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Fishery Characterisation and CPUE Analysis of LIN 1

New Zealand Fisheries Assessment Report 2017/48

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EXECUTIVE SUMMARY

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The fisheries taking ling (*Genypterus blacodes*) in Quota Management Area (QMA) LIN 1 are described from 1989–90 to 2015–16 based on compulsory reported commercial catch and effort data held by the Ministry for Primary Industries (MPI). This QMA includes the east coast of the North Island from North Cape to Cape Runaway and the west coast of the North Island down to about New Plymouth. The combined bottom trawl (BT) and bottom longline (BLL) fisheries account for more than 98% of the total accumulated landings of LIN 1 over the 27 year period of record, with the target ling BLL fishery accounting for 42% of the overall total catch in this QMA. The remaining 58% of the landings are spread out amongst a wide range of fisheries, with the most important being the bycatch of ling in BT fisheries targeting scampi (14%), hoki (9%), gemfish (8%) and tarakihi (4%). About 11% of the total landings are taken by BT target fishing for ling. Detailed characteristics of the LIN 1 landing data, as well as the spatial, temporal, target species and depth distributions relative to the catch of ling in LIN 1 are presented. Annual performance of the LIN 1 catches and some regulatory information are also presented.

The TACC for LIN 1 was raised from 265 t/year to 400 t/year at the beginning of the 2002–03 fishing year, when the QMA entered the Adaptive Management Programme (AMP). That programme was discontinued in 2009, but the higher TACC for LIN 1 remained. Reviews of LIN 1, under the provisions of the AMP, were conducted in 2005, 2007 and 2009, with a further MPI review conducted in 2013. Only one standardised analysis of commercial Catch Per Unit Effort (CPUE) survived the 2013 review: this was the BLL(LIN) CPUE series which covered the Bay of Plenty and East Northland and was accepted by the NINSWG with a Science Information Quality (SIQ) ranking of “2” (“Medium or Mixed Quality”) due to the lack of data in the analysis. This acceptance was combined with the requirement that each accepted CPUE index value in the series had to be determined by at least three vessels. This latter requirement removed an apparently spurious 1998–99 index value based on only two vessels fishing in a localised manner. A second CPUE index series was proposed by the current review: an expanded BLL(MIX2) series covering the same region but with a wider target species definition, including hapuku/bass (HPB), bluenose (BNS) and ribaldo (RIB). This expanded analysis was accepted by the NINSWG with a SIQ rating of “2” because of the strong standardisation effect associated with the target species explanatory variable.

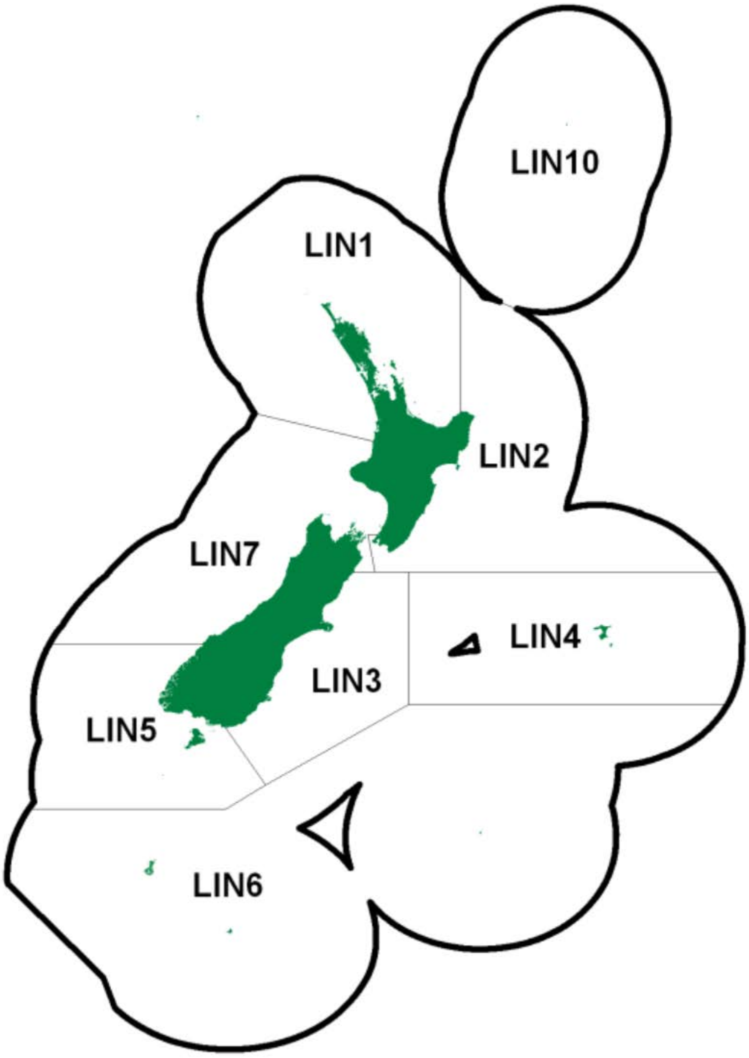

Figure 1: Map of LIN QMAs.

1 INTRODUCTION

This document describes work conducted under Objectives 1 and 2 of the Ministry for Primary Industries (MPI) contract LIN2016/01.

Overall Objective:

1. To characterise the Ling (*Genypterus blacodes*) fishery and undertake a CPUE analysis in LIN 1

Specific Objectives:

1. To characterise the LIN 1 fisheries.
2. To analyse existing commercial catch and effort data to the end of the 2015–16 fishing year with the aim of developing a standardised CPUE index of abundance based on the target longline fishery.

The TACC for LIN 1 (Figure 1) was increased from 265 t to 400 t within the Adaptive Management Programme (AMP) on 1 October 2002. Reviews of the LIN 1 AMP were carried out in 2005 (SeaFIC

2005), in 2007 (Starr et al. 2007) and in 2009 (Starr et al. 2009). The AMP was discontinued by the Minister of Fisheries in 2009–10, but the higher TACC remained in place (Table 1; Figure 2). A further review was commissioned in 2013 by the Ministry for Primary Industries (MPI) and is documented in Starr & Kendrick (2016b). The results of the 2013 review are summarised in Chapter 42 of the MPI Plenary stock assessment report (Ministry for Primary Industries 2016). This review, also commissioned by MPI (LIN2016/01), updates the 2013 review.

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

2 INFORMATION ABOUT THE STOCK/FISHERY

2.1 TRENDS IN COMMERCIAL CATCH

The fishery for ling in QMA 1 exceeded the previous TACC of 265 t in five of the six years prior to the introduction of this Fishstock into the AMP (Table 1; Figure 2). Landings declined in the first two years (2002–03 and 2003–04) at the higher TACC, but have since risen, exceeding 300 t in every year since 2005–06 and rising above the TACC in 2010–11 with a catch of 438 t, the highest since the Fishstock was introduced into the QMS in 1986 and again in 2015–16 with a catch of 423 t.

Table 1: Reported landings (t), TACC (t) and adjusted landings of ling in LIN 1 from 1989–90 to 2015–16 (Data sources: QMR [1986–87 to 2000–01]; MHR [2001–02 to 2015–16). $\tilde{SL}_y$ is the sum of landings in a year adjusted for changes in conversion factor (see caption for Table 2) and SL_y is the sum of the same landings without adjustment.

Year	QMR_y	$TACC_y$	$R_y = \tilde{SL}_y / SL_y$	$\tilde{QMR}_y = QMR_y * R_y$
1986–87	105	200	0.981[1]	103
1987–88	248	237	0.981[1]	243
1988–89	218	238	0.981[1]	213
1989–90	121	265	0.975	118
1990–91	207	265	0.986	204
1991–92	241	265	0.982	237
1992–93	253	265	0.982	249
1993–94	237	265	1.000	237
1994–95	261	265	1.000	261
1995–96	240	265	1.000	240
1996–97	313	265	1.000	313
1997–98	300	265	0.998	300
1998–99	208	265	0.996	208
1999–00	313	265	0.996	311
2000–01	296	265	0.992	294
2001–02	303	265	0.996	302
2002–03	246	400	1.000	246
2003–04	249	400	1.000	249
2004–05	283	400	1.000	283
2005–06	364	400	1.000	364
2006–07	301	400	1.001	301
2007–08	381	400	1.000	381
2008–09	320	400	1.000	320
2009–10	386	400	1.000	386
2010–11	438	400	1.000	438
2011–12	384	400	1.000	384
2012–13	383	400	1.000	383
2013–14	380	400	1.000	380
2014–15	374	400	1.000	374
2015–16	423	400	1.000	423

[1] average: 1989–90 to 1992–93

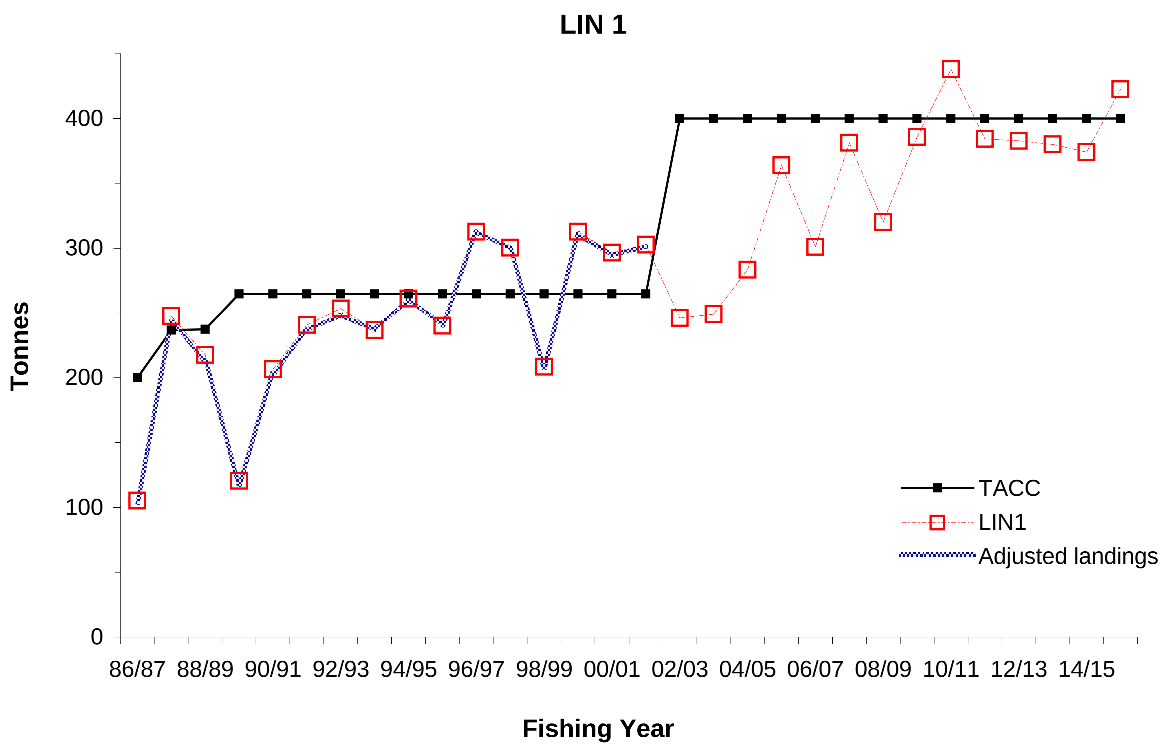

Figure 2: Annual landings and TACCs for the LIN 1 fishery by fishing year from 1986–87 to 2015–16 (Table 1). Landings adjusted from 1986–87 to 2001–02 as presented in Table 1.

2.2 REGULATIONS AFFECTING THE FISHERY

There have been changes to the factors used to convert processed weight to greenweight at the time of landing in this data series and landings have been adjusted to a constant conversion factor when preparing the data for the analyses presented in this report (see Table 7 in Section 3.2). The changes are minor, resulting in small shifts in the declared landings of about 1 to 4% for LIN 1 in the early 1990s compared to the sum of the greenweights as declared at the time of landing (Table 1; Figure 2).

3 ANALYSIS OF LIN 1 CATCH AND EFFORT DATA

3.1 METHODS USED FOR ANALYSIS OF MPI CATCH AND EFFORT DATA

3.1.1 DATA EXTRACTS AND INITIAL DATA PREPARATION

Three data extracts were obtained from the Ministry for Primary Industries (MPI) Warehou database (Ministry of Fisheries 2010). One extract consisted of the complete data (all fishing event information along with all ling landing information) from every trip which recorded landing ling in LIN 1, starting from 1 October 1989 and extending to 30 September 2016). Two further extracts were obtained: one consisting of all trips using the method BT (bottom trawl) which targeted or caught scampi (SCI), gemfish (SKI), tarakihi (TAR), ling (LIN), or hoki (HOK) and fished at least once in a valid LIN 1 statistical area. The third extract requested all trips which used the bottom longline (BLL) method to target or catch ling (LIN), hapuku/bass (HPB), hapuku (HAP), bass (BAS), bluenose (BNS), or ribaldo (RIB) and fished at least once in a valid LIN 1 statistical area. Once these trips were identified, all fishing event data and ling landing data from the entire trip, regardless of method of capture, were obtained. These data extracts (MPI replog 10958) were received 17 February 2017. The first data extract was used to characterise and understand the fisheries taking LIN 1. These characterisations are reported in Sections 3.2 and 3.3. The BLL extract was used to calculate CPUE standardisations (Section 4, Appendix D, Appendix E and Appendix F). The BT extract was obtained for completeness, but was not used because the NINSWG had decided in 2013 to drop the BT standardisations because of the small amounts of data involved and a lack of consistency in the evaluated series (Ministry for Primary Industries 2016).

Data were prepared by linking the effort ("fishing event") section of each trip to the landing section, based on trip identification numbers supplied in the database. Effort and landing data were groomed to remove "out-of-range" outliers (the method used to groom the landings data is documented in Appendix C; the remaining procedures used to prepare these data are documented in Starr (2007)). This landing grooming procedure, identified trips, based on the reported fine scale positions, that never actually fished in LIN 1. These trips were removed from the data set, even if they had reported LIN 1 landings. Three hundred and fourteen tonnes of LIN 1 landings (about 4%) of landings were dropped from the data set when implementing this procedure.

Table 2: Comparison of the total adjusted LIN 1 QMR/MHR catch (t), reported by fishing year, with the sum of the corrected landed catch totals (bottom part of the MPI CELR form or the 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 10958: 1989–90 to 2015–16.

Fishing Year	QMR/MHR (t)[1]	Total landed catch (t)[1,2]	% landed/ QMR/MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis
89/90	118	106	91	101	95	53	53
90/91	204	200	98	195	98	120	62
91/92	237	245	103	235	96	159	68
92/93	249	246	99	245	99	151	62
93/94	237	248	105	247	99	169	69
94/95	261	254	97	243	96	178	73
95/96	240	240	100	239	100	190	79
96/97	313	294	94	286	97	228	80
97/98	300	291	97	290	100	221	76
98/99	208	209	101	201	96	150	75
99/00	311	372	119	370	99	311	84
00/01	294	294	100	291	99	255	88
01/02	302	304	101	301	99	241	80
02/03	246	246	100	246	100	201	82
03/04	249	239	96	237	99	191	81
04/05	283	268	95	268	100	207	77
05/06	364	356	98	356	100	288	81
06/07	301	299	99	299	100	227	76
07/08	381	380	100	380	100	356	94
08/09	320	319	100	319	100	294	92
09/10	386	381	99	381	100	346	91
10/11	438	433	99	433	100	384	89
11/12	384	392	102	392	100	349	89
12/13	383	370	97	370	100	334	90
13/14	380	381	100	381	100	361	95
14/15	374	360	96	360	100	362	101
15/16	423	412	98	403	98	383	95
Total	8 185	8 140	99	8 068	99	6 712	83

[1] Annual totals adjusted to a constant conversion factor: see Table 7 in Section 3.2
[2.]Totals summed after applying procedure described in Appendix C.

The original level of time stratification for a trip is either by tow, or day of fishing, depending on the type of form used to report the trip information. These data were amalgamated into a common level of stratification known as a "trip stratum" (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 ling by trip were allocated to the “trip strata” in proportion to the estimated ling catches in each “trip stratum”. In situations when trips recorded landings of ling 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 ling landings were allocated proportionally to effort (tows for trawl data and number of sets for longline data) in each “trip stratum”. Trips which fished within an ambiguous statistical area and landed to multiple LIN 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 less than 1% of the landings remaining in the data set after the grooming procedure described in Appendix C. This low level of loss is attributable to the low level of overlap between LIN 1 with LIN 2 on the east and LIN 7 on the west, with only Area 041 shared with LIN 7. Because there was such a low level of data loss, this procedure was used for both the characterisation and CPUE data sets and results in catch and effort data that are entirely attributable to LIN 1.

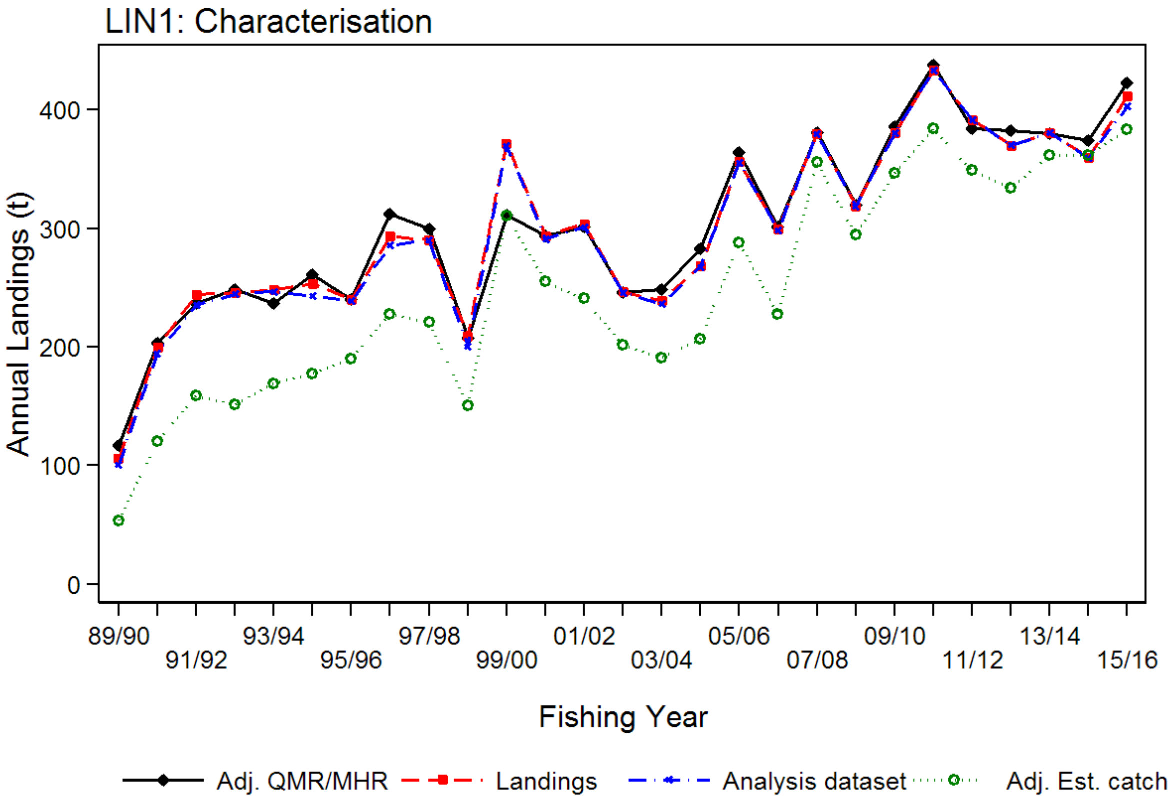

Figure 3: **Plot of catch datasets presented in Table 2. The estimated catch total is the sum of the estimated catch in the analysis dataset. The QMR/MHR catches have been adjusted as shown in Table 1, landings have been purged of spurious trips (Appendix C), and the Analysis and estimated catches are as presented in Table 2.**

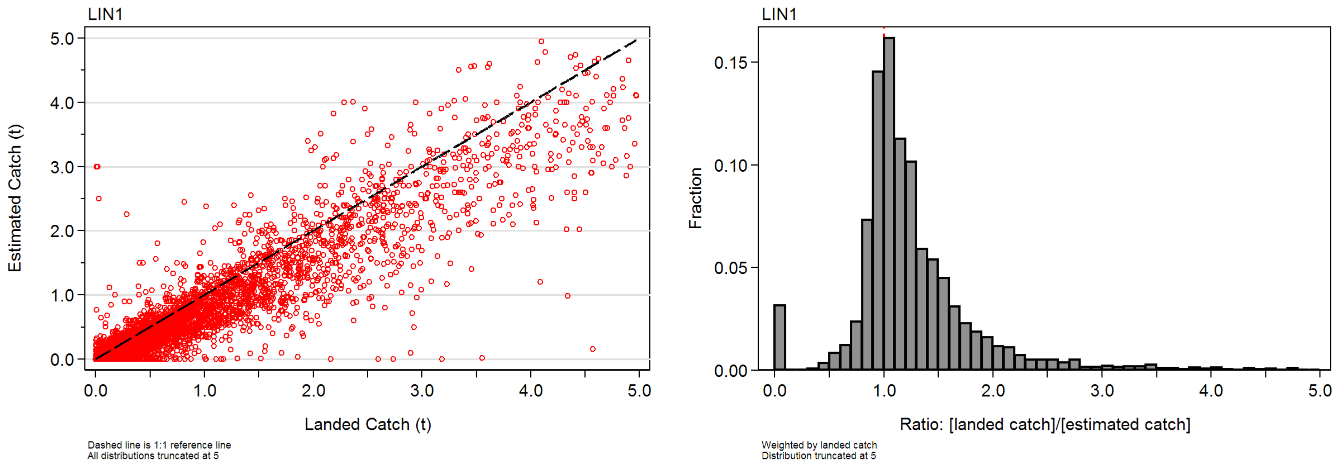

Figure 4: [left panel]: Scatter plot of the sum of landed and estimated ling catch for each trip in the LIN 1 analysis dataset. [right panel]: Distribution (weighted by the landed catch) of the ratio of landed to estimated catch per trip. Trips where the estimated catch=0 have been assigned a ratio=0.

Annual totals from this data set compared with the annual QMR/MHR totals in Table 1 are presented in Table 2 and Figure 3. Total landings from the bottom part of the CELR form or CLR form are very close to the QMR/MHR totals after applying the procedure to drop spurious non-LIN 1 landing described in Appendix C, with the exception of 1999–00 which was not affected by the available correction procedures (Table C.2). The sum of the estimated catches from the analysis dataset ranges between 56 and 101% of the sum of the "Analysis" catches (Table 2; Figure 3). A comparison scatter plot of the estimated and landed catch by trip shows that most trips underestimate the landing total for the trip and that the majority of the trips are below the 1:1 line (Figure 4; [left panel]). The distribution of the ratios of the landed to estimated catch shows that there is a strong mode of the ratios grouped near one, but with a long tail to the right (Figure 4; [right panel]).

For the LIN 1 dataset across all years, 40% of all trips which landed ling estimated no catch of ling but reported LIN in the landings (Table 3). 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 and LTCER forms in 2007–08). These landings only represented 3% of the total LIN 1 landings over the period, for a total of 254 tonnes (Table 3). The introduction of the new inshore trawling and lining forms (TCER and LTCER), which record fishing activity at the level of a fishing event (tow or line set) and report more species, have dropped the proportion of trips which estimated nil ling to below 40% while landing this species and has reduced the proportion of LIN landings by weight in this category. These now account for less than 1% of the LIN 1 landings after the introduction of the new forms (Table 3).

Catch totals in the fishery characterisation tables have been scaled to the adjusted QMR/MHR totals reported in column 5, 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 annual ratio:

$$\tilde{L}'_{i,y} = \tilde{L}_{i,y} \frac{\tilde{\mathbf{QMR}}_y}{\tilde{A}L_y} \qquad \text{Eq. 1}$$

where $\tilde{\mathbf{QMR}}_y$, $\tilde{L}_{i,y}$ and $\tilde{A}L_y$ are landings adjusted for changes in the conversion factors as defined in Table 1 and Table 2.

Table 3: Summary statistics pertaining to the reporting of estimated catch from the LIN 1 analysis dataset. All calculations made on the landings data set resulting from the procedure described in Appendix A.

	Trips with landed catch but which report no estimated catch			Dataset statistics (excluding 0s) for the ratio of landed/estimated catch by trip			
Fishing year	**Trips: % relative to total trips**	**Landings: % relative to total landings**	**Landings (t)**	**5% quantile**	**Median**	**Mean**	**95% quantile**
89/90	53	11	13	0.62	1.30	2.36	3.72
90/91	44	6	12	0.64	1.34	1.83	3.96
91/92	46	5	12	0.60	1.20	1.50	3.10
92/93	44	7	17	0.53	1.37	1.70	4.13
93/94	46	5	12	0.48	1.33	1.72	3.37
94/95	47	5	13	0.50	1.37	2.14	3.60
95/96	39	6	14	0.50	1.20	1.53	2.99
96/97	37	5	14	0.53	1.27	1.75	3.60
97/98	39	4	12	0.58	1.23	1.98	4.00
98/99	42	6	11	0.57	1.23	1.63	3.94
99/00	49	5	15	0.56	1.11	1.65	3.80
00/01	40	4	11	0.55	1.20	1.57	3.60
01/02	39	3	8	0.57	1.20	1.57	3.44
02/03	46	4	11	0.58	1.21	1.51	3.33
03/04	39	4	9	0.56	1.20	1.59	3.80
04/05	43	3	8	0.58	1.33	1.79	4.32
05/06	41	2	7	0.53	1.28	1.73	3.97
06/07	40	2	6	0.50	1.30	1.73	4.12
07/08	35	2	6	0.53	1.18	1.89	4.15
08/09	36	2	6	0.50	1.25	1.91	4.00
09/10	32	1	5	0.58	1.26	1.76	3.86
10/11	34	1	6	0.64	1.30	1.78	4.20
11/12	34	1	5	0.59	1.23	1.89	4.50
12/13	33	1	5	0.63	1.20	1.71	4.25
13/14	37	1	4	0.63	1.16	1.74	4.15
14/15	35	1	4	0.64	1.22	1.67	4.00
15/16	41	1	5	0.60	1.22	1.63	3.13
Total	40	3	254	0.57	1.24	1.73	3.80

3.1.2 PREPARATION OF DATA FOR CPUE ANALYSIS

Data used for CPUE analysis were prepared using the “daily 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 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 just 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 catch for that day of fishing;
- create a list of "most relevant" target species by summing the landings in the LIN 1 characterisation data set across all years to identify the main target fisheries which capture ling using BLL. Nine species from the list accounted for over 99% of the ling landings (Table 4). The remaining 26 species were dropped from the analysis. This was done by removing the entire trip which reported one of the 26 target species shaded blue in Table 4. Early use of this procedure found that simply dropping the offending daily record and leaving the remaining partial trip in the data set led to bias in the analysis because a daily record is "rolled up" and will contain effort not necessarily directed at the specified species.
- distribute landings proportionately to each day of the trip based on the ling estimated catch or to the daily effort for trips with no estimated ling catch.

Note that the above procedure was also applied to the daily effort (CELR) forms to ensure that each of these trips was also reduced to "daily strata" if fishers reported more than one statistical area or target species in a day of fishing. The expansion from estimated to landed catches was done by QMA, with the loss of 27 t (0.7%) from the data set. A further 148 t of landings were dropped through out-of-range grooming (Starr 2007).

Table 4: Table of ranked target species fisheries which take LIN 1 BLL, summed over the period 1989–90 to 2015–16 and showing the total LIN 1 BLL landings in the characterisation data set attributed to each target species. Species coloured in blue were dropped from the BLL CPUE data set as described in the text.

Rank	Target species	Common Name	Total LIN 1 landings (t)	Cumulative %
1	LIN	Ling	3315.10	81.53
2	BNS	Bluenose	360.79	90.41
3	RIB	Ribaldo	198.76	95.29
4	HPB	Hapuku & Bass	140.80	98.76
5	SPO	Rig	22.20	99.30
6	SNA	Snapper	14.78	99.67
7	SKI	Gemfish	3.94	99.76
8	SCH	School Shark	3.93	99.86
9	TAR	Tarakihi	3.82	99.95
10	HOK	Hoki	0.37	99.96
11	GUR	Gurnard	0.35	99.97
12	BWS	Blue Shark	0.26	99.98
13	RSN	Red Snapper	0.26	99.98
14	TRE	Trevally	0.15	99.99
15	OFH	Oilfish	0.10	99.99
16	SWA	Silver Warehou	0.09	99.99
17	KIN	Kingfish	0.09	100.00
18	KAH	Kahawai	0.08	100.00
19	BYX	Alfonsino & Long-finned Beryx	0.04	100.00
20	SKJ	Skipjack Tuna	0.03	100.00
21	TRU	Trumpeter	0.01	100.00
22	BCO	Blue Cod	0.01	100.00
23	BRC	Northern Bastard Cod	0.01	100.00
24	SCA	Scallop	0.01	100.00
25	ALB	Albacore Tuna	0.00	100.00
26	RRC	Red Scorpion Fish	0.00	100.00
27	FLY	Flying Fish	0.00	100.00
28	BIG	Bigeye Tuna	0.00	100.00
29	FRO	Frostfish	0.00	100.00
30	SWO	Broadbill Swordfish	0.00	100.00
31	RAT	Rattails	0.00	100.00
32	RBM	Rays Bream	0.00	100.00
33	SPE	Sea Perch	0.00	100.00
34	BSH	Seal Shark	0.00	100.00
35	KTA	King Tarakihi	0.00	100.00

3.2 DESCRIPTION OF LIN 1 LANDING INFORMATION

Landing data for ling were provided for all trips which landed LIN 1 at least once, with one record for every reported LIN landing (this will include LIN QMAs from all other LIN Fishstocks) from the trip. The LIN 1 data request stipulated that every landing record associated with each trip be provided because previous extracts have shown large amounts of statistical area misreporting for ling, with operators reporting the FMA rather than the actual statistical area fished (see Appendix C). This is a problem for ling because a large amount of the ling catch is taken by autolongliners operating on the Chatham Rise and the Sub-Antarctic. In the past, these vessels reported on the CELR forms which had no requirement to report the position of the fishing event. If the operators reported 4, 5 or 6 (for LIN 4, LIN 5 or LIN 6) in the statistical area field, the CPUE data extracts will identify these trips as being valid for LIN 1, even though they were not fishing in LIN 1. Appendix C describes the procedure followed to identify spurious landings in the LIN 1 data set. A total of 1128 t of landings (314 t from LIN 1) were dropped from the data set on the basis of this procedure.

Each landing record contained a reported greenweight (in kilograms), a code indicating the processed state of the landing, along with other auxiliary information such as the conversion factor used, the number of containers involved and the average weight of the containers. Every landing record also contained a "destination code" (Table 5), which indicated the category under which the landing occurred. The majority of the landings were made using destination code "L" (landed to a Licensed Fish Receiver; Table 5). However, other codes (e.g., A, O and C; Table 5) also potentially describe valid landings which were included in this analysis. A number of other codes (notably R, Q and T; Table 5) were not included because these landings were likely to be reported at a later date under the 'L' destination category. Table 5 indicates that a large amount of LIN 1 landings (about 1400 t) use destination code 'R' (retained on board). However, excluding these landings from further analysis appears to be the correct decision because including the 'R' landings would further inflate the landings above those reported to the QMR (Figure C.1).

Table 5: Destination codes in the unedited landing data received for the LIN 1 analysis. The "how used" column indicates which destination codes were included in the characterisation and CPUE analyses.

Destination code	Number events	Green weight (t)	Description	How used
L	27 195	8 530.6	Landed in NZ (to LFR)	keep
C	19	3.4	Disposed to Crown	keep
E	47	0.6	Eaten	keep
F	50	0.5	Section 111 Recreational Catch	keep
A	23	0.2	Accidental loss	keep
U	11	0.2	Bait used on board	keep
S	1	0.1	Seized by Crown	keep
W	3	0.0	Sold at wharf	keep
J	2	0.0	Returned to sea [Section 72(5)(2)]	keep
R	111	1 441.5	Retained on board	drop
T	3	3.1	Transferred to another vessel	drop
Q	92	1.7	Holding receptacle on land	drop
[NULL]	13	0.7	Missing	drop
B	5	0.0	Bait stored for later use	drop
D	2	0.0	Discarded (non-ITQ)	drop

A range of state codes (GRE, HGU, DRE, HGT) are used to report LIN 1 landings (Table 6). State codes GRE, HGU, DRE, and HGT have been reported for ling using variable conversion factors over the data period, resulting small changes to the greenweight landed over the 27 year period of reported data (Table 7). Greenweight landings $\left(G_{i,s,y}^{'}\right)$ were adjusted in the CPUE analysis and for some parts of the characterisation analysis for state codes HGU, DRE, HGT to consistent conversion factors using the following equation:

$$G'_{i,s,y} = G_{i,s,y} \, cf_{i,s,endyr} / cf_{i,s,y} \qquad \text{Eq. 2}$$

where

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

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

$cf_{i,s,endyr}$ is the conversion factor for record *i* using landed state code *s* in *endyr* (last year in data)

Table 6: Total greenweight reported and number of events by state code in the unedited landing file used to process the LIN 1 characterisation data, arranged in descending order of landed weight.

State code	Number Events	Total reported greenweight (t)	Description
GRE	20 463	4 743.5	Green (or whole)
HGU	5 914	2 574.4	Headed and gutted
DRE	824	975.7	Dressed
HGT	56	101.5	Headed, gutted, and tailed
USK	4	98.0	Fillets: skin-off untrimmed
GUT	57	23.4	Gutted
ROE	2	8.9	Roe
GGO	13	3.8	Gilled and gutted tail-on
Other[1]	20	6.4	Other (misc)

[1] SCT [Tailed (scampi)], UTF (Fillets: skin-on), TSK (untrimmed Fillets: skin-off), FIL (trimmed Fillets: skin-on)

Table 7: Median conversion factor for the four most important state codes reported in Table 6 (in terms of total landed greenweight) and the total reported greenweight by fishing year in the edited file used to process the LIN 1 landing data.

	Landed State Code					Landed State Code				
	GRE	HGU	DRE	HGT	OTH	GRE	HGU	DRE	HGT	OTH
	Median conversion factor					Landed weight (t)				
89/90	1	1.5	–	1.7	1.1	18.2	33.4	–	58.7	2.0
90/91	1	1.5	1.8	1.7	–	37.0	87.5	78.1	0.1	–
91/92	1	1.5	1.8	–	1.25	48.7	132.3	68.1	–	0.0
92/93	1	1.5	1.8	–	1.25	69.1	135.2	46.7	–	0.0
93/94	1	1.45	1.8	–	1.15	51.2	146.7	50.9	–	0.0
94/95	1	1.45	1.8	–	0.575	62.1	160.4	28.1	–	3.6
95/96	1	1.45	1.8	1.55	1.15	84.8	137.5	21.2	0.3	0.4
96/97	1	1.45	1.8	–	1.15	175.0	102.1	23.3	–	0.7
97/98	1	1.45	1.85	–	1.15	169.5	97.9	21.4	1.2	4.2
98/99	1	1.45	1.85	–	1.15	138.6	40.7	31.4	–	0.0
99/00	1	1.45	1.85	–	–	195.7	115.8	61.9	0.0	–
00/01	1	1.45	1.85	–	1.15	138.6	74.9	82.9	0.0	0.0
01/02	1	1.45	1.85	1.55	1.15	172.9	69.8	53.1	4.5	5.2
02/03	1	1.45	1.8	–	1.15	133.5	84.7	26.0	1.6	0.6
03/04	1	1.45	1.8	–	1.15	95.1	100.3	52.8	0.4	0.0
04/05	1	1.45	1.8	1.55	1.15	100.7	123.9	43.8	0.0	0.0
05/06	1	1.45	1.8	–	1.15	173.8	160.8	21.4	0.5	0.0
06/07	1	1.45	1.8	1.6	1.15	152.8	121.5	20.5	7.1	0.0
07/08	1	1.45	1.8	1.625	1.15	228.5	137.1	16.0	1.4	0.1
08/09	1	1.45	1.8	–	1.15	256.6	42.5	21.0	–	0.1
09/10	1	1.45	1.8	–	1.15	299.8	62.5	19.7	–	0.0
10/11	1	1.45	1.8	–	1.15	303.9	106.7	25.9	–	0.4
11/12	1	1.45	1.8	–	–	287.6	88.8	21.8	–	0.0
12/13	1	1.45	1.8	–	–	283.6	58.5	31.1	–	–
13/14	1	1.45	1.8	–	1.15	339.1	21.5	20.4	–	–
14/15	1	1.45	1.8	–	1.15	319.9	15.3	16.7	–	8.2
15/16	1	1.45	1.8	1.65	1.15	372.4	7.9	31.2	0.6	8.7
Total	–	–	–	–	–	4 708.8	2 466.3	935.4	76.5	34.3

Landings in the final data set are primarily from LIN 1 but there are significant landings from LIN 2, LIN 4 and LIN 6 (Table 8). This is because the data request included all ling landings from every trip that fished in LIN 1 and it appears that many of the trips are wide ranging, even after implementing the procedure described in Appendix C.

Table 8: Distribution of total landings (t) by ling Fishstock and by fishing year for the set of trips that recorded LIN 1 landings. Landing records with improbable greenweights have been dropped, including trip 973634.

Fishing year	LIN 1	LIN 2	LIN 3	LIN 4	LIN 5	LIN 6	LIN 7	Total
89/90	110	35	3.7	25	5.9	0.1	45	223
90/91	200	43	14	308	11	5	12	593
91/92	245	57	25	44	23	24	13	431
92/93	247	46	63	114	161	107	59	796
93/94	249	71	52	250	27	161	50	858
94/95	254	82	97	557	16	353	101	1 461
95/96	244	90	197	618	10	95	31	1 284
96/97	301	168	254	643	137	531	66	2 100
97/98	294	262	65	170	28	2.0	25	846
98/99	210	198	11	13	0.6	–	19	451
99/00	372	80	62	6.6	22	123	32	697
00/01	294	26	38	44	25	50	38	515
01/02	304	60	18	16	17	17	11	443
02/03	247	63	26	7.1	0.1	0.1	39	382
03/04	249	41	10	10	0.9	4.5	31	345
04/05	269	20	17	10	1.1	–	9	326
05/06	357	40	1.9	15	0.2	–	13	426
06/07	302	46	0.5	0.0	–	–	42	390
07/08	383	50	–	0.4	–	–	2.4	436
08/09	320	48	3.3	–	22	0	74	466
09/10	382	37	0.1	0.6	0.2	–	8.2	429
10/11	437	34	0.4	0.7	–	–	32	504
11/12	398	45	2.9	5.3	24	1.3	22	498
12/13	373	48	–	0.3	–	–	51	472
13/14	381	36	0.6	0.4	–	–	24	442
14/15	360	34	1.1	–	0	–	11	407
15/16	421	22	2.3	0	–	–	11	456
Total	8 200	1 780	965	2 858	528	1 474	869	16 676

About 70% of the LIN 1 landings were reported on CELR forms until the form change in 2007–08, with the remainder on CLR forms (Catch Landing Returns; Table 9). The CLR forms are used by larger vessels using the TCEPR and LCER forms to report their effort and, after 2007–08, by smaller trawl and longline (between 6 and 28 m) vessels using the new event-based forms. Only a negligible amount of landings of LIN 1 are reported on the NCELR form (Table 9). After 2007–08, there was a clear increase in the use of the fishing event based forms (TCER and LTCER), with the percentage of the LIN 1 catch reported on CELR forms dropping to less than 2% of the annual total in recent years (Table 9).

Table 9: Distribution by form type for landed catch by weight for each fishing year in LIN 1. Also provided are the number of days fishing and the associated distribution of days fishing by form type for the effort data using statistical areas consistent with LIN 1. CELR: Catch, Effort, Landing Return; CLR: Catch Landing Return; NCELR: Netting Catch Effort Landing Return, TCEPR: Trawl Catch Effort Processing Return; TCER: Trawl Catch Effort Return; LTCER: Lining Trip Catch Effort Return. Forms other than CELR and NCELR have their related landings reported on CLR forms.

Fishing	Landings[1]		Days Fishing (%)[2]				Days Fishing[3]				
Year	CELR	CLR	CELR	TCEPR	TCER	LTCER	CELR	TCEPR	TCER	LTCER	Total
89/90	35	65	79	21	–	–	1 742	453	–	–	2 195
90/91	48	52	76	24	–	–	2 202	699	–	–	2 901
91/92	68	32	85	15	–	–	2 719	484	–	–	3 203
92/93	78	22	85	15	–	–	3 026	529	–	–	3 555
93/94	77	23	81	19	–	–	2 846	649	–	–	3 495
94/95	79	21	72	28	–	–	2 391	952	–	–	3 343
95/96	61	39	41	59	–	–	1 361	1 925	–	–	3 286
96/97	41	59	42	58	–	–	1 728	2 374	–	–	4 102
97/98	42	58	38	62	–	–	1 734	2 780	–	–	4 514
98/99	35	65	38	62	–	–	1 516	2 430	–	–	3 946
99/00	45	55	44	56	–	–	2 028	2 533	–	–	4 561
00/01	37	64	39	61	–	–	1 705	2 614	–	–	4 319
01/02	31	69	43	57	–	–	1 630	2 126	–	–	3 756
02/03	43	57	44	56	–	–	1 660	2 113	–	–	3 773
03/04	45	55	40	60	–	–	1 538	2 332	–	–	3 870
04/05	68	32	40	60	–	–	1 599	2 395	–	–	3 994
05/06	62	38	45	55	–	–	1 746	2 174	–	–	3 920
06/07	70	30	47	52	–	–	1 687	1 868	–	–	3 577
07/08	6.9	93	7.2	38	24	29	268	1 422	908	1 084	3 715
08/09	1.5	99	6	39	26	28	224	1 433	947	1 024	3 690
09/10	1.1	99	6	37	26	31	219	1 410	1 006	1 179	3 829
10/11	0.5	99	7	36	20	38	259	1 422	777	1 501	3 974
11/12	0.3	100	2	43	20	34	87	1 487	705	1 178	3 488
12/13	0.3	100	3.8	42	22	30	124	1 375	720	958	3 246
13/14	0.9	99	4.7	35	25	31	158	1 195	848	1 055	3 377
14/15	0.2	99	2.8	30	27	36	98	1 049	953	1 260	3 518
15/16	0.1	100	2.9	39	26	30	96	1 279	868	978	3 303
Total	32	68	37	44	8	10	36 391	43 502	7 732	10 217	98 450

[1] Percentages of landed greenweight (about 100 kg of total landings using the NCELR form have been omitted)
[2] Percentages of number of days fishing
[3] 521 days for NCELR (Netting Catch Effort Lining Return) and 87 days for LCER (Lining Catch Effort Return) are omitted from the table

3.3 DESCRIPTION OF THE LIN 1 FISHERY

Distributions by statistical area, major fishing method and target species in this section are provided by summarised statistical areas, methods and target species in Table 10.

Table 10: Definitions of statistical area regions (see Appendix B for the locations of the indicated statistical areas), major method codes and target species codes used in the distribution tables and plots in this report. Number events=number of effort records in analysis dataset; number records=number of records in analysis dataset after rolling up to trip/statistical area/method/target species.

Code used in report	Statistical area region definition	Number events	Number records
001	001	2 361	1 042
002	002	15 646	6 464
003	003	13 188	4 652
004	004	5 748	1 994
HG	005, 006, 007	8 675	2 876
008	008	27 656	6 398
009	009	43 657	13 979
010	010	31 420	10 489
041–045	041, 042, 043, 044, 045	21 459	6 443
046	046	9 731	3 631
047–048	047, 048	19 272	6 159
101–107	101, 102, 103, 104, 105, 106, 107	1 708	542

Region code	Statistical area definition for Regions	Number events	Number records
EN	001, 002, 003, 004, 105, 106	37 918	14 446
HG	005, 006, 007	8 675	2 876
BoP	008, 009, 010, 107	102 989	30 979
WCNI	041, 042, 043, 044, 045, 046, 047, 048, 101, 102, 103, 104	50 939	16 368

Method designation	Methods included	Number events	Number records
BLL	Bottom longline	31 599	13 285
BT	Bottom trawl	158 838	46 853
OTH	All other methods: reporting >1 t of LIN 1 total landings in ranked descending order: trot line, setnet, bottom pair trawl, Dahn line, Danish seine, midwater trawl	10 084	4 534

Target species code[1]	Target species definition	Number events	Number records
SCI	Scampi	20 117	1 222
LIN	Gemfish	1 368	823
HOK	Ling	4 053	1 975
SKI	Hoki	8 210	2 749
TAR	Tarakihi	39 581	14 064
SNA	Snapper	34 856	10 030
TRE	Trevally	25 519	7 124
RBY	Rubyfish	583	383
BAR	Barracouta	3 548	1 504
GUR	Red gurnard	7 580	2 637
OTH	All other species: > 3 t of total LIN 1 landings in ranked descending order: look-down dory, john dory, silver dory, alfonsino, silver warehou, mirror dory, arrow squid, orange roughy, school shark	13 423	4 342

Target species code[2]	Target species definition	Number events	Number records
LIN	Ling	5 828	1 742
BNS	Bluenose	14 230	5 775
RIB	Ribaldo	1 007	318
HPB	Hapuku/bass	6 470	2 956
SPO	Rig	157	45
SNA	Snapper	2 830	1 785
OTH	All other species: > 1 t of total LIN 1 landings in ranked descending order: gemfish, school shark, tarakihi	1 077	664

[1] bottom trawl method only [2] bottom longline method only

3.3.1 DISTRIBUTION OF LANDINGS BY STATISTICAL AREA REGION

LIN 1 shares only Statistical Area 041 with LIN 7. The remaining statistical area boundaries coincide with the QMA boundaries (Appendix B). The LIN 1 fishery is taken primarily by the bottom longline and bottom trawl methods, with only minor amounts of landings using other methods (Table 11; Figure 5). The bottom longline fishery has taken 52% percent of the landings and 47% has been taken by the bottom trawl fishery over the 27 years of available catch history. The remaining methods have taken less than 2% of the total landings over the same period.

Forty five percent of the LIN 1 bottom longline landings are taken in the Bay of Plenty (Figure 6; Table 12) while two-thirds of the bottom trawl landings come from this region (Figure 7; Table 12). East Northland is the other important area for bottom longline landings, taking about one-third of the total BLL landings while the WCNI accounts for one-quarter of the overall bottom trawl landings (Figure 7; Table 12).

Table 11: Total landings (t) and distribution of landings (%) of ling from trips which landed LIN 1 by statistical area group and important fishing methods (Table 10), summed from 1989–90 to 2015–16. Landings (t) have been scaled to the adjusted QMR totals $\left(\tilde{\mathrm{Q}}\mathrm{MR}_y\right)$ using Eq. 1.

Statistical	**Fishing Method**				**Fishing Method**		
Area	**BLL**	**BT**	**Other**	**Total**	**BLL**	**BT**	**Other**
	Total landings (t)				**Distribution (%)**		
001	177	13	17	208	2.2	0.2	0.21
002	1 051	147	8. 5	1 207	12.8	1.8	0.10
003	59	53	6.0	118	0.7	0.6	0.07
004	53	56	1.0	110	0.6	0.7	0.01
HG	32	12	0.7	45	0.4	0.2	0.01
008	116	1 127	2. 4	1 245	1.4	13.7	0.03
009	837	1 161	18	2 016	10.2	14.1	0.22
010	946	422	39	1 406	11.5	5.1	0.47
041–045	663	250	5. 3	919	8.1	3.1	0.06
046	164	350	5. 9	520	2.0	4.3	0.07
047–048	112	267	7. 3	387	1.4	3.3	0.09
101–107	14	12	. 05	25	0.2	0.1	0.001
Region							
EN	1 352	280	33	1 665	16.5	3.4	0.4
HG	32	12	0.7	45	0.4	0.2	0.0
BoP	1 899	2 710	59	4 669	23.1	33.0	0.7
WCNI	939	869	18	1 827	11.4	10.6	0.2
Total	4 223	3 871	111	8 206	51.5	47.2	1.4

Table 12: Percent distribution of landings by region (Table 10) from 1989–90 to 2011–12 for the bottom trawl and bottom longline methods for trips which landed LIN 1. Annual landings by method are available in Table 13 and the rows sum to 100% for each capture method. '–': no data.

Fishing				Region				Region
Year	EN	HG	BoP	WCNI	EN	HG	BoP	WCNI
			Bottom trawl (%)				Bottom longline (%)	
89/90	6	0.23	92	1	2	0.06	98	–
90/91	5	1.36	92	2	7	–	93	–
91/92	3	0.43	84	13	2	0.10	98	0.02
92/93	4	0.20	90	5	35	0.04	65	0.5
93/94	4	0.21	82	13	16	0.17	84	0.1
94/95	6	0.33	64	30	23	0.09	75	1.5
95/96	13	0.36	59	28	37	0.02	50	13
96/97	7	0.33	55	38	48	0.02	40	12
97/98	7	0.31	62	31	59	0.05	34	7.4
98/99	4	0.27	71	25	44	0.10	39	17
99/00	16	2.21	41	40	42	32	25	1.3
00/01	3	0.08	67	29	49	0.05	48	2.3
01/02	5	0.02	79	16	61	0.07	36	3.0
02/03	4	0.09	71	25	66	0.09	32	2.0
03/04	3	0.06	87	10	49	2.1	40	8.9
04/05	2	0.11	88	10	43	0.01	51	6.5
05/06	14	0.17	62	23	40	0.01	50	10
06/07	16	0.29	61	23	36	0.01	47	17
07/08	7	0.10	49	44	17	0.02	53	30
08/09	9	0.10	50	41	22	0.01	24	54
09/10	16	0.09	66	17	19	0.00	41	39
10/11	5	0.22	76	20	27	0.02	29	44
11/12	3	0.07	59	38	36	0.01	35	28
12/13	4	0.10	78	18	40	0.01	28	31
13/14	12	0.09	71	17	18	0.01	33	48
14/15	6	0.10	81	13	34	0.00	35	31
15/16	7	0.06	88	5	30	0.07	36	35
Total	7	0.17	68	25	32	0.76	45	22

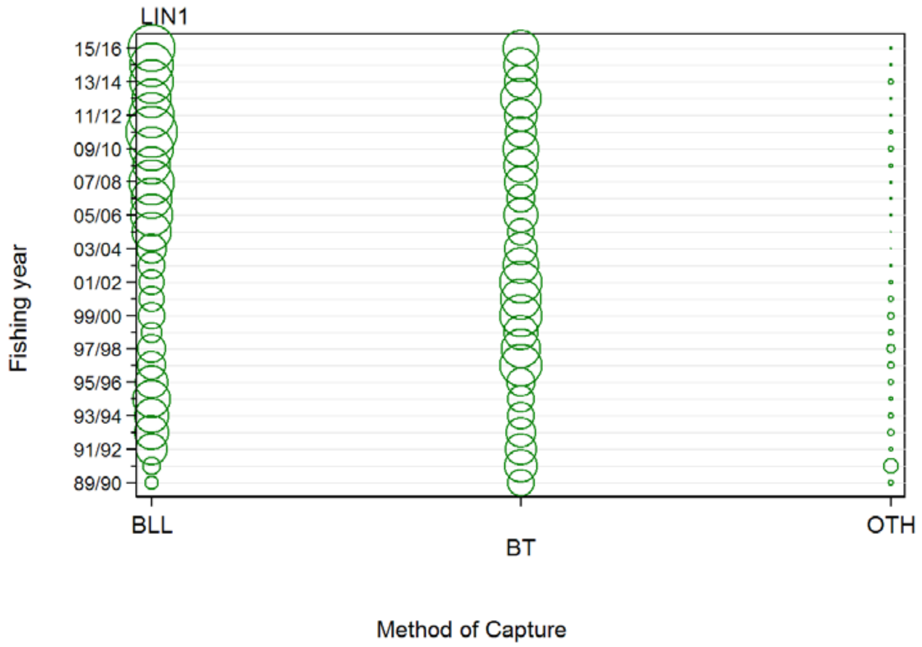

Figure 5: Distribution of catches for the major fishing methods by fishing year from trips which landed LIN 1. Circles are proportional to the catch totals by method and fishing year, with the largest circle representing: 318 t in 10/11 for BLL.

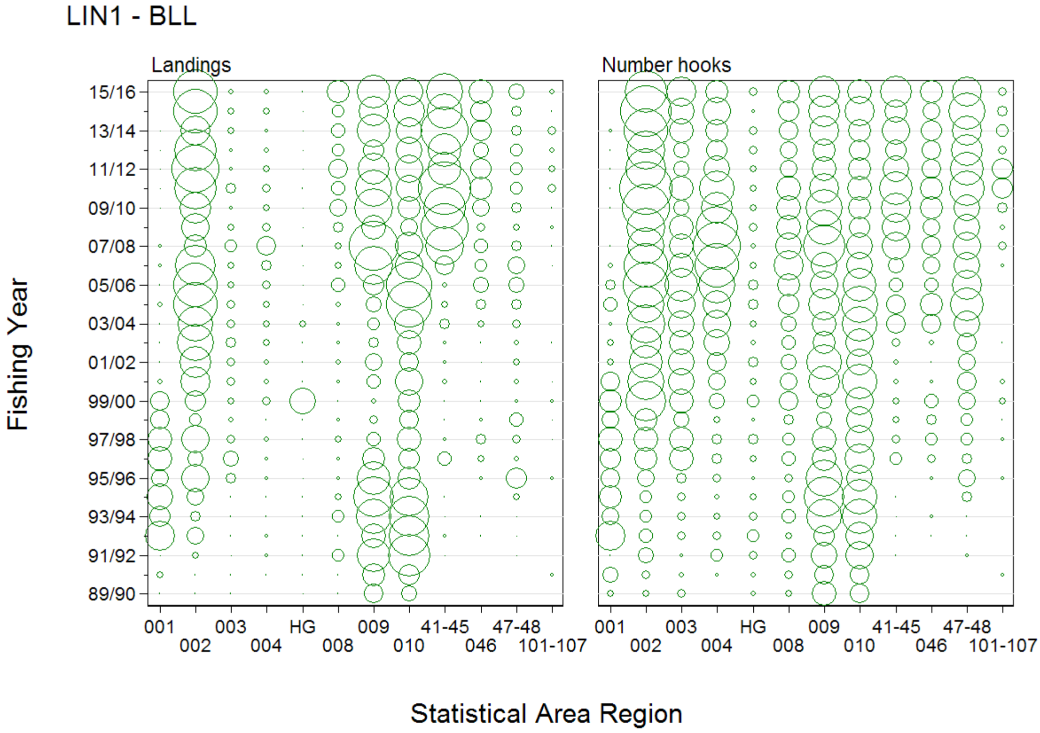

Figure 6: Distribution of landings and number of hooks/sets for the bottom longline method by Statistical Area Region (see Table 10 for definition) and fishing year from trips landing to LIN 1. Circles are proportional within each panel: [landings] largest circle= 113 t in 10/11 for Region 041–045; [number hooks] largest circle= 9.23×10^5 hooks in 10/11 for Area 002.

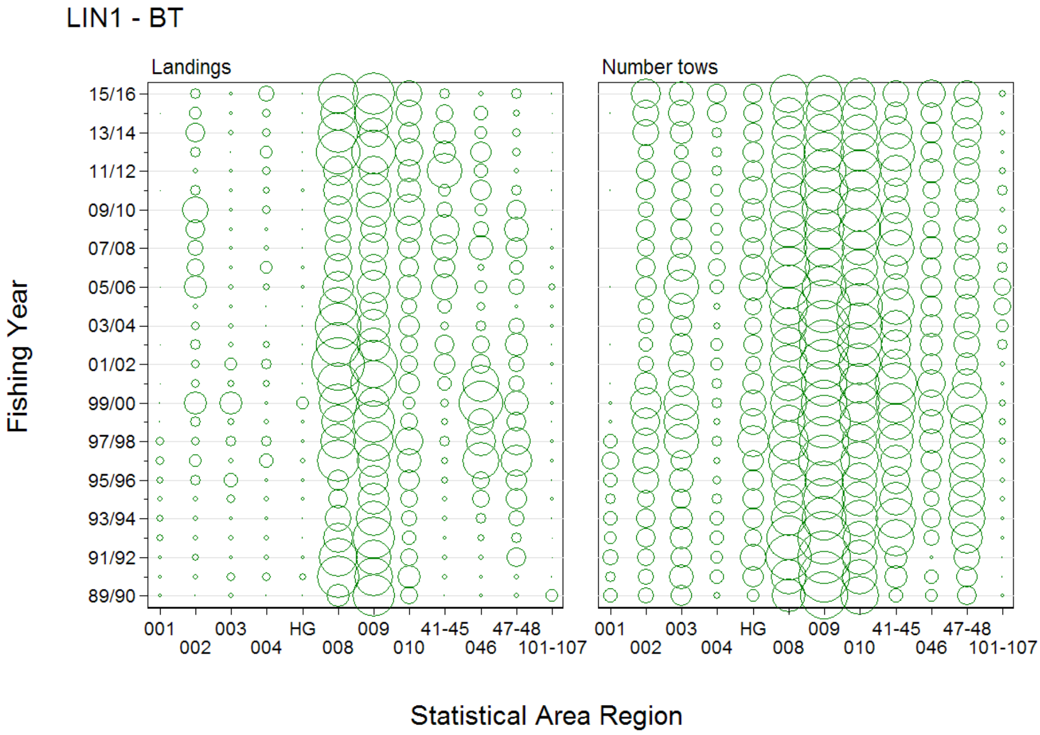

Figure 7: Distribution of landings and number of tows for the bottom trawl method by Statistical Area Region (see Table 10 for definition) and fishing year from trips landing to LIN 1. Circles are proportional within each panel: [landings] largest circle= 92 t in 01/02 for Area 008; [number tows] largest circle=2116 tows in 92/93 for Area 009.

Bottom longline landings of LIN 1 have a wide sporadic distribution, with the Bay of Plenty landings coming primarily from Statistical Areas 009 and 010 (Figure 6). Bottom longline landings increased since about 2000 in East Northland Statistical Area 002, then fell off in 2007–08 but have since increased to levels similar to those observed in the mid-2000s (Figure 6). The distribution of bottom longline effort by year shows much effort in Areas 003 and 004 and on the west coast North Island, areas which take relatively less LIN 1 (Figure 6). It is likely that this is effort directed at other species, such as snapper. The distribution of bottom trawl effort is broader than the distribution of the catch, with effort taking some LIN 1 in East Northland and on the west coast in most years (Figure 7). It is difficult to know if there are any trends in the effort or landings, due to the small amount of landings and the diverse fisheries which take this species. While the landings of LIN 1 in the Bay of Plenty trawl fishery dropped in the late 2000s and early 2010s, they have since recovered to levels seen in the early 2000s. BLL landings of ling have been strong since 2011–12 in 002, 008, 009 and the WCNI while BT landings of ling have been strong in 008, 009 and 010 in the same time period (Figure 6 and Figure 7).

3.3.2 FINE SCALE DISTRIBUTION OF LANDINGS

3.3.2.1 Bottom longline

Comprehensive fine scale landing and effort data are available for the LIN 1 bottom longline fleet from 1 Oct 2007, after the introduction of the new LTCER forms. A plot (Figure 8) of bottom longline landings of ling, gridded into 0.1°×0.1° cells and summed over nine years from 2007–08 to 2015–16, shows that ling are taken with line gear all along the west coast of the North Island (WCNI). Bottom longline landings of ling continue around to North Cape and Three Kings Islands, but are not visible in Figure 8 because of the MPI restriction not allowing the presentation of information attributable to fewer than three vessels. Bottom longline landings of ling continue down the coast of East Northland and into the Bay of Plenty where there are heavy concentrations of line fishing for ling. Ling are taken by bottom long line gear throughout LIN 1, but the full extent of the spatial distribution is not always apparent because of the “3 vessel rule”. This rule prevents Figure 8 from showing the small amounts of ling taken the outer Hauraki Gulf, particularly in Area 005 and some in Area 006. This observation invalidates the assumption made by Starr & Kendrick (2016b) that was used to exclude “spurious” LIN 1 trips for the 2013 analysis. This rule also prevented the presentation of sequential spatial maps for the BLL fishery to show how the fishery has evolved spatially over time because the resulting plots are too sparse to be informative.

3.3.2.2 Bottom trawl

Fine scale landing and effort data have been available for LIN 1 from the inshore bottom trawl fleet since 1 Oct 1989, based on vessels which used the deepwater TCEPR forms. The amount of fine scale positional data available from the FMA 1 and FMA 9 trawl fleet increased dramatically in the mid-1990s when some of the North Island fishing companies elected to use the TCEPR forms for their inshore fishing fleet (this was a voluntary option available to all inshore vessels). Plots summarising landings gridded into 0.1°×0.1° cells, summed over three-year periods to show the progression of the LIN 1 landings in the FMA1 and FMA9 trawl fisheries, are presented in Figure 9 (1989–90 to 2003–04) and Figure 10 (2004–05 to 2015–16). While the first quadrant plot (1989–90 to 1993–94) is sparsely populated because relatively few vessels used the TCEPR forms in those years, the remaining quadrant plots are well populated after the majority of the inshore bottom trawl fleet switched to reporting with the TCEPR forms. The next three quadrant plots (1994–95 to 1997–98, 1998–99 to 2000–01, 2001–02 to 2003–04) all show considerable amounts of ling bycatch in the WCNI target gemfish fishery in Areas 046 and 047 (off 90-mile beach). The western sections of the Bay of Plenty (Areas 008 and 009) also show high levels of ling by-catch, which originated from a number of trawl fisheries, including a target gemfish fishery, a target scampi fishery and a mixed trawl fishery targeted at hoki, ling and tarakihi. The by-catch of ling in the Bay of Plenty trawl fisheries has been continuous over the 27 years of data, while the by-catch of ling in the East Northland trawl fisheries has waned since the early 2000s (see Figure 10).

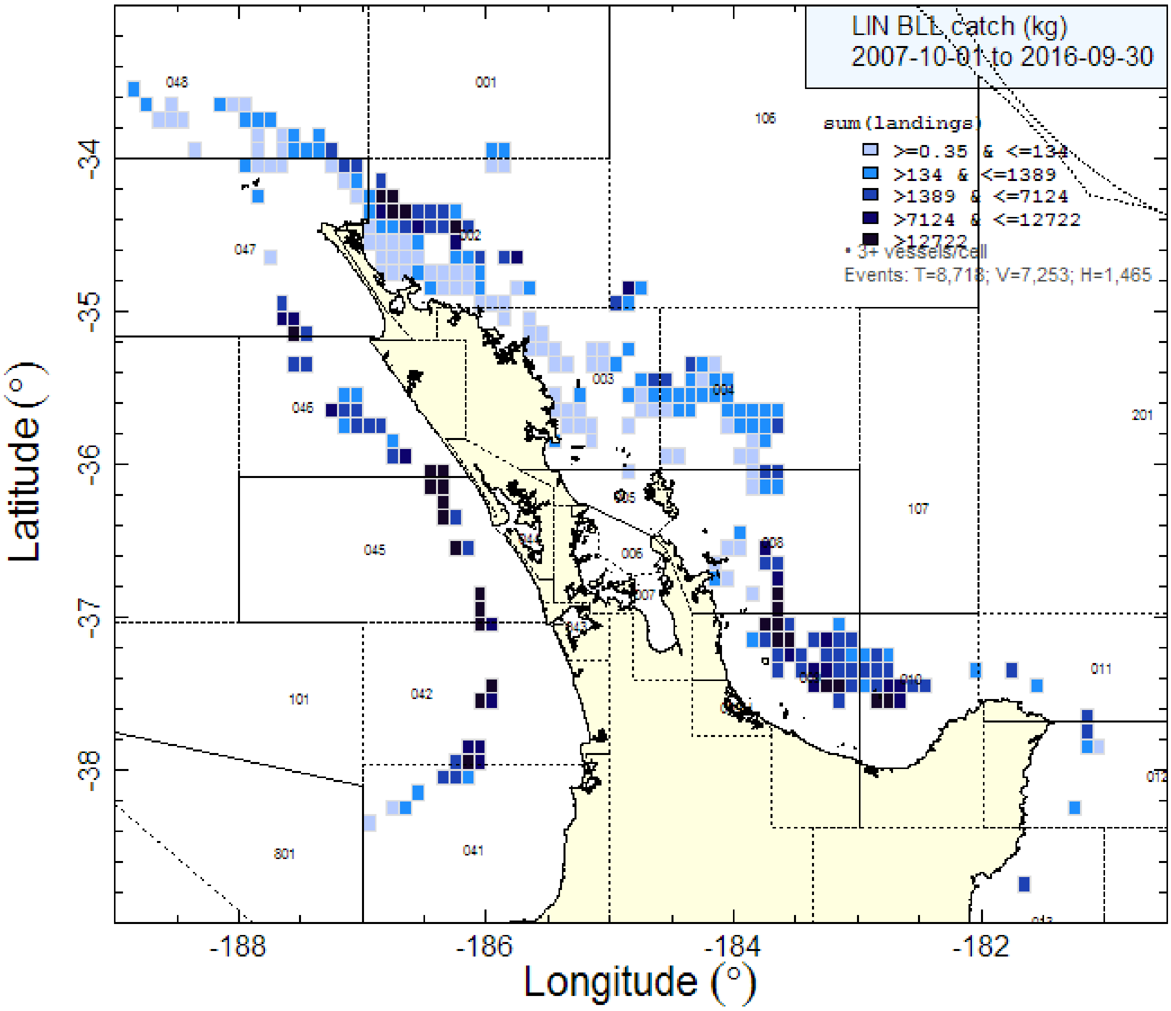

Figure 8: Spatial distribution of ling bottom longline landings (kg) in LIN 1, arranged in 0.1° × 0.1° grids, summed from 2007–08 to 2015–16. Legend colours divide the distribution of total landings into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Note that this requirement has dropped 1465 of 8718 (17%) events. Boundaries are shown for the general statistical areas plotted in Appendix B.

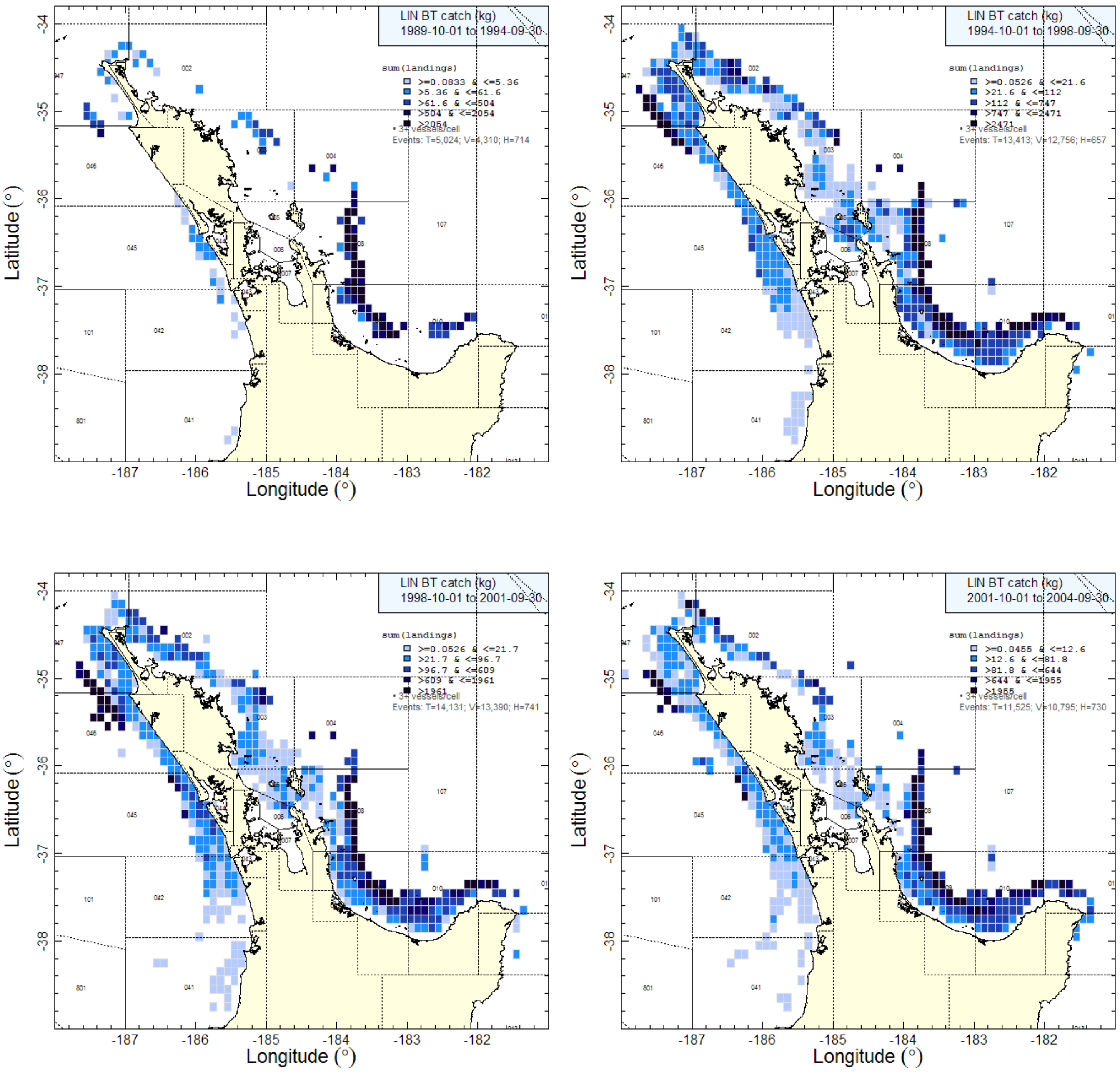

Figure 9: **Spatial distribution of ling bottom trawl landings (kg) in LIN 1, arranged in 0.1° × 0.1° grids, summed in three or four year blocks from 1989–90 to 2003–04. Legend colours divide the distribution of total landings in each plot into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B.**

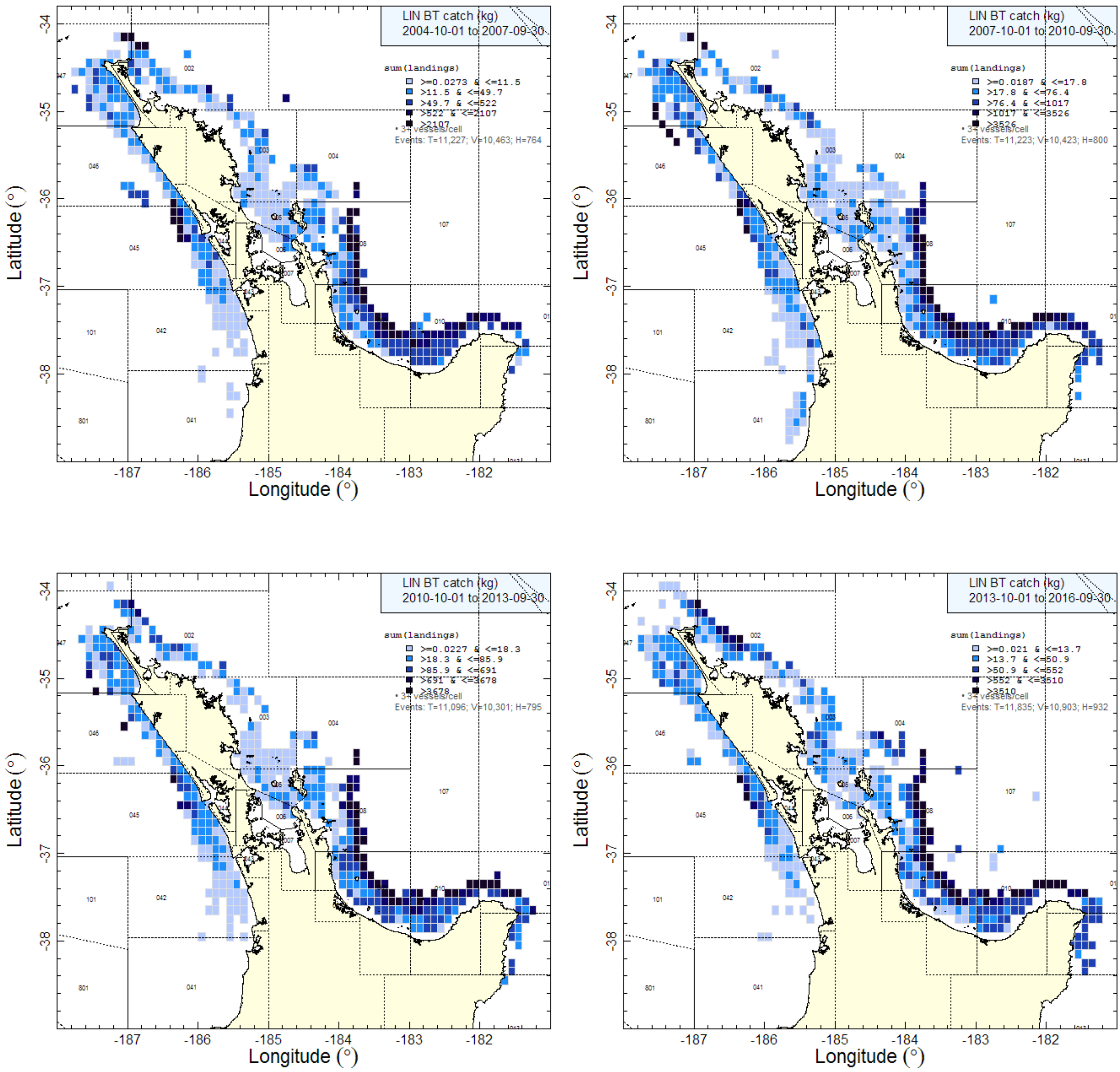

Figure 10: Spatial distribution of ling bottom trawl landings (kg) in LIN 1, arranged in 0.1° × 0.1° grids, summed in three year blocks from 2004–05 to 2015–16. Legend colours divide the distribution of total landings in each plot into 25%, 50%, 75%, 90% and 95% quantiles. Only grids which have at least three reporting vessels are plotted. Boundaries are shown for the general statistical areas plotted in Appendix B.

3.3.3 SEASONAL DISTRIBUTION OF LANDINGS

The bottom longline landings of LIN 1 are taken mainly in the final two months of the fishing year while the bottom trawl landings of LIN 1 have been more evenly distributed across the year (Figure 11; Table 13). BLL landings became more seasonally widespread for a short period from 2007–08 to 2010–11, but have since reverted to the previous pattern; there is a suggestion that bottom trawl landings in August and September are slightly elevated compared to the months immediately before (Figure 11; Table 13). Both fisheries show relatively sporadic seasonal patterns when viewed by Region, reflecting the small amount of landings in most years and the by-catch nature of many of the fisheries. Bottom longline landings of ling are concentrated in the last two months of the fishing year in both East Northland and the Bay of Plenty while the west coast North Island longline fishery is more spread out in the fishing year (Figure 12). The seasonal pattern of the bottom trawl fishery by region shows that the Bay of Plenty fishery extends relatively evenly through the fishing year while the other regions are more sporadic in their seasonal timing (Figure 13). This broader seasonal pattern in the west coast fishery probably reflects the large commitment required to fish in this area.

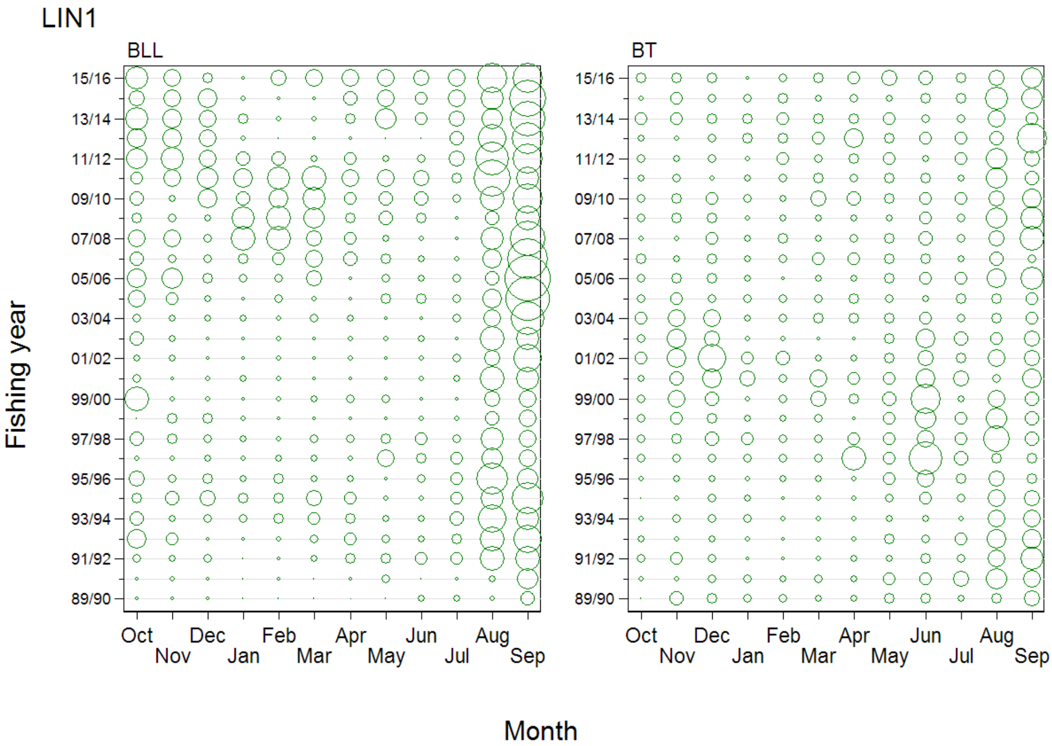

Figure 11: Total landings by month and fishing year for bottom longline and bottom trawl based on trips which landed LIN 1. Circle sizes are proportional across panels with the largest circle= 119 t for bottom longline in September 05/06.

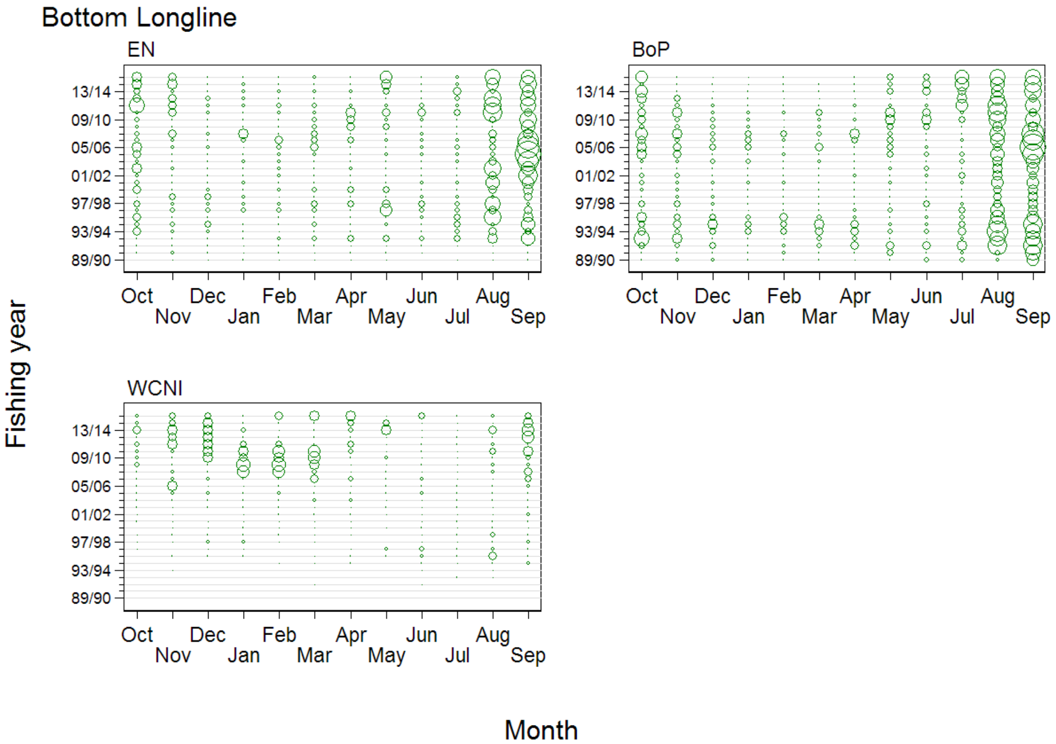

Figure 12: **Distribution of landings for the bottom longline method by grouped statistical area (see Table 10 for definition) for month and fishing year from trips which landed LIN 1. Circle sizes are proportional across panels: maximum value: 67 t for EN 04/05 in September. HG plot not shown because of negligible BLL landings.**

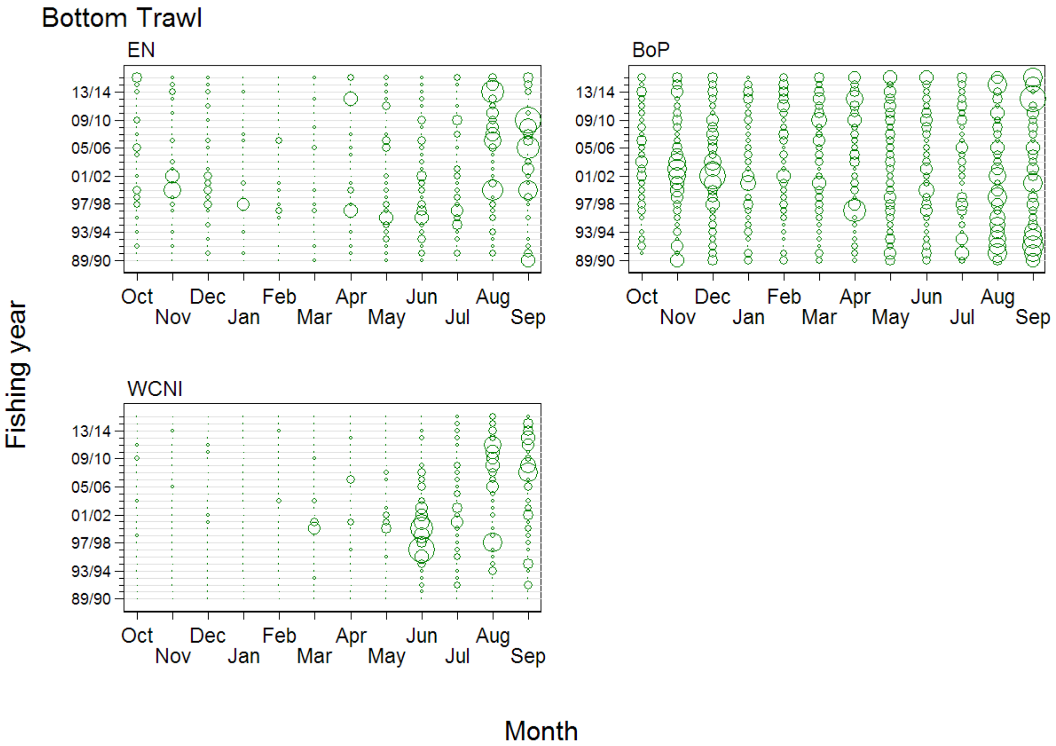

Figure 13: **Distribution of landings for the bottom trawl method by grouped statistical area (see Table 10 for definition) for month and fishing year from trips which landed LIN 1. Circle sizes are proportional within each panel: maximum values: [EN]: 17 t in 09/10 for Sep; [BoP]: 58 t in 01/02 for Dec; [WCNI]: 72 t in 96/97 for Jun. HG plot not shown because of negligible BT landings.**

Table 13: Percent distribution of landings by month and total annual landings (t) of LIN 1 from 1989–90 to 2011–12 for the bottom trawl and bottom longline methods for trips which landed LIN 1. Landings (t) have been scaled to the adjusted QMR totals $\left(\tilde{\text{Q}}\text{MR}_y\right)$ using Eq. 1.

Fishing												Month	
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total (t)
Bottom Longline (%)													
89/90	2.2	4.6	3.5	1.4	1.3	1.2	0.1	1.7	10.1	12.5	7.2	54.4	23.5
90/91	1.5	4.0	1.2	0.6	2.3	0.9	2.1	11.4	0.5	2.4	7.8	65.3	40.0
91/92	4.4	2.5	3.9	0.3	0.9	1.9	5.3	5.8	7.1	7.6	30.9	29.5	121.7
92/93	15.7	6.9	0.4	0.6	0.8	3.4	5.9	3.3	1.6	4.5	25.2	31.7	140.3
93/94	8.7	2.1	3.0	3.0	4.3	6.0	5.0	2.0	2.2	7.4	34.3	22.0	143.3
94/95	4.0	7.0	9.2	3.5	3.5	8.2	5.5	1.3	0.9	4.7	18.2	34.0	169.9
95/96	11.3	3.5	4.5	2.4	4.6	2.7	1.7	0.7	3.8	5.7	41.2	18.0	137.7
96/97	1.3	2.2	2.8	2.0	2.8	3.3	1.3	19.5	7.8	9.0	27.7	20.3	95.1
97/98	10.3	5.3	4.0	3.5	1.8	5.0	3.6	7.0	8.1	4.0	31.3	16.0	103.6
98/99	0.4	12.0	11.6	3.5	1.8	1.4	1.5	2.2	3.0	3.5	25.3	33.8	51.4
99/00	41.5	1.3	1.6	1.0	2.3	3.8	4.9	4.9	0.9	0.6	15.9	21.3	89.8
00/01	5.6	1.3	2.0	2.9	2.0	1.0	1.1	1.2	1.7	2.8	41.8	36.5	84.0
01/02	4.1	3.7	1.2	1.2	2.3	0.9	1.8	0.6	1.8	6.1	19.8	56.5	78.6
02/03	12.1	2.5	1.0	1.1	1.3	1.0	1.4	1.9	2.7	0.8	39.6	34.7	89.2
03/04	3.4	2.5	3.2	2.9	1.9	4.4	2.8	0.5	0.5	4.0	17.1	57.0	111.1
04/05	9.1	4.2	1.6	0.5	2.7	0.7	0.6	3.0	3.0	2.4	12.5	59.7	189.3
05/06	9.9	11.6	2.6	1.7	1.8	6.3	0.4	2.4	1.5	2.0	5.3	54.6	217.4
06/07	5.7	2.6	2.7	3.7	4.4	8.9	6.3	3.8	1.5	1.0	11.6	47.9	200.3
07/08	7.0	7.3	1.6	15.2	13.7	5.5	4.0	1.4	0.8	0.4	13.5	29.6	244.8
08/09	4.3	2.8	1.7	17.7	19.5	13.7	4.1	5.9	3.2	0.5	7.1	19.5	176.9
09/10	5.2	1.4	10.5	5.3	9.2	13.8	3.4	5.0	5.7	2.0	15.1	23.3	227.1
10/11	3.0	6.0	7.7	7.5	10.1	11.3	5.8	6.3	4.7	2.2	25.8	9.7	317.6
11/12	11.0	11.6	7.6	4.5	4.5	1.0	3.8	1.3	1.7	5.9	27.2	19.9	254.0
12/13	11.2	12.2	10.6	1.0	0.2	0.3	0.3	0.2	0.1	6.7	26.3	31.0	183.7
13/14	12.2	9.5	7.3	3.0	0.8	0.6	2.8	10.8	3.7	6.4	11.9	31.1	237.3
14/15	6.3	8.6	9.3	0.6	0.3	0.4	4.7	7.8	3.9	8.5	13.7	35.8	229.1
15/16	11.0	6.6	2.6	0.2	6.1	6.9	7.4	6.7	5.6	7.1	19.6	20.3	266.3
Mean	8.4	6.0	4.9	4.0	4.9	5.1	3.7	4.4	3.1	4.2	20.3	31.0	4 222.9[1]
Bottom Trawl(%)													
89/90	0.1	18.0	8.6	5.8	6.1	3.8	3.3	10.8	8.4	3.7	11.1	20.3	93.2
90/91	1.2	1.9	4.9	4.1	3.2	4.9	3.3	8.9	9.2	13.8	24.7	20.0	136.6
91/92	5.4	10.4	4.7	0.6	0.7	1.5	2.9	3.1	7.4	4.9	20.7	37.7	117.2
92/93	3.9	1.5	4.3	1.6	1.4	2.9	2.8	8.5	6.2	12.9	26.7	27.4	105.7
93/94	2.8	8.0	6.6	7.8	2.4	2.6	2.2	4.0	4.4	2.9	27.2	29.1	89.1
94/95	0.3	3.1	7.1	4.3	1.0	3.2	2.6	5.8	14.0	6.9	28.7	23.0	88.6
95/96	2.9	4.1	3.9	2.1	3.6	3.5	2.7	13.0	26.1	7.8	22.1	8.2	99.0
96/97	2.9	3.0	2.5	2.6	3.0	3.0	21.8	5.2	41.1	6.7	4.3	3.9	211.5
97/98	3.9	4.4	9.3	6.0	3.3	3.7	6.1	6.4	13.4	7.0	28.2	8.5	188.2
98/99	4.3	8.4	6.5	3.3	3.2	4.0	1.0	7.8	22.5	7.5	22.0	9.6	151.4
99/00	2.5	10.5	7.2	0.8	2.4	10.4	4.1	8.3	33.5	1.7	11.5	7.0	216.4
00/01	1.9	7.2	13.8	10.3	3.5	11.2	5.2	5.6	14.8	8.8	3.4	14.3	207.2
01/02	4.8	12.8	27.2	5.2	6.9	1.9	2.3	4.4	10.1	3.6	12.2	8.6	222.3
02/03	3.8	20.8	13.2	1.6	1.8	0.8	0.9	5.0	18.0	11.2	8.4	14.5	155.5
03/04	8.8	19.6	19.1	2.4	4.2	6.6	6.2	6.3	8.3	4.5	6.3	7.8	137.4
04/05	5.7	13.8	6.9	6.8	6.3	7.8	10.0	7.8	4.9	10.3	8.3	11.4	93.4
05/06	4.1	6.5	7.0	2.4	1.0	3.2	3.1	6.6	7.6	9.6	21.8	26.9	145.8
06/07	9.4	3.9	8.9	3.3	6.8	11.8	11.2	9.4	8.0	4.8	15.2	7.2	100.1
07/08	1.6	1.3	9.0	2.4	6.5	3.5	4.7	7.3	11.4	3.9	13.9	34.4	135.5
08/09	5.4	5.5	6.6	1.3	3.2	2.9	3.5	3.1	8.6	4.3	24.9	30.7	140.6
09/10	4.0	5.2	7.2	4.8	2.1	12.6	10.7	5.9	8.4	6.8	14.0	18.2	154.6
10/11	3.9	4.9	2.2	2.7	6.0	8.8	6.2	8.7	8.3	3.4	32.5	12.5	117.7
11/12	4.1	2.7	5.0	1.7	9.0	5.5	6.5	10.9	3.5	9.2	25.8	16.1	128.9
12/13	2.3	1.3	3.8	4.0	5.1	7.1	14.7	4.9	5.6	5.4	8.0	37.9	198.1
13/14	7.9	10.1	6.7	7.0	8.1	6.7	7.0	9.7	3.8	5.4	17.9	9.5	138.9
14/15	2.0	7.5	4.5	4.9	7.1	2.9	5.2	2.7	5.4	6.0	28.0	23.8	143.6
15/16	6.2	5.8	5.8	0.6	3.9	5.5	8.2	12.1	11.0	6.6	12.0	22.5	154.7
Mean	3.9	7.5	8.4	3.8	4.1	5.4	6.3	6.9	13.1	6.6	16.7	17.5	3 871.4[1]

[1] Total for all fishing years for method

3.3.4 DISTRIBUTION OF LANDINGS BY TARGET SPECIES

About one-half of the LIN 1 landings are taken by target fishing for ling, mainly in the longline fishery (Table 14). The most important bottom trawl fishery taking ling is the scampi fishery, but it still only accounts for about one-third of the bottom trawl catch of LIN 1 (Table 14; Figure 14). Other important bottom trawl fisheries which take LIN 1 include (in descending order of importance) the target ling, gemfish, hoki and tarakihi fisheries (Figure 14). The other longline fisheries which take significant amounts of LIN 1 include the target bluenose, ribaldo, and hapuku/bass fisheries. There has been some variation in the importance of some of these fisheries over the 27 years of data, with an apparent decline in recent years of the by-catch of LIN 1 in the target scampi and gemfish bottom trawl fisheries, reflecting quota cuts in both of these fisheries (Table 15, Figure 14). On the other hand, there has been an increase in recent years in the bottom longline landings of ling in the target ling and hoki fisheries, probably contributing to the recent rise in overall LIN 1 landings (Figure 14).

Target bottom longline fishing for ling predominates in all three regions: the Bay of Plenty, East Northland and WCNI, with all fisheries showing an increase in recent fishing years (Figure 15).

Target fishing patterns in the bottom trawl fishery by region show a decline in LIN 1 landings in the Bay of Plenty scampi trawl fishery in recent years as well as the disappearance of ling by-catch in the gemfish Bay of Plenty trawl fishery (coinciding with the reduction in SKI 1 TACC; Figure 16). The by-catch of ling by the west coast North Island gemfish trawl fishery ceased around 2002–03, again coinciding with the reduction in SKI 1 TACC, but this fishery has been replaced with a trawl fishery targeting ling. In recent years, bottom trawl target fishing for hoki and ling has accounted for most of the ling catch in the Bay of Plenty and East Northland, along with a small but consistent level of ling bycatch resulting from the target tarakihi BT fishery (Figure 16).

Table 14: Landings (t) and distribution of landings (%) of ling from trips which landed LIN 1 by target species and important fishing methods (Table 10), summed from 1989–90 to 2015–16. Landings (t) have been scaled to the adjusted QMR totals $\left(\tilde{\text{Q}}\text{MR}_y\right)$ using Eq. 1. '–': no landings.

Target Species	Fishing Method: BLL	BT	Other	Total	Fishing Method: BLL	BT	Other	Total
	Total landings (t)				Distribution (%)			
LIN	3 449	862	32	4 343	42.0	10.5	0.4	52.9
SCI	–	1 134	–	1 134	–	13.8	–	13.8
HOK	0.4	716	5.2	722	0.00	8.7	0.1	8.8
SKI	4.1	647	11	662	0.05	7.9	0.1	8.1
BNS	377	.8 330	10	388	4.6	0.01	0.1	4.7
TAR	3.9	298	15	316	0.05	3.6	0.2	3.9
RIB	202	0.04		202	2.5	0.0004	0.0	2.5
HPB	144	0.4	27	171	1.8	0.01	0.3	2.1
SNA	15	56	3.2	74	0.2	0.7	0.04	0.9
TRE	0.1	33	3.3	37	0.00	0.4	0.04	0.4
RBY	–	33	0.4	34	–	0.4	0.00	0.4
OTH	27	91	4.5	123	0.3	1.1	0.1	1.5
Total	4 223	3 871	111	8 206	51.5	47.2	1.4	100.0

Table 15A: Percent distribution of landings by target species (Table 10) from 1989–90 to 2015–16 for bottom longline which landed LIN 1. The final column shows the percent landing for BLL in each fishing year. Annual landings by method are available in Table 13. '–': no data.

Fishing	Declared Target Species							
year	LIN	BNS	RIB	HPB	SPO	SNA	OTH	Total
			Bottom longline					
89/90	11.3	83.8	1.2	1.3	–	1.6	0.9	0.6
90/91	66.5	29.6	0.6	2.7	–	0.5	0.0	0.9
91/92	79.4	5.6	13.2	1.5	–	0.1	0.1	2.9
92/93	83.3	6.1	5.9	4.4	–	0.3	0.1	3.3
93/94	68.7	9.8	5.6	7.1	8.7	0.1	0.1	3.4
94/95	52.5	20.5	14.4	11.1	–	0.9	0.7	4.0
95/96	70.2	13.9	8.1	5.2	–	2.2	0.4	3.3
96/97	73.5	16.8	0.3	5.5	–	2.9	1.0	2.3
97/98	70.8	17.9	1.1	7.3	–	1.9	0.9	2.5
98/99	84.3	8.5	0.3	5.6	–	1.0	0.3	1.2
99/00	71.6	11.7	3.6	12.2	–	0.6	0.3	2.1
00/01	79.2	12.1	3.7	4.7	–	0.2	0.2	2.0
01/02	78.6	8.8	8.6	3.7	–	0.1	0.1	1.9
02/03	78.1	11.0	7.5	3.2	–	0.2	0.1	2.1
03/04	86.7	8.2	3.5	1.5	0.0	0.1	0.0	2.6
04/05	84.8	6.5	7.1	1.2	–	0.2	0.2	4.5
05/06	89.9	7.4	1.0	1.4	0.0	0.1	0.2	5.1
06/07	91.1	5.7	0.4	2.6	–	0.1	0.1	4.7
07/08	92.7	5.0	0.1	2.1	–	0.1	0.0	5.8
08/09	84.8	6.5	7.1	1.2	–	0.2	0.2	4.2
09/10	89.9	7.4	1.0	1.4	0.0	0.1	0.2	5.4
10/11	91.1	5.7	0.4	2.6	–	0.1	0.1	7.5
11/12	92.7	5.0	0.1	2.1	–	0.1	0.0	6.0
12/13	87.7	4.7	3.9	3.3	–	0.2	0.1	4.4
13/14	87.5	4.6	5.1	1.8	–	0.2	0.8	5.6
14/15	87.4	7.0	2.0	2.9	–	0.3	0.4	5.4
15/16	91.8	3.2	2.3	2.2	–	0.2	0.4	6.3
Mean	81.7	8.9	4.8	3.4	0.5	0.4	0.3	100.0

Table 15B. Percent distribution of landings by target species (Table 10) from 1989–90 to 2015–16 for bottom trawl which landed LIN 1. The final column shows the percent landing for BT in each fishing year. Annual landings by method are available in Table 13.

Fishing											Declared Target Species	
year	SCI	SKI	LIN	HOK	TAR	SNA	TRE	RBY	BAR	GUR	OTH	Total
	Bottom trawl											
89/90	78.7	0.2	0.3	10.7	4.4	3.6	0.6	0.002	0.7	0.02	0.9	2.4
90/91	78.8	–	0.3	10.6	6.7	1.8	0.5	0.002	0.2	0.1	1.1	3.5
91/92	67.8	6.8	0.5	14.0	7.0	2.5	0.2	0.1	0.3	0.2	0.4	3.0
92/93	47.8	4.4	6.7	21.6	10.2	2.6	0.7	0.2	4.1	1.0	0.6	2.7
93/94	56.0	6.6	1.3	8.4	20.0	2.3	1.0	0.04	3.2	0.7	0.5	2.3
94/95	38.6	5.4	3.2	25.6	20.9	3.0	0.8	0.00	1.2	0.2	1.2	2.3
95/96	17.8	0.8	6.0	52.2	15.1	5.8	0.4	0.02	1.1	0.2	0.6	2.6
96/97	11.7	0.3	28.1	46.3	9.3	1.7	1.0	0.01	0.5	0.3	0.9	5.5
97/98	12.4	0.9	26.7	45.4	8.8	1.8	0.9	0.5	0.7	0.3	1.5	4.9
98/99	17.9	11.3	23.0	34.4	8.2	1.8	1.3	0.4	1.0	0.3	0.7	3.9
99/00	31.3	8.3	23.6	28.2	4.2	0.9	1.0	0.0	0.4	0.3	1.9	5.6
00/01	39.4	4.5	11.4	32.0	7.5	1.1	1.0	1.3	0.4	0.6	0.9	5.4
01/02	41.9	13.1	16.0	14.2	4.3	0.7	0.6	0.5	0.3	0.3	8.1	5.7
02/03	32.5	23.1	5.9	27.2	6.6	0.9	0.7	0.1	0.1	1.4	1.5	4.0
03/04	39.6	13.5	25.4	9.8	8.5	1.4	0.8	0.0	0.2	0.4	0.5	3.6
04/05	49.7	11.7	18.0	5.0	9.6	2.0	1.3	0.3	0.2	0.9	1.3	2.4
05/06	15.6	59.2	11.4	2.5	6.4	1.3	0.7	0.1	0.1	0.5	2.2	3.8
06/07	27.2	37.4	19.2	2.9	7.4	2.3	1.1	0.5	0.02	0.2	1.8	2.6
07/08	11.8	58.3	11.8	7.5	5.0	0.9	0.8	0.9	0.01	0.4	2.6	3.5
08/09	14.7	61.1	10.8	2.0	7.0	0.9	0.9	1.5	0.01	0.3	0.8	3.6
09/10	12.3	48.2	26.1	2.4	6.3	0.5	0.6	2.1	0.01	0.3	1.2	4.0
10/11	21.0	33.7	25.5	2.4	9.8	0.7	1.7	2.4	0.2	0.2	2.4	3.0
11/12	16.5	36.6	29.8	3.2	8.2	1.2	1.6	1.9	0.05	0.2	0.7	3.3
12/13	16.1	44.0	30.0	2.3	3.3	0.6	0.8	2.1	0.002	0.2	0.6	5.1
13/14	14.8	29.0	39.8	6.1	6.2	0.6	1.1	1.6	0.01	0.1	0.6	3.6
14/15	11.7	38.6	37.9	0.4	7.0	0.4	0.4	2.4	0.03	0.1	1.2	3.7
15/16	20.1	41.4	24.4	1.6	6.5	0.4	0.6	3.0	0.02	0.1	1.9	4.0
Mean	29.3	22.3	18.5	16.7	7.7	1.4	0.9	0.9	0.5	0.3	1.6	100.0

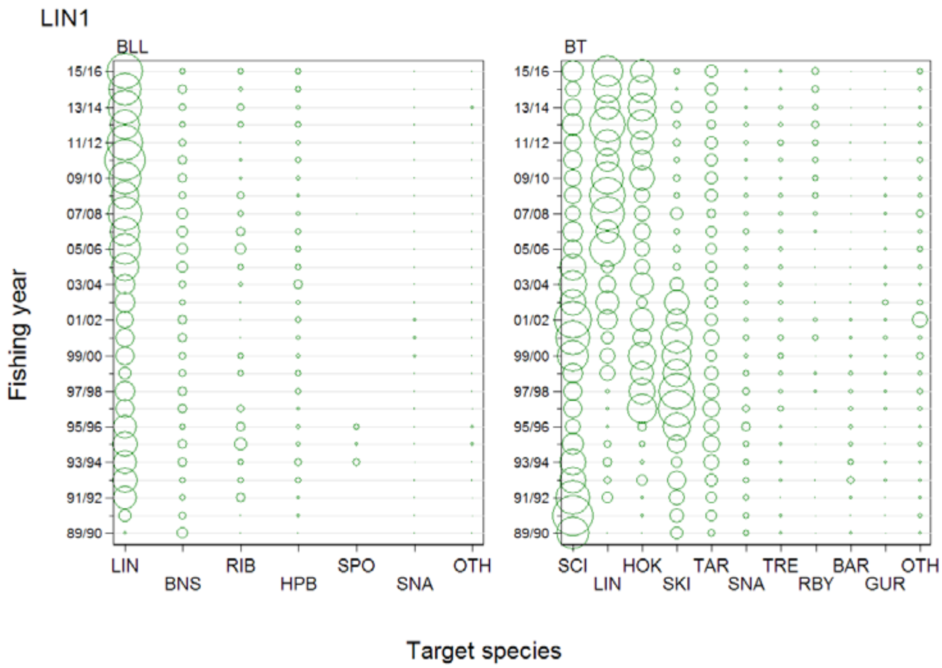

Figure 14: Total landings by target species (Table 10) and fishing year for the bottom longline and bottom trawl methods based on trips which landed LIN 1. Circle sizes are proportional within panels with the largest circle: [BLL]: 289 t for targeting LIN by bottom longline in 10/11; [BT]: 108 t for targeting scampi in 90/91.

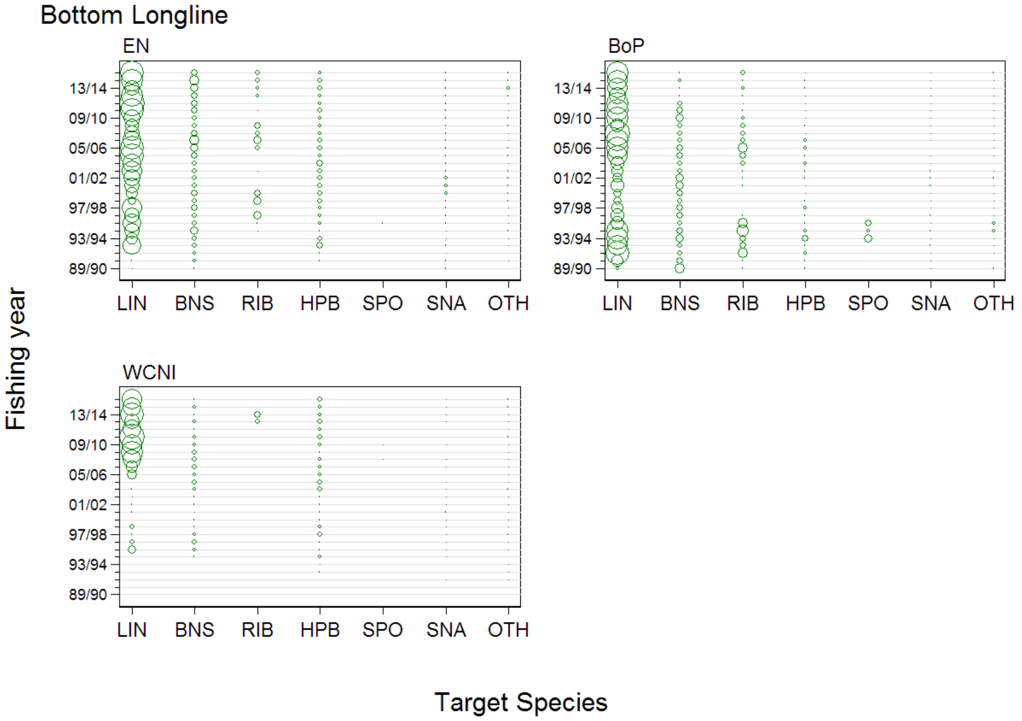

Figure 15: Distribution of landings for the bottom longline method by grouped statistical area (see Table 10 for definition) for target species and fishing year from trips which landed LIN 1. Circle sizes are proportional within panels: maximum value: [EN]: 84 t in 11/12 for LIN; [BoP]: 119 t in 07/08 for LIN; [WCNI]: 133 t in 10/11 for LIN. HG plot not shown because of negligible BLL landings.

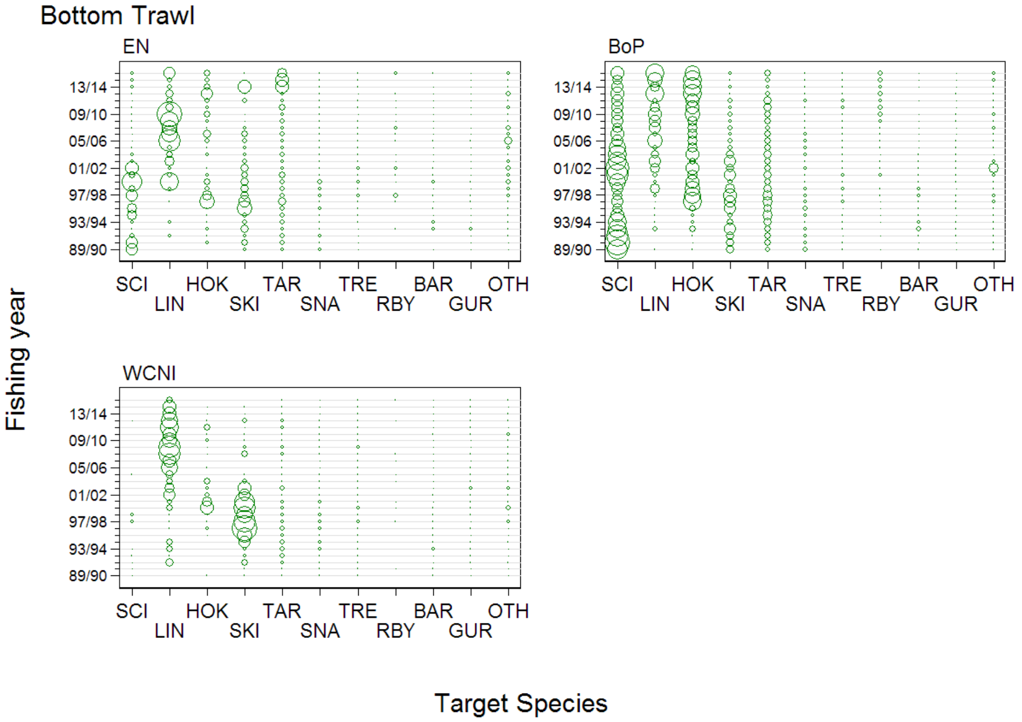

Figure 16: Distribution of landings for the bottom trawl method by grouped statistical area (see Table 10 for definitions) for target species and fishing year from trips which landed LIN 1. Circles sizes are proportional across panels: maximum value: [EN]: 22 t in 09/10 for LIN; [BoP]: 103 t in 90/91 for SCI; [WCNI]: 73 t in 96/97 for SKI. HG plot not shown because of negligible BT landings.

Table 16: Summary statistics from distributions of bottom depth from TCEPR, TCER, LCER, and LTCER forms using the bottom trawl and bottom longline methods for effort that targeted or caught ling by target species category. These statistics are derived from a set of effort data selected for LIN 1 for the period 2007–08 to 2015–16.

		Depth (m)			
Target species category	**Number observations**	**Lower 5% of distribution**	**Mean of distribution**	**Median (50%) of distribution**	**Upper 95% of distribution**
Bottom trawl					
SCI	2 512	350	395	395	435
TAR	1 947	86	186	190	300
HOK	1 170	320	404	402	470
LIN	816	235	406	420	477
SKI	267	168	316	340	398
RBY	258	165	341	350	405
SNA	65	31	108	100	195
JDO	58	57	92	90	130
GUR	45	45	86	90	120
TRE	29	36	67	67	110
SDO	23	320	412	420	450
SCH	20	148	214	199	352
Other	92	210	445	392	858
Total	7 302	104	329	378	450
Bottom longline					
LIN	3,596	320	531	550	661
BNS	2,083	320	471	466	620
HPB	736	170	311	300	500
SNA	278	24	77	75	140
RIB	213	500	637	650	675
Other	102	50	191	153	365
Total	7 008	150	470	500	660

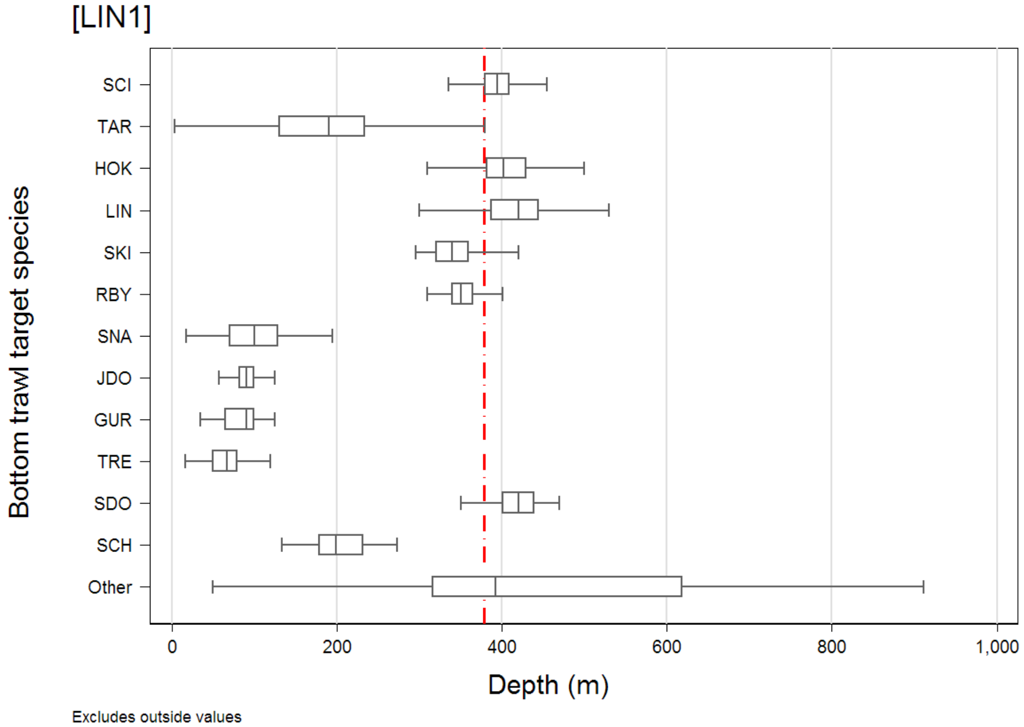

Figure 17: Box plot distributions of bottom depth from TCEPR and TCER forms using the bottom trawl method for effort that targeted or caught ling by target species category. These statistics are derived from a set of effort data for LIN 1 for the period 2007–08 to 2015–16. Vertical line indicates the median depth from all tows which caught or targeted ling.

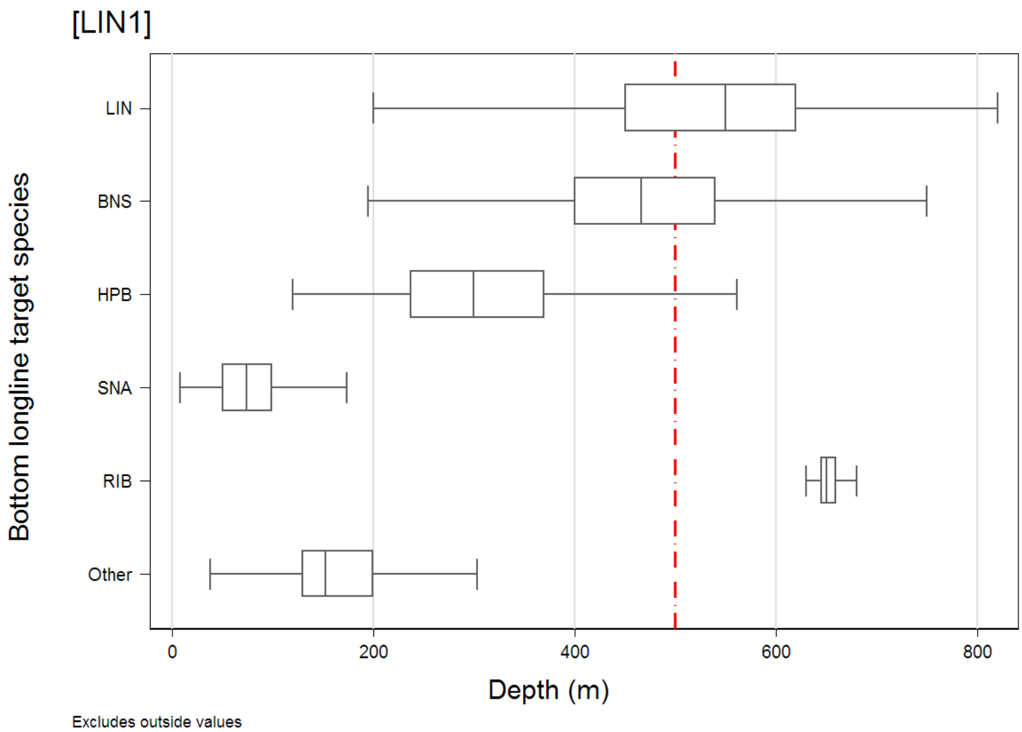

Figure 18: Box plot distributions of bottom depth from LCER and LTCER forms using the bottom longline method for effort that targeted or caught ling by target species category. These statistics are derived from a set of effort data for LIN 1 covering the period 2007–08 to 2015–16. Vertical line indicates the median depth from all tows which caught or targeted ling.

3.3.5 LIN 1 CAPTURE DEPTHS BY TARGET SPECIES

Depth information by fishing event is available from TCEPR and the new TCER forms which report bottom trawl catches pertaining to ling (either recording an estimated catch or as target species; Table 16) and from longline vessels completing the new LCER and LTCER forms. These reports show that trawl-caught ling are mainly taken between 100 and 450 m of depth, with the median value at 380 m). Bottom longline fisheries went deeper: the 5–95 percentiles are 170 to 660 m, with mean 470 m and median 500 m.

The distribution of tows which caught or targeted ling varies mainly according to the target fishery, with deeper fisheries such as scampi, gemfish, hoki, and ling target bottom trawl taking ling in deeper waters compared to the more shallow trawl fisheries such as tarakihi, John dory, trevally, gurnard and snapper (Figure 17). The ling target bottom longline fishery has a relatively deep depth distribution, deeper than the target trawl hoki, gemfish and scampi fisheries: 5–95% range is 320–660 m for target LIN bottom longline and 235–480 m for target LIN bottom trawl (Figure 18; Table 16).

4 LIN 1 STANDARDISED CPUE ANALYSIS

The geographic complexity of the ling fishery in LIN 1 is great, with diverse fisheries operating on the west coast of the North Island as well as off the upper east coast in East Northland and in the Bay of Plenty (see Figure 8, Figure 9, and Figure 10). The main difficulty is that the amount of available catch data becomes small when it is parcelled out among the fisheries, given the size of the TACC. When the total QMA catch is divided among eight to ten fisheries (Table 17 shows the amount of LIN 1 landings summed over the 27 year period for the most important LIN 1 fisheries), the quantity available for any one fishery is usually too little to perform a reliable standardised CPUE analysis. Each of the previous reviews of the LIN 1 fisheries has attempted to extract as much information as possible from these data, with little success because most of the potential fisheries have too little associated landings or effort (SeaFIC 2005, Starr et al. 2007, 2009, Starr & Kendrick 2016b).

The following quote, taken from a recent MPI Plenary Report (MPI 2016), summarises the NINSWG interpretation of the LIN 1 CPUE series:

> *In 2009, the WG concluded that the BT(SCI) index was not an appropriate index for LIN 1, and had numerous shortcomings related to limited number of vessels, particularly in the most recent 4 years and poor linkage across years. In 2013, the NINSWG agreed with these conclusions, which also applied to the alternative BT(LIN, HOK, TAR) series developed in response to a 2009 WG recommendation. Consequently the NINSWG agreed that neither BT series was adequate for monitoring LIN 1 CPUE and should be discarded. The WG requirement that CPUE index values should be determined by at least 3 vessels furthermore resulted the discarding of a large number of index values from both BT series.*
>
> *In 2009, the WG concluded that the BLL(LIN) target index appeared to have more potential as an index for LIN 1, but thought that the anomalous peak in 1998–99 was troubling and was also concerned about the relatively small amount of data in this analysis. Closer examination of the data in 2013 has shown that the anomalous 1998–99 peak was caused by a small amount of very localised fishing by two experienced vessels. The NINSWG concluded that this pattern was extremely non-representative of the fishery and the standardisation model was unable to use these data to estimate a credible year index. While this solved the mystery of the "anomalous 1998–99 index", the problem of very small amount of data in this analysis remains. The NINSWG tentatively accepted the BLL(LIN) index with the 1998–99 index value removed (ref. Fig. 16) as an index of LIN 1 abundance with a research credibility rating of "2".*

Table 17: Summary of information available for the major LIN 1 fisheries from the characterisation dataset, with all catch and efforts totals summed from 1989–90 to 2015–16. Codes for target species, region and method codes are described in Table 10 and Appendix A. Effort totals are in number of tows for BT and number of sets for BLL. Fisheries in green are used for standardised CPUE analysis. Fisheries previously examined as potential standardised CPUE analyses are indicated in grey.

	Bottom longline				Bottom trawl			
Fishery	**EN**	**BoP**	**WCNI**	**Total**	**EN**	**BoP**	**WCNI**	**Total**
Landings (t)								
BoP BT(SCI)	–	–	–	–	–	1 078	–	1 078
EN_BoP BT(LIN/HOK/TAR)	–	–	–	–	169	1 249	–	1 418
EN_BoP BLL(LIN)	1 071	1 527	–	2 598	–	–	–	–
EN_BoP BT(SKI)	–	–	–	–	42	242	–	284
EN_BoP BLL(BNS/RIB/HPB)	263	343	–	606	–	–	–	–
WCNI BT(SKI)	–	–	–	–	–	–	363	363
WCNI BLL(LIN)	–	–	820	820	–	–	–	–
WCNI BLL(BNS/RIB/HPB)	–	–	116	116	–	–	–	–
Effort (BLL=sets; BT=tows)								
BoP BT(SCI)	–	–	–	–	–	19 056	–	19 056
EN_BoP BT(LIN/HOK/TAR)	–	–	–	–	10 279	33 940	–	44 219
EN_BoP BLL(LIN)	2 112	3 498	–	5 610	–	–	–	–
EN_BoP BT(SKI)	–	–	–	–	2 596	6 458	–	9 054
EN_BoP BLL(BNS/RIB/HPB)	13 257	10 714	–	23 971	–	–	–	–
WCNI BT(SKI)	–	–	–	–	–	–	1 984	1 984
WCNI BLL(LIN)	–	–	1 677	1 677	–	–	–	–
WCNI BLL(BNS/RIB/HPB)	–	–	6 672	6 672	–	–	–	–

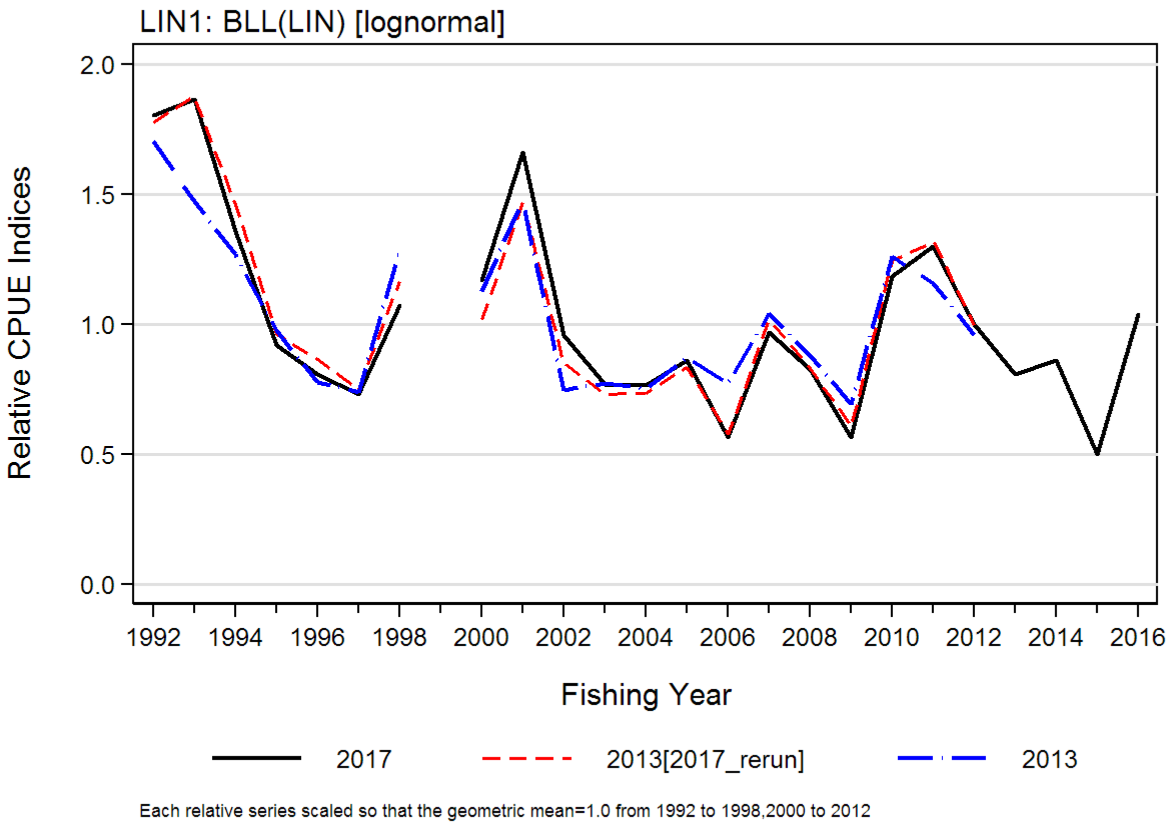

Figure 19: Comparison of three LIN 1 bottom longline standardised CPUE models: A) Weibull positive model fitted to LIN target data prepared using "daily effort" method (see Section 3.1.2); B) the same model and data stopped in 2012 for comparison with the model accepted by the NINSWG in 2013; C) Weibull positive model accepted by NINSWG in 2013 based on target ling data but prepared using "trip stratum" method (see Section 3.1.1).

This project extended by four years the standardised CPUE series selected in 2013 by the NINSWG to monitor LIN 1: bottom longline target ling fishing in the Bay of Plenty and East Northland, after dropping the 1998–99 index. The only change in the analysis methodology was to implement the "daily effort" preparation method (described in Section 3.1.2) which has become the standard in the Inshore Fishery Assessment Working Groups since the BLL(LIN) series was last done in 2013. A plot comparing the 2013 analysis, which used the "trip stratum" preparation method (described in Section 3.1.1) with new series shows acceptable compatibility between the two data preparation methods (Figure 19). Model selection procedure and model equations are presented in Appendix D, while detailed supporting diagnostics for the BLL(LIN) positive catch Weibull model are presented in Appendix E.

This standardised series shows considerable modification from the unstandardised series (Figure 20), with the standardisation procedure raising the early part of the series with addition of the `vessel` variable, changing an increasing trend into a strongly decreasing trend (see step and influence plot: Figure E.5). At the other end of the series, the `vessel` variable pushes down the series, giving an overall decreasing trend to the time series.

One advantage of moving to the "daily effort" data preparation procedure over the previous "trip stratum" procedure was to increase the number of records in the model. The 2013 model had only 971 records available to estimate 114 parameters, including 19 annual indices (after dropping the 1998–99 index). The 2017 model has 2851 records, with 2328 to the end of 2011–12: there are more daily records than there are trip-stratum records. No binomial model was required as the number of records with zero catch was very small (see lower left quadrant of Figure E.2 and Table E.1).

The 2017 MPI Plenary added a second bottom longline series [BLL(MIX2)] for monitoring LIN 1, as an alternative to the relatively small amount of data in the BLL(LIN) series and the missing years in that series (MPI 2017) (Appendix F). This analysis extended the target species definition to include BNS, RIB and HPB, but kept the same Bay of Plenty/East Northland statistical area definition. This data set contained a high proportion of zero records ([lower left panel] Figure F.2 and Table F.1), requiring the estimation of a binomial (presence/absence) series and the calculation of the combined model using the delta-lognormal method (Eq. D.4). The Inshore WGs have adopted the standard of combining positive catch and fishing success models when there is a trend in the proportion zero catch. As well, simulation work has indicated that calculating a combined index may reduce bias when reporting small catch amounts (Langley 2015). The combined model shows a flat or slightly increasing trend (Figure 21) after a fourfold decrease between 1989–90 and 1990–91 (the Plenary discarded the 1989–90 index year from this series because it was unlikely to have been caused by a corresponding drop in abundance) (MPI 2017).

The BLL(LIN) series shows an overall declining trend while the BLL(MIX2) series shows a very gradually increasing trend after the strong four-fold decline from 1990 to 1991 (Figure 22). While the Plenary accepted both series for monitoring LIN 1, it did not have a great deal of confidence in either series, assigning both a Research Ratings of “2”:

> *2 – Medium or Mixed Quality: information that has been subjected to some level of peer review against the requirements of the Standard and has been found to have some shortcomings with regard to the key principles for science information quality, but is still useful for informing management decisions. Such information should be accompanied by a description of its shortcomings.*

This designation was applied to both series because of the very strong standardisation effects from `[vessel]` in the BLL(LIN) series (Figure E.5) and from `[target_species]` in the BLL(MIX2) series (Figure F.7). The sparseness of the data in the BLL(LIN) series also contributed to this designation. This rating meant that these series could not be used to set a B_{msy} proxy (MPI 2017).

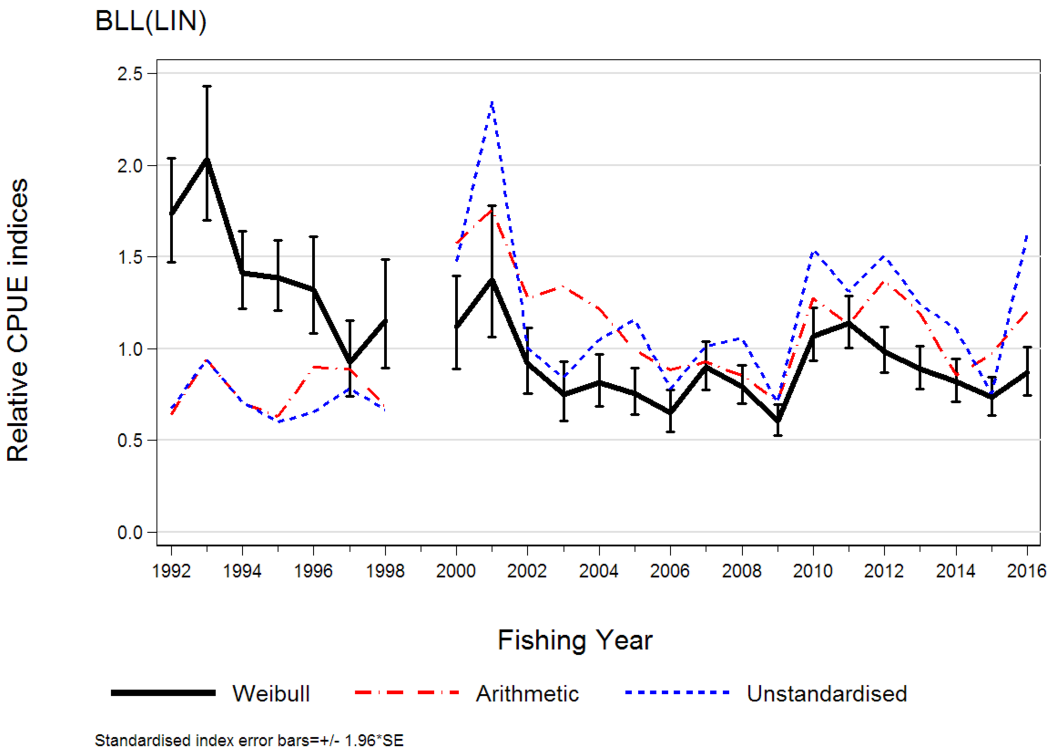

Figure 20: Relative CPUE indices for ling using the Weibull non-zero model based on the BLL(LIN) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. D.1) and b) Unstandardised (Eq. D.2).

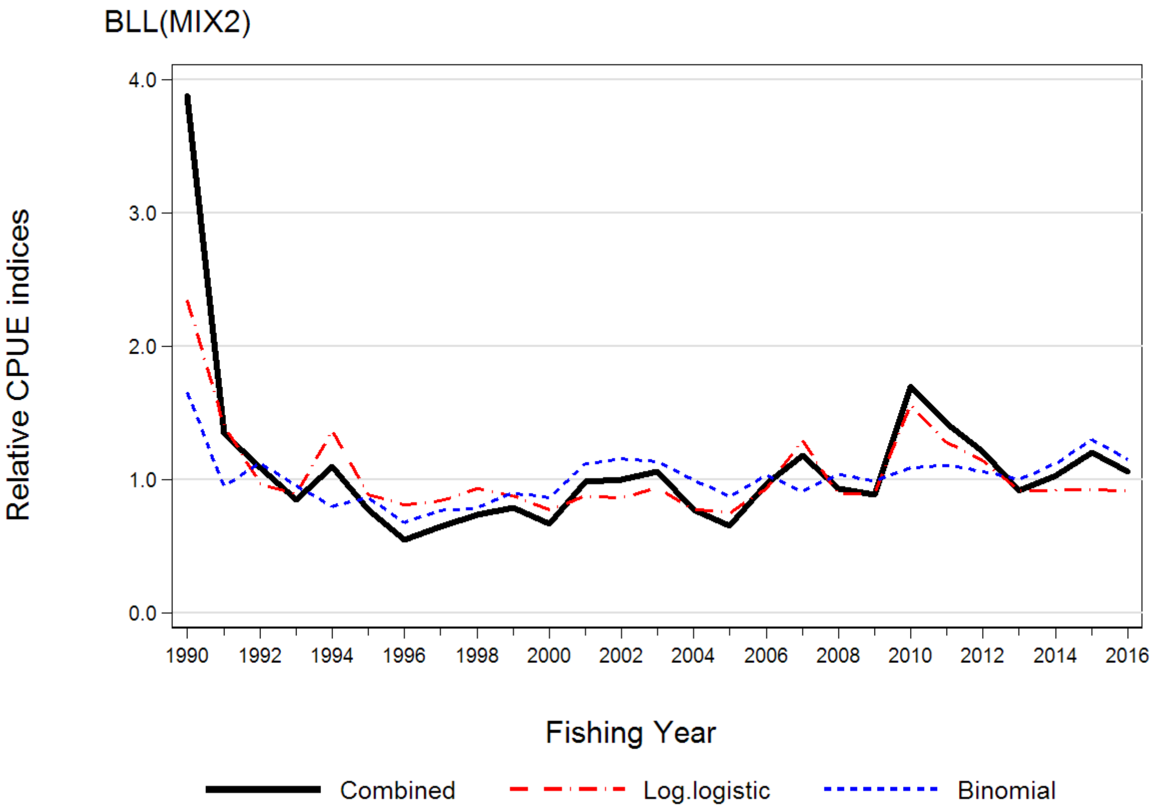

Figure 21: Relative CPUE indices for ling using the log-logistic non-zero model based on the BLL(MIX2) fishery definition, the binomial standardised model using the logistic distribution, and the combined model using the delta-lognormal procedure (Eq. D.4).

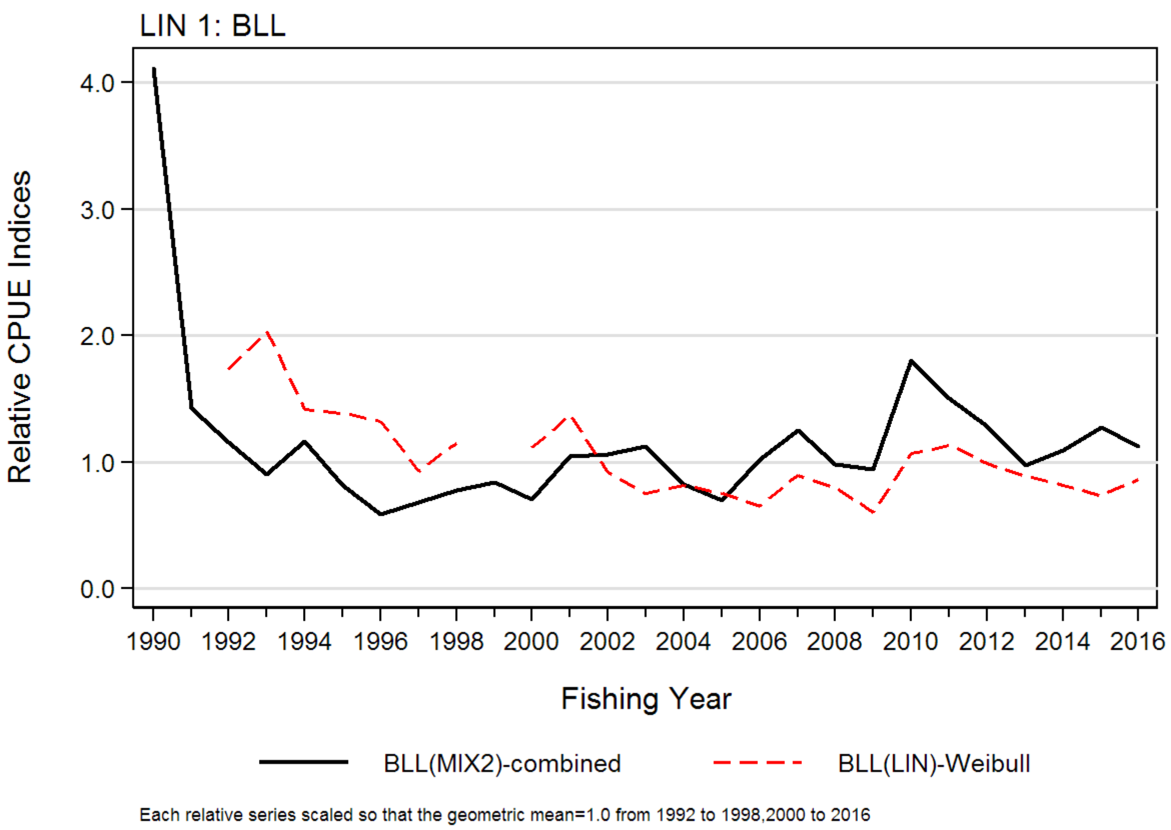

Figure 22: Comparison of the BLL(LIN) positive catch Weibull series (Appendix E) with the combined model (Eq. D.4) series generated from the BLL(MIX2) series (Appendix F).

5 ACKNOWLEDGEMENTS

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

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

Term/Abbreviation	Definition
AIC	Akaike Information Criterion: used to select between different models (lower is better)
AMP	Adaptive Management Programme
AMPWG	Adaptive Management Programme Fishery Assessment Working Group
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 (see Figure E.7 for an example) (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 5)
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 ling captured, which is then recorded as part of the "fishing event". Only the top 5 species are required for any fishing event in the CELR and TCEPR data (expanded to 8 for the TCER and LTCER form types)
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 ling
FMA	MPI Fishery Management Areas: 10 legally defined areas used by MPI to define large scale stock management units (Appendix B); QMAs consist of one or more of these regions
landing event	weight of ling off-loaded from a vessel at the end of a trip or otherwise disposed of as part of a transaction. 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
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
NINSWG	Northern Inshore Working Group: MPI Working Group overseeing the work presented in this report
QMA	Quota Management Area: legally defined unit area used for ling management (Figure 1)
QMR	Quota Management Report: monthly harvest reports submitted by commercial fishermen to MPI. Considered to be best estimates of commercial harvest. In use from 1986 to 2001.
QMS	Quota Management System: name of the management system used in New Zealand to control commercial and non-commercial catches
replog	data extract identifier issued by MPI data unit
residual implied coefficient plots	plots which mimic interaction effects between the year coefficients and a categorical variable by adding the mean of the categorical variable residuals in each fishing year to the year coefficient, creating a plot of the "year effect" for each value of the categorical variable
rollup	a term describing the average number of records per "trip-stratum"
RTWG	MPI Recreational Technical Working Group

Term/Abbreviation	Definition
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
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 of 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. MPI generates a unique database code to identify each trip, using the trip start and end dates and the vessel code (Ministry of Fisheries 2010)
trip-stratum	summarisation within a trip by fishing method used, the statistical area of occupancy and the declared target species
unstandardised CPUE	geometric mean of all individual CPUE observations, usually summarised over a year within the stratum of interest
WCNI	West coast North Island

Table A.2: Code definitions used in the body of the main report and in Appendix C, Appendix D, Appendix E and Appendix F.

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
SQU	Arrow squid
STA	Giant stargazer
SWA	Silver warehou
TAR	Tarakihi
TRE	Trevally
WAR	Blue warehou

Appendix B. MAP OF MPI STATISTICAL AND MANAGEMENT AREAS

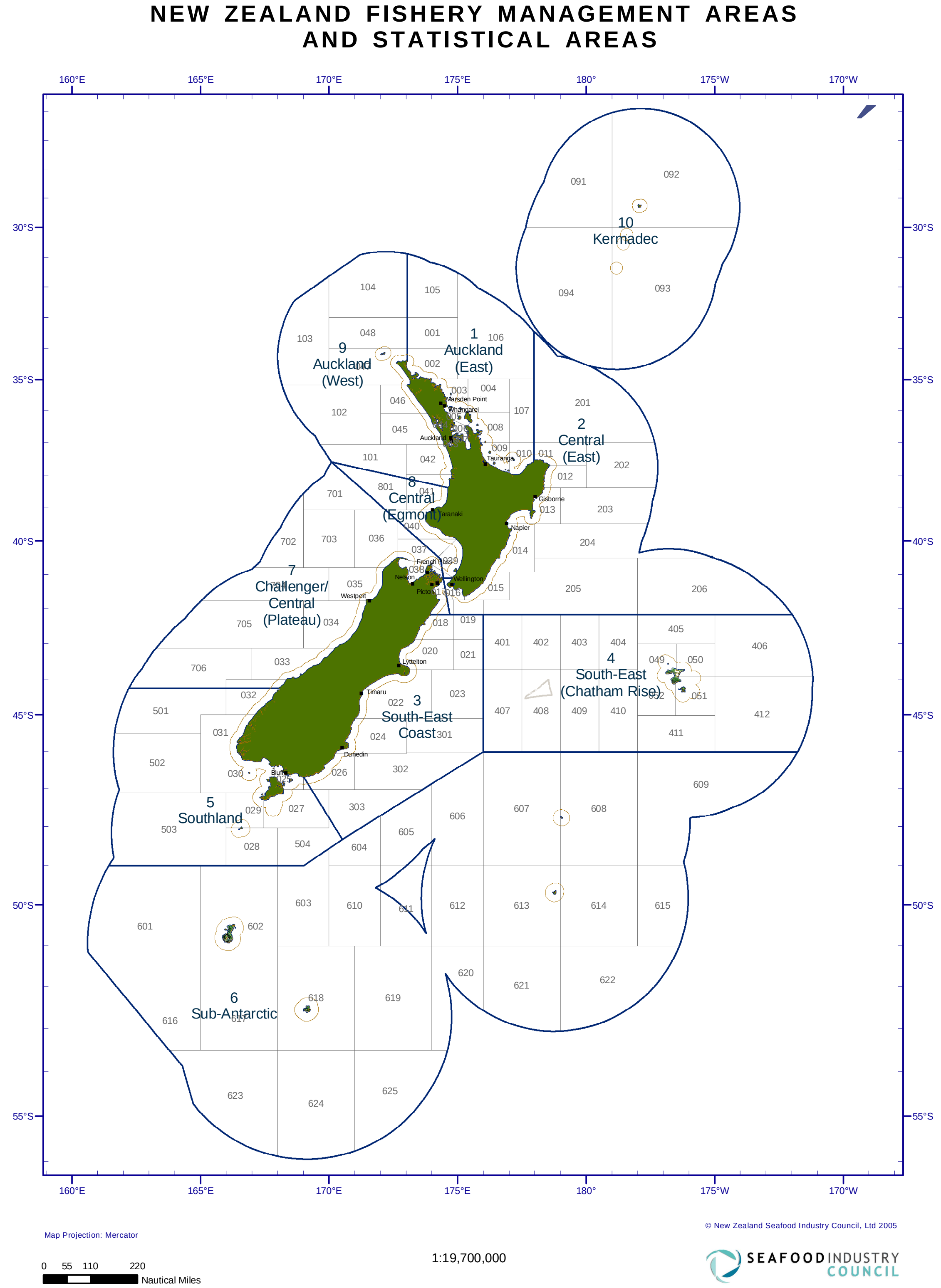

Figure B.1: Map of Ministry for Primary Industries statistical areas and Fishery Management Area (FMA) boundaries, showing locations where FMA boundaries are not contiguous with the statistical area boundaries.

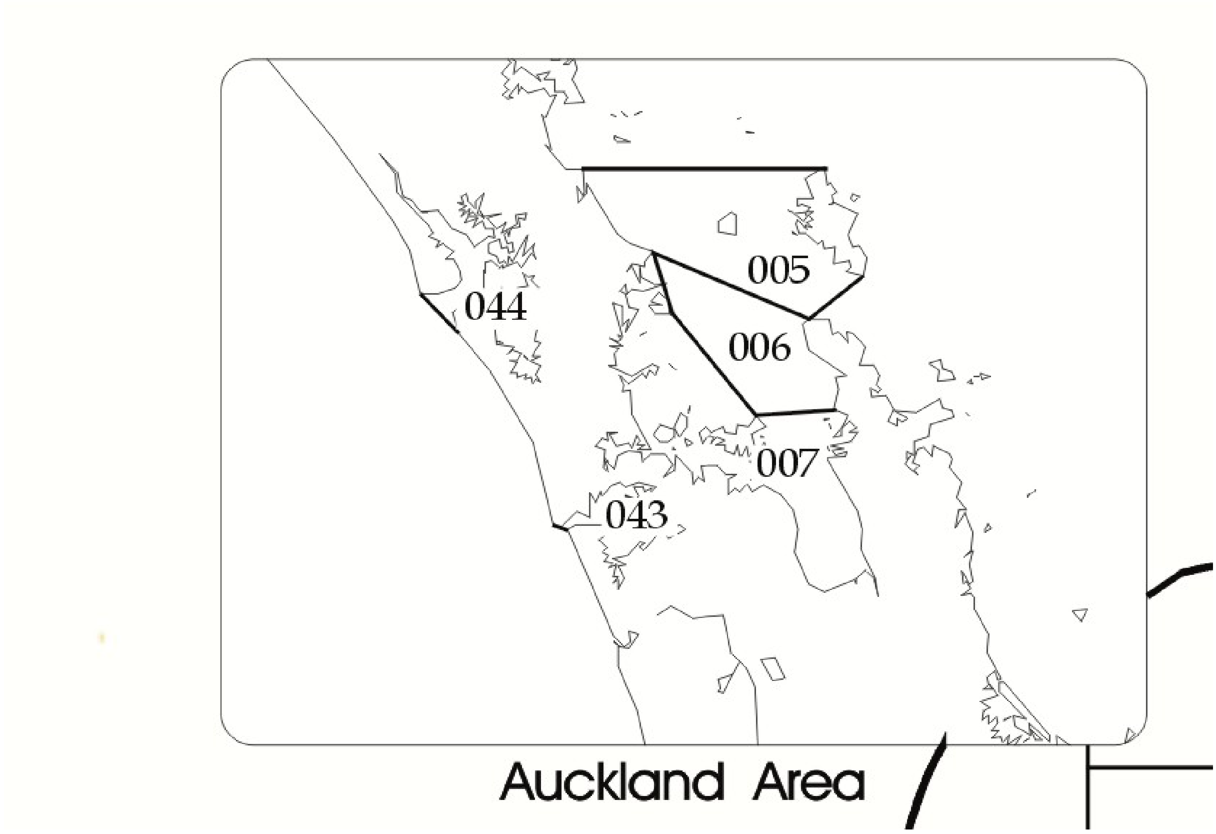

Figure B.2: Inset map of showing location of the Hauraki Gulf Statistical Areas (005, 006 and 007). Statistical Areas 043 and 044 are the Kaipara and Manukau Harbours respectively.

Appendix C. FINDING SPURIOUS LIN 1 LANDINGS

C.1 General overview

A three step procedure was used to screen implausible trips from the LIN 1 data set. This was required because Starr et al. (2009) had previously identified the problem that many fishers designated “5”, “6” or “7” when asked to identify the “area” of capture. What they probably meant was LIN 5, LIN 6 and LIN 7 but, in many instances, these entries were interpreted at the point of data entry as statistical areas 005, 006 or 007, all within the inner Hauraki Gulf and part of LIN 1 (Appendix B: all MPI finfish Statistical Areas; Figure B.2: inset map showing location of Areas 005, 006 and 007). The Hauraki Gulf is not strong ling habitat and it is unlikely that this supports much of a ling fishery.

The forms used to report catch to MPI are in two parts, with the “top” part used to report location and date of capture, the area of capture, the effort expended and some information about the most important species catch. The “bottom” part of the form (or else in a separate form, known as the Catch Landing Return [CLR]) is used to report landings, linked by the trip number with the effort data (in both instances). It is only at this latter step that the QMA is reported, with the top part of the form only reporting the “area” of capture. Consequently, it is not possible to simply use the QMA of record to exclude the spurious or implausible trips. The presence of spurious trips in the landing data set can be seen in Figure C.1, with the sum of the declared landings (shown by the blue line) exceeding the sum of LIN 1 landings from the QMR/MHR system, particularly in the years 1993–94, 1994–95, 1997–98 to 1999–2000, 2001–02, 2010–11 and 2011–12.

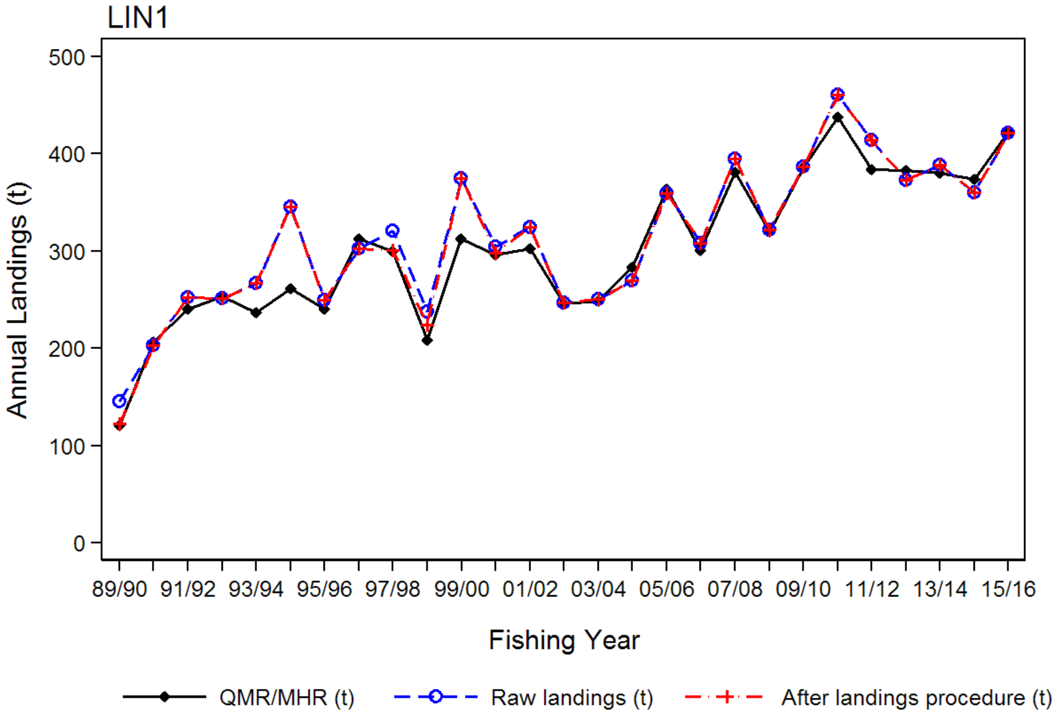

Figure C.1: Comparison of the total annual QMR/MHR landings with the total annual raw landings in the LIN 1 data set (blue line) and the annual landings which remained after excluding the six trips identified in Table C.1.

C.2 Methods

The following three steps were used to exclude spurious trips in LIN 1:

1. identify "out-of-range" landings, where large landings are recorded without adequate corroborative information in the trip, using the procedure described in Starr & Kendrick (2016a).
2. starting with trips that have used forms giving position data for each event in the trip, identify trips which never ventured into FMA1 or FMA9. The coordinates in the table below are where the FMA1/FMA2 boundary hits land in the eastern Bay of Plenty (Appendix B). Similarly, the coordinates for FMA9 are where the boundary between the FMA8/FMA9 hit land in the North Taranaki Bight (Appendix B).

	FMA1	FMA9
Latitude	-38.0333	-38.1
Longitude	-182.017	-185.05

3. for those trips with no position data, identify trips that never reported an event in a North Island statistical area. Statistical areas in western Cook Strait were also included in this group. Trips which never reported any of the statistical areas in the list below were dropped from the data set:

FMA1	001–010, 105–107
FMA2	011–019, 201–206
FMA9	041–048, 101–104
FMA8 & W Cook Strait	036–040, 701–703, 801

C.3 Results

C.3.1 Identifying "out-of-range" landings

The method described in detail by Starr & Kendrick (2016a) was followed, resulting in identifying six trips which failed the screening (Table C.1), indicating that large and potentially unreasonable trips were not a problem with this data set. These trips only accounted for 63 t of total catch (Table C.3) and had negligible effect on the problem identified in Figure C.1.

Table C.1: Six trips identified in the LIN 1 data set as having unreasonably large landings relative to the internal evidence in the trip (see appendix D in Starr & Kendrick 2016a for a description of the method). Landings are the sum for the entire trip while calculated landings are based on the number of containers multiplied by the average weight of the containers for the trip. Ratio 1 is calculated relative to the calculated landings and Ratio 2 is calculated relative to the estimated catch. These are the only trips which exceeded 1.44 t (the 95th quantile of landing sum) and also had a Ratio of at least 3 in either Ratio 1 or Ratio 2.

Fishing year	Trip number	Sum landings (t)	Sum calculated landings (t)	Sum estimated catch (t)	N events	N landing events	Ratio 1	Ratio 2
89/90	2163108	7.91	0.11	0	5	1	75.4	–
89/90	2287261	14.87	1.67	1.6	63	1	8.9	9.3
97/98	1989979	13.9	0.12	0.07	4	1	119.8	185.4
97/98	2979605	6.23	0.63	0.65	14	1	9.9	9.6
98/99	3181389	13.85	0.08	0.08	1	1	173.2	173.2
00/01	3658739	6.0	0.02	0	3	1	344.8	–

C.3.2 Identifying trips which did not fish in LIN 1 but which reported LIN 1 landings

One hundred and sixty-eight trips which reported positional data appeared to have never fished in LIN 1 even though they reported 231 t of LIN 1 landings (Table C.3). A further 81 trips were identified as never reporting an event from a North Island statistical area; these trips reported 21 t of LIN 1 landings (Table C.3). These 255 trips (including trips identified in Table C.1), with an associated 314 t of LIN 1 landings, were dropped from the LIN 1 data set. When the remaining landings were compared with the QMR/MHR annual totals from Table 1, there was reasonably good correspondence for the annual totals in every year except for 1999–00 (Figure C.2). An examination of the trips which reported in 1999–00 did not reveal any anomalies that could be easily identified: 1350 trips landed LIN 1 in that year, but only 87 landed more than 1 tonne of LIN 1 greenweight. The largest landing was for 18.6 t and only 5 trips landed more than 5 tonnes (Table C.2). Consequently, the pruning of the LIN 1 landing data stopped with trips identified in Table C.3

Table C.2: Statistics for landed green weight (t) for trips which landed LIN 1 in 1999–00

```
-------------------------------------------------------------
      Percentiles      Smallest
 1%         .001          .0008
 5%         .002           .001
10%       .00375           .001       Obs               1,350
25%        .0065           .001       Sum of Wgt.       1,350

50%         .016                      Mean           .2775435
                        Largest       Std. Dev.      1.116878
75%         .052          8.989
90%         .399           9.42       Variance       1.247417
95%        1.551        15.0133       Skewness       8.039966
99%        5.461        18.5977       Kurtosis       93.95991
```

Table C.3: LIN 1 landings (t) and number of trips represented by trips dropped from the LIN 1 data set by fishing year and sequence step described in Section C.2. '–': no data.

Fishing	Exclude out of range trips		Exclude trips with position data which never fished in LIN 1		Exclude trips which never reported a North Island statistical area		Total	
year	N trips	Sum landings (t)	N trips	Sum landings (t)	N trips	Sum landings (t)	N trips	Sum landings (t)
89/90	2	22.8	5	9.8	7	0.9	14	33.4
90/91	–	–	4	0.4	5	0.2	9	0.6
91/92	–	–	6	0.4	1	3.0	7	3.4
92/93	–	–	0	0.0	2	0.1	2	0.2
93/94	–	–	4	17.9	2	0.1	6	18.0
94/95	–	–	9	91.3	3	0.1	12	91.4
95/96	–	–	15	3.2	11	2.4	26	5.5
96/97	–	–	6	1.1	6	0.0	12	1.2
97/98	2	20.1	7	1.4	7	5.3	16	26.8
98/99	1	13.9	4	13.0	6	0.4	11	27.3
99/00	–	–	4	1.0	4	0.2	8	1.2
00/01	1	6.0	4	0.9	9	1.1	14	8.0
01/02	–	–	2	19.2	5	0.1	7	19.3
02/03	–	–	2	0.3	1	0.0	3	0.3
03/04	–	–	2	0.1	2	1.8	4	1.8
04/05	–	–	6	1.1	4	0.1	10	1.2
05/06	–	–	6	3.1	2	0.1	8	3.2
06/07	–	–	3	1.7	3	4.7	6	6.4
07/08	–	–	8	12.0	–	–	8	12.0
08/09	–	–	9	1.8	–	–	9	1.8
09/10	–	–	6	4.5	–	–	6	4.5
10/11	–	–	14	27.0	1	0.2	15	27.2
11/12	–	–	13	12.1	–	–	13	12.1
12/13	–	–	4	0.1	–	–	4	0.1
13/14	–	–	13	7.0	–	–	13	7.0
14/15	–	–	4	0.3	–	–	4	0.3
15/16	–	–	8	0.2	–	–	8	0.2
Total	6	62.8	168	230.9	81	20.7	255	314.4

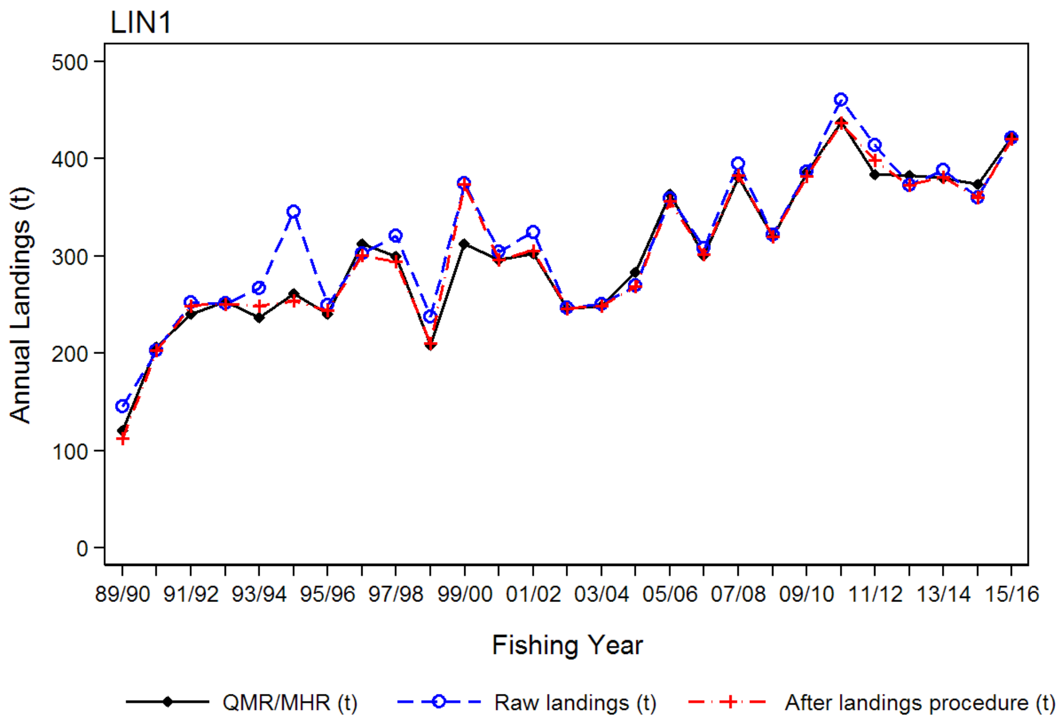

Figure C.2: Comparison of the total annual QMR/MHR landings with the total annual raw landings in the LIN 1 data set (blue line) and the annual landings which remained after excluding the 255 trips listed in Table C.3.

Appendix D. LIN 1 CPUE ANALYSIS

D.1 General overview

This Appendix describes an update of a LIN 1 CPUE analysis that was first presented in Starr et al. (2009) and then updated by Starr & Kendrick (2016b). This Appendix and Appendix E and Appendix F support the analyses presented in Section 4 of the main report. This Appendix contains the definitions for the modelled fisheries, equations used, and procedures followed. Appendix E and Appendix F provide detailed tables and figures with statistics and diagnostics, and final tables giving the estimated indices with the standard error.

D.2 Methods

D.3 Data Preparation

The identification of candidate trips for these analyses and the methods used to prepare them are described in Section 3.1 in the main report. Landings were allocated to effort at the “daily effort stratum” resolution procedure described in Section 3.1.2. The CPUE data set was prepared using the “Fishstock” expansion procedure, whereby the trip expansion was based on the landed Fishstock. This procedure maintained the integrity of the data to LIN 1 only and was possible because only one statistical area (Area 041) is shared with another QMA (LIN 7) and ling landings in that statistical area are relatively small (see Figure 8 to Figure 10). Furthermore, many of the spurious LIN 1 landings have been removed using the procedure documented in Appendix C. Consequently, the “Fishstock” expansion procedure, unlike for some other QMAs with many shared statistical areas, only resulted in the loss of less than 1% of the available landing data.

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 ling 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 also incorporates some zero catch information.

The potential explanatory variables available from each trip in the bottom longline data set include fishing year, the number of sets, the number of hooks, 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 LIN. 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.

This dataset was further restricted to a 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.

D.4 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. D.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 $E_{i,y} = H_{i,y}$ ([*hooks*]–for bottom longline) 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. D.2 $$\hat{U}_y = \exp\left[\frac{\sum_{i=1}^{N_y} \ln\left(C_{i,y} / E_{i,y}\right)}{N_y}\right]$$

where C_i, $E_{i,y}$ and N_y are as defined for Eq. D.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 (if a lognormal distribution is assumed), 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. D.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. D.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 factorial 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 factorial 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 sets $\left(\ln\left(S\right)_i\right)$ and fishing duration $\left(\ln\left(H_i\right)\right)$ were offered to the bottom longline models as continuous third order polynomial variables.

Trial regression models using five different distributional assumptions (lognormal, log-logistic, inverse Gaussian, gamma and Weibull) that predicted catch based on a fixed set of explanatory variables (year, month, area, vessel and $\ln\left(S\right)$) were evaluated by examining the residual diagnostics for each fitted model and then selecting the error distribution with the lowest negative log likelihood. The selected distribution was then used for the final stepwise positive catch regression.

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. D.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 ling as the dependent variable (where 1 is substituted for $\ln(I_i)$ in Eq. D.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. D.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, which integrates the positive catch and binomial annual abundance coefficients, was estimated using the delta distribution, which allows zero and positive observations (Vignaux 1994):

Eq. D.4 $${}^{C}Y_y = \frac{{}^{L}Y_y}{\left(1 - P_0\left[1 - {}^{1}\!/_{{}^{B}Y_y}\right]\right)}$$

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

${}^{L}Y_y$ = positive catch index for year *i*

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

P_0 = proportion zero for base year *0*

Confidence bounds, while straightforward to calculate for the binomial and positive catch 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.

D.5 Fishery definitions

The following selection criteria were used for defining the two bottom longline fishery models described in this report. The first model (BLL(LIN)) is the model selected by the NINSWG for monitoring LIN 1 in 2013 (MPI 2016). The second model was initially run as a sensitivity analysis to test the robustness of the BLL(LIN) series, using the same core fleet definition and year selection as BLL(LIN) [designated BLL(MIX)]. The NINSWG thought this second model could serve as an alternative monitoring series, given the larger quantity of data made available from the wider target species definition. Consequently, this model was repeated with a more restrictive core fleet definition and including all available years. This model, with the more restrictive core fleet definition, was designated BLL(MIX2).

Model	**Target species**	**Year Selection**	**Statistical Areas**	**Core Fleet Definition**	**Document Reference**
BLL(LIN)	LIN	1992–1998, 2000–2016	002–004, 008–010	1 year with 3+ trips	Appendix E
BLL(MIX2)	LIN, BNS, RIB, HPB	1990–2016	002–004, 008–010, 106	4 years with 5+ trips	Appendix F

The “best” distribution for the positive catch model was selected for each model as described in Section D.4. The Weibull distribution was selected for the BLL(LIN) model while the log.logistic distribution was selected for the BLL(MIX2) model. A binomial model based on the presence/absence of ling in each data set was also calculated for the latter model as there was a high proportion of sets with no ling. The two series were then combined using the delta-lognormal method (Eq. D.4). The proportion of zero sets in the BLL(LIN) was very low, so it was not necessary to fit the binomial model for that series.

Appendix E. DIAGNOSTICS AND SUPPORTING ANALYSES FOR BLL(LIN)

E.1 Introduction

This CPUE analysis was accepted for monitoring LIN 1 in 2013 by the NINSWG (MPI 2016). This analysis was reviewed and accepted again in 2017, but was assigned a research rating of “2” (Medium or Mixed Quality: poor vessel continuity and sparse data), which meant it could not be used to set a B_{msy} proxy.

E.2 Fishery definition

BLL(LIN): The fishery is defined from bottom longline fishing events which fished in Statistical Areas 002, 003, 004, 008, 009, and 010 and declared target species LIN.

E.3 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 3 trips in any year using trips with at least 1 kg of catch. These criteria resulted in a core fleet size of 53 vessels which took 97% of the catch (Figure E.1). This relaxed core vessel definition was used to maximise the amount of data retained in the analysis, given that this analysis is hampered by the small amount of available data and poor overlap in the core vessel fleet (Figure E.2).

E.4 Data summary

Table E.1: Summaries by fishing year for core vessels, trips, daily effort strata, number of events that have been “rolled up” into daily effort strata, number of events per daily-effort stratum, sets, hooks, landed LIN (t), and proportion of trips with catch for the core vessel data set (based on a minimum of 3 trips in any year) in the BLL(LIN) fishery. Final two columns apply to trips which declared no estimated catch of ling but reported LIN landings, giving the proportion of these trips relative to trips which reported LIN and the proportion of the reported catch from these trips relative to the total annual LIN reported catch.

Fishing year	Vessels	Trips	Daily effort strata	Events	Events per stratum	Sum (sets)	Sum (hooks/ 1000)	Catch (t)	% trips with catch	% trips: 0 estimated catch	% catch: 0 estimated catch trips
1992	11	80	220	220	1.000	303	233.31	94.37	97.5	3.77	4.11
1993	13	55	113	113	1.000	174	140.17	80.55	96.4	2.56	0.28
1994	14	71	187	188	1.005	270	297.05	88.27	97.2	0	0
1995	17	83	185	190	1.027	269	291.50	88.58	95.2	0	0
1996	12	50	85	87	1.024	139	138.40	60.25	100.0	0	0
1997	5	15	40	40	1.000	48	56.65	23.44	100.0	0	0
1998	6	22	42	43	1.024	82	58.95	35.11	100.0	0	0
2000	6	15	34	34	1.000	44	47.50	31.39	100.0	0	0
2001	4	19	46	46	1.000	62	94.60	60.07	100.0	0	0
2002	8	22	48	48	1.000	80	74.92	50.30	95.5	0	0
2003	10	28	71	71	1.000	138	142.55	64.99	100.0	0	0
2004	9	29	78	78	1.000	119	98.92	70.97	100.0	0	0
2005	8	29	128	128	1.000	221	278.26	126.33	100.0	0	0
2006	11	34	116	117	1.009	272	276.79	119.32	100.0	0	0
2007	12	41	125	126	1.008	254	277.04	101.37	97.6	0	0
2008	13	65	231	290	1.255	304	500.55	132.51	100.0	0	0
2009	10	39	110	129	1.173	131	223.61	52.61	100.0	0	0
2010	12	49	133	178	1.338	178	295.08	114.36	100.0	0	0
2011	13	60	168	273	1.625	273	463.02	148.72	96.7	0	0
2012	11	59	168	253	1.506	253	387.72	169.37	100.0	0	0
2013	9	33	123	195	1.585	195	295.97	109.43	100.0	0	0
2014	6	26	126	231	1.833	231	376.62	103.99	100.0	0	0
2015	7	31	140	286	2.043	286	457.61	123.51	100.0	0	0
2016	5	23	134	249	1.858	249	440.66	143.62	100.0	0	0

E.5 Core vessel selection

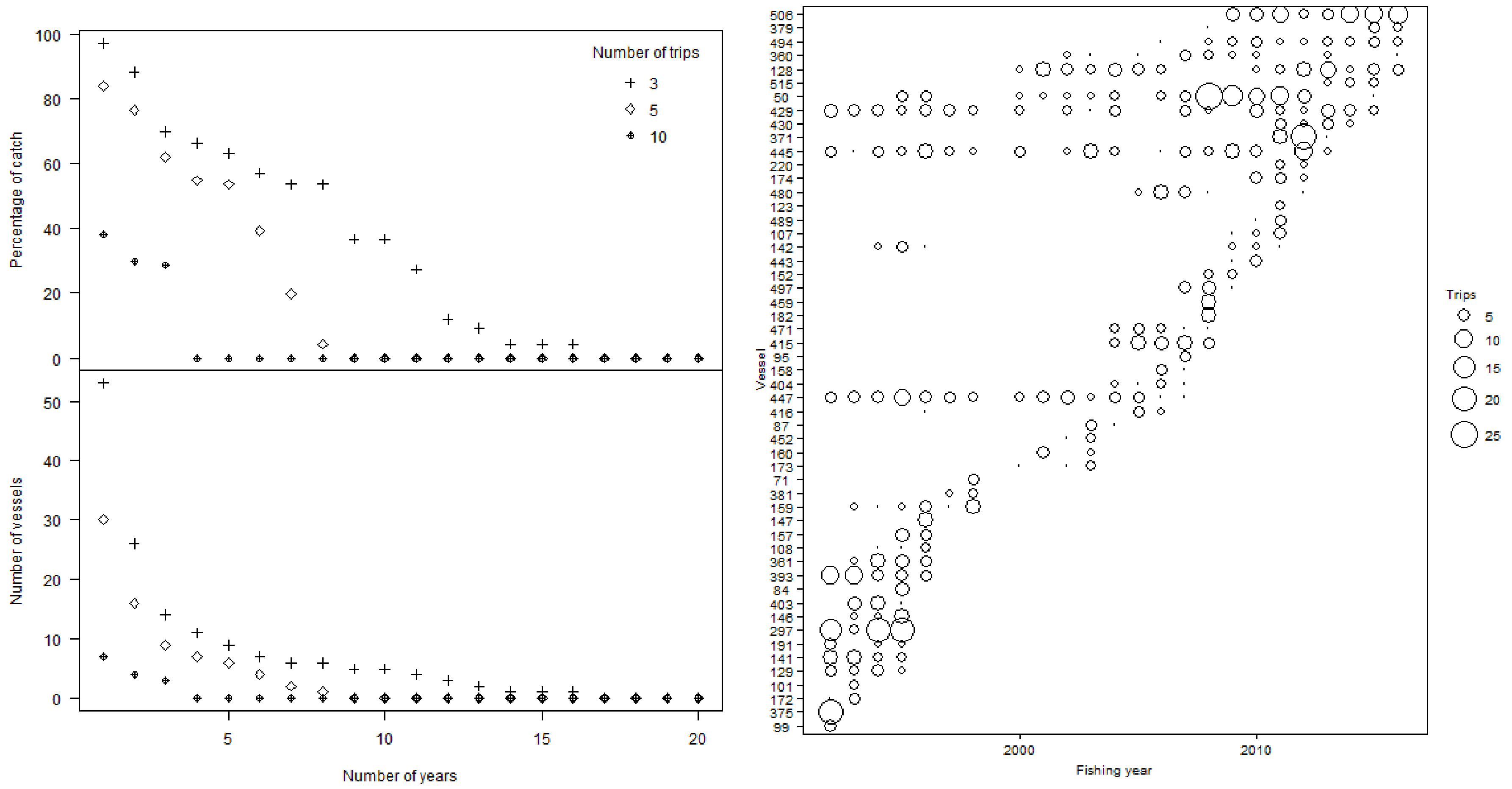

Figure E.1: [left panel] total landed LIN and number of vessels plotted against the number of years used to define core vessels participating in the BLL(LIN) dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot 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.

E.6 Exploratory data plots for core vessel data set

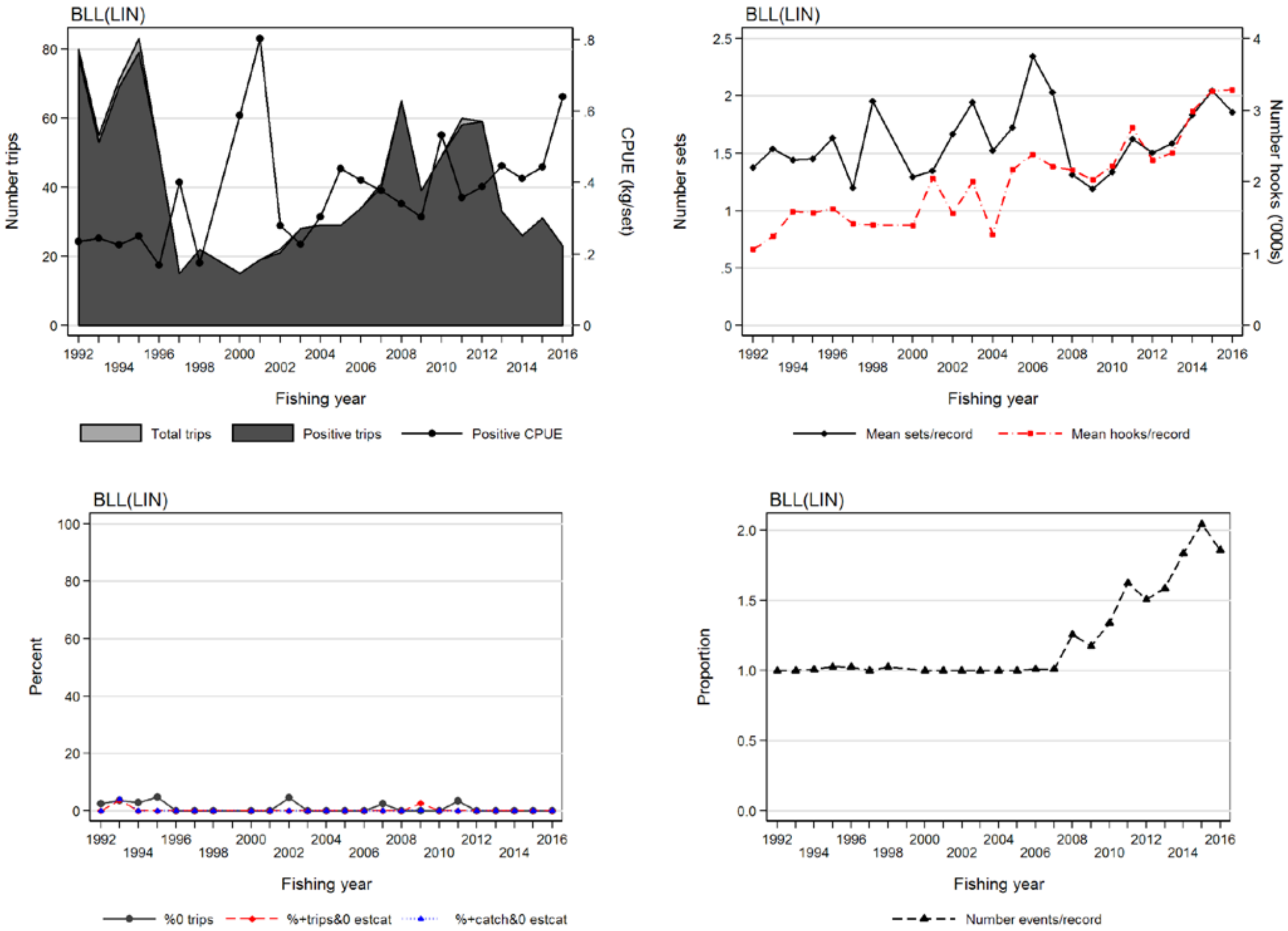

Figure E.2: Core vessel summary plots by fishing year for model BLL(LIN): [upper left panel]: total trips (light grey) and trips with ling catch (dark grey) overlaid with median annual arithmetic CPUE (kg/set) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i}/E_{y,i}\right)$; [upper right panel]: mean number of sets and mean number hooks per daily-effort stratum record; [lower left panel]: a) percentage of trips with no catch of ling, 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.

The best distribution was Weibull.

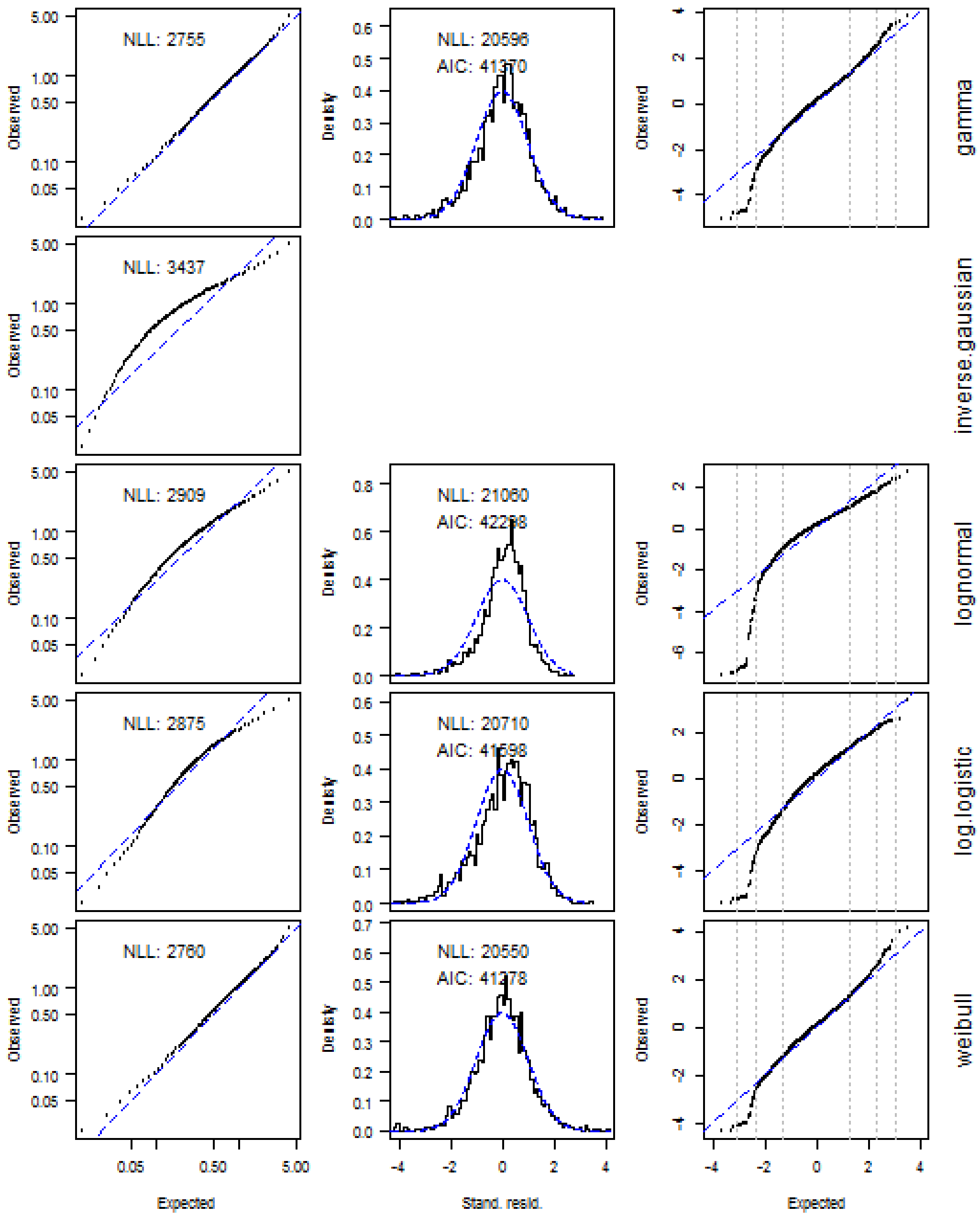

Figure E.3: Diagnostics for alternative distributional assumptions for catch in the BLL(LIN) analysis. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation in log space) versus maximum likelihood fit of distribution (missing panel indicates the fit failed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

E.7 Positive catch model selection table

Four explanatory variables entered the model after fishing year (Table E.2), with only the number of sets being non-significant. A plot of the model is provided in Figure E.4 and the CPUE indices are listed in Table E.3.

Table E.2: Order of acceptance of variables into the Weibull model of successful catches in the BLL(LIN) fishery model for core vessels based on the vessel selection criteria of at least 3 trips in any fishing year), 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	-21 327	42 704	9.1	*
vessel	77	-20 821	41 797	36.7	*
month	88	-20 630	41 435	44.8	*
poly(log(hooks), 3)	91	-20 533	41 248	48.4	*
area	95	-20 501	41 192	**49.6**	*
poly(log(sets), 3)	98	-20 479	41 155	50.4	

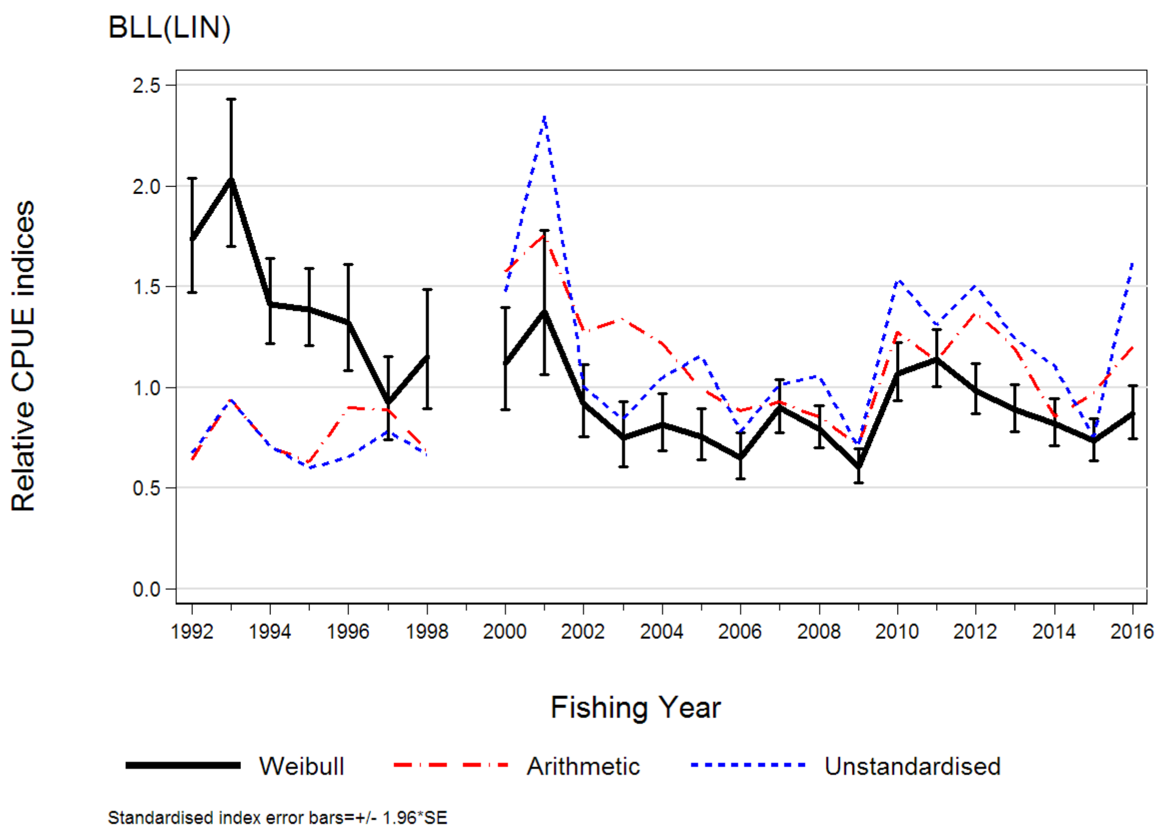

Figure E.4: Relative CPUE indices for ling using the Weibull non-zero model based on the BLL(LIN) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. D.1) and b) Unstandardised (Eq. D.2).

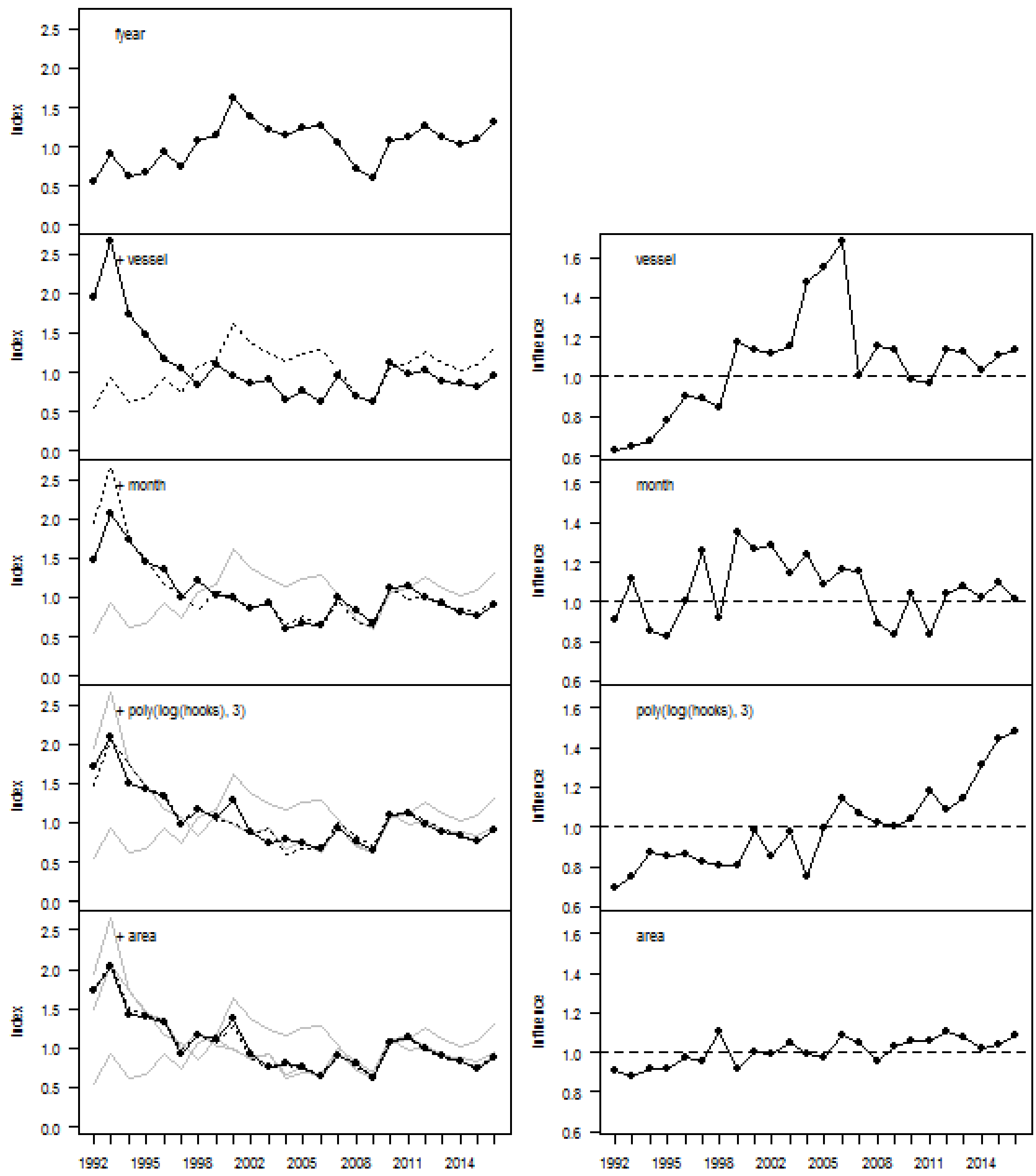

Figure E.5: [left column]: annual indices from the Weibull model of BLL(LIN) at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

E.8 Residual and diagnostic plots

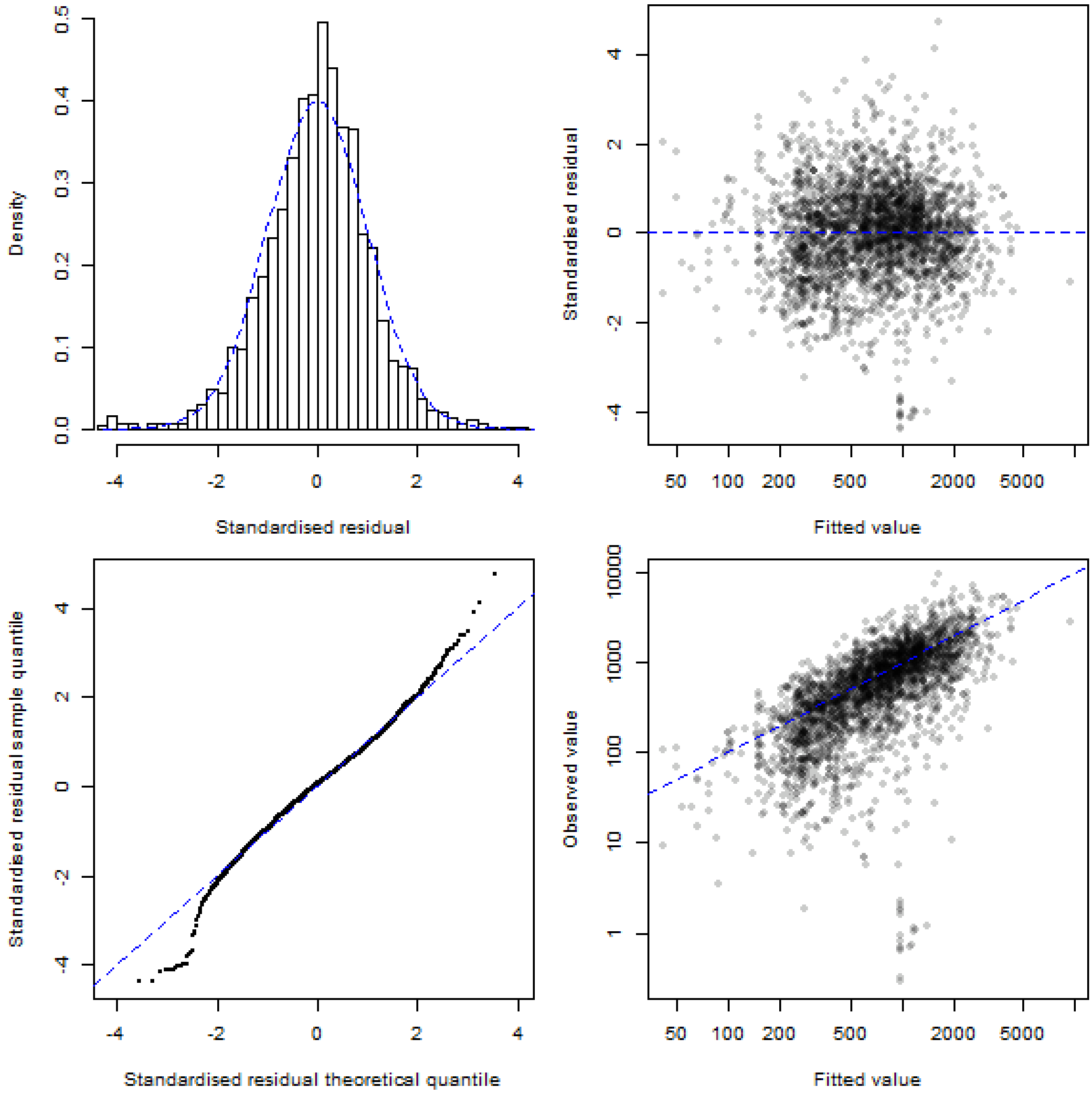

Figure E.6: Plots of the fit of the Weibull standardised CPUE model of successful catches of ling in the BLL(LIN) fishery. [Upper left] histogram of the standardised residuals compared to a Weibull distribution; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

E.9 Model coefficients

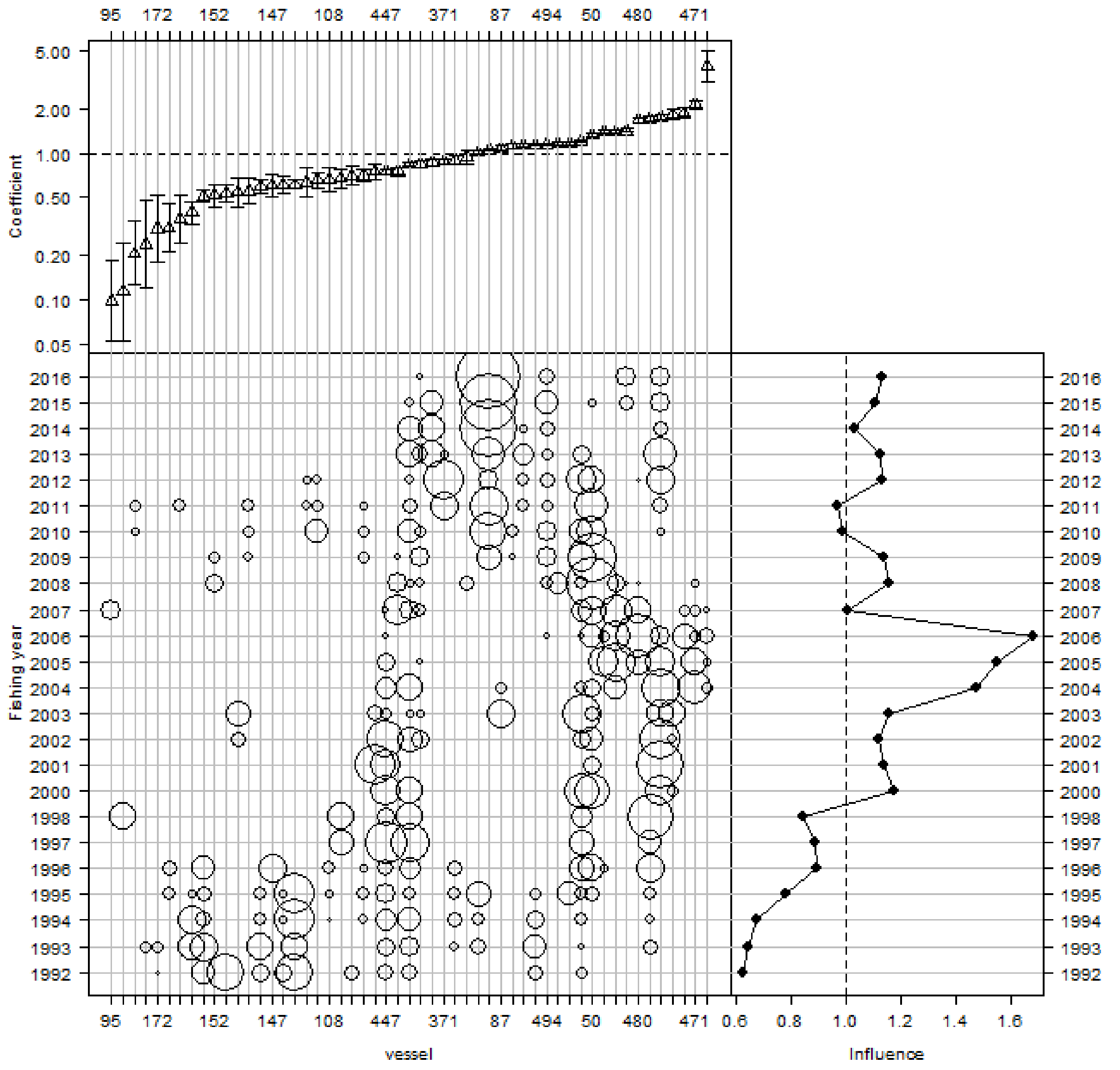

Figure E.7: Effect of vessel in the Weibull model for the ling BLL(LIN) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

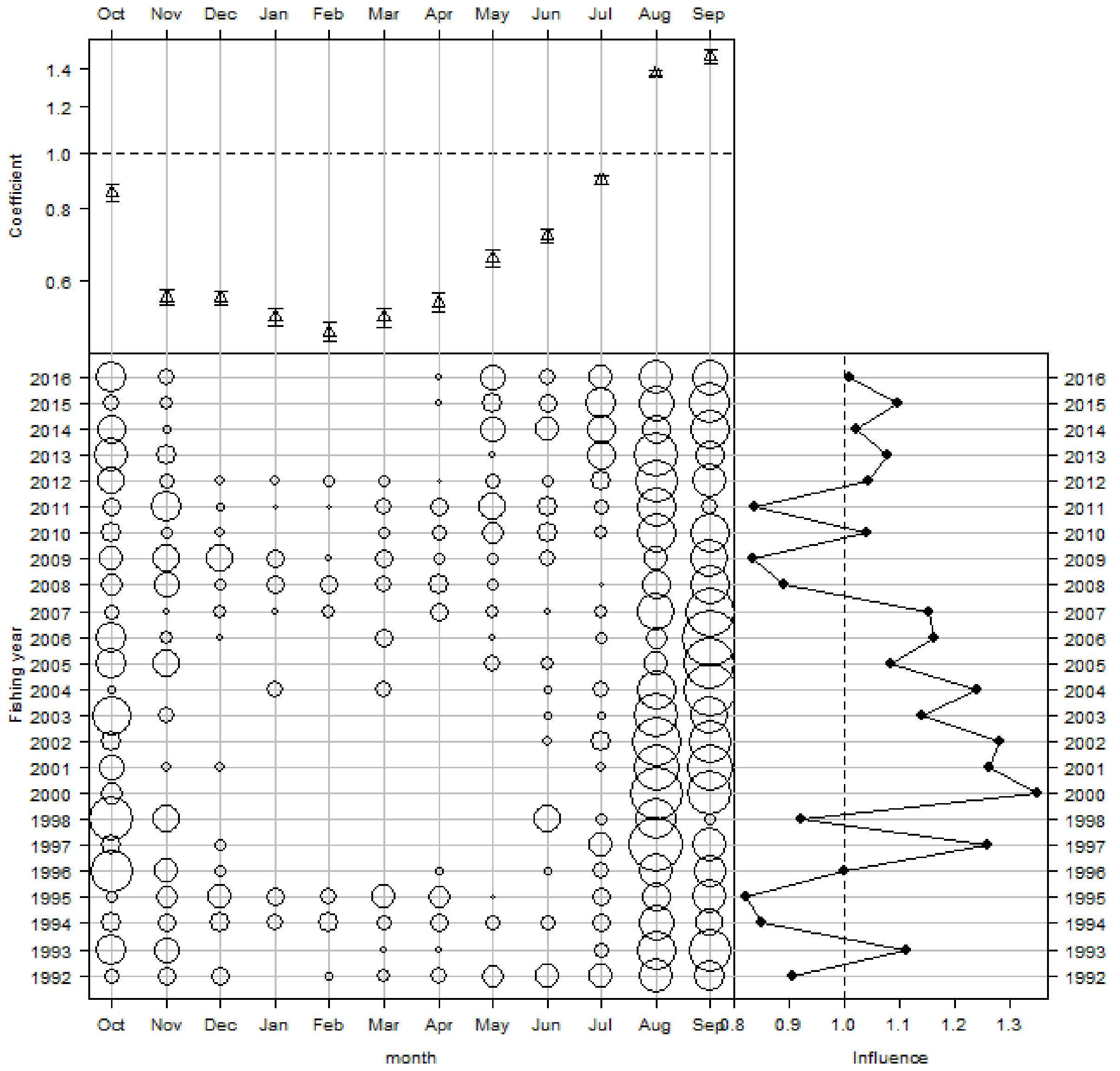

Figure E.8: Effect of month in the Weibull model for the ling BLL(LIN) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

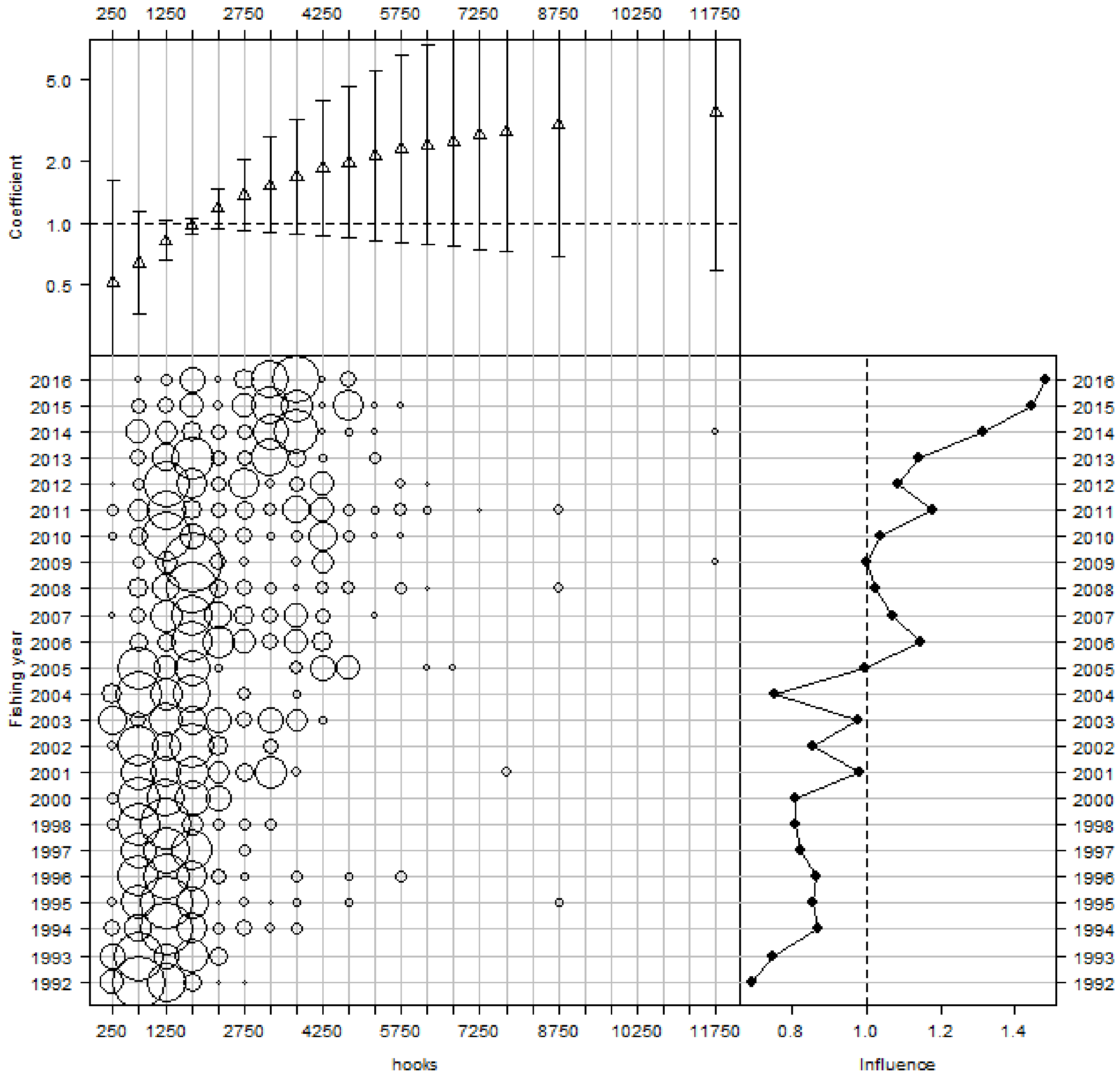

Figure E.9: Effect of log(hooks) in the Weibull model for the ling BLL(LIN) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

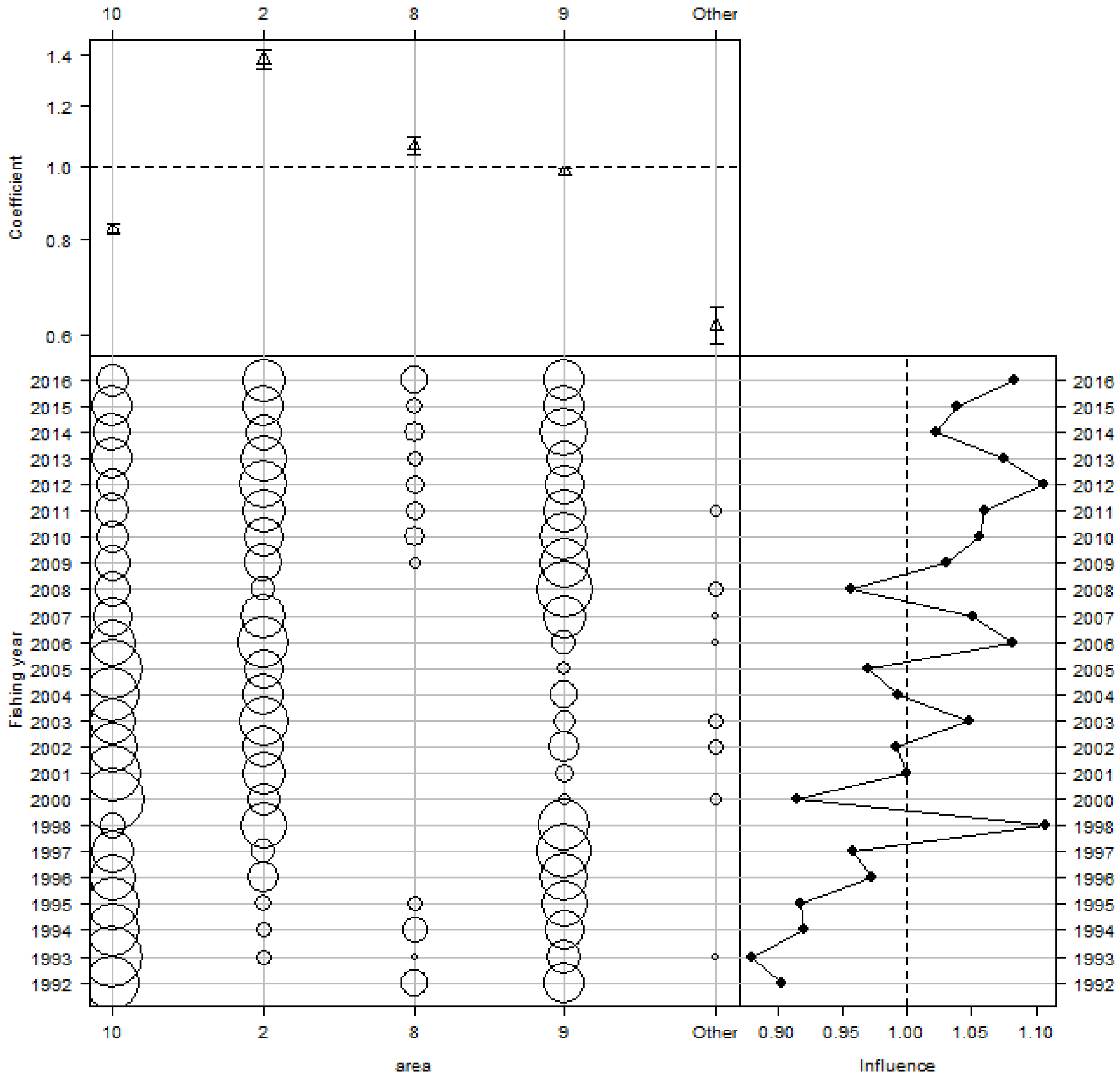

Figure E.10: Effect of area in the Weibull model for the ling BLL(LIN) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

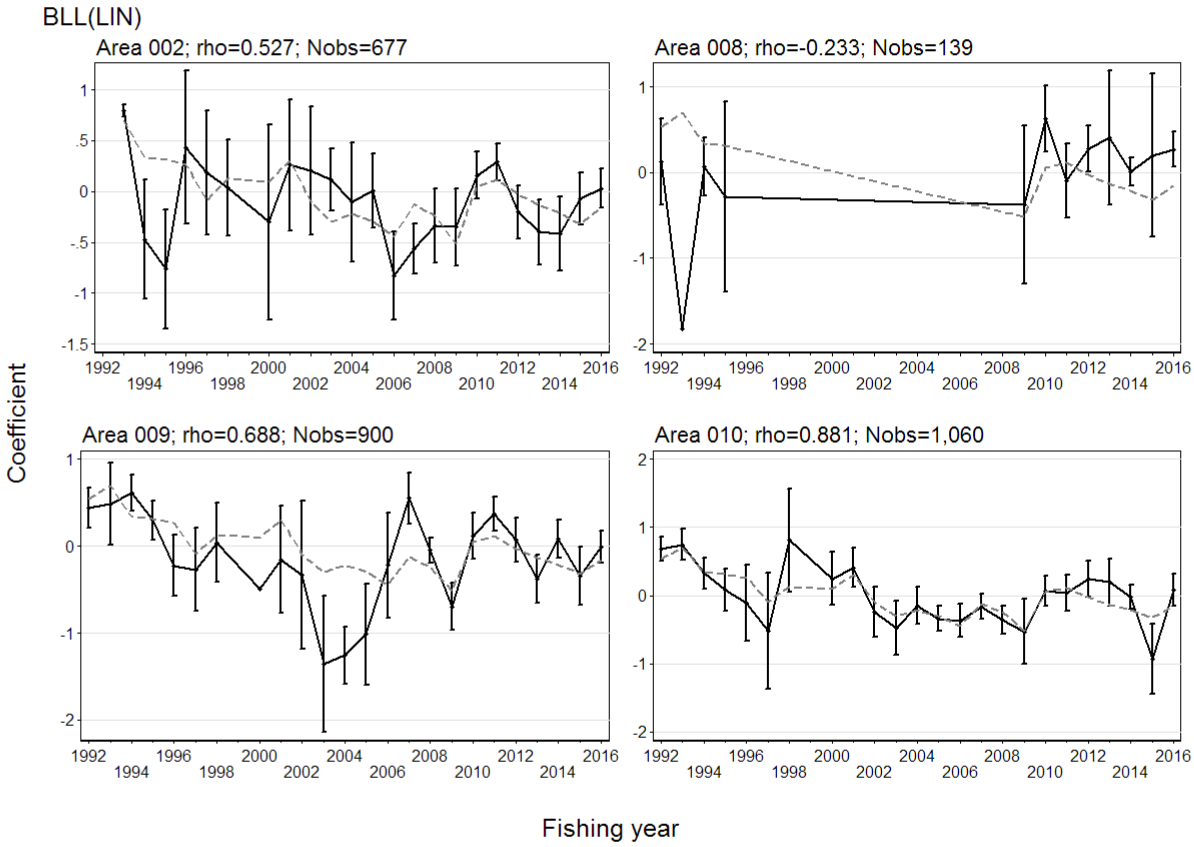

Figure E.11: Residual implied coefficients for area×fishing year interaction (interaction term not offered to the model) in the ling BLL(LIN) Weibull model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. 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. The information at the top of each panel identifies the plotted category, provides the correlation coefficient (*rho*) between the category year index and the overall model index, and the number of records supporting the category.

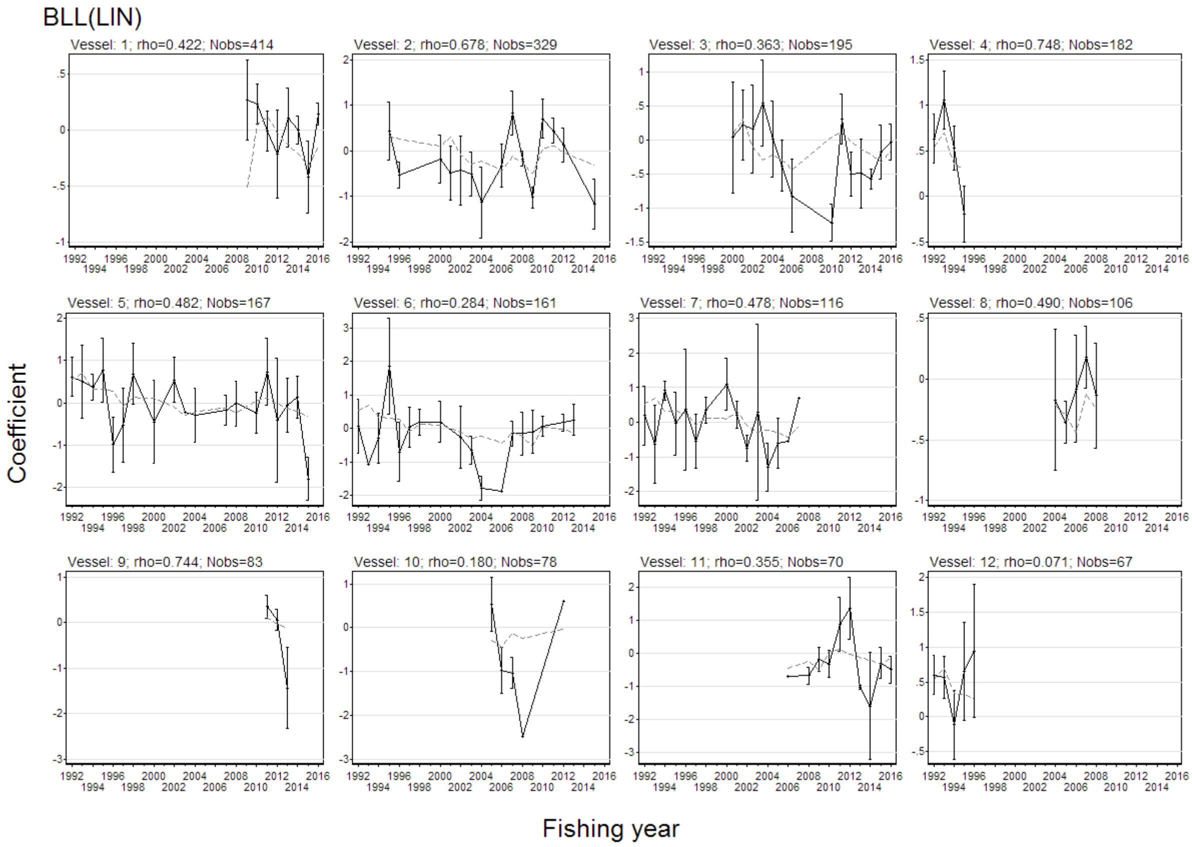

Figure E.12: Residual implied coefficients for the top 12 vessels (in terms of number observations) in the vessel×fishing year interaction (interaction term not offered to the model) in the ling BLL(LIN) Weibull model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. These values approximate the coefficients obtained when a vessel × year interaction term is fitted, particularly for those vessel × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals. The information at the top of each panel identifies the plotted category, provides the correlation coefficient (*rho*) between the category year index and the overall model index, and the number of records supporting the category.

E.10 CPUE indices

Table E.3: Arithmetic indices for the total and core data sets, geometric and Weibull standardised indices and associated standard error (SE) for the core data set by fishing year for the BLL(LIN) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels				Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE
1992	0.651	0.640	0.674	1.735	0.0830
1993	0.925	0.942	0.942	2.035	0.0914
1994	0.719	0.704	0.708	1.414	0.0758
1995	0.644	0.632	0.601	1.388	0.0699
1996	0.912	0.901	0.654	1.322	0.1007
1997	0.906	0.888	0.784	0.926	0.1127
1998	0.594	0.685	0.667	1.152	0.1303
2000	1.609	1.577	1.477	1.116	0.1147
2001	1.755	1.757	2.349	1.376	0.1320
2002	1.326	1.274	1.002	0.918	0.0994
2003	1.256	1.341	0.841	0.751	0.1095
2004	1.130	1.217	1.050	0.815	0.0878
2005	1.033	0.993	1.159	0.756	0.0852
2006	0.922	0.883	0.782	0.651	0.0903
2007	0.929	0.930	1.012	0.897	0.0744
2008	0.850	0.854	1.059	0.797	0.0673
2009	0.719	0.719	0.706	0.605	0.0715
2010	1.266	1.276	1.542	1.067	0.0687
2011	1.149	1.131	1.312	1.138	0.0641
2012	1.388	1.375	1.507	0.987	0.0649
2013	1.205	1.196	1.241	0.889	0.0680
2014	0.867	0.854	1.108	0.820	0.0725
2015	0.971	0.970	0.755	0.735	0.0723
2016	1.244	1.202	1.624	0.868	0.0767

Appendix F. DIAGNOSTICS AND SUPPORTING ANALYSES FOR BLL(MIX2)

F.1 Introduction

This CPUE analysis was accepted in 2017 for monitoring LIN 1 by the NINSWG (MPI 2017) with a research rating of “2” (Medium or Mixed Quality: strong impact of target species on standardisation), which meant it could not be used to set a B_{msy} proxy.

F.2 Fishery definition

BLL(LIN): The fishery is defined from bottom longline fishing events which fished in Statistical Areas 002, 003, 004, 008, 009, 010 and 106 and declared target species LIN, BNS, HPB or RIB.

F.3 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 5 trips in 4 years using trips with at least 1 kg of catch. These criteria resulted in a core fleet size of 57 vessels which took 80% of the catch (Figure F.1). This core vessel definition was used to obtain a good representation of the fishery in the core vessel fleet (Figure F.2).

F.4 Data summary

Table F.1: Summaries by fishing year for core vessels, trips, daily effort strata, number of events that have been “rolled up” into daily effort strata, number of events per daily-effort stratum, sets, hooks, landed LIN (t), and proportion of trips with catch for the core vessel data set (based on a minimum of 5 trips per year in 4 years) in the BLL(MIX2) fishery. Final two columns apply to trips which declared no estimated catch of ling but reported LIN landings, giving the proportion of these trips relative to trips which reported LIN and the proportion of the reported catch from these trips relative to the total annual LIN reported catch.

Fishing year	Vessels	Trips	Daily effort strata	Events	Events per stratum	Sum (sets)	Sum (hooks/ 1000)	Catch (t)	% trips with catch	% trips: 0 estimated catch	% catch: 0 estimated catch trips
1990	8	84	248	258	1.04	307	233.38	12.71	77.4	3.1	0.43
1991	15	185	511	514	1.01	774	399.09	28.74	41.6	13.0	0.94
1992	19	368	869	872	1.00	1 331	738.36	92.83	47.6	11.4	1.72
1993	24	353	820	835	1.02	1 383	769.62	85.60	37.4	14.4	4.29
1994	23	379	898	911	1.01	1 560	963.14	100.32	43.3	7.3	1.00
1995	23	380	864	896	1.04	1 528	918.69	92.72	43.7	8.4	0.81
1996	23	313	697	705	1.01	1 166	634.27	60.03	36.1	12.4	0.74
1997	16	290	772	775	1.00	1 173	696.26	30.77	38.3	6.3	0.62
1998	17	350	805	813	1.01	1 429	752.35	40.44	40.0	7.1	0.36
1999	18	342	699	703	1.01	1 188	696.35	21.39	37.4	11.7	1.19
2000	28	440	904	909	1.01	1 579	1 044.95	41.59	40.2	21.5	9.85
2001	28	510	1 042	1 048	1.01	1 902	1 212.86	56.32	58.2	15.8	1.59
2002	29	489	1 015	1 028	1.01	1 778	1 178.26	64.56	57.5	14.2	1.05
2003	25	441	977	979	1.00	1 710	1 111.17	77.94	55.3	23.0	1.65
2004	28	432	1 106	1 135	1.03	1 973	1 714.60	72.68	60.2	19.2	1.79
2005	24	365	1 014	1 019	1.00	1 759	1 784.86	96.82	57.8	20.4	0.64
2006	23	304	857	871	1.02	1 471	1 912.08	79.08	61.5	14.4	1.09
2007	23	317	914	916	1.00	1 473	2 008.59	96.89	53.0	8.3	0.31
2008	22	296	955	1 248	1.31	1 298	2 284.56	121.23	63.5	9.0	0.13
2009	19	290	877	1 089	1.24	1 163	1 812.93	72.62	60.7	11.4	0.75
2010	20	268	852	1 122	1.32	1 136	1 976.69	118.92	64.9	9.2	0.54
2011	19	241	899	1 243	1.38	1 243	1 974.71	147.55	69.7	11.3	0.22
2012	17	213	734	912	1.24	912	1 307.45	137.95	67.6	16.0	0.33
2013	15	158	528	664	1.26	664	926.17	110.47	67.1	12.3	0.20
2014	15	168	592	796	1.34	796	1 102.54	110.40	73.8	12.1	0.17
2015	15	195	710	1 010	1.42	1 010	1 472.74	138.01	80.5	15.9	0.36
2016	13	143	557	707	1.27	707	1 205.96	158.78	74.1	17.0	0.10

F.5 Core vessel selection

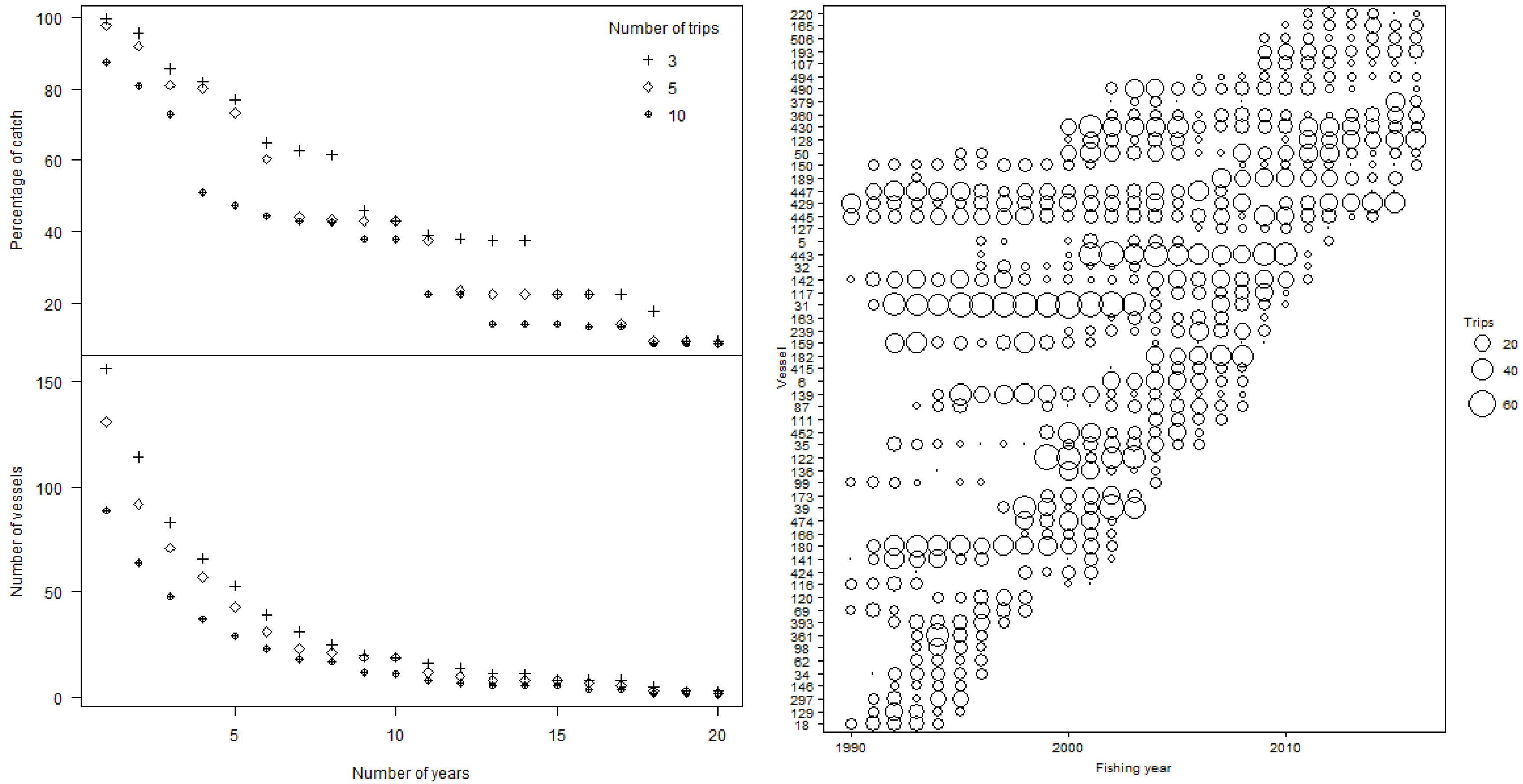

Figure F.1: [left panel] total landed LIN and number of vessels plotted against the number of years used to define core vessels participating in the BLL(MIX2) dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot 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.

F.6 Exploratory data plots for core vessel data set

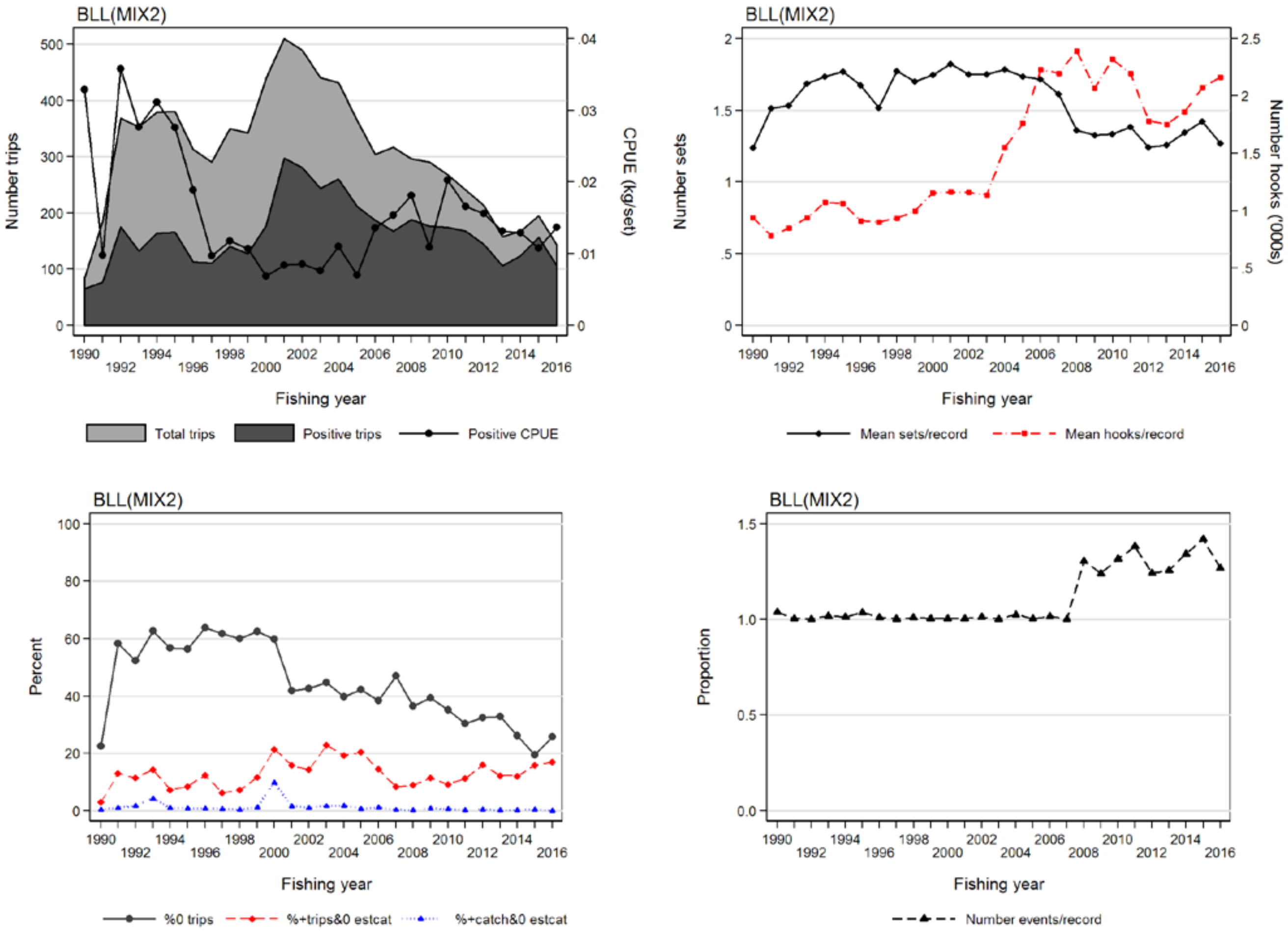

Figure F.2: Core vessel summary plots by fishing year for model BLL(MIX2): [upper left panel]: total trips (light grey) and trips with ling catch (dark grey) overlaid with median annual arithmetic CPUE (kg/set) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i}/E_{y,i}\right)$; [upper right panel]: mean number of sets and mean number hooks per daily-effort stratum record; [lower left panel]: a) percentage of trips with no catch of ling, 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.

The best distribution was log-logistic.

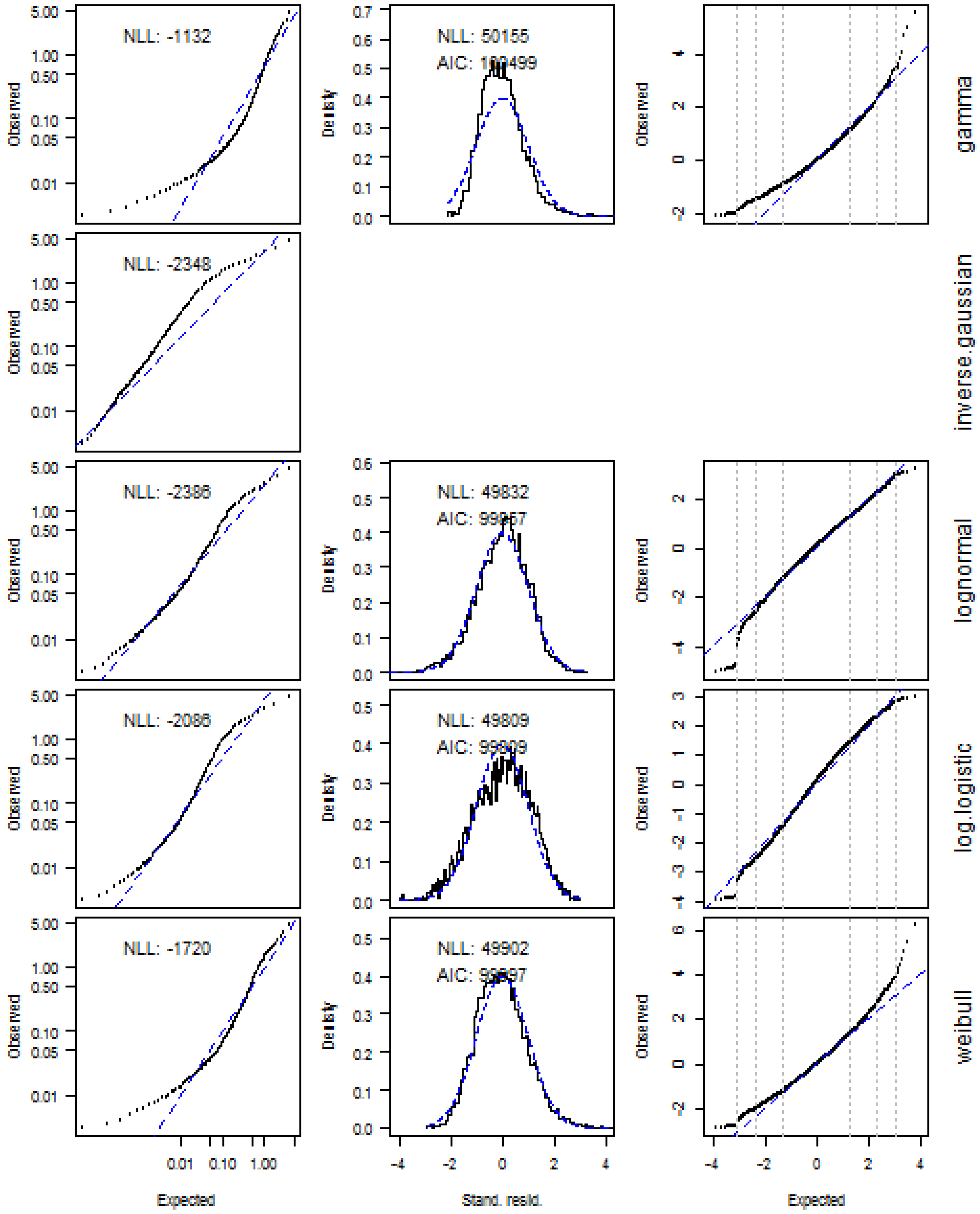

Figure F.3: Diagnostics for alternative distributional assumptions for catch in the BLL(MIX2) analysis. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation in log space) versus maximum likelihood fit of distribution (missing panel indicates the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month +area+ vessel + log(sets) and the distribution (missing panel indicates the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

F.7 Positive catch model selection table

Four categorical explanatory variables entered the model after fishing year (Table F.2), with the two continuous effort variables being non-significant. A plot of the model is provided in Figure F.4 and the CPUE indices are listed in Table F.4.

Table F.2: Order of acceptance of variables into the log-logistic model of successful catches in the BLL(MIX2) fishery model for core vessels (based on the vessel selection criteria of at least 5 trips in 4 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	28	-52 577	105 210	7.0	*
target	31	-49 154	98 370	57.2	*
vessel	87	-48 383	96 939	64.0	*
month	98	-48 163	96 521	65.8	*
area	104	-48 024	96 257	**66.8**	*
poly(log(hooks), 3)	107	-47 918	96 051	67.6	
poly(log(sets), 3)	110	-47 899	96 018	67.8	

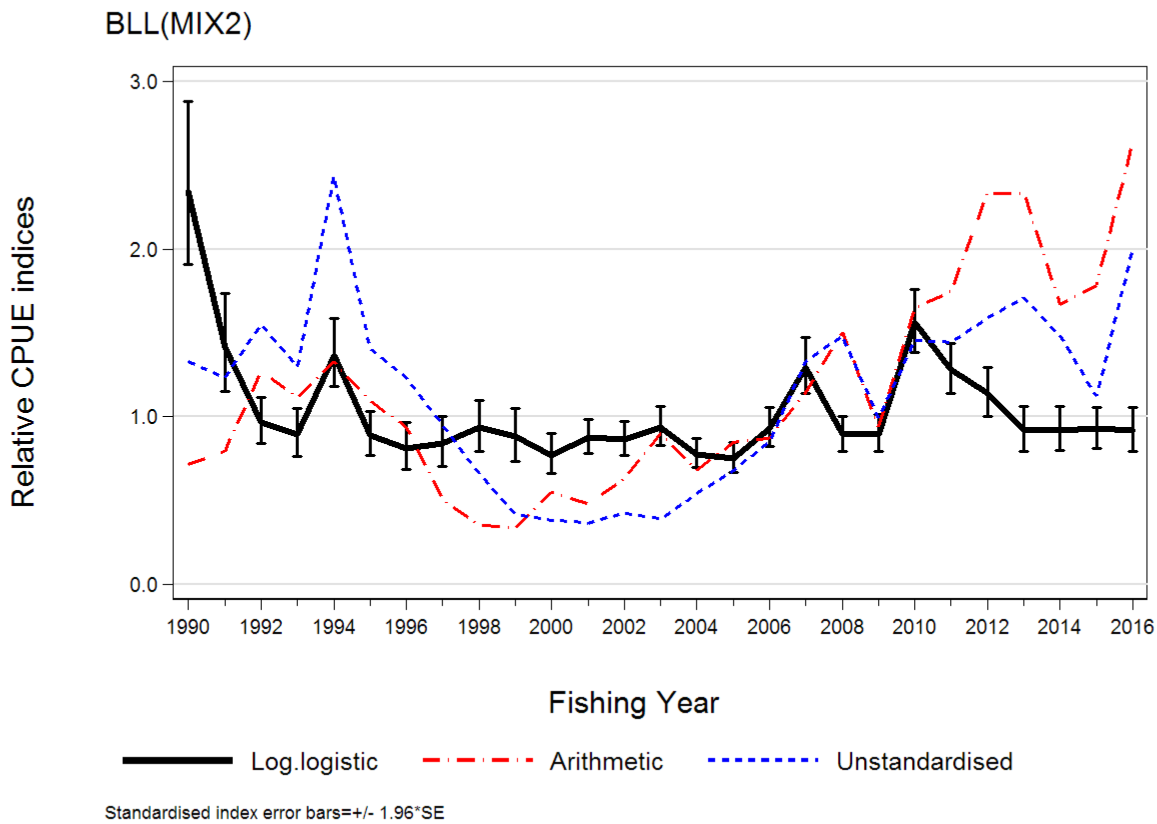

Figure F.4: Relative CPUE indices for ling using the log-logistic non-zero model based on the BLL(MIX2) fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. D.1) and b) Unstandardised (Eq. D.2).

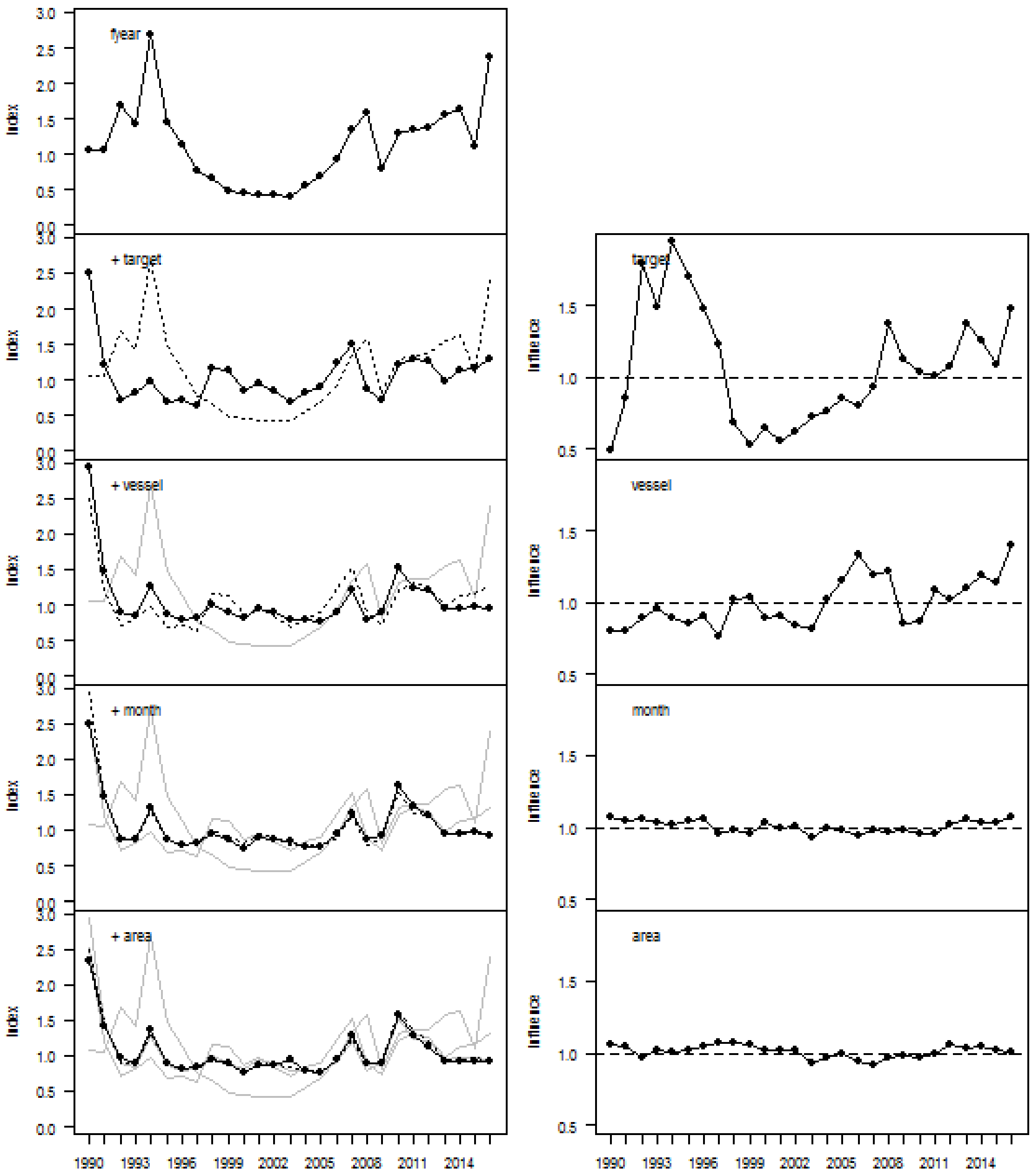

Figure F.5: [left column]: annual indices from the log-logistic model of BLL(MIX2) at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

F.8 Residual and diagnostic plots

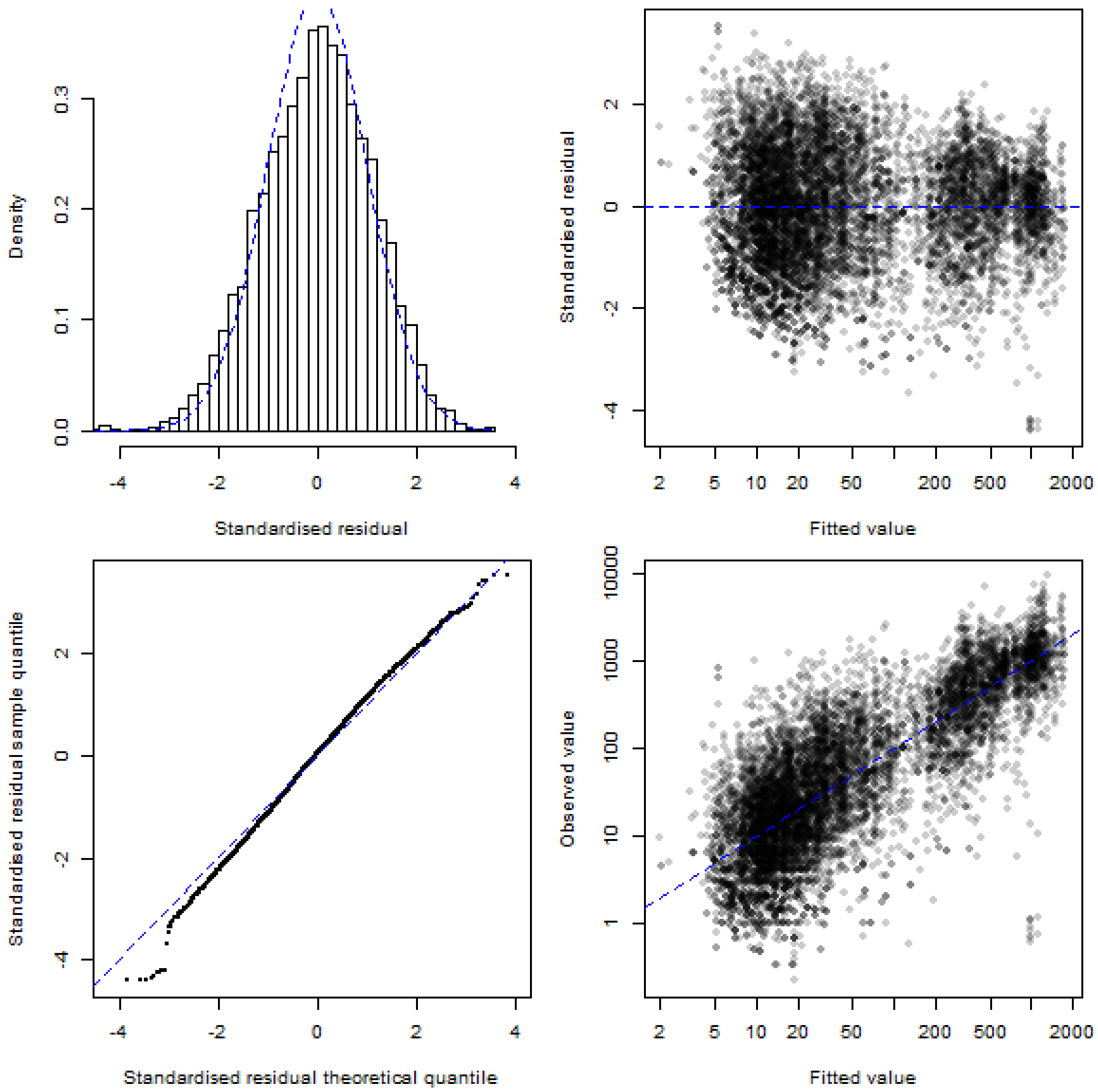

Figure F.6: Plots of the fit of the log-logistic standardised CPUE model of successful catches of ling in the BLL(MIX2) fishery. [Upper left] histogram of the standardised residuals compared to a Log-logistic distribution; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

F.9 Model coefficients

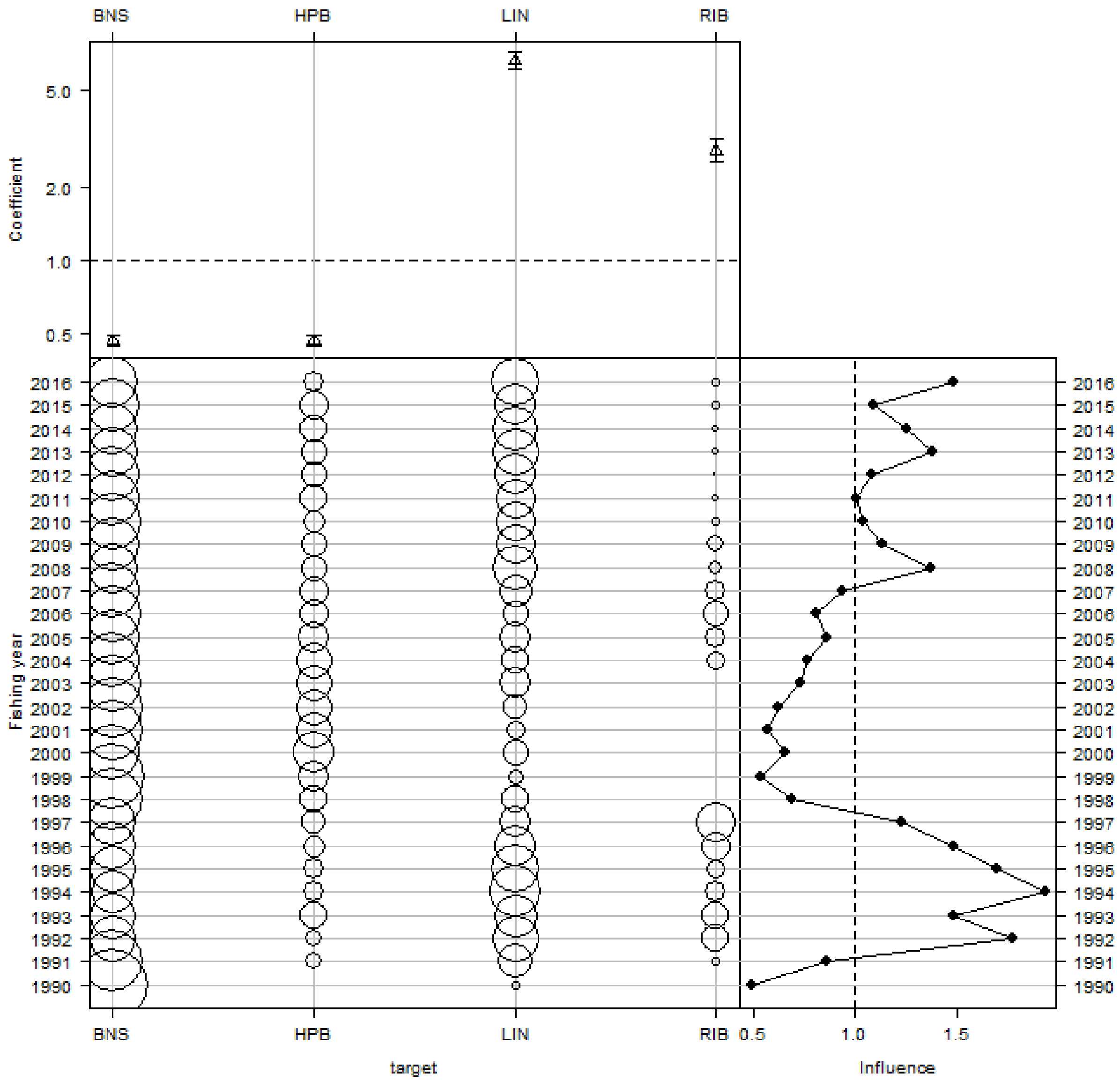

Figure F.7: Effect of target in the log-logistic model for the ling BLL(MIX2) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

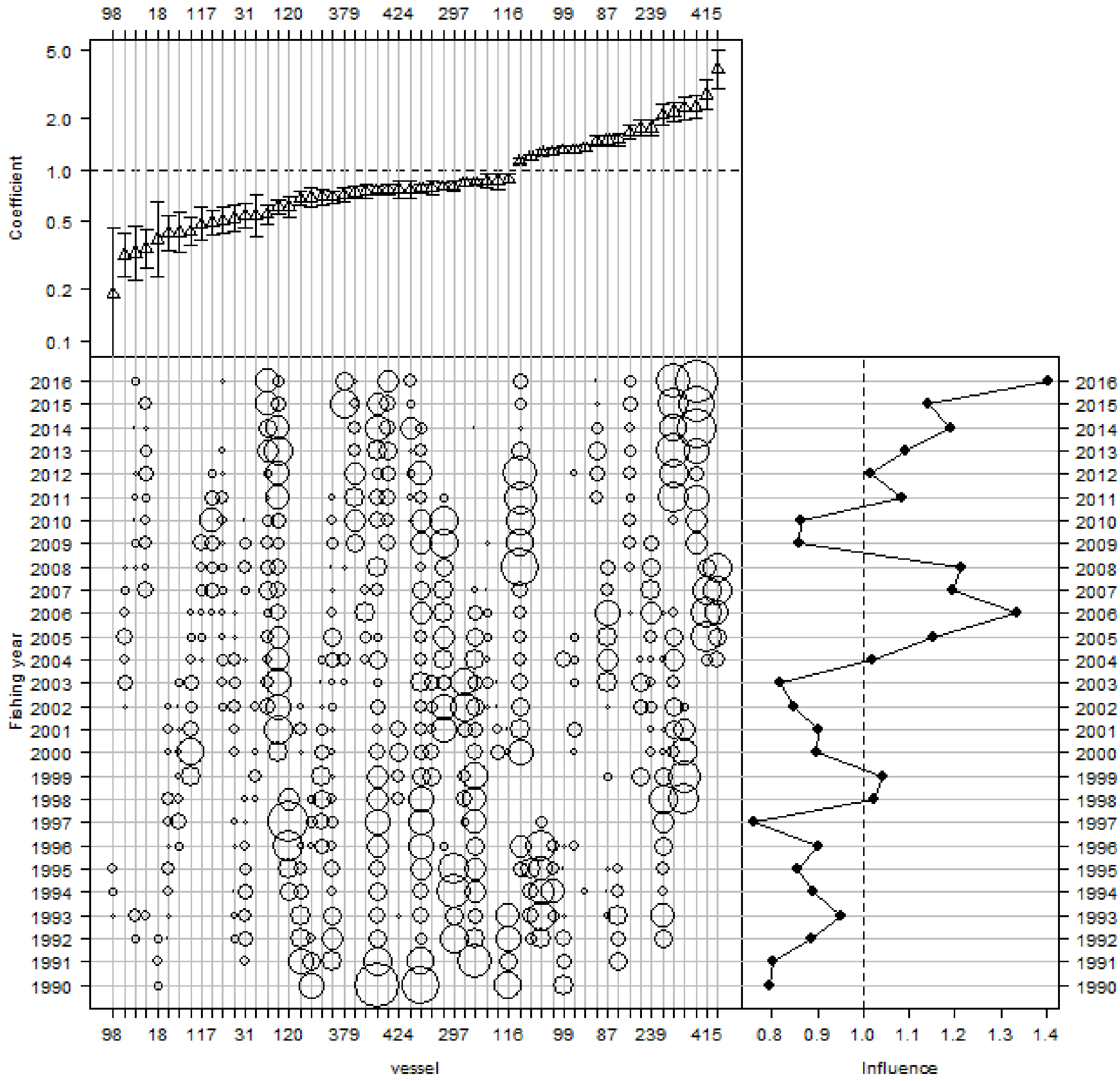

Figure F.8: Effect of vessel in the log-logistic model for the ling BLL(MIX2) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

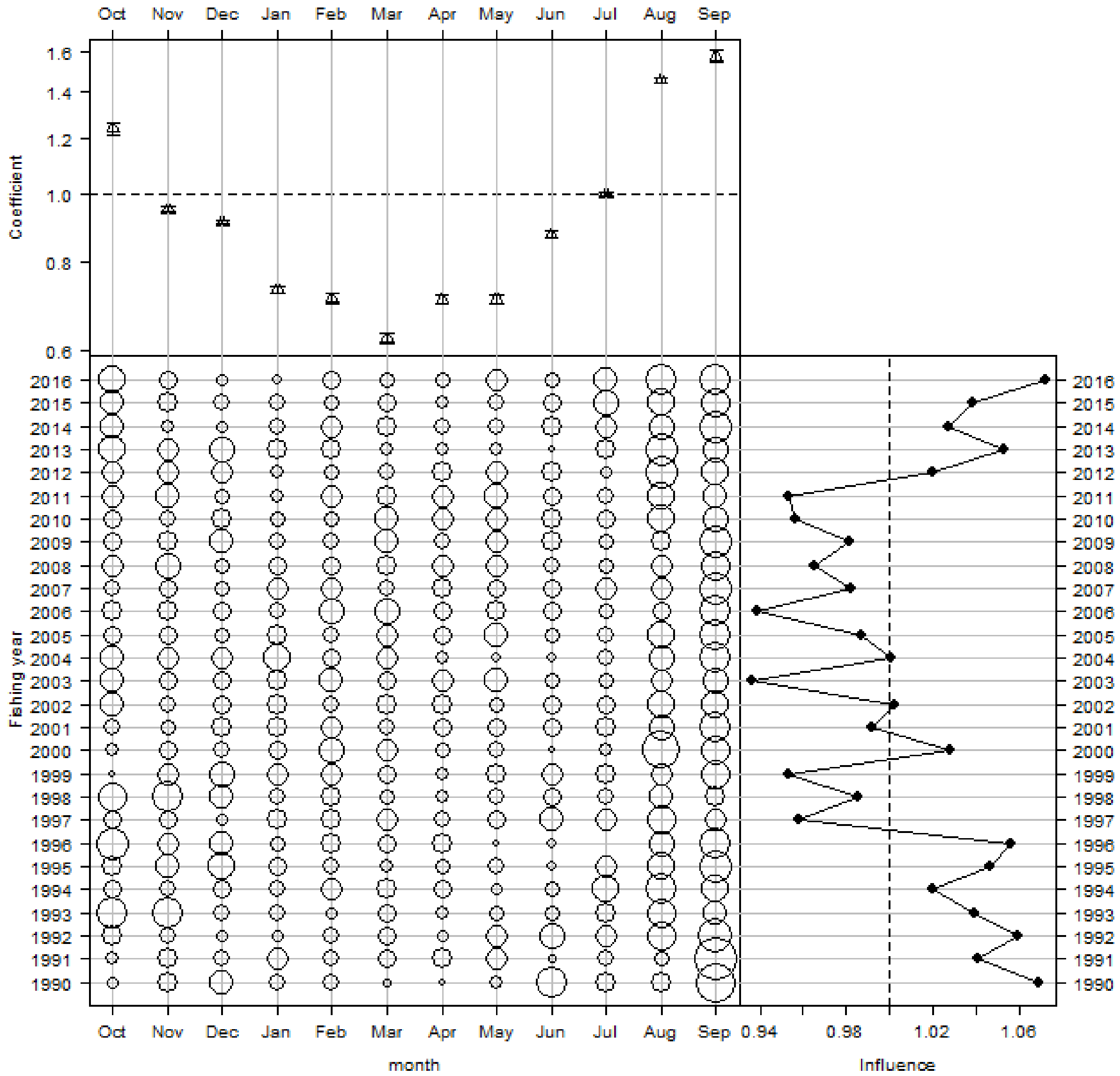

Figure F.9: Effect of month in the log-logistic model for the ling BLL(MIX2) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

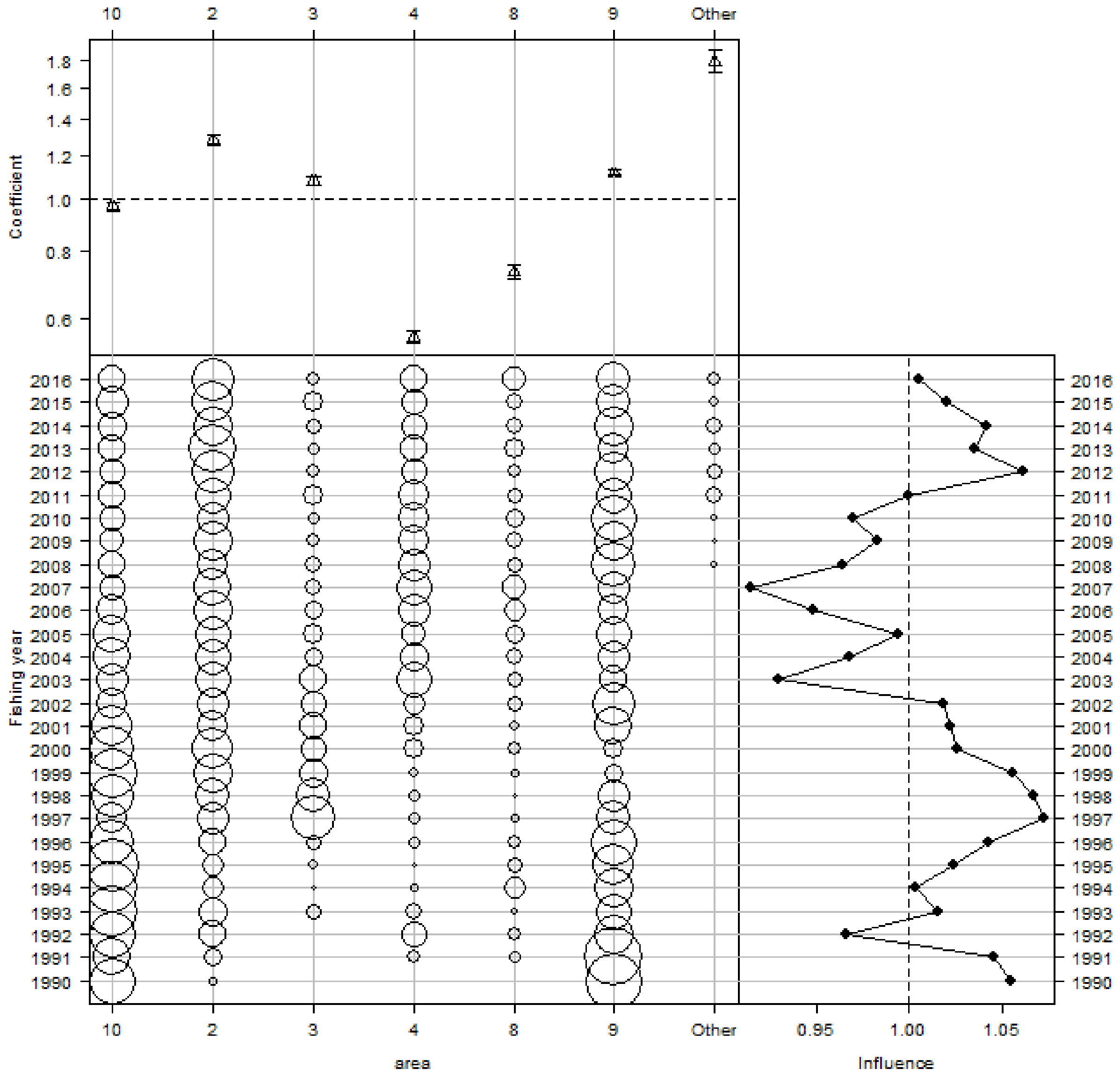

Figure F.10: Effect of area in the log-logistic model for the ling BLL(MIX2) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

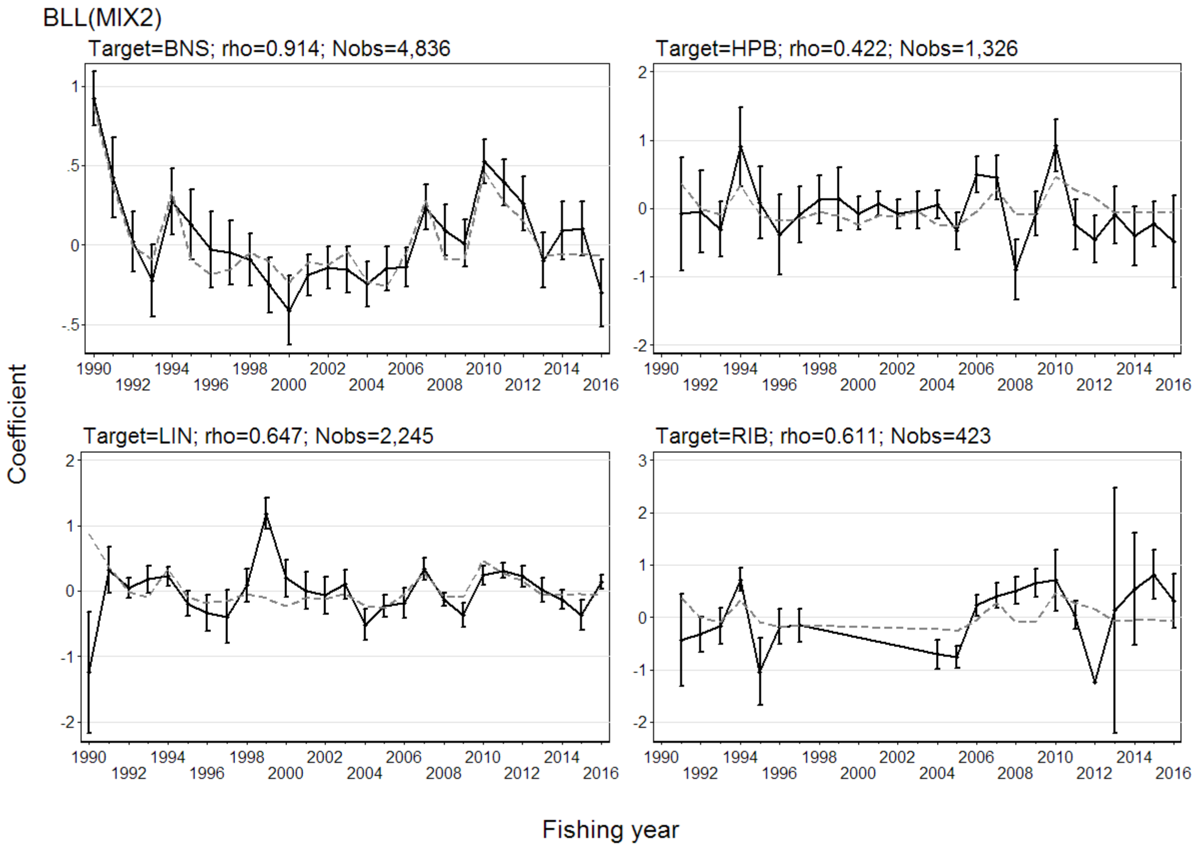

Figure F.11: Residual implied coefficients for target×fishing year interaction (interaction term not offered to the model) in the ling BLL(MIX2) log-logistic model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. These values approximate the coefficients obtained when a target × year interaction term is fitted, particularly for those target × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals. The information at the top of each panel identifies the plotted category, provides the correlation coefficient (*rho*) between the category year index and the overall model index, and the number of records supporting the category.

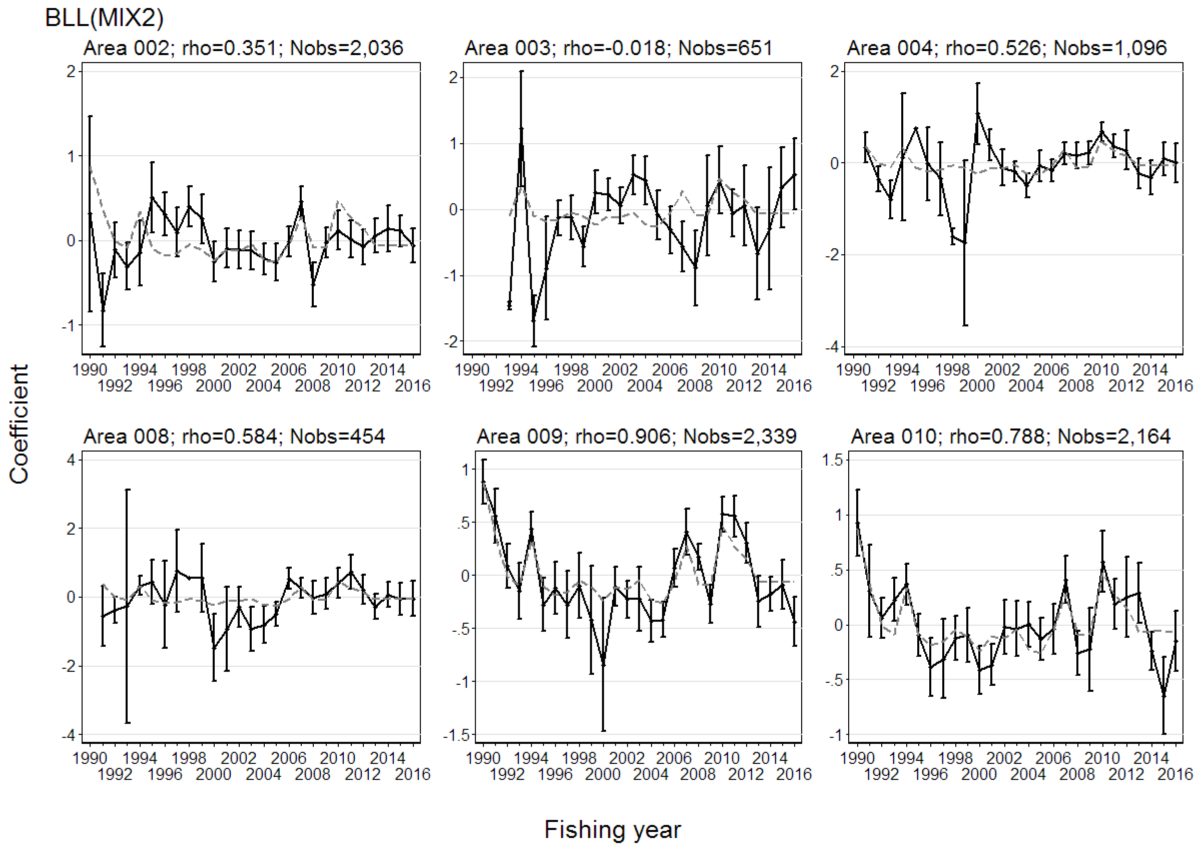

Figure F.12: Residual implied coefficients for area×fishing year interaction (interaction term not offered to the model) in the ling BLL(MIX2) log-logistic model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. 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. The information at the top of each panel identifies the plotted category, provides the correlation coefficient (*rho*) between the category year index and the overall model index, and the number of records supporting the category.

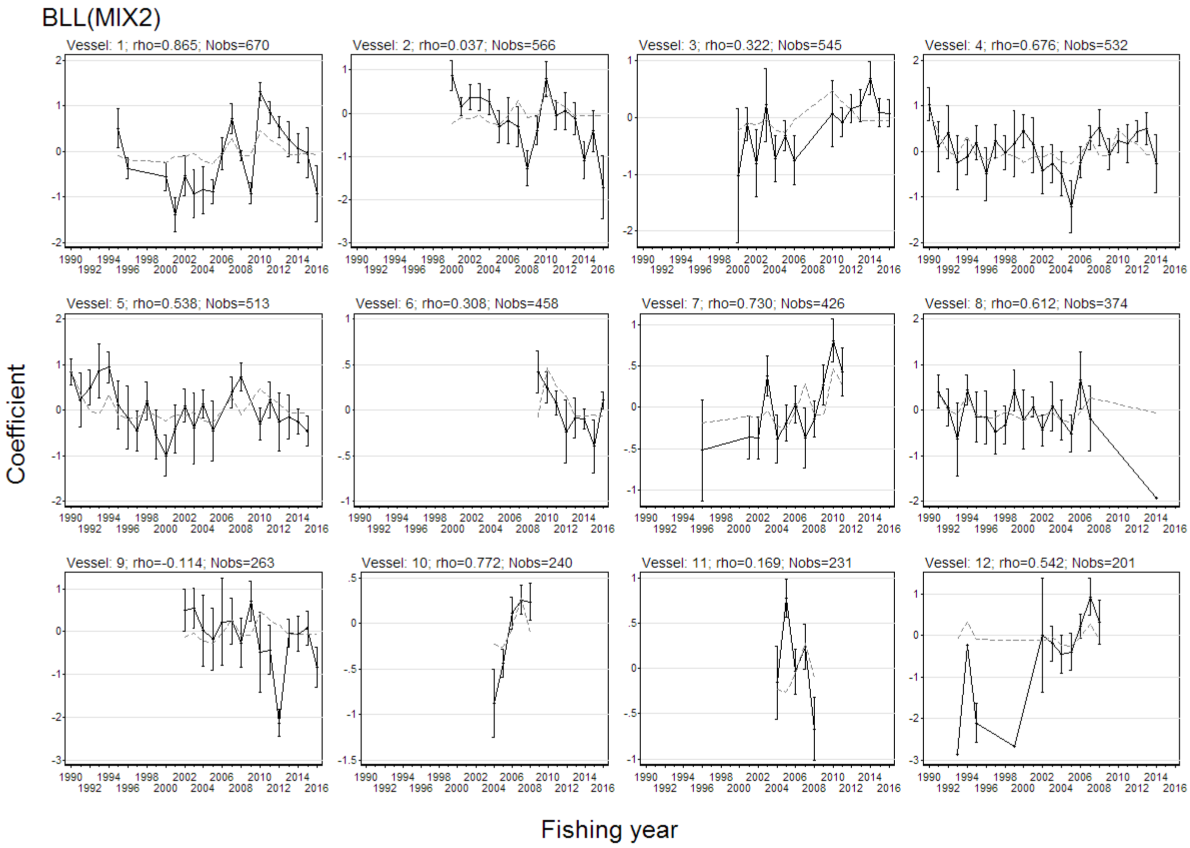

Figure F.13: Residual implied coefficients for the top 12 vessels (in terms of number observations) in the vessel×fishing year interaction (interaction term not offered to the model) in the ling BLL(MIX2) log-logistic model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and vessel. These values approximate the coefficients obtained when a vessel × year interaction term is fitted, particularly for those vessel × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals. The information at the top of each panel identifies the plotted category, provides the correlation coefficient (*rho*) between the category year index and the overall model index, and the number of records supporting the category.

F.10 Presence/absence (binomial) catch model selection table

Two explanatory variables entered the model after fishing year (Table F.3), with all other variables, including the effort variables, being non-significant. A plot of the model is provided in Figure F.14 and the CPUE indices are listed in Table F.4.

Table F.3: Order of acceptance of variables into the binomial model of presence/absence of ling catches in the BLL(MIX2) fishery model for core vessels (based on the vessel selection criteria of at least 5 trips in 4 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	27	-14 320	28 694	4.3	*
target	30	-11 917	23 893	30.2	*
vessel	86	-10 958	22 087	**39.1**	*
area	92	-10 890	21 964	39.7	
month	103	-10 828	21 862	40.2	
poly(log(hooks), 3)	106	-10 809	21 829	40.4	
poly(log(sets), 3)	109	-10 796	21 810	40.5	

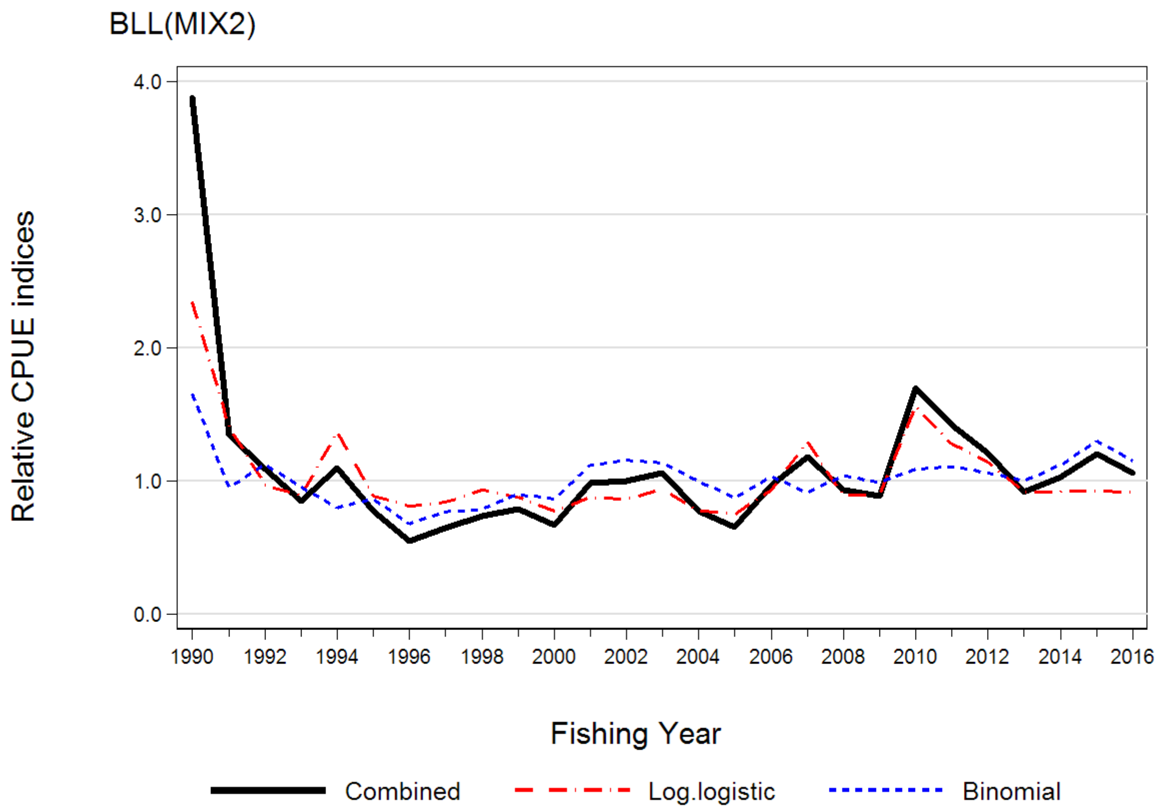

Figure F.14: Relative CPUE indices for ling using the log-logistic non-zero model based on the BLL(MIX2) fishery definition, the binomial standardised model using the logistic distribution, and the combined model using the delta-lognormal procedure (Eq. D.4).

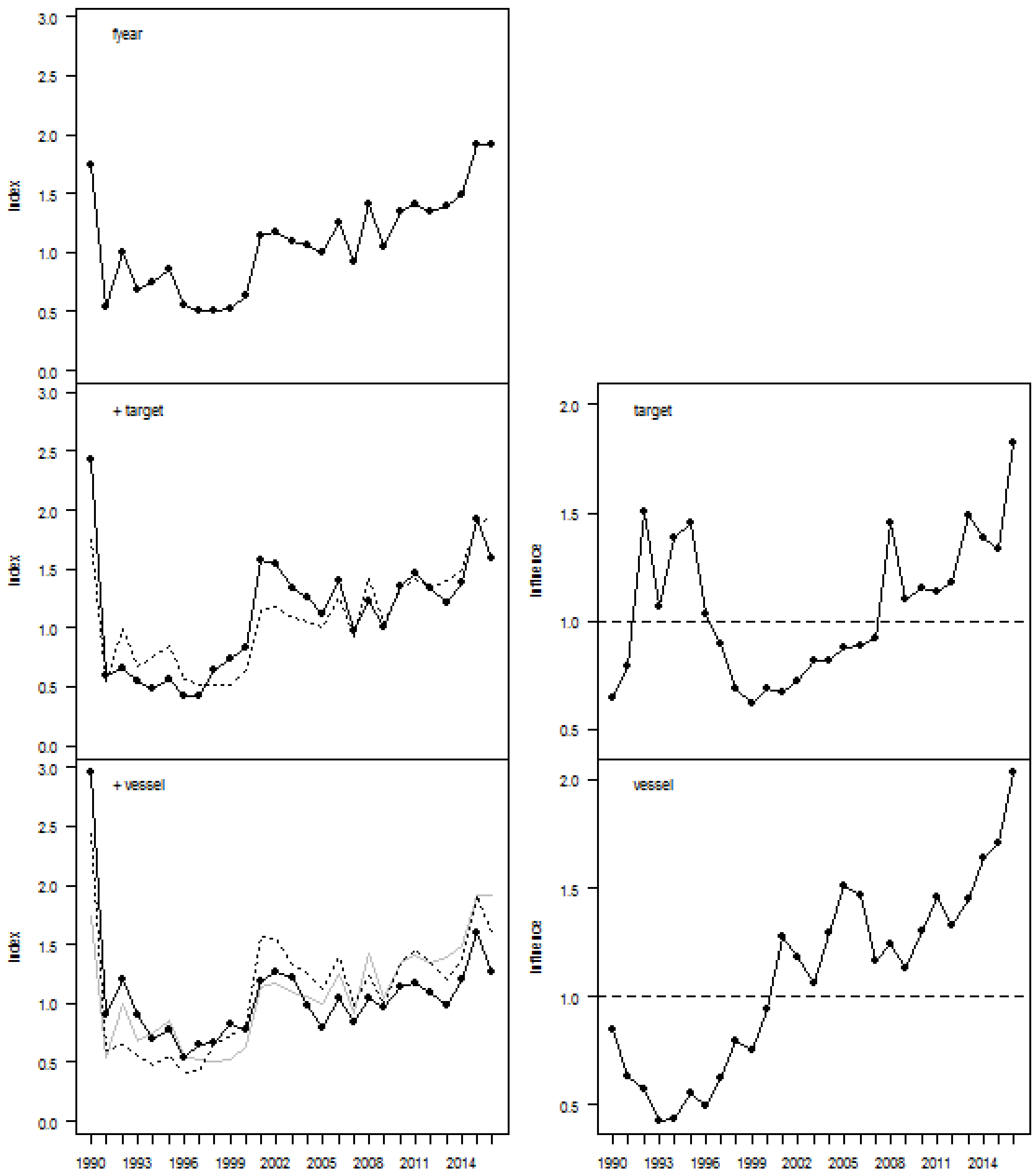

Figure F.15: [left column]: annual indices from the binomial presence/absence model of BLL(MIX2) at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

F.11 Model coefficients

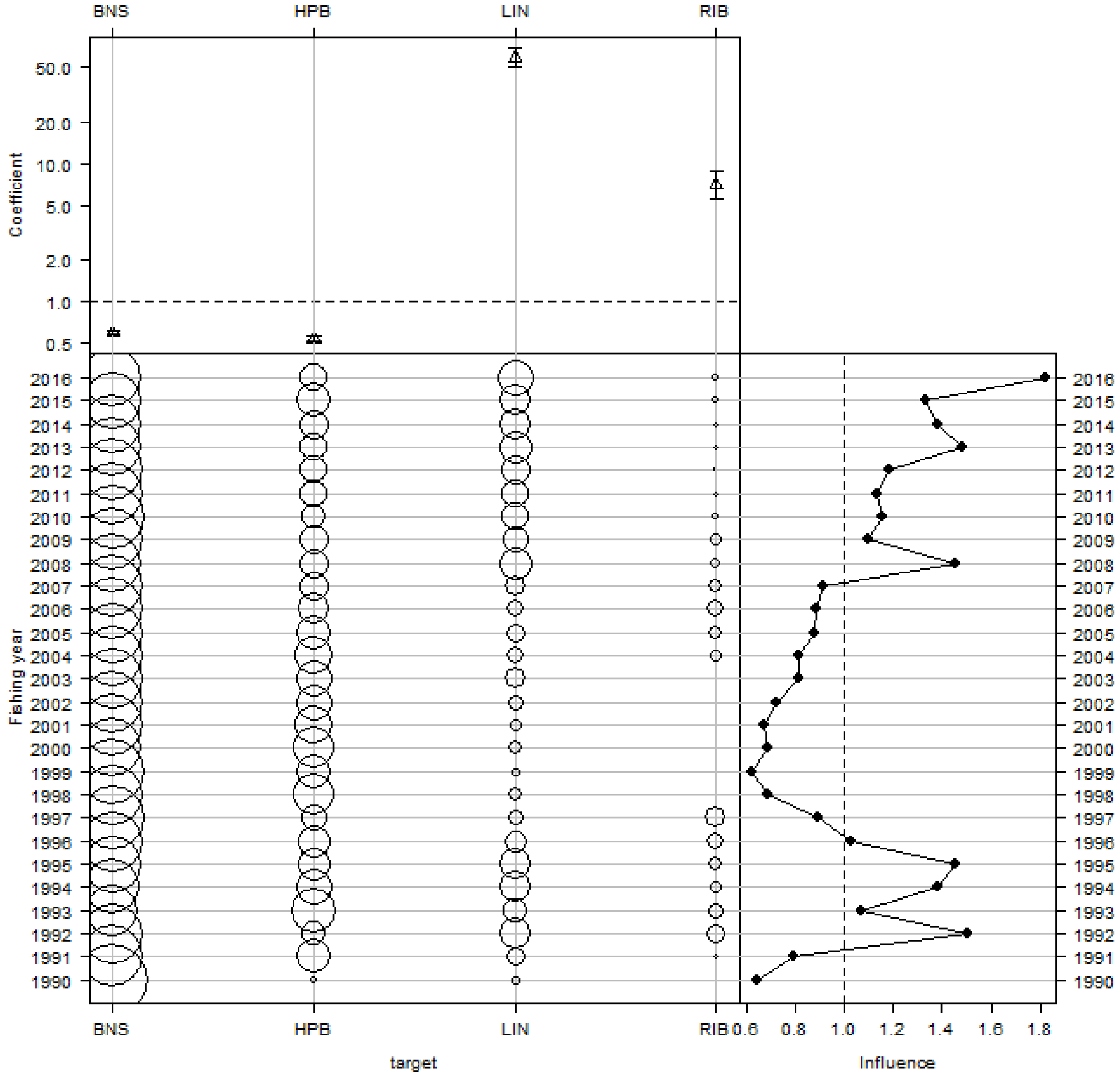

Figure F.16: Effect of target in the binomial presence/absence model for the ling BLL(MIX2) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

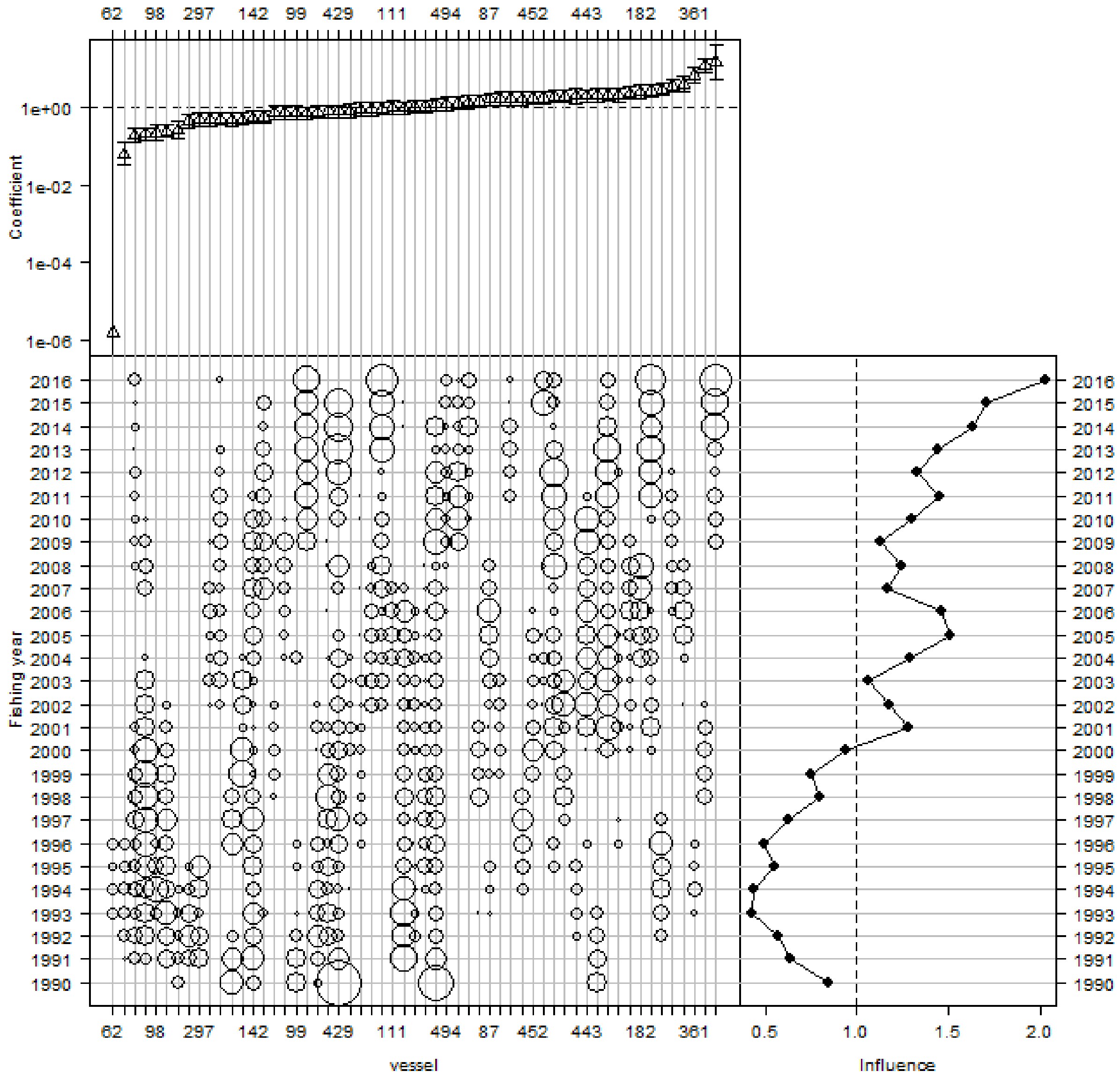

Figure F.17: Effect of vessel in the binomial presence/absence model for the ling BLL(MIX2) fishery. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

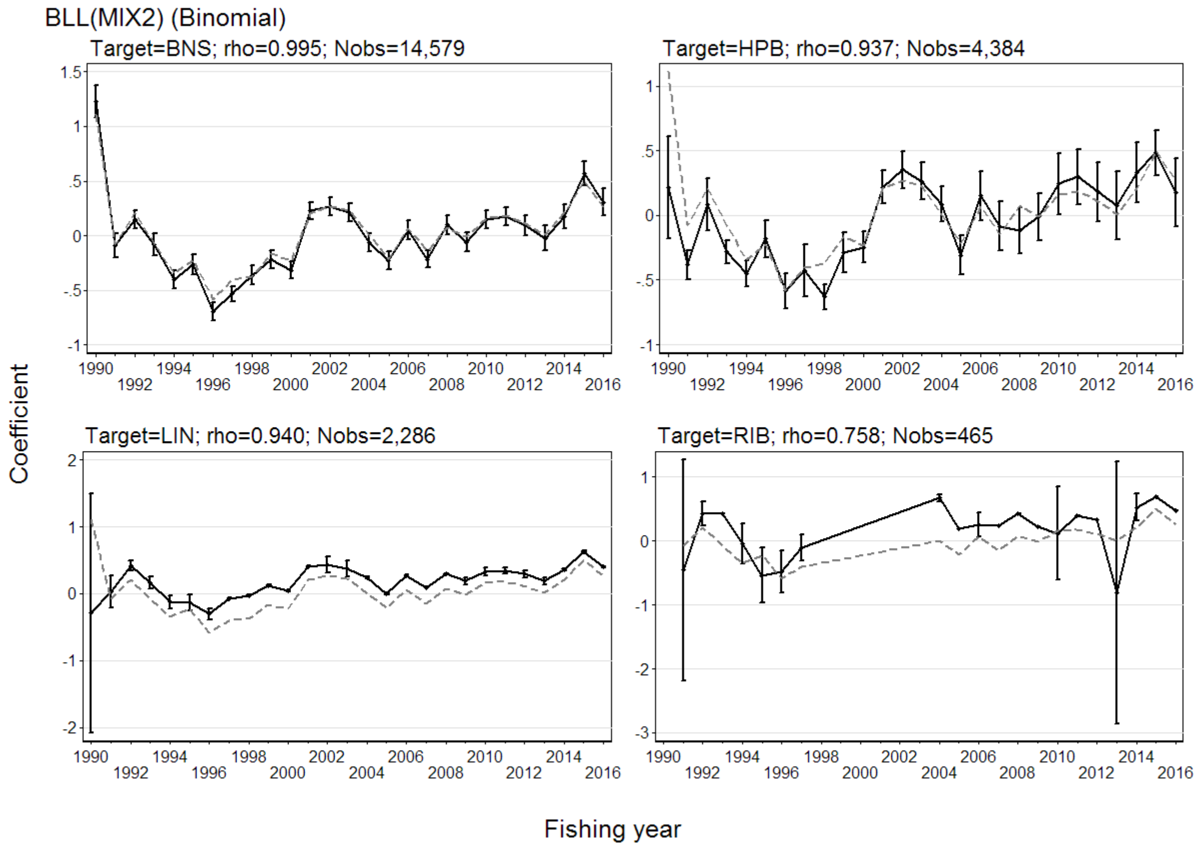

Figure F.18: Residual implied coefficients for target×fishing year interaction (interaction term not offered to the model) in the ling BLL(MIX2) binomial model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. These values approximate the coefficients obtained when a target × year interaction term is fitted, particularly for those target × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals. The information at the top of each panel identifies the plotted category, provides the correlation coefficient (*rho*) between the category year index and the overall model index, and the number of records supporting the category.

F.12 CPUE indices

Table F.4: Arithmetic indices for the total and core data sets, geometric and log-logistic standardised indices and associated standard error (SE), as well as binomial and combined series for the core data set by fishing year for the BLL(MIX2) analysis. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1990	0.648	0.717	1.329	2.345	0.1051	1.654	3.879
1991	0.659	0.795	1.234	1.415	0.1050	0.950	1.345
1992	1.180	1.271	1.550	0.969	0.0712	1.123	1.088
1993	0.915	1.114	1.299	0.894	0.0812	0.952	0.851
1994	1.199	1.329	2.437	1.368	0.0759	0.800	1.094
1995	1.227	1.094	1.407	0.891	0.0760	0.867	0.772
1996	1.055	0.939	1.233	0.813	0.0872	0.678	0.552
1997	0.497	0.501	0.951	0.840	0.0889	0.769	0.646
1998	0.370	0.356	0.662	0.934	0.0824	0.786	0.734
1999	0.305	0.333	0.420	0.880	0.0912	0.901	0.792
2000	0.513	0.550	0.383	0.772	0.0782	0.864	0.667
2001	0.656	0.483	0.366	0.878	0.0587	1.119	0.982
2002	0.630	0.627	0.425	0.863	0.0595	1.159	1.000
2003	0.831	0.902	0.389	0.938	0.0635	1.133	1.062
2004	0.798	0.681	0.542	0.778	0.0566	0.999	0.777
2005	1.090	0.849	0.679	0.754	0.0608	0.872	0.657
2006	1.180	0.873	0.851	0.933	0.0635	1.036	0.967
2007	1.189	1.147	1.331	1.294	0.0653	0.912	1.181
2008	1.608	1.506	1.483	0.893	0.0588	1.040	0.929
2009	0.873	0.942	0.993	0.896	0.0640	0.990	0.887
2010	1.629	1.648	1.457	1.561	0.0613	1.091	1.703
2011	1.634	1.749	1.444	1.282	0.0595	1.107	1.419
2012	2.223	2.334	1.590	1.140	0.0657	1.063	1.211
2013	1.995	2.337	1.710	0.917	0.0739	1.002	0.919
2014	1.511	1.672	1.483	0.921	0.0725	1.121	1.032
2015	1.719	1.784	1.121	0.928	0.0669	1.300	1.206
2016	2.689	2.638	2.003	0.916	0.0733	1.154	1.057