Ministry for Primary Industries
Manatū Ahu Matua

Review of the longline fishery for ling (*Genypterus blacodes*) in LIN 2, and an update of the CPUE abundance index

New Zealand Fisheries Assessment Report 2015/6

M.-J. Roux

ISSN 1179-5352 (online)
ISBN 978-0-477-10547-7 (online)

February 2015

New Zealand Government

Growing and Protecting New Zealand

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-resources/publications.aspx
http://fs.fish.govt.nz go to Document library/Research reports

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Roux, M.-J. (2015). Review of the longline fishery for ling (*Genypterus blacodes*) in LIN 2, and an update of the CPUE index.

***New Zealand Fisheries Assessment Report 2015/6.* 26 p.**

The status of commercial fisheries for ling in FMA 2 was reviewed and estimated catch and effort data from target ling bottom longline fisheries in ECNI Statistical Areas 011–015 were used to update the CPUE abundance index for LIN 2.

The line data were rolled up by vessel/day/statistical area to ensure consistency in effort. A top-5 filter was applied which retained estimated catch from the top five species in each fishing event. This was done to adjust for an increase in reporting precision in recent form types (LTCER and LCER) relative to the older CELR format.

Reductions in catches of ling in trawl fisheries have been occurring since the early and mid-2000s. In contrast, ling catches have remained generally consistent in line fisheries, however with some increase in effort (vessel days) and fishing power (vessel-specific daily number of hooks set).

A lognormal GLM model was fitted to a core vessel fleet consisting of vessels that fished for a minimum of four years and contributed at least 10 fishing days per year. The model selected *vessel*, log(*total hooks)* and *month* as explanatory variables explaining 32% of the deviance in CPUE together with *fishing year* (forced).

The standardised indices demonstrate an initial decline from 1992 to 2001, followed by a period of apparent stability (2002–2005) and a decreasing trend with lower CPUE in 2012–2013. This trend is consistent with the previous assessment.

Sensitivity testing of the CPUE time series was carried out by fitting alternative models to alternative sets of input data and/or explanatory variables. The GLM analysis was generally robust to all sensitivities investigated.

The standardised CPUE index indicates an ongoing decline in the relative abundance of ling in FMA 2.

1. INTRODUCTION

Line fisheries for ling in FMA 2 were previously described by Horn (2003) including data from the 1990–2001 fishing years. Abundance indices were developed using commercial catch and effort data from East Coast North Island (ECNI) Statistical Areas 011, 012, 013, 014 and 015 and Cook Strait (Statistical Areas 016 and 017) (Figure 1). The standardized CPUE for the targeted fishery in ECNI demonstrated a decreasing trend and was deemed to constitute a reliable index of abundance (Horn 2003).

The purpose of the present work is to update the analysis carried out by Horn (2003), including a review of line fisheries in LIN 2 to establish that the CPUE approach and analyses are valid.

2. METHODS

2.1 Data sources and data grooming

Estimated catch and effort data from lining methods (bottom longline (BLL), drop/Dahn lines (DL) and trot lines (TL)) and fishing events that targeted ling, bluenose *Hyperoglyphe antarctica* and hapuku *Polyprion oxygeneios* and/or bass *Polyprion americanus* in FMA 2 between 1 October 1989 and 30 September 2013 were extracted from the fishery statistics database managed by the Ministry for Primary Industries (MPI) and used for analyses. Data from an earlier extract containing all fishing events from all methods that targeted or caught ling throughout the entire EEZ were also used for characterisation purposes.

The dataset was characterised by a transition from data being reported by fishers on CELR forms (Catch Effort Landing Return) to LCER forms (Lining Catch Effort Return) (beginning in 2004) and LTCER forms (Lining Trip Catch Effort Return) (beginning in 2008). This was linked to an increase in reporting precision caused by an increase in the number of species that can be reported in recent form types (up to eight species per fishing event) relative to the older CELR format (maximum five species per day/statistical area). To remove any bias, a ‘top5 filter’ was applied to individual fishing events, which consisted in dropping catches from any species in excess of the five most abundant (by weight) in the catch.

Discrepancies in the number of fishing events (line sets) effectively conducted and reported on a daily basis occurred in the lining data. To ensure consistency in effort, the data were rolled up by vessel, day and statistical area, similar to previous assessment (Horn 2003). Daily spatial coordinates available in LCER/LTCER data were estimated by median imputation.

All data were checked for errors and outliers using simple checking and range checks. Records with missing catch, species, total hooks or statistical area information were excluded from the final dataset. There were instances in which reported numbers of hooks and sets had been inversed and the data was transposed accordingly. Outliers were either corrected by median imputation on larger ranges of data or the record was removed from the dataset.

2.2 Data selection

Bottom longline, target ling data from ECNI Statistical Areas 011–015 were grouped for analyses and are compiled by fishing year in Table 1. Unstandardized (raw) CPUE were calculated as the annual mean catch per vessel-day. Daily number of hooks were constrained to a minimum of 50. The number of sets field contained a large number of missing values and was not considered for analyses.

Dahn line and trot line effort were excluded in order to avoid potential bias caused by catchability differences between lining methods.

The first two fishing years (1990 and 1991) had distinctively less effort and lower catch relative to the remainder of the time series (Table 1). Both years accounted for a steep initial decline (at least 30%) in the CPUE index in the previous assessment (Horn 2003). Thus, 1990 and 1991 were here defined as ‘exploratory fishing years’ and excluded from analyses.

The occurrence of zero catch averaged 1% of the effort strata from 1992 to 2013 and did not exceed 3–4% on an annual basis (Table 1). No trend in the occurrence of zero catch was visible over time. Zero observations were thus removed from analyses, similar to previous assessments (Horn et al. 2013).

The data were restricted to vessels that were in the fishery for at least four years and contributed a minimum of 10 fishing days per year. The four-year threshold was decided in consultation with the working group and deemed appropriate to estimate vessel coefficients. Among the selected (core) vessels, one ‘autoliner’ was characterized by distinctively higher fishing power (as daily number of hooks) relative to the remainder of the fleet. Inclusion of data from this vessel caused residual diagnostics problems during earlier runs. The working group recommended excluding this vessel from the final dataset.

2.3 Selected variables

Variables considered for CPUE standardisation are described in Table 2 and are generally similar to those considered in earlier ling CPUE analyses (e.g. Horn et al. 2013).

CPUE was defined as catch per day (i.e. daily estimated catch (in tonnes) by a vessel in a statistical area) and number of hooks set per day was offered as an explanatory variable. Catch per day (rather than catch per hook) was used to estimate CPUE as the relationship between catch per hook and number of hooks set per day is nonlinear (Horn 2002).

Total hooks set per day ranged from 100–18 050 in the final dataset and 100–38 000 hooks when including data from the outlier (autoliner) vessel (in sensitivity analysis). *Total hooks* was offered as both an untransformed and log-transformed continuous variable, and as a categorical variable consisting of 12 groups of 1000 hooks (ranging from fewer than 1000 to more than 10000 hooks per day).

Fishing year (Oct 1–Sep 30) was used to characterize year effects. Fishing year was rounded to the next calendar year (i.e. the fishing year beginning on 1st October 1989 and ending on 30th September 1990 is referred to as 1990).

Day, month and *oceanographic season* were included to allow temporal variations within fishing years.

Vessel was included to allow for differences in fishing power and/or efficiency within the fleet. Spatial variations were accounted for by including *statistical area*.

2.4 CPUE standardisation/GLM analyses

The commercial CPUE index of abundance was updated following the CPUE standardisation method described in Horn et al. (2013, Appendix B). Estimates of relative year effects were obtained from a stepwise multiple regression method, where the data were fitted using a lognormal model on log-transformed, non-zero catch-effort data. A forward stepwise Generalised Linear Model (Chambers & Hastie 1991) implemented in R code (R Development Core Team 2014) was used to select among explanatory variables offered in the saturated model. *Fishing year* was forced into the model as the first term, and the algorithm added variables based on changes in residual deviance. The explanatory power of a particular model is described by the reduction in residual deviance relative to the null deviance defined by a simple intercept model (R^2). Variables were added to the model up to a 2% improvement in explained residual deviance.

Since the primary interest was here to characterize relative year effects, potential interactions between explanatory variables and *fishing year* were not considered. Other possible interactions between explanatory variables including *vessel*, *total hooks*, and *month* were found to be unbalanced (i.e. not all vessels used all number of hooks per day or fished in all months), thereby leading to unrealistic coefficient values. For this reason, interaction terms were included as a sensitivity check but excluded from the final model.

The standardised indices were calculated using GLM, with associated standard errors. Indices are presented using the canonical form (Francis 1999) so that the year effects were standardised to have a geometric mean of 1. The CVs represent the ratio of the standard error to the index. The 95% confidence intervals were calculated for each index. Unstandardised CPUE were derived for each year from the available catch-effort data as the mean individual daily catch (t) per vessel-day.

Model fits were investigated using standard residual diagnostics. A plot of residuals against fitted values and a plot of residuals against quantiles of the standard normal distribution were produced to check for departures from the regression assumptions of homoscedasticity and normality of errors in log-space (i.e., log-normal errors).

The influence of each explanatory variable in the final model was quantified and described using the ‘overall influence’ statistic and coefficient-distribution-influence (CDI) plots (Bentley et al. 2012). ‘Overall influence’ measures the extent to which a variable changes CPUE from year to year and is expressed as a percentage. Influence plots depict the combined effects of (a) the expected log catch for each level of the variable (model coefficients) and (b) the distribution of the levels of the variable in each year (distributional changes), thereby describing the influence that the variable has on the unstandardised CPUE in the standardisation.

The sensitivity of the CPUE index was tested by fitting a number of different models to alternative sets of input data and/or using different explanatory variables. Alternative scenarios included an interaction model, all-target model, ECNI-Cook Strait model, recent-period (2001–2013) model, and a model including data from one outlier (autoliner) vessel (Table 3).

2.5 Anecdotal information

Anecdotal information was collected during informal discussions with commercial fishers of the LIN 2 fleet and other FMA 2 stakeholders. This information, consisting of facts and observations, is summarized in point format and used to inform the discussion.

3. RESULTS

3.1 Fishery review and characterization

Lining methods account for most of the estimated ling catch from FMA 2 (Figure 2A). Line catches have generally remained consistent over time. In contrast, there has been a reduction in catches of ling in mid-water and bottom trawl fisheries since the early/mid 2000s (Figure 2A).

Among lining methods, bottom longline (BLL) clearly dominates the fishery, on average contributing 94% of the estimated ling catch over the time series (Figure 2B). The vast majority of ling are caught in the targeted fishery (Figure 3a). Target ling bottom longline effort has remained consistent over time while effort targeting bluenose has increased in recent years, peaking in 2008–2010 (Figure 3a). Changes in bluenose effort had no obvious impacts on the ling fishery, with most ling (at least 94%) still being caught by target ling effort in the mid- and late-2000s (Figure 3A, Table 4).

Ling, bluenose and hapuku and bass are the main commercial species caught in FMA 2 BLL fisheries (Figure 4). Other species include ribaldo *Mora moro*, gemfish *Rexea spp.*, school shark *Galeorhinus galeus*, alfonsino and long-finned beryx *Beryx splendens* and *B. decadactylus*, rough skate *Zearaja nasuta*, and shovelnose spiny dogfish *Deania calcea*. The ECNI statistical areas support a mixed species fishery (Figure 4A). Catches of bluenose predominate in offshore areas 201–206 (Figure 4B). Within Cook Strait, catches of ling dominate in area 016 while hapuku and bass and other species are mainly caught in area 017 since 1996 (Figure 4C).

The ECNI statistical areas (011–015) accounted for 86% of the effort that targeted or caught ling and 82% of the estimated ling catch from FMA 2 bottom longline fisheries in 1990–2013. Together, ECNI and Statistical Area 016 (in Cook Strait) explained 98% and 96% of total catch and effort, respectively. Area 016 supports as much bottom longline effort as some ECNI areas on an annual basis (Figure 3B). From 1999 to 2007, area 016 accounted for more than 20% of total ling catches in bottom longline fisheries (Figure 3B). Examination of spatial effort distribution in recent years (2008–2013) indicates that target ling effort is spatially continuous from Statistical Area 011 (at the FMA 1 boundary) to Statistical Area 016 (in Cook Strait) (Figure 5). The available information suggests that Statistical Areas 011–016 constitute one fishery for ling. Few catches of ling occur in offshore Statistical Areas 201–206 (Figure 3B).

3.2 CPUE standardisation

The final (core vessels) dataset retained 67% of the effort and 61% of the ling catch and are summarized in Table 5. Temporal differences in fleet composition and vessel-specific effort (in vessel-days) between the raw and final datasets are shown in Figure 6. Nominal catch and effort information by fishing year are similarly contrasted in Figure 7.

The final data consisted of 5126 vessel-days performed by a total of 25 vessels over 22 years. Effort was characterized by a change in fleet composition mainly occurring around 2000–2001 (Figure 6). Some of the vessels present in earlier years (1990s) dropped out of the fishery in 2000, while new vessels appeared in the early- and late- 2000s (Figure 6). Fishing years 2001–2006 constitute the 'overlapping period' during which time vessels from pre/post 2000 fleets fished simultaneously.

The core vessels selection served to dampen the observed changes in fleet. The selection criteria (at least four years in the fishery) excluded a number of vessels that were in the fishery only in 2012–2013 and contributed a large amount of effort with limited catch (Figure 6, Figure 7A).

The core dataset time series is characterized by two distinct periods of increase in effort: 1) increasing effort from 1992–1994 to 1998–1999; and 2) increasing effort from 2002 to 2011 (Figure 7B). These were associated with a period of decrease in nominal CPUE from 1994 to 2001, and a period of apparent stability in CPUE in 2002–2009 followed by a decreasing trend (Figure 7B).

A greater proportion of the annual ling catch is generally taken from Statistical Areas 013, 014 and 015 relative to 011 and 012 (Figure 3B). However, statistical area was not selected during model runs, indicating that the all-areas model was appropriate.

The lognormal model explained a total of 32% of the deviance in the ECNI target ling bottom longline CPUE. Four variables were selected with *fishing year*, *vessel*, log(*total hooks)* and *month* sequentially explaining 6%, 17%, 25% and 32% of the total deviance (Table 6). *Total hooks* had the most overall influence (13%), followed by vessel (9%) and month (4%) (Table 6). The lognormal standardised CPUE indices are compiled in Table 7.

The standardised year effects demonstrate an initial decline from 1992 to 2001 followed by a period of apparent stability in 2002–2005 and a decreasing trend with lower CPUE in 2012–2013. The unstandardized (raw) index instead suggested stability from 2002 to 2009 (Figure 8A). Residuals diagnostics are shown in Figure 9.

Influence plots illustrate contrasting changes in fleet efficiency and fishing power (as *total hooks*) over the time series (Figure 10A and 10B). In 1992–2000, the fishery was characterised by greater proportions of higher coefficients vessels using fewer hooks per day. In contrast, more vessels of generally lower efficiency (coefficients) but greater fishing power as *total hooks* fished in 2001–2013. An increase in fishing power as *total hooks* characterized the time series, with influence ranging between 0.7 and 1.3 (Figure 10B). Month had comparatively limited influence ranging from 0.9 and 1.1 in most years except 1997 and 2013 (Figure 8C). The influence of month was enhanced by comparatively more (1997) or less (2013) fishing occurring outside the main fishing season from August to November.

The standardised CPUE indices were consistent across all scenarios examined (Figure 11). Allowing interaction terms in the lognormal model or including data from an outlier vessel contributed to increase the level of explained deviance (44% and 42% respectively), however with limited or no impacts on the resulting index but rather obvious residuals diagnostics or coefficients estimation problems (Table 3, Figure 11). Including Statistical Area 016 in the input dataset caused a sharper increase in the standardised CPUE from 2001 to 2002, followed by a continuous decline (Figure 11). The all target model produced a slightly different trend, corresponding to an increase in CPUE from 2001 to 2007 followed by a steeper decline (Figure 11). Model fitting to post-2000 data resulted in an almost identical index (Figure 11), indicating that pre/post 2000 changes in fleet composition, fishery efficiency and fishing power were well accounted for by the lognormal model.

3.3 Anecdotal information – input from commercial fishers

- Bottom longline fisheries in FMA 2 use similar baits (mainly squid and barracouta) for all target species.
- More vessels are setting more hooks per day. However, when setting more hooks, not all hooks (perhaps only 80–90%) are baited.
- Fishing practices and spatial effort distribution differ between target ling and mixed target fisheries. More hooks can be set on ‘easier’ grounds when targeting ling, as opposed to mixed species effort which is typically conducted on ‘harder’ grounds.
- Ling aggregations are mainly encountered in August and September in FMA 2, whereas the species is widely dispersed for 5–6 weeks from December to February.
- There are no obvious differences in ling caught from ECNI, Cook Strait and FMA 1.
- Variations in effort within and among fishing years are related to weather patterns and tuna fisheries, the later determining fleet availability.

4. DISCUSSION

The ECNI Statistical Areas 011–015 support a mixed species bottom longline fishery in which target ling effort on average contributed about half the total estimated ling catch from FMA 2 (all methods/fisheries) from 1992 to 2013. The consistency of commercial bottom longline fisheries for ling in ECNI support the use of these data for developing an abundance index for the species in FMA 2.

The standardised CPUE index of abundance demonstrates an initial decline from 1992 to 2001 that is consistent with the unstandardized nominal CPUE (Figure 8A) and previous assessment (Horn 2003) (Figure 8B). This is followed by a period of apparent stability in 2002–2005 and a decreasing trend with lower CPUE in 2012–2013. This pattern was consistent across all models fitted to alternative sets of input data and/or explanatory variables.. The updated CPUE index indicates an ongoing decline in relative abundance of ling in FMA 2.

The fishery review indicated that target ling bottom longline fisheries are spatially continuous from Statistical Area 011 (at the FMA1 boundary) to Statistical Area 016 (in Cook Strait). Area 016 may contribute substantial catch and effort information for ling on an annual basis. Including data from Statistical Area 016 in GLM analyses resulted in a similar CPUE index, however with a continuous decline since 2002. Further work on ling stock structure, as this relates to the spatial extent of line fisheries and stock assessment for the species, is recommended.

Anecdotal information revealed both similarities (bait) and potential differences in fishing grounds and fishing power (as number of hooks) between ling target and mixed target bottom longline effort in FMA 2. More input from commercial fishers should be sought and may be used effectively to inform commercial catch and effort data and provide guidelines for future work and investigations.

5. ACKNOWLEDGMENTS

Thanks are extended to Peter Horn and Sira Ballara for their assistance and guidance with data grooming and analyses, and to Ian Doonan for reviewing an earlier report draft. Pat Reid (Area 2 Inshore Finfish Management Company) and two anonymous skippers contributed anecdotal knowledge information. This work was funded under Ministry for Primary Industries project SEA201301, LIN 2.

6. REFERENCES

Bentley, N.; Kendrick, T.H.; Starr, P.J.; Breen, P.A. (2012). Influence plots and metrics: tools for better understanding fisheries catch-per-unit-effort standardizations. *ICES Journal of Marine Science 69(1)*: 84–88.

Chambers, J.M.; Hastie, T.J. (1991). Statistical models in S. Wadsworth & Brooks/Cole, Pacific Grove, CA. 608 p.

Francis, R.I.C.C. (1999). The impact of correlations in standardised CPUE indices. New Zealand Fisheries Assessment Research Document 99/42. 30 p. (Unpublished report held in NIWA library, Wellington.)

Horn, P.L. (2002). CPUE from commercial line fisheries for ling (*Genypterus blacodes*) around the South Island (Fishstocks LIN 3, 4, 5, 6, and 7). *New Zealand Fisheries Assessment Report 2002/17*. 32 p.

Horn, P.L. (2003). CPUE from commercial fisheries for ling (*Genypterus blacodes*) around the North Island, New Zealand: an evaluation of series for LIN 1, LIN2, and Cook Strait. *New Zealand Fisheries Assessment Report 2003/13*. 49 p.

Horn, P.L.; Dunn, M.R.; Ballara, S.L. (2013). Stock assessment of ling (*Genypterus blacodes*) on the Chatham Rise (LIN 3&4) and in the Sub-Antarctic (LIN 5&6) for the 2011–12 fishing year. *New Zealand Fisheries Assessment Report 2013/06*. 87 p.

R Development Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. http://www.R-project.org.

Table 1: Summary of bottom longline, target ling data for ECNI Statistical Areas 011–015, 1990–2013 fishing years. All vessels and zero catch included. Vdays =annual effort as total number of vessel-days; Vessels =number of unique vessels fishing; Catch =estimated ling catch; CPUE =unstandardized annual mean CPUE (including zero catch); Zero catch =number of vessel-days with zero catch of ling expressed as a percentage relative to annual effort (Vdays).

	Vdays	Vessels	Catch (t)	CPUE (t/Vday)	Zero catch (%)
1990	147	7	112	0.80	0.7
1991	118	10	118	1.00	2.5
1992	245	18	279	1.10	0.0
1993	302	14	361	1.20	0.7
1994	335	22	361	1.10	2.1
1995	316	23	338	1.10	0.9
1996	333	25	332	1.00	2.7
1997	277	16	236	0.90	1.8
1998	307	13	373	1.20	0.7
1999	292	12	246	0.80	0.3
2000	263	16	282	1.10	0.0
2001	320	16	339	1.10	4.4
2002	269	18	361	1.30	0.0
2003	393	23	325	0.80	2.8
2004	345	23	371	1.10	1.7
2005	323	12	298	0.90	2.2
2006	294	19	320	1.10	0.3
2007	405	22	376	0.90	1.5
2008	384	21	410	1.10	0.3
2009	318	19	354	1.10	0.9
2010	438	24	373	0.90	0.2
2011	615	23	395	0.60	0.3
2012	451	24	273	0.60	0.7
2013	499	21	304	0.60	0.0

Table 2: Summary of the variables offered in CPUE models for the LIN 2 ECNI target ling bottom longline fishery. All continuous variables were offered as third order polynomials.

Variable	Type	Description
Year	Factor	Fishing year (Oct 1-Sep 30)
Month	Factor	Calendar month
Statistical area	Factor	Statistical area for the vessel-day
Vessel	Factor	Unique vessel identifier
Fishing day	Continuous	Day of the fishing year, starting October 1
Total hooks	Continuous	Number of hooks set per vessel-day in a statistical area
Log (total hooks)	Continuous	Logarithm of the variable Total hooks
Hooks (×1000 bins)	Factor	Number of hooks grouped into 12 bins of 1000 hooks.
Oceanographic season	Factor	Austral seasons delayed by a month (i.e. Spring = Oct-Dec, Fall=Apr-Jun, etc.)

Table 3: Summary of alternative lognormal models developed for sensitivity testing of the LIN 2 ECNI ling target bottom longline CPUE time series.

Model	Input data	Terms offered	R^2
Final model	BLL/statareas 011–015/target ling/positive catch/1992–2013	Table 2 variables	32
Alternative models	**Input data**	**Terms offered**	
Interaction model	BLL/statareas 011–015/target ling/positive catch/1992–2013	Table 2 variables + interactions terms between Vessel/Total hooks and Month	44
Autoliner model	BLL/statareas 011–015/target ling/positive catch/1992–2013/outlier vessel included	Table 2 variables	42
Recent-period model	BLL/statareas 011–015/target ling/positive catch/2000–2013	Table 2 variables	36
ECNI-Cook Strait model	BLL/statareas 011–016/target ling/positive catch	Table 2 variables	30
All target	BLL/statareas 011–015/targeted or caught ling/positive catch	Table 2 variables + target species	67

Table 4: Percent annual ling catch among target species (ling (LIN), bluenose (BNS) and hapuku/bass (HPB)) in FMA 2 bottom longline fisheries, 1990–2013.

	LIN target	BNS target	HPB target
1990	89.6	0.9	9.5
1991	87.8	5.6	6.6
1992	96.9	2.4	0.7
1993	96.2	3.2	0.6
1994	93.7	3.6	2.7
1995	93.4	4.5	2.1
1996	97.0	2.5	0.5
1997	97.8	1.7	0.5
1998	96.7	2.9	0.4
1999	98.4	1.5	0.1
2000	98.4	1.2	0.4
2001	98.7	0.8	0.5
2002	98.8	0.7	0.5
2003	97.8	0.9	1.3
2004	98.0	1.3	0.7
2005	97.6	1.6	0.8
2006	95.4	4.2	0.4
2007	93.9	5.3	0.9
2008	95.5	4.0	0.5
2009	95.2	3.7	1.1
2010	95.9	2.8	1.2
2011	97.0	1.8	1.2
2012	97.7	1.4	0.9
2013	97.4	0.9	1.6

Table 5: Final (core vessels) dataset summary for GLM analysis of LIN 2 ECNI target ling bottom longline fishery. Vdays =annual effort as total number of vessel-days; Vessels =number of unique vessels fishing; Catch =estimated ling catch; CPUE =unstandardized annual mean CPUE.

	Vdays	Vessels	Catch (t)	CPUE (t/Vday)
1992	160	5	207	1.30
1993	181	5	244	1.30
1994	153	6	233	1.50
1995	215	10	250	1.20
1996	251	10	284	1.10
1997	246	10	213	0.90
1998	277	9	275	1.00
1999	275	8	179	0.70
2000	222	9	175	0.80
2001	199	6	96	0.50
2002	175	9	160	0.90
2003	204	9	161	0.80
2004	244	11	186	0.80
2005	190	8	147	0.80
2006	241	14	197	0.80
2007	289	11	246	0.90
2008	250	10	206	0.80
2009	202	8	189	0.90
2010	312	12	263	0.80
2011	386	13	279	0.70
2012	253	12	138	0.50
2013	201	10	131	0.70

Table 6: Summary of the final lognormal model for LIN 2 ECNI target ling bottom longline fishery. Retained variables are in order of decreasing explanatory value, with the corresponding degrees of freedom (df), residual deviance (Res. Deviance), percent total deviance explained (R-squared) and overall influence (percent contribution to inter-annual variations in CPUE).

	Res. df	Res. Deviance		
NULL model	5124	5049		
Variables	**df**	**Res. Deviance**	**R-squared**	**Influence**
Fishing year	21	4739	6.1	-
Vessel	24	4178	17.3	9.4
Log(Total hooks)	3	3771	25.3	13.1
Month	11	3426	32.1	4.4

Table 7: Lognormal CPUE standardized indices for the LIN 2 ECNI target ling bottom longline fishery, including 95% confidence intervals (lower and upper CI) and coefficients of variation (CVs).

Year	CPUE index	Lower CI	Upper CI	CV
1992	1.64	1.39	1.95	0.09
1993	1.40	1.18	1.65	0.08
1994	1.55	1.30	1.84	0.09
1995	1.54	1.33	1.79	0.07
1996	1.34	1.17	1.54	0.07
1997	1.29	1.11	1.49	0.07
1998	1.27	1.11	1.46	0.07
1999	1.13	0.98	1.29	0.07
2000	0.80	0.69	0.93	0.07
2001	0.60	0.51	0.69	0.08
2002	0.97	0.83	1.13	0.08
2003	0.88	0.76	1.01	0.07
2004	1.07	0.93	1.24	0.07
2005	1.00	0.85	1.18	0.08
2006	0.88	0.76	1.01	0.07
2007	0.95	0.83	1.09	0.07
2008	0.85	0.73	0.98	0.07
2009	0.89	0.76	1.05	0.08
2010	0.90	0.78	1.03	0.07
2011	0.82	0.73	0.93	0.06
2012	0.56	0.49	0.65	0.07
2013	0.65	0.55	0.76	0.08

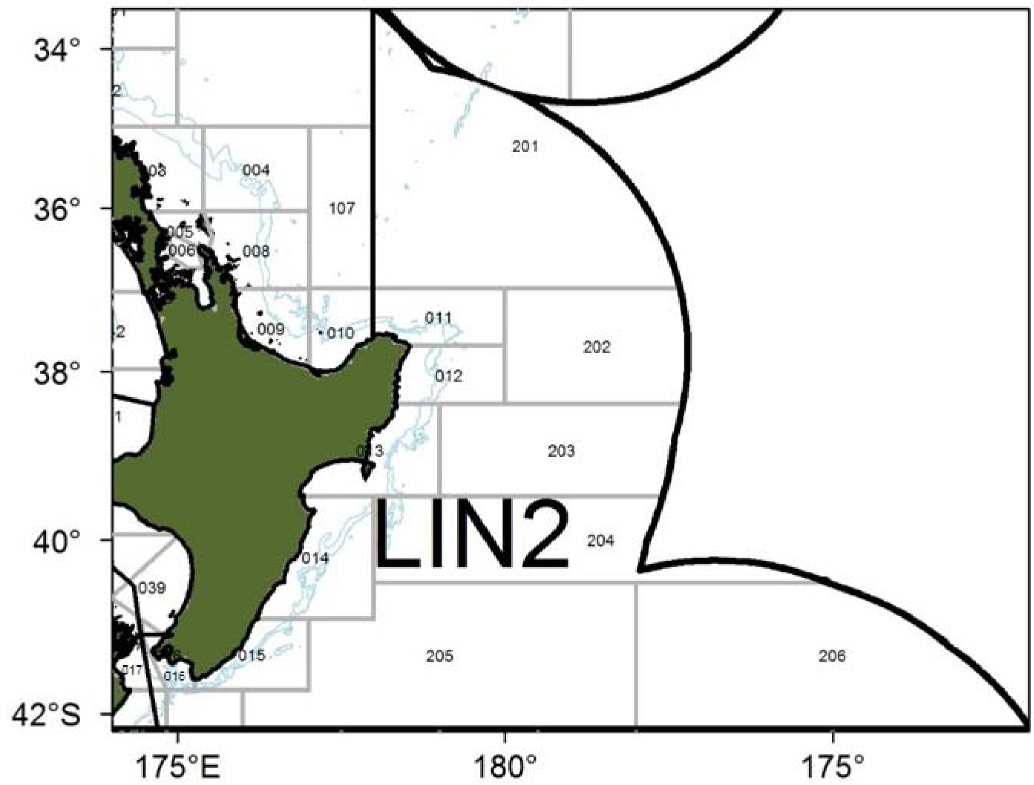
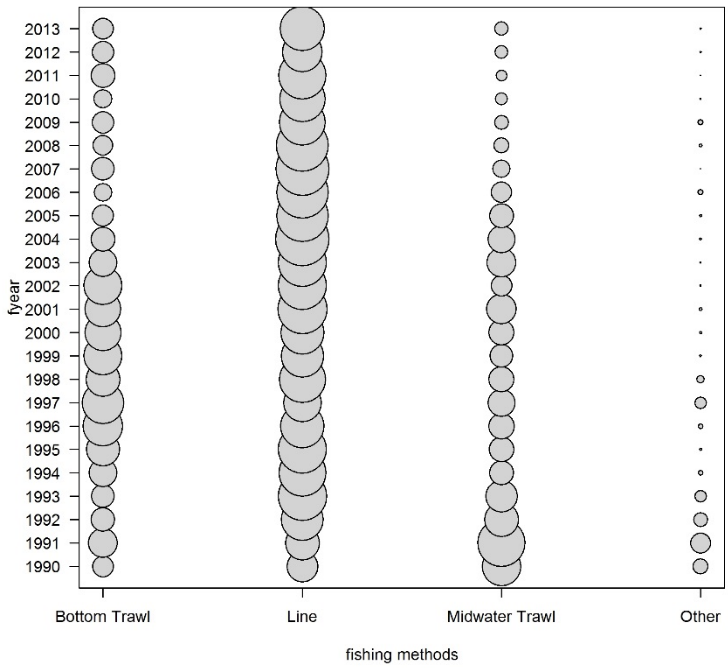


Figure 1: Map of the LIN 2 management area within the boundaries of the New Zealand EEZ. LIN 2 includes East Coast North Island (ECNI) Statistical Areas 011–015, Cook Strait Statistical Areas 016–017 and offshore Statistical Areas 201–206. 1000 m and 500 m depth contours are shown.

(A)



(B)

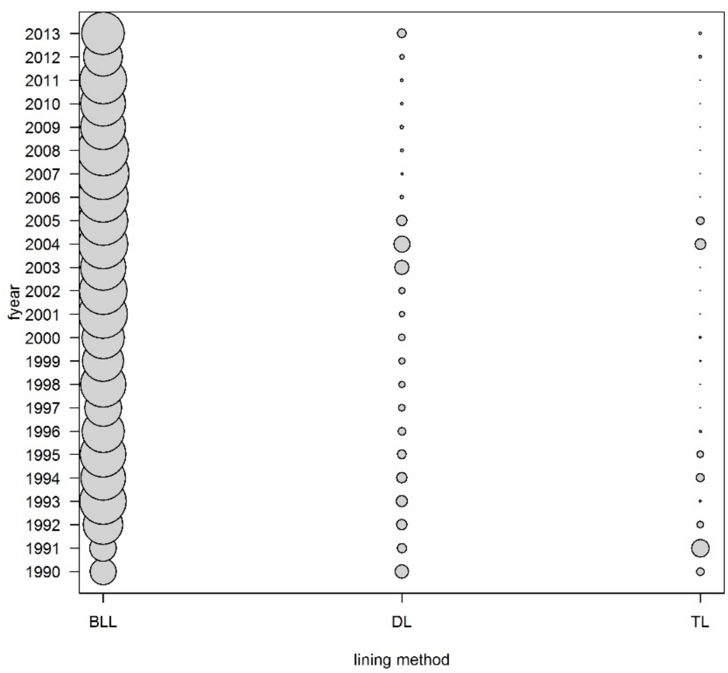


Figure 2: Annual estimated LIN 2 ling catch among (A) fishing methods and (B) lining methods. 'Line'= bottom longline (BLL), Dahn line (DL) and trot line (TL).

(A)

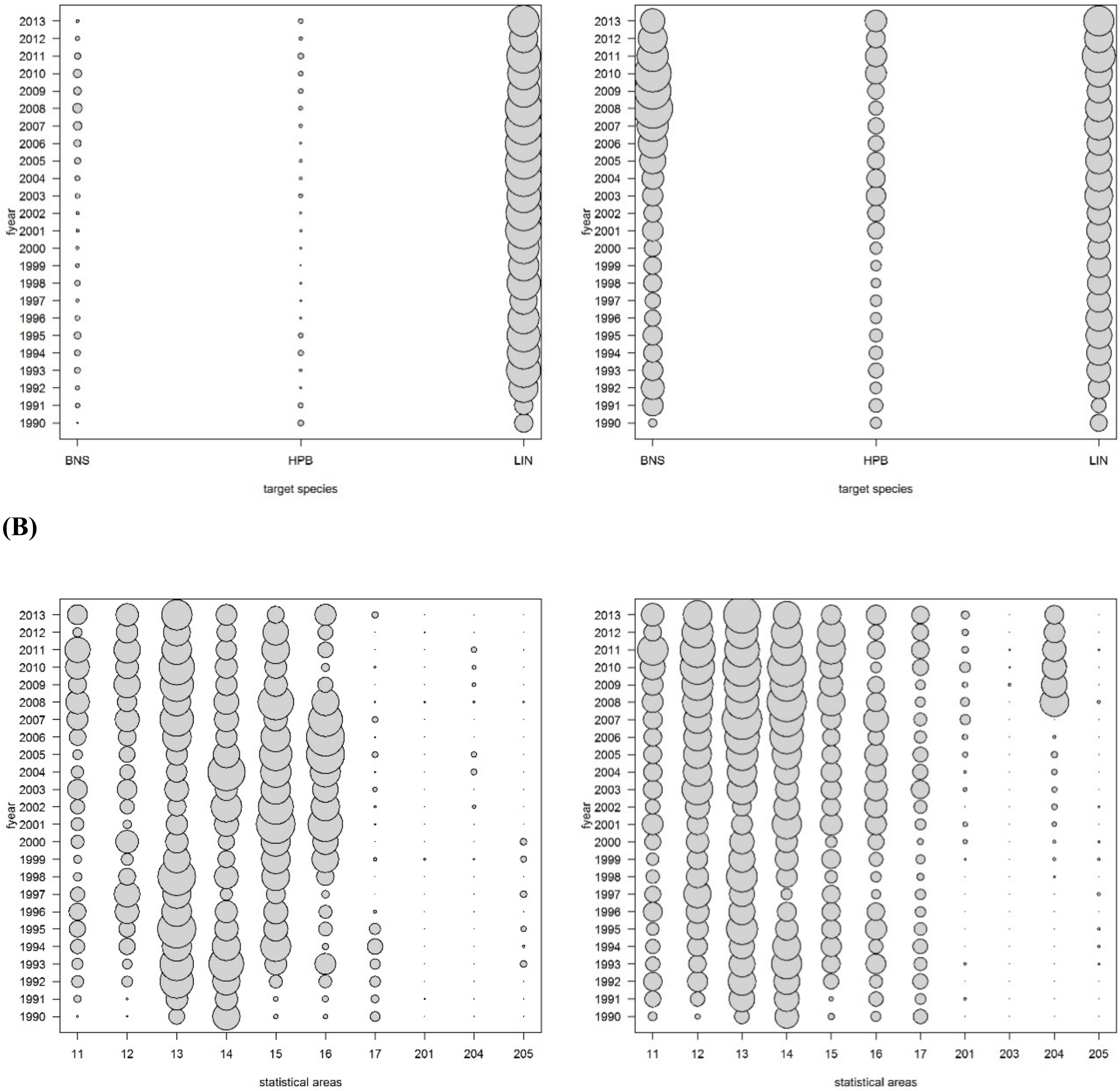


Figure 3: Annual BLL estimated ling catch (left) and effort (right) among (A) target species and (B) statistical areas in FMA 2.

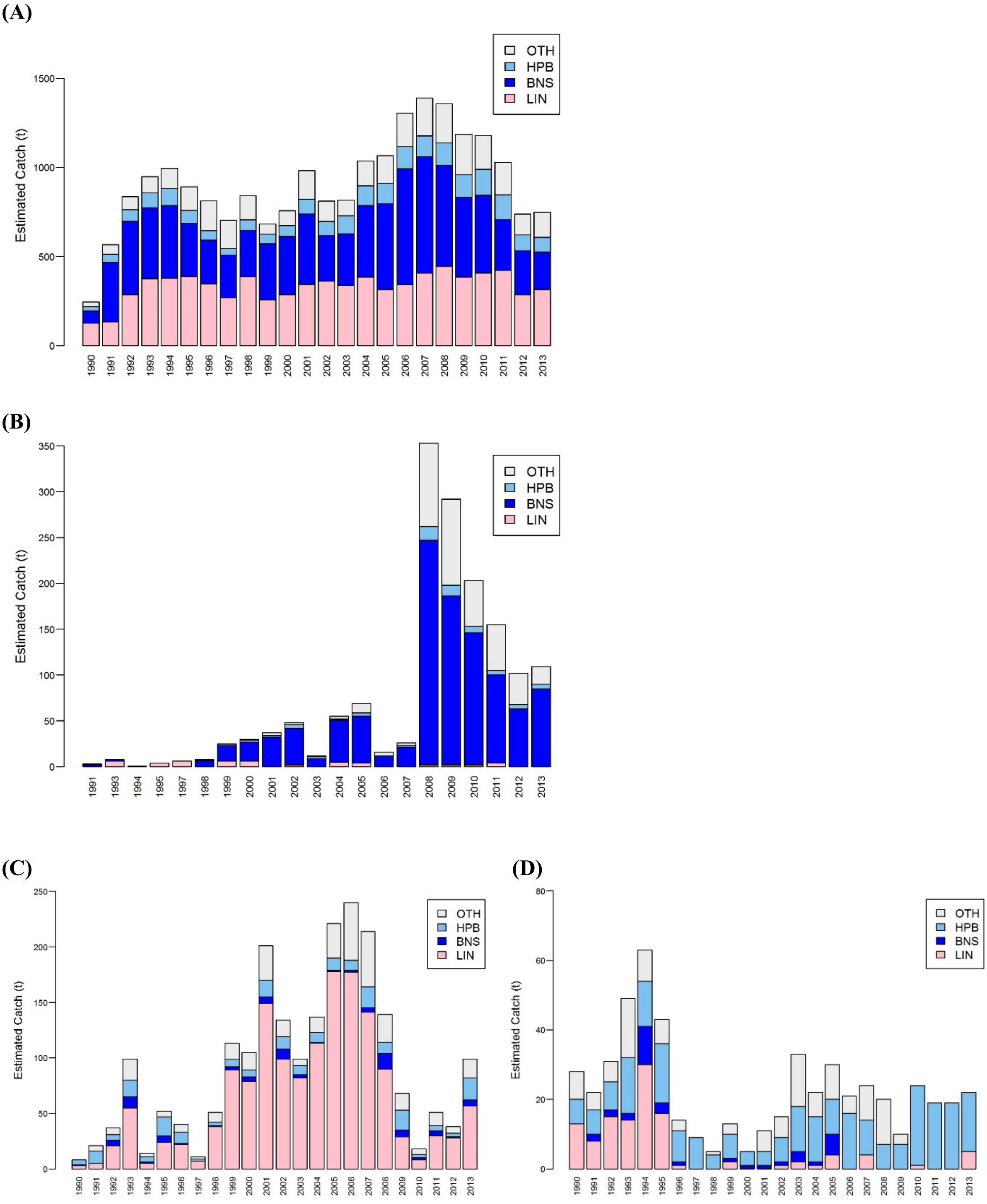


Figure 4: Annual BLL estimated catch composition by species in (A) ECNI Statistical Areas 011–015; (B) offshore Statistical Areas 201-206; (C) Statistical Area 016 (Cook Strait); and (D) Statistical Area 017 (Cook Strait). OTH = other species (see text); HPB = hapuku and/or bass; BNS =bluenose; LIN= ling.

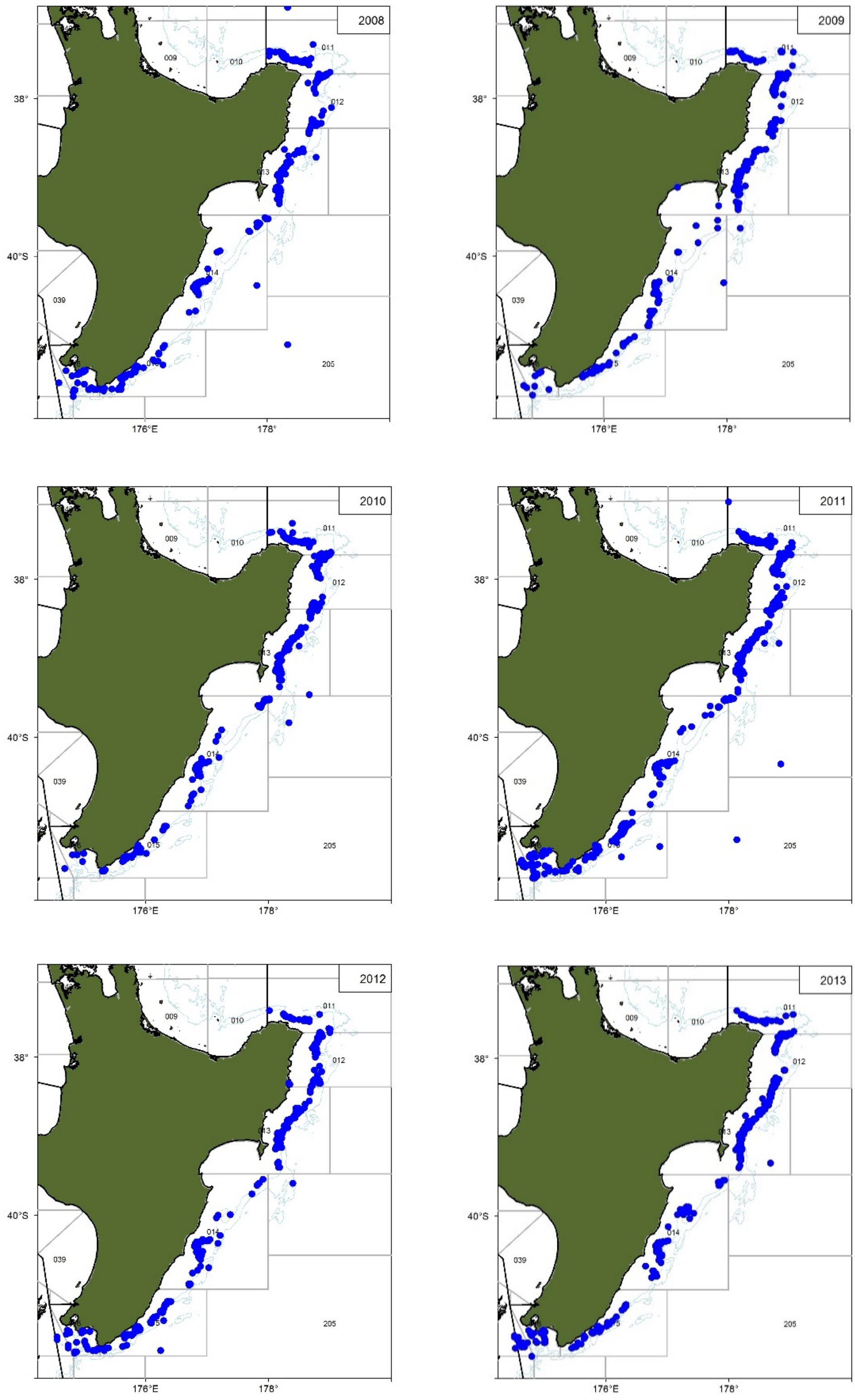
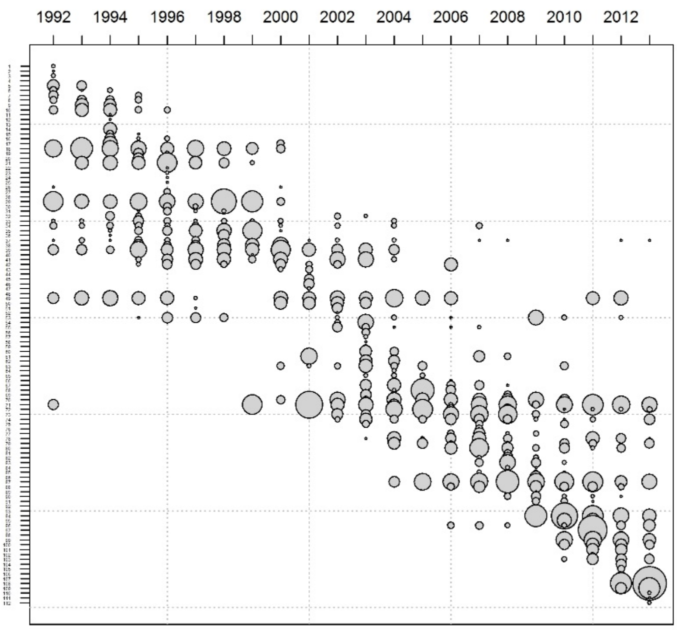


Figure 5: Annual bottom longline target ling spatial effort distribution in FMA 2 (as reported on LTCER and LCER forms). 1 filled circle = 1 vessel day.

(A)



(B)

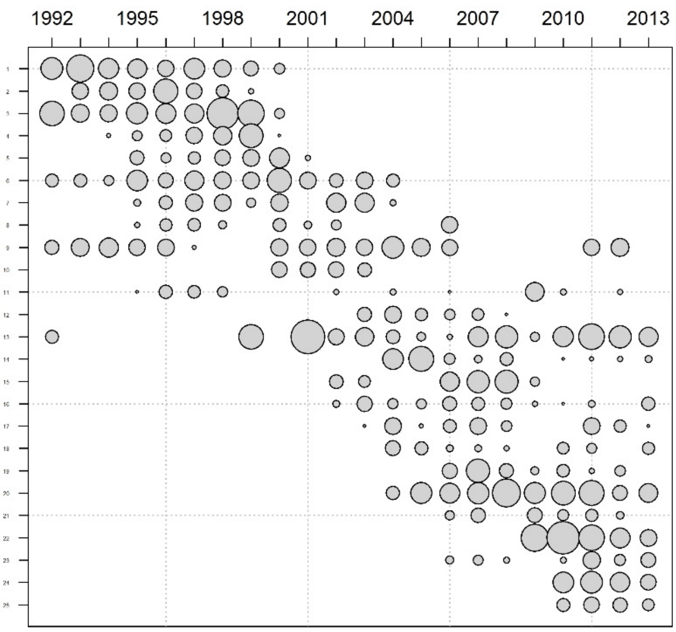
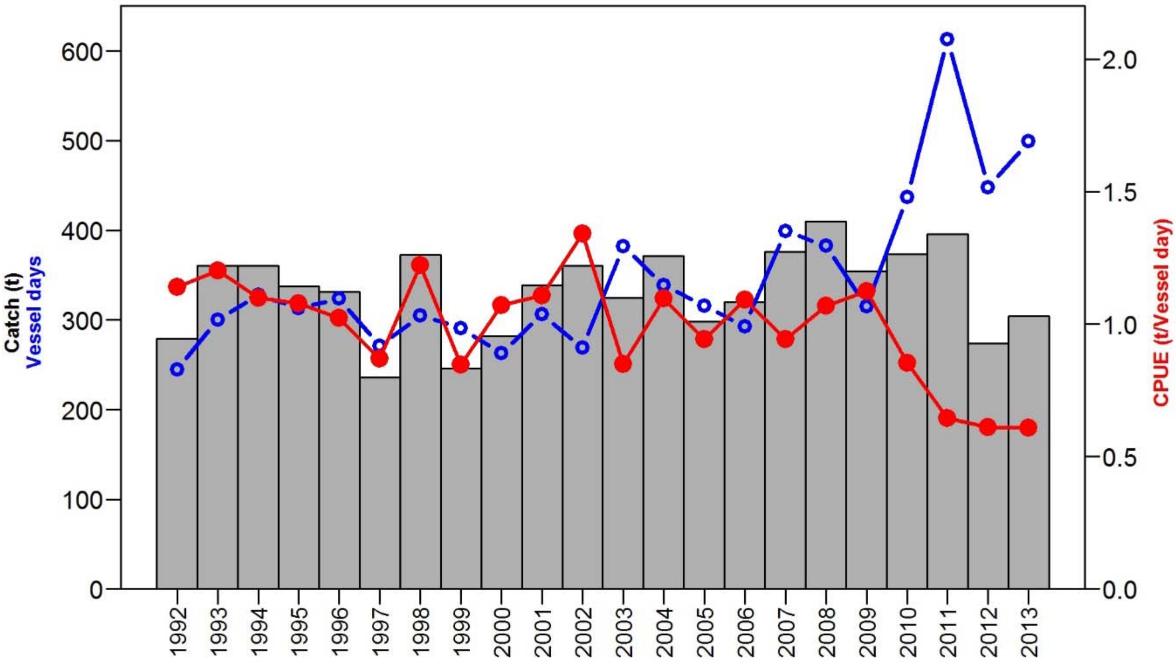


Figure 6: Effort by fishing year and vessel for A) all fleet (raw data) (n=112 vessels) and B) core fleet (final dataset) (n=25 vessels). Circle area is proportional to effort as vessel-days. Individual vessels are denoted anonymously by sequential numbers on the y-axis.

(A)



(B)

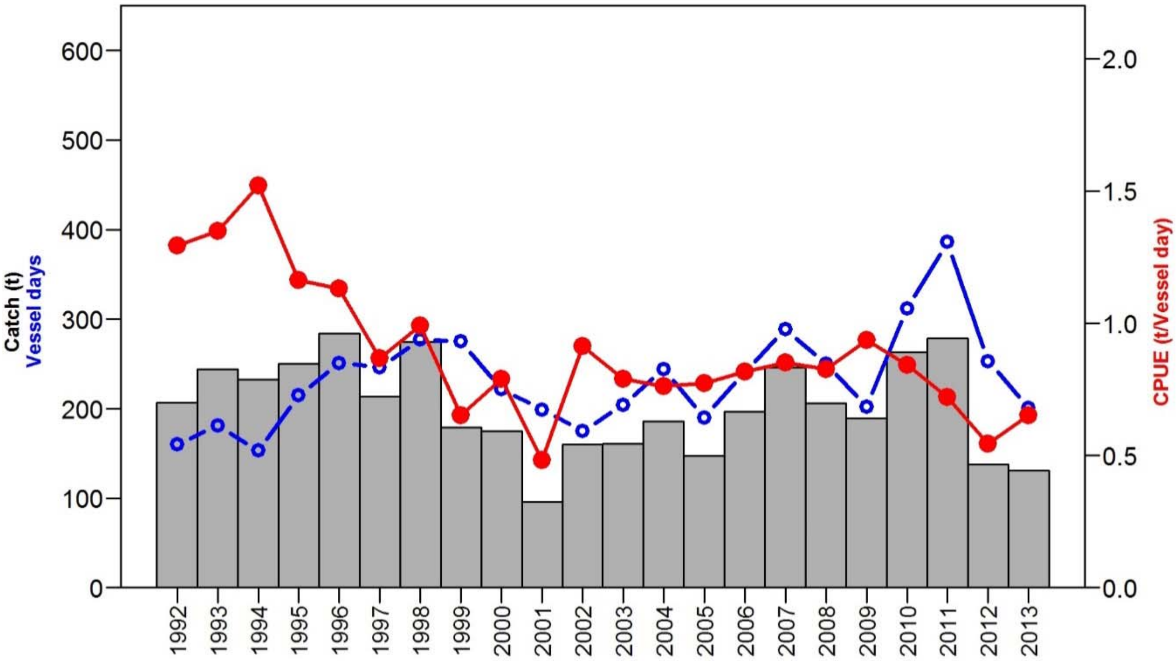
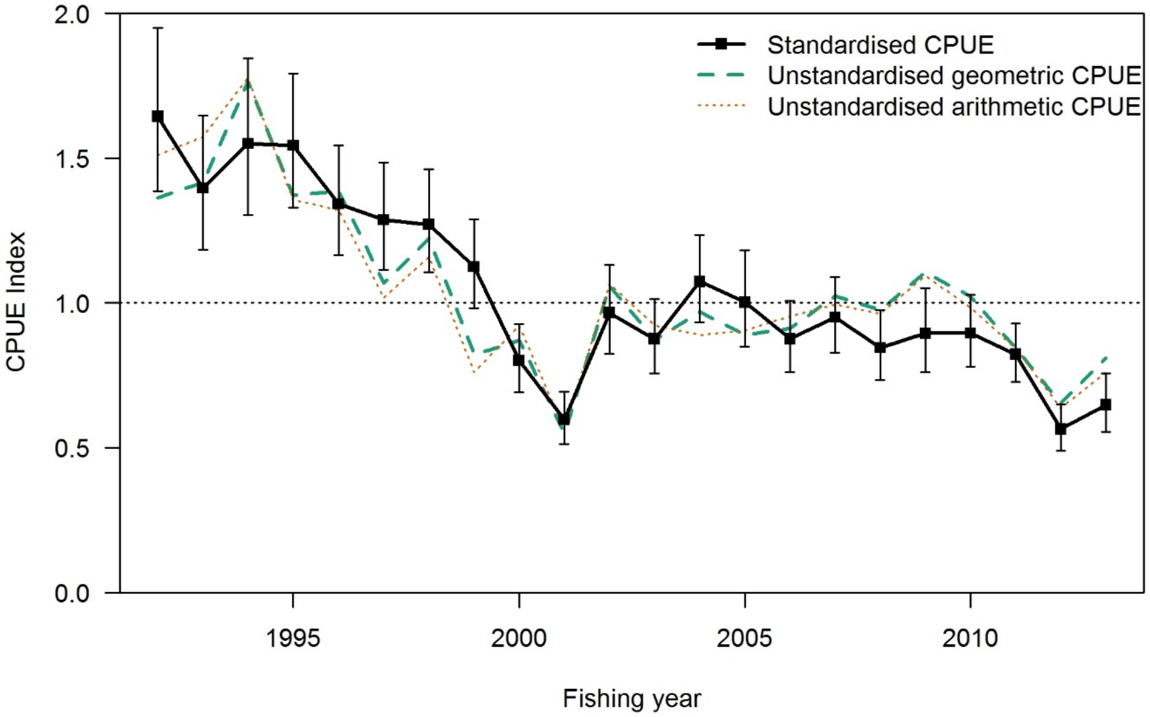


Figure 7: Nominal catch and effort information by fishing year for the LIN 2 ECNI ling target, bottom longline fishery. (A) All vessels (n=112), positive catch, ling target data; (B) Core vessels (n=25), positive catch, ling target data. Bars= estimated ling catch; Empty circles/broken line = Effort (as vessel days). Filled circles/line: unstandardized catch per unit effort (CPUE).

(A)



(B)

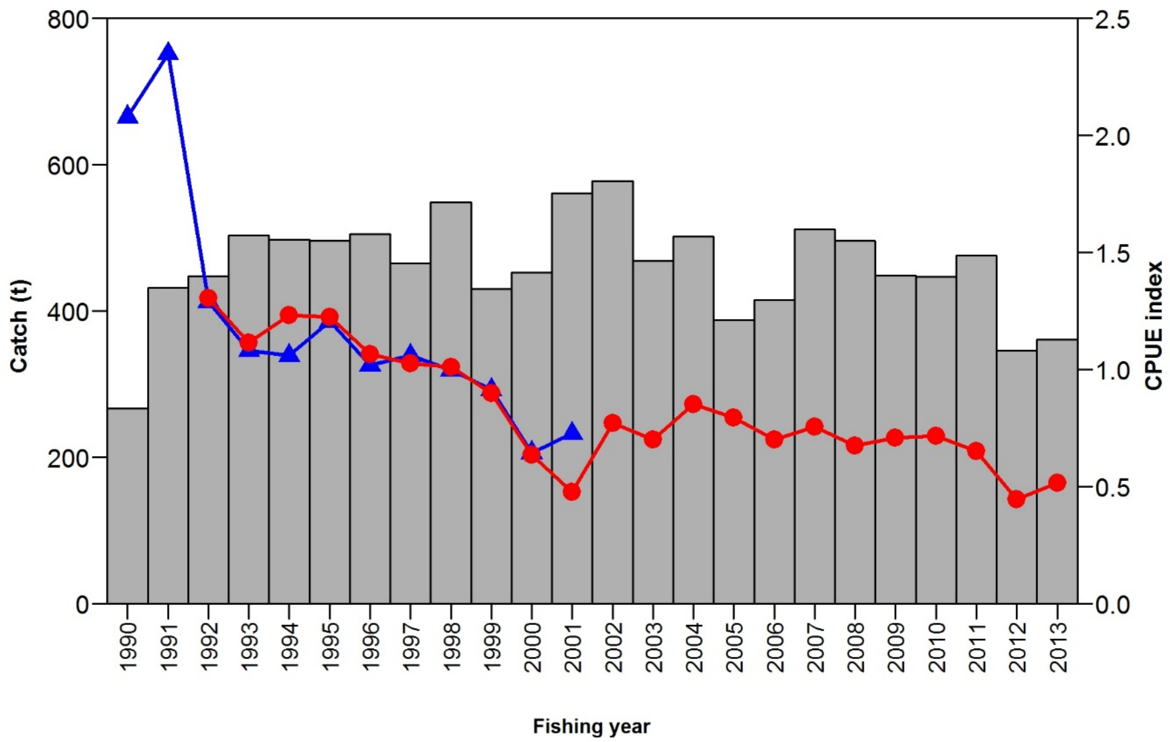


Figure 8: (A) Standardised CPUE index (± 95% CI) for the LIN 2 ECNI ling target bottom longline fishery, 1992–2013. (B) Comparison of the total estimated ling catch (bars) and standardized CPUE indices (previous (Horn 2003) (triangles) and current (circles)) for ECNI line fisheries.

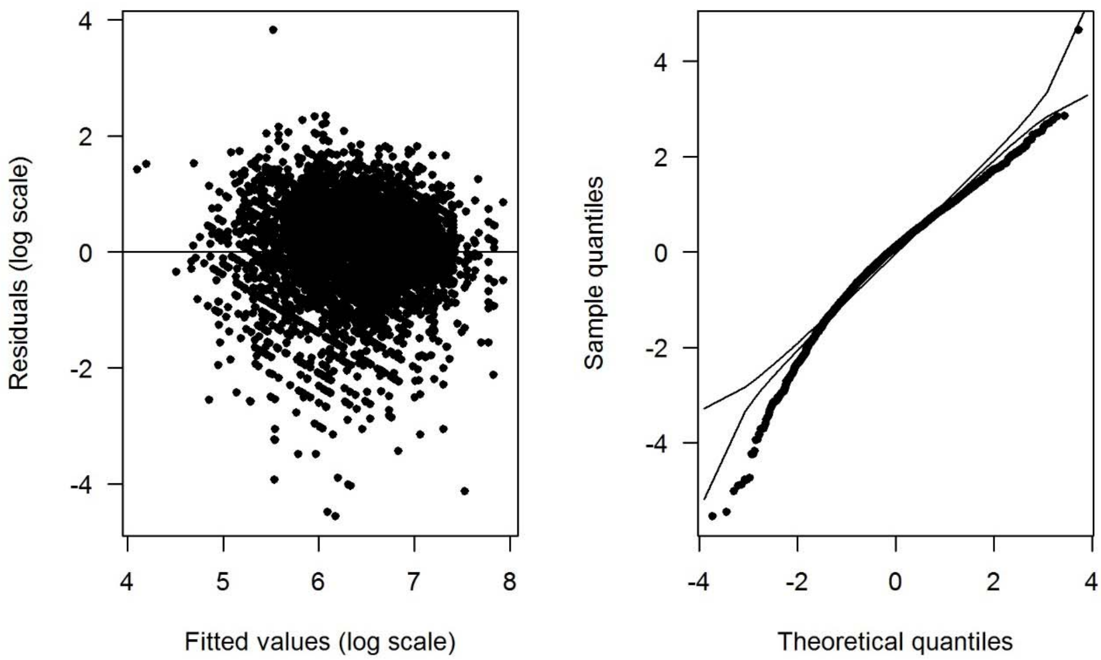
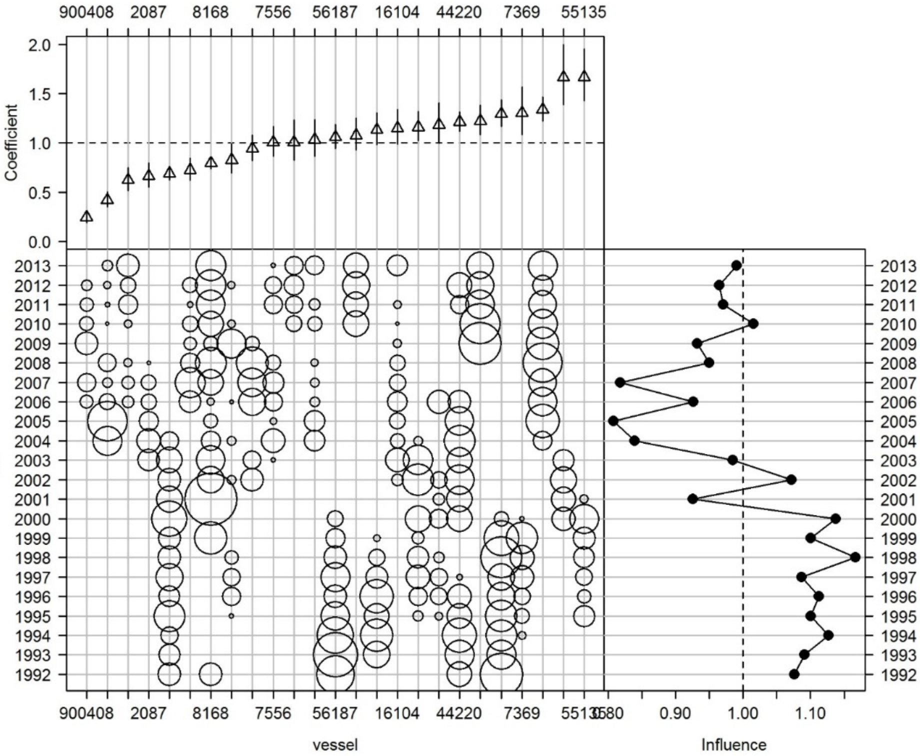


Figure 9: Residuals diagnostic plots of the selected lognormal CPUE model for the LIN2 ECNI, ling target bottom longline fishery.

(A)



(B)

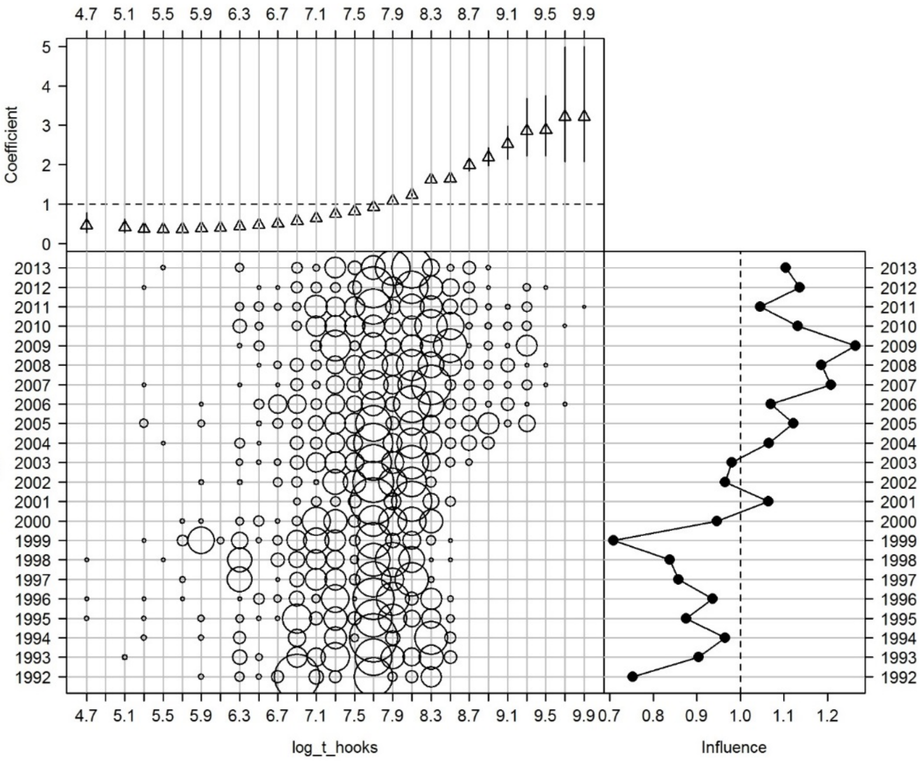


Figure 10: Coefficient-Distribution-Influence plots for selected variables in the final, lognormal CPUE model for LIN 2 ECNI ling target bottom longline fishery. (A) *Vessel*; (B) *Log(Total hooks)*; (C) *month*. Each plot shows the relative effects by levels of the variable (top panel), the relative distribution of the variable by fishing year (bottom left panel) and the calculated influence of the variable on the unstandardized CPUE by fishing year (bottom right panel)

(C)

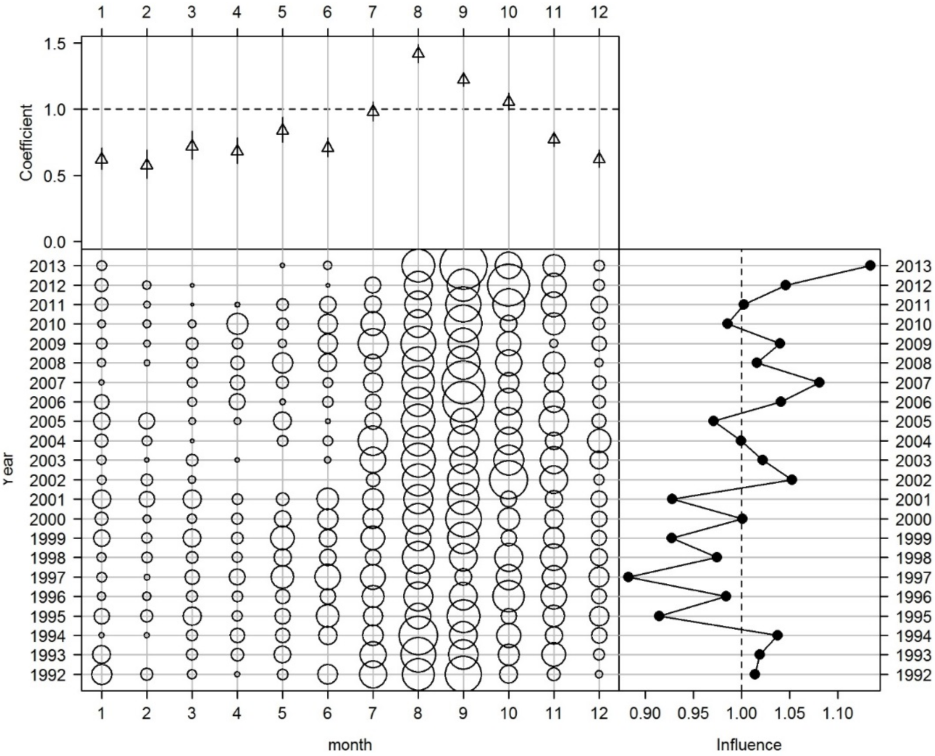


Figure 10: (continued)

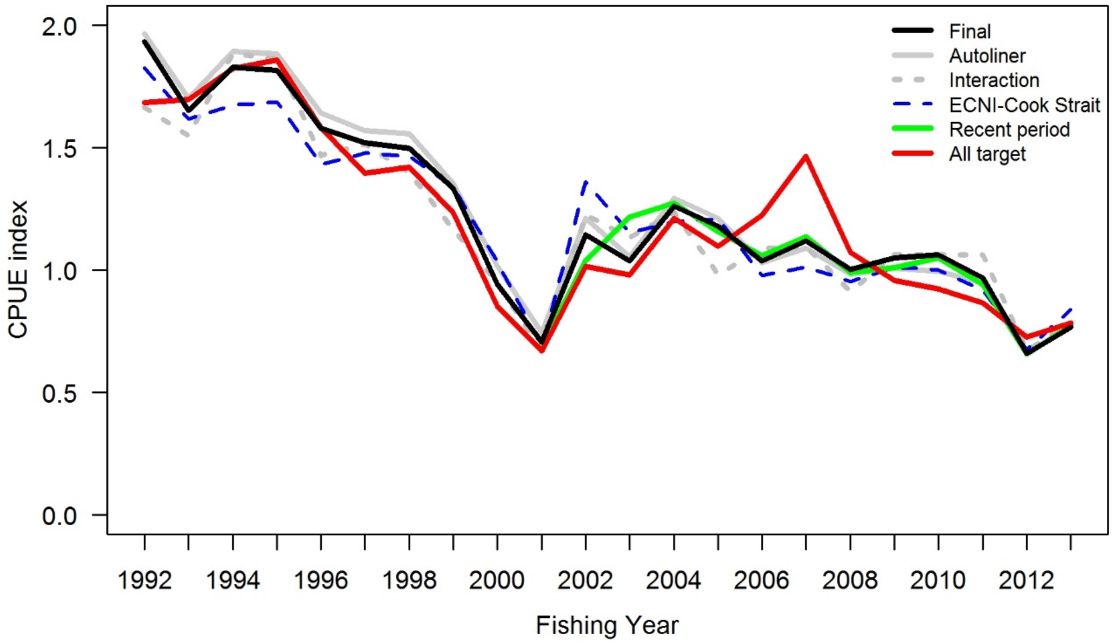


Figure 11: Sensitivity analysis/comparison of the standardised lognormal CPUE index for the LIN 2 ECNI ling target bottom longline fishery ('Final'), against alternative sets of input data (details in Table 3).