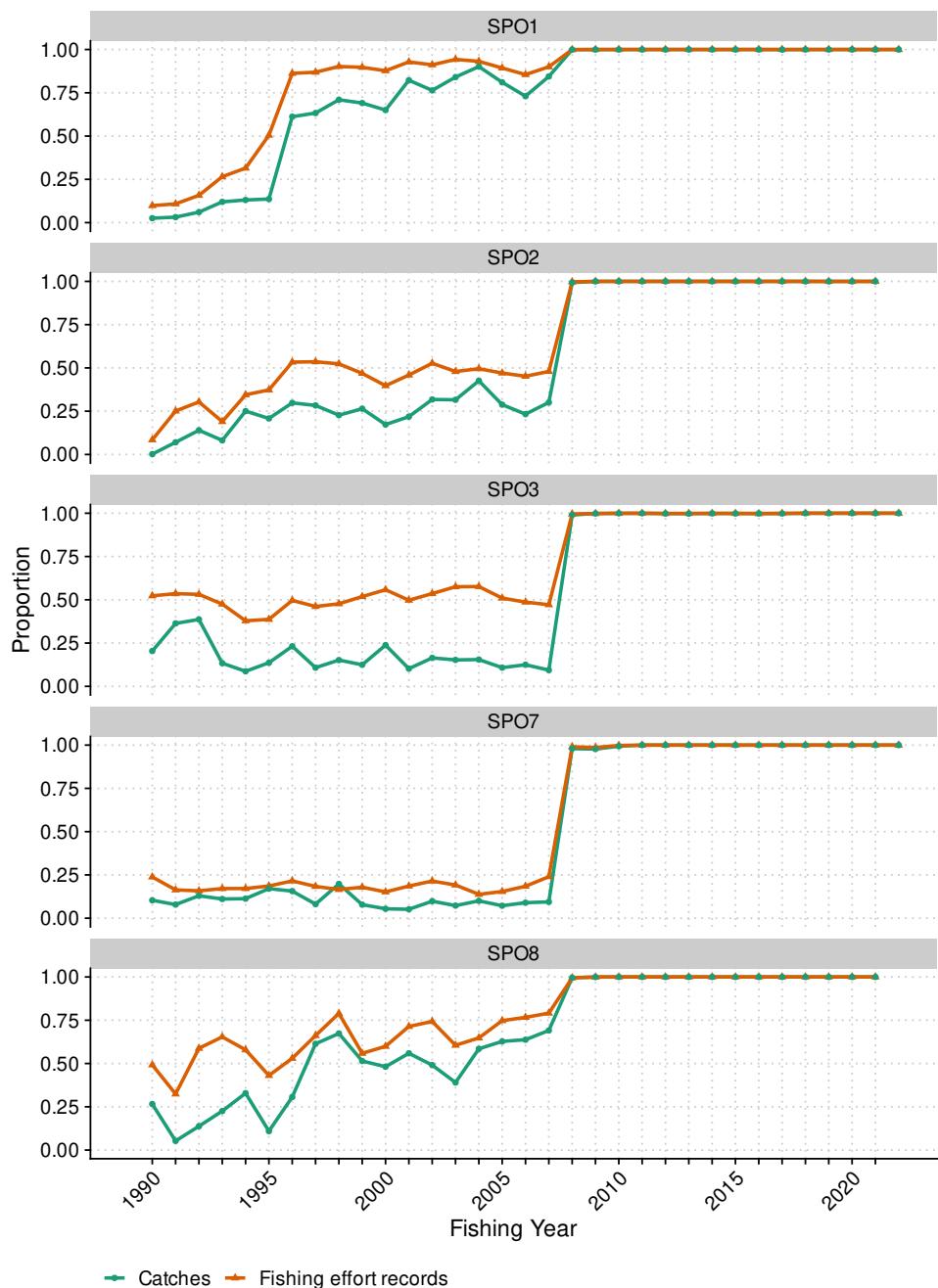


Figure 58: The proportion of records and catches reported with a latitude/longitude for the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 bottom trawl (including PRB) fishery.

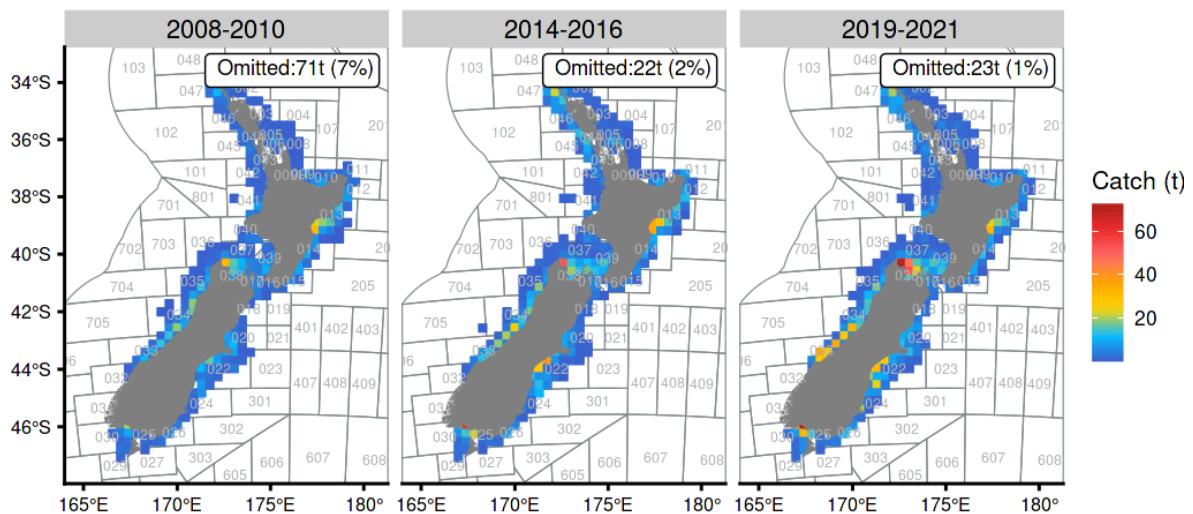


Figure 59: Catches (t) for the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 bottom trawl (including PRB) fishery, for 3-year periods within the era during which at least 80% of catch was reported with spatial information. These plots use a 32 km grid and include records where catches were allocated in proportion 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.

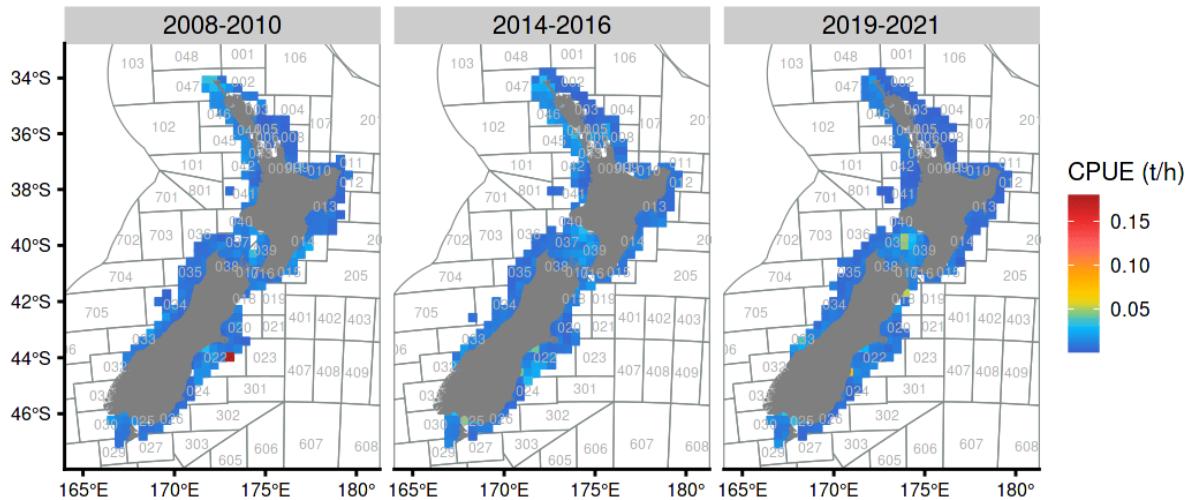


Figure 60: Raw aggregate CPUE (t/h) for the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 bottom trawl (including PRB) fishery, for 3-year periods within the era during which at least 80% of catch was reported with spatial information. These plots use a 32 km grid and include records where catches were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted.

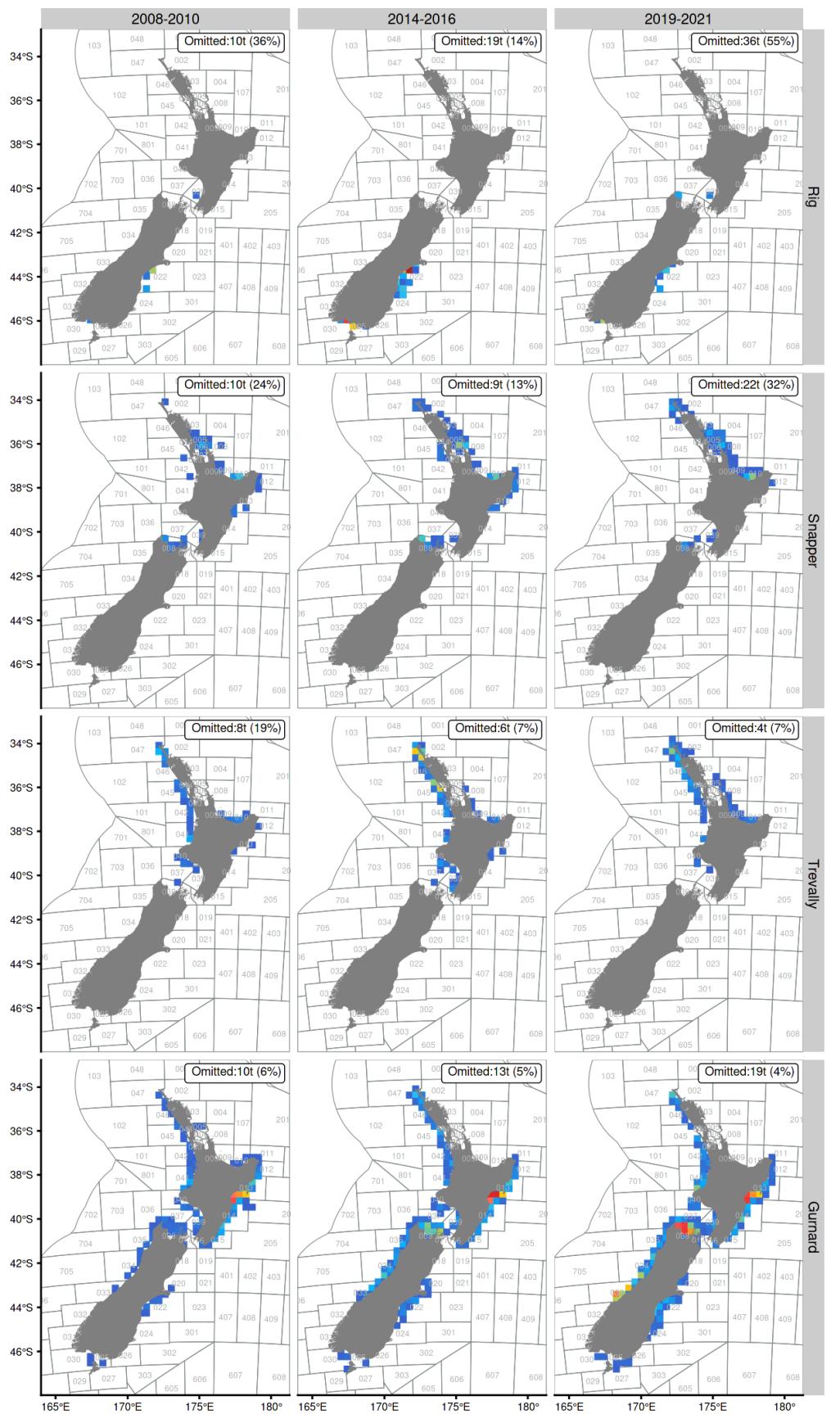


Figure 61: Catches of rig from the bottom trawl (including PRB) fishery by key target species. These plots use a 32 km grid and include records where landings were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

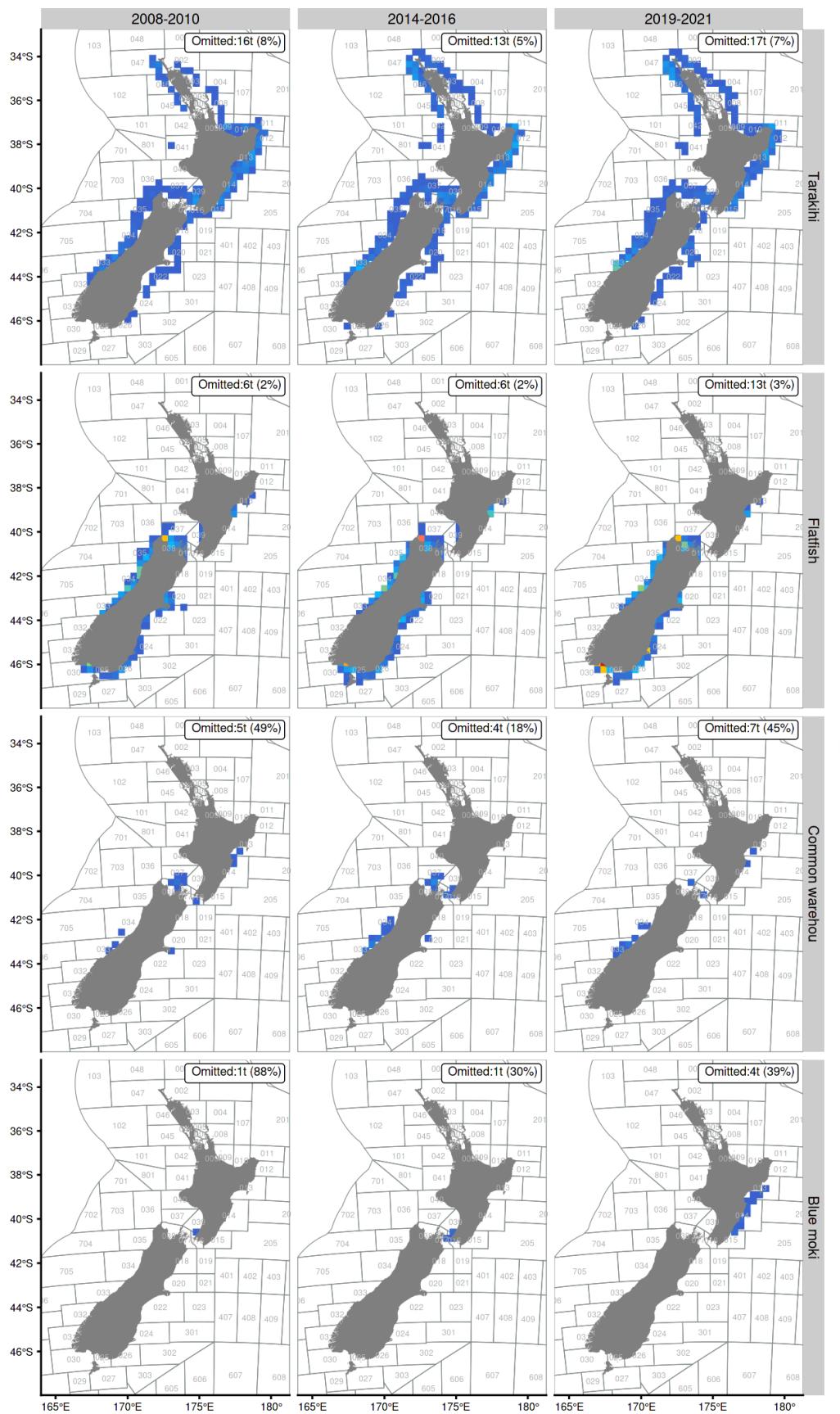


Figure 62: Catches of rig from the bottom trawl (including PRB) fishery by key target species. These plots use a 32 km grid and include records where landings were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

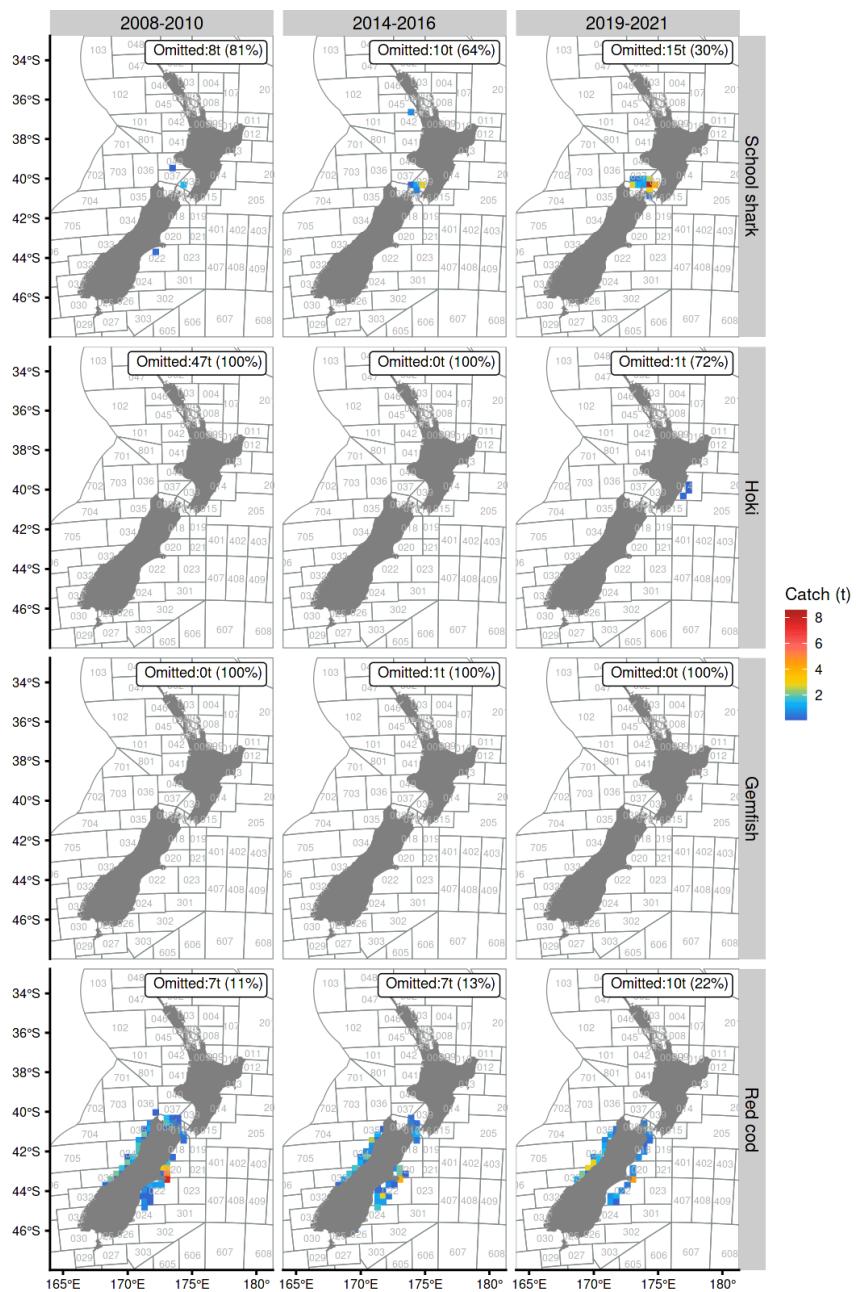


Figure 63: Catches of rig from the bottom trawl (including PRB) fishery by key target species. These plots use a 32 km grid and include records where landings were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

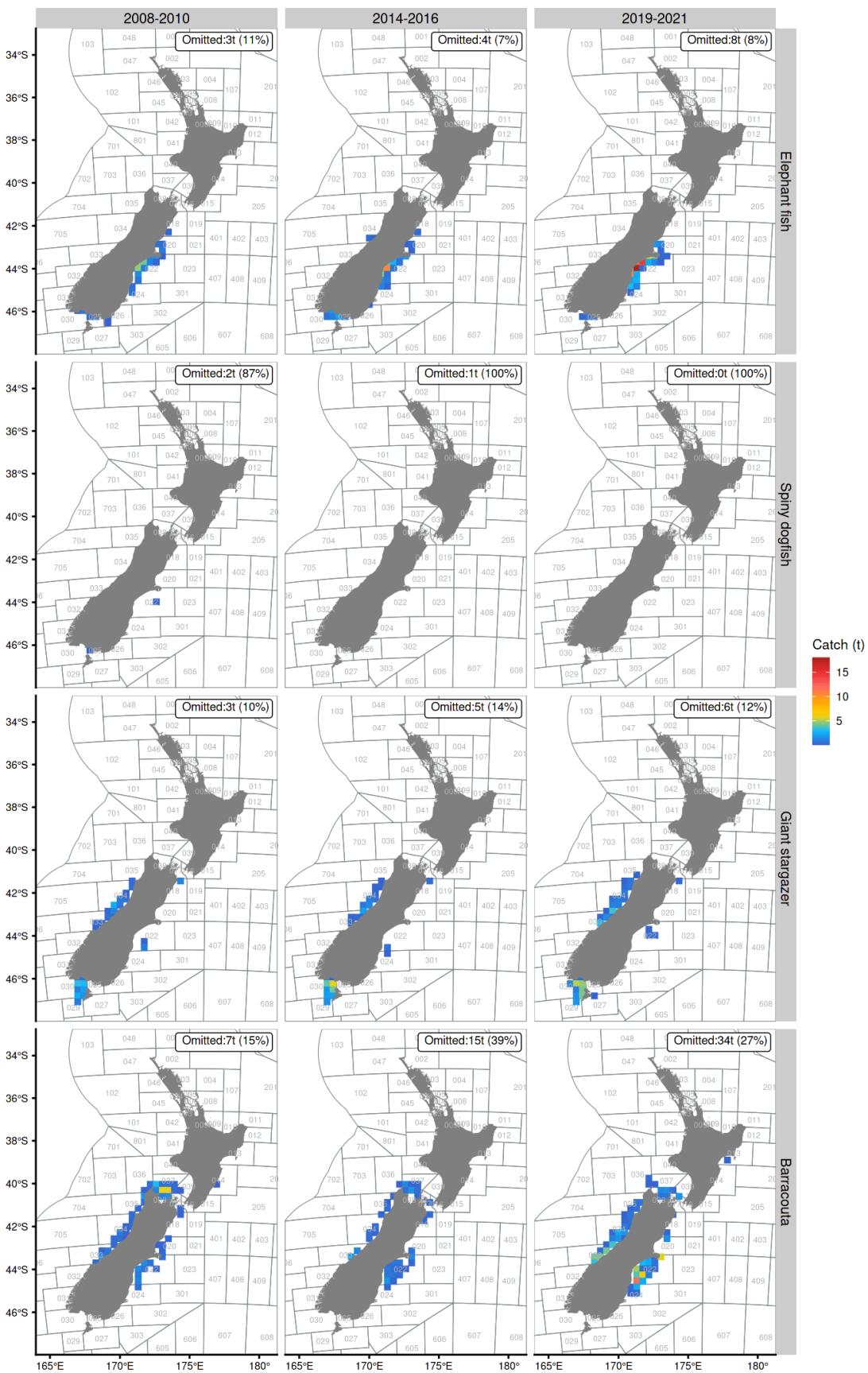


Figure 64: Catches of rig from the bottom trawl (including PRB) fishery by key target species. These plots use a 32 km grid and include records where landings were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

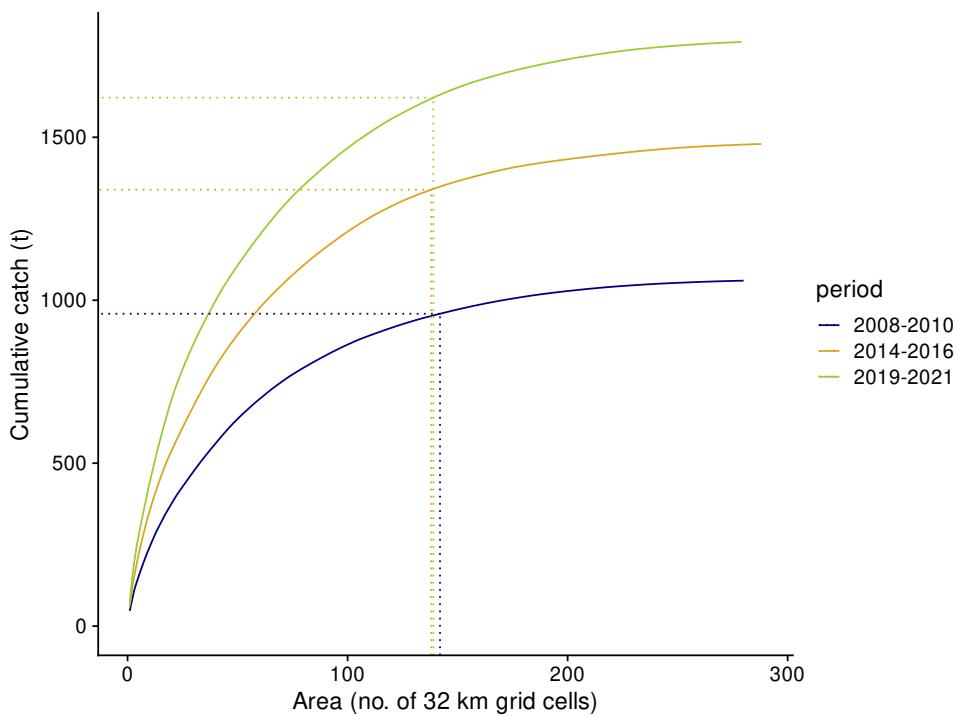


Figure 65: Cumulative SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 catch by area (grid cells) for the bottom trawl (including PRB) fishery, aggregated for the first, middle, and last 3-year period of reporting. Dotted lines indicate the 90th percentile for the first, middle, and last 3-year period of reporting.

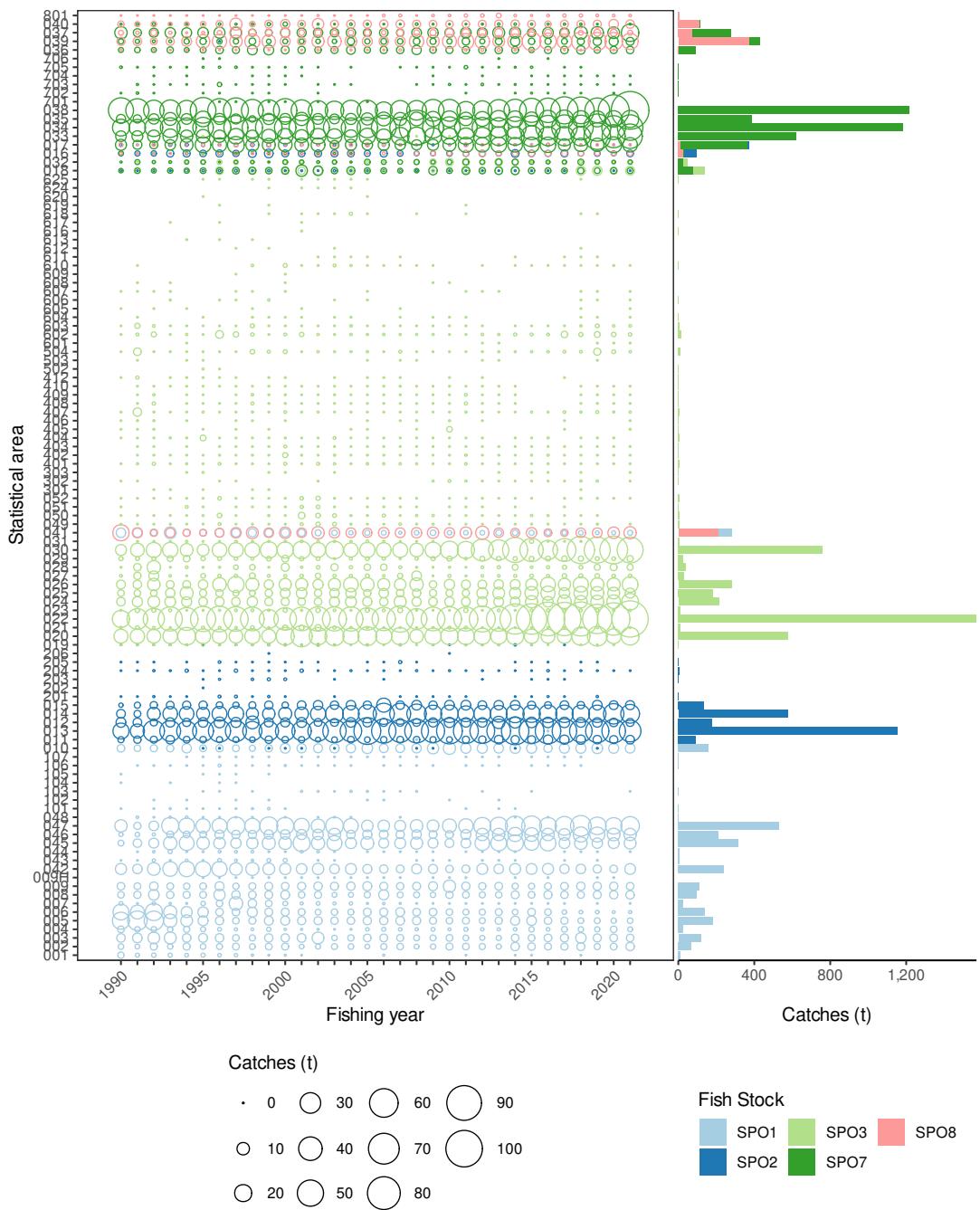


Figure 66: Annual SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 catches (t) by statistical area for the bottom trawl (including PRB) fishery. The circle size scales with the catches by statistical area. The bar plot (right) shows the total catches of SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 for each statistical area.

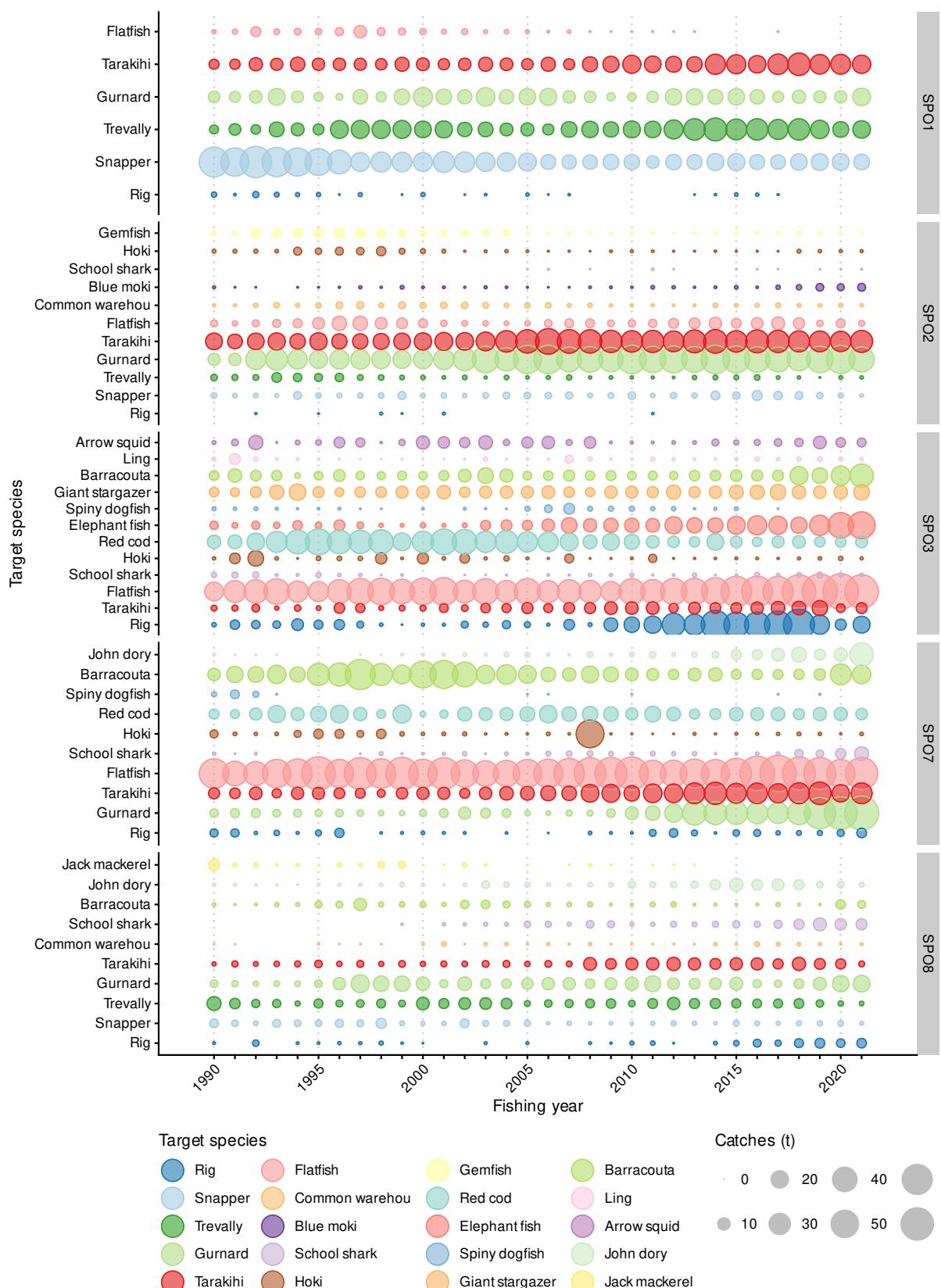


Figure 67: Rig catches by fishing year and target species for the bottom trawl (including PRB) fishery. The area of the circle scales with the yearly catches.

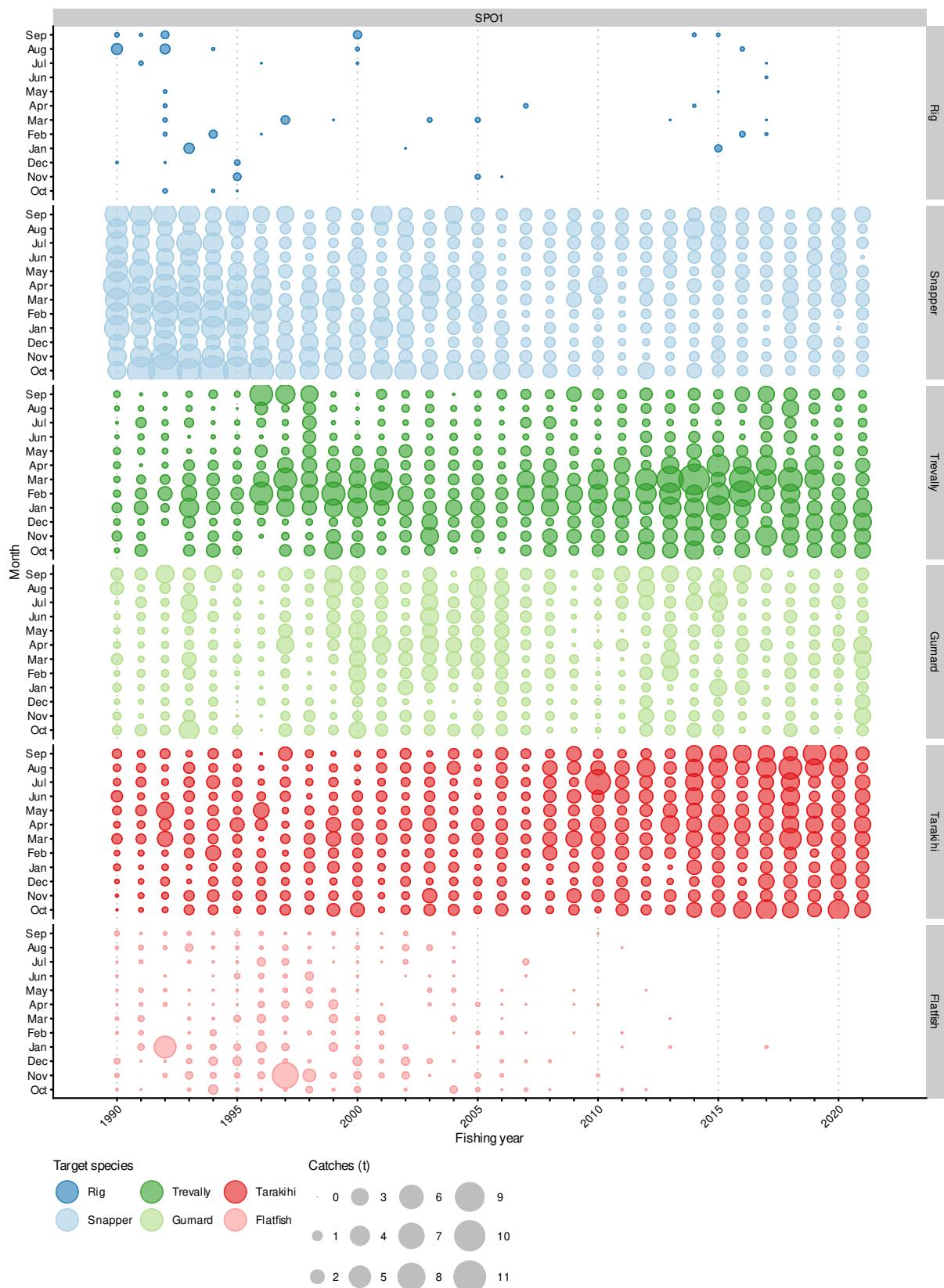


Figure 68: Seasonal distribution of SPO 1 catches by month and fishing year for the bottom trawl (including PRB) SPO 1 target fisheries. The area of the circle scales with the monthly catches.

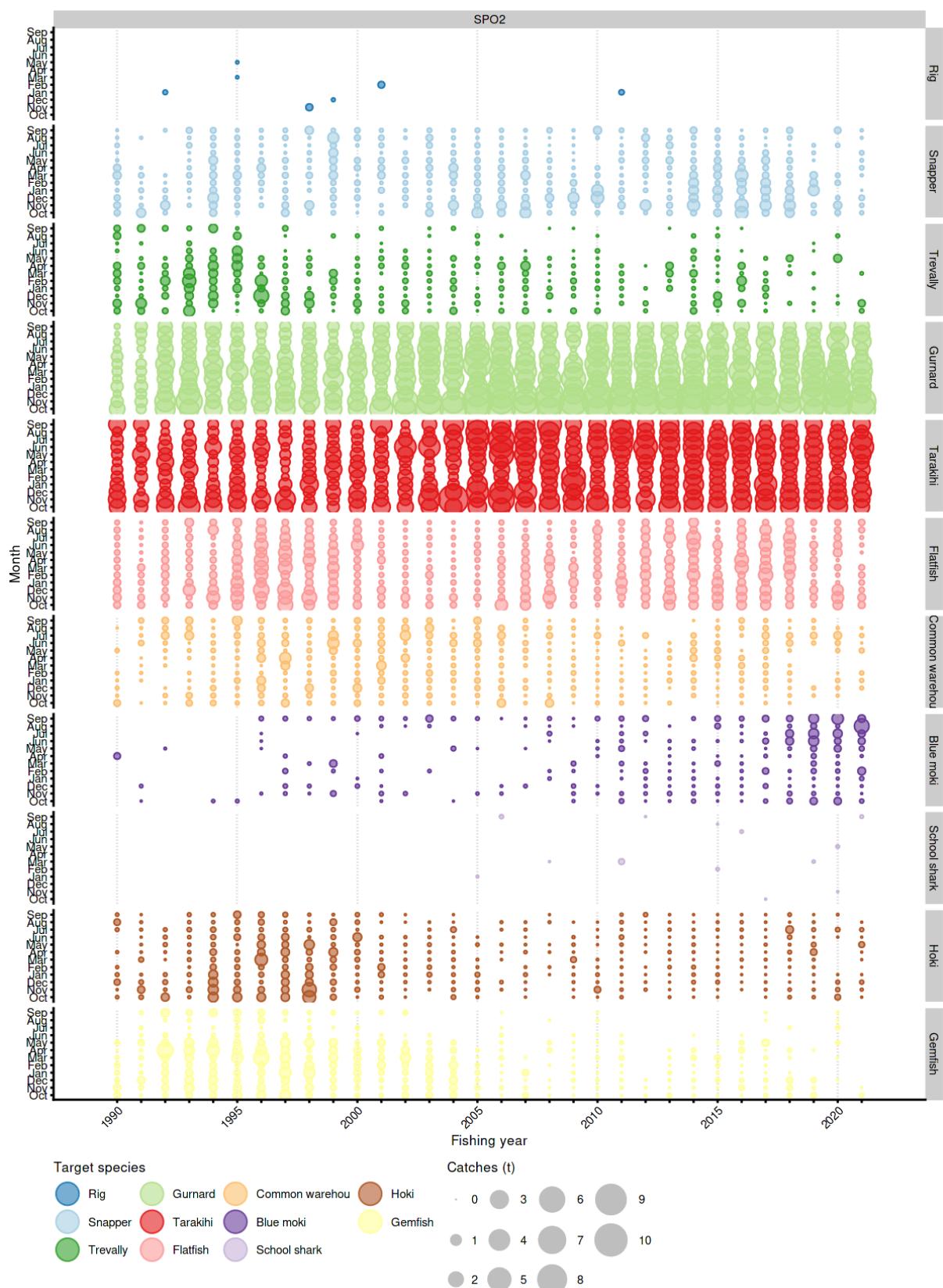


Figure 69: Seasonal distribution of SPO 2 catches by month and fishing year for the bottom trawl (including PRB) SPO 2 target fisheries. The area of the circle scales with the monthly catches.

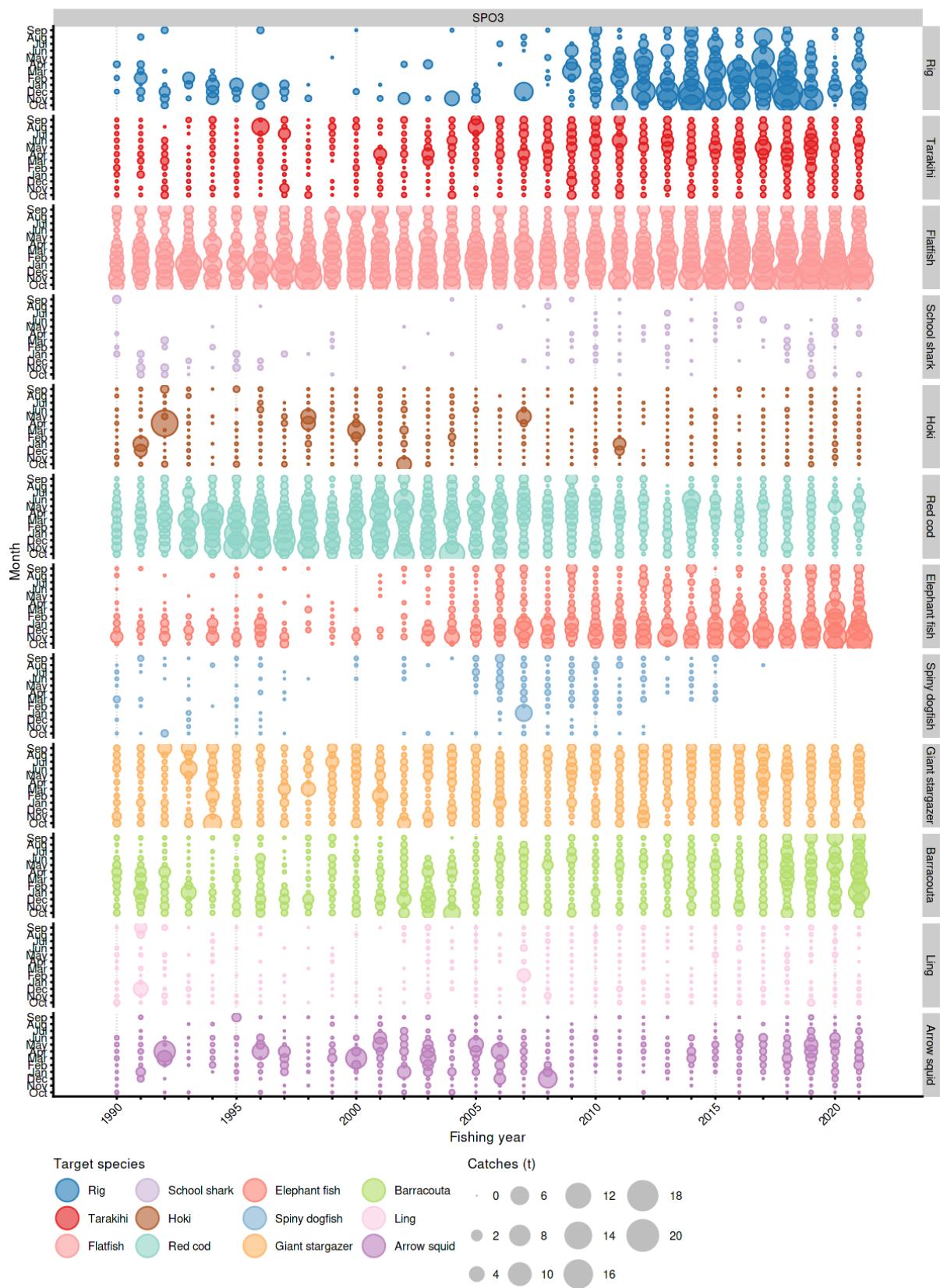


Figure 70: Seasonal distribution of SPO 3 catches by month and fishing year for the bottom trawl (including PRB) SPO 3 target fisheries. The area of the circle scales with the monthly catches.

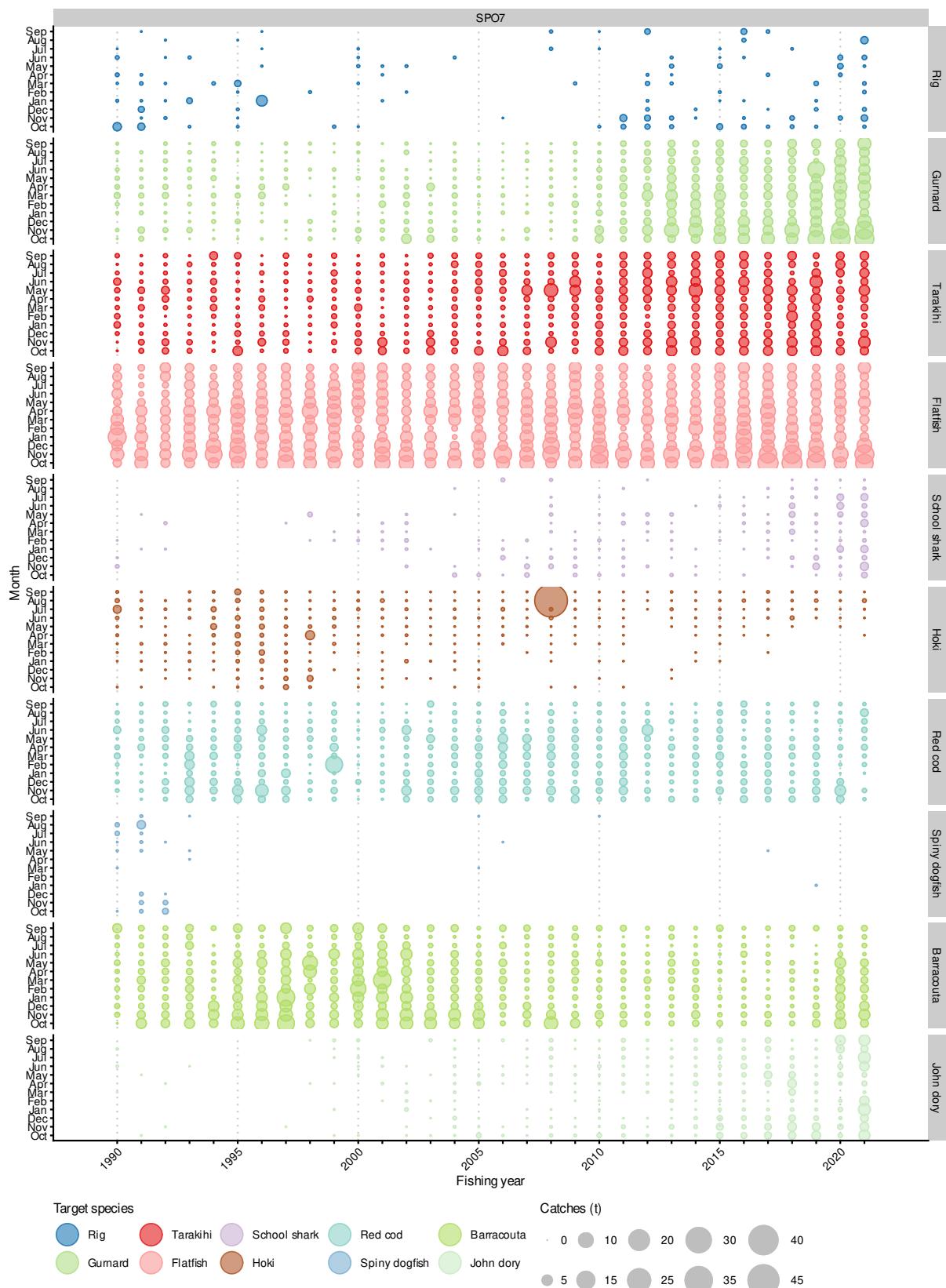


Figure 71: Seasonal distribution of SPO 7 catches by month and fishing year for the bottom trawl (including PRB) SPO 7 target fisheries. The area of the circle scales with the monthly catches.

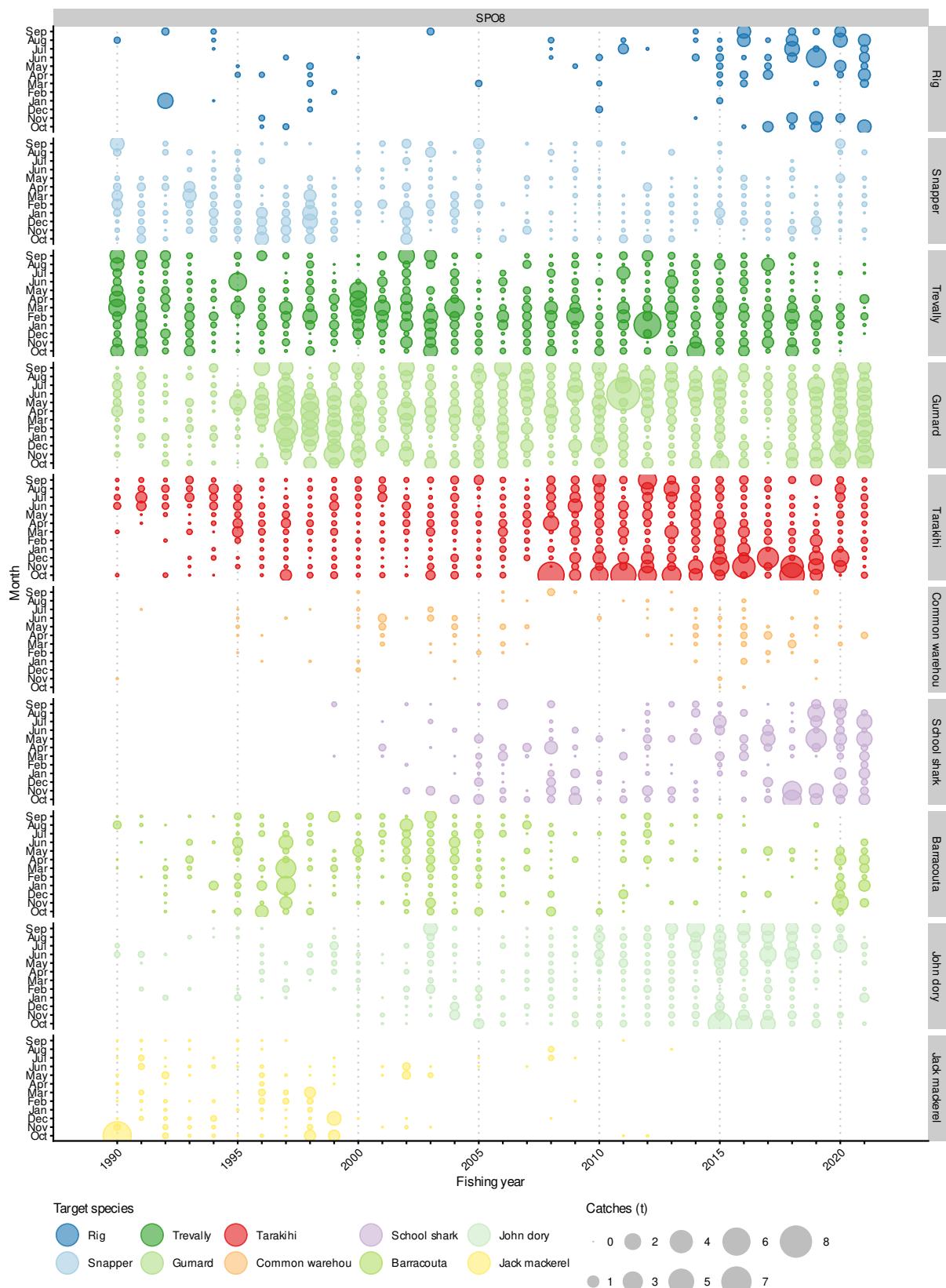


Figure 72: Seasonal distribution of SPO 8 catches by month and fishing year for the bottom trawl (including PRB) SPO 8 target fisheries. The area of the circle scales with the monthly catches.

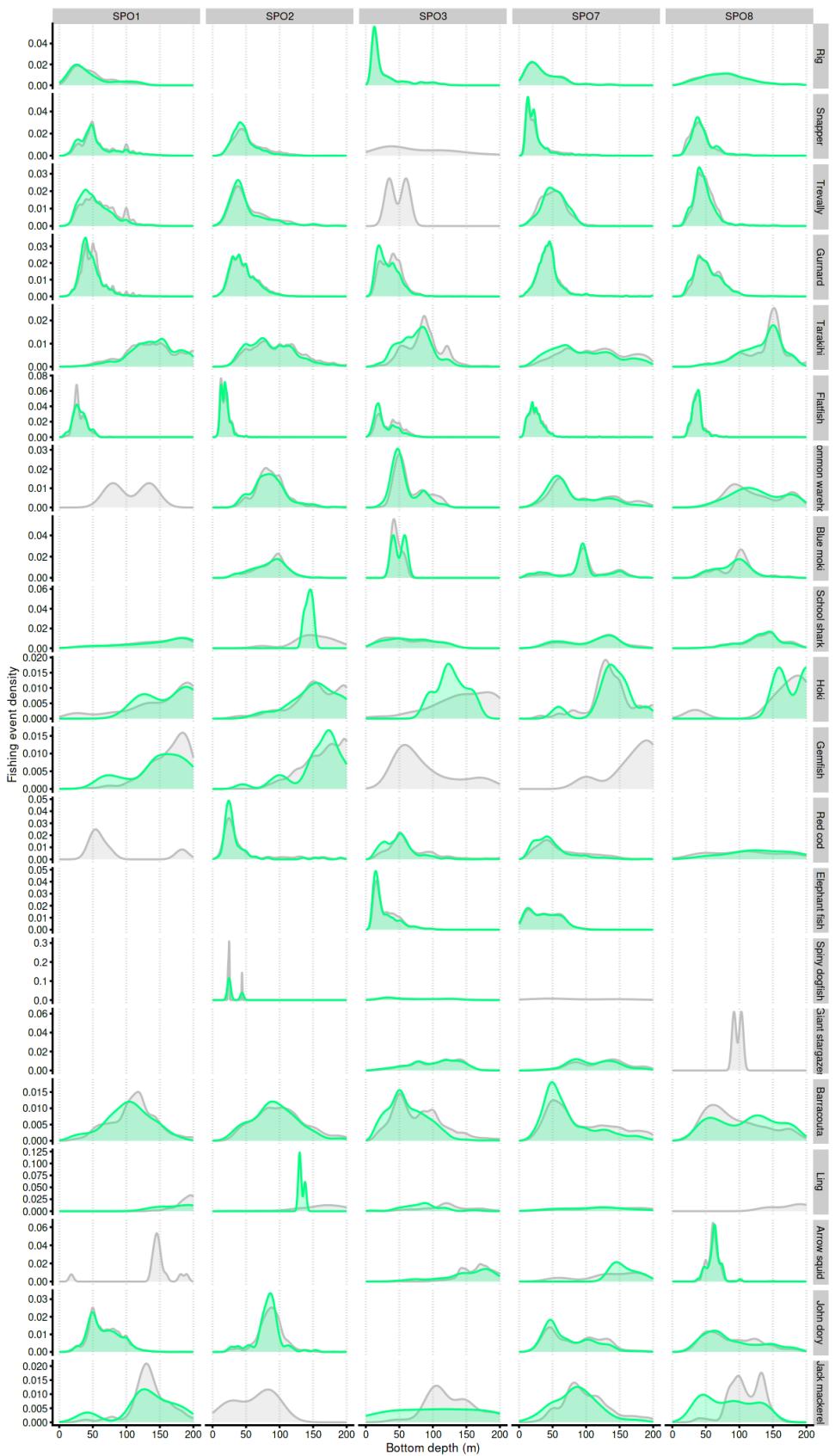


Figure 73: Effort depth distribution by target species for trips landing SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 from the bottom trawl (including PRB) fishery. Target species are included if they are represented in at least 30 events. Grey fill = total effort, Green fill = positive effort (i.e., estimated catch > 0).

4.11 The Danish seine fishery

4.11.1 Spatial catch information

Spatial catch information for SPO Danish seine (DS) catches was not available on a New Zealand-wide basis until the introduction of electronic reporting in 2019–20 (Figure 74). Unlike for set net and inshore bottom trawl, an event-based paper form requiring fine scale position reporting was never introduced for the Danish seine method. Instead, the Danish seine fleet was allowed to continue with the daily CELR paper form until the switch was made to electronic reporting which required position information for every event. The paper CELR form allowed for optional reporting of the position fished during a day of fishing which may account for the presence of pre-2019 spatial data in Figure 74, particularly in SPO 1.

Danish seine catches of rig tended to be localised, being concentrated in the upper Hauraki Gulf, the Bay of Plenty, Hawke’s Bay, Kaikoura, Timaru and Tasman Bay/Golden Bay (note: over 95% of the spatial DS rig catch cannot be shown in a plot because of the Fisheries New Zealand rule to omit cells with less than three vessels). The spatial CPUE plot showed that rig abundance as observed by Danish seine vessels tended to be highest off the east coast of the South Island and in Tasman/Golden bays. Danish seine rig CPUE was lower in the North Island than in the South Island. When the DS spatial catches were disaggregated by the primary DS target species, target DS fishing for rig took place around Kaikoura while rig bycatch in the DS fleet targeting snapper and gurnard took place on the North Island. Other DS fisheries with rig bycatch targeted tarakihi, flatfish and red cod and were also extremely localised off Banks Peninsula, Kaikoura and the western Bay of Plenty. Fewer than twenty 32 x 32 km grid cells were needed to reach the 90th percentile of the cumulative 2019–2021 DS catch, compared to about 80 to 120 grid cells needed to reach the same percentile for the SN and BT methods (Figure 75), demonstrating the highly localised nature of the DS fishery. The statistical areas with the highest accumulated rig catch included Statistical Areas 022 (Canterbury Bight), 020 (Pegasus Bay), 038 (Tasman Bay/Golden Bay), and 006 (outer Hauraki Gulf) (Figure 76; see Figure 3 for the location of the statistical areas).

4.11.2 Seasonal catch information by target species

The Danish seine catch of rig was mainly made when targeting for snapper and gurnard in SPO 1 and for rig and red cod in SPO 3 (Figure 77). The DS fishery in the remaining three SPO QMAs was negligible in terms of total rig catch (see Table B.24, Table B.26, Table B.27).

The seasonal distribution of rig DS catches is only presented for SPO 1 and SPO 3 (SPO 1: Figure 78, SPO 3: Figure 79). The snapper and gurnard DS fisheries that take rig bycatch in SPO 1 operate throughout the year while the SPO 3 target rig sets were made during the late summer/early autumn.

4.11.3 Depth distribution information by target species

Depth information is not available from the commercial DS fishery because bottom depth of an event is not recorded in any of the existing recording forms.

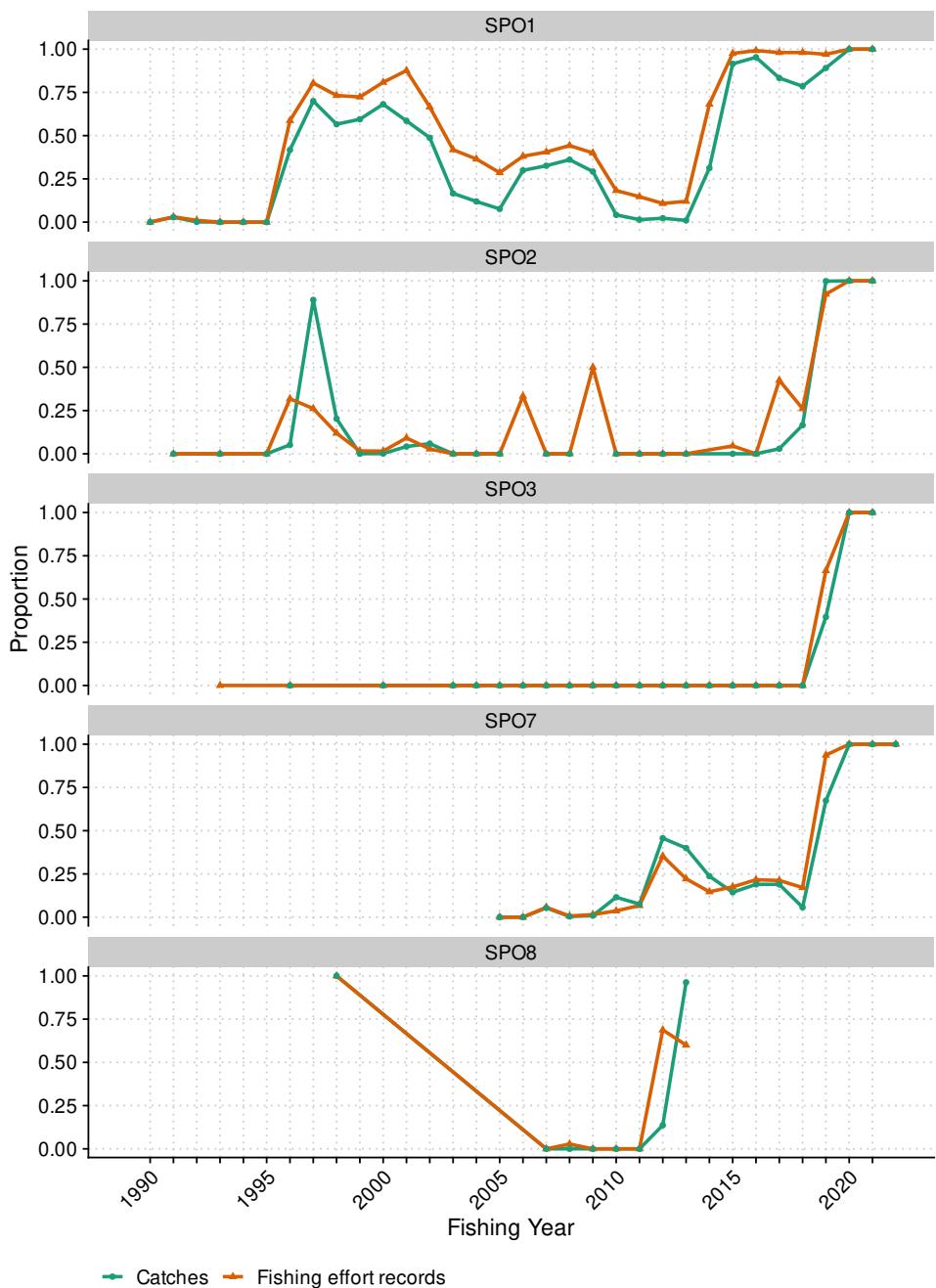


Figure 74: The proportion of records and catches reported with a latitude/longitude for the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 Danish seine fishery.

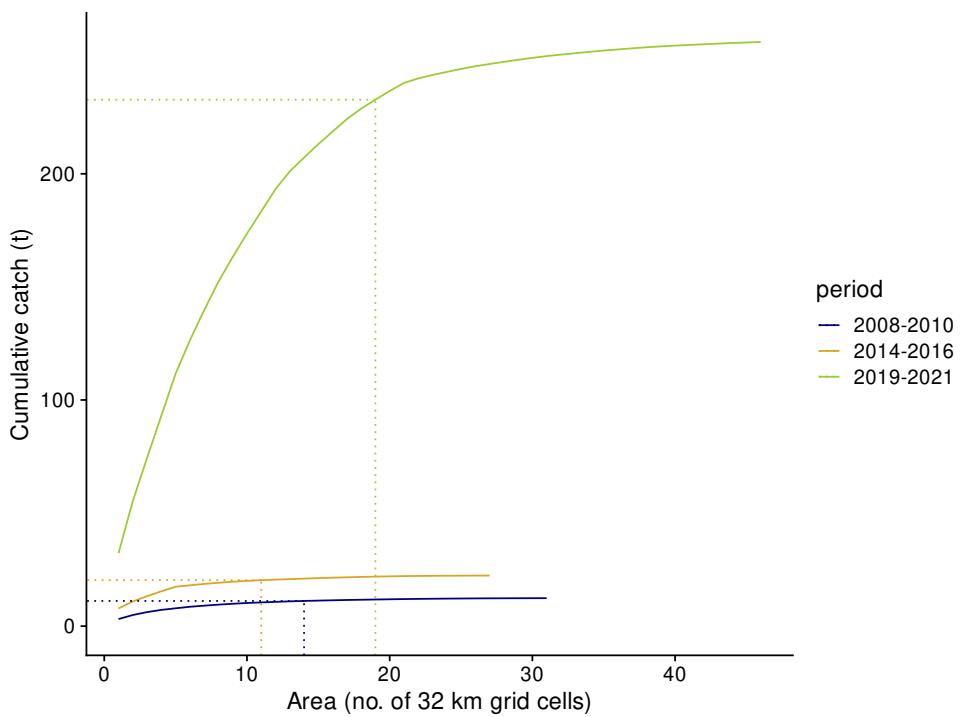


Figure 75: Cumulative SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 catch by area (grid cells) for the Danish seine fishery, aggregated for the first, middle, and last 3-year period of reporting. Dotted lines indicate the 90th percentile for the first, middle, and last 3-year period of reporting.

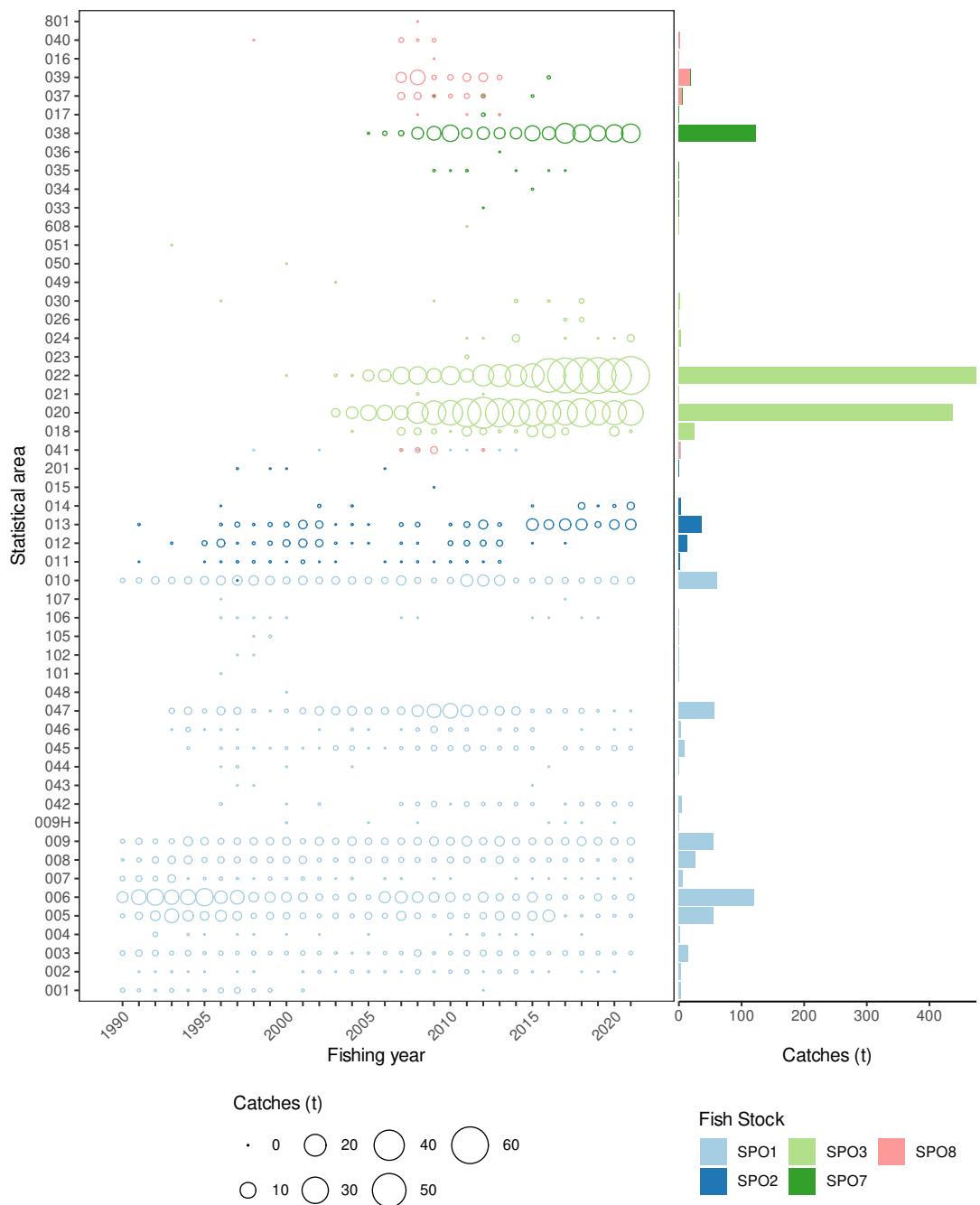


Figure 76: Annual SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 catches (t) by statistical area for the Danish seine fishery. The circle size scales with the catches by statistical area. The bar plot (right) shows the total catches of SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 for each statistical area.

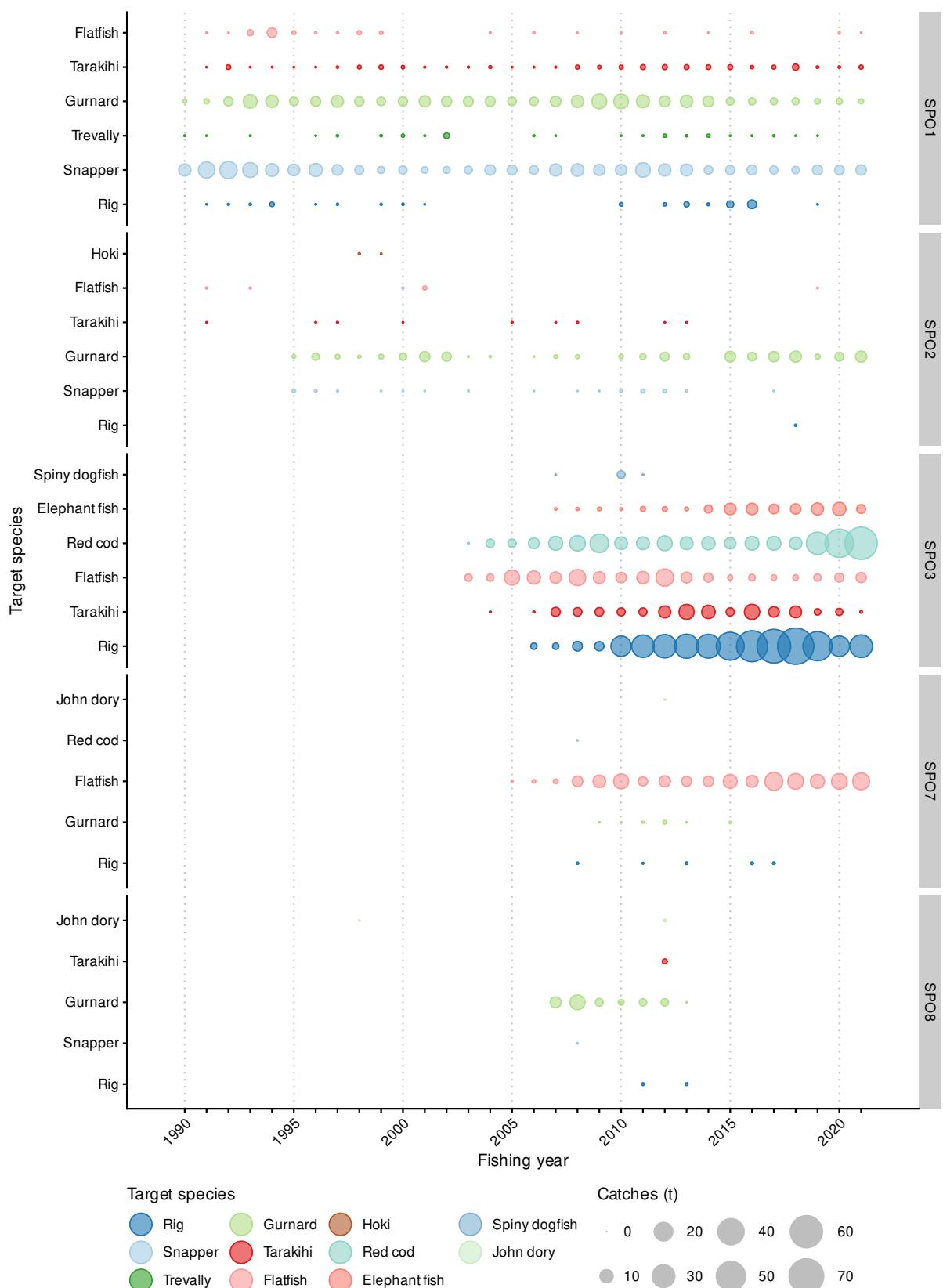


Figure 77: Rig catches by fishing year and target species for the Danish seine fishery. The area of the circle scales with the yearly catches.

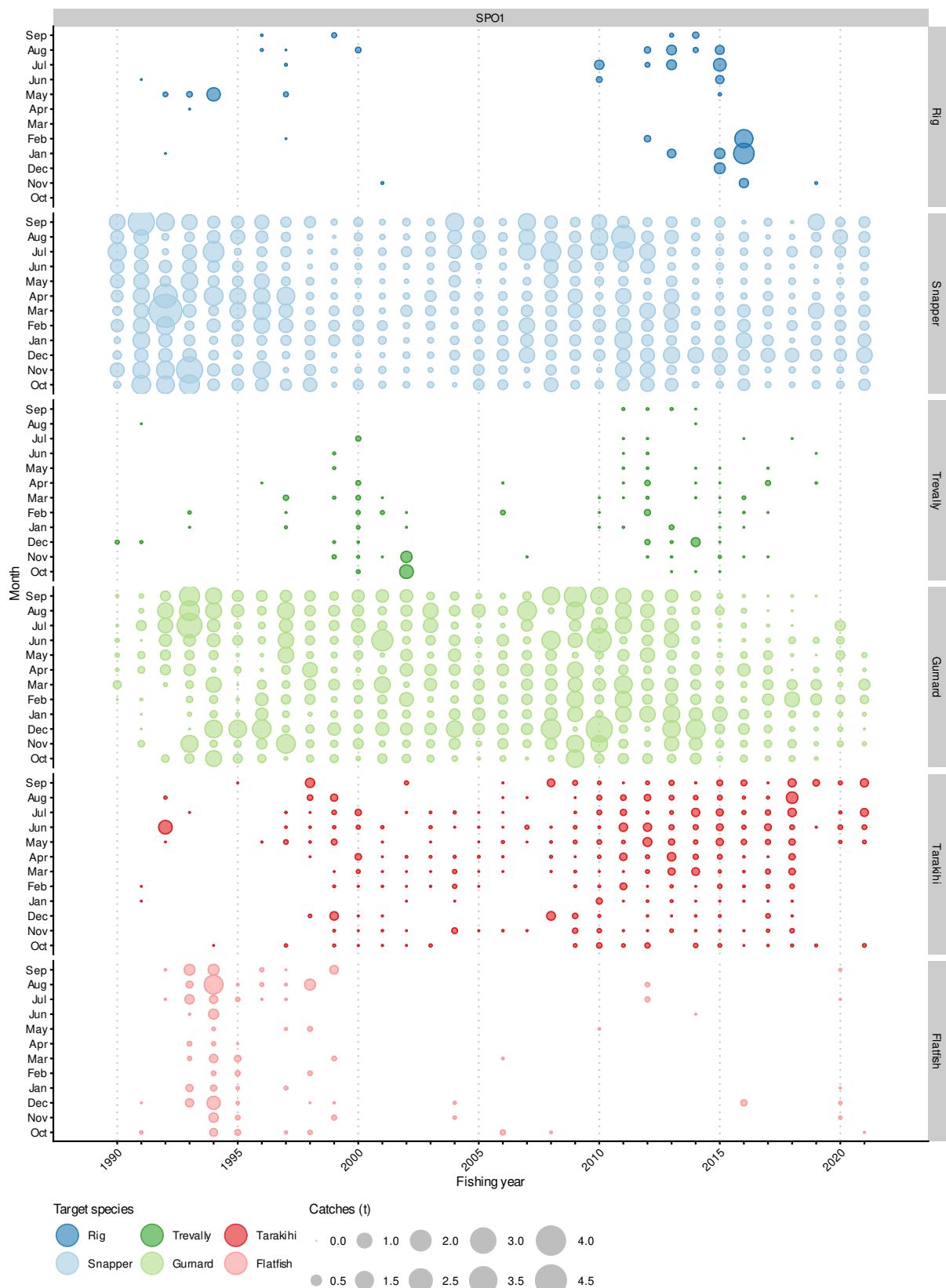


Figure 78: Seasonal distribution of SPO 1 catches by month and fishing year for the Danish seine SPO 1 target fisheries. The area of the circle scales with the monthly catches.

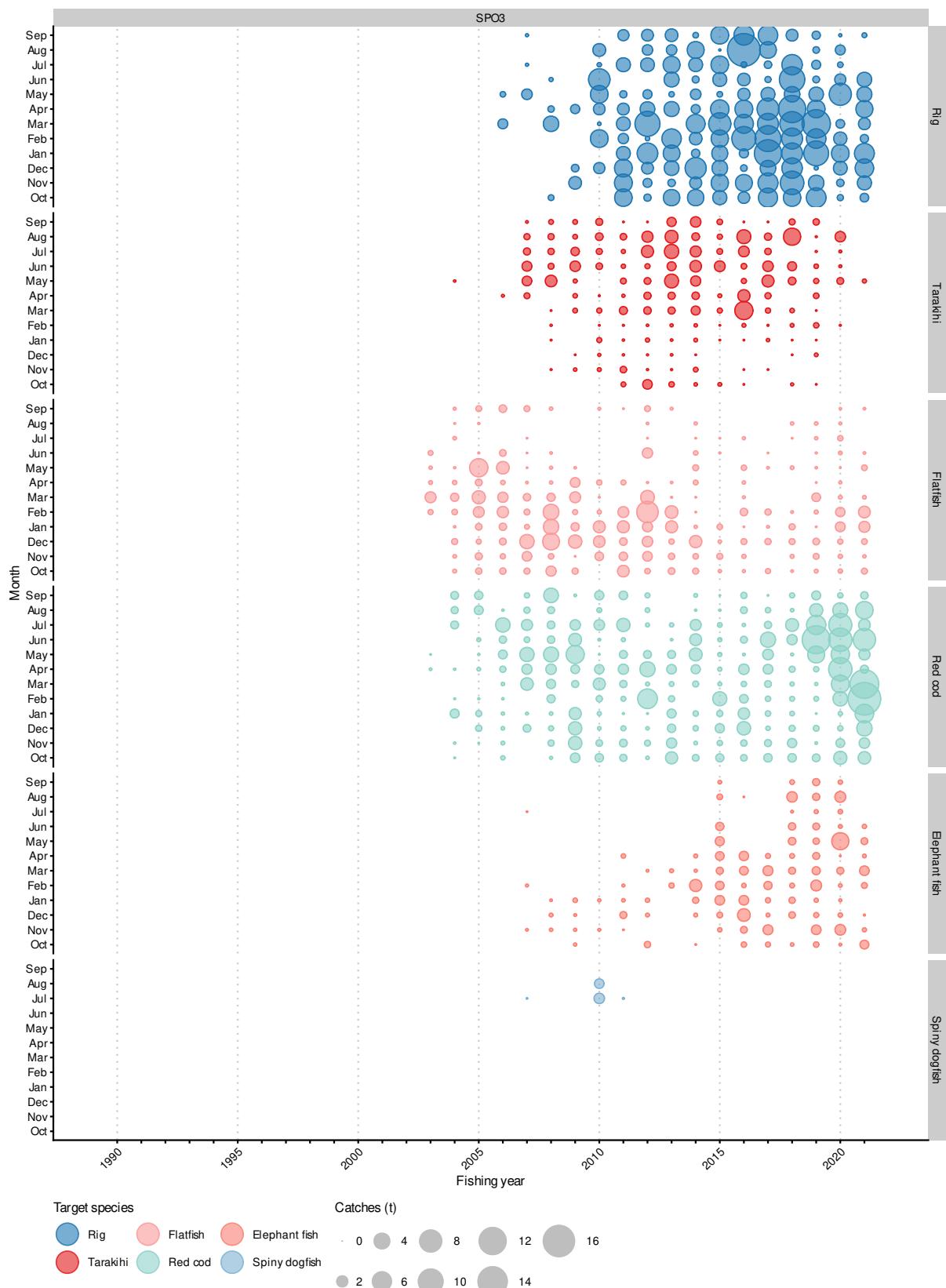


Figure 79: Seasonal distribution of SPO 3 catches by month and fishing year for the Danish seine SPO 3 target fisheries. The area of the circle scales with the monthly catches.

4.12 The bottom longline fishery

4.12.1 Spatial catch information

Spatial catch information for SPO bottom longline catches was not available on a New Zealand-wide basis from the inshore longline fleet until the introduction of the LTCER form in 1 October 2007 (Figure 80).

Most rig caught by bottom longline were taken from North Cape to the Bay of Plenty, on the top part of the North Island (Figure 81). Some rig were also taken in the North and South Taranaki Bights and off the east coast of the North Island. There were no catch ‘hot spots’ where the bottom longline fleet consistently took greater amounts of rig (Figure 81). The spatial CPUE plots showed a similar distribution of rig abundance compared to the catch distribution map, again without consistent CPUE ‘hot spots’. This observation corroborates the equivalent set net and bottom trawl spatial maps which showed a New Zealand-wide distribution of rig at relatively low levels of abundance (Figure 82). There was virtually no target fishing for rig using bottom longline with the majority of the bottom longline bycatch of rig taken when fishing for snapper. The spatial extent of rig catches using bottom longline gear changed over the three time periods, with the first time period (2008–2010) having the highest catch distributed over the greatest number of 32 x 32 km cells (Figure 83). The fishery contracted from this level in the second (2014–2016) time period but grew again to near the level of the first period in terms of total catch in the final (2019–2021) time block (Figure 83). The statistical areas with the greatest amount of rig catch taken by bottom longline were all in the North, including Statistical Areas 003 (Bay of Islands), 006 (Hauraki Gulf) and 009 (western Bay of Plenty) (Figure 84; see Figure 3 for the location of the statistical areas).

4.12.2 Seasonal catch information by target species

The only target species that caught rig as bycatch using bottom longline gear was snapper in SPO 1 (Figure 85). There was a small amount of BLL target fishing for rig in SPO 3 from 2011 to 2020 and in 1994/1996 in SPO 1 (Figure 85).

The seasonal distribution of the SPO 1 BLL target snapper rig bycatch showed no seasonal pattern and there was no consistent pattern to the small amount of BLL target rig fishing in SPO 1 (Figure 86).

4.12.3 Depth distribution information by target species

All the rig bycatch from the target SPO 1 BLL snapper fishery was from 0–50+ m, indicating that this was a shallow inshore fishery (Figure 87).

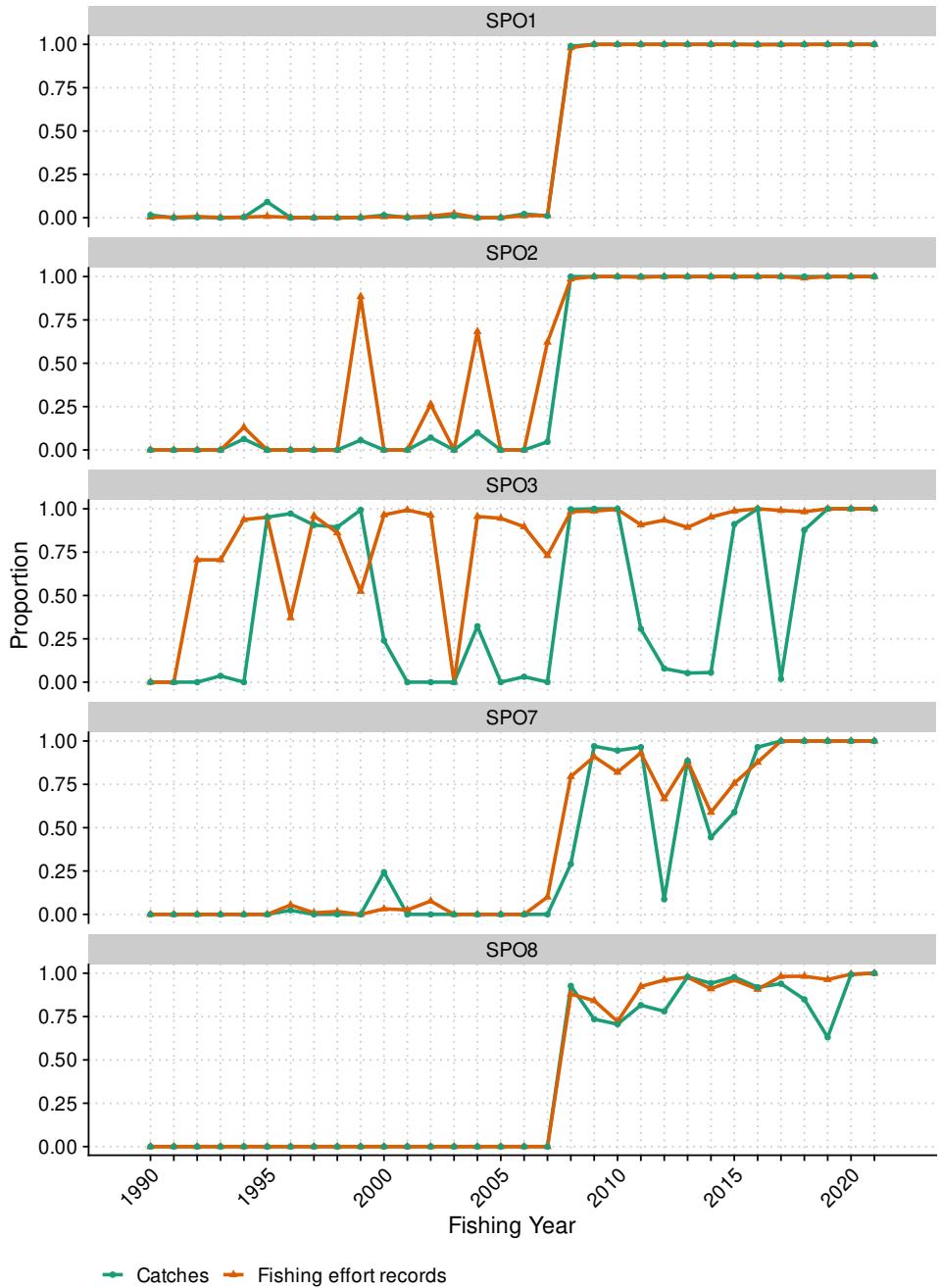


Figure 80: The proportion of records and catches reported with a latitude/longitude for the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 bottom longline fishery.

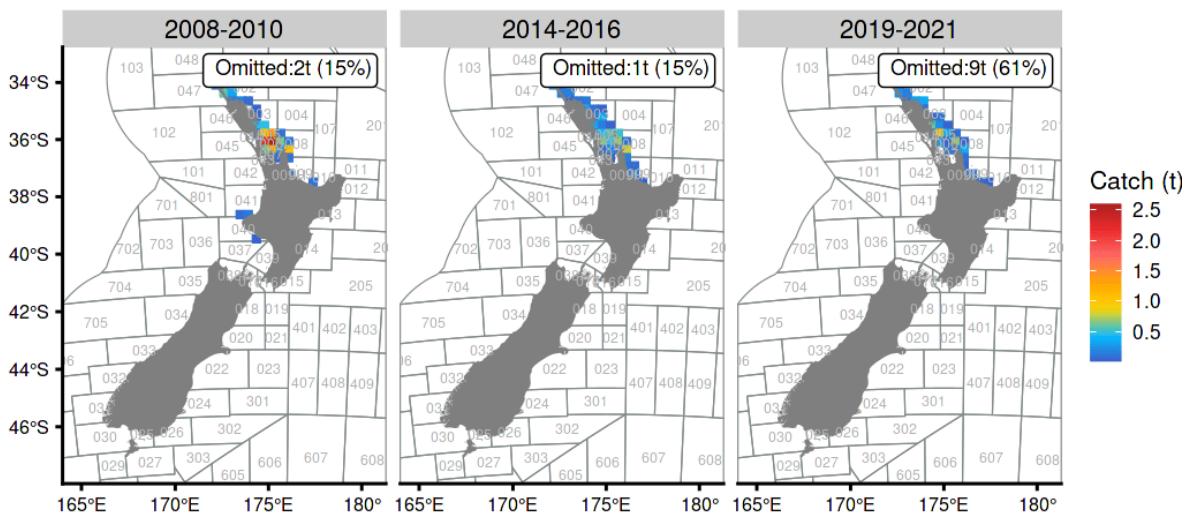


Figure 81: Catches (t) for the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 bottom longline fishery, for 3-year periods within the era during which at least 80% of catch was reported with spatial information. These plots use a 32 km grid and include records where catches were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted; the quantity of catch affected is indicated on each panel.

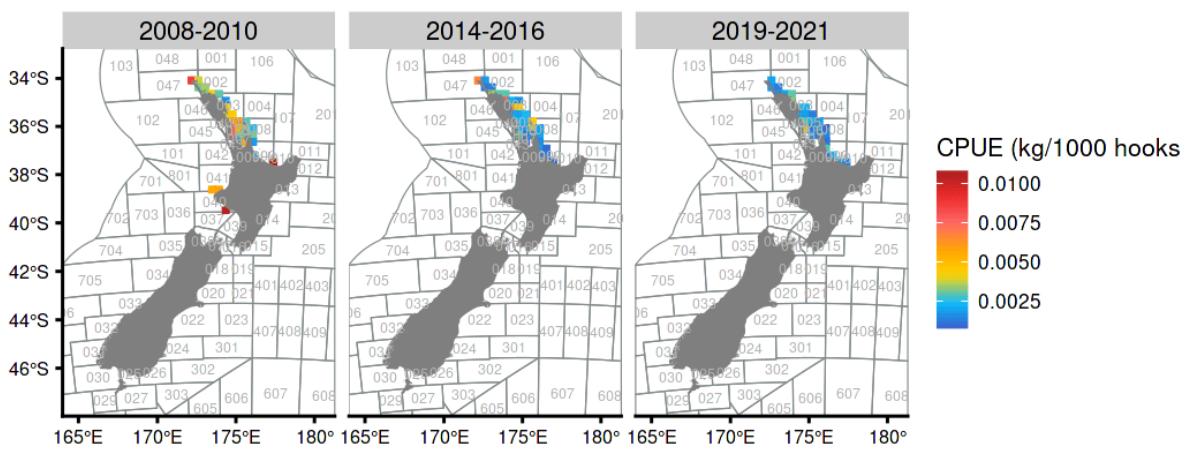


Figure 82: Raw aggregate CPUE (kg/1000 hooks) for the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 bottom longline fishery, for 3-year periods within the era during which at least 80% of catch was reported with spatial information. These plots use a 32 km grid and include records where catches were allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted.

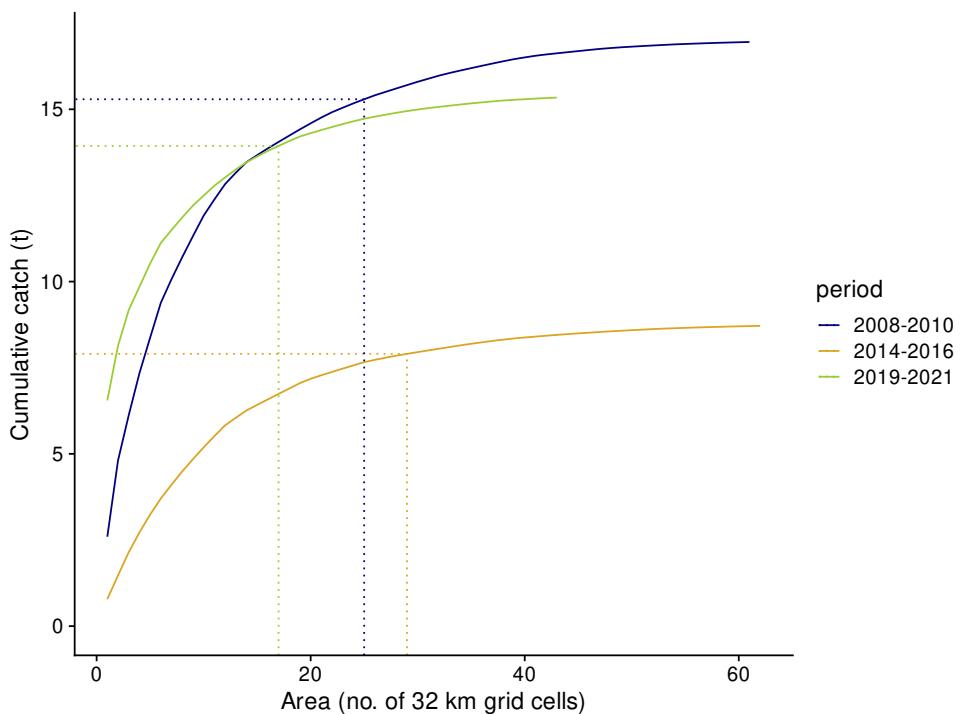


Figure 83: Cumulative SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 catch by area (grid cells) for the bottom longline fishery, aggregated for the first, middle, and last 3-year period of reporting. Dotted lines indicate the 90th percentile for the first, middle, and last 3-year period of reporting.

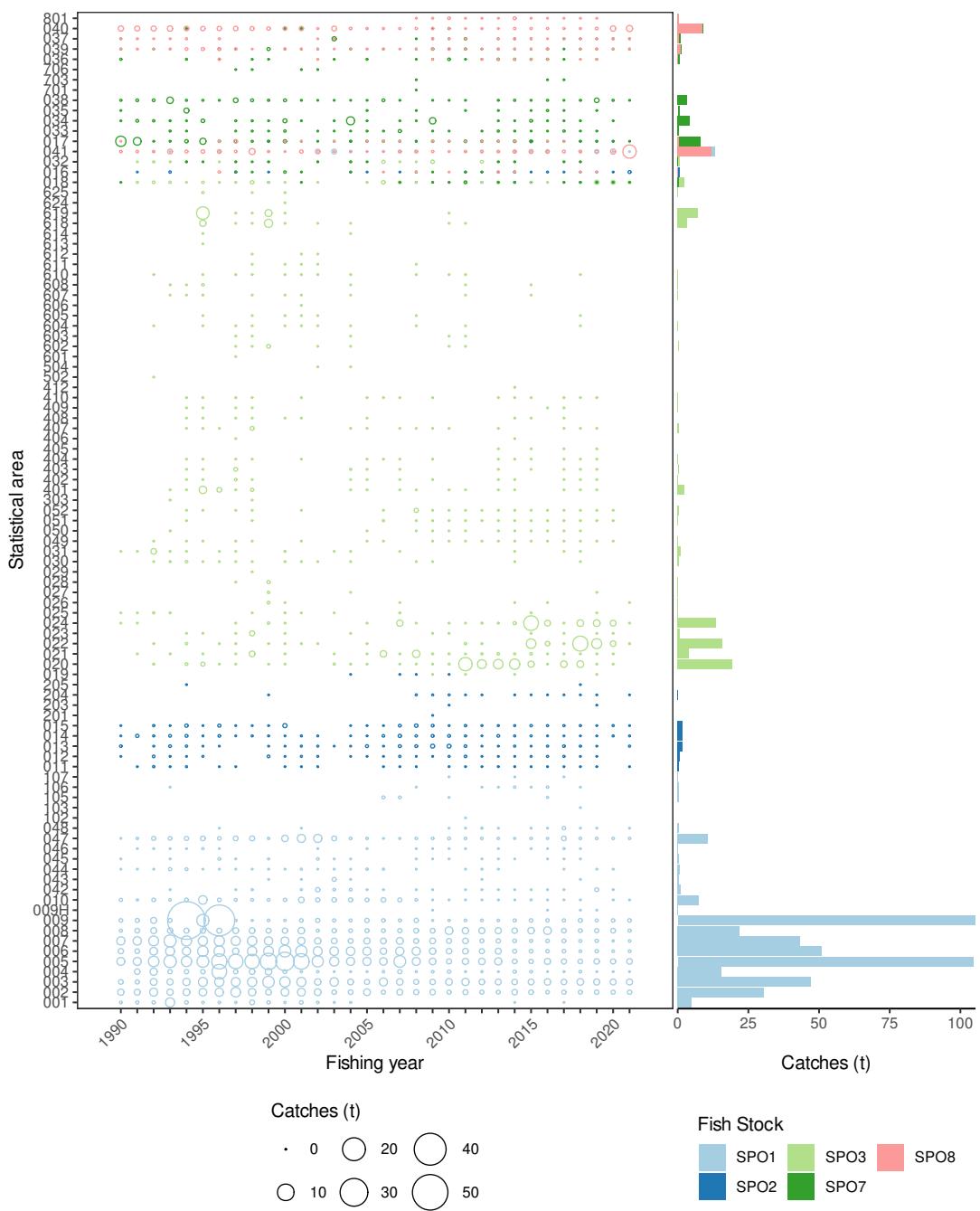


Figure 84: Annual SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 catches (t) by statistical area for the bottom longline fishery. The circle size scales with the catches by statistical area. The bar plot (right) shows the total catches of SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 for each statistical area.

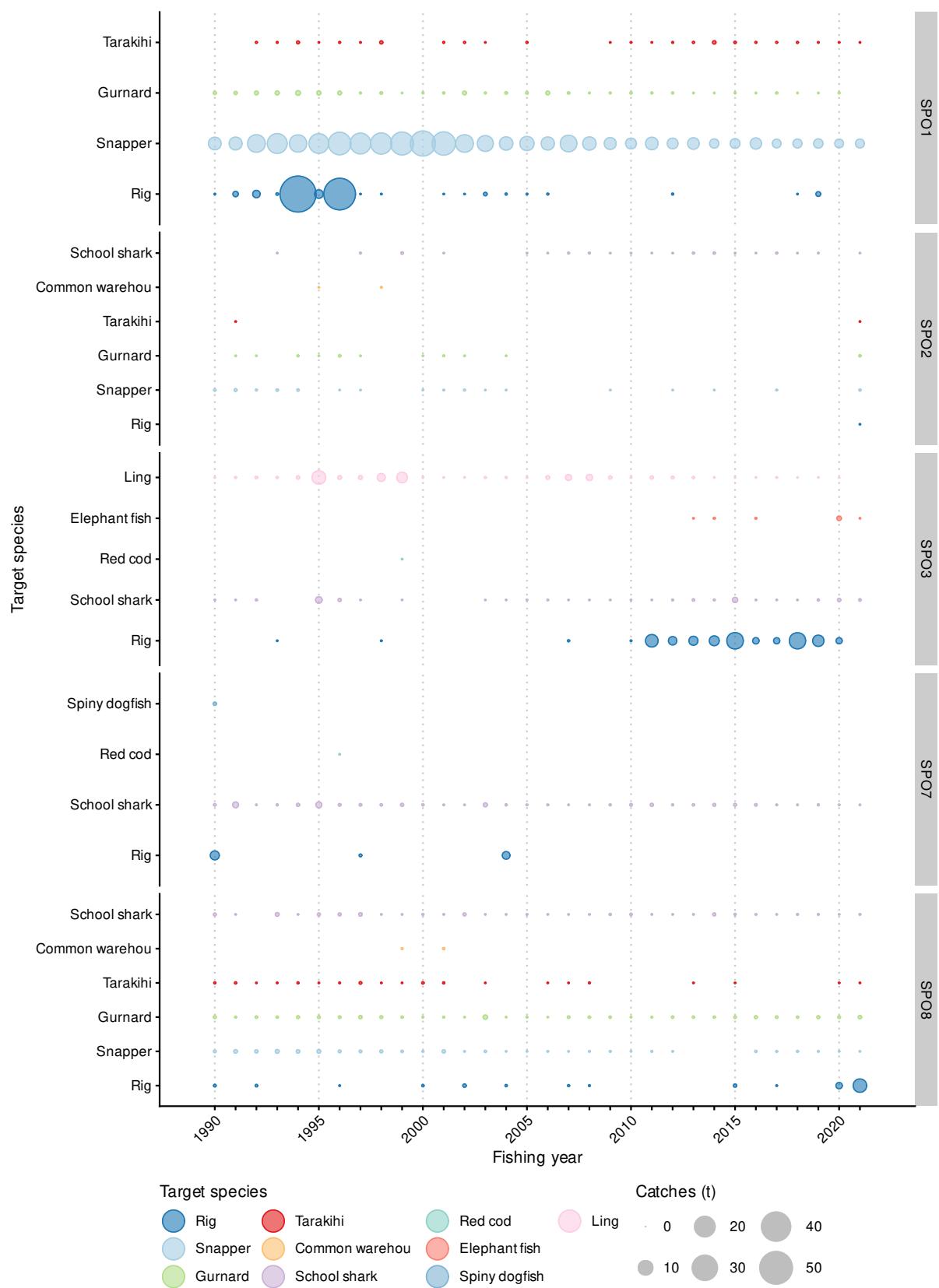


Figure 85: Rig catches by fishing year and target species for the bottom longline fishery. The area of the circle scales with the yearly catches.

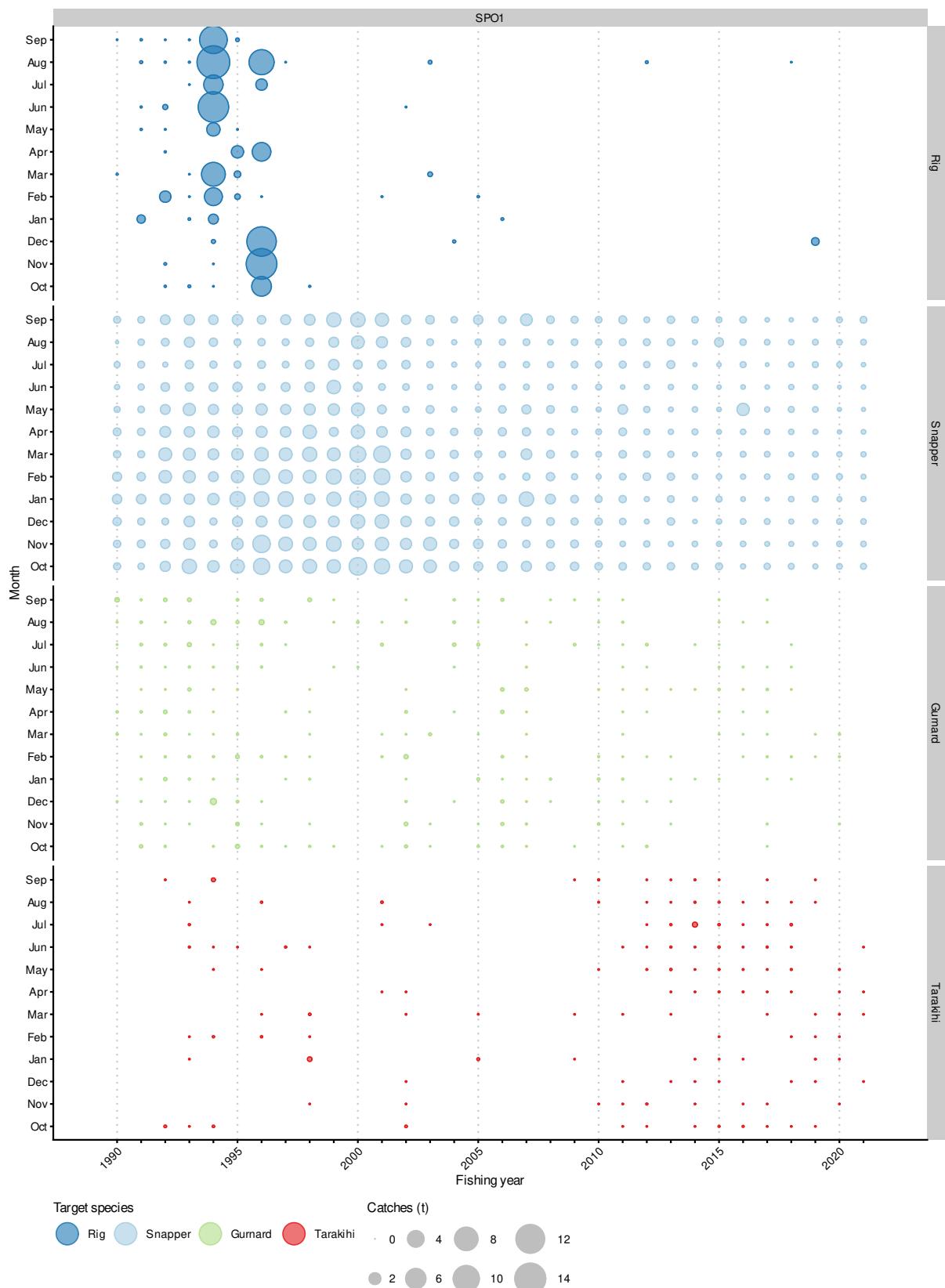


Figure 86: Seasonal distribution of SPO 1 catches by month and fishing year for the bottom longline SPO 1 target fisheries. The area of the circle scales with the monthly catches.

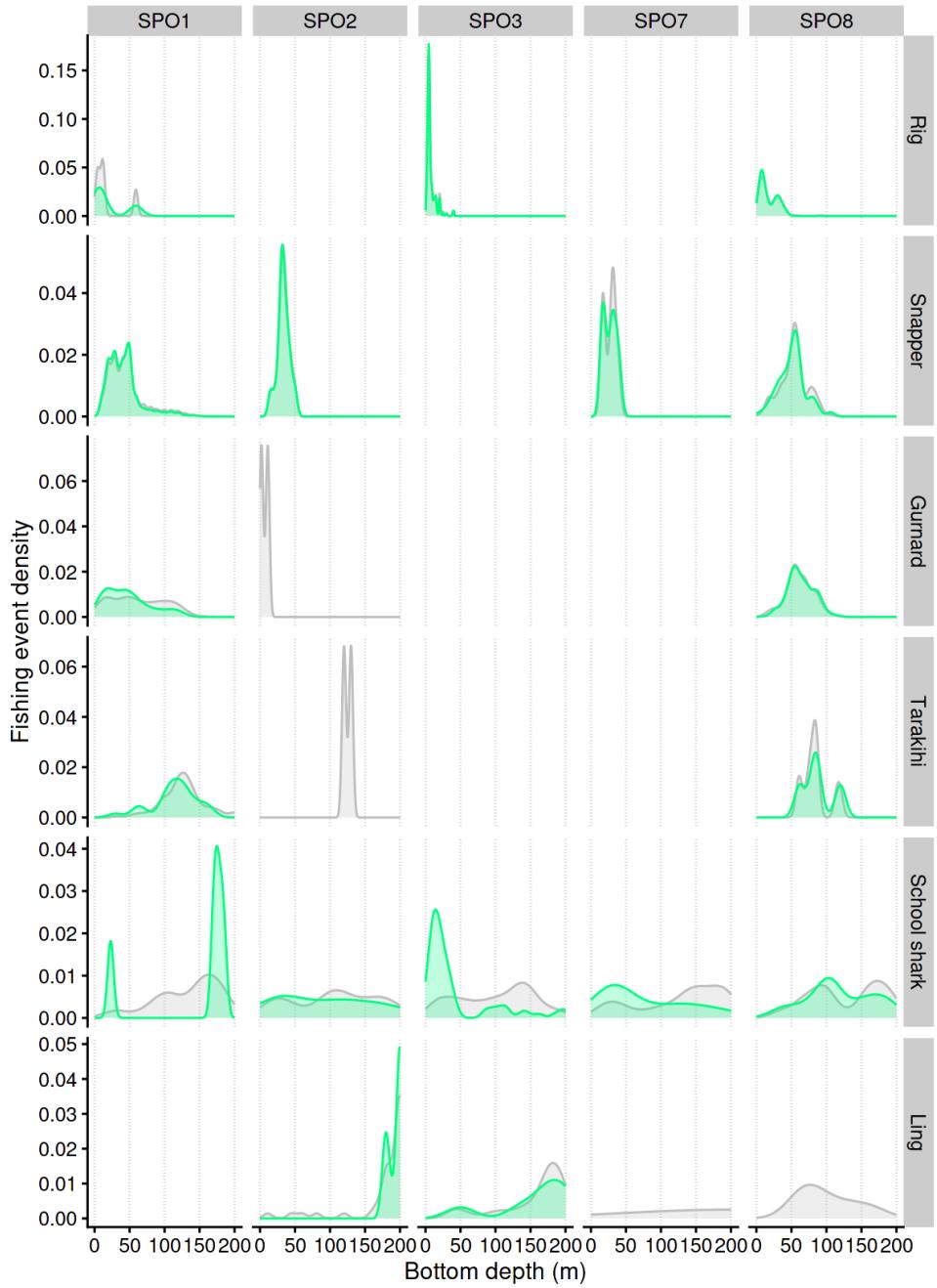


Figure 87: Effort depth distribution by target species for trips landing SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 from the bottom longline fishery. Target species are included if they are represented in at least 30 events. Grey fill = total effort, Green fill = positive effort (i.e., estimated catch > 0).

5. CATCH-PER-UNIT-EFFORT

5.1 Introduction

Nineteen fisheries (Table 3) were considered for CPUE analysis for inclusion as biomass index series in this update of rig fisheries off the North Island and South Island of New Zealand. These fisheries are primarily extensions of fisheries that have been previously defined and analysed in earlier versions of this national rig summary analysis (Starr & Kendrick 2016, 2017, 2020), particularly since previous versions of these series have been presented to and accepted by the Inshore Working Group as indices of abundance. Data preparation procedures and analysis methodology are presented in Section 3 and Appendix A. For the CPUE analyses of SN fisheries in SPO 1, estimated catches of rig were scaled to annual landings, by vessel. Following appendix H in Starr & Kendrick (2020), records where the annual scalar (i.e., total annual landings divided by total estimated catches, by species, vessel and fishing year) was outside the range [0.75, 2] were dropped from the CPUE dataset. Use of this range is attributed to Kendrick & Bentley (2012), who considered that it accommodated cases where the skipper was reporting either greenweight or processed weight as the estimated catch for an event.

A Delta (Hurdle) Generalised Linear modelling approach was used for all CPUE analyses (except for the four SN analyses in confined statistical Areas [007], [043], [044], and [038] where the frequency of sets with zero SPO catches was effectively nil), which combined a binomial model of presence/absence (occurrence) and a model of positive catches. Although several error distributions were available for the positive catch models, including lognormal, Weibull and gamma, each model continued to use the error distribution used in previous iterations of the same models (unless it was a model not previously used where the best distribution was selected). Trip-based models were used for the five bottom trawl series because of the large number of events which recorded no estimated catch, even though rig appeared in the landing data. This issue was caused by the Fisheries New Zealand requirement that, when using the daily CELR paper forms, only the top five species by weight needed to be recorded from an event, rendering event-based analyses useless in the long-term data set. Hurdle models were simulation tested and found to be generally unbiased as long as both the occurrence and positive catch components were included in the model (Langley 2019).

Diagnostic plots and tables, as well as plots and a table of the component models for each analysis, can be found for the 11 primary BT and SN analyses in separate chapters below. Eight supporting sensitivity analyses can be found in Appendix D - Additional CPUE analyses. Full diagnostics are presented for these latter analyses, but without supporting descriptive text.

Table 4 lists the full range of BT standardised CPUE analyses considered over the history of the four New Zealand national rig summary compilations, including those presented in this report and those which have been dropped.

Table 5 lists the full range of SN standardised CPUE analyses considered over the history of the four New Zealand national rig summary compilations, including those presented in this report and those which have been dropped.

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
SPO 1W BT trip	trip	landkg	Stepwise	4	5	lognormal
SPO 1W BT event	event	allockg	Stepwise	4	5	lognormal
SPO 2 BT trip	trip	landkg	Stepwise	8	10	lognormal
SPO 2 BT event	event	allockg	Stepwise	8	10	lognormal
SPO 3 BT trip East Coast	trip	landkg	Stepwise	8	10	lognormal
SPO 3 BT trip Foveaux St	trip	landkg	Stepwise	8	10	lognormal
SPO 3 BT trip	trip	landkg	Stepwise	8	10	lognormal
SPO 3 BT trip (positive trip criterion)	trip	landkg	Stepwise	8	10	lognormal
SPO 3 BT event	event	allockg	Stepwise	8	10	lognormal
SPO 7 BT trip	trip	landkg	Stepwise	10	5	lognormal
SPO 7 BT event	event	allockg	Stepwise	10	5	lognormal
SPO 1E(007) SN daily	daily	scaledkg	Stepwise	4	5	gamma
SPO 1W(043) SN daily	daily	scaledkg	Stepwise	4	5	gamma
SPO 1W(044) SN daily	daily	scaledkg	Stepwise	4	5	gamma
SPO 3 SN daily East Coast	daily	allockg	Stepwise	4	4	lognormal
SPO 3 SN daily Foveaux St	daily	allockg	Stepwise	4	4	lognormal
SPO 3 SN daily (soak time)	daily	allockg	Stepwise	5	5	lognormal
SPO 3 SN daily (fishing duration)	daily	allockg	Stepwise	5	5	lognormal
SPO 7 SN daily	daily	allockg	Stepwise	3	3	lognormal

Table 4: History of SPO bottom trawl (BT) CPUE standardisation analyses, showing the analysis years along with the statistical area and target species definitions. Standardised series that have been dropped are shaded in grey. Explanation of research ratings: 1=High Quality (accepted); 2=Medium or Mixed Quality (accepted with specified reservations); 3=Low Quality (rejected).

Model.name	Statistical.areas	Target.species	Assessment_years	Research_rating
SPO 1W BT trip	041,042,045,046,047	SNA,TRE,GUR,TAR	2011,2013,2016,2019,2022	1
SPO 1W BT event	041,042,045,046,047	SNA,TRE,GUR,TAR	2019,2022	2
SPO 2 BT trip	011,012,013,014,015	FLA,GUR,TAR	2009,2011,2013,2015,2016,2019,2022	1
SPO 2 BT event	011,012,013,014,015	FLA,GUR,TAR	2022	2
SPO 3 BT trip East Coast	018,020,022,024,026	FLA,BAR,STA,RCO,SPD,SPO,TAR	2022	1
SPO 3 BT trip Foveaux St	025,027,028,029,030,031,032	FLA,BAR,STA,RCO,SPD,SPO,TAR	2022	1
SPO 3 BT trip	018,020,022,024,025,026,027,028,029,030,031,032	FLA,BAR,STA,RCO,SPD,SPO,TAR	2016,2019,2022	1
SPO 3 BT trip (positive trip criterion)	018,020,022,024,025,026,027,028,029,030,031,032	FLA,BAR,STA,RCO,SPD,SPO,TAR	2022	1
SPO 3 BT event	018,020,022,024,025,026,027,028,029,030,031,032	FLA,BAR,STA,RCO,SPD,SPO,TAR	2019,2022	2
SPO 7 BT trip	016,017,018,032,033,034,035,036,037,038,039,040	FLA,RCO,SPO,BAR,TAR,GUR,TRE,SNA,WAR	2006,2010,2013,2015,2016,2019,2022	1
SPO 7 BT event	016,017,018,032,033,034,035,036,037,038,039,040	FLA,RCO,SPO,BAR,TAR,GUR,TRE,SNA,WAR	2019,2022	2
SPO 1 E BT	002-010	SNA,TRE,GUR,JDO,BAR,TAR	2011,2013,2016	3
SPO 3 BT (FLA)	018,020,022,024-032	FLA (all species)	2005,2007,2008,2011,2013	3
SPO 3 BT (MIX)	018,020,022,024-032	BAR,STA,RCO,SPD,TAR, ELE,GUR	2005,2007,2008,2011,2013	1
SPO 8 BT	039,040,041	SNA,TRE,GUR,TAR,BAR, JDO	2011,2013	3

Table 5: History of SPO set net (SN) CPUE standardisation analyses, showing the analysis years along with the statistical area and target species definitions. Standardised series that have been dropped are shaded in grey. Explanation of research ratings: 1=High Quality (accepted); 2=Medium or Mixed Quality (accepted with specified reservations); 3=Low Quality (rejected).

Model.name	Statistical.areas	Target.species	Assessment_years	Research_rating
SPO 1E(007) SN daily	007	SPO,SCH,SPD,NSD	2011,2013,2016,2019,2022	2
SPO 1W(043) SN daily	043	SPO,SCH,SPD,NSD	2011,2013,2016,2019,2022	2
SPO 1W(044) SN daily	044	SPO,SCH,SPD,NSD	2011,2013,2016,2019,2022	2
SPO 3 SN daily East Coast	018,020,022,024,026	SPO,SCH,SPD,ELE	2022	1
SPO 3 SN daily Foveaux St	025,027,028,029,030,031,032	SPO,SCH,SPD,ELE	2022	1
SPO 3 SN daily (soak time)	018,020,022,024,025,026,027,028,029,030,031,032	SPO,SCH,SPD,ELE	2022	1
SPO 3 SN daily (fishing duration)	018,020,022,024,025,026,027,028,029,030,031,032	SPO,SCH,SPD,ELE	2022	1
SPO 7 SN daily	038	SPO,SCH,SPD	2002,2004,2006,2010,2013,2015,2016,2019,2022	1
SPO 1E SN(coast)	002-006,008-010	SPO,SCH,SPD,NSD	2011,2013,2016	3
SPO 1W SN(041-047)	041,042,045,046,047	SPO,SCH,SPD,NSD	2011,2013,2016	3
SPO 2 SN	011-016	Not restricted	2009,2011,2013	3
SPO 7 SN (WC)	032-037	SPO,SCH,SPD,NSD	2002,2004,2006,2010,2013	3
SPO 7 SN (STB)	037,039,040	SPO,SCH,SPD,NSD	2016	3
SPO 8 SN	039,040,041	SPO,SCH,SPD,NSD	2011,2013	3

5.2 SPO 1W BT trip

This series was based on the trip bycatch of rig from the west coast North Island BT mixed target species fishery. The analysis included five west coast North Island statistical areas, stretching from the top of North Taranaki Bight to North Cape: Statistical Areas 041 (North Taranaki Bight), 042 (Kawhia), 045 (Manukau), 046 (Kaipara), 047 (Ninety Mile Beach) (Table 6). The target species suite included snapper (SNA), trevally (TRE), tarakihi (TAR), and red gurnard (GUR). The core fleet was defined by having fished at least five trips in each of four years, retaining 94% of the catch and reducing the fleet from over 100 vessels to 49 vessels (Figure 88). The pattern of vessel participation in this fishery was characterised by a lack of continuity in this fishery, with many vessels entering and exiting the fishery over the 32 years in the analysis (Figure 89). Only two vessels were present in the fishery for more than 20 years (Figure 89). The final groomed dataset represented 19% (1991) to 68% (2014) of the annual ungroomed catch (Table 7). The total annual bycatch of rig in the defined fishery ranged from 19 t (in 1991) to 68 t (in 2014) over the 32 years in the data set and was characterised by a high incidence of rig in the trip landings, ranging from 71% (in 1997) to 94% (in 2021) (Table 8).

The binomial (occurrence) model accepted three predictive variables after fishing year (vessel, total_effort_num and month), with the model explaining 23% of the deviance (Table 9). Both the unstandardised and standardised series showed a gradually increasing trend from early 1990s to 2021, with not much overall standisation effect (Figure 90). Even though three covariates entered the model, none changed the overall trend very much from the original unstandardised series (Figure 91). Although the vessel coefficient-distribution-influence (CDI; Bentley et al. 2012) plot indicates that there was considerable contrast in the covariate over time (Figure 92), the effect of this covariate when added to the model appeared to be small (Figure 91). Similarly, the total_effort_num covariate showed a strong corrective pattern (Figure 93), but the effect of this covariate when added to the model appeared to be small (Figure 91). Finally, the month covariate entered the occurrence model with almost no standardisation effect from this variable (Figure 94, see Figure 91).

The lognormal model accepted four predictive variables after fishing year (vessel, total_fishing_duration, month and statistical area), with the total model explaining 57% of the deviance (Table 10). Residuals to the lognormal model showed some slight skewness in the distribution residuals, but overall there was reasonable conformity to the lognormal assumption over most of the distribution, even in the tails (Figure 95). Both the gamma and the Weibull distributions showed lesser fits to the positive catch data compared to the lognormal model (Figure 96). While the unstandardised series showed a variable but increasing overall trend, the effect of standardisation was to flatten out some of the variation and to remove most of the trend (Figure 97). Most of the standardisation effect came with the addition of the vessel covariate, which removed the strong rise in the final two years of the series (Figure 98). This impact is likely due to the addition of two new vessels into the fishery which had extremely high, but uncertain, catch rate coefficients (Figure 99). The other three covariates (total_fishing_duration: Figure 100; month: Figure 101; statistical area: Figure 102) resulted in almost no standardisation effect (see Figure 98). Implied residual plots of rig annual CPUE showed reasonable conformity with the overall annual CPUE trend across three of the four target species, with reduced correlation for TAR (Figure 103). The conformity with the overall annual CPUE trend was good for three southern statistical areas, but showed some divergence from the overall series trend for the two northernmost areas (Statistical Areas 046 and 047; Figure 104) which had a reduced amount data in the analysis.

The combined model followed the variable but somewhat increasing trend in the lognormal model with little impact from the slowly increasing trend in the binomial model (Figure 105, Figure 106, Table 11). A comparison of this series with the equivalent series calculated in 2019 (Starr & Kendrick 2020) shows that this series is a close match to the previous series for the overlapping years (Figure 279).

Table 6: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 1W BT trip CPUE series.

Series	SPO 1W BT trip
QMS stock	SPO1
Reporting forms	CEL, ERS - Trawl, TCE, TCP
Fishing methods	BT
Target species	SNA, TRE, GUR, TAR
Statistical Areas	041, 042, 045, 046, 047
Period	1989-10-01, 2021-09-30
Resolution	Trip
Core fleet years	4
Core fleet trips	5
Default model	<code>landkg ~ fyear + vessel_key + modal_stat_area + modal_month + target_species + ns(log(total_fishing_duration), 3) + bs(log(total_effort_num), 3)</code>
Stepwise selection	Yes
Positive catch distribution	Lognormal

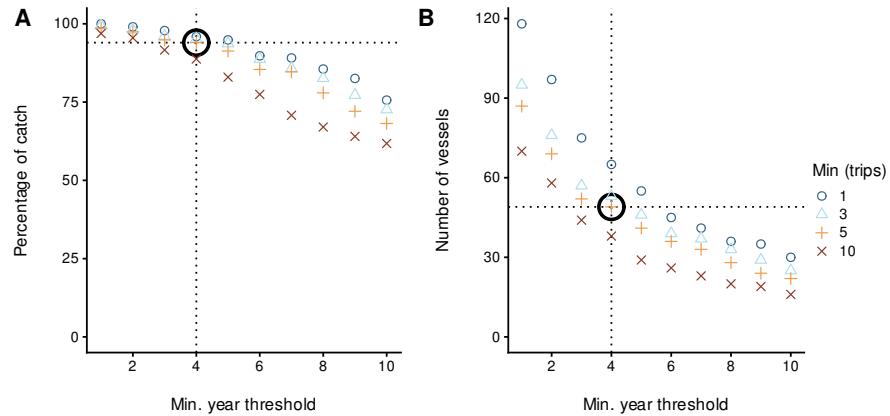


Figure 88: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 1W BT trip CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

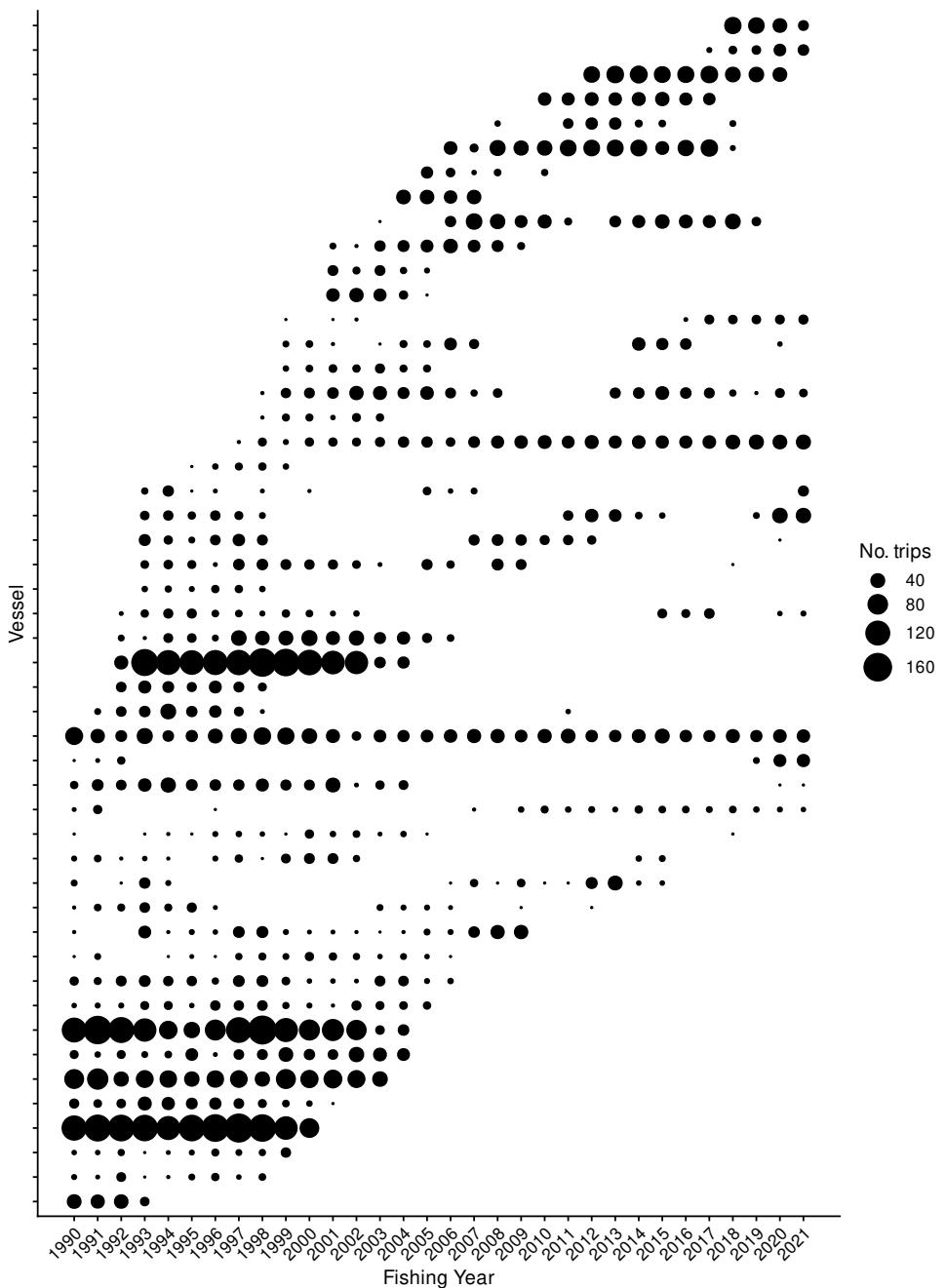


Figure 89: Number of trips by fishing year for core vessels. The area of the circles is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 7: Summary of the SPO 1W BT trip 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	37 (100%) n: 672	27 (100%) n: 768	28 (100%) n: 655	63 (100%) n: 837	54 (100%) n: 725	47 (100%) n: 630	51 (100%) n: 723	53 (100%) n: 892	58 (100%) n: 924
Positive fishing duration	37 (100%) n: 671	27 (100%) n: 761	28 (100%) n: 653	63 (100%) n: 837	54 (100%) n: 723	47 (100%) n: 627	51 (100%) n: 719	53 (100%) n: 889	57 (100%) n: 915
Trim extreme effort num	37 (100%) n: 670	27 (100%) n: 760	27 (95%) n: 650	60 (100%) n: 833	53 (100%) n: 720	47 (100%) n: 625	50 (100%) n: 717	49 (93%) n: 886	55 (100%) n: 912
Trim extreme duration	37 (100%) n: 670	27 (100%) n: 760	27 (95%) n: 650	60 (100%) n: 833	53 (100%) n: 720	47 (100%) n: 625	50 (100%) n: 717	49 (93%) n: 886	55 (100%) n: 912
Core fleet selection	28 (76%) n: 505	19 (70%) n: 571	24 (86%) n: 575	57 (90%) n: 822	51 (95%) n: 692	46 (100%) n: 617	47 (92%) n: 699	47 (89%) n: 859	46 (79%) n: 875
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	60 (100%) n: 876	52 (100%) n: 675	58 (100%) n: 632	47 (100%) n: 567	56 (100%) n: 405	40 (100%) n: 380	37 (100%) n: 305	28 (100%) n: 318	32 (100%) n: 322
Positive fishing duration	60 (100%) n: 866	52 (100%) n: 673	58 (100%) n: 632	47 (100%) n: 567	56 (100%) n: 405	40 (100%) n: 380	37 (100%) n: 305	28 (100%) n: 318	32 (100%) n: 322
Trim extreme effort num	59 (100%) n: 862	52 (100%) n: 672	55 (100%) n: 631	47 (100%) n: 567	56 (100%) n: 405	40 (100%) n: 380	37 (100%) n: 305	28 (100%) n: 317	32 (100%) n: 322
Trim extreme duration	59 (100%) n: 862	52 (100%) n: 672	55 (100%) n: 631	47 (100%) n: 567	56 (100%) n: 405	40 (100%) n: 380	37 (100%) n: 305	28 (100%) n: 317	32 (100%) n: 322
Core fleet selection	50 (83%) n: 753	50 (100%) n: 635	51 (89%) n: 579	44 (92%) n: 535	55 (100%) n: 388	38 (100%) n: 355	34 (92%) n: 284	24 (85%) n: 275	25 (79%) n: 282

Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	34 (100%) n: 306	32 (100%) n: 261	28 (100%) n: 268	35 (100%) n: 270	63 (100%) n: 340	56 (100%) n: 378	68 (100%) n: 353	66 (100%) n: 368	52 (100%) n: 305
Positive fishing duration	34 (100%) n: 306	32 (100%) n: 261	28 (100%) n: 268	35 (100%) n: 270	63 (100%) n: 340	56 (100%) n: 378	68 (100%) n: 353	66 (100%) n: 368	52 (100%) n: 305
Trim extreme effort num	34 (100%) n: 306	32 (100%) n: 261	28 (100%) n: 267	35 (100%) n: 269	63 (100%) n: 340	56 (100%) n: 378	68 (100%) n: 353	66 (100%) n: 368	52 (100%) n: 305
Trim extreme duration	34 (100%) n: 306	32 (100%) n: 261	28 (100%) n: 267	35 (100%) n: 269	63 (100%) n: 340	56 (100%) n: 378	68 (100%) n: 353	66 (100%) n: 368	52 (100%) n: 304
Core fleet selection	33 (100%) n: 297	30 (100%) n: 239	26 (93%) n: 216	35 (100%) n: 225	60 (100%) n: 303	55 (100%) n: 343	68 (100%) n: 339	65 (100%) n: 343	51 (100%) n: 294

Filter	2017	2018	2019	2020	2021
Ungroomed data	42 (100%) n: 298	49 (100%) n: 277	41 (100%) n: 232	48 (100%) n: 303	56 (100%) n: 301
Positive fishing duration	42 (100%) n: 298	49 (100%) n: 277	41 (100%) n: 232	48 (100%) n: 303	56 (100%) n: 301
Trim extreme effort num	42 (100%) n: 298	49 (100%) n: 277	41 (100%) n: 232	48 (100%) n: 303	56 (100%) n: 301
Trim extreme duration	42 (100%) n: 298	49 (100%) n: 277	41 (100%) n: 232	48 (100%) n: 303	56 (100%) n: 301
Core fleet selection	41 (100%) n: 295	49 (100%) n: 277	40 (100%) n: 228	47 (100%) n: 298	54 (100%) n: 250

Table 8: Summary of the SPO 1W BT trip dataset after core fleet selection. Trips caught represents the percentage of trips with rig catch.

Fishing year	Vessels	Trips	Events	Hrs	Catch (t)	Trips caught
1990	20	505	2 534	7 089.35	28.18	78.02
1991	18	571	3 148	8 252.92	18.97	71.63
1992	21	575	3 788	10 609.45	24.24	75.30
1993	27	822	7 095	19 500.02	56.65	82.60
1994	27	692	6 206	16 740.32	51.19	81.65
1995	26	617	5 109	14 635.75	46.13	85.41
1996	28	699	4 751	15 733.57	46.57	80.40
1997	26	859	5 516	18 436.73	46.68	70.55
1998	29	875	6 058	18 334.65	45.70	79.89
1999	25	753	5 554	17 508.60	50.28	76.36
2000	23	635	5 287	18 909.93	50.26	88.50
2001	25	579	4 895	17 378.33	51.34	83.94
2002	23	535	4 062	15 311.25	43.54	80.56
2003	23	388	3 961	15 447.22	54.84	88.92
2004	20	355	4 185	15 535.62	37.89	89.01
2005	19	284	3 502	13 295.43	34.28	88.73
2006	17	275	2 785	10 388.17	23.56	77.82
2007	14	282	2 899	10 073.03	24.93	84.40
2008	12	297	3 366	11 895.30	33.36	79.46
2009	11	239	2 956	10 798.83	30.48	90.79
2010	9	216	2 503	8 001.77	26.03	89.81
2011	11	225	2 446	7 967.28	34.80	93.78
2012	11	303	3 474	11 821.20	60.49	93.07
2013	11	343	3 665	12 064.90	55.26	87.17
2014	13	339	3 424	11 769.47	67.79	92.04
2015	14	343	3 531	12 254.22	64.54	93.59
2016	11	294	3 165	10 740.18	51.23	91.84
2017	11	295	3 131	11 134.10	41.48	88.81
2018	13	277	2 756	8 859.82	49.28	89.89
2019	11	228	2 248	7 552.68	40.11	91.23
2020	14	298	3 014	10 814.09	47.33	87.92
2021	12	250	2 732	10 329.80	54.28	94.40

Table 9: 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	30.00	12 509	3.60	3.60	*
+ vessel_key	48.00	11 187	14.60	11.00	*
+ bs(log(total_effort_num), 3)	3.00	10 315	21.40	6.80	*
+ modal_month	11.00	10 106	23.20	1.80	*
+ ns(log(total_fishing_duration), 3)	3.00	10 064	23.50	0.40	
+ modal_stat_area	4.00	10 035	23.80	0.30	
+ target_species	3.00	10 027	23.90	0.10	

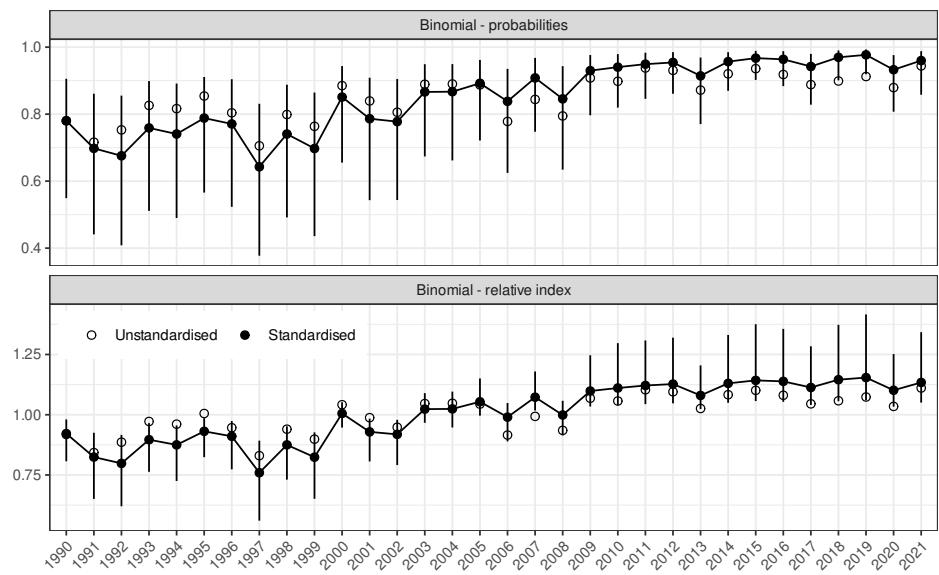


Figure 90: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 1W BT trip dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

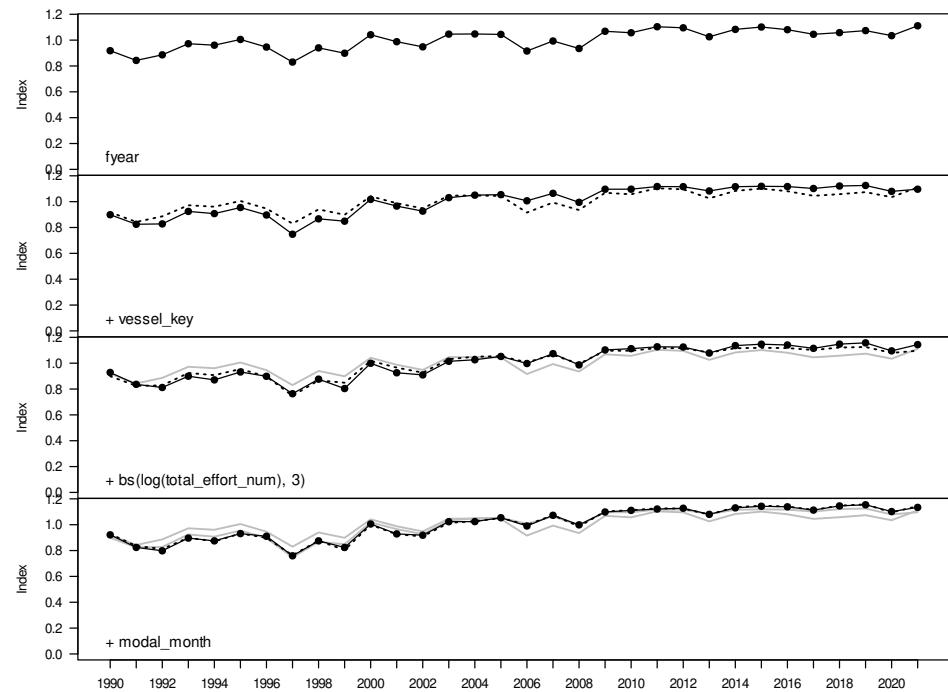


Figure 91: Step plot for occurrence of catch in the SPO 1W BT trip dataset.

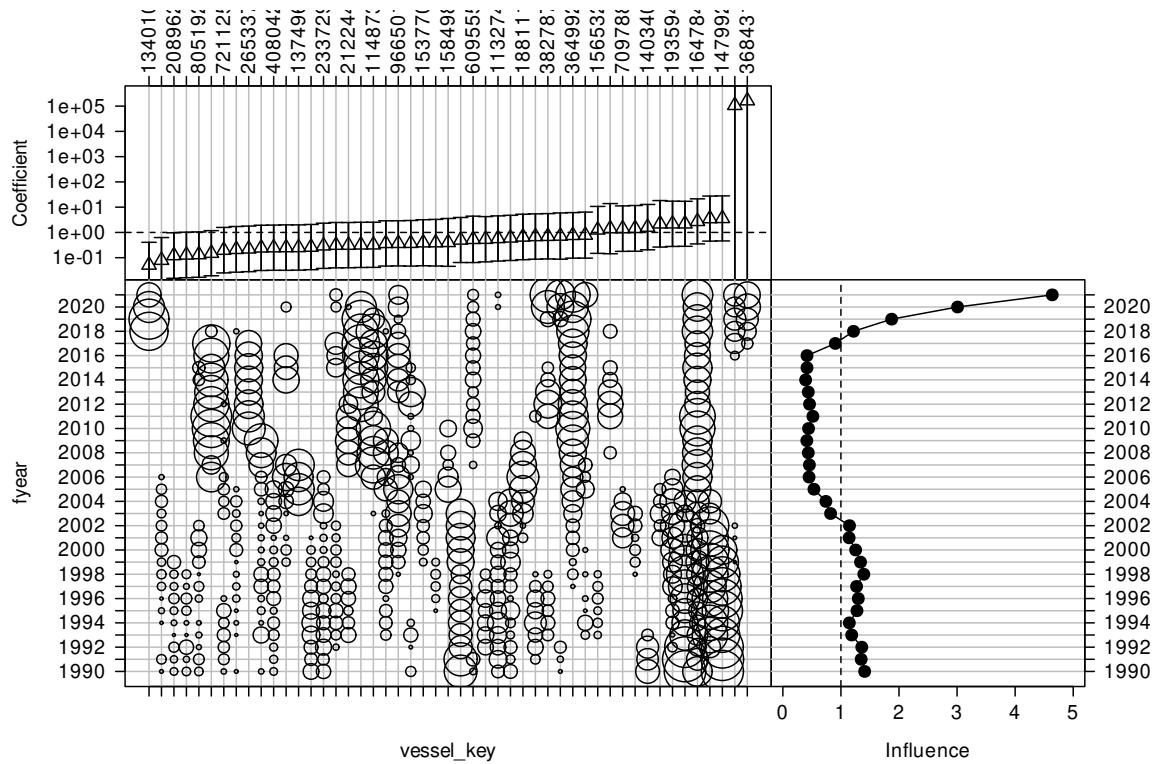


Figure 92: CDI plot for vessel key for the occurrence of positive catch SPO 1W BT trip catch-per-unit-effort dataset.

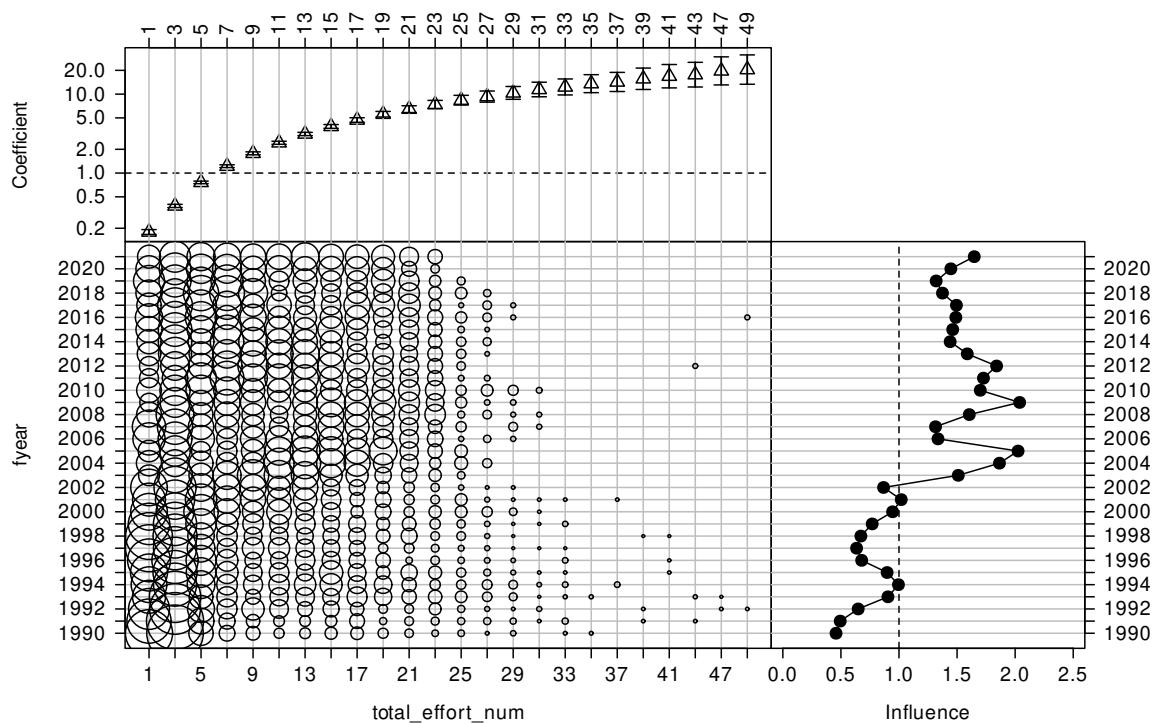


Figure 93: CDI plot for total effort num for the occurrence of positive catch SPO 1W BT trip catch-per-unit-effort dataset.

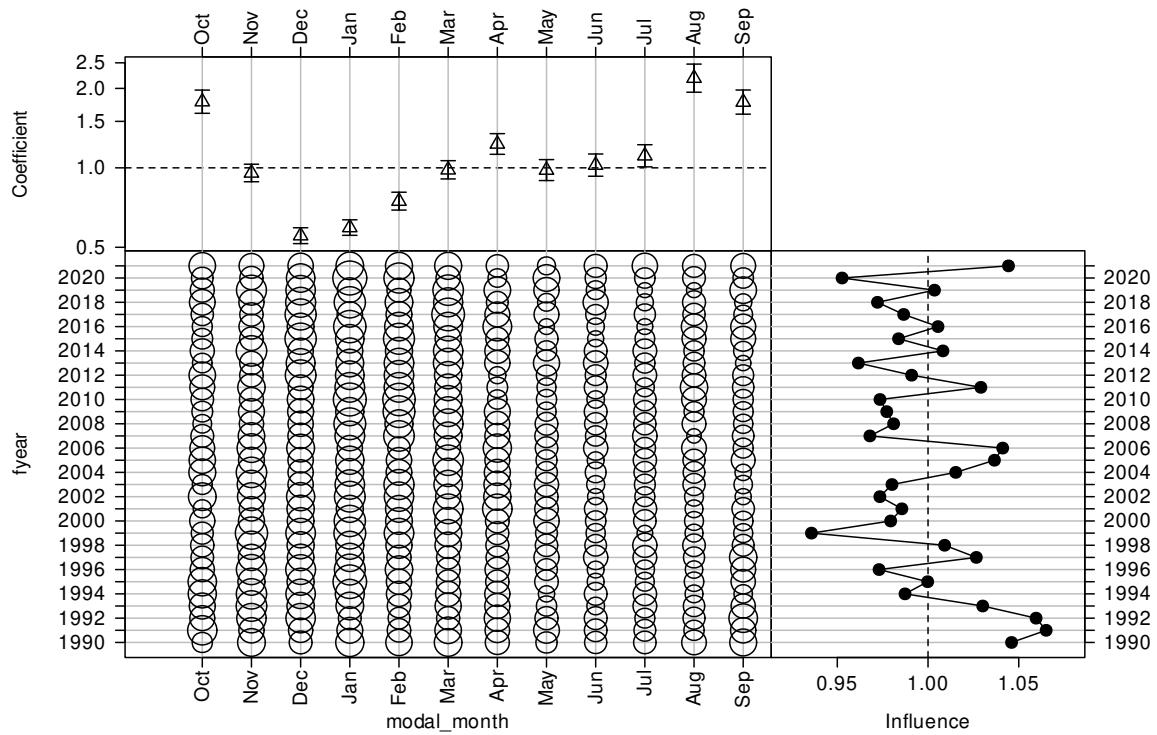


Figure 94: CDI plot for modal month for the occurrence of positive catch SPO 1W BT trip catch-per-unit-effort dataset.

Table 10: 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	30	43 860	5.7	5.7	*
+ vessel key	48	37 713	44.3	38.6	*
+ ns(log(total fishing duration), 3)	3	35 806	52.6	8.3	*
+ modal month	11	34 930	56.1	3.5	*
+ modal stat area	4	34 653	57.1	1.0	*
+ bs(log(total effort num), 3)	3	34 530	57.6	0.5	
+ target species	3	34 483	57.8	0.2	

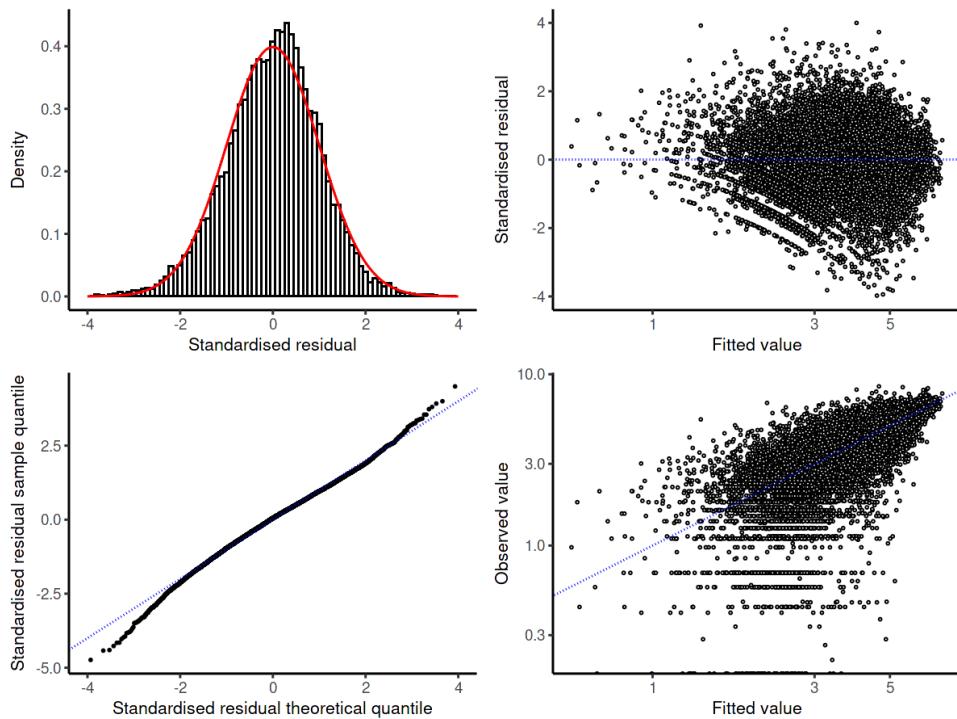


Figure 95: Diagnostic plots for the lognormal model for the SPO 1W BT trip dataset.

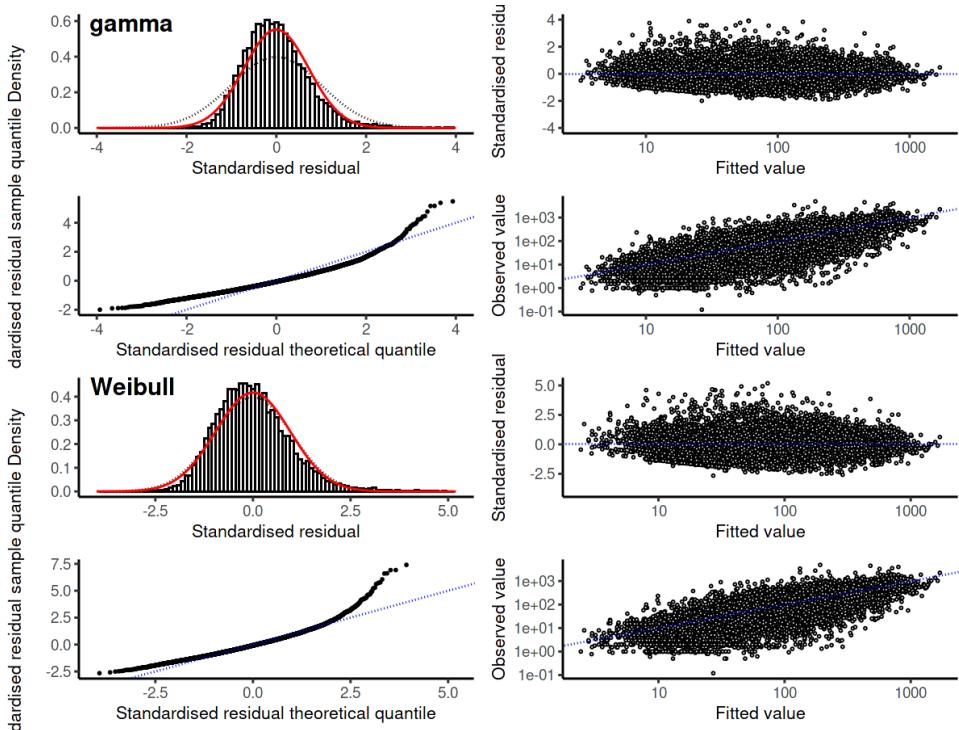


Figure 96: Diagnostic plots for the gamma and Weibull model for the SPO 1W BT trip dataset.

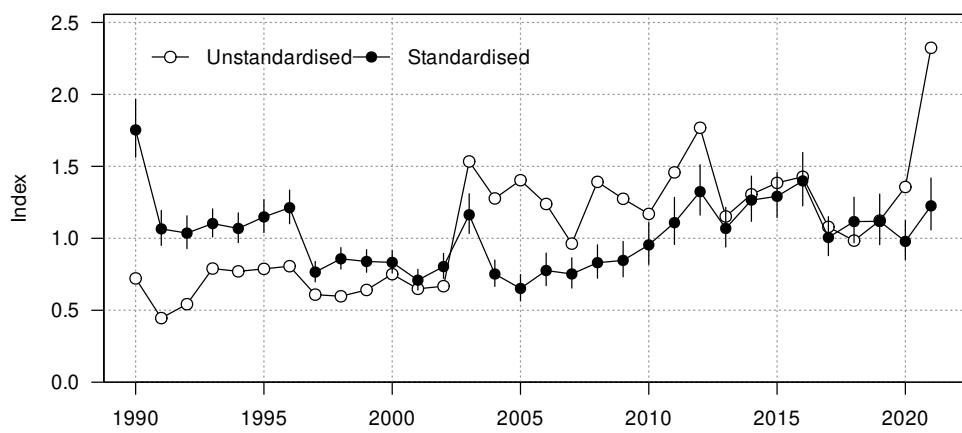


Figure 97: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 1W BT trip dataset.

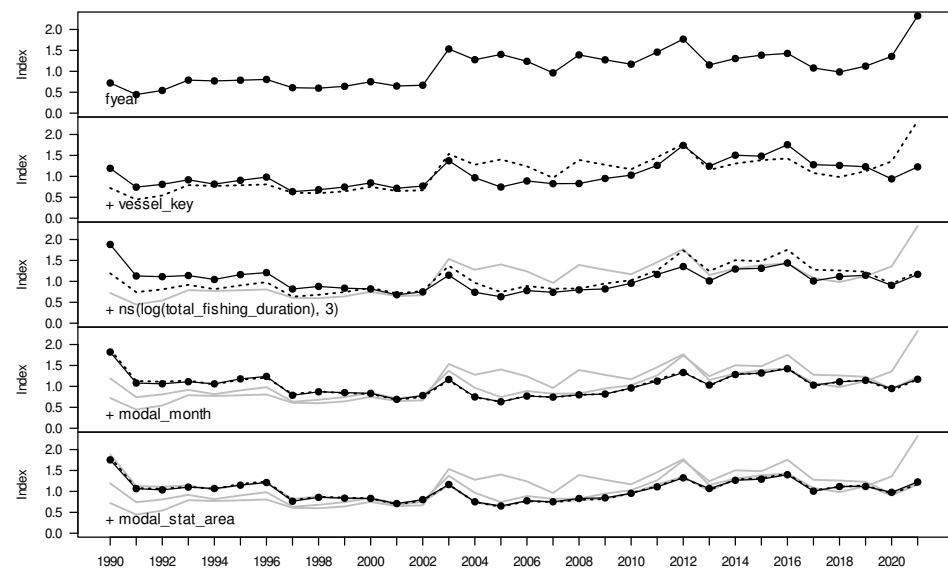


Figure 98: Changes to the SPO 1W BT trip positive catch index as terms are successively entered into the model.

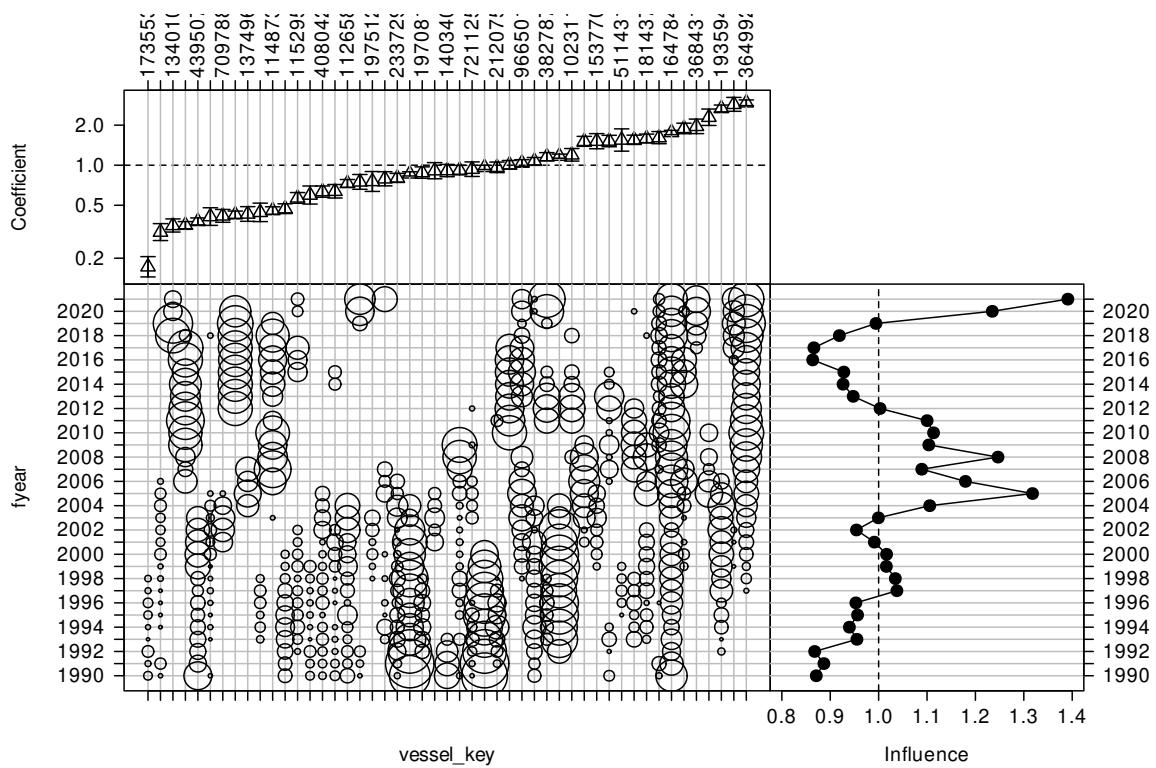


Figure 99: CDI plot for vessel key for the positive catch SPO 1W BT trip catch-per-unit-effort dataset.

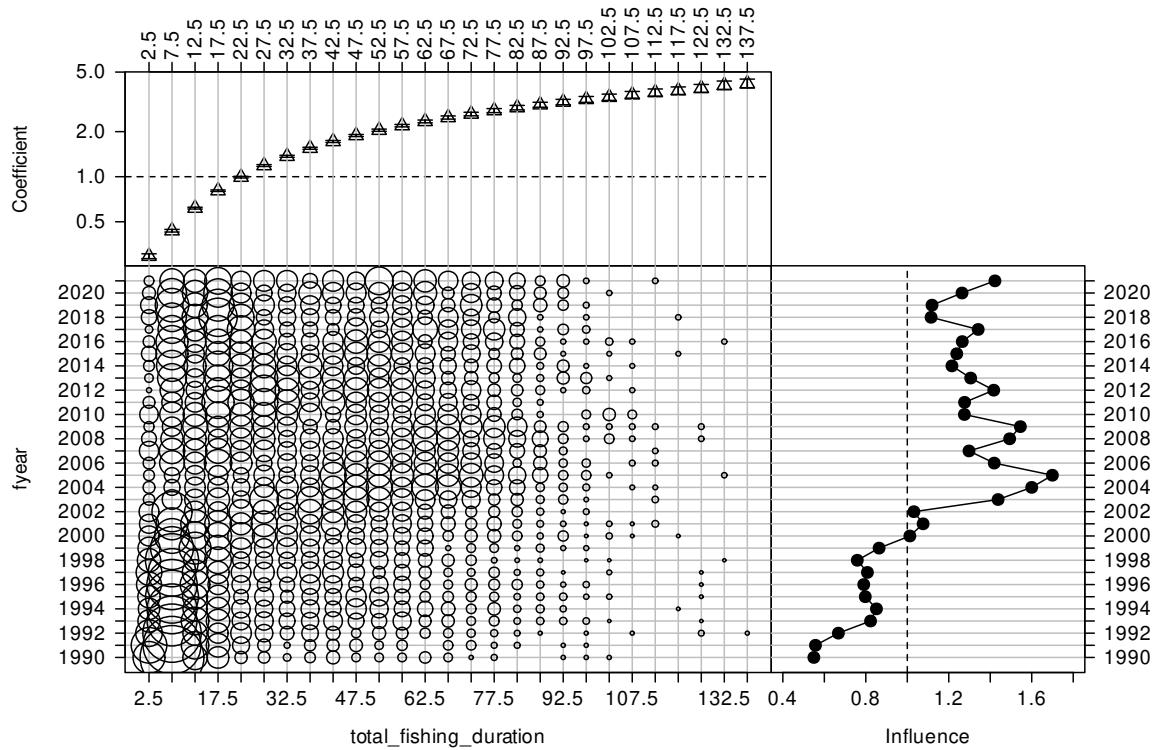


Figure 100: CDI plot for total fishing duration (h) for the positive catch SPO 1W BT trip catch-per-unit-effort dataset.

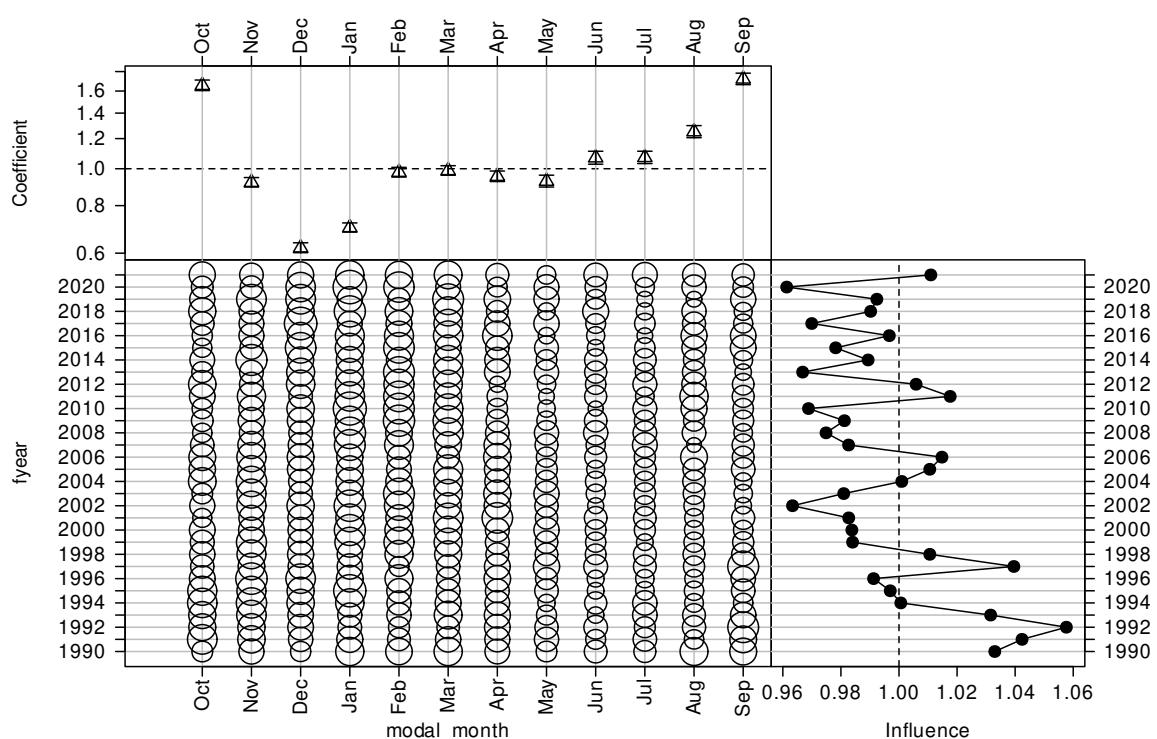


Figure 101: CDI plot for modal month for the positive catch SPO 1W BT trip catch-per-unit-effort dataset.

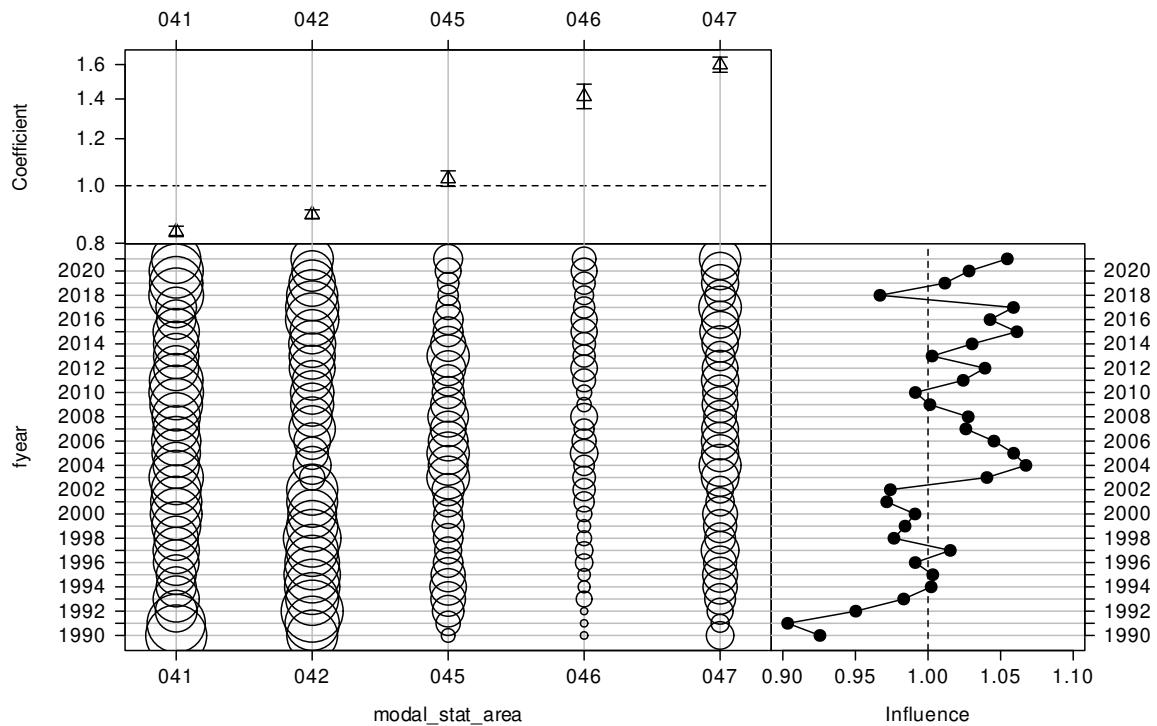


Figure 102: CDI plot for modal statistical area for the positive catch SPO 1W BT trip catch-per-unit-effort dataset.

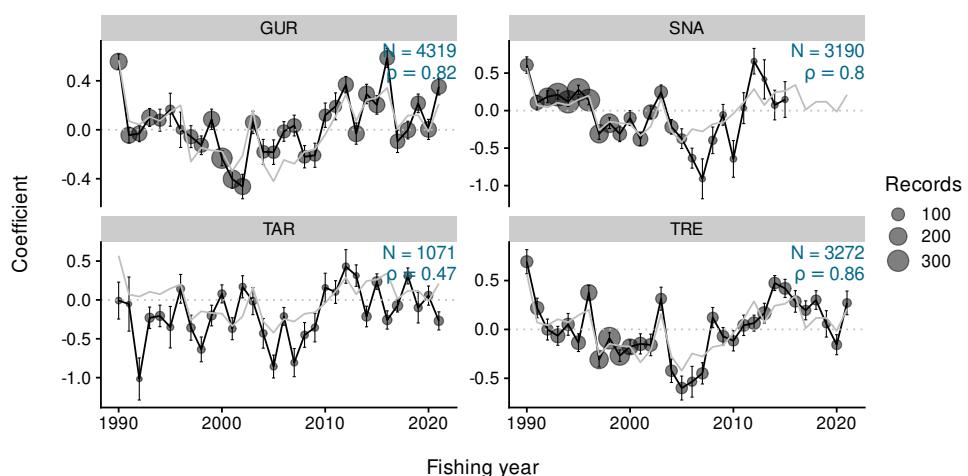


Figure 103: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 1W BT trip dataset.

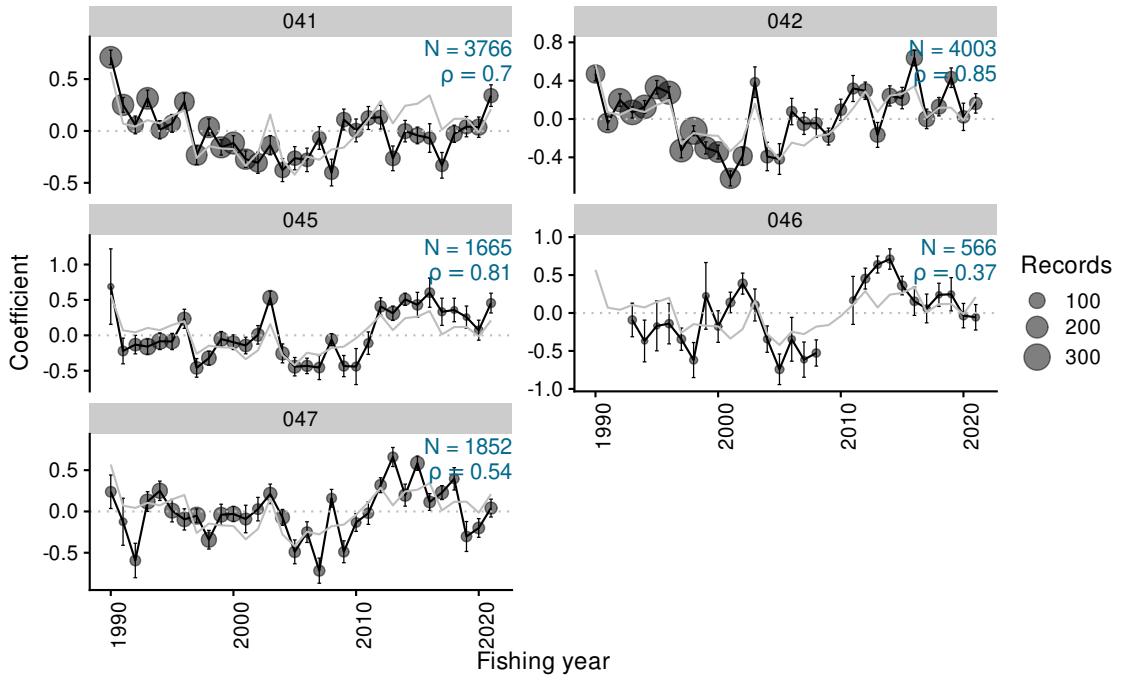


Figure 104: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 1W BT trip dataset.

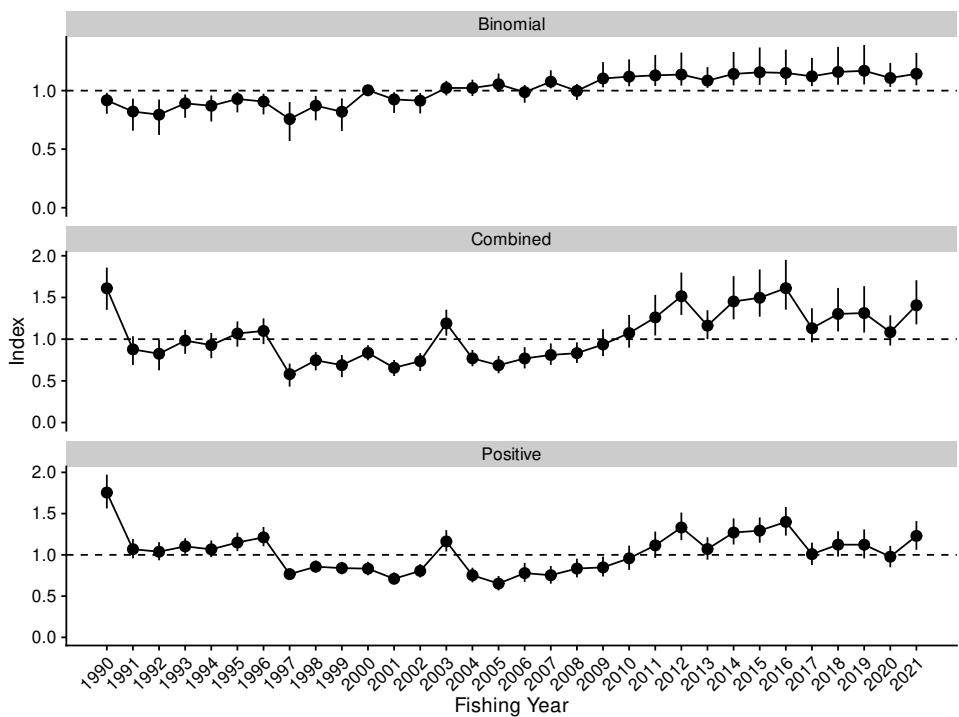


Figure 105: Standardised indices and 95% confidence intervals for the SPO 1W BT trip dataset.



Figure 106: Standardised indices for the SPO 1W BT trip dataset.

Table 11: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 1W BT trip.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.917	0.046	0.803	0.981	1.610	0.129	1.352	1.858	1.755	0.104	1.563	1.972
1991	0.821	0.070	0.658	0.932	0.878	0.088	0.690	1.035	1.069	0.059	0.958	1.191
1992	0.795	0.077	0.621	0.924	0.825	0.093	0.626	0.992	1.038	0.056	0.934	1.153
1993	0.891	0.051	0.768	0.967	0.983	0.073	0.823	1.111	1.103	0.048	1.013	1.200
1994	0.871	0.057	0.736	0.959	0.929	0.077	0.772	1.075	1.067	0.052	0.972	1.175
1995	0.929	0.044	0.814	0.988	1.068	0.077	0.911	1.213	1.150	0.057	1.046	1.269
1996	0.907	0.045	0.797	0.974	1.099	0.079	0.941	1.249	1.212	0.060	1.104	1.338
1997	0.757	0.085	0.570	0.903	0.580	0.070	0.431	0.707	0.766	0.035	0.698	0.837
1998	0.872	0.053	0.746	0.955	0.747	0.056	0.626	0.844	0.856	0.037	0.788	0.931
1999	0.820	0.071	0.655	0.934	0.688	0.067	0.545	0.809	0.840	0.039	0.764	0.916
2000	1.004	0.025	0.952	1.049	0.836	0.046	0.747	0.928	0.833	0.042	0.753	0.916
2001	0.925	0.045	0.809	0.986	0.657	0.049	0.558	0.750	0.710	0.037	0.643	0.788
2002	0.914	0.045	0.805	0.979	0.736	0.055	0.618	0.832	0.806	0.041	0.727	0.888
2003	1.023	0.032	0.959	1.084	1.190	0.080	1.042	1.354	1.163	0.066	1.041	1.300
2004	1.023	0.036	0.954	1.093	0.770	0.050	0.674	0.871	0.753	0.045	0.666	0.844
2005	1.054	0.040	0.988	1.146	0.687	0.053	0.592	0.798	0.652	0.045	0.569	0.744
2006	0.987	0.039	0.897	1.048	0.769	0.065	0.649	0.904	0.779	0.059	0.673	0.903
2007	1.076	0.039	1.020	1.174	0.811	0.066	0.691	0.949	0.753	0.054	0.651	0.864
2008	0.998	0.034	0.921	1.056	0.832	0.063	0.714	0.961	0.834	0.058	0.727	0.953
2009	1.104	0.055	1.028	1.243	0.936	0.083	0.796	1.120	0.848	0.062	0.738	0.980
2010	1.120	0.059	1.037	1.267	1.073	0.100	0.898	1.291	0.958	0.075	0.819	1.111
2011	1.130	0.068	1.040	1.305	1.261	0.124	1.044	1.531	1.115	0.082	0.962	1.282
2012	1.137	0.072	1.043	1.325	1.515	0.130	1.290	1.799	1.332	0.086	1.177	1.513
2013	1.086	0.045	1.023	1.201	1.162	0.088	1.001	1.347	1.071	0.069	0.942	1.213
2014	1.143	0.073	1.045	1.330	1.452	0.132	1.238	1.756	1.271	0.081	1.126	1.442
2015	1.157	0.081	1.049	1.368	1.496	0.144	1.270	1.836	1.294	0.078	1.147	1.453
2016	1.151	0.077	1.047	1.350	1.611	0.152	1.354	1.951	1.400	0.089	1.234	1.581
2017	1.122	0.062	1.039	1.280	1.132	0.104	0.961	1.371	1.008	0.069	0.878	1.149
2018	1.159	0.083	1.050	1.374	1.303	0.133	1.092	1.614	1.124	0.078	0.979	1.286
2019	1.170	0.086	1.053	1.389	1.313	0.142	1.080	1.635	1.123	0.090	0.957	1.308
2020	1.108	0.052	1.032	1.237	1.084	0.092	0.924	1.286	0.978	0.066	0.850	1.109
2021	1.144	0.071	1.046	1.323	1.407	0.135	1.177	1.707	1.230	0.089	1.061	1.409

5.3 SPO 2 BT trip

This series was based on the trip bycatch of rig from the east coast North Island BT mixed target species fishery. The analysis included five east coast North Island statistical areas, stretching from Cape Runaway to Cape Palliser: Statistical Areas 011 (East Cape), 012 (Mahia), 013 (Hawke's Bay), 014 (Wairarapa), 015 (Cape Palliser) (Table 12). The target species suite included generic flatfish (FLA), tarakihi (TAR), and red gurnard (GUR). The core fleet was defined by having fished at least ten trips in each of eight years, retaining 72% of the catch and reducing the fleet from over 150 vessels to 41 vessels (Figure 107). The pattern of vessel participation in this fishery was characterised by a mix of continuity, with some vessels entering and exiting the fishery over the 32 years in the analysis while there were a considerable number of vessels that remained the fishery for 20 years or more (Figure 108). The final groomed dataset represented 50% (1990, 1993) to 85% (2005, 2014, 2016) of the annual ungroomed catch (Table 13). The total annual bycatch of rig in the defined fishery ranged from 12.5 t (in 1991) to 78 t (in 2014) over the 32 years in the data set and was characterised by an increasing occurrence of rig in the trip landings, ranging from 39% (in 1991) to 87% (in 2020 and 2021) (Table 14).

The binomial (occurrence) model accepted two predictive variables after fishing year (vessel, total_fishing_duration), with the model explaining 37% of the deviance (Table 15). Both the unstandardised and standardised series showed a gradually increasing trend from early 1990s to 2021, with the last two fishing years (2020 and 2021) lifted by the standardisation analysis (Figure 109). The overall trend did not change very much from the unstandardised series, with most of the change occurring in 2020 and 2021 with the addition of the total_fishing_duration covariate (Figure 110). Although the vessel CDI plot indicated that there was contrast in this covariate over time (Figure 111), the effect of this covariate when added to the model appeared to be relatively small (Figure 110). While the total_fishing_duration covariate showed a less strong corrective pattern compared to the vessel covariate (Figure 112), the effect of this covariate when added to the model was to raise the year indices for 2020 and 2021 (Figure 110).

The lognormal model accepted four predictive variables after fishing year (total_fishing_duration, vessel, target species and month), with the total model explaining 51% of the deviance (Table 16). The lognormal model showed some slight skewness in the residual distribution, but overall there was good conformity to the lognormal assumption over all of the distribution, even in the tails (Figure 113). Both the gamma and the Weibull distributions showed reasonable fits to the positive catch data but neither was better than seen for the lognormal model (Figure 114). The unstandardised and the standardised series showed a variable but increasing overall trend, with the standardised series having a slightly less steep trend overall (Figure 115, Figure 116). The standardisation effect came with the addition of the total_fishing_duration covariate, which reduced the steepness of the increasing trend (Figure 117), followed by the vessel covariate, which further reduced the steepness of the increasing trend (Figure 118, see Figure 116). The other two covariates (target species: Figure 119; month: Figure 120) resulted in almost no standardisation effect (see Figure 116). Implied residual plots of rig annual CPUE showed good conformity with the overall annual CPUE trend across all three target species (FLA, TAR, GUR) (Figure 121). The conformity with the overall annual CPUE trend was reasonable for the four statistical areas with data (Statistical Areas 011, 012, 013 and 014), but was dominated by Statistical Area 013 where most of the data reside (Figure 122).

All three models (lognormal, binomial and combined) follow similar trajectories up to 2009, after which the combined model tracks the lognormal model (to 2017) because the binomial model is without trend at the mean (about 1.0) of the series over the period 2010 to 2017 (Figure 123, Figure 124, Table 17). Both the binomial and lognormal models increase after 2017, resulting in the combined model increasing at an even greater rate due to the multiplicative nature of the delta-lognormal function. A comparison of this series with the equivalent series calculated in 2019 (Starr & Kendrick 2020) shows that this series matches that series closely in the overlapping years, but that the strong increase seen in this series had not begun three years ago (see Figure 280).

Table 12: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 2 BT trip CPUE series.

Series	SPO 2 BT trip
QMS stock	SPO2
Reporting forms	CEL, ERS - Trawl, TCE, TCP
Fishing methods	BT
Target species	FLA, GUR, TAR
Statistical Areas	011, 012, 013, 014, 015
Period	1989-10-01, 2021-09-30
Resolution	Trip
Core fleet years	8
Core fleet trips	10
Default model	$\text{landkg} \sim \text{fyear} + \text{vessel_key} + \text{modal_stat_area} + \text{modal_month} + \text{target_species} + \text{ns}(\log(\text{total_fishing_duration}), 3) + \text{bs}(\log(\text{total_effort_num}), 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

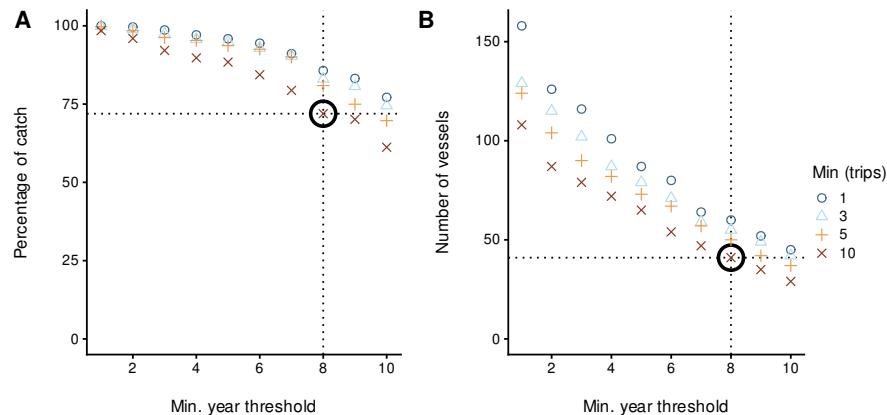


Figure 107: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 2 BT trip CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

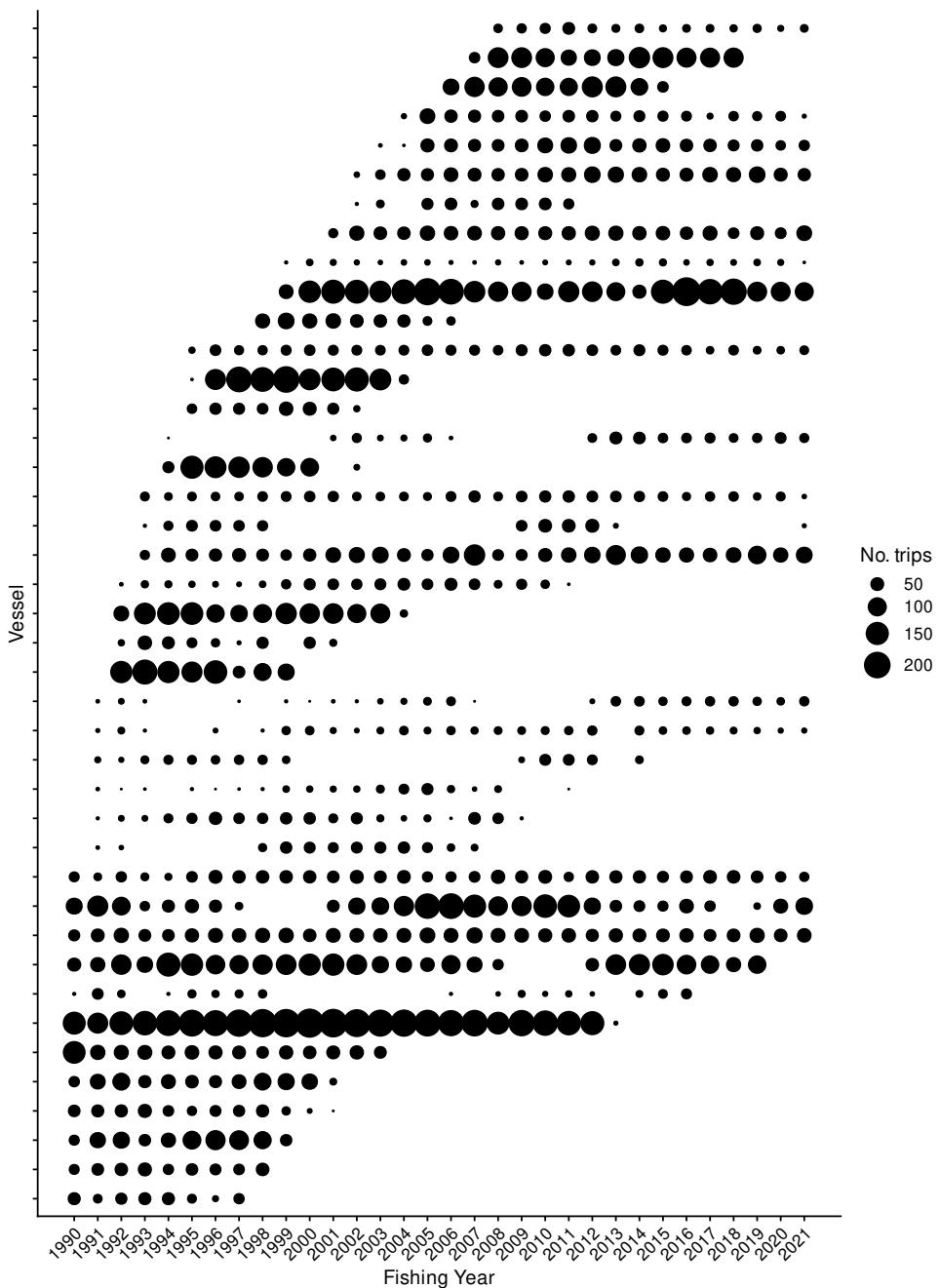


Figure 108: Number of trips by fishing year for core vessels. The area of the circles is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 13: Summary of the SPO 2 BT trip 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	26 (100%) n: 1362	20 (100%) n: 1441	40 (100%) n: 1960	46 (100%) n: 1815	38 (100%) n: 1894	43 (100%) n: 2158	45 (100%) n: 1998	44 (100%) n: 1761	40 (100%) n: 1923
Positive fishing duration	26 (100%) n: 1358	20 (100%) n: 1432	40 (100%) n: 1959	46 (100%) n: 1815	38 (100%) n: 1894	43 (100%) n: 2154	45 (100%) n: 1975	44 (100%) n: 1748	39 (100%) n: 1898
Trim extreme effort num	26 (100%) n: 1358	20 (100%) n: 1432	40 (100%) n: 1959	46 (100%) n: 1815	37 (100%) n: 1892	42 (100%) n: 2152	43 (100%) n: 1968	43 (100%) n: 1743	39 (100%) n: 1896
Trim extreme duration	26 (100%) n: 1358	20 (100%) n: 1432	40 (100%) n: 1959	46 (100%) n: 1815	37 (100%) n: 1892	42 (100%) n: 2151	43 (100%) n: 1965	43 (100%) n: 1743	38 (100%) n: 1894
Core fleet selection	13 (50%) n: 669	13 (61%) n: 748	23 (58%) n: 1106	23 (50%) n: 1092	22 (59%) n: 1257	28 (67%) n: 1448	35 (77%) n: 1538	33 (74%) n: 1447	32 (81%) n: 1608
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	38 (100%) n: 1913	39 (100%) n: 1797	41 (100%) n: 1625	44 (100%) n: 1692	57 (100%) n: 1485	57 (100%) n: 1277	77 (100%) n: 1455	92 (100%) n: 1610	74 (100%) n: 1574
Positive fishing duration	37 (100%) n: 1891	38 (100%) n: 1785	41 (100%) n: 1625	44 (100%) n: 1692	57 (100%) n: 1485	57 (100%) n: 1277	77 (100%) n: 1455	92 (100%) n: 1610	74 (100%) n: 1574
Trim extreme effort num	36 (100%) n: 1886	38 (100%) n: 1785	41 (100%) n: 1625	44 (100%) n: 1692	57 (100%) n: 1485	57 (100%) n: 1276	77 (100%) n: 1455	92 (100%) n: 1610	72 (100%) n: 1572
Trim extreme duration	36 (100%) n: 1886	38 (100%) n: 1784	41 (100%) n: 1625	44 (100%) n: 1692	57 (100%) n: 1485	57 (100%) n: 1276	77 (100%) n: 1455	92 (100%) n: 1610	72 (100%) n: 1572
Core fleet selection	30 (80%) n: 1586	32 (82%) n: 1496	29 (71%) n: 1417	32 (74%) n: 1428	40 (70%) n: 1300	40 (70%) n: 1137	66 (85%) n: 1299	58 (63%) n: 1368	41 (55%) n: 1317

Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	78 (100%) n: 1352	72 (100%) n: 1362	84 (100%) n: 1424	77 (100%) n: 1362	76 (100%) n: 1321	79 (100%) n: 1129	92 (100%) n: 1327	79 (100%) n: 1222	78 (100%) n: 1199
Positive fishing duration	78 (100%) n: 1352	72 (100%) n: 1362	84 (100%) n: 1422	77 (100%) n: 1362	76 (100%) n: 1321	79 (100%) n: 1129	92 (100%) n: 1327	79 (100%) n: 1221	78 (100%) n: 1199
Trim extreme effort num	78 (100%) n: 1352	72 (100%) n: 1362	84 (100%) n: 1422	77 (100%) n: 1361	76 (100%) n: 1321	79 (100%) n: 1128	92 (100%) n: 1327	79 (100%) n: 1220	78 (100%) n: 1199
Trim extreme duration	78 (100%) n: 1351	72 (100%) n: 1362	84 (100%) n: 1422	77 (100%) n: 1361	76 (100%) n: 1321	79 (100%) n: 1128	92 (100%) n: 1327	79 (100%) n: 1220	78 (100%) n: 1199
Core fleet selection	46 (60%) n: 1153	43 (61%) n: 1222	55 (65%) n: 1261	56 (72%) n: 1243	62 (82%) n: 1259	65 (82%) n: 1042	78 (85%) n: 1038	64 (81%) n: 994	66 (85%) n: 1012

Filter	2017	2018	2019	2020	2021
Ungroomed data	75 (100%) n: 1106	61 (100%) n: 1033	68 (100%) n: 899	76 (100%) n: 790	64 (100%) n: 799
Positive fishing duration	75 (100%) n: 1106	61 (100%) n: 1033	68 (100%) n: 897	76 (100%) n: 789	64 (100%) n: 798
Trim extreme effort num	75 (100%) n: 1106	61 (100%) n: 1033	67 (100%) n: 896	76 (100%) n: 789	64 (100%) n: 798
Trim extreme duration	75 (100%) n: 1106	61 (100%) n: 1033	67 (100%) n: 896	76 (100%) n: 789	64 (100%) n: 798
Core fleet selection	50 (67%) n: 890	45 (73%) n: 831	50 (73%) n: 728	54 (72%) n: 574	48 (74%) n: 601

Table 14: Summary of the SPO 2 BT trip dataset after core fleet selection. Trips caught represents the percentage of trips with rig catch.

Fishing year	Vessels	Trips	Events	Hrs	Catch (t)	Trips caught
1990	12	669	2 609	8 734.75	13.00	47.23
1991	18	748	3 881	13 168.93	12.53	39.30
1992	22	1 106	4 906	17 211.37	23.10	51.63
1993	23	1 092	5 563	19 139.65	23.00	43.04
1994	23	1 257	5 849	20 933.17	22.42	46.30
1995	26	1 448	7 083	23 814.57	28.45	48.34
1996	27	1 538	7 831	24 259.28	34.70	48.11
1997	27	1 447	6 892	23 350.70	32.80	48.79
1998	27	1 608	7 496	26 140.90	32.16	45.15
1999	26	1 586	7 482	27 561.73	30.07	50.06
2000	24	1 496	7 024	26 934.95	31.53	56.02
2001	26	1 417	6 635	24 256.72	29.44	54.34
2002	26	1 428	6 755	24 550.70	32.44	57.14
2003	25	1 300	6 537	24 179.08	40.12	57.54
2004	24	1 137	6 341	22 913.05	39.77	61.21
2005	23	1 299	7 487	27 484.80	65.80	57.12
2006	25	1 368	7 637	27 030.12	58.12	59.65
2007	23	1 317	7 124	24 469.30	40.55	62.19
2008	23	1 153	7 098	24 474.94	46.38	62.45
2009	23	1 222	7 393	25 645.50	43.49	53.76
2010	22	1 261	7 796	26 888.25	54.53	60.67
2011	23	1 243	8 226	28 500.95	56.15	62.83
2012	23	1 259	7 935	27 564.95	62.06	63.15
2013	20	1 042	7 131	25 068.96	64.77	68.52
2014	21	1 038	7 972	27 901.44	78.26	72.06
2015	20	994	6 807	24 149.40	63.97	67.20
2016	19	1 012	6 222	22 302.45	66.39	65.22
2017	18	890	5 410	19 417.32	50.46	68.09
2018	17	831	5 040	18 668.23	44.68	72.80
2019	17	728	4 686	17 871.62	49.78	74.73
2020	16	574	3 867	14 908.08	54.19	87.46
2021	17	601	3 721	14 100.28	47.86	87.02

Table 15: 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	30.00	49 022	3.10	3.10	*
+ vessel_key	40.00	34 483	32.10	28.90	*
+ ns(log(total_fishing_duration), 3)	3.00	32 213	36.60	4.50	*
+ modal_month	11.00	31 809	37.40	0.80	
+ target_species	2.00	31 560	37.90	0.50	
+ modal_stat_area	4.00	31 423	38.20	0.30	
+ bs(log(total_effort_num), 3)	3.00	31 395	38.30	0.10	

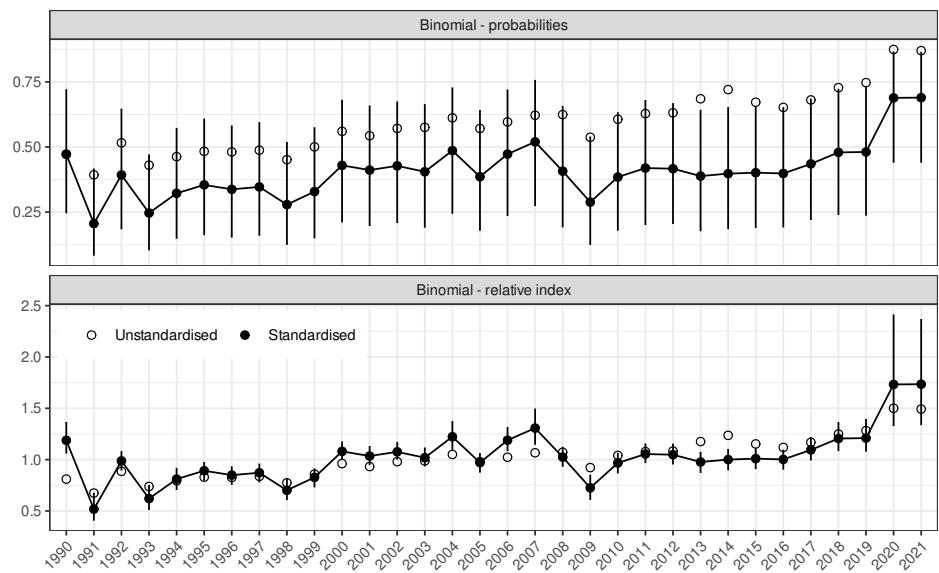


Figure 109: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 2 BT trip dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

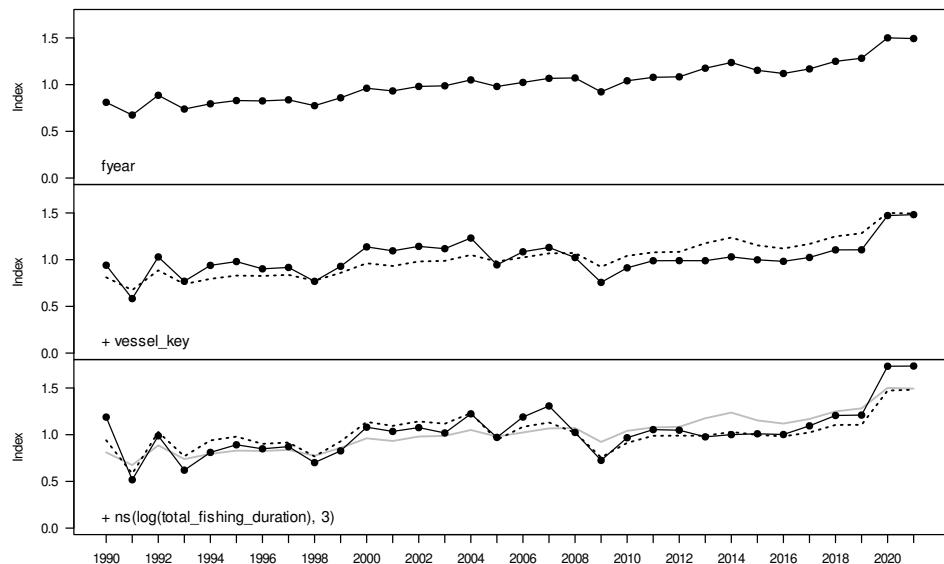


Figure 110: Step plot for occurrence of catch in the SPO 2 BT trip dataset.

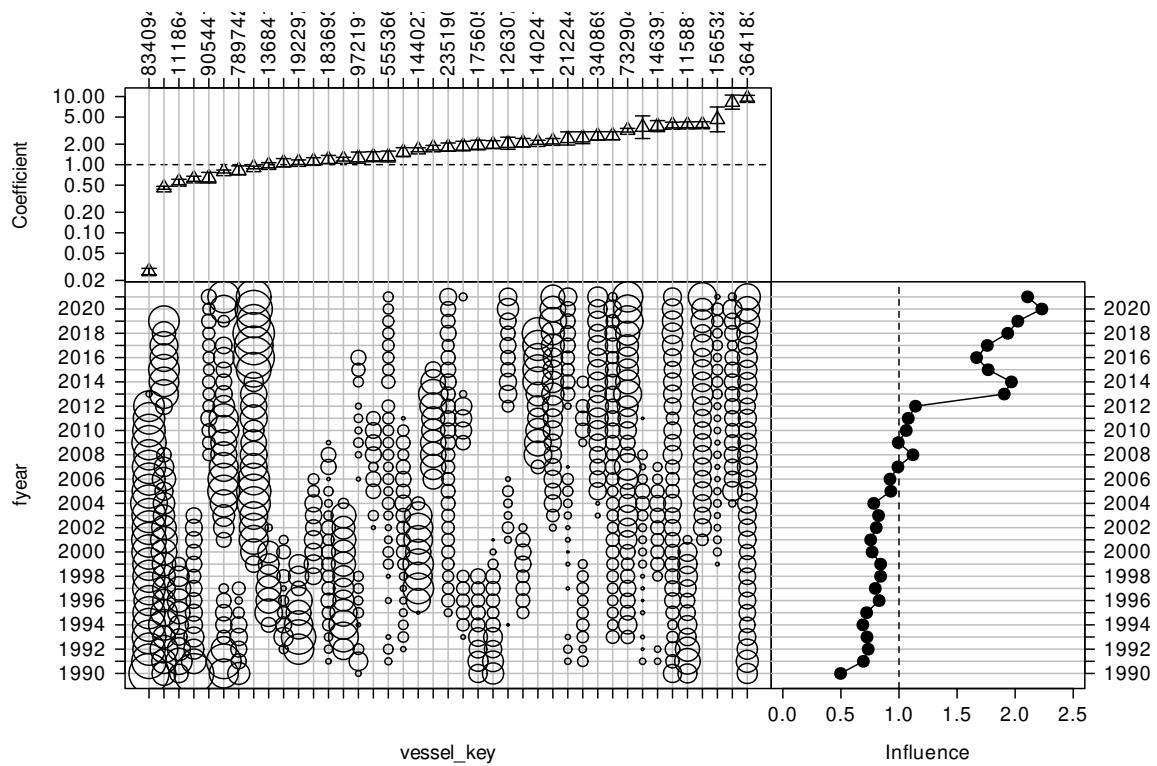


Figure 111: CDI plot for vessel key for the occurrence of positive catch SPO 2 BT trip catch-per-unit-effort dataset.

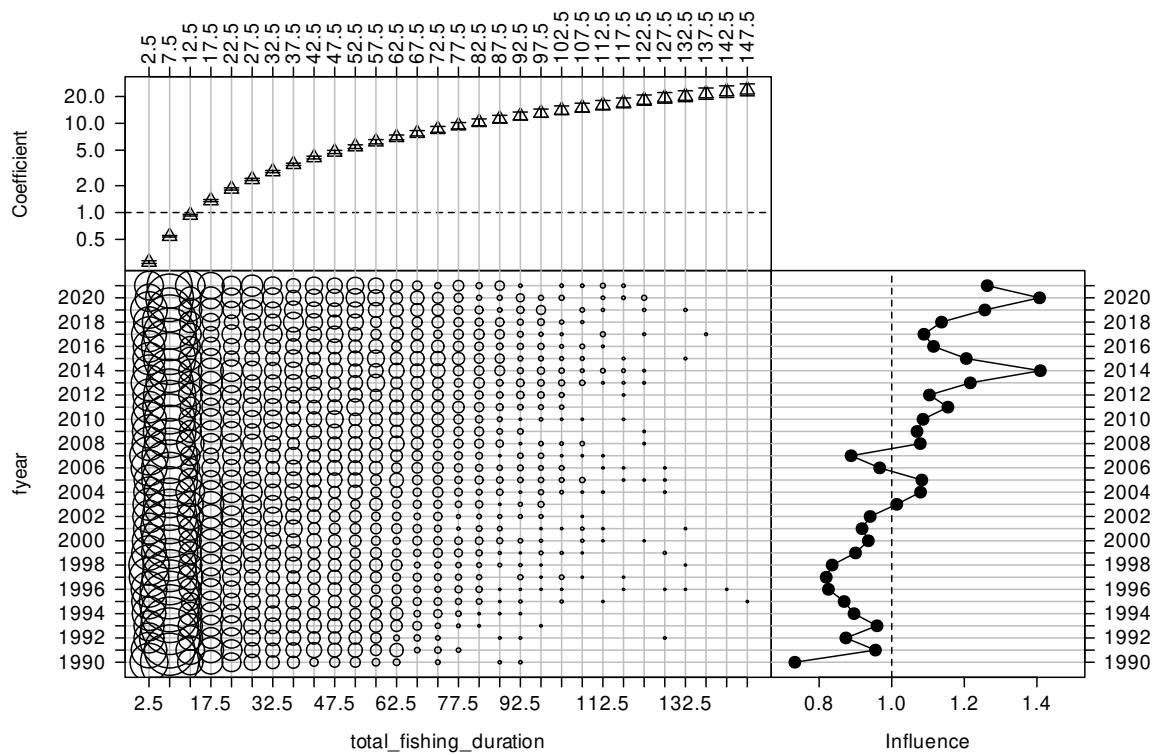


Figure 112: CDI plot for total fishing duration (h) for the occurrence of positive catch SPO 2 BT trip catch-per-unit-effort dataset.

Table 16: 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	30	75 443	6.0	6.0	*
+ ns(log(total fishing duration), 3)	3	65 842	40.0	33.9	*
+ vessel key	40	62 612	48.6	8.6	*
+ target species	2	61 929	50.2	1.6	*
+ modal month	11	61 512	51.2	1.0	*
+ modal stat area	4	61 282	51.7	0.5	
+ bs(log(total effort num), 3)	3	61 276	51.8	0.0	

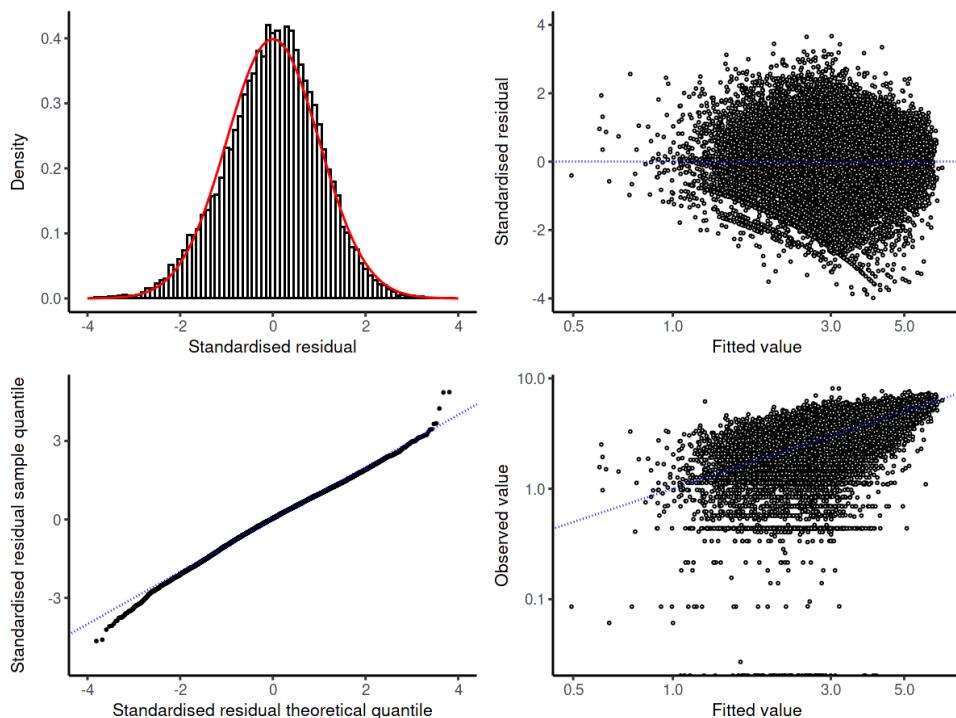


Figure 113: Diagnostic plots for the lognormal model for the SPO 2 BT trip dataset.

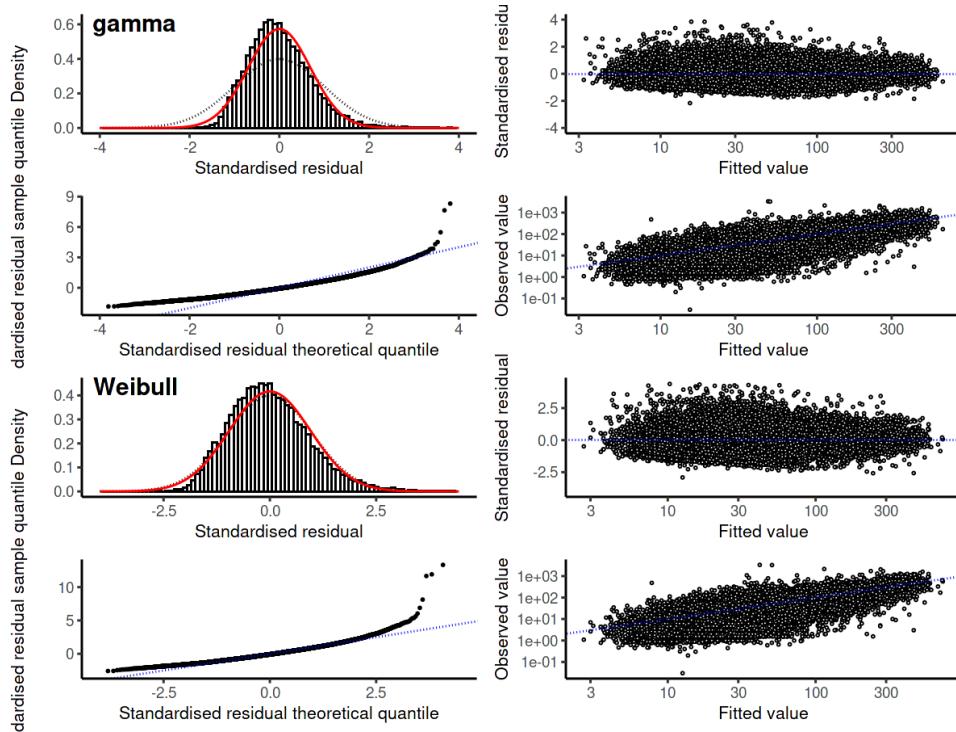


Figure 114: Diagnostic plots for the gamma and Weibull model for the SPO 2 BT trip dataset.

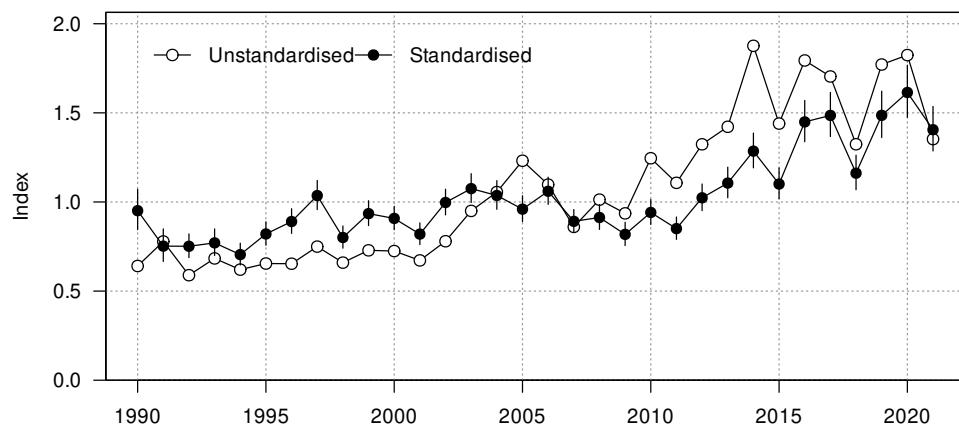


Figure 115: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 2 BT trip dataset.

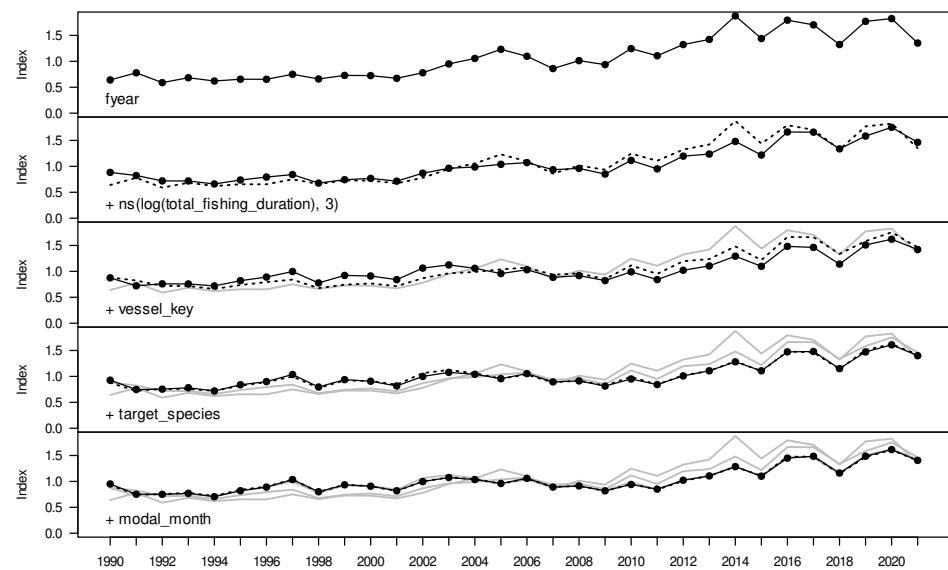


Figure 116: Changes to the SPO 2 BT trip positive catch index as terms are successively entered into the model.

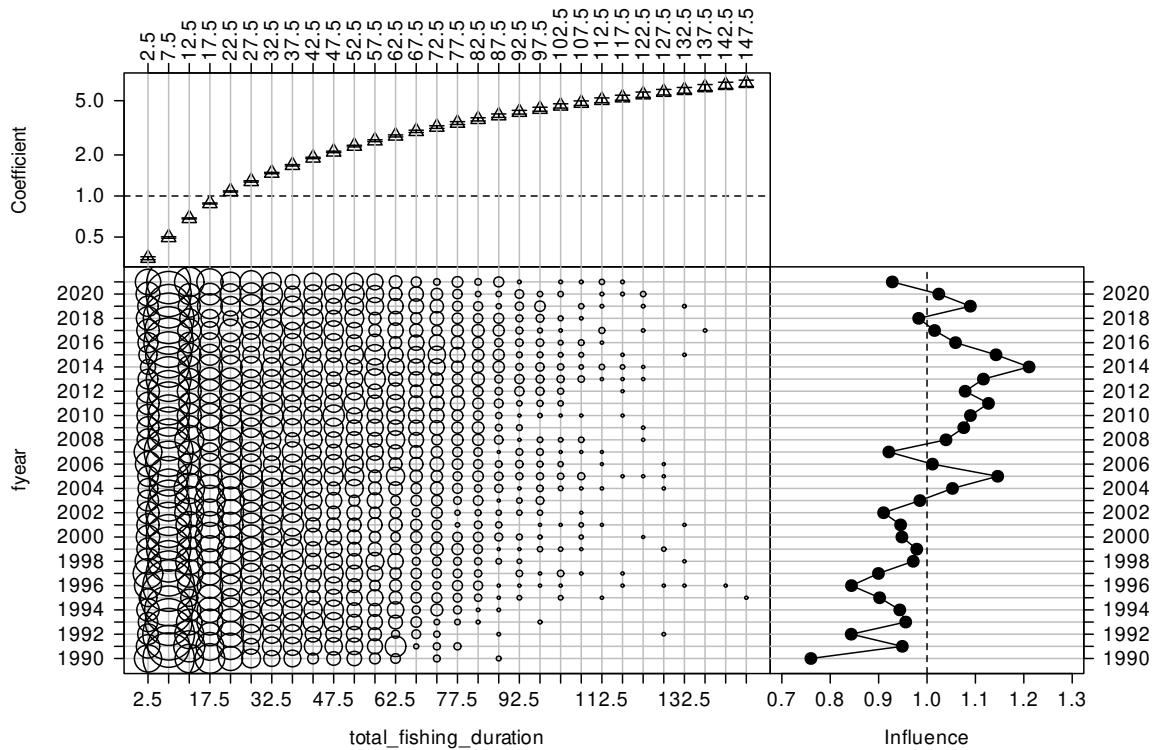


Figure 117: CDI plot for total fishing duration (h) for the positive catch SPO 2 BT trip catch-per-unit-effort dataset.

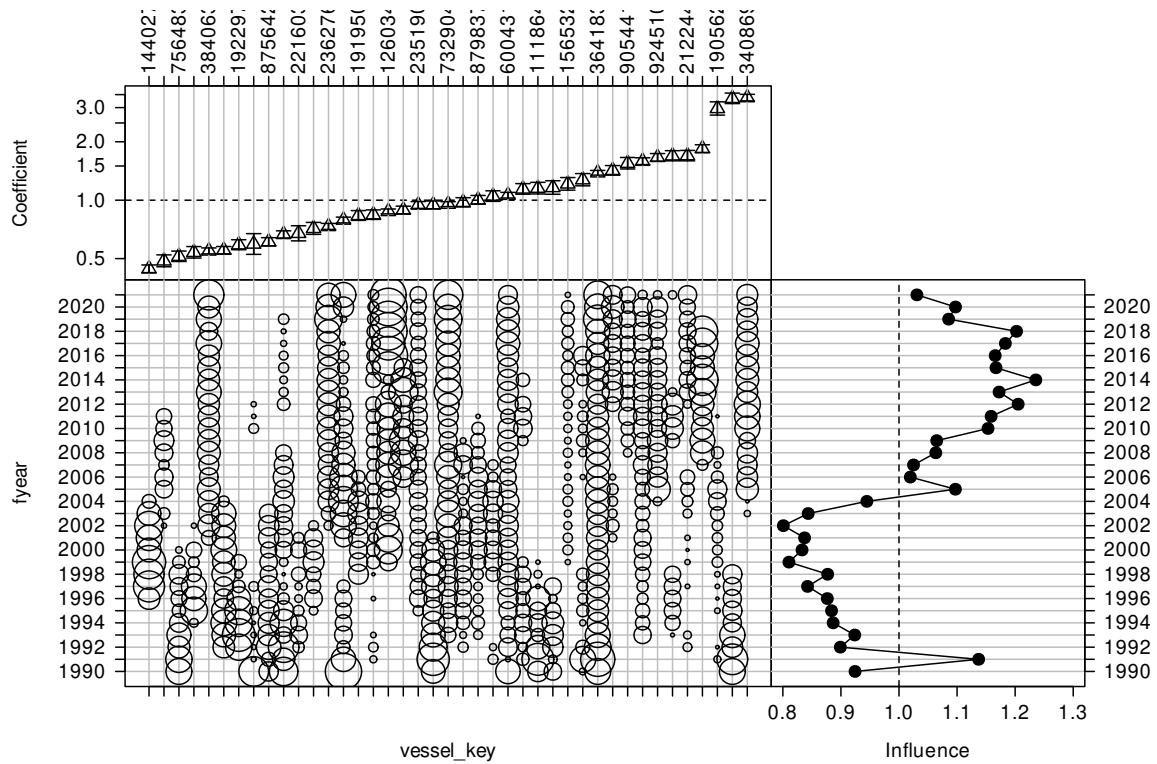


Figure 118: CDI plot for vessel key for the positive catch SPO 2 BT trip catch-per-unit-effort dataset.

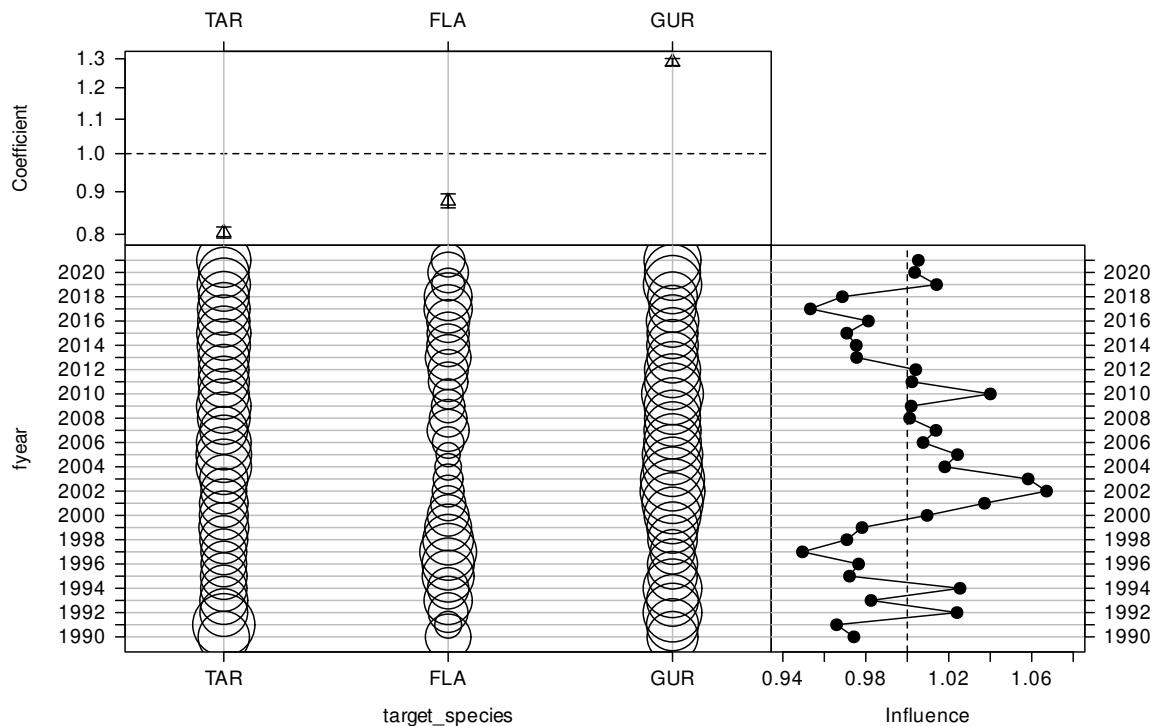


Figure 119: CDI plot for target species for the positive catch SPO 2 BT trip catch-per-unit-effort dataset.

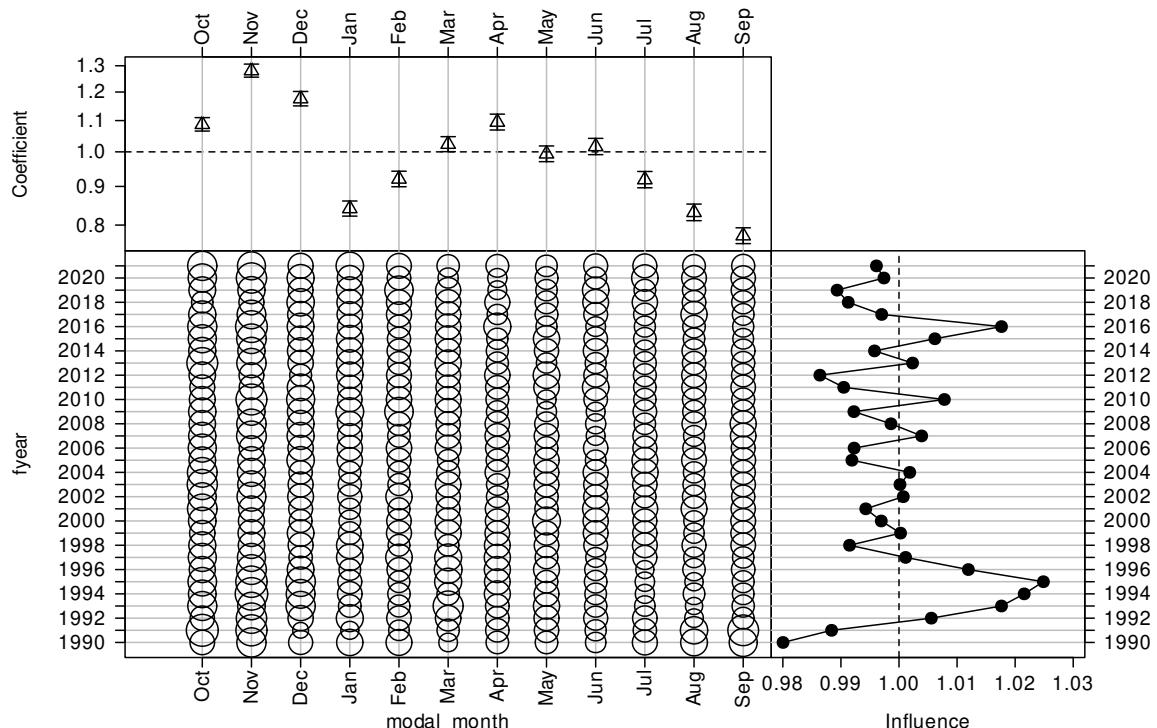


Figure 120: CDI plot for modal month for the positive catch SPO 2 BT trip catch-per-unit-effort dataset.

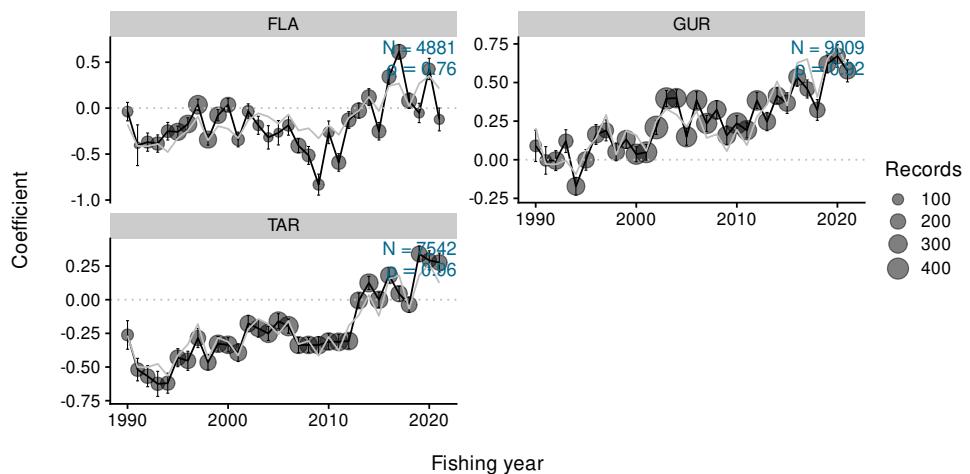


Figure 121: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 2 BT trip dataset.

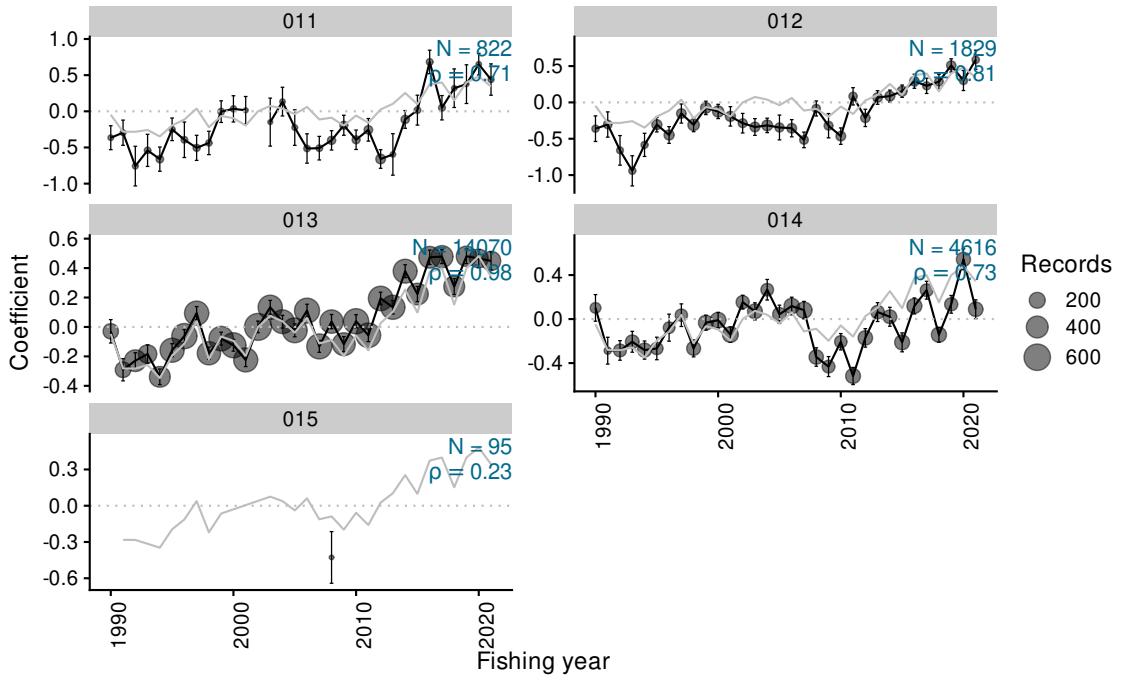


Figure 122: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 2 BT trip dataset.

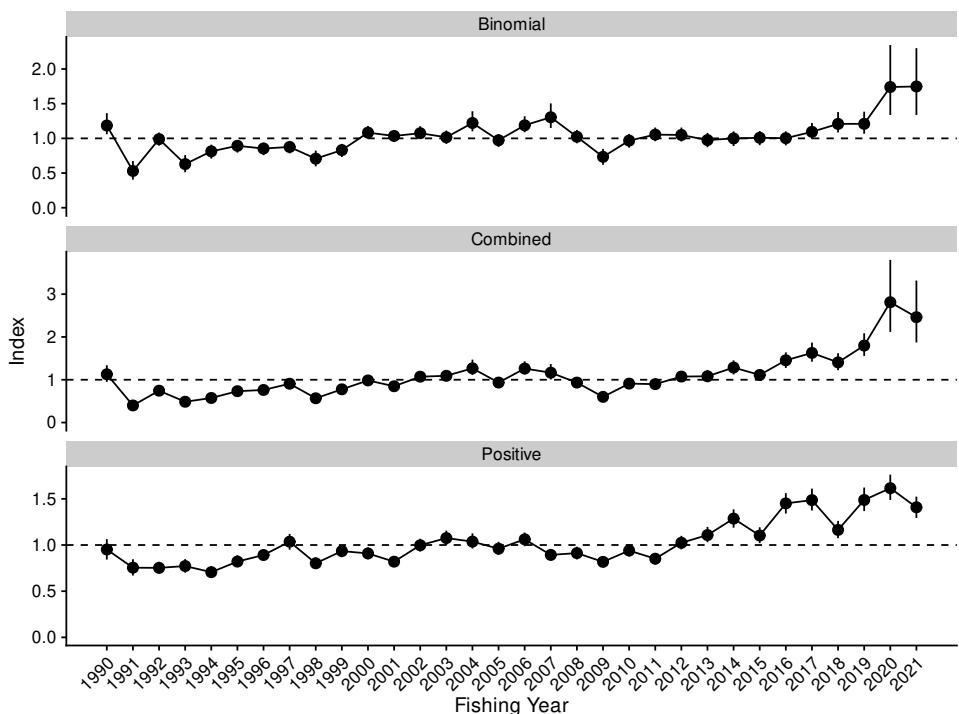


Figure 123: Standardised indices and 95% confidence intervals for the SPO 2 BT trip dataset.



Figure 124: Standardised indices for the SPO 2 BT trip dataset.

Table 17: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 2 BT trip.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	1.185	0.078	1.059	1.364	1.128	0.099	0.951	1.339	0.952	0.057	0.842	1.064
1991	0.530	0.068	0.405	0.673	0.400	0.059	0.296	0.527	0.754	0.045	0.669	0.846
1992	0.989	0.048	0.895	1.084	0.744	0.046	0.658	0.839	0.752	0.032	0.691	0.818
1993	0.629	0.063	0.512	0.758	0.486	0.055	0.385	0.600	0.772	0.037	0.700	0.847
1994	0.813	0.051	0.708	0.909	0.574	0.044	0.491	0.663	0.706	0.031	0.648	0.770
1995	0.893	0.045	0.795	0.971	0.733	0.047	0.636	0.822	0.821	0.033	0.761	0.890
1996	0.853	0.047	0.758	0.941	0.761	0.048	0.663	0.853	0.892	0.033	0.828	0.956
1997	0.876	0.046	0.784	0.964	0.907	0.061	0.785	1.025	1.036	0.043	0.949	1.120
1998	0.707	0.058	0.596	0.824	0.567	0.051	0.472	0.673	0.802	0.031	0.743	0.866
1999	0.831	0.048	0.731	0.920	0.776	0.053	0.670	0.878	0.934	0.033	0.868	0.998
2000	1.083	0.046	1.000	1.179	0.984	0.055	0.889	1.103	0.909	0.033	0.845	0.974
2001	1.035	0.042	0.956	1.121	0.848	0.045	0.763	0.941	0.820	0.029	0.766	0.879
2002	1.074	0.046	0.994	1.176	1.071	0.060	0.970	1.204	0.997	0.035	0.929	1.068
2003	1.016	0.049	0.921	1.113	1.092	0.063	0.969	1.214	1.075	0.040	0.998	1.156
2004	1.222	0.074	1.102	1.391	1.267	0.091	1.111	1.470	1.037	0.042	0.962	1.127
2005	0.973	0.047	0.876	1.062	0.934	0.057	0.826	1.048	0.960	0.036	0.894	1.035
2006	1.188	0.059	1.088	1.319	1.261	0.079	1.123	1.431	1.062	0.038	0.987	1.135
2007	1.305	0.090	1.149	1.504	1.165	0.092	1.006	1.366	0.893	0.032	0.831	0.958
2008	1.023	0.049	0.929	1.121	0.934	0.056	0.829	1.050	0.912	0.035	0.843	0.982
2009	0.734	0.058	0.619	0.848	0.600	0.054	0.497	0.707	0.818	0.031	0.758	0.881
2010	0.968	0.050	0.866	1.063	0.910	0.062	0.787	1.028	0.940	0.034	0.876	1.008
2011	1.054	0.050	0.959	1.156	0.897	0.056	0.789	1.009	0.851	0.032	0.788	0.915
2012	1.049	0.051	0.955	1.156	1.074	0.062	0.955	1.199	1.024	0.037	0.953	1.099
2013	0.975	0.052	0.872	1.078	1.081	0.071	0.947	1.227	1.108	0.042	1.031	1.196
2014	0.999	0.054	0.890	1.101	1.285	0.084	1.124	1.452	1.286	0.051	1.188	1.386
2015	1.008	0.052	0.901	1.107	1.112	0.070	0.975	1.249	1.103	0.044	1.021	1.192
2016	1.003	0.052	0.899	1.101	1.454	0.093	1.276	1.640	1.451	0.056	1.341	1.562
2017	1.094	0.059	0.990	1.222	1.627	0.114	1.422	1.868	1.486	0.060	1.374	1.611
2018	1.209	0.075	1.085	1.379	1.406	0.101	1.223	1.620	1.163	0.048	1.074	1.261
2019	1.209	0.081	1.067	1.385	1.799	0.135	1.558	2.086	1.487	0.065	1.368	1.622
2020	1.740	0.257	1.337	2.346	2.811	0.429	2.119	3.801	1.616	0.070	1.488	1.762
2021	1.748	0.246	1.337	2.301	2.462	0.369	1.871	3.318	1.408	0.059	1.293	1.524

5.4 SPO 3 BT trip East Coast

This series was based on the trip bycatch of rig from the mixed target species BT fishery on the east coast South Island. The analysis included five east coast South Island statistical areas, stretching from Cloudy Bay to the Catlins: Statistical Areas 018 (Kaikoura), 020 (Pegasus Bay), 022 (Canterbury Bight), 024 (Timaru), 026 (Otago) (Table 18). The target species suite included generic flatfish (FLA), tarakihi (TAR), red cod (RCO), barracouta (BAR), stargazer (STA), spiny dogfish (SPD) and rig (SPO). The core fleet was defined by having fished at least ten trips in each of eight years, retaining 86% of the catch and reducing the fleet from about 300 vessels to 111 vessels (Figure 125). The pattern of vessel participation in this fishery was characterised by a large number of vessels which remained the fishery for 20 years or more (Figure 126). The final groomed dataset represented 52% (1990) to 100% (2008, 2009, 2014) of the annual ungroomed catch (Table 19). The total annual bycatch of rig in the defined fishery ranged from 20 t (in 1990) to 99 t (in 2018) over the 32 years in the data set and was characterised by an increasing occurrence of rig in the trip landings, ranging from 18% (in 1990) to 72% (in 2021) (Table 20).

The binomial (occurrence) model accepted three predictive variables after fishing year (vessel, month, total_fishing_duration), with the model explaining 24% of the deviance (Table 21). Both the unstandardised and standardised series showed a gradually increasing trend from early 1990s to 2019, after which the incidence of rig leveled off (Figure 127). There was almost no standardisation effect from the operation of the binomial model, in spite of the acceptance of three explanatory covariates (Figure 128). Although the vessel CDI plot indicated that there was contrast in this covariate over time (Figure 129), the effect when added to the model was negligible (Figure 128). Similarly, both the month and total_fishing_duration covariates entered the occurrence model with no standardisation effect (Figure 130, Figure 131, see Figure 128).

The lognormal model accepted three predictive variables after fishing year (total_fishing_duration, vessel and target species), with the total model explaining 26% of the deviance (Table 22). The lognormal model showed good conformity to the lognormal assumption over the total residual distribution, with some minor skewness in the upper tail (Figure 132). Both the gamma and the Weibull distributions showed poor fits to the positive catch data (Figure 133). Both the unstandardised and the standardised series showed little trend from the beginning of the series in 1990 to 2017, after which both series showed a strong increasing trend to 2021, with almost no effect from the standardisation analysis over the entire series (Figure 134). As seen for the binomial model, there was almost no effect from the addition of each of the three selected explanatory covariates (Figure 135; vessel: Figure 136, total_fishing_duration: Figure 137, target species: Figure 138). Implied residual plots of rig annual CPUE showed good conformity with the overall annual CPUE trend across the four target species with most of the model data (BAR, FLA, TAR, RCO) (Figure 139). The other three target species (SPO, SPD, STA) had only a limited amount of data. The conformity with the overall annual CPUE trend was very good for the four more southerly statistical areas which also held the majority of the data (020, 022, 024 and 026) (Figure 140). The fifth statistical area (Statistical Area 018-Kaikoura) did not match the overall annual trend estimated by the model.

Both contributing models (lognormal and binomial) showed increasing trends over the 32 year period of the data, with the binomial series increasing over all years while the lognormal series was relatively flat until the mid-2010s and then increased (Figure 141, Figure 142, Table 23). These respective trends resulted in a strongly increasing combined model, rising to a level greater than either of the contributing series given the multiplicative nature of the delta-lognormal function.

Table 18: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 3 BT trip East Coast CPUE series.

Series	SPO 3 BT trip East Coast
QMS stock	SPO3
Reporting forms	CEL, ERS - Trawl, TCE, TCP
Fishing methods	BT
Target species	FLA, BAR, STA, RCO, SPD, SPO, TAR
Statistical Areas	018, 020, 022, 024, 026
Period	1989-10-01, 2021-09-30
Resolution	Trip
Core fleet years	8
Core fleet trips	10
Default model	<code>landkg ~ fyear + vessel_key + modal_stat_area + modal_month + target_species + ns(log(total_fishing_duration), 3) + ns(log(total_effort_num), 3)</code>
Stepwise selection	Yes
Positive catch distribution	Lognormal

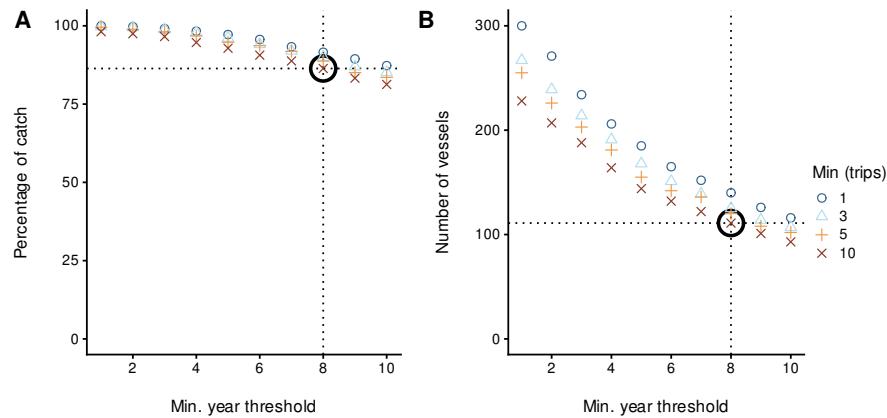


Figure 125: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 3 BT trip East Coast CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

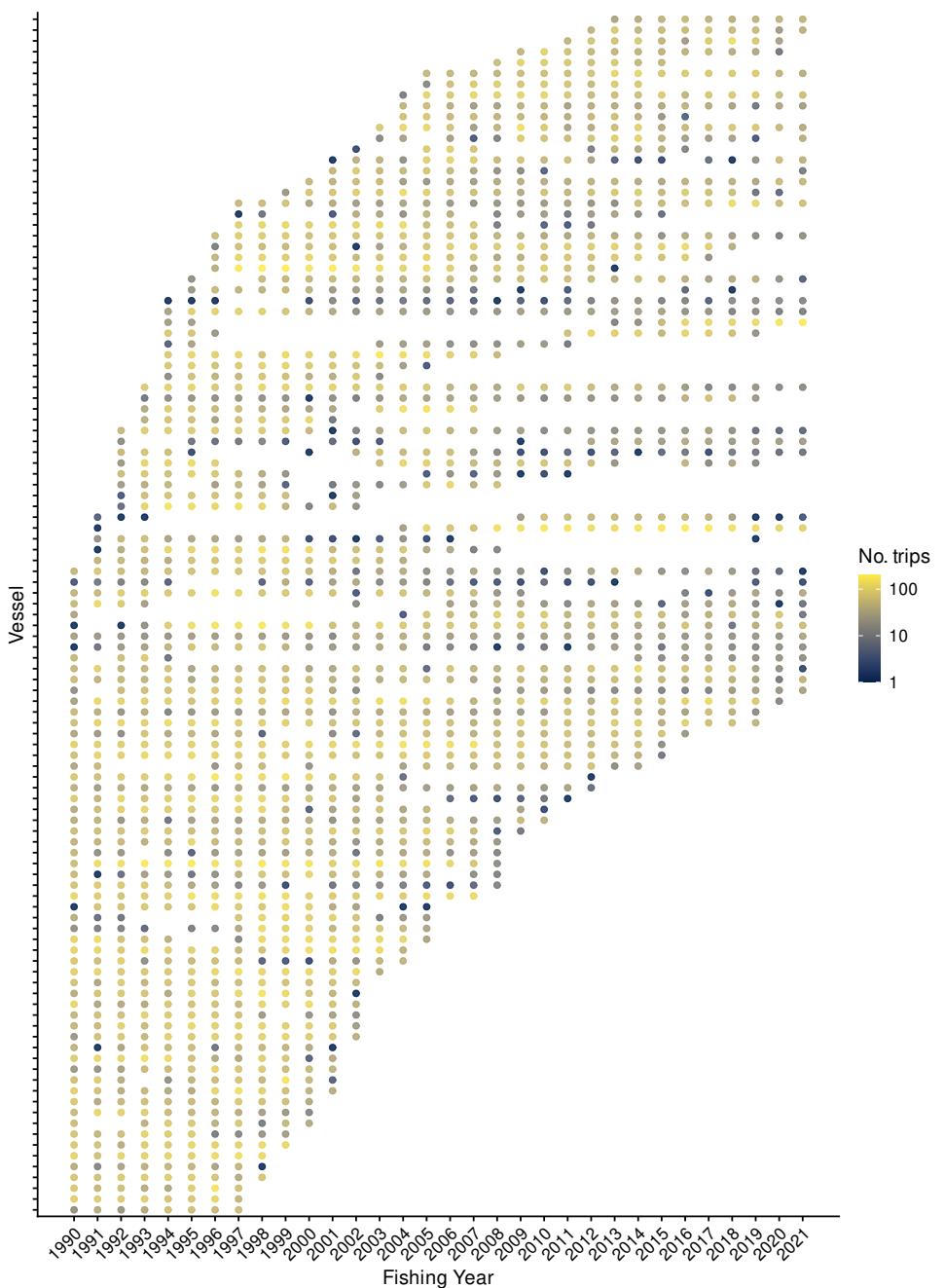


Figure 126: Number of trips by fishing year for core vessels. The colour of the points is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 19: Summary of the SPO 3 BT trip East Coast 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	39 (100%) n: 6179	48 (100%) n: 5748	58 (100%) n: 6098	70 (100%) n: 6896	69 (100%) n: 6974	72 (100%) n: 7220	78 (100%) n: 6880	76 (100%) n: 7179	77 (100%) n: 6960
Positive fishing duration	39 (100%) n: 6175	48 (100%) n: 5736	58 (100%) n: 6086	70 (100%) n: 6885	69 (100%) n: 6960	72 (100%) n: 7212	78 (100%) n: 6817	76 (100%) n: 7079	76 (100%) n: 6856
Trim extreme effort num	39 (100%) n: 6164	48 (100%) n: 5726	56 (100%) n: 6080	70 (100%) n: 6872	69 (100%) n: 6954	72 (100%) n: 7204	76 (100%) n: 6804	73 (100%) n: 7065	75 (100%) n: 6844
Trim extreme duration	39 (100%) n: 6164	47 (100%) n: 5724	56 (100%) n: 6079	69 (100%) n: 6871	69 (100%) n: 6954	72 (100%) n: 7204	76 (100%) n: 6803	73 (100%) n: 7065	75 (100%) n: 6843
Core fleet selection	20 (52%) n: 3549	32 (65%) n: 3582	36 (63%) n: 3964	52 (74%) n: 4753	56 (81%) n: 5213	64 (89%) n: 5617	67 (86%) n: 5601	65 (85%) n: 6022	66 (86%) n: 6209
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	53 (100%) n: 6323	66 (100%) n: 5499	89 (100%) n: 4701	78 (100%) n: 4217	72 (100%) n: 4642	73 (100%) n: 4607	75 (100%) n: 4714	58 (100%) n: 3778	69 (100%) n: 2972
Positive fishing duration	53 (100%) n: 6254	66 (100%) n: 5467	89 (100%) n: 4700	78 (100%) n: 4217	72 (100%) n: 4642	73 (100%) n: 4607	75 (100%) n: 4714	58 (100%) n: 3778	69 (100%) n: 2972
Trim extreme effort num	52 (100%) n: 6247	66 (100%) n: 5466	89 (100%) n: 4699	78 (100%) n: 4214	72 (100%) n: 4641	73 (100%) n: 4604	75 (100%) n: 4714	58 (100%) n: 3778	69 (100%) n: 2970
Trim extreme duration	52 (100%) n: 6247	66 (100%) n: 5466	89 (100%) n: 4699	78 (100%) n: 4214	72 (100%) n: 4641	73 (100%) n: 4604	75 (100%) n: 4714	58 (100%) n: 3778	69 (100%) n: 2970
Core fleet selection	44 (83%) n: 5799	56 (84%) n: 4850	77 (87%) n: 3971	64 (82%) n: 3529	62 (86%) n: 3743	63 (86%) n: 3839	60 (80%) n: 4014	50 (86%) n: 3455	64 (92%) n: 2802

Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	44 (100%) n: 2386	57 (100%) n: 2840	61 (100%) n: 2937	58 (100%) n: 2713	58 (100%) n: 2725	62 (100%) n: 2951	77 (100%) n: 2939	76 (100%) n: 2146	95 (100%) n: 2501
Positive fishing duration	44 (100%) n: 2385	57 (100%) n: 2840	61 (100%) n: 2937	58 (100%) n: 2713	58 (100%) n: 2725	62 (100%) n: 2951	77 (100%) n: 2939	76 (100%) n: 2146	95 (100%) n: 2501
Trim extreme effort num	44 (100%) n: 2384	57 (100%) n: 2837	61 (100%) n: 2937	57 (100%) n: 2710	56 (100%) n: 2722	61 (100%) n: 2949	77 (100%) n: 2939	74 (100%) n: 2144	94 (100%) n: 2499
Trim extreme duration	44 (100%) n: 2383	57 (100%) n: 2837	61 (100%) n: 2934	57 (100%) n: 2709	56 (100%) n: 2720	61 (100%) n: 2948	77 (100%) n: 2939	74 (100%) n: 2144	94 (100%) n: 2496
Core fleet selection	42 (100%) n: 2331	56 (100%) n: 2714	55 (91%) n: 2615	51 (87%) n: 2411	53 (91%) n: 2468	57 (93%) n: 2675	74 (100%) n: 2716	71 (94%) n: 1994	88 (93%) n: 2259

Filter	2017	2018	2019	2020	2021
Ungroomed data	96 (100%) n: 2467	113 (100%) n: 2246	81 (100%) n: 1767	63 (100%) n: 1401	98 (100%) n: 1372
Positive fishing duration	96 (100%) n: 2467	113 (100%) n: 2245	81 (100%) n: 1767	63 (100%) n: 1398	98 (100%) n: 1368
Trim extreme effort num	96 (100%) n: 2467	113 (100%) n: 2245	81 (100%) n: 1767	63 (100%) n: 1398	98 (100%) n: 1368
Trim extreme duration	96 (100%) n: 2466	113 (100%) n: 2245	81 (100%) n: 1767	63 (100%) n: 1397	98 (100%) n: 1367
Core fleet selection	83 (87%) n: 2200	99 (88%) n: 1977	73 (90%) n: 1559	54 (86%) n: 1158	83 (85%) n: 1130

Table 20: Summary of the SPO 3 BT trip East Coast dataset after core fleet selection. Trips caught represents the percentage of trips with rig catch.

Fishing year	Vessels	Trips	Events	Hrs	Catch (t)	Trips caught
1990	60	3 549	13 700	38 229.20	20.34	18.17
1991	60	3 582	13 737	42 841.25	31.70	20.99
1992	69	3 964	16 386	52 978.20	36.21	27.67
1993	70	4 753	19 639	61 022.05	51.99	23.59
1994	77	5 213	20 289	58 829.61	55.92	25.36
1995	77	5 617	20 504	60 229.08	64.14	23.95
1996	79	5 601	20 795	62 082.33	66.61	25.39
1997	81	6 022	24 813	68 313.88	64.61	24.49
1998	80	6 209	25 523	71 432.82	65.87	27.25
1999	74	5 799	23 647	65 884.57	44.12	28.66
2000	72	4 850	20 340	56 868.08	55.92	34.35
2001	75	3 971	19 565	55 074.95	77.26	36.51
2002	71	3 529	17 227	46 282.75	64.12	34.43
2003	64	3 743	19 469	54 175.33	61.83	36.87
2004	67	3 839	17 803	49 430.70	63.17	34.25
2005	66	4 014	17 981	51 430.58	60.26	36.22
2006	62	3 455	15 769	46 969.62	49.85	40.58
2007	61	2 802	13 605	42 018.35	63.72	49.14
2008	60	2 331	10 520	33 169.87	42.05	42.99
2009	56	2 714	11 553	40 001.83	55.69	43.15
2010	53	2 615	11 910	39 912.21	55.24	47.34
2011	53	2 411	10 872	37 162.62	50.52	47.45
2012	53	2 468	10 682	35 249.48	53.22	42.95
2013	52	2 675	11 542	38 596.20	57.28	48.26
2014	50	2 716	11 976	42 427.92	73.61	54.09
2015	48	1 994	8 917	32 758.87	71.18	56.42
2016	46	2 259	9 363	33 334.25	87.92	54.14
2017	43	2 200	9 128	32 284.38	83.15	58.23
2018	43	1 977	8 574	31 104.20	99.21	64.85
2019	43	1 559	7 148	24 913.23	72.88	72.03
2020	35	1 158	5 734	19 755.13	54.30	64.59
2021	34	1 130	6 174	20 629.22	82.92	71.50

Table 21: 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	30.00	136 785	5.40	5.40	*
+ vessel_key	110.00	121 578	16.10	10.70	*
+ modal_month	11.00	115 416	20.40	4.30	*
+ ns(log(total_fishing_duration), 3)	3.00	109 927	24.20	3.80	*
+ ns(log(total_effort_num), 3)	3.00	109 507	24.50	0.30	
+ target_species	6.00	109 308	24.60	0.10	
+ modal_stat_area	4.00	109 126	24.80	0.10	

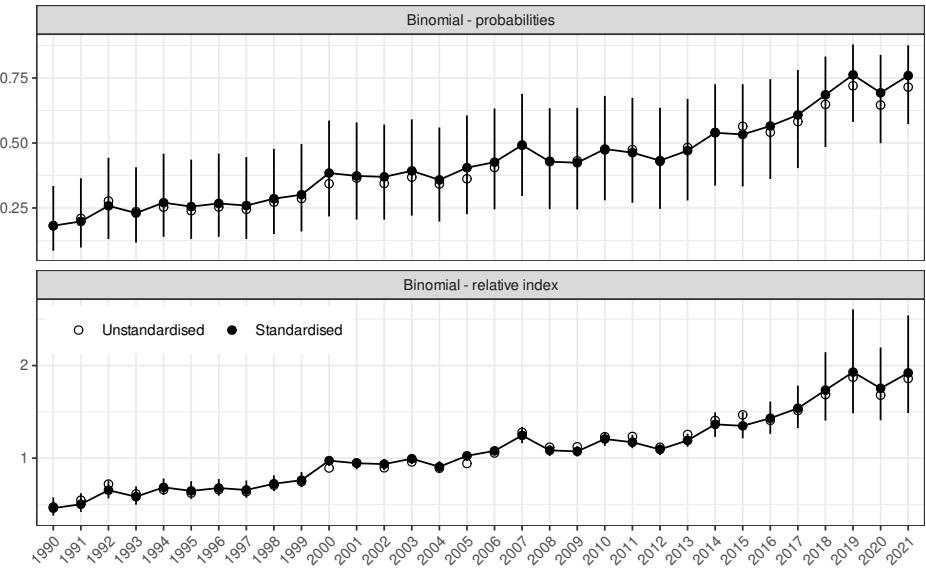


Figure 127: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 3 BT trip East Coast dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

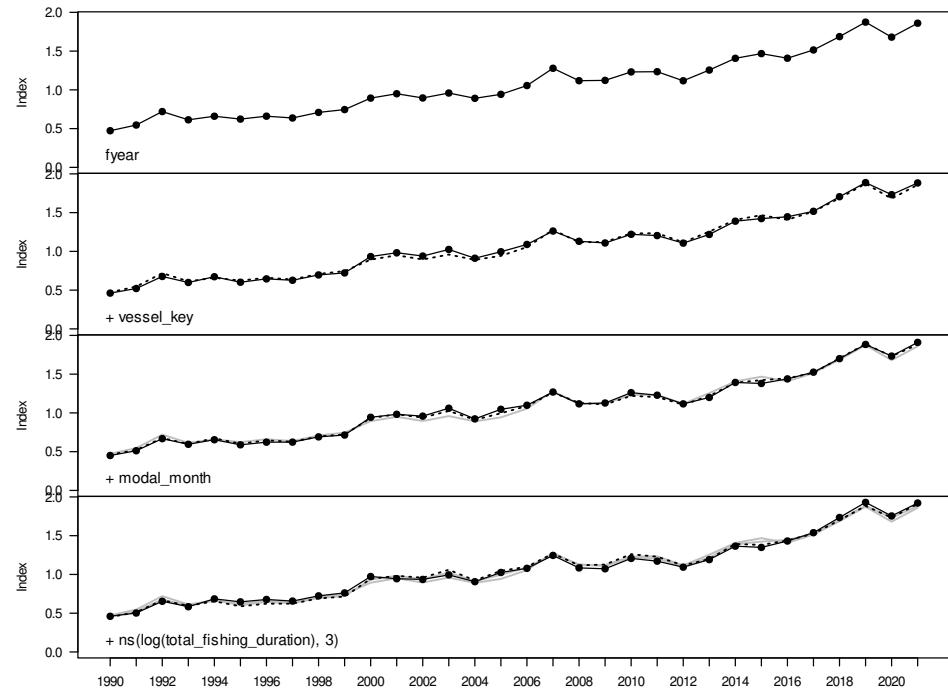


Figure 128: Step plot for occurrence of catch in the SPO 3 BT trip East Coast dataset.

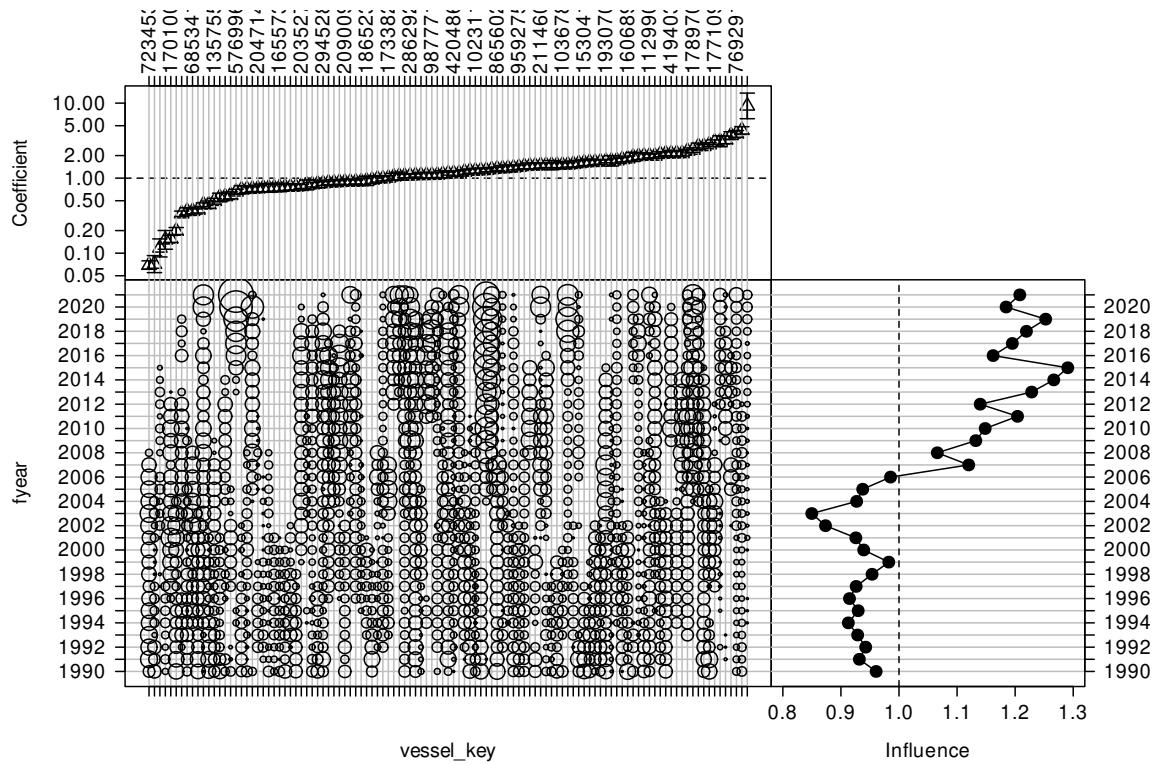


Figure 129: CDI plot for vessel key for the occurrence of positive catch SPO 3 BT trip East Coast catch-per-unit-effort dataset.

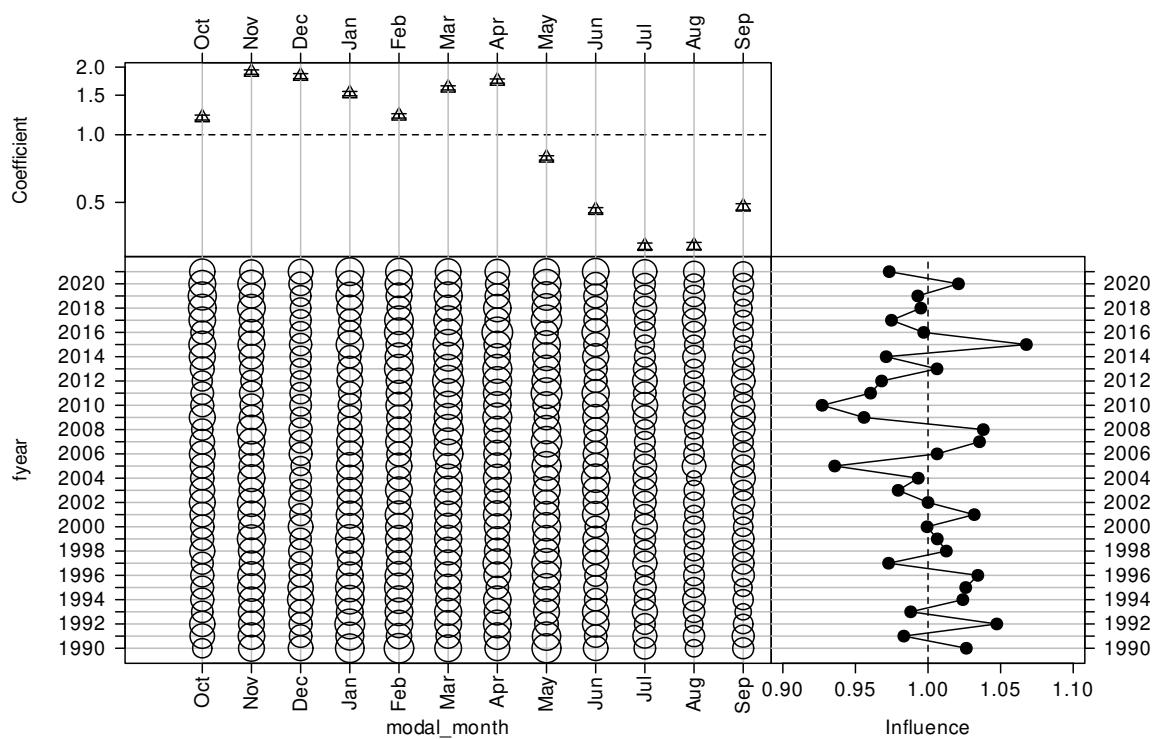


Figure 130: CDI plot for modal month for the occurrence of positive catch SPO 3 BT trip East Coast catch-per-unit-effort dataset.

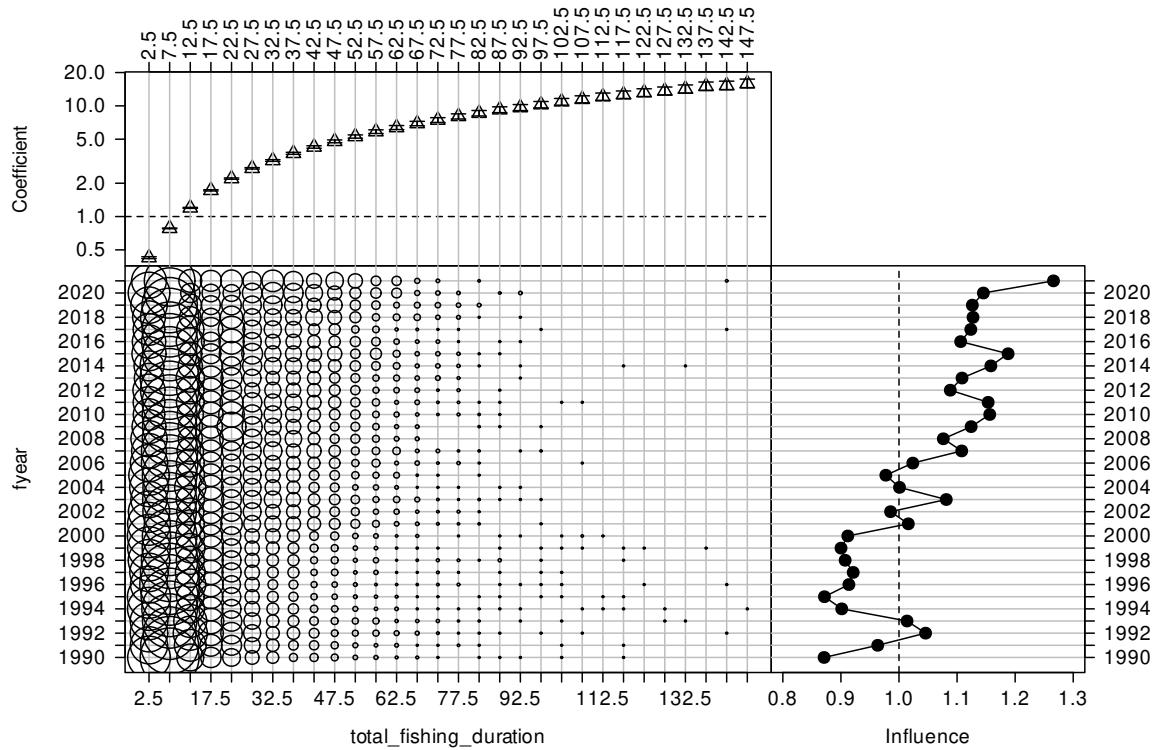


Figure 131: CDI plot for total fishing duration (h) for the occurrence of positive catch SPO 3 BT trip East Coast catch-per-unit-effort dataset.

Table 22: 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	30	142 297	1.9	1.9	*
+ vessel key	110	135 045	18.7	16.8	*
+ ns(log(total fishing duration), 3)	3	132 566	23.6	4.9	*
+ target species	6	131 345	25.9	2.3	*
+ modal month	11	130 864	26.9	0.9	
+ modal stat area	4	130 772	27.0	0.2	
+ ns(log(total effort num), 3)	3	130 651	27.3	0.2	

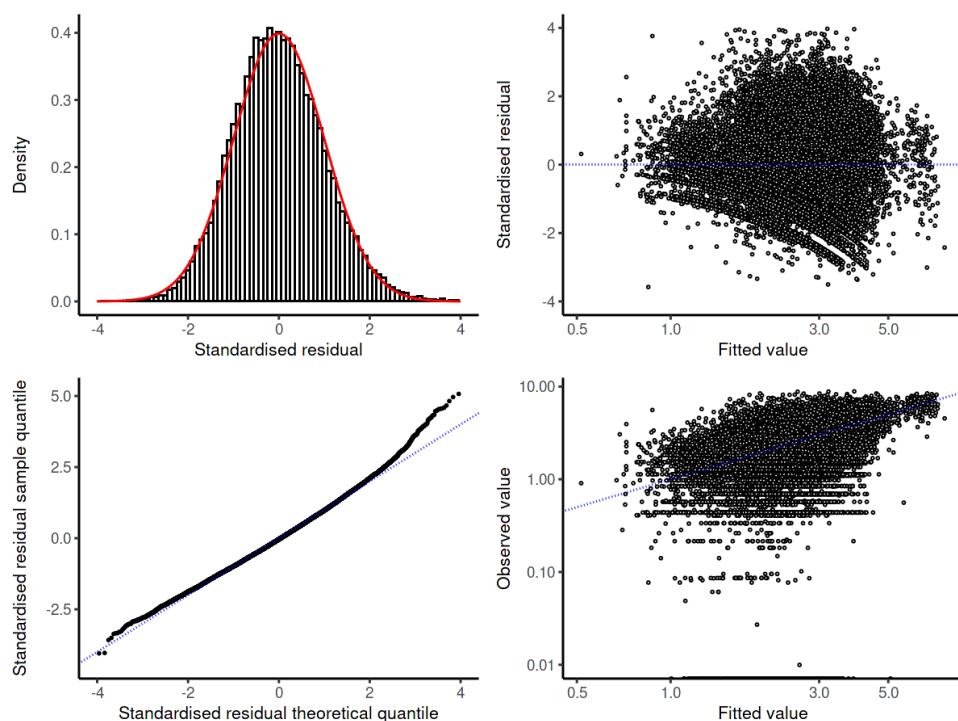


Figure 132: Diagnostic plots for the lognormal model for the SPO 3 BT trip East Coast dataset.

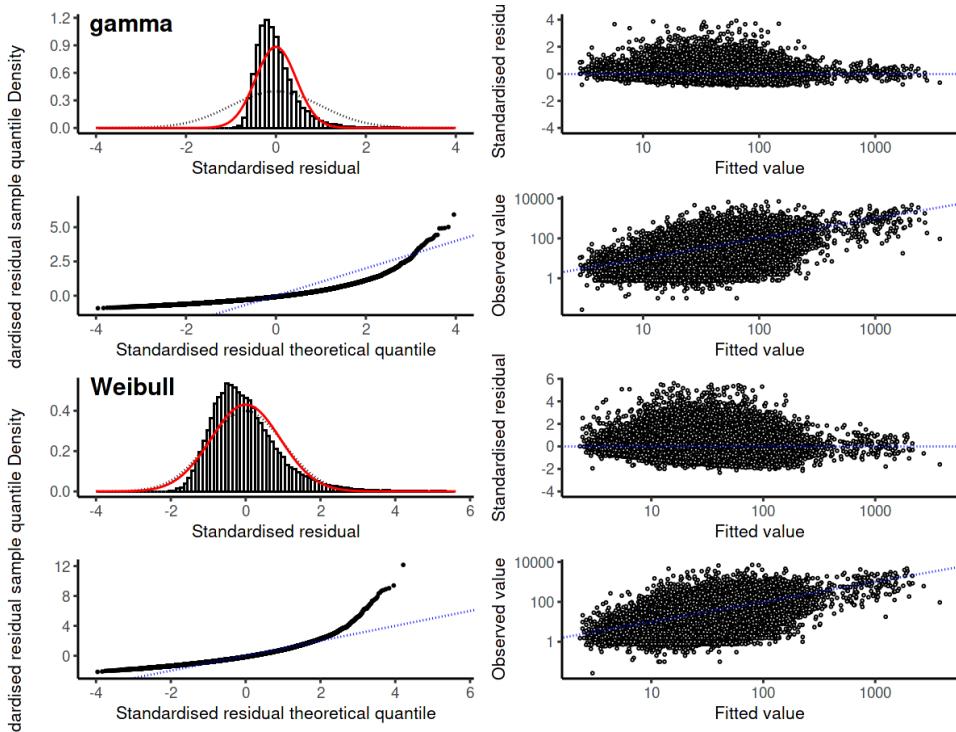


Figure 133: Diagnostic plots for the gamma and Weibull model for the SPO 3 BT trip East Coast dataset.

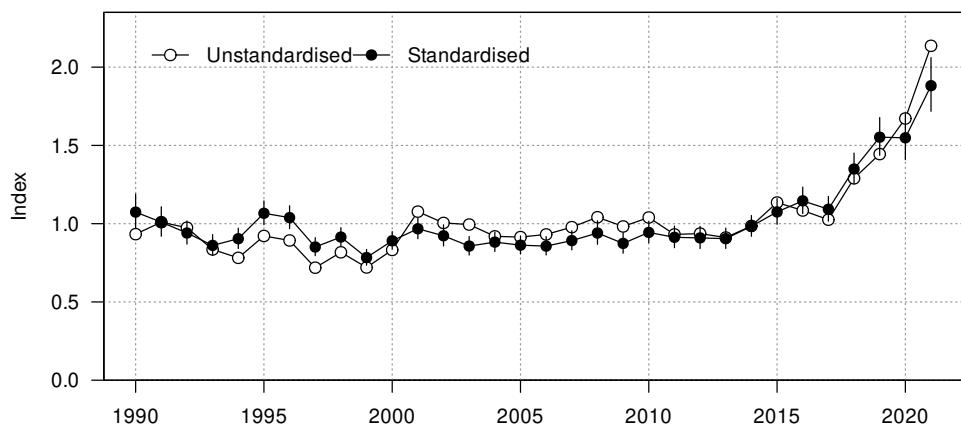


Figure 134: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 3 BT trip East Coast dataset.

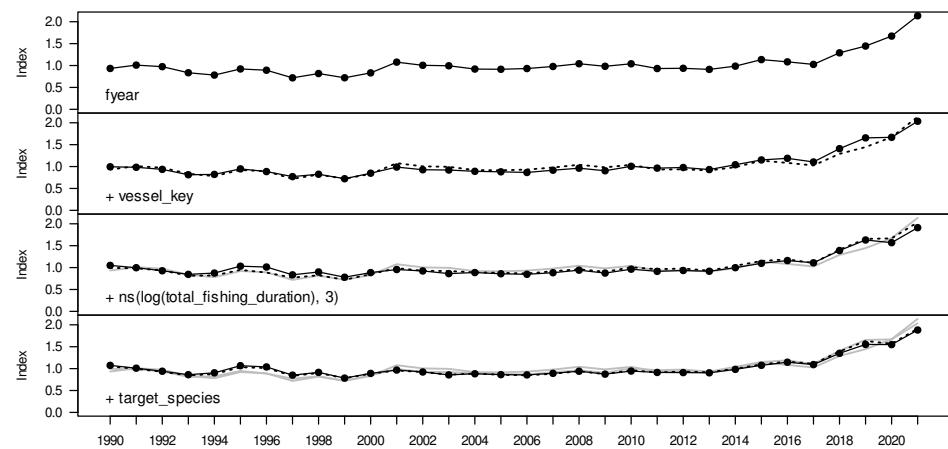


Figure 135: Changes to the SPO 3 BT trip East Coast positive catch index as terms are successively entered into the model.

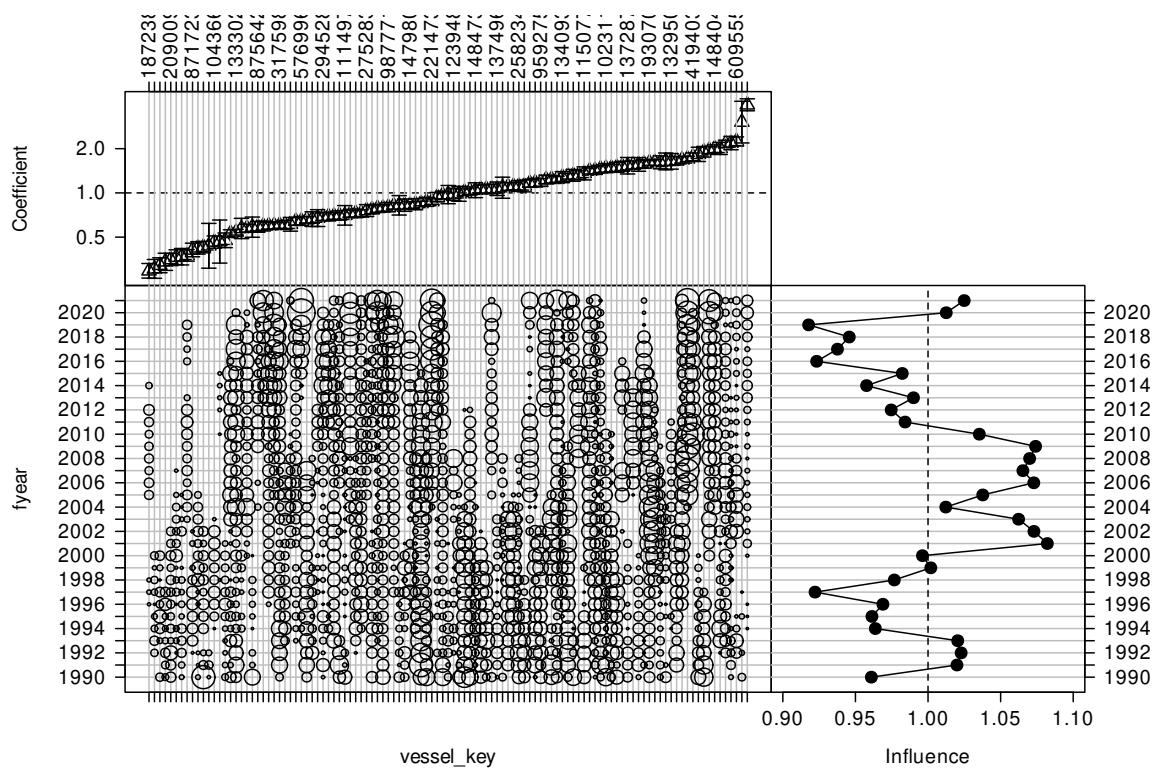


Figure 136: CDI plot for vessel key for the positive catch SPO 3 BT trip East Coast catch-per-unit-effort dataset.

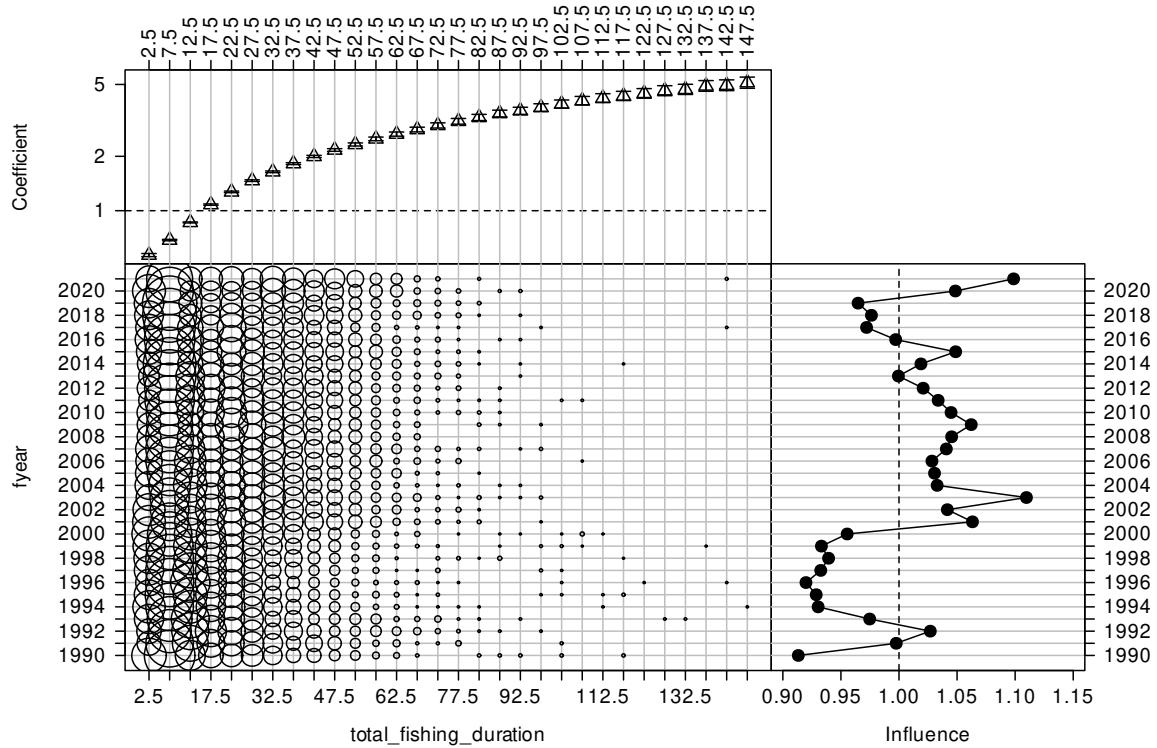


Figure 137: CDI plot for total fishing duration (h) for the positive catch SPO 3 BT trip East Coast catch-per-unit-effort dataset.

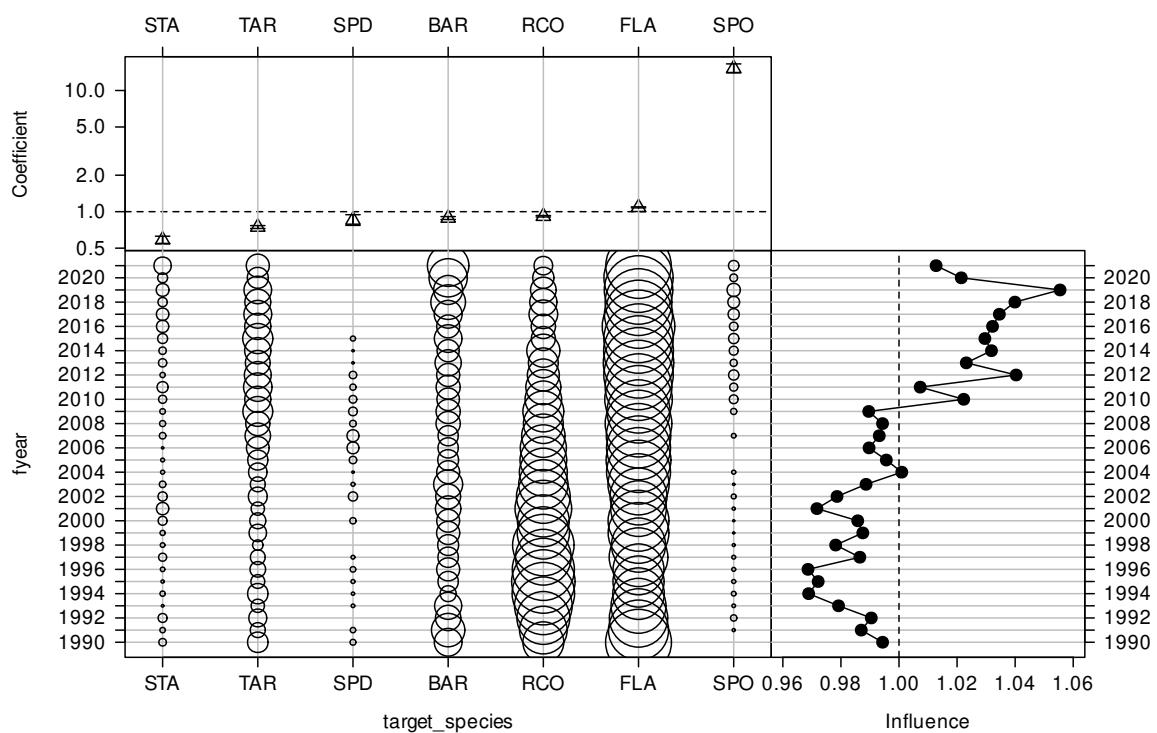


Figure 138: CDI plot for target species for the positive catch SPO 3 BT trip East Coast catch-per-unit-effort dataset.

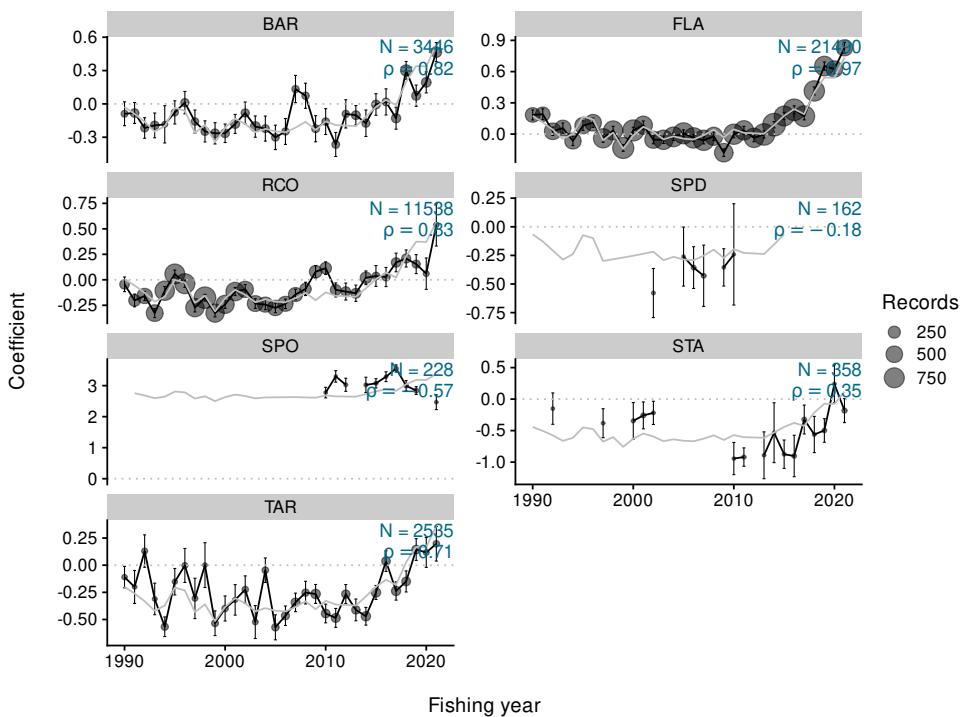


Figure 139: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 3 BT trip East Coast dataset.

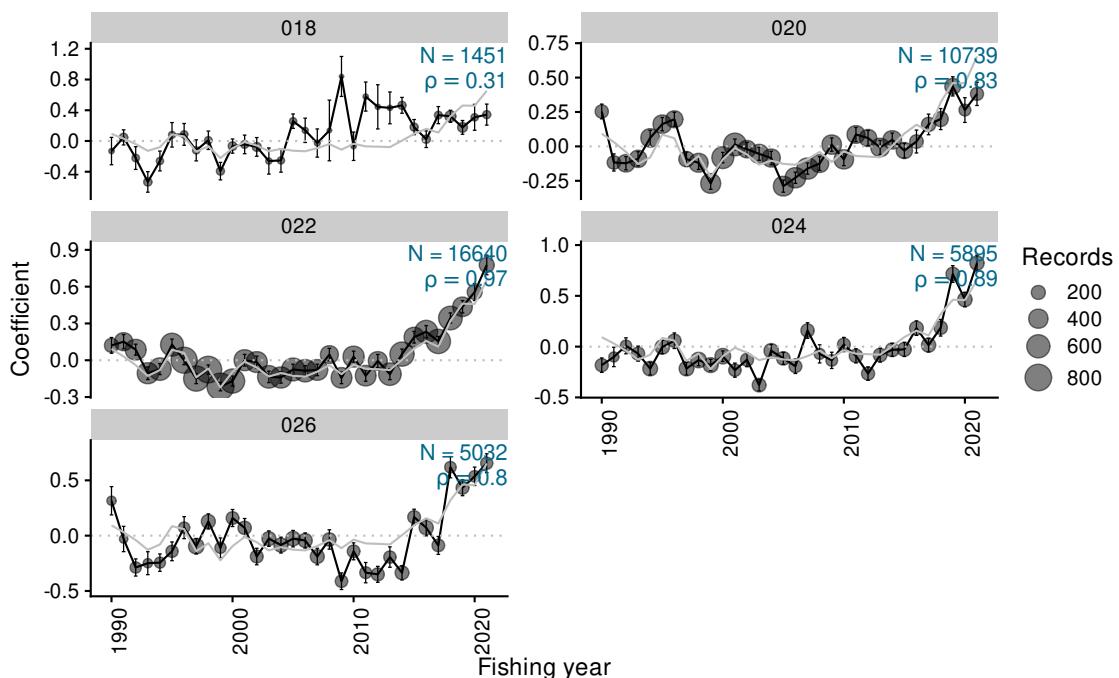


Figure 140: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 3 BT trip East Coast dataset.

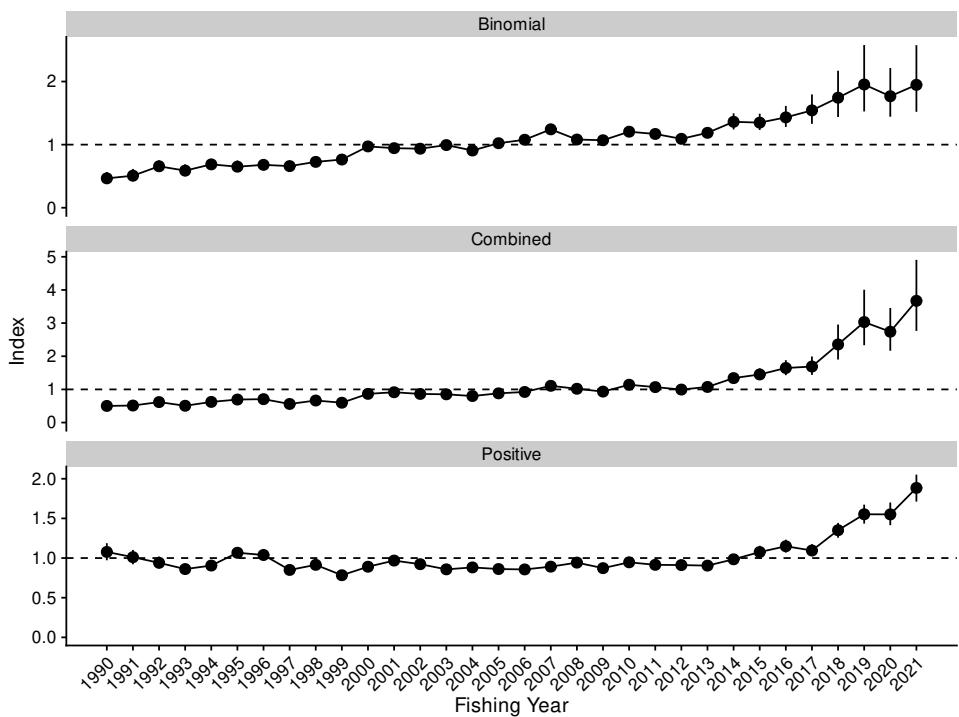


Figure 141: Standardised indices and 95% confidence intervals for the SPO 3 BT trip East Coast dataset.

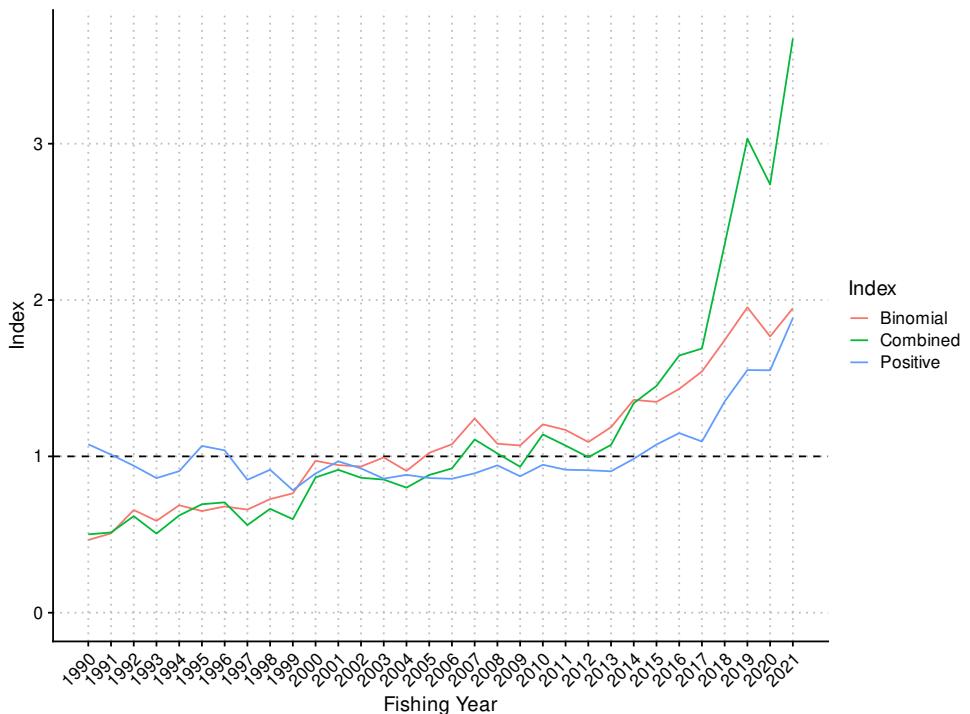


Figure 142: Standardised indices for the SPO 3 BT trip East Coast dataset.

Table 23: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 3 BT trip East Coast.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.465	0.048	0.377	0.567	0.501	0.058	0.397	0.626	1.077	0.055	0.972	1.187
1991	0.508	0.050	0.419	0.615	0.513	0.053	0.415	0.622	1.011	0.046	0.922	1.102
1992	0.657	0.047	0.567	0.750	0.618	0.051	0.521	0.719	0.940	0.038	0.870	1.019
1993	0.588	0.048	0.499	0.688	0.506	0.047	0.425	0.608	0.861	0.033	0.799	0.930
1994	0.687	0.043	0.604	0.773	0.622	0.046	0.539	0.719	0.905	0.031	0.845	0.968
1995	0.650	0.046	0.568	0.749	0.694	0.054	0.595	0.808	1.067	0.036	0.997	1.138
1996	0.680	0.044	0.595	0.769	0.706	0.056	0.603	0.823	1.039	0.037	0.968	1.115
1997	0.660	0.044	0.574	0.746	0.561	0.043	0.480	0.648	0.850	0.029	0.796	0.911
1998	0.727	0.042	0.645	0.810	0.664	0.044	0.577	0.749	0.914	0.029	0.856	0.971
1999	0.764	0.039	0.685	0.839	0.598	0.037	0.526	0.671	0.784	0.026	0.734	0.836
2000	0.972	0.026	0.915	1.017	0.865	0.038	0.792	0.940	0.891	0.028	0.839	0.948
2001	0.944	0.030	0.883	1.002	0.914	0.044	0.827	1.001	0.968	0.032	0.907	1.032
2002	0.935	0.032	0.868	0.992	0.863	0.043	0.782	0.950	0.923	0.033	0.861	0.990
2003	0.993	0.026	0.941	1.043	0.852	0.036	0.784	0.925	0.858	0.029	0.802	0.916
2004	0.907	0.032	0.840	0.964	0.800	0.039	0.726	0.877	0.882	0.030	0.823	0.940
2005	1.023	0.025	0.971	1.070	0.881	0.037	0.808	0.953	0.862	0.028	0.807	0.918
2006	1.077	0.027	1.028	1.134	0.923	0.039	0.851	1.004	0.857	0.028	0.802	0.912
2007	1.242	0.042	1.166	1.330	1.108	0.053	1.008	1.216	0.892	0.032	0.831	0.957
2008	1.081	0.031	1.023	1.144	1.019	0.049	0.925	1.117	0.943	0.036	0.873	1.013
2009	1.070	0.029	1.014	1.127	0.934	0.042	0.855	1.017	0.873	0.032	0.814	0.939
2010	1.205	0.040	1.135	1.290	1.140	0.054	1.040	1.250	0.946	0.034	0.882	1.015
2011	1.169	0.034	1.105	1.239	1.069	0.050	0.972	1.168	0.915	0.033	0.852	0.981
2012	1.092	0.031	1.031	1.155	0.995	0.046	0.908	1.088	0.911	0.034	0.846	0.981
2013	1.187	0.035	1.123	1.261	1.073	0.049	0.984	1.178	0.905	0.031	0.844	0.967
2014	1.362	0.065	1.241	1.496	1.340	0.078	1.195	1.502	0.984	0.032	0.923	1.047
2015	1.349	0.066	1.231	1.490	1.451	0.090	1.285	1.637	1.076	0.038	1.005	1.155
2016	1.432	0.085	1.281	1.614	1.645	0.116	1.429	1.882	1.149	0.041	1.069	1.232
2017	1.543	0.119	1.329	1.796	1.690	0.142	1.437	1.994	1.095	0.039	1.024	1.175
2018	1.744	0.187	1.438	2.171	2.356	0.270	1.900	2.957	1.351	0.048	1.256	1.443
2019	1.953	0.269	1.526	2.578	3.031	0.427	2.333	4.007	1.552	0.061	1.434	1.673
2020	1.767	0.197	1.442	2.214	2.740	0.329	2.166	3.457	1.551	0.073	1.414	1.700
2021	1.947	0.269	1.520	2.576	3.671	0.547	2.764	4.908	1.884	0.087	1.712	2.051

5.5 SPO 3 BT trip Foveaux St

This series was based on the trip bycatch of rig from the mixed target species BT fishery taking place in the most southern part of the South Island. The analysis included seven South Island statistical areas, encompassing the southern end of the South Island: Statistical Areas 025 (east Foveaux Strait), 027 (east coast Stewart Island), 028 (south coast Stewart Island), 029 (west coast Stewart Island), 030 (west Foveaux Strait), 031 (Puysegur) and 032 (Fiordland) (Table 24). The target species suite included generic flatfish (FLA), tarakihi (TAR), red cod (RCO), barracouta (BAR), stargazer (STA), spiny dogfish (SPD) and rig (SPO). The core fleet was defined by having fished at least ten trips in each of eight years, retaining 82% of the catch and reducing the fleet from nearly 150 vessels to 28 vessels (Figure 143). The pattern of vessel participation in this fishery was characterised by a reasonable number of vessels which remained in the fishery for 20 years or more along with vessels with shorter periods of participation (Figure 144). The final groomed dataset represented 32% (1991) to 100% (1998, 2015, 2016, 2018) of the annual ungroomed catch (Table 25). The total annual bycatch of rig in the defined fishery ranged from 4.0 t (in 1990) to 63 t (in 2018) over the 32 years in the data set and was characterised by an increasing occurrence of rig in the trip landings, ranging from 39% (in 1998) to 89% (in 2021) (Table 26).

The binomial (occurrence) model accepted three predictive variables after fishing year (total_fishing_duration, vessel, statistical area), with the model explaining 17% of the deviance (Table 27). Both the unstandardised and standardised series showed an increasing trend from early 1990s to 2020, interrupted by a “hump” from 1999 to 2007, after which the incidence of rig levelled off or dropped slightly (Figure 145). As seen for the east coast North Island and east coast South Island analyses, there was almost no standardisation effect from the operation of the binomial model, in spite of the acceptance of three explanatory covariates (Figure 146). The only discernible effect was a small drop in the standardised index in 2021 with the introduction of the total_fishing_duration covariate resulting from the disappearance of short tows (Figure 147). Although the vessel CDI plot indicated that there was contrast in this covariate over time (Figure 148), the effect when added to the model was negligible (see Figure 146). The statistical area covariate showed no consistent trend over time and had no impact when added to the occurrence model (Figure 149, see Figure 146).

The lognormal model accepted five predictive variables after fishing year (statistical area, vessel, target species, total_effort_num and month), with the total model explaining 25% of the deviance (Table 28). The lognormal model showed excellent conformity to the lognormal assumption over the total residual distribution, without any skewness in either tail (Figure 150). Both the gamma and the Weibull distributions showed much poorer fits to the positive catch data than did the lognormal model (Figure 151). The unstandardised and the standardised series showed little trend from the beginning of the series in 1990 up to 2011, after which both series showed an increasing trend (Figure 152). Unlike for the SPO 3 BT East Coast series, the effect of the standardisation analysis was to reduce the steepness of the increasing trend in the final years of the series (Figure 153). There was a minor effect from the addition of the statistical area covariate (Figure 154), but most of the standardisation effect was made with the addition of the vessel covariate (Figure 155, see Figure 153). The remaining three accepted covariates had no impact on the final model (target species: Figure 156, total_effort_num: Figure 157, month: Figure 158, see Figure 153). Implied residual plots of rig annual CPUE showed good conformity with the overall annual CPUE trend for the two target species with practically all the model data (FLA, STA) (Figure 159). The other five target species (SPO, SPD, BAR, TAR, RCO) had very little data. The conformity with the overall annual CPUE trend was good for the two Foveaux Strait statistical areas (Statistical Areas 025, 030) but the other five statistical areas (Statistical Areas 027, 028, 029, 031, 032) had insufficient data to make a contribution to the analysis (Figure 160).

Both contributing models (lognormal and binomial) showed little trend over the first 25 years of the series (up to about 2014), being near to or below the long-term average (Figure 161, Figure 162, Table 29). Both series then increased, with the lognormal model increasing more steeply than the binomial series. As seen in the SPO 3 East Coast BT series, these increasing trends resulted in a strongly increasing combined

model, rising to a level greater than either of the contributing series given the multiplicative nature of the delta-lognormal function.

Table 24: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 3 BT trip Foveaux St CPUE series.

Series	SPO 3 BT trip Foveaux St
QMS stock	SPO3
Reporting forms	CEL, ERS - Trawl, TCE, TCP
Fishing methods	BT
Target species	FLA, BAR, STA, RCO, SPD, SPO, TAR
Statistical Areas	025, 027, 028, 029, 030, 031, 032
Period	1989-10-01, 2021-09-30
Resolution	Trip
Core fleet years	8
Core fleet trips	10
Default model	$\text{landkg} \sim \text{fyear} + \text{vessel_key} + \text{modal_stat_area} + \text{modal_month} + \text{target_species} + \text{ns}(\log(\text{total_fishing_duration}), 3) + \text{ns}(\log(\text{total_effort_num}), 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

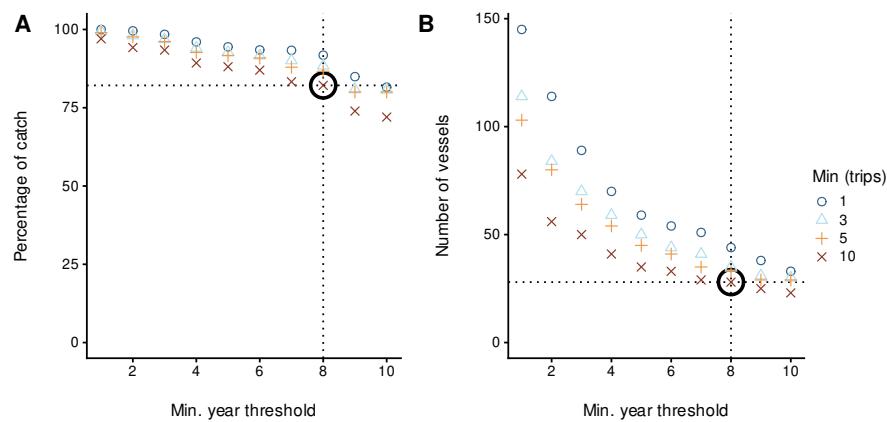


Figure 143: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 3 BT trip Foveaux St CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

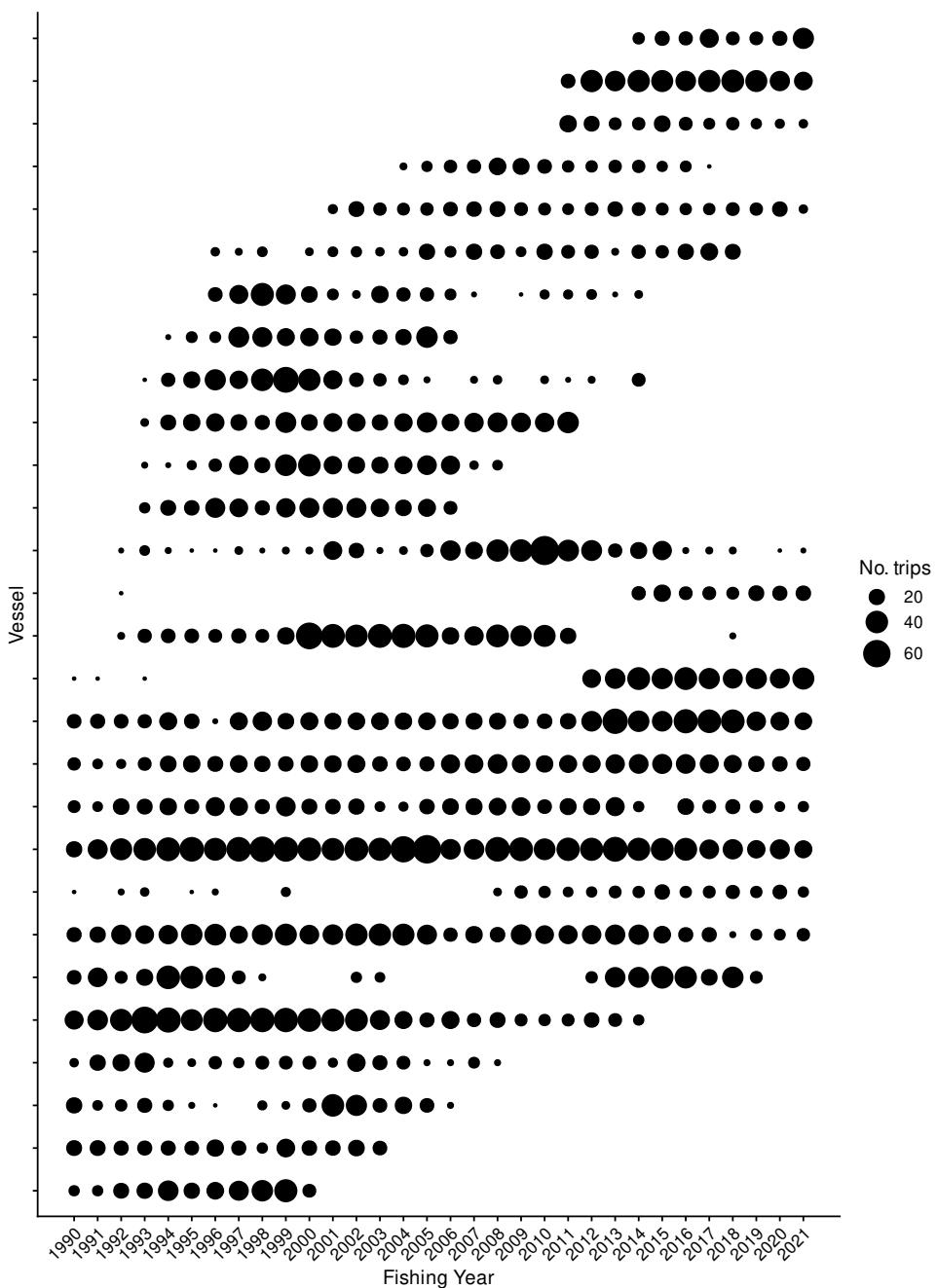


Figure 144: Number of trips by fishing year for core vessels. The area of the circles is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 25: Summary of the SPO 3 BT trip Foveaux St 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	8.7 (100%) n: 544	14 (100%) n: 637	17 (100%) n: 540	23 (100%) n: 523	23 (100%) n: 576	13 (100%) n: 501	14 (100%) n: 614	18 (100%) n: 515	17 (100%) n: 515
Positive fishing duration	8.7 (100%) n: 544	14 (100%) n: 636	17 (100%) n: 540	23 (100%) n: 523	23 (100%) n: 576	13 (100%) n: 500	14 (100%) n: 611	18 (100%) n: 508	17 (100%) n: 507
Trim extreme effort num	8.7 (100%) n: 541	14 (100%) n: 636	16 (93%) n: 534	23 (100%) n: 521	23 (100%) n: 575	13 (100%) n: 492	14 (100%) n: 605	18 (100%) n: 502	17 (100%) n: 501
Trim extreme duration	8.7 (100%) n: 541	13 (100%) n: 635	16 (93%) n: 533	23 (100%) n: 521	23 (100%) n: 574	13 (100%) n: 492	14 (100%) n: 603	18 (100%) n: 502	17 (100%) n: 499
Core fleet selection	4 (46%) n: 178	4.4 (32%) n: 204	8.1 (46%) n: 244	14 (62%) n: 327	15 (65%) n: 379	8.4 (64%) n: 362	12 (85%) n: 420	17 (91%) n: 456	16 (100%) n: 459
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	22 (100%) n: 616	25 (100%) n: 630	30 (100%) n: 589	18 (100%) n: 596	26 (100%) n: 514	18 (100%) n: 447	17 (100%) n: 485	21 (100%) n: 413	26 (100%) n: 458
Positive fishing duration	22 (100%) n: 613	25 (100%) n: 629	30 (100%) n: 589	18 (100%) n: 596	26 (100%) n: 514	18 (100%) n: 447	17 (100%) n: 485	21 (100%) n: 413	26 (100%) n: 458
Trim extreme effort num	22 (100%) n: 613	25 (100%) n: 628	29 (100%) n: 588	17 (100%) n: 593	26 (100%) n: 506	18 (100%) n: 447	17 (100%) n: 483	21 (100%) n: 413	26 (100%) n: 454
Trim extreme duration	22 (100%) n: 613	25 (100%) n: 628	29 (100%) n: 588	17 (100%) n: 593	26 (100%) n: 505	18 (100%) n: 447	17 (100%) n: 483	21 (100%) n: 412	26 (100%) n: 453
Core fleet selection	19 (86%) n: 534	22 (87%) n: 490	24 (81%) n: 474	13 (73%) n: 485	18 (68%) n: 407	14 (80%) n: 389	15 (86%) n: 429	16 (75%) n: 333	11 (41%) n: 299

Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	15 (100%) n: 504	20 (100%) n: 461	27 (100%) n: 516	24 (100%) n: 456	42 (100%) n: 467	38 (100%) n: 482	53 (100%) n: 484	49 (100%) n: 436	36 (100%) n: 410
Positive fishing duration	15 (100%) n: 504	20 (100%) n: 461	27 (100%) n: 516	24 (100%) n: 456	42 (100%) n: 467	38 (100%) n: 482	53 (100%) n: 484	49 (100%) n: 436	36 (100%) n: 410
Trim extreme effort num	15 (100%) n: 504	20 (100%) n: 460	27 (100%) n: 516	24 (100%) n: 456	42 (100%) n: 467	38 (100%) n: 482	53 (100%) n: 484	49 (100%) n: 436	36 (100%) n: 410
Trim extreme duration	15 (100%) n: 502	20 (100%) n: 460	27 (100%) n: 516	24 (100%) n: 456	42 (100%) n: 467	38 (100%) n: 480	53 (100%) n: 484	49 (100%) n: 436	36 (100%) n: 408
Core fleet selection	11 (77%) n: 353	15 (78%) n: 323	18 (66%) n: 338	18 (76%) n: 334	34 (81%) n: 360	34 (89%) n: 378	50 (94%) n: 405	47 (100%) n: 384	34 (100%) n: 366

Filter	2017	2018	2019	2020	2021
Ungroomed data	44 (100%) n: 397	65 (100%) n: 363	55 (100%) n: 299	62 (100%) n: 314	55 (100%) n: 306
Positive fishing duration	44 (100%) n: 397	65 (100%) n: 363	55 (100%) n: 299	62 (100%) n: 313	55 (100%) n: 305
Trim extreme effort num	44 (100%) n: 396	65 (100%) n: 363	55 (100%) n: 299	62 (100%) n: 313	55 (100%) n: 305
Trim extreme duration	44 (100%) n: 396	65 (100%) n: 362	55 (100%) n: 299	62 (100%) n: 312	55 (100%) n: 304
Core fleet selection	40 (91%) n: 332	63 (100%) n: 323	47 (86%) n: 249	54 (87%) n: 233	48 (88%) n: 227

Table 26: Summary of the SPO 3 BT trip Foveaux St dataset after core fleet selection. Trips caught represents the percentage of trips with rig catch.

Fishing year	Vessels	Trips	Events	Hrs	Catch (t)	Trips caught
1990	13	178	1 213	3 785.78	3.98	46.63
1991	12	204	1 348	4 116.33	4.44	45.10
1992	15	244	1 700	4 933.70	8.05	52.05
1993	19	327	2 220	6 762.50	14.24	42.51
1994	18	379	2 753	7 180.05	14.95	53.03
1995	19	362	3 098	7 874.38	8.37	49.45
1996	21	420	3 610	9 179.07	12.10	44.29
1997	19	456	3 689	9 127.98	16.71	47.59
1998	20	459	3 396	8 168.17	16.02	39.43
1999	19	534	4 085	10 141.67	19.34	59.36
2000	19	490	3 673	10 223.72	21.56	61.02
2001	19	474	4 007	10 565.57	23.87	61.39
2002	20	485	3 606	9 468.62	13.03	62.27
2003	20	407	3 064	7 627.97	17.54	68.06
2004	19	389	2 864	7 604.42	14.26	69.92
2005	19	429	3 302	8 992.15	14.55	71.10
2006	18	333	2 866	8 156.23	15.53	74.17
2007	16	299	2 855	8 539.87	10.59	74.92
2008	16	353	2 616	7 482.83	11.24	56.66
2009	14	323	2 197	6 528.88	15.46	56.97
2010	15	338	2 417	7 321.17	17.76	57.69
2011	17	334	2 153	6 899.10	18.19	60.48
2012	17	360	2 592	8 798.03	34.25	62.50
2013	16	378	2 747	9 177.30	34.42	66.93
2014	19	405	3 147	10 194.98	50.07	69.14
2015	15	384	2 927	9 548.68	47.07	67.97
2016	16	366	2 765	9 092.12	34.11	70.22
2017	16	332	2 686	8 904.55	40.41	77.11
2018	16	323	2 521	8 649.40	62.97	75.54
2019	13	249	1 989	6 582.75	47.30	81.12
2020	13	233	2 187	7 077.63	54.19	87.98
2021	13	227	2 110	7 249.05	48.33	88.55

Table 27: 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	30.00	14 599	4.70	4.70	*
+ ns(log(total_fishing_duration), 3)	3.00	13 560	11.50	6.90	*
+ vessel_key	27.00	13 125	14.70	3.20	*
+ modal_stat_area	5.00	12 841	16.60	1.90	*
+ modal_month	11.00	12 746	17.40	0.80	
+ target_species	6.00	12 648	18.10	0.70	
+ ns(log(total_effort_num), 3)	3.00	12 587	18.60	0.40	

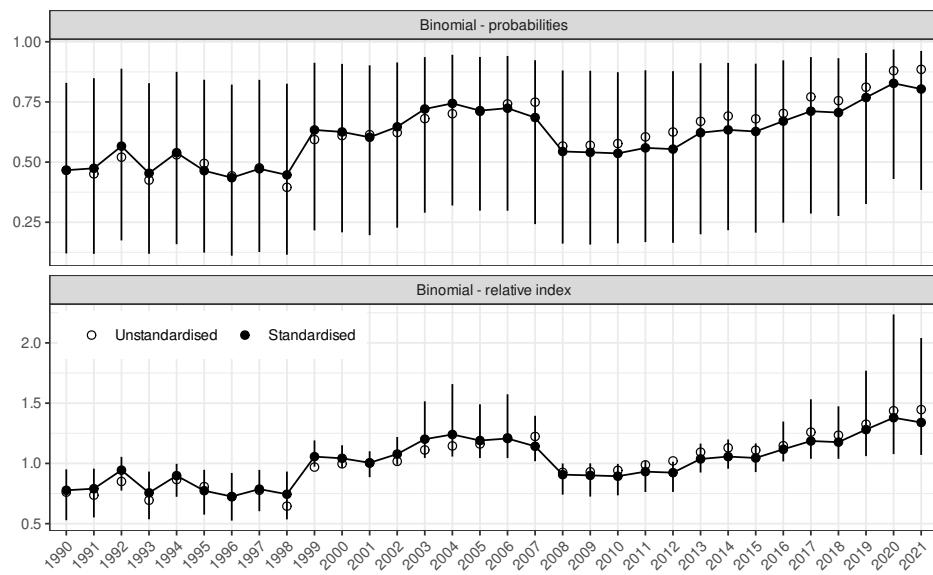


Figure 145: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 3 BT trip Foveaux St dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

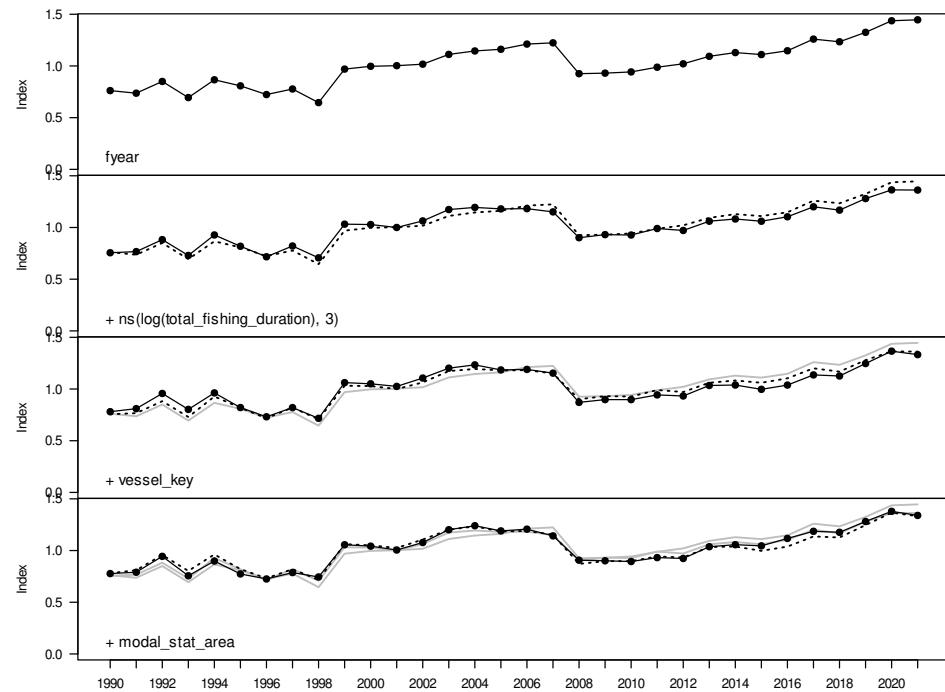


Figure 146: Step plot for occurrence of catch in the SPO 3 BT trip Foveaux St dataset.

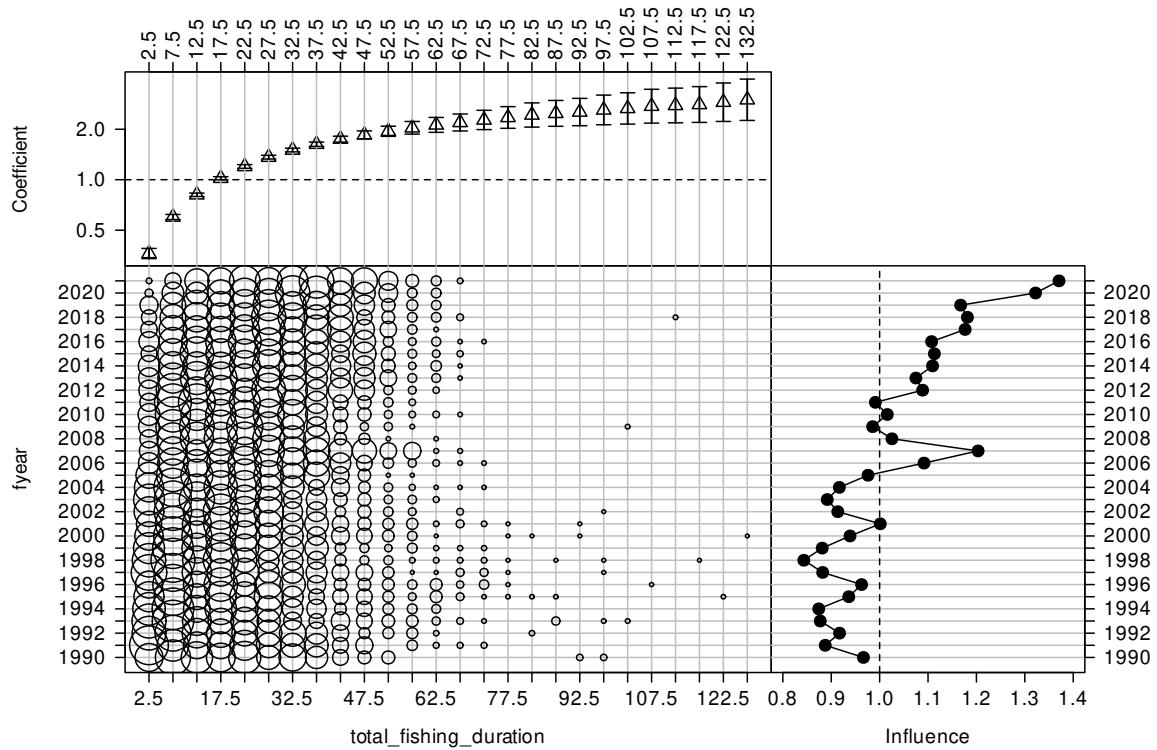


Figure 147: CDI plot for total fishing duration (h) for the occurrence of positive catch SPO 3 BT trip Foveaux St catch-per-unit-effort dataset.

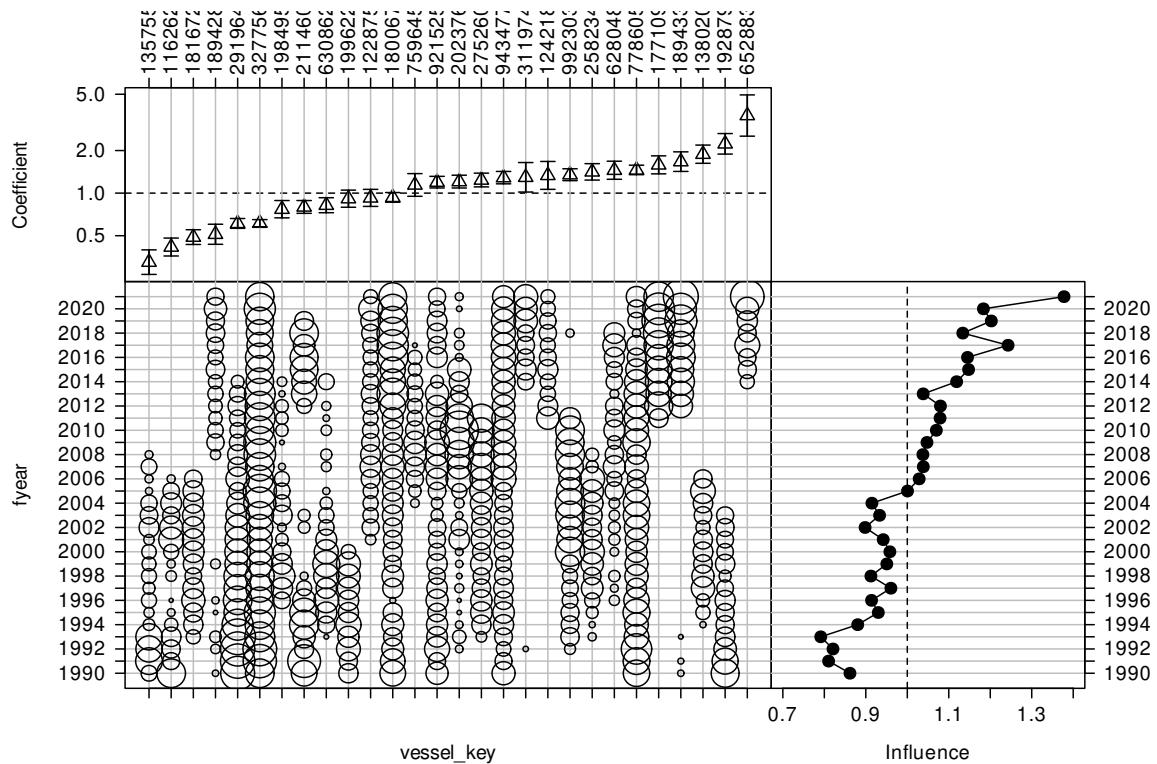


Figure 148: CDI plot for vessel key for the occurrence of positive catch SPO 3 BT trip Foveaux St catch-per-unit-effort dataset.

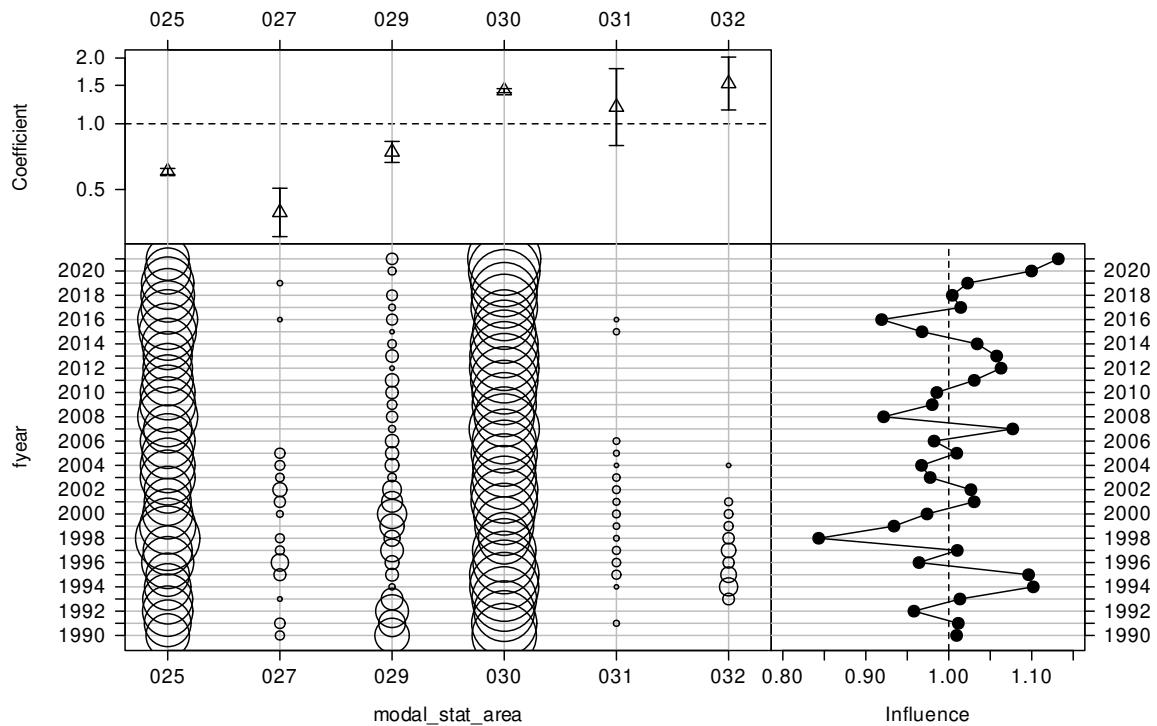


Figure 149: CDI plot for modal statistical area for the occurrence of positive catch SPO 3 BT trip Foveaux St catch-per-unit-effort dataset.

Table 28: 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	30	26 066	7.0		*
+ modal stat area	5	25 567	13.5	6.4	*
+ vessel key	27	25 210	18.3	4.9	*
+ target species	6	24 966	21.2	2.9	*
+ ns(log(total effort num), 3)	3	24 700	24.2	3.0	*
+ modal month	11	24 616	25.3	1.1	*
+ ns(log(total fishing duration), 3)	3	24 615	25.4	0.1	

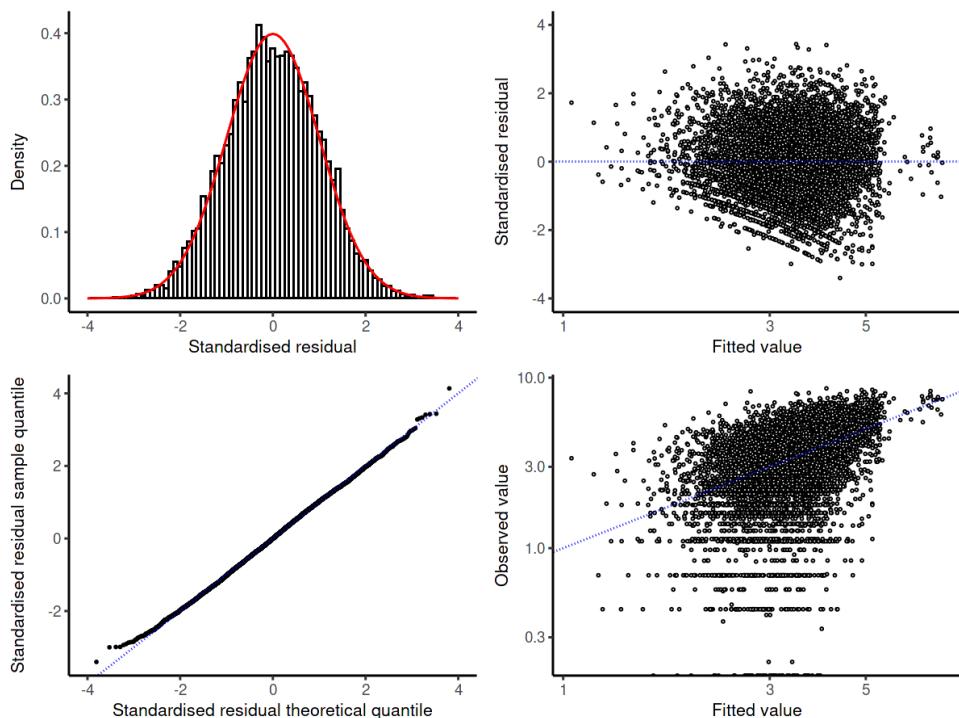


Figure 150: Diagnostic plots for the lognormal model for the SPO 3 BT trip Foveaux St dataset.

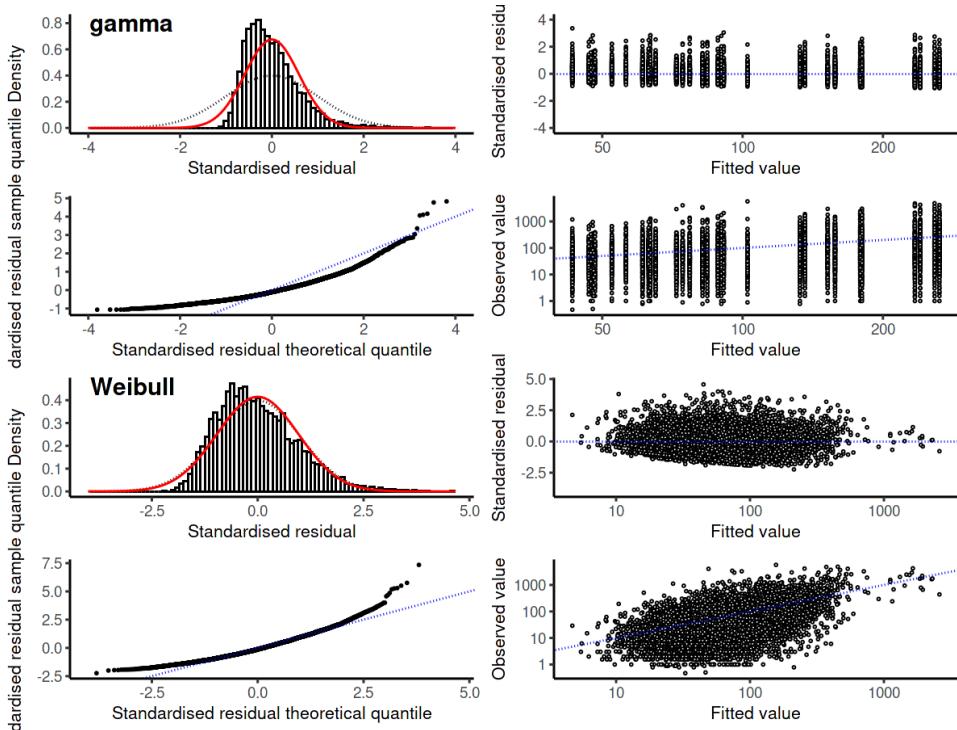


Figure 151: Diagnostic plots for the gamma and Weibull model for the SPO 3 BT trip Foveaux St dataset.

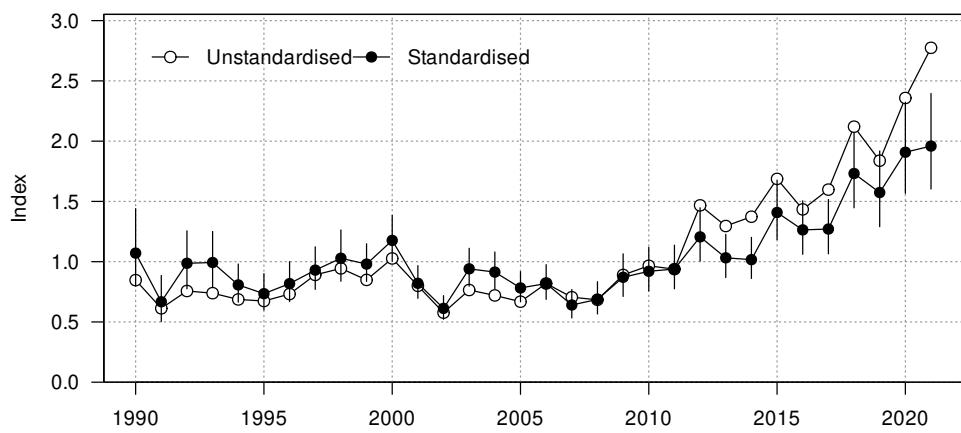


Figure 152: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 3 BT trip Foveaux St dataset.

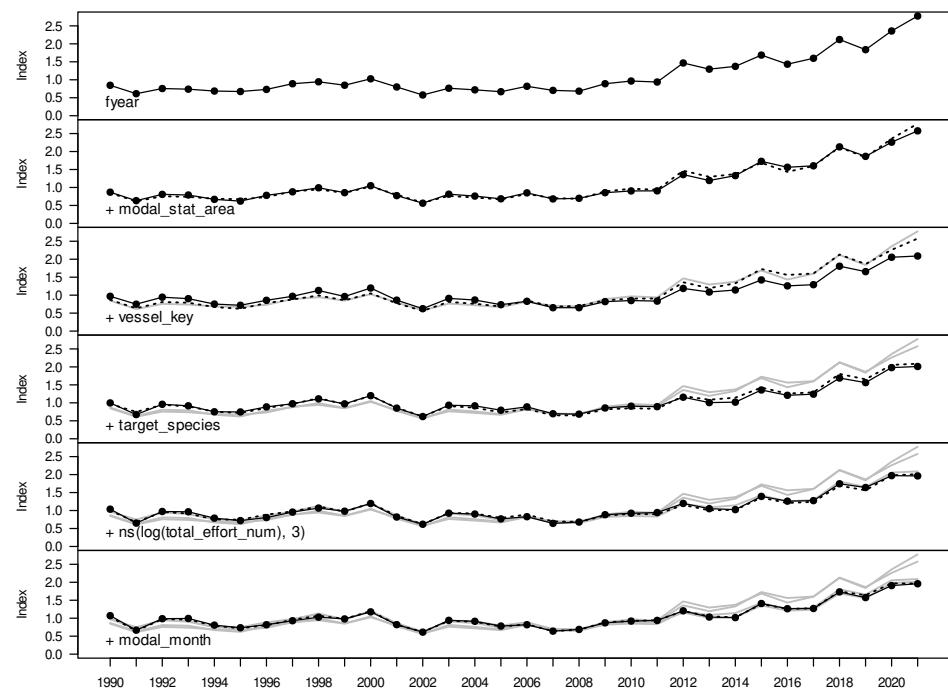


Figure 153: Changes to the SPO 3 BT trip Foveaux St positive catch index as terms are successively entered into the model.

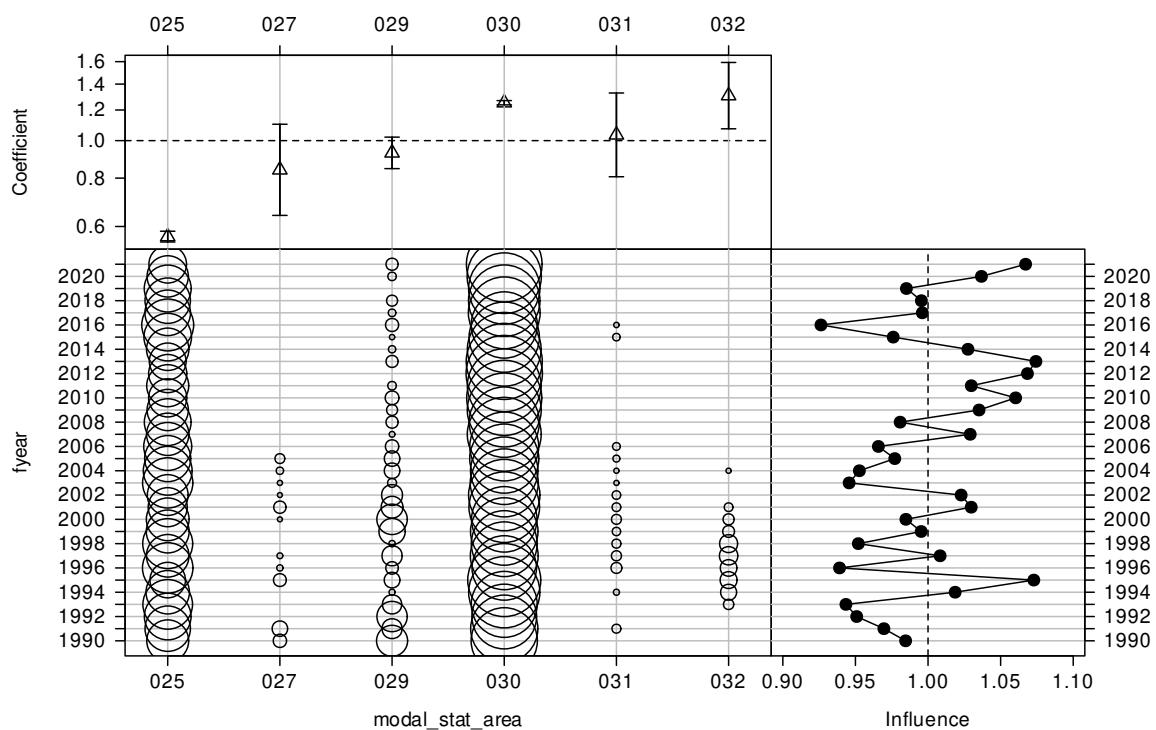


Figure 154: CDI plot for modal statistical area for the positive catch SPO 3 BT trip Foveaux St catch-per-unit-effort dataset.

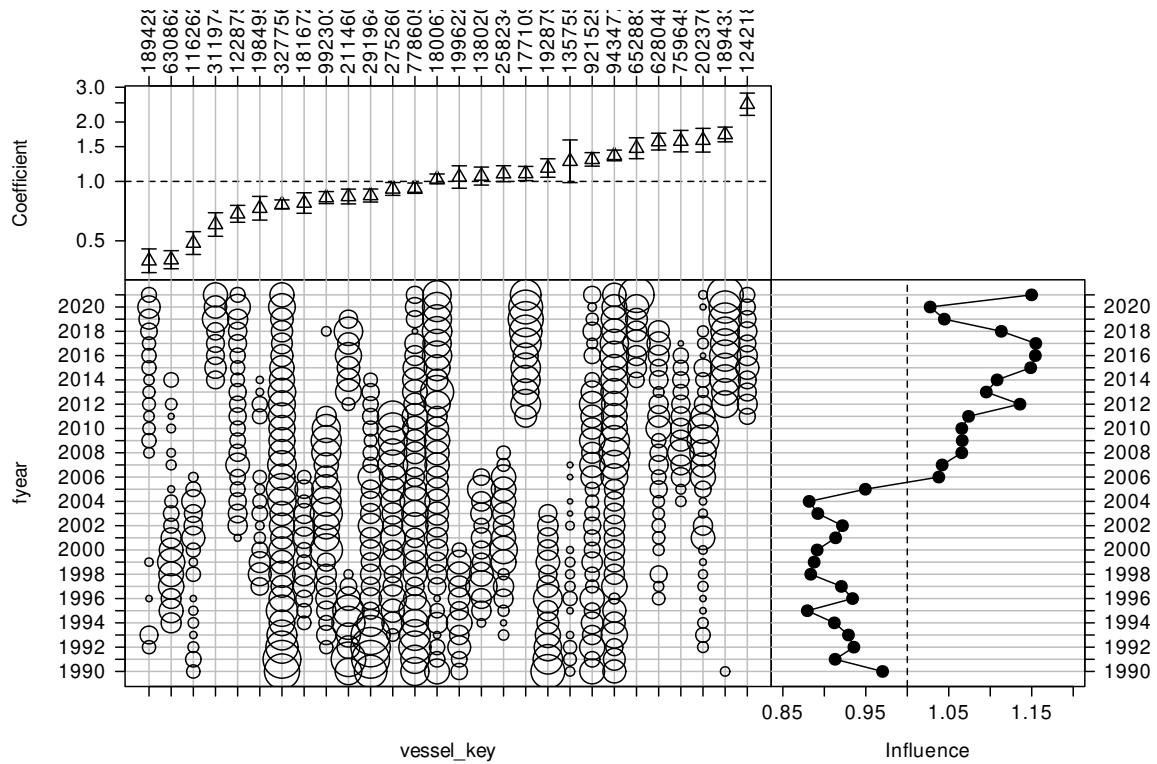


Figure 155: CDI plot for vessel key for the positive catch SPO 3 BT trip Foveaux St catch-per-unit-effort dataset.

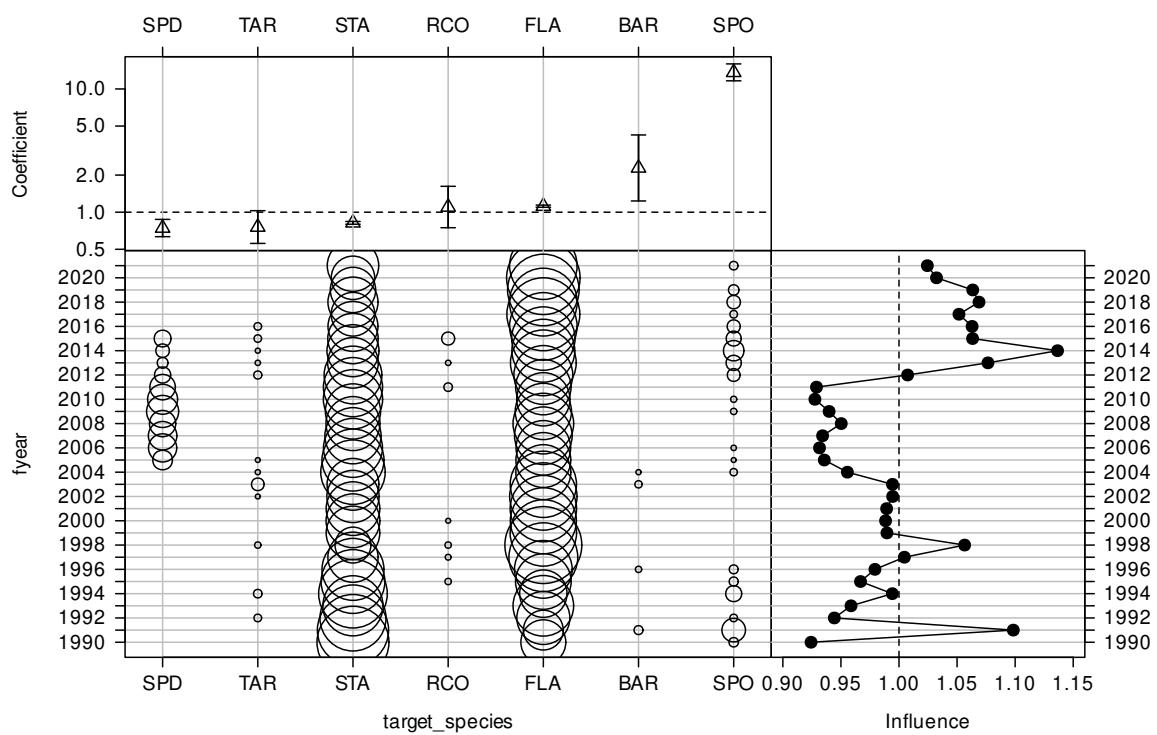


Figure 156: CDI plot for target species for the positive catch SPO 3 BT trip Foveaux St catch-per-unit-effort dataset.

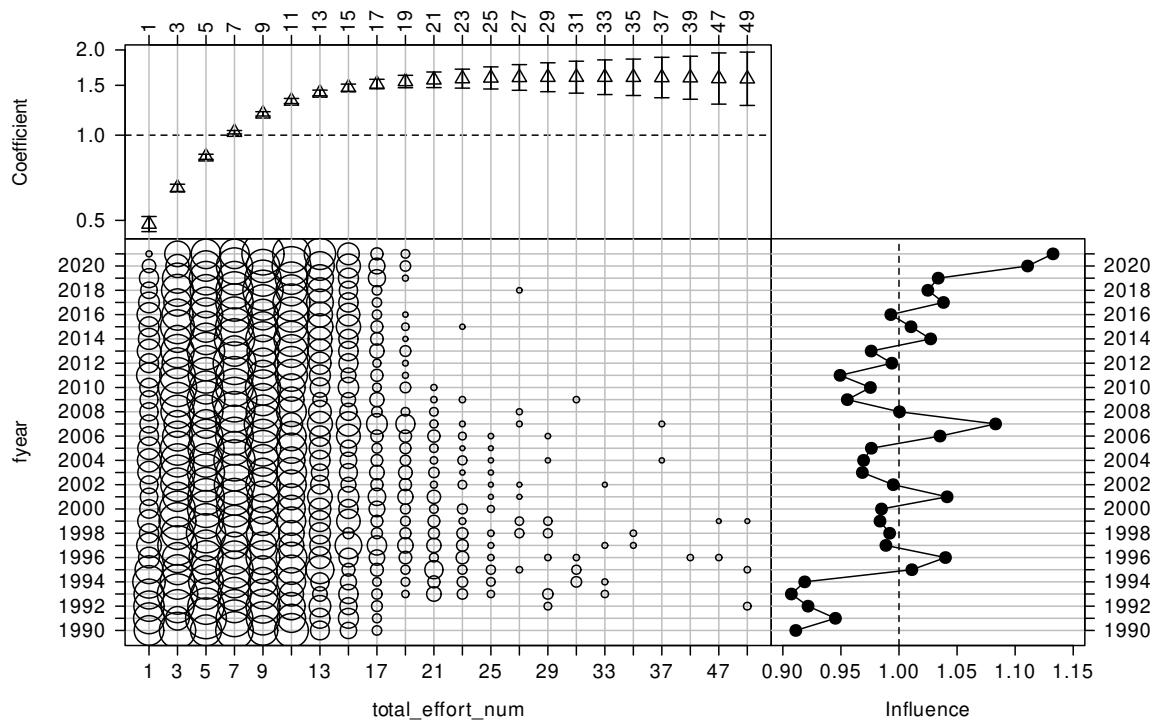


Figure 157: CDI plot for total effort num for the positive catch SPO 3 BT trip Foveaux St catch-per-unit-effort dataset.

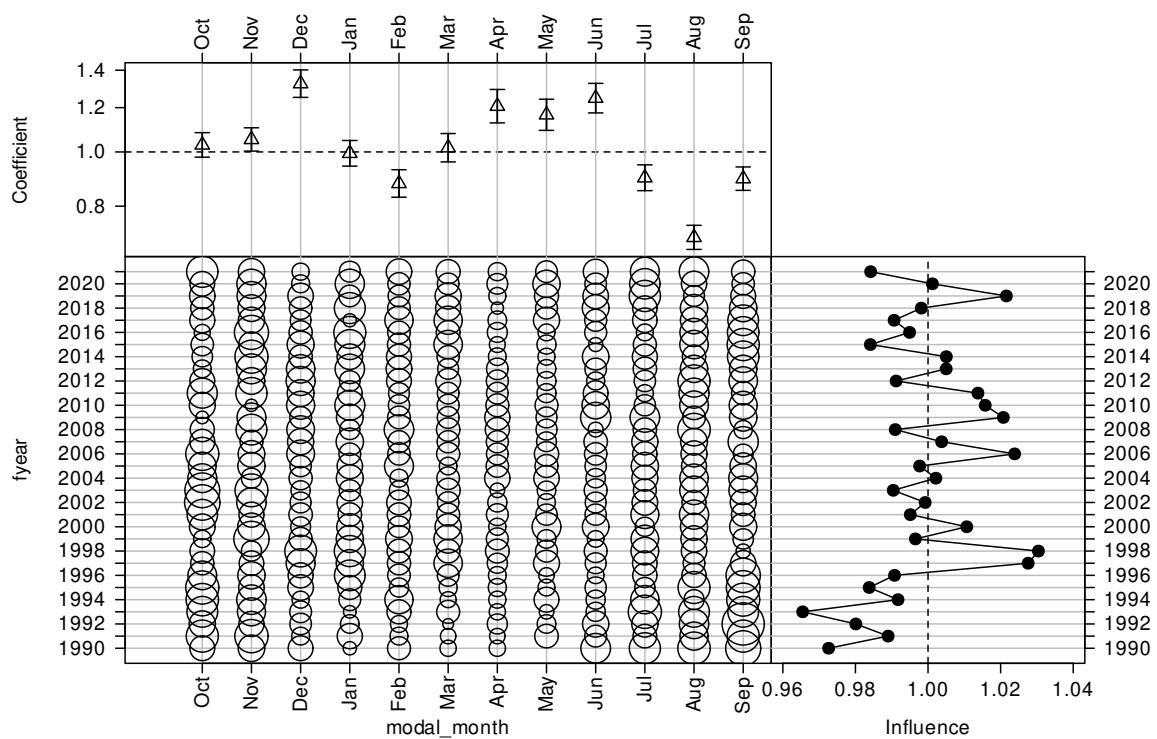


Figure 158: CDI plot for modal month for the positive catch SPO 3 BT trip Foveaux St catch-per-unit-effort dataset.

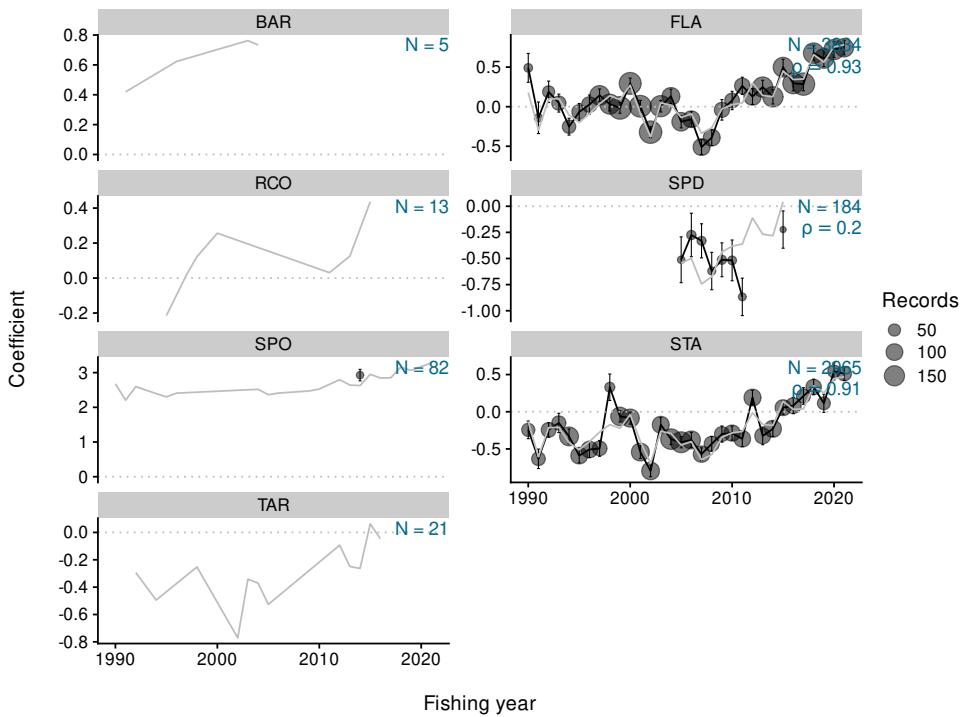


Figure 159: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 3 BT trip Foveaux St dataset.

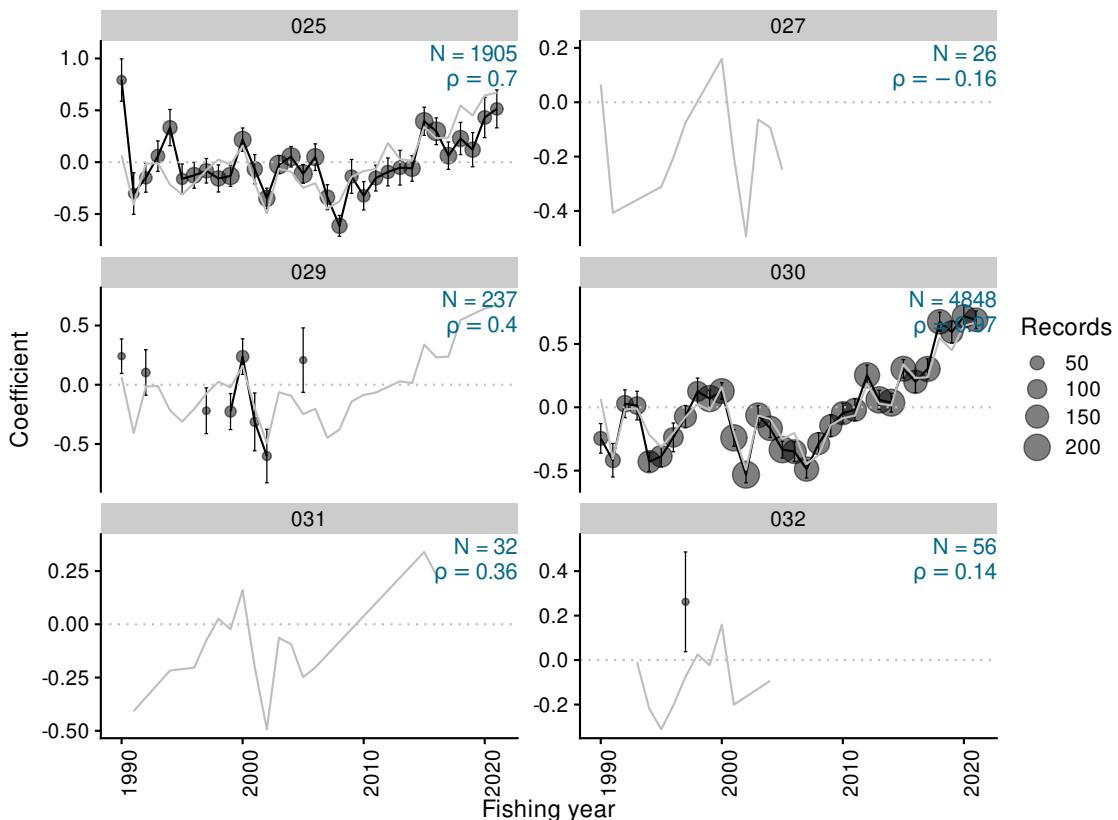


Figure 160: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 3 BT trip Foveaux St dataset.

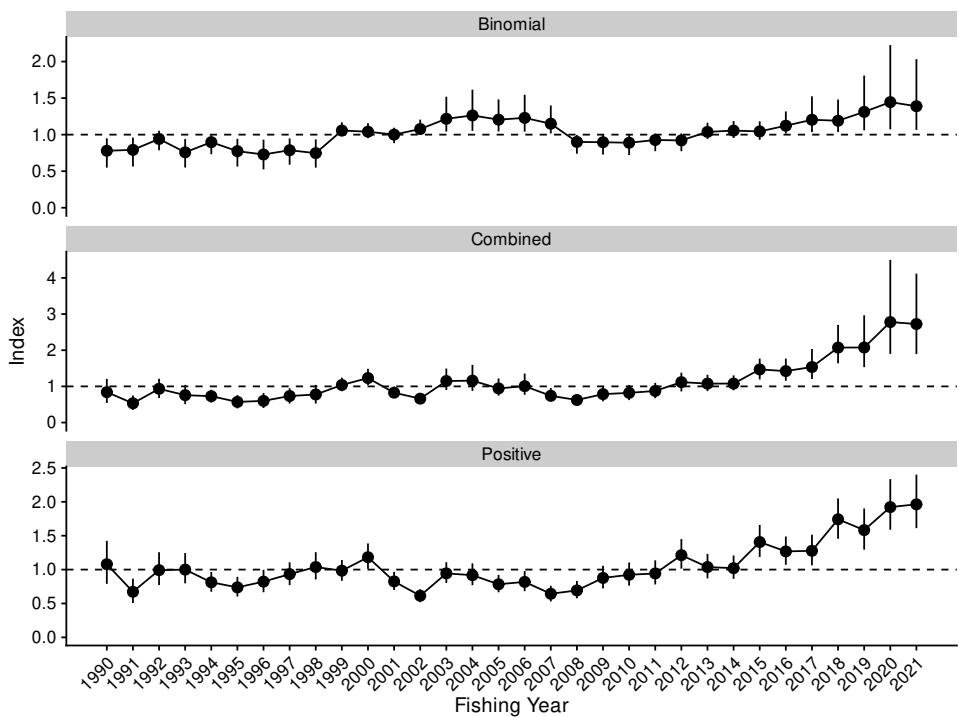


Figure 161: Standardised indices and 95% confidence intervals for the SPO 3 BT trip Foveaux St dataset.

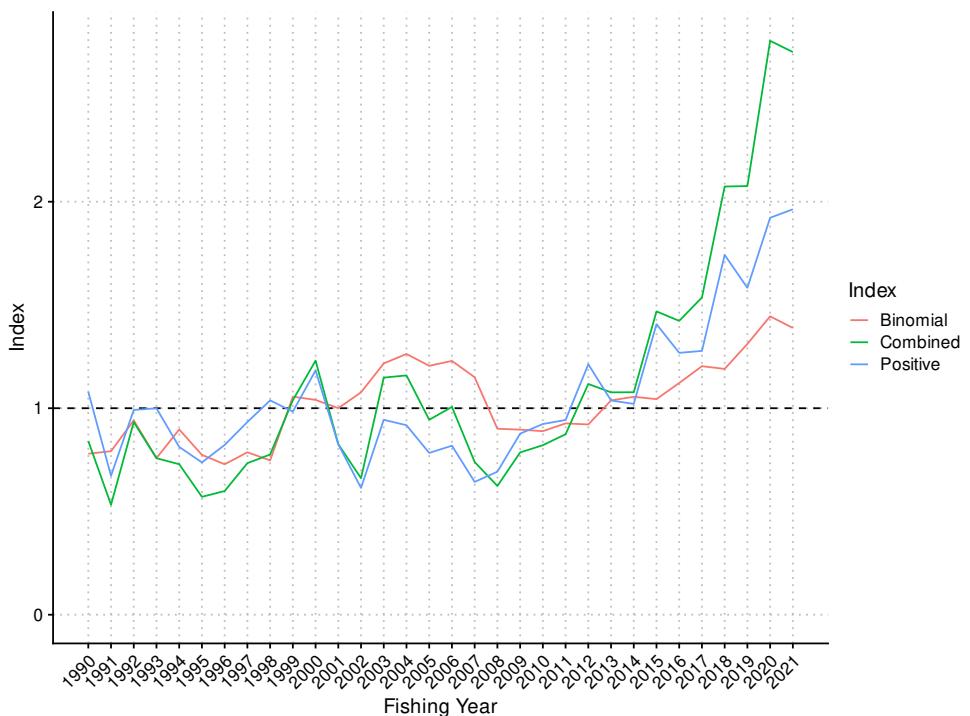


Figure 162: Standardised indices for the SPO 3 BT trip Foveaux St dataset.

Table 29: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 3 BT trip Foveaux St.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.780	0.102	0.549	0.950	0.841	0.170	0.541	1.206	1.079	0.162	0.790	1.425
1991	0.792	0.101	0.563	0.959	0.532	0.102	0.350	0.748	0.673	0.092	0.506	0.866
1992	0.941	0.068	0.786	1.053	0.933	0.136	0.678	1.212	0.992	0.124	0.772	1.256
1993	0.758	0.099	0.550	0.940	0.758	0.136	0.510	1.042	1.000	0.114	0.797	1.245
1994	0.897	0.066	0.733	0.992	0.729	0.090	0.553	0.907	0.812	0.074	0.673	0.965
1995	0.774	0.097	0.563	0.943	0.571	0.094	0.391	0.759	0.738	0.074	0.603	0.894
1996	0.729	0.104	0.525	0.931	0.599	0.106	0.403	0.818	0.822	0.084	0.666	0.996
1997	0.787	0.092	0.589	0.948	0.734	0.109	0.525	0.951	0.933	0.086	0.771	1.108
1998	0.747	0.098	0.549	0.934	0.776	0.132	0.525	1.042	1.038	0.102	0.855	1.256
1999	1.056	0.049	0.977	1.169	1.039	0.096	0.866	1.242	0.984	0.078	0.834	1.142
2000	1.040	0.052	0.952	1.157	1.230	0.116	1.032	1.486	1.183	0.096	1.011	1.386
2001	1.000	0.054	0.884	1.095	0.826	0.080	0.681	0.993	0.825	0.068	0.699	0.968
2002	1.077	0.053	0.997	1.205	0.661	0.061	0.550	0.788	0.614	0.049	0.520	0.711
2003	1.217	0.122	1.042	1.519	1.148	0.152	0.900	1.494	0.944	0.078	0.803	1.109
2004	1.263	0.144	1.052	1.615	1.159	0.184	0.875	1.596	0.917	0.082	0.770	1.091
2005	1.205	0.112	1.044	1.482	0.944	0.121	0.745	1.221	0.783	0.065	0.665	0.921
2006	1.229	0.129	1.041	1.546	1.006	0.150	0.768	1.354	0.818	0.076	0.682	0.979
2007	1.150	0.098	1.017	1.399	0.739	0.094	0.584	0.954	0.643	0.059	0.529	0.762
2008	0.901	0.066	0.739	0.996	0.624	0.075	0.480	0.775	0.693	0.065	0.577	0.833
2009	0.896	0.069	0.728	0.997	0.786	0.101	0.589	0.984	0.877	0.085	0.722	1.056
2010	0.889	0.070	0.720	0.996	0.821	0.107	0.621	1.041	0.923	0.087	0.763	1.105
2011	0.927	0.061	0.774	1.014	0.874	0.108	0.673	1.097	0.943	0.091	0.781	1.137
2012	0.921	0.062	0.774	1.016	1.117	0.132	0.861	1.379	1.213	0.111	1.014	1.450
2013	1.038	0.057	0.941	1.164	1.077	0.115	0.870	1.321	1.038	0.092	0.871	1.231
2014	1.055	0.059	0.954	1.185	1.077	0.105	0.891	1.304	1.021	0.088	0.864	1.208
2015	1.044	0.064	0.929	1.182	1.469	0.147	1.193	1.769	1.407	0.121	1.186	1.659
2016	1.122	0.077	1.015	1.318	1.423	0.156	1.155	1.768	1.268	0.106	1.071	1.488
2017	1.203	0.125	1.035	1.524	1.536	0.212	1.204	2.033	1.277	0.115	1.063	1.515
2018	1.190	0.114	1.035	1.480	2.074	0.271	1.639	2.701	1.742	0.152	1.455	2.050
2019	1.311	0.191	1.059	1.808	2.076	0.366	1.533	2.966	1.583	0.155	1.295	1.902
2020	1.445	0.294	1.073	2.226	2.779	0.663	1.898	4.499	1.922	0.191	1.588	2.335
2021	1.389	0.247	1.065	2.033	2.725	0.567	1.896	4.119	1.963	0.201	1.612	2.401

5.6 SPO 7 BT trip

This series was based on the trip bycatch of rig from the west coast South Island BT mixed target species fishery. The analysis included twelve South Island statistical areas, based on the spatial extent of the combined SPO 7 and SPO 8 QMAs: Statistical Areas 016, 017, 018 (eastern Cook Strait), 032–036 (west coast South Island), 037 (Cape Farewell), 038 (Tasman/Golden bays), 039 (South Taranaki Bight), 040 (North Taranaki Bight) (Table 30). The eastern Cook Strait statistical areas are part of the SPO 7 spatial definition and Statistical Areas 016 (with SPO 2), 018 (with SPO 3), 032 (with SPO 3), 040 (with SPO 1W) are shared with adjacent SPO QMAs as indicated. The target species suite included generic flatfish (FLA), tarakihi (TAR), red cod (RCO), barracouta (BAR), snapper (SNA), red gurnard (GUR), trevally (TRE), common warehou (WAR) and rig (SPO). The core fleet was defined by having fished at least five trips in each of ten years, retaining 85% of the catch and reducing the fleet from about 350 vessels to 103 vessels (Figure 163). The pattern of vessel participation in this fishery was characterised by a large number of vessels which remained in the fishery for 20 years or more (Figure 164). The final groomed dataset represented 52% (1992) to 100% (2012–2015) of the annual ungroomed catch (Table 31). The total annual bycatch of rig in the defined fishery ranged from 43.6 t (in 1992) to 184 t (in 2021) over the 32 years in the data set and was characterised by an increasing occurrence of rig in the trip landings, ranging from 53% (in 1991) to 98% (in 2021) (Table 32).

The binomial (occurrence) model accepted three predictive variables after fishing year (vessel, total_fishing_duration, month), with the model explaining 30% of the deviance (Table 33). Both the unstandardised and standardised series showed a gradually increasing trend from early 1990s to 2021, with the last two fishing years (2020 and 2021) characterised by considerable uncertainty in these standardised indices (Figure 165). The overall trend did not change very much from the unstandardised series, although the standardised indices lay above the unstandardised indices in the 1990s and below the unstandardised indices from the mid-2000s to the end of the 2010s; both series converged in 2020 and 2021 (Figure 165). All this shift occurred with the addition of the vessel covariate (Figure 166) with the vessel CDI plot showing a pattern of contrast over time coincident with the shift seen in the annual occurrence indices (Figure 167). The remaining two accepted covariates (total_fishing_duration: Figure 168, month: Figure 169) had no impact on the annual occurrence indices (Figure 166).

The lognormal model accepted the same three predictive variables in the same order after fishing year (vessel, total_fishing_duration and month) as did the binomial model, with the total model explaining 47% of the deviance (Table 34). The lognormal model showed some slight skewness to the right of the mode in the residual distribution, but overall there was good conformity to the lognormal assumption, even in the tails (Figure 170). Both the gamma and the Weibull distributions showed reasonable fits to the positive catch data but neither was better than seen for the lognormal model (Figure 171). The unstandardised and the standardised series showed little trend up to 2012, after which both series showed strong increases, particularly the unstandardised series (Figure 172). The standardisation effect came with the addition of the vessel covariate (Figure 173), which reduced the steepness of the increasing trend in 2019, 2020 and 2021 (Figure 174, see Figure 173). The other two covariates (total_fishing_duration: Figure 175; month: Figure 176) resulted in almost no standardisation effect (see Figure 173). Implied residual plots of rig annual CPUE showed good conformity with the overall annual CPUE trend across the five target species with data (FLA, TAR, GUR, SNA, WAR) (Figure 177). The other two target species (SPO, TRE) had almost no observations in this data set. The conformity with the overall annual CPUE trend was surprisingly good for most of the statistical areas, including the eastern Cook Strait Statistical Areas (016, 017, 018), the west coast of the South Island (033, 034, 35), Tasman/Golden bays (038) and South Taranaki Bight (039) (Figure 178). In general, the statistical areas with the lesser amount of data were the areas that lacked correspondence with the overall model CPUE trend.

As seen for the SPO 3 Foveaux Strait BT model, both contributing models (lognormal and binomial) showed little trend over the first 20+ years of the series (up to about 2012), being near to or below the long-term average (Figure 179, Figure 180, Table 35). Both series then increased, with the lognormal model increasing more steeply than the binomial series. As seen in both SPO 3 BT series, these increasing trends

resulted in a strongly increasing combined model, rising to a level greater than either of the contributing series given the multiplicative nature of the delta-lognormal function. A comparison of this series with the equivalent series calculated in 2019 (Starr & Kendrick 2020) shows that this series matches that series closely in the overlapping years, but that the strong increase seen in this series had not begun three years ago (Figure 281).

Table 30: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 7 BT trip CPUE series.

Series	SPO 7 BT trip
QMS stock	SPO7
Reporting forms	CEL, ERS - Trawl, TCE, TCP
Fishing methods	BT
Target species	FLA, RCO, SPO, BAR, TAR, GUR, TRE, SNA, WAR
Statistical Areas	016, 017, 018, 032, 033, 034, 035, 036, 037, 038, 039, 040
Period	1989-10-01, 2021-09-30
Resolution	Trip
Core fleet years	10
Core fleet trips	5
Default model	$\text{landkg} \sim \text{fyear} + \text{vessel_key} + \text{modal_stat_area} + \text{modal_month} + \text{target_species} + \text{ns}(\log(\text{total_fishing_duration}), 3) + \text{ns}(\log(\text{total_effort_num}), 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

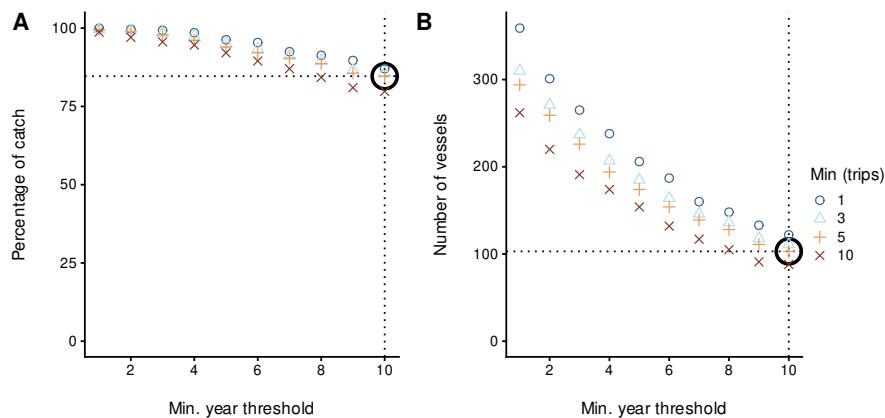


Figure 163: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 7 BT trip CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

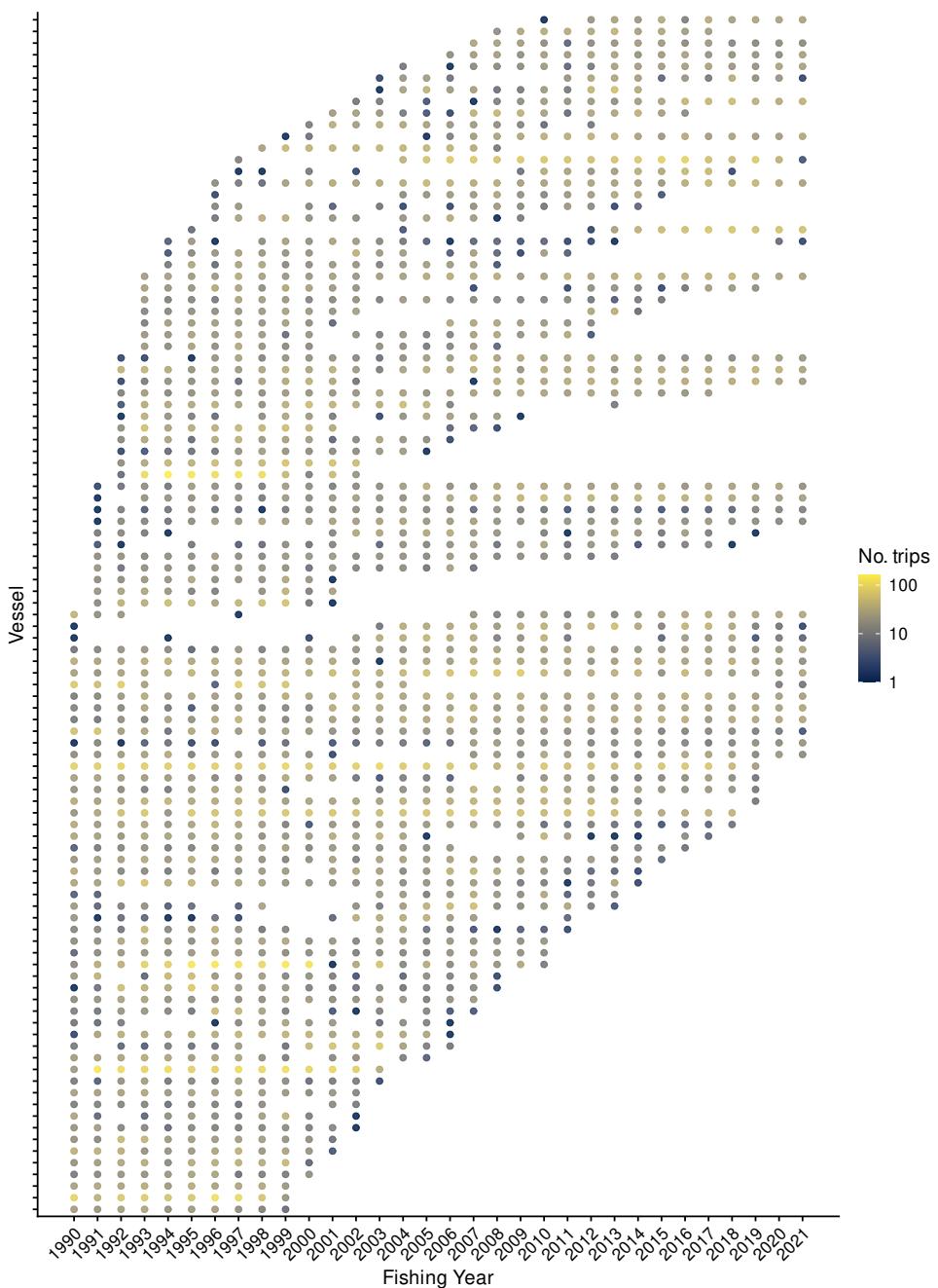


Figure 164: Number of trips by fishing year for core vessels. The colour of the points is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 31: Summary of the SPO 7 BT trip 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	95 (100%) n: 2506	80 (100%) n: 2589	83 (100%) n: 2687	108 (100%) n: 3685	108 (100%) n: 3129	145 (100%) n: 3450	135 (100%) n: 3257	170 (100%) n: 3343	102 (100%) n: 2811
Positive fishing duration	94 (100%) n: 2495	80 (100%) n: 2584	83 (100%) n: 2683	108 (100%) n: 3684	108 (100%) n: 3124	145 (100%) n: 3446	134 (100%) n: 3229	169 (100%) n: 3320	102 (100%) n: 2795
Core fleet selection	55 (58%) n: 1162	45 (56%) n: 1255	44 (52%) n: 1619	71 (65%) n: 2164	68 (63%) n: 1836	97 (67%) n: 2108	104 (77%) n: 2222	126 (74%) n: 2361	84 (82%) n: 2116
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	145 (100%) n: 2737	139 (100%) n: 2076	155 (100%) n: 2033	143 (100%) n: 2006	115 (100%) n: 1938	116 (100%) n: 2044	116 (100%) n: 1986	116 (100%) n: 1885	113 (100%) n: 2000
Positive fishing duration	144 (100%) n: 2725	139 (100%) n: 2074	155 (100%) n: 2033	143 (100%) n: 2006	115 (100%) n: 1938	116 (100%) n: 2044	116 (100%) n: 1986	116 (100%) n: 1885	113 (100%) n: 1999
Core fleet selection	129 (89%) n: 2266	123 (88%) n: 1716	143 (92%) n: 1682	122 (85%) n: 1519	95 (83%) n: 1504	97 (84%) n: 1631	94 (81%) n: 1580	98 (84%) n: 1546	103 (92%) n: 1788
Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	137 (100%) n: 1510	129 (100%) n: 1497	135 (100%) n: 1717	131 (100%) n: 1345	128 (100%) n: 1455	150 (100%) n: 1481	162 (100%) n: 1375	163 (100%) n: 1204	170 (100%) n: 1380
Positive fishing duration	137 (100%) n: 1510	129 (100%) n: 1497	135 (100%) n: 1717	131 (100%) n: 1345	128 (100%) n: 1455	150 (100%) n: 1481	162 (100%) n: 1375	163 (100%) n: 1204	170 (100%) n: 1380
Core fleet selection	122 (89%) n: 1417	114 (89%) n: 1369	122 (91%) n: 1523	118 (90%) n: 1228	122 (100%) n: 1324	146 (100%) n: 1382	157 (100%) n: 1240	158 (100%) n: 1072	159 (93%) n: 1228

Filter	2017	2018	2019	2020	2021
Ungroomed data	169 (100%) n: 1397	172 (100%) n: 1299	196 (100%) n: 1103	208 (100%) n: 978	224 (100%) n: 902
Positive fishing duration	169 (100%) n: 1397	172 (100%) n: 1299	196 (100%) n: 1103	208 (100%) n: 978	224 (100%) n: 902
Core fleet selection	160 (95%) n: 1191	161 (94%) n: 1013	177 (90%) n: 853	174 (84%) n: 747	184 (82%) n: 669

Table 32: Summary of the SPO 7 BT trip dataset after core fleet selection. Trips caught represents the percentage of trips with rig catch.

Fishing year	Vessels	Trips	Events	Hrs	Catch (t)	Trips caught
1990	52	1 162	8 488	22 856.00	54.72	59.81
1991	60	1 255	9 533	25 806.67	44.53	53.78
1992	68	1 619	12 549	36 243.98	43.58	52.87
1993	75	2 164	17 790	50 440.85	70.54	56.79
1994	77	1 836	14 434	37 522.73	67.82	55.34
1995	78	2 108	15 551	42 615.43	96.77	60.39
1996	81	2 222	18 265	51 193.40	103.81	57.97
1997	81	2 361	21 352	57 553.58	126.43	57.86
1998	81	2 116	16 774	46 827.78	84.04	57.28
1999	80	2 266	19 226	55 420.77	128.75	64.65
2000	74	1 716	15 056	45 235.03	123.11	71.45
2001	73	1 682	15 202	51 298.20	143.14	72.12
2002	69	1 519	13 958	45 678.17	121.64	69.85
2003	67	1 504	13 841	47 455.18	95.00	69.81
2004	70	1 631	15 773	53 477.75	97.07	76.39
2005	68	1 580	15 543	53 288.00	94.15	70.76
2006	70	1 546	14 783	51 210.72	98.06	71.93
2007	68	1 788	17 014	58 728.37	103.17	68.12
2008	64	1 417	13 478	50 585.44	121.64	71.56
2009	60	1 369	13 177	49 620.75	114.31	71.22
2010	60	1 523	14 742	51 722.09	121.88	73.47
2011	58	1 228	12 787	45 306.49	118.05	77.61
2012	58	1 324	13 582	49 422.23	121.62	77.19
2013	57	1 382	14 002	50 219.33	146.25	80.10
2014	52	1 240	12 727	47 415.63	156.84	84.52
2015	46	1 072	11 042	40 936.32	158.13	86.57
2016	44	1 228	12 318	45 938.32	158.87	86.07
2017	42	1 191	11 397	43 908.47	160.16	86.23
2018	38	1 013	10 180	39 085.99	161.15	83.91
2019	36	853	9 199	36 342.03	177.02	91.32
2020	32	747	7 798	31 841.23	174.29	96.65
2021	32	669	7 399	29 774.03	183.96	98.21

Table 33: 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	30.00	56 300	5.40	5.40	*
+ vessel_key	102.00	45 835	23.40	17.90	*
+ ns(log(total_fishing_duration), 3)	3.00	43 442	27.40	4.00	*
+ modal_month	11.00	42 153	29.60	2.20	*
+ target_species	8.00	41 914	30.00	0.40	
+ modal_stat_area	11.00	41 738	30.40	0.30	
+ ns(log(total_effort_num), 3)	3.00	41 616	30.60	0.20	

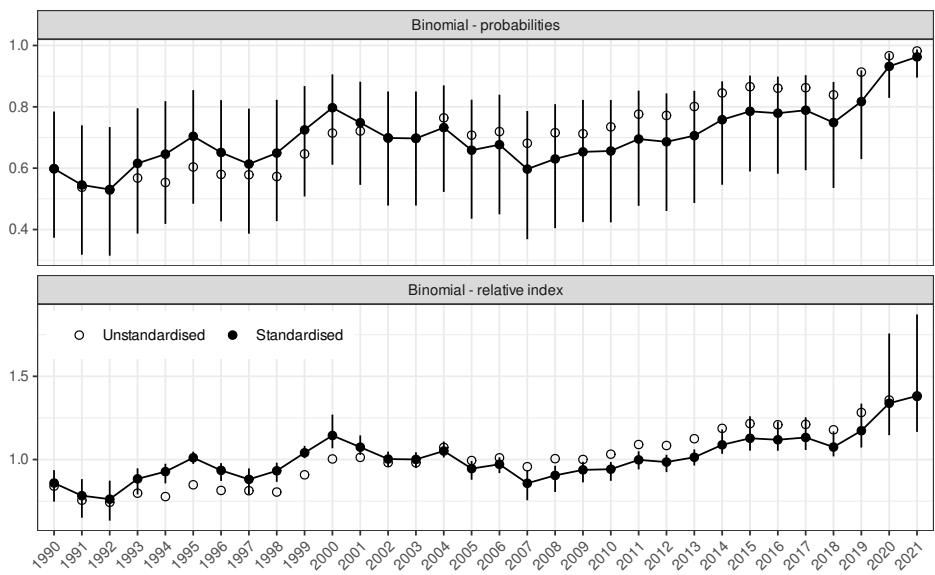


Figure 165: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 7 BT trip dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

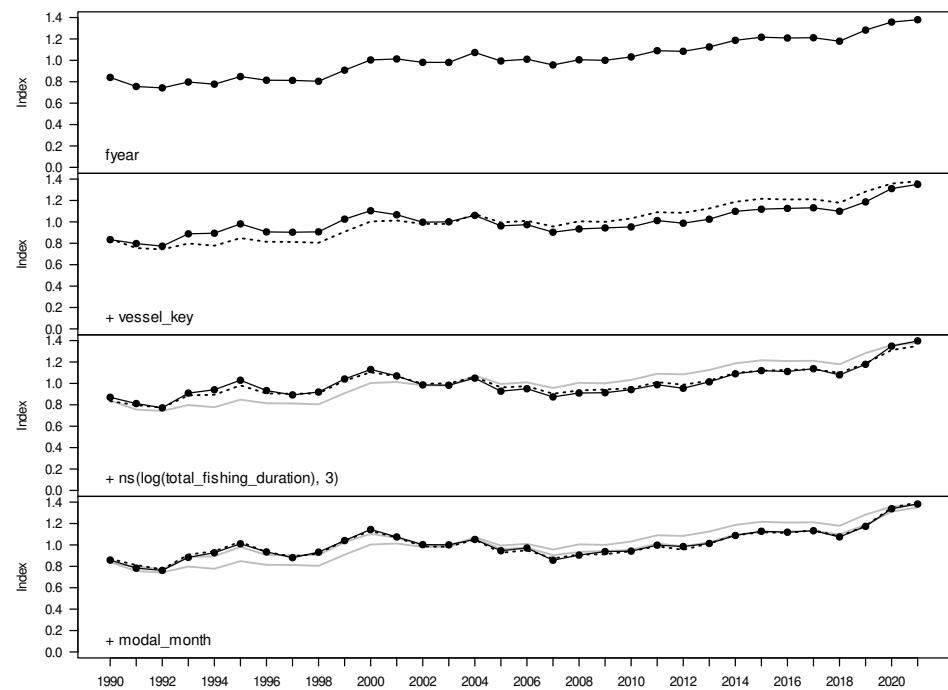


Figure 166: Step plot for occurrence of catch in the SPO 7 BT trip dataset.

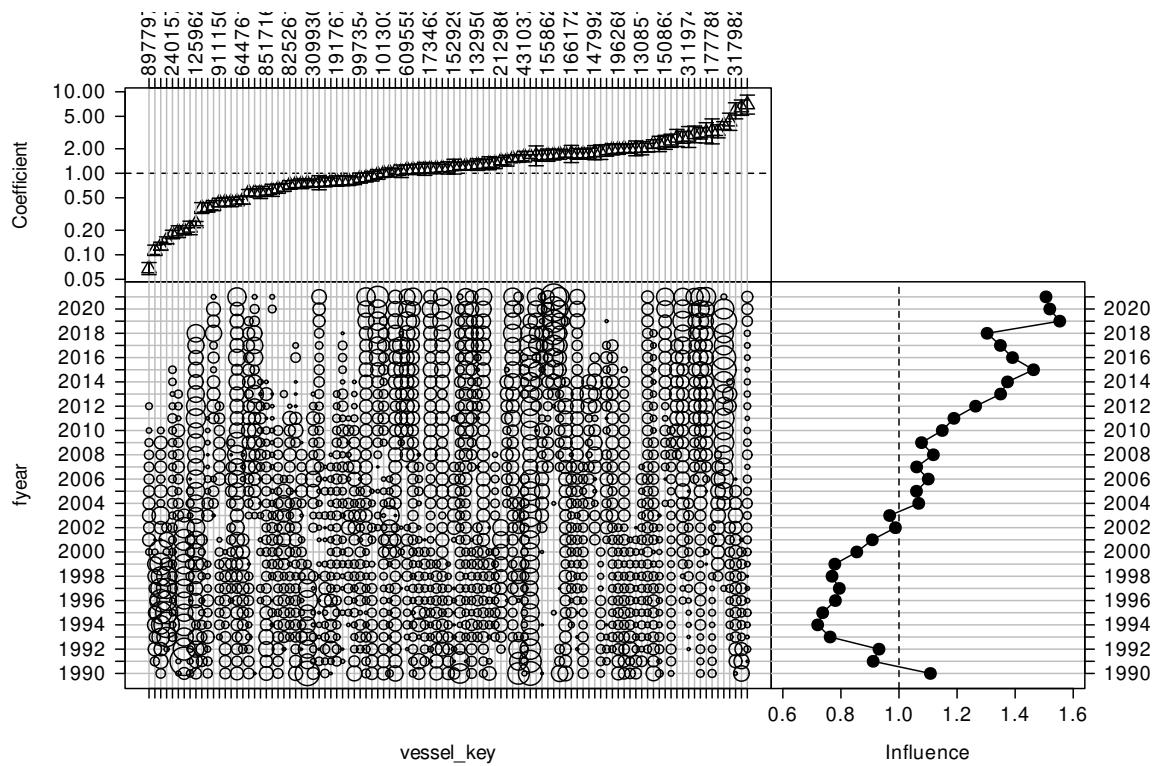


Figure 167: CDI plot for vessel key for the occurrence of positive catch SPO 7 BT trip catch-per-unit-effort dataset.

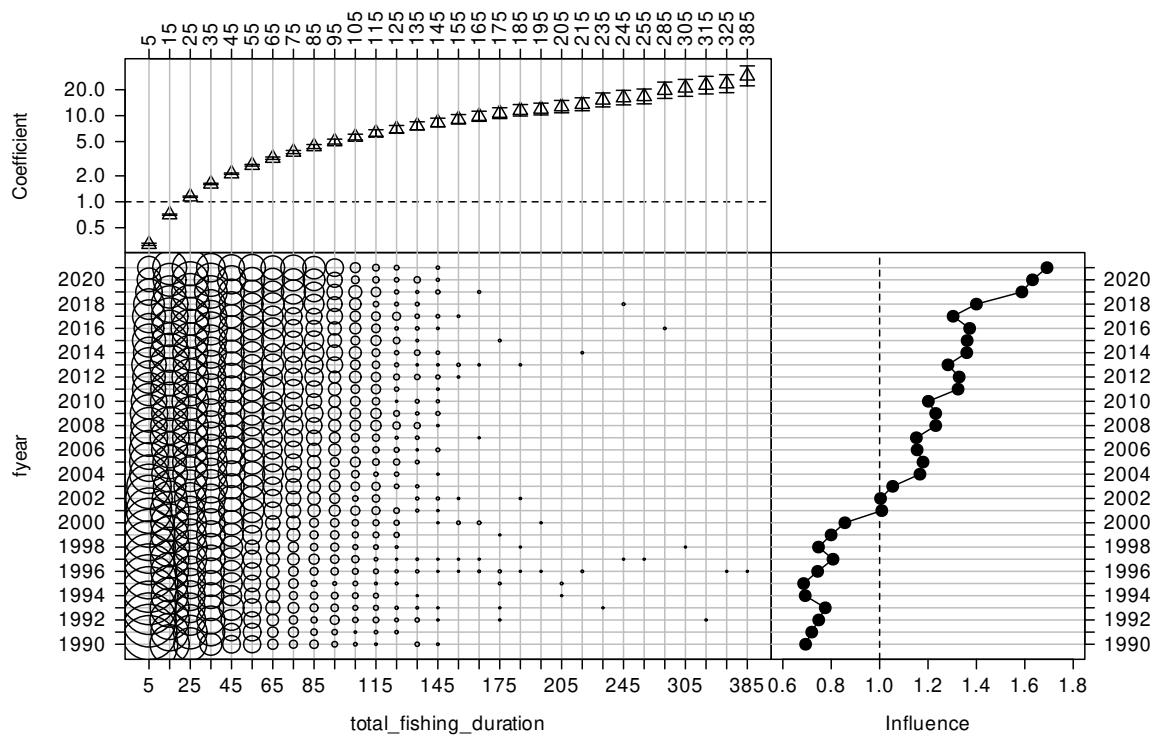


Figure 168: CDI plot for total fishing duration (h) for the occurrence of positive catch SPO 7 BT trip catch-per-unit-effort dataset.

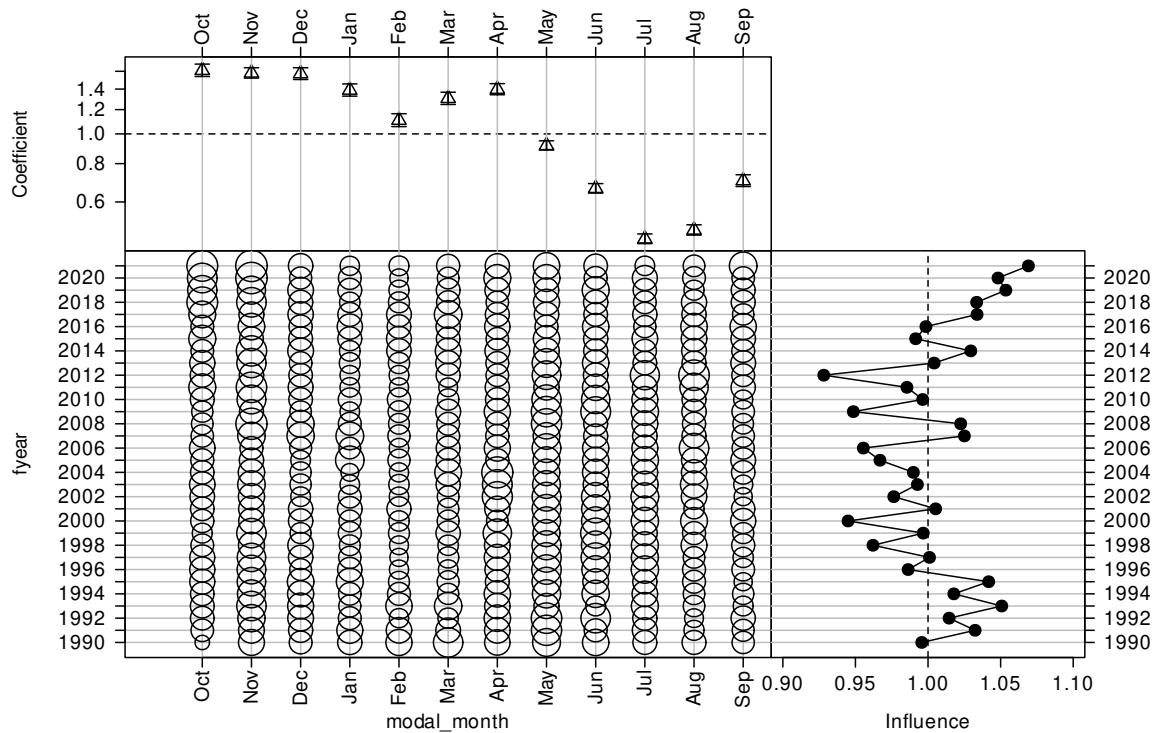


Figure 169: CDI plot for modal month for the occurrence of positive catch SPO 7 BT trip catch-per-unit-effort dataset.

Table 34: 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	30	123 502	8.3	8.3	*
+ vessel key	102	110 926	37.4	29.0	*
+ ns(log(total fishing duration), 3)	3	106 930	44.4	7.0	*
+ modal month	11	105 582	46.6	2.2	*
+ target species	8	105 115	47.4	0.8	
+ modal stat area	11	104 809	47.9	0.5	
+ ns(log(total effort num), 3)	3	104 525	48.3	0.4	

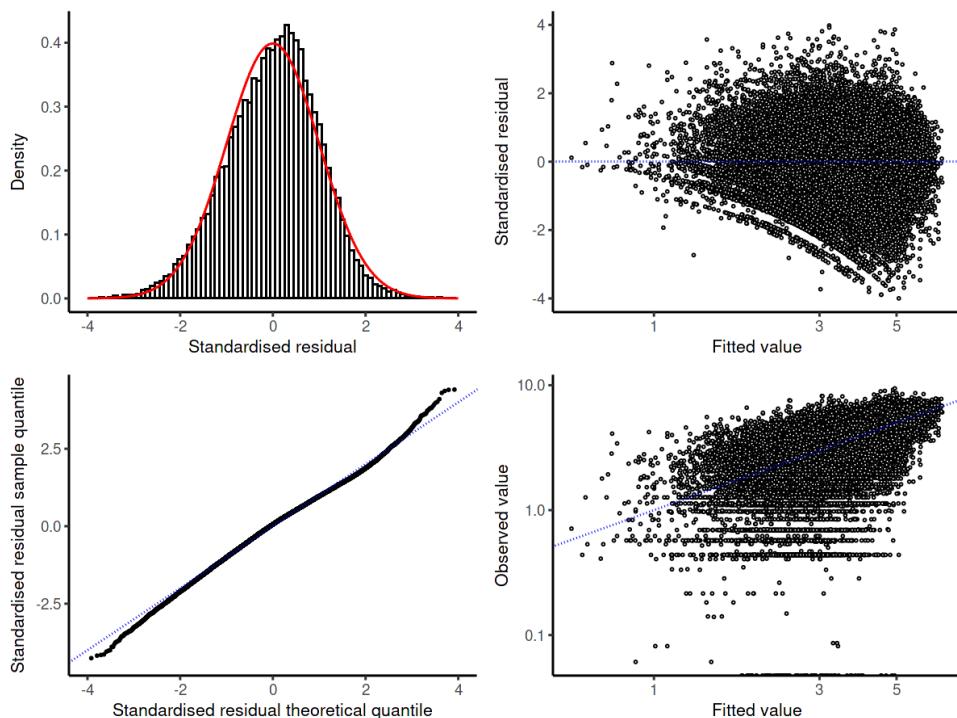


Figure 170: Diagnostic plots for the lognormal model for the SPO 7 BT trip dataset.

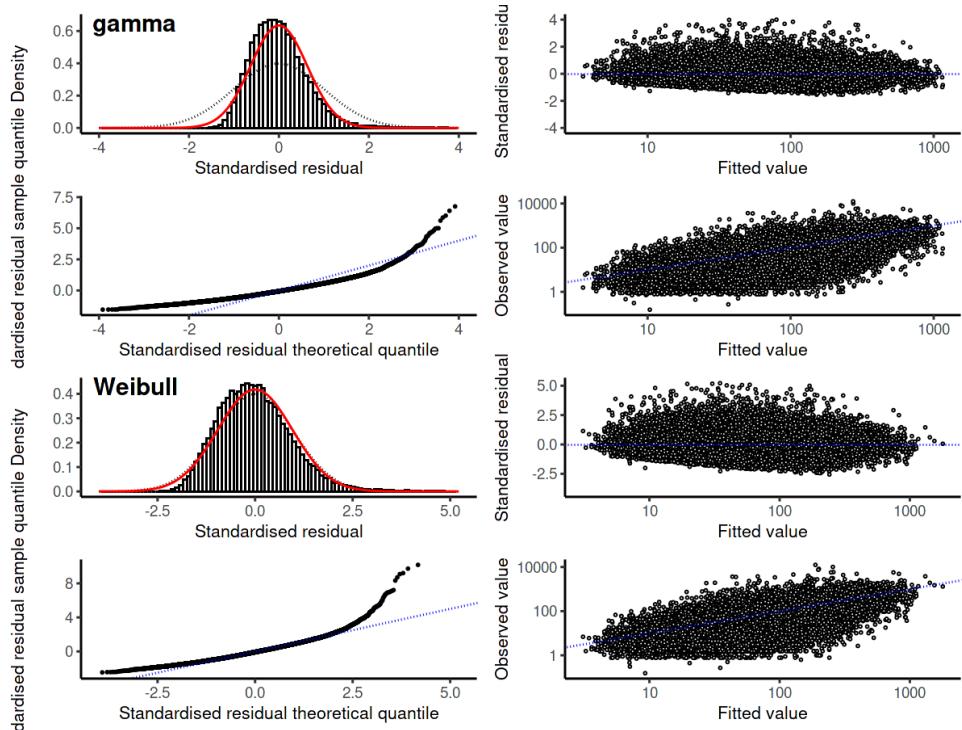


Figure 171: Diagnostic plots for the gamma and Weibull model for the SPO 7 BT trip dataset.

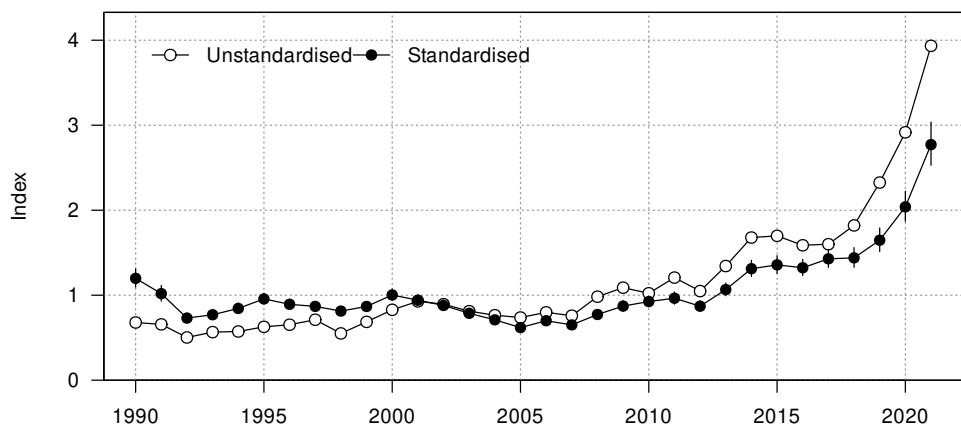


Figure 172: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 7 BT trip dataset.

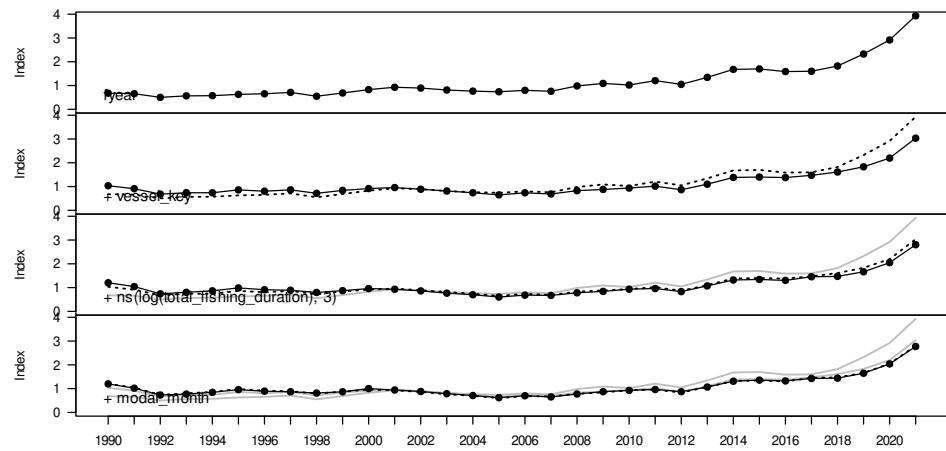


Figure 173: Changes to the SPO 7 BT trip positive catch index as terms are successively entered into the model.

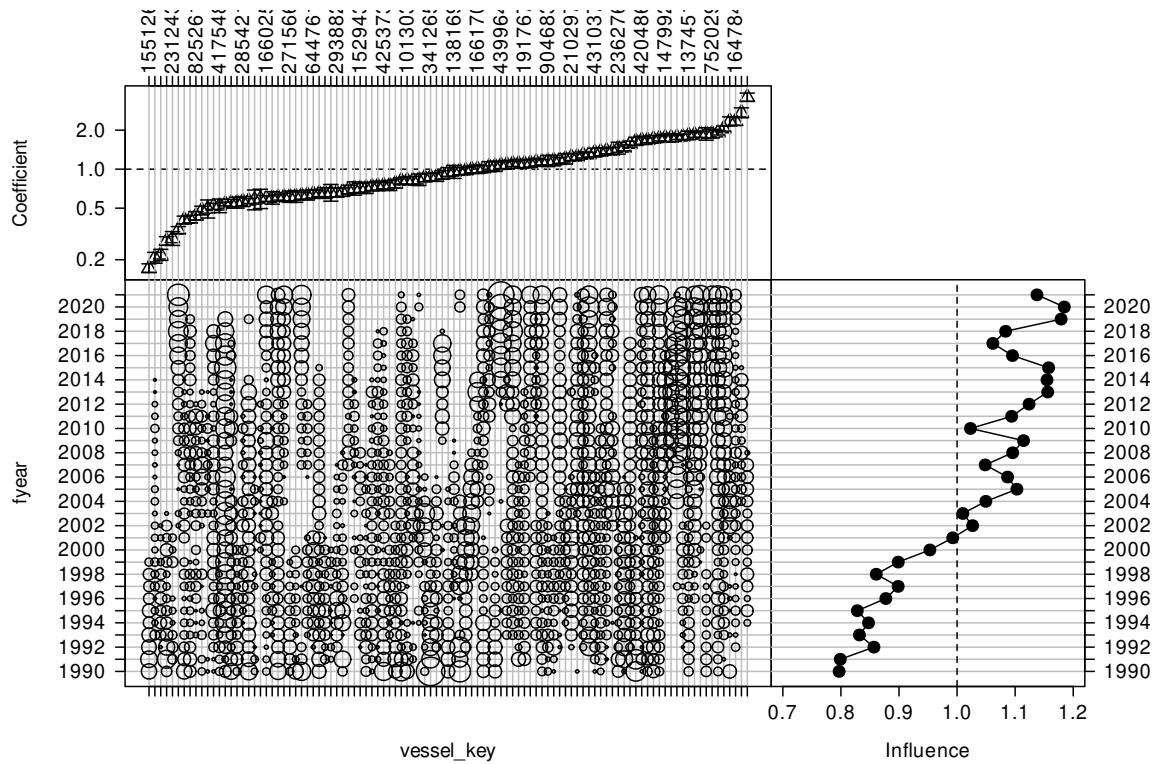


Figure 174: CDI plot for vessel key for the positive catch SPO 7 BT trip catch-per-unit-effort dataset.

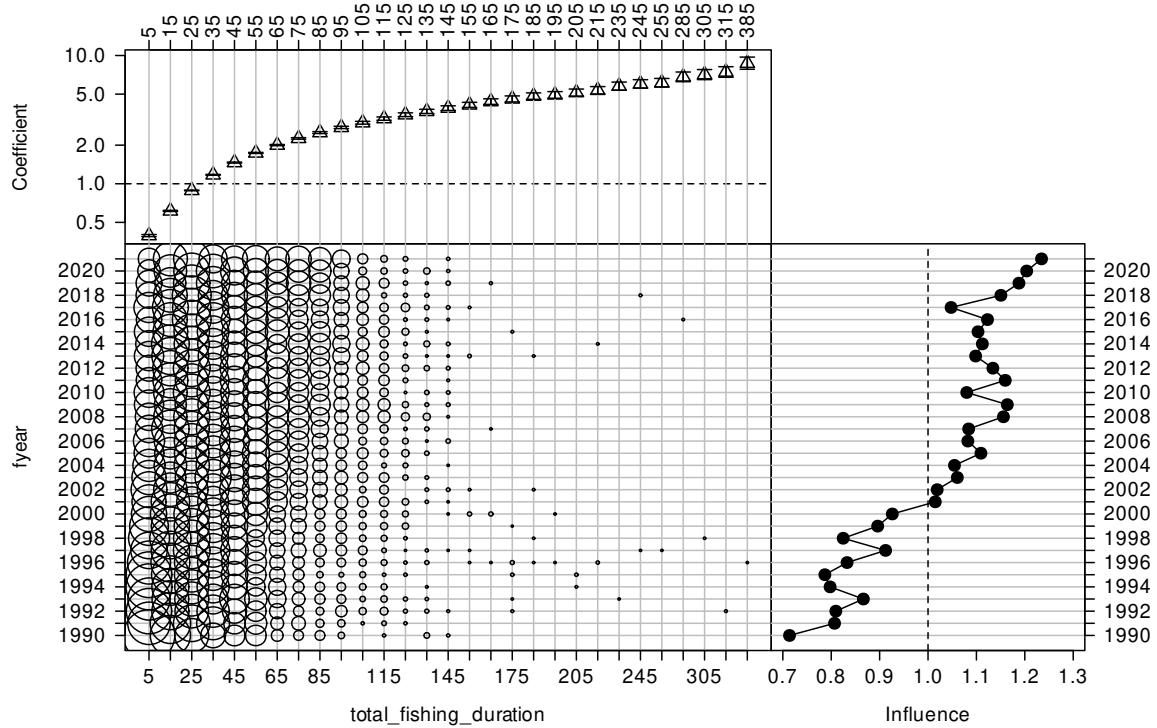


Figure 175: CDI plot for total fishing duration (h) for the positive catch SPO 7 BT trip catch-per-unit-effort dataset.

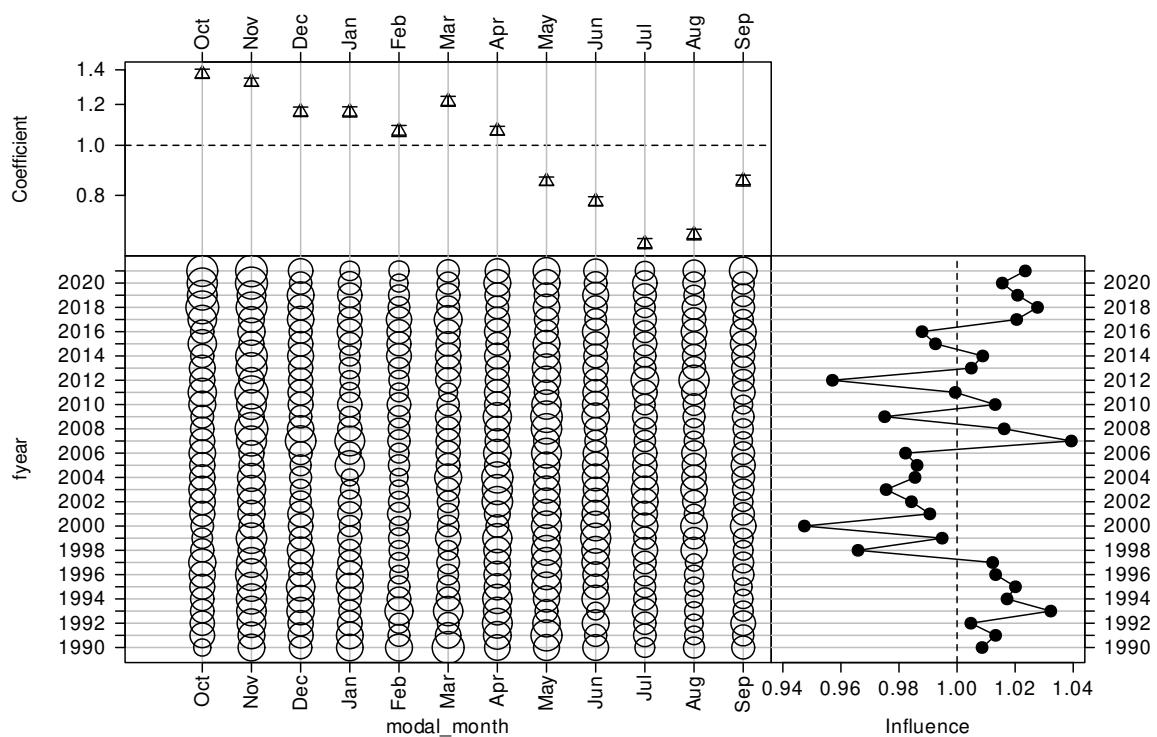


Figure 176: CDI plot for modal month for the positive catch SPO 7 BT trip catch-per-unit-effort dataset.

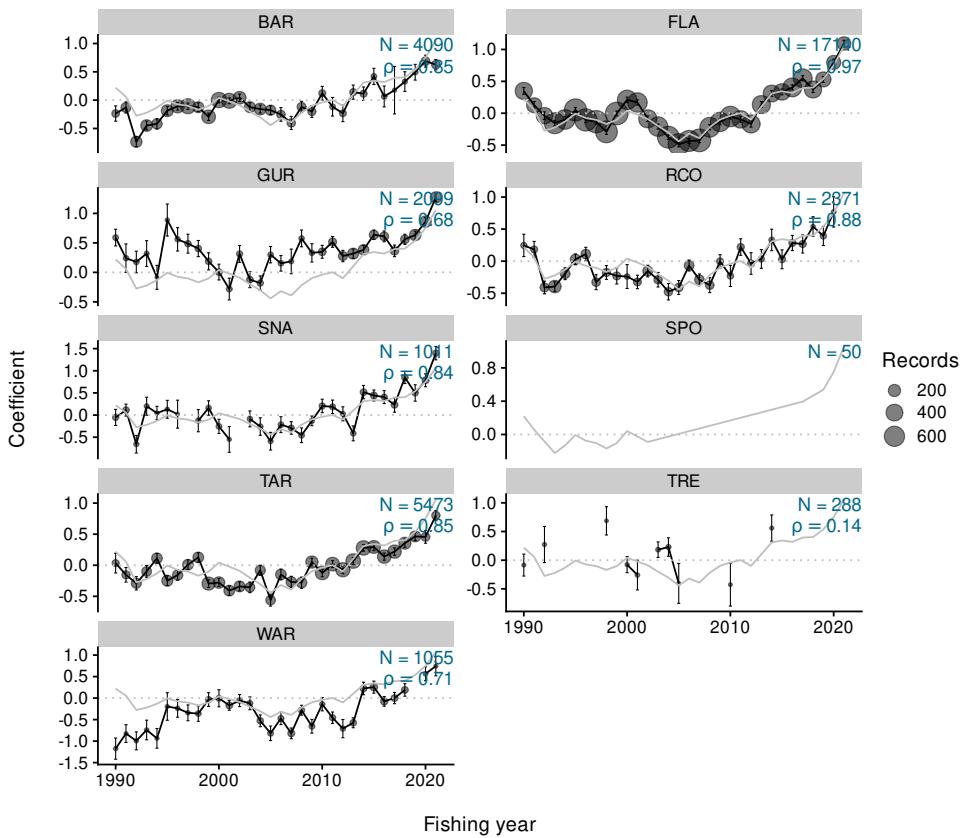


Figure 177: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 7 BT trip dataset.

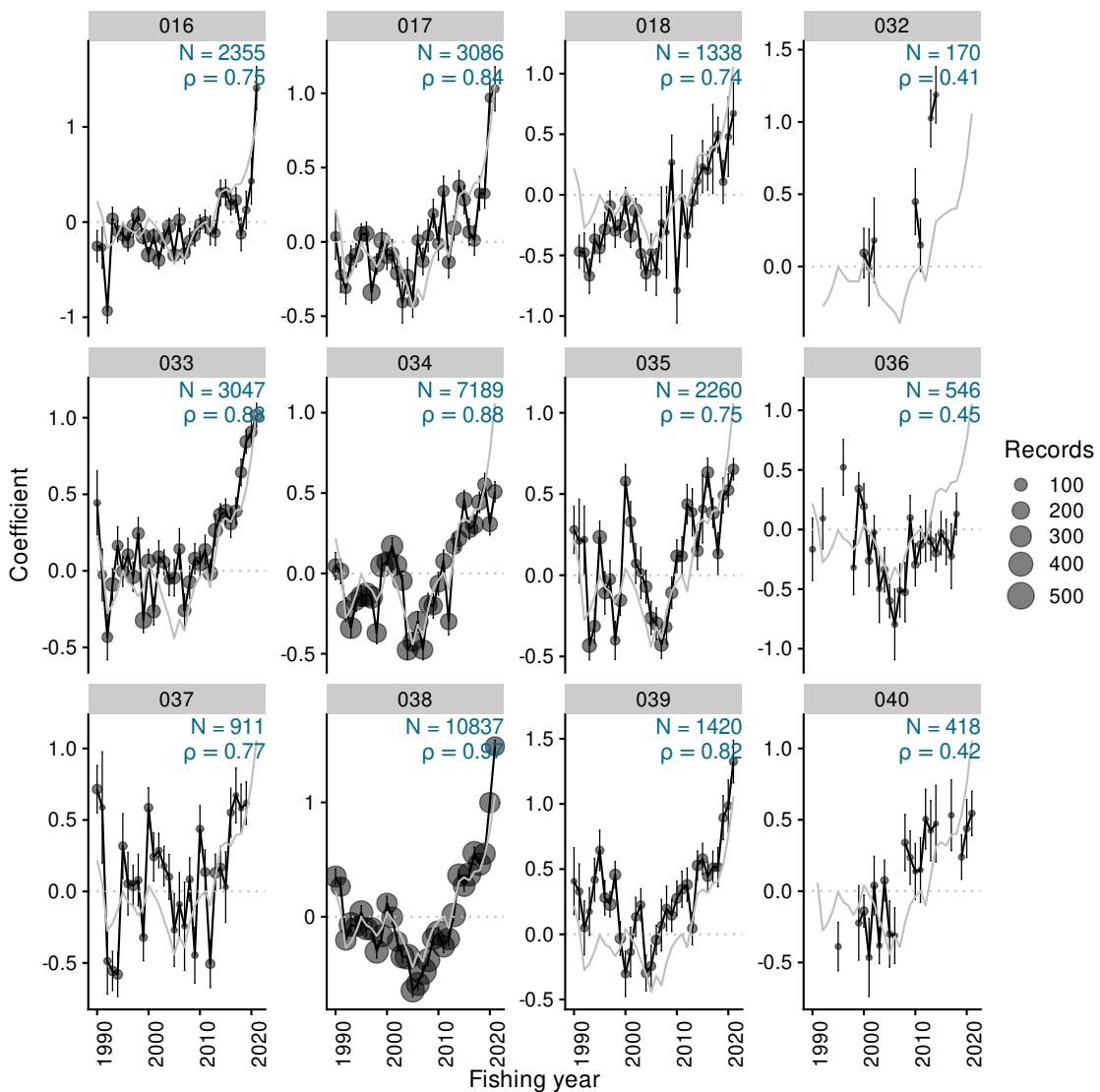


Figure 178: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 7 BT trip dataset.

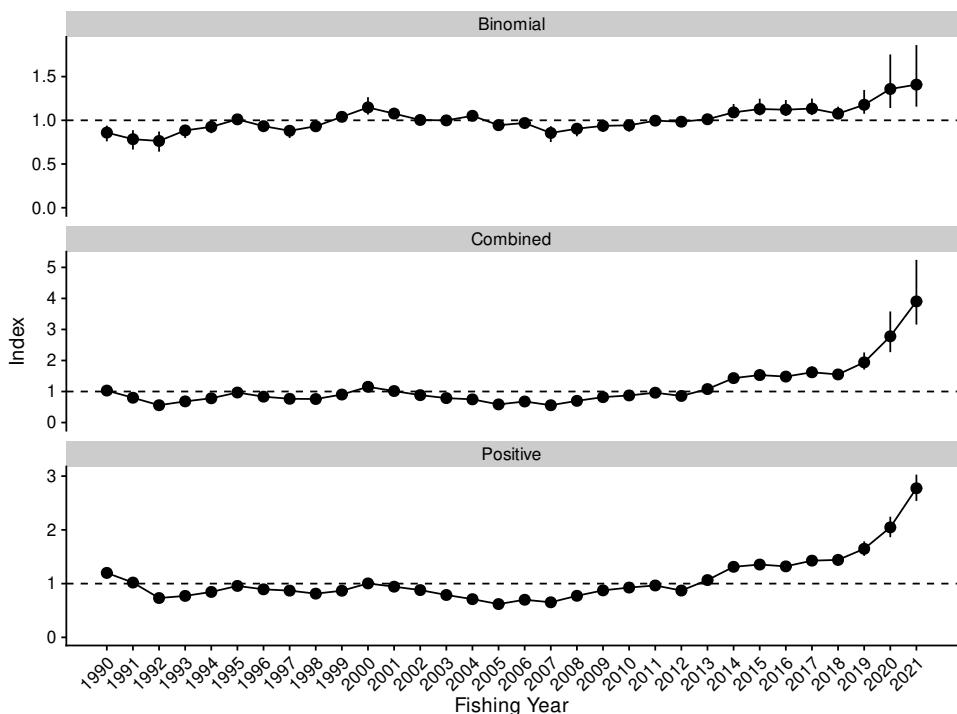


Figure 179: Standardised indices and 95% confidence intervals for the SPO 7 BT trip dataset.

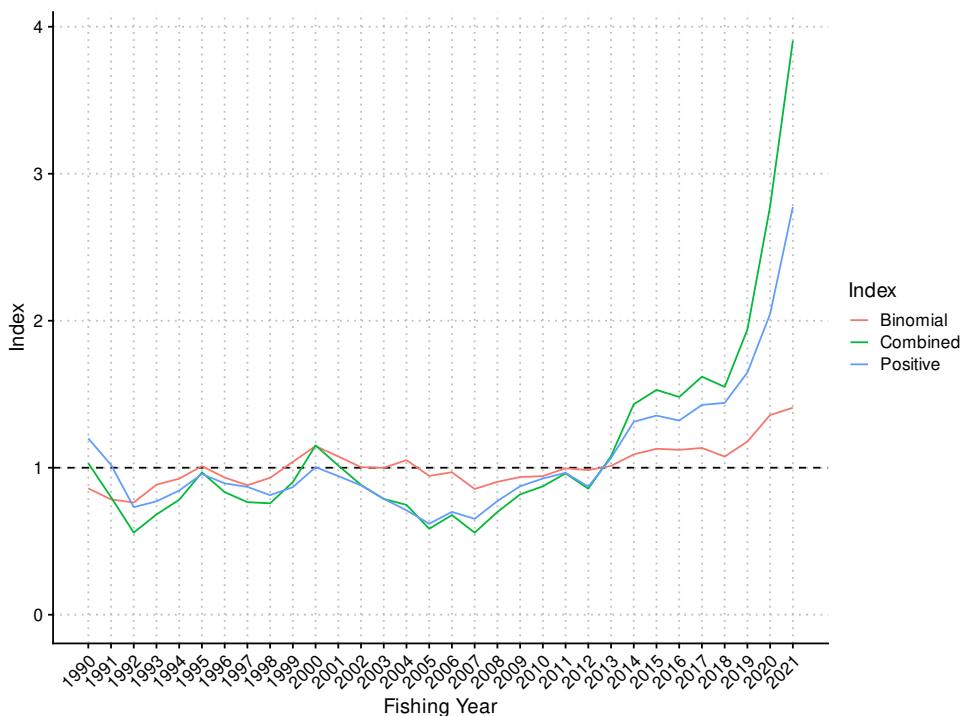


Figure 180: Standardised indices for the SPO 7 BT trip dataset.

Table 35: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 7 BT trip.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.859	0.046	0.759	0.939	1.031	0.070	0.886	1.161	1.199	0.054	1.095	1.305
1991	0.784	0.057	0.666	0.887	0.799	0.073	0.652	0.939	1.019	0.047	0.931	1.117
1992	0.764	0.059	0.641	0.871	0.559	0.048	0.469	0.658	0.732	0.030	0.673	0.791
1993	0.884	0.038	0.797	0.948	0.682	0.039	0.603	0.758	0.771	0.026	0.723	0.823
1994	0.926	0.031	0.853	0.973	0.782	0.038	0.702	0.852	0.845	0.030	0.790	0.908
1995	1.011	0.018	0.976	1.048	0.968	0.036	0.902	1.044	0.957	0.032	0.897	1.021
1996	0.933	0.029	0.865	0.977	0.834	0.039	0.756	0.907	0.894	0.030	0.834	0.951
1997	0.881	0.038	0.798	0.946	0.766	0.041	0.680	0.843	0.870	0.028	0.816	0.926
1998	0.932	0.028	0.867	0.977	0.758	0.035	0.685	0.823	0.813	0.027	0.761	0.867
1999	1.040	0.020	1.005	1.084	0.902	0.034	0.839	0.970	0.868	0.026	0.814	0.917
2000	1.148	0.051	1.065	1.265	1.152	0.065	1.043	1.296	1.004	0.032	0.946	1.073
2001	1.077	0.028	1.031	1.143	1.015	0.043	0.939	1.108	0.943	0.032	0.884	1.009
2002	1.004	0.024	0.956	1.048	0.883	0.037	0.811	0.958	0.880	0.032	0.818	0.944
2003	0.999	0.022	0.954	1.042	0.788	0.035	0.719	0.857	0.788	0.029	0.733	0.849
2004	1.052	0.024	1.012	1.107	0.747	0.031	0.691	0.813	0.711	0.023	0.669	0.760
2005	0.944	0.028	0.878	0.989	0.585	0.027	0.532	0.638	0.619	0.022	0.578	0.662
2006	0.969	0.026	0.908	1.011	0.678	0.030	0.617	0.734	0.700	0.024	0.653	0.747
2007	0.855	0.046	0.751	0.933	0.558	0.036	0.483	0.624	0.652	0.023	0.608	0.697
2008	0.904	0.038	0.817	0.965	0.699	0.037	0.623	0.766	0.773	0.027	0.724	0.829
2009	0.937	0.030	0.868	0.986	0.819	0.041	0.738	0.900	0.874	0.033	0.813	0.944
2010	0.943	0.031	0.871	0.992	0.873	0.040	0.795	0.952	0.926	0.030	0.867	0.985
2011	0.996	0.025	0.942	1.040	0.962	0.043	0.881	1.049	0.965	0.036	0.898	1.038
2012	0.984	0.027	0.929	1.034	0.857	0.038	0.783	0.933	0.871	0.033	0.808	0.937
2013	1.012	0.026	0.962	1.065	1.079	0.046	0.992	1.174	1.066	0.037	0.997	1.140
2014	1.091	0.039	1.033	1.187	1.432	0.073	1.305	1.592	1.313	0.049	1.218	1.409
2015	1.129	0.049	1.056	1.247	1.529	0.090	1.372	1.726	1.355	0.050	1.258	1.456
2016	1.122	0.047	1.050	1.232	1.481	0.083	1.330	1.655	1.321	0.048	1.228	1.418
2017	1.134	0.048	1.061	1.249	1.619	0.086	1.468	1.805	1.427	0.051	1.330	1.529
2018	1.076	0.035	1.019	1.156	1.550	0.080	1.405	1.720	1.441	0.056	1.334	1.553
2019	1.178	0.069	1.075	1.347	1.940	0.140	1.708	2.258	1.647	0.069	1.517	1.786
2020	1.358	0.156	1.141	1.754	2.779	0.335	2.268	3.580	2.046	0.097	1.864	2.245
2021	1.408	0.180	1.156	1.861	3.904	0.532	3.158	5.242	2.774	0.125	2.538	3.027

5.7 SPO 1E(007) SN daily

This series was based on the daily catch of rig from the inner Hauraki Gulf set net (SN) target shark species fishery. The analysis was based on a single Statistical Area (007), covering the inner Hauraki Gulf including the Firth of Thames (Table 36). The target species suite included the four commercially harvested shark species: rig (SPO), school shark (SCH), spiny dogfish (SPD) and northern dogfish (NSD). The core fleet was defined by having fished at least five trips in each of four years, retaining 79% of the catch and reducing the fleet from about 170 vessels to 34 vessels (Figure 181). The pattern of vessel participation in this fishery was characterised by eight or nine vessels which were in the fishery for 15 to more than 25 years, as well as many vessels which entered and exited the fishery but only operated in the fishery for five to ten years (Figure 182). The final groomed dataset represented 19% (1990) to 100% (2007, 2009, 2011, 2017) of the annual ungroomed catch (Table 37). The total annual catch of rig in the defined fishery ranged from 6.3 t (in 1990) to 99 t (in 2002) over the 32 years in the data set and was characterised by a high incidence of rig in the daily landings, ranging from 85% (in 2021) to 100% (in 2005, 2012, 2013, 2016, 2018) (Table 38). The final column in Table 38 indicated that nearly all daily records reported a catch of rig. Consequently, no binomial (occurrence) model was prepared because it would have no weight in a combined model, given the small proportion of zero daily records. All landed catch in this data set was allocated by multiplying the estimated catch by the ratio of landed to estimated for each vessel/year in this data set (Figure 183) (see Kendrick & Bentley 2012, section 2.2.6).

The gamma model accepted three predictive variables after fishing year (vessel, month, total_net_length), with the total model explaining 32% of the deviance (Table 39). The gamma model showed some skewness in the residual distribution, especially in the upper tail of the distribution, but overall there was good conformity to the assumption of the gamma distribution (Figure 184). The lognormal distribution showed a poor fit to this data set while the Weibull distribution showed a fit that appeared to be equivalent to that of the gamma model (Figure 185). The standardised series showed little trend over the first half of the series, but had two periods of increase, one from 2003 to 2009 and the second from 2013 to 2019 (Figure 186). The final two years of the standardised series dropped from a relative index that was above 1.5 to nearly 1.0 (i.e., near the long-term mean of the series). The main impact of the standardisation procedure was to smooth out the unstandardised series (Figure 187). Each covariate contributed to the smoothing process, but the overall trend of the standardised series did not change much from the unstandardised series (vessel: Figure 188, month: Figure 189, total_net_length: Figure 190, see Figure 187). Almost all of the target information in this data set came from rig target records, so it is not surprising that the implied residual plot of target rig annual CPUE would have good conformity with the overall annual CPUE trend across this effectively single target species data set (Figure 191). The final positive catch model was characterised by a climb to the highest point in the series in 2019, followed by a strong drop in 2021 to a level near to, but still above, the long-term mean of the series (Figure 192, Table 40). A comparison of this series with the equivalent series calculated in 2019 (Starr & Kendrick 2020) shows that this series matched that series well in the overlapping years (Figure 282).

Table 36: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 1E(007) SN daily CPUE series.

Series	SPO 1E(007) SN daily
QMS stock	SPO1
Reporting forms	CEL, ERS - Netting, NCE
Fishing methods	SN
Target species	SPO, SCH, SPD, NSD
Statistical Areas	007
Period	1989-10-01, 2021-09-30
Resolution	Day
Core fleet years	4
Core fleet trips	5
Default model	<code>scaledkdg ~ fyear + vessel_key + month + target_species + ns(log(soak_time), 3) + ns(log(total_net_length), 3)</code>
Stepwise selection	Yes
Positive catch distribution	Gamma

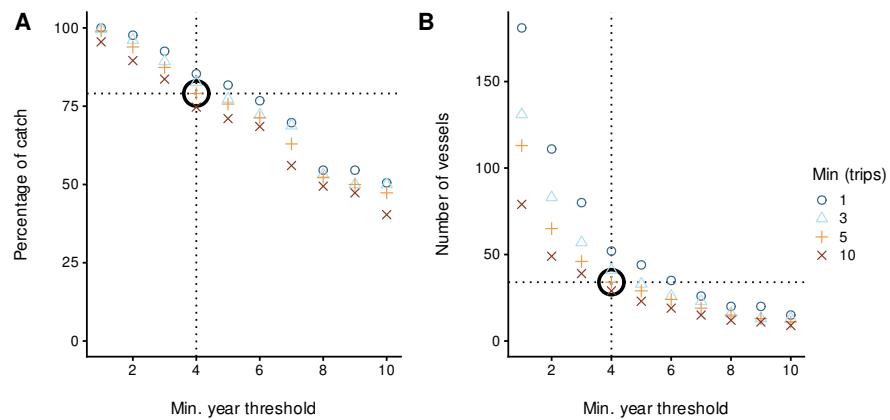


Figure 181: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 1E(007) SN daily CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

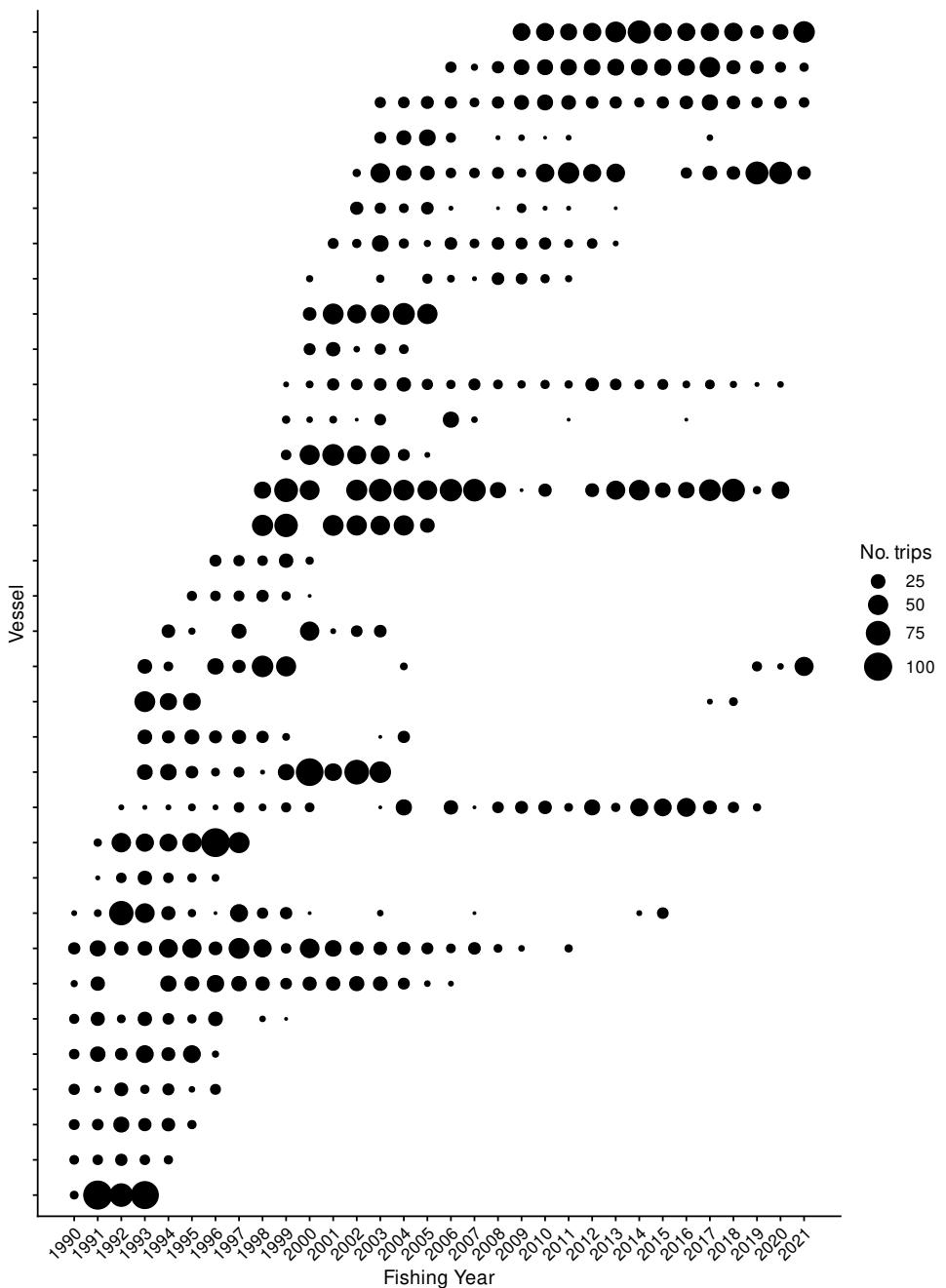


Figure 182: Number of trips by fishing year for core vessels. The area of the circles is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 37: Summary of the SPO 1E(007) SN 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	45 (100%) n: 206	113 (100%) n: 543	170 (100%) n: 743	151 (100%) n: 934	90 (100%) n: 587	87 (100%) n: 459	95 (100%) n: 476	96 (100%) n: 533	84 (100%) n: 496
Positive soak time	45 (100%) n: 206	113 (100%) n: 541	165 (100%) n: 729	151 (100%) n: 932	90 (100%) n: 582	86 (100%) n: 453	95 (100%) n: 470	94 (100%) n: 522	82 (100%) n: 485
Positive net length	45 (100%) n: 206	113 (100%) n: 540	165 (100%) n: 728	151 (100%) n: 932	90 (100%) n: 581	86 (100%) n: 452	95 (100%) n: 470	93 (100%) n: 521	78 (93%) n: 472
Scaler in range	42 (92%) n: 189	87 (77%) n: 473	125 (73%) n: 595	141 (94%) n: 809	88 (100%) n: 576	83 (100%) n: 437	88 (93%) n: 440	84 (87%) n: 482	68 (82%) n: 427
Trim extreme length	41 (90%) n: 188	83 (74%) n: 466	124 (73%) n: 592	138 (92%) n: 801	82 (91%) n: 557	78 (90%) n: 419	88 (92%) n: 437	84 (87%) n: 475	68 (81%) n: 425
Core fleet selection	6.3 (14%) n: 93	33 (29%) n: 268	57 (33%) n: 354	79 (53%) n: 530	50 (56%) n: 370	62 (71%) n: 320	67 (70%) n: 361	61 (63%) n: 337	53 (63%) n: 319
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	90 (100%) n: 468	100 (100%) n: 576	84 (100%) n: 459	115 (100%) n: 468	99 (100%) n: 603	76 (100%) n: 532	83 (100%) n: 391	57 (100%) n: 254	40 (100%) n: 172
Positive soak time	88 (100%) n: 457	99 (100%) n: 572	84 (100%) n: 459	115 (100%) n: 468	99 (100%) n: 603	76 (100%) n: 531	83 (100%) n: 391	57 (100%) n: 254	40 (100%) n: 172
Positive net length	88 (100%) n: 455	99 (100%) n: 571	84 (100%) n: 459	115 (100%) n: 468	99 (100%) n: 603	76 (100%) n: 531	83 (100%) n: 391	57 (100%) n: 254	40 (100%) n: 172
Scaler in range	81 (91%) n: 429	76 (76%) n: 483	67 (80%) n: 388	115 (100%) n: 462	95 (100%) n: 581	74 (100%) n: 521	46 (55%) n: 322	55 (100%) n: 237	40 (100%) n: 172
Trim extreme length	81 (91%) n: 429	76 (76%) n: 483	67 (80%) n: 388	111 (100%) n: 456	95 (100%) n: 578	74 (100%) n: 519	45 (55%) n: 321	53 (93%) n: 234	39 (100%) n: 171
Core fleet selection	69 (77%) n: 353	65 (65%) n: 387	64 (76%) n: 337	99 (86%) n: 399	90 (91%) n: 524	65 (86%) n: 404	42 (51%) n: 273	53 (93%) n: 223	38 (100%) n: 144

Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	40 (100%) n: 177	53 (100%) n: 205	53 (100%) n: 294	33 (100%) n: 224	54 (100%) n: 246	49 (100%) n: 304	52 (100%) n: 275	46 (100%) n: 242	60 (100%) n: 256
Positive soak time	40 (100%) n: 177	53 (100%) n: 205	53 (100%) n: 294	33 (100%) n: 224	54 (100%) n: 246	49 (100%) n: 304	52 (100%) n: 275	46 (100%) n: 242	60 (100%) n: 256
Positive net length	40 (100%) n: 177	53 (100%) n: 205	53 (100%) n: 294	33 (100%) n: 224	54 (100%) n: 246	49 (100%) n: 304	52 (100%) n: 275	46 (100%) n: 242	60 (100%) n: 256
Scaler in range	40 (100%) n: 177	53 (100%) n: 205	52 (100%) n: 290	33 (100%) n: 218	54 (100%) n: 246	49 (100%) n: 303	52 (100%) n: 265	46 (100%) n: 239	59 (100%) n: 241
Trim extreme length	39 (100%) n: 175	51 (100%) n: 200	52 (100%) n: 289	33 (100%) n: 218	52 (100%) n: 244	48 (100%) n: 300	51 (100%) n: 263	46 (100%) n: 238	59 (100%) n: 241
Core fleet selection	38 (95%) n: 161	51 (100%) n: 189	47 (90%) n: 234	32 (100%) n: 196	51 (93%) n: 222	39 (80%) n: 219	45 (86%) n: 215	41 (89%) n: 185	52 (87%) n: 193

Filter	2017	2018	2019	2020	2021
Ungroomed data	68 (100%) n: 274	64 (100%) n: 246	48 (100%) n: 231	59 (100%) n: 261	44 (100%) n: 231
Positive soak time	68 (100%) n: 274	64 (100%) n: 246	48 (100%) n: 231	59 (100%) n: 261	44 (100%) n: 231
Positive net length	68 (100%) n: 274	64 (100%) n: 246	48 (100%) n: 231	59 (100%) n: 261	44 (100%) n: 231
Scaler in range	68 (100%) n: 274	64 (100%) n: 246	45 (95%) n: 200	58 (100%) n: 259	42 (100%) n: 210
Trim extreme length	68 (100%) n: 272	64 (100%) n: 246	45 (93%) n: 199	58 (100%) n: 259	42 (100%) n: 210
Core fleet selection	67 (100%) n: 244	57 (89%) n: 201	40 (83%) n: 158	44 (75%) n: 179	32 (73%) n: 153

Table 38: Summary of the SPO 1E(007) SN 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 rig.

Fishing year	Vessels	Trips	Records	Net length (km)	Catch (t)	Records caught
1990	9	93	93	113.40	6.31	94.62
1991	11	260	268	330.75	32.89	97.39
1992	11	323	354	544.72	56.87	98.31
1993	15	472	530	823.26	79.33	94.53
1994	16	350	370	545.60	50.17	97.30
1995	15	295	320	478.21	61.66	95.31
1996	14	303	361	646.10	66.92	96.12
1997	11	295	337	558.71	60.85	98.22
1998	12	283	319	525.28	52.83	98.43
1999	15	336	353	650.50	68.99	94.90
2000	15	379	387	661.66	65.38	95.35
2001	11	321	337	622.60	63.58	98.22
2002	14	386	399	822.80	98.91	99.00
2003	20	501	524	1159.40	90.40	97.33
2004	16	392	404	886.62	64.87	97.77
2005	13	270	273	588.11	42.11	100.00
2006	13	219	223	457.64	52.80	98.65
2007	11	142	144	318.24	37.82	98.61
2008	11	153	161	349.36	38.11	99.38
2009	12	178	189	343.26	50.75	99.47
2010	11	219	234	462.22	47.31	99.15
2011	12	188	196	350.55	32.23	98.47
2012	8	214	222	413.15	50.53	100.00
2013	9	218	219	413.56	39.45	100.00
2014	7	214	215	427.90	44.86	99.07
2015	7	185	185	320.80	41.31	97.84
2016	8	191	193	354.42	52.12	100.00
2017	9	244	244	392.15	66.56	99.18
2018	8	198	201	330.85	57.01	100.00
2019	8	148	158	235.97	39.89	96.20
2020	7	168	179	209.99	44.05	97.21
2021	5	143	153	203.50	31.89	84.97

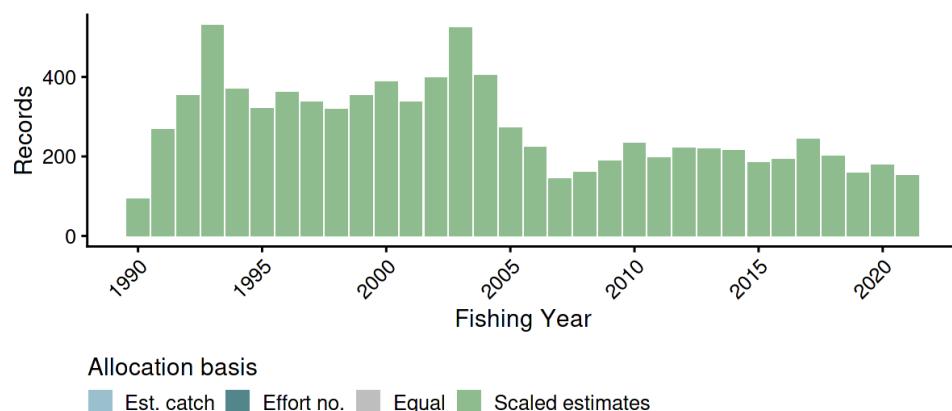


Figure 183: Allocation basis for attributing landings to records in the SPO 1E(007) SN daily catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table 39: Summary of stepwise selection for the gamma 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	30	106 835	4.9	4.9	*
+ vessel key	33	104 194	28.1	23.2	*
+ month	11	103 830	31.0	2.9	*
+ ns(log(total net length), 3)	3	103 647	32.3	1.4	*
+ ns(log(soak time), 3)	3	103 626	32.5	0.2	
+ target species	2	103 618	32.6	0.1	

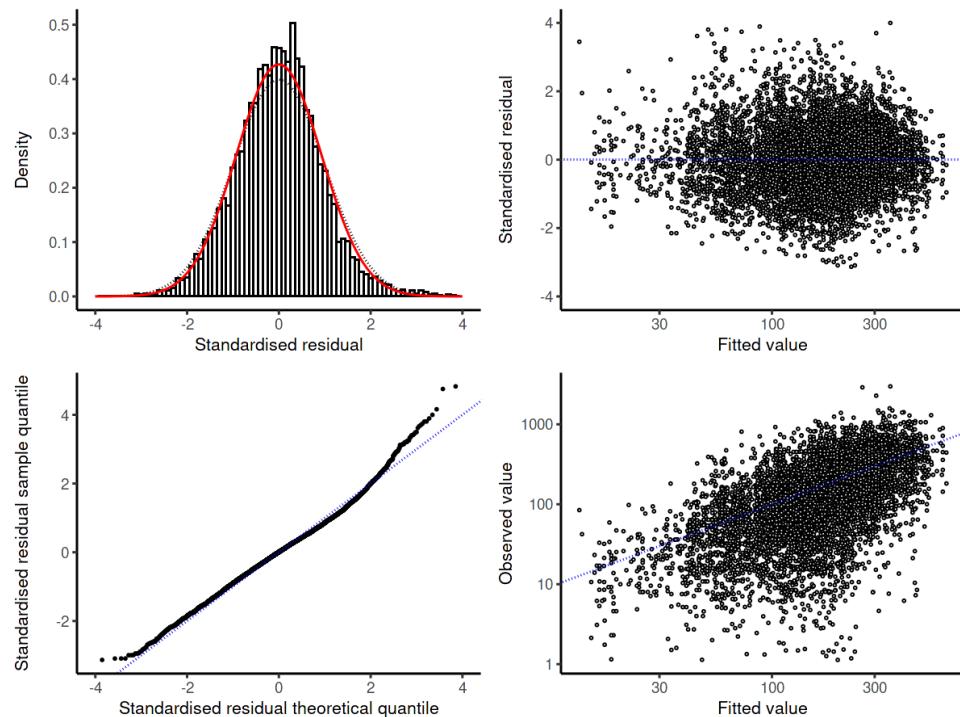


Figure 184: Diagnostic plots for the gamma model for the SPO 1E(007) SN daily dataset.

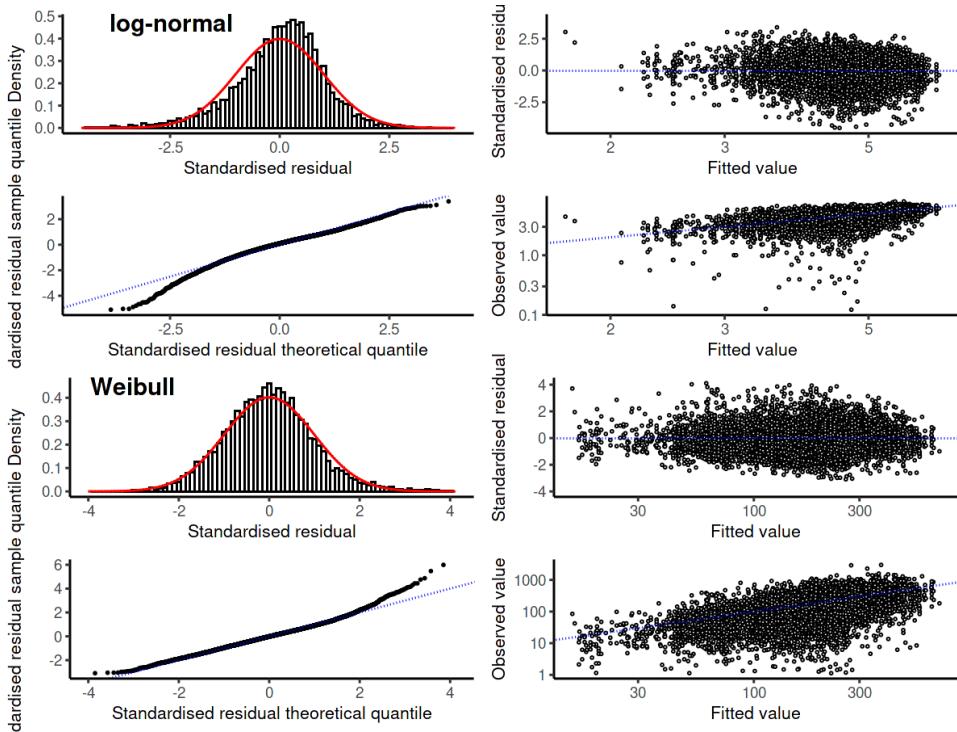


Figure 185: Diagnostic plots for the log-normal and Weibull model for the SPO 1E(007) SN daily dataset.

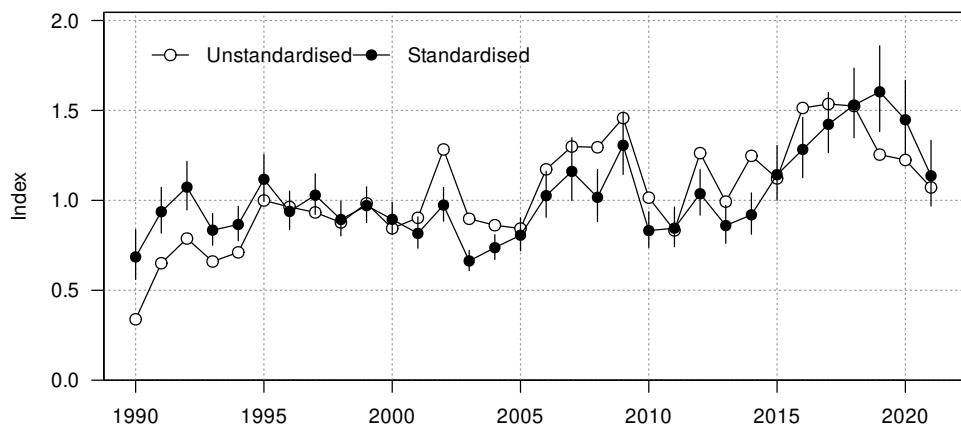


Figure 186: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 1E(007) SN daily dataset.

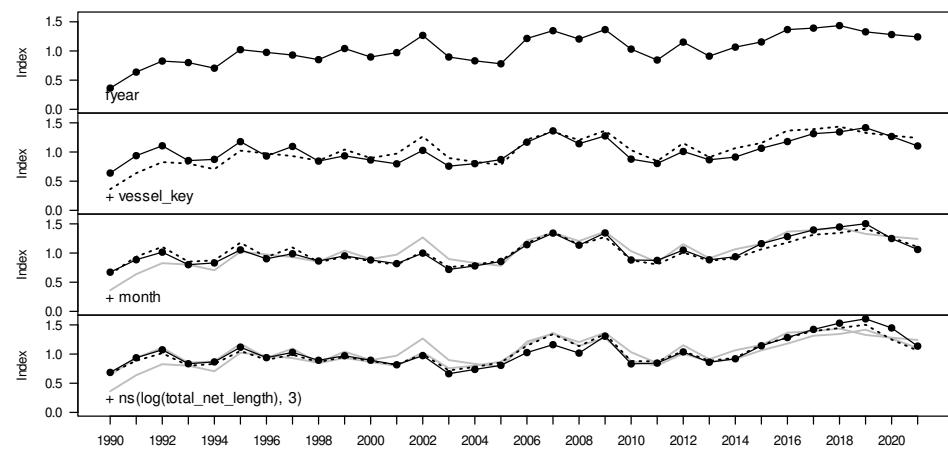


Figure 187: Changes to the SPO 1E(007) SN daily positive catch index as terms are successively entered into the model.

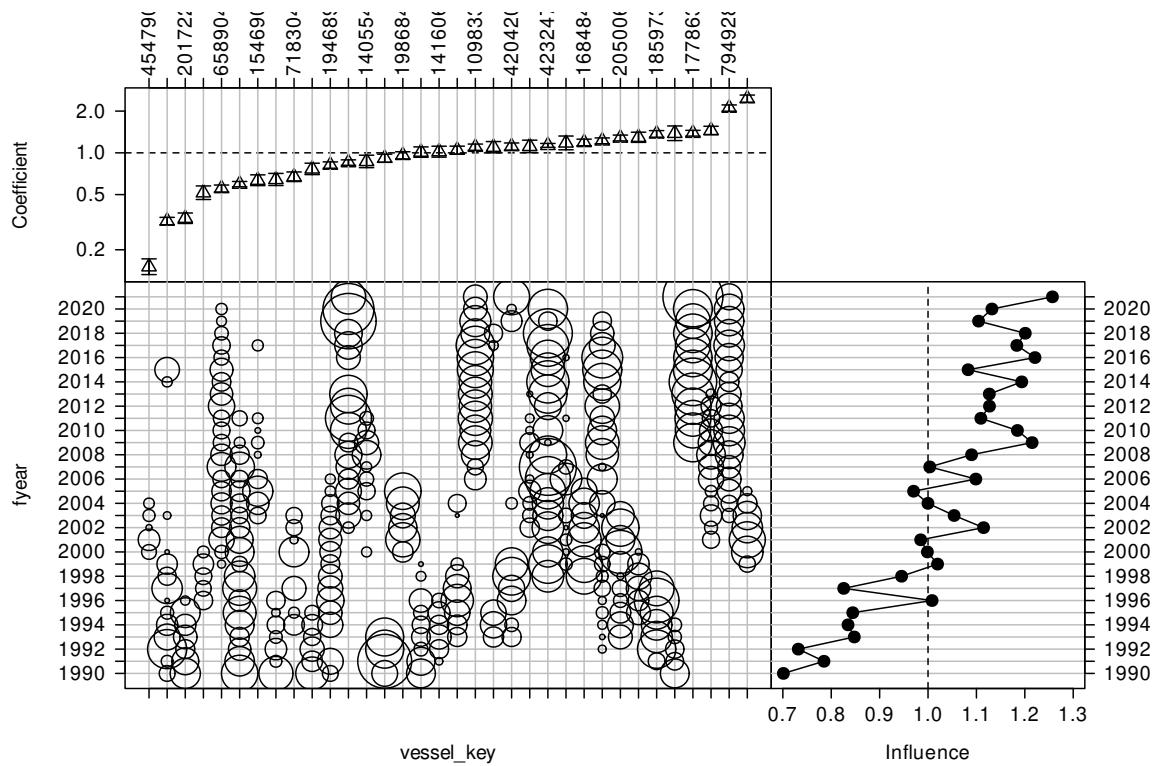


Figure 188: CDI plot for vessel key for the positive catch SPO 1E(007) SN daily catch-per-unit-effort dataset.

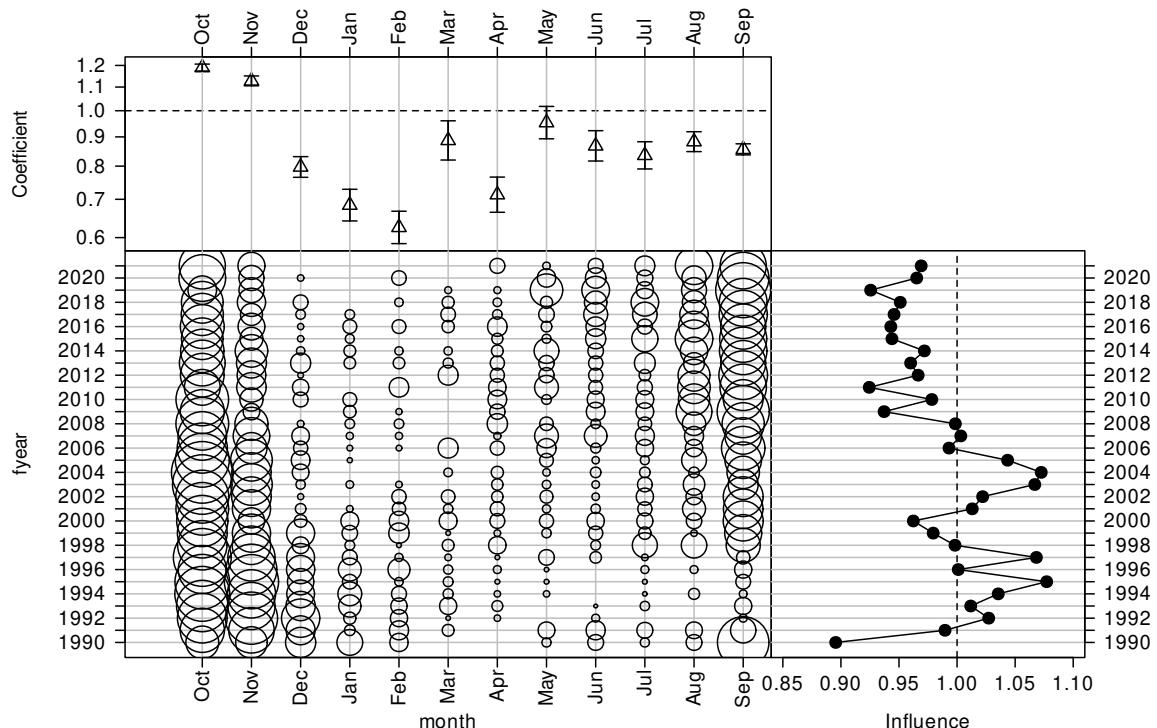


Figure 189: CDI plot for month for the positive catch SPO 1E(007) SN daily catch-per-unit-effort dataset.

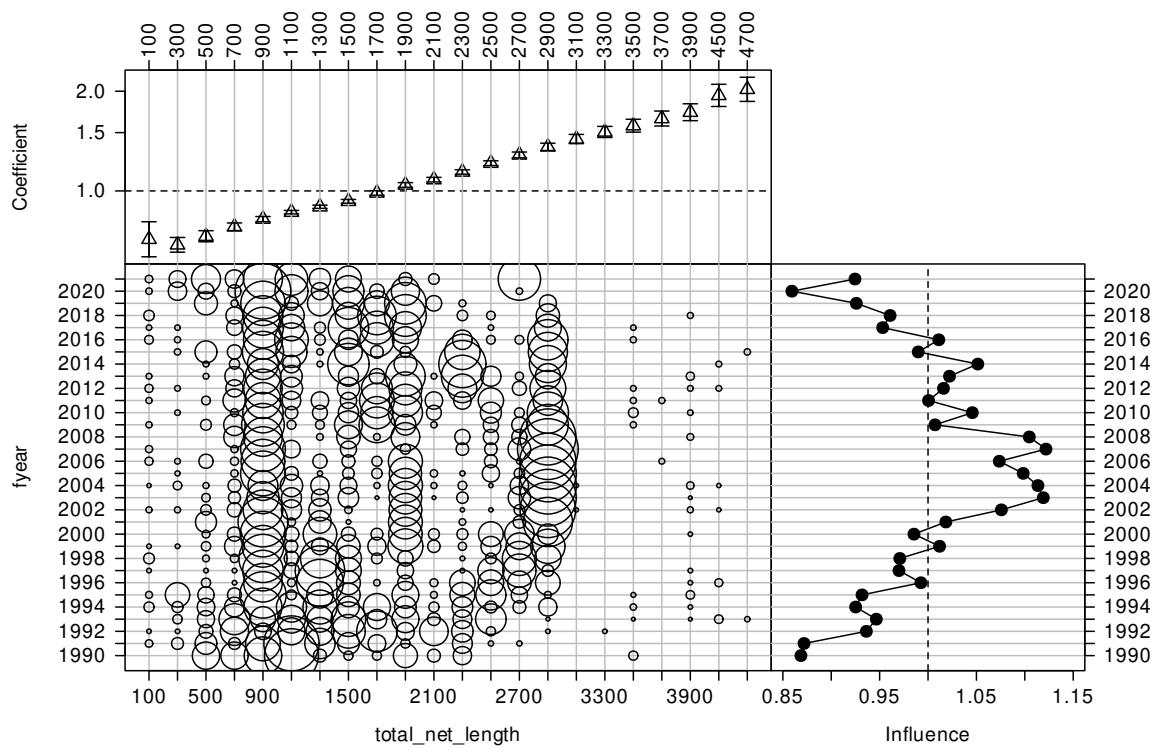


Figure 190: CDI plot for total net length for the positive catch SPO 1E(007) SN daily catch-per-unit-effort dataset.

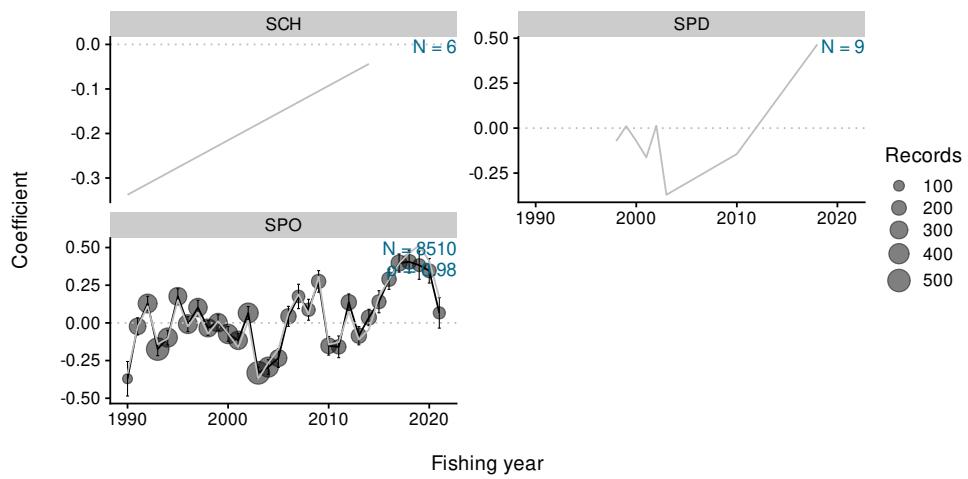


Figure 191: Residual implied coefficients for target-year in the gamma positive catch model for the SPO 1E(007) SN daily dataset.

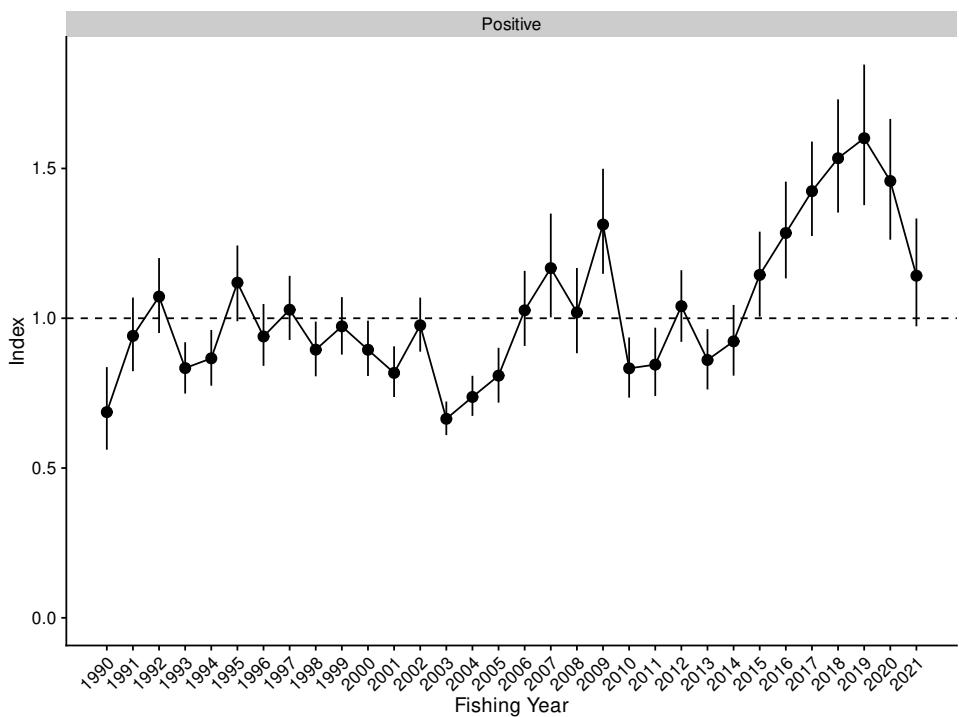


Figure 192: Standardised indices and 95% confidence intervals for the SPO 1E(007) SN daily dataset.

Table 40: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 1E(007) SN daily.

Fishing year	Positive			
	index	SE	LCI	UCI
1990	0.687	0.070	0.561	0.837
1991	0.941	0.063	0.823	1.069
1992	1.072	0.064	0.951	1.201
1993	0.834	0.044	0.749	0.920
1994	0.866	0.047	0.775	0.961
1995	1.119	0.065	0.990	1.243
1996	0.939	0.053	0.841	1.048
1997	1.028	0.055	0.928	1.142
1998	0.895	0.047	0.806	0.989
1999	0.973	0.049	0.879	1.071
2000	0.895	0.047	0.807	0.992
2001	0.818	0.043	0.737	0.906
2002	0.977	0.046	0.889	1.069
2003	0.664	0.029	0.610	0.722
2004	0.737	0.034	0.674	0.808
2005	0.808	0.047	0.718	0.901
2006	1.027	0.064	0.908	1.158
2007	1.167	0.088	1.003	1.349
2008	1.020	0.073	0.883	1.168
2009	1.313	0.089	1.148	1.499
2010	0.833	0.051	0.735	0.936
2011	0.845	0.058	0.740	0.969
2012	1.040	0.061	0.921	1.160
2013	0.861	0.051	0.762	0.964
2014	0.923	0.060	0.808	1.044
2015	1.145	0.072	1.005	1.289
2016	1.285	0.082	1.133	1.456
2017	1.424	0.080	1.275	1.590
2018	1.534	0.096	1.353	1.731
2019	1.601	0.120	1.378	1.847
2020	1.458	0.103	1.262	1.665
2021	1.142	0.092	0.973	1.333

5.8 SPO 1W(043) SN daily

This series was based on the daily catch of rig by target rig set net (SN) fishing in the Manukau Harbour. The analysis was based on a single Statistical Area (043) specific to Manukau Harbour (Table 41). The target species suite included the four commercially harvested shark species: rig (SPO), school shark (SCH), spiny dogfish (SPD) and northern dogfish (NSD). The core fleet was defined by having fished at least five trips in each of four years, retaining 86% of the catch and reducing the fleet from just over 100 vessels to 28 vessels (Figure 193). The pattern of vessel participation in this fishery was characterised by a few vessels (four or five) which were in the fishery for 15 to more than 25 years, as well as many vessels which entered and exited the fishery but only operated in the fishery for five to ten years (Figure 194). The final groomed dataset represented 48% (1998) to 100% (2006, 2008, 2011–2013, 2015, 2016, 2019) of the annual ungroomed catch by year (Table 42). The total annual catch of rig in the defined fishery ranged from 9.5 t (in 2020) to 55 t (in 2000) over the 32 years in the data set and was characterised by a high incidence of rig in the daily landings, ranging from 95% (in 2021) to 100% (in 1991, 1992, 1994, 2005, 2019) (Table 43). The final column in Table 43 indicated that nearly all daily records reported a catch of rig. Consequently, no binomial (occurrence) model was prepared because it would have no weight in a combined model, given the small proportion of zero daily records. All landed catch in this data set was allocated by multiplying the estimated catch by the ratio of landed to estimated for each vessel/year in this data set (Figure 195) (see Kendrick & Bentley 2012, section 2.2.6).

The gamma model accepted four predictive variables after fishing year (vessel, month, total_net_length, soak time), with the total model explaining 42% of the deviance (Table 44). The gamma model showed an excess of residuals at the mode of the distribution, but overall there was good conformity to the assumption of the gamma distribution even in the tails of the distribution (Figure 196). Both the lognormal and the Weibull distributions showed poorer fits to this data set than did the gamma model (Figure 197). The standardised series showed a strong drop from 1990 to 1998, followed by a period of little or no trend up to 2018, after which the series rose steeply to 2021 (Figure 198). The main impact of the standardisation procedure was to smooth out the unstandardised series, which showed more variability than the standardised series (Figure 199). The unstandardised series dropped when the vessel covariate was added (Figure 200), but then rose with the introduction of each successive covariate, starting with the month covariate (Figure 201), then the total_net_length covariate (Figure 202), and finally the soak time covariate (Figure 203). This progression can be seen in Figure 199. Almost all of the target information in this data set came from rig target records, so it is not surprising that the implied residual plot of target rig annual CPUE would have good conformity with the overall annual CPUE trend across this effectively single target species data set (Figure 204). The final positive catch model was characterised by a decline from 1990 to 1998, followed no trend to 2018 and a subsequent rise to 2021 (Figure 205, Table 45). A comparison of this series with the equivalent series calculated in 2019 (Starr & Kendrick 2020) shows that this series matches that series reasonably well in the overlapping years, but that the strong increase seen in the last three years had not yet begun (Figure 283).

Table 41: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 1W(043) SN daily CPUE series.

Series	SPO 1W(043) SN daily
QMS stock	SPO1
Reporting forms	CEL, ERS - Netting, NCE
Fishing methods	SN
Target species	SPO, SCH, SPD, NSD
Statistical Areas	043
Period	1989-10-01, 2021-09-30
Resolution	Day
Core fleet years	4
Core fleet trips	5
Default model	scaledkg ~ fyear + vessel_key + month + target_species + ns(log(soak_time), 3) + ns(log(total_net_length), 3)
Stepwise selection	Yes
Positive catch distribution	Gamma

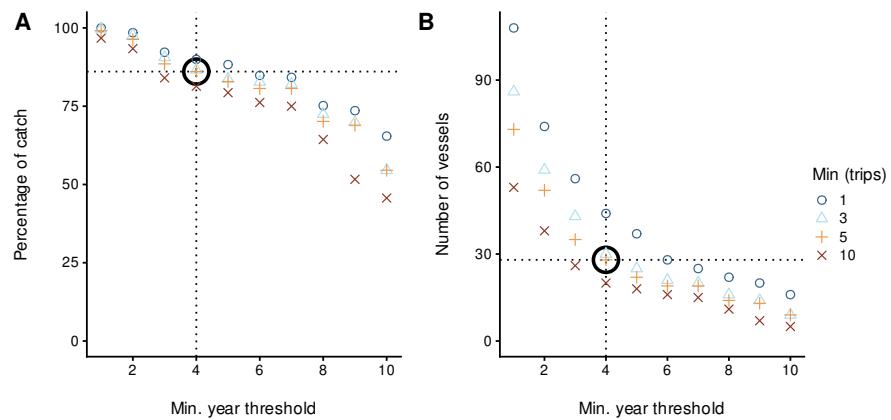


Figure 193: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 1W(043) SN daily CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

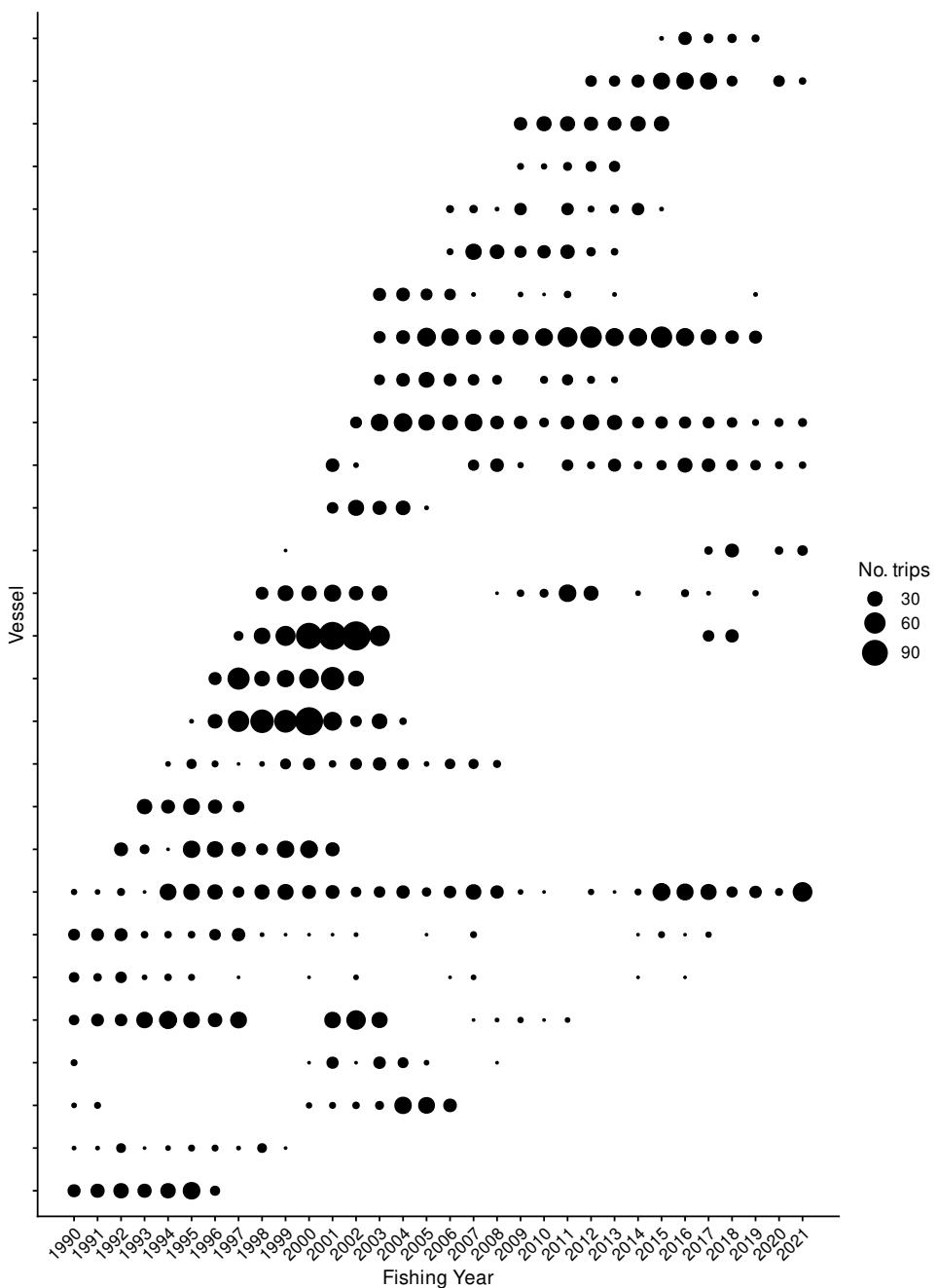


Figure 194: Number of trips by fishing year for core vessels. The area of the circles is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 42: Summary of the SPO 1W(043) SN 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	41 (100%) n: 197	37 (100%) n: 208	38 (100%) n: 200	22 (100%) n: 144	47 (100%) n: 267	73 (100%) n: 404	41 (100%) n: 331	51 (100%) n: 408	48 (100%) n: 353
Positive soak time	41 (100%) n: 197	37 (100%) n: 205	38 (100%) n: 199	22 (100%) n: 144	47 (100%) n: 267	72 (100%) n: 402	41 (100%) n: 328	51 (100%) n: 405	47 (100%) n: 345
Positive net length	41 (100%) n: 197	37 (100%) n: 205	38 (100%) n: 197	22 (100%) n: 143	47 (100%) n: 267	72 (100%) n: 401	39 (95%) n: 312	50 (100%) n: 399	47 (100%) n: 343
Scaler in range	41 (100%) n: 197	37 (100%) n: 204	35 (93%) n: 179	22 (100%) n: 136	47 (100%) n: 266	72 (100%) n: 400	38 (91%) n: 299	49 (100%) n: 391	25 (53%) n: 271
Trim extreme length	41 (100%) n: 197	37 (100%) n: 204	35 (93%) n: 179	22 (100%) n: 136	47 (100%) n: 265	72 (100%) n: 400	38 (91%) n: 299	49 (100%) n: 391	25 (53%) n: 271
Core fleet selection	25 (62%) n: 91	23 (63%) n: 90	33 (86%) n: 131	20 (90%) n: 112	38 (82%) n: 157	42 (57%) n: 233	29 (70%) n: 206	38 (75%) n: 266	23 (48%) n: 224
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	47 (100%) n: 346	73 (100%) n: 514	59 (100%) n: 524	42 (100%) n: 436	48 (100%) n: 445	37 (100%) n: 313	37 (100%) n: 226	25 (100%) n: 210	47 (100%) n: 252
Positive soak time	47 (100%) n: 338	72 (100%) n: 508	59 (100%) n: 521	42 (100%) n: 436	48 (100%) n: 445	37 (100%) n: 313	37 (100%) n: 226	25 (100%) n: 210	47 (100%) n: 252
Positive net length	47 (100%) n: 338	72 (100%) n: 508	59 (100%) n: 521	42 (100%) n: 436	48 (100%) n: 445	37 (100%) n: 313	37 (100%) n: 226	25 (100%) n: 210	47 (100%) n: 252
Scaler in range	35 (74%) n: 291	56 (77%) n: 389	55 (94%) n: 506	41 (100%) n: 434	48 (100%) n: 441	37 (100%) n: 312	36 (100%) n: 215	25 (100%) n: 209	47 (100%) n: 252
Trim extreme length	35 (74%) n: 290	56 (77%) n: 389	55 (94%) n: 506	41 (100%) n: 433	47 (100%) n: 440	37 (100%) n: 310	36 (100%) n: 215	25 (100%) n: 209	47 (100%) n: 252
Core fleet selection	34 (71%) n: 282	55 (75%) n: 370	46 (79%) n: 421	31 (75%) n: 347	40 (84%) n: 363	31 (83%) n: 243	34 (93%) n: 191	24 (100%) n: 181	45 (95%) n: 200

Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	29 (100%) n: 172	25 (100%) n: 168	25 (100%) n: 180	34 (100%) n: 245	33 (100%) n: 226	31 (100%) n: 175	23 (100%) n: 170	38 (100%) n: 227	32 (100%) n: 213
Positive soak time	29 (100%) n: 172	25 (100%) n: 168	25 (100%) n: 180	34 (100%) n: 245	33 (100%) n: 226	31 (100%) n: 175	23 (100%) n: 170	38 (100%) n: 227	32 (100%) n: 213
Positive net length	29 (100%) n: 172	25 (100%) n: 168	25 (100%) n: 180	34 (100%) n: 245	33 (100%) n: 226	31 (100%) n: 175	23 (100%) n: 170	38 (100%) n: 227	32 (100%) n: 213
Scaler in range	28 (100%) n: 171	25 (100%) n: 168	19 (77%) n: 132	34 (100%) n: 245	33 (100%) n: 226	31 (100%) n: 175	23 (100%) n: 170	38 (100%) n: 227	32 (100%) n: 212
Trim extreme length	28 (100%) n: 171	25 (100%) n: 168	19 (77%) n: 132	34 (100%) n: 245	33 (100%) n: 226	31 (100%) n: 175	23 (100%) n: 170	38 (100%) n: 227	32 (100%) n: 211
Core fleet selection	27 (100%) n: 151	23 (93%) n: 150	19 (77%) n: 131	34 (100%) n: 245	33 (100%) n: 224	31 (100%) n: 174	21 (93%) n: 153	37 (100%) n: 217	31 (100%) n: 205

Filter	2017	2018	2019	2020	2021
Ungroomed data	39 (100%) n: 213	22 (100%) n: 156	18 (100%) n: 78	14 (100%) n: 88	30 (100%) n: 166
Positive soak time	39 (100%) n: 213	22 (100%) n: 156	18 (100%) n: 78	14 (100%) n: 88	30 (100%) n: 166
Positive net length	39 (100%) n: 213	22 (100%) n: 156	18 (100%) n: 78	14 (100%) n: 88	30 (100%) n: 166
Scaler in range	39 (100%) n: 213	21 (100%) n: 155	18 (100%) n: 77	12 (87%) n: 75	30 (100%) n: 166
Trim extreme length	39 (100%) n: 213	21 (100%) n: 154	18 (100%) n: 77	12 (87%) n: 75	30 (100%) n: 166
Core fleet selection	37 (94%) n: 186	21 (92%) n: 143	18 (100%) n: 73	9.5 (68%) n: 48	19 (63%) n: 85

Table 43: Summary of the SPO 1W(043) SN 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 rig.

Fishing year	Vessels	Trips	Records	Net length (km)	Catch (t)	Records caught
1990	8	78	91	56.02	25.07	98.90
1991	7	83	90	54.64	23.41	100.00
1992	7	128	131	88.35	32.58	100.00
1993	8	112	112	65.65	19.76	97.32
1994	9	152	157	124.33	38.23	100.00
1995	10	215	233	175.57	41.82	98.71
1996	10	201	206	149.48	29.20	99.51
1997	11	256	266	208.21	38.28	97.74
1998	9	222	224	182.09	22.81	95.54
1999	10	282	282	243.68	33.61	97.52
2000	11	370	370	321.31	55.27	98.65
2001	13	415	421	368.39	46.36	98.81
2002	14	334	347	309.32	31.16	99.14
2003	13	334	363	310.46	40.00	96.14
2004	10	239	243	219.68	30.93	99.59
2005	10	184	191	191.82	34.25	100.00
2006	10	177	181	171.78	23.73	99.45
2007	12	197	200	201.05	44.75	99.00
2008	11	147	151	167.20	27.35	98.68
2009	11	139	150	129.44	22.90	99.33
2010	10	126	131	132.38	19.36	97.71
2011	11	238	245	234.98	33.88	99.18
2012	11	211	224	216.30	32.95	98.21
2013	11	170	174	168.14	30.81	99.43
2014	10	148	153	144.74	21.43	98.69
2015	9	209	217	215.10	36.92	98.62
2016	9	196	205	190.01	31.34	98.05
2017	10	184	186	181.75	36.62	99.46
2018	8	137	143	132.47	20.64	98.60
2019	7	71	73	66.10	17.97	100.00
2020	5	47	48	33.37	9.52	97.92
2021	5	85	85	64.28	18.62	95.29

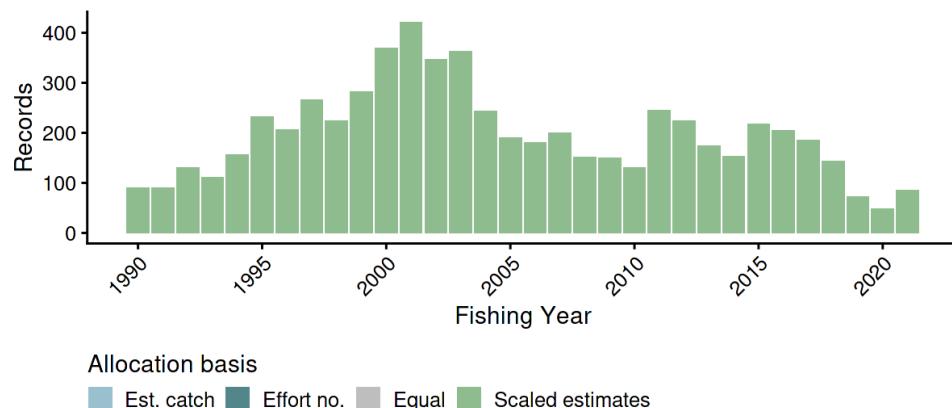


Figure 195: Allocation basis for attributing landings to records in the SPO 1W(043) SN daily catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table 44: Summary of stepwise selection for the gamma 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	30	74 612	7.3	7.3	*
+ vessel key	27	72 691	30.1	22.8	*
+ month	11	72 022	36.8	6.7	*
+ ns(log(total net length), 3)	3	71 664	40.1	3.3	*
+ ns(log(soak time), 3)	3	71 424	42.2	2.1	*

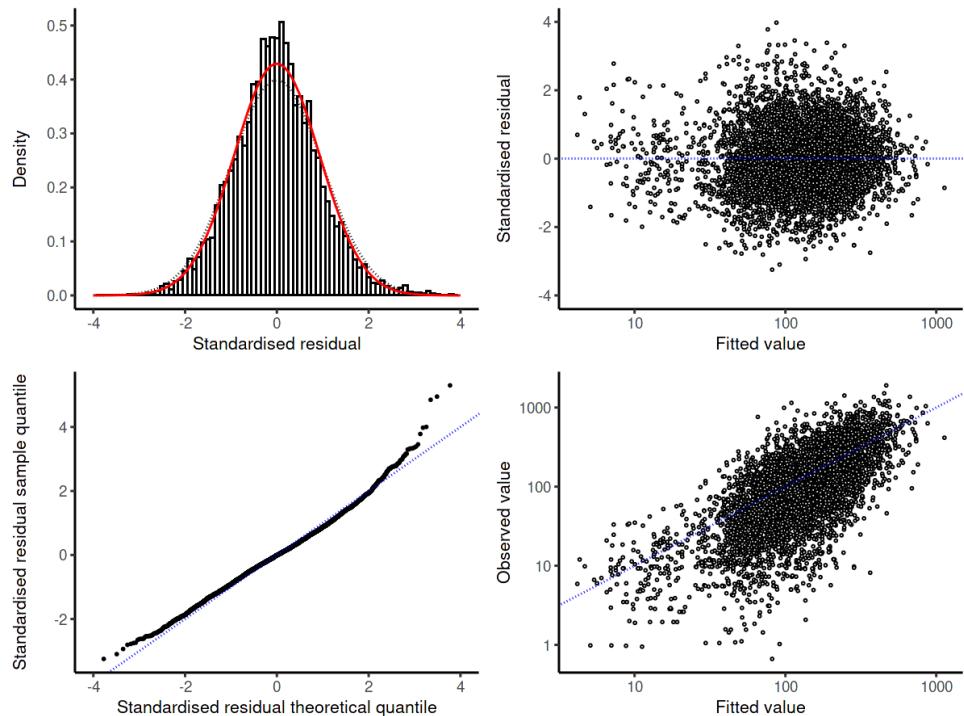


Figure 196: Diagnostic plots for the gamma model for the SPO 1W(043) SN daily dataset.

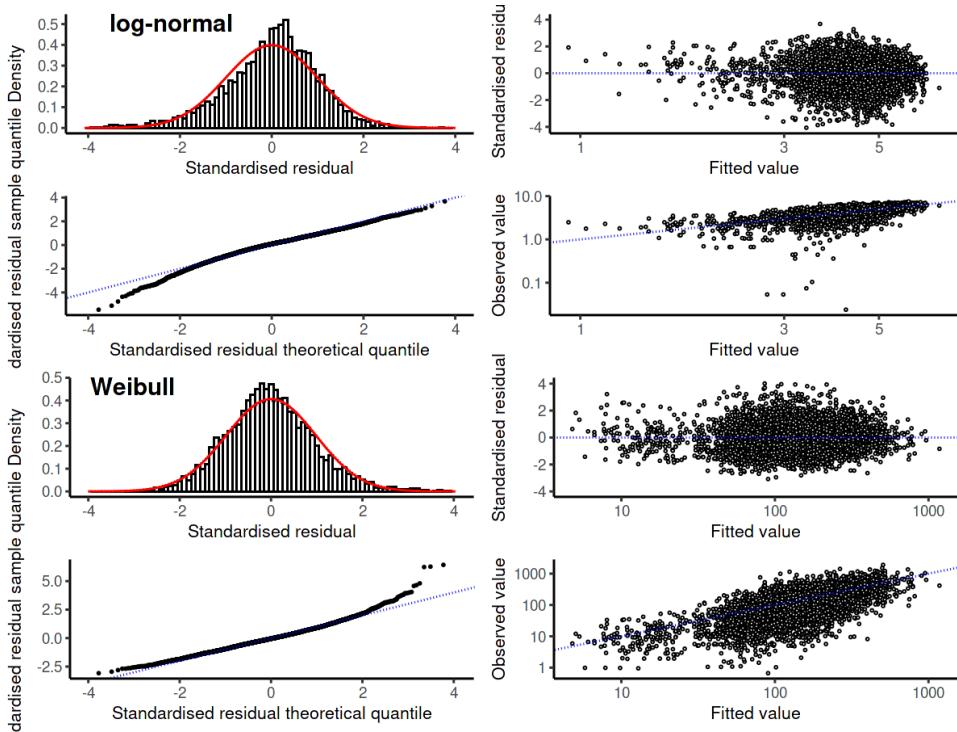


Figure 197: Diagnostic plots for the log-normal and Weibull model for the SPO 1W(043) SN daily dataset.

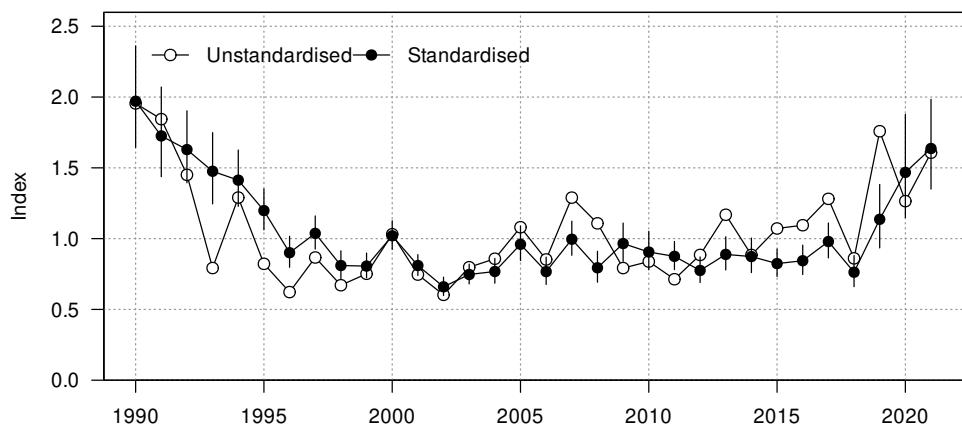


Figure 198: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 1W(043) SN daily dataset.

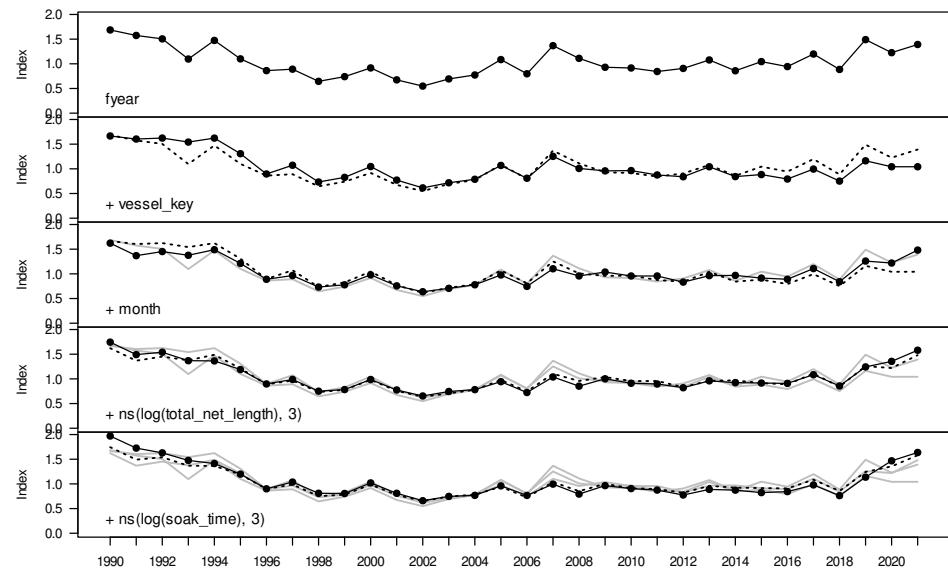


Figure 199: Changes to the SPO 1W(043) SN daily positive catch index as terms are successively entered into the model.

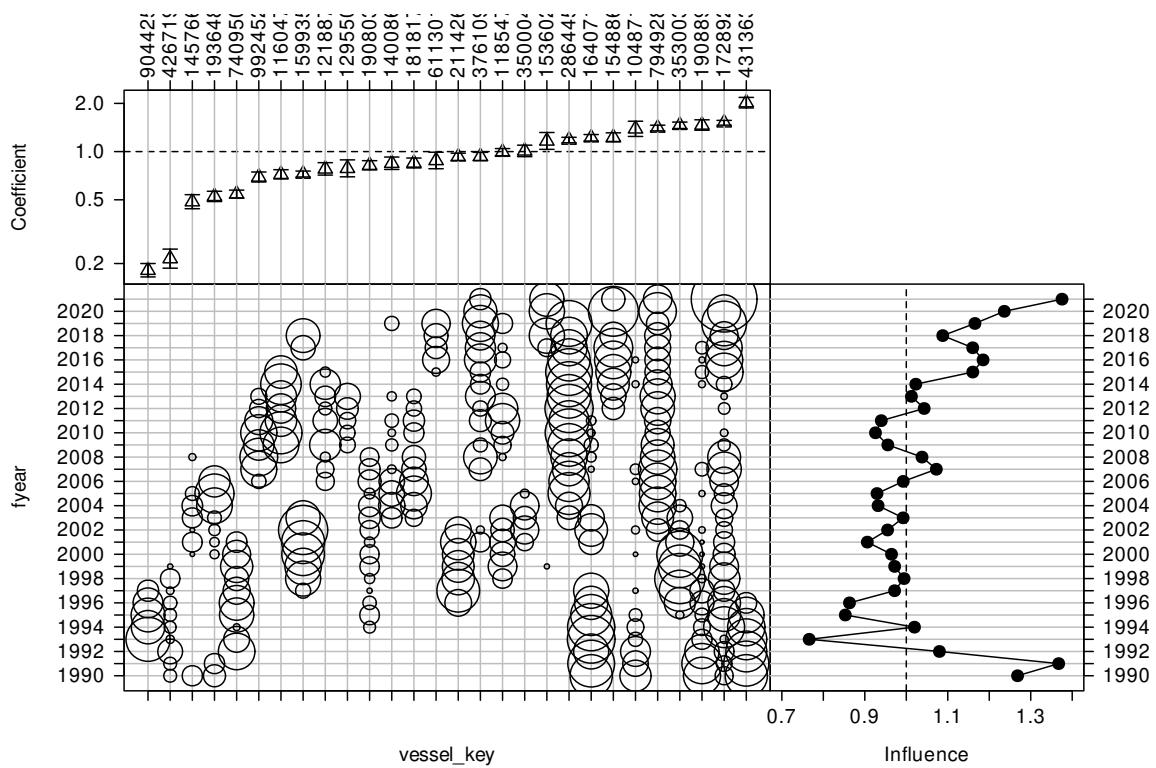


Figure 200: CDI plot for vessel key for the positive catch SPO 1W(043) SN daily catch-per-unit-effort dataset.

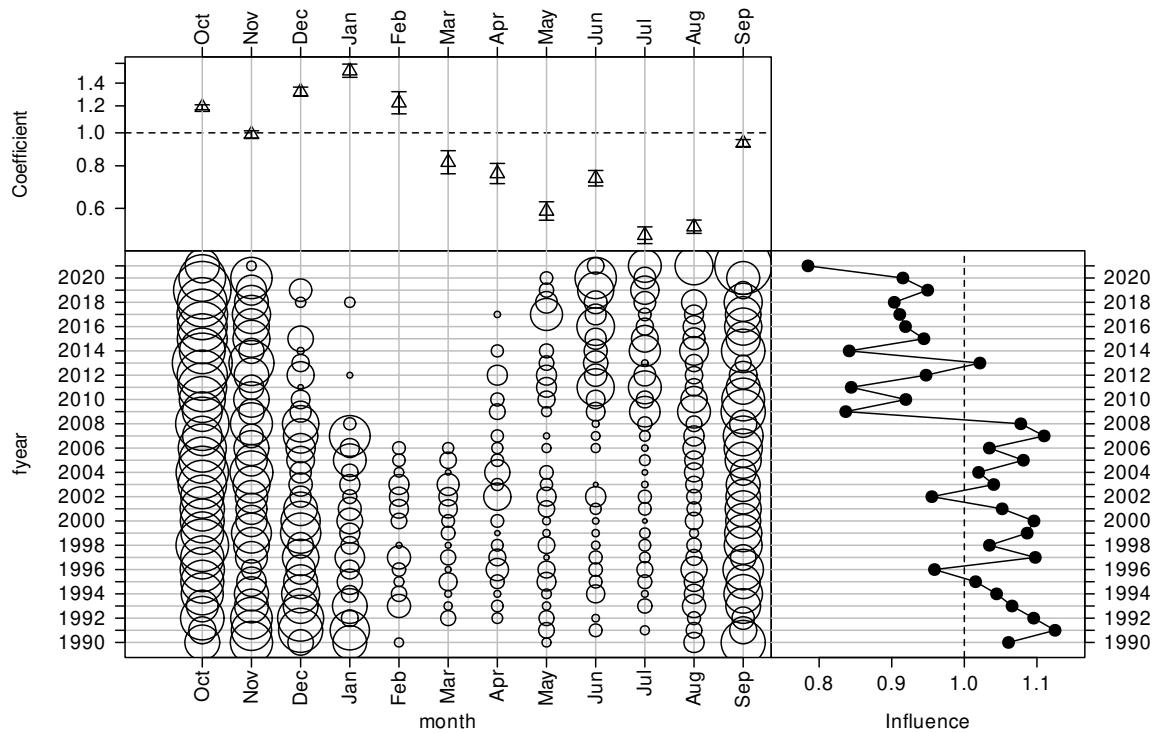


Figure 201: CDI plot for month for the positive catch SPO 1W(043) SN daily catch-per-unit-effort dataset.

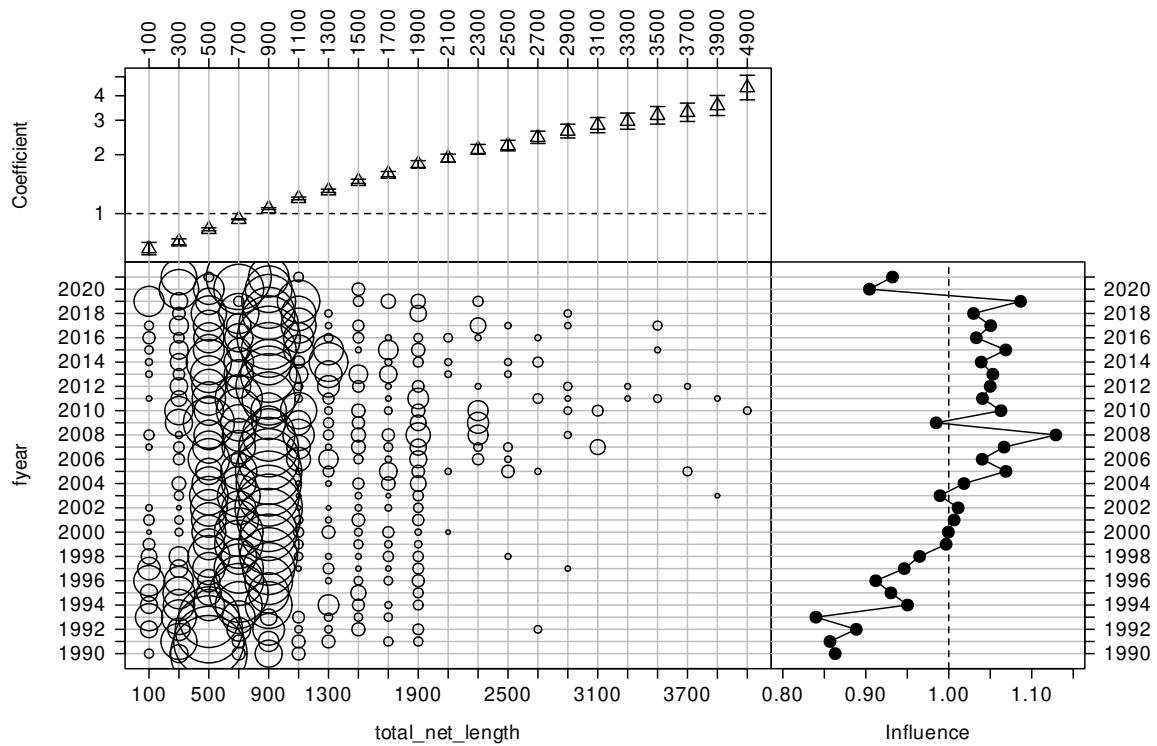


Figure 202: CDI plot for total net length for the positive catch SPO 1W(043) SN daily catch-per-unit-effort dataset.

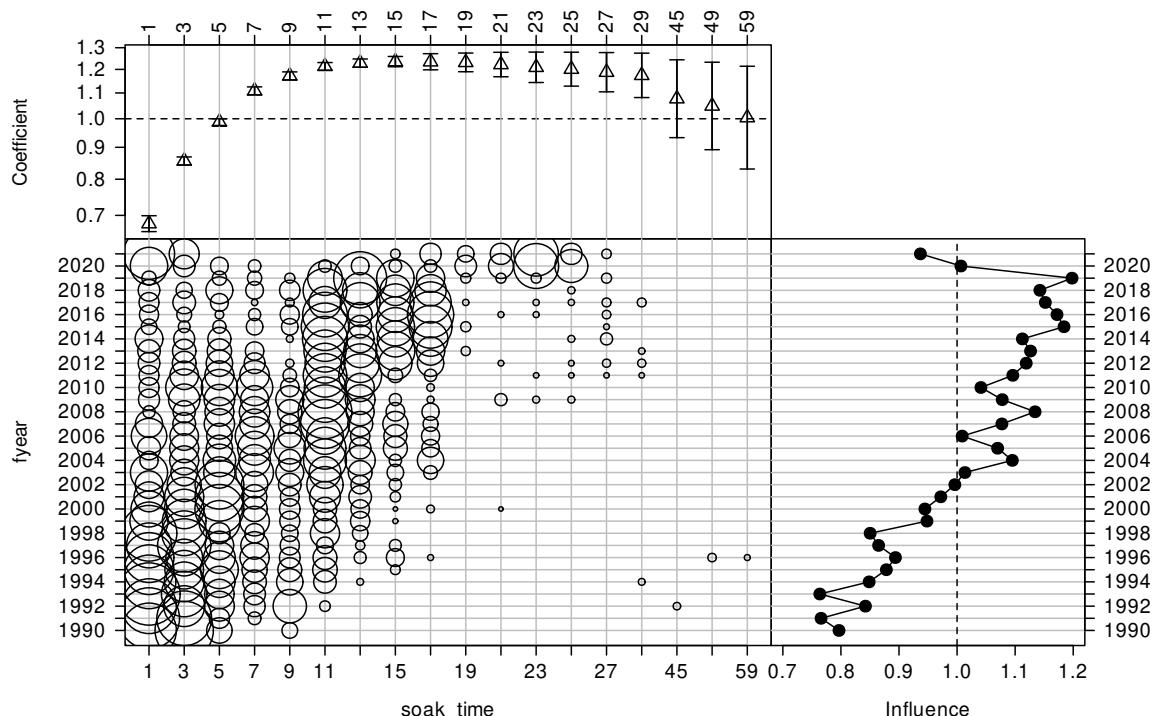


Figure 203: CDI plot for soak time for the positive catch SPO 1W(043) SN daily catch-per-unit-effort dataset.

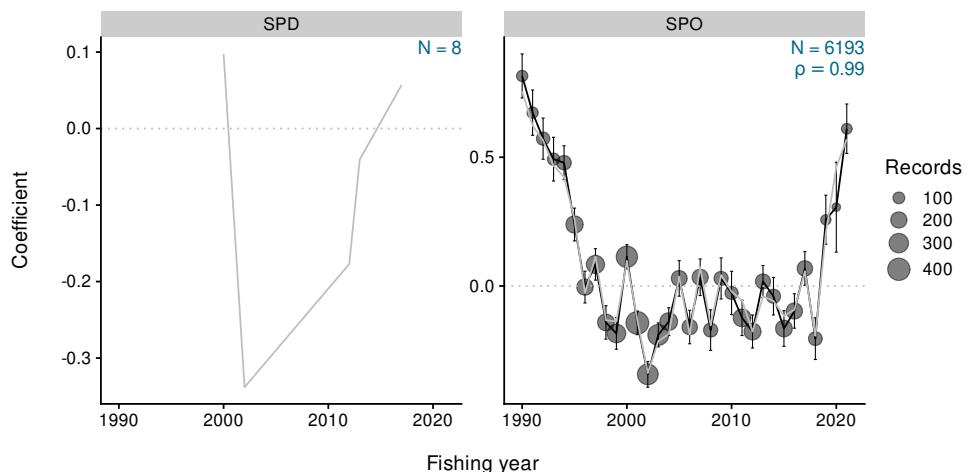


Figure 204: Residual implied coefficients for target-year in the gamma positive catch model for the SPO 1W(043) SN daily dataset.

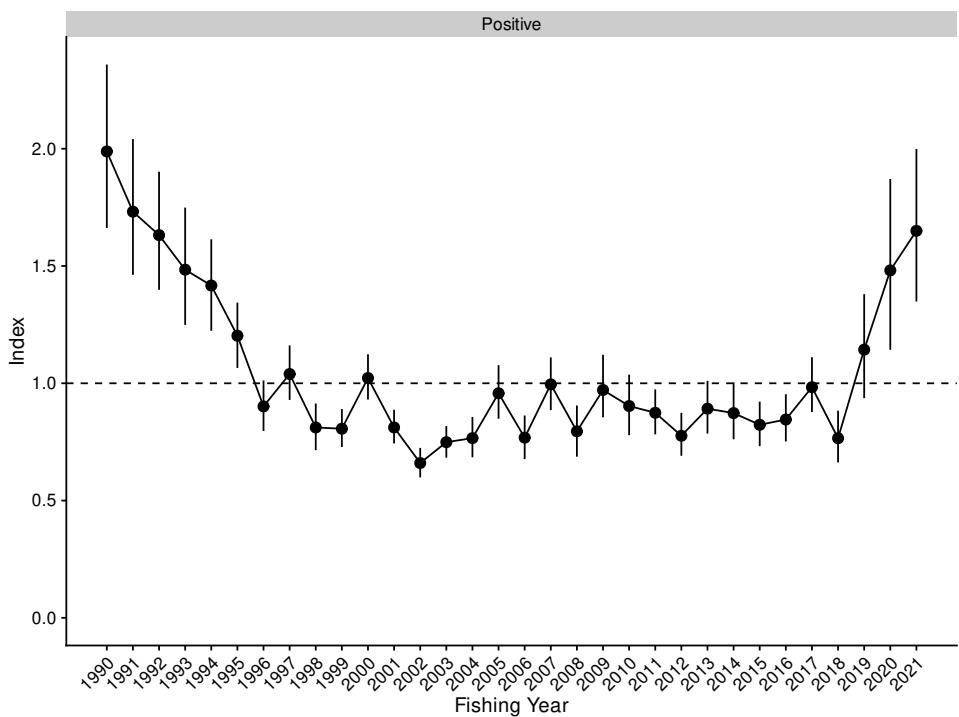


Figure 205: Standardised indices and 95% confidence intervals for the SPO 1W(043) SN daily dataset.

Table 45: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 1W(043) SN daily.

Fishing year	Positive			
	index	SE	LCI	UCI
1990	1.989	0.178	1.662	2.359
1991	1.732	0.148	1.462	2.041
1992	1.632	0.128	1.399	1.902
1993	1.484	0.128	1.249	1.749
1994	1.417	0.100	1.224	1.614
1995	1.203	0.071	1.065	1.344
1996	0.901	0.055	0.797	1.012
1997	1.039	0.059	0.929	1.161
1998	0.812	0.051	0.715	0.914
1999	0.806	0.041	0.728	0.890
2000	1.022	0.049	0.931	1.124
2001	0.812	0.037	0.744	0.887
2002	0.660	0.032	0.599	0.725
2003	0.749	0.034	0.683	0.818
2004	0.766	0.044	0.685	0.856
2005	0.957	0.058	0.849	1.077
2006	0.768	0.048	0.676	0.863
2007	0.995	0.057	0.886	1.110
2008	0.795	0.056	0.687	0.905
2009	0.971	0.068	0.855	1.122
2010	0.903	0.066	0.779	1.037
2011	0.874	0.049	0.782	0.974
2012	0.776	0.047	0.691	0.874
2013	0.892	0.057	0.786	1.010
2014	0.873	0.062	0.761	1.004
2015	0.823	0.048	0.732	0.922
2016	0.845	0.051	0.752	0.953
2017	0.983	0.060	0.877	1.111
2018	0.766	0.056	0.663	0.883
2019	1.143	0.113	0.937	1.380
2020	1.481	0.186	1.143	1.871
2021	1.650	0.166	1.349	1.999

5.9 SPO 1W(044) SN daily

This series was based on the daily catch of rig by target rig set net (SN) fishing in the Kaipara Harbour. The analysis was based on a single Statistical Area (044) specific to Kaipara Harbour (Table 46). The target species suite included the four commercially harvested shark species: rig (SPO), school shark (SCH), spiny dogfish (SPD) and northern dogfish (NSD). The core fleet was defined by having fished at least five trips in each of four years, retaining 90% of the catch and reducing the fleet from just over 100 vessels to 33 vessels (Figure 206). The pattern of vessel participation in this fishery was characterised by only a few vessels (less than five) which were active in the fishery for 15 to more than 25 years, with the rest of the vessels entering and exiting the fishery, operating in the fishery for only five to ten years (Figure 207). The final groomed dataset represented 56% (1997) to 100% (2008–2012, 2015, 2017, 2018, 2020) of the annual ungroomed catch by year (Table 47). The total annual catch of rig in the defined fishery ranged from 7.7 t (in 1991) to 76 t (in 2000) over the 32 years in the data set and was characterised by a high incidence of rig in the daily landings, ranging from 90% (in 1991) to 100% (in 1990, 1993, 1995, 2005, 2006, 2010, 2011, 2013, 2014, 2016, 2018) (Table 48). The final column in Table 48 indicated that nearly all daily records reported a catch of rig. Consequently, no binomial (occurrence) model was prepared because it would have no weight in a combined model, given the small proportion of zero daily records. All landed catch in this data set was allocated by multiplying the estimated catch by the ratio of landed to estimated for each vessel/year in this data set (Figure 208) (see Kendrick & Bentley 2012, section 2.2.6).

The gamma model accepted three predictive variables after fishing year (vessel, month, total_net_length), with the total model explaining 33% of the deviance (Table 49). The gamma model showed an excess of residuals at the mode of the distribution, but overall there was reasonable conformity to the assumption of the gamma distribution with some minor deviations in the tails of the distribution (Figure 209). The lognormal distribution showed a poor fit to this data set while the Weibull distribution showed a fit that appeared to be equivalent to that of the gamma model (Figure 210). The standardised series showed a declining trend from 1990 to 2003, followed by a period of little or no trend up to the end of the series in 2021 (Figure 211). The standardisation procedure smoothed out the unstandardised series and lifted the 2020 and 2021 index values (Figure 212). Most of this effect occurred when the vessel covariate was added (Figure 213), with the other two covariates having little standardisation impact (month: Figure 214; total_net_length: Figure 215). These successive effects can be seen in Figure 212. Almost all of the target information in this data set came from rig target records, so it is not surprising that the implied residual plot of target rig annual CPUE would have good conformity with the overall annual CPUE trend across this effectively single target species data set (Figure 216). The final positive catch model was characterised by a decline from 1990 to 2003, followed no trend to the end of the series in 2021 (Figure 217, Table 50). A comparison of this series with the equivalent series calculated in 2019 (Starr & Kendrick 2020) shows that this series matches that series reasonably well in the overlapping years, but, unlike for SPO 1W(043), the last three years show a drop to a level near the long-term series mean (Figure 284).

Table 46: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 1W(044) SN daily CPUE series.

Series	SPO 1W(044) SN daily
QMS stock	SPO1
Reporting forms	CEL, ERS - Netting, NCE
Fishing methods	SN
Target species	SPO, SCH, SPD, NSD
Statistical Areas	044
Period	1989-10-01, 2021-09-30
Resolution	Day
Core fleet years	4
Core fleet trips	5
Default model	scaledkg ~ fyear + vessel_key + month + target_species + ns(log(soak_time), 3) + ns(log(total_net_length), 3)
Stepwise selection	Yes
Positive catch distribution	Gamma

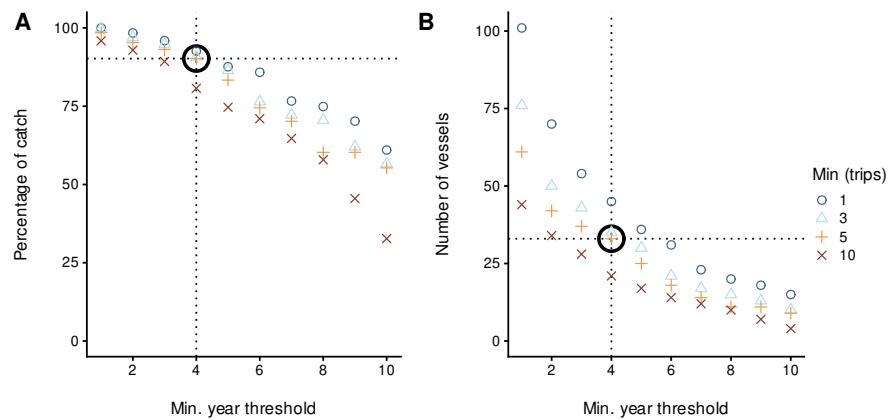


Figure 206: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 1W(044) SN daily CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

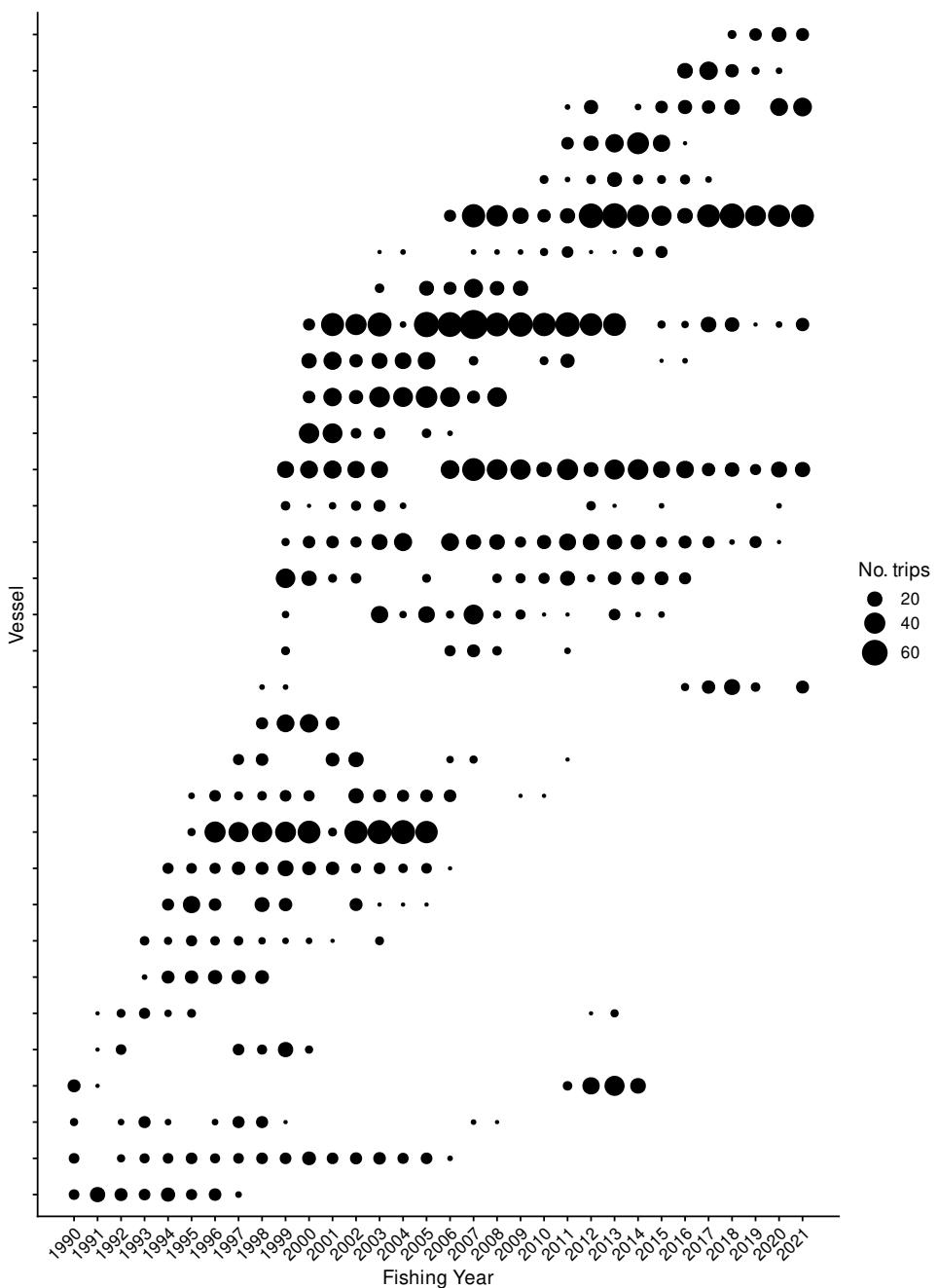


Figure 207: Number of trips by fishing year for core vessels. The area of the circles is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 47: Summary of the SPO 1W(044) SN 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	21 (100%) n: 66	13 (100%) n: 59	21 (100%) n: 79	21 (100%) n: 87	27 (100%) n: 131	53 (100%) n: 197	54 (100%) n: 203	64 (100%) n: 275	41 (100%) n: 217
Positive soak time	21 (100%) n: 65	13 (100%) n: 59	21 (100%) n: 79	21 (100%) n: 87	27 (100%) n: 131	53 (100%) n: 197	53 (100%) n: 202	63 (100%) n: 274	40 (100%) n: 211
Positive net length	21 (100%) n: 65	13 (100%) n: 59	21 (100%) n: 79	21 (100%) n: 87	27 (100%) n: 131	53 (100%) n: 197	52 (100%) n: 200	57 (90%) n: 270	39 (93%) n: 205
Scaler in range	21 (100%) n: 65	13 (100%) n: 56	21 (100%) n: 79	21 (100%) n: 87	26 (100%) n: 129	52 (100%) n: 180	52 (100%) n: 196	41 (64%) n: 218	38 (92%) n: 204
Trim extreme length	21 (100%) n: 65	13 (100%) n: 56	21 (100%) n: 79	21 (100%) n: 87	26 (100%) n: 129	52 (100%) n: 180	50 (94%) n: 193	41 (64%) n: 217	38 (92%) n: 204
Core fleet selection	16 (72%) n: 44	7.7 (61%) n: 30	14 (67%) n: 46	16 (76%) n: 59	20 (75%) n: 104	42 (78%) n: 140	41 (76%) n: 158	35 (56%) n: 165	37 (89%) n: 190
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	68 (100%) n: 342	92 (100%) n: 470	106 (100%) n: 530	61 (100%) n: 417	66 (100%) n: 531	60 (100%) n: 345	65 (100%) n: 418	38 (100%) n: 289	58 (100%) n: 364
Positive soak time	65 (100%) n: 331	92 (100%) n: 466	106 (100%) n: 530	61 (100%) n: 417	66 (100%) n: 531	60 (100%) n: 345	65 (100%) n: 418	38 (100%) n: 289	58 (100%) n: 364
Positive net length	64 (94%) n: 322	91 (100%) n: 461	106 (100%) n: 529	61 (100%) n: 417	65 (100%) n: 527	60 (100%) n: 345	65 (100%) n: 418	38 (100%) n: 289	58 (100%) n: 364
Scaler in range	56 (83%) n: 298	77 (84%) n: 412	83 (79%) n: 467	61 (100%) n: 417	65 (100%) n: 527	55 (92%) n: 314	54 (82%) n: 315	37 (100%) n: 282	58 (100%) n: 361
Trim extreme length	56 (83%) n: 298	77 (84%) n: 412	83 (79%) n: 467	61 (100%) n: 416	65 (100%) n: 526	55 (92%) n: 314	54 (82%) n: 315	37 (100%) n: 282	58 (100%) n: 361
Core fleet selection	56 (82%) n: 291	76 (82%) n: 393	74 (70%) n: 397	47 (78%) n: 318	48 (74%) n: 408	42 (70%) n: 228	53 (82%) n: 308	36 (93%) n: 269	54 (93%) n: 333

Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	31 (100%) n: 247	29 (100%) n: 185	34 (100%) n: 170	44 (100%) n: 265	53 (100%) n: 303	53 (100%) n: 344	40 (100%) n: 266	38 (100%) n: 205	40 (100%) n: 243
Positive soak time	31 (100%) n: 247	29 (100%) n: 185	34 (100%) n: 170	44 (100%) n: 265	53 (100%) n: 303	53 (100%) n: 344	40 (100%) n: 266	38 (100%) n: 205	40 (100%) n: 242
Positive net length	31 (100%) n: 247	29 (100%) n: 185	34 (100%) n: 170	44 (100%) n: 265	53 (100%) n: 303	53 (100%) n: 344	40 (100%) n: 266	38 (100%) n: 205	40 (100%) n: 242
Scaler in range	31 (100%) n: 239	28 (100%) n: 179	33 (100%) n: 161	44 (100%) n: 265	53 (100%) n: 303	53 (100%) n: 344	33 (82%) n: 239	38 (100%) n: 205	40 (100%) n: 242
Trim extreme length	31 (100%) n: 239	28 (100%) n: 179	33 (100%) n: 161	44 (100%) n: 265	53 (100%) n: 303	53 (100%) n: 344	33 (82%) n: 239	38 (100%) n: 205	40 (100%) n: 242
Core fleet selection	31 (100%) n: 238	28 (100%) n: 174	32 (100%) n: 151	43 (100%) n: 255	53 (100%) n: 284	49 (92%) n: 325	32 (81%) n: 235	37 (100%) n: 196	35 (88%) n: 194

Filter	2017	2018	2019	2020	2021
Ungroomed data	39 (100%) n: 216	46 (100%) n: 212	32 (100%) n: 148	20 (100%) n: 145	26 (100%) n: 181
Positive soak time	39 (100%) n: 216	46 (100%) n: 212	32 (100%) n: 148	20 (100%) n: 145	26 (100%) n: 181
Positive net length	39 (100%) n: 216	46 (100%) n: 212	32 (100%) n: 148	20 (100%) n: 145	26 (100%) n: 181
Scaler in range	39 (100%) n: 216	46 (100%) n: 211	22 (68%) n: 101	20 (100%) n: 145	26 (100%) n: 181
Trim extreme length	38 (100%) n: 215	46 (100%) n: 211	22 (68%) n: 101	20 (100%) n: 145	26 (100%) n: 181
Core fleet selection	37 (100%) n: 202	45 (100%) n: 205	22 (68%) n: 101	20 (100%) n: 145	24 (94%) n: 168

Table 48: Summary of the SPO 1W(044) SN 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 rig.

Fishing year	Vessels	Trips	Records	Net length (km)	Catch (t)	Records caught
1990	4	37	44	35.70	15.51	100.00
1991	4	23	30	27.70	7.71	90.00
1992	5	37	46	45.50	13.91	97.83
1993	6	50	59	51.98	16.29	100.00
1994	8	74	104	90.31	20.00	96.15
1995	9	95	140	127.10	41.72	100.00
1996	9	122	158	150.45	40.95	98.10
1997	10	126	165	153.76	35.38	99.39
1998	12	155	190	164.12	36.90	97.37
1999	16	233	291	281.61	55.73	92.10
2000	15	271	393	365.00	75.85	94.40
2001	14	259	397	340.17	74.12	97.73
2002	14	257	318	313.04	47.44	99.69
2003	16	313	408	347.10	48.31	99.75
2004	12	182	228	195.32	41.54	99.56
2005	12	262	308	292.46	53.45	100.00
2006	13	213	269	234.17	35.73	100.00
2007	12	305	333	293.48	53.95	99.10
2008	11	225	238	224.20	31.06	99.58
2009	9	163	174	167.40	27.93	98.85
2010	10	130	151	137.04	32.13	100.00
2011	14	215	255	223.02	43.23	100.00
2012	12	228	284	246.54	52.60	99.65
2013	12	278	325	269.46	49.26	100.00
2014	10	200	235	192.03	32.00	100.00
2015	12	155	196	170.42	37.27	98.98
2016	11	132	194	165.03	35.32	100.00
2017	8	158	202	154.93	37.29	99.01
2018	8	157	205	163.30	44.83	100.00
2019	7	87	101	84.44	21.57	99.01
2020	8	122	145	106.01	20.07	97.93
2021	6	141	168	111.02	24.42	97.62

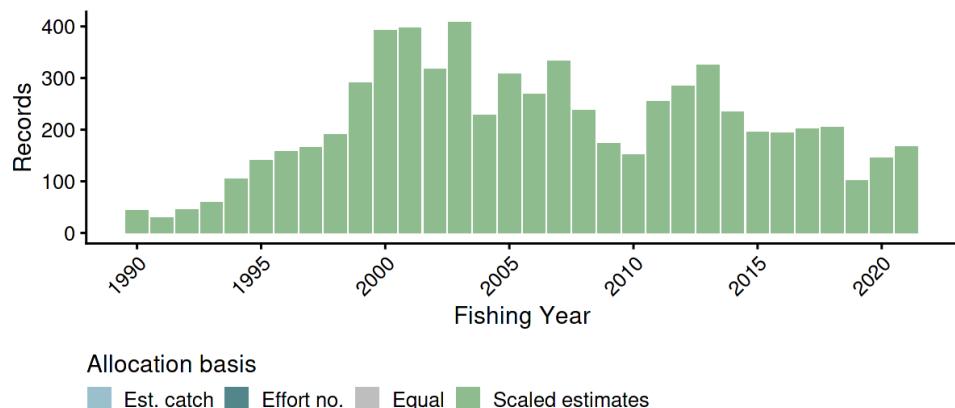


Figure 208: Allocation basis for attributing landings to records in the SPO 1W(044) SN daily catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table 49: Summary of stepwise selection for the gamma 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	30	81 170	7.5	7.5	*
+ vessel key	32	80 130	20.5	13.0	*
+ month	11	79 326	29.1	8.6	*
+ ns(log(total net length), 3)	3	78 973	32.6	3.5	*
+ ns(log(soak time), 3)	3	78 931	33.0	0.5	

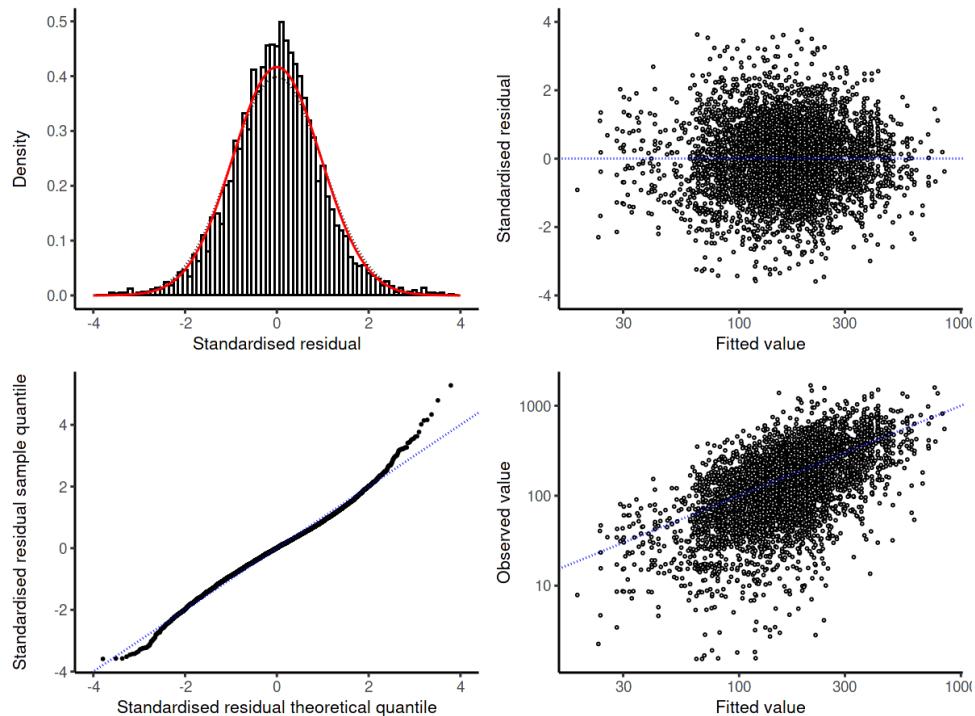


Figure 209: Diagnostic plots for the gamma model for the SPO 1W(044) SN daily dataset.

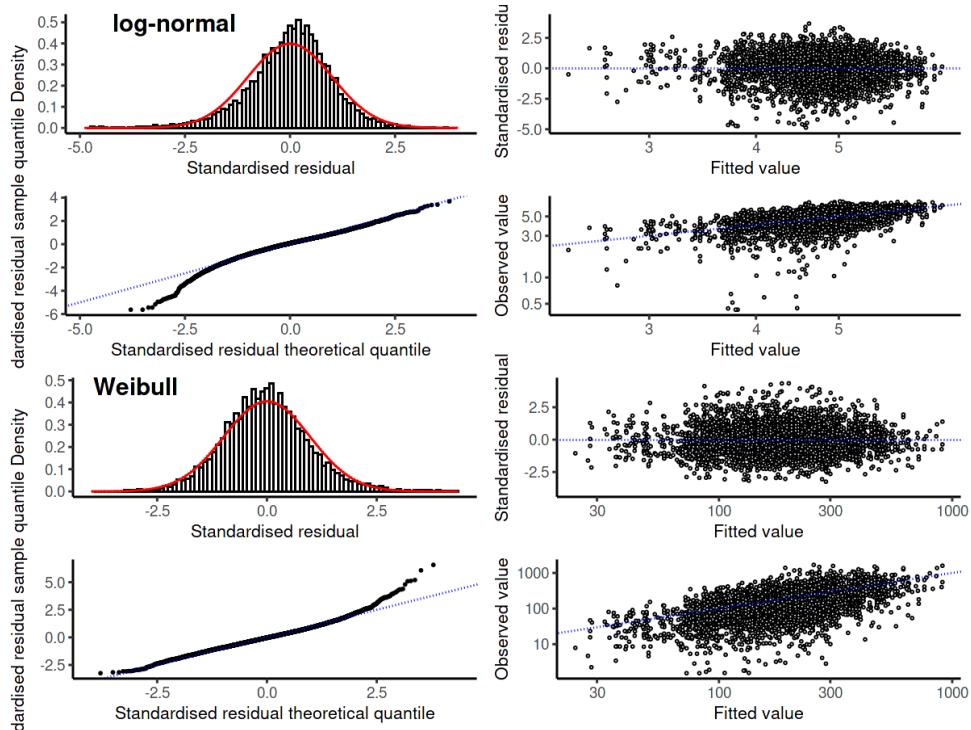


Figure 210: Diagnostic plots for the log-normal and Weibull model for the SPO 1W(044) SN daily dataset.

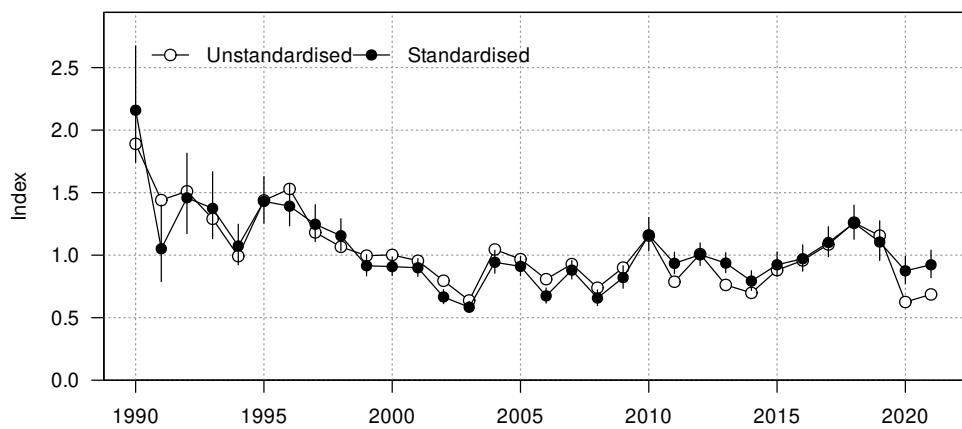


Figure 211: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 1W(044) SN daily dataset.

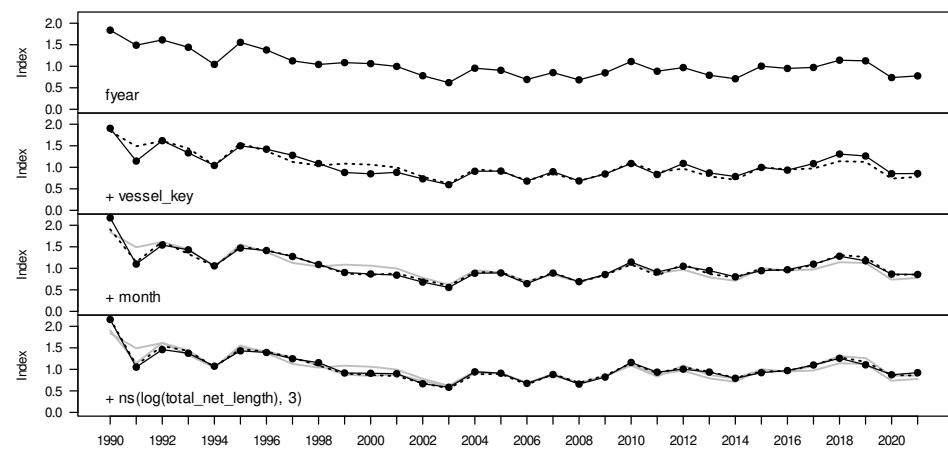


Figure 212: Changes to the SPO 1W(044) SN daily positive catch index as terms are successively entered into the model.

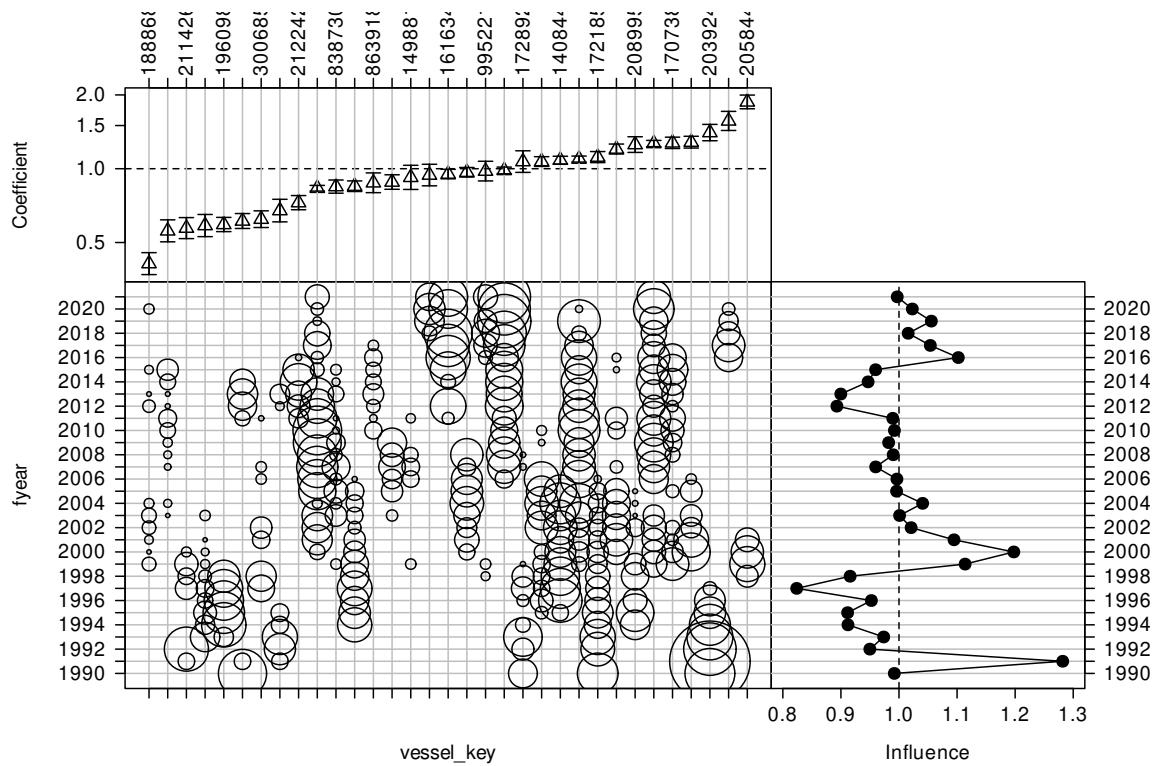


Figure 213: CDI plot for vessel key for the positive catch SPO 1W(044) SN daily catch-per-unit-effort dataset.

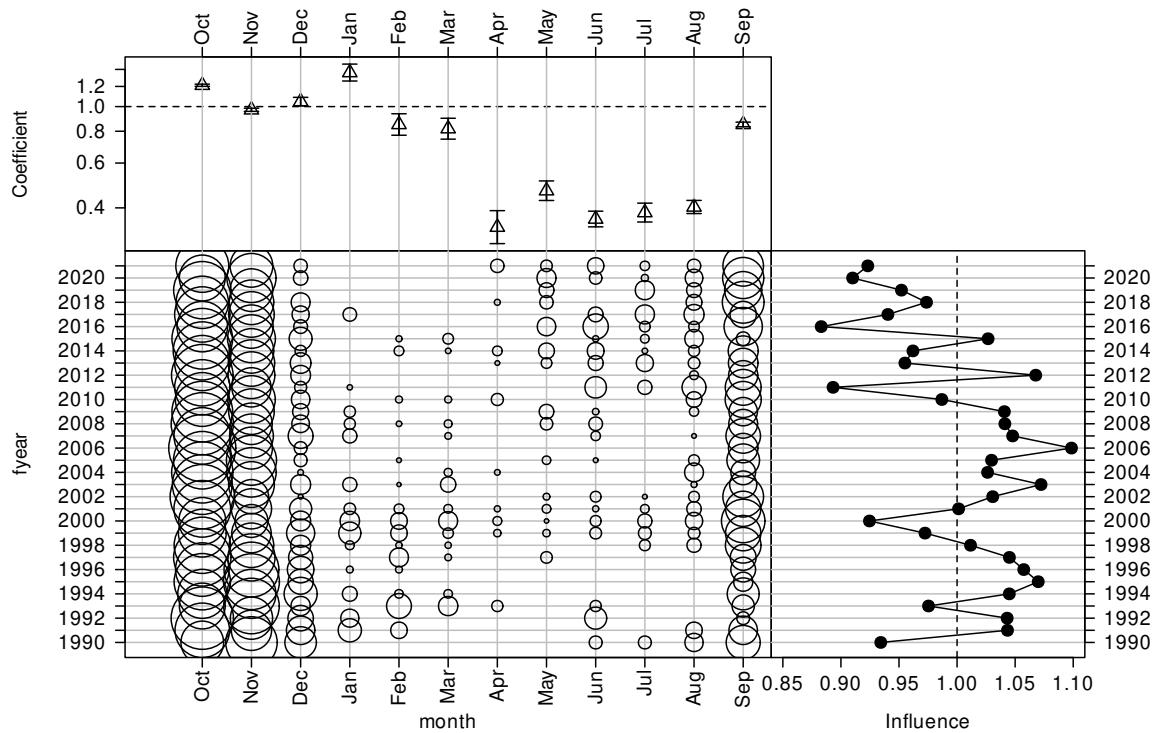


Figure 214: CDI plot for month for the positive catch SPO 1W(044) SN daily catch-per-unit-effort dataset.

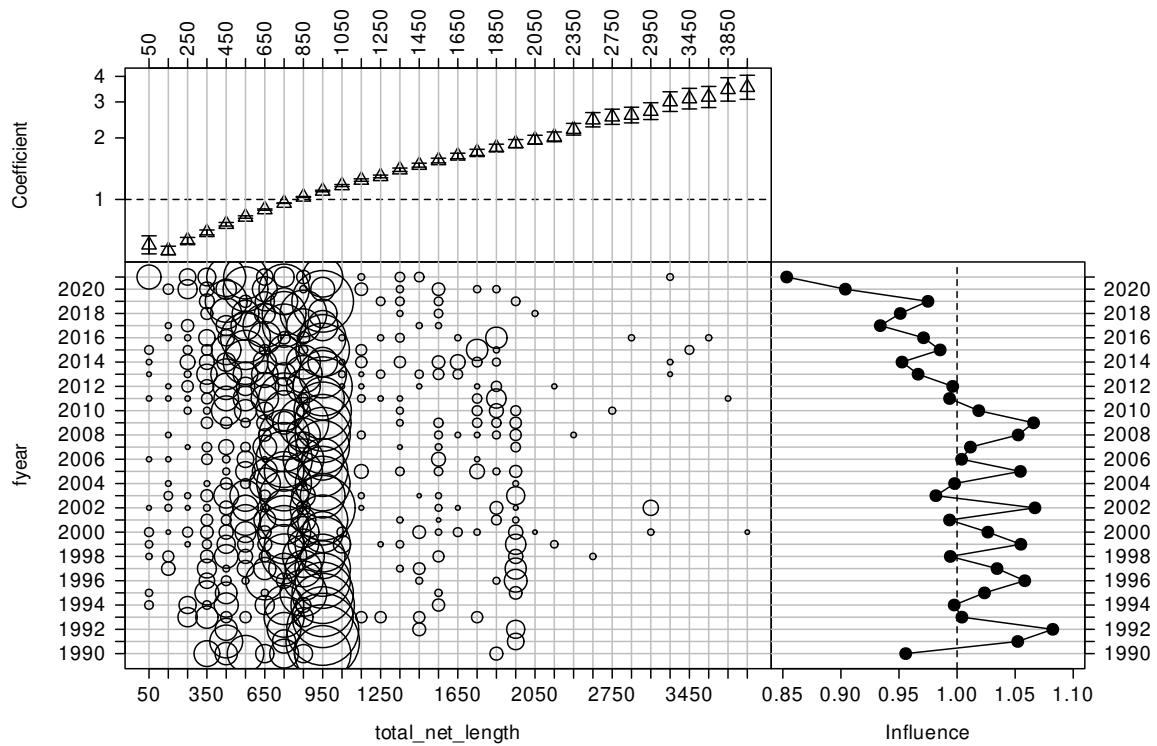


Figure 215: CDI plot for total net length for the positive catch SPO 1W(044) SN daily catch-per-unit-effort dataset.

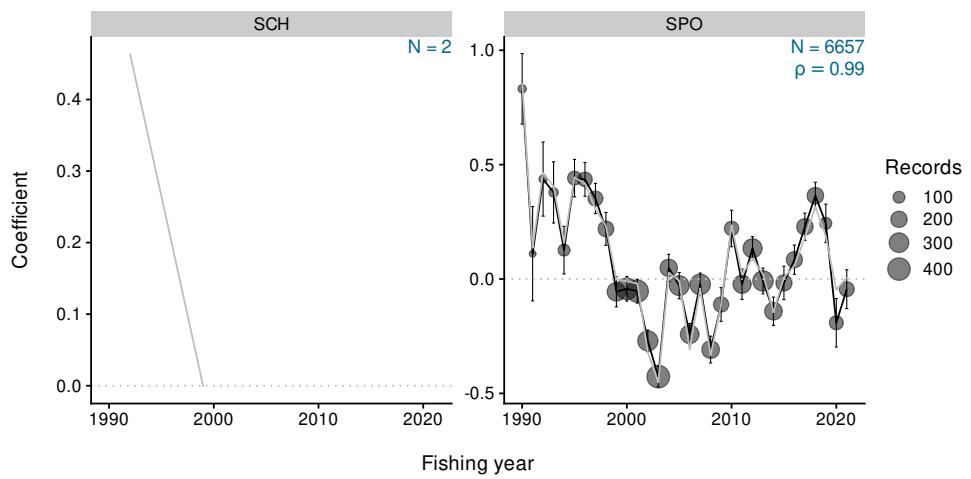


Figure 216: Residual implied coefficients for target-year in the gamma positive catch model for the SPO 1W(044) SN daily dataset.

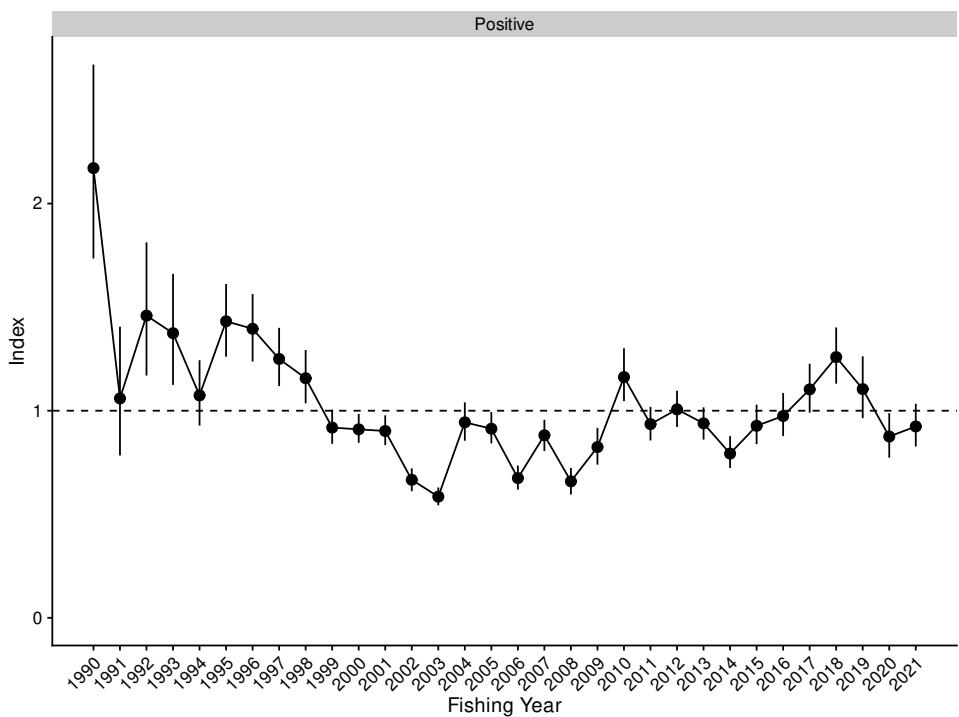


Figure 217: Standardised indices and 95% confidence intervals for the SPO 1W(044) SN daily dataset.

Table 50: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 1W(044) SN daily.

Fishing year	index	SE	Positive	
			LCI	UCI
1990	2.171	0.239	1.735	2.671
1991	1.059	0.159	0.784	1.406
1992	1.459	0.164	1.170	1.813
1993	1.374	0.137	1.125	1.661
1994	1.074	0.081	0.928	1.244
1995	1.432	0.090	1.261	1.612
1996	1.395	0.083	1.238	1.563
1997	1.250	0.072	1.119	1.400
1998	1.157	0.066	1.035	1.293
1999	0.918	0.042	0.840	1.005
2000	0.910	0.036	0.845	0.984
2001	0.902	0.037	0.834	0.978
2002	0.666	0.028	0.611	0.722
2003	0.585	0.022	0.543	0.629
2004	0.944	0.047	0.855	1.040
2005	0.913	0.039	0.842	0.994
2006	0.675	0.030	0.619	0.735
2007	0.881	0.039	0.805	0.956
2008	0.659	0.033	0.595	0.724
2009	0.824	0.045	0.740	0.917
2010	1.162	0.065	1.046	1.302
2011	0.935	0.041	0.856	1.019
2012	1.007	0.045	0.922	1.097
2013	0.939	0.040	0.861	1.016
2014	0.793	0.039	0.723	0.877
2015	0.927	0.049	0.839	1.029
2016	0.974	0.053	0.877	1.086
2017	1.103	0.060	0.991	1.227
2018	1.259	0.069	1.131	1.402
2019	1.104	0.076	0.964	1.263
2020	0.875	0.055	0.773	0.988
2021	0.924	0.053	0.827	1.034

5.10 SPO 3 SN daily East Coast

This series was based on the daily catch of rig from the shark target species fishery off the east coast South Island. The analysis included five east coast South Island statistical areas, stretching from Cloudy Bay to the Catlins: Statistical Areas 018 (Kaikoura), 020 (Pegasus Bay), 022 (Canterbury Bight), 024 (Timaru), 026 (Otago) (Table 51). The target species suite included the four commercially harvested shark species: rig (SPO), school shark (SCH), spiny dogfish (SPD) and elephant fish (ELE). The core fleet was defined by having fished at least four trips in each of four years, retaining 93% of the catch and reducing the fleet from over 160 vessels to 69 vessels (Figure 218). The pattern of vessel participation in this fishery was characterised by 15 to 20 vessels which remained the fishery for 15 years or more (Figure 219) along with vessels with shorter periods of activity. The final groomed dataset represented 68% (1993) to 100% (2002, 2006, 2009–2011, 2013–2015, 2017–2021) of ungroomed catch for each year (Table 52). The total annual catch of rig in the defined fishery ranged from 60 t (in 1990) to 275 t (in 2020) over the 32 years in the data set and was characterised by an increasing occurrence of rig in the daily landings, ranging from 53% (in 1991) to 88% (in 2017) (Table 53). All landed catch in this data set was allocated by distributing the total trip landings proportionately to the estimated catches within the trip (Figure 220).

The binomial (occurrence) model accepted three predictive variables after fishing year (vessel, target species, month), with the model explaining 27% of the deviance (Table 54). Both the unstandardised and standardised series showed little overall trend over the entire series (Figure 221). Although the standardisation model modified the unstandardised series, there was little change to the overall trend (Figure 222). The vessel covariate (Figure 223) and the target species covariate (Figure 224) generated an observable standardisation impact, but the net effect of adding these covariates was to slightly change the tilt of the series without affecting the overall trend very much (Figure 222). The last covariate to enter the occurrence model (month) had no visible standardisation effect (Figure 225, see Figure 222).

The lognormal model accepted four predictive variables after fishing year (vessel, target species, month, total_net_length), with the total model explaining 45% of the deviance (Table 55). Residuals to the positive catch model showed good conformity to the lognormal assumption over the total distribution, with some minor skewness in the upper and lower tails (Figure 226). Both the gamma and the Weibull distributions showed reasonable fits to the positive catch data, but were clearly inferior to the lognormal model fit (Figure 227). While the unstandardised series showed a strong increase from 2010 to 2021, rising from below the series average to more than twice the series average, the standardisation model completely removed this strong increase, leaving no long-term trend over the entire time period (Figure 228). This negation of the unstandardised increase occurred with the addition of the vessel covariate, which completely flattened the series (Figure 229, Figure 230). The other three covariates had no impact when added to the model (target species: Figure 231, month: Figure 232, total_net_length: Figure 233, see Figure 229). Implied residual plots of rig annual CPUE showed good conformity with the overall annual CPUE trend just for the rig (SPO) target species (Figure 234). The other three target species (SCH, SPD, ELE) all showed a limited correlation ($\tilde{0.5}$) with the overall annual CPUE trend. The conformity with the overall annual CPUE trend was not very good for three of the model statistical areas ($\text{rho}=\tilde{0.5}$ for Statistical Areas 020, 022, 024), while the correlation with Statistical Area 018 was better but not that good (Figure 235). The fifth statistical area (Statistical Area 026-Otago) had too few data to make a meaningful comparison. It is notable that each statistical area showed a drop in the final (2021) model year.

Both contributing models (lognormal and binomial) showed little overall trend during the 32 year time period of the data, with the lognormal series showing an upward excursion in 2019 and 2020, followed by a return to the mean in 2021 (Figure 236, Figure 237, Table 56). The combined model tended to follow the lognormal model, including the drop in 2021.

Table 51: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 3 SN daily East Coast CPUE series.

Series	SPO 3 SN daily East Coast
QMS stock	SPO3
Reporting forms	CEL, ERS - Netting, NCE
Fishing methods	SN
Target species	SPO, SCH, SPD, ELE
Statistical Areas	018, 020, 022, 024, 026
Period	1989-10-01, 2021-09-30
Resolution	Day
Core fleet years	4
Core fleet trips	4
Default model	allockg ~ fyyear + vessel_key + stat_area + month + target_species + ns(log(soak_time), 3) + ns(log(total_net_length), 3)
Stepwise selection	Yes
Positive catch distribution	Lognormal

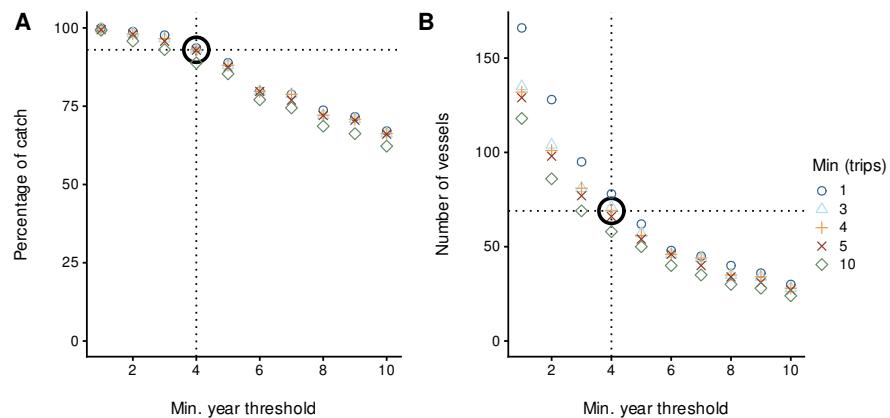


Figure 218: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 3 SN daily East Coast CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

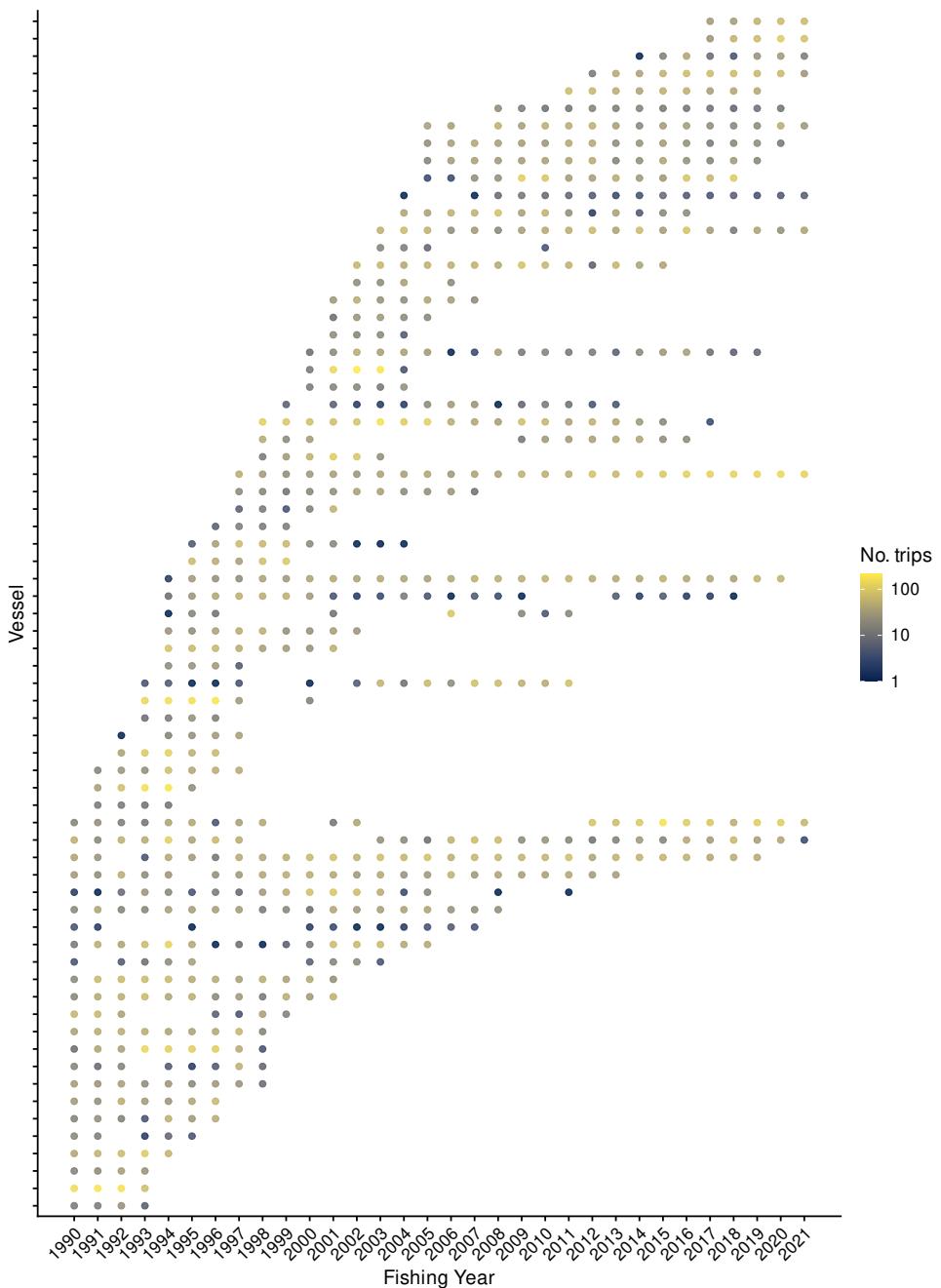


Figure 219: Number of trips by fishing year for core vessels. The colour of the points is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 52: Summary of the SPO 3 SN daily East Coast 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	84 (100%) n: 1076	96 (100%) n: 1406	110 (100%) n: 1411	91 (100%) n: 1551	139 (100%) n: 1996	182 (100%) n: 1721	166 (100%) n: 1503	177 (100%) n: 1158	192 (100%) n: 1125
Positive soak time	83 (100%) n: 1067	95 (100%) n: 1402	110 (100%) n: 1405	90 (100%) n: 1542	138 (100%) n: 1987	182 (100%) n: 1710	165 (100%) n: 1483	176 (100%) n: 1124	180 (94%) n: 1061
Positive net length	83 (100%) n: 1065	95 (100%) n: 1402	110 (100%) n: 1402	90 (100%) n: 1528	134 (100%) n: 1972	181 (100%) n: 1693	164 (100%) n: 1478	175 (100%) n: 1115	170 (89%) n: 1001
Core fleet selection	60 (71%) n: 757	74 (77%) n: 949	84 (76%) n: 1088	62 (68%) n: 1299	129 (93%) n: 1711	161 (88%) n: 1314	144 (87%) n: 1298	159 (90%) n: 1028	158 (82%) n: 955
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	179 (100%) n: 1025	166 (100%) n: 944	218 (100%) n: 1410	218 (100%) n: 1199	192 (100%) n: 1322	153 (100%) n: 980	144 (100%) n: 966	157 (100%) n: 903	166 (100%) n: 978
Positive soak time	163 (91%) n: 981	154 (93%) n: 907	209 (100%) n: 1393	217 (100%) n: 1198	192 (100%) n: 1321	153 (100%) n: 980	144 (100%) n: 966	157 (100%) n: 903	166 (100%) n: 977
Positive net length	148 (83%) n: 935	139 (84%) n: 857	204 (93%) n: 1369	217 (100%) n: 1198	192 (100%) n: 1321	153 (100%) n: 980	144 (100%) n: 966	157 (100%) n: 903	166 (100%) n: 977
Core fleet selection	133 (74%) n: 866	127 (77%) n: 792	189 (86%) n: 1292	216 (100%) n: 1165	181 (95%) n: 1259	143 (93%) n: 838	134 (93%) n: 911	154 (100%) n: 875	126 (76%) n: 839
Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	167 (100%) n: 974	125 (100%) n: 935	105 (100%) n: 930	131 (100%) n: 935	149 (100%) n: 953	167 (100%) n: 907	171 (100%) n: 864	200 (100%) n: 1019	211 (100%) n: 1130
Positive soak time	167 (100%) n: 974	125 (100%) n: 934	105 (100%) n: 930	131 (100%) n: 934	149 (100%) n: 952	167 (100%) n: 906	171 (100%) n: 863	200 (100%) n: 1019	211 (100%) n: 1130
Positive net length	167 (100%) n: 974	125 (100%) n: 934	105 (100%) n: 930	131 (100%) n: 934	149 (100%) n: 952	167 (100%) n: 906	171 (100%) n: 863	200 (100%) n: 1019	211 (100%) n: 1130
Core fleet selection	155 (93%) n: 914	123 (100%) n: 915	105 (100%) n: 930	131 (100%) n: 934	124 (83%) n: 849	161 (100%) n: 879	171 (100%) n: 862	200 (100%) n: 1010	188 (89%) n: 1034

Filter	2017	2018	2019	2020	2021
Ungroomed data	175 (100%) n: 883	191 (100%) n: 831	219 (100%) n: 886	276 (100%) n: 854	181 (100%) n: 579
Positive soak time	175 (100%) n: 883	191 (100%) n: 830	219 (100%) n: 886	276 (100%) n: 854	181 (100%) n: 579
Positive net length	175 (100%) n: 883	191 (100%) n: 830	219 (100%) n: 886	276 (100%) n: 854	181 (100%) n: 579
Core fleet selection	175 (100%) n: 883	191 (100%) n: 830	219 (100%) n: 886	275 (100%) n: 850	179 (100%) n: 573

Table 53: Summary of the SPO 3 SN daily East Coast 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 rig.

Fishing year	Vessels	Trips	Records	Net length (km)	Catch (t)	Records caught
1990	23	672	757	1414.08	59.68	55.09
1991	25	885	949	1513.03	73.85	52.69
1992	25	1 003	1 088	1860.97	83.95	59.65
1993	27	1 265	1 299	2026.91	61.89	59.82
1994	32	1 627	1 711	2901.68	129.08	64.64
1995	32	1 185	1 314	2306.89	160.67	72.53
1996	31	1 193	1 298	2272.80	143.79	65.72
1997	29	959	1 028	1551.63	158.60	67.22
1998	26	876	955	1330.76	157.92	68.06
1999	22	778	866	1399.00	133.27	70.44
2000	25	732	792	1428.92	127.24	76.64
2001	28	1 161	1 292	2536.68	188.78	81.42
2002	26	1 102	1 165	2181.67	215.60	81.97
2003	27	1 157	1 259	2418.24	181.26	81.97
2004	27	748	838	1622.29	142.50	82.22
2005	25	858	911	1676.96	133.97	85.73
2006	23	782	875	1600.94	154.20	81.94
2007	21	729	839	1442.21	126.47	84.39
2008	21	758	914	1642.37	154.95	80.74
2009	21	801	915	1458.69	122.74	70.05
2010	21	807	930	1495.71	105.01	70.43
2011	22	825	934	1634.12	130.66	74.63
2012	21	773	849	1571.64	123.66	75.85
2013	22	764	879	1698.04	160.57	78.61
2014	21	728	862	1558.56	170.69	70.53
2015	21	855	1 010	1764.45	199.94	77.13
2016	19	894	1 034	1918.02	188.33	74.27
2017	20	688	883	1754.12	174.64	87.43
2018	19	744	830	1535.57	191.06	86.51
2019	17	764	886	1653.81	218.92	80.47
2020	13	732	850	1671.61	274.53	86.71
2021	10	463	573	1236.05	178.72	85.17

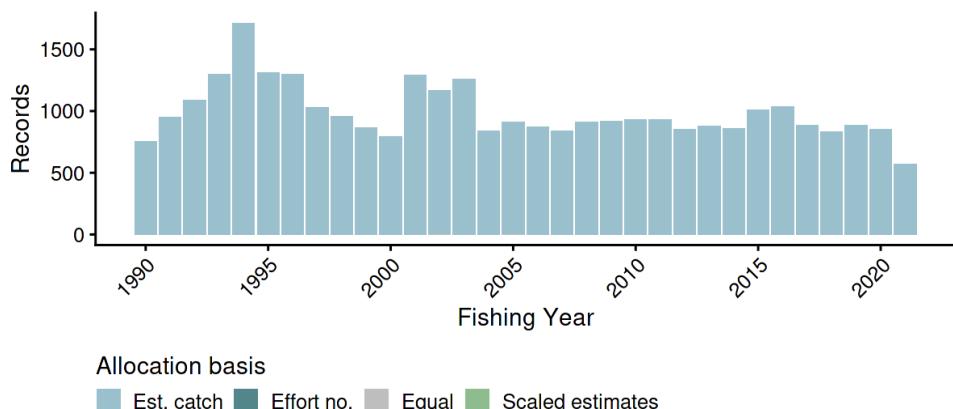


Figure 220: Allocation basis for attributing landings to records in the SPO 3 SN daily East Coast catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table 54: 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	30.00	34 804	3.90	3.90	*
+ vessel_key	68.00	30 018	17.50	13.60	*
+ target_species	3.00	27 712	23.90	6.40	*
+ month	11.00	26 494	27.30	3.40	*
+ stat_area	4.00	26 391	27.70	0.30	
+ ns(log(total_net_length), 3)	3.00	26 313	27.90	0.20	
+ ns(log(soak_time), 3)	3.00	26 256	28.10	0.20	

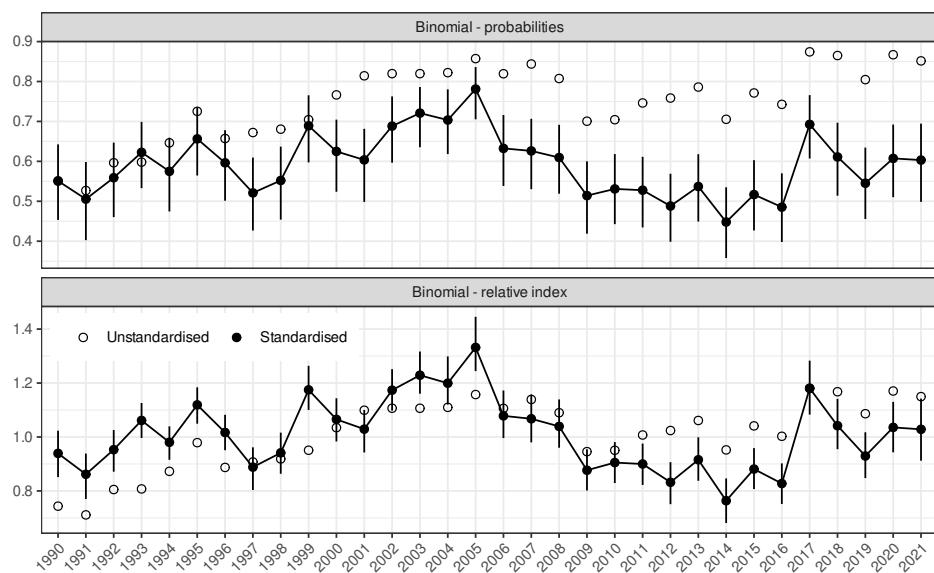


Figure 221: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 3 SN daily East Coast dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

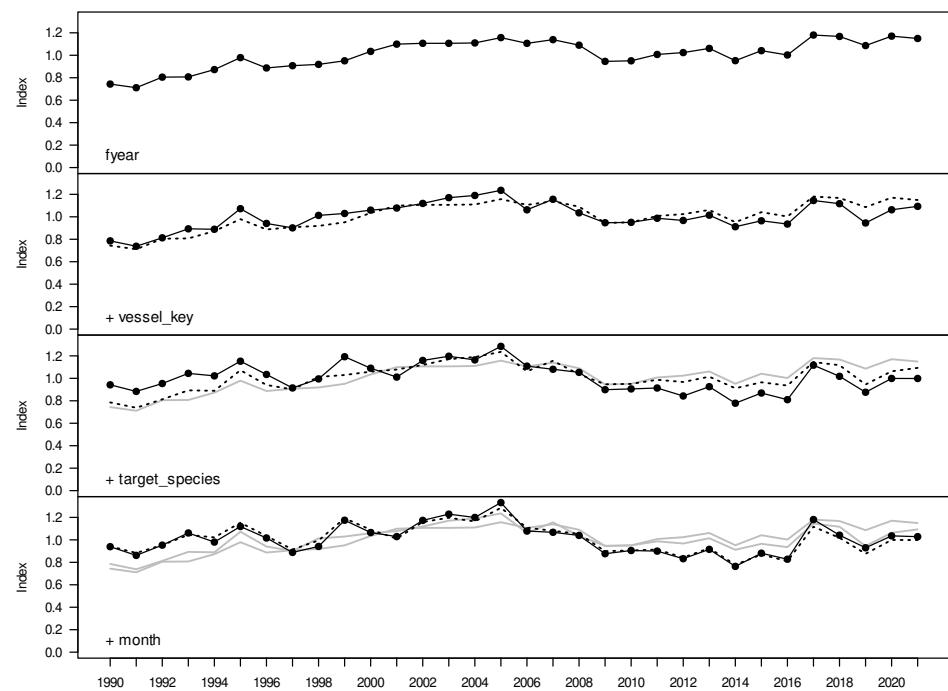


Figure 222: Step plot for occurrence of catch in the SPO 3 SN daily East Coast dataset.

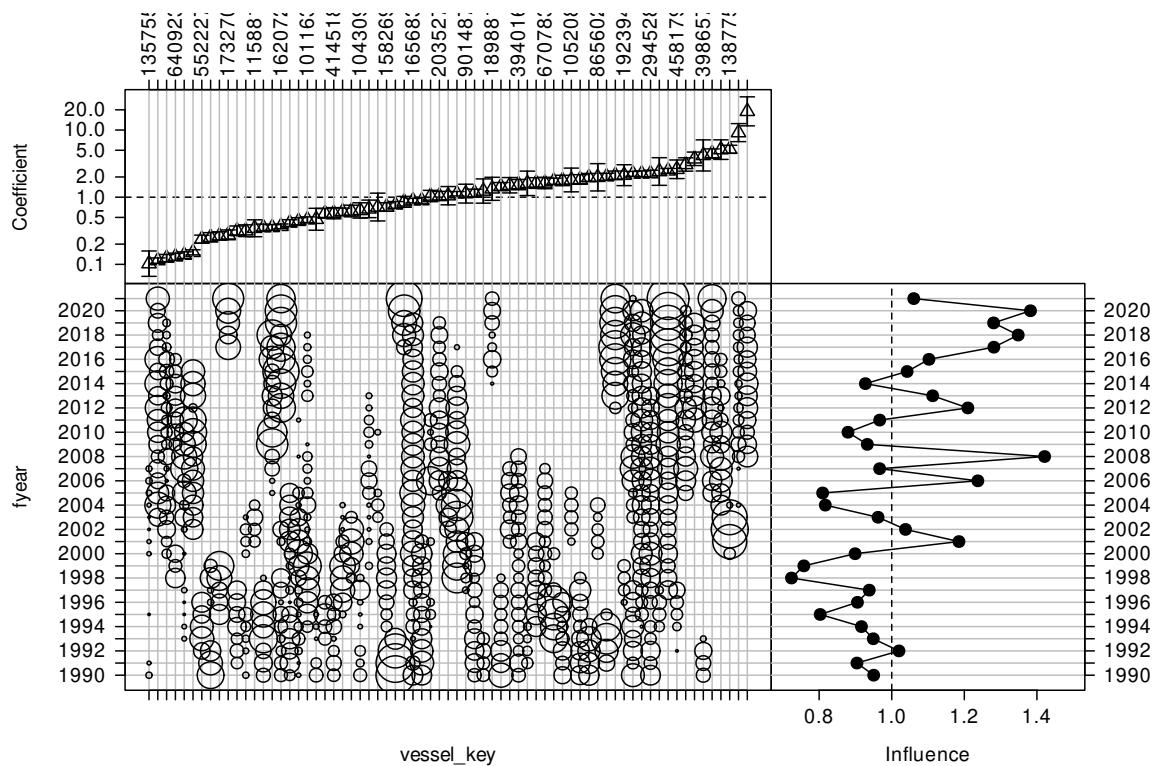


Figure 223: CDI plot for vessel key for the occurrence of positive catch SPO 3 SN daily East Coast catch-per-unit-effort dataset.

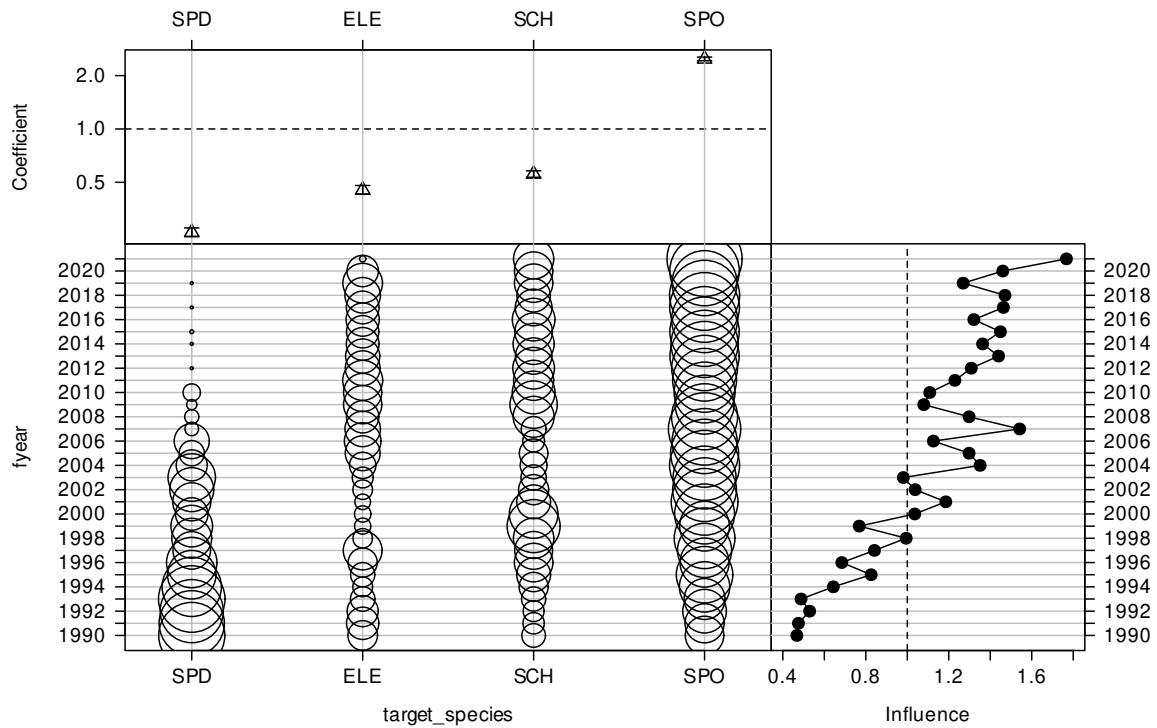


Figure 224: CDI plot for target species for the occurrence of positive catch SPO 3 SN daily East Coast catch-per-unit-effort dataset.

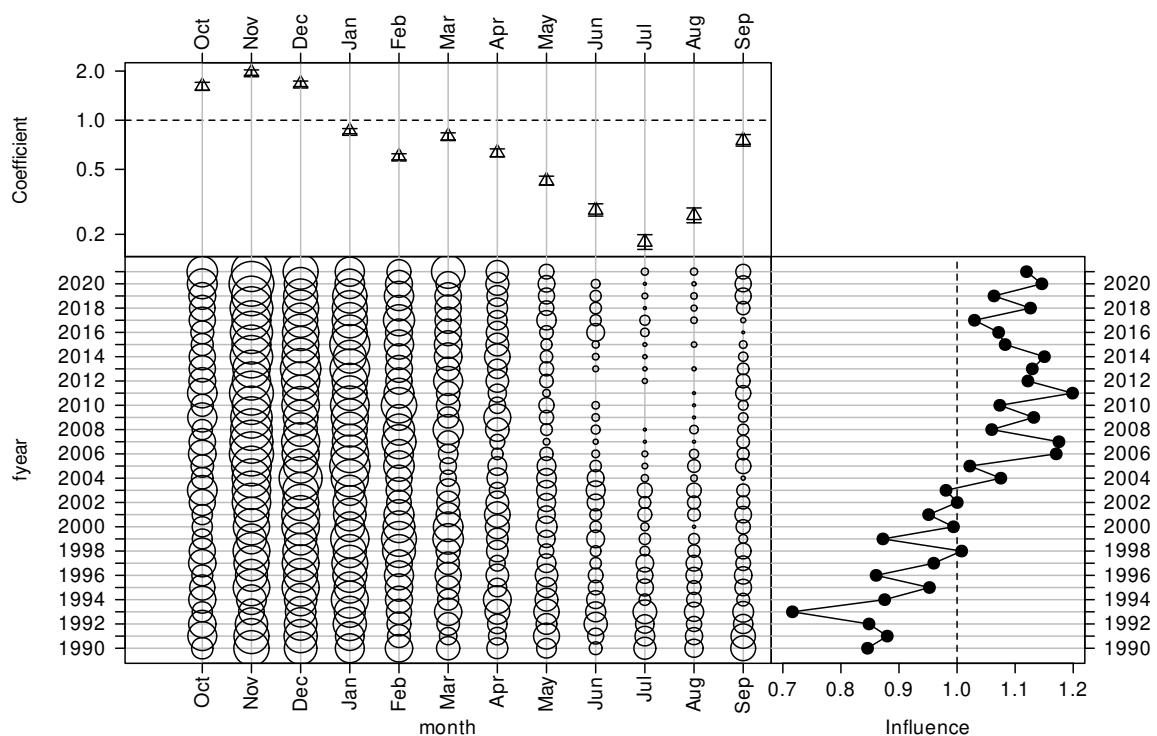


Figure 225: CDI plot for month for the occurrence of positive catch SPO 3 SN daily East Coast catch-per-unit-effort dataset.

Table 55: 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	30	85 243	6.3	6.3	*
+ vessel key	68	77 271	33.7	27.4	*
+ target species	3	75 014	39.9	6.1	*
+ month	11	73 524	43.6	3.8	*
+ ns(log(total net length), 3)	3	73 035	44.8	1.2	*
+ ns(log(soak time), 3)	3	72 699	45.6	0.8	
+ stat area	4	72 475	46.1	0.5	

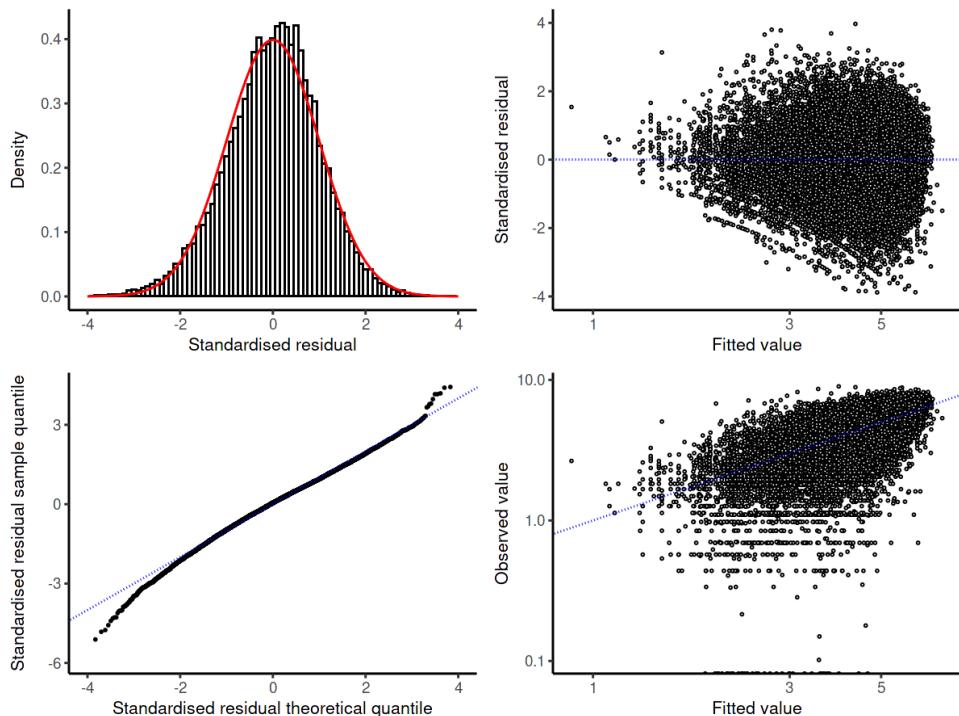


Figure 226: Diagnostic plots for the lognormal model for the SPO 3 SN daily East Coast dataset.

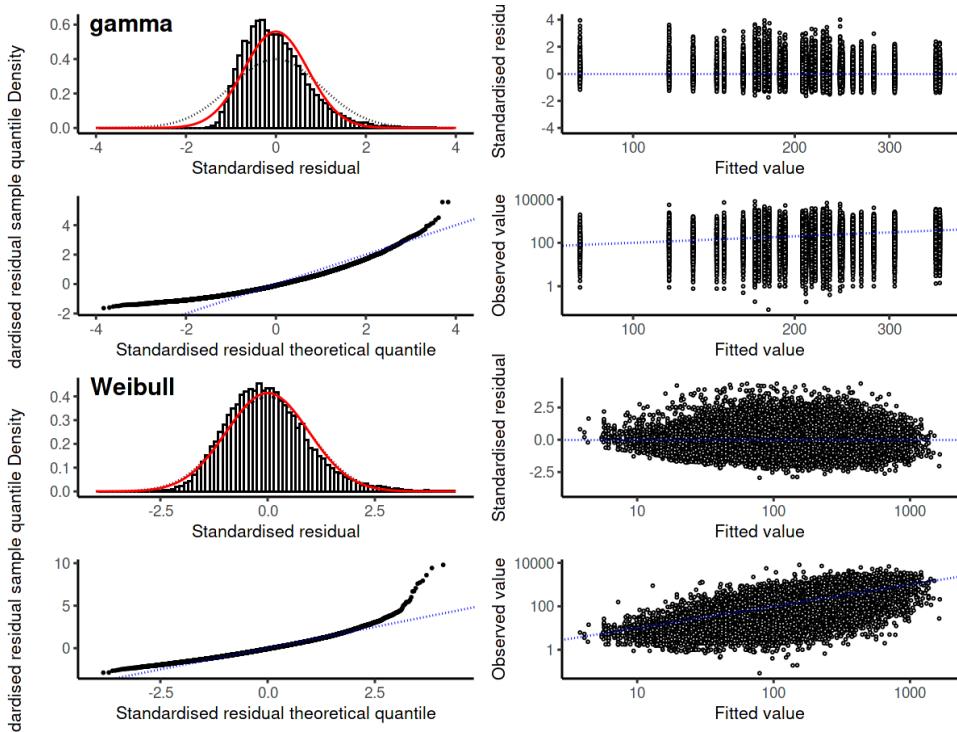


Figure 227: Diagnostic plots for the gamma and Weibull model for the SPO 3 SN daily East Coast dataset.

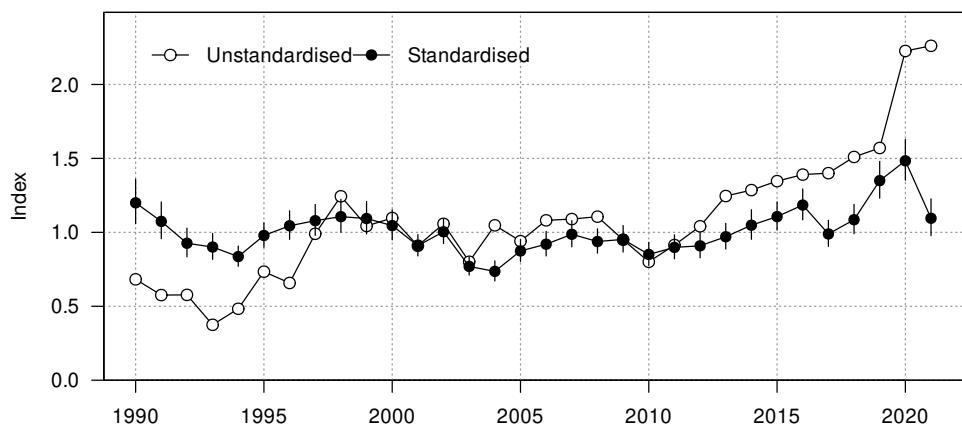


Figure 228: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 3 SN daily East Coast dataset.

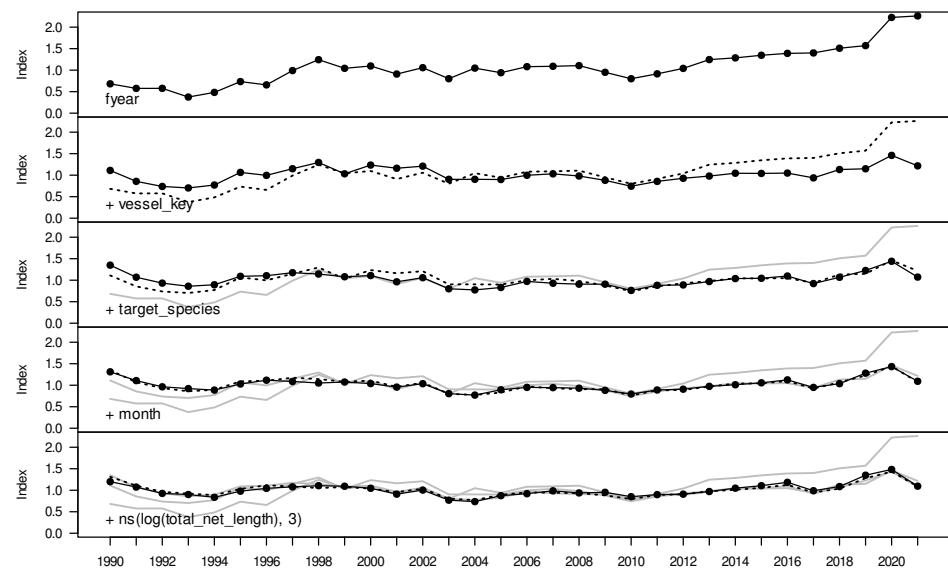


Figure 229: Changes to the SPO 3 SN daily East Coast positive catch index as terms are successively entered into the model.

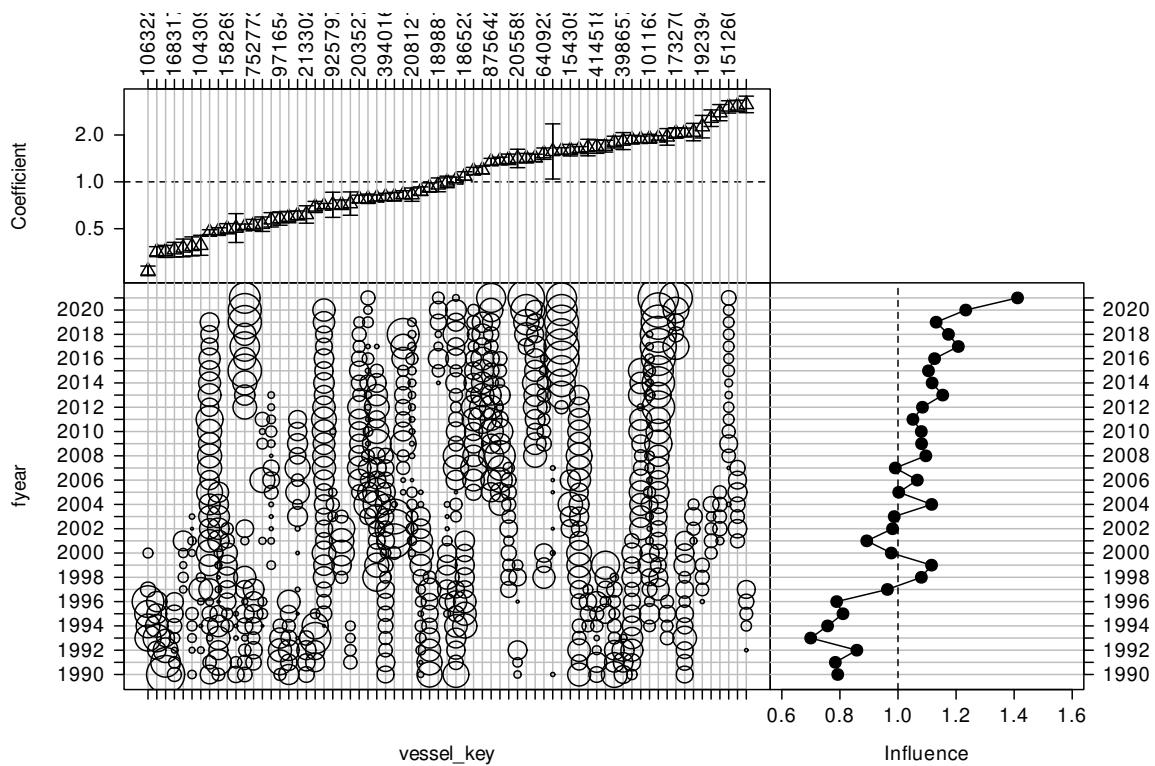


Figure 230: CDI plot for vessel key for the positive catch SPO 3 SN daily East Coast catch-per-unit-effort dataset.

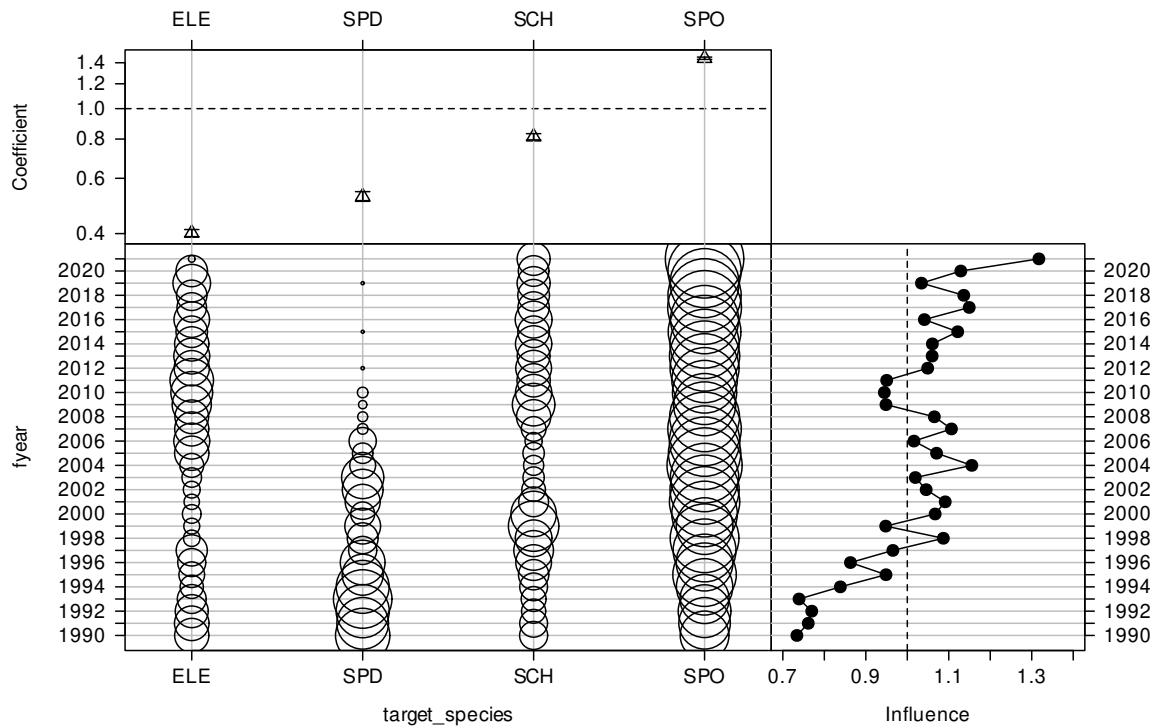


Figure 231: CDI plot for target species for the positive catch SPO 3 SN daily East Coast catch-per-unit-effort dataset.

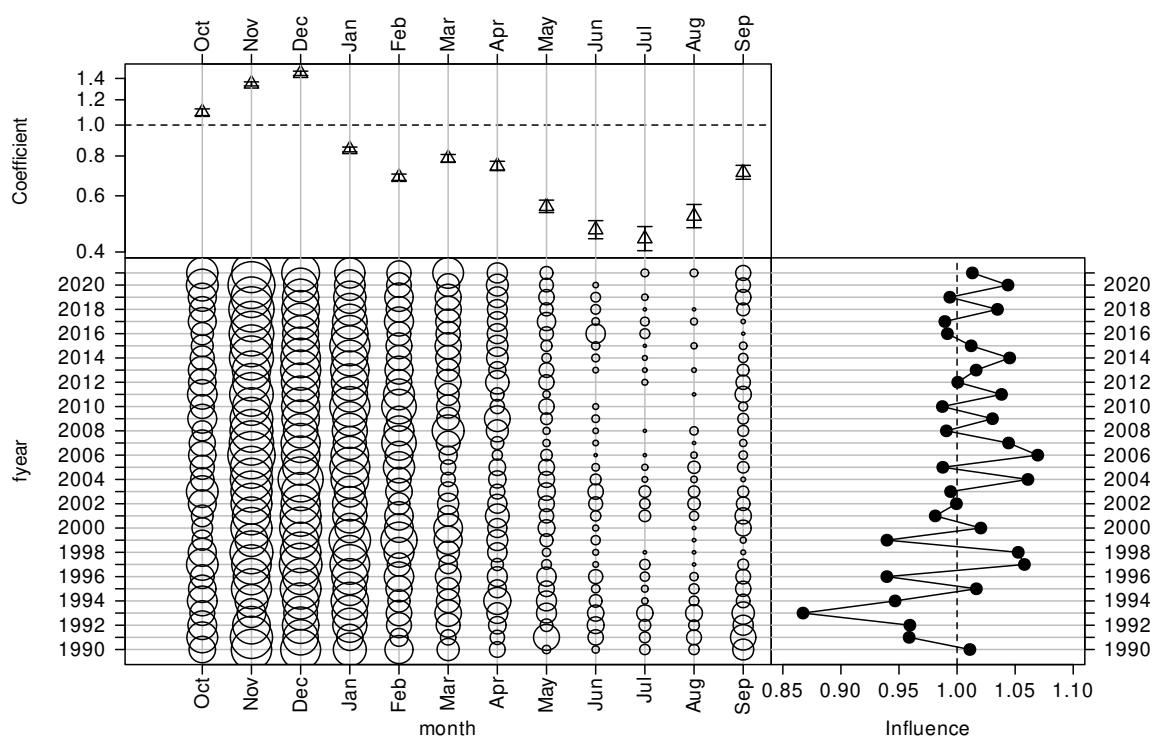


Figure 232: CDI plot for month for the positive catch SPO 3 SN daily East Coast catch-per-unit-effort dataset.

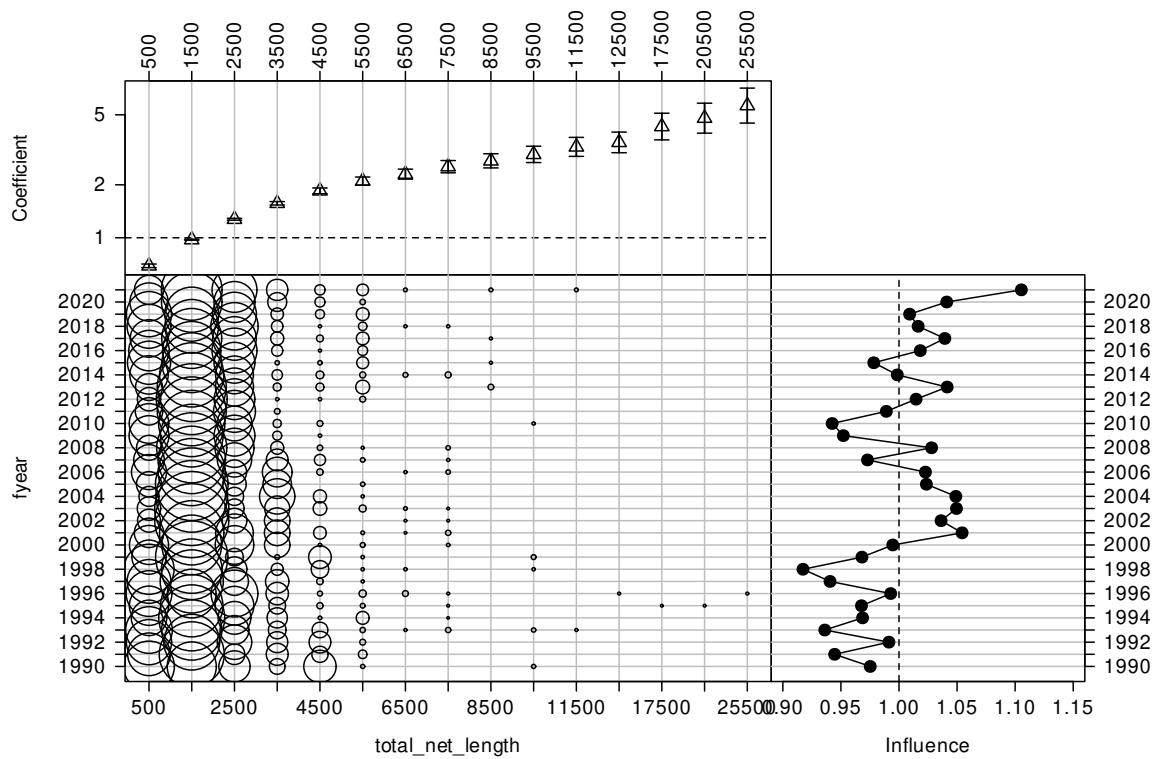


Figure 233: CDI plot for total net length for the positive catch SPO 3 SN daily East Coast catch-per-unit-effort dataset.

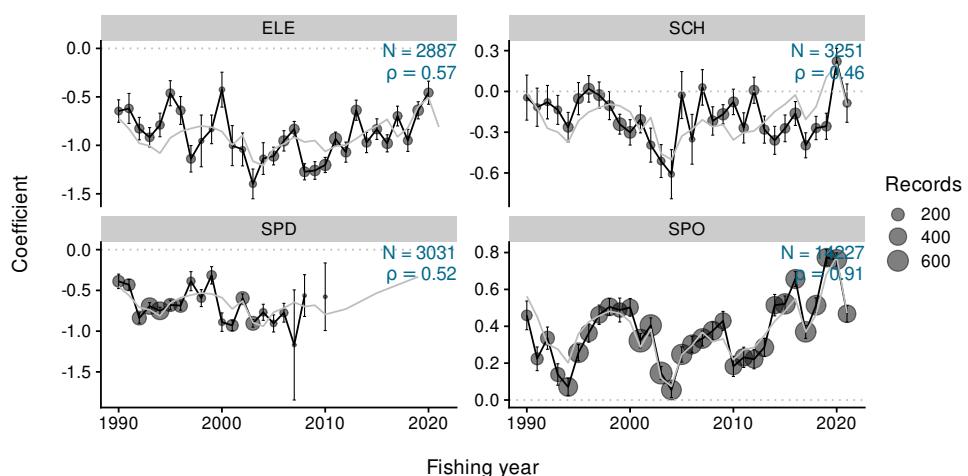


Figure 234: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 3 SN daily East Coast dataset.

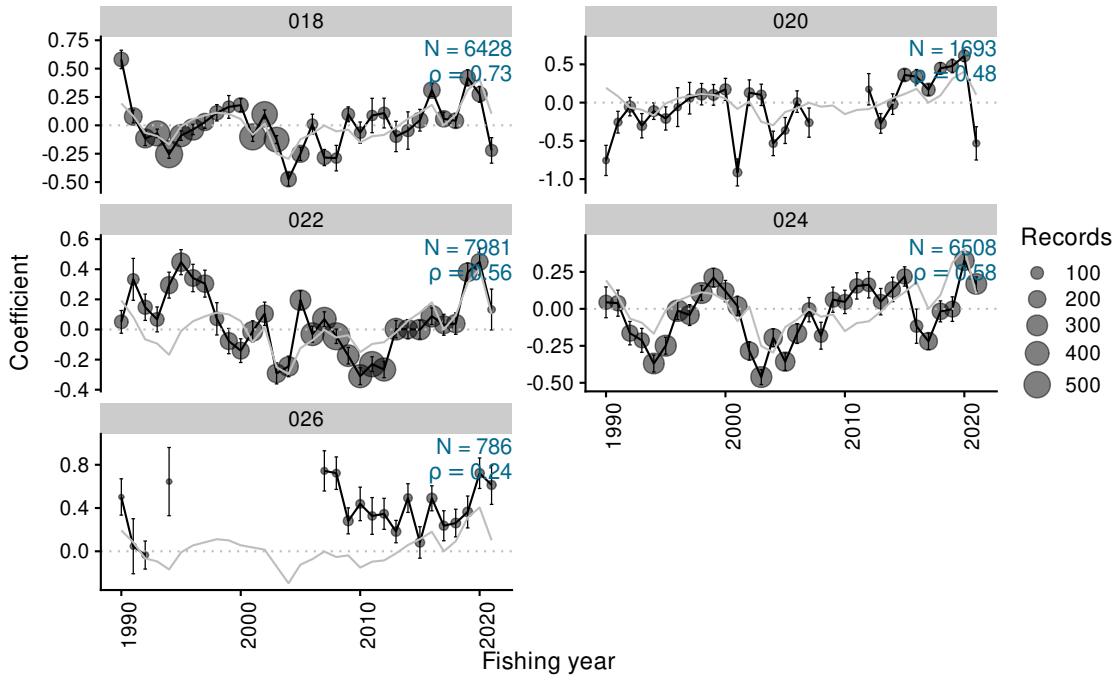


Figure 235: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 3 SN daily East Coast dataset.

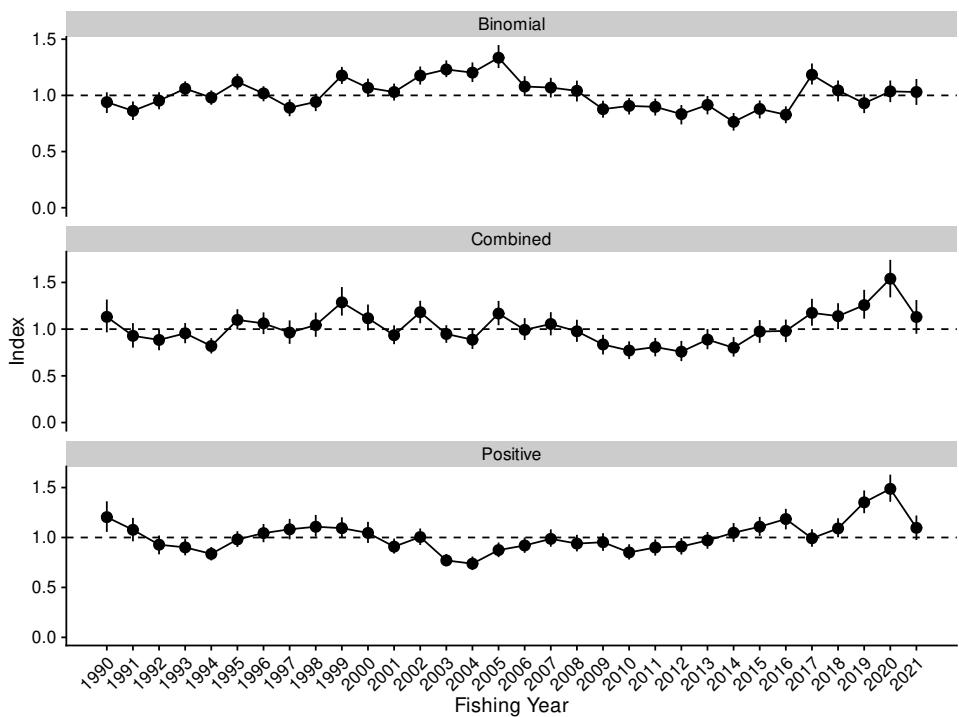


Figure 236: Standardised indices and 95% confidence intervals for the SPO 3 SN daily East Coast dataset.

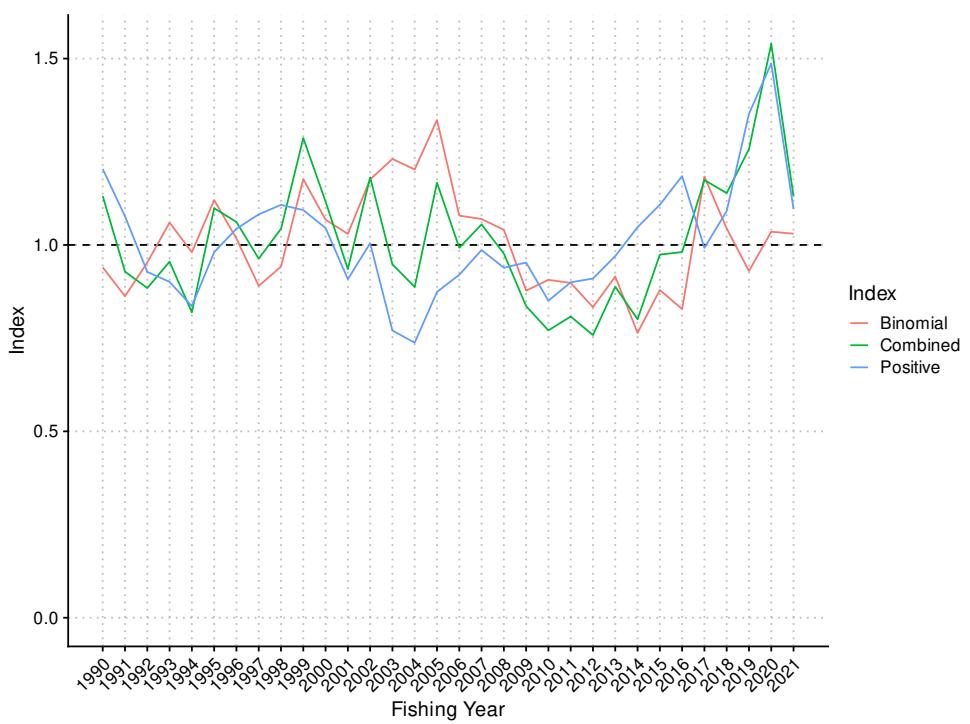


Figure 237: Standardised indices for the SPO 3 SN daily East Coast dataset.

Table 56: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 3 SN daily East Coast.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.940	0.047	0.843	1.027	1.131	0.090	0.965	1.317	1.204	0.078	1.056	1.363
1991	0.862	0.042	0.781	0.946	0.929	0.067	0.802	1.065	1.077	0.060	0.962	1.196
1992	0.953	0.039	0.876	1.028	0.884	0.057	0.774	0.995	0.928	0.048	0.831	1.020
1993	1.060	0.033	0.995	1.125	0.955	0.055	0.849	1.065	0.901	0.043	0.821	0.988
1994	0.980	0.033	0.917	1.044	0.819	0.042	0.739	0.904	0.836	0.034	0.770	0.905
1995	1.121	0.036	1.051	1.192	1.099	0.055	0.997	1.213	0.980	0.040	0.905	1.063
1996	1.017	0.034	0.947	1.081	1.062	0.059	0.947	1.179	1.044	0.047	0.953	1.136
1997	0.890	0.038	0.815	0.964	0.963	0.064	0.843	1.094	1.082	0.052	0.982	1.186
1998	0.942	0.039	0.860	1.014	1.043	0.066	0.918	1.176	1.108	0.055	1.009	1.226
1999	1.177	0.039	1.102	1.253	1.287	0.078	1.145	1.451	1.094	0.053	0.995	1.202
2000	1.068	0.041	0.987	1.149	1.117	0.071	0.986	1.264	1.046	0.054	0.945	1.157
2001	1.030	0.039	0.954	1.105	0.935	0.051	0.839	1.040	0.908	0.038	0.839	0.989
2002	1.176	0.041	1.096	1.257	1.181	0.061	1.063	1.304	1.005	0.042	0.925	1.090
2003	1.231	0.038	1.162	1.312	0.948	0.048	0.853	1.042	0.770	0.031	0.712	0.835
2004	1.202	0.044	1.119	1.293	0.887	0.054	0.788	0.997	0.738	0.035	0.674	0.809
2005	1.335	0.052	1.243	1.448	1.167	0.066	1.042	1.302	0.874	0.037	0.803	0.950
2006	1.079	0.045	0.993	1.171	0.993	0.060	0.884	1.117	0.920	0.039	0.846	0.999
2007	1.070	0.045	0.981	1.156	1.055	0.063	0.934	1.182	0.986	0.044	0.908	1.081
2008	1.041	0.047	0.946	1.131	0.977	0.060	0.864	1.100	0.939	0.042	0.861	1.027
2009	0.877	0.038	0.802	0.952	0.836	0.054	0.728	0.940	0.953	0.045	0.866	1.043
2010	0.906	0.037	0.830	0.976	0.771	0.048	0.679	0.869	0.850	0.039	0.779	0.932
2011	0.898	0.038	0.821	0.972	0.808	0.050	0.709	0.906	0.900	0.042	0.818	0.982
2012	0.833	0.044	0.742	0.914	0.758	0.055	0.657	0.874	0.910	0.042	0.829	0.995
2013	0.915	0.042	0.831	0.995	0.888	0.055	0.785	1.001	0.970	0.043	0.887	1.055
2014	0.764	0.040	0.686	0.843	0.801	0.053	0.706	0.914	1.048	0.048	0.956	1.145
2015	0.879	0.041	0.795	0.955	0.974	0.062	0.853	1.097	1.108	0.048	1.016	1.206
2016	0.828	0.038	0.752	0.902	0.981	0.062	0.861	1.102	1.185	0.052	1.081	1.287
2017	1.184	0.048	1.097	1.284	1.174	0.073	1.037	1.324	0.992	0.045	0.907	1.083
2018	1.044	0.047	0.947	1.133	1.139	0.071	1.000	1.278	1.091	0.048	1.003	1.192
2019	0.930	0.043	0.842	1.011	1.257	0.079	1.112	1.421	1.352	0.058	1.243	1.471
2020	1.035	0.049	0.940	1.133	1.540	0.102	1.340	1.742	1.487	0.069	1.357	1.629
2021	1.030	0.059	0.915	1.146	1.130	0.092	0.950	1.312	1.097	0.063	0.975	1.220

5.11 SPO 3 SN daily Foveaux St

This series was based on the daily catch of rig from the shark target species fishery taking place in the most southern part of the South Island. The analysis included seven South Island statistical areas, encompassing the southern end of the South Island: Statistical Areas 025 (east Foveaux Strait), 027 (east coast Stewart Island), 028 (south coast Stewart Island), 029 (west coast Stewart Island), 030 (west Foveaux Strait), 031 (Puysegur) and 032 (Fiordland) (Table 57). The target species suite included the four commercially harvested shark species: rig (SPO), school shark (SCH), spiny dogfish (SPD) and elephant fish (ELE). The core fleet was defined by having fished at least four trips in each of four years, retaining 91% of the catch and reducing the fleet from about 80 vessels to 18 vessels (Figure 238). The pattern of vessel participation in this fishery was characterised by 5 to 6 vessels which remained the fishery for 15 years or more, along with the remaining vessels having shorter periods of activity (Figure 239). The final groomed dataset represented 49% (1993) to 100% (1994, 1995, 2002–2004, 2009–2020) of ungroomed catch for each year (Table 58). The total annual catch of rig in the defined fishery ranged from 20.5 t (in 1993) to 132 t (in 2021) over the 32 years in the data set and was characterised by an increasing occurrence of rig in the daily landings, ranging from 49% (in 1991) to 92% (in 2018) (Table 59). All landed catch in this data set was allocated by distributing the total trip landings proportionately to the estimated catches within the trip (Figure 240)

The binomial (occurrence) model accepted three predictive variables after fishing year (month, vessel, target species), with the model explaining 18% of the deviance (Table 60). Both the unstandardised and standardised series showed an increasing trend from the beginning of the series to about 2000, after which the series leveled out with no trend (Figure 241). The standardisation procedure modified the unstandardised series by raising the catch rate that characterised the long period with no trend after 2000 while making the initial increasing trend a bit steeper (Figure 242). The first covariate to enter the occurrence model (month) was responsible for steepening the initial increasing trend but showed no trend in the monthly catch rates (Figure 243). The vessel covariate was responsible for raising the catch rate over the period from 2000 to 2021. This occurred because that period was dominated by three vessels that had below average catch rates, resulting in an increased in the standardised catch rate (Figure 244). The target species covariate had no standardisation impact because it consisted almost entirely of target SCH effort (Figure 245).

The lognormal model accepted five predictive variables after fishing year (month, target species, vessel, soak time, statistical area), with the total model explaining 33% of the deviance (Table 61). Residuals to the positive catch model showed good conformity to the lognormal assumption over the total distribution, with some minor skewness in the lower tail and near the mode of the distribution (Figure 246). Both the gamma and the Weibull distributions had fits to the positive catch data that were clearly inferior to the lognormal model fit (Figure 247). Neither the standardised nor the unstandardised series showed any trend from the beginning of the series in 1990 to the mid 2010s, but the unstandardised series had an increasing trend from 2016 to 2021 which was removed by the standardisation procedure (Figure 248). The only covariate that had much effect on the latter part of the series was the month covariate, which entered the model first, and the soak time covariate, which was the fourth variable to enter the model (Figure 249). The month covariate pulled down the 2019, 2020 and 2021 indices because there was more effort in the higher catch rate months of October to December (Figure 250). The next two covariates (target species: Figure 251, vessel: Figure 252) did not show any contrast in the final years of the series. It was the soak time covariate that was responsible for downgrading the increasing unstandardised catch rates from 2016 to 2021 because the effort data indicated that there had been a trend towards longer soak times in those years (Figure 253). The final covariate (statistical area) had little impact overall on the series (Figure 254). Implied residual plots of rig annual CPUE showed good conformity with the overall annual CPUE trend for school shark (SCH) target effort which dominated the SN fishery in this region (Figure 255). Rig, the other target species of consequence in this region, did not show good correspondence with the annual CPUE trend in this model. The conformity with the overall annual CPUE trend was best for Statistical Area 030 (western Foveaux Strait) while the other three statistical

areas with data (Statistical Areas 025, 027, 028) showed moderate conformity with the annual CPUE trends (Figure 256). The other three statistical areas had too few data to make a meaningful comparison.

The lognormal model showed considerable interannual variability while the binomial showed a consistent increasing trend to the early 2000s and then flattened (Figure 257, Figure 258, Table 62). The early increasing trend in the binomial model coincided with a shorter increasing period in the lognormal model to result in an increasing trend in the combined model over the 1990s. Once the binomial model went into its period of stability, the combined model tended to follow the lognormal model, including its considerable interannual variability. All series ended in 2021 above the long-term average, with the lognormal and combined series showing a strong uptick in that year.

Table 57: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 3 SN daily Foveaux St CPUE series.

Series	SPO 3 SN daily Foveaux St
QMS stock	SPO3
Reporting forms	CEL, ERS - Netting, NCE
Fishing methods	SN
Target species	SPO, SCH, SPD, ELE
Statistical Areas	025, 027, 028, 029, 030, 031, 032
Period	1989-10-01, 2021-09-30
Resolution	Day
Core fleet years	4
Core fleet trips	4
Default model	$\text{allockg} \sim \text{fyear} + \text{vessel_key} + \text{stat_area} + \text{month} + \text{target_species} + \text{ns}(\log(\text{soak_time}), 3) + \text{ns}(\log(\text{total_net_length}), 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

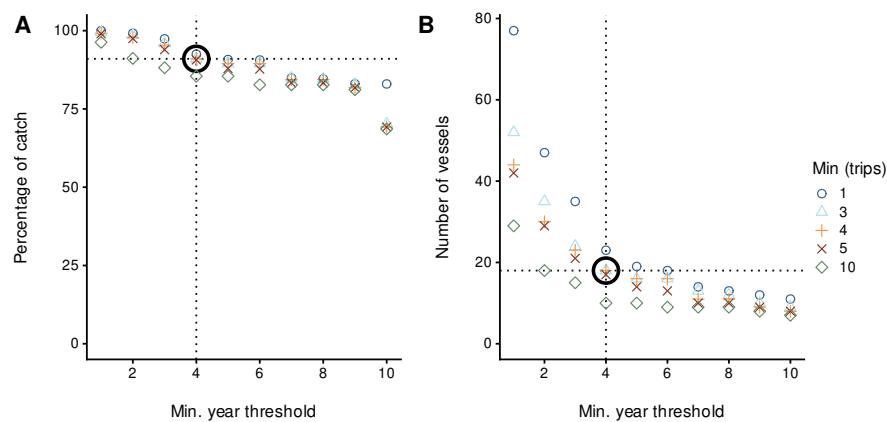


Figure 238: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 3 SN daily Foveaux St CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

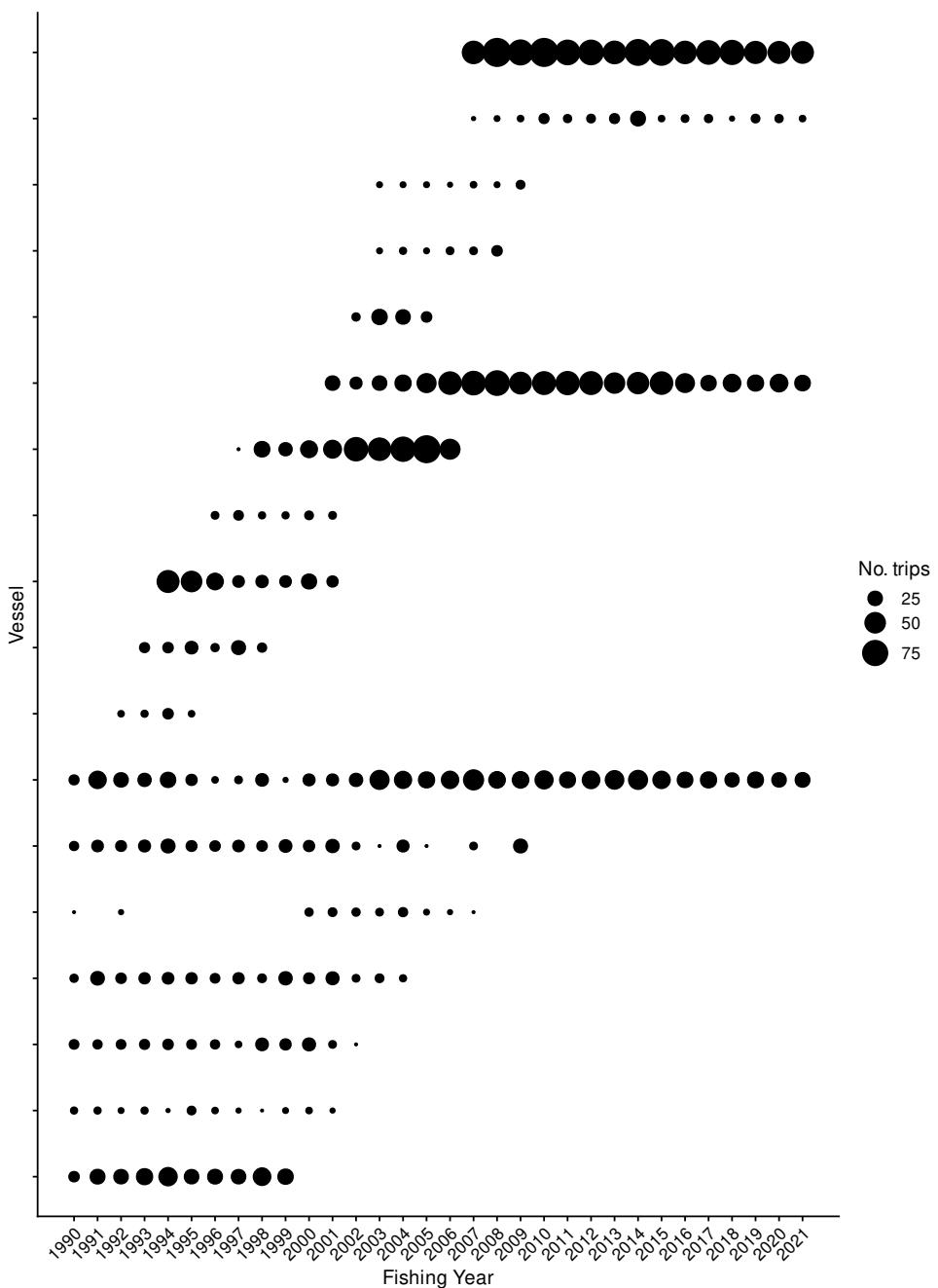


Figure 239: Number of trips by fishing year for core vessels. The area of the circles is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 58: Summary of the SPO 3 SN daily Foveaux St 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	44 (100%) n: 260	50 (100%) n: 399	48 (100%) n: 390	42 (100%) n: 404	46 (100%) n: 308	58 (100%) n: 348	63 (100%) n: 300	69 (100%) n: 337	78 (100%) n: 322
Positive soak time	44 (100%) n: 259	49 (100%) n: 396	48 (100%) n: 390	40 (100%) n: 396	46 (100%) n: 305	58 (100%) n: 345	57 (90%) n: 280	65 (95%) n: 316	74 (94%) n: 282
Positive net length	44 (100%) n: 259	49 (100%) n: 396	48 (100%) n: 390	40 (100%) n: 396	46 (100%) n: 305	58 (100%) n: 342	54 (85%) n: 263	63 (91%) n: 284	70 (90%) n: 275
Core fleet selection	33 (74%) n: 165	32 (65%) n: 255	27 (56%) n: 179	21 (49%) n: 229	46 (100%) n: 305	56 (100%) n: 280	52 (82%) n: 215	57 (83%) n: 241	69 (88%) n: 262
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	78 (100%) n: 302	85 (100%) n: 318	93 (100%) n: 308	68 (100%) n: 239	108 (100%) n: 329	99 (100%) n: 350	107 (100%) n: 390	100 (100%) n: 356	131 (100%) n: 405
Positive soak time	65 (83%) n: 245	79 (92%) n: 283	91 (100%) n: 306	68 (100%) n: 239	108 (100%) n: 329	99 (100%) n: 350	107 (100%) n: 390	100 (100%) n: 356	131 (100%) n: 405
Positive net length	64 (82%) n: 244	78 (92%) n: 282	91 (100%) n: 304	68 (100%) n: 239	108 (100%) n: 329	99 (100%) n: 350	107 (100%) n: 390	100 (100%) n: 356	131 (100%) n: 405
Core fleet selection	62 (79%) n: 235	72 (85%) n: 238	82 (89%) n: 250	65 (100%) n: 224	108 (100%) n: 320	98 (100%) n: 335	89 (83%) n: 323	72 (72%) n: 280	93 (71%) n: 325
Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	163 (100%) n: 434	75 (100%) n: 352	100 (100%) n: 341	85 (100%) n: 351	71 (100%) n: 355	91 (100%) n: 380	74 (100%) n: 465	90 (100%) n: 404	71 (100%) n: 332
Positive soak time	163 (100%) n: 434	75 (100%) n: 351	100 (100%) n: 341	85 (100%) n: 351	71 (100%) n: 355	91 (100%) n: 380	74 (100%) n: 465	90 (100%) n: 404	71 (100%) n: 332
Positive net length	163 (100%) n: 434	75 (100%) n: 351	100 (100%) n: 341	85 (100%) n: 351	71 (100%) n: 355	91 (100%) n: 380	74 (100%) n: 465	90 (100%) n: 404	71 (100%) n: 332
Core fleet selection	126 (77%) n: 375	75 (100%) n: 351	99 (100%) n: 340	84 (100%) n: 344	68 (100%) n: 348	91 (100%) n: 378	74 (100%) n: 465	90 (100%) n: 404	71 (100%) n: 332

Filter	2017	2018	2019	2020	2021
Ungroomed data	90 (100%) n: 348	101 (100%) n: 303	94 (100%) n: 295	104 (100%) n: 354	139 (100%) n: 348
Positive soak time	90 (100%) n: 348	101 (100%) n: 303	94 (100%) n: 295	104 (100%) n: 354	139 (100%) n: 348
Positive net length	90 (100%) n: 348	101 (100%) n: 303	94 (100%) n: 295	104 (100%) n: 354	139 (100%) n: 348
Core fleet selection	90 (100%) n: 347	101 (100%) n: 303	91 (100%) n: 286	100 (100%) n: 339	132 (94%) n: 321

Table 59: Summary of the SPO 3 SN daily Foveaux St 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 rig.

Fishing year	Vessels	Trips	Records	Net length (km)	Catch (t)	Records caught
1990	7	61	165	350.00	32.58	57.58
1991	6	116	255	580.29	32.13	49.02
1992	8	100	179	383.60	26.88	58.66
1993	8	120	229	526.79	20.52	59.39
1994	9	205	305	721.66	46.02	65.25
1995	9	163	280	638.76	55.85	82.14
1996	9	118	215	527.86	52.08	87.91
1997	10	122	241	538.35	57.33	75.52
1998	10	161	262	619.37	69.17	89.31
1999	9	133	235	517.30	62.10	85.11
2000	9	149	238	556.88	71.88	86.55
2001	10	162	250	542.68	82.42	83.60
2002	8	134	224	557.33	65.48	90.62
2003	9	181	320	850.10	108.00	83.12
2004	9	204	335	836.00	98.25	85.97
2005	8	186	323	873.91	88.72	79.88
2006	6	156	280	780.26	72.23	90.71
2007	8	196	325	696.02	92.63	88.92
2008	6	219	375	962.48	125.98	85.33
2009	6	200	351	981.54	74.78	85.19
2010	4	206	340	1 023.12	99.26	84.12
2011	4	174	344	1 037.30	84.06	80.23
2012	4	180	348	1 062.11	68.32	85.06
2013	4	163	378	1 254.22	90.83	82.80
2014	4	202	465	1 487.10	73.78	83.23
2015	4	179	404	1 311.10	90.40	86.88
2016	4	138	332	1 089.64	71.48	89.76
2017	4	133	347	1 191.96	89.89	90.49
2018	4	133	303	1 154.40	100.75	93.07
2019	4	128	286	967.42	91.35	87.41
2020	4	127	339	1 136.93	99.71	83.48
2021	4	116	321	1 128.50	131.54	85.98

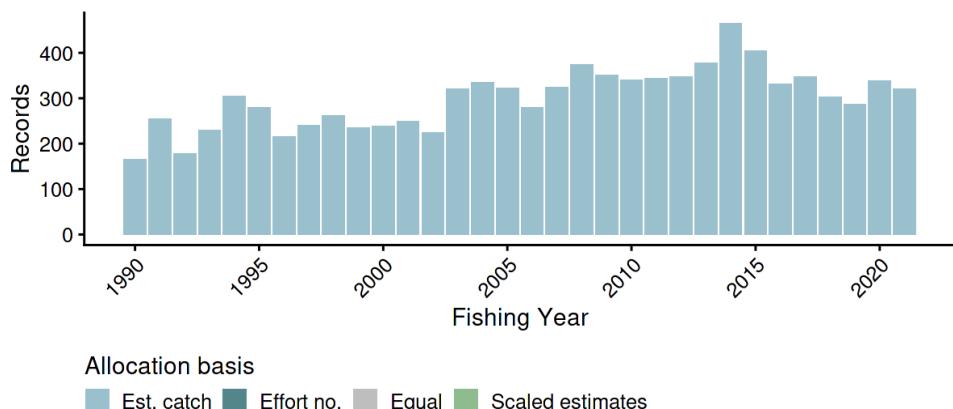


Figure 240: Allocation basis for attributing landings to records in the SPO 3 SN daily Foveaux St catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table 60: 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	30.00	8 483	5.90	5.90	*
+ month	11.00	7 891	12.80	6.90	*
+ vessel_key	17.00	7 598	16.40	3.70	*
+ target_species	3.00	7 467	18.00	1.50	*
+ stat_area	6.00	7 402	18.80	0.90	
+ ns(log(soak_time), 3)	3.00	7 386	19.10	0.20	
+ ns(log(total_net_length), 3)	3.00	7 378	19.20	0.10	

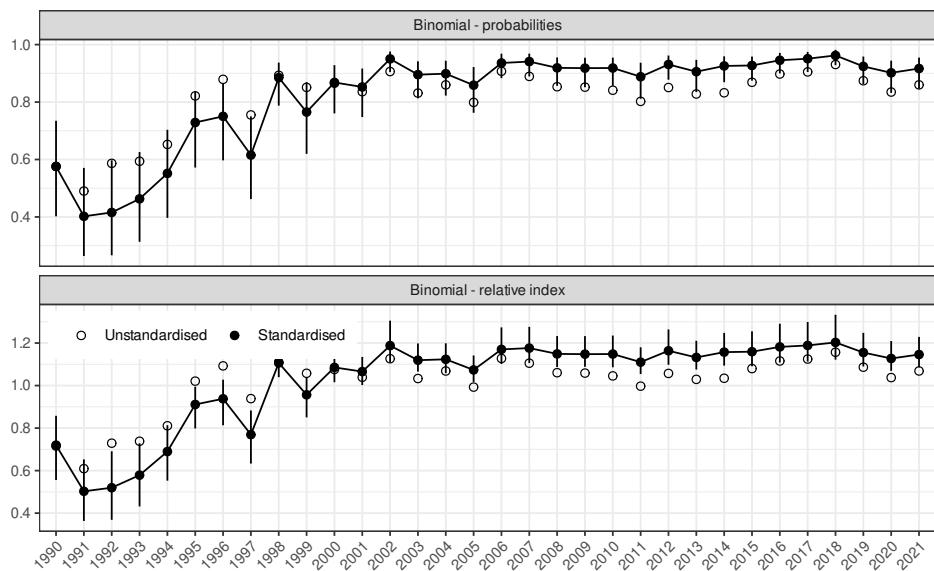


Figure 241: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 3 SN daily Foveaux St dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

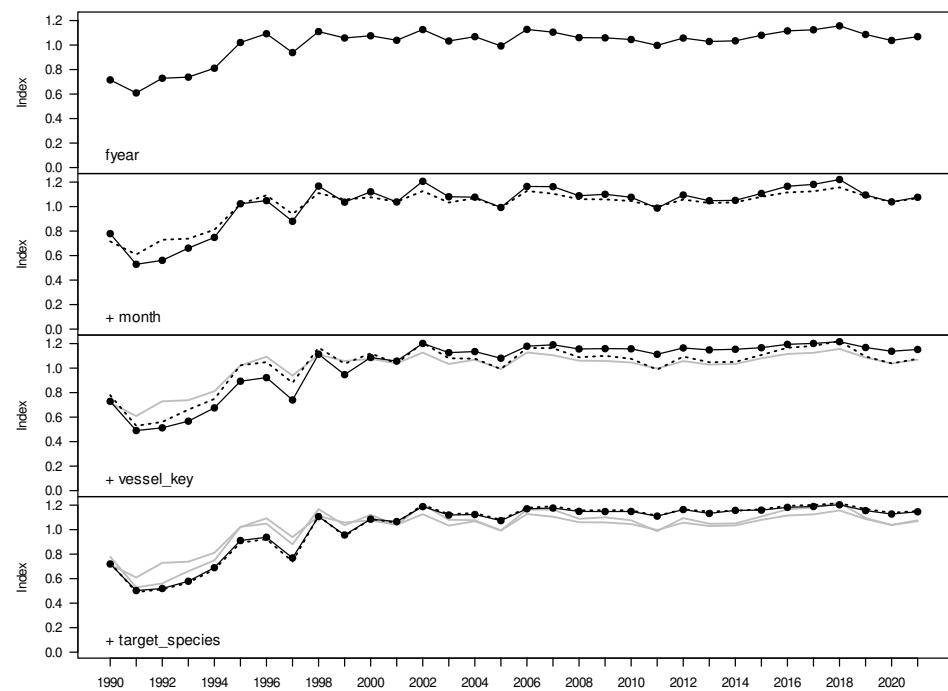


Figure 242: Step plot for occurrence of catch in the SPO 3 SN daily Foveaux St dataset.

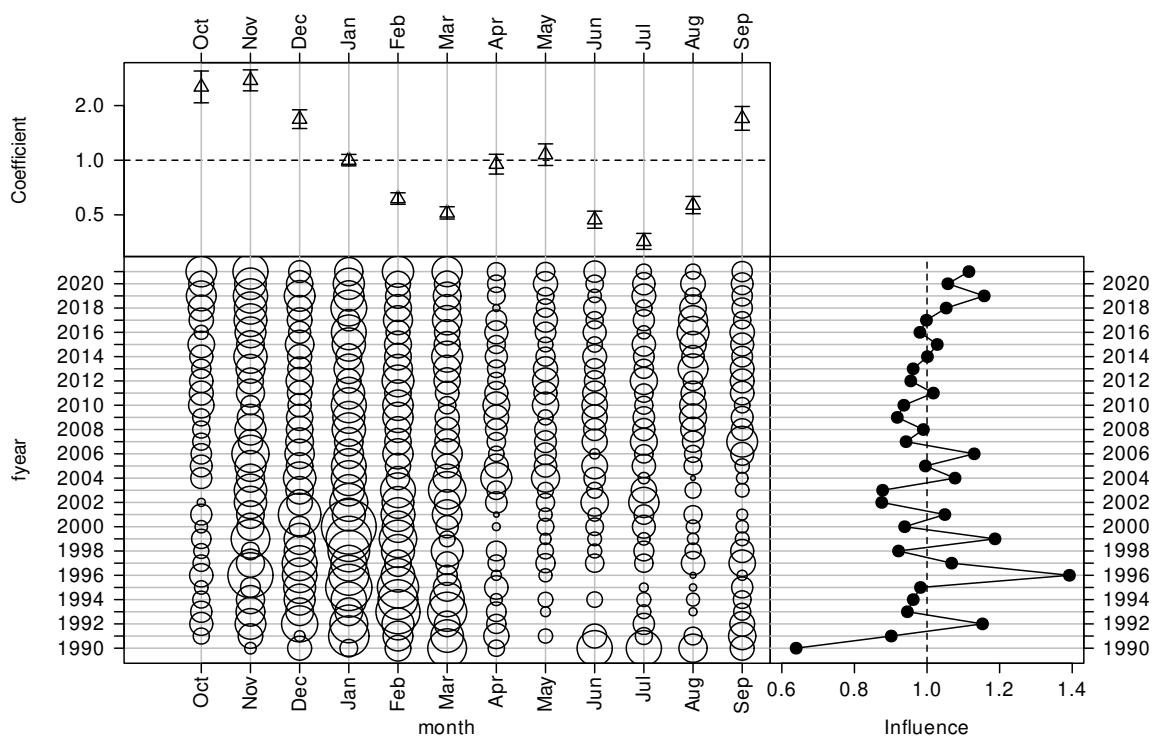


Figure 243: CDI plot for month for the occurrence of positive catch SPO 3 SN daily Foveaux St catch-per-unit-effort dataset.

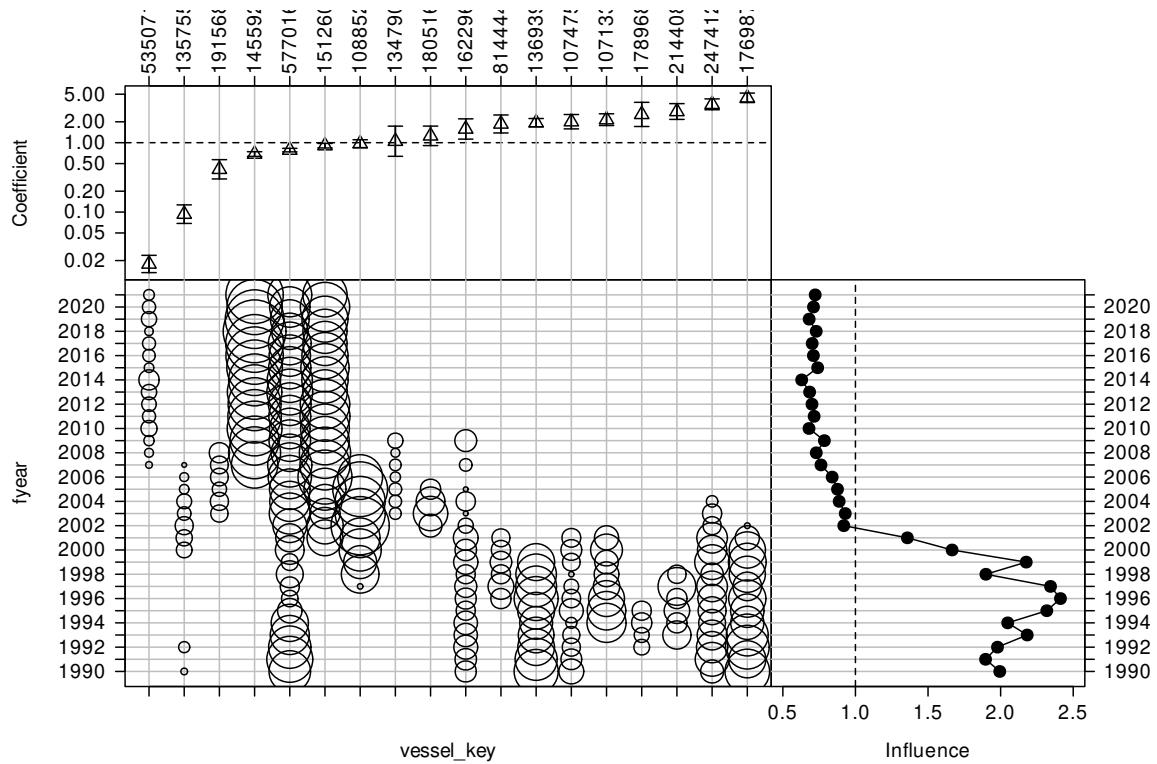


Figure 244: CDI plot for vessel key for the occurrence of positive catch SPO 3 SN daily Foveaux St catch-per-unit-effort dataset.

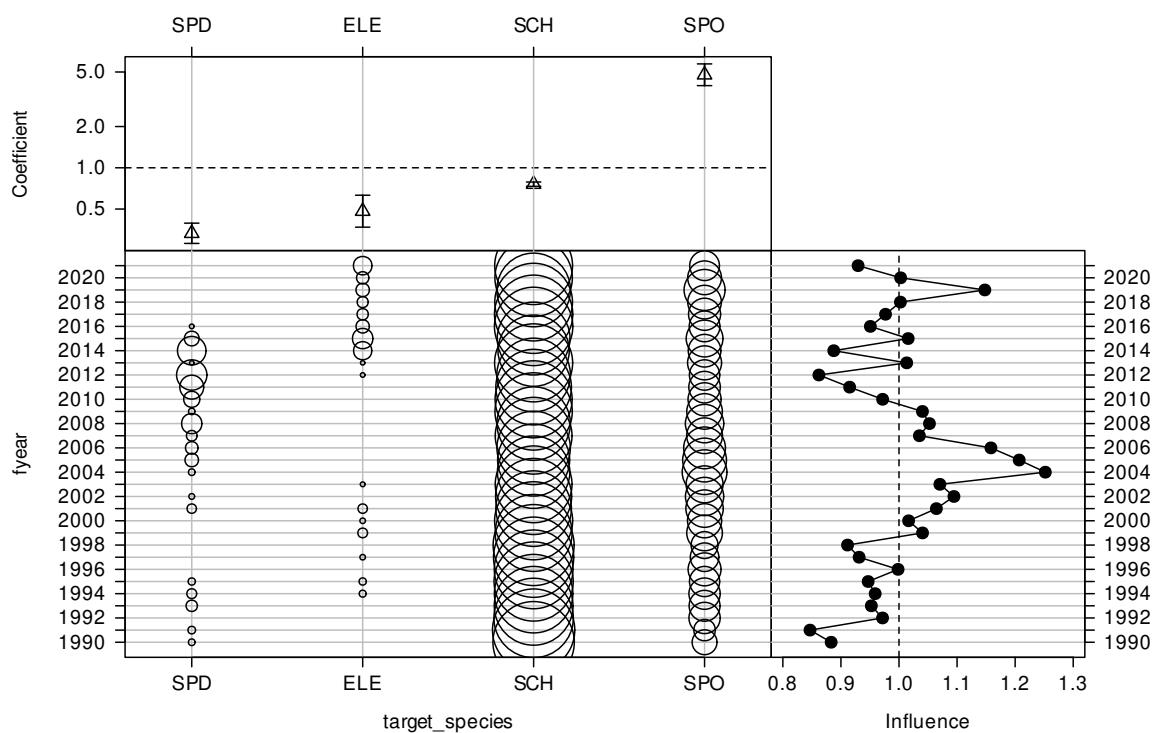


Figure 245: CDI plot for target species for the occurrence of positive catch SPO 3 SN daily Foveaux St catch-per-unit-effort dataset.

Table 61: 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	30	27174	2.1	2.1	*
+ month	11	25514	20.8	18.8	*
+ target species	3	24892	26.9	6.1	*
+ vessel key	17	24552	30.3	3.4	*
+ ns(log(soak time), 3)	3	24364	32.0	1.7	*
+ stat area	6	24236	33.2	1.2	*
+ ns(log(total net length), 3)	3	24217	33.4	0.2	

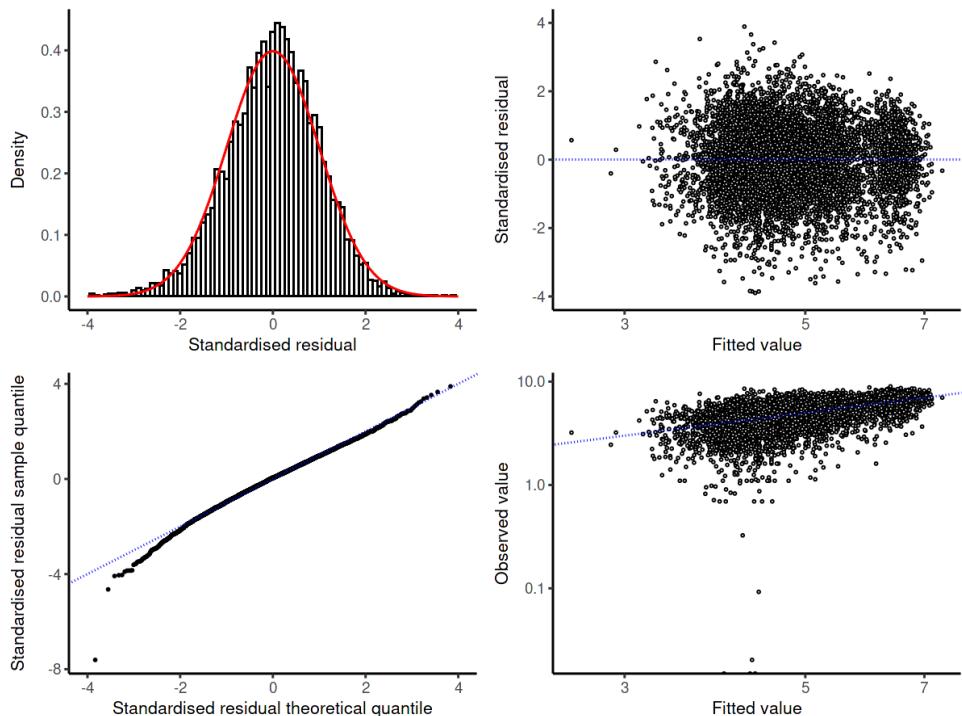


Figure 246: Diagnostic plots for the lognormal model for the SPO 3 SN daily Foveaux St dataset.

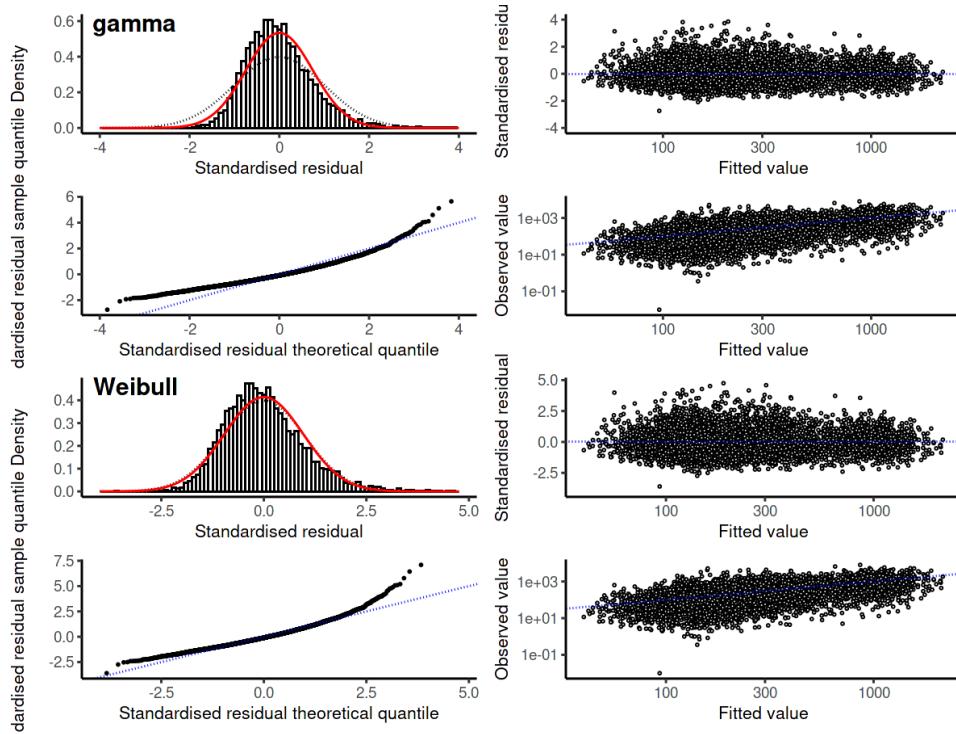


Figure 247: Diagnostic plots for the gamma and Weibull model for the SPO 3 SN daily Foveaux St dataset.

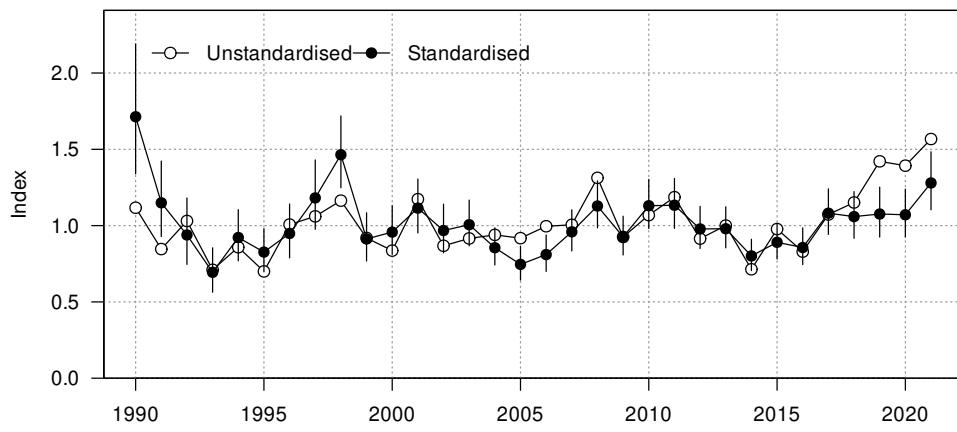


Figure 248: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 3 SN daily Foveaux St dataset.

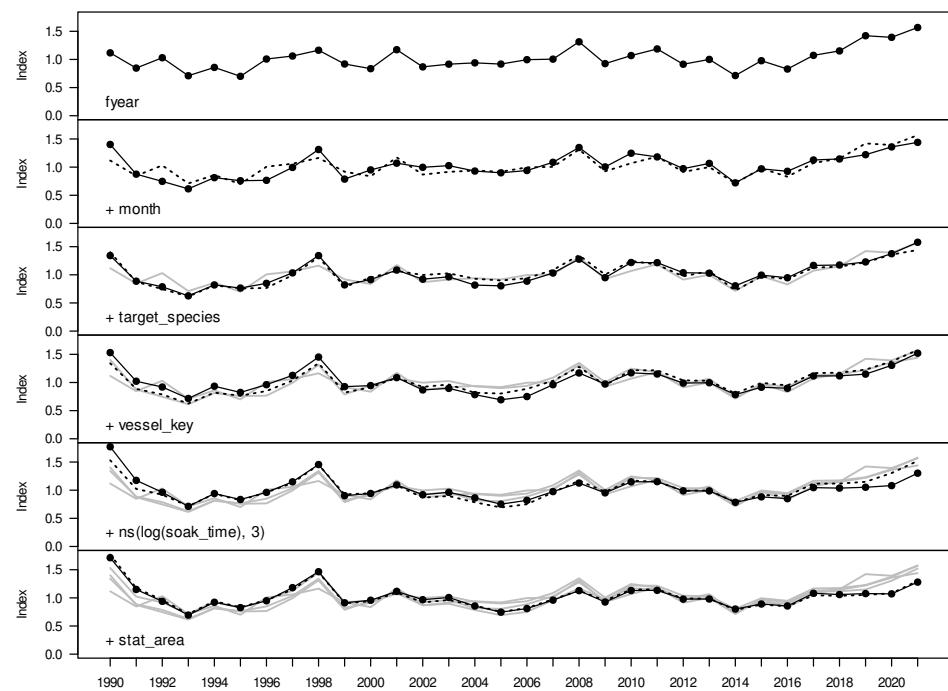


Figure 249: Changes to the SPO 3 SN daily Foveaux St positive catch index as terms are successively entered into the model.

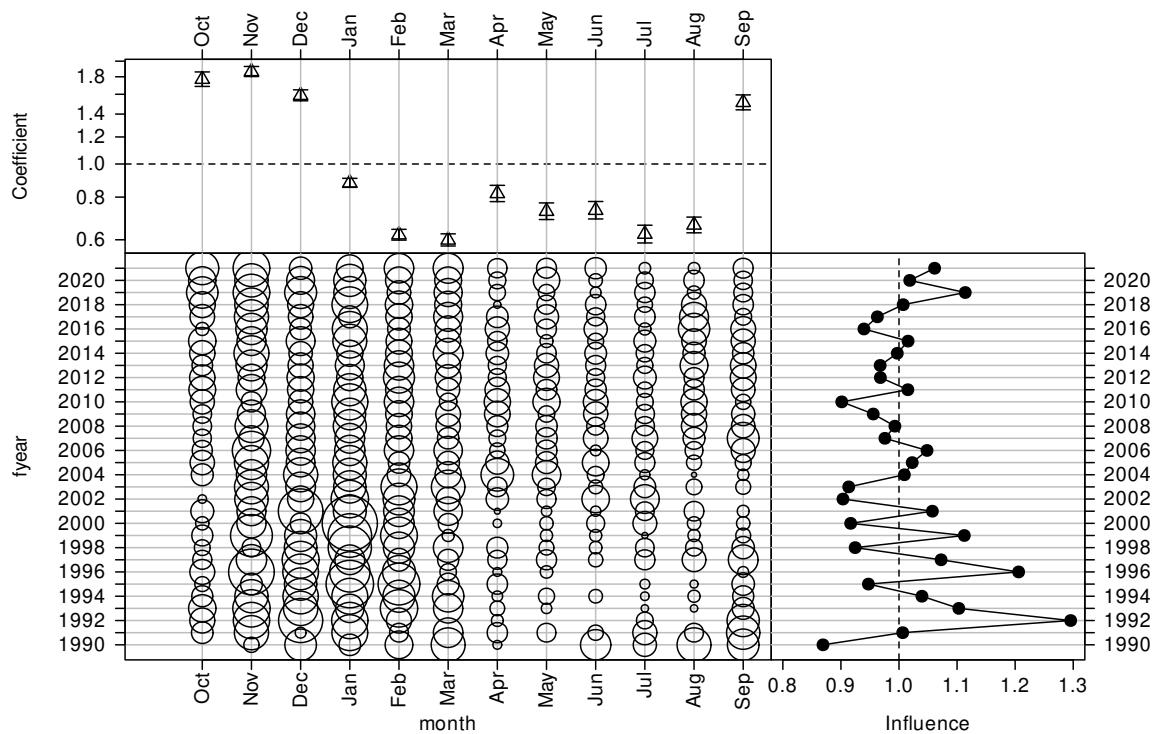


Figure 250: CDI plot for month for the positive catch SPO 3 SN daily Foveaux St catch-per-unit-effort dataset.

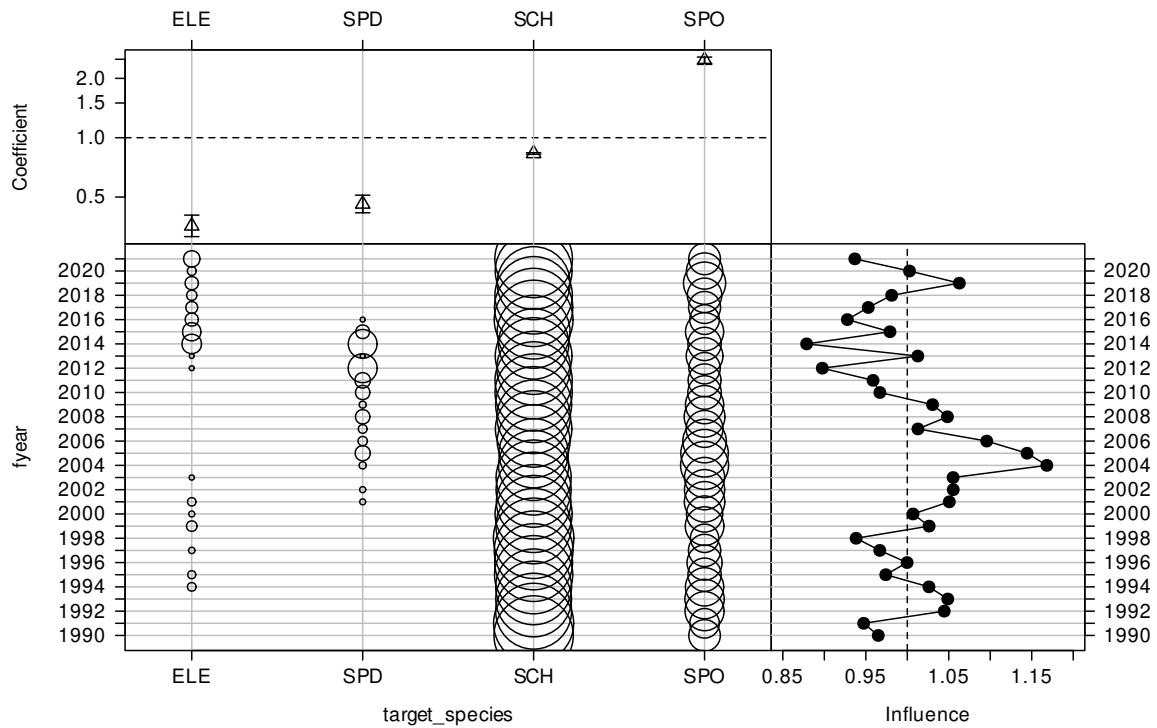


Figure 251: CDI plot for target species for the positive catch SPO 3 SN daily Foveaux St catch-per-unit-effort dataset.

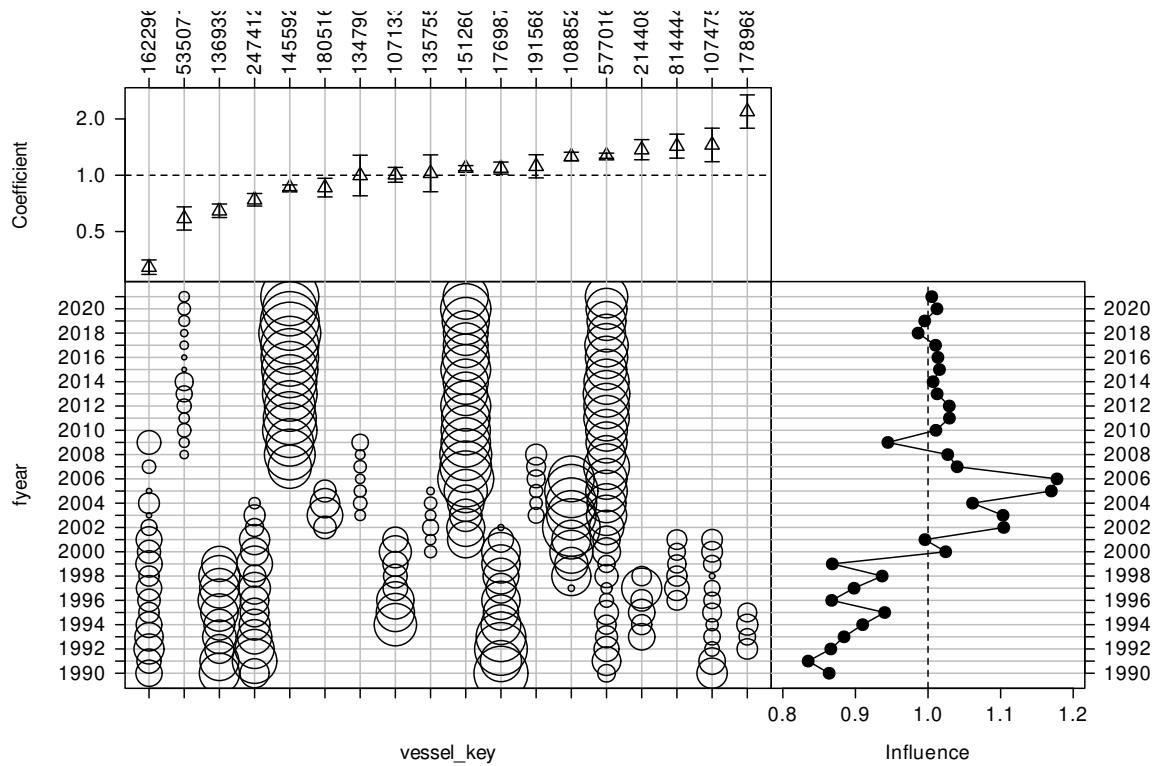


Figure 252: CDI plot for vessel key for the positive catch SPO 3 SN daily Foveaux St catch-per-unit-effort dataset.

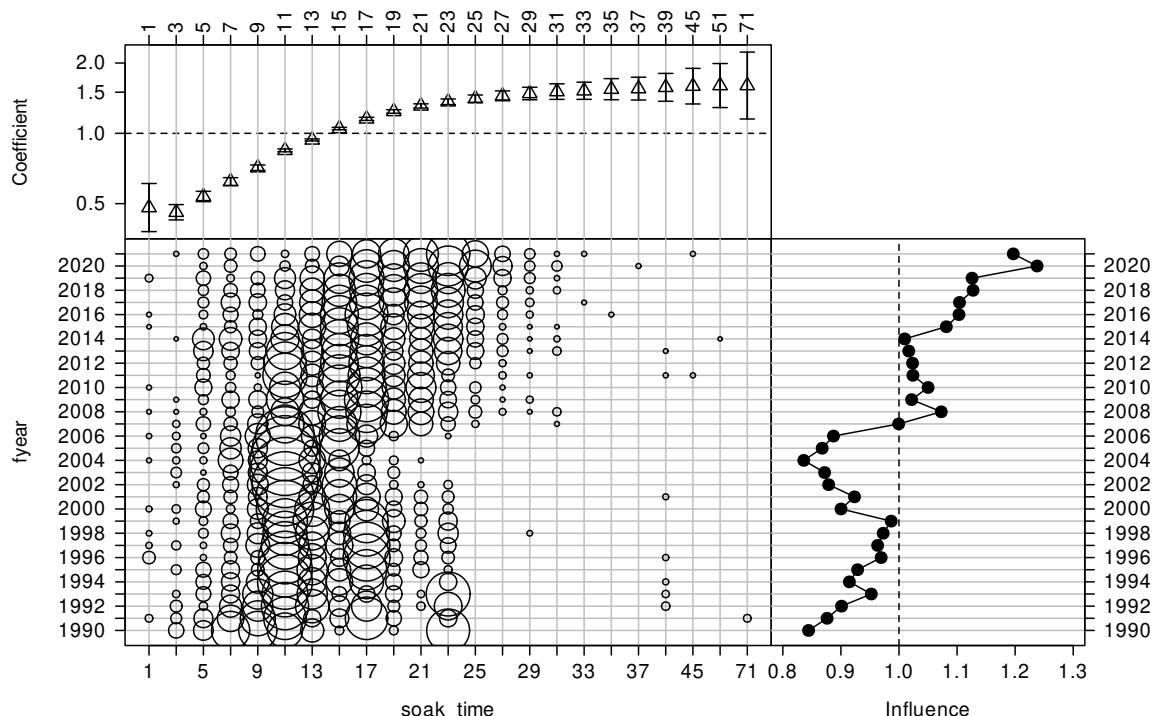


Figure 253: CDI plot for soak time for the positive catch SPO 3 SN daily Foveaux St catch-per-unit-effort dataset.

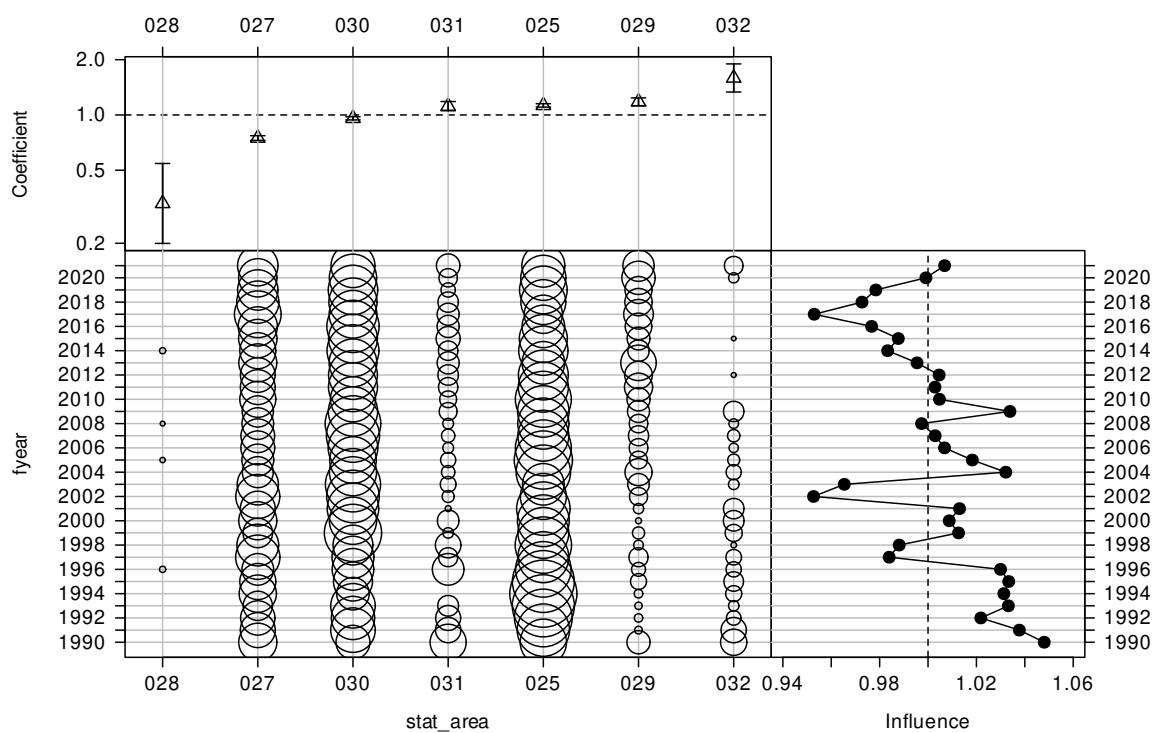


Figure 254: CDI plot for statistical area for the positive catch SPO 3 SN daily Foveaux St catch-per-unit-effort dataset.

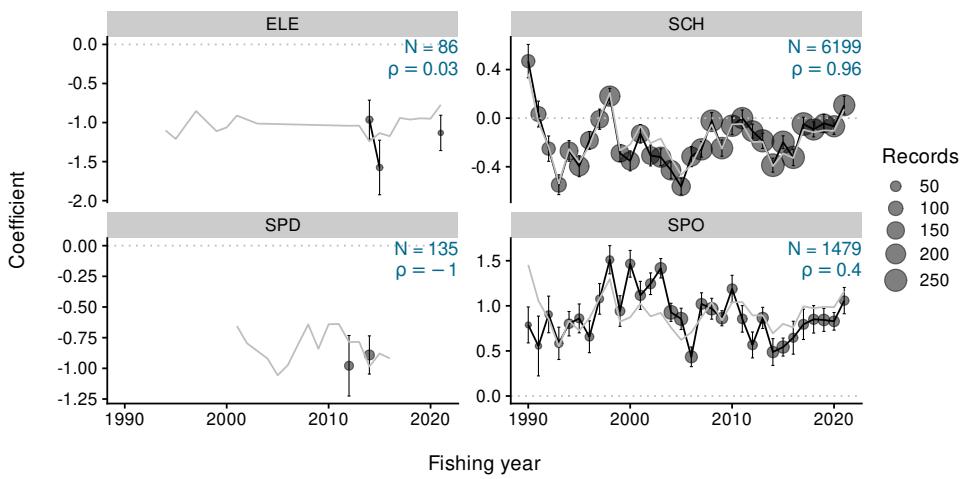


Figure 255: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 3 SN daily Foveaux St dataset.

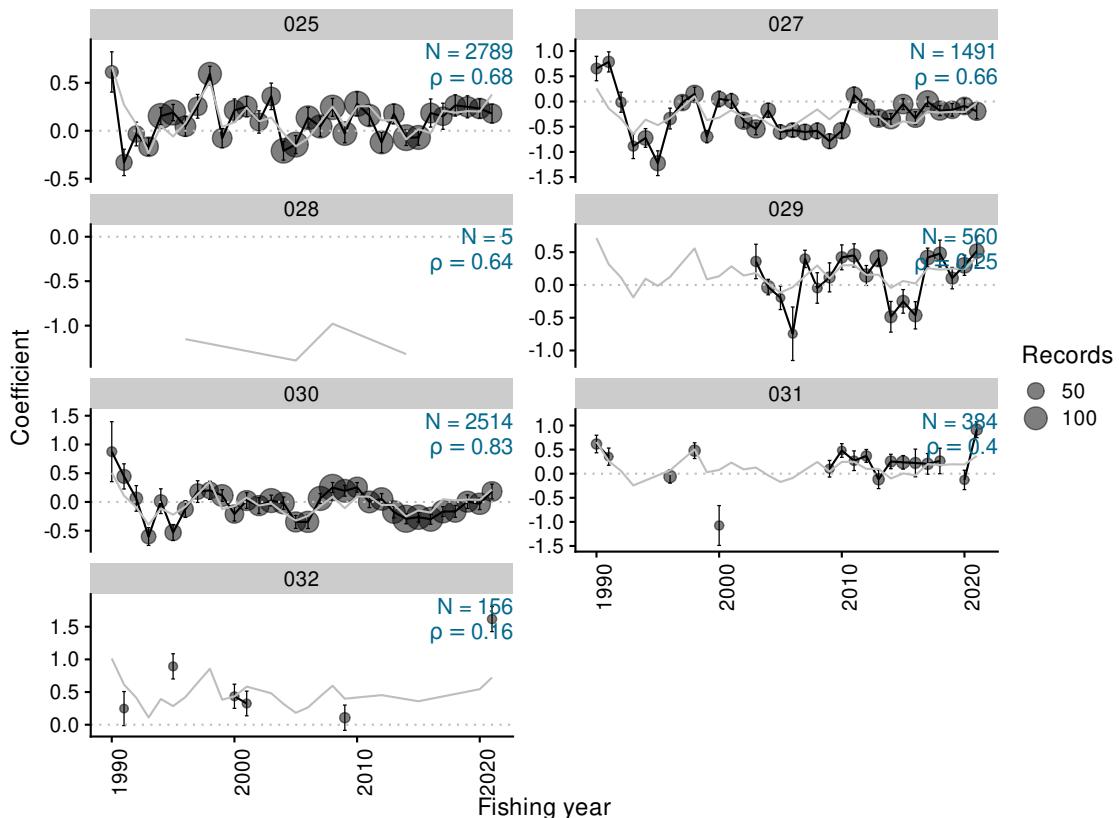


Figure 256: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 3 SN daily Foveaux St dataset.

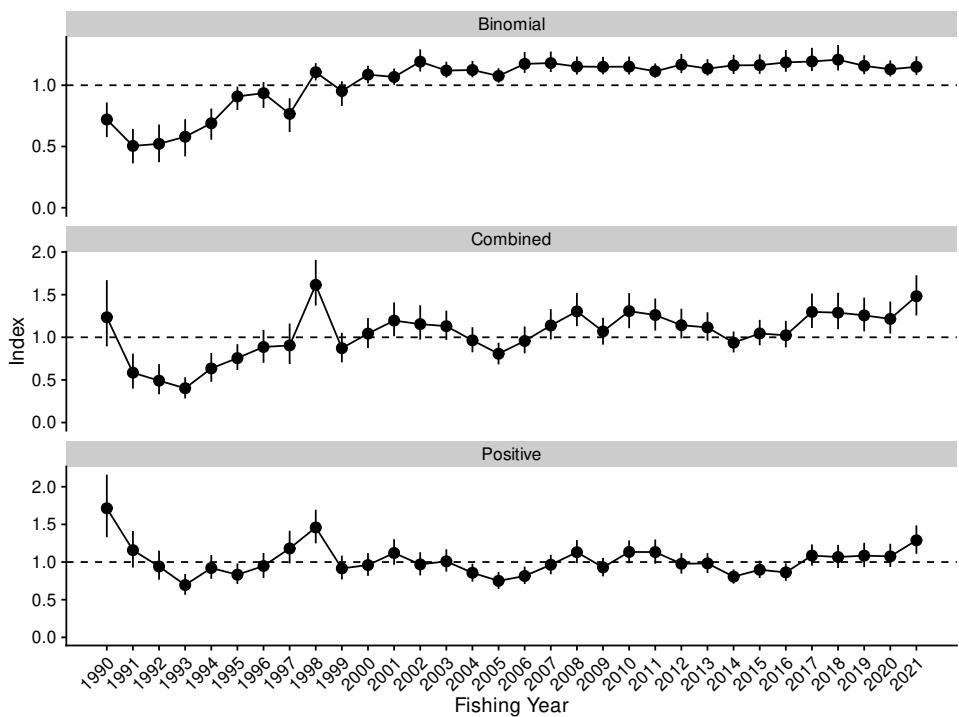


Figure 257: Standardised indices and 95% confidence intervals for the SPO 3 SN daily Foveaux St dataset.

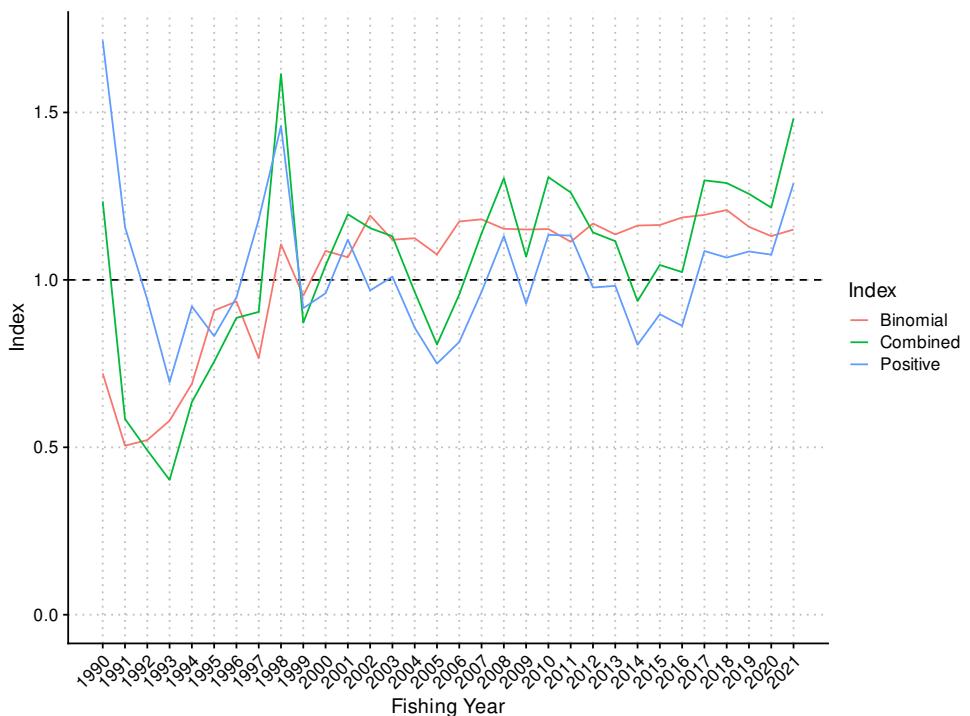


Figure 258: Standardised indices for the SPO 3 SN daily Foveaux St dataset.

Table 62: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 3 SN daily Foveaux St.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.720	0.072	0.577	0.859	1.235	0.198	0.894	1.670	1.714	0.212	1.330	2.160
1991	0.505	0.072	0.362	0.644	0.585	0.104	0.399	0.808	1.158	0.123	0.928	1.412
1992	0.522	0.078	0.372	0.679	0.491	0.090	0.332	0.685	0.941	0.098	0.766	1.151
1993	0.580	0.077	0.420	0.722	0.403	0.064	0.282	0.532	0.695	0.070	0.566	0.842
1994	0.690	0.065	0.555	0.810	0.635	0.086	0.478	0.816	0.921	0.081	0.777	1.093
1995	0.909	0.049	0.799	0.989	0.756	0.077	0.617	0.919	0.832	0.070	0.708	0.982
1996	0.935	0.054	0.815	1.026	0.886	0.098	0.701	1.087	0.948	0.085	0.789	1.121
1997	0.766	0.070	0.618	0.894	0.904	0.121	0.685	1.161	1.181	0.111	0.982	1.416
1998	1.106	0.036	1.039	1.180	1.615	0.137	1.373	1.908	1.460	0.114	1.249	1.695
1999	0.953	0.051	0.831	1.032	0.872	0.088	0.706	1.053	0.915	0.081	0.769	1.085
2000	1.087	0.036	1.016	1.159	1.043	0.090	0.874	1.226	0.960	0.077	0.817	1.118
2001	1.068	0.034	1.003	1.137	1.196	0.101	1.013	1.409	1.120	0.086	0.964	1.303
2002	1.192	0.046	1.112	1.293	1.155	0.103	0.973	1.375	0.969	0.078	0.823	1.130
2003	1.120	0.033	1.062	1.192	1.130	0.088	0.968	1.313	1.009	0.076	0.873	1.169
2004	1.124	0.034	1.065	1.198	0.964	0.075	0.824	1.118	0.857	0.060	0.741	0.978
2005	1.076	0.030	1.020	1.139	0.807	0.065	0.682	0.936	0.750	0.058	0.641	0.868
2006	1.174	0.044	1.101	1.271	0.957	0.081	0.811	1.127	0.815	0.059	0.708	0.938
2007	1.181	0.042	1.108	1.275	1.139	0.091	0.975	1.330	0.964	0.066	0.838	1.096
2008	1.153	0.038	1.087	1.234	1.304	0.100	1.130	1.521	1.131	0.078	0.986	1.292
2009	1.150	0.036	1.089	1.231	1.069	0.080	0.914	1.229	0.929	0.062	0.810	1.055
2010	1.152	0.037	1.088	1.234	1.307	0.105	1.107	1.518	1.134	0.077	0.984	1.288
2011	1.114	0.030	1.061	1.178	1.261	0.096	1.079	1.455	1.132	0.082	0.977	1.299
2012	1.168	0.040	1.099	1.256	1.142	0.089	0.987	1.335	0.977	0.069	0.846	1.119
2013	1.136	0.034	1.078	1.213	1.116	0.085	0.960	1.294	0.982	0.067	0.854	1.119
2014	1.162	0.040	1.091	1.248	0.937	0.063	0.822	1.068	0.806	0.048	0.713	0.902
2015	1.164	0.040	1.094	1.251	1.045	0.076	0.906	1.204	0.897	0.059	0.788	1.018
2016	1.186	0.045	1.110	1.287	1.023	0.079	0.881	1.192	0.863	0.059	0.751	0.983
2017	1.194	0.048	1.116	1.305	1.297	0.103	1.109	1.514	1.086	0.072	0.953	1.234
2018	1.209	0.053	1.120	1.328	1.289	0.109	1.095	1.522	1.067	0.078	0.921	1.228
2019	1.158	0.039	1.090	1.245	1.257	0.101	1.069	1.465	1.085	0.082	0.933	1.255
2020	1.131	0.034	1.072	1.203	1.216	0.096	1.043	1.419	1.075	0.079	0.935	1.243
2021	1.150	0.039	1.083	1.236	1.482	0.120	1.256	1.727	1.288	0.096	1.110	1.487

5.12 SPO 7 SN daily

This series was based on the daily catch of rig from the shark target species fishery in Tasman/Golden bays. The analysis was based on Statistical Area 038 that included Tasman Bay and Golden Bay, bounded in the north by a line from Farewell Spit to D'Urville Island (Table 63). The target species suite included three commercially harvested shark species: rig (SPO), school shark (SCH) and spiny dogfish (SPD). The core fleet was defined by having fished at least three trips in each of three years, retaining 96% of the catch and reducing the fleet from about 60 vessels to 17 vessels (Figure 259). The pattern of vessel participation in this fishery was characterised by 5 vessels which remained the fishery for 17 years or more, along with the remaining vessels having shorter periods of activity (Figure 260). The final groomed dataset generally represented more than 80% of the ungroomed catch for each year, with only one year at 61% (1999) and with 23 years where 100% of the ungroomed catch was retained in the analysis (Table 64). The total annual catch of rig in the defined fishery ranged from 14.1 t (in 2021) to 120 t (in 1998) over the 32 years in the data set and was characterised by a high level of occurrence of rig in the daily landings, ranging from 63% (in 1994) to 100% (in 2021) (Table 65). Note that the very small amount of catch in 2021 was based only on a single vessel. All landed catch in this data set was allocated by distributing the total trip landings proportionately to the estimated catches within the trip (Figure 261)

The binomial (occurrence) model accepted four predictive variables after fishing year (target species, vessel, month, total_net_length), with the model explaining 44% of the deviance (Table 66). While the unstandardised series showed some variation without trend, all variation was removed through the standardisation procedure, leaving a flat standardised series fixed at a value of one (Figure 262, Figure 263). The first covariate to enter the occurrence model (target species) was responsible for removing the ‘bulge’ in the early 1990s attributable to SPD targeting, a tactic often used to circumvent quota holding rules which required owning quota for targeted species (SPD could be used because it wasn’t a quota species at the time; Figure 264). The remaining three covariates had no discernible impact on the occurrence series (vessel: Figure 265, month: Figure 266, total_net_length: Figure 267). Note that this model was undefined in 2021 because all effort records caught rig in that year (Table 65).

The lognormal model accepted four predictive variables after fishing year (vessel, target species, month, total_net_length), with the total model explaining 43% of the deviance (Table 67). Residuals to the positive catch model showed reasonable conformity to the lognormal assumption over the total distribution, with some skewness at the centre of the distribution and in the lower tail (Figure 268). Both the gamma and the Weibull distributions had fits to the positive catch data that were similar to the lognormal model fit but not noticeably better (Figure 269). The standardised and unstandardised series had little trend from 1991 to 2019, followed by a strong increase in both 2020 and 2021 (Figure 270). The only covariate that resulted in an apparent standardisation effect was vessel, which brought down the very high 2021 catch rate (Figure 271), attributed to a single vessel (Figure 272). The remaining three covariates had not much impact on the standardisation procedure (target species: Figure 273, month: Figure 274, total_net_length: Figure 275). Implied residual plots of rig annual CPUE showed good conformity with the overall annual CPUE trend for rig (SPO) target effort which dominated the SN fishery in this statistical area (Figure 276). Spiny dogfish (SPD), which likely was an alias for rig when declared, also showed reasonable correspondence with the annual CPUE trend in this model for the years it was used. However, school shark (SCH) target effort was a very poor fit with the overall annual CPUE trend.

Because the binomial model had no trend and was centred at one, the combined model was nearly the same as the lognormal model (Figure 277, Figure 278, Table 68). The lognormal (and combined) model declined from the beginning of the series to the mid-2000s, followed by an increasing trend to 2011. At this point, both series flattened to 2019, followed by a very strong two-year increase in 2020 and 2021. Note that the combined series is undefined in 2021 because there was no corresponding 2021 binomial index. A comparison of the lognormal positive catch series with the equivalent series calculated in 2019 (Starr & Kendrick 2020) shows that this series matched that series well in the overlapping years, but that

the strong increase seen in the final two years had not yet begun (Figure 285). Note that the 2021 index value is based on a single vessel.

Table 63: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 7 SN daily CPUE series.

Series	SPO 7 SN daily
QMS stock	SPO7
Reporting forms	CEL, ERS - Netting, NCE
Fishing methods	SN
Target species	SPO, SCH, SPD
Statistical Areas	038
Period	1989-10-01, 2021-09-30
Resolution	Day
Core fleet years	3
Core fleet trips	3
Default model	$\text{allockg} \sim \text{fyear} + \text{vessel_key} + \text{month} + \text{target_species} + \text{ns}(\log(\text{soak_time}), 3) + \text{ns}(\log(\text{total_net_length}), 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

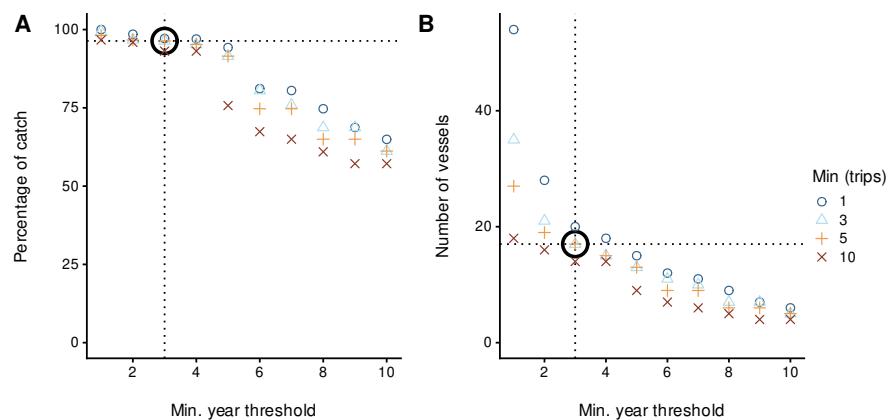


Figure 259: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 7 SN daily CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

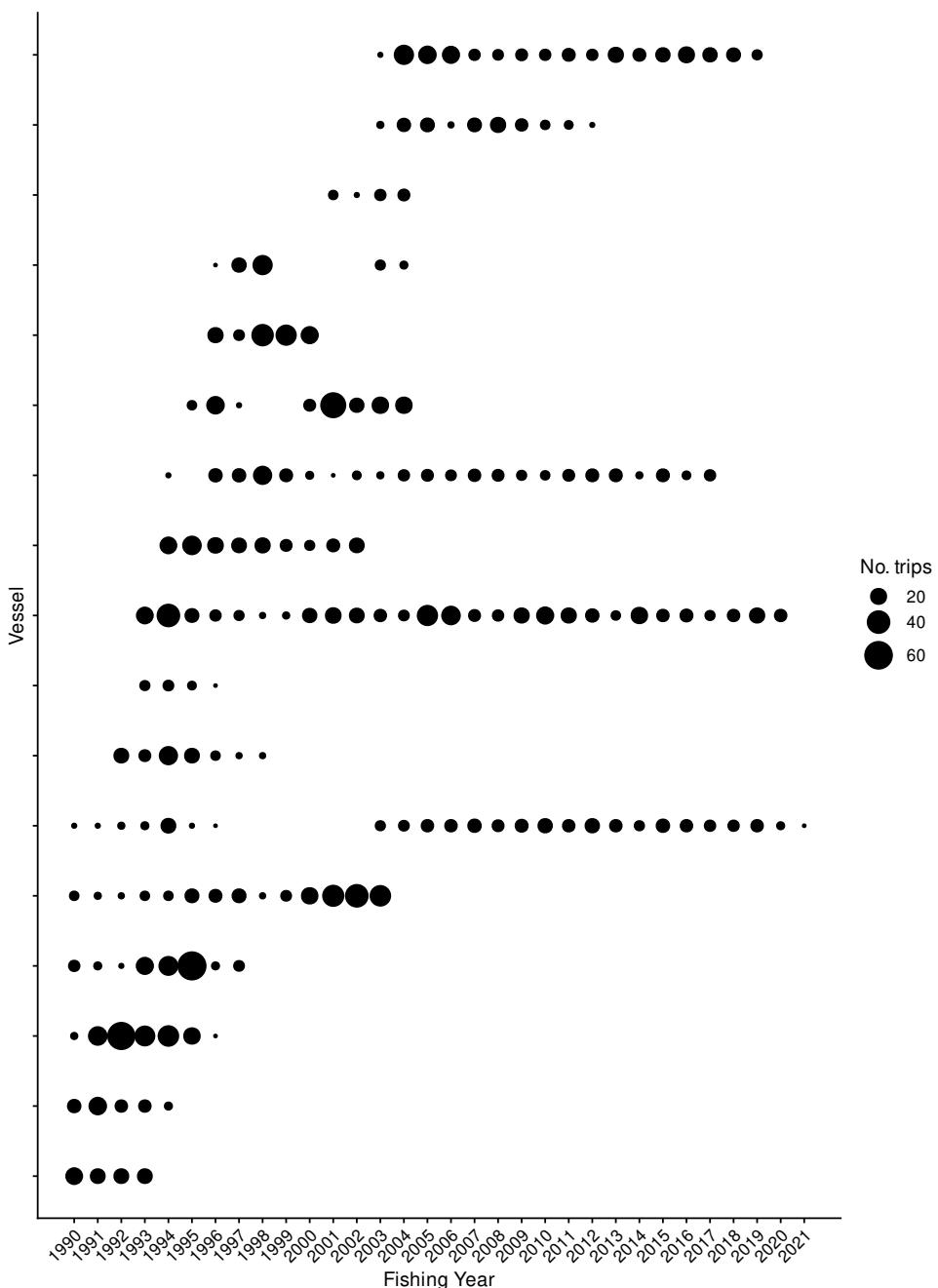


Figure 260: Number of trips by fishing year for core vessels. The area of the circles is proportional to the number of trips undertaken by a vessel in a fishing year.

Table 64: Summary of the SPO 7 SN 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	81 (100%) n: 103	69 (100%) n: 160	93 (100%) n: 187	117 (100%) n: 256	111 (100%) n: 375	97 (100%) n: 313	110 (100%) n: 226	99 (100%) n: 195	122 (100%) n: 204
Positive soak time	81 (100%) n: 103	69 (100%) n: 160	93 (100%) n: 186	117 (100%) n: 256	111 (100%) n: 375	97 (100%) n: 313	108 (100%) n: 212	81 (82%) n: 168	122 (100%) n: 203
Positive net length	81 (100%) n: 103	69 (100%) n: 160	93 (100%) n: 186	111 (100%) n: 252	111 (100%) n: 375	97 (100%) n: 312	107 (100%) n: 211	81 (82%) n: 168	121 (100%) n: 199
Core fleet selection	75 (93%) n: 87	56 (81%) n: 108	87 (94%) n: 170	106 (90%) n: 234	107 (100%) n: 357	93 (100%) n: 297	100 (91%) n: 187	81 (82%) n: 165	119 (100%) n: 188
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	80 (100%) n: 184	57 (100%) n: 184	74 (100%) n: 267	60 (100%) n: 251	63 (100%) n: 288	80 (100%) n: 320	86 (100%) n: 339	87 (100%) n: 267	103 (100%) n: 211
Positive soak time	80 (100%) n: 183	57 (100%) n: 184	74 (100%) n: 267	60 (100%) n: 251	63 (100%) n: 288	80 (100%) n: 319	86 (100%) n: 339	87 (100%) n: 267	103 (100%) n: 211
Positive net length	80 (100%) n: 183	57 (100%) n: 184	74 (100%) n: 267	60 (100%) n: 251	63 (100%) n: 288	80 (100%) n: 319	86 (100%) n: 339	87 (100%) n: 267	103 (100%) n: 211
Core fleet selection	49 (61%) n: 97	54 (94%) n: 178	73 (100%) n: 264	60 (100%) n: 249	59 (94%) n: 270	80 (100%) n: 306	85 (100%) n: 330	87 (100%) n: 267	103 (100%) n: 208
Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	90 (100%) n: 183	89 (100%) n: 168	84 (100%) n: 162	89 (100%) n: 140	89 (100%) n: 137	83 (100%) n: 147	71 (100%) n: 120	73 (100%) n: 149	80 (100%) n: 153
Positive soak time	90 (100%) n: 183	89 (100%) n: 168	84 (100%) n: 162	89 (100%) n: 140	89 (100%) n: 137	83 (100%) n: 147	71 (100%) n: 120	73 (100%) n: 149	80 (100%) n: 153
Positive net length	90 (100%) n: 183	89 (100%) n: 168	84 (100%) n: 162	89 (100%) n: 140	89 (100%) n: 137	83 (100%) n: 147	71 (100%) n: 120	73 (100%) n: 149	80 (100%) n: 153
Core fleet selection	90 (100%) n: 183	89 (100%) n: 168	84 (100%) n: 162	89 (100%) n: 138	86 (100%) n: 133	80 (100%) n: 133	71 (100%) n: 120	73 (100%) n: 149	80 (100%) n: 153

Filter	2017	2018	2019	2020	2021
Ungroomed data	86 (100%) n: 117	76 (100%) n: 114	80 (100%) n: 100	65 (100%) n: 57	14 (100%) n: 7
Positive soak time	86 (100%) n: 117	76 (100%) n: 114	80 (100%) n: 100	65 (100%) n: 57	14 (100%) n: 7
Positive net length	86 (100%) n: 117	76 (100%) n: 114	79 (100%) n: 99	65 (100%) n: 57	14 (100%) n: 7
Core fleet selection	86 (100%) n: 117	76 (100%) n: 114	79 (100%) n: 99	65 (100%) n: 57	14 (100%) n: 7

Table 65: Summary of the SPO 7 SN 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 rig.

Fishing year	Vessels	Trips	Records	Net length (km)	Catch (t)	Records caught
1990	6	59	87	137.81	74.85	90.80
1991	6	79	108	146.07	56.02	92.59
1992	7	113	170	284.62	87.23	79.41
1993	9	136	234	415.82	105.75	76.92
1994	10	189	357	696.60	107.15	62.75
1995	9	172	297	499.19	92.67	81.82
1996	12	114	187	356.01	100.06	85.03
1997	9	93	165	314.66	80.52	87.88
1998	7	118	188	504.28	119.50	93.62
1999	5	69	97	264.90	49.30	92.78
2000	6	84	178	376.80	53.89	92.70
2001	6	124	264	390.85	72.56	98.11
2002	6	98	249	403.14	59.56	94.38
2003	9	102	270	474.93	58.94	94.81
2004	8	108	306	528.93	79.55	99.35
2005	5	94	330	632.50	85.50	96.36
2006	5	74	267	536.10	87.08	95.13
2007	5	62	208	495.85	102.91	98.08
2008	5	59	183	490.47	89.58	98.36
2009	5	62	168	417.01	88.55	92.26
2010	5	63	162	396.95	84.47	91.36
2011	5	60	138	316.55	88.77	88.41
2012	5	55	133	364.01	85.51	95.49
2013	4	50	133	364.81	80.21	96.99
2014	4	46	120	291.64	71.06	89.17
2015	4	55	149	409.50	73.46	93.96
2016	4	51	153	371.72	80.46	95.42
2017	4	44	117	318.08	85.80	96.58
2018	3	37	114	287.10	75.68	92.98
2019	3	38	99	293.10	78.90	95.96
2020	2	17	57	116.35	65.09	96.49
2021	1	1	7	30.00	14.08	100.00

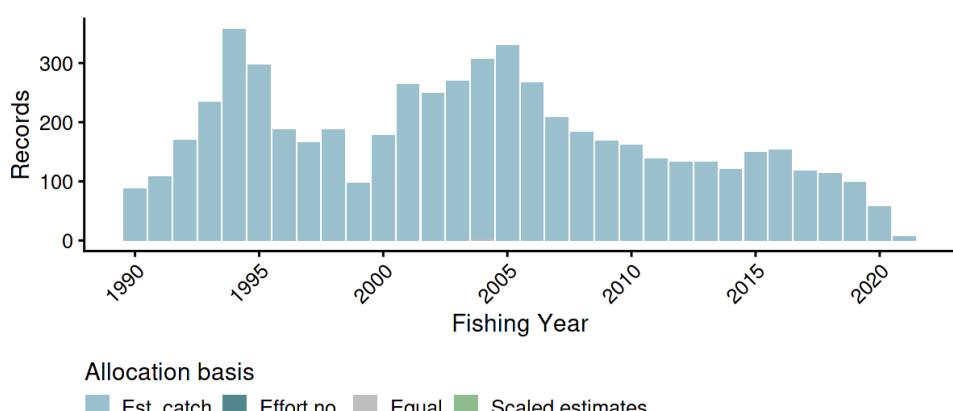


Figure 261: Allocation basis for attributing landings to records in the SPO 7 SN daily catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table 66: 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	30.00	3 156	13.30	13.30	*
+ target_species	2.00	2 343	36.20	22.90	*
+ vessel_key	16.00	2 215	40.70	4.50	*
+ month	11.00	2 116	44.10	3.40	*
+ ns(log(total_net_length), 3)	3.00	2 087	45.10	1.00	*

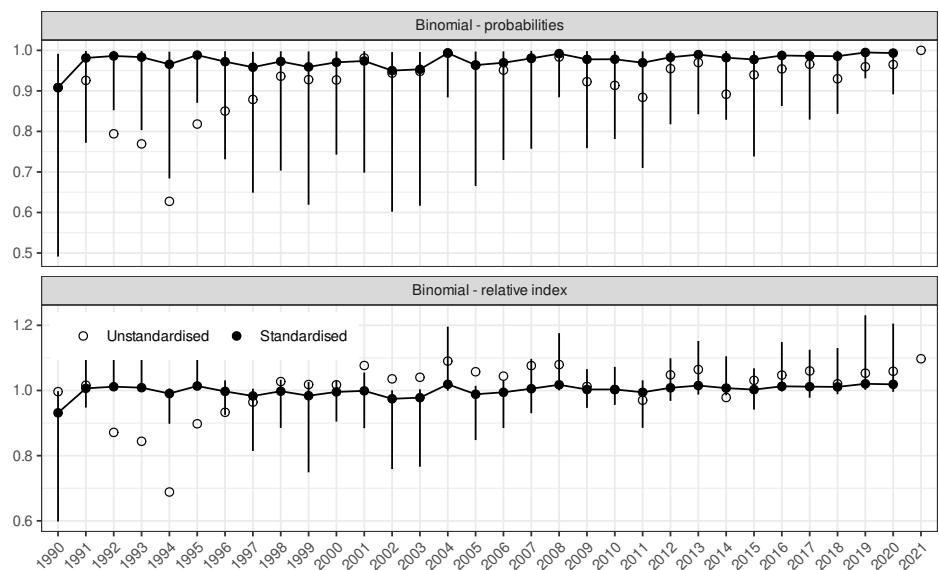


Figure 262: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 7 SN daily dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

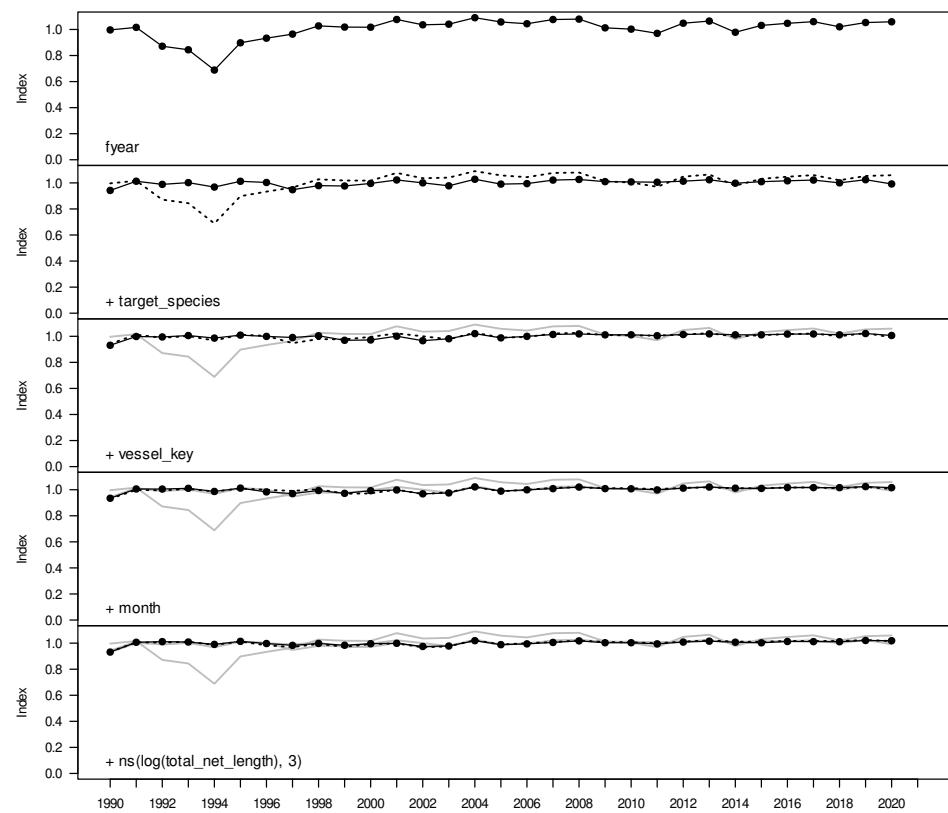


Figure 263: Step plot for occurrence of catch in the SPO 7 SN daily dataset.

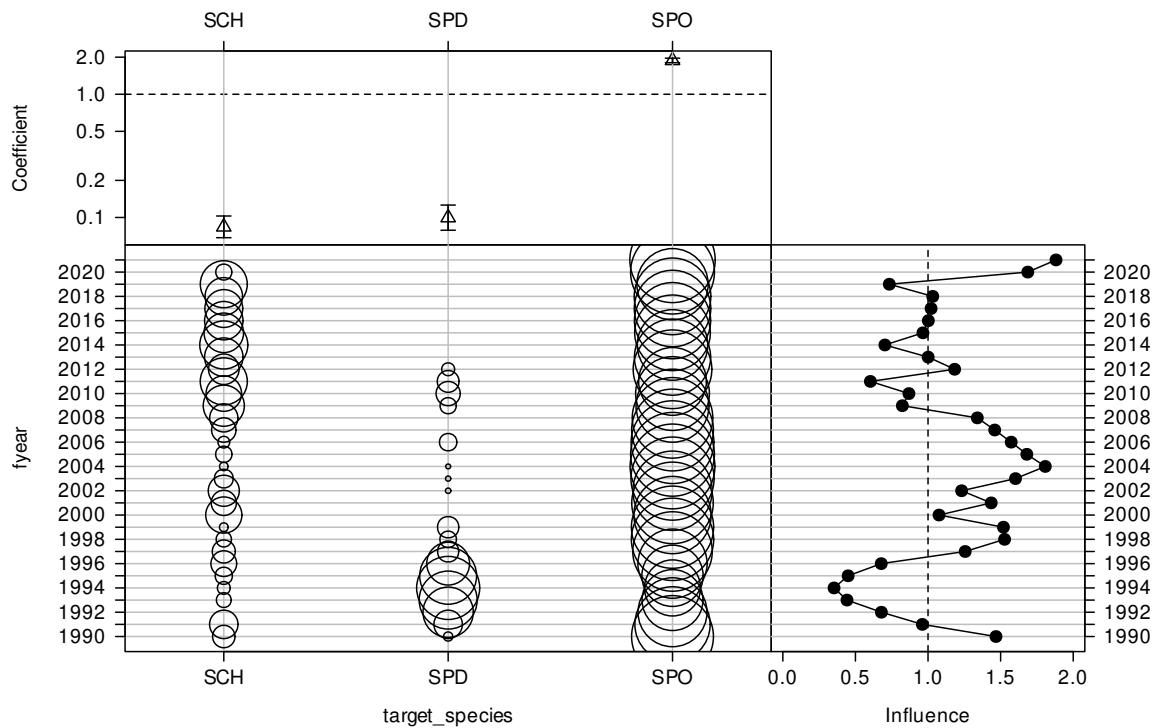


Figure 264: CDI plot for target species for the occurrence of positive catch SPO 7 SN daily catch-per-unit-effort dataset.

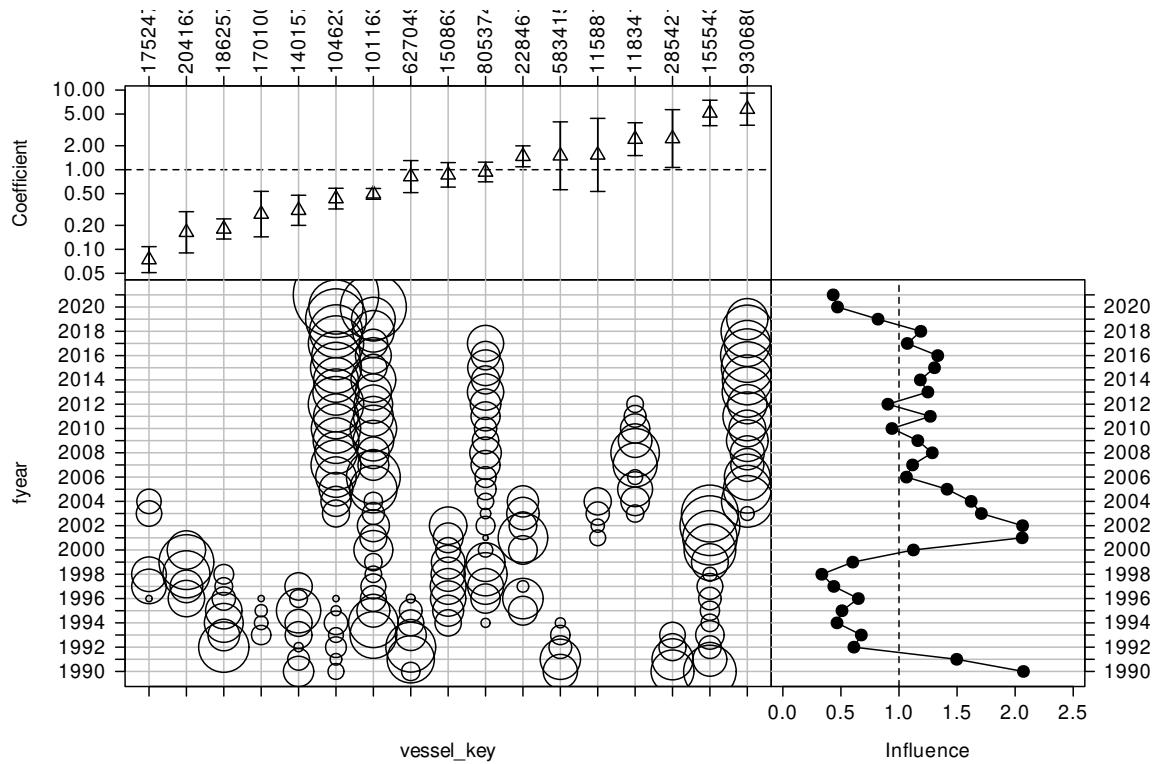


Figure 265: CDI plot for vessel key for the occurrence of positive catch SPO 7 SN daily catch-per-unit-effort dataset.

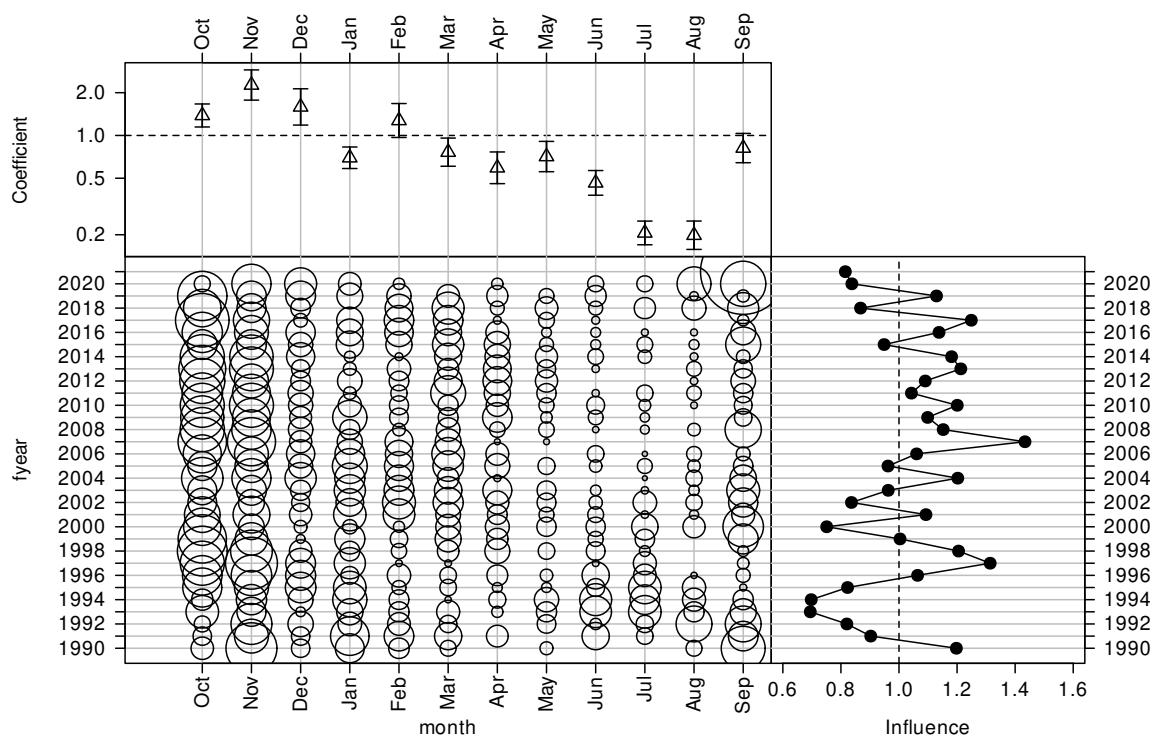


Figure 266: CDI plot for month for the occurrence of positive catch SPO 7 SN daily catch-per-unit-effort dataset.

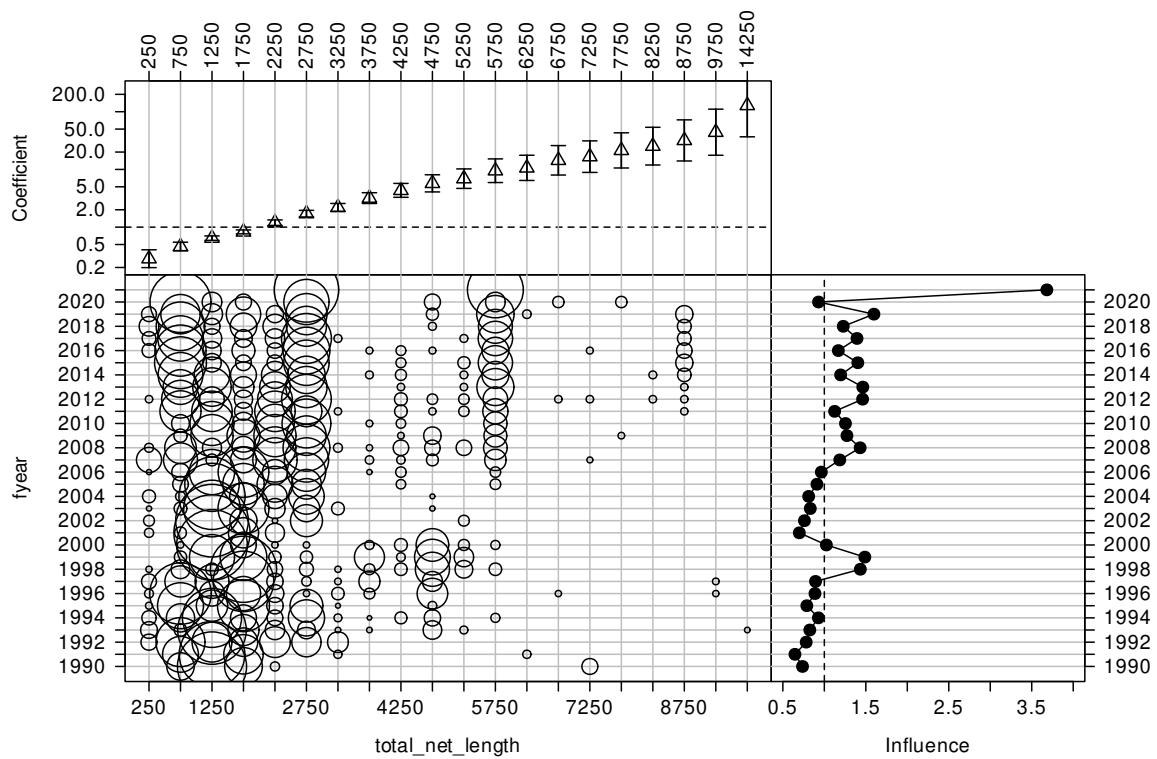


Figure 267: CDI plot for total net length for the occurrence of positive catch SPO 7 SN daily catch-per-unit-effort dataset.

Table 67: 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	30	17 904	7.6	7.6	*
+ vessel key	16	16 663	27.9	20.2	*
+ target species	2	16 053	36.0	8.1	*
+ month	11	15 667	40.8	4.9	*
+ ns(log(total net length), 3)	3	15 479	43.0	2.2	*
+ ns(log(soak time), 3)	3	15 473	43.1	0.1	

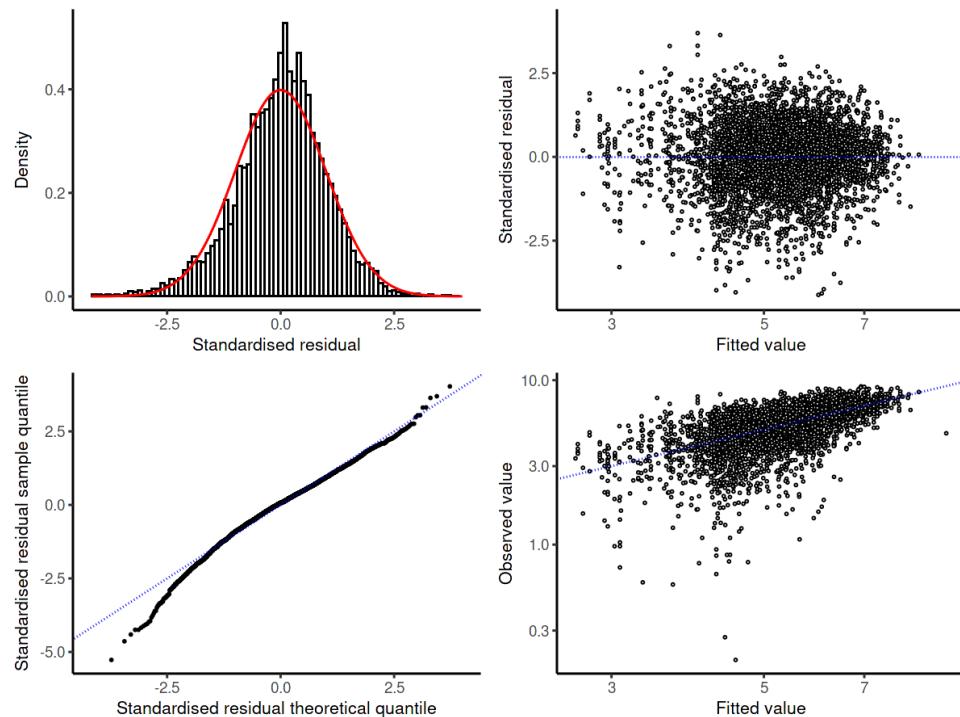


Figure 268: Diagnostic plots for the lognormal model for the SPO 7 SN daily dataset.

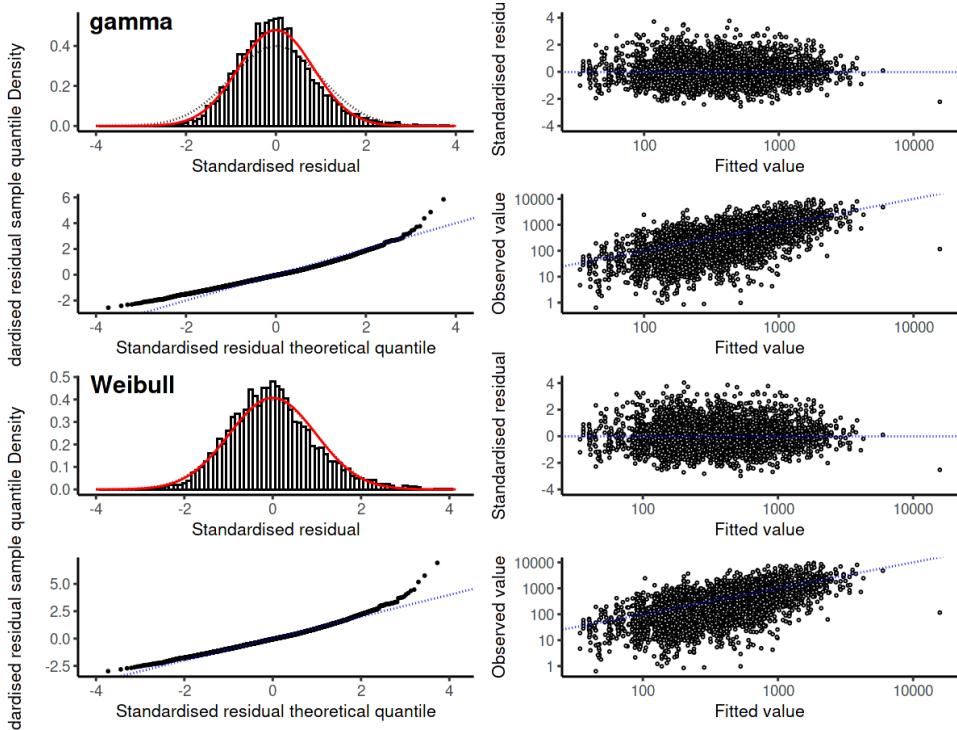


Figure 269: Diagnostic plots for the gamma and Weibull model for the SPO 7 SN daily dataset.

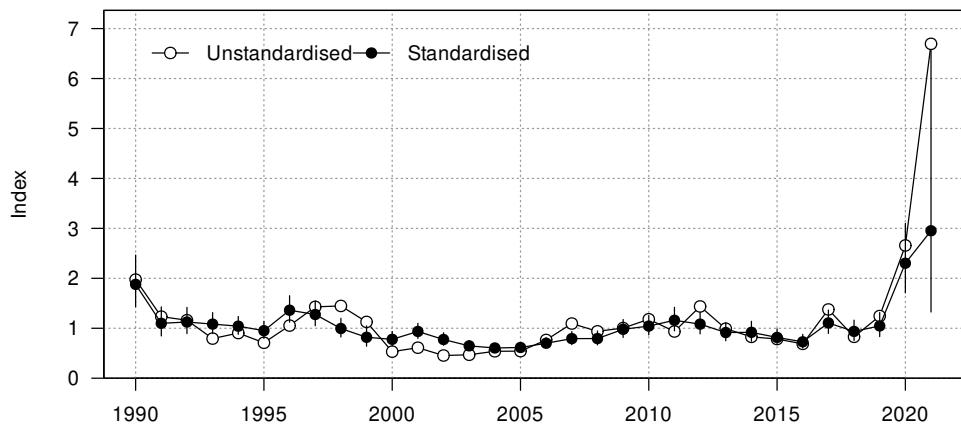


Figure 270: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 7 SN daily dataset.

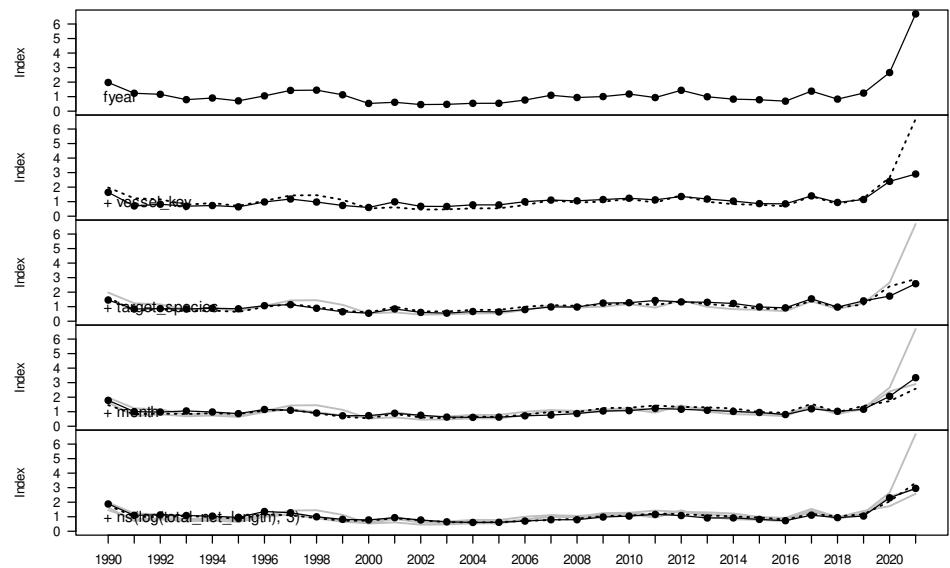


Figure 271: Changes to the SPO 7 SN daily positive catch index as terms are successively entered into the model.

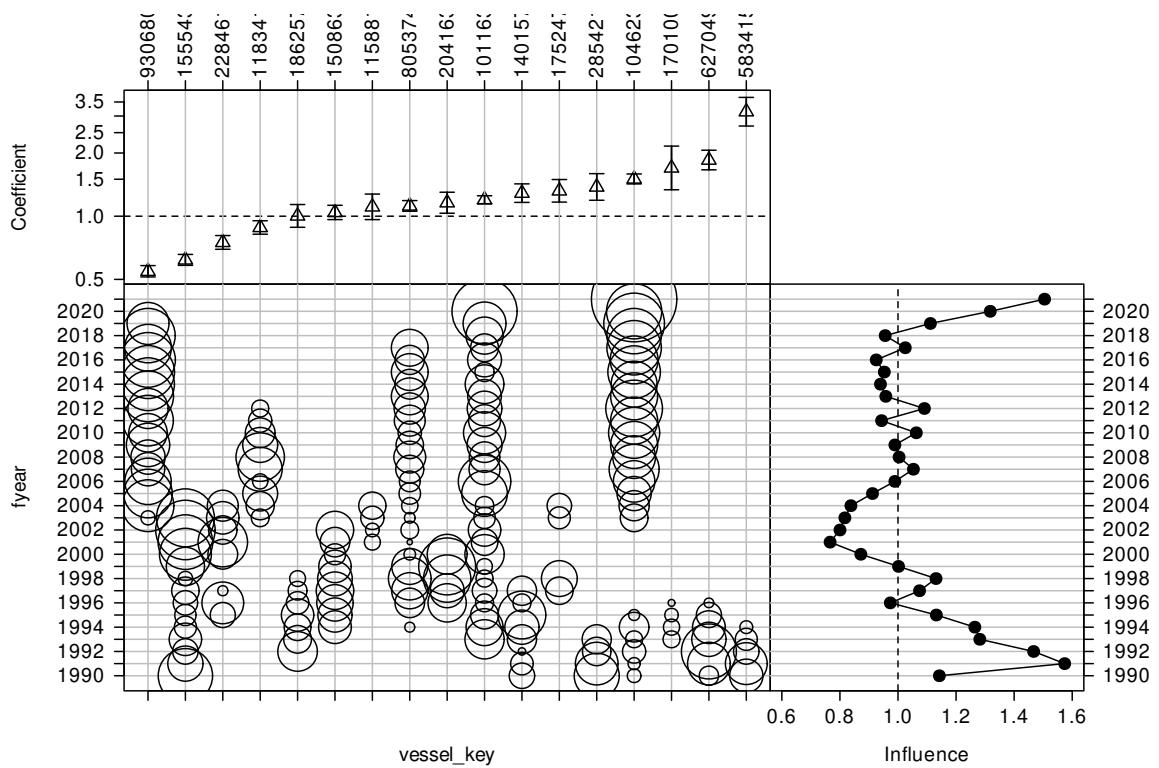


Figure 272: CDI plot for vessel key for the positive catch SPO 7 SN daily catch-per-unit-effort dataset.

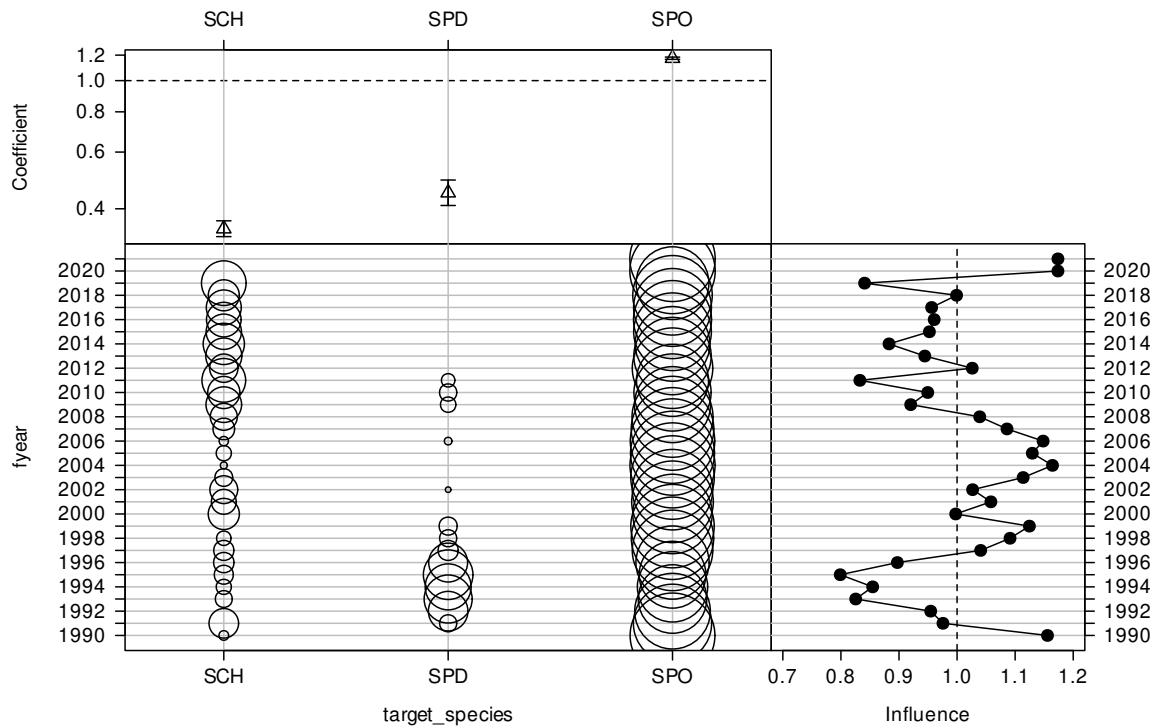


Figure 273: CDI plot for target species for the positive catch SPO 7 SN daily catch-per-unit-effort dataset.

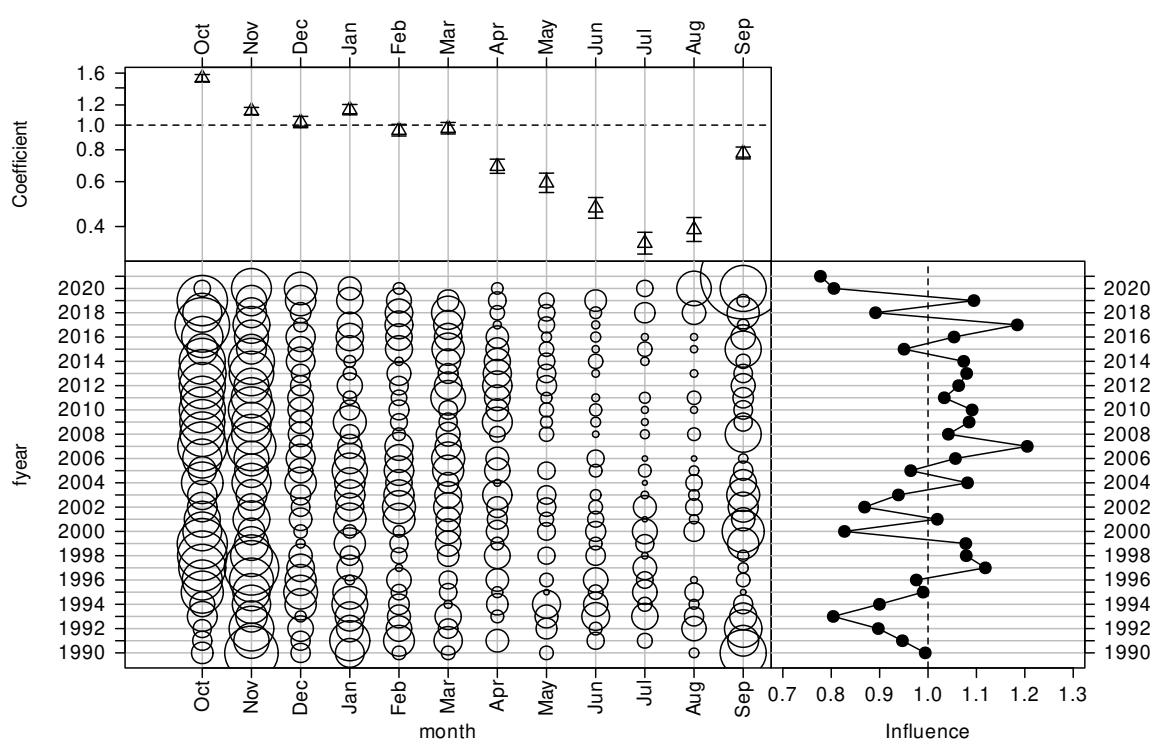


Figure 274: CDI plot for month for the positive catch SPO 7 SN daily catch-per-unit-effort dataset.

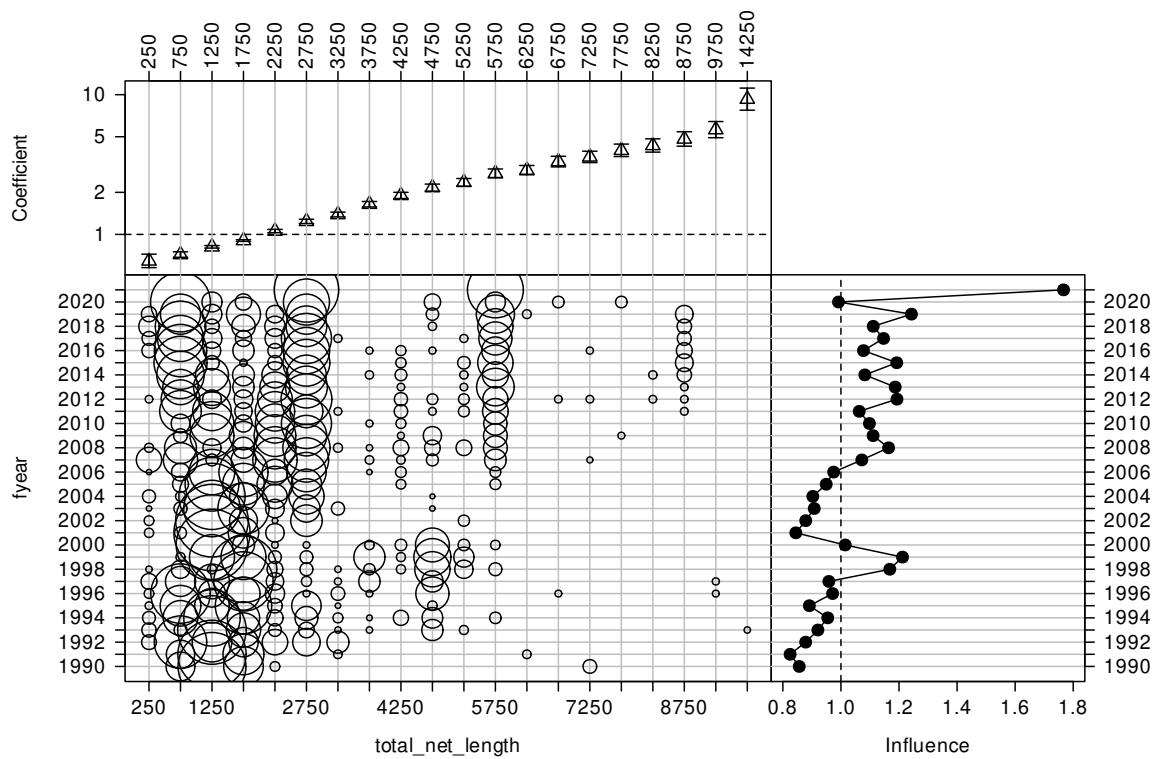


Figure 275: CDI plot for total net length for the positive catch SPO 7 SN daily catch-per-unit-effort dataset.

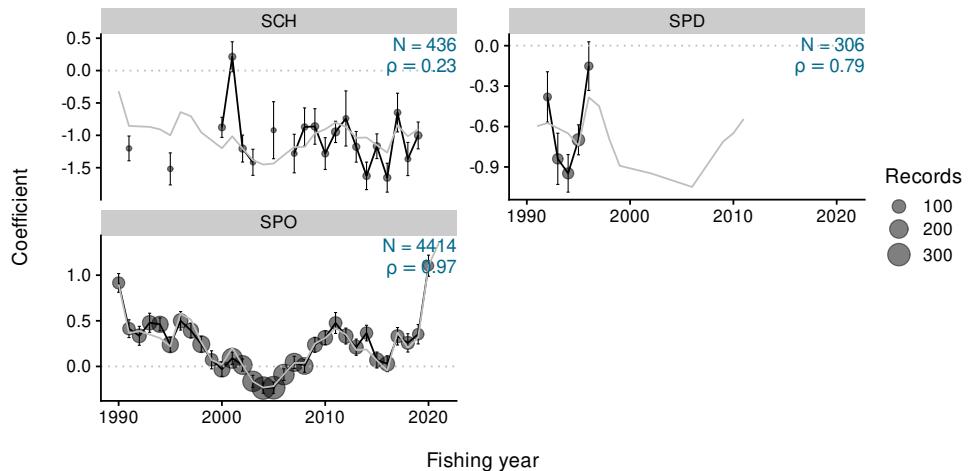


Figure 276: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 7 SN daily dataset.

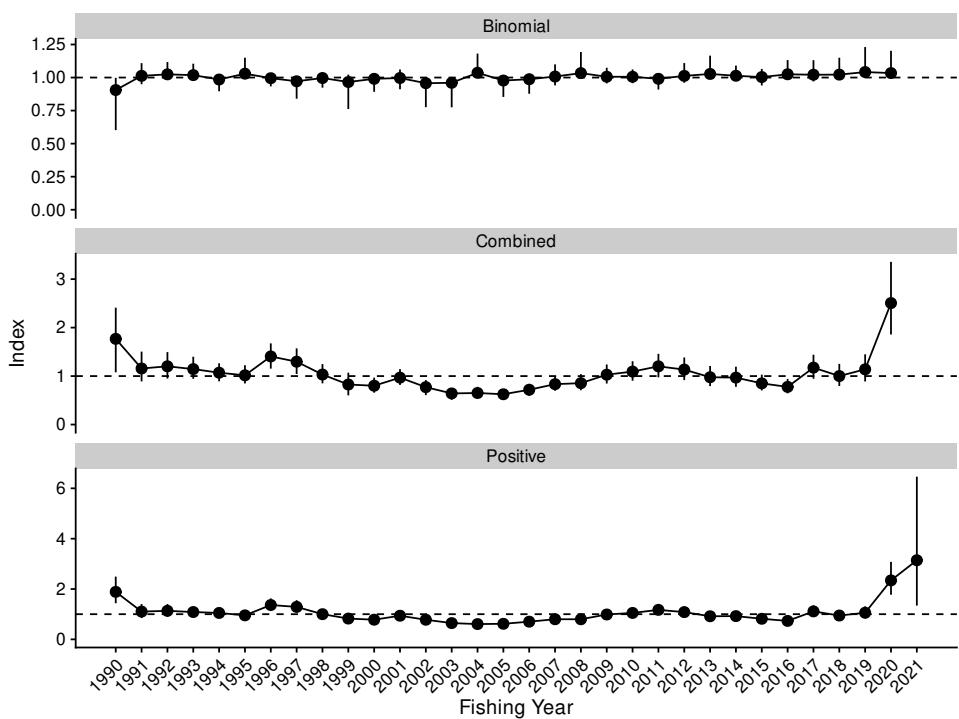


Figure 277: Standardised indices and 95% confidence intervals for the SPO 7 SN daily dataset.

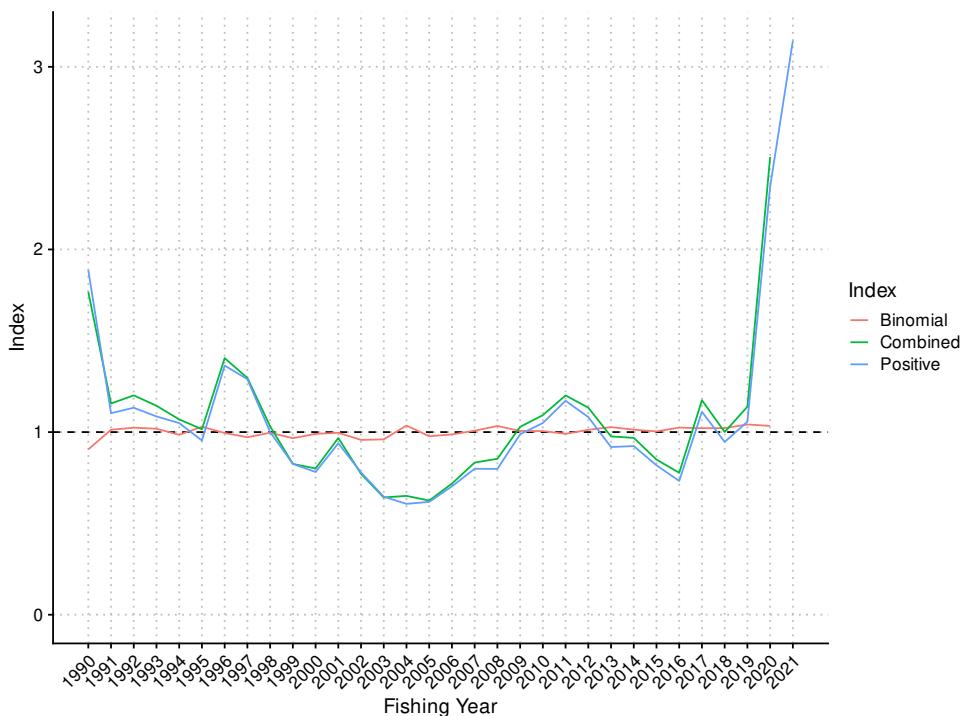


Figure 278: Standardised indices for the SPO 7 SN daily dataset.

Table 68: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 7 SN daily.

Fishing year	Binomial				Combined				Positive				
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI	
1990	0.905	0.101	0.603	0.998	1.768	0.340	1.078	2.411	1.887	0.270	1.435	2.493	
1991	1.013	0.041	0.949	1.109	1.157	0.157	0.890	1.504	1.104	0.142	0.846	1.403	
1992	1.024	0.030	1.000	1.117	1.201	0.139	0.949	1.494	1.133	0.129	0.895	1.401	
1993	1.018	0.027	0.998	1.105	1.144	0.116	0.944	1.399	1.086	0.106	0.893	1.309	
1994	0.985	0.028	0.896	1.007	1.070	0.095	0.892	1.263	1.049	0.089	0.880	1.227	
1995	1.029	0.038	1.001	1.150	1.016	0.096	0.848	1.224	0.954	0.083	0.805	1.129	
1996	0.995	0.025	0.933	1.029	1.405	0.133	1.154	1.674	1.364	0.127	1.129	1.627	
1997	0.972	0.042	0.840	1.004	1.297	0.135	1.043	1.571	1.290	0.124	1.070	1.557	
1998	0.996	0.030	0.923	1.041	1.032	0.101	0.850	1.247	1.001	0.096	0.831	1.206	
1999	0.966	0.066	0.762	1.022	0.826	0.119	0.602	1.070	0.826	0.104	0.643	1.050	
2000	0.990	0.036	0.892	1.032	0.801	0.079	0.657	0.967	0.781	0.071	0.658	0.936	
2001	0.996	0.038	0.911	1.061	0.968	0.083	0.817	1.143	0.939	0.077	0.803	1.104	
2002	0.957	0.057	0.776	1.001	0.772	0.079	0.607	0.917	0.779	0.062	0.665	0.908	
2003	0.960	0.058	0.775	1.002	0.642	0.062	0.511	0.754	0.646	0.046	0.563	0.745	
2004	1.036	0.046	1.001	1.181	0.651	0.057	0.556	0.778	0.607	0.043	0.528	0.695	
2005	0.977	0.040	0.853	1.012	0.625	0.052	0.518	0.724	0.618	0.042	0.538	0.701	
2006	0.987	0.039	0.877	1.029	0.718	0.063	0.594	0.839	0.703	0.051	0.609	0.809	
2007	1.007	0.040	0.941	1.100	0.833	0.073	0.698	0.986	0.799	0.067	0.678	0.939	
2008	1.033	0.050	0.998	1.193	0.854	0.084	0.708	1.039	0.798	0.067	0.674	0.938	
2009	1.006	0.030	0.956	1.074	1.029	0.100	0.846	1.239	0.988	0.093	0.818	1.184	
2010	1.006	0.027	0.957	1.061	1.093	0.102	0.904	1.306	1.050	0.093	0.876	1.242	
2011	0.990	0.030	0.909	1.025	1.201	0.124	0.974	1.459	1.171	0.114	0.963	1.408	
2012	1.012	0.038	0.961	1.109	1.134	0.119	0.917	1.383	1.082	0.107	0.895	1.313	
2013	1.027	0.044	0.992	1.166	0.976	0.106	0.793	1.208	0.918	0.091	0.750	1.106	
2014	1.013	0.029	0.976	1.090	0.968	0.106	0.778	1.194	0.923	0.097	0.747	1.127	
2015	1.004	0.032	0.940	1.065	0.850	0.083	0.704	1.029	0.818	0.075	0.685	0.978	
2016	1.025	0.034	0.997	1.132	0.777	0.076	0.644	0.941	0.733	0.068	0.613	0.879	
2017	1.021	0.041	0.970	1.131	1.174	0.126	0.945	1.440	1.111	0.115	0.897	1.347	
2018	1.022	0.041	0.990	1.150	1.001	0.117	0.795	1.252	0.946	0.105	0.757	1.170	
2019	1.042	0.058	1.002	1.231	1.139	0.143	0.889	1.448	1.057	0.122	0.834	1.312	
2020	1.034	0.053	0.996	1.202	2.506	0.382	1.857	3.356	2.343	0.333	1.773	3.079	
2021	-	-	-	-	-	-	-	-	-	3.142	1.306	1.342	6.463

5.13 CPUE comparisons: 2022 with 2019

5.13.1 Bottom Trawl

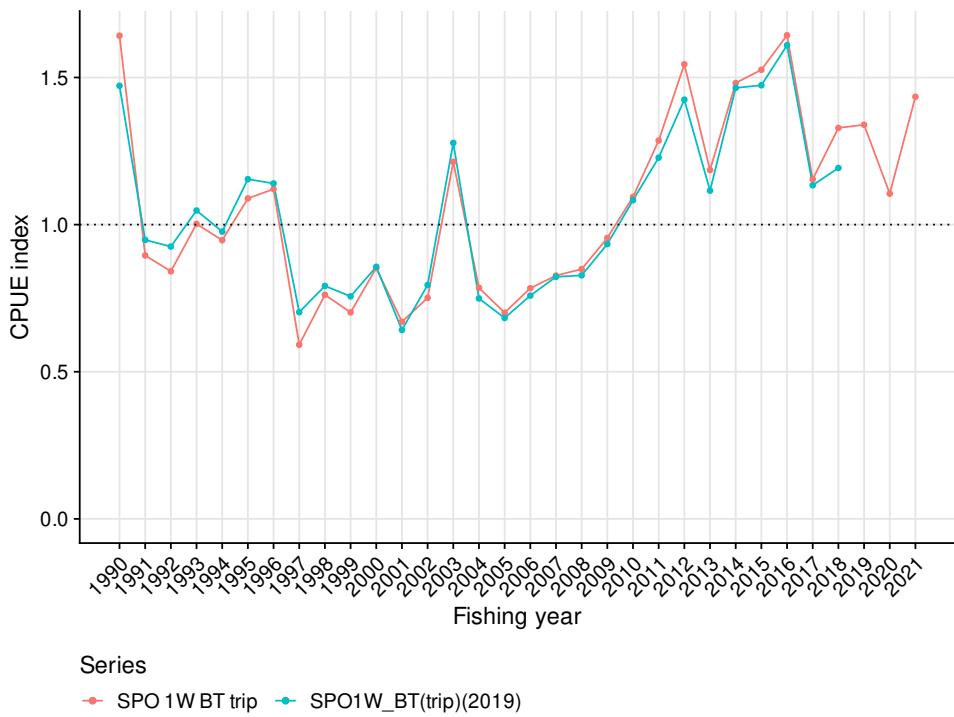


Figure 279: Compare the SPO 1W bottom trawl (trip) combined CPUE series to the equivalent series calculated in 2019.

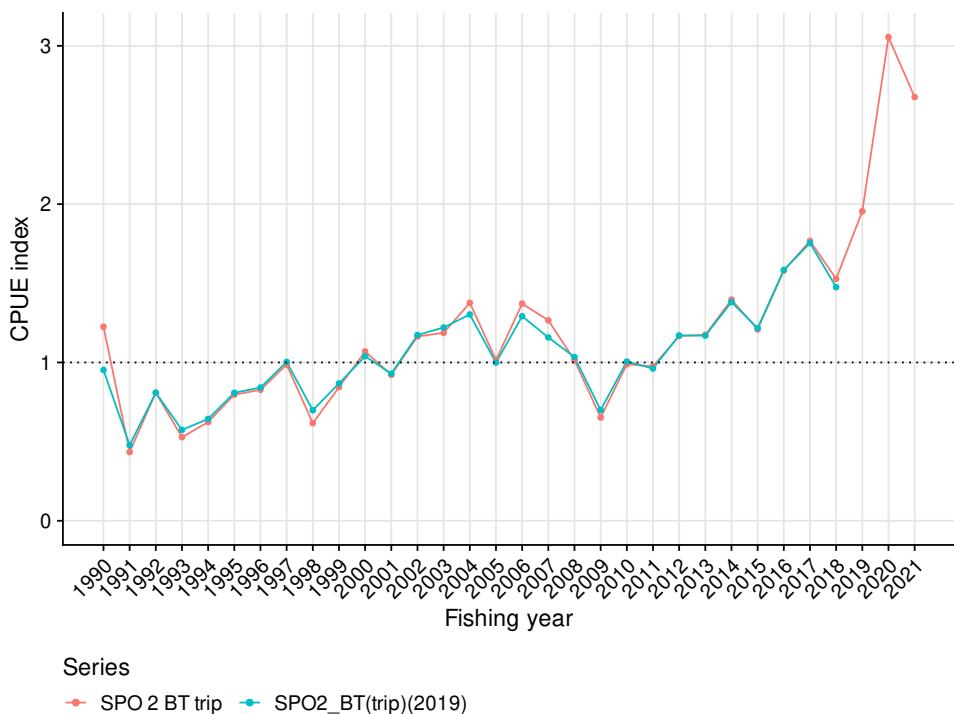


Figure 280: Compare the SPO 2 bottom trawl (trip) combined CPUE series to the equivalent series calculated in 2019.

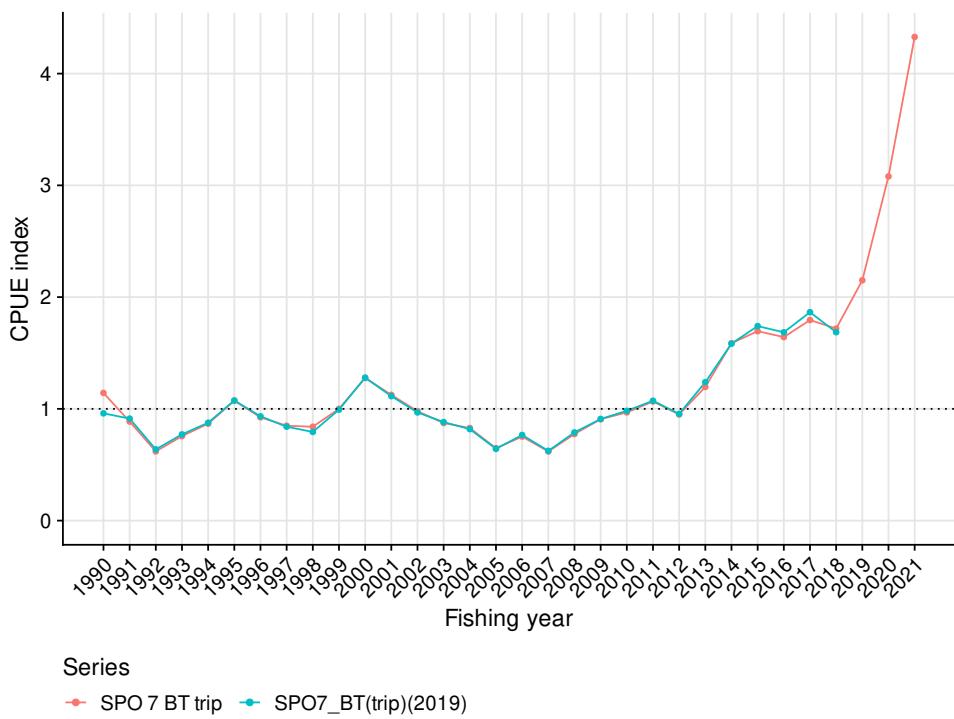


Figure 281: Compare the SPO 7 bottom trawl (trip) combined CPUE series to the equivalent series calculated in 2019.

5.13.2 Set net

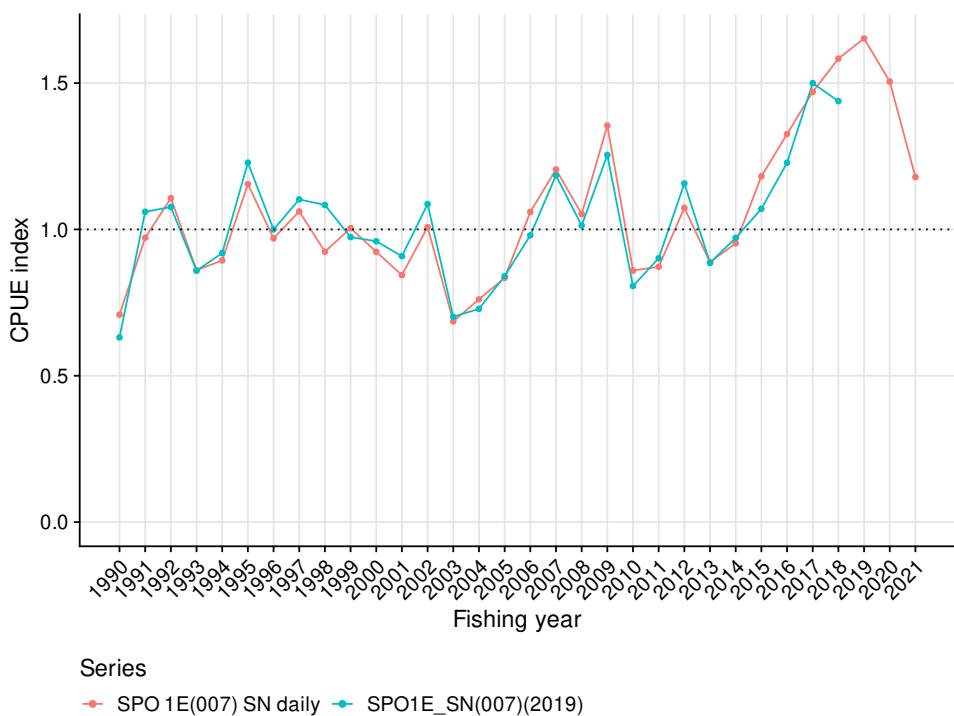


Figure 282: Compare the positive catch SPO 1E set net CPUE series for area 007 to the equivalent series calculated in 2019.

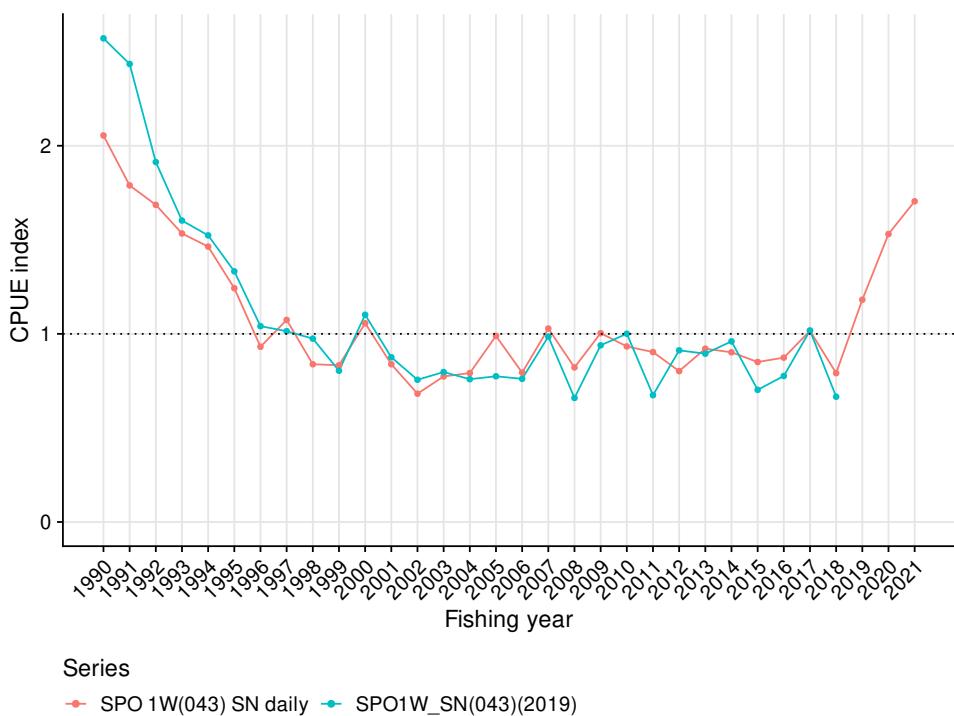


Figure 283: Compare the positive catch SPO 1W daily set net CPUE series for area 043 to the equivalent series calculated in 2019.

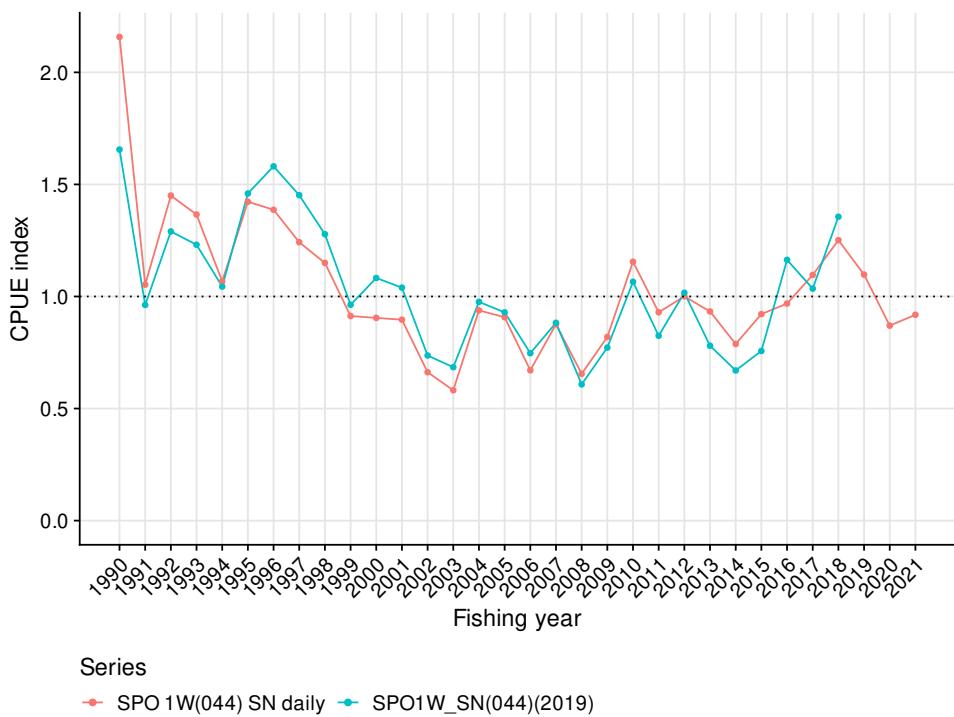


Figure 284: Compare the positive catch SPO 1W daily set net CPUE series for area 044 to the equivalent series calculated in 2019.

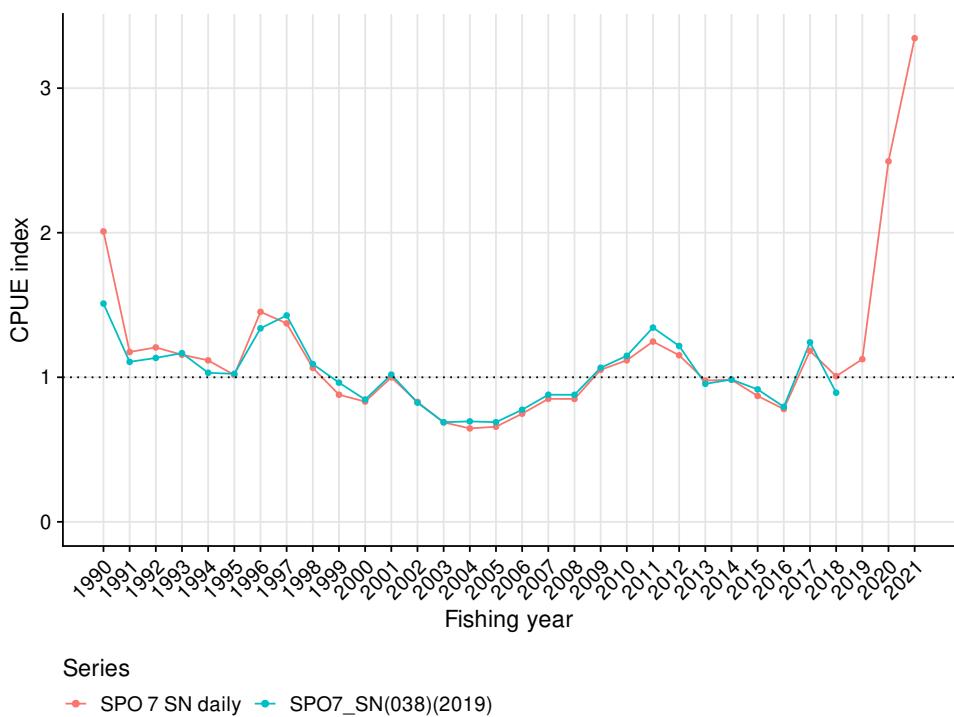


Figure 285: Compare the daily positive catch SPO 7 daily set net CPUE series to the equivalent series calculated in 2019. The 2021 index value is based on a single vessel.

6. DISCUSSION

6.1 SPO 1

In 2016, standardised CPUE indices were calculated for five SPO 1 set net fisheries by modelling (GLM) non-zero catches by core vessels targeting rig and other shark species (Starr & Kendrick 2017). As well, two coastal bottom trawl fisheries targeting a range of species were analysed by combining a non-zero catch series with a binomial presence/absence series. The SPO 1 set net analyses were complicated by the fact that up to 50% of the set net landings were accumulated ashore using intermediate destination codes for subsequent landing to a Licensed Fish Receiver, thus breaking the link between effort and landing within a trip. Estimated catches are unreliable in rig fisheries because many fishers report the processed weight rather than the equivalent green weight. This problem was solved by applying a “vessel correction factor” (*vcf*), calculated for each vessel and year, to correct the estimated catch observations (see Section 5.1).

6.1.1 SPO 1E

Three CPUE analyses for SPO 1E were presented to the Working Group in 2016: a) a target shark (NSD, SPO, SHK, SPD) set net fishery operating in the Firth of Thames (Statistical Area 007) [SN(007)]; b) a target shark set net fishery operating in the remaining SPO 1E Statistical Areas (002 to 006 and 008 to 010) [SN(coast)]; and c) a mixed target species (SNA, TRE, GUR, JDO, BAR, TAR) bottom trawl fishery operating in all SPO 1E Statistical Areas (002 to 010) [BT(coast)].

The Southern Inshore Working Group (SINSGW) and Plenary gave the SN(007) series a research rating of ‘2’ because, although this fishery targeted mature female rig and the diagnostics were considered credible, it provided an index of abundance for only a portion of the total area. The Plenary gave the BT(coast) and SN(coast) series research ratings of ‘3’ because annual catches were unacceptably low and, in the case of the set net index, the fishing locations were widely dispersed and occupied sporadically. The latter two series were not updated in 2019 (Starr & Kendrick 2020) or in this report because of their low research rating. The SN(007) analysis was updated, showing a relatively strong upturn from 2013 to 2019, followed by a decline in 2020 and 2021 analysis (Figure 282).

6.1.2 SPO 1W

In 2016, four CPUE analyses for SPO 1W were presented to the Working Group: a) a target shark (NSD, SPO, SHK, SPD) set net fishery operating in Manukau Harbour (Statistical Area 043) [SN(043)]; b) a target shark set net fishery operating in Kaipara Harbour (Statistical Area 044) [SN(044)]; c) a target shark set net fishery operating in all the remaining SPO 1W Statistical Areas (042, 045–048) plus the most northerly SPO 8 Statistical Area (041) [SN(41–47)]; and d) a mixed target species (SNA, TRE, GUR, JDO, BAR, TAR) bottom trawl fishery operating in all SPO 1W Statistical Areas (042, 045–048) [BT(coast)] outside the two harbours plus the most northerly SPO 8 Statistical Area (041).

The 2016 Plenary assigned the BT index a quality ranking of ‘1’, but noted that, although the analysis was credible, the method of capture did not representatively sample large female rig. The two harbour-based set net indices were given a ranking of ‘2’ (medium or mixed quality) because they were likely indexing localised abundance. The Plenary rejected the coastal set net index as an index of abundance on account of the considerable impact the dolphin closures have had on this fishery.

The coastal set net index series was not updated in 2019 (Starr & Kendrick 2020) or in this report because of its rejection in 2016 and the implementation of additional closures in 2020 (see Section 2.2). The other three series were updated for this report. The coastal BT series showed a slow increasing trend since the mid-2000s to about 2012, although the 2016–17 and 2017–18 indices appeared to have dropped relative to 2015–16, followed by a period of relative stability extending to 2021 (Figure 106).

An event based (tow-by-tow) standardised analysis was also produced (Appendix D.1) as a diagnostic to test whether amalgamating the data to the level of a complete trip was introducing bias. This analysis determined that this series agreed acceptably well in the overlapping years (Figure D.156). The SN(043 Manukau Harbour) series showed a strong decline in the early part of the series (Figure 205) while the SN(044 Kaipara Harbour) series declined only in the first one or two years (Figure 217). Both set net indices showed a slowly declining trend into the early 2000s, followed by a period of relative stability (Figure 286). The series diverge a bit at the end, with the Manukau series trending upward beginning in 2019 while the Kaipara series dropped to near the series mean. Figure 286 also shows that the indices from west coast North Island survey are broadly consistent with the three SPO 1W CPUE series.

6.2 SPO 2

As done in 2016 (Starr & Kendrick 2017) and 2019 (Starr & Kendrick 2020), a trip-based bottom trawl series was used to index SPO 2 relative abundance from 1989–90 to 2020–21. The corresponding set net analysis was not repeated due to the small amount of available data. The SPO 2 landings data, regardless of the method of capture, did not exhibit the behaviour observed in SPO 1 of landing to temporary holding receptacles. A trip-based SPO 2 (BT) analysis was conducted for this report, selecting trips that fished exclusively in the Statistical Areas 011–015 and targeted flatfish, gurnard, or tarakihi (Section 5.3).

The trip-based combined SPO 2 series constructed from bottom trawl data showed a gradually increasing trend from 1989–90 to 2011–12, after which the series showed an increasing trend to the end of the series (Figure 280). There was some year-to-year variability beginning around 2014, but the overall trajectory appeared to be upward. The Plenary gave the BT(trip) series an overall assessment quality rank of ‘1’ but noted that, although the analysis was credible, the method of capture did not representatively sample large female rig. An event based (tow-by-tow) standardised analysis was also produced (Appendix D.2) as a diagnostic to test whether amalgamating the data to the level of a complete trip was introducing bias. This analysis determined that this series agreed in the overlapping years except for the final two years (2020 and 2021) where the event-based series did not increase as much as the trip-based series (Figure D.157).

6.3 SPO 3

Two CPUE standardisations were accepted by the Working Group in 2016 (Starr & Kendrick 2017), one based on a target shark set net fishery (SN[SHK]) and the other based on a mixed target species (flatfish, barracouta, red cod, tarakihi, stargazer, spiny dogfish, and rig) bottom trawl fishery (BT[All]). Two bottom trawl series had previously been constructed from the bottom trawl data, separating the target flatfish data from other target species that are taken at deeper depths. However, the switch to a trip-based analysis showed that the two SPO 3 bottom trawl fisheries (FLA and MIX) had very similar CPUE trends for rig. The SINSWG agreed that it would be advisable to perform a single analysis on the full suite of bottom trawl target species, amalgamated at the level of a trip. The final two fisheries (set net and trawl) have different selectivities, harvesting a different size range of rig, with the set net fishery taking larger fish and the trawl fishery taking juveniles and sub-adults.

Although the 2019 SPO review (Starr & Kendrick 2020) accepted the BT(All) and SN(SHK) analyses, the INSWG requested in 2022 to split the SPO 3 QMA into two parts: a) east coast, incorporating Statistical Areas 018 (Kaikoura/Motunau), 020 (Pegasus Bay), 022 (Canterbury Bight), 024 (Timaru) and 026 (Catlins) and b) Foveaux Strait, incorporating Statistical Areas 025 (eastern Foveaux St), 027 (south east side Stewart Island), 028 (south end Stewart Island), 029 (west side Stewart Island), 030 (western Foveaux Strait), and 031/032 (Fiordland). This decision was prompted by the diagnostics from the full SPO 3 SN (daily) model, with the implied residuals showing poor correlations for most of the statistical areas compared to the overall annual model trend (Figure D.133). The same was true for the SCH and SPO target species (Figure D.132), again showing low correlation with the overall annual model trend. Implied residual correlations between statistical areas and target species with the overall

model annual trend were much better for the SPO 3 BT (trip) model (Figure D.54). However, there were several anomalies which suggested that a split region model should be explored for this series as well.

The split SPO 3 BT east coast (trip) and the SPO 3 BT Foveaux St (trip) models showed implied residual correlations for all statistical areas that were similar to the full SPO 3 BT (trip) model, except for Statistical Area 025, which was improved under the split SPO 3 BT Foveaux St (trip) model (Figure 160). Similarly, the two split SPO 3 BT models and the full SPO 3 BT model had similar implied target species residuals, except for STA target, which again were better under the SPO 3 BT Foveaux St model because the majority of STA targeting was in the more southerly statistical areas (Figure 159). Figure 287 shows that the SPO 3 BT east coast (trip) model closely resembles the full SPO 3 BT (trip) model while the SPO 3 BT Foveaux St (trip) model is more variable (likely due to limited data for this model) but still provides good correspondence with the SPO 3 BT east coast (trip) model.

The implied residual comparisons were more problematic for the SPO 3 SN (daily) model, with none of the statistical areas in the full model showing strong correlations with the overall model annual trend (Figure D.133). Although the statistical area implied residual correlations were weaker for the SPO 3 SN split models than for the corresponding split SPO 3 BT models, they were better in the two spatially split models than in the full SPO 3 SN model (Figure 235 and Figure 256). The INSWG accepted the two spatially split SPO 3 SN models over the full SPO 3 SN model, reasoning that the relatively poor implied residual statistical area correlations in these models were likely evidence that there is spatial heterogeneity among mature rig in SPO 3 at a finer scale than the QMA. As for the target species implied residuals in the spatially split SPO 3 SN models, the correlation was considerably improved for SPO (the dominant target species) in the SPO 3 SN east coast model (Figure 234) while the SCH (again the dominant target species) correlation was much better in the SPO 3 SN Foveaux St model (Figure 255). As seen for the SPO 3 BT models, all three of the SPO 3 SN models resembled each other, with the SPO 3 SN east coast model (which has the majority of the data) closer to the full SPO 3 SN model while the SPO 3 SN Foveaux St model was more variable than the other two models (Figure 288). The three SN models had similar relative levels in 2020 and 2021 even though they had different intermediate trajectories.

The SPO 3 landing data, regardless of the method of capture, did not exhibit the behaviour observed in SPO 1 of landing to temporary holding receptacles.

6.3.1 SPO 3 east coast

The SPO 3 BT east coast (trip) series showed an increasing trend from 1989–90 to 2016–17, after which the trend accelerated, more than doubling the relative CPUE between 2018 and 2021 (Figure 289). The SPO 3 SN east coast (daily) series fluctuated without trend over the same period (Figure 289). The point estimates for rig from the East Coast South Island (ECSI) winter trawl survey all strata (10–400 m) largely followed the pattern of the SPO 3 BT east coast (trip) series, except for the 2007 observation which did not match the equivalent SPO 3 BT east coast (trip) index very well. The 2021 ECSI trawl survey index value mirrors the large increase for the same year in the SPO 3 BT east coast series. Unfortunately, the associated CV for this index value (63%) was so large that this index must be considered unreliable.

By combining length frequency (LF) distributions across years to overcome small sample sizes, Figure 290 shows there were substantial differences in the mean LF distributions between the ECSI trawl survey, the SPO 3 BT east coast fishery, and the SPO 3 SN east coast fishery, with the set net LF distributions lying to the right of the bottom trawl LF distributions which are again to the right of the survey LF distributions. There is also a suggestion that the female set net LF distributions lay to the right of the equivalent male SN LF distributions while the corresponding bottom trawl and survey LF distributions are reasonably similar between the two sexes.

6.3.2 SPO 3 Foveaux Strait

The SPO 3 BT Foveaux St (trip) series showed a slow increasing trend from 1989–90 to 2013–14, after which the trend accelerated, doubling the relative CPUE between 2015 and 2021 (Figure 291). The SPO 3 SN Foveaux St (daily) series showed a slowly increasing trend over the same period (Figure 291). This difference in trends may be due to the different nature of the fisheries, with the set net fishery being primarily composed of the bycatch of rig while targeting school shark while the bottom trawl fishery is a mix of target flatfish and target stargazer fishing. It is likely that the set net fishery is capturing mature rig while the set net fishery will be taking immature and sub-adult rig.

By combining length distributions across years to overcome small sample sizes, Figure 292 shows there were substantial differences in the mean length frequency (LF) distributions between the SPO 3 BT Foveaux Strait fishery and the SPO 3 SN Foveaux Strait fishery, with the set net LF distributions lying to the right of the bottom trawl LF distributions. There is also a suggestion that the female LF distributions lie to the right of the equivalent male LF distributions for AMP SN and BT as well as the observer BT distributions.

6.3.3 SPO 3 BT series

Although the SPO 3 BT series was superseded by the spatially split east coast and Foveaux Strait series, an event-based series was developed as a diagnostic for this larger series for comparison with the equivalent trip-based series. This comparison indicated that the two series agreed in the overlapping years except for the final two years (2020 and 2021) where the event-based series increased more than the trip-based series (Figure D.160).

6.4 SPO 7

Two SPO 7 CPUE standardisations have been accepted by the Working Group: 1) a set net fishery in Statistical Area 038 targeting rig, spiny dogfish, and school shark [SN(038)]; and 2) a bottom trawl fishery in Statistical Areas 016–018, 032–037, 038, 039, and 040 targeting flatfish, red cod, rig, barracouta, tarakihi, red gurnard, snapper, common warehou, and trevally [BT(ALL)]. An analysis of the set net fishery in Statistical Areas 032–037 was rejected by the SINSWG in 2016 (after being accepted in the 2006–2013 analyses) because of lack of sufficient data to create a reliable index (Starr & Kendrick 2017). This lack was attributed to the movement of ACE to other SPO 7 fisheries and to the management regulations imposed to protect Hector's dolphins. Examination of the distribution of set net effort off the west coast of the South Island showed that there had been a substantial decline in the number of vessels operating in these statistical areas since 2005–06, with less than 2% of the set net fishery catches originating from statistical areas other than 038 during 2015–16 to 2017–18. In 2016, an alternative set net fishery analysis was trialled (SN[STB]), covering the South Taranaki Bight Statistical Areas (037, 039, and 040) (Starr & Kendrick 2017). This was done after examining the fine scale spatial distribution of catches in these three statistical areas, showing that most of the catch came from the coastal section of South Taranaki Bight. This analysis also showed there was catch in Statistical Area 037 on the line separating Statistical Areas 037 and 038 (between D'Urville Island and Farewell Spit) which may belong more logically to the Statistical Area 038 analysis. However, spatial data at this level of detail were not available before October 2007 from the earlier daily forms. The SN(STB) series was rejected by the 2016 Plenary (quality ranking of '3') on account of the impact the dolphin closures have had on this fishery.

The SPO 7 landings data, regardless of the method of capture, did not exhibit the behaviour of landing to temporary holding receptacles observed in SPO 1.

The SN(038) index, which was assigned a quality ranking of '1' in 2019 (Starr & Kendrick 2020), showed a continuous declining trend from the beginning of the series to a low in the mid-2000s, approximately

coincident with the lowering of the SPO 7 TACC. This low point was followed by an increasing trend to a peak in 2010–11, after which the series varied about the series mean up to 2018–19 when it trebled over the next two years (Figure 293). However, the interpretation of these increases is unreliable, given that only two vessels participated in this fishery in 2019–20, falling to a single vessel in 2020–21. It is now likely this series will have to be abandoned due to lack of data.

The BT(ALL) series (with a quality ranking of ‘1’) showed an increasing trend since the mid-2000s, with low points observed in both 2004–05 and 2006–07, but has since shown a generally increasing trend, which, like the two SPO 3 BT series, has accelerated in 2019–20 and 2020–21 to three and four times the longterm average index. The Plenary noted that the BT(ALL) index does not adequately sample large female rig. Event-based (tow-by-tow) standardised analyses were undertaken in both 2019 and 2022 as diagnostics to test whether amalgamating the data to the level of a complete trip was introducing bias. These analyses determined that the series agreed well in the overlapping years (Figure D.161).

Although large rig are not effectively targeted with bottom trawl gear, the WCSI trawl survey is believed to provide reliable indices of the relative biomass of adult males and younger females in SPO 7. Relative biomass declined by more than 50% between 1995 and 2005, and subsequently increased to a stable level from 2007 to 2013. It then increased sharply in 2015, with total biomass remaining high in the 2017 survey, but then dropping relative to the 2015 index in 2019 and even more in 2021 (Figure 293). The 2021 WCSI rig biomass index contradicts the strong increase in CPUE observed in the BT(ALL) series.

By combining length frequency (LF) distributions across years to overcome small sample sizes, Figure 294 shows there were substantial differences in the mean LF distributions between the WCSI trawl survey, the SPO 7 BT fishery, and the SPO 7 SN fishery, with the female set net LF distributions lying to the right of the bottom trawl LF distributions (AMP and observer) which are again to the right of the survey LF distributions. However, the male LF distributions from both the SN and BT fisheries are very similar while the survey distribution lies to the left of the commercial fishery LFs.

6.5 Summary

Four of the five BT fisheries show similar strong increasing trends in recent years, with only the SPO 1W BT(trip) series remaining steady, but above the series mean, from the early 2010s. The SN fisheries have a mixed response, with the SPO 1W(043) SN and SPO 7(038) SN fisheries showing strong recent increases while the SPO 1E(007) SN and SPO 3 SN East Coast fisheries showed a strong increase in 2020 but fell back to just above the series mean in 2021. The remaining two SN fisheries (SPO 3 SN Foveaux Strait and SPO 1W(044) SN) showed a more complex response over the most recent three years, with the Foveaux Strait SN series holding steady or possibly increasing at a level above the series mean while the 1W(044)SN series dropped to a level near the series mean. The increasing trends in the BT fisheries are interpreted as indicating good recruitment, an observation that seems to be corroborated by the east coast South Island trawl survey but not by the two west coast surveys. Although the SN fisheries give a mixed signal, none show signs of long-term population decline. These contradictory signals are difficult to reconcile and suggest that the fisheries that capture this species need to continue to be closely monitored.

6.6 Discussion Plots

6.6.1 SPO 1W

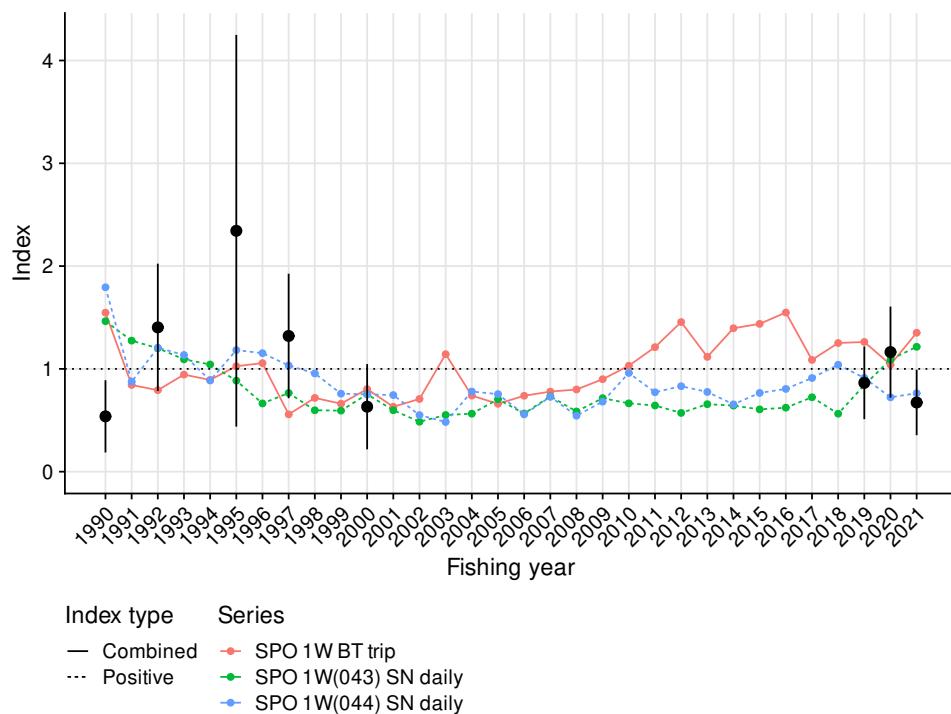


Figure 286: Comparison of standardised CPUE for SPO 1W in three fisheries: a) target shark set net in Manukau Harbour (Statistical Area 043) [SN(043)]; b) target shark set net in Kaipara Harbour (Statistical Area 044) [SN(044)]; c) coastal bottom trawl north of Cape Egmont [BT(041-047)]. Also shown are the WCNI trawl survey core 10–100 m biomass indices (black circles) offset by one year to match the fishing year definition. Error bars are ± 2 standard errors.

6.6.2 SPO 3

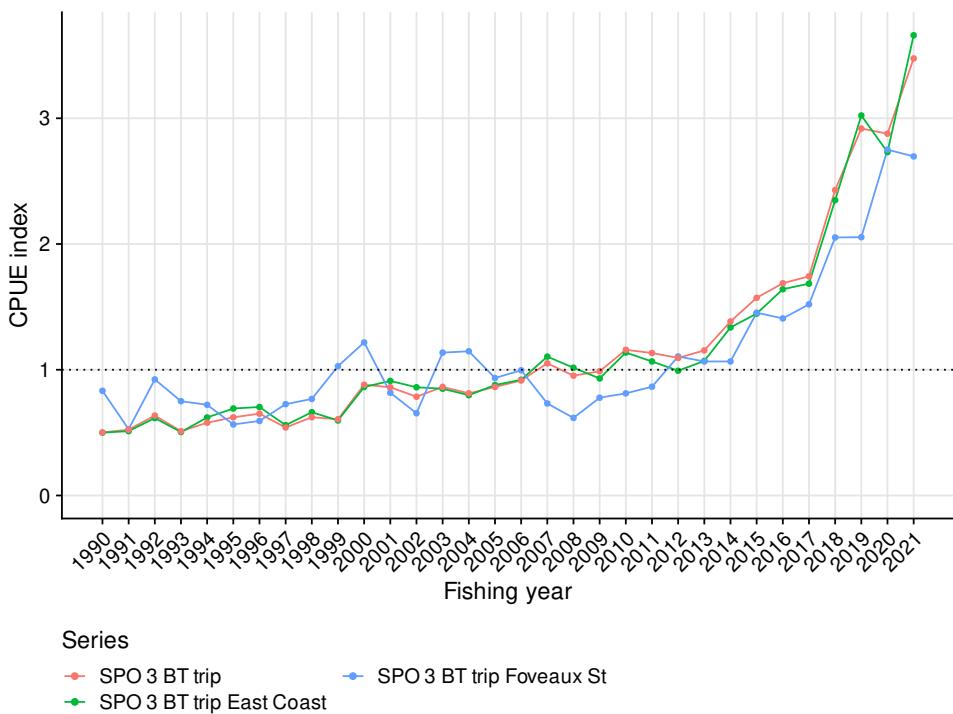


Figure 287: Compare the SPO 3 bottom trawl combined CPUE series: both regions combined with the regions analysed separately.

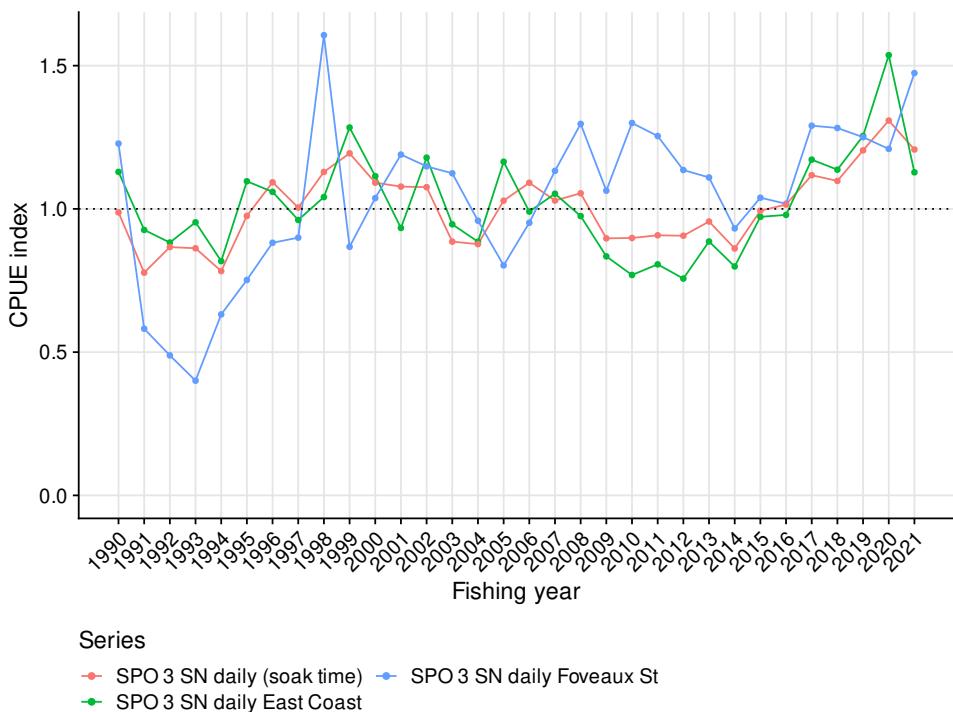


Figure 288: Comparing the SPO 3 set net combined CPUE series: both regions combined with the regions analysed separately.

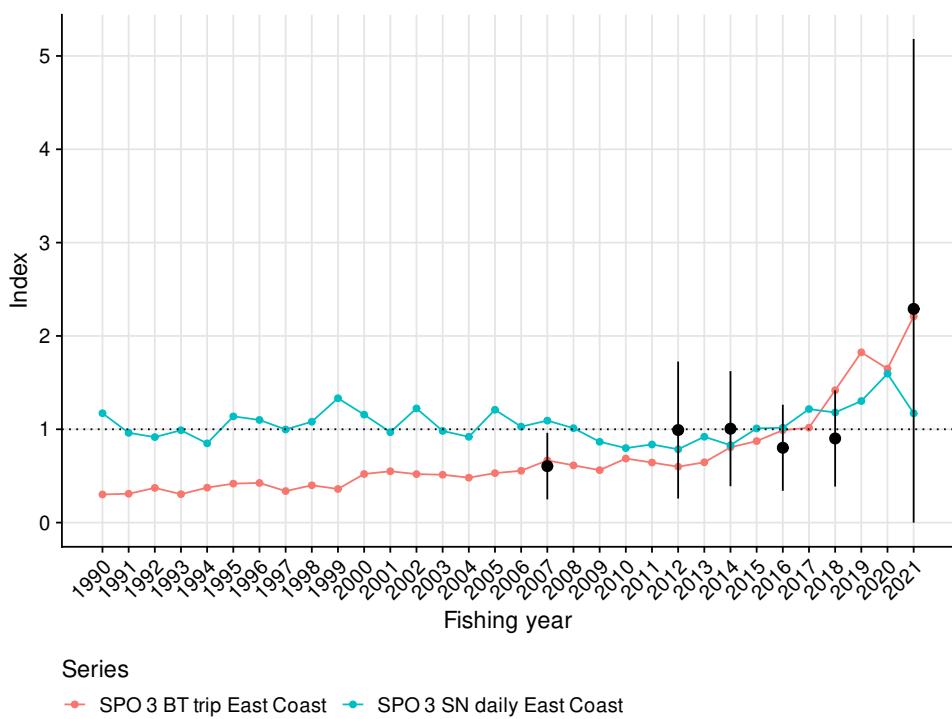


Figure 289: Comparison of two SPO 3 east coast (Statistical Areas 018, 020, 022, 024, and 026) standardised CPUE series: a) bottom trawl fishery (mix of targets in SPO 3 east coast statistical areas) [BT(018-024&026)]; b) shark target set net fishery [SN(018-024&026)]. Also shown are rig index values from the east coast South Island (ECSI) trawl survey (all strata, 10–400 m - black circles): 2007, 2012, 2014, 2016, 2018, and 2021, with error bars ± 2 standard errors.

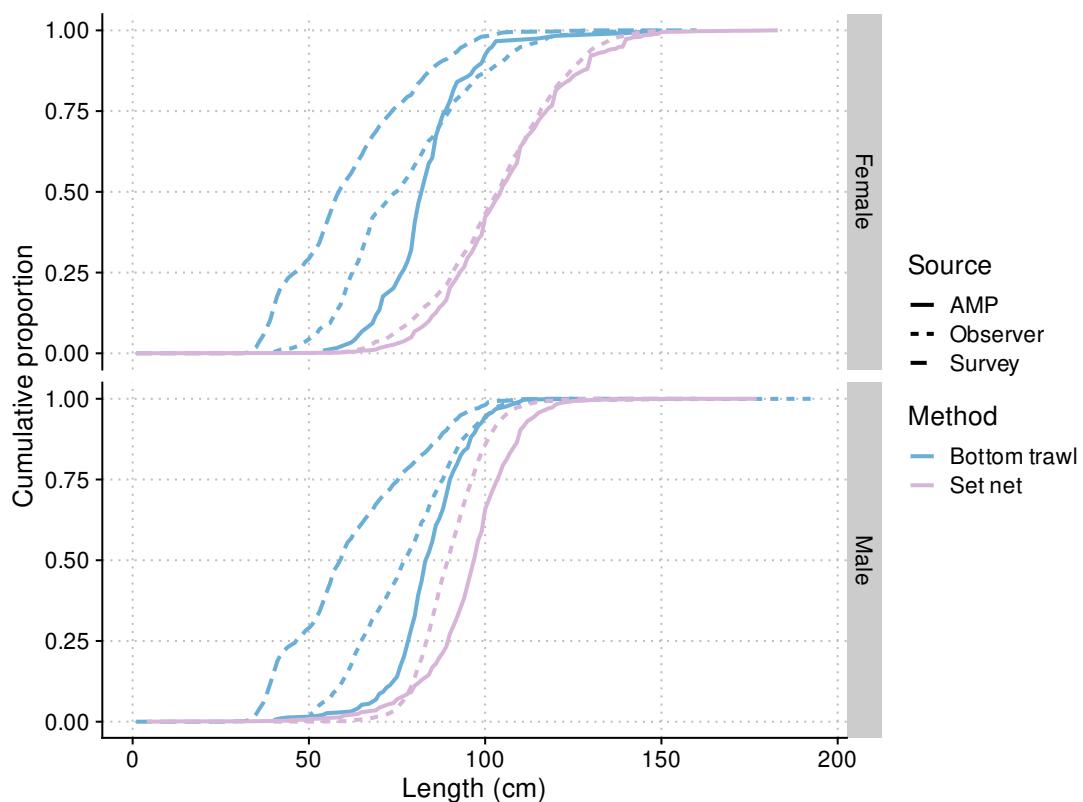


Figure 290: Empirical cumulative length frequency for male and female rig from ECSI trawl surveys (2007, 2012, 2014, 2016, 2018, 2021; 10–400 m strata), and observer sampling and AMP data from Statistical Areas 018–024 and 026. The AMP data were collected in the 1995–2008 fishing years and the observer data in the 2008, 2010–2021 fishing years.

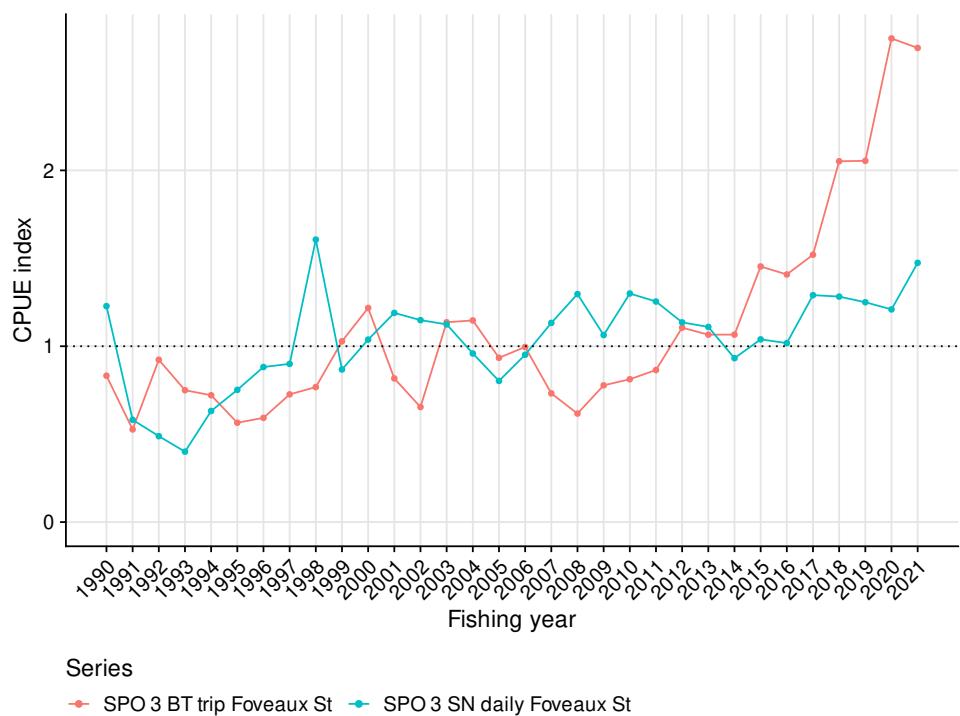


Figure 291: Comparison of two SPO 3 Foveaux Strait (Statistical Areas 025, 027, 028, 029, 030, 031, and 032) standardised CPUE series: a) bottom trawl fishery (mix of targets in SPO 3 Foveaux St statistical areas) [BT(025&027–032)]; b) shark target set net fishery [SN(025&027–032)].

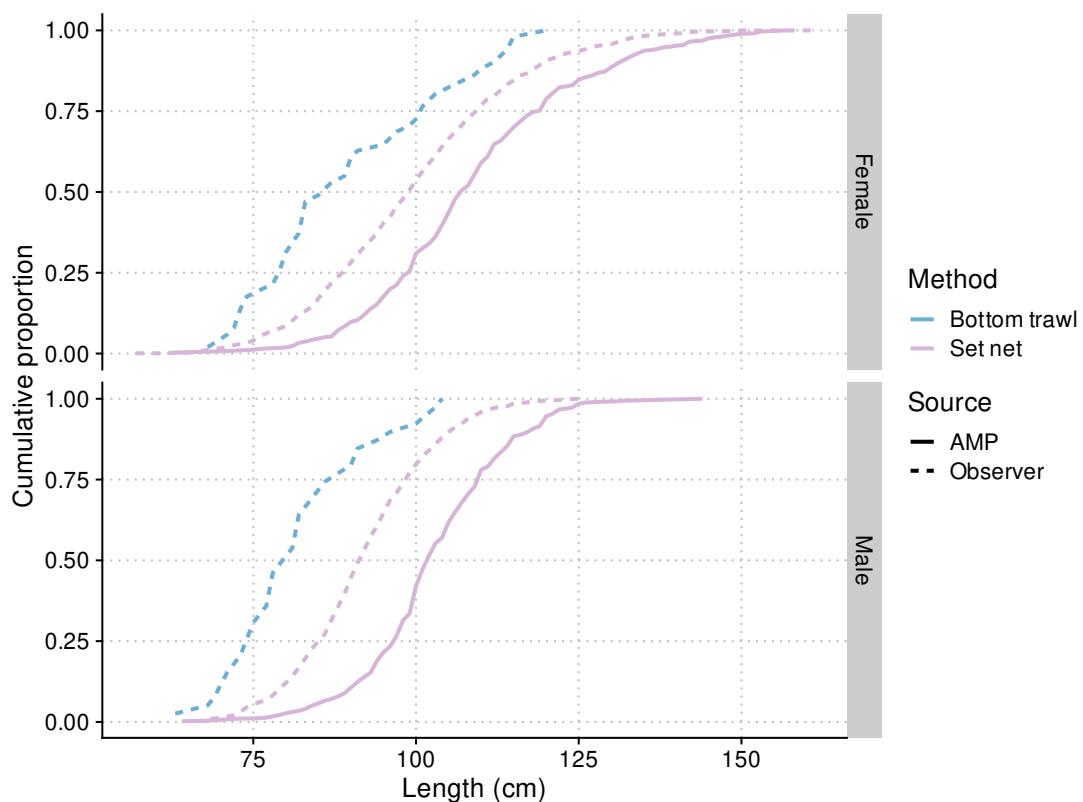


Figure 292: Empirical cumulative length frequency for male and female rig from observer sampling and AMP data from Statistical Areas 025 and 027–031. The AMP data were collected in the 1996, 1997, 1999–2001, 2004 fishing years and the observer data in the 2008, 2010, 2012, 2015–2021 fishing years.

6.6.3 SPO 7

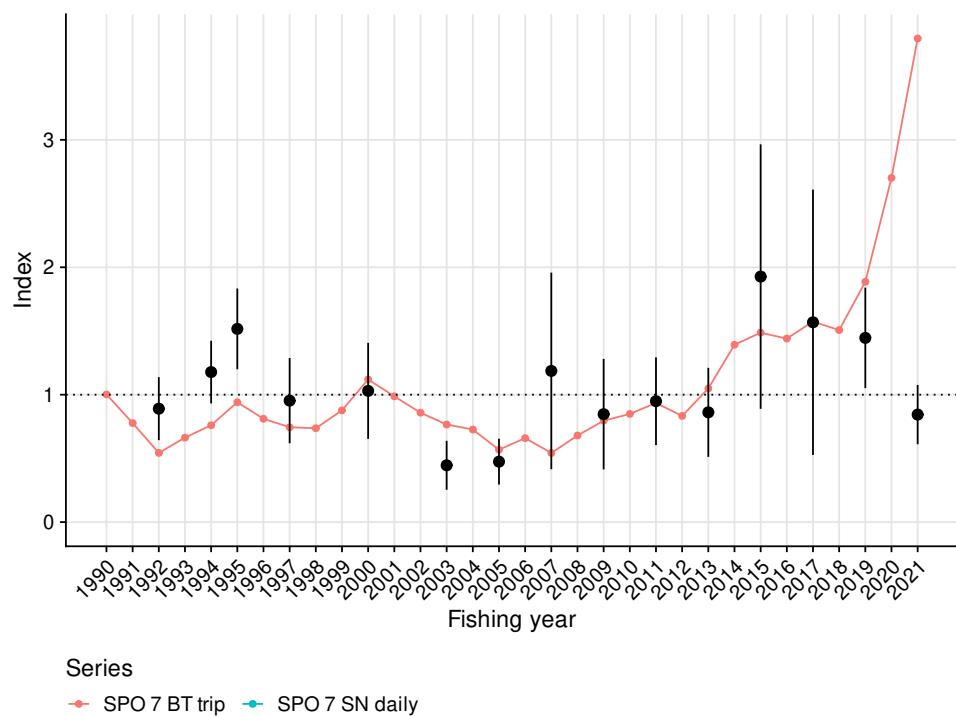


Figure 293: Comparison of two SPO 7 standardised CPUE series: a) bottom trawl fishery (mix of targets in all SPO 7) [BT(016-018&032-040)]; b) shark target set net fishery in Tasman Bay/Golden Bay [SN(038)]. Also shown are rig index values from the west coast South Island (WCSI) trawl survey: 1992–2021 (black circles). Error bars are ± 2 standard errors. The 2021 index value for the SN(038) analysis was dropped because it was based on a single vessel.

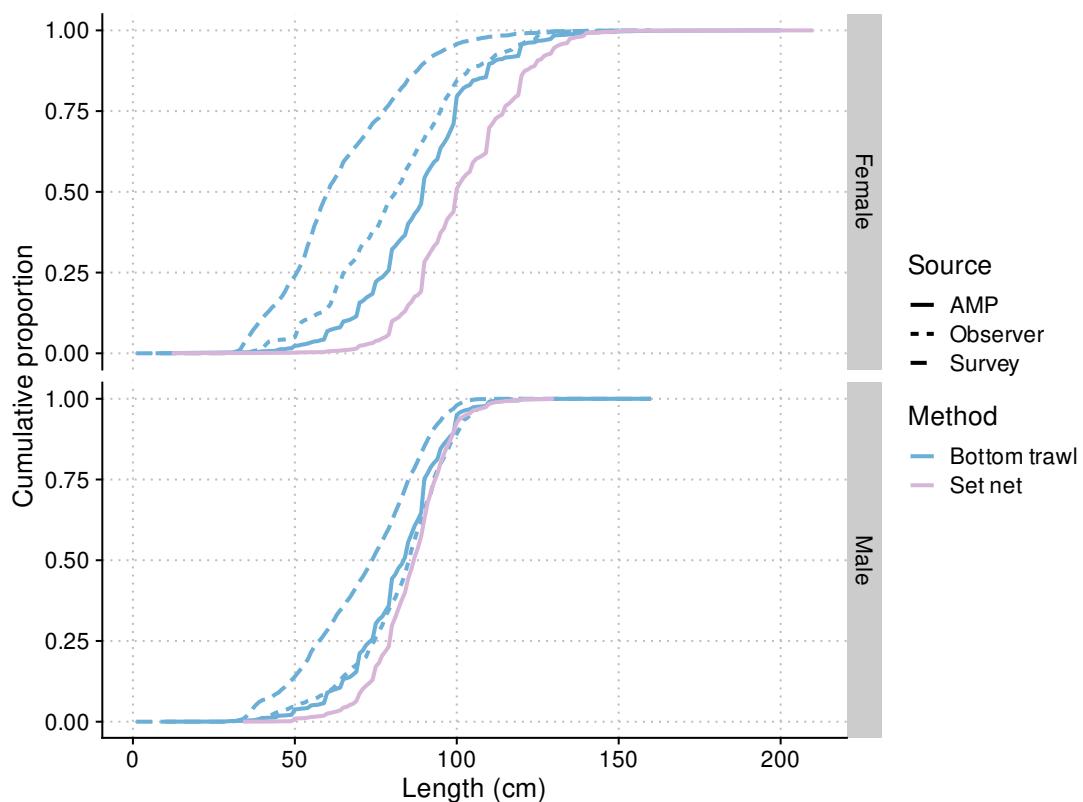


Figure 294: Empirical cumulative length frequency for male and female rig from WCSI trawl surveys (1992, 1994, 1995, 1997, 2000, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021; 10–400 m strata), and observer sampling and AMP data from Statistical Areas 032–038. The AMP data were collected in the 1996, 1997, 2001–2012, 2014 fishing years and the observer data in the 1995, 2005, 2010–2013, 2016, 2017 fishing years.

7. ACKNOWLEDGEMENTS

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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 proper 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 transhipments
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

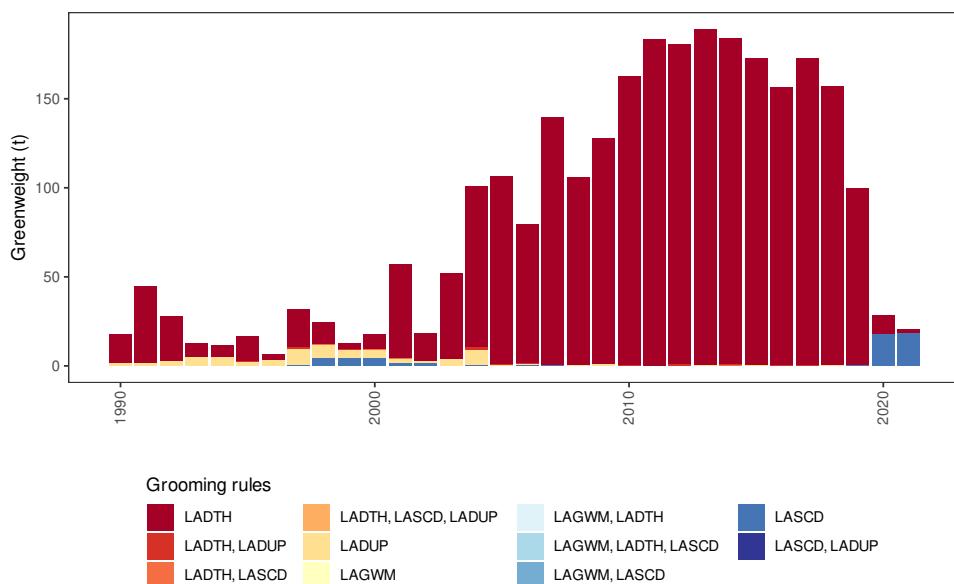


Figure A.1: The quantity of landings dropped, with the relevant grooming rules indicated.

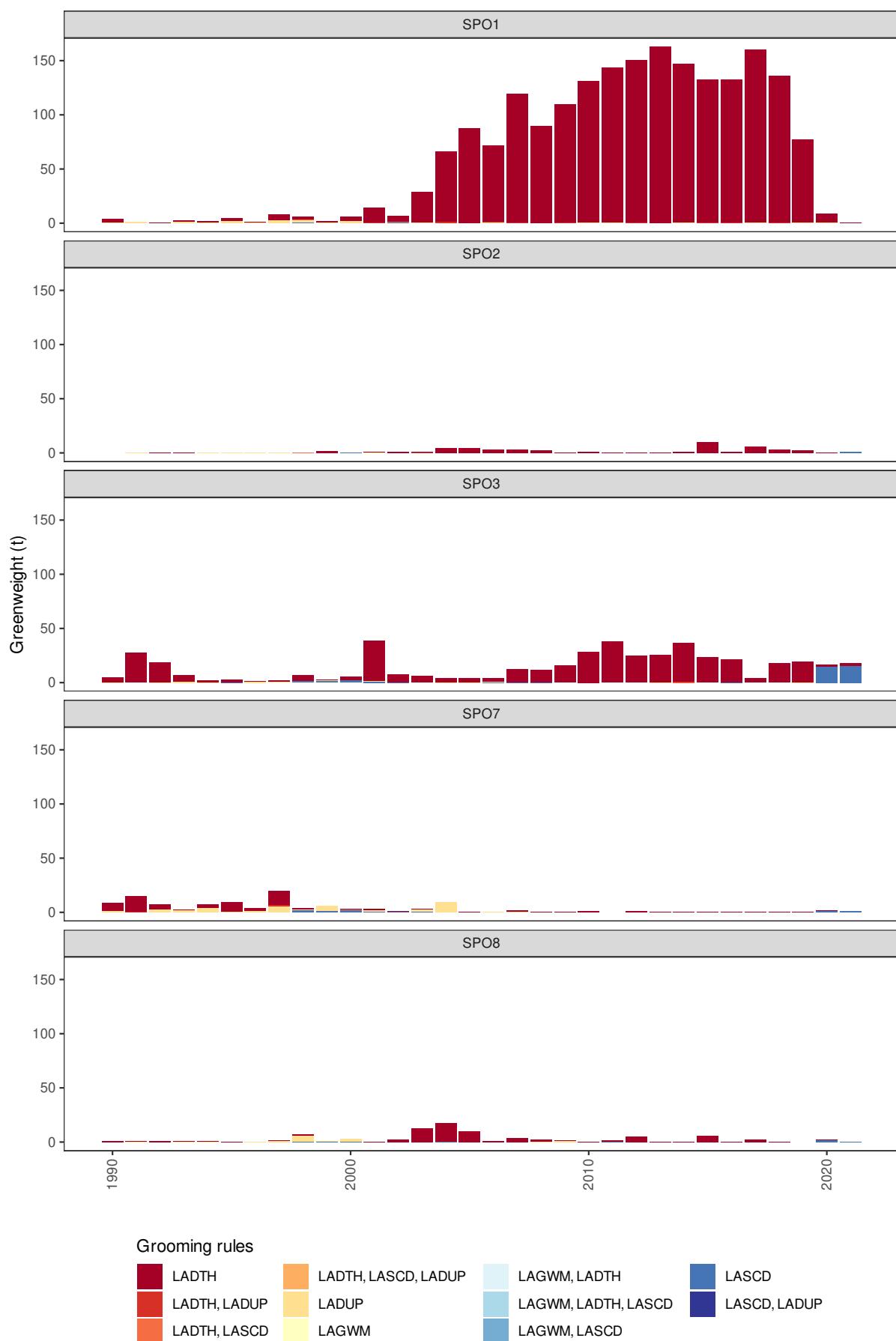


Figure A.2: The quantity of landings dropped, with the relevant grooming rules indicated, by QMA.

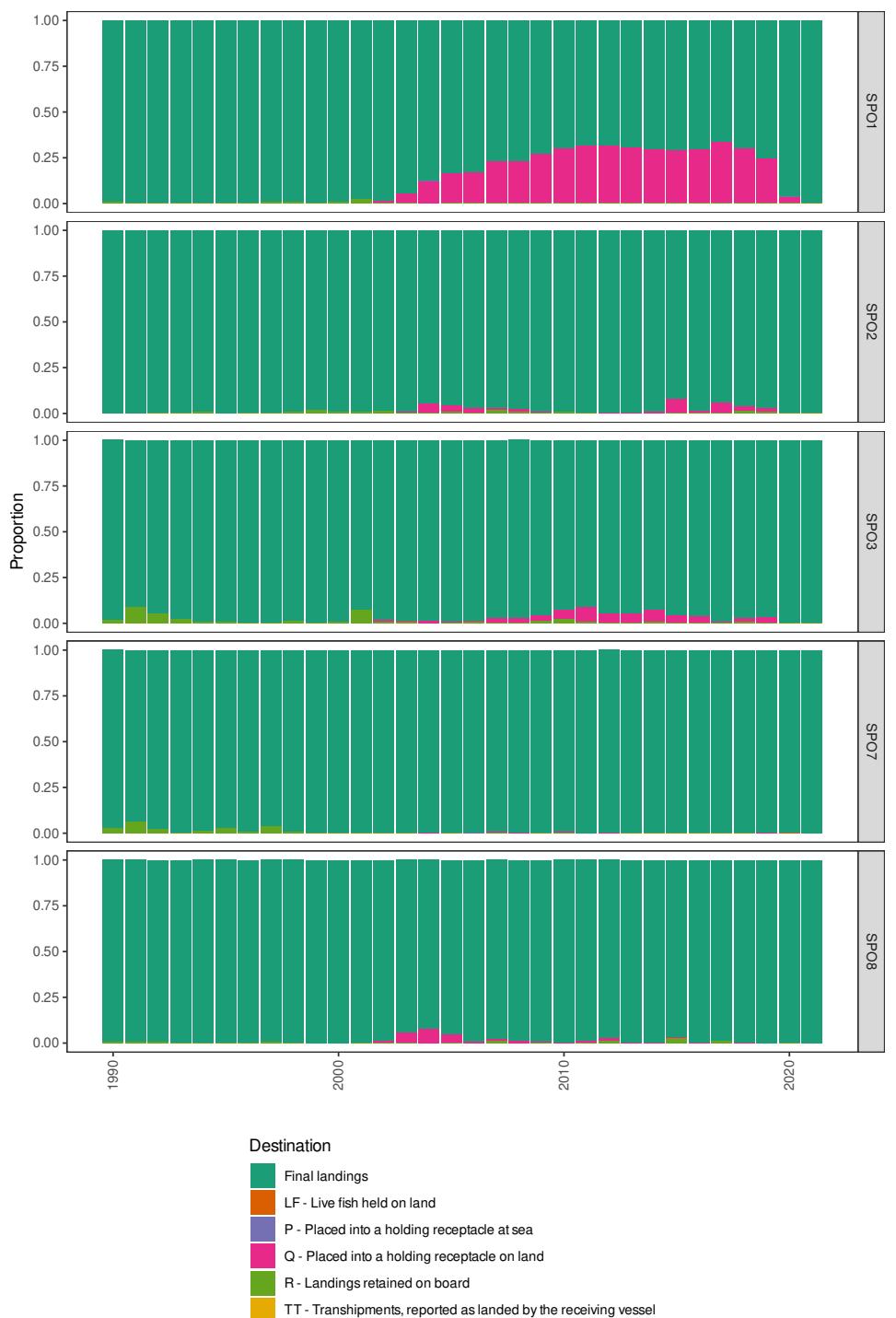


Figure A.3: The proportion of total (final and non-final) landings that are initially to non-final destinations, by stock and fishing year.

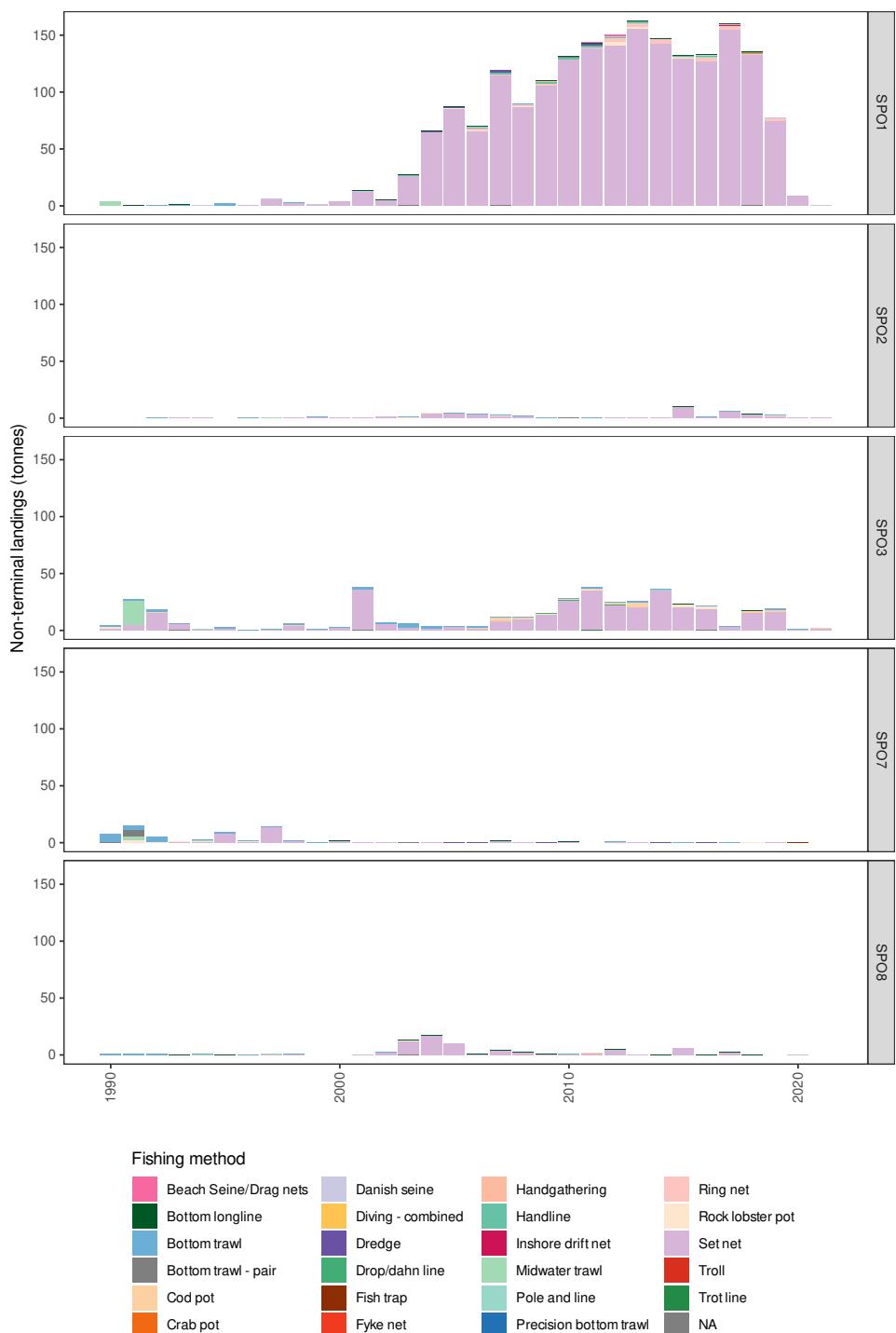


Figure A.4: The quantity of non-final landings, by stock, fishing year, and the modal fishing method used on the trip.

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
SPO1	1990	1	3 152.00	3.15200
SPO1	1991	1	312 199.00	31.21990
SPO1	1992	1	818.00	6.33950
SPO1	1993	1	2 398.00	21.23943
SPO1	1995	2	6 550.00	16.95400
SPO1	1997	2	3 187.00	28.22771
SPO1	1998	2	26 880.00	238.08000
SPO1	2004	1	9 514.60	95.14600
SPO1	2005	1	1 445.00	14.45000
SPO1	2006	1	1 465.00	14.65000
SPO1	2007	1	2 164.00	21.64000
SPO1	2008	2	8 315.00	83.15000
SPO1	2009	1	1 237.00	12.37000
SPO1	2011	2	1 791.00	17.91000
SPO1	2016	1	665.00	6.65000
SPO1	2017	1	1 062.00	10.62000
SPO1	2020	1	824.43	8.24430
SPO1	2021	1	167.00	1.67000
SPO2	1996	4	15 141.75	137.94350
SPO2	1998	1	14 200.00	14.20000
SPO2	2001	1	3 325.00	33.25000
SPO2	2005	1	464.38	4.64380
SPO2	2009	2	4 061.00	40.61000
SPO2	2010	1	709.00	7.09000
SPO2	2011	1	145.00	1.45000
SPO2	2012	1	3 677.00	36.77000
SPO3	1991	2	250 069.00	502.10770
SPO3	1994	1	2 633.00	23.32086
SPO3	1995	2	21 207.00	32.15143
SPO3	1996	3	44 759.00	436.39571
SPO3	1997	1	19 014.00	19.01400
SPO3	1999	1	588.00	5.20800
SPO3	2001	1	5 330.00	53.30000
SPO3	2003	1	5 330.00	53.30000
SPO3	2004	1	7 548.00	7.54800
SPO3	2007	2	4 973.00	49.73000
SPO3	2008	2	7 216.90	41.48890
SPO3	2010	1	2 809.53	28.09530
SPO3	2011	1	1 788.00	17.88000
SPO3	2012	1	463.00	4.63000
SPO3	2013	1	1 368.00	13.68000
SPO3	2014	2	8 859.00	88.59000
SPO3	2015	1	7 499.00	74.99000
SPO3	2016	2	8 849.23	75.11623
SPO3	2018	2	5 045.00	50.45000
SPO3	2019	1	1 243.00	12.43000
SPO3	2020	1	50.00	0.50000
SPO3	2021	1	3 512.30	35.12300
SPO7	1991	2	8 072.00	80.72000
SPO7	1995	1	642.00	6.42000
SPO7	1996	1	12 350.00	12.35000
SPO7	1997	2	8 750.00	77.50000

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. (continued)

QMA	Fishing year	Trips	Greenweight (kg)	
			Original	Adjusted
SPO7	1998	1	10262.50	102.32500
SPO7	2002	1	4310.00	43.10000
SPO7	2003	1	9000.00	90.00000
SPO7	2004	1	4000.00	40.00000
SPO7	2008	1	51.00	0.51000
SPO7	2019	1	9734.00	97.34000
SPO8	1995	1	36666.00	32.47560
SPO8	2003	1	1569.00	15.69000
SPO8	2004	1	1527.00	15.27000
SPO8	2006	1	1322.00	13.22000
SPO8	2020	1	3052.00	30.52000

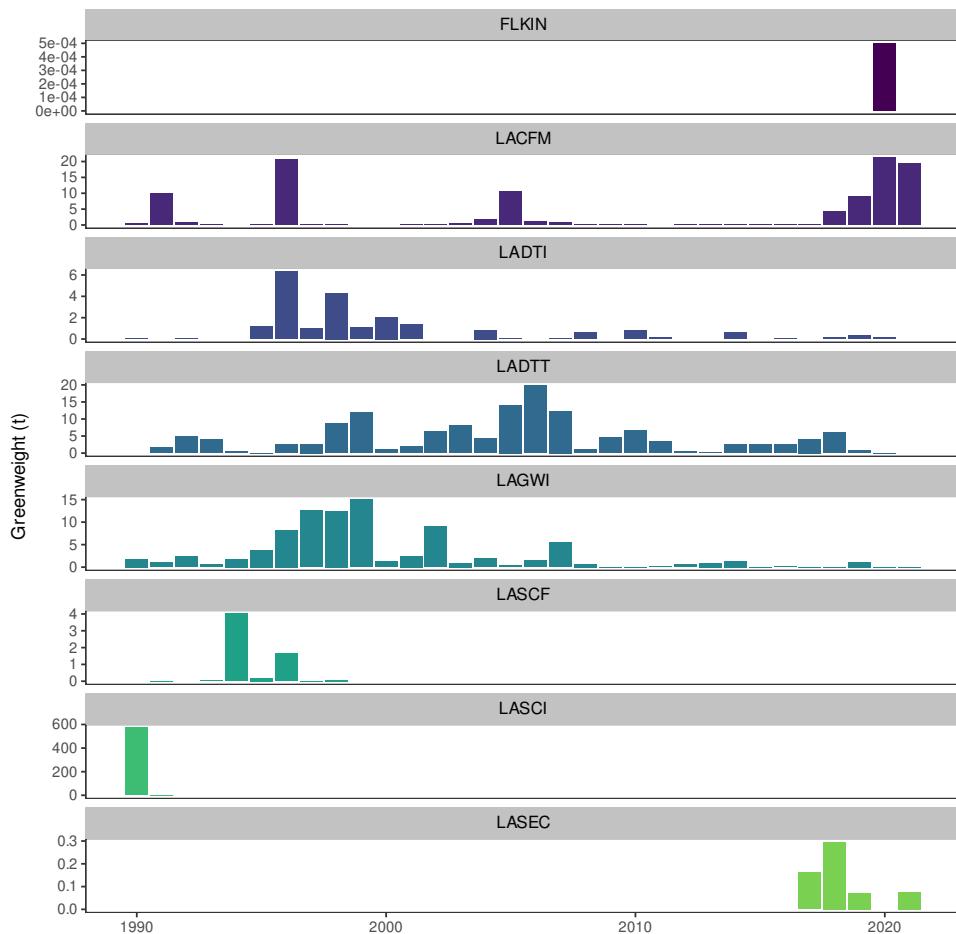


Figure A.5: The quantity of landings flagged by the grooming rules, or where fixes were applied to fields other than the landed greenweight. Note that some landing events may be affected by multiple rules.

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)
FEPMW	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

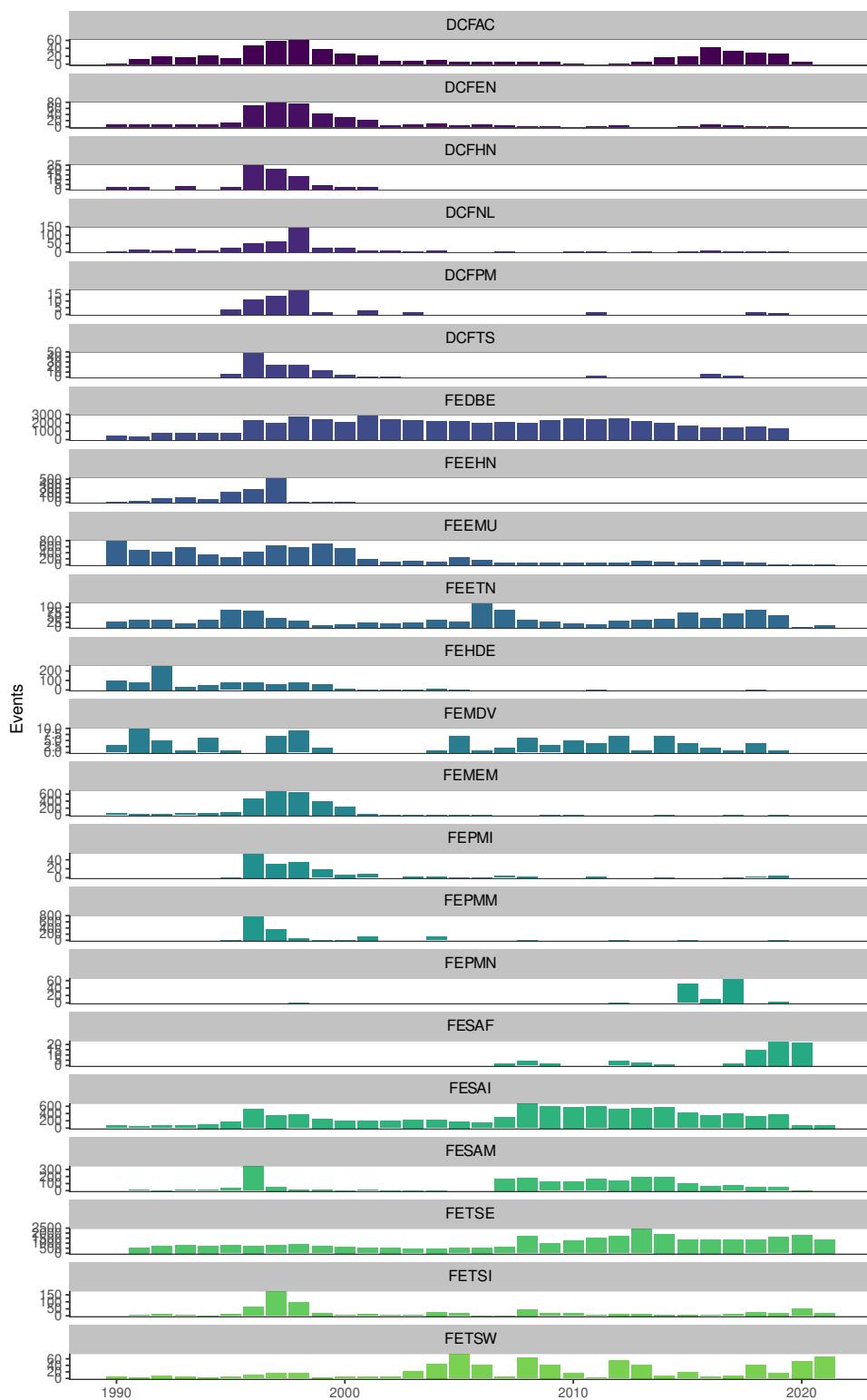


Figure A.6: The number of fishing events flagged or fixed by the grooming rules. Note that some events may be affected by multiple rules.

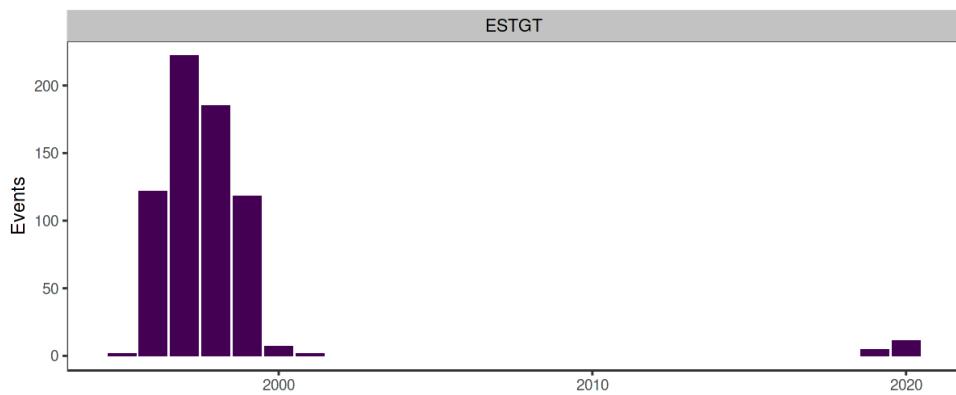


Figure A.7: The number of fishing events where the estimated catch of rig was flagged or fixed by the grooming rules. Note that some events may be affected by multiple rules.

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 SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 from 1990 to 2021.

Fishing year	SPO1		SPO2		SPO3		SPO7		SPO8	
	TACC	MHR/QMR								
1990	652.60	689.08	69.90	61.50	351.80	292.18	283.50	265.95	294.60	206.24
1991	686.70	655.56	70.40	62.87	358.80	283.91	291.00	267.78	310.40	196.39
1992	825.00	865.12	85.00	105.05	430.00	351.39	350.00	294.20	370.00	145.40
1993	825.00	714.56	85.00	90.36	430.00	277.88	350.00	323.71	370.00	238.72
1994	825.00	626.88	85.50	95.87	431.60	327.15	350.00	309.08	370.00	255.02
1995	829.00	660.76	85.50	85.80	452.10	403.06	350.00	341.00	370.00	272.58
1996	829.00	602.12	85.50	107.81	453.90	409.56	350.00	400.14	370.00	329.77
1997	829.00	683.77	85.50	98.71	453.90	434.28	350.00	397.54	370.00	277.37
1998	692.00	621.40	72.00	84.95	453.90	441.64	350.00	325.02	310.00	286.85
1999	692.00	563.72	72.00	86.51	453.90	422.01	350.00	337.12	310.00	234.38
2000	692.00	608.30	72.00	86.73	453.90	427.15	350.00	330.66	310.00	219.08
2001	692.00	553.88	72.00	81.14	600.00	458.46	350.00	338.25	310.00	174.32
2002	692.06	436.20	72.01	86.13	600.00	391.02	350.00	281.95	310.00	215.71
2003	692.06	476.58	72.01	85.80	600.00	416.51	350.00	263.68	310.00	208.60
2004	692.06	481.35	72.01	80.64	600.00	354.45	350.00	293.63	310.00	203.01
2005	692.06	431.17	86.00	108.18	600.00	366.46	350.00	266.17	310.00	208.30
2006	692.06	345.85	86.00	110.42	600.00	389.31	350.00	287.94	310.00	162.57
2007	692.06	400.30	86.00	101.52	600.00	423.32	221.00	264.58	310.00	175.89
2008	692.06	297.16	86.00	104.96	600.00	461.56	221.00	230.61	310.00	219.89
2009	692.06	297.56	86.00	105.89	600.00	328.38	221.00	233.43	310.00	221.83
2010	692.06	302.14	86.00	113.92	600.00	371.12	221.00	229.37	310.00	245.50
2011	692.06	311.21	86.00	105.72	600.00	394.71	221.00	228.53	310.00	220.22
2012	692.06	328.89	108.00	116.76	600.00	433.79	221.00	227.06	310.00	198.14
2013	692.06	369.07	108.00	105.74	600.00	462.86	221.00	225.83	310.00	120.31
2014	692.06	348.72	108.00	125.08	600.00	488.97	221.00	230.32	310.00	192.37
2015	692.06	323.55	108.00	116.68	600.00	556.51	221.00	235.05	310.00	180.96
2016	692.06	315.81	108.00	105.84	600.00	557.04	246.00	247.68	310.00	180.04
2017	692.06	317.73	108.00	100.56	600.00	542.75	246.00	258.23	310.00	197.03
2018	692.06	317.27	108.00	89.02	600.00	647.66	246.00	246.56	310.00	159.00
2019	692.06	238.56	108.00	105.28	600.00	614.56	271.00	264.61	310.00	141.70
2020	692.06	217.49	108.00	116.53	600.00	651.07	298.00	273.14	310.00	117.90
2021	692.06	233.80	119.00	109.17	660.00	631.89	298.00	284.12	310.00	46.90

Table B.2: Annual SPO 1 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/discard 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 rig was targeted. – : no observations.

Fishing year	QMR/MHR (t)	Catches (t)	Allocated catches					Target catches	
			Total (t)	SN (%)	BT-PRB (%)	DS (%)	BLL (%)	tonnes	%
1990	689.08	397.47	396.63	71.86	20.54	1.86	1.73	231.38	58.34
1991	655.56	468.61	466.62	75.81	15.78	3.25	1.68	249.87	53.55
1992	865.12	630.41	634.03	76.31	15.52	3.10	2.51	363.94	57.40
1993	714.55	635.08	634.45	75.57	16.09	3.60	3.05	358.52	56.51
1994	626.88	631.53	634.29	69.62	13.98	3.60	11.10	437.51	68.98
1995	660.76	610.17	613.97	78.37	11.97	3.30	3.94	422.09	68.75
1996	602.12	581.01	592.66	69.77	13.61	3.24	11.19	392.53	66.23
1997	683.77	614.20	632.07	80.79	12.45	2.97	2.94	442.07	69.94
1998	621.40	574.05	583.21	82.48	11.52	1.85	3.44	369.10	63.29
1999	563.72	532.42	520.58	75.83	15.14	2.16	4.33	312.18	59.97
2000	608.30	574.33	574.11	78.42	13.56	1.75	4.72	383.88	66.87
2001	553.88	572.50	563.78	78.99	13.13	1.85	4.18	386.57	68.57
2002	436.20	466.03	468.98	79.99	14.58	1.87	2.94	329.82	70.33
2003	476.58	487.95	490.81	78.61	14.51	1.60	2.27	316.70	64.53
2004	481.35	479.04	487.11	83.39	11.00	2.23	1.49	315.85	64.84
2005	431.17	440.02	437.43	81.97	12.86	1.74	1.85	294.81	67.40
2006	345.85	345.32	329.97	76.20	15.67	3.16	2.20	201.04	60.93
2007	400.30	403.88	400.67	78.50	11.49	3.92	2.85	273.18	68.18
2008	297.16	299.91	299.59	72.41	17.35	5.46	2.32	192.39	64.22
2009	297.56	294.74	296.09	73.69	16.35	6.00	1.85	184.19	62.21
2010	302.14	307.38	306.74	70.92	18.46	5.89	1.90	185.79	60.57
2011	311.21	313.99	305.36	72.52	16.77	6.47	2.01	191.35	62.66
2012	328.89	324.97	321.28	70.52	21.76	4.96	1.43	198.26	61.71
2013	369.07	368.46	363.85	72.66	20.18	4.72	1.46	229.37	63.04
2014	348.72	351.56	348.08	68.00	26.83	2.98	1.10	204.39	58.72
2015	323.55	326.77	323.02	67.68	27.20	3.14	1.20	196.53	60.84
2016	315.81	316.57	315.70	69.77	24.32	3.34	1.57	195.84	62.03
2017	317.73	314.73	314.11	73.34	22.48	1.71	1.19	210.88	67.14
2018	317.27	316.82	315.02	68.34	28.17	1.80	0.99	199.30	63.27
2019	238.56	238.42	238.84	64.64	29.69	2.47	1.59	139.65	58.47
2020	217.49	216.39	214.09	62.00	29.68	2.59	1.33	120.23	56.16
2021	233.80	230.63	229.60	58.90	32.22	2.75	1.24	119.27	51.95

Table B.3: Annual SPO 2 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/discard 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 rig was targeted. – : no observations.

Fishing year	QMR/MHR (t)	Catches (t)	Allocated catches					Target catches	
			Total (t)	SN (%)	BT-PRB (%)	DS (%)	BLL (%)	tonnes	%
1990	61.50	48.03	48.45	32.97	65.47	-	0.17	8.13	16.78
1991	62.87	39.82	41.14	34.12	63.82	0.16	0.48	5.46	13.28
1992	105.05	71.94	71.75	24.91	74.33	-	0.33	4.98	6.95
1993	90.36	82.72	83.18	26.11	73.18	0.07	0.34	8.64	10.39
1994	95.87	88.61	89.15	34.62	62.41	-	0.46	14.35	16.09
1995	85.80	82.88	81.87	23.44	68.77	0.82	0.06	5.00	6.11
1996	107.81	108.10	108.67	32.17	59.53	2.04	0.24	12.18	11.21
1997	98.71	88.69	87.47	26.56	69.94	0.93	0.05	3.45	3.94
1998	84.95	72.58	77.13	23.51	70.41	0.43	0.04	5.68	7.36
1999	86.51	78.84	78.89	27.13	68.60	1.10	0.16	6.90	8.75
2000	86.73	78.65	79.13	30.73	63.51	2.74	0.48	3.36	4.25
2001	81.14	83.58	84.68	28.15	63.38	6.01	0.10	7.79	9.20
2002	86.13	90.04	88.96	28.44	64.39	4.16	0.08	8.68	9.76
2003	85.80	90.18	89.21	17.92	81.39	0.08	0.01	4.09	4.58
2004	80.64	86.22	83.60	16.98	80.79	0.11	0.04	2.19	2.62
2005	108.18	108.68	106.66	17.08	81.85	0.03	0.15	5.16	4.84
2006	110.42	112.54	112.18	13.76	85.90	0.00	0.09	0.66	0.59
2007	101.52	100.73	99.53	18.29	80.62	0.37	0.47	6.35	6.38
2008	104.96	102.69	100.76	19.54	79.24	0.55	0.43	4.20	4.17
2009	105.89	109.28	110.70	34.81	64.66	0.00	0.50	14.02	12.66
2010	113.92	112.21	112.22	23.59	75.30	0.64	0.42	11.43	10.19
2011	105.72	104.33	104.34	23.42	74.46	1.78	0.27	12.79	12.26
2012	116.76	118.27	117.12	29.75	66.80	3.23	0.04	22.72	19.40
2013	105.74	106.73	106.99	22.80	75.35	1.40	0.16	13.86	12.95
2014	125.08	127.47	127.65	22.60	77.16	-	0.12	22.81	17.87
2015	116.68	118.94	116.88	25.15	70.24	4.40	0.13	14.42	12.34
2016	105.84	107.71	107.33	16.46	80.16	3.00	0.14	9.09	8.47
2017	100.56	100.56	99.63	10.44	83.90	4.88	0.16	4.37	4.39
2018	89.02	88.56	88.55	11.14	82.09	6.64	0.09	4.96	5.60
2019	105.28	103.33	100.81	22.66	76.28	1.00	0.03	14.85	14.73
2020	116.53	116.76	116.87	25.75	71.30	2.88	0.06	22.15	18.95
2021	109.17	109.05	109.50	27.24	67.21	5.29	0.19	15.83	14.45

Table B.4: Annual SPO 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/discard 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 rig was targeted. – : no observations.

Fishing year	QMR/MHR (t)	Catches (t)	Allocated catches					Target catches	
			Total (t)	SN (%)	BT-PRB (%)	DS (%)	BLL (%)	tonnes	%
1990	292.18	224.35	218.14	75.28	24.58	-	0.00	80.72	37.00
1991	283.91	277.14	273.30	66.62	32.31	-	0.02	74.20	27.15
1992	351.39	323.03	318.78	61.44	32.23	-	0.33	98.92	31.03
1993	277.88	260.64	257.01	64.32	35.53	0.00	0.04	78.49	30.54
1994	327.15	319.08	307.02	69.08	30.59	-	0.08	103.42	33.69
1995	403.06	416.82	399.69	72.06	22.20	-	2.21	154.80	38.73
1996	409.56	412.36	402.24	71.92	26.48	0.01	0.14	166.13	41.30
1997	434.28	431.51	422.77	74.36	23.61	-	0.10	157.42	37.23
1998	441.63	430.06	424.23	76.28	23.07	-	0.51	193.32	45.57
1999	422.01	397.88	398.93	80.80	18.07	-	1.06	203.85	51.10
2000	427.15	410.28	407.99	73.20	26.67	0.01	0.02	171.25	41.97
2001	458.46	497.92	483.92	73.26	25.32	-	0.00	230.41	47.61
2002	391.02	417.37	411.62	74.56	25.28	-	0.00	241.83	58.75
2003	416.51	452.97	446.40	73.04	26.35	0.55	0.01	264.36	59.22
2004	354.45	383.19	379.14	70.97	27.55	1.40	0.03	223.70	59.00
2005	366.46	388.74	379.58	69.42	26.82	3.67	0.01	217.50	57.30
2006	389.31	388.46	385.21	71.05	24.25	3.94	0.42	216.66	56.24
2007	423.32	458.38	456.51	70.91	24.20	4.56	0.27	260.49	57.06
2008	461.56	483.91	478.79	75.40	17.29	6.83	0.42	265.43	55.44
2009	328.38	333.57	333.81	63.58	26.64	9.68	0.07	143.57	43.01
2010	371.12	375.23	371.94	60.60	28.76	10.56	0.01	168.12	45.20
2011	394.71	391.67	389.13	61.20	25.54	11.48	1.61	189.78	48.77
2012	433.79	436.08	434.16	56.56	28.43	14.32	0.61	221.27	50.96
2013	462.86	466.50	461.31	61.94	25.33	12.00	0.67	251.68	54.56
2014	488.97	485.68	485.28	54.89	33.05	10.95	0.76	277.26	57.13
2015	556.51	548.98	544.37	58.45	28.72	10.59	2.17	332.33	61.05
2016	557.04	556.67	553.70	55.79	29.32	14.54	0.25	311.07	56.18
2017	542.75	547.07	537.96	52.69	31.77	15.17	0.22	309.86	57.60
2018	647.66	644.27	638.11	50.80	32.98	14.39	1.67	385.59	60.43
2019	614.56	609.94	603.68	54.23	31.30	13.61	0.80	329.82	54.64
2020	651.07	668.92	665.95	59.24	28.47	11.82	0.31	316.02	47.45
2021	631.89	652.12	646.05	51.54	34.16	14.23	0.02	246.47	38.15

Table B.5: Annual SPO 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/discard 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 rig was targeted. – : no observations.

Fishing year	QMR/MHR (t)	Catches (t)	Allocated catches					Target catches	
			Total (t)	SN (%)	BT-PRB (%)	DS (%)	BLL (%)	tonnes	%
1990	265.95	244.42	238.89	54.68	41.40	-	1.51	118.96	49.80
1991	267.78	222.08	216.08	58.60	37.73	-	0.94	118.29	54.74
1992	294.20	235.90	230.78	64.89	34.46	-	0.08	131.58	57.01
1993	323.71	297.29	289.32	64.66	34.58	-	0.43	151.64	52.41
1994	309.08	287.23	276.47	62.05	33.20	-	0.33	142.28	51.46
1995	341.00	342.31	340.20	58.61	40.04	-	0.39	168.46	49.52
1996	400.13	382.31	369.81	65.34	33.10	-	0.04	200.18	54.13
1997	397.54	382.28	352.39	58.42	40.66	-	0.19	184.08	52.24
1998	325.02	316.31	289.58	63.98	34.75	-	0.07	173.82	60.02
1999	337.12	326.08	318.60	59.56	39.80	-	0.08	179.50	56.34
2000	330.66	313.84	303.71	57.60	40.39	-	0.26	161.09	53.04
2001	338.25	366.71	348.74	61.97	37.27	-	0.01	204.08	58.52
2002	281.95	306.57	288.96	59.24	39.21	-	0.01	166.22	57.52
2003	263.68	267.23	268.63	63.19	34.81	-	0.16	160.55	59.76
2004	293.63	293.85	288.89	64.78	33.50	-	0.71	185.29	64.14
2005	266.17	268.95	263.69	60.77	38.80	0.02	0.03	151.63	57.50
2006	287.94	295.62	291.18	61.99	37.52	0.17	0.06	169.08	58.07
2007	264.58	265.58	266.74	59.14	39.76	0.29	0.06	150.18	56.30
2008	230.61	298.49	294.75	39.18	58.88	1.76	0.01	101.27	34.36
2009	233.43	237.40	235.55	43.89	52.32	3.19	0.53	84.93	36.06
2010	229.37	231.18	231.77	40.89	54.23	4.75	0.07	82.77	35.71
2011	228.53	235.18	234.19	45.83	52.33	1.65	0.15	95.68	40.86
2012	227.06	230.03	231.68	46.08	51.03	2.67	0.02	99.49	42.94
2013	225.83	242.23	243.87	40.23	57.82	1.86	0.05	82.03	33.63
2014	230.32	239.16	238.21	36.28	61.25	2.02	0.09	77.44	32.51
2015	235.05	253.97	249.99	32.74	61.63	3.71	0.11	76.18	30.47
2016	247.68	258.76	256.75	33.72	63.48	2.63	0.05	81.88	31.89
2017	258.23	278.08	278.64	32.76	61.15	5.87	0.03	80.03	28.72
2018	246.56	266.73	266.87	29.94	65.47	4.52	0.02	74.56	27.94
2019	264.61	279.30	289.19	28.27	68.20	3.28	0.19	75.96	26.27
2020	273.14	287.52	285.85	24.09	71.67	4.19	0.02	70.93	24.81
2021	284.12	293.23	291.01	5.15	89.97	4.85	0.01	18.86	6.48

Table B.6: Annual SPO 8 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/discard 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 rig was targeted. – : no observations.

Fishing year	QMR/MHR (t)	Catches (t)	Allocated catches					Target catches	
			Total (t)	SN (%)	BT-PRB (%)	DS (%)	BLL (%)	tonnes	%
1990	206.24	170.02	140.50	78.82	18.17	-	0.58	80.77	57.49
1991	196.39	142.86	118.46	86.01	10.21	-	0.65	79.59	67.18
1992	145.41	106.26	94.03	84.32	9.71	-	0.75	63.89	67.94
1993	238.72	198.52	184.09	89.33	5.37	-	0.71	141.01	76.60
1994	255.02	229.20	210.09	91.08	4.62	-	0.37	168.88	80.38
1995	272.57	242.17	232.36	88.78	7.00	-	0.36	184.96	79.60
1996	329.77	294.82	263.06	89.96	8.47	-	0.38	198.88	75.60
1997	277.37	232.76	211.62	80.35	17.44	-	0.41	145.65	68.83
1998	286.85	239.96	196.04	84.49	14.37	0.00	0.69	140.78	71.81
1999	234.38	201.79	176.06	86.14	13.54	-	0.14	134.11	76.17
2000	219.08	185.27	149.25	82.55	17.11	-	0.22	105.82	70.91
2001	174.32	167.62	140.35	88.80	10.27	-	0.45	103.06	73.44
2002	215.71	215.11	186.76	83.24	16.30	-	0.28	138.74	74.29
2003	208.60	207.08	181.25	85.91	13.68	-	0.33	142.10	78.40
2004	203.01	200.59	157.20	86.19	13.67	-	0.08	121.99	77.60
2005	208.30	211.18	153.33	88.59	11.18	-	0.05	118.22	77.10
2006	162.57	166.82	137.51	87.01	12.75	-	0.04	107.25	78.00
2007	175.89	176.55	168.28	85.17	11.10	3.57	0.11	122.51	72.80
2008	219.89	222.69	222.28	83.24	11.68	4.87	0.09	167.93	75.55
2009	221.83	221.99	209.69	87.13	11.52	1.22	0.10	161.08	76.82
2010	245.50	246.21	236.54	88.01	11.37	0.48	0.08	178.13	75.31
2011	220.22	216.86	211.86	82.40	16.24	1.29	0.04	148.97	70.32
2012	198.14	204.99	193.33	80.28	17.98	1.65	0.07	136.38	70.54
2013	120.31	123.26	119.13	78.98	20.39	0.47	0.14	71.34	59.88
2014	192.37	192.02	190.68	84.57	14.76	-	0.24	134.49	70.53
2015	180.97	183.07	187.73	79.34	20.33	-	0.22	127.42	67.87
2016	180.04	178.88	179.48	83.80	15.97	-	0.20	130.73	72.84
2017	197.03	196.03	194.49	86.74	13.12	-	0.09	144.36	74.22
2018	159.00	159.80	158.97	77.62	22.26	-	0.10	104.69	65.85
2019	141.70	144.59	143.21	74.91	24.89	-	0.18	95.22	66.49
2020	117.90	118.39	119.08	65.58	33.24	-	1.17	72.49	60.88
2021	46.90	46.61	46.46	11.06	73.21	-	15.66	11.95	25.72

Table B.7: Annual rig catches (t) by destination code for the SPO 1 Quota Management Area. L = Landings to an LFR, QL = Landings to an LFR after storing in a holding receptacle on land, X = Permitted returns. A complete list of destination codes is provided in Table 2. – : no observations.

Fishing year	L	X	QL	Other	Total
1990	395.50	-	-	1.97	397.47
1991	465.91	-	-	2.70	468.61
1992	627.60	-	-	2.81	630.41
1993	634.16	-	-	0.92	635.08
1994	630.74	-	-	0.79	631.53
1995	608.54	-	-	1.63	610.17
1996	579.21	-	-	1.79	581.01
1997	612.22	-	-	1.98	614.20
1998	568.87	-	-	5.17	574.05
1999	531.17	-	-	1.25	532.42
2000	571.43	-	-	2.90	574.33
2001	571.48	-	-	1.02	572.50
2002	465.19	-	-	0.84	466.03
2003	487.06	-	-	0.89	487.95
2004	477.65	-	-	1.39	479.04
2005	439.21	-	-	0.80	440.02
2006	344.44	-	-	0.88	345.32
2007	401.79	-	-	2.09	403.88
2008	298.96	-	-	0.95	299.91
2009	293.74	-	-	1.00	294.74
2010	306.57	-	-	0.81	307.38
2011	313.05	-	-	0.93	313.99
2012	324.15	0.09	-	0.73	324.97
2013	367.57	0.01	-	0.88	368.46
2014	350.17	0.55	-	0.84	351.56
2015	325.38	0.31	-	1.08	326.77
2016	315.91	0.12	-	0.53	316.57
2017	312.96	0.37	-	1.41	314.73
2018	315.20	0.10	-	1.53	316.82
2019	212.11	0.04	24.79	1.48	238.42
2020	119.23	0.01	93.78	3.36	216.39
2021	112.28	0.02	115.19	3.14	230.63

Table B.8: Annual rig catches (t) by destination code for the SPO 2 Quota Management Area. L = Landings to an LFR, QL = Landings to an LFR after storing in a holding receptacle on land, X = Permitted returns. A complete list of destination codes is provided in Table 2. – : no observations.

Fishing year	L	X	QL	Other	Total
1990	44.41	-	-	3.61	48.03
1991	38.33	-	-	1.49	39.82
1992	64.80	-	-	7.15	71.94
1993	80.71	-	-	2.01	82.72
1994	87.65	-	-	0.95	88.61
1995	76.12	-	-	6.76	82.88
1996	107.51	-	-	0.59	108.10
1997	88.23	-	-	0.46	88.69
1998	70.47	-	-	2.11	72.58
1999	75.58	-	-	3.26	78.84
2000	76.81	-	-	1.84	78.65
2001	83.50	-	-	0.08	83.58
2002	89.24	-	-	0.80	90.04
2003	90.15	-	-	0.03	90.18
2004	85.67	-	-	0.55	86.22
2005	108.63	-	-	0.05	108.68
2006	112.44	-	-	0.10	112.54
2007	100.57	-	-	0.16	100.73
2008	102.25	-	-	0.44	102.69
2009	108.74	-	-	0.53	109.28
2010	111.80	-	-	0.40	112.21
2011	104.17	-	-	0.16	104.33
2012	117.97	0.14	-	0.15	118.27
2013	105.24	0.88	-	0.62	106.73
2014	125.72	1.46	-	0.29	127.47
2015	116.80	1.94	-	0.20	118.94
2016	106.13	1.11	-	0.47	107.71
2017	99.36	0.82	-	0.38	100.56
2018	88.18	0.28	-	0.09	88.56
2019	102.26	0.04	0.11	0.91	103.33
2020	106.80	0.71	7.64	1.61	116.76
2021	106.48	0.90	1.30	0.37	109.05

Table B.9: Annual rig catches (t) by destination code for the SPO 3 Quota Management Area. L = Landings to an LFR, QL = Landings to an LFR after storing in a holding receptacle on land, X = Permitted returns. A complete list of destination codes is provided in Table 2. – : no observations.

Fishing year	L	X	QL	Other	Total
1990	220.44	-	-	3.91	224.35
1991	244.47	-	-	32.66	277.14
1992	309.34	-	-	13.69	323.03
1993	260.38	-	-	0.26	260.64
1994	317.50	-	-	1.58	319.08
1995	404.27	-	-	12.56	416.82
1996	398.62	-	-	13.74	412.36
1997	428.18	-	-	3.33	431.51
1998	420.35	-	-	9.71	430.06
1999	396.36	-	-	1.52	397.88
2000	399.56	-	-	10.72	410.28
2001	494.09	-	-	3.84	497.92
2002	415.71	-	-	1.66	417.37
2003	442.63	-	-	10.34	452.97
2004	376.02	-	-	7.17	383.19
2005	376.90	-	-	11.84	388.74
2006	386.72	-	-	1.73	388.46
2007	457.45	-	-	0.93	458.38
2008	478.06	-	-	5.85	483.91
2009	333.37	-	-	0.19	333.57
2010	374.74	-	-	0.48	375.23
2011	391.36	-	-	0.31	391.67
2012	435.26	-	-	0.82	436.08
2013	465.56	0.15	-	0.79	466.50
2014	484.11	0.55	-	1.02	485.68
2015	546.87	0.69	-	1.42	548.98
2016	552.02	1.43	-	3.23	556.67
2017	536.49	2.13	-	8.45	547.07
2018	638.40	0.49	-	5.38	644.27
2019	601.91	1.12	0.40	6.50	609.94
2020	642.83	2.56	17.64	5.89	668.92
2021	615.26	4.96	25.43	6.47	652.12

Table B.10: Annual rig catches (t) by destination code for the SPO 7 Quota Management Area. L = Landings to an LFR, QL = Landings to an LFR after storing in a holding receptacle on land, X = Permitted returns. A complete list of destination codes is provided in Table 2. – : no observations.

Fishing year	L	X	QL	Other	Total
1990	237.00	-	-	7.42	244.42
1991	220.39	-	-	1.69	222.08
1992	232.35	-	-	3.55	235.90
1993	296.02	-	-	1.27	297.29
1994	285.35	-	-	1.88	287.23
1995	336.93	-	-	5.38	342.31
1996	379.01	-	-	3.31	382.31
1997	374.36	-	-	7.92	382.28
1998	315.75	-	-	0.56	316.31
1999	313.80	-	-	12.27	326.08
2000	301.07	-	-	12.77	313.84
2001	354.16	-	-	12.56	366.71
2002	298.74	-	-	7.83	306.57
2003	265.64	-	-	1.59	267.23
2004	292.39	-	-	1.46	293.85
2005	268.78	-	-	0.17	268.95
2006	294.73	-	-	0.89	295.62
2007	264.20	-	-	1.38	265.58
2008	296.01	-	-	2.48	298.49
2009	236.80	-	-	0.61	237.40
2010	230.19	-	-	0.99	231.18
2011	234.62	-	-	0.56	235.18
2012	227.16	2.57	-	0.29	230.03
2013	232.94	8.81	-	0.48	242.23
2014	226.23	12.66	-	0.26	239.16
2015	237.79	15.83	-	0.36	253.97
2016	245.67	12.03	-	1.06	258.76
2017	257.65	19.09	-	1.34	278.08
2018	244.49	21.70	-	0.54	266.73
2019	262.37	16.01	-	0.92	279.30
2020	272.55	13.76	-	1.21	287.52
2021	265.41	10.26	0.04	17.52	293.23

Table B.11: Annual rig catches (t) by destination code for the SPO 8 Quota Management Area. L = Landings to an LFR, QL = Landings to an LFR after storing in a holding receptacle on land, X = Permitted returns. A complete list of destination codes is provided in Table 2. – : no observations.

Fishing year	L	X	QL	Other	Total
1990	169.26	-	-	0.76	170.02
1991	142.22	-	-	0.64	142.86
1992	104.05	-	-	2.20	106.26
1993	197.51	-	-	1.01	198.52
1994	226.95	-	-	2.24	229.20
1995	239.93	-	-	2.24	242.17
1996	291.42	-	-	3.40	294.82
1997	232.47	-	-	0.29	232.76
1998	236.87	-	-	3.09	239.96
1999	201.55	-	-	0.24	201.79
2000	185.14	-	-	0.13	185.27
2001	167.10	-	-	0.52	167.62
2002	212.82	-	-	2.29	215.11
2003	204.65	-	-	2.43	207.08
2004	200.56	-	-	0.03	200.59
2005	209.07	-	-	2.12	211.18
2006	166.77	-	-	0.05	166.82
2007	176.20	-	-	0.35	176.55
2008	221.47	-	-	1.21	222.69
2009	221.88	-	-	0.11	221.99
2010	246.15	-	-	0.06	246.21
2011	216.83	-	-	0.04	216.86
2012	203.38	0.06	-	1.55	204.99
2013	122.93	0.02	-	0.32	123.26
2014	191.86	0.10	-	0.06	192.02
2015	181.30	1.69	-	0.08	183.07
2016	178.66	0.20	-	0.02	178.88
2017	196.00	-	-	0.03	196.03
2018	159.77	0.01	-	0.02	159.80
2019	144.51	0.01	-	0.07	144.59
2020	118.08	0.04	-	0.28	118.39
2021	46.14	0.04	0.42	0.01	46.61

Table B.12: Annual catches by landed state of rig from the SPO 1 Quota Management Area. DRE = Dressed, FIN = Fins, GGU = Gilled and gutted, GRE = Green (or whole), GUT = Gutted, HGT = Headed, gutted, and tailed, HGU = Headed and gutted, MEA = Fish meal. 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	GUT	HGT	FIN	GGU	MEA	Other	Total
1990	0.06	84.90	85.91	3.26	8.82	-	-	-	0.07	183.02
1991	205.26	110.27	126.83	22.92	2.37	-	-	-	0.01	467.66
1992	229.06	165.23	184.21	51.92	-	-	-	-	-	630.41
1993	283.24	134.02	194.58	23.21	-	-	-	-	0.04	635.08
1994	274.31	109.16	233.89	14.17	-	-	-	-	-	631.53
1995	270.45	146.05	184.03	8.53	-	0.01	-	-	-	609.07
1996	299.95	145.05	128.33	5.11	0.21	0.12	0.43	-	0.01	579.22
1997	333.12	179.02	90.06	7.65	1.70	2.09	0.03	-	0.09	613.76
1998	297.34	170.15	82.92	11.17	11.10	0.28	0.29	-	0.20	573.45
1999	280.01	127.99	72.75	18.59	30.87	0.20	0.46	-	0.35	531.21
2000	331.58	81.24	84.66	24.04	51.60	0.21	0.01	-	1.00	574.33
2001	383.98	74.14	52.32	15.30	39.15	6.30	0.35	-	0.95	572.50
2002	356.88	49.54	37.93	1.60	17.08	2.51	0.41	0.01	0.04	466.00
2003	352.33	80.32	37.98	1.36	14.38	0.66	-	-	0.91	487.94
2004	344.16	84.83	44.03	1.52	3.31	0.71	-	-	0.31	478.87
2005	322.36	69.70	27.94	0.70	1.93	15.93	-	-	1.27	439.83
2006	271.01	43.51	26.42	1.73	1.55	0.69	-	-	0.42	345.32
2007	316.66	47.08	38.69	1.16	-	0.28	-	-	0.01	403.88
2008	240.11	36.95	22.31	0.50	-	0.05	-	-	-	299.91
2009	232.02	41.09	20.31	1.07	-	-	-	-	-	294.49
2010	230.57	53.45	18.45	3.59	-	1.32	-	-	-	307.38
2011	245.80	50.08	17.45	0.63	-	0.02	-	-	0.01	313.99
2012	233.61	70.61	20.19	0.34	-	0.22	-	-	0.00	324.97
2013	263.85	84.86	18.45	0.41	-	0.69	-	-	0.21	368.46
2014	248.95	86.59	15.40	0.16	-	0.15	-	0.03	0.28	351.56
2015	231.36	80.67	14.29	0.21	-	0.00	-	-	0.24	326.77
2016	221.34	77.71	17.06	0.41	-	-	-	-	0.05	316.57
2017	213.11	83.04	17.59	0.37	-	-	-	-	0.13	314.24
2018	207.00	94.51	13.77	1.24	-	-	-	-	0.31	316.82
2019	142.71	71.88	22.45	1.16	-	-	-	-	0.22	238.42
2020	128.63	53.70	32.19	1.53	-	-	-	-	0.34	216.39
2021	99.30	59.99	68.30	2.78	-	-	-	-	0.26	230.63

Table B.13: Annual catches by landed state of rig from the SPO 2 Quota Management Area. DRE = Dressed, FIN = Fins, GGU = Gilled and gutted, GRE = Green (or whole), GUT = Gutted, HGT = Headed, gutted, and tailed, HGU = Headed and gutted, MEA = Fish meal. 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	GUT	HGT	FIN	MEA	Other	Total
1990	-	6.48	6.25	3.64	2.23	-	-	-	18.59
1991	13.20	11.16	5.90	5.45	3.97	-	-	-	39.68
1992	18.45	40.08	7.20	6.21	-	-	-	-	71.94
1993	27.92	35.49	9.52	9.79	-	-	-	0.01	82.72
1994	36.45	39.44	7.49	5.21	-	0.01	-	-	88.61
1995	35.63	29.07	11.91	6.26	-	0.01	-	-	82.88
1996	45.29	42.64	10.64	9.47	-	0.02	-	-	108.06
1997	50.64	25.33	3.52	6.67	0.18	2.08	0.01	0.09	88.52
1998	46.74	16.08	5.76	1.58	2.35	-	-	0.06	72.58
1999	62.10	9.84	4.91	0.17	1.51	-	-	0.32	78.84
2000	63.98	8.09	5.53	0.51	0.34	0.08	-	0.12	78.65
2001	72.75	5.64	3.61	1.05	0.22	0.31	-	-	83.58
2002	78.59	5.22	4.18	1.66	0.31	0.07	-	0.02	90.04
2003	80.34	4.14	5.06	0.02	0.58	0.03	-	0.01	90.18
2004	77.44	3.66	3.60	0.13	0.41	0.94	-	0.03	86.22
2005	101.87	0.71	5.52	0.00	0.40	0.04	-	0.14	108.68
2006	110.94	0.28	1.29	0.02	-	-	-	-	112.54
2007	98.71	0.39	1.36	0.02	-	0.00	0.00	0.24	100.73
2008	99.49	0.30	2.89	-	-	-	-	0.01	102.69
2009	107.74	0.07	1.30	0.01	-	-	-	0.16	109.28
2010	108.50	1.38	2.32	0.01	-	-	-	-	112.21
2011	102.22	0.32	1.73	0.01	-	0.04	-	0.01	104.33
2012	115.11	0.55	2.25	0.33	-	-	-	0.03	118.27
2013	100.04	1.92	4.13	0.02	-	0.60	-	0.02	106.73
2014	122.65	2.17	2.31	0.03	-	0.31	0.00	0.00	127.47
2015	112.52	3.18	3.10	0.12	-	-	-	0.02	118.94
2016	102.46	2.30	2.87	0.02	-	-	-	0.07	107.71
2017	96.16	1.66	2.70	0.04	-	-	-	0.01	100.56
2018	83.80	1.80	2.87	0.08	-	-	-	0.01	88.56
2019	94.26	1.59	7.33	0.11	-	-	-	0.04	103.33
2020	108.37	1.51	4.52	-	-	-	-	2.35	116.76
2021	98.70	1.23	9.12	-	-	-	-	-	109.05

Table B.14: Annual catches by landed state of rig from the SPO 3 Quota Management Area. DRE = Dressed, FIN = Fins, GGU = Gilled and gutted, GRE = Green (or whole), GUT = Gutted, HGT = Headed, gutted, and tailed, HGU = Headed and gutted, MEA = Fish meal. 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	GUT	FIN	MEA	GGU	HGT	Other	Total
1990	1.40	117.13	6.79	3.24	-	-	15.10	10.76	0.95	155.38
1991	60.01	126.75	27.21	51.17	-	2.71	3.84	2.51	1.15	275.35
1992	65.84	170.21	16.70	38.15	-	30.18	-	-	1.95	323.03
1993	75.52	152.53	2.81	27.16	-	-	-	-	2.61	260.64
1994	133.39	163.72	9.21	7.86	1.90	-	-	-	3.00	319.08
1995	267.26	116.49	12.49	10.32	8.67	-	-	-	1.59	416.82
1996	266.60	123.40	8.80	4.77	2.69	-	-	1.25	3.44	410.94
1997	299.00	101.65	21.93	1.65	1.38	1.14	-	1.03	3.59	431.38
1998	322.74	84.53	14.31	1.46	2.88	-	-	0.68	3.04	429.65
1999	326.00	45.61	2.45	0.09	19.19	-	-	0.43	3.00	396.78
2000	331.81	50.03	25.25	0.45	0.29	0.01	0.23	0.48	1.73	410.27
2001	402.16	60.57	15.04	5.02	3.77	0.01	0.22	0.02	10.72	497.52
2002	325.25	60.91	16.81	1.38	9.44	-	-	0.12	2.59	416.49
2003	369.46	50.52	20.17	2.12	8.46	-	-	0.03	2.21	452.97
2004	305.63	35.95	28.05	5.58	2.19	0.79	-	0.02	4.98	383.19
2005	290.50	79.96	14.41	0.32	0.08	-	-	0.14	3.34	388.74
2006	315.15	57.32	13.98	0.14	1.47	-	-	-	0.40	388.45
2007	411.51	18.22	14.59	0.12	12.72	0.01	-	-	1.22	458.38
2008	432.93	28.09	18.68	0.35	3.59	0.01	-	-	0.26	483.91
2009	293.96	31.85	2.91	0.27	0.34	0.01	-	-	4.22	333.57
2010	358.34	12.70	2.28	0.28	0.07	1.50	-	-	0.06	375.23
2011	379.99	4.85	2.28	0.55	0.65	3.21	-	-	0.14	391.67
2012	426.09	8.08	1.05	0.55	0.30	-	-	-	0.01	436.07
2013	432.83	32.42	1.05	0.02	0.05	0.12	-	-	0.01	466.50
2014	465.84	13.79	3.53	0.34	2.15	-	-	-	0.03	485.68
2015	539.20	4.24	3.86	1.46	-	0.04	-	-	0.18	548.98
2016	542.76	6.07	7.26	0.39	0.00	0.03	-	0.01	0.15	556.67
2017	522.59	9.97	13.80	0.26	0.00	0.32	-	-	0.12	547.07
2018	632.43	4.14	6.96	0.02	-	0.61	-	-	0.11	644.27
2019	591.51	6.61	8.07	0.78	-	2.95	-	0.01	0.01	609.94
2020	642.43	4.64	13.60	6.16	-	2.02	-	-	0.07	668.92
2021	627.13	6.91	11.38	5.63	-	0.97	-	-	0.10	652.12

Table B.15: Annual catches by landed state of rig from the SPO 7 Quota Management Area. DRE = Dressed, FIN = Fins, GGU = Gilled and gutted, GRE = Green (or whole), GUT = Gutted, HGT = Headed, gutted, and tailed, HGU = Headed and gutted, MEA = Fish meal. 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	GUT	FIN	HGT	MEA	GGU	Other	Total
1990	-	45.34	5.19	5.25	-	8.37	-	32.02	0.50	96.67
1991	103.42	59.82	2.50	41.94	-	-	-	13.82	0.10	221.60
1992	120.83	76.50	8.94	29.51	-	-	-	-	0.13	235.90
1993	139.47	131.74	3.28	22.66	-	-	-	-	0.15	297.29
1994	138.76	118.25	7.80	11.82	10.47	-	-	-	0.13	287.23
1995	195.85	114.62	13.26	15.93	2.30	0.04	-	0.00	0.30	342.31
1996	202.48	106.06	23.95	38.13	9.77	0.61	-	0.54	-	381.53
1997	213.16	113.82	13.67	25.68	12.00	2.50	-	0.65	0.55	382.02
1998	199.52	85.34	14.22	2.25	13.00	1.61	-	0.06	0.14	316.14
1999	184.75	91.10	14.68	1.71	18.54	15.25	-	0.05	0.00	326.08
2000	201.20	79.52	15.95	0.54	5.13	11.48	0.01	-	-	313.84
2001	226.89	105.66	16.06	1.94	8.70	6.48	-	-	0.98	366.71
2002	207.88	78.29	12.68	0.18	5.41	0.52	0.30	0.81	0.50	306.57
2003	170.84	88.60	2.75	0.15	3.06	0.71	0.00	-	1.13	267.23
2004	217.03	66.45	3.30	1.07	3.93	1.48	-	-	0.58	293.85
2005	202.74	59.76	3.11	0.54	1.94	0.86	-	-	0.00	268.95
2006	207.45	78.11	7.69	0.52	1.07	0.30	-	-	0.45	295.61
2007	241.64	18.55	3.17	0.29	1.63	-	-	-	0.29	265.58
2008	222.52	4.87	15.61	0.84	7.70	-	46.87	-	0.09	298.49
2009	222.42	7.56	3.02	1.44	2.67	-	0.08	-	0.21	237.40
2010	215.63	9.65	4.44	1.06	0.11	-	0.01	-	0.29	231.18
2011	217.58	9.54	1.85	1.37	4.73	-	0.01	-	0.09	235.18
2012	207.34	12.51	3.76	1.56	4.80	-	0.01	-	0.03	230.02
2013	206.36	13.23	9.88	4.82	7.87	-	0.05	-	0.03	242.23
2014	210.67	8.24	13.74	4.46	0.13	-	1.83	-	0.01	239.09
2015	222.58	9.64	17.45	4.21	0.01	-	0.04	-	0.05	253.97
2016	229.18	11.48	12.86	5.21	-	-	-	-	0.03	258.76
2017	243.99	11.91	21.86	0.01	-	-	0.24	-	0.05	278.08
2018	236.46	7.90	22.10	0.12	-	-	0.11	-	0.05	266.73
2019	251.16	9.94	17.94	0.17	-	-	0.07	-	0.03	279.30
2020	233.06	1.41	52.92	0.05	-	-	0.04	-	0.04	287.52
2021	276.73	1.44	14.72	0.01	-	-	0.28	-	0.04	293.23

Table B.16: Annual catches by landed state of rig from the SPO 8 Quota Management Area. DRE = Dressed, FIN = Fins, GGU = Gilled and gutted, GRE = Green (or whole), GUT = Gutted, HGT = Headed, gutted, and tailed, HGU = Headed and gutted, MEA = Fish meal. 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	FIN	GUT	GGU	MEA	Other	Total
1990	-	15.90	12.38	14.13	-	0.06	15.43	-	-	57.89
1991	62.53	50.52	8.32	0.11	-	19.46	1.83	-	0.03	142.79
1992	34.01	65.31	6.56	-	-	0.19	-	-	0.19	106.26
1993	94.57	92.98	10.97	-	-	-	-	0.00	-	198.52
1994	136.19	71.88	19.96	-	0.34	0.81	-	0.01	-	229.20
1995	161.45	57.62	22.80	0.00	0.10	0.01	-	-	0.17	242.15
1996	202.10	66.21	24.72	-	1.09	0.02	0.38	0.02	-	294.54
1997	153.25	54.09	13.58	0.06	11.24	0.26	0.02	-	0.11	232.62
1998	155.83	67.44	13.22	1.37	1.52	0.25	-	-	0.27	239.88
1999	153.01	19.22	2.91	26.34	0.04	0.28	-	-	-	201.79
2000	149.58	15.76	10.83	9.06	0.01	0.04	-	-	-	185.27
2001	138.77	12.62	9.02	5.64	0.06	0.76	0.05	-	0.70	167.62
2002	189.49	19.93	4.15	0.25	0.90	0.04	-	0.01	0.35	215.11
2003	187.23	15.85	3.47	0.01	0.24	0.26	-	-	0.02	207.08
2004	187.82	7.87	3.94	-	0.38	0.24	-	-	0.34	200.59
2005	201.90	2.79	4.36	-	2.07	-	-	-	0.05	211.18
2006	159.47	1.33	5.45	-	0.51	0.00	-	0.04	0.02	166.82
2007	173.20	1.93	0.79	-	0.62	0.01	-	-	0.00	176.55
2008	217.20	1.35	2.15	-	1.91	0.01	-	-	0.08	222.69
2009	218.21	1.44	2.33	-	-	-	-	0.01	0.00	221.99
2010	242.70	0.16	1.12	-	1.52	0.69	-	0.01	0.00	246.21
2011	210.36	1.21	4.02	-	0.20	0.74	-	-	0.33	216.86
2012	194.29	2.45	1.57	-	6.67	-	-	0.01	-	204.99
2013	120.25	2.18	0.82	-	-	-	-	0.00	-	123.26
2014	189.92	0.92	0.78	-	-	0.35	-	0.06	-	192.02
2015	176.25	1.23	3.88	-	0.45	1.23	-	0.01	0.02	183.07
2016	175.07	1.93	1.87	-	-	-	-	0.01	-	178.88
2017	189.01	1.33	5.68	-	-	-	-	0.00	-	196.03
2018	154.52	4.11	1.16	-	-	-	-	0.01	0.01	159.80
2019	140.09	1.66	2.82	-	-	-	-	-	0.01	144.58
2020	116.60	1.01	0.75	-	-	-	-	0.01	0.03	118.39
2021	45.86	0.45	0.25	-	-	-	-	0.04	-	46.61

Table B.17: Annual modal conversion factor reported for product state codes of rig from the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 Quota Management Areas. DRE = Dressed, FIL = Fillets: skin-on, FIN = Fins, FIT = Fish tails, FLP = Flaps, GGU = Gilled and gutted, GRE = Green (or whole), GUT = Gutted, HGT = Headed, gutted, and tailed, HGU = Headed and gutted, LIV = Livers, MEA = Fish meal, SHF = Shark fins, SKF = Fillets: skin-off. – : no observations.

Fishing year	FIL	GGU	GRE	GUT	HGT	HGU	DRE	MEA	FIN	SKF	FLP	SHF	LIV	FIT
1990	2.70	1.10	1.00	1.10	2.00	2.00	-	-	-	-	-	-	-	-
1991	2.70	1.10	1.00	1.10	2.00	2.00	2.00	5.60	-	-	-	-	-	-
1992	2.70	-	1.00	1.10	-	2.00	2.00	5.60	-	-	-	-	-	-
1993	2.30	-	1.00	1.10	-	1.75	1.75	5.60	-	-	-	-	-	-
1994	2.10	-	1.00	1.10	-	1.75	1.75	5.60	30.00	-	-	-	-	-
1995	2.10	-	1.00	1.10	-	1.75	1.75	-	30.00	-	-	-	-	-
1996	2.10	-	1.00	1.10	-	1.75	1.75	5.60	30.00	2.30	-	-	-	-
1997	2.10	-	1.00	1.10	-	1.75	1.75	5.60	30.00	2.30	0.00	-	-	-
1998	2.10	-	1.00	1.10	-	1.75	1.75	-	30.00	2.30	0.00	-	-	-
1999	2.10	-	1.00	1.10	-	1.75	1.75	-	30.00	2.30	-	-	-	-
2000	2.10	-	1.00	1.10	-	1.75	1.75	5.60	30.00	2.30	-	-	-	-
2001	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	0.00	0.00	-	-
2002	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	0.00	0.00	3.85	-
2003	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	0.00	-	0.00
2004	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	0.00	0.00	3.85	-
2005	2.10	-	1.00	1.10	-	1.55	1.55	-	30.00	2.30	0.00	0.00	-	-
2006	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	0.00	-	-
2007	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	0.00	-	-
2008	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	0.00	-	-
2009	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	0.00	-	-
2010	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	0.00	3.85	-
2011	-	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	0.00	3.85	-
2012	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	0.00	-	-
2013	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	0.00	3.85	-
2014	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	0.00	-	-
2015	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	0.00	3.85	-
2016	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	0.00	-	-
2017	2.10	-	1.00	1.10	-	1.55	1.55	5.60	30.00	2.30	-	-	-	-
2018	2.10	-	1.00	1.10	-	1.55	1.55	-	-	2.30	-	0.00	-	-
2019	2.10	-	1.00	1.10	-	1.55	1.55	-	-	2.30	-	0.00	-	-
2020	2.10	-	1.00	1.10	-	1.55	1.55	-	-	2.30	-	-	-	-
2021	-	-	1.00	1.10	-	1.55	1.55	-	-	2.30	-	-	-	-

Table B.18: Reporting forms used for effort on trips landing rig from the SPO 1 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)							
	CEL	TCP	Other	NCE	TCE	ERS - Trawl	ERS - Netting	Total	CEL	TCP	Other	NCE	TCE	ERS - Trawl	ERS - Netting	Total
1990	9 183	493	-	-	-	-	-	9 676	393.89	2.75	-	-	-	-	-	396.63
1991	10 788	310	-	-	-	-	-	11 098	465.22	1.41	-	-	-	-	-	466.62
1992	13 485	626	-	-	-	-	-	14 111	630.82	3.21	-	-	-	-	-	634.03
1993	14 728	1 490	-	-	-	-	-	16 218	624.20	10.25	-	-	-	-	-	634.45
1994	13 230	1 852	-	-	-	-	-	15 082	621.75	12.54	-	-	-	-	-	634.29
1995	11 877	3 770	-	-	-	-	-	15 647	594.89	19.08	-	-	-	-	-	613.97
1996	10 470	9 715	-	-	-	-	-	20 185	534.09	58.57	-	-	-	-	-	592.66
1997	11 571	9 525	1	-	-	-	-	21 097	581.90	50.17	0.00	-	-	-	-	632.07
1998	10 499	11 415	6	-	-	-	-	21 920	536.26	46.64	0.32	-	-	-	-	583.21
1999	10 105	11 812	2	-	-	-	-	21 919	457.94	62.37	0.26	-	-	-	-	520.58
2000	11 176	10 487	3	-	-	-	-	21 666	520.05	53.92	0.13	-	-	-	-	574.11
2001	9 720	11 567	2	-	-	-	-	21 289	494.17	69.60	0.01	-	-	-	-	563.78
2002	7 919	10 154	38	-	-	-	-	18 111	414.35	54.34	0.30	-	-	-	-	468.98
2003	7 904	9 819	12	-	-	-	-	17 735	417.96	72.85	0.00	-	-	-	-	490.81
2004	7 440	10 890	-	-	-	-	-	18 330	430.63	56.48	-	-	-	-	-	487.11
2005	8 144	10 523	-	-	-	-	-	18 667	386.70	50.73	-	-	-	-	-	437.43
2006	8 331	8 214	-	1	-	-	-	16 546	292.01	37.86	-	0.10	-	-	-	329.97
2007	8 048	7 910	3	1 314	-	-	-	17 275	237.92	37.07	0.00	125.67	-	-	-	400.67
2008	3 792	5 809	1 586	1 152	5 254	-	-	17 593	132.07	30.95	6.88	103.01	26.68	-	-	299.59
2009	3 850	5 989	1 783	1 192	5 378	-	-	18 192	124.29	28.56	5.48	113.98	23.78	-	-	296.09
2010	4 515	5 541	1 920	1 112	5 725	-	-	18 813	151.04	28.01	5.82	87.01	34.85	-	-	306.74
2011	4 984	5 588	2 320	1 035	5 347	-	-	19 274	141.70	28.62	6.14	102.92	25.99	-	-	305.36
2012	4 787	6 240	2 020	935	4 732	-	-	18 714	170.74	40.65	4.59	75.72	29.58	-	-	321.28
2013	5 308	5 650	1 799	1 354	5 327	-	-	19 438	161.43	43.21	5.33	123.62	30.25	-	-	363.85
2014	5 209	5 362	1 659	1 242	5 243	-	-	18 715	126.82	51.34	3.83	123.69	42.39	-	-	348.08
2015	4 591	4 908	1 574	1 144	5 389	-	-	17 606	120.79	49.34	3.88	109.91	39.10	-	-	323.02
2016	4 609	4 825	1 729	743	4 895	-	-	16 801	148.18	41.30	4.96	85.72	35.54	-	-	315.70
2017	4 593	5 048	1 570	637	5 112	-	-	16 960	160.44	44.43	3.75	79.05	26.45	-	-	314.11
2018	4 028	2 791	1 301	658	4 610	1 279	-	14 667	146.82	13.90	3.10	76.21	36.14	38.85	-	315.02
2019	2 983	1 148	1 631	442	3 885	2 880	400	13 369	89.60	4.41	5.78	44.51	26.89	39.68	27.97	238.84
2020	191	-	2 790	33	-	7 216	2 923	13 153	19.31	-	8.38	3.02	-	63.55	119.81	214.09
2021	-	-	2 618	-	-	7 265	3 695	13 578	-	-	9.16	-	-	73.97	146.46	229.60

Table B.19: Reporting forms used for effort on trips landing rig from the SPO 2 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)								
	CEL	TCP	Other	NCE	TCE	ERS - Trawl	ERS - Netting	Total	CEL	TCP	Other	NCE	TCE	ERS - Trawl	ERS - Netting	Total
1990	2031	161	-	-	-	-	-	2192	48.39	0.06	-	-	-	-	-	48.45
1991	2256	571	-	-	-	-	-	2827	39.84	1.30	-	-	-	-	-	41.14
1992	3655	1262	-	-	-	-	-	4917	65.65	6.09	-	-	-	-	-	71.75
1993	3842	794	-	-	-	-	-	4636	78.30	4.88	-	-	-	-	-	83.18
1994	3855	1792	-	-	-	-	-	5647	74.04	15.11	-	-	-	-	-	89.15
1995	3700	1861	-	-	-	-	-	5561	65.04	16.83	-	-	-	-	-	81.87
1996	3210	3535	-	-	-	-	-	6745	83.63	25.04	-	-	-	-	-	108.67
1997	3316	3156	-	-	-	-	-	6472	69.16	18.31	-	-	-	-	-	87.47
1998	3436	3225	-	-	-	-	-	6661	63.89	13.25	-	-	-	-	-	77.13
1999	3635	2791	-	-	-	-	-	6426	63.48	15.41	-	-	-	-	-	78.89
2000	3762	2411	-	-	-	-	-	6173	69.17	9.96	-	-	-	-	-	79.13
2001	3728	2946	-	-	-	-	-	6674	72.02	12.67	-	-	-	-	-	84.68
2002	3435	3379	2	-	-	-	-	6816	68.28	20.59	0.09	-	-	-	-	88.96
2003	3374	2921	-	-	-	-	-	6295	66.48	22.73	-	-	-	-	-	89.21
2004	2833	2698	28	-	-	-	-	5559	53.21	30.39	0.00	-	-	-	-	83.60
2005	3209	2647	1	-	-	-	-	5857	80.81	25.85	0.00	-	-	-	-	106.66
2006	3312	2439	-	-	-	-	-	5751	89.65	22.53	-	-	-	-	-	112.18
2007	3162	2855	171	354	-	-	-	6542	60.08	24.26	0.02	15.17	-	-	-	99.53
2008	150	2118	288	482	7207	-	-	10245	2.28	22.00	0.43	18.58	57.47	-	-	100.76
2009	127	1975	349	648	6604	-	-	9703	1.69	18.25	0.55	36.86	53.34	-	-	110.70
2010	169	2366	299	566	7690	-	-	11090	2.27	24.72	0.47	24.95	59.81	-	-	112.22
2011	315	1693	269	383	8015	-	-	10675	3.52	15.53	0.28	22.85	62.16	-	-	104.34
2012	359	1148	110	400	7316	-	-	9333	5.66	6.31	0.05	33.04	72.07	-	-	117.12
2013	292	506	129	359	7964	-	-	9250	3.53	2.24	0.17	22.61	78.43	-	-	106.99
2014	145	1509	162	289	7817	-	-	9922	1.31	10.43	0.15	27.58	88.17	-	-	127.65
2015	144	1171	179	419	6896	-	-	8809	6.66	10.31	0.15	27.90	71.87	-	-	116.88
2016	191	809	217	252	6487	-	-	7956	5.67	6.70	0.15	15.29	79.52	-	-	107.33
2017	163	1152	109	178	6237	-	-	7839	6.77	10.05	0.17	8.51	74.14	-	-	99.63
2018	223	460	117	277	6381	285	-	7743	7.86	2.45	0.08	7.89	67.97	2.29	-	88.55
2019	97	187	153	213	4215	1921	81	6867	0.85	0.26	1.01	19.57	54.15	22.52	2.44	100.81
2020	-	-	262	-	224	5253	624	6363	-	-	3.44	-	5.19	78.14	30.10	116.87
2021	-	-	378	-	-	4935	721	6034	-	-	6.07	-	-	73.60	29.83	109.50

Table B.20: Reporting forms used for effort on trips landing rig from the SPO 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)						
	CEL	TCP	Other	NCE	TCE	ERS - Trawl	ERS - Netting	Total	CEL	TCP	Other	NCE	TCE	ERS - Trawl	ERS - Netting	Total
1990	4543	2693	-	-	-	-	-	7236	207.37	10.78	-	-	-	-	-	218.14
1991	5603	3803	-	-	-	-	-	9406	239.16	34.14	-	-	-	-	-	273.30
1992	6341	3816	-	-	-	-	-	10157	261.20	57.58	-	-	-	-	-	318.78
1993	6222	2855	-	-	-	-	-	9077	247.15	9.86	-	-	-	-	-	257.01
1994	7025	2322	5	-	-	-	-	9352	300.78	6.24	0.00	-	-	-	-	307.02
1995	7689	2263	16	-	-	-	-	9968	377.55	22.03	0.10	-	-	-	-	399.69
1996	6440	3141	8	-	-	-	-	9589	382.52	19.71	0.01	-	-	-	-	402.24
1997	7274	2977	3	-	-	-	-	10254	406.79	15.97	0.02	-	-	-	-	422.77
1998	7008	3155	-	-	-	-	-	10163	413.12	11.12	-	-	-	-	-	424.23
1999	6487	4098	-	-	-	-	-	10585	394.75	4.18	-	-	-	-	-	398.93
2000	6769	5335	-	-	-	-	-	12104	384.62	23.37	-	-	-	-	-	407.99
2001	7379	4479	-	-	-	-	-	11858	473.03	10.89	-	-	-	-	-	483.92
2002	6521	4948	-	-	-	-	-	11469	394.83	16.79	-	-	-	-	-	411.62
2003	6834	6416	-	-	-	-	-	13250	428.73	17.66	-	-	-	-	-	446.40
2004	6106	5484	250	-	-	-	-	11840	370.31	8.79	0.04	-	-	-	-	379.14
2005	6494	4857	346	-	-	-	-	11697	368.50	11.08	0.00	-	-	-	-	379.58
2006	6591	4229	156	-	-	-	-	10976	373.53	11.63	0.05	-	-	-	-	385.21
2007	4944	3847	195	2608	-	-	-	11594	162.57	10.36	0.00	283.57	-	-	-	456.51
2008	583	2701	353	2760	10043	-	-	16440	34.46	12.42	1.99	360.31	69.61	-	-	478.79
2009	587	2371	464	2123	10023	-	-	15568	38.53	2.66	0.24	206.55	85.83	-	-	333.81
2010	484	2620	569	2566	12088	-	-	18327	42.54	3.34	0.04	222.41	103.60	-	-	371.94
2011	618	2399	450	2674	11081	-	-	17222	56.94	5.40	2.02	230.68	94.08	-	-	389.13
2012	679	1322	374	2705	11212	-	-	16292	71.02	1.64	0.21	239.56	121.72	-	-	434.16
2013	855	2125	379	2478	12450	-	-	18287	93.39	2.23	0.19	251.11	114.39	-	-	461.31
2014	832	1762	556	2369	13444	-	-	18963	86.25	4.03	0.21	239.18	155.61	-	-	485.28
2015	799	1821	711	2498	11282	-	-	17111	78.64	2.76	10.73	298.74	153.49	-	-	544.37
2016	673	2364	266	2752	10878	-	-	16933	104.34	6.64	1.36	285.39	155.96	-	-	553.70
2017	580	3230	424	2659	11855	-	-	18748	86.72	8.34	0.03	279.95	162.93	-	-	537.96
2018	565	631	462	2207	11529	2862	-	18256	95.79	3.40	9.34	322.09	202.43	5.05	-	638.11
2019	357	253	1052	2146	8602	6798	423	19631	51.88	1.27	37.41	312.48	146.06	41.73	12.85	603.68
2020	-	-	1451	1	86	15204	3341	20083	-	-	81.26	0.34	0.47	189.72	394.15	665.95
2021	-	-	1373	-	-	15040	3024	19437	-	-	92.27	-	-	220.82	332.96	646.05

Table B.21: Reporting forms used for effort on trips landing rig from the SPO 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)								
	CEL	TCP	NCE	Other	TCE	ERS - Trawl	ERS - Netting	Total	CEL	TCP	NCE	Other	TCE	ERS - Trawl	ERS - Netting	Total		
1990	4549	1334	-	-	-	-	-	5883	230.41	8.48	-	-	-	-	-	-	238.89	
1991	5099	608	-	-	-	-	-	5707	214.21	1.87	-	-	-	-	-	-	216.08	
1992	5237	808	-	-	-	-	-	6045	225.48	5.30	-	-	-	-	-	-	230.78	
1993	6562	846	-	-	-	-	-	7408	285.56	3.76	-	-	-	-	-	-	289.32	
1994	5554	1354	-	-	-	-	-	6908	262.55	13.92	-	-	-	-	-	-	276.47	
1995	6680	1272	-	-	-	-	-	7952	323.01	17.19	-	-	-	-	-	-	340.20	
1996	6221	1640	-	-	-	-	-	7861	353.51	16.31	-	-	-	-	-	-	369.81	
1997	6837	1531	-	-	-	-	-	8368	344.81	7.58	-	-	-	-	-	-	352.39	
1998	5295	1001	-	-	-	-	-	6296	271.06	18.52	-	-	-	-	-	-	289.58	
1999	6101	1450	-	-	-	-	-	7551	311.73	6.86	-	-	-	-	-	-	318.60	
2000	5339	1408	-	-	-	-	-	6747	294.08	9.63	-	-	-	-	-	-	303.71	
2001	5304	1276	-	-	-	-	-	6580	342.58	6.16	-	-	-	-	-	-	348.74	
2002	4660	1626	-	-	-	-	-	6286	274.50	14.46	-	-	-	-	-	-	288.96	
2003	5168	1976	-	-	-	-	-	7144	257.94	10.70	-	-	-	-	-	-	268.63	
2004	6056	1236	-	-	-	-	-	7292	279.88	9.01	-	-	-	-	-	-	288.89	
2005	5701	1335	-	-	-	-	-	7036	255.71	7.98	-	-	-	-	-	-	263.69	
2006	5302	1170	-	-	-	-	-	6472	281.20	9.98	-	-	-	-	-	-	291.18	
2007	4793	1794	626	3	-	-	-	7216	114.61	9.91	142.21	0.00	-	-	-	-	266.74	
2008	560	1142	433	31	11867	-	-	14033	9.12	56.03	115.44	0.00	114.15	-	-	-	294.75	
2009	715	772	386	122	11834	-	-	13829	27.14	1.60	86.84	1.22	118.76	-	-	-	235.55	
2010	448	558	321	39	14266	-	-	15632	20.88	0.19	85.86	0.14	124.69	-	-	-	231.77	
2011	252	449	321	135	12420	-	-	13577	4.06	0.97	107.17	0.33	121.65	-	-	-	234.19	
2012	436	295	340	68	12475	-	-	13614	6.61	0.85	106.52	0.00	117.71	-	-	-	231.68	
2013	332	369	294	159	13036	-	-	14190	4.81	1.24	97.92	0.11	139.79	-	-	-	243.87	
2014	314	841	292	83	11831	-	-	13361	5.15	3.10	86.22	0.10	143.64	-	-	-	238.21	
2015	280	995	292	93	11061	-	-	12721	9.59	1.50	81.67	0.17	157.06	-	-	-	249.99	
2016	251	600	326	50	11772	-	-	12999	7.13	0.80	86.25	0.13	162.45	-	-	-	256.75	
2017	249	1212	276	83	11379	-	-	13199	16.48	1.87	91.19	0.06	169.04	-	-	-	278.64	
2018	226	38	216	86	10080	925	-	11571	12.19	0.12	79.86	0.04	172.54	2.12	-	-	266.87	
2019	237	19	221	182	7530	3398	1	11588	7.62	0.00	81.70	2.56	166.70	30.58	0.01	289.19		
2020	4	-	2	426	-	10156	117	10705	0.00	-	2.10	12.05	-	204.95	66.75	285.85		
2021	-	-	-	335	-	10075	60	10470	-	-	14.14	-	261.88	14.99	291.01			

Table B.22: Reporting forms used for effort on trips landing rig from the SPO 8 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)						
	CEL	TCP	Other	NCE	TCE	ERS - Trawl	ERS - Netting	Total	CEL	TCP	Other	NCE	TCE	ERS - Trawl	ERS - Netting	Total	
1990	1696	319	-	-	-	-	-	2015	134.20	6.30	-	-	-	-	-	140.50	
1991	1739	237	-	-	-	-	-	1976	117.63	0.84	-	-	-	-	-	118.46	
1992	1697	445	-	-	-	-	-	2142	92.64	1.40	-	-	-	-	-	94.03	
1993	2301	494	-	-	-	-	-	2795	181.83	2.26	-	-	-	-	-	184.09	
1994	2098	536	-	-	-	-	-	2634	206.05	4.04	-	-	-	-	-	210.09	
1995	2093	491	-	-	-	-	-	2584	230.35	2.01	-	-	-	-	-	232.36	
1996	1892	552	2	-	-	-	-	2446	256.24	6.82	0.00	-	-	-	-	263.06	
1997	1588	797	-	-	-	-	-	2385	189.22	22.40	-	-	-	-	-	211.62	
1998	1487	1075	-	-	-	-	-	2562	177.48	18.56	-	-	-	-	-	196.04	
1999	1498	661	-	-	-	-	-	2159	165.22	10.84	-	-	-	-	-	176.06	
2000	1384	883	-	-	-	-	-	2267	136.92	12.33	-	-	-	-	-	149.25	
2001	1270	884	-	-	-	-	-	2154	132.10	8.24	-	-	-	-	-	140.35	
2002	1223	1336	-	-	-	-	-	2559	171.82	14.94	-	-	-	-	-	186.76	
2003	1417	1172	-	-	-	-	-	2589	171.57	9.68	-	-	-	-	-	181.25	
2004	1254	1118	-	-	-	-	-	2372	144.63	12.57	-	-	-	-	-	157.20	
2005	1094	885	-	-	-	-	-	1979	142.36	10.97	-	-	-	-	-	153.33	
2006	913	1124	-	4	-	-	-	2041	124.77	11.32	-	1.42	-	-	-	137.51	
2007	426	932	-	551	-	-	-	1909	25.48	12.93	-	129.87	-	-	-	168.28	
2008	172	499	66	808	996	-	-	2541	16.84	3.78	0.19	179.24	22.23	-	-	222.28	
2009	431	248	165	767	1348	-	-	2959	44.15	2.67	0.15	141.47	21.26	-	-	209.69	
2010	262	174	90	816	1572	-	-	2914	8.77	1.92	0.13	200.68	25.05	-	-	236.54	
2011	203	184	145	835	1614	-	-	2981	9.70	1.14	0.07	167.68	33.27	-	-	211.86	
2012	191	422	148	796	1651	-	-	3208	5.57	2.24	0.11	152.88	32.54	-	-	193.33	
2013	163	242	213	692	1315	-	-	2625	2.36	2.25	0.16	92.31	22.05	-	-	119.13	
2014	183	257	195	729	1478	-	-	2842	2.84	1.91	0.42	158.47	27.04	-	-	190.68	
2015	261	253	170	662	1259	-	-	2605	4.04	1.65	0.40	145.11	36.53	-	-	187.73	
2016	121	193	126	647	1198	-	-	2285	2.46	1.17	0.32	148.02	27.51	-	-	179.48	
2017	149	144	99	608	1046	-	-	2046	4.32	1.51	0.15	164.49	24.03	-	-	194.49	
2018	142	-	106	553	1130	208	-	2139	0.93	-	0.13	122.52	31.48	3.91	-	158.97	
2019	193	-	161	439	860	697	111	2461	2.46	-	0.16	101.92	20.81	14.86	3.01	143.21	
2020	1	-	353	15	-	1655	681	2705	0.01	-	1.38	2.82	-	39.60	75.27	119.08	
2021	-	-	327	-	-	1664	188	2179	-	-	7.28	-	-	34.04	5.14	46.46	

Table B.23: Allocated catches (t) of rig in SPO 1 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	SN	Other	Total
1990	6.85	81.46	7.37	285.02	15.93	396.63
1991	7.84	73.64	15.15	353.75	16.25	466.62
1992	15.90	98.38	19.68	483.81	16.26	634.03
1993	19.35	102.11	22.81	479.44	10.73	634.45
1994	70.39	88.65	22.86	441.60	10.80	634.29
1995	24.22	73.48	20.26	481.20	14.81	613.97
1996	66.35	80.69	19.20	413.47	12.95	592.66
1997	18.59	78.71	18.78	510.63	5.37	632.07
1998	20.06	67.18	10.82	481.02	4.14	583.21
1999	22.52	78.81	11.27	394.76	13.22	520.58
2000	27.07	77.84	10.05	450.22	8.92	574.11
2001	23.55	74.04	10.42	445.31	10.45	563.78
2002	13.78	68.36	8.76	375.13	2.96	468.98
2003	11.16	71.23	7.85	385.81	14.76	490.81
2004	7.28	53.59	10.89	406.19	9.17	487.11
2005	8.08	56.27	7.61	358.56	6.91	437.43
2006	7.25	51.70	10.43	251.43	9.15	329.97
2007	11.43	46.04	15.72	314.51	12.96	400.67
2008	6.95	51.98	16.35	216.94	7.37	299.59
2009	5.49	48.41	17.76	218.18	6.25	296.09
2010	5.82	56.61	18.08	217.53	8.70	306.74
2011	6.14	51.20	19.74	221.46	6.83	305.36
2012	4.59	69.90	15.93	226.58	4.28	321.28
2013	5.33	73.44	17.16	264.36	3.56	363.85
2014	3.83	93.40	10.38	236.70	3.77	348.08
2015	3.88	87.87	10.16	218.61	2.51	323.02
2016	4.96	69.45	10.56	220.28	10.46	315.70
2017	3.75	60.53	5.38	230.36	14.10	314.11
2018	3.11	58.60	5.69	215.28	32.35	315.02
2019	3.80	52.10	5.90	154.39	22.65	238.84
2020	2.84	55.94	5.54	132.74	17.03	214.09
2021	2.84	63.58	6.32	135.24	21.63	229.60

Table B.24: Allocated catches (t) of rig in SPO 2 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	SN	DS	Other	Total
1990	0.08	31.72	15.97	-	0.67	48.45
1991	0.20	26.25	14.03	0.07	0.59	41.14
1992	0.24	53.33	17.88	-	0.30	71.75
1993	0.28	60.87	21.72	0.06	0.25	83.18
1994	0.41	55.64	30.86	-	2.24	89.15
1995	0.05	56.30	19.19	0.67	5.66	81.87
1996	0.26	64.70	34.96	2.22	6.53	108.67
1997	0.04	61.17	23.23	0.81	2.21	87.47
1998	0.03	54.31	18.13	0.33	4.34	77.13
1999	0.12	54.12	21.40	0.87	2.38	78.89
2000	0.38	50.25	24.32	2.16	2.02	79.13
2001	0.08	53.68	23.84	5.09	2.00	84.68
2002	0.07	57.28	25.30	3.70	2.61	88.96
2003	0.01	72.60	15.98	0.07	0.54	89.21
2004	0.03	67.55	14.19	0.09	1.74	83.60
2005	0.16	87.31	18.22	0.03	0.95	106.66
2006	0.10	96.36	15.44	0.00	0.28	112.18
2007	0.47	80.25	18.20	0.37	0.24	99.53
2008	0.43	79.84	19.69	0.56	0.24	100.76
2009	0.55	71.58	38.54	0.00	0.03	110.70
2010	0.47	84.50	26.47	0.72	0.06	112.22
2011	0.28	77.69	24.44	1.86	0.07	104.34
2012	0.05	78.23	34.85	3.78	0.21	117.12
2013	0.17	80.61	24.39	1.49	0.32	106.99
2014	0.15	98.49	28.85	-	0.15	127.65
2015	0.15	82.10	29.39	5.14	0.09	116.88
2016	0.15	86.04	17.67	3.22	0.25	107.33
2017	0.16	82.78	10.40	4.87	1.42	99.63
2018	0.08	65.24	9.86	5.88	7.49	88.55
2019	0.03	76.34	22.84	1.00	0.59	100.81
2020	0.07	83.19	30.10	3.37	0.14	116.87
2021	0.20	73.38	29.83	5.79	0.30	109.50

Table B.25: Allocated catches (t) of rig in SPO 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	SN	DS	Other	Total
1990	0.00	53.62	164.23	-	0.29	218.14
1991	0.05	88.29	182.06	-	2.89	273.30
1992	1.05	102.73	195.86	-	19.15	318.78
1993	0.11	91.31	165.32	0.00	0.27	257.01
1994	0.25	93.91	212.09	-	0.77	307.02
1995	8.82	88.74	288.03	-	14.09	399.69
1996	0.57	106.52	289.28	0.02	5.86	402.24
1997	0.41	99.83	314.37	-	8.17	422.77
1998	2.16	97.89	323.60	-	0.59	424.23
1999	4.23	72.09	322.32	-	0.29	398.93
2000	0.06	108.80	298.64	0.02	0.45	407.99
2001	0.00	122.51	354.53	-	6.88	483.92
2002	0.01	104.05	306.90	-	0.66	411.62
2003	0.05	117.63	326.05	2.45	0.22	446.40
2004	0.12	104.45	269.08	5.30	0.19	379.14
2005	0.02	101.80	263.49	13.93	0.34	379.58
2006	1.60	93.42	273.70	15.20	1.29	385.21
2007	1.22	110.46	323.72	20.82	0.29	456.51
2008	2.00	82.77	361.00	32.70	0.32	478.79
2009	0.25	88.92	212.23	32.31	0.11	333.81
2010	0.04	106.97	225.41	39.28	0.23	371.94
2011	6.26	99.37	238.15	44.66	0.67	389.13
2012	2.66	123.44	245.56	62.17	0.33	434.16
2013	3.08	116.86	285.72	55.37	0.28	461.31
2014	3.68	160.40	266.38	53.16	1.66	485.28
2015	11.79	156.35	318.20	57.65	0.39	544.37
2016	1.36	162.33	308.90	80.53	0.57	553.70
2017	1.20	170.93	283.43	81.62	0.77	537.96
2018	10.65	210.47	324.15	91.82	1.02	638.11
2019	4.85	188.89	327.40	82.14	0.40	603.68
2020	2.06	189.61	394.50	78.73	1.05	665.95
2021	0.10	220.69	332.96	91.90	0.40	646.05

Table B.26: Allocated catches (t) of rig in SPO 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	SN	DS	Other	Total
1990	3.61	98.91	130.63	-	5.74	238.89
1991	2.04	81.53	126.62	-	5.90	216.08
1992	0.18	79.53	149.76	-	1.31	230.78
1993	1.23	100.04	187.07	-	0.99	289.32
1994	0.91	91.79	171.56	-	12.21	276.47
1995	1.34	136.21	199.38	-	3.26	340.20
1996	0.15	122.42	241.65	-	5.59	369.81
1997	0.66	143.29	205.85	-	2.60	352.39
1998	0.21	100.62	185.28	-	3.48	289.58
1999	0.25	126.79	189.75	-	1.80	318.60
2000	0.79	122.68	174.94	-	5.30	303.71
2001	0.03	129.97	216.11	-	2.63	348.74
2002	0.02	113.29	171.18	-	4.47	288.96
2003	0.42	93.52	169.76	-	4.93	268.63
2004	2.06	96.79	187.14	-	2.91	288.89
2005	0.08	102.31	160.24	0.05	1.01	263.69
2006	0.17	109.24	180.49	0.48	0.79	291.18
2007	0.16	106.05	157.75	0.76	2.00	266.74
2008	0.02	173.56	115.48	5.19	0.51	294.75
2009	1.26	123.23	103.39	7.52	0.15	235.55
2010	0.15	125.69	94.76	11.01	0.15	231.77
2011	0.34	122.55	107.33	3.86	0.10	234.19
2012	0.05	118.22	106.77	6.19	0.45	231.68
2013	0.13	141.01	98.12	4.55	0.08	243.87
2014	0.22	145.90	86.42	4.82	0.85	238.21
2015	0.29	154.07	81.85	9.27	4.52	249.99
2016	0.13	162.97	86.58	6.75	0.32	256.75
2017	0.07	170.39	91.27	16.36	0.54	278.64
2018	0.05	174.72	79.91	12.05	0.14	266.87
2019	0.54	197.21	81.76	9.49	0.18	289.19
2020	0.06	204.86	68.85	11.98	0.10	285.85
2021	0.02	261.82	14.99	14.11	0.07	291.01

Table B.27: Allocated catches (t) of rig in SPO 8 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	SN	DS	Other	Total
1990	0.82	25.53	110.73	-	3.41	140.50
1991	0.77	12.10	101.89	-	3.71	118.46
1992	0.71	9.13	79.29	-	4.91	94.03
1993	1.32	9.88	164.45	-	8.45	184.09
1994	0.78	9.72	191.34	-	8.25	210.09
1995	0.84	16.26	206.30	-	8.96	232.36
1996	1.01	22.28	236.66	-	3.12	263.06
1997	0.87	36.91	170.05	-	3.79	211.62
1998	1.36	28.17	165.63	0.00	0.87	196.04
1999	0.25	23.83	151.65	-	0.32	176.06
2000	0.33	25.54	123.20	-	0.18	149.25
2001	0.63	14.42	124.63	-	0.67	140.35
2002	0.51	30.45	155.45	-	0.34	186.76
2003	0.59	24.80	155.71	-	0.15	181.25
2004	0.12	21.48	135.50	-	0.10	157.20
2005	0.08	17.15	135.83	-	0.27	153.33
2006	0.06	17.53	119.64	-	0.28	137.51
2007	0.19	18.68	143.33	6.00	0.09	168.28
2008	0.21	25.96	185.03	10.82	0.26	222.28
2009	0.21	24.16	182.70	2.56	0.07	209.69
2010	0.19	26.89	208.17	1.14	0.15	236.54
2011	0.08	34.41	174.58	2.74	0.05	211.86
2012	0.14	34.77	155.20	3.20	0.03	193.33
2013	0.17	24.29	94.09	0.56	0.02	119.13
2014	0.46	28.15	161.26	-	0.81	190.68
2015	0.40	38.17	148.95	-	0.21	187.73
2016	0.36	28.66	150.39	-	0.06	179.48
2017	0.17	25.52	168.70	-	0.11	194.49
2018	0.16	35.13	123.39	-	0.29	158.97
2019	0.25	35.16	107.28	-	0.52	143.21
2020	1.39	38.91	78.09	-	0.69	119.08
2021	7.28	33.22	5.14	-	0.83	46.46

APPENDIX C: COMPOSITION DATA

This appendix summarises available data on the composition of rig catches.

C.1 Observer length-frequency data

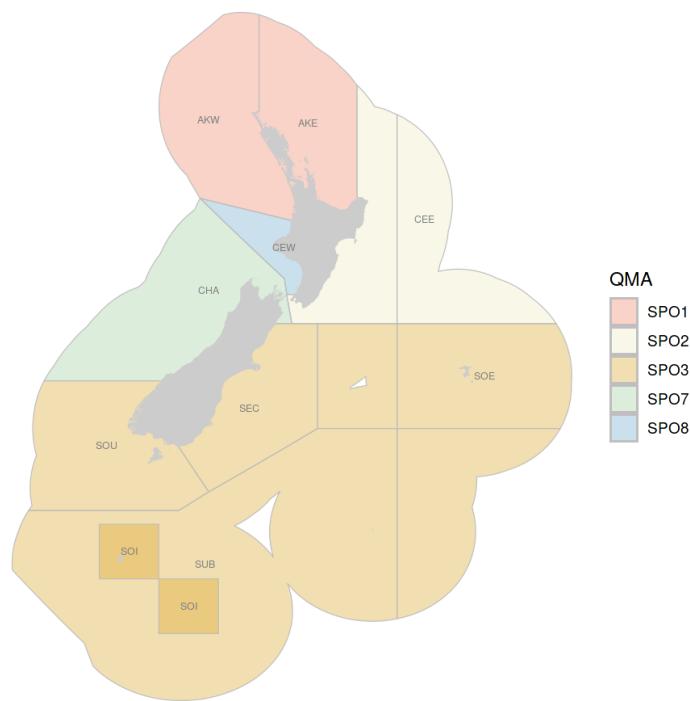


Figure C.1: Observer Fisheries Management Areas in relation to the Quota Management Areas (QMA) for rig.

Table C.1: Length-frequency samples of rig by area and method, sampled by the Observer Programme from fishing years 1995 to 2021. Observer Fisheries Management Area (FMA) codes and method codes are defined in the glossary.

QMA	Observer FMA	Method	Sampled events	Number of fish
SPO1	AKE	BLL	39	99
SPO1	AKE	BT	76	227
SPO1	AKE	PRB	6	29
SPO1	AKW	BT	185	1 045
SPO1	AKW	PRB	19	245
SPO1	AKW	SN	18	432
SPO2	CEE	BT	82	741
SPO3	SEC	BT	160	1 380
SPO3	SEC	MW	1	2
SPO3	SEC	POT	3	59
SPO3	SEC	SN	284	7 618
SPO3	SOU	BT	15	157
SPO3	SOU	SN	169	2 822
SPO7	CHA	BT	133	1 175
SPO7	CHA	MW	2	18
SPO8	CEW	MW	1	3
SPO8	CEW	SN	99	1 792

C.1.1 Length composition by area and method

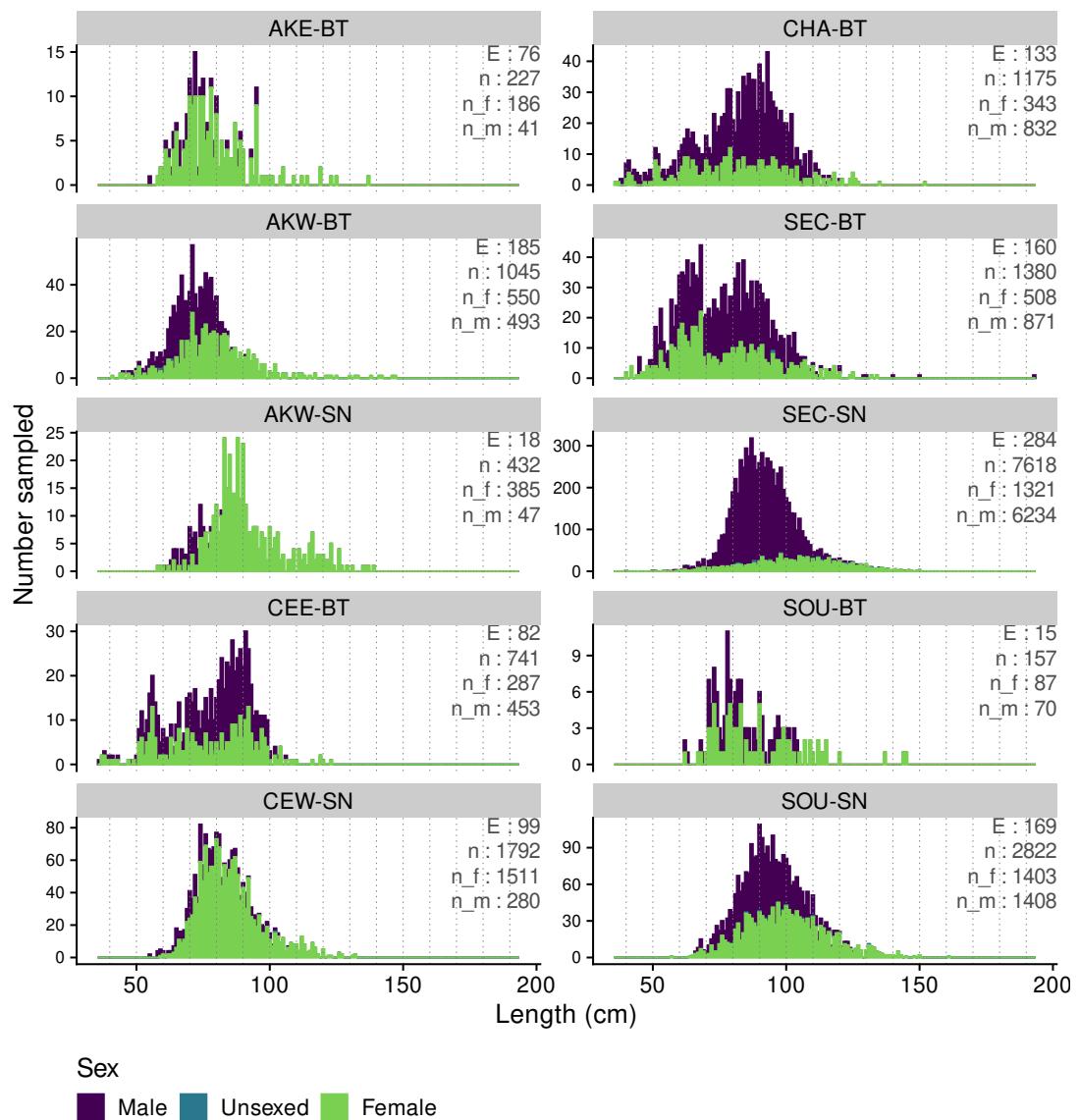


Figure C.2: Length-frequency distributions of rig for the AKE, AKW, CEE, CEW, CHA, SEC, SOU areas by fishing method. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area-method. Only area-methods with at least 100 fish measurements are included. The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

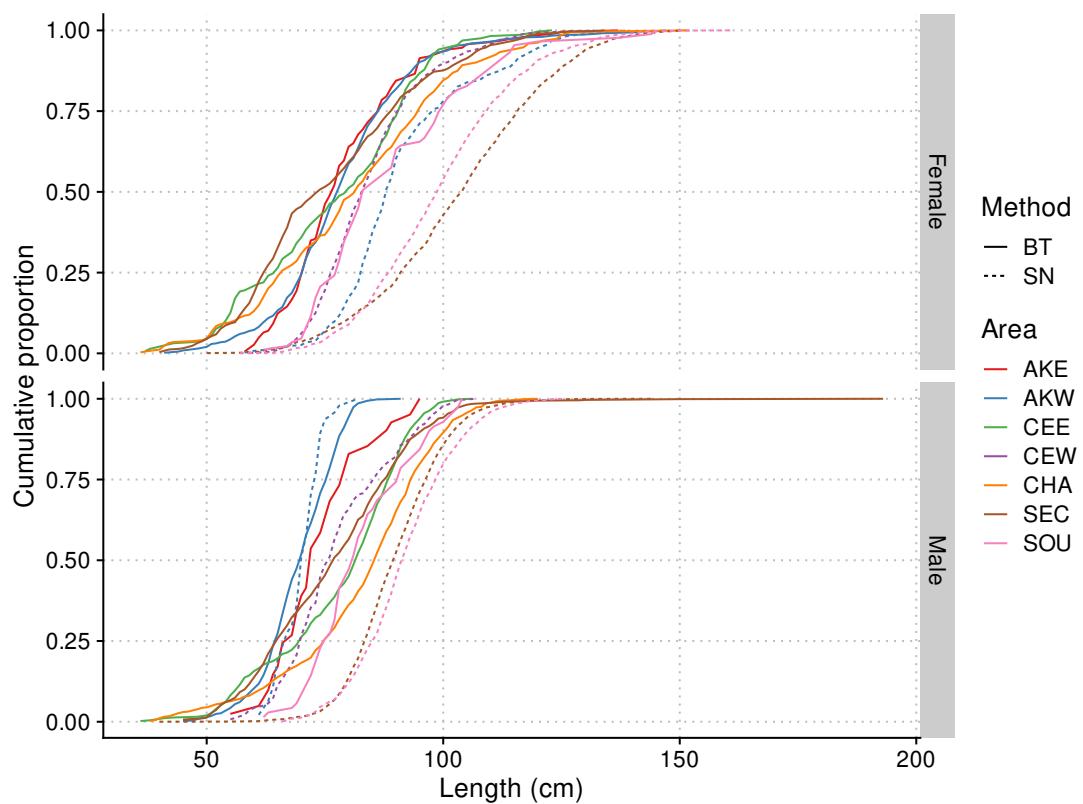


Figure C.3: Cumulative length-frequency distributions of rig for the AKE, AKW, CEE, CEW, CHA, SEC, SOU area by fishing method, using raw, unscaled observer samples.

C.1.2 The bottom trawl fishery

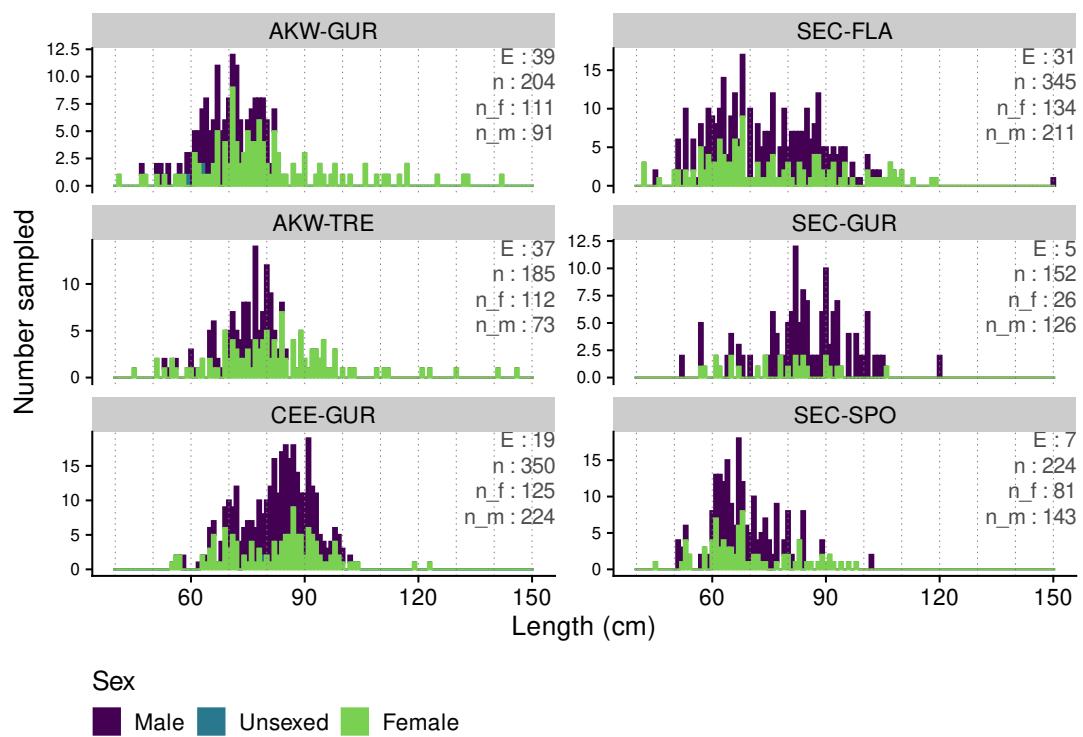


Figure C.4: Length-frequency distributions for rig caught in the bottom trawl fishery, by area, target species, and sex. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area-target and sex. Only area-targets at least 100 fish measurements are included.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

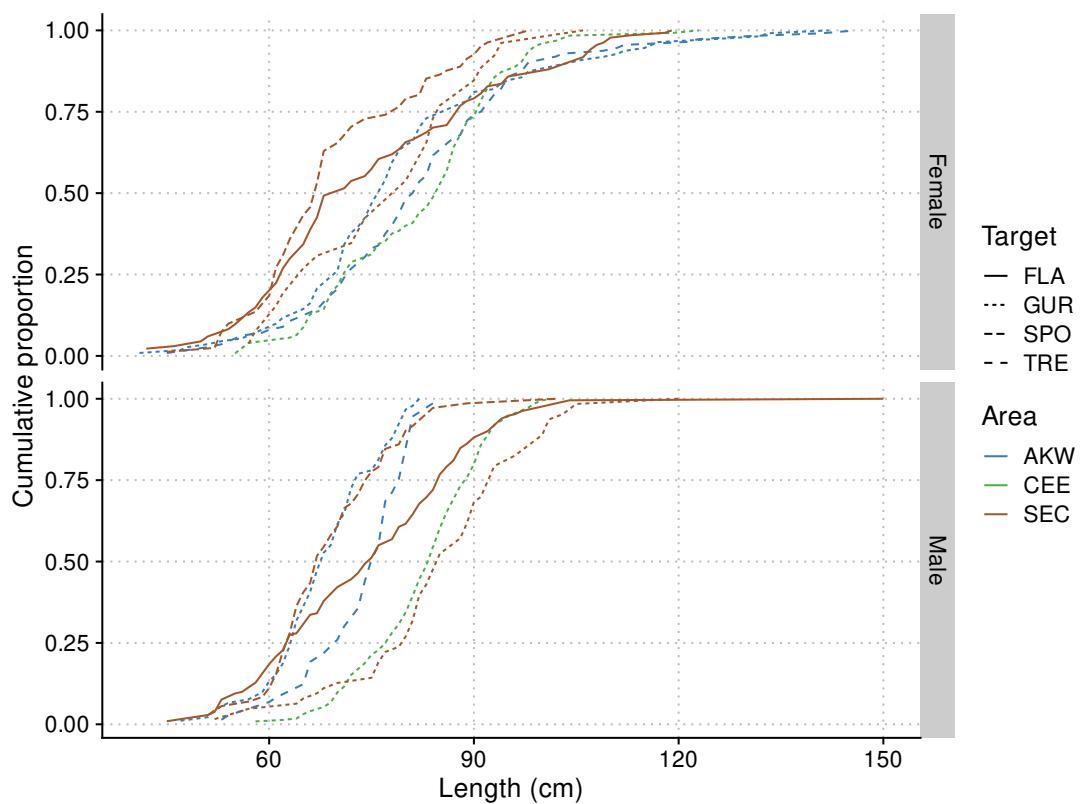


Figure C.5: Cumulative length-frequency distributions for rig caught in the bottom trawl fishery, by area and target species. Only area-targets at least 100 fish measurements are included. Observer area codes are defined in the glossary.

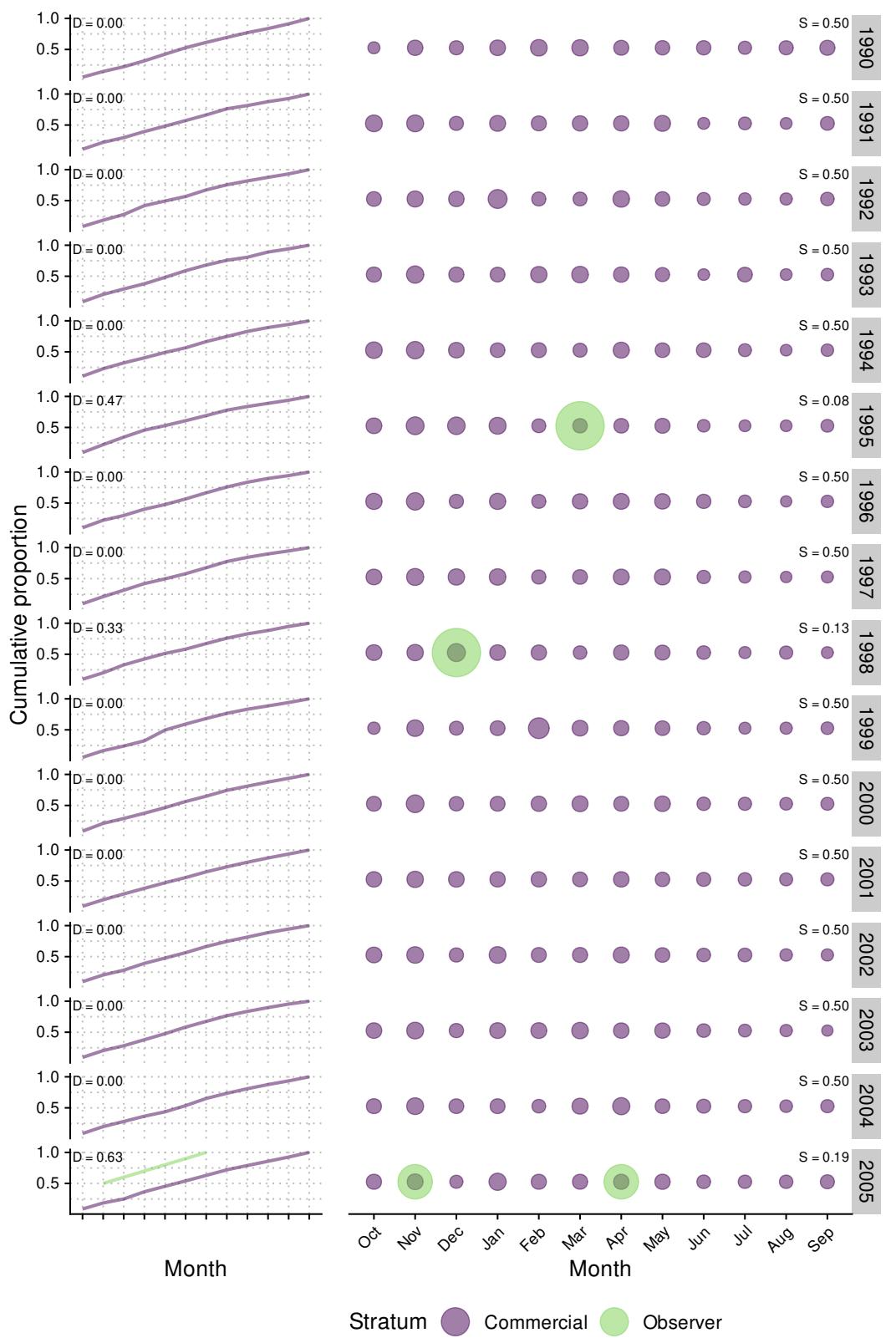


Figure C.6: Representativeness of observer sampling coverage of bottom trawl fishing events that caught rig in 1990 to 2005 by fishing year and month. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a month, with proportions summing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

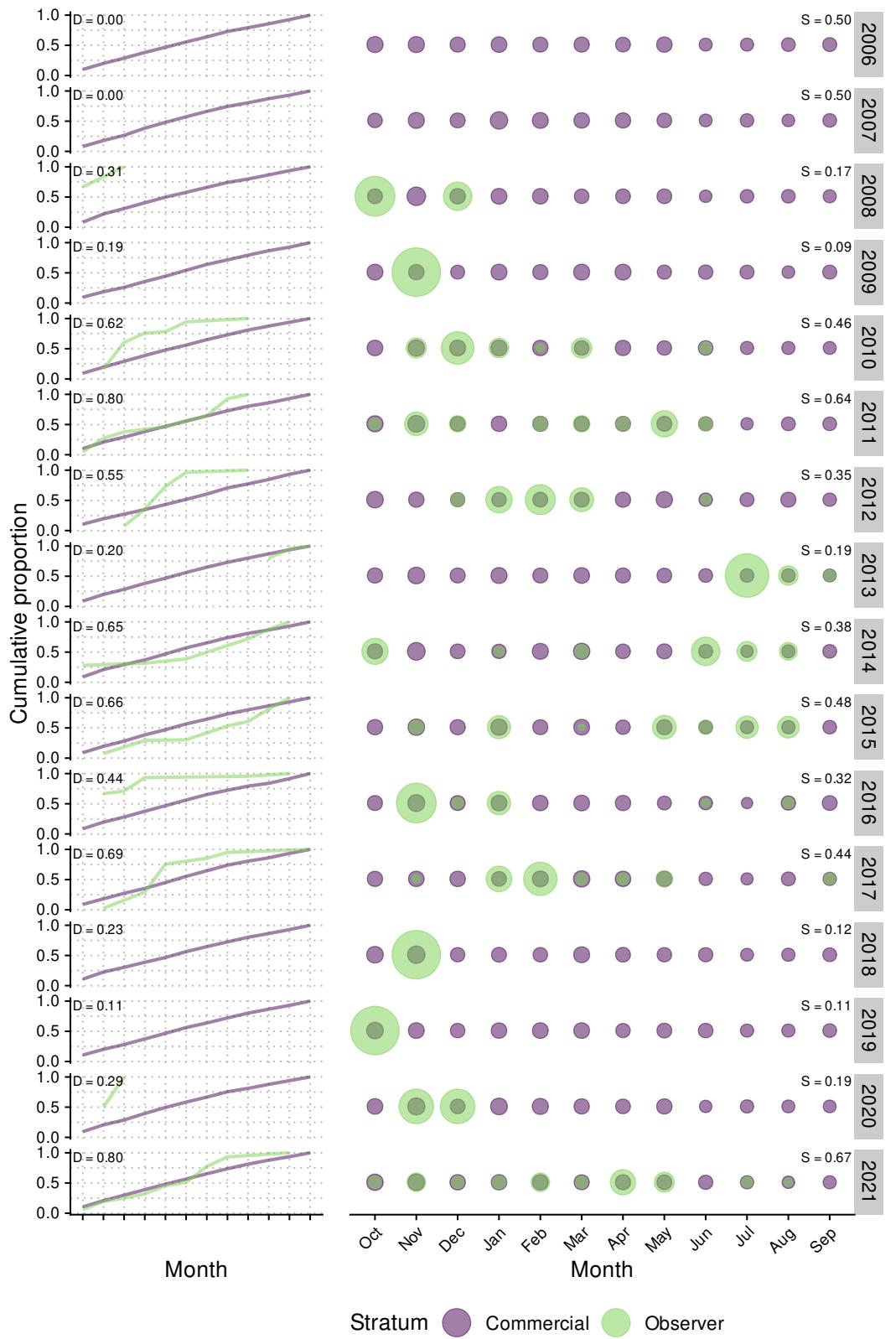


Figure C.7: Representativeness of observer sampling coverage of bottom trawl fishing events that caught rig in 2006 to 2021 by fishing year and month. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a month, with proportions summing to one within each fishing year. D: Kolmogorov-Smirnov maximum absolute difference; S: Manhattan block distance.

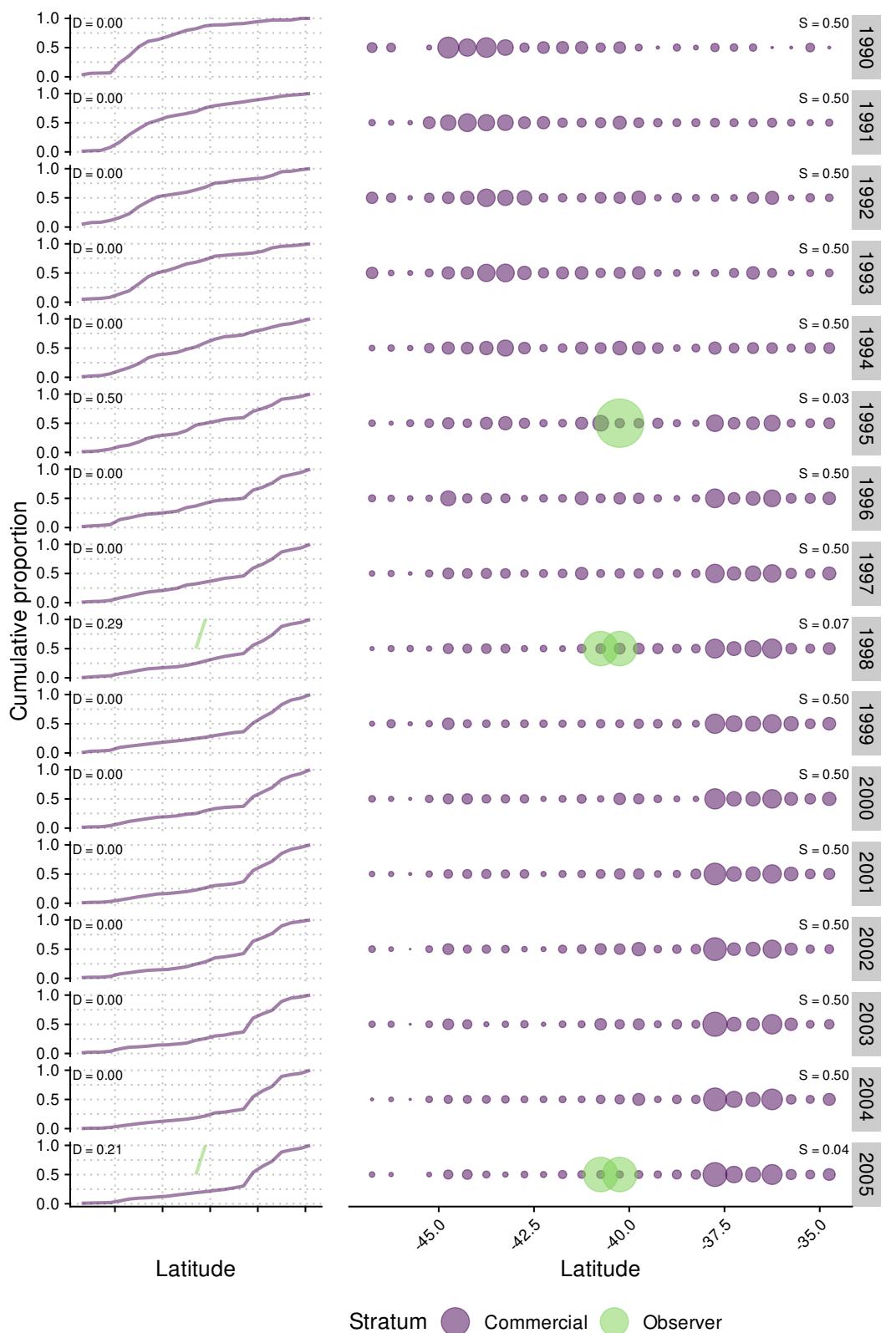


Figure C.8: Representativeness of observer sampling coverage of bottom trawl fishing events that caught rig in 1990 to 2005 by fishing year and latitude. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a latitude bin, with proportions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

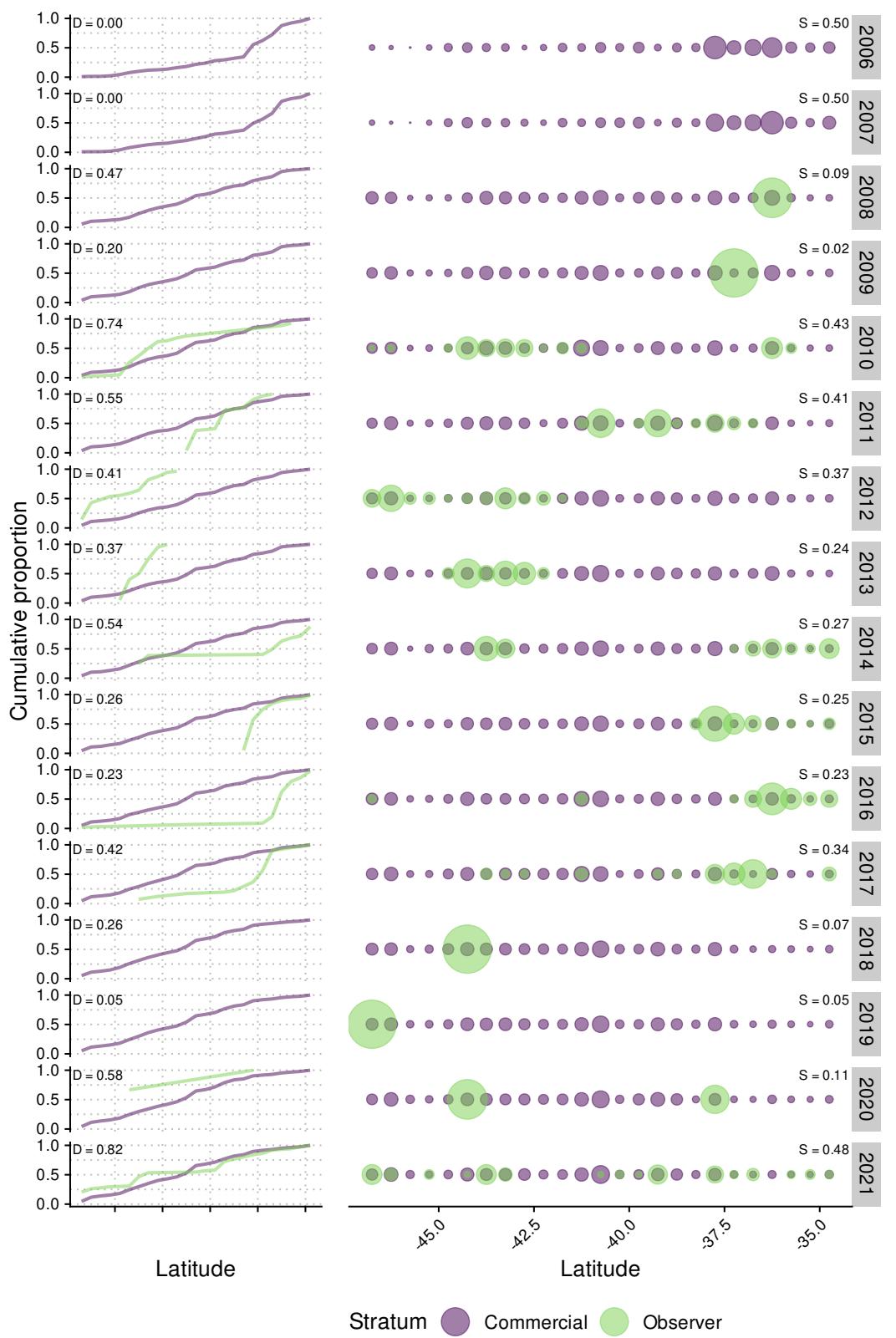


Figure C.9: Representativeness of observer sampling coverage of bottom trawl fishing events that caught rig in 2006 to 2021 by fishing year and latitude. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a latitude bin, with proportions summing to one within each fishing year.

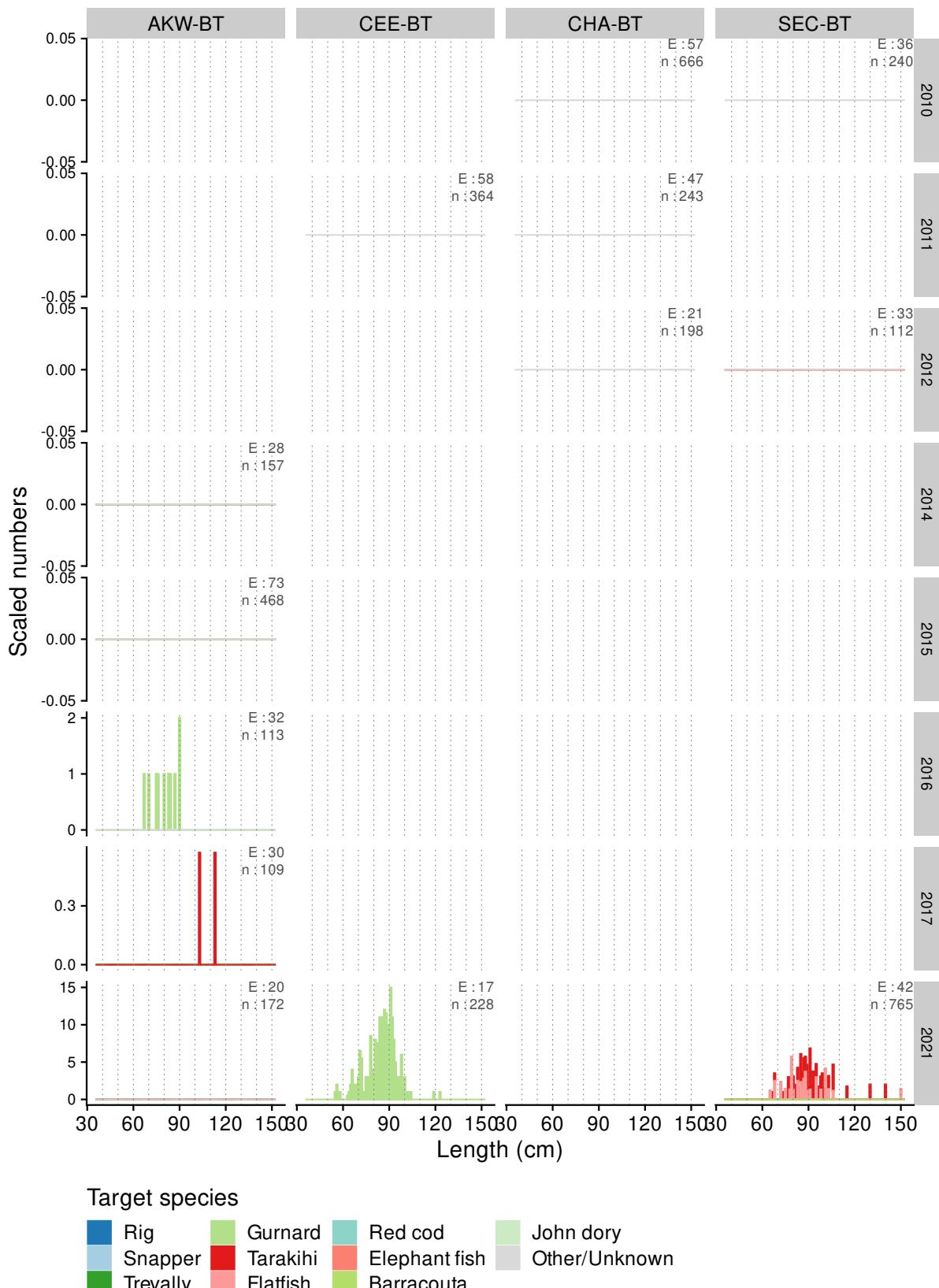


Figure C.10: Length-frequency distributions for rig caught in the bottom trawl fishery, by area, fishing year, and target species. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area, target and year. Sampled numbers are scaled to the catch weight 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.

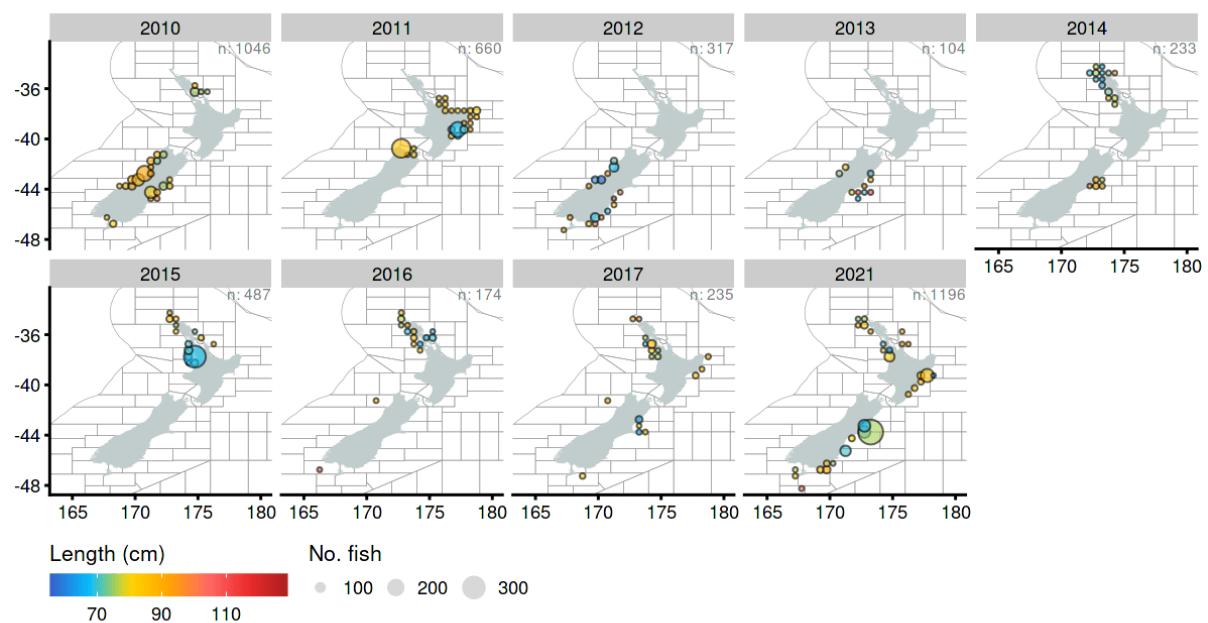


Figure C.11: Mean length (cm) of rig sampled by the Observer Programme from the bottom trawl fishery, by fishing year. Circles are coloured by length, and the size of the circle scales with the sample size in each 0.5 degree grid cell.

C.1.3 The set net fishery

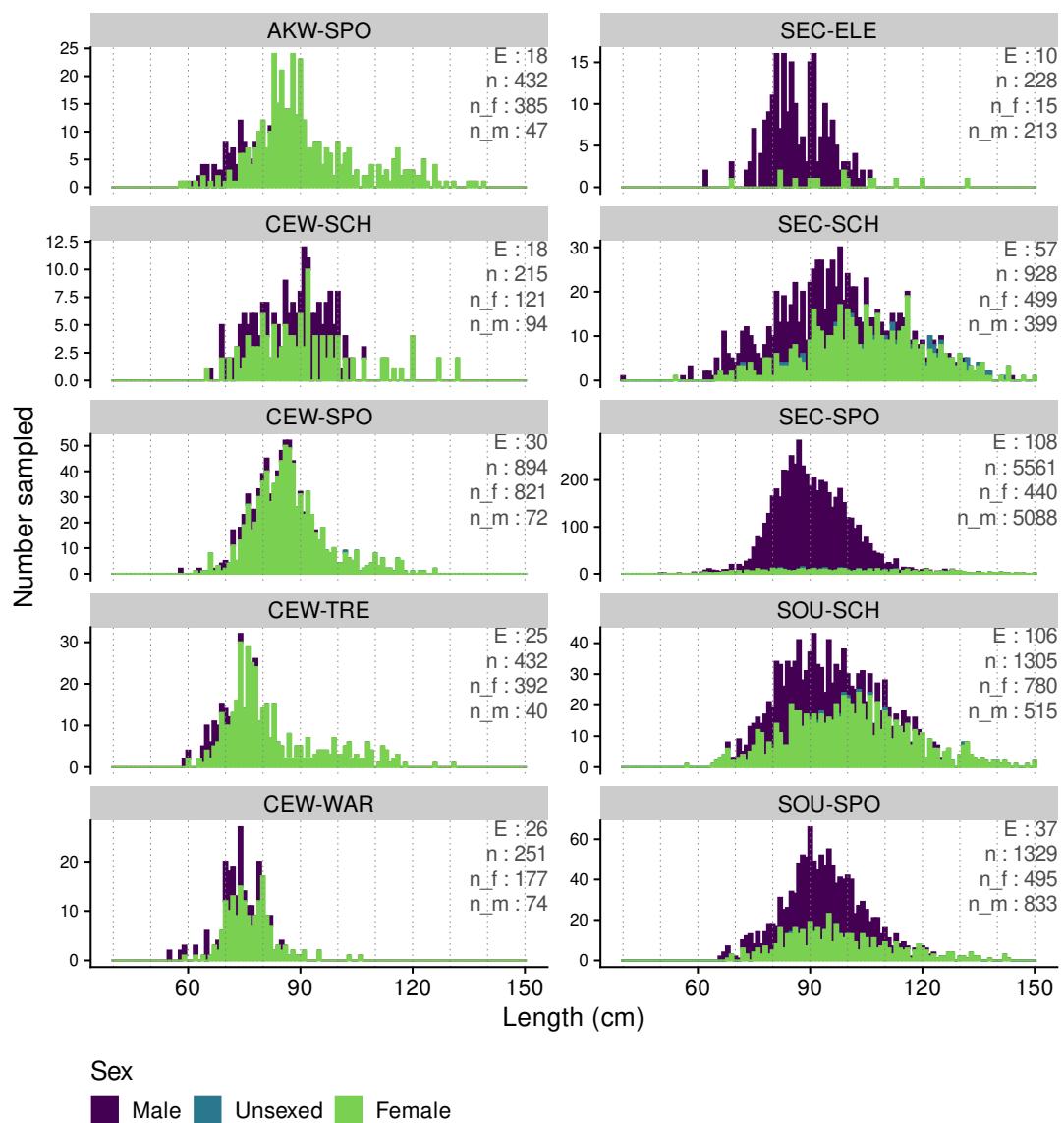


Figure C.12: Length-frequency distributions for rig caught in the set net fishery, by area, target species, and sex. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area-target and sex. Only area-targets at least 100 fish measurements are included. Observer area codes are defined in the glossary.

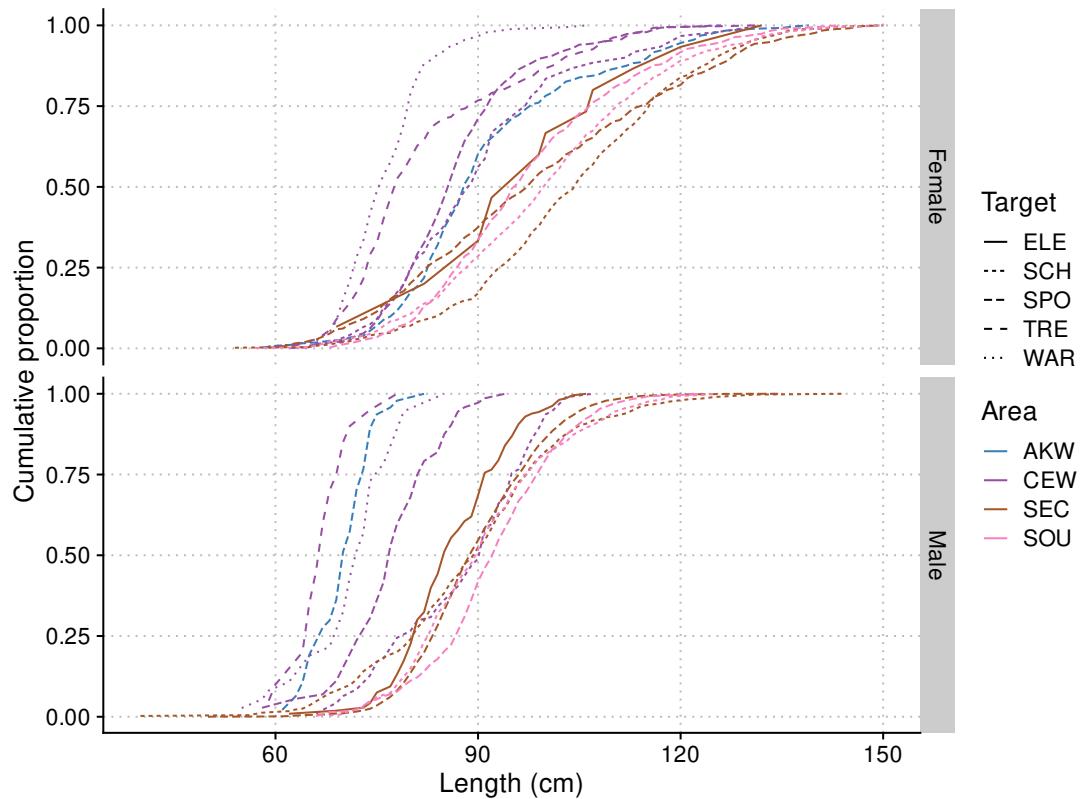


Figure C.13: Cumulative length-frequency distributions for rig caught in the set net fishery, by area and target species. Only area-targets at least 100 fish measurements are included. Observer area codes are defined in the glossary.

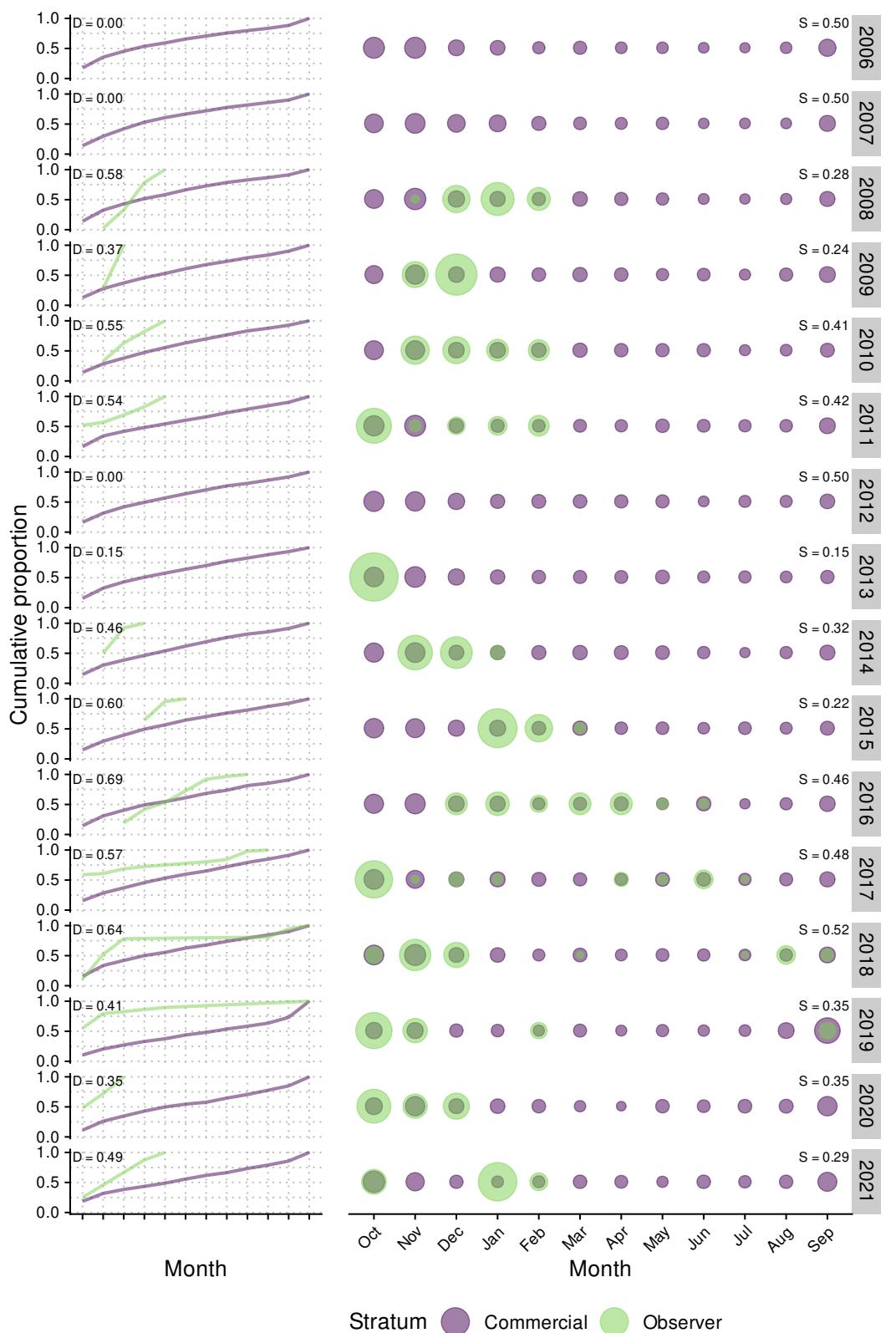


Figure C.14: Representativeness of observer sampling coverage of set net fishing events that caught rig in 2006 to 2021 by fishing year and month. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a month, with proportions summing to one within each fishing year. D: Kolmogorov-Smirnov maximum absolute difference; S: Manhattan block distance.

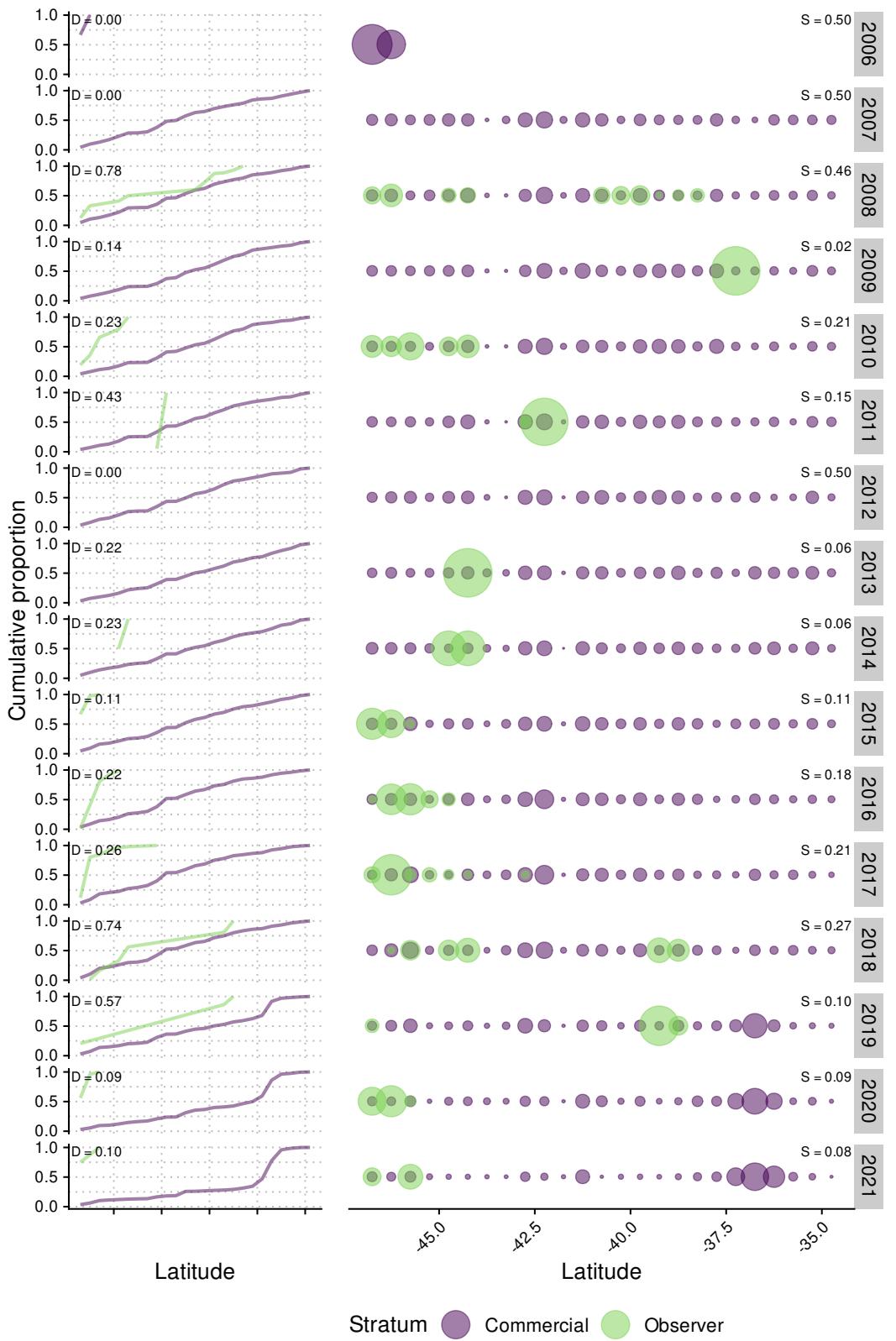


Figure C.15: Representativeness of observer sampling coverage of set net fishing events that caught rig in 2006 to 2021 by fishing year and latitude. Observer data are for observed events with length sampling. Circle area is proportional to the proportion of events in a latitude bin, with proportions summing to one within each fishing year.

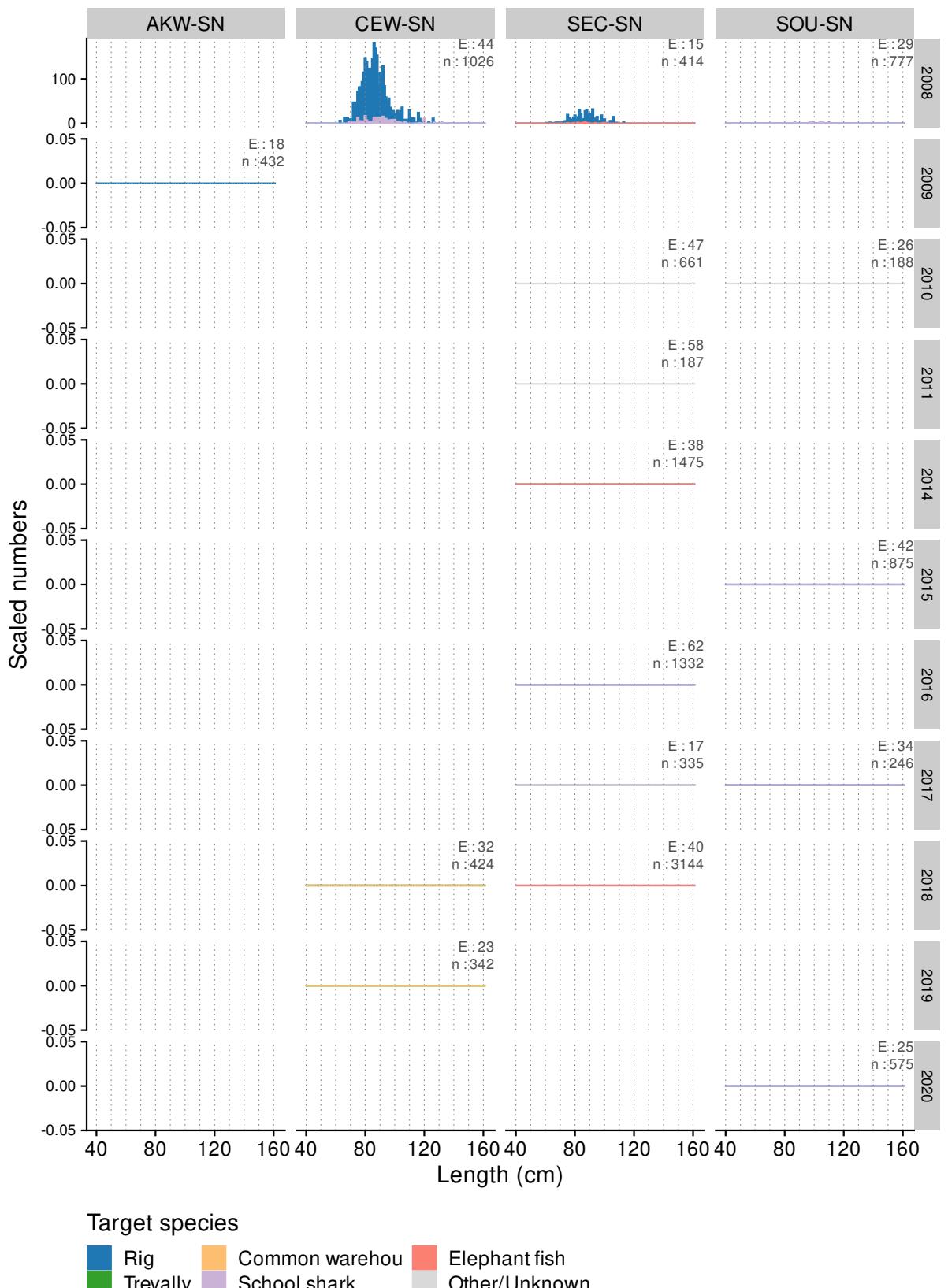


Figure C.16: Length-frequency distributions for rig caught in the set net fishery, by area, fishing year, and target species. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area, target and year. Sampled numbers are scaled to the catch weight in 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.

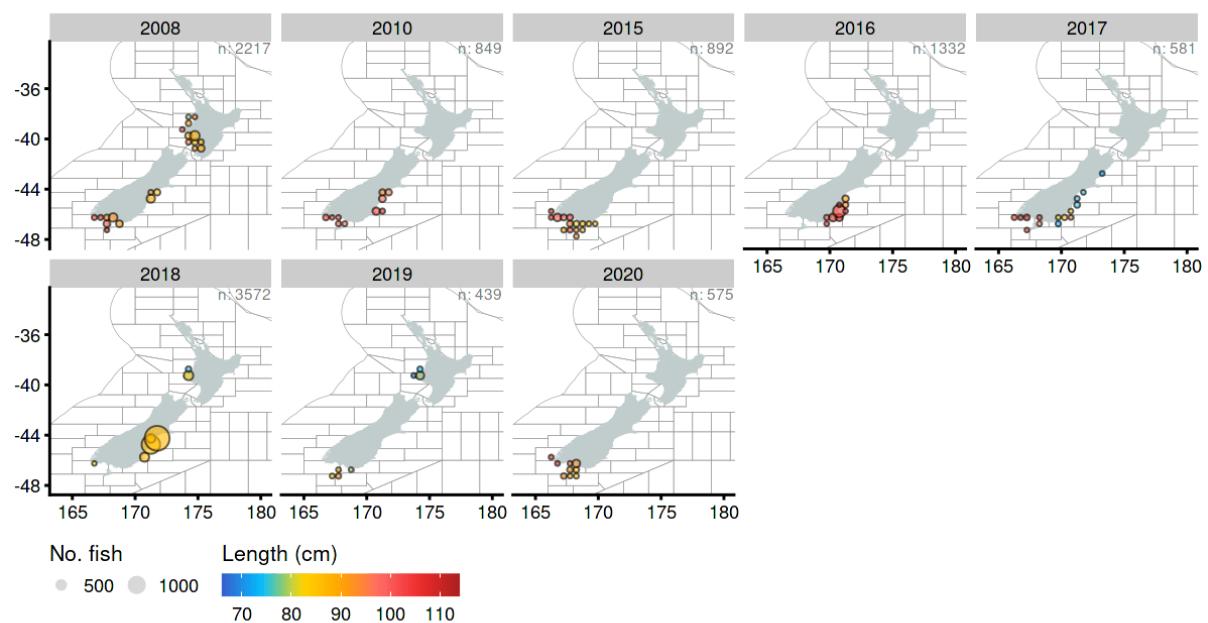


Figure C.17: Mean length (cm) of rig sampled by the Observer Programme from the set net fishery, by fishing year. Circles are coloured by length, and the size of the circle scales with the sample size in each 0.5 degree grid cell.

C.2 Adaptive Management Programme

Table C.2: Length frequency samples of rig by area and method, sampled by the Adaptive Management Programme from fishing years 1995 to 2014.

QMA	Method	Sampled events	Number of fish
SPO1	SN	27	270
SPO2	BT	2	12
SPO2	SN	5	31
SPO3	BT	16	115
SPO3	SN	1820	14675
SP07	BT	3600	18706
SP07	DS	326	1301
SP07	SN	1021	8645
SPO8	BT	11	102
SPO8	SN	33	296

C.2.1 Length composition by area and method

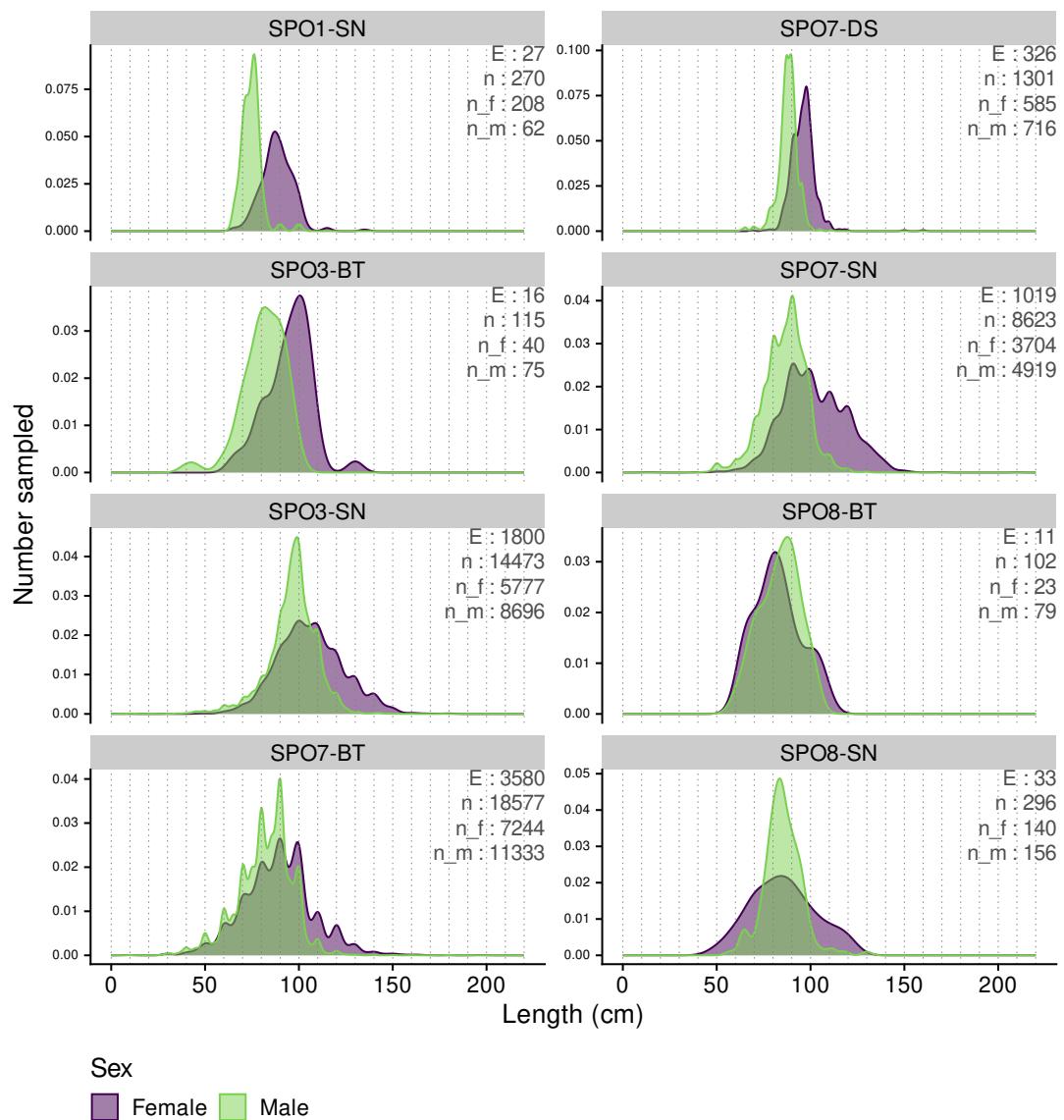


Figure C.18: Raw (unscaled) length-frequency distributions of rig in SPO 1, SPO 3, SPO 7 and SPO 8 by fishing method, from AMP sampling. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area-method. Only area-methods with at least 100 fish measurements are included.

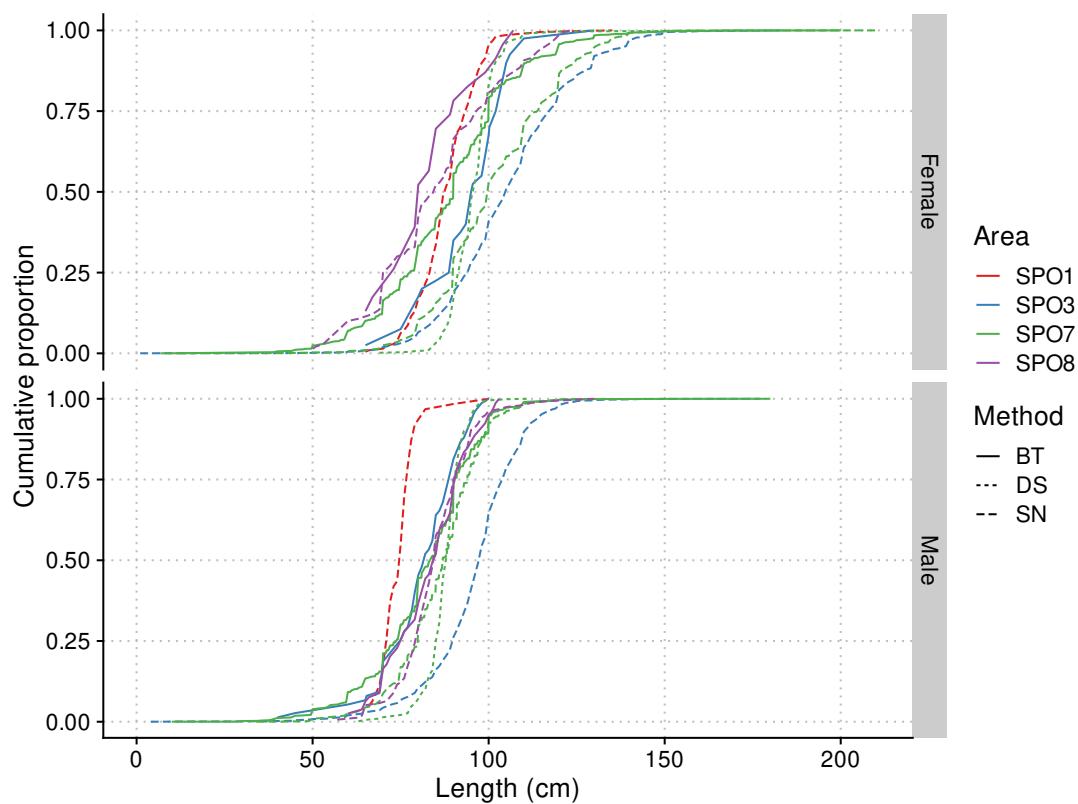


Figure C.19: Cumulative length-frequency distributions of rig in SPO 1, SPO 3, SPO 7 and SPO 8 by fishing method, using raw, unscaled AMP samples.

C.2.2 The bottom trawl fishery

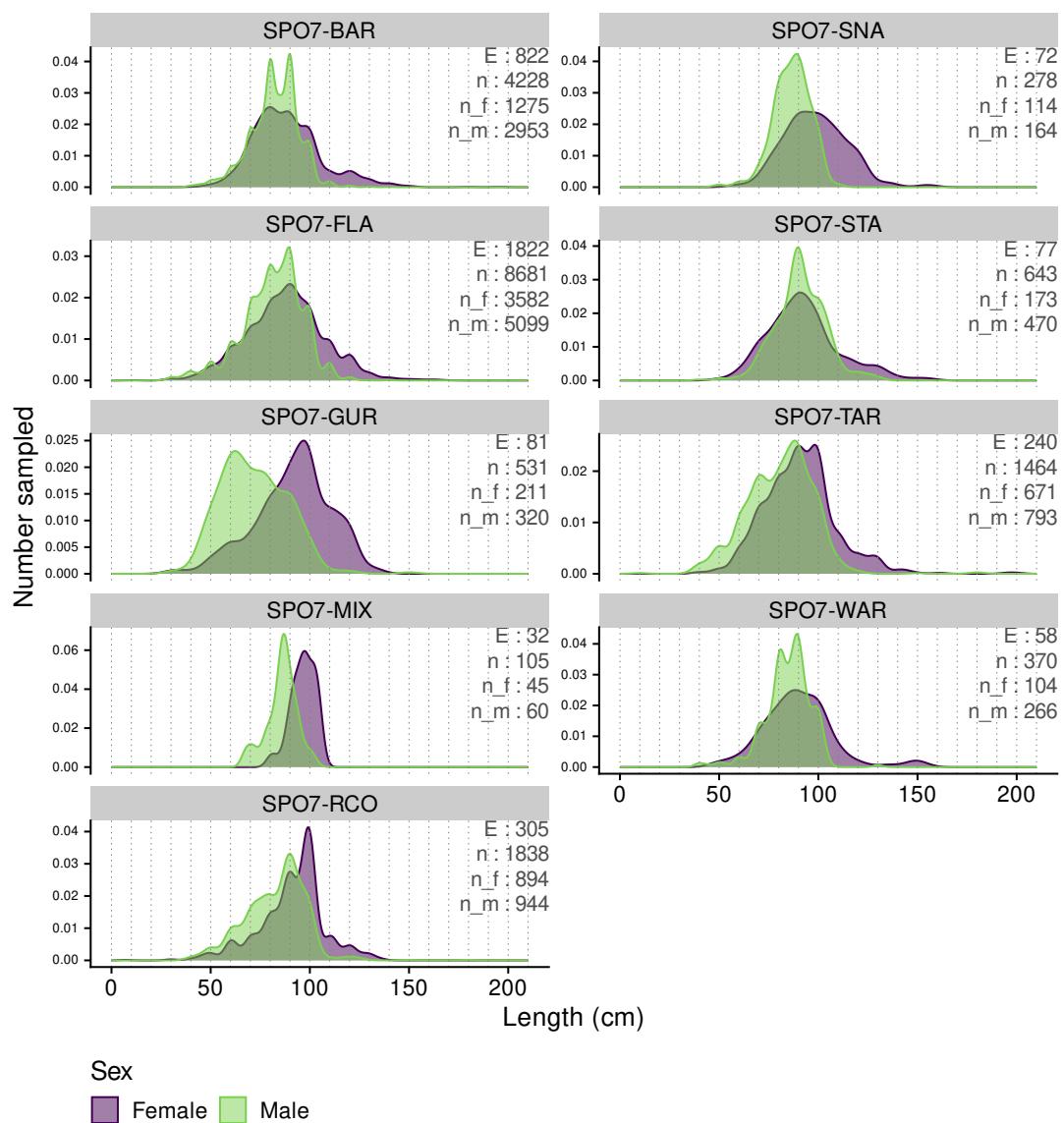


Figure C.20: Raw length-frequency distributions for rig caught in the bottom trawl fishery, by area and target species. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area-target. Only area-targets at least 100 fish measurements are included.

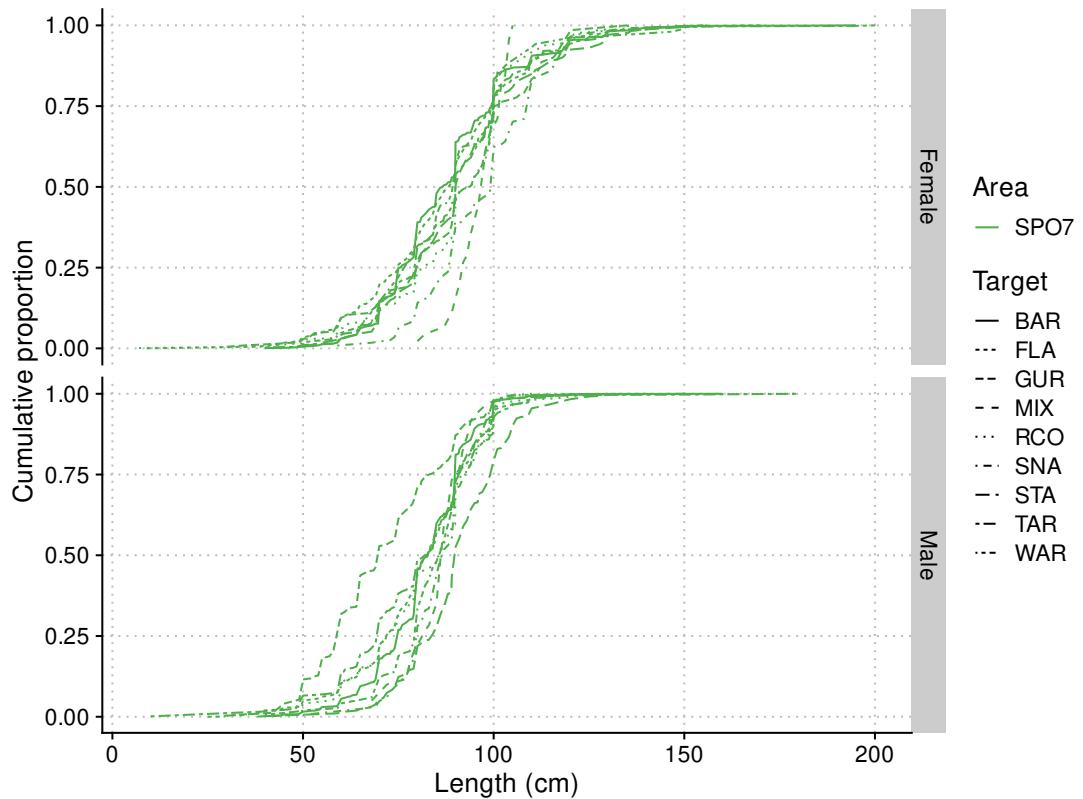


Figure C.21: Cumulative length-frequency distributions for rig caught in the bottom trawl fishery, by area and target species. Only area-targets at least 100 fish measurements are included.

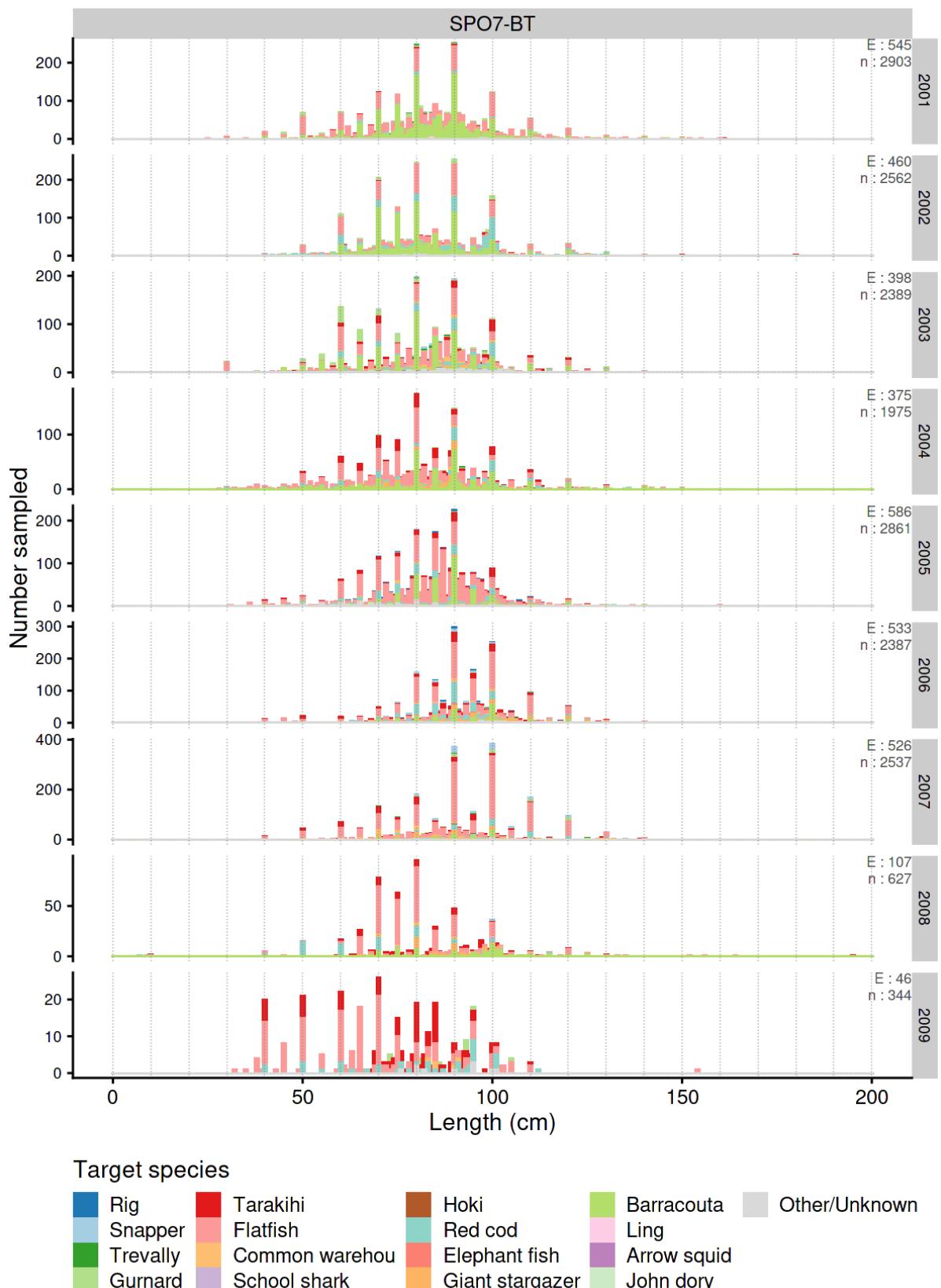


Figure C.22: Raw length-frequency distributions for rig caught in the bottom trawl fishery, by area, fishing year, and target species. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area, target and year. The Other grouping includes both minor target species and events where the target species was not recorded.

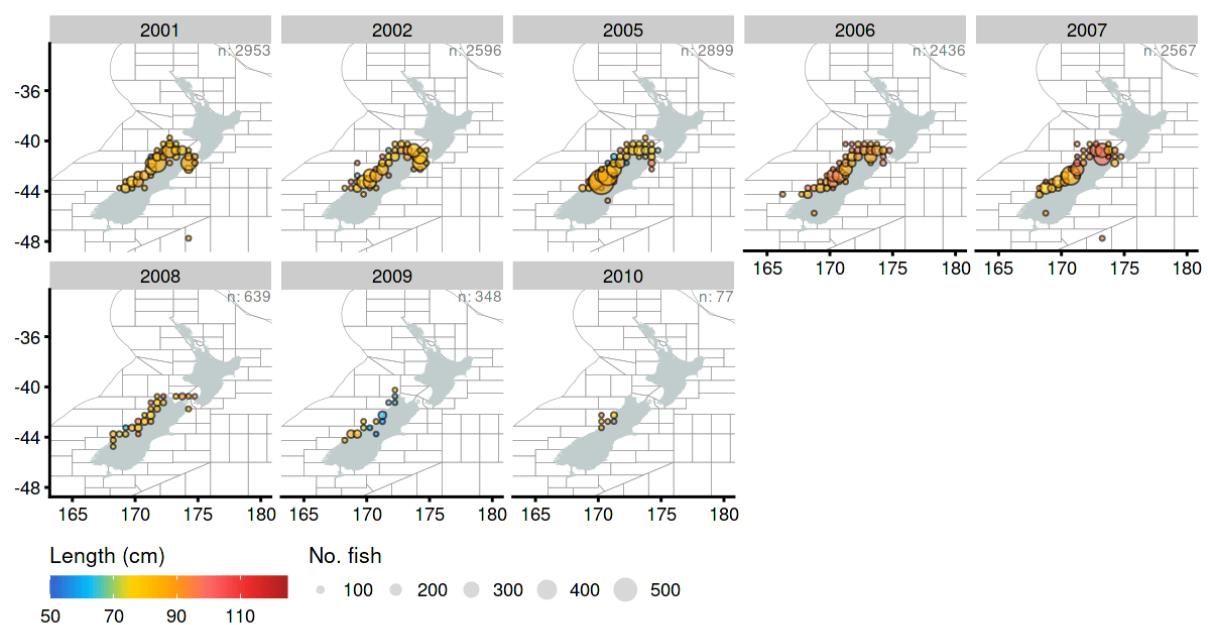


Figure C.23: Mean length (cm) of rig sampled by the Adaptive Management Programme from the bottom trawl fishery, by fishing year. Circles are coloured by length, and the size of the circle scales with the sample size in each 0.5 degree grid cell.

C.2.3 The Danish seine fishery

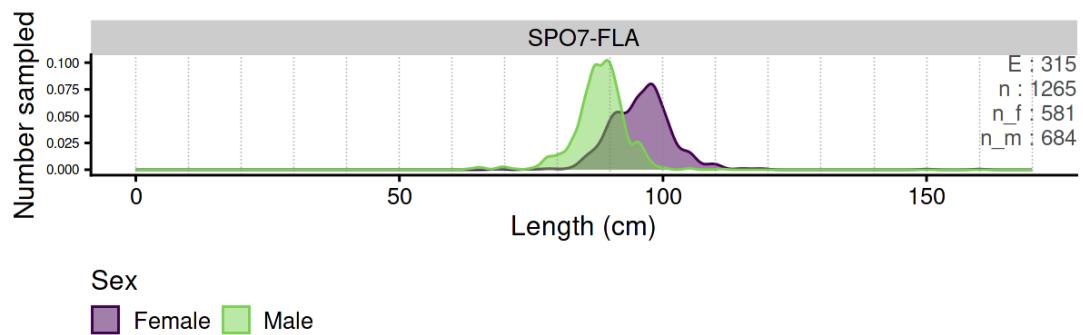


Figure C.24: Raw length-frequency distributions for rig caught in the Danish seine fishery, by area and target species. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area-target. Only area-targets at least 100 fish measurements are included.

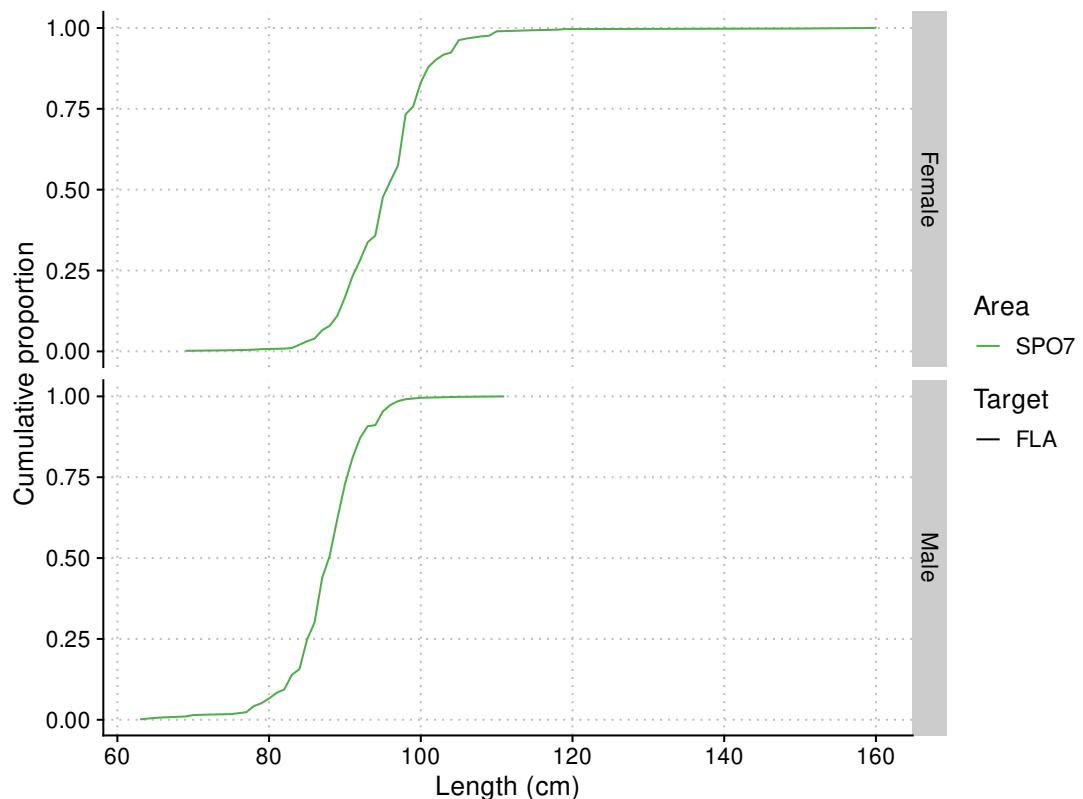


Figure C.25: Cumulative length-frequency distributions for rig caught in the Danish seine fishery, by area and target species. Only area-targets at least 100 fish measurements are included.

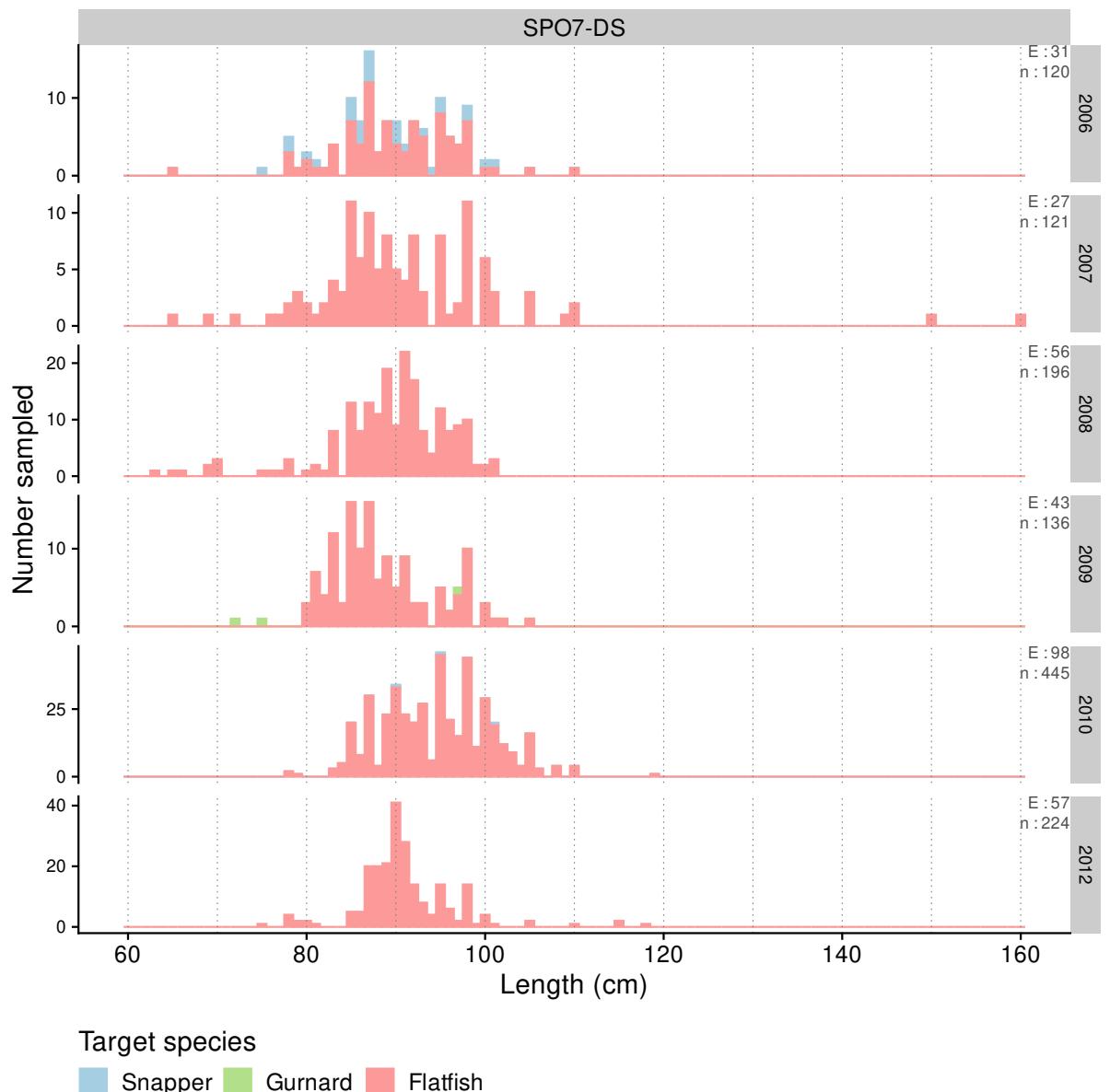


Figure C.26: Raw length-frequency distributions for rig caught in the Danish seine fishery, by area, fishing year, and target species. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area, target and year. The Other grouping includes both minor target species and events where the target species was not recorded.

C.2.4 The set net fishery

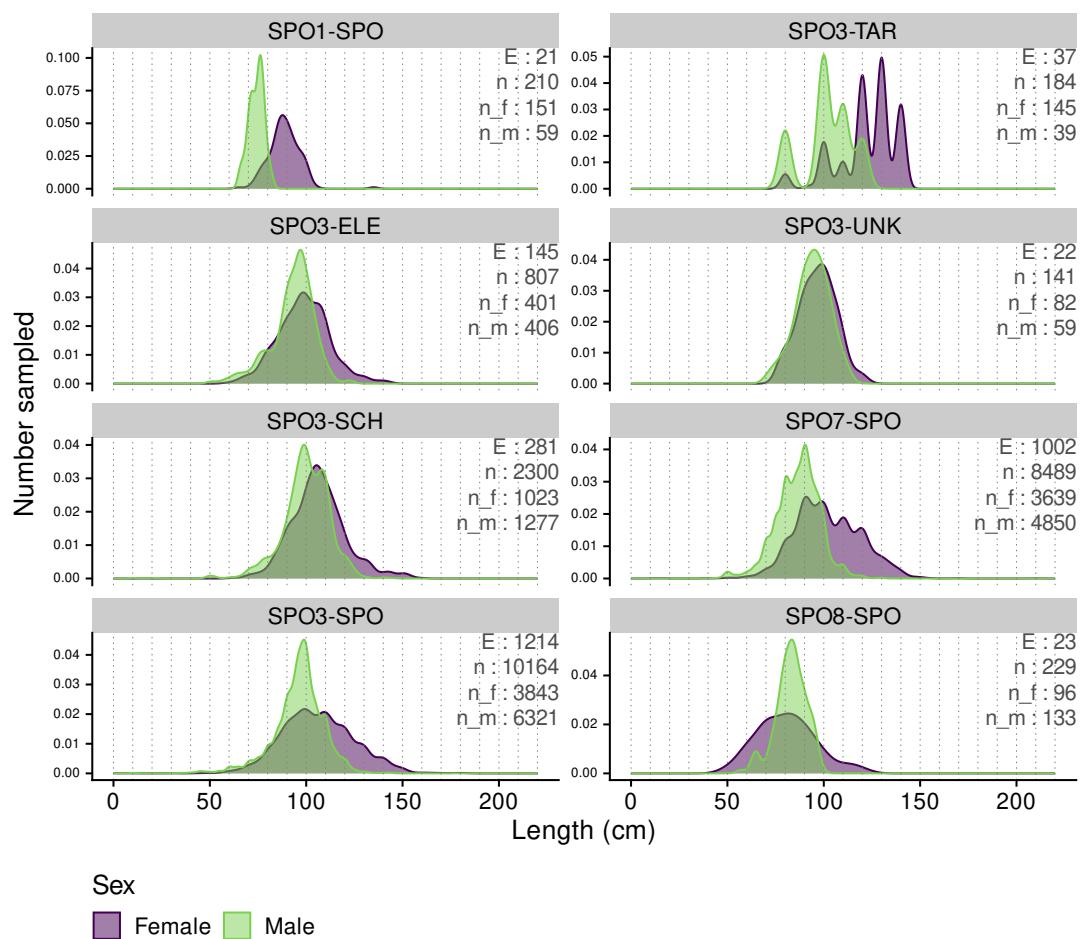


Figure C.27: Raw length-frequency distributions for rig caught in the set net fishery, by area and target species. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area-target. Only area-targets at least 100 fish measurements are included.

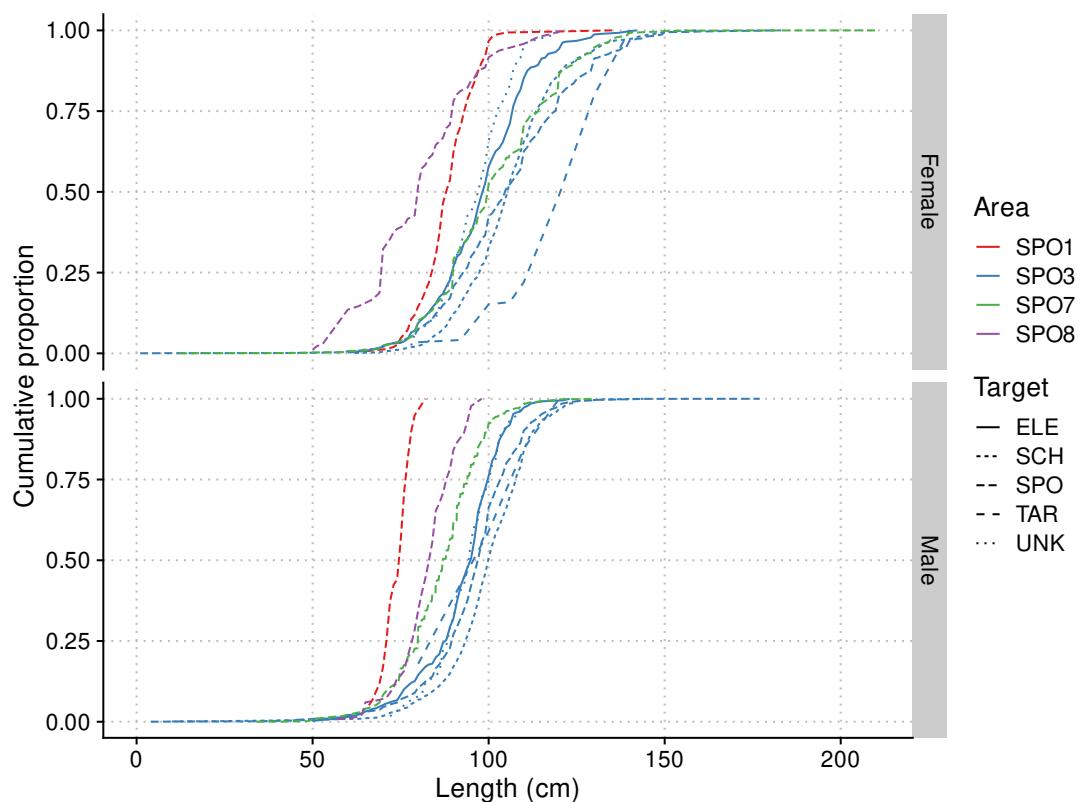


Figure C.28: Cumulative length-frequency distributions for rig caught in the set net fishery, by area and target species. Only area-targets at least 100 fish measurements are included.

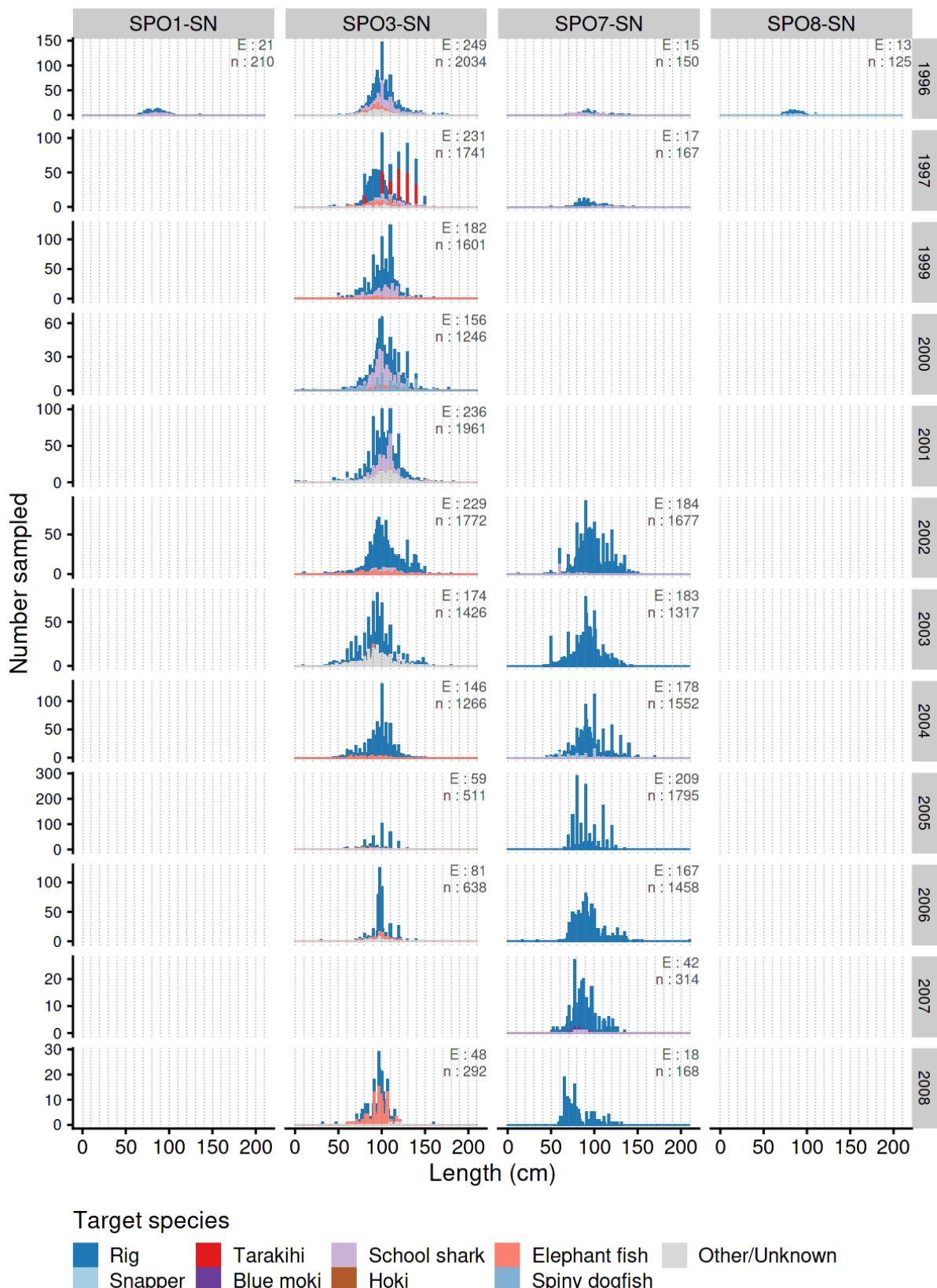


Figure C.29: Raw length-frequency distributions for rig caught in the set net fishery, by area, fishing year, and target species. Annotations indicate the number of unique sampling events (E) and sampled number of fish (n) for each area, target and year. The Other grouping includes both minor target species and events where the target species was not recorded.

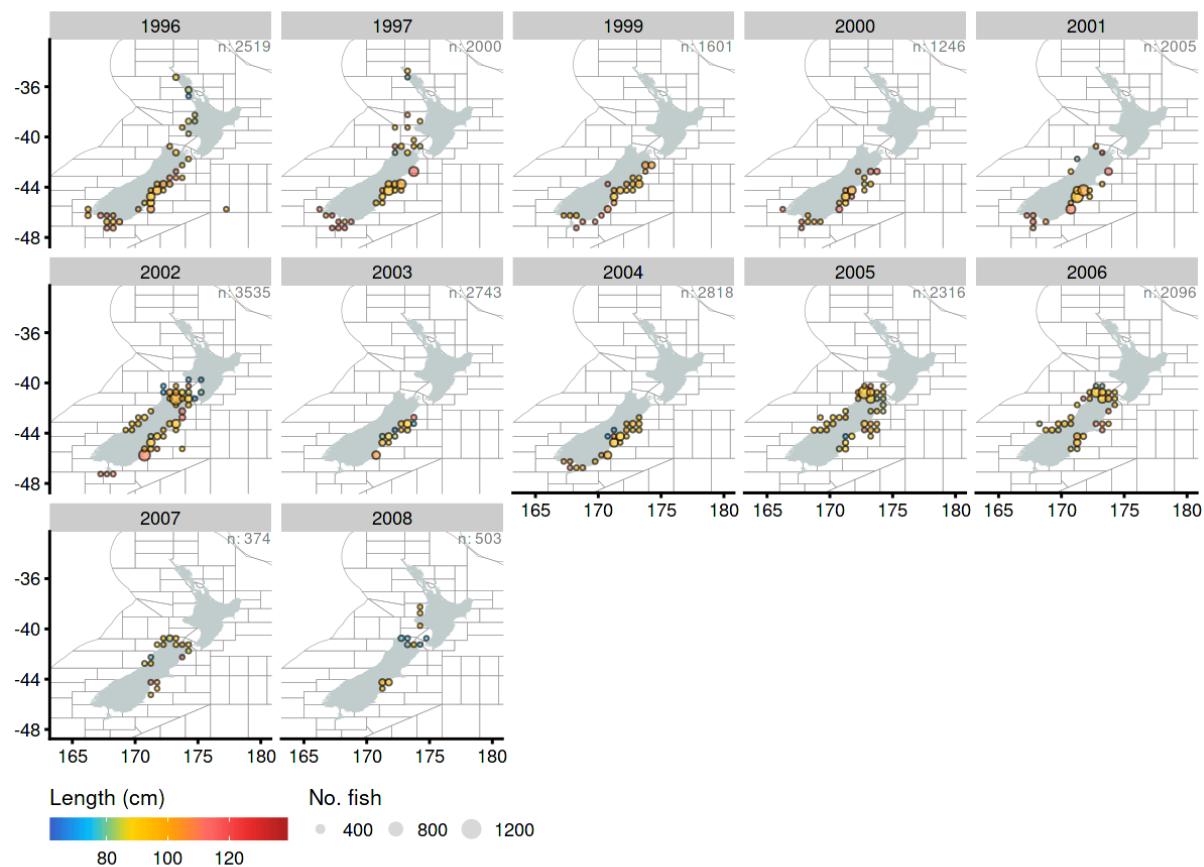


Figure C.30: Mean length (cm) of rig sampled by the Adaptive Management Programme from the set net fishery, by fishing year. Circles are coloured by length, and the size of the circle scales with the sample size in each 0.5 degree grid cell.

APPENDIX D: ADDITIONAL CPUE SERIES

Eight additional CPUE series are presented in this Appendix. These series are not described in detail although full diagnostics are supplied for each series. An introductory paragraph for each series provides a brief description of the analysis and puts it into context with the eleven CPUE analyses described in Section 5.

D.1 SPO 1W BT event

This analysis is the tow-by-tow (event) analogue to the SPO 1W BT trip analysis presented in Section 5.2. It repeats that analysis at the level of an individual event, adding detailed explanatory information to the analysis that is not available to the trip-based analysis. Such information includes the duration of the tow, the starting depth of the tow, the speed of the tow, and the relative start time of the tow within the 24-hour period. As well, the location of the tow and the target species can be assigned explicitly to the tow, rather than using the modal value for the trip as is used in the trip-based analysis. This analysis begins with the 2006–07 fishing year, which is when the detailed event-based data became available. A plot comparing the event-based CPUE series with the longer trip-based series is presented in Figure D.156.

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 SPO 1W BT event CPUE series.

Series	SPO 1W BT event
QMS stock	SPO1
Reporting forms	ERS - Trawl, TCE
Fishing methods	BT
Target species	SNA, TRE, GUR, TAR
Statistical Areas	041, 042, 045, 046, 047
Period	2007-10-01, 2021-09-30
Resolution	Fishing event
Core fleet years	4
Core fleet trips	5
Default model	$\text{allocg} \sim \text{fyear} + \text{vessel_key} + \text{stat_area} + \text{month} + \text{target_species} + \text{ns}(\log(\text{fishing_duration}), 3) + \text{ns}(\text{bottom_depth}, 3) + \text{ns}(\text{effort_speed}, 3) + \text{ns}(\text{start_time}, 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

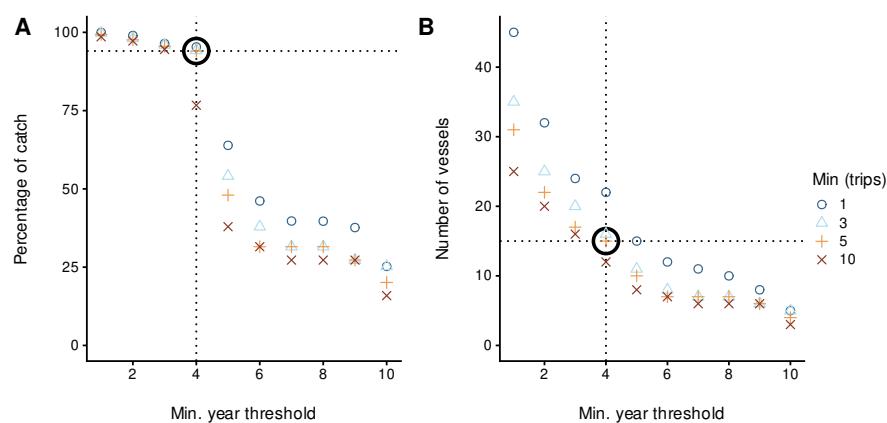


Figure D.1: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 1W BT event CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

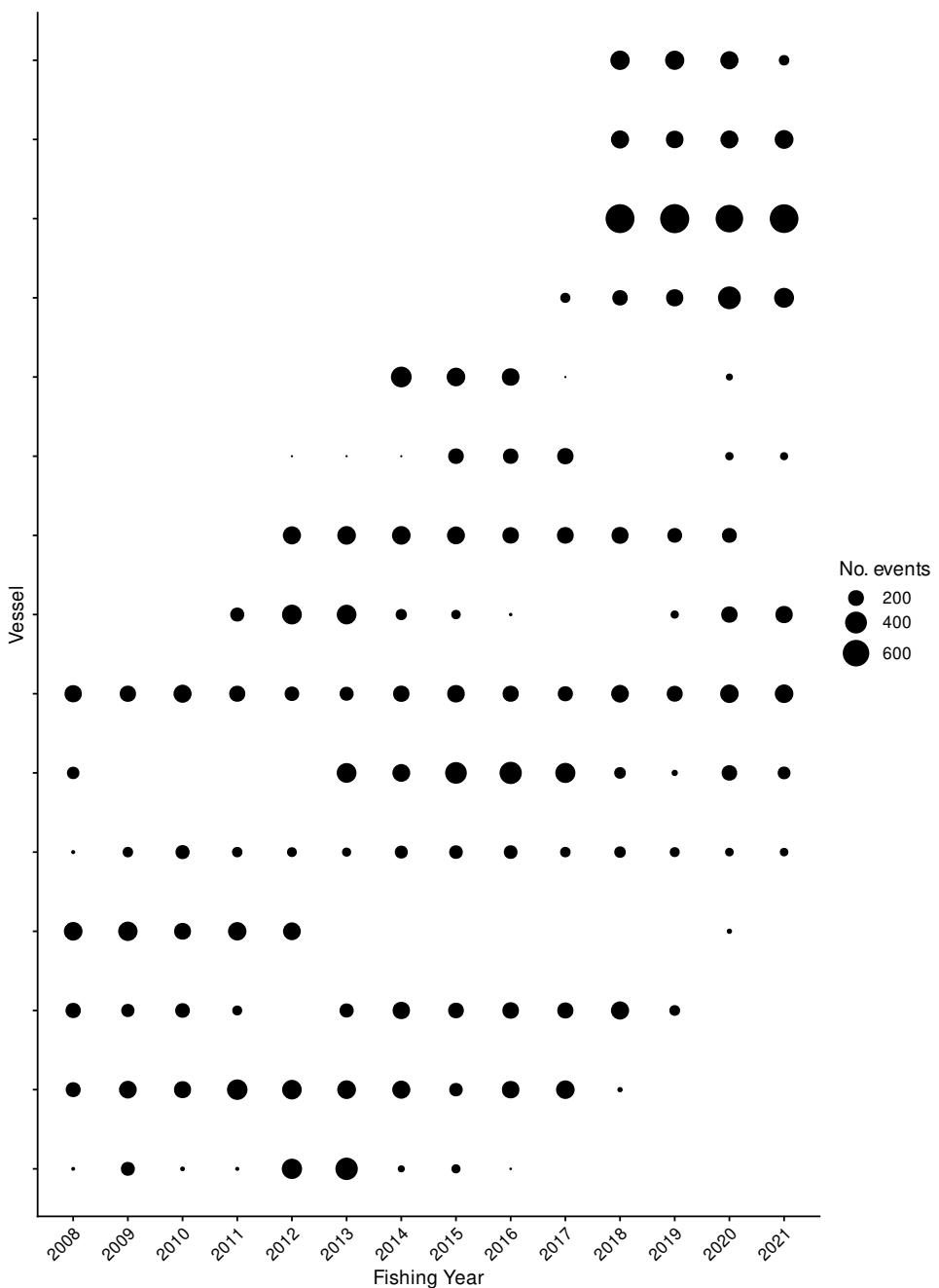


Figure D.2: Number of events by fishing year for core vessels. The area of the circles is proportional to the number of events undertaken by a vessel in a fishing year.

Table D.2: Summary of the SPO 1W BT 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	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	15 (100%) n: 1390	13 (100%) n: 1320	14 (100%) n: 1223	16 (100%) n: 1383	30 (100%) n: 2064	23 (100%) n: 2302	31 (100%) n: 2100	30 (100%) n: 2344	22 (100%) n: 1993
Positive fishing duration	15 (100%) n: 1390	13 (100%) n: 1320	14 (100%) n: 1222	16 (100%) n: 1379	30 (100%) n: 2064	23 (100%) n: 2302	31 (100%) n: 2100	30 (100%) n: 2344	22 (100%) n: 1993
Core fleet selection	11 (73%) n: 1024	12 (92%) n: 1147	13 (100%) n: 1070	15 (100%) n: 1149	29 (100%) n: 1747	22 (100%) n: 2005	29 (93%) n: 1885	27 (91%) n: 1991	21 (100%) n: 1906
Filter	2017	2018	2019	2020	2021				
Ungroomed data	11 (100%) n: 1660	46 (100%) n: 2488	41 (100%) n: 2195	47 (100%) n: 2947	56 (100%) n: 3072				
Positive fishing duration	11 (100%) n: 1660	46 (100%) n: 2488	41 (100%) n: 2195	47 (100%) n: 2945	56 (100%) n: 3071				
Core fleet selection	11 (100%) n: 1605	46 (100%) n: 2463	41 (100%) n: 2127	46 (100%) n: 2631	49 (88%) n: 2152				

Table D.3: Summary of the SPO 1W BT 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 rig.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
2008	7	187	1 024	3 653.30	10.89	36.33
2009	6	163	1 147	4 087.52	11.91	51.44
2010	6	175	1 070	3 745.55	13.34	42.71
2011	7	179	1 149	3 948.73	15.41	48.22
2012	8	242	1 747	6 213.00	28.96	51.00
2013	9	292	2 005	6 514.70	22.07	49.28
2014	10	308	1 885	6 405.68	29.17	52.25
2015	10	297	1 991	7 171.87	27.18	50.28
2016	10	281	1 906	6 588.35	21.25	49.48
2017	9	265	1 605	5 936.98	10.72	50.47
2018	10	306	2 463	7 747.47	45.92	55.66
2019	10	262	2 127	7 170.05	40.77	59.66
2020	12	300	2 631	9 412.67	45.52	60.21
2021	9	240	2 152	7 858.08	48.72	74.77

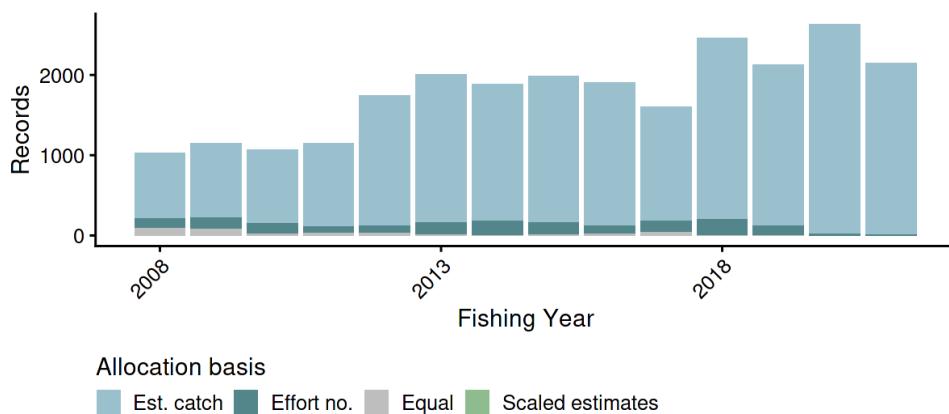


Figure D.3: Allocation basis for attributing landings to records in the SPO 1W BT event catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

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	12.00	33 667	2.10	2.10	*
+ vessel_key	14.00	32 583	5.40	3.20	*
+ month	11.00	32 214	6.50	1.10	*
+ ns(bottom_depth, 3)	3.00	31 893	7.40	1.00	*
+ stat_area	4.00	31 724	8.00	0.50	
+ ns(log(fishing_duration), 3)	3.00	31 658	8.20	0.20	
+ ns(start_time, 3)	3.00	31 612	8.30	0.10	
+ target_species	3.00	31 577	8.40	0.10	
+ ns(effort_speed, 3)	3.00	31 573	8.50	0.00	

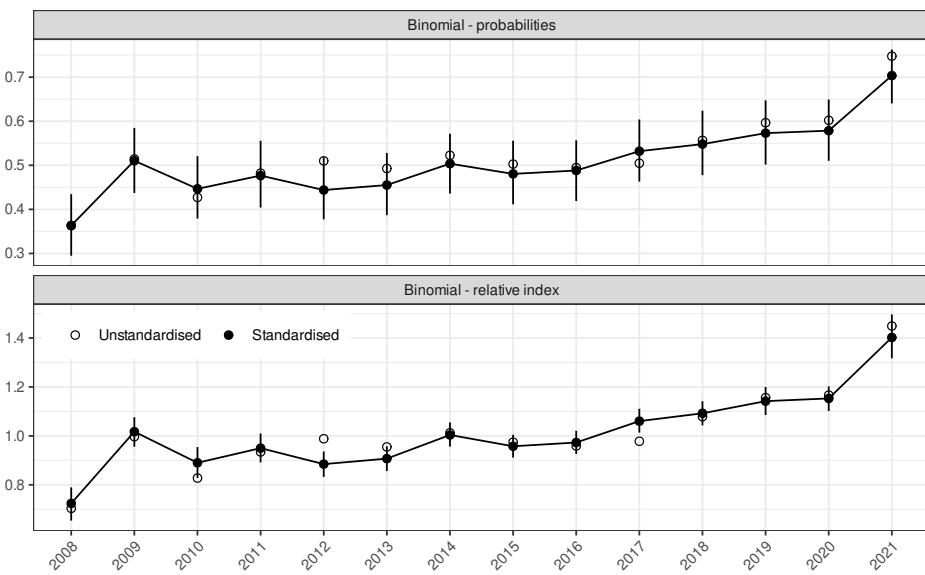


Figure D.4: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 1W BT event dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

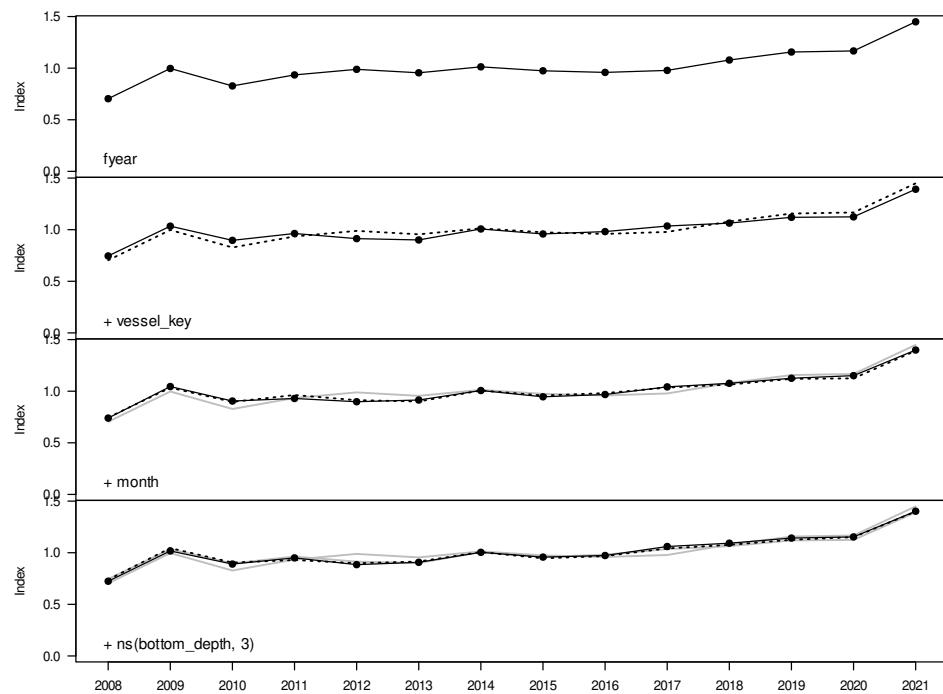


Figure D.5: Step plot for occurrence of catch in the SPO 1W BT event dataset.

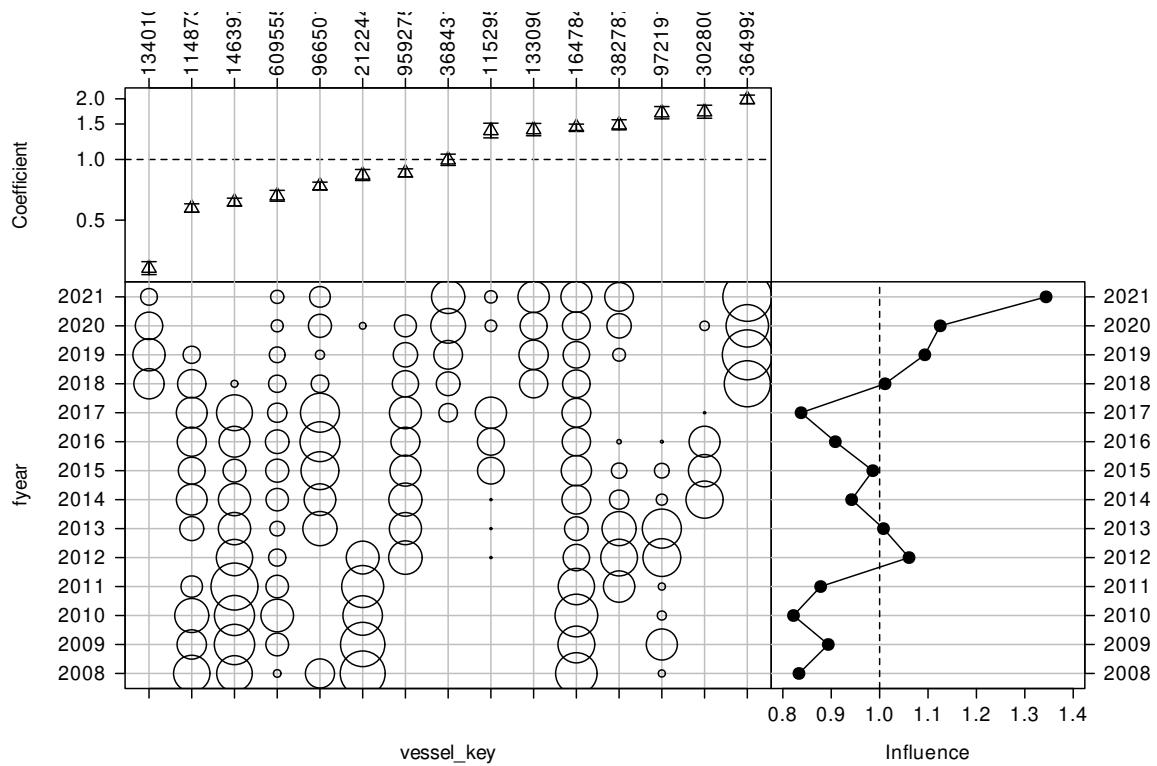


Figure D.6: CDI plot for vessel key for the occurrence of positive catch SPO 1W BT event catch-per-unit-effort dataset.

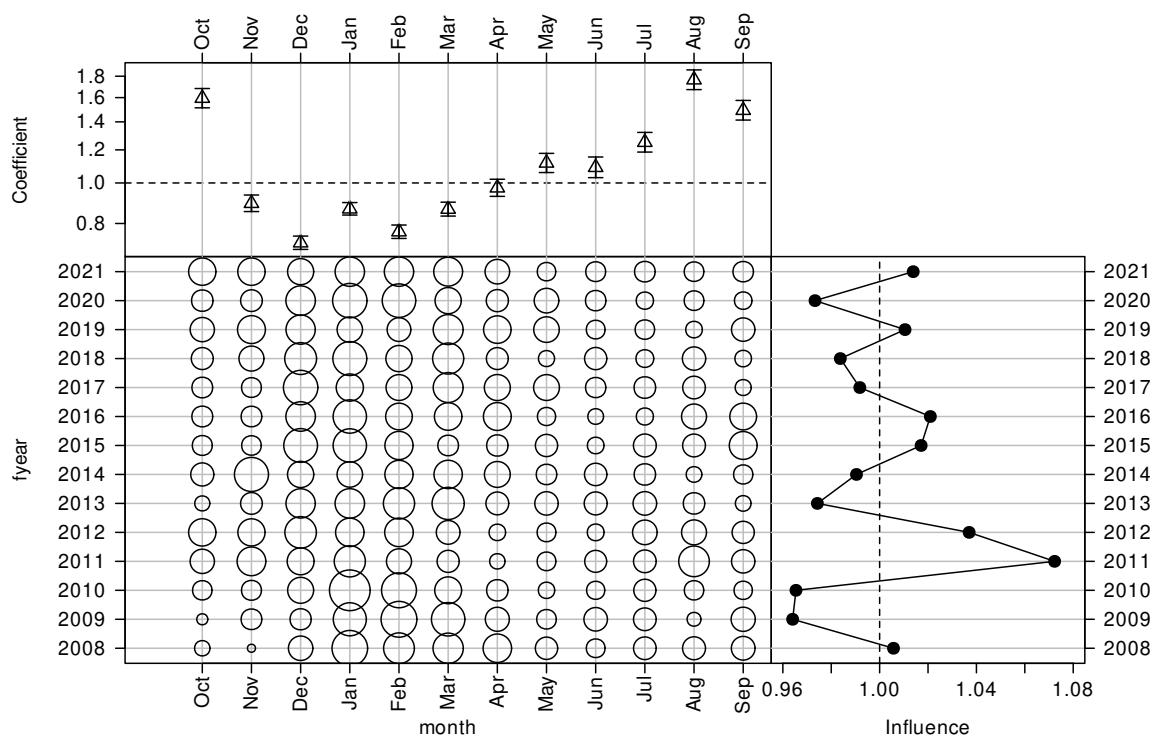


Figure D.7: CDI plot for month for the occurrence of positive catch SPO 1W BT event catch-per-unit-effort dataset.

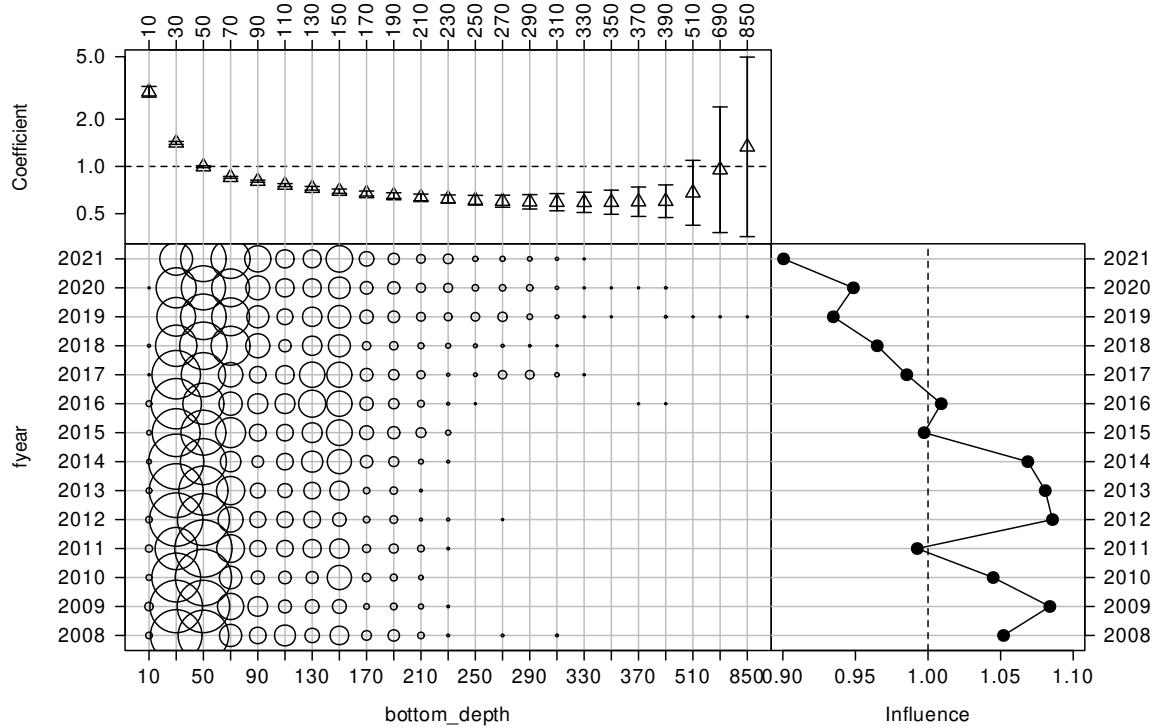


Figure D.8: CDI plot for bottom depth (m) for the occurrence of positive catch SPO 1W BT event catch-per-unit-effort dataset.

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	12	47460	4.4	4.4	*
+ vessel key	14	42296	35.0	30.7	*
+ month	11	41535	38.7	3.7	*
+ ns(bottom depth, 3)	3	41188	40.3	1.6	*
+ stat area	4	40891	41.7	1.3	*
+ ns(log(fishing duration), 3)	3	40682	42.6	0.9	
+ target species	3	40635	42.8	0.2	
+ ns(effort speed, 3)	3	40599	43.0	0.2	
+ ns(start time, 3)	3	40580	43.1	0.1	

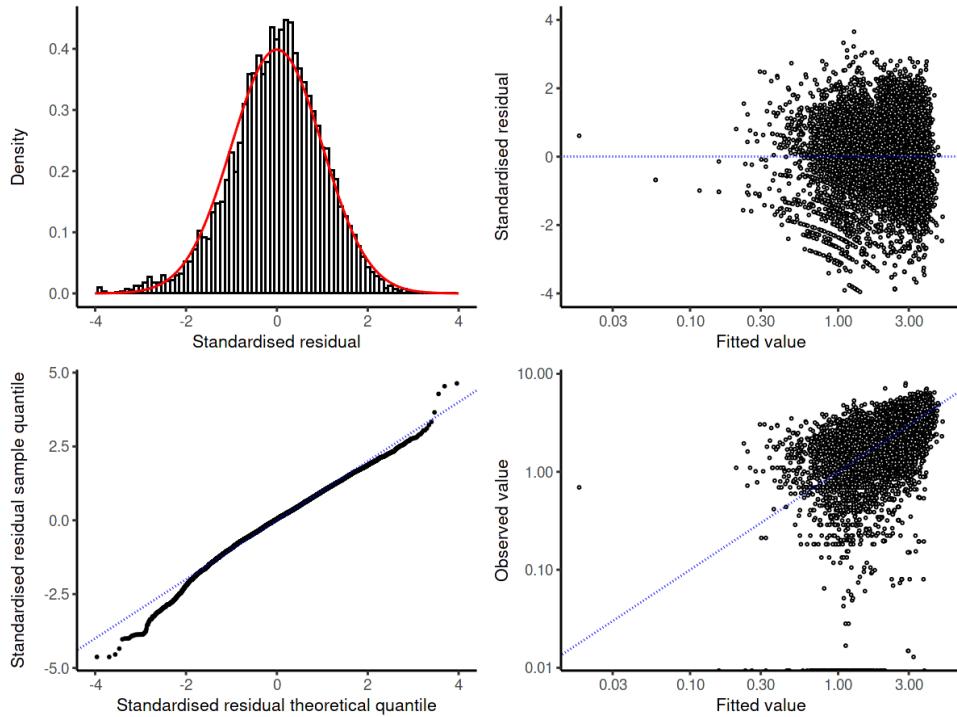


Figure D.9: Diagnostic plots for the lognormal model for the SPO 1W BT event dataset.

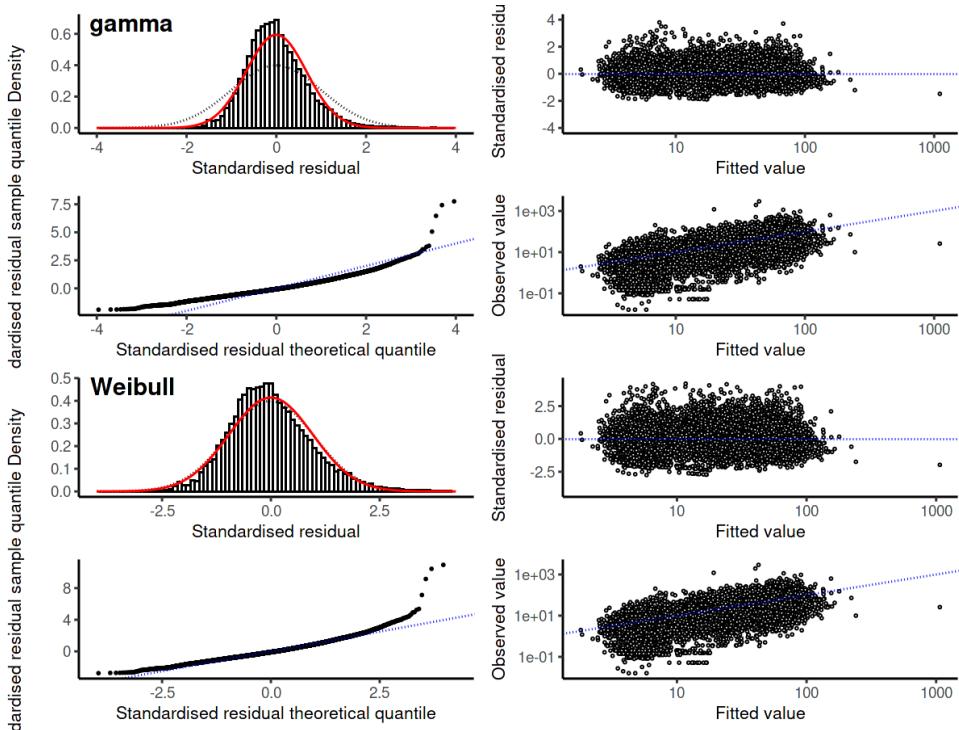


Figure D.10: Diagnostic plots for the gamma and Weibull model for the SPO 1W BT event dataset.

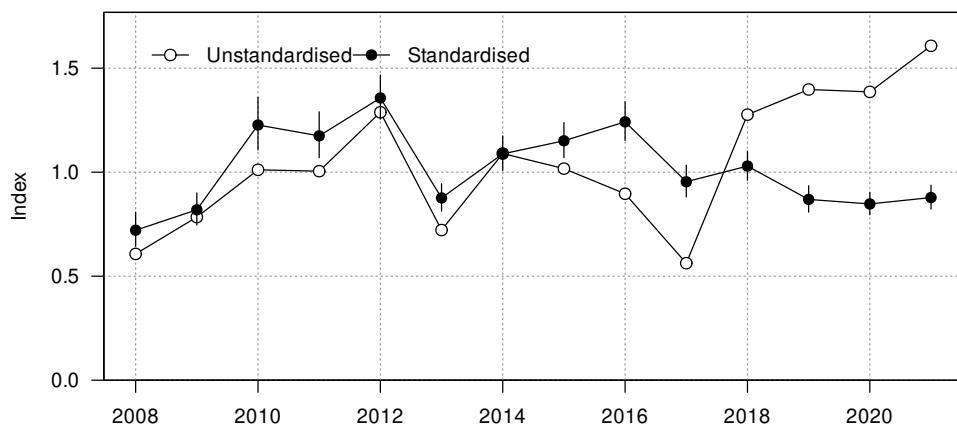


Figure D.11: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 1W BT event dataset.

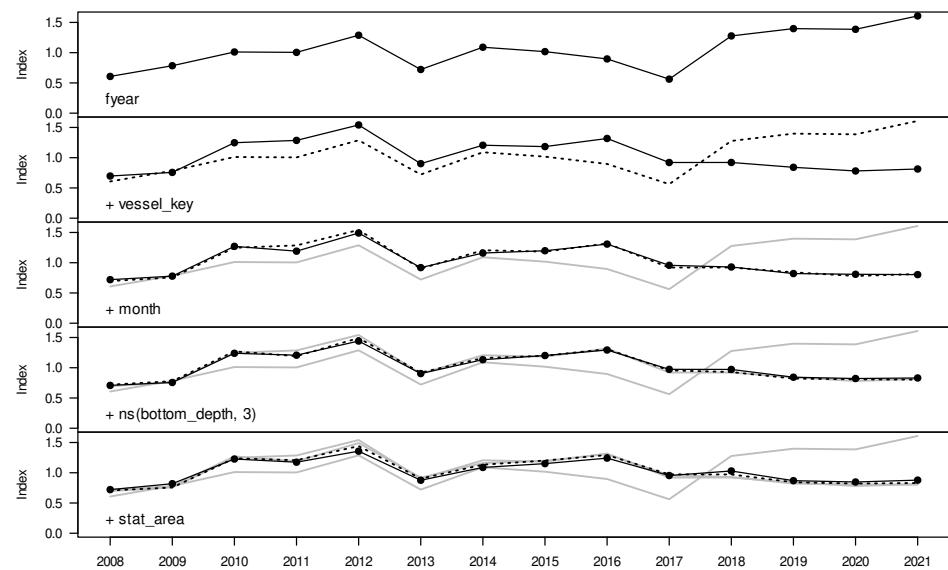


Figure D.12: Changes to the SPO 1W BT event positive catch index as terms are successively entered into the model.

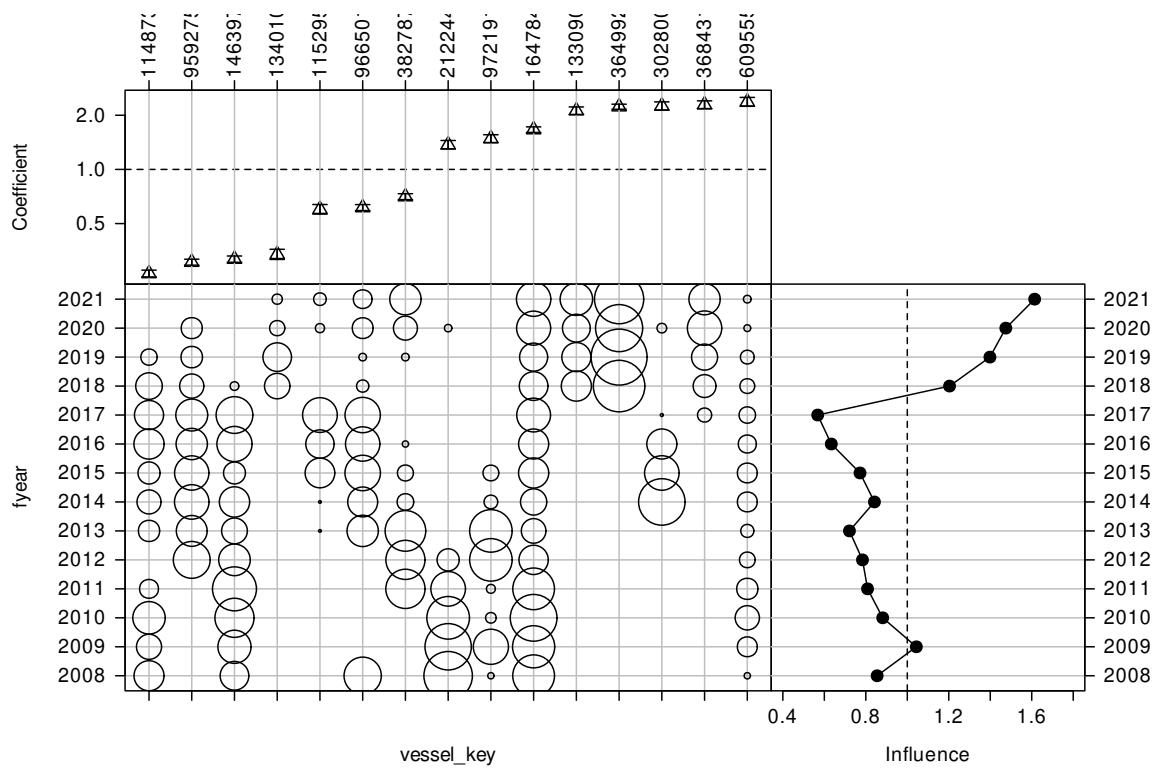


Figure D.13: CDI plot for vessel key for the positive catch SPO 1W BT event catch-per-unit-effort dataset.

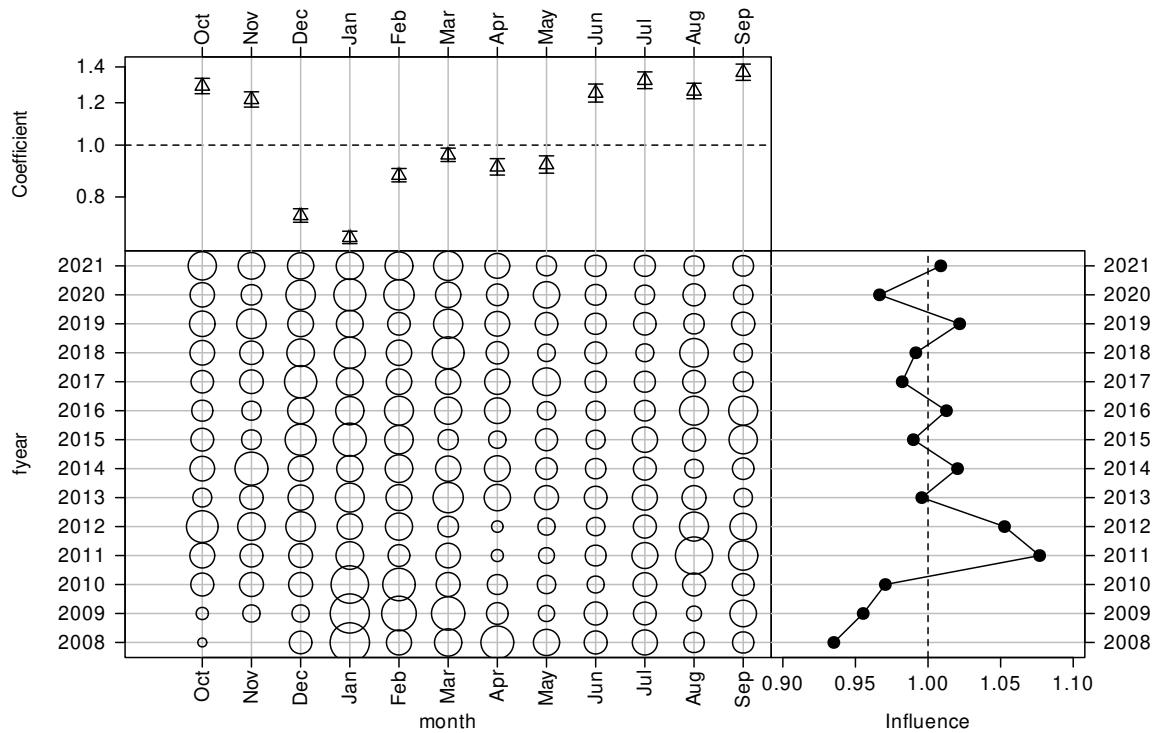


Figure D.14: CDI plot for month for the positive catch SPO 1W BT event catch-per-unit-effort dataset.

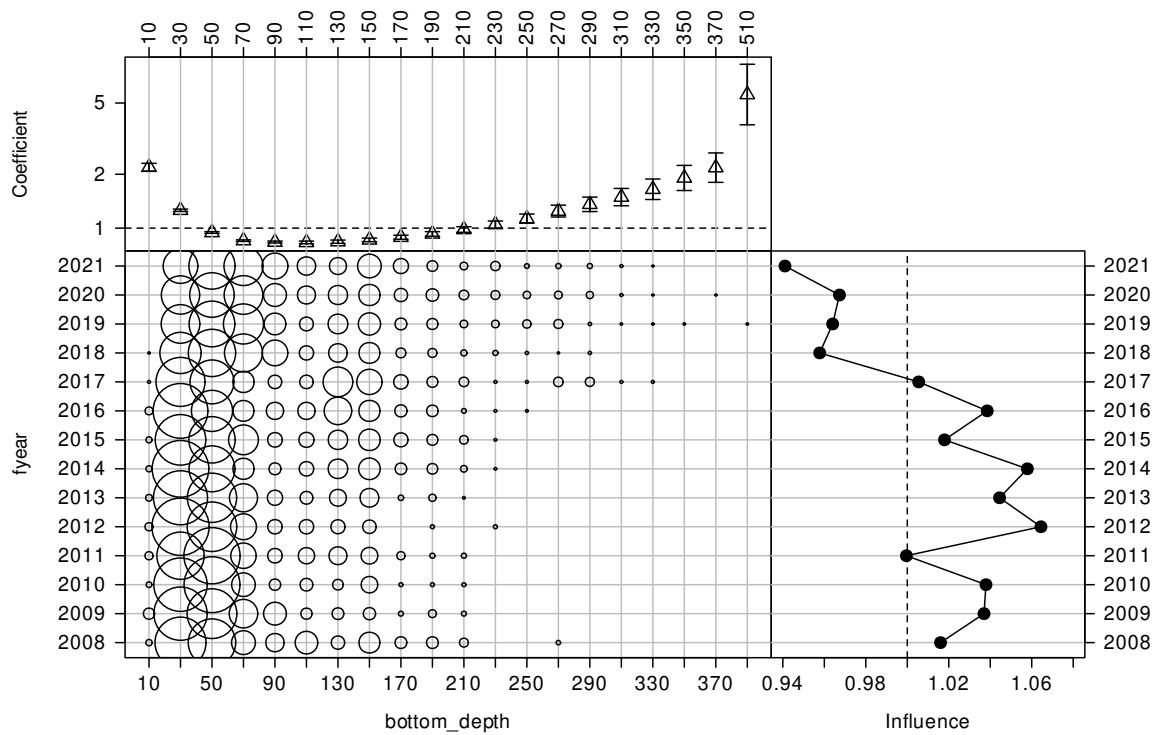


Figure D.15: CDI plot for bottom depth (m) for the positive catch SPO 1W BT event catch-per-unit-effort dataset.

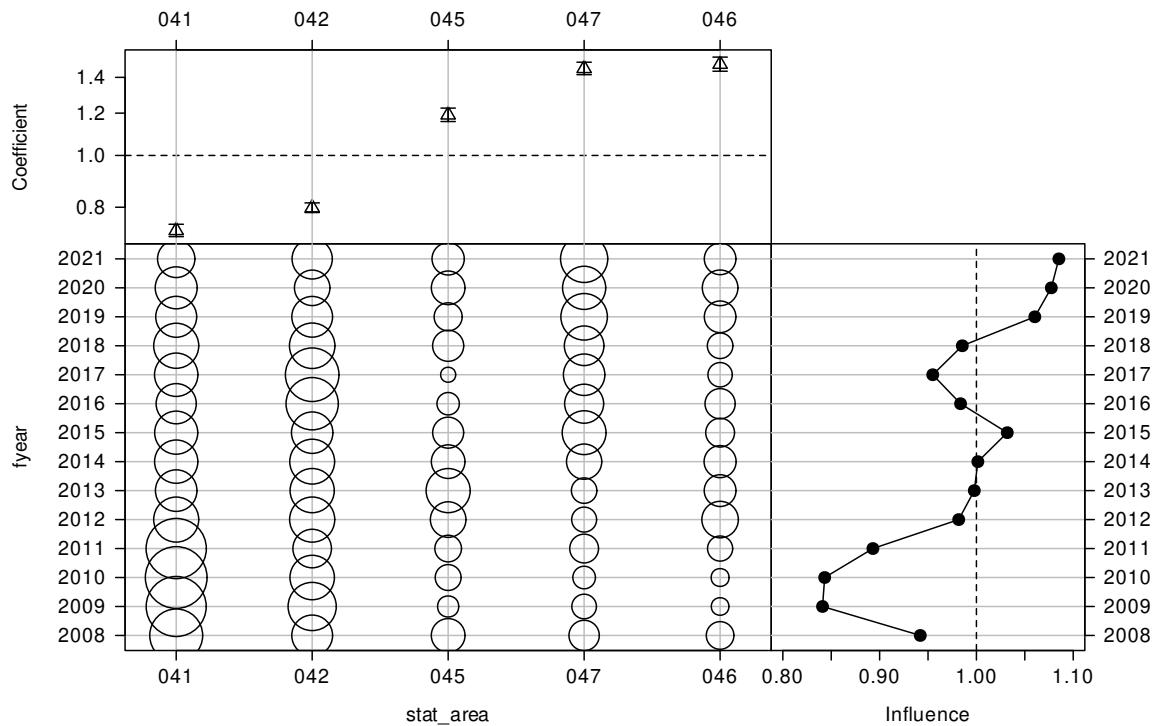


Figure D.16: CDI plot for statistical area for the positive catch SPO 1W BT event catch-per-unit-effort dataset.

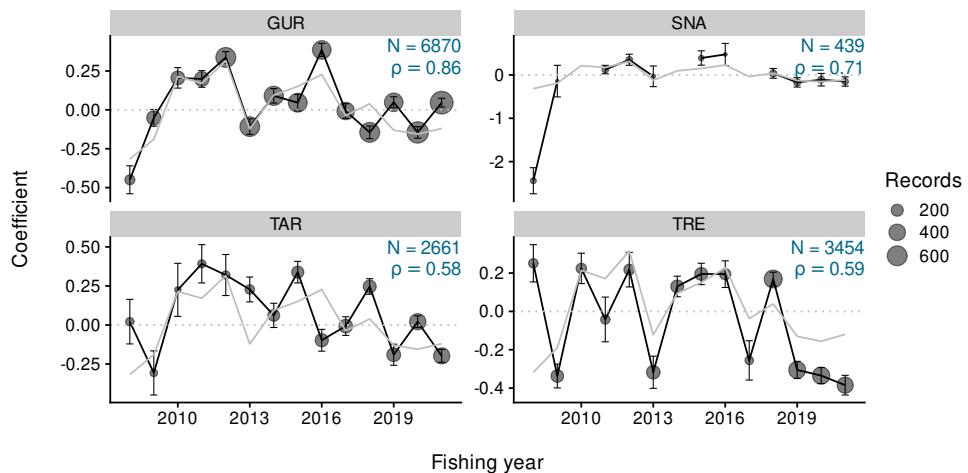


Figure D.17: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 1W BT event dataset.

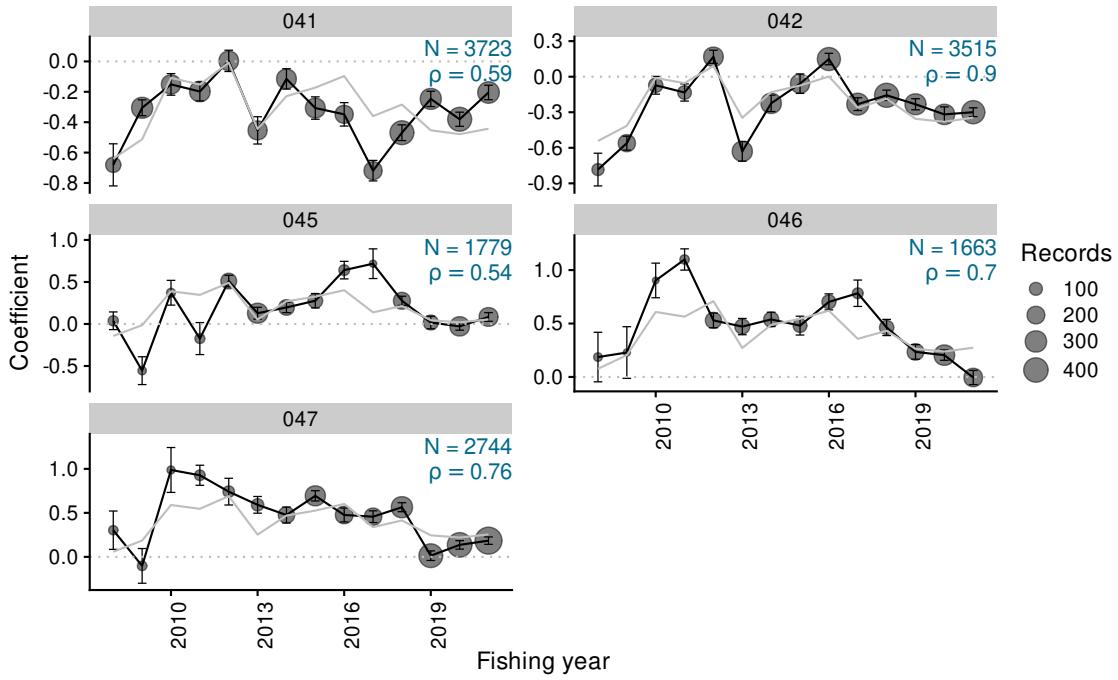


Figure D.18: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 1W BT event dataset.

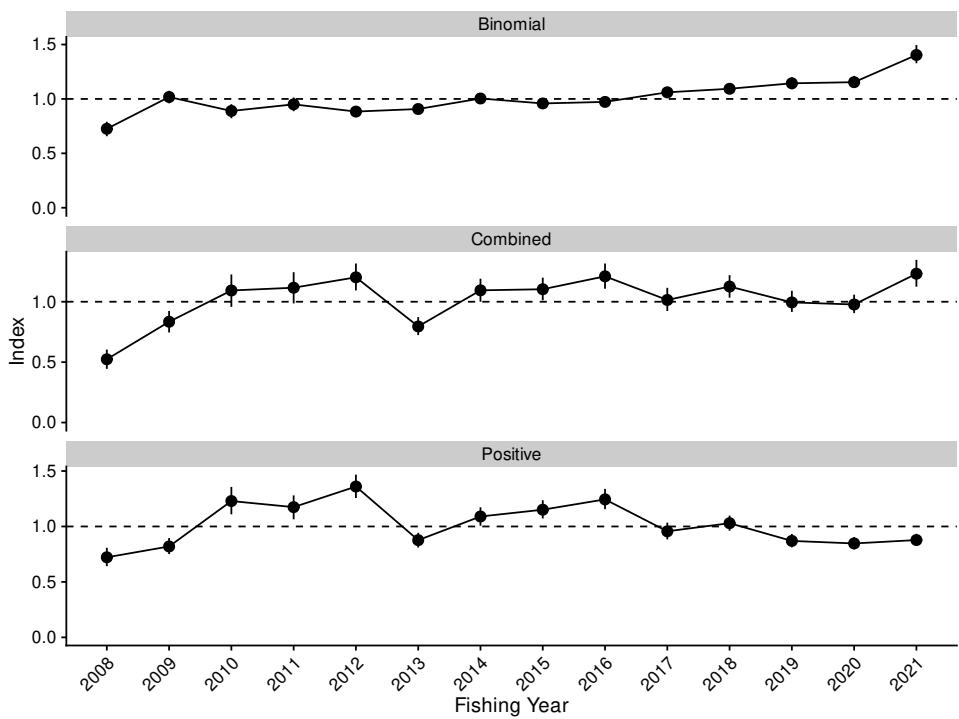


Figure D.19: Standardised indices and 95% confidence intervals for the SPO 1W BT event dataset.

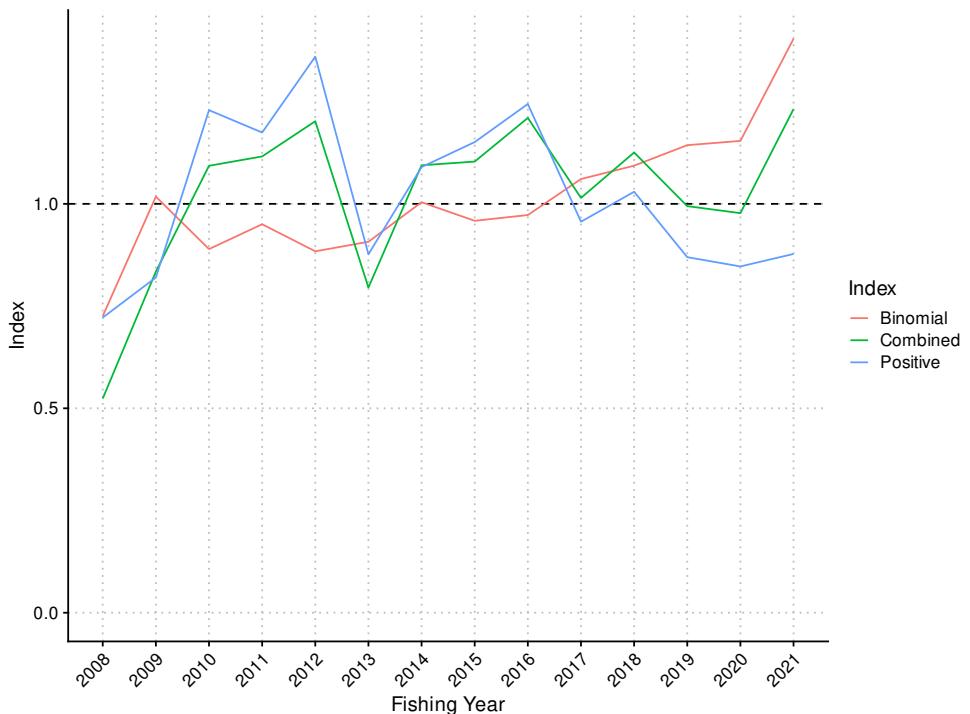


Figure D.20: Standardised indices for the SPO 1W BT event dataset.

Table D.6: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 1W BT event.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
2008	0.725	0.034	0.657	0.790	0.524	0.041	0.444	0.604	0.722	0.042	0.642	0.808
2009	1.018	0.029	0.960	1.075	0.834	0.045	0.746	0.923	0.820	0.037	0.752	0.895
2010	0.889	0.033	0.823	0.952	1.093	0.068	0.958	1.226	1.229	0.063	1.110	1.356
2011	0.950	0.032	0.887	1.013	1.116	0.066	0.986	1.244	1.174	0.055	1.065	1.280
2012	0.884	0.026	0.833	0.936	1.202	0.057	1.094	1.316	1.360	0.054	1.257	1.467
2013	0.907	0.024	0.859	0.953	0.795	0.038	0.724	0.873	0.877	0.034	0.810	0.943
2014	1.004	0.024	0.957	1.051	1.094	0.049	1.000	1.190	1.090	0.042	1.007	1.173
2015	0.959	0.024	0.910	1.004	1.103	0.048	1.012	1.199	1.151	0.042	1.072	1.236
2016	0.973	0.024	0.926	1.022	1.210	0.053	1.107	1.316	1.244	0.047	1.156	1.339
2017	1.061	0.027	1.008	1.112	1.015	0.049	0.923	1.115	0.956	0.039	0.883	1.035
2018	1.093	0.024	1.044	1.140	1.126	0.047	1.033	1.220	1.030	0.035	0.962	1.098
2019	1.144	0.028	1.089	1.200	0.994	0.045	0.916	1.090	0.870	0.031	0.812	0.932
2020	1.154	0.027	1.106	1.212	0.977	0.039	0.906	1.058	0.847	0.028	0.793	0.904
2021	1.404	0.043	1.328	1.495	1.232	0.057	1.124	1.347	0.878	0.028	0.824	0.934

D.2 SPO 2 BT event

This analysis is the tow-by-tow (event) analogue to the SPO 2 BT trip analysis presented in Section 5.3. It repeats that analysis at the level of an individual event, adding detailed explanatory information to the analysis that is not available to the trip-based analysis. Such information includes the duration of the tow, the starting depth of the tow, the speed of the tow, and the relative start time of the tow within the 24-hour period. As well, the location of the tow and the target species can be assigned explicitly to the tow, rather than using the modal value for the trip as is used in the trip-based analysis. This analysis begins with the 2006–07 fishing year, which is when the detailed event-based data became available. A plot comparing the event-based CPUE series with the longer trip-based series is presented in Figure D.157.

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 SPO 2 BT event CPUE series.

Series	SPO 2 BT event
QMS stock	SPO2
Reporting forms	ERS - Trawl, TCE, TCP
Fishing methods	BT
Target species	FLA, GUR, TAR
Statistical Areas	011, 012, 013, 014, 015
Period	2007-10-01, 2021-09-30
Resolution	Fishing event
Core fleet years	8
Core fleet trips	10
Default model	$\text{allockg} \sim \text{fyear} + \text{vessel_key} + \text{stat_area} + \text{month} + \text{target_species} + \text{ns(log(fishing_duration), 3)} + \text{ns(bottom_depth, 3)} + \text{ns(effort_speed, 3)} + \text{ns(start_time, 3)}$
Stepwise selection	Yes
Positive catch distribution	Lognormal

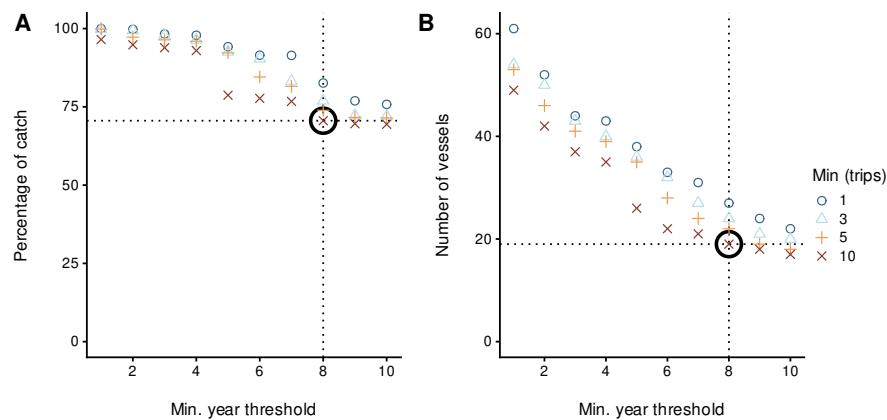


Figure D.21: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 2 BT event CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

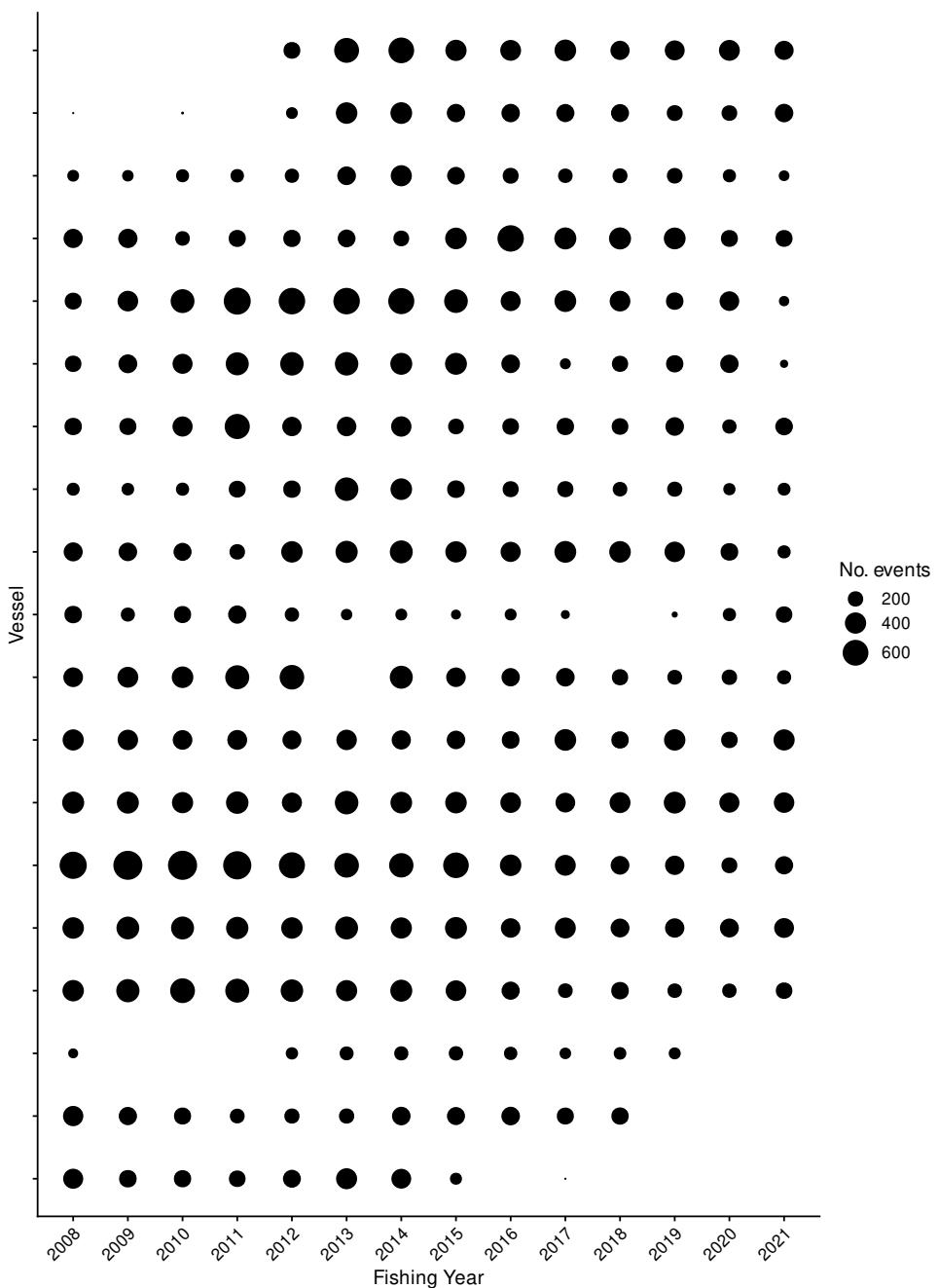


Figure D.22: Number of events by fishing year for core vessels. The area of the circles is proportional to the number of events undertaken by a vessel in a fishing year.

Table D.8: Summary of the SPO 2 BT 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	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	75 (100%) n: 9202	67 (100%) n: 9225	79 (100%) n: 9900	73 (100%) n: 9605	73 (100%) n: 8506	77 (100%) n: 8268	89 (100%) n: 9026	75 (100%) n: 7880	76 (100%) n: 6950
Positive fishing duration	75 (100%) n: 9200	67 (100%) n: 9220	79 (100%) n: 9897	73 (100%) n: 9604	73 (100%) n: 8506	77 (100%) n: 8268	89 (100%) n: 9025	75 (100%) n: 7879	76 (100%) n: 6950
Core fleet selection	40 (54%) n: 5335	36 (54%) n: 5401	44 (55%) n: 5661	45 (61%) n: 6248	54 (74%) n: 6352	64 (83%) n: 7060	75 (85%) n: 7390	61 (81%) n: 6268	60 (79%) n: 5510
Filter	2017	2018	2019	2020	2021				
Ungroomed data	74 (100%) n: 6591	57 (100%) n: 5979	68 (100%) n: 5739	76 (100%) n: 4894	66 (100%) n: 4600				
Positive fishing duration	74 (100%) n: 6589	57 (100%) n: 5979	68 (100%) n: 5732	76 (100%) n: 4887	66 (100%) n: 4595				
Core fleet selection	50 (68%) n: 5150	42 (74%) n: 4780	51 (75%) n: 4551	54 (71%) n: 3801	47 (72%) n: 3664				

Table D.9: Summary of the SPO 2 BT 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 rig.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
2008	18	935	5 335	17 800.82	40.47	42.40
2009	16	936	5 401	18 540.57	36.05	35.22
2010	17	943	5 661	19 492.27	43.54	41.37
2011	16	971	6 248	21 807.45	44.68	41.89
2012	19	1 051	6 352	22 308.45	53.66	44.32
2013	18	1 064	7 060	24 906.60	64.21	45.91
2014	19	1 059	7 390	25 868.02	75.50	43.57
2015	19	1 008	6 268	22 330.80	60.79	42.58
2016	18	1 040	5 510	19 769.70	60.12	47.88
2017	19	945	5 150	18 498.18	50.19	43.57
2018	17	874	4 780	17 673.63	42.06	46.69
2019	17	774	4 551	17 315.40	50.91	55.59
2020	16	617	3 801	14 686.48	54.12	66.98
2021	16	646	3 664	13 733.03	47.44	61.65

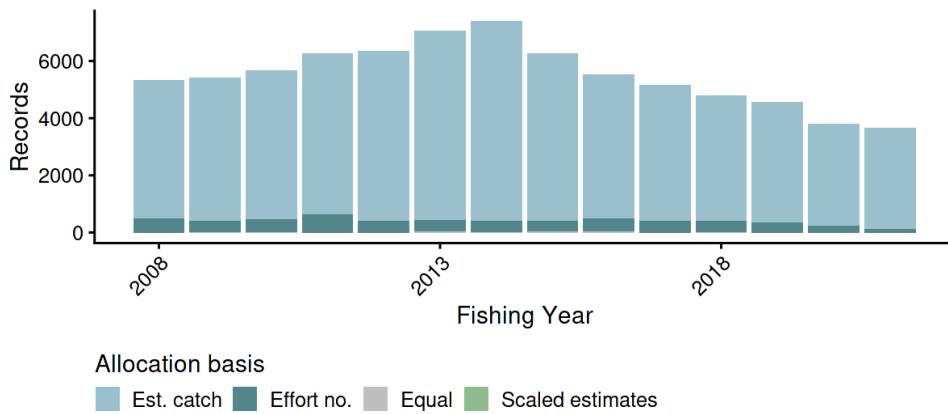


Figure D.23: Allocation basis for attributing landings to records in the SPO 2 BT event catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

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	12.00	104 860	1.60	1.60	*
+ vessel_key	18.00	100 770	5.40	3.90	*
+ target_species	2.00	99 688	6.50	1.00	*
+ ns(start_time, 3)	3.00	99 272	6.90	0.40	
+ ns(bottom_depth, 3)	3.00	98 782	7.30	0.50	
+ stat_area	4.00	98 486	7.60	0.30	
+ month	11.00	98 217	7.90	0.30	
+ ns(log(fishing_duration), 3)	3.00	98 054	8.00	0.20	
+ ns(effort_speed, 3)	3.00	98 033	8.10	0.00	

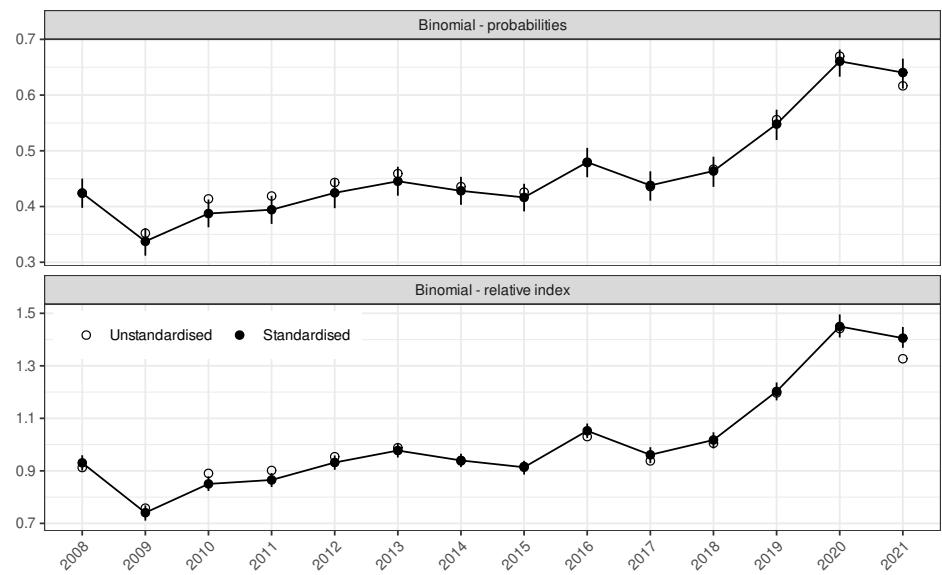


Figure D.24: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 2 BT event dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

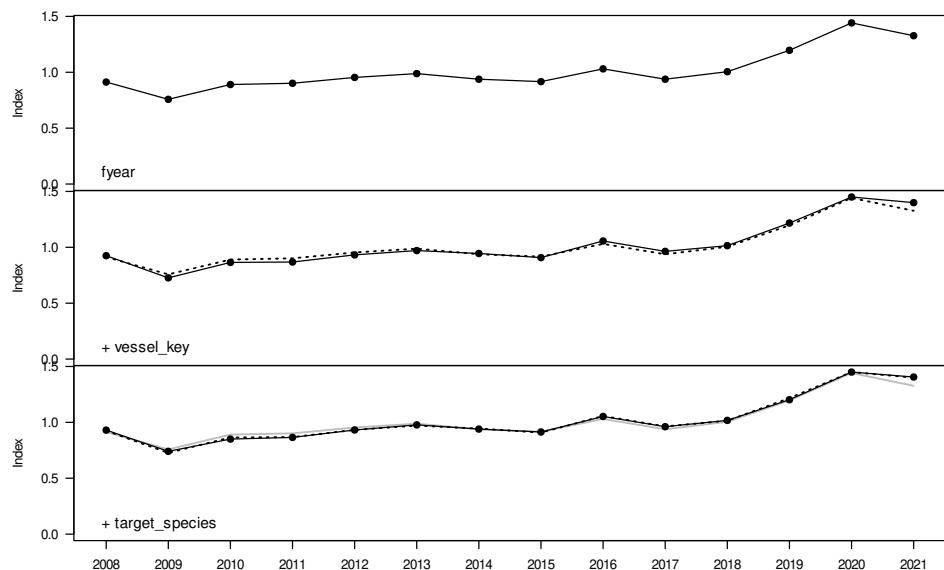


Figure D.25: Step plot for occurrence of catch in the SPO 2 BT event dataset.

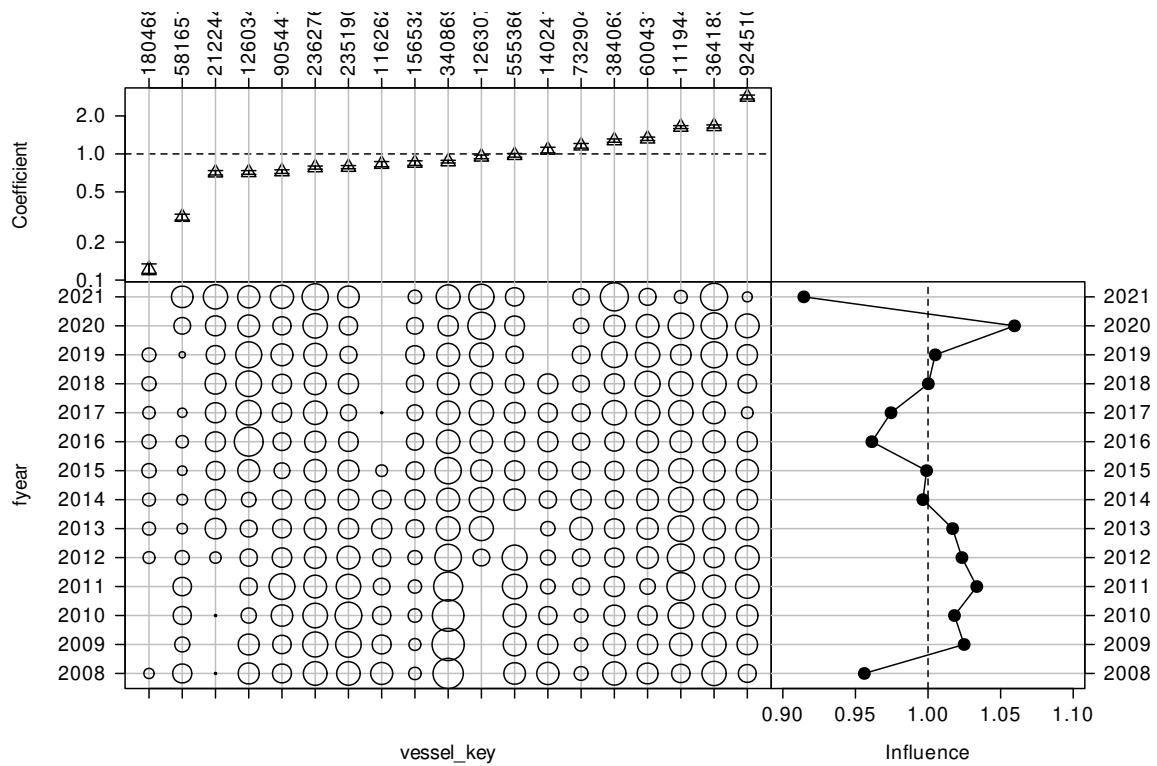


Figure D.26: CDI plot for vessel key for the occurrence of positive catch SPO 2 BT event catch-per-unit-effort dataset.

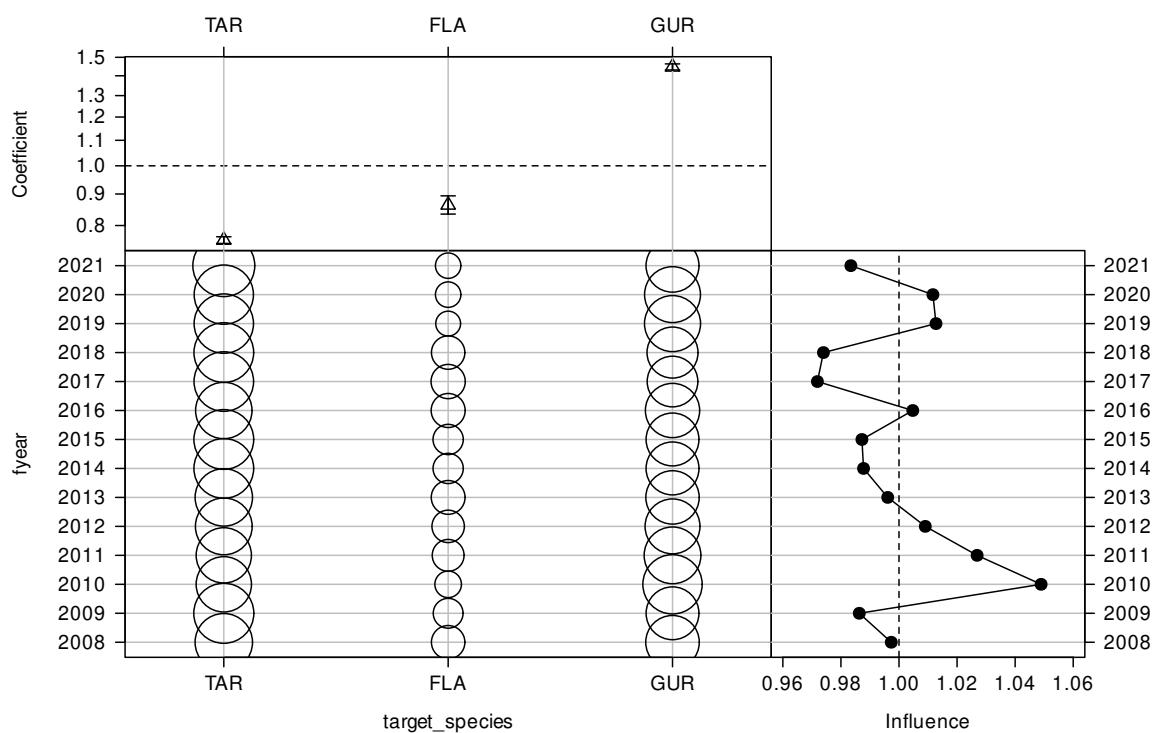


Figure D.27: CDI plot for target species for the occurrence of positive catch SPO 2 BT event catch-per-unit-effort dataset.

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	12	118 886	1.5	1.5	*
+ vessel key	18	109 677	24.1	22.6	*
+ ns(bottom depth, 3)	3	108 998	25.5	1.5	*
+ month	11	108 554	26.5	1.0	*
+ ns(log(fishing duration), 3)	3	108 130	27.4	0.9	
+ target species	2	107 788	28.1	0.7	
+ ns(start time, 3)	3	107 439	28.8	0.7	
+ stat area	4	107 247	29.2	0.4	
+ ns(effort speed, 3)	3	107 150	29.4	0.2	

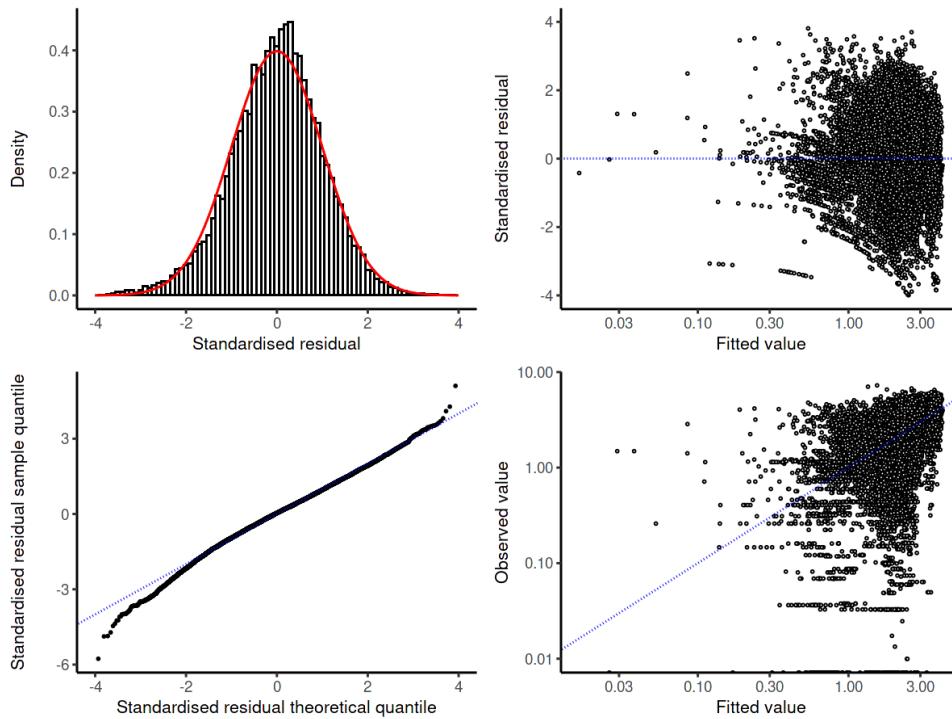


Figure D.28: Diagnostic plots for the lognormal model for the SPO 2 BT event dataset.

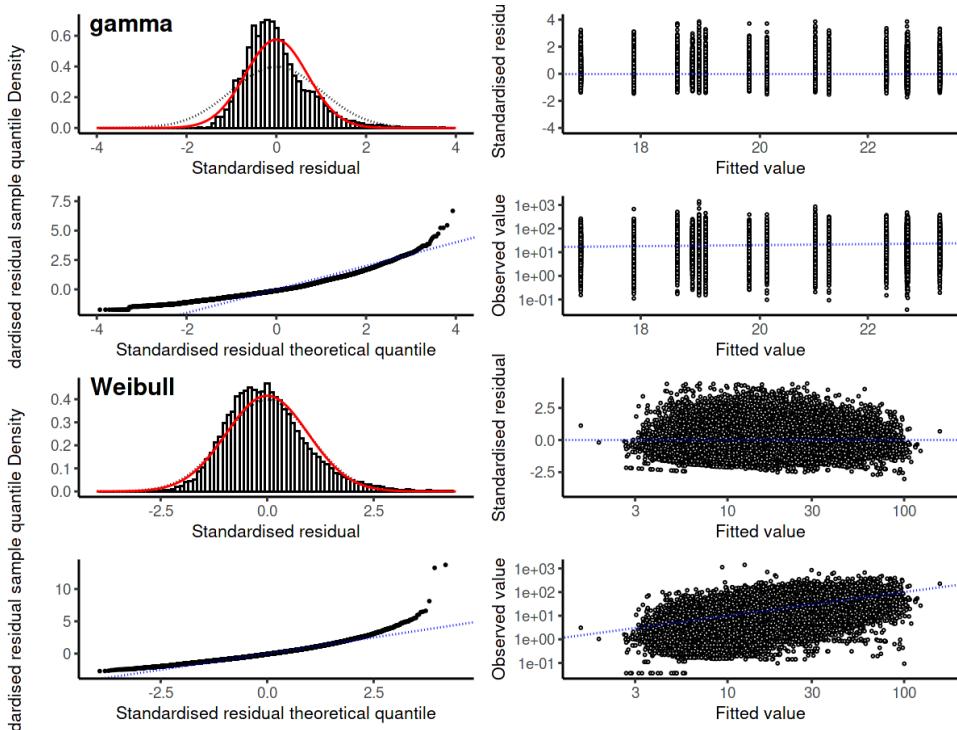


Figure D.29: Diagnostic plots for the gamma and Weibull model for the SPO 2 BT event dataset.

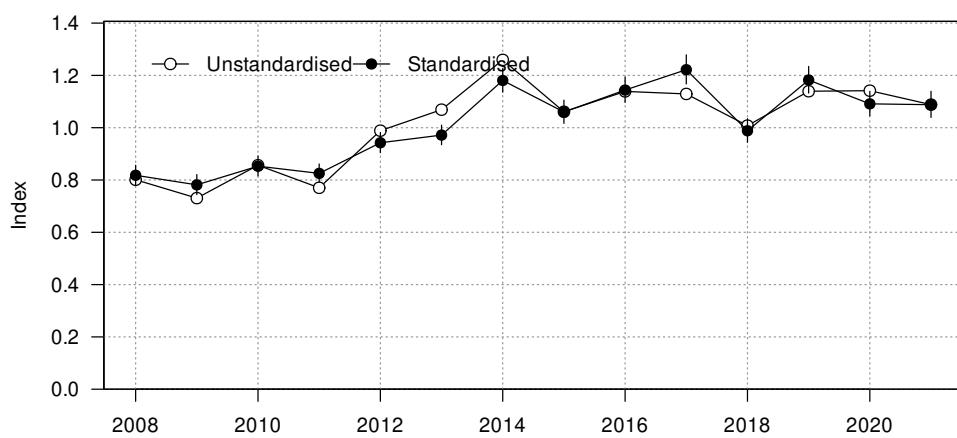


Figure D.30: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 2 BT event dataset.

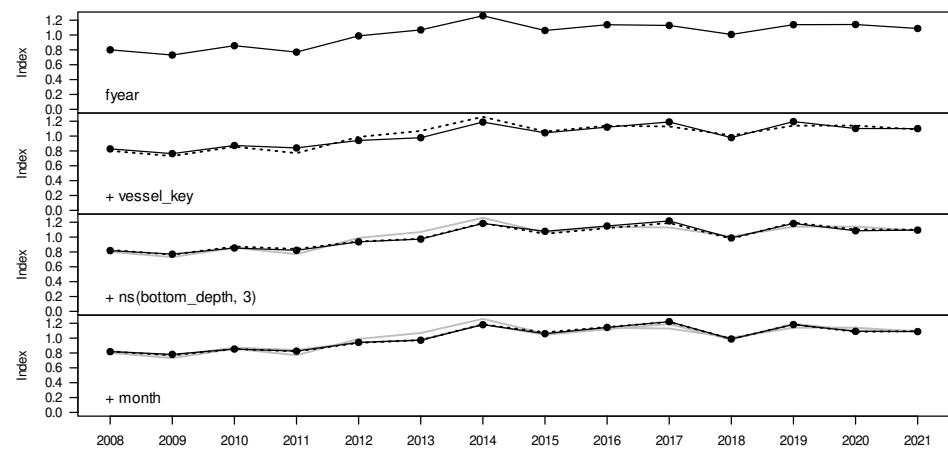


Figure D.31: Changes to the SPO 2 BT event positive catch index as terms are successively entered into the model.

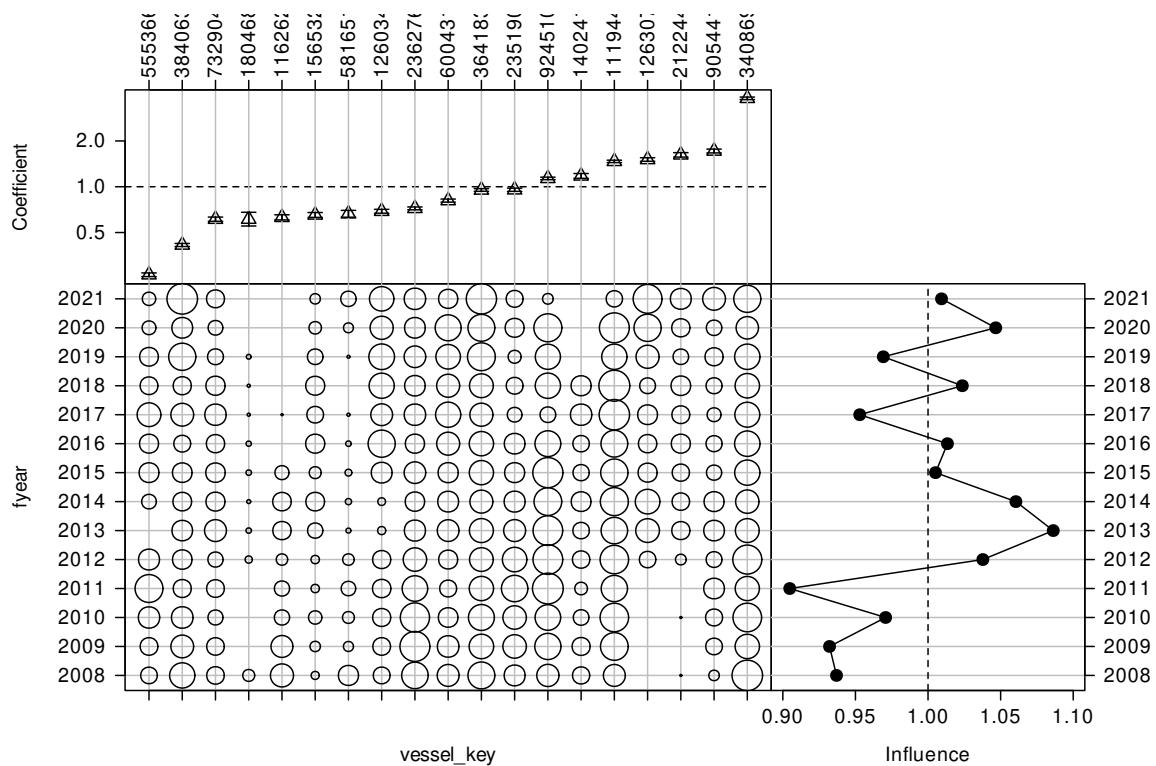


Figure D.32: CDI plot for vessel key for the positive catch SPO 2 BT event catch-per-unit-effort dataset.

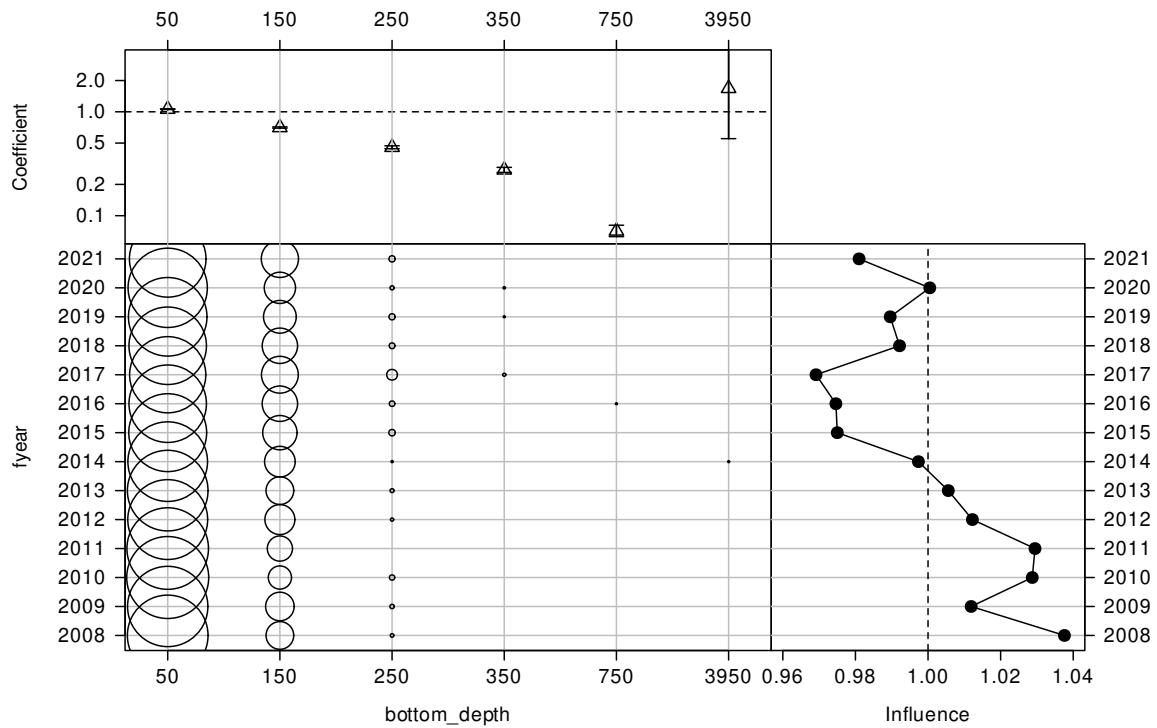


Figure D.33: CDI plot for bottom depth (m) for the positive catch SPO 2 BT event catch-per-unit-effort dataset.

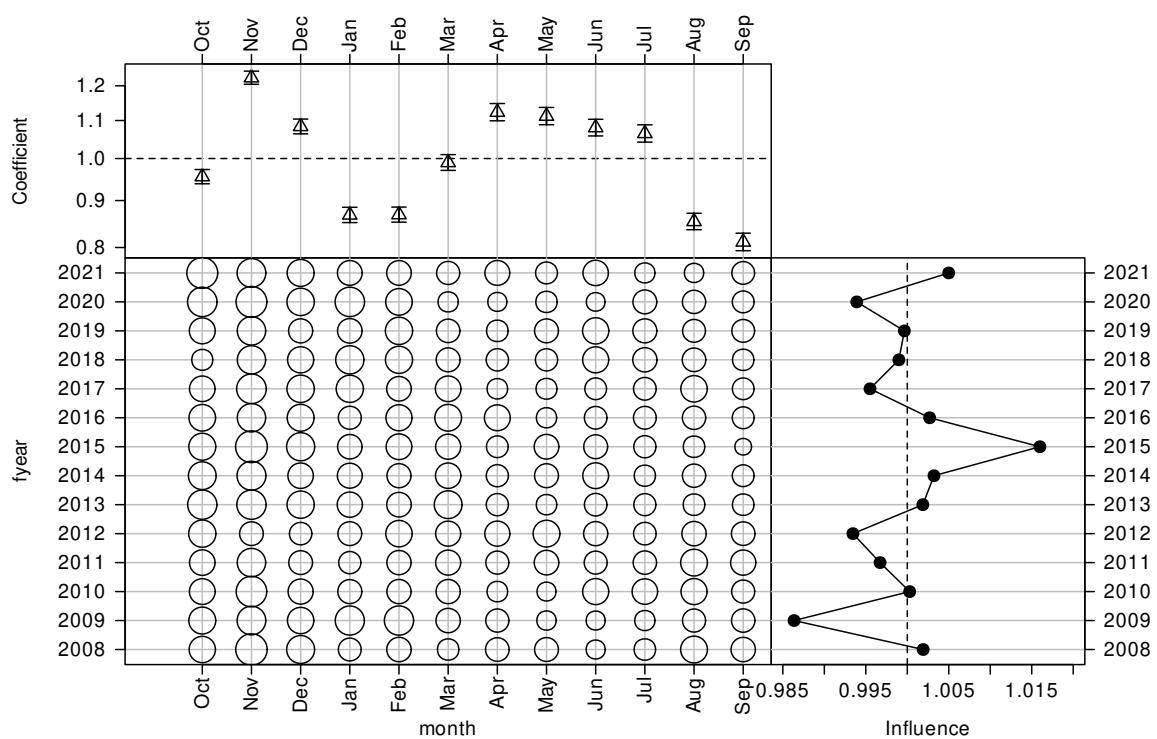


Figure D.34: CDI plot for month for the positive catch SPO 2 BT event catch-per-unit-effort dataset.

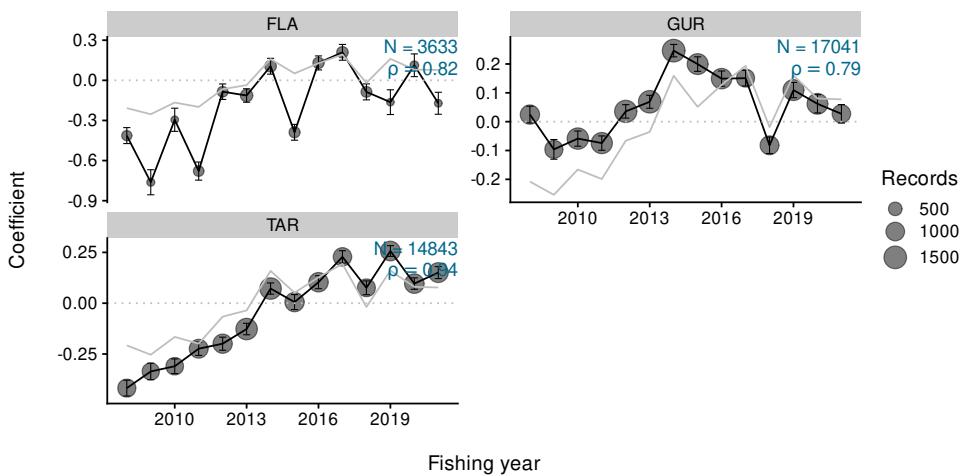


Figure D.35: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 2 BT event dataset.

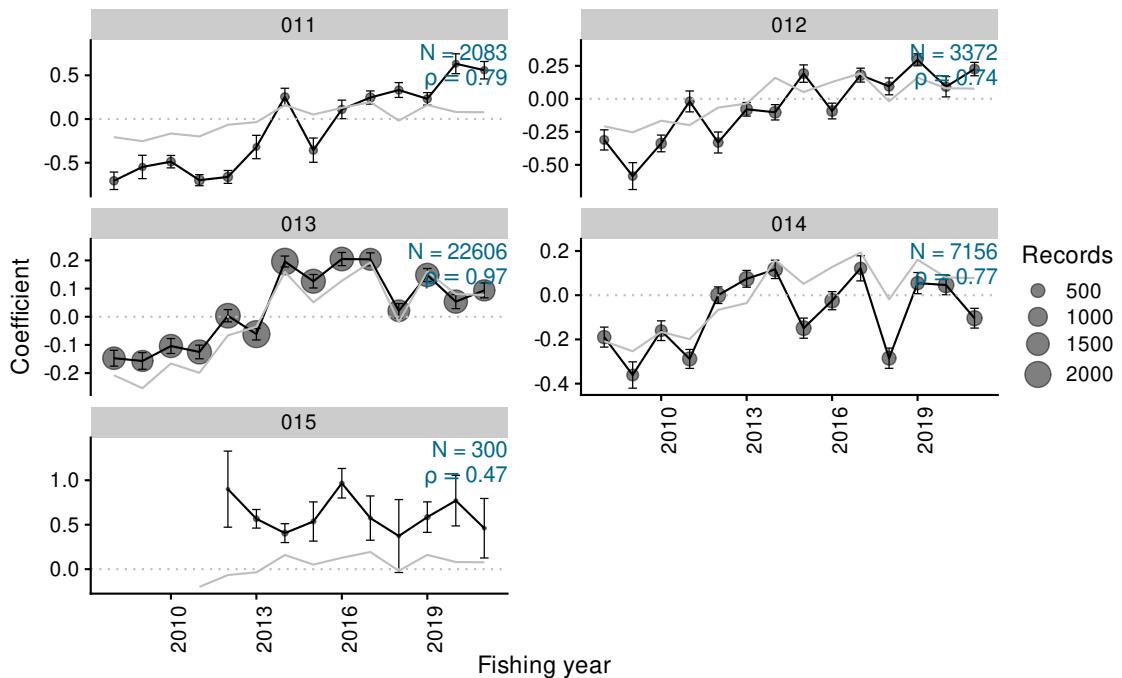


Figure D.36: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 2 BT event dataset.

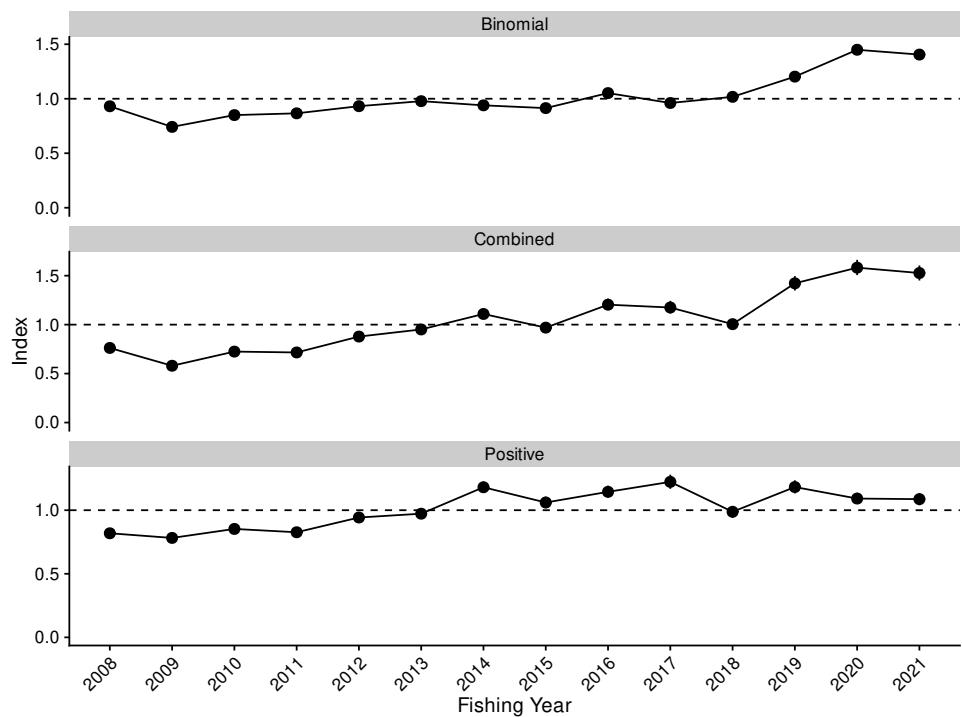


Figure D.37: Standardised indices and 95% confidence intervals for the SPO 2 BT event dataset.

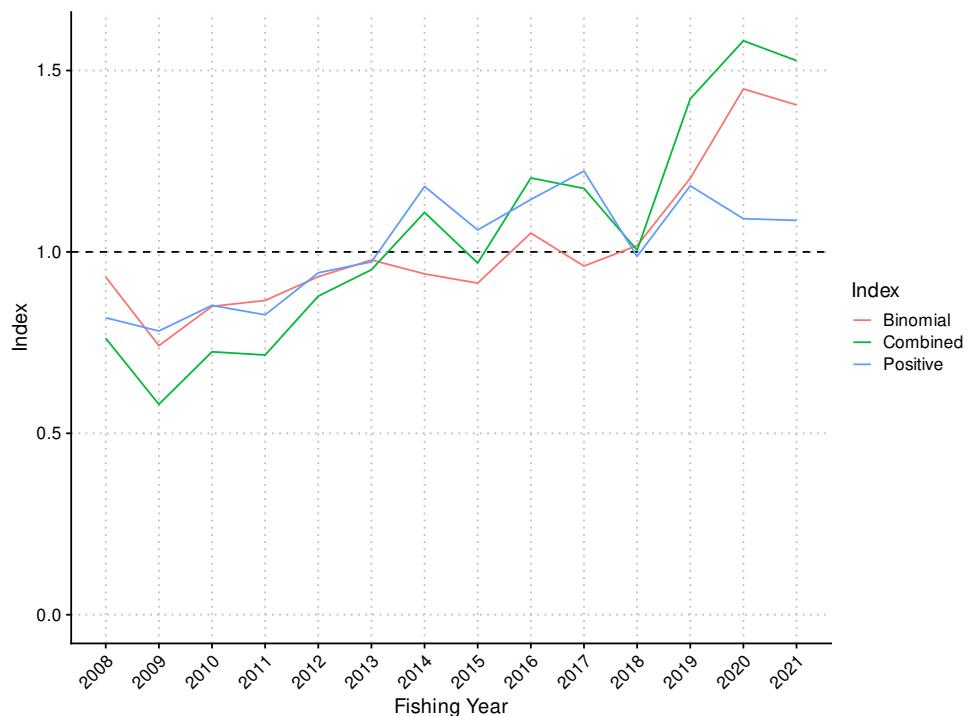


Figure D.38: Standardised indices for the SPO 2 BT event dataset.

Table D.12: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 2 BT event.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
2008	0.931	0.015	0.902	0.960	0.762	0.021	0.723	0.806	0.819	0.019	0.785	0.858
2009	0.742	0.014	0.715	0.769	0.580	0.017	0.547	0.613	0.782	0.019	0.745	0.818
2010	0.850	0.014	0.824	0.878	0.725	0.020	0.688	0.766	0.853	0.018	0.817	0.889
2011	0.866	0.013	0.839	0.891	0.716	0.018	0.681	0.751	0.827	0.017	0.794	0.861
2012	0.932	0.014	0.905	0.958	0.878	0.021	0.838	0.920	0.943	0.019	0.904	0.980
2013	0.978	0.014	0.953	1.006	0.951	0.022	0.907	0.995	0.973	0.019	0.936	1.009
2014	0.939	0.013	0.915	0.964	1.109	0.026	1.059	1.160	1.180	0.023	1.137	1.226
2015	0.914	0.014	0.887	0.942	0.969	0.026	0.918	1.019	1.061	0.023	1.016	1.107
2016	1.052	0.015	1.025	1.082	1.204	0.030	1.149	1.266	1.144	0.024	1.099	1.193
2017	0.961	0.015	0.932	0.992	1.175	0.033	1.113	1.243	1.223	0.028	1.168	1.279
2018	1.017	0.017	0.986	1.051	1.005	0.028	0.951	1.060	0.988	0.024	0.940	1.033
2019	1.203	0.017	1.171	1.238	1.422	0.037	1.349	1.496	1.182	0.026	1.132	1.235
2020	1.449	0.021	1.409	1.493	1.582	0.040	1.506	1.662	1.092	0.022	1.049	1.137
2021	1.405	0.020	1.369	1.447	1.527	0.039	1.451	1.604	1.087	0.024	1.039	1.134

D.3 SPO 3 BT trip

This trip-based analysis is equivalent to the SPO 3 BT analysis made by the 2019 SPO review (Starr & Kendrick 2020) but which has been superseded by the split analyses for SPO 3 BT(east coast) trip and SPO 3 BT(Foveaux St) trip that are presented in Sections 5.4 and 5.5 respectively. However, the analysis presented here provides the basis upon which the two child analyses have been split away, as well as providing continuity with the 2019 analysis. A comparison of this series with the equivalent series calculated in 2019 (Starr & Kendrick 2020) shows that this series matches that series closely in the overlapping years, with the increasing trend observed in 2018 continuing since then (Figure D.158). Vessels selected for this analysis needed to catch at least one kg of rig among all the trips included in the selection. The close match between the 2019 and 2022 SPO 3 BT trip analyses indicates that the 2019 analysis also used the same one kg vessel selection criterion, despite what was reported by Starr & Kendrick (2020) (see discussion in the following Section D.4).

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 SPO 3 BT trip CPUE series.

Series	SPO 3 BT trip
QMS stock	SPO3
Reporting forms	CEL, ERS - Trawl, TCE, TCP
Fishing methods	BT
Target species	FLA, BAR, STA, RCO, SPD, SPO, TAR
Statistical Areas	018, 020, 022, 024, 025, 026, 027, 028, 029, 030, 031, 032
Period	1989-10-01, 2021-09-30
Resolution	Trip
Core fleet years	8
Core fleet trips	10
Default model	$\text{landkg} \sim \text{fyear} + \text{vessel_key} + \text{modal_stat_area} + \text{modal_month} + \text{target_species} + \text{ns}(\log(\text{total_fishing_duration}), 3) + \text{ns}(\log(\text{total_effort_num}), 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

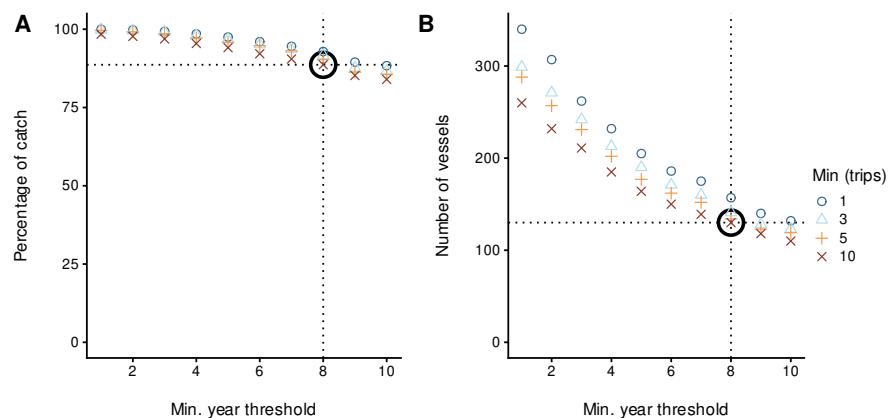


Figure D.39: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 3 BT trip CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

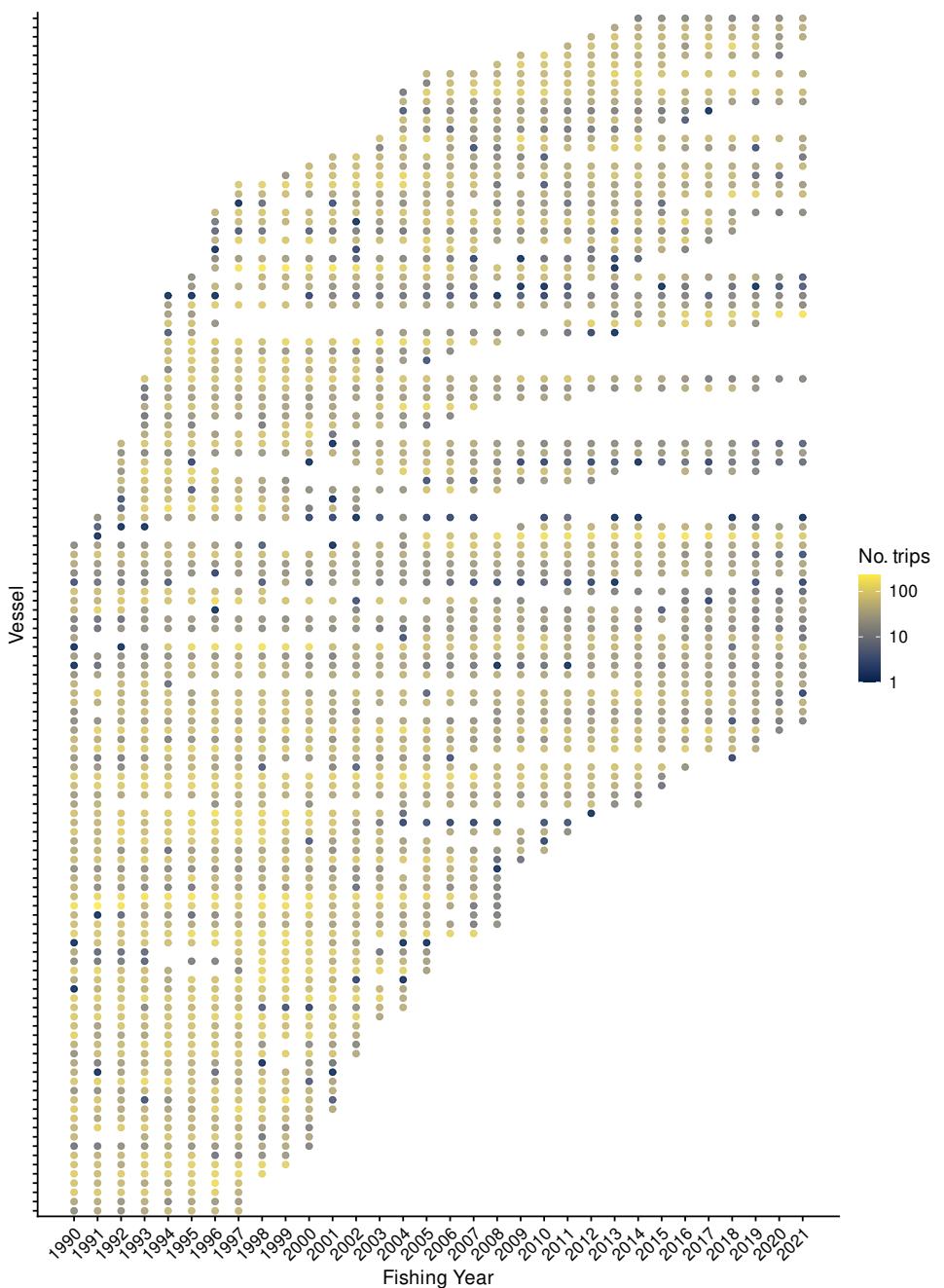


Figure D.40: Number of trips by fishing year for core vessels. The colour of the points is proportional to the number of trips undertaken by a vessel in a fishing year.

Table D.14: Summary of the SPO 3 BT trip 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	48 (100%) n: 6724	62 (100%) n: 6386	75 (100%) n: 6638	93 (100%) n: 7419	93 (100%) n: 7551	85 (100%) n: 7721	92 (100%) n: 7494	94 (100%) n: 7694	93 (100%) n: 7475
Positive fishing duration	48 (100%) n: 6720	62 (100%) n: 6373	75 (100%) n: 6626	93 (100%) n: 7408	92 (100%) n: 7537	85 (100%) n: 7712	92 (100%) n: 7428	94 (100%) n: 7587	92 (100%) n: 7363
Trim extreme effort num	47 (100%) n: 6706	62 (100%) n: 6363	72 (100%) n: 6614	92 (100%) n: 7393	92 (100%) n: 7529	85 (100%) n: 7696	91 (100%) n: 7409	92 (100%) n: 7567	92 (100%) n: 7345
Trim extreme duration	47 (100%) n: 6706	61 (100%) n: 6360	72 (100%) n: 6612	92 (100%) n: 7392	92 (100%) n: 7528	85 (100%) n: 7696	91 (100%) n: 7406	92 (100%) n: 7567	92 (100%) n: 7342
Core fleet selection	27 (56%) n: 3954	41 (66%) n: 4075	49 (65%) n: 4400	69 (74%) n: 5208	72 (78%) n: 5786	74 (87%) n: 6205	82 (90%) n: 6221	83 (88%) n: 6576	85 (91%) n: 6758
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	75 (100%) n: 6940	91 (100%) n: 6129	119 (100%) n: 5293	96 (100%) n: 4815	98 (100%) n: 5156	91 (100%) n: 5061	92 (100%) n: 5201	79 (100%) n: 4193	95 (100%) n: 3430
Positive fishing duration	75 (100%) n: 6868	91 (100%) n: 6096	119 (100%) n: 5292	96 (100%) n: 4815	98 (100%) n: 5156	91 (100%) n: 5061	92 (100%) n: 5201	79 (100%) n: 4193	95 (100%) n: 3430
Trim extreme effort num	75 (100%) n: 6861	91 (100%) n: 6094	118 (100%) n: 5290	96 (100%) n: 4809	97 (100%) n: 5147	91 (100%) n: 5058	92 (100%) n: 5199	79 (100%) n: 4193	95 (100%) n: 3424
Trim extreme duration	75 (100%) n: 6860	91 (100%) n: 6094	118 (100%) n: 5290	96 (100%) n: 4809	97 (100%) n: 5146	91 (100%) n: 5058	92 (100%) n: 5199	79 (100%) n: 4192	95 (100%) n: 3423
Core fleet selection	64 (85%) n: 6476	80 (87%) n: 5534	103 (87%) n: 4588	79 (82%) n: 4115	84 (86%) n: 4285	82 (90%) n: 4328	84 (91%) n: 4561	70 (89%) n: 3912	80 (84%) n: 3259

Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	59 (100%) n: 2890	77 (100%) n: 3301	88 (100%) n: 3453	82 (100%) n: 3170	101 (100%) n: 3192	100 (100%) n: 3433	131 (100%) n: 3424	124 (100%) n: 2582	131 (100%) n: 2912
Positive fishing duration	59 (100%) n: 2889	77 (100%) n: 3301	88 (100%) n: 3453	82 (100%) n: 3170	101 (100%) n: 3192	100 (100%) n: 3433	131 (100%) n: 3424	124 (100%) n: 2582	131 (100%) n: 2912
Trim extreme effort num	59 (100%) n: 2888	77 (100%) n: 3297	88 (100%) n: 3453	81 (100%) n: 3167	98 (100%) n: 3189	99 (100%) n: 3431	131 (100%) n: 3424	123 (100%) n: 2580	130 (100%) n: 2910
Trim extreme duration	59 (100%) n: 2885	77 (100%) n: 3297	88 (100%) n: 3450	81 (100%) n: 3166	98 (100%) n: 3187	99 (100%) n: 3428	131 (100%) n: 3424	123 (100%) n: 2580	129 (100%) n: 2905
Core fleet selection	57 (100%) n: 2808	75 (100%) n: 3167	81 (92%) n: 3106	73 (89%) n: 2859	94 (93%) n: 2934	94 (94%) n: 3154	125 (100%) n: 3176	119 (100%) n: 2400	122 (94%) n: 2641

Filter	2017	2018	2019	2020	2021
Ungroomed data	140 (100%) n: 2865	178 (100%) n: 2609	136 (100%) n: 2066	125 (100%) n: 1715	153 (100%) n: 1678
Positive fishing duration	140 (100%) n: 2865	178 (100%) n: 2608	136 (100%) n: 2066	125 (100%) n: 1711	153 (100%) n: 1673
Trim extreme effort num	140 (100%) n: 2863	178 (100%) n: 2608	136 (100%) n: 2066	125 (100%) n: 1711	153 (100%) n: 1673
Trim extreme duration	140 (100%) n: 2862	177 (100%) n: 2607	136 (100%) n: 2066	125 (100%) n: 1709	153 (100%) n: 1671
Core fleet selection	125 (89%) n: 2559	164 (93%) n: 2322	122 (89%) n: 1837	116 (93%) n: 1457	138 (90%) n: 1433

Table D.15: Summary of the SPO 3 BT trip dataset after core fleet selection. Trips caught represents the percentage of trips with rig catch.

Fishing year	Vessels	Trips	Events	Hrs	Catch (t)	Trips caught
1990	73	3 954	15 827	44 816.78	26.89	20.61
1991	71	4 075	16 344	50 069.58	41.37	23.44
1992	80	4 400	19 037	60 452.37	48.94	30.09
1993	88	5 208	22 813	70 559.98	68.82	25.19
1994	93	5 786	24 005	68 529.38	72.38	27.19
1995	93	6 205	24 705	70 884.32	74.35	25.79
1996	97	6 221	25 582	74 296.57	82.41	27.21
1997	97	6 576	29 351	79 325.32	82.90	26.38
1998	96	6 758	29 758	81 383.95	84.80	28.35
1999	88	6 476	28 466	77 938.40	64.14	30.96
2000	91	5 534	25 003	69 959.30	79.73	36.70
2001	90	4 588	24 334	67 906.17	103.07	38.88
2002	85	4 115	21 487	57 610.95	79.36	37.91
2003	79	4 285	23 590	64 875.55	84.33	40.14
2004	85	4 328	21 501	59 179.79	81.71	37.92
2005	84	4 561	22 446	63 792.15	83.53	40.06
2006	79	3 912	19 656	58 629.85	70.29	44.04
2007	76	3 259	17 962	55 182.30	80.12	52.47
2008	73	2 808	14 166	43 772.08	57.15	45.33
2009	67	3 167	14 854	49 824.58	74.52	45.12
2010	68	3 106	15 745	51 421.73	80.68	48.84
2011	68	2 859	14 028	47 143.90	73.36	49.81
2012	66	2 934	14 426	47 371.46	94.26	46.11
2013	68	3 154	15 338	50 935.80	94.06	51.11
2014	65	3 176	15 616	54 321.68	125.13	56.11
2015	59	2 400	12 065	43 083.80	118.53	58.25
2016	58	2 641	12 350	43 175.58	122.44	56.42
2017	54	2 559	12 097	42 205.03	125.19	60.57
2018	55	2 322	11 418	40 887.93	164.25	66.49
2019	53	1 837	9 437	32 448.42	121.72	73.49
2020	45	1 457	8 435	28 693.90	116.06	68.50
2021	45	1 433	8 952	30 320.12	137.50	74.74

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	30.00	159 096	5.50	5.50	*
+ vessel_key	129.00	140 717	16.50	11.10	*
+ ns(log(total_effort_num), 3)	3.00	134 181	20.40	3.90	*
+ modal_month	11.00	128 442	23.90	3.40	*
+ modal_stat_area	11.00	127 573	24.40	0.50	
+ ns(log(total_fishing_duration), 3)	3.00	127 173	24.60	0.20	
+ target_species	6.00	126 846	24.80	0.20	

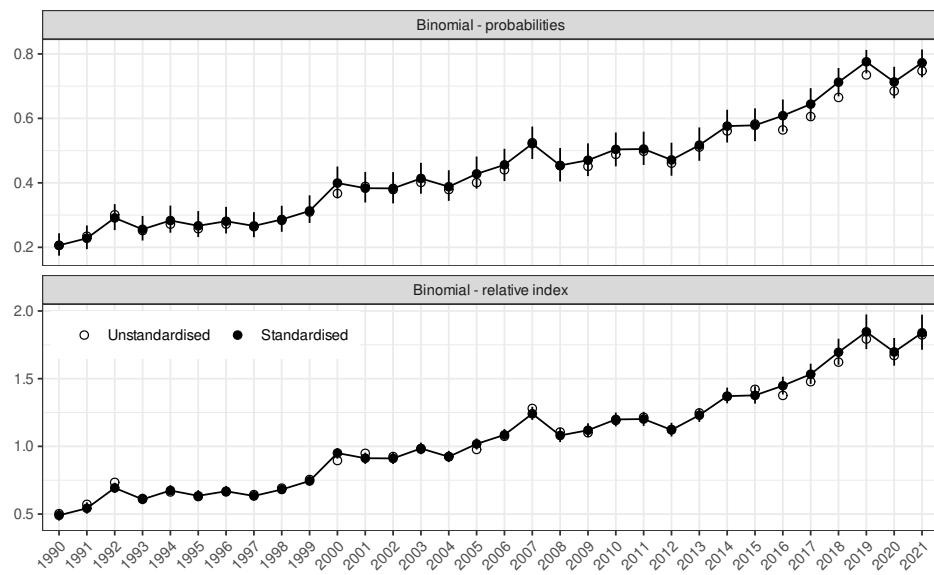


Figure D.41: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 3 BT trip dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

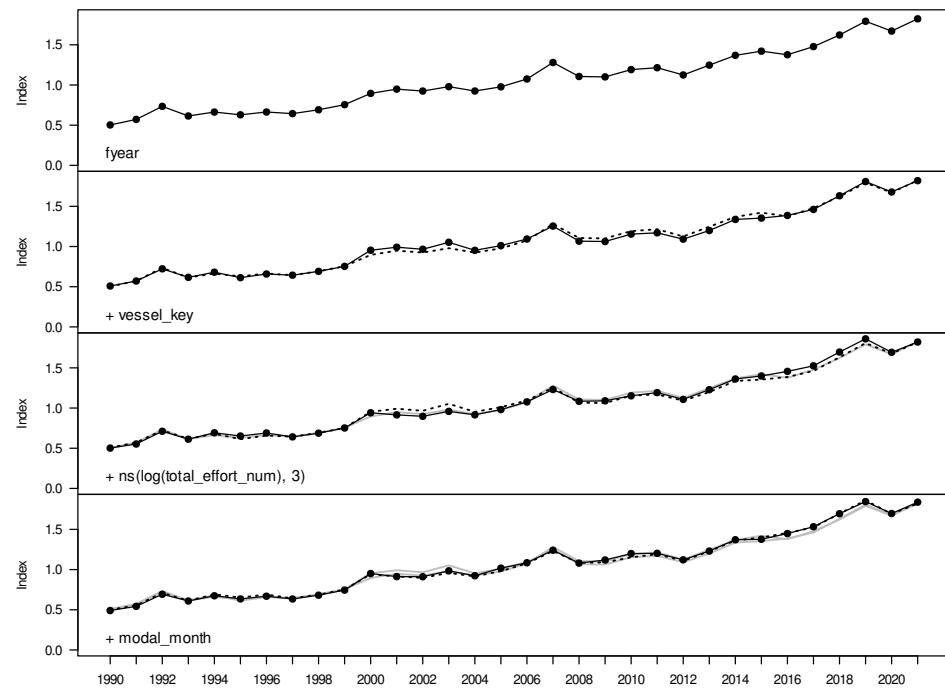


Figure D.42: Step plot for occurrence of catch in the SPO 3 BT trip dataset.

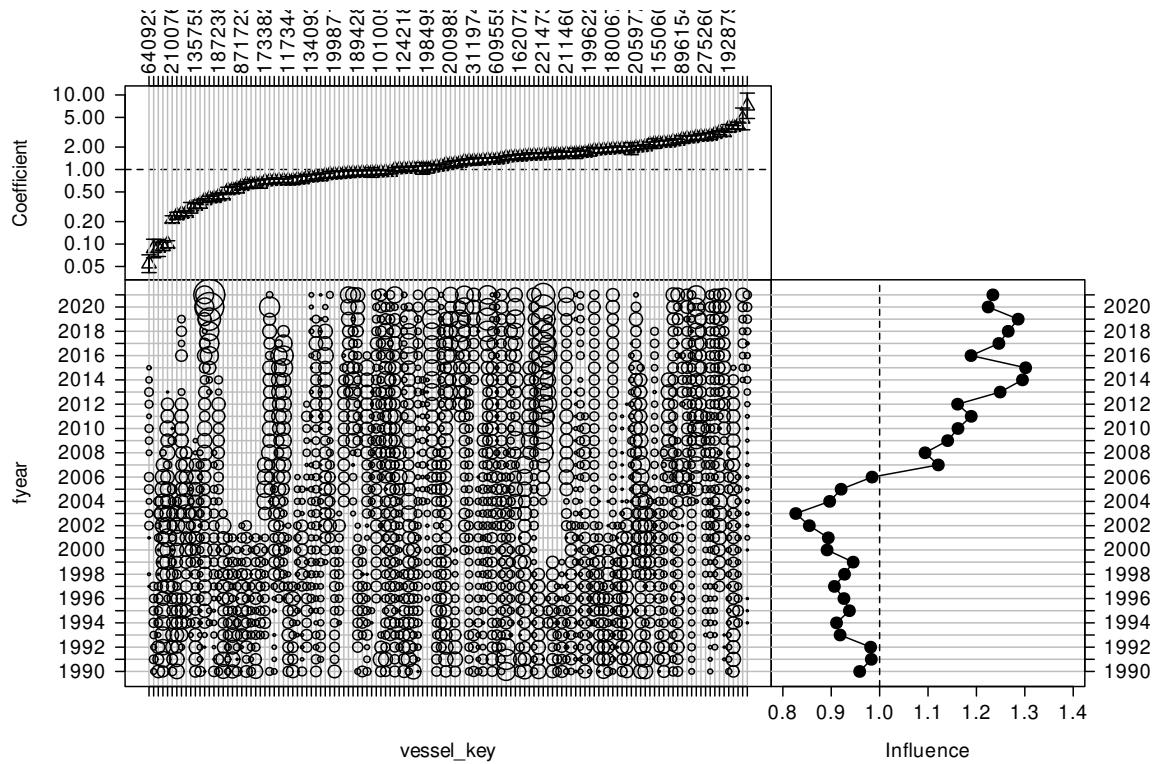


Figure D.43: CDI plot for vessel key for the occurrence of positive catch SPO 3 BT trip catch-per-unit-effort dataset.

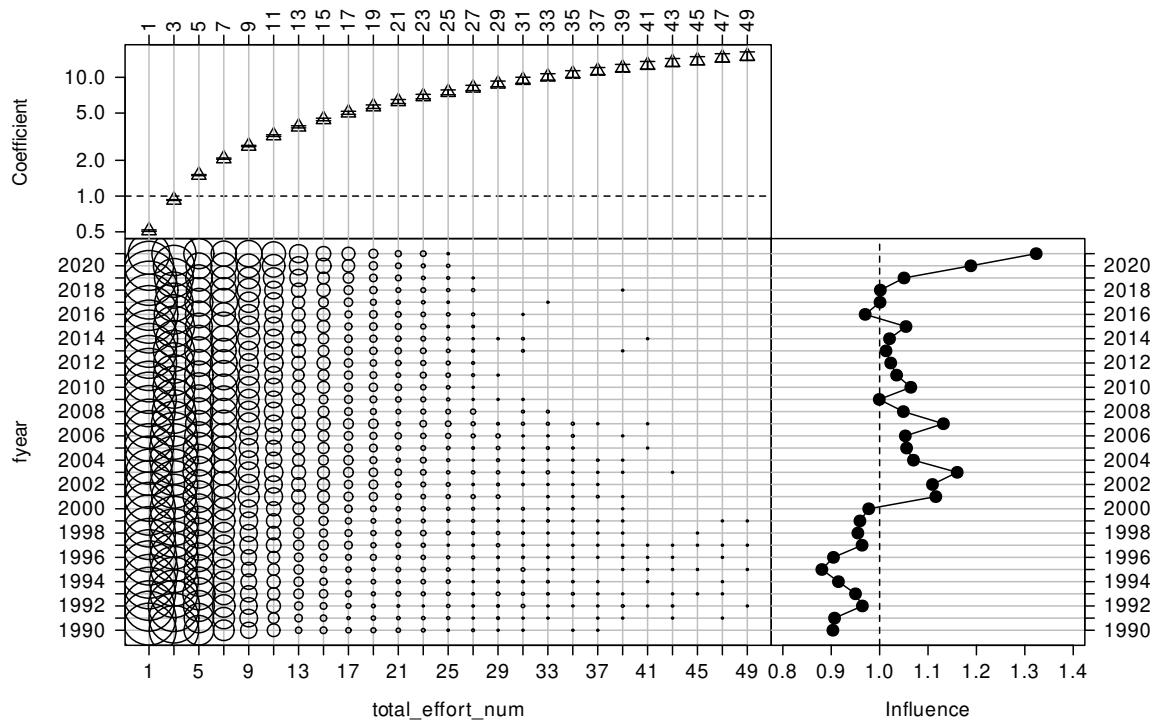


Figure D.44: CDI plot for total effort num for the occurrence of positive catch SPO 3 BT trip catch-per-unit-effort dataset.

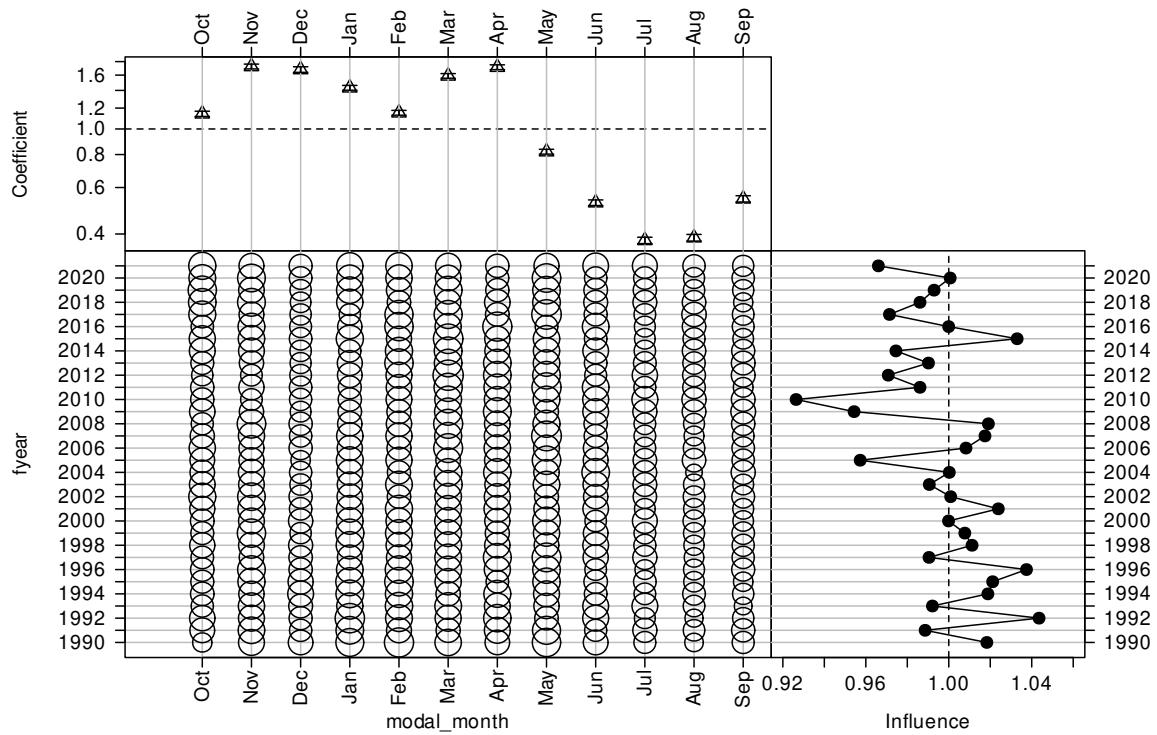


Figure D.45: CDI plot for modal month for the occurrence of positive catch SPO 3 BT trip catch-per-unit-effort dataset.

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	30	176 888	2.4	2.4	*
+ vessel key	129	167 724	19.5	17.2	*
+ ns(log(total fishing duration), 3)	3	164 763	24.3	4.8	*
+ target species	6	163 261	26.6	2.3	*
+ modal stat area	11	162 683	27.5	0.9	
+ modal month	11	162 116	28.4	0.9	
+ ns(log(total effort num), 3)	3	161 947	28.6	0.3	

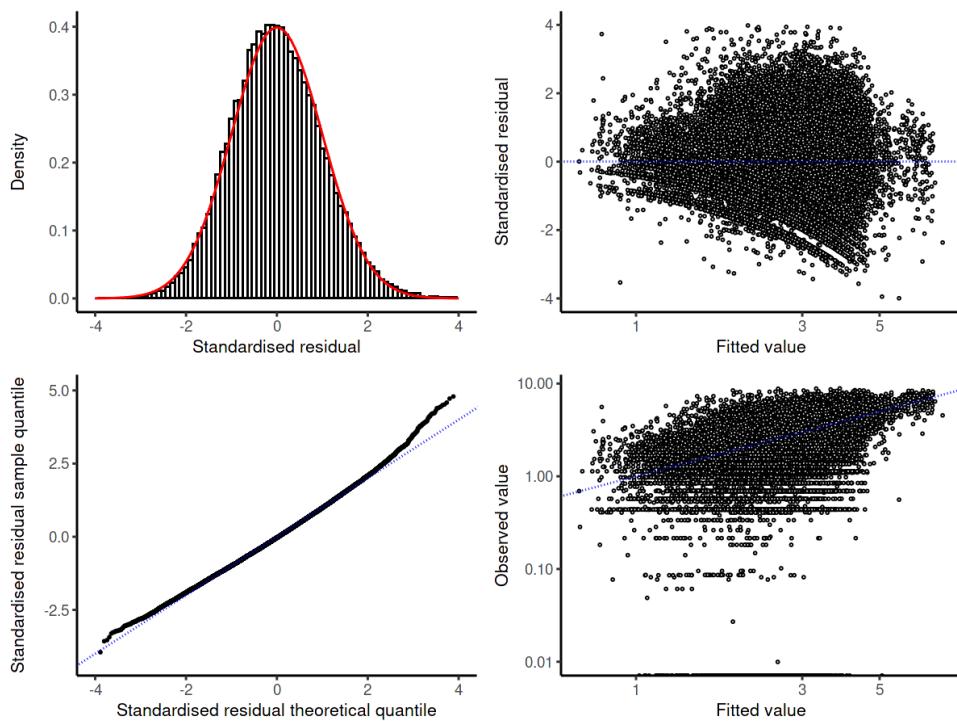


Figure D.46: Diagnostic plots for the lognormal model for the SPO 3 BT trip dataset.

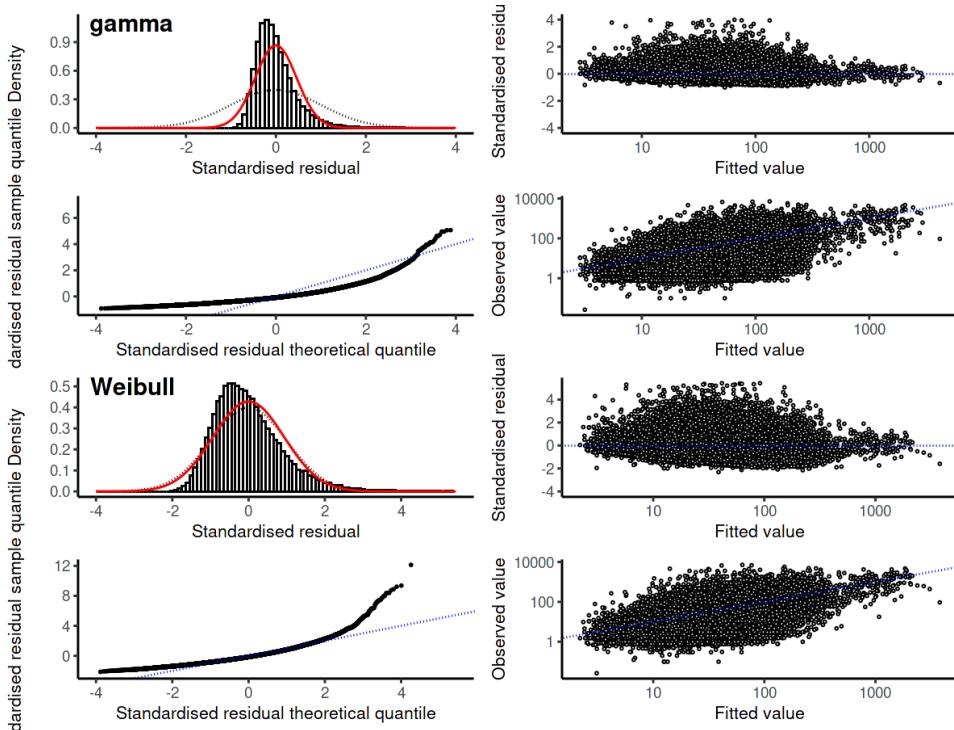


Figure D.47: Diagnostic plots for the gamma and Weibull model for the SPO 3 BT trip dataset.

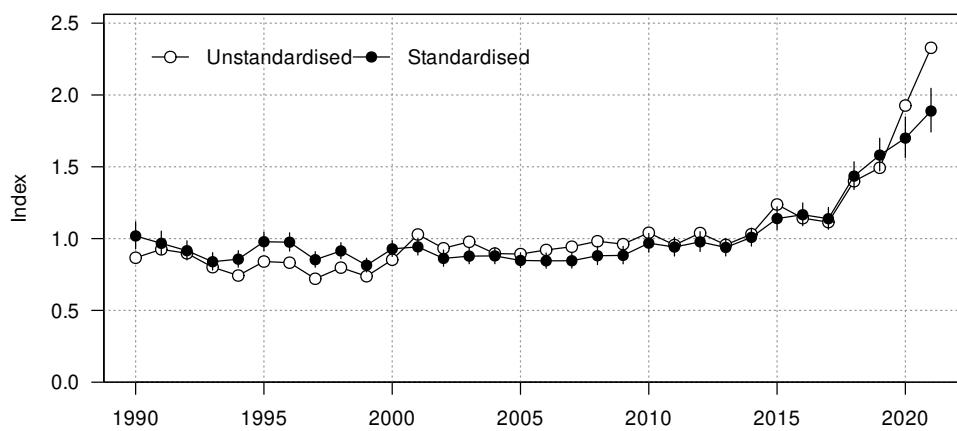


Figure D.48: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 3 BT trip dataset.

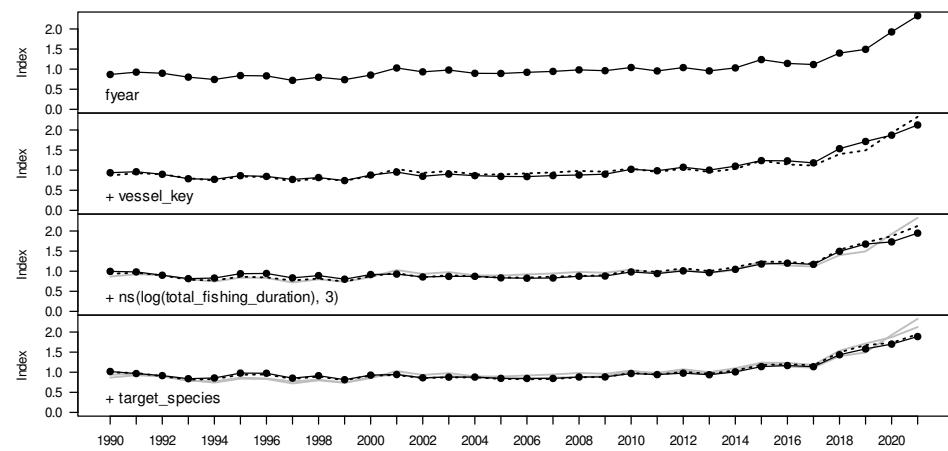


Figure D.49: Changes to the SPO 3 BT trip positive catch index as terms are successively entered into the model.

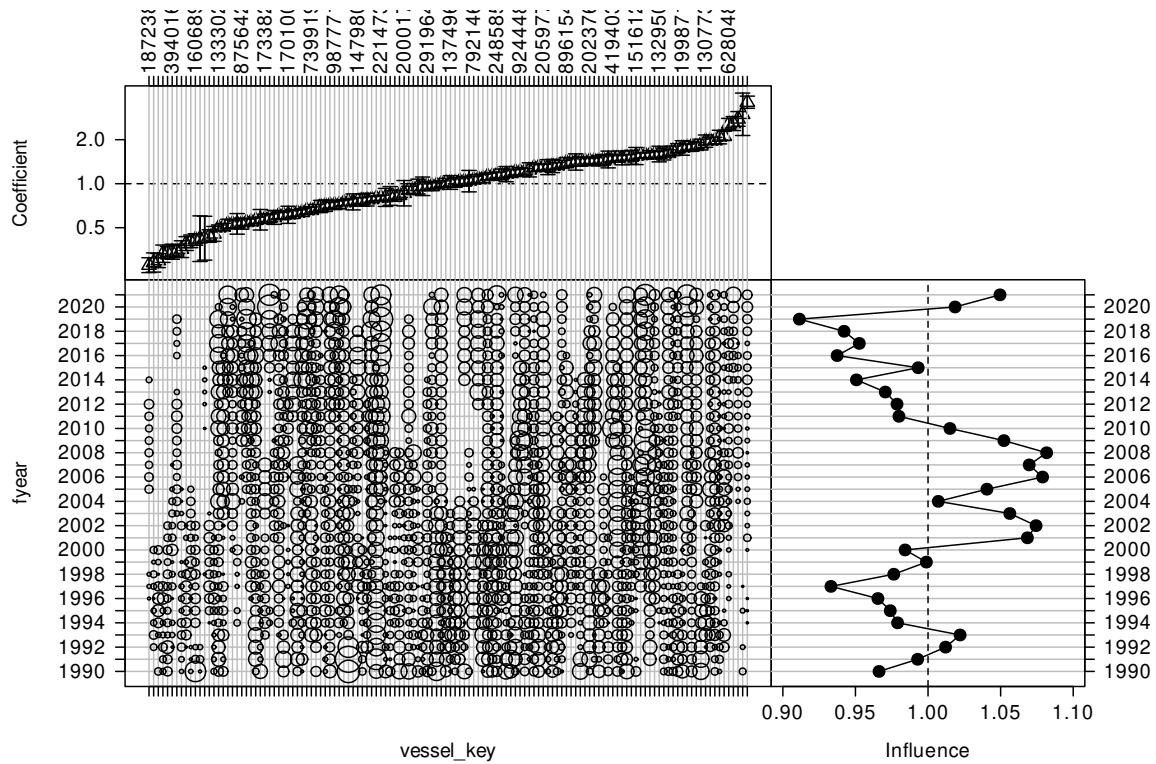


Figure D.50: CDI plot for vessel key for the positive catch SPO 3 BT trip catch-per-unit-effort dataset.

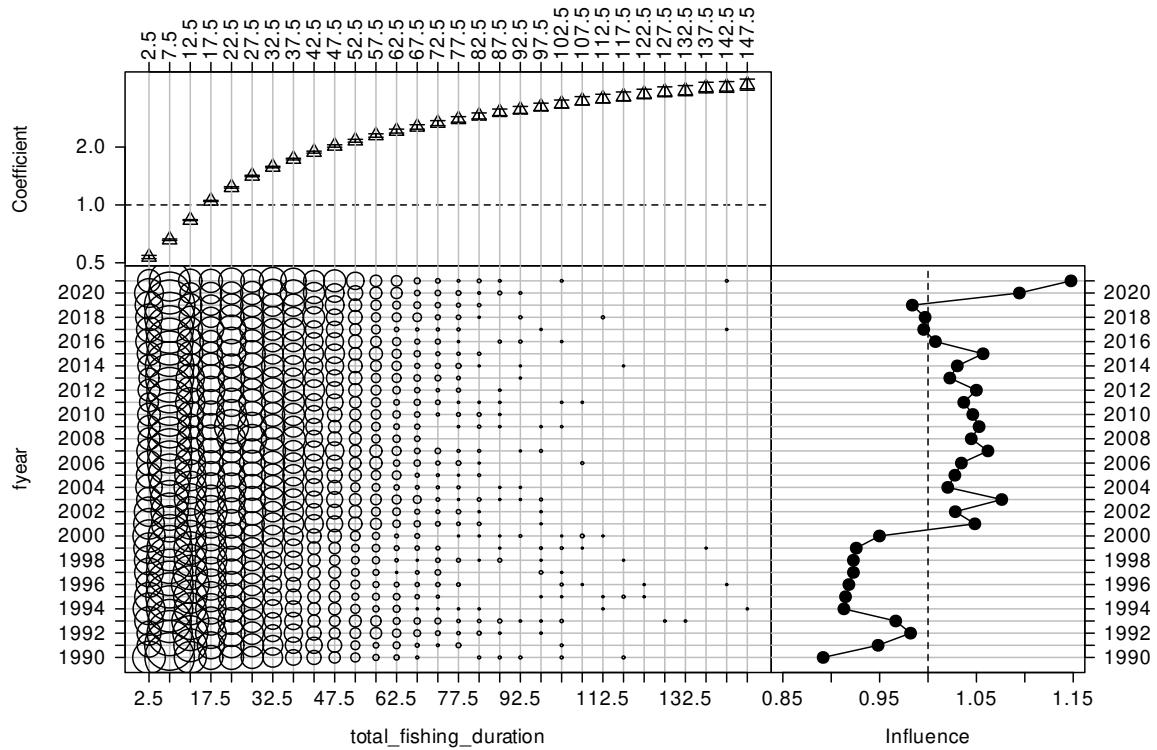


Figure D.51: CDI plot for total fishing duration (h) for the positive catch SPO 3 BT trip catch-per-unit-effort dataset.

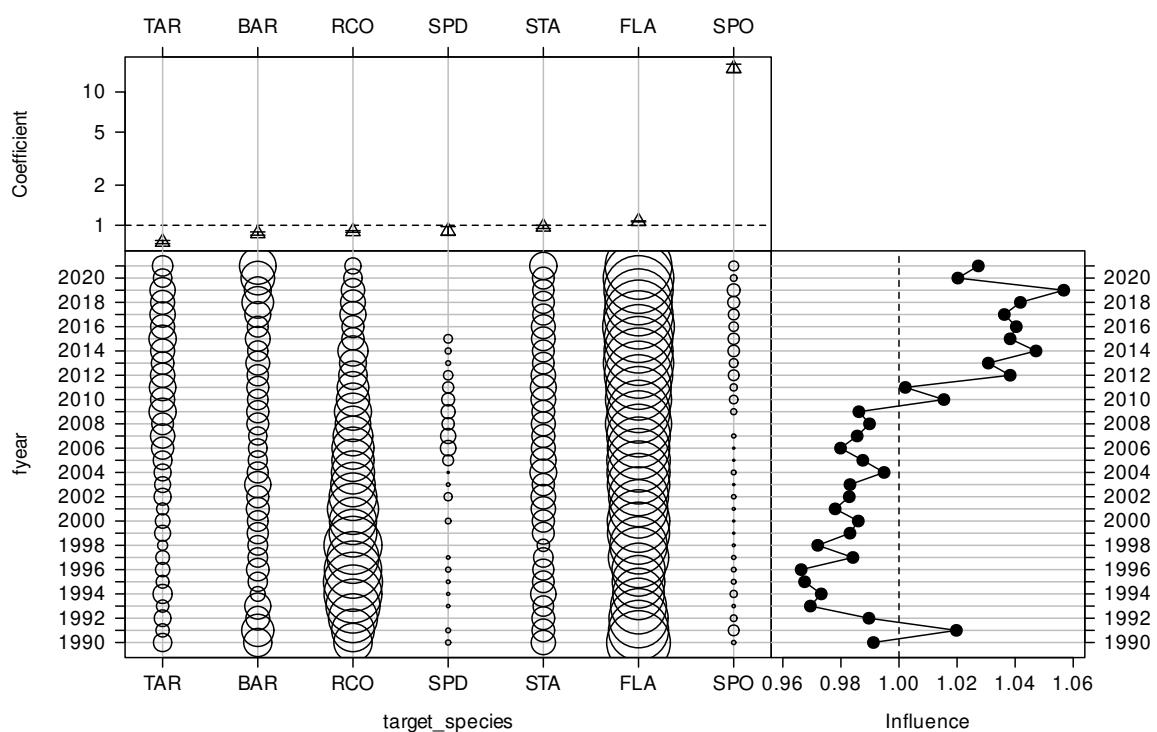


Figure D.52: CDI plot for target species for the positive catch SPO 3 BT trip catch-per-unit-effort dataset.

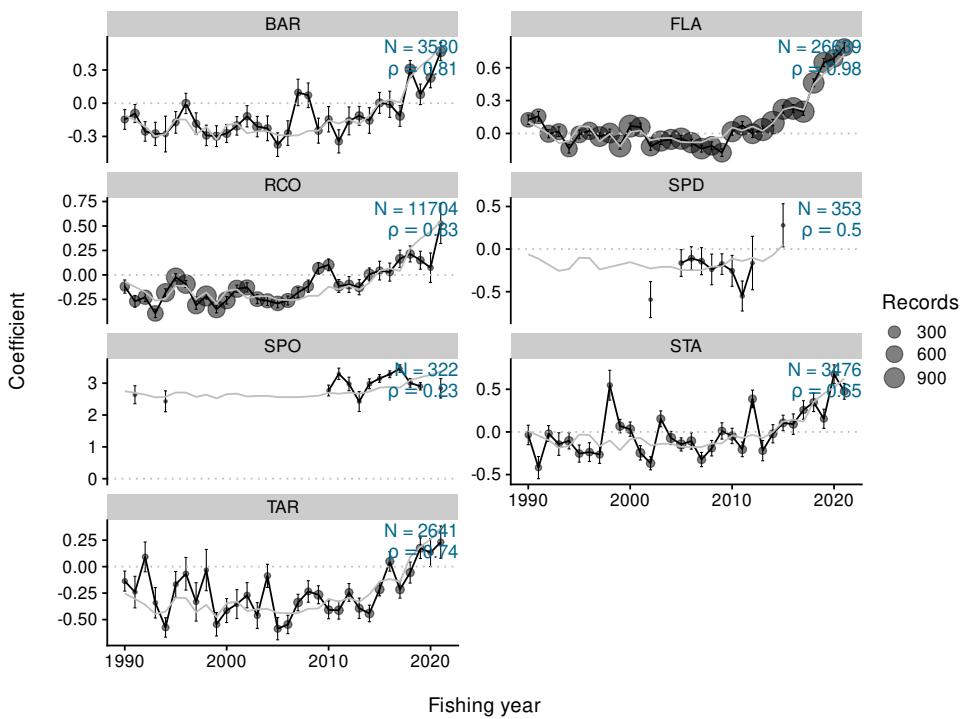


Figure D.53: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 3 BT trip dataset.

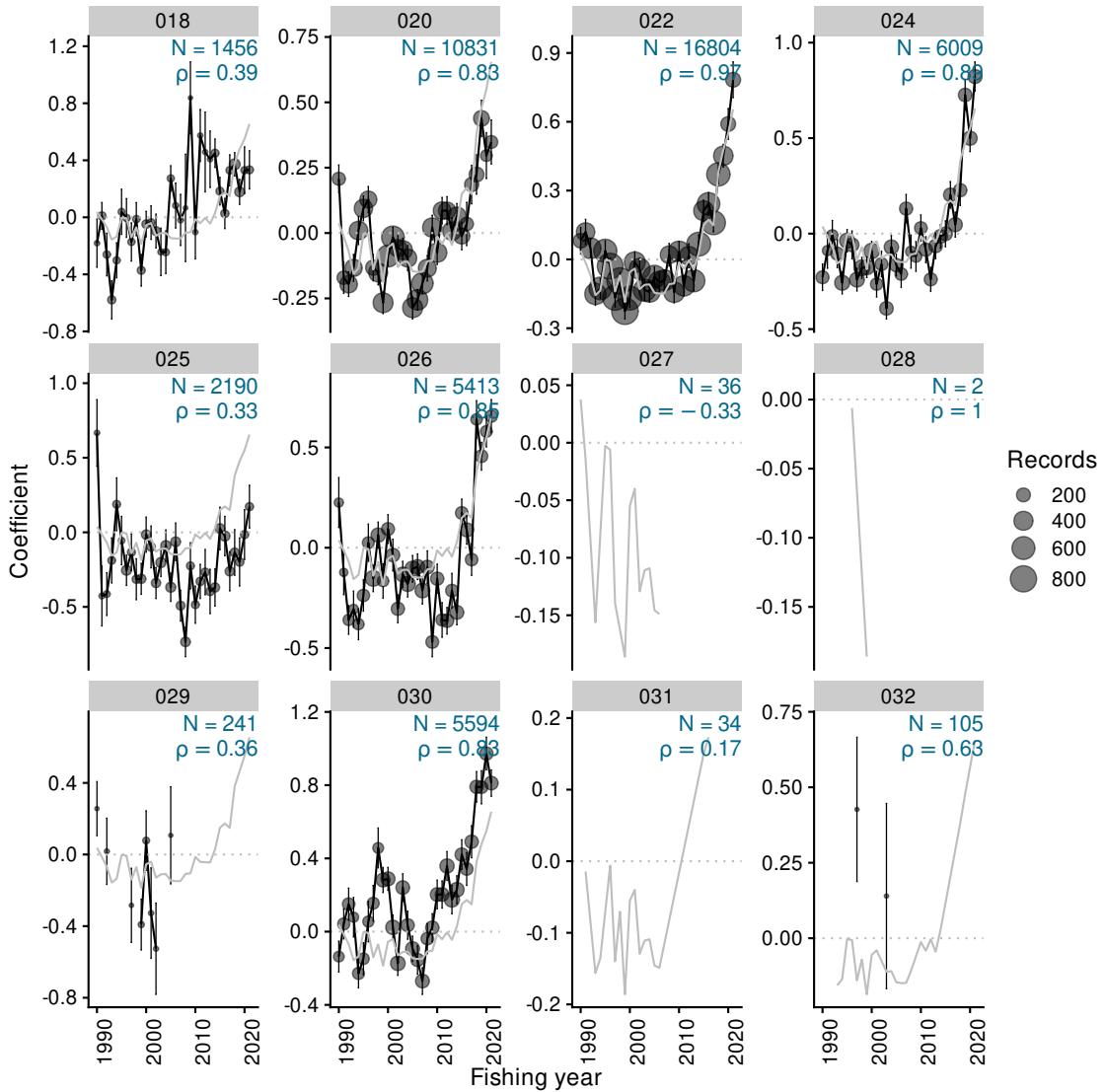


Figure D.54: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 3 BT trip dataset.

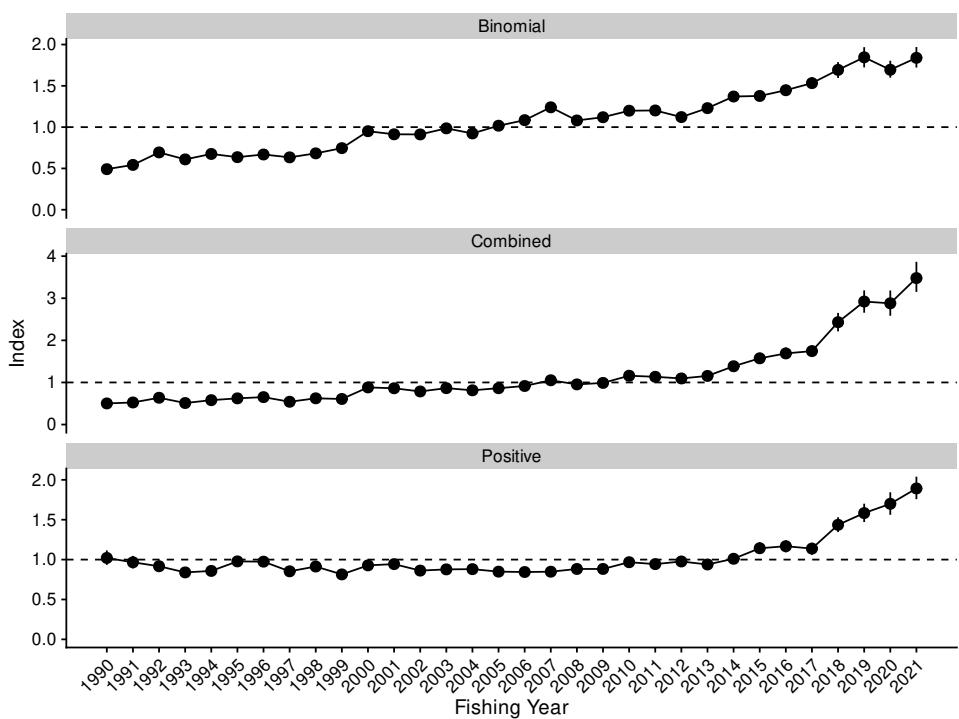


Figure D.55: Standardised indices and 95% confidence intervals for the SPO 3 BT trip dataset.

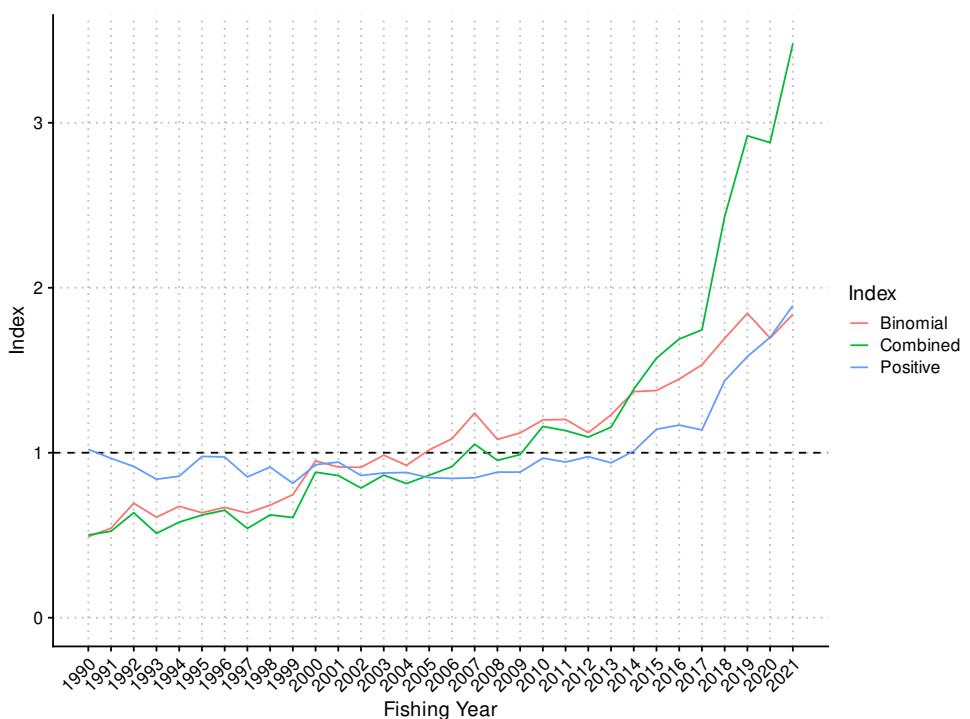


Figure D.56: Standardised indices for the SPO 3 BT trip dataset.

Table D.18: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 3 BT trip.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.491	0.019	0.454	0.530	0.501	0.032	0.445	0.569	1.021	0.046	0.934	1.115
1991	0.543	0.021	0.502	0.584	0.524	0.029	0.468	0.582	0.966	0.040	0.889	1.047
1992	0.694	0.021	0.655	0.737	0.636	0.029	0.581	0.695	0.917	0.034	0.854	0.987
1993	0.609	0.019	0.573	0.647	0.511	0.024	0.466	0.560	0.839	0.030	0.781	0.899
1994	0.675	0.019	0.638	0.714	0.579	0.024	0.534	0.629	0.858	0.029	0.807	0.919
1995	0.636	0.018	0.601	0.672	0.622	0.027	0.571	0.677	0.978	0.032	0.915	1.042
1996	0.669	0.019	0.632	0.706	0.652	0.030	0.597	0.713	0.974	0.032	0.913	1.037
1997	0.634	0.017	0.601	0.667	0.541	0.022	0.498	0.586	0.853	0.026	0.804	0.908
1998	0.682	0.018	0.648	0.717	0.623	0.024	0.575	0.670	0.913	0.026	0.861	0.965
1999	0.746	0.018	0.709	0.781	0.607	0.023	0.562	0.652	0.814	0.025	0.766	0.862
2000	0.951	0.019	0.914	0.988	0.882	0.030	0.825	0.943	0.928	0.026	0.876	0.978
2001	0.913	0.021	0.875	0.956	0.862	0.034	0.798	0.932	0.943	0.030	0.890	1.006
2002	0.912	0.022	0.867	0.954	0.786	0.033	0.725	0.854	0.862	0.028	0.809	0.918
2003	0.985	0.022	0.940	1.027	0.864	0.032	0.803	0.928	0.877	0.027	0.825	0.933
2004	0.924	0.021	0.880	0.962	0.813	0.032	0.749	0.876	0.880	0.028	0.823	0.933
2005	1.017	0.022	0.975	1.060	0.864	0.031	0.804	0.924	0.849	0.026	0.797	0.901
2006	1.085	0.023	1.042	1.131	0.916	0.034	0.849	0.983	0.844	0.026	0.795	0.896
2007	1.240	0.026	1.188	1.290	1.052	0.038	0.978	1.127	0.848	0.026	0.801	0.904
2008	1.081	0.025	1.030	1.128	0.954	0.040	0.875	1.030	0.883	0.031	0.823	0.944
2009	1.120	0.024	1.072	1.167	0.989	0.041	0.906	1.068	0.883	0.030	0.820	0.939
2010	1.199	0.026	1.148	1.251	1.160	0.047	1.071	1.256	0.967	0.034	0.902	1.034
2011	1.202	0.026	1.154	1.254	1.134	0.047	1.048	1.233	0.944	0.033	0.879	1.009
2012	1.122	0.025	1.073	1.172	1.095	0.047	1.010	1.195	0.976	0.034	0.912	1.046
2013	1.230	0.026	1.182	1.283	1.155	0.047	1.066	1.250	0.939	0.032	0.877	1.001
2014	1.371	0.028	1.317	1.427	1.385	0.053	1.286	1.493	1.010	0.033	0.947	1.076
2015	1.377	0.034	1.311	1.443	1.573	0.064	1.453	1.706	1.142	0.038	1.072	1.220
2016	1.447	0.033	1.385	1.513	1.689	0.067	1.567	1.831	1.168	0.039	1.091	1.242
2017	1.533	0.036	1.464	1.606	1.745	0.071	1.604	1.882	1.138	0.038	1.060	1.211
2018	1.693	0.049	1.595	1.787	2.431	0.112	2.213	2.651	1.436	0.047	1.346	1.531
2019	1.845	0.063	1.723	1.968	2.921	0.135	2.656	3.187	1.583	0.059	1.472	1.701
2020	1.694	0.052	1.599	1.804	2.880	0.153	2.584	3.184	1.700	0.072	1.562	1.844
2021	1.839	0.063	1.722	1.970	3.479	0.182	3.151	3.864	1.892	0.072	1.757	2.040

D.4 SPO 3 BT trip (positive trip criterion)

This analysis is equivalent to the SPO 3 BT trip analysis presented in Section D.3, except that only trips which reported at least one kg of SPO in the landing were included in the dataset. This alternative vessel selection criterion has been included here because that was the criterion incorrectly reported by Starr & Kendrick (2020). Comparison of this series with the SPO 3 BT trip series shows that some bias has been introduced into the trajectory because it is based only on trips which captured SPO (Figure D.159). This effect is likely more pronounced in situations where there is a lot of vessel turnover and high contrast in the abundance series.

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 SPO 3 BT trip (positive trip criterion) CPUE series.

Series	SPO 3 BT trip (positive trip criterion)
QMS stock	SPO3
Reporting forms	CEL, ERS - Trawl, TCE, TCP
Fishing methods	BT
Target species	FLA, BAR, STA, RCO, SPD, SPO, TAR
Statistical Areas	018, 020, 022, 024, 025, 026, 027, 028, 029, 030, 031, 032
Period	1989-10-01, 2021-09-30
Resolution	Trip
Core fleet years	8
Core fleet trips	10
Default model	$\text{landkg} \sim \text{fyear} + \text{vessel_key} + \text{modal_stat_area} + \text{modal_month} + \text{target_species} + \text{ns}(\log(\text{total_fishing_duration}), 3) + \text{ns}(\log(\text{total_effort_num}), 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

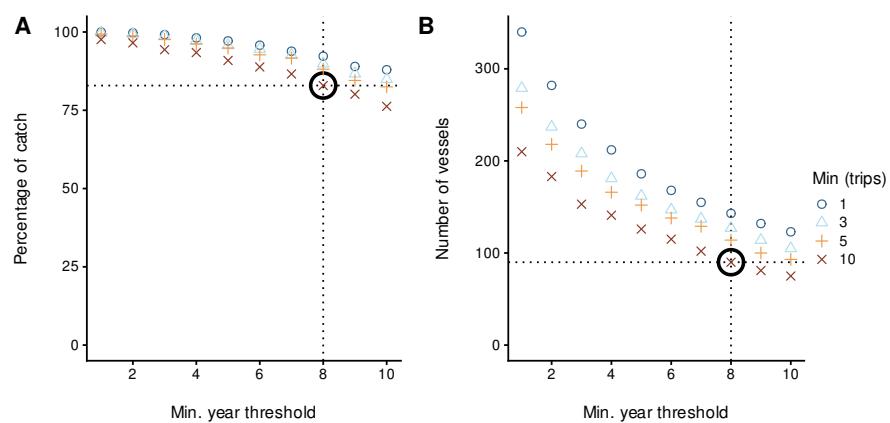


Figure D.57: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 3 BT trip (positive trip criterion) CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

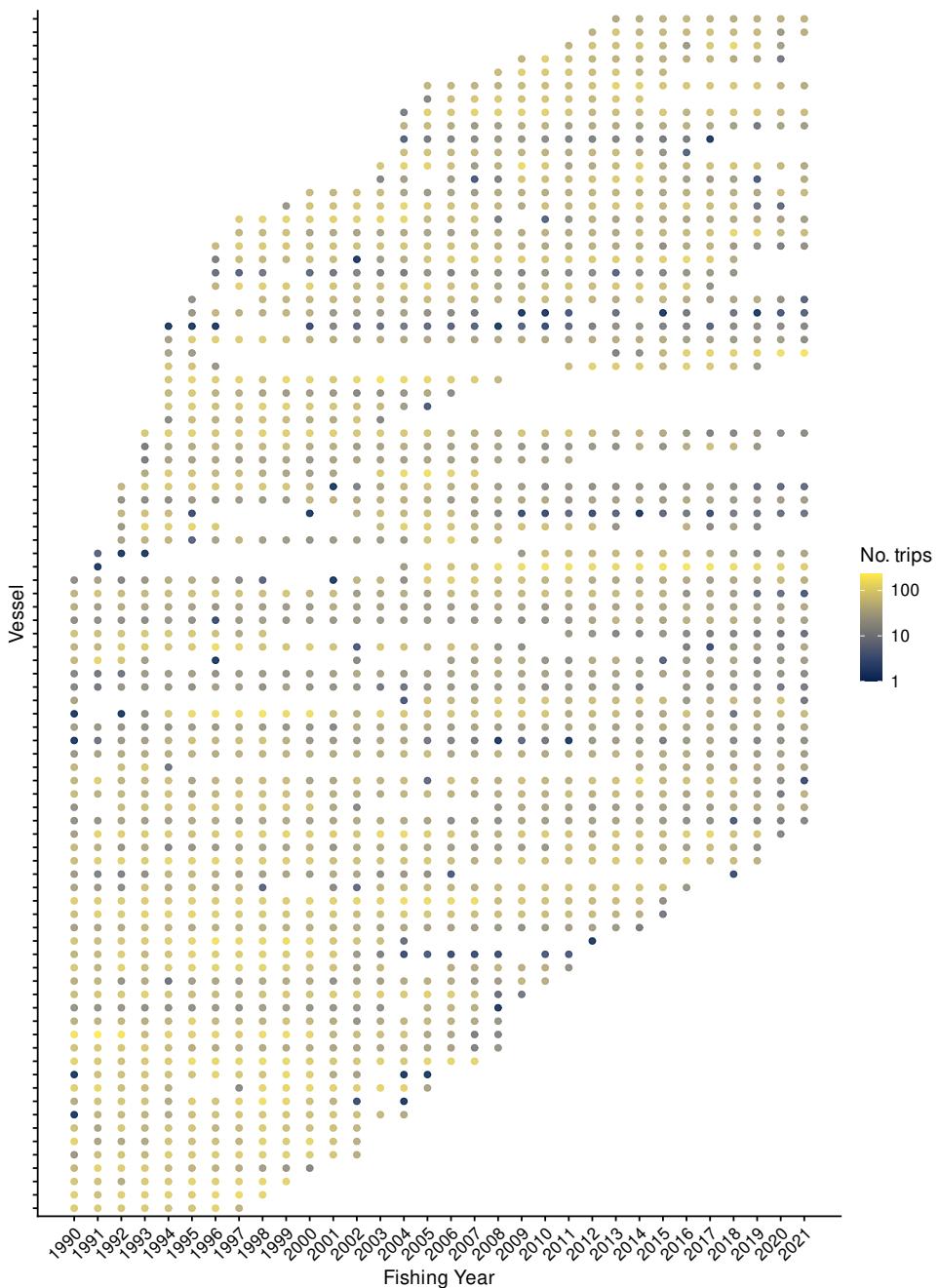


Figure D.58: Number of trips by fishing year for core vessels. The colour of the points is proportional to the number of trips undertaken by a vessel in a fishing year.

Table D.20: Summary of the SPO 3 BT trip (positive trip criterion) 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	48 (100%) n: 6724	62 (100%) n: 6386	75 (100%) n: 6638	93 (100%) n: 7419	93 (100%) n: 7551	85 (100%) n: 7721	92 (100%) n: 7494	94 (100%) n: 7694	93 (100%) n: 7475
Positive fishing duration	48 (100%) n: 6720	62 (100%) n: 6373	75 (100%) n: 6626	93 (100%) n: 7408	92 (100%) n: 7537	85 (100%) n: 7712	92 (100%) n: 7428	94 (100%) n: 7587	92 (100%) n: 7363
Trim extreme effort num	47 (100%) n: 6706	62 (100%) n: 6363	72 (100%) n: 6614	92 (100%) n: 7393	92 (100%) n: 7529	85 (100%) n: 7696	91 (100%) n: 7409	92 (100%) n: 7567	92 (100%) n: 7345
Trim extreme duration	47 (100%) n: 6706	61 (100%) n: 6360	72 (100%) n: 6612	92 (100%) n: 7392	92 (100%) n: 7528	85 (100%) n: 7696	91 (100%) n: 7406	92 (100%) n: 7567	92 (100%) n: 7342
Core fleet selection	21 (44%) n: 2543	36 (58%) n: 2845	41 (55%) n: 3123	55 (59%) n: 3383	63 (69%) n: 3943	67 (78%) n: 3943	74 (81%) n: 4294	78 (83%) n: 4308	73 (78%) n: 4377
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	75 (100%) n: 6940	91 (100%) n: 6129	119 (100%) n: 5293	96 (100%) n: 4815	98 (100%) n: 5156	91 (100%) n: 5061	92 (100%) n: 5201	79 (100%) n: 4193	95 (100%) n: 3430
Positive fishing duration	75 (100%) n: 6868	91 (100%) n: 6096	119 (100%) n: 5292	96 (100%) n: 4815	98 (100%) n: 5156	91 (100%) n: 5061	92 (100%) n: 5201	79 (100%) n: 4193	95 (100%) n: 3430
Trim extreme effort num	75 (100%) n: 6861	91 (100%) n: 6094	118 (100%) n: 5290	96 (100%) n: 4809	97 (100%) n: 5147	91 (100%) n: 5058	92 (100%) n: 5199	79 (100%) n: 4193	95 (100%) n: 3424
Trim extreme duration	75 (100%) n: 6860	91 (100%) n: 6094	118 (100%) n: 5290	96 (100%) n: 4809	97 (100%) n: 5146	91 (100%) n: 5058	92 (100%) n: 5199	79 (100%) n: 4192	95 (100%) n: 3423
Core fleet selection	57 (76%) n: 4476	75 (82%) n: 3942	93 (79%) n: 3308	72 (74%) n: 2971	82 (84%) n: 3305	78 (86%) n: 3305	78 (84%) n: 3573	66 (84%) n: 3733	76 (80%) n: 3361

Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	59 (100%) n: 2890	77 (100%) n: 3301	88 (100%) n: 3453	82 (100%) n: 3170	101 (100%) n: 3192	100 (100%) n: 3433	131 (100%) n: 3424	124 (100%) n: 2582	131 (100%) n: 2912
Positive fishing duration	59 (100%) n: 2889	77 (100%) n: 3301	88 (100%) n: 3453	82 (100%) n: 3170	101 (100%) n: 3192	100 (100%) n: 3433	131 (100%) n: 3424	124 (100%) n: 2582	131 (100%) n: 2912
Trim extreme effort num	59 (100%) n: 2888	77 (100%) n: 3297	88 (100%) n: 3453	81 (100%) n: 3167	98 (100%) n: 3189	99 (100%) n: 3431	131 (100%) n: 3424	123 (100%) n: 2580	130 (100%) n: 2910
Trim extreme duration	59 (100%) n: 2885	77 (100%) n: 3297	88 (100%) n: 3450	81 (100%) n: 3166	98 (100%) n: 3187	99 (100%) n: 3428	131 (100%) n: 3424	123 (100%) n: 2580	129 (100%) n: 2905
Core fleet selection	55 (93%) n: 2549	70 (90%) n: 2918	77 (88%) n: 2863	69 (84%) n: 2655	92 (91%) n: 2735	90 (90%) n: 3040	121 (93%) n: 3064	114 (92%) n: 2336	120 (92%) n: 2614

Filter	2017	2018	2019	2020	2021
Ungroomed data	140 (100%) n: 2865	178 (100%) n: 2609	136 (100%) n: 2066	125 (100%) n: 1715	153 (100%) n: 1678
Positive fishing duration	140 (100%) n: 2865	178 (100%) n: 2608	136 (100%) n: 2066	125 (100%) n: 1711	153 (100%) n: 1673
Trim extreme effort num	140 (100%) n: 2863	178 (100%) n: 2608	136 (100%) n: 2066	125 (100%) n: 1711	153 (100%) n: 1673
Trim extreme duration	140 (100%) n: 2862	177 (100%) n: 2607	136 (100%) n: 2066	125 (100%) n: 1709	153 (100%) n: 1671
Core fleet selection	119 (85%) n: 2531	160 (90%) n: 2307	118 (86%) n: 1818	109 (87%) n: 1440	131 (86%) n: 1386

Table D.21: Summary of the SPO 3 BT trip (positive trip criterion) dataset after core fleet selection. Trips caught represents the percentage of trips with rig catch.

Fishing year	Vessels	Trips	Events	Hrs	Catch (t)	Trips caught
1990	48	2 543	11 717	34 308.83	21.05	24.70
1991	46	2 845	13 075	39 889.43	36.21	29.24
1992	53	3 123	15 195	48 306.40	41.43	34.10
1993	57	3 383	16 337	51 150.00	55.17	30.89
1994	63	3 943	17 939	52 263.68	63.49	32.46
1995	63	4 294	18 678	55 047.77	66.77	30.97
1996	65	4 308	19 618	57 442.20	74.04	32.45
1997	64	4 377	22 659	61 851.60	78.38	33.22
1998	64	4 684	23 529	64 968.17	73.36	35.25
1999	60	4 476	22 624	61 519.28	57.10	37.76
2000	63	3 942	20 628	58 294.48	74.64	44.75
2001	63	3 308	20 425	57 735.39	93.34	48.34
2002	64	2 971	18 025	48 284.12	71.55	46.85
2003	61	3 305	20 427	57 036.03	81.98	48.14
2004	66	3 573	18 804	52 466.85	77.94	42.57
2005	65	3 733	19 728	57 767.15	77.67	44.82
2006	65	3 361	17 855	54 714.45	66.44	47.07
2007	63	2 917	16 674	52 012.97	76.37	54.61
2008	62	2 549	13 201	41 430.10	54.92	47.31
2009	57	2 918	13 908	47 410.78	69.80	46.88
2010	57	2 863	14 581	48 352.50	77.17	50.58
2011	59	2 655	13 035	44 589.89	69.29	50.62
2012	57	2 735	13 516	44 964.70	91.51	46.80
2013	59	3 040	14 698	48 514.85	89.80	51.09
2014	58	3 064	14 928	51 812.10	120.94	55.84
2015	56	2 336	11 609	41 225.63	114.49	57.71
2016	56	2 614	12 157	42 516.16	119.59	56.16
2017	53	2 531	11 828	41 402.51	119.08	60.21
2018	53	2 307	11 259	40 388.88	160.01	66.28
2019	50	1 818	9 271	31 979.75	117.76	73.32
2020	44	1 440	8 273	28 141.33	108.53	68.12
2021	41	1 386	8 546	28 645.25	131.48	74.17

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	30.00	131 213	3.90	3.90	*
+ ns(log(total_fishing_duration), 3)	3.00	118 565	13.20	9.30	*
+ modal_month	11.00	113 820	16.70	3.50	*
+ vessel_key	89.00	110 019	19.60	2.90	*
+ modal_stat_area	10.00	109 406	20.10	0.50	
+ ns(log(total_effort_num), 3)	3.00	108 816	20.50	0.40	
+ target_species	6.00	108 474	20.80	0.30	

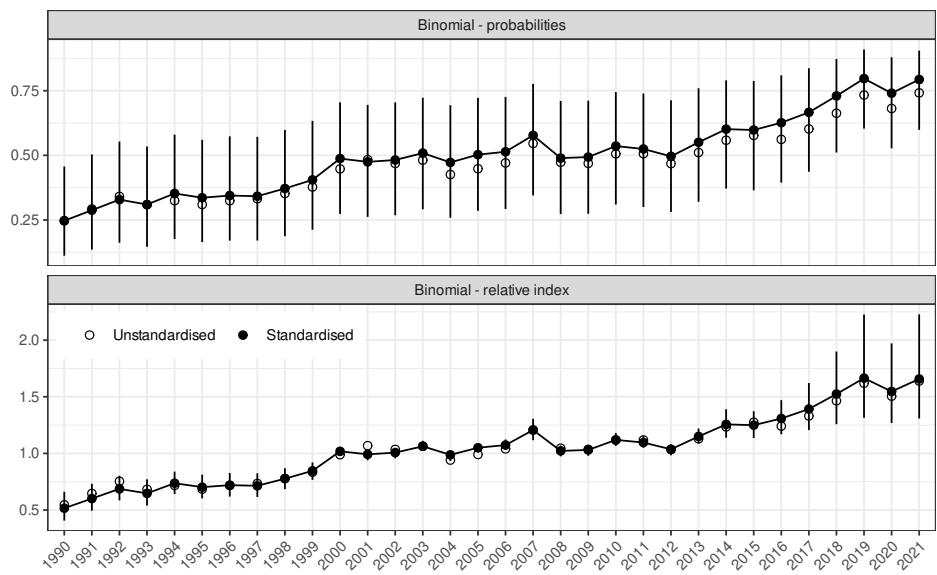


Figure D.59: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 3 BT trip (positive trip criterion) dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

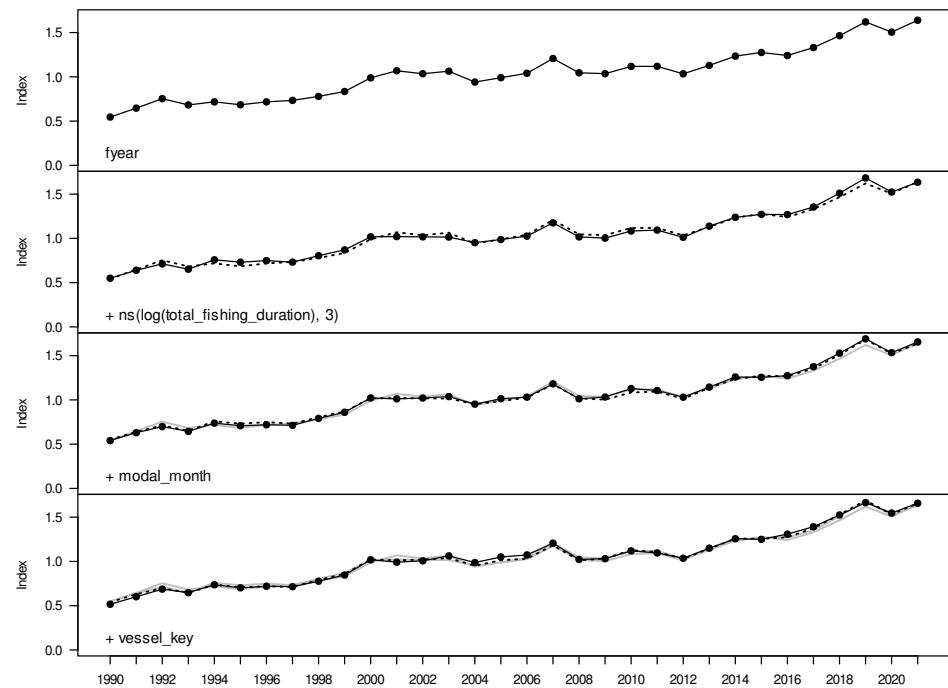


Figure D.60: Step plot for occurrence of catch in the SPO 3 BT trip (positive trip criterion) dataset.

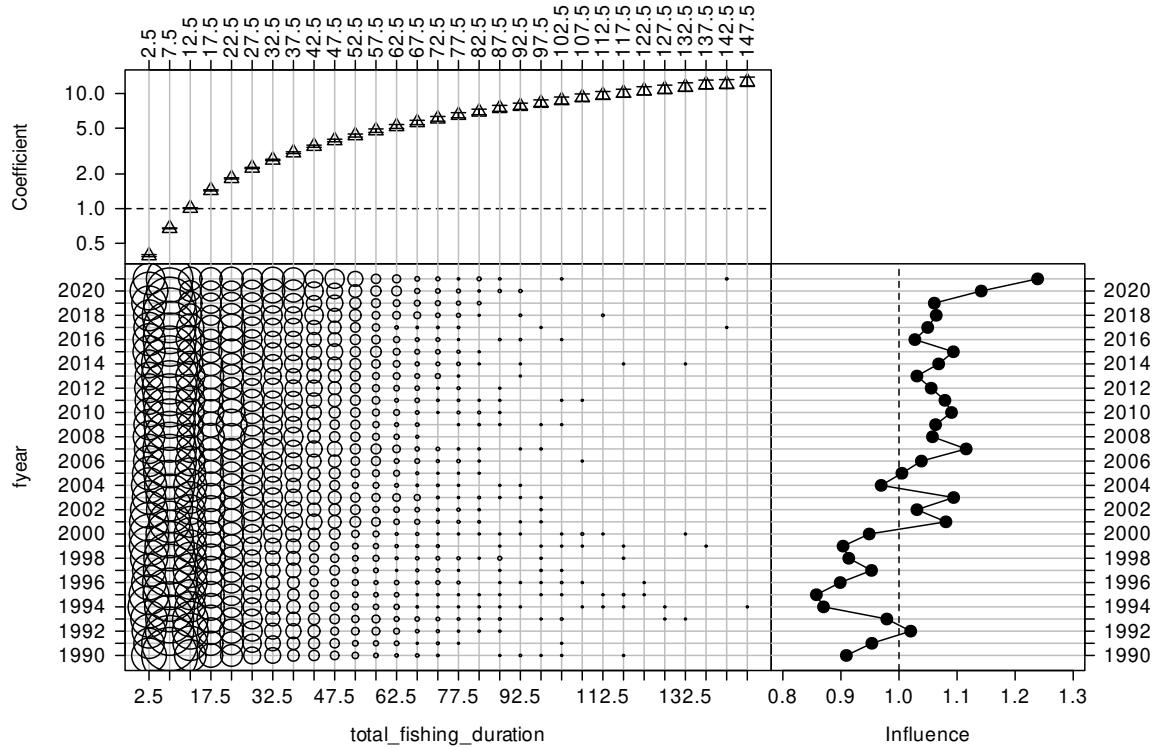


Figure D.61: CDI plot for total fishing duration (h) for the occurrence of positive catch SPO 3 BT trip (positive trip criterion) catch-per-unit-effort dataset.

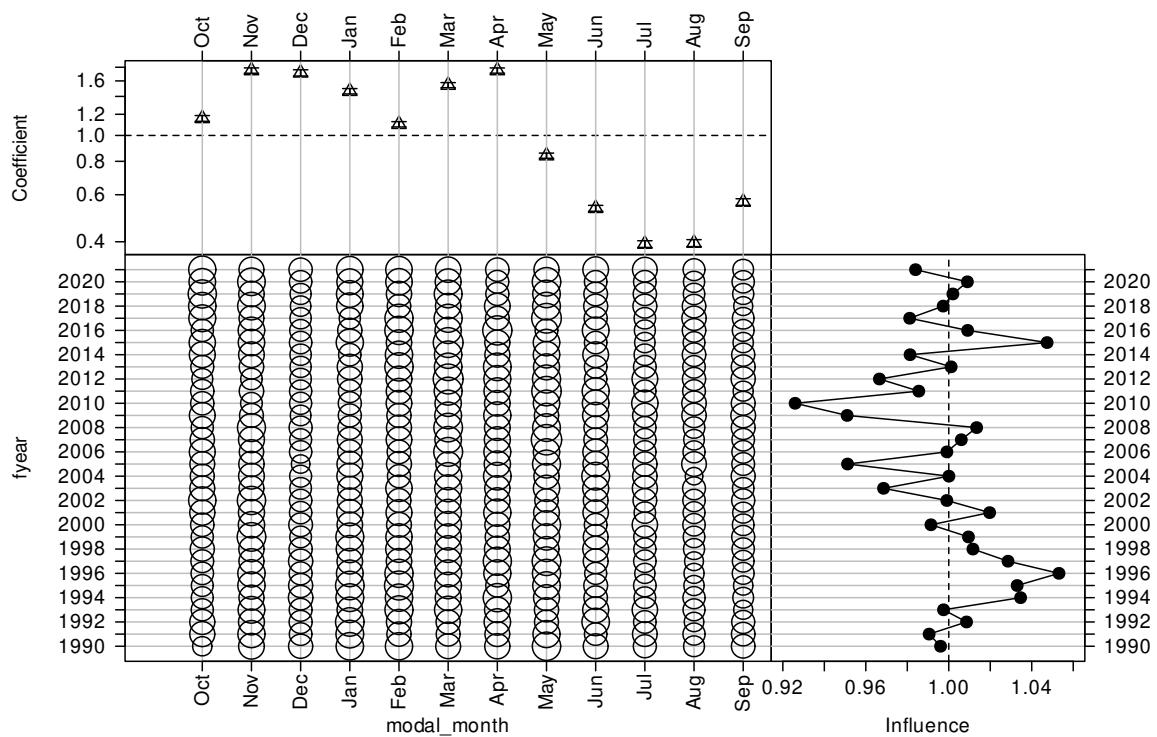


Figure D.62: CDI plot for modal month for the occurrence of positive catch SPO 3 BT trip (positive trip criterion) catch-per-unit-effort dataset.

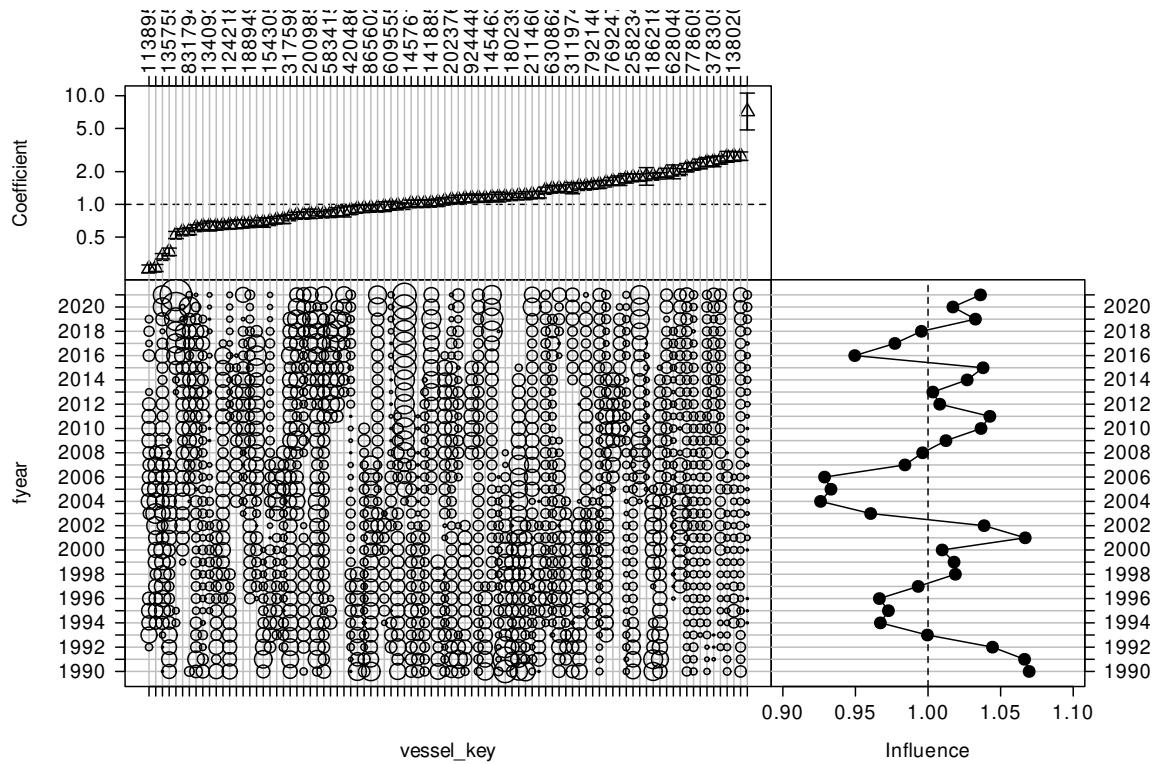


Figure D.63: CDI plot for vessel key for the occurrence of positive catch SPO 3 BT trip (positive trip criterion) catch-per-unit-effort dataset.

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	30	160503	1.9	1.9	*
+ vessel key	89	153042	17.5	15.6	*
+ ns(log(total fishing duration), 3)	3	150276	22.5	5.0	*
+ target species	6	148781	25.1	2.6	*
+ modal stat area	10	148235	26.1	1.0	*
+ modal month	11	147731	26.9	0.9	
+ ns(log(total effort num), 3)	3	147588	27.2	0.2	

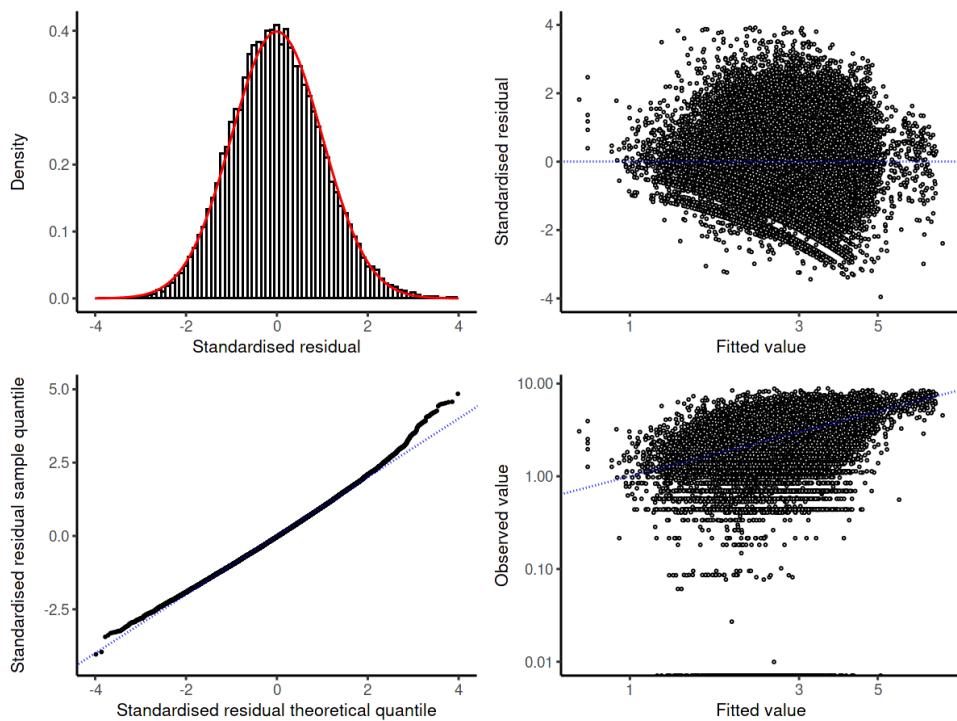


Figure D.64: Diagnostic plots for the lognormal model for the SPO 3 BT trip (positive trip criterion) dataset.

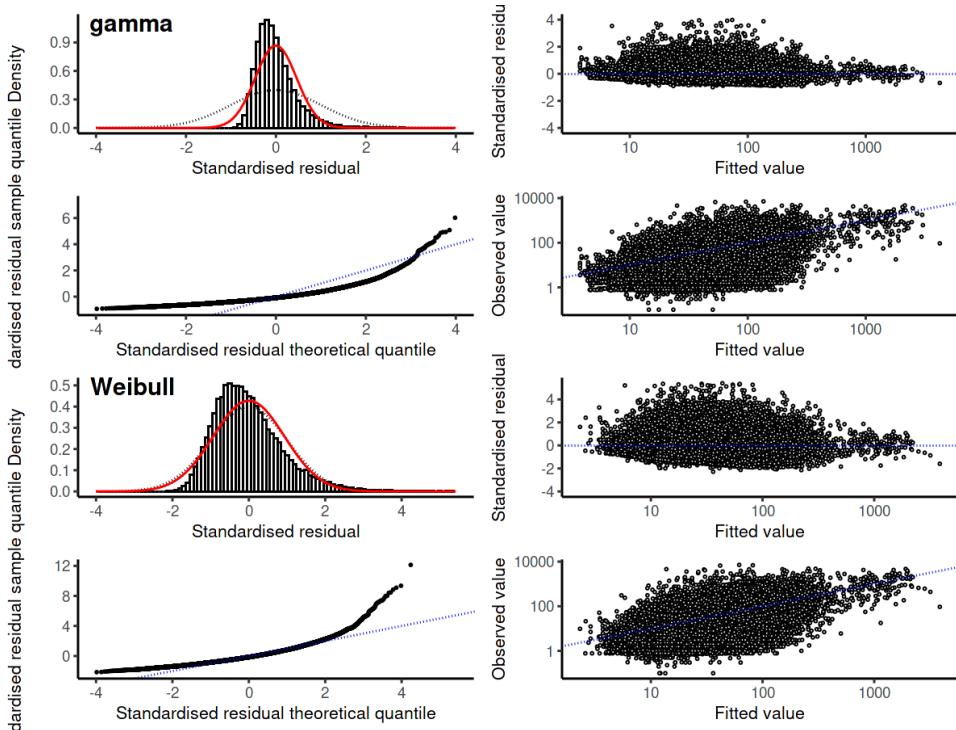


Figure D.65: Diagnostic plots for the gamma and Weibull model for the SPO 3 BT trip (positive trip criterion) dataset.

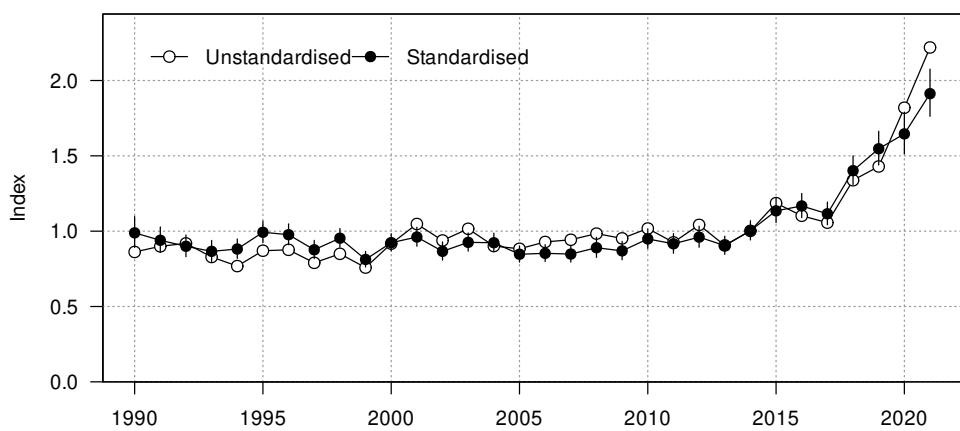


Figure D.66: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 3 BT trip (positive trip criterion) dataset.

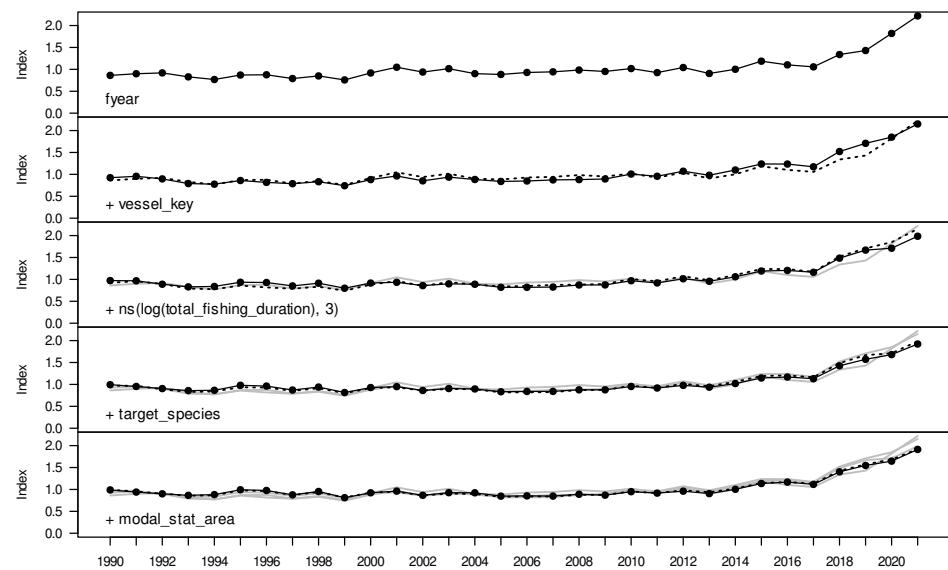


Figure D.67: Changes to the SPO 3 BT trip (positive trip criterion) positive catch index as terms are successively entered into the model.

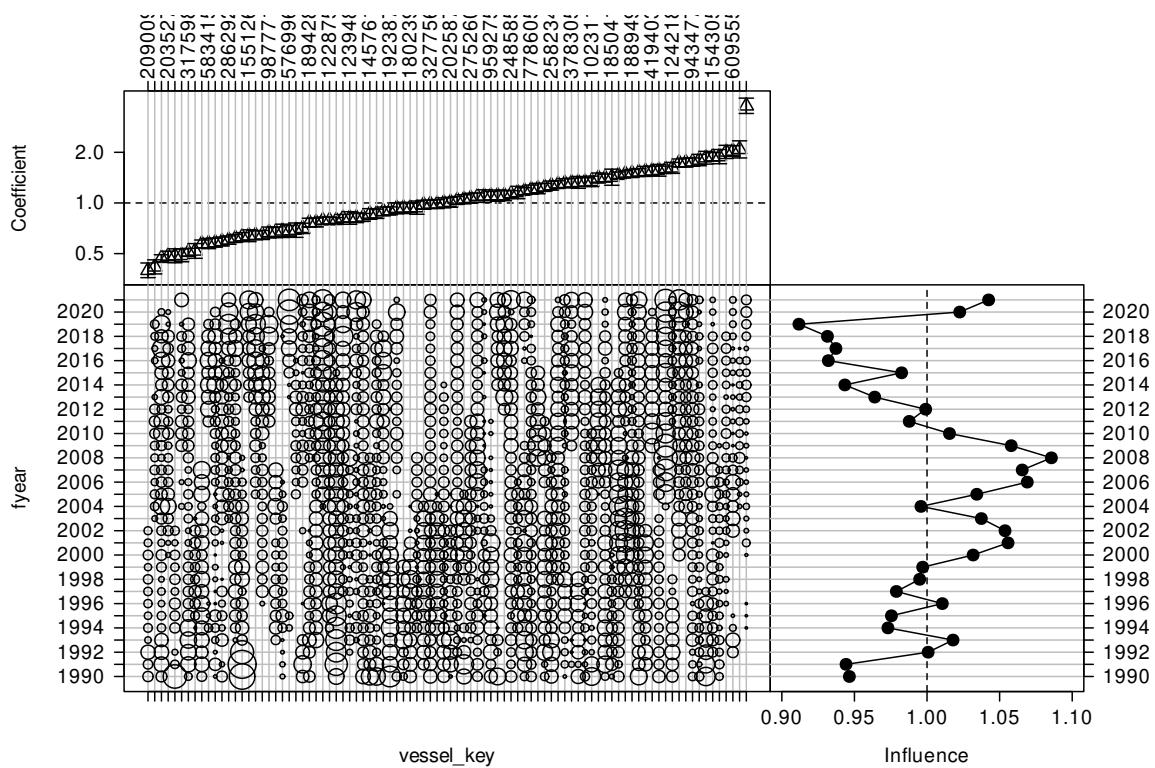


Figure D.68: CDI plot for vessel key for the positive catch SPO 3 BT trip (positive trip criterion) catch-per-unit-effort dataset.

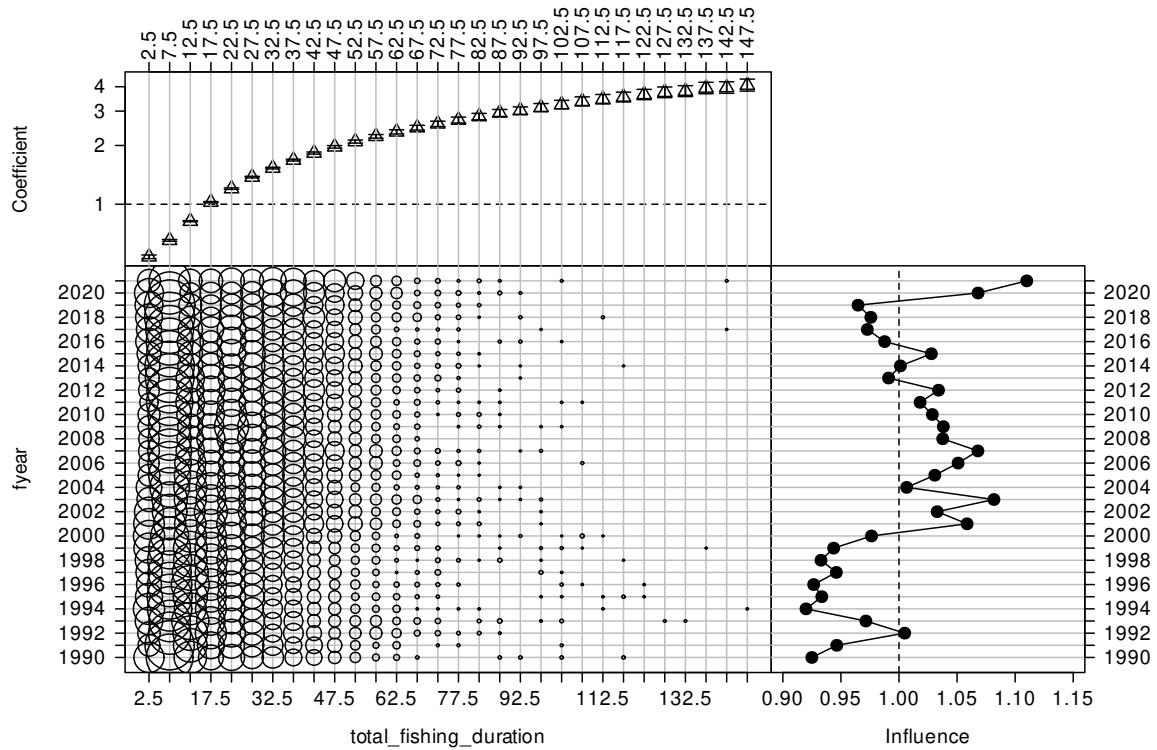


Figure D.69: CDI plot for total fishing duration (h) for the positive catch SPO 3 BT trip (positive trip criterion) catch-per-unit-effort dataset.

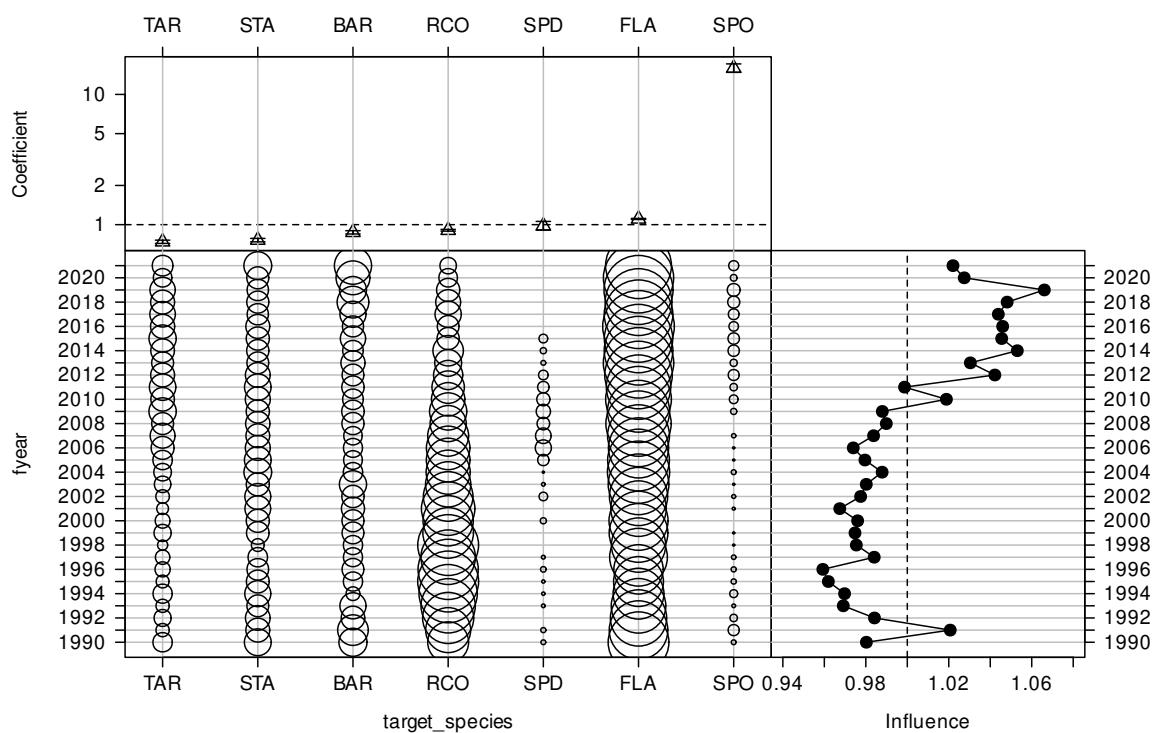


Figure D.70: CDI plot for target species for the positive catch SPO 3 BT trip (positive trip criterion) catch-per-unit-effort dataset.

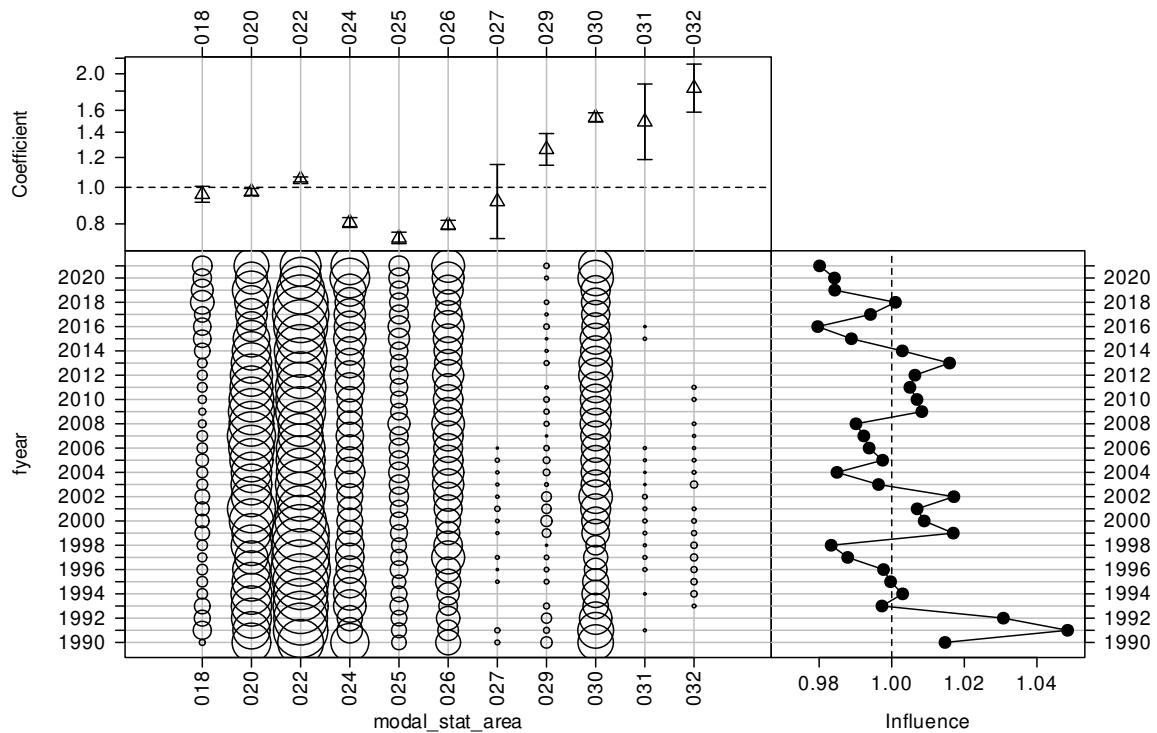


Figure D.71: CDI plot for modal statistical area for the positive catch SPO 3 BT trip (positive trip criterion) catch-per-unit-effort dataset.

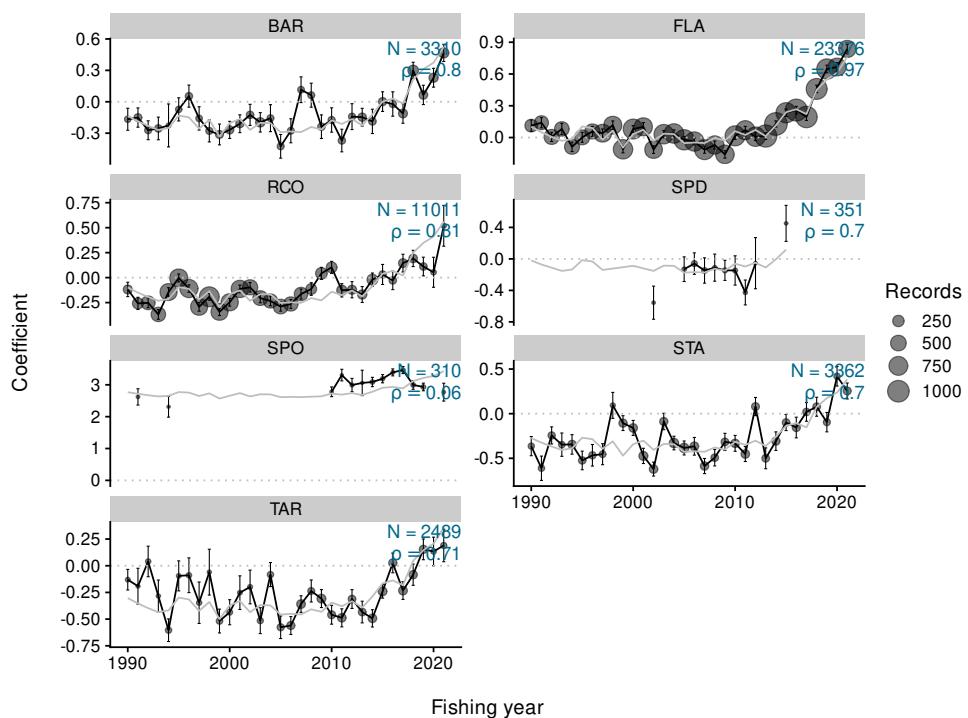


Figure D.72: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 3 BT trip (positive trip criterion) dataset.

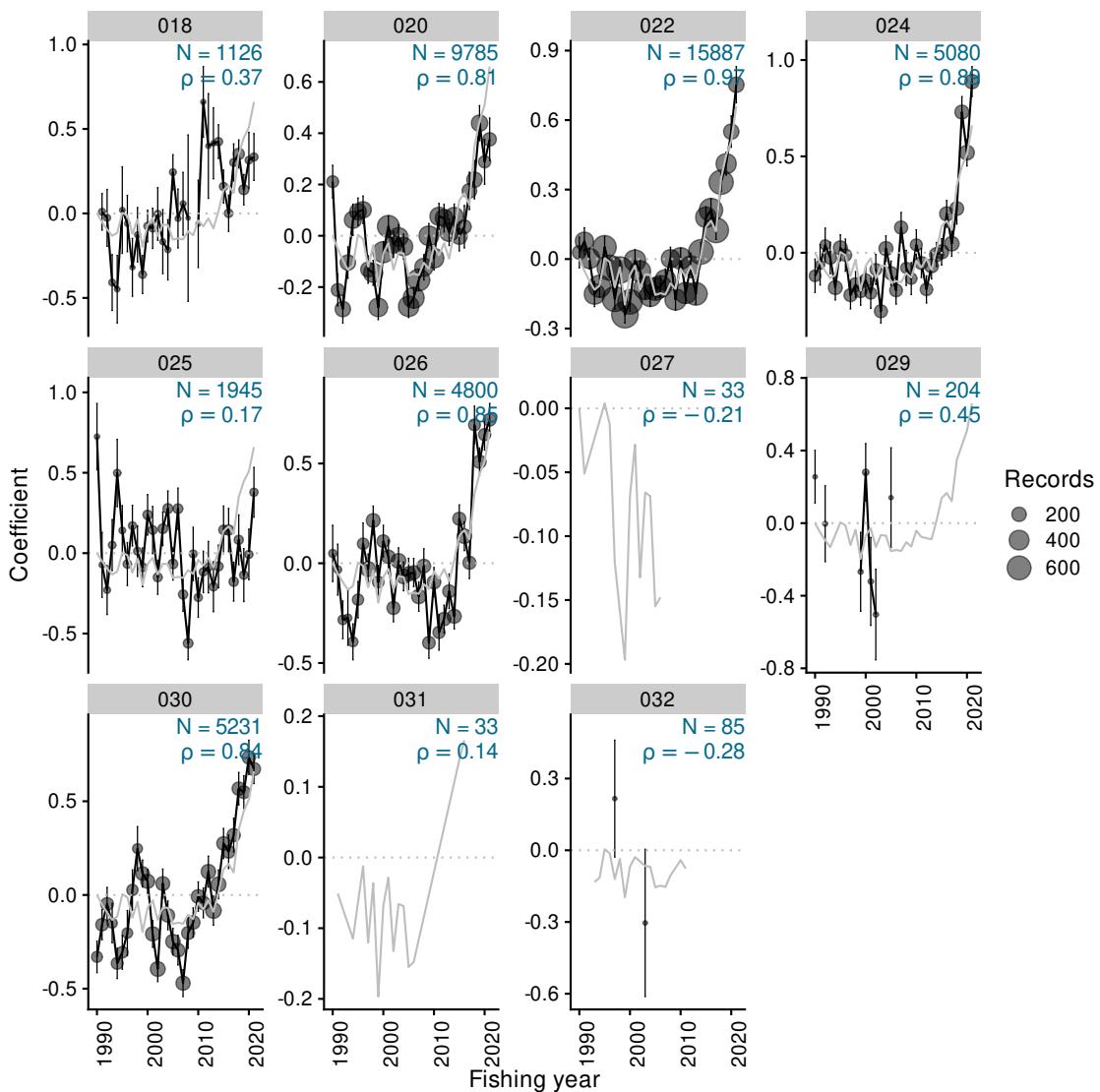


Figure D.73: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 3 BT trip (positive trip criterion) dataset.

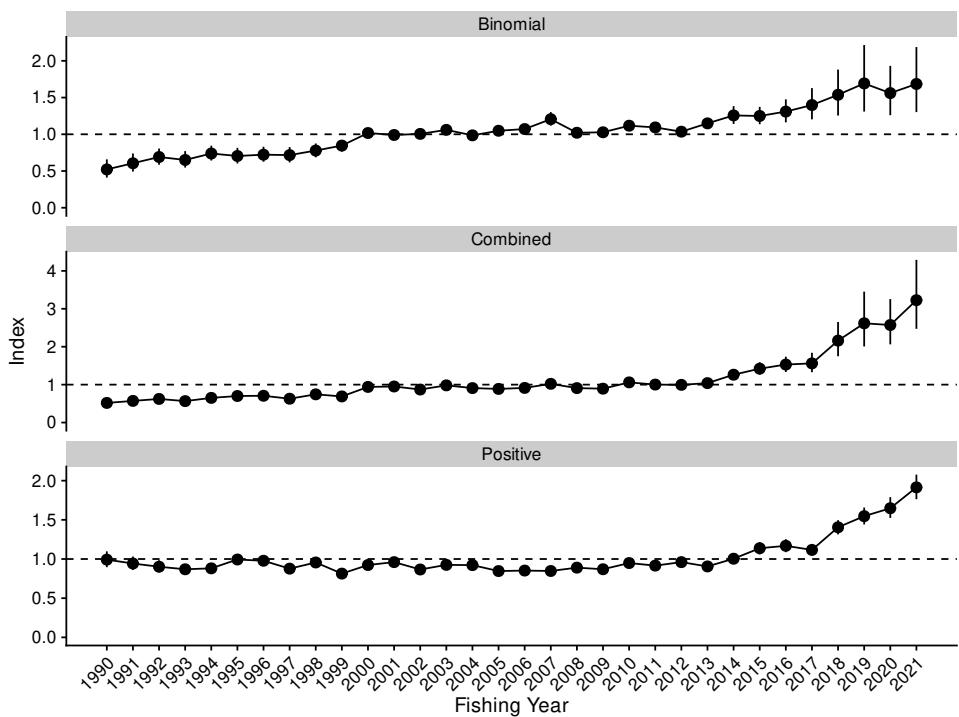


Figure D.74: Standardised indices and 95% confidence intervals for the SPO 3 BT trip (positive trip criterion) dataset.



Figure D.75: Standardised indices for the SPO 3 BT trip (positive trip criterion) dataset.

Table D.24: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 3 BT trip (positive trip criterion).

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.521	0.063	0.410	0.659	0.517	0.070	0.400	0.675	0.992	0.052	0.896	1.098
1991	0.606	0.063	0.492	0.739	0.571	0.065	0.456	0.709	0.942	0.044	0.860	1.032
1992	0.691	0.056	0.586	0.806	0.623	0.057	0.520	0.744	0.902	0.040	0.829	0.984
1993	0.651	0.057	0.547	0.771	0.565	0.055	0.467	0.681	0.869	0.035	0.799	0.937
1994	0.738	0.051	0.643	0.845	0.650	0.052	0.553	0.756	0.881	0.033	0.816	0.947
1995	0.705	0.054	0.603	0.815	0.700	0.061	0.584	0.823	0.994	0.035	0.925	1.064
1996	0.722	0.052	0.626	0.830	0.706	0.057	0.605	0.826	0.978	0.034	0.913	1.047
1997	0.717	0.053	0.617	0.826	0.629	0.053	0.529	0.738	0.877	0.031	0.821	0.944
1998	0.779	0.048	0.686	0.875	0.744	0.052	0.647	0.852	0.956	0.031	0.898	1.021
1999	0.846	0.040	0.764	0.921	0.689	0.039	0.613	0.764	0.814	0.025	0.765	0.862
2000	1.017	0.021	0.974	1.056	0.939	0.034	0.873	1.006	0.923	0.029	0.869	0.982
2001	0.990	0.024	0.938	1.034	0.951	0.037	0.876	1.022	0.960	0.031	0.900	1.021
2002	1.005	0.024	0.954	1.049	0.871	0.037	0.799	0.943	0.866	0.030	0.806	0.924
2003	1.060	0.023	1.016	1.106	0.981	0.038	0.905	1.055	0.925	0.030	0.866	0.983
2004	0.986	0.023	0.935	1.025	0.909	0.038	0.831	0.980	0.922	0.032	0.859	0.984
2005	1.048	0.020	1.011	1.090	0.887	0.032	0.827	0.954	0.846	0.027	0.795	0.899
2006	1.071	0.022	1.030	1.115	0.913	0.036	0.846	0.988	0.852	0.029	0.795	0.910
2007	1.206	0.047	1.118	1.302	1.021	0.049	0.928	1.121	0.847	0.028	0.796	0.904
2008	1.021	0.024	0.972	1.065	0.908	0.041	0.831	0.991	0.890	0.033	0.825	0.956
2009	1.027	0.023	0.980	1.069	0.893	0.036	0.821	0.962	0.869	0.031	0.811	0.932
2010	1.117	0.028	1.066	1.174	1.059	0.046	0.973	1.152	0.948	0.033	0.885	1.013
2011	1.094	0.028	1.047	1.158	1.001	0.045	0.921	1.097	0.916	0.032	0.855	0.980
2012	1.035	0.025	0.985	1.081	0.994	0.042	0.915	1.078	0.960	0.034	0.899	1.031
2013	1.149	0.035	1.083	1.222	1.040	0.045	0.955	1.133	0.905	0.030	0.846	0.966
2014	1.257	0.062	1.141	1.383	1.262	0.073	1.125	1.410	1.004	0.031	0.945	1.067
2015	1.249	0.060	1.137	1.373	1.421	0.083	1.264	1.590	1.138	0.040	1.059	1.217
2016	1.309	0.080	1.163	1.476	1.529	0.103	1.333	1.737	1.168	0.042	1.087	1.252
2017	1.398	0.109	1.203	1.629	1.560	0.130	1.328	1.839	1.116	0.037	1.046	1.193
2018	1.538	0.160	1.255	1.881	2.160	0.230	1.748	2.651	1.405	0.046	1.314	1.496
2019	1.693	0.231	1.309	2.215	2.618	0.369	2.007	3.452	1.547	0.055	1.441	1.657
2020	1.561	0.171	1.260	1.932	2.573	0.305	2.062	3.256	1.648	0.068	1.524	1.789
2021	1.685	0.226	1.302	2.188	3.227	0.464	2.473	4.291	1.915	0.080	1.763	2.077

D.5 SPO 3 BT event

This analysis is the tow-by-tow (event) analogue to the SPO 3 BT trip analysis presented in Section D.3. It repeats that analysis at the level of an individual event, adding detailed explanatory information to the analysis that is not available to the trip-based analysis. Such information includes the duration of the tow, the starting depth of the tow, the speed of the tow, and the relative start time of the tow within the 24-hour period. As well, the location of the tow and the target species can be assigned explicitly to the tow, rather than using the modal value for the trip as is used in the trip-based analysis. This analysis begins with the 2006–07 fishing year, which is when the detailed event-based data became available. A plot comparing the event-based CPUE series with the longer trip-based series is presented in Figure D.160.

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 SPO 3 BT event CPUE series.

Series	SPO 3 BT event
QMS stock	SPO3
Reporting forms	ERS - Trawl, TCE, TCP
Fishing methods	BT
Target species	FLA, BAR, STA, RCO, SPD, SPO, TAR
Statistical Areas	018, 020, 022, 024, 025, 026, 027, 028, 029, 030, 031, 032
Period	2007-10-01, 2021-09-30
Resolution	Fishing event
Core fleet years	8
Core fleet trips	10
Default model	$\text{allockg} \sim \text{fyear} + \text{vessel_key} + \text{stat_area} + \text{month} + \text{target_species} + \text{ns}(\log(\text{fishing_duration}), 3) + \text{ns}(\text{bottom_depth}, 3) + \text{ns}(\text{effort_speed}, 3) + \text{ns}(\text{start_time}, 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

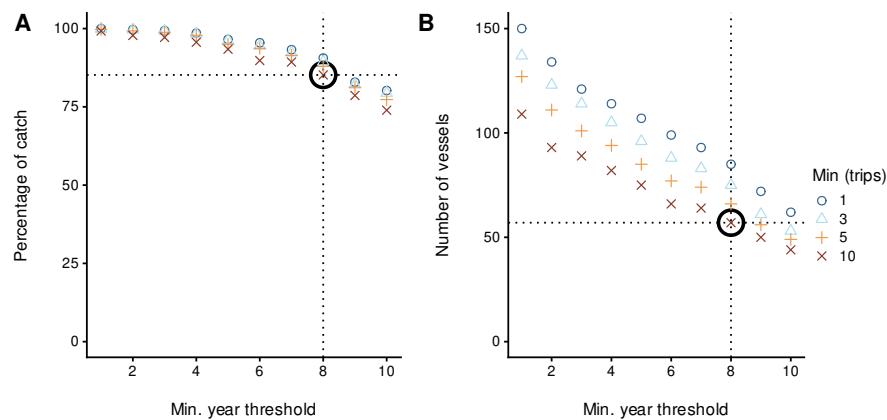


Figure D.76: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 3 BT event CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

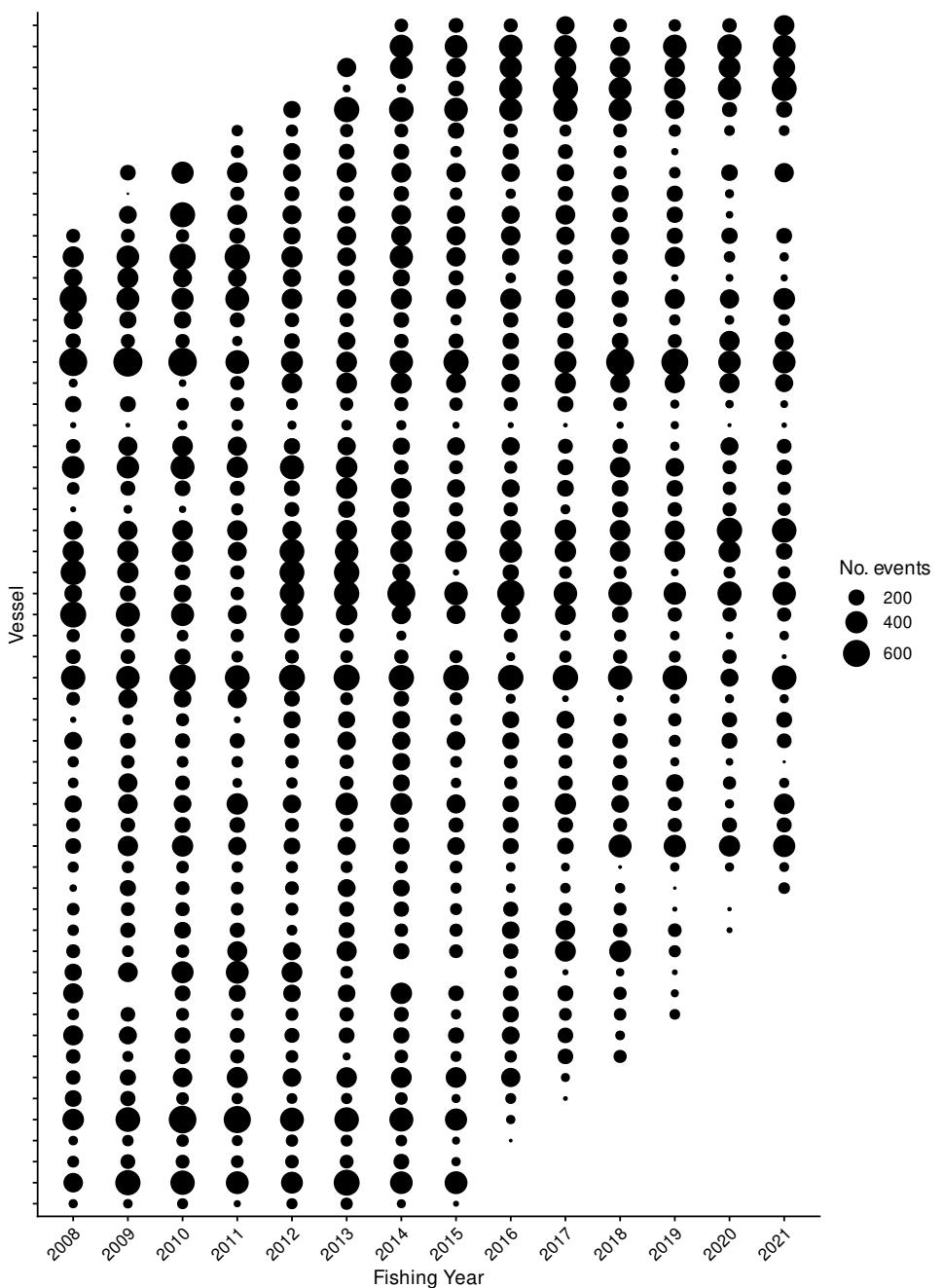


Figure D.77: Number of events by fishing year for core vessels. The area of the circles is proportional to the number of events undertaken by a vessel in a fishing year.

Table D.26: Summary of the SPO 3 BT 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	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	58 (100%) n: 14374	78 (100%) n: 14857	90 (100%) n: 17144	85 (100%) n: 15499	102 (100%) n: 15933	98 (100%) n: 16875	137 (100%) n: 16777	127 (100%) n: 13039	129 (100%) n: 13639
Positive fishing duration	58 (100%) n: 14369	78 (100%) n: 14857	90 (100%) n: 17143	85 (100%) n: 15499	102 (100%) n: 15932	98 (100%) n: 16874	137 (100%) n: 16775	127 (100%) n: 13039	129 (100%) n: 13638
Core fleet selection	38 (67%) n: 10282	59 (76%) n: 11551	66 (73%) n: 12373	60 (70%) n: 11592	86 (84%) n: 12536	80 (82%) n: 13995	121 (88%) n: 14377	120 (94%) n: 11659	119 (92%) n: 11649
Filter	2017	2018	2019	2020	2021				
Ungroomed data	140 (100%) n: 13799	180 (100%) n: 12738	142 (100%) n: 10690	128 (100%) n: 9773	149 (100%) n: 10194				
Positive fishing duration	140 (100%) n: 13795	180 (100%) n: 12722	141 (100%) n: 10682	128 (100%) n: 9746	149 (100%) n: 10185				
Core fleet selection	125 (90%) n: 11702	164 (91%) n: 10648	123 (87%) n: 8786	113 (88%) n: 7904	123 (83%) n: 8255				

Table D.27: Summary of the SPO 3 BT 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 rig.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
2008	47	2 132	10 282	31 977.68	38.45	30.46
2009	48	2 637	11 551	39 058.60	58.89	31.04
2010	49	2 689	12 373	40 418.63	65.78	31.15
2011	52	2 619	11 592	38 752.29	59.87	33.14
2012	53	2 751	12 536	40 520.90	86.47	30.26
2013	55	3 083	13 995	45 205.55	79.92	31.83
2014	56	3 140	14 377	48 972.68	120.86	34.46
2015	55	2 501	11 659	41 205.50	120.04	35.70
2016	54	2 711	11 649	41 195.06	118.89	34.15
2017	52	2 678	11 702	40 945.05	125.50	37.33
2018	50	2 447	10 648	37 785.76	164.01	40.43
2019	48	1 902	8 786	30 011.48	122.67	41.73
2020	42	1 471	7 904	26 418.17	113.35	37.93
2021	39	1 434	8 255	27 715.90	123.49	39.98

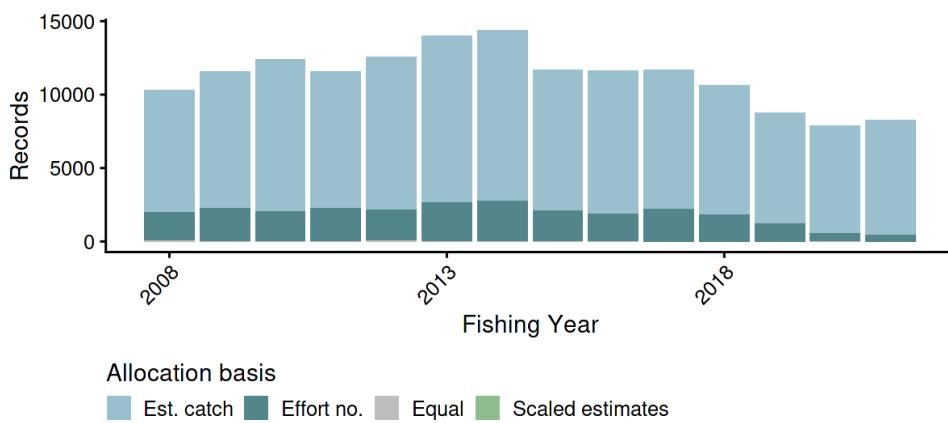


Figure D.78: Allocation basis for attributing landings to records in the SPO 3 BT event catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

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	12.00	201 977	0.40	0.40	*
+ vessel_key	56.00	196 787	3.10	2.60	*
+ ns(bottom_depth, 3)	3.00	194 022	4.40	1.40	*
+ target_species	6.00	192 103	5.40	1.00	*
+ month	11.00	191 164	5.90	0.50	
+ stat_area	11.00	190 478	6.20	0.30	
+ ns(start_time, 3)	3.00	190 042	6.40	0.20	
+ ns(log(fishing_duration), 3)	3.00	189 952	6.50	0.00	
+ ns(effort_speed, 3)	3.00	189 941	6.50	0.00	

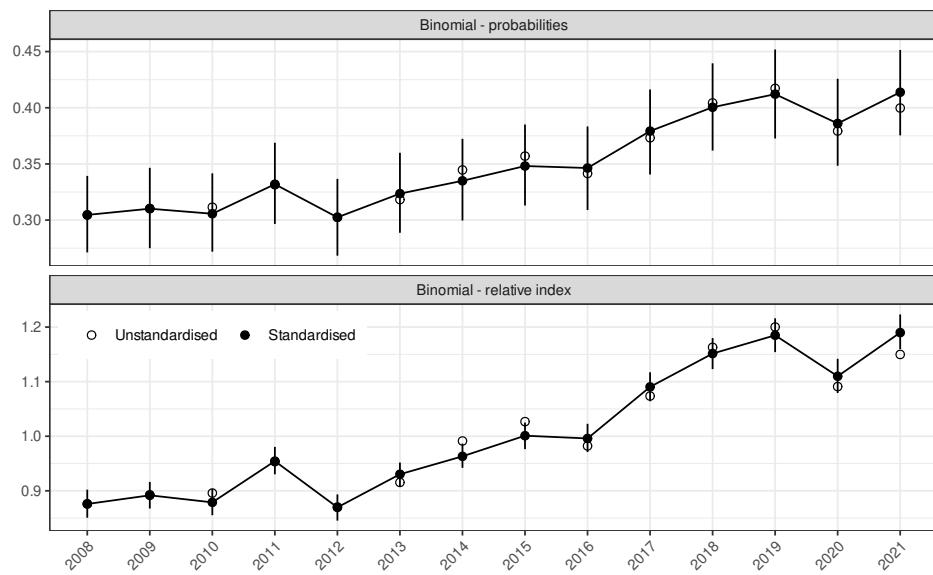


Figure D.79: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 3 BT event dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

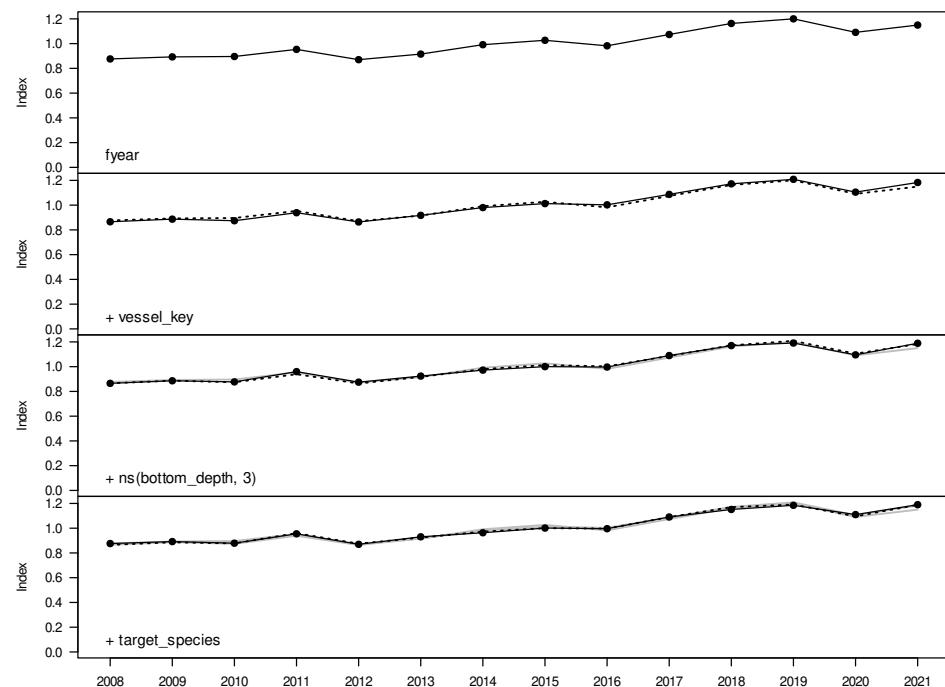


Figure D.80: Step plot for occurrence of catch in the SPO 3 BT event dataset.

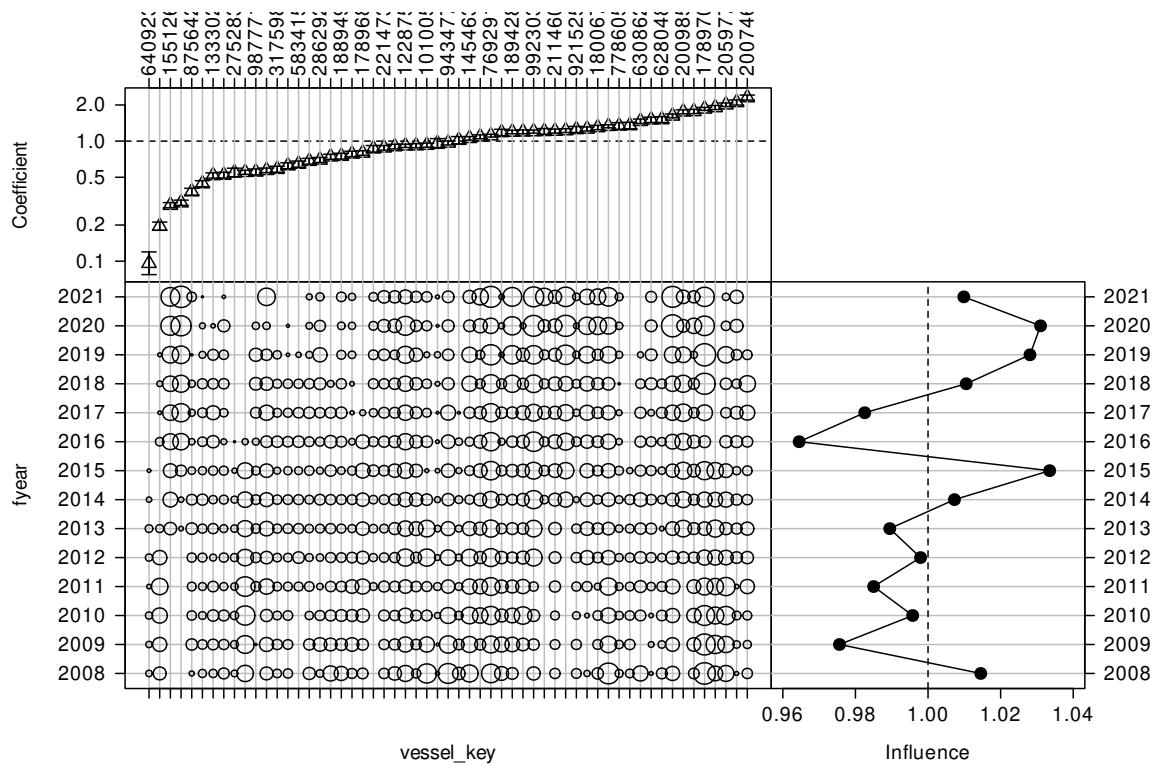


Figure D.81: CDI plot for vessel key for the occurrence of positive catch SPO 3 BT event catch-per-unit-effort dataset.

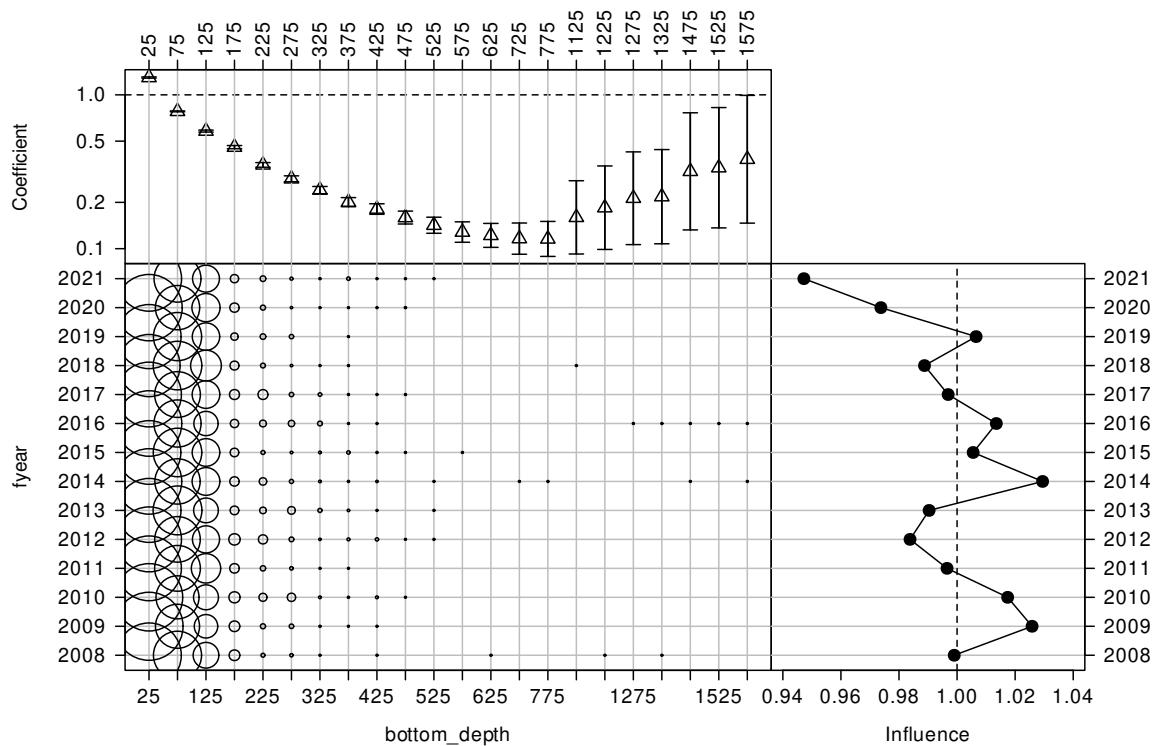


Figure D.82: CDI plot for bottom depth (m) for the occurrence of positive catch SPO 3 BT event catch-per-unit-effort dataset.

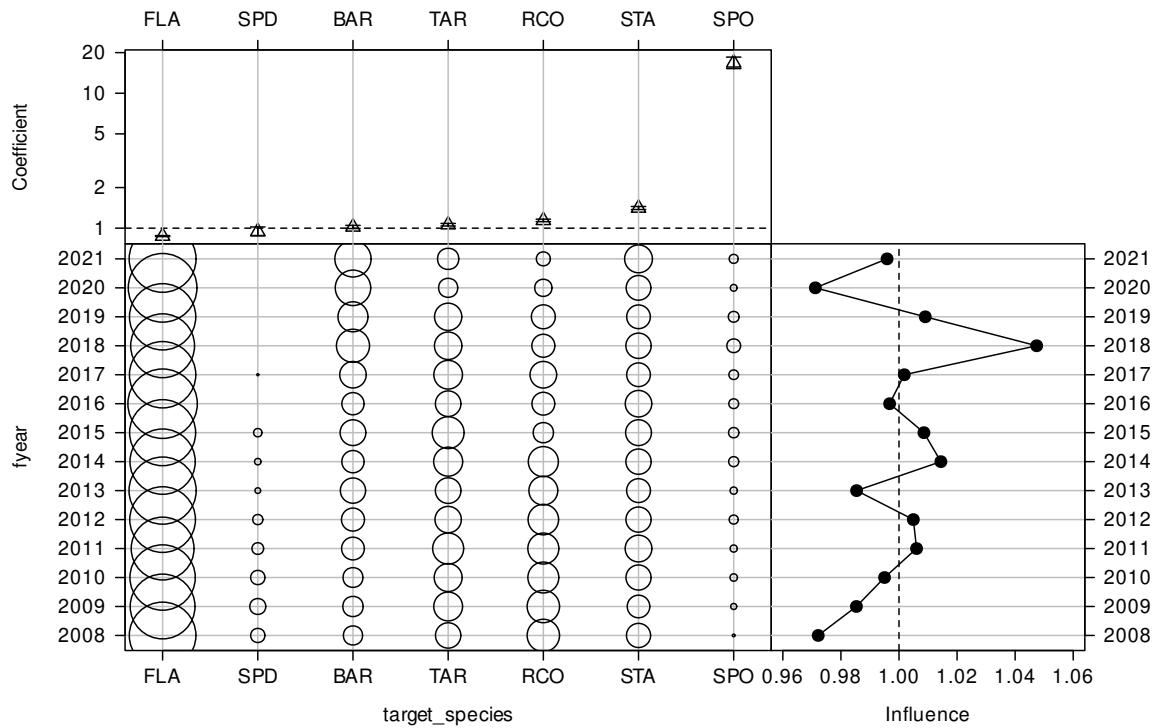


Figure D.83: CDI plot for target species for the occurrence of positive catch SPO 3 BT event catch-per-unit-effort dataset.

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	12	220938	5.3	5.3	*
+ vessel key	56	212751	18.7	13.4	*
+ target species	6	207950	25.6	6.9	*
+ ns(bottom depth, 3)	3	204760	29.9	4.2	*
+ stat area	11	203933	30.9	1.1	*
+ month	11	203233	31.9	0.9	
+ ns(start time, 3)	3	202681	32.6	0.7	
+ ns(log(fishing duration), 3)	3	202494	32.8	0.2	
+ ns(effort speed, 3)	3	202439	32.9	0.1	

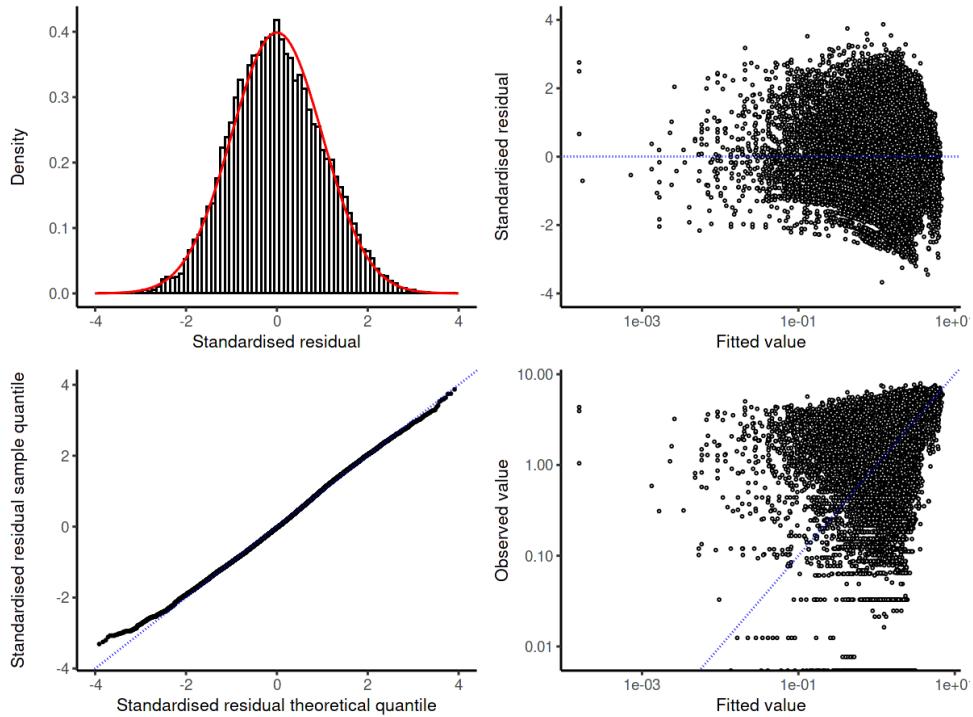


Figure D.84: Diagnostic plots for the lognormal model for the SPO 3 BT event dataset.

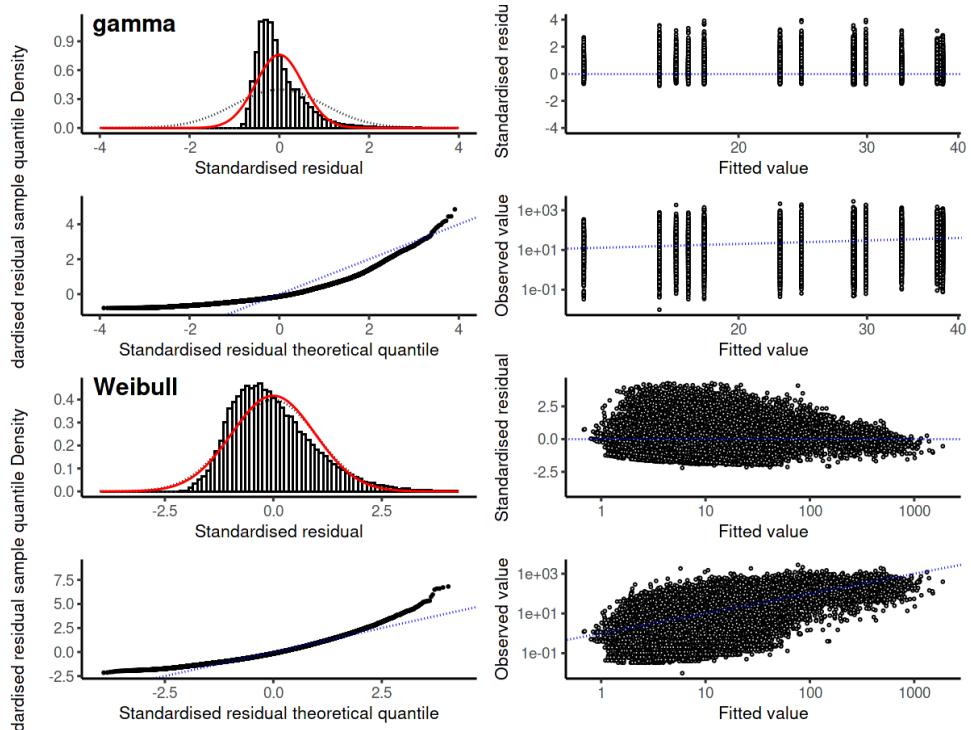


Figure D.85: Diagnostic plots for the gamma and Weibull model for the SPO 3 BT event dataset.

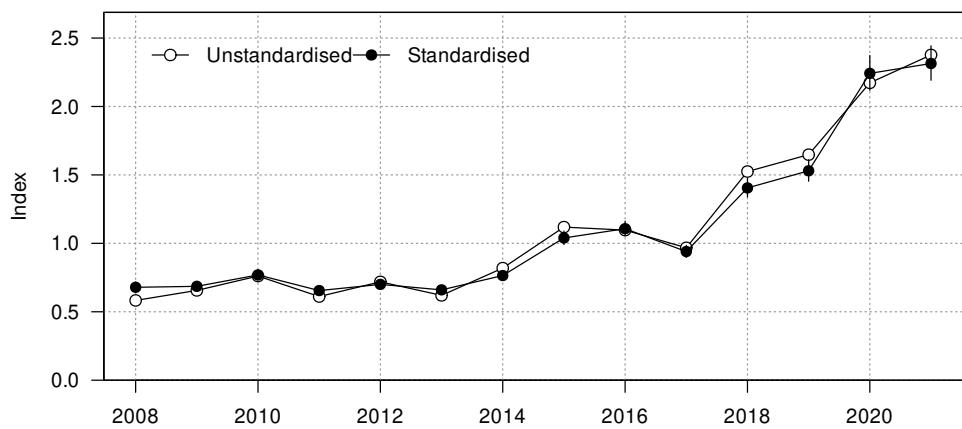


Figure D.86: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 3 BT event dataset.

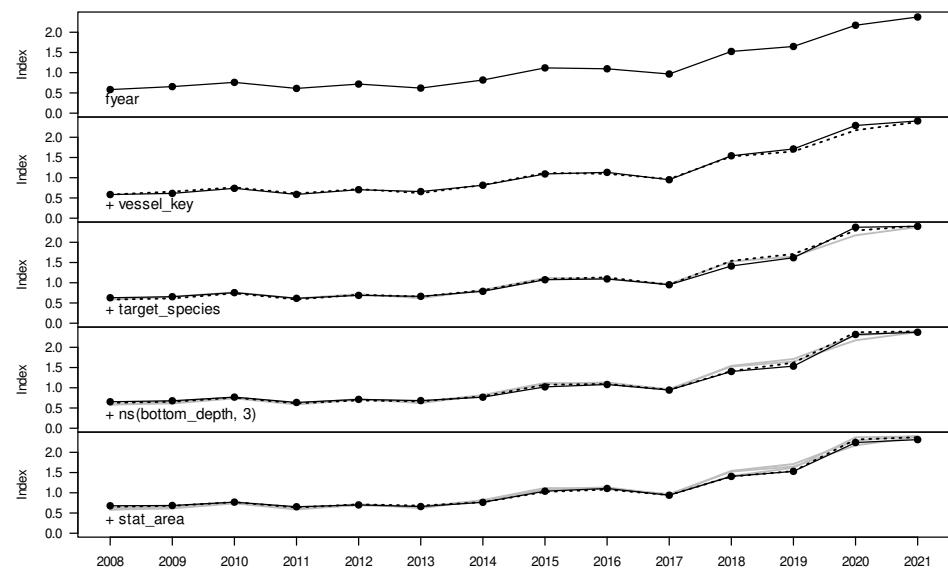


Figure D.87: Changes to the SPO 3 BT event positive catch index as terms are successively entered into the model.

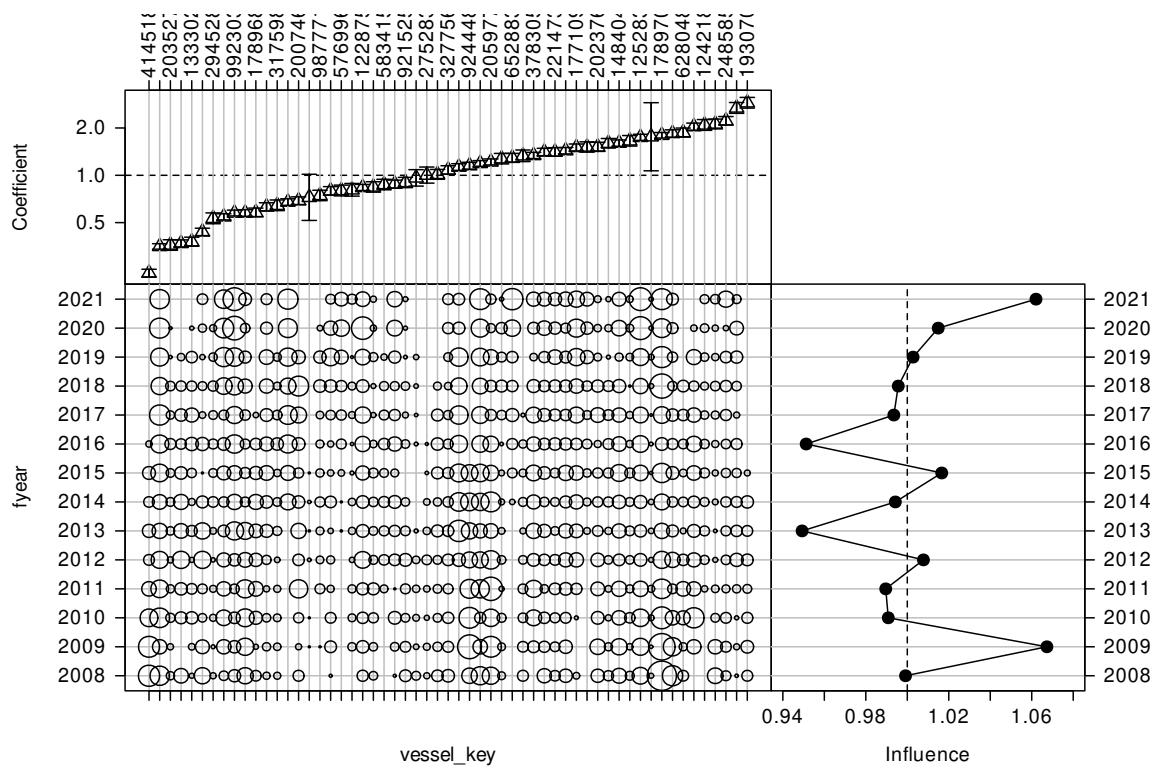


Figure D.88: CDI plot for vessel key for the positive catch SPO 3 BT event catch-per-unit-effort dataset.

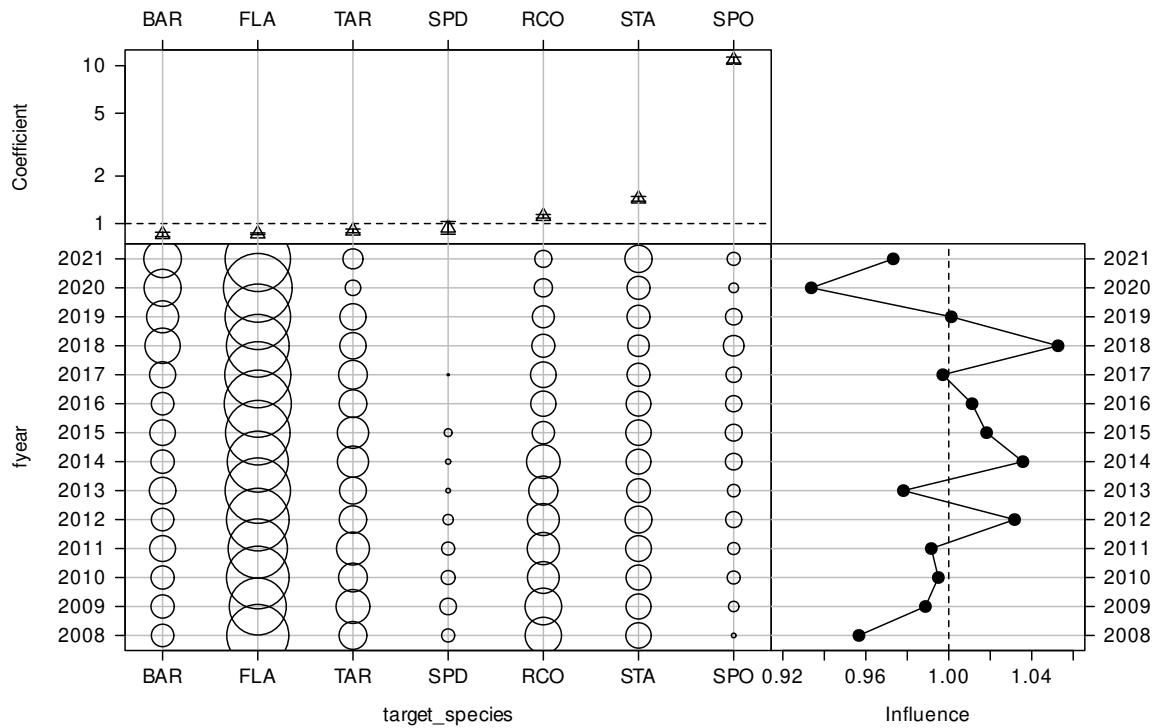


Figure D.89: CDI plot for target species for the positive catch SPO 3 BT event catch-per-unit-effort dataset.

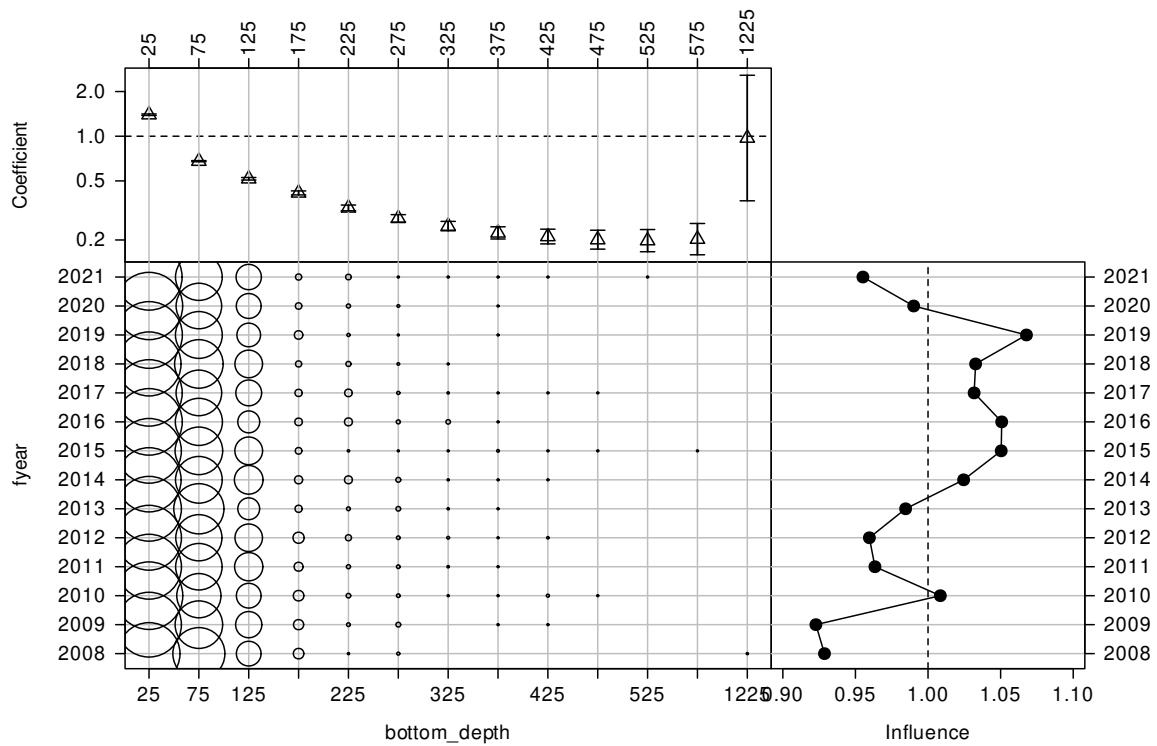


Figure D.90: CDI plot for bottom depth (m) for the positive catch SPO 3 BT event catch-per-unit-effort dataset.

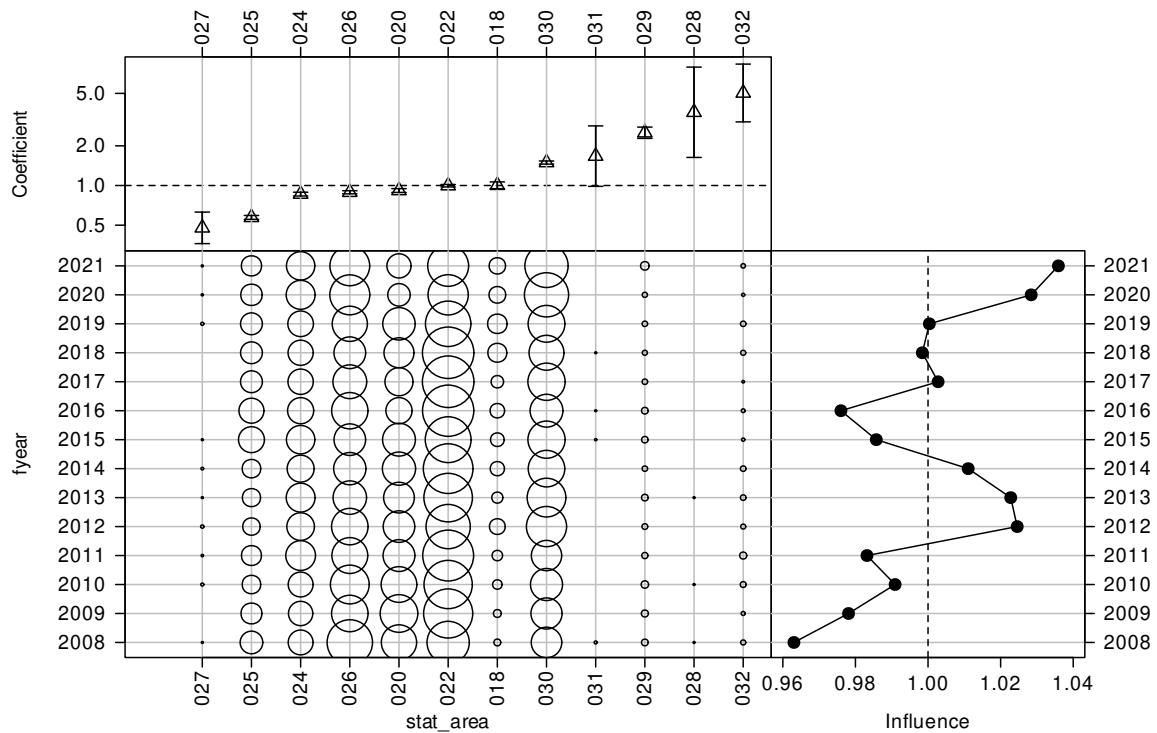


Figure D.91: CDI plot for statistical area for the positive catch SPO 3 BT event catch-per-unit-effort dataset.

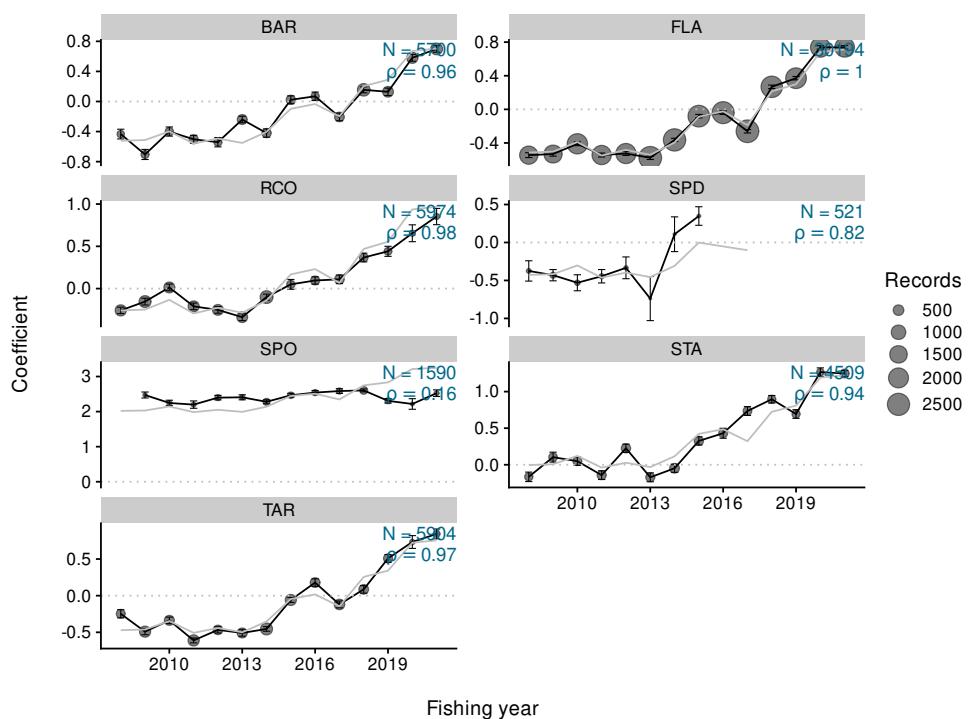


Figure D.92: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 3 BT event dataset.

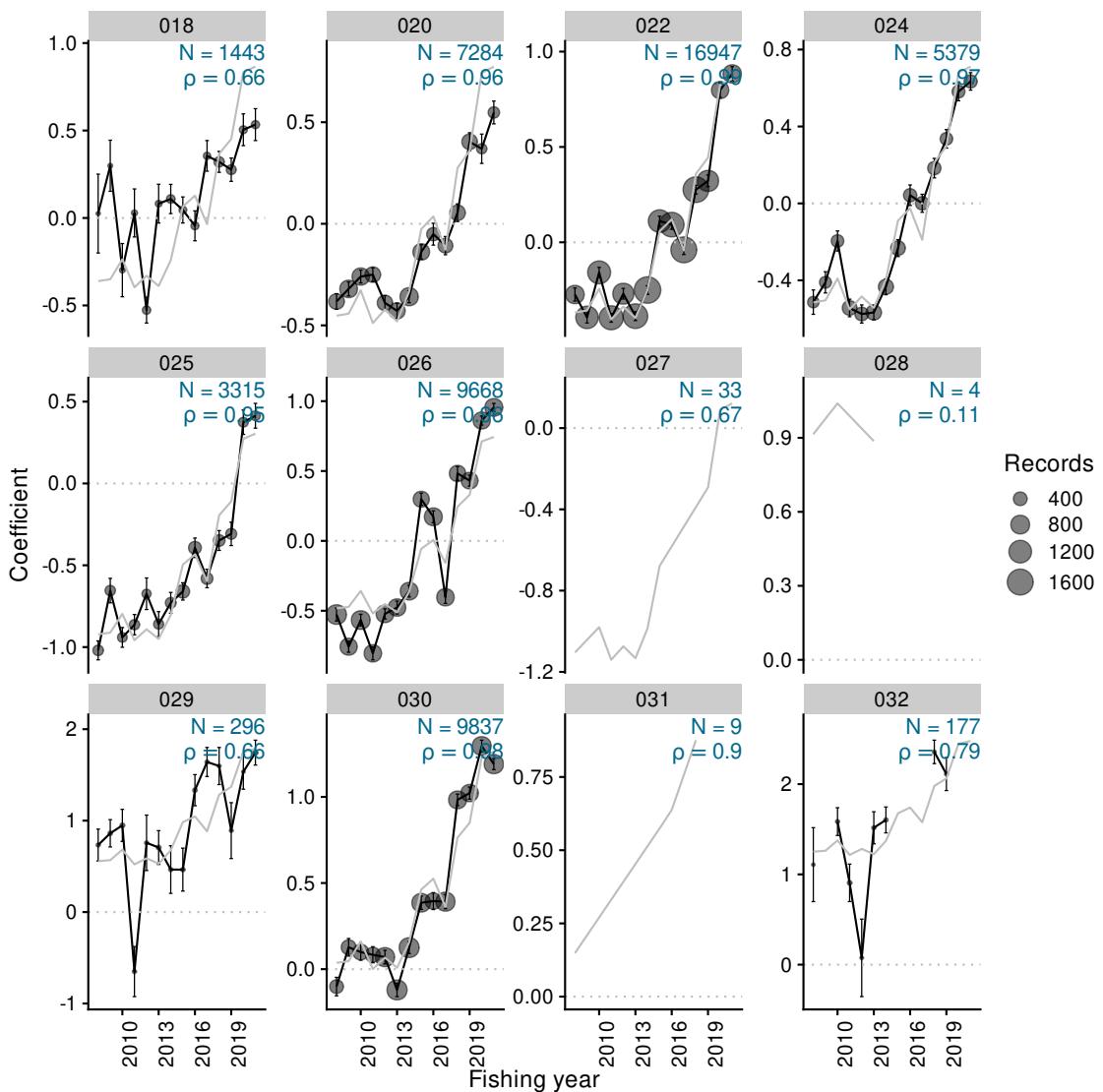


Figure D.93: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 3 BT event dataset.

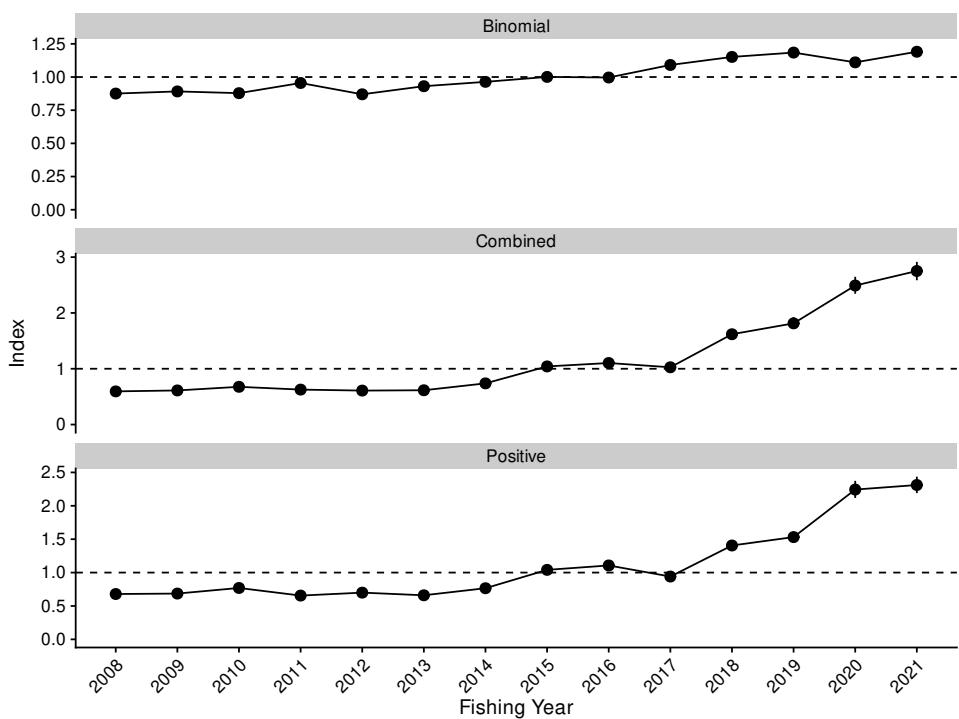


Figure D.94: Standardised indices and 95% confidence intervals for the SPO 3 BT event dataset.

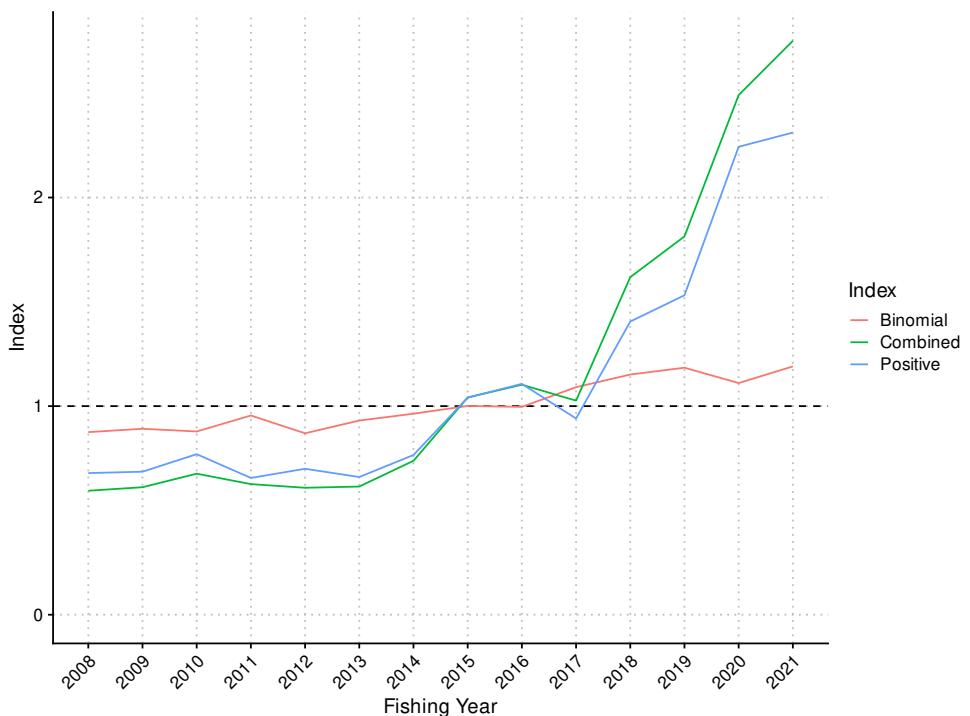


Figure D.95: Standardised indices for the SPO 3 BT event dataset.

Table D.30: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 3 BT event.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
2008	0.875	0.013	0.850	0.902	0.594	0.019	0.558	0.633	0.679	0.019	0.644	0.718
2009	0.891	0.013	0.866	0.917	0.611	0.018	0.578	0.648	0.686	0.018	0.652	0.722
2010	0.878	0.012	0.854	0.903	0.676	0.020	0.639	0.716	0.770	0.019	0.735	0.809
2011	0.955	0.013	0.930	0.980	0.626	0.018	0.592	0.663	0.656	0.017	0.624	0.691
2012	0.870	0.012	0.847	0.894	0.609	0.018	0.572	0.644	0.700	0.018	0.665	0.735
2013	0.931	0.012	0.907	0.955	0.614	0.016	0.582	0.645	0.660	0.015	0.631	0.689
2014	0.964	0.011	0.942	0.987	0.738	0.018	0.703	0.775	0.766	0.016	0.736	0.798
2015	1.001	0.013	0.976	1.026	1.042	0.028	0.986	1.097	1.041	0.025	0.992	1.089
2016	0.996	0.013	0.971	1.021	1.103	0.030	1.047	1.164	1.107	0.026	1.058	1.161
2017	1.091	0.013	1.066	1.117	1.026	0.027	0.973	1.078	0.941	0.022	0.899	0.984
2018	1.151	0.015	1.123	1.181	1.618	0.046	1.528	1.710	1.406	0.035	1.338	1.474
2019	1.184	0.016	1.153	1.216	1.813	0.054	1.716	1.926	1.531	0.040	1.460	1.617
2020	1.111	0.016	1.079	1.142	2.491	0.077	2.344	2.647	2.243	0.065	2.118	2.374
2021	1.190	0.017	1.158	1.226	2.751	0.084	2.586	2.915	2.311	0.063	2.190	2.436

D.6 SPO 7 BT event

This analysis is the tow-by-tow (event) analogue to the SPO 7 BT trip analysis presented in Section 5.6. It repeats that analysis at the level of an individual event, adding detailed explanatory information to the analysis that is not available to the trip-based analysis. Such information includes the duration of the tow, the starting depth of the tow, the speed of the tow, and the relative start time of the tow within the 24-hour period. As well, the location of the tow and the target species can be assigned explicitly to the tow, rather than using the modal value for the trip as is used in the trip-based analysis. This analysis begins with the 2006–07 fishing year, which is when the detailed event-based data became available. A plot comparing the event-based CPUE series with the longer trip-based series is presented in Figure D.161.

Table D.31: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 7 BT event CPUE series.

Series	SPO 7 BT event
QMS stock	SPO7
Reporting forms	ERS - Trawl, TCE, TCP
Fishing methods	BT
Target species	FLA, RCO, SPO, BAR, TAR, GUR, TRE, SNA, WAR
Statistical Areas	016, 017, 018, 032, 033, 034, 035, 036, 037, 038, 039, 040
Period	2007-10-01, 2021-09-30
Resolution	Fishing event
Core fleet years	10
Core fleet trips	5
Default model	$\text{allockg} \sim \text{fyear} + \text{vessel_key} + \text{stat_area} + \text{month} + \text{target_species} + \text{ns}(\log(\text{fishing_duration}), 3) + \text{ns}(\text{bottom_depth}, 3) + \text{ns}(\text{start_time}, 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

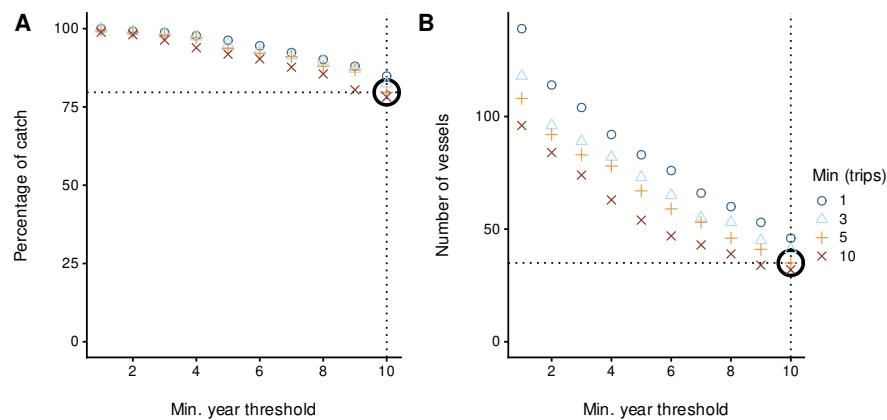


Figure D.96: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 7 BT event CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

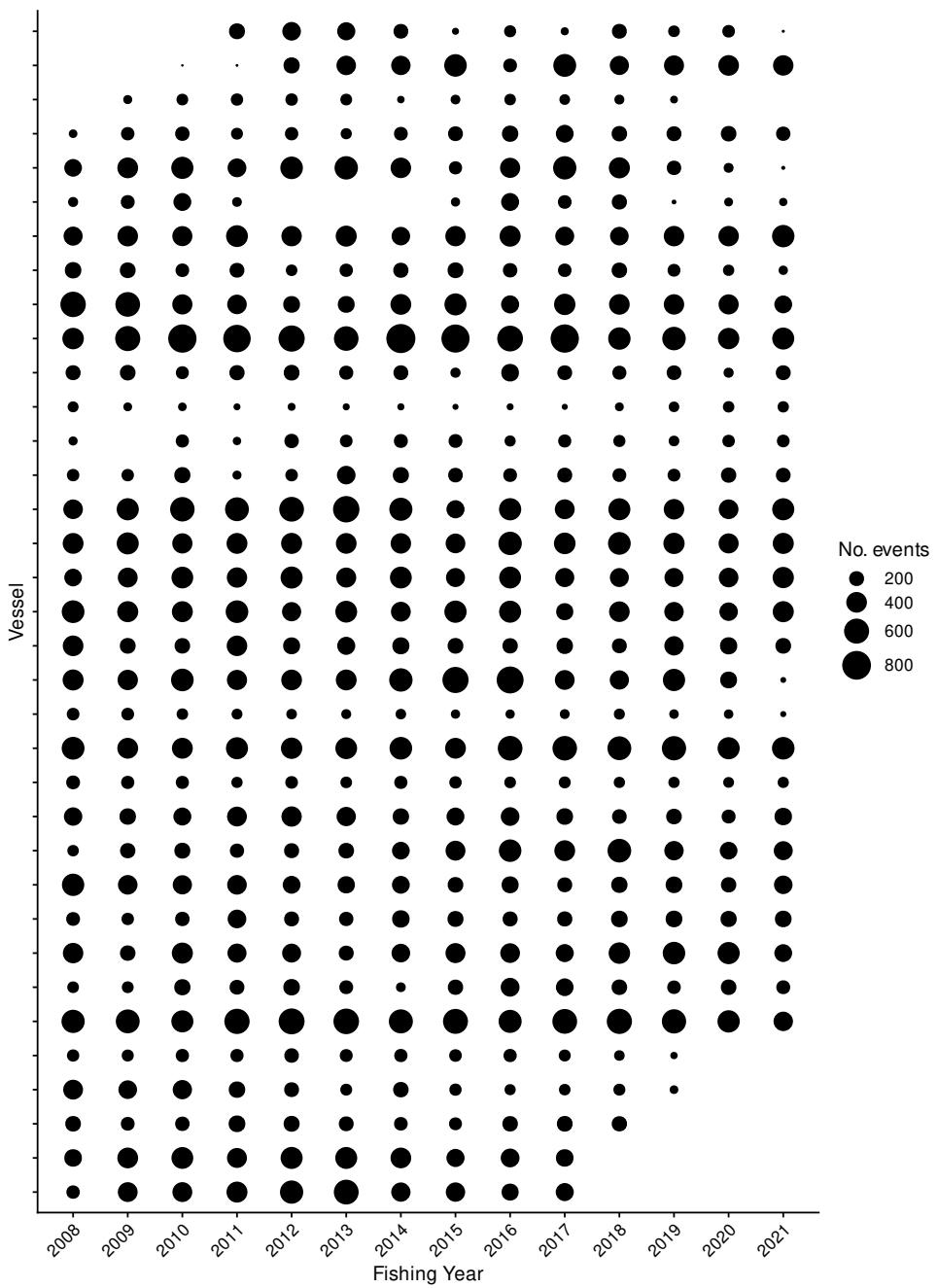


Figure D.97: Number of events by fishing year for core vessels. The area of the circles is proportional to the number of events undertaken by a vessel in a fishing year.

Table D.32: Summary of the SPO 7 BT 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	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	130 (100%) n: 14287	127 (100%) n: 14137	131 (100%) n: 16408	135 (100%) n: 13752	129 (100%) n: 14535	154 (100%) n: 14593	162 (100%) n: 13388	163 (100%) n: 11812	172 (100%) n: 12876
Positive fishing duration	130 (100%) n: 14286	127 (100%) n: 14135	131 (100%) n: 16406	135 (100%) n: 13751	129 (100%) n: 14532	154 (100%) n: 14591	162 (100%) n: 13388	163 (100%) n: 11812	172 (100%) n: 12876
Core fleet selection	91 (70%) n: 8952	93 (73%) n: 9224	94 (72%) n: 10185	110 (81%) n: 10032	102 (79%) n: 10346	110 (72%) n: 10235	124 (77%) n: 10076	144 (88%) n: 9624	141 (82%) n: 10541
Filter	2017	2018	2019	2020	2021				
Ungroomed data	171 (100%) n: 12444	179 (100%) n: 11382	197 (100%) n: 10577	205 (100%) n: 9360	228 (100%) n: 9105				
Positive fishing duration	171 (100%) n: 12443	179 (100%) n: 11381	197 (100%) n: 10572	205 (100%) n: 9357	228 (100%) n: 9103				
Core fleet selection	147 (86%) n: 9948	156 (87%) n: 9253	167 (85%) n: 8340	163 (80%) n: 7372	175 (77%) n: 7140				

Table D.33: Summary of the SPO 7 BT 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 rig.

Fishing year	Vessels	Trips	Records	Hrs	Catch (t)	Records caught
2008	32	996	8952	34196.80	91.28	37.15
2009	32	1037	9224	35418.77	92.58	37.11
2010	34	1184	10185	37266.30	94.38	38.07
2011	35	1084	10032	35886.35	109.57	37.75
2012	34	1094	10346	38073.65	101.77	38.03
2013	34	1102	10235	37285.05	110.31	39.40
2014	34	1075	10076	37665.83	124.44	39.65
2015	35	1044	9624	35686.02	144.08	42.88
2016	35	1145	10541	39276.82	141.18	42.20
2017	35	1149	9948	38600.67	147.36	46.21
2018	33	1033	9253	35524.99	156.12	42.43
2019	32	858	8340	32855.06	166.75	45.98
2020	29	758	7372	30387.33	163.27	61.79
2021	29	710	7140	28959.20	175.06	58.22

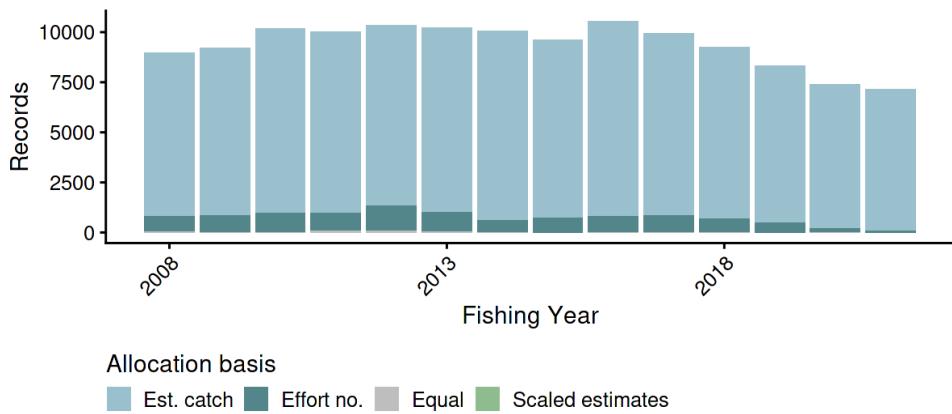


Figure D.98: Allocation basis for attributing landings to records in the SPO 7 BT event catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table D.34: 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	12.00	176711	1.40	1.40	*
+ vessel_key	34.00	171537	4.30	2.90	*
+ ns(bottom_depth, 3)	3.00	169066	5.70	1.40	*
+ ns(start_time, 3)	3.00	168279	6.10	0.40	
+ stat_area	11.00	167492	6.60	0.50	
+ month	11.00	166772	7.00	0.40	
+ target_species	8.00	166205	7.30	0.30	
+ ns(log(fishing_duration), 3)	3.00	166020	7.40	0.10	

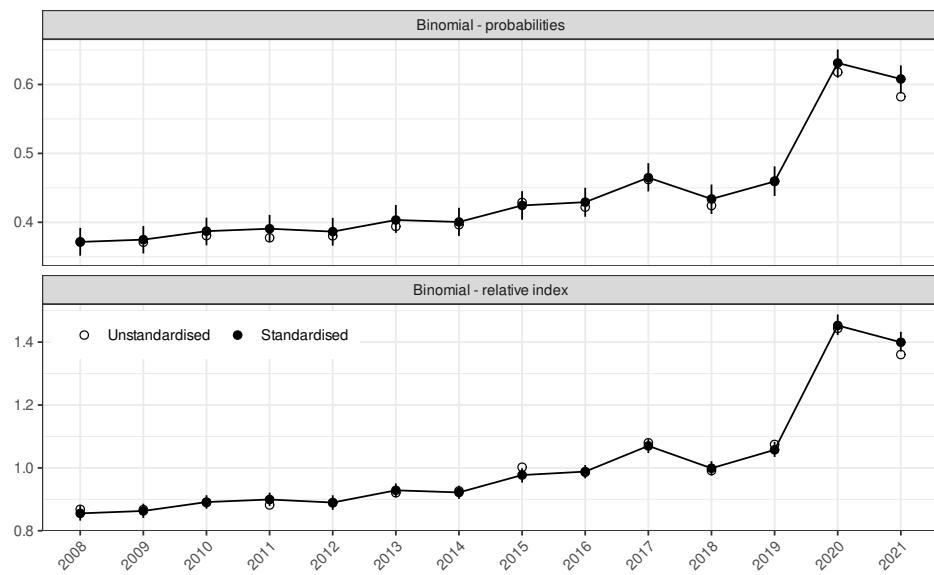


Figure D.99: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 7 BT event dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

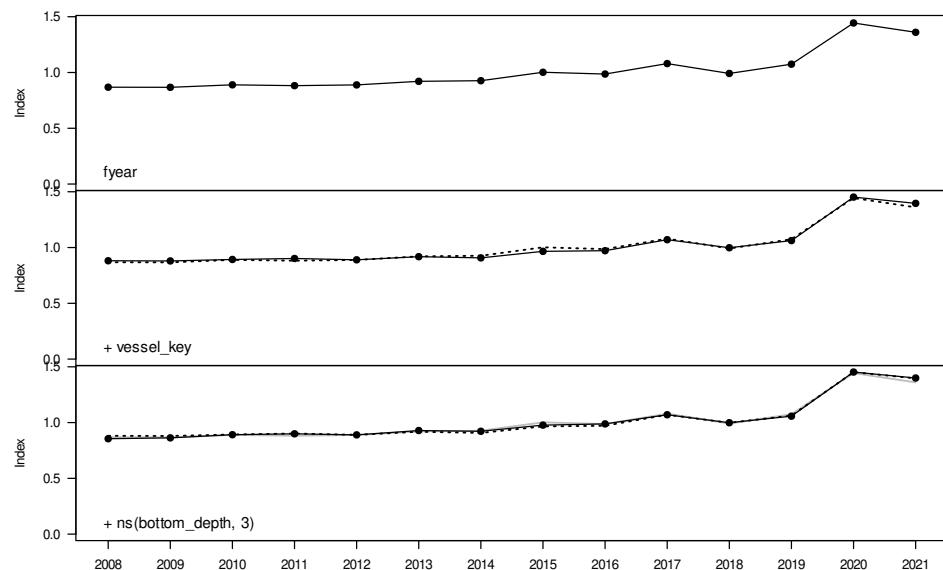


Figure D.100: Step plot for occurrence of catch in the SPO 7 BT event dataset.

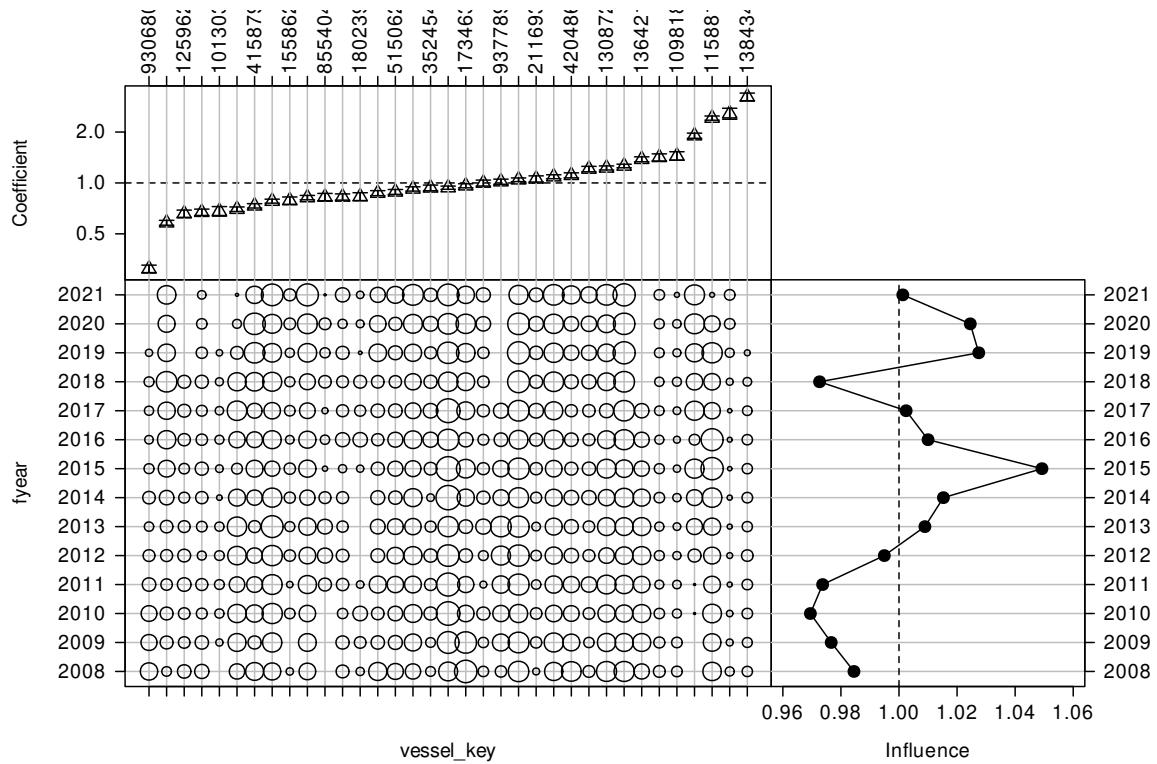


Figure D.101: CDI plot for vessel key for the occurrence of positive catch SPO 7 BT event catch-per-unit-effort dataset.

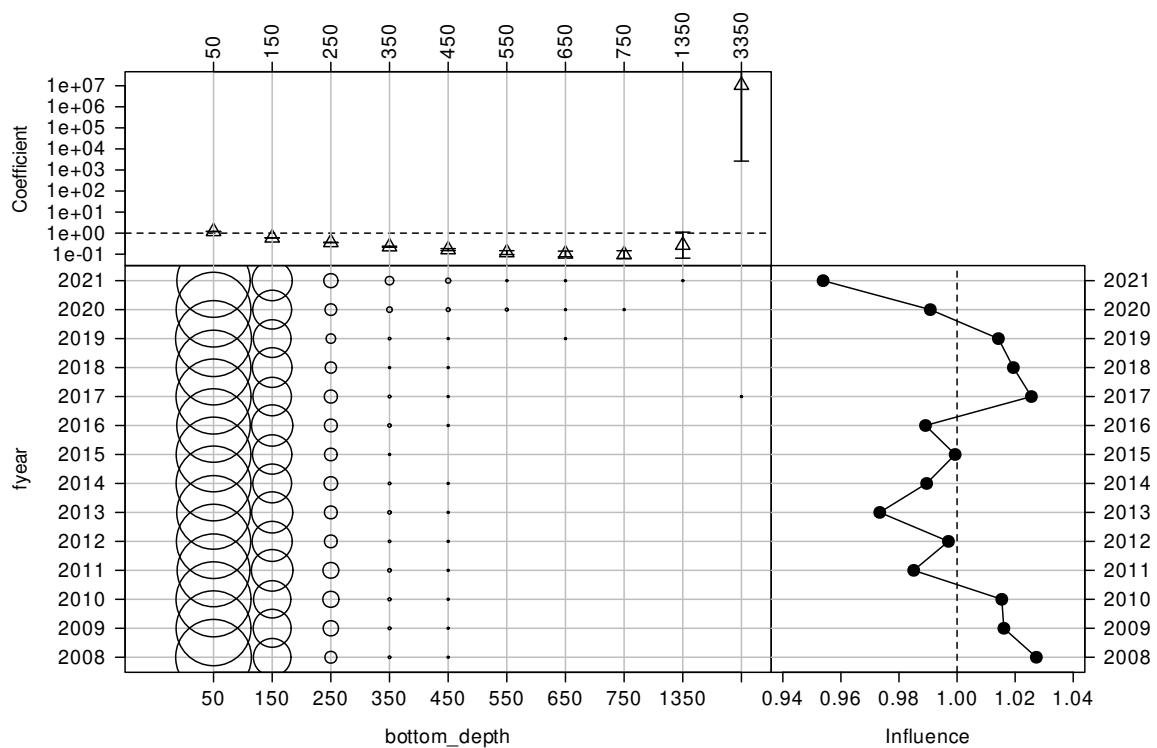


Figure D.102: CDI plot for bottom depth (m) for the occurrence of positive catch SPO 7 BT event catch-per-unit-effort dataset.

Table D.35: 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	12	205 659	4.3	4.3	*
+ vessel key	34	196 076	19.5	15.1	*
+ ns(bottom depth, 3)	3	193 112	23.6	4.2	*
+ month	11	191 541	25.8	2.1	*
+ stat area	11	190 060	27.7	2.0	*
+ ns(log(fishing duration), 3)	3	189 234	28.8	1.1	*
+ target species	8	188 595	29.6	0.8	
+ ns(start time, 3)	3	188 382	29.9	0.3	

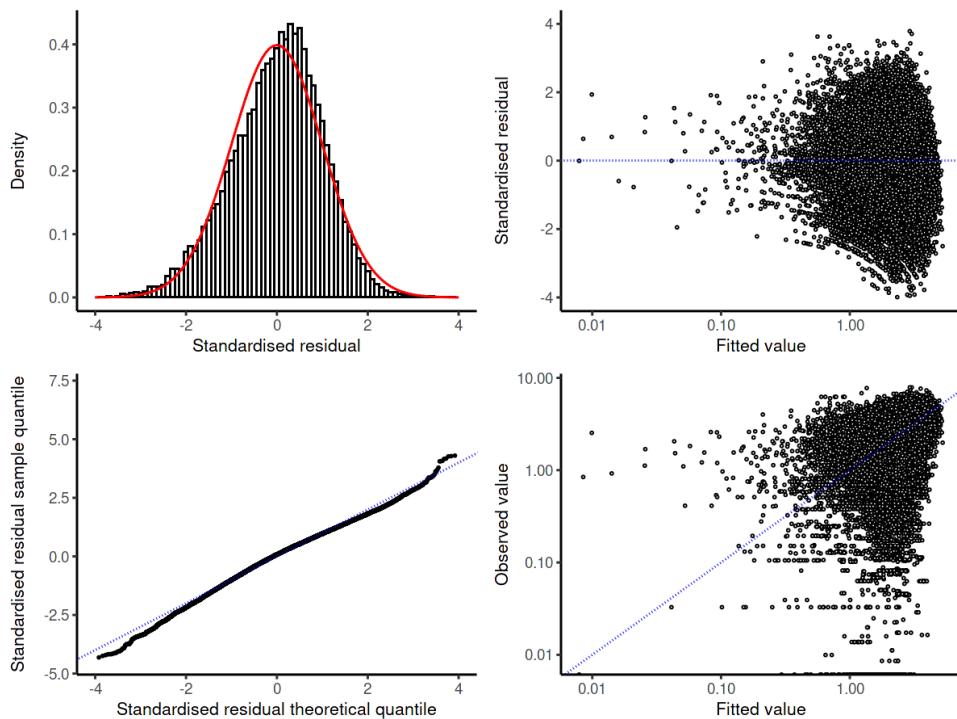


Figure D.103: Diagnostic plots for the lognormal model for the SPO 7 BT event dataset.

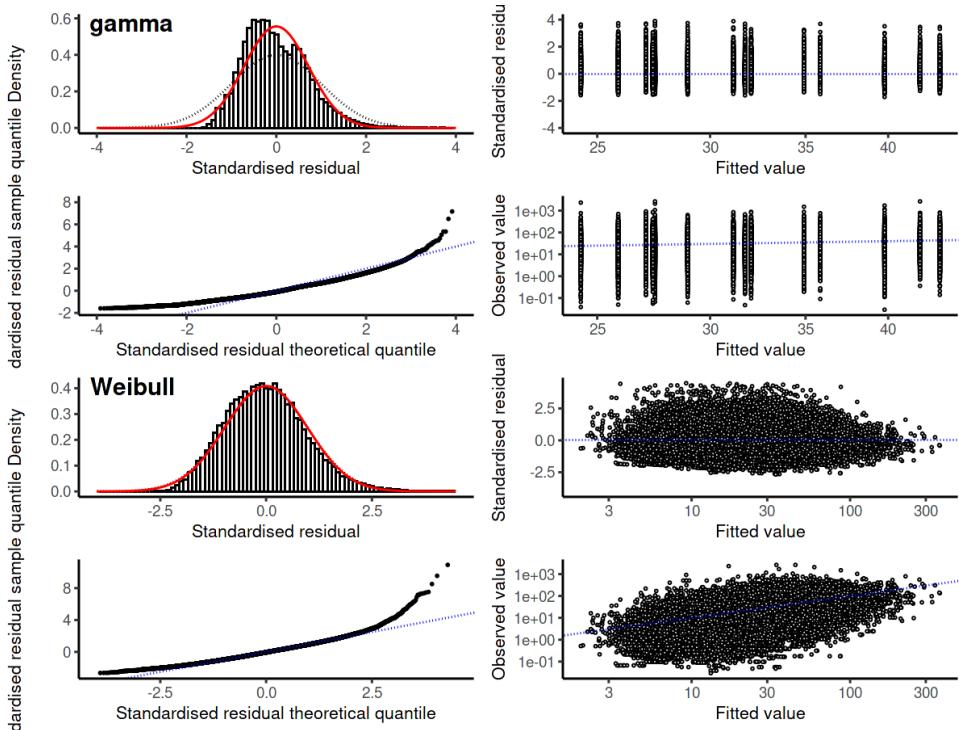


Figure D.104: Diagnostic plots for the gamma and Weibull model for the SPO 7 BT event dataset.

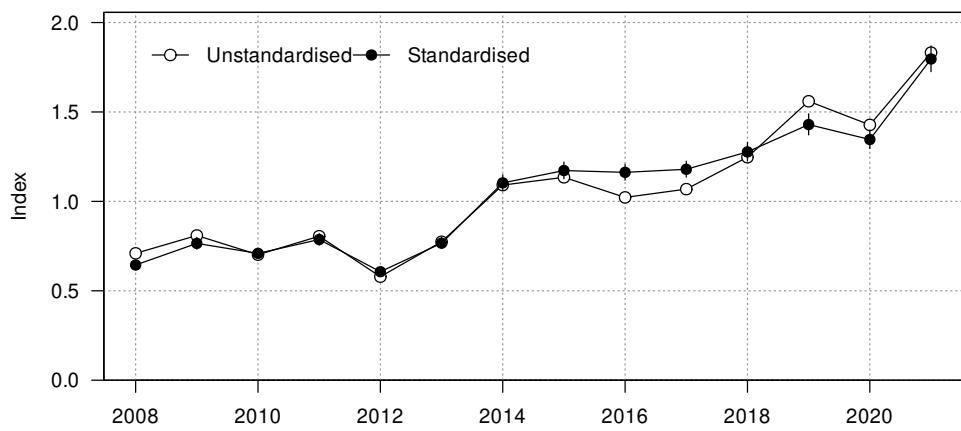


Figure D.105: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 7 BT event dataset.

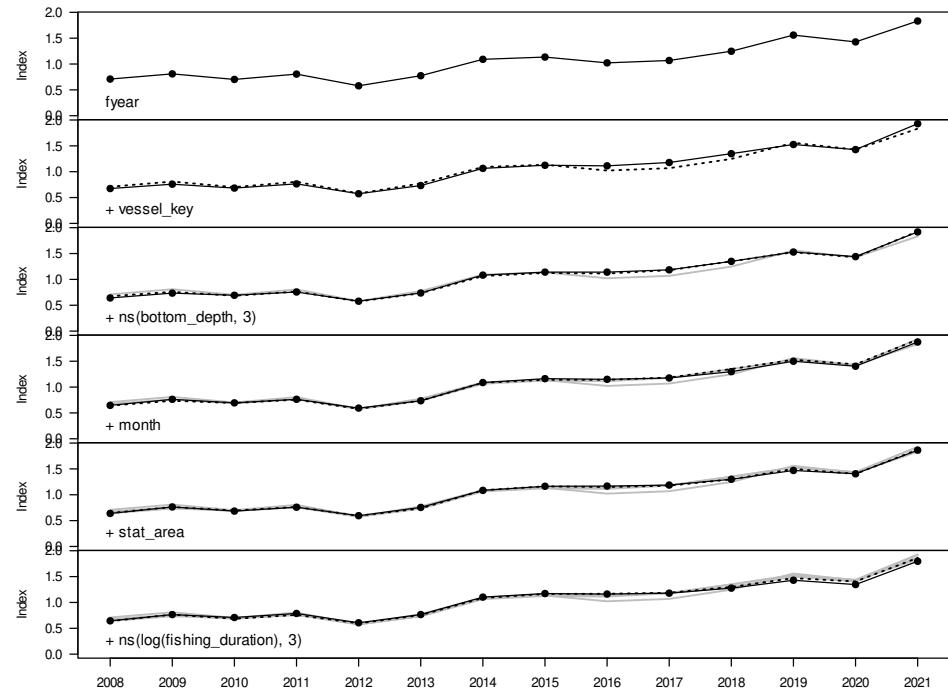


Figure D.106: Changes to the SPO 7 BT event positive catch index as terms are successively entered into the model.

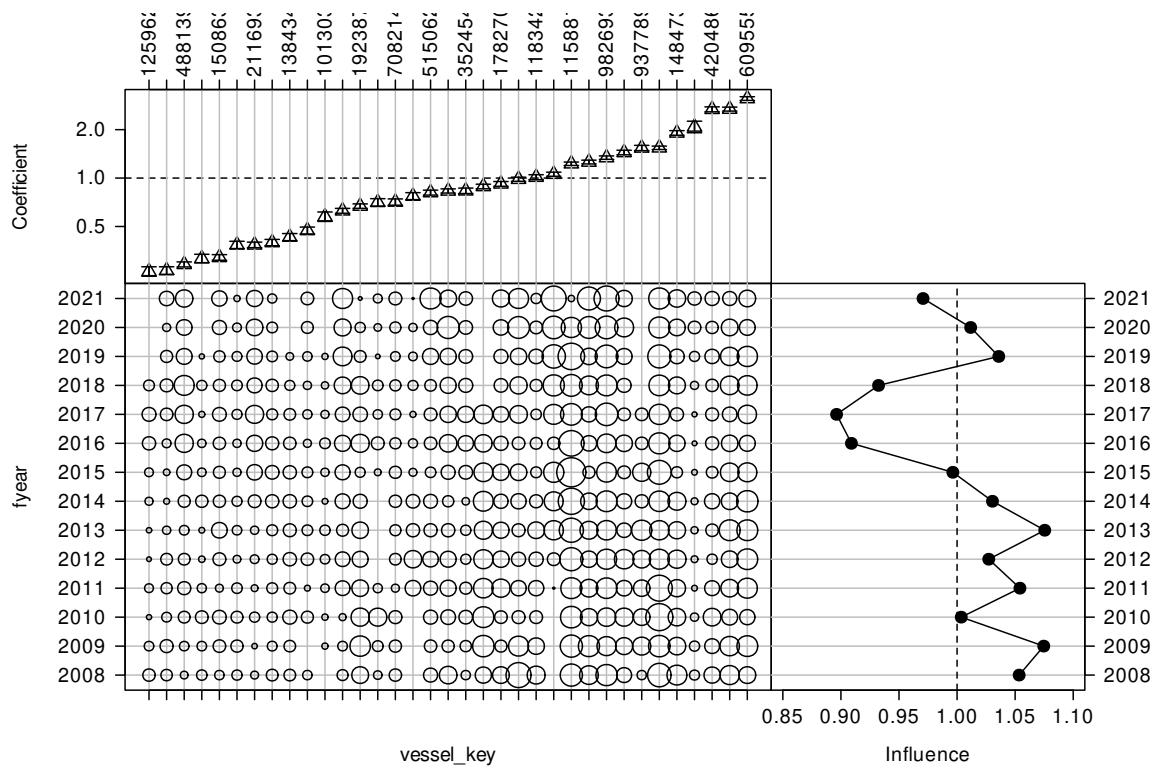


Figure D.107: CDI plot for vessel key for the positive catch SPO 7 BT event catch-per-unit-effort dataset.

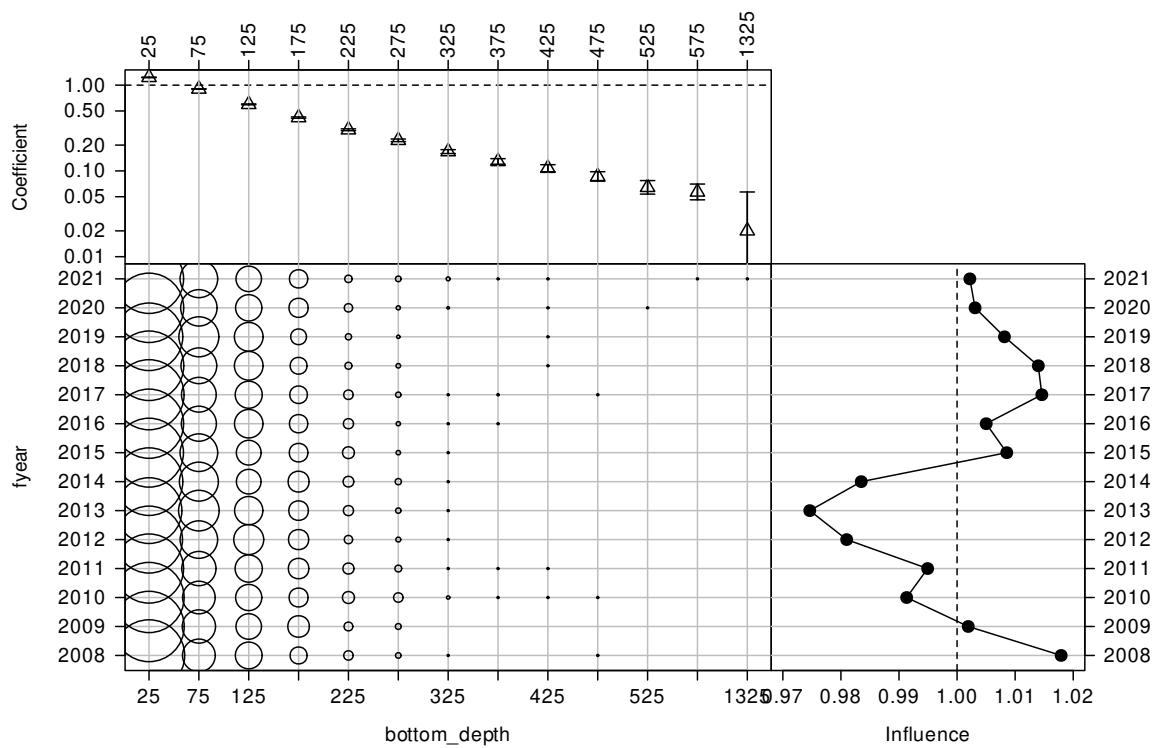


Figure D.108: CDI plot for bottom depth (m) for the positive catch SPO 7 BT event catch-per-unit-effort dataset.

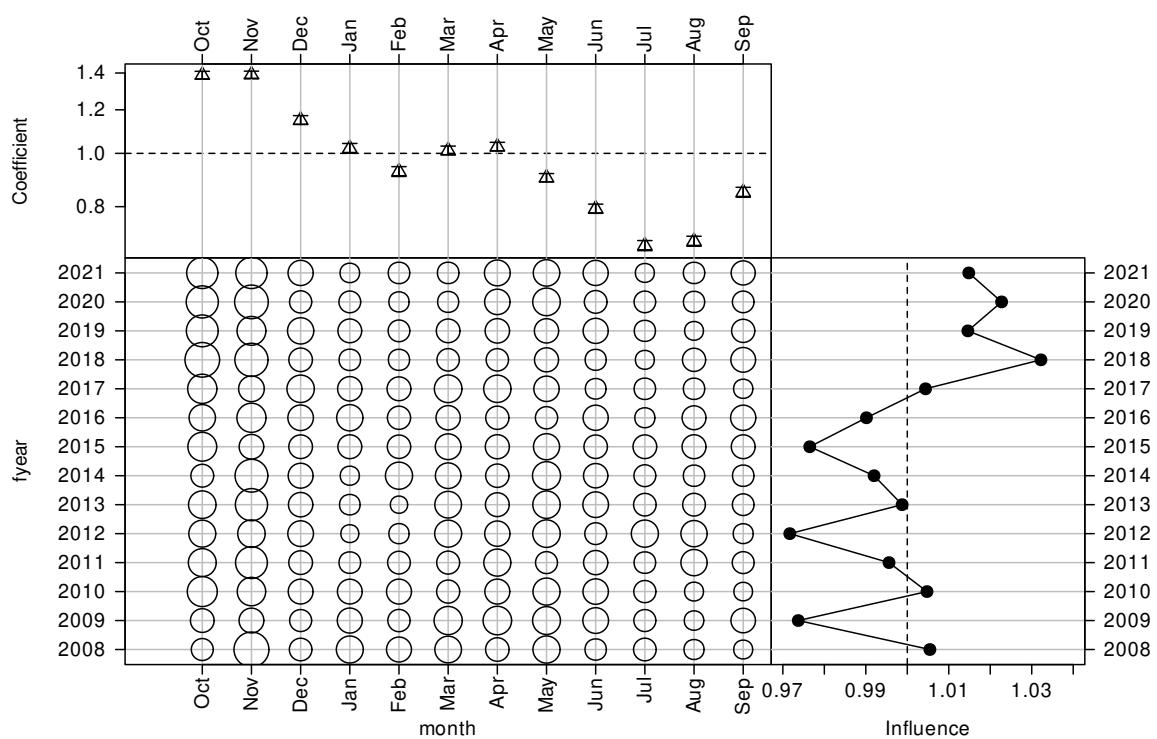


Figure D.109: CDI plot for month for the positive catch SPO 7 BT event catch-per-unit-effort dataset.

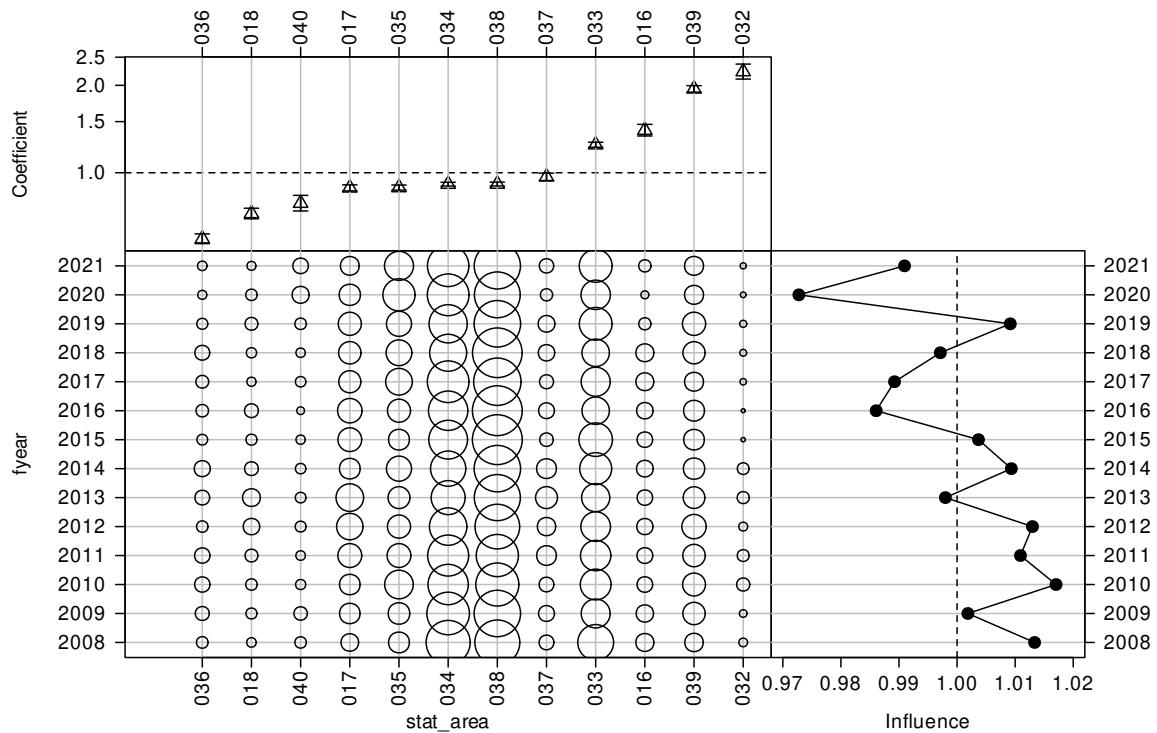


Figure D.110: CDI plot for statistical area for the positive catch SPO 7 BT event catch-per-unit-effort dataset.

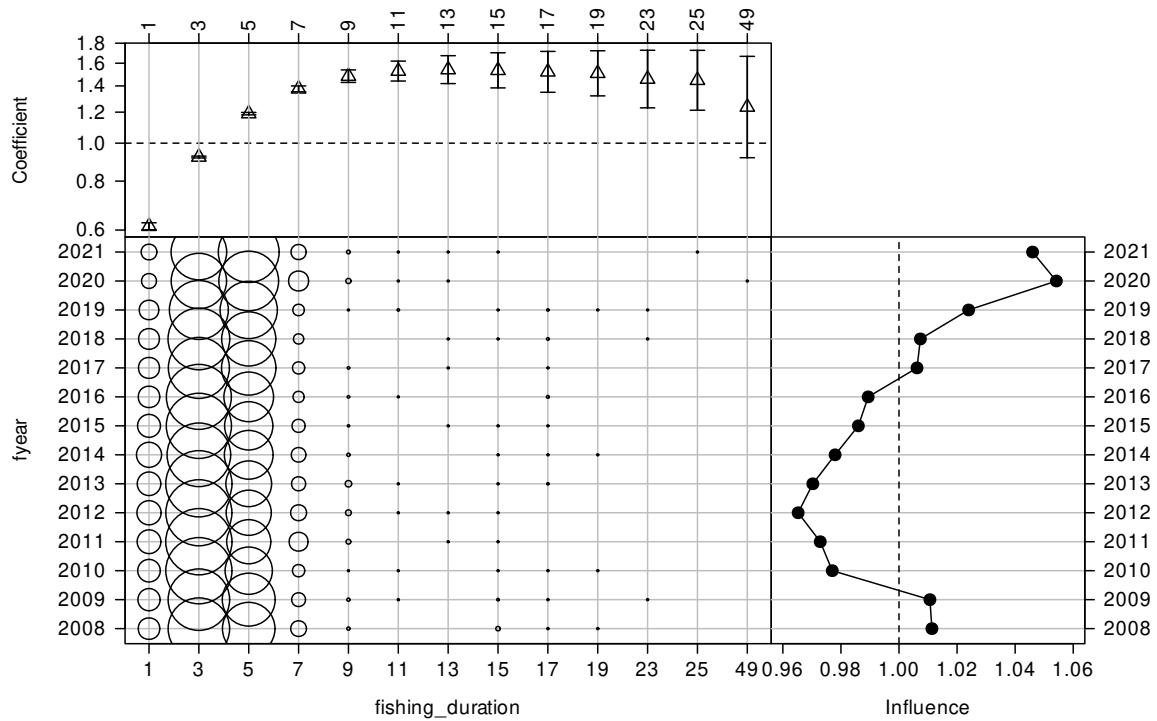


Figure D.111: CDI plot for fishing duration (h) for the positive catch SPO 7 BT event catch-per-unit-effort dataset.

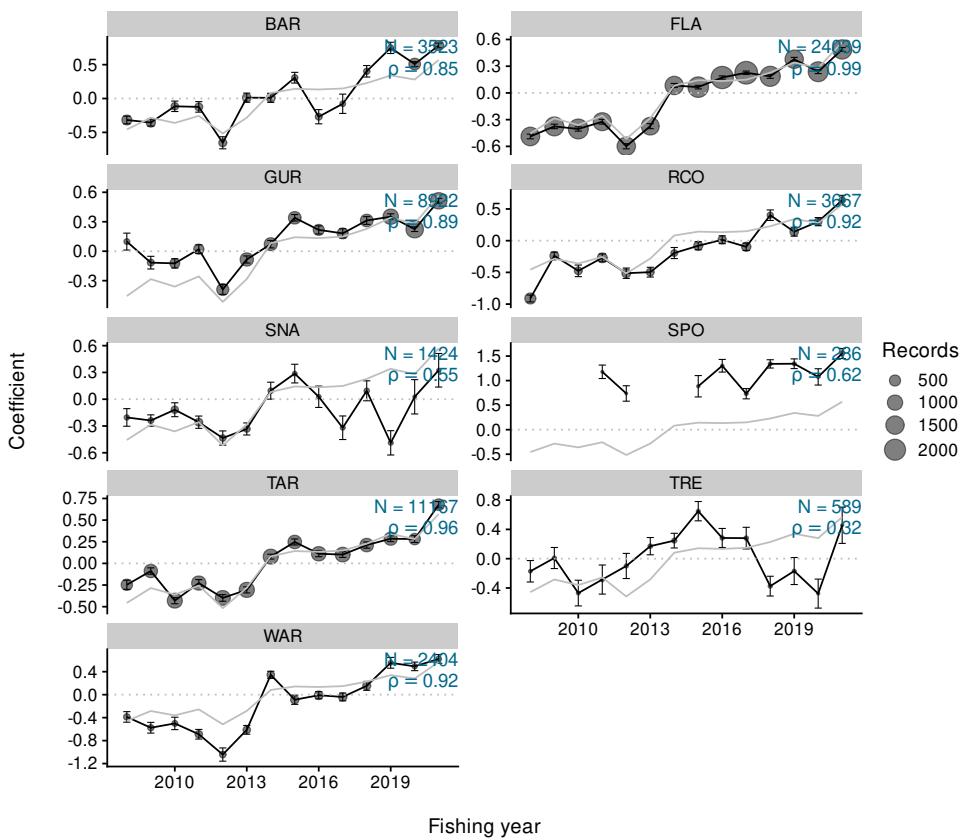


Figure D.112: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 7 BT event dataset.

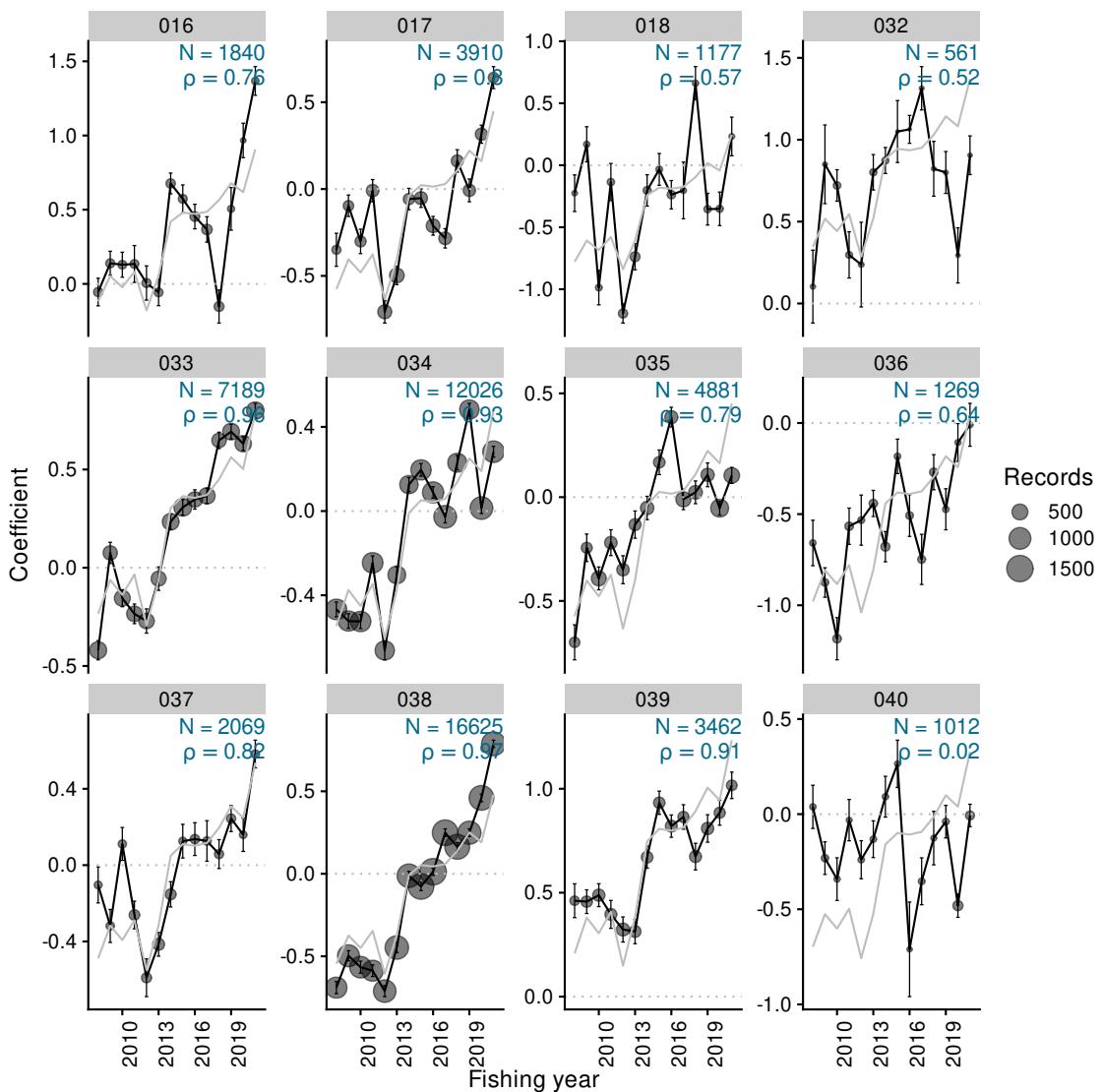


Figure D.113: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 7 BT event dataset.

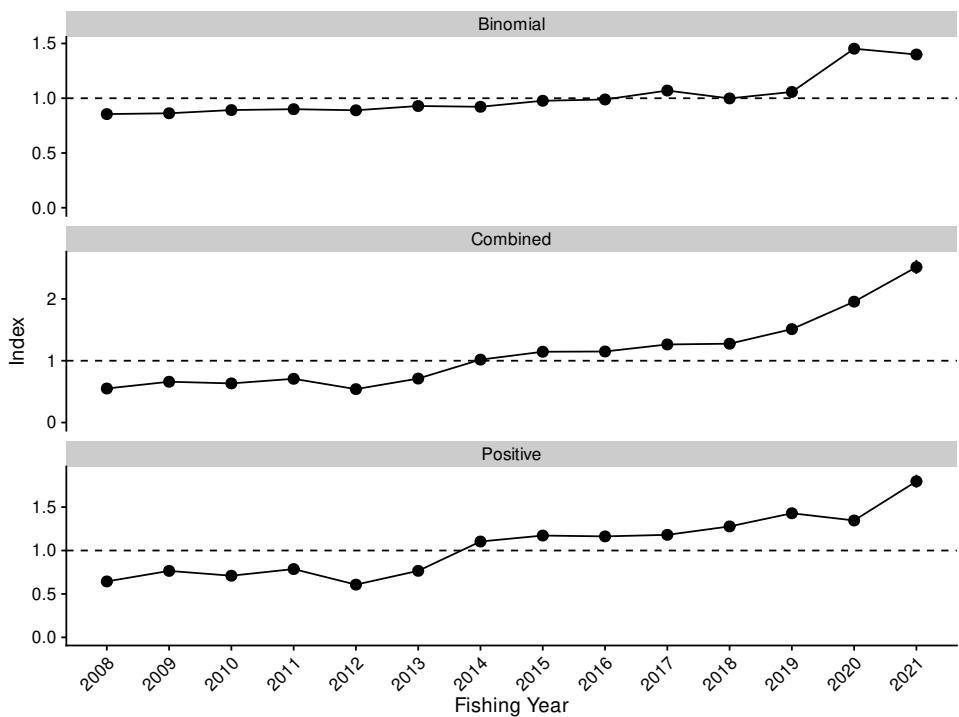


Figure D.114: Standardised indices and 95% confidence intervals for the SPO 7 BT event dataset.

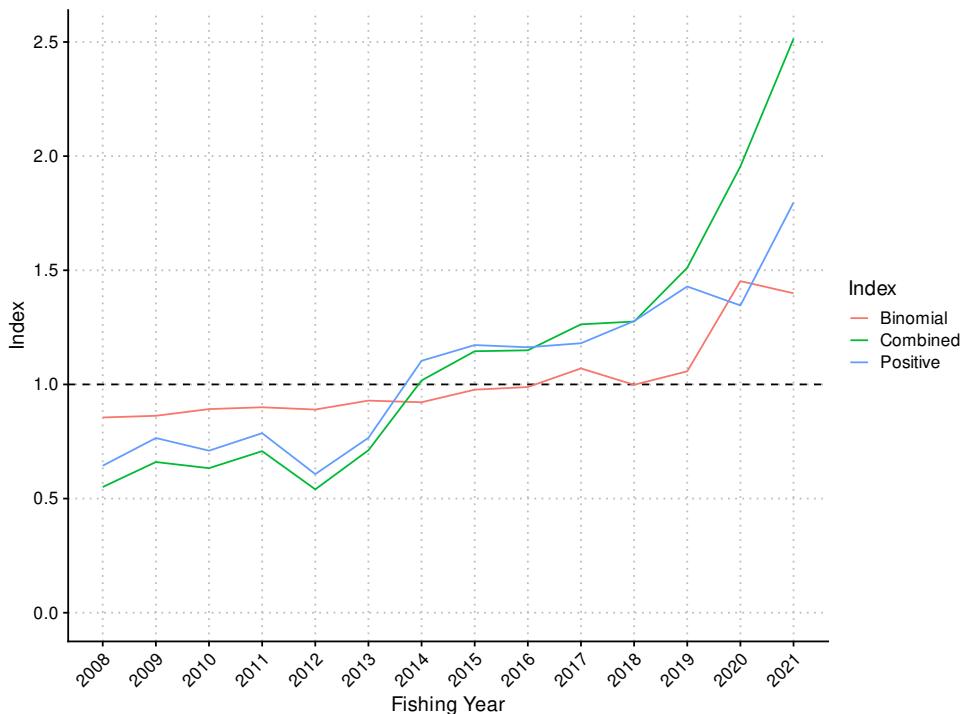


Figure D.115: Standardised indices for the SPO 7 BT event dataset.

Table D.36: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 7 BT event.

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
2008	0.855	0.012	0.832	0.878	0.551	0.015	0.521	0.581	0.644	0.015	0.616	0.673
2009	0.863	0.012	0.839	0.886	0.660	0.017	0.628	0.694	0.765	0.016	0.733	0.798
2010	0.892	0.011	0.870	0.912	0.633	0.015	0.605	0.664	0.710	0.015	0.683	0.741
2011	0.900	0.011	0.878	0.922	0.708	0.018	0.675	0.745	0.786	0.017	0.753	0.820
2012	0.890	0.011	0.868	0.911	0.540	0.012	0.516	0.565	0.607	0.012	0.584	0.631
2013	0.929	0.012	0.906	0.952	0.712	0.016	0.680	0.744	0.766	0.015	0.736	0.795
2014	0.922	0.011	0.900	0.944	1.017	0.023	0.973	1.065	1.104	0.022	1.062	1.148
2015	0.977	0.011	0.955	0.999	1.145	0.026	1.096	1.196	1.172	0.022	1.129	1.216
2016	0.989	0.011	0.966	1.010	1.150	0.025	1.100	1.199	1.163	0.022	1.119	1.206
2017	1.070	0.012	1.047	1.092	1.263	0.027	1.210	1.317	1.180	0.023	1.137	1.227
2018	0.998	0.011	0.977	1.022	1.275	0.029	1.220	1.334	1.277	0.025	1.229	1.327
2019	1.057	0.013	1.033	1.083	1.511	0.036	1.441	1.582	1.429	0.029	1.370	1.485
2020	1.452	0.017	1.417	1.486	1.955	0.045	1.870	2.045	1.346	0.026	1.298	1.398
2021	1.399	0.016	1.368	1.432	2.514	0.058	2.404	2.632	1.797	0.038	1.724	1.873

D.7 SPO 3 SN daily (soak time)

This daily analysis is equivalent to the SPO 3 SN analysis made by the 2019 SPO review (Starr & Kendrick 2020) but which has been superseded by the split analyses for SPO 3 SN(east coast) trip and SPO 3 SN(Foveaux St) trip that are presented in Sections 5.10 and 5.11 respectively. However, the analysis presented here provides the basis upon which the two child analyses have been split away, as well as providing continuity with the 2019 analysis. This analysis also explores the best interpretation of the set net effort data (see Section 3.4) when rolling up event-based data into a day of fishing. The event-based data report each individual net set in a day and it has been determined that it is not appropriate to sum the duration of time that multiple nets were in the water because there will be overlapping times and the potential for exaggerating the time of fishing. This analysis uses a “soak time” variable which is based on the interval of time between the first net was set in a day relative to the time when the last net was pulled. This “soak time” variable returned better model diagnostics when compared to the same model using a summed duration variable or to dropping the duration variable. This model is compared with the alternative “fishing duration” summation procedure in Figure D.162. Figure D.162 also compares this analysis with the 2019 analysis (Starr & Kendrick 2020).

Table D.37: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 3 SN daily (soak time) CPUE series.

Series	SPO 3 SN daily (soak time)
QMS stock	SPO3
Reporting forms	CEL, ERS - Netting, NCE
Fishing methods	SN
Target species	SPO, SCH, SPD, ELE
Statistical Areas	018, 020, 022, 024, 025, 026, 027, 028, 029, 030, 031, 032
Period	1989-10-01, 2021-09-30
Resolution	Day
Core fleet years	5
Core fleet trips	5
Default model	$\text{allockg} \sim \text{fyear} + \text{vessel_key} + \text{stat_area} + \text{month} + \text{target_species} + \text{ns}(\log(\text{soak_time}), 3) + \text{ns}(\log(\text{total_net_length}), 3)$
Stepwise selection	Yes
Positive catch distribution	Lognormal

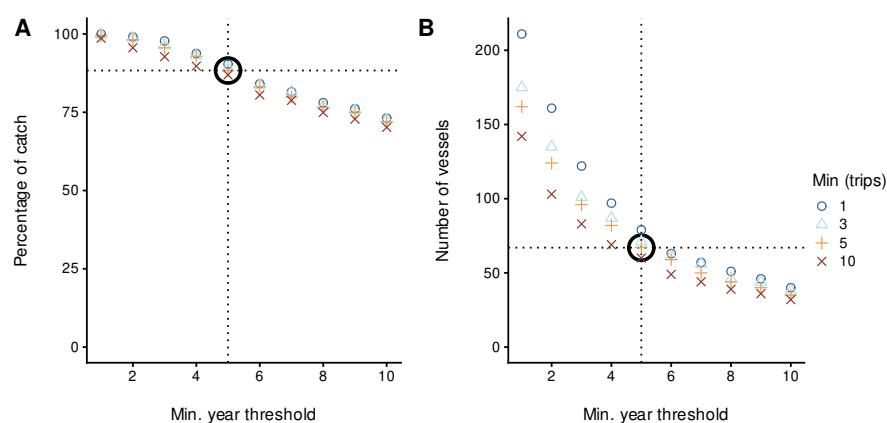


Figure D.116: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 3 SN daily (soak time) CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

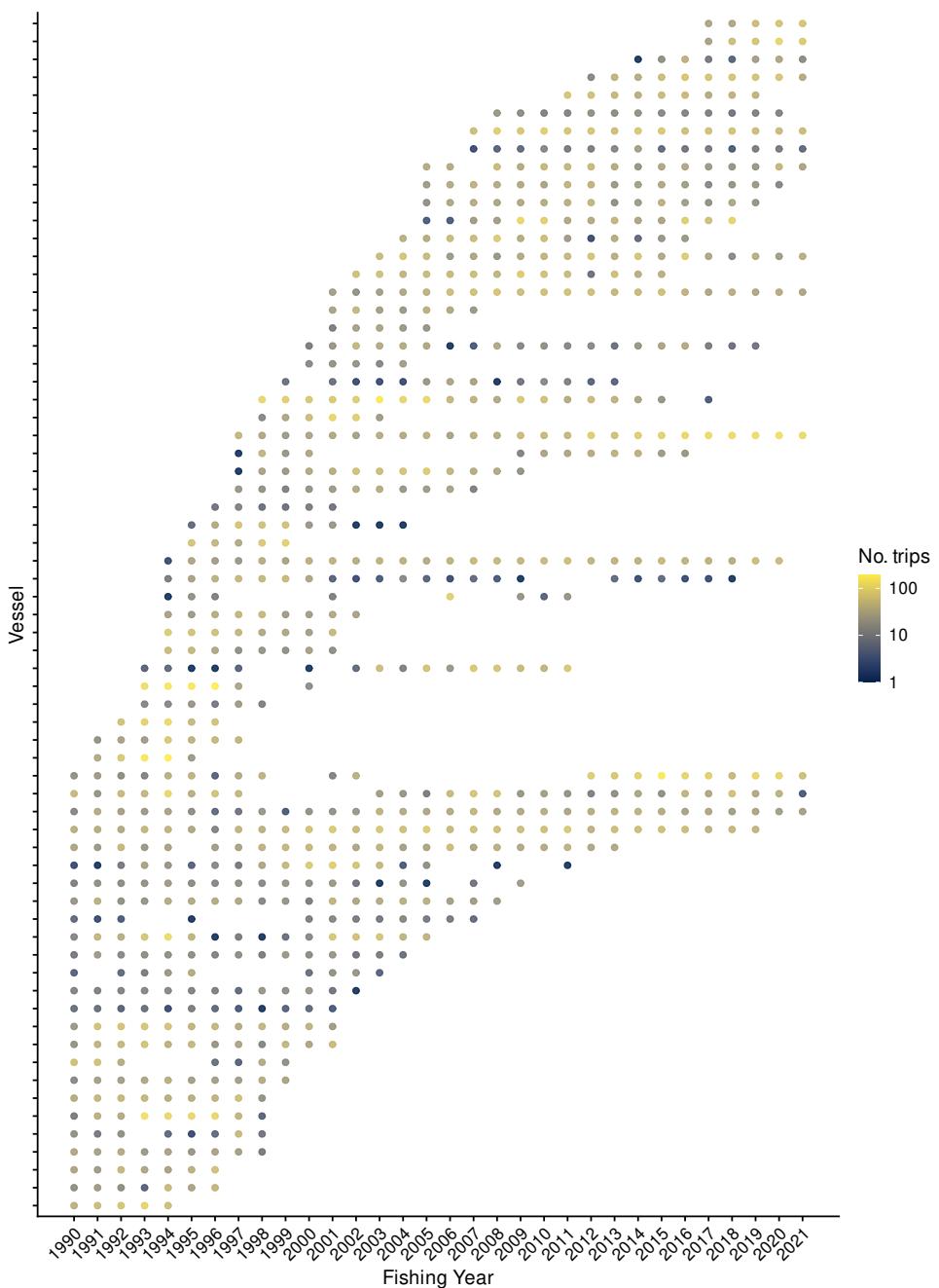


Figure D.117: Number of trips by fishing year for core vessels. The colour of the points is proportional to the number of trips undertaken by a vessel in a fishing year.

Table D.38: Summary of the SPO 3 SN daily (soak time) 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	127 (100%) n: 1336	145 (100%) n: 1805	158 (100%) n: 1801	133 (100%) n: 1955	185 (100%) n: 2304	241 (100%) n: 2069	229 (100%) n: 1803	246 (100%) n: 1495	270 (100%) n: 1447
Positive soak time	127 (100%) n: 1326	145 (100%) n: 1798	158 (100%) n: 1795	130 (100%) n: 1938	184 (100%) n: 2292	240 (100%) n: 2055	222 (100%) n: 1763	242 (100%) n: 1440	254 (94%) n: 1343
Positive net length	127 (100%) n: 1324	145 (100%) n: 1798	158 (100%) n: 1792	130 (100%) n: 1924	180 (100%) n: 2277	239 (100%) n: 2035	218 (100%) n: 1741	238 (100%) n: 1399	241 (89%) n: 1276
Core fleet selection	77 (61%) n: 713	93 (64%) n: 945	93 (59%) n: 1061	78 (59%) n: 1414	148 (80%) n: 1897	185 (77%) n: 1444	174 (76%) n: 1414	199 (81%) n: 1201	222 (82%) n: 1189
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	258 (100%) n: 1327	251 (100%) n: 1262	311 (100%) n: 1718	286 (100%) n: 1438	300 (100%) n: 1651	252 (100%) n: 1330	251 (100%) n: 1356	257 (100%) n: 1259	297 (100%) n: 1383
Positive soak time	228 (88%) n: 1226	233 (93%) n: 1190	301 (100%) n: 1699	285 (100%) n: 1437	300 (100%) n: 1650	252 (100%) n: 1330	251 (100%) n: 1356	257 (100%) n: 1259	297 (100%) n: 1382
Positive net length	213 (83%) n: 1179	217 (87%) n: 1139	294 (95%) n: 1673	285 (100%) n: 1437	300 (100%) n: 1650	252 (100%) n: 1330	251 (100%) n: 1356	257 (100%) n: 1259	297 (100%) n: 1382
Core fleet selection	190 (74%) n: 1080	199 (79%) n: 1003	257 (82%) n: 1261	238 (83%) n: 1089	240 (80%) n: 1182	208 (82%) n: 1018	210 (84%) n: 1200	218 (85%) n: 1100	214 (72%) n: 1183
Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	329 (100%) n: 1408	200 (100%) n: 1287	205 (100%) n: 1271	216 (100%) n: 1286	219 (100%) n: 1308	258 (100%) n: 1287	244 (100%) n: 1329	291 (100%) n: 1423	282 (100%) n: 1462
Positive soak time	329 (100%) n: 1408	200 (100%) n: 1285	205 (100%) n: 1271	216 (100%) n: 1285	219 (100%) n: 1307	258 (100%) n: 1286	244 (100%) n: 1328	291 (100%) n: 1423	282 (100%) n: 1462
Positive net length	329 (100%) n: 1408	200 (100%) n: 1285	205 (100%) n: 1271	216 (100%) n: 1285	219 (100%) n: 1307	258 (100%) n: 1286	244 (100%) n: 1328	291 (100%) n: 1423	282 (100%) n: 1462
Core fleet selection	275 (83%) n: 1298	197 (100%) n: 1273	204 (100%) n: 1266	215 (100%) n: 1278	192 (88%) n: 1197	251 (100%) n: 1258	244 (100%) n: 1327	290 (100%) n: 1414	260 (92%) n: 1366

Filter	2017	2018	2019	2020	2021
Ungroomed data	265 (100%) n: 1231	292 (100%) n: 1134	312 (100%) n: 1181	381 (100%) n: 1208	320 (100%) n: 927
Positive soak time	265 (100%) n: 1231	292 (100%) n: 1133	312 (100%) n: 1181	381 (100%) n: 1208	320 (100%) n: 927
Positive net length	265 (100%) n: 1231	292 (100%) n: 1133	312 (100%) n: 1181	381 (100%) n: 1208	320 (100%) n: 927
Core fleet selection	265 (100%) n: 1231	292 (100%) n: 1133	312 (100%) n: 1181	379 (100%) n: 1204	319 (100%) n: 925

Table D.39: Summary of the SPO 3 SN daily (soak time) 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 rig.

Fishing year	Vessels	Trips	Records	Net length (km)	Catch (t)	Records caught
1990	25	530	713	1527.68	77.12	53.58
1991	26	767	945	1785.72	93.09	53.44
1992	28	918	1061	2007.23	93.01	62.30
1993	28	1293	1414	2357.00	78.27	60.75
1994	35	1751	1897	3375.38	147.52	64.36
1995	36	1269	1444	2596.02	185.00	74.93
1996	36	1234	1414	2584.54	174.04	68.18
1997	36	1021	1201	1951.64	199.00	67.86
1998	34	1013	1189	1902.63	222.08	72.33
1999	29	894	1080	1882.70	190.26	73.24
2000	31	855	1003	1937.55	198.79	79.26
2001	34	1105	1261	2530.98	256.61	82.08
2002	29	976	1089	2185.85	238.25	81.36
2003	28	1054	1182	2516.34	239.79	81.05
2004	27	860	1018	2145.79	207.83	83.01
2005	28	1016	1200	2530.72	210.49	84.08
2006	25	911	1100	2267.50	217.86	83.64
2007	26	949	1183	2166.91	214.47	85.55
2008	25	988	1298	2582.95	274.78	82.20
2009	26	1003	1273	2455.11	196.93	74.00
2010	23	1003	1266	2517.83	204.25	74.09
2011	25	995	1278	2671.42	214.72	76.13
2012	24	948	1197	2633.75	191.98	78.53
2013	25	926	1258	2954.66	251.45	79.89
2014	24	926	1327	3045.66	244.46	74.98
2015	24	1028	1414	3075.55	290.34	79.92
2016	22	1028	1366	3007.66	259.81	78.04
2017	23	820	1231	2950.08	264.62	88.30
2018	22	873	1133	2689.97	291.81	88.26
2019	20	892	1181	2651.22	312.43	82.30
2020	16	860	1204	2857.54	378.91	85.71
2021	13	583	925	2481.55	319.21	85.73

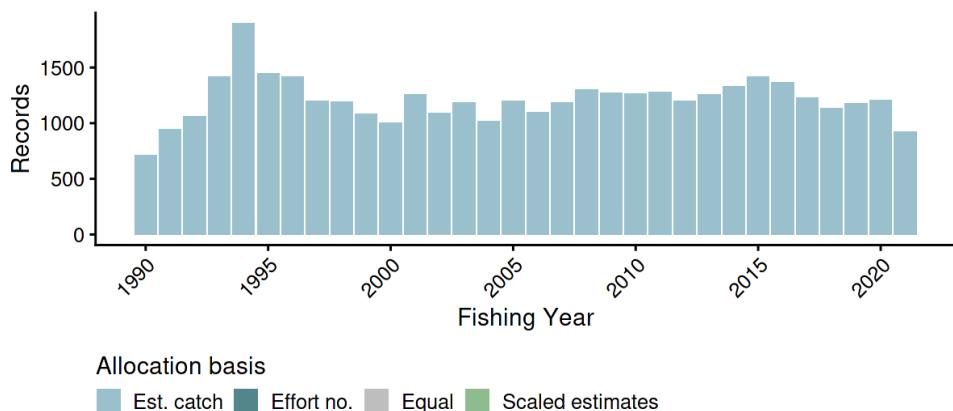


Figure D.118: Allocation basis for attributing landings to records in the SPO 3 SN daily (soak time) catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table D.40: 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	30.00	40 971	3.70	3.70	*
+ vessel_key	66.00	36 096	15.50	11.80	*
+ target_species	3.00	33 676	21.20	5.70	*
+ month	11.00	32 290	24.50	3.30	*
+ stat_area	11.00	32 171	24.90	0.30	
+ ns(log(total_net_length), 3)	3.00	32 057	25.10	0.30	
+ ns(log(soak_time), 3)	3.00	32 001	25.30	0.10	

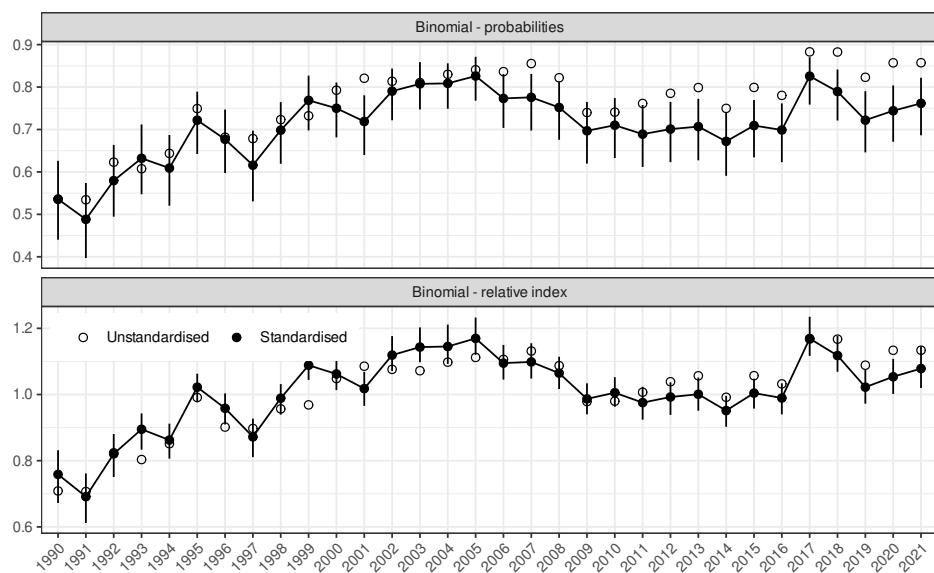


Figure D.119: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 3 SN daily (soak time) dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

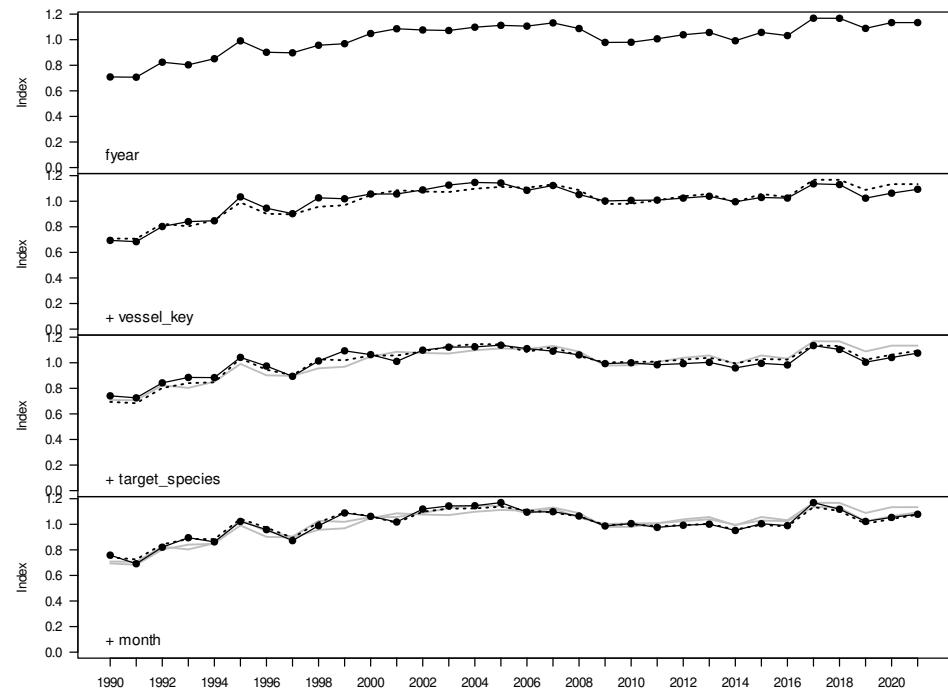


Figure D.120: Step plot for occurrence of catch in the SPO 3 SN daily (soak time) dataset.

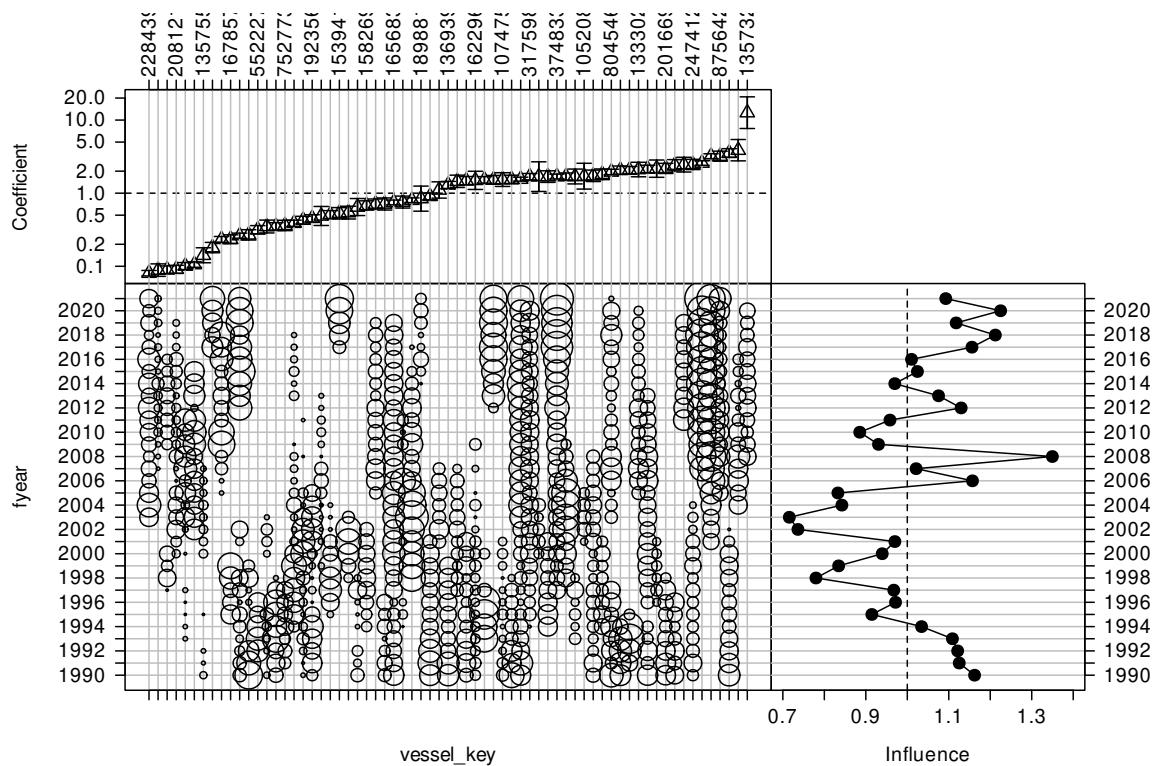


Figure D.121: CDI plot for vessel key for the occurrence of positive catch SPO 3 SN daily (soak time) catch-per-unit-effort dataset.

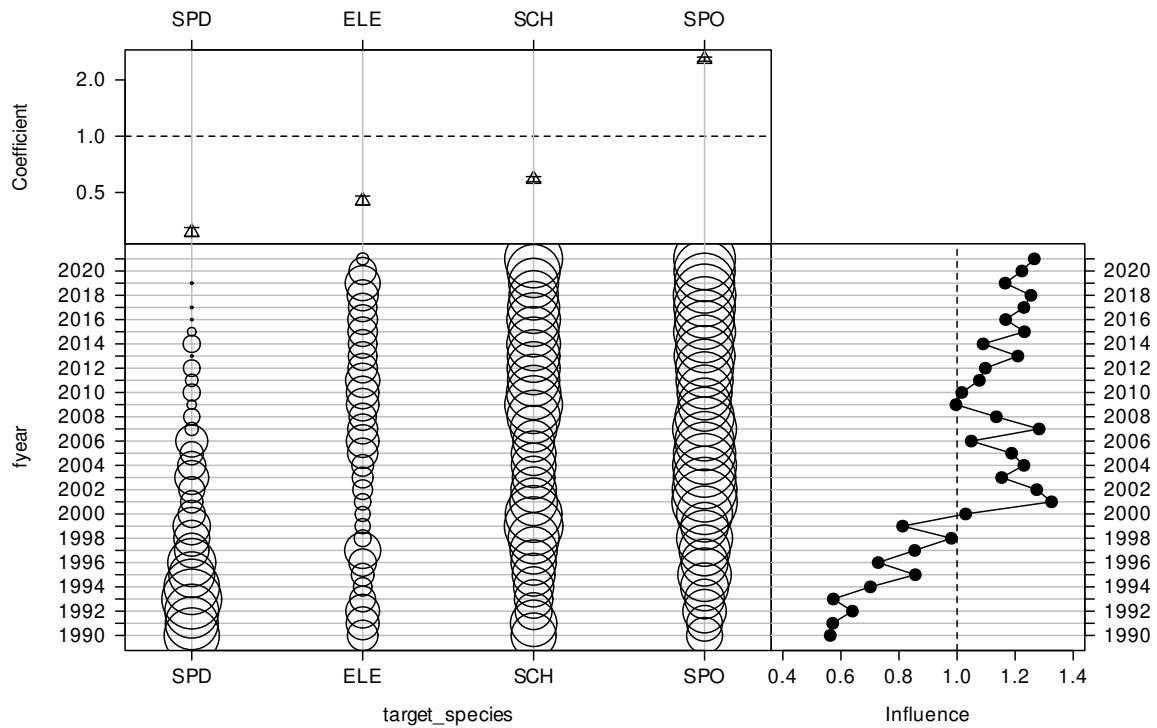


Figure D.122: CDI plot for target species for the occurrence of positive catch SPO 3 SN daily (soak time) catch-per-unit-effort dataset.

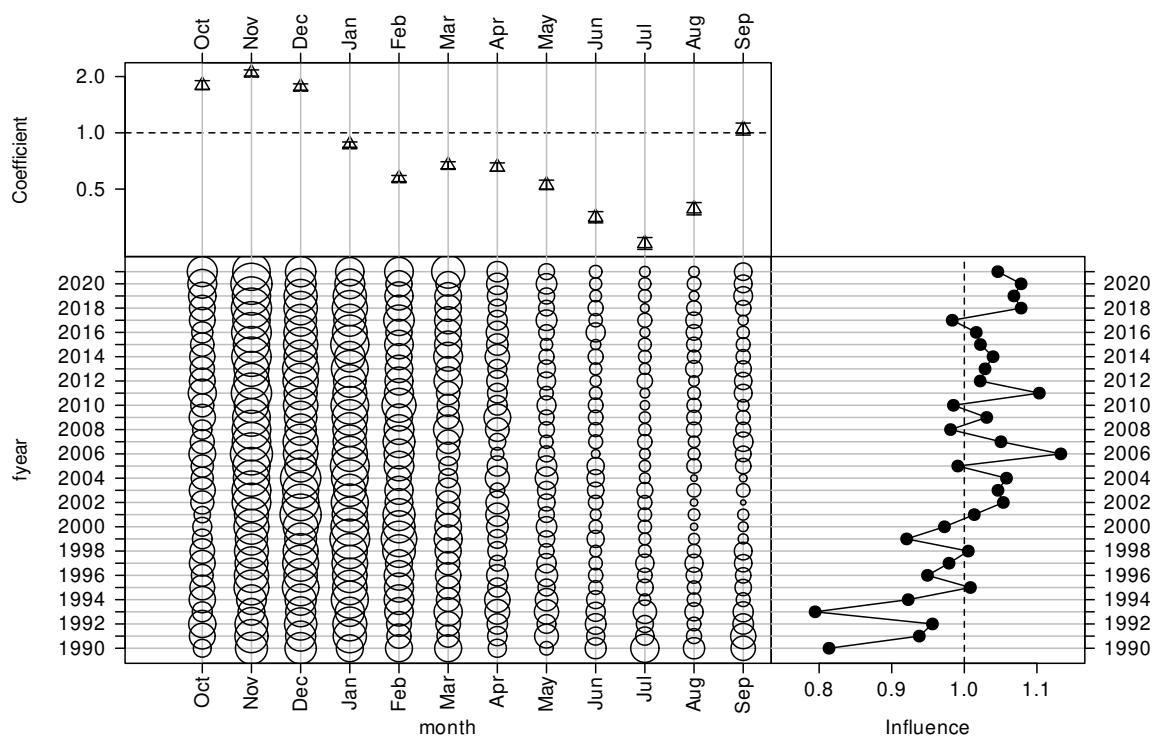


Figure D.123: CDI plot for month for the occurrence of positive catch SPO 3 SN daily (soak time) catch-per-unit-effort dataset.

Table D.41: 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	30	106621	5.5	5.5	*
+ vessel key	66	99051	27.2	21.7	*
+ target species	3	95470	35.5	8.3	*
+ month	11	93290	40.1	4.6	*
+ ns(log(soak time), 3)	3	92758	41.2	1.1	*
+ stat area	11	92323	42.1	0.9	
+ ns(log(total net length), 3)	3	92010	42.7	0.6	

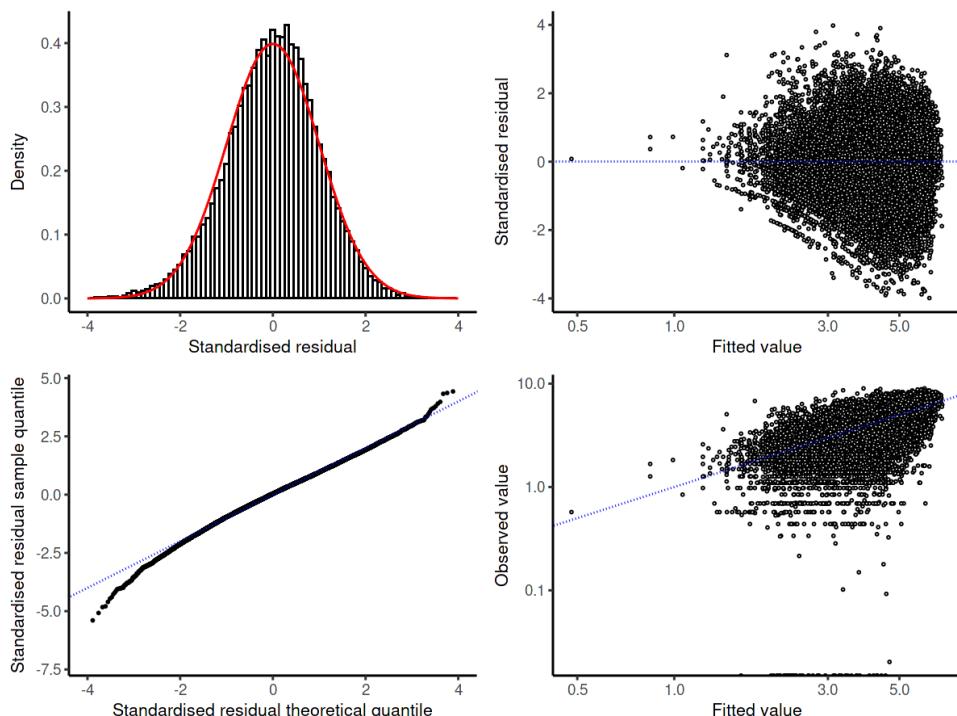


Figure D.124: Diagnostic plots for the lognormal model for the SPO 3 SN daily (soak time) dataset.

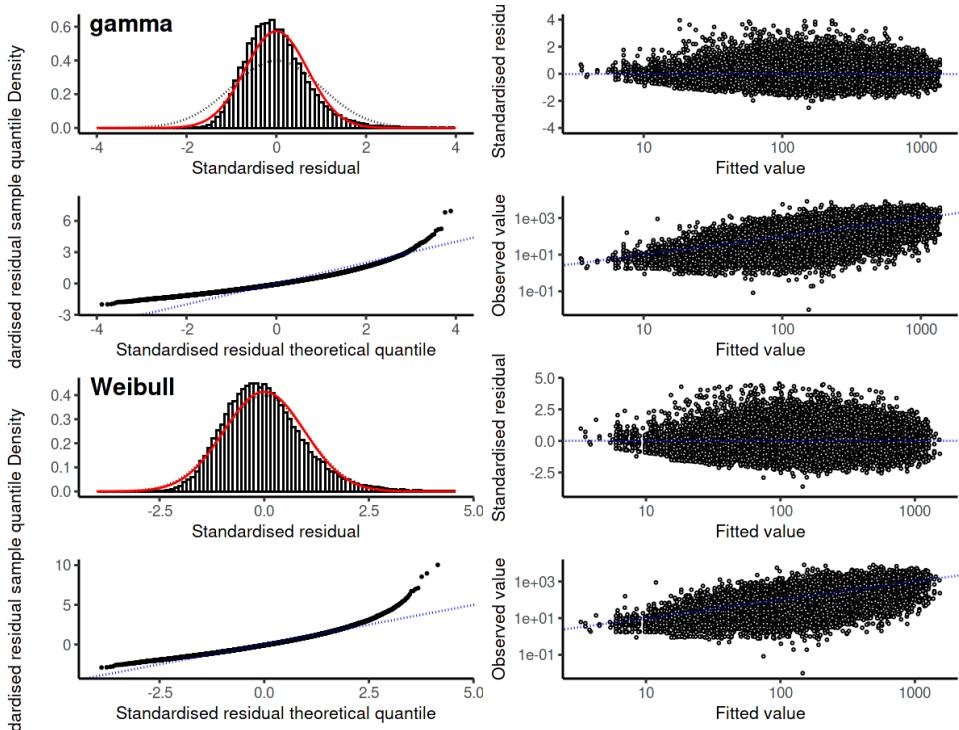


Figure D.125: Diagnostic plots for the gamma and Weibull model for the SPO 3 SN daily (soak time) dataset.

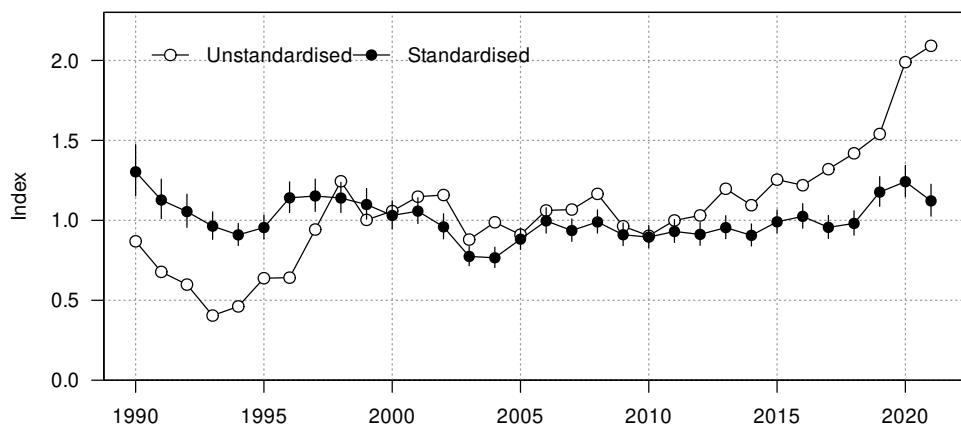


Figure D.126: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 3 SN daily (soak time) dataset.

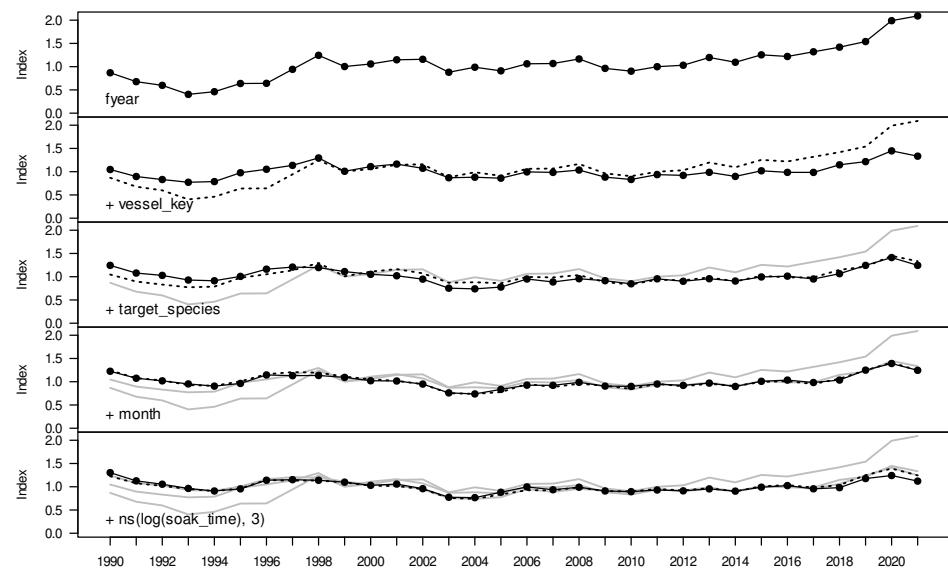


Figure D.127: Changes to the SPO 3 SN daily (soak time) positive catch index as terms are successively entered into the model.

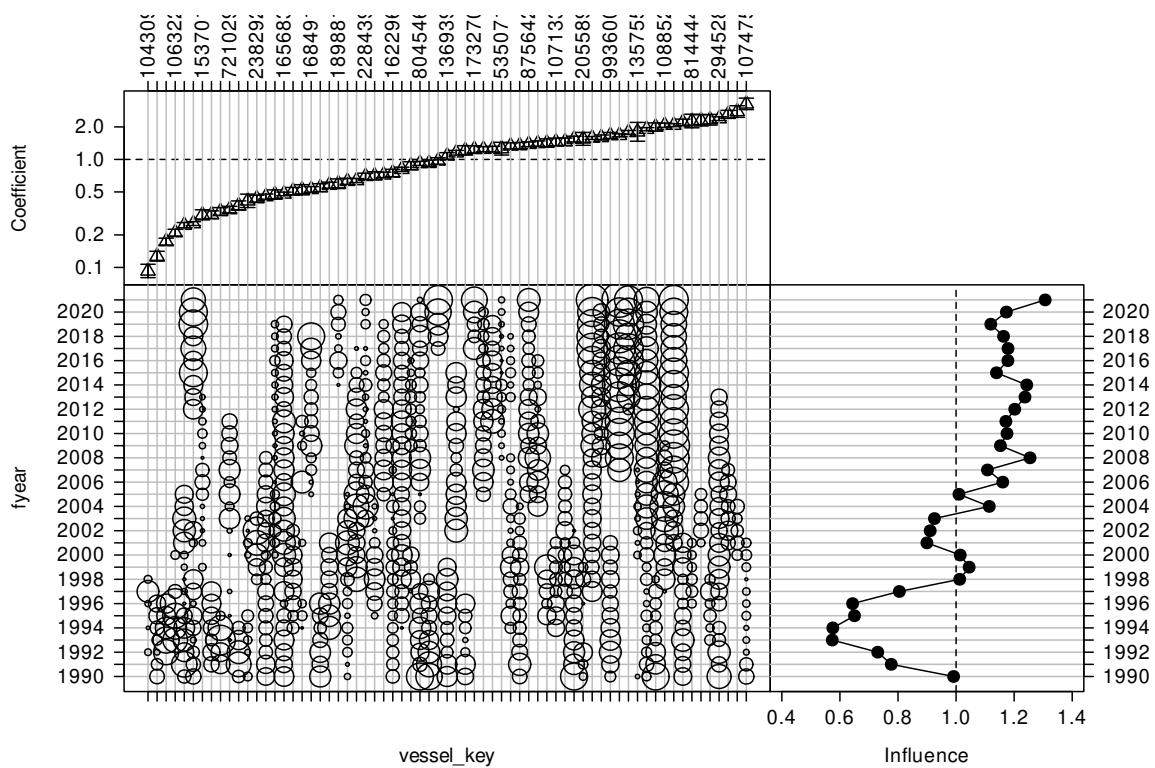


Figure D.128: CDI plot for vessel key for the positive catch SPO 3 SN daily (soak time) catch-per-unit-effort dataset.

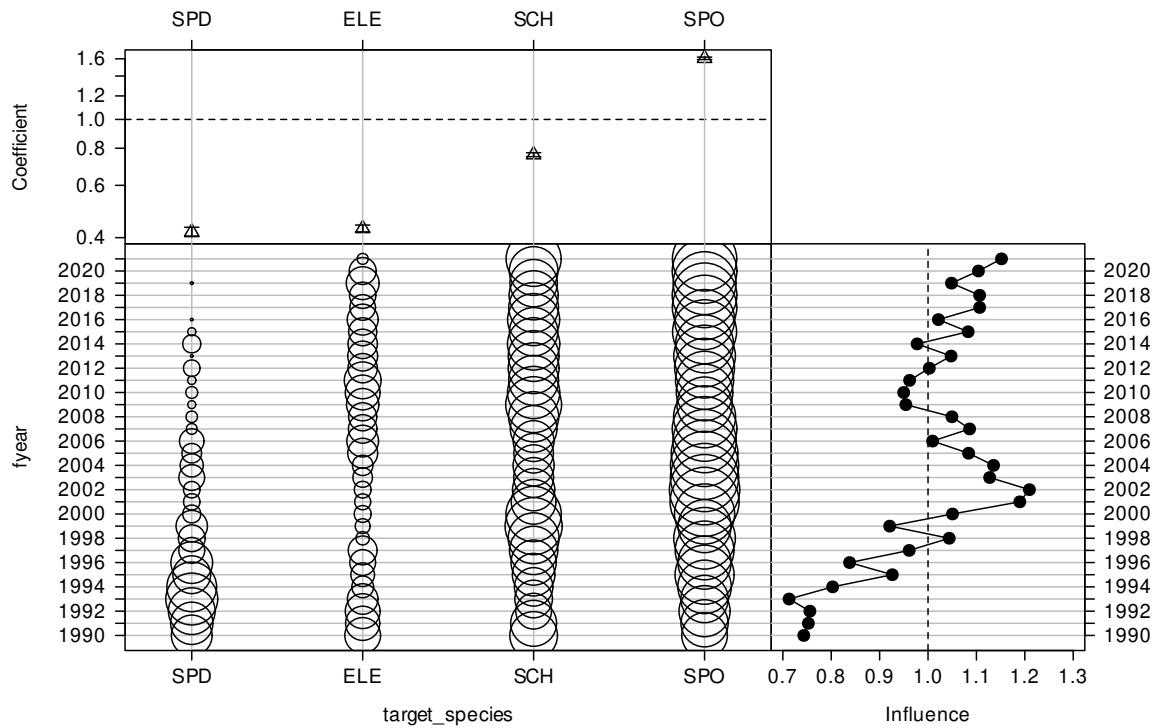


Figure D.129: CDI plot for target species for the positive catch SPO 3 SN daily (soak time) catch-per-unit-effort dataset.

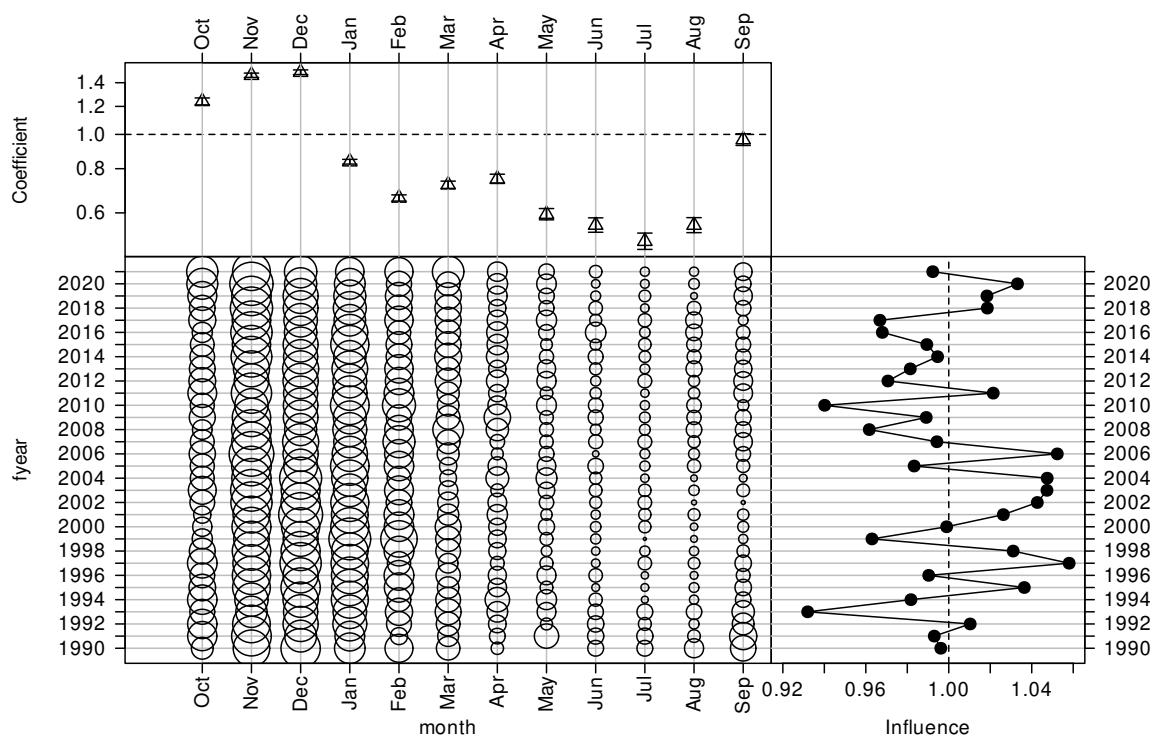


Figure D.130: CDI plot for month for the positive catch SPO 3 SN daily (soak time) catch-per-unit-effort dataset.

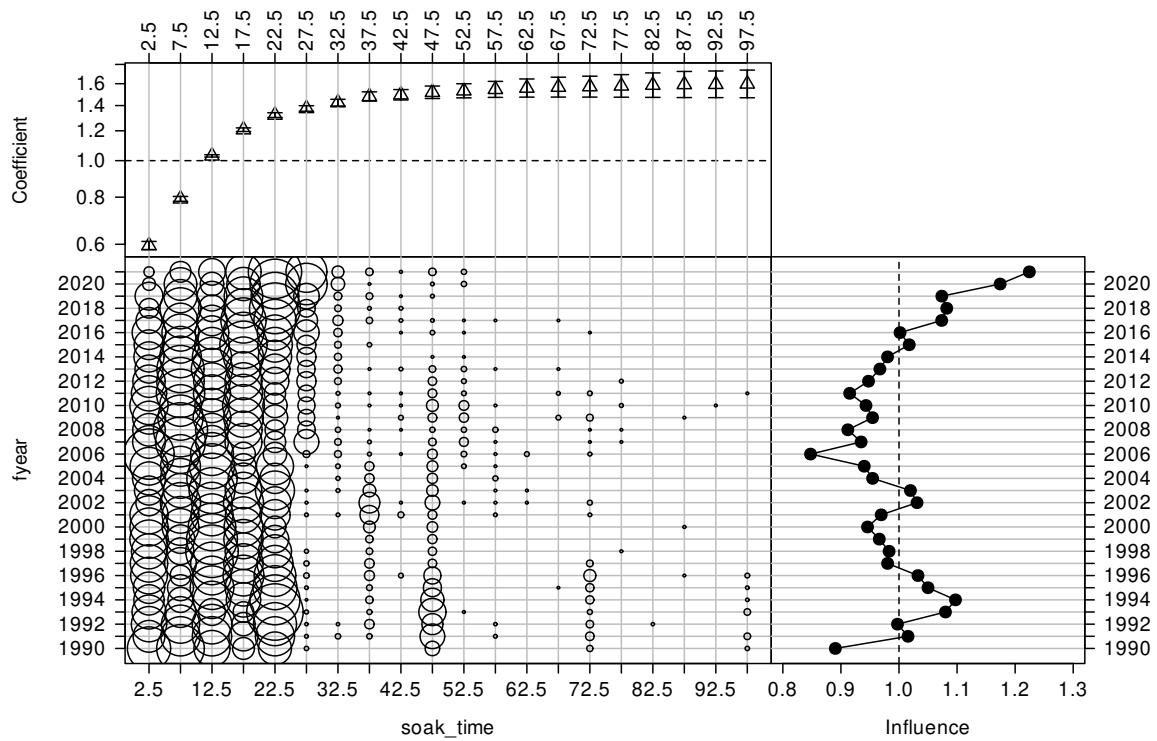


Figure D.131: CDI plot for soak time for the positive catch SPO 3 SN daily (soak time) catch-per-unit-effort dataset.

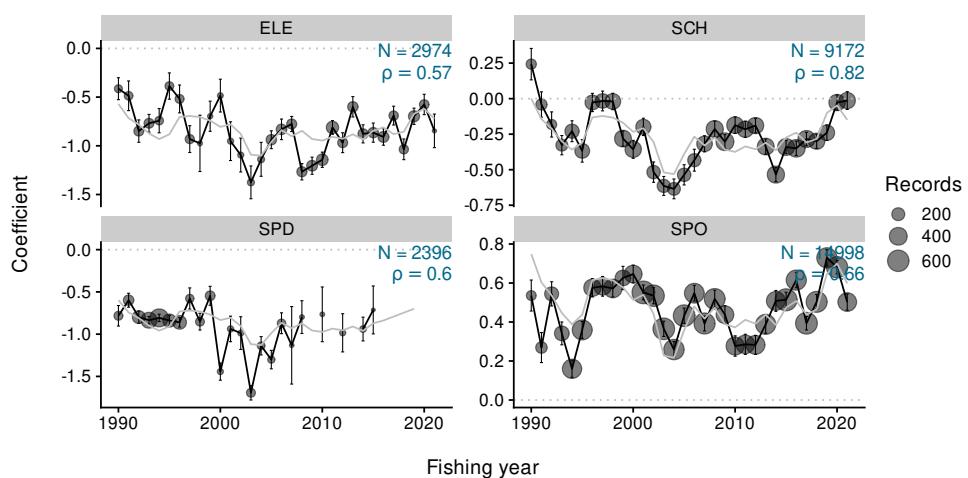


Figure D.132: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 3 SN daily (soak time) dataset.

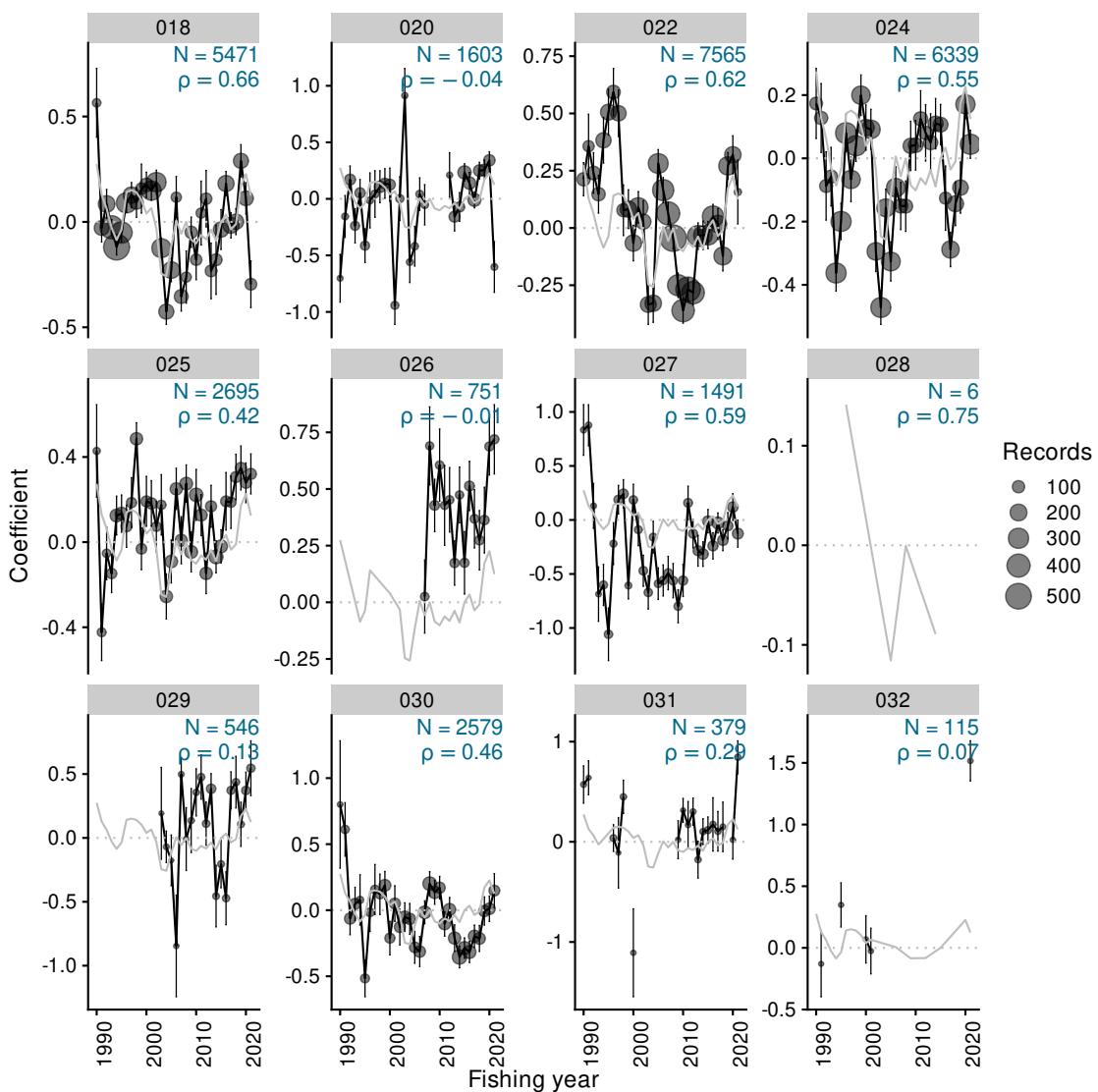


Figure D.133: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 3 SN daily (soak time) dataset.

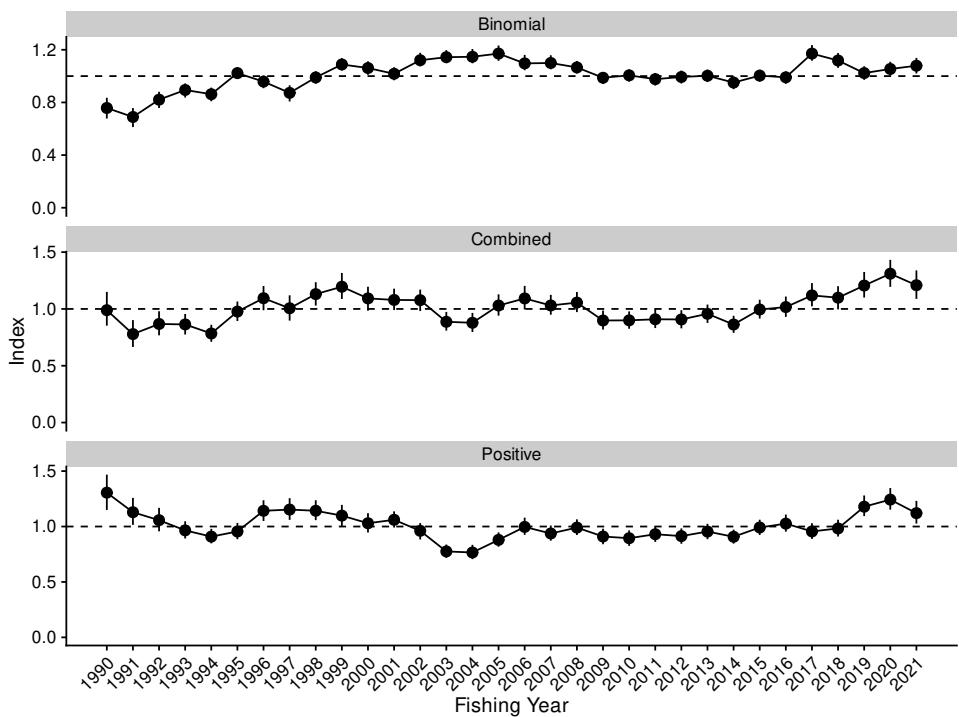


Figure D.134: Standardised indices and 95% confidence intervals for the SPO 3 SN daily (soak time) dataset.

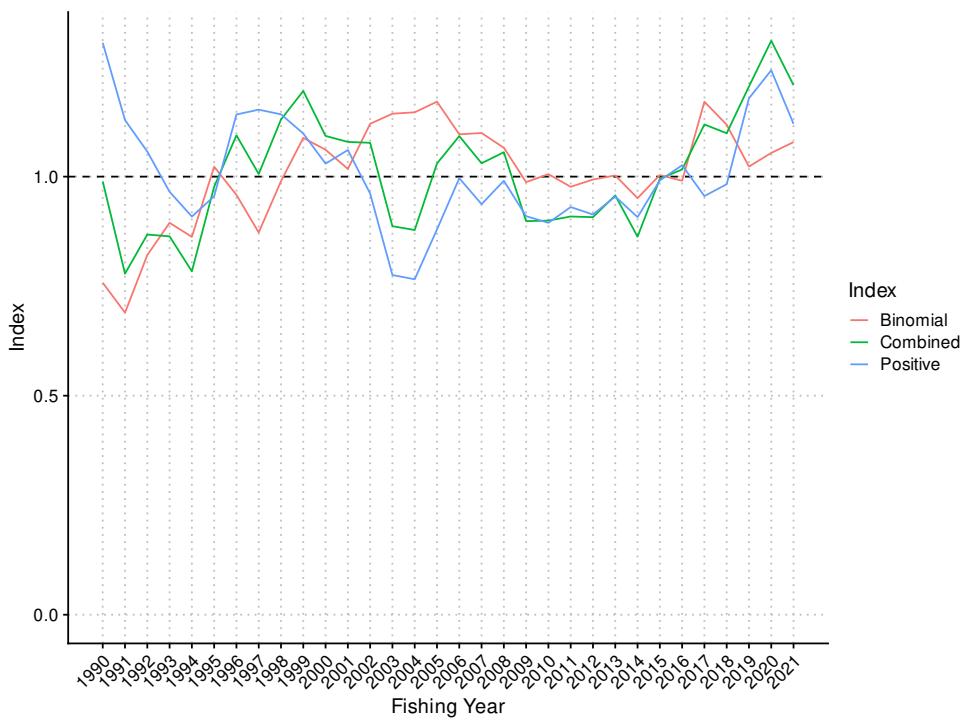


Figure D.135: Standardised indices for the SPO 3 SN daily (soak time) dataset.

Table D.42: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 3 SN daily (soak time).

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.758	0.040	0.678	0.836	0.989	0.076	0.853	1.150	1.305	0.081	1.150	1.468
1991	0.689	0.037	0.613	0.757	0.778	0.060	0.665	0.902	1.129	0.062	1.015	1.258
1992	0.821	0.031	0.758	0.881	0.868	0.054	0.768	0.980	1.057	0.054	0.957	1.168
1993	0.895	0.027	0.837	0.944	0.864	0.046	0.775	0.956	0.965	0.039	0.892	1.047
1994	0.862	0.026	0.809	0.913	0.784	0.038	0.711	0.860	0.909	0.033	0.848	0.979
1995	1.023	0.023	0.977	1.067	0.977	0.044	0.894	1.065	0.955	0.037	0.886	1.032
1996	0.958	0.025	0.908	1.004	1.094	0.054	0.988	1.202	1.142	0.048	1.050	1.237
1997	0.873	0.031	0.807	0.930	1.006	0.057	0.897	1.120	1.153	0.050	1.060	1.256
1998	0.990	0.024	0.942	1.037	1.130	0.053	1.030	1.235	1.142	0.046	1.057	1.237
1999	1.088	0.024	1.042	1.136	1.195	0.058	1.088	1.317	1.098	0.048	1.006	1.195
2000	1.061	0.026	1.010	1.112	1.093	0.054	0.985	1.195	1.030	0.044	0.947	1.121
2001	1.017	0.025	0.968	1.067	1.079	0.048	0.990	1.178	1.061	0.037	0.991	1.137
2002	1.121	0.026	1.074	1.177	1.077	0.048	0.982	1.170	0.961	0.038	0.883	1.031
2003	1.144	0.025	1.098	1.197	0.887	0.042	0.809	0.974	0.775	0.031	0.717	0.838
2004	1.147	0.028	1.097	1.206	0.878	0.043	0.797	0.965	0.766	0.033	0.706	0.835
2005	1.171	0.030	1.116	1.232	1.030	0.048	0.941	1.128	0.880	0.033	0.818	0.947
2006	1.097	0.030	1.044	1.161	1.093	0.053	0.995	1.203	0.996	0.040	0.925	1.080
2007	1.100	0.027	1.051	1.158	1.030	0.044	0.949	1.124	0.937	0.035	0.872	1.009
2008	1.066	0.024	1.019	1.115	1.056	0.045	0.972	1.149	0.990	0.036	0.923	1.065
2009	0.987	0.023	0.940	1.030	0.898	0.043	0.818	0.986	0.910	0.036	0.840	0.980
2010	1.006	0.024	0.957	1.051	0.900	0.039	0.826	0.978	0.895	0.035	0.826	0.965
2011	0.977	0.024	0.928	1.024	0.909	0.043	0.832	1.001	0.931	0.035	0.861	1.000
2012	0.993	0.025	0.944	1.042	0.907	0.041	0.829	0.989	0.914	0.035	0.844	0.983
2013	1.003	0.024	0.955	1.049	0.957	0.041	0.877	1.038	0.955	0.035	0.886	1.025
2014	0.951	0.025	0.901	0.998	0.863	0.038	0.789	0.939	0.908	0.032	0.846	0.972
2015	1.004	0.023	0.958	1.049	0.995	0.042	0.916	1.081	0.991	0.035	0.924	1.062
2016	0.991	0.024	0.942	1.037	1.016	0.046	0.930	1.109	1.026	0.039	0.954	1.108
2017	1.171	0.030	1.117	1.236	1.119	0.052	1.023	1.227	0.956	0.036	0.889	1.029
2018	1.118	0.029	1.063	1.175	1.099	0.052	0.996	1.200	0.983	0.039	0.910	1.061
2019	1.023	0.026	0.971	1.075	1.206	0.057	1.100	1.325	1.179	0.047	1.094	1.280
2020	1.054	0.027	1.003	1.109	1.310	0.061	1.194	1.432	1.243	0.050	1.152	1.347
2021	1.079	0.030	1.020	1.138	1.209	0.064	1.089	1.339	1.120	0.052	1.027	1.231

D.8 SPO 3 SN daily (fishing duration)

This is an alternative analysis for the SPO 3 SN daily data which explores another interpretation of the set net effort data (see Section 3.4) when rolling up time fished to represent a day of fishing. In this case, the duration of time that multiple nets were in the water is summed when amalgamating this variable into a daily event. This model is compared with the “soak time” alternative interpretation in Figure D.162.

Table D.43: Definition for the dataset, core fleet criteria, and Generalised Linear Modelling approach used in the catch-per-unit-effort (CPUE) standardisation for the SPO 3 SN daily (fishing duration) CPUE series.

Series	SPO 3 SN daily (fishing duration)
QMS stock	SPO3
Reporting forms	CEL, ERS - Netting, NCE
Fishing methods	SN
Target species	SPO, SCH, SPD, ELE
Statistical Areas	018, 020, 022, 024, 025, 026, 027, 028, 029, 030, 031, 032
Period	1989-10-01, 2021-09-30
Resolution	Day
Core fleet years	5
Core fleet trips	5
Default model	allockg ~ fyyear + vessel_key + stat_area + month + target_species + ns(log(fishing_duration), 3) + ns(log(total_net_length), 3)
Stepwise selection	Yes
Positive catch distribution	Lognormal

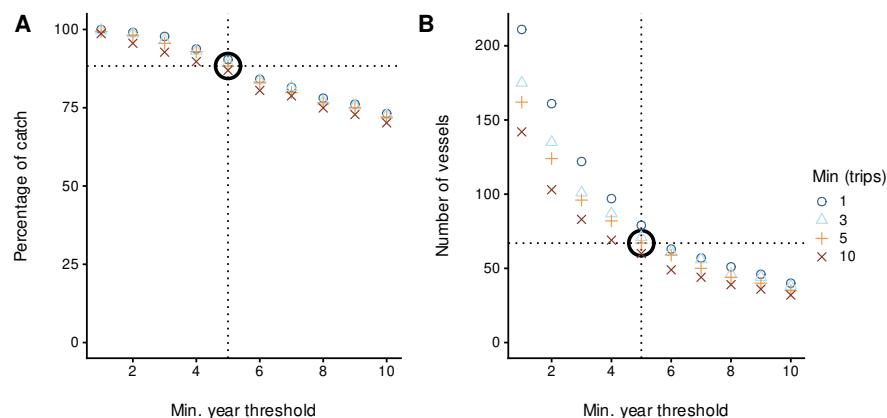


Figure D.136: Percentage of catch and number of vessels for different core vessel selection criteria for the SPO 3 SN daily (fishing duration) CPUE series. The bold open circle represents the core vessel selection criteria applied in the modelling dataset, specified by the number of years a vessel participated in the fishery and the number of trips per year.

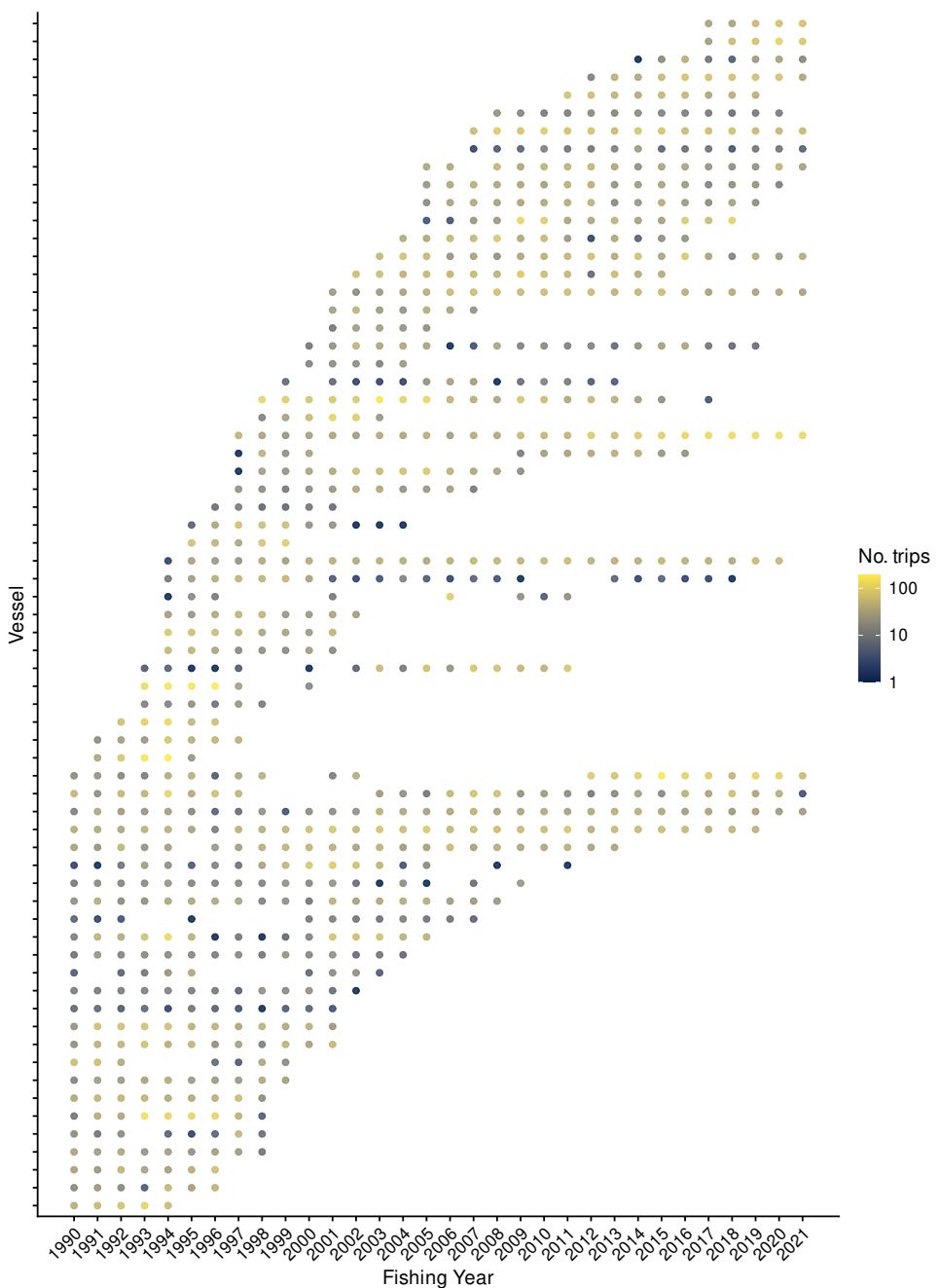


Figure D.137: Number of trips by fishing year for core vessels. The colour of the points is proportional to the number of trips undertaken by a vessel in a fishing year.

Table D.44: Summary of the SPO 3 SN daily (fishing duration) 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	127 (100%) n: 1336	145 (100%) n: 1805	158 (100%) n: 1801	133 (100%) n: 1955	185 (100%) n: 2304	241 (100%) n: 2069	229 (100%) n: 1803	246 (100%) n: 1495	270 (100%) n: 1447
Positive fishing duration	127 (100%) n: 1326	145 (100%) n: 1798	158 (100%) n: 1795	130 (100%) n: 1938	184 (100%) n: 2292	240 (100%) n: 2055	222 (100%) n: 1763	242 (100%) n: 1440	254 (94%) n: 1343
Positive net length	127 (100%) n: 1324	145 (100%) n: 1798	158 (100%) n: 1792	130 (100%) n: 1924	180 (100%) n: 2277	239 (100%) n: 2035	218 (100%) n: 1741	238 (100%) n: 1399	241 (89%) n: 1276
Core fleet selection	77 (61%) n: 713	93 (64%) n: 945	93 (59%) n: 1061	78 (59%) n: 1414	148 (80%) n: 1897	185 (77%) n: 1444	174 (76%) n: 1414	199 (81%) n: 1201	222 (82%) n: 1189
Filter	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ungroomed data	258 (100%) n: 1327	251 (100%) n: 1262	311 (100%) n: 1718	286 (100%) n: 1438	300 (100%) n: 1651	252 (100%) n: 1330	251 (100%) n: 1356	257 (100%) n: 1259	297 (100%) n: 1383
Positive fishing duration	228 (88%) n: 1226	233 (93%) n: 1190	301 (100%) n: 1699	285 (100%) n: 1437	300 (100%) n: 1650	252 (100%) n: 1330	251 (100%) n: 1356	257 (100%) n: 1259	297 (100%) n: 1382
Positive net length	213 (83%) n: 1179	217 (87%) n: 1139	294 (95%) n: 1673	285 (100%) n: 1437	300 (100%) n: 1650	252 (100%) n: 1330	251 (100%) n: 1356	257 (100%) n: 1259	297 (100%) n: 1382
Core fleet selection	190 (74%) n: 1080	199 (79%) n: 1003	257 (82%) n: 1261	238 (83%) n: 1089	240 (80%) n: 1182	208 (82%) n: 1018	210 (84%) n: 1200	218 (85%) n: 1100	214 (72%) n: 1183
Filter	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ungroomed data	329 (100%) n: 1408	200 (100%) n: 1287	205 (100%) n: 1271	216 (100%) n: 1286	219 (100%) n: 1308	258 (100%) n: 1287	244 (100%) n: 1329	291 (100%) n: 1423	282 (100%) n: 1462
Positive fishing duration	329 (100%) n: 1408	200 (100%) n: 1285	205 (100%) n: 1271	216 (100%) n: 1285	219 (100%) n: 1307	258 (100%) n: 1286	244 (100%) n: 1328	291 (100%) n: 1423	282 (100%) n: 1462
Positive net length	329 (100%) n: 1408	200 (100%) n: 1285	205 (100%) n: 1271	216 (100%) n: 1285	219 (100%) n: 1307	258 (100%) n: 1286	244 (100%) n: 1328	291 (100%) n: 1423	282 (100%) n: 1462
Core fleet selection	275 (83%) n: 1298	197 (100%) n: 1273	204 (100%) n: 1266	215 (100%) n: 1278	192 (88%) n: 1197	251 (100%) n: 1258	244 (100%) n: 1327	290 (100%) n: 1414	260 (92%) n: 1366

Filter	2017	2018	2019	2020	2021
Ungroomed data	265 (100%) n: 1231	292 (100%) n: 1134	312 (100%) n: 1181	381 (100%) n: 1208	320 (100%) n: 927
Positive fishing duration	265 (100%) n: 1231	292 (100%) n: 1133	312 (100%) n: 1181	381 (100%) n: 1207	320 (100%) n: 927
Positive net length	265 (100%) n: 1231	292 (100%) n: 1133	312 (100%) n: 1181	381 (100%) n: 1207	320 (100%) n: 927
Core fleet selection	265 (100%) n: 1231	292 (100%) n: 1133	312 (100%) n: 1181	379 (100%) n: 1203	319 (100%) n: 925

Table D.45: Summary of the SPO 3 SN daily (fishing duration) 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 rig.

Fishing year	Vessels	Trips	Records	Net length (km)	Catch (t)	Records caught
1990	25	530	713	1527.68	77.12	53.58
1991	26	767	945	1785.72	93.09	53.44
1992	28	918	1061	2007.23	93.01	62.30
1993	28	1293	1414	2357.00	78.27	60.75
1994	35	1751	1897	3375.38	147.52	64.36
1995	36	1269	1444	2596.02	185.00	74.93
1996	36	1234	1414	2584.54	174.04	68.18
1997	36	1021	1201	1951.64	199.00	67.86
1998	34	1013	1189	1902.63	222.08	72.33
1999	29	894	1080	1882.70	190.26	73.24
2000	31	855	1003	1937.55	198.79	79.26
2001	34	1105	1261	2530.98	256.61	82.08
2002	29	976	1089	2185.85	238.25	81.36
2003	28	1054	1182	2516.34	239.79	81.05
2004	27	860	1018	2145.79	207.83	83.01
2005	28	1016	1200	2530.72	210.49	84.08
2006	25	911	1100	2267.50	217.86	83.64
2007	26	949	1183	2166.91	214.47	85.55
2008	25	988	1298	2582.95	274.78	82.20
2009	26	1003	1273	2455.11	196.93	74.00
2010	23	1003	1266	2517.83	204.25	74.09
2011	25	995	1278	2671.42	214.72	76.13
2012	24	948	1197	2633.75	191.98	78.53
2013	25	926	1258	2954.66	251.45	79.89
2014	24	926	1327	3045.66	244.46	74.98
2015	24	1028	1414	3075.55	290.34	79.92
2016	22	1028	1366	3007.66	259.81	78.04
2017	23	820	1231	2950.08	264.62	88.30
2018	22	873	1133	2689.97	291.81	88.26
2019	20	892	1181	2651.22	312.43	82.30
2020	16	859	1203	2857.24	378.91	85.79
2021	13	583	925	2481.55	319.21	85.73

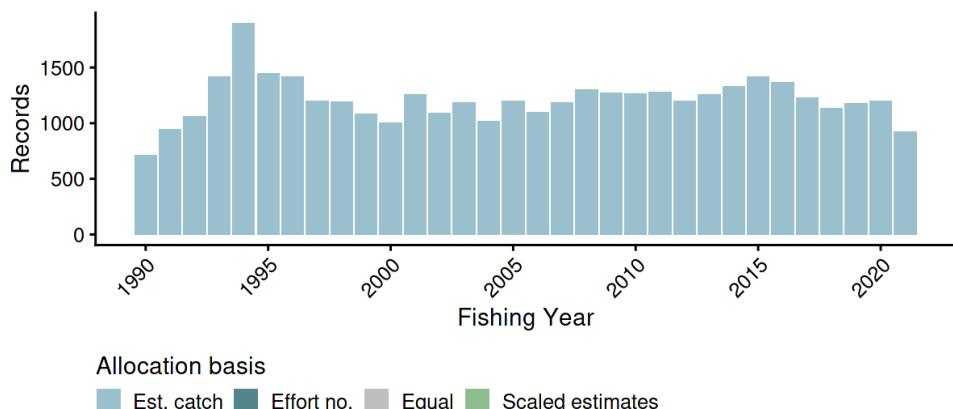


Figure D.138: Allocation basis for attributing landings to records in the SPO 3 SN daily (fishing duration) catch-per-unit-effort dataset. Allocation basis is in terms of estimated catch, effort number, and/or equal.

Table D.46: 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	30.00	40967	3.70	3.70	*
+ vessel_key	66.00	36093	15.50	11.80	*
+ target_species	3.00	33672	21.20	5.70	*
+ month	11.00	32287	24.50	3.30	*
+ ns(log(fishing_duration), 3)	3.00	32148	24.90	0.30	
+ stat_area	11.00	32028	25.20	0.30	
+ ns(log(total_net_length), 3)	3.00	31911	25.50	0.30	

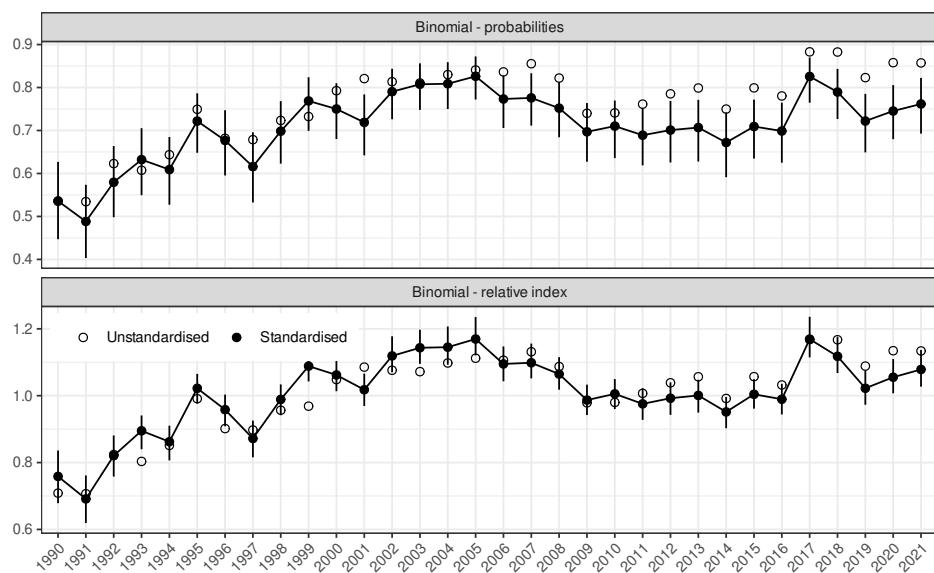


Figure D.139: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for occurrence of catch in the SPO 3 SN daily (fishing duration) dataset, plotted as both probability of occurrence and as a relative index standardised to the geometric mean.

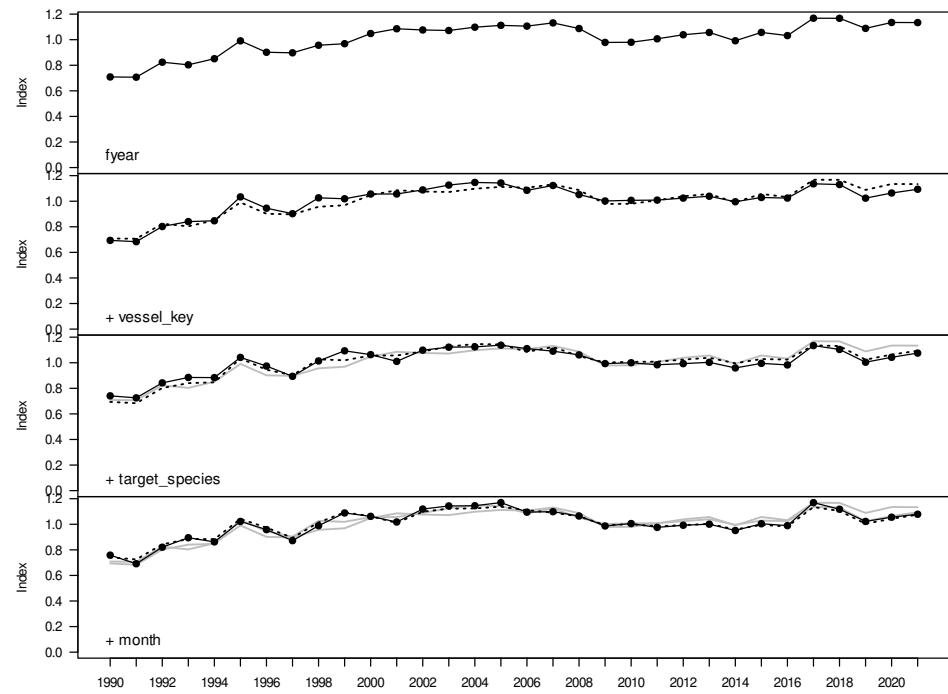


Figure D.140: Step plot for occurrence of catch in the SPO 3 SN daily (fishing duration) dataset.

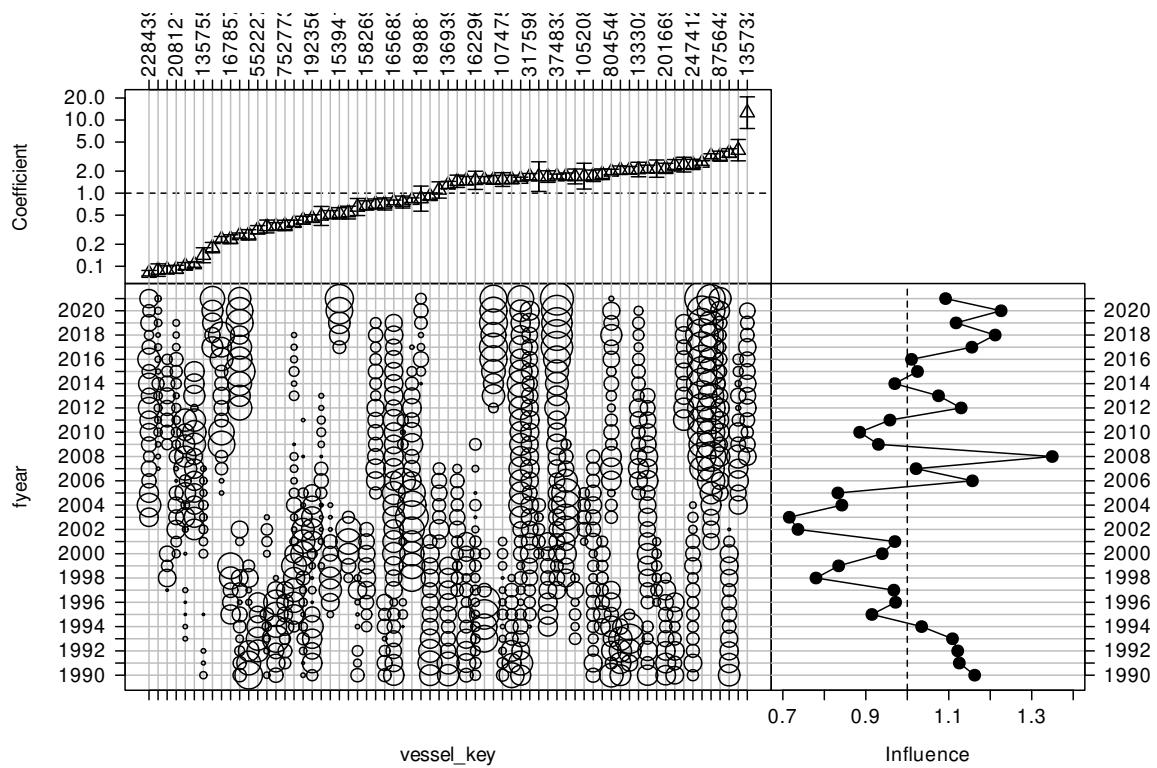


Figure D.141: CDI plot for vessel key for the occurrence of positive catch SPO 3 SN daily (fishing duration) catch-per-unit-effort dataset.

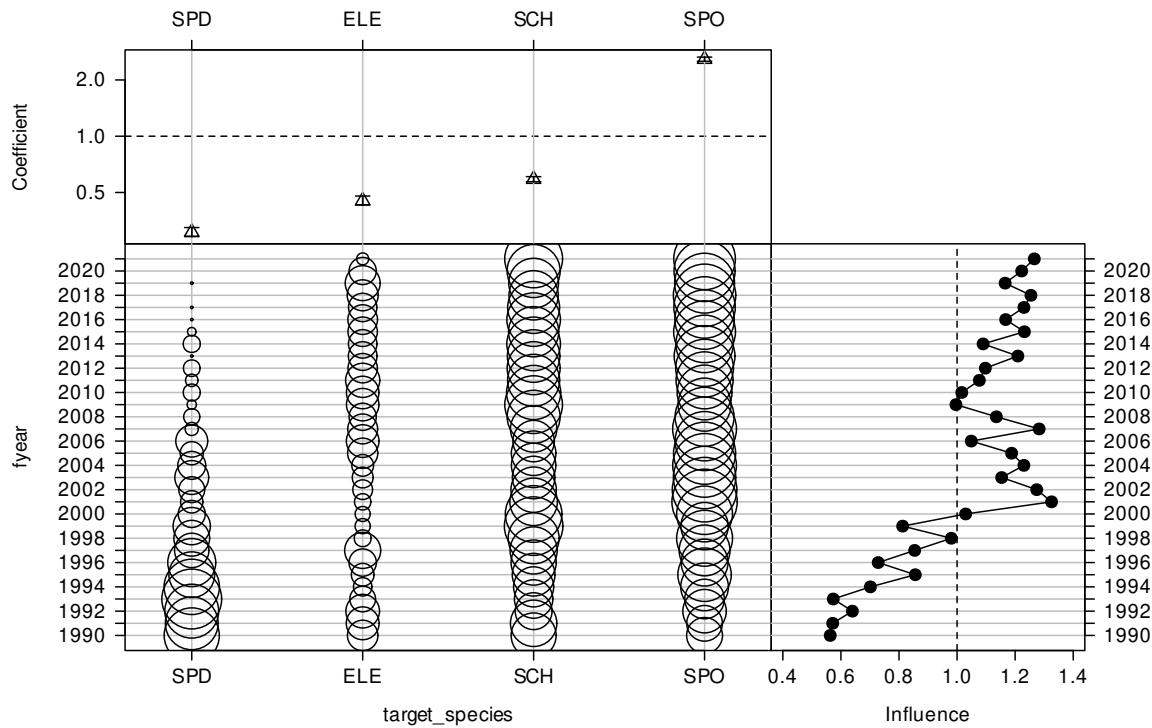


Figure D.142: CDI plot for target species for the occurrence of positive catch SPO 3 SN daily (fishing duration) catch-per-unit-effort dataset.

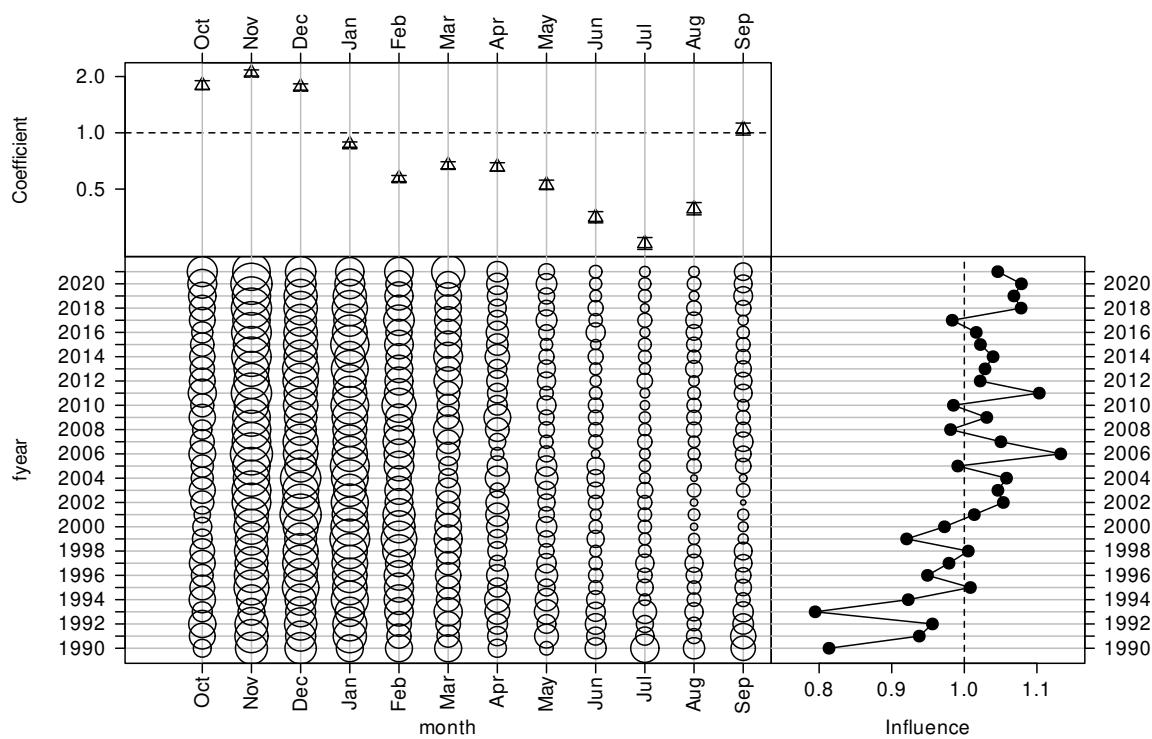


Figure D.143: CDI plot for month for the occurrence of positive catch SPO 3 SN daily (fishing duration) catch-per-unit-effort dataset.

Table D.47: 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	30	106 621	5.5	5.5	*
+ vessel key	66	99 051	27.2	21.7	*
+ target species	3	95 470	35.5	8.3	*
+ month	11	93 290	40.1	4.6	*
+ ns(log(fishing duration), 3)	3	92 769	41.2	1.1	*
+ stat area	11	92 338	42.1	0.9	
+ ns(log(total net length), 3)	3	92 042	42.7	0.6	

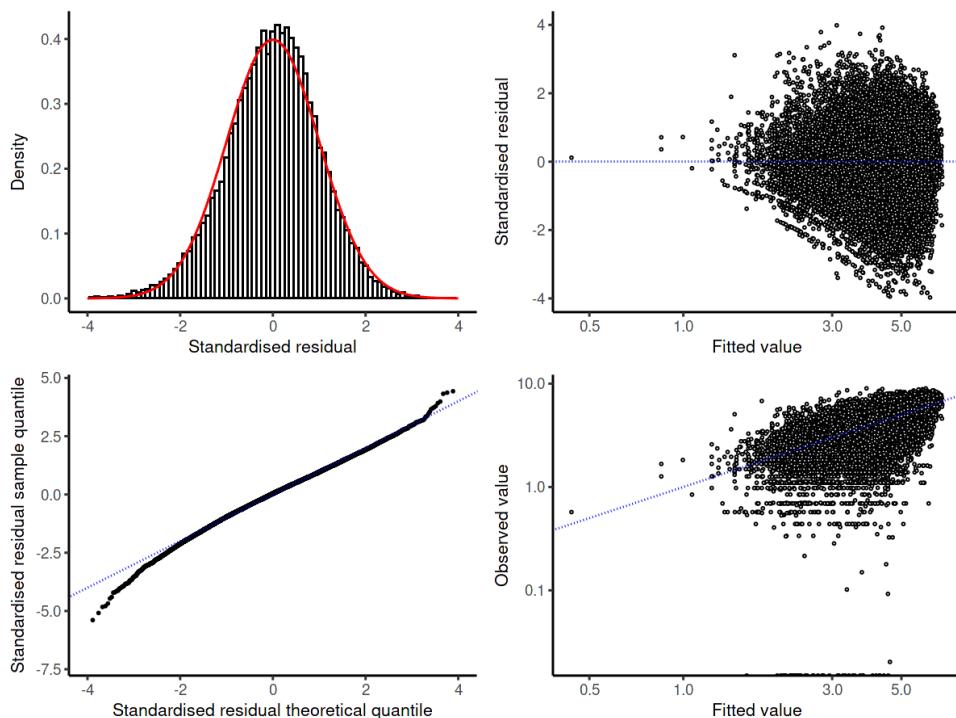


Figure D.144: Diagnostic plots for the lognormal model for the SPO 3 SN daily (fishing duration) dataset.

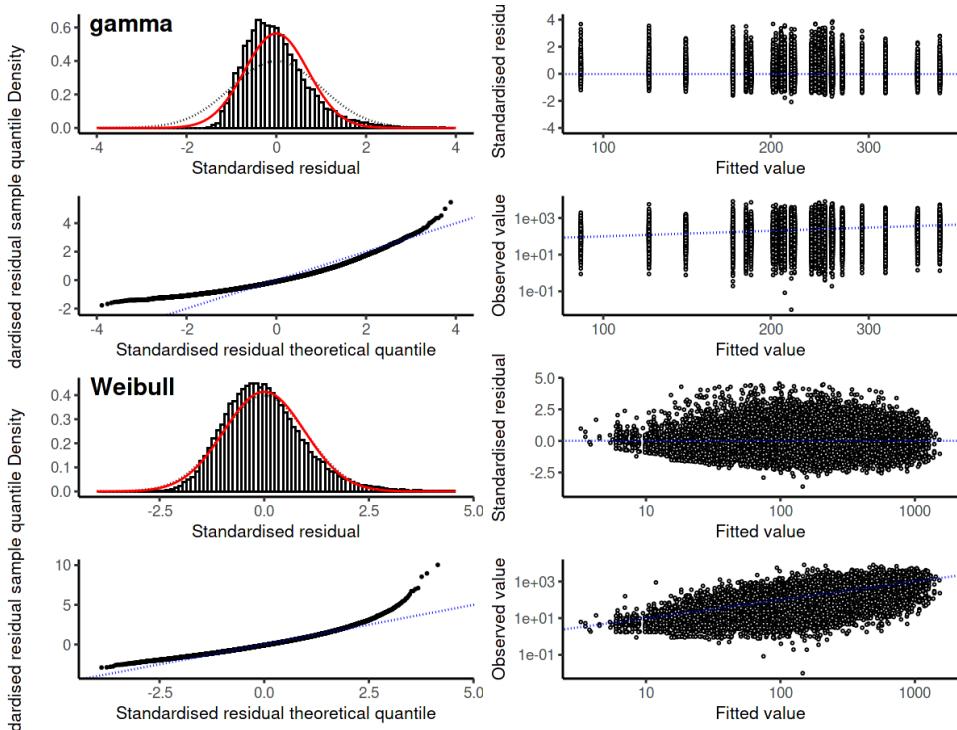


Figure D.145: Diagnostic plots for the gamma and Weibull model for the SPO 3 SN daily (fishing duration) dataset.

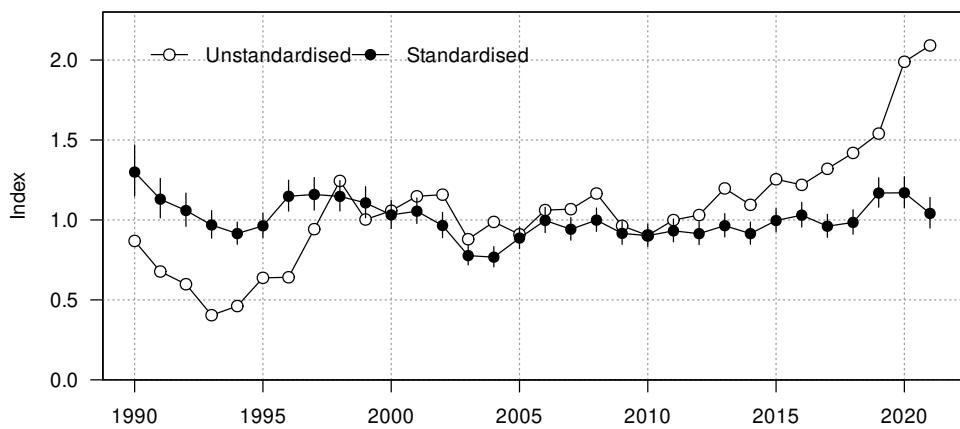


Figure D.146: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for positive catch in the SPO 3 SN daily (fishing duration) dataset.

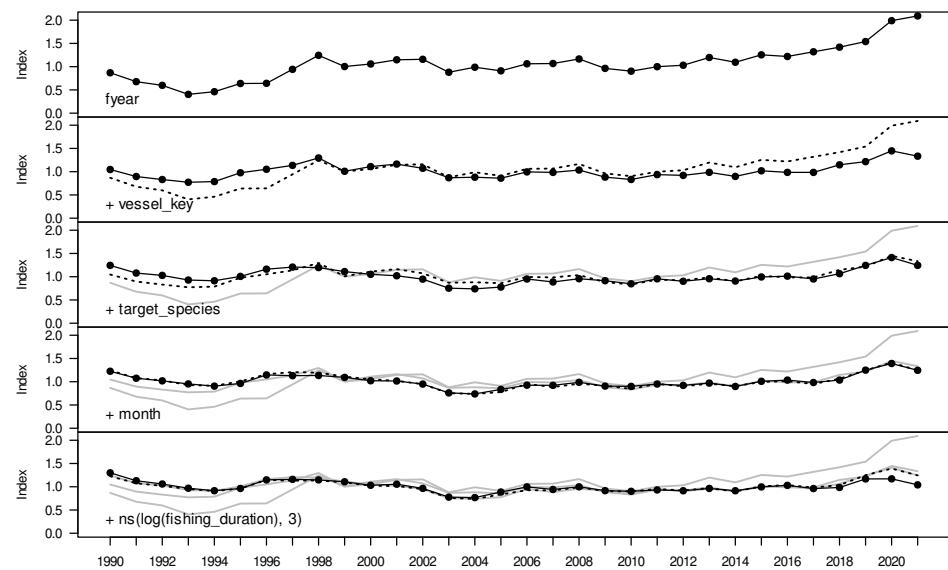


Figure D.147: Changes to the SPO 3 SN daily (fishing duration) positive catch index as terms are successively entered into the model.

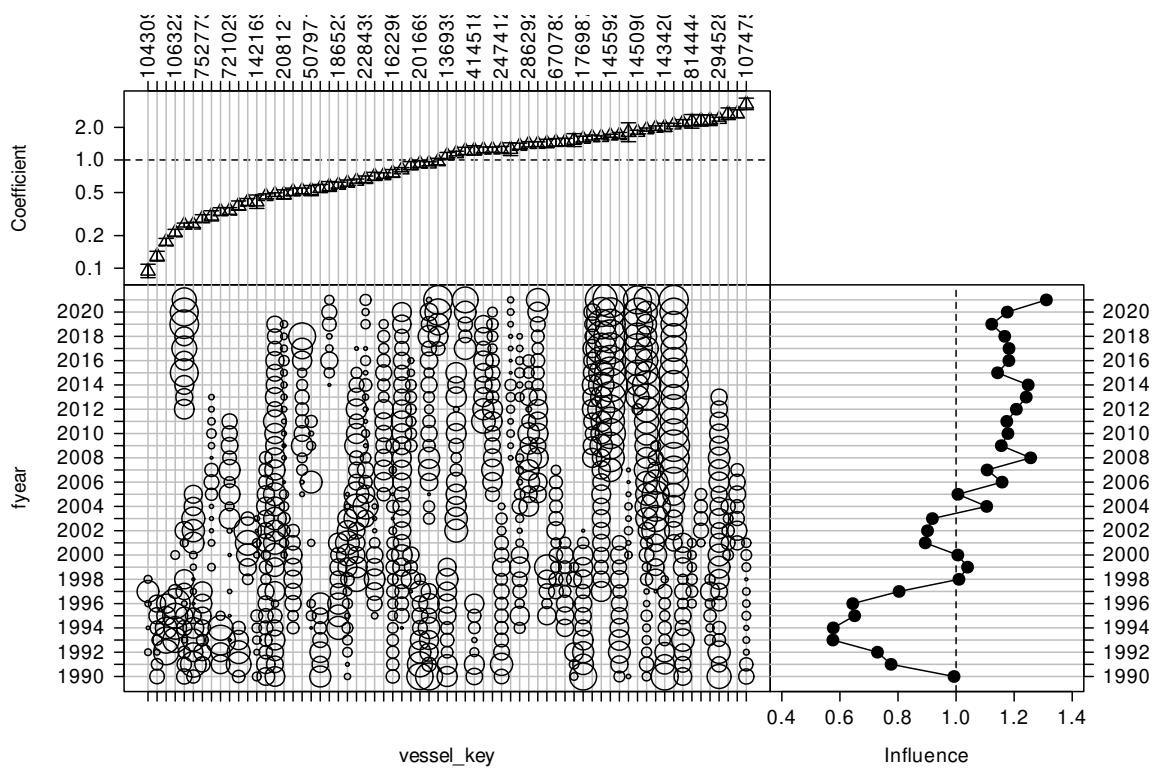


Figure D.148: CDI plot for vessel key for the positive catch SPO 3 SN daily (fishing duration) catch-per-unit-effort dataset.

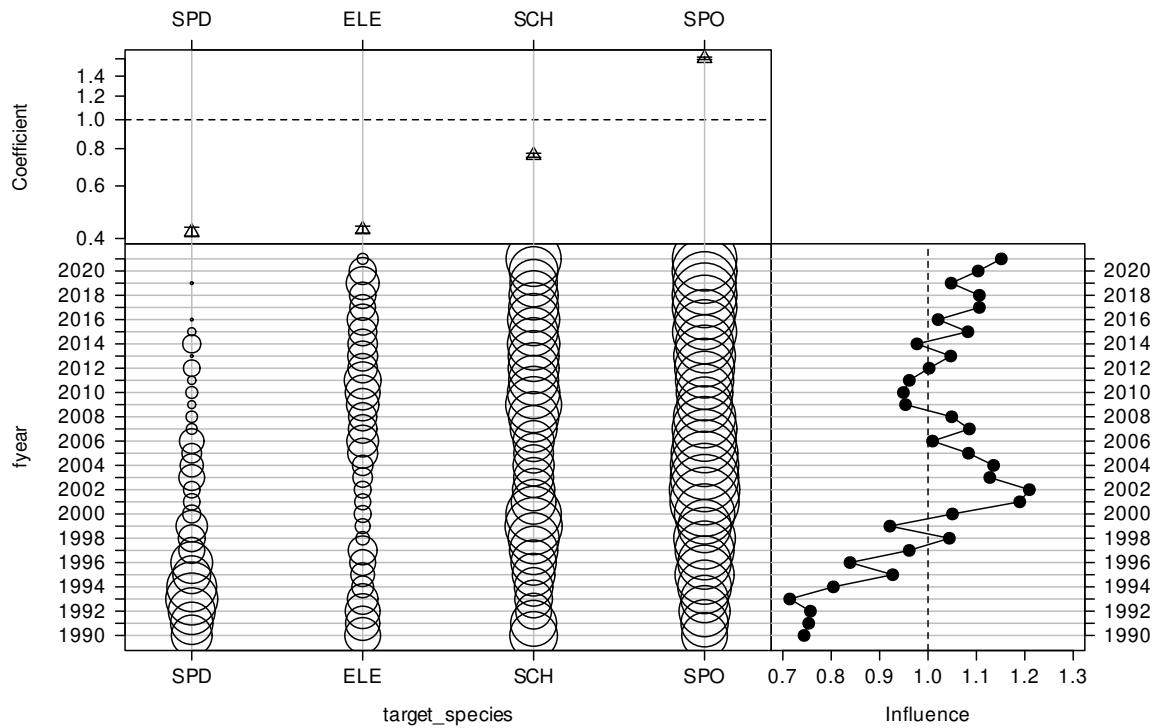


Figure D.149: CDI plot for target species for the positive catch SPO 3 SN daily (fishing duration) catch-per-unit-effort dataset.

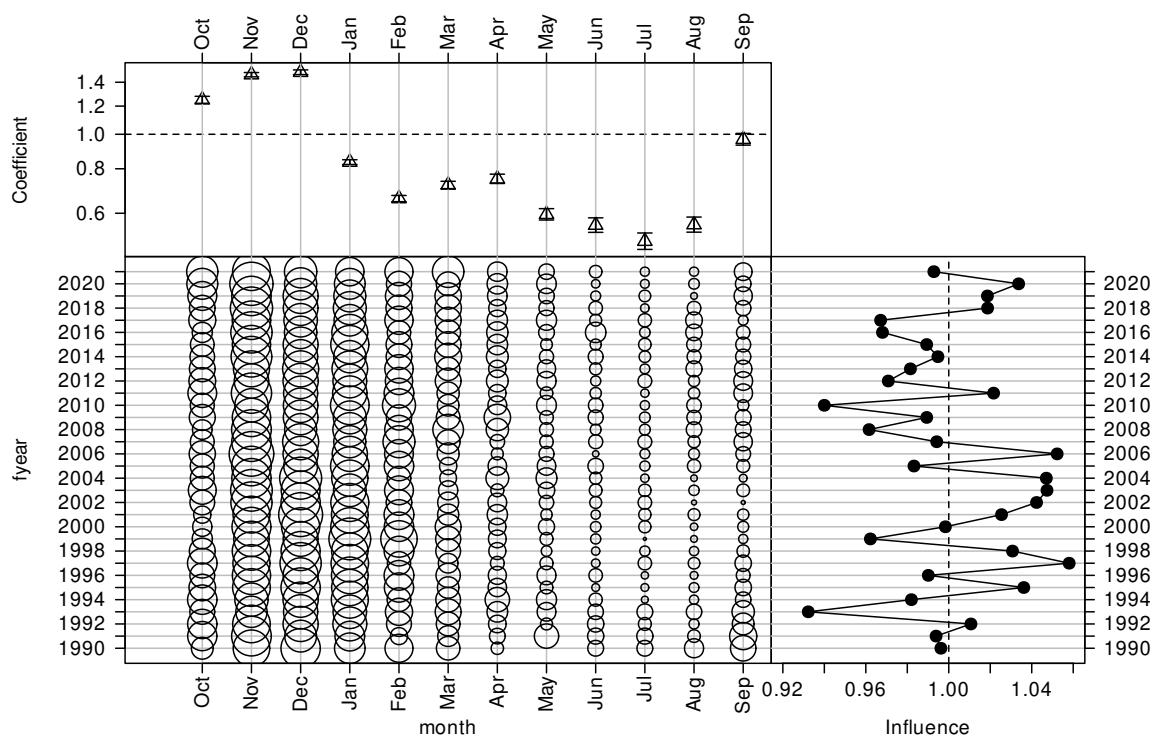


Figure D.150: CDI plot for month for the positive catch SPO 3 SN daily (fishing duration) catch-per-unit-effort dataset.

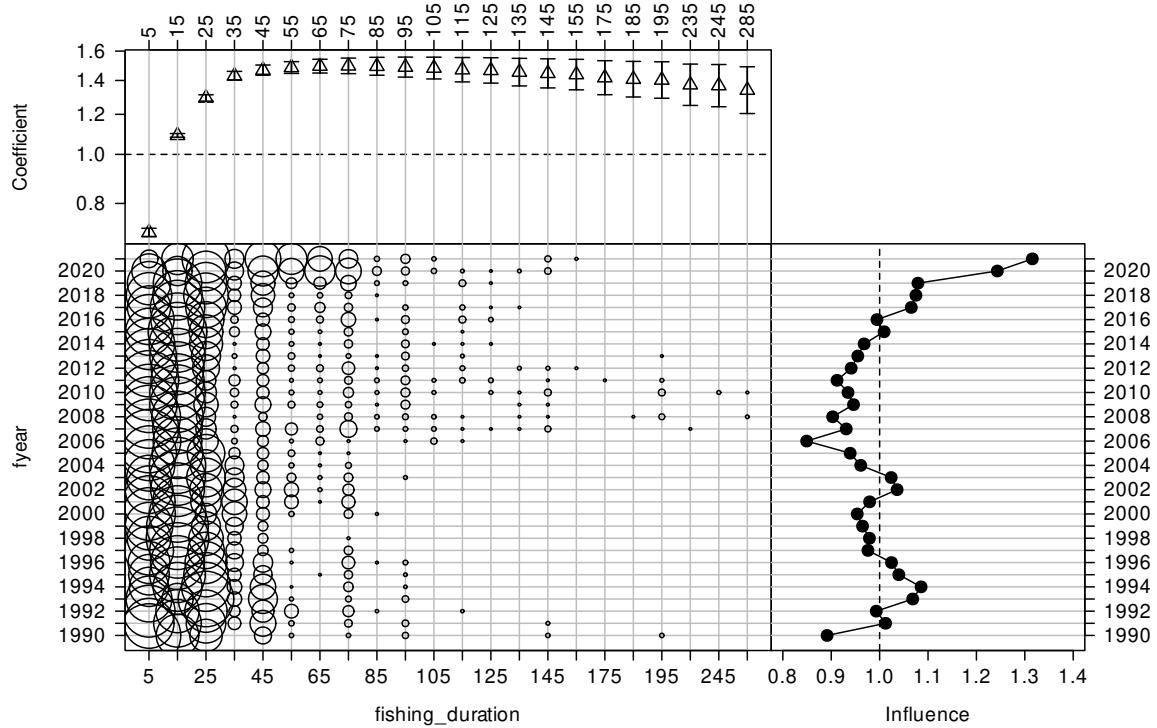


Figure D.151: CDI plot for fishing duration (h) for the positive catch SPO 3 SN daily (fishing duration) catch-per-unit-effort dataset.

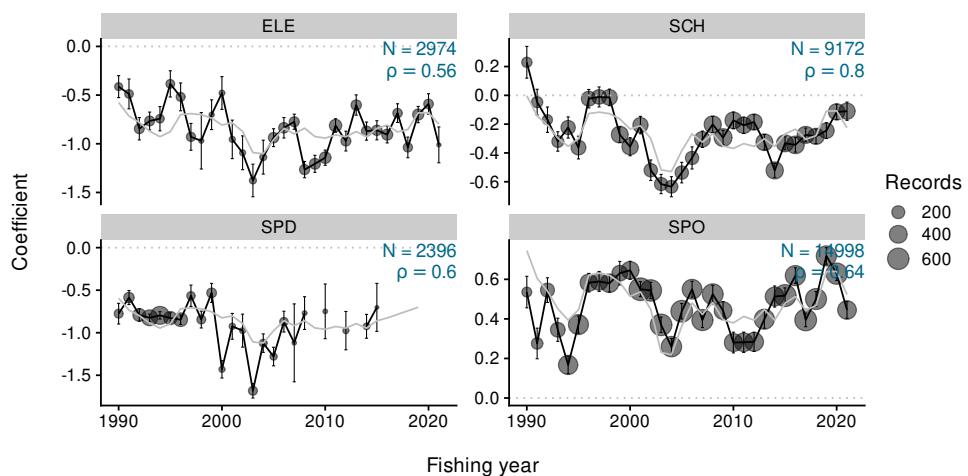


Figure D.152: Residual implied coefficients for target-year in the lognormal positive catch model for the SPO 3 SN daily (fishing duration) dataset.

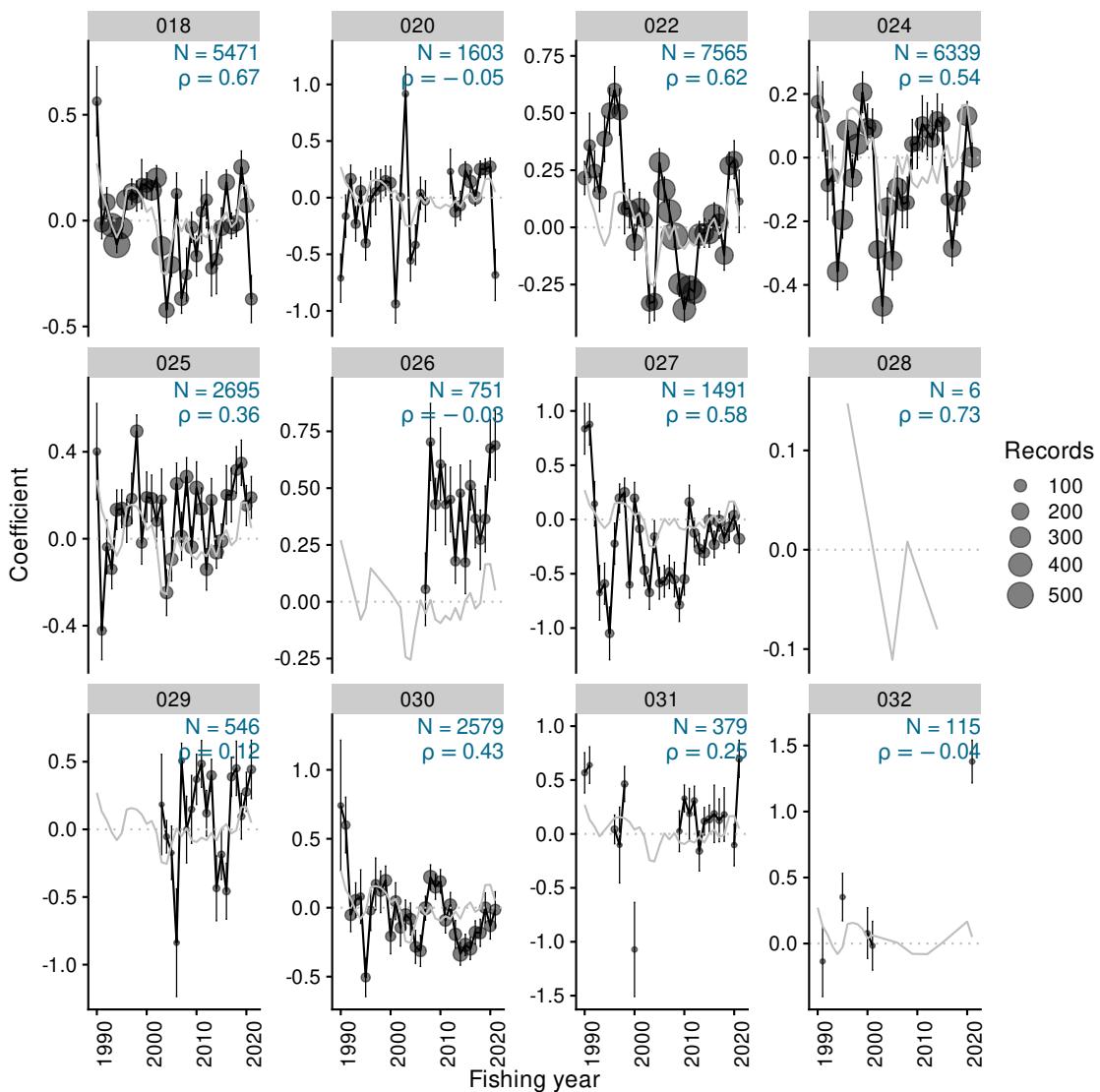


Figure D.153: Residual implied coefficients for area-year in the lognormal positive catch model for the SPO 3 SN daily (fishing duration) dataset.

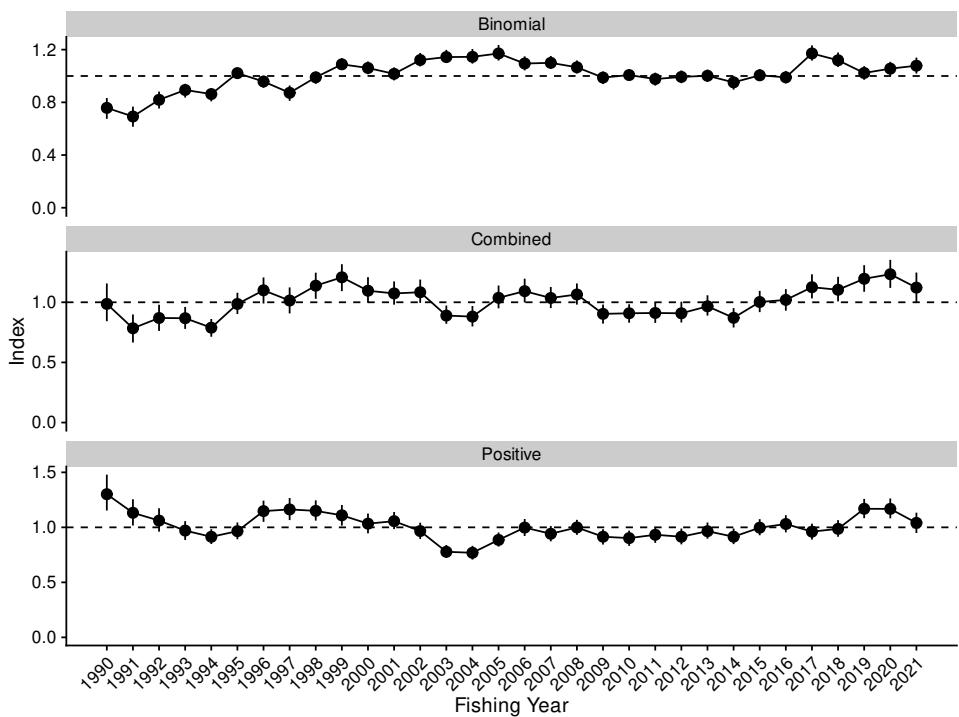


Figure D.154: Standardised indices and 95% confidence intervals for the SPO 3 SN daily (fishing duration) dataset.

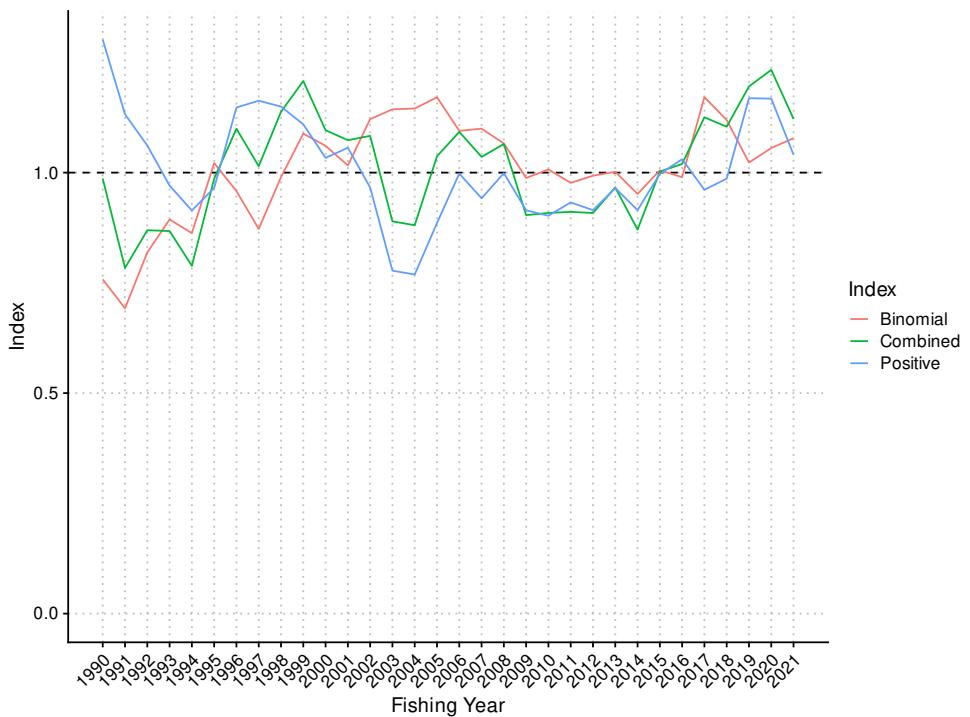


Figure D.155: Standardised indices for the SPO 3 SN daily (fishing duration) dataset.

Table D.48: Annual indices and standard errors, with upper and lower bounds (LCI: 2.5%, UCI: 97.5%) for each model in SPO 3 SN daily (fishing duration).

Fishing year	Binomial				Combined				Positive			
	index	SE	LCI	UCI	index	SE	LCI	UCI	index	SE	LCI	UCI
1990	0.758	0.040	0.675	0.833	0.986	0.080	0.843	1.156	1.301	0.083	1.153	1.479
1991	0.692	0.039	0.615	0.767	0.784	0.060	0.665	0.899	1.132	0.061	1.017	1.255
1992	0.819	0.033	0.753	0.882	0.869	0.055	0.762	0.979	1.061	0.054	0.961	1.173
1993	0.894	0.027	0.836	0.941	0.867	0.046	0.779	0.961	0.971	0.044	0.885	1.057
1994	0.863	0.026	0.807	0.908	0.789	0.038	0.713	0.861	0.914	0.034	0.849	0.983
1995	1.022	0.023	0.977	1.065	0.986	0.045	0.903	1.079	0.965	0.039	0.892	1.044
1996	0.958	0.023	0.910	1.002	1.100	0.055	0.990	1.206	1.148	0.049	1.050	1.243
1997	0.872	0.030	0.812	0.928	1.015	0.055	0.907	1.123	1.163	0.051	1.066	1.267
1998	0.990	0.024	0.941	1.034	1.138	0.055	1.029	1.246	1.150	0.047	1.061	1.246
1999	1.088	0.023	1.046	1.135	1.208	0.057	1.093	1.317	1.110	0.048	1.016	1.203
2000	1.061	0.025	1.013	1.110	1.096	0.054	0.997	1.209	1.033	0.046	0.946	1.125
2001	1.016	0.025	0.967	1.065	1.074	0.049	0.980	1.173	1.056	0.040	0.984	1.140
2002	1.121	0.026	1.073	1.175	1.083	0.050	0.995	1.189	0.966	0.038	0.895	1.042
2003	1.144	0.025	1.098	1.198	0.889	0.039	0.821	0.973	0.778	0.030	0.722	0.840
2004	1.145	0.028	1.094	1.205	0.881	0.043	0.799	0.969	0.769	0.032	0.707	0.832
2005	1.171	0.030	1.117	1.235	1.037	0.048	0.950	1.139	0.886	0.033	0.825	0.954
2006	1.095	0.027	1.042	1.149	1.092	0.050	0.999	1.196	0.998	0.039	0.921	1.076
2007	1.100	0.025	1.053	1.152	1.036	0.045	0.952	1.127	0.942	0.036	0.873	1.012
2008	1.066	0.025	1.019	1.118	1.065	0.045	0.981	1.156	0.999	0.035	0.932	1.068
2009	0.988	0.024	0.939	1.035	0.904	0.040	0.823	0.981	0.915	0.036	0.844	0.983
2010	1.007	0.022	0.964	1.050	0.909	0.039	0.830	0.983	0.902	0.035	0.832	0.970
2011	0.977	0.025	0.927	1.025	0.911	0.043	0.829	0.998	0.932	0.037	0.859	1.005
2012	0.993	0.025	0.945	1.042	0.908	0.044	0.832	1.005	0.915	0.037	0.845	0.989
2013	1.002	0.024	0.955	1.048	0.967	0.043	0.889	1.058	0.965	0.038	0.897	1.045
2014	0.952	0.026	0.897	0.998	0.871	0.041	0.790	0.952	0.915	0.036	0.848	0.990
2015	1.005	0.023	0.962	1.053	1.002	0.045	0.918	1.095	0.997	0.037	0.928	1.075
2016	0.990	0.024	0.944	1.038	1.020	0.046	0.930	1.109	1.030	0.040	0.954	1.110
2017	1.171	0.029	1.117	1.232	1.125	0.051	1.032	1.233	0.961	0.037	0.889	1.033
2018	1.119	0.028	1.069	1.178	1.104	0.052	1.008	1.212	0.986	0.038	0.915	1.066
2019	1.023	0.026	0.971	1.075	1.195	0.056	1.087	1.309	1.169	0.045	1.083	1.259
2020	1.056	0.027	1.004	1.108	1.233	0.059	1.120	1.353	1.168	0.046	1.082	1.263
2021	1.078	0.031	1.018	1.140	1.122	0.063	0.999	1.247	1.041	0.047	0.948	1.133

D.9 Comparison of additional CPUE series

D.9.1 Bottom Trawl

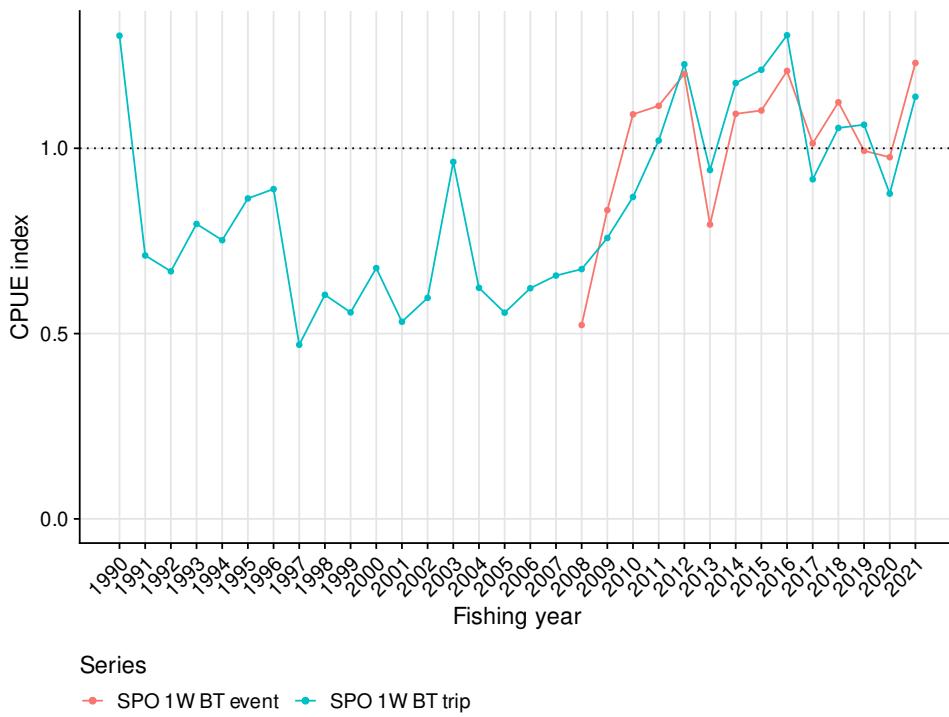


Figure D.156: Compare the SPO 1W bottom trawl trip- with the event-based CPUE series.

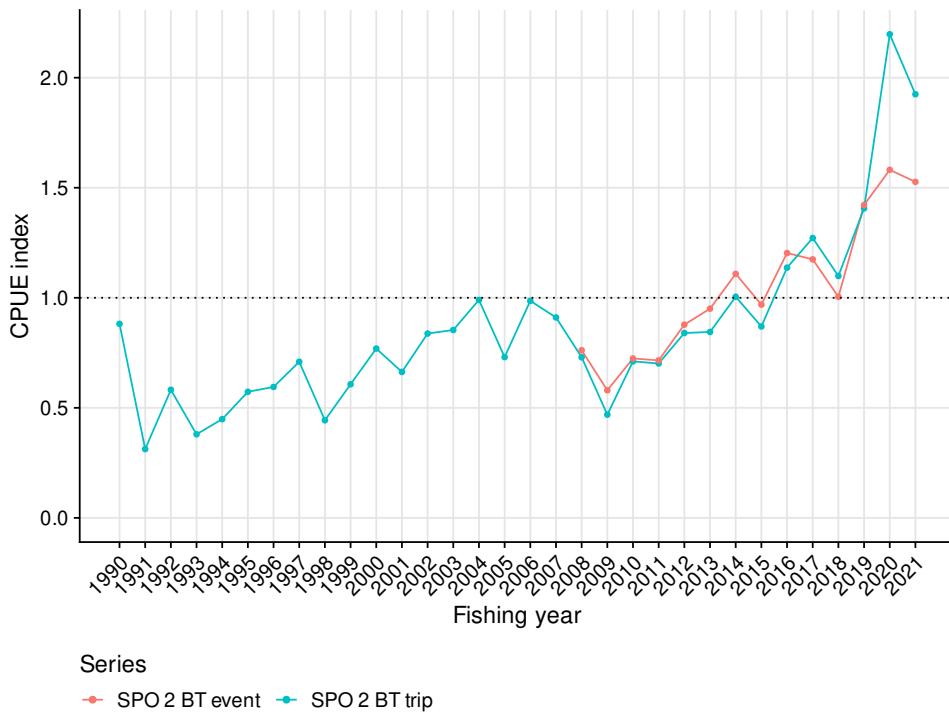


Figure D.157: Compare the SPO 2 bottom trawl trip- with the event-based CPUE series.

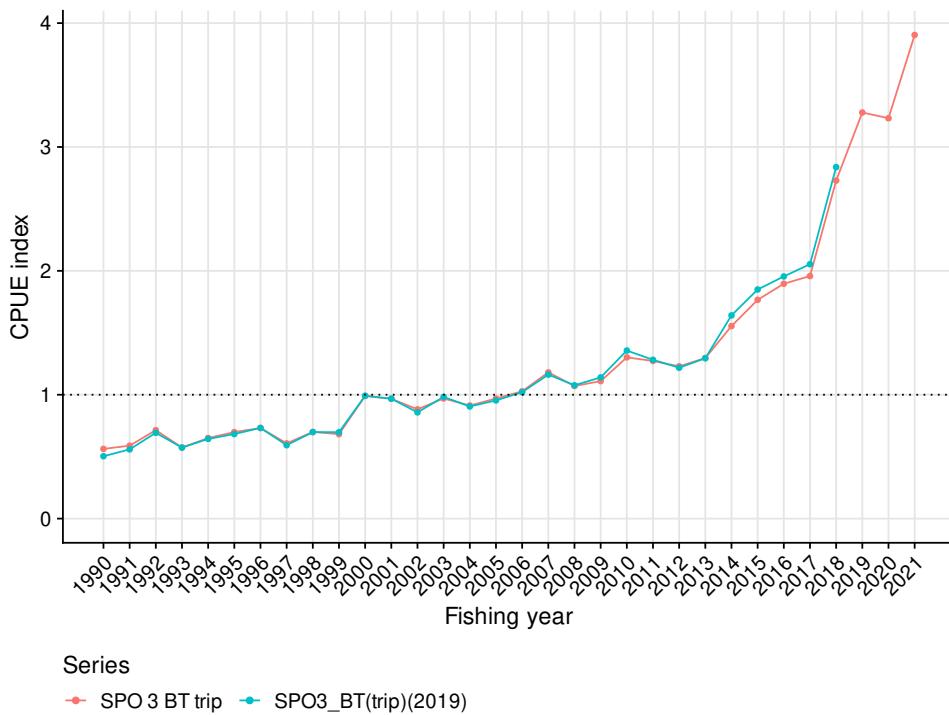


Figure D.158: Compare the SPO 3 bottom-trawl trip CPUE series with the equivalent 2019 series.

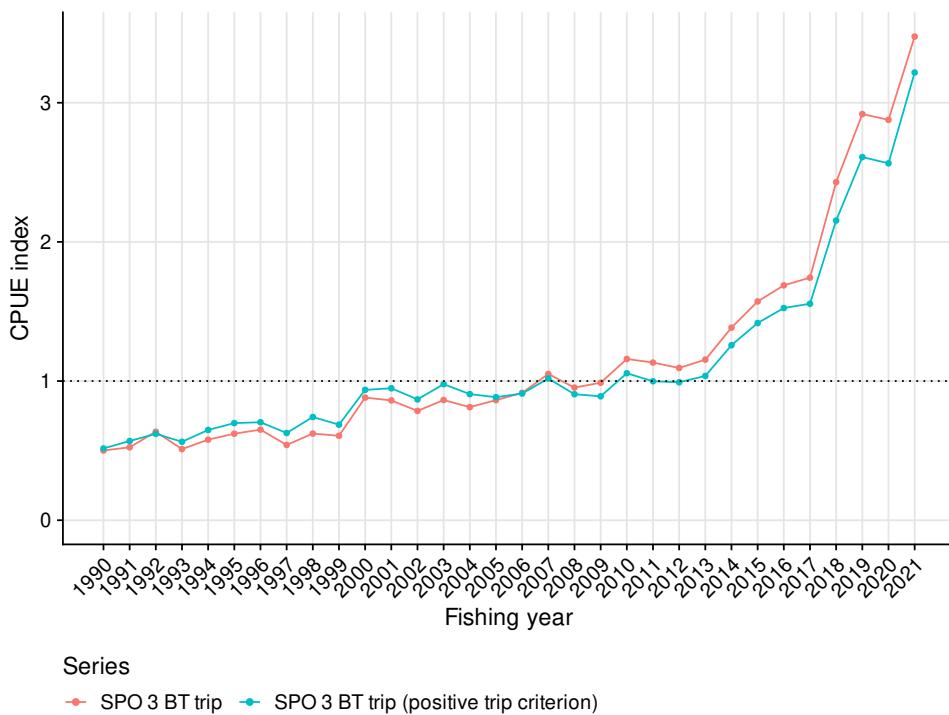


Figure D.159: Compare two vessel selection criteria using the SPO 3 bottom trawl combined CPUE series: at least one kg among all trips for a vessel with only using trips which caught SPO.

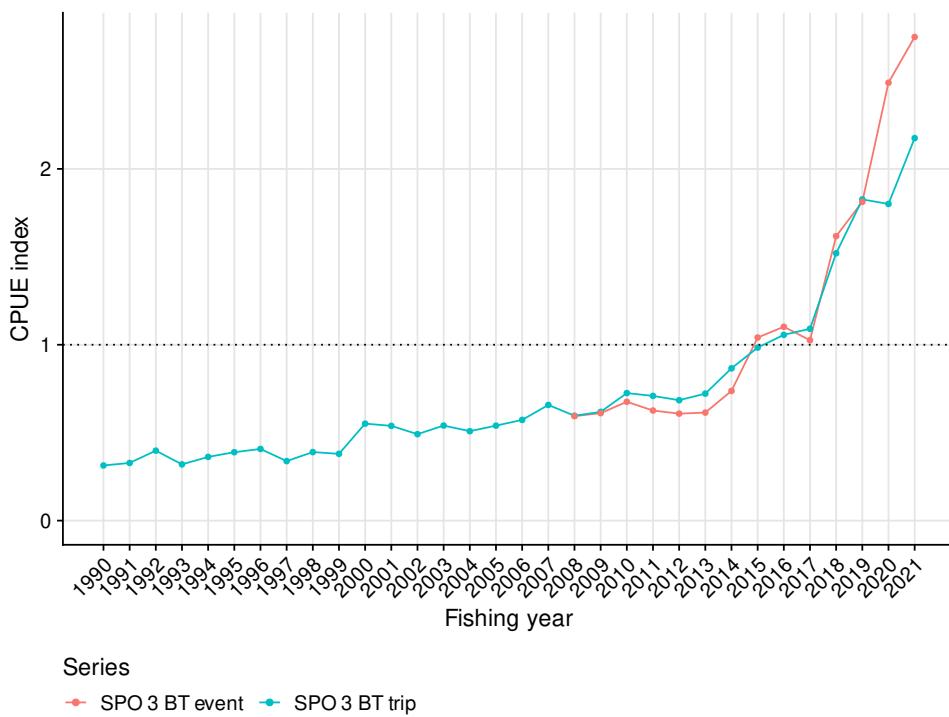


Figure D.160: Compare the SPO 3 bottom trawl trip- with event-based CPUE series.

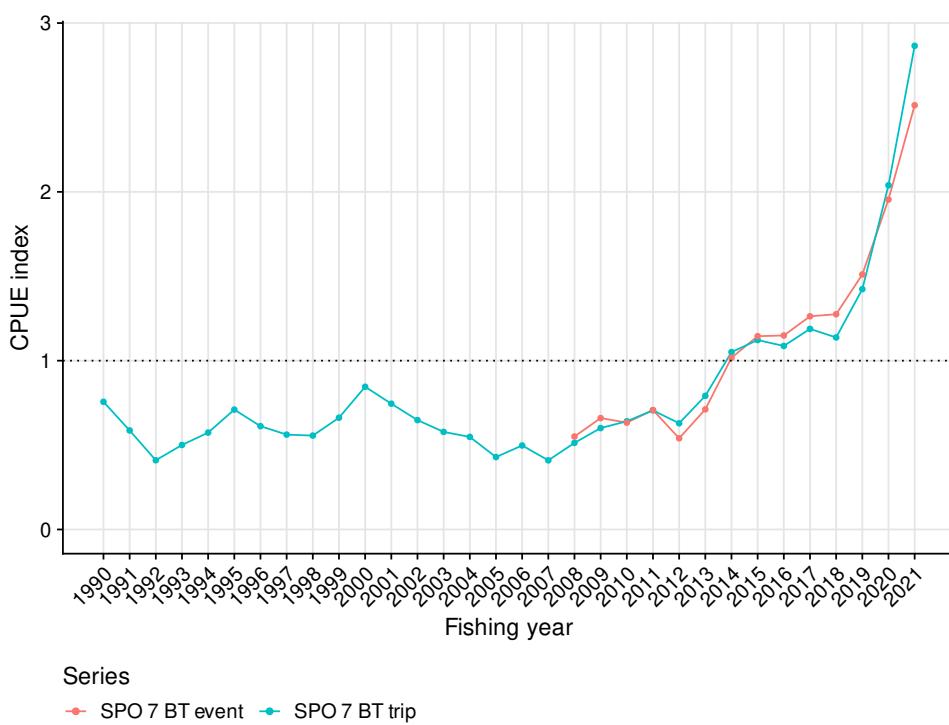


Figure D.161: Compare the SPO 7 bottom trawl trip- with event-based CPUE series.

D.9.2 Set net

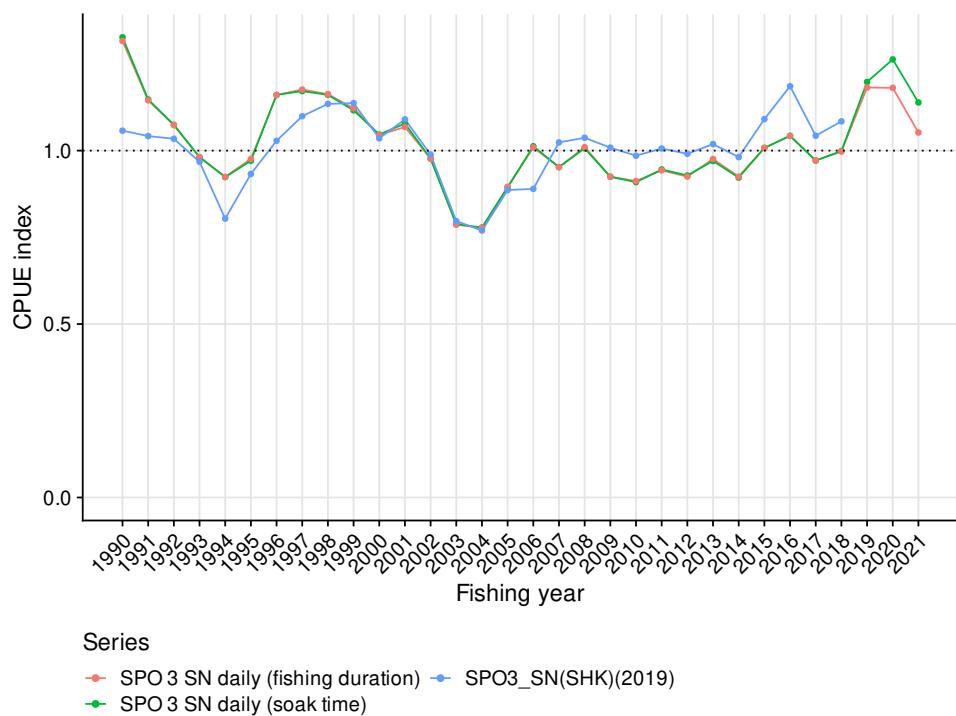


Figure D.162: Compare the SPO 3 set net CPUE series using two definitions of daily effort and with the equivalent 2019 series.

APPENDIX E: GLOSSARY

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

Code	Description
DRE	Dressed
FIL	Fillets: skin-on
FIN	Fins
FIT	Fish tails
FLP	Flaps
GGU	Gilled and gutted
GRE	Green (or whole)
GUT	Gutted
HGT	Headed, gutted, and tailed
HGU	Headed and gutted
LIV	Livers
MEA	Fish meal
SHF	Shark fins
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 Longlining 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)
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
PRB	Precision bottom trawl
SN	Set net

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

Code	Common name	Scientific name
BAR	Barracouta	<i>Thyrsites atun</i>
ELE	Elephant fish	<i>Callorhinchus milii</i>
FLA	Flatfish	
GMU	Grey mullet	<i>Mugil cephalus</i>
GUR	Gurnard	<i>Chelidonichthys kumu</i>
HOK	Hoki	<i>Macruronus novaezelandiae</i>
JDO	John dory	<i>Zeus faber</i>
JMA	Jack mackerel	<i>Trachurus declivis, Trachurus murphyi, Trachurus novaezelandiae</i>
LIN	Ling	<i>Genypterus blacodes</i>
MOK	Blue moki	<i>Latridopsis ciliaris</i>
RCO	Red cod	<i>Pseudophycis bachus</i>
SCH	School shark	<i>Galeorhinus galeus</i>
SKI	Gemfish	<i>Rexea spp.</i>
SNA	Snapper	<i>Pagrus auratus (Chrysophrys auratus)</i>
SPD	Spiny dogfish	<i>Squalus acanthias</i>
SPO	Rig	<i>Mustelus lenticulatus</i>
SQU	Arrow squid	<i>Nototodarus sloanii, Nototodarus gouldi</i>
STA	Giant stargazer	<i>Kathetostoma spp.</i>
TAR	Tarakihi	<i>Nemadactylus macropterus, Nemadactylus sp. (King tarakihi)</i>
TRE	Trevally	<i>Pseudocaranx georgianus</i>
WAR	Common warehou	<i>Seriola brama</i>

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

Code	Description
AKE	Auckland (East) (FMA 1)
AKW	Auckland (West) (FMA 9)
CEE	Central (East) (FMA 2)
CEW	Central (Egmont) (FMA 8)
CHA	Challenger/Central (Plateau) (FMA 7)
SEC	South-East (Coast) (FMA 3)
SOU	Southland (FMA 5)