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Tini a Tangaroa

FLA 3 Fishery Characterisation, CPUE and Management Procedure Review

New Zealand Fisheries Assessment Report 2018/51

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Starr, P.J.; Kendrick, T.H.; Bentley, N.; Langley, A.D. (2018). FLA 3 Fishery Characterisation, CPUE and Management Procedure Review.

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The mixed species flatfish fishery, FLA 3, located off the east and south coasts of the New Zealand South Island, is described for the period 1989–90 to 2013–14 using compulsory reported commercial catch and effort data held by Fisheries New Zealand. These species are almost entirely captured by bottom trawl, accounting for 94% of the accumulated landings over the 25 year period. The balance of the flatfish catch is taken by setnet and some Danish seine. Flatfish are the target species of a shallow bottom trawl fishery, but, because the FLA code can be used to designate up to 18 different species, the distribution of species-specific flatfish catch is not well known. A subset of the catch/effort data was extracted for trips which routinely report FLA catch using a specific species code, a practice that is encouraged but not required. The "*trip splitter*" data set formed the basis for characterising the catch for the three top species taken in FLA 3 (New Zealand sole [ESO], Lemon sole [LSO] and Sand flounder [SFL]) and is used to present fine scale position plots, depth distributional plots and seasonal catch information for each of the three species. Landing characterisation information is necessarily constrained to the amalgamated FLA 3 code.

Standardised commercial Catch Per Unit Effort (CPUE) analyses have been prepared for each of the three key species (ESO, LSO and SFL) based on bottom trawl data from the "*trip splitter*" data set. Positive lognormal catch and binomial presence/absence series were combined into a single delta-lognormal series, with the trends from these relative abundance series differing among the three species over the 25 year period: the LSO series showed no overall trend, while the ESO series declined after the early 2000s and the SFL series increased from the mid-2000s. A fourth positive catch series for the combined bottom trawl target FLA fishery was prepared using the full FLA 3 data set [FLA 3(TOT)], providing an all species trend for FLA 3. No binomial presence/absence series was prepared for this data set because of the very low incidence of zero catch records. This series resembled the LSO series the most, which showed considerable fluctuations around the long-term mean CPUE.

The FLA 3(TOT) series was used to drive an in-season management procedure (MP) for FLA 3 under a special provision of the 1996 Fisheries Act which allows for the setting of a "base" TACC with the provision that additional catch can be added during the fishing season if the abundance data warrant it. The FLA 3 MP, initially developed by Bentley (2010), uses early data from the current fishing year to predict the overall annual CPUE index for the year. This CPUE is then multiplied by the slope of a regression which relates CPUE with the realised catches for the period 1989–90 to 2006–07, which is the period of unconstrained fishing in FLA 3. This slope effectively represents an average exploitation rate for that period. The accuracy of the CPUE predictions was evaluated using a retrospective analysis which stepped through each fishing year, starting with 2007–08, and which used the data available in that year. The CPUE estimates over the seven years ranged from –22% to +10% of the final CPUE when basing the CPUE predictions on data available up to the end of November. While this range seems wide, the mean is relatively unbiased at –0.3% and the performance doesn't improve much by adding December and even January data to the analysis. The Fishery Assessment Plenary deemed this level of accuracy to be acceptable, allowing the FLA 3 MP to be operated with two months of data.

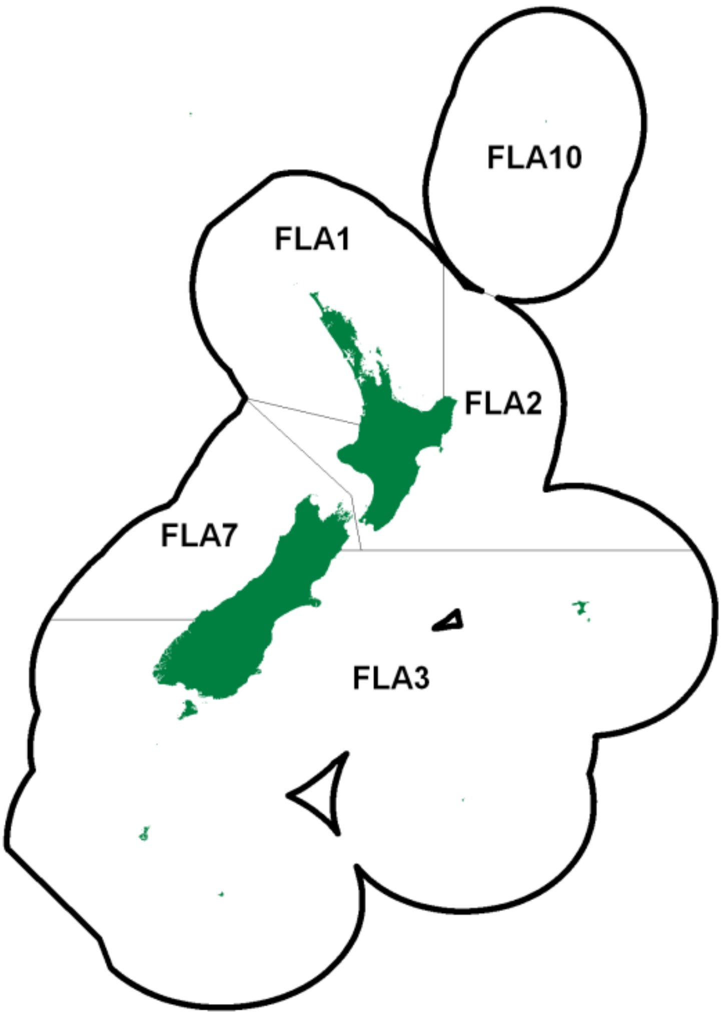


Figure 1: Map of FLA QMAs.

1. INTRODUCTION

This document describes work conducted under Specific Objectives 1, 2 and 3 of the Ministry for Primary Industries (MPI) contract FLA2014-02.

Overall Objective:

1. To characterise flatfish fisheries and undertake CPUE analyses in FLA 3.

Specific Objectives:

1. To characterise the FLA 3 fisheries.
2. To analyse existing commercial catch and effort data to the end of 2013/14 fishing year and undertake CPUE standardisations for each stock.
3. Use the above information to update the CPUE analysis and core vessel set used in the in-season increase model.

This project builds on a previous project: "*Bentley, N (2010). An examination of in-season increases in the total allowable catch for flatfish in FLA 3*", which was work presented to the Southern Inshore Fishery Assessment Working Group in 2010, with data current up to 2008–09. This project presents data current up to 2013–14, This report summarises fishery and landings characterisations for FLA 3, as well as presenting four CPUE standardisations derived from trawl data originating from FLA 3. Because FLA 3 is a composite of at least 18 species, an attempt has been made to separate out the catches of the three most important species in order to estimate separate CPUE series for each of these species as well as a composite FLA 3 analysis. This work is part of the Fisheries New Zealand schedule for "Tier 2" stocks: stocks which are monitored through periodic reviews of indices generated through accepted CPUE standardisations, rather than through formal stock assessments.

Abbreviations and definitions of terms used in this report are presented in Appendix A. A map showing the FLA Fisheries New Zealand QMAs is presented in Figure 1. Appendix B presents the Fisheries New Zealand FMAs in the context of the contributing statistical reporting areas.

2. INFORMATION ABOUT THE STOCK/FISHERY

2.1 Catches

The TACC for FLA in FLA 3 was set at 2430 t when this Fishstock was first put into the QMS in 1986, but increased by 9% through the process of quota appeals to 2682 t by 1992–93 (Figure 2; Table 1). The management intent at the time was to set a TACC which would not limit catches in the FLA 3 QMA (Figure 2; Table 1). Landings varied between about 1200 t and 2600 t between 1983–84 and 2006–07. However, this form of management for highly productive species was not without problems: the low value of FLA ITQ led to administrative abuses by some fishers and there were questions about the long-term conservation of some of the less productive components of the FLA species complex. A revised approach for the management of FLA 3 was introduced on 1 October 2007: the FLA 3 TACC was reduced by 47% to 1430 t and a management procedure that recommended an in-season increase in the TACC if supported by early CPUE data was implemented. This procedure is described in Section 4. All FLA fisheries have been put on Schedule 2 of the Fisheries Act 1996 which allows an increase in the Allowable Catch Entitlement (ACE) within a fishing season for specified "highly variable" stocks. The base TACC is not changed by this process because ACE expires at the end of each season. The FLA 3 management procedure (Section 4) is an implementation of this form of management.

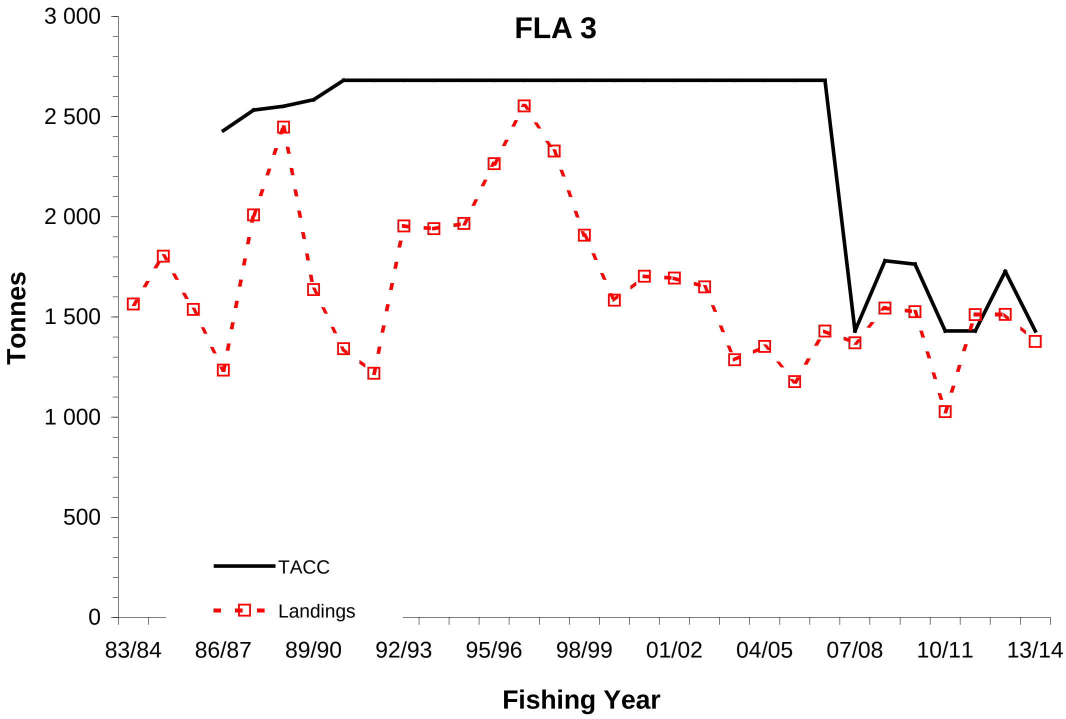


Figure 2: Plot of FLA 3 landings and TACCs from 1983–84 to 2013–14 (see Table 1 for list of landings and TACCs).

Table 1: Reported landings (t) and TACC (t) of flatfish in FLA 3 from 1983–84 to 2013–14 (Data sources: FSU [1983–84 to 1985–86]; QMR [1986–87 to 2000–01]; MHR [2001–02 to 2013–14].

Fishing Year	Landings	TACC	Fishing Year	Landings	TACC
1983–84	1 564	–	1999–00	1 583	2 682
1984–85	1 803	–	2000–01	1 703	2 682
1985–86	1 537	–	2001–02	1 693	2 682
1986–87	1 235	2 430	2002–03	1 650	2 682
1987–88	2 009	2 532	2003–04	1 286	2 682
1988–89	2 447	2 552	2004–05	1 353	2 682
1989–90	1 637	2 585	2005–06	1 177	2 682
1990–91	1 341	2 681	2006–07	1 429	2 682
1991–92	1 219	2 681	2007–08	1 371	1 430
1992–93	1 953	2 682	2008–09	1 544	**1 780
1993–94	1 941	2 682	2009–10	1 525	**1 763
1994–95	1 966	2 682	2010–11	1 027	1 430
1995–96	2 265	2 682	2011–12	1 511	1 430
1996–97	2 552	2 682	2012–13	1 512	**1 727
1997–98	2 328	2 682	2013–14	1 377	1 430
1998–99	1 907	2 682			

** Commercial catch allowance increased with additional 'in-season' ACE provided under S68 of FA1996

2.1.1 Recreational catches

Recreational catches in New Zealand are generally poorly known, and FLA 3 is no exception. 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, MPI 2015)

Table 2: Summary catch information for "Flounder/Sole/other flatfish" from the Large Scale Marine Survey (LSMS: Wynne-Jones et al. 2014). The 'number fishers' and 'number events' categories are the survey sample size from table 28 in Wynne-Jones et al (2014).

Category	Value	FMA	Value	Capture method	Value	Capture platform	Value
Number fishers	138	1	30 105	Rod/line	711	Trailer boat	30 581
Number events	319	2	4 520	Longline	198	Launch	130
Catch (numbers)	143 619	3	34 773	Net	90 193	Yacht	0
CV (numbers)	0.21	5	18 702	Pot	0	Large yacht	3 685
MeanWgt (kg)[1]	0.40	7	12 259	Dredge	0	Kayak	9 761
Catch (t)	58.92	8	8 365	Hand/shore	51 826	Shore	98 551
CV (catch)	0.21			Diving	0	Other	911
				Spear	691		
				Other	0		
		Total	143 618	Total	143 619	Total	143 619

[1] Estimated from 332 length measurements from unspecified species, with 311 from FLA 1 (Hartill & Davey 2015)

A large scale population-based diary/interview survey was conducted under contract for MPI from 1 October 2011 to 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 NZ-wide recreational "Flounder/Sole/other flatfish" catch to be on the order of 60 t or 144 000 fish (CV=0.21; Table 2), with 35 000 fish (14 t with mean weight=0.4 kg) caught in FLA 3. The reliability of this survey with respect to FLA 3 is unknown. The primary inference to be made from this survey is that the NZ-wide recreational catch of flatfish probably occurs throughout the country with the main locations of activity being FMA 1 and FMA 3.

2.2 Regulations Affecting the Fishery

The commercial minimum legal size for sand flounder is 23 cm, and for all other flatfish species is 25 cm.

From 1 October 2008, a suite of regulations intended to protect Maui's and Hector's dolphins was implemented for all of New Zealand by the Minister of Fisheries. Commercial and recreational set netting was banned in most areas to 4 nautical miles offshore of the east coast of the South Island, extending from Cape Jackson in the Marlborough Sounds to Slope Point in the Catlins. Some exceptions were allowed, including an exemption for commercial and recreational set netting to only one nautical mile offshore around the Kaikoura Canyon, and permitting setnetting in most harbours, estuaries, river mouths, lagoons and inlets except for the Avon-Heathcote Estuary, Lyttelton Harbour, Akaroa Harbour and Timaru Harbour. In addition, trawl gear within 2 nautical miles of shore was restricted to flatfish nets with defined low headline heights.

2.3 Methods used for 2015 analysis of catch and effort data

2.3.1 Obtaining data extracts

Two data extracts were obtained from the Fisheries New Zealand Warehou database (replog 9854) (Ministry of Fisheries 2010), received 03 February 2015. One extract consisted of the complete data set (all fishing event information along with all flatfish landing information) from every trip which recorded landing flatfish in FLA 3, starting from 1 October 1989 and extending to 30 September 2014. A further extract was obtained consisting of all trips which fished in at least one of the valid statistical areas for FLA 3 (018–032, 049–052) using the method BT (bottom trawl), and which excluded the following list of deepwater target species: 'ORH', 'OEO', 'SOE', 'SOR', 'SSO', 'BOE', 'WOE', 'CDL', 'BYX', 'HOK', 'SBW', 'SCI', 'SQU', 'HAK'. Once these trips were identified, all fishing event data and flatfish landing data from the entire trip, regardless of method of capture (or the target species), were obtained. The first data extract was used to characterise and understand the fisheries taking flatfish in FLA 3. These characterisations are reported in Sections 2.4 and 2.5, plus detailed summary tables with greater spatial resolution in Appendix E. The BT extract was used to calculate standardised CPUE series (Section 3).

2.3.2 Preparation of data extracts

Data for the characterisation study 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 is documented in Appendix C, with 4130 t of landings removed from 79 trips which resulted in very close correspondence to the QMR/MHR landing data (see Table C.2 and Figure C.1). The procedures used to prepare the effort data are documented in Starr (2007).

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. The data were amalgamated into a common level of stratification known as a "trip stratum" (see table of definitions: Appendix A) for the characterisation part of this report. 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 flatfish by trip were allocated to the "trip strata" in proportion to the estimated flatfish catches in each "trip stratum". In situations when trips recorded landings of flatfish 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 flatfish landings were allocated proportionally to effort (tows for trawl data and length of net set for setnet data) in each "trip stratum". Trips which fished within an ambiguous statistical area and landed to multiple FLA QMAs were dropped entirely from the characterisation data set. This "Fishstock" expansion is done to maintain the integrity of the data to characterise a specific QMA. This procedure resulted in the loss of just over 1% of the landings in the data set, indicating that vessels landing to FLA 3 are not likely to have landed to other FLA QMAs. This loss was considered acceptable for the characterisation data set, which focuses on the data from only FLA 3.

Fishers and processors are required to use a generic flatfish (FLA) code in the monthly harvest returns to report landed catches of flatfish species as well as in the landings section of the catch and effort forms. Although fishers are now instructed to use specific species codes when reporting estimated catches, they often use the generic FLA code. In other instances, they incorrectly record landings using non-FLA codes (which potentially results in double counting) (see Table C.1). Species that are important contributors to catch in FLA 3 are : ESO, LSO, SFL, BFL, BRI (see Table A.3 for explanation of codes).

Catch totals in the fishery characterisation tables have been scaled to the QMR/MHR totals reported in Table 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*.

2.3.2.1 Characteristics and summary information from data extracts

The annual totals at different stages of the data preparation procedure are presented in Table 3 and Figure 3. Total landings in the data set are very close to the landings in the QMR/MHR system, except for a 10% shortfall in landings in the first year of data (1989–90: see Table 3). Landings by year in the subsequent fishing years vary from –3% to +2% relative to the QMR/MHR annual totals (Table 3). The shortfall between landed and estimated catch by trip varies from –17% to –11% by fishing year and has averaged at -13% over the most recent 10 years (Table 3). 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 a long tail of ratios greater than 1.0, a mode and median slightly above 1.0 and a mean near 1.3 (Figure 4 [right panel]).

For the FLA 3 dataset across all years, 15% of all trips which landed flatfish estimated no catch of flatfish but reported FLA in the landings (Table 4). This occurred 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 TCER forms in 2007–08). These landings represented 3% of the total FLA 3 landings over the period, for a total of 1 336 tonnes (Table 4). The introduction of the new inshore trawling form (TCER), which records fishing activity at the level of a fishing event (or tow) and reports more species, has dropped the proportion of trips which estimated nil flatfish while landing these species, and has reduced the proportion of FLA landings in this category, which now account for less than 1% of the FLA 3 landings since the introduction of the new forms (Table 4).

Table 3: Comparison of the total FLA 3 QMR/MHR catch (t), reported by fishing year, with the sum of the landed catch totals (bottom part of the CELR or CLR 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 9854: 1989–90 to 2013–14.

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	1 637	1 477	90	1 444	98	1 283	89
90/91	1 341	1 328	99	1 280	96	1 096	86
91/92	1 219	1 208	99	1 193	99	1 019	85
92/93	1 953	1 951	100	1 892	97	1 639	87
93/94	1 941	1 932	100	1 896	98	1 603	85
94/95	1 966	1 977	101	1 922	97	1 663	87
95/96	2 265	2 307	102	2 262	98	1 897	84
96/97	2 552	2 464	97	2 424	98	2 092	86
97/98	2 328	2 288	98	2 275	99	1 927	85
98/99	1 907	1 910	100	1 899	99	1 576	83
99/00	1 583	1 573	99	1 567	100	1 339	85
00/01	1 703	1 741	102	1 709	98	1 486	87
01/02	1 693	1 704	101	1 685	99	1 437	85
02/03	1 650	1 660	101	1 654	100	1 422	86
03/04	1 286	1 304	101	1 303	100	1 156	89
04/05	1 353	1 357	100	1 353	100	1 151	85
05/06	1 177	1 162	99	1 157	100	993	86
06/07	1 429	1 415	99	1 407	99	1 182	84
07/08	1 371	1 391	101	1 376	99	1 187	86
08/09	1 544	1 526	99	1 514	99	1 335	88
09/10	1 525	1 481	97	1 464	99	1 294	88
10/11	1 027	995	97	975	98	847	87
11/12	1 511	1 476	98	1 448	98	1 277	88
12/13	1 512	1 480	98	1 468	99	1 280	87
13/14	1 377	1 356	99	1 339	99	1 173	88
Total	40 850	40 465	99	39 905	99	34 356	86

[1] includes all FLA 3 landings in replog 9854 except for 79 trips (Table C.2) excluded for being "out of range" and 478 t of landings with no matching trip information in the effort data file.

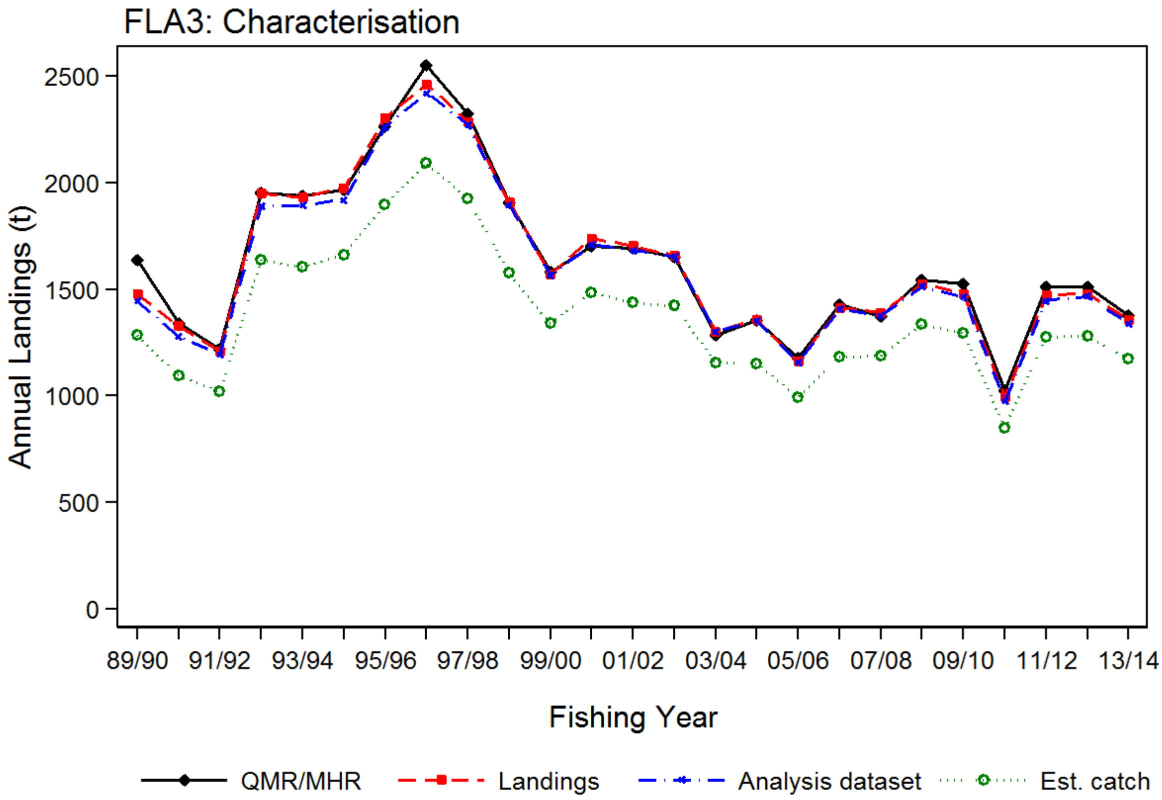


Figure 3: Plot of the FLA 3 catch dataset for totals presented in Table 3.

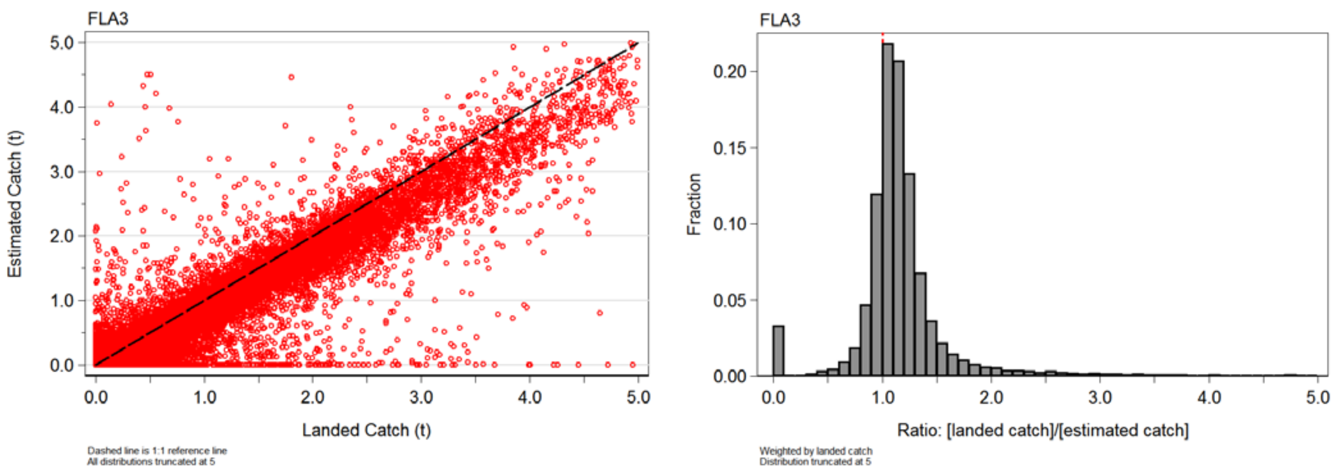


Figure 4: [left panel]: Scatter plot of the sum of landed and estimated flatfish catch for each trip in the FLA 3 analysis dataset. [right panel]: Distribution (weighted by the landed catch) of the ratio of landed to estimated catch per trip. Trips where the estimated catch=0 have been assigned a ratio=0.

Table 4: Summary statistics pertaining to the reporting of estimated catch from the FLA 3 analysis dataset.

Fishing year	Trips with landed catch but which report no estimated catch: Trips: % relative to total trips	Landings: % relative to total landings	Landings (t)	Statistics (excluding 0s) for the ratio of landed/estimated catch by trip: 5% quantile	Median	Mean	95% quantile
89/90	12	3	41	0.60	1.07	1.17	1.80
90/91	12	3	35	0.69	1.09	1.21	1.83
91/92	17	4	45	0.65	1.10	1.35	2.28
92/93	13	3	49	0.71	1.09	1.31	2.00
93/94	16	3	58	0.70	1.08	1.30	2.13
94/95	15	3	52	0.67	1.09	1.33	2.08
95/96	14	4	83	0.70	1.10	1.25	2.00
96/97	16	5	130	0.66	1.09	1.25	1.88
97/98	17	7	156	0.61	1.08	1.22	1.88
98/99	19	9	166	0.59	1.05	1.19	1.93
99/00	20	7	110	0.57	1.07	1.19	1.84
00/01	20	3	54	0.56	1.07	1.20	1.98
01/02	19	3	51	0.67	1.09	1.23	1.93
02/03	17	3	57	0.66	1.09	1.28	2.10
03/04	16	3	43	0.61	1.10	1.28	2.35
04/05	15	4	49	0.64	1.10	1.32	2.32
05/06	20	4	43	0.52	1.10	1.60	2.38
06/07	20	3	40	0.57	1.10	1.32	2.45
07/08	11	1	9	0.52	1.10	1.35	2.20
08/09	10	1	10	0.56	1.09	1.26	2.23
09/10	9	1	9	0.60	1.10	1.29	2.35
10/11	11	1	11	0.50	1.10	1.41	3.08
11/12	11	1	10	0.61	1.12	1.61	2.73
12/13	11	1	14	0.51	1.12	1.33	2.42
13/14	10	1	10	0.58	1.14	1.42	2.20
Total	15	3	1 336	0.63	1.09	1.29	2.10

2.3.3 “*Daily effort stratum*” data preparation procedure

Data used for CPUE analysis were prepared using the “*daily effort stratum*” (Appendix A) procedure proposed by Langley (2014). As noted above, catch/effort data must be summarised to a common level of stratification in order to construct a time series of CPUE indices that spans the change in reporting forms instituted in the late 2000s. Although the “trip-stratum” procedure proposed by Starr (2007) addresses the nominal instructions provided to fishers using the daily-effort CELR forms, Langley (2014) showed that the actual realised stratification in the earlier form types was daily, with the fisher tending to report the “predominant” statistical area of capture and target species rather than explicitly following the instructions. He showed this by noting that the frequency of changes in statistical area of fishing or target species within a day of fishing was much higher for comparable tow-by-tow event-based forms than in the earlier daily forms. Consequently, we have adopted Langley’s (2014) recommendation to use the “daily-stratum” method for preparing data for CPUE analysis. The following steps were used to “rollup” the event-based data (tow-by-tow TCER forms or a single setnet set in the NCELR forms) to a “daily-stratum”:

- discard trips that used more than one method in the trip (except for rock lobster potting, cod potting and fyke nets where these methods were dropped) or used more than one form type;
- sum effort for each day of fishing in the trip;
- sum estimated catch for each day of fishing in the trip and only use the estimated catch from the top five species sorted by weight in descending order;

- calculate the modal statistical area and target species for each day of fishing, each weighted by the number of fishing events: these are the values assigned to the effort and estimated catch for that day of fishing;
- create a list of "most relevant" target species by summing the landings in the FLA 3 characterisation data set across all years to identify the main target fisheries which capture flatfish (Table 5). Target species greater than rank=20 were dropped because the total catches were small (less than 5 t when accumulated over 25 years of data) and the species recorded seemed less probable to have caught flatfish (Table 5). This list was used to screen daily effort by discarding entire trips which reported target species that were not in this list. This was done because the effort from the discarded species was not relevant nor necessary to include in the flatfish CPUE analysis. The decision to discard the entire trip rather than just discarding the effort with the non-relevant target species was made because analysis (non-reported) showed that there was potential for bias when linking flatfish landings by trip with the remaining partial trip, leading to the conclusion that it is safer to drop the entire trip;
- distribute landings proportionately to each day of the trip based on the species estimated catch or to the daily effort when there is no species estimated catch.

Note that the above procedure was also applied to the daily effort (CELR) forms used before 2007–08 to ensure that each of these trips was also reduced to "daily strata" in the situations where fishers would report more than one statistical area or target species in a day of fishing. All species specific codes for flatfish species in the target species field (listed in Table A.3) were converted to FLA for the purposes of this screening.

Table 5: Table of target species fisheries which take FLA 3, summed over the period 1989–90 to 2013–14 based on the characterisation data set. Only the top 20 species were used in the BT CPUE analysis, with trips taking any of the remaining species dropped entirely. All codes in Table A.3 were converted to FLA for this table.

Rank	Target species	Common Name	Total FLA 3 landings (t)	% total landings
1	FLA	Flats	32 187.5	85.16
2	RCO	Red Cod	3 658.9	9.68
3	STA	Giant Stargazer	329.0	0.87
4	TAR	Tarakihi	320.1	0.85
5	BAR	Barracouta	313.7	0.83
6	ELE	Elephant Fish	287.6	0.76
7	GUR	Gurnard	274.8	0.73
8	SQU	Arrow Squid	90.3	0.24
9	SPO	Rig	89.0	0.24
10	WAR	Common Warehou	48.6	0.13
11	SPD	Spiny Dogfish	33.4	0.09
12	SPE	Sea Perch	24.6	0.06
13	SCH	School Shark	22.1	0.06
14	SKI	Gemfish	19.0	0.05
15	LIN	Ling	17.6	0.05
16	HOK	Hoki	14.5	0.04
17	BCO	Blue Cod	11.4	0.03
18	RSK	Rough Skate	10.6	0.03
19	HPB	Hapuku & Bass	5.6	0.01
20	SKA	Skate	5.1	0.01
21	LEA	Leatherjacket	4.8	0.01
22	SWA	Silver Warehou	4.1	0.01
23	SCI	Scampi	2.4	0.01
24	GSH	Ghost Shark	2.4	0.01
25	LDO	Lookdown Dory	2.3	0.01
26	SSK	Smooth Skate	2.0	0.01
27	PAD	Paddle Crab	1.9	0.01
28	YEM	Yellow-eyed Mullet	1.4	0.00

Rank	Target species	Common Name	Total FLA 3 landings (t)	% total landings
29	MOK	Moki	1.1	0.00
30	ROC	Rock Cod	1.0	0.00
31	CRA	Rock Lobster	0.8	0.00
32	RAT	Rattails	0.8	0.00
33	SFE	Short-finned Eel	0.8	0.00
34	HAK	Hake	0.7	0.00
35	ORH	Orange Roughy	0.7	0.00
36	BNS	Bluenose	0.6	0.00
37	OYS	Oysters Dredge	0.5	0.00
38	ALL		0.4	0.00
39	WWA	White Warehou	0.4	0.00
40	KAH	Kahawai	0.2	0.00
41	CRB	Crab	0.2	0.00
42	BEL	Bellowsfish	0.2	0.00
43	OEO	Oreos	0.2	0.00
44	SSO	Smooth Oreo	0.2	0.00
45	SPZ	Spotted Stargazer	0.2	0.00
46	JMA	Jack Mackerel	0.2	0.00
47	SNA	Snapper	0.2	0.00
48	BOE	Black Oreo	0.1	0.00
49	RLA	Resania lanceolata	0.1	0.00
50	BAT	Large Headed Slickhead	0.0	0.00

2.4 Description landing information for FLA 3

2.4.1 Destination codes in the FLA landing data

Landing data for flatfish were provided for every trip which landed FLA 3[1] at least once, with one record for every reported FLA landing from the trip. Each of these records contained a reported green weight (in kilograms), a code indicating the processed state of the landing, along with other auxiliary information such as the conversion factor used, the number of containers involved and the average weight of the containers. Every landing record also contained a “destination code” (Table 6), which indicated the category under which the landing occurred. The majority of landings were made using destination code “L” (landed to a Licensed Fish Receiver; Table 6). However, other codes (e.g., A, C or W; Table 6) 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 6) were not included because these landings would be reported at a later date under the “L” destination category, leading to potential for double counting. 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.

Some of the destination codes (notably “Q”, “R” and “T”) represent intermediate holding categories 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 possible, in these situations, 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 statutory catch reporting system because there is no existing requirement to maintain the integrity of catches from a trip. However, the use of these intermediate destination codes is very low in FLA 3 (less than 2% of the total “L” landings, Table 6), indicating that this is unlikely to be an issue in FLA 3.

[1] FMA 3 landings recorded as a flatfish species other than FLA 3 were treated as FLA 3 (see Table C.1).

Table 6: Destination codes in the unedited landing data received for the combined FLA 3 analysis dataset. The "how used" column indicates which destination codes were included in the characterisation analysis. This data summary has been restricted to FLA 3 over the period 1989–90 to 2013–14. Landing using the codes in the shaded cells were dropped.

Destination code	Number events	Greenweight (t)	Description	How used
L	188 660	44 814.6	Landed in NZ (to LFR)	Keep
W	2 537	60.7	Sold at wharf	Keep
E	1 355	49.3	Eaten	Keep
U	3 286	24.2	Bait used on board	Keep
F	1 071	8.1	Section 111 Recreational Catch	Keep
A	149	5.3	Accidental loss	Keep
J	22	0.8	Returned to sea [Section 72(5)(2)]	Keep
C	7	0.4	Disposed to Crown	Keep
H	1	0.1	Loss from holding pot	Keep
S	5	0.0	Seized by Crown	Keep
Q	3 847	404.0	Holding receptacle on land	Drop
R	3 527	352.5	Retained on board	Drop
D	4 336	319.6	Discarded (non-ITQ)	Drop
T	95	46.0	Transferred to another vessel	Drop
[NULL]	96	10.5	Missing	Drop
B	908	7.6	Bait stored for later use	Drop
P	6	0.1	Holding receptacle in water	Drop

Table 7: Total greenweight reported and number of events by state code in the landing file used to process the FLA 3 characterisation and CPUE data, arranged in descending landed weight. This data summary has been restricted to FLA 3 from 1989–90 to 2013–14.

State code	Number Events	Total reported greenweight (t)	Description
GUT	193 628	44 896.1	Gutted
GRE	13 948	892.3	Green (or whole)
HGU	828	139.9	Headed and gutted
MEA	451	60.4	Fish meal
[NULL]	62	54.2	Missing
GGO	287	28.0	Gilled and gutted tail-on
DRE	190	16.0	Dressed
FIL	384	11.0	Fillets: skin-on
Other	130	6.0	Other (misc)[1]

[1] includes (in descending order): Dressed-V cut (stargazer) Squid wings Surimi Fillets: skin-off Gilled and gutted tail-off Fillets: skin-off trimmed Fins Headed, gutted, and tailed.

2.4.2 State codes in the FLA landing data

Almost all (92%) of the valid landing data for FLA 3 were reported using state code GUT with most of the remaining landings using the state code GRE (7%, Table 7). The few remaining landings (about 1%) were spread out among HGT, MEA, GGO, DRE and FIL codes. There have been no changes in the conversion factors for the primary state code (GUT; GRE by definition has no conversion factor) used for processing FLA (Table 8).

Table 8: Median conversion factors for the five most important state codes (in terms of total landed greenweight) and the total reported greenweight by state code and by fishing year in the edited file used to process FLA 3 landing data. These data summaries are for FLA 3 over the period 1989–90 to 2013–14. '–': no observations.

Fishing	Landed State Code					
Year	GUT	GRE	HGU	MEA	GGO	Other
	Median Conversion Factor					
89/90	1.1	1	1.4	–	1.1	1.8
90/91	1.1	1	1.4	–	1.1	1.8
91/92	1.1	1	1.4	–	–	1.8
92/93	1.1	1	1.4	5.6	–	1.8
93/94	1.1	1	1.4	5.6	–	1.8
94/95	1.1	1	1.4	5.6	–	1.8
95/96	1.1	1	1.4	–	–	1.8
96/97	1.1	1	1.4	5.6	–	1.8
97/98	1.1	1	1.4	5.6	–	1.8
98/99	1.1	1	1.4	5.6	–	1.8
99/00	1.1	1	1.4	5.6	–	1.8
00/01	1.1	1	1.4	5.6	–	1.8
01/02	1.1	1	1.4	5.6	–	1.8
02/03	1.1	1	1.4	5.6	–	1.8
03/04	1.1	1	1.4	5.6	–	1.8
04/05	1.1	1	1.4	5.6	–	2.25
05/06	1.1	1	1.4	5.6	–	1.8
06/07	1.1	1	1.4	5.6	–	1.8
07/08	1.1	1	1.4	5.6	–	1.8
08/09	1.1	1	1.4	5.6	–	1.8
09/10	1.1	1	1.4	5.6	–	1.8
10/11	1.1	1	1.4	5.6	–	1.8
11/12	1.1	1	1.4	5.6	–	1.8
12/13	1.1	1	1.4	5.6	–	2.25
13/14	1.1	1	1.4	5.6	–	2.25
	Total Landings (t)					
89/90	1 443.4	35.1	8.1	–	11.8	0.1
90/91	1 315.3	9.6	10.1	–	1.5	1.3
91/92	1 206.2	9.5	6.0	–	0.2	2.8
92/93	1 930.9	16.2	27.1	0.0	–	1.6
93/94	1 905.7	19.6	13.7	0.0	–	4.2
94/95	1 935.6	42.9	8.8	0.0	–	4.6
95/96	2 286.5	39.9	5.4	–	7.5	5.5
96/97	2 446.3	33.0	10.2	0.0	2.7	4.0
97/98	2 283.8	18.1	1.8	0.0	0.0	0.8
98/99	1 899.4	26.6	1.4	0.5	2.7	3.4
99/00	1 576.3	7.4	0.2	0.8	0.1	1.0
00/01	1 679.5	66.6	0.2	0.4	1.5	2.1
01/02	1 656.8	50.8	0.1	1.0	0.0	1.9
02/03	1 651.5	7.1	0.3	4.0	–	1.6
03/04	1 265.5	8.2	0.9	36.9	–	1.2
04/05	1 340.2	29.0	0.1	3.6	–	0.6
05/06	1 152.4	18.6	0.1	3.1	–	1.3
06/07	1 413.7	10.6	0.6	1.9	–	0.3
07/08	1 398.1	9.9	0.1	1.7	–	0.4
08/09	1 519.4	26.6	0.1	3.4	–	0.4
09/10	1 489.0	20.7	0.9	0.9	–	0.4
10/11	995.6	17.9	0.0	2.9	–	0.1
11/12	1 491.4	14.5	0.1	4.8	–	0.3
12/13	1 477.9	38.9	0.1	3.7	–	0.0
13/14	1 354.5	12.6	0.6	3.8	–	0.1
Total	40 114.8	590.0	97.0	73.5	28.1	40.2

2.4.3 Form types used in the FLA 3 landing and effort data

Seventy-seven percent of the total FLA 3 landings have been reported on CELR forms over the 25 years of record, with the remaining landings recorded on the CLR form (23%) and the NCELR forms (0.6%) (Table 9). The proportion of landings reported on the CELR form dropped to less than 10% per year after the TCER form was introduced in 2007–08. The NCELR form is used exclusively to report setnet effort and landings while the TCER form reports the effort for bottom trawl, with both forms mandatory for vessels between 6 and 28 m in total length. The CLR form is used to report landings when forms other than the CELR and NCELR are used, which include the TCER and TCEPR trawl effort forms. There is some residual use of the CELR form after 2007–08 because there is an exemption from the NCELR and TCER form for vessels less than 6 m in length. The effort data (expressed as days fishing) also show a similar drop in the usage of the CELR, beginning from 2007–08 (Table 9) with a corresponding increase in the use of other form types.

Table 9: Distribution by form type for landed catch by weight for each fishing year in the combined FLA 3 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 FLA 3 dataset. See Appendix A for definitions of abbreviations used in this table.

	Landings			Days Fishing (%)[2]				Days Fishing				
	CELR	CLR	NCELR	CELR	TCEPR	TCER	NCELR	CELR	TCEPR	TCER	NCELR	Total
89/90	99	1.3	–	75	25	–	–	10 752	3 642	–	–	14 394
90/91	99	0.5	–	77	23	–	–	12 129	3 588	–	–	15 717
91/92	95	4.9	–	71	29	–	–	10 211	4 130	–	–	14 341
92/93	96	3.9	–	75	25	–	–	11 079	3 729	–	–	14 808
93/94	98	1.9	–	81	19	–	–	11 354	2 664	–	–	14 018
94/95	99	1.1	–	80	20	–	–	12 334	3 067	–	–	15 401
95/96	98	2.0	–	76	24	–	–	11 502	3 540	–	–	15 042
96/97	99	0.9	–	80	20	–	–	11 783	2 932	–	–	14 715
97/98	99	1.3	–	77	23	–	–	10 963	3 184	–	–	14 147
98/99	99	0.5	–	80	20	–	–	10 771	2 713	–	–	13 484
99/00	99	0.7	–	79	21	–	–	10 220	2 638	–	–	12 858
00/01	99	0.9	–	76	24	–	–	10 135	3 232	–	–	13 367
01/02	99	0.5	–	74	26	–	–	9 390	3 380	–	–	12 770
02/03	99	0.9	–	72	28	–	–	9 643	3 822	–	–	13 465
03/04	96	3.7	–	78	22	–	–	9 431	2 736	–	–	12 167
04/05	98	2.0	–	71	29	–	–	10 081	4 192	–	–	14 273
05/06	99	1.3	–	64	36	–	–	8 826	4 882	–	–	13 708
06/07	99	0.6	0.8	63	34	–	4	7 655	4 086	–	439	12 180
07/08	6	94	0.3	6	35	55	4	583	3 593	5 557	435	10 168
08/09	9	91	0.1	6	36	56	2	601	3 753	5 862	247	10 463
09/10	7	93	0.6	6	31	60	3	651	3 527	6 854	362	11 394
10/11	10	87	3.3	6	33	56	6	616	3 565	6 166	618	10 965
11/12	11	84	5.2	6	27	61	6	597	2 869	6 442	644	10 552
12/13	8	88	4.1	7	27	62	5	728	2 970	6 880	523	11 101
13/14	10	87	3.9	8	24	65	4	832	2 573	7 024	432	10 861
Total	77	23	0.6	59	26	14	1	192 867	85 007	44 785	3 700	326 359

[1] Percentages of landed greenweight
[2] Percentages of number of days fishing

2.4.4 Total landings

Total landings by QMA available in the data set are almost entirely from FLA 3, reflecting the wording of the data request and the small amount of fishing in other FLA QMAs when fishing in FLA 3 (Table 10).

Table 10: Distribution of total landings (t) by flatfish Fishstock and by fishing year for all trips that recorded FLA 3 landings in the edited landings data set. Seventy-nine landing records with improbable greenweights have been dropped (see Appendix C). Total FLA 3 landings in this table are greater than the total in Table 3 by 478.5 t. These landings are lost to the final analysis because there are no matching trip numbers in the effort data.

Fishing year	FLA 1	FLA 2	FLA 3	FLA 7	Total
89/90	0.6	0.4	1 498.5	5.6	1 505.0
90/91	0.4	1.1	1 337.9	9.4	1 348.8
91/92	0.2	1.8	1 224.7	3.7	1 230.5
92/93	0.2	8.4	1 975.8	29.0	2 013.5
93/94	0.1	9.0	1 943.4	17.9	1 970.3
94/95	1.0	6.2	1 991.9	30.2	2 029.4
95/96	2.2	34.3	2 344.8	16.0	2 397.3
96/97	0.6	3.0	2 496.3	16.4	2 516.3
97/98	2.5	20.3	2 304.5	12.7	2 339.9
98/99	0.7	6.1	1 934.0	18.5	1 959.3
99/00	2.4	6.5	1 585.7	11.1	1 605.7
00/01	0.7	11.9	1 750.3	12.7	1 775.5
01/02	0.4	4.7	1 710.7	13.5	1 729.2
02/03	1.5	3.3	1 664.5	20.1	1 689.3
03/04	0.9	9.5	1 312.5	20.9	1 343.8
04/05	3.1	6.7	1 373.5	11.4	1 394.8
05/06	0.6	7.6	1 175.5	22.1	1 205.9
06/07	1.0	5.0	1 427.1	28.4	1 461.5
07/08	0.1	4.9	1 410.2	24.3	1 439.5
08/09	0.4	1.8	1 549.9	34.0	1 586.0
09/10	0.4	5.8	1 512.0	33.1	1 551.2
10/11	7.9	4.4	1 016.6	20.3	1 049.2
11/12	0.4	1.9	1 511.1	23.5	1 536.9
12/13	0.7	2.4	1 520.6	18.6	1 542.3
13/14	1.4	2.9	1 371.5	12.7	1 388.6
Total	30.3	169.8	40 943.5	466.1	41 609.8

2.5 Description of the FLA 3 fisheries

2.5.1 Introduction

As discussed in Section 2.3, landings were matched with effort for every trip while maintaining the integrity of the QMA-specific information, a procedure that works well for FLA 3 because there are few trips which operate in shared statistical areas. Table 3 indicates that the loss of catch when using this procedure is less than 1%.

The landing information in the Warehou database for FLA is necessarily confined to the FLA species code (apart from data entry errors), given the legal requirements for reporting landings. However, MPI has encouraged fishers over the years to report their estimated catches using the actual species code for the catch, rather than using the generic FLA code. Unfortunately, this guidance is not mandatory, so reporting estimated catches using the actual FLA species is not done universally. Appendix D presents procedures by which trips and vessels that consistently report catches using a non-generic species code can be identified (these trips have been collectively designated as "*splitter*" trips). Appendix D also presents analyses that evaluate the "representativeness" of the "*splitter*" data subsets compared to the total FLA 3 data set. The species-specific presentations in the following tables and figures are based on the "*trip splitter*" algorithm (defined in Appendix D) because it was determined that this algorithm preserved the greatest amount of catch, was reasonably representative of the total reported FLA 3 catch and compared favourably with the diagnostics for the alternative vessel "*splitter*" algorithms proposed by Bentley (2010). Table 11 shows the relative importance of the component FLA 3 species, determined by the sum of the declared estimated catches in the "*trip splitter*" data set.

Table 11: List of FLA 3 flatfish species declared in the "*trip splitter*" data set (Appendix D), ranked in descending order of importance by summed estimated catch over the period 1990–91 to 2013–14.

Species code	Common name	Sum(estimated catch) (t)	Relative %	Rank
LSO	Lemon Sole	9 263.0	43.0	1
ESO	N.Z. Sole	6 626.1	30.7	2
SFL	Sand Flounder	2 818.9	13.1	3
BFL	Black Flounder	711.7	3.3	4
BRI	Brill	648.4	3.0	5
YBF	Yellow-belly Flounder	580.8	2.7	6
TUR	Turbot	315.3	1.5	7
GFL	Greenback Flounder	294.6	1.4	8
WIT	Witch	286.6	1.3	9
SOL	Sole	3.7	0.017	10
MAN	Finless Flounder	0.20	0.00093	11
SDF	Spotted Flounder	0.01	0.00005	12
BOT	Lefteyed Flounders	0.002	0.00001	13

The characterisation information in this section has been summarised by amalgamated statistical areas (Appendix B), with the offshore statistical areas in FMA 3 combined with the closest inshore areas. The addition of these offshore statistical areas should have very little impact on the distributions for the inshore statistical areas, given that the preferred depths for flatfish species are shallow (generally less than 100 m) and only small catches are assigned to the offshore statistical areas.

Reported statistical area	Statistical Area definition
018	018, 019
020	020, 021
022	022, 023
024	024, 301
026	026, 302, 303
025	025
030-032	030, 031, 032
027-029	027, 028, 029
Other	049–052, 401–412, 501–504, 601–625

2.5.2 Distribution of landings by method of capture

The distribution of landings by fishing method in FLA 3 is heavily weighted towards bottom trawl, with nearly 95% of all landings attributed to this capture method averaged over the 25 years of catch history (Table 12). Setnet fishing is a distant second with about 5% of the total landings. Similar percentages can be seen in the estimated catches in the "*trip splitter*" data set, with 94% of the estimated "*trip splitter*" FLA 3 catches attributed to BT over 25 years (Figure 5; Table 13). Most of the setnet catch is directed at SFL, which shows a greater percentage of setnet landings (about 11%) compared to near zero for the other two major species (LSO and ESO; Table 13).

Table 12: Distribution of fishing methods in tonnes and percentage for total FLA 3 landings, listed in descending order of importance, from 1989–90 to 2013–14. Tonnages sum to QMR/MHR totals (using Eq. 1). '–': no data.

Fishing				Method (t)					Method (%)
year	BT	SN	DS	OTH	Total	BT	SN	DS	OTH
89/90	1 611	25	–	–	1 637	98	1.5	–	–
90/91	1 053	288	–	–	1 341	79	21	–	–
91/92	1 188	31	0.05	–	1 219	97	2.5	0	–
92/93	1 949	5	–	–	1 953	100	0.2	–	–
93/94	1 929	12	–	–	1 941	99	0.6	–	–
94/95	1 865	101	–	–	1 966	95	5.1	–	–
95/96	2 123	141	–	0.012	2 265	94	6.2	–	0
96/97	2 431	122	–	0	2 552	95	4.8	–	0
97/98	2 317	11	–	–	2 328	100	0.5	–	–
98/99	1 888	19	–	–	1 907	99	1.0	–	–
99/00	1 505	79	–	–	1 583	95	5.0	–	–
00/01	1 624	78	–	–	1 703	95	4.6	–	–
01/02	1 532	161	–	–	1 693	90	10	–	–
02/03	1 590	47	13	0.1	1 650	96	2.8	0.8	0
03/04	1 166	98	22	0.5	1 286	91	7.7	1.7	0
04/05	1 142	172	37	1.5	1 353	84	13	2.8	0.1
05/06	1 062	74	41	1.2	1 177	90	6.3	3.5	0.1
06/07	1 311	79	38	0.9	1 429	92	5.5	2.7	0.1
07/08	1 330	5	36	0.01	1 371	97	0.4	2.7	0
08/09	1 500	7	37	–	1 544	97	0.5	2.4	–
09/10	1 437	53	36	–	1 525	94	3.4	2.4	–
10/11	902	102	24	–	1 027	88	10	2.3	–
11/12	1 307	140	64	–	1 511	87	9.2	4.2	–
12/13	1 359	106	45	1.4	1 512	90	7.0	3.0	0.1
13/14	1 223	119	35	0.05	1 377	89	8.7	2.5	0
Total	38 343	2 074	427	5.7	40 850	94	5.1	1.0	0.01

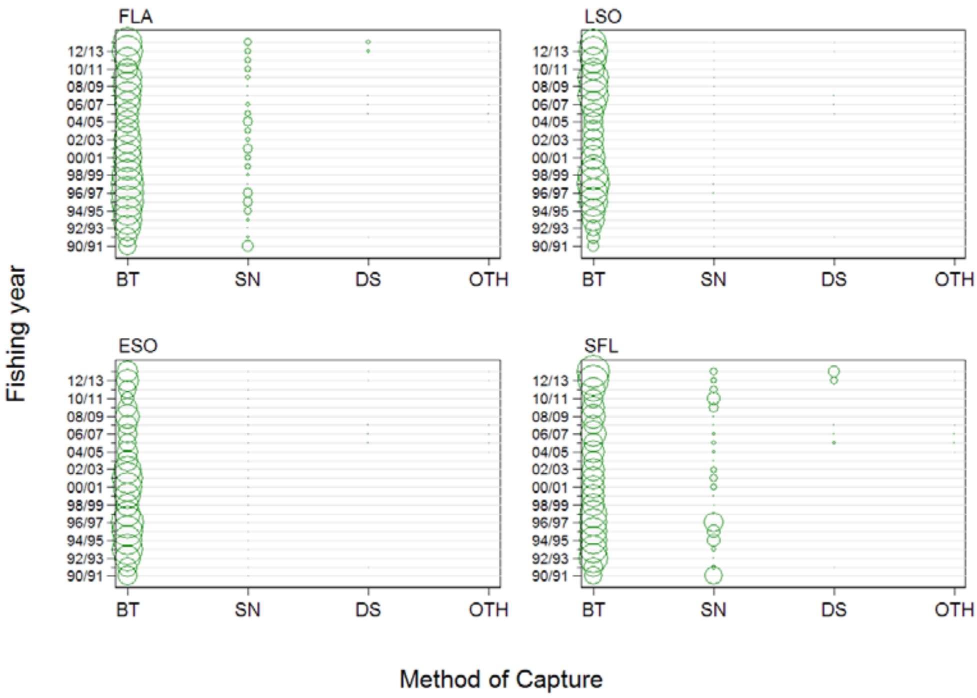


Figure 5: Distribution of estimated flatfish catch for the major fishing methods by fishing year and by species category from 1990–91 to 2013–14. Circles are proportional to the estimated catch totals by method and fishing year within each sub-graph: [FLA]: largest circle= 1194 t in 96/97 for BT; [LSO]: largest circle= 652 t in 97/98 for BT; [ESO]: largest circle= 473 t in 96/97 for BT; [SFL]: largest circle= 185 t in 13/14 for BT. Data for these plots are presented in Table E.1.

Table 13: Distribution (in percent) of estimated catches for total FLA and for the three top flatfish species (in terms of total estimated catch; see Table 11) across four categorical groupings. All estimated catches have been summed over the period 1990–91 to 2013–14.

Category	FLA	LSO	ESO	SFL
	Method of capture			
BT	94.4	99.9	99.9	88.1
SN	5.4	0.04	0.05	10.6
DS	0.2	0.04	0.1	1.2
OTH	0.01	0.002	0.003	0.04
	Statistical Area Group (BT only)			
018	0.3	0.1	0.5	0.1
020	10.1	1.4	13.6	23.8
022	11.2	1.6	16.8	27.2
024	19.2	22.7	18.8	11.6
026	35.8	53.0	28.4	12.7
025	8.7	14.4	3.8	3.4
030–032	14.0	6.1	17.4	21.0
027–029	0.6	0.7	0.7	0.1
Other	0.1	0.02	0.01	0.1
	Month (BT only)			
Oct	8.6	9.7	6.8	8.2
Nov	10.5	12.3	8.2	8.6
Dec	8.5	9.9	7.1	6.3
Jan	10.1	11.6	9.0	7.7
Feb	10.3	12.5	8.6	7.6
Mar	9.2	9.9	9.2	7.5
Apr	7.4	7.8	7.7	7.0
May	7.8	7.8	8.3	7.5
Jun	5.3	4.0	6.7	7.0
Jul	6.8	3.9	9.3	11.2
Aug	8.1	4.9	10.9	11.2
Sep	7.4	5.6	8.2	10.2
	Target species (BT only)			
FLA	90.6	93.1	90.2	88.9
RCO	5.8	3.2	7.7	8.5
STA	0.7	0.8	0.5	0.3
TAR	0.7	1.3	0.1	0.2
BAR	0.4	0.2	0.2	0.1
ELE	0.5	0.4	0.5	0.8
GUR	0.7	0.6	0.6	0.8
OTH	0.6	0.5	0.2	0.5

2.5.3 Distribution of landings by statistical area

About three-quarters of the total FLA 3 bottom trawl landings over 25 years have been taken south of Canterbury Bight (starting with Statistical Area 024: Figure 6, Table 14). This overall distribution is nearly the same in the “*trip splitter*” data set, which also shows that the species with the greatest southern tendency is LSO, where 97% of the total catch is taken south of Canterbury Bight (Table 13). Thirty-one percent of the overall ESO catches come from Canterbury Bight while 51% of the SFL catches have been taken from Areas 018, 020 and 022 (Table 13).

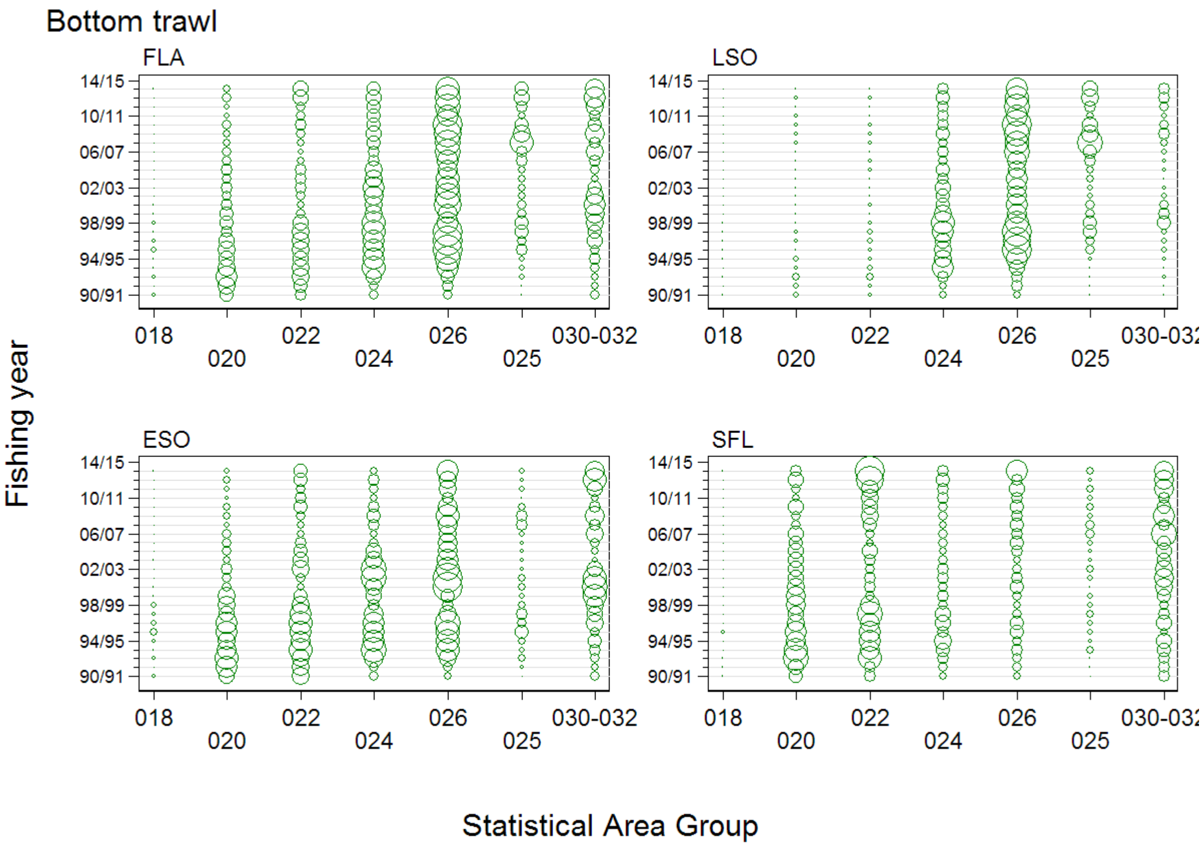


Figure 6: Distribution of bottom trawl estimated flatfish catch for Statistical Area Grouping by fishing year and by species category from 1990–91 to 2013–14. Circles are proportional to the estimated catch totals by method and fishing year within each sub-graph: [FLA]: largest circle= 473 t in 96/97 for 026; [LSO]: largest circle= 354 t in 09/10 for 026; [ESO]: largest circle= 159 t in 01/02 for 026; [SFL]: largest circle= 79 t in 13/14 for 022. Data for these plots are presented in Table E.2.

Table 14: Distribution of FLA 3 bottom trawl landings by Statistical Area Group in tonnes and percentage, listed from north to south, from 1989–90 to 2013–14. Tonnages sum to QMR/MHR totals (using Eq. 1). '–': no data; total annual bottom trawl landings available in Table 12.

Fishing year									Statistical Area Grouping
	018	020	022	024	026	025	030–032	027–029	Other
Distribution (t)									
89/90	27	441	295	262	419	28	135	1.9	3.3
90/91	23	256	297	191	157	23	105	1.2	0.1
91/92	11	329	238	219	207	66	116	0.7	1.3
92/93	19	467	386	467	320	122	160	6.9	0.7
93/94	12	401	353	558	348	82	174	1.1	0.6
94/95	12	330	365	443	478	70	161	4.6	0.8
95/96	52	411	424	384	587	133	106	25.7	1.0
96/97	32	367	503	430	703	157	219	19.9	0.3
97/98	20	245	512	485	585	266	180	21.3	2.8
98/99	12	262	370	400	381	190	251	21.6	0.6
99/00	6	291	210	242	343	98	277	37.4	0.7
00/01	5	250	162	257	498	114	317	17.2	1.9
01/02	13	175	135	301	510	88	294	12.1	3.2
02/03	14	282	231	320	490	66	180	2.9	4.9
03/04	7	208	199	218	407	60	61	1.5	4.1
04/05	13	183	243	201	328	62	102	2.9	6.3
05/06	3.9	118	142	111	426	120	128	3.8	8.2
06/07	2.9	118	86	114	540	151	294	1.8	4.0
07/08	0.4	71	89	125	468	438	130	3.1	4.2
08/09	0.1	79	149	159	555	216	333	3.4	6.0
09/10	0.4	115	143	145	656	150	222	2.1	3.6
10/11	0.4	60	140	134	344	49	162	3.5	8.0
11/12	0.4	70	156	138	484	157	294	1.4	7.8
12/13	0.3	88	185	145	419	163	347	4.2	7.7
13/14	3.6	80	205	104	390	148	280	5.3	7.3
Total	290	5 695	6 218	6 555	11 042	3 219	5 027	208	89
Distribution (%)									
89/90	1.65	27.4	18.3	16.3	26.0	1.7	8.4	0.12	0.21
90/91	2.21	24.3	28.2	18.1	14.9	2.2	10.0	0.11	0.005
91/92	0.92	27.7	20.0	18.5	17.4	5.6	9.7	0.06	0.11
92/93	0.96	24.0	19.8	24.0	16.4	6.3	8.2	0.36	0.03
93/94	0.62	20.8	18.3	28.9	18.0	4.3	9.0	0.05	0.03
94/95	0.67	17.7	19.6	23.7	25.6	3.8	8.6	0.24	0.04
95/96	2.45	19.4	20.0	18.1	27.7	6.3	5.0	1.21	0.05
96/97	1.31	15.1	20.7	17.7	28.9	6.5	9.0	0.82	0.01
97/98	0.84	10.6	22.1	20.9	25.3	11.5	7.8	0.92	0.12
98/99	0.63	13.9	19.6	21.2	20.2	10.1	13.3	1.15	0.03
99/00	0.40	19.3	14.0	16.1	22.8	6.5	18.4	2.49	0.05
00/01	0.34	15.4	10.0	15.8	30.7	7.0	19.5	1.06	0.12
01/02	0.88	11.4	8.8	19.7	33.3	5.8	19.2	0.79	0.21
02/03	0.87	17.7	14.5	20.1	30.8	4.1	11.3	0.18	0.31
03/04	0.58	17.9	17.1	18.7	34.9	5.1	5.2	0.13	0.36
04/05	1.10	16.0	21.3	17.6	28.7	5.4	9.0	0.25	0.56
05/06	0.37	11.1	13.4	10.5	40.1	11.3	12.1	0.36	0.78
06/07	0.22	9.0	6.6	8.7	41.2	11.5	22.4	0.14	0.30
07/08	0.03	5.3	6.7	9.4	35.2	33.0	9.8	0.23	0.31
08/09	0.01	5.2	10.0	10.6	37.0	14.4	22.2	0.23	0.40
09/10	0.03	8.0	10.0	10.1	45.7	10.4	15.4	0.15	0.25
10/11	0.05	6.7	15.5	14.9	38.2	5.4	18.0	0.39	0.89
11/12	0.03	5.3	11.9	10.5	37.0	12.0	22.5	0.11	0.60
12/13	0.02	6.5	13.6	10.6	30.8	12.0	25.5	0.31	0.57
13/14	0.29	6.5	16.8	8.5	31.9	12.1	22.9	0.44	0.60
Total	0.76	14.9	16.2	17.1	28.8	8.4	13.1	0.54	0.23

2.5.4 Seasonal distribution of landings

Overall FLA 3 landings by month tend to be stronger in the spring/summer months, with 8–10% of the summed landings coming in each month from October to March (Figure 7; Table 15). FLA 3 landings drop off somewhat in the winter, with only 5% of the overall landings coming from June and the remaining five autumn/winter months only accounting for about 7% /month (Table 15). The seasonal distribution of landings differs somewhat by species, with LSO showing a distribution even more strongly weighted towards the spring and summer months, while ESO is very evenly distributed throughout the year and fully one-third of the SFL catches coming from the last three months of the fishing year (Table 13).

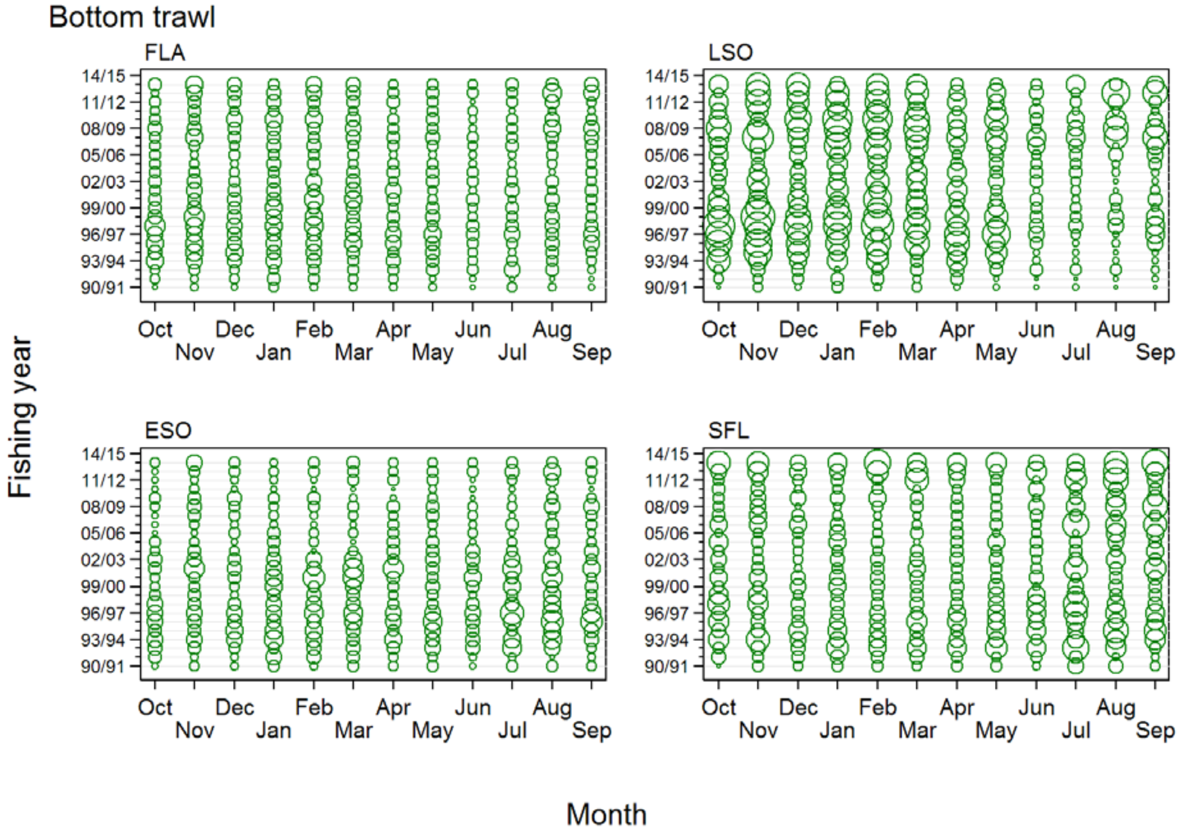


Figure 7: Distribution of monthly bottom trawl estimated flatfish catch by fishing year and by species category from 1990–91 to 2013–14. Circles are proportional to the estimated catch totals by method and fishing year within each sub-graph: [FLA]: largest circle= 173 t in 98/99 for Nov; [LSO]: largest circle= 114 t in 98/99 for Nov; [ESO]: largest circle= 68 t in 96/97 for Jul; [SFL]: largest circle= 26 t in 13/14 for Feb. Data for these plots are presented in Table E.3.

Table 15: Distribution of monthly FLA 3 bottom trawl landings in tonnes and in percentage from 1989–90 to 2013–14. Tonnages sum to QMR/MHR totals (using Eq. 1). '–': no data; total annual bottom trawl landings available in Table 12.

Fishing												Month
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Distribution (t)											
89/90	102	200	169	229	225	155	103	98	72	99	82	78
90/91	102	133	75	109	85	78	79	89	44	111	76	73
91/92	126	102	107	166	138	111	104	73	73	50	45	94
92/93	138	181	147	169	191	170	148	197	125	227	151	105
93/94	220	239	179	224	211	112	167	137	92	131	115	102
94/95	176	226	203	200	179	130	123	194	93	68	153	120
95/96	198	209	169	190	204	198	189	200	126	117	130	193
96/97	249	217	206	187	180	212	231	270	167	198	147	167
97/98	279	233	249	249	288	208	119	119	137	160	126	150
98/99	157	283	132	201	192	136	136	158	81	111	154	148
99/00	139	156	136	209	131	149	86	141	62	128	83	85
00/01	137	125	149	156	255	196	117	87	103	61	143	95
01/02	105	176	124	166	119	181	156	80	89	125	79	133
02/03	145	171	124	180	210	192	83	143	89	85	102	66
03/04	128	118	92	102	97	123	116	86	90	81	47	86
04/05	111	96	63	171	126	69	95	112	55	74	93	78
05/06	100	88	116	113	116	96	76	71	53	49	96	88
06/07	89	106	92	156	159	127	91	97	74	111	97	112
07/08	78	186	115	119	92	122	106	109	83	81	96	143
08/09	117	167	123	144	112	147	107	90	61	75	196	160
09/10	99	93	175	193	189	113	82	127	51	82	141	90
10/11	88	125	83	74	85	76	44	87	75	53	60	51
11/12	79	121	124	130	122	117	106	89	34	118	164	103
12/13	67	173	116	104	138	127	72	87	76	73	187	139
13/14	106	173	115	67	138	113	68	76	57	95	88	127
Total	3 336	4 098	3 384	4 007	3 981	3 459	2 803	3 017	2 064	2 559	2 850	2 786
	Distribution (%)											
89/90	6.3	12.4	10.5	14.2	14.0	9.6	6.4	6.1	4.5	6.1	5.1	4.8
90/91	9.7	12.7	7.2	10.3	8.0	7.4	7.5	8.5	4.2	10.5	7.2	7.0
91/92	10.6	8.5	9.0	14.0	11.6	9.4	8.7	6.1	6.2	4.2	3.7	7.9
92/93	7.1	9.3	7.5	8.7	9.8	8.7	7.6	10.1	6.4	11.6	7.7	5.4
93/94	11.4	12.4	9.3	11.6	11.0	5.8	8.7	7.1	4.8	6.8	6.0	5.3
94/95	9.4	12.1	10.9	10.7	9.6	7.0	6.6	10.4	5.0	3.6	8.2	6.4
95/96	9.3	9.9	8.0	8.9	9.6	9.3	8.9	9.4	6.0	5.5	6.1	9.1
96/97	10.3	8.9	8.5	7.7	7.4	8.7	9.5	11.1	6.9	8.1	6.0	6.9
97/98	12.0	10.1	10.8	10.7	12.4	9.0	5.1	5.1	5.9	6.9	5.5	6.5
98/99	8.3	15.0	7.0	10.6	10.1	7.2	7.2	8.4	4.3	5.9	8.2	7.8
99/00	9.2	10.3	9.0	13.9	8.7	9.9	5.7	9.4	4.1	8.5	5.5	5.6
00/01	8.5	7.7	9.2	9.6	15.7	12.1	7.2	5.3	6.3	3.7	8.8	5.9
01/02	6.8	11.5	8.1	10.8	7.7	11.8	10.2	5.2	5.8	8.1	5.2	8.7
02/03	9.1	10.8	7.8	11.3	13.2	12.1	5.2	9.0	5.6	5.3	6.4	4.2
03/04	11.0	10.1	7.9	8.7	8.3	10.5	10.0	7.4	7.7	6.9	4.0	7.4
04/05	9.7	8.4	5.5	15.0	11.0	6.0	8.3	9.8	4.8	6.5	8.1	6.8
05/06	9.4	8.3	10.9	10.6	10.9	9.0	7.2	6.7	5.0	4.6	9.1	8.3
06/07	6.8	8.1	7.0	11.9	12.1	9.7	6.9	7.4	5.6	8.4	7.4	8.6
07/08	5.9	14.0	8.6	8.9	6.9	9.2	7.9	8.2	6.3	6.1	7.2	10.8
08/09	7.8	11.2	8.2	9.6	7.5	9.8	7.1	6.0	4.1	5.0	13.1	10.7
09/10	6.9	6.5	12.2	13.5	13.1	7.9	5.7	8.9	3.6	5.7	9.8	6.3
10/11	9.7	13.9	9.2	8.2	9.5	8.4	4.8	9.7	8.3	5.9	6.7	5.7
11/12	6.0	9.3	9.5	9.9	9.3	9.0	8.1	6.8	2.6	9.1	12.6	7.8
12/13	4.9	12.7	8.6	7.6	10.1	9.4	5.3	6.4	5.6	5.3	13.7	10.2
13/14	8.7	14.1	9.4	5.5	11.2	9.2	5.6	6.2	4.7	7.7	7.2	10.4
Total	8.7	10.7	8.8	10.4	10.4	9.0	7.3	7.9	5.4	6.7	7.4	7.3

2.5.5 Distribution of landings by declared target species

The bottom trawl fishery for FLA 3 is almost entirely targeted at FLA[2], with 85% of the overall landings targeted at generic FLA (Figure 8; Table 16). The target species which has the greatest amount of FLA by-catch is RCO, which takes 10% of the overall landings, but these landings were concentrated in the mid-1990s when the RCO abundance was much greater than it is now (Figure 8; Table 16). The "*trip splitter*" data set shows a higher percentage of FLA targeting than the total landings data set, with 91% of the estimated catches targeted at FLA (Table 13). FLA targeting is slightly greater for LSO (93%), similar for ESO (90%) and slightly lower for SFL (88%) (Table 13). All three species show greater levels of RCO by-catch in the mid-1990s (Figure 8).

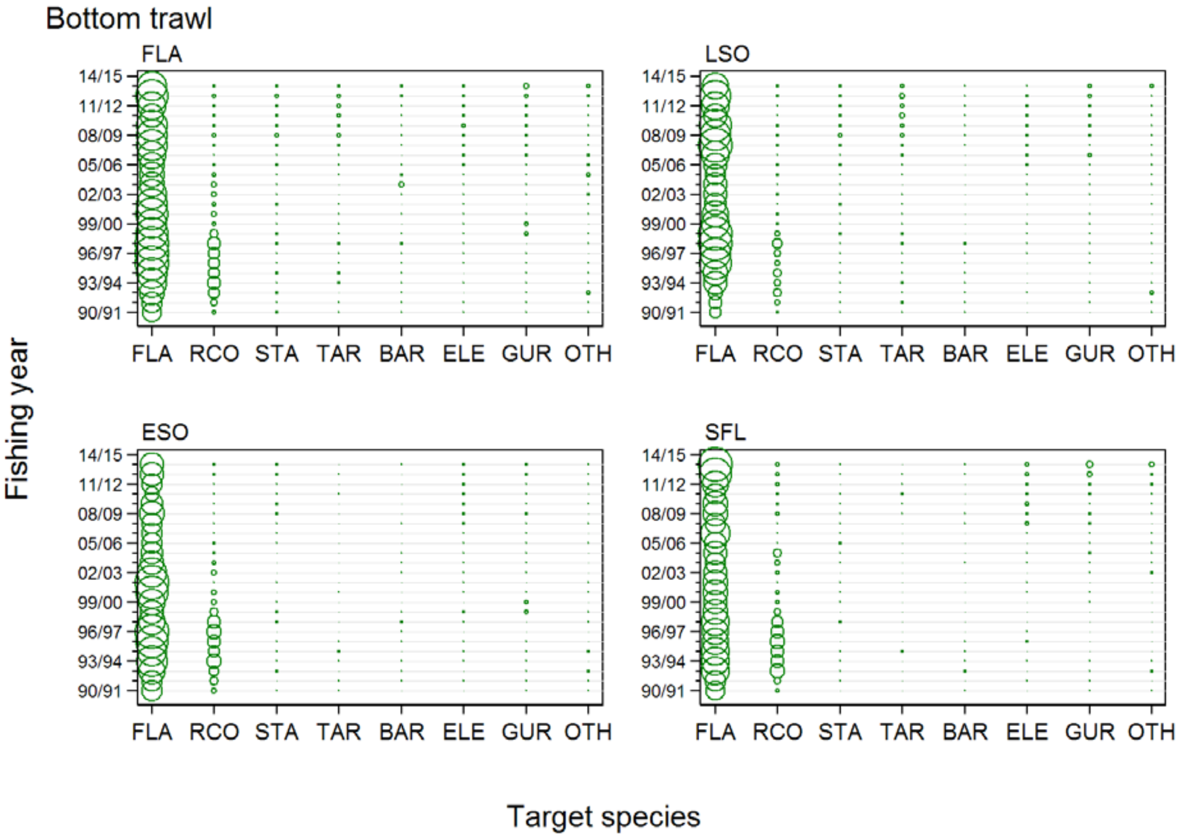


Figure 8: Distribution of bottom trawl estimated flatfish catch for declared target species by fishing year and by species category from 1990–91 to 2013–14. Circles are proportional to the estimated catch totals by method and fishing year within each sub-graph: [FLA]: largest circle= 1051 t in 96/97 for FLA[2]; [LSO]: largest circle= 580 t in 97/98 for FLA[2]; [ESO]: largest circle= 424 t in 01/02 for FLA[2]; [SFL]: largest circle= 167 t in 13/14 for FLA[2]. Data for these plots are presented in Table E.4.

[2] All species specific codes for flatfish species in the target species field (listed in Table A.3) were converted to FLA.

Table 16: Distribution of FLA 3 bottom trawl landings by declared target species in tonnes and in percentage from 1989–90 to 2013–14. Tonnages sum to QMR/MHR totals (using Eq. 1). '–': no data; total annual bottom trawl landings available in Table 12.

Fishing								Target species
year	FLA[3]	RCO	STA	TAR	BAR	ELE	GUR	OTH
Distribution (t)								
89/90	1 389	129	10	10	23	12	23	15
90/91	887	95	15	10	15	3.6	19	9.4
91/92	966	168	13	15	10	5.0	2.3	7.4
92/93	1 552	318	19	5	21	4.0	5.6	24
93/94	1 494	371	20	13	8.8	6.1	5.9	10
94/95	1 416	381	15	17	12	4.3	5.4	13
95/96	1 671	374	10	17	19	8.9	13	10
96/97	1 947	431	9	17	13	3.4	4.1	6.4
97/98	1 802	447	12	13	30	2.5	3.8	8.0
98/99	1 604	211	13	8.7	21	3.8	15	12
99/00	1 341	114	10	8.0	11	2.0	13	6.1
00/01	1 399	165	12	5.3	16	1.9	7.3	17
01/02	1 397	89	12	5.5	7.2	3.3	7.0	11
02/03	1 413	117	5.7	4.6	19	8.2	10	12
03/04	993	100	4.6	5.9	35	13	4.0	10
04/05	972	86	9.5	10	17	15	11	22
05/06	930	49	23	8.5	4.2	19	10	18
06/07	1 178	43	20	14	5.4	19	18	13
07/08	1 229	27	12	15	5.3	20	8.5	14
08/09	1 348	37	27	23	9.0	26	13	17
09/10	1 298	28	27	20	4.5	32	11	17
10/11	779	13	21	30	5.0	21	10	22
11/12	1 184	11	26	20	4.7	23	15	24
12/13	1 232	16	16	21	8.2	19	23	24
13/14	1 052	21	21	23	7.3	22	35	42
Total	32 474	3 841	382	339	333	298	292	384
Distribution (%)								
89/90	86.2	8.0	0.7	0.6	1.4	0.8	1.4	0.9
90/91	84.2	9.0	1.4	0.9	1.4	0.3	1.8	0.9
91/92	81.3	14.2	1.1	1.3	0.9	0.4	0.2	0.6
92/93	79.6	16.3	1.0	0.3	1.1	0.2	0.3	1.3
93/94	77.5	19.2	1.0	0.7	0.5	0.3	0.3	0.5
94/95	76.0	20.4	0.8	0.9	0.7	0.2	0.3	0.7
95/96	78.7	17.6	0.5	0.8	0.9	0.4	0.6	0.5
96/97	80.1	17.7	0.4	0.7	0.6	0.1	0.2	0.3
97/98	77.7	19.3	0.5	0.5	1.3	0.1	0.2	0.3
98/99	85.0	11.2	0.7	0.5	1.1	0.2	0.8	0.6
99/00	89.1	7.6	0.7	0.5	0.7	0.1	0.9	0.4
00/01	86.2	10.2	0.7	0.3	1.0	0.1	0.5	1.0
01/02	91.2	5.8	0.8	0.4	0.5	0.2	0.5	0.7
02/03	88.9	7.4	0.4	0.3	1.2	0.5	0.6	0.7
03/04	85.2	8.6	0.4	0.5	3.0	1.1	0.3	0.8
04/05	85.1	7.5	0.8	0.8	1.5	1.3	0.9	1.9
05/06	87.6	4.6	2.2	0.8	0.4	1.8	0.9	1.7
06/07	89.9	3.3	1.5	1.1	0.4	1.5	1.3	1.0
07/08	92.4	2.0	0.9	1.1	0.4	1.5	0.6	1.0
08/09	89.9	2.5	1.8	1.5	0.6	1.7	0.9	1.1
09/10	90.3	1.9	1.9	1.4	0.3	2.3	0.8	1.1
10/11	86.4	1.4	2.4	3.4	0.6	2.4	1.1	2.4
11/12	90.5	0.8	2.0	1.6	0.4	1.7	1.1	1.9
12/13	90.6	1.2	1.2	1.5	0.6	1.4	1.7	1.8
13/14	86.1	1.7	1.7	1.9	0.6	1.8	2.8	3.4
Total	84.7	10.0	1.0	0.9	0.9	0.8	0.8	1.0

[3] All species specific codes for flatfish species in the target species field (listed in Table A.3) were converted to FLA.

2.6 Fine scale distribution of estimated catches by species

The “*trip splitter*” data set (Appendix D) was used to provide fine scale gridded plots for each of the three most important flatfish species (Table 11) making up the FLA 3 species complex. These plots are provided in Appendix F.

2.6.1 LSO 3

Section F.1.1 reports the gridded spatial distribution of LSO landings by fishing year, from 2007–08 (Figure F.1) to 2013–14 (Figure F.7). These plots show the concentration of LSO catch starting at the northern boundary of Area 024 and extending continuously to the eastern end of Foveaux Strait. There seems to be little LSO taken in central Foveaux Strait, with catches resuming in the western part of Foveaux Strait and Te Wae Wae Bay. Some LSO catches come from the western side of Stewart Island. There is little annual variation in this distribution, with all seven years being very similar with the exception of more LSO catches coming from Canterbury Bight in 2012–13 and 2013–14.

2.6.2 ESO 3

Section F.2.1 reports the gridded spatial distribution of ESO landings by fishing year, from 2007–08 (Figure F.8) to 2013–14 (Figure F.14). These plots show concentrations of ESO catches above and below the Otago Peninsula, off the Catlins, in eastern Foveaux Strait, a hiatus in central Foveaux Strait, with catches resuming in the western part of Foveaux Strait and Te Wae Wae Bay. ESO are also taken off the northwestern coast of Stewart Island, in the southern part of Canterbury Bight, south of Banks Peninsula and in Pegasus Bay. There is little annual variation in this distribution of catch among years.

2.6.3 SFL 3

Section F.3.1 provides the gridded spatial distribution of SFL landings by fishing year, from 2007–08 (Figure F.15) to 2013–14 (Figure F.21). The catch distribution of SFL seems more concentrated than for either LSO or ESO, with pockets of catches distributed throughout the QMA. There is a strong recurring concentration in Te Wae Wae Bay, off the Catlins and north of the Otago Peninsula. Catches are also strong in Canterbury Bight, south of Banks Peninsula and in Pegasus Bay. SFL catches seem to wane in 2011–12 but resume strongly in 2012–13 and 2013–14.

2.7 Preferred bottom trawl fishing depths for flatfish by species

Depth information is available from TCEPR and TCER forms which report bottom trawl catches pertaining to flatfish (either recording an estimated catch of flatfish or declaring flatfish as the target species). These data come either from the TCER forms introduced from 1 October 2007 or the longstanding TCEPR forms, which are primarily used by the larger offshore vessels and have been in operation since the first year of data in this report (1989–90). Approximately 80% of the depth observations reported in Appendix G originate from the TCER forms, accumulated over seven years. The remaining 20% of the trawl returns are on the older TCEPR forms over the same seven year period, while less than 0.5% of the records use the CELR form. This predominance of TCER reports reflects the inshore nature of the flatfish 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 flatfish fishery.

The analyses reported in Appendix G have been prepared using trips selected by the “*trip splitters*” algorithm (Appendix D), which selects trips which report the catch of flatfish by species and which rejects trips which use the “FLA” code in the estimated catch records. All trips in the master data set were selected because they reported FLA 3 in the landings data. Only tow-by-tow TCER or TCEPR records are included, starting in October 2007, which was when the new TCER forms became mandatory. These plots are weighted by the associated estimated catch on each record, which represents a tow.

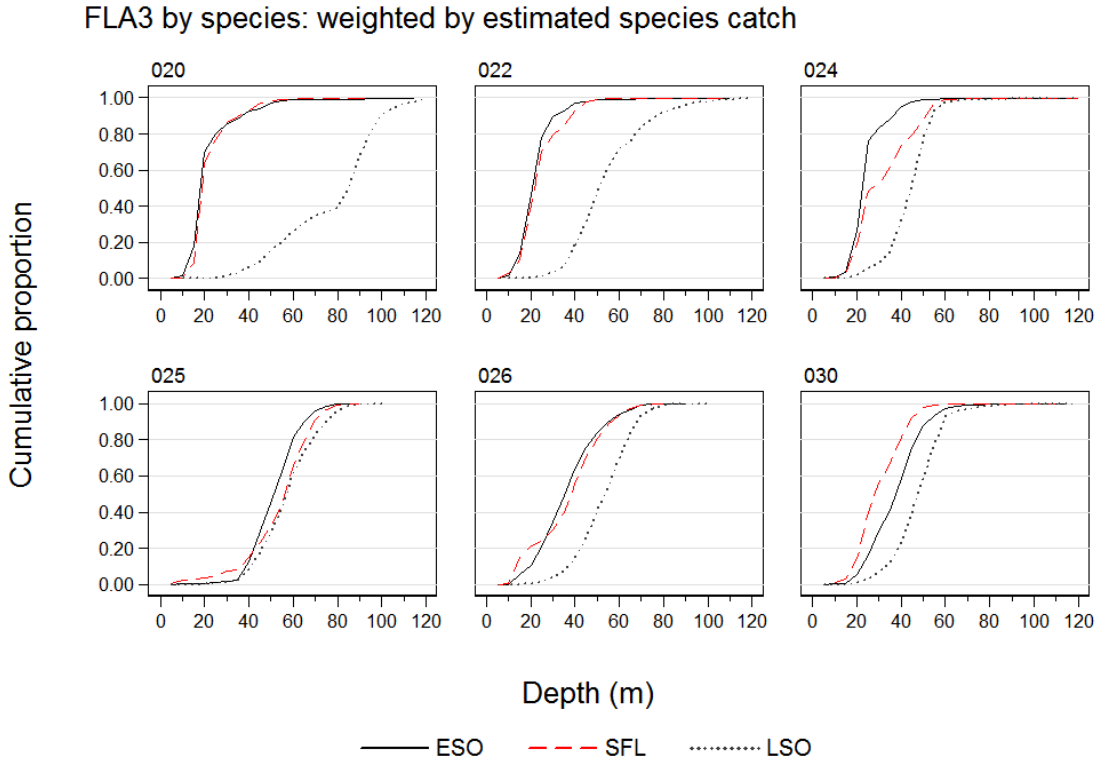


Figure 9: **Empirical cumulative depth profile for FLA 3 comparing the average bottom depth for each of three major flatfish species by statistical area over seven fishing years from 2007–08 to 2013–14.**

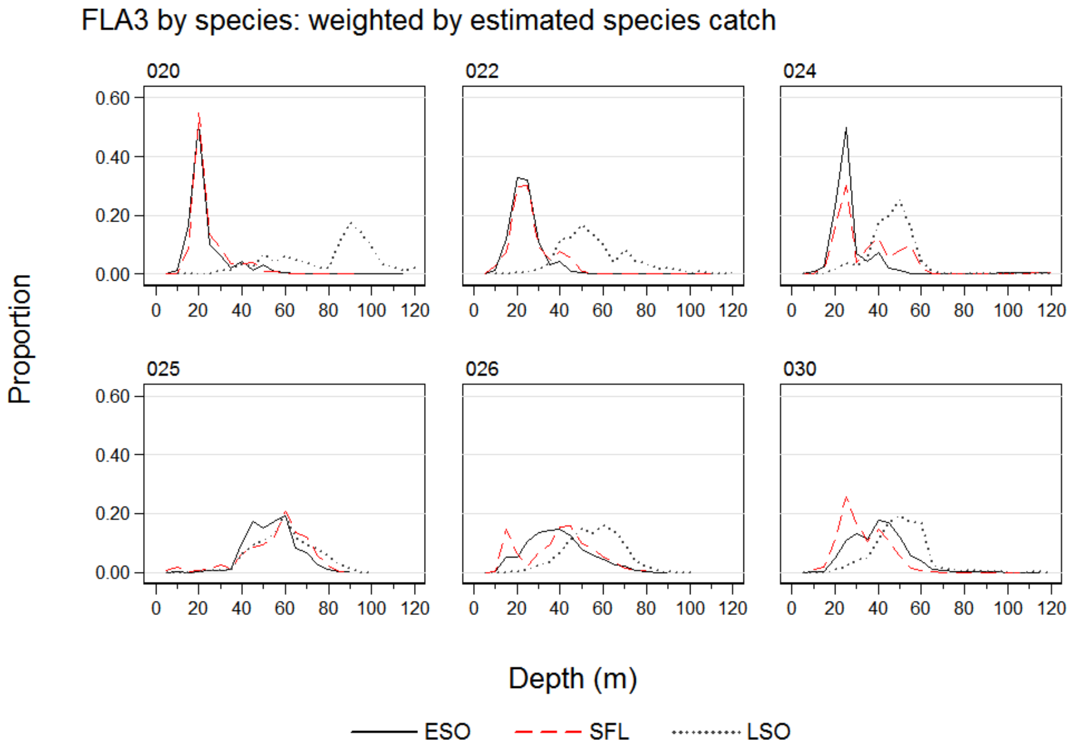


Figure 10: **Proportional depth distribution for FLA 3 comparing the average bottom depth for each of three major flatfish species by statistical area over seven fishing years from 2007–08 to 2013–14.**

Figure 9 shows the seven year average cumulative proportional bottom depth for each of the three main species, panelled for each statistical area. Figure 10 shows the average proportional distribution by depth for each of the three main species, again panelled by statistical area. ESO and SFL have nearly identical depth distributions for four ECSI statistical areas (020, 022, 024 and 026), while LSO is taken at much deeper depths. The two Foveaux Strait statistical areas (025 and 030) show different distributions, with SFL lying to the right of ESO in Area 025 and to the left of ESO in Area 030. LSO is the deepest species in all areas, but the difference is smaller in Areas 025 and 030. A possible explanation for the tendency to fish deeper in Areas 025 and 030 is the presence of foul ground in the shallows where the BCO potting fishery predominates.

Detailed plots showing the proportional distributions by depth over statistical area and fishing year for each of the three species are provided in Appendix G (LSO: G.1; ESO: G.2; SFL: G.3). These plots show some notable features, with LSO taken at much deeper depths in Area 020 (Pegasus Bay, Figure G.2), with the two earliest years (2007–08 and 2008–09) showing more shallow depth range than in later years (Figure G.3). For ESO, the depth range in the southern part of the South Island is deeper than for the northern ECSI, with Area 026 (Catlins) and Area 030 (western Foveaux Strait) showing similar depth profiles, while Area 025 (eastern Foveaux Strait) was much deeper (Figure G.5). ESO showed much less inter-annual variation among years than did LSO (Figure G.6). SFL had a similar depth profile in Area 025 as did ESO, with a mode near 60 m (Figure G.8). The other statistical areas were spread out, with the most shallow profile in Area 020 and with progressively SFL deeper depth profiles in the more southerly statistical areas (Figure G.8). There was considerable interannual variation in the SFL depth profiles in Area 024, Area 025 and Area 030 (Figure G.9).

3. STANDARDISED CPUE ANALYSIS

Standardised CPUE analyses have been prepared for the three principal FLA 3 species (New Zealand sole [ESO 3], Sand flounder [SFL 3] and Lemon sole [LSO 3]) as well as an aggregated flatfish catch series (FLA 3[TOT]). All four series are based on bottom trawl catch and effort data (Appendix H). These analyses updated similar analyses reviewed and accepted by the SINSWG in 2010 (Bentley 2010). The species-specific analyses were based on data derived from "*trip splitter*" trips (see Appendix D), defined as trips which landed FLA 3 but which did not use the FLA code in the estimated catch section of the catch/effort form. Alternative definitions of "*splitters*", based on vessel performance were also investigated (Appendix D), but CPUE trends were found to be similar to those derived from the "*trip splitter*" algorithm (see Figure D.3, Figure D.4 and Figure D.5). The latter procedure was preferred because it retained the greatest amount of catch, particularly in the early years of the series (see Figure D.2).

The CPUE data were prepared using the "*daily-effort stratum*" preparation method described in Section 2.3.3. This procedure was followed so that the event-based data forms that are presently being used in these fisheries can be matched with the earlier daily forms to create a continuous CPUE series. Each analysis was confined to a set of core vessels which had participated consistently in the fishery for a reasonably long period (ESO 3, LSO 3 and SFL 3: 5 trips for at least 5 years; FLA 3(TOT): 10 trips for at least 5 years). The explanatory variables offered to each model included fishing year (forced), month, vessel, statistical area, number tows and duration of fishing. A description of the model can be found in Section H.2.2 and the specifications for the four analyses are summarised in Table H.1.

3.1 FLA 3(TOT):

This analysis is defined from bottom trawl daily fishing events which fished in Statistical Areas 020, 022, 024, 026, 025, and 030 and which declared a target species from one of the 15 species codes in Table A.3. It was accepted for monitoring FLA 3 by the SINSWG in 2010 and 2015 (MPI 2015). It is also used to drive the in-season management procedure (MP) that is operated in January or February of each year (see Section 4). Supporting analyses and diagnostics for the FLA 3(TOT) bottom trawl CPUE analysis can be found in Appendix I.

The updated 2015 FLA 3(TOT) analysis conforms closely to the 2010 analysis, showing no overall trend over the 25 years and generally fluctuating around the long-term mean (Figure 11). The most recent apparent peak in CPUE occurred in 2008–09 and has since dropped to near the long-term average in four of the five succeeding fishing years (Figure 11).

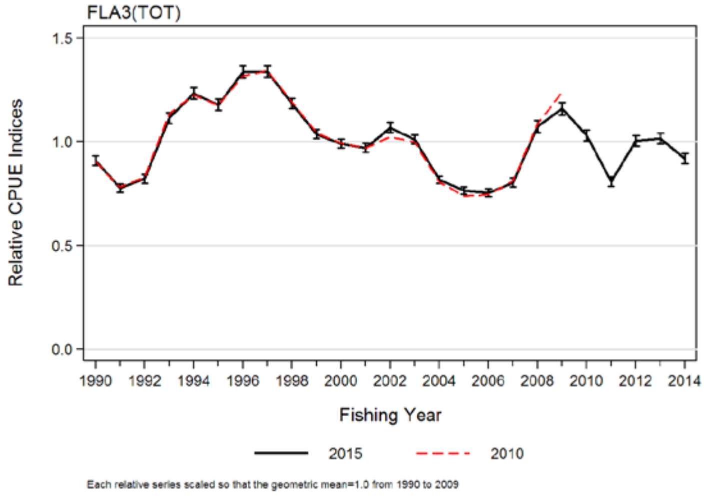


Figure 11: Comparison of the standardised FLA 3(TOT) lognormal CPUE analysis prepared for this report with the equivalent FLA 3(TOT) series prepared by Bentley(2010). Both series assume a lognormal distribution and error bars show plus or minus two standard errors.

3.2 LSO 3:

The fishery is defined from bottom trawl daily fishing events in the "*trip splitter*" data set (Appendix D) which fished in Statistical Areas 020, 022, 024, 026, 025, and 030 and declared a target species from one of the 15 species codes in Table A.3. Positive catch were those records which recorded an estimated catch of LSO while zero catch records were events which did not catch LSO but caught another flatfish species and did not use the generic FLA species designation. It was accepted for monitoring LSO 3 by the SINSWG in 2010 and 2015 (MPI 2015). Supporting analyses and diagnostics for the LSO 3 bottom trawl CPUE analysis can be found in Appendix J.

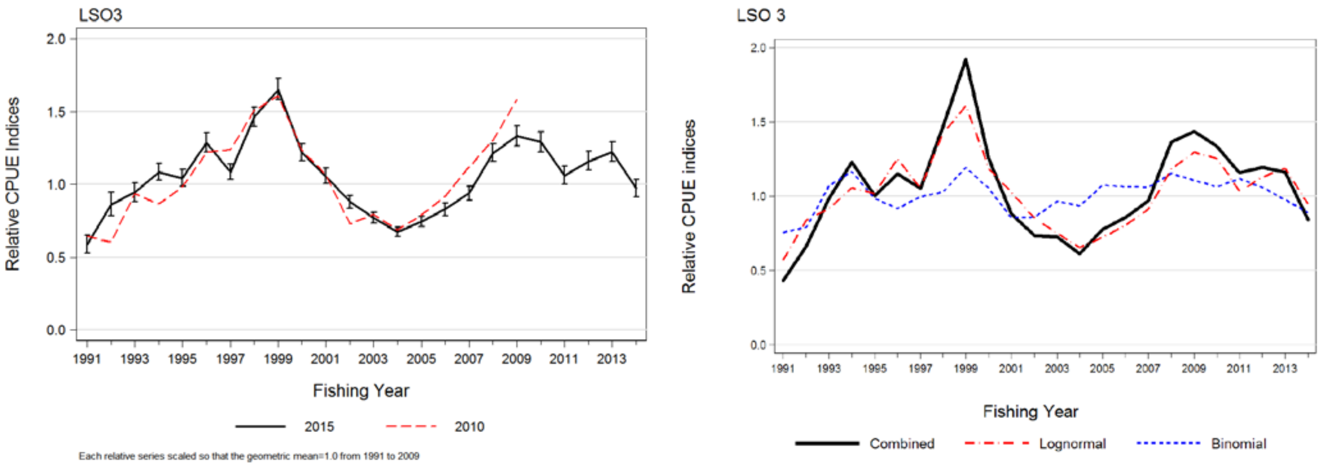


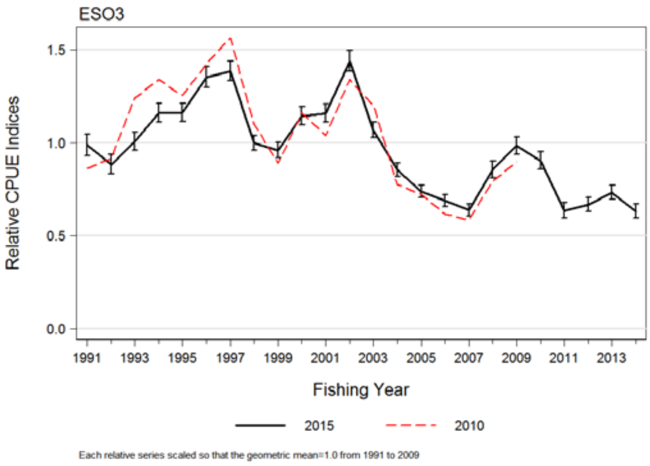
Figure 12: [left panel]: comparison of the standardised lognormal LSO 3 CPUE analysis prepared for this report with the equivalent LSO 3 series prepared by Bentley(2010); both series assume a lognormal distribution and error bars show plus or minus two standard errors; [right panel]: three standardised relative CPUE series for LSO 3, all based on the same data set: a) lognormal for positive catches, b) binomial presence/absence series, c) combined model using delta-lognormal procedure (Eq. H.4).

The updated 2015 LSO 3 standardised analysis corresponded reasonably well to the 2010 series (in spite of using different "*splitter*" algorithms), showing an increasing trend from 1990–91 to the late 1990s, a period of decline and low abundance in the 2000s and then an increase to slightly above the long-term mean CPUE in the 2010s ([left panel]: Figure 12). The combined model using the delta-lognormal method (Eq. H.4) more closely resembled the lognormal model, indicating that the presence/absence binomial model had little impact on the estimated CPUE trend ([right panel]: Figure 12).

3.3 ESO 3:

The fishery is defined from bottom trawl daily fishing events in the "*trip splitter*" data set (Appendix D) which fished in Statistical Areas 020, 022, 024, 026, 025, and 030 and declared a target species from one of the 15 species codes in Table A.3. Positive catch were those records which recorded an estimated catch of ESO, while zero catch records were events which did not catch ESO but caught another flatfish species and did not use the generic FLA species designation. It was accepted for monitoring ESO 3 by the SINSWG in 2010 and 2015 (MPI 2015). Supporting analyses and diagnostics for the ESO 3 bottom trawl CPUE analysis can be found in Appendix K.

The updated 2015 ESO 3 standardised analysis corresponded moderately well with the 2010 series (in spite of using different "*splitter*" algorithms), showing no overall trend from 1990–91 to the early 2000s, followed by an overall decreasing trend to 2013–14 ([left panel]: Figure 13). There is a short three-year period of higher CPUE from 2007–08 to 2010–11. As seen for LSO 3, the combined model using the delta-lognormal method (Eq. H.4) more closely resembled the lognormal model, indicating that the presence/absence binomial model had little impact on the estimated CPUE trend ([right panel]: Figure 13). However, the combined model shows a more pronounced declining trend compared to either the lognormal or binomial models.



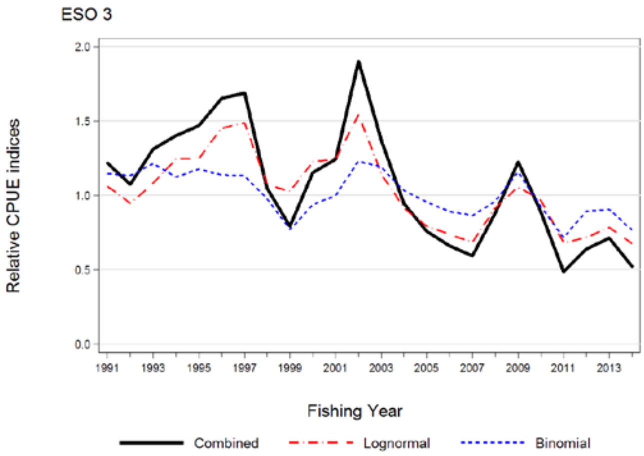


Figure 13: [left panel]: comparison of the standardised lognormal ESO 3 CPUE analysis prepared for this report with the equivalent ESO 3 series prepared by Bentley(2010); both series assume a lognormal distribution and error bars show plus or minus two standard errors; [right panel]: three standardised relative CPUE series for ESO 3, all based on the same data set: a) lognormal for positive catches, b) binomial presence/absence series, c) combined model using delta-lognormal procedure (Eq. H.4).

3.4 SFL 3:

The fishery is defined from bottom trawl daily fishing events in the "*trip splitter*" data set (Appendix D) which fished in Statistical Areas 020, 022, 024, 026, 025, and 030 and declared a target species from one of the 15 species codes in Table A.3. Positive catch were those records which recorded an estimated catch of SFL while zero catch records were events which did not catch SFL but caught another flatfish species and did not use the generic FLA species designation. It was accepted for monitoring SFL 3 by the SINSWG in 2010 and 2015 (MPI 2015). Supporting analyses and diagnostics for the SFL 3 bottom trawl CPUE analysis can be found in Appendix L.

The updated 2015 SFL 3 standardised analysis conformed moderately well to the 2010 series (in spite of using different "*splitter*" algorithms), showing an increasing trend from 1990–91 to 1995–96, little trend from 1995–96 to the mid-2000s, followed by an increasing trend to 2013–14 ([left panel]: Figure 14). As seen for LSO 3 and ESO 3, the combined model using the delta-lognormal method (Eq. H.4) more closely resembled the lognormal model, indicating that the presence/absence binomial model had little impact on the estimated CPUE trend ([right panel]: Figure 14). However, the combined model shows a more pronounced increasing trend compared to either the lognormal or binomial models.

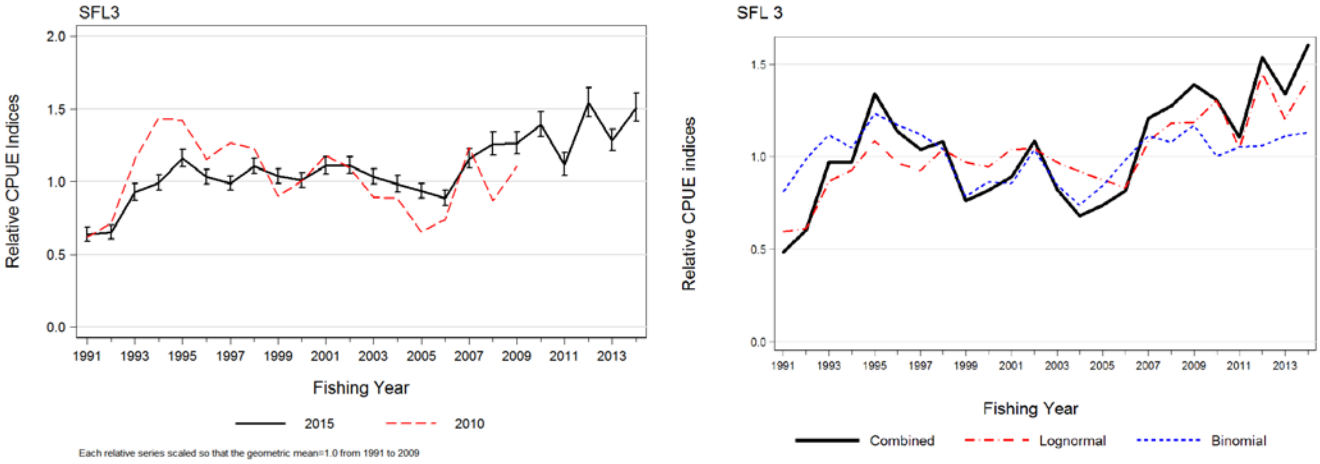


Figure 14: **[left panel]: comparison of the standardised lognormal SFL 3 CPUE analysis prepared for this report with the equivalent SFL 3 series prepared by Bentley(2010); both series assume a lognormal distribution and error bars show plus or minus two standard errors; [right panel]: three standardised relative CPUE series for SFL, all based on the same data set: a) lognormal for positive catches, b) binomial presence/absence series, c) combined model using delta-lognormal procedure (Eq. H.4).**

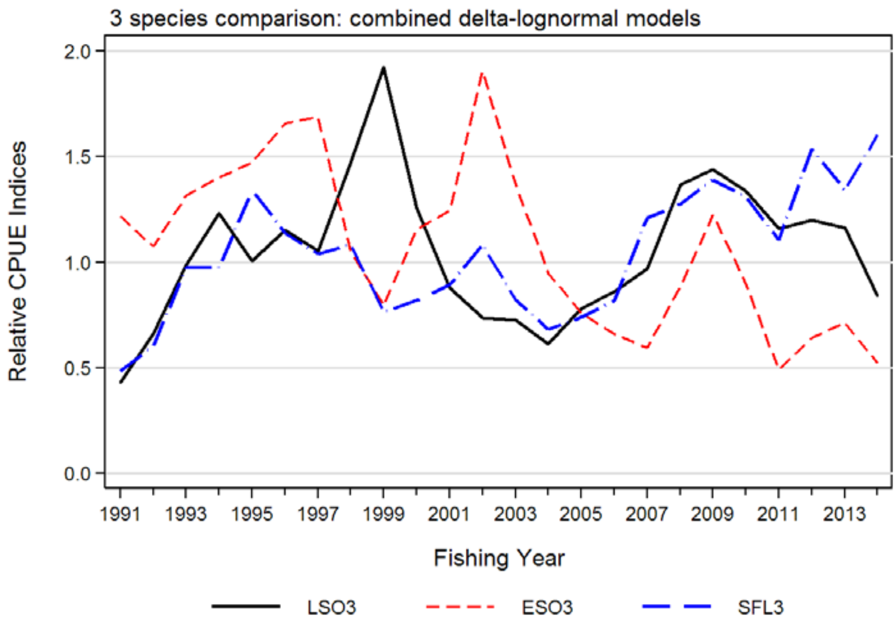


Figure 15: **Three species comparison plot using the combined delta-lognormal model. Each series has the same geometric mean (1.0).**

3.5 Three species comparison

A comparison of the delta-lognormal models for the three species-specific FLA 3 models indicated that the series trends differed among species, with the LSO 3 series showing no overall trend, the ESO 3 series declining since the early 2000s, and the SFL 3 series increasing since the mid-2000s (Figure 15). There are also some similarities, with all three species showing increased CPUE indices in 2008–09 and SFL 3/ESO 3 showing peaks in 2002–03 and a trough in 1999–2000 (LSO 3 has a strong peak in 1999–2000).

4. FLA 3 MANAGEMENT PROCEDURE EVALUATION

4.1 Data preparation

The data set used to estimate the FLA 3(TOT) standardised CPUE was used to evaluate the FLA 3 Management Procedure (MP). This data set included all catch and effort records regardless of whether fishers were consistent in their identification of the FLA species set. For the purposes of this data set, all FLA species records were combined into a single species and then filtered on the following criteria:

- core vessels: 10 trips in at least 5 years
- Statistical Areas: 018, 020, 022, 024, 025, 026, 030
- bottom trawl
- target species FLA (with all non-FLA flatfish codes treated as FLA)
- drop daily records with >24 hours duration
- drop daily records with >12 tows
- trip landings scaled to estimated daily catches of total (all codes) FLA (daily trip stratum)

This data set is the same data set used for the CPUE standardisation (see Section 3.1).

4.2 Geometric mean predictors

The geometric mean of the daily CPUE (catch/tow) was taken for all positive catch records in all years from the above data set, accumulated from the beginning of the fishing year to the end of each month. The resulting mean cumulative monthly CPUE was then regressed with the standardised CPUE series derived from the same data set (see Section 3.1), resulting in a calculated monthly mean CPUE for each year which served as a predictor for the final standardised index in the same year.

These geometric mean predictors appear to be highly biased and relatively inaccurate as predictors of the final standardised CPUE (Figure 16). This conclusion is the same as that made in the previous FLA 3 MP investigation (Bentley 2010). The correlations with the final CPUE series are generally poor and do not improve with the introduction of additional data (Table 17). The residual patterns are also poor and high CPUE values lead to strong negative residuals (Figure 17).

4.3 Standardised CPUE predictors

Instead of calculating the cumulative monthly geometric mean CPUE as described in Section 4.2, the same cumulative data were standardised using the model described in Section H.2.2, resulting in a standardised CPUE index which was based on the data from all years up to the indicated month. The correlations for this procedure were much better than for the geometric mean predictor, even in the first month (which is November to allow for a minimum two months in the standardisation procedure) and they obviously converge on the final series as the data accumulate (Table 17). The predictive fits are acceptable even in the earliest months (Figure 18), although there continued to be trends in the residuals, particularly in the earlier months (Figure 19). The analyses presented in Figure 18 and

Figure 19 were based on scaled landed catches. These analyses were repeated using estimated catches (predictions: Figure 20, residuals: Figure 21, correlations: Table 17). It seems from these results that the predictive capabilities of the estimated catch resembled those of the landed catch, but appeared to be slightly more uncertain and displayed more patterns in the residuals.

A further refinement to the predictive capacity of the above standardised method was investigated by adding preceding months from the previous fishing year into the prediction procedure. Each fishing year begins in October, so it was reasoned that data from the preceding September (for instance) might improve the predictive capability of the model in the early months. Three variants of this approach were tested, going back 1 month (September), 2 months (August) and 3 months (July), and then projecting forward for 6 months. Unfortunately, while this idea seemed reasonable, the outcome was not encouraging, with the correlations lower than seen for the model which only used the data within the current fishing year as well as noting that the correlations deteriorated as more data were added to the analysis from the earlier months (Table 17). Plots of the predictive fits (Figure 22) and the associated residuals (Figure 23) confirm that adding additional data from the preceding fishing year did not improve on the equivalent patterns observed in the models which were confined to the same fishing year (for instance, compare the fitted plots for November in Figure 18 with Figure 22 and the residual patterns for November in Figure 19 and Figure 23).

4.4 Definition of the FLA 3 MP

The following series of equations define the current FLA 3 MP, which estimates an increase in the amount of available ACE in incomplete (predicted) year y (note: fishing year 2006–2007 coded as 2007):

Eq. 2

$$
\begin{aligned}
& TACC_{\text{base}} = 1430 \text{ t} \\
& b = \text{slope}\left\{C_{1990} \text{ to } C_{2007}, I_{1990} \text{ to } I_{2007}\right\} \text{ (no constant)} \\
& ACE_y = b * I_y - TACC_{\text{base}} \\
& ACE_{\max} = 2500 - TACC_{\text{base}} \\
& \text{if } b * I_y < TACC_{\text{base}} \text{ then } ACE_y = 0
\end{aligned}
$$

where

C_i = QMR/MHR catch in year 1990 to 2007

I_i = standardised FLA 3 CPUE index in year 1990 to year y

4.5 Predictive models for driving the FLA 3 MP

The predictive procedures described in Section 4.3 used incomplete data from all years as the predictor, but it is probably more desirable to use complete fishing year data for all years except the current (predictive) year. Bentley (2010) used this approach, developing a procedure that mimicked the full CPUE standardisation procedure to reduce biases introduced from using the un-standardised geometric mean in the previous section. This method relied on a fixed set of core vessels and fixed standardisation coefficients over the life of the MP. This approach was adopted because it was felt at the time that it would be onerous to repeat the standardisation procedure in every year that the MP operated. However, over time it was noted that the main difficulties in operating the MP were in obtaining and grooming the data, with the final operation of the calculation being relatively straightforward. Consequently, it was felt that it would be better to rely on the predictive properties of the GLM standardisation procedure because such procedures are now well understood and require less development time.

The model (Eq. 2) used to drive the FLA 3 MP begins with the data set assembled for the FLA 3(TOT) standardised CPUE defined in Section 4.1. The regression is performed as described in

Appendix I, except that data from the current (predictive) year are also included in the analysis. Consequently, the final year in the regression uses incomplete data and estimates the complete final year CPUE. Four predictive models were tested using the accumulated catch/effort data up to the end of the indicated month to predict the total fishing year CPUE. The annual CPUE indices from 1989–90 to 2006–07 are regressed against the total annual QMR/MHR FLA 3 landings to estimate the slope (only a single parameter required because the regression is forced through the origin–Eq. 2). This slope is then multiplied by the predicted CPUE to generate a catch prediction. The four selected months were from November, the earliest month that could be used to generate a catch estimate, to February, which is the end of the likely window that could be used to make an in-season adjustment to the TACC (because a February analysis would have to be done in the latter half of March, after the monthly deadline for reporting catch/effort data by fishers plus allowing for some time for the data to be entered). Unlike the model proposed by Bentley (2010), the core vessels were reselected and the standardised model was refitted for each of the four models.

These four models are all characterised by extremely close fits to the observed landings and very high levels of explanatory power (Figure 24). These models were only fit to the observed catches from 1989–90 to 2006–07 because it was considered that the TACC was not constraining catch in that period. Only one set of plots are used to show the model performance because the four models do not show a great deal of visual contrast in these years. Figure 25 shows an example of the operation of the MP, with six predictive years and using the first 18 fitted years to set the slope. Note that this slope effectively represents an average exploitation rate for that period and the design of this MP ensures that the recommended increases are within the range of the average exploitation rate that existed over the period of unconstrained fishing.

Although the regression model fits are good, the predictive power of the model is much poorer, with negative residuals near to –500 t in 2008–09 and 2010–11 (Table 18). It is also notable that almost all the residuals are negative, with the model tending to over-predict the catches in most years. The predictions were close to the actual landings in only two of the six years (2011–12 and 2013–14) (Table 18). This pattern of strong negative residuals is most likely due, at least in some years, to MP implementation issues, given the long lead times required for consultation and review of any proposed increase.

4.6 Retrospective performance of the FLA 3 MP

A retrospective analysis was conducted to more rigorously test the predictive capacity of the FLA 3 MP (Eq. 2). This analysis, starting with the 2007–08 (coded 2008) fishing year, only used the accumulated data available up to and including the predictive fishing year. Within the predictive fishing year, only data up to the end of each predictive month was used to estimate the final standardised CPUE for the year in question. While this analysis approximates the situation that would exist during the actual operation of the FLA 3 MP, the simulation is not completely correct. That is because the predictive month data used in this retrospective analysis will be complete, unlike the situation that exists when the MP is operated in real time. During the actual MP operation, there will always be a component of the data that is not available, either because fishers have yet to turn in their data or there is a lag in the data entry process. This component (missing data within the predictive month) was not simulated in this retrospective analysis.

Table 19 shows the predicted CPUE and the recommended TACC for the FLA 3 MP procedure using November as the predictive month (i.e.: only two months of recent data) in each prediction year as coloured cells on the diagonal. By reading across each row, Table 19 also shows how these estimates progress over time with the accumulation of additional years of data. The operation of the November MP is plotted for each retrospective year in Figure 26. Table 20 summarises the shifts in the estimated CPUE across all four MP models for each retrospective year, showing that the CPUE estimates in the seven years ranged from –22% to +10% of the final CPUE when using the prediction year data up to the end of November. While this range may seem wide, the mean is relatively unbiased at –0.3% and the performance of the MP doesn’t improve much by adding December and even January data to the analysis. If the level of accuracy implied by Table 20 is acceptable, then this MP can be used with only two months of data in the prediction year to drive the MP defined in Eq. 2.

Table 17: Correlation coefficients with the final standardised CPUE series with several predictive options for annual standardised CPUE based on the FLA 3(TOT) core vessel data set (10 trips/5 years). Also shown are three sets of correlation coefficients from Bentley (2010). '–': analysis not performed.

		Standardised CPUE					INS2008-02 Correlations		
	Geometric	Landed	Estimated	shift back 1	shift back 2	shift back 3	Geometric	Geometric	Adjusted
Oct	0.577	–	–	0.676	0.645	0.614	0.70	0.64	0.83
Nov	0.621	0.877	0.809	0.799	0.762	0.739	0.77	0.74	0.91
Dec	0.620	0.892	0.815	0.835	0.802	0.782	0.79	0.77	0.91
Jan	0.621	0.920	0.849	0.869	0.836	0.817	0.80	0.79	0.93
Feb	0.635	0.942	0.887	0.904	0.873	0.856	0.81	0.79	0.93
Mar	0.674	0.967	0.920	0.942	0.919	0.903	0.83	0.80	0.95
Apr	0.715	0.980	0.939	–	–	–	0.84	0.80	0.96
May	0.731	0.986	0.953	–	–	–	0.86	0.81	0.97
Jun	0.742	0.990	0.962	–	–	–	0.86	0.91	0.98
Jul	0.717	0.995	0.968	–	–	–	0.84	0.79	0.98
Aug	0.671	0.999	0.975	–	–	–	0.81	0.75	0.99
Sep	0.641	0.999	0.978	–	–	–	0.79	0.70	0.99

[1] "shift back *x* month" refers to using data from *x* months in the previous fishing year in the regression prediction

Table 18: Predictive performance statistics for each monthly model defined in Section 4.4. Large residuals (less than –400 t) indicated in grey.

Analysis month	Fishing year	QMR/MHR landings	TACC	Predictive CPUE	Predicted landings	[Observed-Predicted] catch (t)
November	2008	1,371.0	1 430	0.986	1,625.9	-254.8
	2009	1 543.9	1 430	1.286	2 120.3	-576.4
	2010	1 525.5	1 430	1.079	1 778.1	-252.7
	2011	1 026.9	1 430	0.915	1 508.7	-481.8
	2012	1 510.8	1 430	0.784	1 292.9	218.0
	2013	1 512.0	1 430	1.060	1 747.9	-235.9
	2014	1 376.9	1 430	0.835	1 376.3	0.6
December	2008	1 371.0	1 430	0.976	1 626.6	-255.5
	2009	1 543.9	1 430	1.247	2 077.0	-533.1
	2010	1 525.5	1 430	1.120	1 866.1	-340.6
	2011	1 026.9	1 430	0.916	1 526.2	-499.3
	2012	1 510.8	1 430	0.845	1 407.1	103.8
	2013	1 512.0	1 430	1.043	1 737.3	-225.3
	2014	1 376.9	1 430	0.841	1 401.0	-24.1
January	2008	1 371.0	1 430	0.988	1 658.7	-287.6
	2009	1 543.9	1 430	1.184	1 989.5	-445.6
	2010	1 525.5	1 430	1.157	1 942.6	-417.1
	2011	1 026.9	1 430	0.901	1 513.5	-486.6
	2012	1 510.8	1 430	0.909	1 526.9	-16.0
	2013	1 512.0	1 430	1.010	1 697.0	-185.0
	2014	1 376.9	1 430	0.836	1 403.6	-26.7
February	2008	1 371.0	1 430	0.982	1 649.1	-278.1
	2009	1 543.9	1 430	1.164	1 953.8	-409.9
	2010	1 525.5	1 430	1.128	1 894.2	-368.7
	2011	1 026.9	1 430	0.874	1 467.5	-440.6
	2012	1 510.8	1 430	0.919	1 543.1	-32.2
	2013	1 512.0	1 430	1.020	1 712.4	-200.3
	2014	1 376.9	1 430	0.853	1 432.7	-55.8

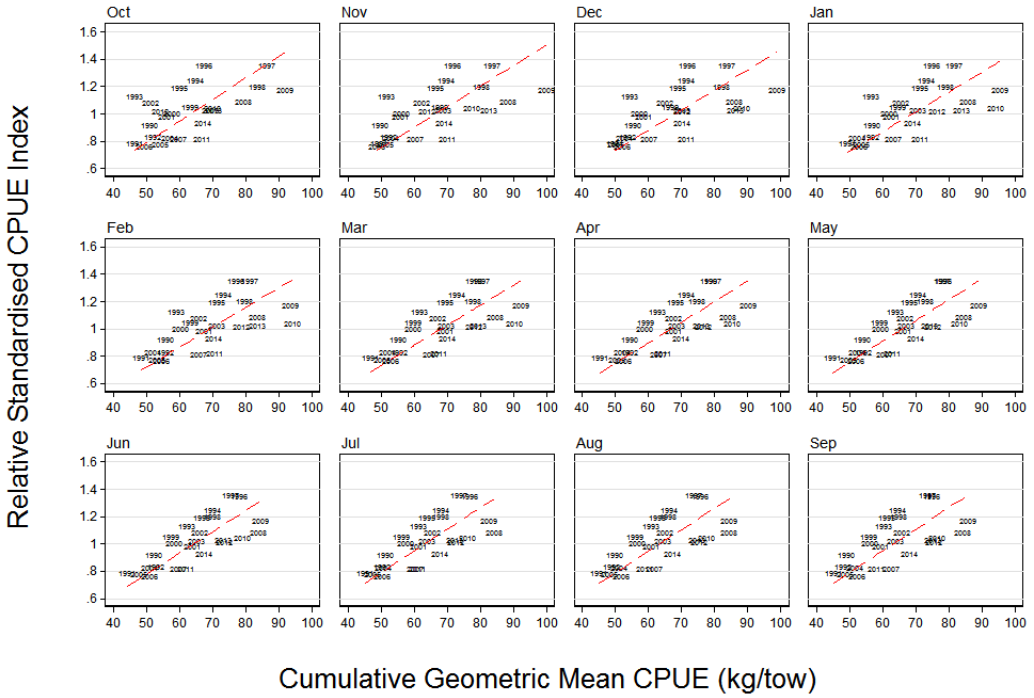


Figure 16: Plot of cumulative monthly core vessel geometric mean CPUE (showing the final month in the accumulation) used as a predictor of the annual standardised FLA 3(TOT) CPUE series. Dashed red line is a linear regression forced through the origin.

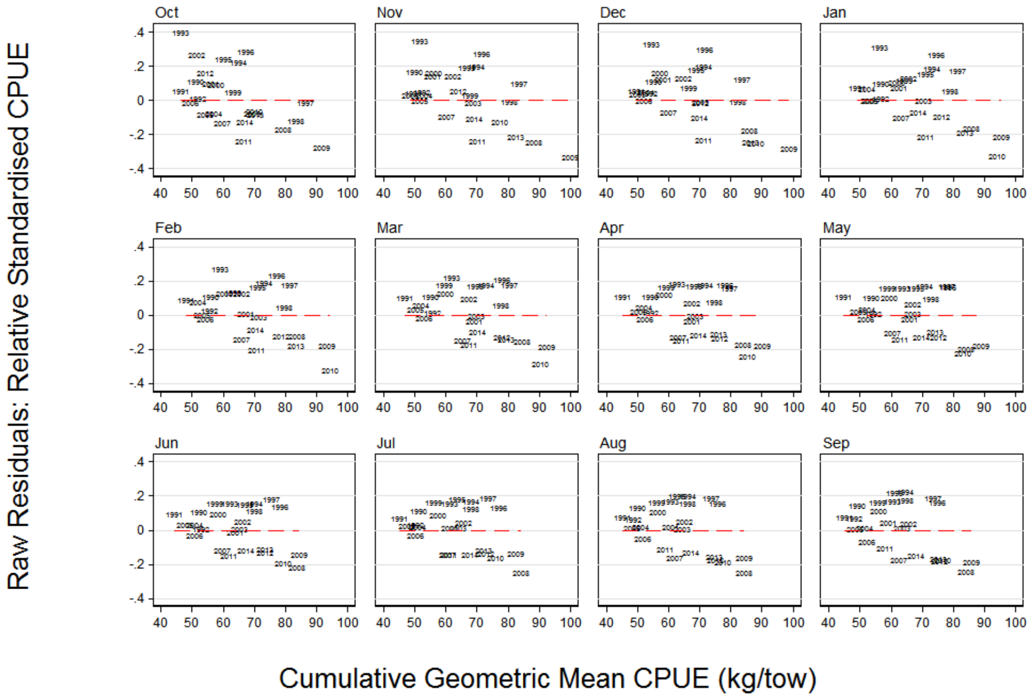


Figure 17: Raw residuals from the linear regression plotted in Figure 16.

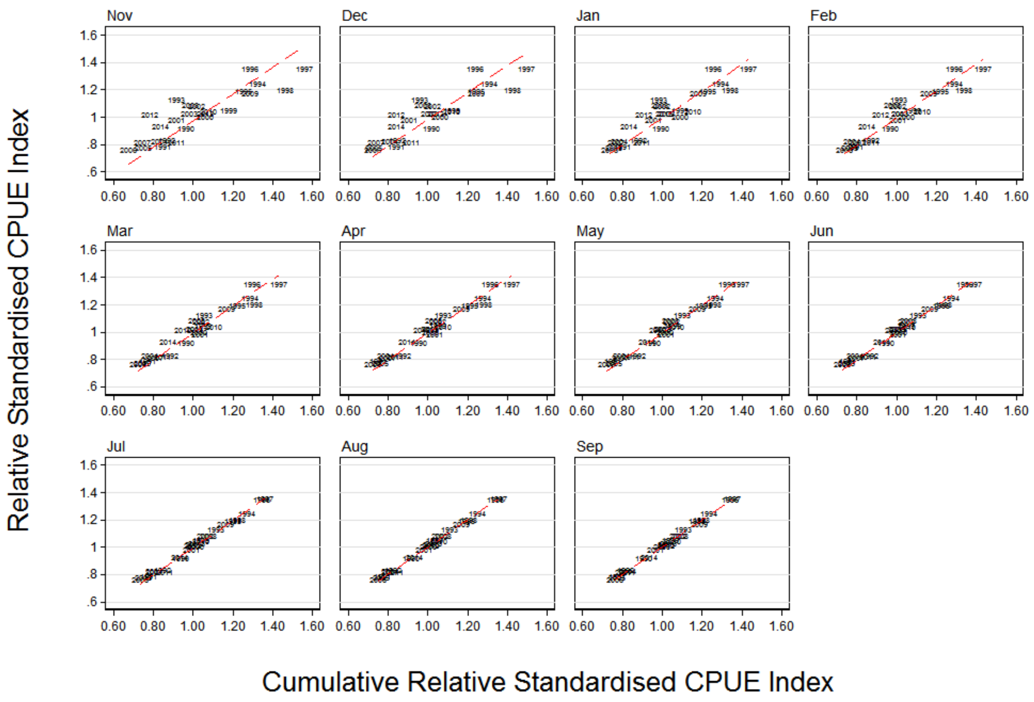


Figure 18: Plot of cumulative monthly core vessel standardised CPUE (showing the final month in the accumulation and based on landed catches) used as a predictor of the annual standardised FLA 3(TOT) CPUE series. Dashed red line is a linear regression forced through the origin.

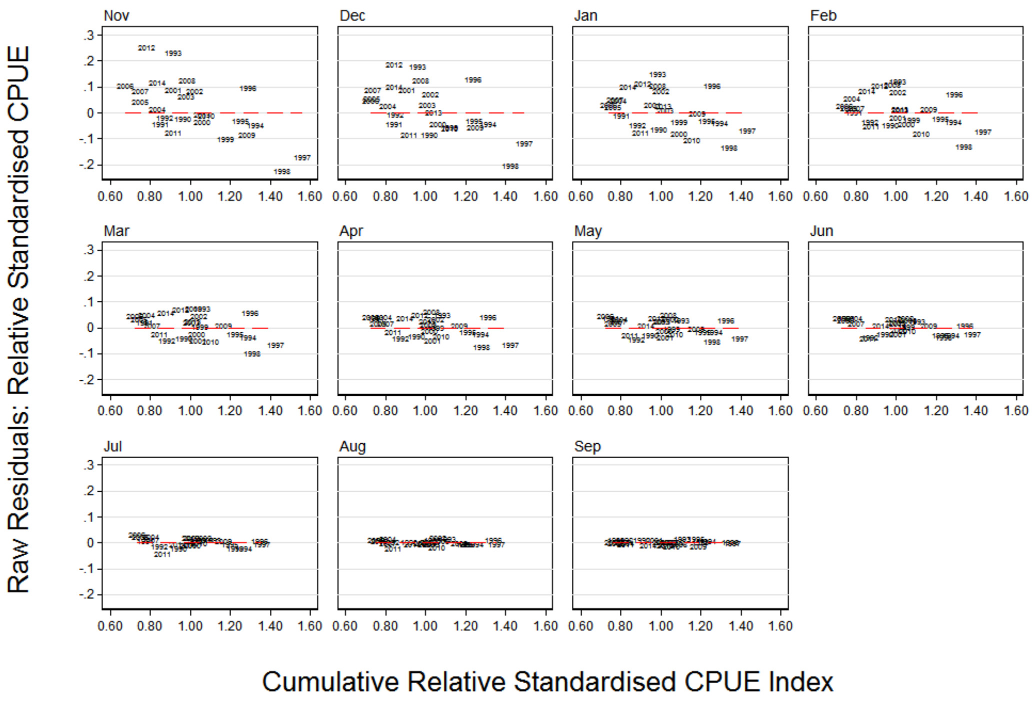


Figure 19: Raw residuals from the linear regression plotted in Figure 18.

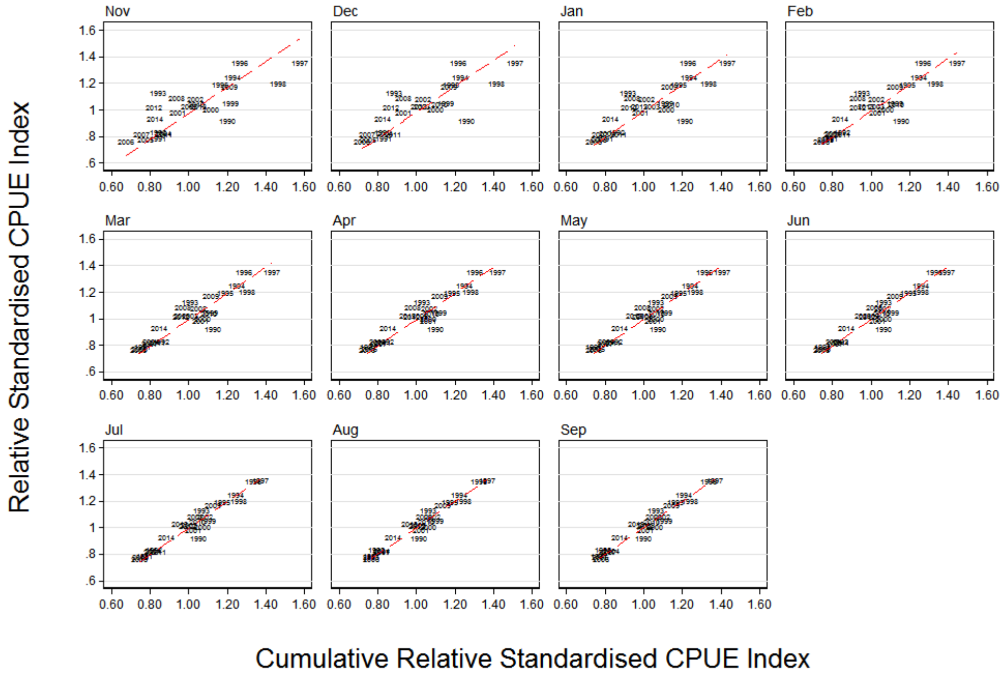


Figure 20: **Plot of cumulative monthly core vessel standardised CPUE (showing the final month in the accumulation and based on estimated catches) used as a predictor of the final standardised CPUE series for the FLA 3(TOT) core vessel data set. Dashed red line is a linear regression forced through the origin.**

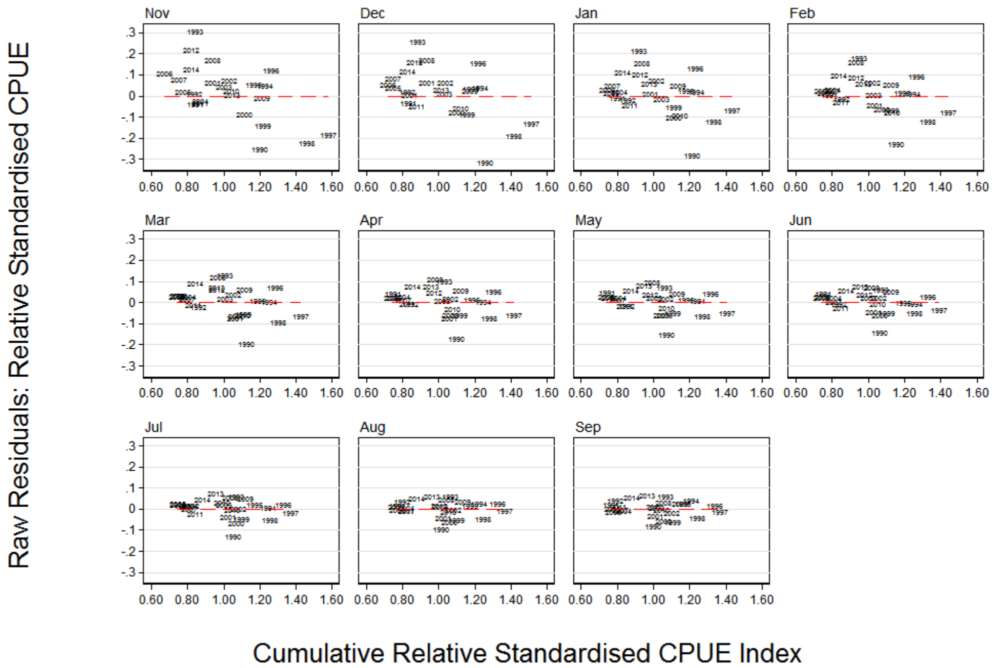


Figure 21: **Raw residuals from the linear regression plotted in Figure 20.**

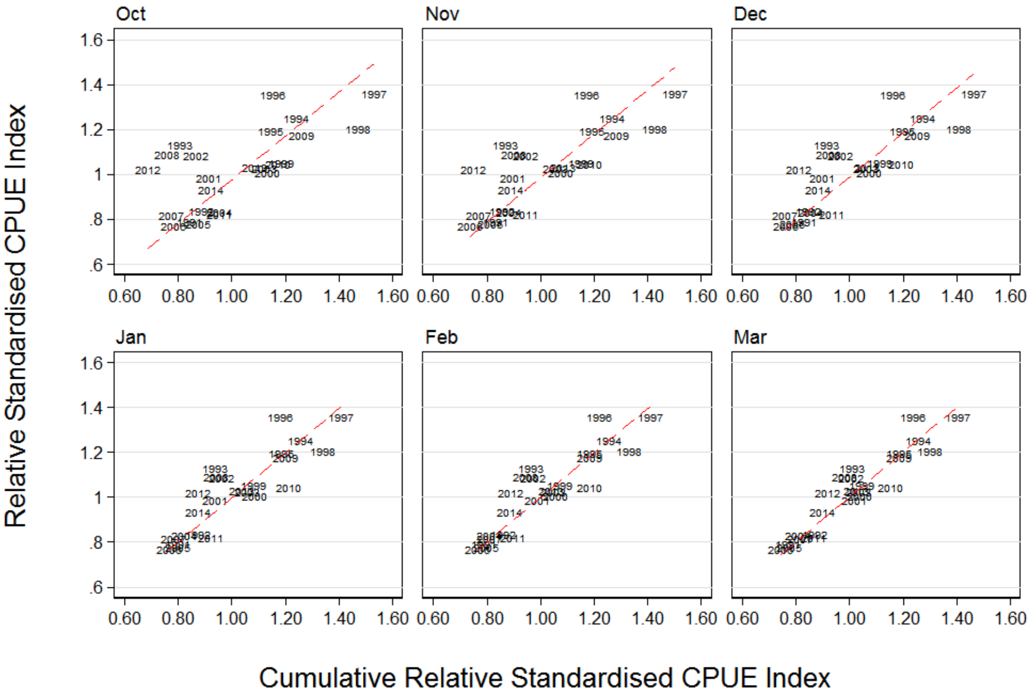


Figure 22: Plot of cumulative monthly (starting with the preceding September) core vessel standardised CPUE (showing the final month in the accumulation and based on landed catches) used as a predictor of the final standardised CPUE series for the FLA 3(TOT) core vessel data set. Dashed red line is a linear regression forced through the origin.

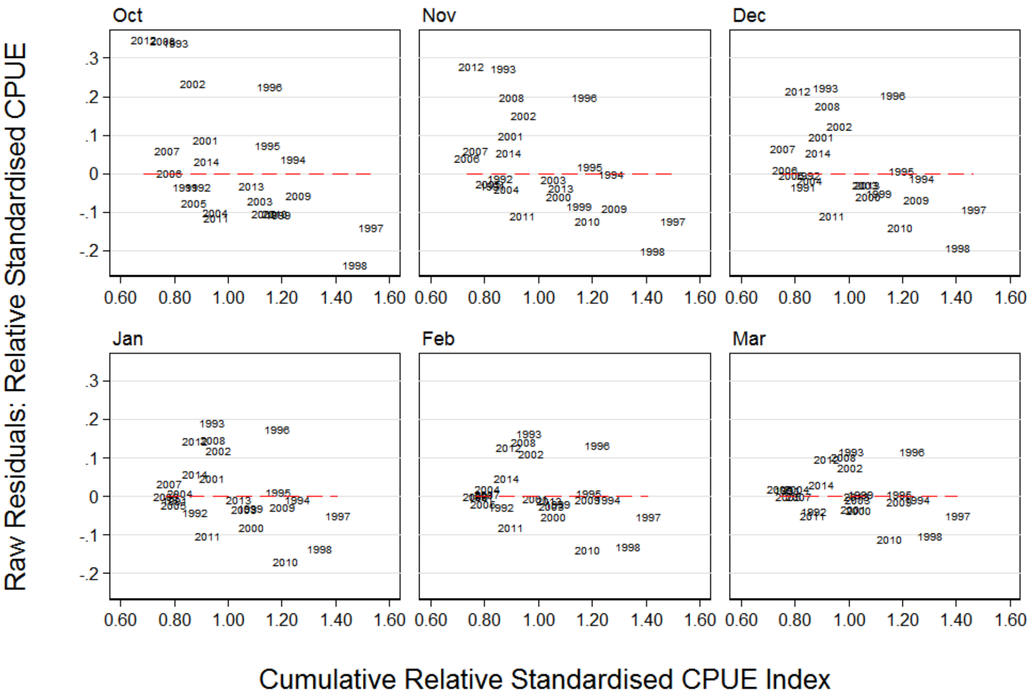


Figure 23: Raw residuals from the linear regression plotted in Figure 22.

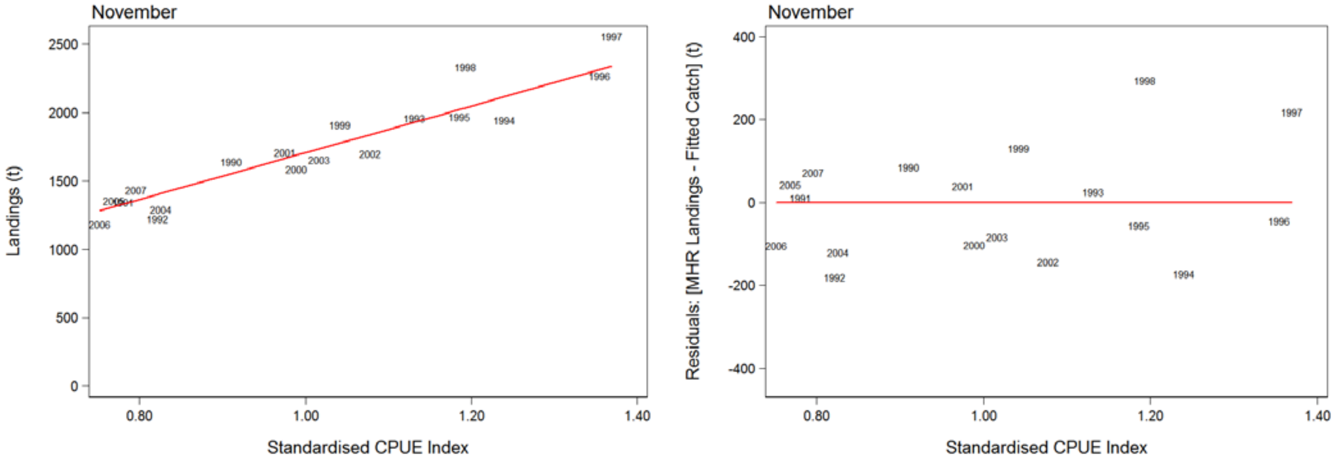


Figure 24: **Regression (forced through the origin) of standardised CPUE index against the observed QMR/MHR catches for the period 1989–90 to 2006–07 (period before the implementation of the FLA 3 MP). The slope (1697 t; R^2=.994) from this regression is used to predict the catch from the CPUE index estimated from the partial year data. [left panel]: fitted model; [right panel]: residuals from the [observed-predicted] landings.**

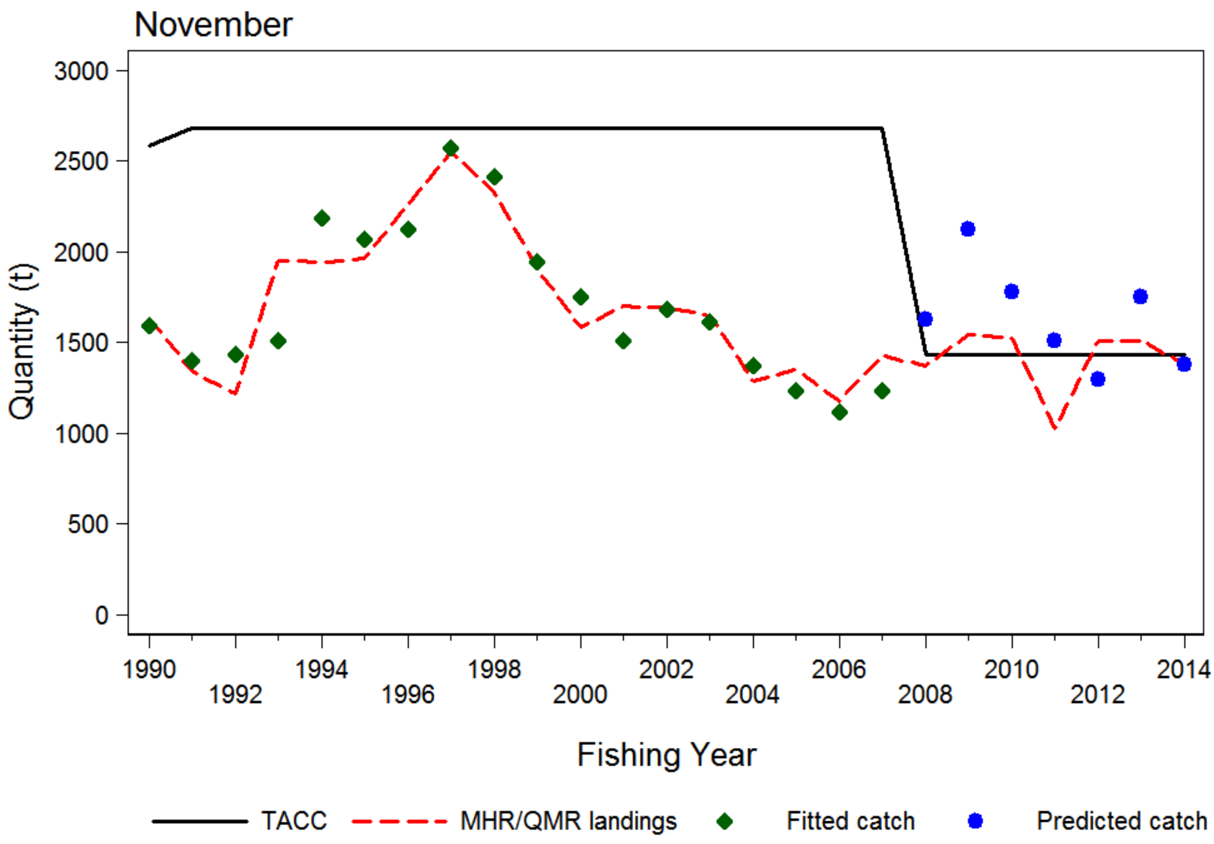


Figure 25: **Example operation of the FLA 3 MP (Eq. 2) based on accumulated in-season data to November, using the full 1989–90 to 2013–14 data set. The plot shows the estimated catches resulting from the fitted regression model (see Figure 24), the predicted catches (based on the regression model slope and the estimated standardised CPUE) for the period after the TACC was reduced and the observed QMR/MHR landings. Only the base TACC of 1430 t has been plotted after 2006–07.**

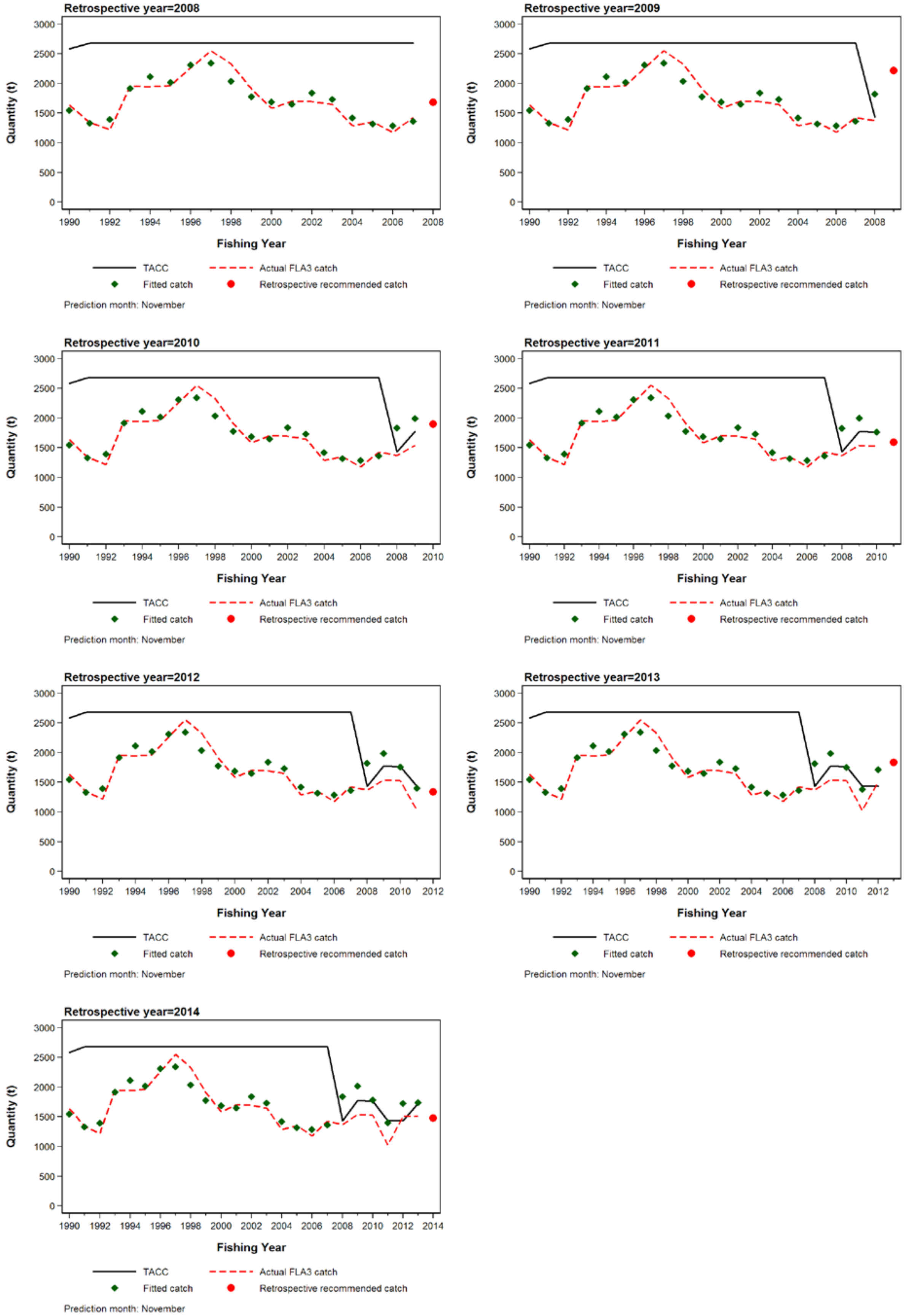


Figure 26: Plots showing the operation of the FLA 3 MP (Eq. 2) for each retrospective year with November as the prediction month, plotting the estimated catches from the fitted model, the observed QMR/MHR landings and the recommended catch for the retrospective year. Red dots are the highlighted catch predictions in Table 19.

Table 19: Retrospective performance of the FLA 3(TOT) MP (Eq. 2) based on the predictive data available up to the end of November in each retrospective year. Predictive years based on partial year data are highlighted in yellow, showing the catch recommendation and the total year CPUE based on the partial year data. Non-highlighted cells show the recommended catch and updated CPUE in subsequent years.

Fishing Year	Retrospective Year 2008	2009	2010	2011	2012	2013	2014
	Recommended catch (t)						
2008	1 680	1 823	1 832	1 828	1 819	1 814	1 838
2009		2 215	1 991	1 998	1 989	1 986	2 017
2010			1 900	1 762	1 755	1 753	1 785
2011				1 591	1 400	1 381	1 400
2012					1 337	1 715	1 727
2013						1 833	1 737
2014							1 476
	Standardised CPUE						
2008	0.99	1.06	1.06	1.07	1.08	1.06	1.08
2009		1.28	1.15	1.17	1.18	1.16	1.19
2010			1.10	1.03	1.04	1.03	1.05
2011				0.93	0.83	0.81	0.83
2012					0.79	1.01	1.02
2013						1.07	1.02
2014							0.87

Table 20: Performance of the retrospective analysis, showing the predicted final CPUE for each of four predictive months, compared to the realised final CPUE obtained when all twelve months of data were available.

Retrospective fishing year	Predictive month November	December	January	February	Final CPUE
	Predicted CPUE				
2008	0.991	0.963	0.956	0.945	1.084
2009	1.284	1.252	1.173	1.137	1.170
2010	1.102	1.123	1.133	1.089	1.039
2011	0.929	0.919	0.883	0.862	0.815
2012	0.794	0.845	0.891	0.905	1.014
2013	1.075	1.059	1.019	1.020	1.025
2014	0.870	0.864	0.849	0.855	0.928
	Performance relative to final CPUE (%)				
2008	-8.5	-11.1	-11.8	-12.8	
2009	9.8	7.0	0.3	-2.8	
2010	6.1	8.1	9.1	4.8	
2011	14.0	12.8	8.4	5.8	
2012	-21.7	-16.7	-12.2	-10.8	
2013	4.9	3.3	-0.5	-0.5	
2014	-6.3	-6.9	-8.5	-7.9	

4.7 Management procedure evaluation discussion

In May 2015, the MPI Fishery Assessment Plenary reviewed and accepted the information and analyses presented in Sections 4.1 to 4.6, agreeing that Section 4.4 could be used as the procedure for setting in-season ACE increases for FLA 3. The Plenary recommended, based on the information in Table 20, that the accumulation of the first two months of data (October and November) was sufficient to provide an acceptable level of accuracy to the CPUE prediction. This means that the MP can be operated in late January/early February, improving the opportunity to take the ACE increase (if warranted), given the often lengthy approval process. The Plenary also accepted the recommendation that the standardised GLM should be refitted, including the reselection of the core fleet, each time the FLA 3 MP was operated.

5. ACKNOWLEDGEMENTS

This work was funded by MPI Research Project 2014-02. We thank the MPI Information & Data Management team for providing the catch/effort data in a timely manner. Members of the Southern Inshore Working Group provided important input and advice through several iterations of the analyses contained in this report.

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Appendix A. ABBREVIATIONS, CODES, AND DEFINITIONS OF TERMS

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

Term/Abbreviation	Definition
ACE	Annual Catch Entitlement: authority under which commercial catch is taken. Usually issued in direct proportion to the TACC, but can be issued using procedures such as the FLA 3 MP
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. 2012)
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 6)
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 flatfish 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 form type)
fishing event	a "fishing event" is a record of activity in 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 flatfish
FMA	Fishery Management Areas: 10 legal areas used by Fisheries New Zealand to define large scale stock management units; QMAs consist of one or more of these regions
landing event	weight of flatfish 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 reports 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 reports 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 (now Fisheries New Zealand)
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 reports individual fishing events
QMA	Quota Management Area: legally defined unit area used for flatfish management (Figure 1)
QMR	Quota Management Report: monthly harvest reports submitted by commercial fishermen. 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 Fisheries New Zealand 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"
SINSWG	Southern Inshore Fisheries Assessment Working Group: Fisheries New Zealand 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

Term/Abbreviation	Definition
statistical area	sub-areas (Appendix B) within an FMA which are identified 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 responsible for Fisheries for a QMA that applies to commercial fishing
TCEPR	Trawl Catch Effort Processing Return (Ministry of Fisheries 2010): active since July 1989 for deepwater vessels larger than 28 m and reports 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 reports 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. Fisheries New Zealand 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 E.

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

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

Table A.3: List of valid codes used for flatfish in FLA 3.

3-letter code	Scientific name	Common name
BFL	*Rhombosolea retiaria*	Black Flounder
BOT	*Bothidae*	Lefteyed Flounders
BRI	*Colistium guntheri*	Brill
ESO	*Peltorhamphus novaezeelandiae*	New Zealand Sole
FLA		Generic Flatfish
GFL	*Rhombosolea tapirina*	Greenback Flounder
LSO	*Pelotretis flavilatus*	Lemon Sole
MAN	*Neoachiropsetta milfordi*	Finless Flounder
SDF	*Azygopus pinnifasciatus*	Spotted Flounder
SFL	*Rhombosolea plebeia*	Sand Flounder
SLS	*Peltorhamphus tenuis*	Slender Sole
SOL		Generic Sole
TUR	*Colistium nudipinnis*	Turbot
WIT	*Arnoglossus scapha*	Witch
YBF	*Rhombosolea leporina*	Yellow-belly Flounder

Appendix B. MAP OF FISHERIES NEW ZEALAND STATISTICAL AND MANAGEMENT AREAS

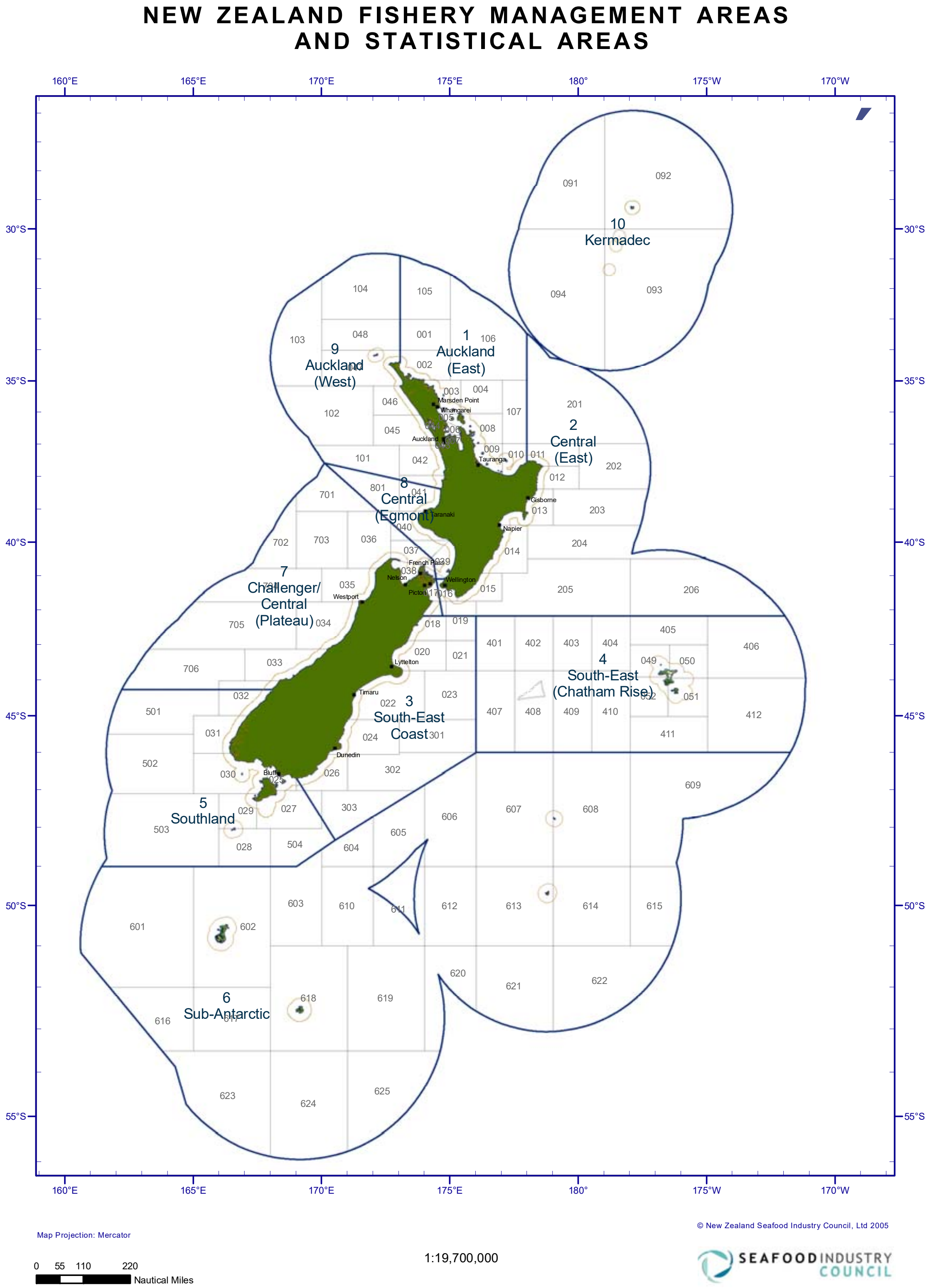


Figure B.1: Map of Fisheries New Zealand statistical areas and Fishery Management Area (FMA) boundaries, showing locations where FMA boundaries are not contiguous with the statistical area boundaries

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

C.1 Introduction

The procedure used to identify "implausibly large" landings (Starr 2007) was based on arithmetic CPUE, with the presumption that trips with extremely large arithmetic CPUE values existed because the contributing landings were implausibly large. This procedure 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 QMAs. These errors can result in substantial deviations from the accepted QMR/MHR catches and affect the credibility of the characterisation and CPUE analyses. A complication in the FLA 3 landing data set is that about 7% by weight of the total FLA 3 landings were recorded with flatfish species codes, not with the generic FLA code (Table C.1). These additional codes were all treated as if they were from FLA 3 in the analyses presented in this report.

Table C.1: Total landings (t) summed from 1989–90 to 2013–14 by FMA and flatfish species code in the unedited landings file. All species codes in this table point to a specific flatfish species. These codes are not legal codes and should not be present in this data set.

Species code	FMA 1	FMA 2	FMA 3	FMA 7	Total
BFL	0.0	–	31.2	–	31.2
BOT	–	–	0.1	0.0	0.1
BRI	0.2	0.3	52.2	0.0	52.7
ESO	0.3	2.1	703.4	0.4	706.1
FLA	29.0	161.6	41 995.9	447.4	42 633.9
GFL	–	–	55.2	–	55.2
LSO	0.4	2.8	1 701.3	1.5	1 705.9
MAN	–	–	5.7	0.0	5.7
SFL	0.1	1.6	151.7	4.0	157.4
SLS	–	–	0.5	–	0.5
SOL	–	0.1	0.3	–	0.4
TUR	0.2	0.8	76.1	0.2	77.2
WIT	0.2	0.5	253.8	12.6	267.1
YBF	–	–	1.7	–	1.7
Total	30.3	169.8	45 029.0	466.1	45 695.2

C.2 Methods

The method used 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. C.1). The ratio of each of these totals was taken with the declared greenweight for the trip, with the minimum of the two ratios taken as the "best" validation (Eq. C.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. C.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.

A further issue was discovered with the FLA 3 data set: there were landings included that used codes for flatfish other than the legal code FLA 3 (Table C.1). Fifteen codes that were not FLA were found, none of which should have been present because it is not legal to land flatfish using a code other than FLA. Two of these landings, coded as LSO 3, were for one day trips which landed 339 t and 254 t respectively, landings which are clearly spurious and must be dropped. The remaining incorrectly coded landings were all changed to FLA 3.

Initial explorations of the landing data led to dropping a large number of trips which seemed unreasonable, 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. C.2) was used (from 5 to 10) and only the upper end of the trip landing distribution (from the 97% to 99.99% quantiles) was investigated.

C.3 Equations

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

Eq. C.1

$$G^d_{t,s} = \sum_{i=1}^{n_t} gwt_{t,s,i}$$

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

$$G^e_{t,s} = \sum_{j=1}^{m_t} est_{t,s,j}$$

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

$G^c_{t,s}$ = 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 $B_{t,i}$;

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

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

Eq. C.2

$$r1_{t,s} = G^d_{t,s} \big/ G^c_{t,s}$$

$$r2_{t,s} = G^d_{t,s} \big/ G^e_{t,s}$$

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

where $G^d_{t,s}$, $G^c_{t,s}$ and $G^e_{t,s}$ are defined in Eq. C.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 $G^d_{t,s}$, 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. C.3) relative to the annual QMR/MHR totals:

Eq. C.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 cutoff 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.

C.4 Results

Seventy-seven trips were identified for dropping in addition to the two LSO 3 trips mentioned in the previous section (Table C.2). Although a better minimum Ssq^2 was identified in the search (see top panel in Table C.3), the one selected seemed "good enough" and meant dropping 30 fewer trips. The 79 dropped trips represented just over 4 000 t (3rd panel in Table C.3) and their removal resulted in a much improved approximation of the time series of FLA 3 landings (Table C.4, Figure C.1). A list of the 79 trip numbers that have been dropped is provided in Table C.5 so that future analyses can exclude the same set of trips.

Table C.2: 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. C.2.

Fishstock	Quantile	$rat_{t,s}$	Number trips dropped	Total trips in data set	Sum landings dropped (t)	$\sum_{y=89/90}^{y=13/14} MHR_y$	$\sum_{y=89/90}^{y=13/14} gg_y^0$	$\sum_{y=89/90}^{y=13/14} gg_y$	$\sum_{y=89/90}^{y=13/14} \left(gg_y - MHR_y\right)$
FLA 3	99.5	9	79	157 849	4 130	40 850	45 029	40 899	49

Table C.3: Sum of Ssq^2, number of dropped trips, sum of dropped landings, and overage/underage relative to the total QMR/MHR FLA 3 landings from 1989/90–2013–14 over a two parameter search using the following quantities: 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. C.2) which sets the maximum criterion for accepting a landing. The quantile/ratio pair with the lowest Ssq^2 (Eq. C.3) is coloured grey and the selected pairing used in this analysis is coloured yellow (Table C.2).

	$rat_{t,s}$ (Eq. C.2)					
Quantile	5	6	7	8	9	10
	Sum of Ssq^2 (Eq. C.3)					
97	34 902	35 583	34 644	34 034	35 469	34 027
98	34 978	35 363	34 645	34 086	35 920	34 820
99	34 655	35 077	35 115	34 720	36 606	35 636
99.5	36 463	36 463	36 463	36 035	38 057	37 513
99.9	39 475	39 475	39 475	39 048	40 531	39 363
99.99	245 726	245 726	245 726	245 726	245 726	245 726
	Number of dropped trips					
97	141	135	128	125	116	108
98	113	112	108	105	100	94
99	100	99	97	95	92	86
99.5	83	83	83	82	79	76
99.9	69	69	69	68	67	66
99.99	16	16	16	16	16	16
	Sum of dropped landings (t)					
97	4 324	4 311	4 294	4 281	4 226	4 191
98	4 270	4 266	4 255	4 241	4 195	4 164
99	4 236	4 232	4 226	4 215	4 173	4 143
99.5	4 180	4 180	4 180	4 172	4 130	4 110
99.9	4 108	4 108	4 108	4 100	4 068	4 056
99.99	3 104	3 104	3 104	3 104	3 104	3 104
	Overage/underage relative to sum of FLA 3 QMR/MHR total					
97	- 145	- 132	- 115	- 102	- 47	- 12
98	- 90	- 87	- 76	- 62	- 15	15
99	- 57	- 53	- 47	- 36	6	37
99.5	0	0	0	7	49	70
99.9	72	72	72	79	112	123
99.99	1 075	1 075	1 075	1 075	1 075	1 075

Table C.4: Annual statistics associated with the selected minima in FLA 3, showing the result of removing 79 trips as summarised in Table C.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. C.3 to the unedited landings and to the selected QMA "minimum" defined in Table C.2.

Fishing year	MHR_y	gg_y^0	gg_y	$\left(gg_y^0 - MHR_y\right)$	$\left(gg_y - MHR_y\right)$
89/90	1 637	1 748	1 490	12 261	21 527
90/91	1 341	1 431	1 334	8 170	44
91/92	1 219	1 252	1 221	1 084	7
92/93	1 953	1 975	1 970	465	284
93/94	1 941	2 706	1 937	586 209	13
94/95	1 966	2 611	1 983	415 810	286
95/96	2 265	2 824	2 339	313 129	5 524
96/97	2 552	3 081	2 496	278 859	3 229
97/98	2 328	3 015	2 304	472 409	557
98/99	1 907	2 199	1 934	85 010	716
99/00	1 583	1 866	1 586	79 970	6
00/01	1 703	1 750	1 750	2 278	2 278
01/02	1 693	1 710	1 710	270	270
02/03	1 650	1 671	1 665	435	216
03/04	1 286	1 313	1 313	700	700
04/05	1 353	1 374	1 374	434	434
05/06	1 177	1 180	1 176	9	3
06/07	1 429	1 427	1 427	4	4
07/08	1 371	1 410	1 410	1 531	1 531
08/09	1 544	1 550	1 550	36	36
09/10	1 526	1 512	1 512	183	183
10/11	1 027	1 017	1 017	107	107
11/12	1 511	1 511	1 511	0	0
12/13	1 512	1 527	1 521	211	73
13/14	1 377	1 371	1 371	31	31
Total	40 850	45 029	40 899	2 259 604	38 058

Table C.5: List of 79 trip numbers identified and dropped from this analysis.

3492	844545	1114728	2012007
71317	844959	1133404	2021759
110795	845532	1134318	2082739
425646	845881	1134419	2093137
426301	846106	1136823	2096739
616309	846108	1137818	2118691
693173	846120	1137835	2216229
719253	846121	1195569	2287738
719430	856742	1625884	2879470
719768	893281	1847309	2909727
719899	910330	1854317	2986569
724356	910954	1918142	3046325
724395	1004144	1922548	3056849
724588	1004149	1922554	3112658
725318	1005268	1947763	3145060
725469	1005510	1967784	3315597
725470	1005648	1967799	4068762
725472	1005652	1980789	4671362
725475	1080458	1996828	5879926
838227	1082196	2008988	

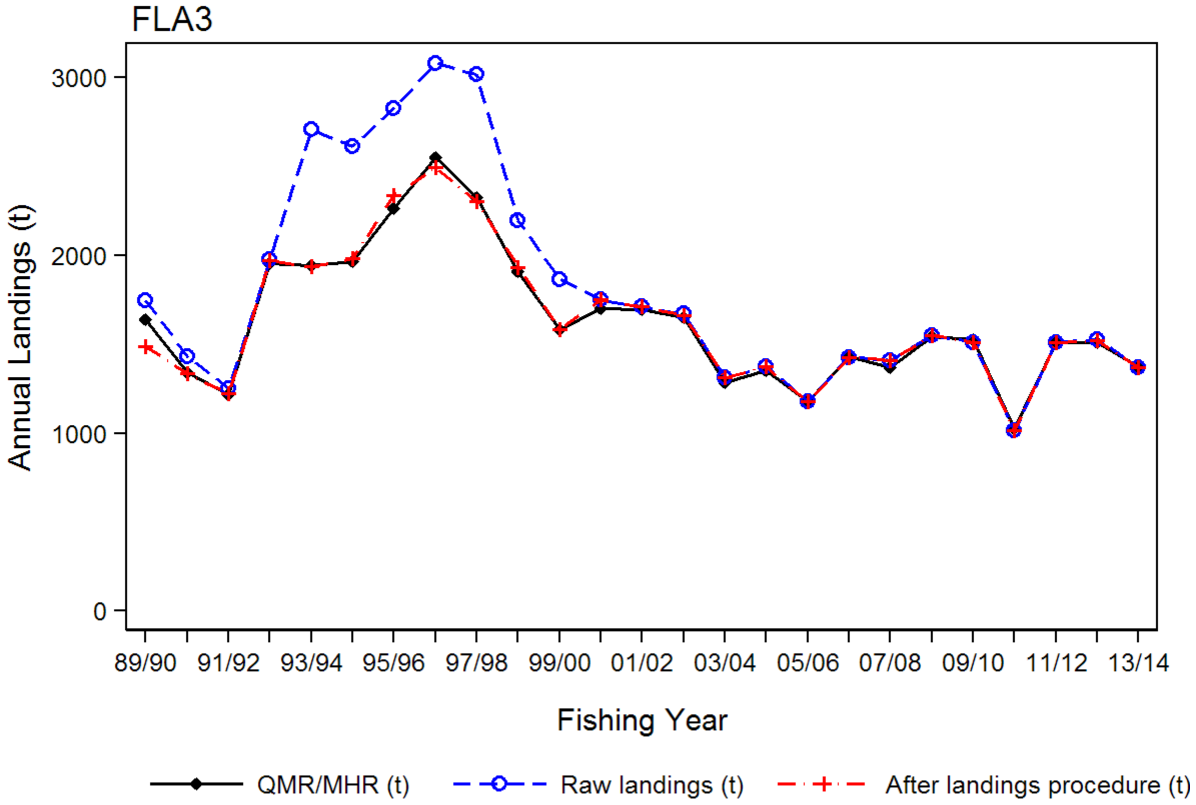


Figure C.1: Comparison of QMR/MHR annual total landings for FLA 3 showing two annual summaries: A: unedited or “raw” landings; and B: total landings after dropping the 79 trips identified at the selected QMA “minimum” quantile/ratio pairing defined in Table C.2.

Appendix D. IDENTIFYING "*SPLITTER*" TRIPS IN THE FLA 3 DATA SET

D.1 Introduction

At least 14 species codes are included in the in "catch-all" statutory reporting code FLA (see Table A.3). While fishers are required to report their flatfish landings using the generic code "FLA", they are requested to report their estimated catches using species-specific codes. Unfortunately, many fishers continue to use the generic "FLA" code to report their estimated catches as well. This Appendix describes a range of procedures used to identify trips and/or vessels which comply with the request to report estimated catches using a species code rather than the generic "FLA" code.

D.2 Description of procedure used to find "*splitters*" in FLA 3

Bentley (2010) described an algorithm used to detect "*splitters*" in the FLA 3 data set, based on vessels that reported at least 95% of the estimated catch with species-specific codes. The total catches from these vessels was then summed and compared to the overall FLA 3 catch. Figure D.1, taken from Bentley (2010), shows the proportion of qualifying catches peaking near 0.45 in 1996 and then gradually declines to near 0.30 by the end of the series.

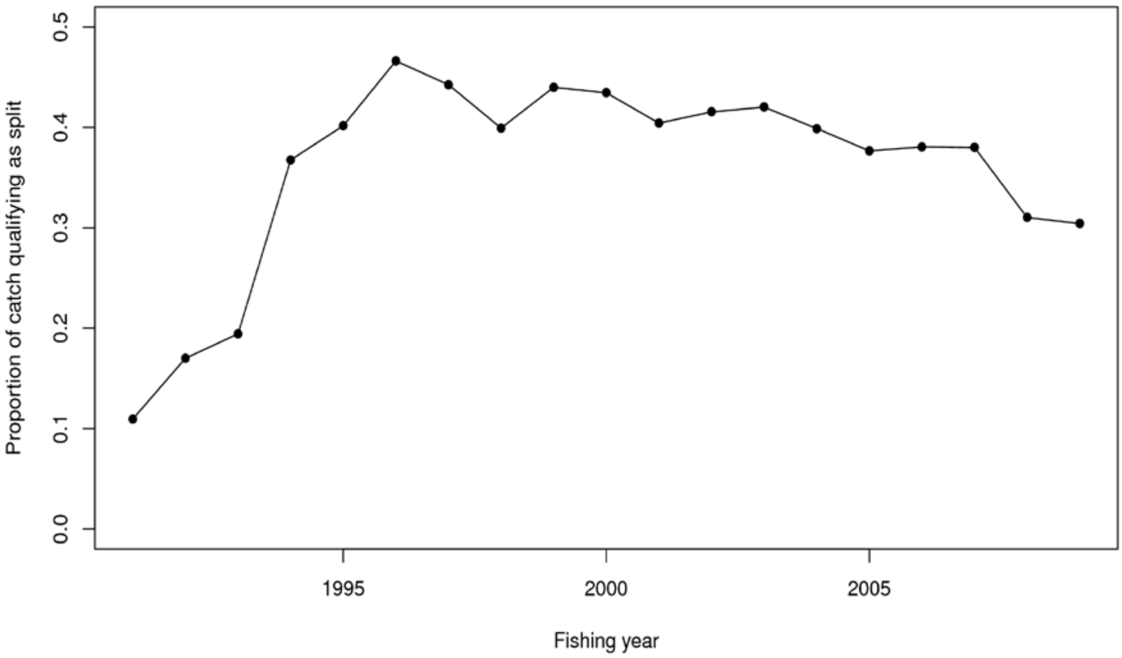


Figure D.1. Proportion of total FLA 3 catch assigned to "*splitters*" (from Bentley 2010).

The following algorithm was implemented to define "vessel" *splitters* for the current study:

a) starting with a FLA 3 file where every trip was reduced to a "trip-stratum" (Appendix A), every flatfish estimated catch record was identified based on a list of 19 possible species codes
b) summed the total estimated catch by species code (without the FLA code) for a vessel in a fishing year
c) summed all FLA species codes, including FLA, for each vessel/fishing year combination and calculated the annual proportion of the catch represented by the species code "FLA"
d) discarded vessel/fishing year combinations if "FLA">0.05 of the total FLA catch
e) defined "*splitters*" from the remaining vessel/fishing year combinations by counting the number of years that "FLA"≤0.05 of the total FLA catch, assigning 1, 2 and 3 year threshold definitions

"Trip" *splitters* were defined as follows:

f) any trip which landed FLA but did <u>not</u> use the FLA code to estimate catch

D.3 "*Splitter*" results

The proportion of the total FLA 3 landings represented by the three categories of vessel "*splitters*" started out near 0.2 at the beginning of the series, but increased to over 0.6 by the end of the series (Figure D.2). The "*trip splitter*" proportion was higher, starting above 0.4 in 1990–91 and ending above 0.8 by 2012–13 and 2013–14. These proportions were higher (generally exceeding 0.6) than those reported by Bentley (2010) (Figure D.1) and showed an increasing trend over time, rather than a decreasing trend. This plot begins in 1990–91 because only FLA was used for estimated catches by all fishers in 1989–90.

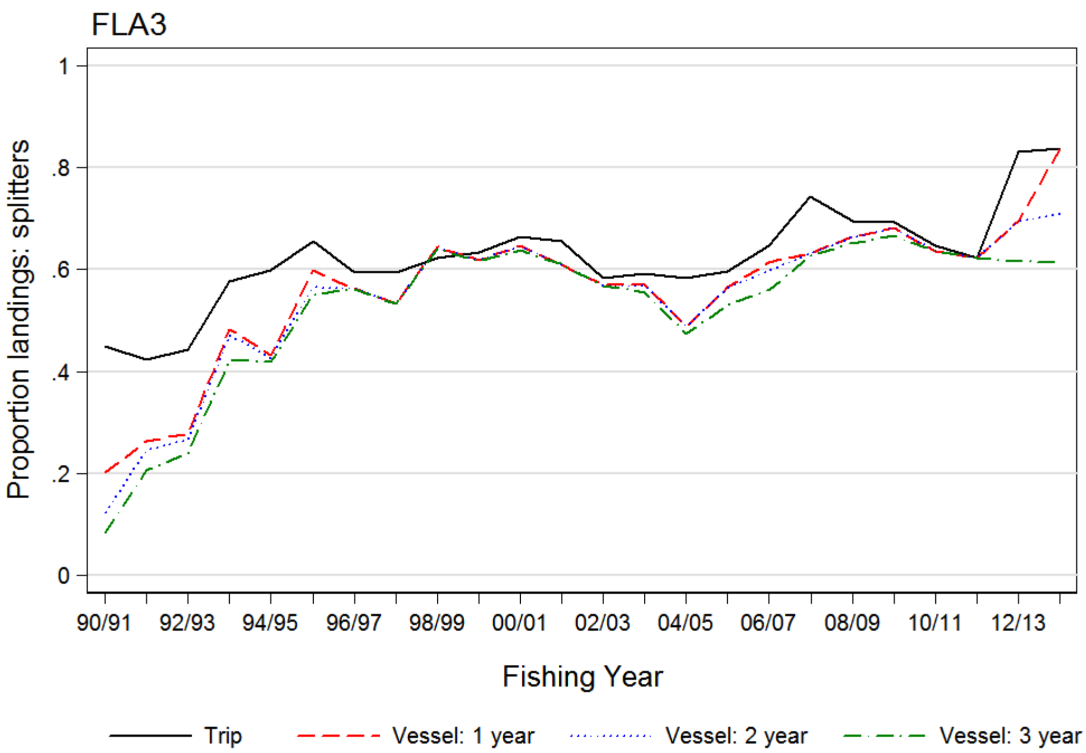


Figure D.2. Proportion of total FLA 3 landings represented by the four "*splitter*" definitions using the algorithms in Section D.2.

The unstandardised (geometric) mean CPUE was calculated by fishing year for the three primary FLA 3 species: ESO, LSO and SFL, using the four definitions of "*splitters*" (3 year cutoff thresholds and a trip definition that is independent of vessel). The differences in CPUE trends between the four definitions of "*splitters*" are small for ESO (Figure D.3) and LSO (Figure D.4), with the exception of the first four or five years in the early 1990s, where the "*trip splitter*" definition of "*splitters*" appears to be more stable than the other methods. The three vessel definitions of "*splitters*" appear to estimate similar SFL CPUE values (Figure D.5) but there is more divergence in CPUE from the "*trip splitter*" definition of "*splitters*" for this species than for ESO or LSO.

It is not clear which of these "*splitter*" definitions should be preferred. The "*trip splitter*" definition seems to be more stable in the first four or five years in the early 1990s compared to the vessel definition. Apart from this observation, all four definitions seem acceptable in terms of unstandardised CPUE performance. However, the "*trip splitter*" definition seems preferable, given the proportions shown in Figure D.2, because more catch at the beginning of the series is included, resulting in better overall performance.

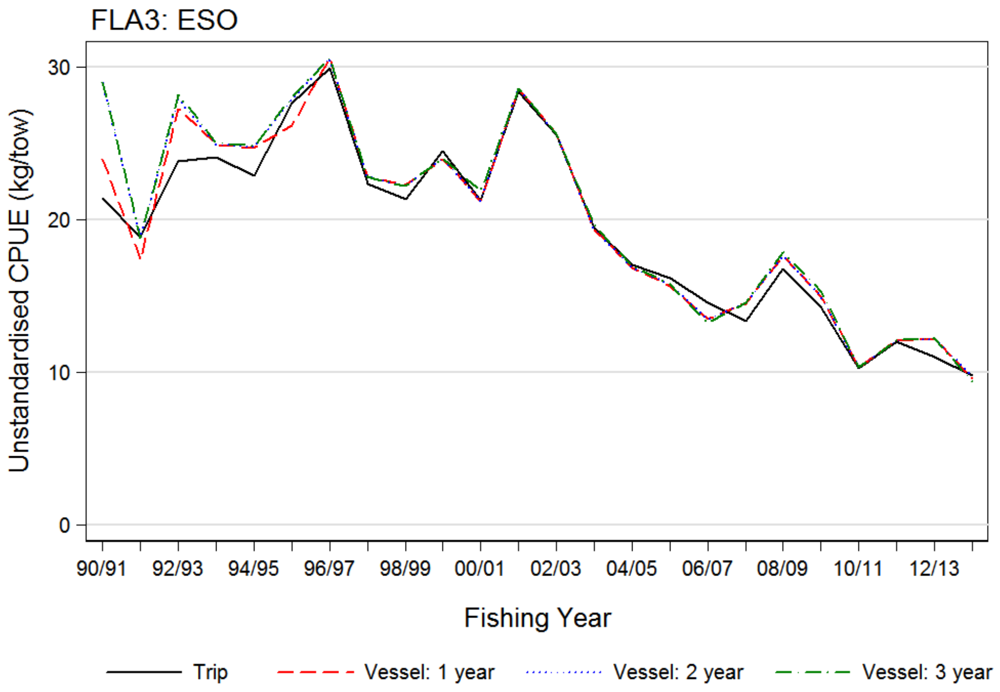


Figure D.3. Unstandardised (geometric mean) trip ESO CPUE by the four "*splitter*" definitions using the algorithms in Section D.2.

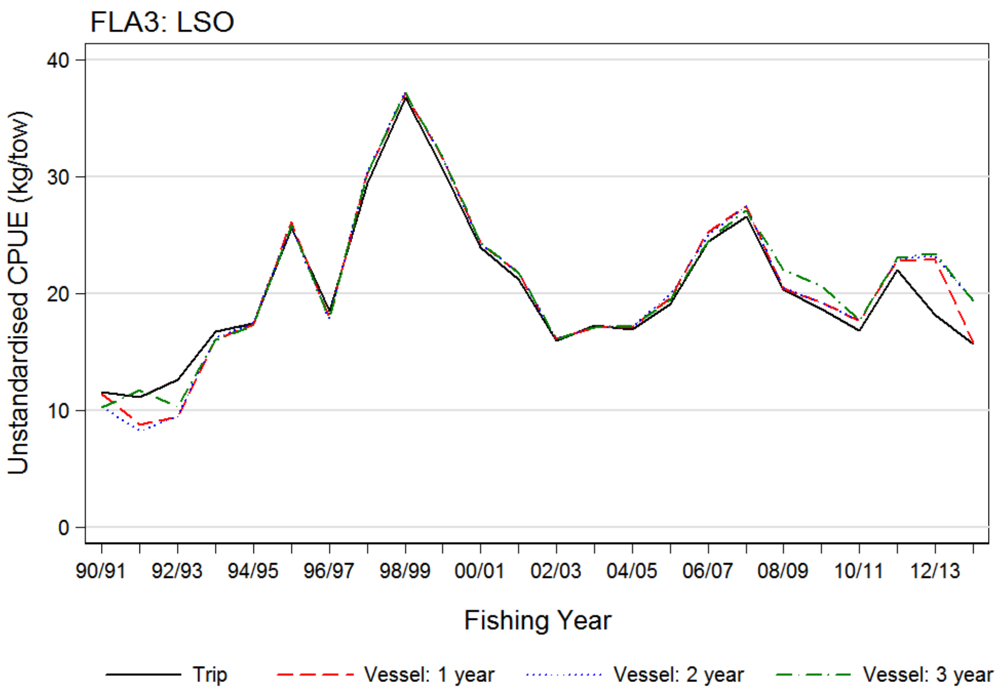


Figure D.4. Unstandardised (geometric mean) trip LSO CPUE by the four "*splitter*" definitions using the algorithms in Section D.2.

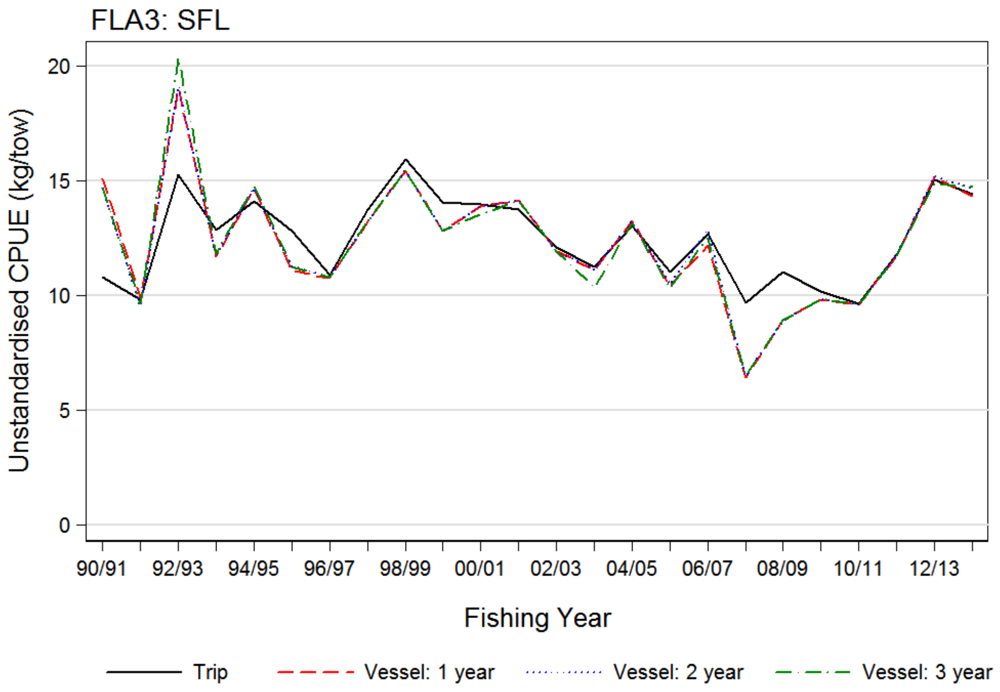


Figure D.5. Unstandardised (geometric mean) trip SFL CPUE by the four "*splitter*" definitions using the algorithms in Section D.2.

D.4 Representativeness of the four "*splitter*" data subsets

A comparison was made of the distributions of the complete FLA 3 dataset with the equivalent distribution from the four "*splitter*" datasets for each of five variables:

Variable

a) Landings (t) (continuous) (Figure D.2)
b) Duration (h) (continuous) (Figure D.7)
c) Tows (continuous) (Figure D.8)
d) Trip stratum date (continuous) (Figure D.9)
e) Statistical Area (categorical) (Figure D.10)

Four of these variables were continuous and one (statistical area) was categorical. The continuous distributions were split into approximately 100 equal (in terms of number of records) bins in every fishing year. The mean of each bin was calculated, then sorted into ascending order and the empirical cumulative proportional distribution was used to compare between distributions. For the categorical variable, a proportional cumulative distribution by fishing year was created for each dataset based on the annual mean for each category:

These comparisons show that all four of the "*splitter*" datasets are nearly equivalent, with only minor differences between them. The "*splitter*" datasets tend to differ from the "total" dataset in both effort variables (duration and tows) but not too severely (Figure D.7 and Figure D.8). There is evidence that the "*splitter*" vessels fish more in the southern statistical areas than on the east coast of the South Island, with the "*splitter*" distributions over-represented on the former and under-represented on the latter (Figure D.10). The "*splitter*" datasets are very close to the total FLA 3 data set for landings (Figure D.2) and timing of capture (Figure D.9). Given the equivalency of the four "*splitter*" definitions, this analysis will preferentially use the "*trip splitter*" dataset because it holds proportionately more catch than any of the three "*vessel splitter*" datasets.

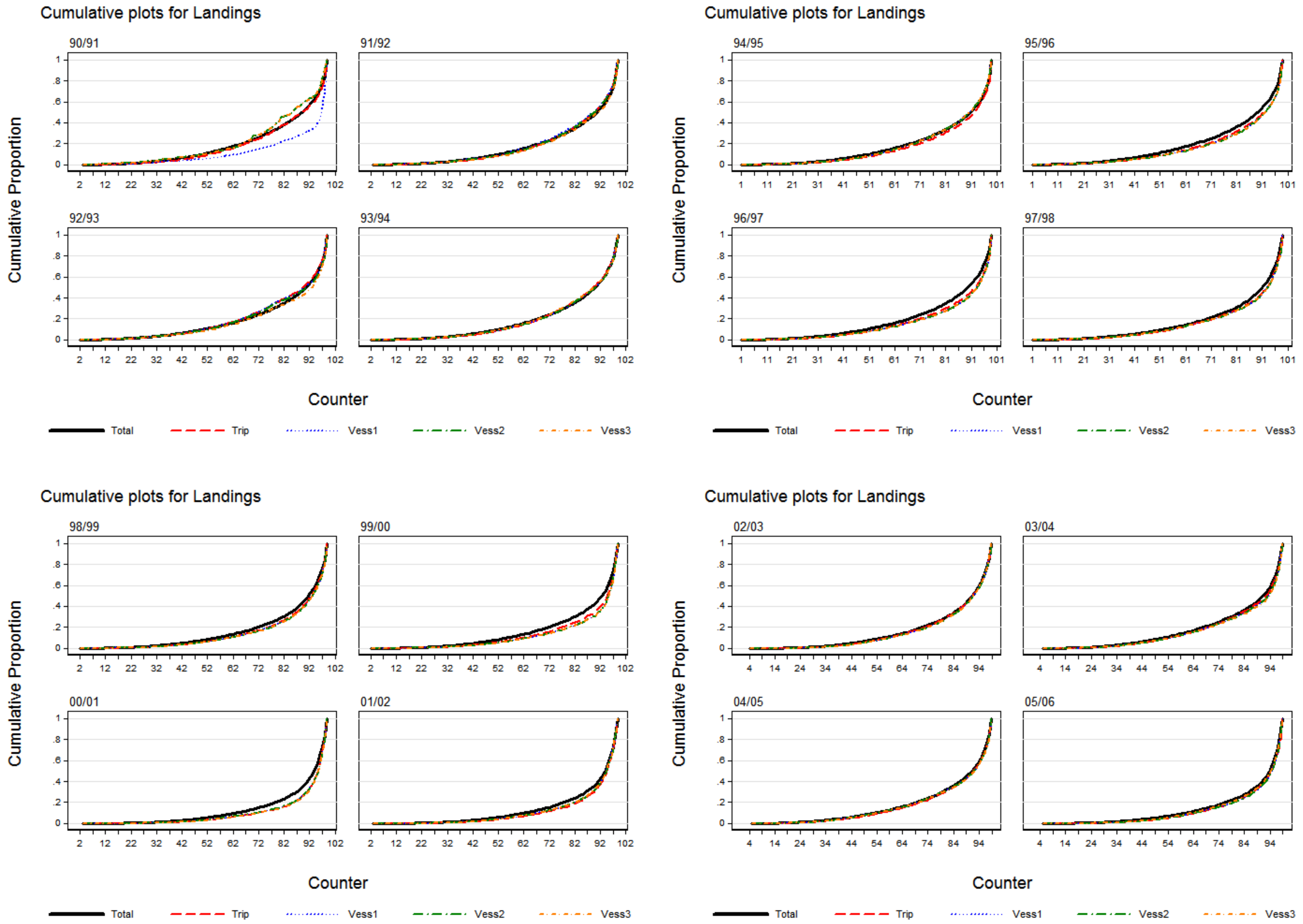


Figure D.6A: Cumulative proportional distributions of landings for the total FLA 3 dataset and the four "*splitter*" definitions using the algorithms in Section D.2 from 1990–91 to 2005–06.

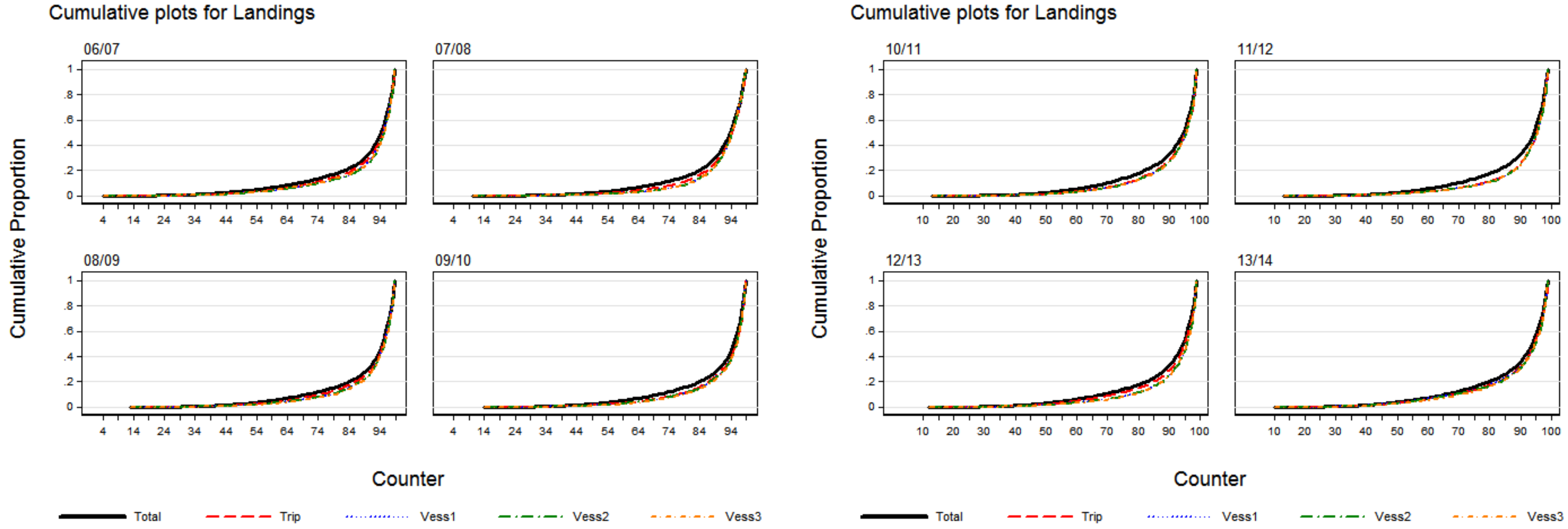


Figure D.6B: (cont.) 2006–07 to 2013–14.

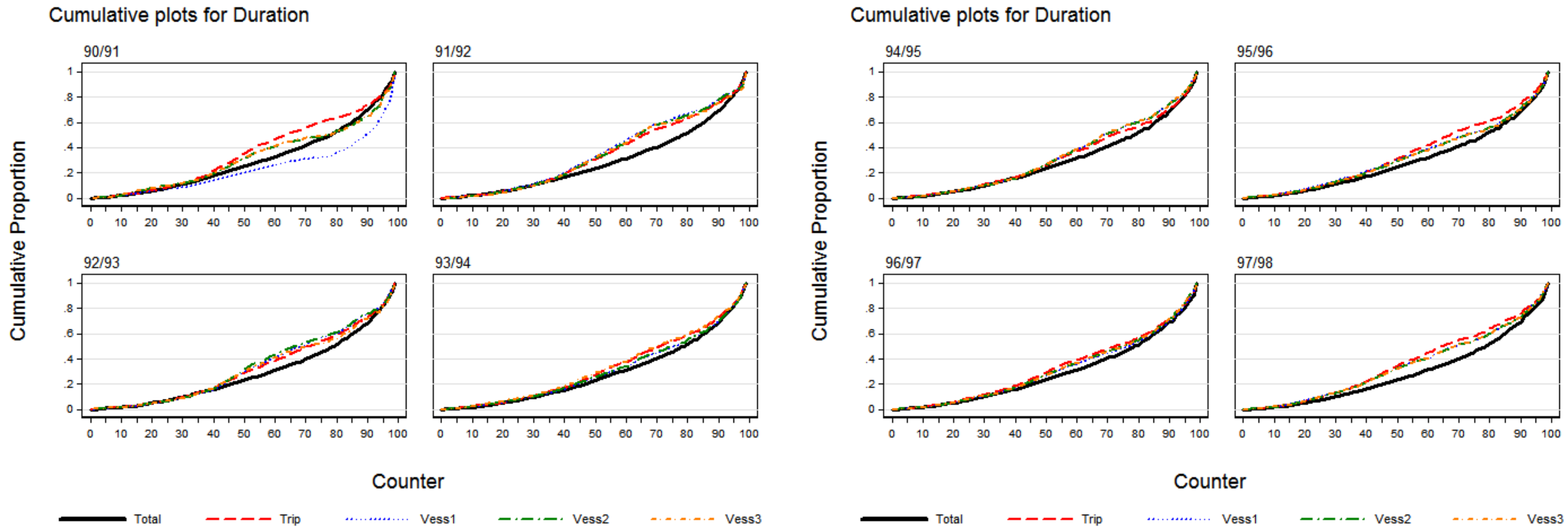


Figure D.7A: Cumulative proportional distributions of duration (hours towed) for the total FLA 3 dataset and the four "*splitter*" definitions using the algorithms in Section D.2 from 1990–91 to 1997–98.

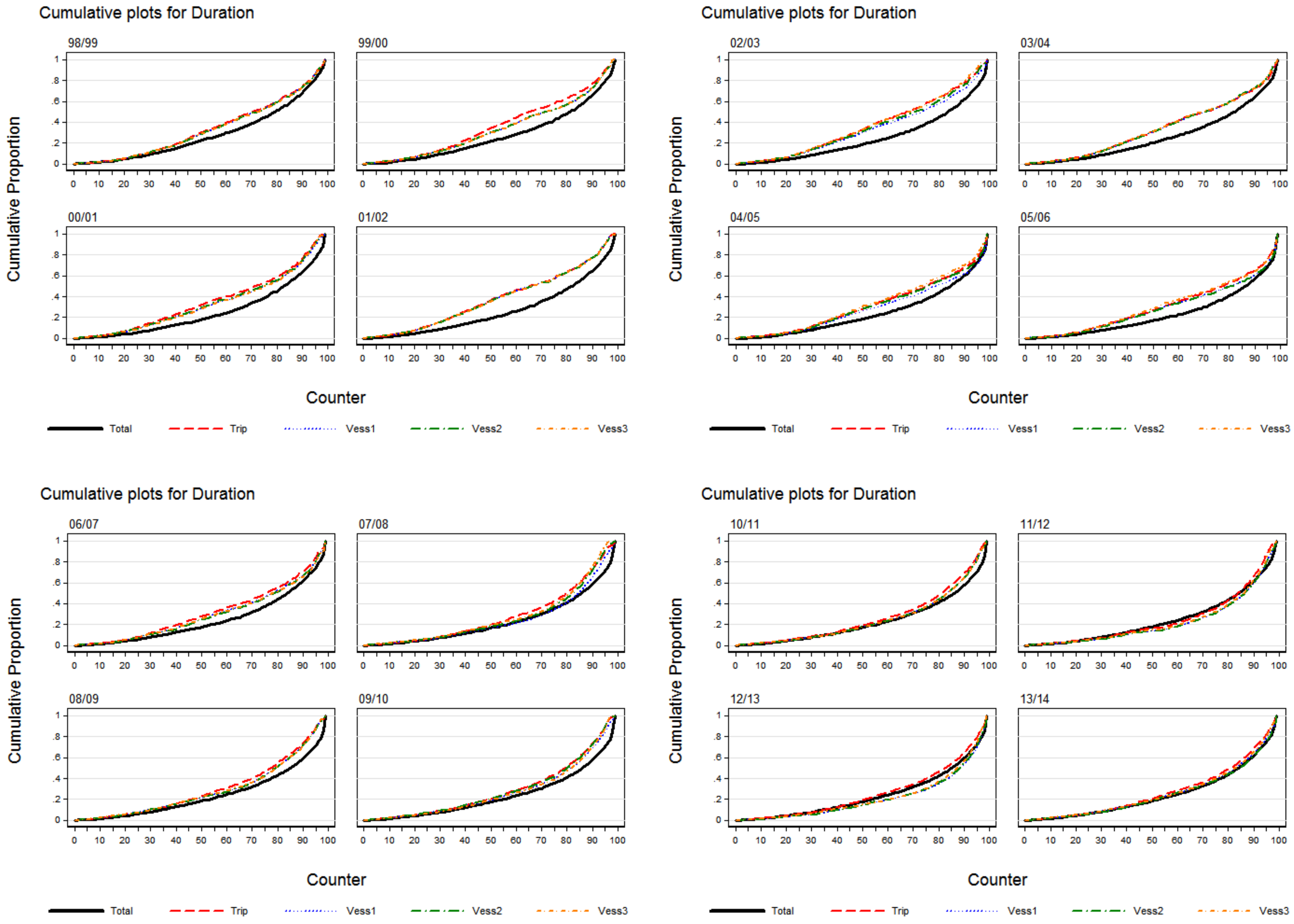


Figure D.7B: (cont.) 1998–99 to 2013–14.

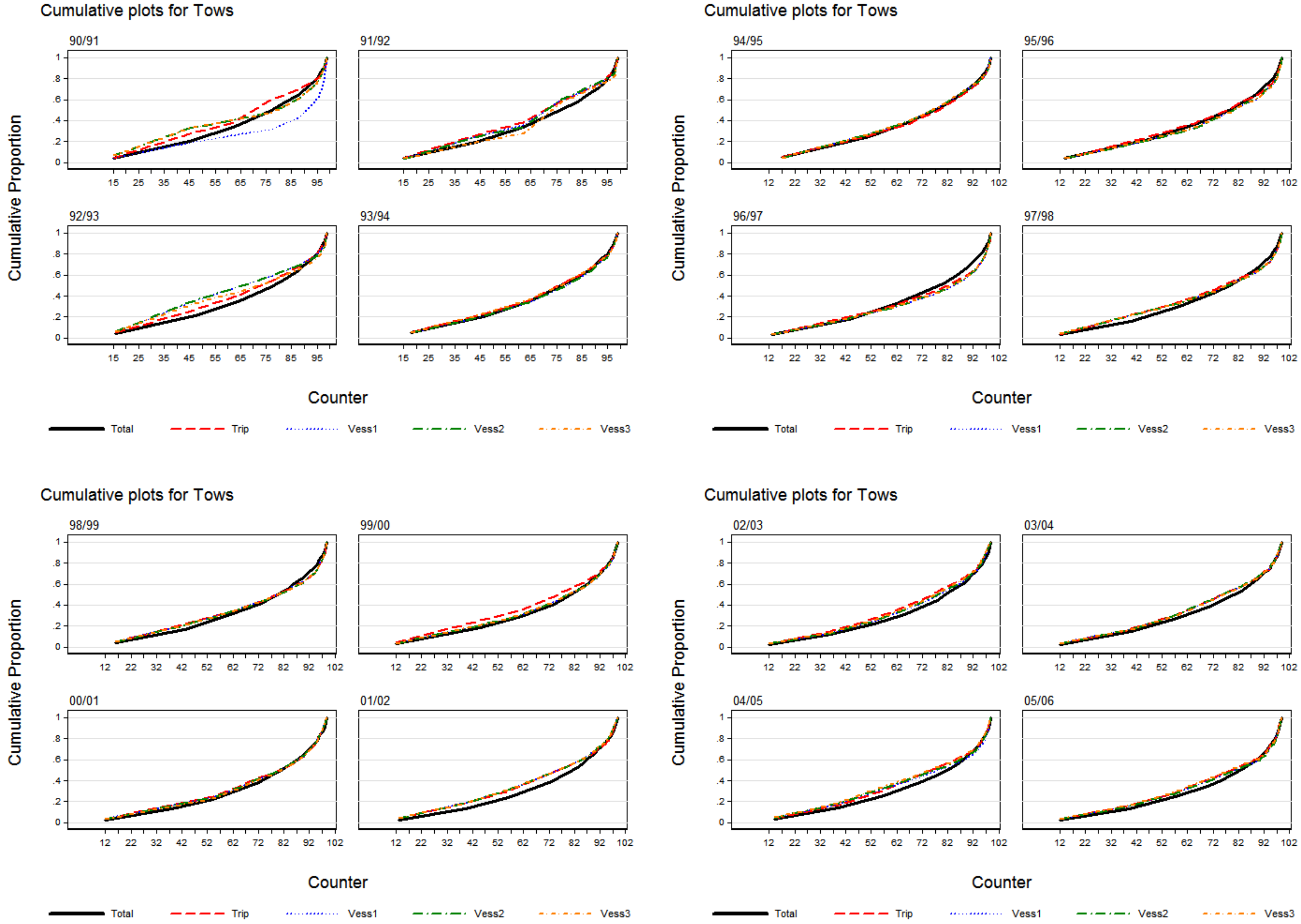


Figure D.8A: Cumulative proportional distributions of number tows for the total FLA 3 dataset and the four "*splitter*" definitions using the algorithms in Section D.2 from 1990–91 to 2005–06.

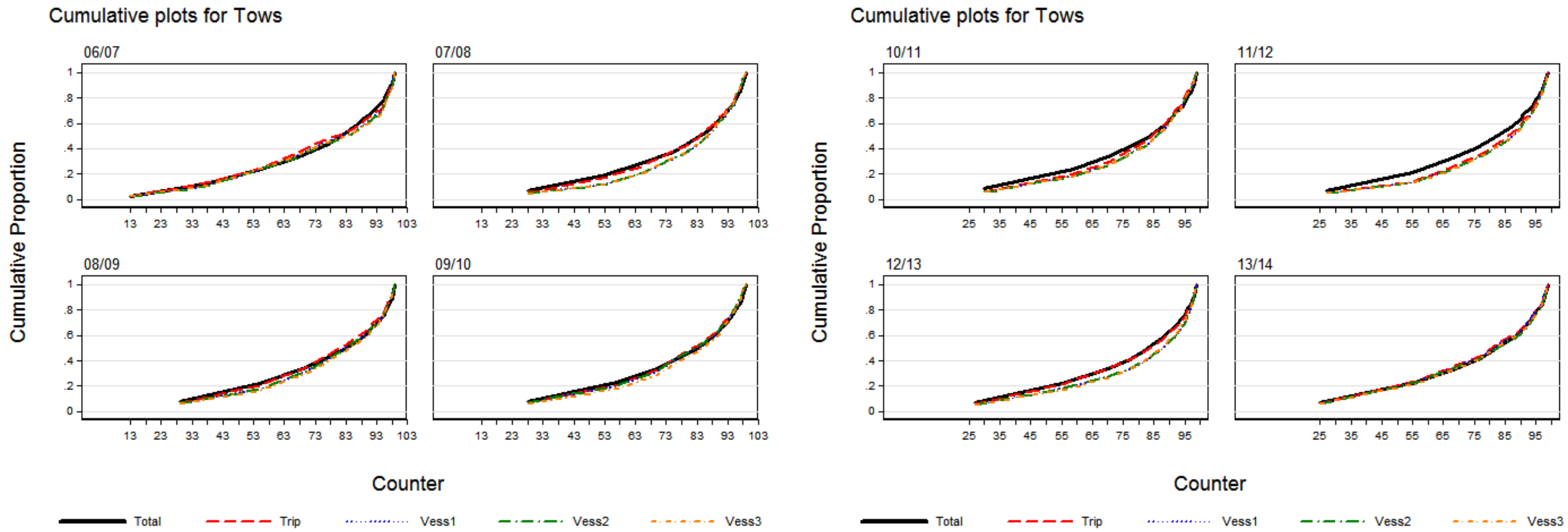


Figure D.8B: (cont.) 2007–08 to 2013–14.

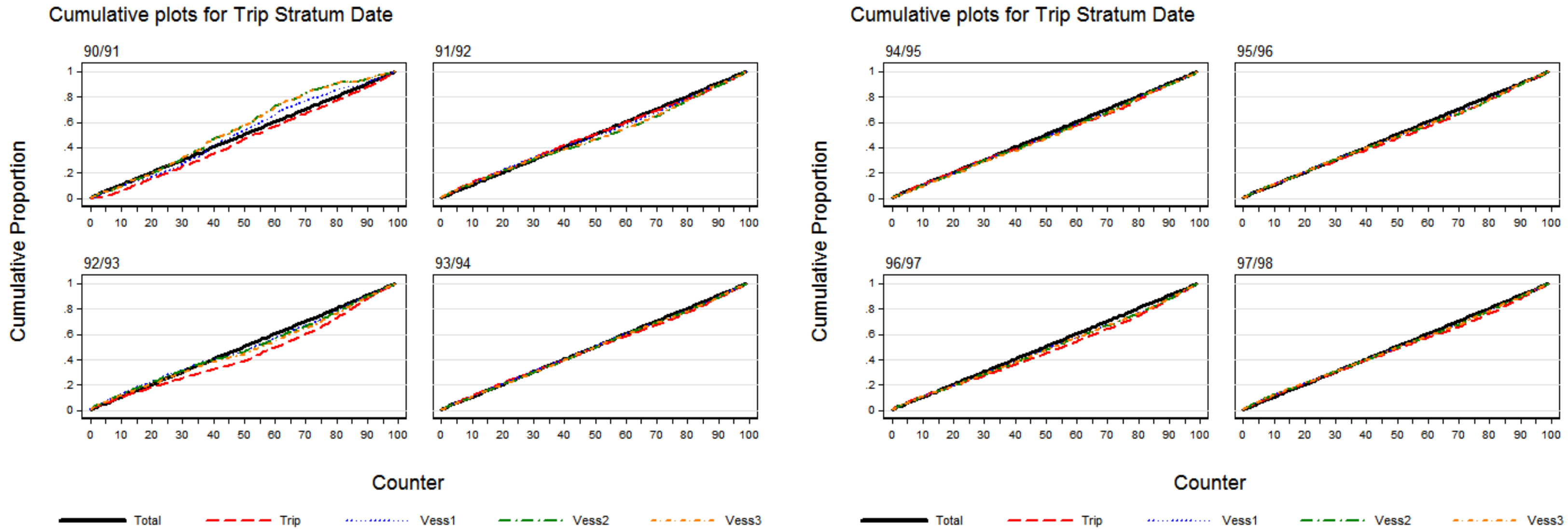


Figure D.9A: Cumulative proportional distributions of date recorded for the trip-stratum for the total FLA 3 dataset and the four *"splitter"* definitions using the algorithms in Section D.2 from 1990–91 to 1997–98.

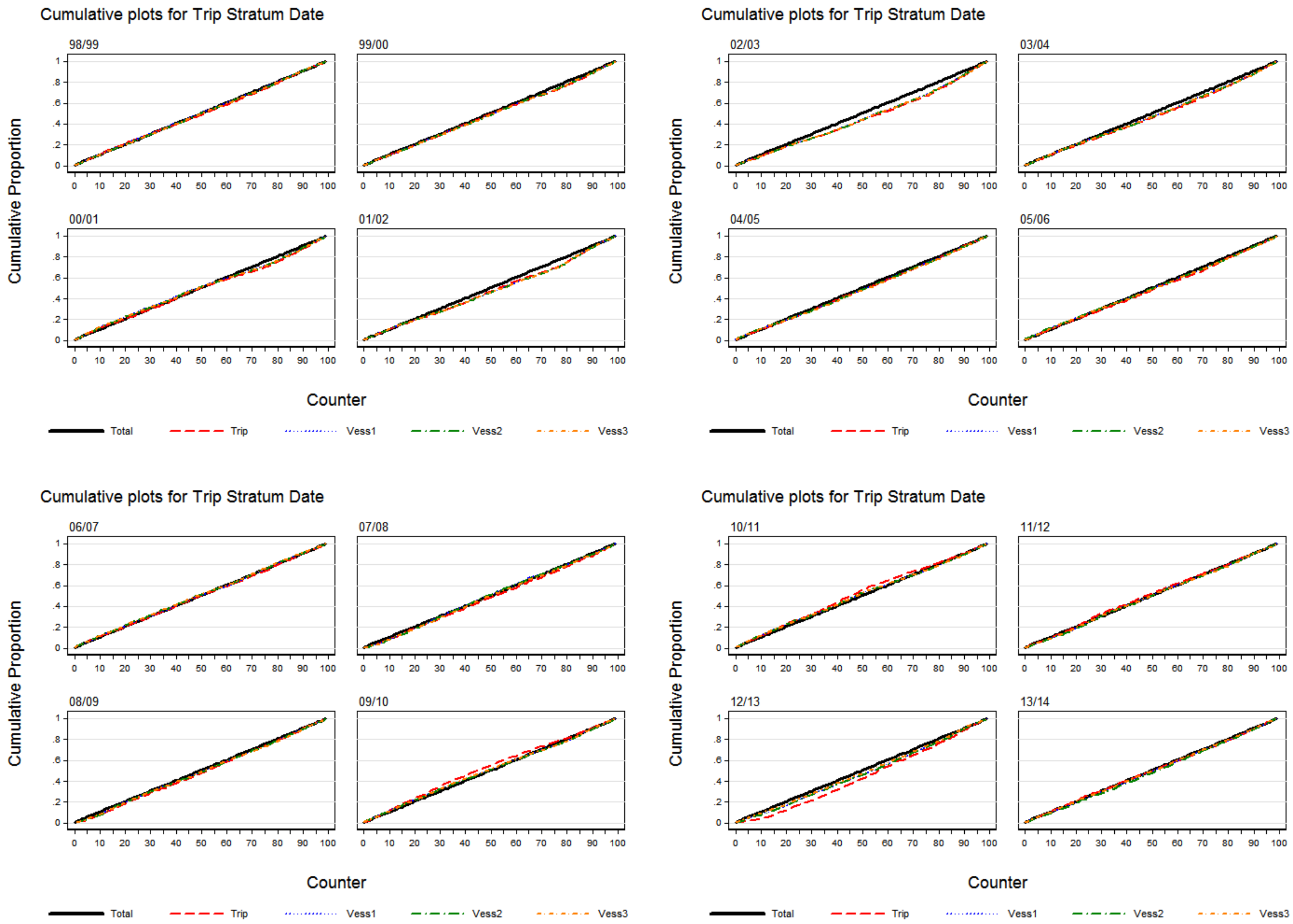


Figure D.9B: (cont.) 1998–99 to 2013–14.

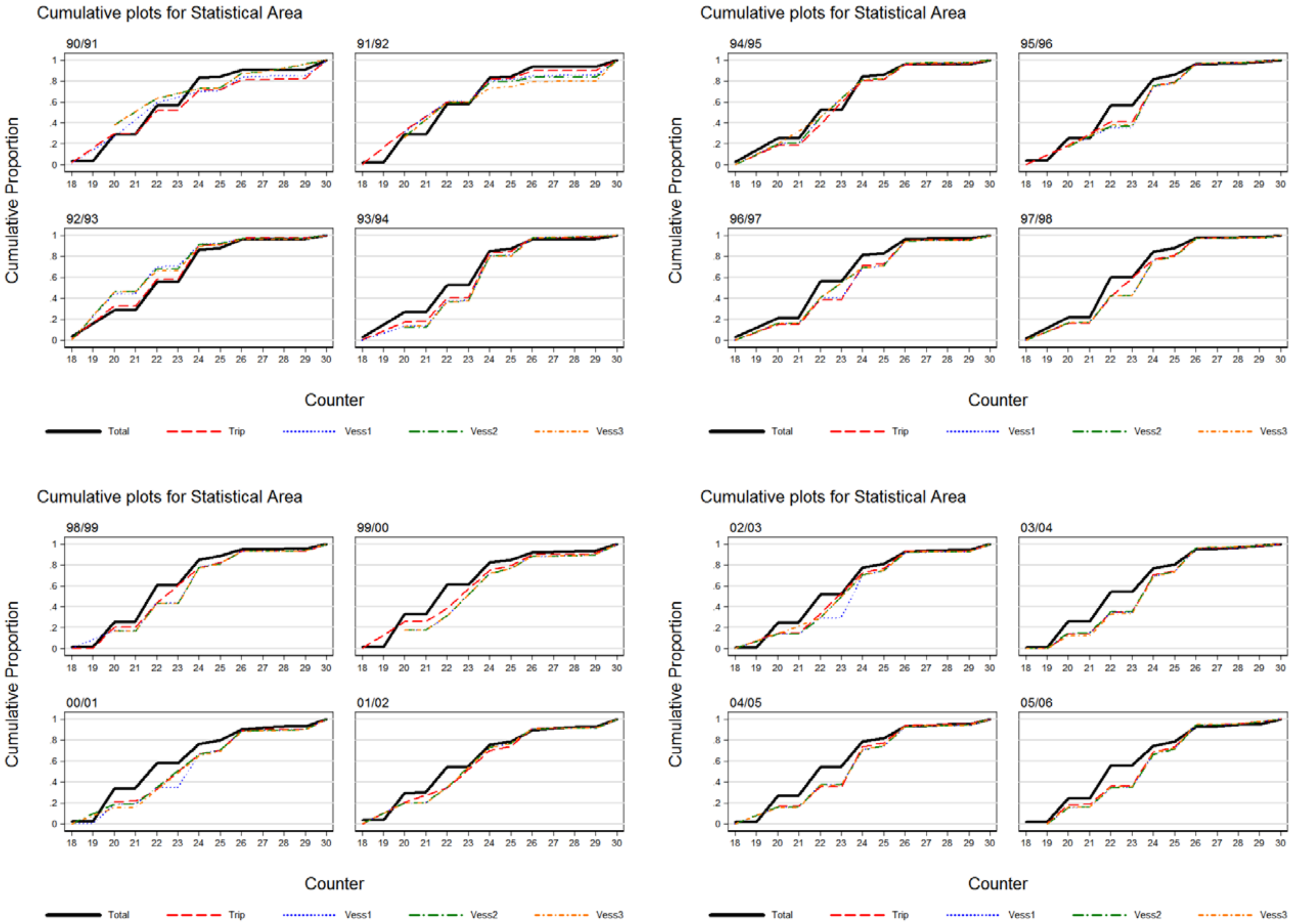


Figure D.10A: Cumulative proportional distributions of statistical area stratum for the total FLA 3 dataset and the four "*splitter*" definitions using the algorithms in Section D.2 from 1990–91 to 1997–98.

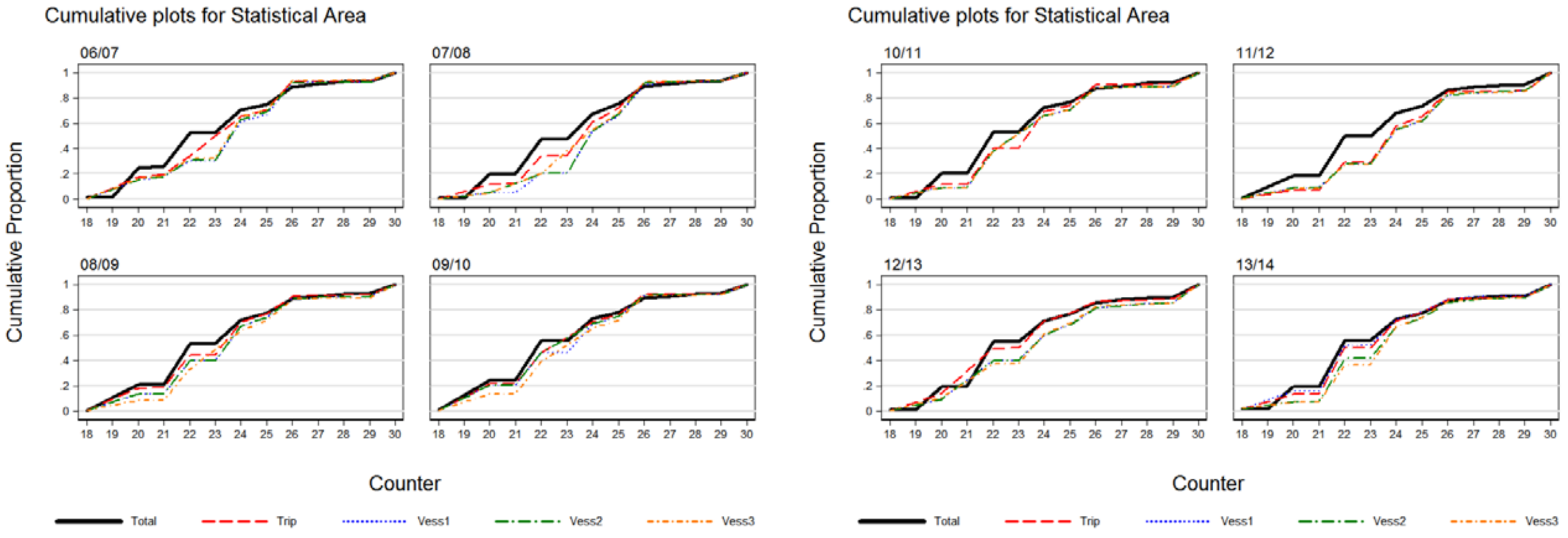


Figure D.10B: (cont.) 2006–07 to 2013–14.

Appendix E. KEY FLATFISH SPECIES SUMMARY CATCH TABLES

Table E.1: Distribution of fishing methods for FLA 3, LSO 3, ESO 3 and SFL 3 estimated catches (t), listed in descending order of importance, from 1990–91 to 2013–14. '–': no data.

Fishing	FLA 3					LSO 3					ESO 3					SFL 3				
Year	BT	SN	DS	OTH	Total	BT	SN	DS	OTH	Total	BT	SN	DS	OTH	Total	BT	SN	DS	OTH	Total
90/91	339.6	153.0	–	–	492.5	72.3	0.0	–	–	72.3	157.9	0.1	–	–	158.0	55.4	53.8	–	–	109.2
91/92	418.7	15.3	0.0	–	434.0	103.8	0.0	0.0	–	103.8	180.9	0.1	0.0	–	180.9	63.4	3.2	0.0	–	66.6
92/93	721.3	1.2	–	–	722.5	170.2	0.0	–	–	170.2	310.1	0.1	–	–	310.2	146.2	0.4	–	–	146.7
93/94	934.9	7.3	–	–	942.2	310.1	0.0	–	–	310.1	407.1	0.3	–	–	407.4	132.4	3.3	–	–	135.7
94/95	947.9	64.3	–	–	1 012.2	352.4	0.3	–	–	352.6	357.6	0.3	–	–	357.9	134.6	30.0	–	–	164.6
95/96	1 171.1	109.7	–	–	1 280.8	520.0	0.4	–	–	520.4	435.0	0.1	–	–	435.1	125.4	26.6	–	–	152.0
96/97	1 193.9	92.9	–	–	1 286.8	490.8	1.3	–	–	492.1	472.8	0.2	–	–	473.0	124.0	64.2	–	–	188.2
97/98	1 193.4	4.1	–	–	1 197.5	651.6	1.0	–	–	652.6	311.9	0.1	–	–	312.0	129.3	0.5	–	–	129.8
98/99	1 045.5	11.1	–	–	1 056.6	604.7	0.1	–	–	604.8	236.1	0.1	–	–	236.2	93.8	0.0	–	–	93.9
99/00	831.3	50.0	–	–	881.3	369.9	0.0	–	–	369.9	280.1	0.1	–	–	280.3	85.1	0.4	–	–	85.6
00/01	961.7	46.5	–	–	1 008.2	367.2	0.0	–	–	367.2	376.0	0.0	–	–	376.0	88.6	8.9	–	–	97.5
01/02	868.8	96.0	–	–	964.8	253.7	0.0	–	–	253.7	428.9	0.2	–	–	429.1	93.2	11.3	–	–	104.6
02/03	810.0	28.9	–	–	838.8	277.1	0.0	–	–	277.2	337.0	0.2	–	–	337.3	87.3	6.5	–	–	93.8
03/04	632.6	56.4	–	–	689.0	269.1	0.0	–	–	269.1	207.1	0.2	–	–	207.3	65.6	0.9	–	–	66.5
04/05	588.5	93.1	–	0.7	682.2	231.4	0.0	–	0.2	231.5	183.8	0.2	–	0.2	184.1	84.7	1.6	–	0.1	86.4
05/06	564.4	38.7	2.4	0.9	606.4	280.7	0.0	0.3	0.0	281.0	150.4	0.1	1.0	0.0	151.4	66.4	5.2	1.1	0.5	73.2
06/07	739.3	29.1	2.8	0.3	771.6	400.2	0.0	0.9	0.0	401.2	158.5	0.1	0.7	0.0	159.2	119.6	2.0	0.7	0.2	122.5
07/08	892.4	1.6	4.6	0.0	898.6	584.7	0.1	2.7	0.0	587.5	162.4	0.1	1.4	0.0	163.9	65.2	0.2	0.3	0.0	65.7
08/09	954.8	2.5	–	–	957.2	525.1	0.0	–	–	525.1	244.7	0.2	–	–	244.9	96.6	0.6	–	–	97.2
09/10	899.3	20.9	–	–	920.2	550.9	0.0	–	–	551.0	177.3	0.0	–	–	177.3	88.2	17.0	–	–	105.2
10/11	515.4	42.0	–	–	557.4	304.9	0.0	–	–	305.0	80.2	0.0	–	–	80.2	65.6	28.1	–	–	93.7
11/12	754.6	46.6	–	–	801.1	408.1	0.1	–	–	408.2	149.2	0.0	–	–	149.2	108.7	11.2	–	–	120.0
12/13	1 011.4	47.0	13.3	0.6	1 072.4	497.8	0.0	0.0	0.0	497.9	222.2	0.0	0.1	0.0	222.4	160.0	7.9	13.2	0.1	181.2
13/14	901.5	72.4	19.8	0.1	993.8	389.2	0.0	0.0	0.0	389.3	206.1	0.0	0.0	0.0	206.2	185.3	12.8	19.6	0.1	217.8
Total	19 891.8	1 130.6	42.9	2.7	21 068.0	8 985.9	3.6	4.0	0.2	8 993.6	6 233.4	2.9	3.1	0.2	6 239.6	2 464.8	296.7	35.0	1.0	2 797.4

Table E.2: Distribution of bottom trawl FLA 3, LSO 3, ESO 3 and SFL 3 estimated catches (t) for Statistical Area groupings (see Section 2.5.1) from 1990–91 to 2013–14. ‘–’: no data. Annual totals by species can be found in Table E.1.

	FLA 3									LSO 3								
Year	018	020	022	024	026	025	030–032	027–029	Other	018	020	022	024	026	025	030–032	027–029	Other
90/91	6.4	89.9	85.8	52.8	55.8	1.0	47.0	0.8	0.0	2.4	10.0	6.9	22.1	28.6	0.6	1.5	0.2	0.0
91/92	0.4	152.5	90.7	54.0	84.1	4.0	32.1	0.1	0.7	0.3	12.7	7.6	26.3	54.3	1.1	0.8	0.1	0.6
92/93	4.8	230.2	170.8	141.3	114.2	15.9	41.1	3.0	0.0	2.5	29.2	20.3	57.1	53.0	2.6	5.0	0.6	0.0
93/94	0.7	156.6	166.8	314.2	230.0	17.4	48.7	0.4	0.2	0.4	4.8	14.6	176.2	107.6	3.0	3.2	0.1	0.2
94/95	2.6	137.2	139.8	253.8	319.5	19.4	72.2	3.4	–	0.8	12.0	7.1	123.4	198.0	5.4	4.0	1.6	–
95/96	14.6	159.0	156.2	226.3	472.0	71.9	48.9	22.2	0.1	1.0	3.2	6.3	110.5	343.4	31.9	13.3	10.3	0.1
96/97	7.8	129.1	155.1	239.0	473.3	52.7	123.4	13.4	0.1	2.2	3.5	9.7	104.6	315.9	31.9	16.7	6.3	0.0
97/98	3.6	84.1	166.2	295.5	432.1	107.5	89.7	14.6	–	1.8	7.0	13.6	183.5	352.3	72.0	13.1	8.2	–
98/99	6.2	98.0	132.6	276.1	262.7	99.9	160.0	10.0	–	0.8	0.8	5.7	220.9	223.7	79.7	65.0	8.1	–
99/00	0.6	110.0	52.0	171.8	207.4	61.2	206.9	21.3	0.0	0.3	1.8	2.1	112.4	158.6	43.3	46.2	5.3	0.0
00/01	1.2	66.6	39.4	178.7	374.1	61.2	230.0	10.4	0.0	0.0	1.9	3.7	79.6	196.7	43.7	35.3	6.3	0.0
01/02	0.1	54.5	44.3	219.8	329.1	35.9	182.2	2.8	0.2	0.0	0.5	1.7	70.5	145.7	16.0	17.2	2.1	0.1
02/03	0.0	73.8	70.3	229.6	285.0	34.5	111.6	1.9	3.2	0.0	0.7	2.4	87.3	162.7	14.9	8.1	0.9	0.0
03/04	0.5	56.0	76.1	150.8	276.1	36.4	36.0	0.5	0.1	0.0	0.5	1.8	60.1	181.9	22.1	2.6	0.1	0.0
04/05	0.3	62.3	79.2	149.5	201.8	36.8	53.9	0.9	3.8	0.0	1.9	3.6	79.0	117.6	22.1	6.7	0.3	0.0
05/06	0.0	54.5	38.1	77.1	255.8	70.9	64.0	2.2	1.9	0.0	1.2	4.9	44.6	162.2	58.7	7.3	1.5	0.2
06/07	0.0	53.2	23.3	76.1	339.3	84.8	159.9	0.2	2.5	0.0	2.2	2.1	51.3	263.7	68.0	12.6	0.1	0.3
07/08	0.1	28.5	40.9	91.7	342.4	307.4	77.8	2.5	1.2	0.1	5.0	3.9	44.2	237.4	265.7	26.6	1.7	0.1
08/09	0.1	38.8	59.2	117.1	377.5	166.4	193.5	1.9	0.2	0.0	7.4	6.3	68.3	251.1	134.6	56.0	1.3	0.0
09/10	0.1	52.4	69.6	101.7	462.8	109.3	102.5	0.8	0.1	0.1	4.1	4.6	59.8	353.5	89.3	38.8	0.7	0.0
10/11	0.1	16.4	61.3	89.5	247.7	31.3	66.9	1.8	0.4	0.0	4.0	3.1	58.0	197.4	27.2	13.4	1.8	0.0
11/12	0.1	20.1	56.6	98.6	342.8	69.6	166.7	0.0	0.1	0.0	1.4	1.8	59.5	254.5	51.5	39.5	0.0	0.0
12/13	0.1	50.4	125.9	125.2	324.7	122.1	261.0	1.0	1.0	0.1	4.1	5.6	79.4	231.8	112.8	63.6	0.3	0.2
13/14	2.8	34.6	137.2	98.3	306.3	109.4	208.6	3.1	1.2	0.2	2.9	3.4	61.1	175.2	93.2	50.4	2.8	0.1
Total	53.0	2 008.6	2 237.5	3 828.4	7 116.5	1 726.7	2 784.5	119.4	17.2	13.1	122.9	142.8	2 039.6	4 766.6	1 291.2	547.1	60.7	2.0

Table E.2: (cont.)

	ESO 3									SFL 3								
Year	018	020	022	024	026	025	030–032	027–029	Other	018	020	022	024	026	025	030–032	027–029	Other
90/91	3.5	48.7	51.7	19.9	13.6	0.1	20.1	0.2	0.0	0.1	17.8	11.2	6.5	6.8	0.0	12.7	0.2	0.0
91/92	0.0	77.0	51.5	17.8	18.9	2.1	13.6	0.0	0.0	0.1	22.9	13.8	7.0	7.7	0.5	11.3	0.0	0.1
92/93	2.0	102.3	58.7	63.5	50.0	12.3	19.2	2.1	0.0	0.2	61.8	51.3	13.8	7.5	0.5	11.1	0.0	0.0
93/94	0.3	69.1	96.2	109.4	103.0	7.3	21.6	0.1	0.0	0.0	48.0	32.4	16.7	13.5	6.0	15.8	0.0	0.0
94/95	1.6	58.2	64.6	87.2	103.0	11.5	30.7	0.9	–	0.1	32.7	42.1	25.4	10.2	1.3	22.9	0.0	–
95/96	12.0	89.9	90.5	88.9	97.1	29.7	16.5	10.3	0.0	0.9	40.5	44.2	13.8	17.0	3.9	4.5	0.6	0.0
96/97	5.0	81.6	97.4	85.8	120.9	16.2	60.7	5.0	0.0	0.0	27.0	33.0	22.9	17.0	2.5	21.4	0.2	0.1
97/98	1.6	42.2	77.9	65.2	55.4	24.5	40.6	4.5	–	0.0	22.2	57.2	21.0	10.0	5.7	12.8	0.5	–
98/99	4.6	52.1	61.7	26.8	27.2	11.4	51.1	1.2	–	0.0	32.7	34.3	9.1	5.0	3.9	8.9	0.0	–
99/00	0.3	50.5	34.2	40.4	31.6	7.0	103.6	12.5	0.0	0.0	35.8	7.9	12.1	9.7	2.4	16.7	0.6	0.0
00/01	1.1	18.5	13.7	55.9	152.1	9.1	122.0	3.5	0.0	0.0	28.4	12.3	7.0	14.4	0.5	25.9	0.1	0.0
01/02	0.1	18.1	16.6	121.3	159.4	11.1	101.6	0.7	0.1	0.0	24.6	11.9	12.0	10.8	2.3	31.5	0.1	0.0
02/03	0.0	20.8	51.9	115.4	101.8	4.3	42.9	0.0	0.0	0.0	23.9	9.3	13.4	8.4	5.8	25.6	0.0	0.8
03/04	0.5	13.3	42.4	60.8	79.2	2.6	8.1	0.1	0.0	0.0	20.4	12.9	7.4	6.7	1.2	16.9	0.0	0.1
04/05	0.0	17.2	37.7	47.3	65.2	3.2	13.2	0.0	0.0	0.0	21.5	23.8	5.1	13.5	1.4	19.3	0.0	0.0
05/06	0.0	17.1	23.4	20.2	70.6	2.3	16.8	0.0	0.0	0.0	16.5	4.4	8.4	16.4	3.3	17.4	0.0	0.0
06/07	0.0	18.3	9.6	9.7	55.4	7.3	57.7	0.0	0.5	0.0	19.5	7.5	9.9	12.2	8.7	61.4	0.1	0.2
07/08	0.0	5.4	12.8	22.8	72.9	22.7	25.3	0.4	0.1	0.0	7.9	15.8	6.5	14.7	8.5	11.7	0.0	0.0
08/09	0.0	8.5	16.0	30.0	100.2	22.2	67.5	0.5	0.0	0.0	9.0	25.8	7.8	12.8	3.3	37.8	0.0	0.0
09/10	0.0	11.3	34.2	23.4	74.8	10.5	22.9	0.1	0.0	0.0	23.1	19.8	9.6	15.1	5.4	15.2	0.0	0.0
10/11	0.0	3.6	24.9	12.2	27.4	0.8	11.2	0.0	0.0	0.0	4.9	25.7	11.0	10.4	2.3	11.2	0.0	0.0
11/12	0.0	5.1	18.5	16.7	55.8	7.6	45.4	0.0	0.0	0.0	8.5	25.9	13.2	20.8	5.7	34.7	0.0	0.0
12/13	0.0	10.1	31.7	20.9	57.9	2.9	98.4	0.4	0.0	0.0	24.0	69.1	14.6	13.2	1.8	37.0	0.2	0.1
13/14	1.5	7.9	30.5	11.7	76.1	6.2	72.1	0.2	0.0	0.6	13.3	78.8	12.9	39.7	6.7	33.2	0.0	0.1
Total	34.1	847.0	1 048.4	1 173.4	1 769.5	235.0	1 082.7	42.7	0.7	2.1	586.8	670.5	287.0	313.6	83.6	517.0	2.7	1.5

Table E.3: Distribution of bottom trawl FLA 3, LSO 3, ESO 3 and SFL 3 estimated catches (t) by month from 1990–91 to 2013–14. Annual totals by species can be found in Table E.1

Fishing												FLA 3												LSO 3
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
90/91	10.9	37.2	20.7	41.0	27.5	35.7	29.4	30.0	13.9	40.5	32.3	20.5	1.6	9.4	4.9	14.2	8.2	11.2	4.5	5.8	2.6	5.3	2.2	2.4
91/92	49.1	35.7	39.5	64.4	54.1	44.3	43.0	24.4	18.5	16.9	10.9	17.8	11.0	9.0	13.6	15.3	15.3	6.8	18.2	2.7	2.5	2.0	2.6	4.8
92/93	44.9	63.0	43.7	45.2	57.4	58.4	60.1	79.1	58.6	109.4	70.3	31.1	11.2	22.4	15.4	5.8	12.6	16.5	19.0	16.8	15.0	13.9	13.2	8.2
93/94	117.0	99.3	86.2	110.3	95.9	52.0	88.7	66.0	44.1	62.2	63.6	49.5	55.2	37.3	28.9	40.1	45.7	15.9	40.3	25.5	6.9	5.2	4.7	4.5
94/95	84.7	121.0	117.9	91.9	102.1	65.1	60.0	95.6	45.4	35.4	70.6	58.3	43.3	77.0	43.6	30.3	44.3	18.7	33.3	43.6	4.6	4.9	3.1	5.6
95/96	117.5	127.4	93.8	98.1	114.8	122.7	110.6	92.7	54.1	58.1	80.4	101.0	64.4	78.9	56.2	51.1	68.3	59.9	58.6	29.6	15.2	4.8	7.0	26.1
96/97	115.7	103.7	91.5	96.9	90.4	100.6	104.3	127.0	78.1	105.4	75.5	104.7	64.5	61.3	46.9	45.9	21.4	43.0	57.6	78.5	24.6	10.3	4.3	32.5
97/98	167.3	117.6	115.0	129.5	141.7	103.4	62.9	57.9	65.7	77.9	81.6	72.8	102.1	71.9	72.1	75.2	98.2	66.1	35.0	27.9	22.2	19.7	26.3	34.8
98/99	86.8	172.6	79.8	111.9	117.3	66.8	78.8	89.6	42.3	53.6	82.7	63.3	46.9	113.8	61.2	75.7	77.3	33.0	53.9	55.2	18.0	14.8	23.3	31.6
99/00	70.3	90.8	65.7	120.0	69.6	88.2	46.5	76.9	40.5	70.5	46.4	45.9	44.4	56.9	35.3	55.4	38.1	44.5	20.9	30.1	11.7	14.0	9.9	8.7
00/01	79.6	75.5	84.2	91.1	159.0	117.0	65.3	43.7	66.2	36.6	90.7	52.7	41.7	35.1	41.7	26.4	75.8	41.0	26.2	17.7	17.0	6.6	17.1	20.9
01/02	52.6	98.8	67.6	95.0	67.8	108.1	99.8	40.7	29.9	85.4	44.5	78.6	14.8	27.9	27.3	46.3	28.0	28.1	39.8	11.8	6.2	10.7	2.6	10.3
02/03	73.4	91.9	57.2	77.1	99.5	90.1	40.9	64.3	50.7	55.6	70.0	39.3	19.5	45.9	23.9	28.8	49.8	37.7	12.6	24.1	16.7	9.7	2.9	5.6
03/04	61.1	61.3	48.2	51.2	34.0	64.0	69.0	67.1	50.2	45.4	26.3	54.9	29.2	27.6	25.5	26.9	21.7	40.6	33.0	16.4	15.5	17.2	8.6	6.7
04/05	60.6	46.0	28.9	85.7	65.5	38.7	53.8	54.9	28.0	33.3	47.6	45.5	20.9	17.9	9.4	43.3	33.3	16.4	18.3	21.7	12.2	13.7	6.9	17.4
05/06	51.0	37.2	53.9	59.7	61.5	56.1	35.7	36.3	30.9	29.1	57.8	55.2	35.5	21.6	27.6	24.5	40.5	26.5	10.1	19.4	11.1	16.5	21.0	26.5
06/07	52.1	55.3	48.8	92.6	81.8	57.9	54.0	57.1	46.1	72.1	49.5	71.9	27.6	25.5	24.8	70.5	65.5	44.4	27.0	32.5	30.1	19.9	4.8	27.6
07/08	57.6	127.7	67.4	75.2	57.8	84.0	69.5	79.9	61.7	50.7	70.8	90.2	39.8	88.6	37.9	51.0	38.2	53.6	43.4	44.5	36.9	36.2	52.5	62.2
08/09	83.3	95.0	74.8	87.6	78.8	102.9	62.9	57.0	37.3	50.5	121.7	103.0	57.2	45.7	49.2	64.2	52.6	70.9	28.8	25.2	10.9	23.2	62.4	34.8
09/10	63.7	58.8	116.2	118.7	123.7	79.9	50.0	77.0	28.9	50.2	81.1	51.0	36.5	22.4	69.1	84.4	83.7	59.8	33.6	50.0	18.0	30.7	40.7	21.9
10/11	43.2	65.9	47.5	50.1	59.9	45.8	19.1	55.1	42.8	23.4	33.7	28.9	23.5	38.5	29.9	36.9	47.6	34.6	10.8	36.2	22.3	8.3	8.4	8.0
11/12	51.6	77.3	73.0	81.1	76.3	68.8	68.3	54.4	17.9	53.2	86.4	46.2	34.5	59.3	48.9	56.1	57.0	29.1	37.0	26.4	8.5	11.8	23.6	16.1
12/13	36.7	109.0	84.4	80.8	99.0	93.9	56.0	70.3	61.0	56.1	156.3	108.0	11.6	59.6	45.1	53.1	53.4	49.7	23.8	37.5	20.6	10.9	71.2	61.3
13/14	77.9	122.4	85.8	54.5	107.9	80.8	48.2	52.7	39.5	74.1	67.8	89.9	36.3	55.9	52.1	25.2	48.9	40.4	15.8	17.4	13.0	37.2	18.6	28.3
Total	1 708.5	2 090.4	1 691.8	2 009.5	2 043.3	1 825.2	1 476.9	1 549.9	1 052.2	1 345.3	1 618.5	1 480.3	873.0	1 109.5	890.5	1 046.8	1 125.0	888.5	701.5	696.4	362.5	347.4	437.8	507.0

Table E.3: (cont.)

Fishing	ESO 3												SFL 3											
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
90/91	6.5	13.0	9.8	15.7	10.6	16.4	14.0	16.8	7.3	18.6	17.8	11.5	0.9	4.3	3.6	5.4	4.9	3.5	5.2	4.3	2.4	9.9	7.5	3.6
91/92	22.1	10.9	10.5	31.7	24.4	21.6	14.5	14.8	8.9	8.2	4.9	8.3	7.1	4.5	6.1	7.7	6.3	7.2	5.3	3.8	4.7	5.5	2.7	2.5
92/93	25.0	24.0	15.3	15.6	28.1	25.2	22.3	34.3	26.7	47.6	32.4	13.7	5.4	8.0	7.6	16.5	10.4	11.8	12.8	17.5	12.2	23.9	15.2	5.0
93/94	35.2	31.2	34.8	48.3	33.7	23.5	35.6	27.4	29.0	39.9	42.7	25.8	15.3	19.6	9.9	9.8	10.0	7.8	9.1	9.0	4.5	9.9	13.0	14.5
94/95	22.6	20.9	40.0	41.0	41.3	29.1	18.3	33.8	22.6	19.3	39.7	28.8	7.5	7.0	12.8	12.0	8.7	8.3	6.2	11.9	12.6	9.4	21.6	16.6
95/96	30.9	27.6	25.7	27.6	27.5	41.0	33.4	43.8	25.9	36.7	57.9	56.9	13.8	7.6	6.5	8.5	9.8	13.8	11.8	11.5	8.9	13.5	8.9	11.0
96/97	33.0	30.3	30.4	35.0	43.3	43.5	31.9	30.8	31.7	68.4	47.4	46.9	8.1	5.6	6.6	6.6	9.8	5.9	11.4	10.1	12.7	19.4	14.2	13.4
97/98	33.1	22.0	23.4	35.0	31.3	24.8	15.3	15.5	23.6	29.4	35.9	22.8	16.6	13.9	7.7	7.7	6.5	8.1	6.2	8.6	12.7	22.7	11.4	7.2
98/99	18.3	20.4	8.3	23.3	28.3	19.9	13.3	19.3	10.3	18.9	37.9	17.9	12.8	12.8	3.6	6.5	5.3	5.5	5.2	8.6	10.0	10.8	6.6	6.2
99/00	13.7	19.4	13.5	39.2	18.5	31.7	16.7	29.5	20.8	37.0	20.5	19.5	4.7	4.9	8.8	10.5	7.0	5.5	7.4	9.8	2.5	9.7	8.0	6.4
00/01	14.5	18.8	21.4	37.4	60.1	55.8	23.8	16.1	37.3	22.1	53.5	15.0	11.0	11.3	7.3	8.7	7.4	7.5	5.3	4.6	7.4	4.1	6.1	8.0
01/02	23.0	51.7	29.2	34.7	28.8	56.5	51.7	21.9	16.6	48.5	28.3	37.8	5.4	6.6	3.1	5.0	6.5	10.0	4.8	4.5	5.0	19.2	6.7	16.6
02/03	24.7	26.9	21.6	27.7	31.9	39.8	16.9	28.4	25.4	33.4	41.2	19.1	9.5	5.4	4.0	8.0	7.0	7.4	8.1	7.0	4.0	8.1	12.7	5.9
03/04	13.4	21.8	12.3	15.4	4.8	12.3	20.3	22.6	25.4	19.4	10.8	28.7	4.9	3.3	4.0	4.4	3.4	6.1	6.7	5.2	6.2	5.9	4.7	10.9
04/05	17.5	15.1	8.1	21.5	14.8	5.3	22.2	19.6	7.9	12.3	25.5	14.2	12.6	6.4	4.6	10.5	6.4	2.0	5.5	10.1	5.6	5.9	8.5	6.6
05/06	5.3	6.4	16.1	22.2	13.4	14.4	15.7	11.1	13.5	6.7	14.5	11.0	2.4	4.2	4.2	8.8	3.5	6.4	6.4	3.0	3.7	1.9	12.1	9.9
06/07	7.7	11.5	8.8	8.4	8.2	7.6	19.4	14.8	10.2	21.8	23.8	16.5	10.4	10.2	10.3	7.4	4.2	3.4	4.5	6.7	3.8	25.1	14.7	19.0
07/08	7.1	19.7	15.4	11.7	9.6	14.8	15.1	23.1	13.4	6.9	8.7	17.0	5.5	11.2	6.1	4.0	2.9	3.1	4.9	5.3	6.6	5.5	5.0	5.1
08/09	15.1	28.9	17.2	14.8	15.5	18.8	20.8	21.3	13.3	12.0	33.3	33.9	5.0	9.1	2.3	2.5	4.4	5.8	6.3	4.7	8.6	11.8	13.7	22.4
09/10	16.9	19.6	27.9	17.3	19.8	10.3	7.1	14.9	4.3	10.0	16.6	12.5	4.3	9.6	9.1	7.4	11.5	6.2	5.2	4.1	2.7	5.8	13.0	9.2
10/11	7.3	12.3	8.0	5.6	3.8	5.0	3.3	9.4	7.7	6.3	6.8	4.8	5.7	8.1	3.0	3.7	4.3	2.7	3.2	6.0	9.8	6.0	7.0	6.3
11/12	6.5	8.7	11.0	11.4	7.8	16.1	15.4	17.8	5.4	14.7	23.5	10.9	4.5	6.0	4.8	5.9	4.5	18.4	9.5	5.3	2.3	17.0	21.5	9.1
12/13	7.1	17.3	18.7	11.4	15.2	16.6	15.1	16.6	19.1	24.5	41.8	18.7	9.9	15.3	11.3	9.7	17.9	16.4	10.6	6.8	13.8	13.1	22.9	12.2
13/14	15.1	32.1	16.8	9.4	17.6	20.6	15.0	14.0	11.9	18.8	16.9	17.9	18.2	16.4	8.3	13.2	25.5	12.1	12.1	15.3	9.3	11.5	19.4	23.9
Total	421.7	510.7	444.0	561.5	538.1	570.5	477.1	517.6	418.3	581.6	682.2	510.1	201.6	211.3	155.5	190.1	188.1	184.9	173.6	183.6	172.0	275.5	276.9	251.5

Table E.4: Distribution of bottom trawl FLA 3, LSO 3, ESO 3 and SFL 3 estimated catches (t) by declared target species from 1990–91 to 2013–14. Annual totals by species can be found in Table E.1

	FLA 3								LSO 3							
	FLA	RCO	STA	TAR	BAR	ELE	GUR	OTH	FLA	RCO	STA	TAR	BAR	ELE	GUR	OTH
90/91	305.8	18.2	8.3	1.8	0.9	0.9	2.2	1.4	64.8	4.5	0.5	1.5	0.4	0.2	0.1	0.4
91/92	352.9	52.7	2.8	4.0	1.2	1.4	0.8	2.8	82.7	15.6	0.5	3.5	0.4	0.2	0.4	0.4
92/93	560.8	131.3	8.0	0.4	4.0	0.5	2.0	14.1	113.0	44.7	2.1	0.4	1.5	0.3	0.4	7.8
93/94	775.5	142.4	2.8	6.0	1.7	1.7	1.9	2.7	274.8	28.3	0.6	4.5	0.4	0.0	0.4	1.2
94/95	806.9	122.9	6.4	6.8	0.6	0.5	1.1	2.8	315.3	32.5	1.5	2.2	0.3	0.1	0.3	0.2
95/96	1 037.8	119.1	3.0	2.4	2.7	3.1	1.3	1.7	494.5	18.3	2.0	1.6	1.6	0.1	0.3	1.5
96/97	1 051.2	135.0	2.1	0.6	2.5	1.8	0.5	0.3	461.6	24.5	1.7	0.6	1.6	0.3	0.4	0.1
97/98	1 024.6	147.1	5.6	6.7	4.9	1.4	0.4	2.7	580.1	57.9	2.0	6.5	2.7	0.3	0.3	1.8
98/99	952.9	61.1	7.5	2.9	2.1	2.6	13.1	3.3	579.4	14.6	4.5	2.8	0.1	0.4	0.6	2.4
99/00	790.2	21.9	4.0	1.4	0.1	0.6	12.9	0.2	363.0	2.9	1.8	1.4	0.1	0.4	0.4	0.0
00/01	924.1	27.5	1.4	1.7	1.1	1.1	1.1	3.7	358.4	5.6	0.8	1.3	0.1	0.2	0.5	0.2
01/02	842.6	14.2	4.9	1.2	0.5	1.5	0.5	3.6	247.0	1.6	2.7	1.1	0.2	0.1	0.2	0.8
02/03	769.8	26.1	1.7	0.4	1.1	1.6	3.0	6.3	269.5	3.1	1.4	0.4	0.0	0.9	1.6	0.2
03/04	576.1	23.9	2.0	0.3	25.4	1.3	1.5	2.1	263.6	1.4	1.5	0.3	0.2	0.8	0.6	0.7
04/05	531.5	21.0	4.1	0.6	5.7	3.1	4.3	18.1	221.3	2.8	2.4	0.6	0.2	2.1	1.4	0.6
05/06	533.3	7.7	7.2	1.1	0.5	4.8	3.2	6.5	264.0	3.8	4.2	1.0	0.2	4.1	1.8	1.7
06/07	711.9	1.9	2.9	3.2	0.3	5.1	9.1	5.0	383.6	0.8	1.4	2.9	0.1	3.3	7.0	1.3
07/08	845.5	10.9	6.3	8.4	2.5	9.6	5.1	4.2	562.3	6.0	3.5	6.1	1.5	2.5	1.6	1.1
08/09	881.4	18.0	16.8	14.1	2.5	10.9	8.8	2.3	485.0	6.6	8.5	12.9	1.2	5.2	4.4	1.4
09/10	844.1	10.2	10.3	9.5	2.3	13.5	5.9	3.5	524.2	3.7	4.6	8.8	0.4	3.2	3.8	2.3
10/11	461.5	5.5	5.9	20.8	1.9	9.0	6.3	4.3	270.4	1.8	3.4	19.0	1.2	3.5	4.4	1.4
11/12	706.1	5.9	5.9	12.2	3.0	9.1	8.7	3.7	382.9	1.2	3.4	11.2	0.4	3.0	5.0	1.0
12/13	932.7	12.4	12.4	14.2	4.9	11.2	17.5	6.1	457.5	4.3	6.3	13.2	1.4	3.5	9.3	2.3
13/14	801.4	12.0	10.7	11.0	8.1	11.5	23.7	23.2	343.2	3.1	6.2	10.4	2.4	2.4	9.0	12.5
Total	18 020.5	1 149.1	142.7	131.7	80.6	107.8	134.8	124.7	8 361.9	289.4	67.6	114.0	18.5	37.1	54.1	43.2

Table E.4: (cont.)

	ESO 3								SFL 3							
	FLA	RCO	STA	TAR	BAR	ELE	GUR	OTH	FLA	RCO	STA	TAR	BAR	ELE	GUR	OTH
90/91	144.7	10.7	0.3	0.3	0.2	0.1	1.1	0.6	52.7	2.0	0.0	0.0	0.1	0.1	0.1	0.4
91/92	150.8	26.2	0.1	0.5	0.6	0.9	0.2	1.6	56.3	6.5	0.1	0.0	0.0	0.3	0.2	0.0
92/93	259.3	41.0	4.1	0.1	1.1	0.1	1.2	3.3	112.4	31.3	0.6	0.0	0.8	0.0	0.2	1.0
93/94	328.7	74.5	1.3	1.0	0.5	0.7	0.3	0.1	104.8	25.7	0.6	0.0	0.5	0.7	0.1	0.2
94/95	306.4	45.7	0.8	1.9	0.1	0.3	0.6	1.8	110.4	22.6	0.1	1.4	0.1	0.0	0.0	0.0
95/96	369.0	62.1	0.7	0.4	0.9	1.2	0.7	0.0	94.3	30.2	0.0	0.0	0.1	0.8	0.0	0.1
96/97	396.4	75.4	0.2	0.0	0.6	0.1	0.1	0.0	100.0	23.7	0.0	0.0	0.0	0.1	0.0	0.1
97/98	250.2	56.0	2.1	0.2	2.1	0.5	0.1	0.6	107.5	20.5	1.2	0.0	0.0	0.1	0.0	0.0
98/99	198.3	24.9	1.9	0.1	0.5	1.9	7.8	0.7	86.6	7.1	0.0	0.0	0.0	0.0	0.1	0.0
99/00	257.8	11.8	1.2	0.0	0.0	0.2	9.1	0.0	81.5	3.2	0.4	0.0	0.0	0.0	0.1	0.0
00/01	362.1	11.8	0.2	0.3	0.0	0.4	0.4	0.8	84.7	3.6	0.1	0.0	0.0	0.1	0.1	0.0
01/02	423.6	1.7	1.5	0.0	0.0	0.5	0.1	1.4	91.8	0.5	0.2	0.0	0.0	0.6	0.1	0.0
02/03	324.6	10.3	0.1	0.0	0.5	0.3	1.0	0.2	83.2	2.9	0.0	0.0	0.0	0.0	0.3	0.9
03/04	195.7	9.4	0.0	0.0	0.8	0.2	0.7	0.2	60.2	4.3	0.2	0.0	0.2	0.1	0.1	0.5
04/05	178.3	3.9	0.0	0.1	0.3	0.4	0.5	0.2	73.1	9.7	0.3	0.0	0.1	0.5	0.7	0.4
05/06	146.2	2.0	0.8	0.1	0.0	0.3	0.6	0.3	64.5	0.7	0.8	0.0	0.0	0.1	0.1	0.1
06/07	155.9	0.3	0.3	0.0	0.0	0.8	1.0	0.1	117.8	0.5	0.2	0.0	0.0	0.5	0.4	0.1
07/08	154.9	1.2	1.7	0.1	0.4	2.6	1.3	0.3	60.7	0.7	0.1	0.0	0.2	2.5	0.9	0.1
08/09	233.4	1.6	4.8	0.1	0.2	2.5	1.9	0.2	88.9	3.4	0.3	0.7	0.1	1.2	1.8	0.2
09/10	167.7	1.7	1.9	0.0	0.2	4.7	0.8	0.3	83.3	1.2	0.6	0.1	0.0	2.3	0.5	0.2
10/11	75.4	0.4	0.6	0.3	0.0	2.6	0.7	0.1	60.4	0.9	0.1	0.8	0.0	1.9	0.8	0.7
11/12	142.2	1.3	0.6	0.1	0.0	3.0	1.7	0.4	101.5	2.1	0.1	0.6	0.0	1.4	1.3	1.8
12/13	209.4	2.7	3.6	0.3	0.2	2.9	2.8	0.4	147.9	2.5	0.7	0.2	0.5	2.9	3.9	1.5
13/14	190.0	2.3	3.2	0.1	0.7	3.7	4.8	1.5	167.3	3.1	0.2	0.0	0.4	3.0	7.0	4.3
Total	5 620.9	479.0	32.0	5.9	9.9	31.0	39.6	15.0	2 191.7	208.9	6.9	3.9	3.2	19.0	18.8	12.4

Appendix F. FINE SCALE DISTRIBUTION PLOTS FOR LSO, ESO AND SFL

F.1 Lemon sole (LSO)

Section F.1.1 reports fine scale estimated catch distribution for Lemon Sole (LSO), using trips selected using the "*trip splitters*" algorithm, which selects trips which report the catch of flatfish by species and which rejects trips which use the "FLA" code in the estimated catch records (see Appendix D). All trips in the data set were selected because they reported FLA 3 in the landings data. Only tow-by-tow TCER or TCEPR records are included, starting in October 2007 which was when the new TCER forms became mandatory. Section F.1.1 reports the gridded spatial distribution of LSO landings by fishing year, from 2007–08 (Figure F.1) to 2013–14 (Figure F.7).

F.1.1 LSO spatial maps

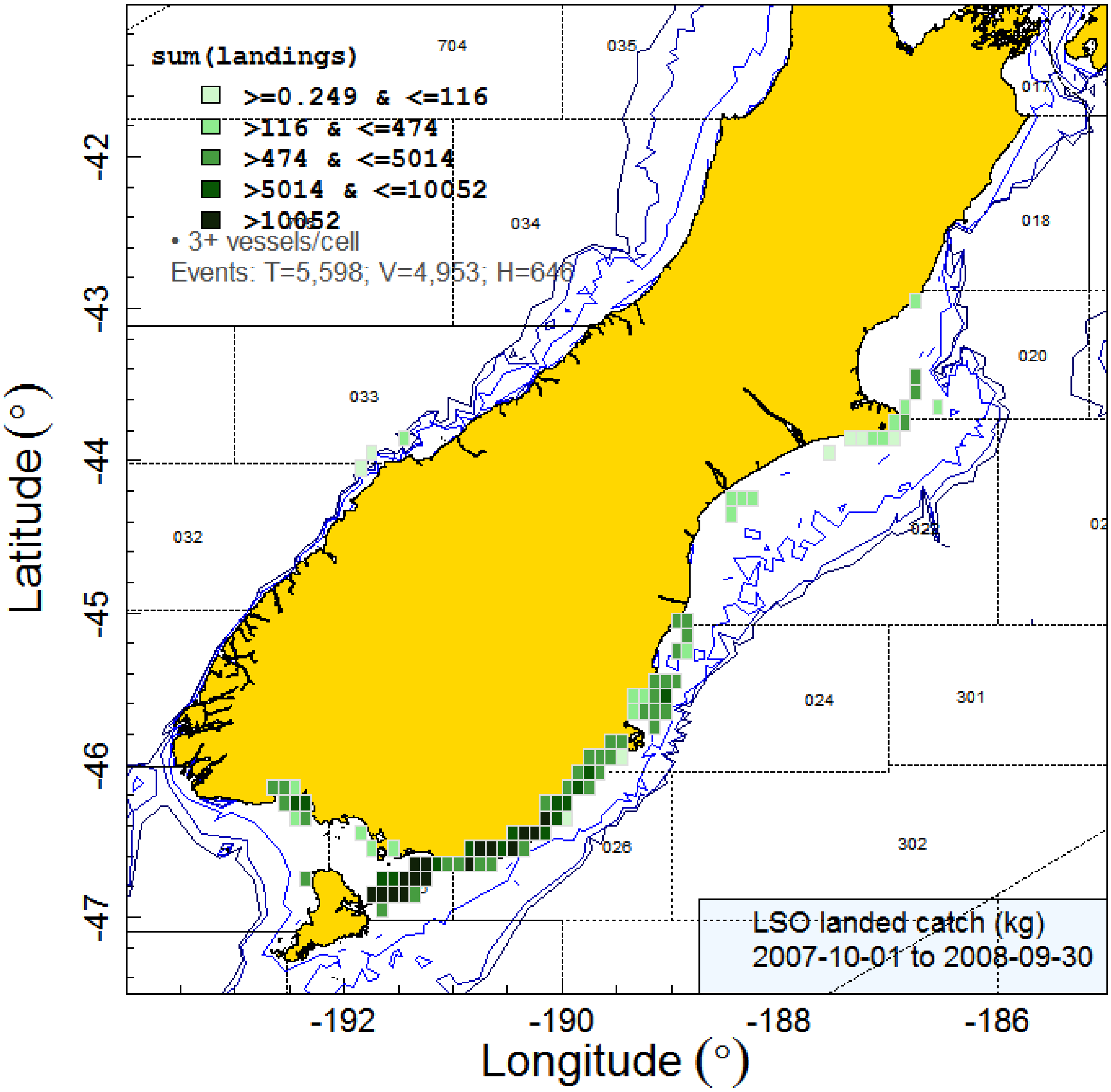


Figure F.1: Spatial distribution of Lemon Sole (LSO) bottom trawl landings (t) reported as FLA 3 in 2007–08, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 646 of 5598 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

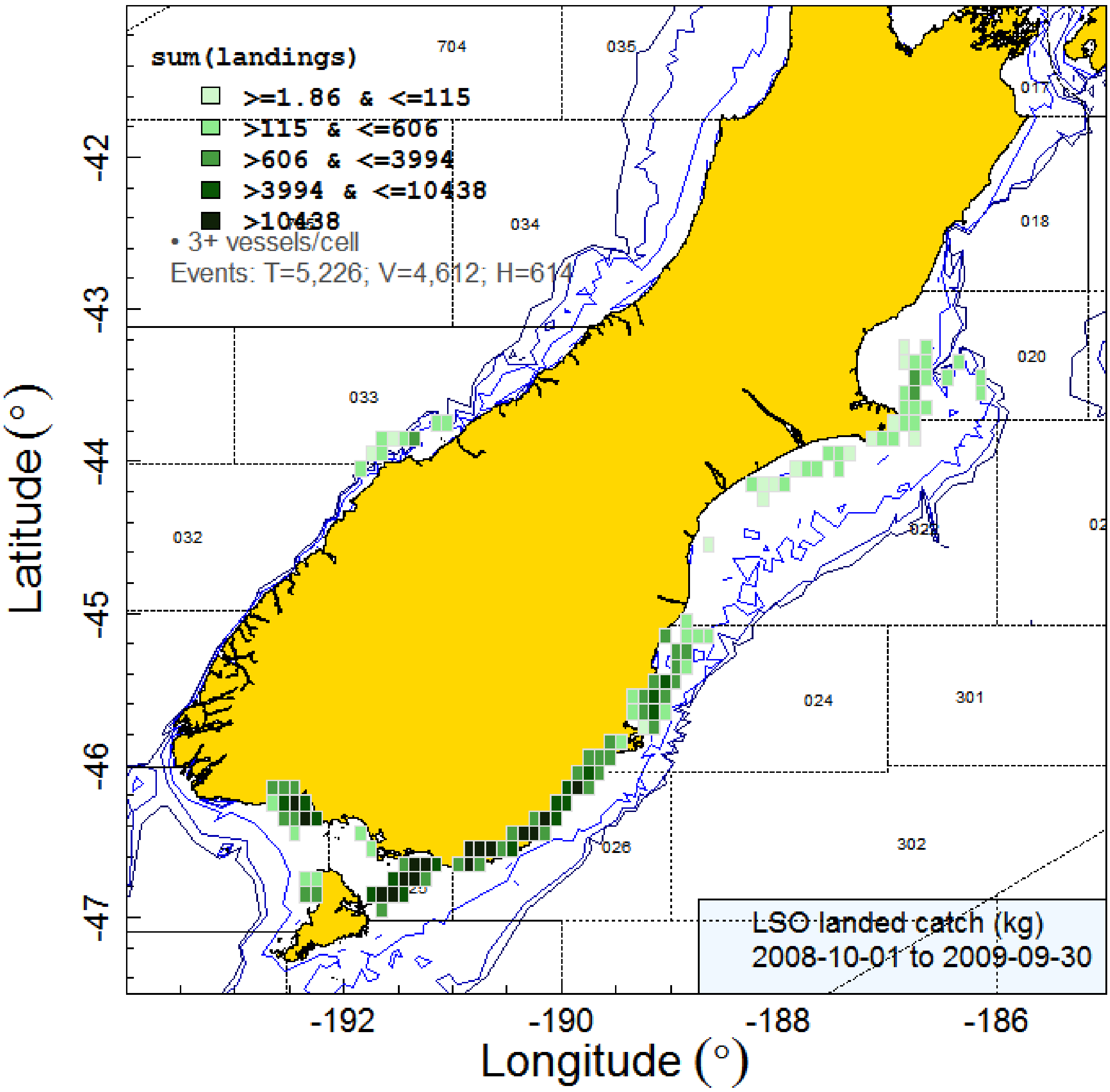


Figure F.2: Spatial distribution of Lemon Sole (LSO) bottom trawl landings (t) reported as FLA 3 in 2008–09, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 614 of 5226 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

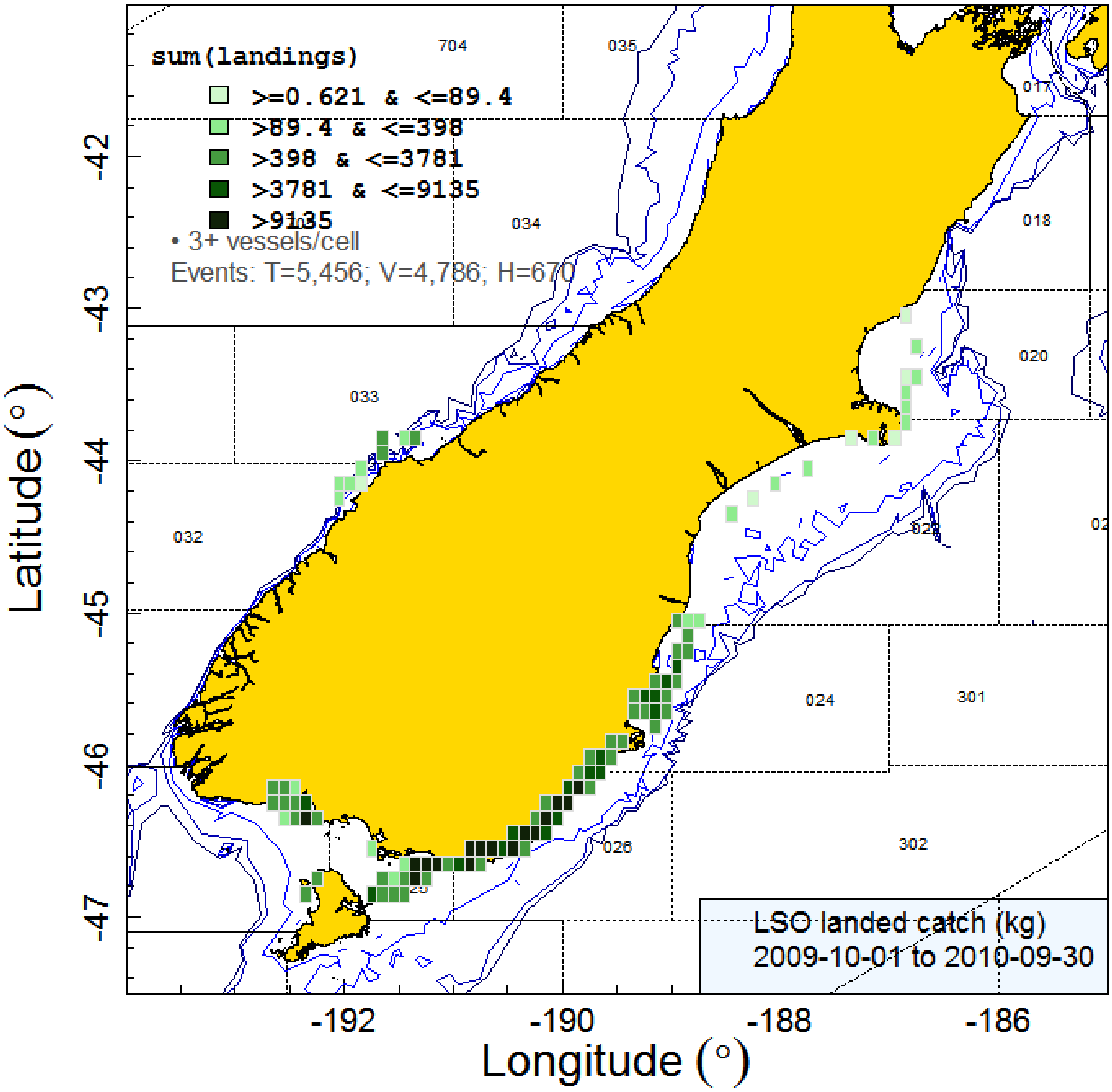


Figure F.3: Spatial distribution of Lemon Sole (LSO) bottom trawl landings (t) reported as FLA 3 in 2009–10, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 670 of 5456 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

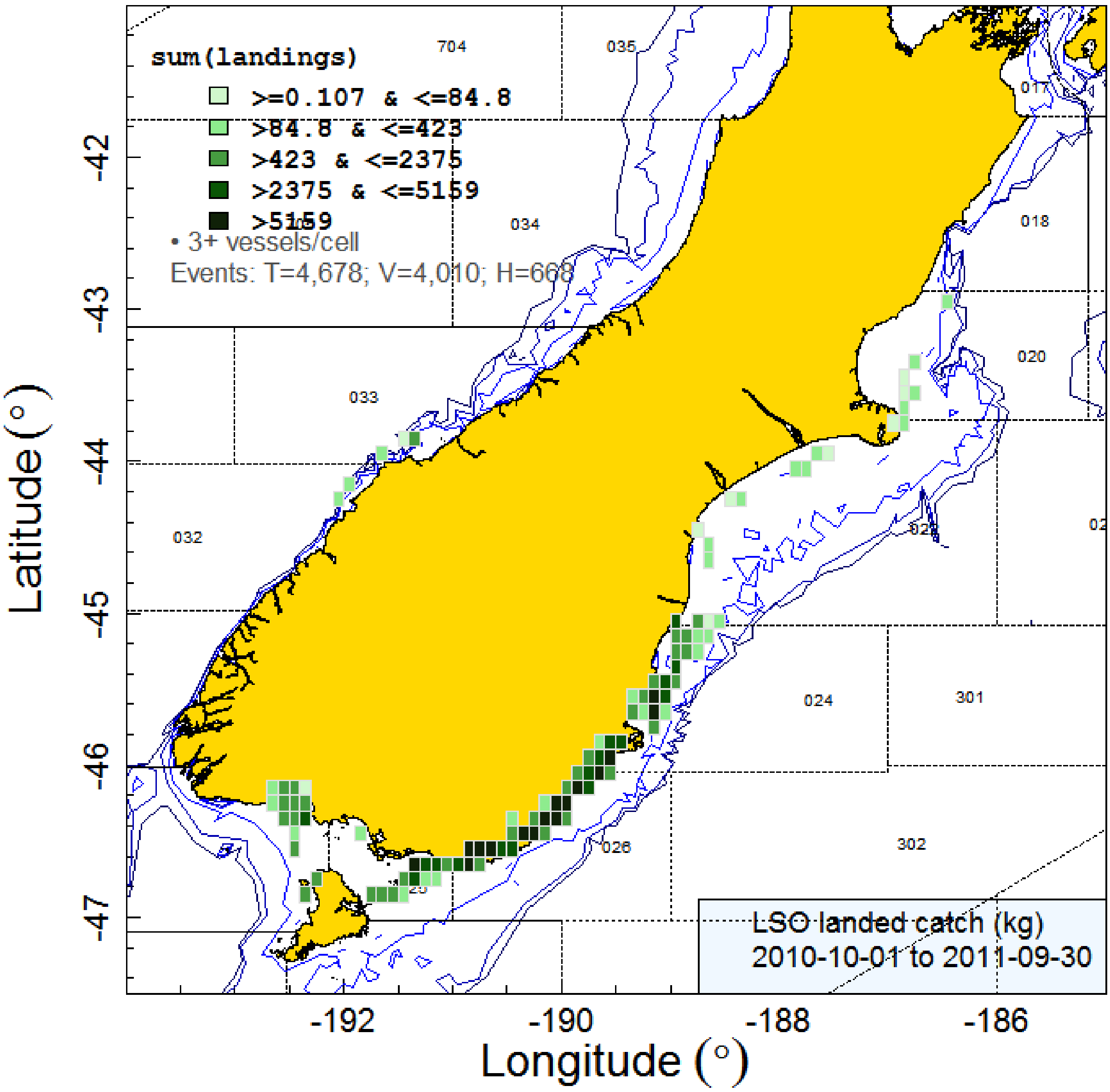


Figure F.4: Spatial distribution of Lemon Sole (LSO) bottom trawl landings (t) reported as FLA 3 in 2010–11, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 668 of 4678 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

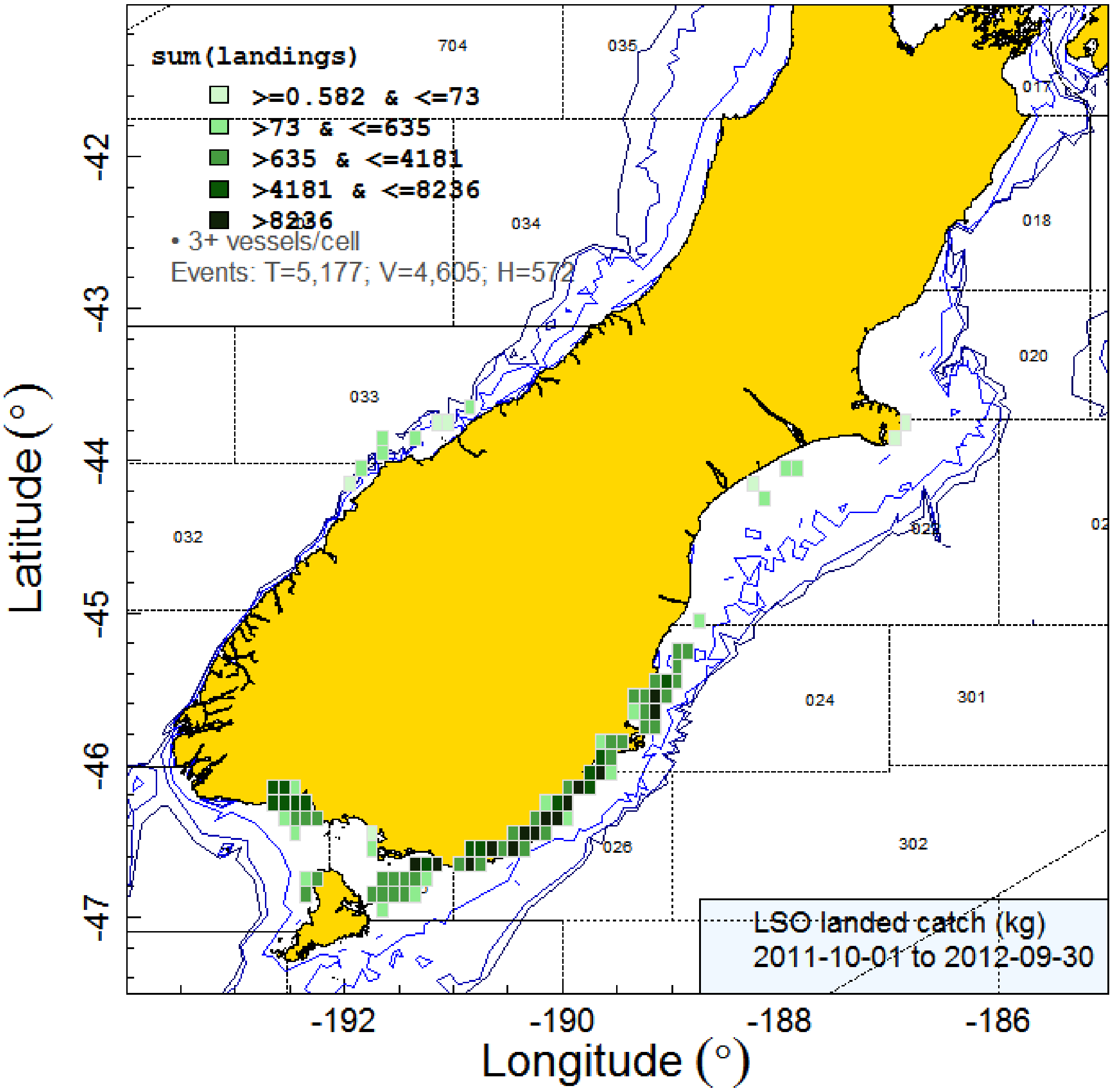


Figure F.5: Spatial distribution of Lemon Sole (LSO) bottom trawl landings (t) reported as FLA 3 in 2011–12, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 572 of 5177 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

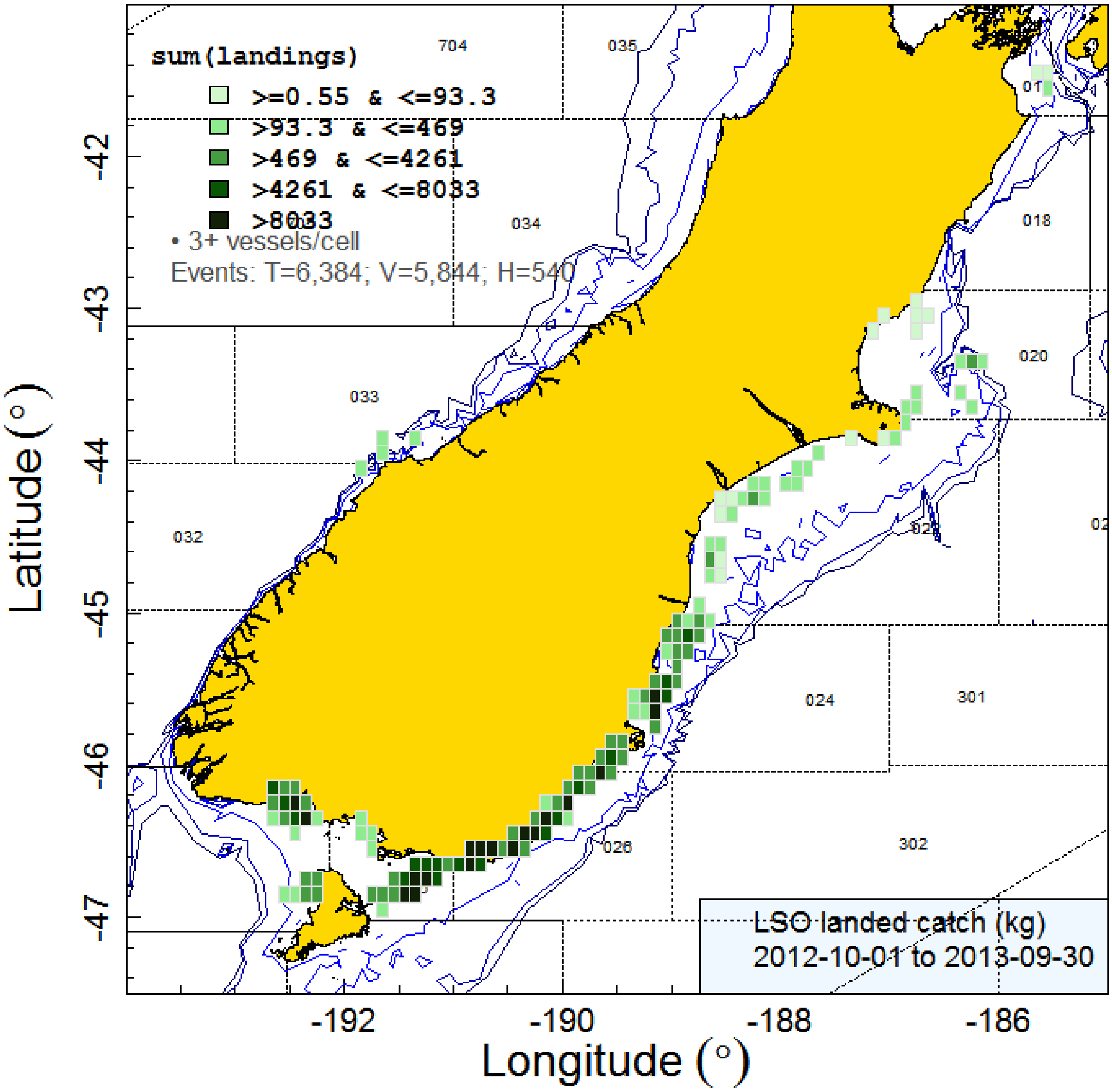


Figure F.6: Spatial distribution of Lemon Sole (LSO) bottom trawl landings (t) reported as FLA 3 in 2012–13, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 540 of 5844 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

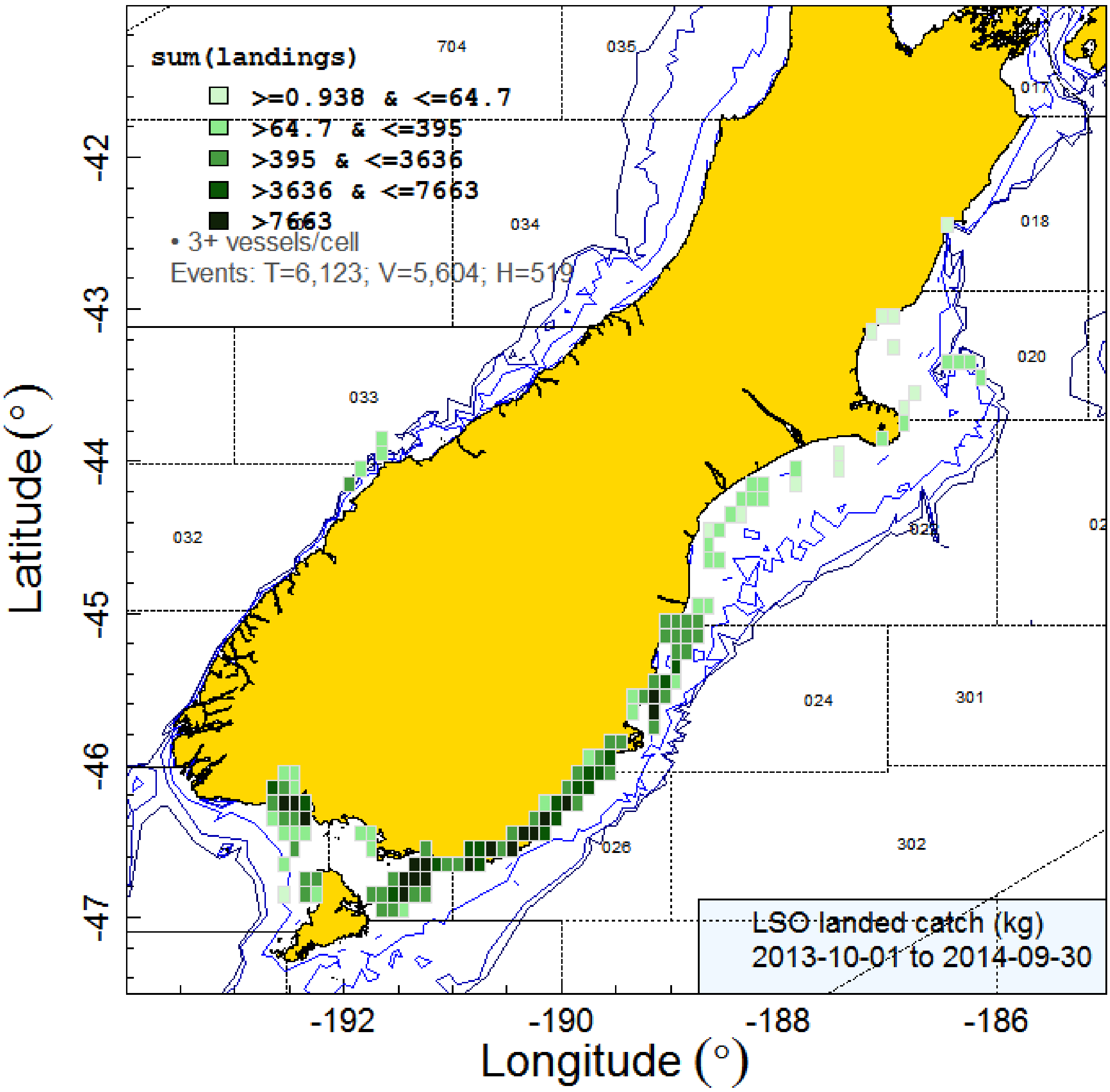


Figure F.7: Spatial distribution of Lemon Sole (LSO) bottom trawl landings (t) reported as FLA 3 in 2013–14, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 519 of 6123 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

F.2 New Zealand Sole (ESO)

Section F.2.1 reports fine scale distribution of estimated catches for New Zealand Sole (ESO), using trips selected using the "*trip splitters*" algorithm, which selects trips which report the catch of flatfish by species and which rejects trips which use the "FLA" code in the estimated catch records (see Appendix D). All trips in the data set were selected because they reported FLA 3 in the landings data. Only tow-by-tow TCER or TCEPR records are included, starting in October 2007 which was when the new TCER forms became mandatory. Section F.2.1 reports the gridded spatial distribution of ESO landings by fishing year, from 2007–08 (Figure F.8) to 2013–14 (Figure F.14).

F.2.1 ESO spatial maps

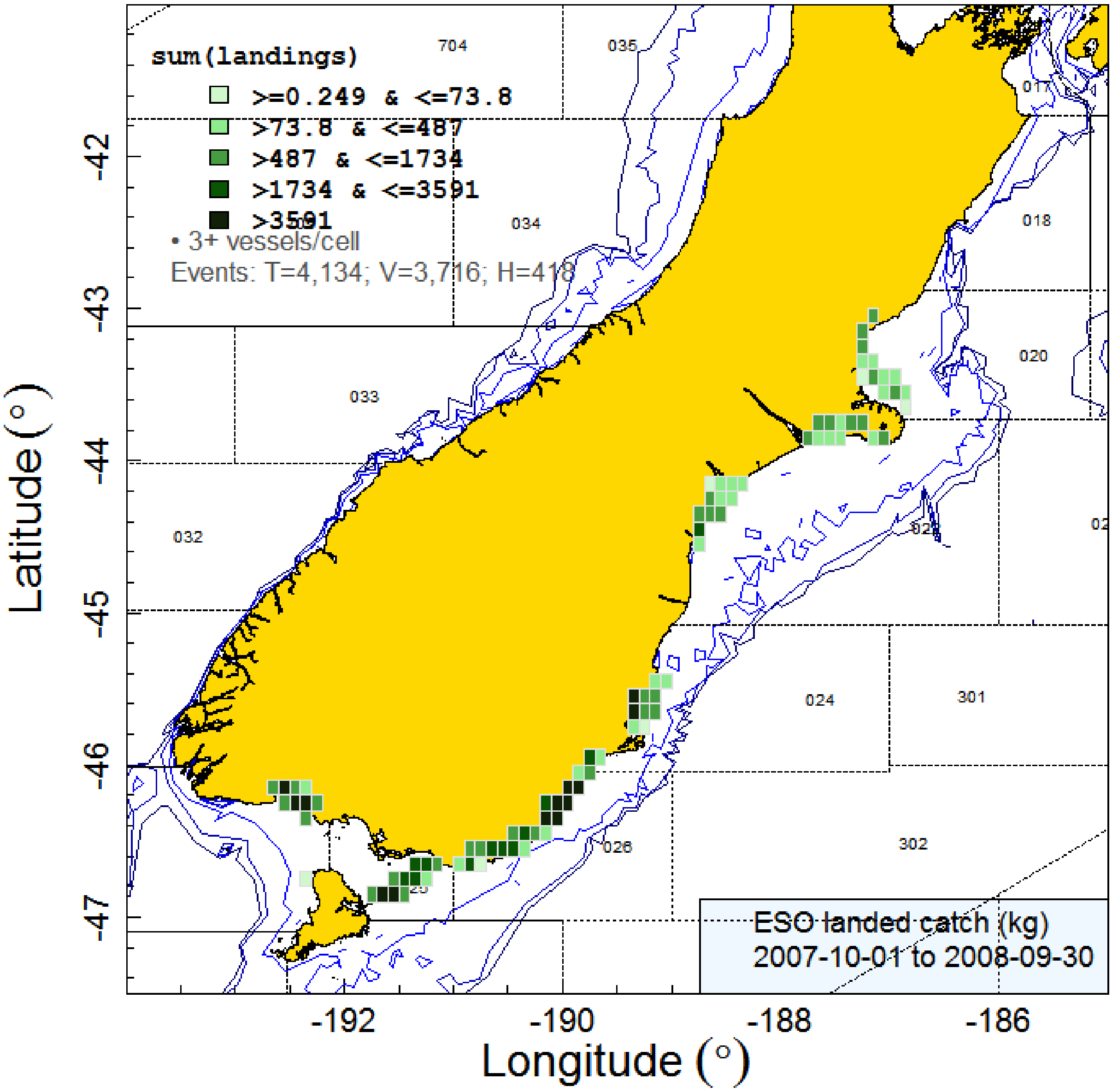


Figure F.8: Spatial distribution of New Zealand Sole (ESO) bottom trawl landings (t) reported as FLA 3 in 2007–08, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 418 of 4134 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

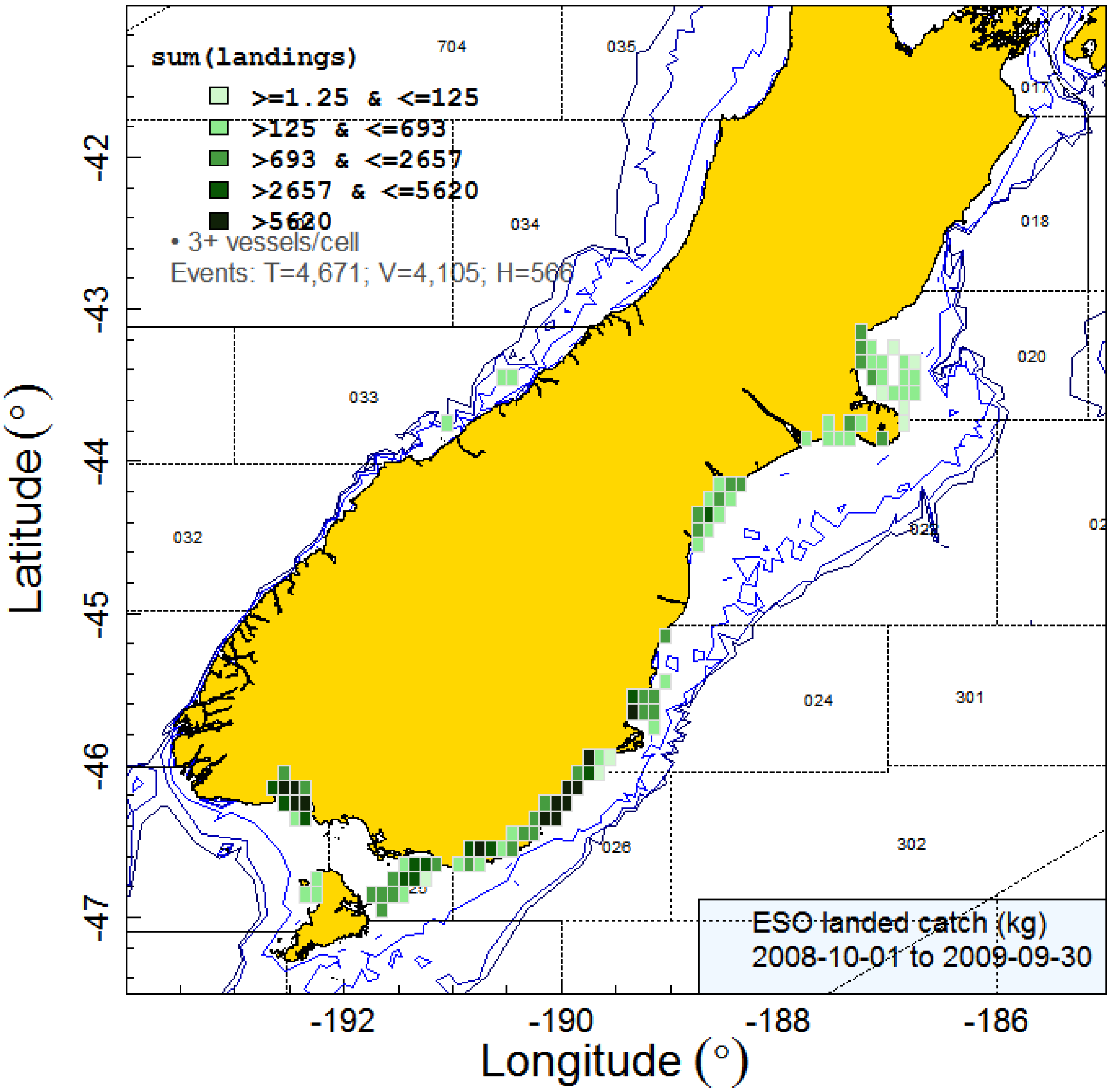


Figure F.9: Spatial distribution of New Zealand Sole (ESO) bottom trawl landings (t) reported as FLA 3 in 2008–09, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 566 of 4671 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

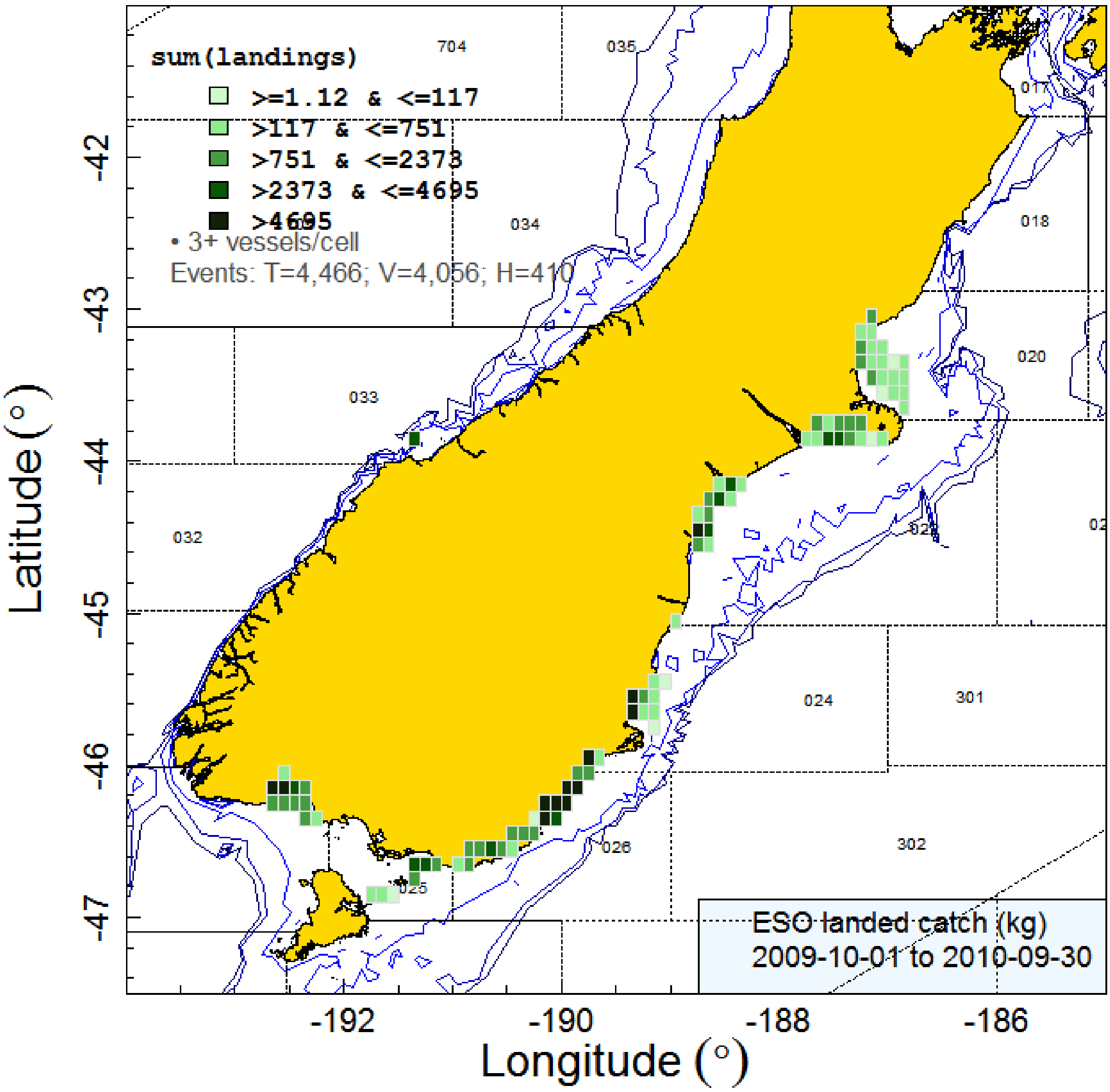


Figure F.10: Spatial distribution of New Zealand Sole (ESO) bottom trawl landings (t) reported as FLA 3 in 2009–10, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 410 of 4466 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

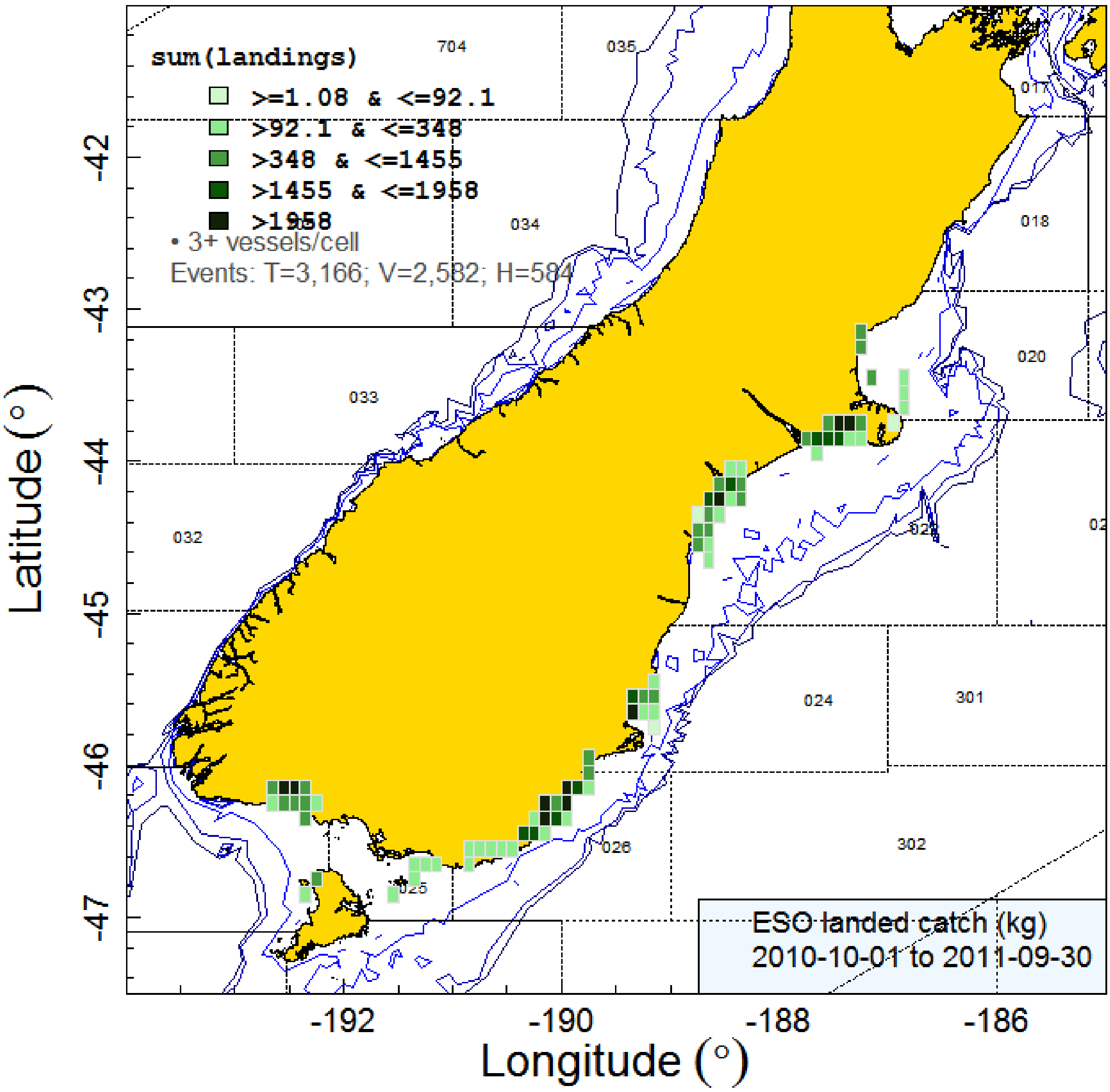


Figure F.11: Spatial distribution of New Zealand Sole (ESO) bottom trawl landings (t) reported as FLA 3 in 2010–11, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 584 of 3166 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

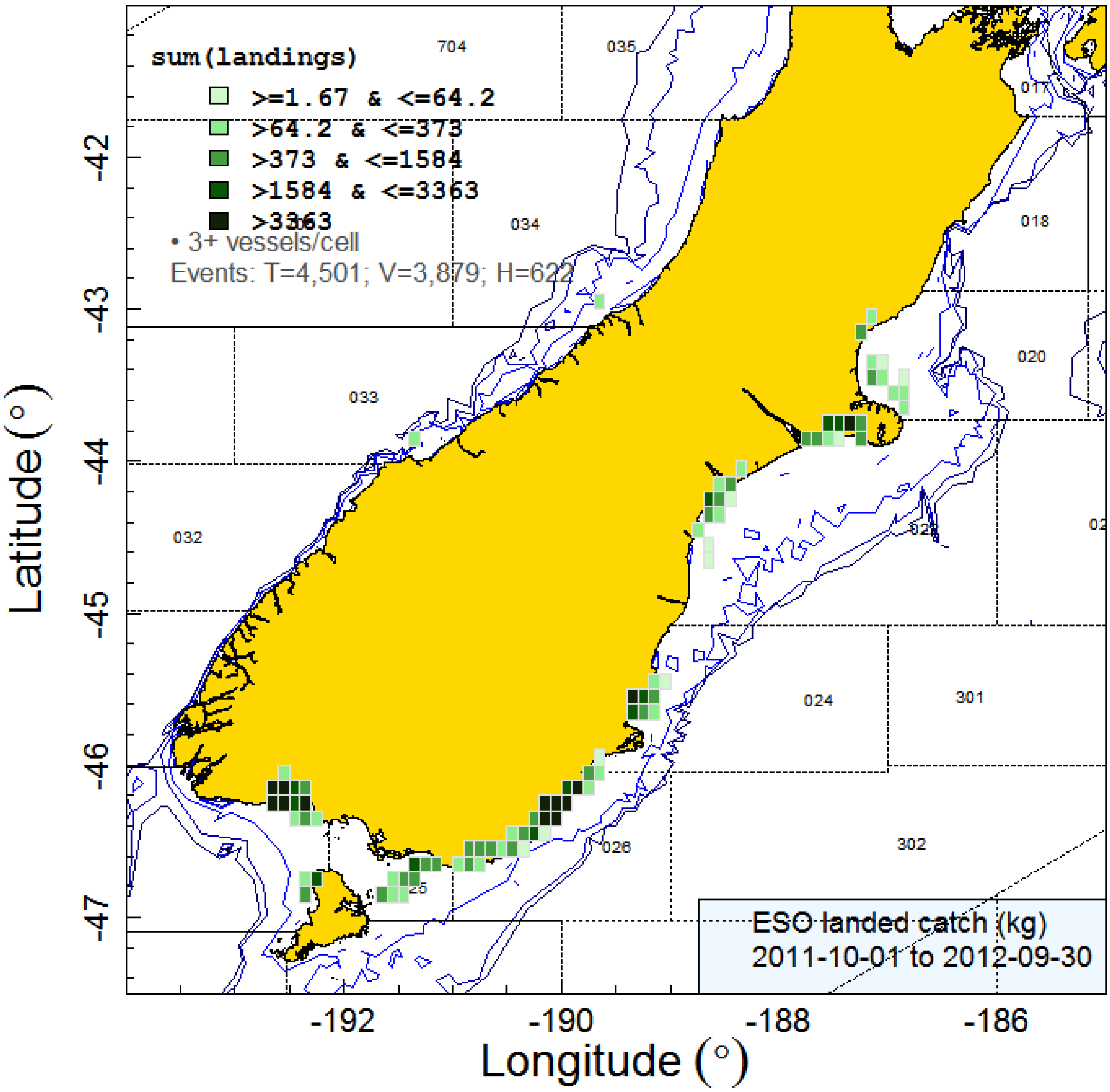


Figure F.12: Spatial distribution of New Zealand Sole (ESO) bottom trawl landings (t) reported as FLA 3 in 2011–12, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 622 of 4501 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

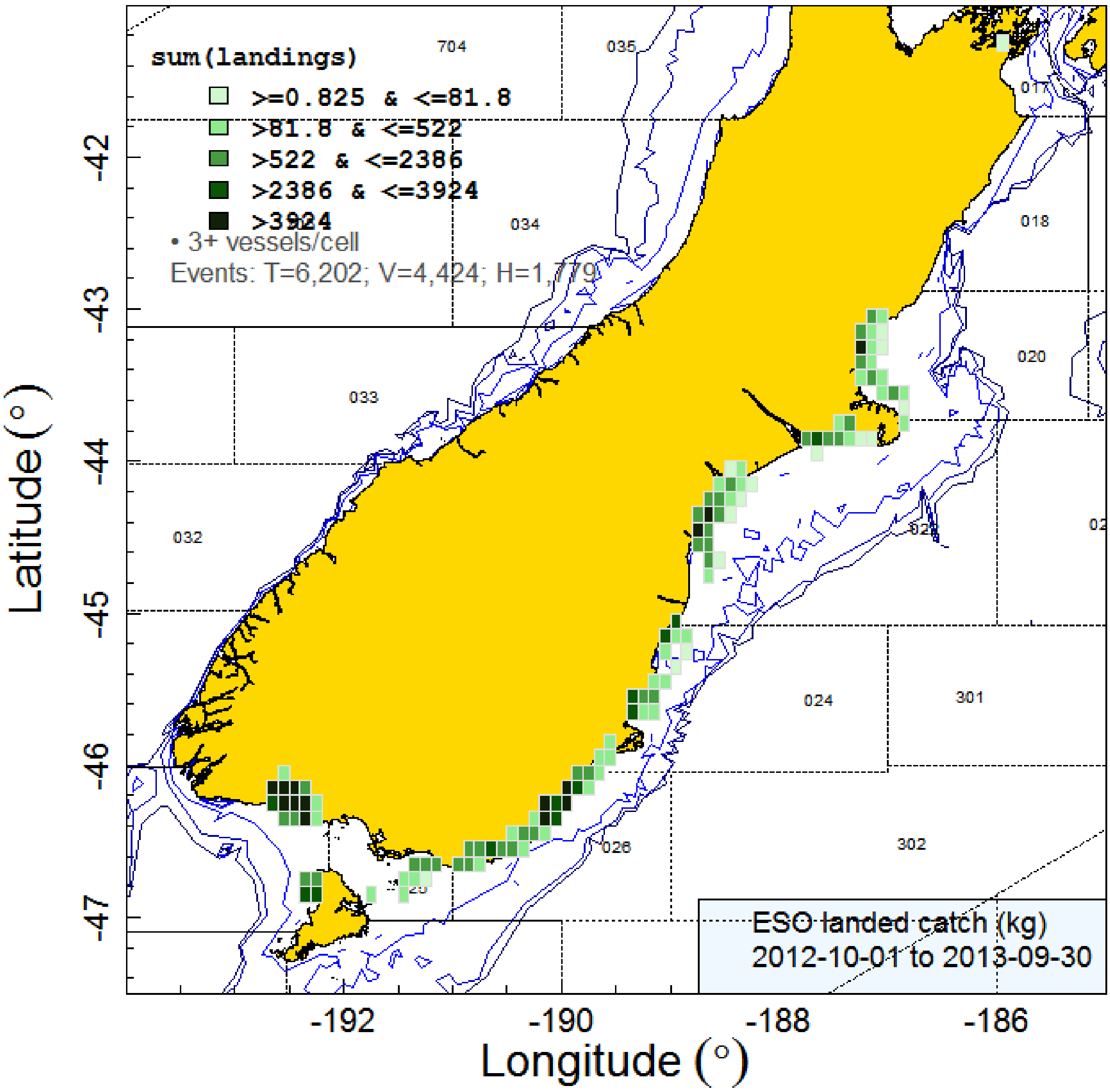


Figure F.13: Spatial distribution of New Zealand Sole (ESO) bottom trawl landings (t) reported as FLA 3 in 2012–13, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 1779 of 6202 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

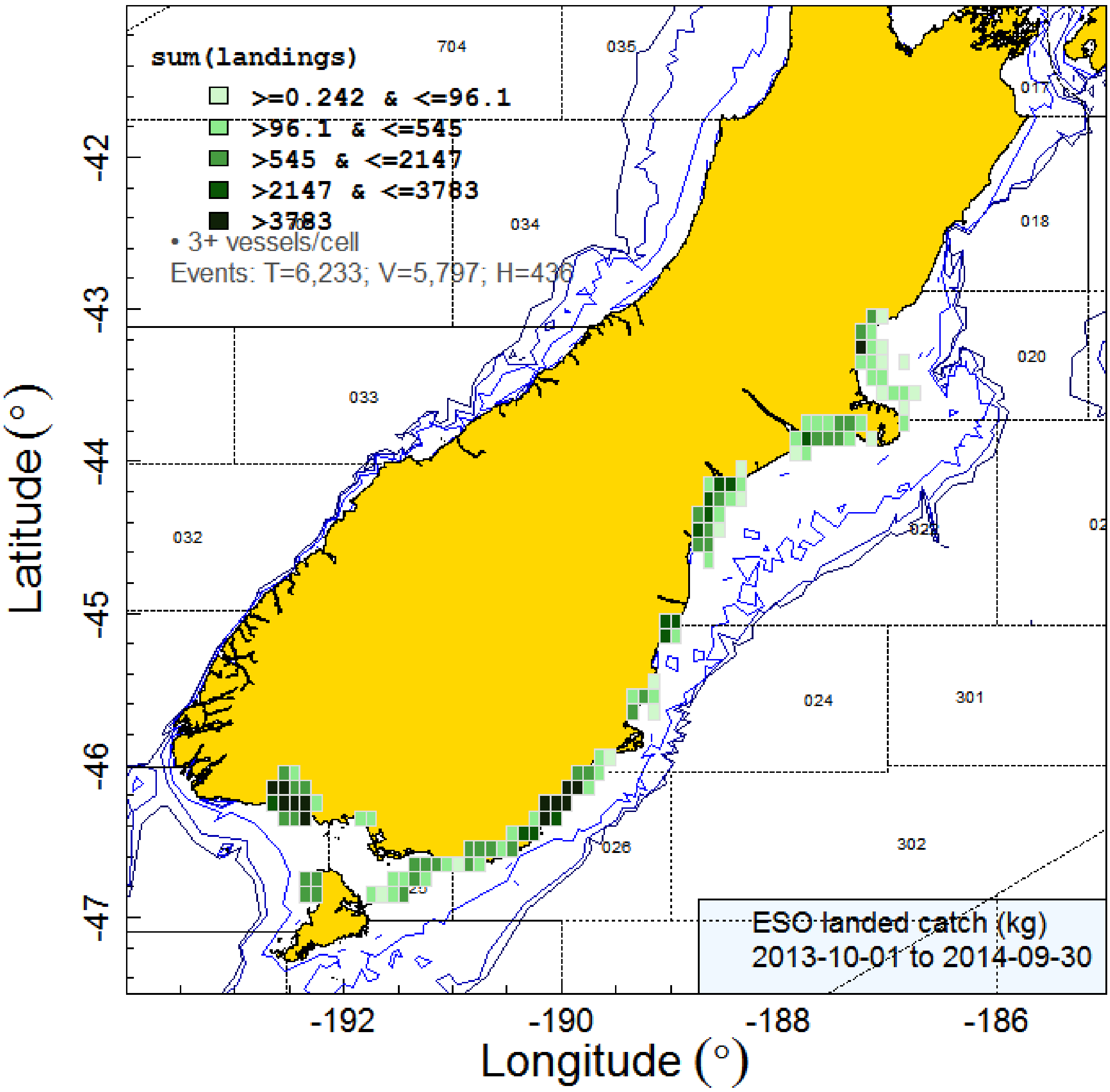


Figure F.14: Spatial distribution of New Zealand Sole (ESO) bottom trawl landings (t) reported as FLA 3 in 2013–14, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 436 of 6233 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

F.3 Sand Flounder (SFL)

Section F.3.1 reports fine scale estimated catch for Sand Flounder (SFL), using trips selected using the "*trip splitters*" algorithm, which selects trips which report the catch of flatfish by species and which rejects trips which use the "FLA" code in the estimated catch records (see Appendix D). All trips in the data set were selected because they reported FLA 3 in the landings data. Only tow-by-tow TCER or TCEPR records are included, starting in October 2007 which was when the new TCER forms became mandatory. Section F.3.1 provides the gridded spatial distribution of SFL landings by fishing year, from 2007–08 (Figure F.15) to 2013–14 (Figure F.21).

F.3.1 SFL spatial maps

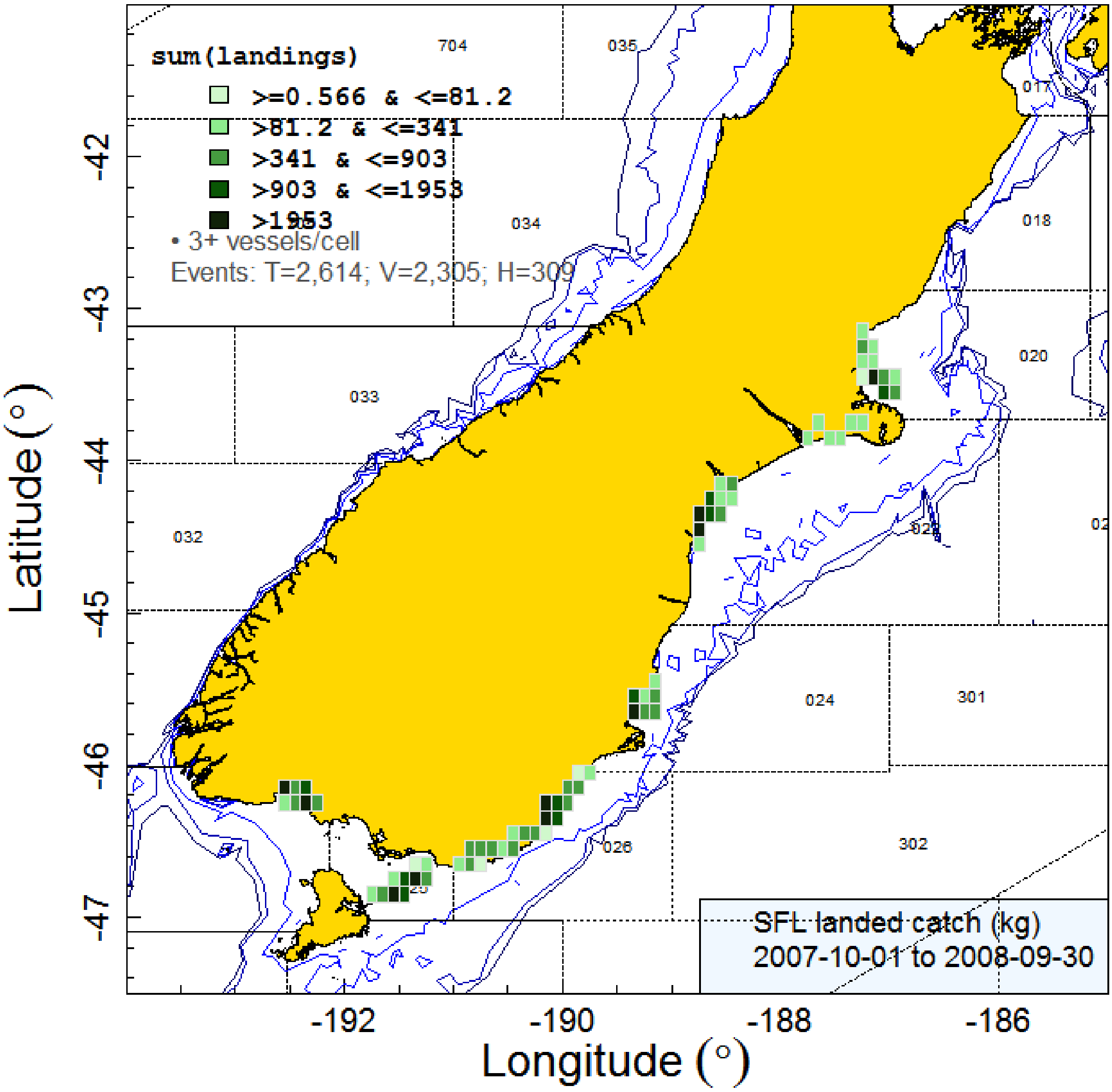


Figure F.15: Spatial distribution of Sand Flounder (SFL) bottom trawl landings (t) reported as FLA 3 in 2007–08, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 309 of 2614 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

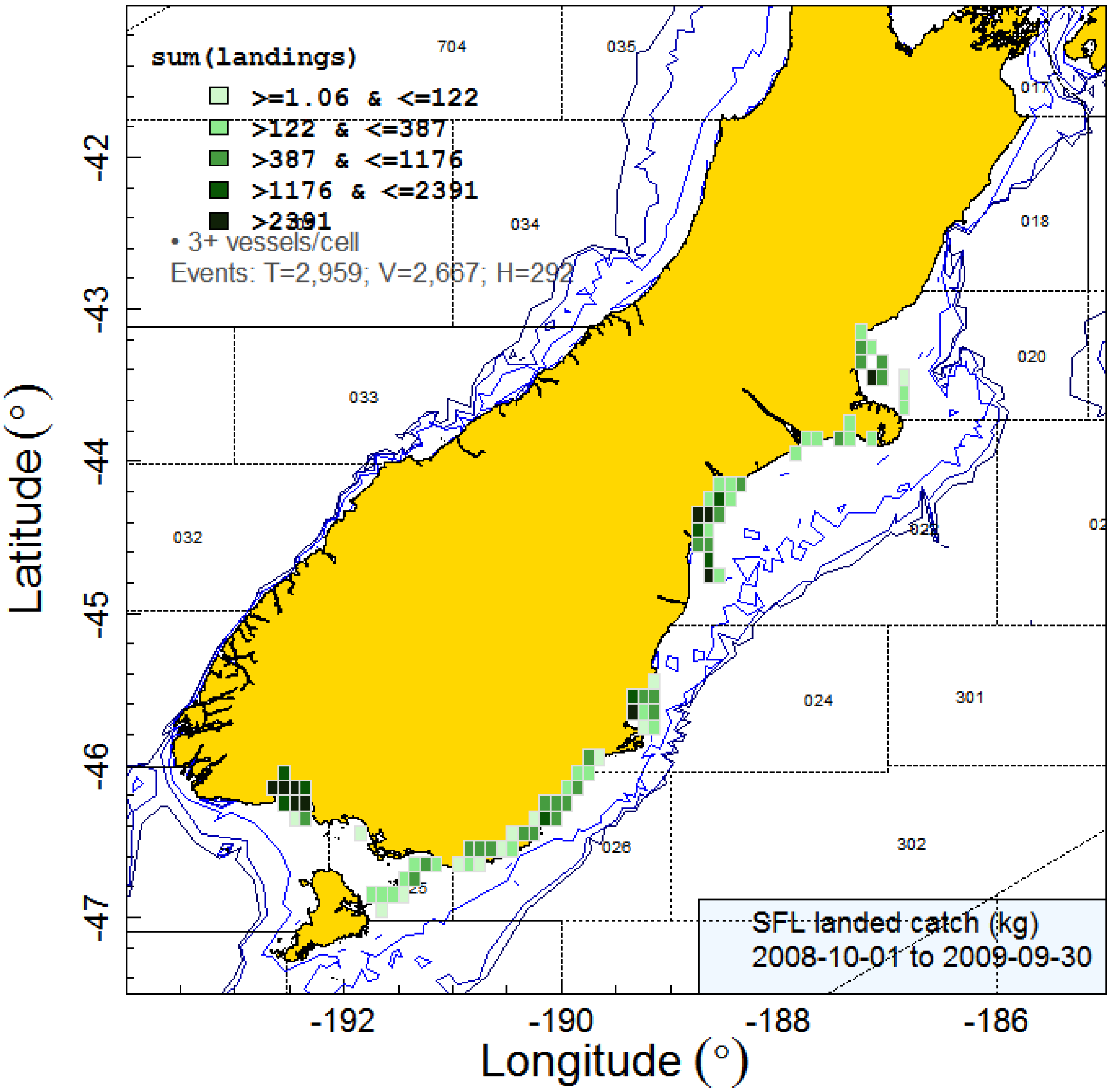


Figure F.16: Spatial distribution of Sand Flounder (SFL) bottom trawl landings (t) reported as FLA 3 in 2008–09, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 292 of 2959 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

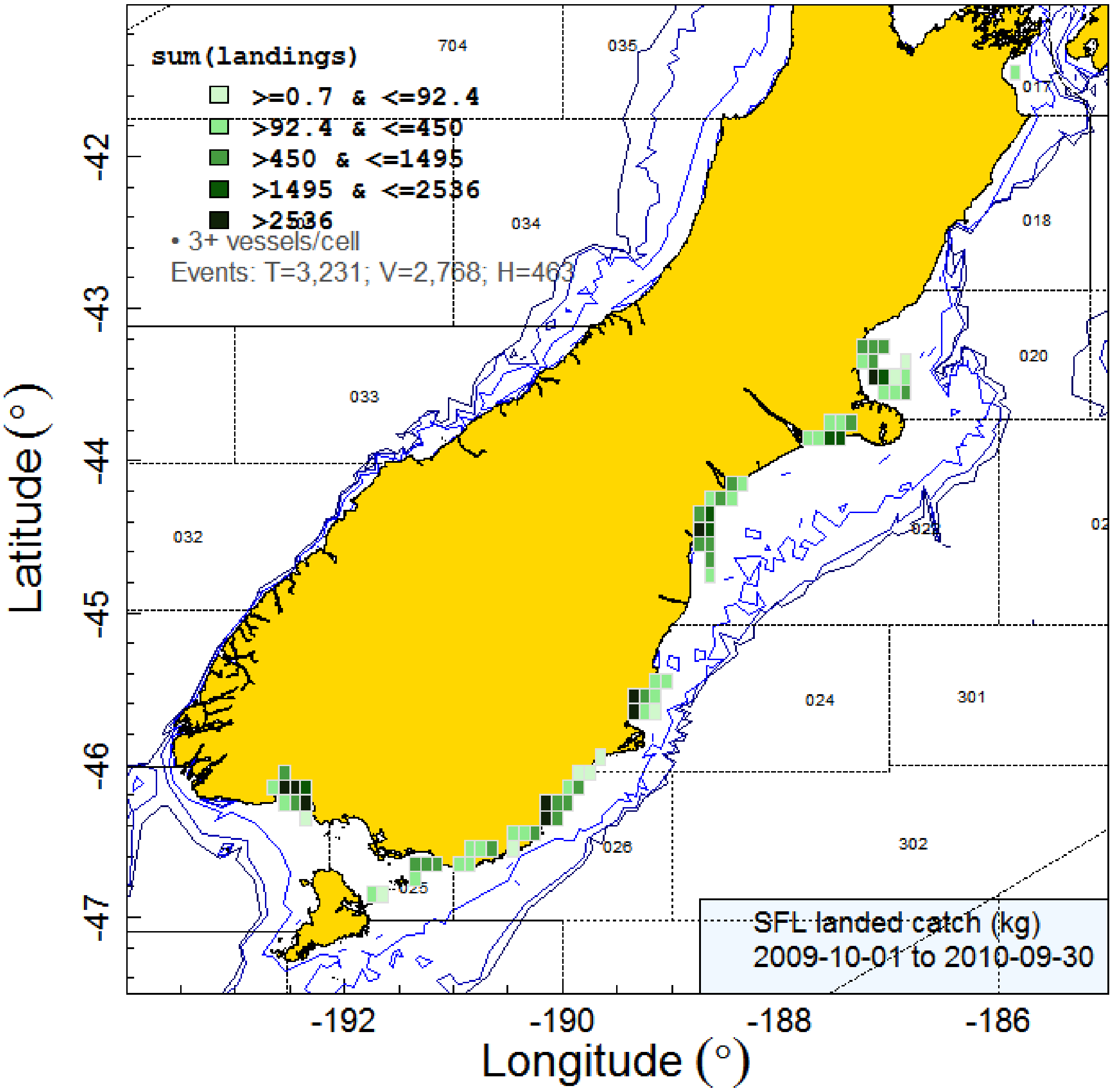


Figure F.17: Spatial distribution of Sand Flounder (SFL) bottom trawl landings (t) reported as FLA 3 in 2009–10, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 463 of 3231 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

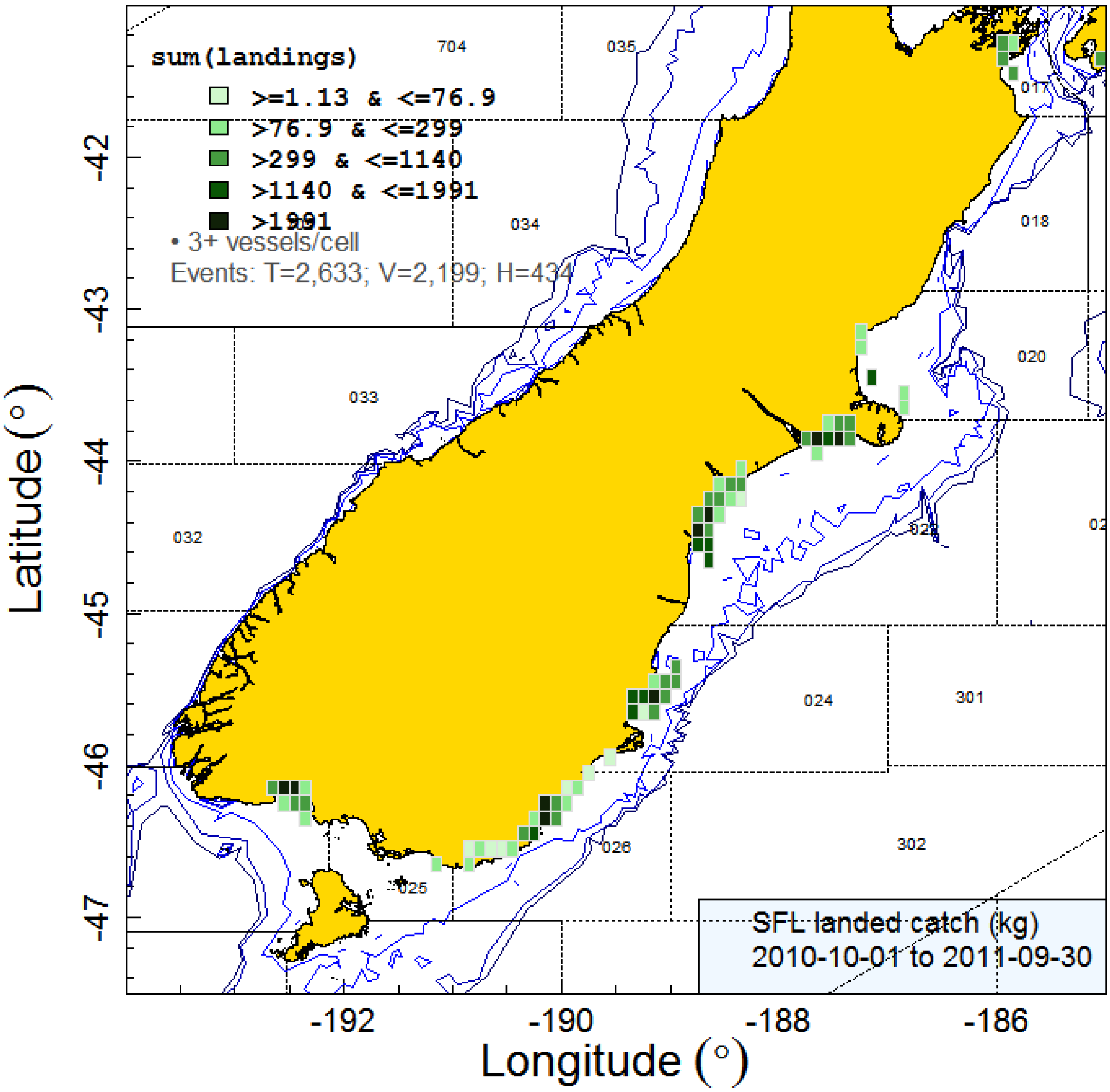


Figure F.18: Spatial distribution of Sand Flounder (SFL) bottom trawl landings (t) reported as FLA 3 in 2010–11, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 434 of 2633 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

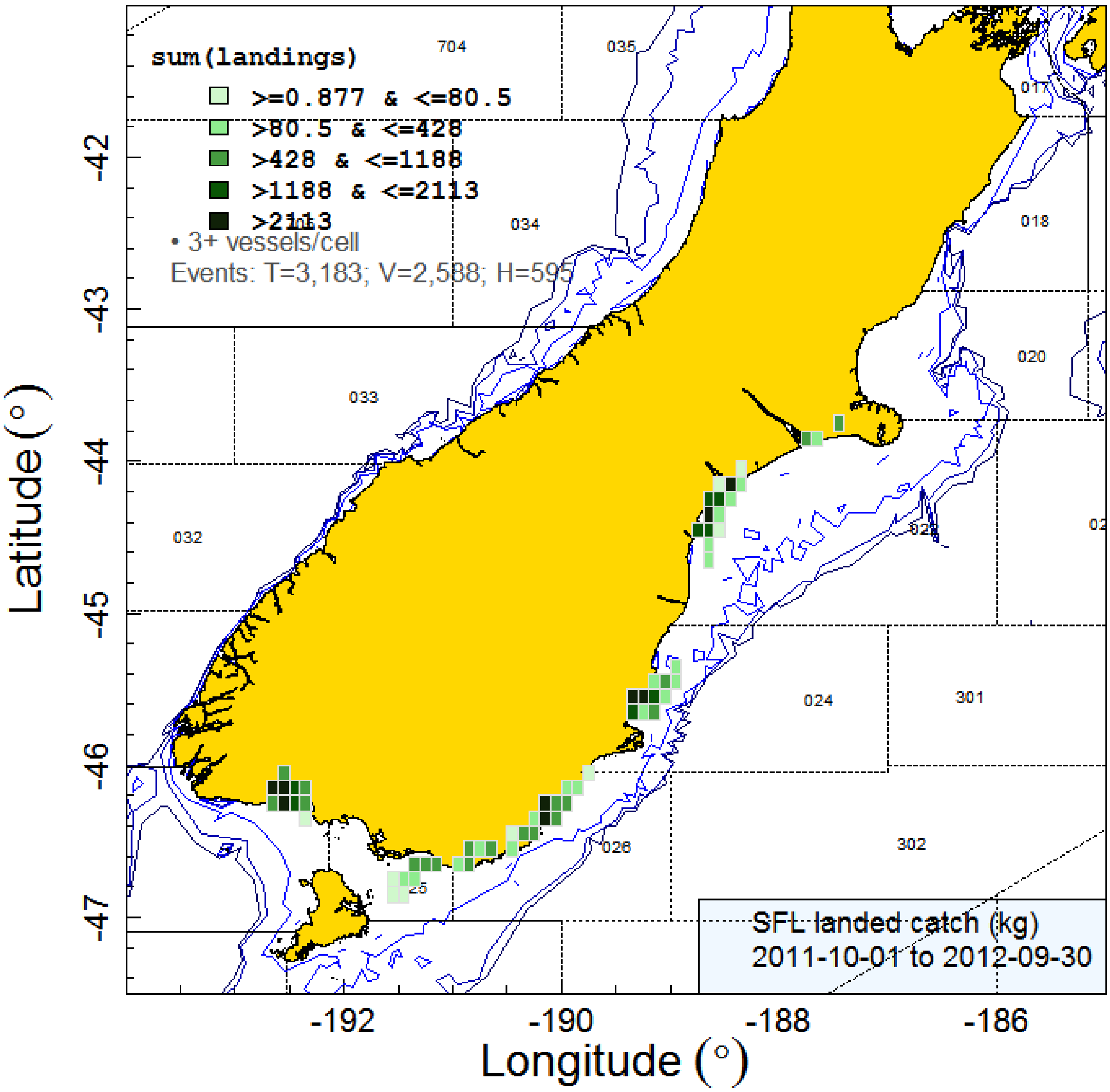


Figure F.19: Spatial distribution of Sand Flounder (SFL) bottom trawl landings (t) reported as FLA 3 in 2011–12, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 595 of 3183 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

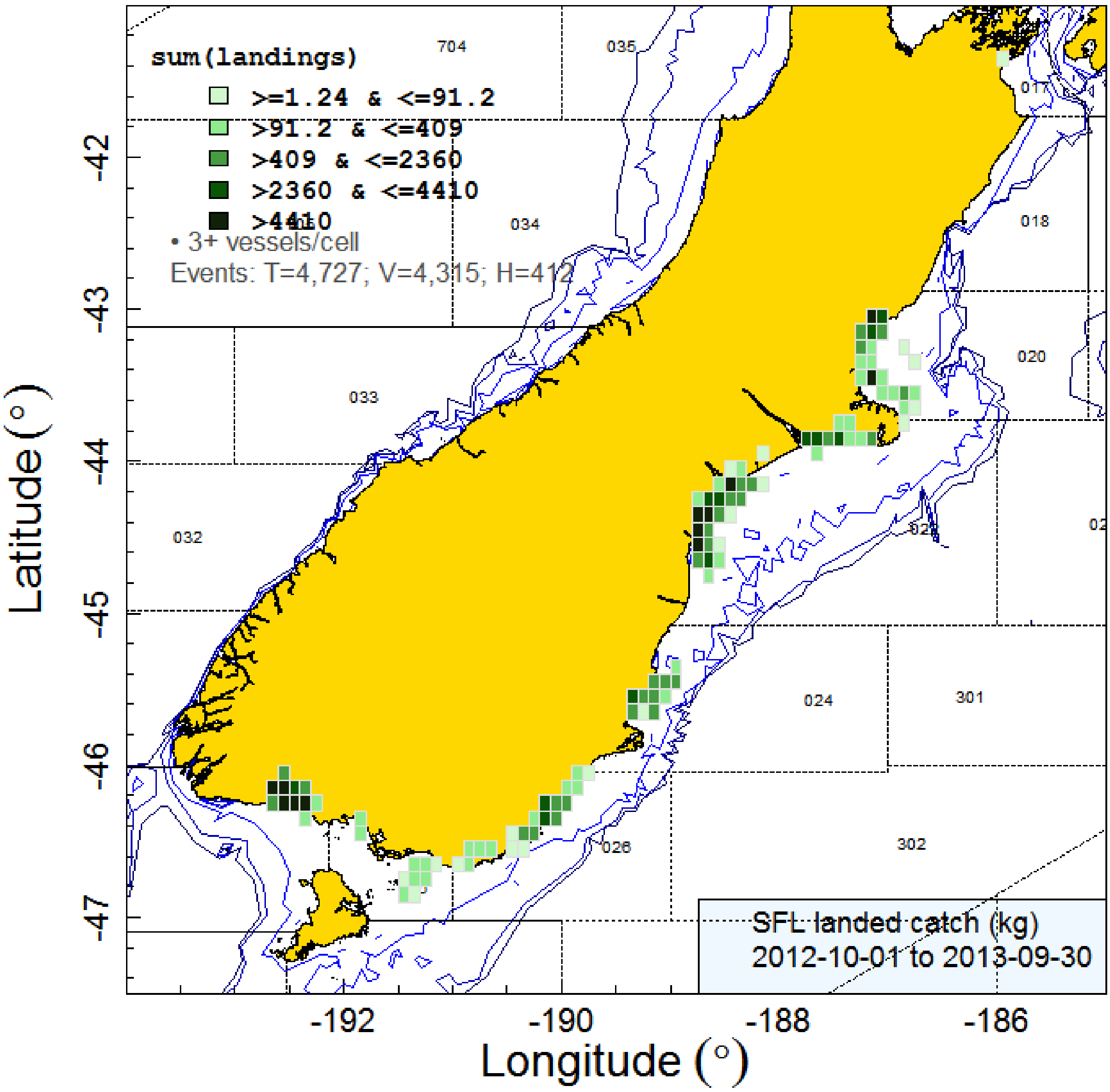


Figure F.20: **Spatial distribution of Sand Flounder (SFL) bottom trawl landings (t) reported as FLA 3 in 2012–13, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 412 of 4727 events. Boundaries are shown for the general statistical areas plotted in Appendix B.**

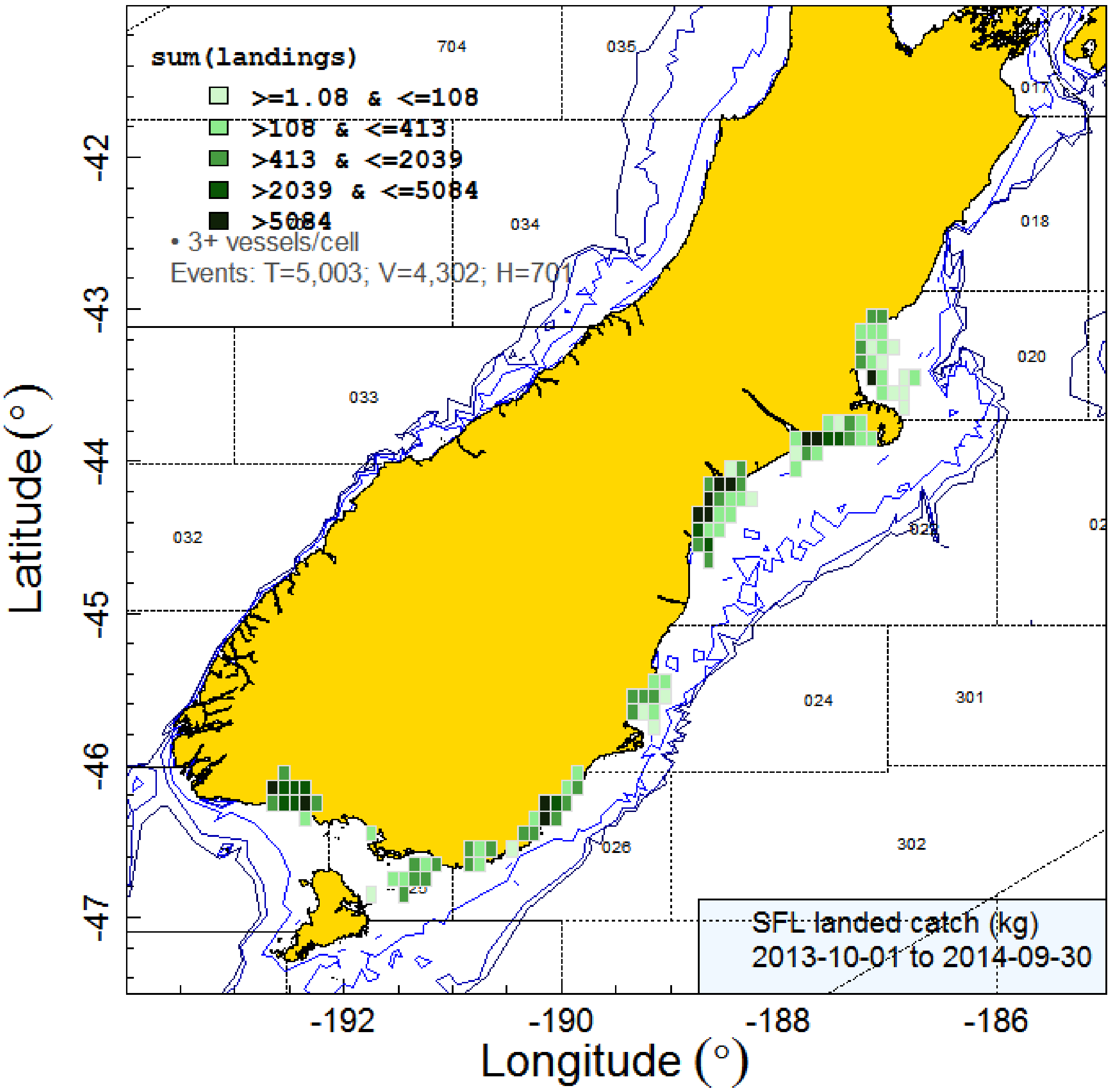


Figure F.21: Spatial distribution of Sand Flounder (SFL) bottom trawl landings (t) reported as FLA 3 in 2013–14, arranged in 0.1° × 0.1° grids. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 701 of 5003 events. Boundaries are shown for the general statistical areas plotted in Appendix B.

Appendix G. DEPTH DISTRIBUTION PLOTS FOR LSO, ESO AND SFL

G.1 Lemon sole (LSO)

Section G.1.1 reports weighted depth profiles for Lemon Sole (LSO), estimated from trips selected using the "*trip splitters*" algorithm, which selects trips which report the catch of flatfish by species and which rejects trips which use the "FLA" code in the estimated catch records (see Appendix D). All trips in the data set were selected because they reported FLA 3 in the landings data. Only tow-by-tow TCER or TCEPR records are included, starting in October 2007 which was when the new TCER forms became mandatory.

G.1.1 LSO depth profiles, weighted by estimated catch

These plots are weighted by the associated estimated catch on each record, which represents a tow. Consequently, the weighting is actually catch/tow. Table G.1 shows the number of trips, tows and the sum of catches in the LSO data set.

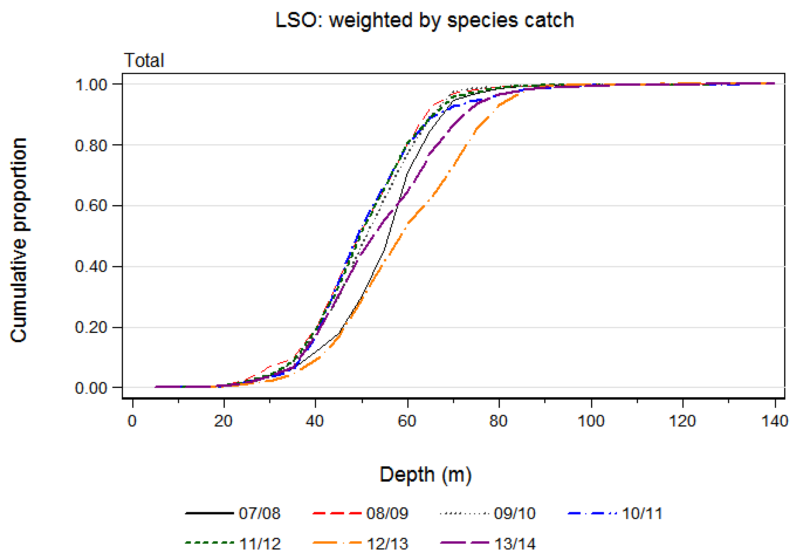
Table G.1: Annual statistics associated with the LSO data used to create depth profiles in Figure G.1 to Figure G.3. Landings have been scaled to total FLA 3 by apportioning the trip landings proportional to the species catch. Trips selected using the "*trip splitters*" algorithm.

Fishing year	N trips	N tows	Scaled landings (t)	Estimated catch (t)
07/08	989	5 531	655.7	562.9
08/09	1 123	5 096	519.5	473.4
09/10	1 099	5 273	587.3	540.4
10/11	991	4 531	320.2	297.8
11/12	958	5 064	427.1	400.9
12/13	1 350	6 235	543.9	492.7
13/14	1 272	5 945	425.2	382.9
Total	7 782	37 675	3 478.9	3 151.0

Figure G.1 [left panel] shows the cumulative bottom depth by fishing year; Figure G.1 [right panel] shows the proportional distribution by depth for each fishing year. Unlike ESO, there is some variation in preferred depths by fishing year for this species, with 2007–08 and 2008–09 deeper than the other years, followed by four shallow years and then with 2013–14 once again at a much deeper level.

Figure G.2 [left panel] shows the cumulative bottom depth by statistical area; Figure G.2 [right panel] shows the proportional distribution by depth for each statistical area. None of the statistical areas line up for this species, with Area 024 being the most shallow, followed by 030, 022, 026, 025 and 020. Surprisingly, the statistical area showing the most shallow distribution for LSO is the deepest for ESO (Area 020).

Figure G.3 [top panel] shows the cumulative bottom depth by fishing year, panelled for each statistical area; Figure G.3 [bottom panel] shows the proportional distribution by depth by fishing year, again panelled by statistical area. The deep distribution in Area 020 is not consistent by year, with the first two years (2007–08 and 2008–09) being much more shallow, followed by 2009–10 which is an intermediate year, and then with the final three years being quite deep (and 2013–14 the deepest of all 7 years). The other statistical areas show relatively little year-to-year variation, except for Area 025, with both 2012–13 and 2013–14 showing deeper depth distributions.



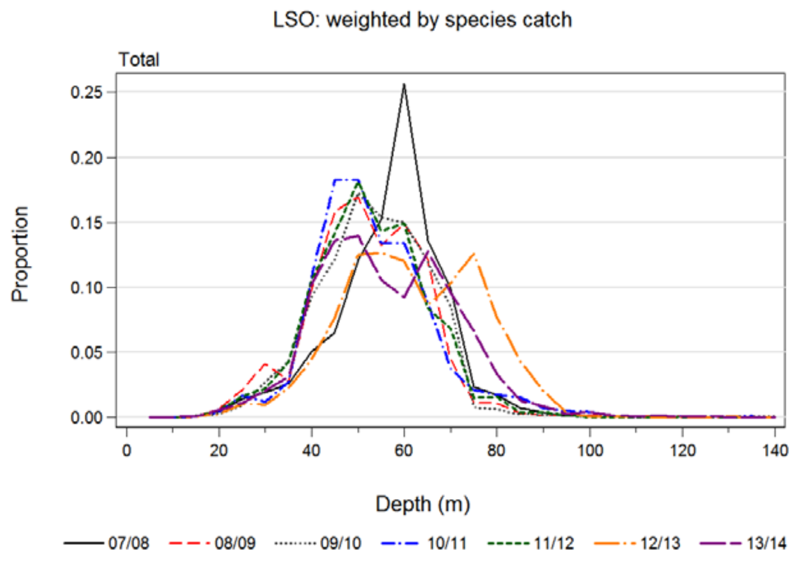


Figure G.1: LSO 3: bottom depth distribution by fishing year: [left panel]: empirical cumulative depth profile; [right panel] proportional depth distribution.

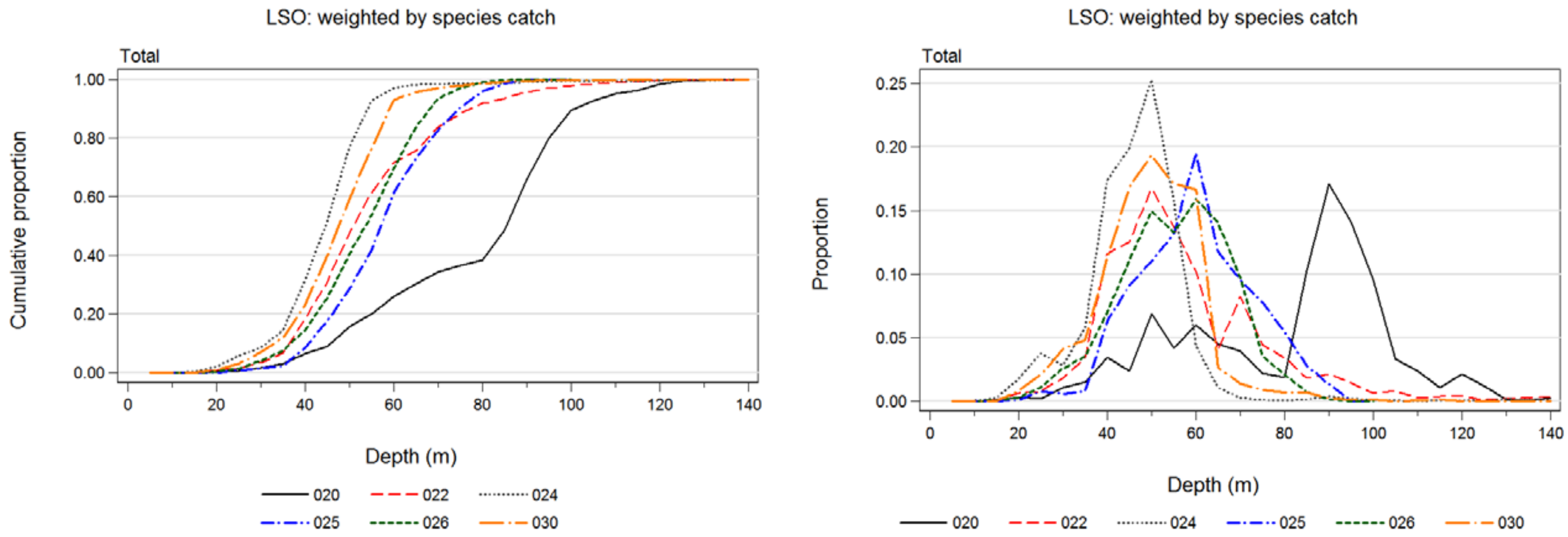
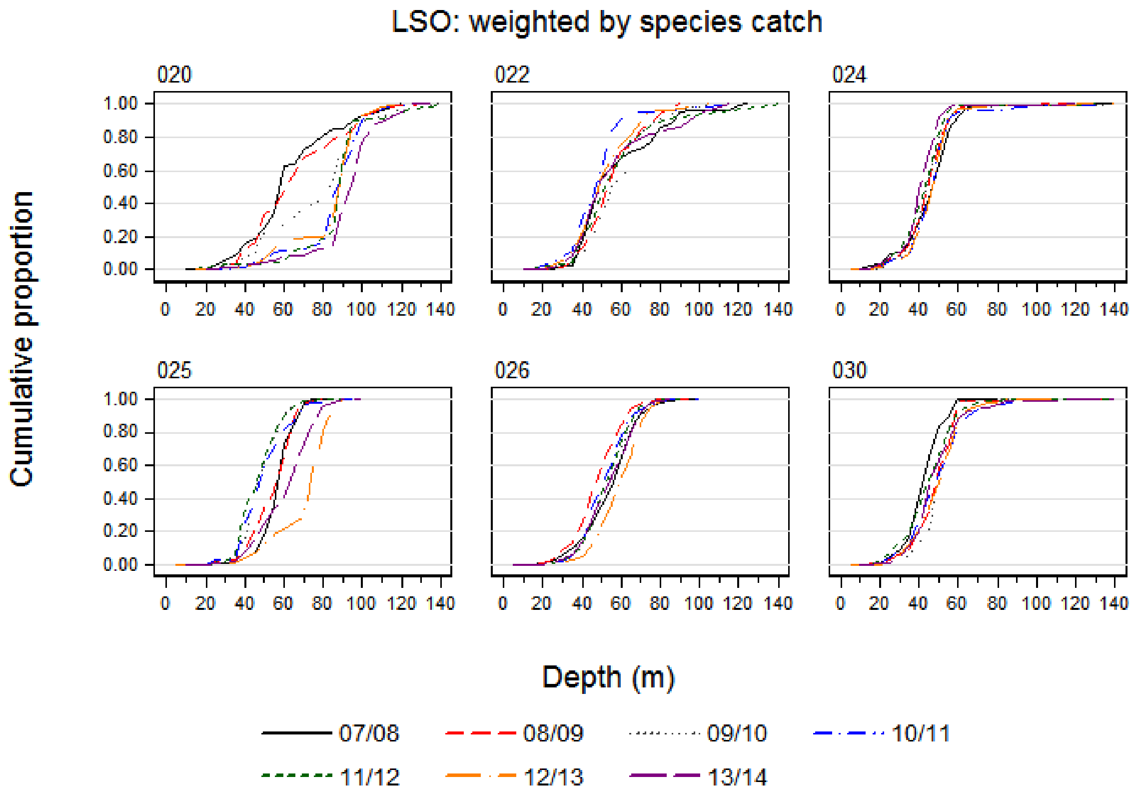


Figure G.2: LSO 3: bottom depth distribution by statistical area: [left panel]: empirical cumulative depth profile; [right panel] proportional depth distribution.



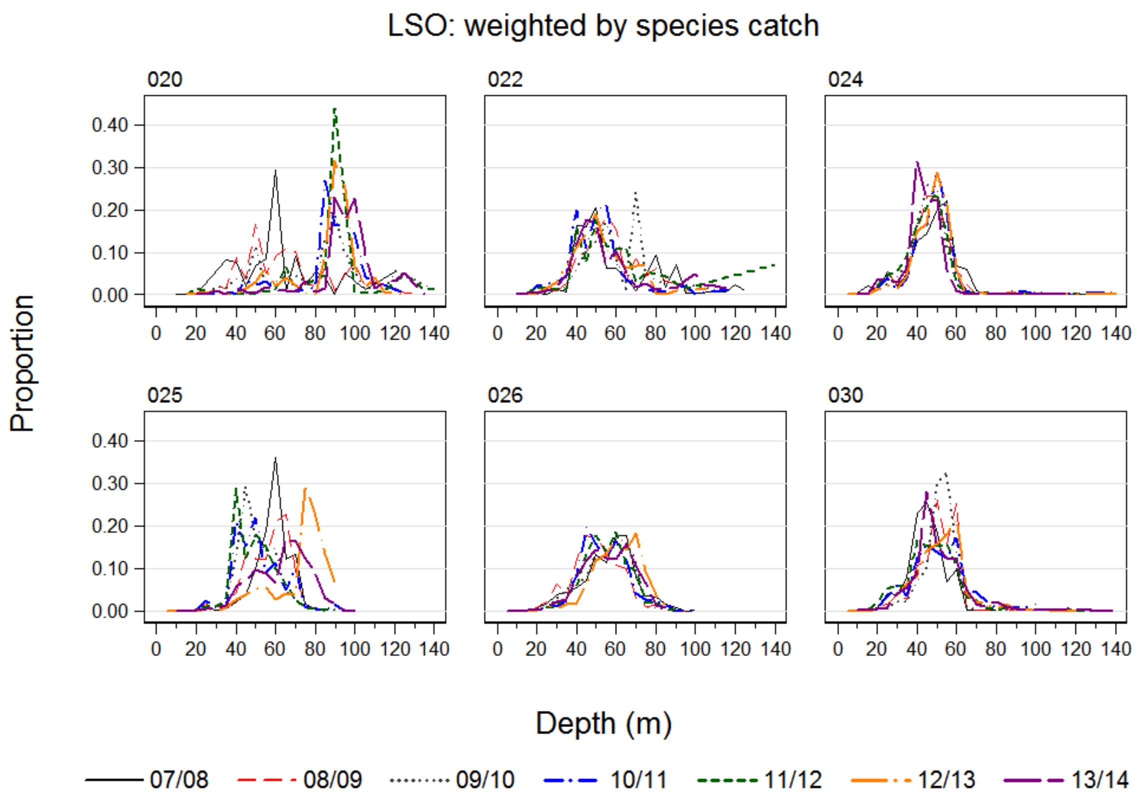


Figure G.3: LSO 3: bottom depth by statistical area and fishing year: [top panel]: empirical cumulative depth profile; [bottom panel] proportional depth distribution.

G.2 New Zealand Sole (ESO)

Section G.2.1 reports weighted depth profiles for New Zealand Sole (ESO), estimated from trips selected using the "*trip splitters*" algorithm, which selects trips which report the catch of flatfish by species and which rejects trips which use the "FLA" code in the estimated catch records (see Appendix D). All trips in the data set were selected because they reported FLA 3 in the landings data. Only tow-by-tow TCER or TCEPR records are included, starting in October 2007 which was when the new TCER forms became mandatory.

G.2.1 ESO depth profiles, weighted by estimated catch

These plots are weighted by the associated estimated catch on each record, which represents a tow. Consequently, the weighting is actually catch/tow. Table G.2 shows the number of trips, tows and the sum of catches in the ESO data set.

Table G.2: Annual statistics associated with the ESO data used to create depth profiles in Figure G.4 to Figure G.6. Landings have been scaled to total FLA 3 by apportioning the trip landings proportional to the species catch. Trips selected using the "*trip splitters*" algorithm.

Fishing year	N trips	N tows	Scaled landings (t)	Estimated catch (t)
07/08	1 057	4 089	168.5	148.3
08/09	1 256	4 590	251.5	225.7
09/10	1 200	4 387	187.1	169.9
10/11	885	3 117	85.5	78.7
11/12	958	4 428	155.5	141.9
12/13	1 764	6 125	239.4	214.0
13/14	1 659	6 114	217.3	199.0
Total	8 779	32 850	1 304.8	1 177.6

Figure G.4 [left panel] shows the cumulative bottom depth by fishing year; Figure G.4 [right panel] shows the proportional distribution by depth for each fishing year. There seems to be little difference in the preferred depths by fishing year for this species, although there is a suggestion that some years (e.g. 2010–11) are perhaps a bit more shallow than the other fishing years.

Figure G.5 [left panel] shows the cumulative bottom depth by statistical area; Figure G.5 [right panel] shows the proportional distribution by depth for each statistical area. There is considerable variation in the preferred depths by statistical area for this species, with the three ECSI statistical areas (020, 022 and 024) fishing at more shallow depths than the three SCSI statistical areas. The SCSI statistical areas show different patterns as well, with the Catlins (026) and western Foveaux Strait (030) showing similar depth profiles while the intermediate statistical area (eastern Foveaux Strait – 025) catches this species deeper than in all the other areas.

Figure G.6 [top panel] shows the cumulative bottom depth by fishing year, panelled for each statistical area; Figure G.6 [bottom panel] shows the proportional distribution by depth by fishing year, again panelled by statistical area. There is little variation by fishing year in the preferred depths for the three ECSI statistical areas (020, 022 and 024). There is more year-to-year variation in the three SCSI statistical areas, but this may be due to data issues because there is no consistency in pattern within a fishing year across the three SCSI statistical areas. For instance, 2010/11 is the deepest fishing year in Area 026, but it is most shallow in Area 030 and is mid-range in Area 025.

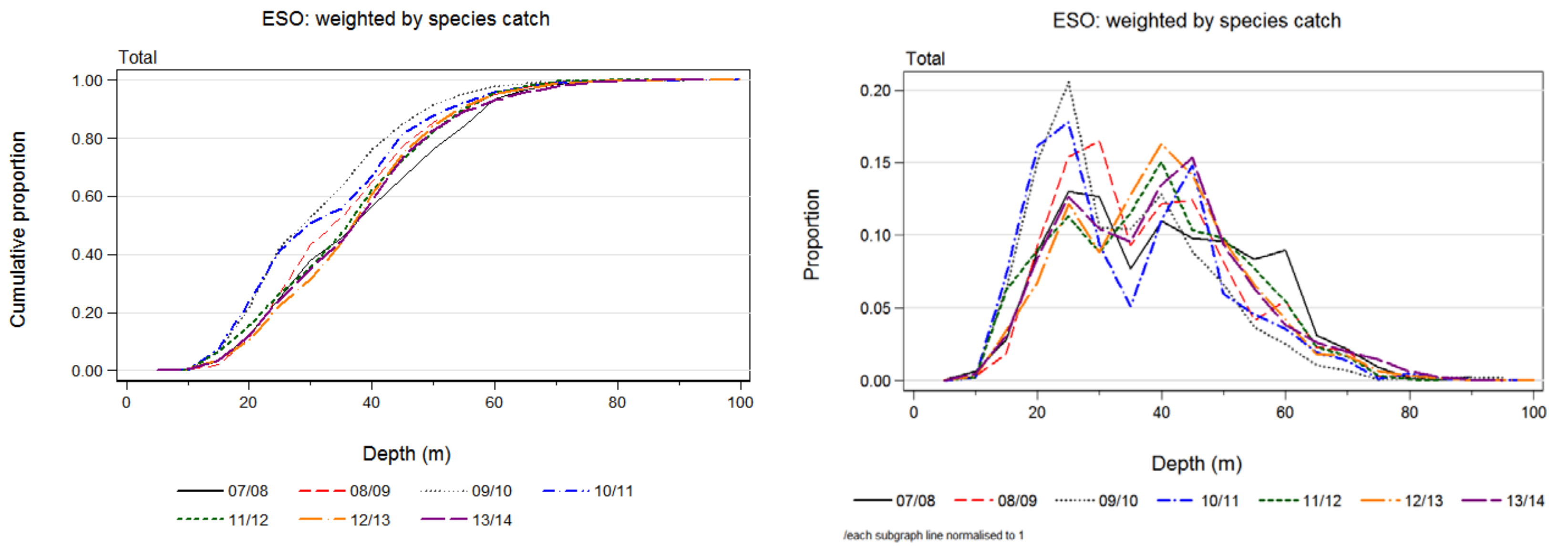


Figure G.4: ESO 3: bottom depth distribution by fishing year: [left panel]: empirical cumulative depth profile; [right panel] proportional depth distribution.

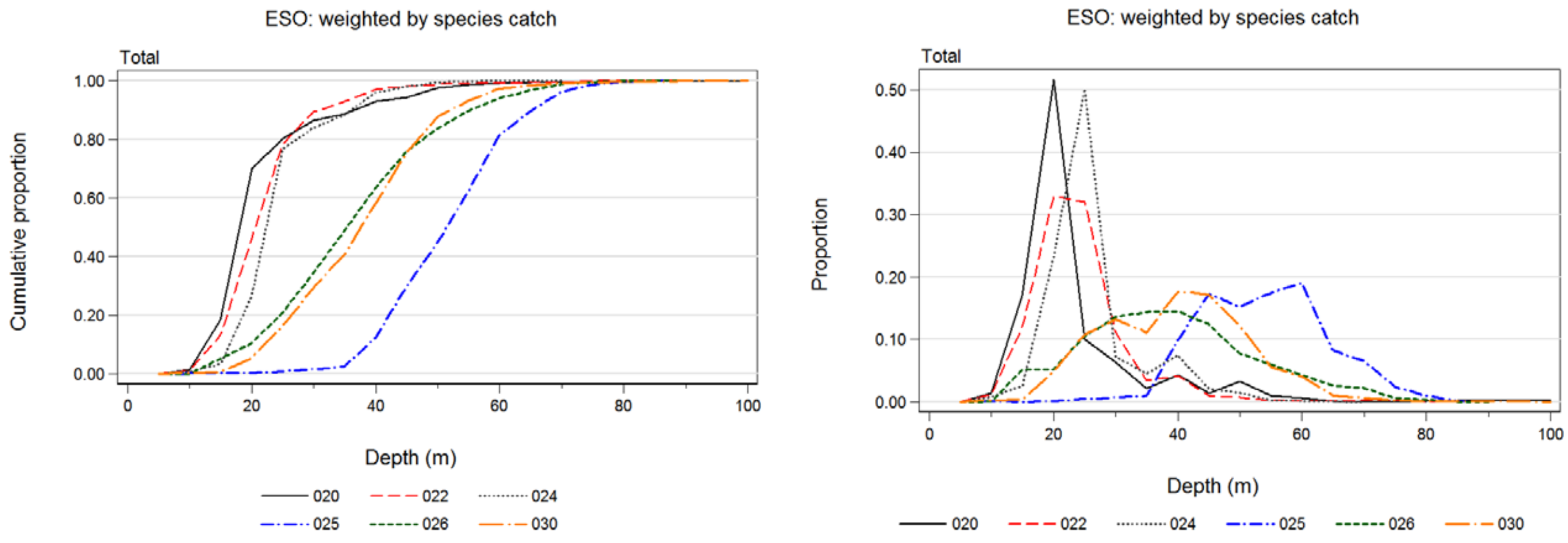
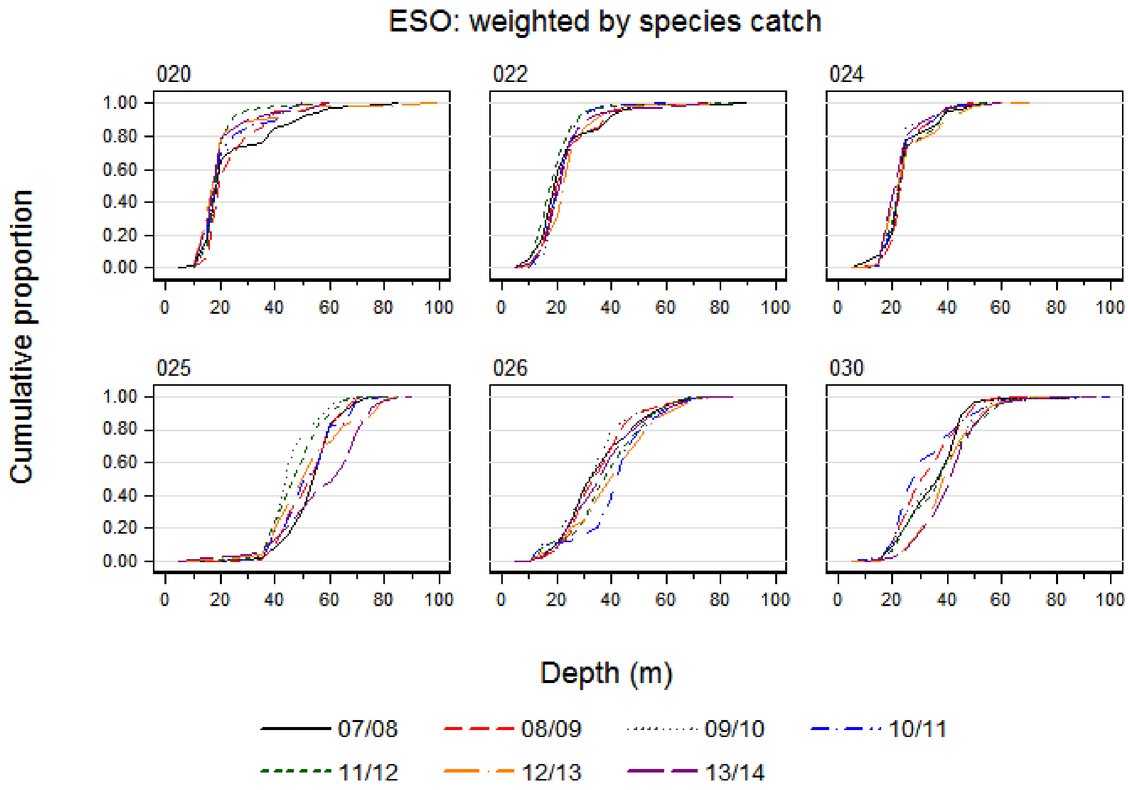


Figure G.5: ESO 3: bottom depth distribution by statistical area: [left panel]: empirical cumulative depth profile; [right panel] proportional depth distribution.



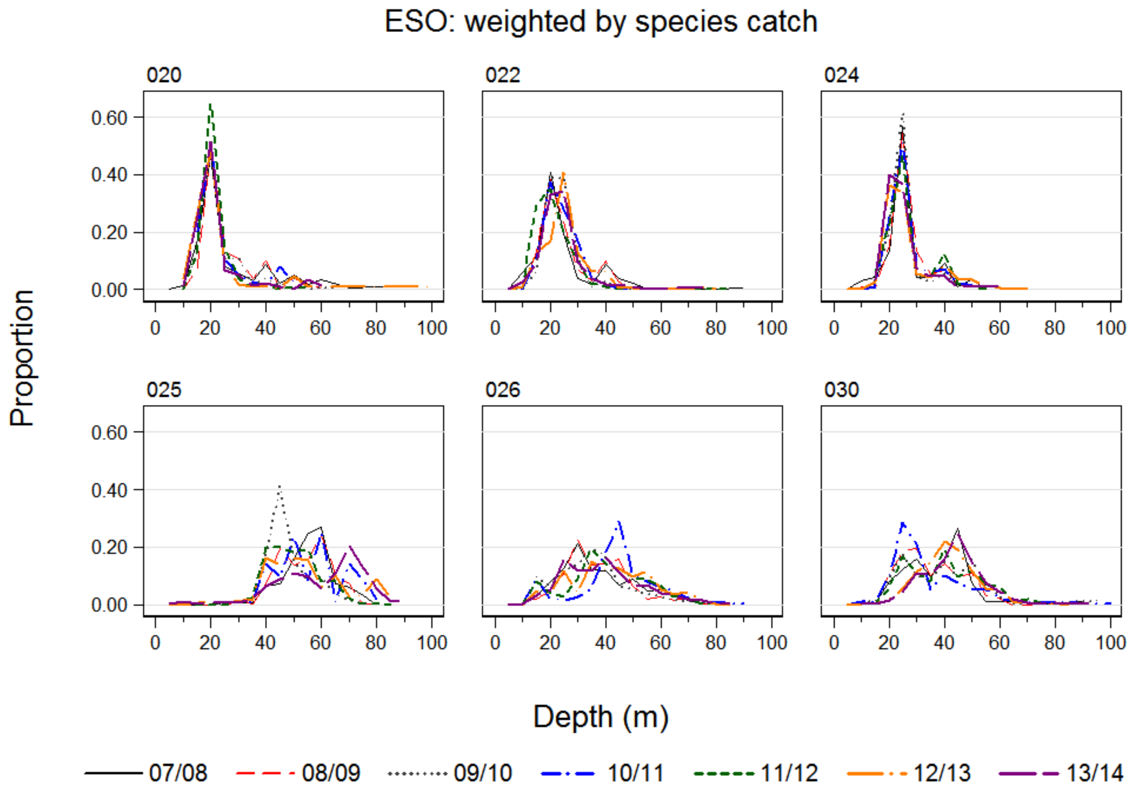


Figure G.6: ESO 3: bottom depth by statistical area and fishing year: [top panel]: empirical cumulative depth profile; [bottom panel] proportional depth distribution.

G.3 Sand Flounder (SFL)

Section G.3.1 reports weighted depth profiles for Sand Flounder (SFL), estimated from trips selected using the "*trip splitters*" algorithm, which selects trips which report the catch of flatfish by species and which rejects trips which use the "FLA" code in the estimated catch records (see Appendix D). All trips in the data set were selected because they reported FLA 3 in the landings data. Only tow-by-tow TCER or TCEPR records are included, starting in October 2007 which was when the new TCER forms became mandatory. Section F.3.1 uses the same selected trips to provide the spatial distribution of SFL landings by fishing year, from 2007–08 (Figure F.15) to 2013–14 (Figure F.21).

G.3.1 SFL depth profiles, weighted by estimated catch

These plots are weighted by the associated estimated catch on each record, which represents a tow. Consequently, the weighting is actually catch/tow. Table G.3 shows the number of trips, tows and the sum of catches in the SFL data set.

Table G.3: Annual statistics associated with the SFL data used to create depth profiles in Figure G.7 to Figure G.9. Landings have been scaled to total FLA 3 by apportioning the trip landings proportional to the species catch. Trips selected using the "*trip splitters*" algorithm.

Fishing year	N trips	N tows	Scaled landings (t)	Estimated catch (t)
07/08	840	2 590	73.5	63.6
08/09	915	2 939	104.5	93.7
09/10	971	3 188	94.6	86.5
10/11	773	2 591	69.6	65.2
11/12	804	3 130	115.3	106.9
12/13	1 516	4 676	176.6	158.0
13/14	1 512	4 912	209.3	183.1
Total	8 540	24 738	1 001.5	863.0

Figure G.7 [left panel] shows the cumulative proportional bottom depth by fishing year; Figure G.7 [right panel] shows the proportional distribution by depth for each fishing year. Like ESO and unlike LSO, there is little variation in preferred depths by fishing year for this species, except for 2007–08 which is considerably deeper than the other fishing years.

Figure G.8 [left panel] shows the cumulative proportional bottom depth by statistical area; Figure G.8 [right panel] shows the proportional distribution by depth for each statistical area. As seen for LSO, none of the statistical areas line up for this species, with Area 020 being the most shallow, followed by 022, 030, 024, 026 and 025. SFL shares Area 020 with ESO as being the statistical area with the most shallow distribution.

Figure G.9 [top panel] shows the cumulative proportional bottom depth by fishing year, panelled for each statistical area; Figure G.9 [bottom panel] shows the proportional distribution by depth by fishing year, again panelled by statistical area. The SFL depth distributions by statistical area and fishing year are very unstable, with lots of variation between fishing years. This may be an artefact of the smaller amounts of data available for this species, with about 25 000 tows and less than 900 t of estimated catch, compared to higher comparable totals for ESO (33 000 tows and 1200 t) and LSO (37 700 tows and 3100 t). Also, Table G.3 shows a trend in the data, with number of tows and annual catch nearly doubling in the seven years of available data.

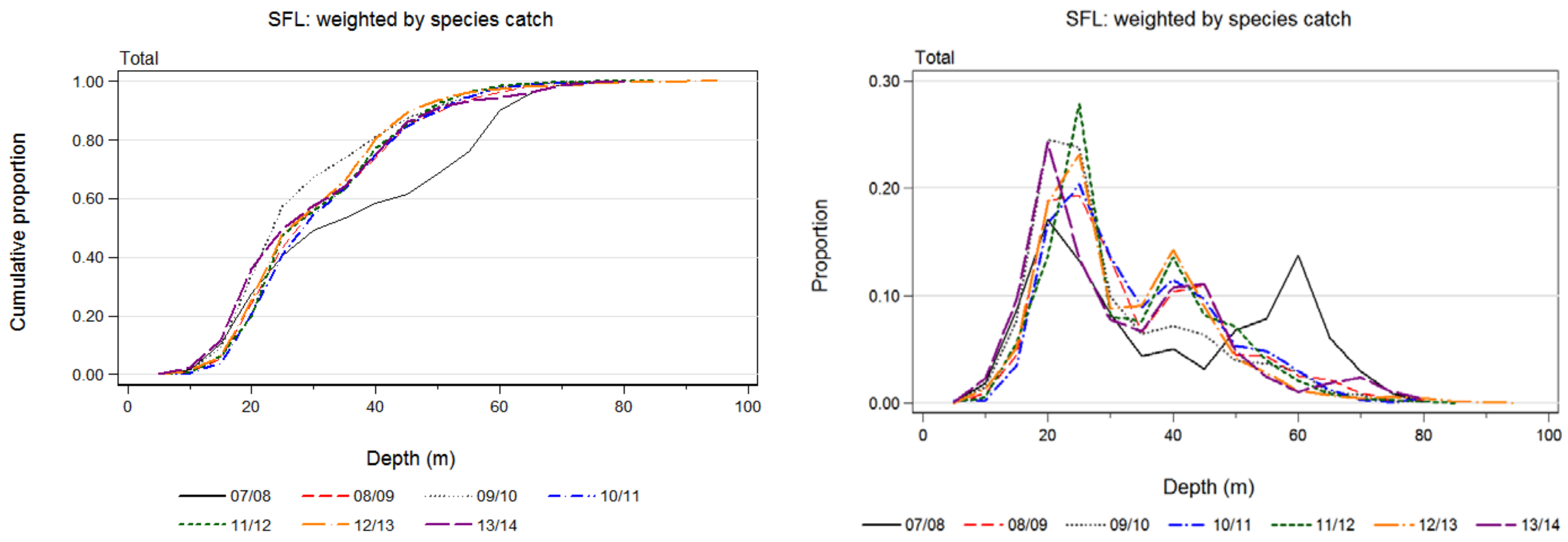


Figure G.7: SFL 3: bottom depth distribution by fishing year: [left panel]: empirical cumulative depth profile; [right panel] proportional depth distribution.

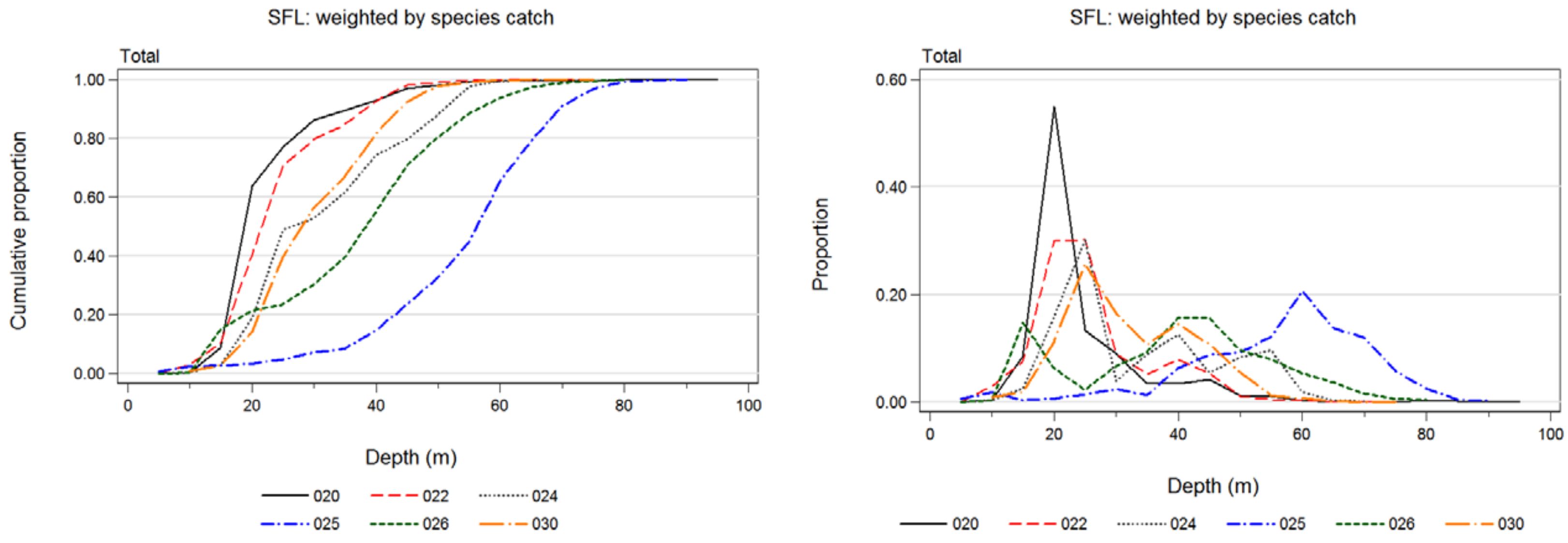
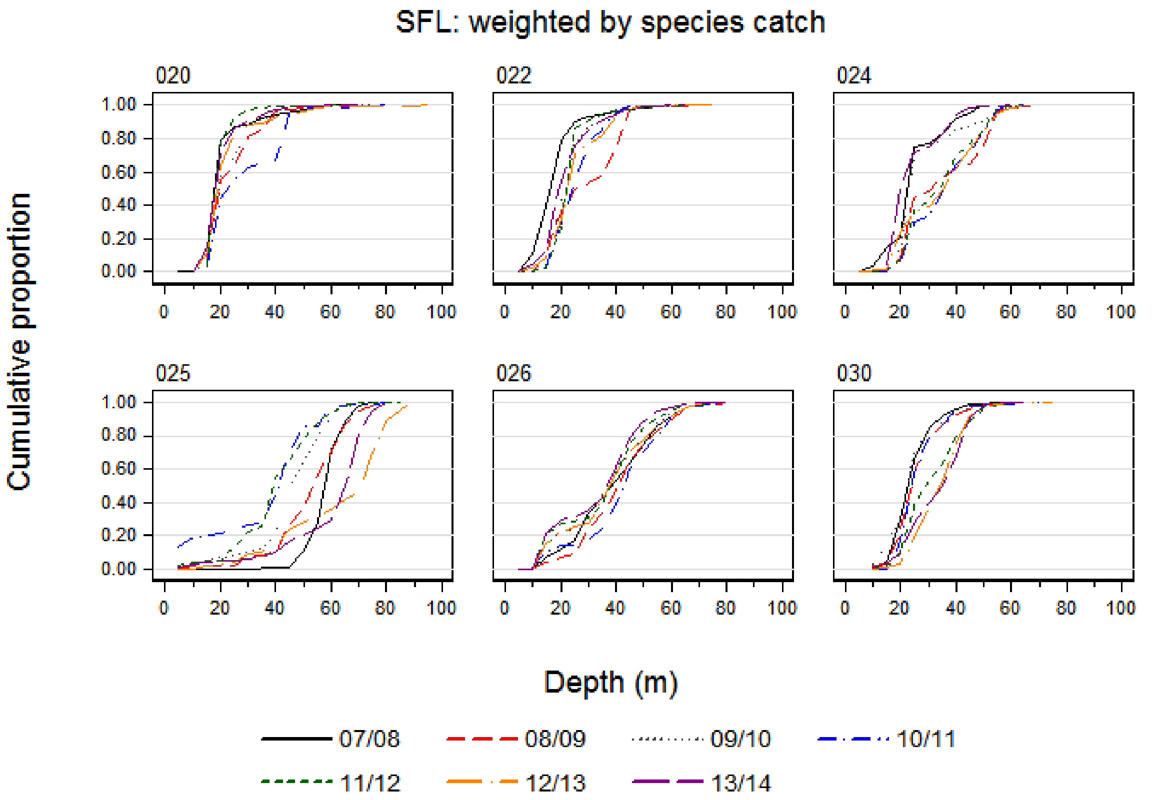


Figure G.8: SFL 3: bottom depth distribution by statistical area: [left panel]: empirical cumulative depth profile; [right panel] proportional depth distribution.



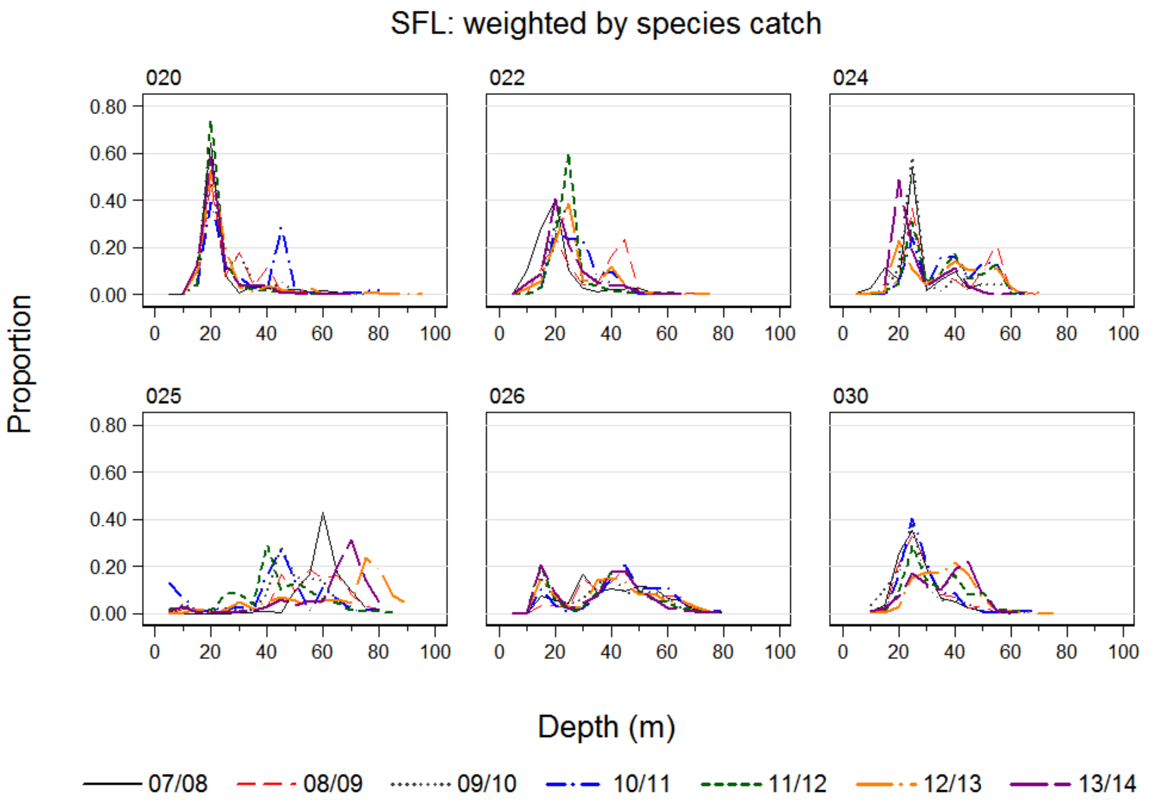


Figure G.9: SFL 3: bottom depth by statistical area and fishing year: [top panel]: empirical cumulative depth profile; [bottom panel] proportional depth distribution.

Appendix H. FLA 3 CPUE ANALYSES: INTRODUCTION

H.1 General overview

Results and detailed diagnostics for an overall FLA 3 CPUE standardisation and three species-specific standardised analyses are presented from Appendix I to Appendix L. These analyses support the descriptions and conclusions presented in Section 3 of the main report. This appendix contains the procedures followed in data preparation, the equations used, and definitions of each standardisation analysis. Appendix I to Appendix L provide detailed tables and figures with statistics and diagnostics, and final tables giving the estimated indices with the standard error for each of the four analyses defined in Table H.1.

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 in the main report. Landings were allocated to effort at the "*daily effort stratum*" resolution procedure described in Section 2.3.3. The CPUE data set was prepared using the "Fishstock" expansion procedure, whereby trips which fished in shared statistical areas and which landed to more than one FLA QMA were dropped. Because of the localised nature of FLA 3, this procedure only resulted in the loss of about 1% of the landings, with the remaining data unequivocally from FLA 3.

Those groups of events that satisfied the criteria of target species, method of capture and statistical areas that defined each fishery were selected from available fishing trips. Any effort strata that were matched to a landing of generic flatfish were termed "successful" and may include relevant but unsuccessful effort given that a "daily-effort stratum" represents amalgamated catch and effort. Consequently, the analysis of catch rates in successful strata may also incorporate some zero catch information.

The potential explanatory variables available from each trip in these data sets include fishing year, the number of tows, the duration of fishing, statistical area, target species, month of landing, and a unique vessel identifier. The dependent variable will be either log(catch), where catch will be the scaled daily landings, or presence/absence of flatfish/species. 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.

Datasets were further restricted to core fleets of vessels, defined by their activity in the fishery, thus selecting only the most active vessels without dropping too much of the available catch and effort data.

H.2.2 Analytical methods for standardisation

Arithmetic CPUE $\left(\hat{A}_y\right)$ in year y was calculated as the mean of catch divided by effort for each observation in the year:

Eq. H.1
$$\hat{A}_y = \frac{\sum_{i=1}^{N_y} C_{i,y} / E_{i,y}}{N_y}$$

where $C_{i,y}$ is the [*catch*] and $E_{i,y} = L_{i,y}$ ([*tows*]–for bottom trawl) in record i in year y, and N_y is the number of records in year y.

Unstandardised CPUE $\left(\hat{U}_y\right)$ in year *y* is the geometric mean of the ratio of catch to effort for each record *i* in year *y*:

Eq. H.2 $$\hat{U}_y = \exp\left[\frac{\sum_{i=1}^{N_y} \ln\left(C_{i,y} \big/ E_{i,y}\right)}{N_y}\right]$$

where C_i, $E_{i,y}$ and N_y are as defined for Eq. H.1. Unstandardised CPUE assumes a log-normal distribution, but does not take into account changes in the fishery. This index is the same as the "year index" calculated by the standardisation procedure, when not using additional explanatory variables and using the same definition for $E_{i,y}$. Presenting the arithmetic and unstandardised CPUE indices in this report provides measures of how much the standardisation procedure has modified the series from these two sets of indices.

A standardised abundance index (Eq. H.3) was calculated from a generalised linear model (GLM) (Quinn & Deriso 1999) using a range of explanatory variables including [*year*], [*month*], [*vessel*] and other available factors:

Eq. H.3 $$\ln(I_i) = B + Y_{y_i} + \alpha_{a_i} + \beta_{b_i} + ... + f\left(\chi_i\right) + f\left(\delta_i\right).... + \varepsilon_i$$

where $I_i = C_i$ for the *i*th record, Y_{y_i} is the year coefficient for the year corresponding to the *i*th record, α_{a_i} and β_{b_i} are the coefficients for categorical variables *a* and *b* corresponding to the *i*th record, and $f\left(\chi_i\right)$ and $f\left(\delta_i\right)$ are polynomial functions (to the 3rd order) of the continuous variables χ_i and δ_i corresponding to the *i*th record, *B* is the intercept and ε_i is an error term. The actual number of categorical and continuous explanatory variables in each model depends on the model selection criteria. Fishing year was always forced as the first variable, and month (of landing), statistical area, target species, and a unique vessel identifier were also offered as categorical variables. Number of tows $\left(\ln\left(T\right)_i\right)$ and fishing duration $\left(\ln\left(H_i\right)\right)$ were offered as continuous third order polynomial variables.

It was decided to force the lognormal distribution for analysing the positive catch part of this CPUE analysis. This was done for consistency with the previous FLA 3 standardised analyses, which selected the lognormal as the "best" distribution (Bentley 2010).

For the positive catch records, log(catch) was regressed 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.

The procedure described by Eq. H.3 is necessarily confined to the positive catch observations in the data set because the logarithm of zero is undefined. Observations with zero catch were modelled by fitting a linear regression model based on a binomial distribution and using the presence/absence of flatfish species as the dependent variable (where 1 is substituted for $\ln(I_i)$ in Eq. H.3 if it is a successful catch record and 0 if it is not successful), using the same data set. Explanatory factors were estimated in the model in the same manner as described for Eq. H.3. Such a model provides an alternative series of standardised coefficients of relative annual changes that is analogous to the equivalent series estimated from the positive catch regression.

A combined model, integrating the two sets of relative annual changes estimated by the lognormal and binomial models, can be estimated using the delta distribution, which allows zero and positive observations (Fletcher et al. 2005). Such a model provides a single index of abundance which integrates the signals from the positive (lognormal) and binomial series. This approach uses the following equation to calculate an index based on the two contributing indices, after standardising each series to a geometric mean=1.0:

Eq. H.4 $$^{C}Y_y = {}^{L}Y_y \; {}^{B}Y_y$$

where $^{C}Y_y$ = combined index for year ,

$^{L}Y_y$ = lognormal index for year ,

$^{B}Y_y$ = binomial index for year

Confidence bounds, while straightforward to calculate for the binomial and lognormal models, were not calculated for the combined model because a bootstrap procedure (recommended by Francis 2001) has not yet been implemented in the available software. The index series plots below present normalised values, i.e., each series is divided by its geometric mean so that the series is centred on 1. This facilitates comparison among series.

H.3 Fishery definitions

The following selection criteria were used for defining the four bottom trawl fishery models described in this report. Estimated catches were scaled to the trip landings using the daily effort-stratum method of Langley (2014) (described in Section 2.3.3). The overall FLA 3 model was fitted to the entire data set less the 79 trips identified in Appendix C. The three species-specific standardised CPUE analyses were performed on the "*trip splitter*" data set described in Appendix D, which uses flatfish species specific estimated catch information. The FLA 3(TOT) analysis combined all species-specific flatfish codes (see Table A.3) in both the target species field and the species catch field into a single generic FLA code.

Table H.1: List of specifications for modelled FLA bottom trawl (BT) fisheries. All models used the same statistical area definition (020, 022, 024, 026, 025, 030) and used records which targeted one of the 15 species codes in Table A.3.

Model	Core fleet definition	Number vessels and % retained landings	Positive distribution	Document reference
FLA 3(TOT)	10 trips/5 years	118 vessels/90%	lognormal	Appendix I
LSO 3	5 trips/5 years	55 vessels/92%	lognormal	Appendix J
ESO 3	5 trips/5 years	81 vessels/89%	lognormal	Appendix K
SFL 3	5 trips/5 years	56 vessels/78%	lognormal	Appendix L

All four bottom trawl positive catch models were forced to the lognormal distribution to ensure continuity with previous analyses (Bentley 2010). No binomial model was run on the FLA 3(TOT) data set because of the very low proportion of zero days fishing which was also without trend. A binomial model based on the presence/absence of species in each data set was also calculated for the three species-specific models as there were reasonable proportions of records with no species catch in each analysis (see final rightmost column in Table J.1, Table K.1, and Table L.1). The two series were then combined using the delta-lognormal method (Eq. H.4).

Appendix I. DIAGNOSTICS AND SUPPORTING ANALYSES FOR FLA 3(TOT) BOTTOM TRAWL CPUE

I.1 Model definition and preliminary analyses

This CPUE analysis was accepted for monitoring FLA 3 by the Southern Inshore Fishery Assessment Working Group in 2010 and 2015 (MPI 2015). It is also used to drive the in-season management procedure (MP) that is operated in January or February of each year (see Section 4).

I.1.1 Fishery definition

FLA 3(TOT): The fishery is defined from bottom trawl daily fishing events which fished in Statistical Areas 020, 022, 024, 026, 025, and 030, declaring a target species from one of the 15 species codes in Table A.3. Daily events with more than 12 tows or 24 hours of accumulated effort were excluded from the analysis.

I.1.2 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 10 trips in each of at least 5 years using trips with at least 1 kg of FLA catch. These criteria resulted in a core fleet size of 118 vessels which took 90% of the catch (Figure I.1).

I.1.3 Data summary

Table I.1: Summaries by fishing year for core vessels, trips, daily effort strata, events that have been "rolled up" into daily effort strata, events per daily-effort stratum, tows, hours fished, landed FLA (t), and percentage of trips with catch for the core vessel data set (based on a minimum of 10 trips per year in 5 years) in the FLA 3(TOT) fishery. Final two columns apply to trips which declared no estimated catch of flatfish but reported FLA landings, giving the percent of trips relative to trips which reported FLA and the percent of the reported catch from these trips relative to the total annual FLA reported catch.

Fishing year	Vessels	Trips	Daily effort strata	Events	Events per stratum	Sum (tows)	Sum (hours)	Catch (t)	% trips with catch	% trips: 0 estimated catch	% catch: 0 estimated catch trips
1990	72	3 173	3 646	3 680	1.01	10 324	25 240	774	94.61	1.07	0.49
1991	66	3 105	3 563	3 712	1.04	9 739	27 061	552	93.37	1.07	0.33
1992	73	2 970	3 543	3 685	1.04	10 259	27 673	656	93.13	0.87	0.18
1993	80	3 860	4 703	4 892	1.04	13 847	35 829	1 137	94.51	0.66	0.27
1994	84	3 866	4 610	4 712	1.02	13 814	33 559	1 215	95.71	0.65	0.35
1995	78	3 973	4 555	4 652	1.02	13 046	31 572	1 188	96.22	1.02	0.34
1996	80	3 722	4 435	4 560	1.03	13 591	33 717	1 405	97.07	1.41	0.74
1997	82	3 938	4 848	5 035	1.04	15 891	37 159	1 585	97.44	0.83	0.29
1998	76	3 990	4 898	5 037	1.03	15 319	36 379	1 446	97.27	1.75	0.35
1999	69	4 075	5 107	5 263	1.03	15 572	38 683	1 298	96.52	4.60	2.08
2000	73	3 783	4 797	4 845	1.01	14 030	35 876	1 162	97.73	4.22	3.05
2001	74	3 193	4 327	4 363	1.01	13 488	33 362	1 298	95.96	1.50	0.29
2002	67	3 114	4 251	4 366	1.03	13 023	30 754	1 292	97.05	1.56	0.33
2003	63	3 342	4 754	4 868	1.02	15 446	36 841	1 278	96.74	0.84	0.23
2004	64	3 241	4 424	4 459	1.01	13 721	33 345	929	96.85	0.80	0.18
2005	66	3 346	4 475	4 495	1.00	13 590	34 036	880	97.01	1.23	0.31
2006	58	2 581	3 560	3 584	1.01	11 125	29 285	855	96.63	1.24	0.22
2007	56	2 184	3 289	3 314	1.01	10 595	28 412	1 070	96.43	2.80	0.27
2008	55	2 009	3 085	8 523	2.76	8 886	24 081	1 199	98.41	2.48	0.32
2009	51	2 165	3 203	8 307	2.59	8 690	25 090	1 254	99.03	1.96	0.20
2010	49	2 176	3 394	9 202	2.71	9 362	27 159	1 168	98.58	1.77	0.11
2011	50	1 863	2 812	7 673	2.73	7 730	22 264	680	99.30	2.59	0.38
2012	49	2 121	3 365	9 258	2.75	9 386	27 827	1 069	98.40	0.86	0.45
2013	47	2 282	3 422	9 224	2.70	9 332	28 502	1 063	98.64	1.51	0.24
2014	48	2 095	3 052	7 883	2.58	7 953	25 549	794	98.90	2.90	0.49

I.1.4 Core vessel plots

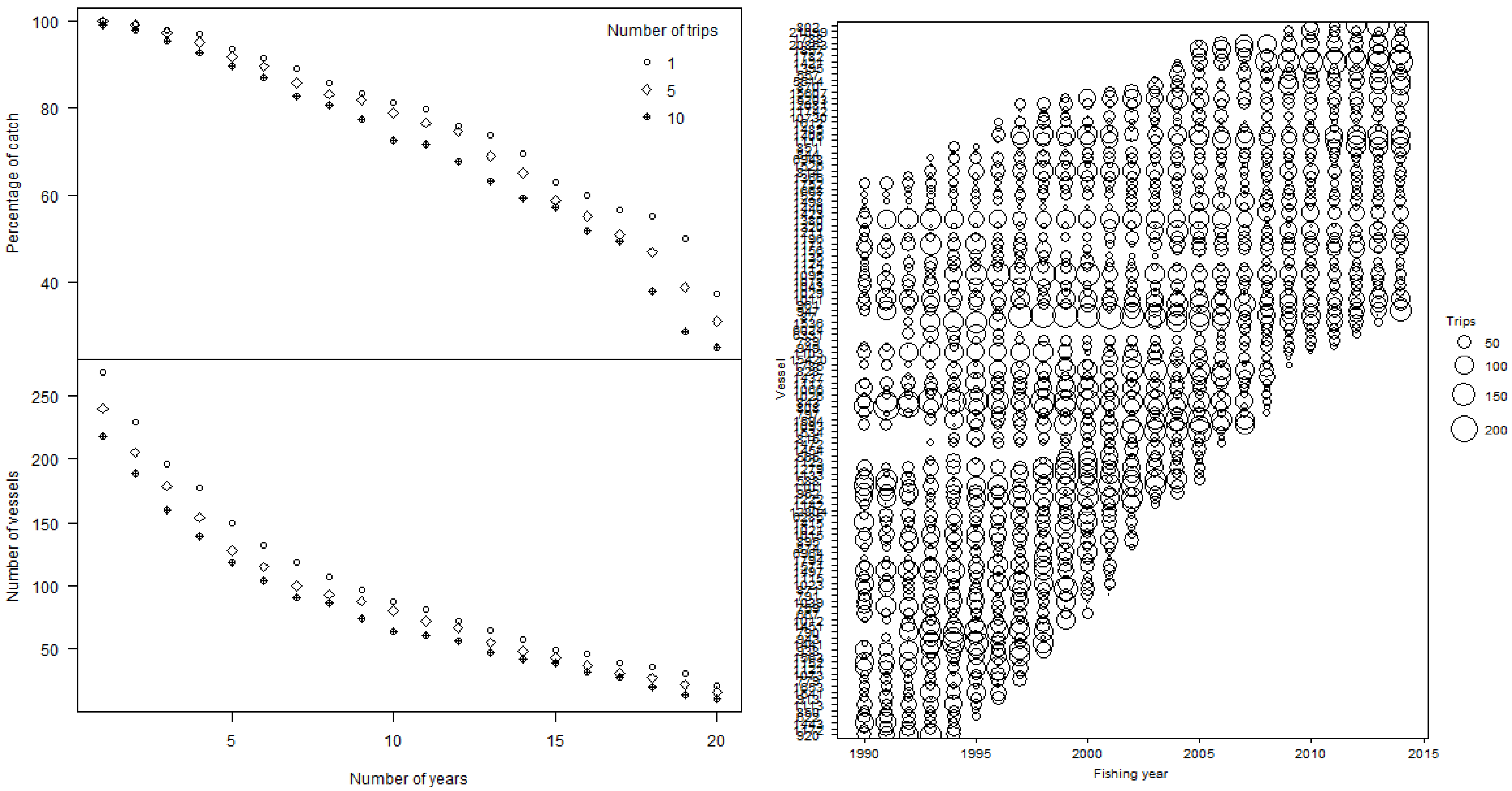


Figure I.1: [left panel] total landed FLA and number of vessels plotted against the number of years used to define core vessels participating in the FLA 3(TOT) dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot showing the number of daily-effort strata for selected core vessels (based on at least 10 trips in 5 or more fishing years) by fishing year.

I.1.5 Exploratory data plots for core vessel data set

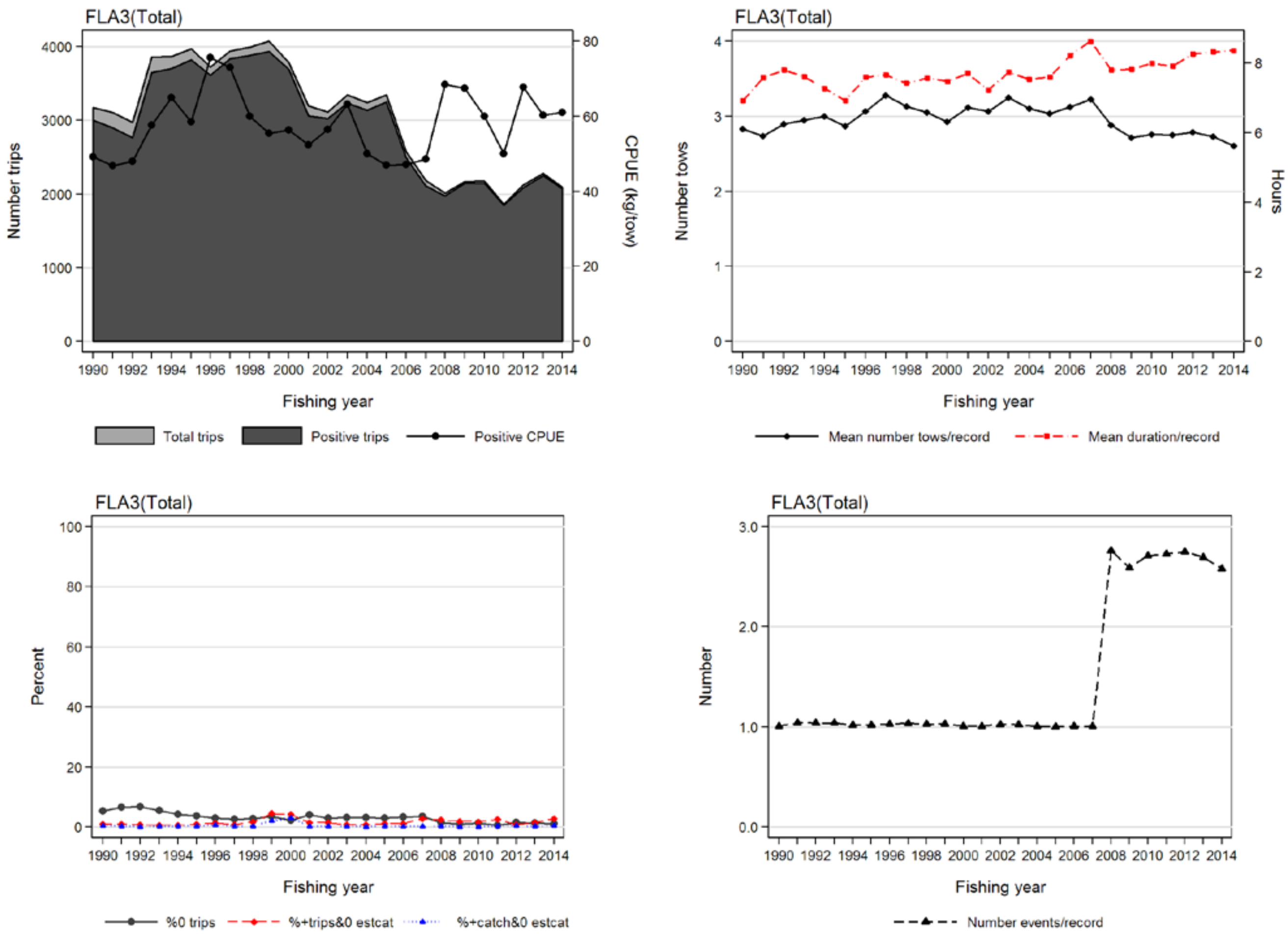


Figure I.2: Core vessel summary plots by fishing year for model FLA 3(TOT): [upper left panel]: total trips (light grey) and trips with flatfish catch (dark grey) overlaid with median annual arithmetic CPUE (kg/tow) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i}/E_{y,i}\right)$; [upper right panel]: mean number of tows and mean duration per daily-effort stratum record; [lower left panel]: a) percentage of trips with no catch of flatfish, b) percentage of trips with no estimated catch but with landed catch; c) percentage of catch with no estimated catch relative to total landed catch; [lower right panel]: mean number of events per daily-effort stratum record.

I.2 Positive catch model

Four explanatory variables entered the model after fishing year (number tows, vessel, duration fishing and area; Table I.2), with month non-significant. A plot of the model is provided in Figure I.3 and the CPUE indices are listed in Table I.3.

Table I.2: Order of acceptance of variables into the lognormal model of successful catches in the FLA 3(TOT) fishery model for core vessels (based on the vessel selection criteria of at least 10 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	26	-638 622	1 277 296	2.3	*
poly(log(tows), 3)	29	-616 984	1 234 027	37.5	*
vessel	146	-604 040	1 208 373	52.2	*
poly(log(duration), 3)	149	-599 942	1 200 181	56.1	*
area	154	-598 146	1 196 600	57.7	*
month	165	-597 557	1 195 443	58.2	

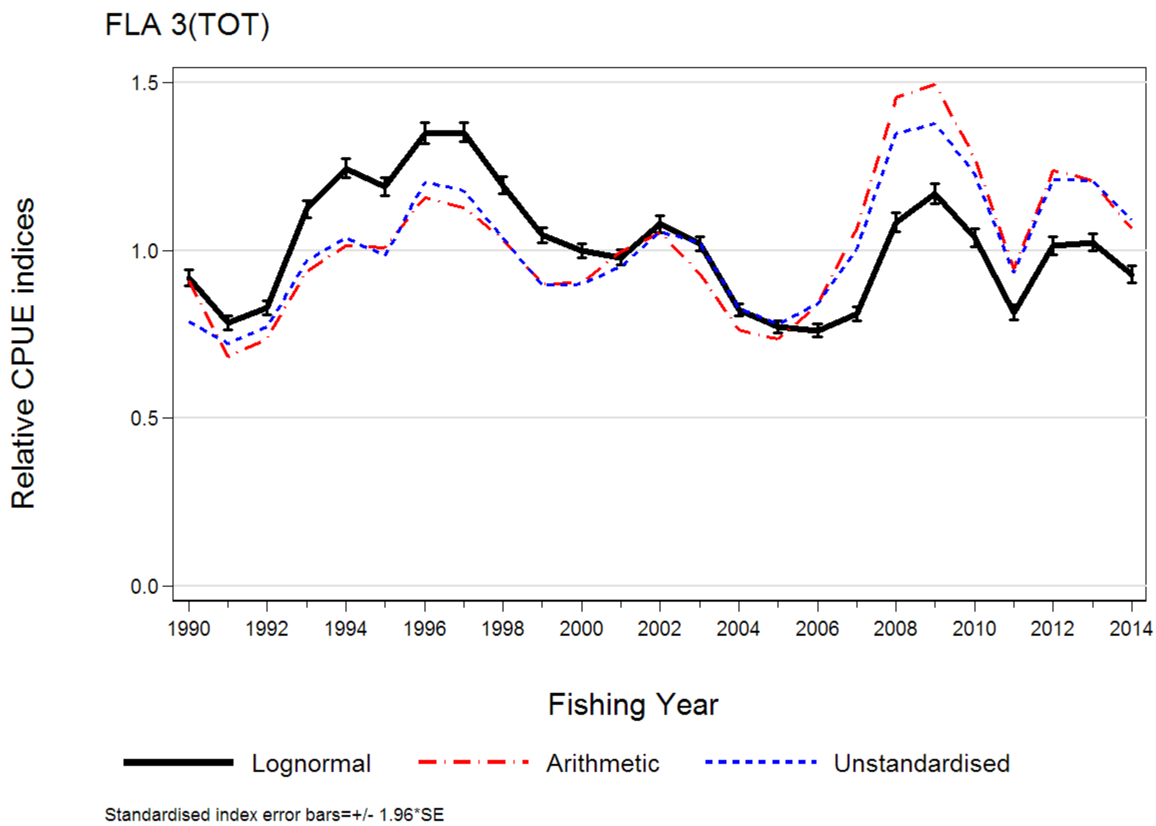


Figure I.3: Relative CPUE indices for FLA using the lognormal non-zero model based on the FLA 3(TOT) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. H.1) and b) Unstandardised (Eq. H.2).

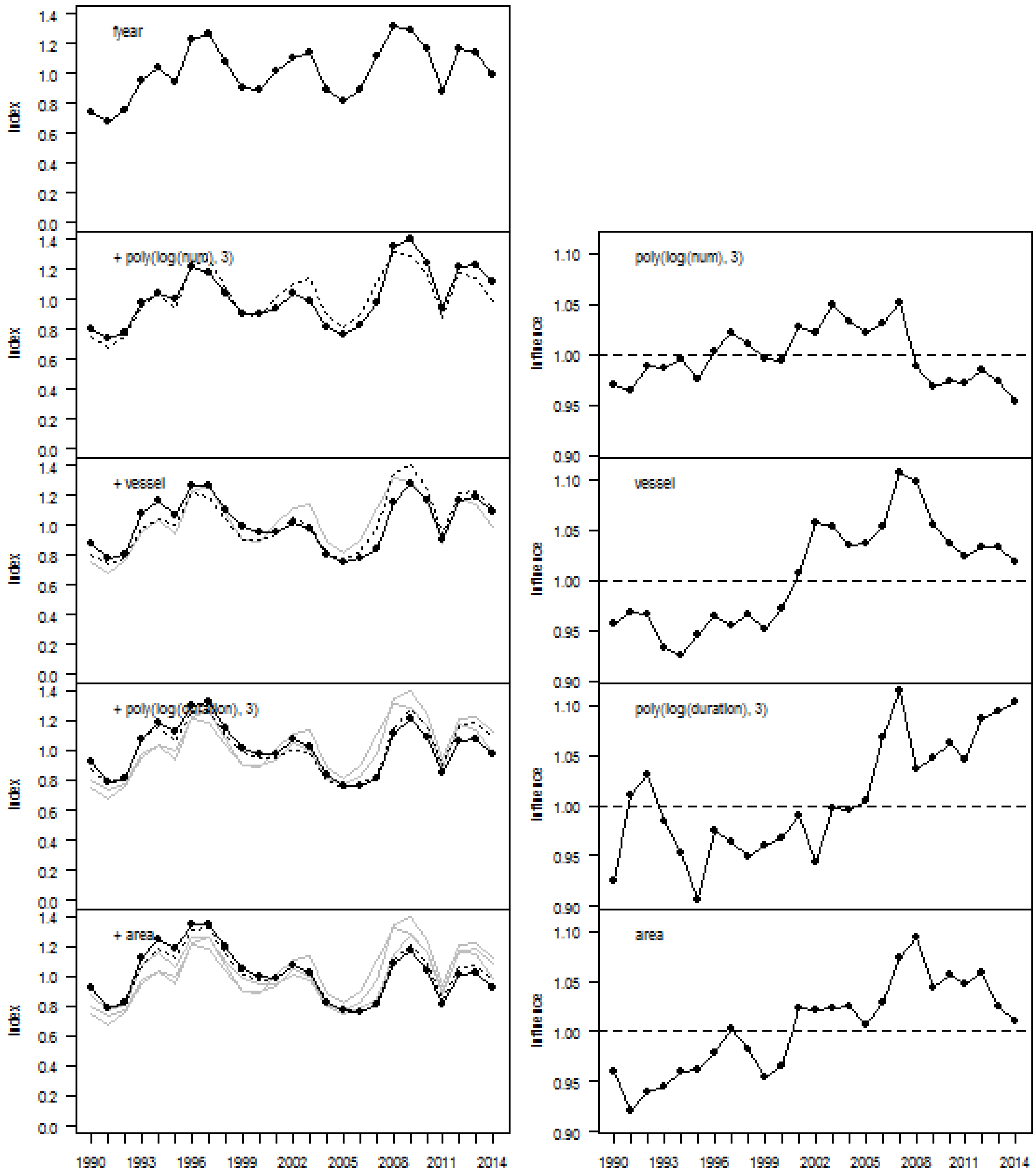


Figure I.4: [left column]: annual indices from the lognormal model of FLA 3(TOT) at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

I.2.1 Residual and diagnostic plots

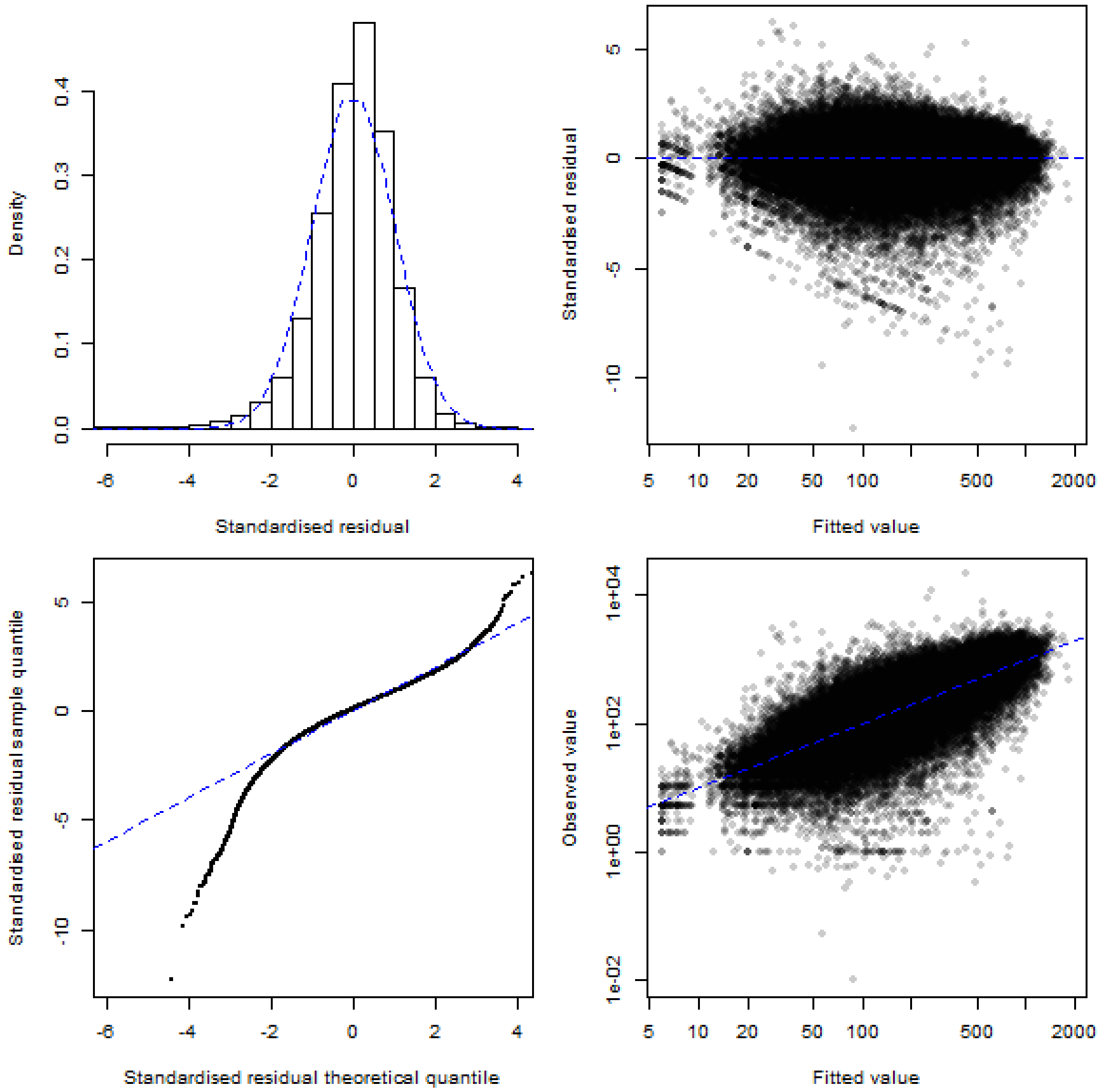


Figure I.5: Plots of the fit of the lognormal standardised CPUE model of successful catches of flatfish in the FLA 3(TOT) fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

I.2.2 Model coefficient plots

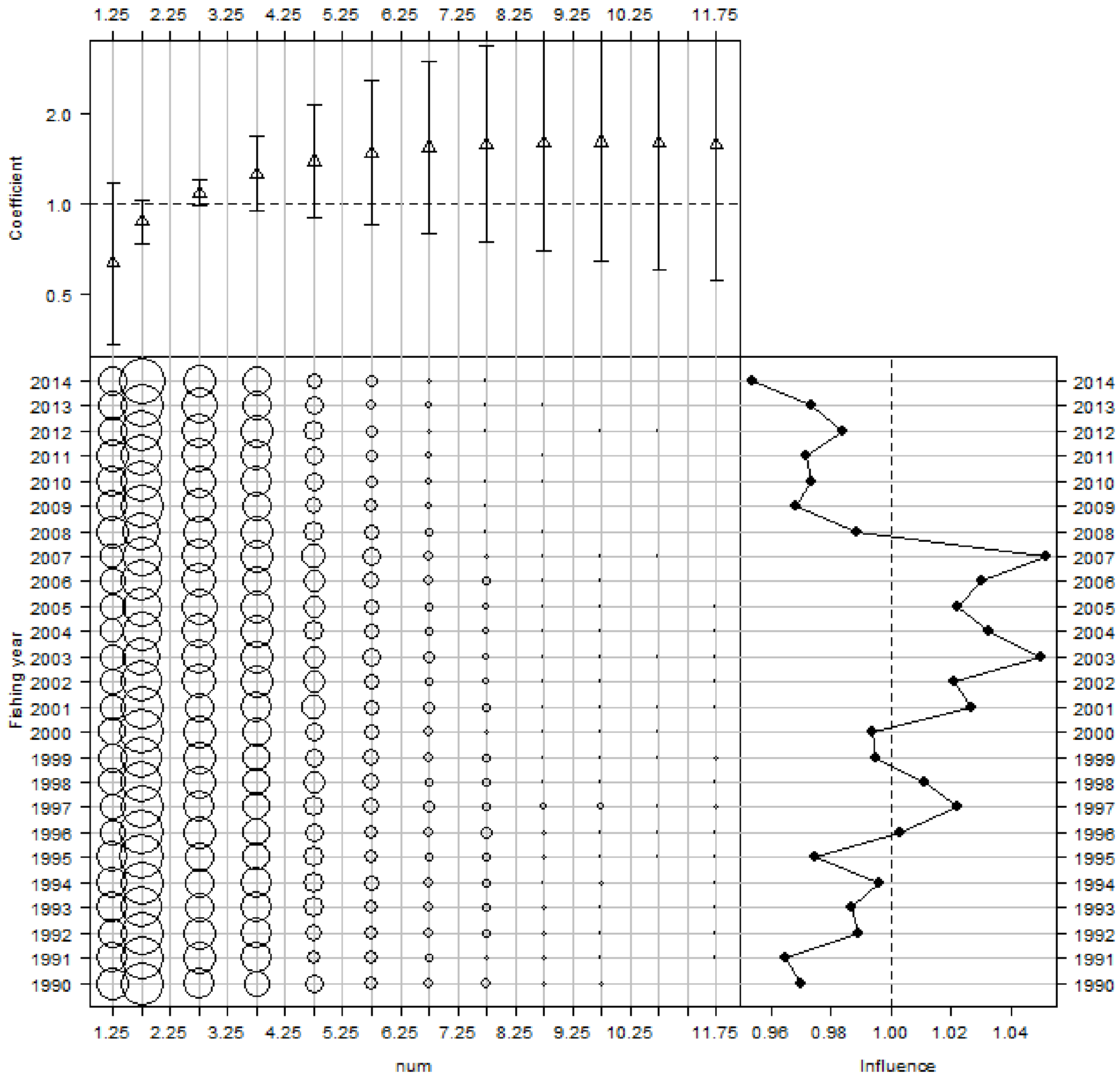


Figure I.6: Effect of log(number tows) in the lognormal model for the flatfish FLA 3(TOT) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

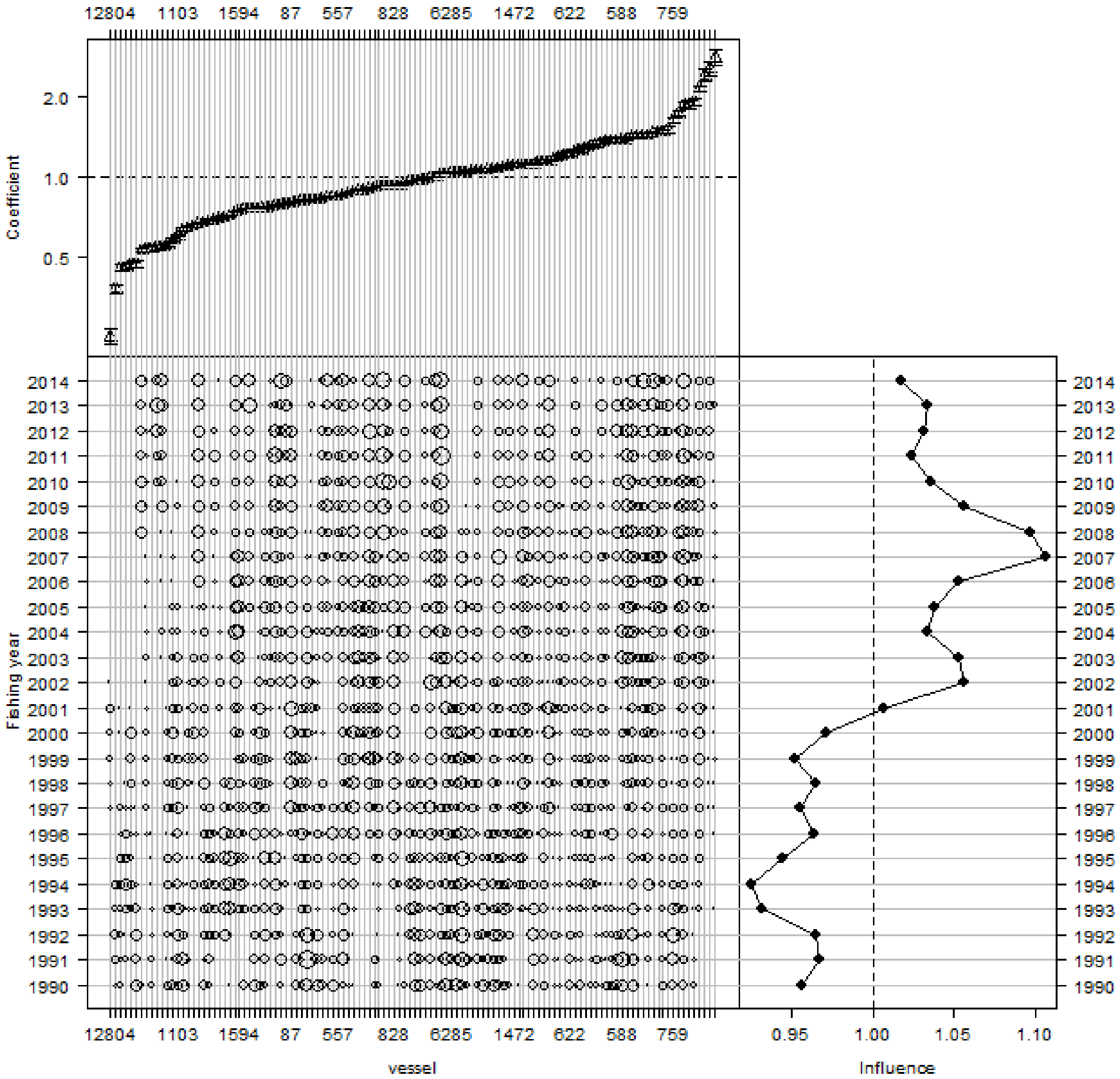


Figure I.7: Effect of vessel in the lognormal model for the flatfish FLA 3(TOT) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

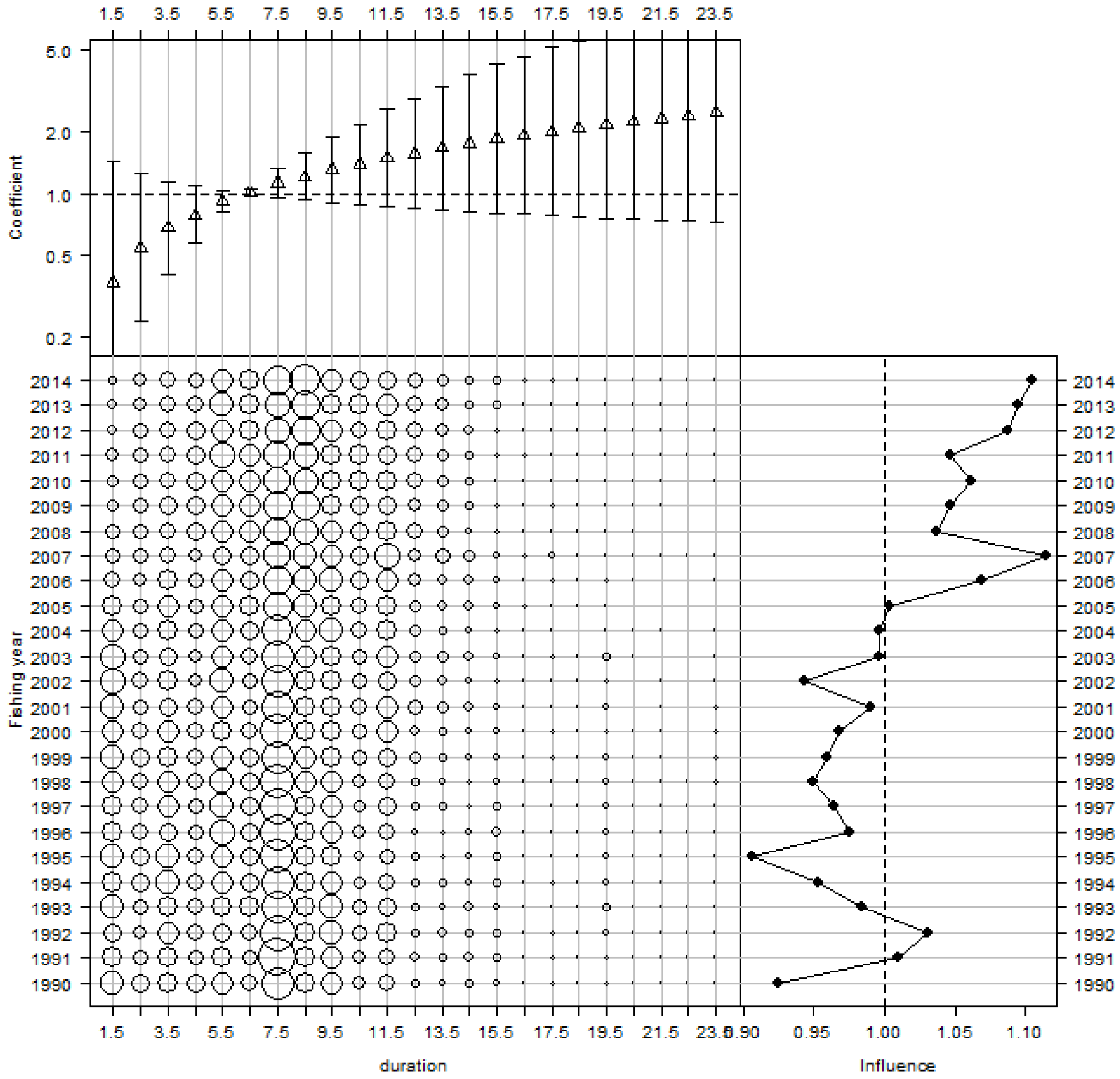


Figure I.8: Effect of log(duration) in the lognormal model for the flatfish FLA 3(TOT) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

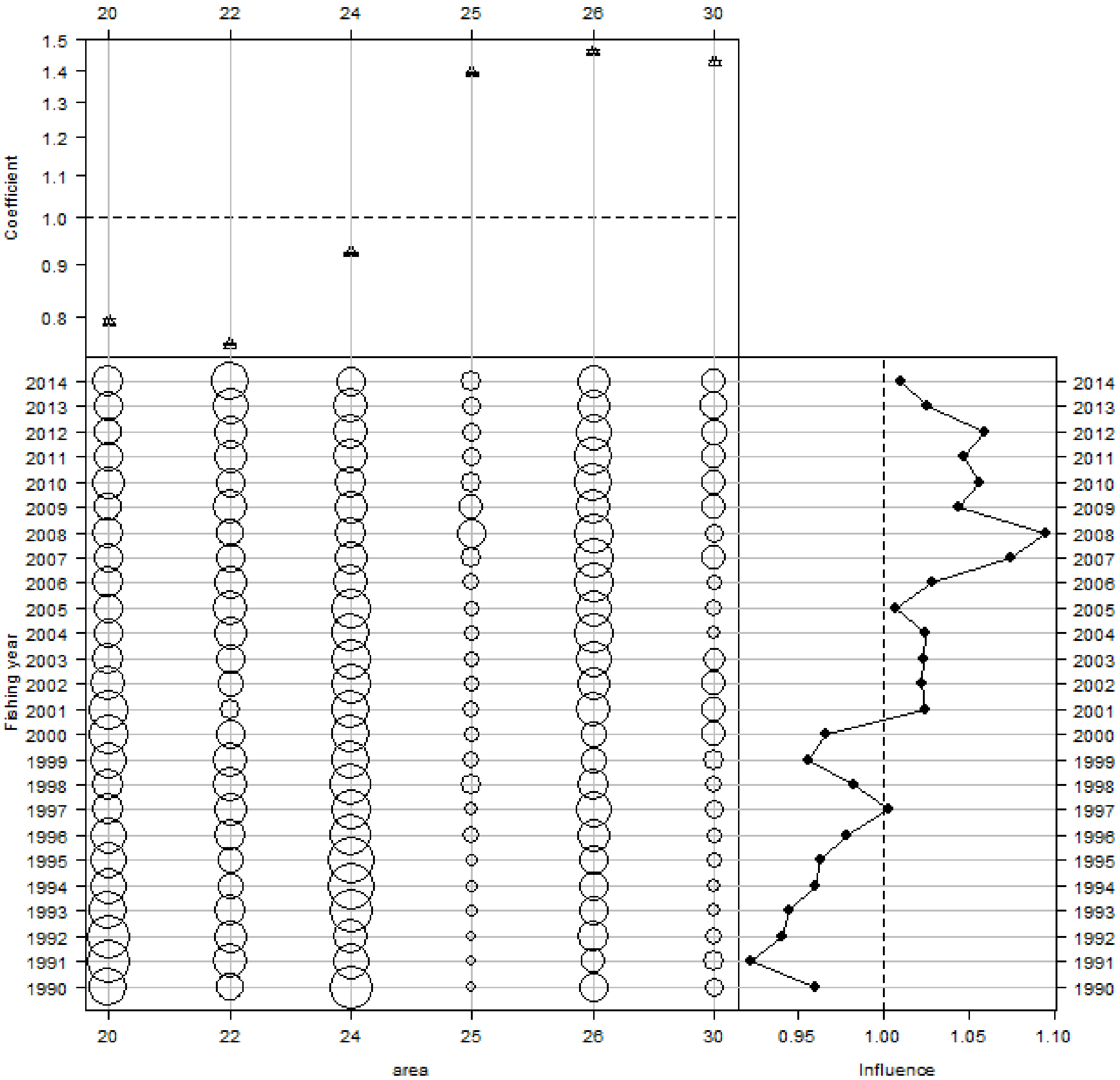


Figure I.9: Effect of area in the lognormal model for the flatfish FLA 3(TOT) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

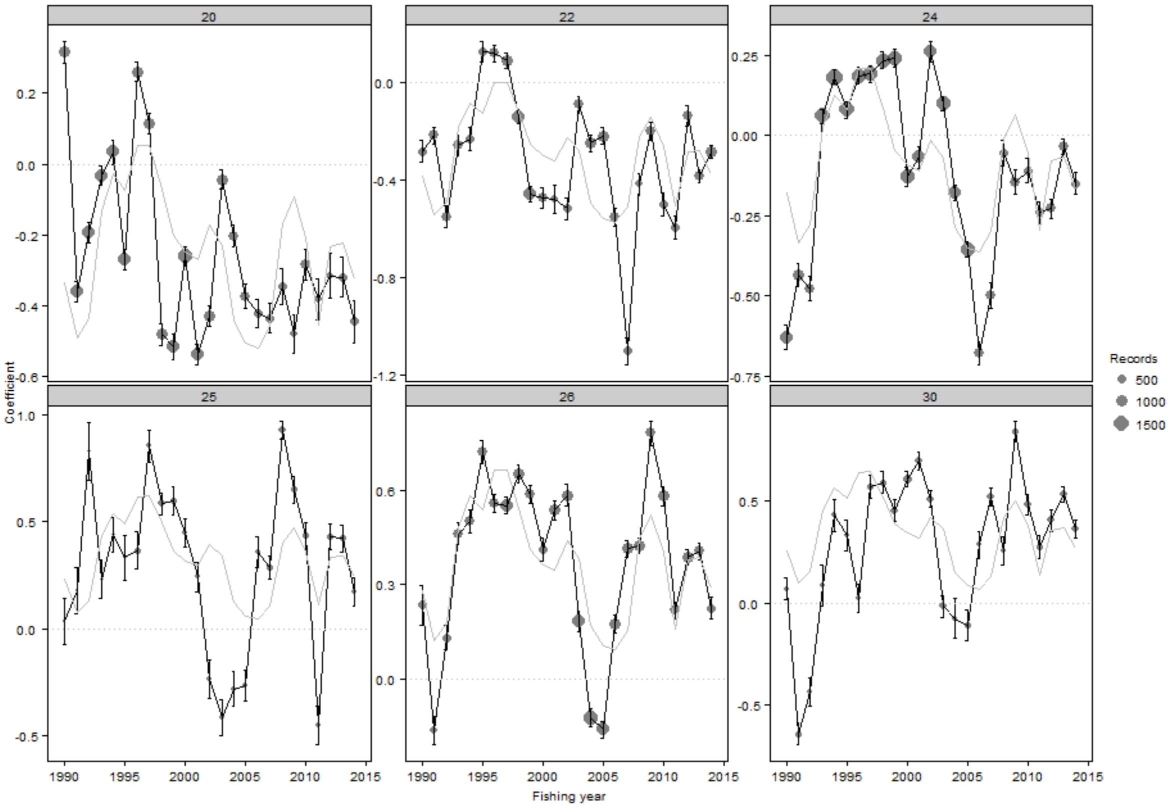


Figure I.10: Residual implied coefficients for area × fishing year interaction (interaction term not offered to the model) in the flatfish FLA 3(TOT) lognormal model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and target species. These values approximate the coefficients obtained when an area × year interaction term is fitted, particularly for those area × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals.

I.3 CPUE indices

Table I.3: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error (SE) for the core data set by fishing year for the flatfish FLA 3(TOT) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels				Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE
1990	0.932	0.909	0.788	0.918	0.0130
1991	0.681	0.683	0.723	0.785	0.0133
1992	0.730	0.738	0.773	0.830	0.0132
1993	0.970	0.938	0.970	1.125	0.0115
1994	1.004	1.015	1.038	1.245	0.0115
1995	1.000	1.009	0.985	1.189	0.0115
1996	1.143	1.159	1.204	1.350	0.0116
1997	1.125	1.129	1.180	1.353	0.0111
1998	1.052	1.033	1.037	1.195	0.0110
1999	0.909	0.901	0.896	1.047	0.0109
2000	0.892	0.904	0.900	1.000	0.0111
2001	0.963	0.996	0.952	0.980	0.0116
2002	1.040	1.055	1.057	1.079	0.0116
2003	0.929	0.932	1.024	1.020	0.0110
2004	0.762	0.763	0.827	0.824	0.0114
2005	0.745	0.736	0.782	0.773	0.0113
2006	0.839	0.837	0.841	0.762	0.0126
2007	1.074	1.066	1.004	0.811	0.0131
2008	1.447	1.455	1.350	1.084	0.0135
2009	1.496	1.496	1.378	1.170	0.0133
2010	1.260	1.276	1.230	1.039	0.0131
2011	0.929	0.946	0.933	0.815	0.0142
2012	1.239	1.239	1.213	1.014	0.0132
2013	1.223	1.209	1.209	1.025	0.0132
2014	1.105	1.066	1.093	0.928	0.0139

Appendix J. DIAGNOSTICS AND SUPPORTING ANALYSES FOR LSO 3 BOTTOM TRAWL CPUE

J.1 Model definition and preliminary analyses

This CPUE analysis was accepted for monitoring LSO 3 by the Southern Inshore Fishery Assessment Working Group in 2015 (MPI 2015).

J.1.1 Fishery definition

LSO 3: The fishery is defined from bottom trawl daily fishing events in the "*trip splitter*" data set which fished in Statistical Areas 020, 022, 024, 026, 025, and 030, declaring target species from one of the 15 species codes in Table A.3. Positive catch will be those records which recorded an estimated catch of LSO while zero catch records will be events which did not catch LSO but caught another flatfish species and did not use the generic FLA species designation. Daily events with more that 12 tows or 24 hours of accumulated effort were excluded from the analysis.

J.1.2 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 5 trips in each of at least 5 years using trips with at least 1 kg of LSO catch. These criteria resulted in a core fleet size of 55 vessels which took 92% of the catch (Figure J.1).

J.1.3 Data summary

Table J.1: Summaries by fishing year for core vessels, trips, daily effort strata, events that have been "rolled up" into daily effort strata, events per daily-effort stratum, tows, hours fished, landed FLA (t) but declared LSO in the estimated catch data, and percentage of trips with catch for the core vessel data set (based on a minimum of 5 trips per year in 5 years) in the LSO 3 fishery. There are no trips where there is LSO estimated catch but none in the landings, given the definition of the "*trip splitter*" data set.

Fishing year	Vessels	Trips	Daily effort strata	Events	Events per stratum	Sum (tows)	Sum (hours)	Catch (t)	% trips with catch
1991	18	407	519	522	1.01	1 726	3 387	36.3	54.6
1992	23	474	635	662	1.04	2 310	4 555	74.5	64.1
1993	33	804	1 089	1 121	1.03	3 623	7 447	107.3	68.4
1994	34	1 390	1 732	1 744	1.01	5 909	11 937	235.9	79.2
1995	35	1 658	1 964	1 995	1.02	6 268	12 649	260.7	62.7
1996	42	1 610	2 144	2 198	1.03	7 397	15 126	482.9	61.1
1997	37	1 789	2 420	2 516	1.04	8 951	16 804	464.2	64.7
1998	39	2 083	2 718	2 784	1.02	9 417	18 509	604.6	61.9
1999	35	1 906	2 598	2 697	1.04	9 079	18 850	595.3	66.2
2000	34	1 819	2 455	2 469	1.01	8 097	16 869	394.2	63.2
2001	38	1 616	2 371	2 398	1.01	8 498	17 656	370.7	59.5
2002	35	1 497	2 205	2 290	1.04	7 793	15 052	287.7	60.7
2003	30	1 624	2 423	2 502	1.03	8 982	17 650	310.5	65.5
2004	36	1 554	2 226	2 246	1.01	7 852	16 198	288.4	66.5
2005	34	1 739	2 323	2 339	1.01	7 990	17 766	245.3	67.8
2006	32	1 316	1 861	1 876	1.01	6 579	15 606	267.1	64.9
2007	28	1 148	1 838	1 850	1.01	6 712	16 757	407.7	67.1
2008	31	961	1 727	5 560	3.22	5 873	14 188	628.9	81.0
2009	29	981	1 666	4 864	2.92	5 232	13 283	523.9	77.8
2010	27	874	1 597	5 072	3.18	5 231	13 212	563.1	77.2
2011	25	684	1 240	3 918	3.16	3 975	10 239	288.1	81.7
2012	23	734	1 469	4 708	3.20	4 836	12 714	393.9	78.1
2013	25	824	1 586	5 111	3.22	5 219	13 905	447.6	73.8
2014	23	667	1 298	4 148	3.20	4 205	11 380	288.7	77.7

J.1.4 Core vessel plots

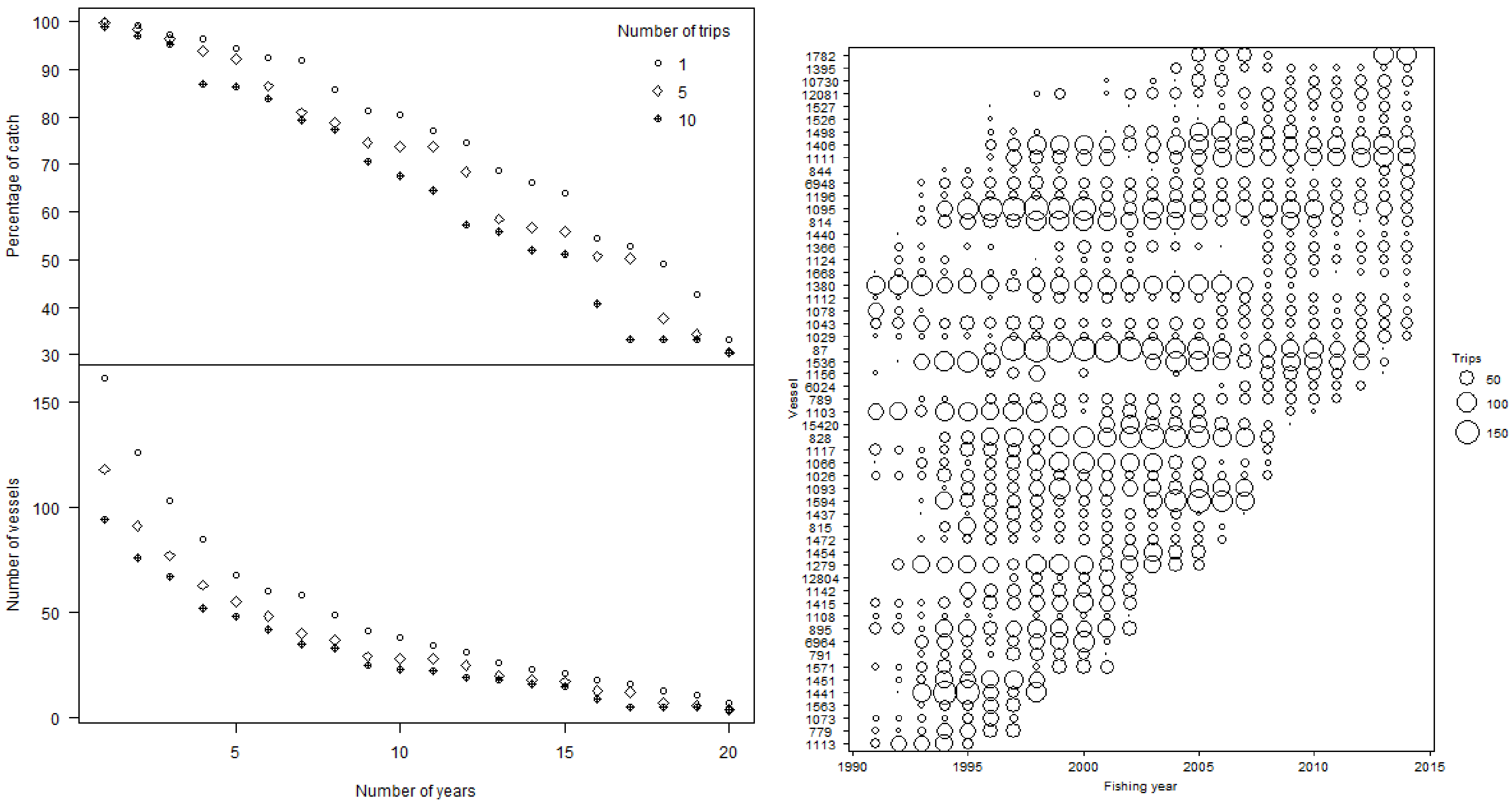


Figure J.1: [left panel] total landed LSO and number of vessels plotted against the number of years used to define core vessels participating in the LSO 3 dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot showing the number of daily-effort strata for selected core vessels (based on at least 5 trips in 5 or more fishing years) by fishing year.

J.1.5 Exploratory data plots for core vessel data set

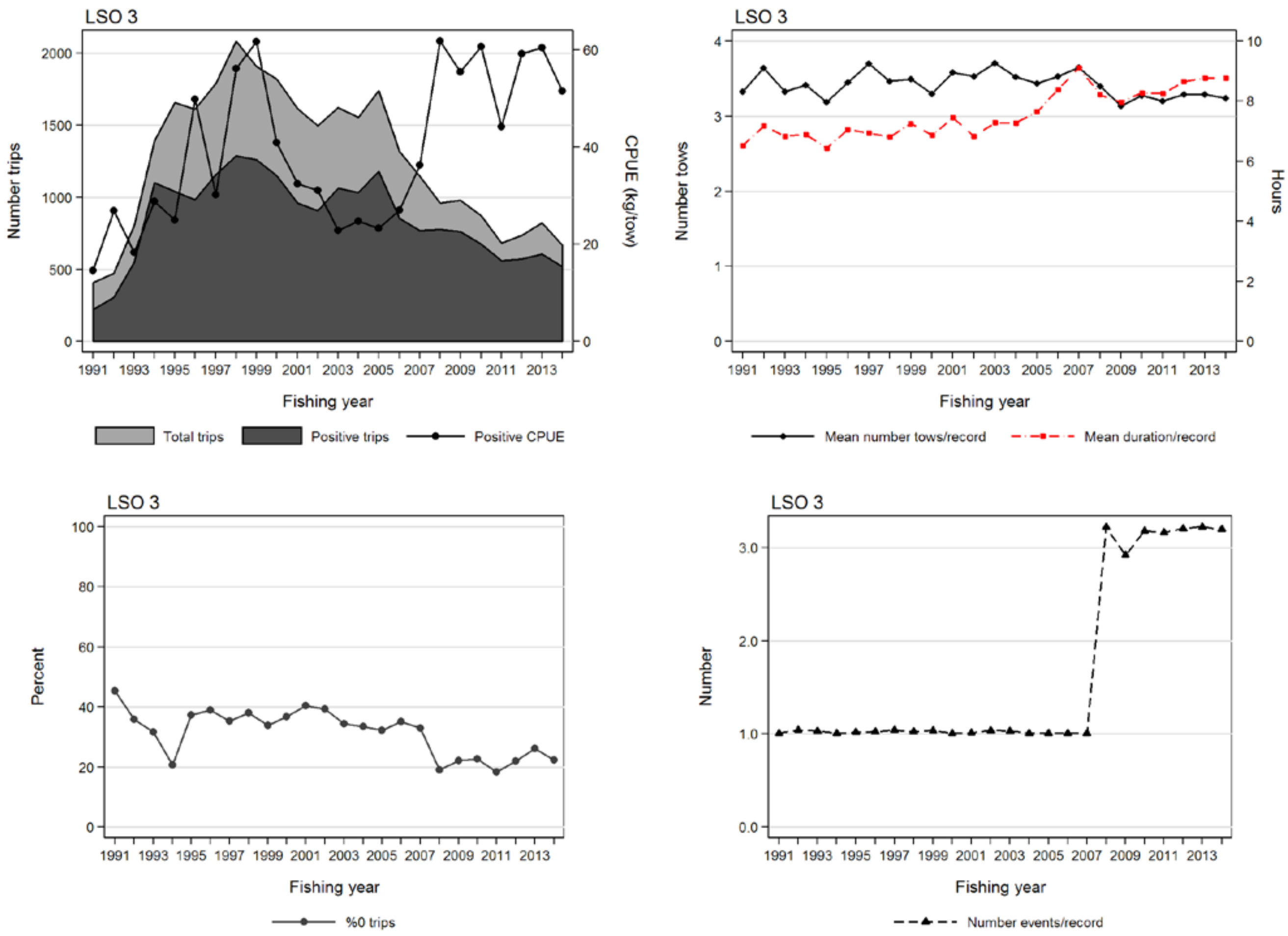


Figure J.2: Core vessel summary plots by fishing year for model LSO 3: [upper left panel]: total trips (light grey) and trips with lemon sole catch (dark grey) overlaid with median annual arithmetic CPUE (kg/tow) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i}/E_{y,i}\right)$; [upper right panel]: mean number of tows and mean duration per daily-effort stratum record; [lower left panel]: percentage of trips with no catch of lemon sole; [lower right panel]: mean number of events per daily-effort stratum record.

J.2 Positive catch model

All available explanatory variables entered the model after fishing year (vessel, number tows, month, area and duration fishing; Table J.2). A plot of the model is provided in Figure J.3 and the CPUE indices are listed in Table J.4.

Table J.2: Order of acceptance of variables into the lognormal model of successful catches in the LSO 3 fishery model for core vessels (based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	25	-200 172	400 394	7.23	*
vessel	79	-193 726	387 611	39.33	*
poly(log(tows), 3)	82	-190 665	381 495	50.41	*
month	93	-189 607	379 400	53.75	*
area	98	-188 820	377 837	56.08	*
poly(log(duration), 3)	101	-188 391	376 984	57.31	*

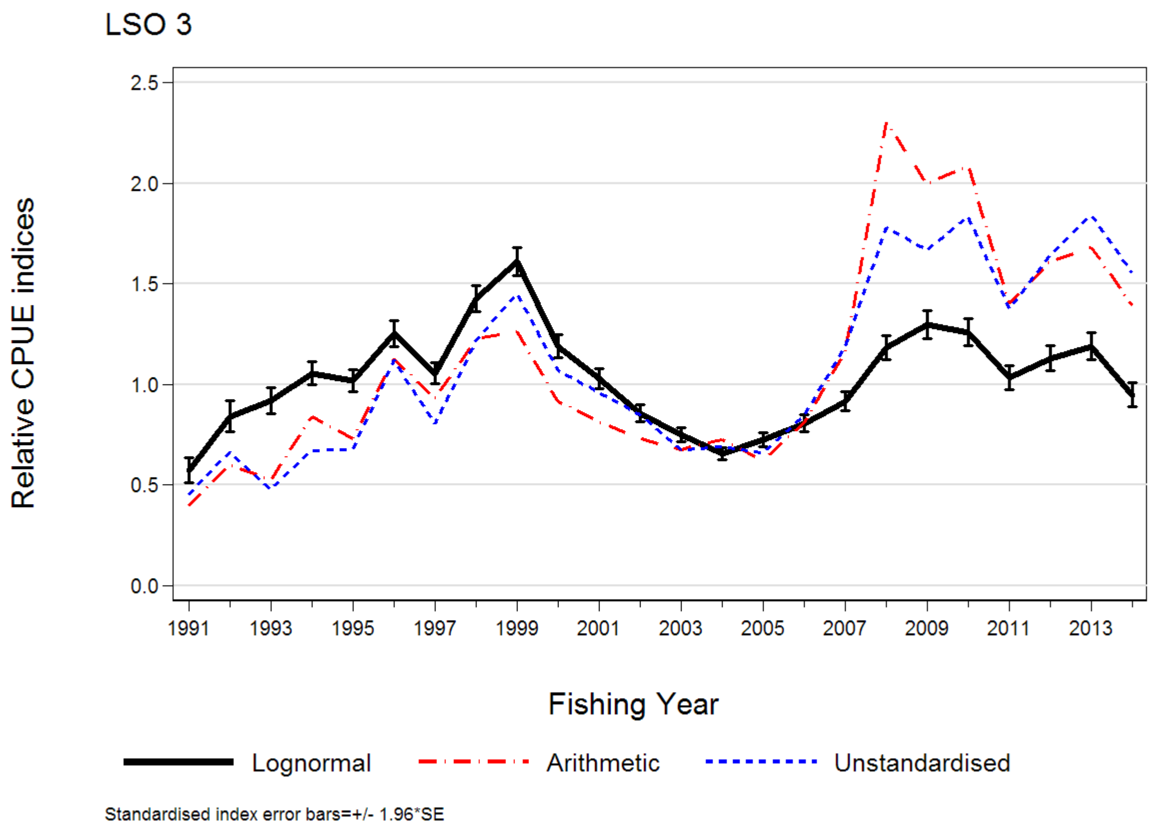


Figure J.3: Relative CPUE indices for LSO using the lognormal non-zero model based on the LSO 3 fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. H.1) and b) Unstandardised (Eq. H.2).

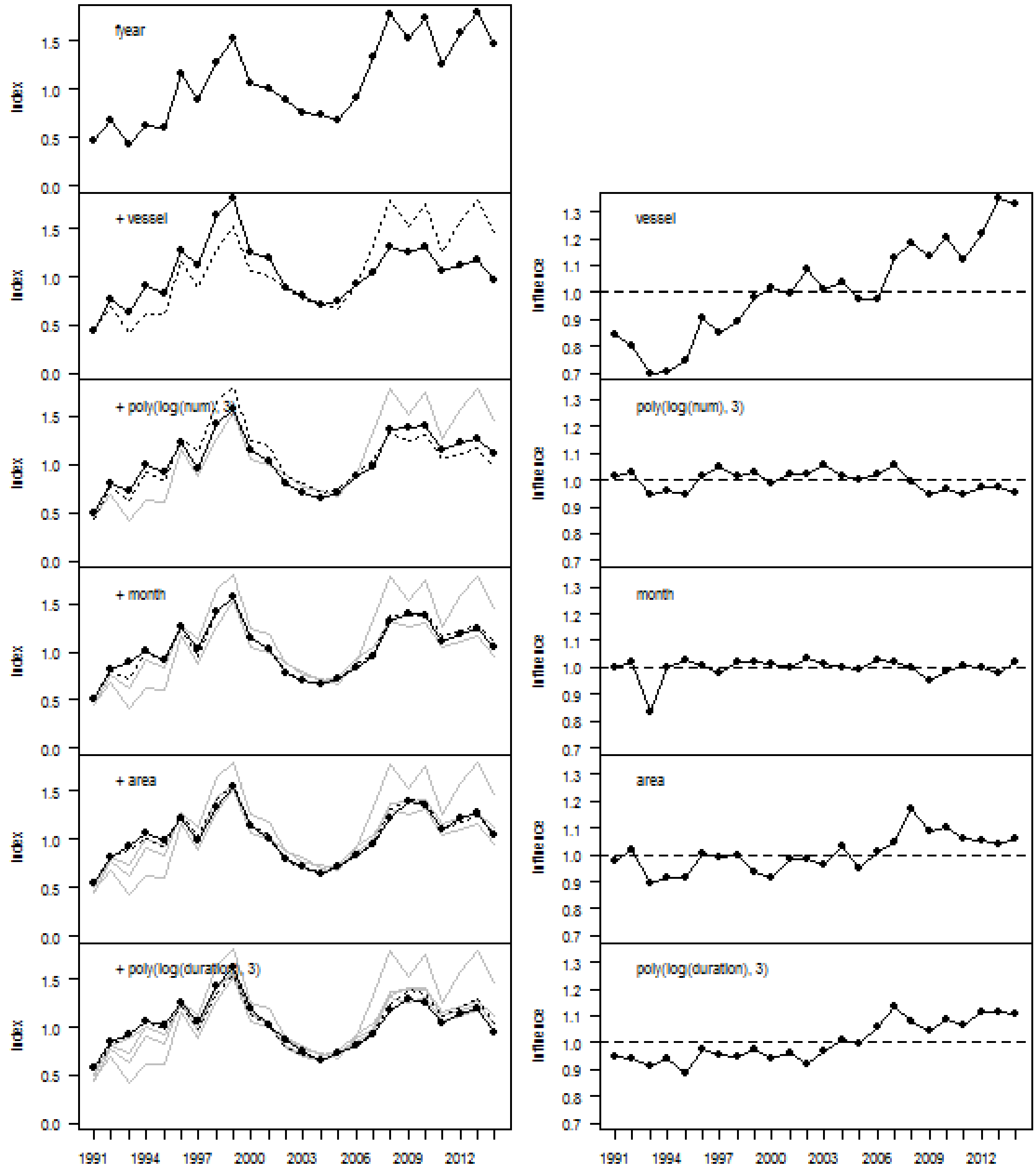


Figure J.4: **[left column]: annual indices from the lognormal model of LSO 3 at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.**

J.2.1 Residual and diagnostic plots

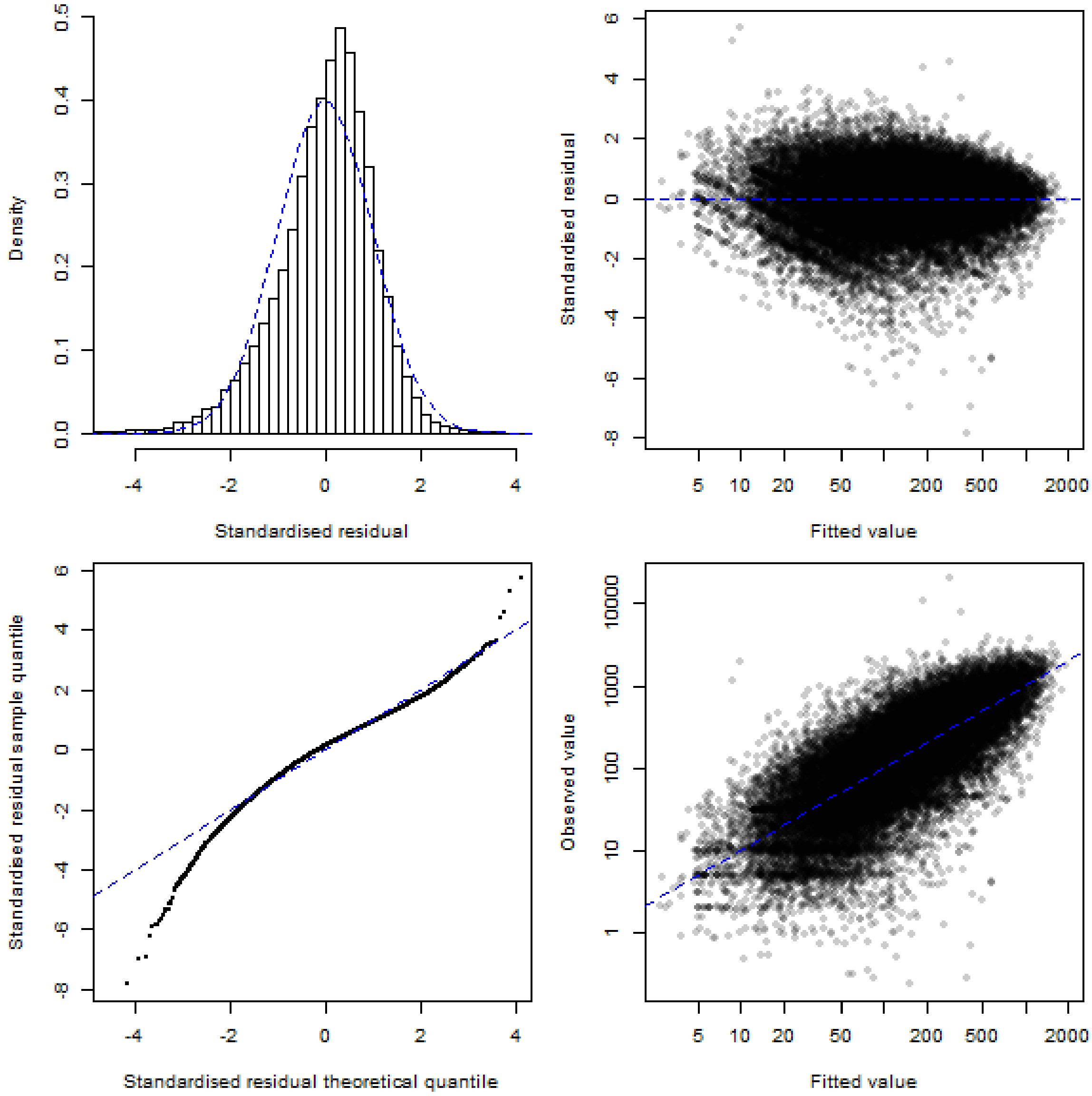


Figure J.5: Plots of the fit of the lognormal standardised CPUE model of successful catches of lemon sole in the LSO 3 fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

J.2.2 Model coefficient plots

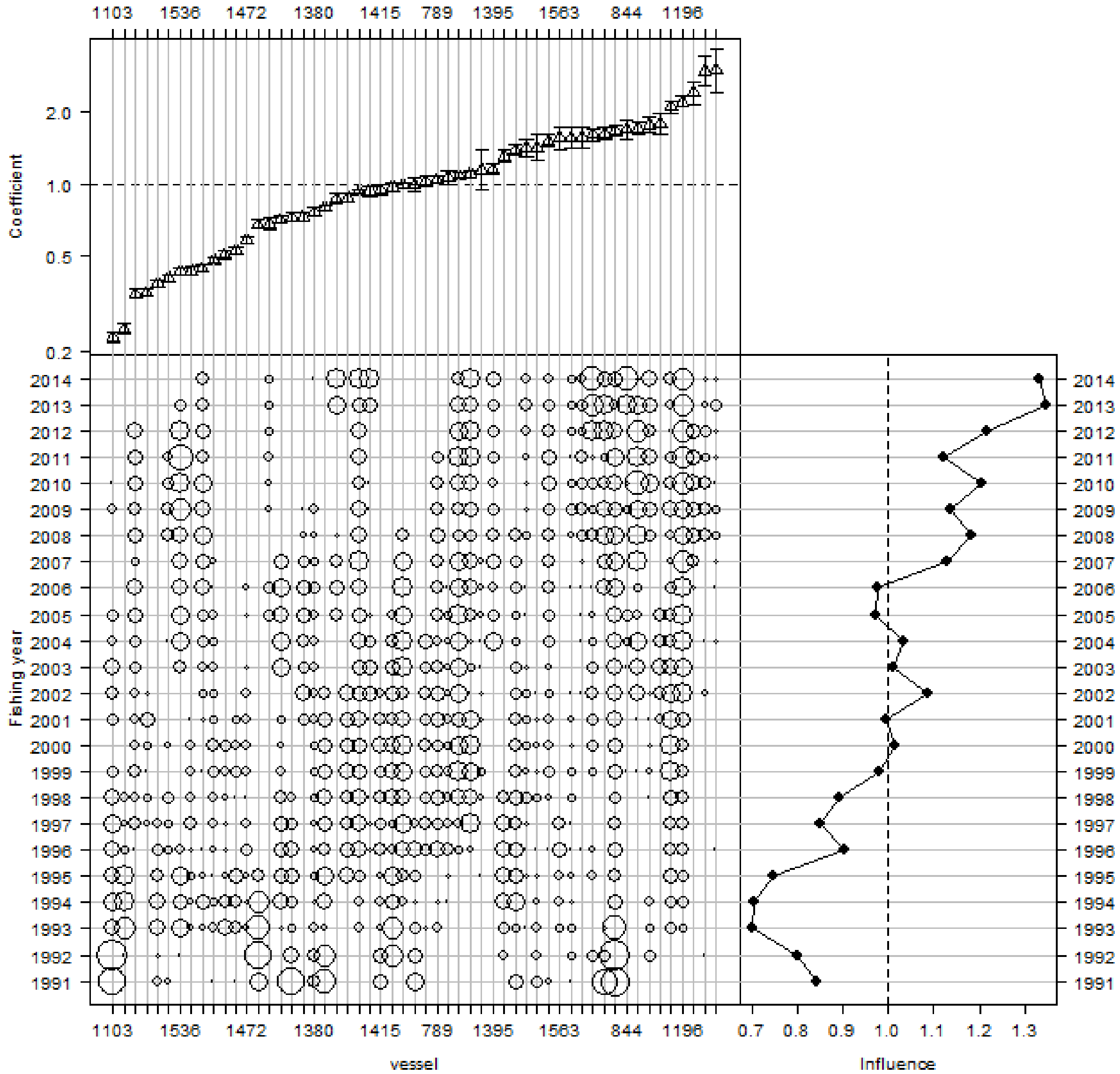


Figure J.6: Effect of vessel in the lognormal model for the lemon sole LSO 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

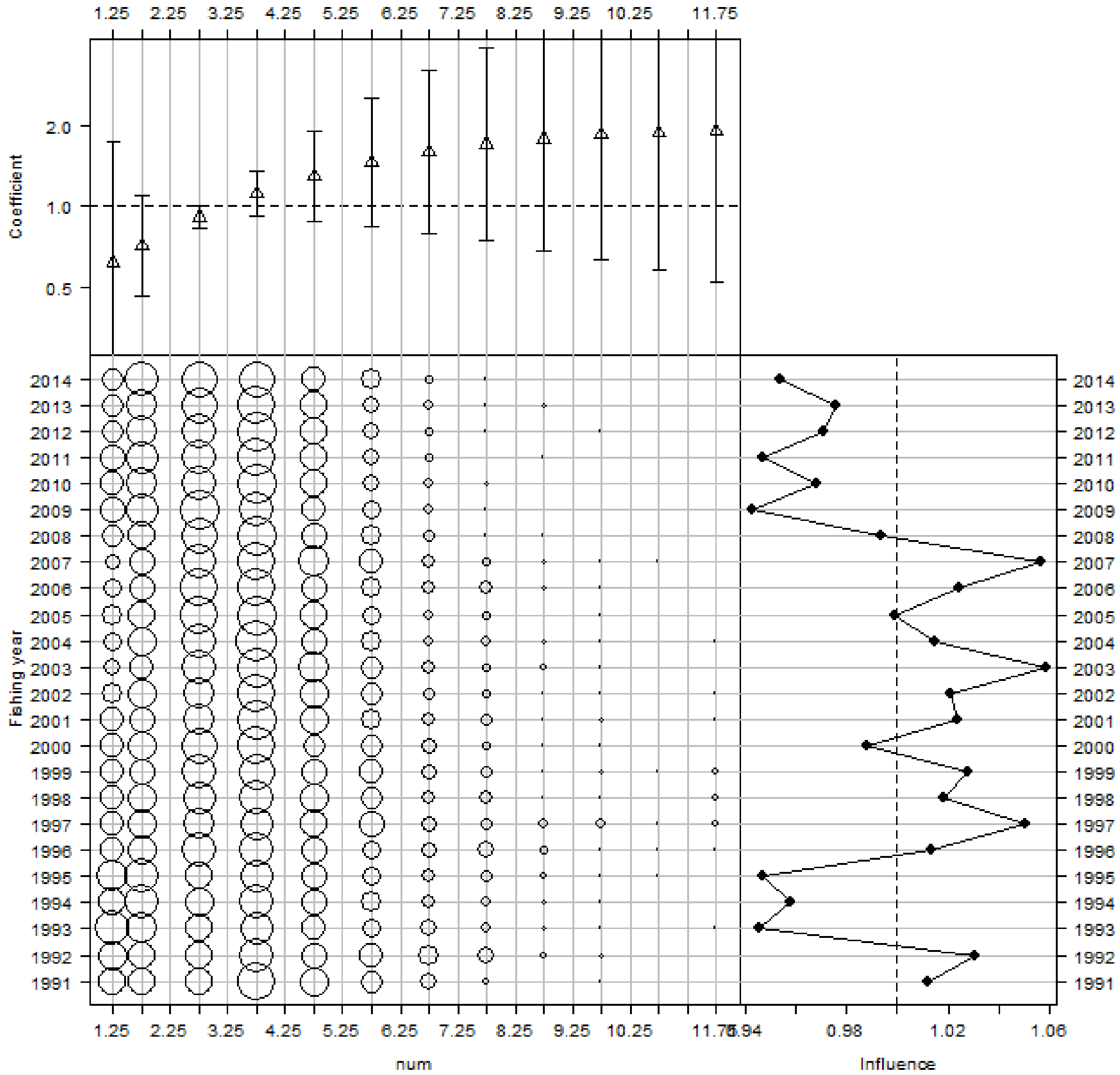


Figure J.7: Effect of log(number tows) in the lognormal model for the lemon sole LSO 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

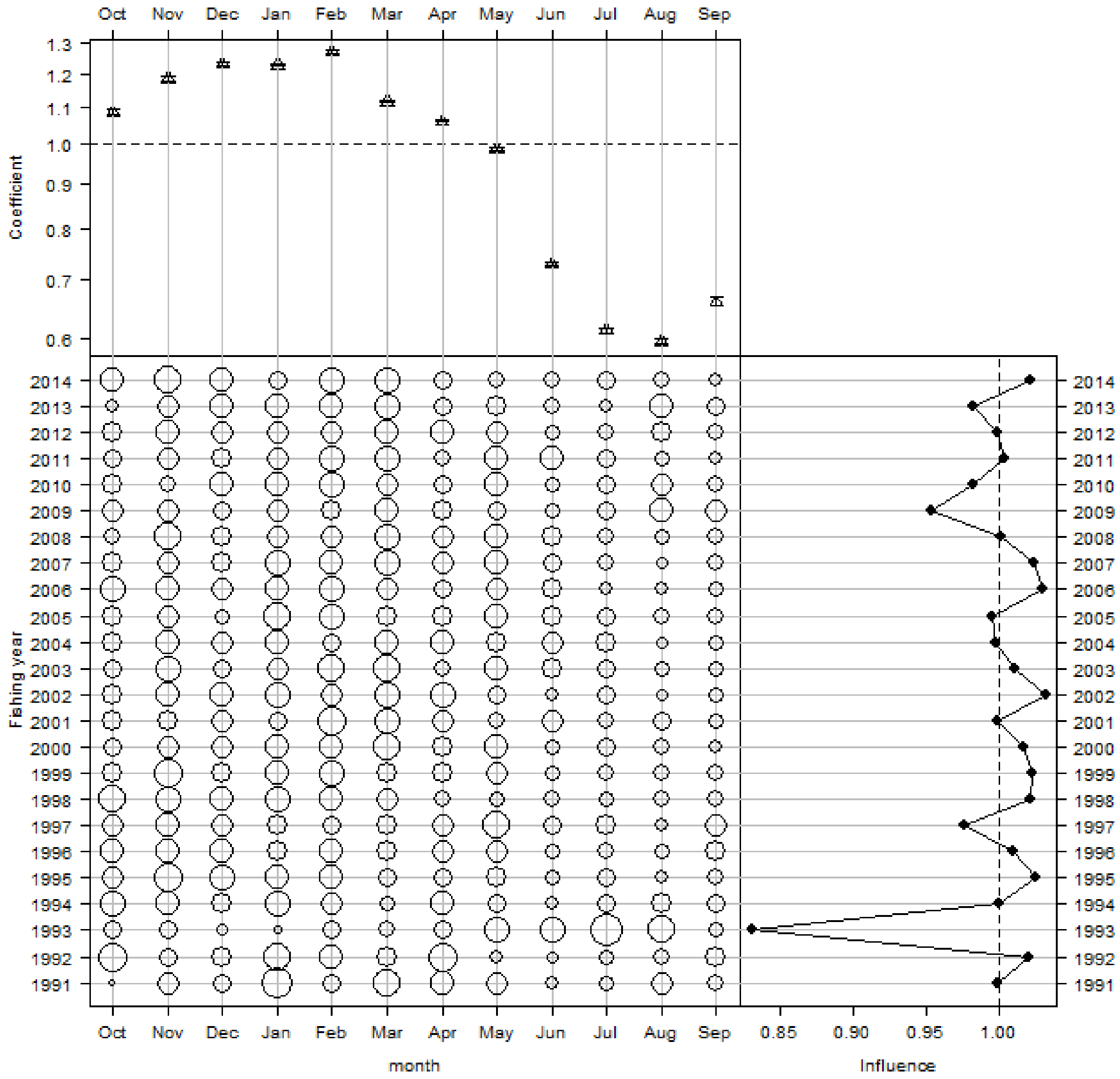


Figure J.8: Effect of month in the lognormal model for the lemon sole LSO 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

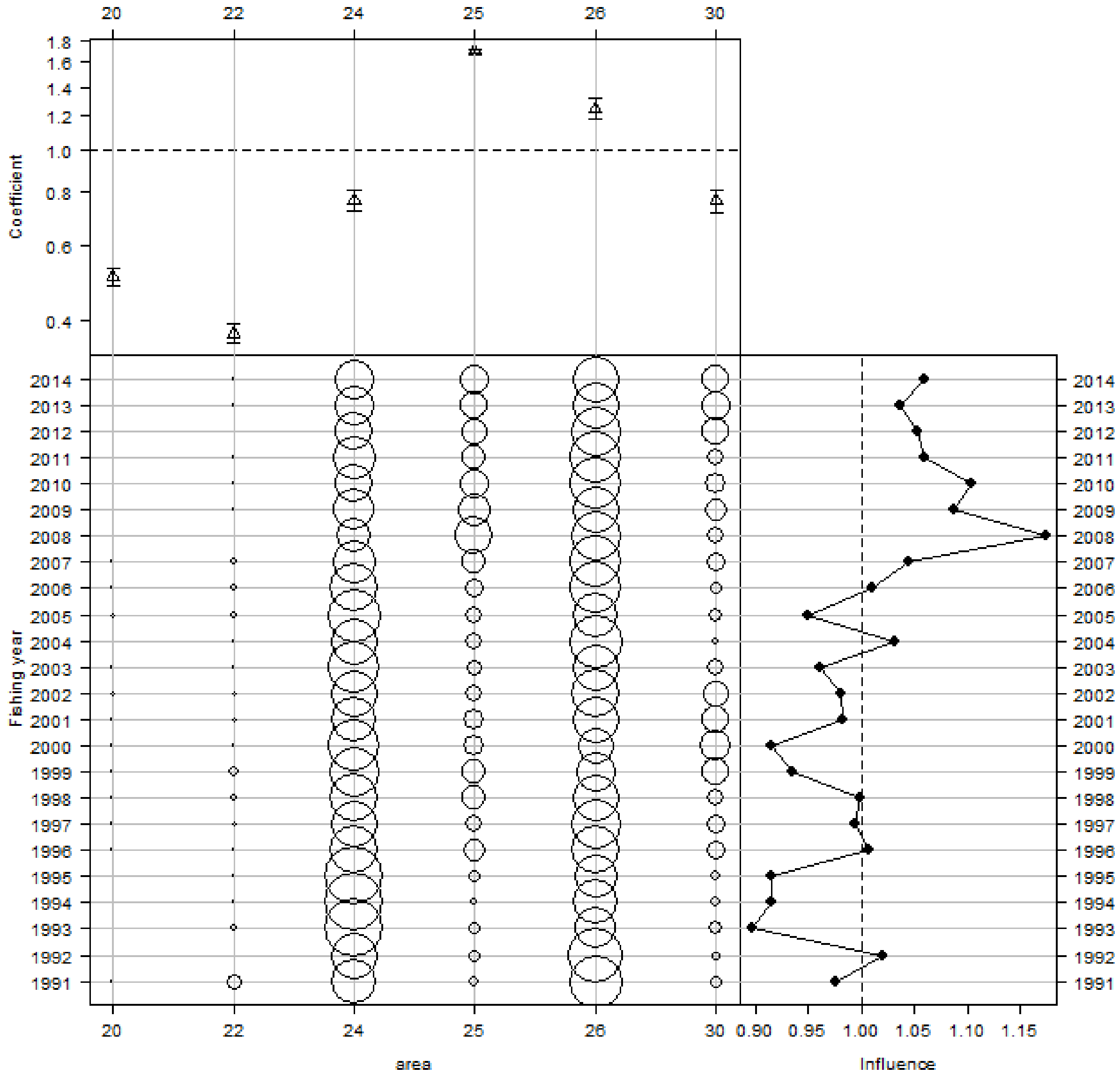


Figure J.9: Effect of area in the lognormal model for the lemon sole LSO 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

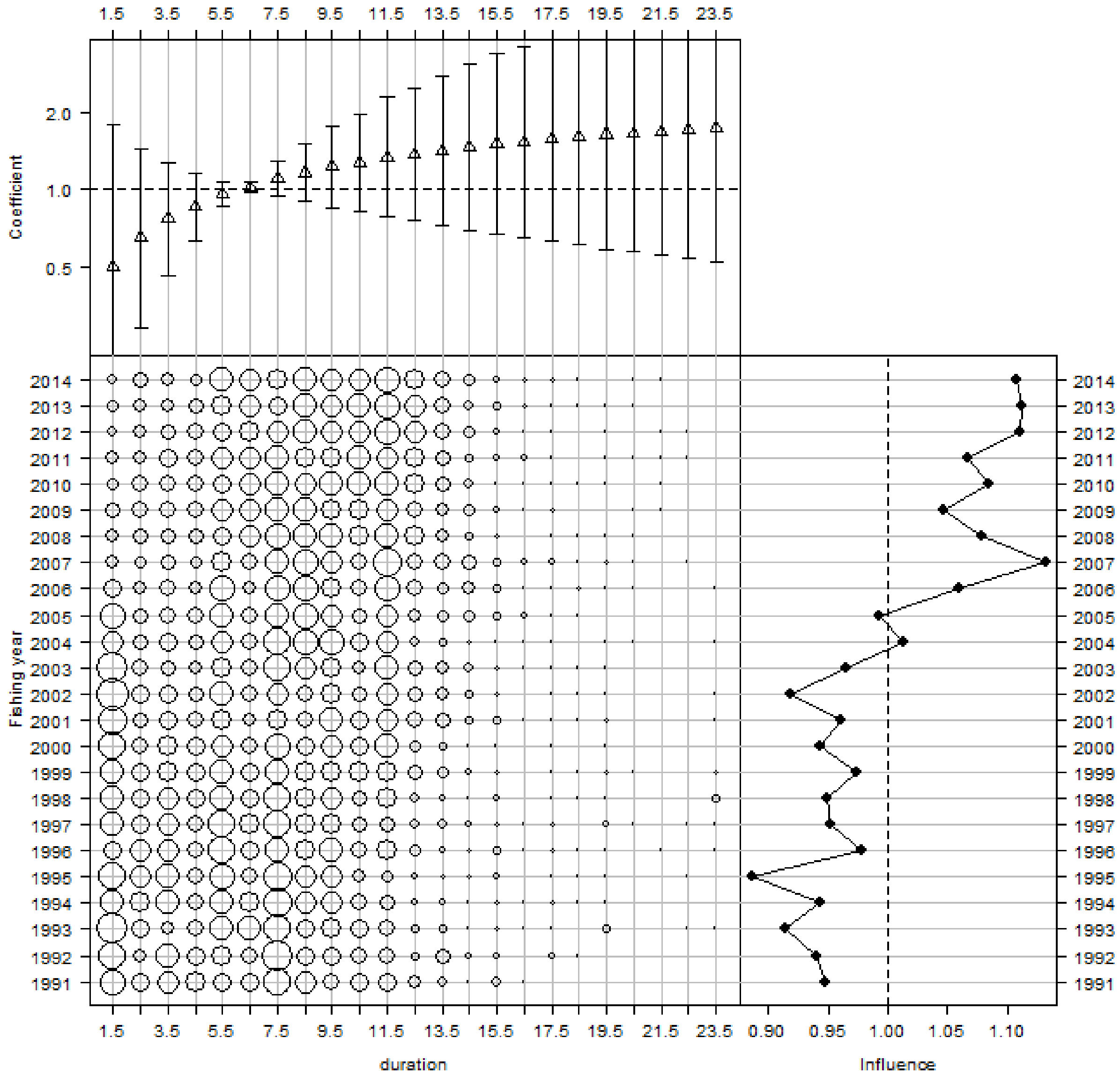


Figure J.10: Effect of log(duration) in the lognormal model for the lemon sole LSO 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

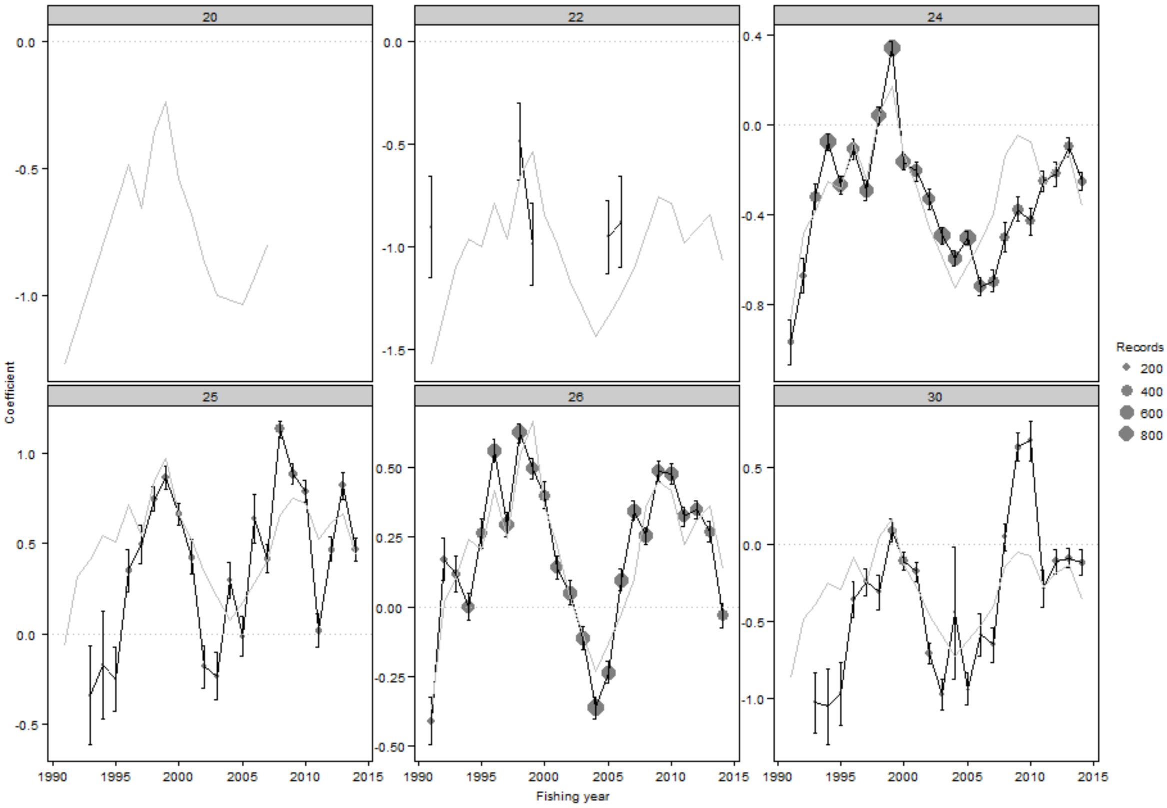


Figure J.11: Residual implied coefficients for area × fishing year interaction (interaction term not offered to the model) in the lemon sole LSO 3 lognormal model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and target species. These values approximate the coefficients obtained when an area × year interaction term is fitted, particularly for those area × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals.

J.3 Binomial presence/absence model

Four explanatory variables, with the exception of number tows, entered the model after fishing year (vessel, area, month, and duration fishing; Table J.3). A plot of the model is provided in Figure J.12 and the CPUE indices are listed in Table J.4.

Table J.3: Order of acceptance of variables into the binomial presence/absence model in the LSO 3 fishery model for core vessels (based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	Deviance R^2	Nagelkerke R^2	Model use
fishing year	24	-26 831	53 711	1.41	2.43	*
vessel	78	-22 241	44 637	18.27	28.51	*
area	83	-20 055	40 276	26.31	39.14	*
month	94	-19 444	39 076	28.55	41.93	*
poly(log(duration), 3)	97	-19 145	38 484	29.65	**43.27**	*
poly(log(tows), 3)	100	-19 086	38 371	29.87	43.53	

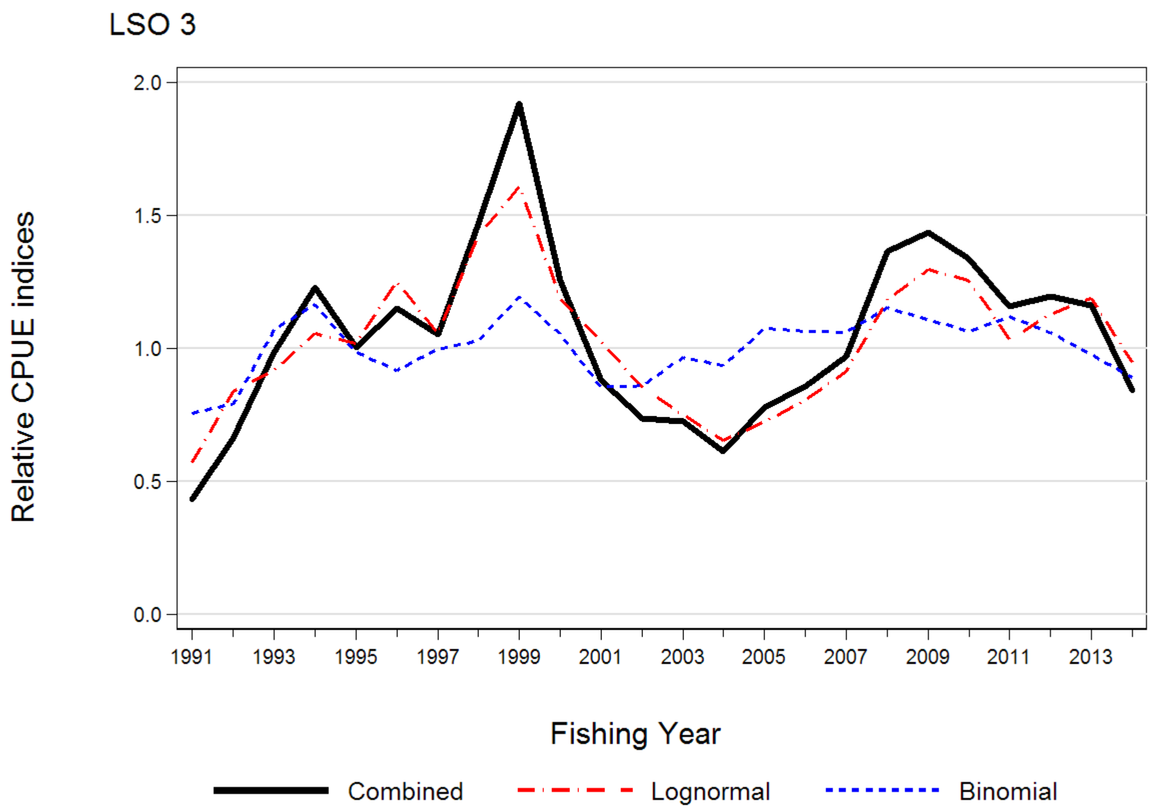


Figure J.12: Relative CPUE indices for Lemon sole using the lognormal non-zero model based on the LSO 3 fishery definition, the binomial standardised model using the logistic distribution and a regression based on presence/absence of LSO, and the combined model using the delta-lognormal procedure (Eq. H.4).

J.4 CPUE indices

Table J.4: Arithmetic indices for the total and core data sets, geometric, lognormal (including standard error [SE]), binomial and combined indices for the core data set by fishing year for the lemon sole LSO 3 analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1991	0.321	0.396	0.452	0.571	0.0538	0.510	0.432
1992	0.336	0.602	0.665	0.839	0.0471	0.534	0.664
1993	0.354	0.523	0.479	0.919	0.0355	0.722	0.984
1994	0.783	0.840	0.671	1.055	0.0267	0.787	1.230
1995	0.768	0.733	0.678	1.017	0.0279	0.666	1.005
1996	1.141	1.127	1.122	1.253	0.0262	0.619	1.150
1997	1.007	0.929	0.803	1.056	0.0247	0.673	1.053
1998	1.351	1.225	1.218	1.425	0.0229	0.695	1.469
1999	1.306	1.265	1.452	1.610	0.0227	0.806	1.923
2000	0.953	0.917	1.070	1.188	0.0240	0.712	1.255
2001	0.908	0.815	0.960	1.028	0.0251	0.577	0.880
2002	0.757	0.732	0.851	0.856	0.0255	0.580	0.736
2003	0.687	0.677	0.675	0.750	0.0237	0.651	0.724
2004	0.781	0.727	0.692	0.656	0.0242	0.632	0.614
2005	0.672	0.624	0.659	0.724	0.0237	0.725	0.779
2006	0.980	0.810	0.846	0.806	0.0266	0.719	0.859
2007	1.373	1.163	1.189	0.914	0.0261	0.716	0.971
2008	2.871	2.305	1.781	1.183	0.0253	0.778	1.365
2009	2.223	1.997	1.669	1.296	0.0267	0.748	1.438
2010	2.128	2.085	1.836	1.257	0.0271	0.718	1.338
2011	1.483	1.400	1.376	1.033	0.0301	0.755	1.158
2012	1.762	1.612	1.643	1.130	0.0286	0.715	1.197
2013	1.518	1.683	1.842	1.191	0.0285	0.659	1.163
2014	1.255	1.393	1.556	0.947	0.0315	0.601	0.844

Appendix K. DIAGNOSTICS AND SUPPORTING ANALYSES FOR ESO 3 BOTTOM TRAWL CPUE

K.1 Model definition and preliminary analyses

This CPUE analysis was accepted for monitoring ESO 3 by the Southern Inshore Fishery Assessment Working Group in 2015 (MPI 2015).

K.1.1 Fishery definition

ESO 3: The fishery is defined from bottom trawl daily fishing events in the "*trip splitter*" data set which fished in Statistical Areas 020, 022, 024, 026, 025, and 030, declaring target species from one of the 15 species codes in Table A.3. Positive catch will be those records which recorded an estimated catch of ESO while zero catch records will be events which did not catch ESO but caught another flatfish species and did not use the generic FLA species designation. Daily events with more than 12 tows or 24 hours of accumulated effort were excluded from the analysis.

K.1.2 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 5 trips in each of at least 5 years using trips with at least 1 kg of ESO catch. These criteria resulted in a core fleet size of 81 vessels which took 89% of the catch (Figure K.1).

K.1.3 Data summary

Table K.1: Summaries by fishing year for core vessels, trips, daily effort strata, events that have been "rolled up" into daily effort strata, events per daily-effort stratum, tows, hours fished, landed FLA (t) but declared ESO in the estimated catch data, and percentage of trips with catch for the core vessel data set (based on a minimum of 5 trips per year in 5 years) in the ESO 3 fishery. There are no trips where there is ESO estimated catch but none in the landings, given the definition of the "*trip splitter*" data set.

Fishing year	Vessels	Trips	Daily effort strata	Events	Events per stratum	Sum (tows)	Sum (hours)	Catch (t)	% trips with catch
1991	31	1 246	1 398	1 445	1.03	3 923	10 528	110.0	76.6
1992	35	1 206	1 420	1 515	1.07	4 387	11 210	116.9	73.7
1993	48	1 629	1 951	2 032	1.04	5 730	14 482	211.3	76.8
1994	50	2 182	2 561	2 616	1.02	7 835	18 077	285.8	75.7
1995	48	2 323	2 657	2 698	1.02	7 796	17 883	288.9	76.1
1996	53	2 244	2 817	2 877	1.02	8 801	20 848	331.5	76.4
1997	49	2 423	3 090	3 190	1.03	10 300	22 558	388.2	78.8
1998	50	2 772	3 433	3 502	1.02	10 888	24 167	251.1	66.2
1999	46	2 752	3 510	3 616	1.03	10 952	26 082	207.7	54.7
2000	43	2 532	3 246	3 263	1.01	9 603	22 986	267.0	60.2
2001	48	2 180	3 005	3 033	1.01	9 857	22 477	386.4	64.5
2002	44	2 213	3 004	3 094	1.03	9 292	20 895	464.0	73.7
2003	41	2 395	3 278	3 357	1.02	10 519	24 310	356.3	74.5
2004	44	2 168	2 902	2 923	1.01	9 190	21 497	215.4	66.8
2005	43	2 387	3 040	3 056	1.01	9 314	23 516	198.2	62.7
2006	41	1 771	2 396	2 413	1.01	7 665	19 970	157.7	60.3
2007	37	1 537	2 298	2 316	1.01	7 657	20 646	164.2	56.3
2008	42	1 274	2 072	6 162	2.97	6 475	16 935	166.6	63.4
2009	40	1 375	2 095	5 659	2.70	6 027	16 701	258.7	74.8
2010	36	1 217	2 064	6 043	2.93	6 202	17 324	176.6	66.7
2011	31	883	1 515	4 534	2.99	4 591	12 832	69.0	58.4
2012	27	932	1 775	5 289	2.98	5 417	15 750	131.3	63.8
2013	34	1 367	2 228	6 421	2.88	6 529	19 491	176.0	61.7
2014	32	1 204	1 945	5 496	2.83	5 553	17 130	115.1	50.3

K.1.4 Core vessel plots

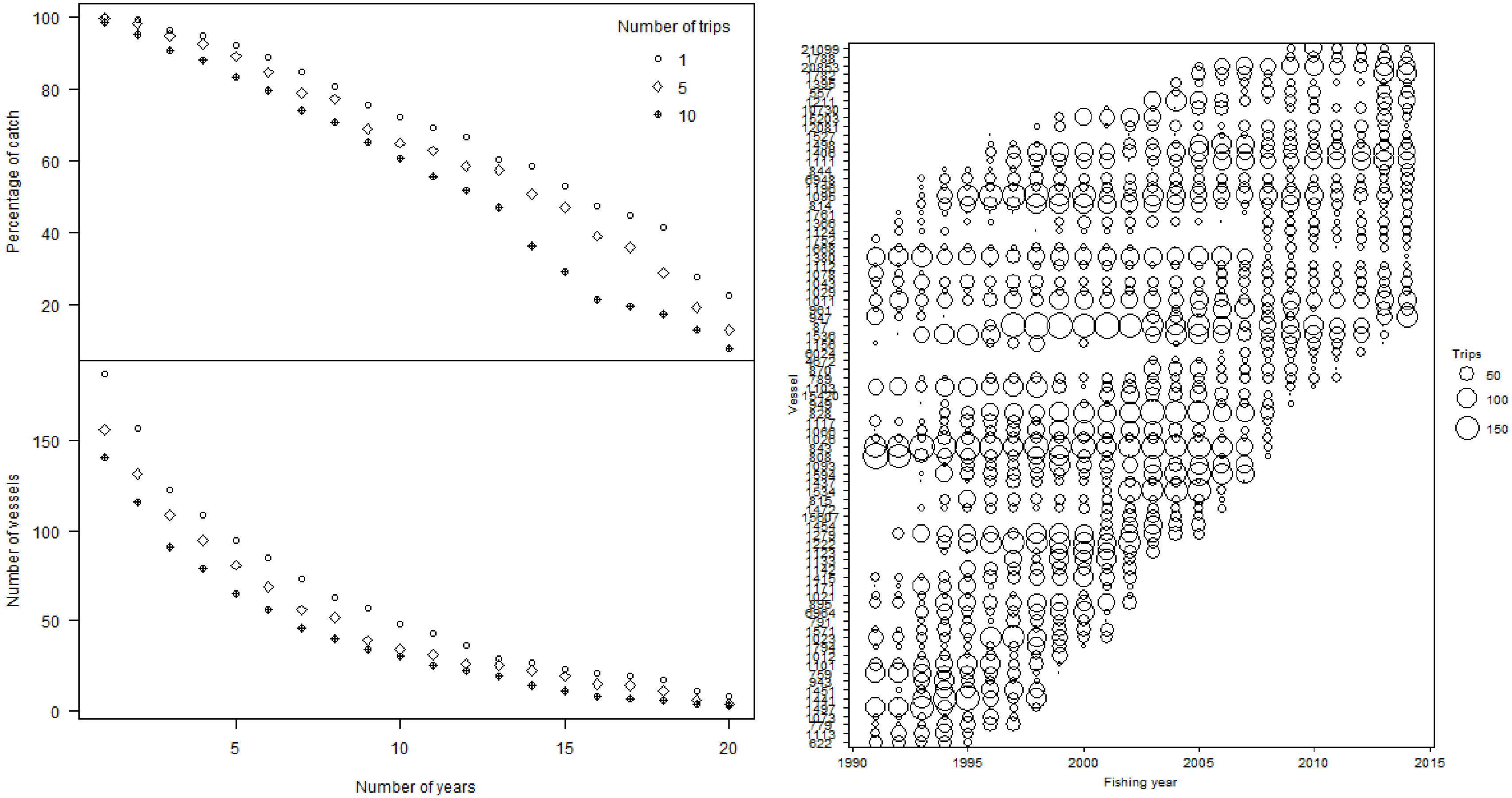


Figure K.1: [left panel] total landed ESO and number of vessels plotted against the number of years used to define core vessels participating in the ESO 3 dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot showing the number of daily-effort strata for selected core vessels (based on at least 5 trips in 5 or more fishing years) by fishing year.

K.1.5 Exploratory data plots for core vessel data set

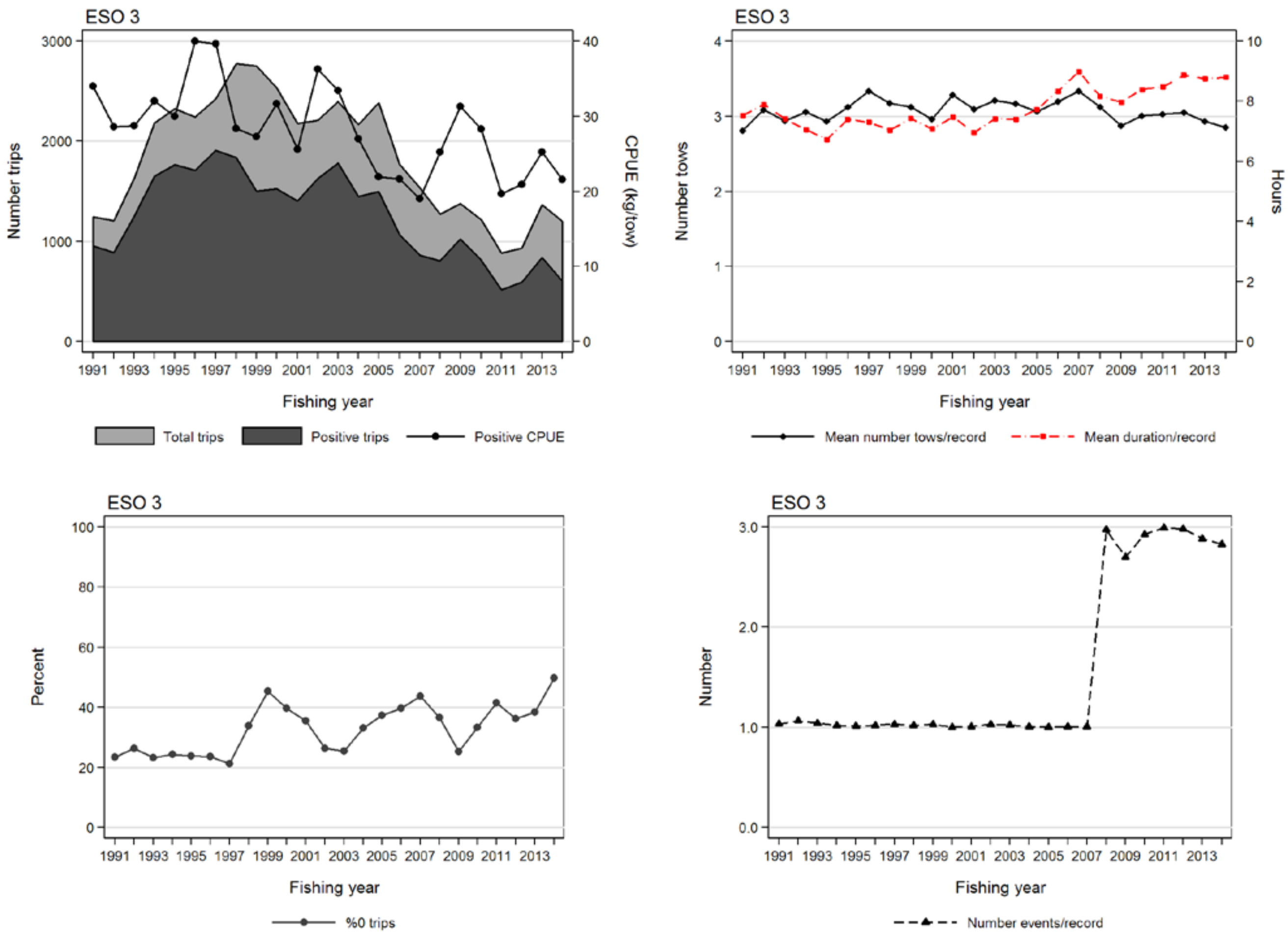


Figure K.2: Core vessel summary plots by fishing year for model ESO 3: [upper left panel]: total trips (light grey) and trips with New Zealand sole catch (dark grey) overlaid with median annual arithmetic CPUE (kg/tow) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i}/E_{y,i}\right)$; [upper right panel]: mean number of tows and mean duration per daily-effort stratum record; [lower left panel]: percentage of trips with no catch of New Zealand sole; [lower right panel]: mean number of events per daily-effort stratum record.

K.2 Positive catch model

Four explanatory variables, except for month, entered the model after fishing year (vessel, duration fishing, area, and number tows; Table K.2). A plot of the model is provided in Figure K.3 and the CPUE indices are listed in Table K.4.

Table K.2: Order of acceptance of variables into the lognormal model of successful catches in the ESO 3 fishery model for core vessels (based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	25	-227 413	454 876	2.17	*
vessel	105	-222 874	445 958	22.80	*
poly(log(duration), 3)	108	-219 344	438 904	35.79	*
area	113	-218 756	437 739	37.73	*
poly(log(tows), 3)	116	-218 447	437 126	**38.73**	*
month	127	-218 279	436 812	39.27	

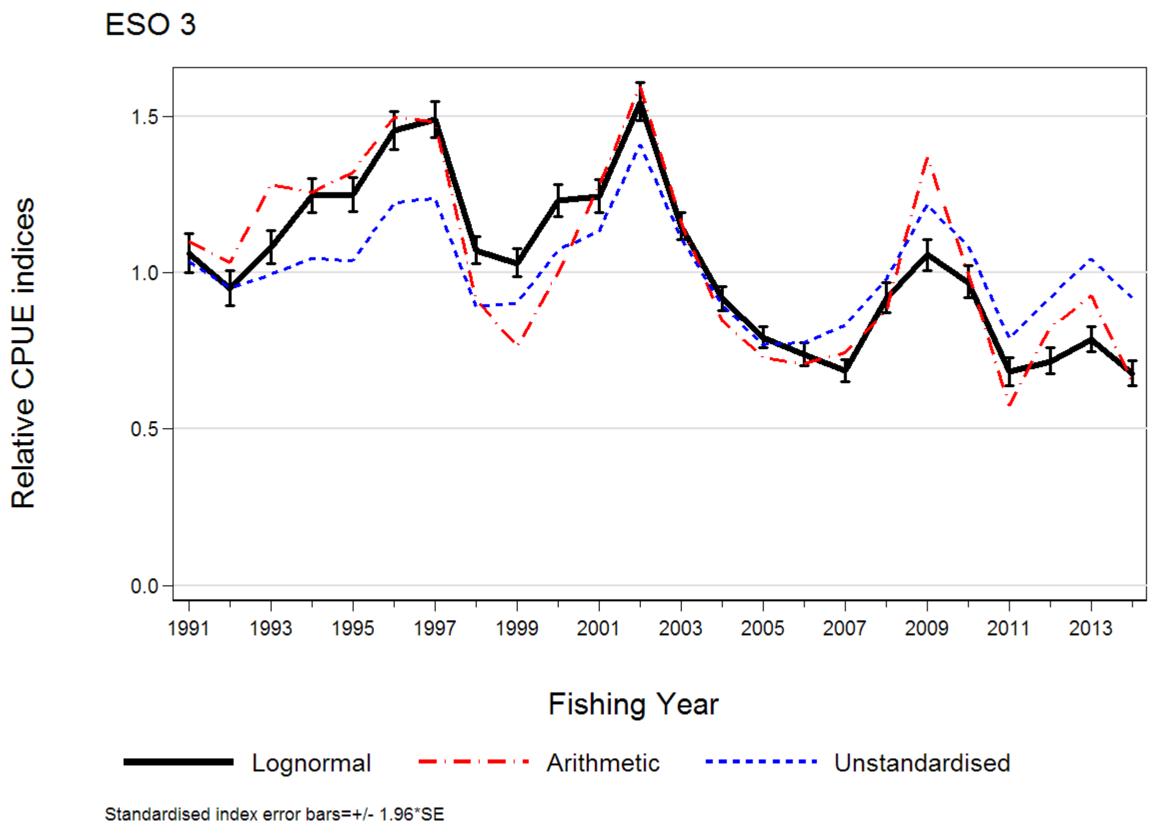


Figure K.3: Relative CPUE indices for ESO using the lognormal non-zero model based on the ESO 3 fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. H.1) and b) Unstandardised (Eq. H.2).

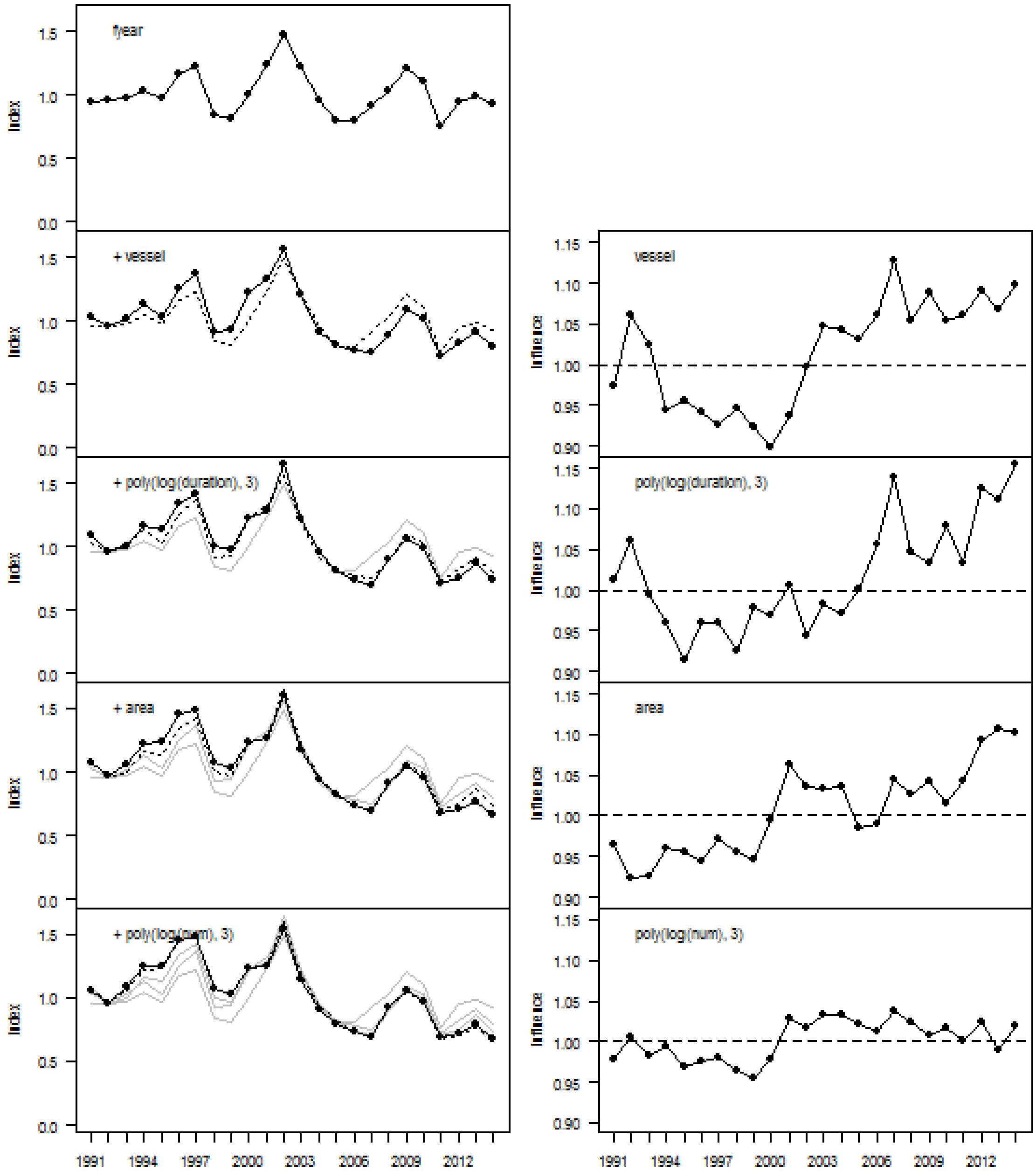


Figure K.4: [left column]: annual indices from the lognormal model of ESO 3 at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

K.2.1 Residual and diagnostic plots

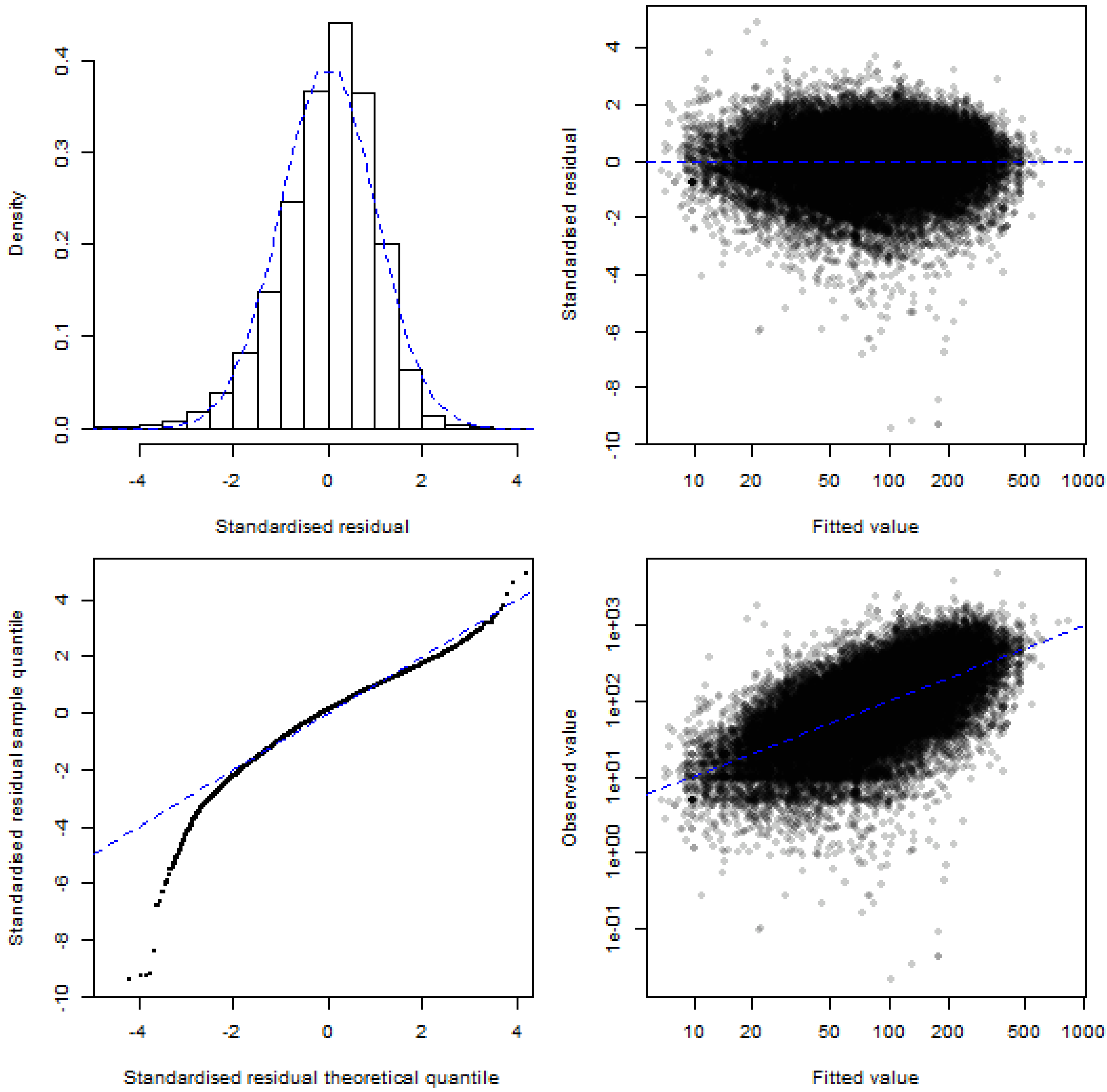


Figure K.5: Plots of the fit of the lognormal standardised CPUE model of successful catches of New Zealand sole in the ESO 3 fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

K.2.2 Model coefficient plots

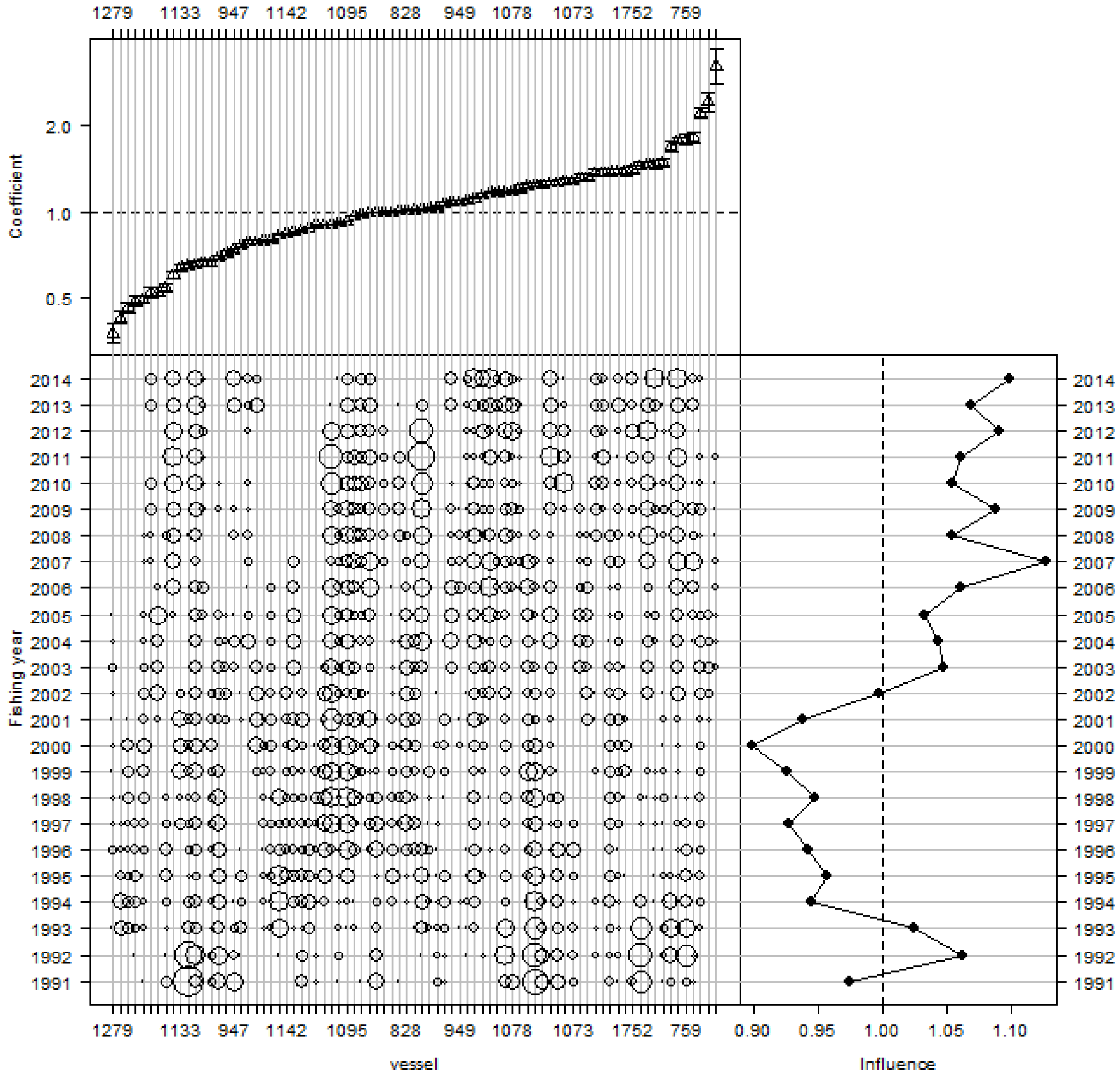


Figure K.6: Effect of vessel in the lognormal model for the New Zealand sole ESO 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

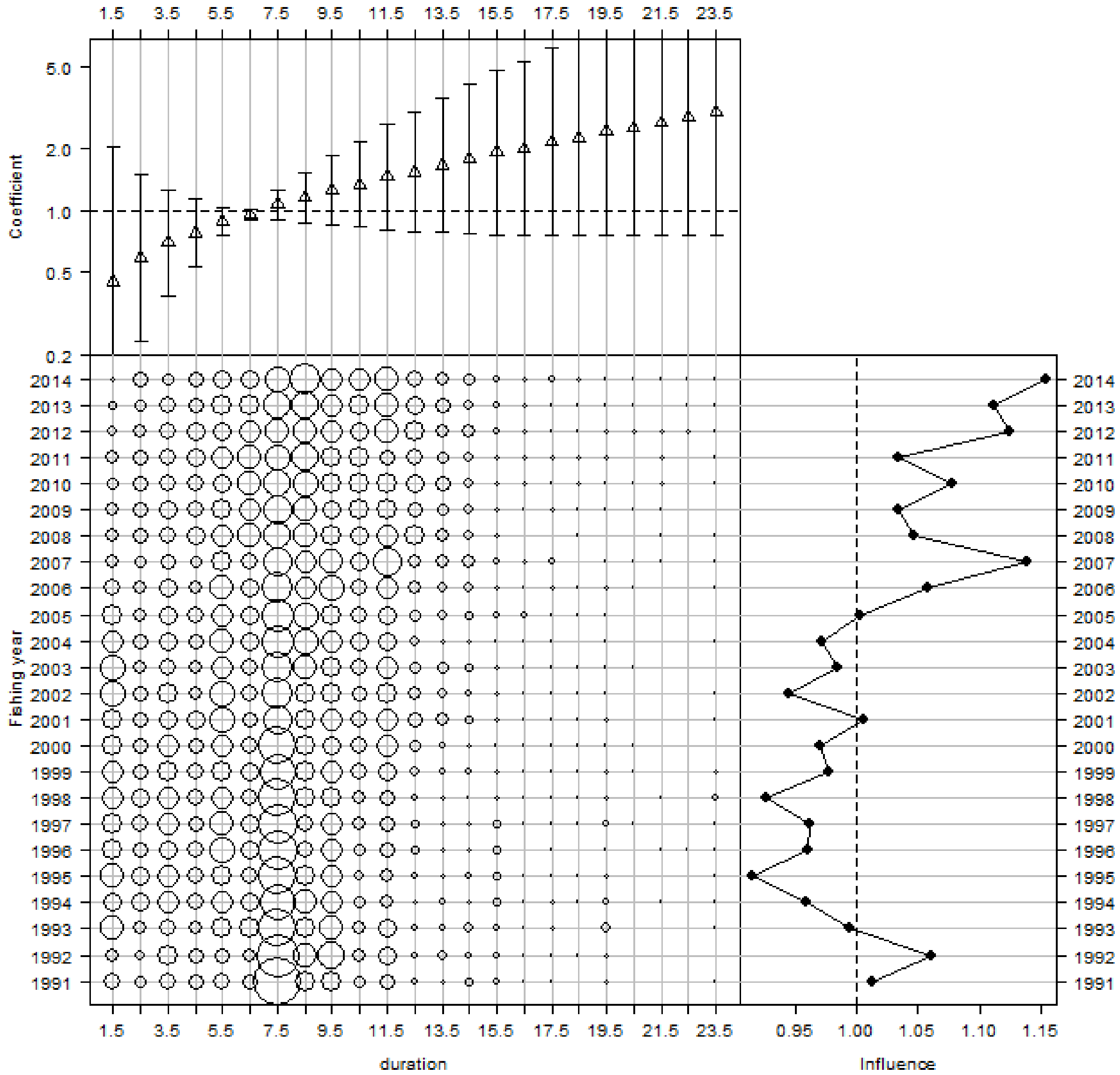


Figure K.7: Effect of log(duration) in the lognormal model for the New Zealand sole ESO 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

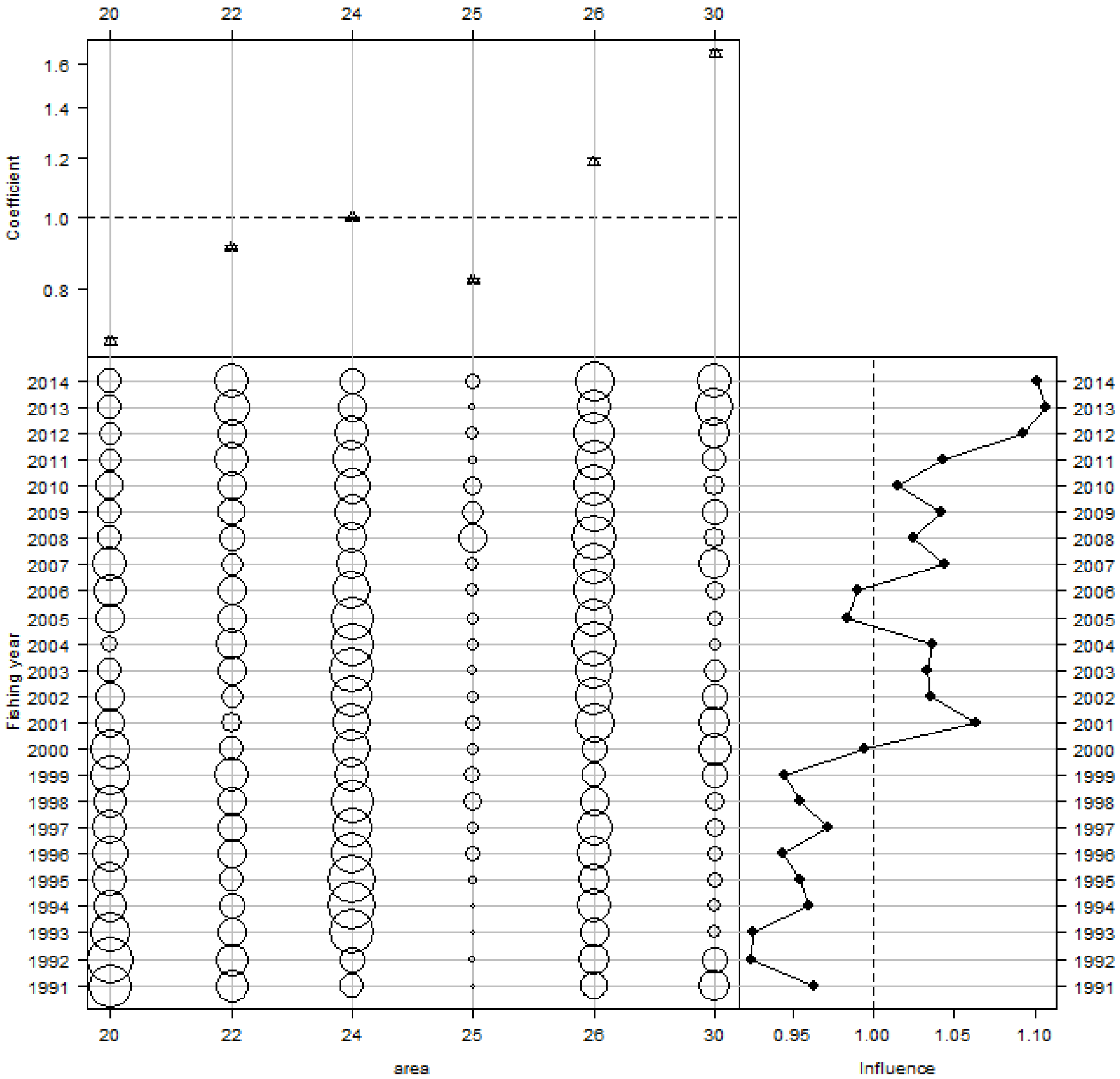


Figure K.8: Effect of area in the lognormal model for the New Zealand sole ESO 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

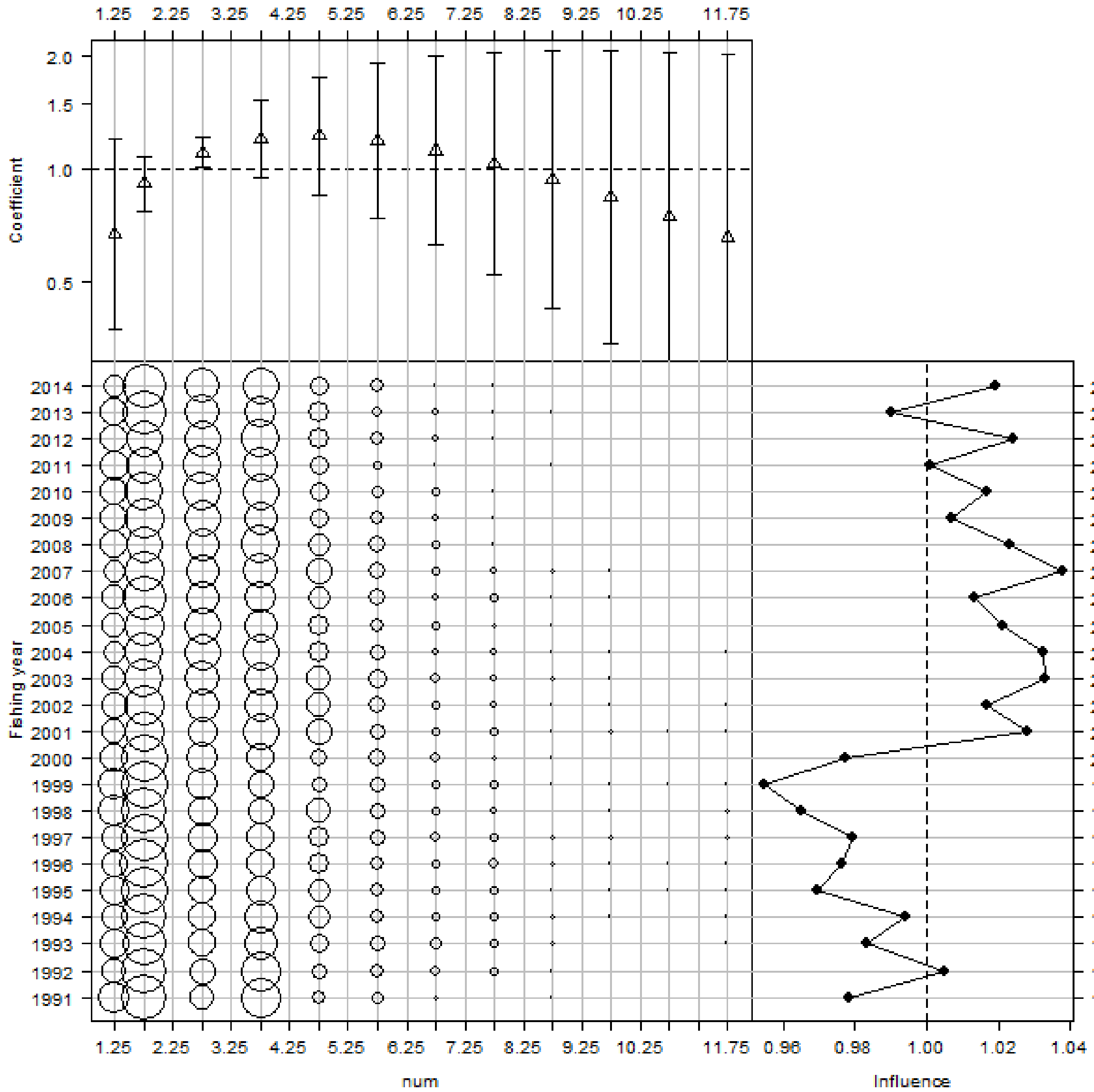


Figure K.9: Effect of log(number tows) in the lognormal model for the New Zealand sole ESO 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

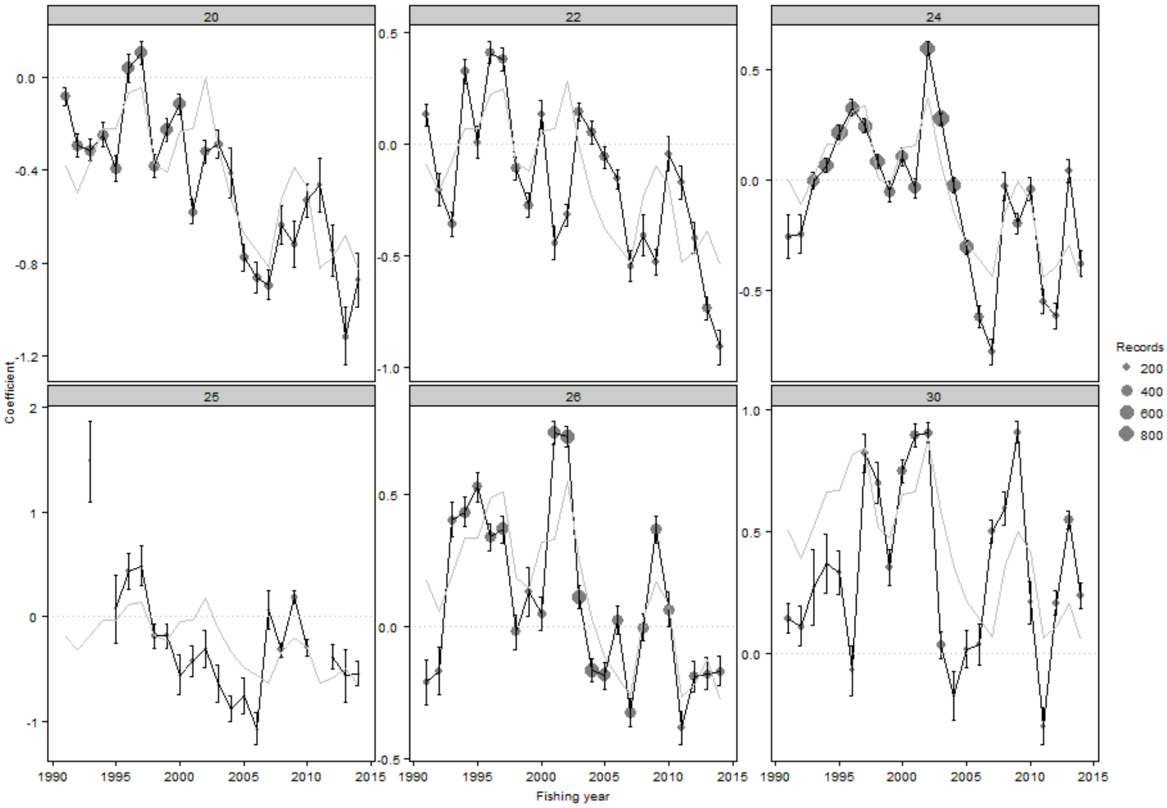


Figure K.10: Residual implied coefficients for area × fishing year interaction (interaction term not offered to the model) in the New Zealand sole ESO 3 lognormal model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and target species. These values approximate the coefficients obtained when an area × year interaction term is fitted, particularly for those area × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals.

K.3 Binomial presence/absence model

Three explanatory variables, with the exception of number tows and duration fishing, entered the model after fishing year (vessel, month and area; Table K.3). A plot of the model is provided in Figure K.11 and the CPUE indices are listed in Table K.4.

Table K.3: Order of acceptance of variables into the binomial presence/absence model in the ESO 3 fishery model for core vessels (based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	Deviance R^2	Nagelkerke R^2	Model use
fishing year	24	-37 759	75 565	2.7	4.7	*
vessel	104	-33 498	67 203	13.7	22.4	*
month	115	-32 699	65 628	15.7	25.4	*
area	120	-32 158	64 556	17.1	27.5	*
poly(log(tows), 3)	123	-31 932	64 110	17.7	28.3	
poly(log(duration), 3)	126	-31 907	64 067	17.8	28.4	

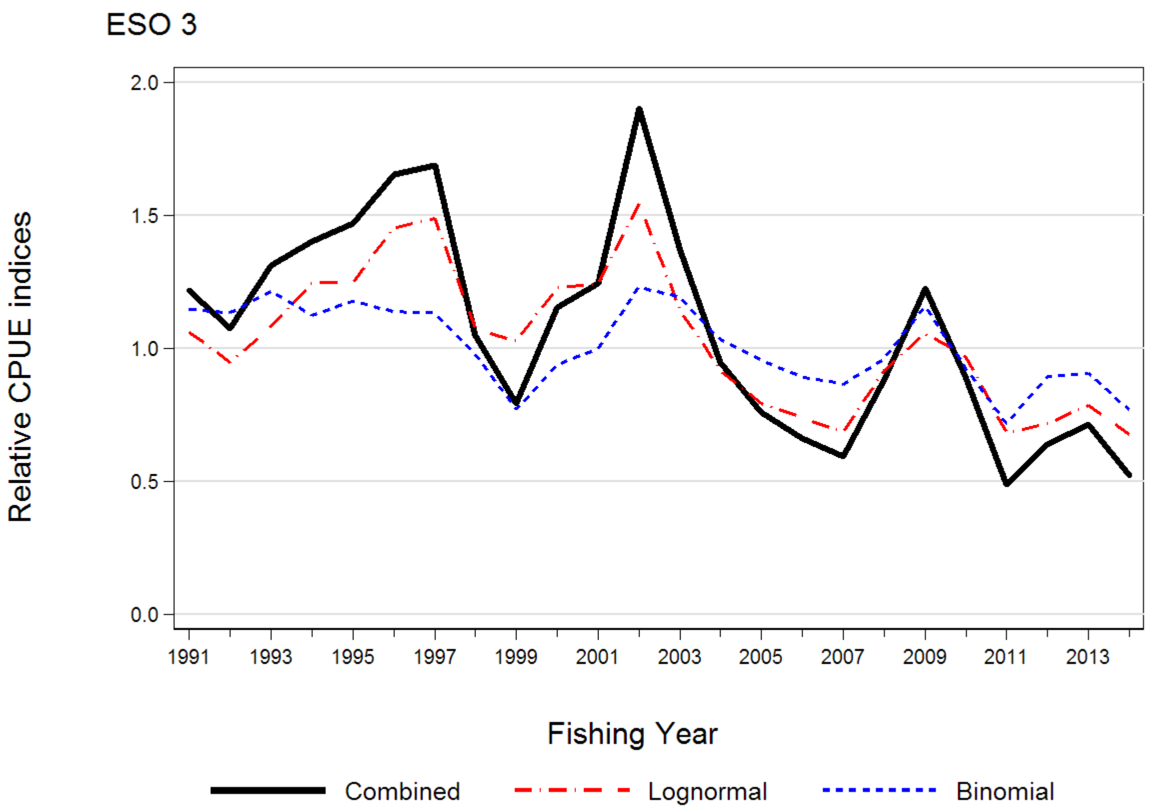


Figure K.11: Relative CPUE indices for ESO using the binomial presence/absence model based on the ESO 3 fishery definition. Also shown are the lognormal and binomial standardised series.

K.4 CPUE indices

Table K.4: Arithmetic indices for the total and core data sets, geometric, lognormal (including standard error [SE]), binomial and combined indices for the core data set by fishing year for the New Zealand sole ESO 3 analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1991	1.114	1.099	1.036	1.061	0.0298	0.721	1.218
1992	0.992	1.033	0.951	0.948	0.0302	0.713	1.076
1993	1.312	1.282	0.995	1.081	0.0250	0.764	1.315
1994	1.247	1.258	1.046	1.247	0.0225	0.707	1.402
1995	1.255	1.321	1.038	1.249	0.0217	0.741	1.472
1996	1.452	1.498	1.223	1.454	0.0211	0.717	1.657
1997	1.457	1.481	1.239	1.489	0.0198	0.713	1.689
1998	0.913	0.918	0.893	1.072	0.0202	0.616	1.050
1999	0.761	0.763	0.903	1.030	0.0221	0.485	0.795
2000	0.983	1.002	1.072	1.229	0.0214	0.590	1.155
2001	1.249	1.276	1.133	1.244	0.0212	0.629	1.243
2002	1.628	1.595	1.409	1.546	0.0199	0.775	1.904
2003	1.167	1.161	1.111	1.147	0.0193	0.751	1.370
2004	0.831	0.848	0.897	0.917	0.0218	0.650	0.948
2005	0.734	0.728	0.771	0.794	0.0219	0.601	0.759
2006	0.714	0.710	0.777	0.740	0.0249	0.562	0.661
2007	0.768	0.743	0.832	0.686	0.0260	0.545	0.595
2008	0.879	0.878	0.978	0.918	0.0264	0.605	0.883
2009	1.337	1.367	1.218	1.057	0.0238	0.729	1.225
2010	0.960	0.998	1.088	0.970	0.0266	0.581	0.896
2011	0.565	0.576	0.790	0.684	0.0333	0.451	0.491
2012	0.810	0.825	0.919	0.717	0.0289	0.562	0.641
2013	0.934	0.927	1.045	0.787	0.0266	0.571	0.714
2014	0.796	0.654	0.920	0.678	0.0306	0.484	0.522

Appendix L. DIAGNOSTICS AND SUPPORTING ANALYSES FOR SFL 3 BOTTOM TRAWL CPUE

L.1 Model definition and preliminary analyses

This CPUE analysis was accepted for monitoring SFL 3 by the Southern Inshore Fishery Assessment Working Group in 2015 (MPI 2015).

L.1.1 Fishery definition

SFL 3: The fishery is defined from bottom trawl daily fishing events in the "*trip splitter*" data set which fished in Statistical Areas 020, 022, 024, 026, 025, and 030, declaring target species from one of the 15 species codes in Table A.3. Positive catch will be those records which recorded an estimated catch of SFL while zero catch records will be events which did not catch SFL but caught another flatfish species and did not use the generic FLA species designation. Daily events with more than 12 tows or 24 hours of accumulated effort were excluded from the analysis.

L.1.2 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 5 trips in each of at least 5 years using trips with at least 1 kg of SFL catch. These criteria resulted in a core fleet size of 56 vessels which took 78% of the catch (Figure L.1).

L.1.3 Data summary

Table L.1: Summaries by fishing year for core vessels, trips, daily effort strata, events that have been "rolled up" into daily effort strata, events per daily-effort stratum, tows, hours fished, landed FLA (t) but declared SFL in the estimated catch data, and percentage of trips with catch for the core vessel data set (based on a minimum of 5 trips per year in 5 years) in the SFL 3 fishery. There are no trips where there is SFL estimated catch but none in the landings, given the definition of the "*trip splitter*" data set.

Fishing year	Vessels	Trips	Daily effort strata	Events	Events per stratum	Sum (tows)	Sum (hours)	Catch (t)	% trips with catch
1991	24	1 057	1 183	1 229	1.04	3 380	8 749	28.8	47.4
1992	26	1 015	1 167	1 262	1.08	3 795	9 236	37.2	55.0
1993	33	1 212	1 471	1 542	1.05	4 478	11 493	63.9	62.9
1994	34	1 690	1 996	2 047	1.03	6 254	14 798	86.6	58.6
1995	34	1 812	2 085	2 123	1.02	6 209	14 922	109.1	67.0
1996	36	1 776	2 218	2 270	1.02	6 858	16 729	96.5	65.8
1997	34	1 946	2 513	2 609	1.04	8 337	18 512	99.8	62.1
1998	37	2 204	2 743	2 809	1.02	8 452	19 890	112.6	57.2
1999	35	2 273	2 861	2 958	1.03	8 531	22 103	94.9	48.4
2000	33	2 015	2 607	2 618	1.00	7 499	19 352	86.5	52.5
2001	35	1 689	2 393	2 415	1.01	7 727	18 807	87.9	53.1
2002	30	1 692	2 319	2 401	1.04	7 060	16 815	89.1	57.2
2003	31	1 915	2 637	2 714	1.03	8 254	20 174	74.6	47.2
2004	31	1 730	2 301	2 320	1.01	7 176	17 576	51.9	40.9
2005	30	1 905	2 382	2 392	1.00	7 050	18 714	68.9	43.3
2006	29	1 490	1 938	1 945	1.00	6 067	15 804	59.1	49.1
2007	26	1 264	1 835	1 849	1.01	6 065	16 236	95.3	55.5
2008	28	990	1 583	4 766	3.01	5 053	12 495	50.0	60.5
2009	27	1 081	1 597	4 271	2.67	4 639	12 520	81.4	62.7
2010	26	1 031	1 687	4 830	2.86	4 989	13 879	78.6	59.9
2011	22	717	1 201	3 663	3.05	3 720	9 826	45.1	61.0
2012	20	862	1 567	4 880	3.11	5 008	13 313	83.2	64.0
2013	26	1 177	1 878	5 468	2.91	5 576	15 993	102.8	68.0
2014	24	930	1 478	4 290	2.90	4 347	12 990	92.5	65.9

L.1.4 Core vessel plots

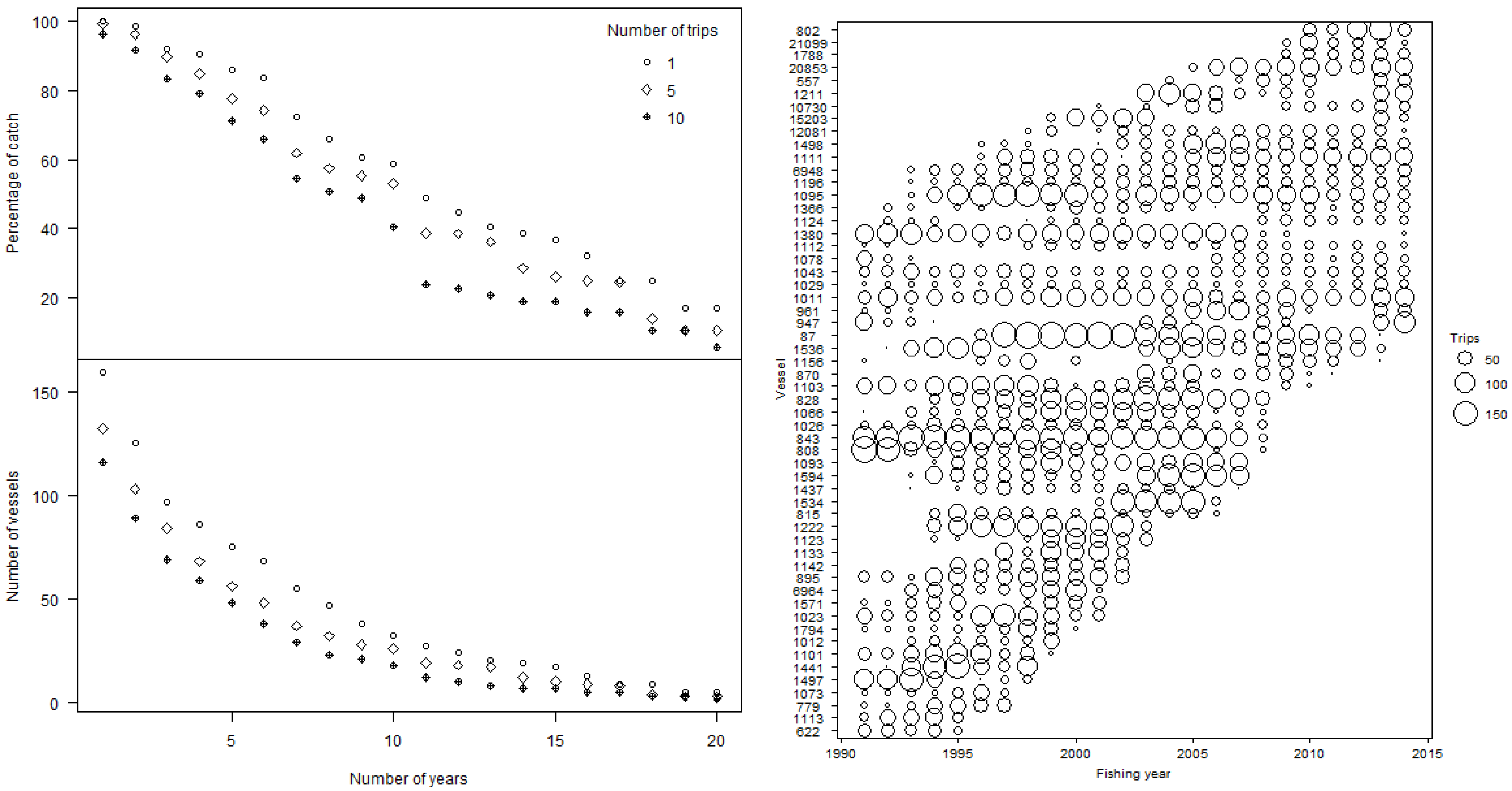


Figure L.1: [left panel] total landed SFL and number of vessels plotted against the number of years used to define core vessels participating in the SFL 3 dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot showing the number of daily-effort strata for selected core vessels (based on at least 5 trips in 5 or more fishing years) by fishing year.

L.1.5 Exploratory data plots for core vessel data set

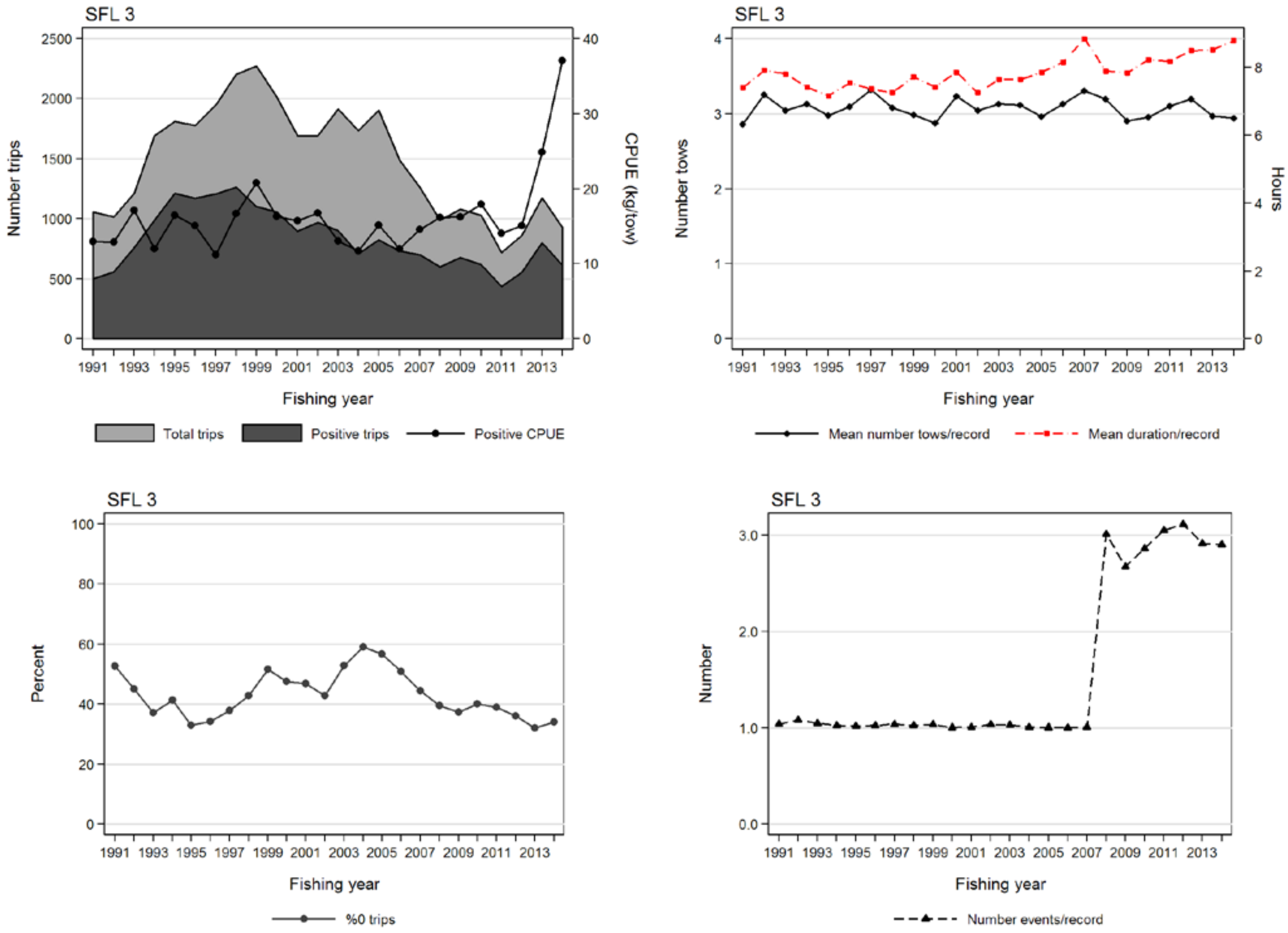


Figure L.2: Core vessel summary plots by fishing year for model SFL 3: [upper left panel]: total trips (light grey) and trips with Sand flounder catch (dark grey) overlaid with median annual arithmetic CPUE (kg/tow) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i}/E_{y,i}\right)$**; [upper right panel]: mean number of tows and mean duration per daily-effort stratum record; [lower left panel]: percentage of trips with no catch of Sand flounder; [lower right panel]: mean number of events per daily-effort stratum record.**

L.2 Positive catch model

Four explanatory variables, except for number tows, entered the model after fishing year (vessel, duration fishing, area, and month; Table L.2). A plot of the model is provided in Figure L.3 and the CPUE indices are listed in Table L.4.

Table L.2: Order of acceptance of variables into the lognormal model of successful catches in the SFL 3 fishery model for core vessels (based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	25	-124 104	248 257	2.54	*
vessel	80	-120 150	240 460	30.53	*
poly(log(duration), 3)	83	-118 135	236 437	41.53	*
area	88	-117 648	235 471	43.93	*
month	99	-117 407	235 011	**45.07**	*
poly(log(tows), 3)	102	-117 393	234 989	45.14	

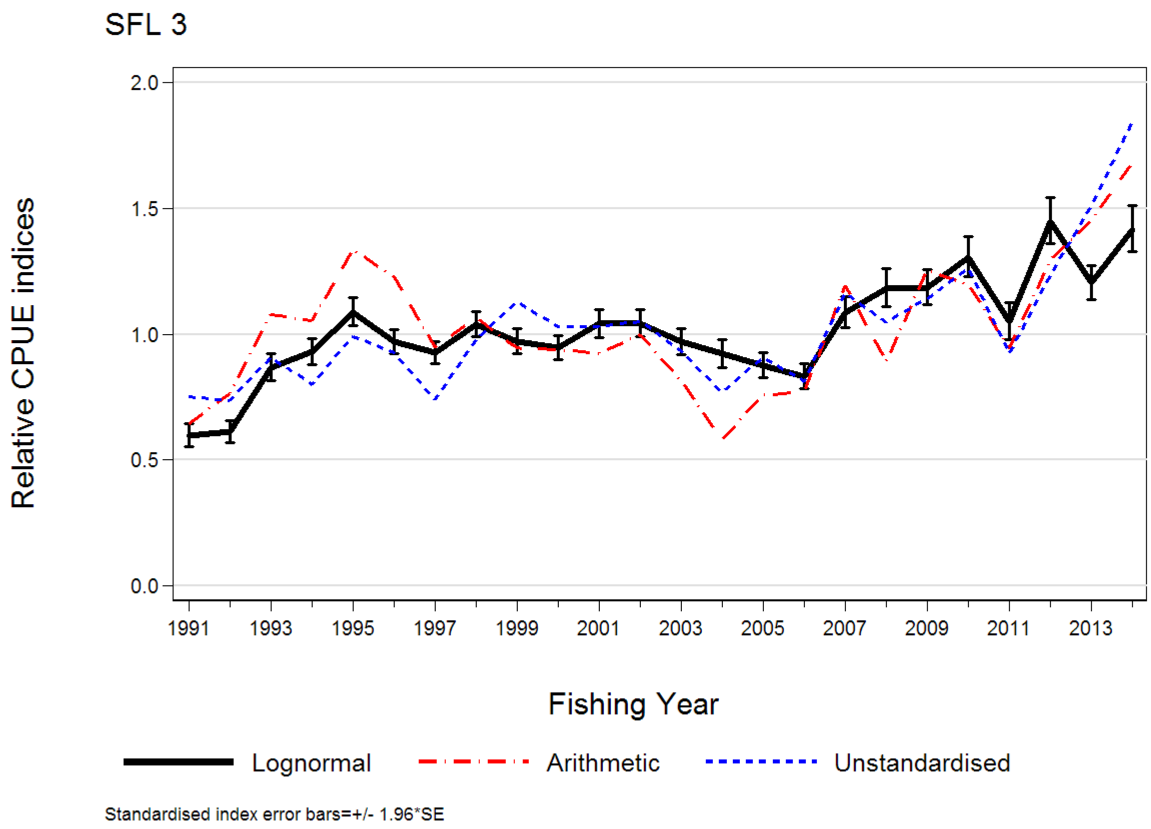


Figure L.3: Relative CPUE indices for SFL using the lognormal non-zero model based on the SFL 3 fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. H.1) and b) Unstandardised (Eq. H.2).

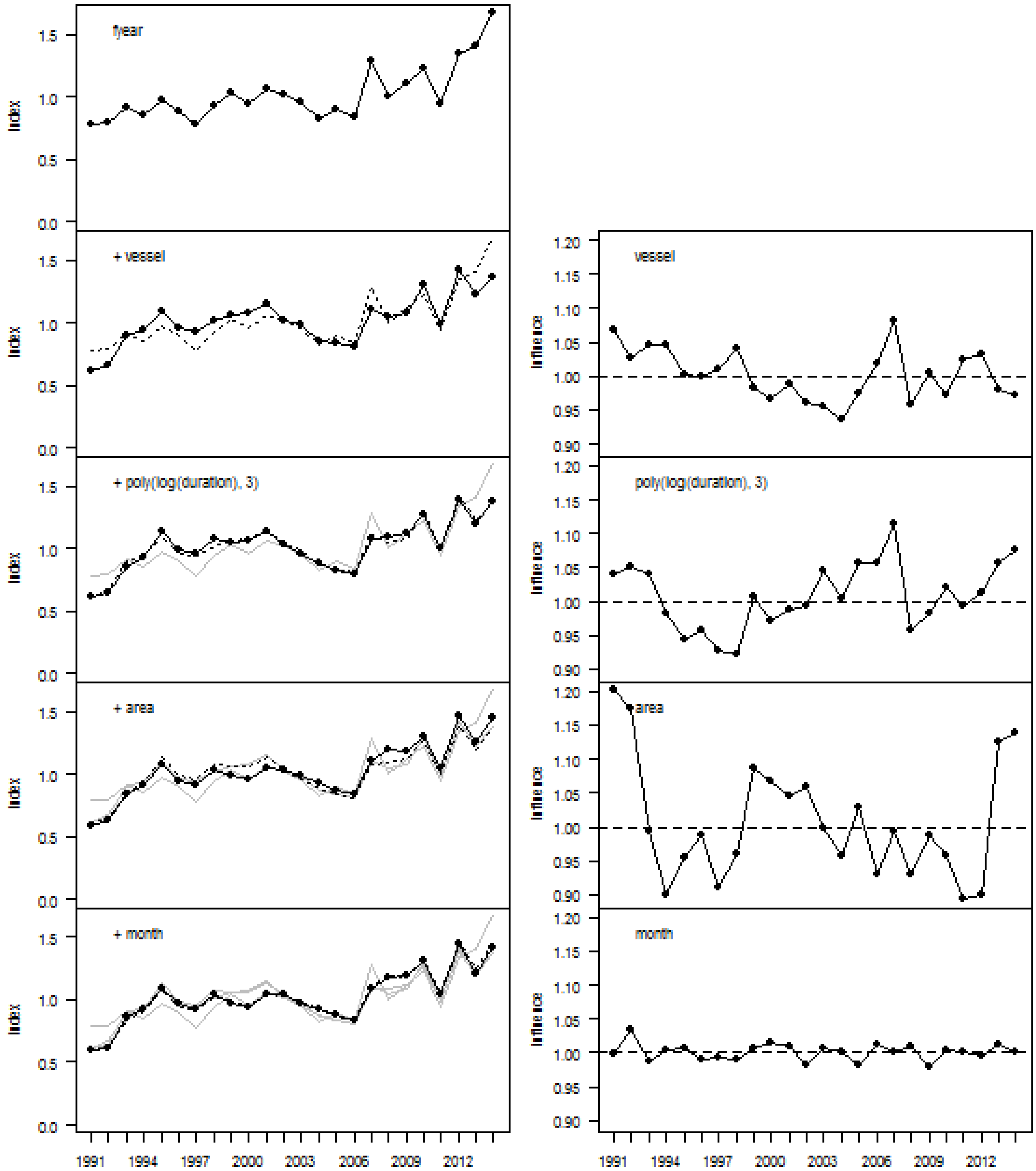


Figure L.4: [left column]: annual indices from the lognormal model of SFL 3 at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

L.2.1 Residual and diagnostic plots

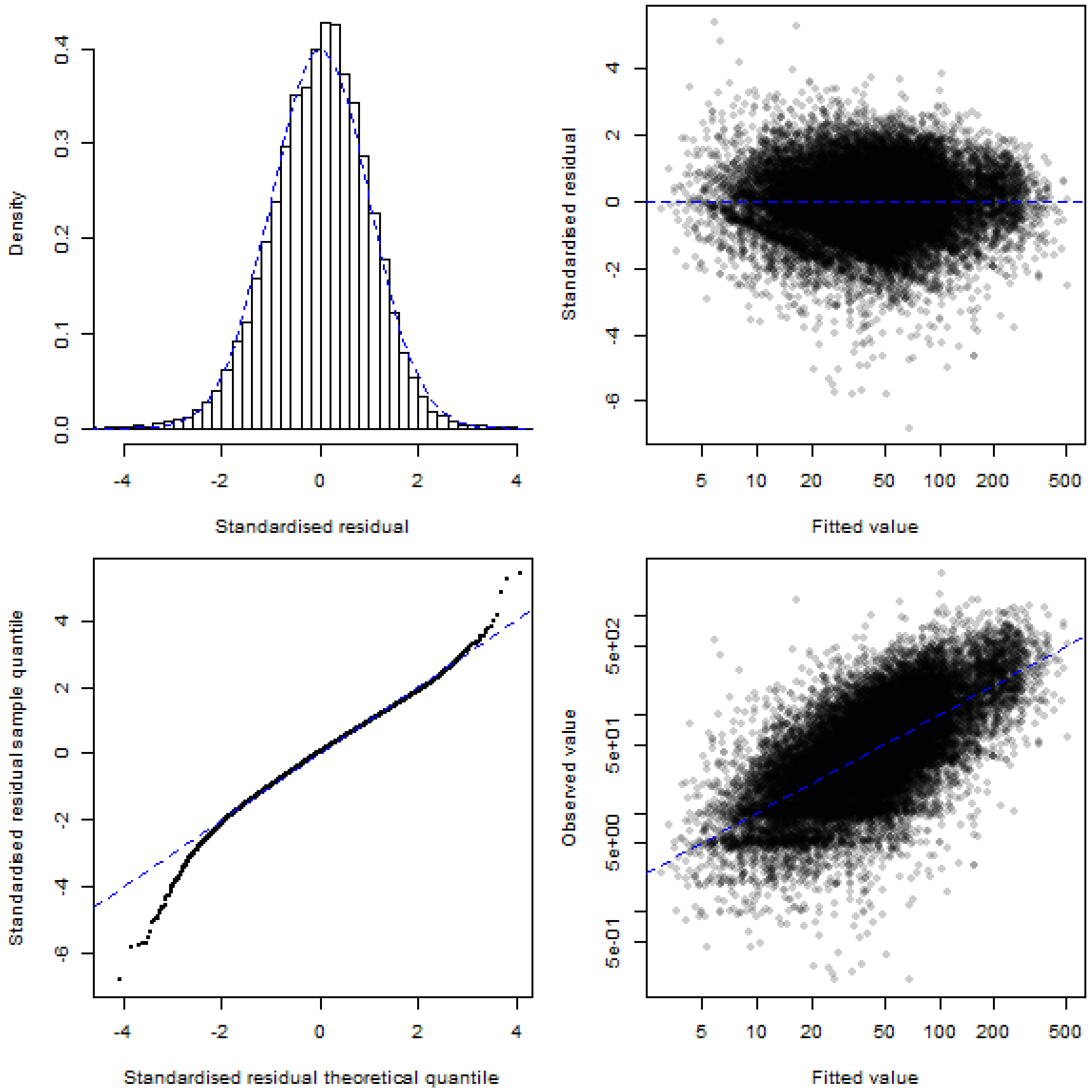


Figure L.5: Plots of the fit of the lognormal standardised CPUE model of successful catches of Sand flounder in the SFL 3 fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

L.2.2 Model coefficient plots

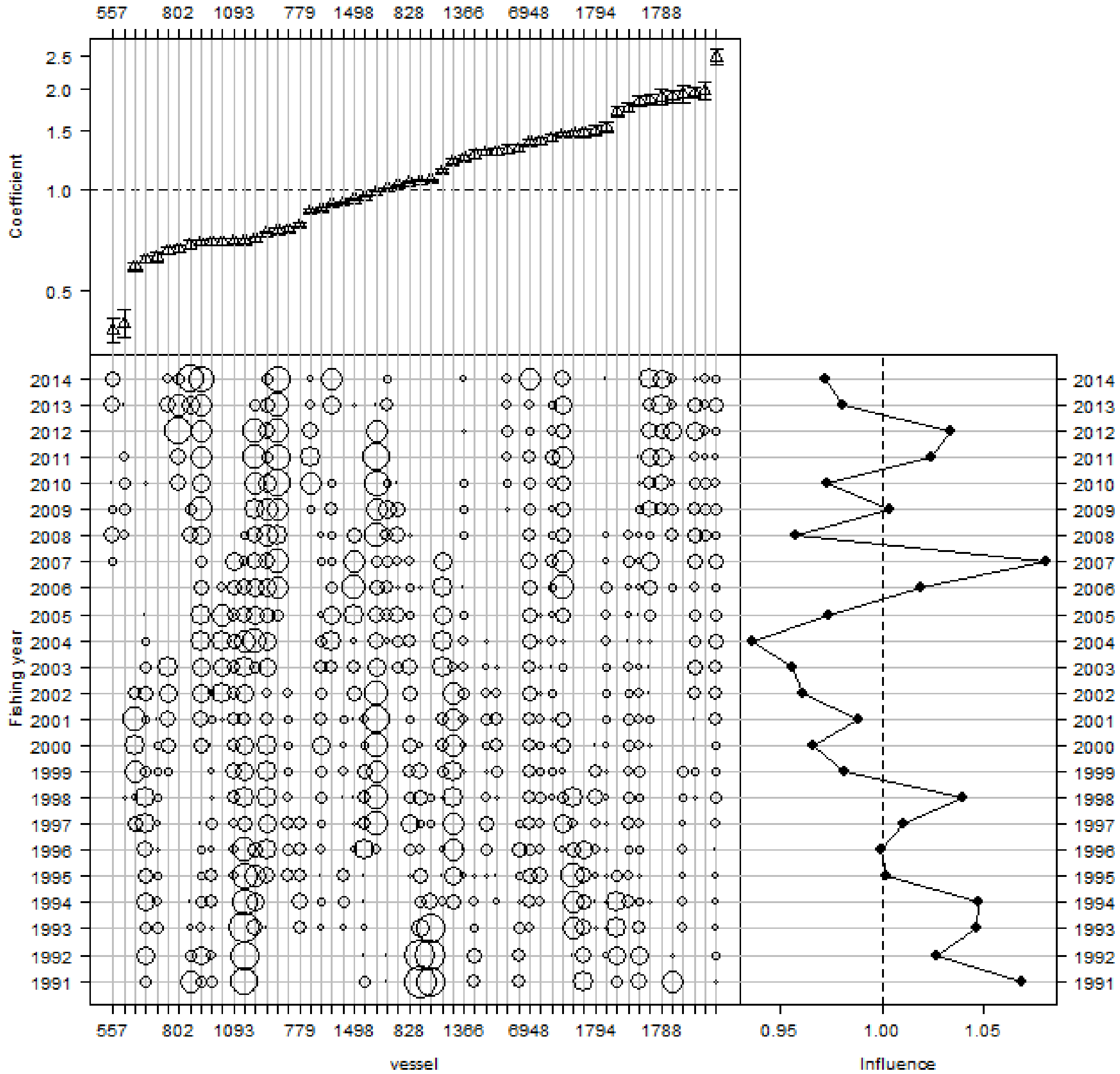


Figure L.6: Effect of vessel in the lognormal model for the Sand flounder SFL 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

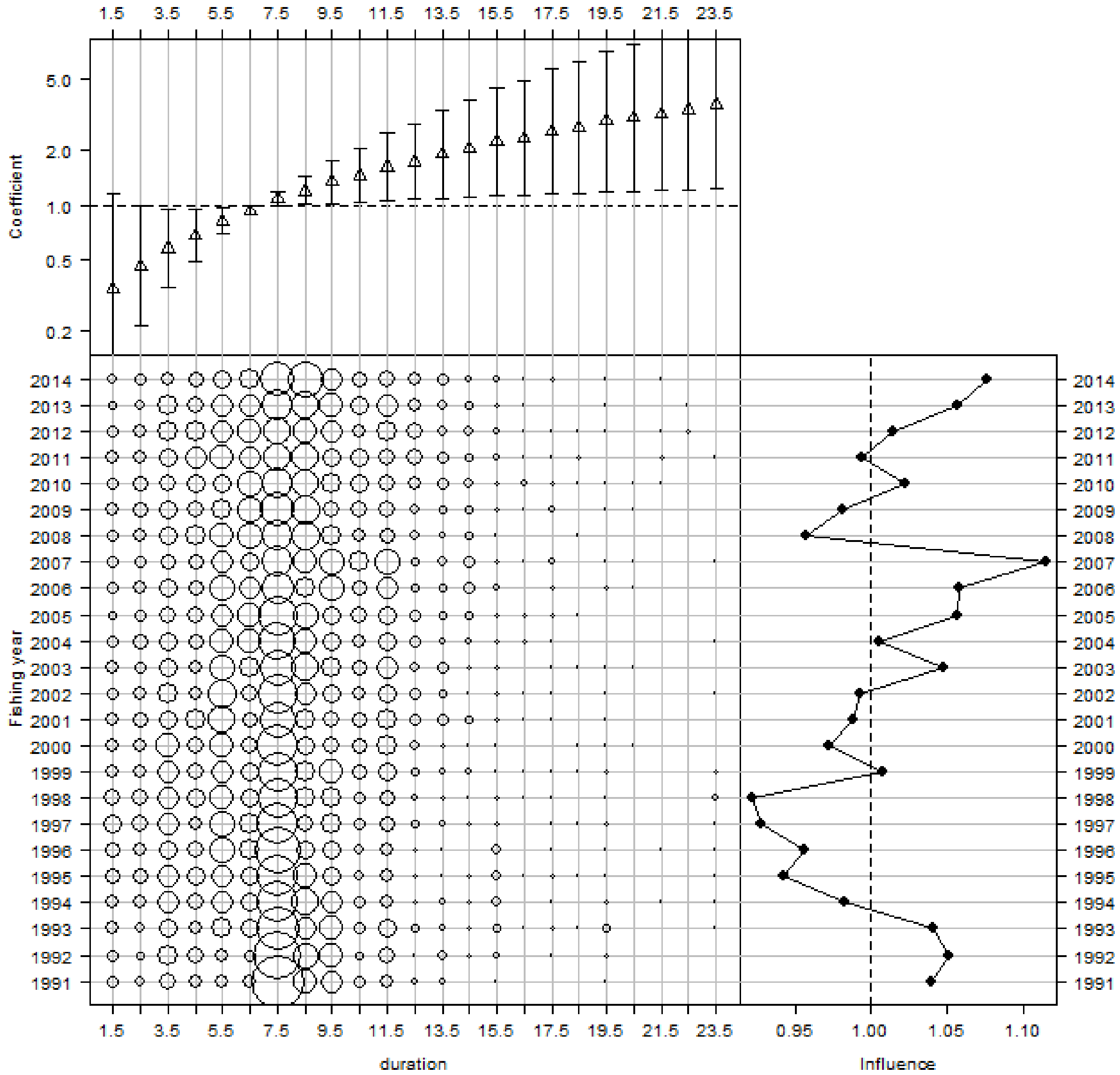


Figure L.7: Effect of log(duration) in the lognormal model for the Sand flounder SFL 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

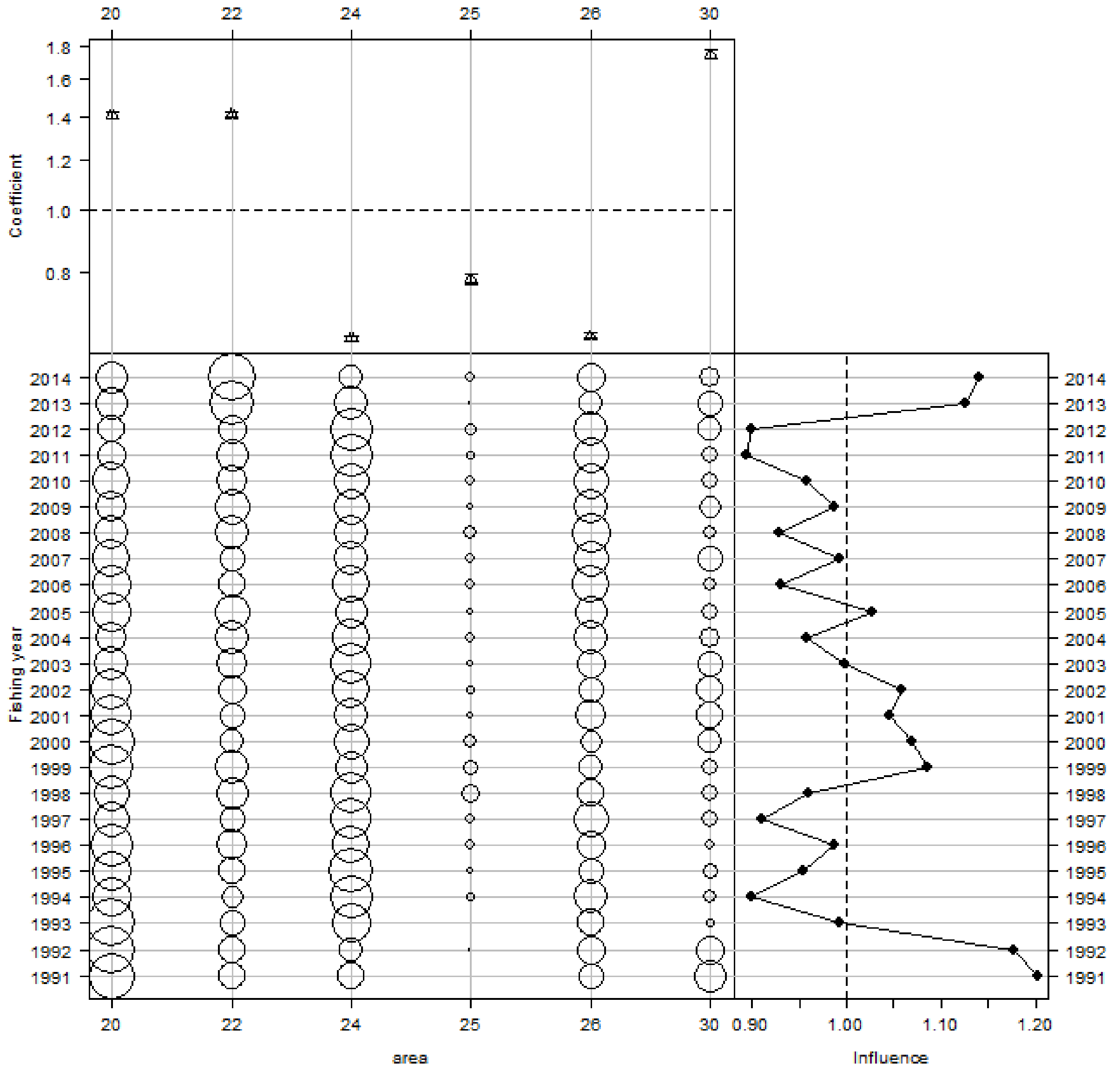


Figure L.8: Effect of area in the lognormal model for the Sand flounder SFL 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

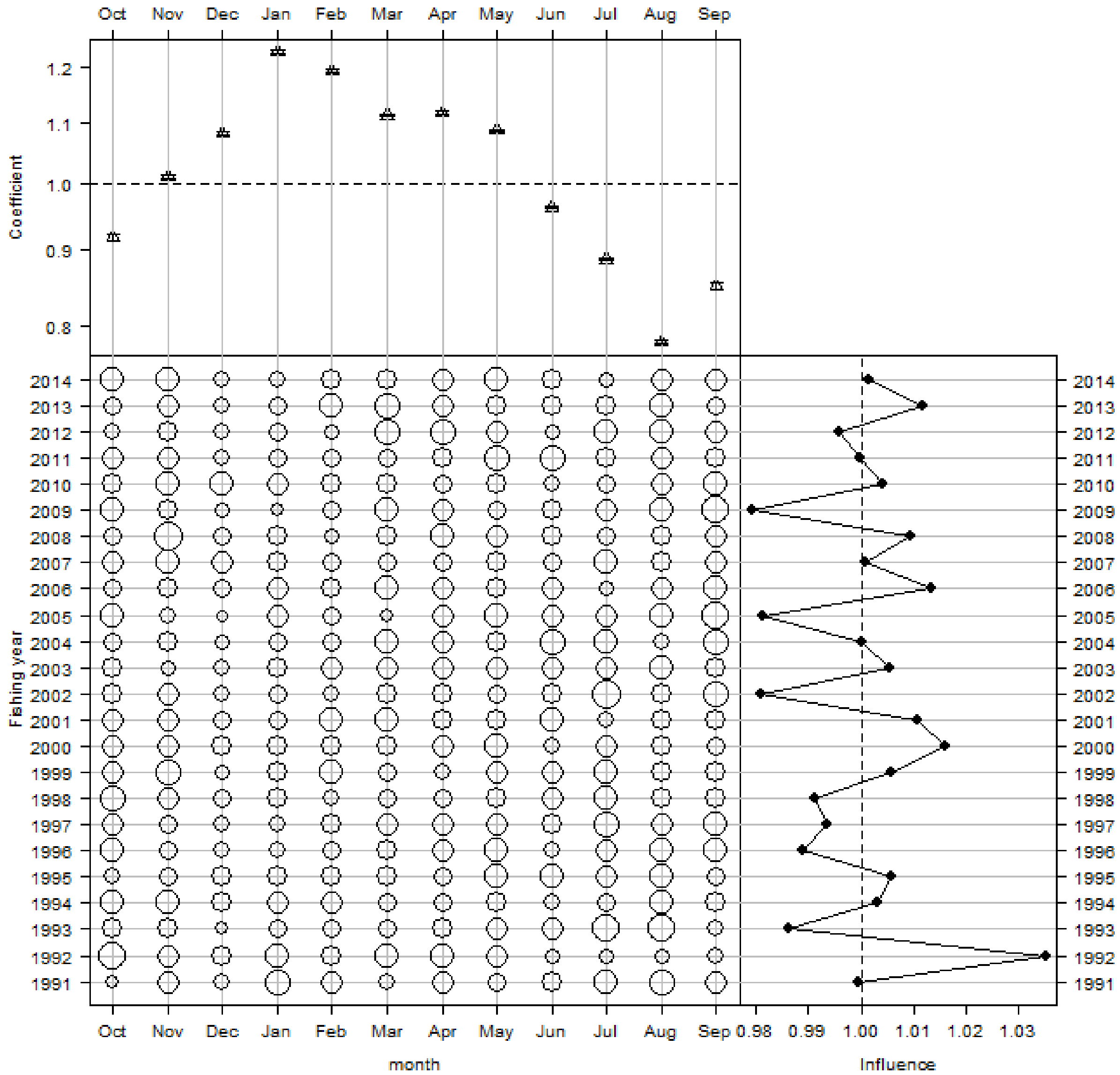


Figure L.9: Effect of month in the lognormal model for the Sand flounder SFL 3 fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

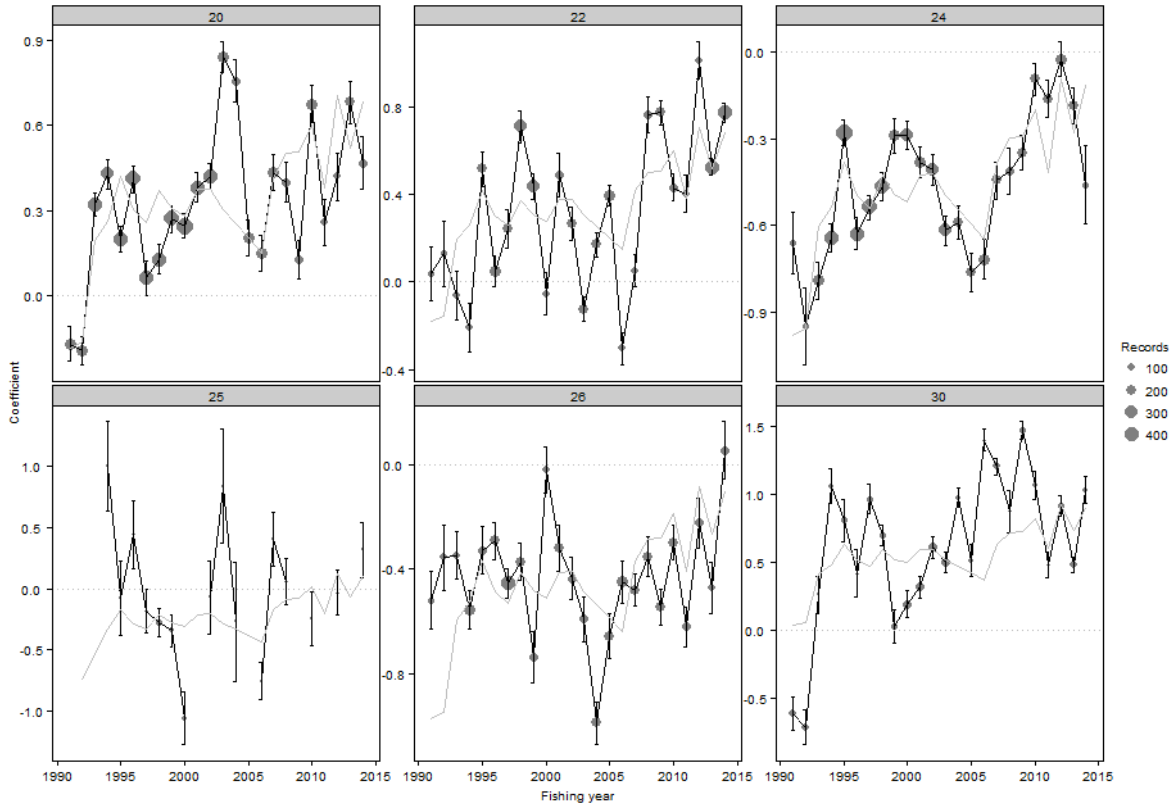


Figure L.10: Residual implied coefficients for area × fishing year interaction (interaction term not offered to the model) in the Sand flounder SFL 3 lognormal model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and target species. These values approximate the coefficients obtained when an area × year interaction term is fitted, particularly for those area × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals.

L.3 Binomial presence/absence model

Only vessel and area entered this binomial model, dropping month, duration fishing and number tows as explanatory variables, after fishing year (Table L.3). A plot of the model is provided in Figure L.11 and the CPUE indices are listed in Table L.4.

Table L.3: Order of acceptance of variables into the binomial presence/absence model in the SFL 3 fishery model for core vessels (based on the vessel selection criteria of at least 5 trips in 5 or more fishing years), with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Variable	DF	Neg. Log likelihood	AIC	Deviance R^2	Nagelkerke R^2	Model use
fishing year	24	-32 488	65 024	1.4	2.5	*
vessel	79	-28 136	56 430	14.6	24.4	*
area	84	-27 736	55 640	15.8	**26.2**	*
month	95	-27 551	55 292	16.4	27.0	
poly(log(duration), 3)	98	-27 381	54 959	16.9	27.8	
poly(log(tows3)	101	-27 371	54 943	16.9	27.9	

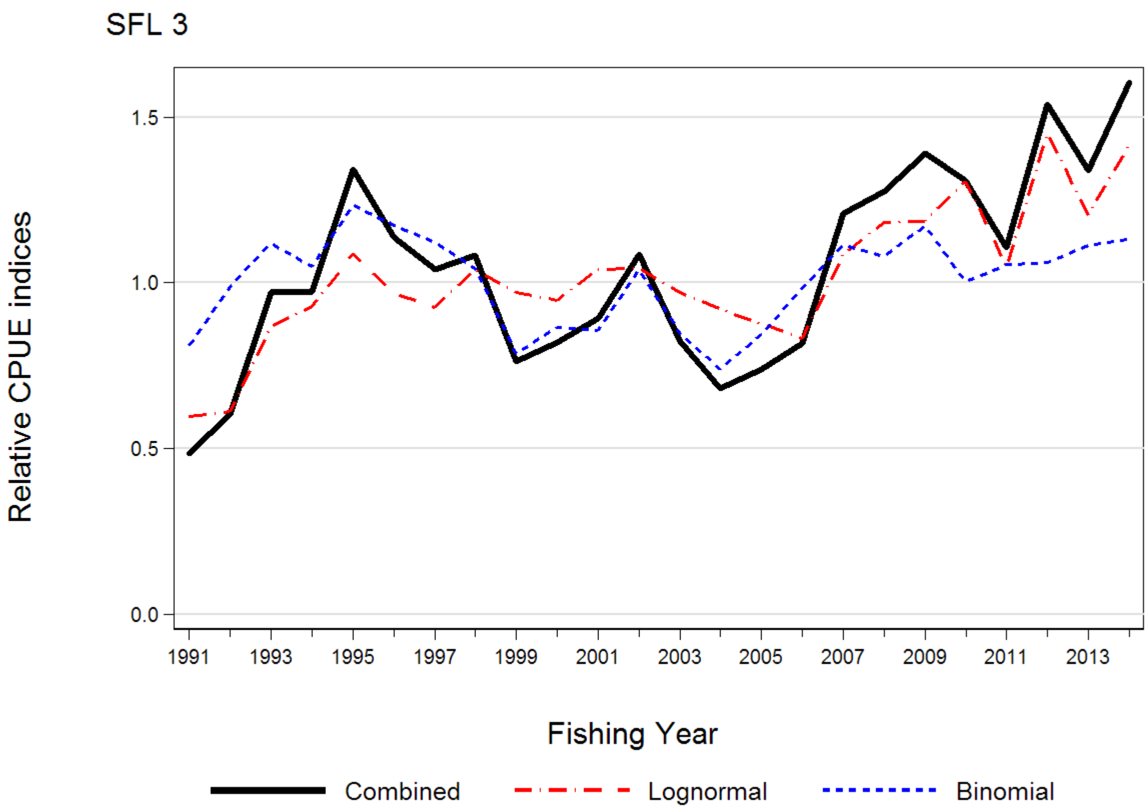


Figure L.11: Relative CPUE indices for SFL using the binomial presence/absence model based on the SFL 3 fishery definition. Also shown are the lognormal and binomial standardised series.

L.4 CPUE indices

Table L.4: Arithmetic indices for the total and core data sets, geometric, lognormal (including standard error [SE]), binomial and combined indices for the core data set by fishing year for the Sand flounder SFL 3 analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1991	0.866	0.644	0.752	0.596	0.0390	0.400	0.484
1992	0.821	0.765	0.736	0.610	0.0372	0.487	0.603
1993	1.323	1.078	0.908	0.869	0.0315	0.551	0.972
1994	0.992	1.054	0.800	0.929	0.0276	0.517	0.975
1995	1.122	1.337	0.992	1.088	0.0257	0.609	1.343
1996	0.987	1.231	0.927	0.969	0.0255	0.579	1.137
1997	0.848	0.947	0.740	0.926	0.0241	0.553	1.040
1998	0.948	1.067	0.978	1.039	0.0241	0.514	1.083
1999	0.855	0.945	1.129	0.972	0.0258	0.388	0.764
2000	0.839	0.938	1.030	0.946	0.0256	0.427	0.819
2001	0.798	0.924	1.032	1.041	0.0269	0.422	0.892
2002	0.940	1.000	1.051	1.044	0.0259	0.512	1.084
2003	0.827	0.816	0.934	0.969	0.0268	0.418	0.822
2004	0.642	0.580	0.769	0.921	0.0308	0.365	0.682
2005	0.781	0.759	0.907	0.876	0.0286	0.416	0.739
2006	0.790	0.769	0.813	0.832	0.0295	0.484	0.817
2007	1.373	1.194	1.164	1.087	0.0291	0.549	1.210
2008	0.876	0.891	1.048	1.182	0.0329	0.532	1.276
2009	1.168	1.255	1.143	1.186	0.0303	0.577	1.389
2010	1.052	1.198	1.262	1.305	0.0311	0.494	1.309
2011	1.002	0.943	0.923	1.049	0.0358	0.520	1.106
2012	1.449	1.294	1.234	1.450	0.0326	0.523	1.537
2013	1.640	1.452	1.512	1.204	0.0293	0.548	1.339
2014	1.938	1.680	1.843	1.416	0.0327	0.558	1.603