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SPO 1, 2, 3, 7 and 8 Fishery Characterisation and CPUE Report

New Zealand Fisheries Assessment Report 2016/34

P.J. Starr
T.H. Kendrick

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EXECUTIVE SUMMARY

Starr, P.J.; Kendrick, T.H. (2016). SPO 1, 2, 3, 7 and 8 Fishery Characterisation and CPUE Report.

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The fisheries taking rig (*Mustelus lenticulatus*) around the New Zealand North and South Islands are described from 1989–90 to 2011–12, based on compulsory reported commercial catch and effort data held by the Ministry for Primary Industries (MPI). A number of setnet and bottom trawl fisheries take rig throughout New Zealand. The setnet fisheries tend to be fisheries targeted at rig or, less frequently, at another shark species such as 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 landing 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 SPO QMAs. Annual performance of the SPO QMA catches and some regulatory information are also presented.

Commercial Catch Per Unit Effort (CPUE) analyses for ten setnet (SN) and seven bottom trawl (BT) fisheries were considered as candidates for use as biomass indices to track population trends in these QMAs. These analyses were based on the compulsory reported commercial catch and effort data which are collected by MPI. One of these fisheries (SPO 2 SN) had been previously rejected by the Northern Inshore Fishery Assessment Working Group (NINSWG) and was not updated. The two fisheries in the open ocean off the west coast of the North Island (SN and BT) were rejected after review by the Southern Inshore Fishery Assessment Working Group (SINSWG) as having too few data, particularly in recent years, to provide a reliable biomass index series. The SINSWG rejected the BT fishery targeted at flatfish species on the east coast of the South Island because it deemed the low headline height used by this fishery to optimise flatfish catch meant that rig catchability in this fishery would be low. CPUE series for 9 of the remaining 13 fisheries (6 SN and 3 BT) were deemed to be of High Quality (Research Ranking=1) and consequently could be used for monitoring rig abundance. Four fisheries (2 SN and 2 BT) CPUE series were given a Research Ranking of 2 (Medium or Mixed Quality). CPUE series for these fisheries were downgraded because of concern that data availability in these series was compromised due to factors other than rig abundance. The most frequent cause was loss of fisher participation due to restrictions to protect Hector's and Maui dolphins.

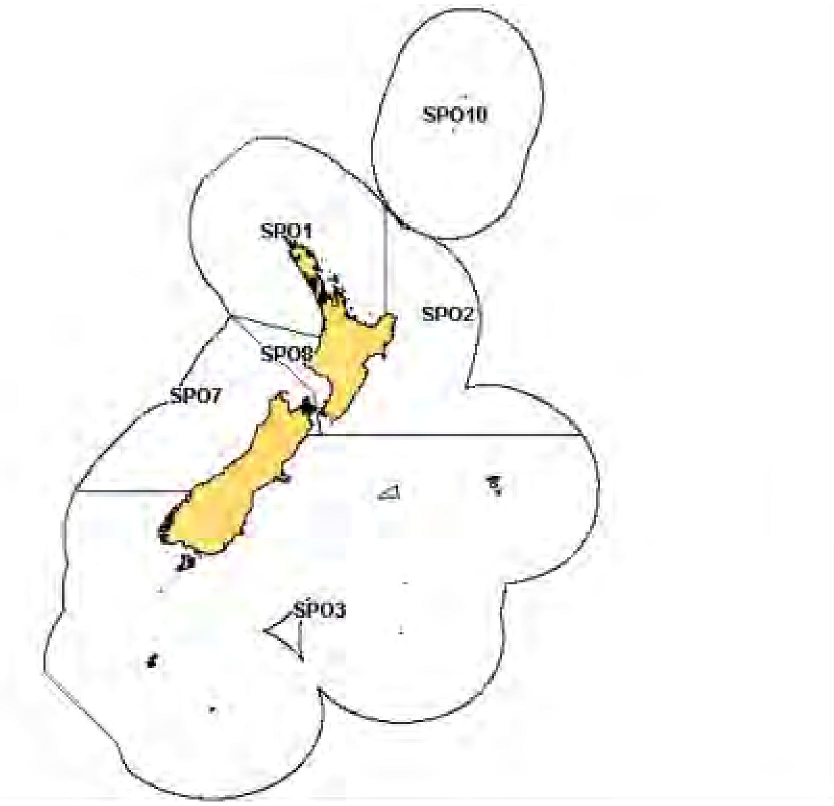

Figure 1: Map of SPO QMAs.

1. INTRODUCTION

This document describes work conducted under Objectives 1 and 2 of the Ministry for Primary Industries (MPI) contract SPO2011-01.

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 2011/12 fishing year and undertake CPUE standardisations for each stock.

This project extends a number of previous projects in a single document:

Fishstock	Reference	Last fishing year in analysis
SPO 1	Kendrick & Bentley (2012)	2009–10
SPO 2	Kendrick et al. (2011); Starr (2011)	2009–10
SPO 3	Starr & Kendrick (2011)	2009–10
SPO 7	Starr et al. (2010)	2008–09
SPO 8	Kendrick & Bentley (2012)	2009–10

This report summarises fishery and landings characterisations for SPO 1, SPO 2, SPO 3, SPO 7, SPO 8, as well as presenting 16 CPUE standardisations derived from trawl and setnet data originating from each of the above QMAs. This work is part of the MPI schedule for Group 5 stocks: chondrichthian stocks which 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 MPI QMAs is presented in Figure 1. Appendix B presents the MPI FMAs in the context of the contributing statistical reporting areas.

2. INFORMATION ABOUT THE STOCK/FISHERY

2.1 Catches

The TACC for rig in SPO 1 was set at 540 t when this Fishstock was first put in the QMS in 1986, but increased through the process of quota appeals to 688 t by 1990–91 (Figure 2; Table C.1). The TACC was increased to 829 t in 1991–92 under the provisions of the Adaptive Management Programme (AMP) (Table C.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 in 2007–08, after which catches have been steady at levels slightly above 300 t/year (Figure 2; Table C.1).

The TACC for rig in SPO 2 was set at 55 t when this Fishstock was first put into the QMS in 1986. It was increased from 71 t to 86 t in 1991–92 under the provisions of the AMP (Figure 2; Table C.1). Catch levels first exceeded the TACC in the early 1990s and have since exceeded the TACC in every year starting with 1991–92 (Figure 2; Table C.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 and raised again to 108 t in 2011–12. Landings have exceeded the SPO 2 TACC between 10 and 32% since 2001–02 (Table C.1).

The TACC for SPO 3 was increased from 364 to 430 t for the 1991–92 fishing year when it was increased under the provisions of the AMP (Figure 2; Table C.1). Landings increased but did not approach the new TACC until 1994–95. The TACC was again increased under the AMP to 600 t/year in 2000–01 but landings never approached this level, staying above or near 400 t/year until 2002–03, after which landings dropped below 400 t until 2006–07, when they rose to 423 t and then to 472 t in 2007–08 (Table C.1; Figure 2). Landings dropped to 328 t in 2008–09 but have since risen to 433 t in 2011–12.

The TACC for SPO 7 was increased from 294 to 350 t for the 1991–92 fishing year under the provisions of the AMP (Figure 2; Table C.1). Landings increased but did not exceed the higher TACC until 1995–96. 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 C.1). The TACC was lowered to 221 t for the 2006–07 fishing year in response to a stock assessment which was based on the west coast South Island trawl survey indices and two CPUE series, one from the Area 038 (Tasman/Golden Bays) and the other from the west coast of the South Island. Landings have exceeded the new, lower, TACC in each year since then, by 20% in 2006–07 and then by 3 to 6% from 2007–08 to 2011–12.

The TACC for SPO 8 increased gradually from 240 to 310 t through quota appeals between 1986–87 and 1990–91 (Figure 2; Table C.1). The TACC was then 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 have since averaged around 200 t/year, ranging from a low of 163 t in 2005–06 and a maximum of 246 t in 2009–10 (Table C.1; Figure 2).

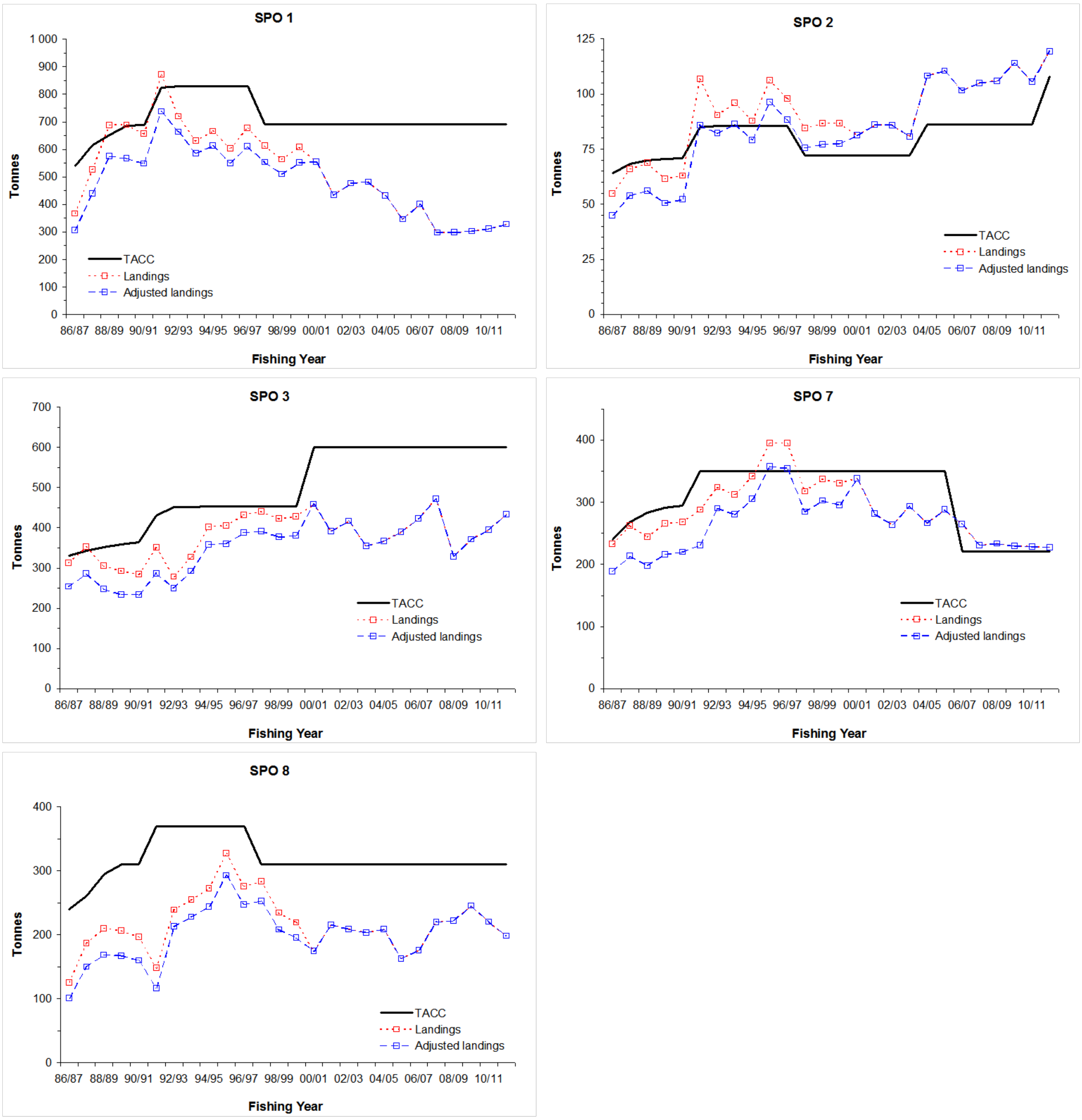

Figure 2: Plots of SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 landings and TACCs from 1986–87 to 2011–12 (see Table C.1 for list of landings and TACCs by SPO QMA). "Adjusted landings" before 2000–01 have been adjusted to reflect changes in historical conversion factors (see Eq.2 in Section 2.3.2.2).

2.1.1 Recreational catches

Recreational catches in New Zealand are poorly known, a conclusion which applies to all rig QMAs (SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8). A series of regional and national surveys, which combined phone interviews with randomly selected diarists, have been conducted since the early 1990s (Teirney et al. 1997, Bradford 1998, Boyd & Reilly 2005), but the results from these surveys are not considered to be reliable by most of the Fishery Assessment Working Groups. In particular, the Recreational Technical Working Group (RTWG) concluded that the framework used for the telephone interviews for the 1996 and previous surveys contained a methodological error, resulting in biased eligibility figures. Consequently the harvest estimates derived from these surveys are unreliable. This group also indicated concerns with some of the harvest estimates from the 2000–01 survey. The following summarises that group's views on the telephone /diary estimates:

> "*The RTWG recommends that the harvest estimates from the diary surveys should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and, c) the 2000 and 2001 harvest estimates are implausibly high for many important fisheries*." (quoted from the chapter on kahawai, Ministry of Fisheries 2011)

A large scale population-based diary/interview survey was conducted under contract for MPI from 1 October 2011–30 September 2012, with the intention of estimating FMA-specific annual catches for all major finfish and non-finfish species (Heinemann et al. 2015). This survey estimated the coastwide recreational rig catch to be on the order of 48 000 rig or about 50 t, assuming a mean catch weight of approximately 1 kg per rig (CV=0.14; Table 1). Catches were distributed reasonably evenly across FMAs, with the largest number caught in FMA 7 (equivalent to SPO 7). The reliability of this survey with respect to rig is unknown, but it is likely that the estimate of number of rig captured is more reliable than the estimate of mean weight, which was estimated separately from the survey design. This mean weight estimate was based on 71 rig measurements from boat ramp interviews, 60 of which were obtained in the summer months from SPO 2 and SPO 7 (Hartill & Davey 2015).

Table 1: Summary catch information for rig from the Large Scale Marine Survey (LSMS: Wynne-Jones et al. 2014). The 'number fishers' and 'number events' categories are the survey sample size.

Category	Value	FMA	Value	Capture method	Value	Capture platform	Value
Number fishers	159	1	4 976	Rod/line	35 888	Trailer boat	14 138
Number events	241	2	7 172	Longline	7 937	Launch	2 015
Catch (numbers)	47718	3	7 280	Net	3 429	Yacht	0
CV (numbers)	0.14	5	862	Pot	0	Large yacht	0
MeanWgt (kg)[1]	1.09	7	19 126	Dredge	0	Kayak	1 971
Catch (t)	52.05	8	5 499	Hand/shore	0	Shore	27 440
CV (catch)	0.14	9	2 804	Diving	0	Other	2 154
				Spear	415		
				Other	48		
		Total	47 719	Total	47 717	Total	47 718

[1] Estimated by NIWA from 71 length measurements (Hartill & Davey 2015)

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 "head & gutted" or HGU, has been industry practice for at least twenty years and there has been no known systematic change in processing procedure over that period (P. Dawson *pers. comm.*). What has changed is the "conversion factor" used to translate the processed HGU (and DRE or "dressed") weight back into green weight (GRE). The conversion factor in use for these landing states from at least 1960 to the 1991–92 fishing year was 2.0 (information presented in Section 2.3.2.2). The HGU and DRE conversion factors were dropped to 1.75 from 1992–93 to 1999–2000, and then again to 1.55. This means that landings of rig are not directly comparable across years unless a correction is made for the changes in conversion factor.

2.3 Analysis of SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 catch and effort data

2.3.1 Methods used for 2013 analysis of MPI catch and effort data

Three data extracts were obtained from the Ministry for Primary Industries (MPI) Warehou database (Ministry of Fisheries 2010). One extract consisted of the complete data set (all fishing event information along with all rig landing information) from every trip which recorded landing rig in any New Zealand rig QMA (SPO 1, SPO 2, SPO 3, SPO 7 or SPO 8, starting from 1 October 1989 and extending to 30 September 2012). Two further extracts were obtained: one consisting of all New Zealand trips using the methods BT (bottom trawl), BPT (bottom pair trawl), MW (midwater trawl) or MWPT (midwater pair trawl) and which did **not** target ORH (orange roughy), OEO (oreo) or CDL (cardinalfish). The final extract requested data pertaining to all New Zealand trips which used the setnet method, with regard to target species. Once these trips were identified, all fishing event data and rig landing data from the entire trip, regardless of method of capture, were obtained. These data extracts (MPI replog 8807) were received 22 February 2013. The first data extract was used to characterise and understand the fisheries taking rig. These characterisations are reported in Sections 2.3.2 and 2.3.3, plus detailed summary tables in Appendix G. The remaining two extracts were used to calculate CPUE standardisations (Section 3 and Appendix H to Appendix R).

Table 2: Comparison of the total adjusted QMR/MHR catch (t), reported by fishing year, with the sum of the corrected landed catch totals (bottom part of the MPI CELR form), the total catch after matching effort with landing data ('Analysis' data set) and the sum of the estimated catches from the Analysis data set, all representing the combined SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 QMAs. Data source: MPI replog 8809: 1989–90 to 2011–12. Landings and QMR/MHR totals have been adjusted to consistent conversion factors across years (see Section 2.3.2.2).

Fishing Year	QMR/MHR (t)	Total landed catch (t)[1]	% landed/ QMR/MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis
89/90	1 233	933	76	901	97	817	91
90/91	1 212	1 064	88	1 029	97	886	86
91/92	1 457	1 275	88	1 241	97	1 060	85
92/93	1 497	1 397	93	1 366	98	1 108	81
93/94	1 471	1 536	104	1 489	97	1 194	80
94/95	1 598	1 640	103	1 621	99	1 323	82
95/96	1 656	1 716	104	1 625	95	1 264	78
96/97	1 688	1 707	101	1 628	95	1 188	73
97/98	1 557	1 543	99	1 446	94	1 101	76
98/99	1 474	1 486	101	1 429	96	1 027	72
99/00	1 500	1 529	102	1 462	96	1 100	75
00/01	1 606	1 642	102	1 580	96	1 166	74
01/02	1 407	1 450	103	1 394	96	1 058	76
02/03	1 451	1 465	101	1 428	97	1 039	73
03/04	1 413	1 409	100	1 347	96	935	69
04/05	1 380	1 348	98	1 273	94	892	70
05/06	1 296	1 273	98	1 208	95	845	70
06/07	1 366	1 354	99	1 268	94	900	71
07/08	1 324	1 315	99	1 201	91	927	77
08/09	1 187	1 152	97	1 016	88	781	77
09/10	1 262	1 231	98	1 109	90	846	76
10/11	1 260	1 217	97	1 116	92	842	75
11/12	1 305	1 267	97	1 179	93	923	78
Total	32 601	31 949	98	30 356	95	23 220	76

[1] includes all SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 landings in replog 8807 except for 132 trips excluded for being "out of range" (Table D.1).

Data were prepared by linking the effort ("fishing event") section of each trip to the landing section, based on trip identification numbers supplied in the database. Effort and landing data were groomed to remove "out-of-range" outliers (the method used to groom the landings data are documented in Appendix D; the remaining procedures used to prepare these data are documented in Starr [2007]). See

Section 2.3.2 (below) for a description of how the linking of landings and effort was modified to accommodate the increased use of intermediate landing codes in SPO 1.

The original level of time stratification for a trip is either by tow, or day of fishing, depending on the type of form used to report the trip information. These data were amalgamated into a common level of stratification known as a "trip stratum" (see table of definitions: Appendix A). Depending on how frequently an operator changed areas, method of capture or target species, a trip could consist of one to several "trip strata". This amalgamation was required so that these data could be analysed at a common level of stratification across all reporting form types. Landed catches of rig by trip were allocated to the "trip strata" in proportion to the estimated rig catches in each "trip stratum". In situations when trips recorded landings of rig without any associated estimates of catch in any of the "trip strata" (operators were only required to report the top five species in any fishing event), the rig landings were allocated proportionally to effort (tows for trawl data and length of net set for setnet data) in each "trip stratum".

Catch totals in the fishery characterisation tables have been scaled to the QMR/MHR totals reported in Table C.1 by calculating the ratio of these catches with the total annual landed catch in the analysis dataset and scaling all the landed catch observations (i) within a trip using this ratio:

Eq. 1 $$L'_{i,y} = L_{i,y} \frac{\mathbf{QMR}_y}{AL_y}$$

where $\mathbf{QMR}_y$ is the annual QMR/MHR landings, AL_y is the corresponding total annual landings from the analysis data set and $L_{i,y}$ are the landings for record i in year y.

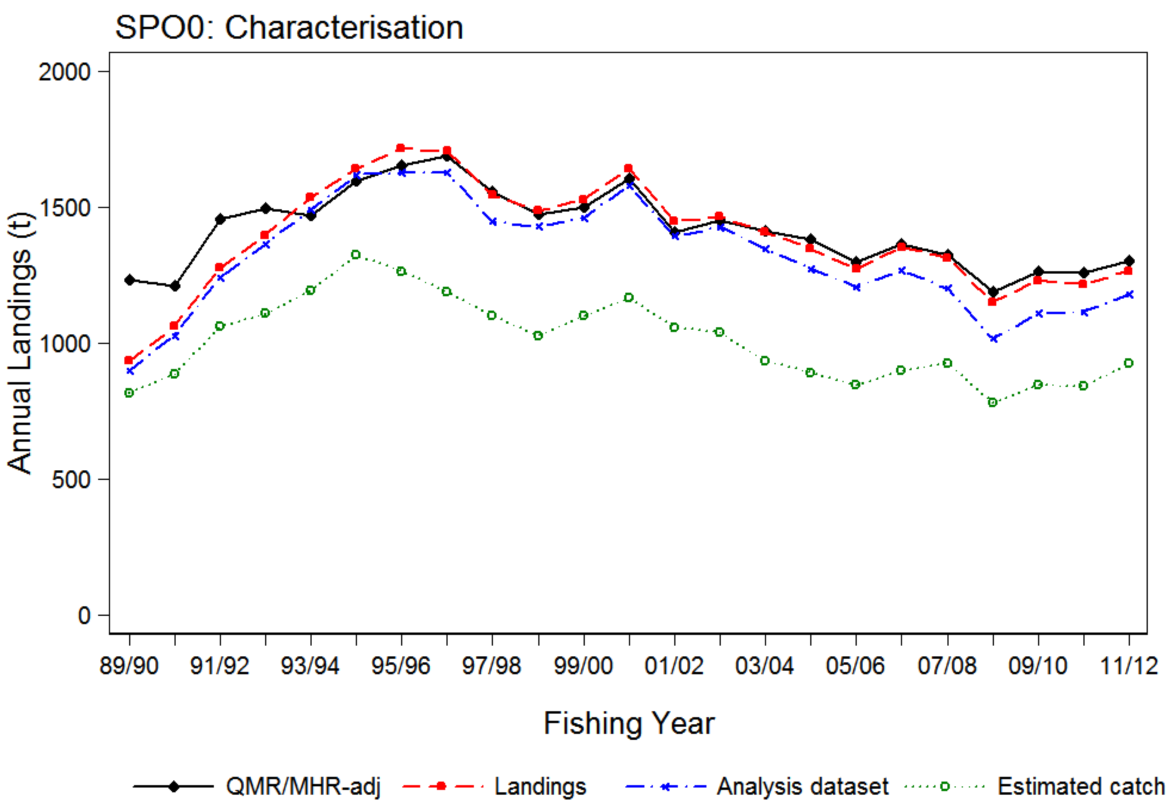

Figure 3: Plot of the combined SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 catch dataset for totals presented in Table 2. Note that both the QMR/MHR totals and the landings have been adjusted to consistent conversion factors for all years.

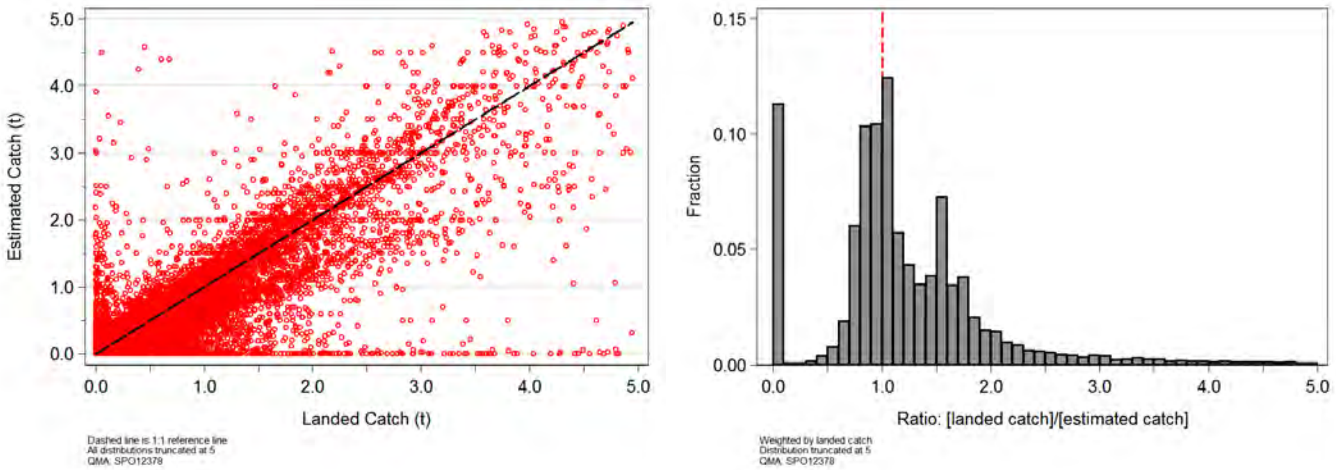

Figure 4: [left panel]: Scatter plot of the sum of landed and estimated rig catch for each trip in the combined SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 analysis dataset. [right panel]: Distribution (weighted by the landed catch) of the ratio of landed to estimated catch per trip. Trips where the estimated catch=0 have been assigned a ratio=0.

Table 3: Summary statistics pertaining to the reporting of estimated catch from the combined SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 analysis dataset.

	Trips with landed catch but which report no estimated catch			Statistics (excluding 0s) for the ratio of landed/estimated catch by trip			
Fishing year	**Trips: % relative to total trips**	**Landings: % relative to total landings**	**Landings (t)**	**5% quantile**	**Median**	**Mean**	**95% quantile**
89/90	35	14	168	0.47	0.93	1.38	2.33
90/91	33	13	157	0.50	0.99	1.31	2.33
91/92	34	12	174	0.47	1.00	1.26	2.43
92/93	35	12	172	0.50	1.00	1.45	2.66
93/94	36	11	163	0.50	1.00	1.43	2.83
94/95	37	12	187	0.50	1.01	1.81	3.10
95/96	38	15	249	0.52	1.03	1.65	3.00
96/97	39	18	306	0.52	1.04	1.58	2.97
97/98	38	14	216	0.50	1.10	1.88	3.06
98/99	37	15	215	0.47	1.10	1.61	3.10
99/00	33	12	184	0.50	1.14	1.75	3.18
00/01	31	11	170	0.56	1.20	1.66	3.15
01/02	31	9	125	0.54	1.18	1.57	3.32
02/03	33	10	142	0.58	1.23	1.76	3.55
03/04	36	11	153	0.50	1.32	1.90	4.03
04/05	38	11	143	0.52	1.28	1.82	4.41
05/06	39	11	142	0.56	1.33	2.07	4.25
06/07	36	11	143	0.56	1.31	2.32	4.48
07/08	18	5	62	0.50	1.24	1.81	4.00
08/09	19	4	52	0.47	1.23	1.81	4.50
09/10	19	4	53	0.48	1.27	1.85	4.65
10/11	19	4	50	0.45	1.25	2.10	4.67
11/12	19	4	46	0.48	1.24	1.86	4.28
Total	33	11	3 472	0.50	1.12	1.71	3.44

The annual totals at different stages of the data preparation procedure are presented in Table 2 and Figure 3. Total landings in the data set are similar to the landings in the QMR/MHR system, except for a 7 to 24% shortfall in landings in the first four years of data (1989–90 to 1992–93: see Table 2). Landings by year in the subsequent fishing years vary from –3% to +4% relative to the QMR/MHR annual totals (Table 2). The shortfall between landed and estimated catch by trip varies from -31% to -9% by fishing year and has averaged -26% over the most recent 10 years (Table 2), indicating that there has not been any recent change in rig reporting practices. A scatter plot of the estimated and landed catch by trip shows that relatively few trips overestimate the landing total for the trip (Figure 4 [left panel]). The distribution of the ratios of the landed relative to estimated catch shows a skewed distribution with many ratios greater than 1.0 and with a mode slightly above 1.0 (Figure 4 [right panel]).

Similar plots and tables are provided by SPO QMA in Appendix E, showing the shortfall in landings by QMA in the analysis datasets relative to the QMR/MHR catches (see Table E.1 for SPO 1 and SPO 2, Table E.2 for SPO 3 and SPO 7 and Table E.3 for SPO 8). Only SPO 8 shows relatively large shortfalls between the actual landings and the landings in the analysis data set, ranging from 39% in 2008–09 to 3% in 1994–95 (see SPO 8 in Figure E.1). However, because the average shortfall was only 25% in the 10 years from 2002–03 to 2011–12, it was deemed that the analysis dataset, prepared using the method of Starr (2007), was adequate to use for the descriptive characterisation analyses (presented in Section 2.3.3).

The procedure described by Starr (2007) drops trips which fished in ambiguous "straddling" statistical areas (the statistical area boundaries do not always coincide with the QMA boundaries–see Appendix B) and which reported multiple rig QMAs in the landing data. This procedure resulted in dropping about 25% of landings in SPO 8 over the last 10 years (Table E.3), which was considered unacceptable for the CPUE phase of this project. Consequently, the method of Starr (2007) was modified to scale estimated catches to the level of landings by statistical area, without regard to the reported QMA, for the CPUE analyses. This modification resulted in much better retention of the landings but at the cost of losing the capacity to link captures and effort to a specific QMA.

For the entire SPO dataset across all years, 33% of all trips which landed rig estimated no catch of rig but reported SPO in the landings (Table 3). This occurs because operators using the CELR form were only required to estimate the catch of the top five species in any single day (8 species by fishing event since the introduction of the TCEER and NCELR forms in 2007–08). These landings represented 11% of the total SPO landings over the period, for a total of 3472 tonnes over all years (Table 3). The introduction of the new inshore forms (NCELR and TCER), which record fishing activity at the level of a fishing event and report more species, has halved the proportion of trips which estimated nil rig while landing this species, and has reduced the proportion of SPO landings in this category accounting for less than about 4% of the total SPO landings in the most recent four years (Table 3).

There is a strong tendency in the SPO dataset to underestimate the landings of rig, with the 5% to 95% quantiles for the ratio of landed to estimated catch (in the total SPO dataset excluding trips where there was no estimated catch) ranging from 0.50 to 3.44. The median and mean ratios have the landed catch at 12% and 71% higher, respectively, than the estimated catch (Table 3), with an increasing trend in these statistics over time. This behaviour is thought to be linked with some operators reporting processed weights for rig rather than greenweight when estimating catches. The mode at 1.6 in the right panel of Figure 4 is evidence that this behaviour is occurring (the conversion factor for DRE and HGU is 1.55 – see discussion in Section 2.3.2 below). This large and consistent shortfall between estimated and landed catches (see Figure 3 and Figure E.1) means that estimated catches must be adjusted to reflect actual landings in the characterisation and CPUE analyses.

Tables equivalent to Table 3 have been prepared for each SPO QMA and are presented in Appendix E (see Table E.4 for SPO 1 and SPO 2; Table E.5 for SPO 3 and SPO 7; Table E.6 for SPO 8). All of the SPO QMAs show a strong tendency to underestimate landings, but to differing degrees, with SPO 3 and SPO 8 showing narrower 5 and 95% quantiles and lower median and means for the ratio landed divided by estimated catch compared to those in Table 3 (see Table E.5 for SPO 7 and Table E.6 for SPO 8) while the values for SPO 2 has much wider quantiles and higher median and mean values, perhaps reflecting the large proportion of rig catch taken in the trawl fishery off the east coast of the North Island. Although SPO 1 has a lower proportion of trips which report no SPO catch compared to the overall average (22% of SPO 1 trips compared to the overall value of 33%), this average shows no response to the change in reporting form, with Table E.4 showing no drop in proportion of trips with nil SPO after 2007–08, unlike the other four SPO QMAs. This is probably due to the lack of uptake in this QMA of the new NCELR formtype (see discussion in Section 2.3.2 below).

2.3.2 Description landing information for SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8

2.3.2.1 Destination codes in the SPO landing data

Landing data for rig were provided for every trip which 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 kg), 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 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; Table 4). However, other codes (e.g., A, C or W; Table 4) also potentially described valid landings and were included in this analysis but these are all minor compared to code "L". A number of other codes (notably Q and R; Table 4) 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 which could not be reconciled without making unwarranted assumptions and these were not included in the landing data set.

Table 4: Destination codes in the unedited landing data received for the combined SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 analysis dataset. The "how used" column indicates which destination codes were included in the characterisation analysis. These data summaries have been restricted to SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 over the period 1989–90 to 2011–12.

Destination code	Number events	Green weight (t)	Description	How used
L	336 135	35 671.2	Landed in NZ (to LFR)	Keep
A	220	71.1	Accidental loss	Keep
C	523	32.9	Disposed to Crown	Keep
W	2 016	24.2	Sold at wharf	Keep
O	14	11.1	Conveyed outside NZ	Keep
E	275	9.2	Eaten	Keep
F	723	6.0	Section 111 Recreational Catch	Keep
X	57	2.9	QMS returned to sea, except 6A	Keep
U	109	0.9	Bait used on board	Keep
S	16	0.5	Seized by Crown	Keep
M	1	0.2	QMS returned to sea (Part 6A)	Keep
H	8	0.0	Loss from holding pot	Keep
Q	19 365	1 179.4	Holding receptacle on land	Drop
R	4 485	179.2	Retained on board	Drop
D	214	174.6	Discarded (non-ITQ)	Drop
T	258	121.5	Transferred to another vessel	Drop
NULL	228	21.0	Nothing	Drop
B	167	5.0	Bait stored for later use	Drop
P	15	0.4	Holding receptacle in water	Drop

Some of the destination codes (notably "P", "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 catch reporting system because there is no procedure in place to ensure that landings are linked to the appropriate effort. 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 2015). Kendrick & Bentley (2012) noted that this was a particular problem in the SPO 1 setnet fishery, where an increasing proportion of landings (Figure 5) use the intermediate code "Q" because operators in this QMA hold landings in freezers before taking them to a 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 have been examined, and, apart from a minor increase in the quantity of Destination code "Q" in SPO 3 beginning around 2009–10 (Figure 5), there seems to be little evidence of this type of behaviour in the other SPO QMAs (Table 5).

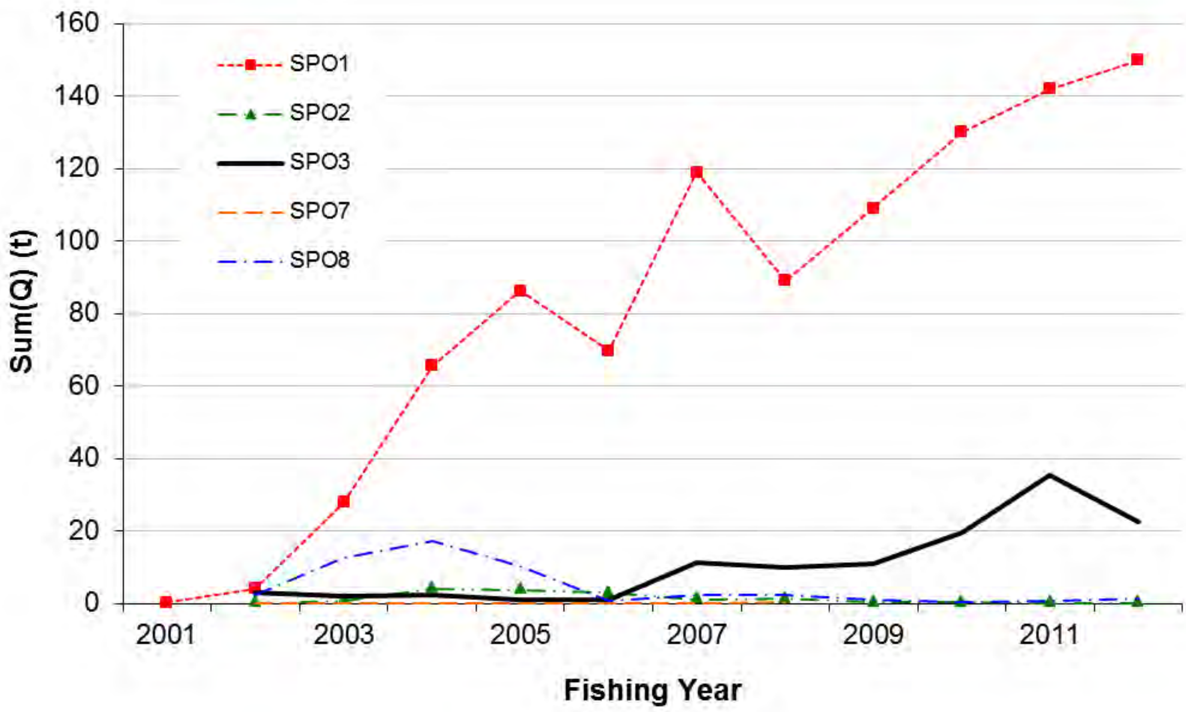

Figure 5: Annual totals for landings with Destination Code "Q" by QMA from 2000–01 to 2011–12.

Table 5: Total landings (t) over the period 1989–90 to 2011–12 by destination codes in the unedited landing data for SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8. The "how used" column indicates which destination codes were included in the characterisation analysis. "–": no landings in the QMA for the indicated destination code.

Destination	SPO 1	SPO 2	SPO 3	SPO 7	SPO 8	How used	Description
L	12 007.6	2 149.9	9 529.9	7 000.7	4 983.2	Keep	Landed in NZ (to LFR)
A	0.6	4.9	28.7	33.1	3.8	Keep	Accidental loss
C	2.3	15.8	9.3	3.8	1.6	Keep	Disposed to Crown
W	15.6	2.3	1.8	0.7	3.9	Keep	Sold at wharf
O	0.2	–	6.0	4.7	0.2	Keep	Conveyed outside NZ
E	0.2	0.0	8.0	0.9	0.1	Keep	Eaten
F	1.7	1.4	1.1	1.5	0.3	Keep	Section 111 Recreational Catch
X	0.1	0.1	–	2.6	0.1	Keep	QMS returned to sea, except 6A
U	0.2	0.1	0.2	0.3	0.0	Keep	Bait used on board
S	0.2	0.0	–	0.3	0.0	Keep	Seized by Crown
M	–	–	0.2	–	–	Keep	QMS returned to sea (Part 6A)
H	0.0	–	0.0	–	–	Keep	Loss from holding pot
Q	993.1	14.4	118.7	2.3	50.8	Drop	Holding receptacle on land
R	37.1	9.6	86.9	33.8	12.0	Drop	Retained on board
D	0.6	24.9	69.3	70.8	9.0	Drop	Discarded (non-ITQ)
T	3.6	0.2	105.1	8.1	4.5	Drop	Transferred to another vessel
Null	6.8	0.7	10.1	1.5	1.9	Drop	Nothing
B	3.7	0.2	0.0	1.0	0.2	Drop	Bait stored for later use
P	0.3	–	–	0.1	–	Drop	Holding receptacle in water

Because it is essential to correct the estimated catches to reflect the landed catch for catch/effort analyses that involve NZ rig (see above and Figure 3), we have adopted the solution proposed by Kendrick & Bentley (2012) when they analysed SPO 1 CPUE. A similar solution has also been adopted for adjusting estimated catches put into holding pots for rock lobster CPUE (Starr 2015). This approach involves estimating, for every vessel participating in the fishery in a fishing year, the ratio of landed/estimated catch. This ratio is then used to correct all estimated catch records without regard to the landed destination code on the form in that fishing year. A description of this algorithm is provided in Appendix F.

Table 6: Total greenweight reported and number of events by state code in the landing file used to process the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 characterisation and CPUE data, arranged in descending landed weight (only for destination codes indicated as "Keep" in Table 4). These data summaries have been restricted to SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 from 1989–90 to 2011–12.

State Code	Number Events	Total reported green weight (t)	Description
DRE	194 068	23 536.9	Dressed
HGU	88 281	7 760.7	Headed and gutted
GRE	34 964	2 852.1	Green (or whole)
GUT	5 607	678.8	Gutted
HGT	3 985	323.8	Headed, gutted, and tailed
MEA	44	288.8	Fish meal
FIN	1 167	214.3	Fins
Other	13 148	174.6	Other[1]

[1] includes (in descending order): gilled and gutted tail-on; fillets: skin-on; dressed-V cut; missing; shark fins; headed, gutted, and finned; fillets: skin-off; flaps.

Table 7: Median conversion factor for the five most important state codes reported in (in terms of total landed greenweight) and the total reported greenweight by fishing year in the edited file used to process SPO landing data. These data summaries include all of the NZ EEZ over the period 1989–90 to 2011–12. '–': no observations. Cells with the same colour indicate periods with consistent conversion factors.

Fishing Year	Landed State Code					
	DRE	HGU	GRE	GUT	HGT	Other
	Median Conversion Factor					
89/90	1.5	2	1	1.1	2	1.1
90/91	2	2	1	1.1	2	1.1
91/92	2	2	1	1.1	–	2.7
92/93	1.75	1.75	1	1.1	–	2.3
93/94	1.75	1.75	1	1.1	–	17.8
94/95	1.75	1.75	1	1.1	–	30
95/96	1.75	1.75	1	1.1	–	30
96/97	1.75	1.75	1	1.1	–	30
97/98	1.75	1.75	1	1.1	–	2.1
98/99	1.75	1.75	1	1.1	–	1
99/00	1.75	1.75	1	1.1	1	1
00/01	1.55	1.55	1	1.1	1	1
01/02	1.55	1.55	1	1.1	1	30
02/03	1.55	1.55	1	1.1	–	30
03/04	1.55	1.55	1	1.1	1	30
04/05	1.55	1.55	1	1.1	1	30
05/06	1.55	1.55	1	1.1	–	2.3
06/07	1.55	1.55	1	1.1	–	5.6
07/08	1.55	1.55	1	1.1	–	30
08/09	1.55	1.55	1	1.1	–	2.1
09/10	1.55	1.55	1	1.1	–	5.6
10/11	1.55	1.55	1	1.1	–	30
11/12	1.55	1.55	1	1.1	1	30

Table 7 (continued):

Fishing Year					Landed State Code	
	DRE	HGU	GRE	GUT	HGT	Other
	Total Landings (t)					
89/90	1.5	911.6	116.0	15.5	47.1	63.9
90/91	573.6	462.4	148.3	137.6	9.0	23.9
91/92	602.0	659.2	206.4	126.1	–	33.0
92/93	692.4	614.2	220.6	82.1	–	3.1
93/94	800.1	565.2	275.3	43.6	–	15.8
94/95	1 033.4	515.6	228.4	38.2	0.0	12.0
95/96	1 110.5	543.4	181.7	59.0	2.1	22.4
96/97	1 170.6	531.1	132.1	41.8	3.3	53.2
97/98	1 132.6	448.3	109.2	15.6	17.1	27.0
98/99	1 128.8	335.0	95.2	21.0	74.3	48.5
99/00	1 211.4	265.8	134.8	25.6	70.7	12.9
00/01	1 208.6	242.6	95.5	24.1	51.5	37.1
01/02	1 147.4	211.2	63.7	4.9	18.3	25.5
02/03	1 161.0	240.0	55.6	3.9	15.6	16.8
03/04	1 135.0	201.3	77.1	8.6	5.2	15.3
04/05	1 109.5	202.5	53.4	1.6	3.3	25.0
05/06	1 058.8	179.7	52.7	2.4	1.9	5.2
06/07	1 234.4	86.2	62.2	1.6	–	15.6
07/08	1 209.8	71.6	66.4	1.7	–	17.4
08/09	1 063.4	80.3	30.6	2.8	–	8.0
09/10	1 155.4	76.6	31.3	5.6	–	4.9
10/11	1 155.7	66.0	28.6	3.3	–	6.2
11/12	1 178.3	94.9	28.8	2.8	0.0	12.1
Total	23 273.9	7 604.7	2 493.7	669.3	319.4	504.7

Table 8.: **Distribution of total adjusted (Eq. 2) landings (t) by rig Fishstock and by fishing year for all trips that recorded SPO landings, regardless of QMA. Landing records with improbable greenweights have been dropped (see Appendix D).**

Fishing year	SPO 1	SPO 2	SPO 3	SPO 7	SPO 8	Total
89/90	349.3	40.9	201.8	206.1	141.2	939.3
90/91	467.1	39.0	245.4	224.8	142.7	1 119.0
91/92	631.2	69.8	302.2	234.4	104.1	1 341.8
92/93	638.3	80.8	255.0	289.9	198.6	1 462.5
93/94	632.0	88.6	306.8	287.4	226.9	1 541.7
94/95	617.1	76.3	380.1	333.9	239.8	1 647.2
95/96	561.9	107.9	394.7	367.9	285.6	1 718.0
96/97	614.2	86.6	438.3	350.0	222.5	1 711.7
97/98	536.6	70.5	402.2	294.9	241.3	1 545.4
98/99	529.3	74.9	379.1	308.9	198.6	1 490.9
99/00	567.7	76.5	400.9	306.8	186.6	1 538.6
00/01	567.9	80.1	480.3	348.4	167.1	1 643.9
01/02	464.5	87.5	400.8	289.1	212.2	1 454.2
02/03	486.2	88.0	434.2	266.0	206.0	1 480.4
03/04	487.4	79.7	368.5	298.0	201.7	1 435.2
04/05	435.4	106.0	373.3	263.3	207.5	1 385.6
05/06	347.5	109.2	384.4	290.1	166.2	1 297.4
06/07	405.8	100.7	445.7	263.4	176.5	1 392.2
07/08	307.7	102.3	482.6	242.1	221.0	1 355.7
08/09	295.0	103.9	328.2	233.5	222.8	1 183.4
09/10	307.3	111.8	377.9	230.0	245.1	1 272.1
10/11	315.9	104.2	387.7	233.5	216.3	1 257.5
11/12	326.9	118.5	434.7	229.5	200.6	1 310.2
Total	10 892.3	2 003.8	8 604.7	6 392.0	4 631.0	32 523.9

Table 9: Distribution by form type for landed catch by weight for each fishing year in the combined SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 landings dataset. Also provided are the number of days fishing and the associated distribution of days fishing by form type for the effort data in the combined SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 dataset. See Appendix A for definitions of abbreviations used in this table.

	Landings (%)[1]			Days Fishing (%)[2]					Days Fishing						
	CELR	CLR	NCELR	CELR	TCEPR	TCER	NCELR	LTCER	CELR	TCEPR	TCER	NCEL	LTCER	Other[3]	Total
89/90	97	3	0	92	8	–	–	–	20 109	1 804	–	–	–	–	21 913
90/91	98	2	0	93	7	–	–	–	23 326	1 804	–	–	–	–	25 130
91/92	96	4	0	93	7	–	–	–	27 568	1 998	–	–	–	–	29 566
92/93	98	2	0	94	6	–	–	–	30 954	1 909	–	–	–	1	32 864
93/94	97	3	0	92	8	–	–	–	28 742	2 665	–	–	–	–	31 407
94/95	97	3	0	90	10	–	–	–	28 761	3 144	–	–	–	–	31 905
95/96	93	7	0	82	18	–	–	–	25 805	5 518	–	–	–	2	31 325
96/97	93	7	0	84	16	–	–	–	26 769	5 144	–	–	–	–	31 913
97/98	94	6	0	81	19	–	–	–	24 848	5 678	–	–	–	5	30 531
98/99	94	6	0	83	17	–	–	–	26 028	5 203	–	–	–	2	31 233
99/00	93	7	0	84	16	–	–	–	26 411	4 983	–	–	–	2	31 396
00/01	93	7	0	82	18	–	–	–	25 409	5 711	–	–	–	–	31 120
01/02	93	7	0	79	21	–	–	–	22 043	5 838	–	–	–	36	27 917
02/03	91	9	0	81	19	–	–	–	23 338	5 651	–	–	–	–	28 989
03/04	92	8	0	80	20	–	–	–	22 540	5 655	–	–	–	56	28 251
04/05	93	8	0	81	19	–	–	–	23 534	5 361	–	–	–	1	28 896
05/06	93	7	0	83	17	–	0	–	22 872	4 681	–	1	–	24	27 578
06/07	43	7	50	70	16	–	14	–	20 089	4 466	–	4 142	–	76	28 773
07/08	14	29	57	18	13	47	16	5	4 709	3 490	12 361	4 235	1 327	89	26 211
08/09	21	30	49	20	11	47	16	6	5 269	2 971	12 284	4 116	1 497	102	26 239
09/10	19	33	49	19	9	52	15	6	5 238	2 607	14 438	4 065	1 558	59	27 965
10/11	18	32	51	20	10	49	14	7	5 408	2 657	13 280	3 884	1 850	28	27 107
11/12	21	33	46	21	11	48	14	6	5 672	2 810	12 797	3 764	1 675	–	26 718
Total	77	11	12	72	14	10	4	1	475 442	91 748	65 160	24 207	7 907	483	664 947

[1] Percentages of landed greenweight
[2] Percentages of number of days fishing
[3] includes 431 days for TUN (tuna lining) and 431 days for LCER (lining)

2.3.2.2 State codes in the SPO landing data

Almost all (87%) of the valid landing data for SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 were reported using state code DRE or HGU, with the majority (8%) of the remaining landings using the state code GRE (Table 6). The few remaining landings (less than 5%) were distributed among GUT, HGT, MEA and FIN codes. There have been substantial changes in the conversion factors for the two primary state codes (DRE and HGU) used for processing SPO (Table 7). These changes occurred twice in the first 12 years of data and led to important changes in how the landings data are interpreted for this species. Consequently, all landings have been converted (Eq. 2) to a consistent conversion factor, representing the conversion factors that have been in place from 2000–01 onward.

Green weight landings $\left(G_{i,y}^{'}\right)$ were adjusted for the CPUE analysis and for some parts of the characterisation analysis for state codes DRE, HGU, FIL and HGT to a consistent conversion factor using the following equation:

Eq. 2 $$G_{i,s,y}^{'} = G_{i,s,y} \, {cf_{i,s,2000-01}} \big/ {cf_{i,s,y}}$$

where

$G_{i,s,y}$ is the reported green weight for record *i* using landed state code *s* in year *y*;

$cf_{i,s,y}$ is the conversion factor for record *i* using landed state code *s* in year *y*;

$cf_{i,s,2000-01}$ is the conversion factor for record *i* using landed state code *s* in year 2000–01 (=1.55 for DRE and HGU)

A convention adopted in this analysis was to drop the landings for state codes FIN, FLP (flaps), SHF (shark fins) and ROE when there was more 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 all were dropped to avoid potential double counting.

Total landings available in the data set are primarily from SPO 1, SPO 3, SPO 7, SPO 8 and finally SPO 2 (in descending order of importance) (Table 8). These annual totals have been adjusted upwards to match the QMR/MHR totals (see Table C.1) using Eq. 1.

2.3.2.3 Form types used in the SPO landing and effort data

Just under eighty percent of the total SPO landings in the NZ EEZ have been reported on CELR forms over the 23 years of record, with the remaining landings split between the CLR and the new NCELR forms (Table 9). However, the proportion of landings reported on the CELR form dropped to less than 20% once both the NCELR and the TCER forms had been introduced in 2006–07 and 2007–08 respectively. The NCELR form is used to report setnet effort and landings while the TCER form reports the effort for bottom trawl vessels between 6 and 28 m in total length. The CLR form is used to report landings forms other than the CELR and NCELR forms, particularly the TCER and TCEPR trawl effort forms. The only exception to this change in form type preference has been in SPO 1, where the proportion of landings reported on the CELR form only dropped from around 90% to 50%, while in the other four SPO QMAs, the proportion of landings reported on the CELR form dropped to less than 20% in most QMAs and was often less than 10% (Figure 6). The reason for this difference in the use of form types in SPO 1 is that MPI does not require that the NCELR and TCER forms be used by vessels less than 6 m in length, and there is a relatively large proportion of SPO 1 setnet vessels which are less than that length threshold, particularly those operating in the more protected waters of Manukau and Kaipara Harbours and the Firth of Thames. There was a corresponding drop in the usage of the CELR form in the effort data, beginning from 2006–07 (calculated as days fishing, Table 9) and an increase in the use of other form types in the effort dataset after that year.

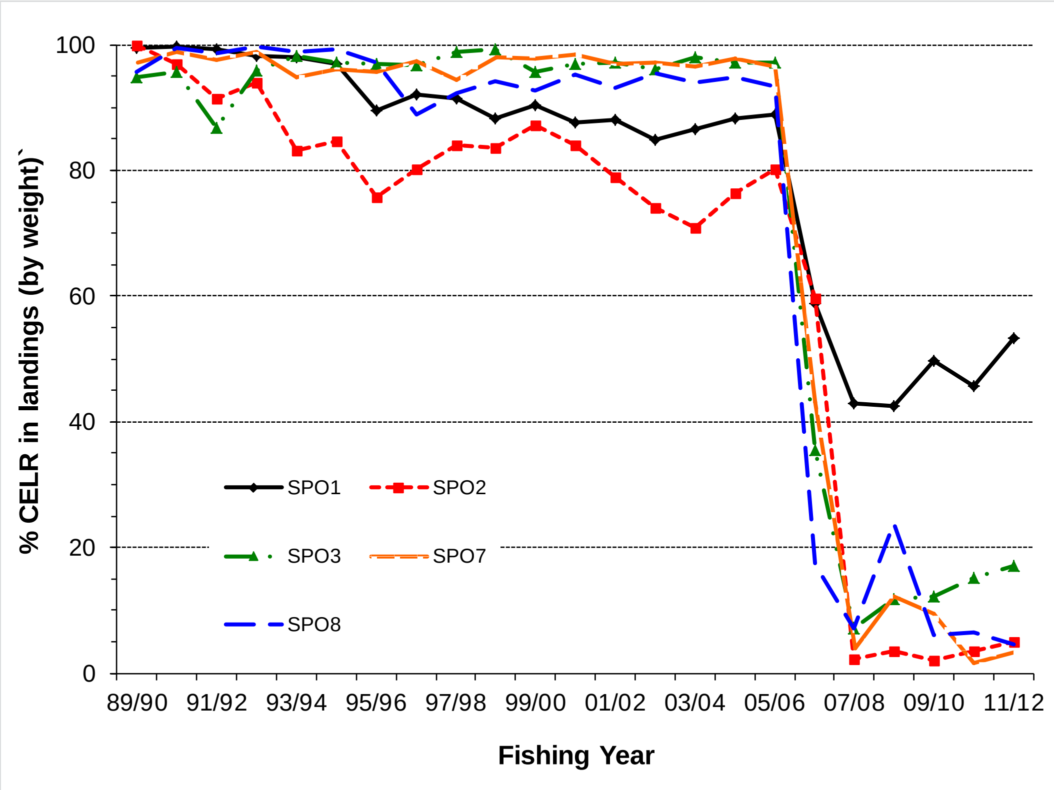

Figure 6: Time series of the percentage of landings (by weight) reported on the CELR form for each QMA in the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 dataset.

2.3.3 Description of the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 fisheries

2.3.3.1 Introduction

As discussed in Section 2.3.1, landings were matched with effort for every trip while maintaining the integrity of the QMA-specific information. This procedure worked well for all SPO QMAs except for SPO 8, where about 25% of the catch was lost because trips were dropped which fished in shared statistical areas and reported landings from more than one QMA. The relatively high level of loss in SPO 8 occurs because nearly all of the SPO 8 statistical areas are shared with either SPO 1 or SPO 7 (Appendix B). This amount of lost landings was considered acceptable for the purpose of characterising the fishery, but was not accepted for CPUE analyses, where trips were assigned to statistical areas without maintaining the integrity of the QMA information. The CPUE analysis data were then selected on the basis of the statistical area fished rather than by the QMA.

The characterisation information in this section is presented by SPO QMA, except for SPO 1, which has been split into "East" and "West" components that correspond to FMAs 1 and 9 (see Appendix B for the locations of these FMAs):

SPO QMA reported	Statistical Area definition
SPO 1E	001–010,105–107
SPO 2	
SPO 3	
SPO 7	
SPO 8	
SPO 1W	041–048, 101–104

Characterisation information from SPO 1E and SPO 1W in the following sections will be treated as if they come from separate QMAs in recognition that these fisheries are located in management areas that substantially differ from each other, at a level similar to the differences seen between the remaining SPO QMAs.

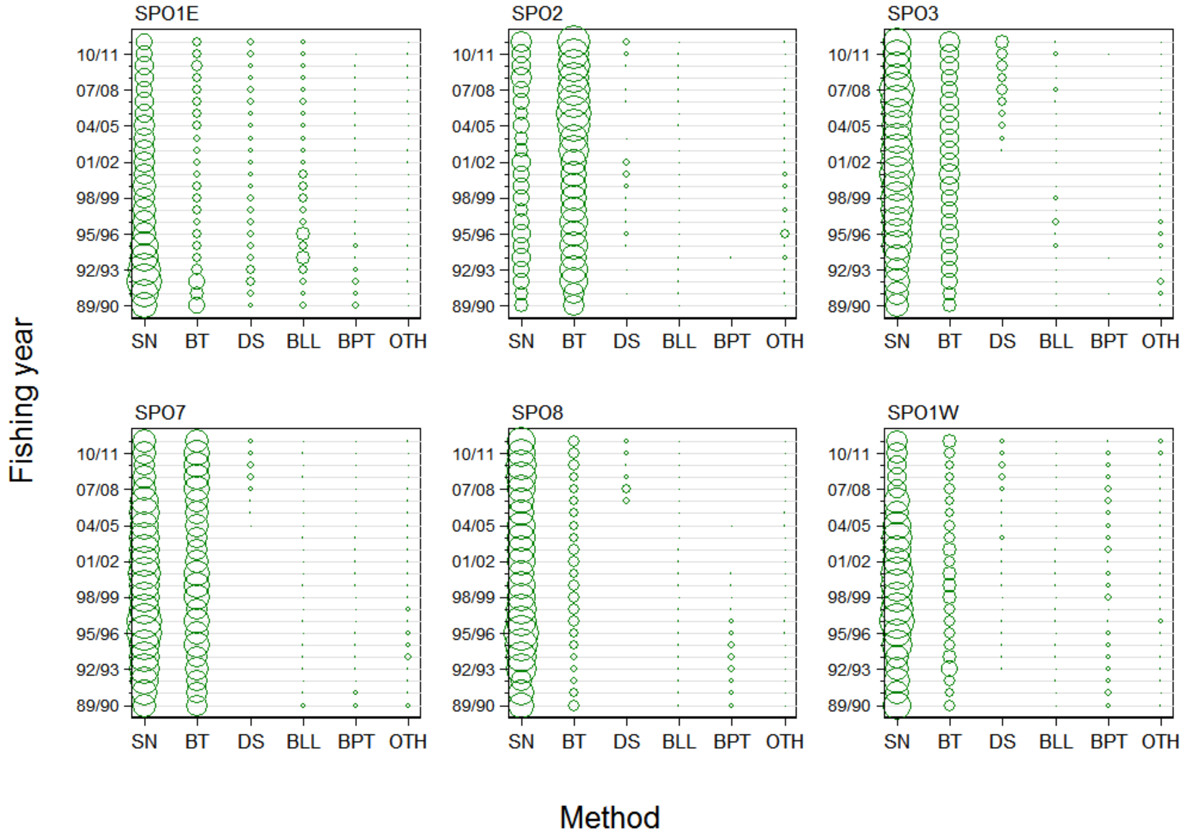

Figure 7: Distribution of rig landings for the major fishing methods by fishing year by SPO QMA from 1989–90 to 2011–12. Circles are proportional to the catch totals by method and fishing year within each sub-graph: [SPO 1E]: largest circle= 383 t in 91/92 for SN; [SPO 2]: largest circle= 96 t in 05/06 for BT; [SPO 3]: largest circle= 352 t in 07/08 for SN; [SPO 7]: largest circle= 237 t in 95/96 for SN; [SPO 8]: largest circle= 265 t in 95/96 for SN; [SPO 1W]: largest circle= 331 t in 96/97 for SN. Data for these plots are presented in Table G.1.

Table 10: Total landings (t) and distribution of landings (%) for rig for important fishing methods over the SPO QMAs from trips which landed rig, summed from 1989–90 to 2011–12.

						Method	
Major Area	**SN**	**BT**	**DS**	**BLL**	**BPT**	**OTH**	**Total**
	Total landings (t)						
SPO 1E	3 893.7	756.8	306.2	429.3	58.1	11.1	5 455.2
SPO 2	517.7	1 487.5	22.1	4.2	0.4	21.1	2 053.1
SPO 3	5 906.2	2 073.9	268.3	48.1	0.2	50.4	8 347.0
SPO 7	3 690.9	2 480.9	37.7	13.5	14.9	41.8	6 279.6
SPO 8	4 156.9	515.7	37.4	13.2	50.3	3.9	4 777.4
SPO 1W	4 499.9	926.5	64.7	11.5	150.7	35.5	5 688.7
Total	22 665.3	8 241.4	736.4	519.7	274.5	163.8	32 601.0
	Distribution of landings (%)						
SPO 1E	71.4	13.9	5.6	7.9	1.1	0.2	16.7
SPO 2	25.2	72.5	1.1	0.2	0.0	1.0	6.3
SPO 3	70.8	24.8	3.2	0.6	0.0	0.6	25.6
SPO 7	58.8	39.5	0.6	0.2	0.2	0.7	19.3
SPO 8	87.0	10.8	0.8	0.3	1.1	0.1	14.7
SPO 1W	79.1	16.3	1.1	0.2	2.6	0.6	17.4
Total	69.5	25.3	2.3	1.6	0.8	0.5	100.0

2.3.3.2 Distribution of landings and effort by method of capture and QMA

Rig in five of the six QMAs are primarily taken by the setnet method, except for SPO 2, where bottom trawl catches of rig exceed setnet catches in most years (Figure 7; Table 10; Table G.1). SPO 2 is also the QMA with the least amount of landings (6% of the total New Zealand rig landings; Table 10). Bottom trawl landings of rig are also relatively large in SPO 7, probably because of the existence of the considerable west coast South Island inshore trawl fisheries for barracouta, stargazer, red gurnard and red cod. Rig landings by other methods are extremely minor in most QMAs, with the combined setnet and bottom trawl landings accounting for over 95% of landings in all QMAs except for SPO 1E, where 85% of the total landings are taken by these two methods. Most of the remaining SPO 1E rig landings are taken by Danish seine (6%) and bottom longline (8%) (Table 10).

2.3.3.3 Fine scale distribution of landings and CPUE for setnet and bottom trawl

Fine scale catch and effort data are available for the setnet fleet from 1 October 2006 onwards. Plots (North Island: Figure 8; South Island: Figure 9) showing scaled estimated catches gridded into 0.1×0.1° cells, summed over six years, show limited locations where rig have been taken using the setnet method, with concentrations of catch on the North Island in the North and South Taranaki Bights (Figure 8) and on the east coast in the western Bay of Plenty. Positional information for the SPO 1E and SPO 1W setnet fisheries will be limited because of the high proportion of the landings which are reported on the CELR form (see Figure 6). The majority of the vessels reporting on the CELR form in SPO 1 will be small vessels (less than 6 m in total length) fishing in the Manukau and Kaipara Harbours on the west and the Thames estuary on the east coasts of the North Island. Fine scale CPUE has not been reported for the North Island, given the low level of uptake for the NCELR data forms and the high proportion of Q destination codes in the SPO 1 data (see Figure 5).

Positional information for the South Island setnet catches are likely to be better reported because of the much greater use of the NCELR forms, with rig setnet catches concentrated in the lower part of the Canterbury Bight, extending down to Dunedin, in Foveaux Strait, and in Tasman and Golden Bays (Figure 9). The distribution of fine scale setnet CPUE resembles the catch distribution, with CPUE being greater in Tasman/Golden Bays than on the east and south coasts of the South Island (Figure 10). The specific nature of the distribution of rig setnet catches may reflect where this species can be caught profitably with this gear, instead of the actual distribution of this species (given the ubiquitous nature of the distribution of trawl landings – see following paragraphs).

Bottom trawl landings of rig occur almost everywhere on both coasts of the North Island (Figure 11). There is a wide range of areas where landings are relatively concentrated, ranging from Hawke Bay northward around East Cape and into the eastern Bay of Plenty. There are areas of relatively high concentrations of trawl landings of rig in North Cape and parts of the North and South Taranaki Bights. Rig trawl CPUE is relatively low along the east coast of the North Island, right up to North Cape (Figure 12), but substantially higher at the top part of the west coast of the North Island and the South Taranaki Bight (Figure 12).

As seen in the North Island, the distribution of rig landings on the South Island is broad and ubiquitous (Figure 13). The entire South Island west coast, extending from Tasman/Golden Bays to Fiordland, show concentrations of rig catches using trawl gear. East coast South Island trawl rig catches are less extensive, with concentrations in the eastern approach to Cook Strait, Pegasus Bay and parts of Canterbury Bight. Rig CPUE based on trawl data is less uniform, but still is relatively strong along the entire west coast of the South Island and the outer parts of Tasman/Golden Bays (Figure 14). CPUE for rig based on trawl gear appears to be relatively low along most of the South Island east coast, with the possible exception of the eastern entrance to Cook Strait. The widespread distribution of rig along both coasts of the North and South Islands, as demonstrated by the broad and even spread of catches of this species by trawl gear, indicates the ubiquitous nature of rig distribution in NZ inshore waters.

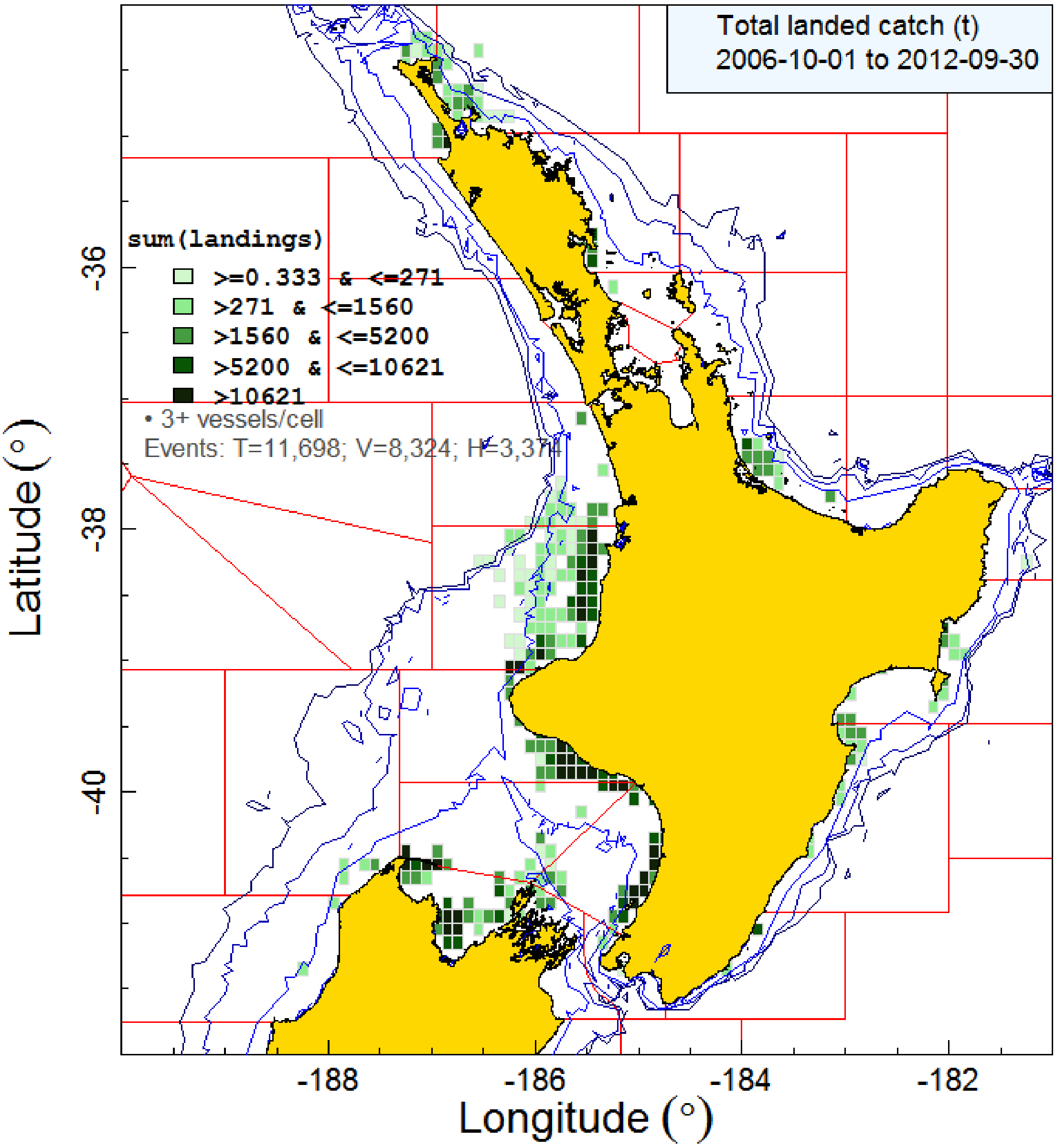

Figure 8. **Total setnet scaled estimated catches (t) for rig around the North Island, arranged in 0.1°×0.1° grids, summed from 2006–07 to 2011–12. Legend colours divide the distribution of total landings into approximate 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.**

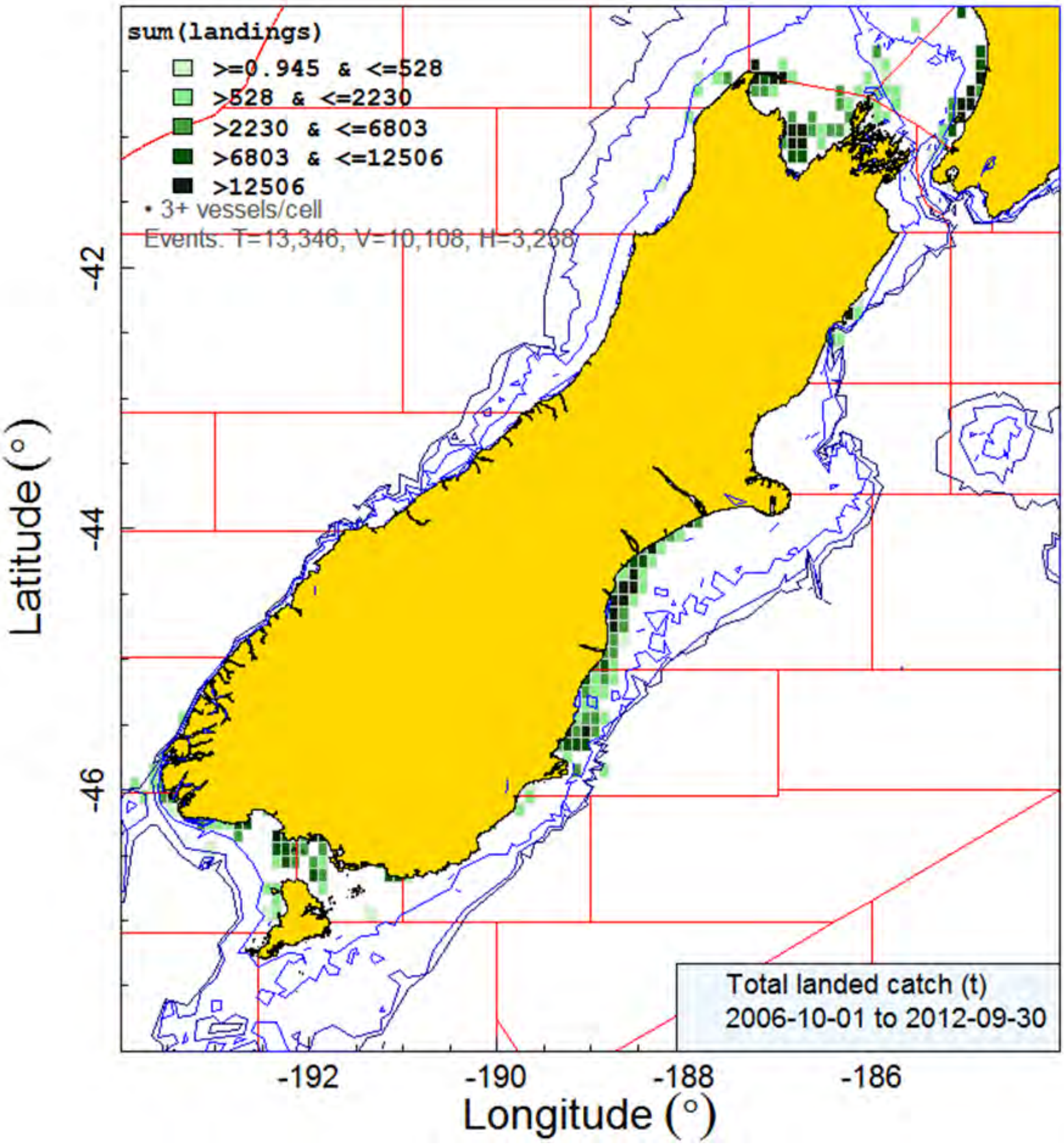

Figure 9: **Total setnet scaled estimated catches (t) for rig around the South Island, arranged in 0.1°×0.1° grids, summed from 2006–07 to 2011–12. Legend colours divide the distribution of total landings into approximate 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.**

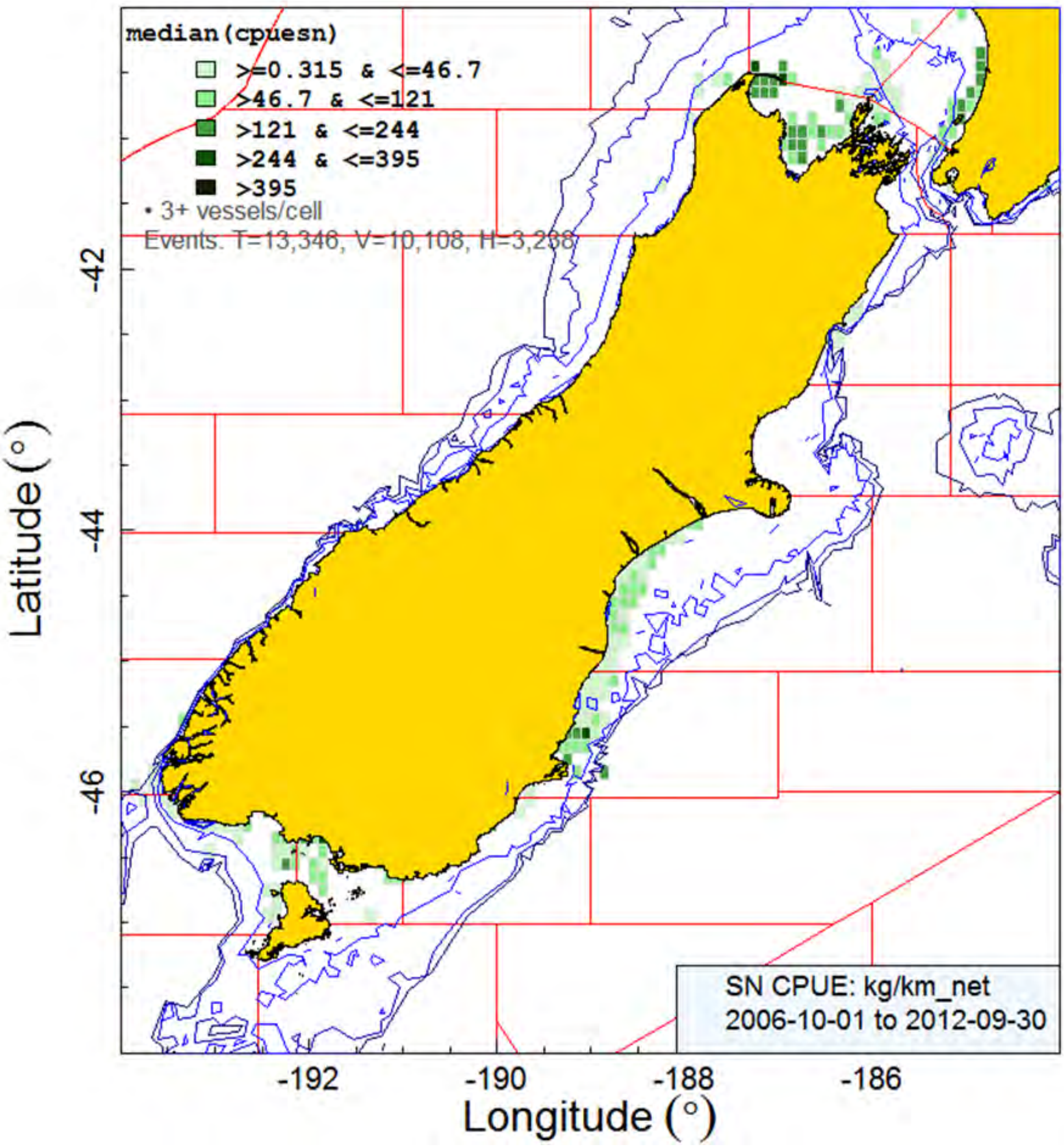

Figure 10: Total setnet CPUE (kg/km) for rig around the South Island, arranged in 0.1°×0.1° grids, averaged from 2006–07 to 2011–12. Legend colours divide the distribution of total landings into approximate 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.

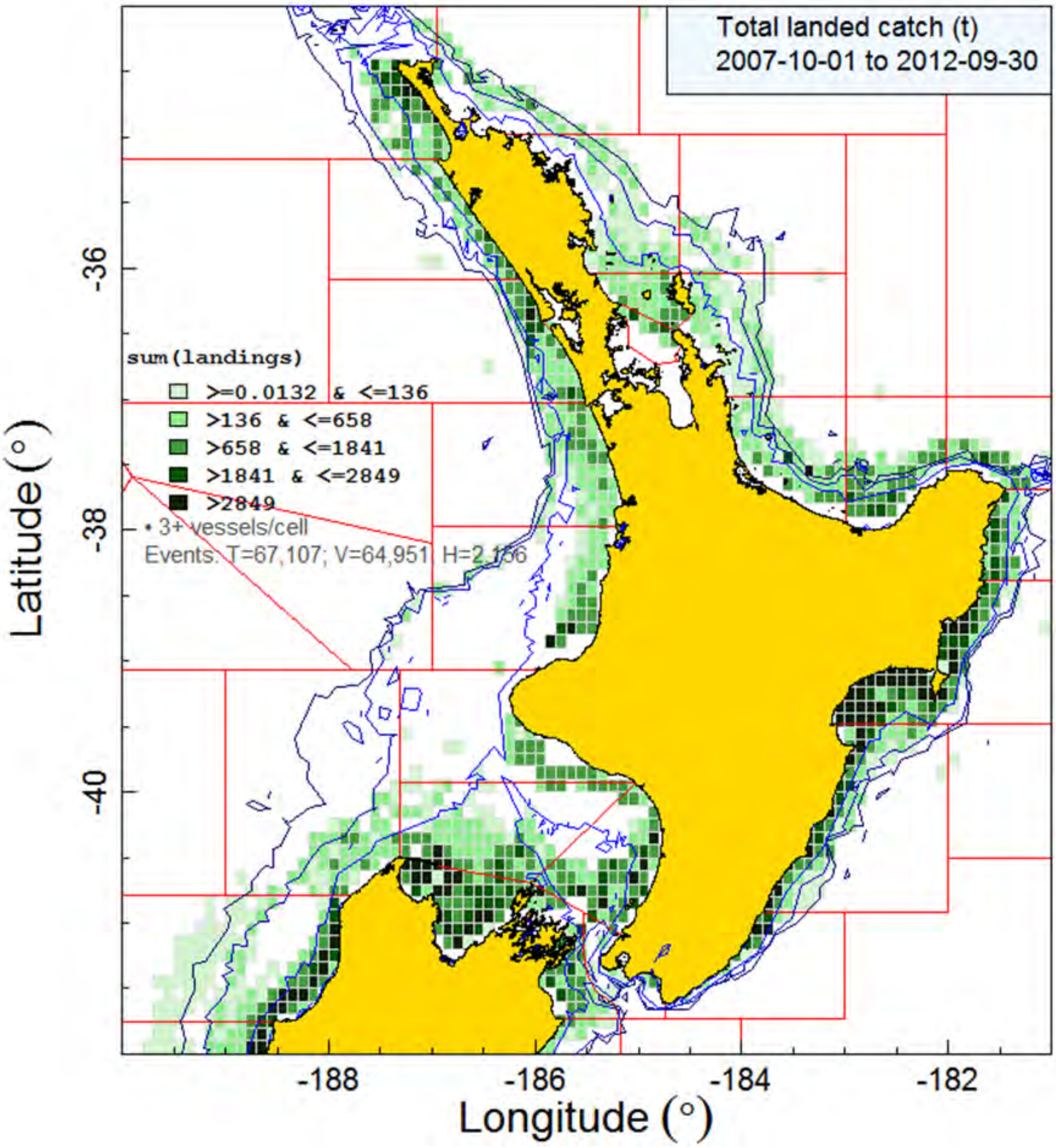

Figure 11: **Total bottom trawl scaled estimated catches (t) for rig around the North Island, arranged in 0.1°×0.1° grids, summed from 2007–08 to 2011–12. Legend colours divide the distribution of total landings into approximate 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.**

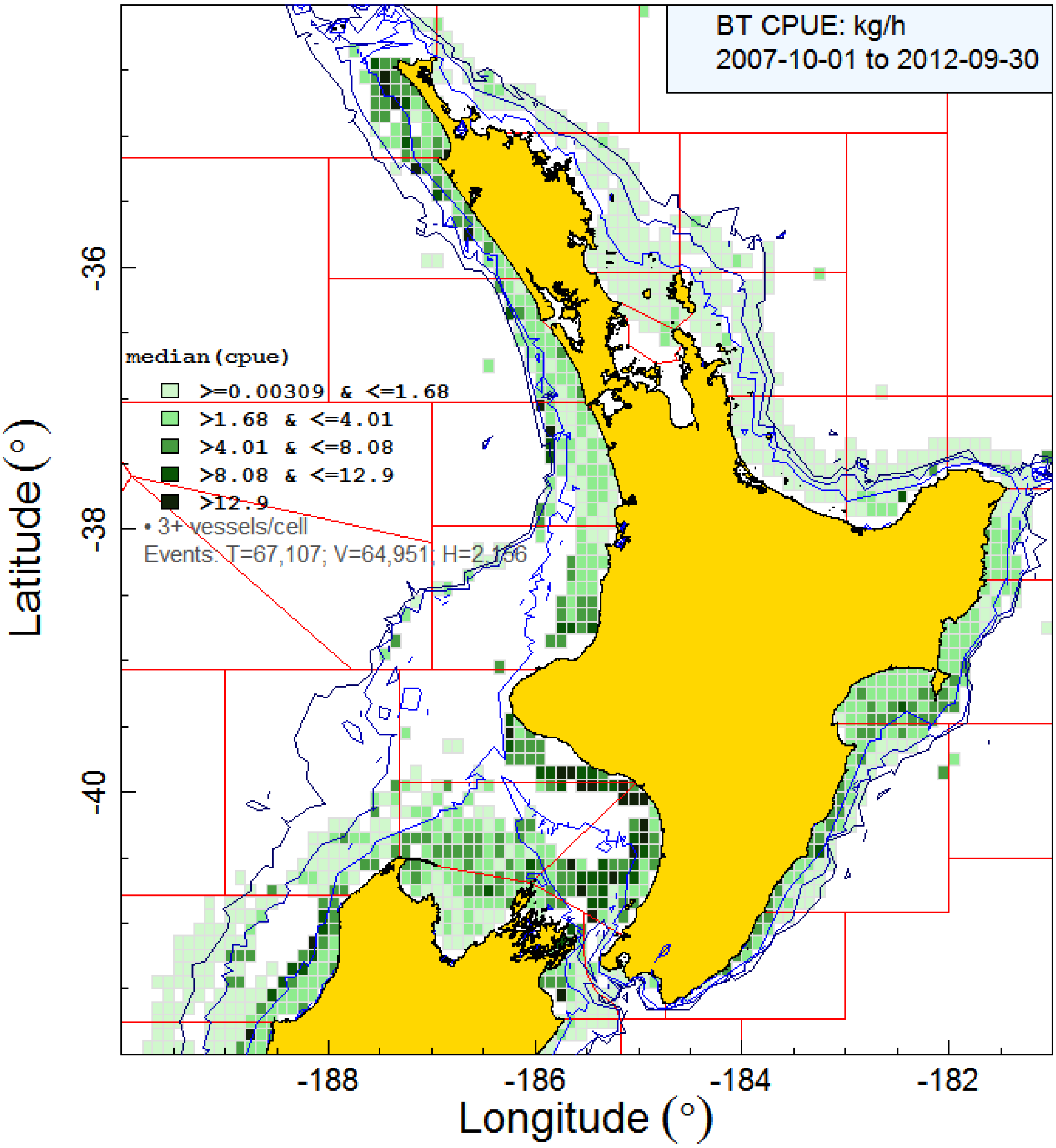

Figure 12: Total bottom trawl CPUE (kg/h) for rig around the North Island, arranged in 0.1°×0.1° grids, summed from 2007–08 to 2011–12. Legend colours divide the distribution of total landings into approximate 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.

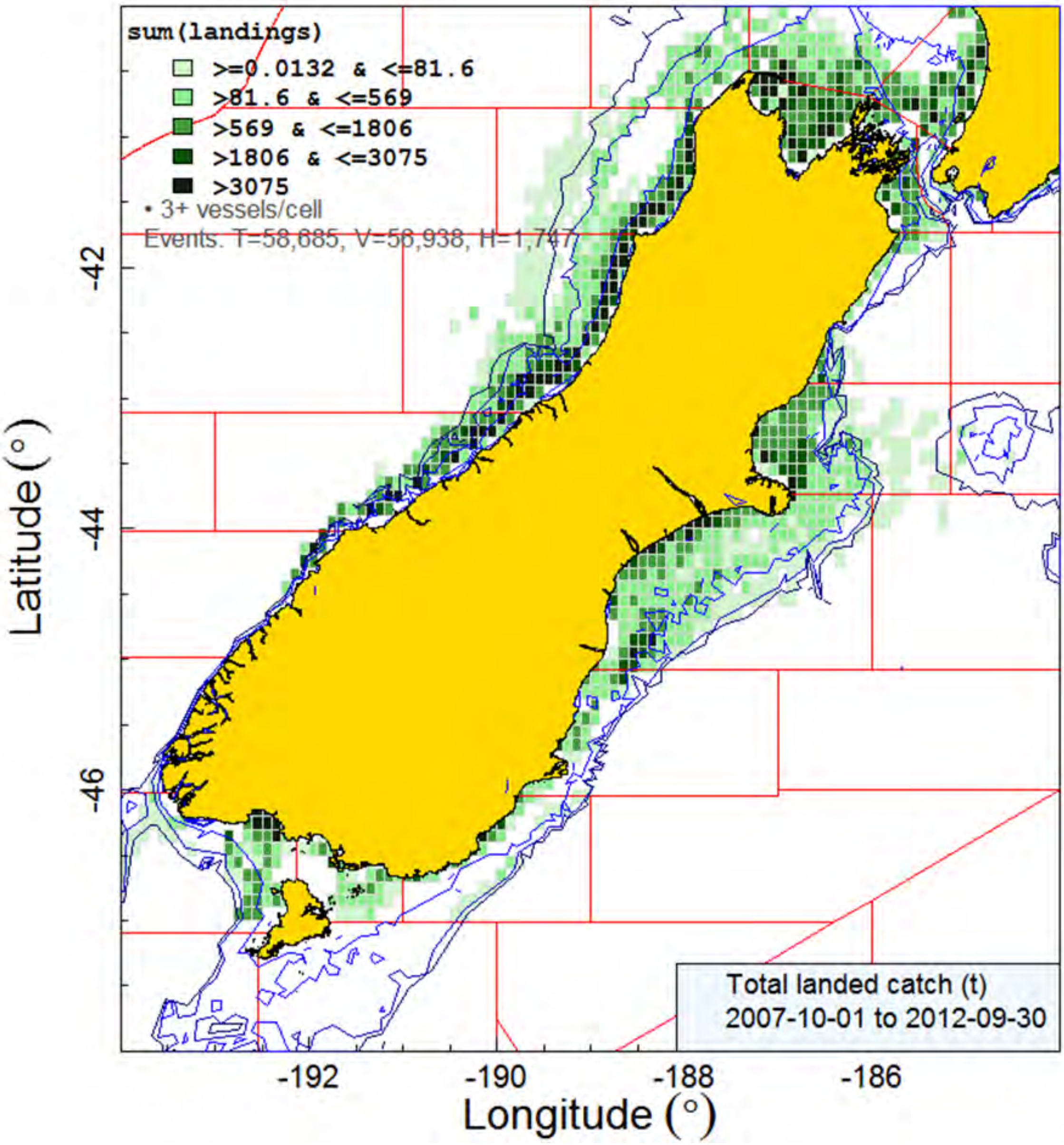

Figure 13: **Total bottom trawl scaled estimated catches (t) for rig on the South Island, arranged in 0.1°×0.1° grids, summed from 2007–08 to 2011–12. Legend colours divide the distribution of total landings into approximate 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.**

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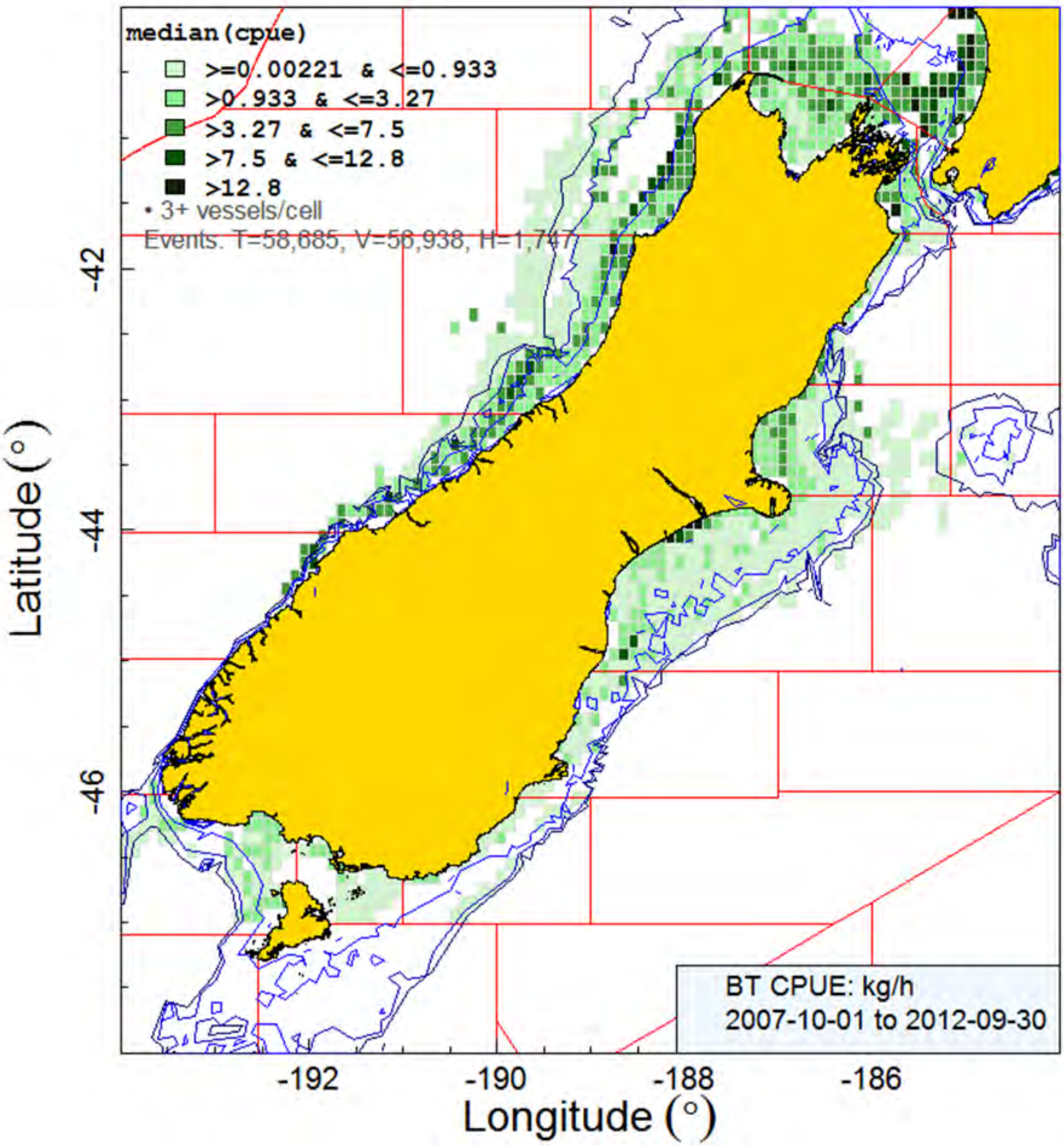

Figure 14: Total bottom trawl CPUE (kg/h) for rig around the South Island, arranged in 0.1°×0.1° grids, summed from 2007–08 to 2011–12. Legend colours divide the distribution of total landings into approximate 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.

2.3.3.4 Seasonal distribution of landings

The rig setnet fishery tends to be seasonal, with the majority of landings taking place in the spring and early summer in four of the six QMAs (Figure 15; Table G.2). Setnet landings in SPO 2 and SPO 8 appear to have greater temporal spread, with landings in both SPO 2 and SPO 8 extending to May in most years. In general, landings in SPO 3 and SPO 7 appear to extend further into the year than in either SPO 1E and SPO 1W; with catches from the South Island QMAs extending to March in many years and those in SPO 1 tending to drop off in December or January (Figure 15). All six QMAs show an increase in landings in September, the final month in the statutory finfish fishing year (Figure 15; Table G.2). This increase in landings probably represents an attempt to catch residual ACE that remains in the fishing year.

The seasonal distribution of bottom trawl rig landings is much more uniform across all months in all six QMAs, particularly when compared to the seasonal setnet landings (Figure 16; Table G.3). This uniformity in the seasonality of trawl landings of rig probably reflects the timing of the target species of interest to the fishery, rather than having much to do with the availability of rig. This is because trawl fisheries rarely target rig (see following Section), but target a range of species throughout the year, and therefore tend to capture rig as an associated catch while targeting the more abundant or desirable species. There is some structure in the seasonal catch of rig in SPO 2, SPO 3 and SPO 7, with winter landings of rig tending to diminish in the 1990s, but this effect appears to have diminished in recent years (Figure 16). However, the broad seasonal distribution of rig landings from the trawl fleet demonstrates that rig are likely to be present year-round in the New Zealand inshore waters.

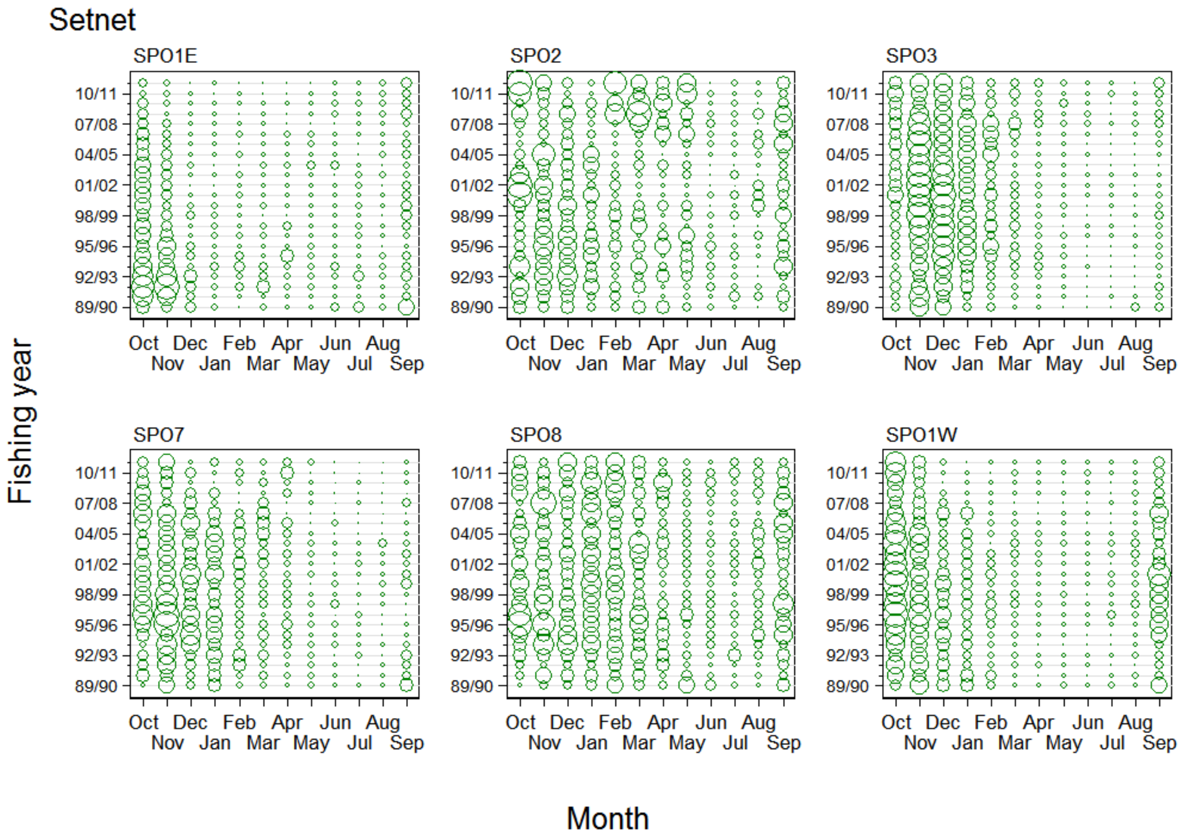

Figure 15: Distribution of landings by month and fishing year for setnet in each SPO QMA based on trips which landed rig. Circle sizes are proportional within each panel: [SPO 1E]: largest circle= 143 t in 91/92 for Nov; [SPO 2]: largest circle= 9.2 t in 01/02 for Oct; [SPO 3]: largest circle= 112 t in 01/02 for Nov; [SPO 7]: largest circle= 84 t in 95/96 for Nov; [SPO 8]: largest circle= 57 t in 95/96 for Oct; [SPO 1W]: largest circle= 99 t in 96/97 for Oct. Values for the plotted data are provided in Table G.2

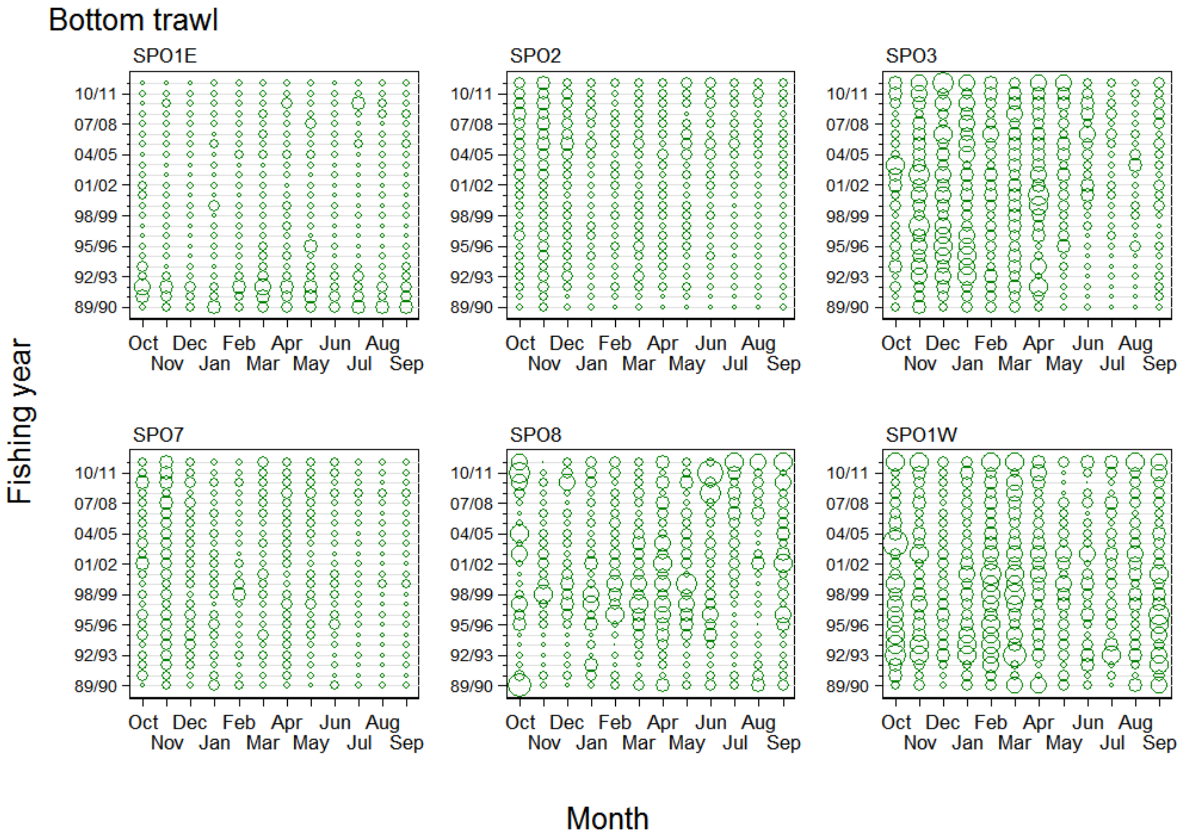

Figure 16: Distribution of landings by month and fishing year for bottom trawl in each SPO QMA based on trips which landed rig. Circle sizes are proportional within each panel: [SPO 1E]: largest circle= 12 t in 91/92 for Oct; [SPO 2]: largest circle= 12 t in 08/09 for Oct; [SPO 3]: largest circle= 26 t in 11/12 for Dec; [SPO 7]: largest circle= 25 t in 09/10 for Nov; [SPO 8]: largest circle= 11 t in 10/11 for Jun; [SPO 1W]: largest circle= 14 t in 03/04 for Oct. Values for the plotted data are provided in Table G.3.

2.3.3.5 Distribution of landings by declared target species

The setnet fisheries taking rig are almost exclusively targeted at this species in each of the six QMAs (Figure 17; Table 11; Table G.4). The only exceptions to this are found in SPO 2, where the setnet fishery also targets blue warehou and blue moki, and in SPO 3 where there is some targeting of school shark. The dominant target species in the remaining four setnet fisheries is rig (Table 11). This is particularly true for the two SPO 1 setnet fisheries: there are virtually no other declared target species other than rig.

Target species for the bottom trawl fisheries is much more complex, with each QMA showing a different set of target species (Figure 18; Table 11; Table G.5). What is clear is that SPO is rarely declared as a target in any of these areas. The SPO 1E bottom trawl fishery is primarily targeted at snapper, with some targeting of tarakihi and red gurnard. The SPO 2 trawl fishery is mainly targeted at gurnard and tarakihi, with some minor targeting of flatfish species. The SPO 3 trawl fishery is more diverse, targeting flatfish, red cod, stargazer and, more recently, elephantfish, while capturing rig as a bycatch. The SPO 7 trawl fishery targets flatfish, red cod, barracouta and tarakihi, while the SPO 8 fishery targets gurnard, trevally and tarakihi. Finally, the SPO 1W trawl fishery targets snapper, trevally, gurnard and tarakihi.

Table 11: Total landings (t) and distribution of landings (%) for rig by target species and method of capture for each major area (Table G.1) from trips which landed rig, summed from 1989–90 to 2011–12. "–": no data for indicated QMA/method/target species cell.

Target species	Method of Capture (t)							Method of Capture (%)						
	SN	BT	DS	BLL	BPT	Other	Total	SN	BT	DS	BLL	BPT	Other	Total
SPO 1E														
SPO	3 140	5	2	108	–	1	3 256	96.4	0.1	0.1	3.3	–	0.0	59.7
SNA	238	369	160	300	49	3	1 120	21.3	33.0	14.3	26.8	4.3	0.3	20.5
TRE	185	69	2	0	7	1	264	69.9	26.1	0.8	0.0	2.6	0.6	4.8
FLA	183	2	7	0	–	0	192	95.3	0.9	3.7	0.0	–	0.1	3.5
GUR	30	51	68	4	1	0	153	19.5	33.2	44.2	2.4	0.5	0.2	2.8
JDO	2	89	60	0	0	0	151	1.0	59.2	39.5	0.0	0.1	0.2	2.8
TAR	16	125	6	1	1	0	149	10.6	84.0	4.1	0.4	0.8	0.1	2.7
KAH	35	0	0	0	–	0	36	99.0	0.2	0.0	0.0	–	0.7	0.7
SKI	1	21	0	0	0	0	22	3.5	96.0	0.0	0.2	0.2	0.1	0.4
OTH	64	26	1	16	1	4	112	57.2	23.5	0.8	14.4	0.5	3.6	2.1
Total	3 894	757	306	429	58	11	5 455	71.4	13.9	5.6	7.9	1.1	0.2	100.0
SPO 2														
GUR	12	707	20	0	0	0	739	1.6	95.6	2.7	0.0	0.1	0.0	36.0
TAR	6	498	0	0	–	0	504	1.2	98.8	0.0	0.0	–	0.0	24.5
SPO	172	1	–	–	–	0	173	99.3	0.4	–	–	–	0.2	8.4
FLA	59	92	1	–	–	0	152	38.6	60.8	0.5	–	–	0.1	7.4
WAR	112	23	–	0	–	0	135	82.7	17.3	–	0.0	–	0.0	6.6
MOK	83	3	–	–	–	0	86	96.4	3.6	–	–	–	0.0	4.2
SKI	0	37	–	0	–	1	38	0.5	97.2	–	0.0	–	2.3	1.9
SNA	0	32	1	1	–	0	35	0.5	94.1	3.5	1.7	–	0.2	1.7
HOK	0	21	0	–	–	12	33	0.2	63.4	0.4	–	–	36.0	1.6
OTH	73	73	–	4	–	7	157	46.6	46.4	–	2.2	–	4.7	7.7
Total	518	1 488	22	4	0	21	2 053	25.2	72.5	1.1	0.2	0.0	1.0	100.0
SPO 3														
SPO	3 739	120	89	9	–	7	3 963	94.4	3.0	2.2	0.2	–	0.2	47.5
SCH	1 361	8	0	2	–	0	1 371	99.2	0.6	0.0	0.1	–	0.0	16.4
FLA	2	751	74	0	–	0	827	0.2	90.8	9.0	0.0	–	0.0	9.9
RCO	5	520	74	0	0	0	600	0.9	86.7	12.4	0.0	0.0	0.0	7.2
ELE	194	125	2	–	–	0	321	60.3	38.8	0.8	–	–	0.1	3.8
SPD	277	18	3	0	–	0	298	93.0	6.1	0.8	0.0	–	0.0	3.6
LIN	128	10	–	36	0	0	175	73.5	5.5	–	20.7	0.0	0.2	2.1
TAR	70	80	24	–	0	0	173	40.2	46.0	13.7	–	0.1	0.0	2.1
STA	2	157	–	–	0	0	159	1.1	98.7	–	–	0.0	0.1	1.9
OTH	129	286	2	1	0	42	460	28.0	62.1	0.4	0.3	0.0	9.2	5.5
Total	5 906	2 074	268	48	0	50	8 347	70.8	24.8	3.2	0.6	0.0	0.6	100.0
SPO 7														
SPO	3 343	19	0	6	0	1	3 369	99.2	0.6	0.0	0.2	0.0	0.0	53.6
FLA	10	1 195	37	–	2	6	1 250	0.8	95.6	2.9	–	0.1	0.5	19.9
BAR	0	457	–	–	0	0	458	0.0	99.9	–	–	0.1	0.1	7.3
RCO	0	237	–	0	0	0	238	0.2	99.7	–	0.0	0.1	0.0	3.8
TAR	0	213	–	–	3	0	217	0.1	98.3	–	–	1.5	0.0	3.4
SCH	186	5	–	1	–	0	192	96.8	2.4	–	0.8	–	0.0	3.1
SPD	93	13	–	0	–	0	106	87.5	12.1	–	0.3	–	0.1	1.7
GUR	1	95	0	–	2	0	98	0.6	97.1	0.5	–	1.7	0.1	1.6
SNA	8	42	0	2	7	0	60	13.7	70.2	0.6	3.7	11.7	0.2	0.9
OTH	49	205	0	3	0	34	292	16.9	70.1	0.0	1.2	0.2	11.6	4.7
Total	3 691	2 481	38	13	15	42	6 280	58.8	39.5	0.6	0.2	0.2	0.7	100.0
SPO 8														
SPO	3 581	6	0	1	–	1	3 589	99.8	0.2	0.0	0.0	–	0.0	75.1
GUR	52	178	35	2	20	0	287	18.1	61.8	12.1	0.9	7.1	0.0	6.0
SCH	249	8	–	1	–	0	258	96.5	3.0	–	0.5	–	0.0	5.4
TRE	56	107	–	0	11	0	174	32.0	61.9	–	0.0	6.2	0.0	3.6
WAR	162	3	–	0	–	0	164	98.2	1.7	–	0.1	–	0.0	3.4
SNA	13	36	–	3	19	0	71	18.7	50.2	–	4.0	26.6	0.5	1.5
TAR	1	64	1	1	0	0	67	0.9	96.2	1.9	0.8	0.2	0.1	1.4
BAR	0	32	–	–	–	0	32	0.0	99.3	–	–	–	0.7	0.7
FLA	4	23	1	–	0	0	28	13.4	81.5	3.8	–	0.7	0.5	0.6
OTH	40	59	0	5	0	2	107	37.9	55.3	0.2	4.8	0.0	1.9	2.2
Total	4 157	516	37	13	50	4	4 777	87.0	10.8	0.8	0.3	1.1	0.1	100.0

Table 11 (continued):

Target species	Method of Capture (t)							Method of Capture (%)						
	SN	BT	DS	BLL	BPT	Other	Total	SN	BT	DS	BLL	BPT	Other	Total
SPO 1W														
SPO	3 768	0	–	1	–	7	3 776	99.8	0.0	–	0.0	–	0.2	66.4
GUR	331	195	60	1	17	0	604	54.8	32.3	10.0	0.1	2.8	0.1	10.6
TRE	95	242	–	0	66	3	406	23.4	59.6	–	0.0	16.3	0.7	7.1
SNA	5	332	3	9	51	1	400	1.2	82.9	0.8	2.2	12.7	0.2	7.0
TAR	1	119	0	0	14	0	135	0.9	88.2	0.3	0.0	10.6	0.0	2.4
FLA	128	0	0	0	–	0	129	99.6	0.1	0.1	0.0	–	0.2	2.3
SCH	95	10	–	1	–	0	106	90.3	9.1	–	0.6	–	0.0	1.9
GMU	49	0	1	0	–	21	70	69.7	0.3	0.8	0.0	–	29.2	1.2
BAR	1	13	–	–	2	–	15	4.5	84.7	–	–	10.8	–	0.3
OTH	26	16	0	1	1	4	48	55.4	33.7	0.4	1.2	1.5	7.9	0.8
Total	4 500	927	65	11	151	35	5 689	79.1	16.3	1.1	0.2	2.6	0.6	100.0

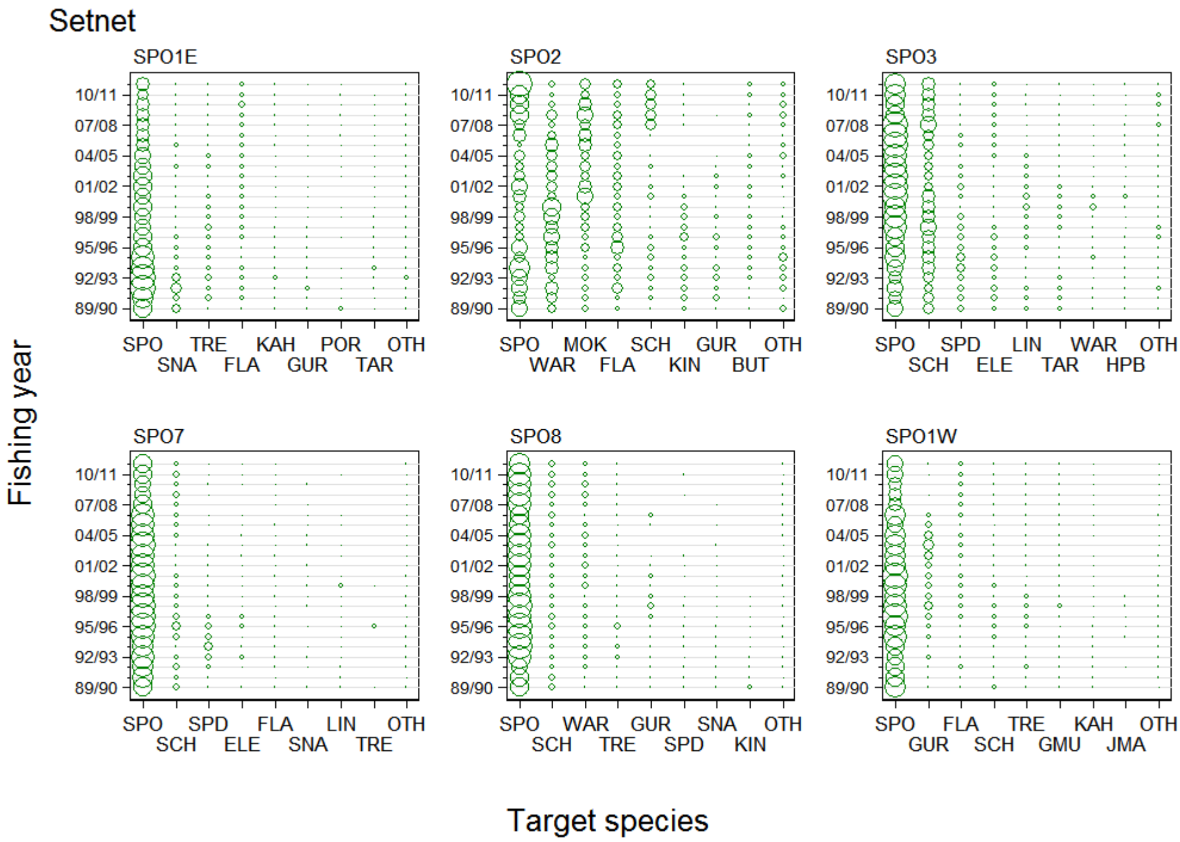

Figure 17: Distribution of landings by target species (ranked in terms of descending order of total landings) and fishing year for setnet in each SPO QMA based on trips which landed rig. Circle sizes are proportional within each panel: [SPO 1E]: largest circle= 295 t in 91/92 for SPO; [SPO 2]: largest circle= 23 t in 11/12 for SPO; [SPO 3]: largest circle= 253 t in 07/08 for SPO; [SPO 7]: largest circle= 205 t in 00/01 for SPO; [SPO 8]: largest circle= 219 t in 95/96 for SPO; [SPO 1W]: largest circle= 290 t in 96/97 for SPO. Values for the plotted data are provided in Table G.4.

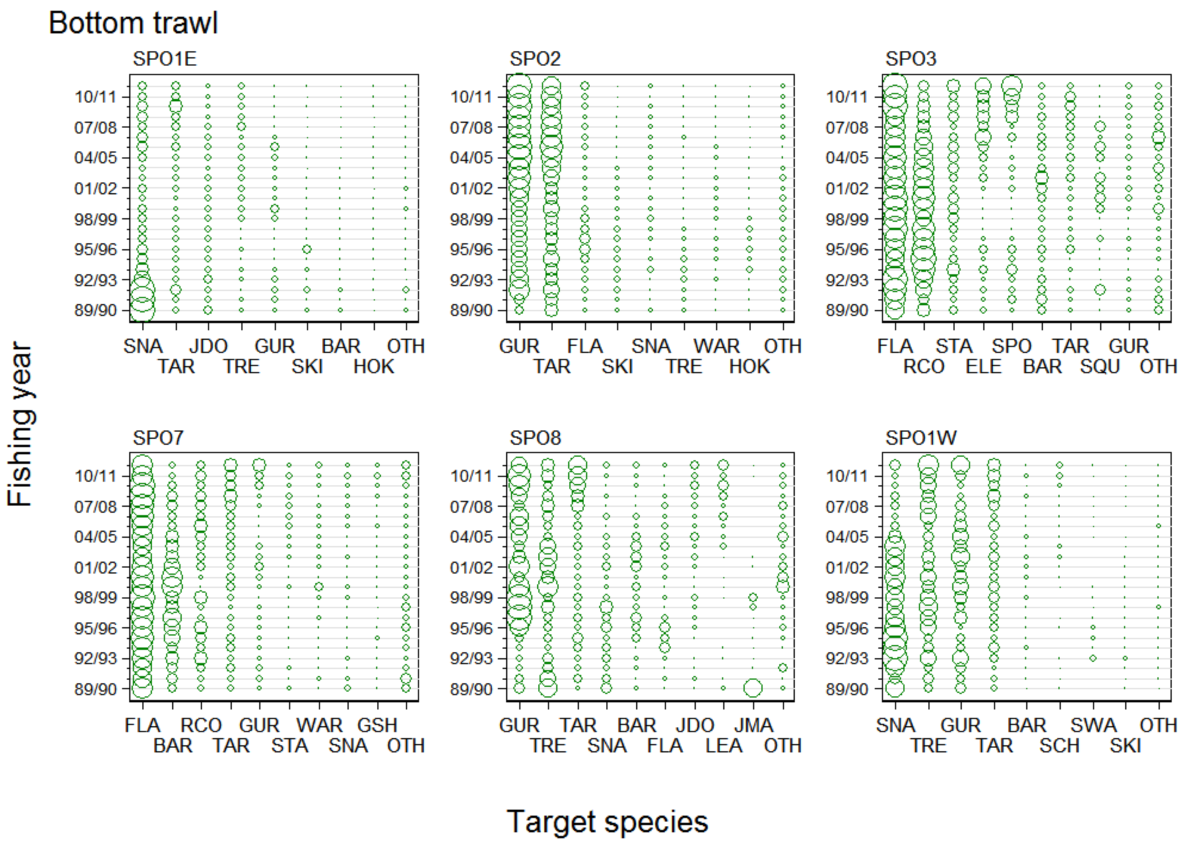

Figure 18: Distribution of landings by target species (ranked in terms of descending order of total landings) and fishing year for bottom trawl in each SPO QMA based on trips which landed rig. Circle sizes are proportional within each panel: [SPO 1E]: largest circle= 61 t in 91/92 for SNA; [SPO 2]: largest circle= 52 t in 09/10 for GUR; [SPO 3]: largest circle= 45 t in 00/01 for FLA; [SPO 7]: largest circle= 75 t in 09/10 for FLA; [SPO 8]: largest circle= 18 t in 96/97 for GUR; [SPO 1W]: largest circle= 36 t in 92/93 for SNA. Values for the plotted data are provided in Table G.5

2.3.3.6 Preferred bottom trawl fishing depths for rig

The setnet forms (NCELR) introduced in 2006–07 do not request depth information from fishermen (Ministry of Fisheries 2010).

Depth information is available from TCEPR and TCER forms which report bottom trawl catches pertaining to rig (either recording an estimated catch of rig or declaring rig as the target species). These data come either from the recently introduced (1 October 2007) TCER forms or the longstanding TCEPR forms, which are primarily used by the larger offshore vessels but have been in operation since the first year of data in this report (1989–90). Approximately 80% of the depth observations reported in Table 12 originate from the TCER forms, accumulated in the five years beginning with 2007–08. The remaining 20% of the trawl returns are on the older TCEPR forms, while less than 0.5% of the records use the CELR form. This predominance of TCER reports reflects the inshore nature of the rig bottom trawl fisheries. Only data from 2007–08 onwards are reported here, so that a complete picture will be obtained for the inshore bottom trawl rig fishery.

Reported depth observations, summarised over both form types, show that target rig bottom trawl fishing tends to be shallow in all QMAs, ranging from a minimum of around 11 m in SPO 7 to a maximum of 200 m for SPO 1E (Table 12). The distribution of tows which caught or targeted rig varies according to the target fishery in all six QMAs, with deep fisheries such as tarakihi, ghost shark and stargazer taking rig at depths up to 200 m compared to the shallower depths for successful rig catches for fisheries like red cod and flatfish (Figure 19).

Table 12: Summary statistics by QMA from distributions from all records (combined TCER and TCEPR formtypes) using the bottom trawl method for effort that targeted or caught rig by target species category. Data are summarised by QMA from 2007–08 to 2011–12.

		Depth (m)			
Target species	Number	Lower 5% of	Mean of	Median (50%) of	Upper 95% of
SPO 1E					
SNA	2 030	17	44	44	80
TAR	920	60	152	152	240
JDO	581	39	64	60	95
TRE	452	20	41	35	80
GUR	136	25	59	53	100
Other	45	22	244	250	450
Total	4 164	22	73	50	201
SPO 2					
GUR	7 535	20	43	40	79
TAR	5 810	40	89	80	159
FLA	1 630	10	23	20	49
GSH	619	43	114	100	200
RCO	334	12	58	40	144
SNA	295	26	49	46	86
BAR	114	30	84	71	200
WAR	93	48	89	85	145
MOK	82	40	89	96	117
JDO	79	34	79	80	117
TRE	68	22	44	40	80
STA	59	106	140	140	168
Other	130	16	135	130	300
Total	16 848	17	62	50	140
SPO 3					
FLA	6 686	10	28	22	60
RCO	1 250	18	48	48	85
STA	1 164	25	106	118	160
ELE	1 155	12	29	21	68
TAR	906	32	70	65	121
SPO	433	10	31	24	98
BAR	338	22	62	55	118
GUR	290	15	34	31	62
SPD	95	27	69	56	136
WAR	91	32	57	50	97
SPE	38	68	89	90	113
Other	156	14	88	57	238
Total	12 602	12	43	30	122

Table 12 (continued):

					Depth (m)
Target species	Number	Lower 5% of	Target species	Number	Lower 5% of
SPO 7					
FLA	11 234	10	25	22	46
TAR	2 926	30	97	94	181
GUR	1 731	21	45	42	76
RCO	1 358	15	45	40	108
BAR	939	28	63	51	146
SNA	764	10	30	22	80
GSH	695	44	110	96	196
JDO	411	35	80	74	138
STA	375	50	114	115	175
LEA	325	32	50	47	74
WAR	310	34	75	63	147
TRE	190	19	45	44	77
SCH	129	40	127	134	197
MOK	77	50	99	100	151
Other	172	13	113	59	370
Total	21 636	11	47	33	140
SPO 8					
GUR	1 317	24	47	45	75
TAR	1 201	59	118	120	181
TRE	395	21	41	40	66
JDO	352	35	81	74	138
FLA	264	13	40	38	65
BAR	259	27	62	55	139
LEA	219	37	53	48	75
SNA	138	20	49	43	109
SCH	100	69	128	135	191
WAR	81	18	70	66	132
GSH	60	58	80	75	156
Other	82	24	76	72	138
Total	4 468	26	72	58	159
SPO 1W					
GUR	1 811	25	44	41	70
TRE	740	25	47	43	78
TAR	453	76	133	130	193
SNA	248	30	58	50	118
JDO	45	35	64	58	108
SCH	38	90	164	172	214
BAR	27	53	104	94	153
Other	22	23	172	50	441
Total	3 384	26	61	46	154

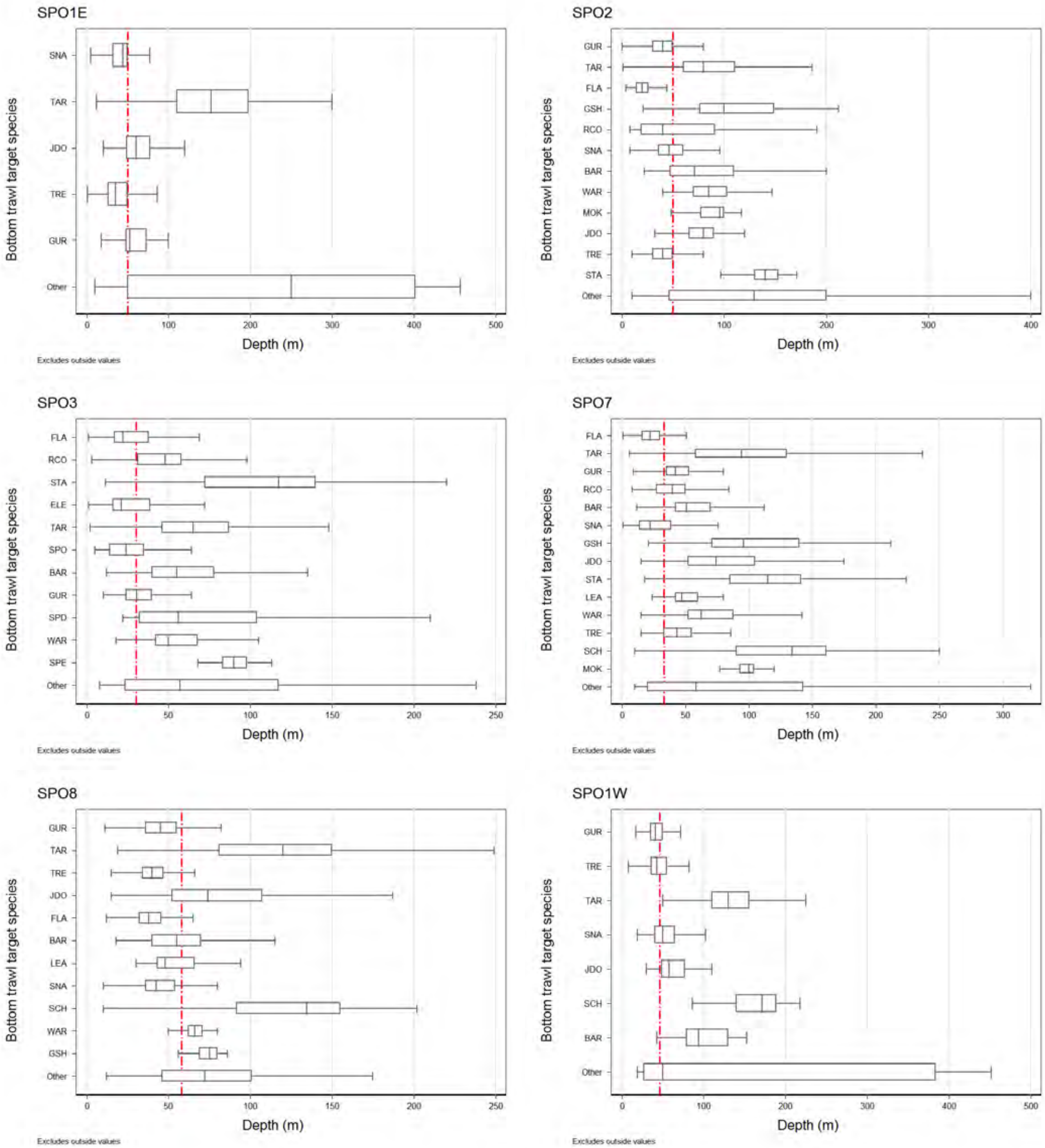

Figure 19: Box plot distributions by QMA of bottom depth from combined TCER and TCEPR formtypes of effort using the bottom trawl method that targeted or caught rig by target species category for the period 2007–08 to 2011–12. Vertical line in each sub graph indicates the median depth from all tows which caught or targeted rig in the indicated QMA.

3. STANDARDISED CPUE ANALYSIS

Seventeen fisheries were considered for detailed CPUE analysis to be included as biomass index series in this summary of rig fisheries on the North and South Islands of New Zealand. See Appendix H for an introduction to the detailed CPUE analyses and with links to the specific analyses and diagnostics.

The following text table defines these fisheries by showing the method of capture, the statistical areas used, and the selected target species specifications. This table also shows the Science Information Quality ranking, with 1=High Quality; 2=Medium or Mixed Quality; 3=Low Quality (not used – marked with grey shading).

QMA	Rank	Fishery	Method	Statistical Area(s)	Target Species
SPO 1E	1	SN(007)	Set net	007	SPO, SCH, SPD, NSD
	2	SN(coast)	Set net	002–006, 008–010	SPO, SCH, SPD, NSD
	1	BT(coast)	Bottom trawl	002–010	SNA, TRE, GUR, JDO,BAR, TAR
SPO 2	1	SPO 2-BT	Bottom trawl	011–016	GUR, TAR, FLA
	3	SPO 2-SN	Set net	011–016	SPO, WAR, MOK, FLA
SPO 3	1	SPO 3-SN(SHK)	Set net	018–032	SPO, SCH, SPD, ELE
	1	SPO 3-BT(MIX)	Bottom trawl	018–032	BAR, STA, RCO, SPO, SPD, TAR
	3	SPO 3-BT(FLA)	Bottom trawl	018–032	all FLA species
SPO 7	2	SPO 7-SN(WC)	Set net	032–037	SPO, SCH, SPD, ELE
	1	SPO 7-SN(038)	Set net	038	SPO, SCH, SPD, ELE
	2	SPO 7-BT(all)	Bottom trawl	016–018, 032–040	SPO, RCO, FLA
SPO 8	1	SPO 8-SN	Set net	037–041	SPO SCH, SPD, NSD
	2	SPO 8-BT	Bottom trawl	037–041	SNA, TRE, GUR, JDO, BAR, TAR
SPO 1W	1	SPO 1W-SN(043)	Set net	043	SPO, SCH, SPD, NSD
	1	SPO 1W-SN(044)	Set net	044	SPO, SCH, SPD, NSD
	3	SPO 1W-SN(coast)	Set net	042, 045–047	SPO, SCH, SPD, NSD
	3	SPO 1W-BT	Bottom trawl	042, 045–048	SNA, TRE, GUR, JDO, BAR, TAR

3.1 SPO 1E (Appendix I):

The analyses presented for this partial QMA were updates of similar analyses presented by Kendrick & Bentley (2012). While the bottom trawl analysis was completed using the trip matching procedure developed by Starr (2007), Kendrick & Bentley (2012) had found that the setnet analyses were complicated by the fact that up to 50% of the setnet catches were accumulated ashore using intermediate destination codes for subsequent landing to Licensed Fish Receiver, thus breaking the link between effort and the landing. Consequently, an alternative data preparation procedure was adopted for the setnet fishery analyses, correcting the estimated catch observations using annual vessel correction factors for each vessel and year (described in Appendix F).

Three CPUE analyses for SPO 1E were evaluated and accepted by the SINSWG: a) a target shark (NSD, SPO, SHK, SPD) setnet fishery operating in the Firth of Thames (Area 007) [SPO 1E-SN(007)]; b) a target shark setnet fishery operating in all the remaining SPO 1E statistical areas (002 to 006 and 008 to 010) [SPO 1E-SN(coast)]; c) a mixed target species (SNA, TRE, GUR, JDO, BAR, TAR) bottom trawl fishery operating in all SPO 1E statistical areas (002 to 010) [SPO 1E-BT]. These three series show broadly similar trends from the mid-1990s, but differ in the early period, with the SN(007) series showing a strong drop in the early portion of the series while the other two series show no trend (Figure 20).

The SINSWG accepted the SPO 1E-SN(007) because this fishery targets mature female rig and the diagnostics were considered credible. The SINSWG accepted the SPO 1E-BT series because the diagnostics were credible but cautioned that the sampled size range of the population would be narrow. The SPO 1E-SN(coast) series was accepted more cautiously because this series was more variable than the other two series and it noted that the fishing locations were widely dispersed, occupied sporadically and may not be representative of the wider population.

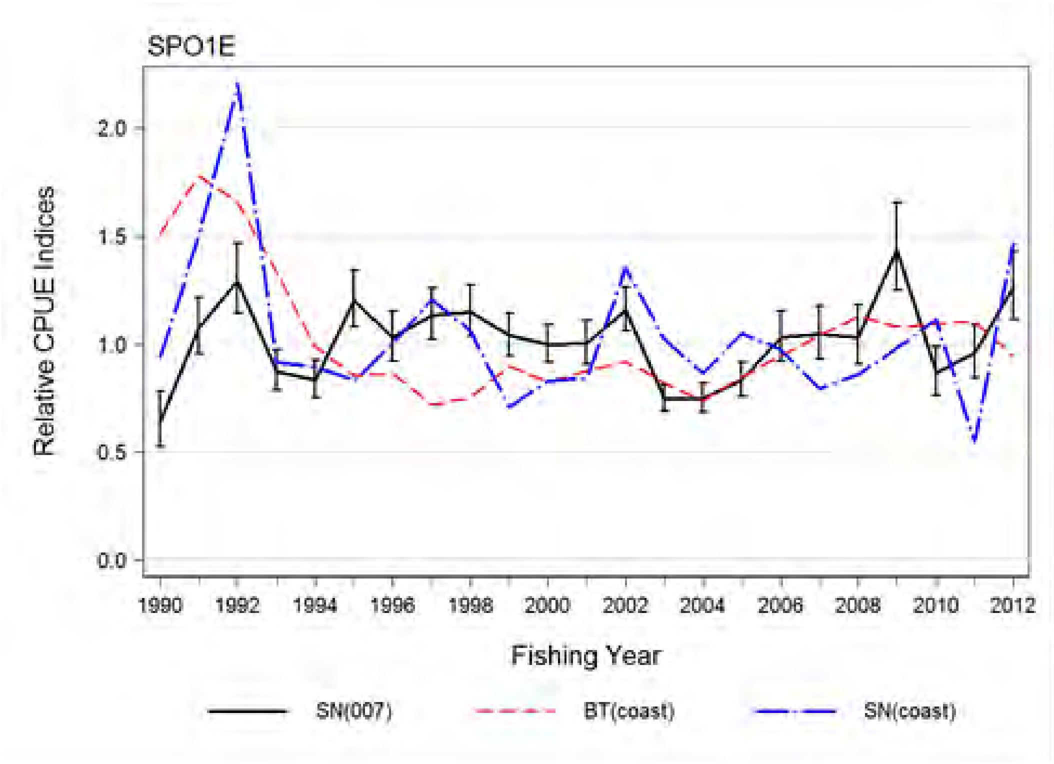

Figure 20: Comparison of standardised CPUE for SPO 1E in three fisheries: a) target shark setnet in the Firth of Thames (Area 007) [SN(007)]; b) mixed target species bottom trawl in Statistical Areas 002 to 010 [BT(coast)]; c) target shark (SPO, SCH, SPD or NSD) setnet in all remaining SPO 1E statistical areas [SN(coast)].

3.2 SPO 2 (Appendix M):

The analysis presented for this QMA was an extension by two years of the analysis prepared by Bentley et. al. (2011). The extended analysis was based on complete trips which landed SPO 2 using the bottom trawl method from 1989–90 to 2011–12, adjusted for changes in conversion factors. The corresponding setnet analysis was dropped because it was rejected by the NINSWG in 2011 due to the small amount of available data and changes in targeting behaviour. The use of complete trips was necessary because of the large proportion of trips which landed SPO 2 but did not report any estimated catch (21% by weight for the dataset). In addition, estimated catches severely underestimated landings (median estimated catch by trip was 70% the landed catch). The use of complete trips limited the number of explanatory factors that could be applied in the analysis. However, no difference was found between analyses which adjusted for zone of capture or target species category compared to the analyses which only corrected for year, month and vessel.

The SPO 2 series constructed from bottom trawl data shows a gradually increasing trend from 1989–90 to 2002–03 after which the series remains reasonably stable through to 2011–12 with three consecutive high years from 2001–02 to 2003-04 (Figure 21). Fishing year 2009–10 was at the same level as the period from 2001–02 to 2003–04. The SINSWG accepted the BT(trip) series but noted that, while the analysis was credible, the method of capture may not monitor the full size range of the population.

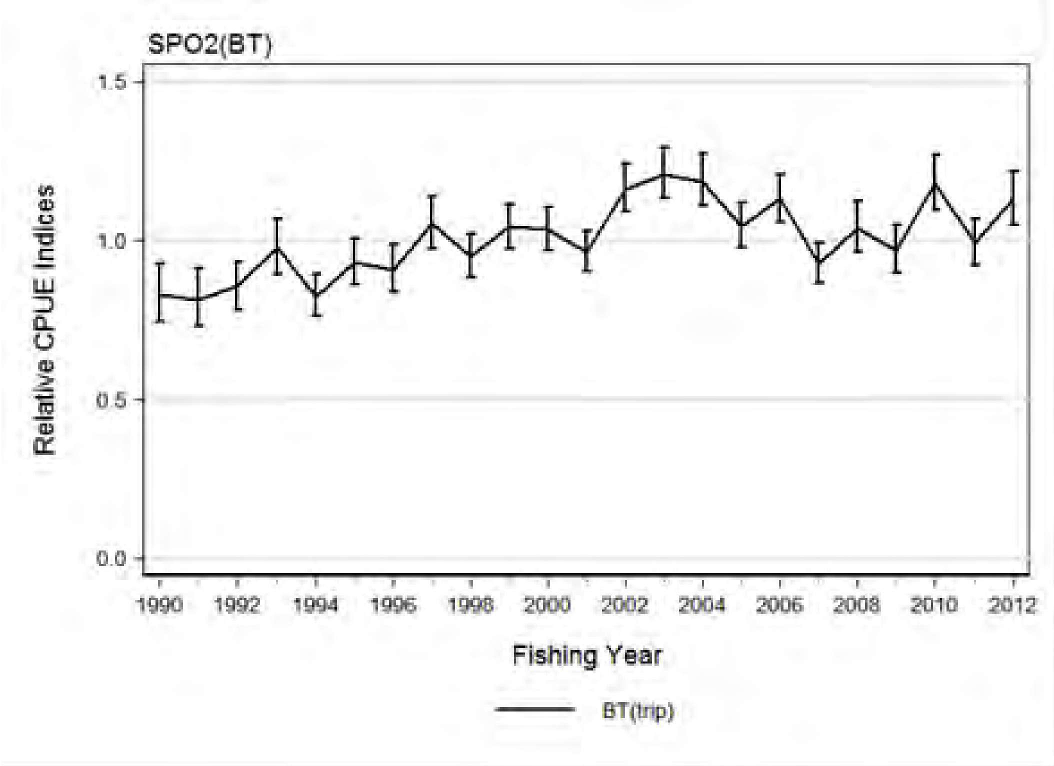

Figure 21: Lognormal standardised CPUE series for SPO 2 based on all valid bottom trawl trips which landed to SPO 2 up to 2011–12.

3.3 SPO 3 (Appendix M):

Two CPUE standardisations for SPO 3 were prepared, one based on a shark target setnet fishery and the other based on a mixed target species (barracouta, red cod, tarakihi, stargazer, elephantfish, and gurnard) bottom trawl fishery. Both CPUE analyses are extensions of equivalent analyses which have been previously reviewed (SeaFIC 2005; Starr et al. 2008, Starr & Kendrick 2011), although gurnard and elephantfish were added to the target species list for the bottom trawl analysis. These two fisheries are modelled separately because they operate at different depth ranges, with rig in the trawl fishery taken strictly as a bycatch while rig is the primary target species of the setnet fishery. These fisheries will have different selectivities, harvesting a different size range of rig, with the setnet fishery taking larger fish while the trawl fishery takes sub-adults.

Each CPUE analysis was performed by matching the effort data with the landing data at the trip level to correct the estimated catch information in the effort part of the form. This procedure was acceptable because the landing data did not break the link within a trip between the effort and landing sections of the form (see Table 5).

The two series fluctuate about the long-term mean over the full period of each series (Figure 22). While the SINSWG accepted these indices as indices of abundance and, although the trend based on the SN(SHK) data should be more reliable because it should be indexing adult fish, the SINSWG discounted this series because the setnet fishery on the east coast of the South Island has been considerably curtailed to reduce the bycatch of protected species. The SINSWG accepted the BT(MIX) series because of the credibility of the analysis and the wide range of target species involved, but noted that the method of capture may not monitor the full size range of the population. A third series, BT(FLA), was not accepted by the SINSWG because the low headline height nets generally used in this fishery would considerably reduce the catchability of rig in this fishery. As well, it is known that bottom trawl nets more suitable for deeper water species are also used in this fishery but that net type was not collected by the catch/effort forms, further reducing the capacity of this fishery for monitoring rig. The agreement between the two CPUE series and the east coast South Island winter survey is poor, given the large positive deviations in 1991, 2008 and 2012 and the run of negative deviations between 1992 and 1996 (Beentjes et al. 2015) (Figure 22).

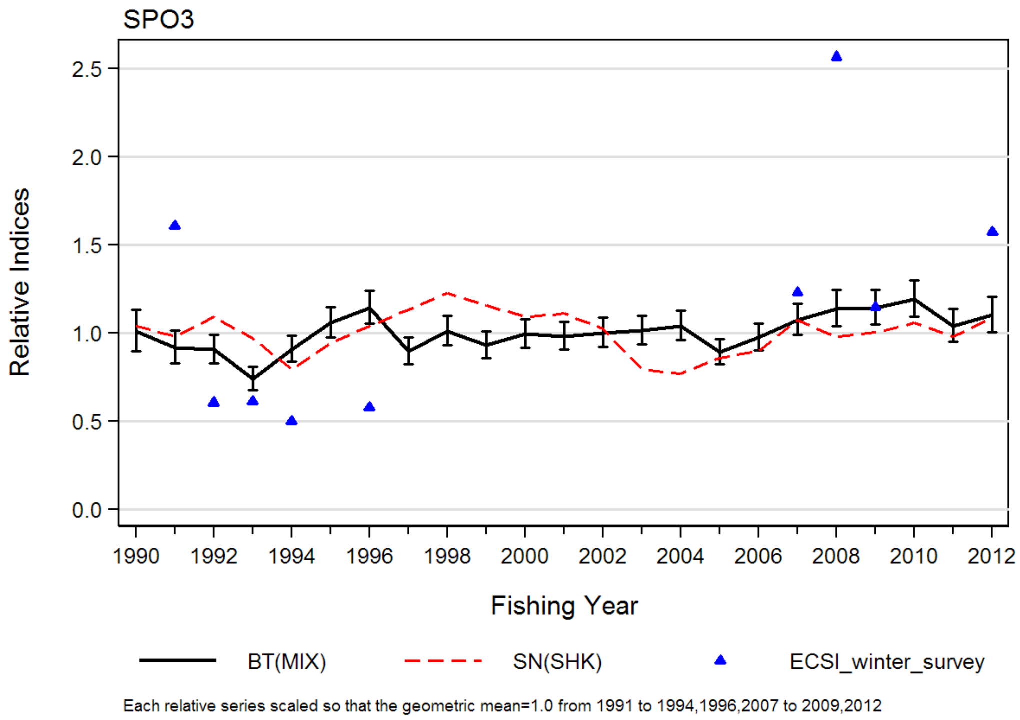

Figure 22: Comparison of the indices from the two CPUE series for SPO 3: a) BT[MIX]: mixed target species bottom trawl fishery; b) SN[SHK]: target shark species setnet fishery. Also shown are the relative indices from the east coast South Island (ECSI) winter survey. All series have been standardised to the same geometric mean.

3.4 SPO 7 (Appendix O):

CPUE analyses standardising non-zero setnet and bottom trawl catches for core vessels were undertaken in 2013 to assess relative abundance of rig in SPO 7. These analyses were updates of analyses previously accepted (Starr et al. 2010). The 2013 analyses used the same or similar fishery definitions as the previous analysis: 1) setnet fishery in Statistical Areas 032–037 targeting rig, school shark and spiny dogfish [SN(WC)]; 2) setnet fishery in Statistical Area 038 targeting rig, spiny dogfish and school shark [SN(038)]; and 3) bottom trawl fishery in Statistical Areas 016–018, 032–037, 038, and 039 targeting flatfish, red cod, rig, barracouta, tarakihi, and gurnard [BT(ALL)].

Each CPUE analysis was performed by matching the effort data with the landing data at the trip level to correct the estimated catch information in the effort part of the form. This procedure was acceptable because the landing data did not break the link within a trip between the effort and landing sections of the form (see Table 5).

The Working Group had previously concluded that the SN(038) index was the most credible series of the three series available to assess SPO 7 abundance (Area 038 accounts for 44% of the total rig landings over 23 years, 73% of which was taken by setnet gear [=32%/44%]). Concerns were raised in 2010 about the continued reliability of the SN(WC) series because the among-year comparisons may be affected by closures and other management measures implemented to protect Hector’s dolphins.

The SN(038) index showed a continuous declining trend from the beginning of the series to a low in the mid-2000s, followed by an increasing trend to a peak in 2009–10 after which the series levelled off (Figure 23). It is this series which led to the decision to reduce the SPO 7 TACC to 221 t in 2006–07.

The BT(ALL) series has shown an increasing trend since the mid-2000s as has the SN(WC) series (Figure 23). Neither of the west coast series show the initial strong decline seen in the Tasman/Golden Bay series, probably because this is the only fishery that takes mature females. The SN(WC) series has become variable, which may be the result of factors such as the reduction in the number of participating vessels because of the management restrictions for the protection of Hector's dolphins. Examination of the distribution of setnet effort on the west coast of the South Island shows that there has been a substantial decline in the number of vessels operating since 2005–06. Although the survey indices show considerable interannual variation, there is general agreement between the three CPUE series and the west coast South Island winter survey (Stevenson & MacGibbon 2015) (Figure 23).

The SINSWG accepted the SN(038) series because this fishery targets mature female rig and there have been relatively few restrictions for the protection of Hector's dolphins because of the low abundance of this marine mammal in this statistical area. However, the amount of data in this analysis is relatively small, which may compromise its utility in future years. The BT(ALL) series was accepted but discounted, because, although the analysis was credible, the sampled size range of the population was narrow. The SN(WC) series was accepted but also discounted because of concerns that it was not sampling the full size range of the population and that the amount of data was diminishing because of vessels dropping out of the fishery.

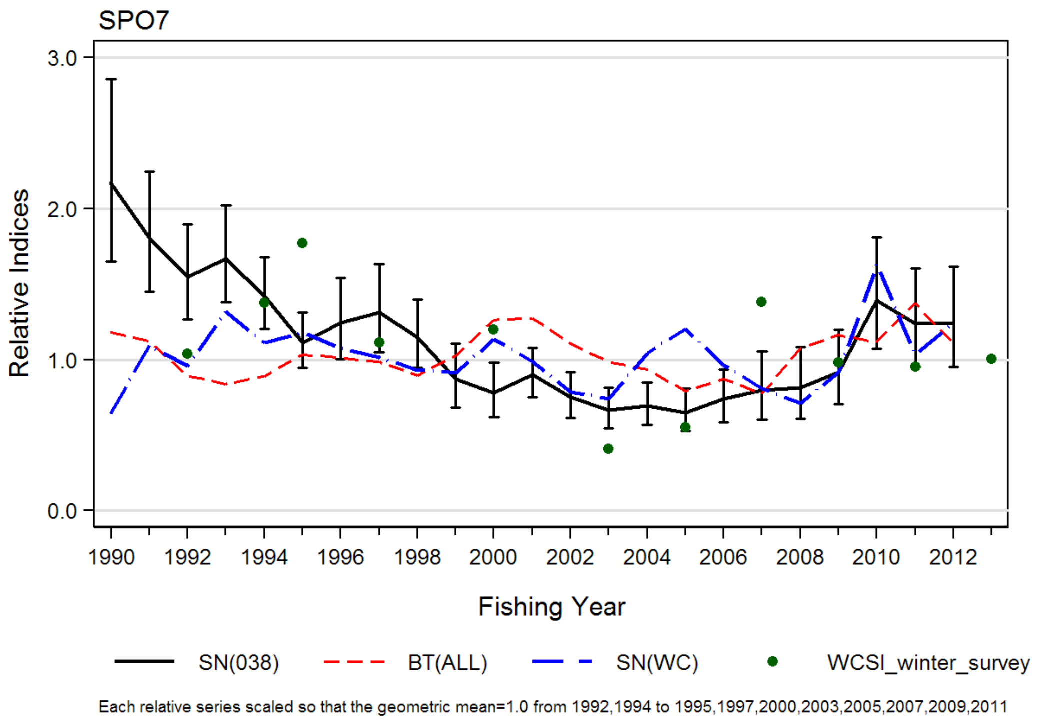

Figure 23: Comparison of three SPO 7 standardised CPUE series: i) setnet fishery (shark target in Tasman/Golden Bays) [SN(038)]; ii) bottom trawl fishery (mix target in all SPO 7) [BT(ALL)]; iii) setnet fishery (shark target on the west coast South Island) [SN(WC)]. Also shown are the relative indices from the west coast South Island winter survey. All series have been standardised to the same geometric mean.

3.5 SPO 8 (Appendix Q):

CPUE analyses standardising non-zero setnet and bottom trawl catches for core vessels were used to assess relative abundance of rig in SPO 8. These analyses were updates of analyses previously accepted (Kendrick & Bentley 2012). SPO 8 landings are primarily by a setnet fishery that operates along the coast from Kapiti to beyond New Plymouth. The SPO 8 bottom trawl fishery operates further offshore in the North and South Taranaki Bights and takes rig as a bycatch in fisheries targeting gurnard, tarakihi, snapper and gurnard. Recent average setnet landings in SPO 8 have been between 150–200 t/year while bottom trawl landings average between 10–30 t/year.

Each CPUE analysis was performed by matching the effort data with the landing data at the trip level to correct the estimated catch information in the effort part of the form. This procedure was acceptable because the landing data did not break the link within a trip between the effort and landing sections of the form (see Table 5). All trips fishing in Areas 039, 040 and 041 were deemed to have fished in SPO 8 (for both the setnet and bottom trawl analysis), adjusting the estimated catches to landings without regard to the QMA and avoiding the problem of discarding about 25% of the catch from the analysis.

The SPO 8(SN) CPUE analysis was variable with relatively large coefficients of variation (Figure 24). The overall pattern was one of gradual decline to the mid-2000s, followed by a recovery to the present. The SPO 8(BT) CPUE series showed no trend (Figure 24). The SINSWG accepted the SPO 8(SN) series, noting that the year trend was similar in all three statistical areas and that a setnet fishery should provide information from a wider range of the rig population. While the SINSWG accepted the SPO 8(BT) CPUE series, it considered it less reliable because the indices were based on small amounts of data in any year, with landings from the core data set ranging from 5 to 20 t of rig per year.

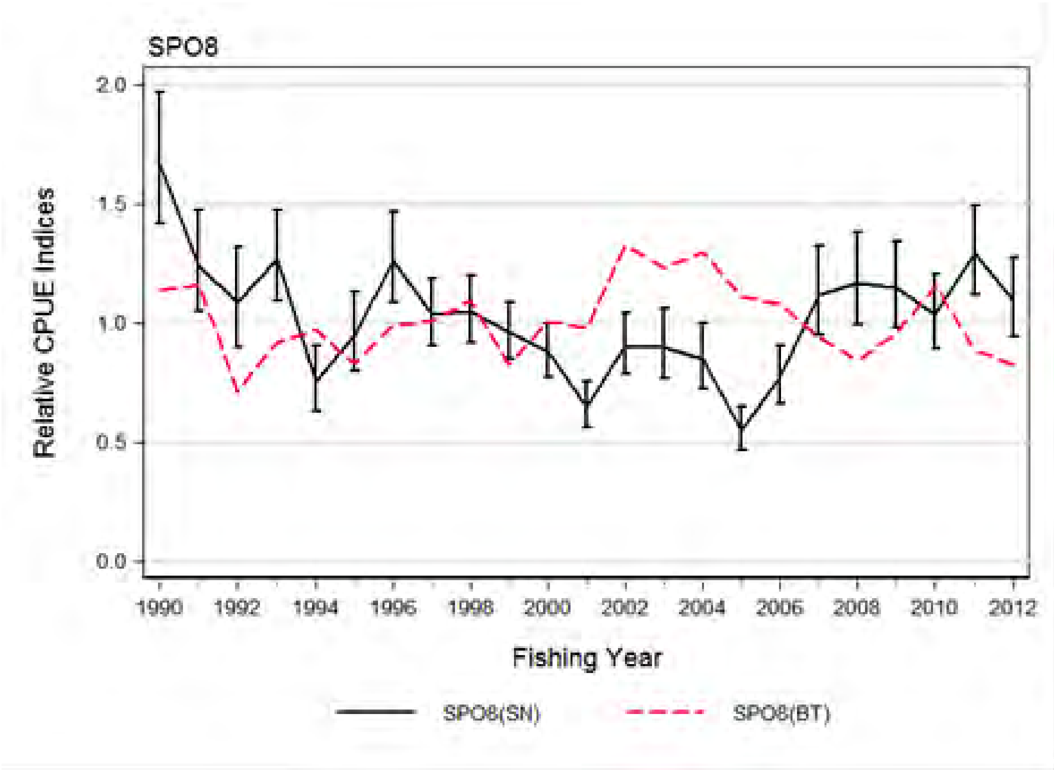

Figure 24: Comparison of two standardised CPUE series from three SPO 8 statistical areas: 039, 040 and 041) i) setnet fishery (shark target) [SPO 8(SN)]; ii) bottom trawl fishery (mixed target) [SPO 8(BT)].

3.6 SPO 1W (Appendix K):

The analyses presented for this partial QMA were updates of similar analyses presented by Kendrick & Bentley (2012). As found for SPO 1E, the setnet analyses in this FMA were complicated by the fact that setnet catches were accumulated using intermediate destination codes for subsequent landing to Licensed Fish Receivers, thus breaking the link between effort and the landing. The alternative data preparation procedure adopted by Kendrick & Bentley (2012) for the setnet fishery analyses, correcting the estimated catch observations using annual vessel correction factors for each vessel and year and described in Appendix F, was also followed for the setnet analyses presented for SPO 1W.

Four CPUE analyses for SPO 1W were prepared: a) a target shark (NSD, SPO, SHK, SPD) setnet fishery operating in Manukau Harbour (Area 043) [SN(043)]; b) a target shark setnet fishery operating in Kaipara Harbour (044) [SN(044)]; c) a target shark setnet fishery operating in all the remaining SPO 1W statistical areas (042, 045 to 048) [SN(coast)]; d) a mixed target species (SNA, TRE, GUR, JDO, BAR, TAR) bottom trawl fishery operating in all outside SPO 1W statistical areas (042, 045 to 048) [BT(coast)]. Only two of these series were accepted by the WG, with the two coastal series rejected because of small amounts of data (recent years had the core vessel data sets for SN(coast) with less than 10 t of landed rig while the BT(coast) core data set showed between 15 t and 35 t of rig landed). The BT(coast) series also showed a doubling and halving of CPUE between 2002 and 2004, a jump that was not considered credible. The two remaining series showed similar trends from the mid-1990s, but differed in the early period, with the SN(043) series showing a strong drop in the early portion of the series while the SN(044) series showed no trend throughout the 1990s (Figure 25). The SINSWG accepted both the SN(043) and SN(044) series because these fisheries target mature female rig and the diagnostics were considered credible.

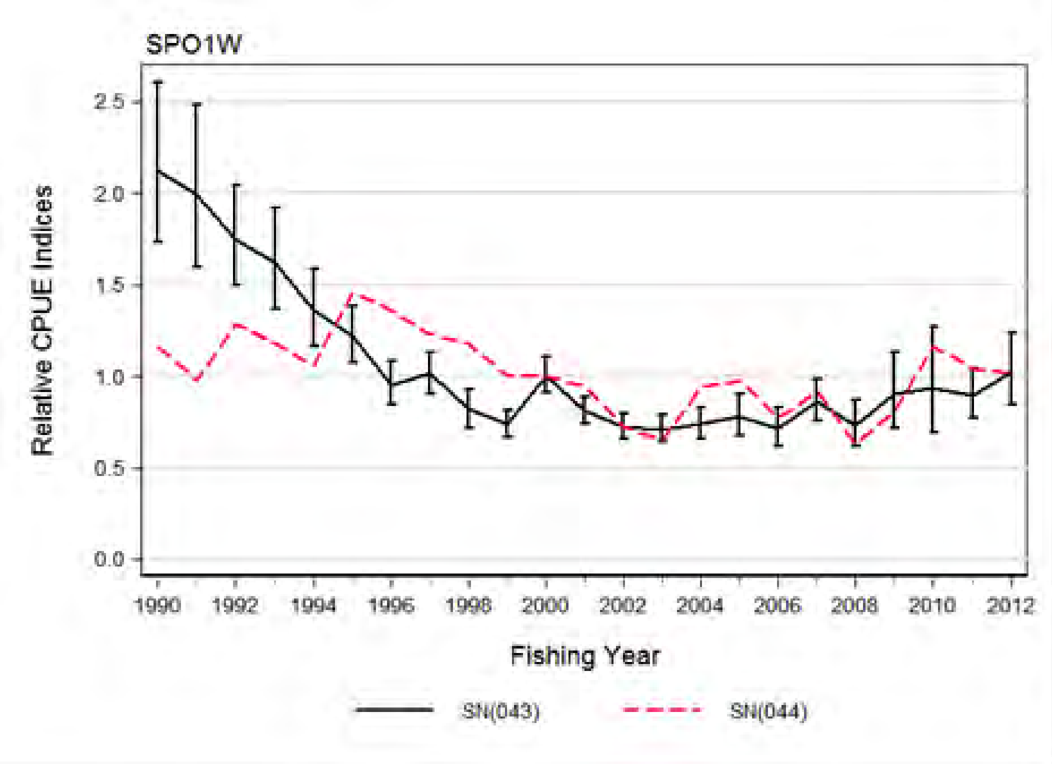

Figure 25: Comparison of standardised CPUE for SPO 1W in two fisheries: a) target shark setnet in Manukau Harbour (Area 043) [SN(043)]; b) target shark setnet in Kaipara Harbour (Area 044) [SN(044)].

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Appendix A. GLOSSARY OF ABBREVIATIONS, CODES, AND DEFINITIONS OF TERMS

Table A.1: Table of abbreviations and definitions of terms

Term/Abbreviation	Definition
AIC	Akaike Information Criterion: used to select between different models (lower is better)
AMP	Adaptive Management Programme
analysis dataset	data set available after completion of grooming procedure (Starr 2007)
arithmetic CPUE	Sum of catch/sum of effort, usually summed over a year within the stratum of interest
CDI plot	Coefficient-distribution-influence plot (Bentley et al. 2011)
CELR	Catch/Effort Landing Return (Ministry of Fisheries 2010): active since July 1989 for all vessels less than 28 m. Fishing events are reported on a daily basis on this form
CLR	Catch Landing Return (Ministry of Fisheries 2010): active since July 1989 for all vessels not using the CELR or NCELR forms to report landings
CPUE	Catch Per Unit Effort
destination code	code indicating how each landing was directed after leaving vessel (see Table 4)
EEZ	Exclusive Economic Zone: marine waters under control of New Zealand
estimated catch	an estimate made by the operator of the vessel of the weight of rig captured, which is then recorded as part of the "fishing event". Only the top 5 species are required for any fishing event in the CELR and TCEPR data (expanded to 8 for the TCER and NCELR form types)
fishing event	a "fishing event" is a record of activity in a trip. It is a day of fishing within a single statistical area, using one method of capture and one declared target species (CELR data) or a unit of fishing effort (usually a tow or a line set) for fishing methods using other reporting forms
fishing year	1 October – 30 September for rig
FMA	MPI Fishery Management Areas: 10 legal areas used by MPI to define large scale stock management units; QMAs consist of one or more of these regions
landing event	weight of rig off-loaded from a vessel at the end of a trip. Every landing has an associated destination code and there can be multiple landing events with the same or different destination codes for a trip
LCER	Lining Catch Effort Return (Ministry of Fisheries 2010): active since October 2003 for lining vessels larger than 28 m and reporting set-by-set fishing events
LFR	Licensed Fish Receiver: processors legally allowed to receive commercially caught species
LTCER	Lining Trip Catch Effort Return (Ministry of Fisheries 2010): active since October 2007 for lining vessels between 6 and 28 m and reporting individual set-by-set fishing events
MHR	Monthly Harvest Return: monthly returns used after 1 October 2001. Replaced QMRs but have same definition and utility
MPI	New Zealand Ministry for Primary Industries
NCELR	Netting Catch Effort Landing Return (Ministry of Fisheries 2010): active since October 2006 for inshore vessels using setnet gear between 6 and 28 m and reporting individual fishing events
QMA	Quota Management Area: legally defined unit area used for rig management (Figure 1)
QMR	Quota Management Report: monthly harvest reports submitted by commercial fishermen to MPI. Considered to be best estimates of commercial harvest. In use from 1986 to 2001.
QMS	Quota Management System: name of the management system used in New Zealand to control commercial and non-commercial catches
replog	data extract identifier issued by MPI data unit
residual implied coefficient plots	plots which mimic interaction effects between the year coefficients and a categorical variable by adding the mean of the categorical variable residuals in each fishing year to the year coefficient, creating a plot of the "year effect" for each value of the categorical variable
Rollup	a term describing the average number of records per "trip-stratum"
RTWG	MPI Recreational Technical Working Group
SINSWG	Southern Inshore Fisheries Assessment Working Group: MPI Working Group overseeing the work presented in this report
standardised CPUE	procedure used to remove the effects of explanatory variables such as vessel, statistical area and month of capture from a data set of catch/effort data for a species; annual abundance is usually modelled as an explanatory variable representing the year of capture and, after removing the effects of the other explanatory variables, the resulting year coefficients represent the relative change in species abundance

Table A.1: (continued)

Term/Abbreviation	Definition
Statistical Area	sub-areas (Appendix B) within an FMA which are used in catch/effort returns. The boundaries for these statistical areas do not always coincide with the QMA/FMA boundaries, leading to ambiguity in the assignment of effort to a QMA.
TACC	Total Allowable Commercial Catch: catch limit set by the Minister of Fisheries for a QMA that applies to commercial fishing
TCEPR	Trawl Catch Effort and Processing Return (Ministry of Fisheries 2010): active since July 1989 for deepwater vessels larger than 28 m and reporting tow-by-tow fishing events
TCER	Trawl Catch Effort Return (Ministry of Fisheries 2010): active since October 2007 for inshore vessels between 6 and 28 m and reporting tow-by-tow fishing events
Trip	a unit of fishing activity by a vessel consisting of “fishing events” and “landing events”, which are activities assigned to the trip. MPI generates a unique database code to identify each trip, using the trip start and end dates and the vessel code (Ministry of Fisheries 2010)
trip-stratum	summarisation within a trip by fishing method used, the statistical area of occupancy and the declared target species
unstandardised CPUE	geometric mean of all individual CPUE observations, usually summarised over a year within the stratum of interest

Table A.2: Code definitions used in the body of the main report and in Appendix G.

Code	Definition
BLL	Bottom longlining
BPT	Bottom trawl—pair
BS	Beach seine/drag nets
BT	Bottom trawl—single
CP	Cod potting
DL	Drop/dahn lines
DS	Danish seining—single
HL	Handlining
MW	Midwater trawl—single
RLP	Rock lobster potting
SLL	Surface longlining
SN	Set netting (includes gill nets)
T	Trolling
TL	Trot lines
SPO 1E	the part of SPO 1 in FMA 1
SPO 1W	the part of SPO 1 in FMA 9

Code	Description
BAR	Barracouta
BNS	Bluenose
BUT	Butterfish
ELE	Elephant Fish
FLA	Flatfish (mixed species)
GMU	Grey mullet
GSH	Ghost shark
GUR	Red gurnard
HOK	Hoki
HPB	Hapuku & Bass
JDO	John Dory
JMA	Jack mackerel
KAH	Kahawai
KIN	Kingfish
LEA	Leatherjacket
LIN	Ling
MOK	Moki
POR	Porae
RCO	Red cod
SCH	School shark
SCI	Scampi
SKI	Gemfish
SNA	Snapper
SPD	Spiny dogfish
SPE	Sea perch
SPO	Rig
SQU	Arrow squid
STA	Giant stargazer
SWA	Silver warehou
TAR	Tarakihi
TRE	Trevally
WAR	Blue warehou

Appendix B. MAP OF MPI STATISTICAL AND MANAGEMENT AREAS

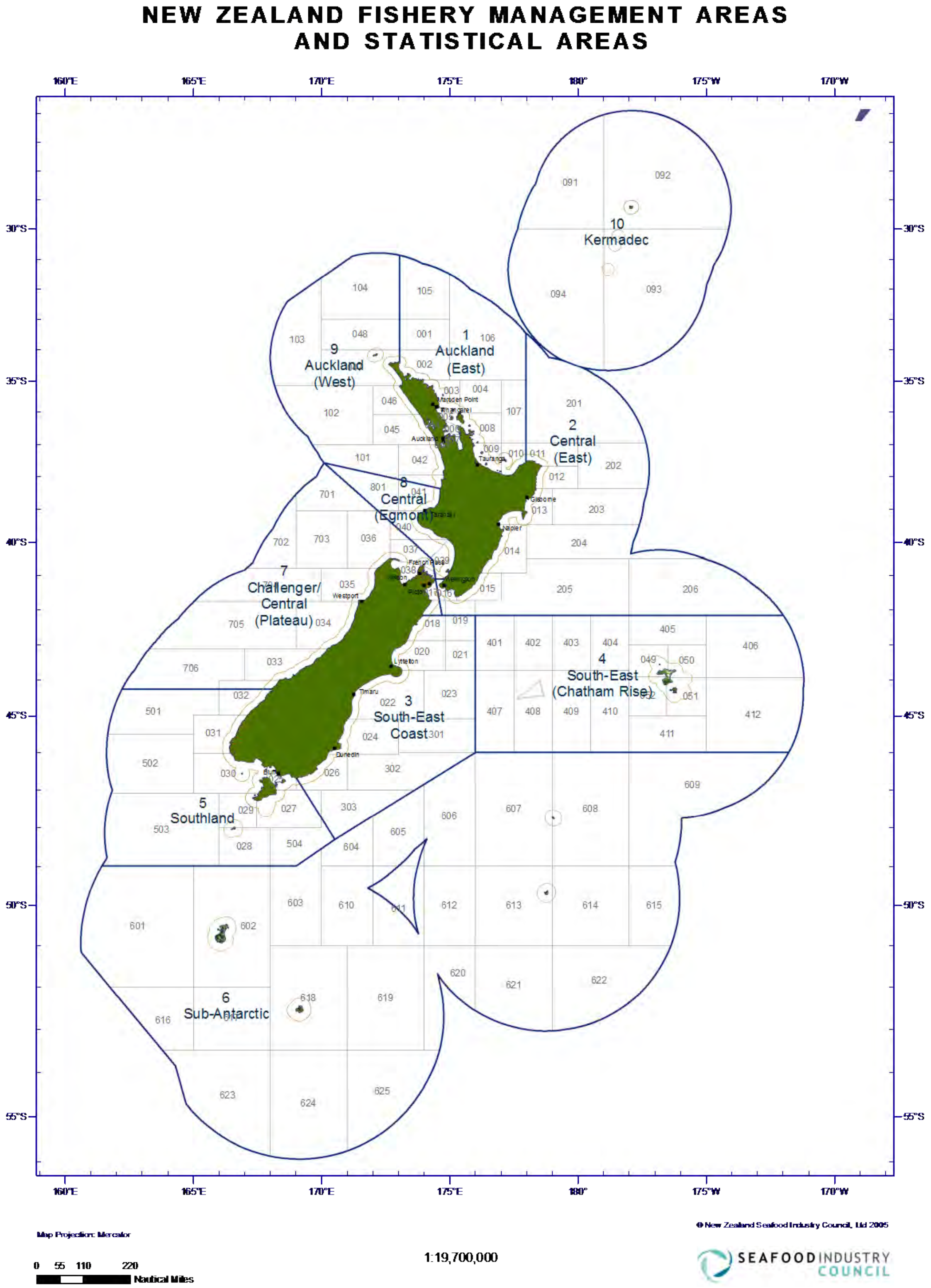


Figure B.1: Map of Ministry for Primary Industries statistical areas and Fishery Management Area (FMA) boundaries, showing locations where FMA boundaries are not contiguous with the statistical area boundaries

Appendix C. QMR/MHR LANDINGS AND TACC BY QMA

Table C.1: Reported landings (t) and TACC (t) of rig in SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 from 1986–87 to 2011–12 (Data sources: QMR [1986–87 to 2000–01]; MHR [2001–02 to 2011–12). $\tilde{S}L_{q,y}$ is the sum of landings for QMA *q* in year *y* adjusted for changes in conversion factor (Eq. 2) and $SL_{q,y}$ is the sum of the same landings for QMA *q* in year *y* without adjustment.

Fishing	QMR/MHR$_{q,y}$						$R_{q,y} = \tilde{S}L_{q,y} / SL_{q,y}$				
Year	SPO 1	SPO 2	SPO 3	SPO 7	SPO 8	Total	SPO 1	SPO 2	SPO 3	SPO 7	SPO 8
1986–87	366.0	54.8	312.3	232.5	125.1	1 090.7	0.835[1]	0.818[1]	0.812[1]	0.812[1]	0.803[1]
1987–88	525.7	65.8	351.9	262.5	186.6	1 392.5	0.835[1]	0.818[1]	0.812[1]	0.812[1]	0.803[1]
1988–89	688.1	68.7	305.0	243.8	209.8	1 515.3	0.835[1]	0.818[1]	0.812[1]	0.812[1]	0.803[1]
1989–90	689.1	61.5	292.2	266.0	206.2	1 515.0	0.822	0.820	0.798	0.813	0.811
1990–91	655.9	62.9	283.9	267.8	196.4	1 466.8	0.835	0.829	0.821	0.820	0.813
1991–92	871.1	106.6	350.6	287.6	147.8	1 763.7	0.846	0.804	0.818	0.803	0.786
1992–93	719.3	90.4	278.1	324.0	238.7	1 650.5	0.922	0.908	0.897	0.895	0.891
1993–94	630.8	95.9	327.1	312.2	254.7	1 620.7	0.927	0.900	0.893	0.897	0.894
1994–95	665.6	87.7	401.6	341.3	272.6	1 768.8	0.920	0.901	0.891	0.894	0.895
1995–96	603.1	106.2	405.2	395.0	327.3	1 836.8	0.910	0.907	0.889	0.904	0.895
1996–97	677.4	97.9	431.9	394.6	275.7	1 877.6	0.902	0.900	0.896	0.898	0.897
1997–98	613.2	84.5	440.0	317.4	283.0	1 738.2	0.902	0.894	0.890	0.895	0.892
1998–99	563.6	86.5	422.0	337.1	234.4	1 643.7	0.904	0.890	0.893	0.897	0.888
1999–00	608.3	86.7	427.1	330.7	219.1	1 671.9	0.906	0.891	0.892	0.893	0.892
2000–01	553.9	81.1	458.5	338.3	174.3	1 606.1	1.000	1.000	1.000	1.000	1.000
2001–02	433.4	85.9	391.0	281.1	215.6	1 407.0	1.000	1.000	1.000	1.000	1.000
2002–03	476.6	85.8	416.5	263.7	208.6	1 451.1	1.000	1.000	1.000	1.000	1.000
2003–04	481.3	80.6	354.4	293.4	203.0	1 412.8	1.000	1.000	1.000	1.000	1.000
2004–05	431.2	108.2	366.5	266.2	208.3	1 380.3	1.000	1.000	1.000	1.000	1.000
2005–06	345.8	110.4	389.3	287.9	162.6	1 296.1	1.000	1.000	1.000	1.000	1.000
2006–07	400.3	101.5	423.3	264.6	175.9	1 365.6	1.000	1.000	1.000	1.000	1.000
2007–08	297.2	105.0	471.7	230.6	219.9	1 324.3	1.000	1.000	1.000	1.000	1.000
2008–09	297.6	105.9	328.4	233.4	221.8	1 187.1	1.000	1.000	1.000	1.000	1.000
2009–10	302.1	113.9	371.1	229.4	245.5	1 262.1	1.000	1.000	1.000	1.000	1.000
2010–11	311.2	105.6	394.7	228.5	220.2	1 260.2	1.000	1.000	1.000	1.000	1.000
2011–12	327.6	119.2	432.7	227.1	198.1	1 304.7	1.000	1.000	1.000	1.000	1.000

[1] average: 1989–90 to 1991–92

Table C.1: (cont.)

Fishing Year	$\tilde{Q}MR/MHR_{q,y} = QMR/MHR_{q,y} * R_{q,y}$ SPO 1	SPO 2	SPO 3	SPO 7	SPO 8	Total	$TACC_{q,y}$ SPO 1	SPO 2	SPO 3	SPO 7	SPO 8	Total
1986–87	305.4	44.8	253.6	188.8	100.5	893.2	540.0	64.1	330.2	240.0	240.4	1 414.7
1987–88	438.7	53.8	285.8	213.1	149.9	1 141.4	614.2	68.3	342.4	268.7	260.8	1 554.4
1988–89	574.2	56.1	247.7	198.0	168.6	1 244.6	652.6	69.9	351.8	283.5	294.6	1 652.4
1989–90	566.4	50.4	233.1	216.1	167.3	1 233.3	686.7	70.4	358.8	291.0	310.4	1 717.3
1990–91	547.8	52.1	233.2	219.7	159.7	1 212.4	688.1	70.9	363.9	294.1	310.4	1 727.4
1991–92	737.2	85.8	286.6	230.9	116.2	1 456.8	825.0	85.0	430.0	350.0	370.0	2 060.0
1992–93	663.0	82.0	249.6	290.0	212.8	1 497.3	829.0	85.5	452.1	350.0	370.0	2 086.6
1993–94	585.0	86.3	292.1	280.2	227.8	1 471.4	829.0	85.5	452.1	350.0	370.0	2 086.6
1994–95	612.2	79.1	357.7	305.1	243.8	1 598.0	829.0	85.5	453.9	350.0	370.0	2 088.4
1995–96	549.1	96.3	360.3	357.1	292.8	1 655.7	829.0	85.5	453.9	350.0	370.0	2 088.4
1996–97	611.4	88.1	387.2	354.3	247.3	1 688.3	829.0	85.5	453.9	350.0	370.0	2 088.4
1997–98	553.1	75.5	391.6	284.3	252.5	1 556.9	692.0	72.0	453.9	350.0	310.0	1 877.9
1998–99	509.6	77.0	376.7	302.4	208.1	1 473.8	692.0	72.0	453.9	350.0	310.0	1 877.9
1999–00	551.0	77.3	380.9	295.4	195.4	1 500.1	692.0	72.0	453.9	350.0	310.0	1 877.9
2000–01	553.9	81.1	458.4	338.3	174.3	1 606.0	692.0	72.0	600.0	350.0	310.0	2 024.0
2001–02	433.4	85.9	391.0	281.1	215.6	1 407.0	692.1	72.0	600.0	350.0	310.0	2 024.1
2002–03	476.6	85.8	416.5	263.7	208.6	1 451.1	692.1	72.0	600.0	350.0	310.0	2 024.1
2003–04	481.3	80.6	354.4	293.4	203.0	1 412.8	692.1	72.0	600.0	350.0	310.0	2 024.1
2004–05	431.2	108.2	366.5	266.2	208.3	1 380.3	692.1	86.0	600.0	350.0	310.0	2 038.1
2005–06	345.8	110.4	389.3	287.9	162.6	1 296.1	692.1	86.0	600.0	350.0	310.0	2 038.1
2006–07	400.3	101.5	423.3	264.6	175.9	1 365.6	692.1	86.0	600.0	221.0	310.0	1 909.1
2007–08	297.2	105.0	471.7	230.6	219.9	1 324.3	692.1	86.0	600.0	221.0	310.0	1 909.1
2008–09	297.6	105.9	328.4	233.4	221.8	1 187.1	692.1	86.0	600.0	221.0	310.0	1 909.1
2009–10	302.1	113.9	371.1	229.4	245.5	1 262.1	692.1	86.0	600.0	221.0	310.0	1 909.1
2010–11	311.2	105.6	394.7	228.5	220.2	1 260.2	692.1	86.0	600.0	221.0	310.0	1 909.1
2011–12	327.4	119.2	432.7	227.1	198.1	1 304.6	692.1	108.0	600.0	221.0	310.0	1 931.1

Appendix D. METHOD USED TO EXCLUDE "OUT-OF-RANGE" LANDINGS

D.1 Introduction

The method previously used to identify "implausibly large" landings used arithmetic CPUE, with the presumption that trips with extremely large arithmetic CPUE values existed because the contributing landings were implausibly large. This method had two major problems: one was that the arithmetic CPUE for mixed-method trips could not be easily calculated and the other was that there was a lot of subjectivity in the process (how does one identify an "implausibly large" arithmetic CPUE?). Dropping "implausibly large" landings is necessary because there are large landings which are due to data errors (possibly at the data entry step), with landings from single trips occasionally exceeding 100–300 t for some species (near to 200 t for SPO). These errors can result in substantial deviations from the accepted QMR/MHR catches and affect the credibility of the characterisation and CPUE analyses. The previous method transferred the problem of identifying "implausibly large" landings to identifying unreasonably large CPUE values. A further problem with the procedure was that the CPUE method was difficult to automate, requiring intermediate evaluations.

D.2 Methods

The method use for this procedure is less subjective and can be automated, evaluating trips with very large landings based on internal evidence within the trip that potentially corroborate the landings. The method proceeds in two steps:

Step 1 Trips with large landings above a specified threshold were selected using the empirical distribution of trip landing totals from all trips in the data set (for instance, all trips in the largest 1% quantile in terms of total trip landings);

Step 2 Internal evidence substantiating the landings within each trip was derived from summing the estimated catch for the species in question, as well as summing the "calculated green weight" (=*number_bins*avg_weight_bin*conversion_factor*) (Eq. D.1). The ratio of each these totals was taken with the declared green weight for the trip, with the minimum of the two ratios taken as the "best" validation (Eq. D.2). High values for this ratio (for instance, a value of 9 for this ratio implies that the declared green weight is 9 times larger than the "best" secondary total) are taken as evidence that the declared greenweight landing for the trip was not corroborated using the other available data, making the trip a candidate for dropping.

A two-way grid search was implemented for this procedure across a range of empirical quantiles (Step 1) and test ratio values (Step 2). The reason for stepping down through the quantiles was to minimise the number of trips removed by starting with trips that returned the largest catches. Similarly, the search starting with the most extreme $rat_{t,s}$ values and stepped down from there. For each pair of values, the "fit" (SSq^z; Eq. D.3) of the annual sum of the landings was evaluated against the QMR/MHR totals, using a least-squares criterion. The pair of quantile and $rat_{t,s}$ values which gave the lowest SSq^z was used to select the set of candidate trips to drop because the resulting landings totals would be the closest overall to the QMR/MHR total catch.

The landing data for rig are especially vexatious because of several important changes which have occurred to the conversion factors for the main landed states over the past 23 years (see Table 7 and the accompanying discussion in Section 2.3.2.2) as well as a tendency for fishers to report dressed weight instead of landed weight when estimating catches (see Figure 4). Initial explorations led to dropping a very large number of trips which seemed unreasonable and a consequence of the many changes to the way landings were reported for this species, so the search was constrained in such a way to only drop the most egregious problem trips. A plausible range for the ratio ($rat_{t,s}$: Eq. D.2) was used (from 2 to 9) and only the upper end of the trip landing distribution (from the 97% to 99.99% quantiles) was investigated.

D.3 Equations

For every trip, there exist three estimates of total greenweight catch for species *s*:

Eq. D.1

$$G_{t,s}^{d} = \sum_{i=1}^{n_t} gwt_{t,s,i}$$

$$G_{t,s}^{c} = \sum_{i=1}^{n_t} CF_s * W_{t,i} * B_{t,i}$$

$$G_{t,s}^{e} = \sum_{j=1}^{m_t} est_{t,s,j}$$

where $G_{t,s}^{d}$ = sum of declared greenweight (*gwt*) for trip *t* over all n_t landing records;

$G_{t,s}^{c}$ = sum of calculated greenweight for trip *t* over all n_t landing records, using conversion factor CF_s, weight of bin $W_{t,i}$ and number of bins $B_{t,i}$;

$G_{t,s}^{e}$ = sum of estimated catch (*est*) for trip *t* over all m_t effort records.

Assuming that $G_{t,s}^{d}$ is the best available estimate of the total landings of species *s* for trip *t*, calculate the following ratios:

Eq. D.2

$$r1_{t,s} = G_{t,s}^{d} \big/ G_{t,s}^{c}$$

$$r2_{t,s} = G_{t,s}^{d} \big/ G_{t,s}^{e}$$

$$rat_{t,s} = \min(r1_{t,s}, r2_{t,s})$$

where $G_{t,s}^{d}$, $G_{t,s}^{c}$ and $G_{t,s}^{e}$ are defined in Eq. D.1, and ignoring $r1_{t,s}$ or $r2_{t,s}$ if missing when calculating $rat_{t,s}$.

The ratio $rat_{t,s}$ can be considered the "best available information" to corroborate the landings declared in the total $G_{t,s}^{d}$, with ratios exceeding a threshold value (e.g. $rat_{t,s} > 9.0$) considered to be uncorroborated. This criterion can be applied to a set of trips selected using a quantile of the empirical distribution of total trip greenweights. The set of trips to drop was selected on the basis of the pair of criteria (quantile and ratio threshold) which gave the lowest SSq^z (Eq. D.3) relative to the annual QMR/MHR totals:

Eq. D.3

$$gg_y^z = \sum_{1}^{p_y^z} L_y^z$$

$$Ssq^z = \sum_{y=89/90}^{y=11/12} \left(gg_y^z - MHR_y\right)^2$$

where p_y^z is the number landing records in year *y* for iteration *z* (i.e.: a combination of a ratio threshold criterion with an empirical quantile cut-off criterion);

L_y^z is a landing record included in year *y* for iteration *z*.

MHR_y is the corresponding MHR/QMR landing total for SPO in year *y*.

D.4 Results

This approach did not work well for rig (SPO) because of the considerable changes in conversion factors that have taken place from the late 1980s up to the 1999–2000 fishing year (see Section 2.3.2.2) as well as problems with interpreting the estimated catches, which were often reported as dressed weight rather than green weight. Although the procedure should be consistent in any fishing year, the landings recorded in the MPI catch/effort data often exceed the reported QMR/MHR landings, particularly in SPO 3. Several arbitrary choices were made to reasonably limit the number of trips dropped, effectively dropping trips only when the landed greenweights seemed excessively large and corroboration was low. As discussed above, the search was confined to the upper end of the distribution of trip landings, examining only trips with the greatest level of catch. A fairly wide range of $rat_{t,s}$ values was examined (from 2 to 9), but the data seemed insensitive to this parameter.

A total of 132 trips were dropped across the five QMAs, representing just over 1000 t of greenweight landings (Table D.1). A true minimum was only found for SPO 2 over the investigated search range and the search minimum was not selected for two of the QMAs. The remainder of the searches ended at the beginning of the search (SPO 1: at the highest $rat_{t,s}$ value and quantile) or the end of the search (SPO 3, SPO 7 and SPO 8) with the lowest quantile and $rat_{t,s}$ value), implying that a better minimum would be found if the search had continued.

In the case of SPO 1, the top quantile (99.99%) gave the best fit to the QMR/MHR annual landings, with the lowest Ssq^z associated with $rat_{t,s}$=9. However, only a single trip (7 instead of 6 trips) was added for the remainder of the $rat_{t,s}$ ratios at quantile=99.99 (Table D.2). These 7 trips all landed more than 10 t (including one which landed >300 t) and exceeded $rat_{t,s}$=2, making all 7 of these trips good candidates for removal (Table D.1).

SPO 3 appeared to be a special case, with the unedited landings data exceeding the QMR/MHR landings in 20 of the 23 years in the dataset (Table D.3), representing over 700 t of landings. When the search was made to find a minimum, hundreds of trips were dropped, many having landed less than 500 kg of SPO with a $rat_{t,s}$<1.4. This behaviour seemed unacceptable, so the search only considered trips that had landed at least 1 000 kg of SPO, fixing the search at $rat_{t,s}$=2 for the 98.5% quantile (setting the trip catch threshold to 1.1 t [Table D.4]). This pairing of $rat_{t,s}$ and the 98.5% quantile dropped 68 trips and 424 t of landings (Table D.1). In comparison, 54 trips representing 387 t were dropped in the previous SPO 3 analysis performed in 2011 (Starr et al. 2011). Both the 2011 and 2013 procedures identified a single trip in 1990–91 where the landings exceeded 200 t. This trip, along with the 300+t trip in SPO 1, exceeded all other trips in the data set by a factor of at least 5.

The other three SPO QMAs were less extreme and showed reasonable correspondence with the reported QMR/MHR landings (Figure D.1; Table D.3), although both SPO 2 and SPO 7 diverge considerably from the QMR/MHR landings in some years. Tables have been prepared showing the total amount of landings dropped (Table D.5), the Ssq^z associated with each $rat_{t,s}$ ratio and quantile pairing (Table D.6), and the overage/underage between the accepted landings dataset by SPO QMA and the corresponding QMR/MHR landings (Table D.7).

Table D.1: Statistics associated with the selected minimum in each QMA. MHR_y = QMR/MHR landings in year *y*; gg_y^0 = unedited landings in year *y*; gg_y = edited landings at selected minimum in year *y*; $rat_{t,s}$ as defined in Eq. D.2. Selected pairings indicated in grey differ from actual minimum for reasons stated in the text.

Fishstock	Quantile	$rat_{t,s}$	Number trips dropped	Total trips in data set	Sum landings dropped (t)	$\sum_{y=89/90}^{y=11/12} MHR_y$	$\sum_{y=89/90}^{y=11/12} gg_y^0$	$\sum_{y=89/90}^{y=11/12} gg_y$	$\sum_{y=89/90}^{y=11/12} \left(gg_y - MHR_y\right)$
SPO 1	99.99	2	7	130 825	391	11 955	12 029	11 637	-318
SPO 2	99.5	2	27	34 993	60	2 170	2 175	2 114	-56
SPO 3	98.5	2	63	86 319	424	8 858	9 585	9 161	303
SPO 7	97	2	34	39 010	143	6 718	7 049	6 905	187
SPO 8	99.99	2	1	23 011	37	5 110	4 993	4 956	-154
Total	–	–	132	314 158	1 056	34 811	35 831	34 774	-38

Table D.2: Number of trips dropped over a two parameter search: A) a threshold quantile cut-off which selected the set of large landings over which to search and B) the ratio $\left(rat_{t,s}\right)$ (Eq. D.2) which sets the maximum criterion for accepting a landing. The quantile/ratio pair with the lowest *Ssq*^{2} (Eq. D.3) is coloured blue for each SPO QMA. Selected pairings (Table D.1) which differed from the actual minimum are marked in grey.

	$\left(rat_{t,s}\right)$							
Quantile	2	3	4	5	6	7	8	9
	SPO 1							
97	242	176	151	133	120	117	110	103
98	173	128	116	107	98	96	92	87
98.5	141	102	93	88	85	83	79	75
99	110	82	76	72	71	69	69	65
99.5	67	53	53	50	50	50	50	48
99.9	31	29	29	27	27	27	27	25
99.99	7	7	7	7	7	7	7	6
	SPO 2							
97	52	38	36	35	32	32	30	28
98	46	35	33	32	29	29	28	26
98.5	42	33	31	30	28	28	27	25
99	32	26	24	23	22	22	21	20
99.5	27	22	21	21	20	20	19	18
99.9	13	13	12	12	11	11	10	10
99.99	3	3	3	3	3	3	2	2
	SPO 3							
97	98	81	74	69	69	68	64	58
98	77	64	61	58	58	58	56	50
98.5	62	52	50	48	48	48	47	42
99	51	46	44	43	43	43	42	37
99.5	32	31	30	29	29	29	28	23
99.9	16	16	16	16	16	16	15	14
99.99	4	4	4	4	4	4	3	3
	SPO 7							
97	34	28	27	27	27	25	25	25
98	27	24	24	24	24	22	22	22
98.5	24	21	21	21	21	20	20	20
99	14	13	13	13	13	13	13	13
99.5	7	7	7	7	7	7	7	7
99.9	2	2	2	2	2	2	2	2
99.99	1	1	1	1	1	1	1	1
	SPO 8							
97	10	7	7	6	6	6	6	6
98	8	5	5	4	4	4	4	4
98.5	6	4	4	3	3	3	3	3
99	5	4	4	3	3	3	3	3
99.5	4	4	4	3	3	3	3	3
99.9	3	3	3	3	3	3	3	3
99.99	1	1	1	1	1	1	1	1

Table D.3: Annual statistics associated with the selected minima in SPO 1 and SPO 2. MHR_y = QMR/MHR landings in year *y*; gg_y^0 = unedited landings in year *y*; gg_y = edited landings at selected minimum in year *y*. The final two columns are the annual result of applying Eq. D.3 to the unedited landings and to the selected QMA "minimum" defined in Table D.1.

	SPO 1					SPO 2				
Fishing year	MHR_y	gg_y^0	gg_y	$\left(gg_y^0 - MHR_y\right)$	$\left(gg_y - MHR_y\right)$	MHR_y	gg_y^0	gg_y	$\left(gg_y^0 - MHR_y\right)$	$\left(gg_y - MHR_y\right)$
89/90	689.1	424.7	424.7	69 888	69 888	61.5	49.8	49.8	138	138
90/91	655.9	871.2	559.0	46 335	9 398	62.9	47.0	47.0	251	251
91/92	871.1	745.7	745.7	15 719	15 719	106.6	88.8	86.7	317	397
92/93	719.3	692.2	692.2	730	730	90.4	91.0	88.9	0	2
93/94	630.8	680.9	680.9	2 512	2 512	95.9	98.4	98.4	6	6
94/95	665.6	670.6	670.6	25	25	87.7	84.7	84.7	9	9
95/96	603.1	635.6	617.2	1 056	199	106.2	134.1	119.0	781	165
96/97	677.4	681.8	681.8	19	19	97.9	98.2	98.2	0	0
97/98	613.2	656.1	595.3	1 844	321	84.5	78.8	78.8	32	32
98/99	563.6	585.7	585.7	486	486	86.5	86.7	84.2	0	5
99/00	608.3	626.9	626.9	345	345	86.7	87.9	85.9	2	1
00/01	553.9	569.0	569.0	227	227	81.1	87.0	80.4	34	1
01/02	433.4	466.2	466.2	1 074	1 074	85.9	89.4	87.5	12	3
02/03	476.6	486.9	486.9	106	106	85.8	90.2	88.0	19	5
03/04	481.3	487.5	487.5	38	38	80.6	85.4	79.8	23	1
04/05	431.2	441.6	441.6	109	109	108.2	109.1	106.1	1	4
05/06	345.8	347.5	347.5	3	3	110.4	112.5	109.2	4	2
06/07	400.3	406.0	406.0	32	32	101.5	100.7	100.7	1	1
07/08	297.2	307.7	307.7	110	110	105.0	102.3	102.3	7	7
08/09	297.6	295.0	295.0	7	7	105.9	113.1	103.9	53	4
09/10	302.1	307.3	307.3	27	27	113.9	112.9	111.8	1	4
10/11	311.2	315.8	315.8	22	22	105.6	104.1	104.1	2	2
11/12	327.6	326.9	326.9	0	0	119.2	122.2	118.5	9	1
Total	11 955.4	12 028.7	11 637.2	140 715	101 397	2 169.9	2 174.6	2 114.2	1 701	1 039

Table D.3 (cont.): Annual statistics associated with the selected minima in SPO 3, SPO 7 and SPO 8. $MHR_y =$ **QMR/MHR landings in year *y*;** $gg_y^0 =$ **unedited landings in year *y*;** $gg_y =$ **edited landings at selected minimum in year *y*. The final two columns are the annual result of applying Eq. D.3 to the unedited landings and to the selected QMA "minimum" defined in Table D.1.**

Fishing year	SPO 3					SPO 7					SPO 8				
	MHR_y	gg_y^0	gg_y	$(gg_y^0 - MHR_y)$	$(gg_y - MHR_y)$	MHR_y	gg_y^0	gg_y	$(gg_y^0 - MHR_y)$	$(gg_y - MHR_y)$	MHR_y	gg_y^0	gg_y	$(gg_y^0 - MHR_y)$	$(gg_y - MHR_y)$
89/90	292.2	257.7	251.9	1 190	1 625	266.0	256.5	253.5	89	154	206.2	174.1	174.1	1 033	1 033
90/91	283.9	511.1	298.6	51 628	217	267.8	277.4	274.0	93	39	196.4	175.6	175.6	434	434
91/92	350.6	390.8	369.6	1 618	363	287.6	291.9	291.9	18	18	147.8	132.4	132.4	237	237
92/93	278.1	290.6	284.2	155	36	324.0	332.6	323.9	74	0	238.7	222.8	222.8	253	253
93/94	327.1	358.9	345.7	1 008	343	312.2	322.6	320.5	108	67	254.7	254.1	254.1	0	0
94/95	401.6	474.4	429.6	5 292	784	341.3	374.1	374.1	1 076	1 076	272.6	304.8	268.1	1 037	20
95/96	405.2	457.8	445.3	2 763	1 610	395.0	414.9	410.2	394	232	327.3	320.0	320.0	53	53
96/97	431.9	497.4	489.9	4 293	3 366	394.6	428.9	398.0	1 172	11	275.7	251.5	251.5	585	585
97/98	440.0	480.1	455.7	1 605	245	317.4	344.0	335.0	705	308	283.0	270.8	270.8	150	150
98/99	422.0	430.4	427.6	70	31	337.1	365.4	362.9	799	665	234.4	223.9	223.9	111	111
99/00	427.1	459.9	450.0	1 070	521	330.7	349.7	344.6	361	193	219.1	208.5	208.5	113	113
00/01	458.5	499.2	482.6	1 663	585	338.3	362.3	350.0	576	138	174.3	167.7	167.7	43	43
01/02	391.0	408.1	400.5	291	91	281.1	299.6	294.6	340	183	215.6	213.1	213.1	6	6
02/03	416.5	446.4	442.6	894	680	263.7	269.0	269.0	29	29	208.6	205.4	205.4	10	10
03/04	354.4	376.7	370.3	493	252	293.4	301.3	301.3	62	62	203.0	201.8	201.8	2	2
04/05	366.5	378.1	373.4	135	48	266.2	268.8	265.2	7	1	208.3	209.2	209.2	1	1
05/06	389.3	385.8	384.4	13	24	287.9	295.4	291.1	55	10	162.6	166.7	166.7	17	17
06/07	423.3	458.0	446.4	1 201	531	264.6	264.8	264.8	0	0	175.9	176.5	176.5	0	0
07/08	471.7	483.6	483.6	143	143	230.6	296.3	249.7	4 312	365	219.9	222.8	222.8	9	9
08/09	328.4	333.6	328.3	27	0	233.4	237.3	235.0	15	3	221.8	222.8	222.8	1	1
09/10	371.1	378.0	378.0	47	47	229.4	230.1	230.1	1	1	245.5	246.6	246.6	1	1
10/11	394.7	392.6	388.1	5	44	228.5	235.2	235.2	44	44	220.2	216.5	216.5	14	14
11/12	432.7	436.2	434.9	12	5	227.1	230.5	230.5	12	12	198.1	205.5	205.5	54	54
Total	8 858.0	9 585.1	9 161.3	75 615	11 591	6 718.0	7 048.5	6 905.3	10 342	3 610	5 109.7	4 993.1	4 956.5	4 164	3 146

Table D.4: Trip threshold (t) associated with each quantile searched: every trip above the indicated threshold tonnage was evaluated for corroboration of declared greenweight catch.

					Fishstock
Quantile	SPO 1	SPO 2	SPO 3	SPO 7	SPO 8
97	0.5	0.3	0.7	1.1	1.6
98	0.6	0.4	0.9	1.6	2.1
98.5	0.8	0.5	1.1	2	2.5
99	0.9	0.6	1.5	2.6	3.1
99.5	1.4	0.8	2.2	3.8	4.3
99.9	3.1	1.8	4.5	8.2	7.7
99.99	9.8	4.6	9.1	15.1	12.2

Table D.5: Total landings (t) dropped over the two parameter search defined in Table D.2. The quantile/ratio pair with the lowest Ssq^2 (Eq. D.3) is coloured blue for each SPO QMA. Selected pairings (Table D.1) which differed from the actual minimum are marked in grey.

								$(rat_{t,s})$
Quantile	2	3	4	5	6	7	8	9
	SPO 1							
97	726.6	653.3	634.2	613.8	604.3	601.5	596.5	576.0
98	687.0	625.6	614.1	599.0	591.8	589.5	586.2	566.7
98.5	664.6	607.5	598.0	585.6	582.6	580.4	577.1	558.3
99	637.7	590.1	583.4	571.7	570.6	568.3	568.3	549.5
99.5	590.1	557.5	557.5	547.0	547.0	547.0	547.0	530.2
99.9	514.5	506.2	506.2	497.6	497.6	497.6	497.6	480.8
99.99	391.4	391.4	391.4	391.4	391.4	391.4	391.4	377.9
	SPO 2							
97	73.1	62.6	59.9	59.2	56.3	56.3	51.4	49.4
98	70.9	61.5	58.8	58.1	55.2	55.2	50.6	48.7
98.5	69.1	60.6	57.9	57.2	54.8	54.8	50.1	48.2
99	63.7	56.8	54.1	53.4	51.6	51.6	46.9	45.5
99.5	60.4	54.1	52.0	52.0	50.2	50.2	45.5	44.1
99.9	44.1	44.1	42.0	42.0	40.2	40.2	35.6	35.6
99.99	16.4	16.4	16.4	16.4	16.4	16.4	11.8	11.8
	SPO 3							
97	456.1	432.2	423.1	416.6	416.6	415.8	404.0	385.6
98	439.2	418.4	412.5	407.5	407.5	407.5	397.3	379.0
98.5	423.9	406.1	401.2	397.2	397.2	397.2	388.0	370.6
99	409.1	398.0	393.2	390.6	390.6	390.6	381.4	364.0
99.5	375.4	371.4	368.2	365.6	365.6	365.6	356.4	339.0
99.9	324.9	324.9	324.9	324.9	324.9	324.9	315.6	309.9
99.99	252.1	252.1	252.1	252.1	252.1	252.1	242.8	242.8
	SPO 7							
97	143.3	131.3	129.7	129.7	129.7	125.8	125.8	125.8
98	133.3	125.4	125.4	125.4	125.4	121.4	121.4	121.4
98.5	128.4	120.4	120.4	120.4	120.4	118.1	118.1	118.1
99	105.5	102.3	102.3	102.3	102.3	102.3	102.3	102.3
99.5	82.8	82.8	82.8	82.8	82.8	82.8	82.8	82.8
99.9	55.2	55.2	55.2	55.2	55.2	55.2	55.2	55.2
99.99	46.6	46.6	46.6	46.6	46.6	46.6	46.6	46.6
	SPO 8							
97	73.4	64.8	64.8	58.9	58.9	58.9	58.9	58.9
98	69.6	61.0	61.0	55.0	55.0	55.0	55.0	55.0
98.5	65.1	58.9	58.9	52.9	52.9	52.9	52.9	52.9
99	62.0	58.9	58.9	52.9	52.9	52.9	52.9	52.9
99.5	58.9	58.9	58.9	52.9	52.9	52.9	52.9	52.9
99.9	52.9	52.9	52.9	52.9	52.9	52.9	52.9	52.9
99.99	36.7	36.7	36.7	36.7	36.7	36.7	36.7	36.7

Table D.6: "Fit" (Ssq^2: Eq. D.3) over the two parameter search defined in Table D.2. The quantile/ratio pair with the lowest Ssq^2 is coloured blue for each SPO QMA. Selected pairings (Table D.1) which differed from the actual minimum are marked in grey.

Quantile	$(rat_{t,s})$ 2	3	4	5	6	7	8	9
	SPO 1							
97	115 299	107 954	107 198	106 502	106 437	106 406	106 332	105 447
98	113 840	107 364	106 859	106 389	106 381	106 354	106 267	105 391
98.5	112 932	106 811	106 290	105 842	105 800	105 774	105 686	104 837
99	111 610	106 297	105 878	105 469	105 449	105 423	105 423	104 599
99.5	107 800	105 364	105 364	105 208	105 208	105 208	105 208	104 473
99.9	105 183	104 369	104 369	104 249	104 249	104 249	104 249	103 663
99.99	101 397	101 397	101 397	101 397	101 397	101 397	101 397	101 096
	SPO 2							
97	1 091	1 078	1 072	1 070	1 121	1 121	1 145	1 135
98	1 078	1 078	1 071	1 070	1 121	1 121	1 144	1 133
98.5	1 071	1 076	1 069	1 068	1 120	1 120	1 143	1 132
99	1 066	1 080	1 077	1 075	1 131	1 131	1 154	1 145
99.5	1 039	1 070	1 066	1 066	1 122	1 122	1 145	1 140
99.9	1 079	1 079	1 075	1 075	1 131	1 131	1 154	1 154
99.99	1 159	1 159	1 159	1 159	1 159	1 159	1 182	1 182
	SPO 3							
97	57 037	57 989	58 568	58 661	58 661	58 699	62 844	63 828
98	57 856	58 491	58 686	58 732	58 732	58 732	62 868	63 857
98.5	58 294	58 819	58 983	59 106	59 106	59 106	63 199	64 177
99	59 079	59 557	59 721	59 856	59 856	59 856	63 974	64 969
99.5	60 043	60 434	60 606	60 740	60 740	60 740	64 858	65 900
99.9	62 476	62 476	62 476	62 476	62 476	62 476	66 594	67 007
99.99	67 313	67 313	67 313	67 313	67 313	67 313	71 431	71 431
	SPO 7							
97	3 610	4 051	4 015	4 015	4 015	4 075	4 075	4 075
98	3 805	4 083	4 083	4 083	4 083	4 148	4 148	4 148
98.5	3 963	4 241	4 241	4 241	4 241	4 253	4 253	4 253
99	4 455	4 574	4 574	4 574	4 574	4 574	4 574	4 574
99.5	5 016	5 016	5 016	5 016	5 016	5 016	5 016	5 016
99.9	6 321	6 321	6 321	6 321	6 321	6 321	6 321	6 321
99.99	6 395	6 395	6 395	6 395	6 395	6 395	6 395	6 395
	SPO 8							
97	3 669	3 464	3 464	3 478	3 478	3 478	3 478	3 478
98	3 610	3 414	3 414	3 428	3 428	3 428	3 428	3 428
98.5	3 565	3 396	3 396	3 410	3 410	3 410	3 410	3 410
99	3 473	3 396	3 396	3 410	3 410	3 410	3 410	3 410
99.5	3 396	3 396	3 396	3 410	3 410	3 410	3 410	3 410
99.9	3 410	3 410	3 410	3 410	3 410	3 410	3 410	3 410
99.99	3 146	3 146	3 146	3 146	3 146	3 146	3 146	3 146

Table D.7: Differences between the edited total landings and the sum of the QMR/MHR landings $\left(\sum_{y=89/90}^{y=11/12}\left(gg_y - MHR_y\right)\right)$ over the two parameter search defined in Table D.2. The quantile/ratio pair with the lowest Ssq^2 is coloured blue for each SPO QMA. Selected pairings (Table D.1) which differed from the actual minimum are marked in grey.

	$\left(rat_{t,s}\right)$							
Quantile	2	3	4	5	6	7	8	9
	SPO 1							
97	-653	-580	-561	-541	-531	-528	-523	-503
98	-614	-552	-541	-526	-519	-516	-513	-493
98.5	-591	-534	-525	-512	-509	-507	-504	-485
99	-564	-517	-510	-498	-497	-495	-495	-476
99.5	-517	-484	-484	-474	-474	-474	-474	-457
99.9	-441	-433	-433	-424	-424	-424	-424	-408
99.99	-318	-318	-318	-318	-318	-318	-318	-305
	SPO 2							
97	-68	-58	-55	-55	-52	-52	-47	-45
98	-66	-57	-54	-53	-51	-51	-46	-44
98.5	-64	-56	-53	-52	-50	-50	-45	-43
99	-59	-52	-49	-49	-47	-47	-42	-41
99.5	-56	-49	-47	-47	-45	-45	-41	-39
99.9	-39	-39	-37	-37	-35	-35	-31	-31
99.99	-12	-12	-12	-12	-12	-12	-7	-7
	SPO 3							
97	270.9	294.8	303.9	310.4	310.4	311.2	323.0	341.4
98	287.8	308.6	314.5	319.5	319.5	319.5	329.7	348.0
98.5	303.1	320.9	325.8	329.8	329.8	329.8	339.0	356.4
99	317.9	329.0	333.8	336.4	336.4	336.4	345.6	363.0
99.5	351.6	355.6	358.8	361.4	361.4	361.4	370.6	388.0
99.9	402.1	402.1	402.1	402.1	402.1	402.1	411.4	417.1
99.99	474.9	474.9	474.9	474.9	474.9	474.9	484.2	484.2
	SPO 7							
97	187	199	201	201	201	205	205	205
98	197	205	205	205	205	209	209	209
98.5	202	210	210	210	210	213	213	213
99	225	228	228	228	228	228	228	228
99.5	248	248	248	248	248	248	248	248
99.9	275	275	275	275	275	275	275	275
99.99	284	284	284	284	284	284	284	284
	SPO 8							
97	-190	-181	-181	-175	-175	-175	-175	-175
98	-186	-178	-178	-172	-172	-172	-172	-172
98.5	-182	-175	-175	-170	-170	-170	-170	-170
99	-179	-175	-175	-170	-170	-170	-170	-170
99.5	-175	-175	-175	-170	-170	-170	-170	-170
99.9	-170	-170	-170	-170	-170	-170	-170	-170
99.99	-153	-153	-153	-153	-153	-153	-153	-153

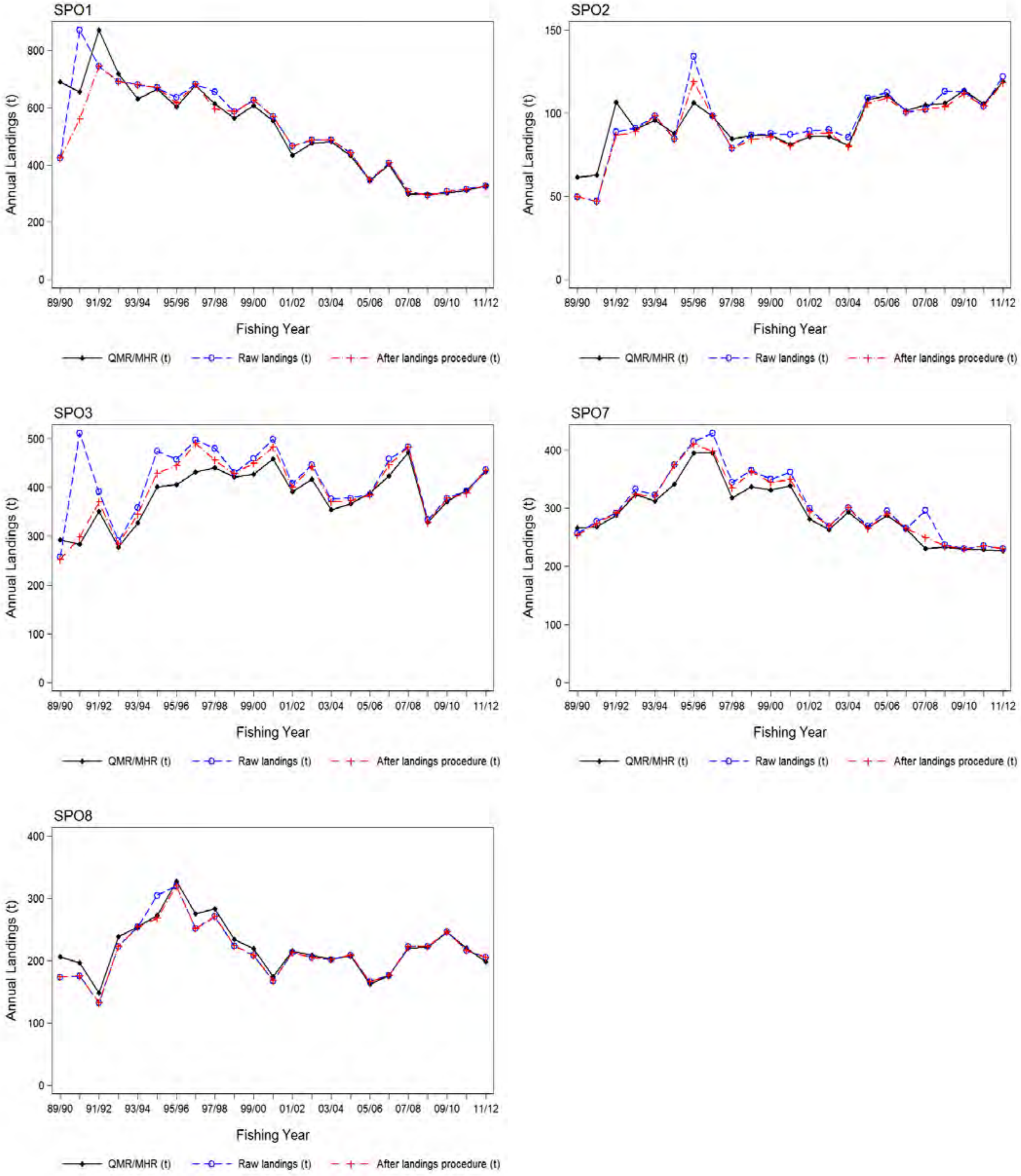


Figure D.1: Comparison of QMR/MHR annual total landings for SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 with two extracts: A: unedited or "raw" landings; and B: total landings after dropping the trips identified at the selected QMA "minimum" quantile/ratio pairing defined in Table D.1.

Appendix E. DATA PREPARATION INFORMATION BY QMA

Table E.1: Comparison of the total adjusted QMR/MHR catch (t) for SPO 1 and SPO 2, reported by fishing year, with the sum of the corrected landed catch totals (bottom part of the MPI CELR form), the total catch after matching effort with landing data ('Analysis' data set) and the sum of the estimated catches from the Analysis data set. Data source: MPI replog 8807: 1989–90 to 2011–12. Landings and QMR/MHR totals have been adjusted to consistent conversion factors across years.

	SPO 1							SPO 2						
Fishing Year	QMR/ MHR (t)	Total landed catch (t)[1]	% landed/ QMR/ MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis	QMR/ MHR (t)	Total landed catch (t)[2]	% landed/ QMR/ MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis
89/90	566	346	61	345	100	338	98	50	41	81	41	99	26	65
90/91	548	415	76	413	99	352	85	52	39	75	38	99	23	61
91/92	737	566	77	562	99	469	84	86	70	81	69	99	38	54
92/93	663	574	87	573	100	462	81	82	81	98	80	99	37	46
93/94	585	628	107	626	100	510	82	86	88	102	87	98	46	53
94/95	612	612	100	610	100	500	82	79	76	96	75	98	33	44
95/96	549	561	102	548	98	427	78	96	108	112	105	97	52	49
96/97	611	613	100	597	97	443	74	88	86	98	84	97	41	49
97/98	553	536	97	523	98	361	69	75	70	93	68	97	30	43
98/99	510	525	103	507	96	321	63	77	75	97	73	97	38	52
99/00	551	560	102	552	99	396	72	77	76	99	76	99	40	53
00/01	554	568	103	557	98	390	70	81	80	99	79	99	41	52
01/02	433	463	107	458	99	332	72	86	88	102	84	96	48	56
02/03	477	475	100	473	100	309	65	86	88	102	85	97	44	51
03/04	481	474	98	470	99	300	64	81	77	95	72	95	35	48
04/05	431	412	95	405	98	248	61	108	104	96	103	99	42	41
05/06	346	326	94	305	94	177	58	110	108	98	107	99	47	44
06/07	400	371	93	349	94	209	60	102	99	98	99	99	44	44
07/08	297	275	93	262	95	150	57	105	101	96	98	98	59	59
08/09	298	266	89	246	92	138	56	106	104	98	99	95	62	62
09/10	302	272	90	259	95	140	54	114	111	97	110	99	65	59
10/11	311	280	90	260	93	141	54	106	104	98	102	98	64	63
11/12	327	293	90	286	98	163	57	119	118	99	116	98	88	76
Total	11 144	10 410	93	10 185	98	7 277	71	2 053	1 991	97	1 949	98	1 040	53

[1] includes all SPO 1 landings in replog 8807 except for 7 trips excluded for being "out of range" (see Table D.1).
[2] includes all SPO 2 landings in replog 8807 except for 27 trips excluded for being "out of range" (see Table D.1).

Table E.2: Caption as for Table E.1, showing annual totals for SPO 3 and SPO 7.

	SPO 3							SPO 7						
Fishing Year	QMR/ MHR (t)	Total landed catch (t)[1]	% landed/ QMR/ MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis	QMR/ MHR (t)	Total landed catch (t)[2]	% landed/ QMR/ MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis
89/90	233	200	86	197	99	157	79	216	205	95	196	95	188	96
90/91	233	245	105	243	99	214	88	220	223	101	217	97	184	85
91/92	287	302	105	300	100	265	88	231	234	101	216	92	201	93
92/93	250	254	102	251	99	217	87	290	290	100	279	96	236	85
93/94	292	306	105	302	99	265	88	280	287	103	267	93	196	73
94/95	358	379	106	372	98	320	86	305	334	109	331	99	270	82
95/96	360	394	109	378	96	314	83	357	367	103	338	92	249	74
96/97	387	438	113	424	97	326	77	354	347	98	321	92	220	69
97/98	392	402	103	392	98	350	89	284	295	104	265	90	192	72
98/99	377	379	101	377	100	333	88	302	309	102	294	95	200	68
99/00	381	400	105	395	99	340	86	295	307	104	290	95	211	73
00/01	458	479	104	469	98	389	83	338	348	103	334	96	234	70
01/02	391	400	102	393	98	350	89	281	289	103	270	93	171	63
02/03	417	434	104	431	99	369	86	264	266	101	251	94	164	65
03/04	354	367	103	365	100	296	81	293	298	102	285	96	180	63
04/05	366	364	99	362	99	307	85	266	263	99	250	95	166	66
05/06	389	384	99	380	99	314	83	288	290	101	282	97	193	68
06/07	423	445	105	437	98	355	81	265	263	99	252	96	181	72
07/08	472	477	101	460	96	406	88	231	242	105	222	92	174	79
08/09	328	327	100	323	99	299	93	233	233	100	212	91	160	76
09/10	371	375	101	372	99	336	90	229	229	100	204	89	157	77
10/11	395	386	98	379	98	326	86	229	233	102	212	91	163	77
11/12	433	433	100	430	100	379	88	227	228	101	214	94	175	82
Total	8 347	8 568	103	8 434	98	7 228	86	6 280	6 379	102	6 001	94	4 466	74

[1] includes all SPO 3 landings in replog 8807 except for 63 trips excluded for being "out of range" (see Table D.1).
[2] includes all SPO 7 landings in replog 8807 except for 34 trips excluded for being "out of range" (see Table D.1).

Table E.3: Caption as for Table E.1, showing annual totals for SPO 8.

Fishing Year	QMR/MHR (t)	Total landed catch (t)[1]	% landed/ QMR/MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis
89/90	167	141	84	122	87	108	88
90/91	160	143	89	118	83	112	95
91/92	116	104	90	93	89	87	94
92/93	213	199	93	183	92	155	85
93/94	228	227	100	207	91	176	85
94/95	244	239	98	233	97	200	86
95/96	293	286	98	257	90	223	87
96/97	247	221	90	202	91	158	78
97/98	252	241	96	199	82	168	84
98/99	208	199	95	178	90	136	76
99/00	195	186	95	149	80	113	76
00/01	174	167	96	141	84	111	79
01/02	216	211	98	188	89	157	84
02/03	209	202	97	188	93	154	82
03/04	203	194	96	155	80	124	80
04/05	208	205	98	152	74	128	84
05/06	163	165	102	134	81	114	85
06/07	176	175	100	132	75	112	85
07/08	220	219	100	159	73	138	87
08/09	222	223	100	136	61	121	89
09/10	246	245	100	164	67	148	90
10/11	220	215	98	163	76	147	90
11/12	198	195	98	133	68	118	89
Total	4 777	4 601	96	3 787	82	3 208	85

[1] includes all SPO 8 landings in replog 8807 except for 1 trip excluded for being “out of range” (Table D.1).

Table E.4: **Summary statistics pertaining to the reporting of estimated catch from the SPO 1 and SPO 2 analysis datasets.**

	SPO 1							SPO 2						
	Trips with landed catch but which report no estimated catch			Statistics (excluding 0s) for the ratio of landed/estimated catch by trip				Trips with landed catch but which report no estimated catch			Statistics (excluding 0s) for the ratio of landed/estimated catch by trip			
Fishing year	Trips: % relative to total trips	Landings: % relative to total landings	Landings (t)	5% quantile	Median	Mean	95% quantile	Trips: % relative to total trips	Landings: % relative to total landings	Landings (t)	5% quantile	Median	Mean	95% quantile
89/90	27	10	56	0.47	0.93	1.18	2.12	48	34	17	0.61	1.00	1.21	2.29
90/91	23	9	52	0.47	1.00	1.36	2.33	56	39	20	0.50	0.98	1.17	2.57
91/92	22	9	65	0.48	1.00	1.30	2.50	51	39	33	0.39	1.00	1.37	3.15
92/93	24	9	58	0.50	1.00	1.43	2.66	52	34	28	0.60	1.10	1.83	4.43
93/94	23	7	43	0.51	1.00	1.45	2.83	53	29	25	0.59	1.22	1.77	4.19
94/95	25	7	45	0.53	1.00	2.15	3.00	53	37	29	0.62	1.39	1.83	4.43
95/96	27	13	70	0.53	1.03	1.42	2.80	52	33	32	0.60	1.43	1.90	5.31
96/97	28	15	94	0.53	1.03	1.47	2.66	52	33	29	0.53	1.46	1.79	4.50
97/98	27	14	77	0.53	1.14	2.01	2.80	52	32	24	0.58	1.50	1.83	4.72
98/99	25	14	72	0.50	1.18	1.61	3.10	49	31	24	0.62	1.41	1.70	4.11
99/00	19	7	36	0.57	1.24	1.91	3.10	51	32	25	0.45	1.30	1.80	4.65
00/01	19	5	30	0.60	1.28	1.68	3.00	45	25	20	0.60	1.55	1.97	4.06
01/02	20	5	23	0.62	1.26	1.59	3.07	39	18	15	0.52	1.55	2.14	5.86
02/03	20	6	28	0.64	1.40	1.69	3.40	40	20	17	0.57	1.51	3.27	5.43
03/04	22	7	35	0.60	1.48	2.12	4.13	42	17	14	0.53	1.56	2.26	6.03
04/05	26	7	30	0.54	1.50	2.02	4.69	45	18	19	0.48	1.54	2.29	6.51
05/06	28	10	34	0.57	1.50	2.60	4.75	44	19	21	0.56	1.62	2.19	5.89
06/07	25	7	29	0.58	1.40	3.03	5.00	41	20	21	0.60	1.71	2.40	6.10
07/08	18	9	28	0.50	1.36	2.10	4.80	17	4	4	0.50	1.42	1.95	5.47
08/09	21	9	26	0.48	1.33	1.95	5.25	15	4	4	0.47	1.44	1.95	5.00
09/10	22	9	26	0.49	1.32	2.05	5.50	14	5	6	0.55	1.50	2.02	5.17
10/11	21	7	21	0.47	1.33	2.74	5.89	14	4	5	0.53	1.47	1.87	4.65
11/12	22	6	20	0.47	1.26	2.26	5.40	12	2	3	0.52	1.36	1.68	3.88
Total	23	9	999	0.52	1.15	1.81	3.50	42	21	436	0.54	1.41	1.95	4.93

Table E.5: Summary statistics pertaining to the reporting of estimated catch from the SPO 3 and SPO 7 analysis datasets.

	SPO 3							SPO 7						
	Trips with landed catch but which report no estimated catch			Statistics (excluding 0s) for the ratio of landed/estimated catch by trip				Trips with landed catch but which report no estimated catch			Statistics (excluding 0s) for the ratio of landed/estimated catch by trip			
Fishing year	Trips: % relative to total trips	Landings: % relative to total landings	Landings (t)	5% quantile	Median	Mean	95% quantile	Trips: % relative to total trips	Landings: % relative to total landings	Landings (t)	5% quantile	Median	Mean	95% quantile
89/90	45	17	40	0.46	0.90	1.92	2.33	48	15	33	0.47	1.01	1.42	3.10
90/91	42	15	36	0.50	0.93	1.18	2.30	42	15	33	0.53	1.01	1.62	3.10
91/92	44	12	35	0.34	0.87	1.12	2.09	47	14	32	0.53	1.00	1.45	2.95
92/93	43	13	32	0.44	0.91	1.50	2.21	56	15	45	0.53	1.05	1.41	2.92
93/94	46	13	37	0.43	0.90	1.26	2.33	51	17	47	0.60	1.24	1.65	3.50
94/95	45	15	52	0.41	0.90	1.27	2.20	46	13	40	0.56	1.37	1.89	4.52
95/96	48	18	66	0.42	0.91	1.34	2.54	46	16	56	0.53	1.38	1.81	4.03
96/97	50	21	80	0.42	0.92	1.80	2.48	49	20	70	0.53	1.33	1.71	4.01
97/98	49	13	52	0.39	0.94	1.53	2.30	50	12	34	0.49	1.48	2.58	4.23
98/99	48	13	51	0.35	0.93	1.48	2.13	47	13	40	0.62	1.44	1.94	3.88
99/00	50	17	67	0.35	0.95	1.18	2.21	41	12	35	0.54	1.31	2.22	4.31
00/01	44	15	68	0.47	1.00	1.43	2.33	42	13	45	0.65	1.29	1.88	4.50
01/02	45	12	48	0.41	1.00	1.17	2.33	41	11	32	0.60	1.32	1.88	4.95
02/03	44	13	53	0.47	1.00	1.22	2.33	47	14	36	0.63	1.45	1.80	4.27
03/04	48	16	55	0.40	1.01	1.27	2.54	49	14	41	0.70	1.51	2.15	4.73
04/05	48	14	53	0.47	1.00	1.24	2.40	47	12	33	0.68	1.55	2.08	5.07
05/06	48	13	50	0.52	1.04	1.25	2.33	43	10	29	0.69	1.58	2.07	4.82
06/07	44	13	55	0.52	1.09	1.35	2.48	47	12	31	0.61	1.55	2.10	5.43
07/08	21	4	21	0.47	1.09	1.44	2.58	15	4	8	0.65	1.43	1.86	4.26
08/09	23	4	13	0.40	1.03	1.35	3.11	17	3	6	0.63	1.46	2.58	4.65
09/10	20	4	15	0.40	1.10	1.47	3.29	16	2	5	0.60	1.55	2.19	5.03
10/11	20	4	14	0.33	1.13	1.61	3.57	15	3	8	0.64	1.43	1.86	4.17
11/12	20	3	12	0.42	1.13	1.50	3.32	19	4	10	0.57	1.45	1.89	4.50
Total	42	12	1 004	0.41	1.00	1.38	2.50	42	12	748	0.60	1.35	1.91	4.20

Table E.6: Summary statistics pertaining to the reporting of estimated catch from the SPO 8 analysis dataset.

Fishing year	Trips with landed catch but which report no estimated catch			Statistics (excluding 0s) for the ratio of landed/estimated catch by trip			
	Trips: % relative to total trips	Landings: % relative to total landings	Landings (t)	5% quantile	Median	Mean	95% quantile
89/90	17	13	23	0.60	0.97	1.20	2.33
90/91	18	10	16	0.60	0.96	1.16	2.02
91/92	19	7	9	0.52	0.93	1.12	1.94
92/93	22	4	10	0.65	1.00	1.25	2.07
93/94	21	4	10	0.66	1.00	1.24	2.04
94/95	27	9	21	0.59	1.02	1.35	2.17
95/96	29	9	25	0.62	1.04	3.16	2.25
96/97	28	14	34	0.64	1.00	1.31	2.31
97/98	27	11	28	0.52	0.98	1.26	2.36
98/99	29	13	28	0.44	0.93	1.37	2.66
99/00	30	11	22	0.53	1.00	1.33	2.48
00/01	18	4	6	0.59	1.16	1.57	2.80
01/02	22	3	7	0.71	1.26	1.49	2.53
02/03	24	4	8	0.59	1.16	1.91	4.26
03/04	25	4	8	0.57	1.25	1.61	3.85
04/05	27	4	9	0.56	1.14	1.59	3.59
05/06	34	5	9	0.69	1.19	1.54	3.40
06/07	28	4	7	0.55	1.10	1.39	2.96
07/08	9	1	2	0.60	1.16	1.60	3.10
08/09	10	1	3	0.60	1.11	1.40	3.17
09/10	11	1	2	0.53	1.12	1.35	2.67
10/11	12	1	2	0.60	1.17	1.56	3.41
11/12	14	2	3	0.59	1.20	1.52	3.10
Total	22	6	292	0.59	1.06	1.46	2.53

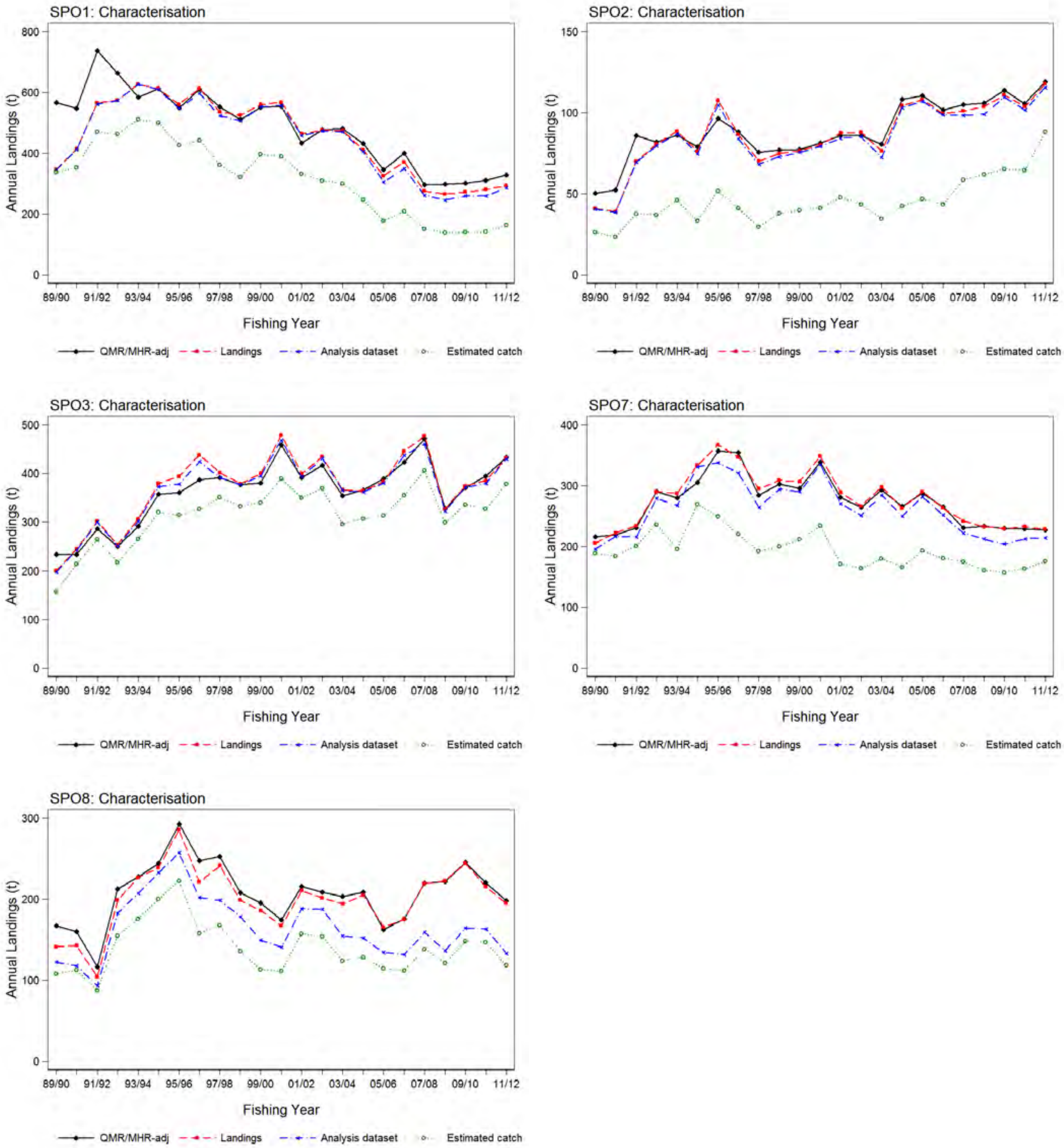


Figure E.1: Plots of the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 catch datasets using annual totals presented in Table E.1, Table E.2 and Table E.3. Note that both the QMR/MHR totals and the landings have been adjusted to consistent conversion factors in all subplots.

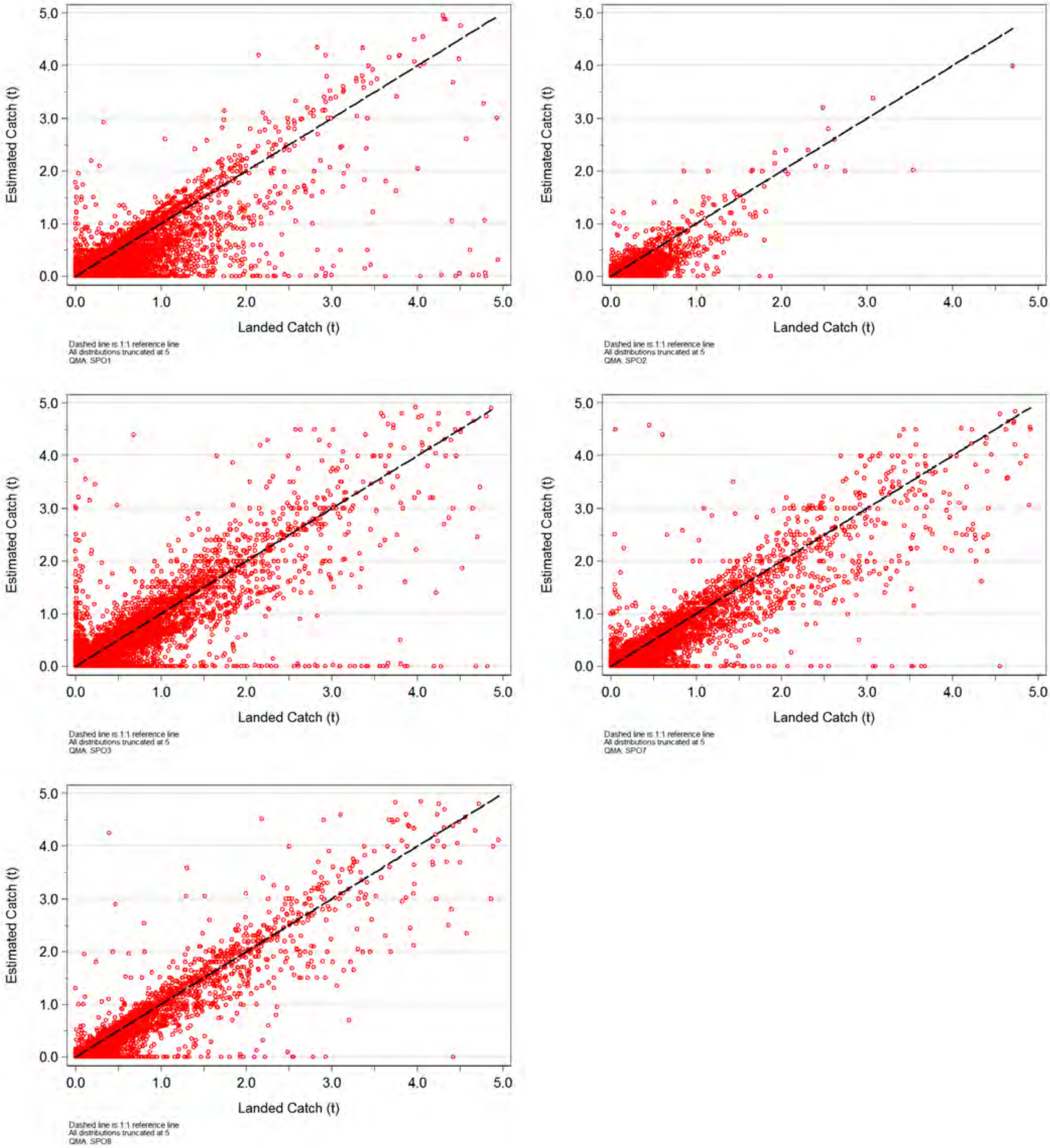


Figure E.2: Scatter plots of the sum of landed and estimated rig catch for every trip in each of the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 analysis datasets.

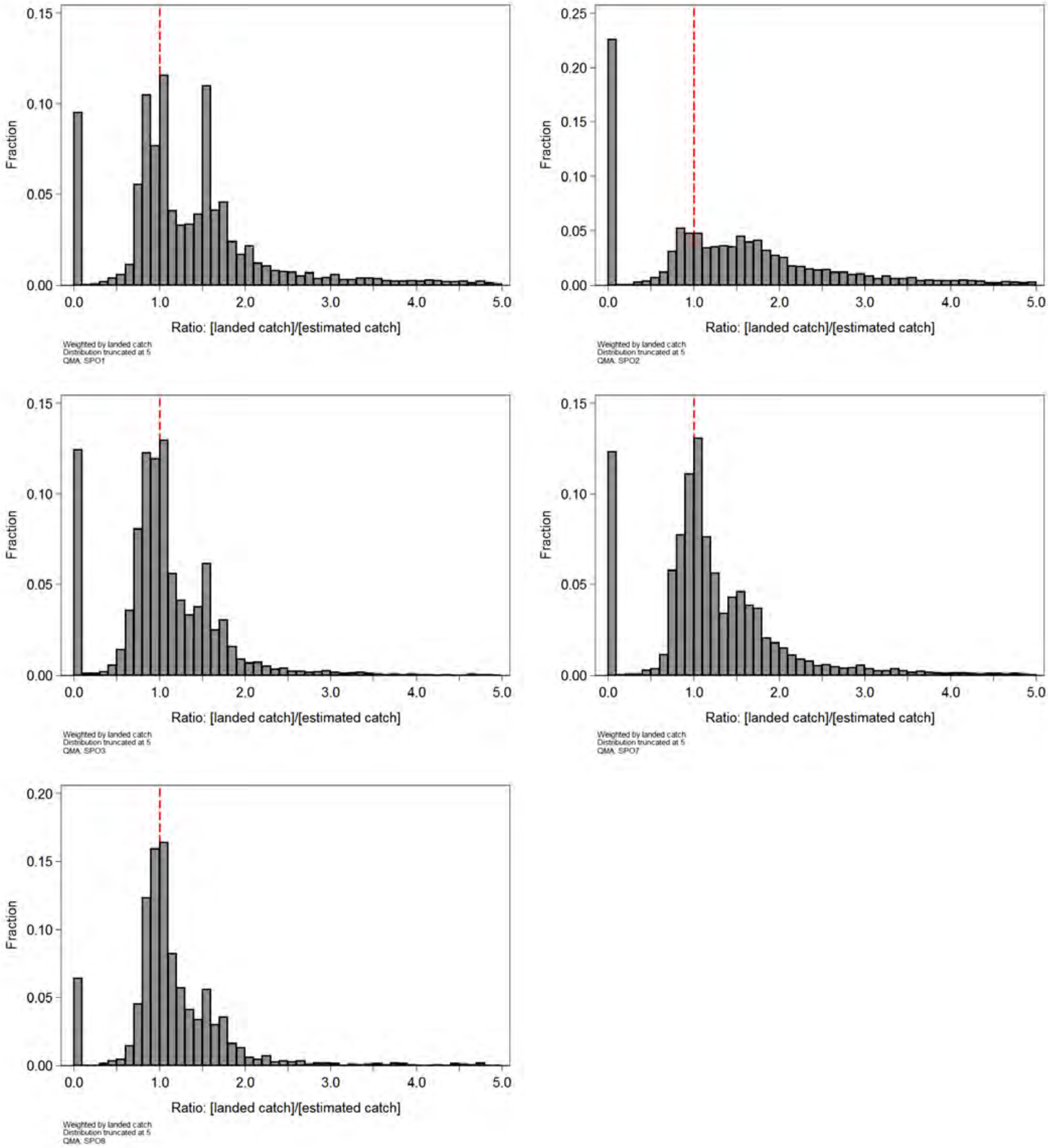


Figure E.3: Distribution (weighted by the landed catch) of the ratio of landed to estimated catch per trip in each of the SPO 1, SPO 2, SPO 3, SPO 7 and SPO 8 analysis datasets. Trips where the estimated catch=0 have been assigned a ratio=0.

Appendix F. ALGORITHM USED TO CORRECT ESTIMATED CATCHES IN THE SPO 1 SN FISHERIES

Step 1: calculate vessel correction factors (*vcf*) $\left(v_{iy}\right)$ for each vessel and fishing year :

Eq. F.1 $$v_{iy} = \frac{\sum_{g=1}^{n_{iy}^{l}} L_{giy}}{\sum_{h=1}^{n_{iy}^{c}} C_{hiy}}$$

where L_{giy} = landed weight in record *g* for vessel *i* in year *y*; there are n_{iy}^{l} such records;
C_{hiy} = estimated catch weight in record *h* for vessel *i* in year *y*; there are n_{iy}^{c} such records;

Step 2: truncate *vcf* by setting lower lb_{iy} and upper ub_{iy} bounds:

Eq. F.2 replace $$\begin{array}{l} v_{iy} = \text{NULL if } v_{iy} < lb_{iy} \\ v_{iy} = \text{NULL if } v_{iy} > ub_{iy} \end{array};$$

Note 1: data for vessels outside these bounds are dropped: $\left(lb_{iy} = 0.75; ub_{iy} = 2.0\right)$ (these are the bounds used Kendrick & Bentley [2012]).

Step 3: Apply the *vcf* to every estimated catch record *h* for vessel *i* in fishing year *y*:

Eq. F.3 $$\hat{L}_{hiy} = v_{iy} C_{hiy}$$

where $\hat{L}_{hiy}$ = estimated landed weight for record *h* associated with estimated catch weight C_{hiy}.

Note 2: every record *h* is used in the CPUE analysis because this algorithm was performed on data that have been previously selected as valid for the analysis.

Appendix G. DATA SUMMARIES BY QMA: SPO 1, SPO 2, SPO 3, SPO 7 AND SPO 8

Table G.1: Distribution of landings (%) by method of capture and fishing year by QMA based on trips which landed rig. The final column gives the annual total landings in each QMA. These values are plotted in Figure 7.

Fishing	Distribution (t)							Distribution (%)						
year	SN	BT	DS	BLL	BPT	Other	Total	SN	BT	DS	BLL	BPT	Other	Total
SPO 1E														
89/90	213.1	73.8	10.2	13.6	15.9	0.2	326.9	65.2	22.6	3.1	4.2	4.9	0.1	6.0
90/91	251.8	71.7	19.3	10.3	8.9	0.2	362.2	69.5	19.8	5.3	2.8	2.5	0.1	6.6
91/92	383.1	88.8	25.6	20.2	11.0	1.8	530.6	72.2	16.7	4.8	3.8	2.1	0.3	9.7
92/93	339.8	46.4	25.5	24.0	4.1	1.1	440.9	77.1	10.5	5.8	5.5	0.9	0.2	8.1
93/94	255.0	30.0	19.1	65.1	2.0	0.2	371.4	68.6	8.1	5.1	17.5	0.5	0.1	6.8
94/95	242.0	23.7	20.1	29.9	5.5	0.5	321.6	75.2	7.4	6.2	9.3	1.7	0.2	5.9
95/96	158.3	29.4	15.6	65.3	1.1	0.3	270.0	58.6	10.9	5.8	24.2	0.4	0.1	4.9
96/97	176.6	17.0	17.7	18.7	0.5	0.2	230.7	76.6	7.4	7.7	8.1	0.2	0.1	4.2
97/98	163.9	21.2	10.9	20.4	0.1	0.5	217.0	75.5	9.8	5.0	9.4	0.1	0.2	4.0
98/99	148.0	24.2	11.3	22.5	0.1	0.4	206.6	71.7	11.7	5.5	10.9	0.0	0.2	3.8
99/00	157.6	27.9	9.4	25.9	0.2	0.3	221.3	71.2	12.6	4.2	11.7	0.1	0.1	4.1
00/01	142.2	20.6	9.5	21.3	0.2	0.0	194.0	73.3	10.6	4.9	11.0	0.1	0.0	3.6
01/02	150.8	20.9	5.9	10.6	0.0	0.4	188.6	80.0	11.1	3.1	5.6	0.0	0.2	3.5
02/03	149.3	18.9	5.3	9.5	0.5	0.6	184.1	81.1	10.2	2.9	5.2	0.3	0.3	3.4
03/04	154.3	18.8	7.5	7.1	1.6	0.1	189.4	81.5	9.9	4.0	3.7	0.8	0.1	3.5
04/05	129.1	25.6	6.4	8.5	0.5	0.1	170.2	75.8	15.1	3.8	5.0	0.3	0.1	3.1
05/06	107.3	32.4	10.1	8.1	1.1	0.3	159.3	67.4	20.3	6.3	5.1	0.7	0.2	2.9
06/07	112.3	26.4	15.6	15.5	1.2	0.7	171.7	65.4	15.4	9.1	9.0	0.7	0.4	3.1
07/08	91.8	27.6	12.1	7.6	1.0	0.4	140.5	65.4	19.6	8.6	5.4	0.7	0.3	2.6
08/09	99.0	28.3	9.3	6.4	1.1	1.0	145.0	68.3	19.5	6.4	4.4	0.7	0.7	2.7
09/10	102.9	36.5	10.2	6.6	1.3	0.8	158.3	65.0	23.1	6.4	4.1	0.8	0.5	2.9
10/11	76.8	25.3	15.4	7.1	0.3	0.5	125.3	61.3	20.2	12.3	5.7	0.2	0.4	2.3
11/12	88.5	21.3	14.4	4.9	–	0.4	129.5	68.3	16.4	11.1	3.8	–	0.3	2.4
Total	3 893.7	756.8	306.2	429.3	58.1	11.1	5 455.2	71.4	13.9	5.6	7.9	1.1	0.2	100.0
SPO2														
89/90	17.6	32.7	–	0.1	–	0.1	50.4	34.9	64.8	–	0.2	–	0.1	2.5
90/91	17.9	32.9	0.1	0.3	–	0.9	52.1	34.4	63.2	0.2	0.5	–	1.7	2.5
91/92	24.2	60.8	–	0.2	–	0.5	85.8	28.2	70.9	–	0.3	–	0.6	4.2
92/93	22.0	59.3	0.1	0.3	–	0.4	82.0	26.9	72.3	0.1	0.3	–	0.5	4.0
93/94	29.2	54.2	–	0.4	0.4	2.1	86.3	33.8	62.8	–	0.5	0.5	2.4	4.2
94/95	20.1	57.6	0.5	0.0	–	0.8	79.1	25.4	72.8	0.6	0.1	–	1.1	3.9
95/96	31.0	57.3	1.3	0.0	–	6.6	96.3	32.2	59.6	1.4	0.0	–	6.8	4.7
96/97	24.1	63.1	0.6	0.0	–	0.3	88.1	27.4	71.6	0.7	0.0	–	0.3	4.3
97/98	17.2	56.8	0.3	0.0	–	1.1	75.5	22.7	75.3	0.4	0.0	–	1.5	3.7
98/99	21.1	54.3	0.6	0.0	–	1.0	77.0	27.3	70.6	0.8	0.0	–	1.3	3.8
99/00	22.5	50.9	2.2	0.0	–	1.7	77.3	29.1	65.8	2.9	0.0	–	2.2	3.8
00/01	23.0	50.9	5.0	0.1	–	2.1	81.1	28.4	62.7	6.2	0.1	–	2.6	4.0
01/02	25.4	56.1	3.8	0.1	–	0.6	85.9	29.5	65.3	4.4	0.1	–	0.7	4.2
02/03	16.0	69.2	–	0.0	–	0.6	85.8	18.7	80.6	–	0.0	–	0.7	4.2
03/04	15.2	64.8	0.1	0.0	–	0.5	80.6	18.9	80.3	0.1	0.0	–	0.7	3.9
04/05	19.1	88.1	–	0.2	–	0.8	108.2	17.7	81.5	–	0.2	–	0.7	5.3
05/06	14.1	96.0	–	0.1	–	0.3	110.4	12.7	86.9	–	0.1	–	0.3	5.4
06/07	18.6	81.8	0.4	0.5	–	0.3	101.5	18.3	80.6	0.4	0.5	–	0.2	4.9
07/08	20.0	84.1	0.5	0.2	–	0.1	105.0	19.0	80.2	0.5	0.2	–	0.1	5.1
08/09	33.6	71.5	–	0.8	–	0.0	105.9	31.7	67.5	–	0.7	–	0.0	5.2
09/10	25.6	87.2	0.6	0.5	–	0.1	113.9	22.5	76.5	0.5	0.4	–	0.0	5.5
10/11	24.6	78.6	1.9	0.4	–	0.0	105.6	23.3	74.5	1.8	0.4	–	0.0	5.1
11/12	35.7	79.3	4.0	0.0	–	0.1	119.2	29.9	66.6	3.4	0.0	–	0.1	5.8
Total	517.7	1 487.5	22.1	4.2	0.4	21.1	2 053.1	25.2	72.5	1.1	0.2	0.0	1.0	100.0

Table G.1: (cont.)

Fishing year	Distribution (t)							Distribution (%)						
	SN	BT	DS	BLL	BPT	Other	Total	SN	BT	DS	BLL	BPT	Other	Total
SPO3														
89/90	174.1	58.1	–	0.0	–	0.9	233.1	74.7	24.9	–	0.0	–	0.4	2.8
90/91	167.5	61.8	–	0.0	0.0	3.8	233.2	71.9	26.5	–	0.0	0.0	1.6	2.8
91/92	187.3	80.8	–	0.1	–	18.4	286.6	65.4	28.2	–	0.0	–	6.4	3.4
92/93	165.0	84.2	–	0.1	–	0.3	249.6	66.1	33.7	–	0.0	–	0.1	3.0
93/94	204.5	86.9	–	0.2	0.0	0.5	292.1	70.0	29.8	–	0.1	0.0	0.2	3.5
94/95	262.1	78.4	–	8.3	–	9.0	357.7	73.3	21.9	–	2.3	–	2.5	4.3
95/96	261.6	92.6	–	0.6	–	5.6	360.3	72.6	25.7	–	0.2	–	1.6	4.3
96/97	280.8	82.2	–	17.7	–	6.5	387.2	72.5	21.2	–	4.6	–	1.7	4.6
97/98	303.6	87.3	–	0.3	–	0.4	391.6	77.5	22.3	–	0.1	–	0.1	4.7
98/99	301.8	70.0	–	4.2	–	0.7	376.7	80.1	18.6	–	1.1	–	0.2	4.5
99/00	281.7	98.7	–	0.0	–	0.4	380.9	74.0	25.9	–	0.0	–	0.1	4.6
00/01	343.2	114.8	–	–	–	0.4	458.4	74.9	25.0	–	–	–	0.1	5.5
01/02	299.3	91.3	–	0.0	–	0.3	391.0	76.6	23.4	–	0.0	–	0.1	4.7
02/03	305.7	107.9	2.4	0.1	–	0.4	416.5	73.4	25.9	0.6	0.0	–	0.1	5.0
03/04	258.0	91.3	4.9	0.1	–	0.1	354.4	72.8	25.8	1.4	0.0	–	0.0	4.2
04/05	255.2	96.9	14.0	0.0	–	0.3	366.5	69.6	26.4	3.8	0.0	–	0.1	4.4
05/06	278.8	93.9	15.4	0.2	–	1.0	389.3	71.6	24.1	3.9	0.1	–	0.3	4.7
06/07	297.8	104.4	19.9	1.1	–	0.1	423.3	70.3	24.7	4.7	0.3	–	0.0	5.1
07/08	351.7	81.7	32.4	5.5	–	0.2	471.7	74.6	17.3	6.9	1.2	–	0.1	5.7
08/09	213.3	83.5	31.1	0.2	–	0.2	328.4	65.0	25.4	9.5	0.1	–	0.1	3.9
09/10	224.5	107.2	39.2	0.0	–	0.2	371.1	60.5	28.9	10.6	0.0	–	0.1	4.4
10/11	244.3	97.0	46.5	6.5	0.1	0.3	394.7	61.9	24.6	11.8	1.6	0.0	0.1	4.7
11/12	244.5	122.8	62.5	2.6	–	0.2	432.7	56.5	28.4	14.5	0.6	–	0.0	5.2
Total	5 906.2	2 073.9	268.3	48.1	0.2	50.4	8 347.0	70.8	24.8	3.2	0.6	0.0	0.6	100.0
SPO7														
89/90	117.1	87.7	–	4.5	2.7	4.0	216.1	54.2	40.6	–	2.1	1.3	1.9	3.4
90/91	126.5	88.2	–	0.3	3.7	1.0	219.7	57.6	40.1	–	0.1	1.7	0.5	3.5
91/92	146.2	82.7	–	0.2	0.1	1.8	230.9	63.3	35.8	–	0.1	0.0	0.8	3.7
92/93	186.5	100.9	–	1.3	0.3	0.9	290.0	64.3	34.8	–	0.4	0.1	0.3	4.6
93/94	172.2	95.0	–	0.3	1.4	11.4	280.2	61.4	33.9	–	0.1	0.5	4.1	4.5
94/95	180.0	121.8	–	0.3	0.5	2.5	305.1	59.0	39.9	–	0.1	0.2	0.8	4.9
95/96	236.7	116.8	–	0.2	0.7	2.7	357.1	66.3	32.7	–	0.0	0.2	0.8	5.7
96/97	230.3	121.0	–	0.7	0.1	2.2	354.3	65.0	34.1	–	0.2	0.0	0.6	5.6
97/98	190.0	91.3	–	0.1	0.2	2.5	284.3	66.9	32.1	–	0.0	0.1	0.9	4.5
98/99	175.8	124.6	–	0.2	0.1	1.8	302.4	58.1	41.2	–	0.1	0.0	0.6	4.8
99/00	171.9	119.3	–	1.1	1.2	1.9	295.4	58.2	40.4	–	0.4	0.4	0.6	4.7
00/01	214.6	121.2	–	0.0	1.1	1.3	338.3	63.4	35.8	–	0.0	0.3	0.4	5.4
01/02	174.4	105.1	–	0.0	0.6	1.1	281.1	62.0	37.4	–	0.0	0.2	0.4	4.5
02/03	173.1	89.0	–	0.0	0.6	1.0	263.7	65.7	33.7	–	0.0	0.2	0.4	4.2
03/04	194.6	94.0	–	2.1	0.8	1.9	293.4	66.3	32.0	–	0.7	0.3	0.6	4.7
04/05	165.9	99.2	0.1	0.1	0.1	0.8	266.2	62.3	37.3	0.0	0.0	0.1	0.3	4.2
05/06	182.2	104.4	0.5	0.1	0.2	0.5	287.9	63.3	36.3	0.2	0.1	0.1	0.2	4.6
06/07	158.7	104.4	0.9	0.0	0.1	0.6	264.6	60.0	39.4	0.3	0.0	0.0	0.2	4.2
07/08	104.9	119.4	5.4	0.0	0.0	0.9	230.6	45.5	51.8	2.3	0.0	0.0	0.4	3.7
08/09	97.8	125.8	8.3	1.4	0.0	0.1	233.4	41.9	53.9	3.5	0.6	0.0	0.1	3.7
09/10	84.1	132.6	12.2	0.3	0.0	0.1	229.4	36.7	57.8	5.3	0.1	0.0	0.1	3.7
10/11	103.1	120.8	4.1	0.4	0.1	0.1	228.5	45.1	52.9	1.8	0.2	0.0	0.0	3.6
11/12	104.3	115.8	6.3	0.0	0.0	0.6	227.1	45.9	51.0	2.8	0.0	0.0	0.3	3.6
Total	3 690.9	2 480.9	37.7	13.5	14.9	41.8	6 279.6	58.8	39.5	0.6	0.2	0.2	0.7	100.0

Table G.1: (cont.)

Fishing year	Distribution (t)							Distribution (%)						
	SN	BT	DS	BLL	BPT	Other	Total	SN	BT	DS	BLL	BPT	Other	Total
SPO8														
89/90	136.0	26.7	–	0.9	3.6	0.0	167.3	81.3	16.0	–	0.6	2.1	0.0	3.5
90/91	138.4	15.4	–	1.0	4.9	0.0	159.7	86.7	9.6	–	0.6	3.0	0.0	3.3
91/92	99.0	10.2	–	0.9	6.0	0.1	116.2	85.2	8.8	–	0.7	5.1	0.1	2.4
92/93	192.1	9.4	–	1.5	9.6	0.2	212.8	90.3	4.4	–	0.7	4.5	0.1	4.5
93/94	209.3	9.3	–	0.7	8.6	0.0	227.8	91.9	4.1	–	0.3	3.8	0.0	4.8
94/95	219.0	14.9	–	0.6	9.2	0.1	243.8	89.8	6.1	–	0.2	3.8	0.0	5.1
95/96	265.3	23.2	–	1.0	2.9	0.4	292.8	90.6	7.9	–	0.4	1.0	0.1	6.1
96/97	210.6	31.6	–	0.7	3.4	1.0	247.3	85.2	12.8	–	0.3	1.4	0.4	5.2
97/98	217.5	32.2	–	1.7	1.1	0.0	252.5	86.2	12.7	–	0.7	0.4	0.0	5.3
98/99	179.8	27.8	–	0.3	0.3	0.0	208.1	86.4	13.3	–	0.1	0.1	0.0	4.4
99/00	164.3	30.3	–	0.4	0.3	0.0	195.4	84.1	15.5	–	0.2	0.2	0.0	4.1
00/01	156.9	16.0	–	0.8	0.5	0.1	174.3	90.0	9.2	–	0.4	0.3	0.0	3.6
01/02	185.2	29.7	–	0.6	–	0.1	215.6	85.9	13.8	–	0.3	–	0.0	4.5
02/03	183.4	24.5	–	0.7	–	0.1	208.6	87.9	11.7	–	0.3	–	0.1	4.4
03/04	180.4	22.3	–	0.2	–	0.1	203.0	88.9	11.0	–	0.1	–	0.1	4.2
04/05	186.0	21.5	–	0.1	0.0	0.7	208.3	89.3	10.3	–	0.0	0.0	0.3	4.4
05/06	145.1	17.1	–	0.1	–	0.3	162.6	89.2	10.5	–	0.0	–	0.2	3.4
06/07	146.3	21.1	8.0	0.2	–	0.2	175.9	83.2	12.0	4.6	0.1	–	0.1	3.7
07/08	186.3	18.3	15.0	0.2	–	0.1	219.9	84.7	8.3	6.8	0.1	–	0.1	4.6
08/09	196.4	21.0	4.2	0.3	–	0.1	221.8	88.5	9.5	1.9	0.1	–	0.0	4.6
09/10	213.9	29.8	1.7	0.1	–	0.0	245.5	87.1	12.1	0.7	0.0	–	0.0	5.1
10/11	183.5	32.8	3.7	0.1	–	0.1	220.2	83.3	14.9	1.7	0.1	–	0.0	4.6
11/12	162.2	30.9	4.8	0.2	–	0.1	198.1	81.8	15.6	2.4	0.1	–	0.0	4.1
Total	4 156.9	515.7	37.4	13.2	50.3	3.9	4 777.4	87.0	10.8	0.8	0.3	1.1	0.1	100.0
SPO1W														
89/90	200.1	34.2	–	0.0	4.7	0.4	239.5	83.6	14.3	–	0.0	2.0	0.2	4.2
90/91	149.9	23.8	–	0.1	11.5	0.2	185.5	80.8	12.8	–	0.0	6.2	0.1	3.3
91/92	166.5	30.6	–	0.5	8.5	0.6	206.6	80.6	14.8	–	0.2	4.1	0.3	3.6
92/93	144.6	68.9	0.9	0.3	6.8	0.6	222.1	65.1	31.0	0.4	0.1	3.1	0.2	3.9
93/94	153.6	49.5	2.3	0.4	7.3	0.4	213.5	71.9	23.2	1.1	0.2	3.4	0.2	3.8
94/95	236.1	44.8	0.4	0.5	8.6	0.3	290.6	81.2	15.4	0.1	0.2	2.9	0.1	5.1
95/96	224.3	44.9	1.5	0.3	7.6	0.4	279.1	80.4	16.1	0.5	0.1	2.7	0.2	4.9
96/97	330.6	43.8	1.7	0.4	0.6	3.6	380.7	86.9	11.5	0.4	0.1	0.1	0.9	6.7
97/98	289.0	43.6	0.3	0.6	0.1	2.4	336.1	86.0	13.0	0.1	0.2	0.0	0.7	5.9
98/99	241.3	48.8	0.0	0.1	10.8	2.0	303.1	79.6	16.1	0.0	0.0	3.6	0.7	5.3
99/00	273.0	46.7	0.4	1.1	5.4	3.0	329.7	82.8	14.2	0.1	0.3	1.6	0.9	5.8
00/01	296.7	49.9	1.0	2.0	8.4	1.8	359.9	82.4	13.9	0.3	0.6	2.3	0.5	6.3
01/02	201.2	36.5	2.4	2.4	1.9	0.4	244.8	82.2	14.9	1.0	1.0	0.8	0.2	4.3
02/03	223.5	51.6	2.6	1.3	13.0	0.4	292.5	76.4	17.7	0.9	0.4	4.5	0.1	5.1
03/04	237.6	43.3	3.5	0.3	6.6	0.5	291.9	81.4	14.8	1.2	0.1	2.3	0.2	5.1
04/05	220.6	31.9	1.7	0.1	5.4	1.2	260.9	84.5	12.2	0.7	0.1	2.1	0.4	4.6
05/06	150.1	25.6	1.7	0.1	7.2	1.8	186.6	80.5	13.7	0.9	0.0	3.9	1.0	3.3
06/07	189.0	24.3	2.4	0.0	11.5	1.4	228.6	82.7	10.6	1.1	0.0	5.0	0.6	4.0
07/08	104.6	33.9	6.6	0.2	10.8	0.7	156.7	66.8	21.6	4.2	0.1	6.9	0.4	2.8
08/09	105.8	28.0	12.3	0.1	3.7	2.6	152.6	69.4	18.4	8.1	0.1	2.4	1.7	2.7
09/10	96.4	28.4	11.1	0.2	5.9	2.0	143.9	67.0	19.7	7.7	0.1	4.1	1.4	2.5
10/11	133.8	35.3	8.1	0.1	3.8	4.7	185.9	72.0	19.0	4.4	0.1	2.0	2.5	3.3
11/12	131.6	58.0	3.7	0.2	0.4	4.1	197.9	66.5	29.3	1.9	0.1	0.2	2.1	3.5
Total	4 499.9	926.5	64.7	11.5	150.7	35.5	5 688.7	79.1	16.3	1.1	0.2	2.6	0.6	100.0

Table G.2: Distribution of landings (%) by month and fishing year for setnet by QMA based on trips which landed rig. The final column gives the annual total landings for setnet in each QMA. These values are plotted in Figure 15.

Fishing												Month	
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
SPO 1E													
89/90	16.3	11.2	10.6	4.3	0.5	3.9	2.6	2.2	6.6	11.4	3.7	26.7	213
90/91	38.0	30.1	7.6	2.7	2.5	2.5	1.4	2.4	1.4	1.6	1.6	8.2	252
91/92	26.1	37.3	7.6	2.2	4.7	10.2	2.6	3.4	1.6	1.3	1.2	1.9	383
92/93	24.6	29.2	10.5	4.0	3.2	4.3	2.9	2.2	2.6	6.9	2.3	7.3	340
93/94	24.6	18.9	5.2	8.4	9.8	6.9	4.8	3.7	6.6	1.5	3.8	5.9	255
94/95	19.2	25.3	6.3	5.3	8.3	2.2	16.0	4.6	2.3	1.3	3.1	6.1	242
95/96	21.5	42.2	8.7	4.1	3.9	1.9	3.7	5.1	2.4	1.6	0.9	4.0	158
96/97	32.6	23.2	2.8	7.6	5.8	5.6	2.1	2.8	3.7	6.1	2.8	4.7	177
97/98	28.6	18.3	3.6	4.5	2.1	7.7	9.5	2.5	4.1	4.8	3.7	10.7	164
98/99	30.1	18.1	10.7	5.7	2.0	0.8	1.1	2.6	2.3	3.4	1.1	22.0	148
99/00	34.8	10.3	4.6	8.5	4.3	4.9	1.9	3.7	3.3	5.2	3.6	15.0	158
00/01	39.8	20.5	3.0	3.8	5.5	2.2	2.5	2.8	2.9	2.6	2.5	11.8	142
01/02	40.5	20.3	1.4	0.7	3.3	1.7	3.5	4.4	3.6	6.3	1.5	12.8	151
02/03	40.4	20.4	4.2	2.4	5.1	1.7	4.4	2.3	1.5	5.0	4.9	7.7	149
03/04	32.0	19.6	6.4	0.9	1.2	6.7	5.6	9.1	9.7	2.2	1.1	5.6	154
04/05	25.8	23.5	5.1	4.2	5.6	4.4	5.0	3.0	3.2	1.9	7.7	10.6	129
05/06	32.5	16.0	3.6	3.3	2.3	5.6	2.5	6.7	4.0	2.0	3.6	17.9	107
06/07	29.8	18.3	3.3	3.9	6.3	3.1	6.5	7.1	3.3	2.7	5.1	10.7	112
07/08	33.6	20.8	3.3	3.6	4.4	3.6	2.4	2.2	2.6	4.3	4.6	14.6	92
08/09	24.1	5.1	3.3	5.1	2.3	3.2	2.0	3.2	7.8	6.0	9.3	28.6	99
09/10	25.1	10.7	4.2	4.7	3.1	2.7	2.9	4.1	10.2	9.4	7.7	15.1	103
10/11	14.1	14.3	4.7	1.4	6.0	2.6	2.4	4.9	3.4	8.7	14.8	22.7	77
11/12	24.0	14.7	1.3	3.1	2.5	2.4	2.5	2.3	3.0	3.4	10.1	30.6	88
Mean	28.3	22.6	6.0	4.2	4.3	4.4	4.1	3.6	3.7	4.1	3.5	11.1	3 894
SPO 2													
89/90	15.4	9.8	14.6	7.2	7.3	14.9	12.4	5.4	3.2	1.9	0.6	7.3	18
90/91	19.0	13.9	16.2	5.4	9.9	0.3	1.6	3.9	1.2	8.2	5.7	14.9	18
91/92	19.6	14.1	14.0	16.1	8.4	9.3	1.5	3.6	5.1	2.7	2.2	3.4	24
92/93	5.0	22.8	24.9	11.1	3.7	4.0	9.7	8.6	3.1	2.1	0.7	4.3	22
93/94	20.3	12.6	12.2	6.5	3.8	11.3	3.4	9.5	3.2	1.2	0.5	15.6	29
94/95	8.8	18.4	16.0	15.6	4.2	3.3	1.3	10.8	3.4	6.5	1.2	10.6	20
95/96	6.7	16.5	15.0	10.3	9.2	7.5	12.8	5.8	4.9	2.3	1.1	7.8	31
96/97	7.8	20.0	17.9	9.8	4.0	0.9	7.1	14.8	2.2	1.2	5.6	8.7	24
97/98	11.6	21.5	17.1	7.2	11.5	20.2	4.2	1.4	1.0	0.1	0.4	3.9	17
98/99	6.2	10.7	14.1	6.2	13.1	12.1	2.0	8.9	3.8	6.6	2.0	14.3	21
99/00	11.3	12.7	22.5	8.7	6.6	7.2	6.6	6.9	0.2	1.8	10.7	4.8	22
00/01	39.1	13.5	9.0	13.7	1.9	1.3	1.3	1.2	2.1	4.0	6.4	6.5	23
01/02	36.3	17.8	11.4	4.0	5.8	2.5	1.2	0.9	0.6	0.0	7.9	11.8	25
02/03	30.0	10.5	12.7	10.6	6.5	3.6	3.2	7.3	0.7	5.5	0.6	8.9	16
03/04	5.9	15.3	14.7	23.1	4.1	10.2	9.5	5.7	0.7	0.4	1.9	8.6	15
04/05	8.9	39.2	9.1	18.0	4.2	5.2	0.5	1.0	0.9	1.1	3.8	7.9	19
05/06	5.5	4.5	17.8	2.1	1.5	3.1	4.3	9.2	3.4	5.2	11.7	31.7	14
06/07	3.9	8.9	9.9	4.9	3.2	7.7	20.8	21.0	3.2	2.3	7.3	6.8	19
07/08	8.9	5.1	8.3	3.0	4.0	24.5	12.1	5.8	4.8	2.8	0.6	20.1	20
08/09	9.4	5.7	9.4	3.6	15.9	26.4	3.7	8.0	1.6	2.0	4.9	9.6	34
09/10	5.3	6.7	7.4	7.5	15.2	28.1	15.5	2.3	0.9	3.2	0.6	7.3	26
10/11	27.9	10.3	3.3	1.8	1.4	8.8	11.2	23.2	2.0	1.1	3.5	5.4	25
11/12	24.3	9.2	4.7	1.5	19.4	10.8	7.9	11.9	0.3	2.0	1.2	6.8	36
Mean	15.1	13.6	12.7	8.2	7.8	10.2	6.7	7.9	2.3	2.6	3.4	9.5	518

Table G.2: (cont.)

Fishing											Month		
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
SPO 3													
89/90	7.5	32.4	22.9	6.1	8.1	2.8	1.9	0.6	1.0	0.8	9.4	6.6	174
90/91	8.9	38.9	19.4	10.0	4.0	3.3	2.7	1.5	1.1	1.9	2.3	6.1	168
91/92	12.1	21.5	28.0	15.5	7.8	3.9	2.0	1.2	0.7	0.6	0.7	6.0	187
92/93	12.9	19.3	28.4	16.3	8.2	3.8	3.4	2.2	1.1	0.6	0.8	3.1	165
93/94	5.0	25.0	26.8	17.6	6.4	5.3	6.4	2.0	1.9	0.3	0.6	2.7	204
94/95	4.5	15.8	31.0	19.1	11.7	7.4	4.6	2.5	0.3	0.7	0.3	2.1	262
95/96	4.3	20.3	26.2	20.3	14.2	5.7	2.4	1.1	0.2	0.7	1.3	3.3	262
96/97	5.3	24.7	29.1	20.6	5.5	2.5	2.4	2.1	1.8	1.5	0.9	3.6	281
97/98	7.0	21.4	28.9	18.2	10.4	6.7	2.4	0.6	0.8	1.0	0.6	2.1	304
98/99	5.7	33.0	23.7	16.5	7.1	5.1	2.2	0.7	0.3	0.3	0.9	4.6	302
99/00	9.0	32.8	29.4	11.3	4.0	5.4	1.7	2.3	0.4	1.1	0.6	2.0	282
00/01	10.9	25.4	29.4	13.2	8.3	3.7	3.1	0.7	1.2	0.7	0.9	2.5	343
01/02	8.8	37.5	25.0	13.0	4.9	3.9	2.1	0.8	1.0	1.7	0.4	0.7	299
02/03	10.0	31.9	29.9	12.2	7.6	3.1	1.1	0.7	0.7	1.0	0.9	0.8	306
03/04	9.8	31.2	29.6	15.1	6.4	1.8	2.8	1.7	0.7	0.2	0.4	0.4	258
04/05	8.5	24.9	21.2	22.6	14.3	2.5	1.9	1.2	1.2	0.6	0.3	0.8	255
05/06	9.6	36.6	18.9	15.5	9.5	3.3	1.3	1.4	0.4	0.6	0.6	2.3	279
06/07	6.1	30.3	20.6	14.6	13.2	6.6	1.3	1.1	1.6	0.6	0.7	3.2	298
07/08	7.7	25.0	15.6	14.6	11.0	10.0	4.9	2.3	1.5	1.0	3.0	3.4	352
08/09	13.6	24.1	23.8	9.9	4.7	4.8	6.3	1.7	3.9	0.6	1.3	5.3	213
09/10	14.2	16.1	20.8	17.2	9.4	3.7	4.6	6.6	1.5	0.6	1.8	3.5	224
10/11	16.4	19.1	22.8	12.1	6.3	7.3	3.2	1.8	1.1	2.7	2.1	5.1	244
11/12	10.8	24.4	23.1	11.2	6.3	5.3	5.3	2.6	0.9	2.1	0.4	7.7	245
Mean	8.9	26.8	25.0	15.1	8.4	4.8	3.0	1.7	1.1	1.0	1.2	3.2	5 906
SPO 7													
89/90	3.4	29.0	8.1	19.0	4.2	5.6	2.2	4.2	1.5	3.0	1.9	17.9	117
90/91	17.8	16.6	8.5	18.8	4.9	7.9	5.6	5.8	2.9	0.4	2.5	8.3	126
91/92	11.4	25.4	12.3	14.9	13.6	4.5	2.5	3.3	1.4	0.7	1.6	8.5	146
92/93	9.1	23.9	7.7	18.0	12.8	9.7	3.1	3.4	0.5	3.5	0.6	7.7	186
93/94	3.9	31.2	23.6	11.8	2.6	3.4	7.3	4.0	4.3	1.5	2.3	4.2	172
94/95	14.1	14.8	26.4	17.5	6.1	7.4	6.6	1.8	1.7	1.1	0.5	2.0	180
95/96	13.0	35.6	13.9	13.8	5.3	3.7	7.1	2.2	2.7	0.9	0.6	1.3	237
96/97	21.6	32.5	19.2	14.8	4.6	1.4	1.8	0.8	0.1	2.8	0.1	0.3	230
97/98	23.6	29.4	10.8	8.4	4.4	5.9	6.2	3.6	5.3	0.6	1.1	0.5	190
98/99	19.5	33.6	11.5	12.2	5.0	5.7	4.8	2.3	1.2	0.9	1.4	1.9	176
99/00	17.2	19.8	19.0	8.0	8.2	5.2	5.3	0.8	3.3	0.8	2.4	10.0	172
00/01	14.7	19.4	23.1	18.2	7.5	3.2	2.7	3.1	1.7	1.0	1.3	4.0	215
01/02	18.1	20.1	15.1	13.6	12.2	8.1	3.4	1.0	0.6	2.5	2.2	3.1	174
02/03	10.5	21.3	11.7	19.7	6.2	9.0	5.6	3.4	1.2	2.3	1.9	7.4	173
03/04	13.5	17.0	18.5	18.7	8.6	6.1	2.9	3.5	1.3	1.8	4.2	3.8	195
04/05	7.7	19.1	11.4	17.6	14.8	15.1	7.2	2.4	0.9	0.7	0.8	2.4	166
05/06	15.2	16.1	21.9	10.0	7.7	14.7	7.7	0.3	3.7	0.2	0.3	2.2	182
06/07	23.5	27.4	11.9	12.6	6.4	16.1	0.8	0.1	0.2	0.6	0.0	0.3	159
07/08	30.6	10.1	19.5	5.2	0.6	16.8	0.7	1.6	0.0	3.7	0.2	11.0	105
08/09	32.1	17.9	16.9	14.7	1.1	2.5	9.2	3.8	0.6	0.3	0.8	0.0	98
09/10	30.6	31.6	2.2	0.4	7.4	11.0	8.8	1.8	0.1	2.9	0.2	3.1	84
10/11	17.3	23.4	18.2	1.6	11.6	2.2	20.3	1.4	0.2	0.1	0.2	3.4	103
11/12	16.5	34.6	3.7	12.2	4.3	7.1	12.2	5.5	1.4	0.0	0.0	2.6	104
Mean	16.0	24.1	15.2	13.7	7.1	7.2	5.4	2.5	1.7	1.4	1.2	4.3	3 691

Table G.2: (cont.)

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Month Sep	Total
SPO 8													
89/90	2.1	5.9	6.5	10.3	19.9	8.8	6.4	16.6	7.9	2.5	1.6	11.5	136
90/91	4.6	15.3	14.7	12.9	9.6	13.2	4.2	9.1	3.3	2.1	4.1	6.8	138
91/92	6.1	4.5	7.6	8.9	17.6	13.8	17.0	4.5	2.3	2.0	1.5	14.2	99
92/93	10.1	9.4	8.6	8.3	13.4	12.8	9.6	3.3	2.0	8.2	4.9	9.5	192
93/94	7.4	18.2	17.1	16.0	13.0	7.8	5.6	2.0	3.1	2.6	3.2	4.1	209
94/95	10.7	9.0	13.0	11.4	8.1	8.9	6.8	2.7	4.5	2.6	6.8	15.5	219
95/96	21.5	18.8	8.6	8.4	7.6	11.1	6.2	2.9	2.5	1.8	2.5	8.2	265
96/97	21.0	5.0	8.9	11.8	7.0	13.7	4.7	9.3	3.6	4.5	3.0	7.5	211
97/98	10.4	12.9	9.8	12.1	7.2	8.8	6.1	3.8	4.0	2.4	3.0	19.5	218
98/99	8.4	15.9	10.0	16.3	17.3	6.7	2.2	4.7	4.5	1.5	5.9	6.7	180
99/00	17.1	10.7	8.4	23.0	15.7	8.1	3.3	3.6	2.4	1.7	1.9	4.0	164
00/01	6.8	8.7	9.9	16.6	18.0	9.2	3.1	6.0	4.0	4.9	4.0	8.8	157
01/02	13.5	14.2	9.4	11.9	8.4	8.7	7.6	3.5	2.2	5.0	9.6	5.9	185
02/03	4.8	10.9	12.9	18.7	7.4	16.9	5.3	5.0	2.2	3.4	3.5	8.9	183
03/04	8.7	8.1	6.1	10.9	8.5	21.3	10.7	3.7	3.9	3.5	6.4	8.3	180
04/05	15.7	12.2	7.1	15.2	6.2	2.2	5.8	3.4	2.6	0.9	10.1	18.7	186
05/06	12.0	11.7	5.3	9.0	10.3	6.3	6.7	5.2	1.8	4.7	4.4	22.5	145
06/07	4.7	8.0	12.7	25.6	17.7	12.5	2.8	4.0	2.7	1.3	1.6	6.6	146
07/08	3.1	29.5	8.7	14.7	6.5	1.8	8.8	5.0	1.8	2.9	1.5	15.8	186
08/09	12.9	8.1	11.5	8.2	16.6	9.2	9.4	2.1	3.9	2.6	6.6	9.1	196
09/10	11.5	7.4	5.6	19.7	17.3	3.2	14.7	4.6	5.3	1.6	3.3	5.8	214
10/11	11.9	9.1	12.3	9.3	11.6	9.0	5.2	4.3	4.6	5.6	6.0	11.1	184
11/12	10.2	5.8	18.5	11.2	18.1	10.6	4.9	2.6	0.9	5.4	5.9	6.0	162
Mean	10.8	11.6	10.2	13.4	11.9	9.6	6.8	4.6	3.3	3.2	4.5	10.1	4 157
SPO 1W													
89/90	9.2	26.7	13.6	11.9	5.3	2.1	1.5	2.6	2.1	2.4	2.0	20.6	200
90/91	26.6	15.4	11.9	16.4	10.5	2.1	1.0	2.4	0.6	1.6	3.3	8.1	150
91/92	29.8	25.9	16.8	6.3	4.0	4.1	3.2	1.5	1.5	0.6	0.6	5.6	167
92/93	18.9	28.4	13.1	9.0	5.5	4.6	2.4	3.0	1.4	2.2	3.3	8.1	145
93/94	30.3	23.4	16.7	10.2	5.1	1.9	0.9	0.4	0.7	0.9	1.8	7.5	154
94/95	27.5	21.7	16.8	8.6	3.3	2.6	1.7	1.0	0.7	0.4	2.0	13.7	236
95/96	26.8	23.3	8.8	4.2	4.3	3.4	1.8	1.5	1.3	1.4	1.5	21.5	224
96/97	29.8	21.2	12.6	6.8	6.5	1.9	1.2	1.4	1.1	3.0	2.0	12.6	331
97/98	28.5	17.8	7.8	7.2	5.6	5.1	2.3	1.2	1.4	0.9	4.0	18.3	289
98/99	20.1	20.3	13.3	6.6	4.7	4.4	1.4	2.7	0.6	0.9	3.2	21.9	241
99/00	34.5	12.6	13.1	7.0	3.3	3.3	1.6	1.5	1.5	2.5	2.7	16.4	273
00/01	28.6	16.2	9.8	5.4	5.6	2.0	1.5	1.2	1.1	1.8	1.7	25.1	297
01/02	38.2	15.2	6.3	11.3	5.7	2.9	3.1	1.6	0.9	0.8	2.3	11.6	201
02/03	25.8	20.6	8.1	10.2	4.6	4.2	3.0	1.5	1.2	2.3	6.2	12.1	223
03/04	41.3	18.1	5.7	7.7	0.6	5.6	3.7	3.0	1.3	3.5	4.0	5.6	238
04/05	28.5	28.4	4.8	8.8	3.2	3.5	3.4	1.4	1.0	0.8	2.3	13.9	221
05/06	43.9	17.3	6.9	2.3	3.9	3.9	2.3	1.2	1.0	0.4	1.4	15.5	150
06/07	21.8	14.2	16.2	13.7	2.1	2.1	0.8	1.4	1.2	0.9	1.6	24.0	189
07/08	29.4	23.3	10.9	3.8	1.8	1.6	1.1	1.2	0.9	2.2	2.1	21.8	105
08/09	36.0	18.8	6.8	4.0	2.2	2.1	1.7	2.3	2.1	1.6	5.7	16.6	106
09/10	41.1	21.7	1.7	2.6	2.8	2.5	2.5	1.2	3.4	1.3	4.2	15.0	96
10/11	41.5	20.7	2.7	1.7	1.2	4.6	2.3	2.6	4.1	2.0	2.6	14.1	134
11/12	45.9	18.7	6.1	0.3	1.8	2.9	1.5	3.1	3.2	2.7	1.4	12.4	132
Mean	29.8	20.1	10.4	7.5	4.3	3.2	2.0	1.7	1.4	1.7	2.7	15.2	4 500

Table G.3: Distribution of landings (%) by month and fishing year for bottom trawl by QMA based on trips which landed rig. The final column gives the annual total landings by QMA for bottom trawl. These values are plotted in Figure 16.

Fishing												Month	
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
SPO 1E													
89/90	3.0	5.5	4.8	10.6	6.1	8.9	8.3	9.7	9.8	11.0	11.0	11.1	74
90/91	12.6	7.7	4.3	6.1	6.6	11.2	8.6	11.6	7.2	7.9	6.5	9.9	72
91/92	13.8	8.8	7.5	5.3	8.4	13.5	9.4	11.2	3.4	5.1	5.7	7.8	89
92/93	10.6	7.2	5.8	5.4	9.2	11.5	8.1	7.8	8.7	13.4	3.5	8.7	46
93/94	17.0	5.0	5.5	3.6	7.4	11.3	9.8	11.0	5.8	7.6	5.8	10.4	30
94/95	6.8	7.3	6.2	6.8	8.0	17.4	12.9	8.0	5.9	5.1	7.6	8.0	24
95/96	5.3	6.8	3.2	6.5	8.1	12.5	7.7	29.8	5.5	4.3	3.7	6.7	29
96/97	6.3	10.2	6.3	11.0	17.1	9.7	10.9	4.8	4.2	5.9	5.8	7.9	17
97/98	5.2	7.5	4.6	12.3	8.0	12.1	14.5	11.8	5.2	6.7	5.9	6.2	21
98/99	8.9	8.7	6.9	5.9	8.8	9.8	6.8	9.1	8.1	7.5	9.8	9.7	24
99/00	8.2	8.2	8.3	18.2	5.5	8.7	12.8	6.6	7.9	4.5	4.5	6.5	28
00/01	17.7	9.5	4.6	4.9	6.4	10.2	11.5	11.9	4.1	5.2	7.8	6.3	21
01/02	15.0	9.3	8.2	7.5	8.6	8.4	6.6	8.3	6.8	6.4	6.6	8.3	21
02/03	13.8	5.9	5.2	6.6	8.2	8.4	14.7	5.9	10.1	6.1	10.4	4.6	19
03/04	10.5	5.6	6.9	11.4	6.0	6.6	8.9	9.0	6.9	8.0	9.8	10.5	19
04/05	5.4	6.3	7.6	4.0	11.8	11.8	13.4	11.9	7.6	5.3	6.9	7.9	26
05/06	7.0	8.8	8.2	10.4	7.3	8.0	8.8	6.8	6.1	9.7	7.5	11.3	32
06/07	8.3	8.2	6.7	5.5	5.9	11.8	11.1	5.9	7.0	9.8	8.9	10.7	26
07/08	6.9	6.2	5.6	9.0	10.0	9.8	8.0	21.5	6.8	3.3	5.2	7.7	28
08/09	5.4	9.2	6.2	5.7	6.1	11.2	7.1	7.7	10.3	7.4	11.2	12.6	28
09/10	3.8	9.3	5.6	4.6	5.4	5.2	14.9	8.1	7.1	22.6	8.2	5.3	36
10/11	7.0	7.3	8.3	6.1	10.2	9.5	7.1	7.8	8.5	8.9	10.0	9.6	25
11/12	5.9	3.8	4.4	7.7	10.7	8.7	9.0	12.2	6.1	12.5	10.5	8.7	21
Mean	9.0	7.5	6.1	7.4	7.9	10.5	9.7	10.5	6.9	8.3	7.4	8.8	757
SPO 2													
89/90	13.3	16.7	11.0	9.9	6.3	7.4	6.8	5.5	3.4	5.8	4.8	9.2	33
90/91	9.6	16.4	6.4	7.0	7.2	8.5	6.5	10.4	4.6	4.9	7.3	11.2	33
91/92	12.4	14.7	8.6	5.5	8.3	7.8	9.2	7.9	6.6	6.3	6.4	6.3	61
92/93	10.9	15.3	12.9	6.8	6.8	12.9	5.6	6.4	6.3	6.6	4.0	5.6	59
93/94	11.9	12.6	12.4	6.0	6.6	7.9	9.7	7.3	7.1	4.8	6.4	7.5	54
94/95	8.9	14.0	8.6	8.6	6.3	11.5	9.2	7.5	9.7	3.7	5.0	7.0	58
95/96	7.5	13.4	10.4	6.9	8.1	14.2	9.4	8.7	7.3	4.6	4.0	5.5	57
96/97	12.2	15.6	10.8	10.3	6.7	8.2	8.3	7.8	4.1	6.0	4.3	5.6	63
97/98	9.6	12.3	12.7	10.2	8.0	8.7	6.7	8.9	7.1	5.6	4.6	5.5	57
98/99	7.7	8.7	10.4	4.7	10.9	10.9	9.1	10.5	9.8	4.9	6.0	6.3	54
99/00	9.4	13.7	9.6	5.0	7.0	11.0	9.7	10.9	7.8	4.1	5.4	6.3	51
00/01	14.2	11.4	5.7	5.5	6.6	10.3	9.3	8.1	7.6	7.8	7.7	5.9	51
01/02	10.5	13.6	8.2	5.6	10.5	7.3	9.7	7.7	10.9	4.8	5.8	5.4	56
02/03	11.7	15.9	9.2	5.9	7.4	6.9	6.0	7.1	9.6	8.1	4.1	8.1	69
03/04	14.3	14.4	7.8	4.3	8.7	6.4	9.8	6.2	6.1	5.8	6.3	9.9	65
04/05	10.2	12.6	11.0	7.9	3.5	5.6	9.4	10.9	9.8	6.1	6.7	6.3	88
05/06	10.4	12.3	12.1	9.0	6.7	8.3	3.6	8.1	9.0	9.0	5.9	5.7	96
06/07	13.8	9.7	10.6	5.4	5.8	7.1	8.8	10.2	5.0	9.1	7.1	7.5	82
07/08	10.8	14.2	12.5	6.6	7.3	7.0	7.9	7.6	5.5	5.8	6.3	8.6	84
08/09	17.2	14.8	10.4	11.7	9.5	8.6	6.9	2.9	3.9	3.8	4.9	5.6	71
09/10	10.4	14.0	11.0	8.1	4.4	6.6	7.3	6.8	9.2	6.2	8.3	7.4	87
10/11	10.7	12.8	10.5	7.8	5.1	6.9	6.5	6.0	8.7	7.2	10.3	7.4	79
11/12	10.1	14.3	8.8	6.2	5.9	6.4	6.8	11.7	10.4	6.7	6.1	6.5	79
Mean	11.2	13.5	10.3	7.2	7.0	8.3	7.8	8.1	7.6	6.2	6.1	6.9	1 488

Table G.3: (cont.)

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Month Sep	Total
SPO 3													
89/90	9.6	19.5	8.3	11.1	10.8	12.6	9.3	4.1	3.8	2.7	2.8	5.4	58
90/91	5.4	9.9	13.4	13.6	12.3	13.7	12.0	4.6	2.4	2.0	2.2	8.5	62
91/92	8.1	10.3	12.6	10.0	9.3	12.4	21.6	3.1	2.8	1.3	2.1	6.4	81
92/93	3.4	14.6	14.9	23.6	12.5	9.0	3.6	3.8	2.0	3.9	2.3	6.2	84
93/94	10.2	15.1	10.1	15.4	5.0	14.0	15.9	5.0	2.1	2.0	1.6	3.6	87
94/95	6.8	15.3	16.2	25.0	6.8	12.1	7.3	2.8	1.1	1.9	1.7	3.1	78
95/96	7.0	14.4	19.5	13.3	6.5	8.9	3.5	10.1	3.3	2.1	6.9	4.6	93
96/97	5.8	14.7	18.2	15.1	8.7	7.6	10.7	7.6	1.9	4.9	1.9	2.7	82
97/98	6.6	24.3	14.9	8.5	7.6	13.9	8.8	4.6	4.5	2.3	2.5	1.5	87
98/99	4.4	11.3	12.3	12.1	6.7	13.0	14.1	7.4	4.1	4.7	6.2	3.8	70
99/00	7.3	10.1	9.1	6.2	7.5	12.0	19.3	6.9	5.7	3.4	3.7	8.7	99
00/01	4.7	11.2	11.0	8.9	9.8	8.5	18.7	7.2	10.1	3.3	2.3	4.3	115
01/02	12.0	12.5	9.8	8.6	6.5	11.3	11.4	4.9	9.9	3.9	2.2	7.2	91
02/03	10.9	20.3	12.2	8.7	8.5	6.3	11.9	9.8	3.5	3.2	2.2	2.7	108
03/04	19.1	13.4	7.6	5.2	6.2	10.2	10.7	6.1	4.6	2.8	10.0	4.0	91
04/05	5.2	9.5	12.1	13.2	7.3	9.8	11.1	11.0	6.4	3.4	6.1	4.8	97
05/06	6.1	10.0	8.4	13.3	8.6	10.6	9.9	11.9	7.6	4.9	2.3	6.4	94
06/07	4.1	9.7	15.8	9.1	12.5	8.8	8.5	4.7	14.0	5.7	3.9	3.1	104
07/08	6.5	13.7	6.6	18.6	9.3	8.8	8.2	9.0	4.6	4.1	2.7	8.0	82
08/09	3.3	6.6	8.0	10.6	6.1	16.5	11.0	6.8	11.5	7.9	3.8	7.9	83
09/10	6.2	10.2	13.1	12.5	6.4	8.9	10.1	10.4	8.3	3.7	3.1	7.2	107
10/11	11.6	13.8	7.6	8.0	10.6	10.3	10.2	9.3	7.8	2.1	3.8	4.8	97
11/12	7.6	10.0	21.2	11.2	7.3	6.4	10.3	10.4	3.9	4.3	2.4	5.2	123
Mean	7.5	12.9	12.5	12.0	8.3	10.4	11.3	7.3	5.7	3.5	3.4	5.2	2 074
SPO 7													
89/90	3.5	11.3	7.3	15.9	9.6	8.9	7.3	4.3	10.8	7.1	6.3	7.6	88
90/91	22.9	15.4	7.0	10.8	5.4	8.2	9.7	7.3	2.2	2.5	4.6	3.8	88
91/92	12.3	17.3	10.4	5.1	4.7	8.1	10.2	8.7	7.2	3.9	4.1	8.1	83
92/93	8.1	15.9	11.7	8.6	9.5	10.9	8.6	6.4	3.1	6.6	4.1	6.5	101
93/94	6.1	20.4	15.5	4.8	5.9	8.0	11.5	7.9	6.8	3.7	3.2	6.1	95
94/95	14.8	15.1	13.4	7.9	5.4	11.4	9.0	8.8	5.8	2.2	3.0	3.3	122
95/96	8.9	15.0	8.6	14.0	5.2	5.8	10.5	9.7	11.7	3.8	2.8	4.0	117
96/97	13.2	14.5	12.2	10.9	5.9	6.6	10.2	6.1	7.7	4.6	3.5	4.5	121
97/98	8.2	9.4	11.1	4.2	6.4	6.7	17.2	18.4	6.5	5.1	2.9	4.1	91
98/99	7.3	14.5	5.9	7.1	17.6	9.7	9.4	7.2	8.6	6.0	3.3	3.3	125
99/00	5.5	9.6	8.7	8.3	13.9	8.4	5.9	11.1	7.1	5.9	7.2	8.3	119
00/01	10.8	13.2	11.0	7.0	5.2	15.4	6.6	7.4	8.6	4.6	3.6	6.6	121
01/02	19.4	16.4	11.2	7.8	9.0	5.5	8.3	5.6	5.3	4.6	3.2	3.6	105
02/03	14.7	16.2	11.6	9.9	3.5	6.9	12.3	8.1	3.6	2.6	3.4	7.3	89
03/04	14.5	15.5	8.9	4.5	4.9	10.4	11.5	8.0	6.1	4.9	4.5	6.2	94
04/05	12.9	17.0	9.0	8.8	4.4	5.4	10.3	9.8	5.8	4.0	4.5	8.1	99
05/06	10.4	14.4	12.1	5.3	6.5	6.9	8.6	10.7	6.5	7.7	5.3	5.6	104
06/07	11.6	16.8	8.0	10.4	6.2	9.2	10.2	9.0	5.6	4.6	2.6	5.7	104
07/08	8.9	17.8	14.0	6.1	5.1	10.1	8.6	10.1	6.7	4.3	3.5	4.7	119
08/09	10.4	10.0	4.6	6.0	6.3	10.8	11.8	11.5	7.8	7.1	7.0	6.8	126
09/10	15.9	18.7	12.2	7.5	8.4	6.3	9.3	6.8	4.7	3.4	2.8	4.1	133
10/11	9.3	17.8	11.1	5.0	4.2	8.8	11.1	8.2	9.2	3.5	5.1	6.6	121
11/12	10.3	18.2	10.3	4.6	3.7	12.3	8.1	7.5	10.2	6.3	4.8	3.8	116
Mean	11.2	15.2	10.3	7.8	6.9	8.8	9.7	8.6	7.0	4.8	4.1	5.5	2 481

Table G.3: (cont.)

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep (Month)	Total
SPO 8													
89/90	33.8	2.6	1.2	2.4	5.9	9.0	10.8	4.9	6.4	5.0	10.1	8.0	27
90/91	11.7	8.9	6.8	12.2	9.1	5.8	5.0	5.2	7.7	8.2	11.7	7.8	15
91/92	6.5	2.9	7.1	26.5	2.1	3.5	9.9	6.7	7.6	4.5	10.0	12.7	10
92/93	9.5	2.1	6.4	4.9	9.6	16.7	14.6	7.8	5.6	6.8	7.7	8.3	9
93/94	2.0	2.9	5.5	10.9	2.0	12.5	19.1	7.9	12.9	7.0	9.3	7.9	9
94/95	3.3	2.1	2.6	3.2	6.7	12.2	18.2	14.8	23.2	4.3	4.7	4.7	15
95/96	12.2	6.1	4.9	12.5	2.6	11.3	13.8	12.2	9.4	2.5	0.6	11.9	23
96/97	6.5	4.9	5.8	4.7	15.6	10.9	12.1	10.6	13.7	0.9	1.8	12.7	32
97/98	11.9	3.6	9.9	13.6	6.8	15.3	11.8	13.4	5.7	2.2	3.0	2.7	32
98/99	5.2	19.8	8.5	13.9	9.4	6.6	7.2	6.9	8.9	3.7	1.9	8.0	28
99/00	1.8	6.9	8.3	4.0	11.9	14.0	12.3	21.5	4.8	5.4	1.6	7.3	30
00/01	1.5	9.1	12.5	4.2	15.0	12.7	11.1	3.3	9.8	10.5	3.4	6.8	16
01/02	2.7	6.4	5.5	8.6	6.6	7.7	19.3	6.2	5.3	5.8	9.2	16.6	30
02/03	14.7	8.9	4.1	6.5	8.9	8.3	7.4	10.0	7.0	6.6	6.2	11.5	24
03/04	3.0	7.1	5.2	6.4	6.8	13.7	20.1	10.8	9.1	9.7	2.3	6.0	22
04/05	23.6	5.2	5.6	4.4	7.1	10.7	6.8	8.4	2.7	6.0	4.7	14.9	21
05/06	3.2	5.2	4.3	9.1	12.8	9.4	8.2	7.1	9.7	13.0	3.6	14.5	17
06/07	1.8	6.7	4.9	4.7	7.7	4.6	9.9	10.1	10.9	13.9	15.6	9.3	21
07/08	4.0	4.8	2.4	8.8	8.1	9.0	16.1	5.0	8.4	13.0	7.5	12.9	18
08/09	8.3	4.4	3.8	2.7	5.9	11.3	4.6	3.9	28.6	12.1	8.7	5.8	21
09/10	15.5	4.5	15.0	5.7	2.8	4.6	9.3	11.6	5.9	5.1	7.5	12.5	30
10/11	22.1	2.5	5.7	5.2	6.2	4.4	1.6	3.7	32.7	10.1	3.6	2.2	33
11/12	13.5	0.6	4.9	5.5	5.6	3.6	10.3	4.5	5.4	18.4	11.8	15.9	31
Mean	10.4	5.7	6.3	7.4	7.7	9.2	10.9	8.8	10.5	7.4	6.0	9.6	516
SPO 1W													
89/90	5.7	7.2	2.3	8.9	7.3	14.5	14.7	6.4	3.9	1.7	12.0	15.4	34
90/91	18.4	7.9	2.8	12.6	13.2	7.1	4.0	9.5	3.3	6.6	3.7	10.8	24
91/92	11.9	8.1	6.3	5.2	16.5	5.6	3.9	3.0	11.0	2.6	5.1	20.8	31
92/93	11.4	11.0	5.2	8.8	8.2	16.9	6.5	4.7	4.8	10.3	4.9	7.3	69
93/94	13.4	13.1	5.4	12.9	14.9	8.2	4.7	5.1	4.5	7.4	4.6	5.8	50
94/95	15.3	8.9	5.0	11.0	10.2	11.1	8.1	6.2	2.8	2.4	5.5	13.4	45
95/96	10.5	9.0	6.6	9.2	17.0	7.2	6.7	6.6	4.1	5.2	3.4	14.6	45
96/97	13.1	5.2	8.1	6.7	8.2	8.8	9.2	4.7	9.2	5.3	3.0	18.3	44
97/98	10.6	11.4	5.7	6.4	12.2	12.6	4.9	7.6	3.8	6.9	7.5	10.3	44
98/99	9.2	8.5	5.4	6.9	13.9	17.3	6.8	8.9	4.6	1.9	7.7	8.9	49
99/00	14.4	6.0	5.2	6.6	11.3	12.3	9.3	10.0	8.2	5.6	4.7	6.2	47
00/01	4.8	5.1	3.7	10.1	15.7	15.0	11.4	4.2	5.5	4.6	7.0	12.9	50
01/02	7.7	6.0	6.8	10.0	11.5	9.0	11.0	10.3	2.4	7.1	9.6	8.5	36
02/03	5.8	13.4	5.0	5.1	9.4	9.4	10.5	9.8	10.1	6.9	9.3	5.3	52
03/04	32.3	6.6	4.0	5.2	7.9	9.6	9.5	3.8	4.3	4.7	5.2	6.9	43
04/05	11.0	10.2	5.6	6.4	11.6	7.6	7.5	7.5	4.9	8.2	7.7	11.8	32
05/06	14.4	7.8	7.3	7.7	9.8	8.7	9.8	7.7	6.3	4.8	9.4	6.3	26
06/07	10.1	6.6	5.7	11.4	9.4	16.5	8.8	6.8	2.1	12.2	4.6	5.8	24
07/08	7.9	9.9	2.0	8.1	10.2	12.1	8.2	6.9	7.3	10.6	7.7	9.2	34
08/09	8.2	10.8	6.6	7.4	8.5	19.5	5.8	2.3	5.3	4.6	9.6	11.4	28
09/10	5.3	7.8	5.7	9.4	15.0	19.4	11.8	1.2	0.7	3.7	8.9	11.0	28
10/11	5.9	10.5	5.3	10.6	7.3	5.8	16.1	1.6	5.9	8.2	9.1	13.7	35
11/12	11.0	12.0	5.0	4.8	10.8	11.8	6.9	4.5	6.2	5.9	12.7	8.6	58
Mean	11.3	9.0	5.2	8.2	11.3	11.7	8.4	6.1	5.4	6.0	7.0	10.3	927

Table G.4: Distribution of landings (%) by fishing year and by target species for setnet in each QMA (see Appendix A for definitions of codes in the table) based on trips which landed rig. The final column for each QMA gives the annual total setnet landings (t) in each QMA. These values are plotted in Figure 17.

Fishing										SPO 1E
year	SPO	SNA	TRE	FLA	KAH	GUR	POR	TAR	OTH	Total
89/90	73.8	15.7	1.6	0.9	0.7	0.6	5.7	0.1	0.8	213
90/91	77.5	10.6	6.3	2.3	1.0	0.9	0.0	0.1	1.2	252
91/92	77.1	14.3	3.2	1.4	0.9	2.2	0.0	0.2	0.7	383
92/93	76.2	9.6	5.3	2.6	2.0	1.4	0.0	1.0	2.0	340
93/94	83.3	5.4	3.8	2.5	0.7	0.8	0.0	2.2	1.5	255
94/95	86.5	3.5	3.8	1.3	1.5	1.0	–	0.6	1.9	242
95/96	84.5	3.9	4.3	1.8	0.9	2.5	–	0.5	1.8	158
96/97	82.2	2.9	7.6	4.0	0.3	1.5	0.0	0.4	1.0	177
97/98	75.6	3.1	10.4	7.9	1.6	0.4	–	0.4	0.7	164
98/99	81.2	2.6	9.2	4.8	0.2	0.2	0.0	0.4	1.3	148
99/00	85.0	2.1	3.3	8.4	0.2	0.1	0.0	0.3	0.5	158
00/01	85.0	2.5	5.8	4.4	0.0	0.1	–	0.2	2.1	142
01/02	90.2	3.2	2.3	3.5	0.0	0.1	–	0.1	0.5	151
02/03	86.4	2.5	2.1	7.5	0.0	0.3	0.0	0.0	1.3	149
03/04	79.7	5.9	8.4	4.8	0.0	–	0.0	0.1	1.1	154
04/05	82.2	1.9	7.2	6.8	0.3	0.0	0.1	0.1	1.4	129
05/06	77.3	6.6	4.1	10.0	0.9	0.0	0.1	0.0	1.0	107
06/07	82.6	3.2	3.2	7.6	0.2	0.2	0.5	0.1	2.2	112
07/08	81.7	2.3	2.9	8.3	3.1	0.0	0.6	0.1	1.1	92
08/09	78.4	1.3	3.0	12.1	2.1	0.1	2.0	0.1	0.9	99
09/10	78.1	1.7	3.2	13.7	1.7	0.1	0.1	0.2	1.2	103
10/11	74.6	4.0	3.2	13.2	1.7	–	1.4	0.0	1.8	77
11/12	82.7	2.9	4.5	7.7	1.0	0.0	0.2	–	0.9	88
Mean	80.6	6.1	4.7	4.7	0.9	0.8	0.4	0.4	1.3	3 894[1]

Fishing										SPO 2
year	SPO	WAR	MOK	FLA	SCH	KIN	GUR	BUT	OTH	Total
89/90	52.4	15.7	11.7	3.8	0.9	2.5	0.9	0.4	11.8	18
90/91	37.9	23.8	8.6	5.6	4.1	7.2	12.0	0.7	0.2	18
91/92	34.8	23.8	5.6	15.5	2.5	8.2	3.4	1.1	5.1	24
92/93	39.1	9.2	8.1	9.7	7.8	8.3	6.7	1.9	9.2	22
93/94	44.5	18.7	5.5	10.5	2.9	5.3	5.6	1.6	5.3	29
94/95	25.7	34.3	4.2	7.0	5.6	4.9	0.8	3.2	14.4	20
95/96	31.9	21.5	9.4	22.6	6.3	2.4	2.4	1.6	1.9	31
96/97	14.0	35.9	7.3	18.2	2.6	9.8	5.8	3.1	3.3	24
97/98	20.4	35.1	12.9	13.5	1.6	7.4	1.4	3.7	4.0	17
98/99	25.3	42.1	10.5	7.9	1.1	5.7	2.9	2.8	1.8	21
99/00	15.3	49.9	12.1	13.0	0.2	7.2	1.3	0.9	0.2	22
00/01	29.6	14.6	32.9	5.9	8.9	2.2	1.5	4.2	0.2	23
01/02	34.8	21.0	23.0	12.2	2.3	0.3	3.2	2.0	1.1	25
02/03	24.1	27.3	15.1	19.5	2.5	1.5	5.7	1.6	2.7	16
03/04	14.8	30.8	33.7	9.4	4.9	–	2.3	2.8	1.3	15
04/05	26.3	27.0	17.6	17.8	0.4	–	0.0	2.9	7.9	19
05/06	4.6	40.7	39.7	9.5	–	–	–	2.7	2.9	14
06/07	34.5	16.1	35.3	10.5	1.1	–	–	2.1	0.4	19
07/08	22.4	10.5	22.4	16.9	19.2	1.7	–	1.5	5.2	20
08/09	32.2	15.1	24.1	8.7	11.9	1.1	0.0	2.8	4.1	34
09/10	40.9	6.4	22.9	8.0	15.3	0.6	–	1.4	4.4	26
10/11	51.7	3.6	12.5	7.9	18.8	0.3	–	2.7	2.6	25
11/12	65.0	5.0	12.1	6.6	7.5	0.1	–	1.7	2.0	36
Mean	33.3	21.6	16.1	11.3	6.1	3.3	2.3	2.1	3.9	518[1]

[1] total landings for all years

Table G.4 (cont.):

Fishing year	SPO 3									
	SPO	SCH	SPD	ELE	LIN	TAR	WAR	HPB	OTH	Total
89/90	47.7	29.8	10.0	4.0	2.6	3.2	0.9	1.4	0.5	174
90/91	40.3	27.7	8.0	12.6	4.0	3.8	1.8	0.4	1.4	168
91/92	48.6	20.2	11.2	9.4	3.7	2.7	0.5	0.6	3.0	187
92/93	45.7	29.3	11.8	6.1	1.8	2.7	0.0	1.7	0.8	165
93/94	43.4	30.3	16.0	6.1	0.5	1.1	0.7	0.3	1.6	204
94/95	55.7	24.8	9.1	4.7	1.2	0.7	2.0	0.8	1.0	262
95/96	52.8	27.4	8.7	4.6	2.6	1.0	1.4	0.6	0.9	262
96/97	48.3	29.3	8.2	6.2	2.8	0.8	1.2	0.8	2.5	281
97/98	59.3	27.6	4.5	1.7	2.6	1.9	0.6	0.1	1.7	304
98/99	61.2	22.7	7.9	1.4	3.7	1.5	0.2	0.1	1.2	302
99/00	56.9	25.0	0.4	1.3	8.4	2.2	4.3	1.0	0.6	282
00/01	64.8	20.5	2.7	0.4	6.3	2.0	1.7	1.5	0.3	343
01/02	77.7	10.5	5.8	1.0	1.5	1.5	0.7	0.2	1.2	299
02/03	81.0	12.3	2.8	0.9	1.5	1.3	0.0	0.1	0.2	306
03/04	83.0	10.7	2.0	1.1	1.8	0.7	0.0	0.1	0.5	258
04/05	81.3	11.4	0.6	3.2	2.2	0.6	0.1	0.3	0.3	255
05/06	78.3	14.5	2.7	3.6	0.0	0.2	0.0	0.5	0.2	279
06/07	77.2	17.8	1.7	2.2	0.1	0.3	0.0	0.4	0.2	298
07/08	72.0	24.0	0.7	1.3	0.0	0.2	0.1	0.3	1.5	352
08/09	60.5	35.0	0.3	2.7	0.1	0.3	–	0.2	0.9	213
09/10	59.0	33.8	1.0	3.0	0.4	0.2	0.0	0.2	2.4	224
10/11	59.1	32.3	0.3	4.7	1.1	0.1	0.0	0.1	2.2	244
11/12	64.3	28.6	1.8	3.0	0.2	0.3	0.1	0.4	1.3	245
Mean	63.3	23.0	4.7	3.3	2.2	1.2	0.7	0.5	1.1	5 906[1]

Fishing year	SPO 7									
	SPO	SCH	SPD	ELE	FLA	SNA	LIN	TRE	OTH	Total
89/90	84.1	11.2	0.5	1.7	0.5	0.3	0.4	0.0	1.3	117
90/91	91.3	6.5	0.7	–	0.2	–	0.9	–	0.3	126
91/92	85.4	7.1	5.8	0.2	0.3	0.1	0.4	–	0.7	146
92/93	83.9	4.4	6.4	4.2	0.5	0.2	0.0	–	0.4	186
93/94	82.5	1.4	13.8	1.0	0.8	0.0	0.2	–	0.3	172
94/95	83.8	6.7	8.8	0.1	0.3	–	0.0	–	0.2	180
95/96	80.9	8.3	6.1	2.1	0.4	0.0	0.1	1.7	0.4	237
96/97	89.0	5.1	2.7	2.5	0.4	–	0.1	–	0.2	230
97/98	93.7	3.9	1.4	0.1	0.2	0.3	0.0	–	0.4	190
98/99	94.9	3.7	0.3	0.1	0.6	0.1	0.0	–	0.4	176
99/00	93.0	2.5	0.3	0.0	0.2	1.4	2.4	0.0	0.1	172
00/01	95.6	2.9	0.4	0.0	0.3	0.1	0.0	–	0.6	215
01/02	96.9	1.8	0.7	0.2	0.0	0.3	–	–	0.1	174
02/03	95.4	1.9	0.7	1.7	0.2	–	0.0	–	0.0	173
03/04	98.0	1.1	0.2	0.1	0.1	0.4	0.0	–	0.1	195
04/05	95.2	2.8	–	1.2	0.1	0.7	–	–	0.1	166
05/06	94.1	5.2	0.1	0.0	0.5	0.2	0.0	–	0.0	182
06/07	96.0	3.7	0.0	0.2	–	0.1	0.0	–	0.1	159
07/08	92.9	7.0	–	–	0.0	0.1	–	–	0.0	105
08/09	83.4	16.1	0.2	–	0.1	–	–	–	0.1	98
09/10	89.9	5.6	3.1	0.3	0.1	0.9	–	–	0.1	84
10/11	89.9	9.8	0.2	0.0	0.0	–	0.0	–	0.1	103
11/12	90.3	9.0	0.0	0.2	0.1	–	–	–	0.5	104
Mean	90.6	5.0	2.5	0.8	0.3	0.2	0.2	0.1	0.3	3 691[1]

[1] total landings for all years

Table G.4 (cont.):

Fishing year	SPO 8									
	SPO	SCH	WAR	TRE	GUR	SPD	SNA	KIN	OTH	Total
89/90	76.0	14.7	1.6	2.5	0.5	0.6	0.6	2.9	0.6	136
90/91	78.0	8.7	2.0	2.7	2.2	1.0	2.6	2.7	0.1	138
91/92	78.0	7.7	5.3	2.1	2.6	0.7	0.9	2.2	0.5	99
92/93	85.8	5.3	3.8	2.2	0.6	0.1	1.1	0.5	0.6	192
93/94	88.8	3.8	2.6	2.0	0.5	1.4	0.8	0.2	0.1	209
94/95	89.6	3.2	2.1	1.6	1.1	1.2	0.7	0.0	0.4	219
95/96	82.4	6.0	2.9	5.4	0.6	1.2	0.3	0.0	1.1	265
96/97	85.3	6.2	3.4	0.8	3.9	0.2	0.1	0.1	0.0	211
97/98	85.3	3.3	3.2	1.2	4.9	0.7	0.2	0.0	1.2	218
98/99	88.9	5.7	1.9	0.8	2.4	0.2	0.2	0.0	0.0	180
99/00	86.7	3.3	6.7	1.5	1.1	–	0.1	–	0.6	164
00/01	83.0	5.0	5.9	0.7	4.5	0.1	0.0	–	0.8	157
01/02	89.9	3.1	6.5	0.1	0.4	0.1	0.0	–	0.0	185
02/03	91.3	3.5	4.1	0.6	0.1	0.3	0.0	–	0.0	183
03/04	90.0	6.4	3.0	0.1	–	–	0.3	–	0.1	180
04/05	86.8	4.8	7.7	0.3	–	–	–	–	0.5	186
05/06	89.5	5.3	3.4	0.1	1.0	–	0.1	–	0.5	145
06/07	82.6	11.2	1.9	0.4	3.4	–	–	–	0.4	146
07/08	91.4	5.5	2.4	0.2	–	–	0.0	–	0.4	186
08/09	85.0	8.0	5.4	0.8	–	0.0	–	–	0.9	196
09/10	85.1	6.5	7.1	1.0	–	–	–	–	0.3	214
10/11	86.8	8.7	3.8	0.3	–	0.3	–	–	0.1	184
11/12	87.8	7.6	2.5	1.8	–	–	–	–	0.3	162
Mean	86.1	6.0	3.9	1.3	1.3	0.4	0.3	0.3	0.4	4 157[1]

Fishing year	SPO 1W									
	SPO	GUR	FLA	SCH	TRE	GMU	KAH	JMA	OTH	Total
89/90	88.0	1.1	1.1	6.7	2.0	0.5	0.6	–	0.1	200
90/91	88.1	1.2	2.3	2.5	3.0	1.7	0.4	–	0.8	150
91/92	87.6	1.4	3.1	1.1	4.3	1.7	0.4	0.0	0.4	167
92/93	84.5	4.5	2.7	2.6	3.3	1.4	0.5	–	0.4	145
93/94	87.6	2.8	2.8	2.0	2.3	0.7	1.5	–	0.4	154
94/95	86.4	5.4	1.6	3.3	1.8	0.5	0.2	0.4	0.3	236
95/96	86.2	5.4	1.5	2.8	2.8	0.2	0.5	0.0	0.4	224
96/97	87.7	4.7	2.0	2.2	2.8	0.4	0.0	0.0	0.2	331
97/98	75.9	9.5	2.4	2.9	4.4	2.6	0.0	1.2	1.0	289
98/99	77.6	11.1	2.9	1.9	4.4	0.4	0.0	0.4	1.2	241
99/00	83.6	7.8	3.6	2.5	1.1	0.8	0.0	–	0.5	273
00/01	87.3	8.8	1.7	1.1	0.2	0.6	0.0	–	0.3	297
01/02	86.0	7.9	2.3	1.9	0.8	0.9	0.1	–	0.1	201
02/03	77.0	18.0	2.3	1.2	0.3	0.5	0.0	–	0.6	223
03/04	74.3	20.3	2.2	1.7	0.3	1.0	–	–	0.1	238
04/05	78.8	14.8	2.8	0.3	2.3	0.7	0.1	–	0.2	221
05/06	76.9	16.5	3.3	0.3	1.6	1.2	0.0	–	0.2	150
06/07	87.9	3.4	4.0	1.2	1.6	1.3	0.2	–	0.5	189
07/08	87.3	–	5.5	1.4	2.6	2.6	0.2	–	0.3	105
08/09	86.0	0.1	6.5	2.3	2.3	2.7	0.1	–	0.0	106
09/10	86.1	–	6.0	1.1	2.7	3.3	0.5	–	0.2	96
10/11	88.1	0.2	6.5	2.7	1.3	1.1	0.0	–	0.0	134
11/12	88.1	2.3	4.5	1.8	0.8	2.4	0.0	–	0.1	132
Mean	83.7	7.4	2.9	2.1	2.1	1.1	0.2	0.1	0.4	4 500[1]

[1] total landings for all years

Table G.5: Distribution of landings (%) by fishing year and by target species for bottom trawl in each QMA (see Appendix A for definitions of codes in the table) based on trips which landed rig. The final column for each QMA gives the annual total bottom trawl landings (t) in each QMA. These values are plotted in Figure 18.

Fishing	SPO 1E										SPO 2									
year	SNA	TAR	JDO	TRE	GUR	SKI	BAR	HOK	OTH	Total	GUR	TAR	FLA	SKI	SNA	TRE	WAR	HOK	OTH	Total
89/90	73.2	5.5	10.1	2.1	1.5	1.9	1.8	0.0	3.9	74	23.9	49.0	7.1	3.2	4.0	6.1	1.1	1.8	3.9	33
90/91	79.1	6.6	4.7	2.9	4.1	1.0	0.2	0.0	1.4	72	32.6	45.5	4.1	2.9	2.0	5.2	1.0	1.3	5.4	33
91/92	69.2	11.6	3.9	1.1	5.1	4.2	1.3	0.3	3.4	89	48.2	29.6	4.5	4.2	1.4	2.1	1.4	1.2	7.4	61
92/93	56.7	9.6	16.0	3.6	10.0	2.3	1.2	0.4	0.2	46	48.0	25.5	5.4	5.2	0.5	8.0	2.1	0.7	4.6	59
93/94	50.4	15.2	13.6	6.3	4.9	7.0	1.0	0.3	1.2	30	39.7	23.7	7.4	6.3	5.4	6.1	1.1	5.6	4.7	54
94/95	51.2	18.7	18.1	2.8	1.1	2.5	1.0	2.1	2.5	24	33.9	30.7	13.1	6.3	1.8	5.4	2.1	2.8	3.9	58
95/96	38.4	14.1	14.0	4.9	0.7	22.1	0.7	1.4	3.6	29	34.9	20.7	18.4	7.5	1.5	2.5	3.4	4.5	6.6	57
96/97	34.5	19.4	21.9	6.0	5.9	2.3	1.3	5.9	2.9	17	35.2	22.2	19.0	7.5	1.5	1.9	3.6	3.8	5.3	63
97/98	44.1	14.0	21.5	4.9	3.2	3.1	1.5	3.9	3.9	21	34.9	27.9	14.3	5.4	2.4	2.2	1.6	8.2	3.3	57
98/99	32.4	14.9	18.8	13.3	12.4	3.5	1.8	1.1	1.7	24	36.5	29.1	11.7	3.6	4.6	1.3	4.1	3.3	5.7	54
99/00	21.3	10.0	17.6	19.1	22.7	1.6	1.2	2.3	4.0	28	41.5	34.0	7.7	3.0	1.8	1.4	2.7	1.8	6.0	51
00/01	24.9	13.9	18.2	19.3	12.0	2.0	3.5	1.7	4.5	21	48.6	31.6	3.5	2.1	2.2	0.9	3.7	1.1	6.3	51
01/02	31.0	14.3	16.1	17.6	9.6	1.9	2.9	0.5	6.2	21	55.1	29.2	2.5	3.3	1.3	1.3	2.8	0.6	4.1	56
02/03	24.3	26.1	16.6	16.0	10.6	2.5	1.1	0.8	1.8	19	61.4	26.7	1.6	1.8	2.0	0.4	1.8	0.2	4.0	69
03/04	29.5	24.4	10.6	22.5	9.3	0.5	1.3	0.8	1.2	19	52.8	35.0	1.4	2.5	3.4	1.1	0.9	0.3	2.6	65
04/05	35.4	16.3	14.1	14.3	16.8	0.5	0.1	1.9	0.5	26	56.7	36.6	1.2	0.3	2.4	0.3	1.4	0.2	0.9	88
05/06	32.3	21.3	11.4	9.3	20.9	1.0	0.3	0.4	3.0	32	50.7	41.8	2.9	0.1	1.9	0.5	1.3	0.0	0.7	96
06/07	41.8	18.0	19.4	10.7	7.4	0.1	0.2	1.4	1.0	26	46.2	41.8	4.8	0.4	2.9	1.3	0.6	0.0	1.8	82
07/08	31.8	23.9	15.9	23.5	3.0	0.3	0.4	0.4	1.0	28	49.2	41.5	4.8	0.1	1.2	0.3	0.9	0.0	1.9	84
08/09	40.0	28.7	8.9	18.1	2.9	0.1	0.0	0.2	1.0	28	50.6	41.2	3.0	0.2	2.1	0.6	0.4	0.3	1.5	71
09/10	36.6	39.6	5.8	10.7	2.9	0.3	0.0	1.1	2.9	36	59.5	32.9	3.0	0.1	2.3	0.3	0.3	0.3	1.2	87
10/11	32.8	34.3	8.1	19.7	2.0	0.3	0.0	1.0	1.8	25	54.6	37.2	4.3	0.1	1.1	0.3	0.3	0.2	2.0	79
11/12	42.4	30.7	8.3	13.8	1.1	0.8	0.3	0.9	1.8	21	56.8	32.5	6.5	0.0	2.0	0.2	0.2	0.1	1.7	79
Mean	48.8	16.5	11.8	9.1	6.7	2.7	1.0	0.9	2.4	757[1]	47.5	33.5	6.2	2.5	2.2	1.8	1.6	1.4	3.4	1 488[1]

[1] total landings for all years

Table G.5 (cont.):

Fishing											SPO 3											SPO 7
year	FLA	RCO	STA	ELE	SPO	BAR	TAR	SQU	GUR	OTH	Total	FLA	BAR	RCO	TAR	GUR	STA	WAR	SNA	GSH	OTH	Total
89/90	38.9	18.3	8.0	6.7	1.4	8.5	2.8	0.7	3.0	11.8	58	54.3	9.0	5.7	7.1	3.9	3.8	0.6	4.3	0.8	10.6	88
90/91	43.9	15.0	6.0	2.2	7.0	12.8	1.9	0.3	1.5	9.4	62	41.4	17.4	4.4	6.6	4.6	1.0	1.9	2.9	0.8	18.9	88
91/92	39.6	20.4	5.8	3.8	4.1	6.1	3.4	11.8	1.6	3.5	81	42.2	19.5	10.4	11.0	5.3	2.0	1.1	1.1	0.5	6.9	83
92/93	46.1	28.2	8.4	2.1	3.2	6.7	0.7	0.0	1.1	3.6	84	49.2	19.8	17.3	4.2	2.7	0.1	0.6	1.8	0.8	3.5	101
93/94	28.5	37.9	15.0	4.9	8.2	1.3	2.0	0.6	0.8	0.8	87	54.9	15.4	10.1	8.8	3.2	0.5	0.5	1.0	0.6	4.9	95
94/95	27.0	50.6	7.9	2.2	4.5	4.0	0.9	0.3	0.4	2.3	78	52.2	21.2	10.4	6.0	1.3	0.7	0.5	0.6	1.2	5.8	122
95/96	29.4	39.2	3.9	6.2	5.6	6.1	5.8	0.5	1.3	1.9	93	42.6	23.7	15.2	5.4	2.2	0.3	0.8	0.3	0.3	9.1	117
96/97	37.8	36.6	4.9	2.2	2.5	3.7	4.4	4.6	2.0	1.4	82	50.6	33.1	5.2	4.1	1.2	0.3	1.5	0.9	0.1	3.2	121
97/98	45.6	40.5	6.8	0.8	0.4	3.6	1.0	0.1	0.3	0.9	87	53.7	26.7	4.0	3.6	1.6	0.5	0.2	0.8	0.1	8.8	91
98/99	50.7	25.8	11.0	0.5	0.0	5.9	2.0	1.0	0.4	2.6	70	52.4	15.9	15.0	5.6	1.0	0.8	2.4	1.8	0.2	5.0	125
99/00	42.4	26.5	8.3	0.8	0.3	3.4	1.4	6.9	1.6	8.3	99	41.9	35.5	1.0	6.8	1.6	1.1	6.8	2.4	0.4	2.4	119
00/01	39.4	32.5	7.5	0.4	0.2	4.3	3.2	8.2	3.2	1.2	115	46.8	37.1	2.6	6.6	3.3	0.4	0.3	0.8	0.1	2.1	121
01/02	31.3	33.7	4.1	0.9	2.4	9.5	2.0	4.8	4.2	7.1	91	44.1	28.1	9.0	5.0	7.8	0.6	1.7	0.7	0.3	2.9	105
02/03	34.8	25.1	6.4	4.5	1.0	12.9	4.1	6.8	1.8	2.7	108	44.4	21.9	10.1	8.9	4.8	1.7	2.3	1.7	0.6	3.5	89
03/04	29.2	30.6	8.6	3.4	3.5	7.6	4.3	0.9	1.3	10.6	91	44.0	23.7	10.3	8.9	3.9	2.6	2.0	1.2	0.6	2.8	94
04/05	38.2	24.1	8.2	5.4	1.7	3.8	6.7	6.6	2.4	3.1	97	47.0	18.7	13.2	10.4	1.3	2.3	2.9	1.1	0.9	2.2	99
05/06	31.0	25.8	9.7	9.3	0.3	4.7	4.2	8.6	1.8	4.7	94	47.3	11.1	17.1	9.2	0.9	4.7	1.6	2.4	2.5	3.1	104
06/07	28.3	17.2	5.2	15.7	5.5	5.8	4.3	1.4	2.7	13.9	104	56.4	8.3	11.2	9.2	1.2	4.8	3.0	1.9	0.7	3.2	104
07/08	37.0	13.1	5.2	11.7	2.5	5.1	7.1	9.1	1.2	8.0	82	52.7	10.7	11.1	13.1	1.2	3.9	2.6	1.3	0.7	2.6	119
08/09	29.1	16.6	10.0	13.6	12.8	5.7	6.4	0.1	2.6	3.0	83	54.8	10.9	9.8	14.3	2.3	2.9	0.9	1.2	1.6	1.4	126
09/10	39.7	11.8	7.2	10.4	12.6	3.4	6.8	0.2	2.4	5.4	107	56.6	7.0	6.1	10.7	7.3	2.3	2.0	2.5	2.5	2.9	133
10/11	37.1	9.1	7.1	10.9	18.4	4.2	7.9	0.2	1.5	3.7	97	37.6	5.7	12.1	14.1	9.7	3.3	2.5	3.6	5.0	6.3	121
11/12	34.4	5.8	9.0	13.7	25.6	2.8	3.0	0.3	3.2	2.3	123	38.1	4.9	8.5	15.7	15.7	2.9	3.1	2.6	2.0	6.5	116
Mean	36.2	25.1	7.6	6.0	5.8	5.6	3.8	3.3	1.9	4.7	2 074[1]	48.2	18.4	9.6	8.6	3.8	1.9	1.9	1.7	1.1	4.9	2 481[1]

[1] total landings for all years

Table G.5 (cont.):

Fishing	SPO 8											SPO 1W									
year	GUR	TRE	TAR	SNA	BAR	FLA	JDO	LEA	JMA	OTH	Total	SNA	TRE	GUR	TAR	BAR	SCH	SWA	SKI	OTH	Total
89/90	11.8	36.7	2.5	13.6	1.4	0.2	1.0	1.4	29.4	2.1	27	56.6	11.2	22.3	7.8	0.1	1.6	–	0.2	0.1	34
90/91	15.0	49.3	14.1	15.1	1.0	2.7	2.2	0.5	–	0.3	15	34.4	31.6	22.5	8.9	1.2	0.0	–	0.1	1.1	24
91/92	12.0	31.3	11.8	10.1	3.9	2.1	1.6	–	2.6	24.6	10	56.0	18.0	19.3	3.4	1.7	0.1	–	0.3	1.1	31
92/93	14.5	37.4	15.5	20.1	8.4	3.4	0.4	0.4	0.0	–	9	51.8	18.0	20.1	5.6	0.4	0.2	2.5	1.1	0.3	69
93/94	17.1	9.3	19.5	18.7	0.6	30.9	–	0.5	0.0	3.2	9	60.5	13.0	11.0	11.6	2.4	–	0.7	0.2	0.6	50
94/95	17.8	16.9	19.2	11.1	14.9	14.4	1.8	–	0.5	3.5	15	70.6	12.4	7.9	5.4	0.8	–	1.5	0.8	0.7	45
95/96	38.6	11.1	4.4	13.0	9.4	17.4	1.4	–	0.1	4.6	23	49.9	33.6	3.7	7.5	0.4	1.1	1.7	1.2	0.8	45
96/97	57.5	7.9	8.8	7.3	10.9	4.0	1.1	–	0.0	2.3	32	35.5	31.7	20.8	9.6	0.2	0.0	0.2	0.7	1.2	44
97/98	51.7	14.2	4.0	17.5	4.8	0.1	1.2	–	3.7	2.6	32	33.4	44.7	9.7	8.8	0.5	–	0.1	0.8	1.9	44
98/99	61.4	7.8	7.4	3.6	4.7	1.8	3.1	0.0	8.7	1.5	28	31.6	29.6	20.9	12.9	2.9	–	0.7	0.9	0.5	49
99/00	33.5	36.7	4.5	2.2	5.9	0.9	0.3	0.0	–	16.0	30	31.7	21.5	31.7	12.5	1.0	0.0	0.5	0.6	0.5	47
00/01	25.4	36.3	7.1	3.4	3.9	3.5	0.6	0.0	–	19.9	16	40.7	24.8	21.2	7.9	3.2	0.3	–	0.8	1.0	50
01/02	37.5	26.3	3.4	9.3	12.5	3.1	1.6	–	0.3	6.1	30	42.9	17.4	22.6	13.3	1.9	0.6	–	0.5	0.7	36
02/03	21.0	34.2	6.9	5.7	16.6	2.8	6.0	0.0	0.5	6.2	24	30.8	18.1	33.1	13.0	2.5	1.5	–	0.5	0.5	52
03/04	17.5	30.4	10.5	5.8	14.2	9.5	2.0	6.9	–	3.1	22	50.2	11.7	23.3	11.7	0.3	1.7	–	0.0	1.1	43
04/05	35.5	8.9	6.2	6.3	9.8	4.7	9.7	3.1	–	15.8	21	28.8	19.3	37.6	10.4	2.4	0.6	0.0	0.0	0.9	32
05/06	50.9	15.0	11.2	1.1	2.6	7.5	3.0	3.6	–	5.2	17	13.3	15.8	42.9	23.3	1.2	0.5	0.0	–	3.0	26
06/07	46.7	15.7	7.1	4.2	5.3	3.9	2.6	10.3	–	4.0	21	7.3	49.1	28.5	11.1	0.9	2.1	0.0	–	1.0	24
07/08	19.8	23.8	26.8	1.0	1.5	7.9	5.8	3.8	–	9.6	18	11.5	39.6	21.5	24.4	1.1	0.3	0.1	0.1	1.3	34
08/09	33.2	18.3	24.1	2.8	1.5	3.3	5.4	9.4	–	2.1	21	18.4	34.2	9.0	32.8	3.9	0.7	0.0	0.0	1.0	28
09/10	36.1	8.8	25.0	1.0	2.1	0.6	9.3	12.9	–	4.2	30	6.2	51.7	10.3	26.7	0.2	4.2	–	0.1	0.5	28
10/11	45.7	14.6	25.6	1.1	1.2	0.8	4.8	3.1	0.0	3.1	33	5.6	37.5	21.5	27.1	2.0	4.8	0.0	0.0	1.4	35
11/12	24.7	15.6	29.1	3.0	3.3	2.2	7.6	11.9	0.1	2.4	31	10.6	37.0	29.1	17.5	0.7	4.2	0.2	0.0	0.7	58
Mean	34.4	20.8	12.5	6.9	6.2	4.4	3.4	3.2	2.3	5.7	516[1]	35.8	26.1	21.0	12.8	1.4	1.0	0.5	0.5	0.9	927[1]

[1] total landings for all years

Appendix H. CPUE ANALYSES AND DIAGNOSTICS FOR SPO

H.1 Introduction

Sixteen detailed CPUE analyses and their accompanying diagnostics are described in the following appendices:

Analysis	Results	Diagnostics
SPO 1E	Appendix I	Appendix J
SPO 1W	Appendix K	Appendix L
SPO 2 & SPO 3	Appendix M	Appendix N
SPO 7	Appendix O	Appendix P
SPO 8	Appendix Q	Appendix R

These appendices correspond to the analyses presented in Section 3 of the main report. Each appendix contains a general introduction to the analyses, definitions for each of the modelled fisheries, detailed tables and figures providing statistics and diagnostics pertaining to each model, and a final table giving the estimated indices and their error bars.

H.2 Methods

H.2.1 Data Preparation

The identification of candidate trips for these analyses and the methods used to prepare them are described in Section 2.3.1 in the main report. For the bottom trawl fisheries and all setnet fisheries other than SPO 1, landings were allocated to effort at trip-stratum resolution. For the setnet fisheries in SPO 1, however, landings data are considered to be unreliable because of catches being accumulated in freezers ashore and not identifiable by the individual trips for which effort information is recorded. For the SPO 1 setnet fisheries analyses were based on estimated catches that had been corrected by the annual reporting ratio for each vessel in each year. This method is described in Appendix F and this problem was not encountered in other QMAs or for trips which used the bottom trawl method.

Those groups of events that satisfied the criteria of target species, method and statistical areas defining the defined fisheries were selected from available fishing trips. Any effort strata that were matched to a landing of rig were termed “successful”, and may include relevant but unsuccessful effort given that a "trip stratum" represents amalgamated catch and effort. Consequently, the analysis of catch rates in successful strata will also incorporates relevant zero catch information.

The potential explanatory variables available from each trip in these data sets, include the number of tows, or length of net (depending on fishing method), total duration of fishing, fishing year, statistical area, target species, month of landing, and a unique vessel identifier. The dependent variable will be LN(catch) where catch will be the scaled landings or the estimated catches adjusted by the vessel correction factor. Data might not represent an entire fishing trip; just those portions of it that qualified. Trips were not dropped because they targeted more than one species or fished in more than one statistical area.

H.2.2 Analytical methods for standardisation

Arithmetic CPUE in each year was calculated as the total catch for the year divided by the total effort in the year. Unstandardised CPUE in each year is the geometric mean of the ratio of catch to effort for each record. It makes the same distributional assumption as the standardised CPUE, but does not take into account changes in the fishery.

A standardised abundance index was calculated from a generalised linear model (GLM) (Quinn & Deriso 1999) fitted to the successful (positive) catch records using a range of explanatory variables after selecting the distributional assumption that most closely describes the data set. Comparisons with unstandardised CPUE in this report provide measures of how much the standardisation procedure has modified the series, and gives insights into how fishing behaviour can affect catch rates of rig.

The exploration of alternative distributional assumptions for the standardisation models was done in two steps. First, alternative regressions based on five statistical distributional assumptions (lognormal, log-logistic, inverse Gaussian, gamma and Weibull) predicted LN(catch) given a dataset with a reduced set of six explanatory variables (year, month, area, vessel, target species and the log of number tows or length of net). The model distribution which fit the data with the lowest negative log-likelihood was then selected for use in the final stepwise model.

The second step involved repeating the regression using the selected distribution: regressing log(catch) against the full set of explanatory variables in a stepwise procedure, selecting variables one at a time until the improvement in the model R^2 was less than 0.01. The order of the variables in the selection process was based on the variable with the lowest AIC, so that the degrees of freedom were minimised.

Canonical coefficients and standard errors were calculated for each categorical variable (Francis 1999). Standardised analyses typically set one of the coefficients to 1.0 without an error term and estimate the remaining coefficients and the associated error relative to the fixed coefficient. This is required because of parameter confounding. The Francis (1999) procedure rescales all coefficients so that the geometric mean of the coefficients is equal to 1.0 and calculates a standard error for each coefficient, including the fixed coefficient.

Datasets were further restricted to core fleets of vessels, defined by their activity in the fishery, thus selecting only the most active vessels without unduly constraining the amount of catch and effort available for analysis.

In New Zealand fisheries, it is common practice to model observations with zero catch by fitting a linear regression model based on a binomial distribution using the presence/absence of the species of interest as the dependent variable; thus providing an alternative series of standardised coefficients. This was not done here, because when data are amalgamated (as was done for this study to trip-stratum resolution), much of the unsuccessful qualifying effort is incorporated into the summarised catch and effort and any remaining signal (of encounter rate) may be an artefact of the data amalgamation procedure and/or uninterpretable as a biomass index.

Appendix I. CPUE ANALYSES FOR EAST NORTHLAND AND BAY OF PLENTY (SPO 1E)

I.1 General overview

The key fisheries for rig in SPO 1 were last described to the end of the 2009–10 fishing year by Kendrick & Bentley (2012). They described a developing trend of setnet catches being accumulated in freezers ashore, with consolidated landings unable to be linked to effort records. They estimated a "vessel correction factor (VCF)" for each vessel/year category and used it to adjust estimated catches.
Indices from bottom trawl in SPO 1E were accepted in 2011 as likely to monitor part (<1 m in length) of the population, but the method for producing setnet indices were considered to be a "work in progress".

In this study, improved grooming to remove erroneous large catches has improved the datasets and given greater confidence in the VCF. Ironically, the improved grooming had the greatest effect on the trawl datasets.

Indices from this study for setnet in Statistical Area 007, and bottom trawl along the wider coast were accepted by the Working Group with a Science Information Quality Rank=1, and indices from the more disparate coastal setnet fishery were accepted with caveats (Science Information Quality Rank=2.).

I.1.1 Fishery definitions for CPUE analysis

Rig around the coast of New Zealand may comprise a single stock, but natural geographical boundaries have traditionally subdivided SPO 1 into three areas: west coast North Island, East Northland and Bay of Plenty.

Fisheries for rig, particularly the setnet fisheries, are often artisanal; based on small vessels that have a high fidelity to locales and harbours, and monitoring is considered more appropriate at the spatial scale of those fisheries. This appendix details three standardised analyses for rig from SPO 1E; a discrete setnet fishery operating in the Hauraki Gulf, and more extensive setnet and bottom trawl fisheries operating along the wider coast of East Northland and including Bay of Plenty. These three fisheries are likely to exploit different parts of the population.

SPO 1E_SN(007) – Shark setnet in Hauraki Gulf – The Fishery is defined from setnet fishing events that fished Statistical Area 007, and targeted SPO, SCH, SPD, or NSD. Very few sets (less than 5% per year) reported a zero catch of rig and they were excluded. Only the analysis of positive catches is presented. Catches have been adjusted by vessel reporting ratios for each year.

SPO 1E_BT – East Northland mixed species bottom trawl – The Fishery is defined from bottom single trawl fishing events which fished in Statistical Areas 002–010, and targeted TAR, SNA, TRE, BAR, JDO, or GUR. This definition potentially allows the use of total effort in the analysis of catch rates, however only the analysis of positive catches is presented.

SPO 1E_SN(COAST)– Shark setnet in coastal east northland and Bay of Plenty -- The Fishery is defined from setnet fishing events which fished in Statistical Areas 002 – 006, 008 – 010, and targeted SPO, SCH, SPD, or NSD. Only the analysis of positive catches is presented. Catches have been adjusted by vessel reporting ratios in each year.

I.2 Unstandardised CPUE

The setnet fishery in Area 007 shows a history of fluctuating effort at around 500 trips per year up until the early 2000s when effort declines to nearer 200 – 300 trips per year. Catch rates fluctuate around 150–200 kg per set over the whole period with no trend up or down (Figure I.1). The fishery is effectively a target fishery with few (< 5%) observations of zero rig catches (Figure I.2), and amalgamation of the data to trip stratum had little effect with between 1.1 and 1.3 original records being combined on average into an effort stratum (Figure I.2). This is consistent with a fishery that is almost entirely reported at daily resolution on CELR forms and which generally fishes in only one statistical area on any one day.

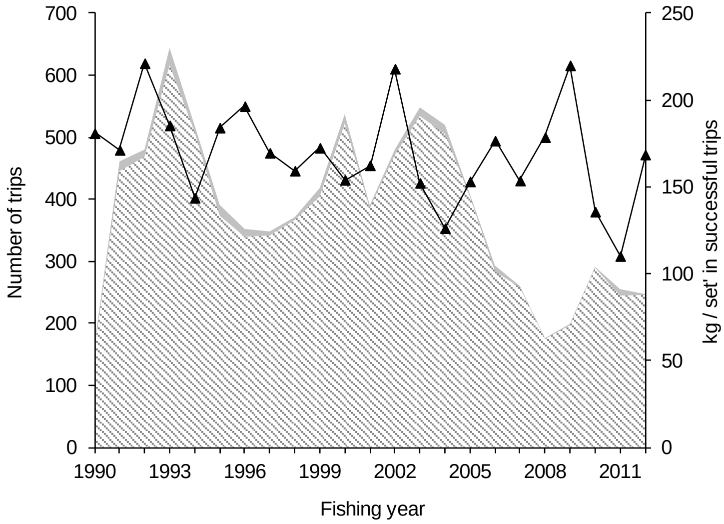
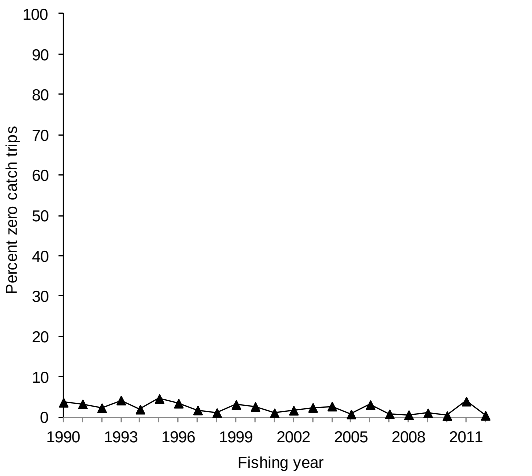


Figure I.1: The number of qualifying trips (dark area), those that landed rig (light area) and the simple catch rate (kg/set, black line) of rig in successful trips, by fishing year for the SPO 1E_SN(007) fishery.



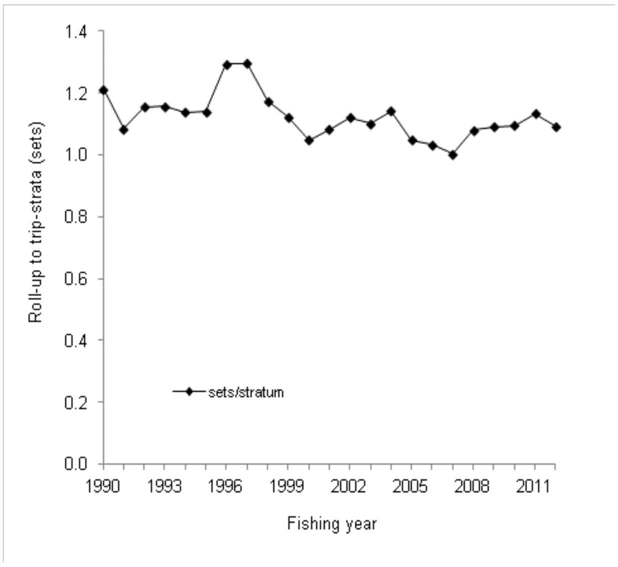


Figure I.2: The percent of trip-strata in SPO 1E_SN(007), with zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum, by fishing year.

Effort in the bottom trawl fishery has declined steadily over the study period, but has landed rig from an increasing proportion of trips (Figure I.3). At trip stratum resolution this trend is not so clear, with the proportion of zero catch strata staying at slightly more than 50%. A change in reporting practice coincident with the shift from daily to tow-by-tow reporting in the mid 1990s is evident in the effect of rolling data up to trip-stratum resolution (Figure I.4). This is probably related to the improved reporting of target species on the TCELR/CER forms that determines the definition of a stratum. The wide target species definition used here was selected to help mitigate the disparity in reporting practices between formtypes.

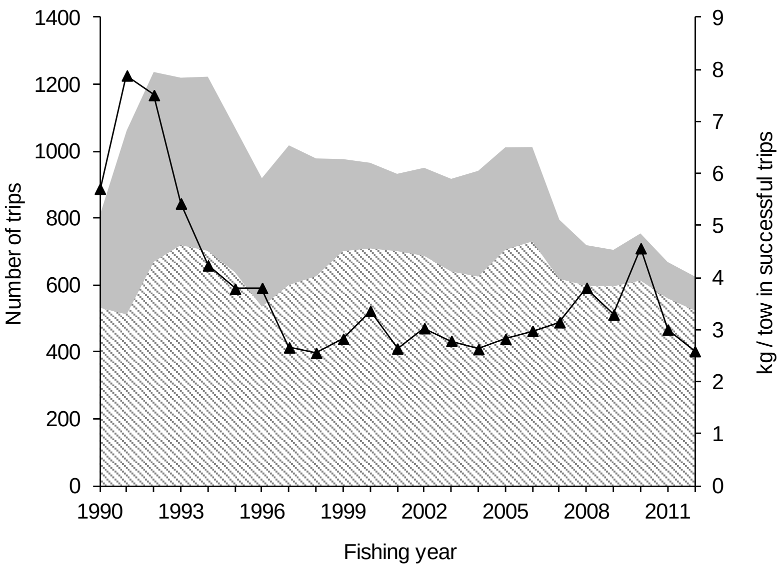


Figure I.3: Number of qualifying trips in SPO 1E_BT (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/tow, black line) of rig in successful trip-strata, by fishing year.

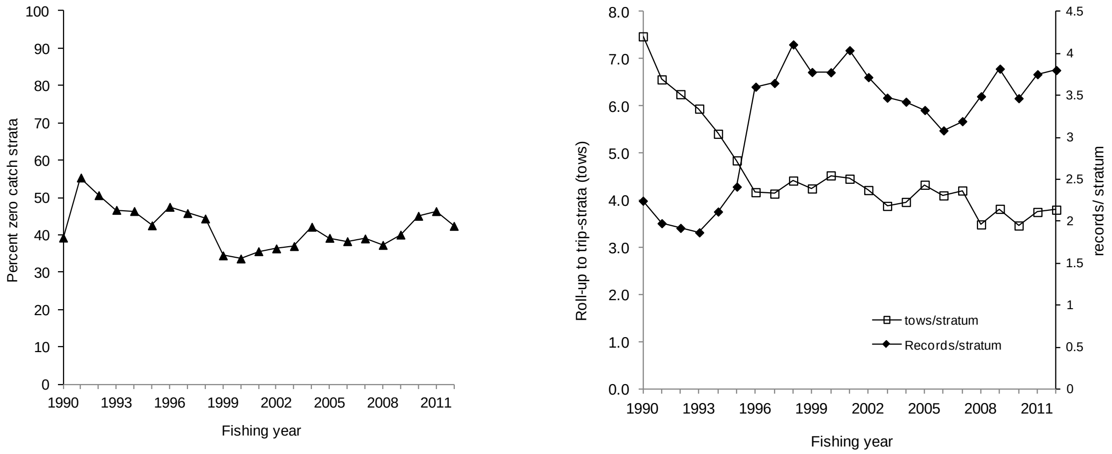


Figure I.4: The proportion of trip-strata in SPO 1E_BT, with zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of tows per trip-stratum, by fishing year.

Effort in the wider coastal setnet fishery has been patchy and inconsistent between years, but shows and overall decline levels that in 2011–12 are the lowest for the series at less than 25% of the peak in 1992–93 (Figure I.5). Success of those trips with respect to rig is also patchy, indicating perhaps the inclusion of other shark target sets in the dataset. Catch rates have remained constant and the rollup of data to trip stratum has not trended in any way that might confound the success rate, but all indicators highlight inconsistencies in the operation of the fishery particularly a clear change in the early 1990s that coincides with changes in the core fleet (Figure I.6).

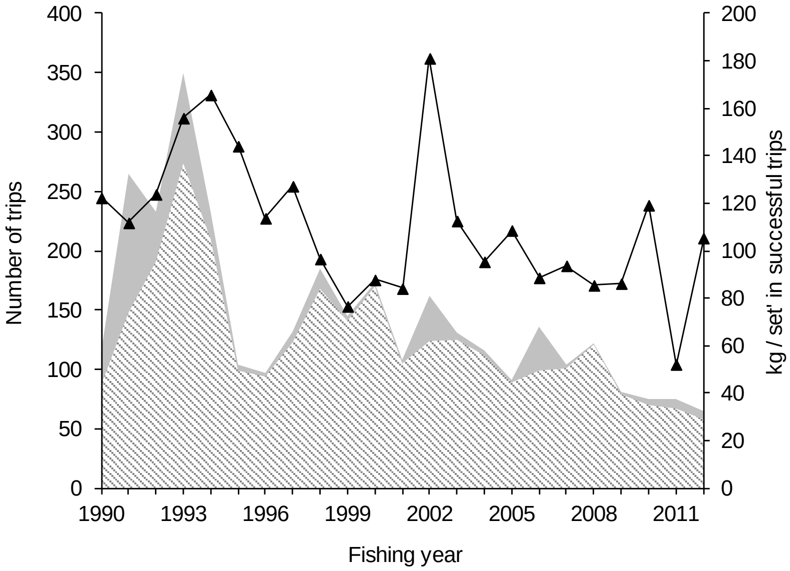


Figure I.5: Number of qualifying trips in SPO 1E_SN(COAST) (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/set, black line) of rig in successful trip-strata, by fishing year.

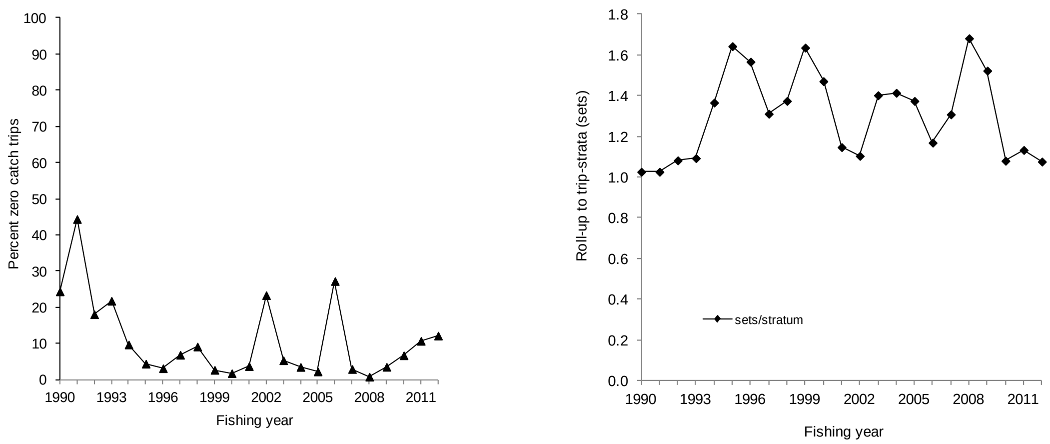


Figure I.6: The proportion of trip-strata in SPO 1E_SN(COAST), with zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of sets per trip-stratum, by fishing year.

I.3 Standardised CPUE analysis

I.3.1 Core fleet definitions

The data sets used for the standardised CPUE analysis were restricted to those vessels that participated with some consistency in the defined fishery. Core vessels were selected by specifying two variables; the number of trips that determined a qualifying year, and the number of qualifying years that each vessel participated in the fishery. The effect of these two variables on the amount of landed rig retained in the dataset and on the number of core vessels, and the length of participation by the core vessels in each fishery are depicted for each fishery in Figure J.1 to Figure J.3 . The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of rig. The selection process usually reduced the number of vessels in the dataset by about 70% while reducing the amount of landed rig by about 20%. Summaries for the core vessel data sets are presented in Table J.1.

I.3.2 Model selection, diagnostics and trends in model year effects

The final models selected for standardising positive catches in each fishery are described in Table I.1 to Table I.3. These tables include those explanatory variables that met the AIC criteria and each is not necessarily a complete list of the variables that were offered[1]. The variables that met the acceptance criteria based on a 1% improvement in R^2 are indicated with asterisks in the table, along with the amount of deviance they explained.

Following each table are step-influence plots that demonstrate the progressive effect on the annual indices of each explanatory variable as it enters the model, and shows the influence of each variable on the annual coefficients in adjacent panels. These plots highlight the observation made in Bentley et al. (2011) that the variables that explain the most deviance are not necessarily the ones responsible for most of the difference between standardised and observed series of CPUE. The influence of an explanatory variable is a combination of its GLM coefficients and its distributional changes over years, and these are contrasted and combined in Coefficient-Distribution-Influence (CDI) plots (Bentley et al. 2011) given for each explanatory variable accepted into the model (see Appendix J.4). The standardised series are compared with unstandardised CPUE and the effect of standardisation discussed. Previous series are also overlaid for the years in common and any differences between them, and/or changes in the fisheries in the intervening years commented on.

Diagnostic plots of the residuals from each final model fit are given in Appendix J.3 and include residual implied coefficient plots for each statistical area and target species by year. These allow the comparison of the annual trends among statistical area and target species categories in each analysis, effectively serving as a proxy for an interaction analysis. The unstandardised and standardised indices from the final model for each fishery are given in Appendix J.5

I.3.2.1 SPO 1E_SN(007) – Shark setnet in Hauraki Gulf

The log logistic error distribution produced the best model fit to SPO 1E _SN(007) data (Figure J.4) and the residuals from the final model show a good fit to the distributional assumptions (Figure J.5). Fishing year was forced as the first variable in the final model and explained about 4% of the variance in catch, Vessel is the most important variable, entering second and explaining an additional 35% of the variance in catch. Month entered the model third and explained a further 5% of variance, and net length was the measure of effort with the greatest explanatory power, entering the model last. The final model explained almost 50% of the variance in log(catch) (Table I.1). The annual indices are plotted at each step in Figure I.7.

Table I.1: Order of acceptance of variables into the log logistic model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 5 trips in 4 or more fishing years) in the SPO 1E_SN(007) fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an *. Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	24	-41 901	83 851	3.93	*
vessel	187	-40 327	81 028	39.72	*
month	198	-40 011	80 418	45.10	*
poly(log(netlength), 3)	201	-39 758	79 918	**49.07**	*
poly(log(duration), 3)	204	-39 716	79 840	49.70	

The coefficients for vessel show consistent differences in performance among vessels with respect to rig catch (Figure J.15). A trend of poorer vessels departing the fishery combined with recent entrants performing above average is predicted to have increased catches about 30% over the entire period. The month coefficients show a fishery that peaks in spring both in terms of catch rates and in effort, with a secondary small peak in May (Figure J.16). Shifts in the seasonality of fishing have been adjusted for

[1] Variables which make no improvement in the AIC are ignored by the software.

from year to year with a small positive influence overall, and a trend towards longer nets has similarly had a slight but positive influence on catches (Figure J.17).

The year effects fluctuate around unity, showing no overall trend. There is very close agreement with the previous series produced for this fishery, and the effect of standardisation is to smooth the series slightly, reducing some anomalous peaks, but not markedly changing the pattern overall (Figure I.8).

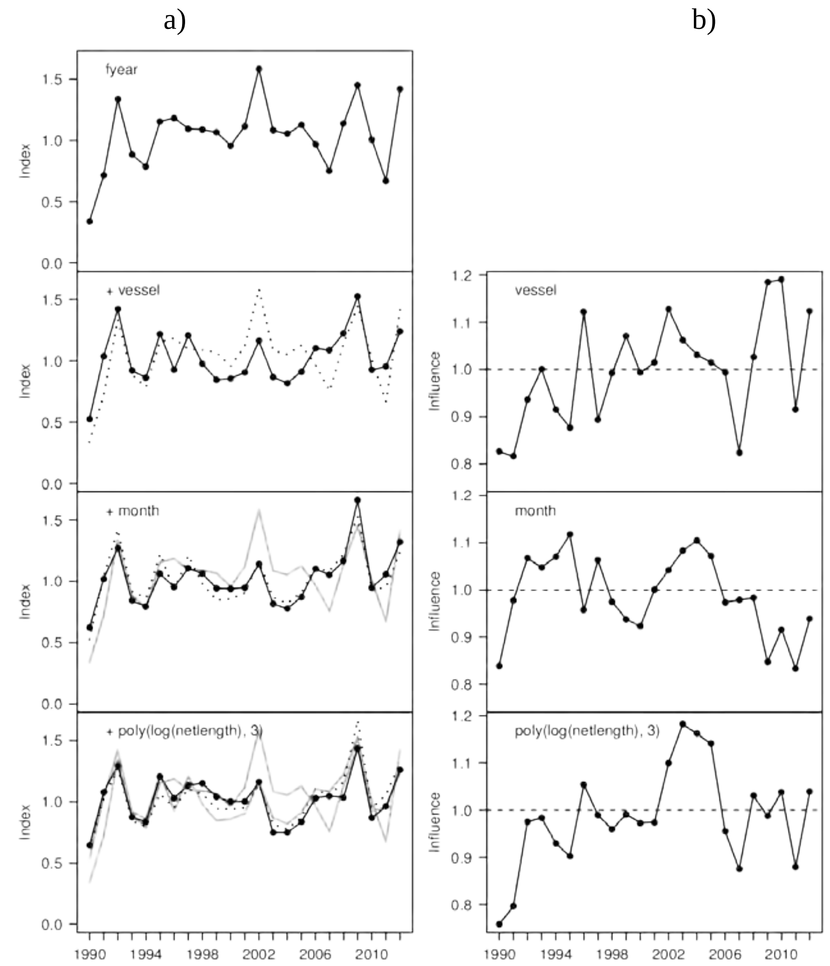


Figure I.7: Step and annual influence plot for SPO 1E_SN(007). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

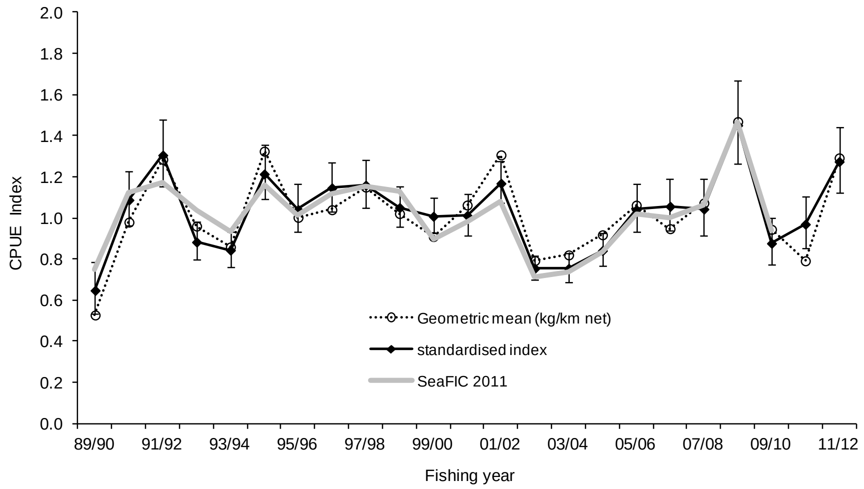


Figure I.8: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 1E_SN(007) fishery. Broken lines are the raw CPUE (kg /tow) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the lognormal series presented in 2011 for a similar fishery. All series are relative to the geometric mean over the years in common.

I.3.2.2 SPO 1E_BT – Mixed species bottom trawl in coastal east northland

The lognormal error distribution produced the best model fit to SPO 1E_BT data (Figure J.7) with a good residual pattern (Figure J.8). Fishing year was forced as the first variable in the final model and explained more than 6% of the variance in catch. The log of the number of tows is the most important variable, entering second and explaining an additional 21% of the variance in catch. Vessel entered the model third and explained a further 9% of variance, and area entered the model last with very little additional explanatory power. The final model explained 38% of the variance in log(catch) (Table I.2). The annual indices are plotted at each step in Figure I.9.

The CDI plot for tows (Figure J.18) shows an early decline in the number of tows per record that coincides with a systematic shift in reporting from the daily CELR form to the tow-by-tow TCEPR form. The trend in the rollup of tows per trip-stratum probably indicates a fundamental change to the way fishers reported target species, but the early decline from high catches is largely an artefact of the roll-up of data across the two form types that the model appears to be able to adequately adjust for. Changes in the core fleet are predicted to have been negative with respect to rig catches (Figure J.19), as have shifts in the spatial distribution of effort (Figure J.20).

The year effects decline over six consecutive years from their peak in 1990–91 to a new level of less than 50% of those initial catches. The series was relatively stable over the following ten years at about 80% of the overall mean, and then increased steadily over four consecutive years to plateau nearer the mean for the series in the late 2000s, with a subsequent decline in the most recent year 2011–12 (Figure I.10). The series is well determined with small confidence limits around each point and trends that are maintained over consecutive years.

The residual implied coefficients which indicate potential interaction effects confirm similar trajectories in the main constituent statistical areas (Figure J.9) and target fisheries (Figure J.10).
The effect of standardisation (after the effect of effort is included in the unstandardised series) is almost indiscernible, indicating considerable stability in the way this fishery has operated with respect to catching rig (Figure I.10). The marked difference from the previous series illustrates the effect of improved grooming done for this study to remove erroneous large landings from the data set.

Table I.2: Order of acceptance of variables into the lognormal model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 5 trips in 4 or more fishing years) in the SPO 1E_BT fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an * . Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	23	-50 503	101 055	6.47	*
poly(log(num) 3)	26	-46 994	94 041	27.87	*
vessel	93	-45 174	90 537	37.01	*
area	101	-44 952	90 109	38.04	*
month	112	-44 868	89 962	38.43	
poly(log(duration) 3)	115	-44 840	89 911	38.56	
target	120	-44 804	89 850	38.73	
poly(log(days) 3)	123	-44 794	89 835	38.77	

a) b)

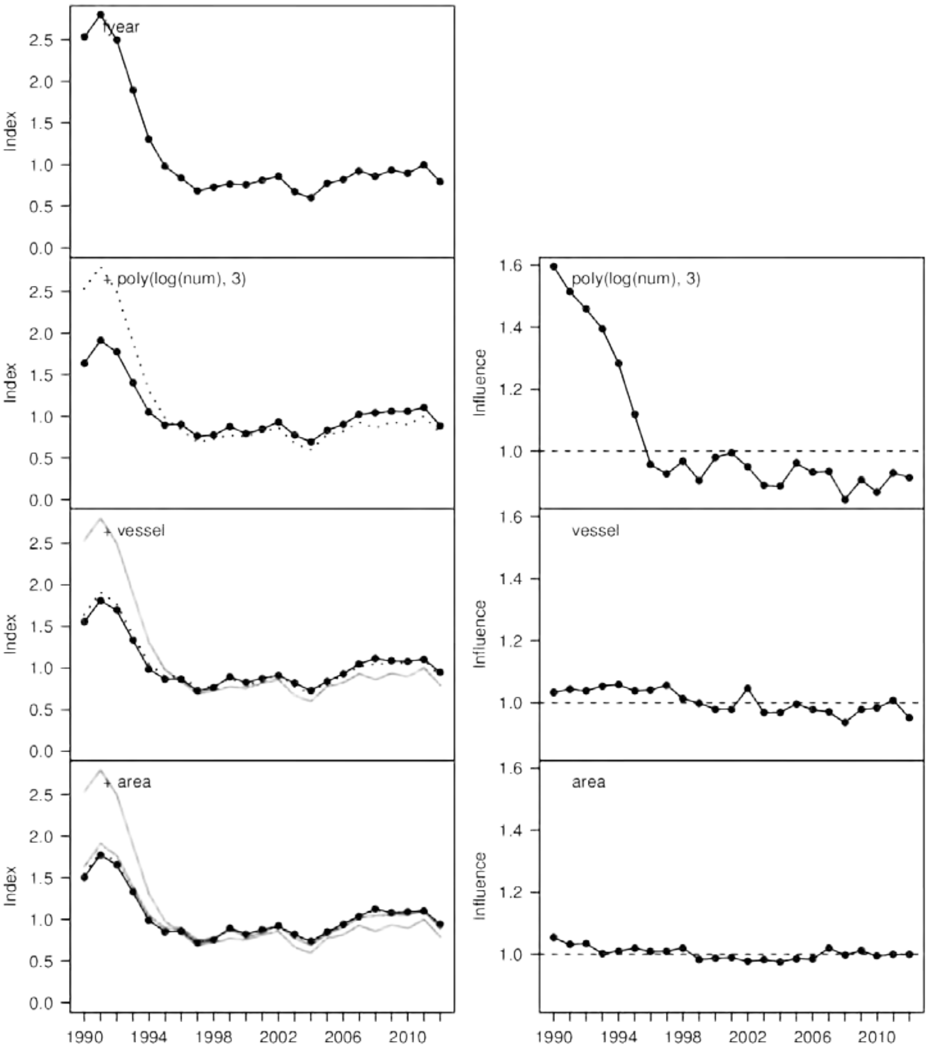


Figure I.9: Step and annual influence plot for SPO 1E_BT. (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

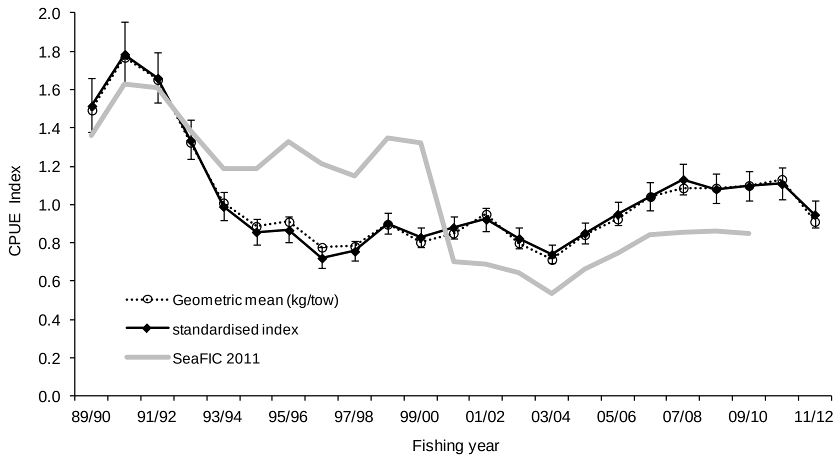


Figure I.10: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 1E_BT fishery. Broken lines are the raw CPUE (kg /tow) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the previous lognormal series presented in 2011 for a similar fishery. All series are relative to the geometric mean over the years in common.

I.3.2.3 SPO 1E_SN(COAST) – Shark setnet in coastal east northland

The lognormal error distribution produced the best model fit to SPO 1E_SN data (Figure J.11) and produced a good residual pattern except at the extreme tails of the distribution (Figure J.12). Fishing year was forced as the first variable in the final model and explained almost 4% of the variance in catch. Vessel entered second and explained almost 19% of the variance and was also the variable with the greatest influence. The log of the length of net entered third, and duration of fishing (soak time), area and month were also accepted into the model with variable influence on catches, but making only slight differences to the overall trajectory of year effects. The final model explained 35% of the variance in log of catch (Table I.3). The annual indices are plotted at each step in Figure I.11.

The CDI plot for vessel (Figure J.21) shows a general improvement in the core fleet that has potentially lifted catches by 20–30% over the study period. Netlength is included in the model largely to explain a shift between 2008–09 and 2010–11 towards fewer kilometres of net per trip-stratum (Figure J.22), and duration is included to account for a marked increase during the early 1990s (Figure J.23). Shifts in area have had a generally negative influence on catches over the entire period (Figure J.24), and seasonality of fishing has been pretty stable over the whole period except that data for the first year (1989–90) may not be complete (Figure J.25).

Table I.3: Order of acceptance of variables into the lognormal model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 3 trips in 3 or more fishing years) in the SPO 1E_SN(COAST) fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an * . Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	23	-4 571	9 190	3.91	*
vessel	60	-4 276	8 675	22.50	*
poly(log(netlength), 3)	63	-4 119	8 366	30.99	*
poly(log(duration), 3)	66	-4 088	8 309	32.57	*
area	72	-4 055	8 255	34.20	*
month	83	-4 027	8 223	35.51	*
target	85	-4 020	8 212	35.86	

The year effects fluctuate noisily about unity with no overall trend up or down (Figure I.12), but agree closely with the previous series presented for this fishery. There is considerable effect of

standardisation from year to year, lifting an initial peak in 1991–92, and diminishing others, but without any overall smoothing effect, and without markedly changing the overall flat trend.
The residual implied coefficients which indicate potential interaction effects confirm noisy trajectories in each area that appear to be similar (Figure J.13). There is very little information from other target species (school shark and spiny dogfish) as the fishery is predominantly targeted at rig (Figure J.14).

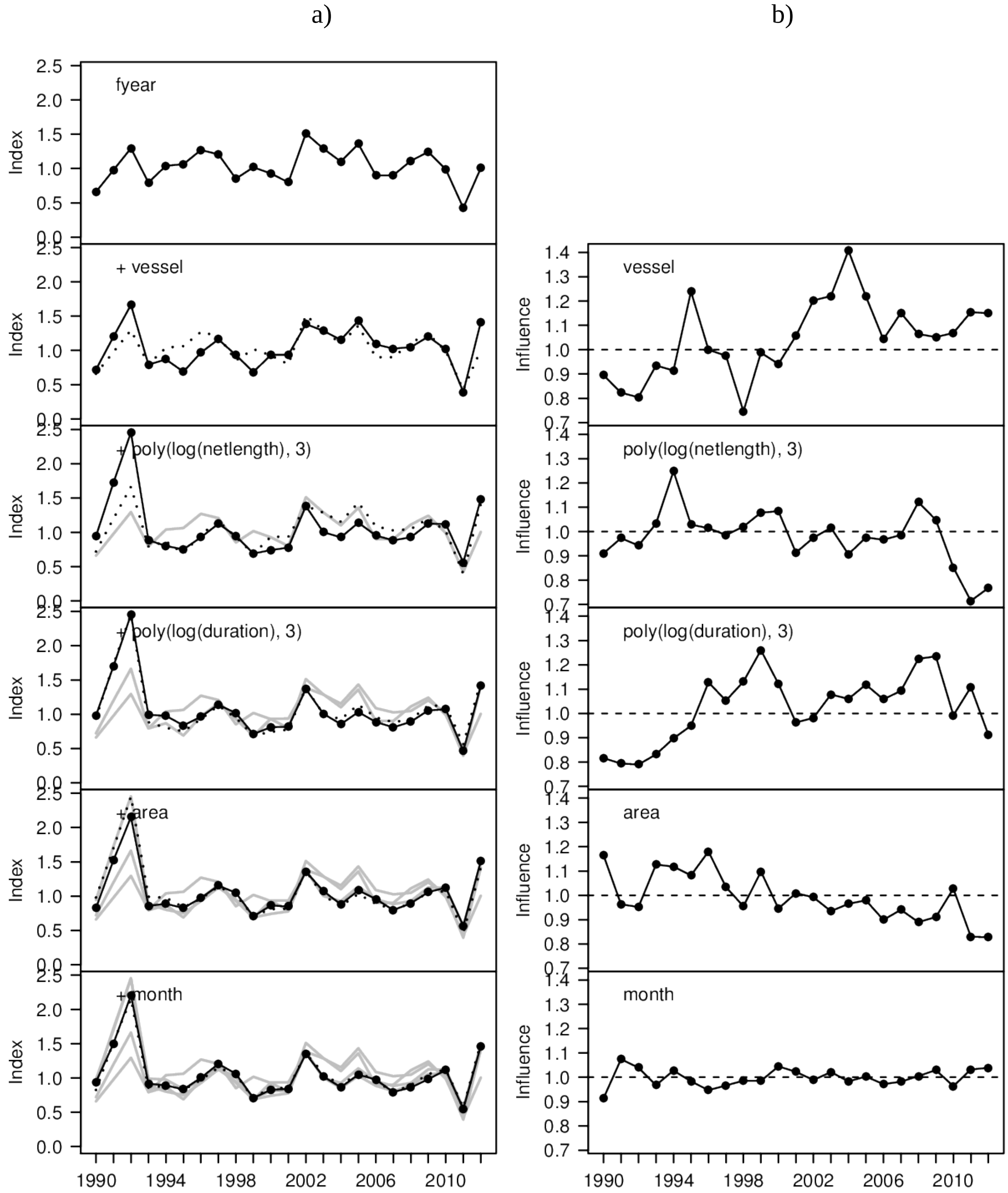


Figure I.11: Step and annual influence plot for SPO 1E_SN(COAST). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

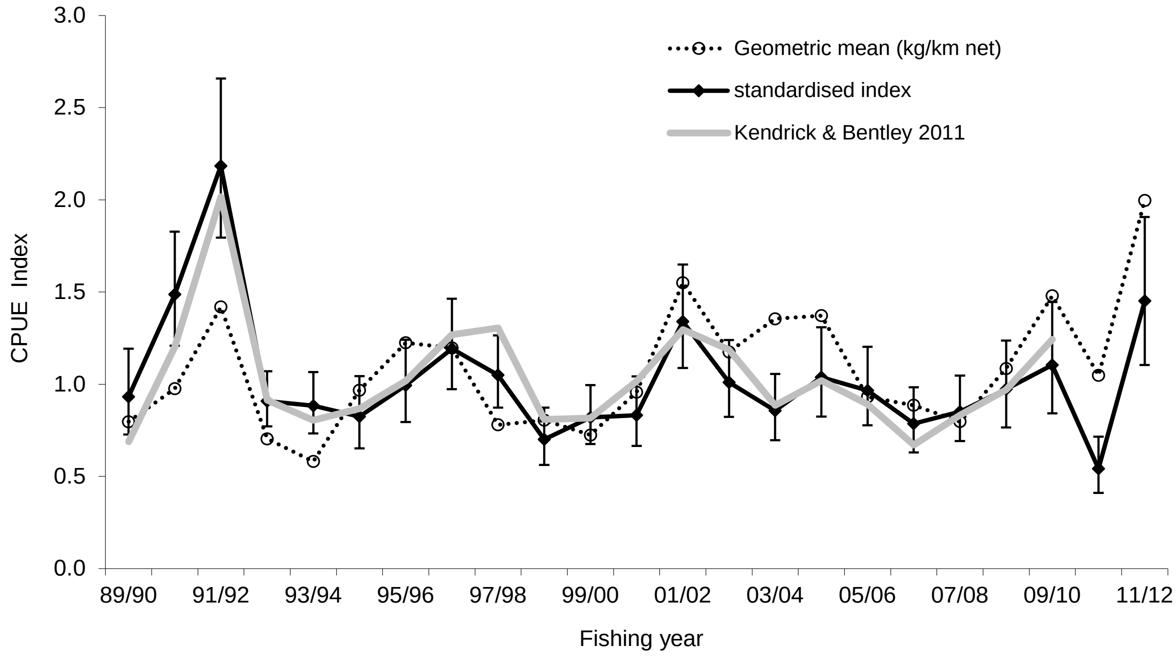


Figure I.12: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 1E_SN(COAST) fishery. Broken lines are the raw CPUE (kg /km net) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the previous lognormal series presented in 2011 for this fishery. All series are relative to the geometric mean over the years in common.

I.3.3 Comparison with models based on the lognormal distribution

The effect of selecting the error distribution that gave the most consistent residual pattern relative to the distributional assumption was not substantial for the SPO 1E_SN(007) model: there is little difference in the estimated year indices when the "best" series is compared to an alternative series based on a lognormal distribution for all three statistical areas (Figure I.13).

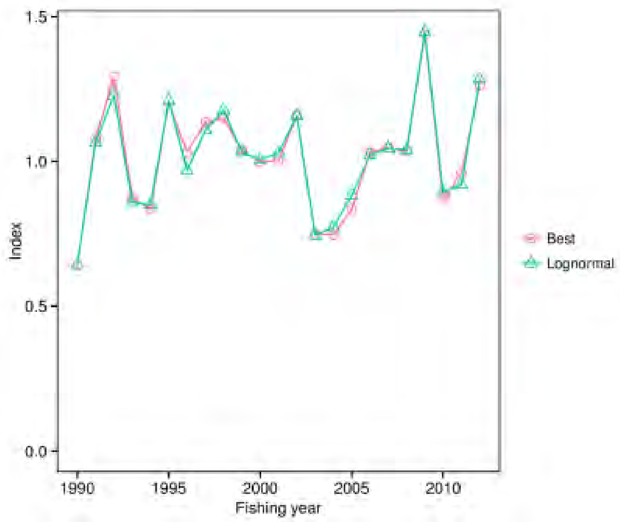


Figure I.13: Comparison between the log-logistic indices and indices obtained from a similar model that assumed lognormal error distribution for SPO 1E_SN(007).

Appendix J. DETAILED DIAGNOSTICS FOR SPO 1E CPUE STANDARDISATIONS

J.1 Core vessel selection

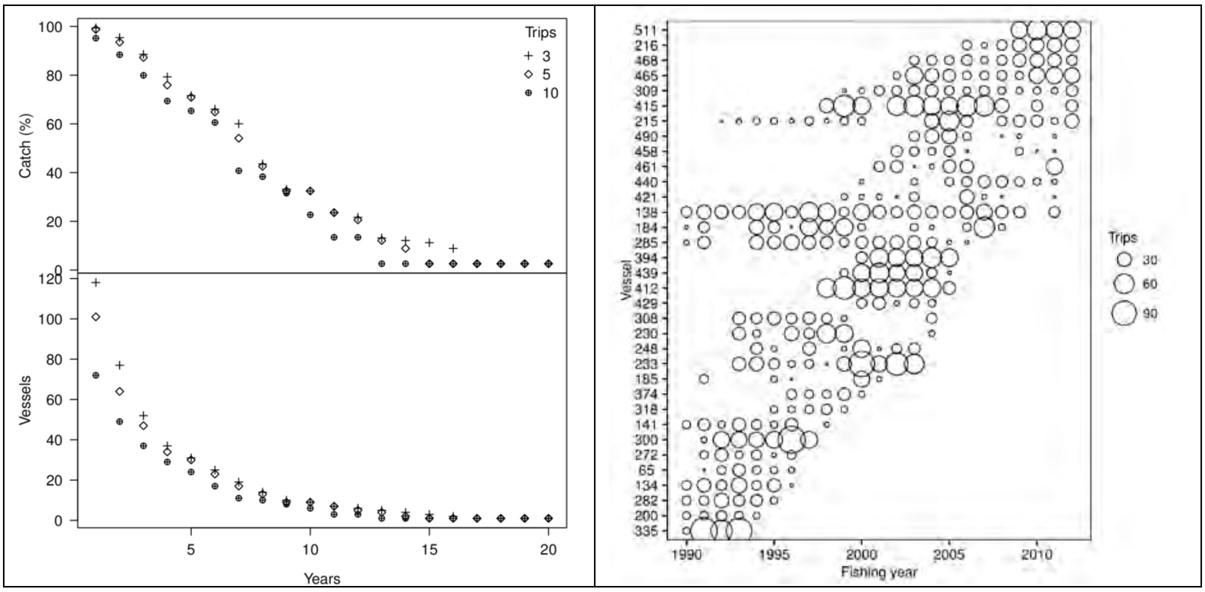


Figure J.1: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 1E_SN(007) dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 5 trips in 4 or more fishing years).

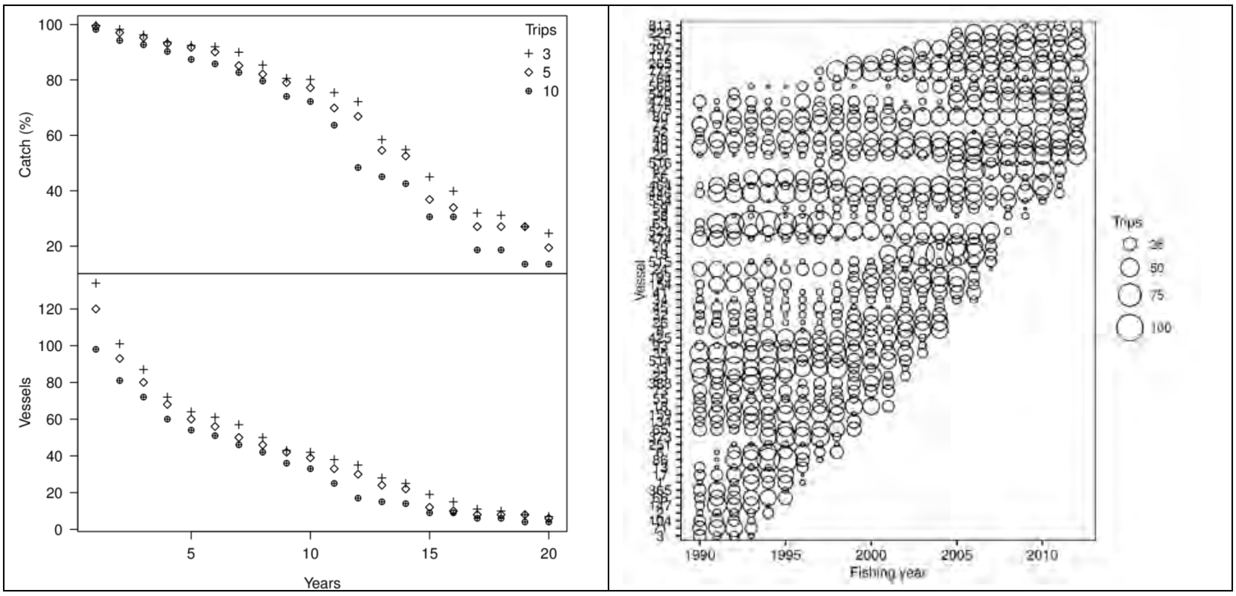


Figure J.2: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 1E_BT dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 5 trips in 4 or more fishing years).

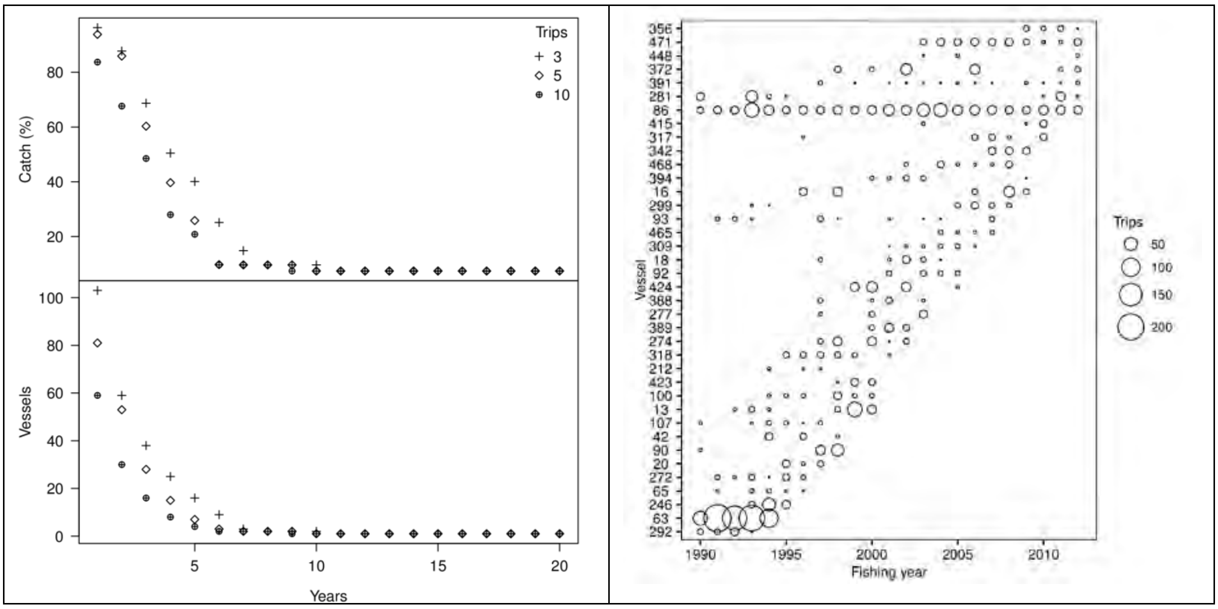


Figure J.3: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 1E_SN(COAST) dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 3 trips in 3 or more fishing years).

J.2 Data summaries

Table J.1: Number of vessels, trips, trip strata, events, sum of catch (t), sum of net length (km) (or tows for SPO 1E_BT) and sum of hours fishing for core vessels in the three CPUE analyses by fishing year.

	SPO 1E_SN(007)							SPO 1E_BT							SPO 1E_SN(COAST)						
Fishing year	Vessel	Trips	Events	Catch	Net length	Hours	% zero	Vessel	Trips	Events	Catch	Tows	Hours	% zero	Vessel	Trips	Events	Catch	Net length	Hours	% zero
1990	8	83	85	4.6	94.4	703	94.0	41	805	2 688	33.8	8 949	22 220	60.7	7	115	118	10.9	181.4	1 273	75.7
1991	12	290	304	33.9	352.3	3 136	95.9	45	1 060	3 359	42.5	11 145	29 726	44.6	6	265	273	17.0	487.1	2 762	55.6
1992	10	255	295	52.6	448.3	3 146	98.8	49	1 235	3 812	50.4	12 395	35 961	49.4	10	233	252	25.6	401.3	2 435	82.0
1993	13	376	443	75.3	694.9	5 205	99.5	50	1 218	3 591	36.6	11 419	33 130	53.3	12	350	387	47.2	988.2	4 231	78.3
1994	15	322	349	44.3	532.9	4 080	98.8	47	1 221	4 212	26.2	10 769	30 613	53.6	12	233	325	48.5	1 271.4	3 692	90.3
1995	15	273	306	57.1	445.5	2 874	98.9	42	1 070	4 285	19.4	8 604	23 201	57.5	9	104	189	25.9	536.8	1 875	95.7
1996	15	308	378	64.9	654.9	5 308	96.1	43	918	6 814	17.5	7 888	21 218	52.5	12	97	152	16.8	254.3	1 915	96.9
1997	11	294	342	56.4	536.2	3 553	98.3	44	1 016	7 564	13.5	8 590	20 176	54.2	15	132	173	20.5	254.7	2 296	93.2
1998	12	300	331	54.3	529.8	3 194	99.0	43	977	9 287	16.4	9 989	24 320	55.6	13	185	272	23.9	455.2	3 727	90.9
1999	16	378	398	66.7	689.7	4 088	96.6	40	975	9 163	21.0	10 307	27 283	65.5	7	145	247	18.4	393.4	3 460	97.4
2000	17	478	490	73.9	825.6	5 373	97.3	38	964	8 518	25.3	10 213	27 670	66.3	14	173	256	22.1	458.6	3 331	98.3
2001	12	328	356	60.2	580.6	3 730	99.4	39	931	8 540	18.7	9 427	26 119	64.4	13	108	125	10.2	158.3	1 590	96.3
2002	14	414	469	101.2	859.3	5 038	98.8	37	949	7 988	19.9	9 062	25 539	63.6	11	162	180	25.0	318.2	2 337	76.7
2003	20	496	544	84.4	1 115.5	6 314	97.8	33	916	7 541	16.4	8 431	22 622	63.0	12	131	185	19.9	284.6	2 408	94.7
2004	17	402	472	65.0	886.5	5 231	98.5	33	940	7 897	16.0	9 145	24 776	57.8	10	116	164	15.1	171.2	2 070	96.6
2005	14	355	374	61.0	774.6	3 654	100.0	32	1 010	8 132	20.9	10 588	30 612	60.8	10	91	125	13.3	168.7	1 726	97.8
2006	14	271	281	51.2	468.5	2 814	96.7	33	1 011	7 512	21.5	10 000	28 975	61.7	14	136	159	10.3	241.3	2 230	72.8
2007	10	238	239	38.7	364.7	2 124	99.2	27	794	6 684	21.6	8 810	23 616	61.0	9	104	136	12.4	194.8	1 873	97.1
2008	12	165	177	32.7	325.5	1 738	99.4	24	718	7 477	23.7	7 477	22 560	62.7	9	122	222	18.8	373.1	2 842	99.2
2009	11	188	206	47.0	351.1	2 154	98.9	24	704	8 240	23.0	8 243	24 263	59.9	9	81	131	11.0	225.2	1 903	96.5
2010	9	220	244	38.3	433.9	2 843	99.6	22	753	8 066	30.0	8 066	24 097	54.9	7	75	81	9.0	109.0	1 160	93.3
2011	12	235	268	29.9	368.7	3 104	97.5	22	668	7 798	19.6	7 798	21 597	53.6	6	75	85	4.0	68.8	1 363	89.3
2012	7	206	225	43.5	395.0	2 626	100.0	18	625	7 408	16.1	7 408	19 673	57.6	7	65	71	6.7	68.3	878	87.9

J.3 Diagnostic plots

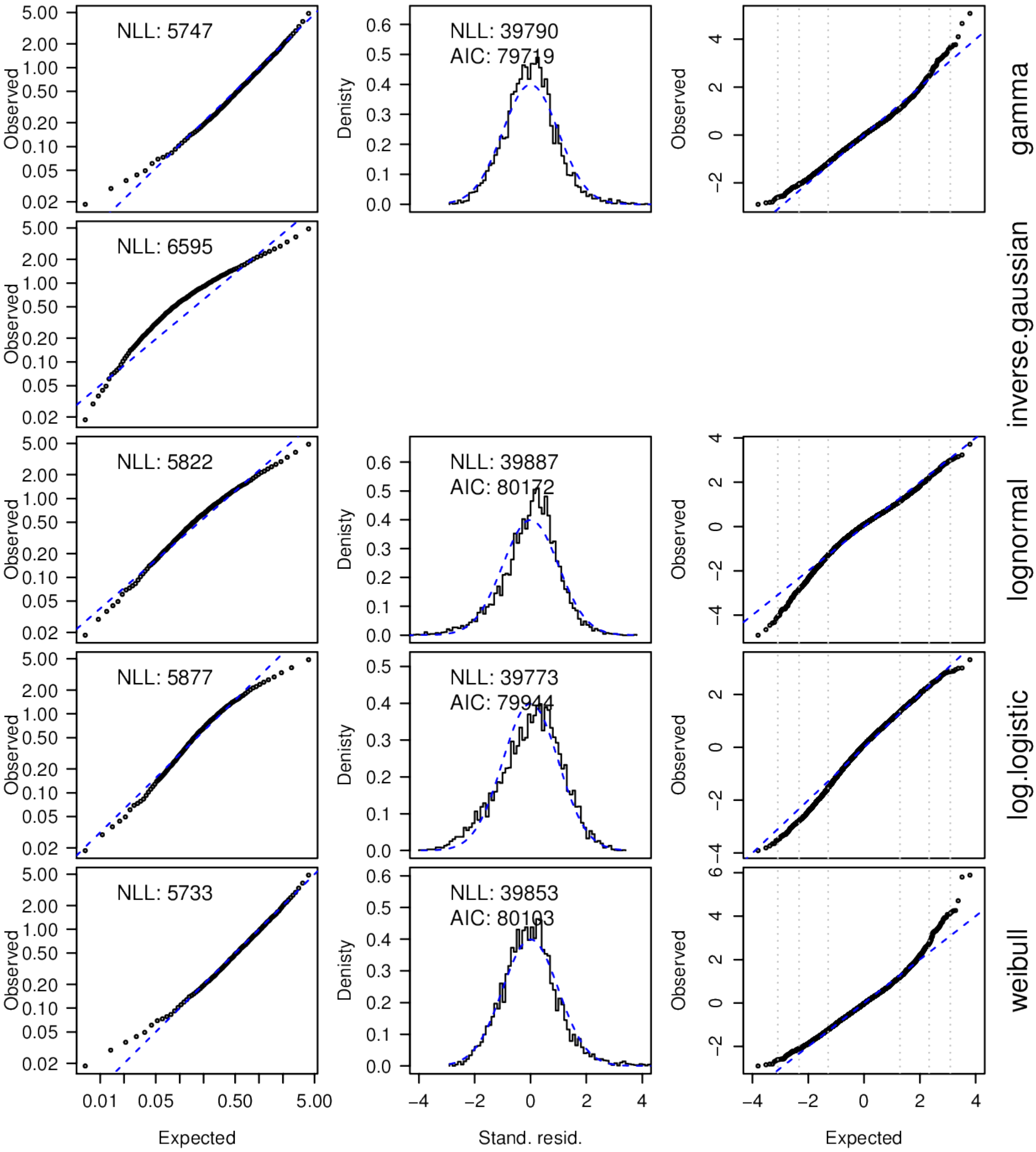


Figure J.4: Diagnostics for alternative distributional assumptions for catch in the SPO 1E_SN(007) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + target +netlength and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

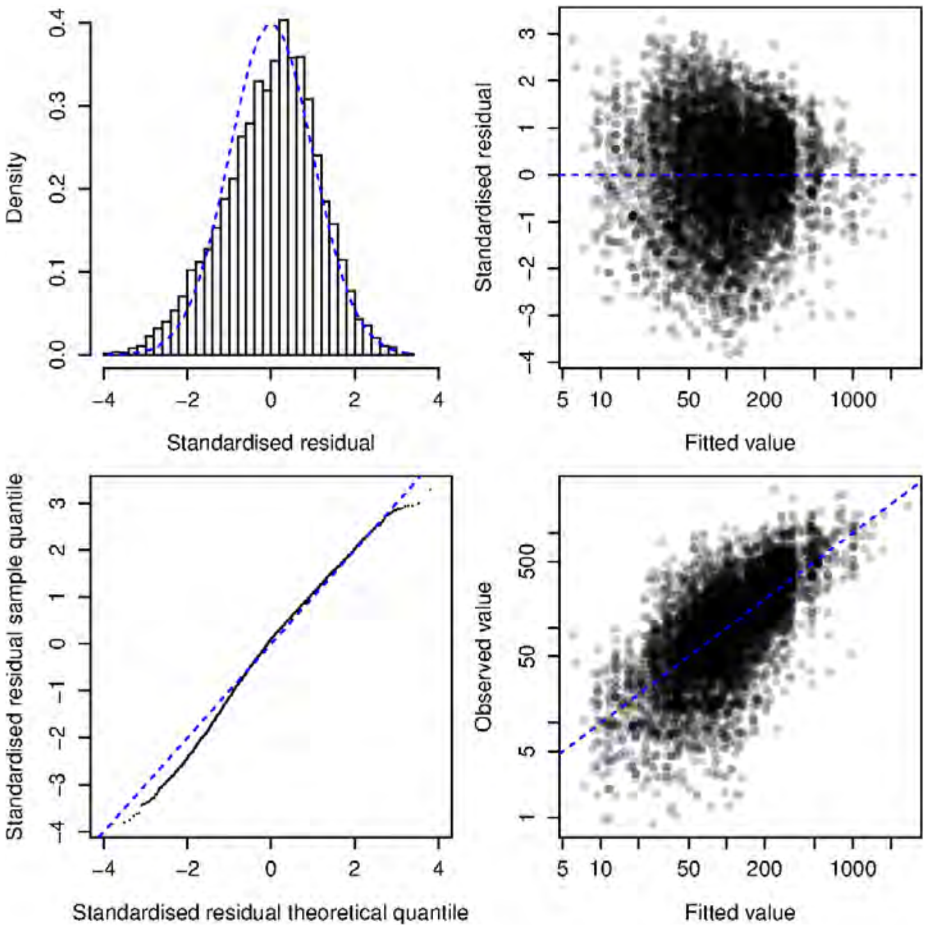


Figure J.5: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 1E_SN(007) fishery. [Upper left] histogram of the standardised residuals compared to a log logistic distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

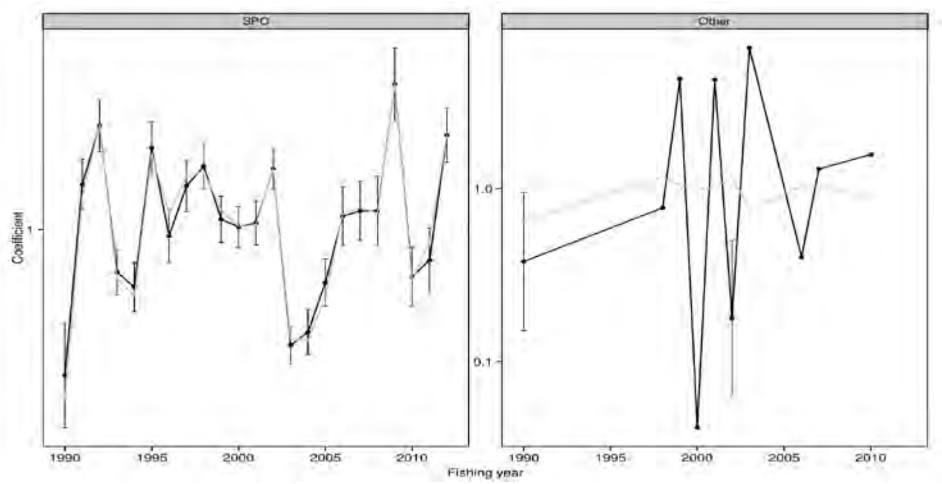


Figure J.6: Residual implied coefficients for each target species in each fishing year in the SPO 1E_SN(007) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

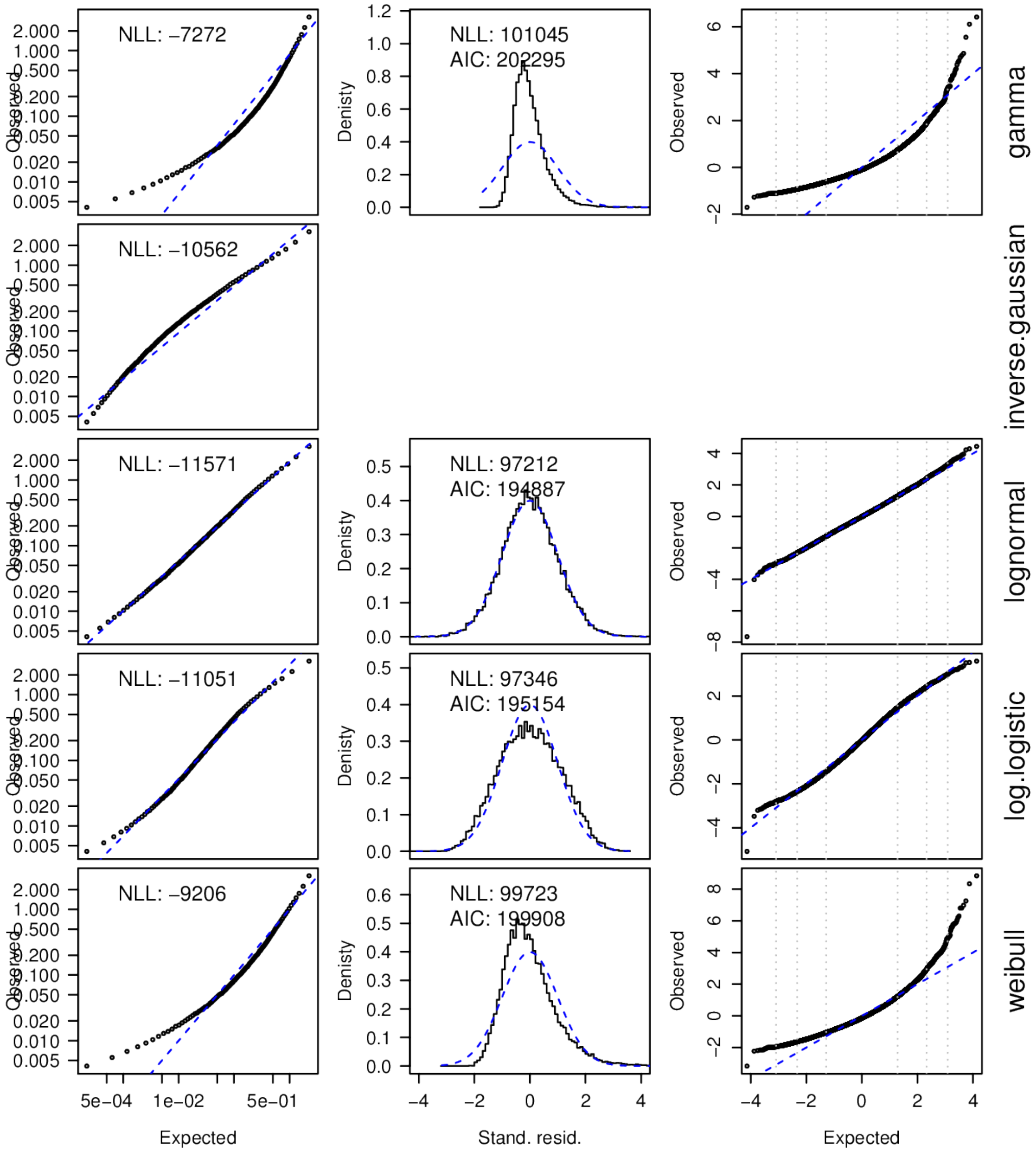


Figure J.7: Diagnostics for alternative distributional assumptions for catch in the SPO 1E_BT fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + num and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

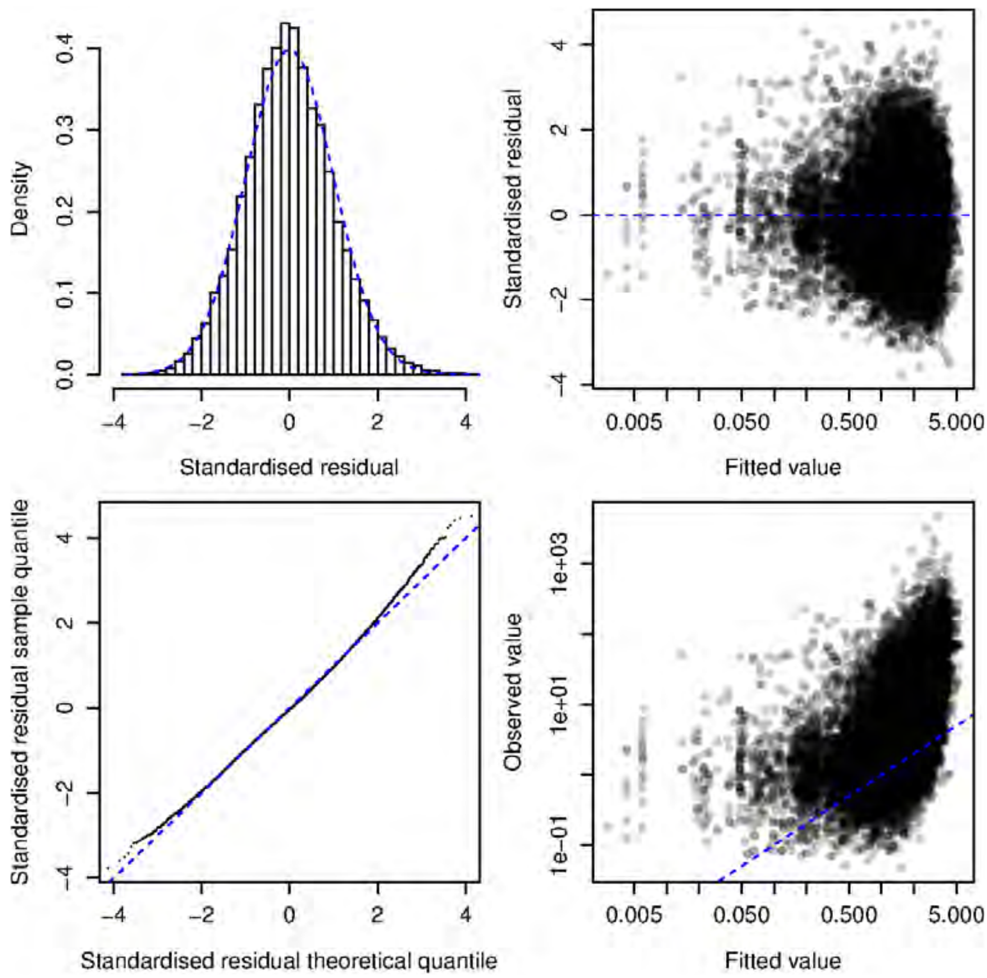


Figure J.8: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 1E_BT fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

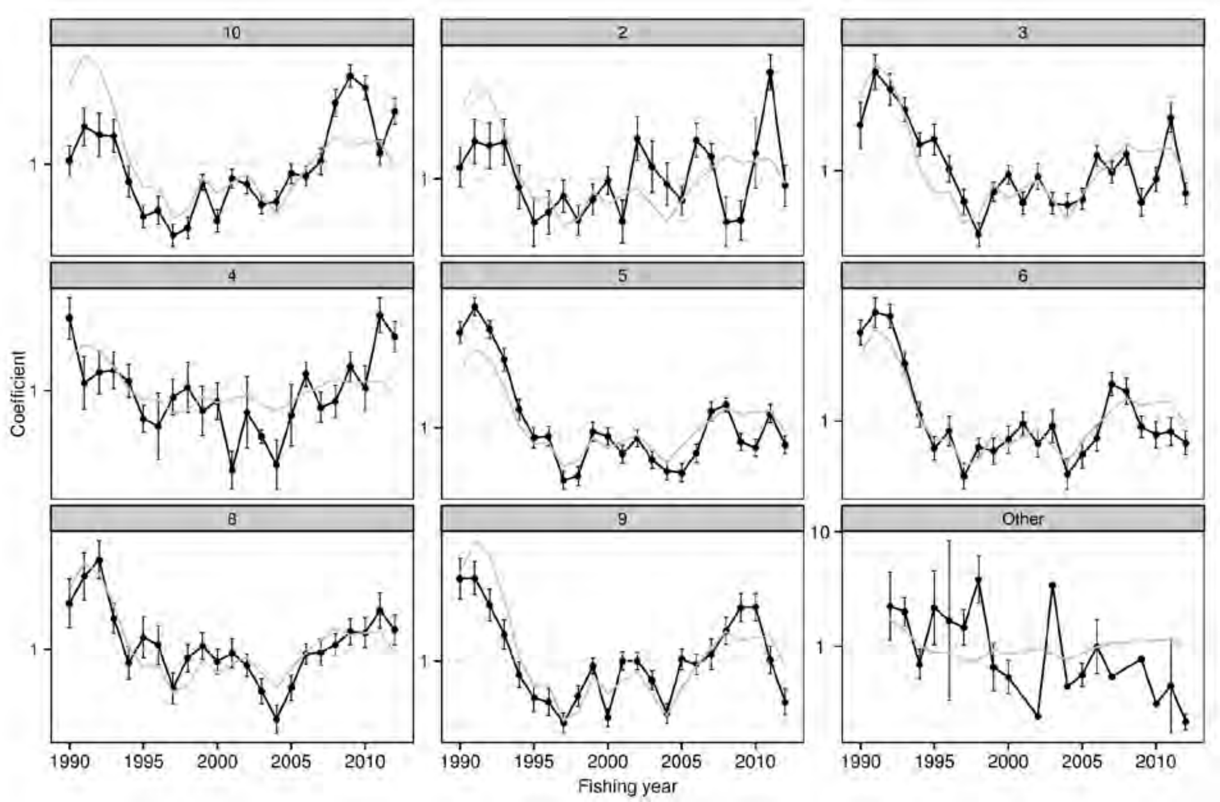


Figure J.9: Residual implied coefficients for each area in each fishing year in the SPO 1E_BT fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

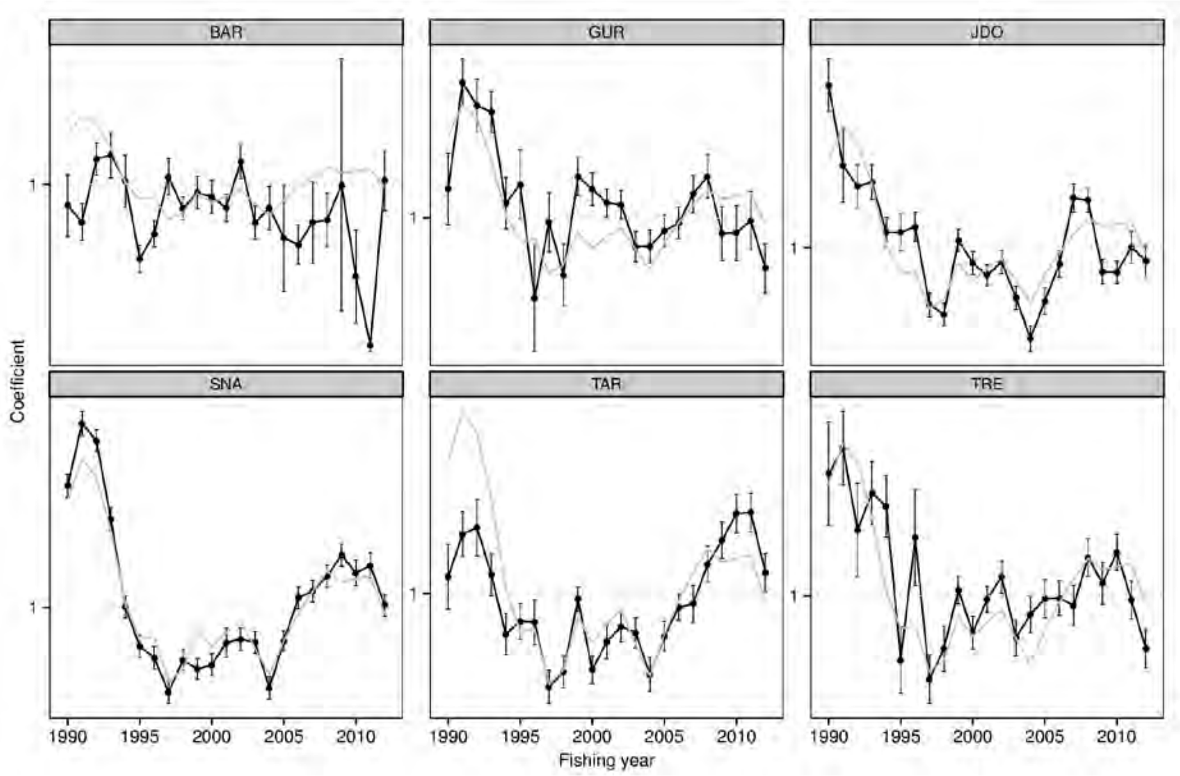


Figure J.10: Residual implied coefficients for each target species in each fishing year in the SPO 1E_BT fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

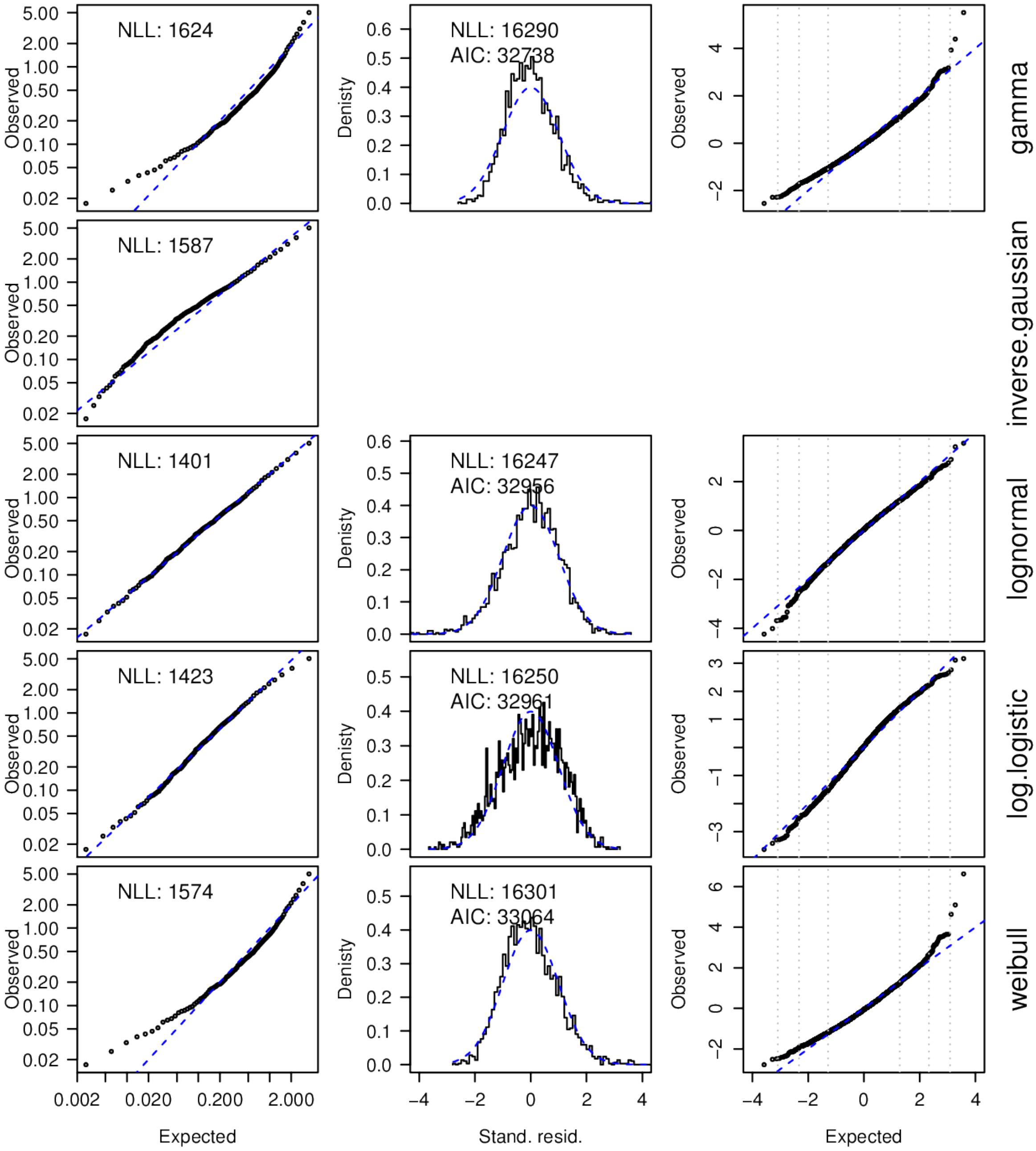


Figure J.11: Diagnostics for alternative distributional assumptions for catch in the SPO 1E_SN(COAST) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + target + netlength and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

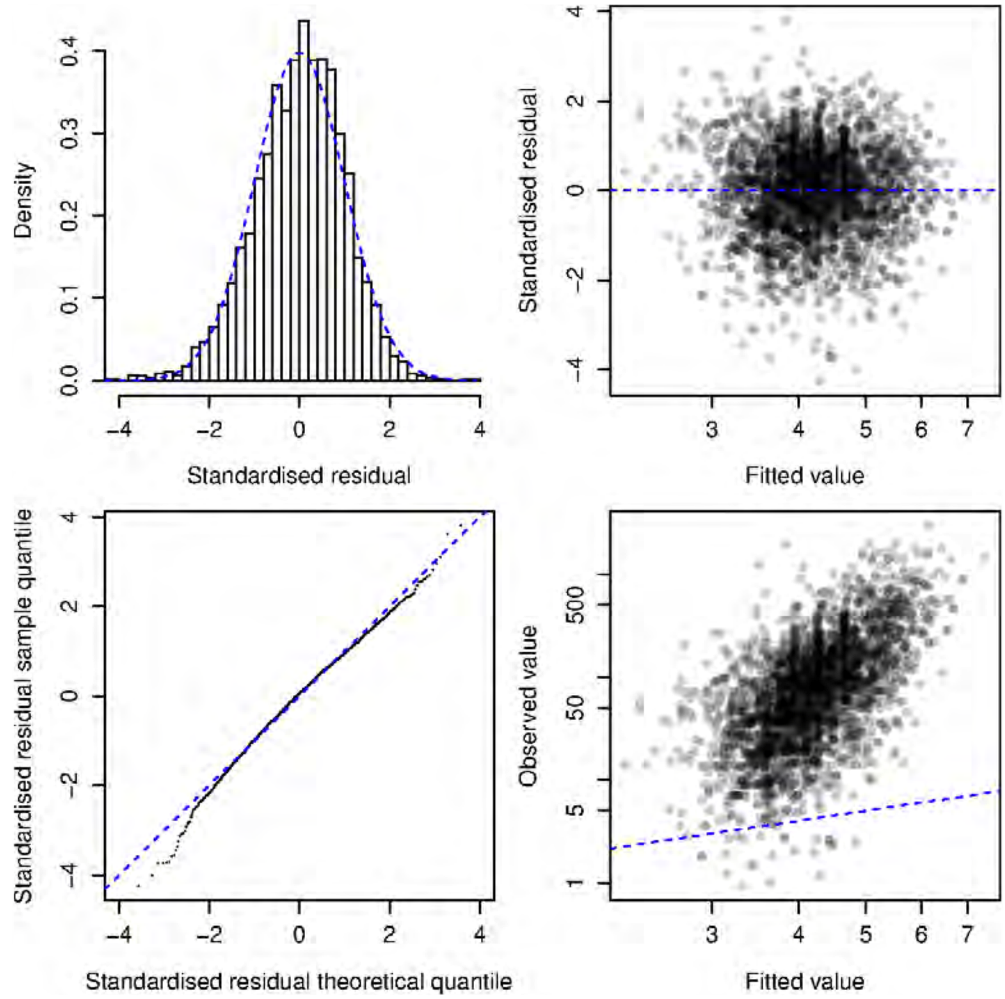


Figure J.12: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 1E_SN(COAST) fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

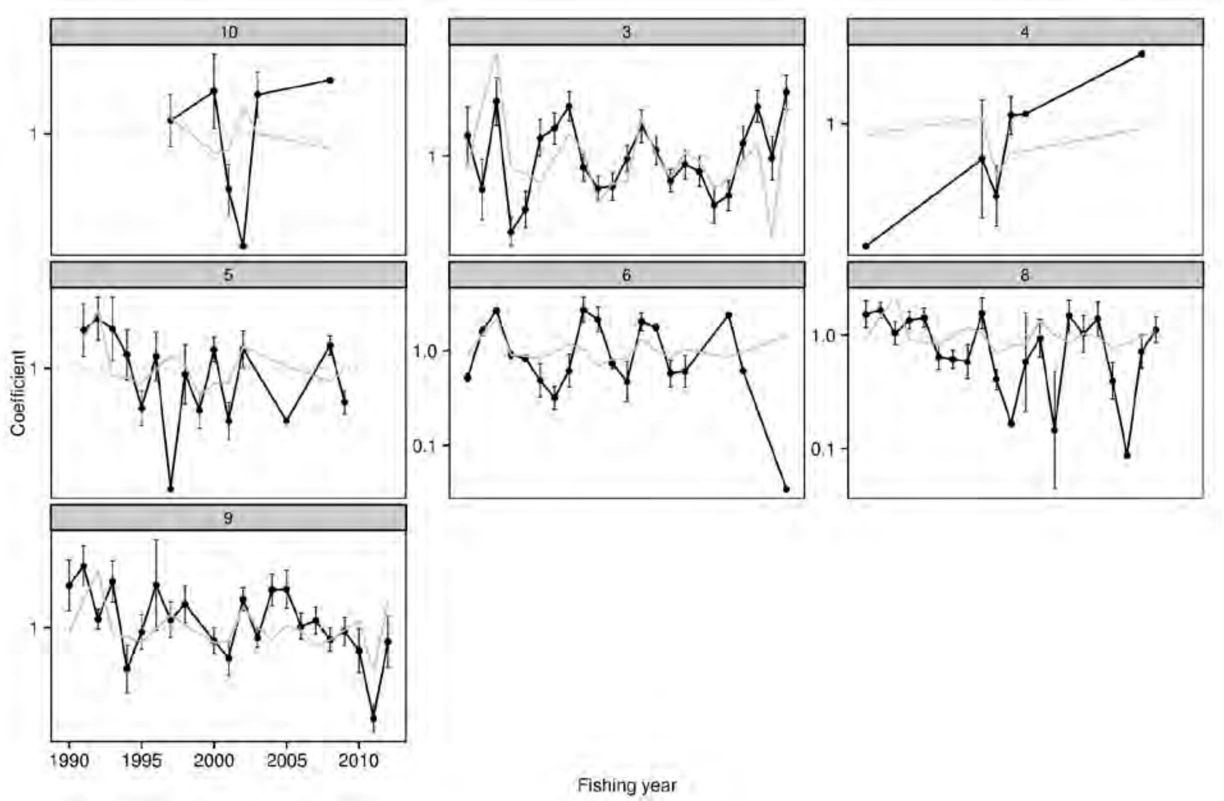


Figure J.13: Residual implied coefficients for each area in each fishing year in the SPO 1E_SN(COAST) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

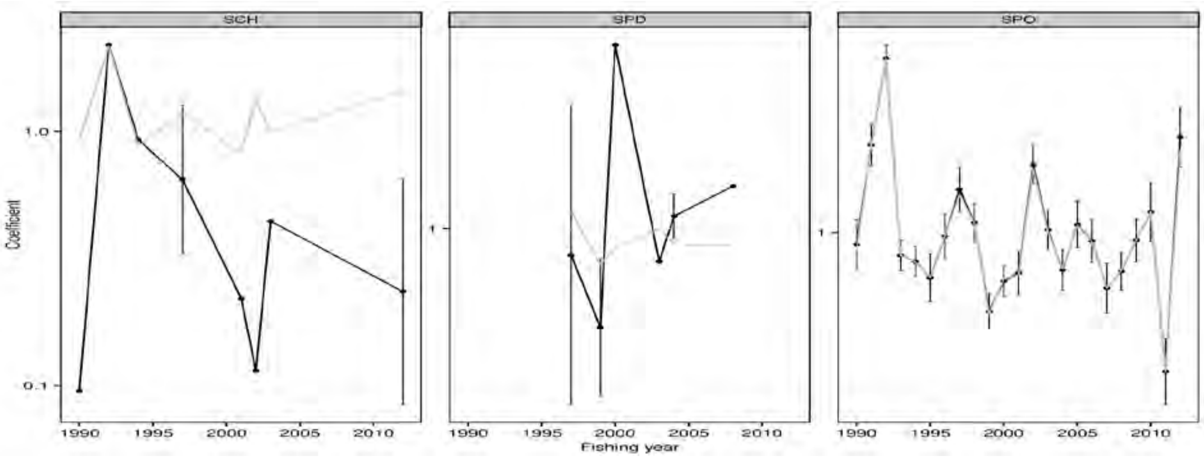


Figure J.14: Residual implied coefficients for each target species in each fishing year in the SPO 1E_SN(COAST) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

J.4 Model coefficients

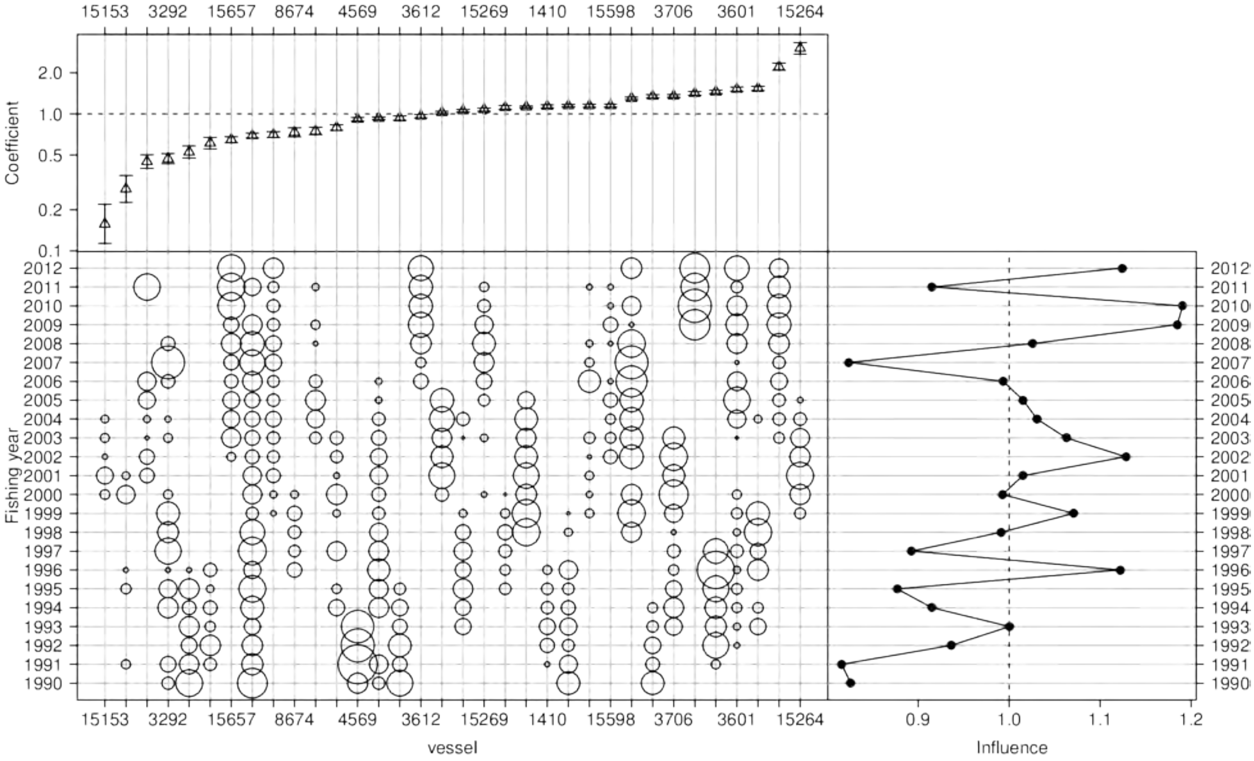


Figure J.15: Effect of vessel **in the log logistic model for the SPO 1E_SN(007) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

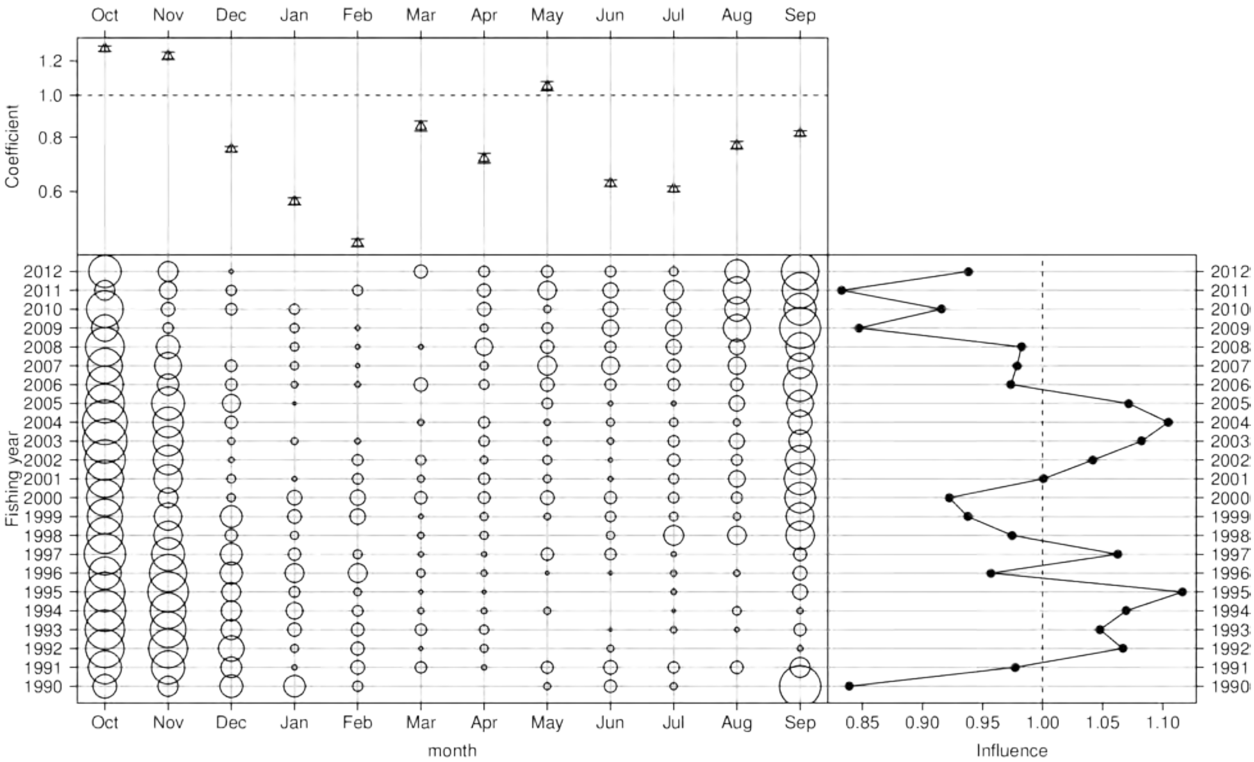


Figure J.16: Effect of month **in the log logistic model for the SPO 1E_SN(007) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

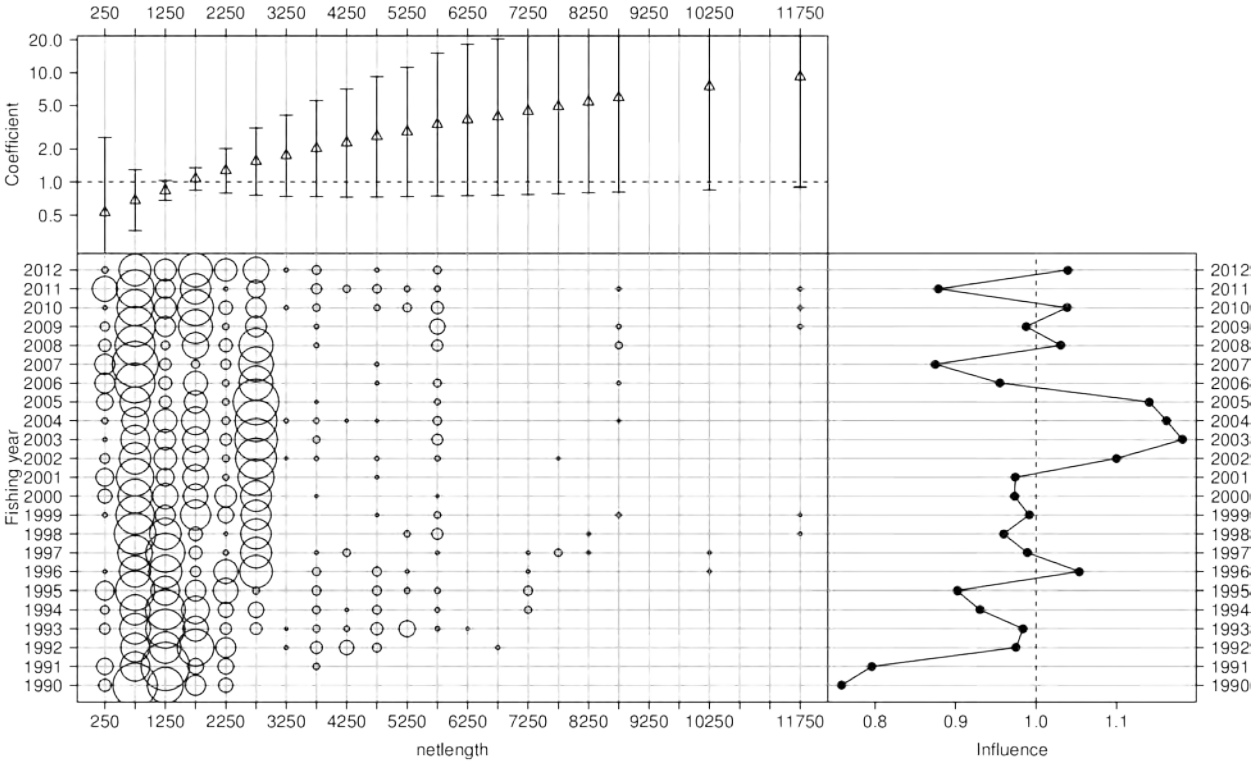


Figure J.17: Effect of netlength **in the log logistic model for the SPO 1E_SN(007) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

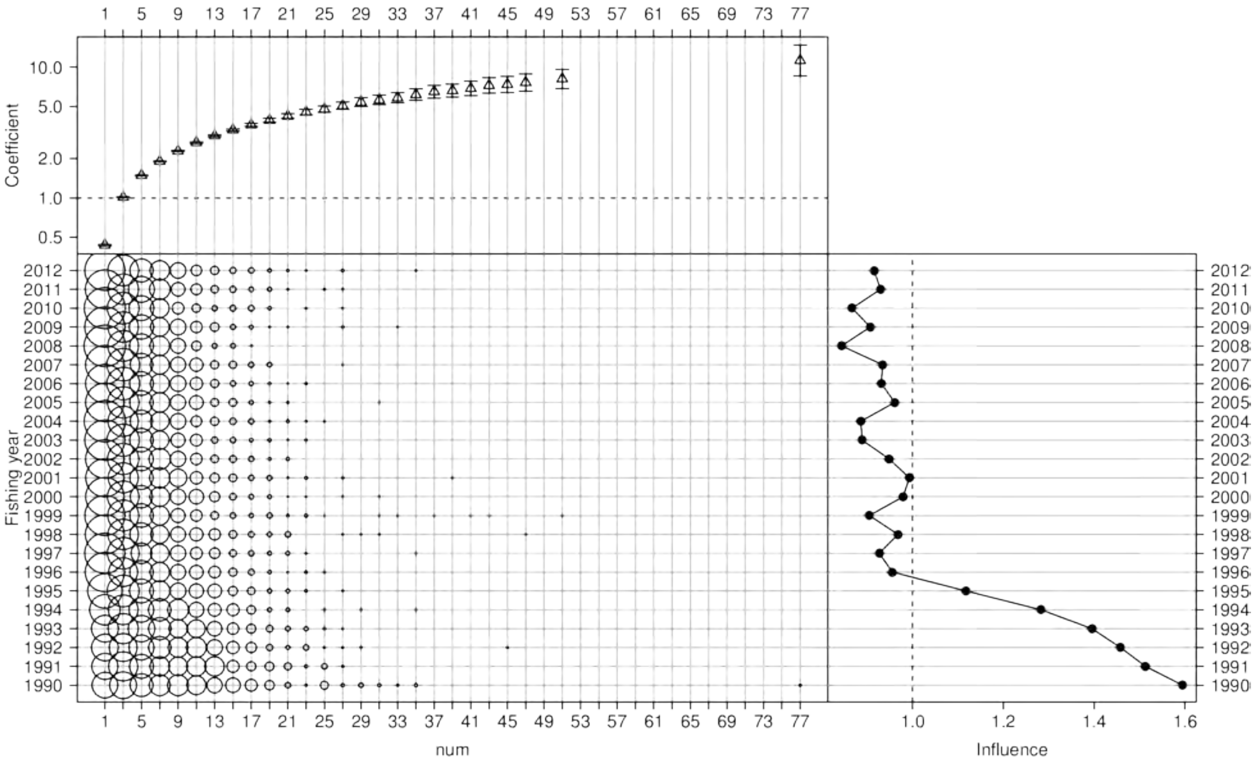


Figure J.18: Effect of number of tows **in the lognormal model for the SPO 1E_BT fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

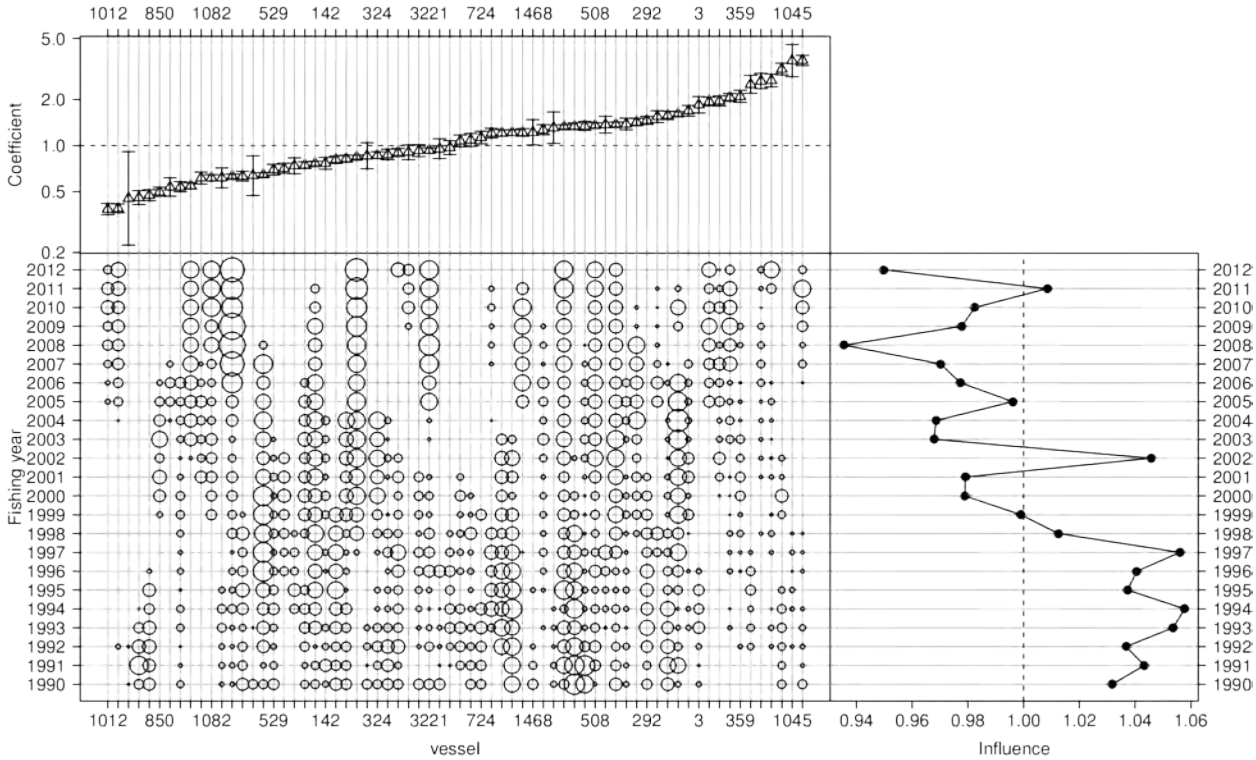


Figure J.19: Effect of vessel **in the lognormal model for the SPO 1E_BT fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

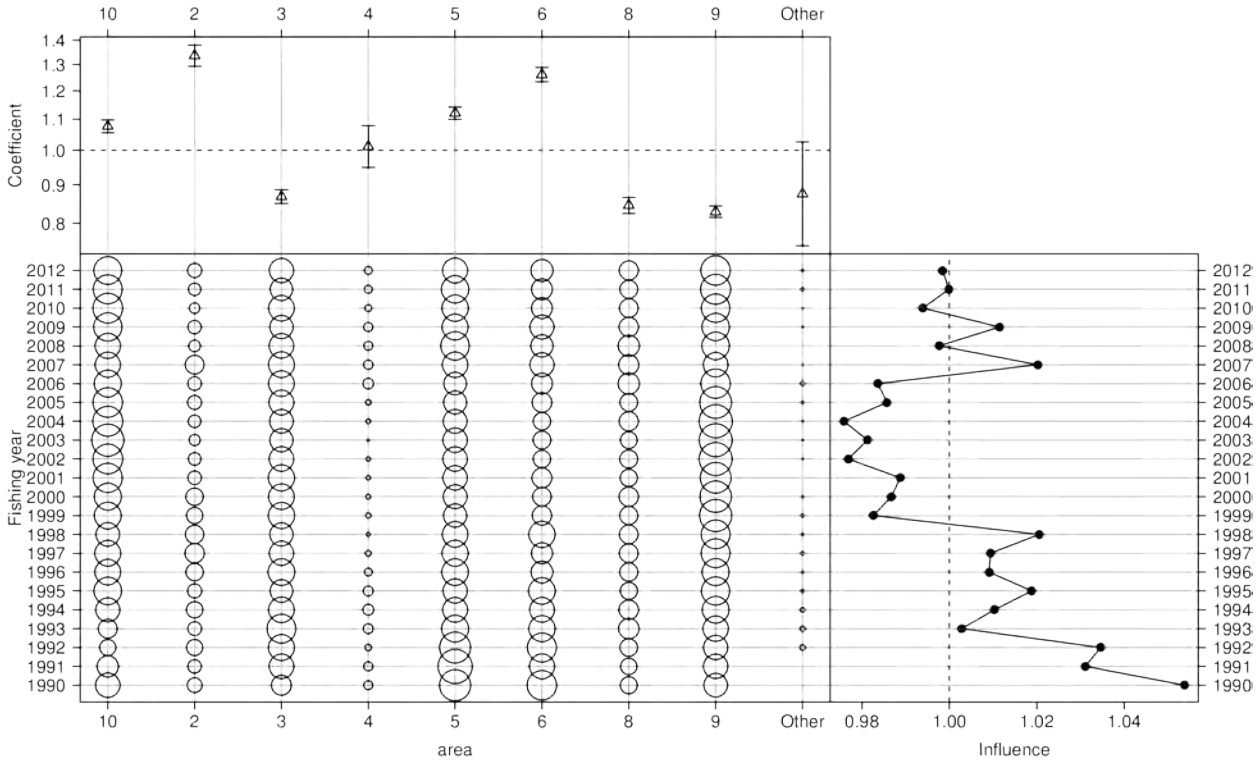


Figure J.20: Effect of area **in the lognormal model for the SPO 1E_BT fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

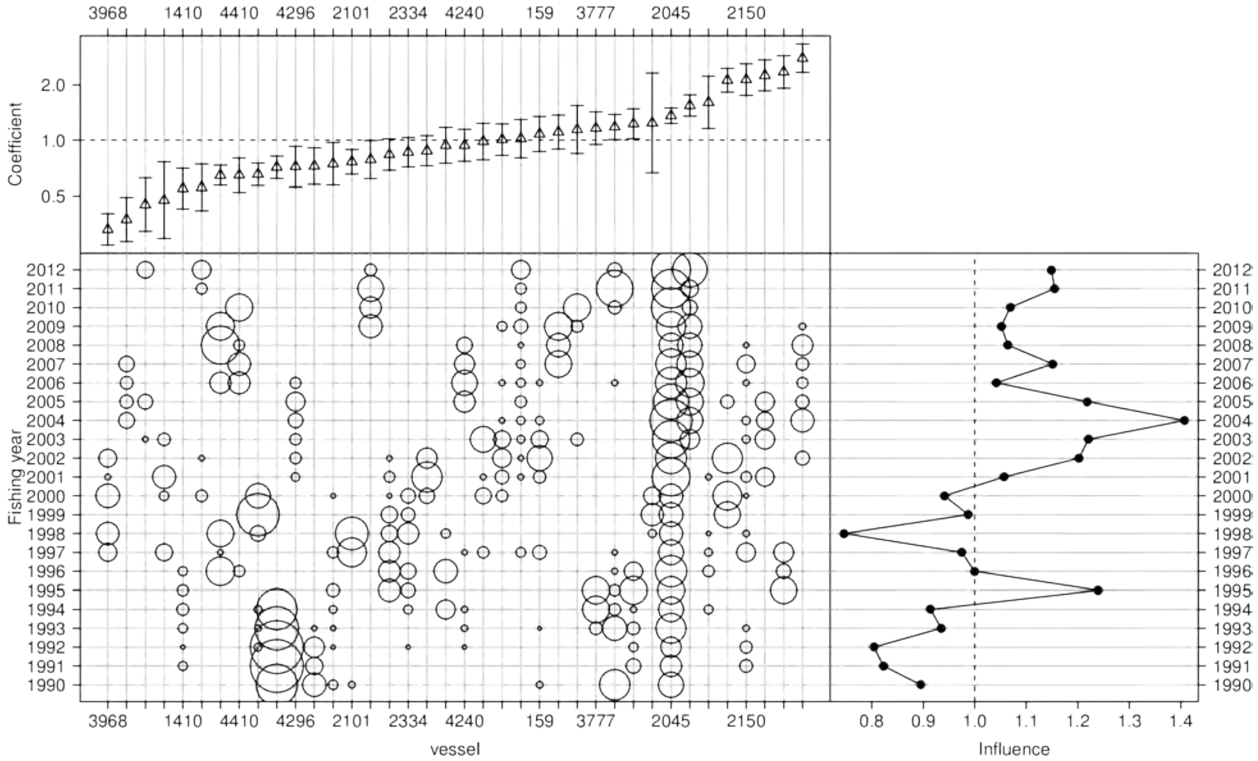


Figure J.21: Effect of vessel **in the lognormal model for the SPO 1E_SN(COAST) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

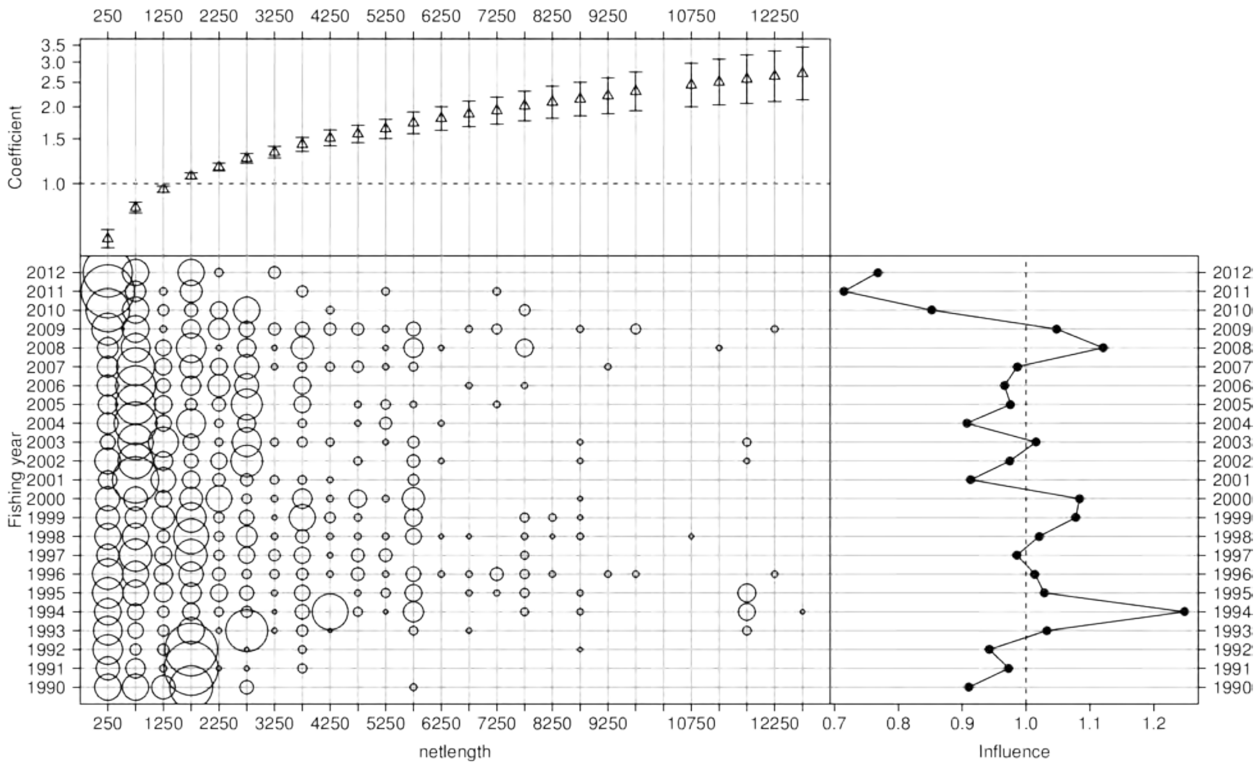


Figure J.22: Effect of netlength **in the lognormal model for the SPO 1E_SN(COAST) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

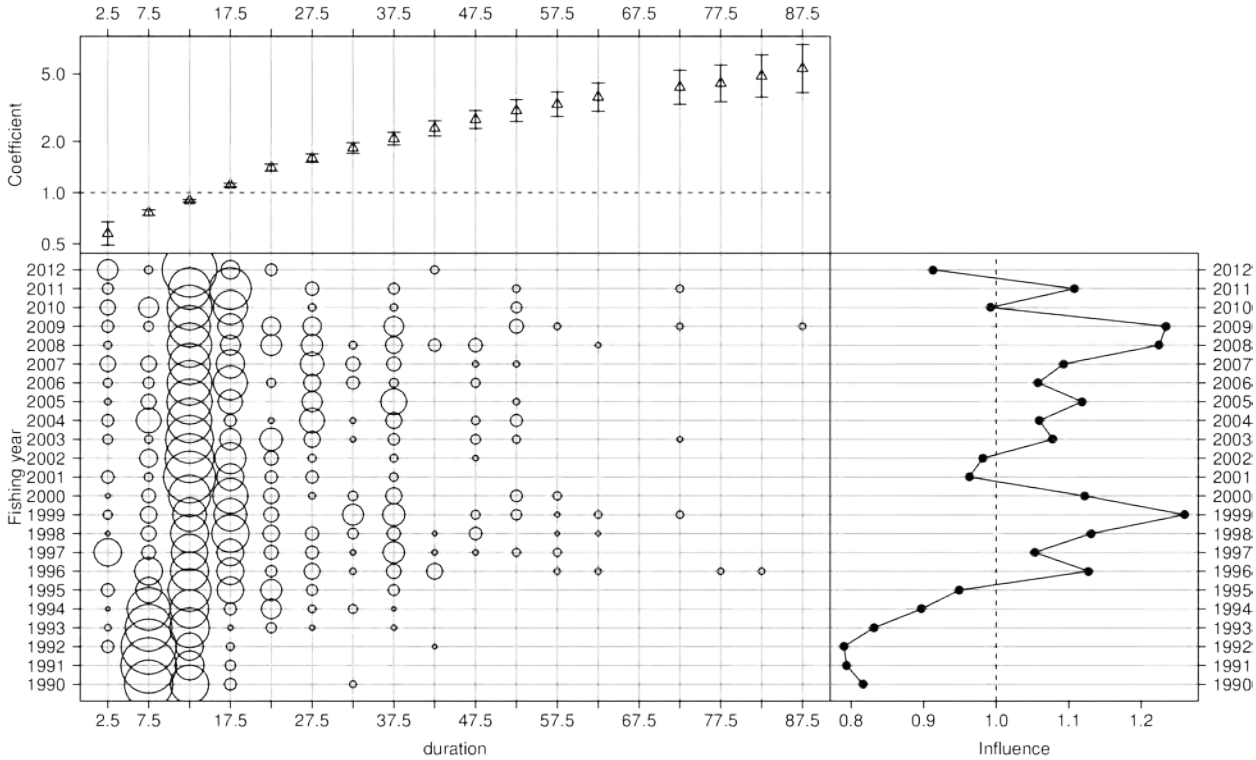


Figure J.23: Effect of duration **in the lognormal model for the SPO 1E_SN(COAST) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

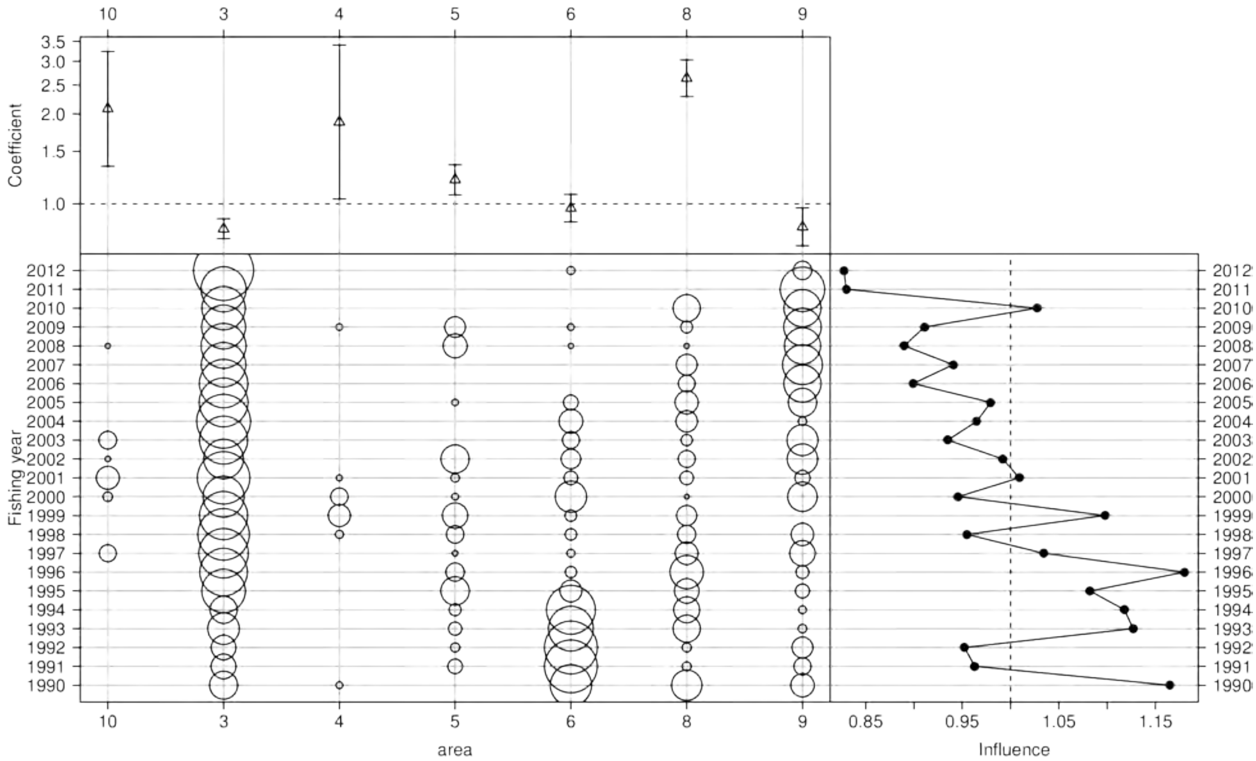


Figure J.24: Effect of area **in the lognormal model for the SPO 1E_SN(COAST) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

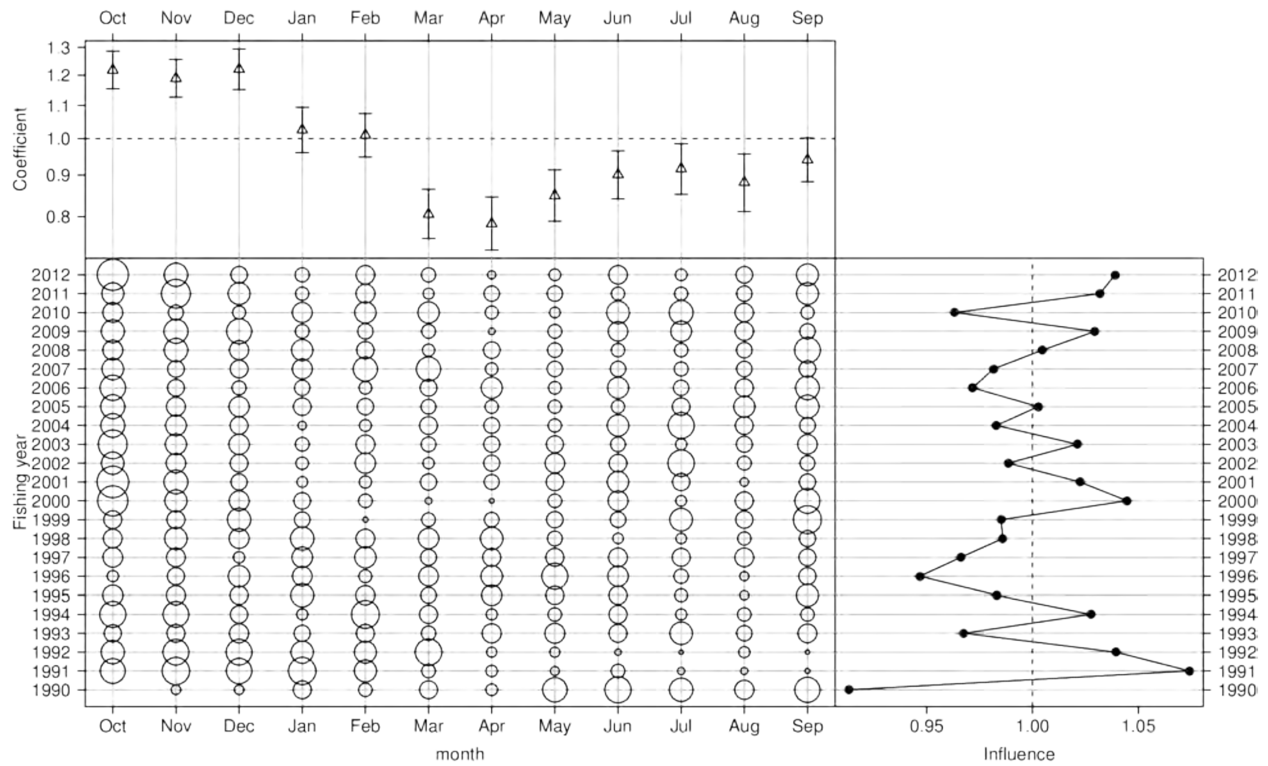


Figure J.25: Effect of month **in the lognormal model for the SPO 1E_SN(COAST) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

J.5 CPUE indices

Table J.2: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error for the core data set by fishing year for each of the three CPUE models.

	SPO 1E_SN(007)					SPO 1E_BT					SPO 1E_SN(COAST)				
Fishing	All	Core vessel indices				All	Core vessel indices				All	Core vessel indices			
Year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Arithmetic	Arithmetic	Geometric	Standardised	SE	Arithmetic	Arithmetic	Geometric	Standardised	SE
1990	0.8691	0.4886	0.5269	0.6411	0.10039	1.5225	1.5423	1.4912	1.5111	0.04705	0.9977	1.0270	0.7714	0.9410	0.12345
1991	1.1833	0.9580	0.9785	1.0776	0.06078	1.3222	1.3614	1.7662	1.7808	0.04598	0.5084	0.5467	0.9451	1.5020	0.10316
1992	1.4740	1.1659	1.2835	1.2931	0.06379	1.3485	1.4409	1.6499	1.6562	0.04006	1.3419	1.0057	1.3743	2.2067	0.09819
1993	1.1386	0.9440	0.9592	0.8747	0.05385	1.1648	1.1853	1.3230	1.3322	0.03911	0.8142	0.8594	0.6820	0.9181	0.08206
1994	0.9064	0.8320	0.8580	0.8357	0.05181	0.9549	0.9635	1.0081	0.9874	0.03856	0.7718	0.7760	0.5632	0.8930	0.09376
1995	1.2339	1.3469	1.3235	1.2029	0.05531	0.9446	0.9520	0.8852	0.8552	0.03929	1.0207	1.1292	0.9371	0.8333	0.11777
1996	1.0238	1.0067	1.0016	1.0308	0.05691	0.9250	0.8670	0.9091	0.8640	0.03922	0.9613	1.1852	1.1857	1.0040	0.11126
1997	0.9682	1.0265	1.0389	1.1352	0.05301	0.7233	0.6931	0.7761	0.7194	0.03712	1.1986	1.2883	1.1596	1.2057	0.10202
1998	1.0105	0.9925	1.1489	1.1488	0.05195	0.6369	0.6618	0.7811	0.7544	0.03467	0.9204	0.8766	0.7552	1.0616	0.09281
1999	0.9633	1.0142	1.0202	1.0400	0.04779	0.8550	0.8299	0.8957	0.8991	0.03092	0.8918	0.9119	0.7793	0.7086	0.10986
2000	0.9188	0.9484	0.9083	0.9980	0.04456	0.8601	0.8872	0.8016	0.8272	0.03212	0.7829	0.8181	0.7018	0.8287	0.09688
2001	1.0162	1.1302	1.0616	1.0026	0.05057	0.8881	0.8639	0.8497	0.8783	0.03337	0.8537	0.8830	0.9272	0.8410	0.11224
2002	1.3395	1.3412	1.3055	1.1577	0.04457	0.9571	0.9643	0.9488	0.9204	0.03323	1.1053	1.0781	1.5019	1.3532	0.10379
2003	0.7058	0.7254	0.7917	0.7479	0.04122	0.8077	0.7856	0.7984	0.8218	0.03346	1.2278	1.0316	1.1381	1.0206	0.10242
2004	0.7196	0.8397	0.8191	0.7475	0.04613	0.7603	0.7453	0.7120	0.7388	0.03393	1.2740	1.1690	1.3122	0.8666	0.10381
2005	0.8320	0.9319	0.9169	0.8337	0.04916	0.7825	0.8004	0.8414	0.8497	0.03247	1.1568	1.2484	1.3289	1.0499	0.11548
2006	1.0085	1.1178	1.0611	1.0305	0.05721	0.9739	0.9202	0.9234	0.9478	0.03248	0.7008	0.6073	0.9019	0.9766	0.10925
2007	1.0628	1.1853	0.9466	1.0468	0.05977	1.0745	1.1029	1.0403	1.0398	0.03505	1.0157	0.9088	0.8581	0.7949	0.11138
2008	0.9362	1.0073	1.0716	1.0336	0.06800	1.3286	1.3616	1.0852	1.1286	0.03486	1.0229	1.0203	0.7724	0.8601	0.10348
2009	1.5498	1.7135	1.4674	1.4379	0.07085	1.1892	1.2156	1.0849	1.0786	0.03545	1.0375	1.0827	1.0512	0.9830	0.11987
2010	0.8445	0.9009	0.9433	0.8680	0.06566	1.4932	1.5047	1.0982	1.0934	0.036	1.4194	1.4799	1.4324	1.1155	0.13503
2011	0.7080	0.7767	0.7904	0.9603	0.06497	1.1396	1.1313	1.1304	1.1055	0.03807	0.9569	0.9663	1.0151	0.5481	0.13892
2012	1.0927	1.2753	1.2909	1.2620	0.06378	0.9738	0.9302	0.9100	0.9456	0.03813	1.7655	1.8846	1.9337	1.4662	0.13639

Appendix K. CPUE ANALYSES FOR KAIPARA AND MANUKAU HARBOURS AND WEST COAST NORTH ISLAND (SPO 1W)

K.1 General overview

Indices from this study for setnet in Statistical Areas 043 (Manukau Harbour) and 044 (Kaipara Harbour) were accepted with a Science Information Quality Rank=1 by the Southern Inshore Working Group in recognition of the considerable data associated with these series and the nature of the target fishery, and indices from the more disparate coastal setnet and bottom trawl fisheries were rejected with a Science Information Quality Rank=3 due to very limited quantity of data in these analyses.

K.2 Methods

K.2.1 Fishery definitions for CPUE analysis

Rig around the coast of New Zealand may comprise a single stock, but natural geographical boundaries have traditionally subdivided SPO 1 into three areas: west coast North Island, East Northland and Bay of Plenty.

Fisheries for rig, particularly the setnet fisheries, are often artisanal; based on small vessels that have a high fidelity to locales and harbours, and monitoring is considered more appropriate at the spatial scale of those fisheries. This appendix details four standardised analyses for rig from SPO 1W; two discrete setnet fisheries operating in the Kaipara and Manukau Harbours, and more extensive setnet and bottom trawl fisheries operating along the wider west Northland and Waikato coasts. The harbour fisheries are focused on spring spawning aggregations and therefore on adult fish. The coastal fishery operates on a more dispersed population and the trawl fisheries are considered likely to be selective for smaller rig as larger rig (generally over 1 m) are able to avoid the trawl net.

SPO 1W_SN(043) – Shark setnet in Manukau Harbour – The Fishery is defined from setnet fishing events which fished in Statistical Area 043, and targeted SPO, SCH, SPD, or NSD. This definition potentially allows the use of total effort in the analysis of catch rates, however only the analysis of positive catches is presented in detail.

SPO 1W_SN(044) – Shark setnet in Kaipara Harbour – The Fishery is defined from setnet fishing events which fished in Statistical Area 044, and targeted SPO, SCH, SPD, or NSD. This definition potentially allows the use of total effort in the analysis of catch rates, however only the analysis of positive catches is presented in detail.

SPO 1W_SN(COAST)– Shark setnet in northwest coastal areas – The Fishery is defined from setnet fishing events which fished in Statistical Areas 042, 045, 046, and 047 and targeted SPO, SCH, SPD, or NSD. This definition potentially allows the use of total effort in the analysis of catch rates, however only the analysis of positive catches is presented in detail.

SPO 1W_BT – Mixed target bottom trawl in SPO 1W - The Fishery is defined from single bottom trawl fishing events which fished in Statistical Areas 042, 045, 046, 047 and 048 and targeted SNA, TRE, GUR, JDO, BAR, TAR. This definition potentially allows the use of total effort in the analysis of catch rates, however only the analysis of positive catches is presented in detail.

K.2.2 Unstandardised CPUE

K.2.3 SPO 1W_SN(043): Shark setnet in Manukau Harbour

Effort in the set fishery in the Manukau harbour (Area 043) peaked in 2000–01 at more than 450 trips and has declined since then to nearer 100 in 2011–12. Catch rates were initially about 180 kg per set but have been relatively stable at about half that rate since the late 1990s (Figure K.1). The fishery is effectively a target fishery with few (less than 5%) observations of zero rig catches (Figure K.2), and amalgamation of the data to trip stratum had little effect with about 1.2 original records being combined on average into an effort stratum (Figure K.2). This is consistent with a fishery that is almost entirely reported at daily resolution on CELR forms and which generally fishes in only one statistical area on any one day.

Figure K.1: Number of qualifying trips in SPO 1W_SN(043) (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/set, black line) of rig in successful trip-strata, by fishing year.

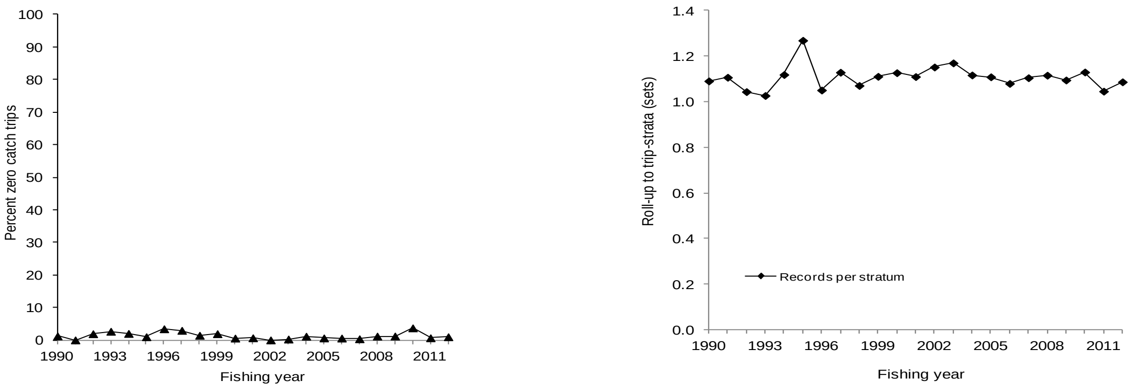


Figure K.2: The proportion of qualifying trips in SPO 1W_SN(043), that landed zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of sets per trip-stratum, by fishing year.

K.2.4 SPO 1W_SN(044) Shark setnet in Kaipara Harbour

The history of the setnet fishery in the Kaipara Harbour (Area 044) is similar with effort peaking in 2002–03 at around 450 trips and declining since then to nearer 200 trips done in 2011–12 (Figure K.3). Catch rates have declined steadily from their peak in 1995–96 of more than 250 kg per set, reaching their lowest level in 2007–08 of about 100 kg per set (Figure K.3). The fishery is effectively a target fishery with few (less than 5%) observations of zero rig catches (Figure K.4), and amalgamation of the data to trip stratum had little effect with about 1.2 original records being combined on average into an effort stratum, increasing in the most recent three years to 1.4.

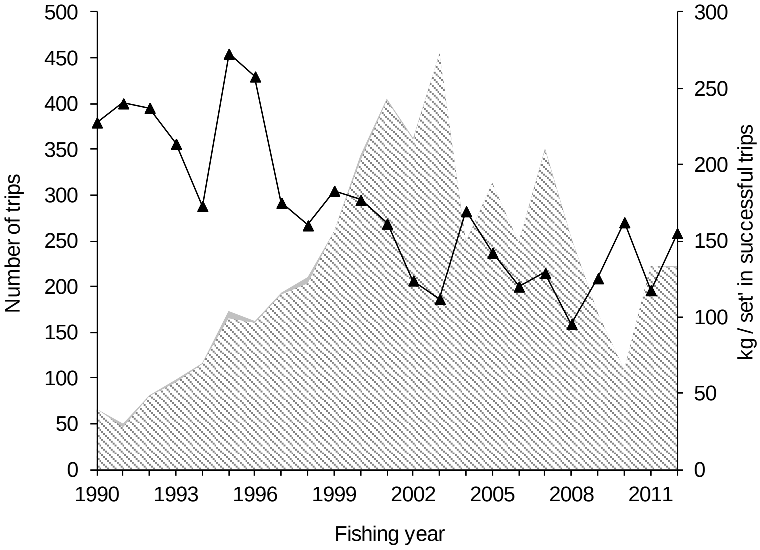
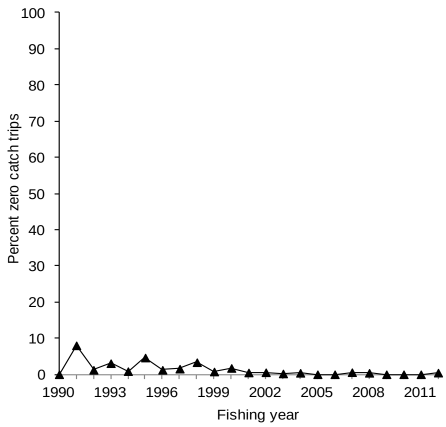


Figure K.3: Number of qualifying trips in SPO 1W_SN(044) (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/set, black line) of rig in successful trip-strata, by fishing year.



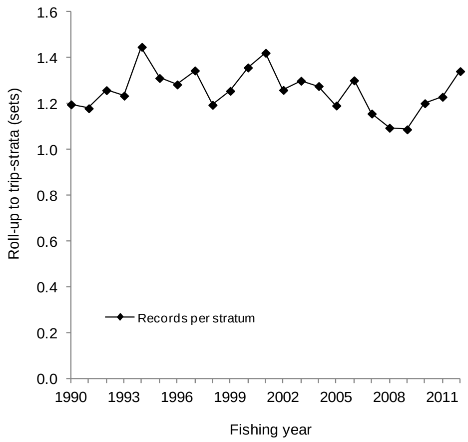


Figure K.4: The proportion of qualifying trips in SPO 1W_SN(044), that landed zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of sets per trip-stratum, by fishing year.

K.2.5 SPO 1W_SN(COAST) Shark setnet in coastal SPO 1W

Effort in the wider coastal setnet fishery has dropped away from its peak in the mid 1990s of more than 450 trips to around 100 trips in 2011–12. Catch rates have a flat trend but have varied between 100 and about 260 kg per set from year to year (Figure K.5). Unsuccessful effort has ranged from zero to more than 10% in some years (Figure K.6). Zero effort is likely to be caused by the inclusion of other target fishing in the dataset. The rollup of data to trip stratum has had an increasing trend, increasing from about 1.1 to nearly 2 original records per stratum in the second half of the 2000s (Figure K.6), perhaps indicating the shift towards targeting other shark species. All indicators highlight inconsistencies in the operation of the fishery over time.

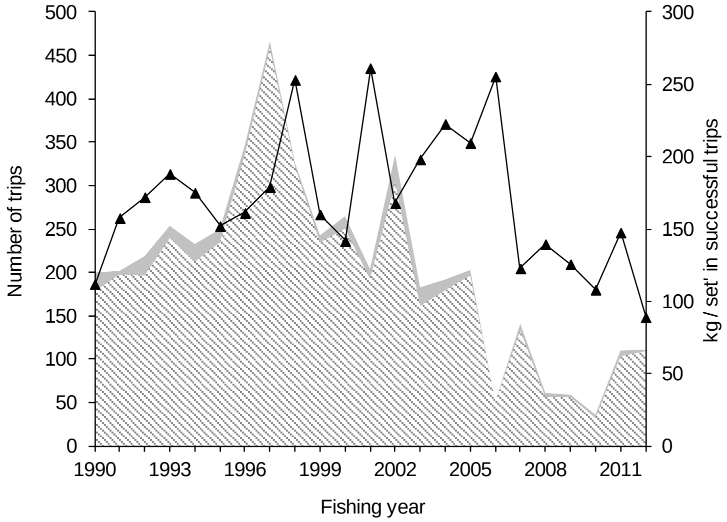


Figure K.5: Number of qualifying trips in SPO1W_SN(coast) (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/set, black line) of rig in successful trip-strata, by fishing year.

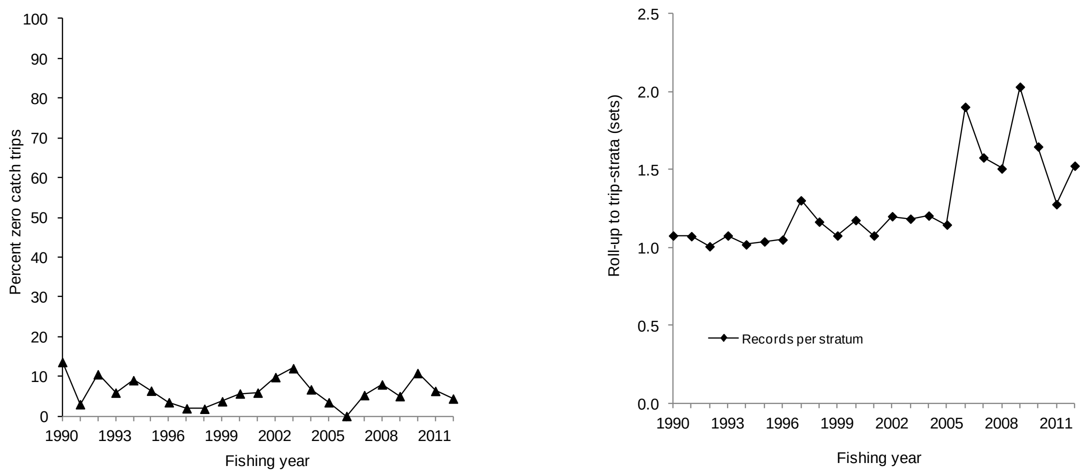


Figure K.6: The proportion of qualifying trips in SPO1W_SN(coast), that landed zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of sets per trip-stratum, by fishing year.

K.2.6 SPO 1W_BT Mixed target bottom trawl in SPO 1W

Effort in the bottom trawl fishery has declined steadily from its peak of more than 700 trips per year in the mid 1990s to about 300 trips in 2011–12, but catch rates have increased steadily from between 5 and 10 kg per tow in early years to near 20 kg/tow in 2011–12 (Figure K.7). The success rate at trip resolution and at stratum resolution show slightly contrasting trends which may be an artefact of the rollup of data to trip stratum. An increasing trend in the number of records rolled up to a trip stratum indicates that there have been changes in reporting practice, much of it coinciding with the switch from daily to tow-by-tow form in the mid 1990s (Figure K.8) This is probably related to the improved reporting of target species on the TCEPR/TCER forms that determines the definition of a stratum. The wide target species definition used here was selected to help mitigate the disparity in reporting practices between formtypes.

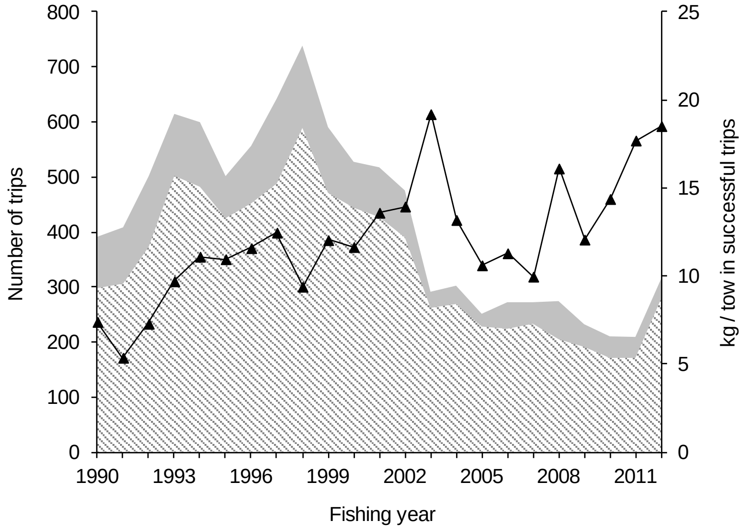


Figure K.7: Number of qualifying trips in SPO 1W_BT (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/tow, black line) of rig in successful trip-strata, by fishing year.

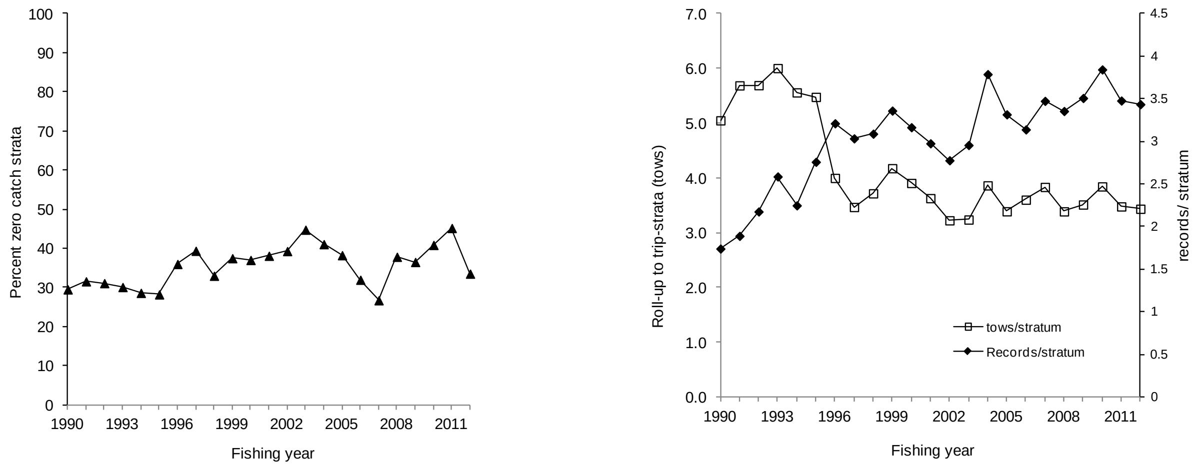


Figure K.8: The proportion of qualifying trips in SPO 1W_BT, that landed zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of tows per trip-stratum, by fishing year.

K.3 Standardised CPUE analysis

K.3.1 Core fleet definitions

The data sets used for the standardised CPUE analysis were restricted to those vessels that participated with some consistency in the defined fishery. Core vessels were selected by specifying two variables; the number of trips that determined a qualifying year, and the number of qualifying years that each vessel participated in the fishery. The effect of these two variables on the amount of landed rig retained in the dataset and on the number of core vessels, and the length of participation by the core vessels in each fishery are depicted in Appendix L.1. The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of rig. The selection process usually reduced the number of vessels in the dataset by about 70% while reducing the amount of landed rig by about 20%. Summaries for the core vessel data sets are presented in Table L.1.

K.3.2 Model selection, diagnostics and trends in model year effects

The final models selected for standardising positive catches in each fishery are described in Table K.1 to Table K.4. These tables include those explanatory variables that met the AIC criteria and each is not necessarily a complete list of the variables that were offered[2]. The variables that met the acceptance criteria based on a 1% improvement in R^2 are indicated with asterisks in the table, along with the amount of deviance they explained.

Following each table are step-influence plots that demonstrate the progressive effect on the annual indices of each explanatory variable as it enters the model, and shows the influence of each variable on the annual coefficients in adjacent panels. These plots highlight the observation made in Bentley et al. (2011) that the variables that explain the most deviance are not necessarily the ones responsible for most of the difference between standardised and observed series of CPUE. The influence of an explanatory variable is a combination of the coefficients and its distributional changes over years, and are plotted as Coefficient-Distribution-Influence (CDI) plots (Bentley et al. 2011) for each variable accepted into the model (see Appendix L.4).

The standardised series are compared with unstandardised CPUE and the effect of standardisation discussed. Previous series are also overlaid for the years in common and any differences between them, and/or changes in the fisheries in the intervening years commented on.
Diagnostic plots of the residuals from each final model fit are presented in Appendix L.3 and include implied coefficient plots for each statistical area and target species by year. These allow the comparison of the annual trends among statistical area and target species categories in each analysis, effectively serving as a proxy for an interaction analysis. The unstandardised and standardised indices from the final model for each fishery are given in Table L.2

K.3.2.1 SPO 1W_SN(043) – Shark setnet in Manukau Harbour

The gamma error distribution produced the best model fit to SPO 1W_SN(043) data (Figure L.5), and the residuals from the final model show a good fit to the distributional assumptions (Figure L.6).

Fishing year was forced as the first variable in the final model (Table K.1) and explained about 11% of the variance in catch, Vessel is the most important variable, entering second and explaining an additional 17% of the variance in catch. Month entered the model third and explained a further 10% of variance, and net length was the measure of effort with the greatest explanatory power, but duration was also selected into the final model, with as much influence as vessel. The final model explained almost 48% of the variance in log(catch) (Table K.1). The annual indices are plotted at each step in Figure K.9.

The coefficients for vessel show consistent differences in performance among vessels with respect to rig catch, and reducing effort in the late 1990s by three of the top performing vessels potentially lowered catches by almost 50% during the first half of the study period (Figure L.19). The month coefficients show a fishery that peaks in spring and summer both in terms of catch rates and in effort (Figure L.20). The influence of shifts in the seasonality of fishing has been neutral overall, but the variable importantly accounts for the loss of much of that peak seasonal effort in the late 2000s. A significant shift in the mid 1990s towards longer nets is predicted to have lifted catches by at least 20% at that time, and a further increase in net length in 2011–12 also had a positive influenced catches (Figure L.21). Duration trends positive (towards longer soak times) over the whole period, and although explaining the least amount of interannual variance, it has as much influence as changes to the fleet (vessel) in shifting the standardised series away from the unstandardised CPUE, and is predicted to have increased catches by almost 40% overall (Figure L.22).

[2] Variables which make no improvement in the AIC are ignored by the software.

Table K.1: **Order of acceptance of variables into the Gamma model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 5 trips in 4 or more fishing years) in the SPO 1W_SN(043) fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an *. Fishing year was forced as the first variable.**

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	23	-23 102	46 252	11.22	*
vessel	42	-22 683	45 451	28.35	*
month	53	-22 377	44 862	38.72	*
poly(log(netlength), 3)	56	-22 159	44 433	45.16	*
poly(log(duration), 3)	59	-22 070	44 261	47.60	*

a) b)

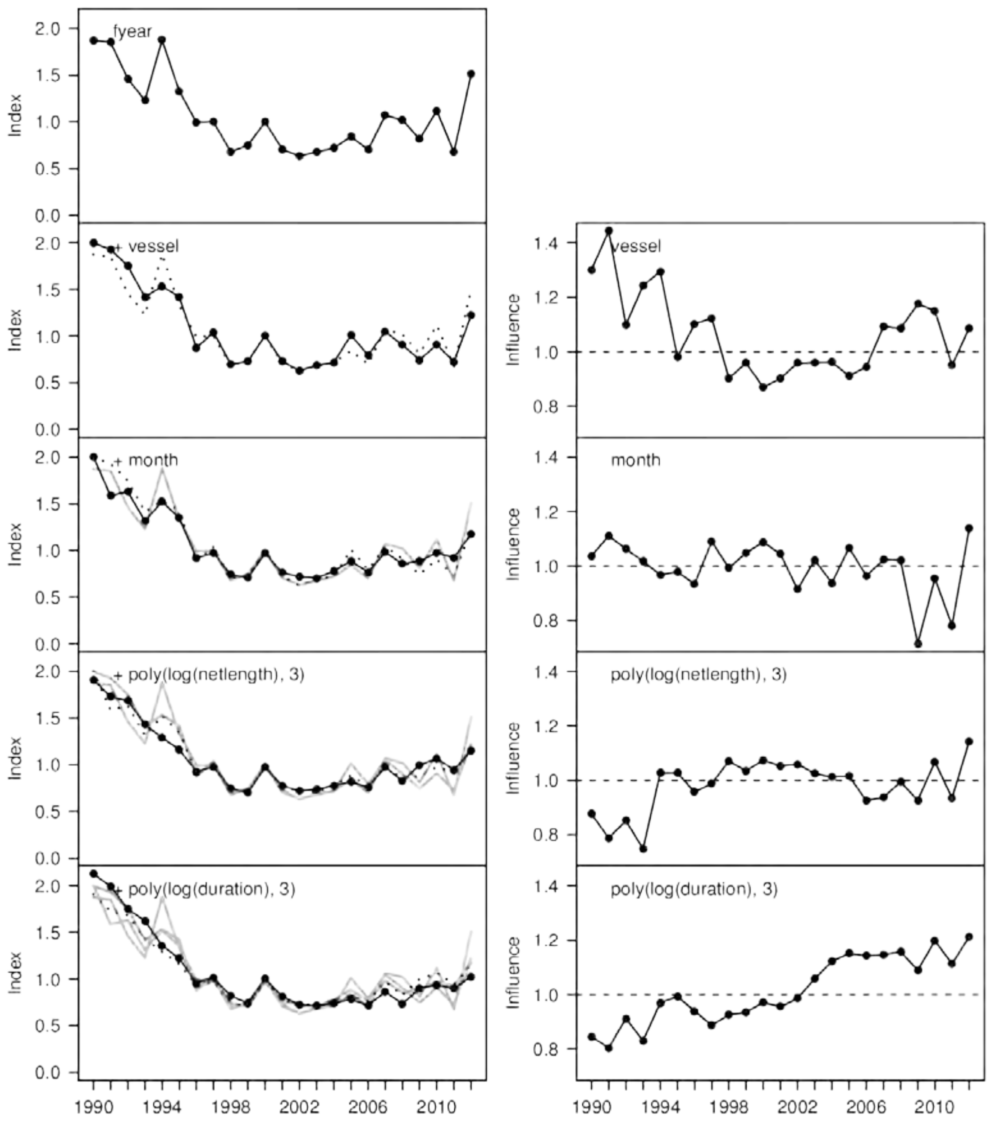


Figure K.9: Step and annual influence plot for SPO 1W_SN(043). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

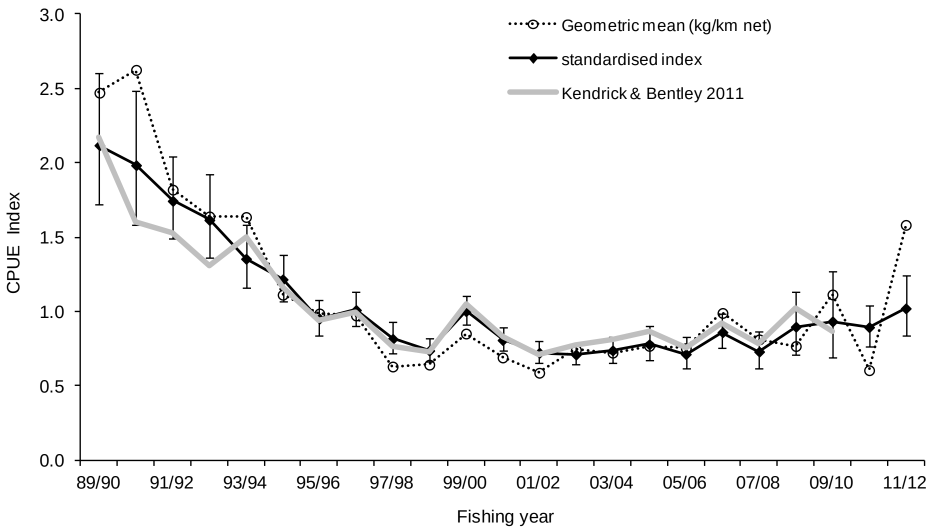


Figure K.10: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 1W_SN(043) fishery. Broken lines are the raw CPUE (kg /km net) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the lognormal series presented in 2011 for a similar fishery. All series are relative to the geometric mean over the years in common.

The year effects decline steadily from their peak in 1989–90 to a lower plateau by 1998–99 of about 80% of the mean for the series where they were relatively stable for the following ten years. There has been some sustained and gradual improvement during the late 2000s, and the index now sits at around unity. There is very close agreement with the previous series produced for this fishery, and the effect of standardisation smoothes the series considerably, reducing some anomalous peaks, and producing a credible looking trajectory without changing the overall trends (Figure K.10). The effect of the choice of error distribution on the annual indices (compared to indices from a lognormal) was not great (Figure K.11).

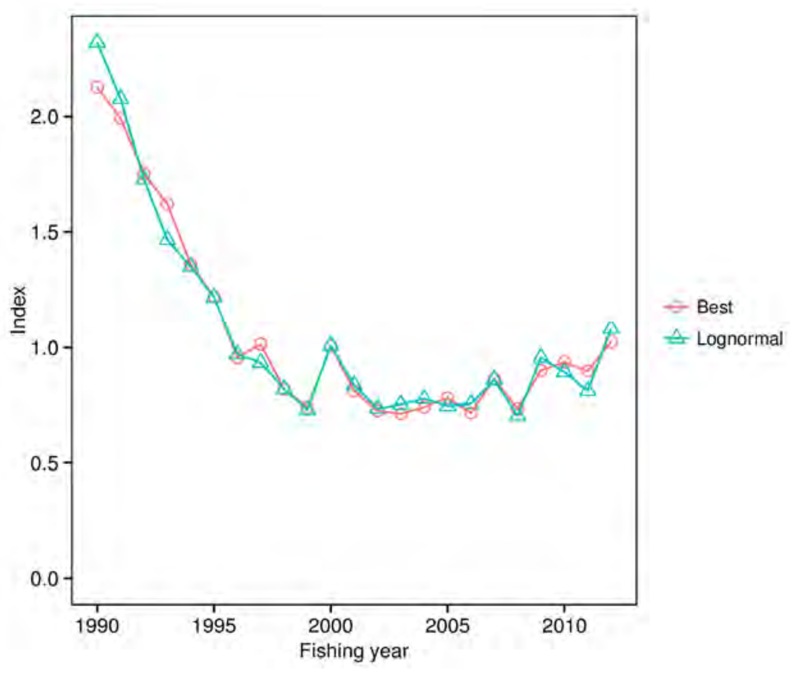


Figure K.11: Comparison between the base index and index from a lognormal for the SPO 1W_SN(043) fishery

K.3.2.2 SPO 1W_SN(044) – Shark setnet in Kaipara Harbour

The gamma error distribution produced the best model fit to SPO 1W_SN(044) data (Figure L.8), and the residuals from the final model show a good fit to the distributional assumptions (Figure L.9). Fishing year was forced as the first variable in the final model (Table K.2) and explained about 11% of the variance in catch, netlength is the most important variable, entering second and explaining an additional 33% of the variance in catch. Month entered the model third and explained a further 4% of variance, and vessel and duration were also included but without much additional explanatory power. The final model explained more than 55% of the variance in log(catch) (Table K.2). The annual indices are plotted at each step in Figure K.12.

A series of shifts towards shorter nets (per stratum) is probably related to the participation of individual vessels and/or to the rollup of original records to trip-strata, and has had a negative influence on catches of about 20% over the study period (Figure L.23). The month coefficients show a fishery that peaks in spring and summer both in terms of catch rates and in effort (Figure L.24). The influence of shifts in the seasonality of fishing has been neutral overall, but the variable importantly accounts for the loss of much of that peak seasonal effort in the late 2000s. The coefficients for vessel show consistent differences in performance among vessels with respect to rig catch, and reducing effort in the late 1990s by several top performing vessels potentially lowered catches by almost 50 % in the first half of the study period (Figure L.25). Duration has a positive trend (towards longer soak times) over the whole period, but has little additional explanatory power or influence on observed CPUE (Figure L.26).

The year effects decline steadily from their peak in 1994–95 by about 50% to reach the lowest point in the series by 2002–03 at below 70% of the mean for the series (Figure K.13). The index has been somewhat erratic since then, generally fluctuating around the mean for the series with no trend, but has been at or above unity in the most recent three years. There is reasonable agreement with the previous series produced for this fishery, and the steep increase and the indications of recent recovery noted at that time are confirmed and have been retained, but without further subsequent increase (Figure K.13). The selection of a gamma error distribution (compared with indices from a lognormal) changed the most recent point from indicating an increase to more suggestive of a downturn (Figure K.14), but overall did not change the trajectory markedly.

Table K.2: Order of acceptance of variables into the Gamma model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 5 trips in 4 or more fishing years) in the SPO 1W_SN(044) fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an * . Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	23	-25 743	51 535	10.53	*
poly(log(netlength), 3)	26	-24 775	49 604	44.25	*
month	37	-24 609	49 294	48.59	*
vessel	62	-24 386	48 897	53.90	*
poly(log(duration), 3)	65	-24 330	48 793	55.13	*
poly(log(days), 3)	68	-24 317	48 772	55.42	

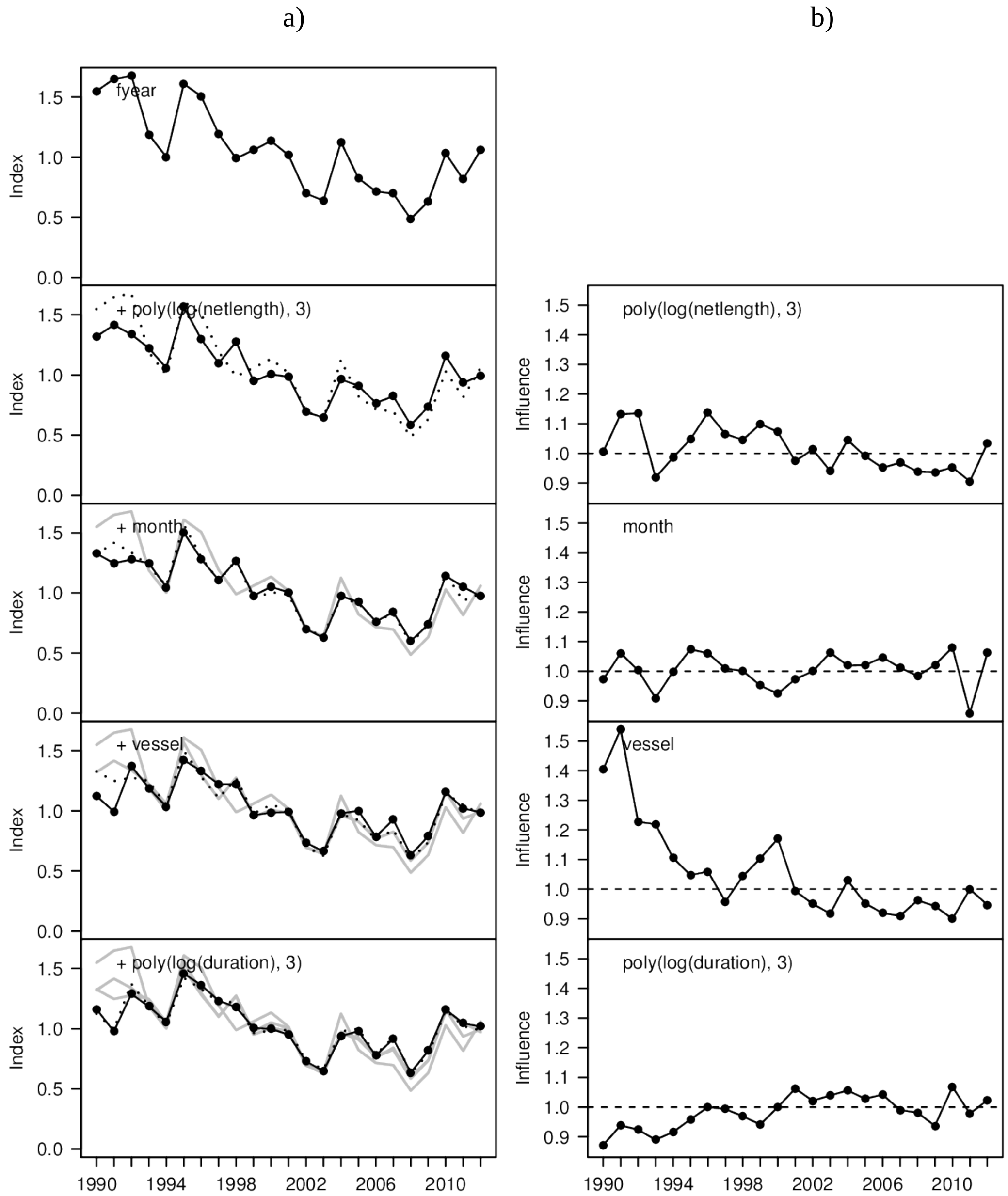


Figure K.12: Step and annual influence plot for SPO 1W_SN(044). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

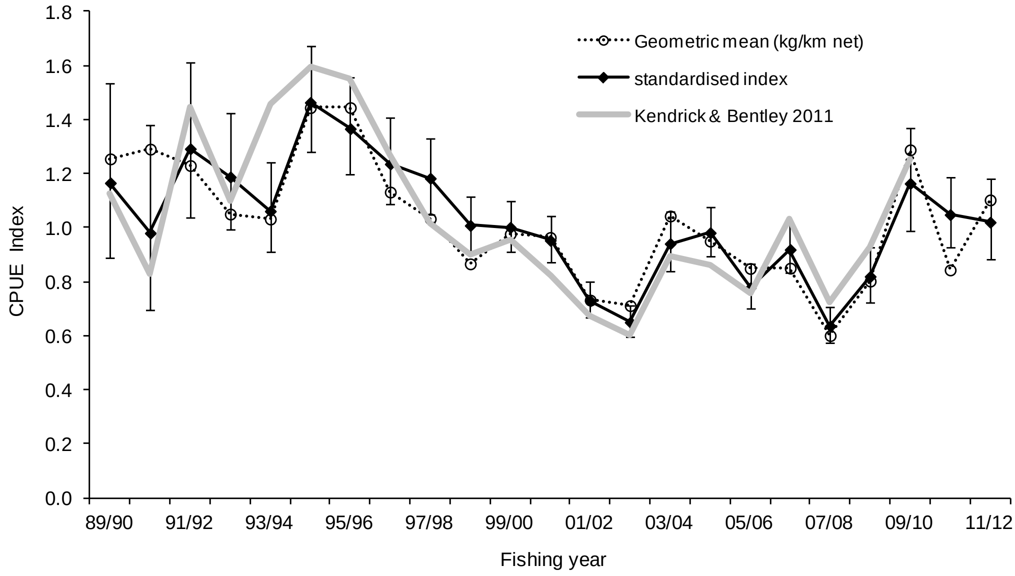


Figure K.13: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 1W_SN(044) fishery. Broken lines are the raw CPUE (kg /km net) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the previous lognormal series presented in 2011 for a similar fishery. All series are relative to the geometric mean over the years in common.

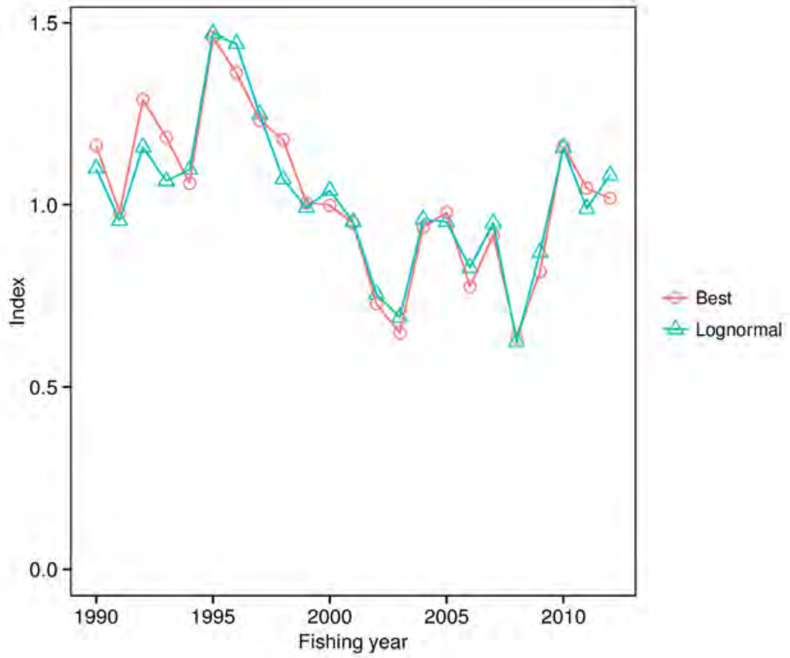


Figure K.14: Comparison between the base index and index from a lognormal for the SPO 1W_SN(044) fishery.

K.3.2.3 SPO 1W_SN(COAST) – Shark setnet in coastal SPO 1W

The Weibull error distribution produced the best model fit to SPO 1W_SN(coast) data (Figure L.11) and the residuals from the final model show a reasonable fit to the distributional assumptions (Figure L.12).

Fishing year was forced as the first variable in the final model (Table K.3) and explained about 5% of the variance in catch, netlength is the most important variable, entering second and explaining an additional 24% of the variance in catch. Month entered the model third and explained a further 6% of variance, and target species and vessel were also included but without much additional explanatory power. The final model explained almost 44% of the variance in log(catch) (Table K.3). The annual indices are plotted at each step in Figure K.15.

A trend towards longer nets (per stratum) in the 2000s is predicted to have positively influenced catches by up to about 30%, but the inclusion of netlength into the model also accounts for an unusual spike in catches in 2005–06 (Figure L.27). The month coefficients show peaks in catch rates in spring in contrast with lower catches in April and May, but less seasonal contrast in terms of effort (Figure L.28). The inclusion of month in the model largely adjusts for those years in which there is a peak in effort in the final month of the fishing year (September). The fishery is based on rig target sets, but an increase in school shark effort in the late 2000s (with consequently lower catches of rig) is accounted for by the model by lifting those points (Figure L.29). Generally, changes to the core fleet have been negative with respect to rig, with most recent entrants (with one notable exception) performing below average (Figure L.30).

The year effects fluctuate around unity with no trend. They are poorly defined with large error bars around each point, and no sustained direction of change (Figure K.16). They are also different from the previous series produced for this fishery, possibly as the result of better grooming out of large landings, but also because of differences in the core vessel dataset. This coastal fishery necessarily combines effort from a wide and disparate range of bays and harbours with possibly little to justify their combination. Residual implied coefficients for each Statistical Area and target species suggest a recent sustained decline in Area 042 that is not evident in other areas (Figure L.13), and also suggest a sustained decline of rig during the early 2000s in school shark sets that is not evident in rig sets (Figure L.14). The correspondence between this series and the series estimated by Kendrick & Bentley (2011) is reasonable, considering the uncertain nature of the analysis (Figure K.16). The assumption of a Weibull distribution in this model compared with the lognormal model leads to an equally unstable series but with a somewhat different trajectory (Figure K.17).

Table K.3: Order of acceptance of variables into the Weibull model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 3 trips in 3 or more fishing years) in the SPO 1W_SN(COAST) fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an * . Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	24	-23 362	46 772	4.69	*
poly(log(netlength) 3)	27	-22 827	45 709	28.41	*
month	38	-22 653	45 382	34.79	*
target	40	-22 562	45 203	37.91	*
vessel	152	-22 386	45 075	43.49	*
poly(log(duration) 3)	155	-22 374	45 057	43.85	
area	158	-22 369	45 053	44.01	
poly(log(days) 3)	161	-22 363	45 047	44.18	

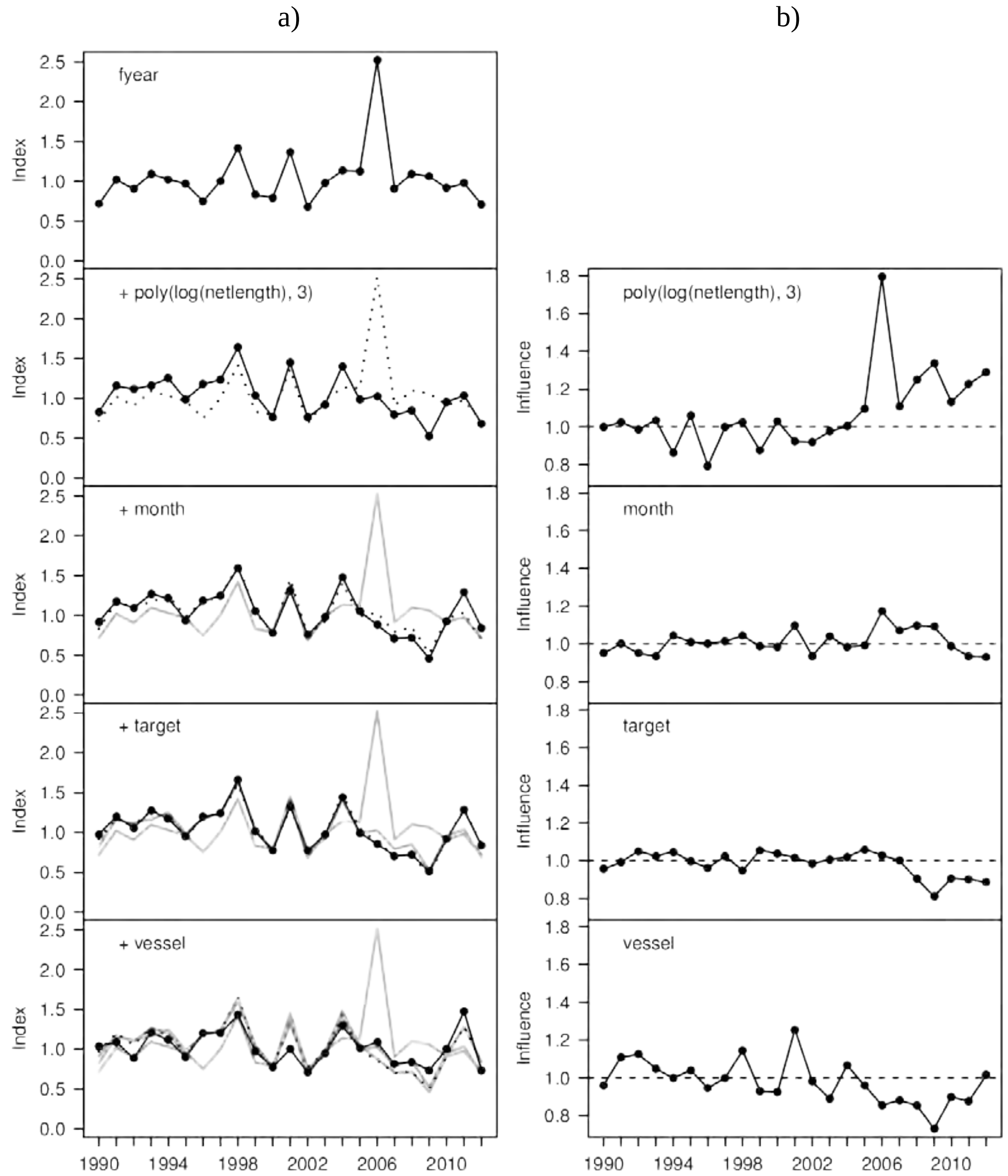


Figure K.15: Step and annual influence plot for SPO 1W_SN(COAST). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

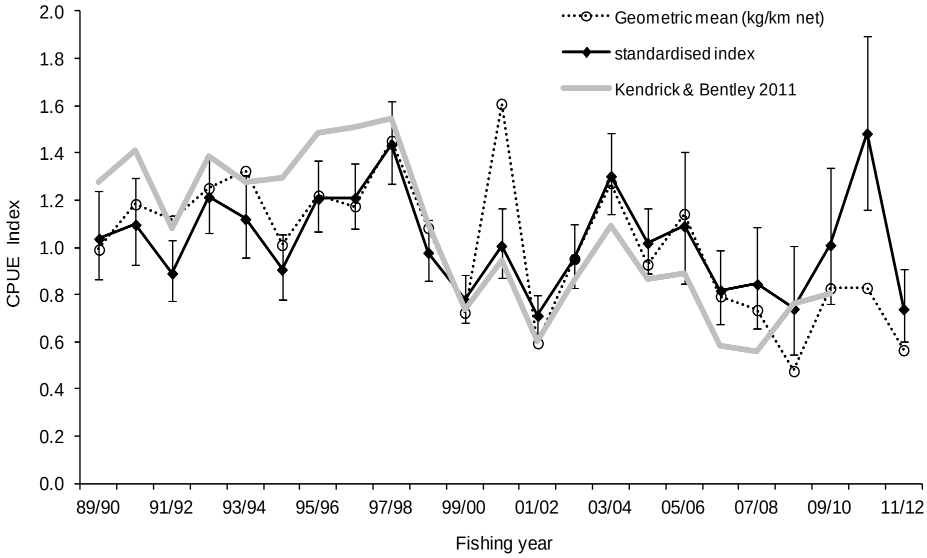


Figure K.16: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 1W_SN(COAST) fishery. Broken lines are the raw CPUE (kg /km net) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the previous lognormal series presented in 2011 for this fishery. All series are relative to the geometric mean over the years in common.

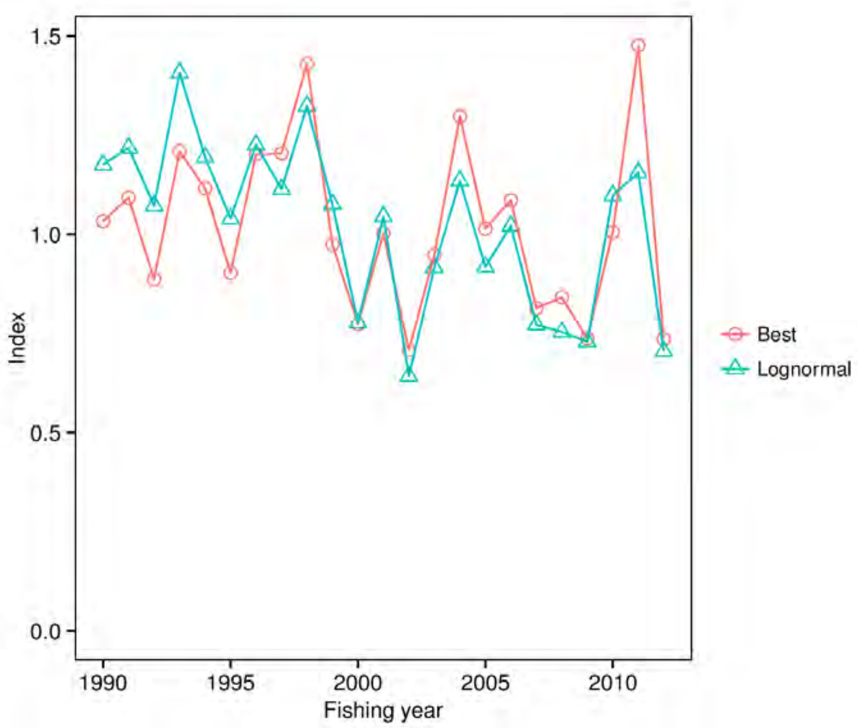


Figure K.17: Comparison between the base index and index from a lognormal for the SPO 1W_SN(COAST) fishery.

K.3.2.4 SPO 1W_BT – Mixed target bottom trawl in coastal SPO 1W

The lognormal error distribution produced the best model fit to SPO 1W_BT data (Figure L.15) and the residuals from the final model show a good fit to the distributional assumptions (Figure L.16).

Fishing year was forced as the first variable in the final model (Table K.4) and explained about 4% of the variance in catch, duration is the most important variable, entering second and explaining an additional 21% of the variance in catch. Vessel entered the model third and explained a further 12% of variance, and month and area were also included but without much additional explanatory power. The final model explained almost 42% of the variance in log(catch) (Table K.4). The annual indices are plotted at each step in Figure K.18.

There is a strong relationship between catch and hours fished, but little contrast and no trend in the duration of fishing (per stratum) (Figure L.31). The model adjusts for differences from year to year, the most relevant being a negative influence on observed catches in the most recent three years. Changes in the core fleet in contrast, have shown a strong trend towards better performance (with respect to rig), and are predicted to have increased catches by about 50% over the time series (Figure L.32). The month coefficients show a strong seasonal pattern of availability but fairly consistent year round effort, so that the inclusion of month into the model adjusts for small variations likely caused by poor weather, with a neutral influence overall (Figure L.33). A shift out of Area 042 in 2002–03 is predicted to have been positive, potentially lifting catches by about 7%, but there is also an earlier trend away from that area (Waikato River) that has accounted for greater improvements over a decade during the 1990s (Figure L.34).

The year effects fluctuate around unity for most of the series with a peak in 2002–03 which is reduced somewhat by standardisation, and an otherwise increasing trend for the eight most recent years, although with increasingly large error bars (Figure K.19). The overall effect of standardisation is to lift the points in the first half of the series, and to lower those in the second half, changing a trajectory that appears to be increasing to one that is much flatter, but still agrees on a greater than 100% increase since 2008–09 (Figure K.19). Residual implied coefficients confirm that the recent increase was common to each Statistical Area (Figure L.17) and each target species (Figure L.18).

Table K.4: Order of acceptance of variables into the lognormal model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 5 trips in 4 or more fishing years) in the SPO 1W_BTfishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an * . Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	23	-20 978	42 003	3.58	*
poly(log(duration), 3)	26	-19 652	39 358	24.14	*
vessel	60	-18 673	37 467	36.53	*
month	71	-18 336	36 817	40.32	*
area	75	-18 220	36 591	41.58	*
poly(log(num), 3)	78	-18 153	36 465	42.29	
target	83	-18 125	36 417	42.59	
poly(log(days), 3)	86	-18 109	36 393	42.75	

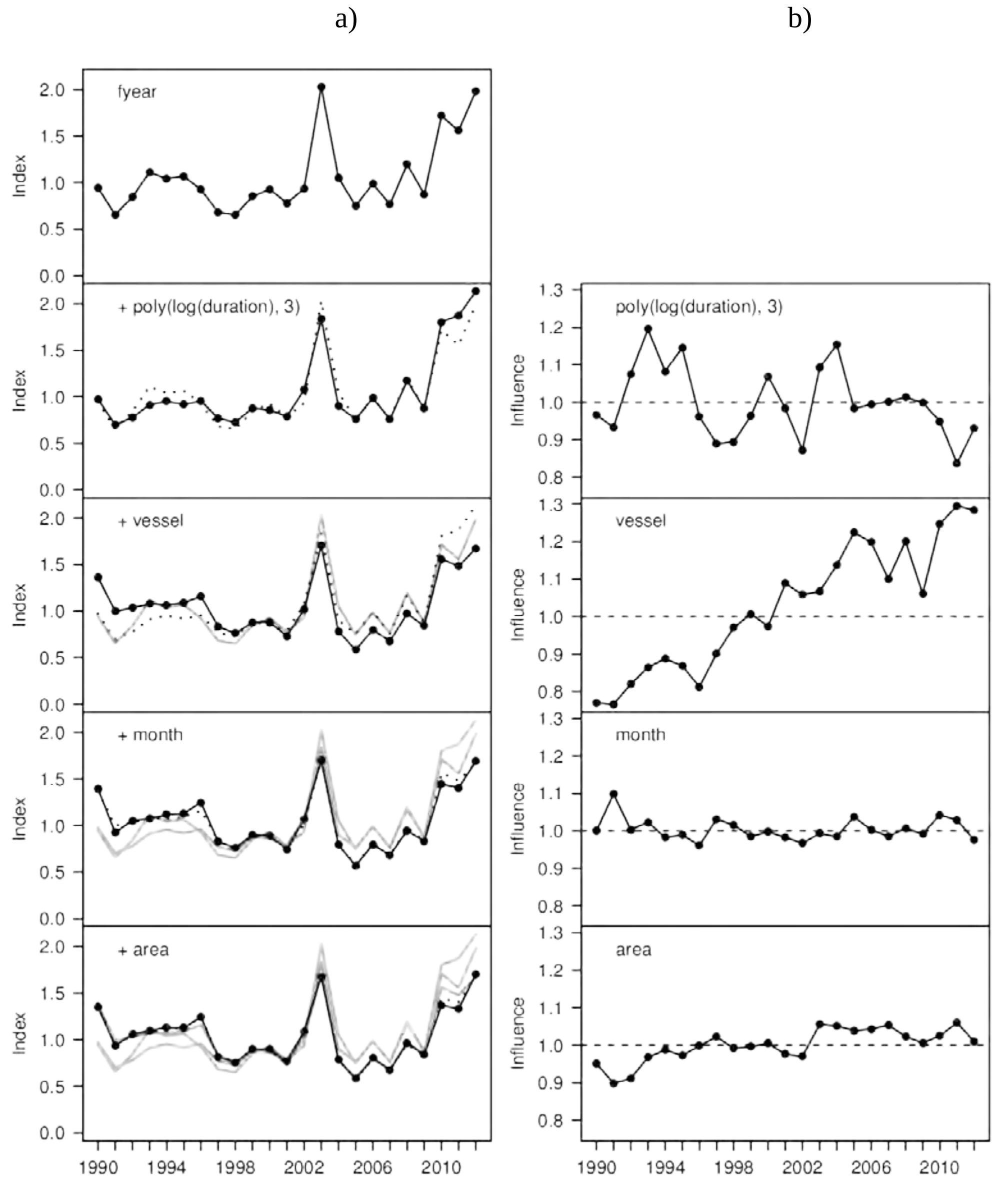


Figure K.18: Step and annual influence plot for SPO 1W_BT. (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

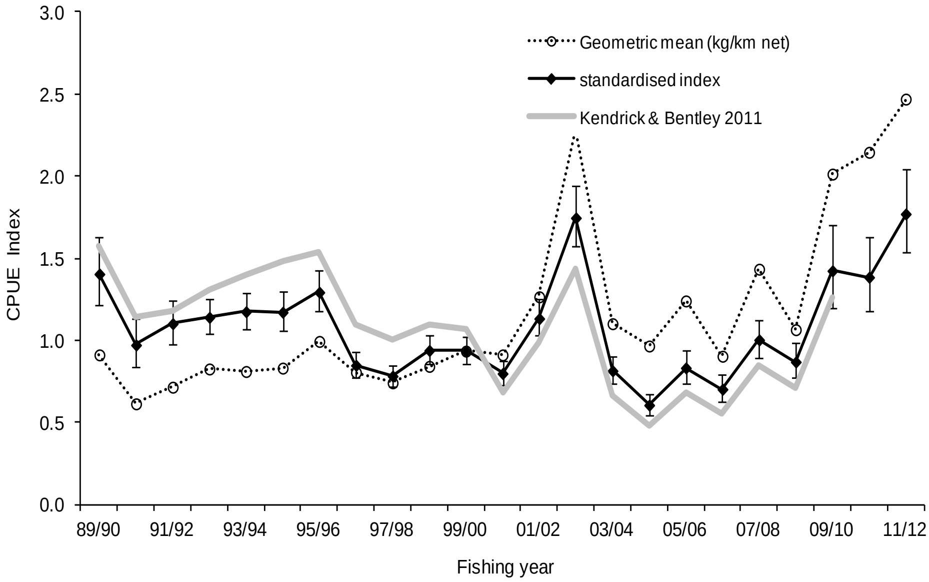


Figure K.19: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 1W_BT fishery. Broken lines are the raw CPUE (kg /tow) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the previous lognormal series presented in 2011 for this fishery. All series are relative to the geometric mean over the years in common.

Appendix L. DETAILED DIAGNOSTICS FOR SPO 1W CPUE STANDARDISATIONS

L.1 Core vessel selection

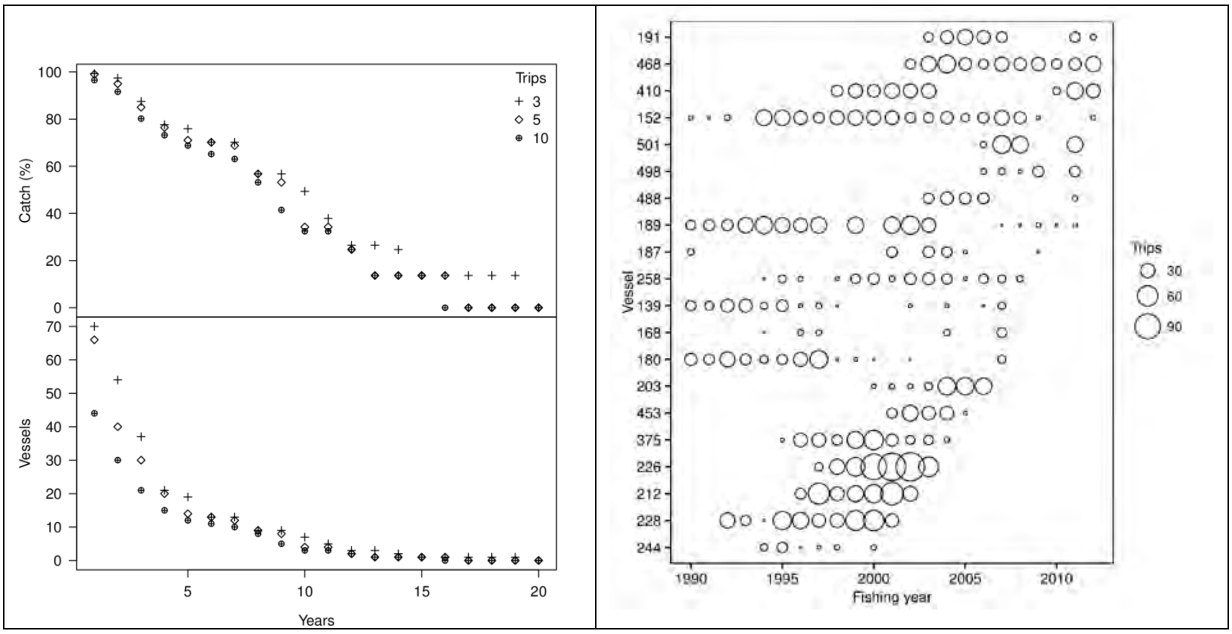


Figure L.1: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 1W_SN(043) dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 5 trips in 4 or more fishing years).

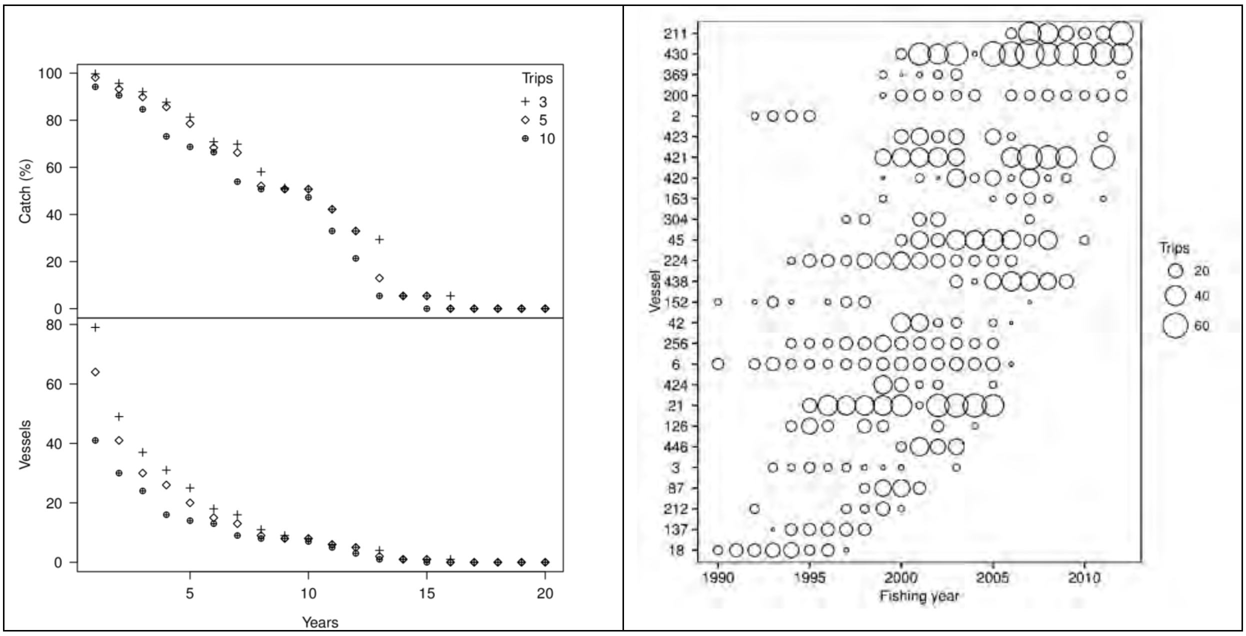


Figure L.2: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 1W_SN(044) dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 5 trips in 4 or more fishing years).

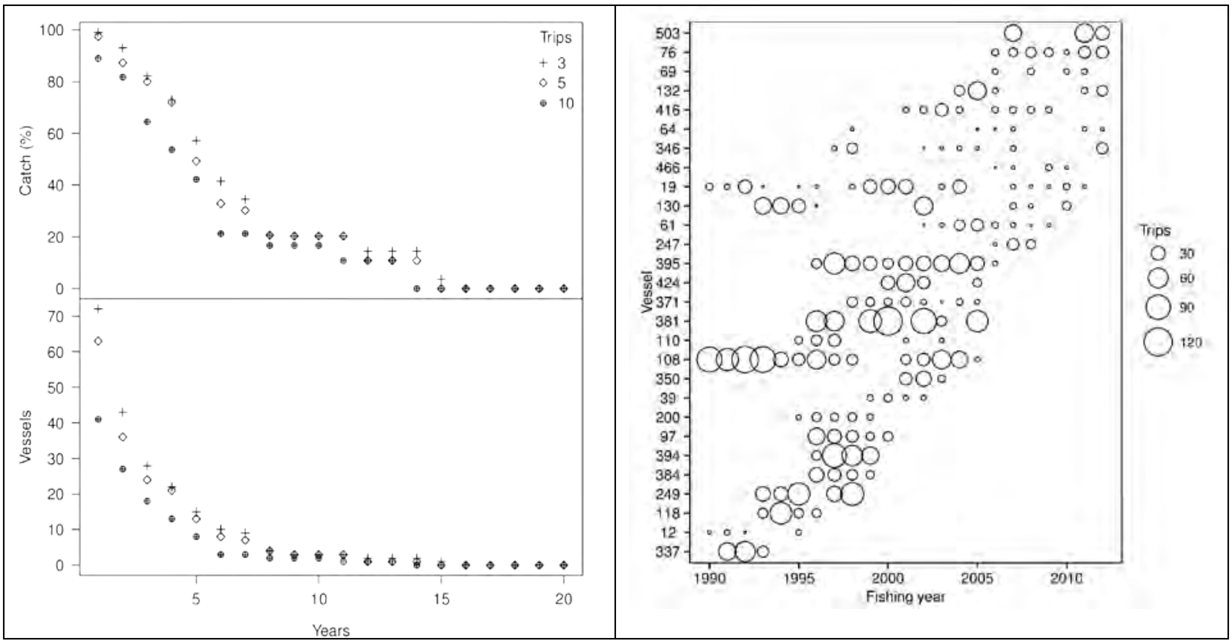


Figure L.3: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 1W_SN(COAST) dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 3 trips in 3 or more fishing years).

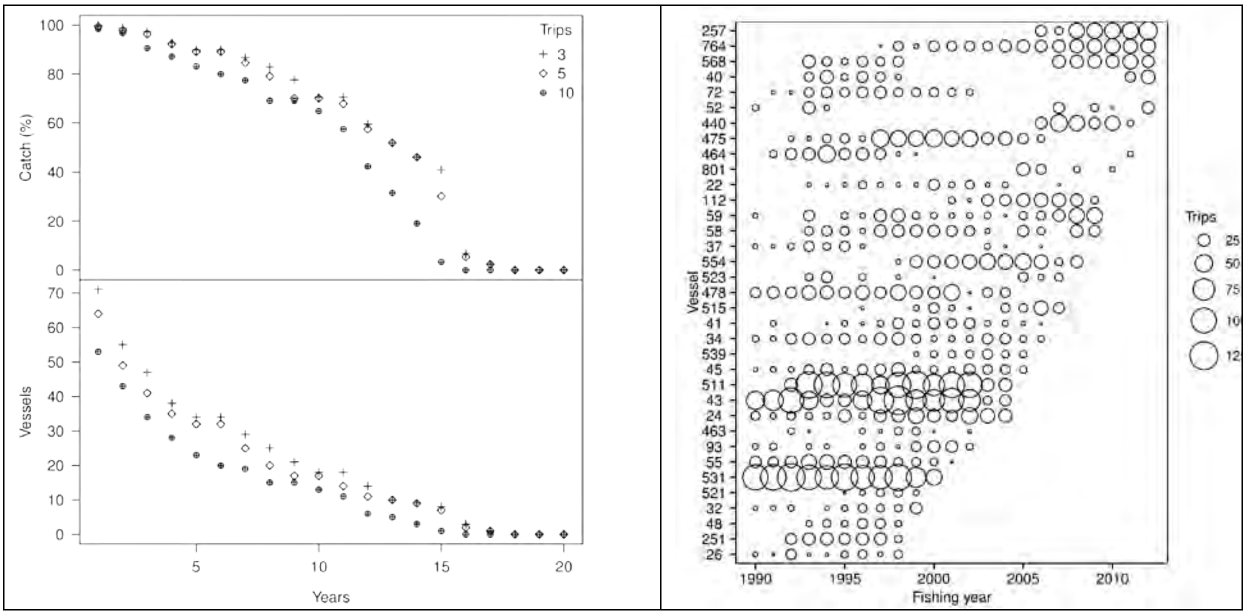


Figure L.4: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 1W_BT dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 10 trips in 5 or more fishing years).

L.2 Data summaries

Table L.1: Number of vessels, trips, trip strata, events, sum of catch (t), sum of net length (km) (or tows for SPO 1W BT) and sum of hours fishing for core vessels in the three CPUE analyses by fishing year.

	SPO 1W_SN(043)								SPO 1W_SN(044)							
Fishing year	Vessel	Trips	Strata	Events	Catch	Net length	Hours	% zero	Vessel	Trips	Strata	Events	Catch	Net length	Hours	% zero
1990	5	62	62	73	17.7	45.9	267	100.0	3	27	27	37	9.4	29.8	268	100.0
1991	5	51	51	60	14.4	31.9	194	100.0	3	20	20	29	7.1	25.8	234	95.0
1992	6	117	117	123	25.9	80.9	662	99.2	5	47	47	64	17.4	60.5	590	97.9
1993	5	95	95	98	17.5	55.1	366	97.9	6	73	73	88	19.3	71.5	768	98.6
1994	9	112	112	118	32.1	99.4	723	100.0	9	97	97	132	21.7	110.5	1 158	99.0
1995	8	182	182	208	36.8	161.6	1 304	99.5	9	134	134	182	48.6	170.4	1 798	100.0
1996	10	186	186	200	28.2	147.8	1 364	100.0	9	130	130	172	43.8	171.6	1 939	99.2
1997	11	245	245	268	36.6	205.4	1 335	98.0	10	133	133	183	35.8	168.3	2 048	100.0
1998	10	166	166	179	17.0	152.8	1 062	98.8	11	169	169	208	36.8	189.4	2 389	97.6
1999	9	302	302	337	33.9	274.6	1 865	98.0	15	248	250	315	59.3	308.4	3 408	100.0
2000	12	340	340	385	51.5	314.0	2 252	99.4	16	310	311	434	79.5	404.4	4 576	100.0
2001	12	372	372	395	39.7	332.0	2 383	99.2	17	335	335	505	83.5	400.7	6 478	99.4
2002	13	331	331	350	31.9	306.7	2 403	100.0	17	301	301	379	47.1	341.2	4 904	99.7
2003	13	288	288	314	29.9	258.5	2 574	100.0	16	354	355	475	51.0	378.7	6 310	100.0
2004	12	236	236	262	25.7	218.8	2 500	99.6	11	160	160	229	40.4	192.2	3 020	99.4
2005	9	142	142	154	18.3	123.4	1 622	100.0	14	281	281	340	52.2	300.8	4 594	100.0
2006	9	141	141	153	15.0	110.4	1 520	99.3	13	229	229	304	36.9	244.9	4 167	100.0
2007	10	177	177	193	28.9	144.3	1 893	100.0	10	305	305	353	47.8	299.2	4 536	99.7
2008	9	100	100	111	15.6	91.8	1 093	100.0	9	234	234	258	25.5	214.1	3 311	99.6
2009	5	54	54	57	6.6	41.9	529	98.2	6	160	160	175	22.8	147.9	2 088	100.0
2010	3	26	26	26	4.4	23.4	308	100.0	5	84	84	106	19.5	88.4	1 600	100.0
2011	7	141	141	147	14.4	108.1	1 416	99.3	8	158	158	203	29.1	156.6	2 520	100.0
2012	4	73	73	75	16.8	71.9	892	100.0	5	122	122	156	28.9	140.9	2 085	99.2

Table L.1: (continued)

	SPO 1W_SN(coast)								SPO 1W_BT							
Fishing year	Vessel	Trips	Strata	Events	Catch	Net length	Hours	% zero	Vessel	Trips	Strata	Events	Catch	Tows	Hours	% zero
1990	3	107	107	122	13.8	168.6	2 174	93.5	17	260	324	571	10.7	1 547	4 450	74.4
1991	4	135	135	146	25.8	231.9	2 365	96.3	14	267	332	610	7.7	1 712	4 938	73.8
1992	4	202	202	202	33.0	326.9	2 989	92.6	19	426	520	1 139	17.8	2 828	8 114	73.3
1993	6	216	216	227	43.5	384.7	3 612	94.4	26	602	925	2 398	43.0	5 549	15 759	70.2
1994	4	175	175	175	34.8	234.4	2 132	97.1	25	566	859	1 926	44.3	4 877	13 357	73.7
1995	9	166	167	174	29.9	318.3	1 961	94.6	24	499	736	2 035	37.6	4 035	11 676	71.9
1996	11	281	281	295	39.7	311.7	3 961	96.1	27	535	946	2 958	34.6	3 734	11 748	64.8
1997	10	367	367	451	71.2	633.4	5 871	98.4	25	626	1 224	3 709	40.4	4 251	12 925	61.0
1998	11	292	294	327	85.4	548.8	4 117	98.0	27	727	1 275	3 938	35.3	4 749	14 032	66.9
1999	11	234	234	253	37.1	320.7	3 089	96.2	24	556	1 051	3 568	41.0	4 436	12 687	63.4
2000	8	240	240	285	36.0	432.1	3 743	94.2	22	496	1 057	3 407	41.2	4 135	13 703	62.8
2001	9	184	184	191	47.1	275.7	2 689	93.5	21	465	1 070	3 242	42.9	3 671	12 515	60.8
2002	11	289	290	307	35.3	420.5	4 171	89.0	19	433	973	2 740	34.2	2 991	10 652	59.4
2003	10	163	163	187	28.1	265.9	2 532	87.1	18	274	863	2 549	49.3	2 800	10 650	55.3
2004	8	189	191	231	48.4	385.3	3 217	93.2	17	279	864	3 257	40.4	3 293	12 130	59.1
2005	10	201	201	231	46.8	420.8	2 964	96.5	14	236	856	2 887	28.4	2 887	10 895	61.7
2006	10	47	48	93	24.2	191.2	1 115	100.0	15	235	609	1 994	21.2	2 113	7 709	67.3
2007	10	115	126	203	23.7	286.8	3 007	98.4	13	235	570	2 008	18.9	2 217	7 657	74.6
2008	7	57	59	91	11.8	149.1	1 148	91.5	12	263	717	2 381	29.6	2 405	8 579	61.9
2009	6	34	35	55	6.8	126.9	760	91.4	9	210	605	2 105	22.2	2 105	7 701	64.0
2010	6	35	36	60	5.8	81.8	661	88.9	7	150	327	1 136	19.4	1 136	3 787	57.2
2011	7	97	98	128	17.8	228.3	1 846	94.9	8	146	370	1 148	21.7	1 148	3 824	60.0
2012	7	97	99	148	13.6	249.4	1 923	98.0	6	167	521	1 616	35.8	1 616	5 632	63.9

L.3 Diagnostic plots

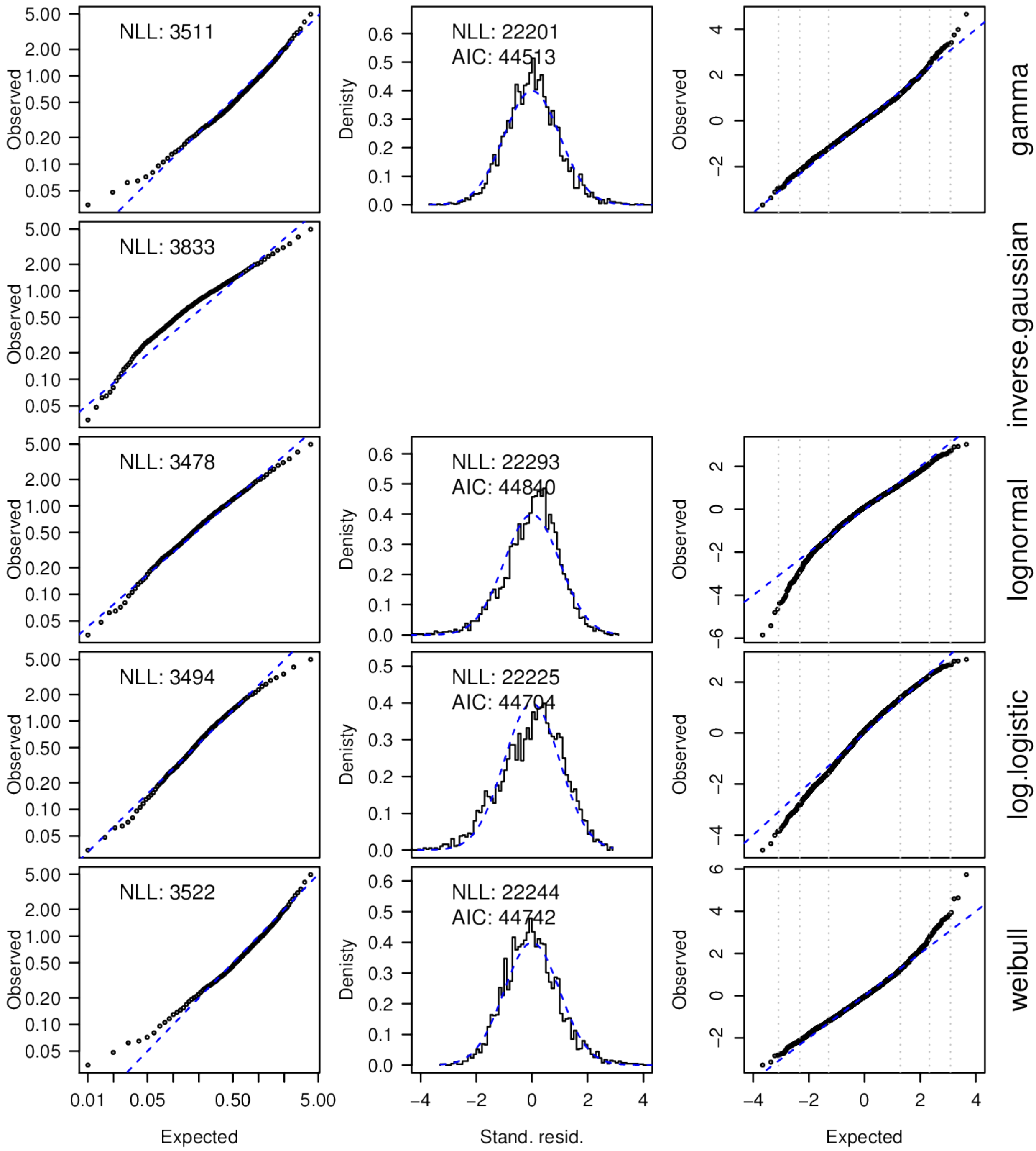


Figure L.5: Diagnostics for alternative distributional assumptions for catch in the SPO 1W_SN(043) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + target +netlength and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

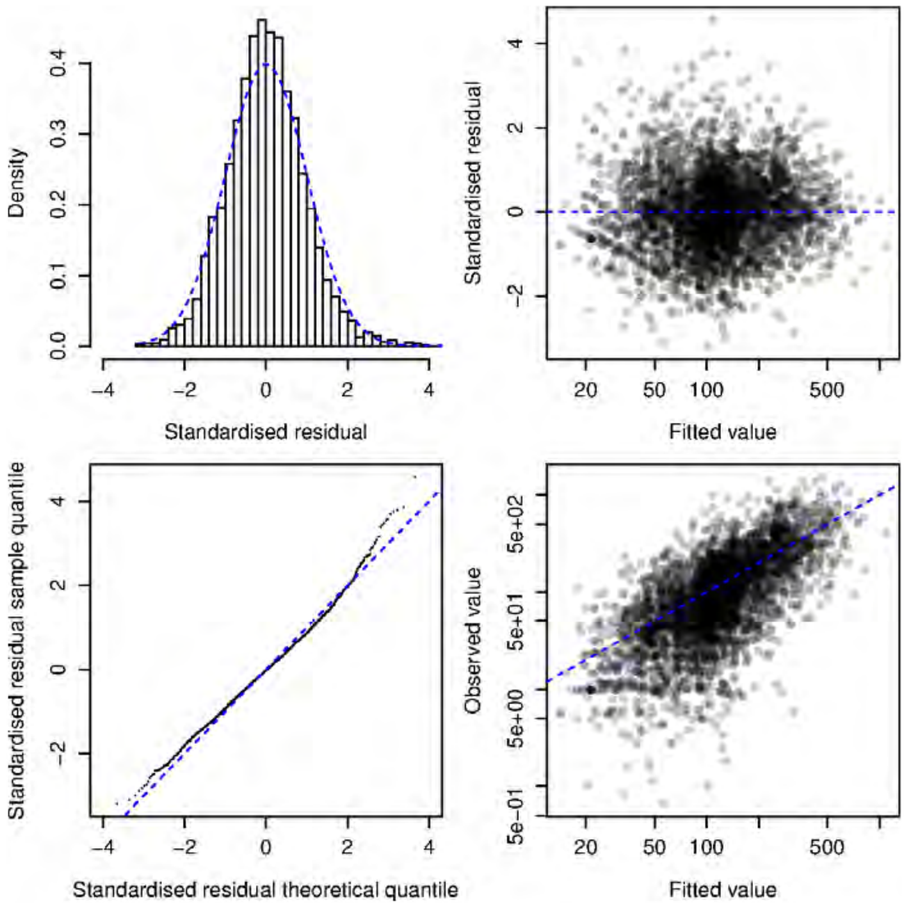


Figure L.6: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 1W_SN(043) fishery. [Upper left] histogram of the standardised residuals compared to a gamma distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

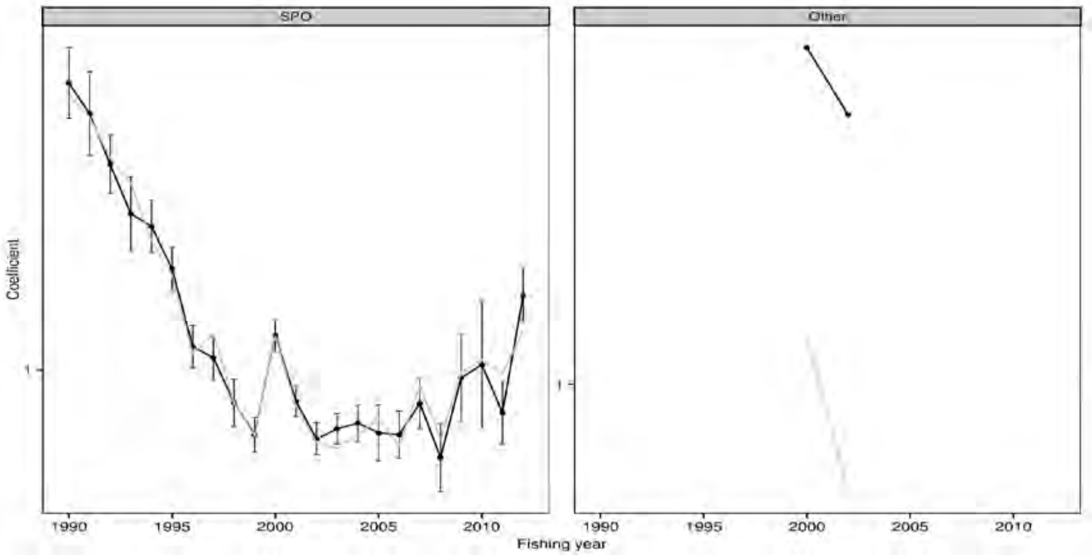


Figure L.7: Residual implied coefficients for each target species in each fishing year in the SPO 1W_SN(043) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

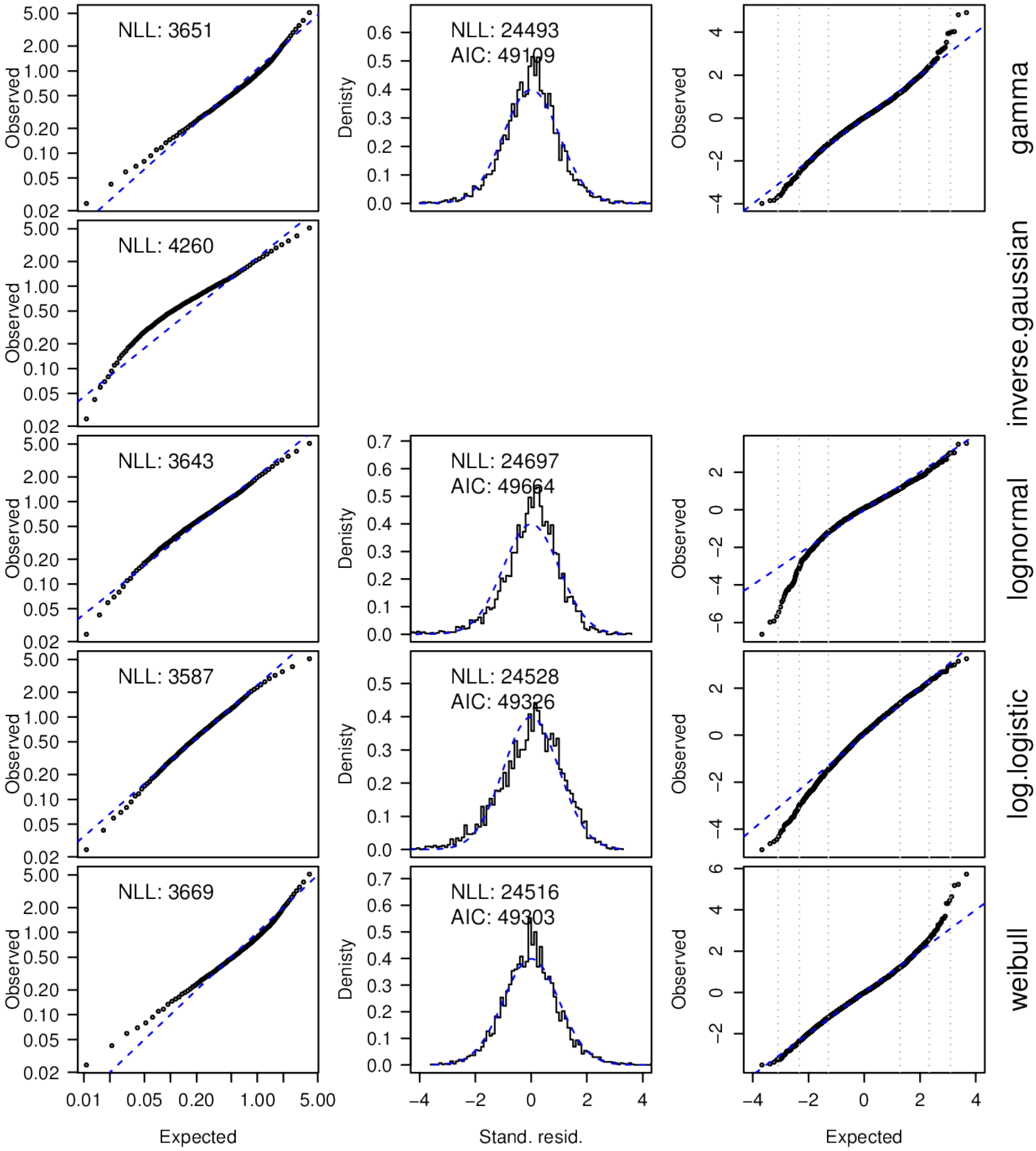


Figure L.8: Diagnostics for alternative distributional assumptions for catch in the SPO 1W_SN(044) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + target + netlength and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

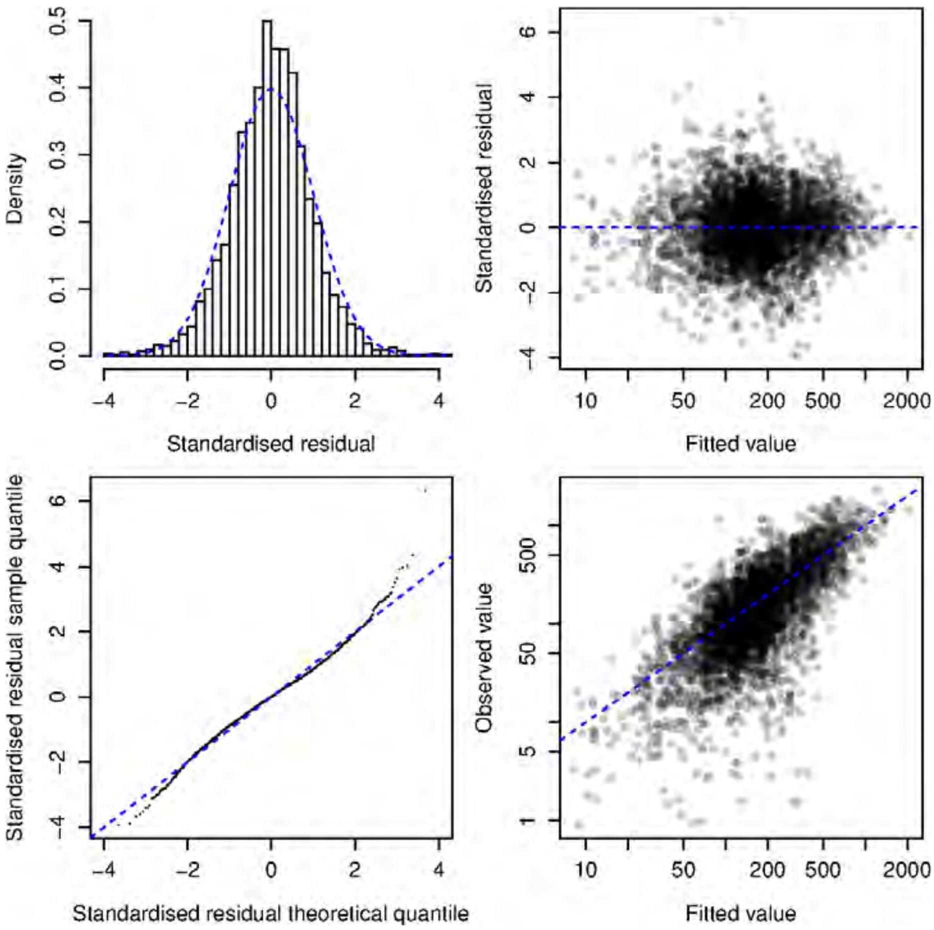


Figure L.9: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 1W_SN(044) fishery. [Upper left] histogram of the standardised residuals compared to a gamma distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

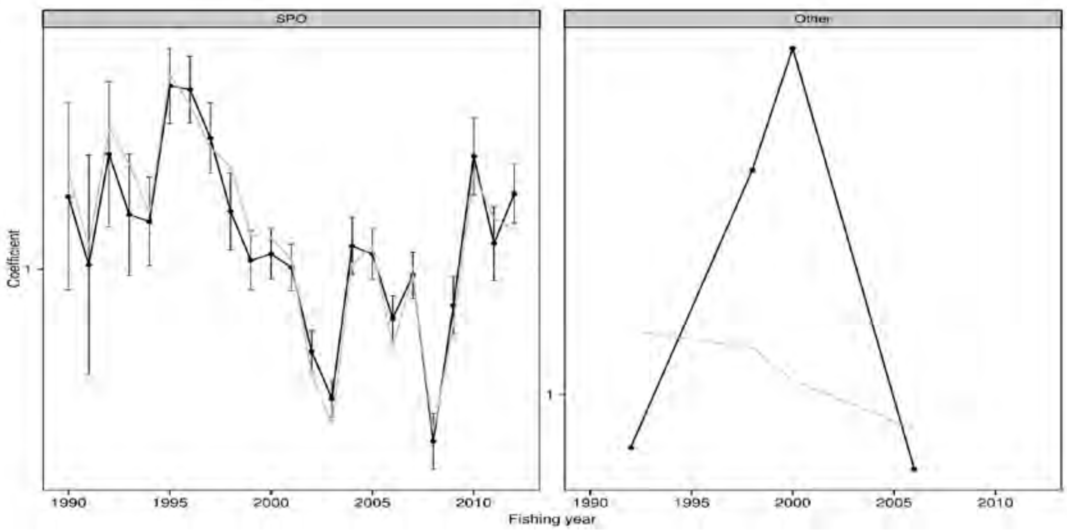


Figure L.10: Residual implied coefficients for each target species in each fishing year in the SPO 1W_SN(044) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

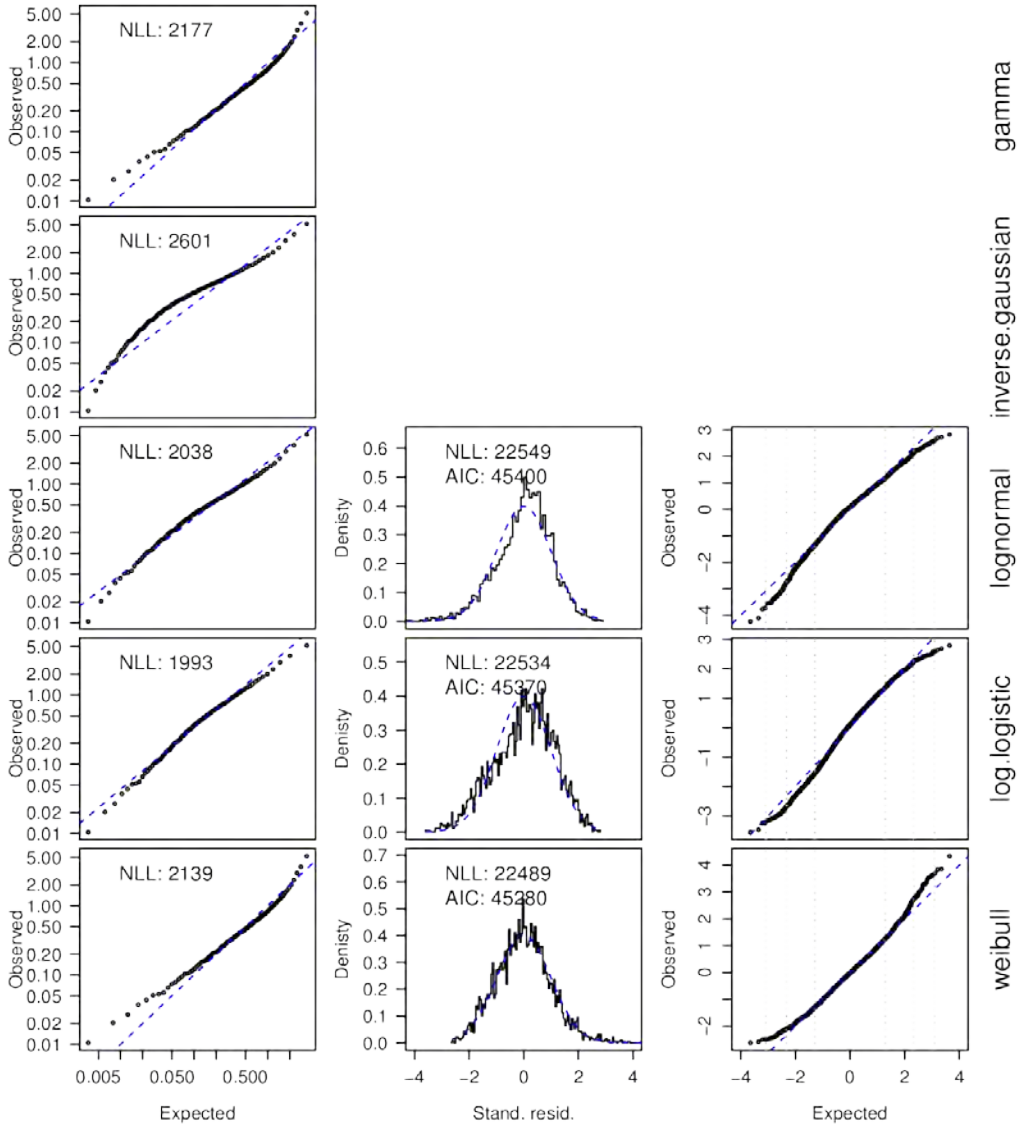


Figure L.11: Diagnostics for alternative distributional assumptions for catch in the SPO 1W_SN(COAST) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + target +netlength and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

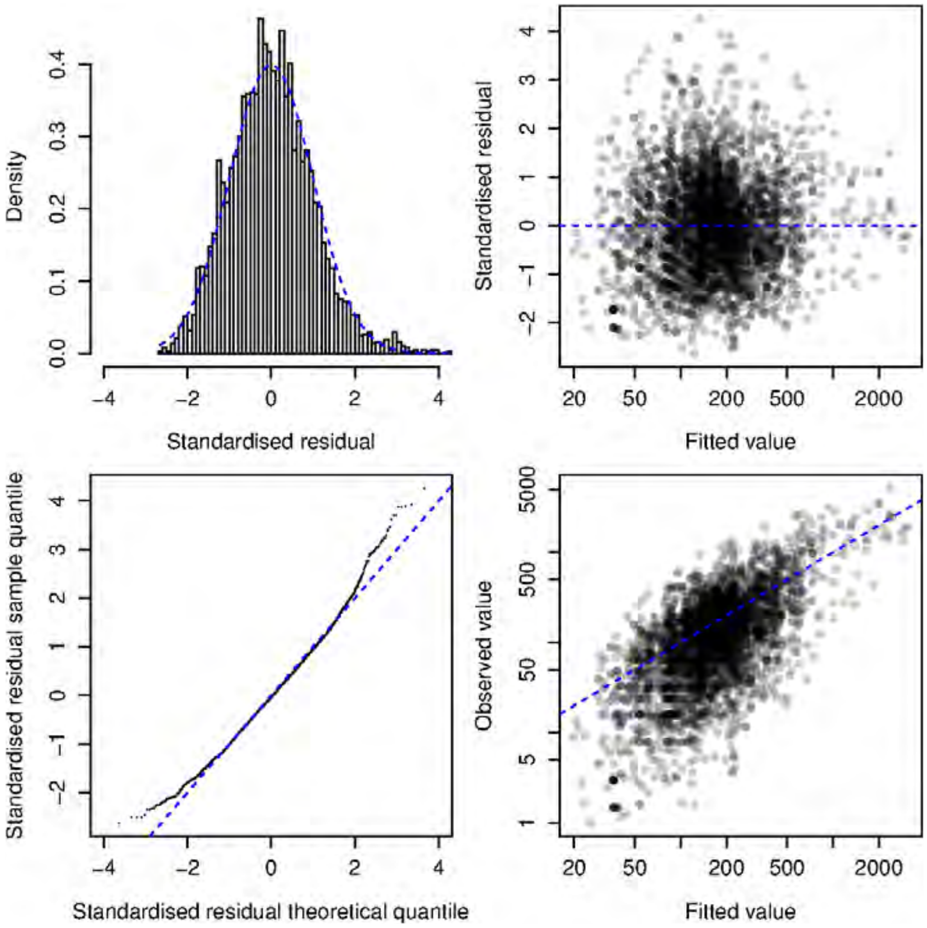


Figure L.12: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 1W_SN(COAST) fishery. [Upper left] histogram of the standardised residuals compared to a Weibull distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

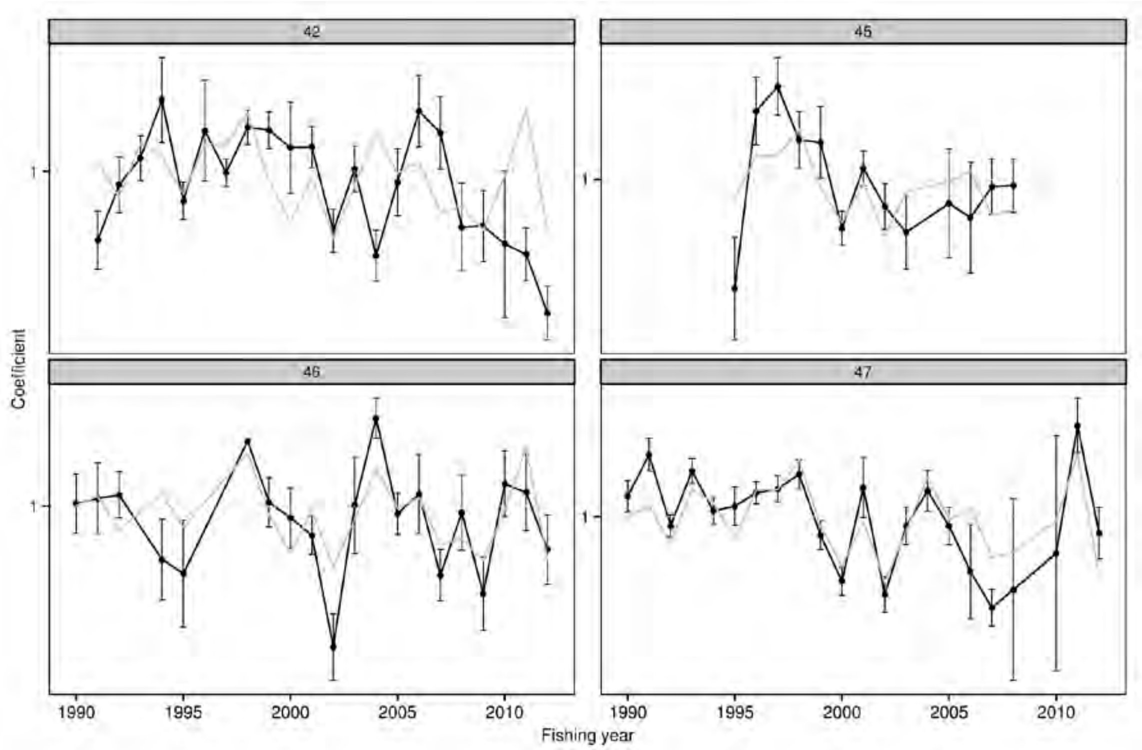


Figure L.13: Residual implied coefficients for each area in each fishing year in the SPO 1W_SN(COAST) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

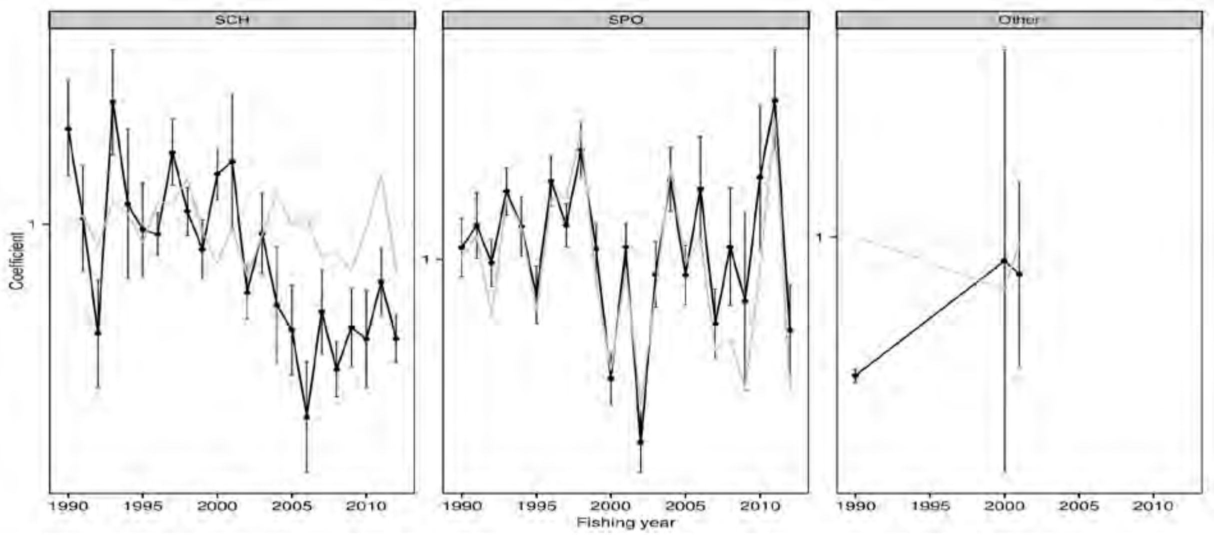


Figure L.14: Residual implied coefficients for each target species in each fishing year in the SPO 1W_SN(COAST) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

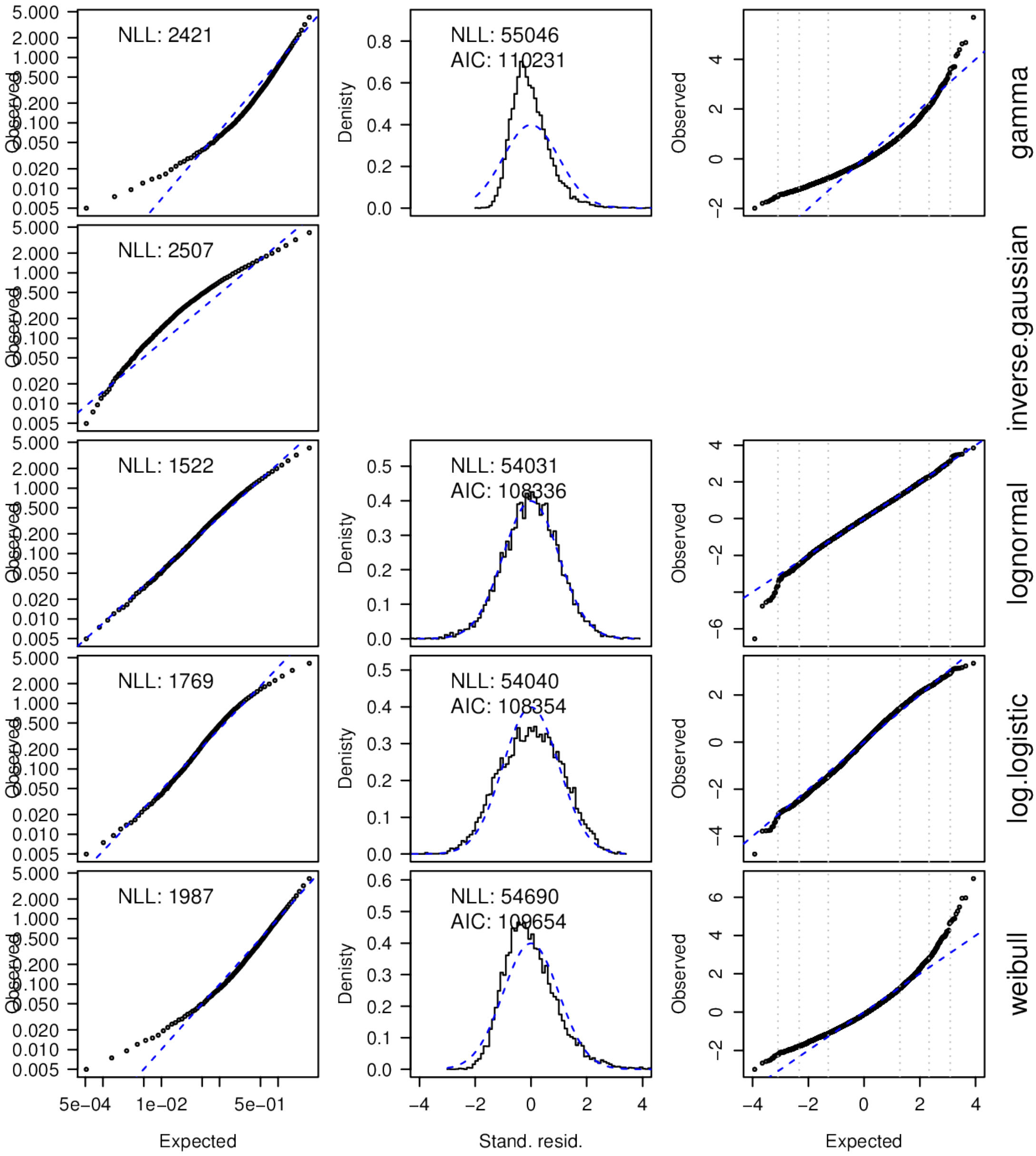


Figure L.15: Diagnostics for alternative distributional assumptions for catch in the SPO 1W_BT fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + target + num and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

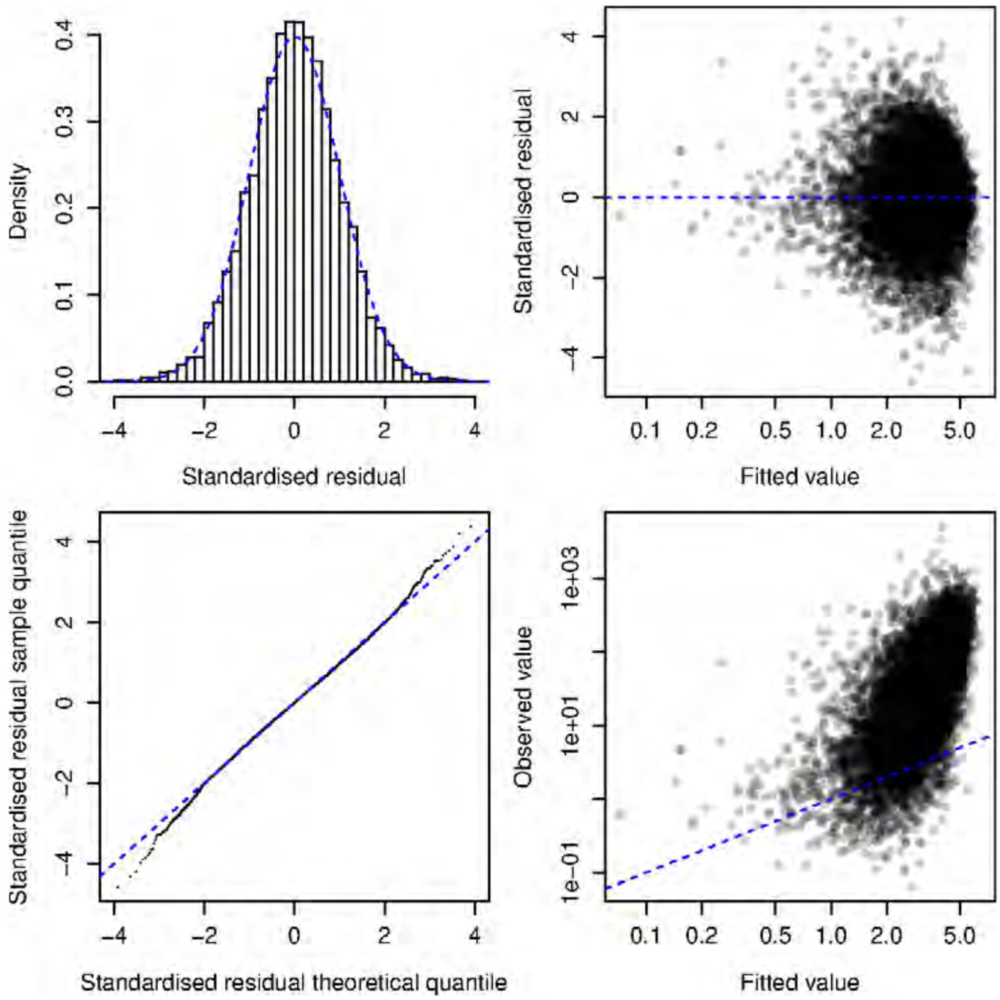


Figure L.16: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 1W_BT fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

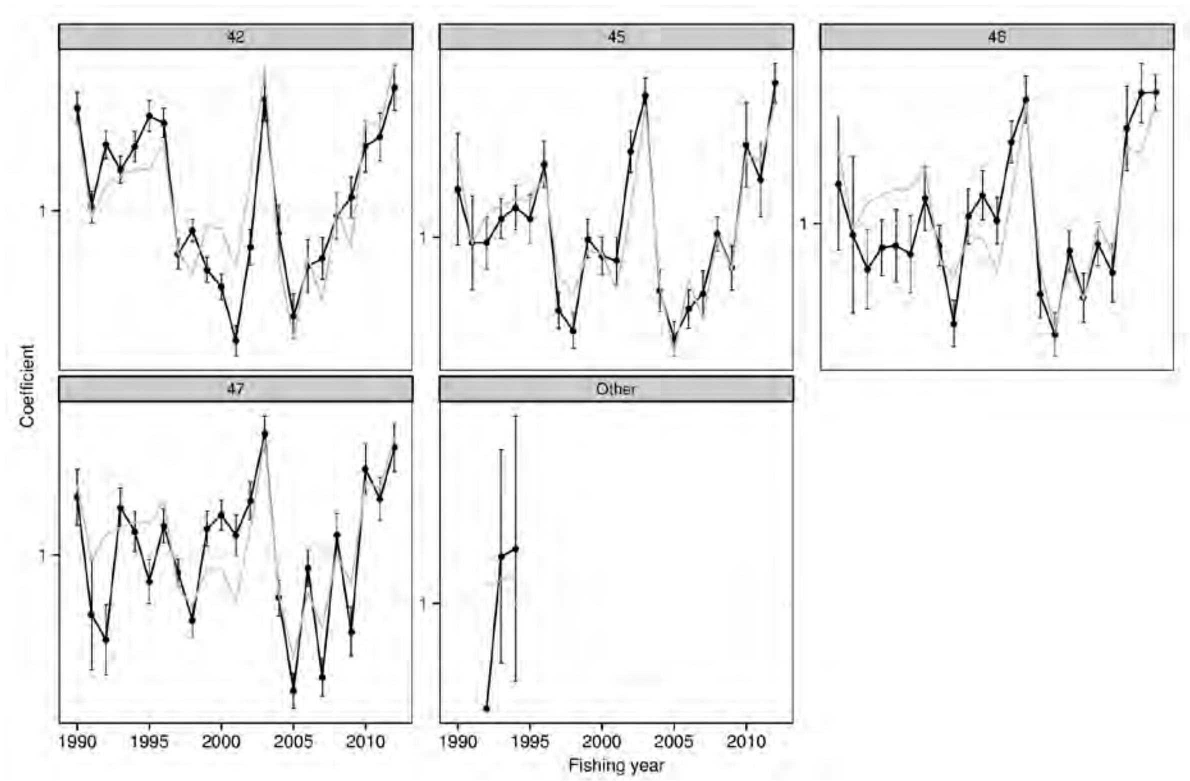


Figure L.17: Residual implied coefficients for each area in each fishing year in the SPO 1W_BT fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

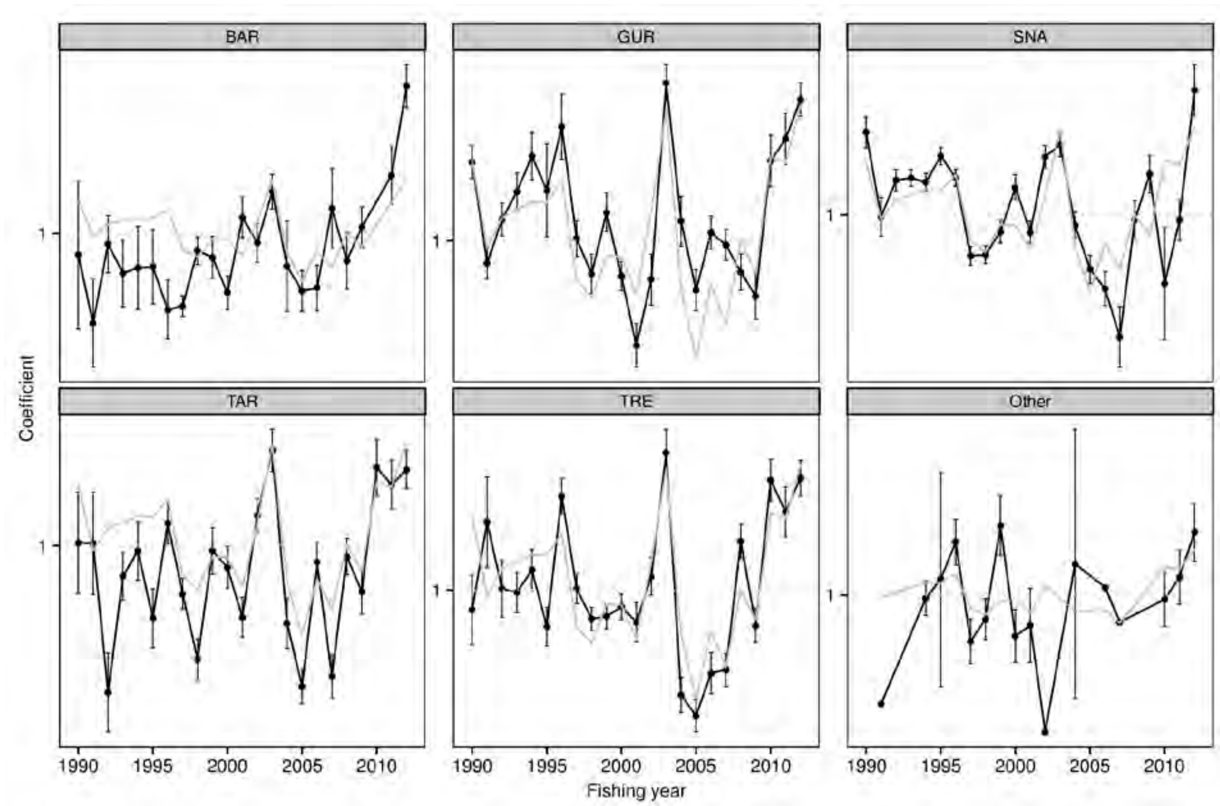


Figure L.18: Residual implied coefficients for each target species in each fishing year in the SPO 1W_BT fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

L.4 Model coefficients

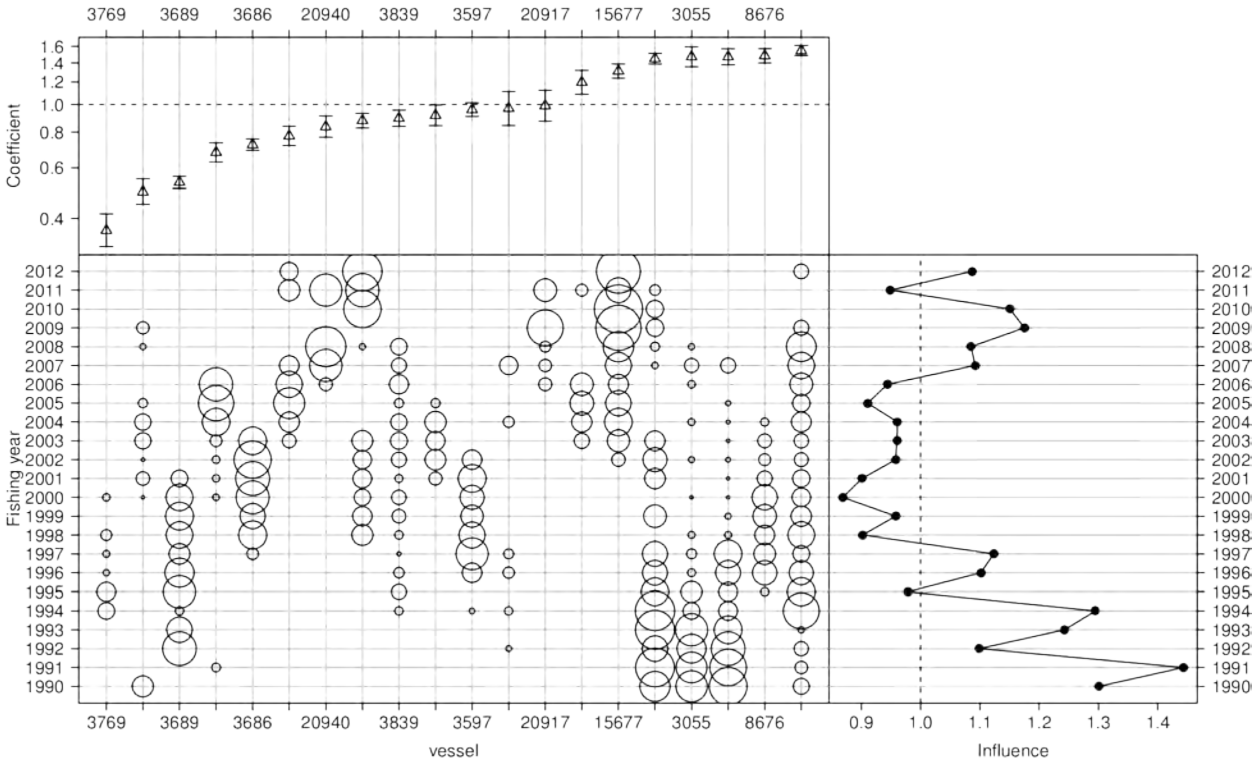


Figure L.19: Effect of vessel **in the Gamma model for the SPO 1W_SN(043) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

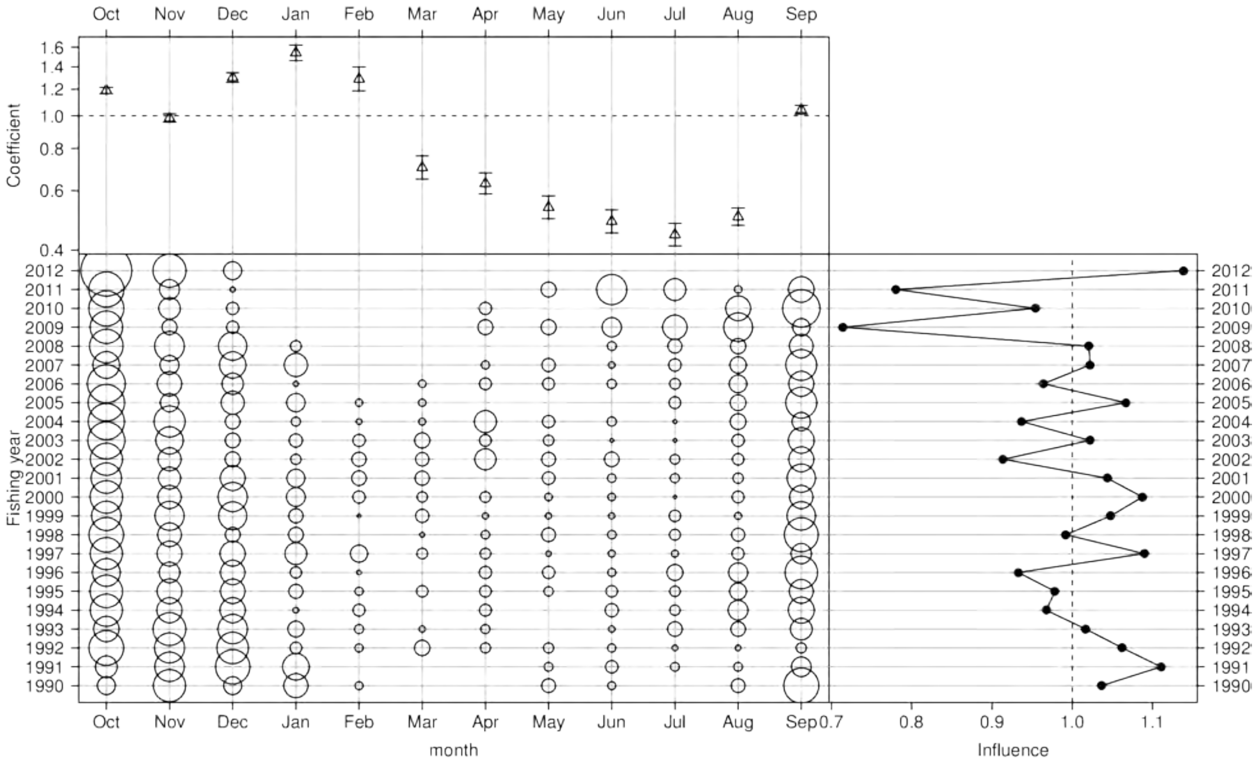


Figure L.20: Effect of month **in the Gamma model for the SPO 1W_SN(043) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

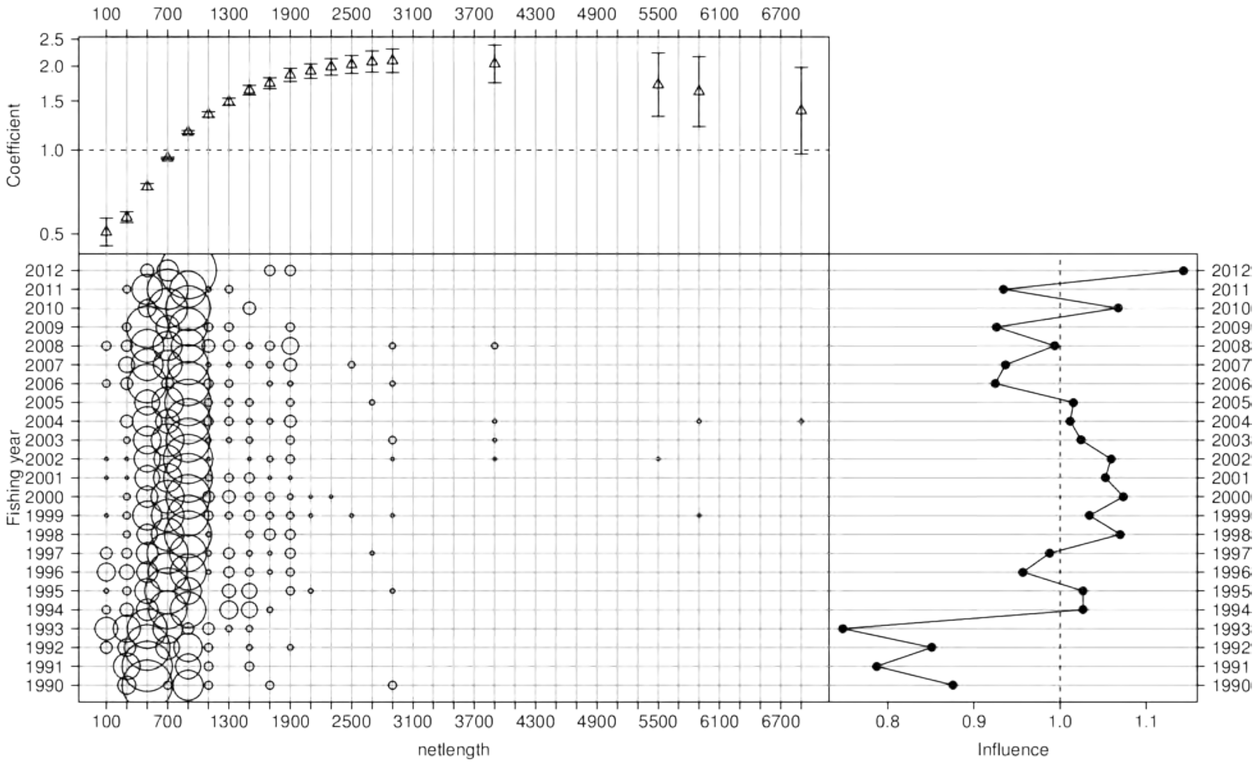


Figure L.21: Effect of netlength **in the Gamma model for the SPO 1W_SN(043) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

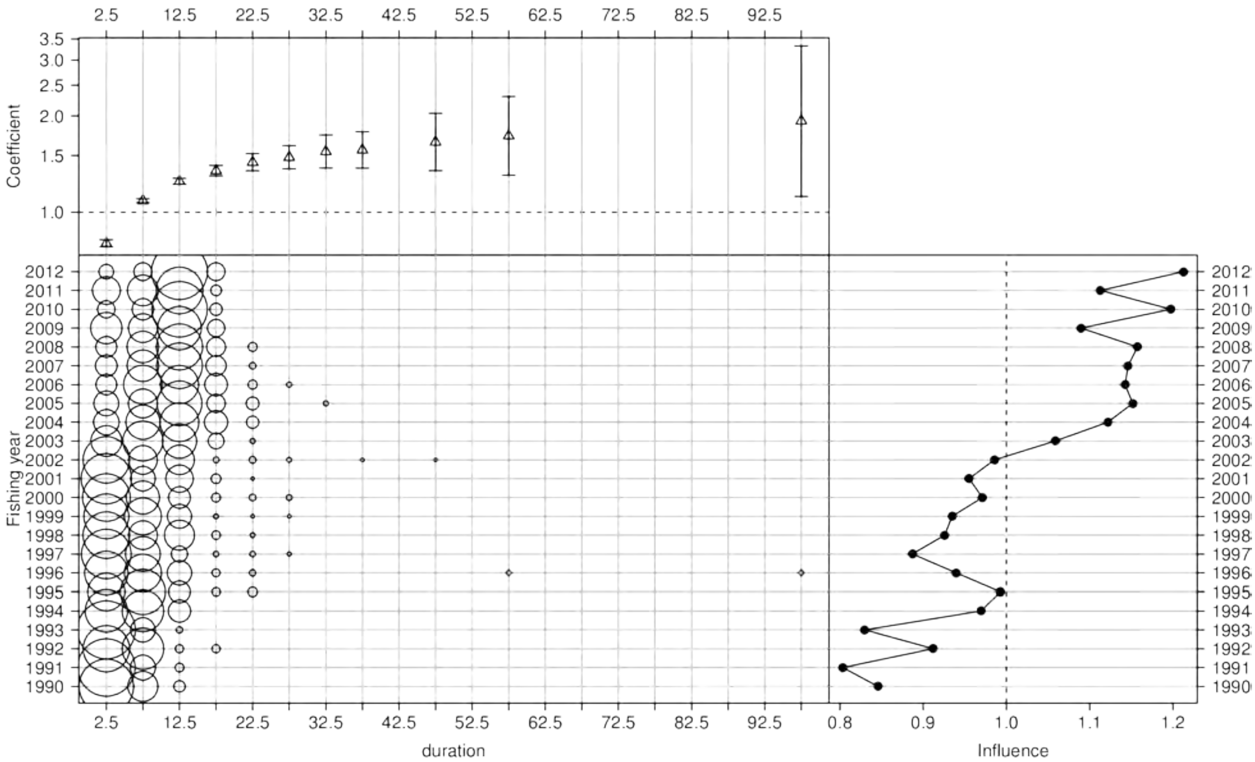


Figure L.22: Effect of duration **in the Gamma model for the SPO 1W_SN(043) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

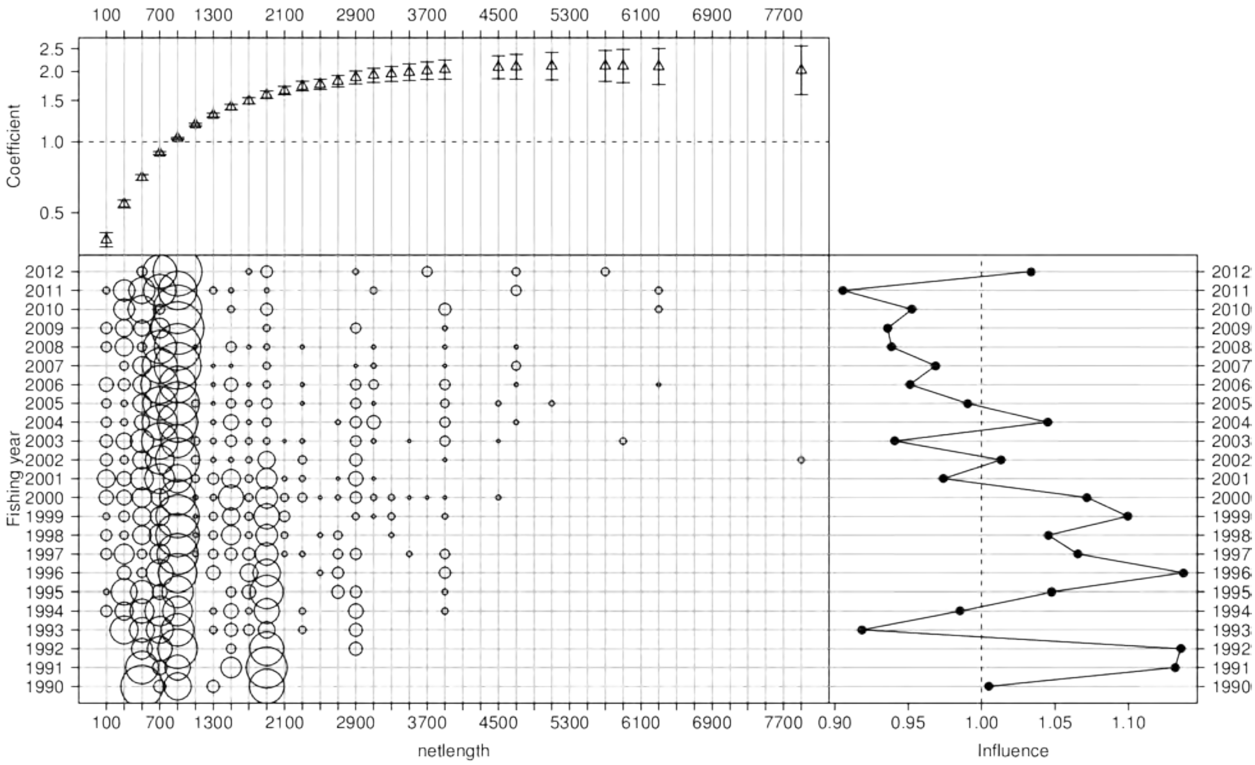


Figure L.23: Effect of netlength **in the Gamma model for the SPO 1W_SN(044) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

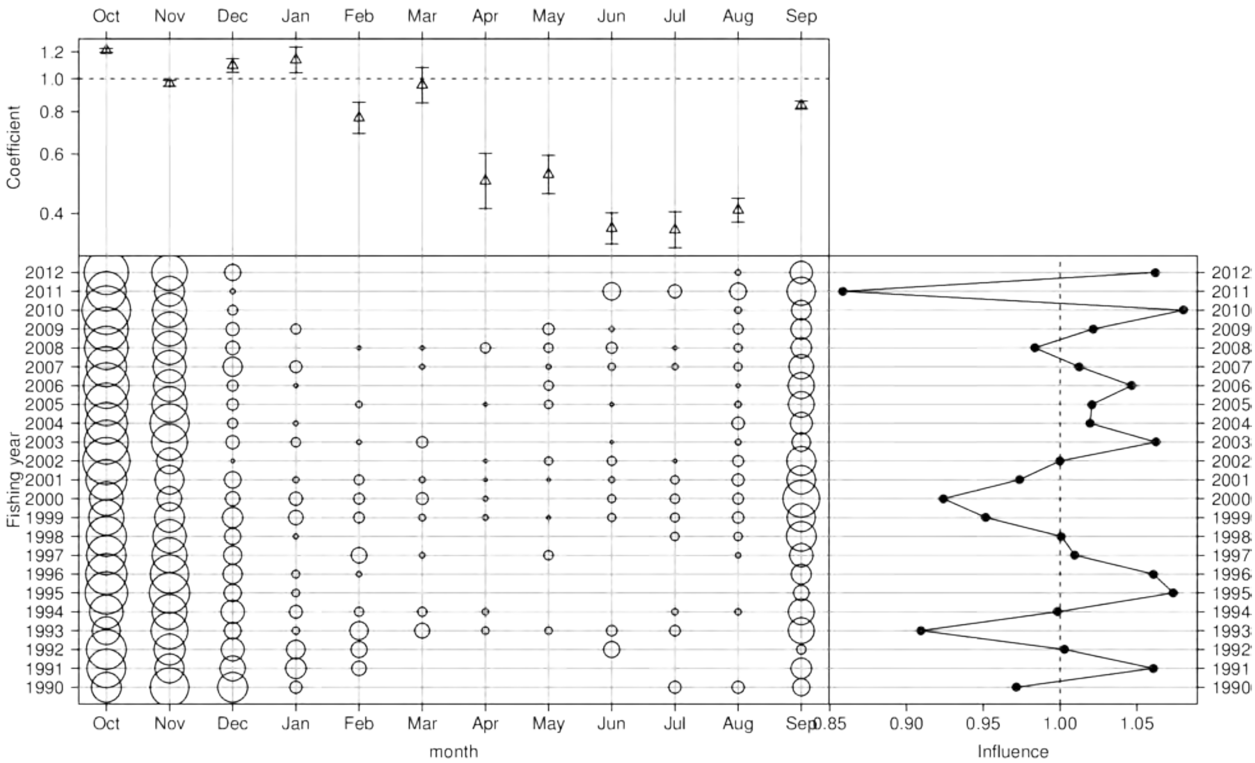


Figure L.24: Effect of month **in the Gamma model for the SPO 1W_SN(044) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

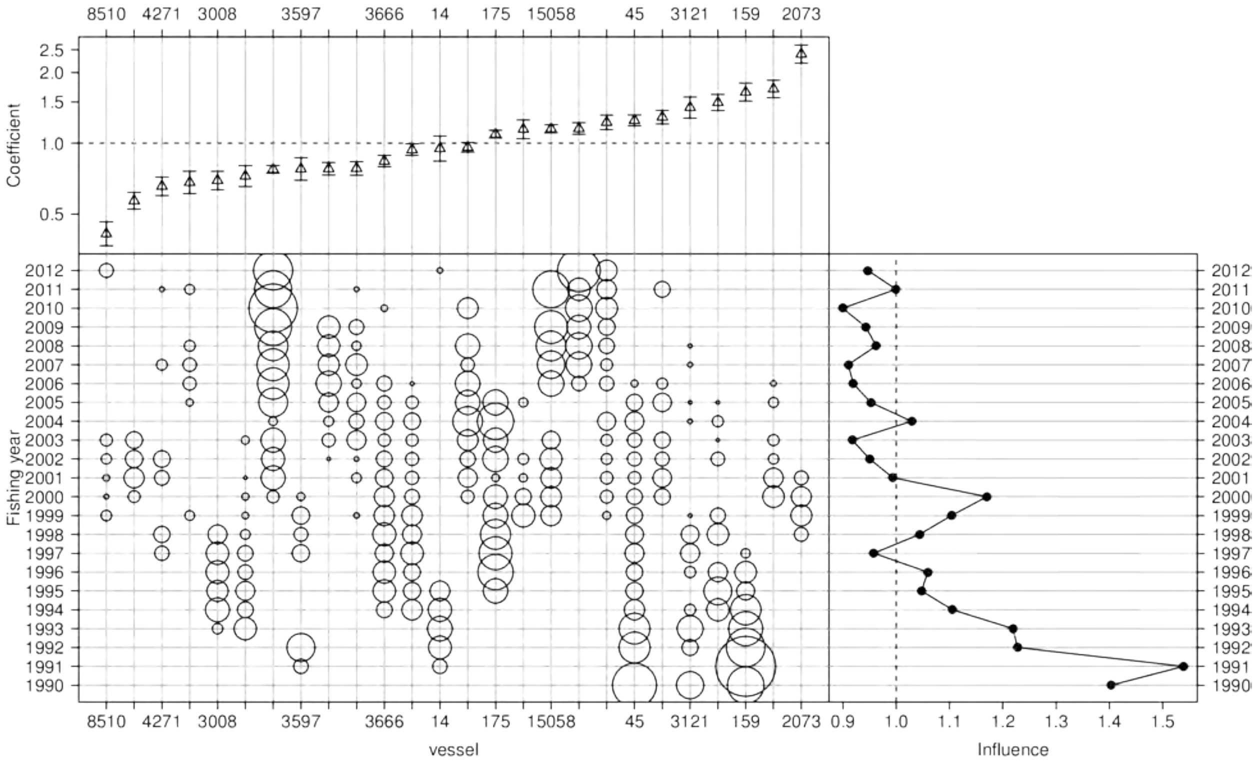


Figure L.25: Effect of vessel **in the Gamma model for the SPO 1W_SN(044) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

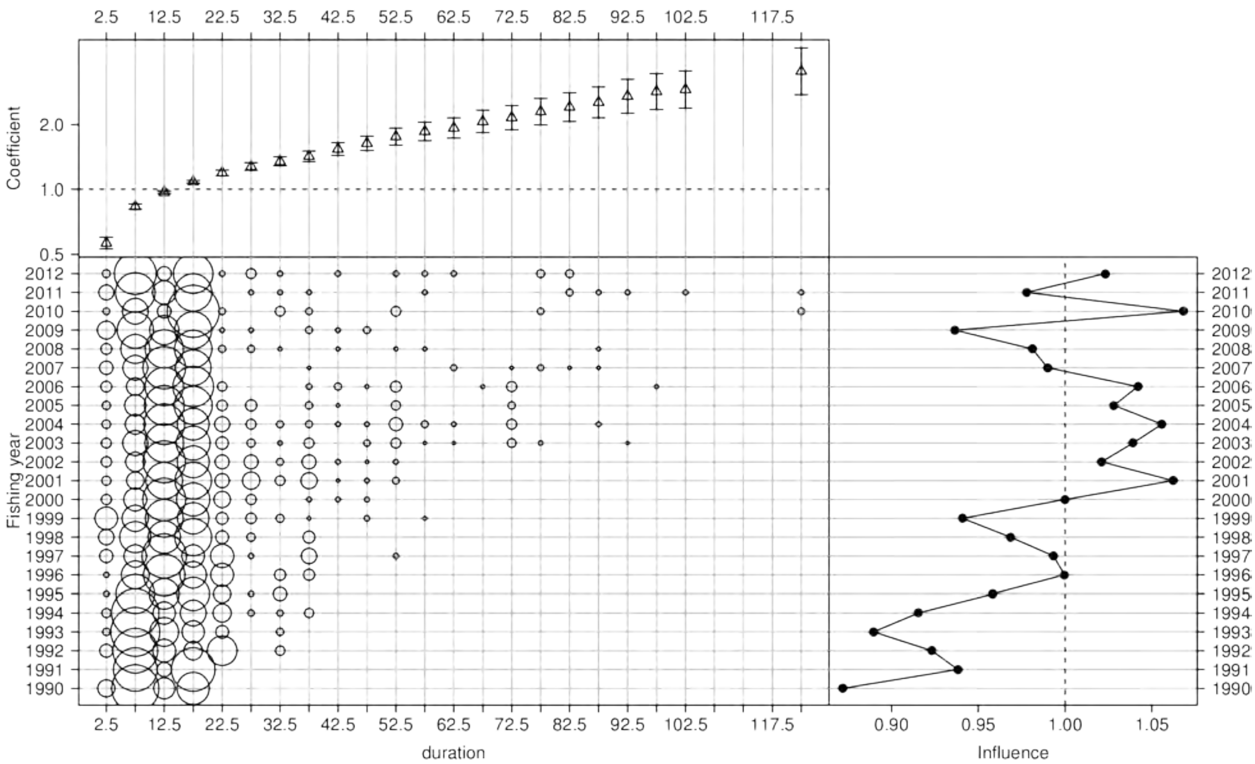


Figure L.26: Effect of duration **in the Gamma model for the SPO 1W_SN(044) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

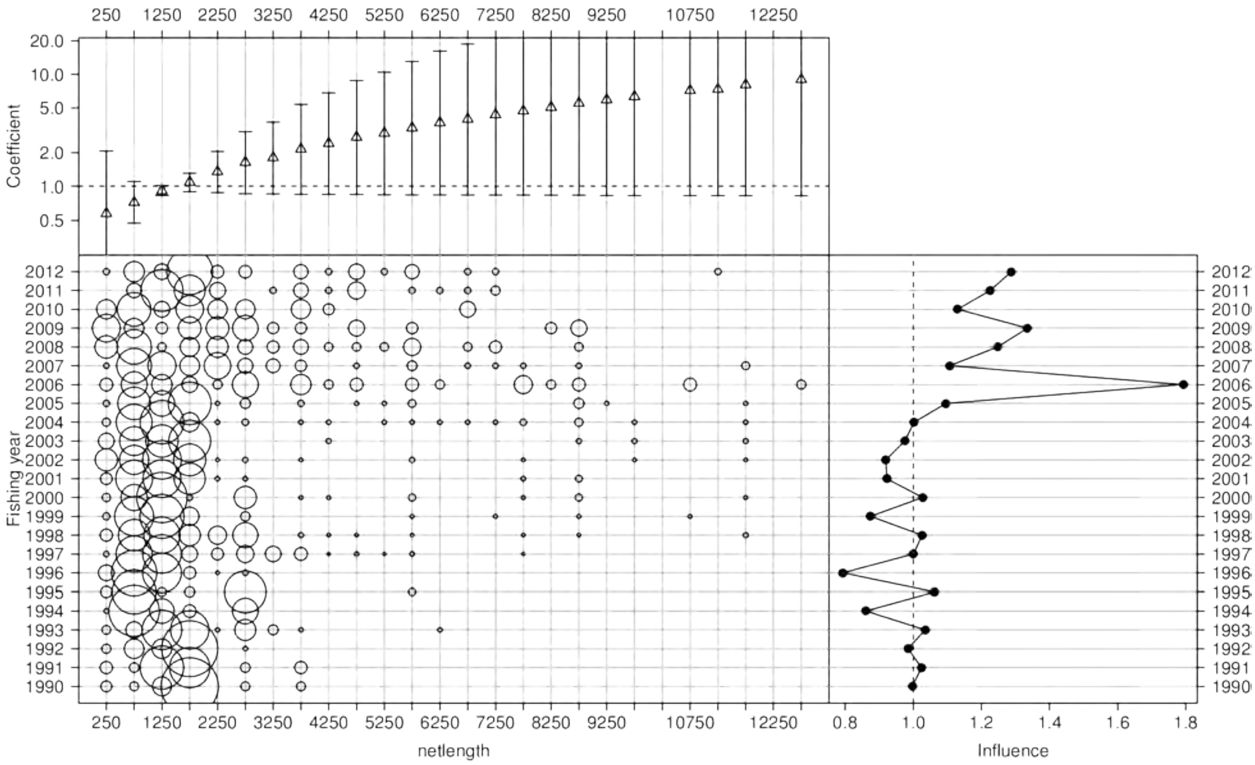


Figure L.27: Effect of netlength **in the Weibull model for the SPO 1W_SN(COAST) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

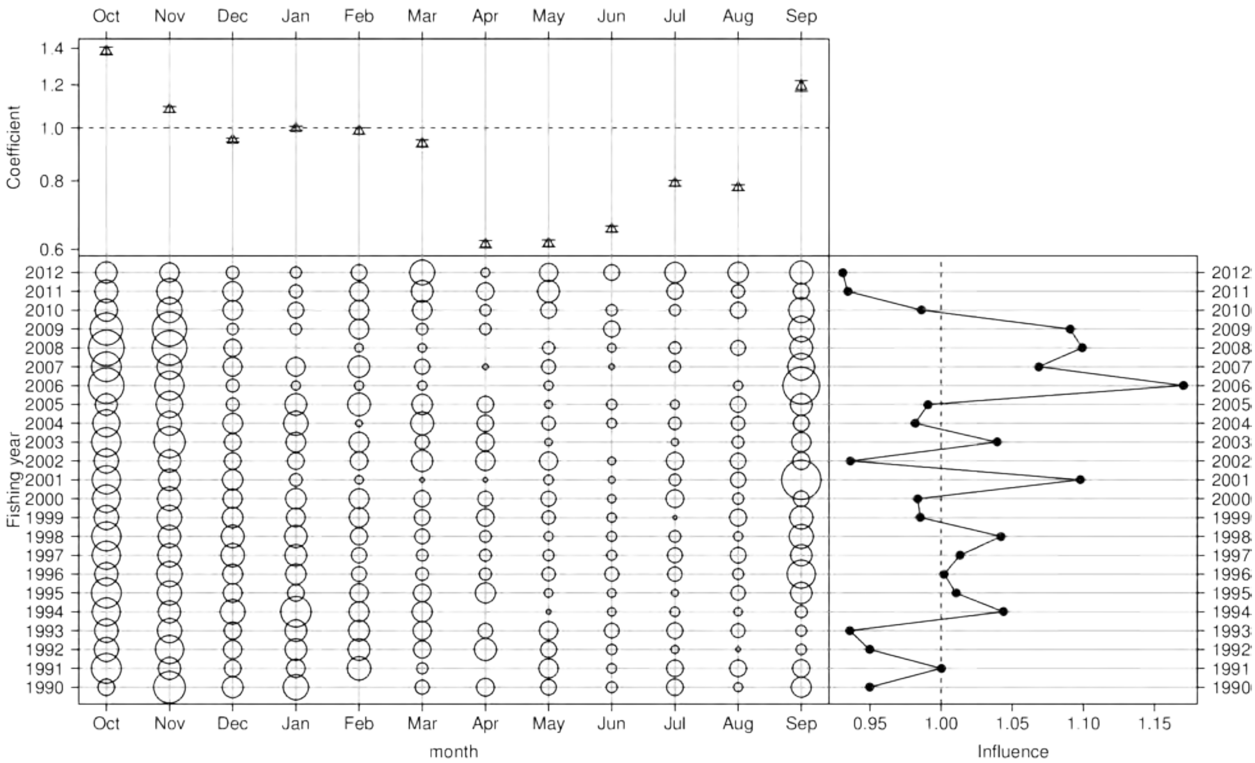


Figure L.28: Effect of month **in the Weibull model for the SPO 1W_SN(COAST) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

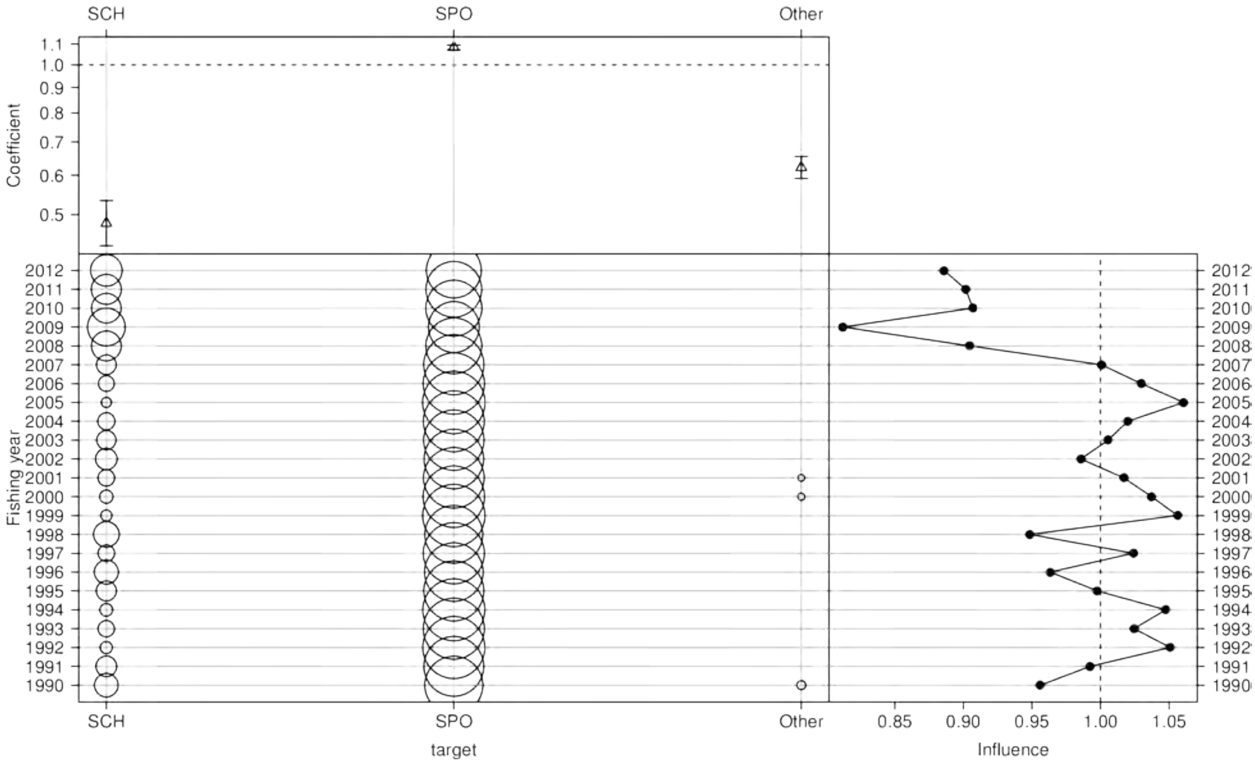


Figure L.29: Effect of target **in the Weibull model for the SPO 1W_SN(COAST) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

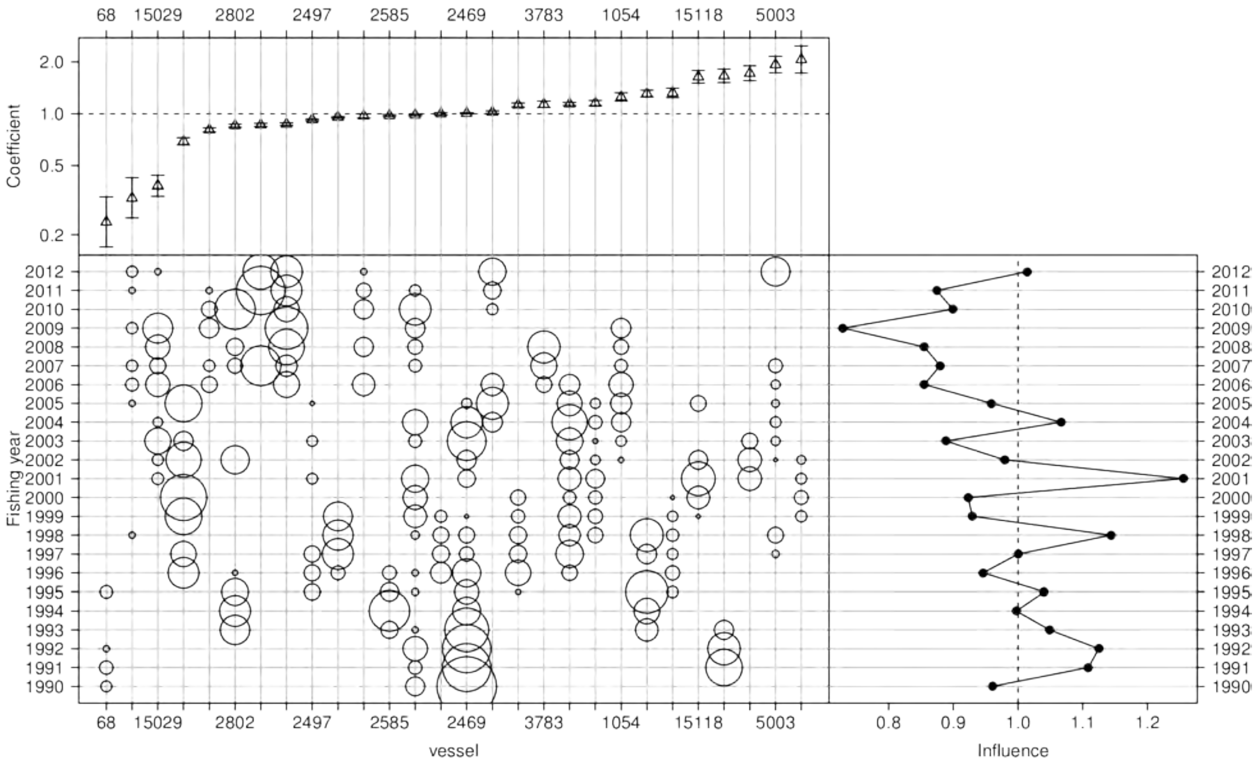


Figure L.30: Effect of vessel **in the Weibull model for the SPO 1W_SN(COAST) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

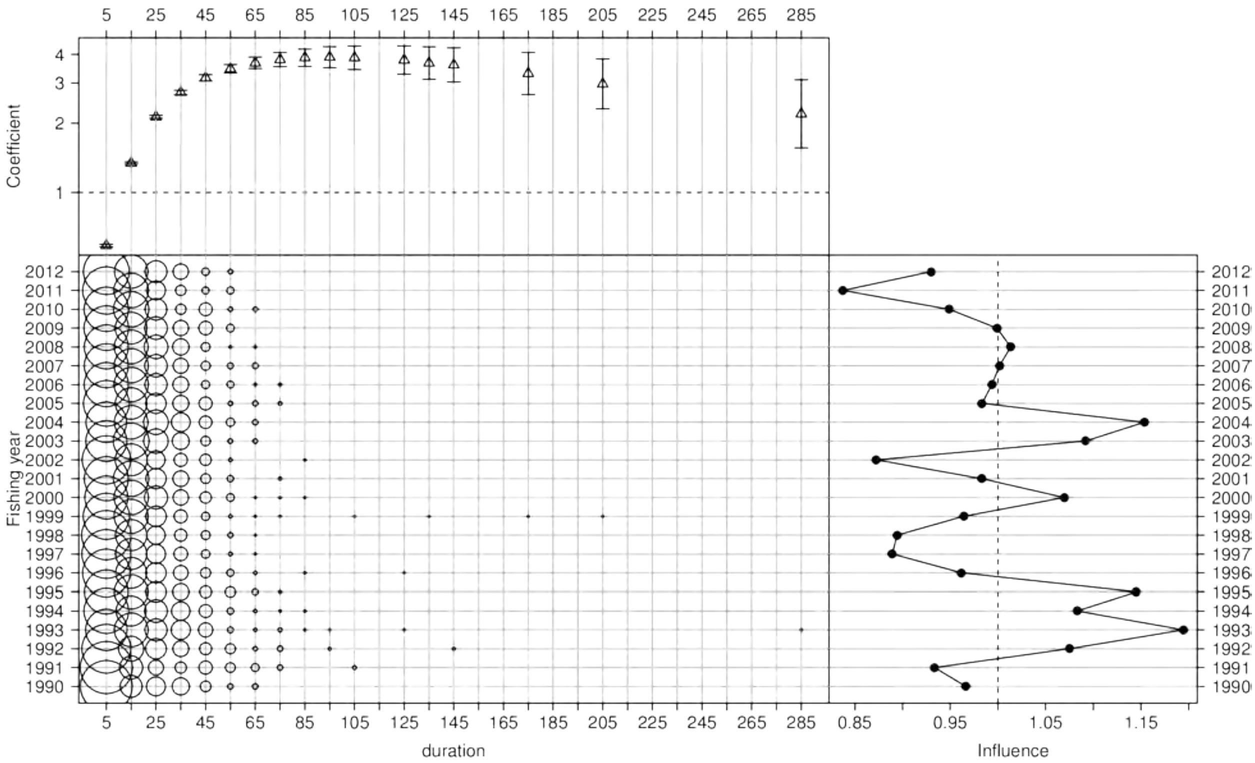


Figure L.31: Effect of duration **in the Lognormal model for the SPO 1W_BT fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

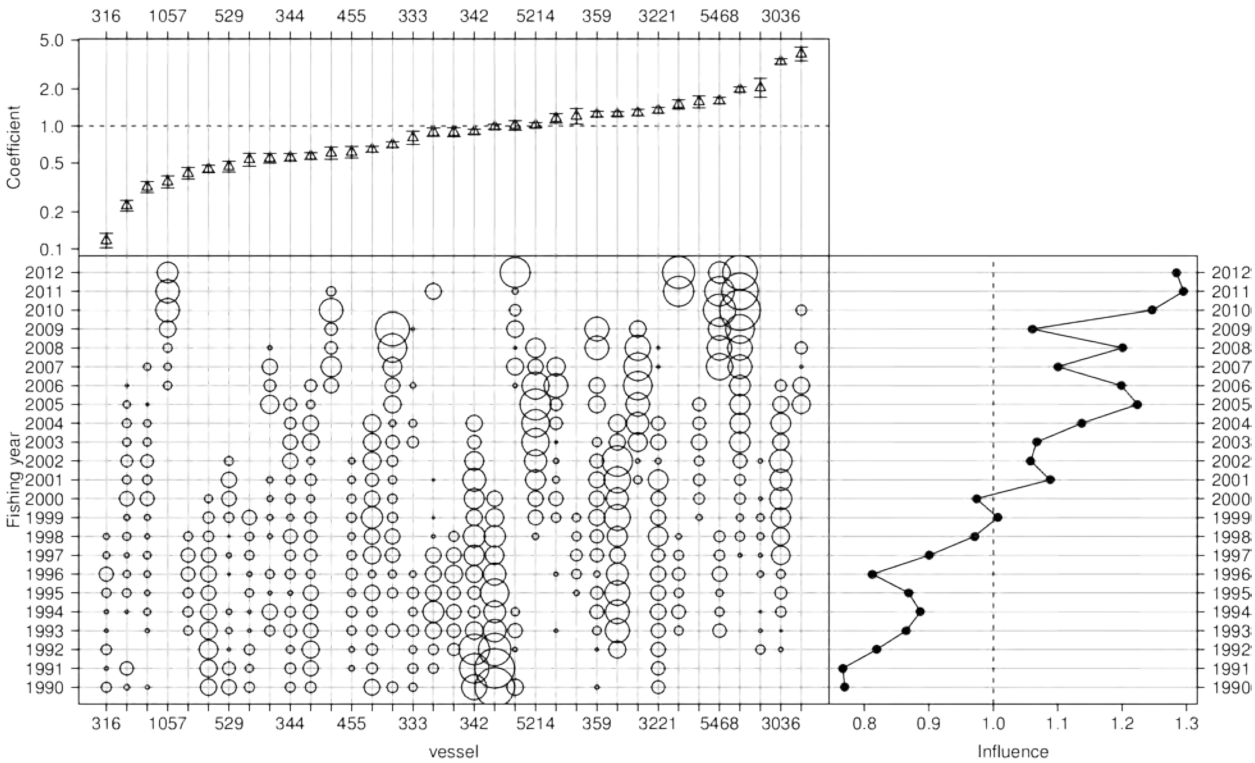


Figure L.32: Effect of vessel **in the Lognormal model for the SPO 1W_BT fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

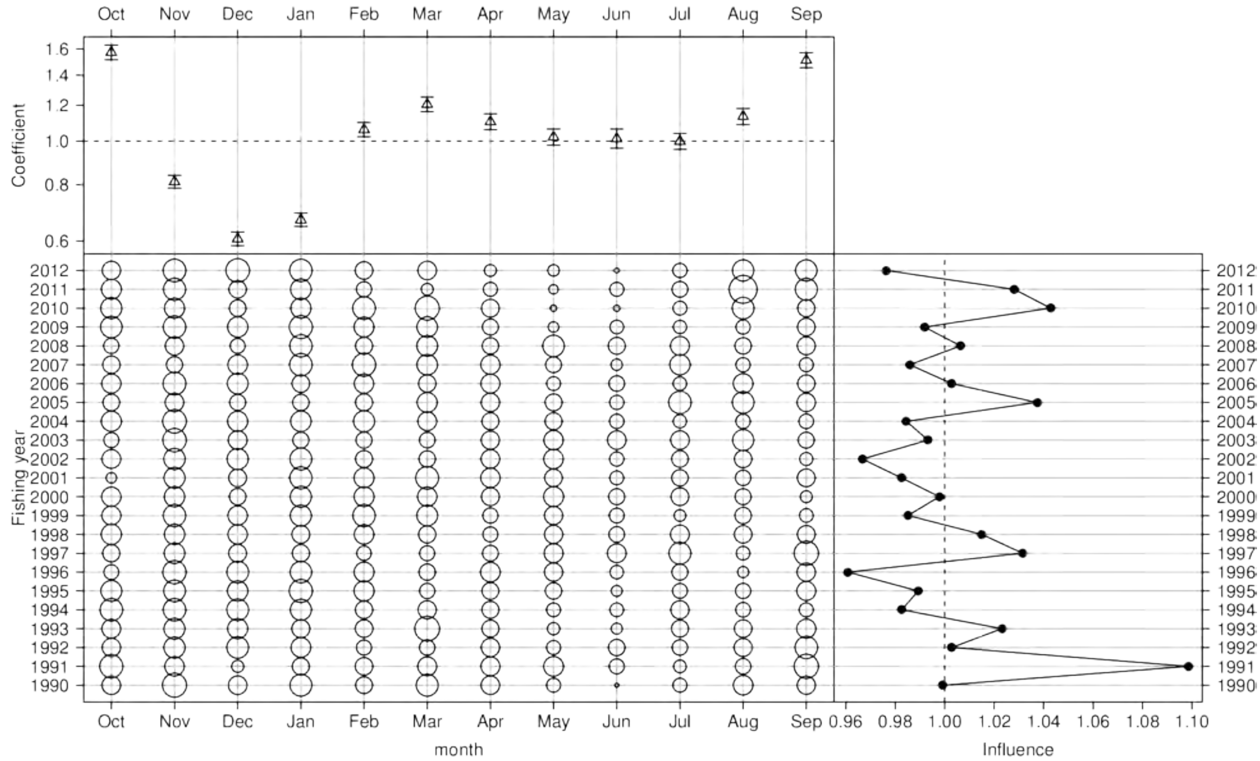


Figure L.33: Effect of month **in the Lognormal model for the SPO 1W_BT fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

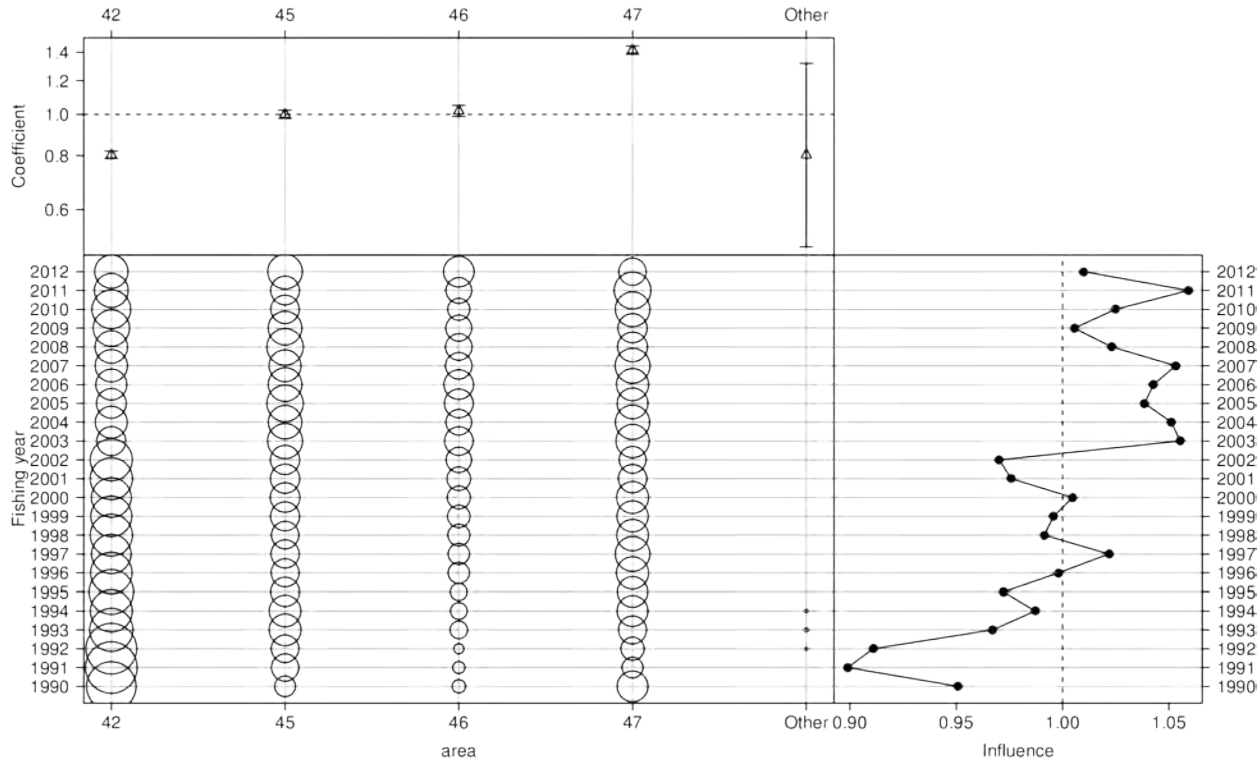


Figure L.34: Effect of area **in the Lognormal model for the SPO 1W_BT fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

L.5 CPUE indices

Table L.2: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error for the core data set by fishing year for each of the four CPUE models.

	SPO 1W_SN(043)					SPO 1W_SN(044)				
Fishing	All	Core				All	Core			
Year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Arithmetic	Arithmetic	Geometric	Standardi	SE
1990	1.726	2.300	2.477	2.127	0.104	1.502	1.330	1.259	1.163	0.139
1991	1.573	2.539	2.631	1.992	0.113	1.431	1.356	1.295	0.978	0.174
1992	1.860	1.929	1.823	1.751	0.078	1.215	1.316	1.234	1.289	0.111
1993	1.716	1.668	1.643	1.622	0.088	1.203	1.216	1.054	1.185	0.092
1994	1.361	1.651	1.639	1.359	0.078	1.104	1.057	1.036	1.059	0.079
1995	1.334	1.236	1.115	1.220	0.064	1.681	1.582	1.449	1.459	0.067
1996	1.049	1.127	0.988	0.956	0.063	1.435	1.294	1.449	1.362	0.066
1997	1.076	1.066	0.975	1.014	0.057	1.119	1.110	1.136	1.232	0.066
1998	0.671	0.631	0.630	0.819	0.066	1.198	1.299	1.036	1.179	0.060
1999	0.771	0.648	0.643	0.739	0.051	0.969	0.948	0.869	1.006	0.051
2000	0.958	0.858	0.853	1.005	0.050	1.001	1.023	0.980	0.999	0.047
2001	0.744	0.661	0.691	0.811	0.048	1.001	0.991	0.967	0.950	0.046
2002	0.663	0.573	0.588	0.725	0.050	0.695	0.693	0.734	0.728	0.046
2003	0.709	0.623	0.744	0.712	0.051	0.648	0.649	0.714	0.649	0.044
2004	0.753	0.664	0.724	0.741	0.060	0.945	0.963	1.047	0.939	0.060
2005	0.846	0.778	0.770	0.781	0.077	0.889	0.913	0.954	0.979	0.047
2006	0.684	0.684	0.754	0.716	0.074	0.799	0.770	0.852	0.775	0.054
2007	1.053	1.053	0.992	0.864	0.067	0.808	0.822	0.853	0.917	0.050
2008	0.853	0.922	0.813	0.732	0.086	0.599	0.585	0.603	0.635	0.054
2009	0.846	0.775	0.768	0.901	0.117	0.751	0.739	0.805	0.817	0.063
2010	1.070	1.092	1.116	0.937	0.155	1.099	1.160	1.293	1.161	0.082
2011	0.798	0.714	0.606	0.898	0.077	0.802	0.936	0.847	1.046	0.064
2012	1.148	1.266	1.586	1.025	0.097	0.949	0.984	1.107	1.018	0.074

Table L.2: (continued)

	SPO 1W_SN(coast)					SPO 1W_BT)				
Fishing	All	Core				All	Core			
Year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Arithmetic	Arithmetic	Geometric	Standardi	SE
1990	0.730	0.773	1.024	1.033	0.091	0.708	0.792	0.848	1.350	0.078
1991	1.037	1.112	1.223	1.092	0.084	0.540	0.571	0.570	0.934	0.078
1992	1.094	1.210	1.152	0.886	0.074	0.632	0.662	0.665	1.059	0.064
1993	1.114	1.086	1.293	1.209	0.068	0.831	0.776	0.768	1.097	0.049
1994	1.086	1.263	1.369	1.115	0.079	0.861	0.833	0.754	1.129	0.050
1995	1.078	0.980	1.044	0.903	0.077	0.960	0.902	0.773	1.127	0.054
1996	1.123	1.173	1.260	1.201	0.063	0.994	0.918	0.924	1.244	0.051
1997	1.384	1.314	1.214	1.204	0.057	0.792	0.749	0.749	0.815	0.047
1998	1.763	1.811	1.501	1.429	0.062	0.721	0.672	0.689	0.753	0.043
1999	1.036	1.064	1.119	0.974	0.066	0.975	0.912	0.783	0.903	0.049
2000	0.764	0.742	0.748	0.773	0.065	1.043	0.999	0.869	0.898	0.049
2001	1.268	1.381	1.663	1.003	0.075	1.158	1.108	0.848	0.767	0.049
2002	0.778	0.739	0.614	0.708	0.060	1.192	1.128	1.177	1.089	0.052
2003	0.859	0.829	0.984	0.948	0.071	1.700	1.621	2.126	1.679	0.056
2004	1.326	1.402	1.316	1.297	0.067	1.245	1.216	1.025	0.784	0.054
2005	0.945	0.972	0.959	1.014	0.068	0.872	0.833	0.898	0.583	0.056
2006	1.137	1.158	1.180	1.086	0.128	1.042	1.035	1.154	0.800	0.063
2007	0.905	0.823	0.820	0.814	0.096	0.952	0.932	0.840	0.675	0.062
2008	0.856	0.864	0.759	0.841	0.127	1.108	1.043	1.334	0.965	0.060
2009	0.934	0.613	0.492	0.737	0.156	1.156	1.150	0.991	0.836	0.065
2010	0.840	0.885	0.854	1.005	0.143	1.344	1.753	1.873	1.370	0.093
2011	0.943	0.954	0.856	1.476	0.125	1.546	1.750	1.996	1.332	0.086
2012	0.618	0.662	0.584	0.736	0.103	1.552	1.871	2.298	1.703	0.075

Appendix M. CPUE ANALYSES FOR SPO 2 AND SPO 3

M.1 General overview

The trawl fishery in SPO 2 only rarely reports estimated catches for rig as this species rarely enters the top five or eight (depending on form version) species in a tow or for a day of fishing. This makes allocating landings to the effort stratum problematic, as this is done proportionate to estimated catch. This study follows Starr (2011) in performing the analysis on complete fishing trips which loses the target species and statistical area information within each trip. Previous work has compared the estimated year indices using this treatment to those from datasets groomed to include only trips that reported to a single target and area, and concluded that the loss of those explanatory variables did not compromise the analysis. That sensitivity analysis was not repeated in this study.

The three analyses done for SPO 3 were all based on landed catch allocated to effort stratum as described in Starr (2007).
Indices from this study for mixed target bottom trawl in SPO 2 and SPO 3 were accepted with a Science Information Quality Rank=1 by the SINSWG with the comment that they should monitor adult population below about 1 m in length, and the index and analysis were credible. Indices from the shallower flatfish trawl fishery in SPO 3 were not accepted due to the low headline height used to capture flatfish. The shark setnet series for SPO 3 was thought likely to be affected by closures aimed at protecting Hector's dolphins and was given a Science Information Quality Rank=2.

M.1.1 Fishery definitions for SPO 2 and SPO 3 CPUE analysis

Fisheries for rig in SPO 2 also include a setnet fishery that has been investigated in the past but was rejected by the NINSWG as a reliable index for rig abundance. It was therefore not updated in this study, leaving only one index of abundance for SPO 2 based on bycatch from a mixed species inshore trawl. Three discrete fishery definitions were updated in SPO 3: a mixed species inshore trawl bycatch, a shallower flatfish trawl bycatch, and a setnet fishery targeted at sharks, including elephantfish.

SPO 2_BT [mixed target bottom trawl (trip-based)] – The fishery is defined from bottom single trawl fishing events that fished Statistical Areas 011 – 016, and targeted GUR, TAR, or FLA. Data are rolled up to trip stratum resolution. Only the analysis of positive catches is presented.

SPO 3_BT(MIX) – SPO 3 mixed target bottom trawl – The fishery is defined from bottom single trawl fishing events that fished Statistical Areas 018 – 032, and targeted BAR, STA, RCO, SPO, SPD, ELE, GUR, or TAR. Only the analysis of positive catches is presented.

SPO 3_BT(FLA) – SPO 3 flatfish bottom trawl – The fishery is defined from bottom single trawl fishing events which fished in Statistical Areas 018 – 032, and targeted FLA. Only the analysis of positive catches is presented.

SPO 3_SN(SHK) – SPO 3 shark setnet -- The Fishery is defined from setnet fishing events which fished in statistical areas 018 – 032, and targeted SPO, SCH, SPD, or ELE. Only the analysis of positive catches is presented.

M.2 Unstandardised CPUE

M.2.1 SPO 2_BT(MIX) Mixed target bottom trawl in SPO 2

Effort in the SPO 2 bottom trawl fishery peaked in the early 1990s at about 1400 trips, and has been declining steadily since then to sit nearer 1000 trips in 2011–12 (Figure M.1). The effort is defined by trips which landed rig which means that there is no information on success rate from individual tows.

Catch rates in the selected trips were flat during the 1990s at about 6 kg per tow but have increased in every year from 2001–02 (except 2005–06), reaching 10 kg per tow in 2011–12 (Figure M.1). The increasing trend evident in the roll-up of data to trip stratum should not affect the calculation of positive catch rate (Figure M.2), and the binomial standardisation of success rate (which could be compromised by such a trend) is not attempted here.

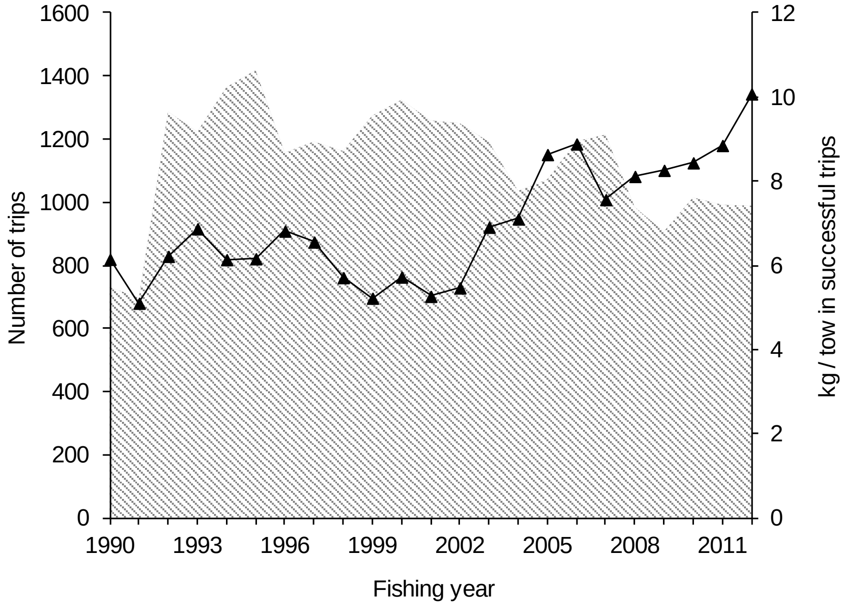
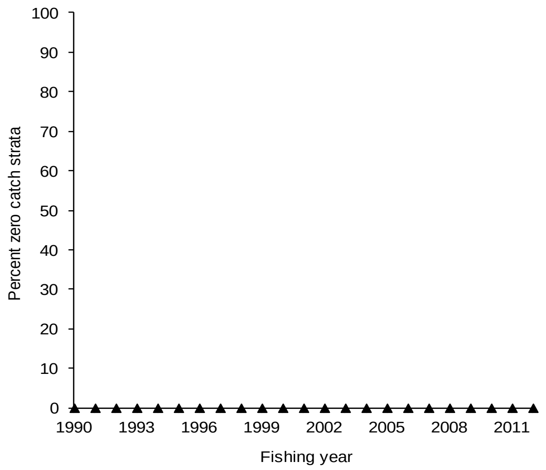


Figure M.1: Number of qualifying trips in SPO 2_BT(MIX) (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/tow, black line) of rig in successful trips, by fishing year.



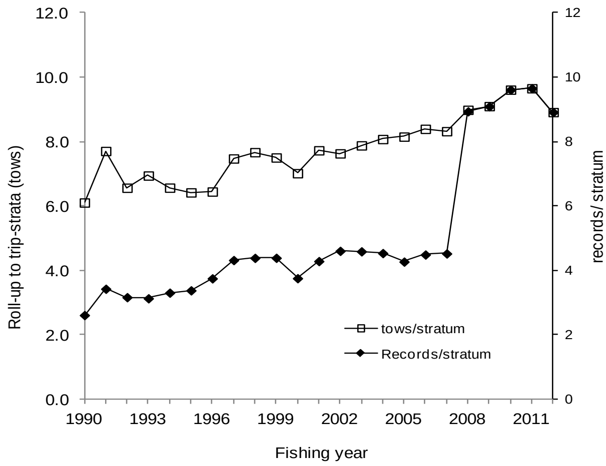


Figure M.2: The percent of trip-strata in SPO 2_BT(MIX), with zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum, by fishing year.

M.2.2 SPO 3_BT(MIX) Mixed target bottom trawl in SPO 3

Effort in the SPO 3 mixed species inshore trawl fishery peaked in the mid 1990s near 4000 trips per year and has declined steadily since then to less than 1500 trips in 2011–12 (Figure M.3). The proportion of those trips that landed rig has increased steadily over the same period. Catch rates in those successful trips have been increasing since 1998–99 from a nadir near 7 kg per tow to almost 20 kg per tow in 2011–12 (Figure M.3). The pattern of zero catches looks a little different at trip stratum resolution, increasing as it does in the most recent five years which reflects changes in reporting of catch and effort coincident with the switch from daily to tow-by-tow form (Figure M.4).

The rollup of data to trip stratum reveals fewer tows per stratum after 2006–07, probably because more detail about targeting is reported on the new form (Figure M.4). This in turn means that more information about zero catches is retained. This trend could potentially compromise an analysis of the probability of capture, but should not affect the analysis of positive catches.

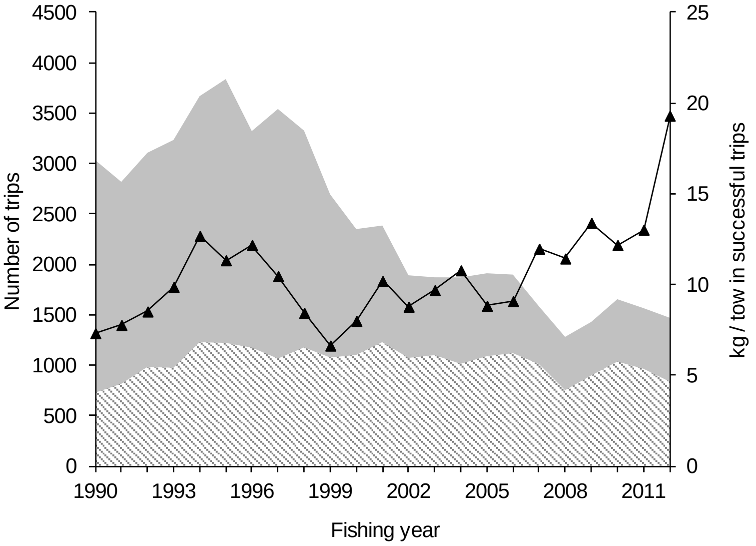
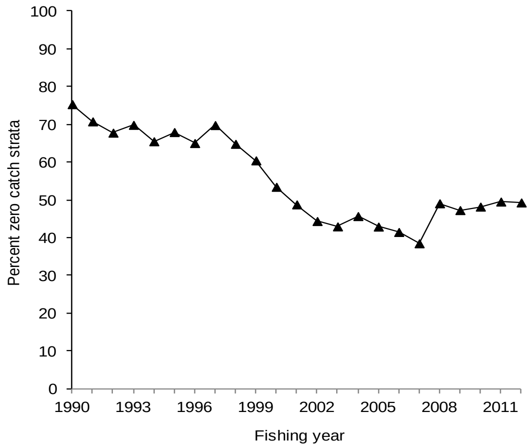


Figure M.3: Number of qualifying trips in SPO 3_BT(MIX) (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/tow, black line) of rig in successful trips, by fishing year.



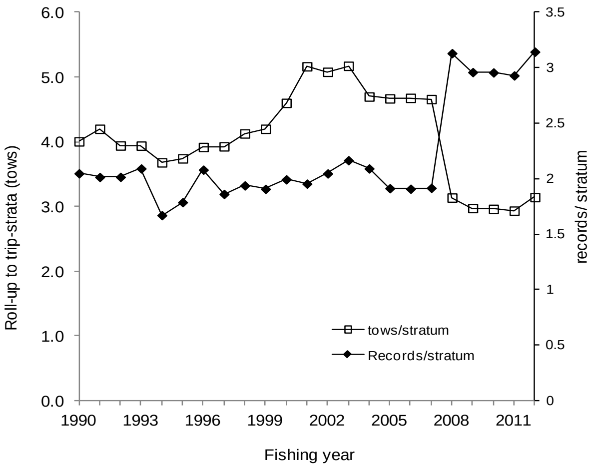


Figure M.4: The percent of trip-strata in SPO 3_BT(MIX), with zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum, by fishing year.

M.2.3 SPO 3_BT(FLA) Flatfish bottom trawl in SPO 3

The SPO 3 flatfish trawl fishery falls into two parts; effort was relatively stable at more than 4000 trips per year during the 1990s, and then declined steadily during the 2000s to reach about half of that level by 2007–08 (Figure M.5). The proportion of those trips reporting a landing of rig has increased, while catch rates in successful trips has been quite flat overall, although with somewhat lower catch rates for much of the 2000s (Figure M.5). There are increasing trends in the number of records (and tows) rolled up per trip stratum that could explain some of the decline in zero catches at trip stratum resolution (but not the decline evident at trip resolution) and may indicate that there has been a shift towards longer trips or greater fidelity to statistical area within trips (Figure M.6).

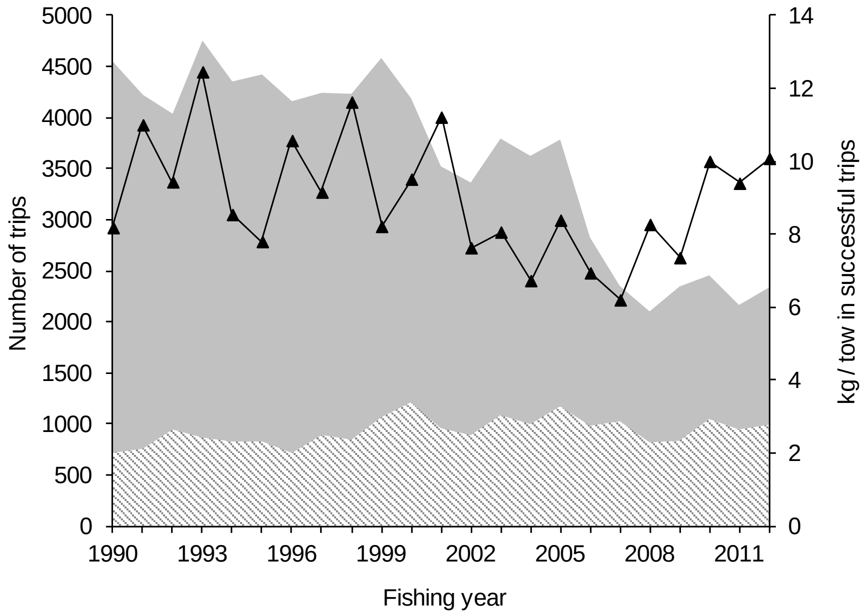


Figure M.5: Number of qualifying trips in SPO 3_BT(FLA) (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/tow, black line) of rig in successful trip-strata, by fishing year.

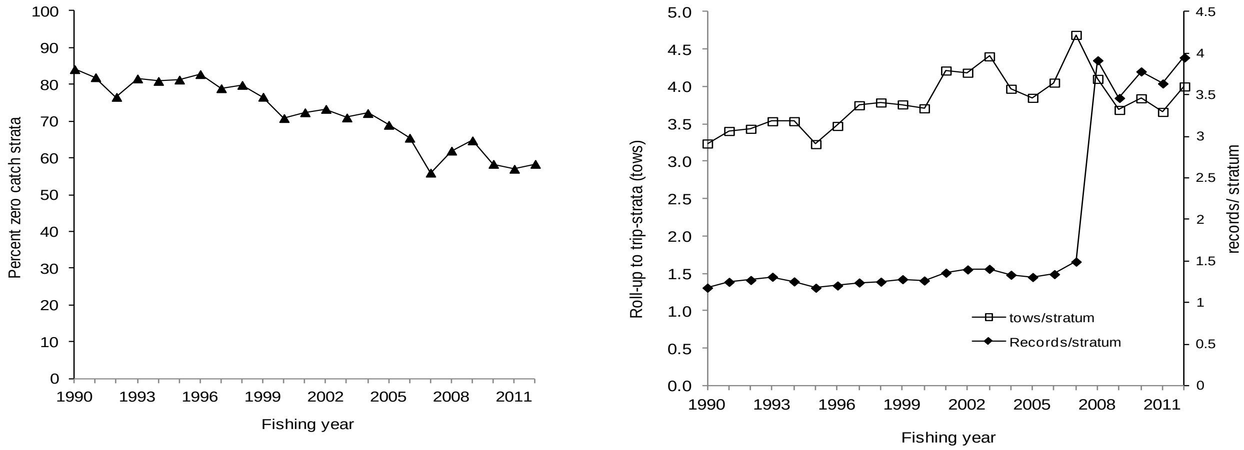


Figure M.6: The proportion of trip-strata in SPO 3_BT(FLA), with zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of tows per trip-stratum, by fishing year.

M.2.4 SPO 3_SN(SHK) Shark setnet in SPO 3

Effort in the SPO 3 setnet fishery peaked in the early 1900s at almost 2500 trips per year and then waned, reaching a new level at about half of the peak activity by the early 2000s where it has been relatively stable since (Figure M.7). Catch rates in successful trips increased during the mid-1990s when effort was declining and peaked in 1997–98 at about 200 kg per successful set, but has declined by about 25% since then (Figure M.7). The pattern of zero catches is consistent; peaking in the beginning of the series when catch rates were low, then declining as catch rates peaked. There is a recent increase in the proportion of zero catches that coincides with the drop in catch rates (Figure M.8). This increase in zero catches is evident despite an increasing trend in the number of records rolled up into trip strata which has the potential to mask some zero catch records.

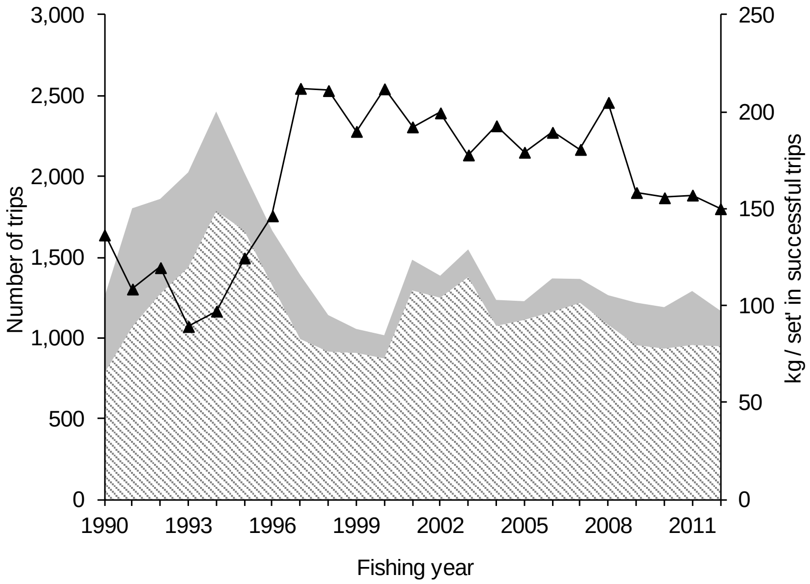


Figure M.7: Number of qualifying trips in SPO 3_SN(SHK) (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/set, black line) of rig in successful trip-strata, by fishing year.

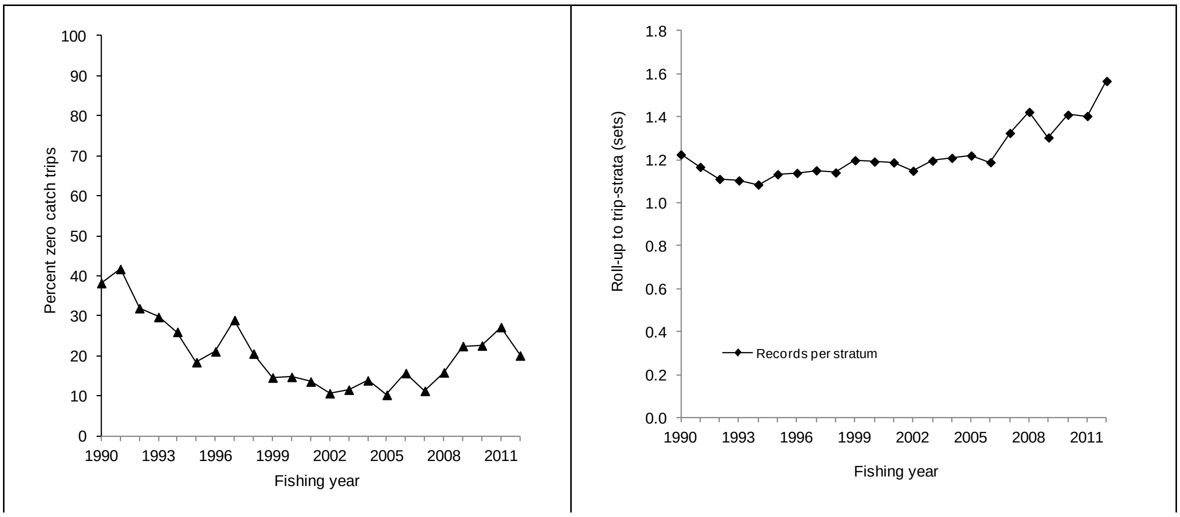


Figure M.8: The proportion of trip-strata in SPO 3_SN(SHK), with zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of sets per trip-stratum, by fishing year.

M.3 Standardised CPUE analysis

M.3.1 Core fleet definitions

The data sets used for the standardised CPUE analysis were restricted to those vessels that participated with some consistency in the defined fishery. Core vessels were selected by specifying two variables; the number of trips that determined a qualifying year, and the number of qualifying years that each vessel participated in the fishery. The effect of these two variables on the amount of landed rig retained in the dataset and on the number of core vessels, and the length of participation by the core vessels in each fishery are depicted in Figure N.1 to Figure N.4. The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of rig. The selection process usually reduced the number of vessels in the dataset by about 70% while reducing the amount of landed rig by about 20%. Summaries for the core vessel data sets are presented in Table N.1.

M.3.2 Model selection, diagnostics and trends in model year effects

The final models selected for standardising positive catches in each fishery are described in Table M.1 to Table M.4. These tables include those explanatory variables that met the AIC criteria and each is not necessarily a complete list of the variables that were offered[3]. The variables that met the acceptance criteria based on a 1% improvement in R^2 are indicated with asterisks in the table, along with the amount of deviance they explained.

Following each table are step-influence plots that demonstrate the progressive effect on the annual indices of each explanatory variable as it enters the model, and shows the influence of each variable on the annual coefficients in adjacent panels. These plots highlight the observation made in Bentley et al. (2011) that the variables that explain the most deviance are not necessarily the ones responsible for most of the difference between standardised and observed series of CPUE. The influence of an explanatory variable is a combination of its GLM coefficients and its distributional changes over years, and these are contrasted and combined in Coefficient-Distribution-Influence (CDI) plots (Bentley et al. 2011) given for each accepted explanatory variable (see Appendix N.4).

Diagnostic plots of the residuals from each final model fit are given in Appendix N.3 and include residual implied coefficient plots for each statistical area and target species by year. These allow the comparison of the annual trends among statistical area and target species categories in each analysis, effectively serving as a proxy for an interaction analysis. The unstandardised and standardised indices from the final model for each fishery are given in Appendix N.5.

M.3.2.1 SPO 2_BT(MIX) – SPO 2 Mixed species bottom trawl

The lognormal error distribution produced the best model fit to SPO 2_BT(MIX) data (Figure N.5), and the residuals from the final model showed a good fit of the data to the distributional assumption (Figure N.6). Fishing year was forced as the first variable and explained about 2% of the variance in catch, duration of fishing is the most important variable, entering second and explaining a further 35% of variance in catch. Vessel entered third and explained a further 10% of variance, and month was also accepted into the model but with little additional explanatory power (Table M.1). Statistical area and target were not available because of the amalgamation of data to fishing trip. The final model explained about 48% of the variance in log(catch). The annual indices are plotted at each step in Figure M.9.

A positive relationship between catch and tow duration, combined with a shift in the middle of the series towards longer tow duration gave effort a positive influence on catches, predicted to be responsible for at least a 30% increase in observed catch (Figure N.17). The coefficients for vessel show consistent differences in performance among vessels with respect to rig catch (Figure N.18). A trend of the higher performing vessels departing the fishery at the end of the 1990s has subsequently been reversed, and the influence of changes in the core fleet falls into two parts; negative during the 1990s and with an increasing trend in the 2000s. Improvements to the fleet are estimated to account for up to a 35% increase in observed catches since 2001–02. The month coefficients show a fishery that peaks in spring in terms of catch rate, with a secondary small peak in April (Figure N.19). Effort in this fishery is remarkably consistent however, and small shifts in the seasonality of fishing have been adjusted for from year to year with little influence overall.

The year effects increase steadily over the first half of the time series from 80 to 120 % of overall mean then fluctuate around unity through the 2000s (Figure M.10). The indices are well determined with small error bars relative to the interannual variance. There is good agreement with the previous series presented for this fishery with no significant change since then. The effect of standardisation is

[3] Variables which make no improvement in the AIC are ignored by the software.

to lift points in the middle of the series and drop the most recent points changing a flat trajectory to one that is more hump-shaped.

Table M.1: Order of acceptance of variables into the lognormal model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 10 trips in 8 or more fishing years) in the SPO 2_BT(MIX) fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an *. Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	23	-29 450	58 947	2.22	*
poly(log(duration), 3)	26	-25 786	51 627	37.69	*
vessel	58	-24 464	49 045	47.17	*
month	69	-24 299	48 738	48.24	*
poly(log(days), 3)	72	-24 292	48 730	48.29	

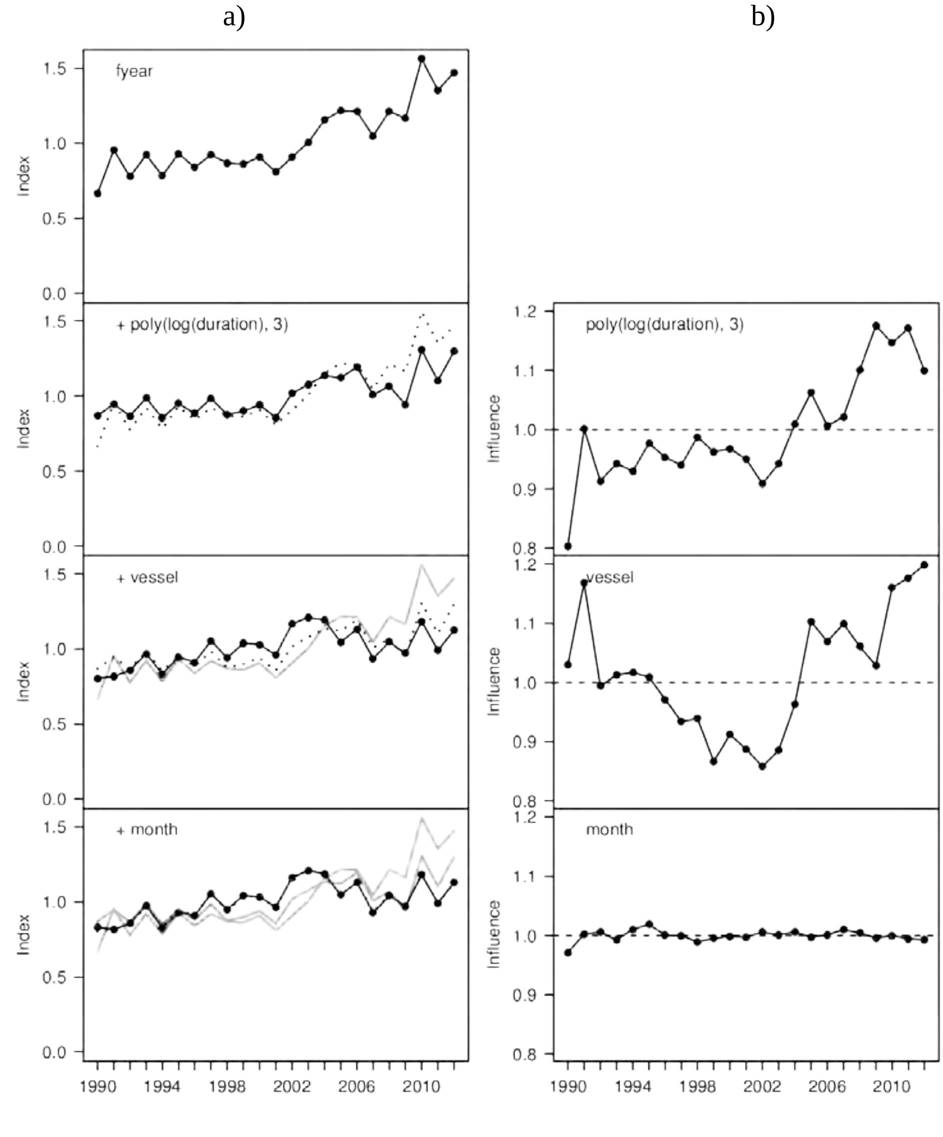


Figure M.9: Step and annual influence plot for SPO 2_BT(MIX). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

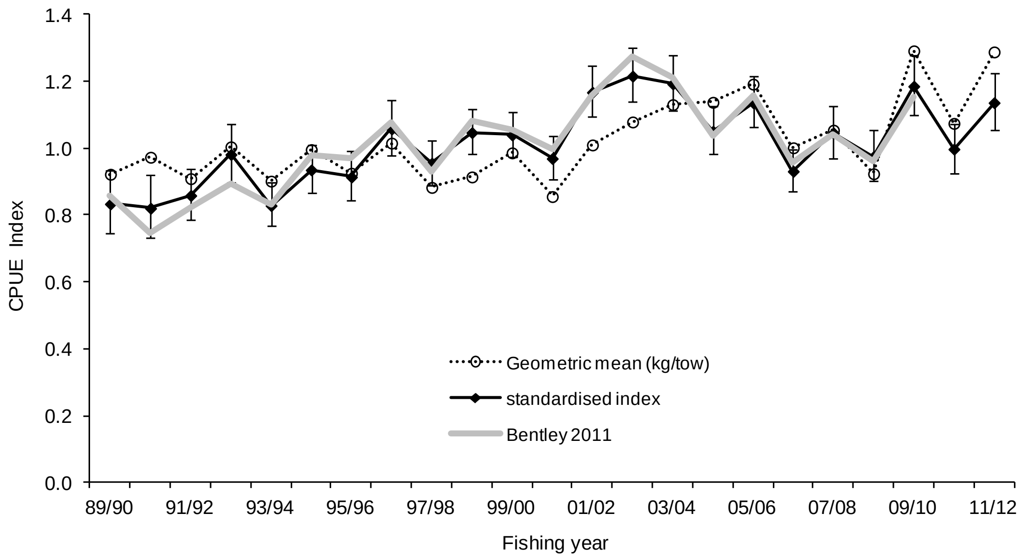


Figure M.10: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 2_BT(MIX) fishery. Broken lines are the raw CPUE (kg /tow) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the lognormal series presented in 2011 for a similar fishery. All series are relative to the geometric mean over the years in common.

M.3.2.2 SPO 3_BT(MIX) – SPO 3 Mixed species bottom trawl

The lognormal was the error distribution selected for the best fitting model to the SPO 3_BT(MIX) data (Figure N.7), showing a very good fit to the lognormal assumption (Figure N.8). Fishing year was forced as the first variable but explained less than 1% of the variance in catch (Table M.2). Duration was the most important explanatory variable, entering second and explaining almost 14% of the variance in catch. It was also the variable with the greatest influence on observed catches. Target species entered third and explained an additional 6% of the variance in catch, and vessel entered last with little additional explanatory power or influence. The final model explained about 24% of the variance in log(catch) (Table M.2). The annual indices are plotted at each step in (Figure M.11).

A positive relationship between catch and tow duration, combined with a shift in the mid 2000s towards shorter tow duration (per stratum) gave effort a negative influence on catches (Figure N.20). The coefficients for target show that catches are predicted to be greatest when targeting elephantfish, and that increased targeting of elephantfish during the 2000s is predicted to have increased catches by about 25% over the decade (Figure N.21). There are consistent differences in performance among vessels with respect to rig catch, and changes in the fleet have had a small positive effect on catches (Figure N.22).

The year effects are flat overall and stable with small error bars relative to the interannual variance (Figure M.12). There is good agreement with the previous series presented for this fishery with no significant trend in the newer indices. The effect of standardisation (after the effect of effort is included) is to drop recent points to adjust for the increase in elephantfish fishing, flattening an increasing trajectory (Figure M.12). Residual implied coefficients suggest that there may be some potentially confounding interaction effects of area (Figure N.9) and target species (Figure N.10) with fishing year.

Table M.2: Order of acceptance of variables into the lognormal model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 10 trips in 8 or more fishing years) in the SPO 3_BT(MIX) fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an *. Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	23	-40 245	80 538	0.82	*
poly(log(duration) 3)	26	-38 674	77 402	14.34	*
target	33	-37 878	75 824	20.49	*
vessel	92	-37 385	74 955	24.08	*
month	103	-37 295	74 798	24.72	
poly(log(num) 3)	106	-37 212	74 638	25.30	
area	114	-37 168	74 566	25.61	
poly(log(days) 3)	117	-37 161	74 558	25.66	

a) b)

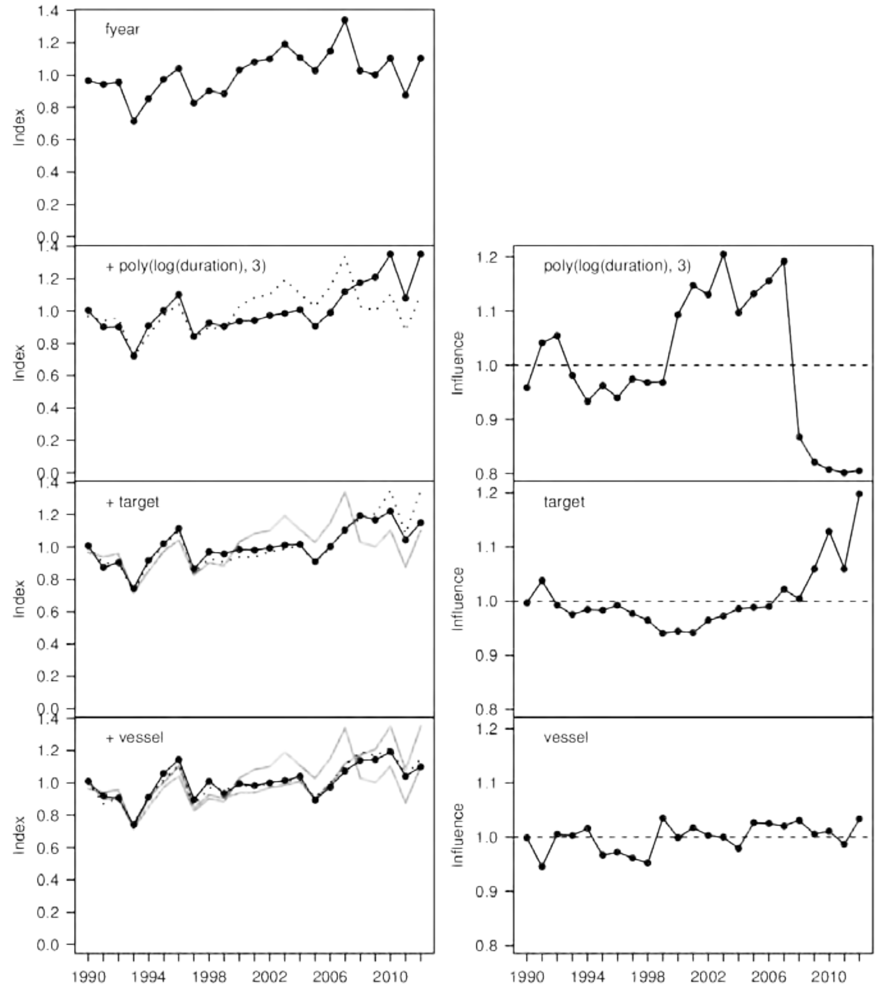


Figure M.11: Step and annual influence plot for SPO 3_BT(MIX). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

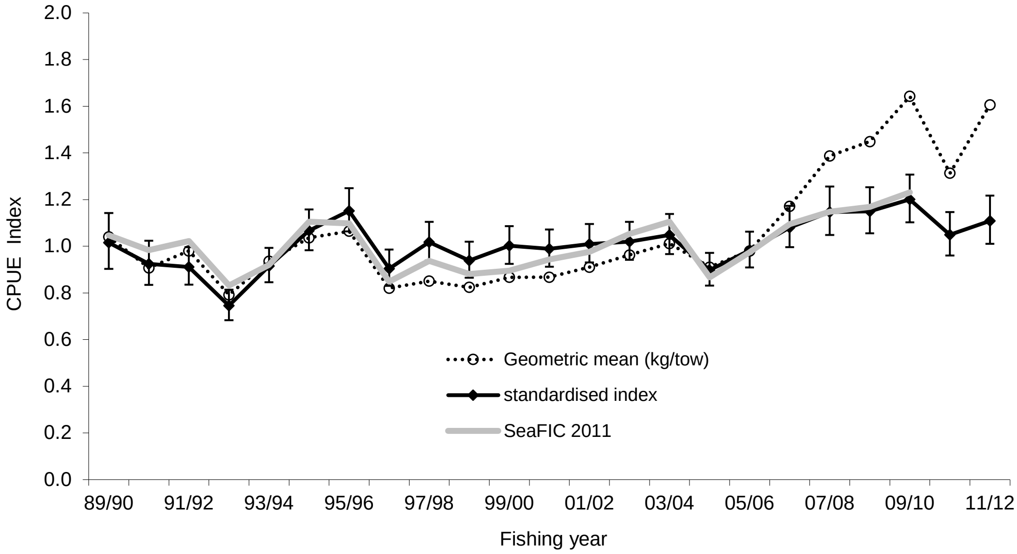


Figure M.12: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 3_BT(MIX) fishery. Broken lines are the raw CPUE (kg /tow) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the lognormal series presented in 2011 for a similar fishery. All series are relative to the geometric mean over the years in common.

M.3.2.3 SPO 3_BT(FLA) – SPO 3 in flatfish bottom trawl

The lognormal error distribution was used for this model for consistency with the SPO 3_BT(MIX) analysis (Section M.3.2.2); this distributional assumption also fit the data well (Figure N.11). Fishing year was forced as the first variable but explained less than 1% of the variance in catch (Table M.3). Vessel was the most important explanatory variable, entering second and explaining almost 18% of the variance in catch. It was also the variable with the greatest influence on observed catches (Figure M.13). Duration entered third and explained an additional 5% of the variance in catch, and area and month were also included but without further altering the year effects discernibly. The final model explained about 27% of the variance in log(catch) (Table M.3).

Table M.3: Order of acceptance of variables into the lognormal model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 10 trips in 8 or more fishing years) in the SPO 3_BT(FLA) fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an * . Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	23	-29 415	58 878	0.47	*
vessel	105	-27 833	55 878	18.23	*
poly(log(duration), 3)	108	-27 277	54 772	23.72	*
area	115	-27 088	54 409	25.49	*
month	126	-26 914	54 081	27.11	*
poly(log(num), 3)	129	-26 862	53 985	27.57	
poly(log(days), 3)	132	-26 848	53 962	27.70	

Coefficients for vessels show large differences in performance between vessels with respect to rig, and also a strong trend towards a preference for better performing vessels that has potentially increased catches by more than 20% (Figure N.23). A positive relationship between catch and tow duration, combined with a shift towards longer tow duration means that shifts in effort have also been positive for rig catch (Figure N.24). There are significant differences in predicted catch of rig with statistical area, but the fishery has operated relatively consistently over time so that spatial shifts have not been greatly influential (Figure N.25). A shift towards more effort in the less productive winter months has had a small negative influence on observed catches (Figure N.26). The year effects decline slightly overall and sit currently just below the mean for the series. There is good agreement with the previous series presented for this fishery with no significant change since then (Figure M.14). The effect of standardisation lifts the series for the 1990s and flattens an apparent increase during the 2000s.

a) b)

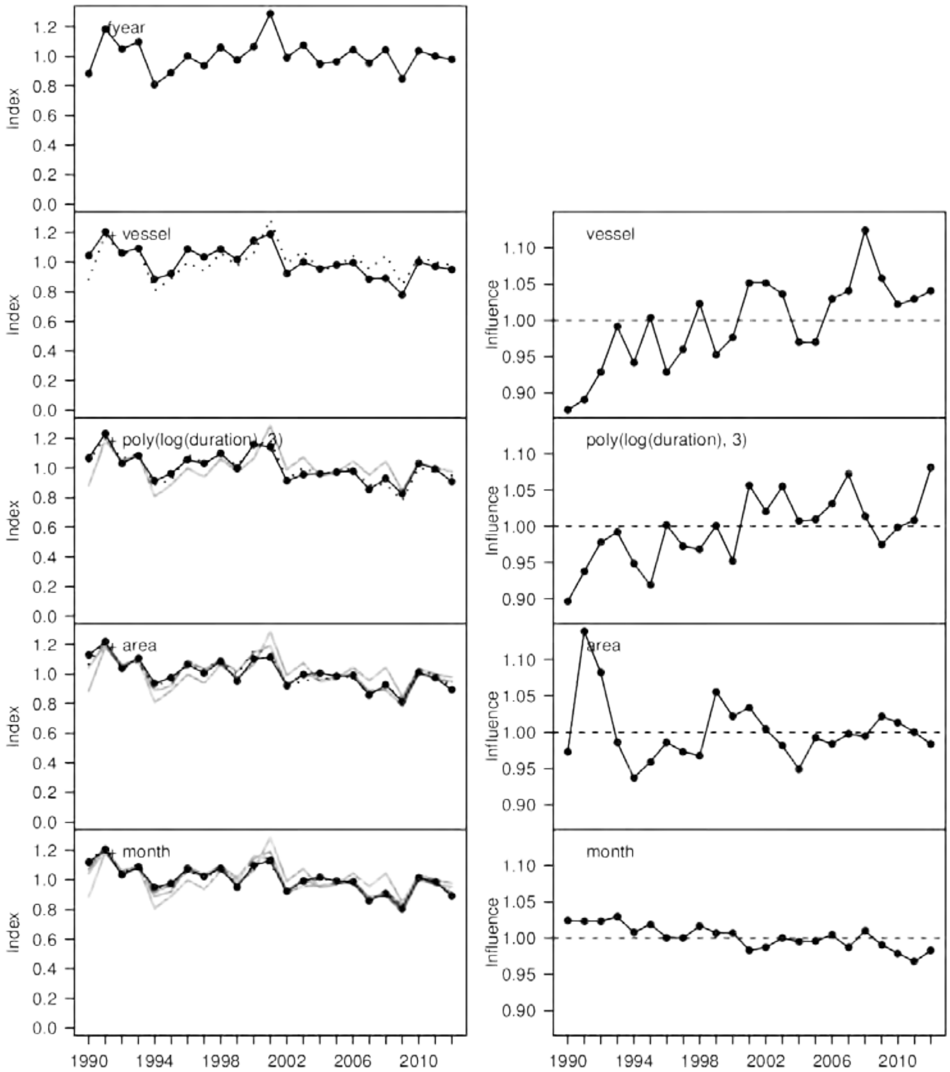


Figure M.13: Step and annual influence plot for SPO 3_BT(FLA). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

Residual implied coefficients suggest some potential year × area interaction effects with the trajectory in Area 020 showing a steep increase in the late 2000s that is in contrast to the flat or declining trajectory in most other areas (Figure N.12).

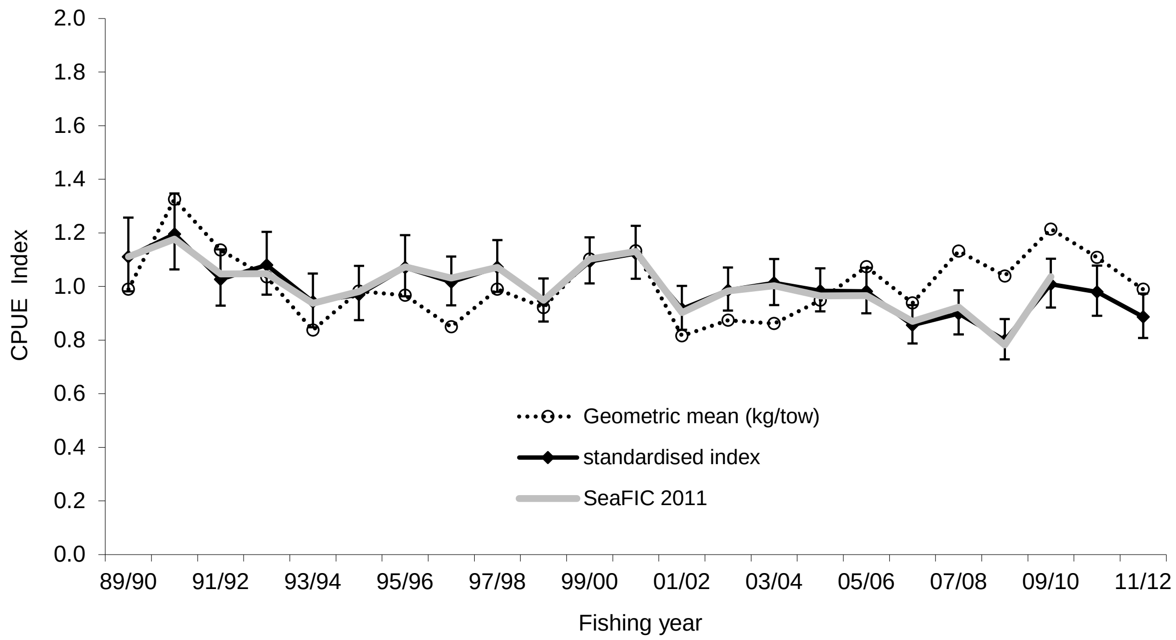


Figure M.14: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 3_BT(FLA) fishery. Broken lines are the raw CPUE (kg /tow) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the previous lognormal series presented in 2011 for a similar fishery. All series are relative to the geometric mean over the years in common.

M.3.2.4 SPO 3_SN(SHK) – SPO 3 Shark setnet

The log logistic error distribution produced the best model fit to SPO 3_SN(SHK) data (Figure N.13) with a good residual pattern (Figure N.14). Fishing year was forced as the first variable and explained almost 5% of the variance in catch (Table M.4). Vessel entered second and explained almost 28% of the variance and target species explained a further 8% but was equally as influential as vessel in shifting the standardised series away from the observed. Month and netlength were also accepted into the model but their influence on catch was almost neutral over the time series. The final model explained about 50% of the variance in log(catch) (Table M.4). The annual indices are plotted at each step in Figure M.15.

Table M.4: Order of acceptance of variables into the log logistic model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 5 trips in 5 or more fishing years) in the SPO 3_SN(SHK) fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an * . Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	24	-132 354	264 755	4.93	*
vessel	240	-128 392	257 265	33.50	*
target	243	-126 943	254 372	41.65	*
month	254	-125 862	252 233	47.07	*
poly(log(netlength) 3)	257	-125 127	250 768	50.47	*
area	265	-125 010	250 550	50.99	
poly(log(duration) 3)	268	-124 918	250 372	51.39	
poly(log(days) 3)	271	-124 910	250 362	51.43	

The CDI plot for vessel shows that major changes to the core fleet took place in the late 1990s that effected at least a 40% improvement in rig catches over the course of three consecutive years (Figure N.27). This coincided with a shift away from targeting elephant fish and spiny dogfish towards more targeting of rig with a similar magnitude of influence on catches of rig, although that trend was reversed after 2000–01 (Figure N.28). Effort in this fishery is concentrated in the summer months when the abundance of rig is greatest, and small differences from year to year in seasonality of effort are accounted for in the model without influencing the year effects markedly (Figure N.29). Net length is included in the model because of the strong relationship to catch and does trend positively over most of the time, in particular, lifting the points in the late 2000s to account for an increasing proportion of shorter nets (per stratum) (Figure N.30).

a) b)

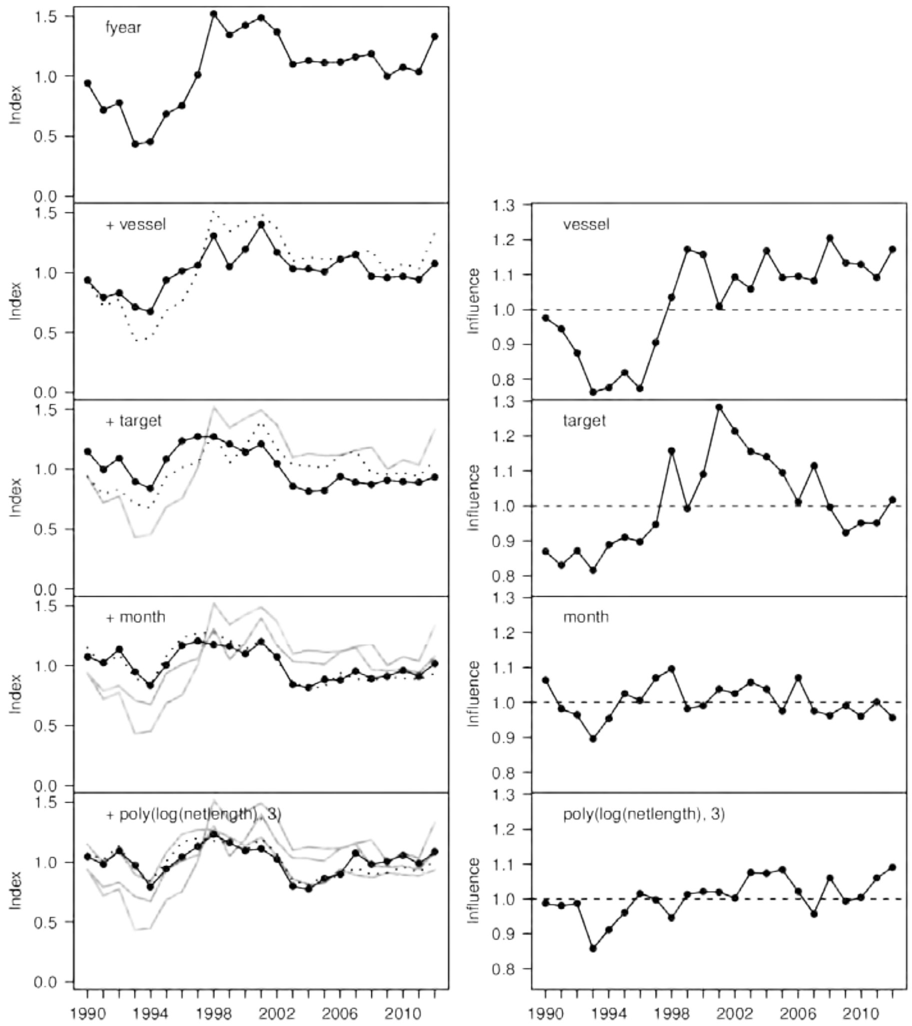


Figure M.15: Step and annual influence plot for SPO 3_SN(SHK). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

The year effects track some shallow cyclical changes in abundance, but show no overall trend (Figure M.16). The effect of standardisation is to moderate the highs and lows in observed catch thus reducing the magnitude of the cycles. There is good agreement with the previous series produced for this fishery. The residuals for potential interaction effects confirm similar trajectories in each area (Figure N.15) and target fishery (Figure N.16), varying in the deepness of the cycles, but not contradictory. The effect of selecting the error distribution that gave the best fit relative to the distributional assumption was not substantial: there is little difference in the estimated year indices when the selected log-logistic series is compared to an alternative series based on a lognormal distribution (Figure M.17).

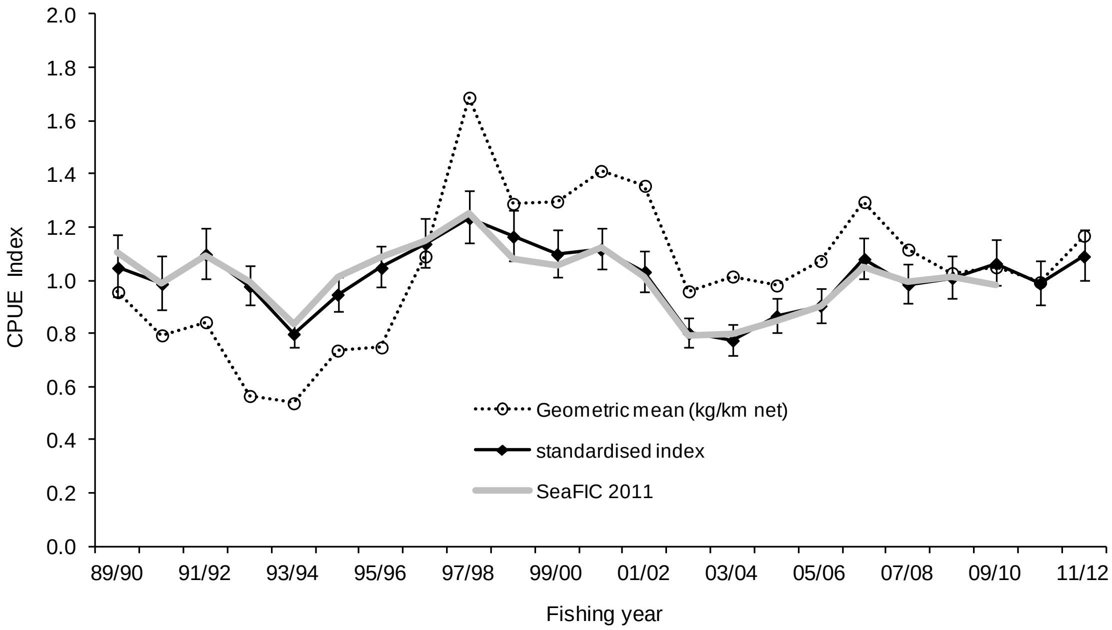


Figure M.16: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 3_SN(SHK) fishery. Broken lines are the raw CPUE (kg /km net) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the previous lognormal series presented in 2011 for this fishery. All series are relative to the geometric mean over the years in common.

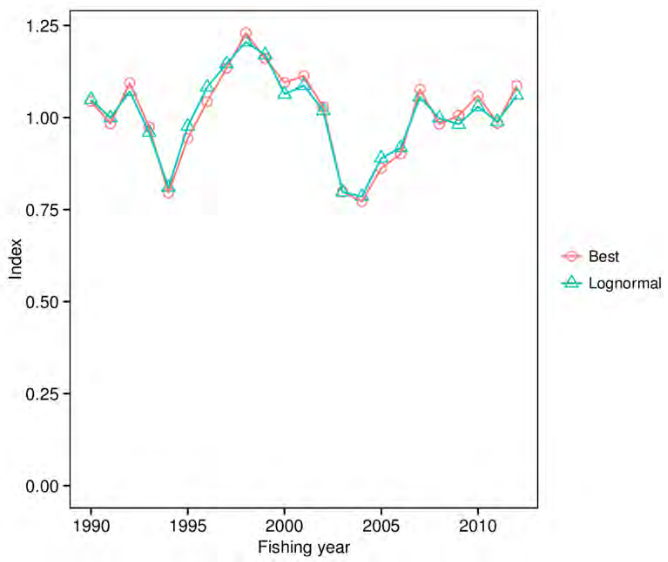


Figure M.17: Comparison between the log-logistic indices and indices obtained from a similar model that assumed a lognormal error distribution for SPO 3_SN(SHK).

Appendix N. DETAILED DIAGNOSTICS FOR SPO 2 AND SPO 3 CPUE STANDARDISATIONS

N.1 Core vessel selection

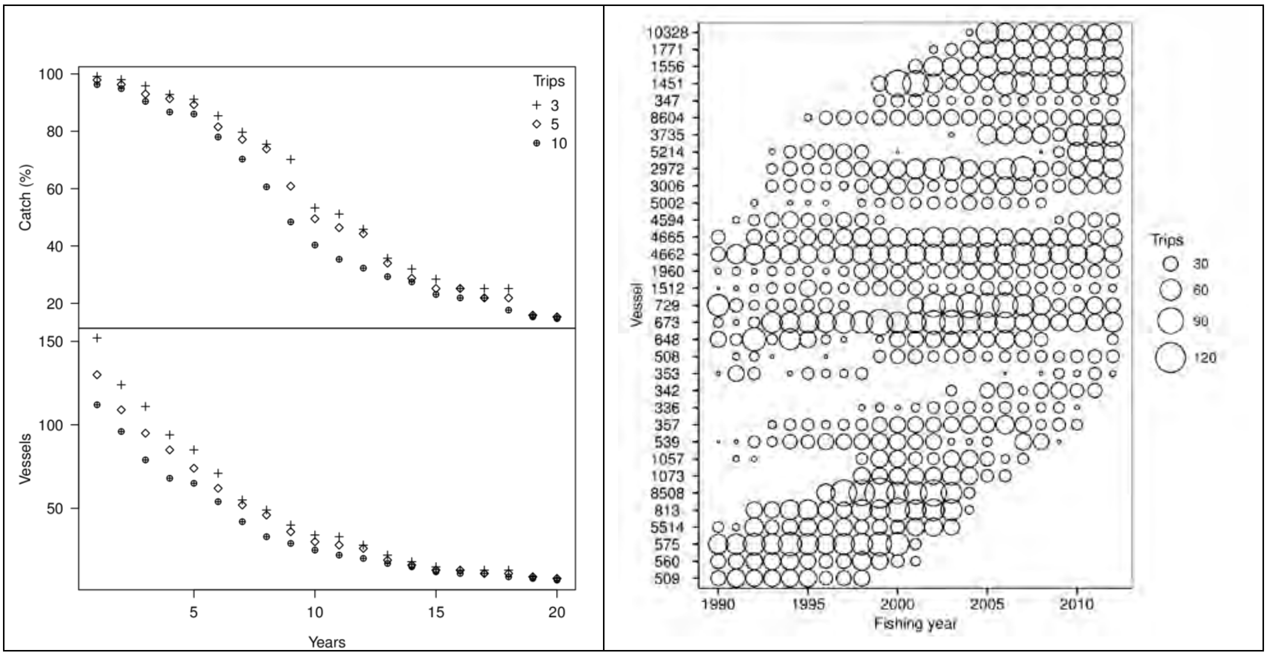


Figure N.1: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 2_BT(MIX) dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 10 trips in 8 or more fishing years).

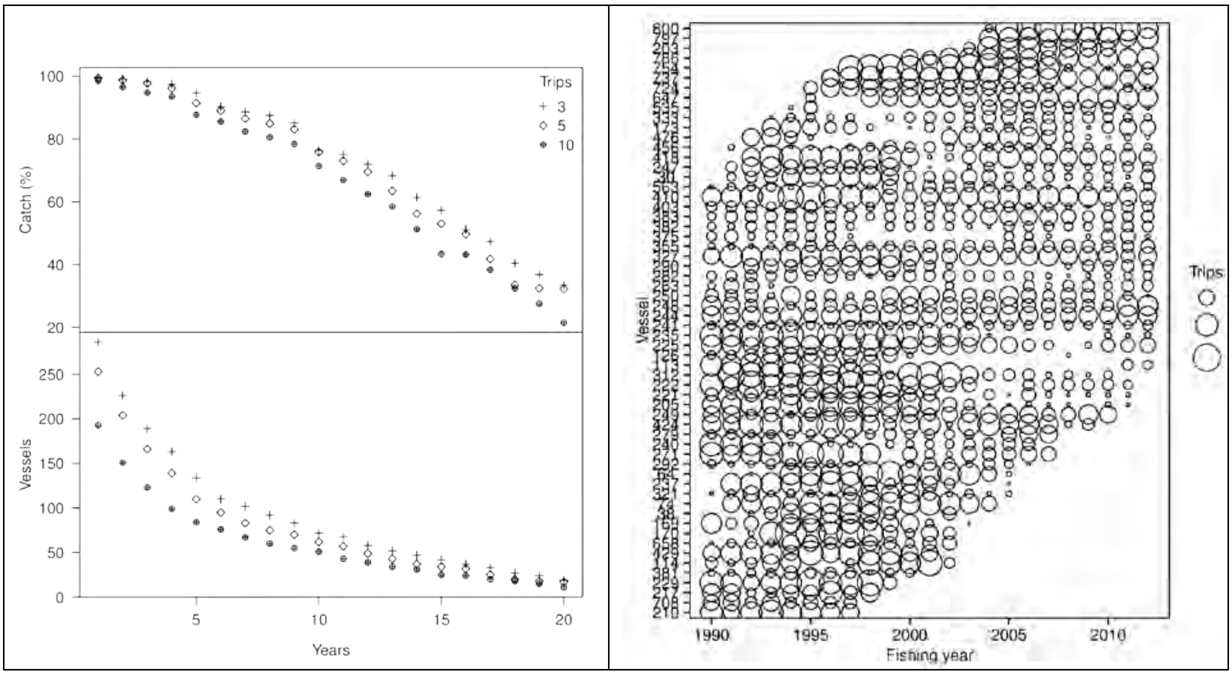


Figure N.2: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 3_BT(MIX) dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 10 trips in 8 or more fishing years).

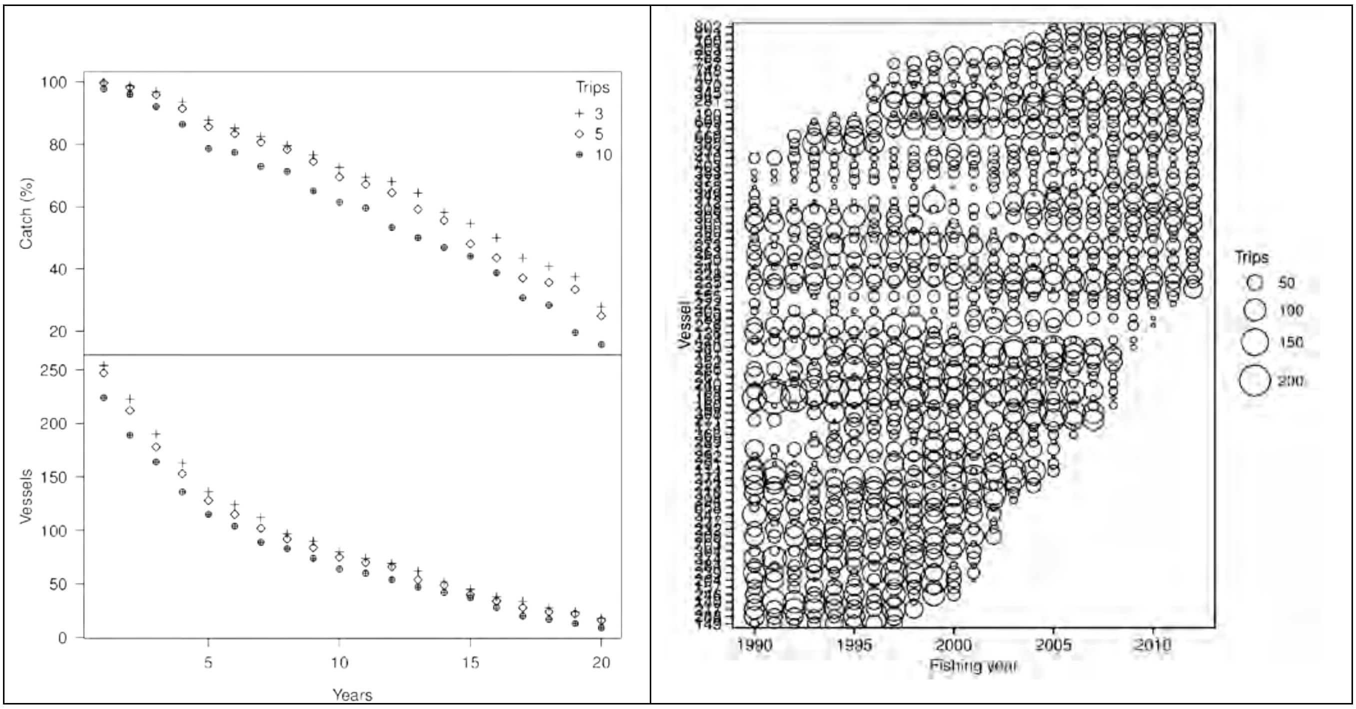


Figure N.3: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 3_BT(FLA) dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 10 trips in 8 or more fishing years).

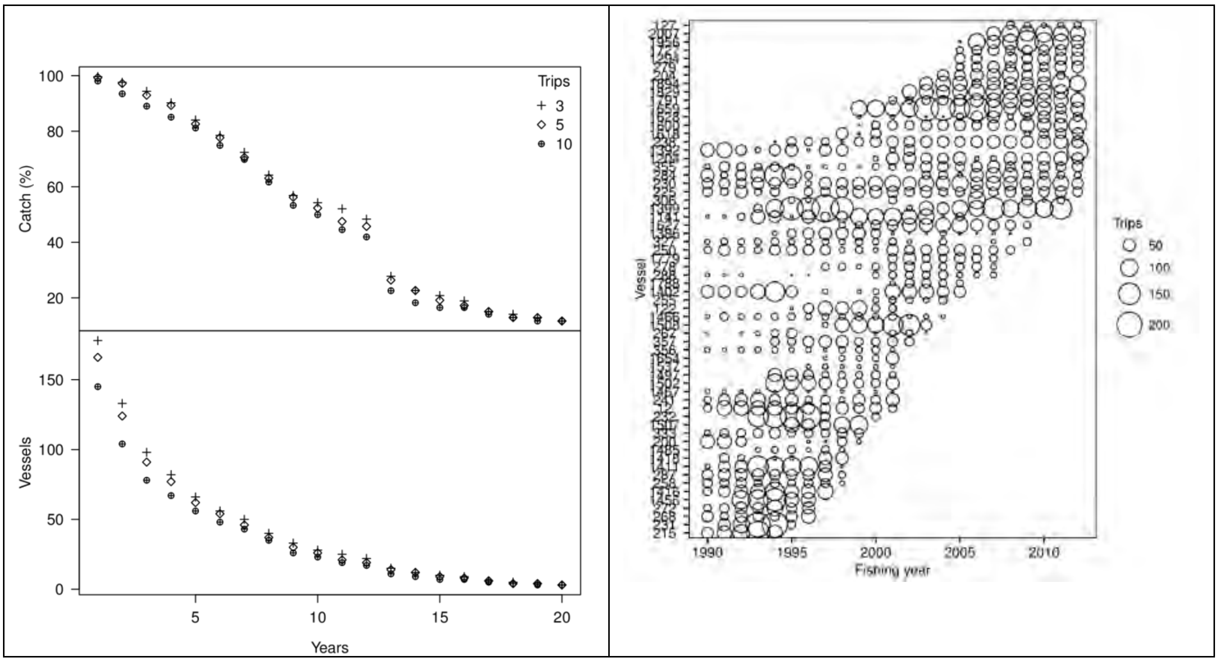


Figure N.4: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 3_SN(SHK) dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 5 trips in 5 or more fishing years).

N.2 Data summaries

Table N.1: Number of vessels, trips, trip strata, events, sum of catch (t), sum of tows and sum of hours fishing for core vessels in the four CPUE analyses by fishing year.

	SPO 2_BT(MIX)							SPO 3_BT(MIX)						
Fishing year	Vessel	Events	Trips	Catch	Tows	Hours	% zero	Vessel	Events	Trips	Catch	Tows	Hours	% zero
1990	15	640	315	11.5	1 618	5 867	100	39	3 186	1 500	14.5	6 647	22 726	28
1991	17	895	320	13.7	2 196	8 074	100	44	3 623	1 685	22.6	8 167	27 256	33
1992	19	1 352	520	21.9	3 143	11 625	100	48	4 718	2 039	27.9	9 837	35 419	36
1993	20	1 187	493	22.0	3 083	11 264	100	49	5 192	2 212	31.9	10 148	36 829	34
1994	20	1 882	649	24.7	3 972	15 097	100	51	4 811	2 543	50.7	10 891	35 913	39
1995	22	2 179	669	29.0	4 389	16 787	100	50	5 088	2 656	47.5	11 153	37 089	36
1996	24	2 150	602	28.9	3 888	14 954	100	50	5 447	2 481	56.7	11 061	35 446	40
1997	21	2 192	689	32.0	4 516	16 989	100	52	5 432	2 690	42.7	11 604	37 000	32
1998	25	2 725	821	36.5	5 664	20 913	100	49	5 478	2 614	37.7	11 967	36 266	37
1999	24	3 060	946	34.5	6 171	23 151	100	46	4 528	2 222	28.8	10 163	31 192	43
2000	24	2 725	947	35.6	6 076	23 290	100	48	4 302	1 939	39.3	9 983	31 384	49
2001	25	3 011	937	31.6	6 119	22 490	100	46	3 723	1 858	51.5	10 326	32 726	53
2002	25	3 010	960	36.1	6 022	21 549	100	47	3 456	1 520	46.2	8 948	28 406	58
2003	26	2 989	919	41.6	5 898	21 427	100	42	3 487	1 515	56.9	9 157	30 577	61
2004	25	3 028	847	42.6	6 044	21 842	100	43	3 524	1 574	51.8	8 479	28 066	56
2005	24	3 013	871	60.4	6 531	24 535	100	42	3 650	1 607	46.6	9 110	30 993	59
2006	25	3 276	925	58.8	6 958	25 096	100	41	3 489	1 564	50.2	8 962	31 022	61
2007	24	3 282	858	42.4	6 750	23 970	100	39	2 929	1 304	65.4	7 785	28 472	66
2008	24	6 014	710	44.8	6 060	21 341	100	39	5 256	1 027	38.8	5 266	18 987	52
2009	24	5 850	646	40.1	5 856	20 295	100	36	5 749	1 080	46.5	5 749	21 116	52
2010	23	6 524	749	53.9	6 524	22 650	100	39	5 876	1 111	48.0	5 876	21 654	51
2011	22	6 975	758	52.7	6 975	23 694	100	37	5 510	1 023	39.1	5 510	20 492	50
2012	21	6 373	756	54.9	6 373	22 106	100	35	5 016	999	57.8	5 016	18 118	52

Table N.1: (continued)

Fishing year	SPO 3_BT(FLA)							SPO 3_SN(SHK)					
	Vessel	Events	Trips	Catch	Tows	Hours	% zero	Vessel	Trips	Events	Catch	Hours	% zero
1990	56	2 999	2 624	9.6	8 198	20 183	16	27	644	850	85	12 501	65
1991	52	3 025	2 546	16.7	7 895	22 128	17	26	914	1 107	77	20 158	55
1992	56	2 913	2 342	16.9	7 929	22 002	26	28	1 082	1 240	99	23 137	71
1993	63	3 679	2 840	26.1	10 010	26 688	18	29	1 572	1 726	93	39 141	71
1994	66	3 610	2 925	15.7	10 221	25 708	18	35	2 055	2 228	154	46 840	77
1995	63	3 815	3 226	13.8	10 263	25 764	17	36	1 565	1 759	186	33 111	83
1996	67	3 859	3 129	18.2	11 266	28 815	17	37	1 398	1 625	180	31 815	78
1997	70	4 495	3 493	24.7	13 944	33 541	21	36	1 237	1 454	208	24 708	71
1998	68	4 633	3 618	30.5	14 008	33 503	20	34	1 084	1 253	206	19 968	79
1999	63	5 084	3 935	25.4	15 038	37 033	23	31	958	1 177	187	16 752	85
2000	67	4 655	3 607	31.4	13 612	34 488	29	32	918	1 117	204	15 850	84
2001	66	4 022	2 864	32.6	12 666	31 655	27	35	1 229	1 445	268	22 491	87
2002	60	4 044	2 815	22.1	12 332	28 874	26	29	1 051	1 221	239	20 295	89
2003	56	4 466	3 016	27.9	14 402	34 233	30	28	1 145	1 348	238	20 501	88
2004	56	3 957	2 915	19.6	12 334	29 749	29	27	1 005	1 224	214	17 038	87
2005	58	4 055	3 015	24.4	12 502	30 820	30	28	1 112	1 366	217	18 951	90
2006	54	3 381	2 445	22.9	10 477	27 522	33	25	1 268	1 521	231	21 904	84
2007	51	3 084	2 058	22.2	9 791	26 563	42	25	1 196	1 663	225	25 727	88
2008	50	7 906	1 819	26.0	8 268	21 755	38	24	1 170	1 791	281	28 276	83
2009	43	7 412	1 875	19.2	7 807	21 739	36	25	1 203	1 661	204	28 311	77
2010	42	7 908	1 763	30.5	8 069	22 305	40	22	1 172	1 779	215	33 299	78
2011	40	6 464	1 473	24.6	6 516	17 791	43	23	1 207	1 861	214	35 000	71
2012	37	7 540	1 582	30.0	7 668	22 013	43	21	1 025	1 752	191	31 472	78

N.3 Diagnostic plots

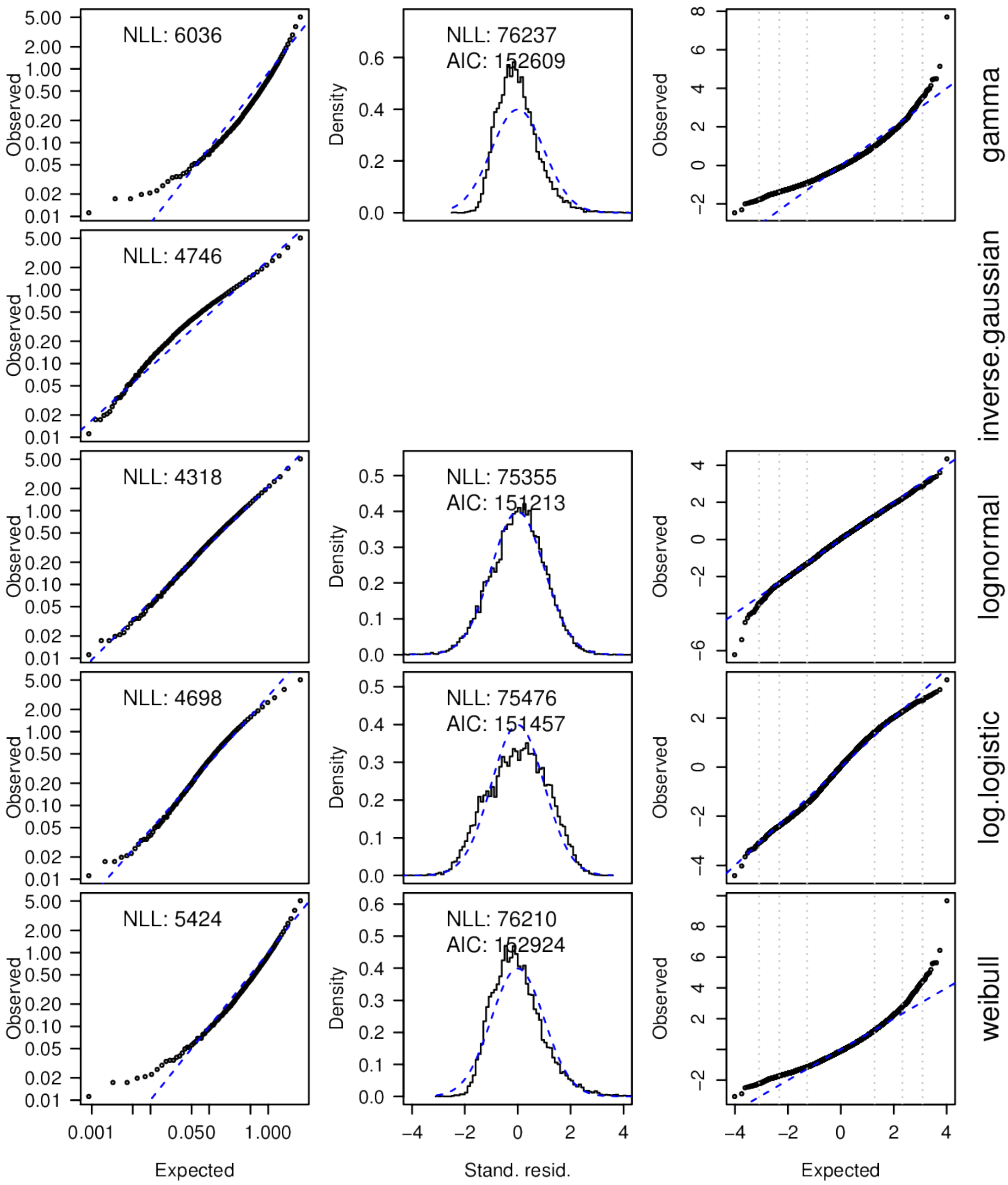


Figure N.5: Diagnostics for alternative distributional assumptions for catch in the SPO 2_BT(MIX) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + num and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

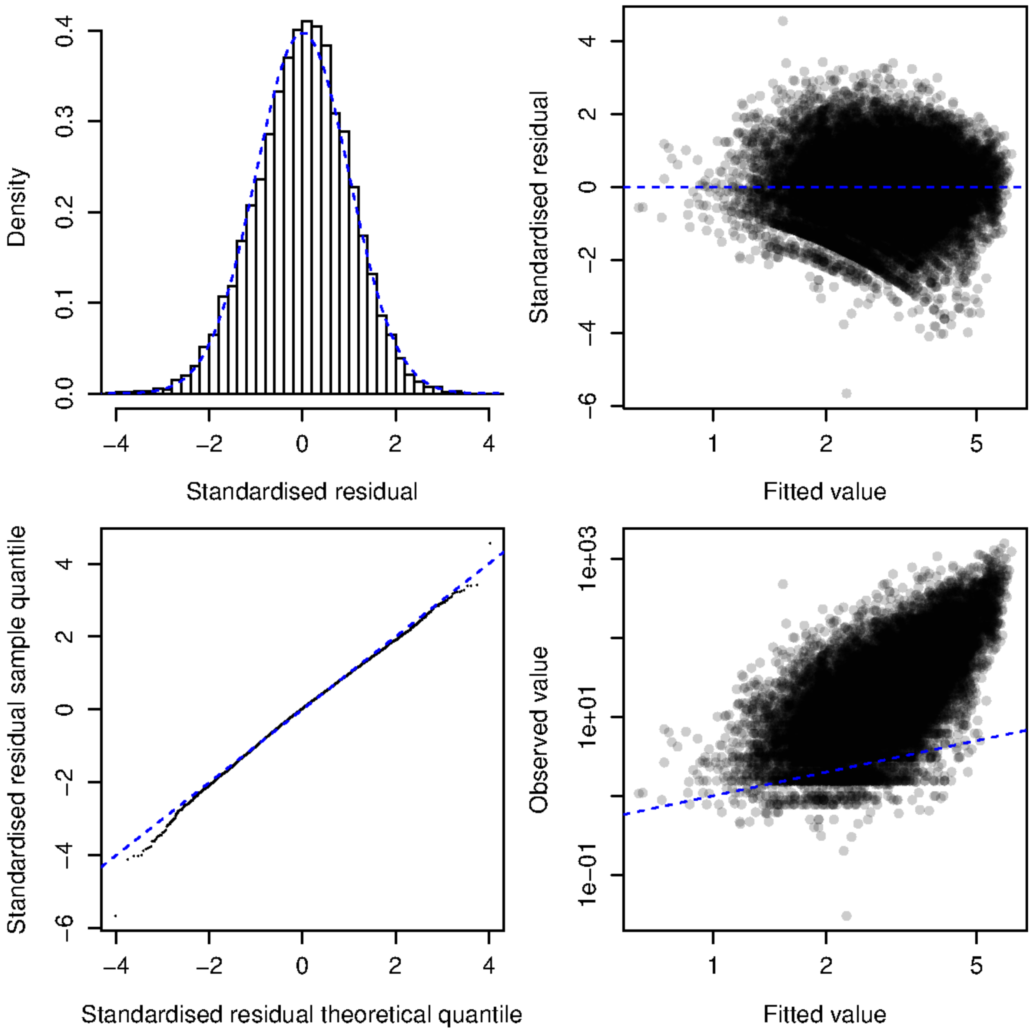


Figure N.6: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 2_BT(MIX) fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

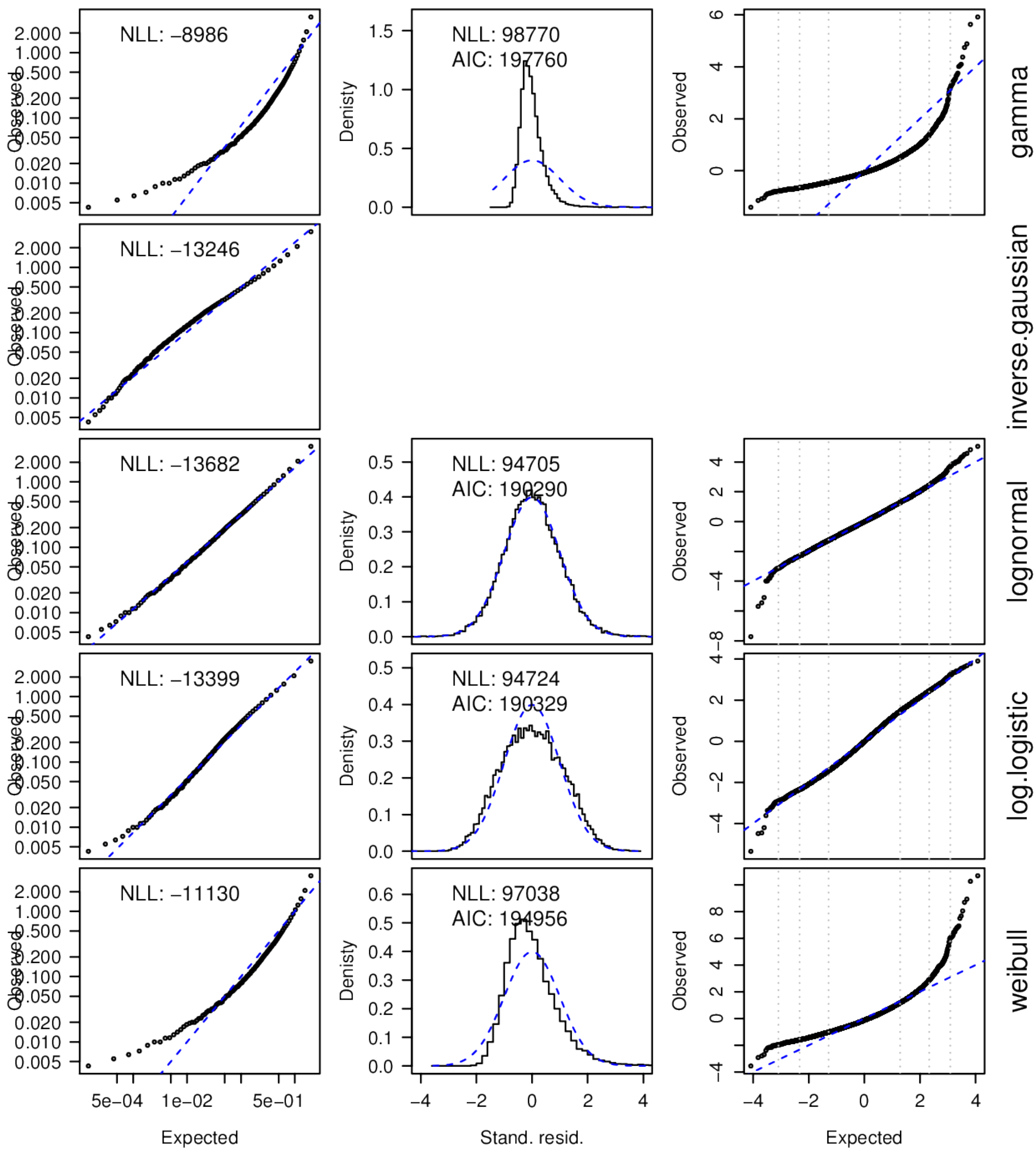


Figure N.7: Diagnostics for alternative distributional assumptions for catch in the SPO 3_BT(MIX) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + num and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

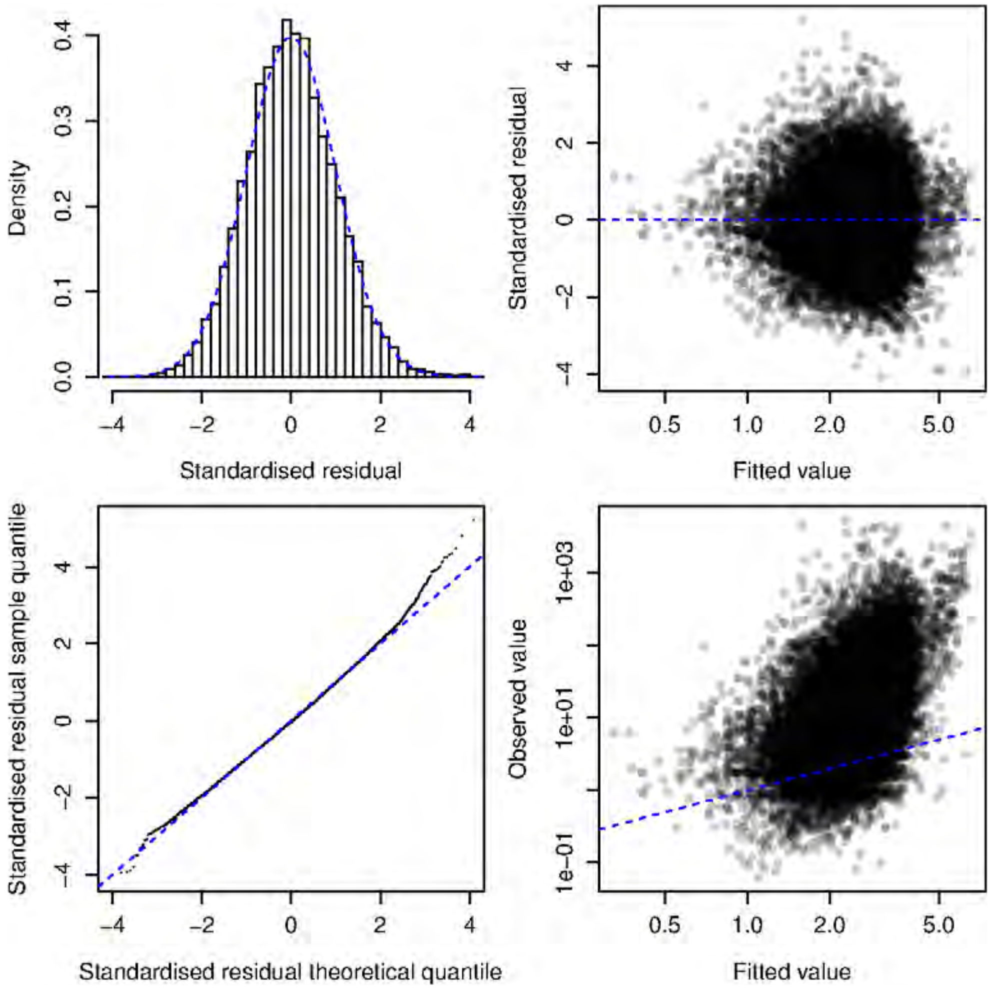


Figure N.8: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 3_BT(MIX) fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

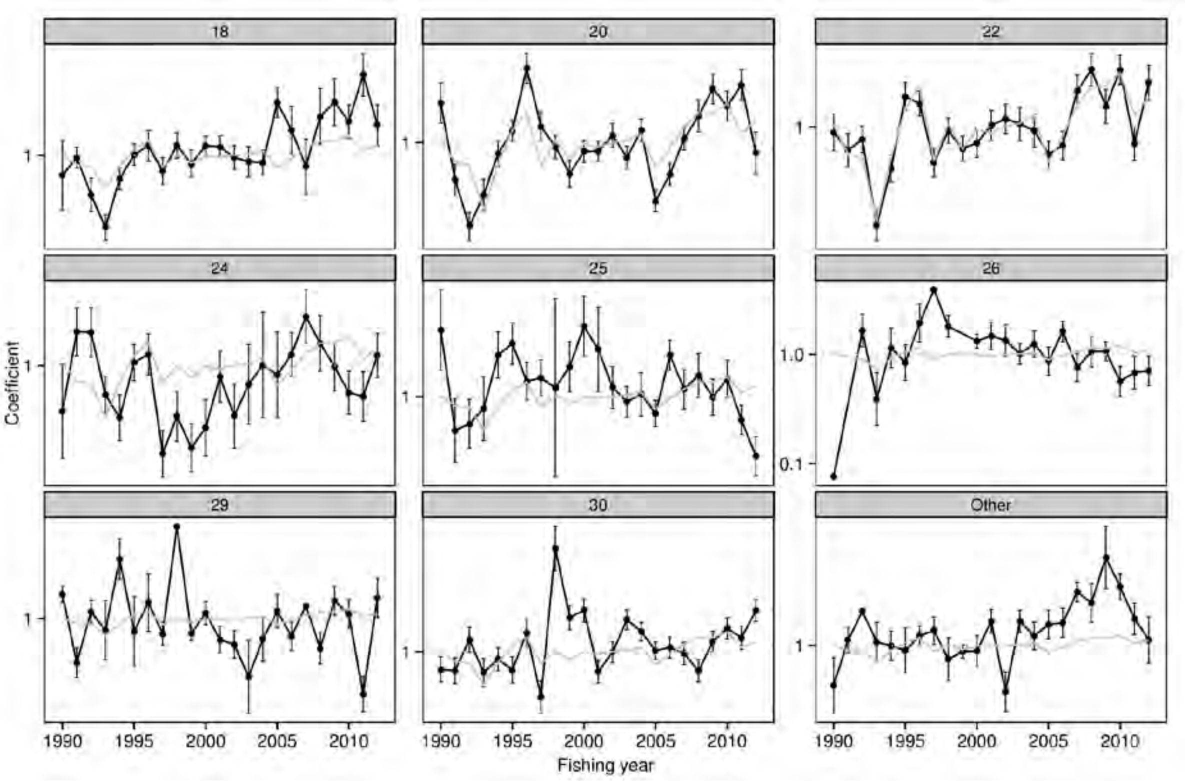


Figure N.9: Residual implied coefficients for each area in each fishing year in the SPO 3_BT(MIX) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

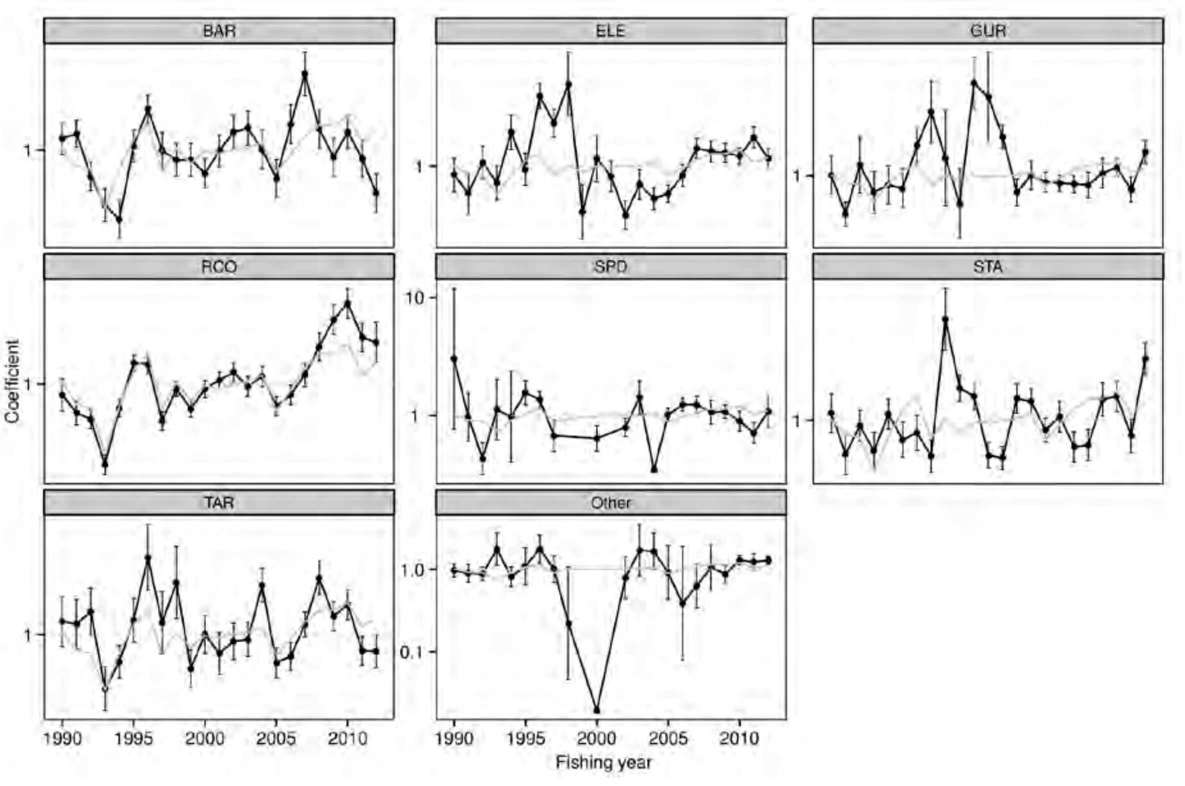


Figure N.10: Residual implied coefficients for each target species in each fishing year in the SPO 3_BT(MIX) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

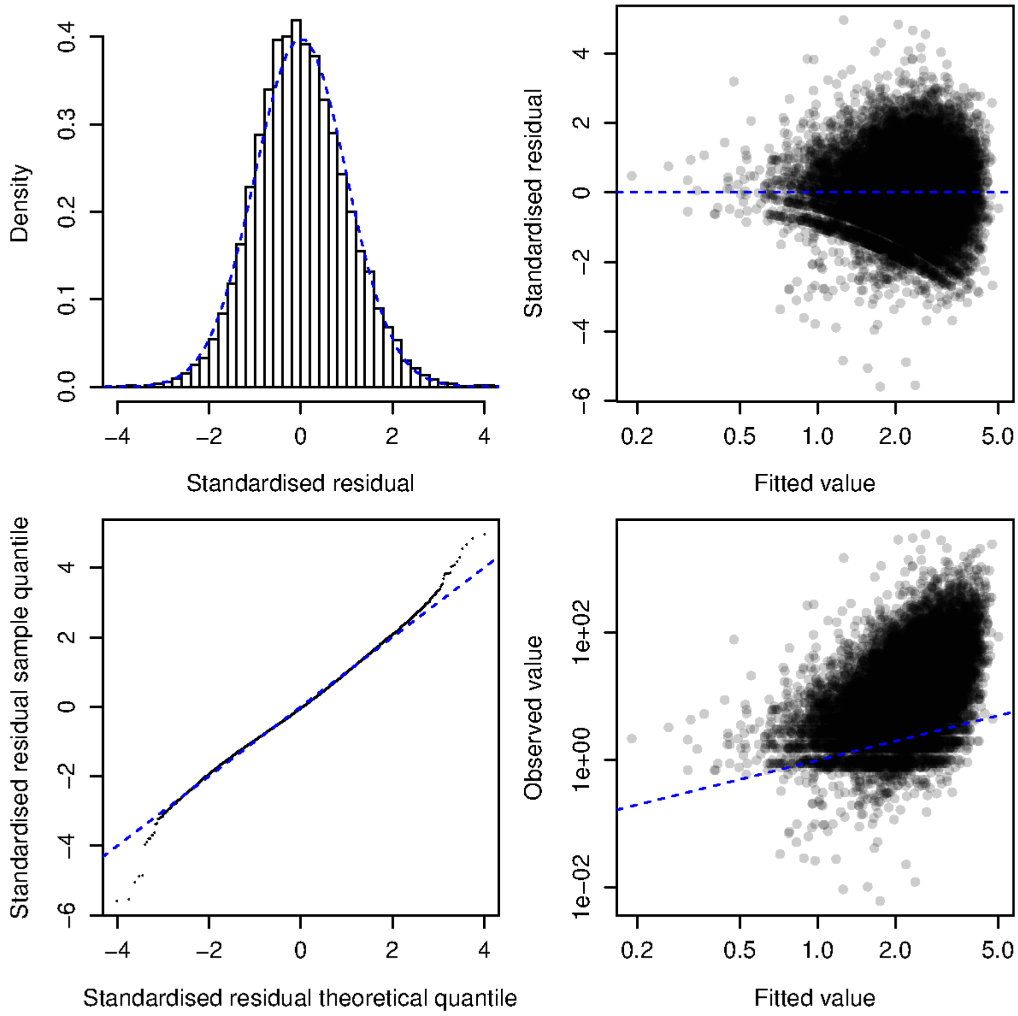


Figure N.11: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 3_BT(FLA) fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

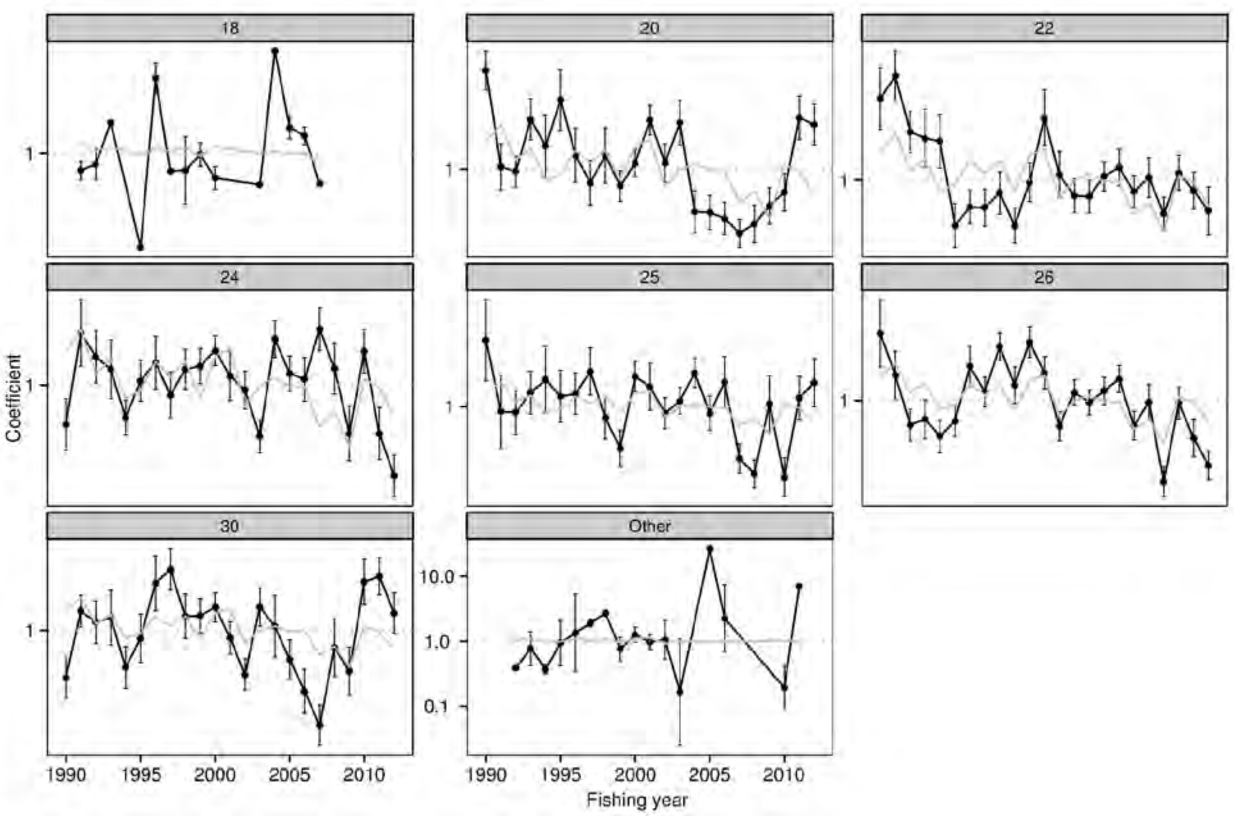


Figure N.12: Residual implied coefficients for each area in each fishing year in the SPO 3_BT(FLA) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

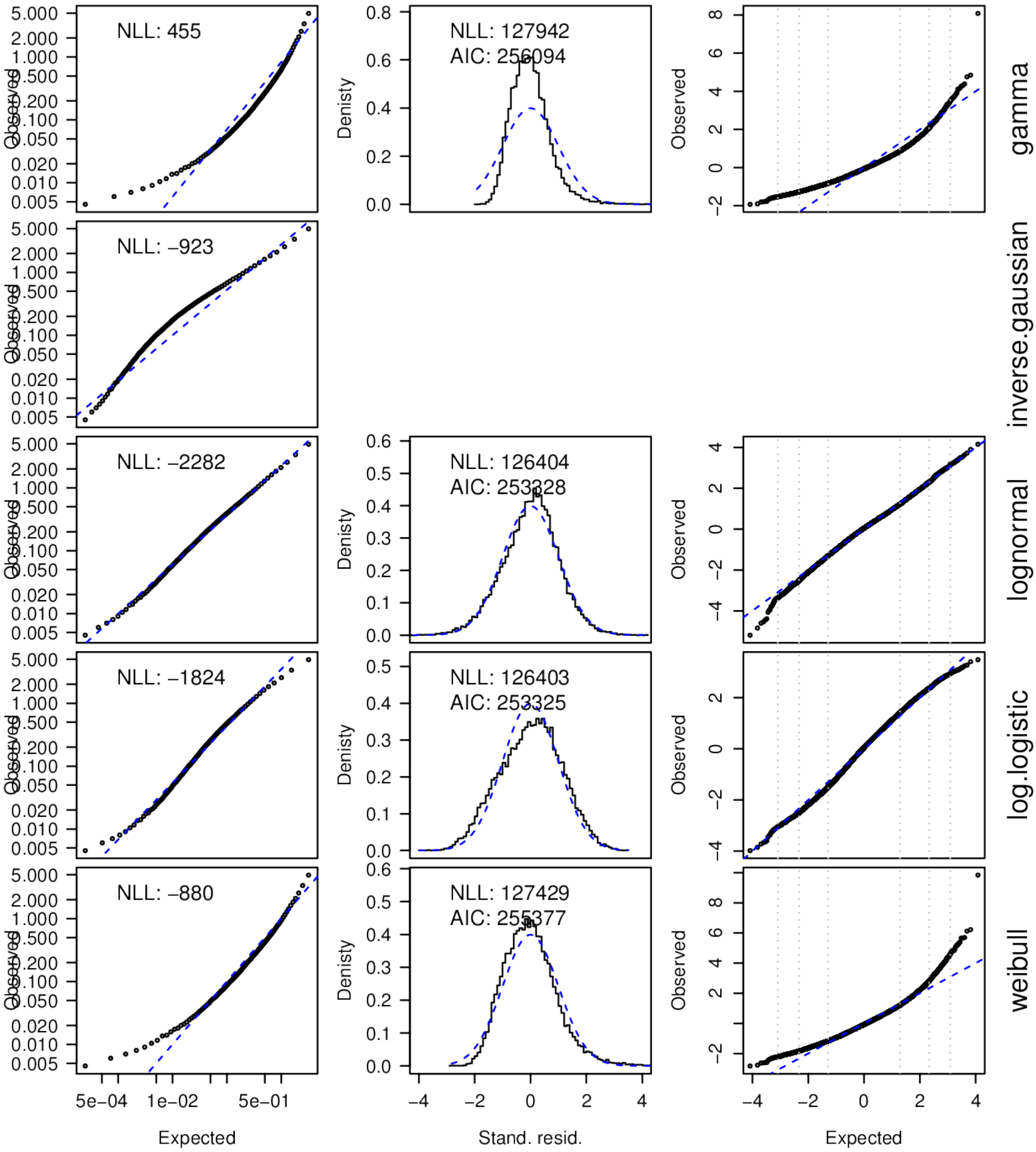


Figure N.13: Diagnostics for alternative distributional assumptions for catch in the SPO 3_SN(SHK) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + netlength and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

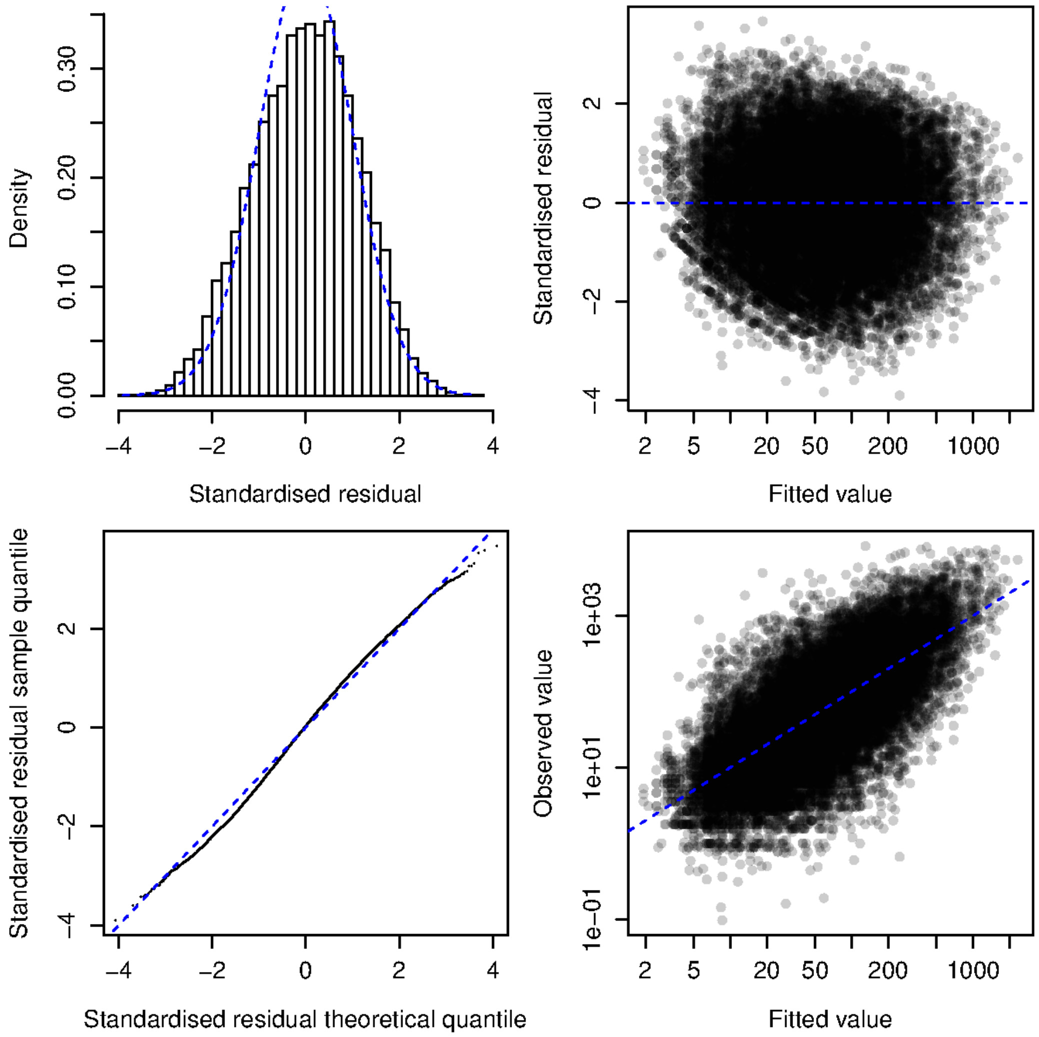


Figure N.14: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 3_SN(SHK) fishery. [Upper left] histogram of the standardised residuals compared to a log logistic distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

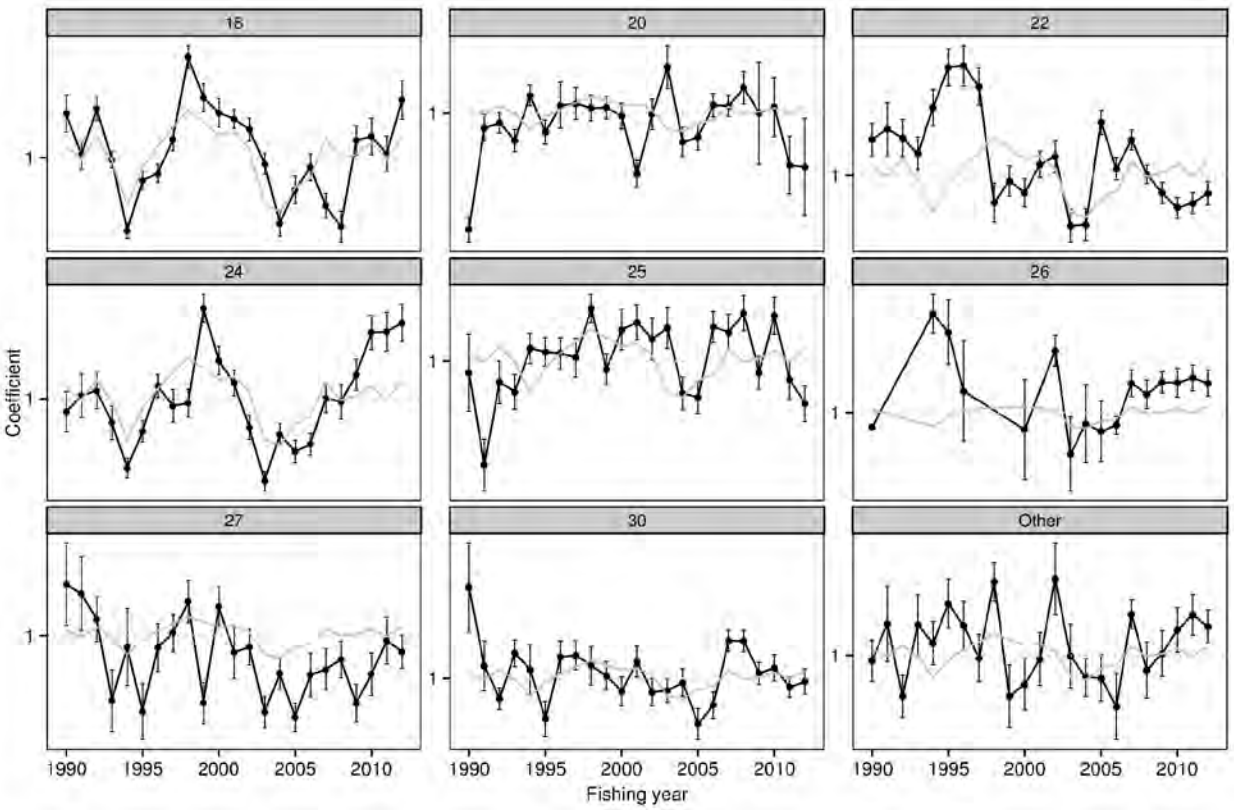


Figure N.15: Residual implied coefficients for each area in each fishing year in the SPO 3_SN(SHK) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

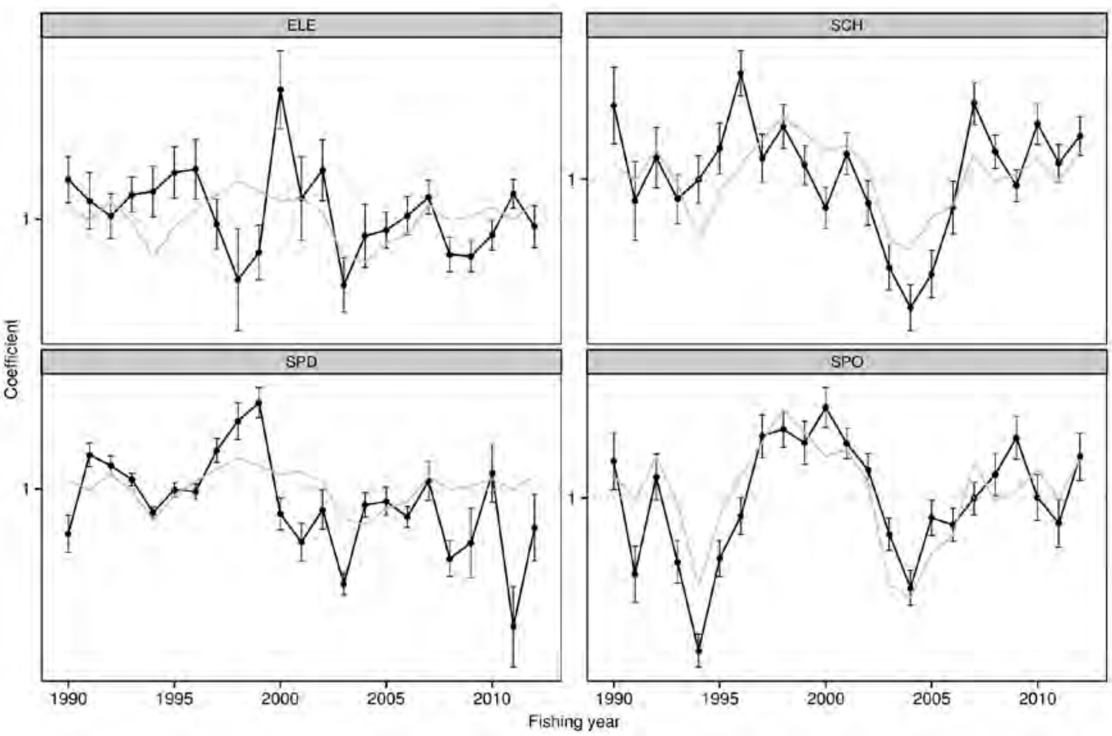


Figure N.16: Residual implied coefficients for each target species in each fishing year in the SPO 3_SN(SHK) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

N.4 Model coefficients

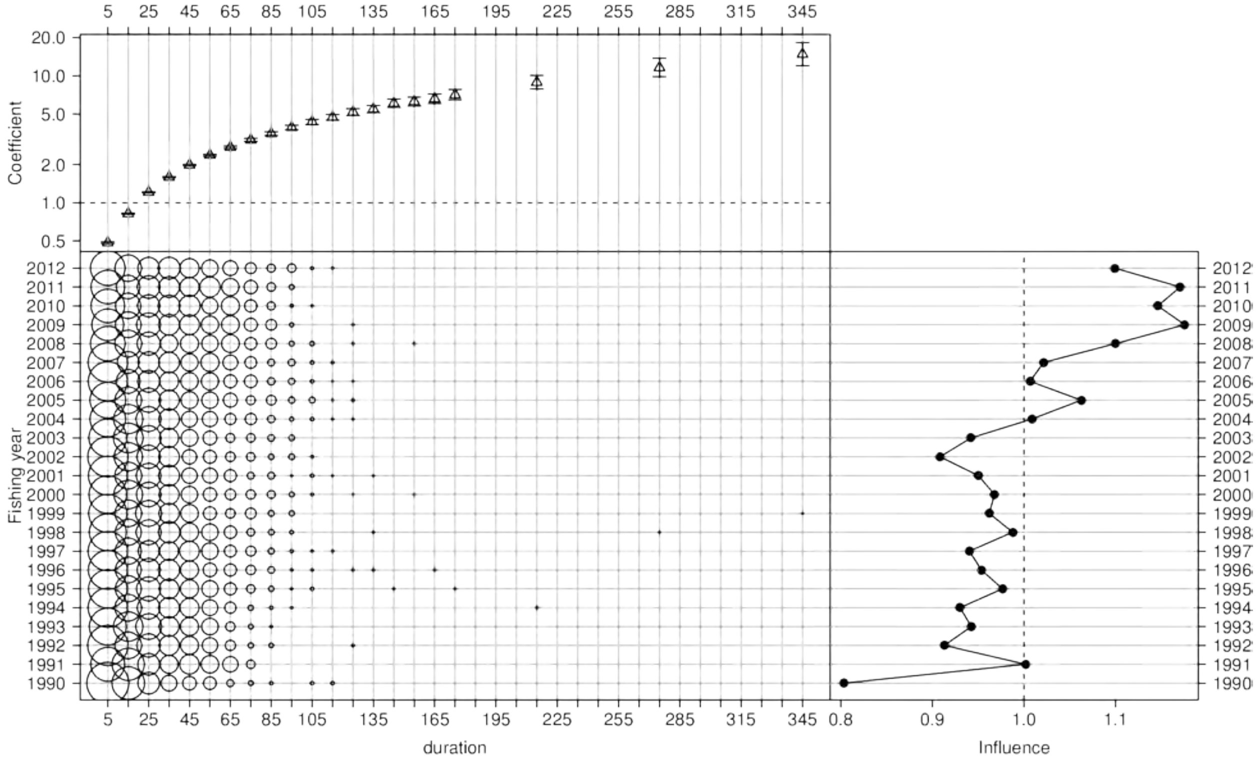


Figure N.17: Effect of duration **in the lognormal model for the SPO 2_BT(MIX) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

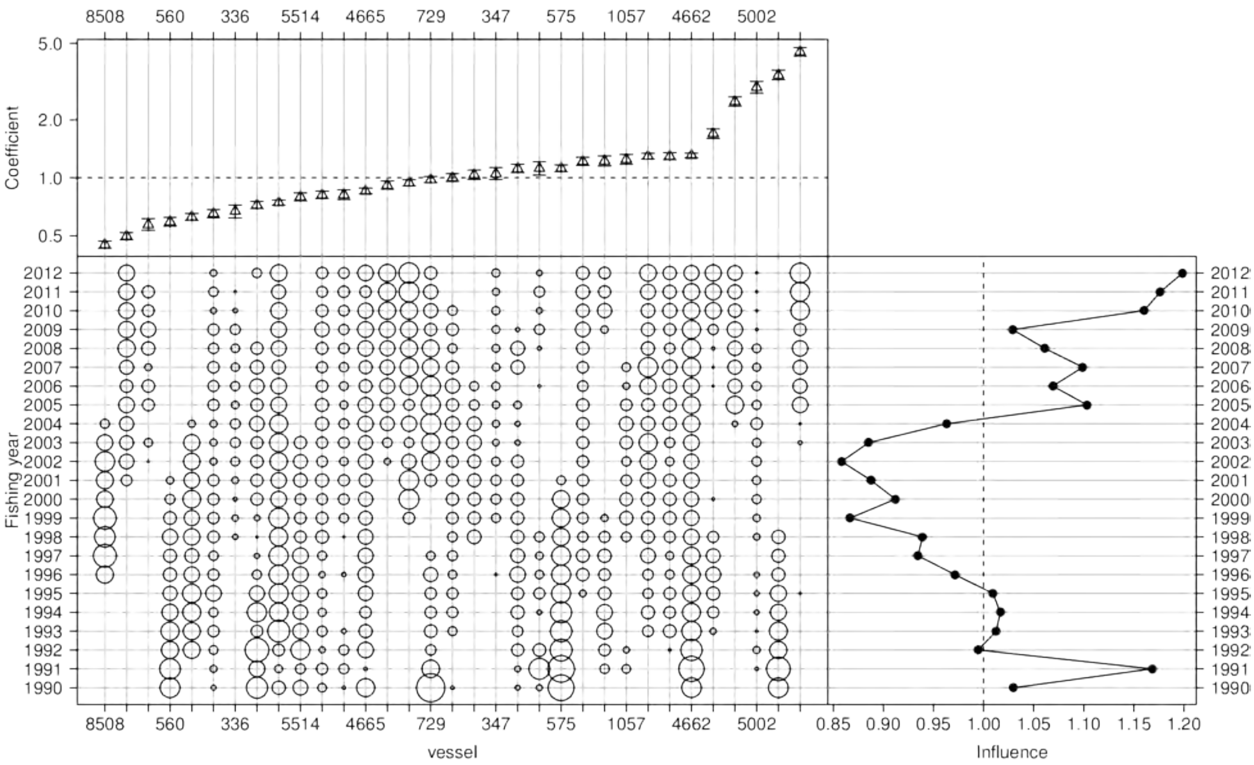


Figure N.18: Effect of vessel **in the lognormal model for the SPO 2_BT(MIX) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

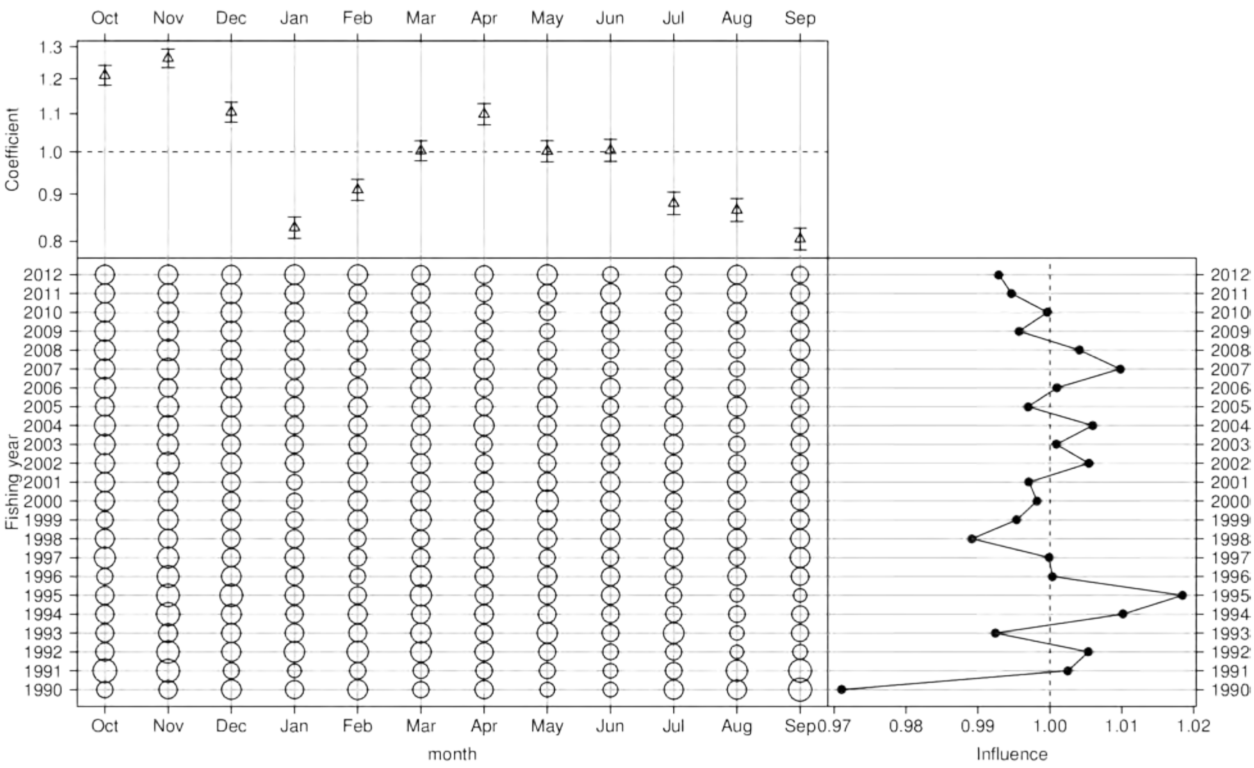


Figure N.19: Effect of month **in the lognormal model for the SPO 2_BT(MIX) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

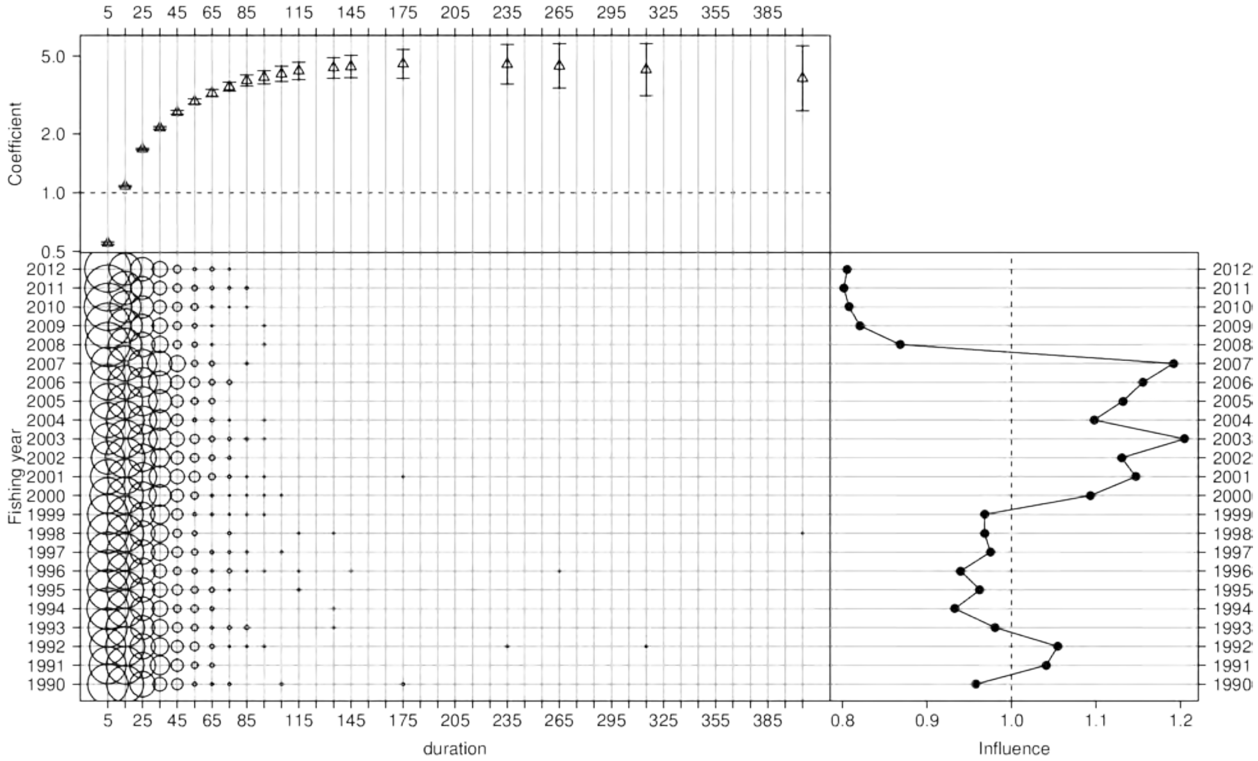


Figure N.20: Effect of duration **in the lognormal model for the SPO 3_BT(MIX) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

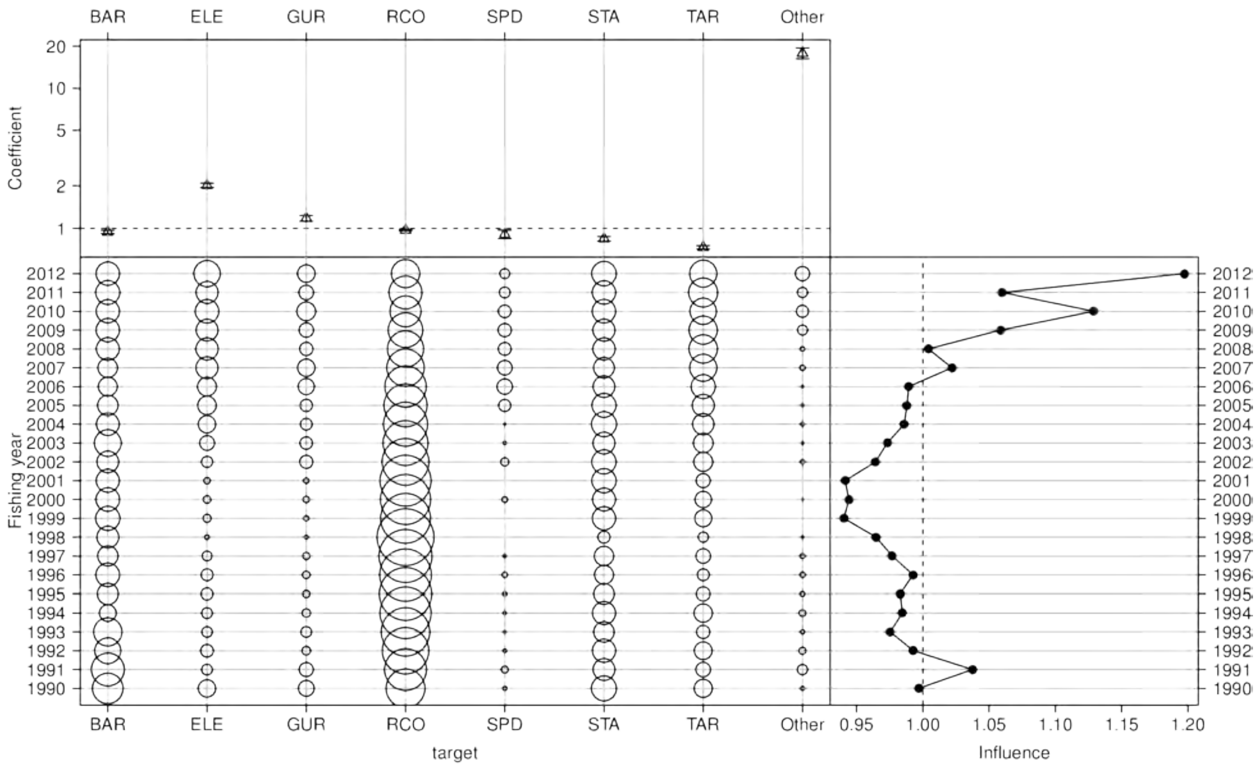


Figure N.21: Effect of target **in the log normal model for the SPO 3_BT(MIX) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

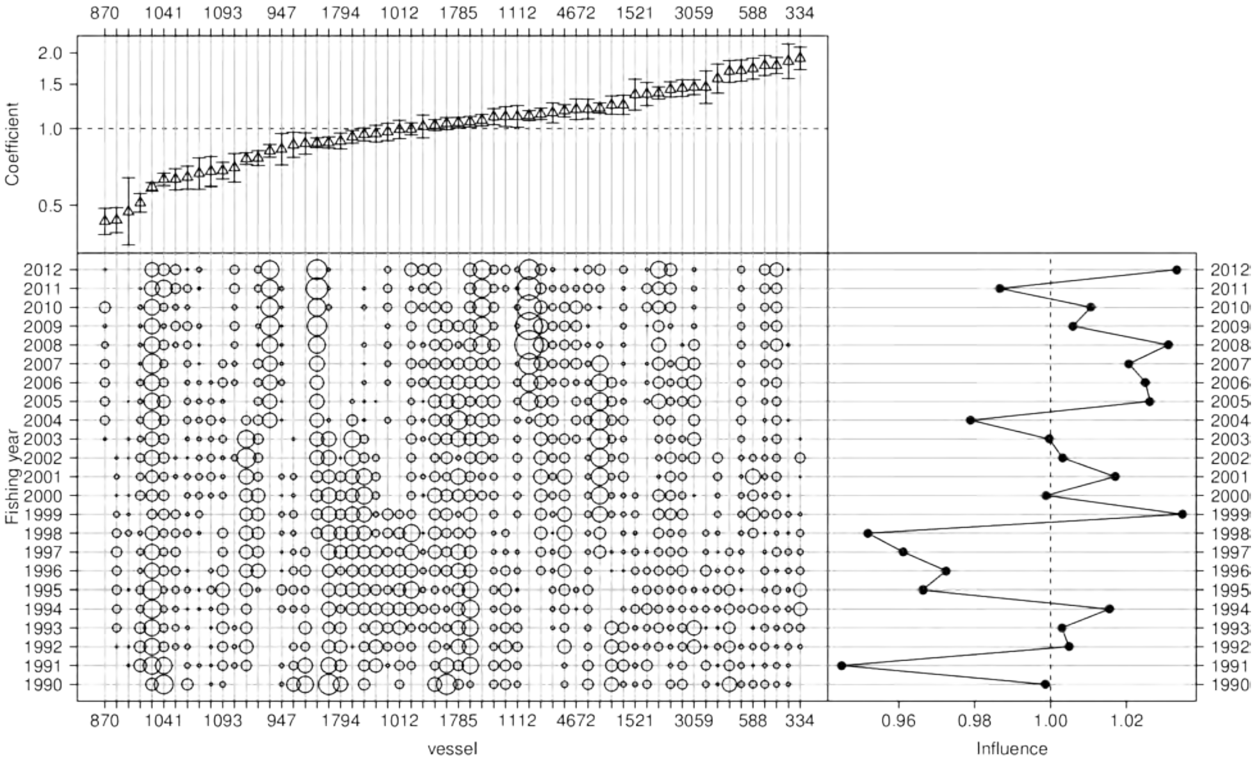


Figure N.22: Effect of vessel **in the lognormal model for the SPO 3_BT(MIX) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

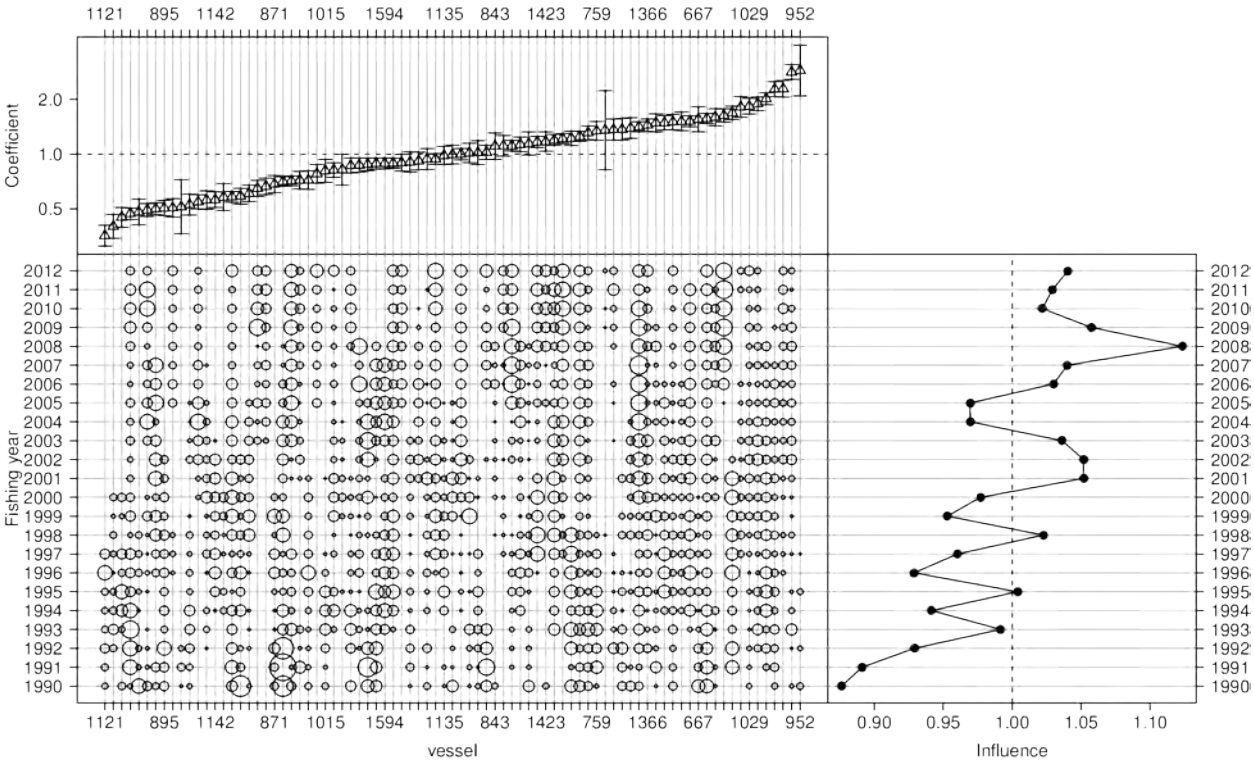


Figure N.23: Effect of vessel **in the lognormal model for the SPO 3_BT(FLA) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

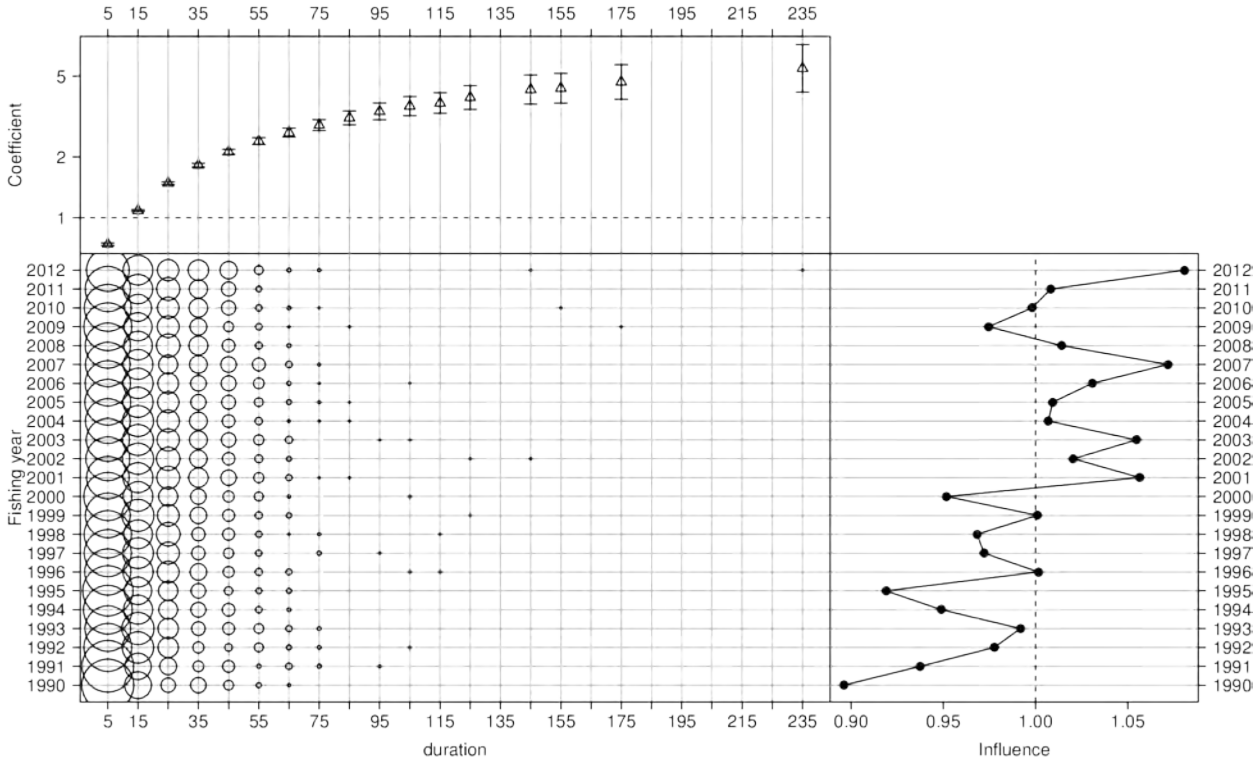


Figure N.24: Effect of duration **in the lognormal model for the SPO 3_BT(FLA) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

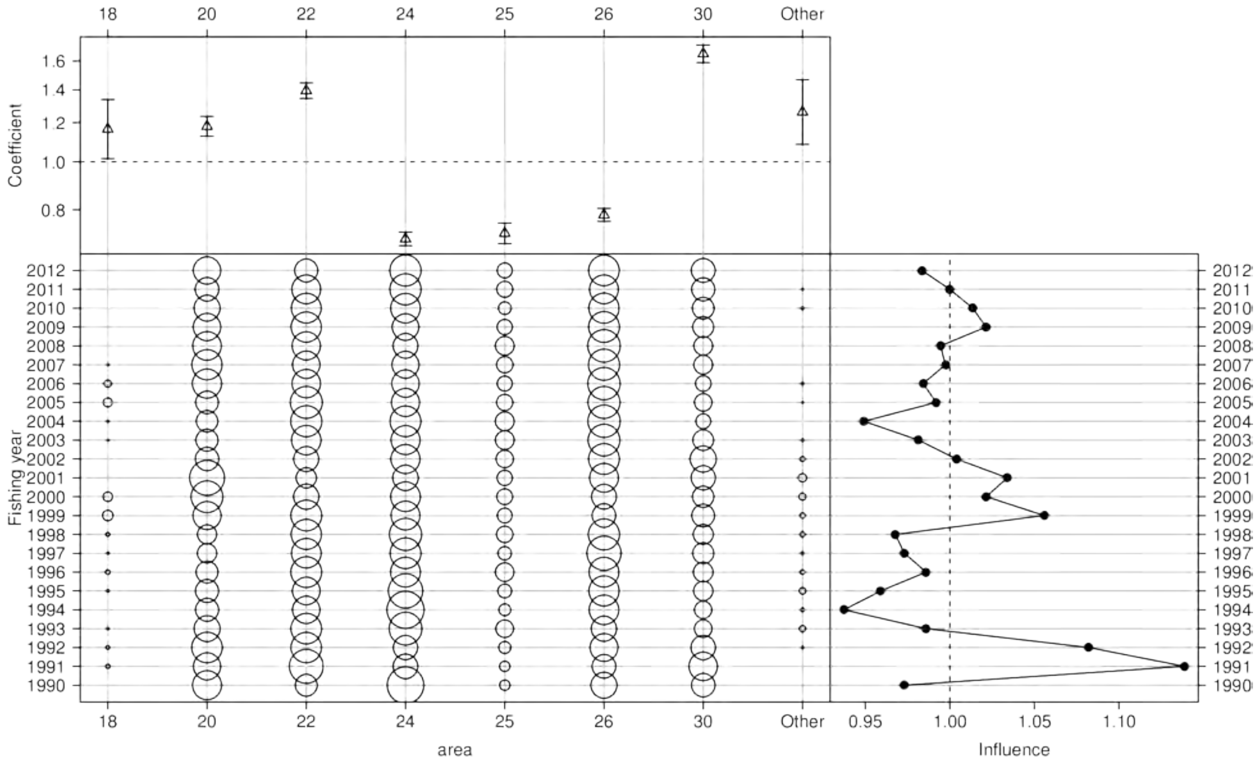


Figure N.25: Effect of area **in the lognormal model for the SPO 3_BT(FLA) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

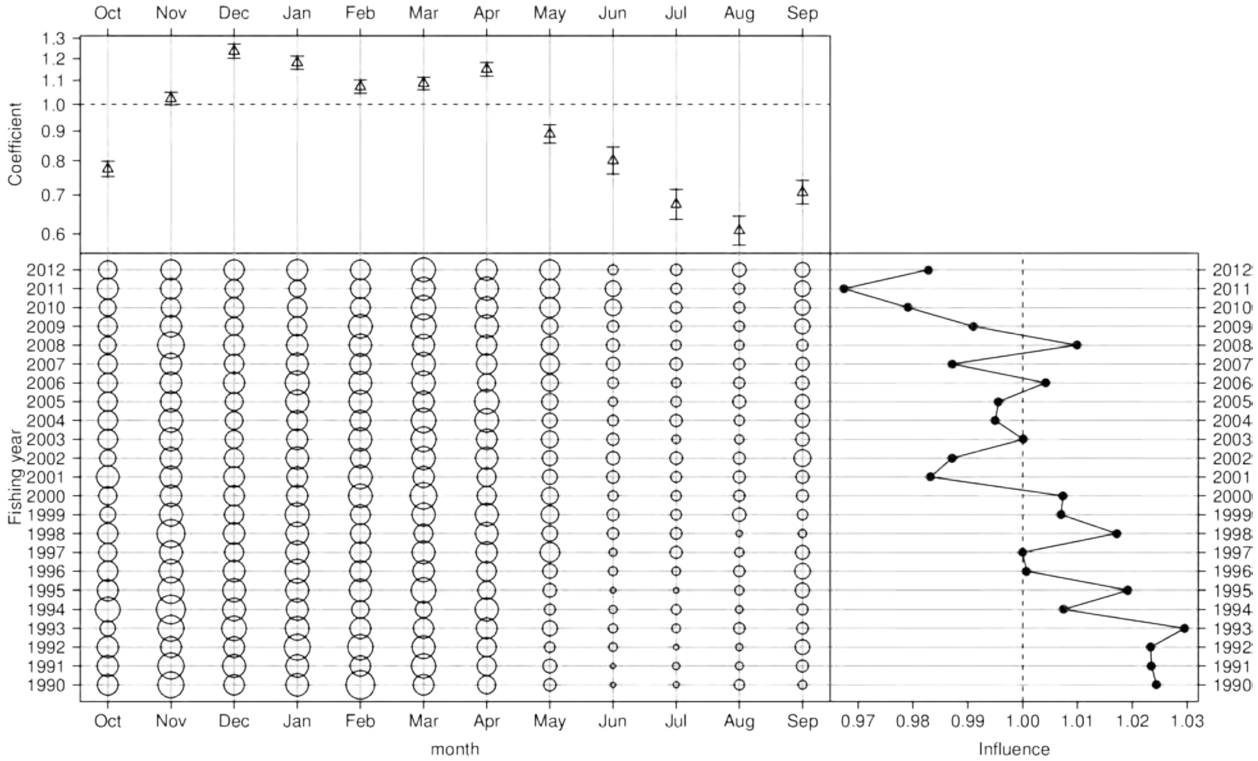


Figure N.26: Effect of month **in the lognormal model for the SPO 3_BT(FLA) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

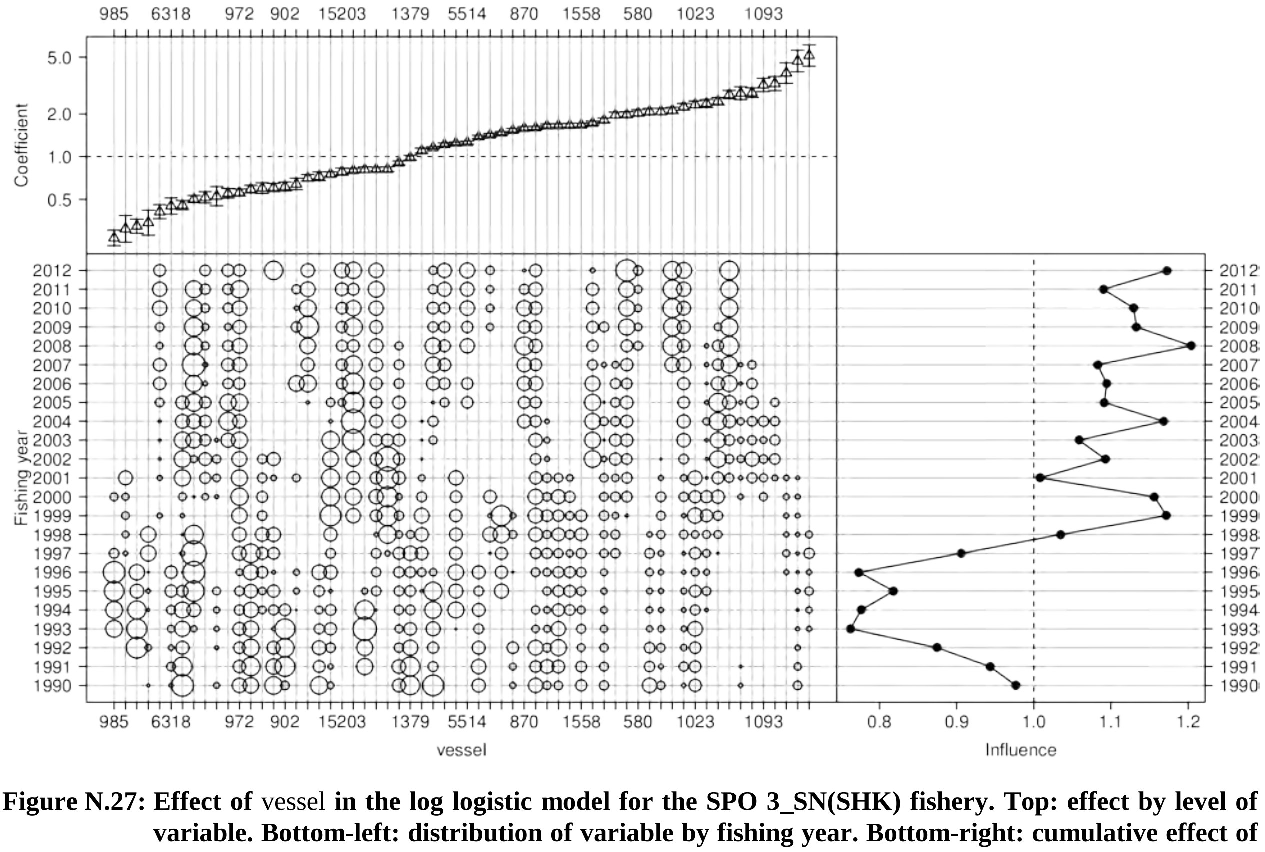


Figure N.27: Effect of vessel **in the log logistic model for the SPO 3_SN(SHK) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

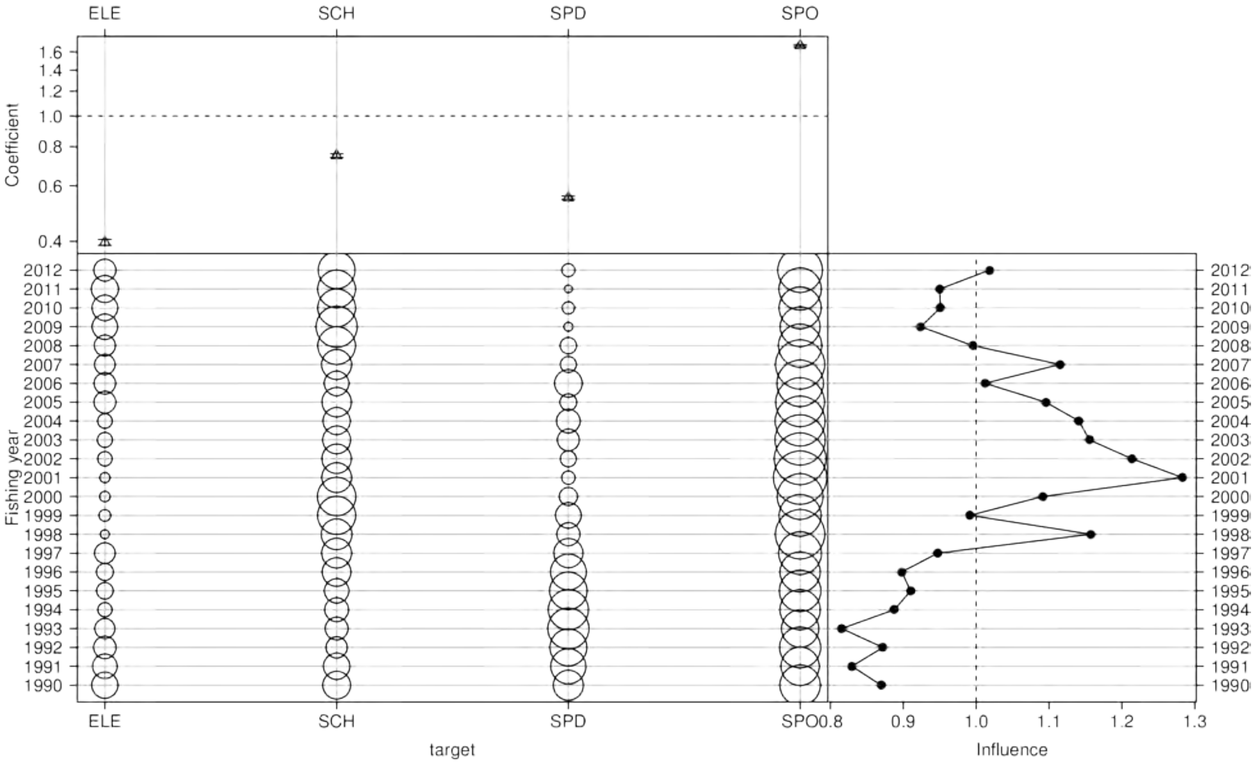


Figure N.28: Effect of target **in the log logistic model for the SPO 3_SN(SHK) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

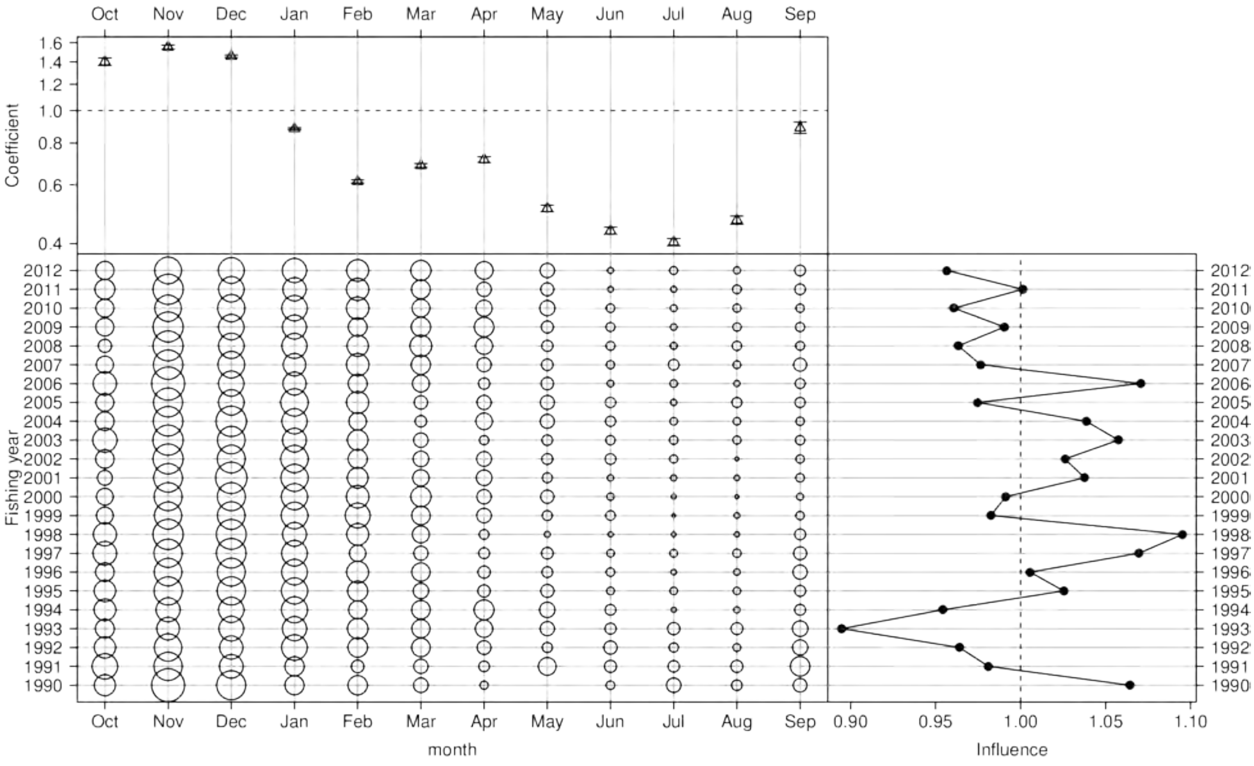


Figure N.29: Effect of month **in the log logistic model for the SPO 3_SN(SHK) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

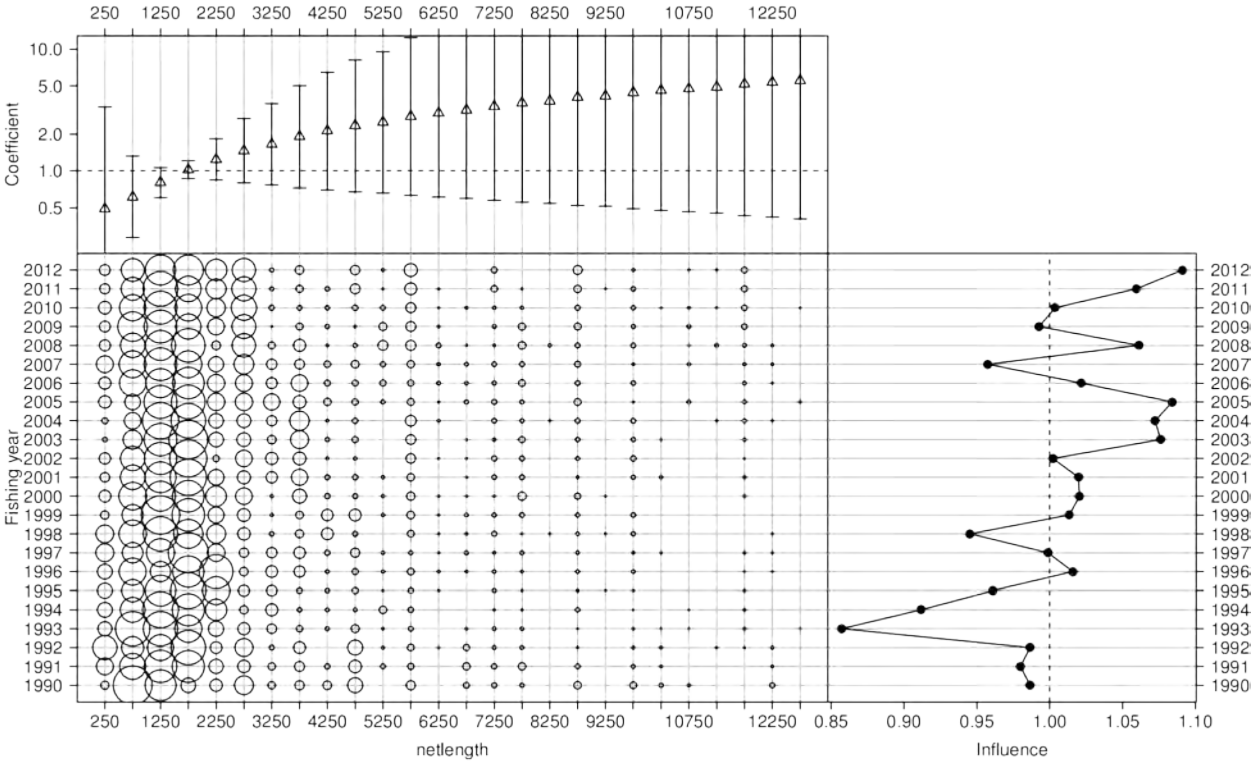


Figure N.30: Effect of netlength **in the log logistic model for the SPO 3_SN(SHK) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

N.5 CPUE indices

Table N.2: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error for the core data set by fishing year for each of the four CPUE models.

	SPO 2 BT(MIX)					SPO 3 BT(MIX)				
Fishing	All	Core vessel indices				All	Core vessel indices			
Year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Arithmetic	Arithmetic	Geometric	Standardised	SE
1990	0.9555	0.9845	0.9097	0.8298	0.05684	0.4510	0.4952	1.0065	1.0085	0.05997
1991	0.8160	0.8814	0.9599	0.8166	0.05706	0.5352	0.5796	0.8785	0.9181	0.05196
1992	0.9411	0.8530	0.8967	0.8546	0.04475	0.5746	0.5797	0.9486	0.9059	0.04496
1993	1.0951	1.1681	0.9906	0.9766	0.04548	0.5896	0.6101	0.7666	0.7406	0.04462
1994	0.8876	0.8911	0.8894	0.8249	0.03996	0.8681	0.8879	0.9059	0.9099	0.04074
1995	0.9345	1.0365	0.9825	0.9300	0.03929	0.7369	0.7952	1.0031	1.0592	0.04172
1996	1.0010	0.9940	0.9127	0.9098	0.04113	1.0050	1.1694	1.0305	1.1445	0.04082
1997	0.9740	1.0018	1.0016	1.0525	0.03883	0.5810	0.6243	0.7944	0.8985	0.04347
1998	0.8025	0.8537	0.8709	0.9504	0.03571	0.5838	0.5732	0.8235	1.0112	0.04128
1999	0.7754	0.7987	0.9018	1.0419	0.03354	0.5465	0.5514	0.7979	0.9329	0.04179
2000	0.7921	0.8417	0.9728	1.0340	0.03340	0.7041	0.7131	0.8393	0.9953	0.04083
2001	0.7953	0.7976	0.8439	0.9647	0.03343	1.1872	0.9128	0.8400	0.9820	0.04109
2002	0.8294	0.8645	0.9962	1.1613	0.03315	1.0060	1.0033	0.8813	1.0026	0.04166
2003	1.0407	1.0995	1.0640	1.2094	0.03381	1.2779	1.3086	0.9319	1.0131	0.04059
2004	1.0759	1.0869	1.1151	1.1860	0.03521	1.3447	1.2982	0.9793	1.0415	0.04144
2005	1.0957	1.1673	1.1220	1.0453	0.03494	1.0011	0.9356	0.8815	0.8928	0.03970
2006	1.2723	1.2554	1.1756	1.1305	0.03397	1.0883	1.0712	0.9487	0.9761	0.03981
2007	1.1127	0.9747	0.9878	0.9267	0.03507	2.1187	2.2515	1.1337	1.0737	0.04149
2008	1.1732	1.1267	1.0398	1.0402	0.03832	1.6034	1.6002	1.3428	1.1394	0.04594
2009	1.0711	0.9627	0.9112	0.9709	0.04014	1.8167	1.6326	1.4023	1.1420	0.04365
2010	1.2929	1.2688	1.2738	1.1796	0.03762	1.8323	1.7933	1.5899	1.1922	0.04326
2011	1.1868	1.0568	1.0598	0.9920	0.03757	2.0635	1.8515	1.2713	1.0420	0.04510
2012	1.4136	1.2798	1.2706	1.1305	0.03757	2.7933	2.7844	1.5551	1.1010	0.04746

Table N.2: (continued)

	SPO 3_BT(FLA)					SPO 3_SN(SHK)				
Fishing	All	Core vessel indices				All	Core vessel indices			
Year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Arithmetic	Arithmetic	Geometric	Standardised	SE
1990	0.5242	0.6134	0.9859	1.1174	0.0619	0.8013	0.7758	0.9495	1.0435	0.05609
1991	0.7261	0.7929	1.3203	1.2035	0.0594	0.5132	0.4685	0.7881	0.9831	0.05271
1992	0.8195	0.9289	1.1315	1.0339	0.0511	0.6956	0.619	0.8372	1.0937	0.04378
1993	0.8357	1.0464	1.0317	1.0865	0.0544	0.477	0.4334	0.5614	0.9745	0.03767
1994	0.6797	0.7740	0.8340	0.9484	0.0532	0.538	0.5504	0.5343	0.7953	0.03285
1995	0.5684	0.6052	0.9787	0.9759	0.0526	0.7664	0.8321	0.7311	0.9432	0.03462
1996	0.6736	0.5827	0.9635	1.0775	0.0532	0.9208	0.9304	0.743	1.043	0.03692
1997	0.7348	0.7577	0.8459	1.0223	0.0451	1.1019	1.1596	1.0829	1.1337	0.04054
1998	1.0275	1.1235	0.9855	1.0787	0.0452	1.3956	1.5087	1.6765	1.2297	0.04079
1999	0.7217	0.6845	0.9180	0.9513	0.0427	1.2281	1.2649	1.2796	1.1605	0.04157
2000	1.0911	0.9988	1.0982	1.1003	0.0395	1.4781	1.5308	1.2883	1.0945	0.04114
2001	1.3500	1.2867	1.1290	1.1294	0.0442	1.3185	1.511	1.4025	1.1129	0.03596
2002	0.7971	0.7927	0.8127	0.9220	0.0450	1.2055	1.4379	1.347	1.0285	0.03815
2003	0.8885	0.8793	0.8706	0.9927	0.0408	0.9665	1.1089	0.9525	0.7983	0.03613
2004	0.8114	0.8046	0.8585	1.0192	0.0425	1.026	1.148	1.008	0.7717	0.0389
2005	1.0511	0.8511	0.9452	0.9897	0.0408	1.4799	1.0759	0.9745	0.8624	0.03722
2006	1.2252	1.2437	1.0694	0.9872	0.0434	1.0174	1.0279	1.066	0.901	0.03639
2007	1.3785	1.3107	0.9350	0.8612	0.0419	2.1317	1.607	1.2864	1.0767	0.0365
2008	1.4971	1.5977	1.1274	0.9049	0.0461	1.2935	1.2459	1.1086	0.9817	0.03842
2009	1.4292	1.4187	1.0353	0.8041	0.0472	1.034	1.0735	1.0207	1.0055	0.03988
2010	2.0693	1.9952	1.2092	1.0142	0.0455	1.0534	1.1012	1.0426	1.0591	0.04073
2011	2.0730	1.6985	1.1041	0.9855	0.0479	0.8607	0.8905	0.9866	0.9847	0.04142
2012	1.9611	1.7319	0.9858	0.8920	0.0467	1.1272	1.1022	1.1605	1.0868	0.04313

Appendix O. CPUE ANALYSES FOR SPO 7

O.1 General overview

This study extends the analyses of two setnet fisheries for SPO 7 that were presented in 2010 (Starr et al. 2010) with an additional three years of data, and also continues an abundance series based on bottom trawl. CPUE indices are estimated for setnet on the west coast of the south Island and for the target fishery in Area 038, as well as for the bottom trawl fishery operating in all SPO 7 statistical areas. The analyses are done on landed greenweight which has been corrected for changes in conversion factors used to back calculate greenweight from processed weight (see Section 2.3.2.2). Improvements made since the previous analyses include the selection of the most appropriate error distributions, improved diagnostic plots for evaluating potentially confounding interaction terms and better grooming of landings data (see Appendix D).

Historically, much of the catch of rig has been reported on the daily CELR form, but new event-based forms for both bottom trawl (TCER: introduced in 2007–08) and for setnet (NCELR: introduced in 2006–07) have resulted in changes to the resolution at which catch and effort data are available. In order to be able to use the full extent of the available data, the more detailed information must be amalgamated to a common resolution with earlier data to effect a sensible combination. Only the analyses of positive catches are presented, as amalgamated data include zero catches and should subsume signals from the probability of capture.

The SINSWG accepted the SPO 7-SN(38) CPUE series with Science Information Quality=1 as being able to monitor all components of the rig population. The west coast South Island setnet series and the SPO 7 bottom trawl series were accepted with Science Information Quality=2. The SINSWG reasoned that the bottom trawl fishery does not monitor the full range of the adult population and there was concern that the coverage of the coastal setnet fishery was compromised in recent years because of the contraction of the fishery in the face of regulatory restrictions implemented to conserve Hector's dolphins.

O.2 Methods

O.2.1 Fishery definitions for CPUE analysis

Two setnet fisheries directed at sub-areas of SPO 7, SN(WC), and SN(038), are defined for CPUE analysis, continuing the same definitions previously presented by Starr et al. (2010). BT(all) was first defined in 2007 to evaluate indices that might be considered representative of the entire SPO 7 Fishstock:

SPO 7_SN(038) – Shark setnet in area 038 – The Fishery is defined from setnet fishing events which fished in Statistical Area 038, and targeted SPO, SCH, SPD, or ELE. This definition potentially allows the use of total effort in the analysis of catch rates, however only the analysis of positive catches is presented in detail.

SPO 7_SN(WC) – west coast setnet – The fishery is defined from setnet events which fished in Statistical Areas 032–037 and targeted SPO, SCH, SPD, or ELE. This definition potentially allows the use of total effort in the analysis of catch rates, however only the analysis of effort associated with positive catches is presented in detail.

SPO 7_BT(all) – SPO 7 mixed species bottom trawl -- The fishery is defined from bottom single trawl fishing events which fished in Statistical Areas 016–018, 032–040, and targeted SPO, RCO, BAR, TAR, GUR, or FLA. This definition potentially allows the use of total effort in the analysis of catch rates, however only the analysis of effort associated with positive catches is presented in detail.

O.3 Unstandardised CPUE

O.3.1 SPO 7_SN(038) Shark setnet in area 038

Effort in this fishery peaked in the early 1990s at 200 trips and has generally declined since then to about 70 trips per year since the mid-2000s (Figure O.1). The fishery is a target rig fishery with very few trips reporting no catch of rig. At trip stratum resolution, there is evidence of peaks in the mid-1990s and again in the late 2000s in the proportion of zero catches, presumably when effort has been directed at other shark species (Figure O.2). Catch rates in successful trips were lowest around the turn of the decade at around 200 kg per set but have increased markedly since then to peak in 2010–11 at greater than 650 kg per set (Figure O.1). A coincident change in reporting is also evident with the number of records per strata increasing from 1.5 to more than 3.5 in 2007–08 before declining again (Figure O.2).

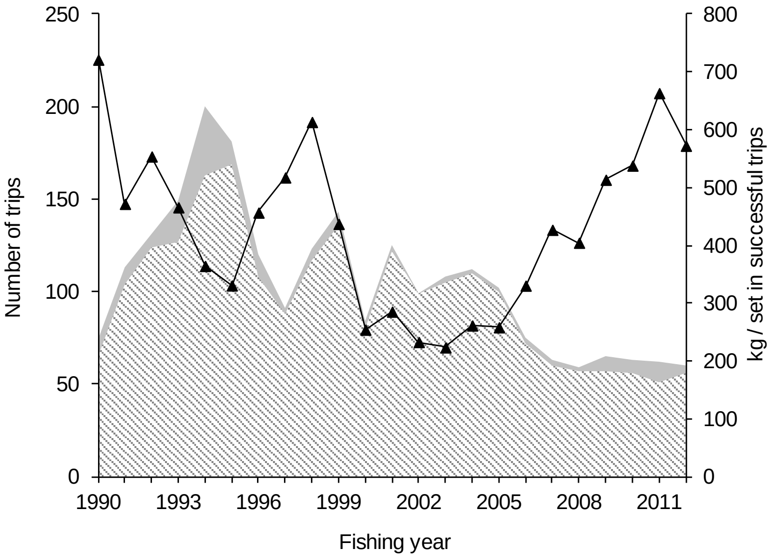
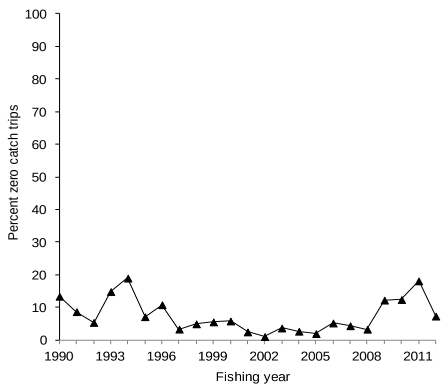


Figure O.1: Number of qualifying trips in SPO 7_SN(038) (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/set, black line) of rig in successful trips, by fishing year.



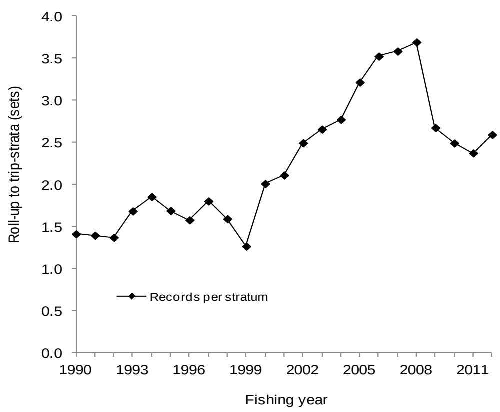


Figure O.2: The proportion of qualifying trips in SPO 7_SN(038), that landed zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of sets per trip-stratum, by fishing year.

O.3.2 SPO 7_SN(WC) Shark setnet on west coast of SPO 7

Effort in this fishery has also declined during the 2000s from around 200 trips per year for most of the 1990s to a new level of about 50 trips per year (Figure O.3). The proportion of trips not landing any rig has been small and consistent, and, at the level of a trip stratum, it varies between 5 and 20% zero strata with no overall trend up or down (Figure O.4). Catch rates in successful trips peaked at more than 450 kg per set in the mid 1990s during a period when effort slumped briefly, and has gradually declined since then to currently fluctuate around 250 kg per set (Figure O.3). The rollup of data to trip stratum shows some pattern during the 2000s, increasing from about 2 records to nearer 2.7 records per stratum in 2006–07 before declining again (Figure O.4).

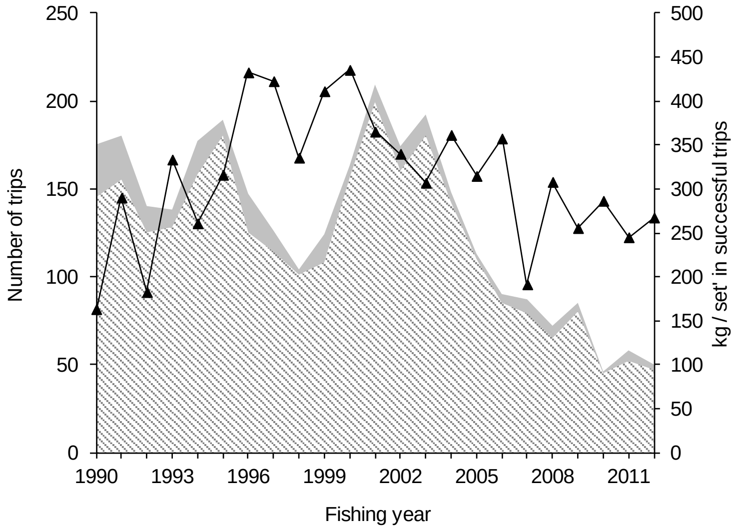


Figure O.3: Number of qualifying trips in SPO 7_SN(WC) (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/set, black line) of rig in successful trip-strata, by fishing year.

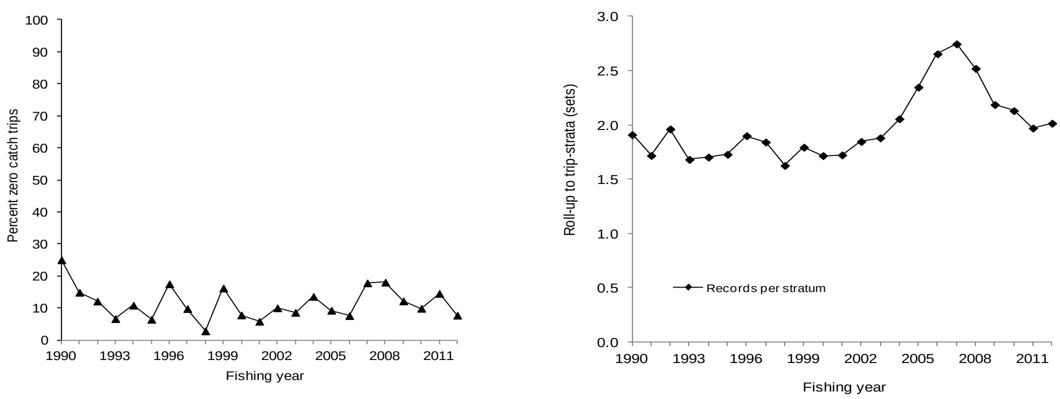


Figure O.4: The proportion of qualifying trips in SPO 7_SN(WC), that landed zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of sets per trip-stratum, by fishing year.

O.3.3 SPO 7_BT(all) Mixed target bottom trawl in SPO 7

Effort in this trawl fishery peaked at about 3500 trips completed in 1992–93, and has declined steadily since then to currently operate at about half of that level of activity (Figure O.5). The earlier activity included more trips that did not land rig, and, at trip stratum resolution, there is a declining trend in unsuccessful effort (from 50% to about 40%) (Figure O.6). Catch rates in successful trips appear to have increased but bycatch rates of rig generally only average around 10–12 kg per tow (Figure O.5).

The rollup of data to trip stratum shows a change in reporting practice after the introduction of the new form in 2007–08 that is likely to reflect better reporting of target species (Figure O.6). The wide fishery definition used in this study should mitigate that effect and include comparable tows both before and after the introduction of the tow-by-tow form.

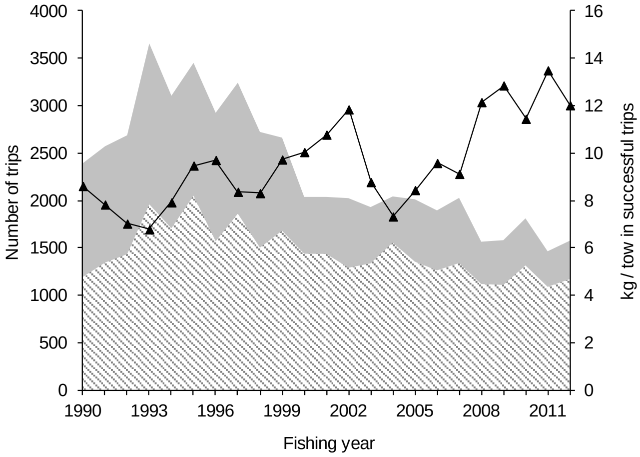


Figure O.5: Number of qualifying trips in SPO 7_BT(all) (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/tow, black line) of rig in successful trip-strata, by fishing year.

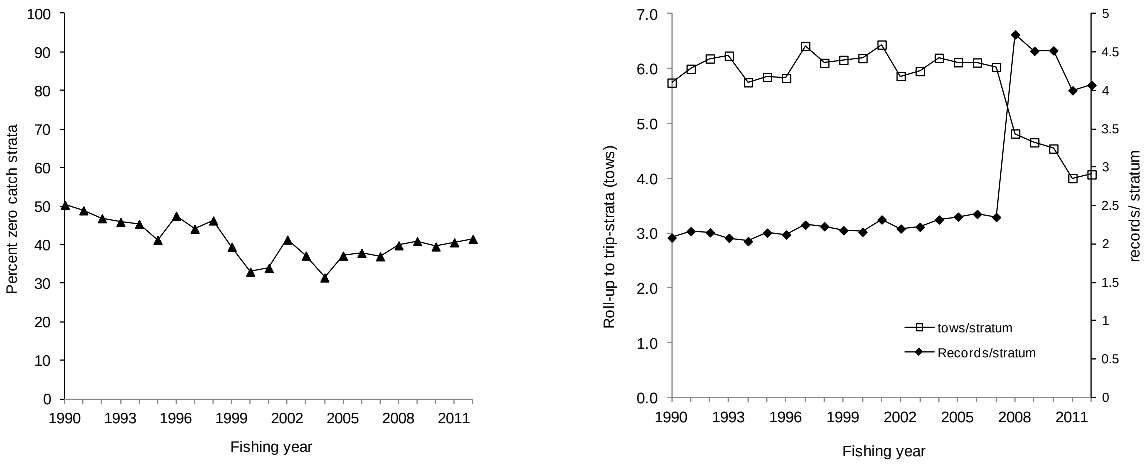


Figure O.6: The proportion of qualifying trips in SPO 7 BT(all), that landed zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of tows per trip-stratum, by fishing year.

O.4 Standardised CPUE analysis

O.4.1 Core fleet definitions

The data sets used for the standardised CPUE analysis were restricted to those vessels that participated with some consistency in the defined fishery. Core vessels were selected by specifying two variables; the number of trips that determined a qualifying year, and the number of qualifying years that each vessel participated in the fishery. The effect of these two variables on the amount of landed rig retained in the dataset and on the number of core vessels, and the length of participation by the core vessels in each fishery are depicted in Figure P.1 to Figure P.3. The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of rig. The selection process usually reduced the number of vessels in the dataset by about 70% while reducing the amount of landed rig by about 20%. All three fisheries selected the core vessel fleet on the basis of a minimum of 10 trips for each of five years Summaries for the core vessel data sets are presented in Table P.1.

O.4.2 Model selection, diagnostics and trends in model year effects

The final models selected for standardising positive catches in each fishery are described in Table O.1 (SPO 7_SN(038)), Table O.2 (SPO 7_SN(WC)) and Table O.3 (SPO 7_BT(all)). These tables include the explanatory variables that met the AIC criteria and each is not necessarily a complete list of the variables that were offered[4]. The variables that met the acceptance criteria based on a 1% improvement in R^2 are indicated with asterisks in the table, along with the amount of deviance they explained.

Following each table are step-influence plots that demonstrate the progressive effect on the annual indices of each explanatory variable as it enters the model, and shows the influence of each variable on the annual coefficients in adjacent panels. These plots highlight the observation made in Bentley et al. (2011) that the variables that explain the most deviance are not necessarily the ones responsible for most of the difference between standardised and observed series of CPUE.

Diagnostic plots of the residuals from each final model fit are given in Appendix P.3 and include implied coefficient plots for each statistical area and target species by year. These allow the comparison of the annual trends among statistical area and target species categories in each analysis, effectively serving as a proxy for an interaction analysis. The influence of an explanatory variable is a combination of the coefficients and its distributional changes over years, and are plotted as Coefficient-Distribution-Influence (CDI) plots (Bentley et al. 2011) for each accepted explanatory variable (see Appendix P.4). The unstandardised and standardised indices from the final model for each fishery are given in Appendix P.5.

O.4.2.1 SPO 7_SN(038) – SPO 7 Shark setnet in Area 038

The log-logistic error distribution produced the best model fit to SPO 7_SN(038) data (Figure P.4) and the residuals from the final model showed a good fit of the data to the distributional assumption (Figure P.5). Fishing year was forced as the first variable and explained about 3% of the variance in catch, target species is the most important variable, entering second and explaining a further 15% of variance in catch, but netlength, which entered third explained a further 14% of variance (Table O.1). Month was also accepted into the final model which explained about 38% of the variance in log(catch) (Table O.1). The annual indices are plotted at each step in Figure O.7, and demonstrate that, despite having similar power to explain variance, the influence of net length was much greater than that of target species in moving the standardised series away from the unstandardised.

Table O.1: Order of acceptance of variables into the log-logistic model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 3 trips in 3 or more fishing years) in the SPO 7_SN(038) fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an *. Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	24	-15 192	30 431	3.07	*
target	27	-15 031	30 116	17.44	*
poly(log(netlength), 3)	30	-14 844	29 747	31.55	*
month	41	-14 736	29 554	38.52	*
poly(log(duration), 3)	44	-14 728	29 545	39.00	
vessel	100	-14 669	29 539	42.49	
poly(log(days), 3)	103	-14 664	29 535	42.79	

The inclusion of target species adjusts for a period of increased targeting of spiny dogfish in the mid 1990s, and a recent increase in targeting school shark, both of which are likely to have led to decreased catches of rig (Figure P.14). The systematic trend towards greater netlength, however, has

[4] Variables which make no improvement in the AIC are ignored by the software.

potentially doubled rig catches over the period (Figure P.15). The month coefficients show a fishery in which catches drop away in the winter months (Figure P.16), but so does effort (Figure P.15). Small shifts in the seasonality of fishing have been adjusted for from year to year with little influence overall.

The year effects decline steadily over the first half of the time series to sit at about 80% of the mean for the first half of the 2000s. Some recovery since then puts the series currently above the series mean. (Figure O.8). The indices appear well determined in that trends are maintained over consecutive years and slopes look credible despite large error bars around each point. There is some divergence from the previous series presented for this fishery that may be due to improved grooming of setnet data. The main effect of standardisation is to lift recent points as the model accounts for a shift towards more targeting on school shark (Figure O.8). Residual implied coefficients are not contradictory for each target fishery however, and describe similar recent increases in catches whether rig or school shark is targeted (Figure P.6).

a) b)

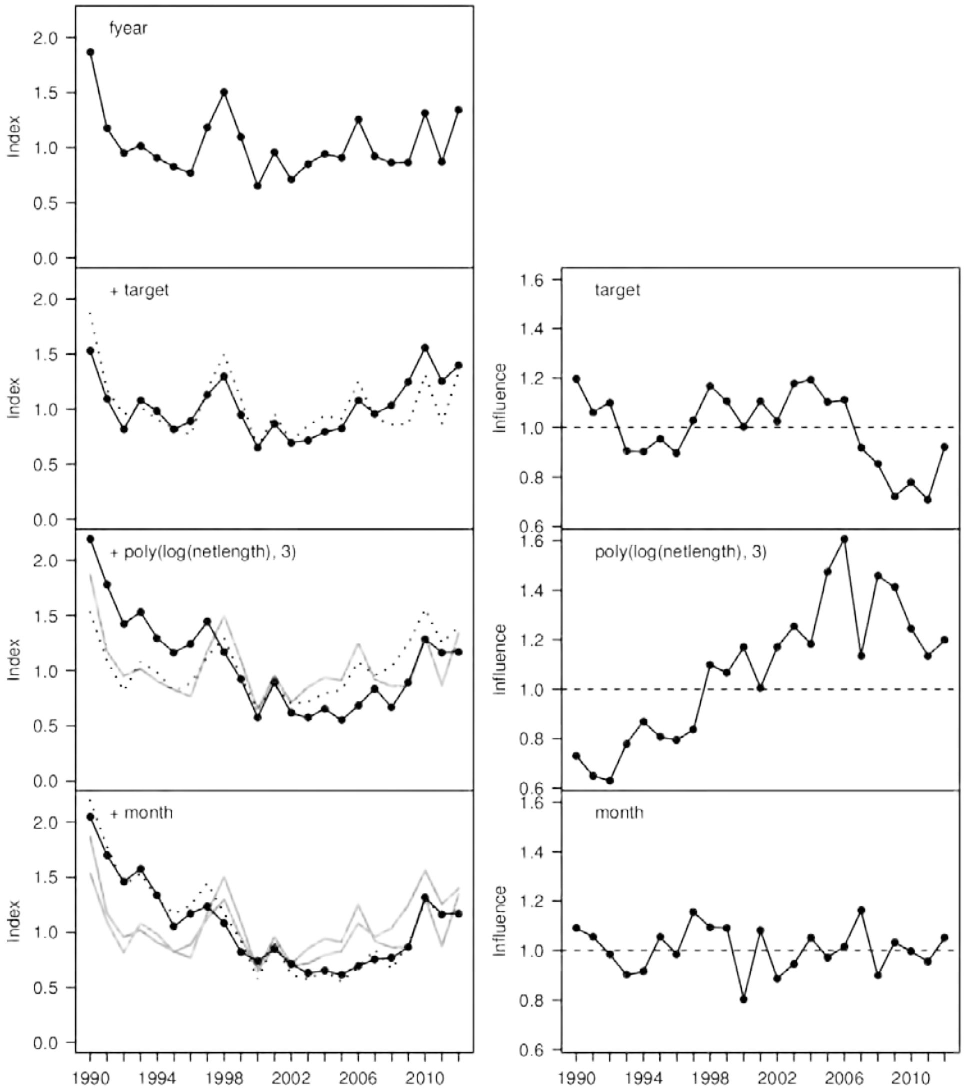


Figure O.7: Step and annual influence plot for SPO 7_SN(038). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

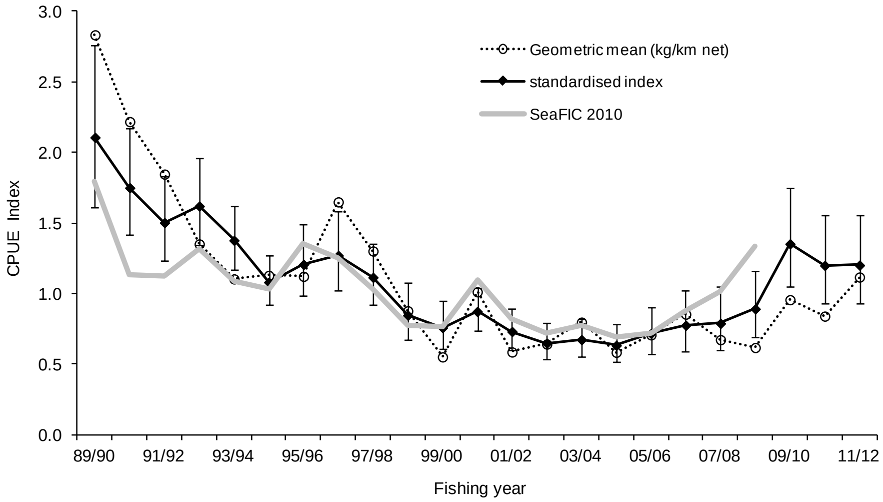


Figure O.8: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 7_SN(038) fishery. Broken lines are the raw CPUE (kg /km net) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the lognormal series presented in 2010 for a similar fishery. All series are relative to the geometric mean over the years in common.

O.4.2.2 SPO 7_SN(WC) – SPO 7 West coast shark setnet

The log logistic error distribution produced the best model fit to SPO 7_SN(WC) data (Figure P.7), and the residuals from the final model showed a good fit of the data to the distributional assumption (Figure P.8). Fishing year was forced as the first variable and explained about 3% of the variance in catch, target species is the most important variable, entering second and explaining a further 26% of variance in catch, and duration was the measure of effort with the greatest explanatory power, it entered third and explained a further 14% of variance (Table O.2). Area and month were also accepted into the final model which explained about 50% of the variance in log(catch). The annual indices are plotted at each step in Figure O.9, and show the negative influence that a shift in target behaviour in the early 2000s had on observed catches, and the positive adjustment to the annual indices made as the model accounts for it. The inclusion of duration and area into the model move the indices back a little, to more resemble the unstandardised trajectory.

A shift in targeting away from rig and towards more targeting of school shark occurred in 2003–04 and was predicted to have lowered catches of rig by at least 70% (Figure P.17). The systematic trend towards greater set times, however, has potentially lifted rig catches by a similar amount over the period (Figure P.18). A shift of effort out of Areas 032 and 033 into Area 037 has increased overall catch success, and catches are estimated to have improved almost 40% as a direct consequence (Figure P.19). Small shifts in the seasonality of fishing have been adjusted for from year to year with little influence overall (Figure P.20).

The year effects have relatively large error bars and fluctuate from year to year with no trend overall (Figure O.10). They do not agree closely with the previous series presented for this fishery, which probably reflects a slightly different core vessel selection that combines data over disparate regions.
The residual implied coefficient plots for each area (Figure P.9) and each target fishery (Figure P.10) in each year confirm that there is no common trend among each of these strata within the defined fishery, indicating that there may be interaction problems with this analysis.

The main effect of standardisation is to smooth and flatten the unstandardised series, in particular, lifting recent points to account for the shift towards more targeting of school shark (Figure O.10).

Table O.2: Order of acceptance of variables into the log logistic model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 5 trips in 5 or more fishing years) in the SPO 7_SN(WC) fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an * . Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	24	-14 664	29 377	3.13	*
target	27	-14 340	28 733	29.44	*
poly(log(duration), 3)	30	-14 120	28 299	43.05	*
area	35	-14 040	28 151	47.29	*
month	46	-13 978	28 048	50.40	*
poly(log(days), 3)	49	-13 967	28 031	50.95	

a) b)

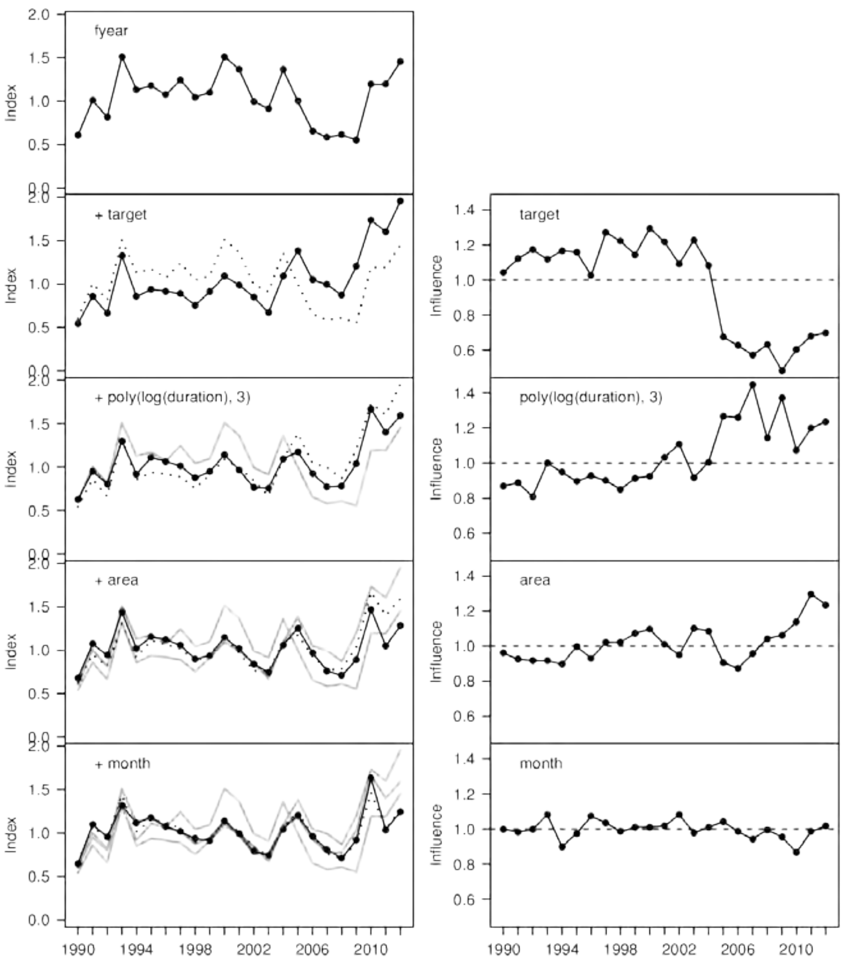


Figure O.9: Step and annual influence plot for SPO 7_SN(WC). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

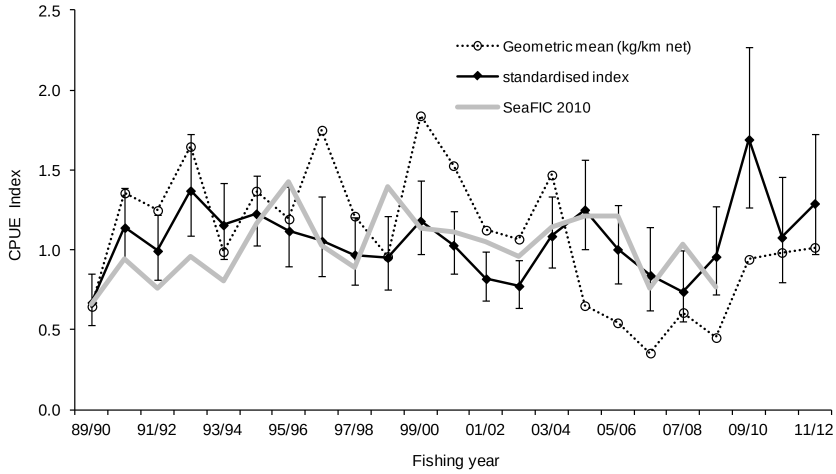


Figure O.10: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 7_SN(WC) fishery. Broken lines are the raw CPUE (kg /km net) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the previous lognormal series presented in 2010 for a similar fishery. All series are relative to the geometric mean over the years in common.

O.4.2.3 SPO 7_BT(all) – SPO 7 Mixed target bottom trawl

The log normal error distribution was forced for the model fit to SPO 7_BT(all) data. This was done for consistency with other trawl method analyses and because the residuals from the fit to the final model showed a good fit to the lognormal assumption (Figure P.11). Fishing year was forced as the first variable and explained about 1% of the variance in catch, vessel is the most important variable, entering second and explaining a further 18% of variance in catch, and the number of tows was the measure of effort with the greatest explanatory power, it entered third and explained a further 10% of variance (Table O.3). Month, area and target species were also accepted into the final model which explained about 34% of the variance in log(catch) (Table O.3). The annual indices are plotted at each step in Figure O.11 and show the strong positive influence that changes to the core fleet have had on observed catches over the whole period, and the effect of adjusting for the change in reporting in the mid-2000s. The effect on the annual indices of including month, area, and target into the model are small.

Table O.3: Order of acceptance of variables into the lognormal model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 5 trips in 10 or more fishing years) in the SPO 7_BT(all) fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an * . Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	23	-55 468	110 983	1.02	*
vessel	111	-52 500	105 225	19.27	*
poly(log(num) 3)	114	-50 479	101 187	29.79	*
month	125	-49 992	100 236	32.12	*
area	136	-49 640	99 554	33.75	*
target	141	-49 388	99 060	34.90	*
poly(log(duration) 3)	144	-49 353	98 996	35.06	

There are well defined differences in performance among vessels in the core fleet, and a steady improvement as the result of the withdrawal from the fishery of many of the poorer performing vessels (Figure P.21). Improvements in the fleet account for an almost 100% increase in rig catch. The switch to tow-by-tow reporting of catch and effort in 2008 has affected the roll-up to trip-stratum, this is likely to be an artefact of more detailed targeting information being recorded (Figure O.5). The model appears to account adequately for the shift towards fewer tows per record (Figure P.22). The fishery has been operated in a consistent manner with respect to season, statistical area and target species, with adjustments made for small differences from year to year not influencing the overall trend markedly (Figure P.23, Figure P.24, Figure P.25).

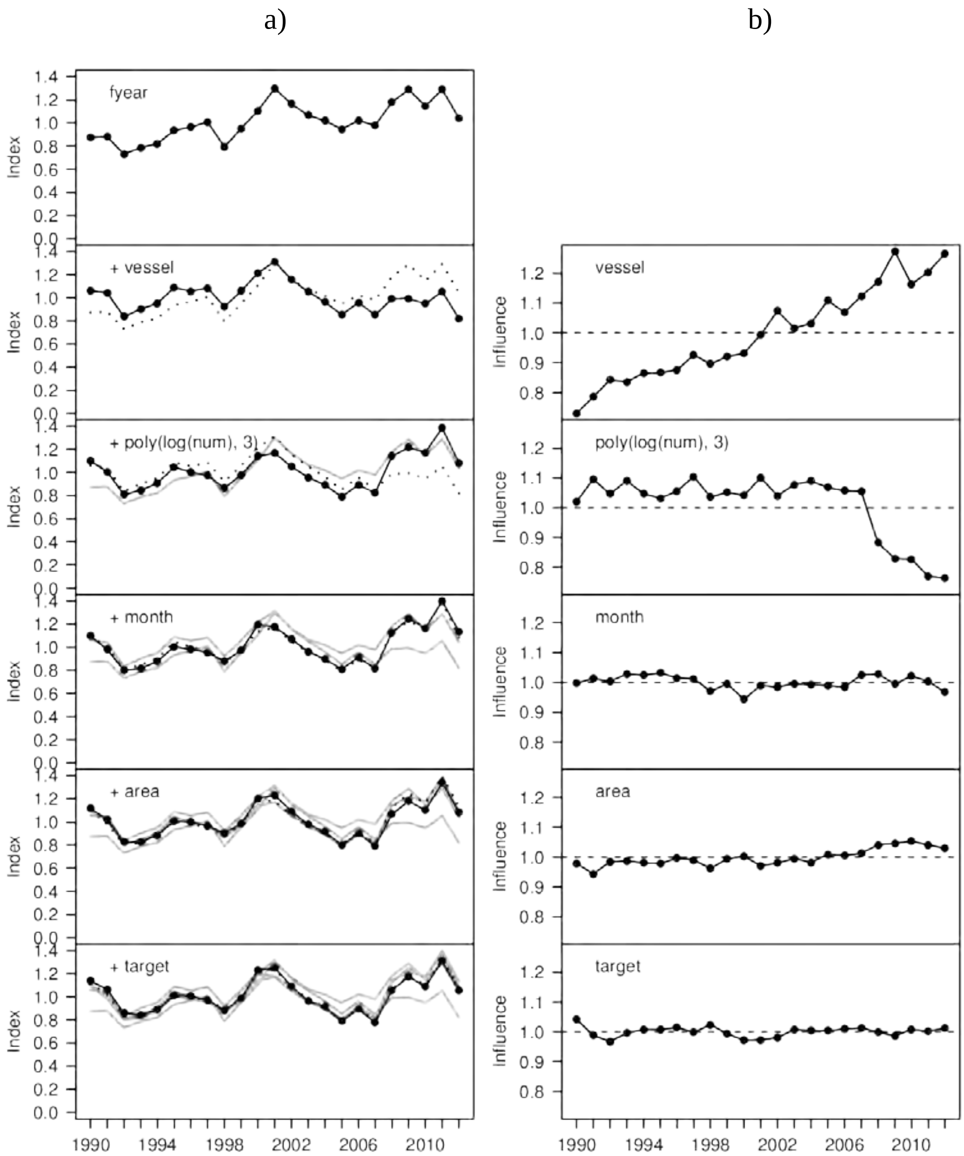


Figure O.11: Step and annual influence plot for SPO 7_BT(all). (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

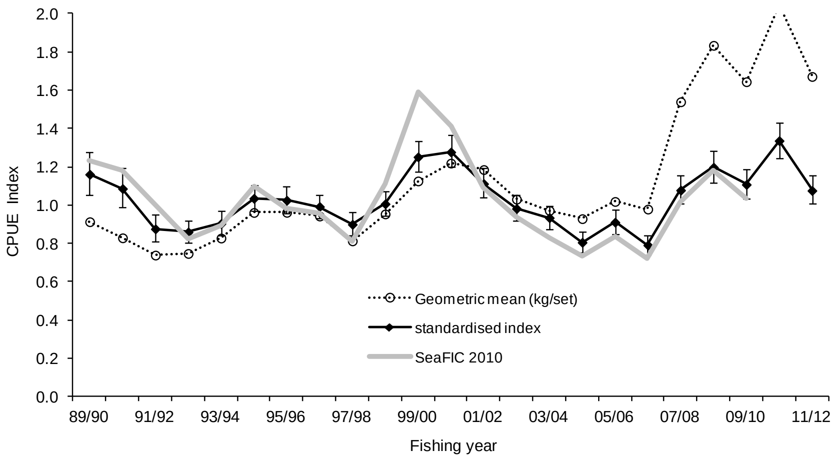


Figure O.12: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 7_BT(all) fishery. Broken lines are the raw CPUE (kg /tow) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the previous lognormal series presented in 2010 for this fishery. All series are relative to the geometric mean over the years in common.

The year effects have small error bars and directions of change are generally maintained over three to four consecutive years giving the series a cyclical appearance that is flat overall (Figure O.12). The effect of standardisation is to flatten the series, in particular, by removing an apparent increase in the late 2000s as the model accounts for improvements in the core fleet. There is good agreement with the previous series presented for this fishery (Figure O.12). Residuals for each area (Figure P.12) and each target fishery (Figure P.13) in each year suggest that the cyclical trend in rig abundance is common to the main statistical areas and target fisheries with some variation in magnitude.

O.4.3 Comparison with Other models

The effect of selecting the error distribution that gave the most consistent residual pattern relative to the distributional assumption was not substantial for either of the two setnet CPUE analyses (Figure O.13) because there is little difference in the estimated year indices when the "best" series is compared to an alternative series based on a lognormal distribution for all three statistical areas.

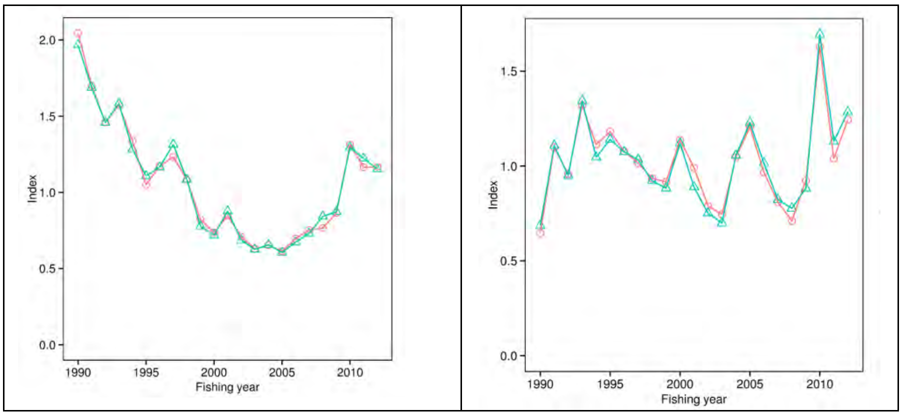


Figure O.13: Comparison between the log-logistic indices and indices obtained from a similar model that assumed a lognormal error distribution for SPO 7_SN(038), SPO 7_SN(WC).

Appendix P. DETAILED DIAGNOSTICS FOR SPO 7 CPUE STANDARDISATIONS

P.1 Core vessel selection

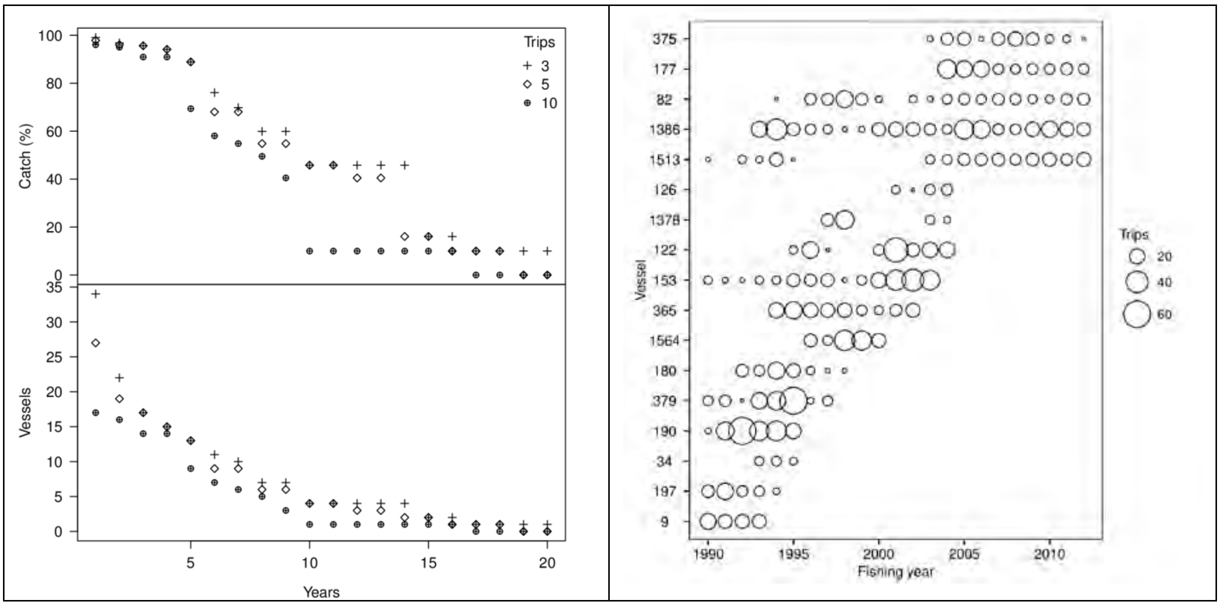


Figure P.1: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 7_SN(038) dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 3 trips in 3 or more fishing years).

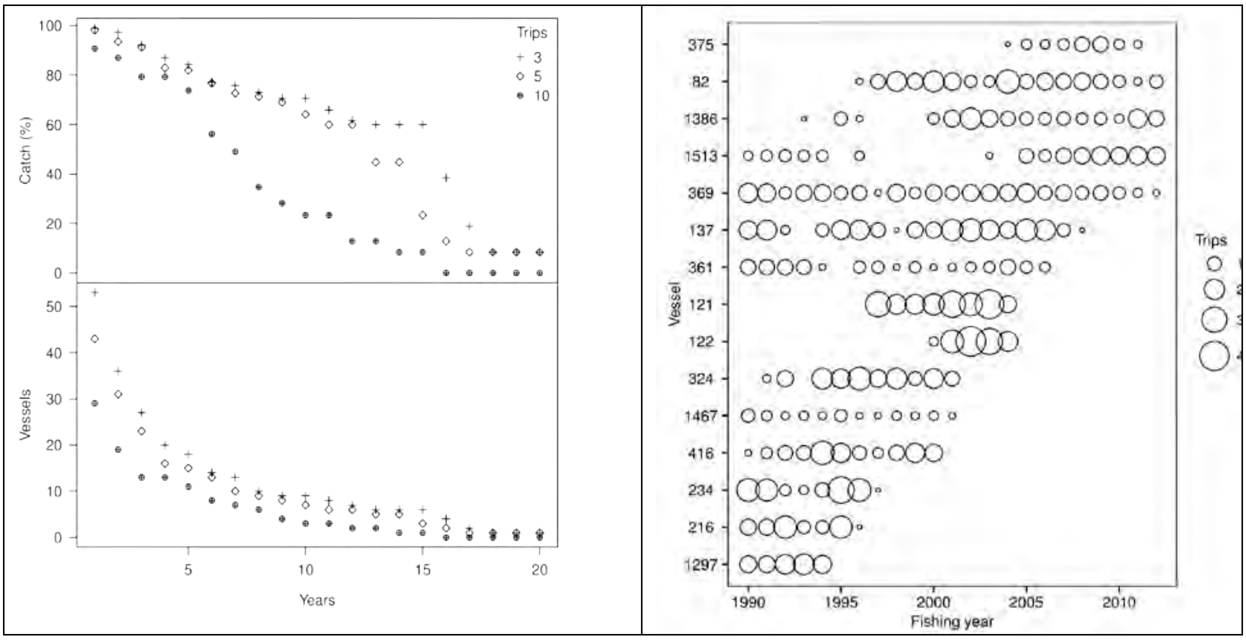


Figure P.2: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 7_SN(WC) dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 5 trips in 5 or more fishing years).

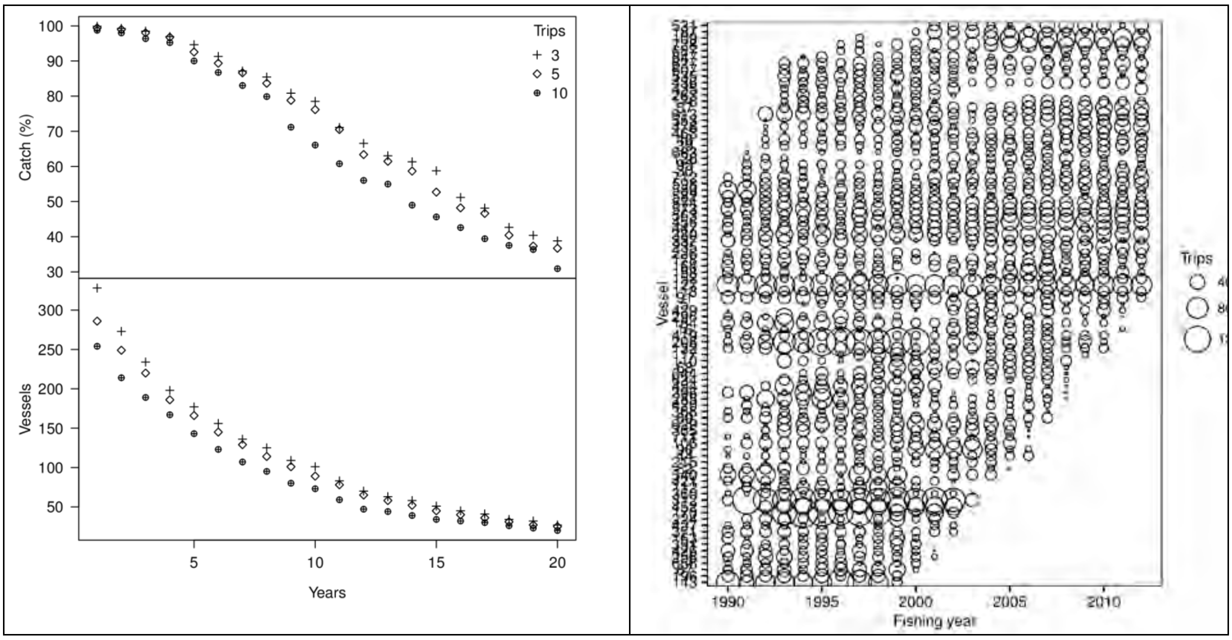


Figure P.3: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 7_BT(ALL) dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 5 trips in 10 or more fishing years).

P.2 Data summaries

Table P.1: Number of vessels, trips, events, sum of catch (t), sum of net length (km) (or tows for SPO 7_BT[All]) and sum of hours fishing for core vessels in the three CPUE analyses by fishing year.

Fishing	SPO 7_SN(038)							SPO 7_SN(WC)							SPO 7_BT(ALL)						
year	Vessel	Trips	Events	Catch	Net length	Hours	% zero	Vessel	Trips	Events	Catch	Net length	Hours	% zero	Vessel	Trips	Events	Catch	Tows	Hours	% zero
1990	6	59	88	61.4	141.3	1 343	90.0	9	115	282	34.0	772.3	3 805	70.5	49	1 004	2 235	36.4	6 576	18 382	58.9
1991	6	85	116	59.0	148.2	2 009	96.6	10	121	223	67.0	597.0	2 623	88.4	54	1 196	2 875	38.8	8 296	22 666	52.3
1992	7	116	164	88.6	258.9	2 492	94.0	10	111	227	47.6	609.0	2 505	91.1	66	1 521	3 628	39.8	10 766	31 744	52.4
1993	9	135	236	96.7	404.9	3 428	88.2	9	84	176	68.9	506.0	2 199	91.4	76	2 119	4 930	65.7	15 643	45 696	56.9
1994	10	185	353	105.8	673.0	4 820	84.4	12	122	223	64.8	623.3	2 604	87.7	78	1 813	4 191	59.1	12 789	34 158	56.4
1995	9	170	295	92.0	496.0	4 114	93.1	9	137	275	71.0	589.1	2 859	93.3	77	2 081	5 017	85.1	14 468	39 716	60.5
1996	11	108	170	74.4	297.4	2 331	89.9	12	115	257	83.2	686.0	2 719	81.9	80	1 926	4 599	76.6	13 523	38 401	54.9
1997	9	90	163	82.9	308.3	2 331	96.7	10	90	190	70.4	480.0	2 007	91.4	79	2 322	6 168	88.1	17 973	52 643	56.5
1998	7	116	184	112.8	490.5	2 662	94.8	8	96	161	51.8	391.3	1 701	98.0	80	2 032	5 280	72.6	14 407	42 085	53.8
1999	5	68	96	50.1	267.2	1 462	91.4	8	91	186	70.1	558.9	1 867	86.1	79	2 175	5 741	108.0	16 474	49 632	61.5
2000	6	79	169	39.0	320.3	2 312	93.9	10	123	245	107.4	595.6	2 568	91.2	73	1 689	4 650	101.6	13 455	40 579	67.2
2001	6	123	260	71.7	384.9	3 560	97.6	9	136	288	115.7	617.4	3 236	91.9	74	1 689	5 051	117.9	14 303	48 358	65.6
2002	6	98	255	59.4	403.1	3 731	99.0	7	140	298	100.8	636.8	3 150	92.3	69	1 504	4 666	102.9	12 840	42 552	62.1
2003	9	101	276	58.7	471.7	3 921	96.2	9	136	297	87.8	693.3	3 092	90.7	65	1 424	4 358	77.1	12 087	42 002	63.0
2004	8	107	305	81.1	526.9	4 196	98.2	9	113	290	110.1	701.4	3 101	84.9	67	1 476	4 919	79.3	13 381	46 790	68.7
2005	5	95	332	85.5	635.5	4 698	99.0	7	84	269	82.1	809.1	2 967	91.8	62	1 467	5 104	75.2	13 709	47 338	65.3
2006	5	75	275	87.2	541.1	3 911	94.9	7	72	278	90.3	778.8	3 158	92.0	62	1 424	4 780	78.1	12 634	44 297	65.4
2007	5	62	247	102.0	495.3	3 433	95.6	6	62	272	28.9	679.8	2 848	77.3	59	1 580	5 149	82.5	13 942	49 175	63.9
2008	5	59	229	89.5	487.1	2 995	96.8	6	56	232	58.9	567.2	2 297	78.6	55	1 246	10 454	90.8	10 551	39 953	59.7
2009	5	65	198	89.2	435.0	2 790	87.8	5	58	199	52.6	501.3	2 232	86.1	50	1 216	9 898	93.4	9 973	38 529	60.0
2010	5	63	182	87.1	405.6	2 607	87.7	5	41	125	35.8	314.3	1 312	89.3	49	1 304	10 829	95.9	10 844	38 391	59.8
2011	5	60	169	93.3	324.2	2 386	82.9	5	46	118	27.8	284.6	1 246	82.5	46	1 094	8 929	93.7	8 929	32 020	58.8
2012	5	58	175	91.7	391.3	2 407	92.5	5	40	115	29.5	301.8	1 300	94.3	44	1 084	9 185	93.1	9 185	34 545	58.2

P.3 Diagnostic plots

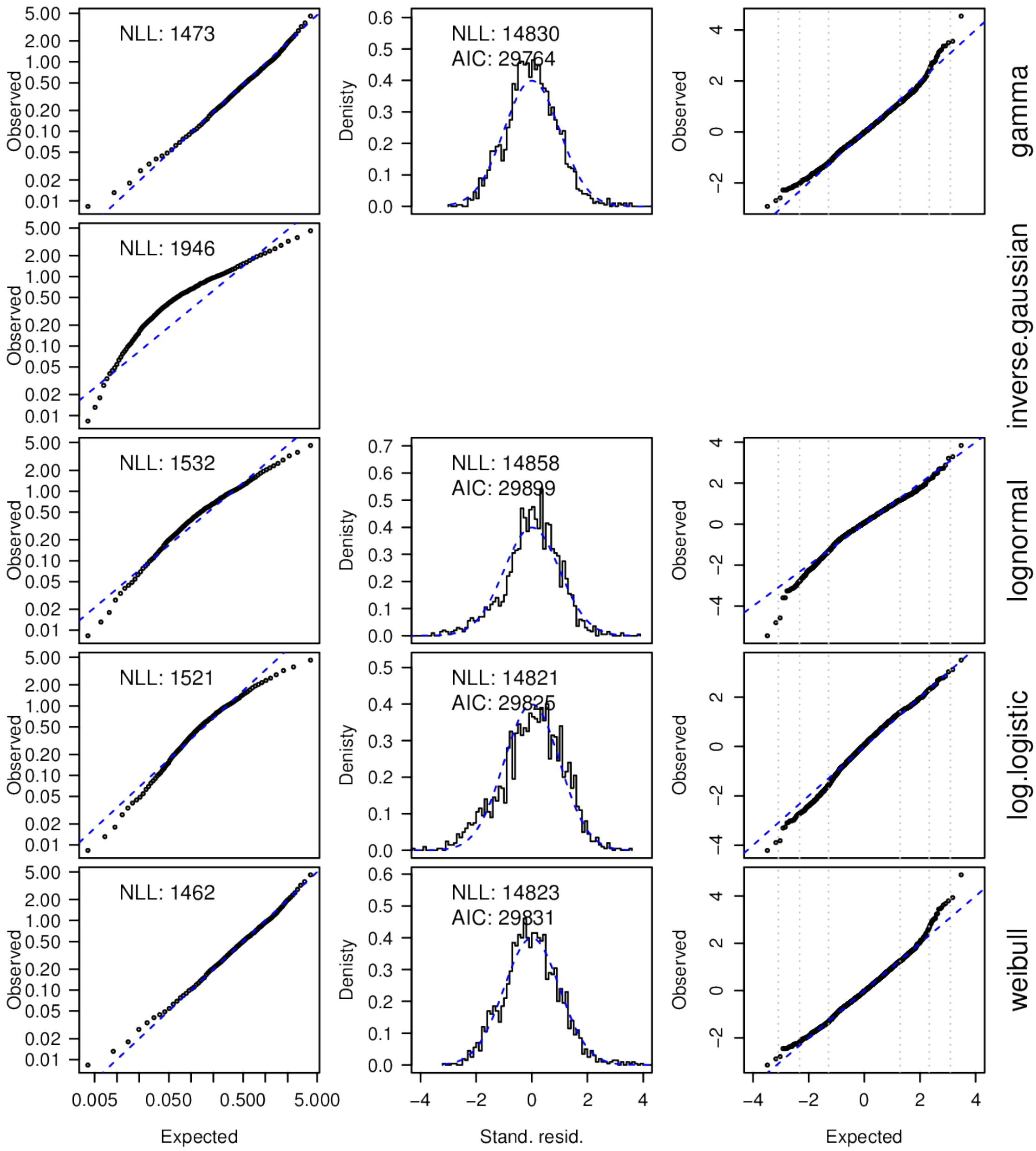


Figure P.4: Diagnostics for alternative distributional assumptions for catch in the SPO 7_SN(038) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + netlength and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

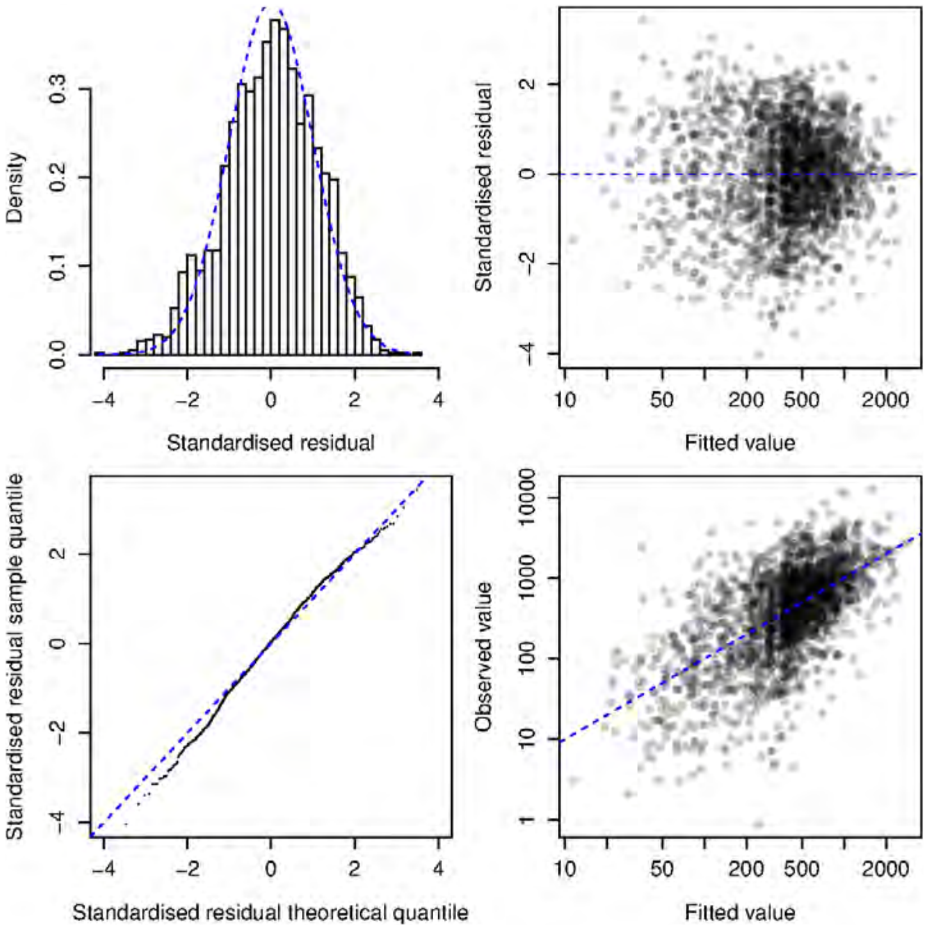


Figure P.5: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 7_SN(038) fishery. [Upper left] histogram of the standardised residuals compared to a log logistic distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

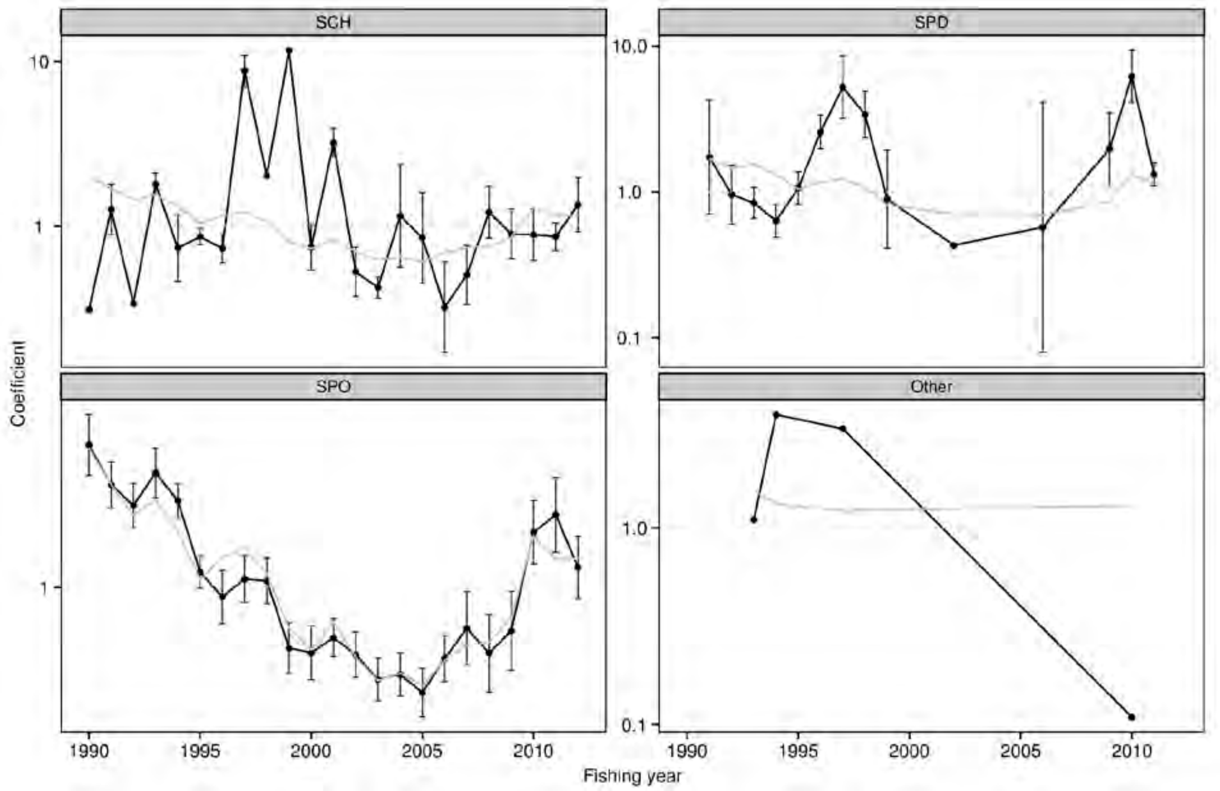


Figure P.6: Residual implied coefficients for each target species in each fishing year in the SPO 7_SN(038) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

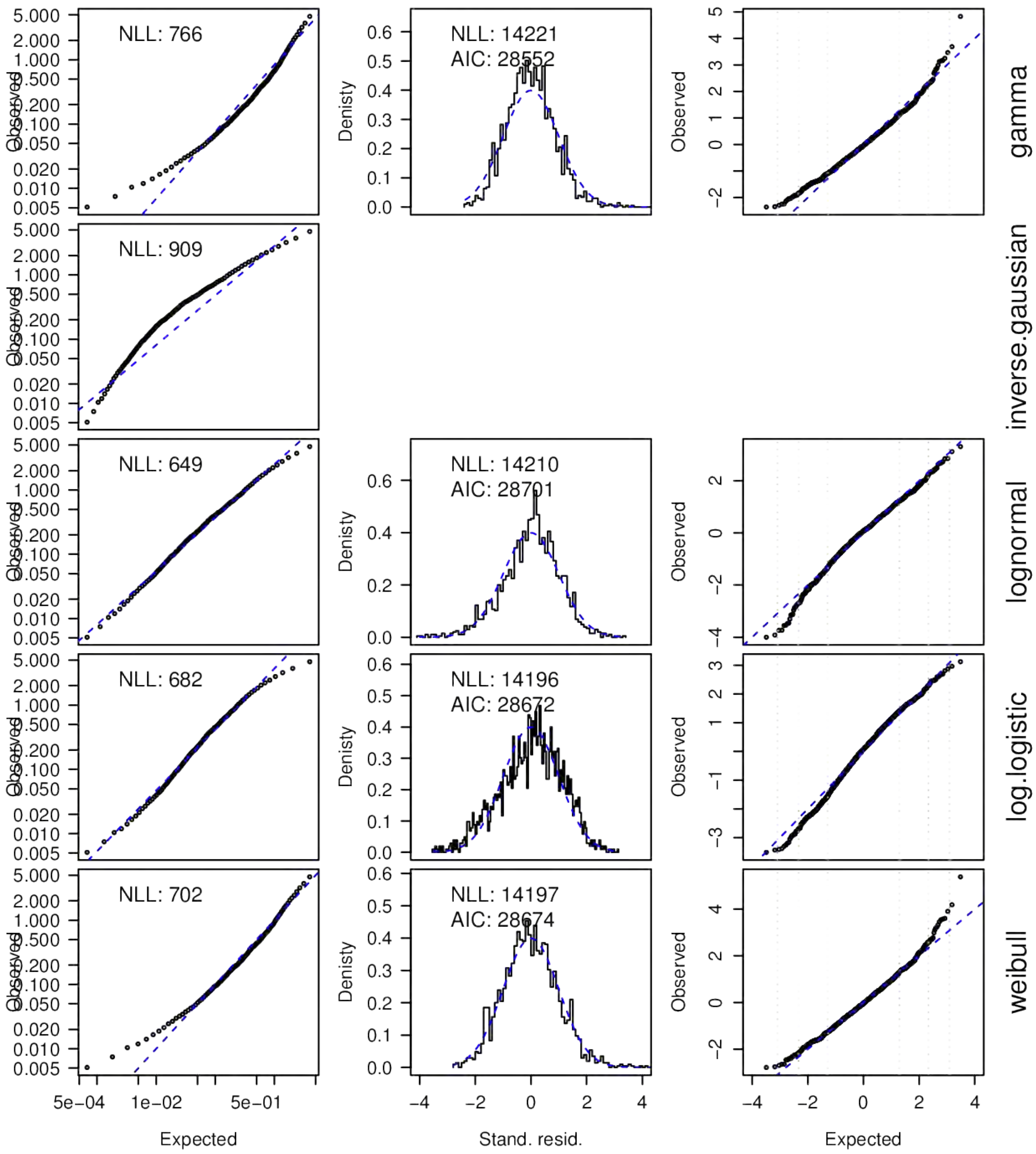


Figure P.7: Diagnostics for alternative distributional assumptions for catch in the SPO 7_SN(WC) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + netlength and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

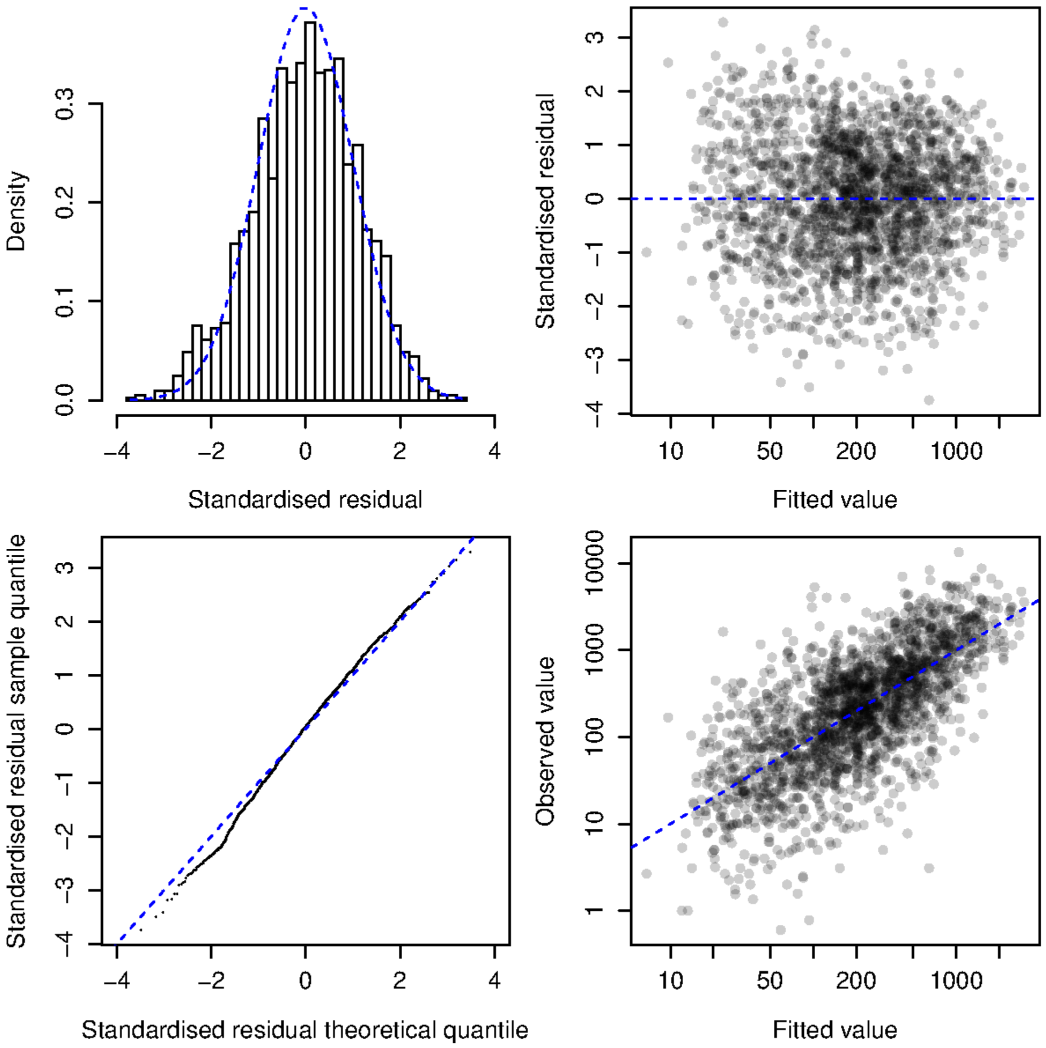


Figure P.8: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 7_SN(WC) fishery. [Upper left] histogram of the standardised residuals compared to a log logistic distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

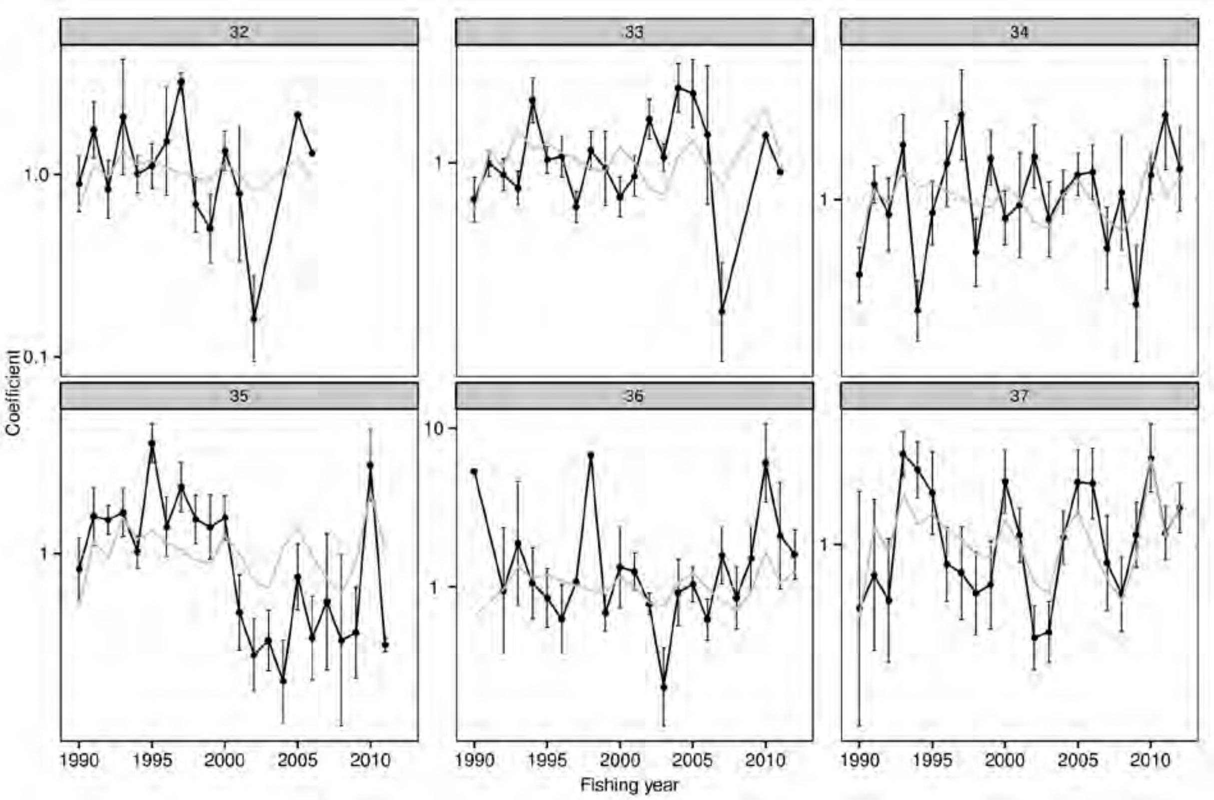


Figure P.9: Residual implied coefficients for each area in each fishing year in the SPO 7_SN(WC) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

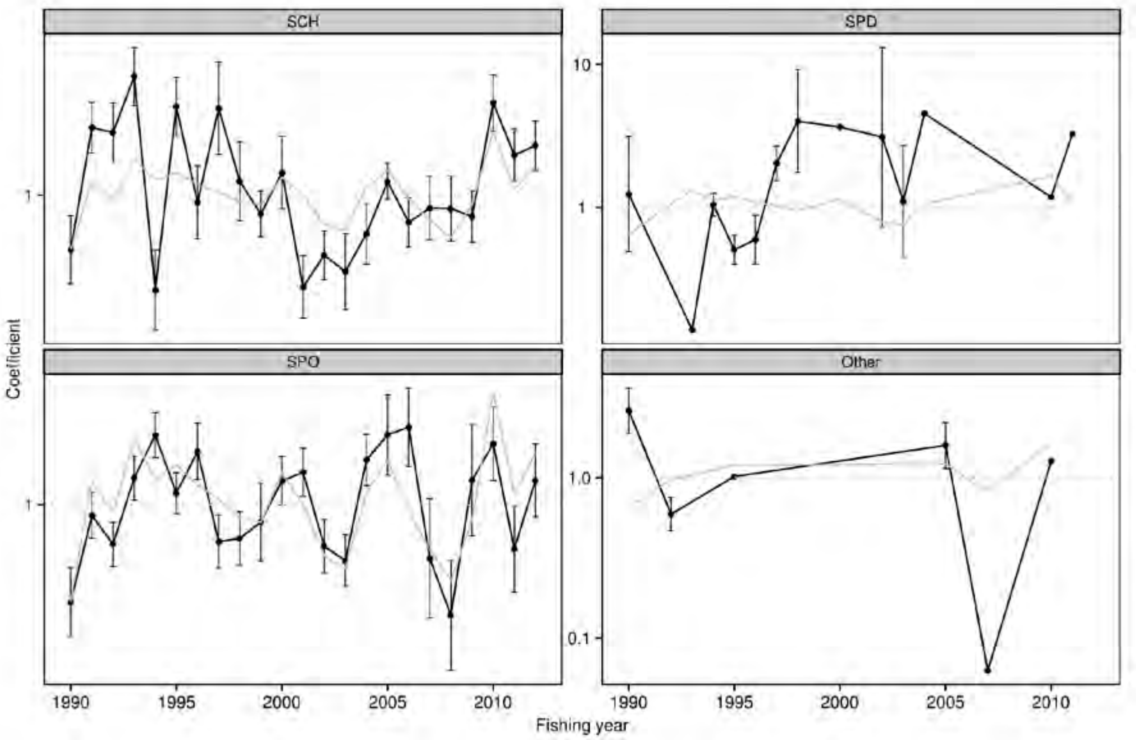


Figure P.10: Residual implied coefficients for each target species in each fishing year in the SPO 7_SN(WC) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

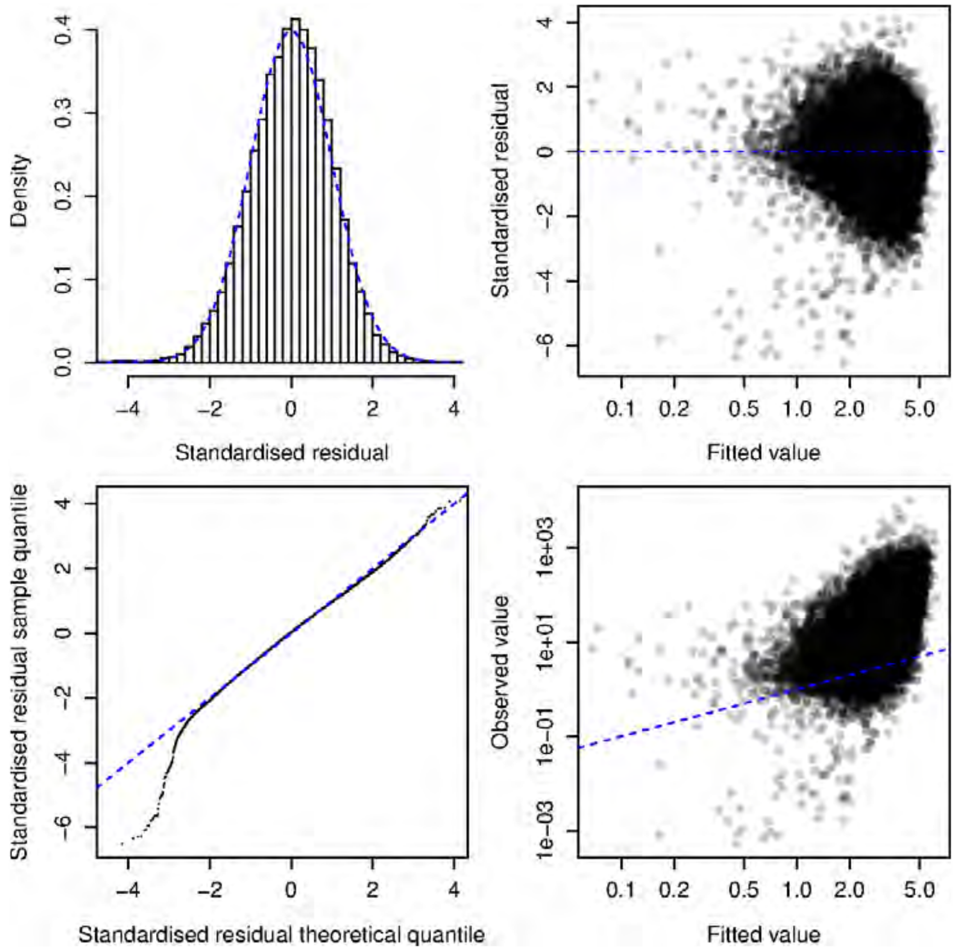


Figure P.11: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 7_BT(ALL) fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

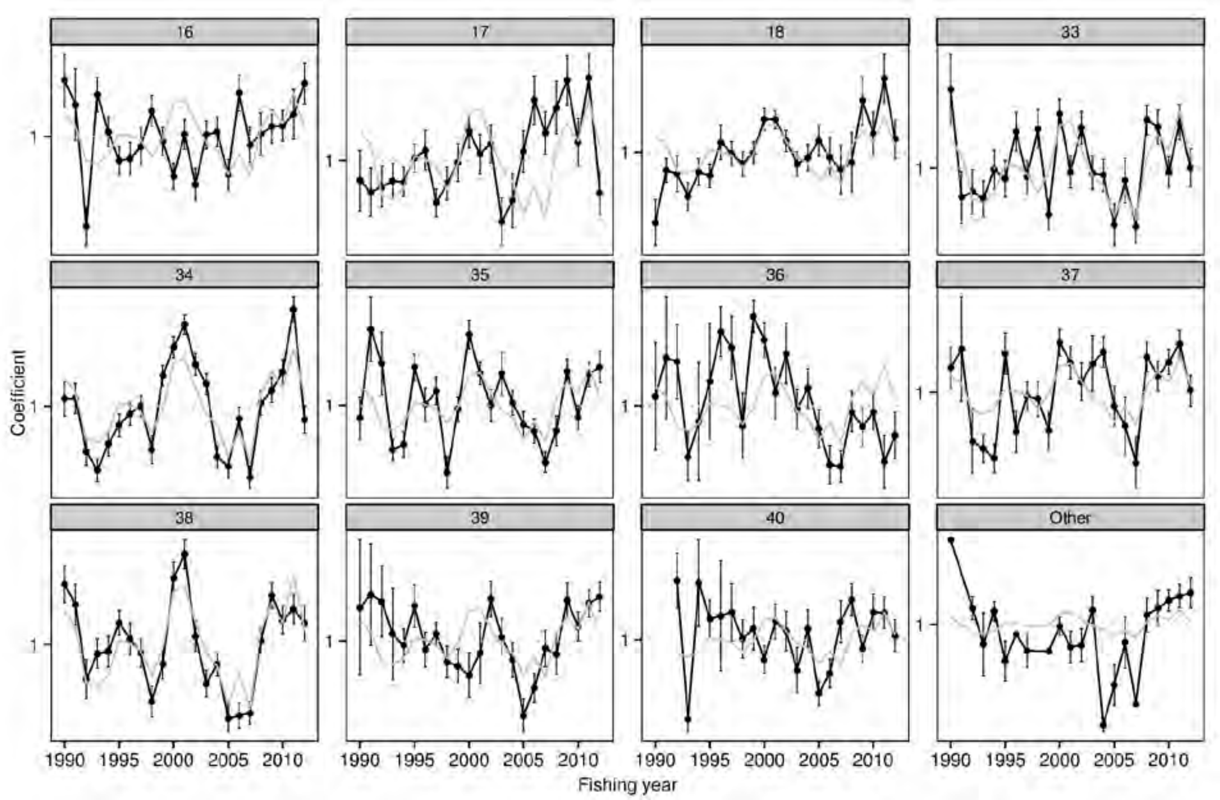


Figure P.12: Residual implied coefficients for each area in each fishing year in the SPO 7_BT(ALL) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

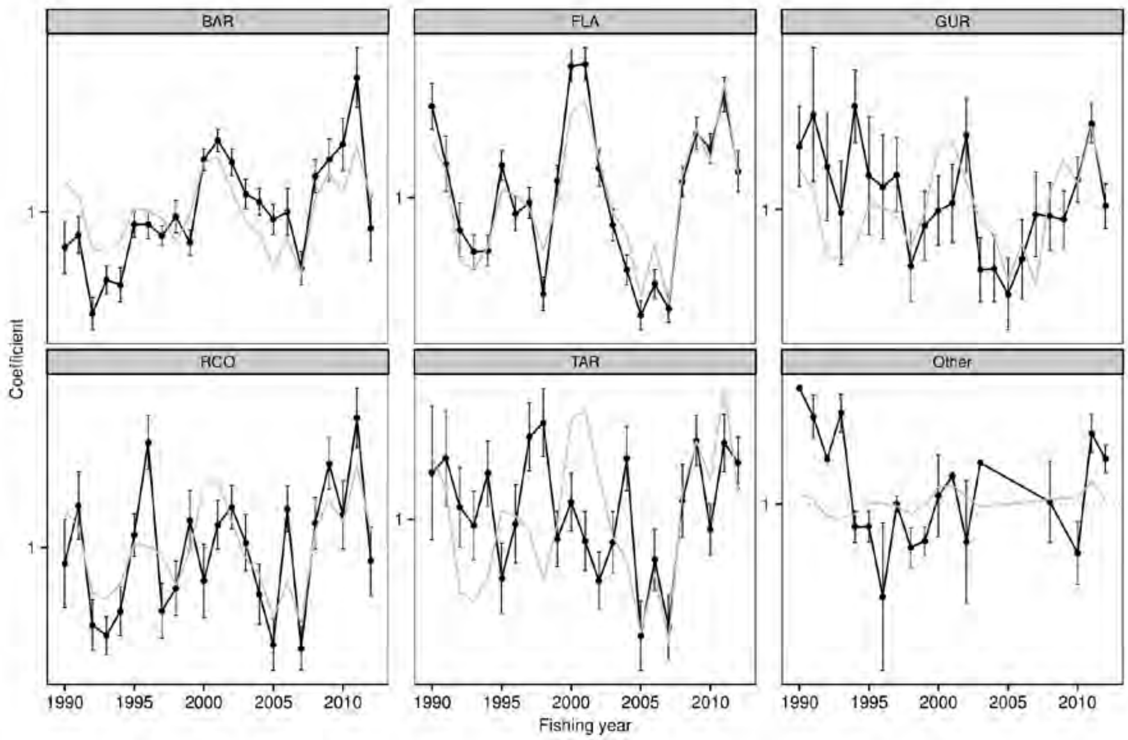


Figure P.13: Residual implied coefficients for each target species in each fishing year in the SPO 7_BT(ALL) fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

P.4 Model coefficients

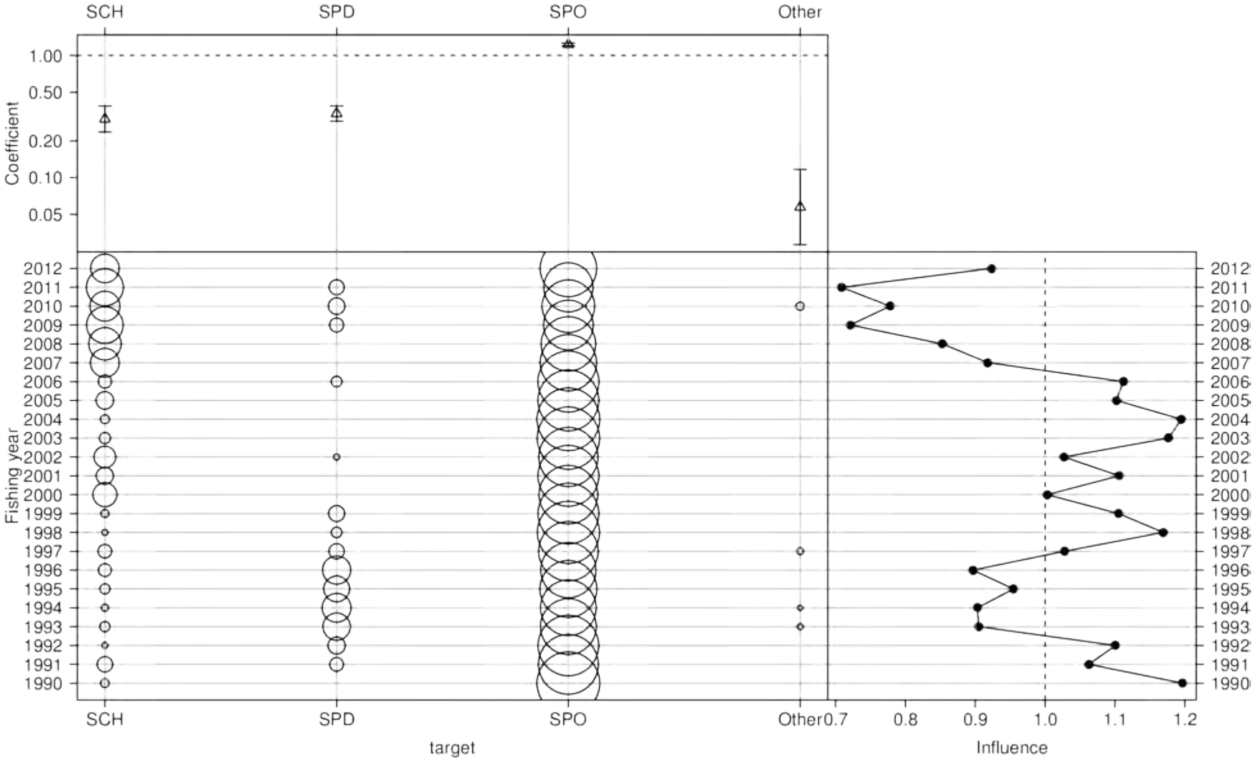


Figure P.14: Effect of target **in the log-logistic model for the SPO 7_SN(038) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

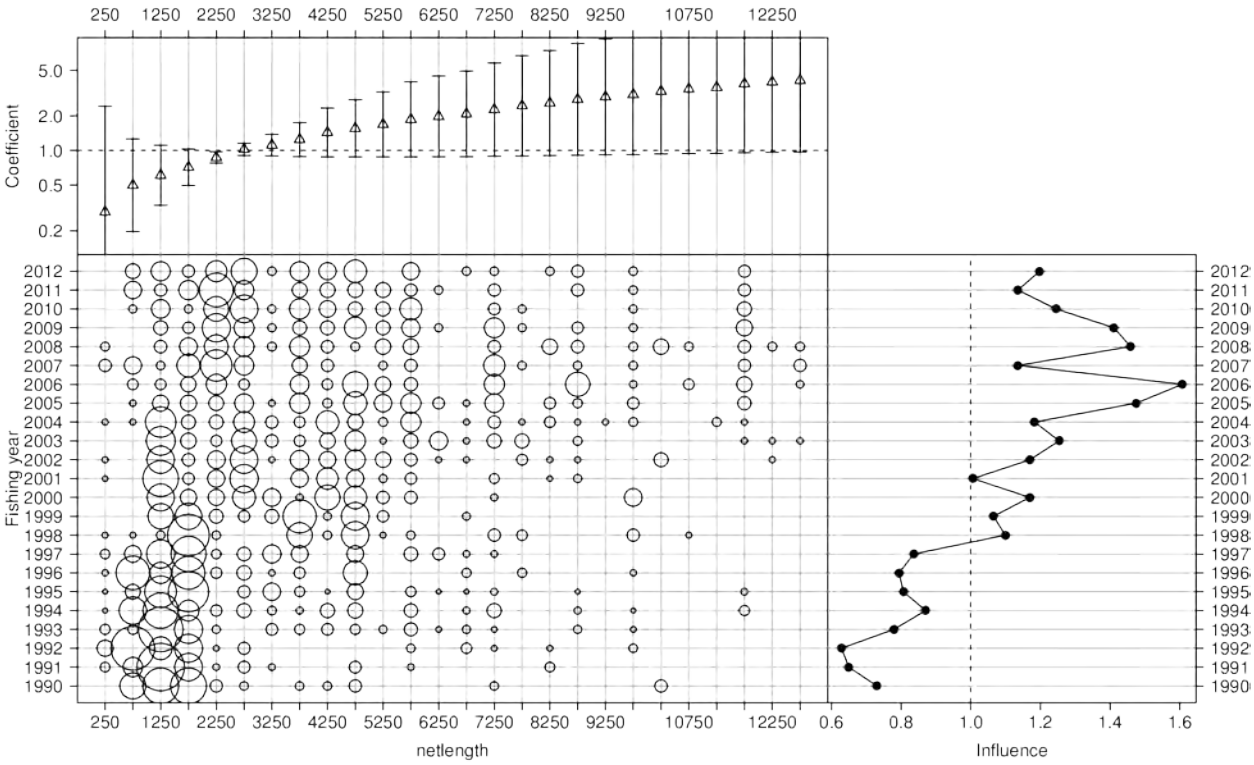


Figure P.15: Effect of netlength **in the log-logistic model for the SPO 7_SN(038) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

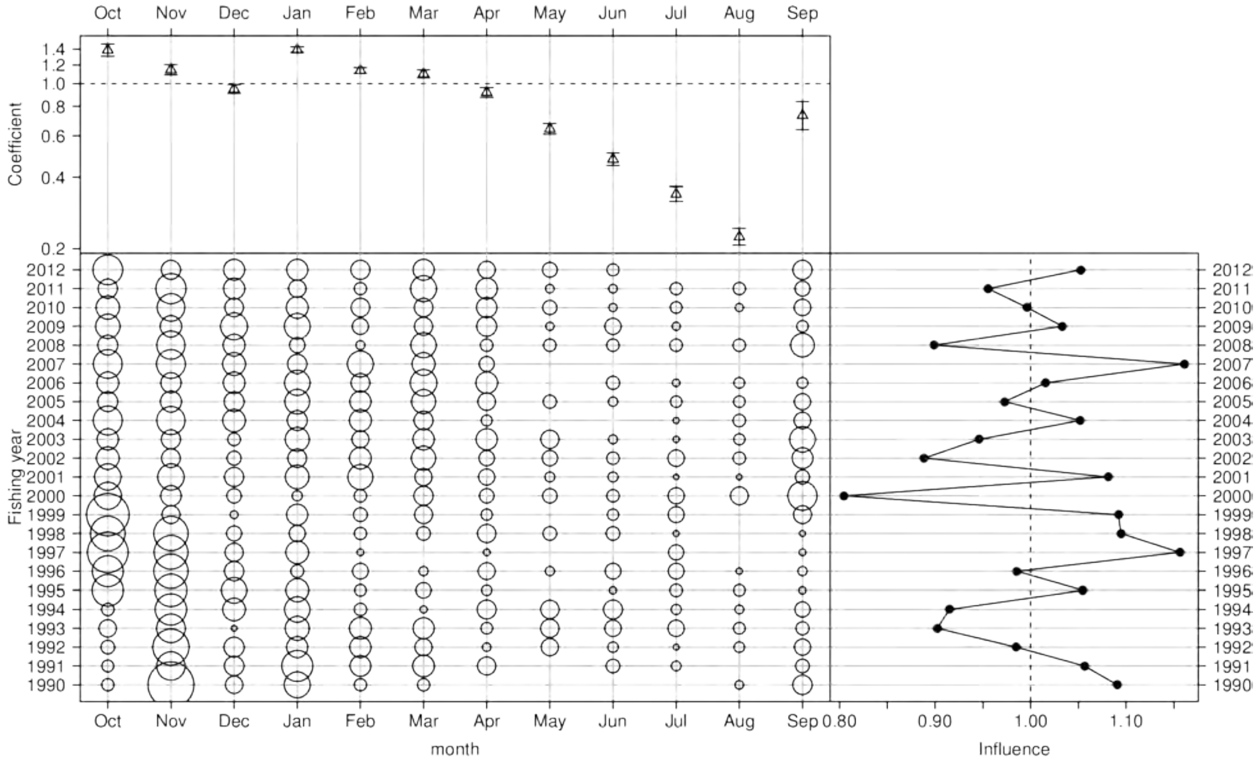


Figure P.16: Effect of month **in the log-logistic model for the SPO 7_SN(038) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

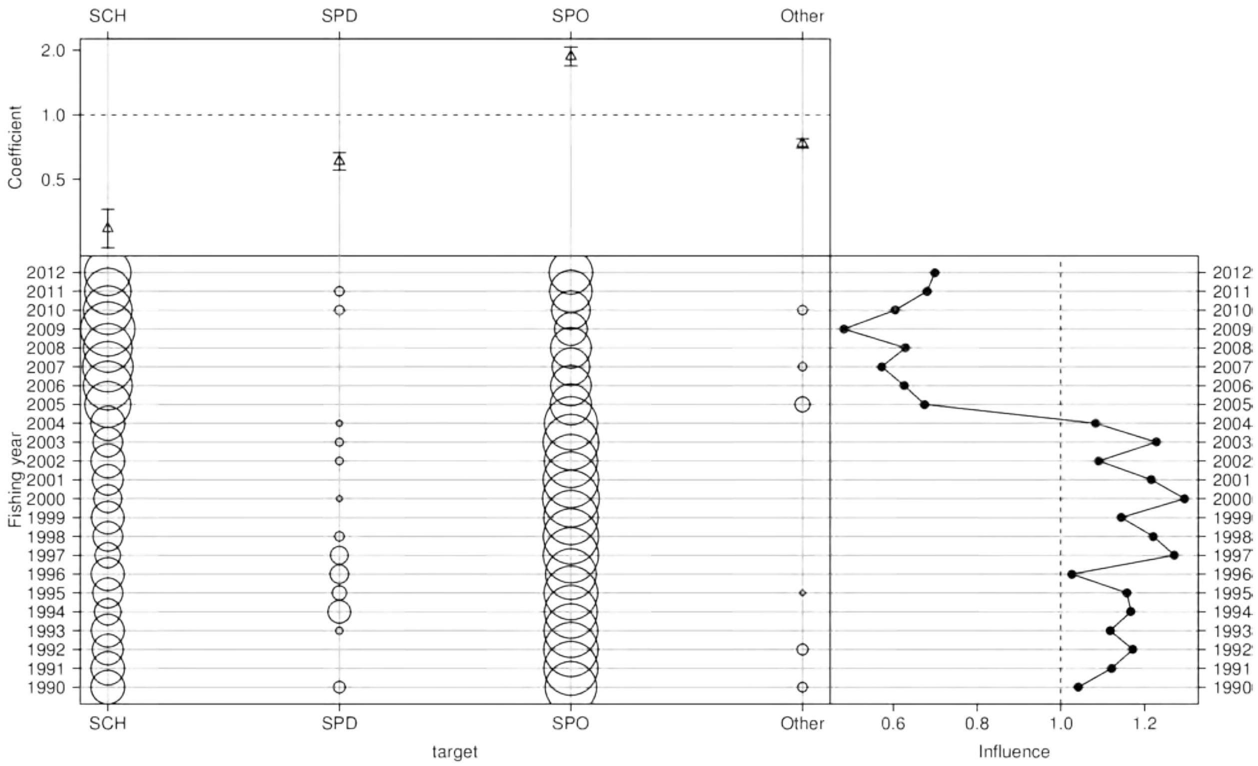


Figure P.17: Effect of target **in the log-logistic model for the SPO 7_SN(WC) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

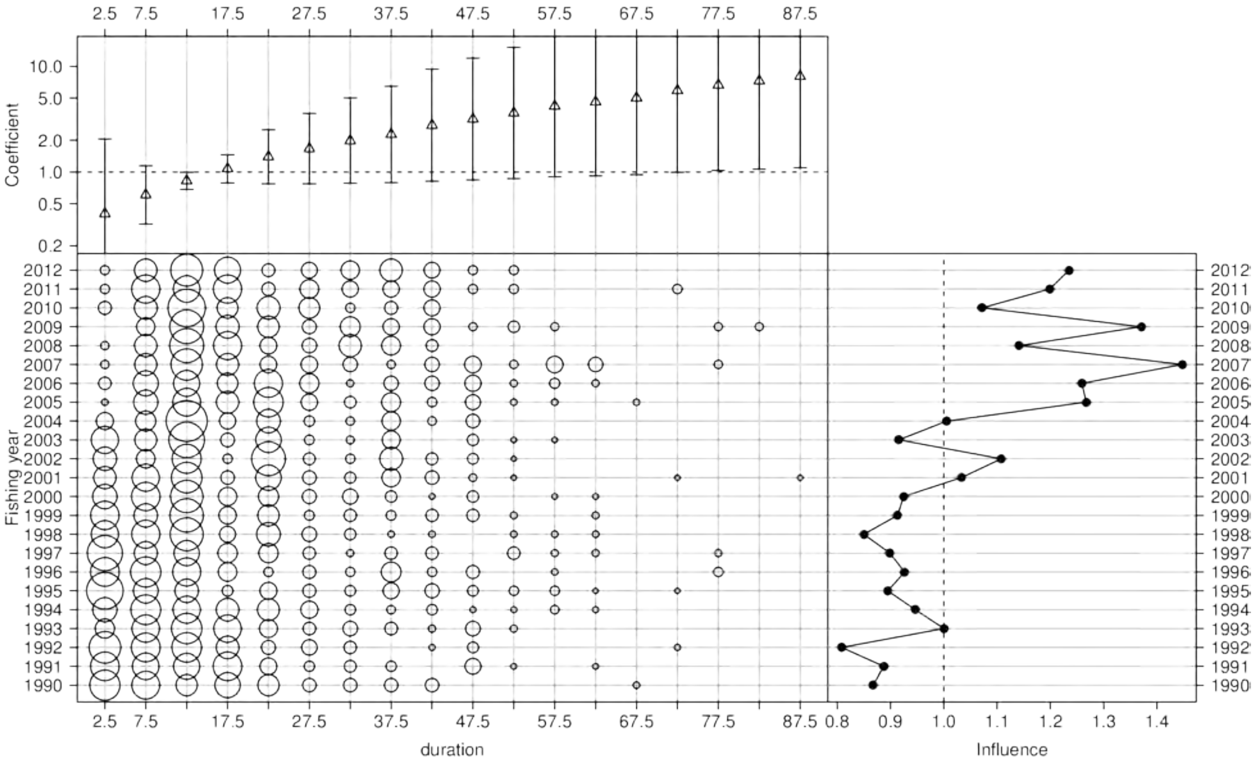


Figure P.18: Effect of duration **in the log-logistic model for the SPO 7_SN(WC) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

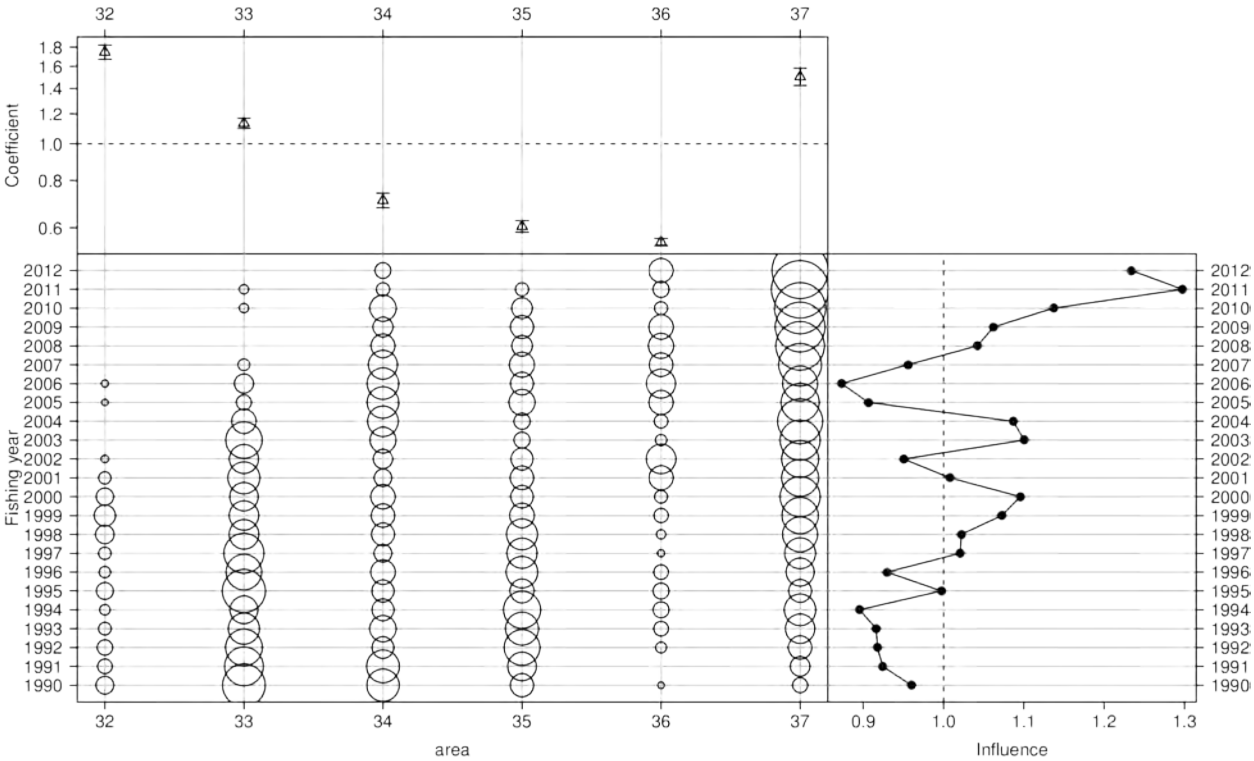


Figure P.19: Effect of area **in the log-logistic model for the SPO 7_SN(WC) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

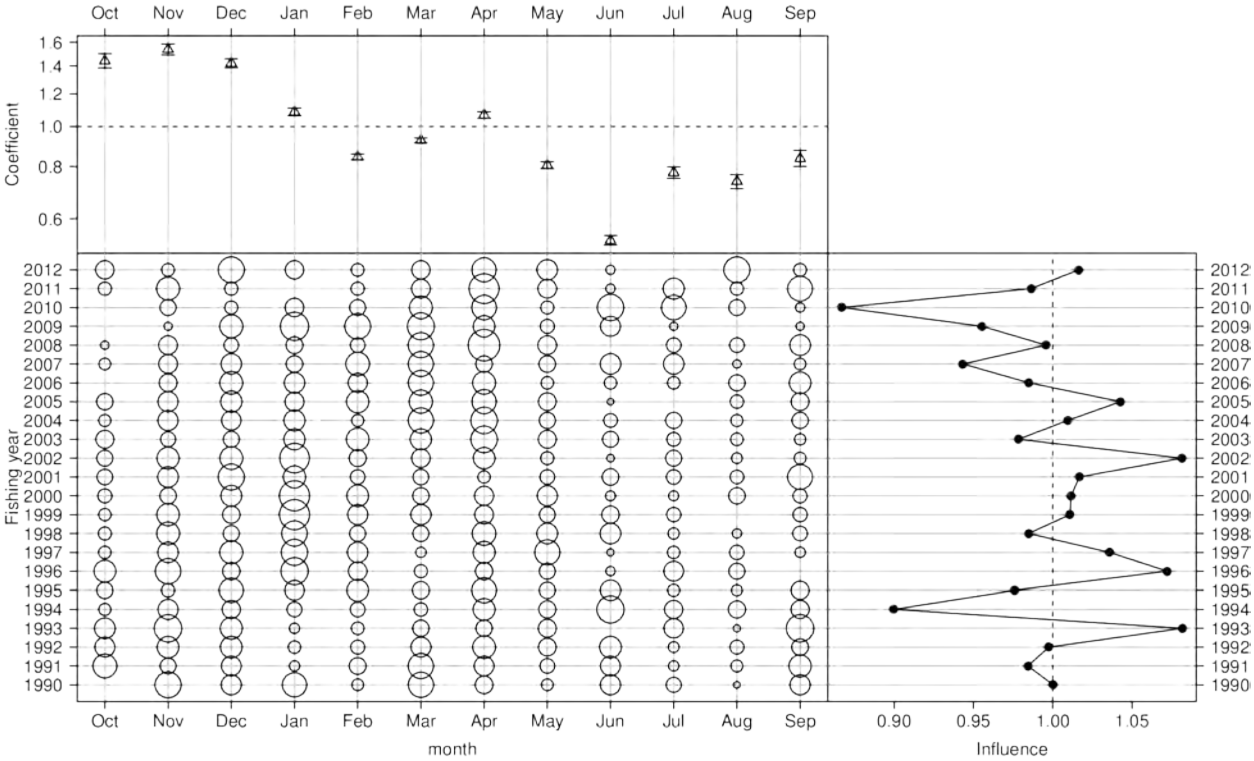


Figure P.20: Effect of month **in the log-logistic model for the SPO 7_SN(WC) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

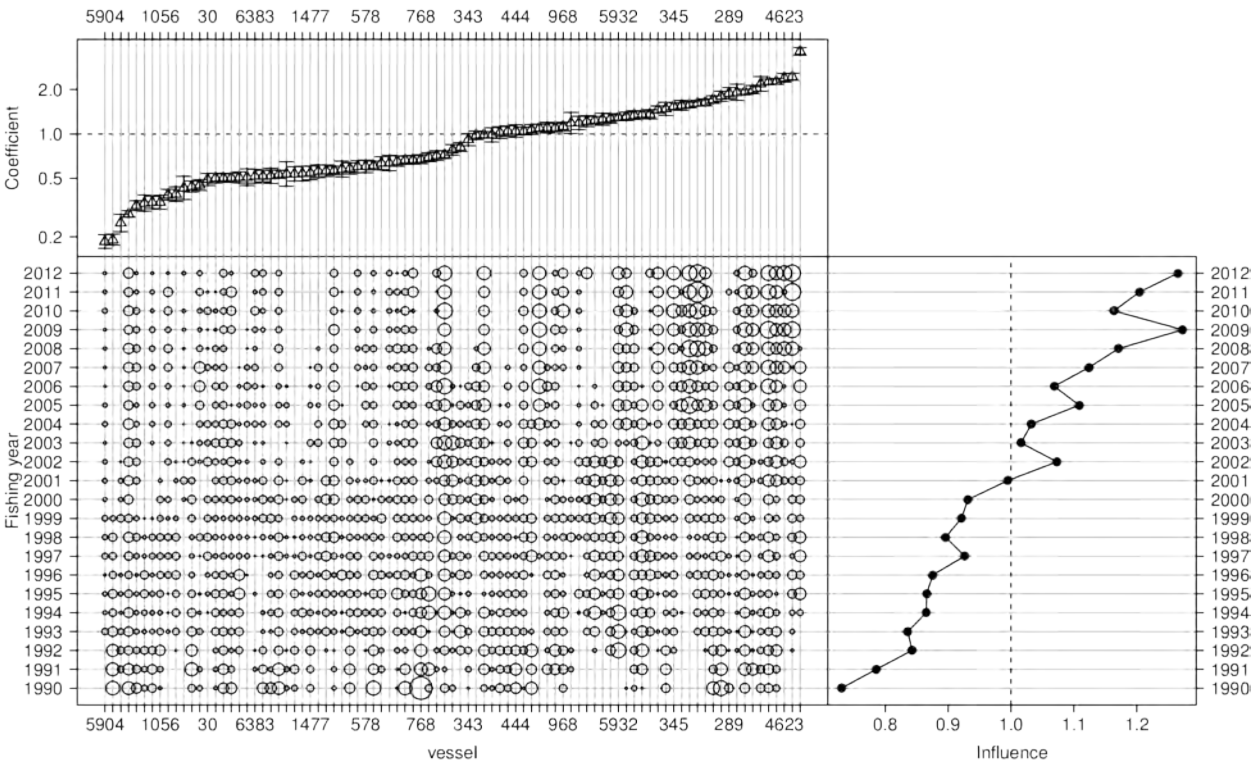


Figure P.21: Effect of vessel **in the Lognormal model for the SPO 7_BT(ALL) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

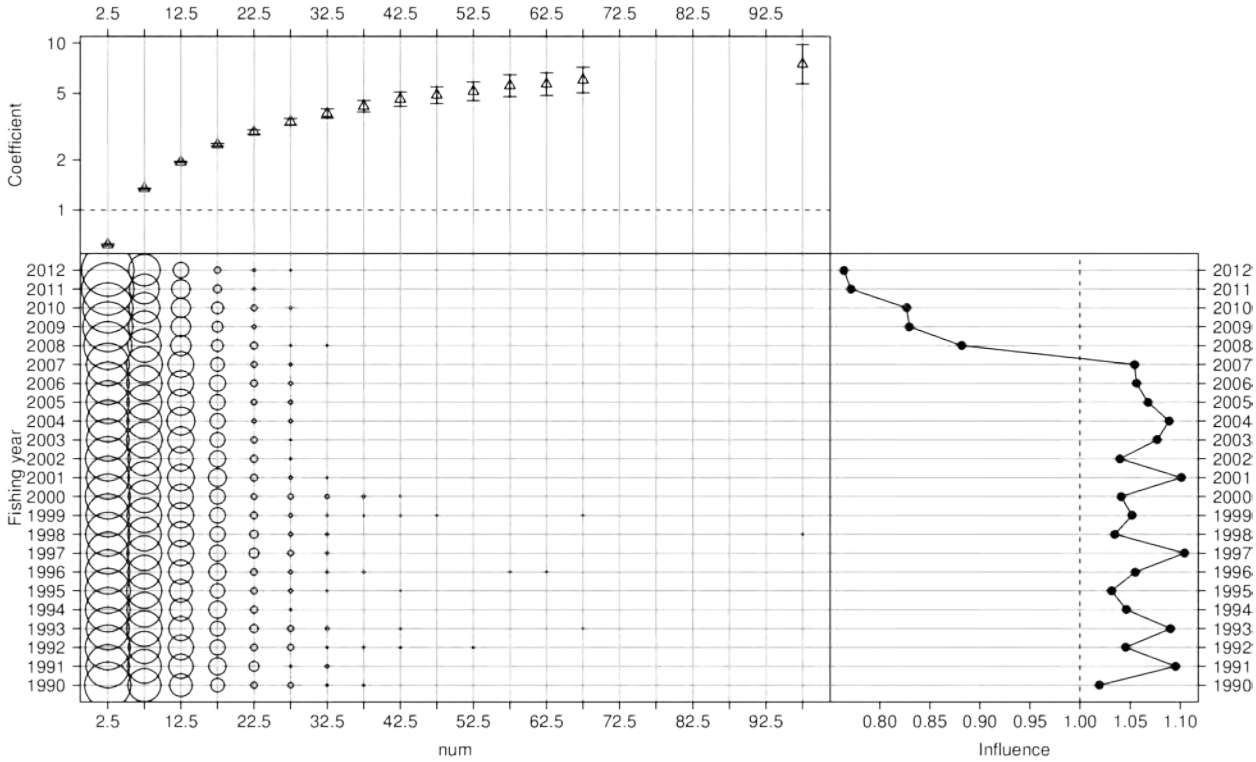


Figure P.22: Effect of number of tows **in the Lognormal model for the SPO 7_BT(ALL) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

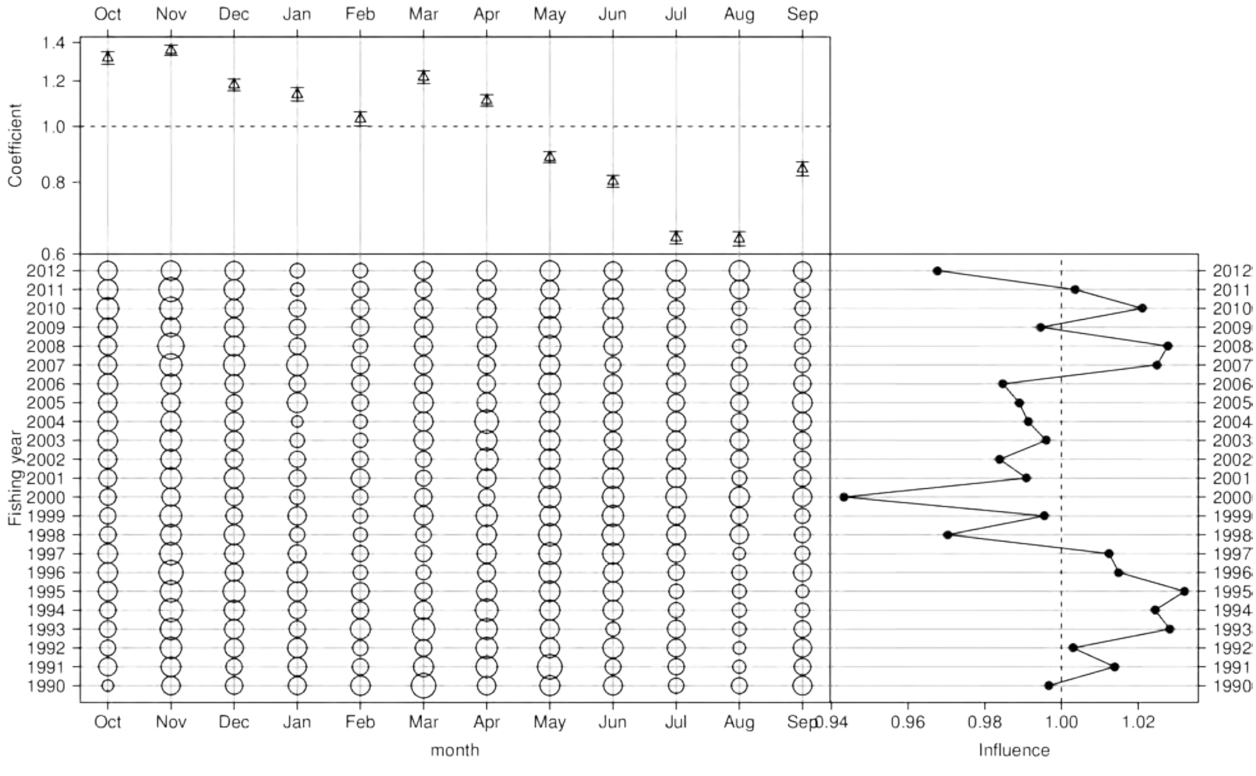


Figure P.23: Effect of month **in the Lognormal model for the SPO 7_BT(ALL) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

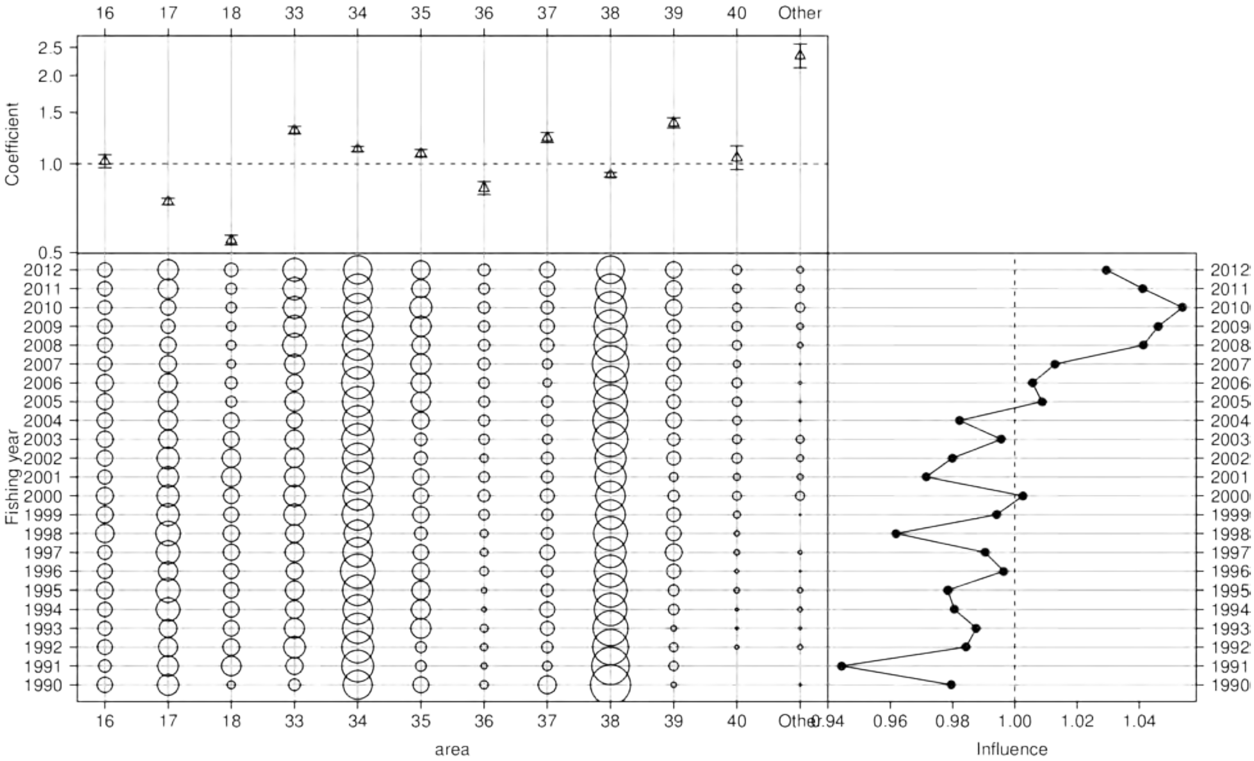


Figure P.24: Effect of area **in the Lognormal model for the SPO 7_BT(ALL) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

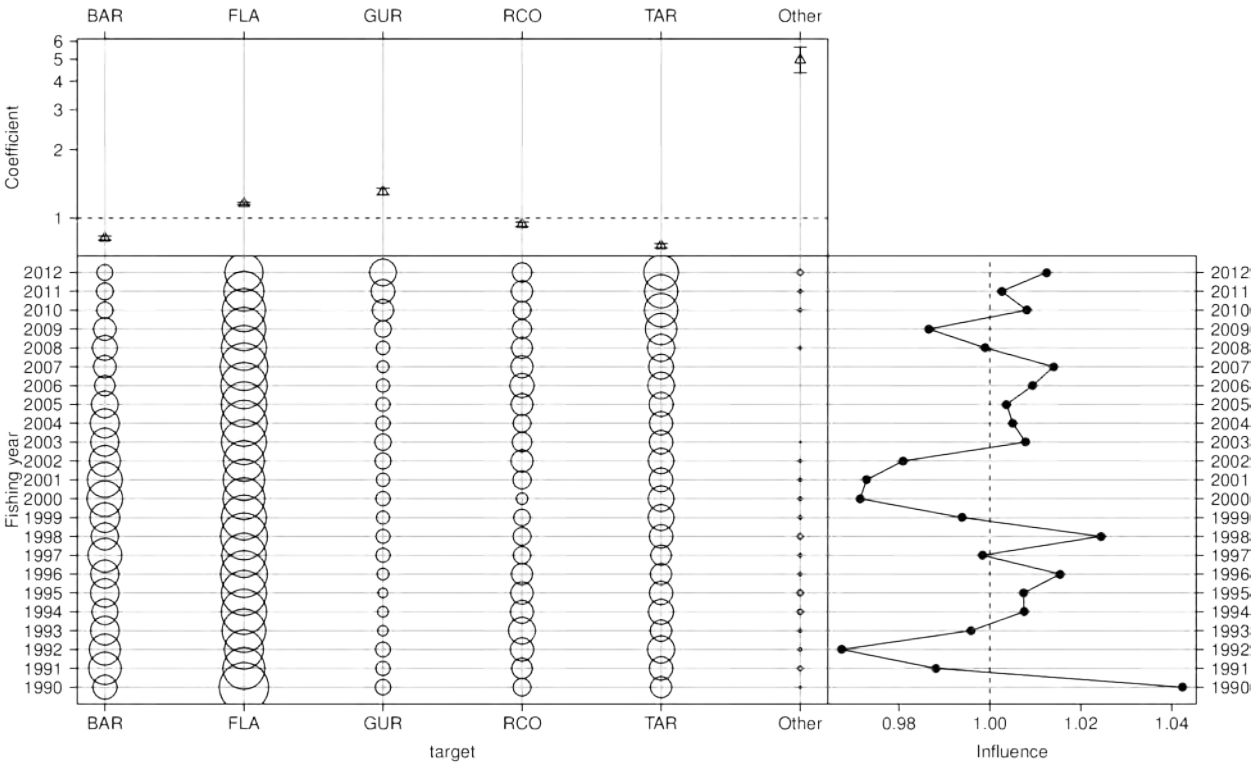


Figure P.25: Effect of target **in the Lognormal model for the SPO 7_BT(ALL) fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

P.5 CPUE indices

Table P.2: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error for the core data set by fishing year for each of the three CPUE models.

	SPO 7_SN(038)					SPO 7_SN(WC)					SPO 7_BT(ALL)				
Fishing	All	Core vessel indices				All	Core vessel indices				All	Core vessel indices			
Year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Arithmetic	Arithmetic	Geometric	Standardised	SE	Arithmetic	Arithmetic	Geometric	Standardised	SE
1990	2.519	2.680	2.848	2.046	0.140	0.556	0.431	0.648	0.646	0.123	0.749	0.864	0.847	1.137	0.050
1991	1.820	1.979	2.230	1.699	0.111	1.022	0.904	1.360	1.097	0.104	0.666	0.647	0.769	1.065	0.047
1992	2.837	3.047	1.855	1.459	0.103	0.687	0.897	1.251	0.958	0.106	0.687	0.706	0.686	0.858	0.042
1993	1.826	1.935	1.358	1.573	0.098	0.917	1.178	1.652	1.321	0.120	0.614	0.627	0.693	0.843	0.034
1994	1.204	1.198	1.109	1.338	0.085	0.717	0.885	0.991	1.113	0.107	0.693	0.694	0.768	0.886	0.036
1995	1.177	1.138	1.134	1.050	0.083	1.660	1.315	1.372	1.182	0.093	0.846	0.837	0.892	1.015	0.033
1996	1.058	1.029	1.127	1.172	0.109	1.294	1.030	1.197	1.078	0.114	0.789	0.817	0.893	1.005	0.036
1997	1.321	1.334	1.658	1.234	0.113	1.832	2.189	1.755	1.016	0.124	0.824	0.839	0.875	0.972	0.032
1998	1.456	1.515	1.308	1.083	0.100	0.959	0.998	1.215	0.934	0.114	0.766	0.801	0.754	0.882	0.035
1999	0.893	0.736	0.882	0.822	0.123	1.204	1.174	0.961	0.917	0.126	0.953	0.939	0.885	0.986	0.031
2000	0.590	0.496	0.553	0.736	0.117	1.834	2.095	1.845	1.138	0.101	1.073	1.092	1.045	1.227	0.033
2001	0.868	0.865	1.017	0.847	0.091	1.930	2.591	1.532	0.991	0.099	1.169	1.219	1.131	1.251	0.034
2002	0.627	0.630	0.588	0.709	0.102	1.191	1.230	1.127	0.789	0.098	1.250	1.266	1.100	1.090	0.035
2003	0.552	0.566	0.644	0.629	0.102	1.196	1.207	1.070	0.745	0.100	0.987	0.947	0.956	0.963	0.036
2004	0.733	0.767	0.800	0.654	0.102	1.318	1.515	1.473	1.047	0.107	0.998	0.994	0.902	0.915	0.033
2005	0.548	0.556	0.586	0.614	0.109	0.871	0.923	0.652	1.206	0.116	1.061	0.943	0.862	0.789	0.034
2006	0.555	0.555	0.710	0.697	0.119	0.937	0.846	0.545	0.966	0.128	1.085	1.023	0.945	0.892	0.035
2007	0.921	0.947	0.857	0.753	0.143	1.000	0.498	0.355	0.810	0.159	0.917	0.877	0.908	0.775	0.034
2008	0.710	0.710	0.676	0.766	0.146	0.738	0.582	0.609	0.711	0.155	1.444	1.333	1.428	1.057	0.035
2009	0.760	0.761	0.620	0.865	0.136	0.521	0.545	0.452	0.922	0.148	1.639	1.632	1.702	1.173	0.035
2010	0.865	0.866	0.961	1.313	0.134	0.748	0.829	0.943	1.629	0.153	1.526	1.449	1.526	1.086	0.034
2011	0.934	0.960	0.843	1.165	0.133	0.647	0.717	0.986	1.039	0.158	1.857	1.887	1.896	1.310	0.036
2012	1.033	0.995	1.122	1.167	0.135	0.852	0.885	1.018	1.244	0.151	1.562	1.696	1.551	1.055	0.035

Appendix Q. CPUE ANALYSES FOR SPO 8

Q.1 General overview

This study extends the analyses of two generalised fisheries (setnet and bottom trawl methods) for SPO 8 that were last presented by Kendrick & Bentley (2012), with an additional two years of data. The analyses are done on landed greenweight which has been corrected for changes in the conversion factors used to back calculate greenweight from processed weight. Problems arising from catch being held ashore for accumulated landing to Licensed Fish Receivers were described by Kendrick & Bentley (2012) for rig setnet fisheries further north in SPO 1, but were not a feature of setnet in SPO 8. Improvements to the analyses include improved grooming of the landings data to exclude unreasonably large catches, which has yielded closer agreement between landings used in the analyses and those reported under the Quota Management System and have altered annual indices for bottom trawl. Other improvements include the selection of the most appropriate error distributions and improved diagnostic plots for evaluating potentially confounding interaction terms.

Historically, much of the catch of rig has been reported on the daily CELR form, but new event-based forms for both bottom trawl (TCER: introduced in 2007–08) and for setnet (NCELR: introduced in 2006–07) have resulted in changes to the resolution at which catch and effort data are available. In order to be able to use the full extent of the available data, the more detailed information must be amalgamated to a common resolution with earlier data to effect a sensible combination. Only the analyses of positive catches are presented, as amalgamated data include zero catches and should subsume signals from the probability of capture.

The SINSWG accepted the SPO 8–SN CPUE series with Science Information Quality=1 as being able to monitor all components of the rig population. The SPO 8–BT bottom trawl series was accepted with Science Information Quality=2 because the SINSWG reasoned that the bottom trawl fishery does not monitor the full range of the adult population.

Q.2 Methods

Q.2.1 Fishery definitions for CPUE analysis

The two fisheries defined for SPO 8 exclude data from straddling areas 036 and 037 as those data are considered to be more appropriately used for monitoring the neighbouring SPO 7.

SPO 8_SN – Shark setnet – The fishery is defined from setnet fishing events which fished in Statistical Areas 039–041 , and targeted SPO, SCH, SPD, NSD. This definition potentially allows the use of total effort in the analysis of catch rates, however only the analysis of positive catches is presented in detail.

SPO 8_BT – mixed species bottom trawl – The fishery is defined from bottom single trawl fishing events which fished in Statistical Areas 039–041, and targeted TAR, SNA, TRE, BAR, JDO, or GUR. This definition potentially allows the use of total effort in the analysis of catch rates, however only the analysis of effort associated with positive catches is presented in detail.

Q.3 Unstandardised CPUE

Q.3.1 SPO 8_SN Shark setnet in SPO 8

Effort in this fishery peaked in the early 1990s at about 750 trips and has since declined steadily to less than half of that level of effort by 2011–12 (Figure Q.1). Catch rates have increased over the study period in a series of wide (possibly seven year) cycles.

The fishery is mainly targeted at rig and only a very few trips land no rig at all. At trip stratum resolution, the proportion of zero catches has occasionally exceeded 20% but has more generally been less than 10% in each year (Figure Q.2). The roll-up of data has shown a trend towards more records included per stratum, most markedly increasing in the late 2000s as an artefact of the change in reporting forms, and the proportion of zero catches declined in consequence (Figure Q.2).

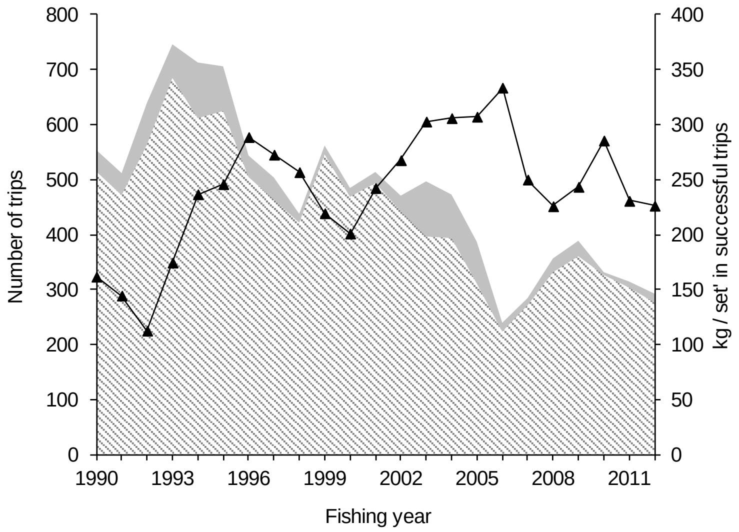
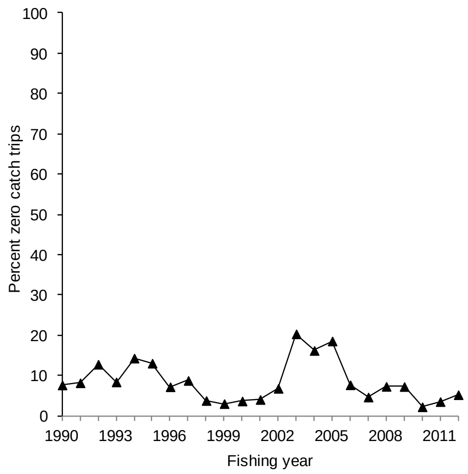


Figure Q.1: Number of qualifying trips in SPO 8_SN (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/set) of rig in successful trip-strata, by fishing year.



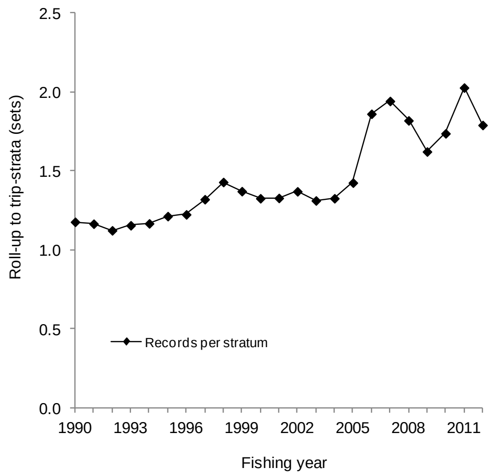


Figure Q.2: The proportion of qualifying trips in SPO 8_SN, that landed zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of tows per trip-stratum, by fishing year.

Q.3.2 SPO 8_BT Mixed target Bottom trawl in SPO 8

Effort in this fishery peaked at the end of the 1990s at more than 600 trips and then slumped to its lowest level of activity in the mid-2000s at about half of peak levels (Figure Q.3). Mean catch rates in successful trips have fluctuated around 15 kg per tow throughout the period but appear to have increased steadily over the 2000s when effort was lower than average (Figure Q.3). Rig has consistently been landed from most trips, and at trip stratum resolution, the proportion of zero catches has varied near to 30% per annum. For much of the time series, a trip stratum has combined between four and five tows on average, with this figure declining to three as the new forms have been adopted (Figure Q.4).

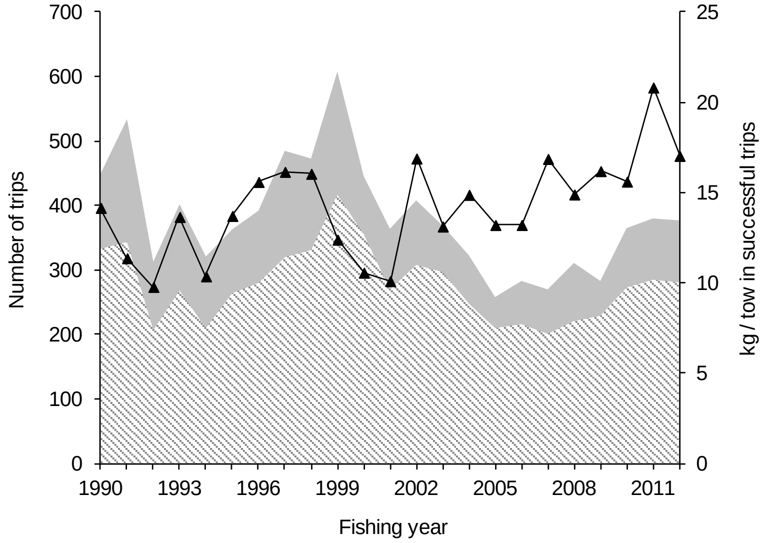


Figure Q.3: Number of qualifying trips in SPO 8_BT (dark area), the number of those trips that landed rig (light area) and the simple catch rate (kg/tow) of rig in successful trip-strata, by fishing year.

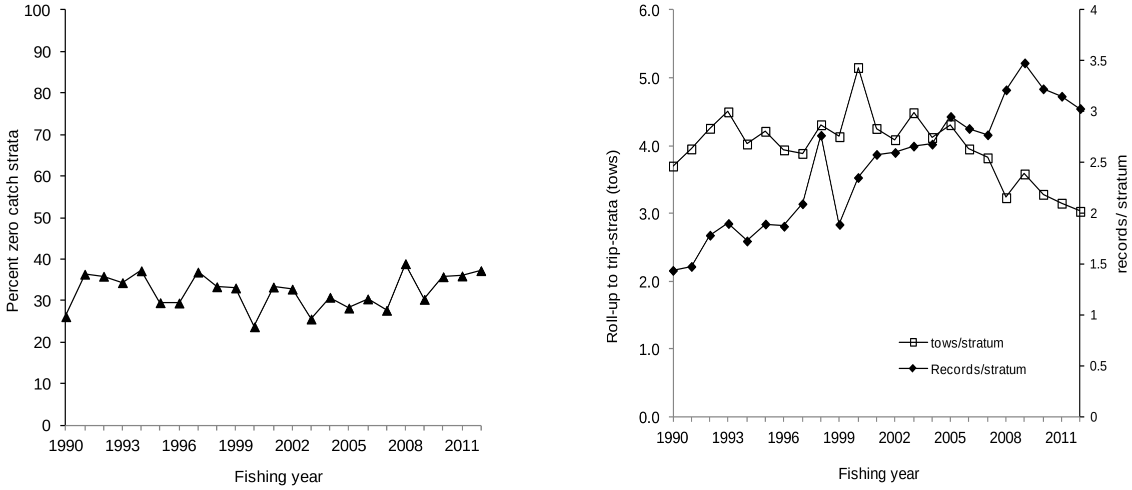


Figure Q.4: The proportion of qualifying trips in SPO 8_BT, that landed zero rig (left), and the effect of amalgamation to trip-strata on the number of original records per trip-stratum and the number of tows per trip-stratum, by fishing year.

Q.4 Standardised CPUE analysis

Q.4.1 Core fleet definitions

The data sets used for the standardised CPUE analysis were restricted to those vessels that participated with some consistency in the defined fishery. Core vessels were selected by specifying two variables; the number of trips that determined a qualifying year, and the number of qualifying years that each vessel participated in the fishery. The effect of these two variables on the amount of landed rig retained in the dataset and on the number of core vessels, and the length of participation by the core vessels in each fishery are shown for the SPO 8_SN fishery (Figure R.1), and SPO 8_BT fishery (Figure R.2). The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of rig. The selection process usually reduced the number of vessels in the dataset by about 70% while reducing the amount of landed rig by about 20%. Summaries for the core vessel data sets are presented in Table R.1.

Q.4.2 Model selection, diagnostics and trends in model year effects

The final models selected for standardising positive catches in each fishery are described in Table Q.1 (SPO 8_SN), and Table Q.2 (SPO 8_BT). These tables include those explanatory variables that met the AIC criteria and each is not necessarily a complete list of the variables that were offered[5]. The variables that met the acceptance criteria based on a 1% improvement in R^2 are indicated with asterisks in the table, along with the amount of deviance they explained.

Following each table are step-influence plots that demonstrate the progressive effect on the annual indices of each explanatory variable as it enters the model, and show the influence of each variable on the annual coefficients in adjacent panels. These plots highlight the observation made in Bentley et al. (2011) that the variables that explain the most deviance are not necessarily the ones responsible for most of the difference between standardised and observed series of CPUE.

Diagnostic plots of the residuals from each final model fit are given in Appendix R.3, and include implied coefficient plots for each statistical area and target species by year. These allow the comparison of the annual trends among statistical area and target species categories in each analysis, effectively serving as a proxy for an interaction analysis. The influence of an explanatory variable is a combination of the coefficients and its distributional changes over years, and are plotted as Coefficient-Distribution-Influence (CDI) plots (Bentley et al. 2011) (see Appendix R.4). The unstandardised and standardised indices from the final model for each fishery are given in Appendix R.5.

Q.4.2.1 SPO 8_SN – SPO 8 Shark setnet

The log logistic error distribution produced the best model fit to SPO 8_SN data (Figure R.3), and the residuals from the final model showed a good fit of the data to the distributional assumption (Figure R.4). Fishing year was forced as the first variable and explained about 4% of the variance in catch (Table Q.1). Vessel is the most important variable, entering second and explaining a further 29% of variance in catch, and target species, which entered third explained a further 10% of variance. Netlength was the measure of effort with the greatest explanatory power, and month and area were also accepted into the final model which explained about 51% of the variance in log(catch) (Table Q.1). The annual indices are plotted at each step in Figure Q.5, and show the adjustments made for improving fleet characteristics in the most recent two years and for less than optimal fishing practices in the earliest few years. The inclusion of month and area effected little further change in the year effects.

Improvements in the core fleet are a feature of the whole time period, but are most marked since 2009–10, largely driven by the increased participation in the fishery of the top few vessels (Figure R.11). The inclusion of target species adjusts for a shift away from targeting rig towards increased targeting of school shark from the mid-2000s that potentially lowered catches of rig by more than 30% (Figure R.12), although this was offset by a trend towards setting greater lengths of net that is predicted to have lifted catches of rig by 60% over the same period, and by more than 80% over the whole study period (Figure R.13). The month coefficients show a fishery in which catches and effort both drop away in the winter months (Figure R.14). Small shifts in the seasonality of fishing have been adjusted for from year to year with little influence overall (Figure R.14). Likewise, a shift away from area 039 and into 041 from the mid-2000s had a small negative influence on catches, but correcting for that influence did not markedly change the year effects (Figure R.15).

[5] Variables which make no improvement in the AIC are ignored by the software.

Table Q.1: Order of acceptance of variables into the Log-logistic model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 5 trips in 5 or more fishing years) in the SPO 8_SN fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an *. Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final
fyear	24	-51 497	103 041	4.01	*
vessel	170	-50 076	100 493	33.16	*
target	172	-49 434	99 212	43.26	*
poly(log(netlength), 3)	175	-49 045	98 441	48.61	*
month	186	-48 900	98 173	50.47	*
area	188	-48 807	97 991	51.63	*
poly(log(days), 3)	191	-48 787	97 957	51.87	
poly(log(duration), 3)	194	-48 772	97 933	52.06	

a) b)

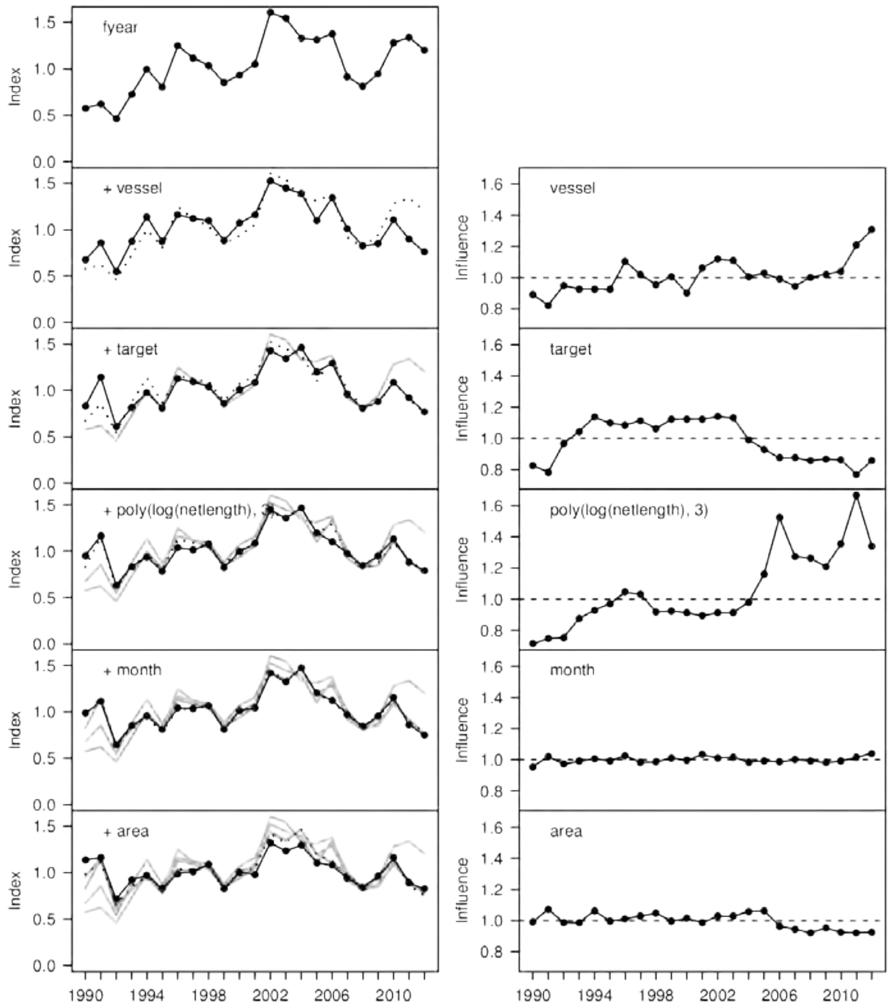


Figure Q.5: Step and annual influence plot for SPO 8_SN. (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

The year effects display more interannual variance than trend in the first half of the series but become more credible from the early 2000s. They then decline smoothly over four consecutive years to a low point in 2007–08 before recovering somewhat, sitting currently at about 0.8 of the overall mean for the series (Figure Q.6).

There is reasonable agreement with the previous series presented for this fishery (Figure Q.6). The main effect of standardisation is to lift initial, and recent points, and to remove a series of peaks in the middle of the time series, and with the effect of flattening the overall trajectory. Residual implied coefficients confirm similar patterns of decline and subsequent recovery during the last decade in each area (Figure R.5) and each target fishery (Figure R.6), although with some differences in timing and magnitude.

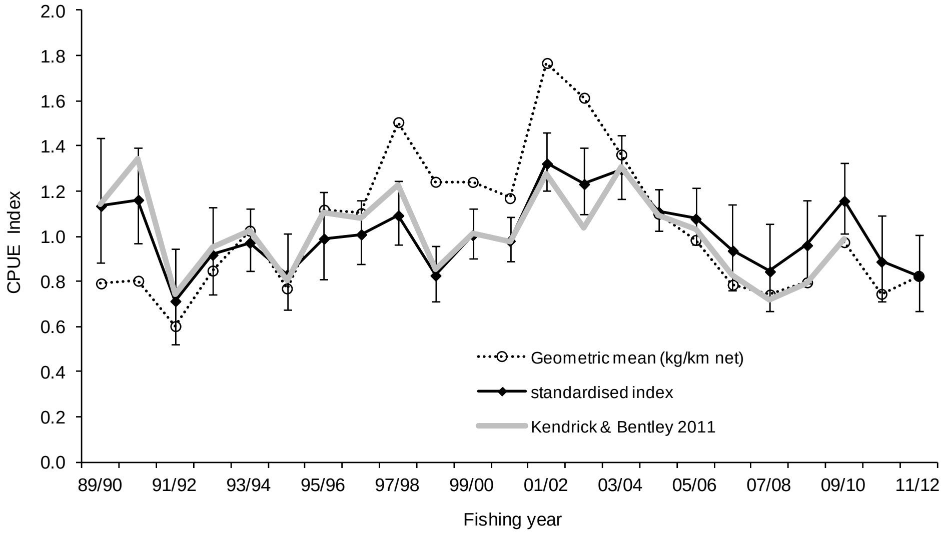


Figure Q.6: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 8_SN fishery. Broken lines are the raw CPUE (kg /km net) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the lognormal series presented in 2011 for a similar fishery (target sets only). All series are relative to the geometric mean over the years in common.

Q.4.2.2 SPO 8_BT Mixed species bottom trawl

The log logistic error distribution produced the best model fit to SPO 8_BT data (Figure R.7) and the residuals from the final model showed a good fit of the data to the distributional assumption (Figure R.8). Fishing year was forced as the first variable and explained less than 2% of the variance in catch, duration of fishing is the most important variable, entering second and explaining a further 33% of variance in catch, and vessel and month were also accepted into the model, explaining a total of 44% of the variance in log(catch) (Table Q.2). The annual indices are plotted at each step in Figure Q.7 and show the influence of changes in effort which was positive during the first half of the time series, but negative in the second half of the series. Improvements in the core fleet also accounted for improved catches. The inclusion of month effected little further change in the year effects.

Table Q.2: Order of acceptance of variables into the log logistic model of successful catches of rig for core vessels (based on the vessel selection criteria of at least 5 trips in 8 or more fishing years) in the SPO 8_BT fishery with the amount of explained deviance for each variable. Variables accepted into the model are marked with an * . Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R2 (%)	Final

fyear	23	-8 316	16 679	1.62	*
poly(log(duration), 3)	26	-7 403	14 860	34.20	*
vessel	42	-7 103	14 292	42.44	*
month	53	-7 037	14 182	44.11	*
target	58	-7 006	14 129	44.89	
area	60	-6 976	14 074	45.62	
poly(log(num), 3)	63	-6 969	14 066	45.79	

a) b)

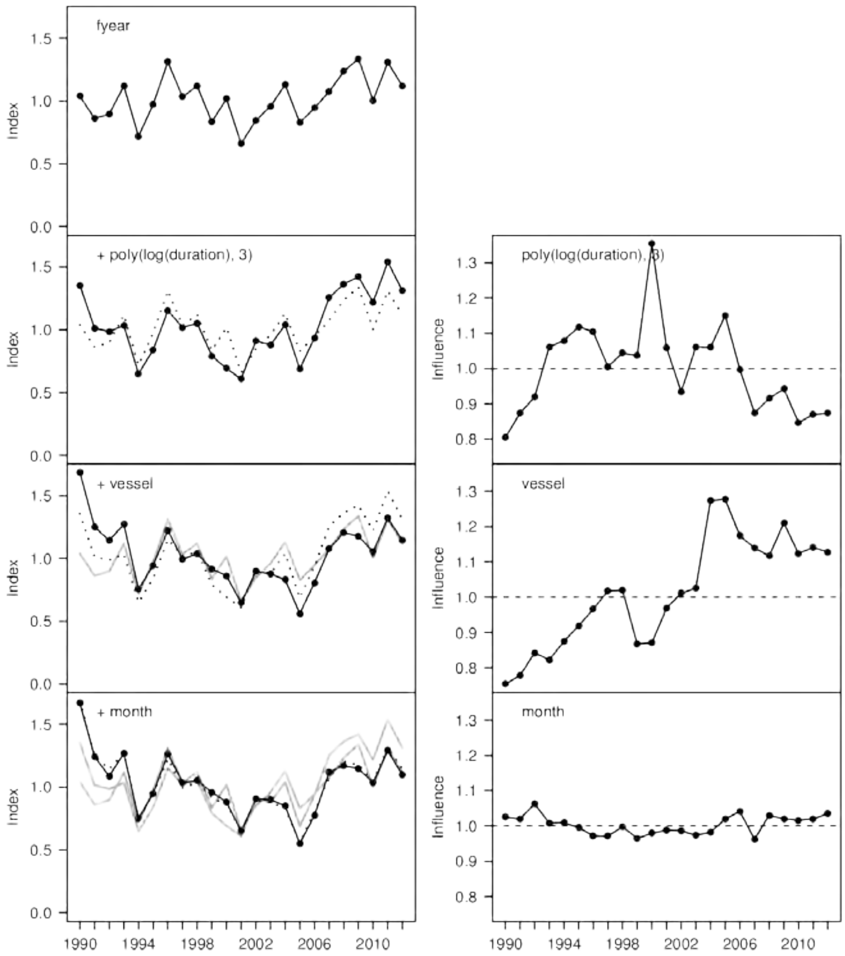


Figure Q.7: Step and annual influence plot for SPO 8_BT. (a) CPUE index at each step in the selection of variables. The index obtained in the previous step (if any) is shown by a dotted line and for steps before that by grey lines. (b) Annual influence on observed catches arising from a combination of its GLM coefficients and its distributional changes over years, for each explanatory variable in the final model.

Shifts in the duration of fishing were initially positive for rig (showing a trend towards longer tows) but conversely negative (showing a trend towards shorter tows) in the second decade (Figure R.16). This may partly be related to changes in the fleet as there was a noticeable turnover of vessels halfway through the time period (Figure R.17). Improvements in the core fleet continued to increase catches until well into the 2000s (Figure R.17). The month coefficients show a quite different seasonal pattern to setnet, with lowest months in summer and greatest catches predicted in winter (Figure R.18). This is consistent with setnet focusing on spawning aggregations of adults and bottom trawl catching dispersed juveniles. Small shifts in the seasonality of fishing have been adjusted for from year to year with only a small negative influence overall.

The year effects have an overall flat trend, although with cycles that vary around 20% either side of the long-term average over every six or seven years (Figure Q.8). The error bars are small and the series looks well determined until the mid 2000s, after which it becomes less stable. The series contrasts markedly with the previous series presented for this fishery, and that is due to the improved grooming used this study to identify and remove unrealistically high landings in the 1990s.

The main effect of standardisation is to remove a recent increase in observed catches by adjusting for increased effort by the top performing vessels. Residual implied coefficients confirm similar patterns in annual indices for each area (Figure R.9) and for each target fishery (Figure R.10), giving some confidence that the series offers a representative index of abundance of (possibly juvenile) rig in SPO 8.

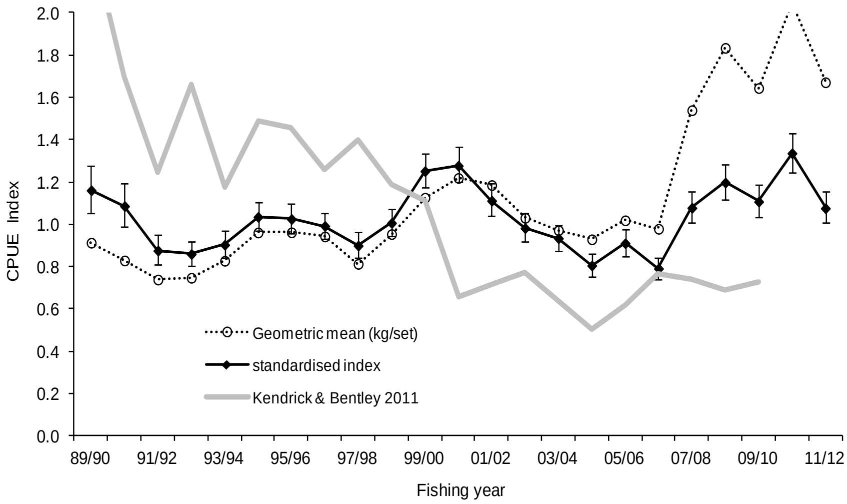


Figure Q.8: The effect of standardisation on the raw CPUE of rig in successful trips by core vessels in the SPO 8_BT fishery. Broken lines are the raw CPUE (kg /tow) for all vessels and for the core fleet only, the solid line is the unstandardised CPUE (annual geometric mean), the bold line is the standardised CPUE canonical indices with ± 2 * SE error bars. Grey line is the previous lognormal series presented in 2011 for a similar fishery. All series are relative to the geometric mean over the years in common.

Appendix R. DETAILED DIAGNOSTICS FOR SPO 8 CPUE STANDARDISATIONS

R.1 Core vessel selection

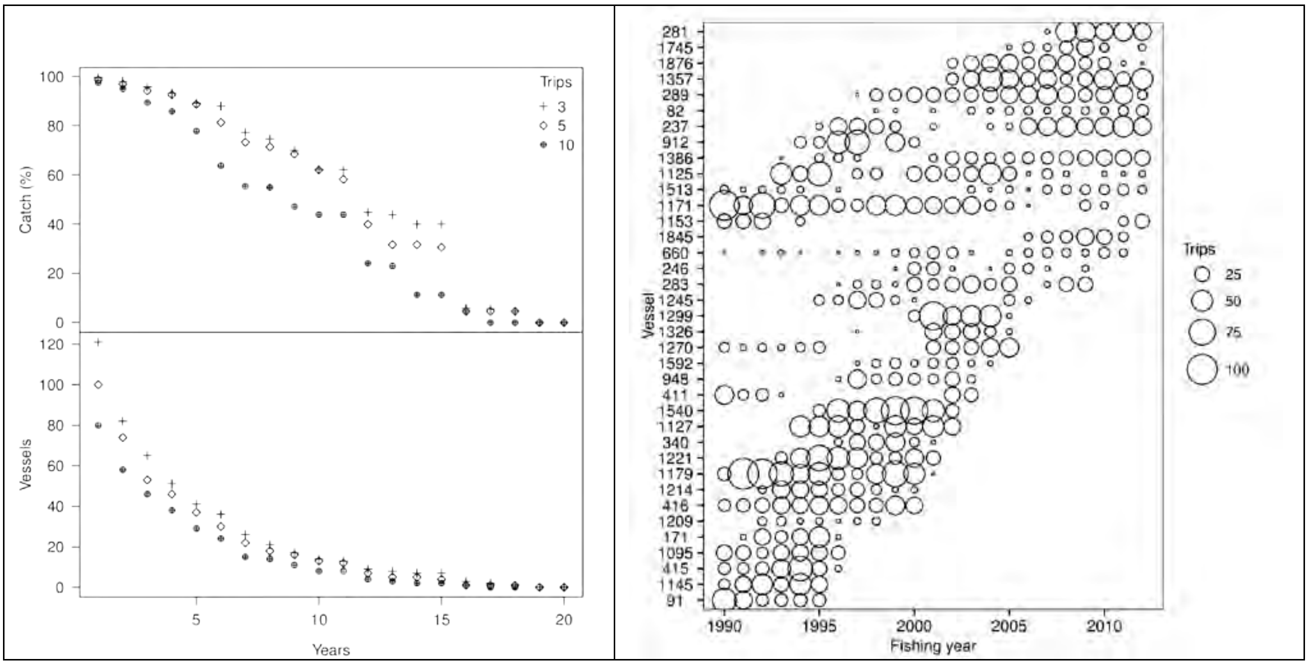


Figure R.1: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 8_SN dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 10 trips in 5 or more fishing years).

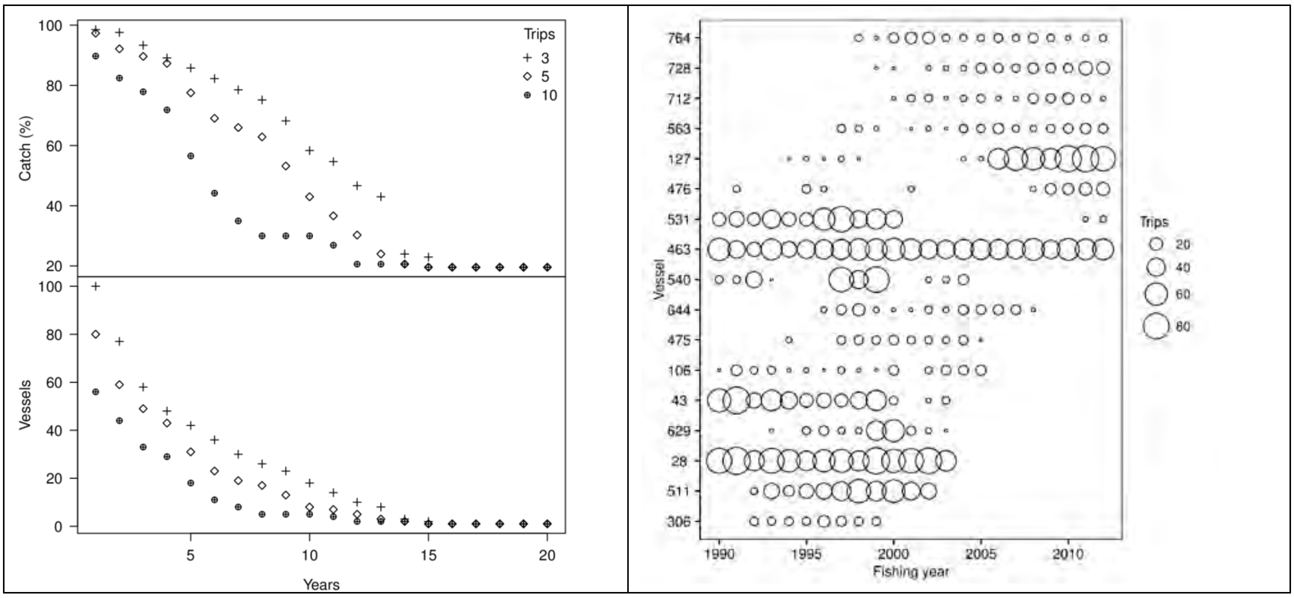


Figure R.2: The total landed rig [top left panel] and the number of vessels [bottom left panel] retained in the SPO 8_BT dataset as a function of the minimum number of qualifying years used to define core vessels. [right panel]: the number of records for each vessel in each fishing year for the selected core vessels (based on at least 5 trips in 8 or more fishing years).

R.2 Data summaries

Table R.1: Number of vessels, trips, trip strata, events, sum of catch (t), sum of net length(km for SPO 8_SN) or sum of tows (for SPO 8_BT) and sum of hours fishing for core vessels in the two CPUE analyses by fishing year.

	SPO 8_SN								SPO 8_BT							
Fishing year	Vessel	Trips	Trip-strata	events	Catch	Tows	Hours	% zero	Vessel	Trips	Trip-strata	events	Catch	Tows	Hours	% zero
1990	12	345	354	414	65.1	776.8	6 876	92.1	6	235	237	302	9.5	714	1 913	73.8
1991	13	326	329	364	61.0	664.2	6 051	91.8	8	273	279	360	9.3	918	2 437	60.9
1992	15	410	420	478	60.4	854.9	7 721	88.3	9	181	189	342	6.6	679	1 969	66.7
1993	18	390	396	491	110.4	964.1	8 711	89.7	9	273	283	436	12.2	1 156	3 148	73.1
1994	18	521	528	617	154.6	1 368.4	9 197	83.9	12	188	207	351	5.1	846	2 373	66.2
1995	21	594	615	757	178.5	1 600.9	11 093	84.7	11	197	209	338	8.8	848	2 674	70.3
1996	21	425	437	548	167.9	1 265.5	7 145	93.6	11	263	287	484	15.9	1 152	3 644	72.1
1997	20	434	445	595	163.4	1 393.9	7 666	91.9	14	392	425	749	17.8	1 449	4 387	62.6
1998	18	370	381	514	128.8	1 037.6	6 728	96.3	16	350	385	875	20.0	1 464	4 827	69.4
1999	18	493	497	647	140.2	1 346.8	8 447	97.0	14	445	484	770	18.0	1 895	5 699	68.2
2000	18	441	447	575	103.5	1 300.7	7 036	96.4	12	340	405	812	17.4	2 033	6 531	79.5
2001	19	453	460	605	143.2	1 284.3	8 091	95.7	12	221	327	741	9.5	1 203	4 003	65.4
2002	19	377	393	554	152.0	1 152.6	7 622	91.9	13	224	361	935	15.5	1 176	4 036	63.4
2003	17	351	361	495	136.2	1 062.2	6 781	88.6	12	150	231	610	9.7	834	2 942	72.7
2004	15	345	363	505	150.7	1 141.1	6 780	94.5	11	130	237	687	12.6	876	3 238	71.3
2005	17	294	316	485	138.2	1 218.2	6 190	91.5	9	119	223	671	9.9	900	3 312	75.3
2006	14	193	201	410	136.7	1 087.5	5 174	95.0	7	151	251	659	10.9	845	3 133	74.5
2007	15	250	267	523	130.2	1 319.4	8 356	95.5	8	150	210	495	10.6	627	2 229	79.1
2008	13	297	326	635	138.0	1 430.4	9 531	92.0	8	171	266	731	11.7	734	2 692	66.5
2009	14	310	336	586	143.4	1 387.0	8 703	92.0	8	147	250	747	14.1	747	2 821	76.8
2010	13	284	317	582	172.6	1 435.5	9 062	97.8	9	199	334	912	12.1	912	3 301	66.5
2011	13	249	278	576	139.7	1 469.6	9 059	97.5	8	212	338	973	17.5	973	3 353	71.0
2012	13	224	258	440	109.9	1 036.6	6 818	95.0	8	193	321	841	13.7	841	3 080	67.9

R.3 Diagnostic plots

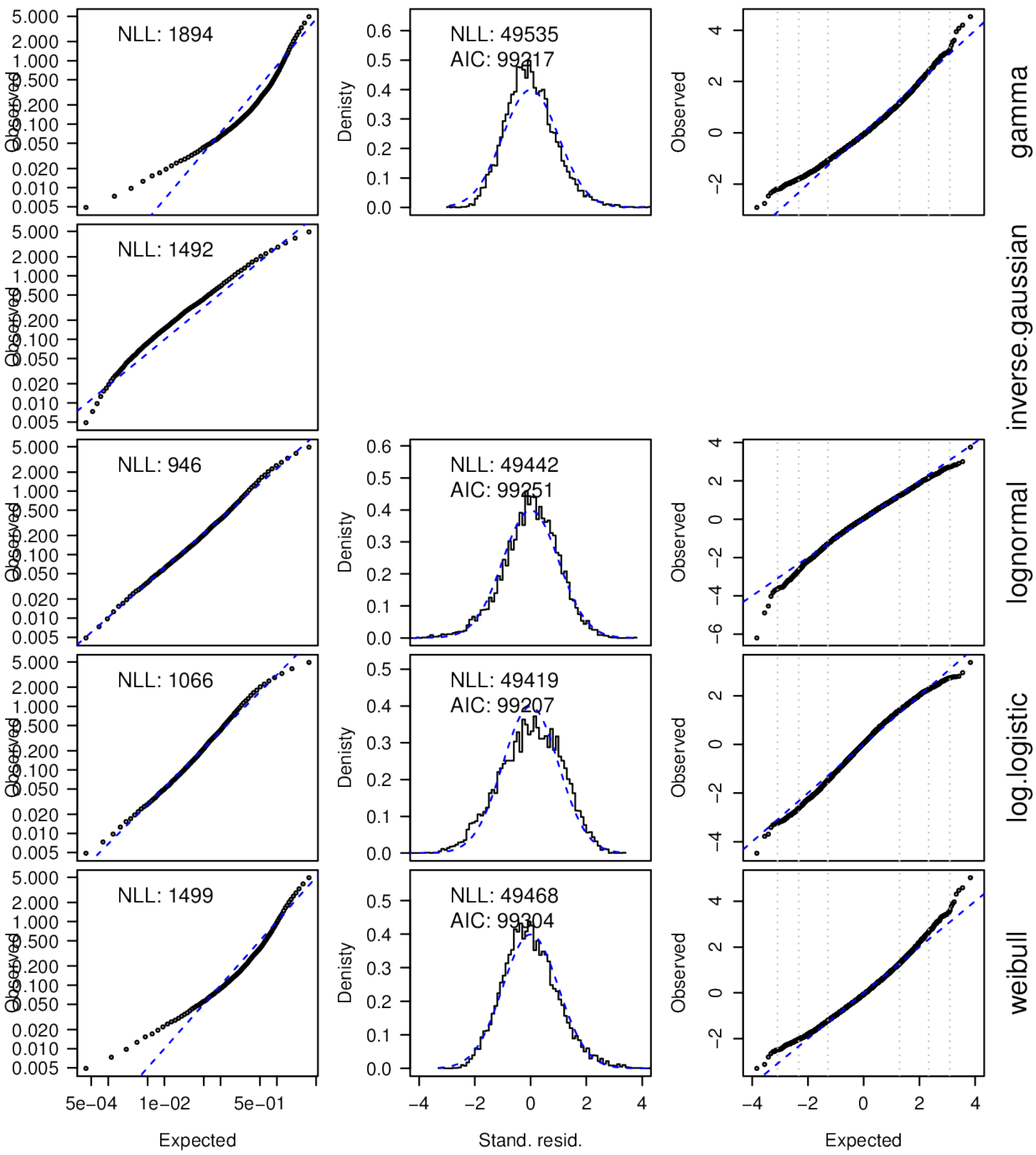


Figure R.3: Diagnostics for alternative distributional assumptions for catch in the SPO 8_SN fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + target + netlength and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

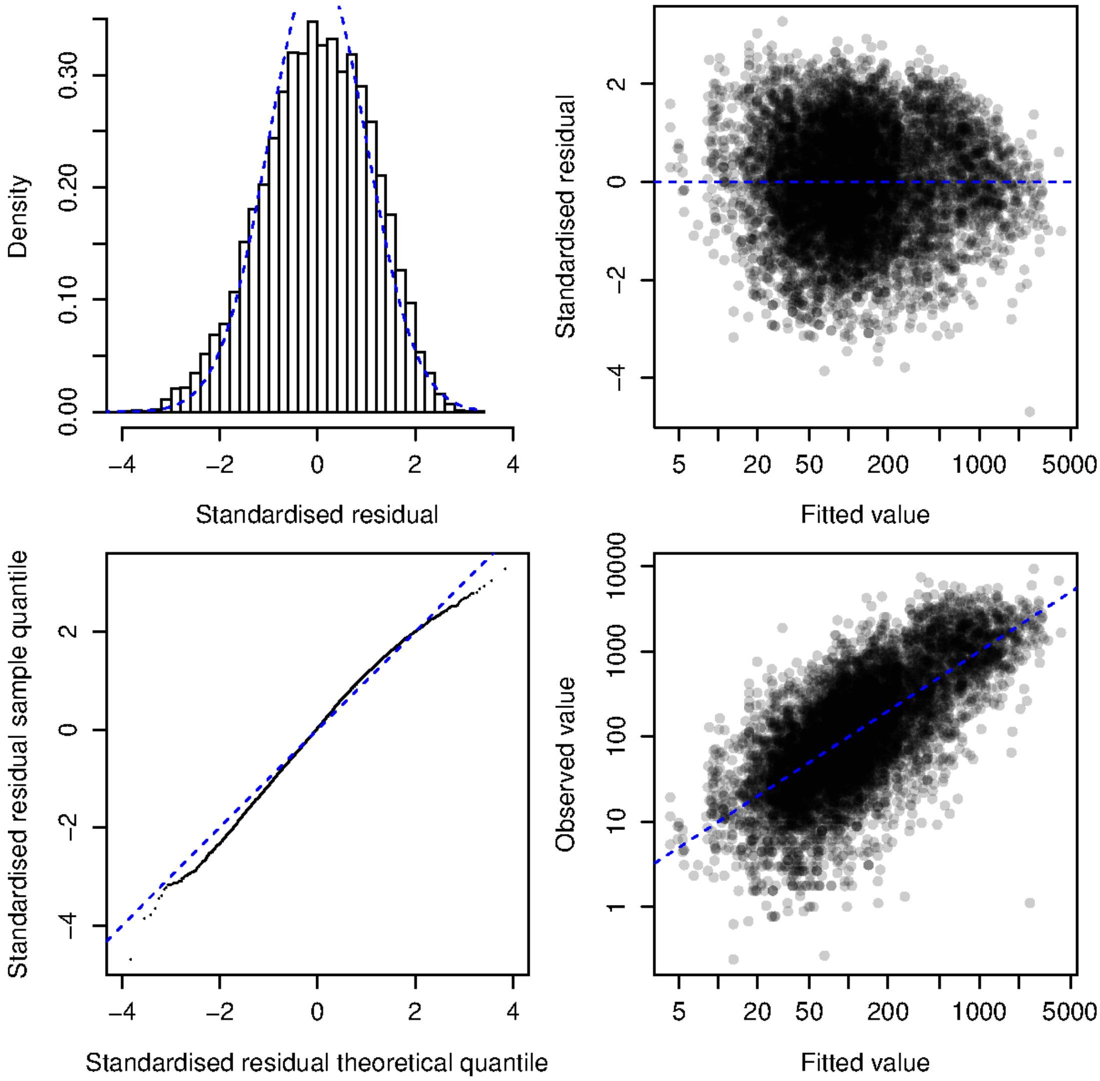


Figure R.4: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 8_SN fishery. [Upper left] histogram of the standardised residuals compared to a log logistic distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

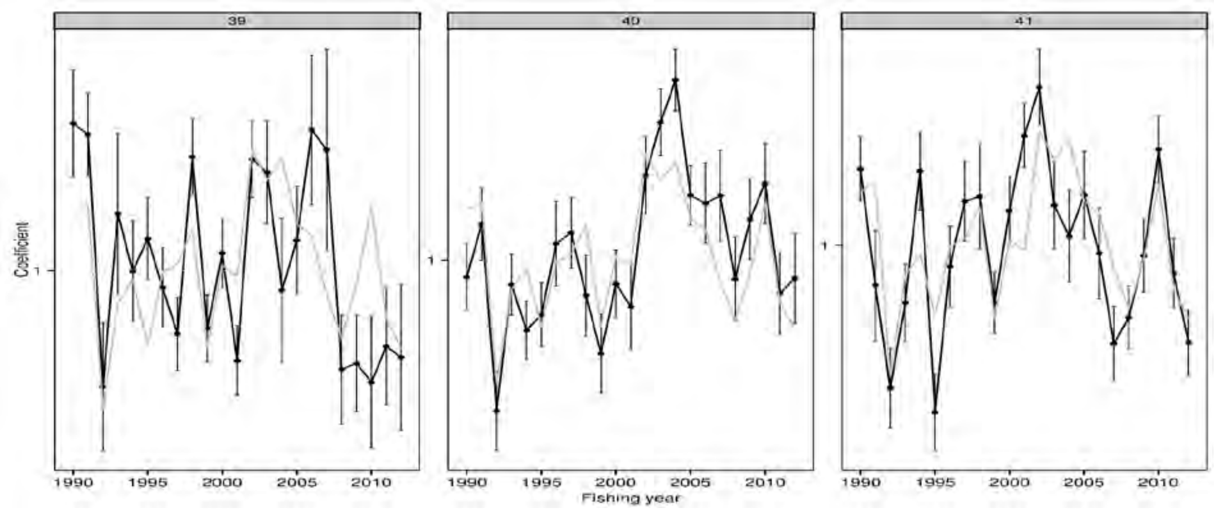


Figure R.5: Residual implied coefficients for each area in each fishing year in the SPO 8_SN fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

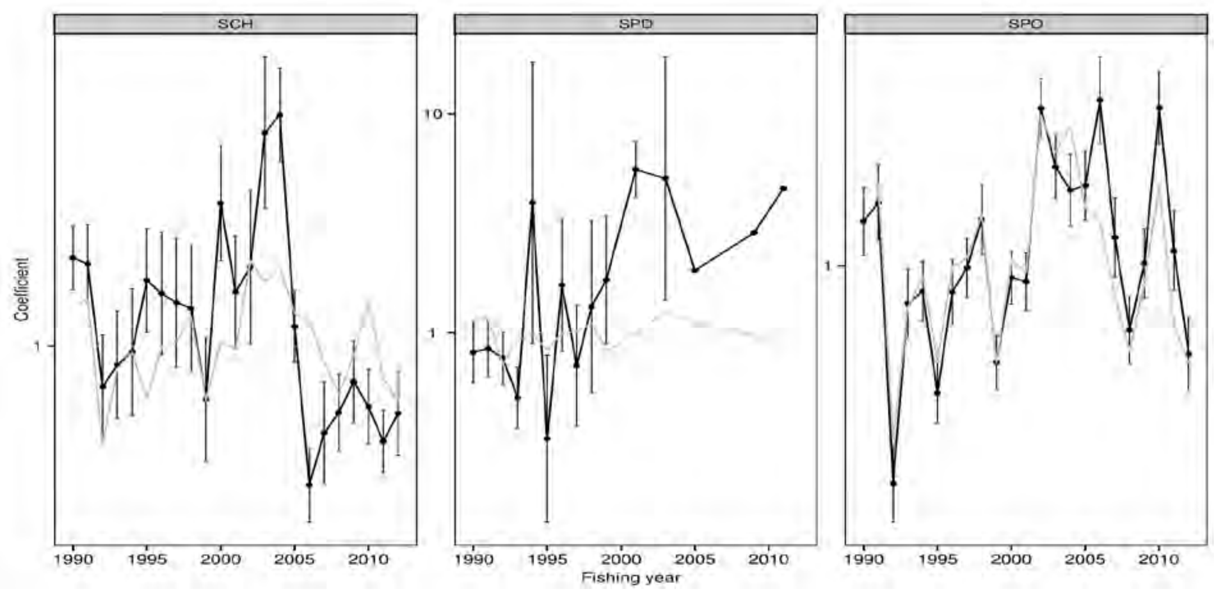


Figure R.6: Residual implied coefficients for each target species in each fishing year in the SPO 8_SN fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

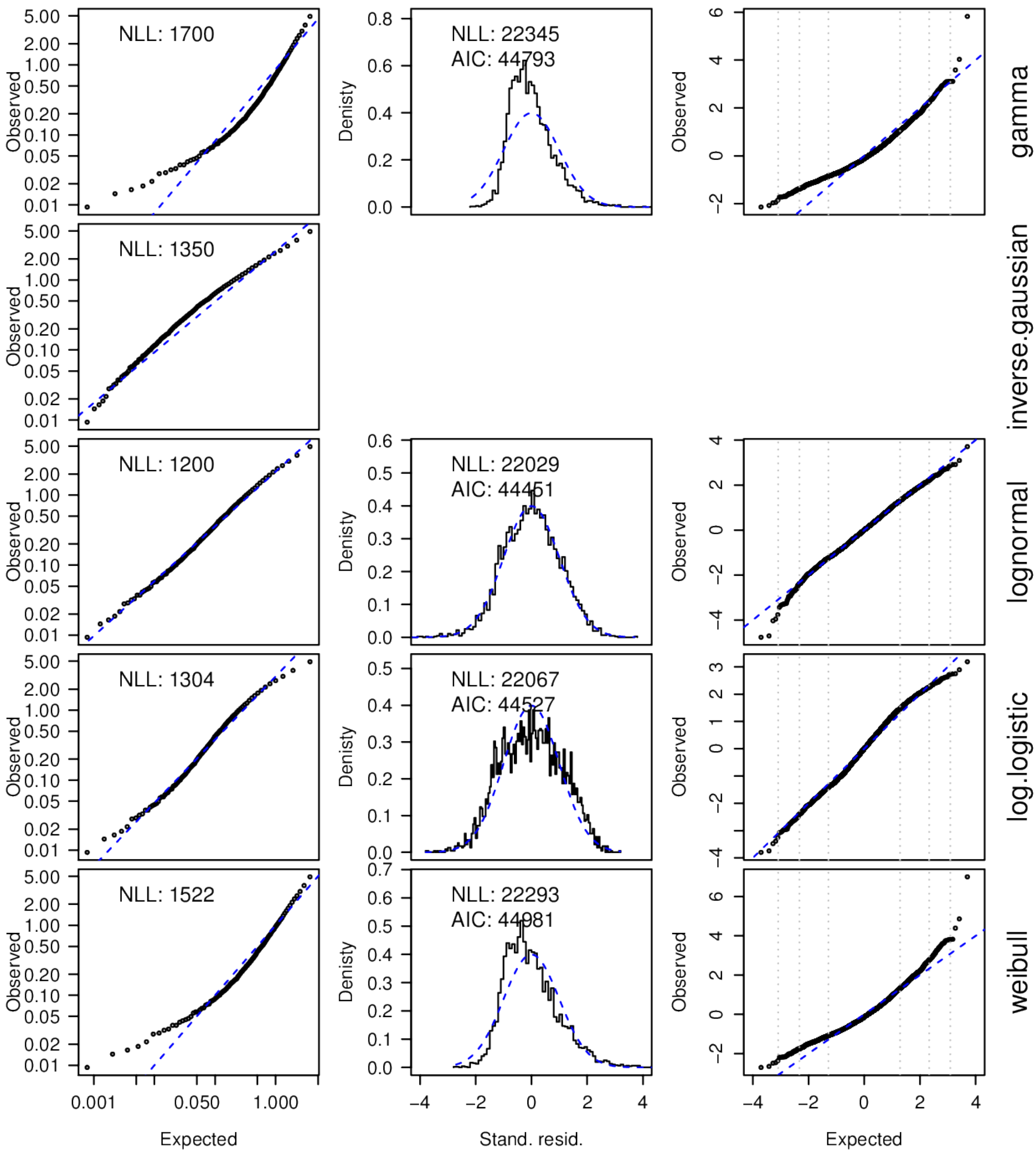


Figure R.7: Diagnostics for alternative distributional assumptions for catch in the SPO 8_BT fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + area + vessel + target +tows and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

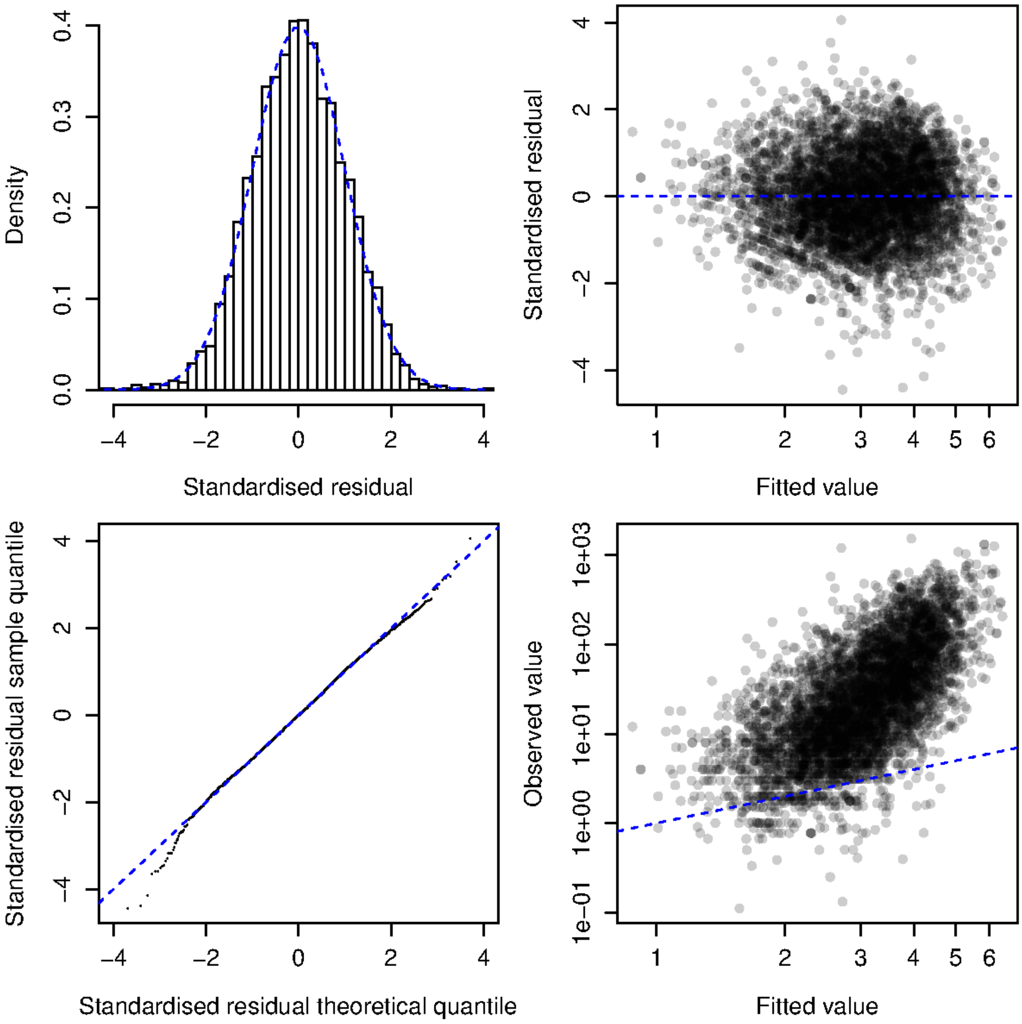


Figure R.8: Plots of the fit of the standardised CPUE model to successful catches of rig in the SPO 8_BT fishery. [Upper left] histogram of the standardised residuals compared to a log-logistic distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

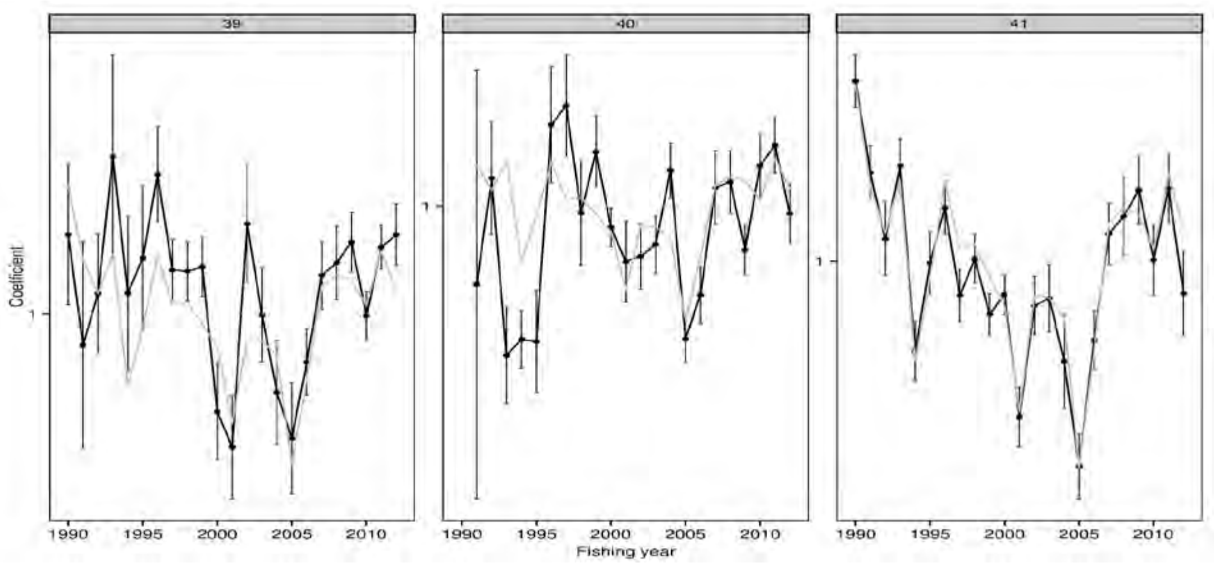


Figure R.9: Residual implied coefficients for each area in each fishing year in the SPO 8_BT fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year in each area. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

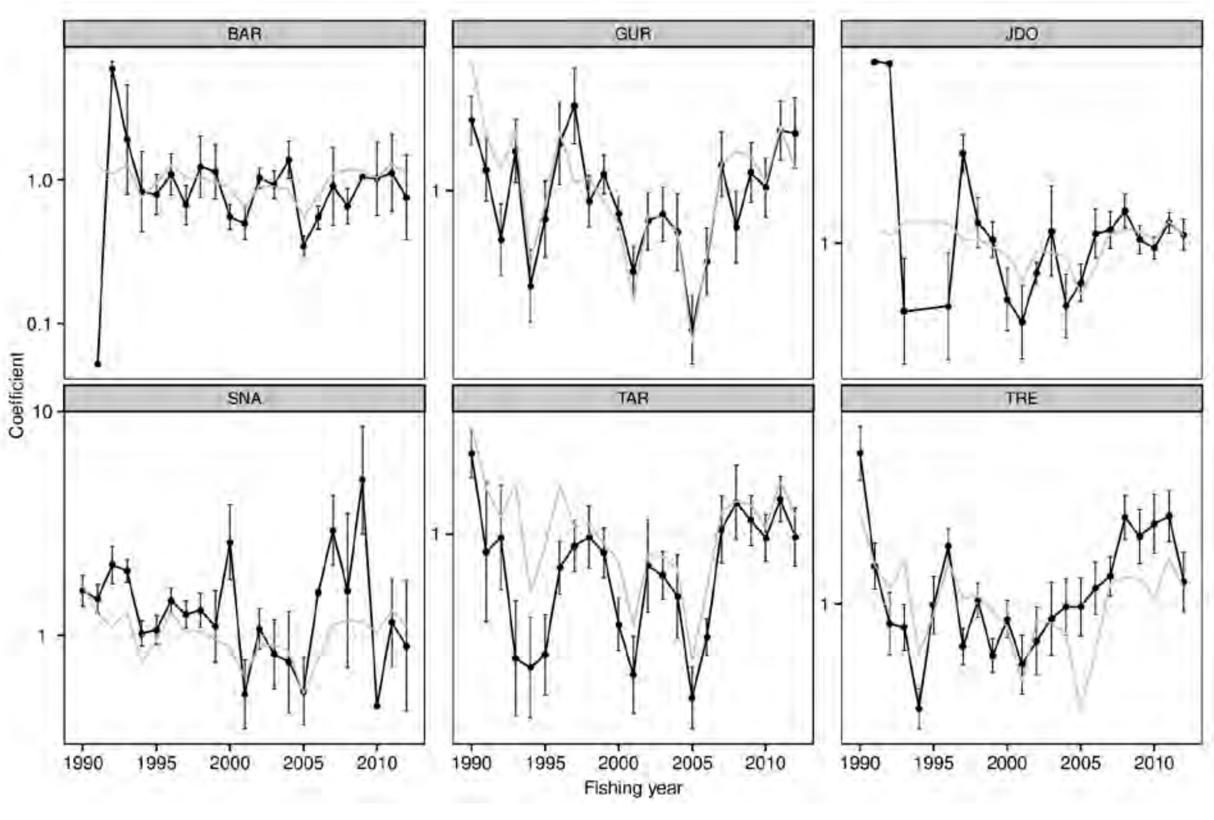


Figure R.10: Residual implied coefficients for each target species in each fishing year in the SPO 8_BT fishery. Implied coefficients are calculated as the sum of the fishing year coefficient plus the mean of the residuals in each fishing year for each target. The error bars indicate one standard error of residuals. The grey line indicates the model's overall fishing year coefficients.

R.4 Model coefficients

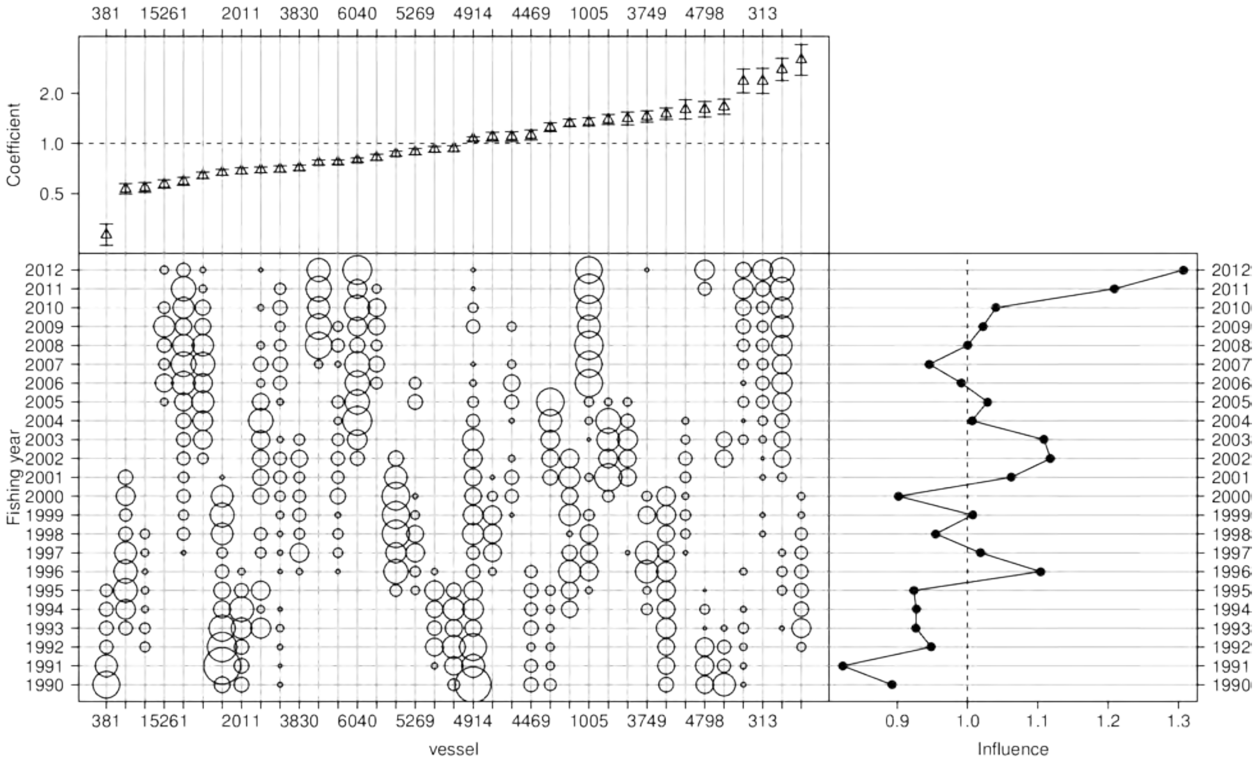


Figure R.11: Effect of vessel **in the Log-logistic model for the SPO 8_SN fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

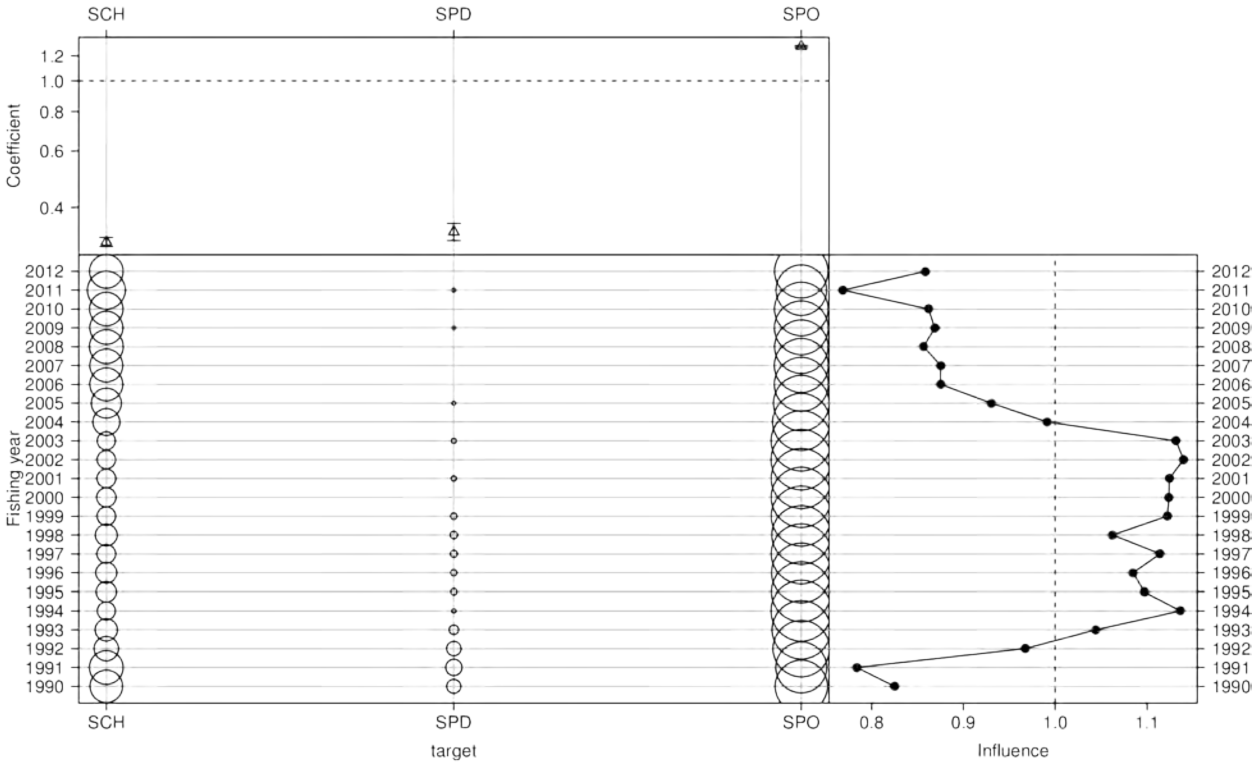


Figure R.12: Effect of target **in the Log-logistic model for the SPO 8_SN fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

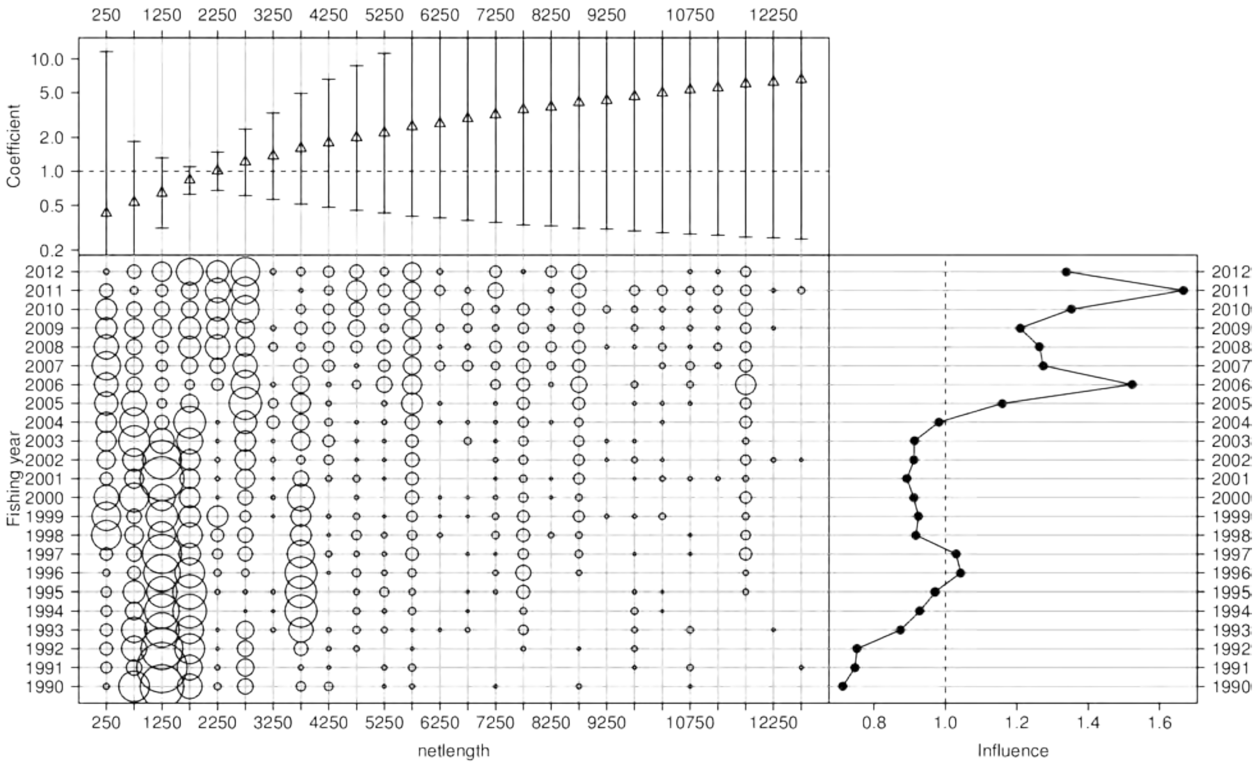


Figure R.13: Effect of netlength **in the Log-logistic model for the SPO 8_SN fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

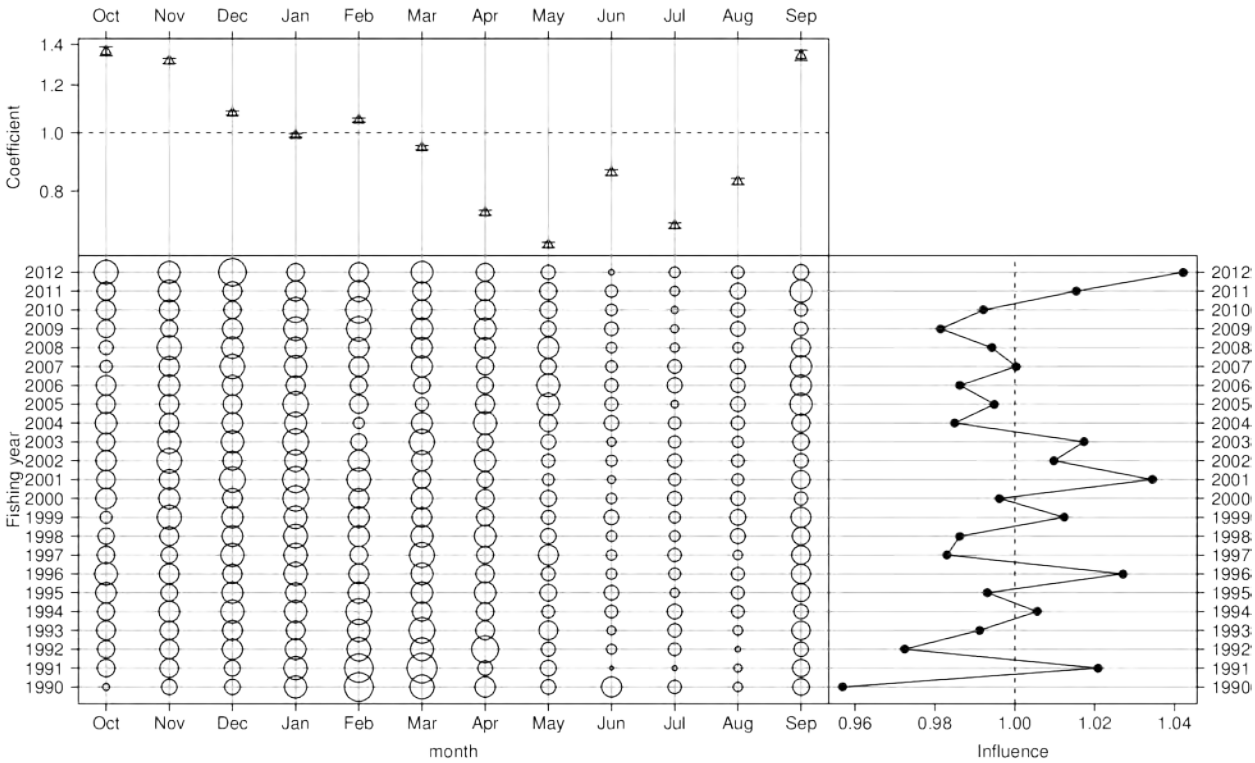


Figure R.14: Effect of month **in the Log-logistic model for the SPO 8_SN fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

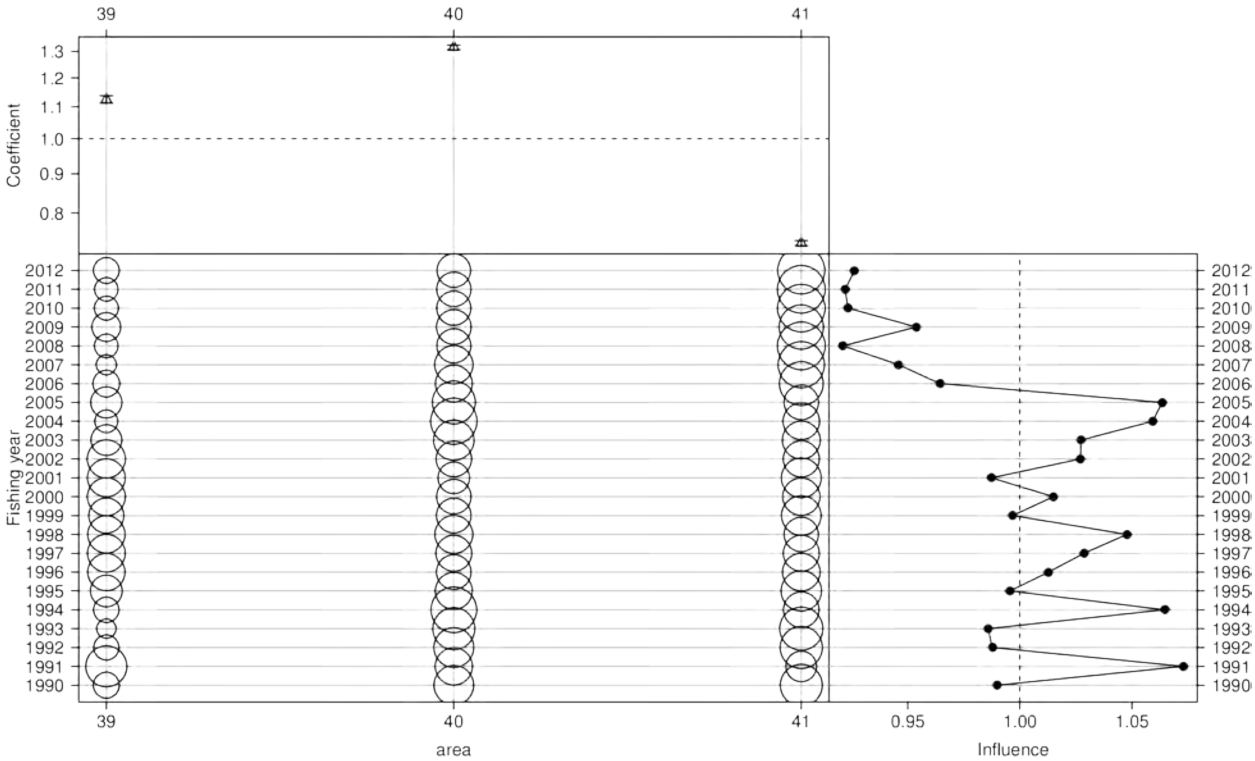


Figure R.15: Effect of area **in the Log-logistic model for the SPO 8_SN fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

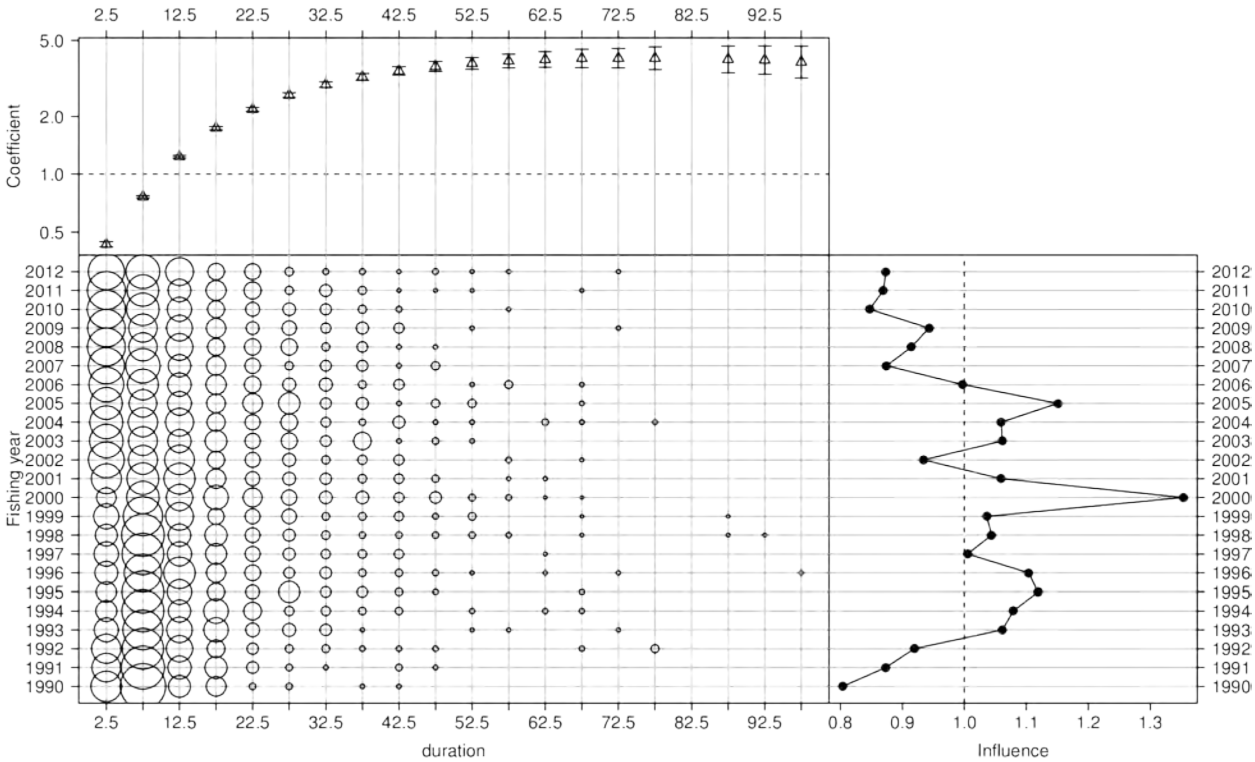


Figure R.16: Effect of duration **in the Log-logistic model for the SPO 8_BT fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

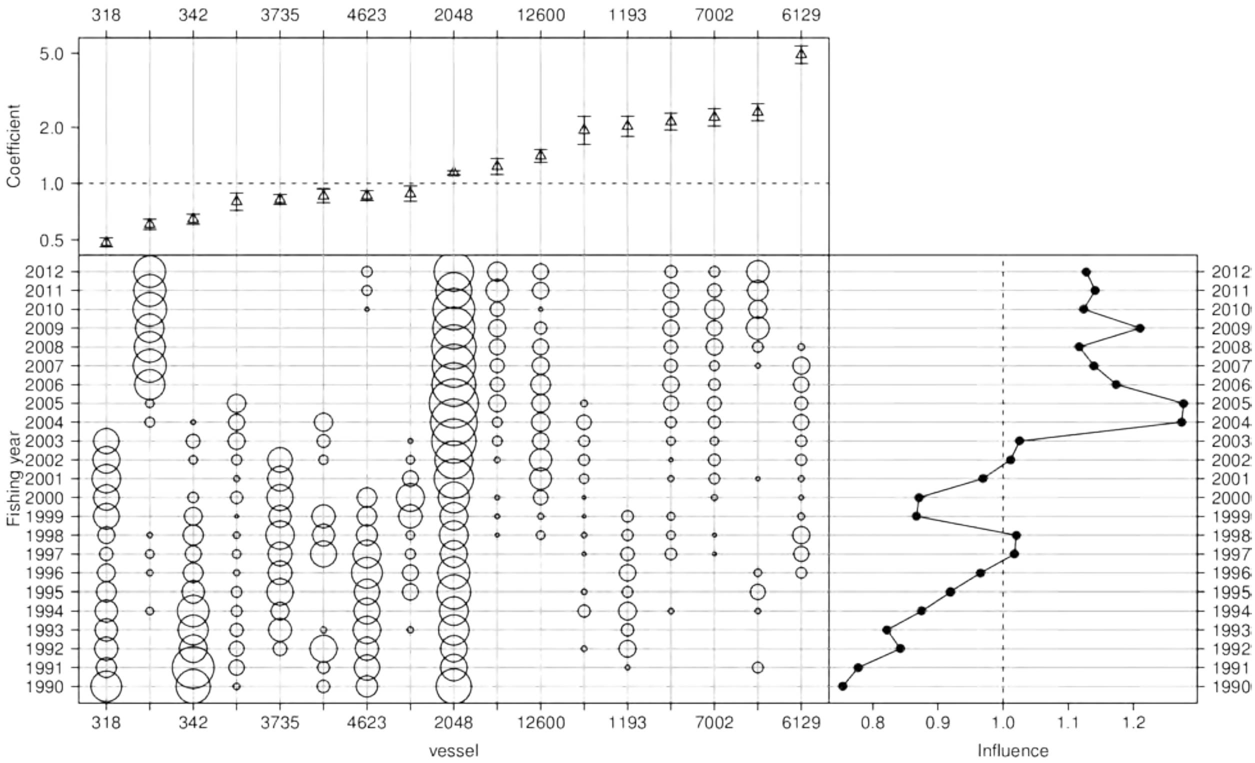


Figure R.17: Effect of vessel **in the Log-logistic model for the SPO 8_BT fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

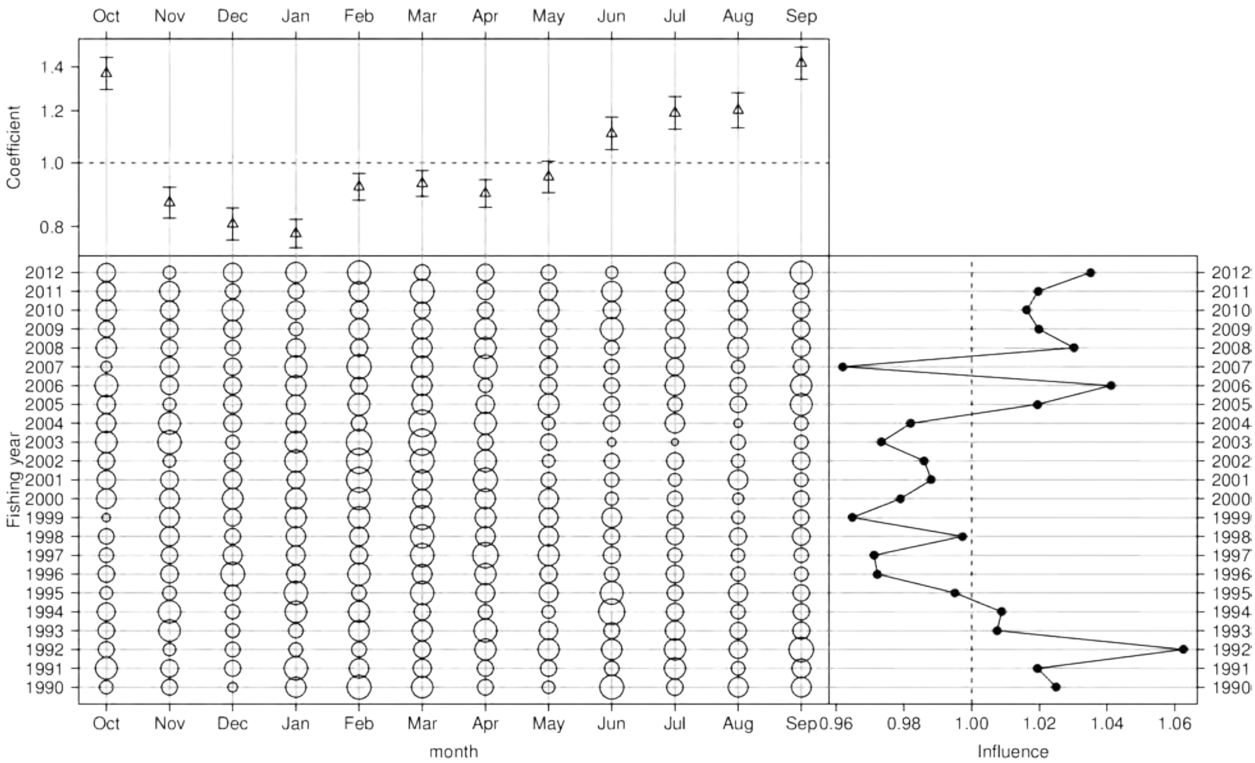


Figure R.18: Effect of month **in the Log-logistic model for the SPO 8_BT fishery. Top: effect by level of variable. Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year.**

R.5 CPUE indices

Table R.2: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error for the core data set by fishing year for the two CPUE models.

	SPO 8_SN					SPO 8_BT				
Fishing	All	Core vessel indices				All	Core vessel indices			
Year	Arithmetic	Arithmetic	Geometric	Standard-ised	SE	Arithmetic	Arithmetic	Geometric	Standard-ised	SE
1990	0.726	0.631	0.791	1.135	0.067	1.115	1.193	1.090	1.668	0.083
1991	0.689	0.723	0.803	1.162	0.070	0.668	0.718	0.822	1.242	0.086
1992	0.616	0.744	0.602	0.713	0.065	0.693	0.871	0.859	1.087	0.097
1993	0.676	0.840	0.848	0.918	0.063	0.912	0.917	0.891	1.269	0.077
1994	0.785	0.871	1.025	0.972	0.059	0.757	0.480	0.570	0.753	0.093
1995	0.790	0.775	0.769	0.829	0.055	0.955	0.774	0.793	0.948	0.089
1996	1.164	1.264	1.118	0.990	0.060	1.147	1.300	1.103	1.263	0.076
1997	1.070	1.032	1.103	1.008	0.059	1.019	0.967	0.953	1.037	0.069
1998	1.802	1.953	1.506	1.092	0.061	0.943	0.947	1.020	1.051	0.068
1999	1.361	1.431	1.242	0.827	0.055	0.758	0.755	0.712	0.960	0.063
2000	1.441	1.443	1.241	1.005	0.054	0.779	0.697	0.683	0.880	0.064
2001	1.156	1.076	1.169	0.980	0.056	0.690	0.606	0.621	0.649	0.075
2002	1.363	1.443	1.768	1.322	0.059	1.342	1.136	0.932	0.906	0.072
2003	1.130	1.322	1.614	1.232	0.063	1.201	1.039	0.940	0.902	0.083
2004	1.146	1.269	1.362	1.296	0.064	1.167	1.377	1.182	0.850	0.084
2005	0.879	0.959	1.100	1.109	0.065	0.977	0.841	0.809	0.552	0.084
2006	1.142	1.110	0.984	1.078	0.080	0.948	1.057	1.068	0.773	0.081
2007	1.018	0.978	0.785	0.936	0.072	1.165	1.285	1.348	1.118	0.085
2008	0.862	0.667	0.742	0.844	0.067	1.249	1.595	1.566	1.170	0.083
2009	0.990	0.837	0.796	0.960	0.068	1.279	1.565	1.637	1.147	0.081
2010	1.188	1.056	0.974	1.157	0.067	1.325	1.187	1.338	1.035	0.076
2011	1.031	0.806	0.745	0.888	0.070	1.273	1.432	1.650	1.289	0.074
2012	0.807	0.769	0.825	0.824	0.072	1.197	1.316	1.460	1.095	0.077