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Characterisation and CPUE analyses of the New Zealand albacore fishery

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Stephen Brouwer[1], McKenzie G. Tornquist[2], Kath Large[2]
David A. J. Middleton[3], Philipp Neubauer[2] and Laura Tremblay-Boyer[2]

[1] Saggitus Consulting

[2] Dragonfly Data Science

[3] Pisces Research

Fisheries New Zealand
Tini a Tangaroa

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Draft New Zealand Fisheries Assessment Report

Stephen Brouwer
McKenzie G. Tornquist
Kath Large
David A. J. Middleton
Philipp Neubauer
Laura Tremblay-Boyer

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EXECUTIVE SUMMARY

Brouwer, S.; Tornquist, M.G.; Large, K.; Middleton, D.A.J.; Neubauer, P.; Tremblay-Boyer, L. (2021) Characterisation and CPUE analyses for the albacore fishery. ***New Zealand Fisheries Assessment Report 2021/xx.*** **. 140 p.**

This paper presents an updated characterisation and CPUE analysis of the New Zealand albacore (*Thunnus alalunga*) fishery. In New Zealand, albacore are landed to a single Fishery Management Area (FMA) ALB 1. Landings vary from year to year, with an increasing trend from the early 1970s to the early 2000s followed by a decline after 2003, and have fluctuated around 2000 t to 3000 t since 2006. Albacore within the New Zealand fishery waters are part of the South Pacific Ocean stock which is distributed from the equator south to about 50°S, and from the Australian east coast to the South American west coast. The broader stock is managed by two Regional Fisheries Management Organisations (RFMOs); the Inter-American Tropical Tuna Commission (IATTC) manages the eastern part of the stock, while the western part is managed under the Western and Central Pacific Fisheries Commission (WCPFC). In the WCPFC Convention Area, albacore are landed in a number of fisheries but primarily from longline (94.6%) and troll (4.9%) fisheries, with 77% of the troll catch and <1% of the longline catch coming from New Zealand fishery waters.

The present analysis was undertaken to provide information for the regional stock assessment undertaken by the Pacific Community (SPC) and focuses primarily on the troll fishery which lands the bulk of the catch in New Zealand, but longline data are also included. The analysis describes the fisheries targeting and catching albacore in New Zealand, and undertakes a CPUE standardisation of the commercial troll fishery. Data for the fishery description included the catch and effort from 1990 to 2020 from albacore troll target sets, all other troll activity, and all trips where ALB 1 was specified as the target or recorded as bycatch. For the CPUE analysis, catch-effort data for albacore target trolling only were modelled using maximum-likelihood generalised linear models (GLMs) predicting the catch as a function of spatial, temporal and environmental predictors. The models provided a minimal standardising effect, producing CPUE series that show little long-term trend. For the years up to the 2008 fishing year, the series reported in this analysis closely follows the trend reported in the previous analyses conducted in 2010 and 2017. Overall, the series, which now extends 30 years, fluctuates without trend over the last two decades. The standardised CPUE index is likely a reflection of availability and/or catchability, rather than an indication of abundance, and is discussed in terms of the coverage of the juvenile portion of albacore stock in New Zealand waters by the troll fishery.

Recommendations for future work include: investigating temporal and spatial trends in the compositional data from market sampling to determine if there is utility in these data for informing size disaggregated CPUE; and, investigating drivers of availability of juvenile albacore to the New Zealand troll fishery, and which environmental datasets may be useful for predicting climate change effects on availability.

1. INTRODUCTION

Albacore (*Thunnus alalunga*) within the New Zealand waters are part of the South Pacific Ocean stock which is distributed from the equator south to about 50°S, and from the Australian east coast to the South American west coast. The broader stock is managed by two Regional Fisheries Management Organisations (RFMOs); the Inter-American Tropical Tuna Commission (IATTC) manages the eastern part of the stock, while the western part is managed under the Western and Central Pacific Fisheries Commission (WCPFC).

The total catch of south Pacific albacore in 2019 was 85 050 t, of which 82% (69 687 t) came from the WCPFC convention area; of that 2751 t (~4%) was landed in New Zealand fisheries waters (WCPFC 2020). In the WCPFC convention area, albacore are landed in a number of fisheries but primarily from longline (94.6%) and troll (4.9%) fisheries, with 77% of the troll catch and <1% of the longline catch coming from New Zealand fishery waters.

Due to the small size of the New Zealand catch and the large mobile nature of the stock, it is not possible to undertake a stock assessment of the albacore within New Zealand. Triennial assessments are undertaken by the WCPFC through their science service provider the Pacific Community (SPC), with the most recent being undertaken by Tremblay-Boyer et al. (2018a) and an updated assessment will be presented to the Scientific Committee of the WCPFC in 2021 (Castillo-Jordan 2021). These assessments use information from the New Zealand troll fishery, which catches juvenile fish, to inform recruitment trends in the assessment. The New Zealand fishery data, therefore, contributes a small but critical data set to the assessment. The 2018 assessment estimated that the stock is currently not overfished, and overfishing is not taking place. However, in order to maintain an economically viable fishery high catch rates are required, and the WCPFC has frozen the number of vessels fishing for albacore south of 20°S (WCPFC 2015).

Juvenile albacore appear in New Zealand fishery waters in the austral summer and then appear to gradually disperse north from the southern latitudes as they grow. Longline catch data indicate that adults appear to migrate seasonally between tropical and subtropical waters (Tremblay-Boyer et al. 2018a). This predictable movement brings albacore to New Zealand fisheries waters annually where they are targeted. Albacore are thought to have been landed in New Zealand since the 1940s, but regular commercial tuna fisheries only began in the 1960s (Kendrick & Bentley (2010) and Kendrick (2021)) with catch reaching a peak in 2003 (Fisheries New Zealand 2019).

The broader south Pacific albacore stock is managed by the WCPFC, and New Zealand is responsible for ensuring that the management measures applied within New Zealand fisheries waters are compatible with those of the Commission (Fisheries New Zealand 2019). Within New Zealand, albacore are managed outside of the Quota Management System (QMS) and have not been allocated a total allowable catch (TAC), but rather the effort restrictions applied under WCPFC (2015) apply within New Zealand.

In New Zealand, albacore are landed to a single Fishery Management Area (FMA) ALB 1 (Figure 1). Landings peaked in 2003 at 6744 t but declined thereafter and have fluctuated around 2000 t to 3000 t since 2006 (Figure 2). Catch is attributed to a statistical area (Figure 3) based on where the catch was made.

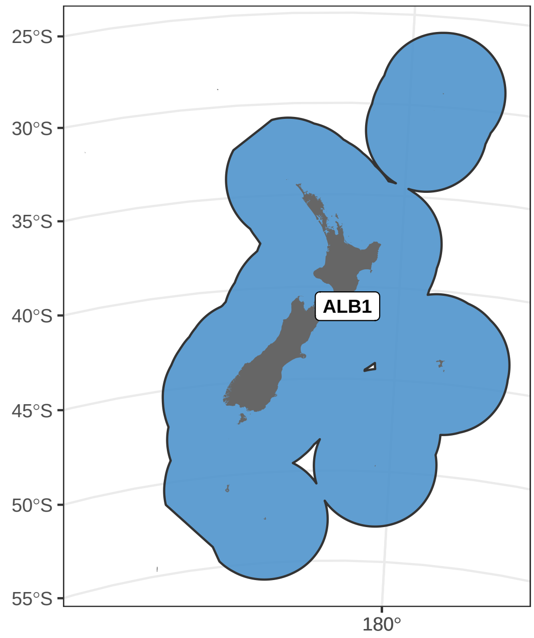

Figure 1: Fisheries Management Areas for albacore with ALB 1 highlighted.

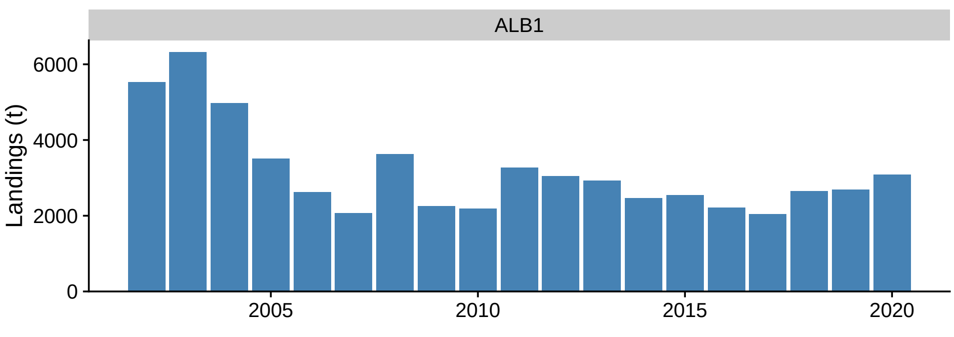

Figure 2: Monthly Harvest Return totals for ALB 1 from 2002 to 2020.

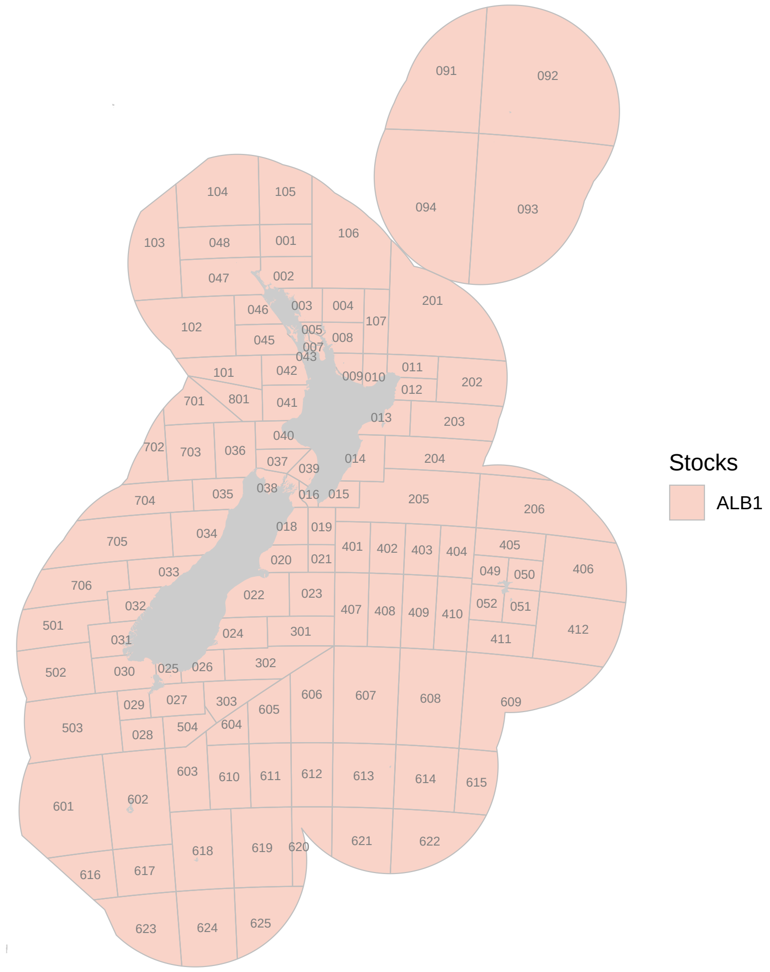

Figure 3: Statistical areas by stock for albacore in New Zealand.

The New Zealand albacore fishery has been characterised a number of times with the most recent being that of Kendrick (2021) and Kendrick & Bentley (2010). These analyses, along with others such as Griggs (2008), have shown that the New Zealand albacore fishery, especially the troll fishery, has been characterised by periodic poor years that have been linked to poor weather or colder than average summer seasons. Despite this, the catch has been fairly consistent since 2006. The New Zealand troll catch is mostly made up of juvenile fish, with the longline catch being made up of adult fish. The troll fishery is monitored through catch and effort data collection as well as catch sampling (Griggs et al. 2018).

This analysis focuses primarily on the troll fishery which lands the bulk of the catch, but longline data are also included. The aim of the analysis is to describe the fisheries targeting and catching albacore in New Zealand. This report will analyse the CPUE from the commercial troll fishery for albacore in New Zealand waters. The analysis includes the catch and effort from 1 October 1989 to 30 September 2020 from albacore troll target sets, all other troll activity, and all trips where ALB 1 was specified as the target or recorded as bycatch. The reported catch and effort information as well as the limited observer data will be assessed spatially and temporally throughout ALB 1. The analysis will largely be descriptive in nature collating the data and aggregating catch and effort information spatially and seasonally to assess trends in the spatial and temporal distribution of this stock, and assess troll catch by target species. Using this information to inform the fisheries, target species, reporting form types and FMA/statistical areas for inclusion in the CPUE analysis. CPUE information will then be standardised to produce a number of indices.

2. METHODS

Extracts (report logs 13159, 13726) of statutory catch, effort and landings data were provided by MPI, and processed using standardised grooming routines (Appendix B).

All years in this report refer to the normal New Zealand fishing year which runs from 1 October to 30 September. Fishing years are labelled using the later calender year; thus, for example, 1990 refers to the fishing year 1 October 1989 to 30 September 1990.

2.1 Characterisation methods

A fishery characterisation dataset was prepared by identifying all trips with landings of ALB 1, and extracting the associated catch and effort data for fishing events within the ALB 1 Fisheries Management Areas (Figure 1). Fishing events were selected based on start position (where available) or statistical area (Figure 3).

Landings from a trip were allocated to fishing events following the approach of Starr (2007):

1. in proportion to estimated catches, where ALB was estimated;
2. in proportion to the `effort_num` in aggregated (CELR) fishing events, where trips used a single fishing method;
3. equally across records.

The standard grooming drops some large landings in the early 1990s because the fish were reported as retained on board (Figure B.1). However, the size of these landings suggests that the quantity reported may also be in error.

A significant quantity of landings in the mid-1990s were recorded to ALB 1 having been reported using other stock codes (Figure B.2); this arises when fishers have reported fish using a fishstock code constructed using the generic Fisheries Management Areas (e.g., ALB 8 for landings from generic FMA 8).

2.2 CPUE methods

Fishing events for catch-per-unit-effort (CPUE) modelling were selected by a combination of some or all of:

- reporting form;
- fishing method;
- target species;
- area; and
- time period.

All fishing events matching the series definition were extracted, whether or not ALB were caught. Datasets for CPUE modelling were prepared at differing levels of aggregation, as appropriate:

fishing event level where records represented individual fishing events such as trawls or longline sets;

daily (pseudo-CELR) resolution where finer scale records were aggregated to vessel-day resolution to provide data that mimic the resolution provided by the Catch, Effort and Landing Return (CELR), following the approach suggested by Langley (2014); or

trip level where each record was for a complete fishing trip with aggregated statistics summarising the fishing effort from the trip.

For the fishing event and pseudo-CELR resolution data, landings were allocated to fishing events following the approach of Starr (2007), and summarised above.

CPUE standardisations in this analysis were prepared using two approaches: catch prepared from pseudo catch effort landing return aggregated daily (ALB 1 T pseudoCELR), with catch in numbers of fish per record; and data collated at the trip level (ALB 1 T CELR trip) from catch effort landing return (CEL) forms, with catch in landed weight per record. Both series are based on troll catch and effort data only.

A filtering process for anomalous data was run on each dataset, screening and removing records with:

- no recorded fishing duration;
- non-positive fishing duration;
- fishing duration >20 hours (ALB 1 T pseudoCELR only);
- total fishing duration >180 hours (ALB 1 T CELR trip only);
- season start day occuring outside the months November to April in each fishing year;
- no recorded ALB catch; and
- no inferred numbers of fish (ALB 1 T pseudoCELR only).

Both CPUE datasets were restricted to a core fleet, defined as those vessels that carried out at least a minimum qualifying number of fishing trips within each of a minimum number of qualifying fishing years.

Finally, environmental variables were added to each dataset for sea surface temperature (SST) and the mulivariate El Niño/Southern Oscillation (ENSO) index (MEI). SST and MEI data was sourced from NOAA Physical Laboratory at https://psl.noaa.gov. The SST data were derived from weekly optimum interpolation (OI) sea surface temperature on a one degree grid (OISST.v2) linearly interpolated to daily values that were then averaged over a month. The monthly average OISST.v2 was matched to ALB 1 T dataset records by year, month and statistical area. The MEI data combines oceanic and atmospheric variables in a single index (sea level pressure, sea surface temperature, zonal and meridian components of surface wind, and outgoing longwave radiation over the Pacific basin). Monthly MEI.v2 records were matched to ALB 1 T model dataset records by year and month.

2.3 Maximum-likelihood CPUE modelling

Catch-effort data were modelled using generalised linear models (GLMs) predicting the logarithm of catch as a function of predictors.

For albacore, estimated catches from trolling or longlining have normally been reported as numbers of fish. CPUE analyses using event based or daily data therefore used the number of fish as the response variable. However, trip-resolution CPUE analyses modelled the landed catch weight. Four CPUE analyses were investigated, two based on the trip resolution data and two based on the daily resolution data.

The same set of seven explanatory variables were offered to each of the four models: fishing year (`fyear`), fishing vessel (`vessel_key`), statistical area (`stat_area`), month (`month`), fishing duration (`log(total_fishing_duration)` in the trip dataset and `log(fishing_duration)` in the daily dataset), sea surface temperature (`SST`) and the multivariate ENSO index (`meiv2`). Fishing year, vessel and statistical area were included as categorical variables. Statistical area and month were offered to the model as an interaction term (`stat_area*month`). The log of fishing duration, sea surface temperature and the multivariate ENSO index (MEI) were included as continuous variables, and formulated as third order polynomials.

The generalised linear model was fitted to the trip resolution data with the formula:

$$log(landkg) \sim fyear + vessel\_key + stat\_area * month + ns(log(total\_fishing\_duration), 3) + ns(SST, 3) + ns(meiv2, 3)$$

and to the daily resolution data with the formula:

$$log(nfish) \sim fyear + vessel\_key + modal\_stat\_area * modal\_month + ns(log(fishing\_duration), 3) + ns(SST, 3) + ns(meiv2, 3)$$

Note, that while it is standard practice when analysing CPUE for New Zealand fisheries to use a combined model, which integrates annual abundance coefficients from a binomial model of zero catches with those from the model of positive catches, we have used a postive catch model only due to the paucity of zero catches in the albacore target troll fishery.

For each of the two datasets, log(catch) was regressed against the full set of explanatory variables in a stepwise procedure where fishing year is forced into the model as the first explanatory variable, and then selecting the remaining variables one at a time until the improvement in the model R^2 was less than 0.05. The order of the variables in the selection process was based on the variable with the lowest AIC (minimising the degrees of freedom). To test how we may account for the annual variance of environmental factors in a model where an explanatory year effect is already forced into the model, a second set of models were run for each dataset where none of the explanatory variables were excluded, irrespective of the contribution each variable made to an improvement in the value of R^2.

Alternative assumed error distributions were explored for each model: the negative binomial and the poisson distributions where the catch in numbers was the response variable, and the lognormal, gamma, and Weibull distributions where the catch in weight (tonnes) was the response variable.

The set of models constructed in this analysis are listed in Table 1.

Table 1: List of models constructed for CPUE standardisation. Supporting diagnostics are reported for the models highlighted in grey, along with the resulting CPUE series. Models with extreme core vessel selection criteria were not reported further. A reduced set of model diagnositics are reported for the remaining models

Series name	Data resolution	Response variable	Explanatory variable selection process	Core fleet years	Core fleet trips	Assumed error distribution
ALB 1 T pseudoCELR	daily	nfish	Stepwise	4	3	negative-binomial
ALB 1 T pseudoCELR full	daily	nfish	All selected	4	3	negative-binomial
ALB 1 T CELR trip	trip	landkg	Stepwise	4	3	gamma
ALB 1 T CELR trip full	trip	landkg	All selected	4	3	gamma
ALB 1 T pseudoCELR 5 trips	daily	nfish	Stepwise	6	5	negative-binomial
ALB 1 T pseudoCELR 1 trip	daily	nfish	Stepwise	2	1	negative-binomial
ALB 1 T pseudoCELR Poisson	daily	nfish	Stepwise	4	3	poisson
ALB 1 T pseudoCELR Poisson Full	daily	nfish	All selected	4	3	poisson
ALB 1 T CELR trip lognormal	trip	landkg	Stepwise	4	3	lognormal
ALB 1 T CELR trip weibull	trip	landkg	Stepwise	4	3	weibull
ALB 1 T CELR trip full lognormal	trip	landkg	All selected	4	3	lognormal
ALB 1 T CELR trip full weibull	trip	landkg	All selected	4	3	weibull

3. FISHERY CHARACTERISATION

Landings data were provided for all trips that landed ALB 1 at least once. Each landing was reported in green weight (kg) along with a processed state, any conversion factors used and a destination code. Almost all fish (99%) are landed to destination code “L” (landed to a Licensed Fish Receiver) with the remaining 1% being landed to a number (22) of other codes mostly prior to 2006 (Figure 4). The other codes include fish that were consumed or used as bait, lost etc. The initial dataset corresponded closely with the QMR/MHR totals with very little catch being lost.

Albacore tend to be landed whole (green) (99.6%) with a very small fraction being landed to a number of processed states mostly as fish meal (MEA) prior to 2017 (Figure 5). As most fish are landed whole there is little need for conversion factors, but for those that are processed there are a number of current conversion factors in use (Figure 6), with GGO (gilled and gutted tail on) and SKF (fillets: skin-off) being the most commonly used in the most recent three years. The code definitions used in the report text and figures can be found in the Glossary - Appendix F (Table G.1). There have been no changes to any of the conversion factors since 1990.

Most landings (98.6%) were retained in the characterisation dataset (Figure 7). Prior to 2020, 61% of records and 84% of the catch was landed on CEL forms, with about 26% of records and 16% of landing reported on TUN forms. In 2020, just over half the records (51%) and almost all the catch (94%) was landed on “ERS - Other Lining” forms (Figure 8). Prior to 1996, most records were reported on CEL forms (average 85%), that dropped steadily to 41% in 2010 with a higher proportion of records being reported on TUN forms (up to 35%). From 2010-2017 around 40% of records were being reported on TCP and TUN forms along with a number of other form types. The majority of the catch was reported on CEL forms from 2004 onwards. In the most recent year there has been an almost total shift to electronic reporting with the catch being reported on “ERS - Other Lining” forms.

The majority (82%) of the albacore catch is landed by troll gear, and from 1998 to 2004 there was a shift from catch being landed by troll gear to longline. Prior to that period the longline fishery landed <20% of the catch. This increases to 36-45%, but the longline catch declined again after 2004 and has remained below 20% since then, with 87% of the catch since 2004 being landed by troll gear (Figure 9).

In the surface longline fishery, prior to 2004, the albacore catch was landed primarily (64%) in sets targeting bigeye tuna, with only about 13% of the catch coming from sets targeting albacore. After 2004, landings from albacore target sets declined sharply, averaging just 2% of target declarations from 2004-2020 (Figure 10). There was also a distinct switch to targeting southern bluefin tuna where 21% of albacore catch was made in southern bluefin tuna sets prior to 2004 and 46% thereafter. Almost 100% of the troll catch come from albacore target sets. While other gears catch few albacore, and only 15% of other gears are albacore target sets. Prior to 2005, albacore made up the bulk of the surface longline catch, but from 2005 to 2010 blue sharks and swordfish were the dominant species in the catch.

In the surface longline fishery, most of the catch records are on TUN forms prior to 2004. Albacore, bigeye, southern bluefin tuna and swordfish were all ranked 1 for events with estimated catch within ALB1 (Figure 11). From 2005-2020, albacore ranked lower in all sets targeting others species, and in the few albacore sets albacore seldom ranked above 2 throughout that time period. On CEL forms for troll, in all set types albacore ranked 1, while on surface longline sets albacore ranked between 1 and 2. In 2020, the only year in the dataset where “ERS - Other Lining” forms were used, albacore ranked 1 in 100% of troll sets, and for surface longline reporting on “ERS - Tuna Lining” forms albacore ranked 2 (Figure 11).

On average vessels report just over one record per day on all form types. There is some variation for CEL forms, but from the mid-1990s most surface longline trips report one record per day, and most but not all troll trips report one record per day (averageing around 1.01 records per day). Landings reported on TUN forms occur in all years for the surface longline fishery and report on average just over one record per day (~1.05). In 2019 and 2020, “ERS - Tuna Lining” and “ERS - Other Lining” forms are used and, on average, just over one record is reported per day for both surface longline and troll gear (Figure 12).

Table 2: Annual ALB 1 landings (t) across the different sources of catch data used in the characterisation analysis. The alllocated catch dataset is the version used for the characterisation, excluding additional steps of data preparation for the catch-per-unit-effort standardisation. QMR, Quota Management Report; MHR, Monthly Harvest Return.

Fishing year	QMR/MHR (t)	Total Landed catch (t)	Total Allocated catch (t)	Allocated T (%)	Allocated SLL (%)
1990		2011.89	2047.50	94.46	2.15
1991		2215.26	2211.80	94.74	1.93
1992		3549.07	3655.53	95.17	3.11
1993		3368.72	3414.32	88.86	8.69
1994		6087.69	6087.41	79.02	19.32
1995		6820.93	6304.30	89.74	8.41
1996		6104.53	6028.77	84.16	13.39
1997		4045.38	4034.66	72.04	25.82
1998		6619.10	6634.73	76.32	22.52
1999		3818.42	3814.69	53.07	45.67
2000		4793.45	4818.05	69.59	29.16
2001		5391.70	5444.72	61.25	37.73
2002	5532.63	5740.64	5767.13	57.81	41.71
2003	6317.26	6423.72	6427.48	63.39	35.68
2004	4968.66	5119.95	5143.23	81.59	17.31
2005	3500.50	3499.51	3523.37	84.55	14.17
2006	2627.14	2703.15	2733.90	82.35	16.39
2007	2068.52	2174.38	2181.47	84.80	13.74
2008	3631.07	3776.13	3775.70	92.72	5.58
2009	2246.38	2246.75	2262.61	80.48	18.23
2010	2186.47	2219.60	2226.65	78.76	19.60
2011	3266.43	3366.38	3363.62	89.50	9.41
2012	3039.25	3054.87	3040.63	91.04	7.55
2013	2927.30	2958.25	2993.00	87.91	9.89
2014	2466.70	2497.85	2517.79	89.01	8.26
2015	2536.81	2586.77	2639.64	91.37	5.71
2016	2218.60	2258.94	2292.93	86.72	11.50
2017	2035.42	2067.76	2084.34	88.85	10.09
2018	2641.78	2673.76	2714.01	87.57	9.82
2019	2691.76	2765.45	2777.99	92.46	6.39
2020	3083.04	3120.52	3075.81	93.16	6.04

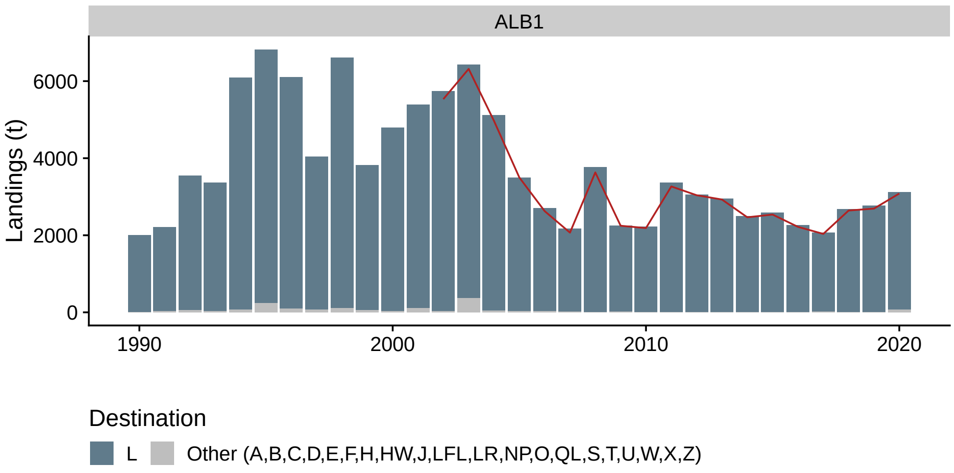

Figure 4: Groomed albacore landings (t) by destination (bars), compared with Quota Management Report/ Monthly Harvest Return (QMR/MHR) totals (line), for Fisheries Management Areas ALB 1 . Destination codes are defined in the glossary.

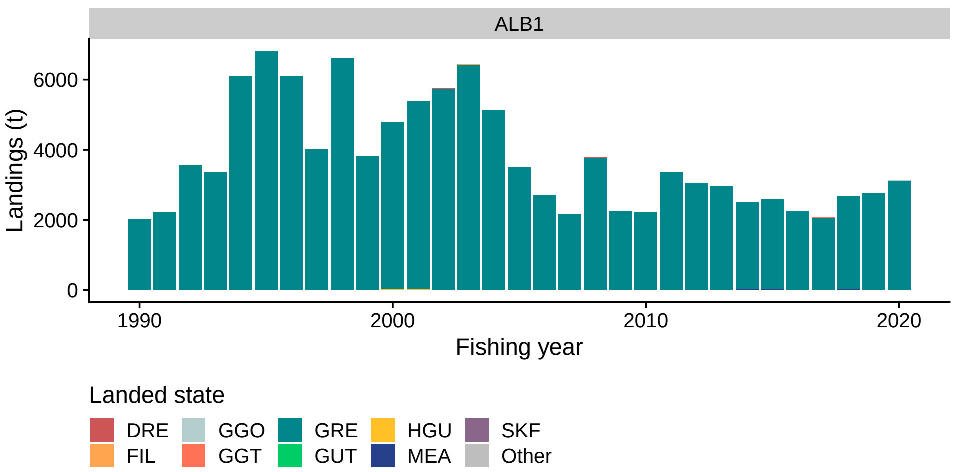

Figure 5: Landed state of albacore landings (t) for Fisheries Management Areas ALB 1 . Landed state codes are defined in the glossary.

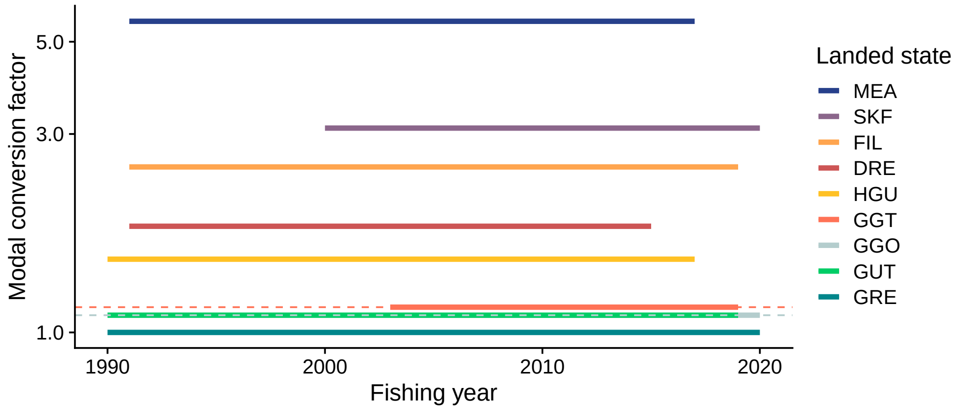

Figure 6: The modal annual conversion factor reported for the key product states used in ALB 1 landings. The current statutory conversion factor is indicated by a dashed line for states where a species-specific value is defined. Landed state codes are defined in the glossary.

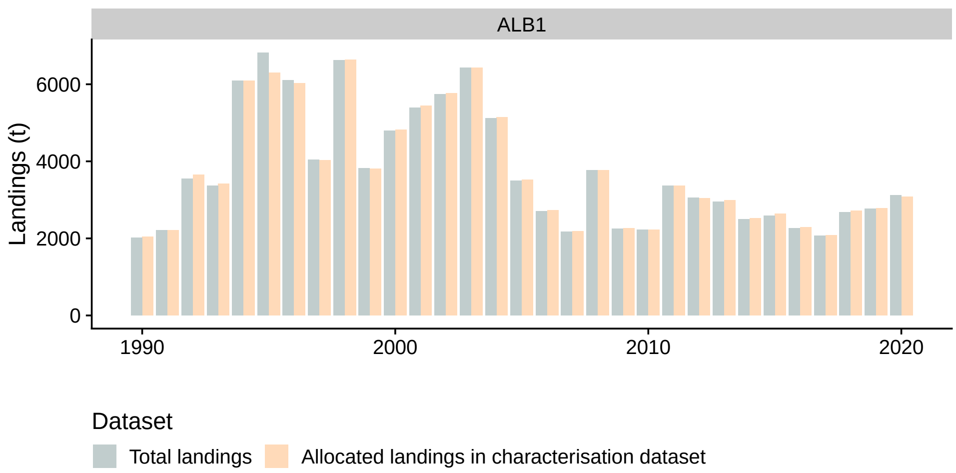

Figure 7: Total landings (t) of albacore and allocated landings (t) assigned to events retained in the characterisation dataset for Fisheries Management Area ALB 1 .

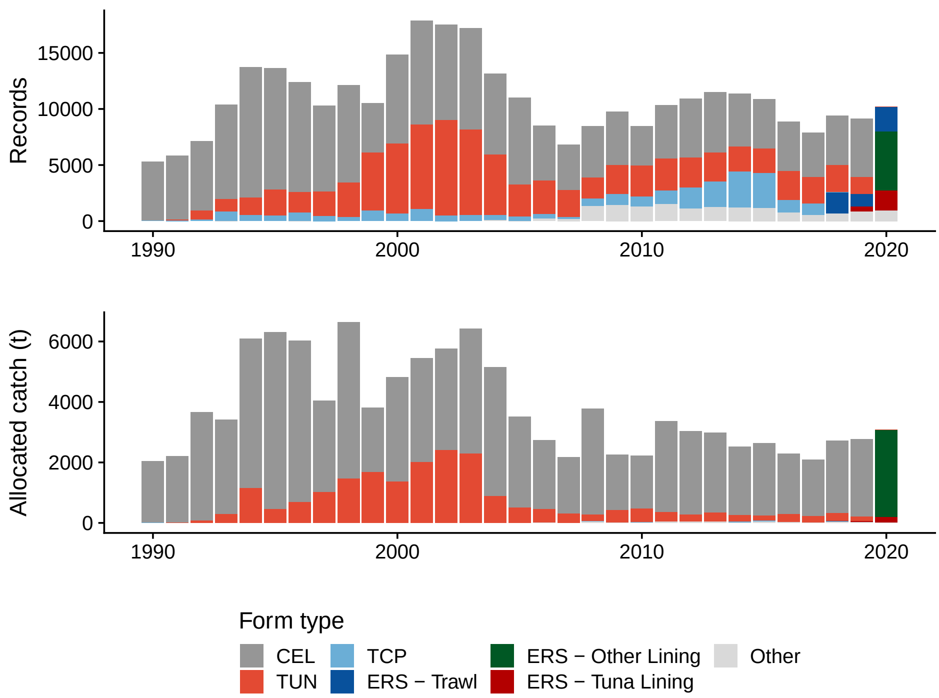

Figure 8: Reporting forms used for effort within the ALB 1 Fisheries Management Area, on trips landing albacore in terms of data records and their allocated catch (in t).

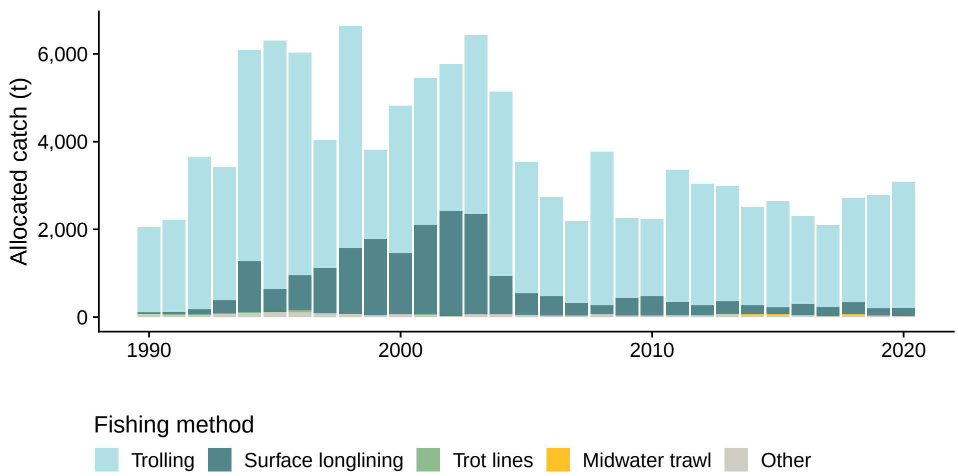

Figure 9: Allocated catch (in t) of albacore by fishing method, for events within the ALB 1 Fisheries Management Area.

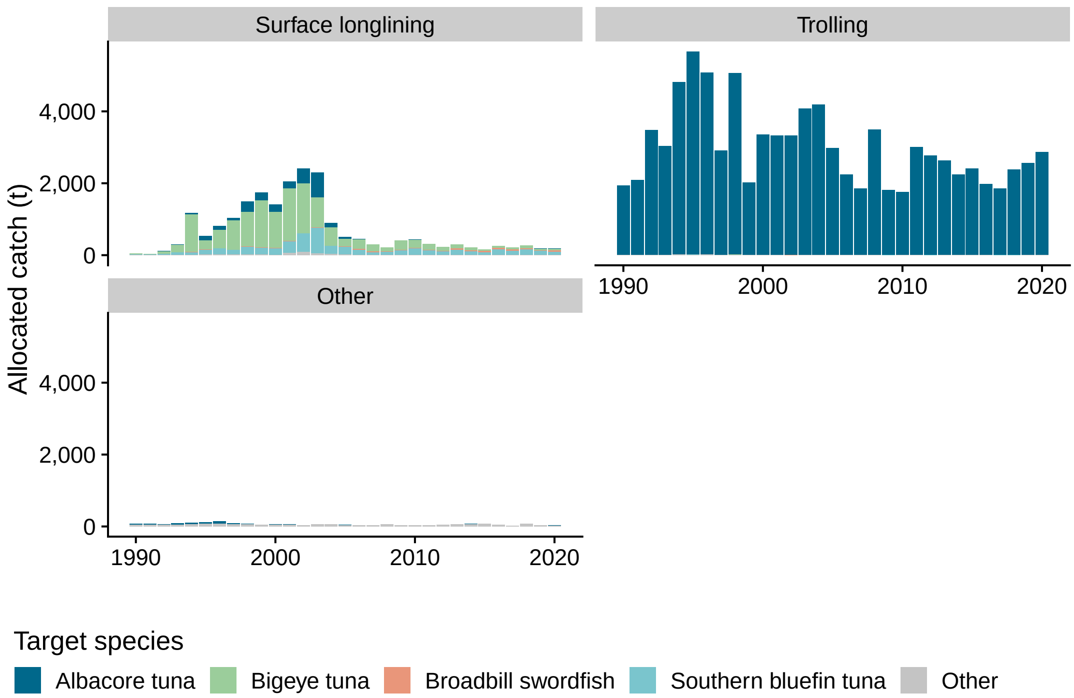

Figure 10: Allocated catch (in t) of albacore by key fishing method and target species declared on the fishing event forms, for events within the ALB 1 Fisheries Management Area.

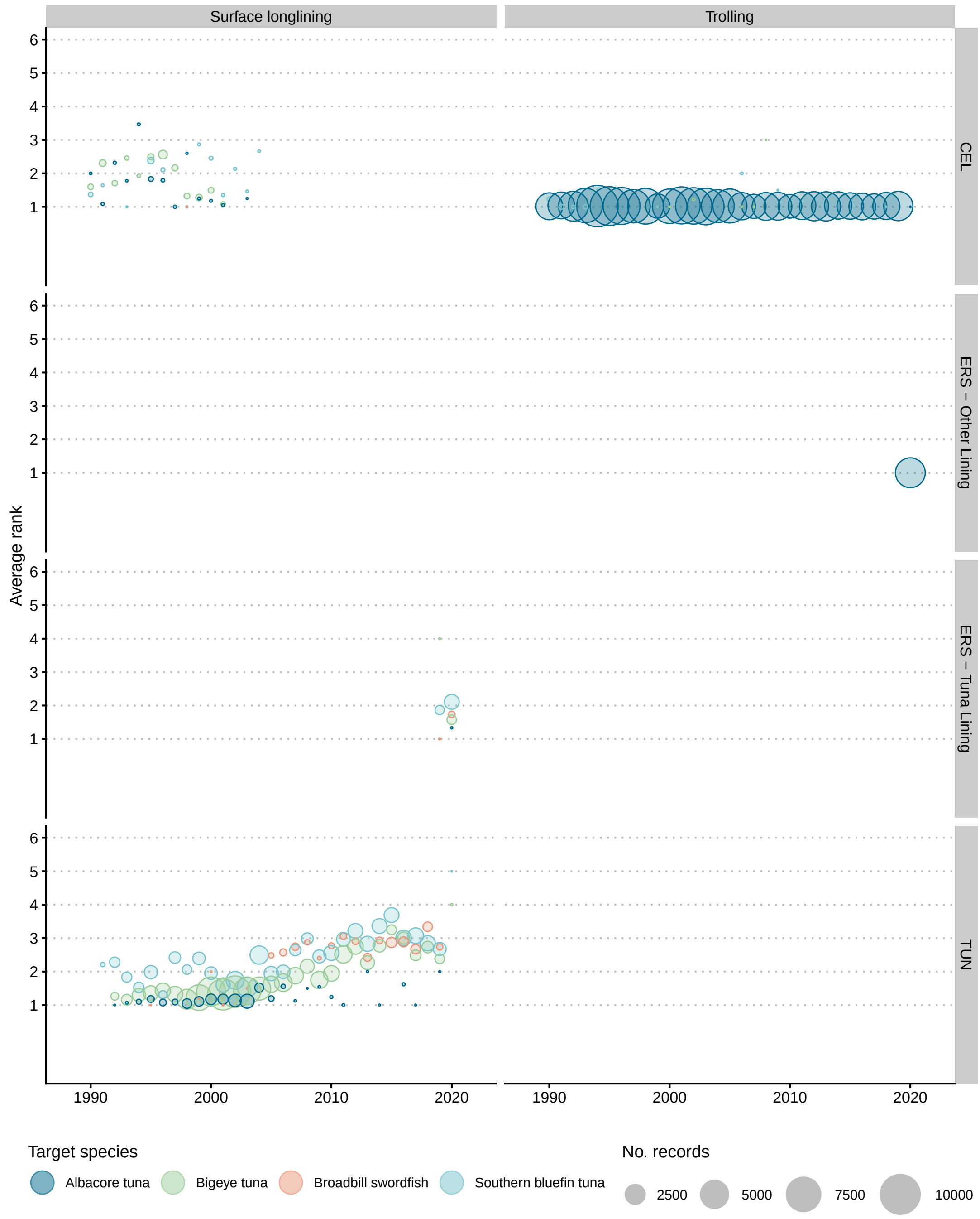

Figure 11: Average rank of albacore in the estimated catch forms by fishing method, aggregated by target species declared on the corresponding fishing event forms, for events with estimated catches within the ALB 1 Fisheries Management Area. The size of the circle scales with the number of records.

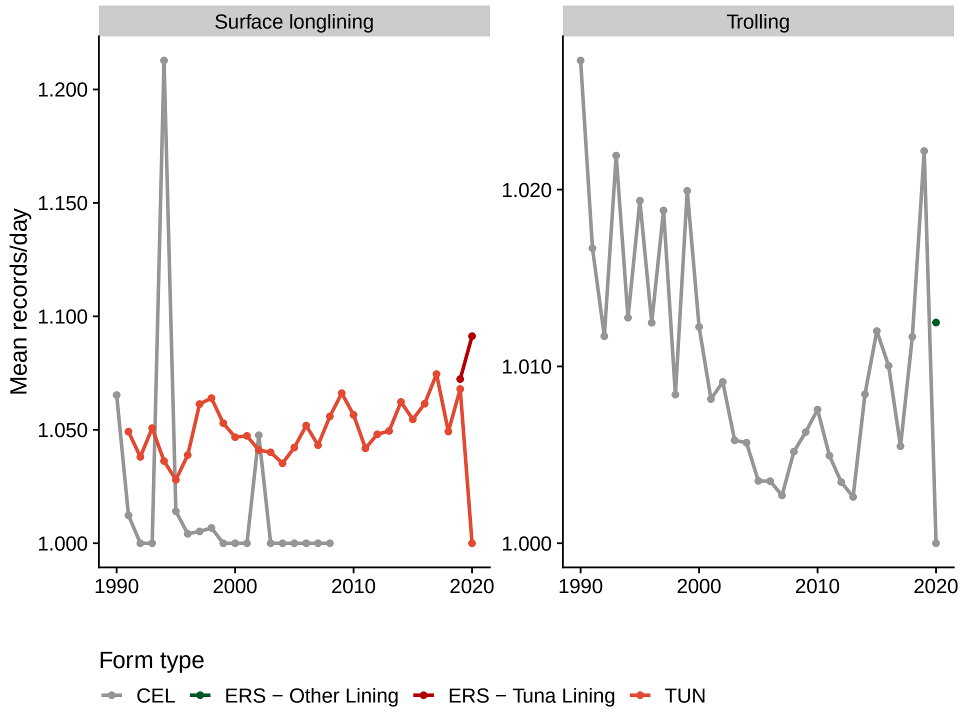

Figure 12: Average number of records per record day by reporting forms used for effort within the ALB 1 FMA on trips landing ALB 1.

3.1 Catch distributions by method

3.1.1 The Trolling fishery

Few (<20%) troll records prior to 2020 provided latitude and longitude information on the CEL forms. With the use of "ERS - Other Lining" forms in 2020, 100% of troll records reported latitude and longitude (Figure 13).

In the troll fishery, most of the catch and the highest catch rates occur on the west coast of both the North and South Islands (Figure 14). There are relatively high concentrations of catch and high catch rates in statistical areas 42 and 45 on the central west coast of the North Island. High catch is also found on the west coast of the South Island in statistical areas 33 to 36. A small amount of catch is taken on the east coast of the North Island, with the highest catch rates in Hawkes Bay. Catch on the east coast of the South Island is negligible. Note however, that prior to 2020 these data are from <20% of records, but with full coverage from 2020.

The spatial distribution of the recent (2016-2020) troll catch increases rapidly in a relatively small area with about half the catch being taken in the first 50 grid cells fished (Figure 15), after which the area fished expands rapidly probably as a result of the fleet moving south as the fishing season progresses, and the main fishing area being in about 100 cells. These data are, however, skewed by the limited latitude and longitude reporting prior to 2020. The recent trend (2016-2020) is likely dominated by 2020 data, and the early series (2003-2007) is constrained by the poor latitude and longitude reporting noted above. Overall, most of the catch come from three distinct areas, the west coast of the upper north Island, the north Taranaki Bight and the west coast of the South Island, with most of the landings coming from statistical areas 34 and 35 (Figure 16).

While in some years catch is made year-round, most of the catch is made during the Austral summer. The troll fishery normally begins in November with small catches of albacore. The catches increase in December and are highest in January to March, with a small catch in April and May (Figure 17). While the catch mostly occurs during the period from January to March, the CPUE is relatively consistent from December through to April in most years (Figure 17). Trolling is almost entirely directed at albacore (Figure 17), and the rapid decline in catch during the Autumn is likely a combination of the fish dispersing (or declining catchability) and the vessels switching gear to target more lucrative species such as southern bluefin tuna at that time of year (see below).

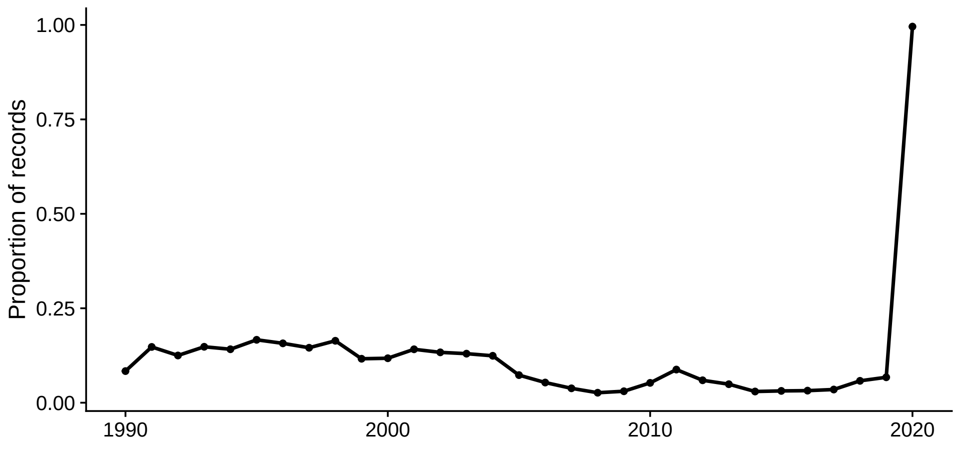

Figure 13: Proportion of records reported with a latitude/longitude for the ALB 1 trolling fishery.

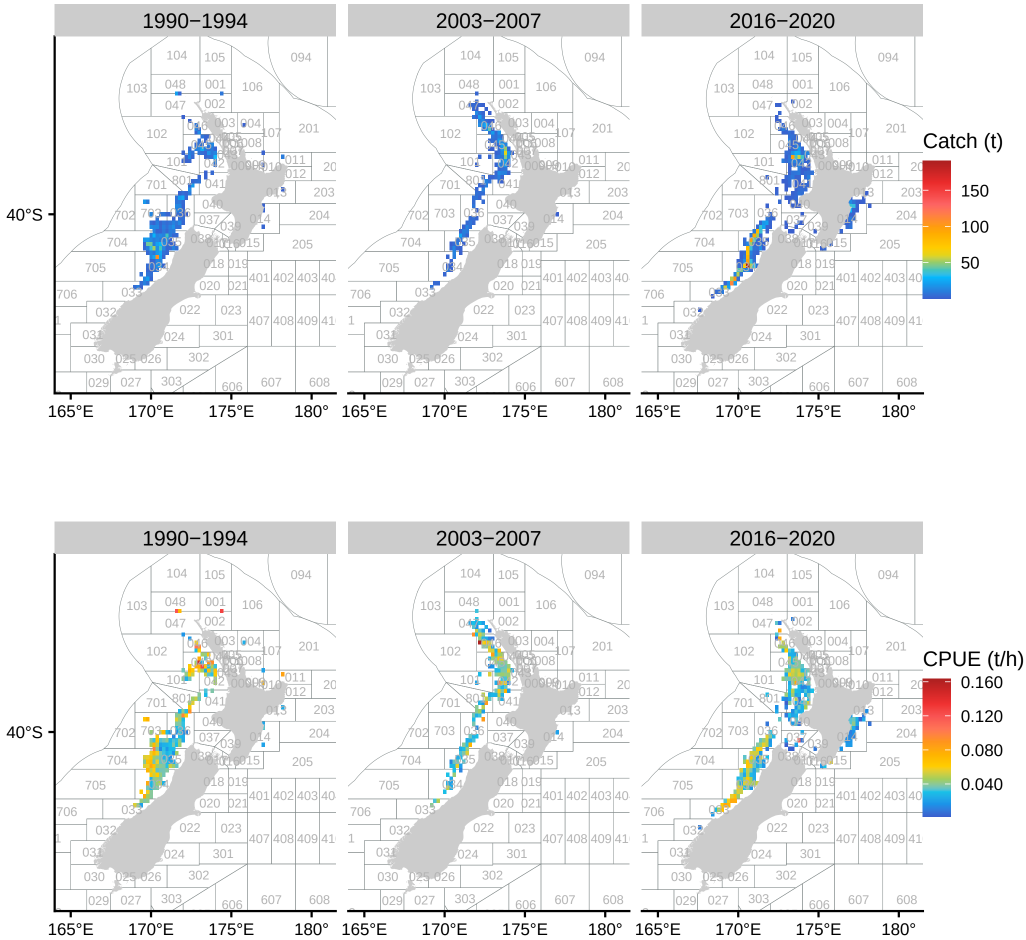

Figure 14: Allocated landings (t) and raw aggregate CPUE (t/h) for the ALB 1 trolling fishery, aggregated for the first, middle, and last 5 year period of reporting by 0.2 latitude/longitude for records where landings are allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted.

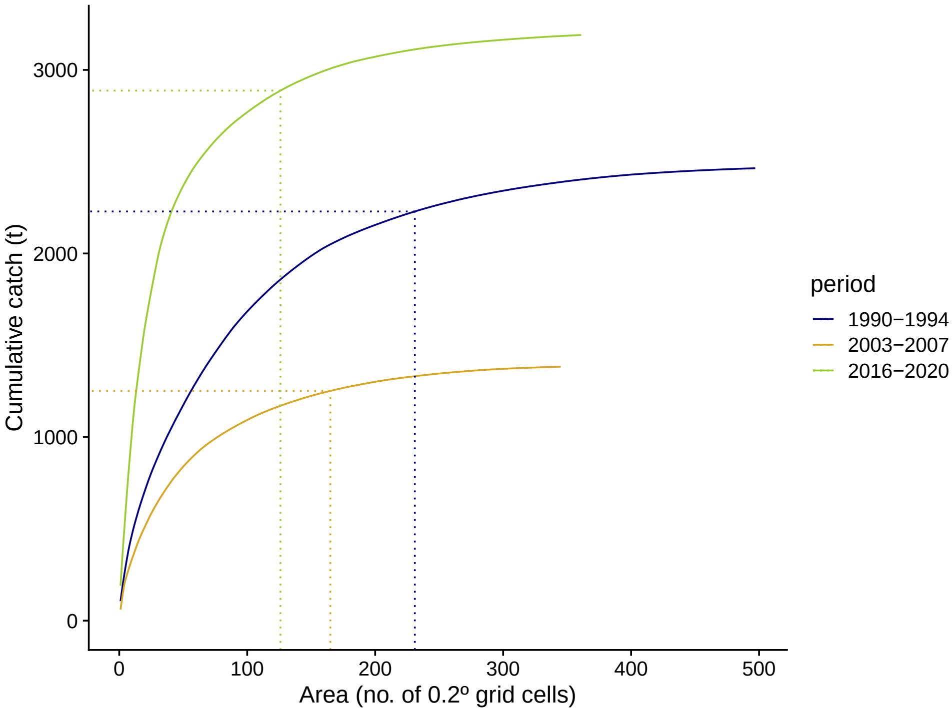

Figure 15: Cumulative ALB 1 catch by area (grid cells) for the trolling fishery, aggregated for the first, middle, and last 5 year period of reporting. Dotted lines indicate the 90th percentile for the first, middle, and last 5 year period of reporting.

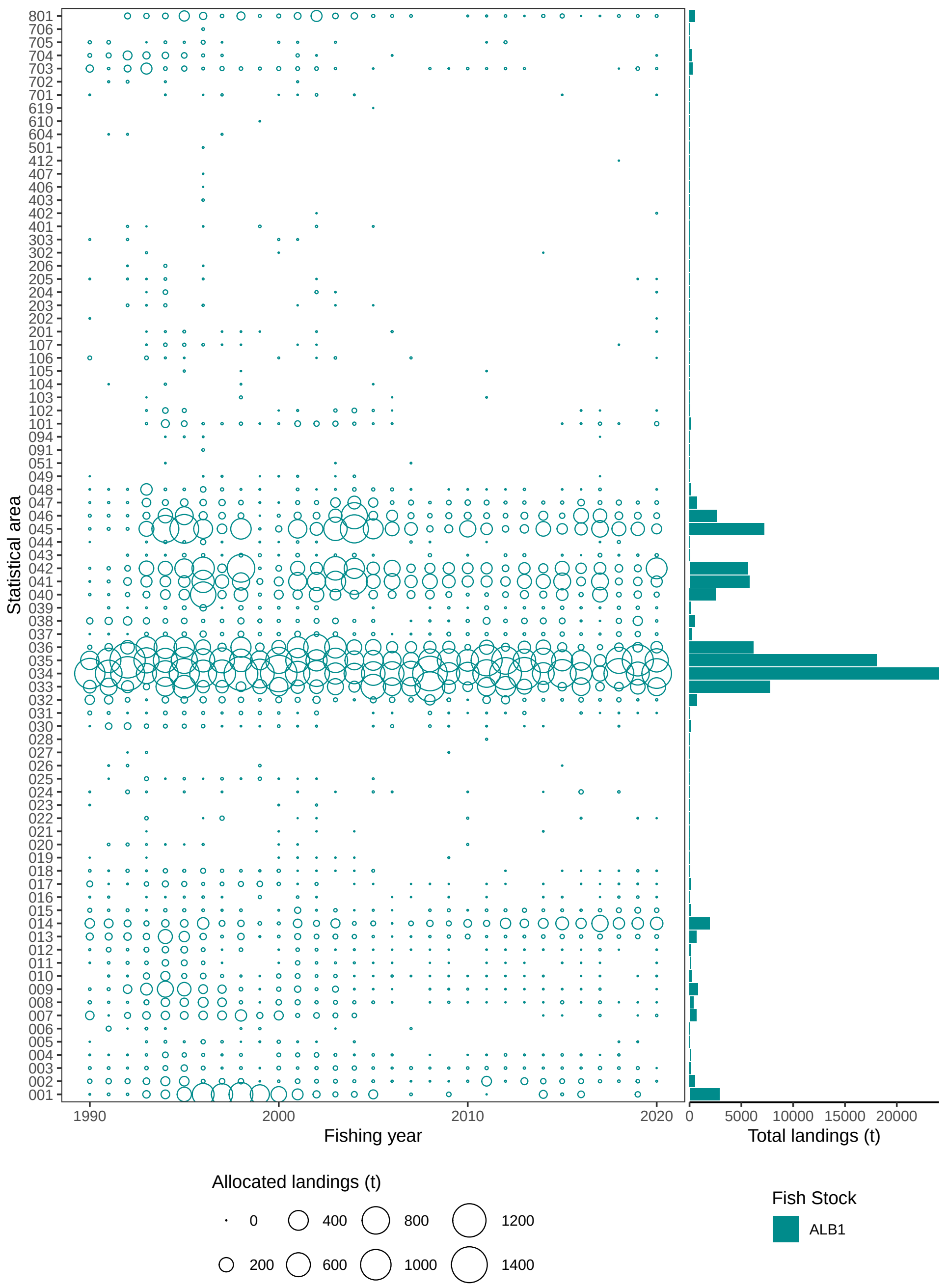

Figure 16: Annual allocated ALB 1 landings (t) by statistical area for the trolling fishery. The size of the cicles scale with the allocated catch by statistical area (in t). The bar plot (right hand side) shows the total landings (in t) of ALB 1 for each statistical area.

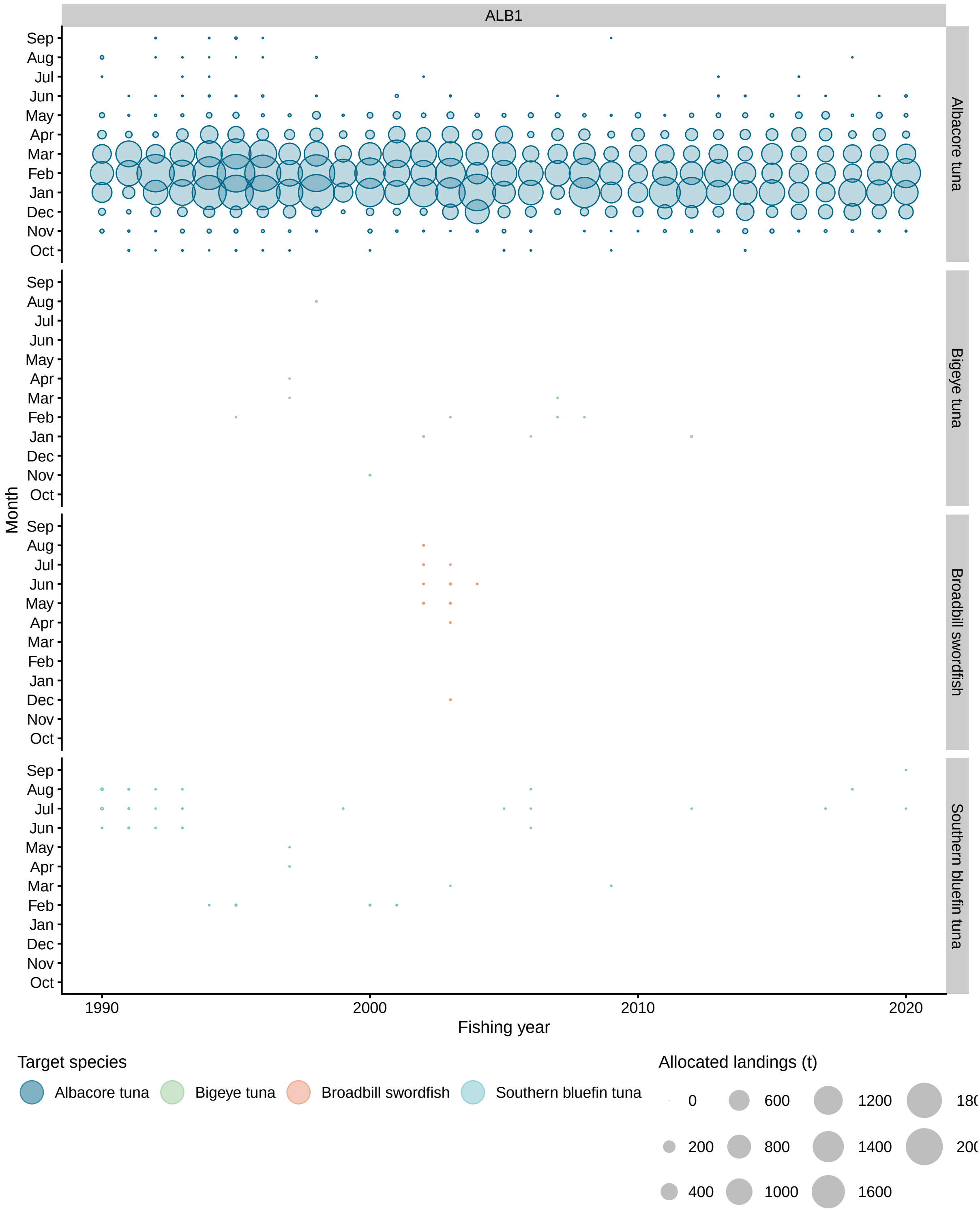

Figure 17: Seasonal distribution of ALB 1 allocated landings (t) by month and fishing year for the trolling fishery. The size of the circle scales with the monthly allocated catch (t).

3.1.2 The Surface longlining fishery

The New Zealand surface longline fishery catches a number of species and has changed over the course of the last three decades. Prior to 2004 most of the catch was albacore with high catch of swordfish as well as bigeye tuna. From 2005 the catch of albacore and bigeye tuna declined substantially, while the catch of blue shark and southern bluefin tuna increased (Figure 18, Table F.1). There is a fairly abrupt change in the surface longline albacore catch in the mid-2000s where the albacore catch declines markedly (Figure 18, Table F.1). To some extent this can be attributed to a reduction in targeting of albacore and bigeye tuna and a slight increase to targeting of swordfish after 2010. But most of the reduction in albacore catch can be attributed to a large reduction in surface longline fishing effort directed at bigeye and albacore tuna in 2005, when the overall fishing effort halved (Figure 19, Table F.2).

Since 1993 almost all surface longline records reported latitude and longitude for sets catching ALB 1 (Figure 20). This trend is consistent between TUN and "ERS - Other Lining" forms.

The troll fishery occurs mainly on the west coast of New Zealand and relatively close inshore. By contrast, the surface longline fishery catching albacore occurs mostly on the east coast of the North Island (Figure 21). Albacore surface longline catch straddles the East Cape and extends from Hawke Bay to north of Cape Reinga out to the boundary of the EEZ. Small patches of catch occur off the southeast coast of the South Island and off the west coast of the North Island. In the earlier period (2003-2007), when the surface longline fishery was albacore focused, the catch distribution is broader than the more recent period when albacore target sets are less frequent. The spatial nature of records in the plots may be influenced by vessels dropping out due to the data grooming rules.

Surface longline sets targeting albacore are sparse but occur off the East Cape and northwest of the North Island. Albacore catch in bigeye tuna sets occur primarily off the east coast of the North Island from Hawke Bay north. Catch in bigeye sets on the west coast of the North Island are sparse. There is a relatively high density of catch off the central west coast of the South Island where vessels are targeting primarily southern bluefin tuna, and the albacore catch off the southeast coast of the South Island are also in southern bluefin target sets (Figure 22).

The surface longline catch of albacore expands in its spatial extent slower than the troll fishery. Nevertheless, in 2003-2007 the initial catch comes from a few cells with around half the catch coming from about 50 cells and the second half coming from the remaining 500+ cells (Figure 23). In the more recent period (2016-2020), however, the area fished is smaller with most of the catch coming from <300 cells. Compared to the troll fishery, the surface longline catch is more widely distributed with high proportions of the catch coming from statistical areas 1-4; 8-14; 33-35; 41-48; and 105-205 (Figure 24). This is due to the dispersed nature of the fishery as well as the relatively high number of target pelagic longline fisheries that catch albacore as a bycatch.

Catch in albacore target sets are more pronounced in April to July (Figure 25), but are relatively consistently caught in the more northerly bigeye tuna surface longline sets throughout the year (Figure 25). The southern bluefin tuna target fishery is relatively short and catches albacore from March to August. While the swordfish target surface longline sets catch albacore year-round, but mostly in the first and second quarters. Targeting in the surface longline sets has change considerably through the year since 1990. From 2010, catch and target has been relatively consistent with swordfish and bigeye targeting throughout the year, southern bluefin tuna targeting through the Austral winter, and very little albacore targeting which tends to occur in the autumn months (Figure 25, Figure E.5). Assessing the monthly CPUE data from these target fisheries reveals that CPUE was higher prior to 1998 for both albacore and bigeye tuna target sets, thereafter CPUE data are sparse for the albacore target sets which dropped off after 2005. Albacore CPUE in bigeye target sets is relatively consistent throughout the year, but prior to 2000 and after 2015 CPUE was higher in March to August (Figure E.6), a trend also apparent in the southern bluefin tuna target sets (Figure E.7). Figure 25 also shows the increasing catch of albacore prior to 2005 followed by large reductions in albacore catch in albacore, bigeye and southern bluefin tuna sets and an increase in swordfish target sets.

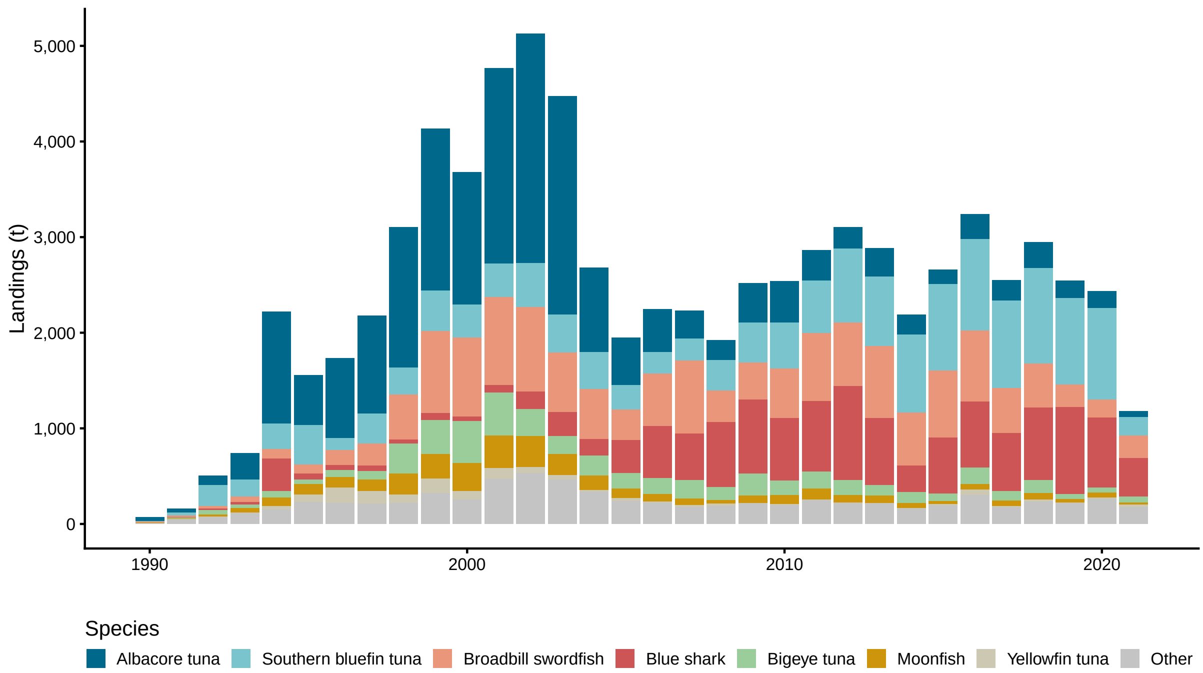

Figure 18: Landings by species and fishing year for the New Zealand surface longline fishery, defined here are those trips where the modal fishing method was surface longlining.

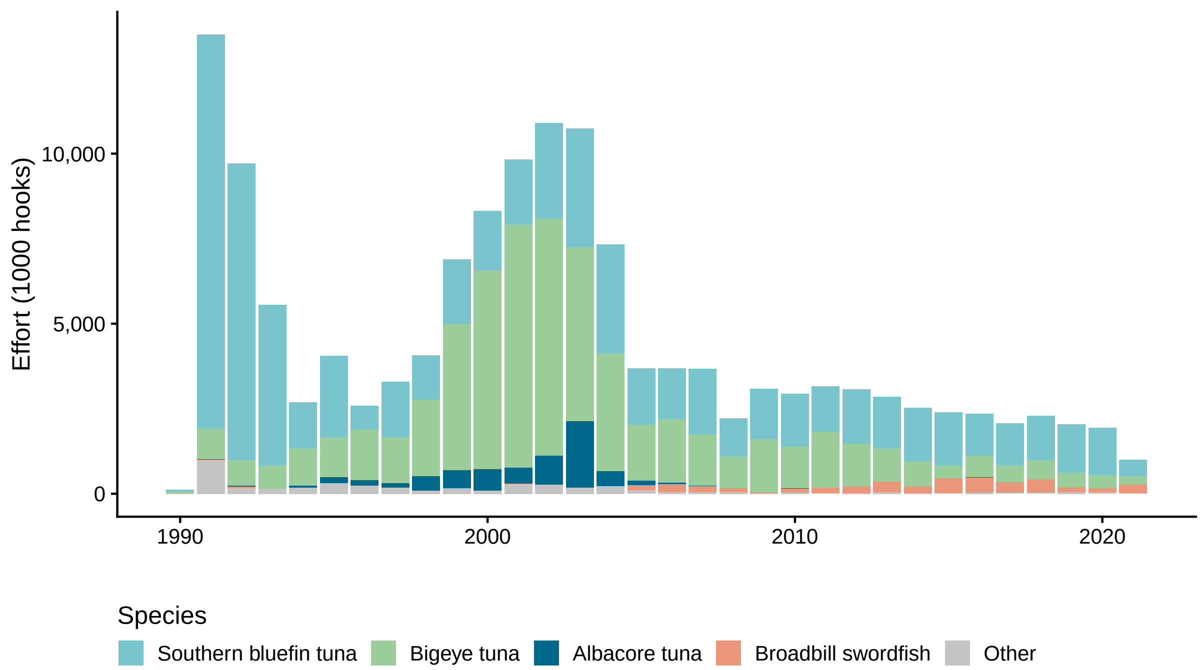

Figure 19: Total effort (no. hooks/1000) by species and fishing year for the New Zealand surface longline fishery, defined here are those trips where the modal fishing method was surface longlining.

Assessing the catch and CPUE in space and time suggests that the troll and surface longline fisheries do not overlap very much. The troll catch starts in November inshore on the North Island northwest coast and then progresses south through the summer. By February and March most of the catch is being made inshore off the central and southern South Island west coast. The catch declines substantially in April and May (Figure E.1 and Figure E.2). This differs from the surface longline albacore catch that occurs in October to December on the North Island east coast, moving further offshore and to the west coast and south along the east coast in January and February. By March, the catch is centred off Hawke Bay and has reasonable catch is being taken off the South Islands west coast. This trend progresses and intensifies through the second quarter of the year and into July. In August and September, the catch is taken from the northeast coast of the North Island (Figure E.3 and Figure E.4). While the troll catch is all albacore target driven, the surface longline catch is from sets directed at other species. Albacore target sets occur off the south and central east coast of the North Island in the first half of the year with a slight shift north in the second quarter (Figure E.5). The bigeye tuna target fishery operates predominantly off the east coast of the North Island all year round but with some catch on the west coast of the North Island in the first quarter and into the second quarter of the year (Figure E.6). The southern bluefin tuna target sets begin in March off the South Island west coast and continue there through the Austral winter while also expanding to the North Island east coast through winter and into spring (Figure E.7).

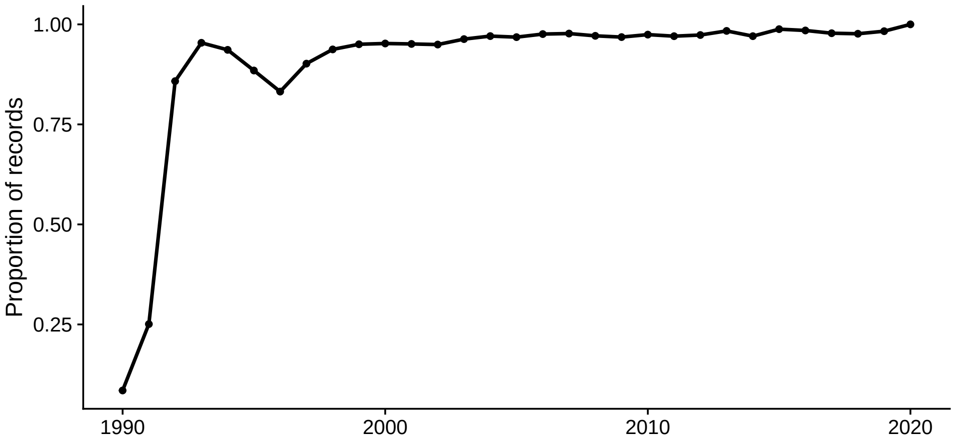

Figure 20: Proportion of records reported with a latitude/longitude for the ALB 1 surface longlining fishery.

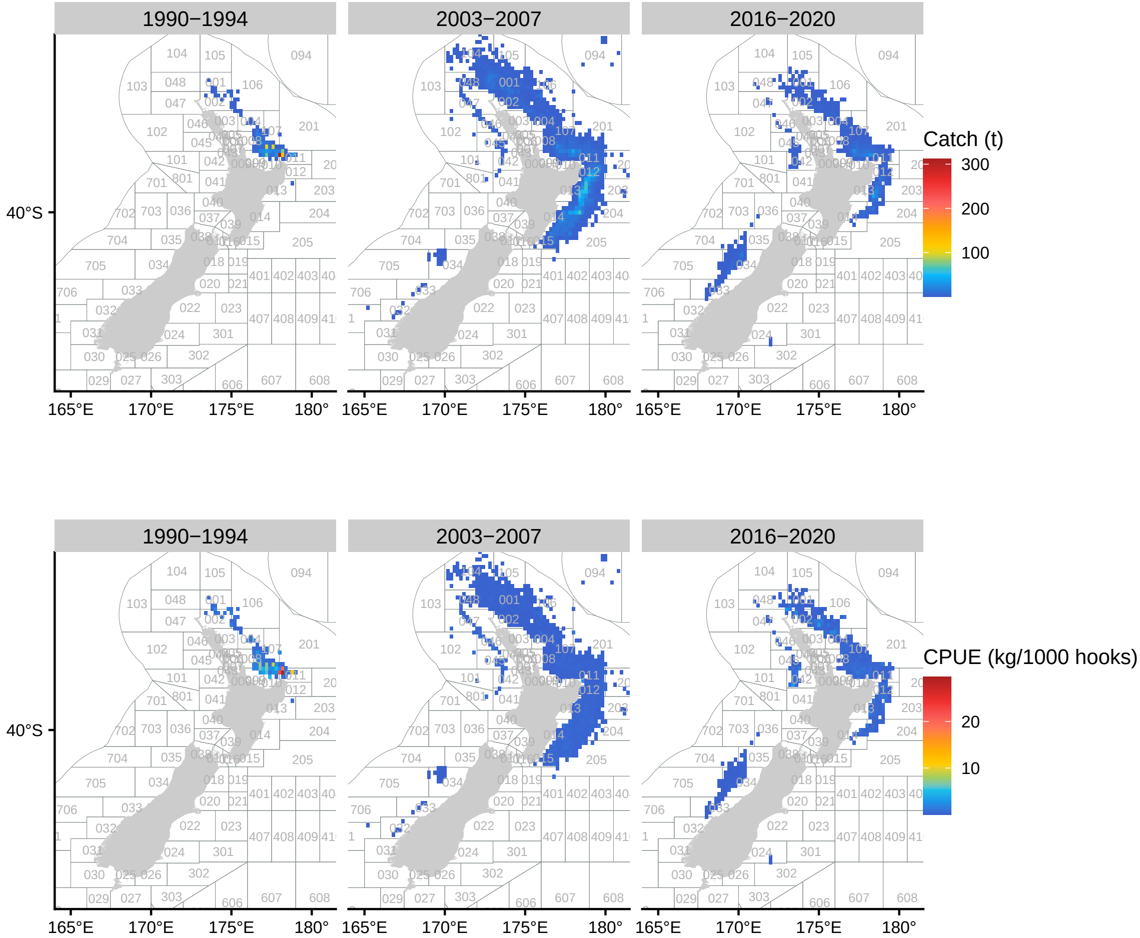

Figure 21: Allocated landings (t) and raw aggregate CPUE (kg/1000 hooks) for the ALB 1 surface longlining fishery, aggregated for the first, middle, and last 5 year period of reporting by 0.2 latitude/longitude for records where landings are allocated in proportion to estimated catch. Cells with data from less than three vessels or permit holders are omitted.

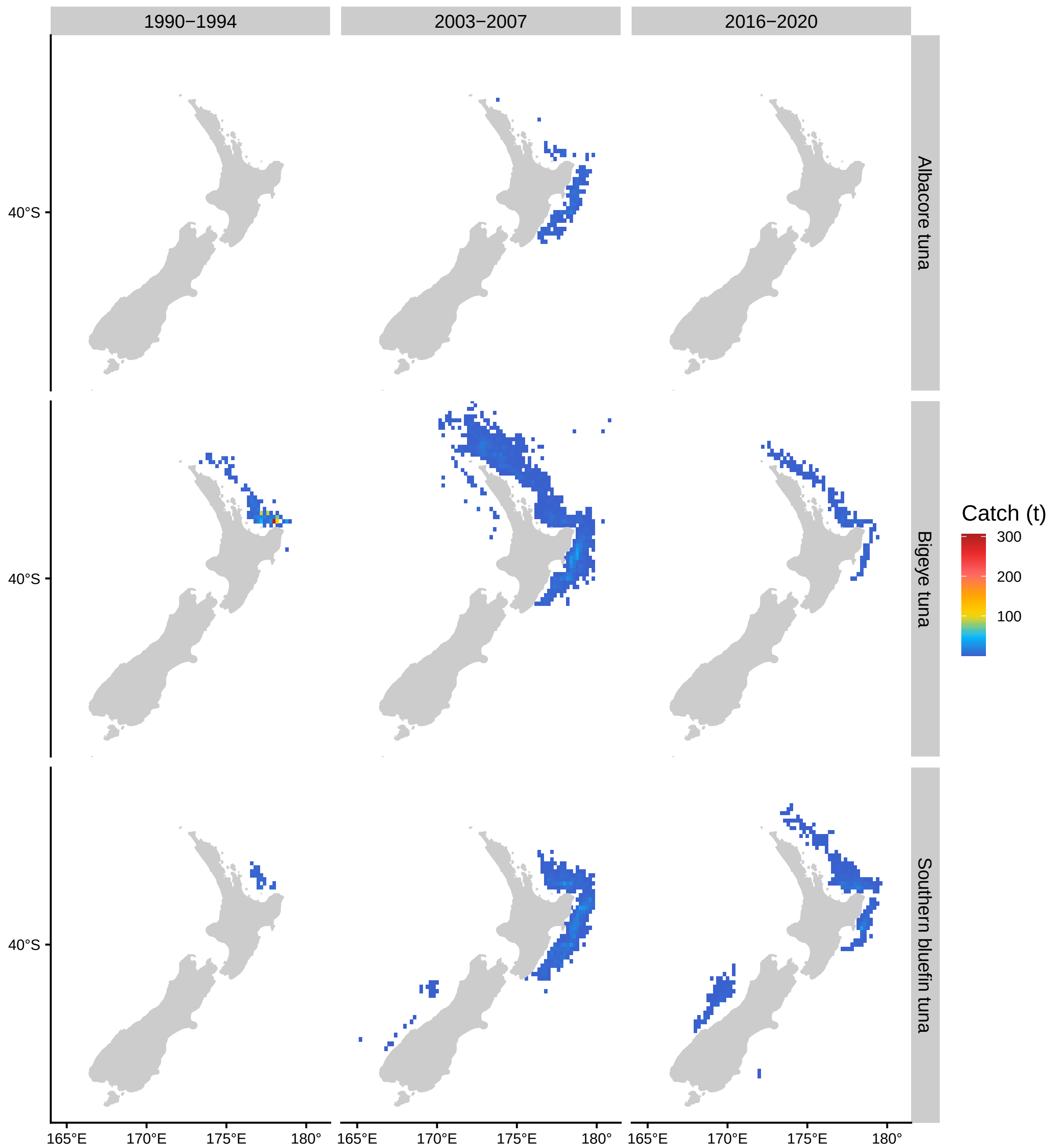

Figure 22: Allocated ALB 1 landings for the surface longlining fishery by key target species, aggregated for the first, middle, and last 5 year period of reporting by 0.2 latitude/longitude for records where landings are allocated in proportion to estimated catch. Grid cells with data from less than three vessels or permit holders are omitted.

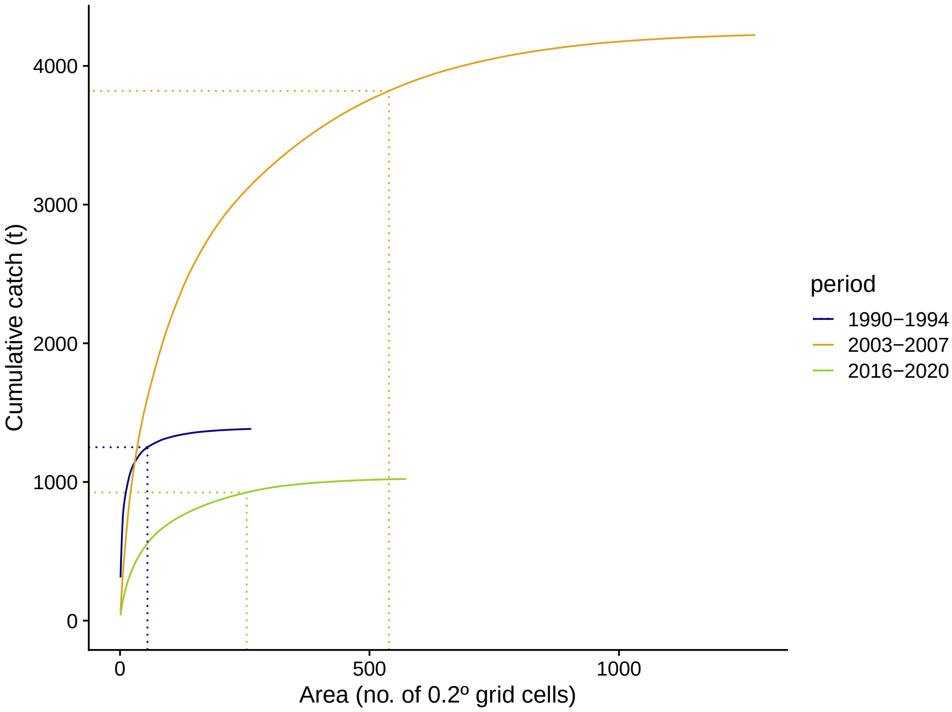

Figure 23: Cumulative ALB 1 catch by area (grid cells) for the surface longlining fishery, aggregated for the first, middle, and last 5 year period of reporting. Dotted lines indicate the 90th percentile for the first, middle, and last 5 year period of reporting.

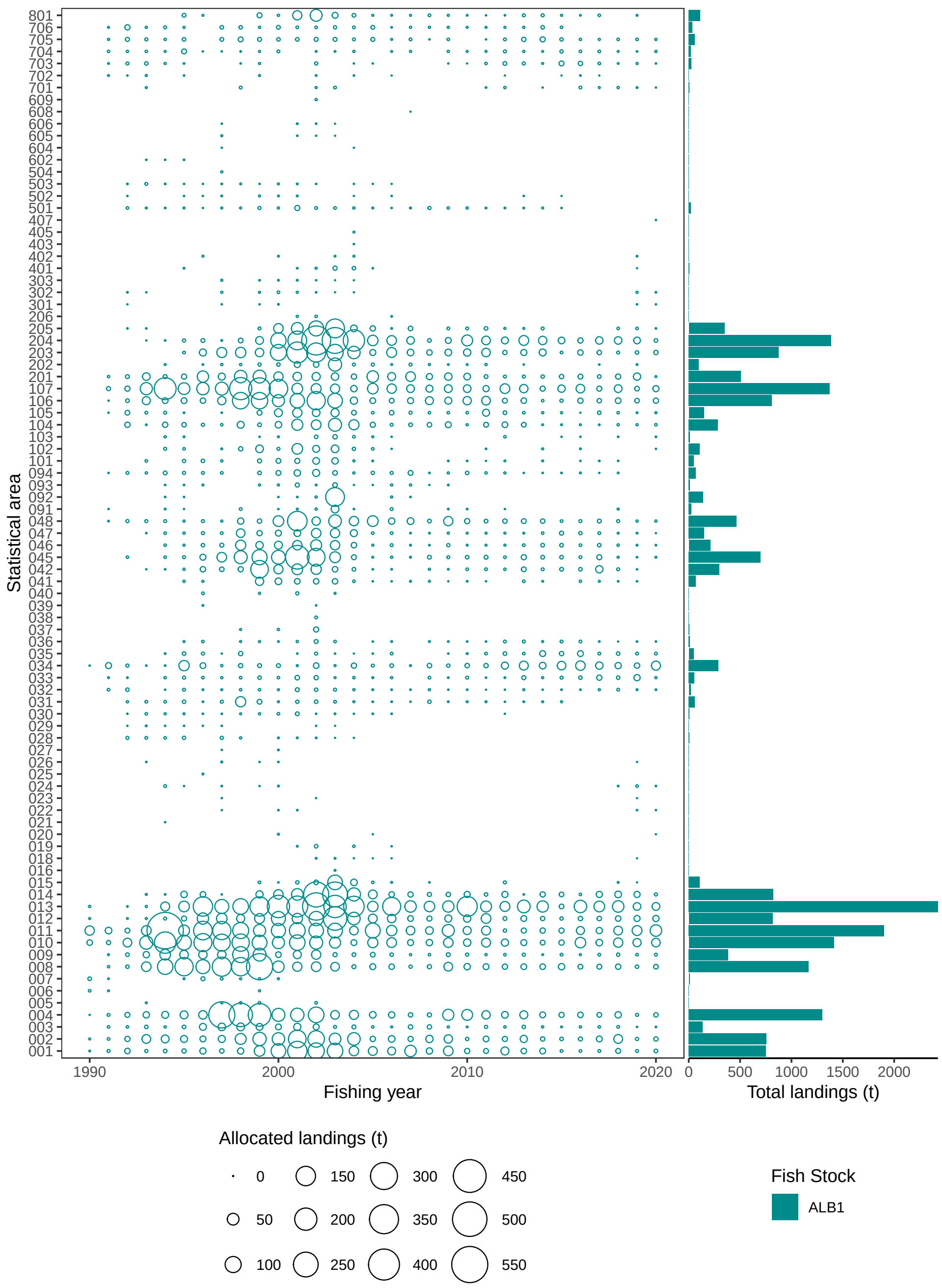

Figure 24: Annual allocated ALB 1 landings (t) by statistical area for the surface longlining fishery. The size of the cicles scale with the allocated catch by statistical area (in t). The bar plot (right hand side) shows the total landings (in t) of ALB 1 for each statistical area.

Figure 25: Seasonal distribution of ALB 1 allocated landings (t) by month and fishing year for the surface longlining fishery. The size of the circle scales with the monthly allocated catch (t).

4. CATCH-PER-UNIT-EFFORT

CPUE standardisations were been prepared using two approaches: catch prepared from pseudo catch effort landing return aggregated daily (ALB 1 T pseudoCELR); and data collated at the trip level (ALB 1 T CELR trip) from catch effort landing return (CEL) forms. Both series are based on troll catch and effort data only.

The ALB 1 T pseudoCELR CPUE series was derived from daily troll records landing to the ALB 1 fishstock on CEL and ERS other lining (2020 only) reporting forms. The target species was albacore, and catch was recorded from 22 statistical areas between 1990 and 2020 (Table 3). Only vessels that had fished for four years or more and that fished at least three trips per year were selected.

A large number of vessels ($\sim$1000) have participated in the albacore troll fishery. The effort in this fishery is almost opportunistic where vessels participate when either the albacore catch is good or catch in their usual target fishery is poor. It is easy for fishers to use albacore opportunistically as it falls outside of the QMS and the requirement to obtain ACE is not a constraint. A set of core fleet selection rules were used to reduce the number of vessels in the dataset to those that had participated with some longevity, with fleet overlap and coverage extending throughout the time series, and while retaining a high proportion of the catch. The final selection criteria required a vessel to have fished for a minimum of four years and to have conducted at least three trips per year. This resulted in the removal of over 600 vessels but retained 373 vessels and 89.96% of the catch (Figure 26). This selection also resulted in retaining a number of vessels that had fished since the early to mid-1990s, with a number of them conducting 10 or more trips per year (Figure 27). Most vessels have fished since the early 2000s with only a few recent entrants that have participated since 2010. The selection did, however, remove a disproportionately high number of vessels and trips from 1999 (Table 4).

In an effort to test the core fleet selection rules we explored model runs where the selection criteria were more extreme: firstly, where vessels were required to have fished for a minimum of 2 years and to have conducted at least 1 trip per year; and secondly, where vessels were required to have fished for a minimum of 6 years and to have conducted at lest 5 trips per year. While these selection criteria had the most effect on the number of vessels excluded from the model data set (<300 vessels for the 1 trip/2 year option, and >700 for the 5 trip/6 year option), rather than on the amount of catch excluded (<10% for the 1 trip/2 year option, and around 25% for the 5 trip/6 year option). These selection criteria did not appreciably change the resulting CPUE series compared to when the 3 trips/4 years selection criteria were used, and are not reported further in this report.

The number of records in the dataset that recorded a positive daily catch are shown by fishing year in Table 4. With the exception of 1999, in most years more than 100 vessels are retained per year, with a high number of trips (>700) and a large number of records (>3000). Overall, the number of records in the dataset peaked in the mid-1990s and early 2000s, but remained relatively consistent from 2013 onwards (Figure 27).

Note, 1999 was an exceptional year, the catch was low and the distribution of the catch was largely constrained to the central west coast of the South Island, with low catch off the North Island in that year. In addition, in 1999 the catch seemed to start later in the year compared to other years. In that year it is conceivable that fewer vessels based off the North Island participated in the fishery, or only undertook a few (relatively unsuccessful) trips before reverting to other target species. These unsuccessful trips are probably lost in the grooming procedures and the core fleet from that year was, therefore, concentrated in statistical areas 33, 34 and 35 that are known for higher catch rates. This trend is evident where the number of records in the ungroomed dataset in 1999 are substantially lower than in other years Table 5. In that year, fish that arrived in New Zealand became accessible to the fishery late in the fishing season, appeared available to the fishery only off the South Island but were part of a strong year class (Kendrick & Bentley 2010) that persisted in the fishery for two consecutive years (Figure C.4).

The data removed by the filtering are presented in Table 5. The first step was the removal of sets with no recorded fishing duration, which removed a few records (except 1997, 1999 and 2000) but in most years retained all the catch. Retaining only records with a positive fishing duration removed three records from 1992 and 1993 but retained all the catch. Limiting the fishing duration to less than 20 hours and limiting the season start day removes a small number of records from all years. Records were also removed that had no catch in numbers recorded and, along with the the core vessel selection, had the greatest effect on the data, removing the highest number of records throughout the time series.

The step-wise method model applied to the albacore troll catches in ALB 1 using the ALB 1 T pseudo-CELR dataset is described in Table 6, and did not provide much of a standardising effect in comparison to the unstandardised series (Figure 28). Fishing year (forced into the model as the first variable) explained 4.9% variation in the catch. Fishing duration and vessel key were also selected in the model, explaining an additional 10.5% and 5.5% variation in the catch, respectively. The stat_area and month interaction term was also selected, explaining <1% additional variation. SST and the MEI were not selected as explanatory variables. The final model explained 23% of the variance in log(catch).

Diagnostic residual plots for the negative binomial-model (Figure 29) indicate that the residuals follow the modelled distribution reasonably well except for extreme values. Note, the Poisson distribution failed to fit these data reasonably (Figure 37) and results using this model are not reported further.

The trends in the ALB 1 T pseudoCELR index do not change appreciably as terms are successively entered into the model (Figure 30). While the influence of fishing duration is seen to fluctuate (Figure 34), it does so over 0.1 influence points and its effect on the series overall is minimal (Figure 31). The influence (CDI) plots for vessel key (Figure 32 shows a slight increasing trend throughout the series which tends to elevate the beginning of the CPUE series and decrease the series in later years (Figure 30, third panel from the top), however, this effect is minimal.

The ALB 1 T CPUE TRIP series was derived from troll records landing to the ALB 1 fishstock on CEL and ERS other lining (2020 only) reporting forms aggregated at the trip level. The target species was albacore, and catch was recorded from 18 statistical areas between 1990 and 2020 (Table 3). Only vessels that had fished for four years or more and that fished at least three trips per year were selected.

A large number of vessels (976) was available for the ALB 1 T CPUE TRIP series. As with the ALB 1 T pseudoCELR series the core fleet selection aimed to create rules that removed a large number of vessels but retained a high proportion of the catch in order to provide an index that is informative for describing trends in the fishstock. The final selection criteria were the same as ALB 1 T CELR trip CPUE series. This resulted in the removal of over 600 vessels but retained around 90% of the catch (Figure 38). This selection also resulted in retaining a number of vessels that had fished since the early to mid-1990s and a number of them conducting 10 or more trips per year (Figure 39). A number of vessels left the fishery in the early to late 2000s, but most vessels have fished since the early 2000s with only a few recent entrants that have participated since 2010 (Table 9). The vessel selection also removed a disproportionately high number of vessels and trips from 1999.

The number of records in the dataset that recorded positive daily catch are shown by fishing year in Table 9. In most years more than 90 vessels are retained per year, with a high number of trips (>700) (also equivalent to the number of records for this dataset). Overall, the number of records in the dataset peaked in the mid-1990s and early 2000s, but remained relatively consistent from 2007 onwards. The number of vessels and trips in the data set delcines slightly after 2014 (Table 9).

The data removed by the filtering are presented in Table 10. The first step was the removal of sets with no recorded fishing duration, which removed a few records in most years along with some of the catch. Retaining only records with a positive fishing duration removed no records or catch. Limiting the fishing duration to less than 180 hours removes a small number of records and catch from a number of years. The core vessel selection had the greatest effect on the data removing the highest number of records and catch throughout the time series.

The step-wise method model applied to the albacore troll catches in ALB 1 using the ALB 1 T CELR trip dataset is described in Table 11 and provided more of standardising effect in comparison to the unstandardised series (Figure 40) than did the same model applied to the daily dataset. This is mainly due to where fishing duration is accounted for in the process. Fishing year (forced into the model as the first variable) explained 3.1% variation in the catch. As with the previous model fishing duration and vessel key were also selected, explaining an additional 44% and 8.3% respectively, variation in the catch. The stat_area and month interaction term was also selected, explaining <1% additional variation. SST and the MEI were not selected as explanatory variables. The final model explained 57.4% of the variance in log(catch).

Diagnostic residual plots for the gamma model are presented in Figure 41. The residuals follow the modelled distribution well except for extreme values.

The ALB 1 T CELR trip indices are mainly standardised by total fishing duration, and vessel key has a similar influence as in the ALB 1 T pseudoCELR stepwise model (Figure 42). The influence of fishing duration increases over the series (Figure 31), with two major steps: firstly, from 2003 with more trips having longer total fishing duration; and, secondly, from 2016 less trips have a total shorter fishing duration and more trips have a longer total fishing duration. The influence of vessel key also increases from the beginning of the series (Figure 32), but it does so over 0.3 influence points and its effect on the resulting series is minimal.

The full model, where all the variables are offered to the model in the order listed (Table A.1), applied to the albacore troll catches using the ALB 1 T pseudoCELR dataset is described in Appendix A. Similarly to the stepwise model, the full model did not provide much of a standardising effect (Table A.4, Figure A.3).

The ALB 1T psuedoCELR full index does not change appreciable as terms are sucessively added to the model (Figure A.5). However, the MEI shows some positive influence for the 1992 and 1998 indices in particular and then a dampening trend later in the series (Figure A.5, bottom panel).

The full model applied to the albacore troll catches using the ALB 1 T CELR trip dataset is described in Table A.6 and Table A.9. As with the stepwise model applied to the trip dataset, this model provided more of standardising effect in comparison to the unstandardised series (Figure A.17) than did the same model applied to the daily dataset. Vessel key and total fishing duration explained most of the variation in the catch. Also, MEI had a similar influence on the resulting series as it did in the full model applied to the daily dataset.

Diagnostic residual plots for each model are presented in Figure A.4 for the negative-binomial model (applied to the daily dataset) and Figure A.18 for the gamma model (applied to the trip dataset). Similarly, and for each model, the residuals follow the modelled distribution fairly well except for extreme values.

The indices from each of the four models are plotted together, along with those from the Kendrick (2021) analysis, in Figure 50. The series show little long-term trend, and the indices from this analysis closely follow those up to 2017 from Kendrick (2021). Comparing the four series from this analysis with the annual mean of the MEI (Figure 52) suggests that including the MEI may have a slightly intensifying effect in El Niño years (1992 and 1998), but a somewhat stronger dampening effect after 1998 when El Niño has not been evident and the La Niña pattern has been more persistent.

4.1 ALB 1 T pseudoCELR

4.1.1 CPUE series

Table 3: Specification for the ALB 1 T pseudoCELR CPUE series.

Series	ALB 1 T pseudoCELR
QMS stock	ALB1
Reporting forms	CEL, "ERS - Other Lining"
Fishing methods	T
Target species	ALB
Areas	002, 007, 008, 009, 013, 014, 030, 031, 032, 033, 034, 035, 036, 037, 038, 039, 040, 041, 042, 045, 046, 047
Period	1990-10-01, 2020-10-01
Core fleet years	4
Core fleet trips	3
Default model	nfish ~ fyear + vessel_key + stat_area*month + ns(log(fishing_duration), 3) + ns(SST, 3) + ns(meiv2, 3)
Stepwise selection	Yes

4.1.2 Core vessel selection

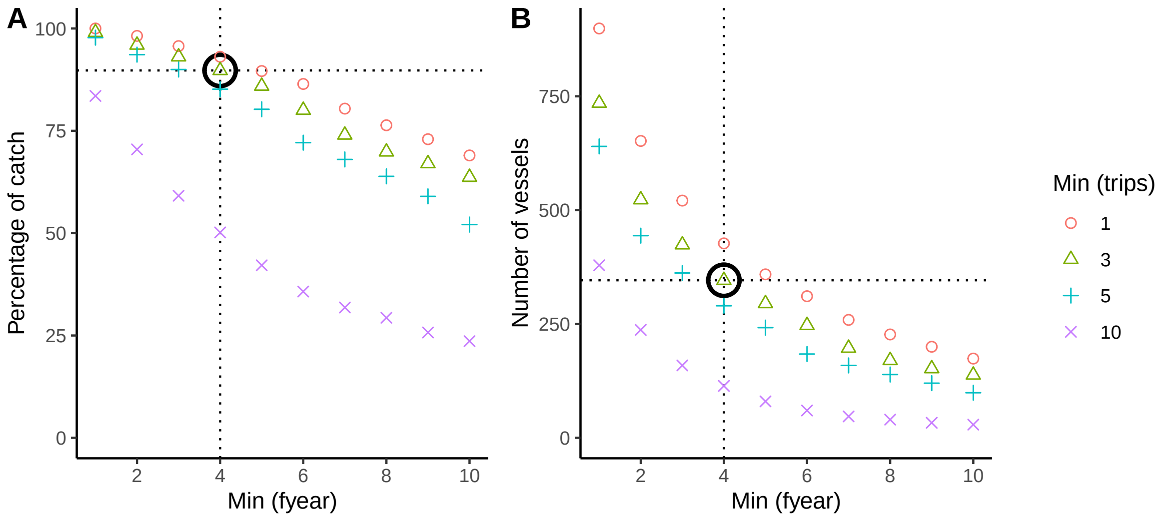

Figure 26: Percentage of catch and number of vessels for different core vessel selection criteria. Bold open circle represents the core vessel selection criteria based on the number of years in the fishery and the amount of trips per fleet

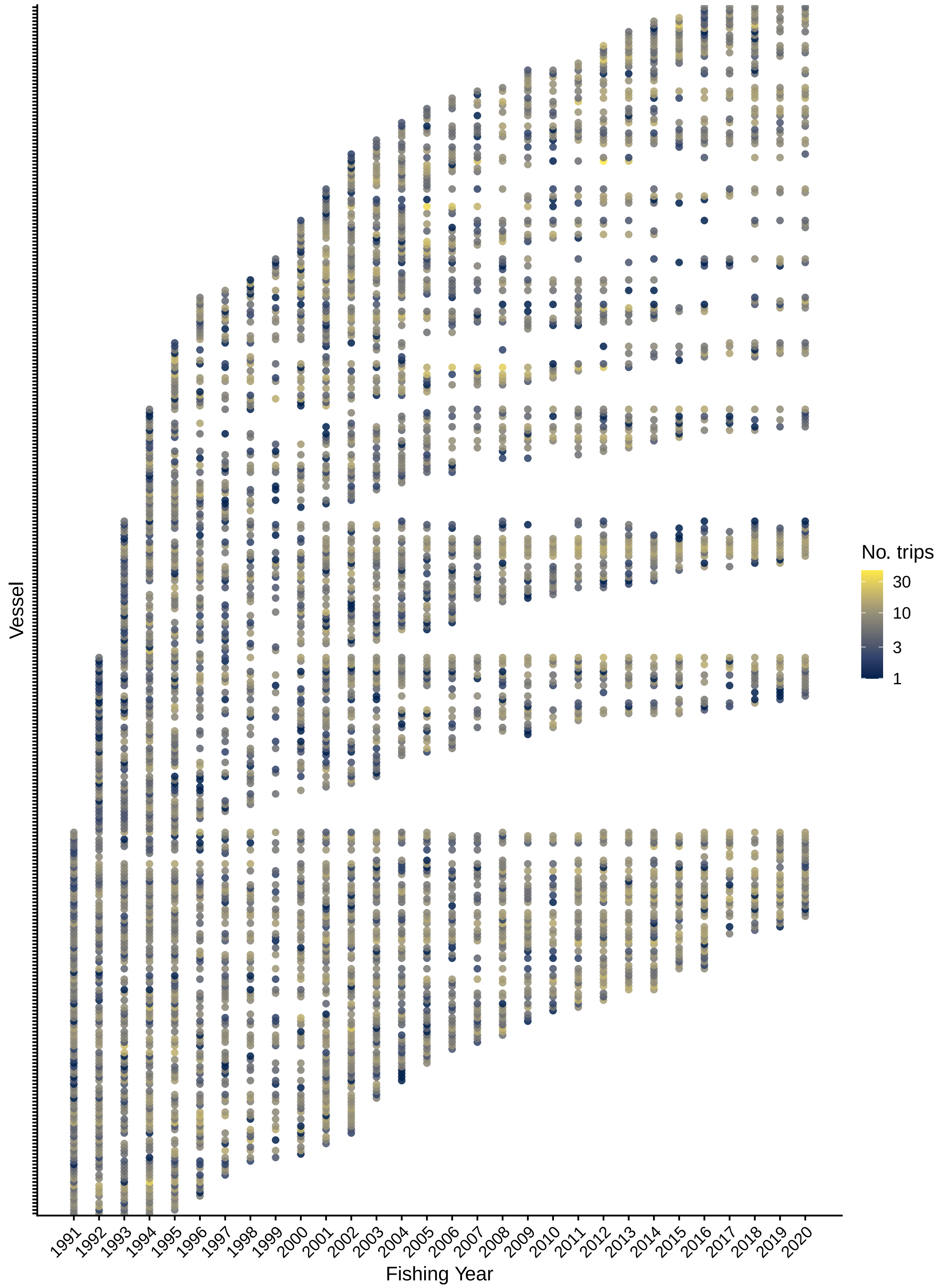

Figure 27: Number of trips by fishing year for core vessels. The area of circles is proportional to the number of trips.

4.1.3 CPUE dataset summary

Table 4: Summary of ALB 1 T pseudoCELR data subset by fishing year after the data was checked for missing values and outliers were removed. Records represent a row in the dataset daily catch. Fishing years are labelled by the later calendar year e.g. 1990 = 1989/1990.

Fishing year	Vessels	Trips	Records	Effort (hrs)	Catch (no. fish)
1991	110	677	2456	31653.72	322245
1992	146	914	3251	43503.70	441967
1993	170	1012	3517	46870.27	308234
1994	203	1494	5699	74557.00	586333
1995	198	1512	5050	66296.15	648424
1996	165	1145	3699	48267.05	494401
1997	143	850	3046	40898.72	268844
1998	139	982	3498	46257.65	452103
1999	93	548	1857	24700.68	250854
2000	161	1177	4018	53924.07	437872
2001	198	1496	5497	74235.70	458260
2002	201	1516	5498	74550.10	477400
2003	183	1319	5554	76865.68	606806
2004	176	1138	4832	66892.27	614067
2005	154	1130	4933	66738.95	408935
2006	137	828	3388	46849.52	365386
2007	105	676	2952	39470.43	357167
2008	122	1014	3800	49761.23	620469
2009	120	853	3673	49266.10	374847
2010	96	675	2738	36803.90	337657
2011	110	929	3741	50519.93	605283
2012	116	1035	3949	53353.40	474356
2013	115	985	4115	56601.68	414788
2014	113	829	3431	47033.10	363641
2015	92	753	3236	44162.65	387205
2016	97	729	3229	43472.82	286154
2017	73	593	2939	40617.73	253718
2018	95	756	3338	45573.62	537437
2019	87	719	3377	45435.83	408504
2020	93	713	3662	47922.80	474999

Table 5: Summary of ALB 1 T pseudoCELR total catch (t) subset by fishing year after the data was groomed by various filters. First row (Ungroomed data) shows catch before filters were applied. Subsequent rows below total catch display the percent of catch, and the total number of records.

Filter	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Ungroomed data	445 (Percent: 100) (Records: 3840)	616 (Percent: 100) (Records: 4935)	491 (Percent: 100) (Records: 5919)	882 (Percent: 100) (Records: 8895)	921 (Percent: 100) (Records: 7556)	728 (Percent: 100) (Records: 6373)	431 (Percent: 100) (Records: 5287)	714 (Percent: 100) (Records: 6490)	313 (Percent: 100) (Records: 2548)	624 (Percent: 100) (Records: 6160)	550 (Percent: 100) (Records: 7211)	586 (Percent: 100) (Records: 7134)
Fishing duration is not NA	444 (Percent: 100) (Records: 3828)	614 (Percent: 100) (Records: 4909)	485 (Percent: 100) (Records: 5844)	872 (Percent: 100) (Records: 8766)	889 (Percent: 100) (Records: 7371)	697 (Percent: 100) (Records: 6083)	384 (Percent: 89) (Records: 4897)	691 (Percent: 100) (Records: 6234)	306 (Percent: 100) (Records: 2452)	573 (Percent: 92) (Records: 5620)	534 (Percent: 100) (Records: 6952)	563 (Percent: 100) (Records: 6837)
Positive fishing duration	444 (Percent: 100) (Records: 3822)	614 (Percent: 100) (Records: 4902)	485 (Percent: 100) (Records: 5842)	870 (Percent: 100) (Records: 8743)	886 (Percent: 100) (Records: 7342)	697 (Percent: 100) (Records: 6077)	384 (Percent: 89) (Records: 4881)	691 (Percent: 100) (Records: 6226)	306 (Percent: 100) (Records: 2452)	563 (Percent: 90) (Records: 5568)	534 (Percent: 100) (Records: 6944)	562 (Percent: 100) (Records: 6827)
Fishing duration <20hrs	429 (Percent: 100) (Records: 3757)	603 (Percent: 100) (Records: 4858)	464 (Percent: 94) (Records: 5767)	853 (Percent: 100) (Records: 8668)	850 (Percent: 92) (Records: 7231)	676 (Percent: 93) (Records: 5975)	371 (Percent: 86) (Records: 4835)	678 (Percent: 95) (Records: 6151)	297 (Percent: 95) (Records: 2417)	552 (Percent: 88) (Records: 5498)	527 (Percent: 100) (Records: 6890)	555 (Percent: 95) (Records: 6753)
Season start day <212	428 (Percent: 100) (Records: 3749)	602 (Percent: 100) (Records: 4847)	463 (Percent: 94) (Records: 5741)	847 (Percent: 100) (Records: 8587)	845 (Percent: 92) (Records: 7128)	675 (Percent: 93) (Records: 5945)	370 (Percent: 86) (Records: 4809)	668 (Percent: 94) (Records: 6009)	297 (Percent: 95) (Records: 2408)	546 (Percent: 87) (Records: 5376)	512 (Percent: 93) (Records: 6625)	553 (Percent: 94) (Records: 6687)
Season start day >31	428 (Percent: 100) (Records: 3748)	602 (Percent: 100) (Records: 4846)	463 (Percent: 94) (Records: 5740)	847 (Percent: 100) (Records: 8587)	845 (Percent: 92) (Records: 7128)	675 (Percent: 93) (Records: 5944)	370 (Percent: 86) (Records: 4807)	668 (Percent: 94) (Records: 6009)	297 (Percent: 95) (Records: 2408)	546 (Percent: 87) (Records: 5376)	512 (Percent: 93) (Records: 6625)	553 (Percent: 94) (Records: 6687)
Positive catch	428 (Percent: 100) (Records: 3575)	602 (Percent: 100) (Records: 4715)	463 (Percent: 94) (Records: 5489)	847 (Percent: 100) (Records: 8407)	845 (Percent: 92) (Records: 6964)	675 (Percent: 93) (Records: 5311)	370 (Percent: 86) (Records: 4331)	668 (Percent: 94) (Records: 5388)	297 (Percent: 95) (Records: 2263)	546 (Percent: 87) (Records: 5277)	512 (Percent: 93) (Records: 6480)	553 (Percent: 94) (Records: 6588)
No inferred numbers	363 (Percent: 82) (Records: 2905)	525 (Percent: 85) (Records: 4034)	438 (Percent: 89) (Records: 5055)	790 (Percent: 90) (Records: 7707)	801 (Percent: 87) (Records: 6527)	581 (Percent: 80) (Records: 4465)	308 (Percent: 71) (Records: 3569)	552 (Percent: 77) (Records: 4236)	256 (Percent: 82) (Records: 1908)	485 (Percent: 78) (Records: 4516)	500 (Percent: 91) (Records: 6133)	538 (Percent: 92) (Records: 6193)
Core fleet selection	322 (Percent: 72) (Records: 2456)	442 (Percent: 72) (Records: 3251)	309 (Percent: 63) (Records: 3544)	587 (Percent: 67) (Records: 5707)	651 (Percent: 71) (Records: 5068)	494 (Percent: 68) (Records: 3699)	269 (Percent: 62) (Records: 3046)	452 (Percent: 63) (Records: 3498)	251 (Percent: 80) (Records: 1857)	439 (Percent: 70) (Records: 4034)	458 (Percent: 83) (Records: 5497)	477 (Percent: 82) (Records: 5498)

Filter	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Ungroomed data	779 (Percent: 100) (Records: 7485)	736 (Percent: 100) (Records: 6178)	503 (Percent: 100) (Records: 6571)	429 (Percent: 100) (Records: 4175)	377 (Percent: 100) (Records: 3234)	682 (Percent: 100) (Records: 4320)	412 (Percent: 100) (Records: 4230)	358 (Percent: 100) (Records: 3040)	659 (Percent: 100) (Records: 4284)	537 (Percent: 100) (Records: 4762)	454 (Percent: 100) (Records: 4757)	405 (Percent: 100) (Records: 4034)
Fishing duration is not NA	760 (Percent: 100) (Records: 7278)	724 (Percent: 100) (Records: 6083)	492 (Percent: 100) (Records: 6414)	409 (Percent: 100) (Records: 3991)	374 (Percent: 100) (Records: 3201)	668 (Percent: 100) (Records: 4187)	407 (Percent: 100) (Records: 4158)	354 (Percent: 100) (Records: 3010)	653 (Percent: 100) (Records: 4215)	517 (Percent: 100) (Records: 4545)	446 (Percent: 100) (Records: 4647)	393 (Percent: 100) (Records: 3870)
Positive fishing duration	760 (Percent: 100) (Records: 7277)	724 (Percent: 100) (Records: 6083)	492 (Percent: 100) (Records: 6413)	409 (Percent: 100) (Records: 3991)	374 (Percent: 100) (Records: 3201)	668 (Percent: 100) (Records: 4186)	407 (Percent: 100) (Records: 4154)	354 (Percent: 100) (Records: 3009)	653 (Percent: 100) (Records: 4215)	517 (Percent: 100) (Records: 4542)	446 (Percent: 100) (Records: 4646)	393 (Percent: 100) (Records: 3868)
Fishing duration <20hrs	752 (Percent: 100) (Records: 7238)	720 (Percent: 100) (Records: 6057)	490 (Percent: 100) (Records: 6398)	407 (Percent: 95) (Records: 3975)	372 (Percent: 100) (Records: 3188)	661 (Percent: 100) (Records: 4169)	405 (Percent: 100) (Records: 4139)	351 (Percent: 100) (Records: 2992)	648 (Percent: 100) (Records: 4198)	515 (Percent: 100) (Records: 4534)	445 (Percent: 100) (Records: 4641)	386 (Percent: 100) (Records: 3840)
Season start day <212	741 (Percent: 100) (Records: 7063)	717 (Percent: 100) (Records: 5994)	487 (Percent: 100) (Records: 6341)	404 (Percent: 94) (Records: 3939)	367 (Percent: 100) (Records: 3127)	659 (Percent: 100) (Records: 4120)	405 (Percent: 100) (Records: 4129)	347 (Percent: 100) (Records: 2925)	648 (Percent: 100) (Records: 4191)	511 (Percent: 100) (Records: 4462)	439 (Percent: 100) (Records: 4563)	380 (Percent: 94) (Records: 3745)
Season start day >31	741 (Percent: 100) (Records: 7063)	717 (Percent: 100) (Records: 5994)	487 (Percent: 100) (Records: 6339)	404 (Percent: 94) (Records: 3939)	367 (Percent: 100) (Records: 3127)	659 (Percent: 100) (Records: 4120)	405 (Percent: 100) (Records: 4128)	347 (Percent: 100) (Records: 2925)	648 (Percent: 100) (Records: 4191)	511 (Percent: 100) (Records: 4462)	439 (Percent: 100) (Records: 4563)	380 (Percent: 94) (Records: 3743)
Positive catch	741 (Percent: 100) (Records: 6973)	717 (Percent: 100) (Records: 5781)	487 (Percent: 100) (Records: 6207)	404 (Percent: 94) (Records: 3886)	367 (Percent: 100) (Records: 3085)	659 (Percent: 100) (Records: 4088)	405 (Percent: 100) (Records: 4082)	347 (Percent: 100) (Records: 2882)	648 (Percent: 100) (Records: 4156)	511 (Percent: 100) (Records: 4413)	439 (Percent: 100) (Records: 4504)	380 (Percent: 94) (Records: 3693)
No inferred numbers	710 (Percent: 91) (Records: 6497)	696 (Percent: 95) (Records: 5464)	451 (Percent: 90) (Records: 5511)	391 (Percent: 91) (Records: 3647)	361 (Percent: 100) (Records: 2982)	648 (Percent: 100) (Records: 3966)	388 (Percent: 94) (Records: 3812)	339 (Percent: 95) (Records: 2768)	623 (Percent: 95) (Records: 3861)	503 (Percent: 94) (Records: 4227)	432 (Percent: 100) (Records: 4336)	375 (Percent: 92) (Records: 3553)
Core fleet selection	607 (Percent: 78) (Records: 5554)	614 (Percent: 83) (Records: 4832)	409 (Percent: 81) (Records: 4933)	365 (Percent: 85) (Records: 3388)	357 (Percent: 95) (Records: 2952)	620 (Percent: 91) (Records: 3800)	375 (Percent: 91) (Records: 3673)	338 (Percent: 94) (Records: 2738)	605 (Percent: 92) (Records: 3741)	474 (Percent: 88) (Records: 3949)	415 (Percent: 91) (Records: 4115)	364 (Percent: 90) (Records: 3431)

Filter	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Ungroomed data	426 (Percent: 100) (Records: 3769)	332 (Percent: 100) (Records: 3861)	289 (Percent: 100) (Records: 3499)	608 (Percent: 100) (Records: 4011)	524 (Percent: 100) (Records: 4599)	578 (Percent: 100) (Records: 4936)
Fishing duration is not NA	419 (Percent: 100) (Records: 3682)	325 (Percent: 100) (Records: 3766)	284 (Percent: 100) (Records: 3423)	601 (Percent: 100) (Records: 3940)	517 (Percent: 100) (Records: 4503)	578 (Percent: 100) (Records: 4936)
Positive fishing duration	419 (Percent: 100) (Records: 3681)	325 (Percent: 100) (Records: 3764)	284 (Percent: 100) (Records: 3422)	601 (Percent: 100) (Records: 3935)	517 (Percent: 100) (Records: 4503)	573 (Percent: 100) (Records: 4871)
Fishing duration <20hrs	406 (Percent: 100) (Records: 3599)	318 (Percent: 100) (Records: 3734)	278 (Percent: 100) (Records: 3407)	591 (Percent: 100) (Records: 3907)	489 (Percent: 93) (Records: 4426)	568 (Percent: 100) (Records: 4849)
Season start day <212	405 (Percent: 100) (Records: 3536)	308 (Percent: 93) (Records: 3580)	272 (Percent: 94) (Records: 3316)	590 (Percent: 100) (Records: 3872)	484 (Percent: 92) (Records: 4304)	566 (Percent: 100) (Records: 4734)
Season start day >31	405 (Percent: 100) (Records: 3536)	308 (Percent: 93) (Records: 3580)	272 (Percent: 94) (Records: 3316)	590 (Percent: 100) (Records: 3872)	484 (Percent: 92) (Records: 4304)	566 (Percent: 100) (Records: 4734)
Positive catch	405 (Percent: 100) (Records: 3485)	308 (Percent: 93) (Records: 3528)	272 (Percent: 94) (Records: 3259)	590 (Percent: 100) (Records: 3758)	484 (Percent: 92) (Records: 4168)	566 (Percent: 100) (Records: 4477)
No inferred numbers	399 (Percent: 94) (Records: 3354)	297 (Percent: 89) (Records: 3332)	261 (Percent: 90) (Records: 3034)	571 (Percent: 94) (Records: 3538)	457 (Percent: 87) (Records: 3836)	566 (Percent: 100) (Records: 4477)
Core fleet selection	387 (Percent: 91) (Records: 3236)	286 (Percent: 86) (Records: 3229)	254 (Percent: 88) (Records: 2939)	537 (Percent: 88) (Records: 3338)	409 (Percent: 78) (Records: 3377)	475 (Percent: 82) (Records: 3662)

4.1.4 Negative-Binomial model diagnostics

Table 6: Summary of stepwise selection for the negative-binomial model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	add % deviance	Included
	28	1305698	4.9	4.9	*
+ ns(log(fishing duration), 3)	3	1296259	15.4	10.5	*
+ vessel key	346	1292022	20.9	5.5	*
+ month	5	1291326	21.7	0.8	*
+ stat area	20	1290992	22.1	0.4	*
+ stat area:month	90	1290369	23.0	0.9	*
+ ns(SST, 3)	3	1290325	23.0	0.1	
+ ns(meiv2, 3)	3	1290271	23.1	0.1	

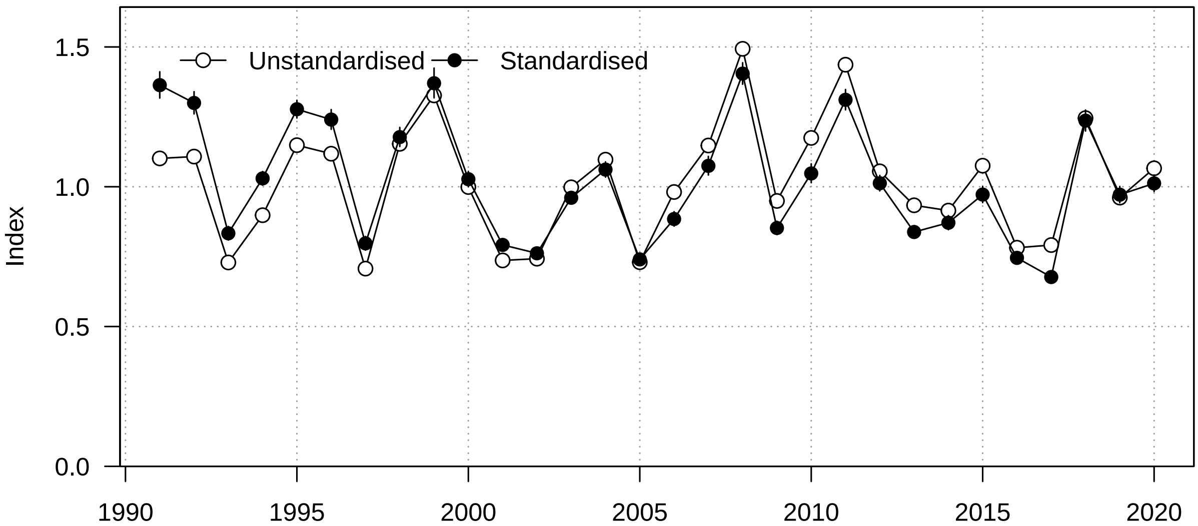

Figure 28: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for catch in the ALB 1 T pseudoCELR dataset.

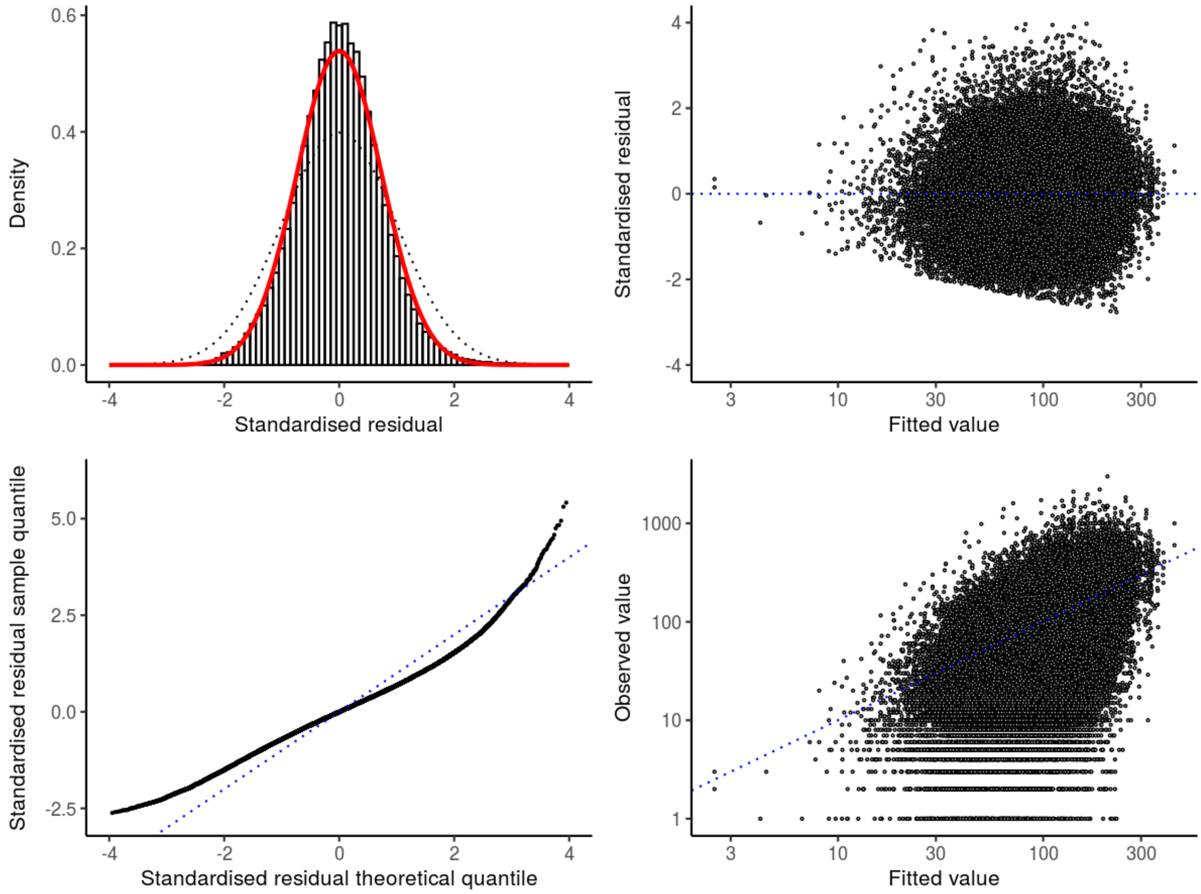

Figure 29: Diagnostic plots for the negative-binomial model for the ALB 1 T pseudoCELR dataset.

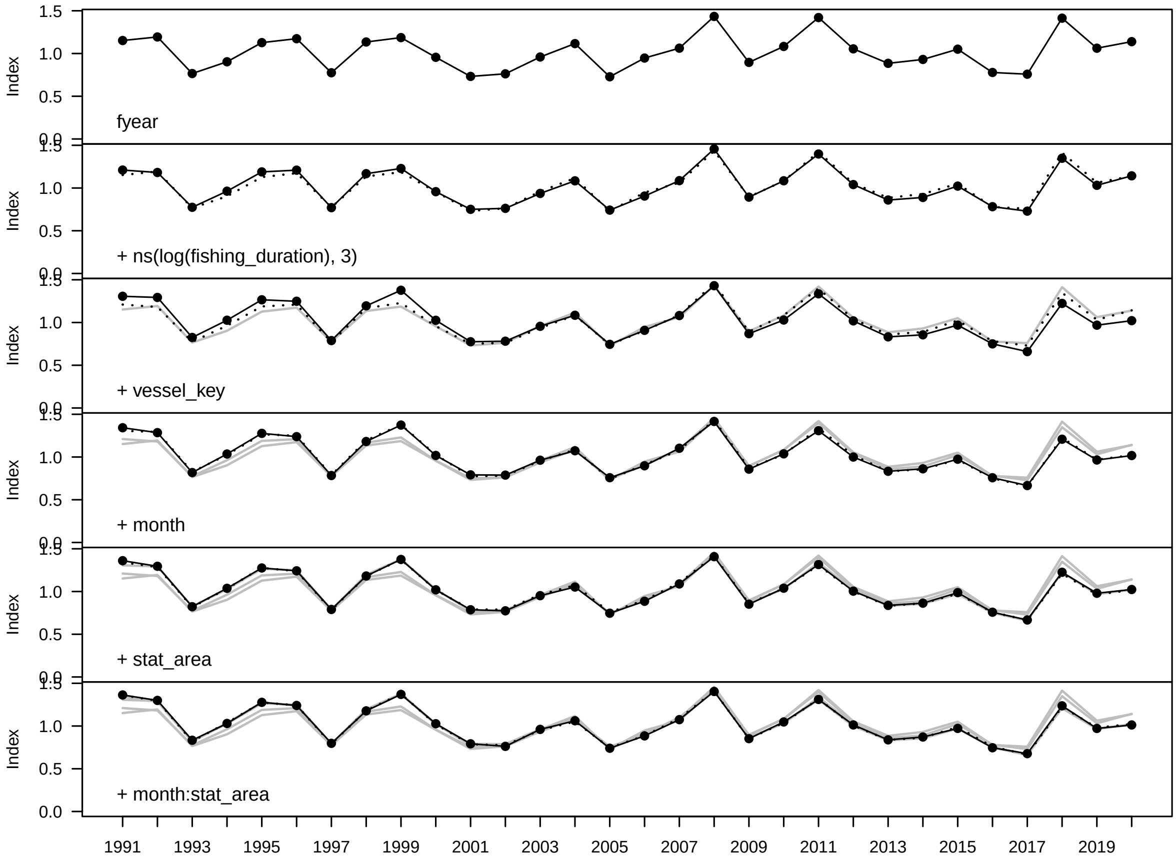

Figure 30: Changes to the ALB 1 T pseudoCELR index as terms are successively entered into the model

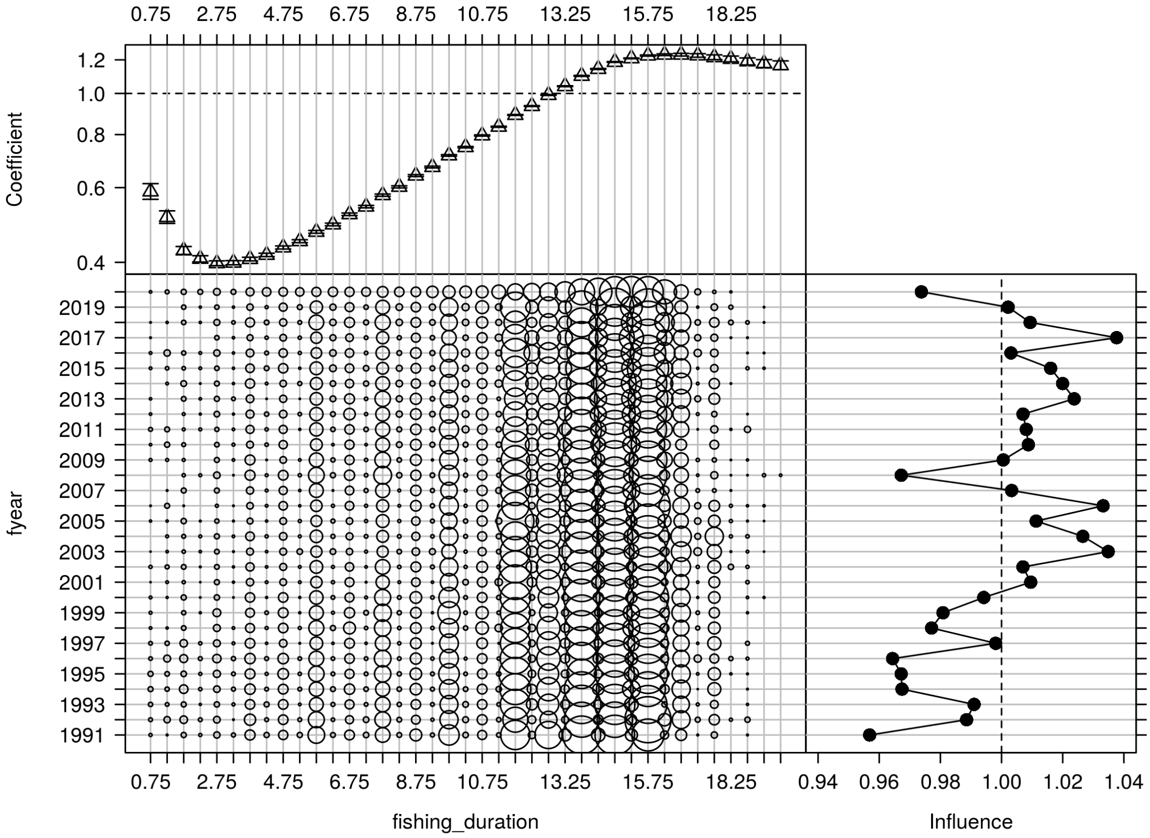

Figure 31: CDI plot for log-fishing-duration for the ALB 1 T pseudoCELR catch-per-unit-effort dataset.

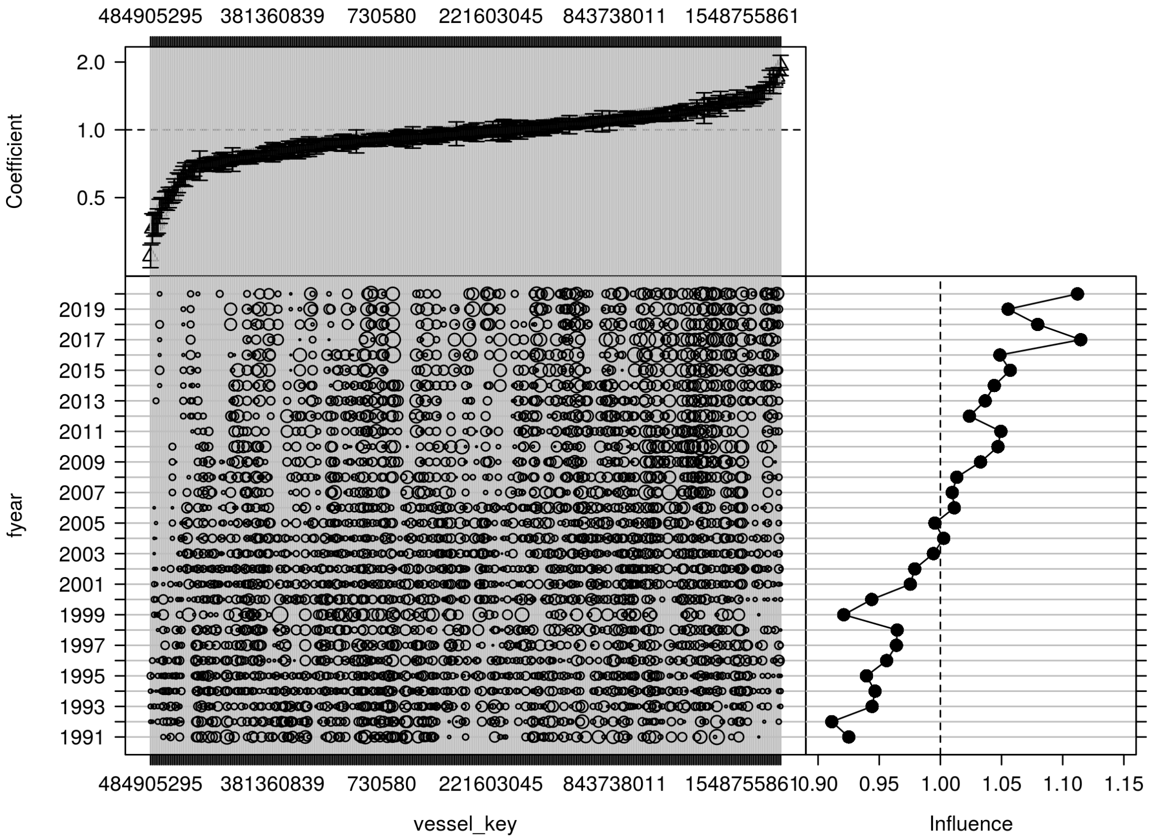

Figure 32: CDI plot for vessel-key for the ALB 1 T pseudoCELR catch-per-unit-effort dataset.

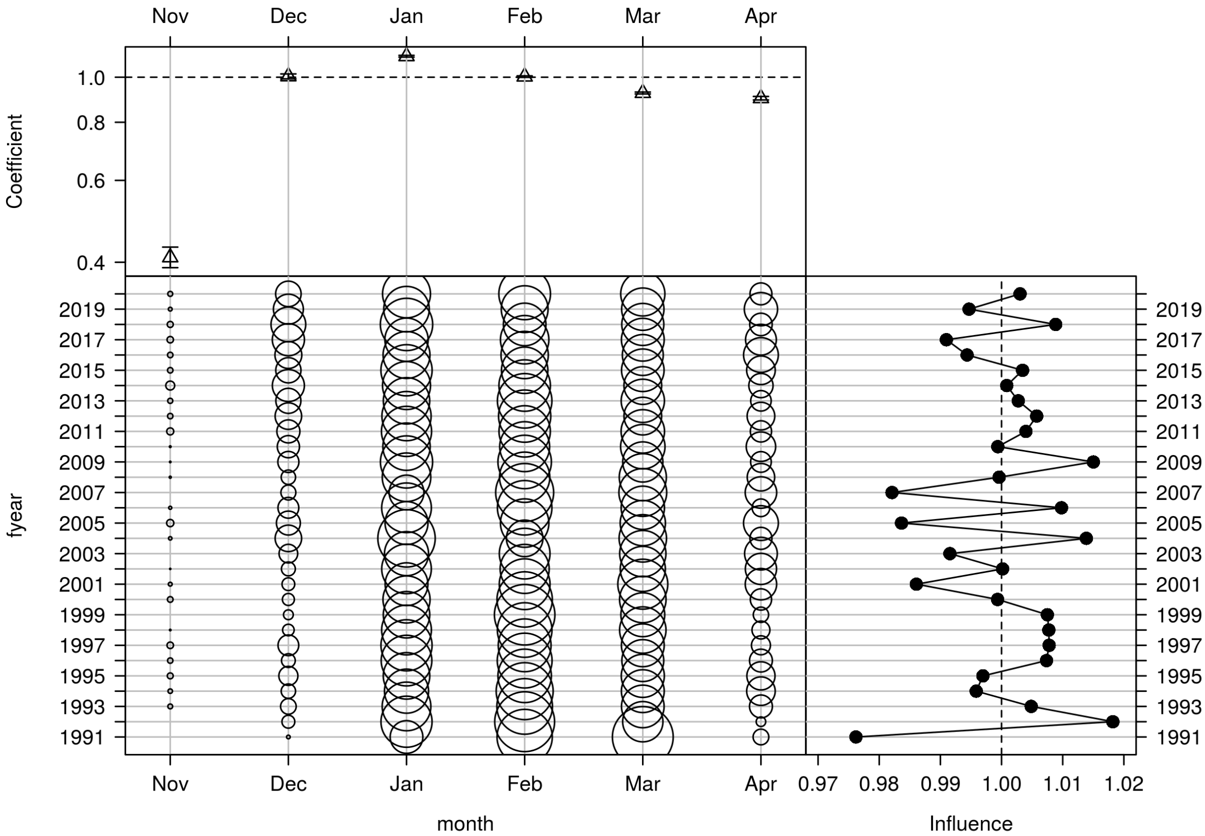

Figure 33: CDI plot for month for the ALB 1 T pseudoCELR catch-per-unit-effort dataset.

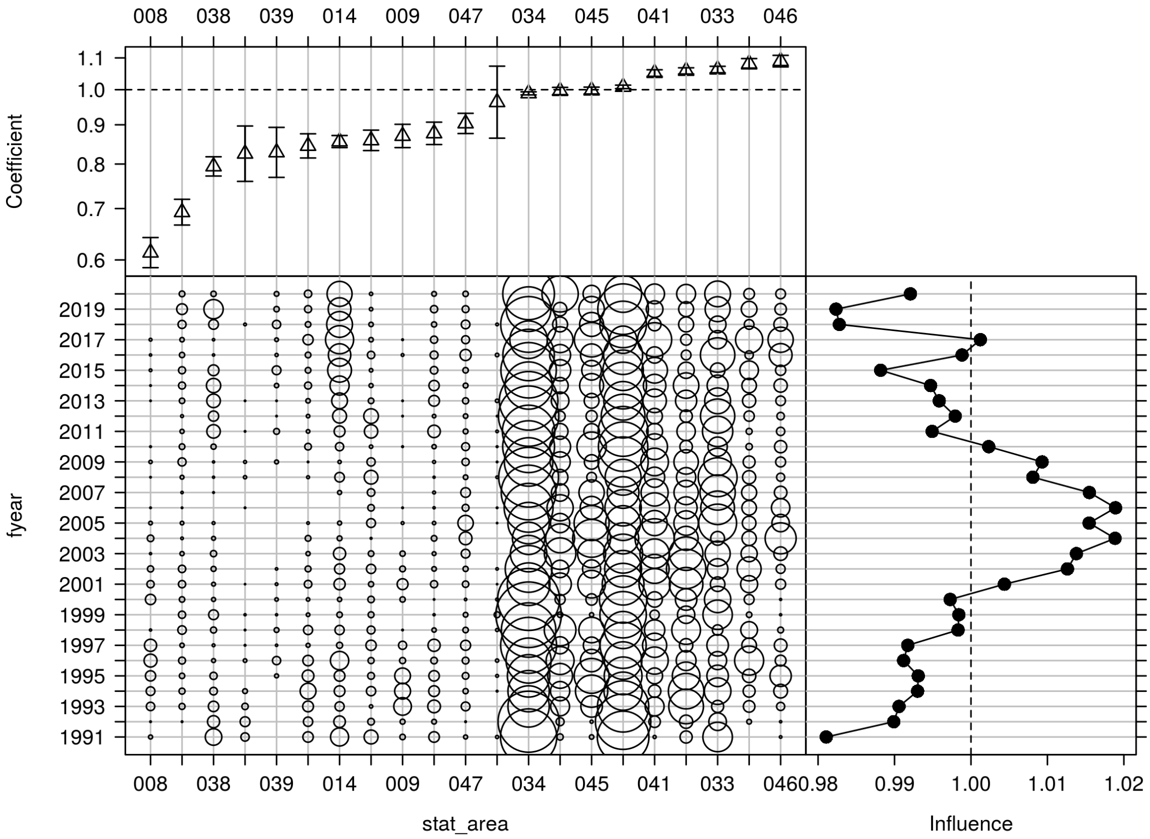

Figure 34: CDI plot for stat-area for the ALB 1 T pseudoCELR catch-per-unit-effort dataset.

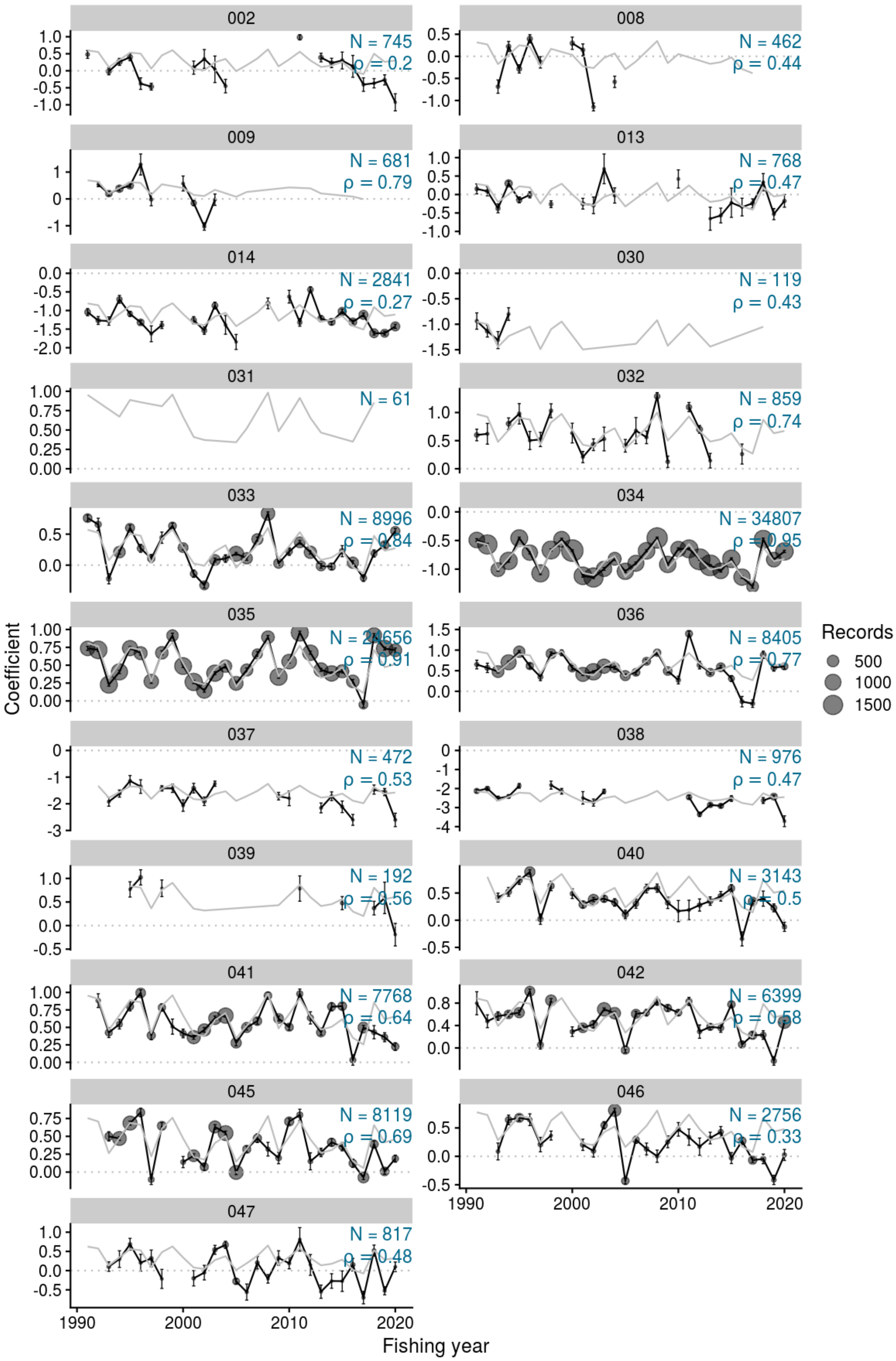

Figure 35: Residual implied coefficients for area-year negative-binomial model for the ALB 1 T pseudo-CELR dataset.

4.1.5 CPUE indices

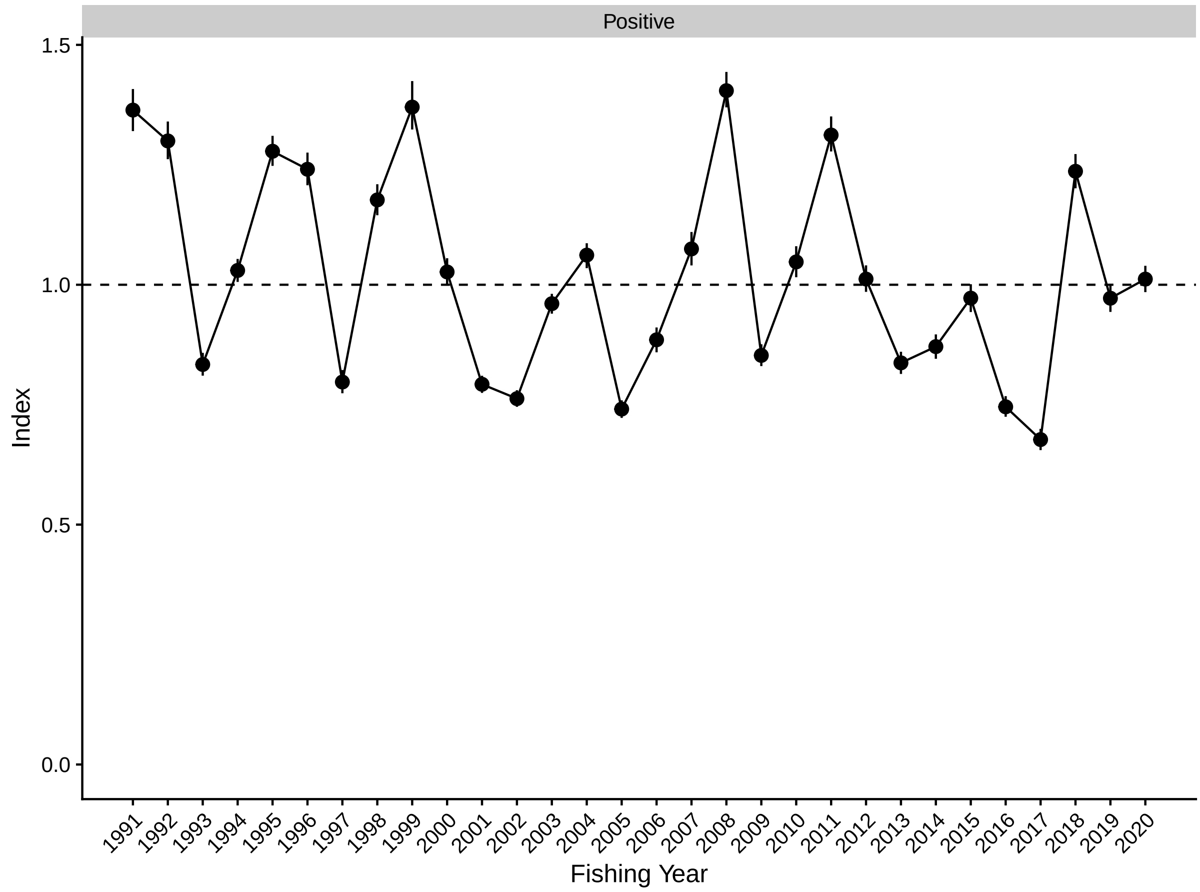

Figure 36: Standardised indices and 95% confidence intervals for the ALB 1 T pseudoCELR dataset.

4.1.6 Alternative distribution diagnostics for CPUE standardisation

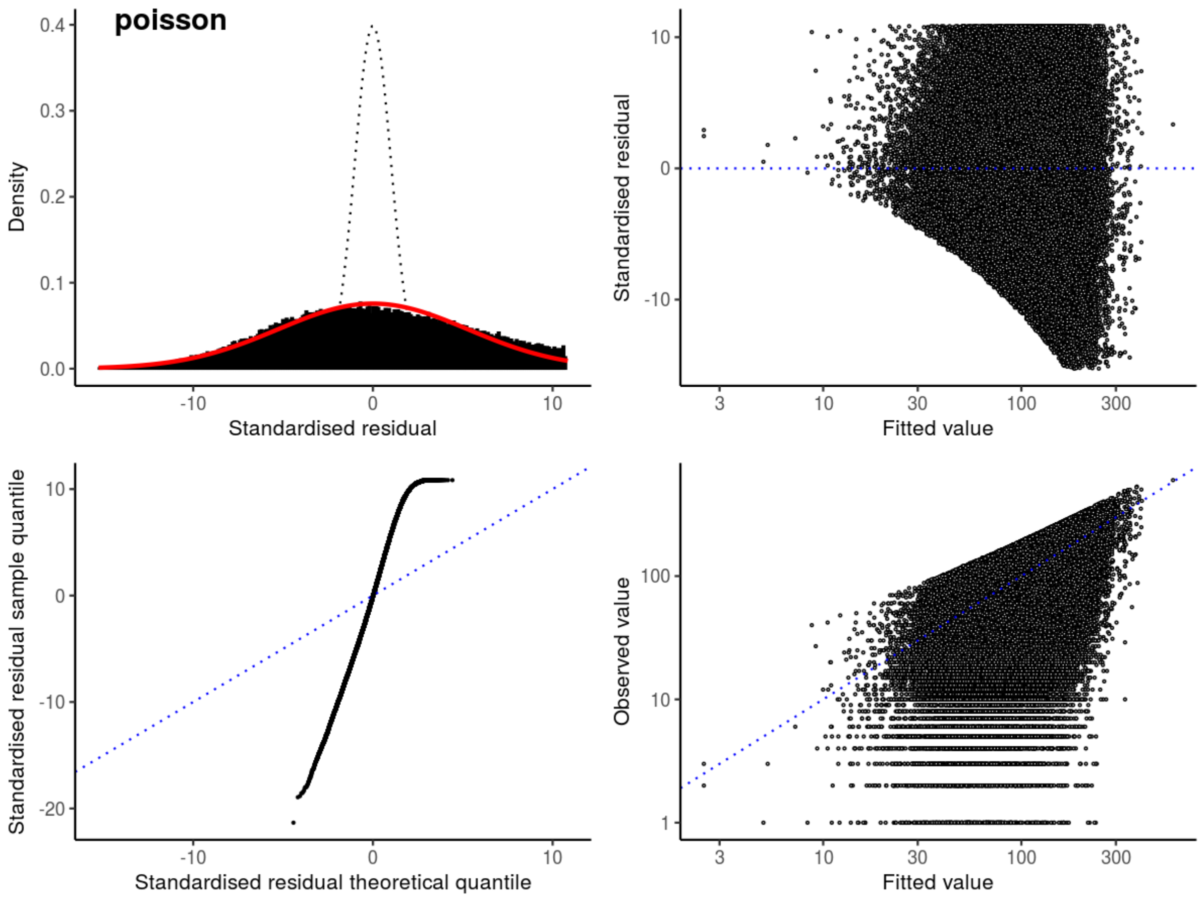

Figure 37: Diagnostic plots for the poisson model for the ALB 1 T pseudoCELR dataset.

Table 7: Annual indices and standard errors for each model in ALB 1 T pseudoCELR. Fishing years are labeled by the later calendar year e.g. 1996 = 1995/1996.

Fishing year	Positive	Positive SE
1991	1.4	0.022
1992	1.3	0.02
1993	0.83	0.012
1994	1	0.012
1995	1.3	0.016
1996	1.2	0.017
1997	0.8	0.012
1998	1.2	0.016
1999	1.4	0.026
2000	1	0.014
2001	0.79	0.0091
2002	0.76	0.0088
2003	0.96	0.011
2004	1.1	0.013
2005	0.74	0.0093
2006	0.89	0.013
2007	1.1	0.018
2008	1.4	0.019
2009	0.85	0.012
2010	1	0.016
2011	1.3	0.019
2012	1	0.014
2013	0.84	0.012
2014	0.87	0.013
2015	0.97	0.015
2016	0.75	0.011
2017	0.68	0.011
2018	1.2	0.018
2019	0.97	0.015
2020	1	0.014

4.2 ALB 1 T CELR trip

4.2.1 CPUE series

Table 8: Specification for the ALB 1 T CELR trip CPUE series.

Series	ALB 1 T CELR trip
QMS stock	ALB1
Reporting forms	CEL, "ERS - Other Lining"
Fishing methods	T
Target species	ALB
Areas	002, 007, 008, 009, 013, 014, 030, 031, 032, 033, 034, 035, 036, 037, 038, 039, 040, 041, 042, 045, 046, 047
Period	1990-10-01, 2020-10-01
Core fleet years	4
Core fleet trips	3
Default model	landkg ~ fyear + vessel_key + modal_stat_area*modal_month + ns(log(total_fishing_duration), 3) + ns(SST, 3) + ns(meiv2, 3)
Stepwise selection	Yes

4.2.2 Core vessel selection

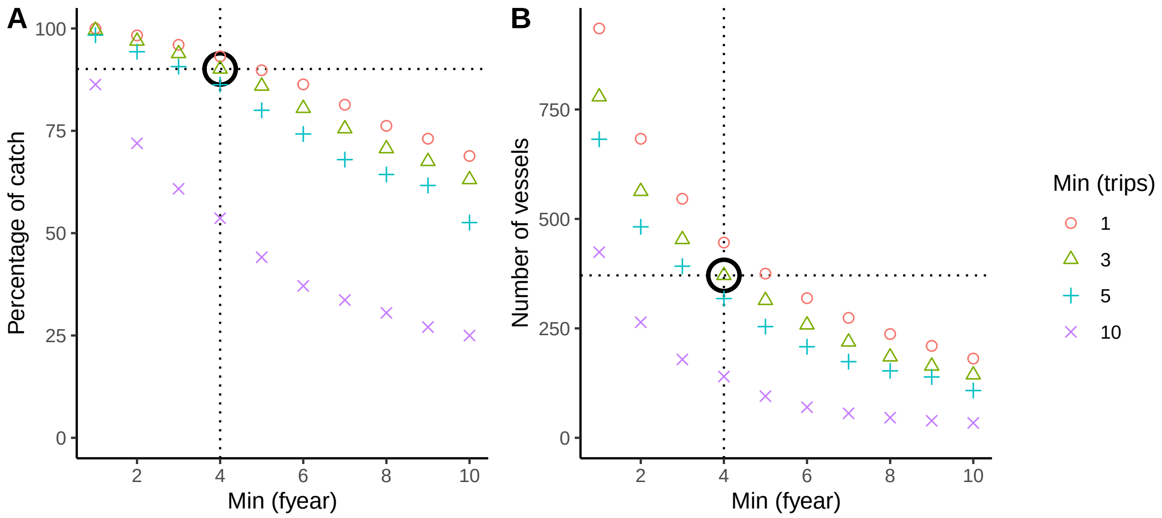

Figure 38: Percentage of catch and number of vessels for different core vessel selection criteria. Bold open circle represents the core vessel selection criteria based on the number of years in the fishery and the amount of trips per fleet

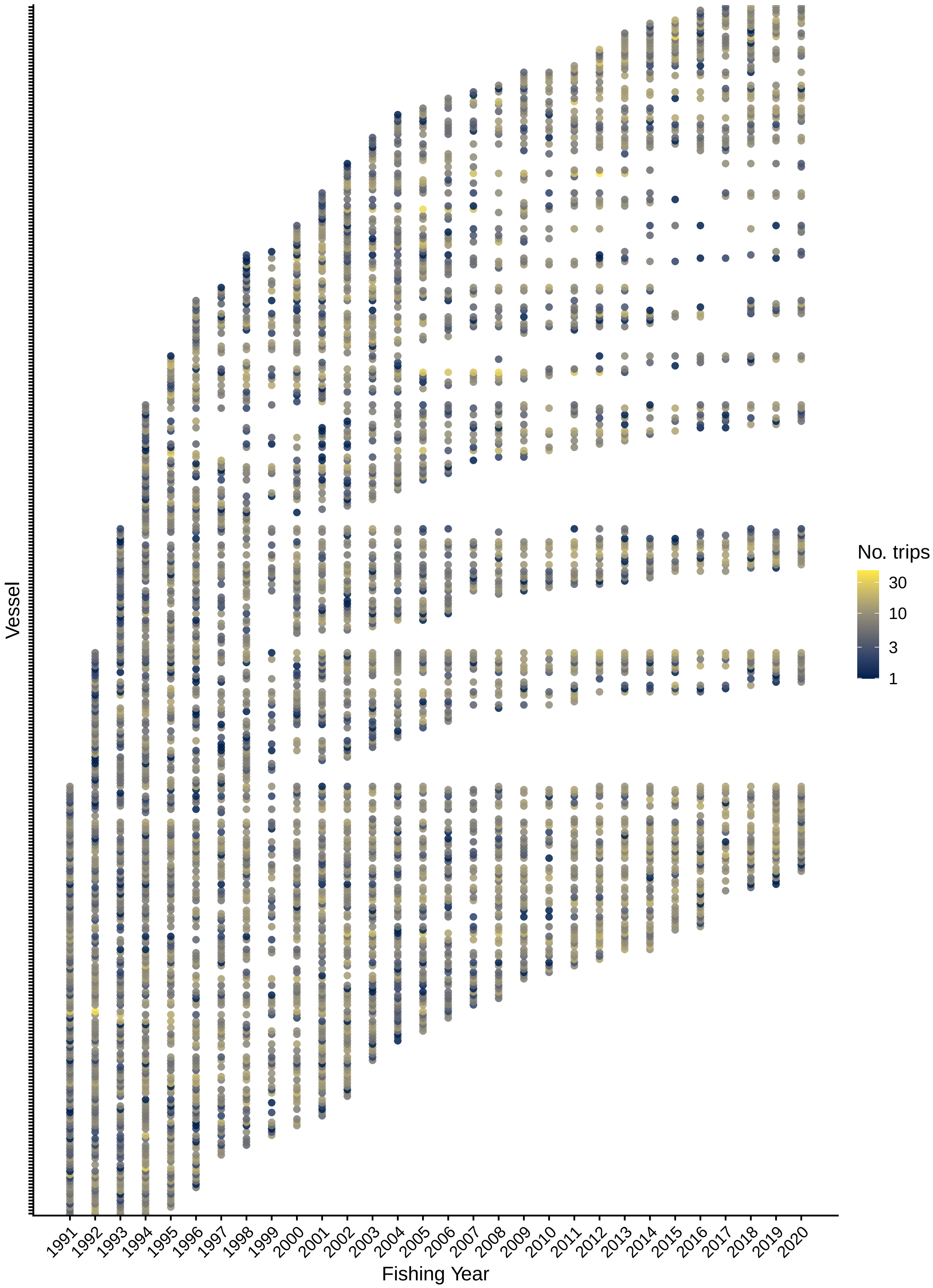

Figure 39: Number of trips by fishing year for core vessels. The area of circles is proportional to the number of trips.

4.2.3 CPUE dataset summary

Table 9: Summary of ALB 1 T CELR trip data subset by fishing year after the data was checked for missing values and outliers were removed. Records represent a row in the dataset trip catch. Fishing years are labelled by the later calendar year e.g. 1990 = 1989/1990.

Fishing year	Vessels	Trips	Records	Effort (hrs)	Catch (t)
1991	132	860	860	39522.13	1729.37
1992	157	1090	1090	50558.10	2632.78
1993	181	1066	1066	51084.58	1811.57
1994	218	1602	1602	82392.30	3097.15
1995	204	1610	1610	71452.07	3681.06
1996	196	1479	1479	64429.18	3152.37
1997	164	1106	1106	52949.35	1809.48
1998	177	1362	1362	64497.98	3395.05
1999	104	665	665	30726.85	1480.26
2000	172	1372	1372	65018.22	2514.20
2001	201	1518	1518	78491.10	2538.35
2002	202	1584	1584	80288.27	2578.87
2003	189	1405	1405	83722.30	3239.05
2004	180	1209	1209	70828.13	3431.31
2005	158	1276	1276	75832.33	2517.86
2006	141	874	874	50306.27	1972.79
2007	105	684	684	40886.33	1766.58
2008	120	1026	1026	51181.17	3205.81
2009	120	921	921	52163.75	1693.35
2010	88	687	687	37420.32	1621.40
2011	112	997	997	53201.88	2818.19
2012	114	1068	1068	55437.82	2461.97
2013	117	1014	1014	58731.85	2424.00
2014	112	846	846	48820.02	2000.77
2015	88	799	799	46966.38	2219.87
2016	97	765	765	47245.18	1750.69
2017	74	611	611	42818.13	1639.63
2018	98	791	791	49127.67	2155.19
2019	93	818	818	51813.13	2129.99
2020	95	739	739	52851.34	2370.96

Table 10: Summary of ALB 1 T CELR trip total catch (t) subset by fishing year after the data was groomed by various filters. First row (Ungroomed data) shows catch before filters were applied. Subsequent rows below total catch display the percent of catch, and the total number of records.

Filter	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Ungroomed data	1994 (Percent: 100) (Records: 1107)	3323 (Percent: 100) (Records: 1496)	2526 (Percent: 100) (Records: 1715)	4380 (Percent: 100) (Records: 2462)	4971 (Percent: 100) (Records: 2488)	3919 (Percent: 100) (Records: 2003)	2295 (Percent: 100) (Records: 1524)	4275 (Percent: 100) (Records: 1805)	1544 (Percent: 100) (Records: 726)	2966 (Percent: 100) (Records: 1788)	2915 (Percent: 100) (Records: 2035)	3061 (Percent: 100) (Records: 1993)
Fishing duration is not NA	1992 (Percent: 100) (Records: 1102)	3316 (Percent: 100) (Records: 1490)	2510 (Percent: 100) (Records: 1697)	4335 (Percent: 100) (Records: 2433)	4858 (Percent: 100) (Records: 2417)	3790 (Percent: 100) (Records: 1910)	2122 (Percent: 92) (Records: 1424)	4167 (Percent: 100) (Records: 1744)	1510 (Percent: 100) (Records: 701)	2756 (Percent: 93) (Records: 1626)	2830 (Percent: 100) (Records: 1954)	2958 (Percent: 100) (Records: 1887)
Positive fishing duration	1992 (Percent: 100) (Records: 1102)	3316 (Percent: 100) (Records: 1490)	2510 (Percent: 100) (Records: 1697)	4335 (Percent: 100) (Records: 2433)	4858 (Percent: 100) (Records: 2417)	3790 (Percent: 100) (Records: 1910)	2122 (Percent: 92) (Records: 1424)	4167 (Percent: 100) (Records: 1744)	1510 (Percent: 100) (Records: 701)	2756 (Percent: 93) (Records: 1626)	2830 (Percent: 100) (Records: 1954)	2958 (Percent: 100) (Records: 1887)
Total fishing duration <180hrs	1987 (Percent: 100) (Records: 1101)	3157 (Percent: 100) (Records: 1484)	2278 (Percent: 90) (Records: 1682)	4021 (Percent: 92) (Records: 2413)	4797 (Percent: 100) (Records: 2411)	3634 (Percent: 93) (Records: 1899)	2076 (Percent: 90) (Records: 1419)	4037 (Percent: 94) (Records: 1736)	1510 (Percent: 100) (Records: 701)	2744 (Percent: 93) (Records: 1624)	2814 (Percent: 100) (Records: 1951)	2912 (Percent: 100) (Records: 1880)
Season Nov Apr	1987 (Percent: 100) (Records: 1099)	3157 (Percent: 100) (Records: 1482)	2274 (Percent: 90) (Records: 1669)	4011 (Percent: 92) (Records: 2392)	4770 (Percent: 100) (Records: 2374)	3632 (Percent: 93) (Records: 1889)	2072 (Percent: 90) (Records: 1407)	3990 (Percent: 93) (Records: 1701)	1509 (Percent: 100) (Records: 697)	2722 (Percent: 92) (Records: 1582)	2761 (Percent: 95) (Records: 1851)	2907 (Percent: 95) (Records: 1863)
Positive catch	1987 (Percent: 100) (Records: 1061)	3157 (Percent: 100) (Records: 1458)	2274 (Percent: 90) (Records: 1621)	4011 (Percent: 92) (Records: 2346)	4770 (Percent: 100) (Records: 2339)	3632 (Percent: 93) (Records: 1854)	2072 (Percent: 90) (Records: 1381)	3990 (Percent: 93) (Records: 1661)	1509 (Percent: 100) (Records: 690)	2722 (Percent: 92) (Records: 1570)	2761 (Percent: 95) (Records: 1803)	2907 (Percent: 95) (Records: 1825)
Core fleet selection	1729 (Percent: 87) (Records: 860)	2633 (Percent: 79) (Records: 1090)	1814 (Percent: 72) (Records: 1076)	3118 (Percent: 71) (Records: 1613)	3704 (Percent: 75) (Records: 1621)	3152 (Percent: 80) (Records: 1479)	1809 (Percent: 79) (Records: 1106)	3396 (Percent: 79) (Records: 1363)	1480 (Percent: 100) (Records: 665)	2522 (Percent: 85) (Records: 1381)	2538 (Percent: 87) (Records: 1518)	2583 (Percent: 84) (Records: 1589)

Filter	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Ungroomed data	3899 (Percent: 100) (Records: 1759)	4062 (Percent: 100) (Records: 1469)	2848 (Percent: 100) (Records: 1522)	2210 (Percent: 100) (Records: 1031)	1817 (Percent: 100) (Records: 751)	3437 (Percent: 100) (Records: 1207)	1776 (Percent: 100) (Records: 1024)	1720 (Percent: 100) (Records: 751)	2970 (Percent: 100) (Records: 1097)	2714 (Percent: 100) (Records: 1296)	2574 (Percent: 100) (Records: 1169)	2160 (Percent: 100) (Records: 968)
Fishing duration is not NA	3820 (Percent: 100) (Records: 1697)	4012 (Percent: 100) (Records: 1439)	2788 (Percent: 100) (Records: 1465)	2112 (Percent: 100) (Records: 966)	1811 (Percent: 100) (Records: 737)	3365 (Percent: 100) (Records: 1125)	1761 (Percent: 100) (Records: 1006)	1713 (Percent: 100) (Records: 742)	2948 (Percent: 100) (Records: 1059)	2627 (Percent: 100) (Records: 1208)	2541 (Percent: 100) (Records: 1127)	2099 (Percent: 100) (Records: 924)
Positive fishing duration	3820 (Percent: 100) (Records: 1697)	4012 (Percent: 100) (Records: 1439)	2788 (Percent: 100) (Records: 1465)	2112 (Percent: 100) (Records: 966)	1811 (Percent: 100) (Records: 737)	3365 (Percent: 100) (Records: 1125)	1761 (Percent: 100) (Records: 1006)	1713 (Percent: 100) (Records: 742)	2948 (Percent: 100) (Records: 1059)	2627 (Percent: 100) (Records: 1208)	2541 (Percent: 100) (Records: 1127)	2099 (Percent: 100) (Records: 924)
Total fishing duration <180hrs	3772 (Percent: 100) (Records: 1690)	3931 (Percent: 100) (Records: 1432)	2777 (Percent: 100) (Records: 1463)	2101 (Percent: 100) (Records: 964)	1811 (Percent: 100) (Records: 737)	3365 (Percent: 100) (Records: 1125)	1757 (Percent: 100) (Records: 1005)	1702 (Percent: 100) (Records: 740)	2917 (Percent: 100) (Records: 1056)	2627 (Percent: 100) (Records: 1208)	2541 (Percent: 100) (Records: 1127)	2085 (Percent: 100) (Records: 920)
Season Nov Apr	3737 (Percent: 100) (Records: 1658)	3920 (Percent: 100) (Records: 1419)	2766 (Percent: 100) (Records: 1449)	2082 (Percent: 94) (Records: 957)	1789 (Percent: 100) (Records: 721)	3359 (Percent: 100) (Records: 1108)	1756 (Percent: 100) (Records: 1002)	1675 (Percent: 100) (Records: 726)	2916 (Percent: 100) (Records: 1054)	2614 (Percent: 100) (Records: 1190)	2522 (Percent: 100) (Records: 1103)	2062 (Percent: 100) (Records: 895)
Positive catch	3737 (Percent: 100) (Records: 1622)	3920 (Percent: 100) (Records: 1379)	2766 (Percent: 100) (Records: 1407)	2082 (Percent: 94) (Records: 941)	1789 (Percent: 100) (Records: 701)	3359 (Percent: 100) (Records: 1098)	1756 (Percent: 100) (Records: 996)	1675 (Percent: 100) (Records: 712)	2916 (Percent: 100) (Records: 1049)	2614 (Percent: 100) (Records: 1179)	2522 (Percent: 100) (Records: 1075)	2062 (Percent: 100) (Records: 885)
Core fleet selection	3239 (Percent: 83) (Records: 1405)	3431 (Percent: 84) (Records: 1209)	2518 (Percent: 88) (Records: 1276)	1973 (Percent: 89) (Records: 874)	1767 (Percent: 100) (Records: 684)	3206 (Percent: 93) (Records: 1026)	1693 (Percent: 100) (Records: 921)	1621 (Percent: 94) (Records: 687)	2818 (Percent: 95) (Records: 997)	2462 (Percent: 91) (Records: 1068)	2424 (Percent: 94) (Records: 1014)	2001 (Percent: 93) (Records: 846)

Filter	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Ungroomed data	2349 (Percent: 100) (Records: 882)	1905 (Percent: 100) (Records: 851)	1811 (Percent: 100) (Records: 702)	2300 (Percent: 100) (Records: 888)	2476 (Percent: 100) (Records: 986)	2851 (Percent: 100) (Records: 1051)
Fishing duration is not NA	2321 (Percent: 100) (Records: 863)	1872 (Percent: 100) (Records: 828)	1800 (Percent: 100) (Records: 690)	2280 (Percent: 100) (Records: 872)	2455 (Percent: 100) (Records: 963)	2851 (Percent: 100) (Records: 1051)
Positive fishing duration	2321 (Percent: 100) (Records: 863)	1872 (Percent: 100) (Records: 828)	1800 (Percent: 100) (Records: 690)	2280 (Percent: 100) (Records: 872)	2455 (Percent: 100) (Records: 963)	2850 (Percent: 100) (Records: 1048)
Total fishing duration <180hrs	2275 (Percent: 100) (Records: 858)	1872 (Percent: 100) (Records: 828)	1766 (Percent: 100) (Records: 687)	2262 (Percent: 100) (Records: 869)	2438 (Percent: 100) (Records: 960)	2828 (Percent: 100) (Records: 1034)
Season Nov Apr	2267 (Percent: 100) (Records: 836)	1830 (Percent: 100) (Records: 803)	1705 (Percent: 94) (Records: 660)	2260 (Percent: 100) (Records: 860)	2409 (Percent: 100) (Records: 932)	2818 (Percent: 100) (Records: 1006)
Positive catch	2267 (Percent: 100) (Records: 823)	1830 (Percent: 100) (Records: 787)	1705 (Percent: 94) (Records: 640)	2260 (Percent: 100) (Records: 846)	2409 (Percent: 100) (Records: 917)	2818 (Percent: 100) (Records: 950)
Core fleet selection	2220 (Percent: 94) (Records: 799)	1751 (Percent: 92) (Records: 765)	1640 (Percent: 91) (Records: 611)	2155 (Percent: 94) (Records: 791)	2130 (Percent: 86) (Records: 818)	2371 (Percent: 83) (Records: 739)

4.2.4 Gamma model diagnostics

Table 11: Summary of stepwise selection for the gamma model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	add % deviance	Included
	28	555500	3.1	3.1	*
+ ns(log(total fishing duration), 3)	3	533680	47.1	44.0	*
+ vessel key	372	528472	55.5	8.3	*
+ modal month	5	527727	56.4	1.0	*
+ modal stat area	20	527465	56.8	0.4	*
+ modal stat area:modal month	88	527134	57.4	0.6	*
+ ns(meiv2, 3)	3	526970	57.6	0.2	
+ ns(SST, 3)	3	526946	57.7	0.0	

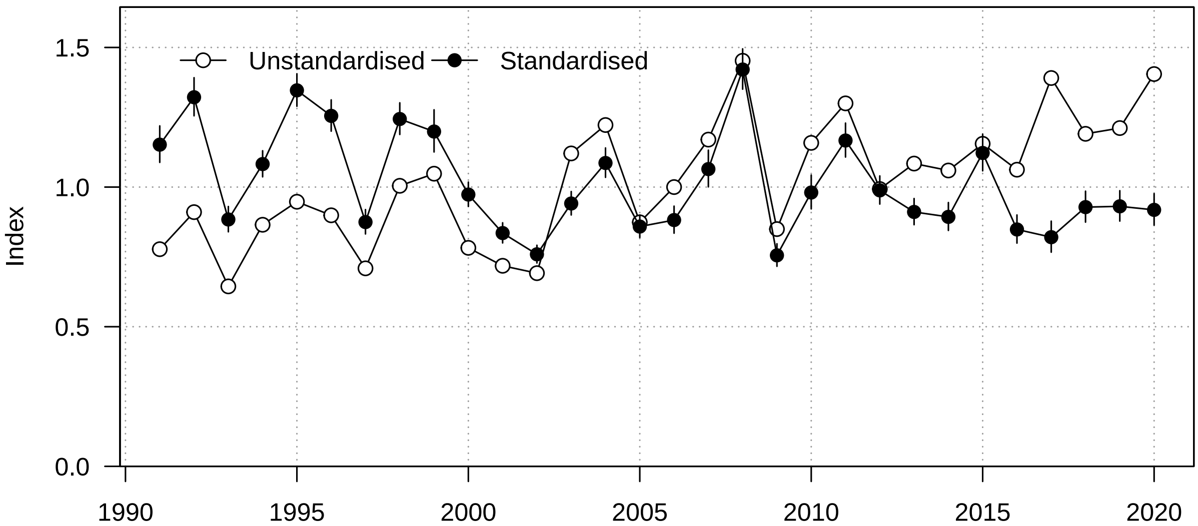

Figure 40: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for catch in the ALB 1 T CELR trip dataset.

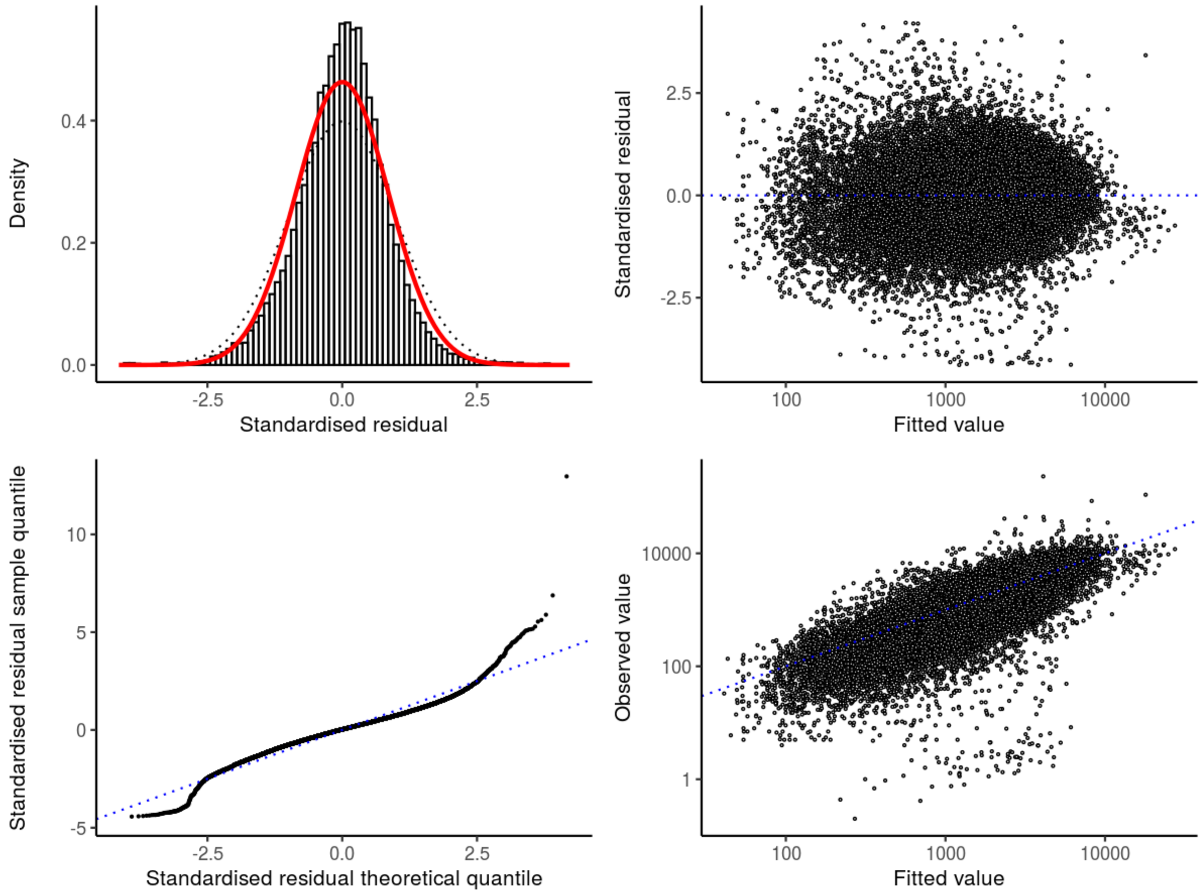

Figure 41: Diagnostic plots for the gamma model for the ALB 1 T CELR trip dataset.

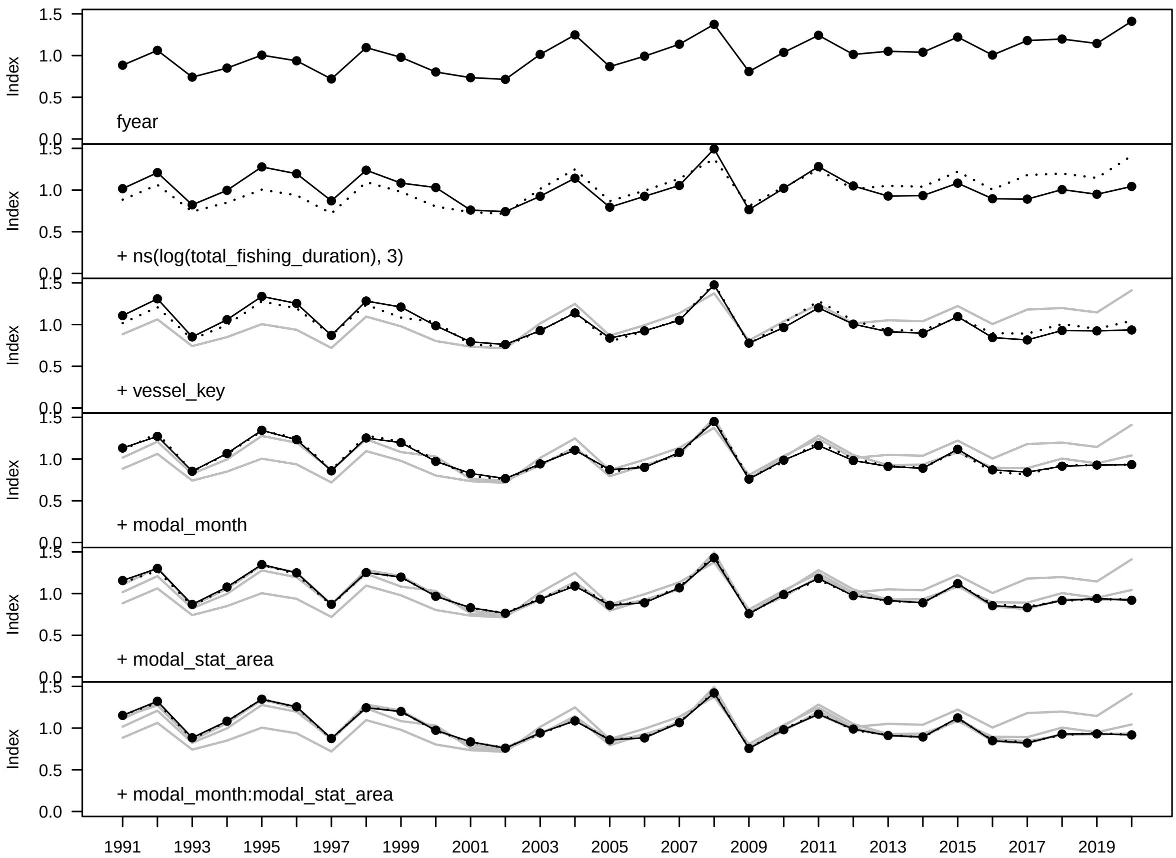

Figure 42: Changes to the ALB 1 T CELR trip index as terms are successively entered into the model

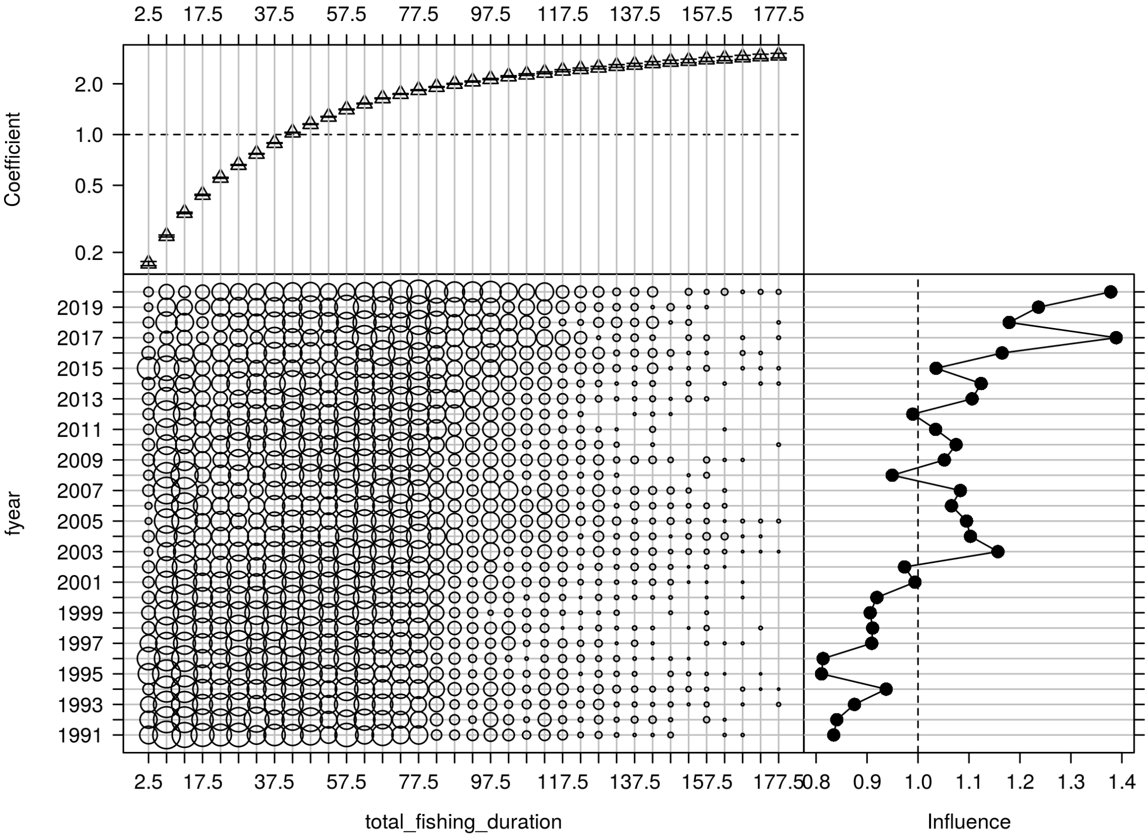

Figure 43: CDI plot for log-total-fishing-duration for the ALB 1 T CELR trip catch-per-unit-effort dataset.

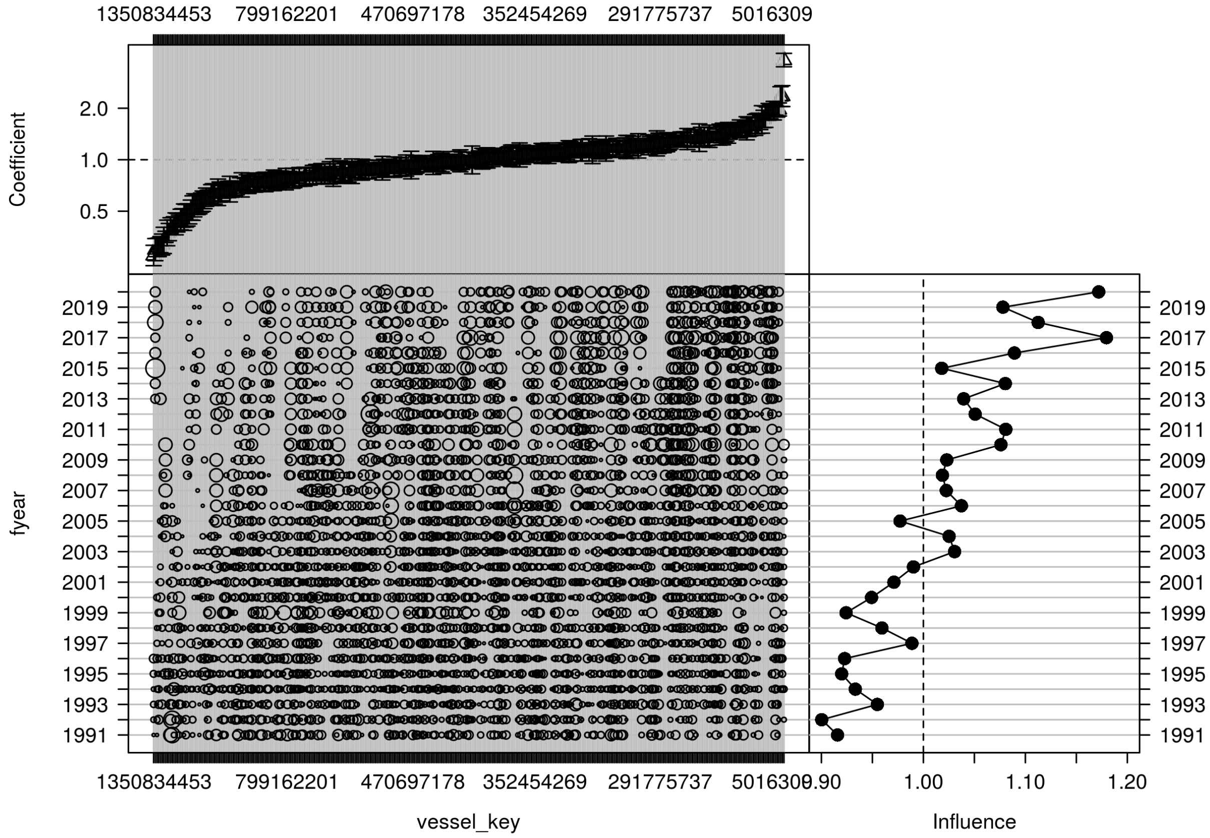

Figure 44: CDI plot for vessel-key for the ALB 1 T CELR trip catch-per-unit-effort dataset.

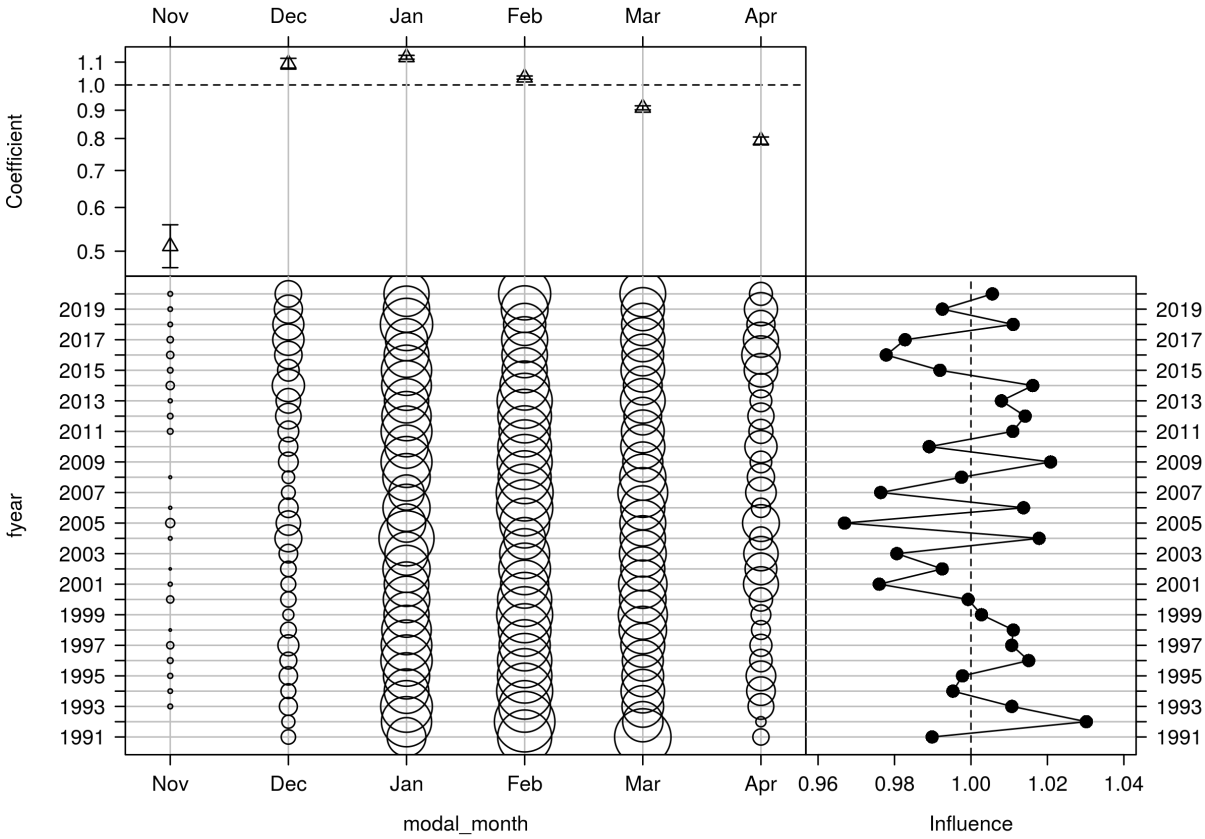

Figure 45: CDI plot for modal-month for the ALB 1 T CELR trip catch-per-unit-effort dataset.

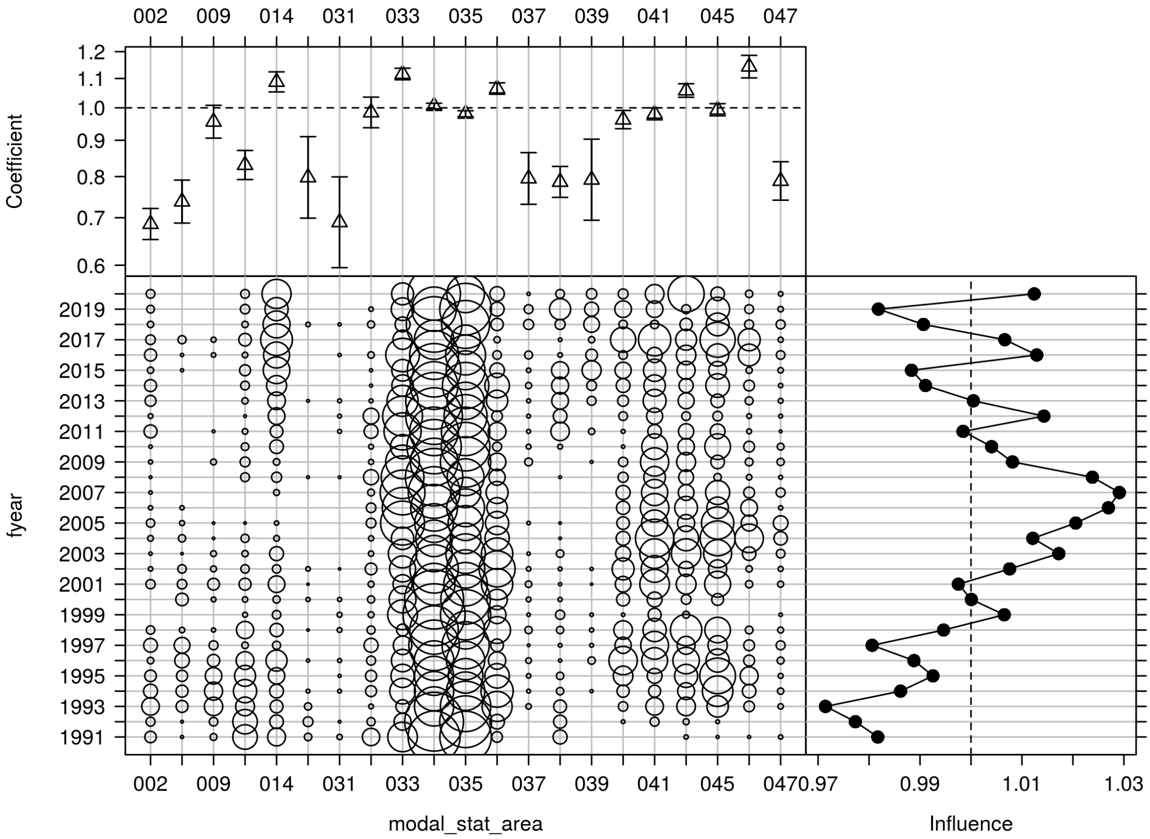

Figure 46: CDI plot for modal-stat-area for the ALB 1 T CELR trip catch-per-unit-effort dataset.

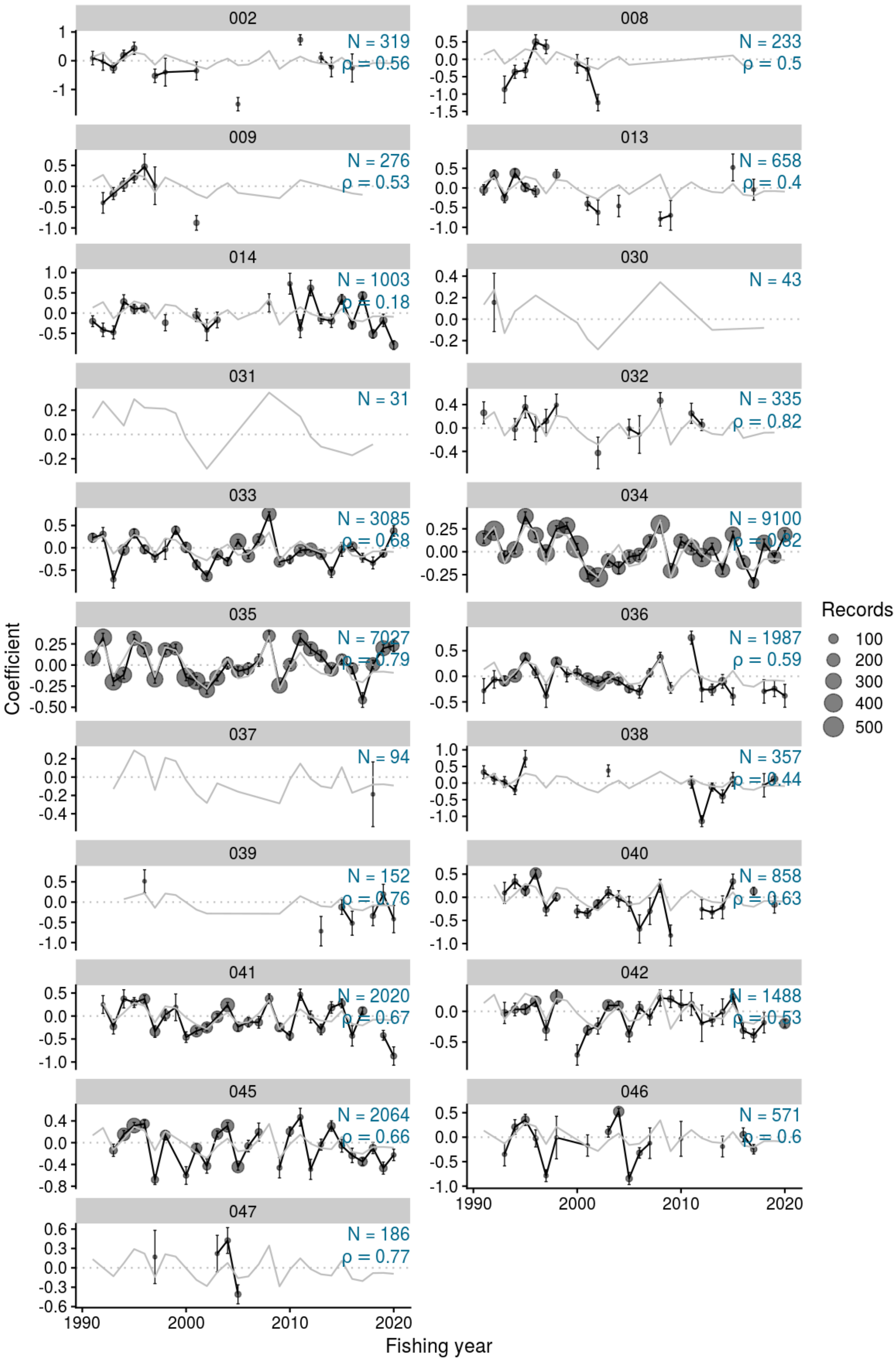

Figure 47: Residual implied coefficients for area-year gamma model for the ALB 1 T CELR trip dataset.

4.2.5 CPUE indices

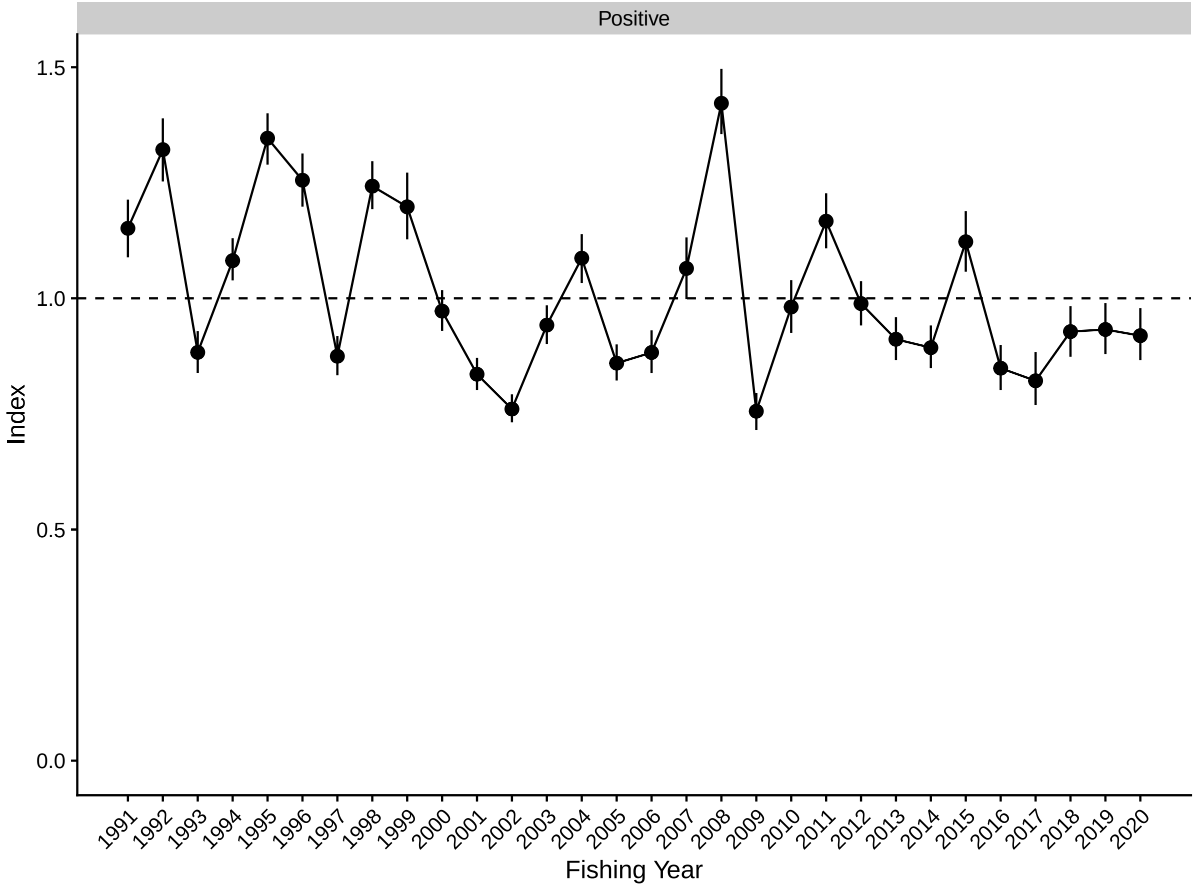

Figure 48: Standardised indices and 95% confidence intervals for the ALB 1 T CELR trip dataset.

4.2.6 Alternative distribution diagnostics for CPUE standardisation

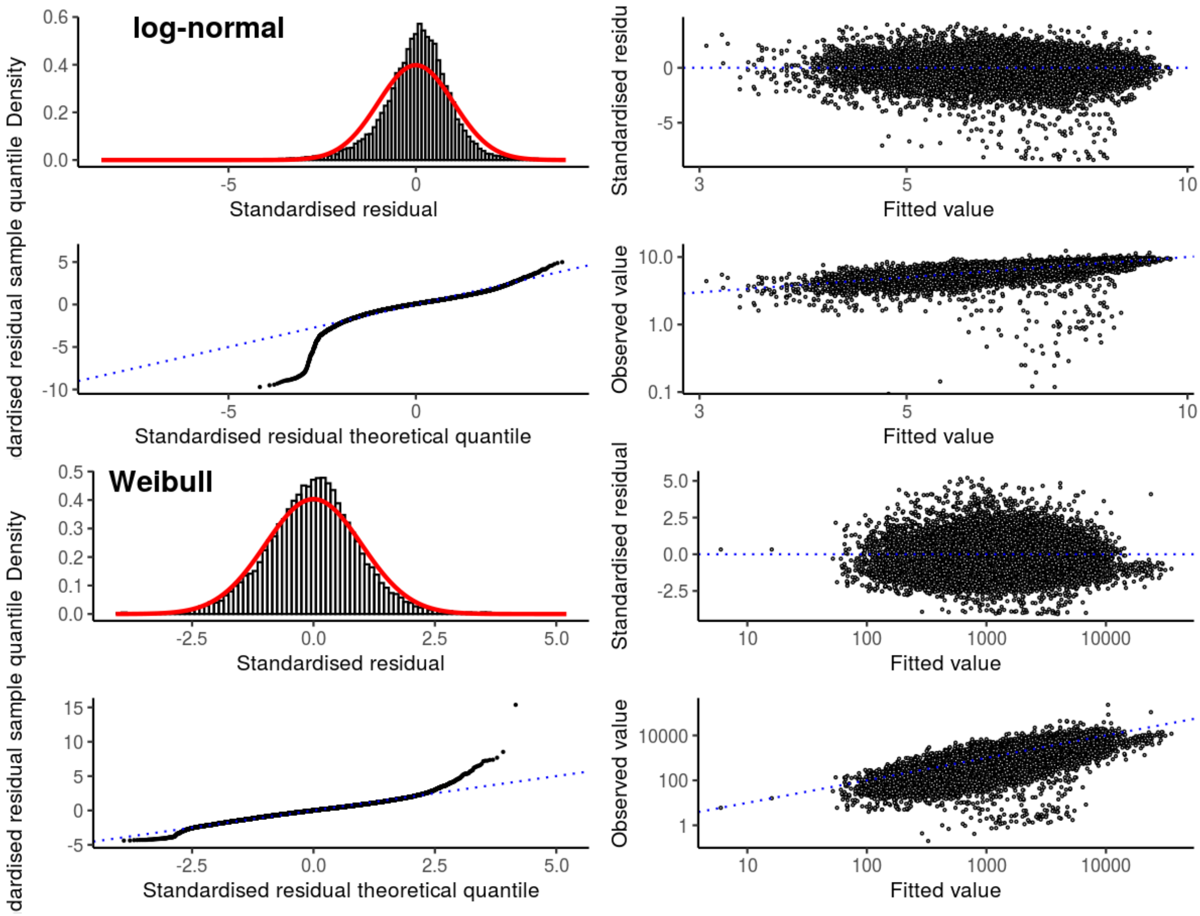

Figure 49: Diagnostic plots for the log-normal and Weibull model for the ALB 1 T CELR trip dataset.

Table 12: Annual indices and standard errors for each model in ALB 1 T CELR trip. Fishing years are labeled by the later calendar year e.g. 1996 = 1995/1996.

Fishing year	Positive	Positive SE
1991	1.2	0.032
1992	1.3	0.035
1993	0.88	0.023
1994	1.1	0.023
1995	1.3	0.028
1996	1.3	0.029
1997	0.87	0.022
1998	1.2	0.026
1999	1.2	0.037
2000	0.97	0.022
2001	0.84	0.018
2002	0.76	0.015
2003	0.94	0.021
2004	1.1	0.027
2005	0.86	0.02
2006	0.88	0.024
2007	1.1	0.034
2008	1.4	0.036
2009	0.76	0.021
2010	0.98	0.029
2011	1.2	0.03
2012	0.99	0.024
2013	0.91	0.024
2014	0.89	0.024
2015	1.1	0.033
2016	0.85	0.025
2017	0.82	0.029
2018	0.93	0.028
2019	0.93	0.028
2020	0.92	0.029

5. CPUE INDICES

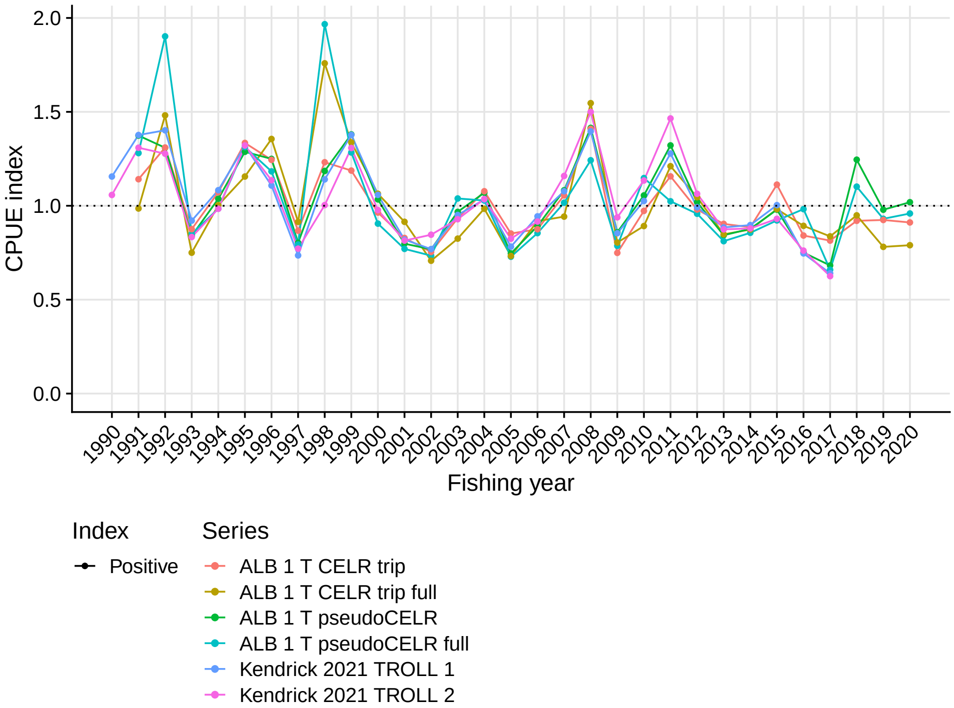

Figure 50: Comparing all ALB CPUE.

6. ENVIRONMENTAL CHARACTERISTICS

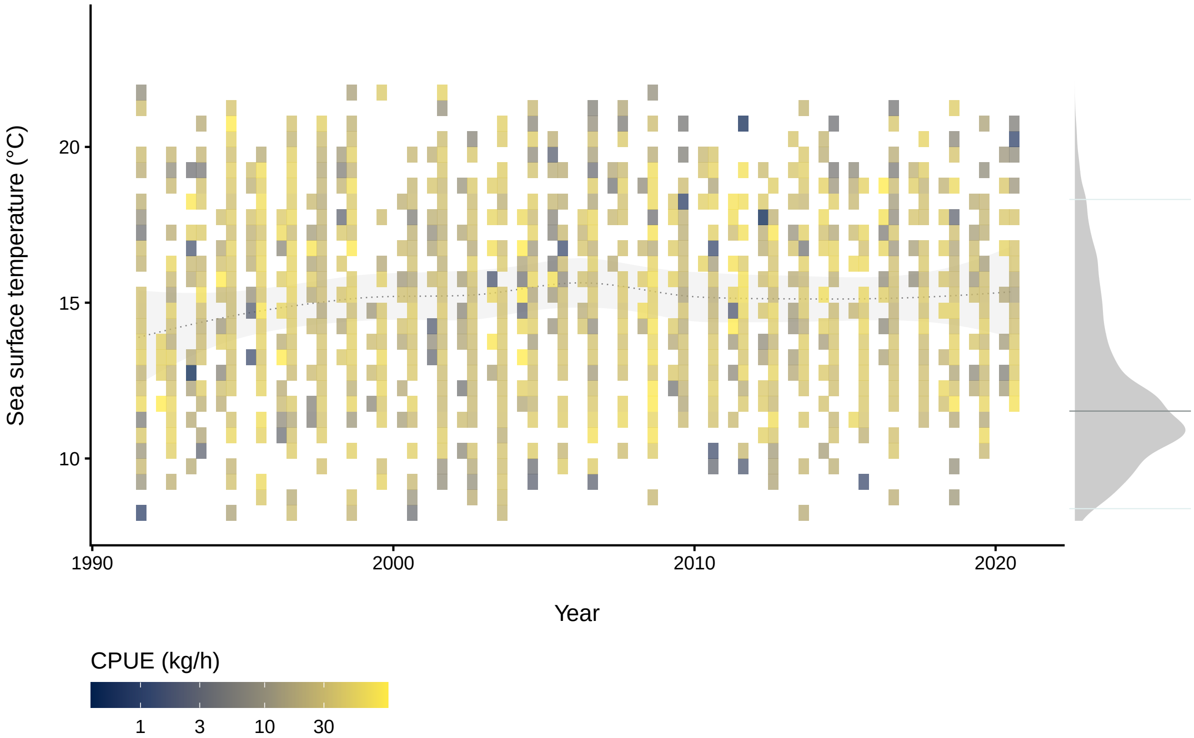

Figure 51: Albacore catch-per-unit-effort (CPUE; tonnes per hour (t/h)), aggregated by month and by sea surface temperature (SST) associated with a set, grouped by 0.5 C. Smoothed trend of overall SST distribution of effort for each target species is overlaid. Marginal density plots (right-hand side) show the overall distribution of Albacore by SST, with the median and 95% quantile range highlighted.

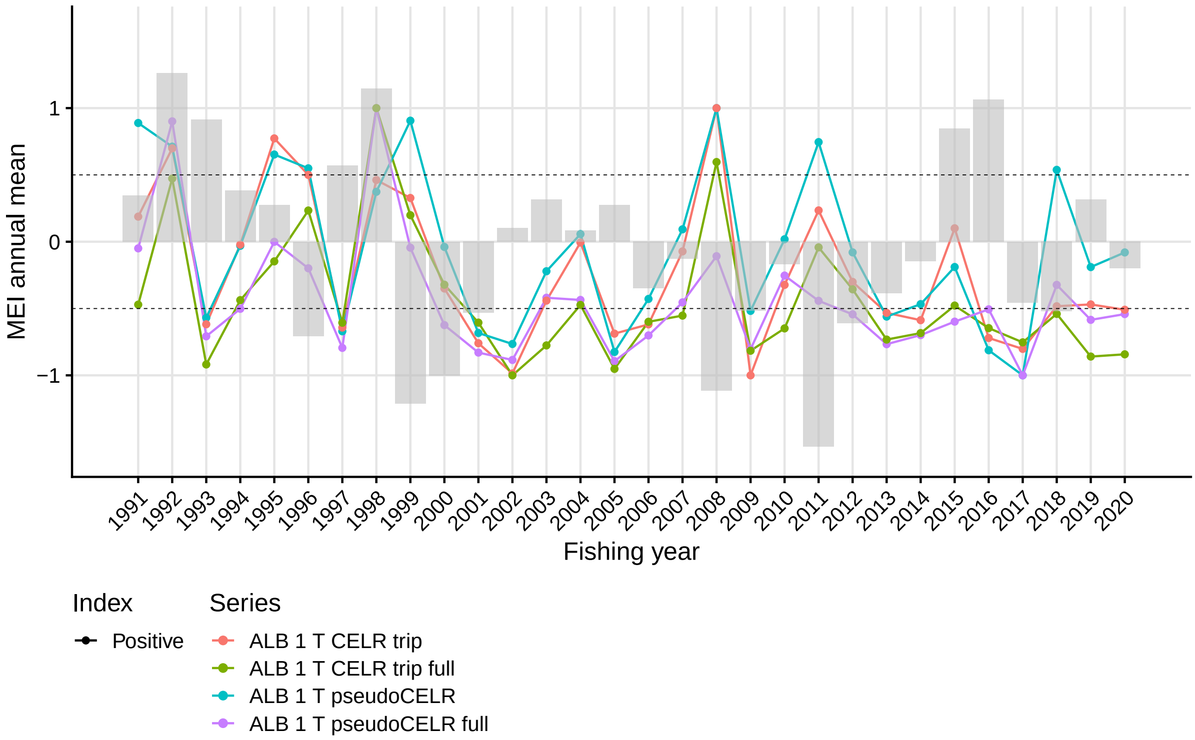

Figure 52: Comparing albacore CPUE indices (normalised to (-1,1)) with annual means (grey bars) of the Multivariate ENSO index (MEI). Dashed lines at +/- 0.5 threshold for El Nino and La Nina events.

7. DISCUSSION

The assessment for south Pacific albacore uses a range of information from New Zealand including tagging, length data and both troll and longline catch and effort data (Tremblay-Boyer et al. 2018b). While New Zealand lands a small amount of the WCPO catch most of the troll catch (77%) comes from New Zealand which provides information on recruitment trends. This work aimed to analyse the CPUE from the commercial troll fishery for albacore in New Zealand waters to contribute to the stock assessment of albacore in the southwest Pacific Ocean.

Most of the New Zealand albacore catch is taken by troll gear and the New Zealand troll fleet is characterised as opportunistic with a large number of vessels, most or which undertake less than three trips or fish for fewer than four years. Overall the catch reporting is consistent over time and the troll catch is relatively stable from year to year. The catch is taken in a relatively predictable manner from north to south off the west coast of New Zealand over a few consecutive months through the Austral summer.

In the years leading up to 2004 the albacore catch in the surface longline fishery was high in albacore, bigeye and southern bluefin tuns target sets. There has been a suggestion that this was a result of high fishing effort in that sector prior to the introduction of many pelagic species into the New Zealand QMS. In 2004, most pelagic species (excluding albacore) were introduced into the QMS (Fisheries New Zealand 2019). Since 2006 the New Zealand longline fisheries seldom target albacore and now catch more lucrative species such as swordfish and southern bluefin tuna, that now (along with blue sharks) that have dominated the since 2006.

Catch reporting has been consistent in the troll fishery, but there have been some changes in the longline catch reporting. The troll and longline fisheries are largely separated with the longline sets predominantly off the east coast of the North Island, while the troll catch occurs closer inshore off the west coast of both the North and South Islands. Some spatial overlap occurs off the lower South Island east coast but, these fisheries are largely separated temporarily where trolling for albacore occurs through the Austral summer and southern bluefin target longlining in winter. The two fisheries also catch fish of different sizes with the longline fishery catching larger subadult and adult fish and the troll fishery catching juveniles. While the longline fisheries outside of New Zealand are better at monitoring the adult portion of the stock, the New Zealand troll fishery, landing the majority of the troll catch, is better placed at monitoring the juvenile fish. The CPUE data presented here therefore focus on the troll catch and effort data and index only the juvenile part of the stock that occur in New Zealand fishery waters.

In addition, annual length data can assist MULTIFAN-CL (MFCL) interpret length progression within the model. Length sampling of troll-caught albacore has been carried out in most years since 1996, while not part of this characterisation these data are reported in the Appendix as they are relevant to the assessment (Figure C.4). Some sampling has occurred from the longline fisheries, but most landings were samples from troll vessels in FMA 7 and FMA 9, with over 62,000 fish sampled in FMA 7 and 23,000 in FMA 9. Only small numbers of samples have been taken from other FMAs and fisheries (Table C.1). Generally, the troll length data has three modes (Figure C.1 and Figure C.2). The cumulative length frequency data are most similar in FMAs 1 and 9, with fish samples in FMA 8 being the smallest. Year class and tracking modal progression is possible and strong year classes are noticeable for up to three years e.g. the $\sim$50cm mode in 2000 can be seen appearing in 2001 ($\sim$60cm) and 2002 ($\sim$75cm) as a strong year class in FMAs 1, 7 and 9 (Figure C.4). The sampling has been most consistent in FMAs 7 and 9, with FMAs 1 and 8 being sampled infrequently. These data are provided to SPC as part of the New Zealand annual data provision.

The standardisation had little effect on the ALB1 T pseudoCELR index, with fishing duration and vessel having the greatest impacts. Generally speaking, the standardisation lifted the start of the series and lowered the terminal years slightly. The standardisation had a greater effect on the ALB 1 T CELR trip dataset. Here the standardisation also lifted the start and reduced the most recent period but to a larger extent than the ALB1 T pseudoCELR index. Note that while the interaction term for month and statistical area was included in both model, it only just made it over the acceptance threshold for inclusion and made little difference to the series trajectory in any of the models. In general, all 4 time series show a similar and unremarkable trend, with greater fluctuations in the earlier part of the series compared to those in more recent years.

Additionally, the series reported in this analysis closely follows the trend in the series reported in the previous analysis by Kendrick (2021) for the years up to the 2017 fishing year. The differences between the two analyses appear when the multivariate ENSO index is forced into the model. While MEI was not selected as an explanatory variable in either of the stepwise models, there appears to be some weak link between El Niño events (MEI> 0.5 for three consecutive months) where in those years CPUE is higher for troll caught albacore in New Zealand in the early part of the series. This link may be further highlighted by the lack of El Niño events for most of the middle and later part of the series corresponding to a dampened trend in the series. However, like the analysis of Kendrick & Bentley (2010) and Kendrick (2021) this was not resolved by the model and it is not clear if these trends are driven by higher recruitment success in La Niña years or higher catchability El Niño years.

Overall, the series, which now extends 30 years, fluctuates without trend over the last two decades. The standardised CPUE index is likely a reflection of availability and/or catchability, rather than an indication of abundance, particularly in terms of the coverage of the juvenile portion of albacore stock in New Zealand waters by the troll fishery.

Recommendations for future work include investigating temporal and spatial trends in the compositional data from market sampling to determine if there is utility in these data for informing size disaggregated CPUE. Also, we recommend further work that would help explain the environmental drivers of availability of juvenile albacore to the New Zealand troll fishery, and to investigate which environmental datasets may be useful for predicting climate change effects on availability.

8. ACKNOWLEDGEMENTS

Thanks to T. Kendrick (Trophia Ltd.) and S. Hoyle (NIWA) for their review of an earlier draft of this report. We thank John Annala and the members of the Highly Migratory Species Working Group for helpful discussion. Also, we thank D. Loder (Talleys) for providing insights to help our understanding of the availability of albacore to the ALB 1 troll fishery.

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APPENDIX A: ADDITIONAL CPUE SERIES

A.1 ALB 1 T pseudoCELR full

A.1.1 CPUE series

Table A.1: Specification for the ALB 1 T pseudoCELR full CPUE series.

Series	ALB 1 T pseudoCELR full
QMS stock	ALB1
Reporting forms	CEL, ”ERS - Other Lining”
Fishing methods	T
Target species	ALB
Areas	002, 007, 008, 009, 013, 014, 030, 031, 032, 033, 034, 035, 036, 037, 038, 039, 040, 041, 042, 045, 046, 047
Period	1990-10-01, 2020-10-01
Core fleet years	4
Core fleet trips	3
Default model	nfish ~ fyear + vessel_key + stat_area*month + ns(log(fishing_duration), 3) + ns(SST, 3) + ns(meiv2, 3)
Stepwise selection	No

A.1.2 Core vessel selection

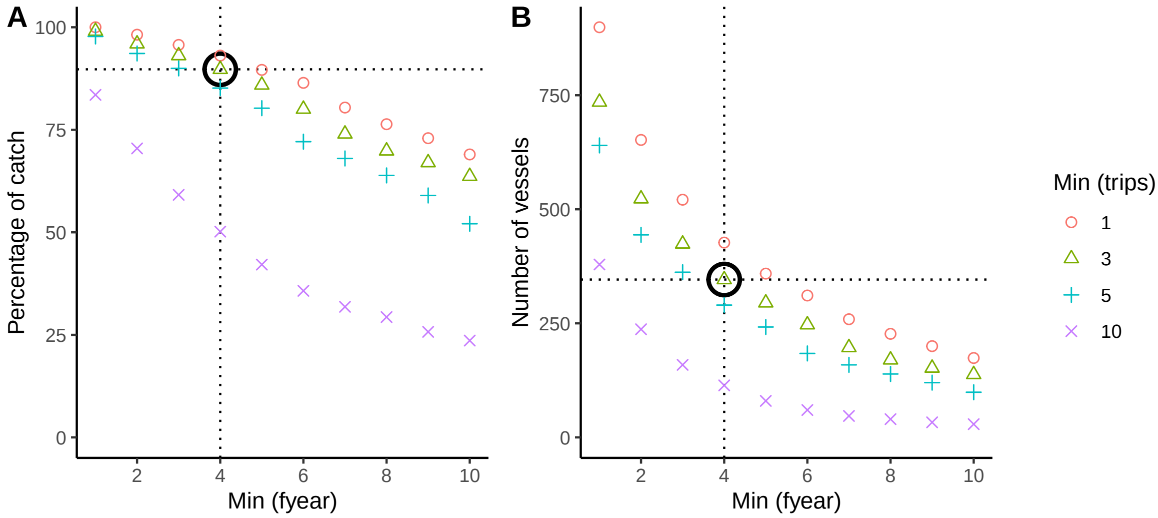

Figure A.1: Percentage of catch and number of vessels for different core vessel selection criteria. Bold open circle represents the core vessel selection criteria based on the number of years in the fishery and the amount of trips per fleet

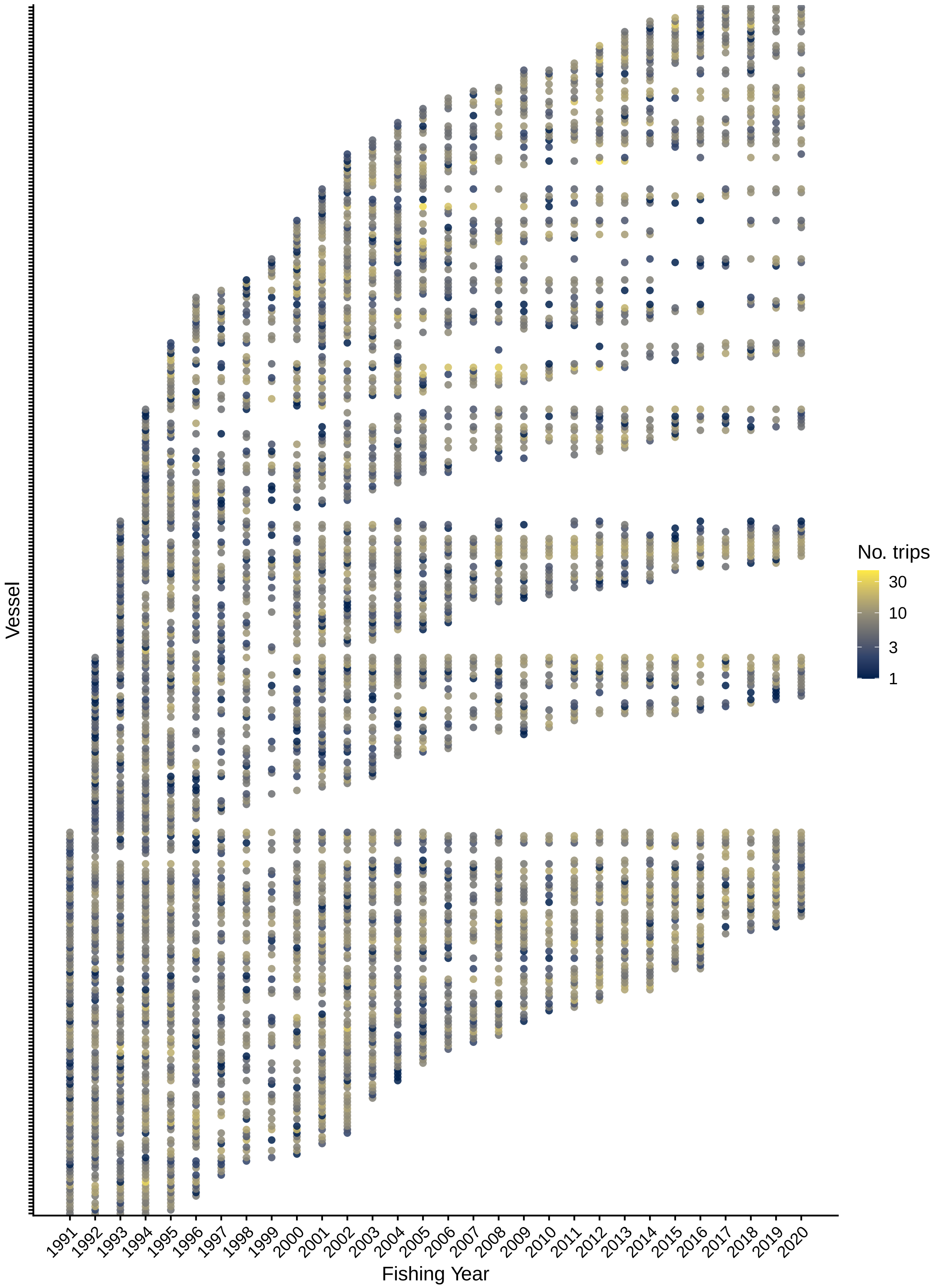

Figure A.2: Number of trips by fishing year for core vessels. The area of circles is proportional to the number of trips.

A.1.3 CPUE dataset summary

Table A.2: Summary of ALB 1 T pseudoCELR full data subset by fishing year after the data was checked for missing values and outliers were removed. Records represent a row in the dataset daily catch. Fishing years are labelled by the later calendar year e.g. 1990 = 1989/1990.

Fishing year	Vessels	Trips	Records	Effort (hrs)	Catch (no. fish)
1991	110	677	2456	31653.72	322245
1992	146	914	3251	43503.70	441967
1993	170	1012	3517	46870.27	308234
1994	203	1494	5699	74557.00	586333
1995	198	1512	5050	66296.15	648424
1996	165	1145	3699	48267.05	494401
1997	143	850	3046	40898.72	268844
1998	139	982	3498	46257.65	452103
1999	93	548	1857	24700.68	250854
2000	161	1177	4018	53924.07	437872
2001	198	1496	5497	74235.70	458260
2002	201	1516	5498	74550.10	477400
2003	183	1319	5554	76865.68	606806
2004	176	1138	4832	66892.27	614067
2005	154	1130	4933	66738.95	408935
2006	137	828	3388	46849.52	365386
2007	105	676	2952	39470.43	357167
2008	122	1014	3800	49761.23	620469
2009	120	853	3673	49266.10	374847
2010	96	675	2738	36803.90	337657
2011	110	929	3741	50519.93	605283
2012	116	1035	3949	53353.40	474356
2013	115	985	4115	56601.68	414788
2014	113	829	3431	47033.10	363641
2015	92	753	3236	44162.65	387205
2016	97	729	3229	43472.82	286154
2017	73	593	2939	40617.73	253718
2018	95	756	3338	45573.62	537437
2019	87	719	3377	45435.83	408504
2020	93	713	3662	47922.80	474999

Table A.3: Summary of ALB 1 T pseudoCELR full total catch (t) subset by fishing year after the data was groomed by various filters. First row (Ungroomed data) shows catch before filters were applied. Subsequent rows below total catch display the percent of catch, and the total number of records.

Filter	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Ungroomed data	445	616	491	882	921	728	431	714	313	624	550	586
	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)
	(Records: 3840)	(Records: 4935)	(Records: 5919)	(Records: 8895)	(Records: 7556)	(Records: 6373)	(Records: 5287)	(Records: 6490)	(Records: 2548)	(Records: 6160)	(Records: 7211)	(Records: 7134)
Fishing duration is not NA	444	614	485	872	889	697	384	691	306	573	534	563
	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 89)	(Percent: 100)	(Percent: 100)	(Percent: 92)	(Percent: 100)	(Percent: 100)
	(Records: 3828)	(Records: 4909)	(Records: 5844)	(Records: 8766)	(Records: 7371)	(Records: 6083)	(Records: 4897)	(Records: 6234)	(Records: 2452)	(Records: 5620)	(Records: 6952)	(Records: 6837)
Positive fishing duration	444	614	485	870	886	697	384	691	306	563	534	562
	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 100)	(Percent: 89)	(Percent: 100)	(Percent: 100)	(Percent: 90)	(Percent: 100)	(Percent: 100)
	(Records: 3822)	(Records: 4902)	(Records: 5842)	(Records: 8743)	(Records: 7342)	(Records: 6077)	(Records: 4881)	(Records: 6226)	(Records: 2452)	(Records: 5568)	(Records: 6944)	(Records: 6827)
Fishing duration <20hrs	429	603	464	853	850	676	371	678	297	552	527	555
	(Percent: 100)	(Percent: 100)	(Percent: 94)	(Percent: 100)	(Percent: 92)	(Percent: 93)	(Percent: 86)	(Percent: 95)	(Percent: 95)	(Percent: 88)	(Percent: 100)	(Percent: 95)
	(Records: 3757)	(Records: 4858)	(Records: 5767)	(Records: 8668)	(Records: 7231)	(Records: 5975)	(Records: 4835)	(Records: 6151)	(Records: 2417)	(Records: 5498)	(Records: 6890)	(Records: 6753)
Season start day <212	428	602	463	847	845	675	370	668	297	546	512	553
	(Percent: 100)	(Percent: 100)	(Percent: 94)	(Percent: 100)	(Percent: 92)	(Percent: 93)	(Percent: 86)	(Percent: 94)	(Percent: 95)	(Percent: 87)	(Percent: 93)	(Percent: 94)
	(Records: 3749)	(Records: 4847)	(Records: 5741)	(Records: 8587)	(Records: 7128)	(Records: 5945)	(Records: 4809)	(Records: 6009)	(Records: 2408)	(Records: 5376)	(Records: 6625)	(Records: 6687)
Season start day >31	428	602	463	847	845	675	370	668	297	546	512	553
	(Percent: 100)	(Percent: 100)	(Percent: 94)	(Percent: 100)	(Percent: 92)	(Percent: 93)	(Percent: 86)	(Percent: 94)	(Percent: 95)	(Percent: 87)	(Percent: 93)	(Percent: 94)
	(Records: 3748)	(Records: 4846)	(Records: 5740)	(Records: 8587)	(Records: 7128)	(Records: 5944)	(Records: 4807)	(Records: 6009)	(Records: 2408)	(Records: 5376)	(Records: 6625)	(Records: 6687)
Positive catch	428	602	463	847	845	675	370	668	297	546	512	553
	(Percent: 100)	(Percent: 100)	(Percent: 94)	(Percent: 100)	(Percent: 92)	(Percent: 93)	(Percent: 86)	(Percent: 94)	(Percent: 95)	(Percent: 87)	(Percent: 93)	(Percent: 94)
	(Records: 3575)	(Records: 4715)	(Records: 5489)	(Records: 8407)	(Records: 6964)	(Records: 5311)	(Records: 4331)	(Records: 5388)	(Records: 2263)	(Records: 5277)	(Records: 6480)	(Records: 6588)
No inferred numbers	363	525	438	790	801	581	308	552	256	485	500	538
	(Percent: 82)	(Percent: 85)	(Percent: 89)	(Percent: 90)	(Percent: 87)	(Percent: 80)	(Percent: 71)	(Percent: 77)	(Percent: 82)	(Percent: 78)	(Percent: 91)	(Percent: 92)
	(Records: 2905)	(Records: 4034)	(Records: 5055)	(Records: 7707)	(Records: 6527)	(Records: 4465)	(Records: 3569)	(Records: 4236)	(Records: 1908)	(Records: 4516)	(Records: 6133)	(Records: 6193)
Core fleet selection	322	442	309	587	651	494	269	452	251	439	458	477
	(Percent: 72)	(Percent: 72)	(Percent: 63)	(Percent: 67)	(Percent: 71)	(Percent: 68)	(Percent: 62)	(Percent: 63)	(Percent: 80)	(Percent: 70)	(Percent: 83)	(Percent: 82)
	(Records: 2456)	(Records: 3251)	(Records: 3544)	(Records: 5707)	(Records: 5068)	(Records: 3699)	(Records: 3046)	(Records: 3498)	(Records: 1857)	(Records: 4034)	(Records: 5497)	(Records: 5498)

Filter	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Ungroomed data	779 (Percent: 100) (Records: 7485)	736 (Percent: 100) (Records: 6178)	503 (Percent: 100) (Records: 6571)	429 (Percent: 100) (Records: 4175)	377 (Percent: 100) (Records: 3234)	682 (Percent: 100) (Records: 4320)	412 (Percent: 100) (Records: 4230)	358 (Percent: 100) (Records: 3040)	659 (Percent: 100) (Records: 4284)	537 (Percent: 100) (Records: 4762)	454 (Percent: 100) (Records: 4757)	405 (Percent: 100) (Records: 4034)
Fishing duration is not NA	760 (Percent: 100) (Records: 7278)	724 (Percent: 100) (Records: 6083)	492 (Percent: 100) (Records: 6414)	409 (Percent: 100) (Records: 3991)	374 (Percent: 100) (Records: 3201)	668 (Percent: 100) (Records: 4187)	407 (Percent: 100) (Records: 4158)	354 (Percent: 100) (Records: 3010)	653 (Percent: 100) (Records: 4215)	517 (Percent: 100) (Records: 4545)	446 (Percent: 100) (Records: 4647)	393 (Percent: 100) (Records: 3870)
Positive fishing duration	760 (Percent: 100) (Records: 7277)	724 (Percent: 100) (Records: 6083)	492 (Percent: 100) (Records: 6413)	409 (Percent: 100) (Records: 3991)	374 (Percent: 100) (Records: 3201)	668 (Percent: 100) (Records: 4186)	407 (Percent: 100) (Records: 4154)	354 (Percent: 100) (Records: 3009)	653 (Percent: 100) (Records: 4215)	517 (Percent: 100) (Records: 4542)	446 (Percent: 100) (Records: 4646)	393 (Percent: 100) (Records: 3868)
Fishing duration <20hrs	752 (Percent: 100) (Records: 7238)	720 (Percent: 100) (Records: 6057)	490 (Percent: 100) (Records: 6398)	407 (Percent: 95) (Records: 3975)	372 (Percent: 100) (Records: 3188)	661 (Percent: 100) (Records: 4169)	405 (Percent: 100) (Records: 4139)	351 (Percent: 100) (Records: 2992)	648 (Percent: 100) (Records: 4198)	515 (Percent: 100) (Records: 4534)	445 (Percent: 100) (Records: 4641)	386 (Percent: 100) (Records: 3840)
Season start day <212	741 (Percent: 100) (Records: 7063)	717 (Percent: 100) (Records: 5994)	487 (Percent: 100) (Records: 6341)	404 (Percent: 94) (Records: 3939)	367 (Percent: 100) (Records: 3127)	659 (Percent: 100) (Records: 4120)	405 (Percent: 100) (Records: 4129)	347 (Percent: 100) (Records: 2925)	648 (Percent: 100) (Records: 4191)	511 (Percent: 100) (Records: 4462)	439 (Percent: 100) (Records: 4563)	380 (Percent: 94) (Records: 3745)
Season start day >31	741 (Percent: 100) (Records: 7063)	717 (Percent: 100) (Records: 5994)	487 (Percent: 100) (Records: 6339)	404 (Percent: 94) (Records: 3939)	367 (Percent: 100) (Records: 3127)	659 (Percent: 100) (Records: 4120)	405 (Percent: 100) (Records: 4128)	347 (Percent: 100) (Records: 2925)	648 (Percent: 100) (Records: 4191)	511 (Percent: 100) (Records: 4462)	439 (Percent: 100) (Records: 4563)	380 (Percent: 94) (Records: 3743)
Positive catch	741 (Percent: 100) (Records: 6973)	717 (Percent: 100) (Records: 5781)	487 (Percent: 100) (Records: 6207)	404 (Percent: 94) (Records: 3886)	367 (Percent: 100) (Records: 3085)	659 (Percent: 100) (Records: 4088)	405 (Percent: 100) (Records: 4082)	347 (Percent: 100) (Records: 2882)	648 (Percent: 100) (Records: 4156)	511 (Percent: 100) (Records: 4413)	439 (Percent: 100) (Records: 4504)	380 (Percent: 94) (Records: 3693)
No inferred numbers	710 (Percent: 91) (Records: 6497)	696 (Percent: 95) (Records: 5464)	451 (Percent: 90) (Records: 5511)	391 (Percent: 91) (Records: 3647)	361 (Percent: 100) (Records: 2982)	648 (Percent: 100) (Records: 3966)	388 (Percent: 94) (Records: 3812)	339 (Percent: 95) (Records: 2768)	623 (Percent: 95) (Records: 3861)	503 (Percent: 94) (Records: 4227)	432 (Percent: 100) (Records: 4336)	375 (Percent: 92) (Records: 3553)
Core fleet selection	607 (Percent: 78) (Records: 5554)	614 (Percent: 83) (Records: 4832)	409 (Percent: 81) (Records: 4933)	365 (Percent: 85) (Records: 3388)	357 (Percent: 95) (Records: 2952)	620 (Percent: 91) (Records: 3800)	375 (Percent: 91) (Records: 3673)	338 (Percent: 94) (Records: 2738)	605 (Percent: 92) (Records: 3741)	474 (Percent: 88) (Records: 3949)	415 (Percent: 91) (Records: 4115)	364 (Percent: 90) (Records: 3431)

Filter	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Ungroomed data	426 (Percent: 100) (Records: 3769)	332 (Percent: 100) (Records: 3861)	289 (Percent: 100) (Records: 3499)	608 (Percent: 100) (Records: 4011)	524 (Percent: 100) (Records: 4599)	578 (Percent: 100) (Records: 4936)
Fishing duration is not NA	419 (Percent: 100) (Records: 3682)	325 (Percent: 100) (Records: 3766)	284 (Percent: 100) (Records: 3423)	601 (Percent: 100) (Records: 3940)	517 (Percent: 100) (Records: 4503)	578 (Percent: 100) (Records: 4936)
Positive fishing duration	419 (Percent: 100) (Records: 3681)	325 (Percent: 100) (Records: 3764)	284 (Percent: 100) (Records: 3422)	601 (Percent: 100) (Records: 3935)	517 (Percent: 100) (Records: 4503)	573 (Percent: 100) (Records: 4871)
Fishing duration <20hrs	406 (Percent: 100) (Records: 3599)	318 (Percent: 100) (Records: 3734)	278 (Percent: 100) (Records: 3407)	591 (Percent: 100) (Records: 3907)	489 (Percent: 93) (Records: 4426)	568 (Percent: 100) (Records: 4849)
Season start day <212	405 (Percent: 100) (Records: 3536)	308 (Percent: 93) (Records: 3580)	272 (Percent: 94) (Records: 3316)	590 (Percent: 100) (Records: 3872)	484 (Percent: 92) (Records: 4304)	566 (Percent: 100) (Records: 4734)
Season start day >31	405 (Percent: 100) (Records: 3536)	308 (Percent: 93) (Records: 3580)	272 (Percent: 94) (Records: 3316)	590 (Percent: 100) (Records: 3872)	484 (Percent: 92) (Records: 4304)	566 (Percent: 100) (Records: 4734)
Positive catch	405 (Percent: 100) (Records: 3485)	308 (Percent: 93) (Records: 3528)	272 (Percent: 94) (Records: 3259)	590 (Percent: 100) (Records: 3758)	484 (Percent: 92) (Records: 4168)	566 (Percent: 100) (Records: 4477)
No inferred numbers	399 (Percent: 94) (Records: 3354)	297 (Percent: 89) (Records: 3332)	261 (Percent: 90) (Records: 3034)	571 (Percent: 94) (Records: 3538)	457 (Percent: 87) (Records: 3836)	566 (Percent: 100) (Records: 4477)
Core fleet selection	387 (Percent: 91) (Records: 3236)	286 (Percent: 86) (Records: 3229)	254 (Percent: 88) (Records: 2939)	537 (Percent: 88) (Records: 3338)	409 (Percent: 78) (Records: 3377)	475 (Percent: 82) (Records: 3662)

A.1.4 Negative-Binomial model diagnostics

Table A.4: Summary table for the negative-binomial model. Model terms are listed in the order offered to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	add % deviance	Included
intercept	1	1310078	0.00	0.00	*
fyear	29	1305698	4.93	4.93	*
vessel key	346	1299492	7.66	12.59	*
stat area	20	1298554	1.09	13.67	*
month	5	1297007	1.73	15.40	*
ns(log(fishing duration), 3)	3	1290992	6.68	22.08	*
ns(SST, 3)	3	1290915	0.09	22.18	*
ns(meiv2, 3)	3	1290877	0.05	22.23	*
stat area:month	100	1290271	0.87	23.10	*

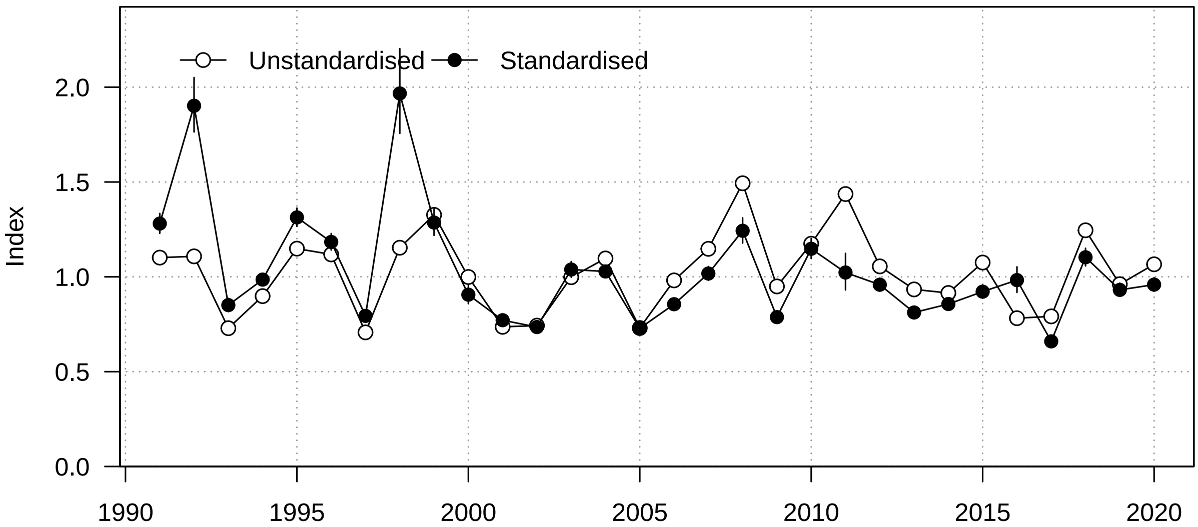

Figure A.3: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for catch in the ALB 1 T pseudoCELR full dataset.

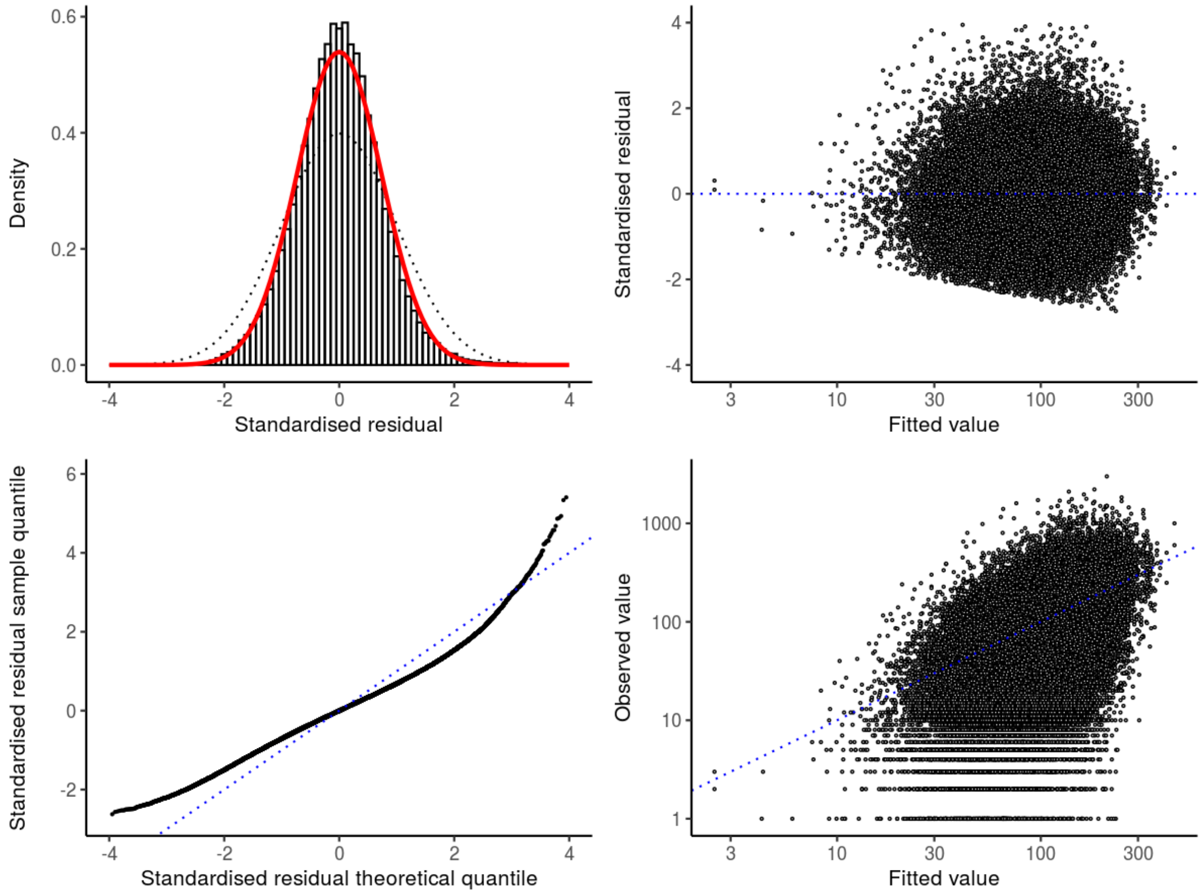

Figure A.4: Diagnostic plots for the negative-binomial model for the ALB 1 T pseudoCELR full dataset.

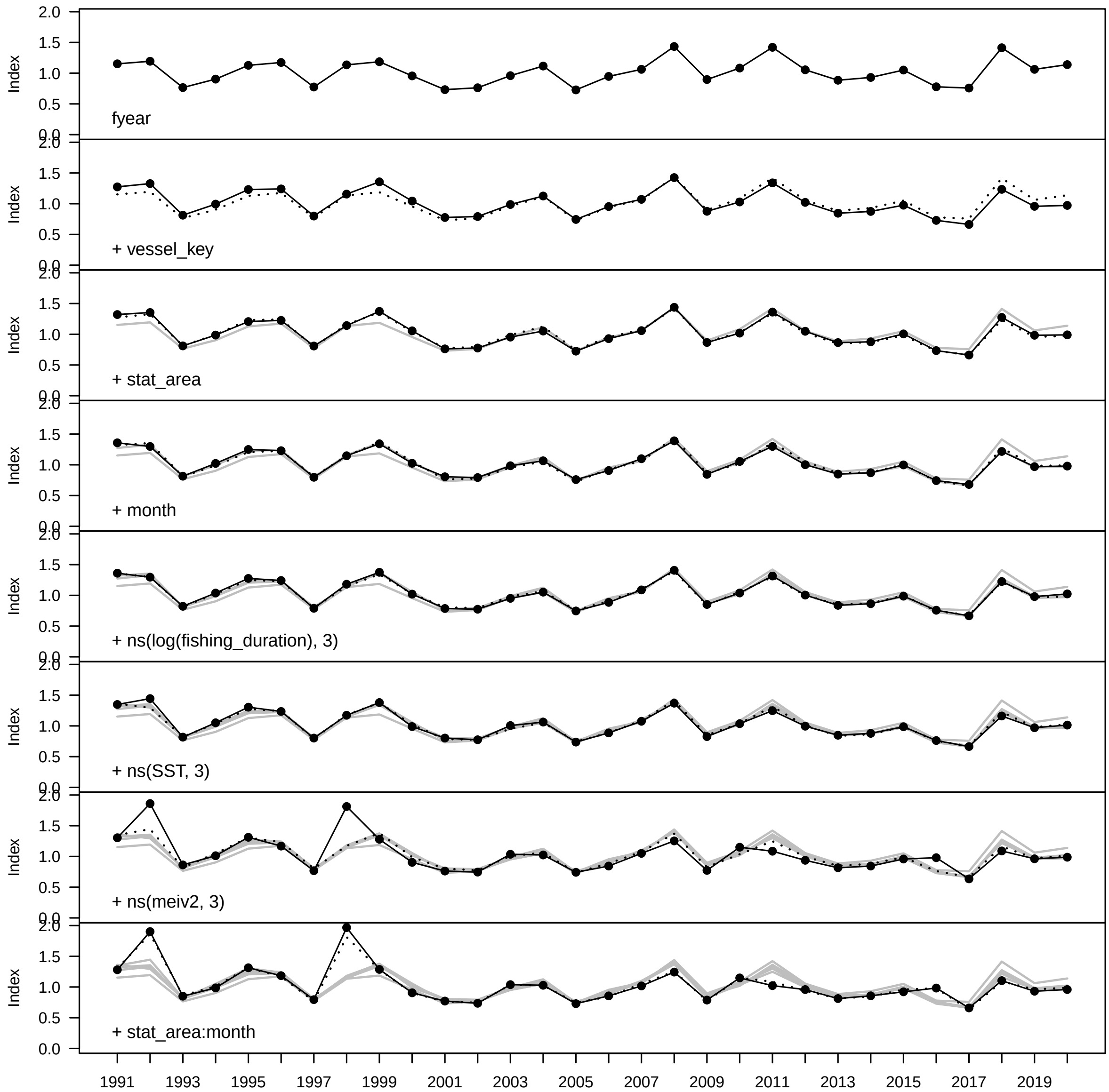

Figure A.5: Changes to the ALB 1 T pseudoCELR full index as terms are successively entered into the model

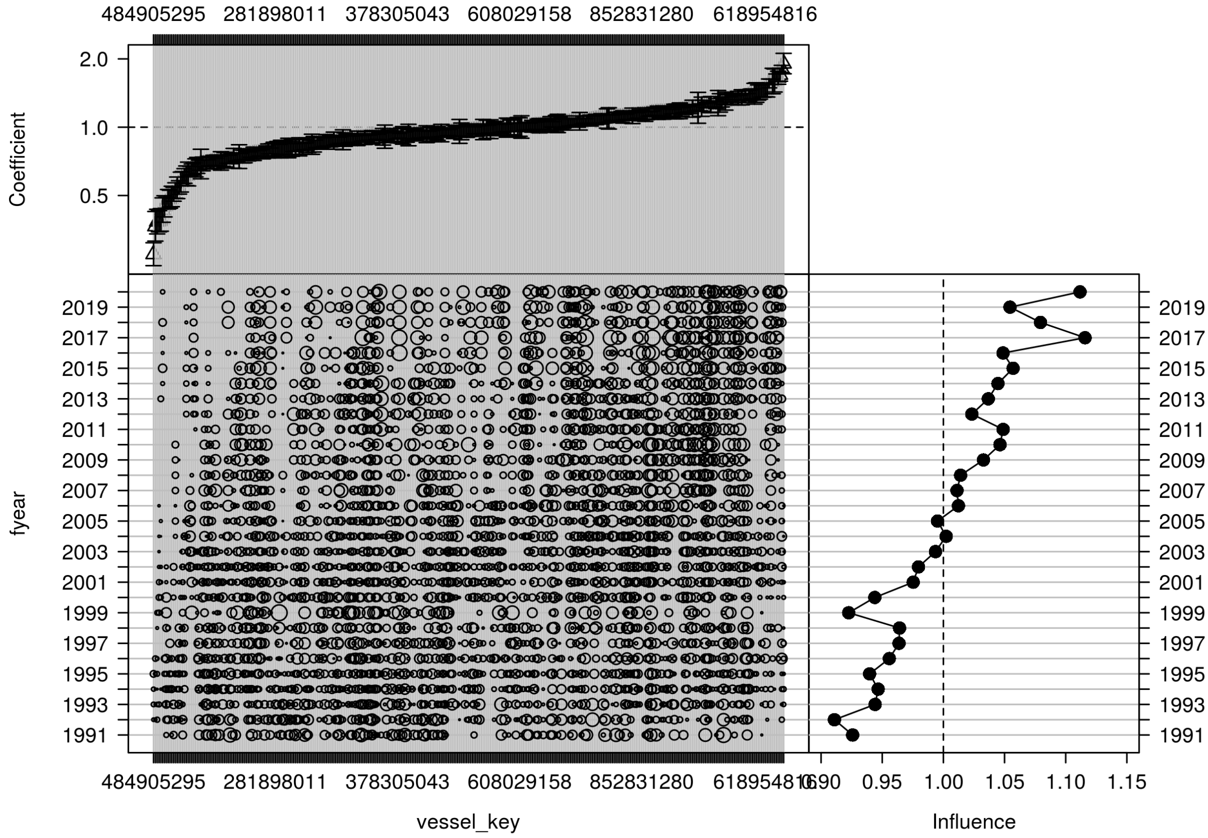

Figure A.6: CDI plot for vessel-key for the ALB 1 T pseudoCELR full catch-per-unit-effort dataset.

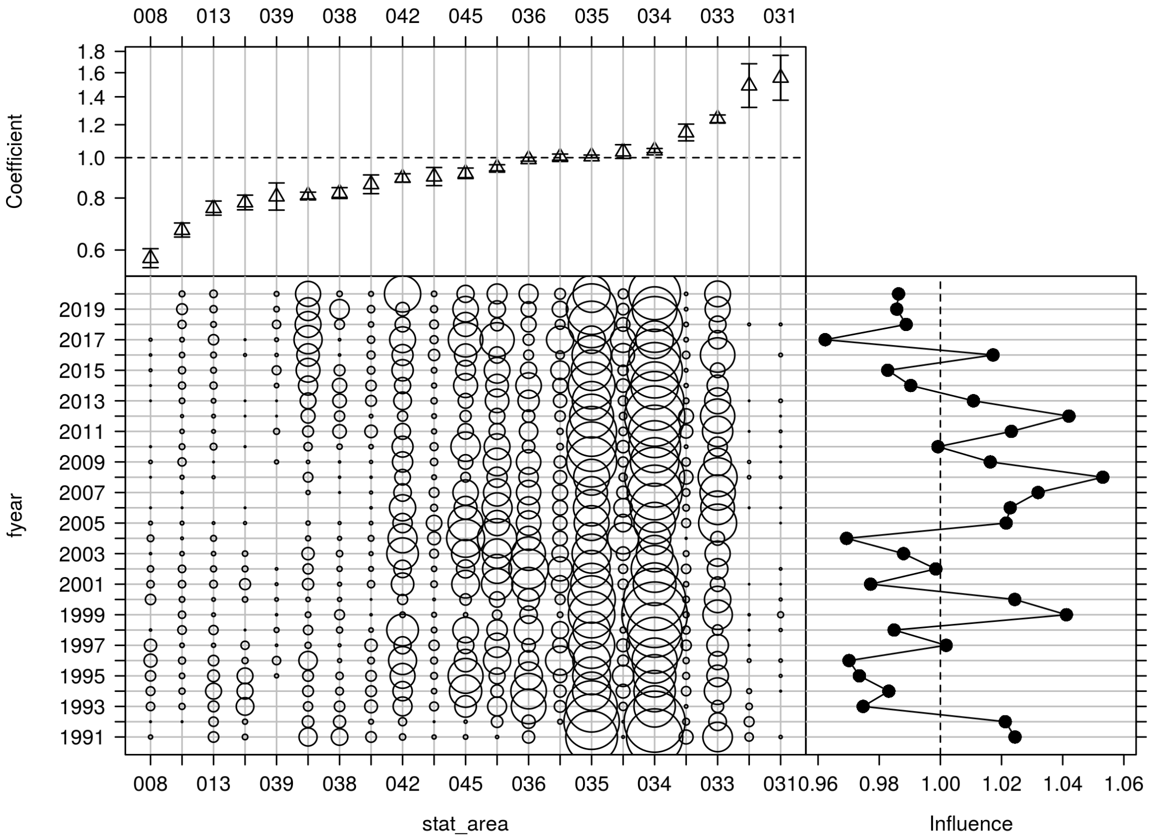

Figure A.7: CDI plot for stat-area for the ALB 1 T pseudoCELR full catch-per-unit-effort dataset.

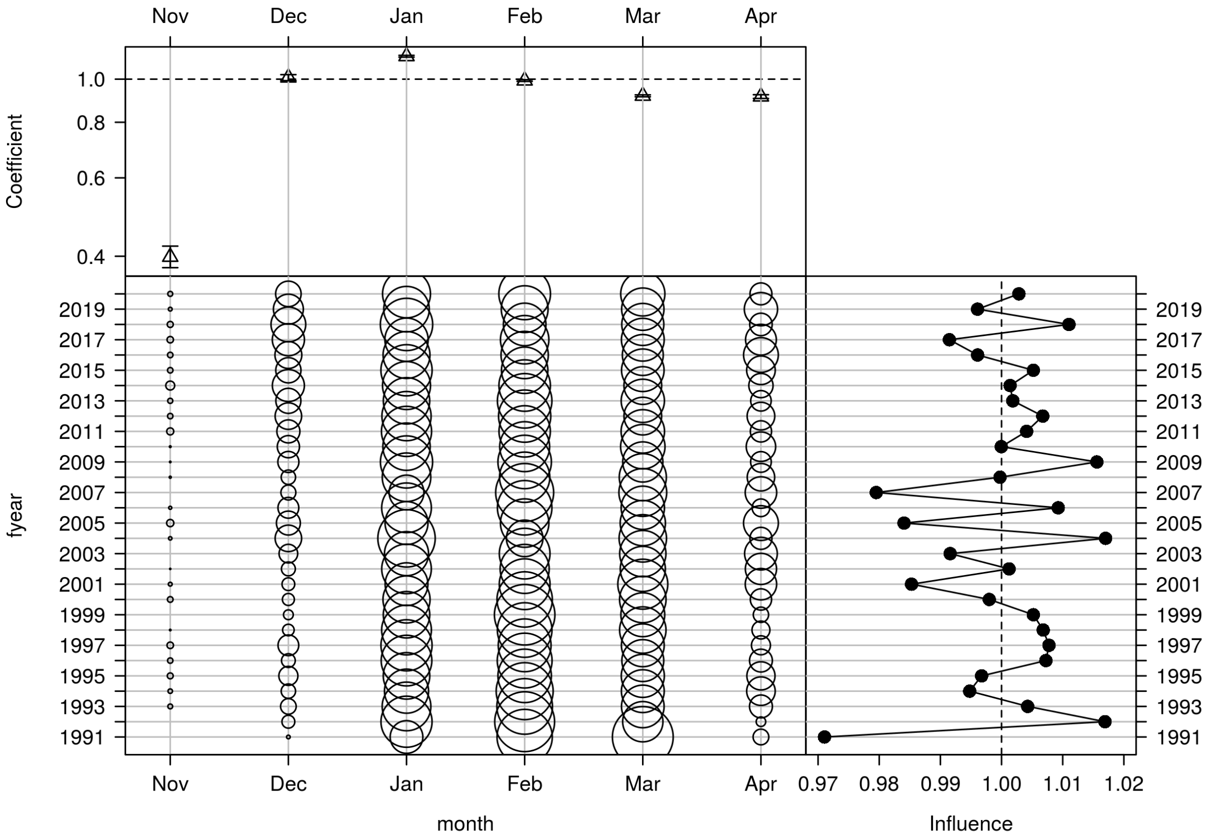

Figure A.8: CDI plot for month for the ALB 1 T pseudoCELR full catch-per-unit-effort dataset.

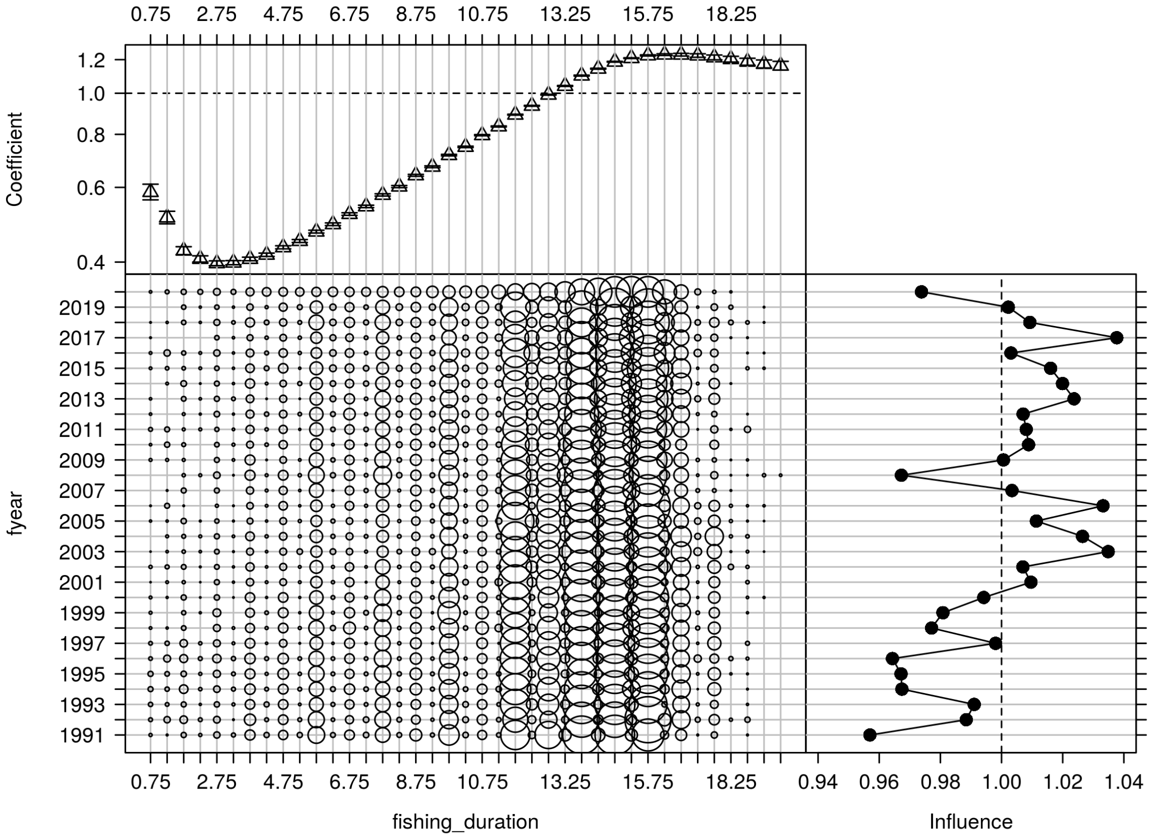

Figure A.9: CDI plot for log-fishing-duration for the ALB 1 T pseudoCELR full catch-per-unit-effort data-set.

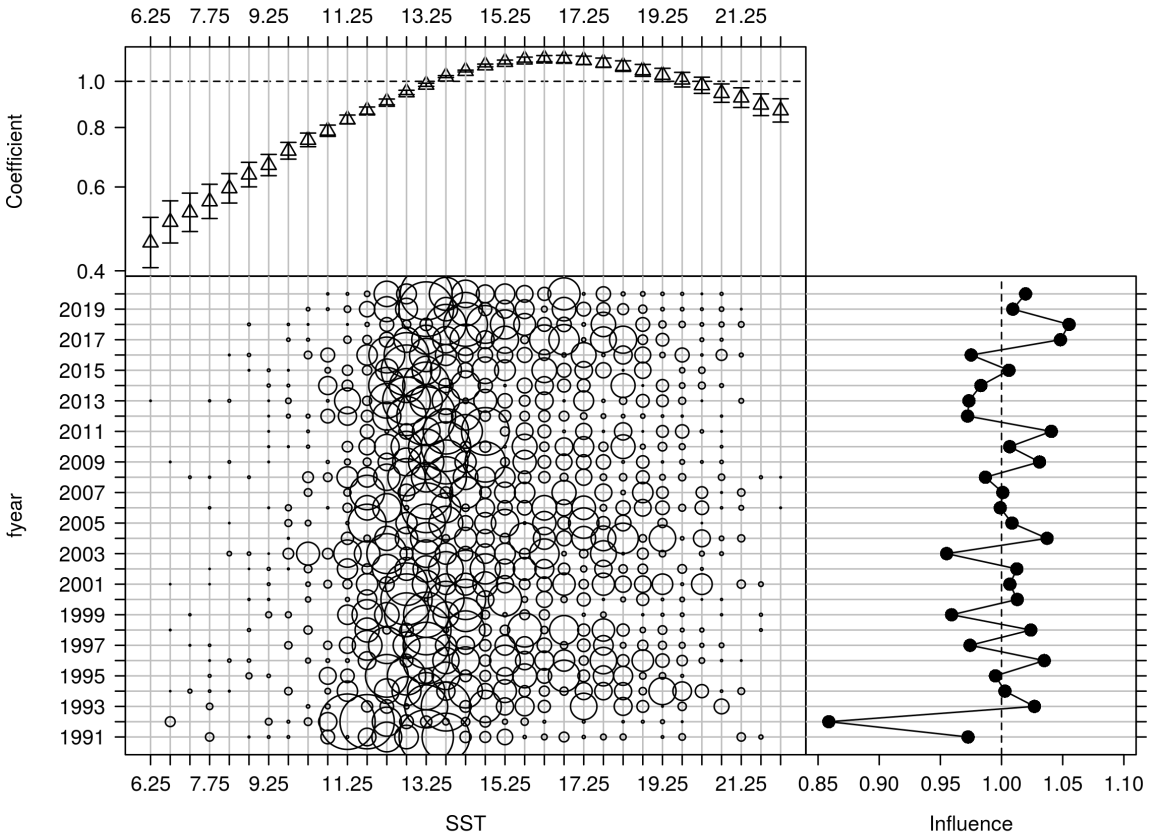

Figure A.10: CDI plot for for the ALB 1 T pseudoCELR full catch-per-unit-effort dataset.

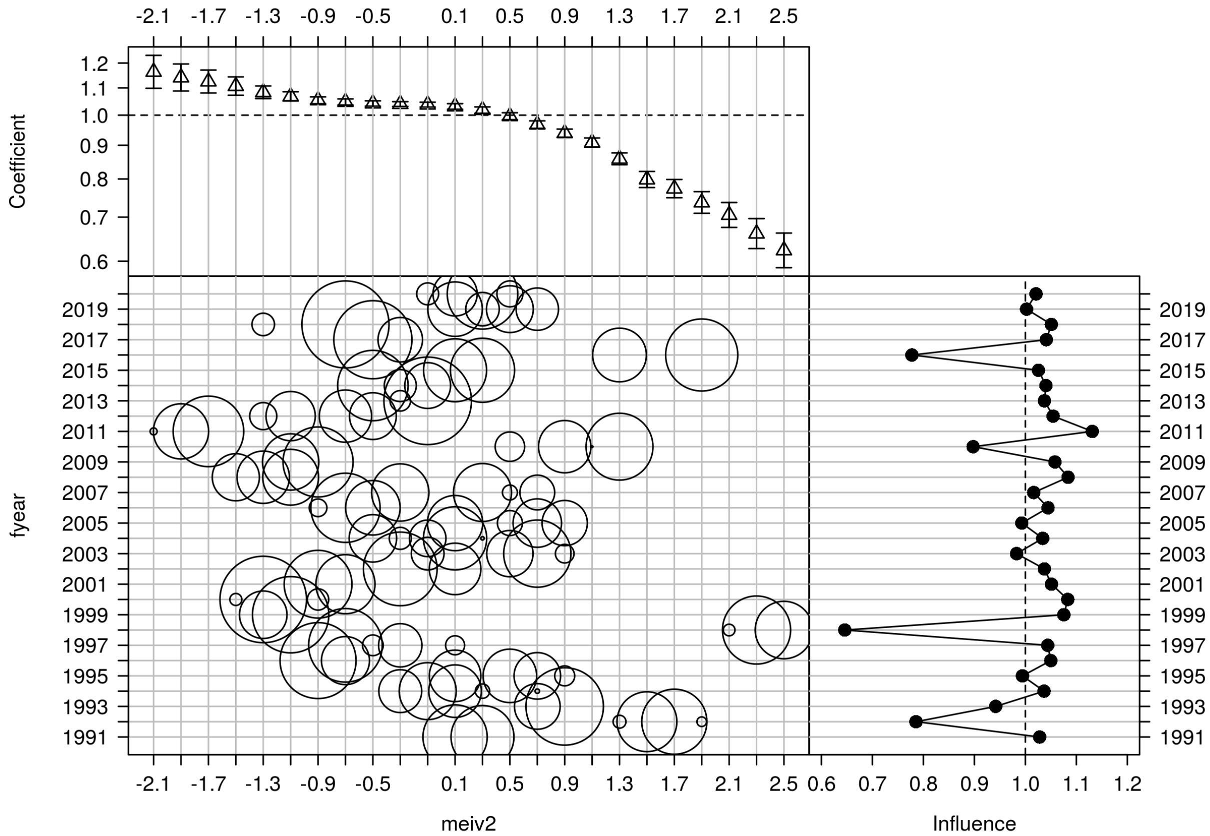

Figure A.11: CDI plot for meiv for the ALB 1 T pseudoCELR full catch-per-unit-effort dataset.

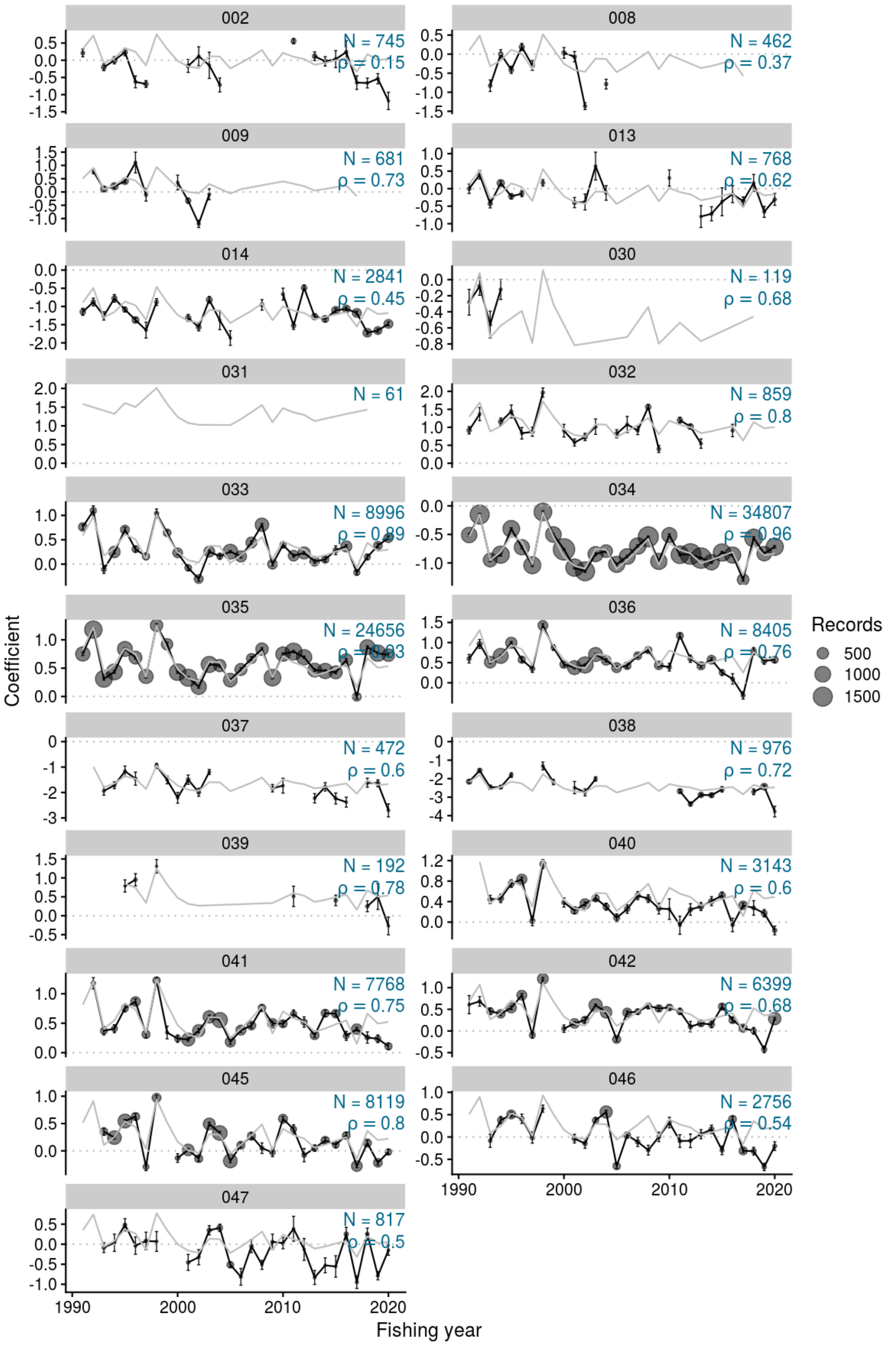

Figure A.12: Residual implied coefficients for area-year negative-binomial model for the ALB 1 T pseudo-CELR full dataset.

A.1.5 CPUE indices

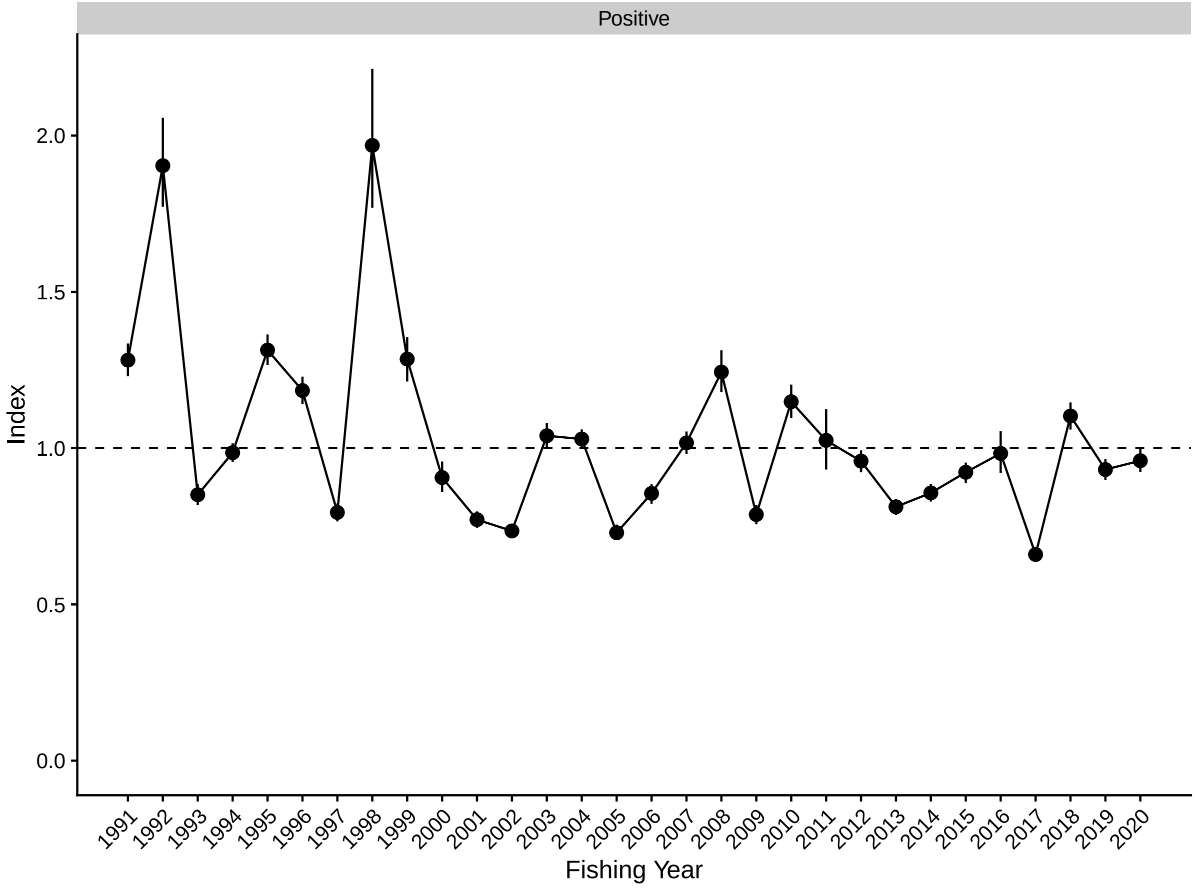

Figure A.13: Standardised indices and 95% confidence intervals for the ALB 1 T pseudoCELR full dataset.

A.1.6 Alternative distribution diagnostics for CPUE standardisation

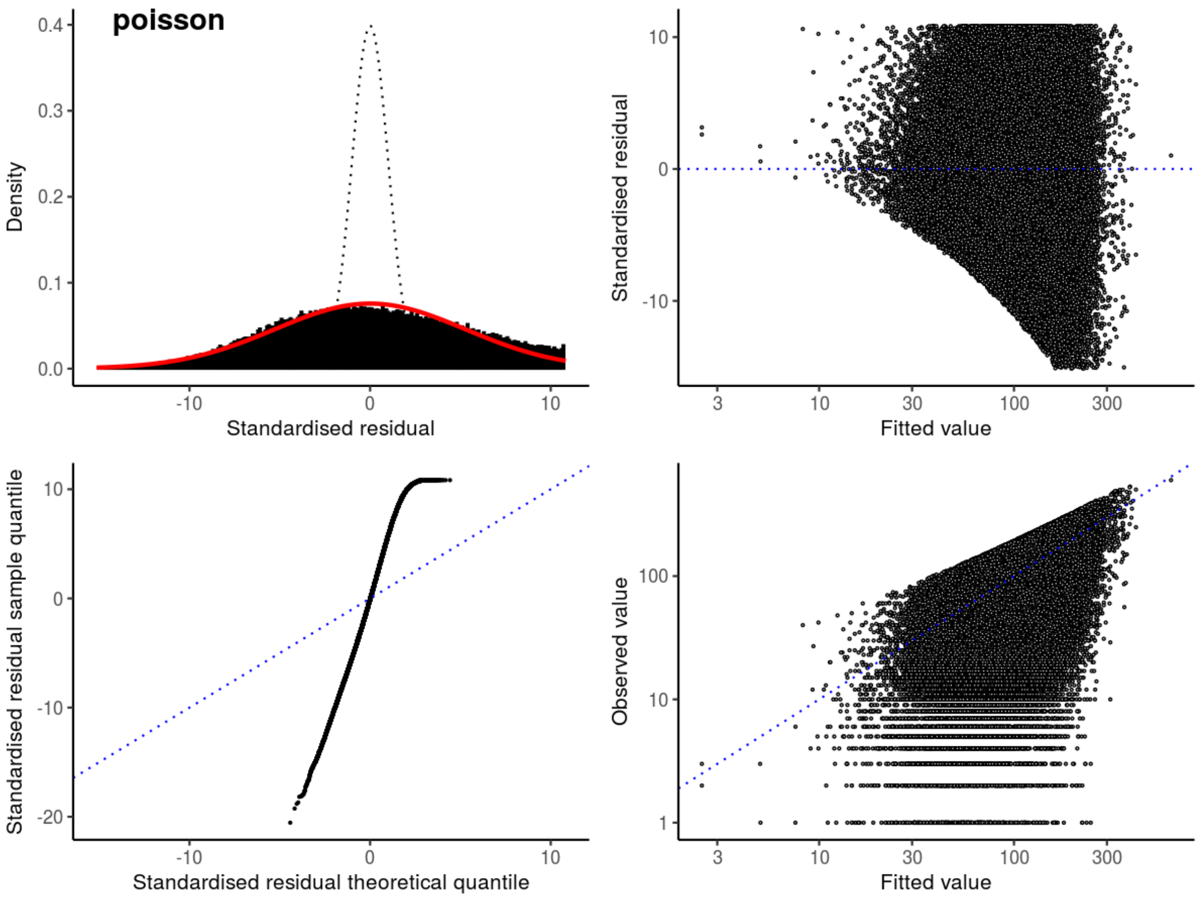

Figure A.14: Diagnostic plots for the poisson model for the ALB 1 T pseudoCELR full dataset.

Table A.5: Annual indices and standard errors for each model in ALB 1 T pseudoCELR full. Fishing years are labeled by the later calendar year e.g. 1996 = 1995/1996.

Fishing year	Positive	Positive SE
1991	1.3	0.027
1992	1.9	0.073
1993	0.85	0.017
1994	0.99	0.015
1995	1.3	0.025
1996	1.2	0.023
1997	0.79	0.015
1998	2	0.11
1999	1.3	0.036
2000	0.91	0.025
2001	0.77	0.013
2002	0.74	0.011
2003	1	0.021
2004	1	0.015
2005	0.73	0.013
2006	0.86	0.016
2007	1	0.018
2008	1.2	0.034
2009	0.79	0.016
2010	1.1	0.027
2011	1	0.049
2012	0.96	0.018
2013	0.81	0.013
2014	0.86	0.014
2015	0.92	0.017
2016	0.98	0.034
2017	0.66	0.012
2018	1.1	0.022
2019	0.93	0.017
2020	0.96	0.019

A.2 ALB 1 T CELR trip full

A.2.1 CPUE series

Table A.6: Specification for the ALB 1 T CELR trip full CPUE series.

Series	ALB 1 T CELR trip full
QMS stock	ALB1
Reporting forms	CEL, ”ERS - Other Lining”
Fishing methods	T
Target species	ALB
Areas	002, 007, 008, 009, 013, 014, 030, 031, 032, 033, 034, 035, 036, 037, 038, 039, 040, 041, 042, 045, 046, 047
Period	1990-10-01, 2020-10-01
Core fleet years	4
Core fleet trips	3
Default model	landkg ~ fyear + vessel_key + modal_stat_area*modal_month + ns(log(total_fishing_duration), 3) + ns(SST, 3) + ns(meiv2, 3)
Stepwise selection	No

A.2.2 Core vessel selection

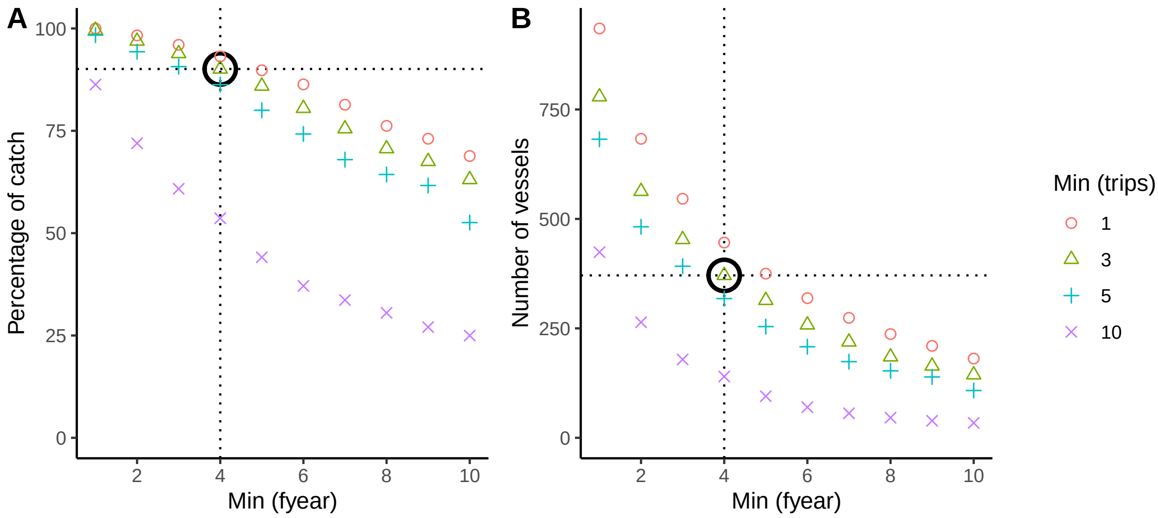

Figure A.15: Percentage of catch and number of vessels for different core vessel selection criteria. Bold open circle represents the core vessel selection criteria based on the number of years in the fishery and the amount of trips per fleet

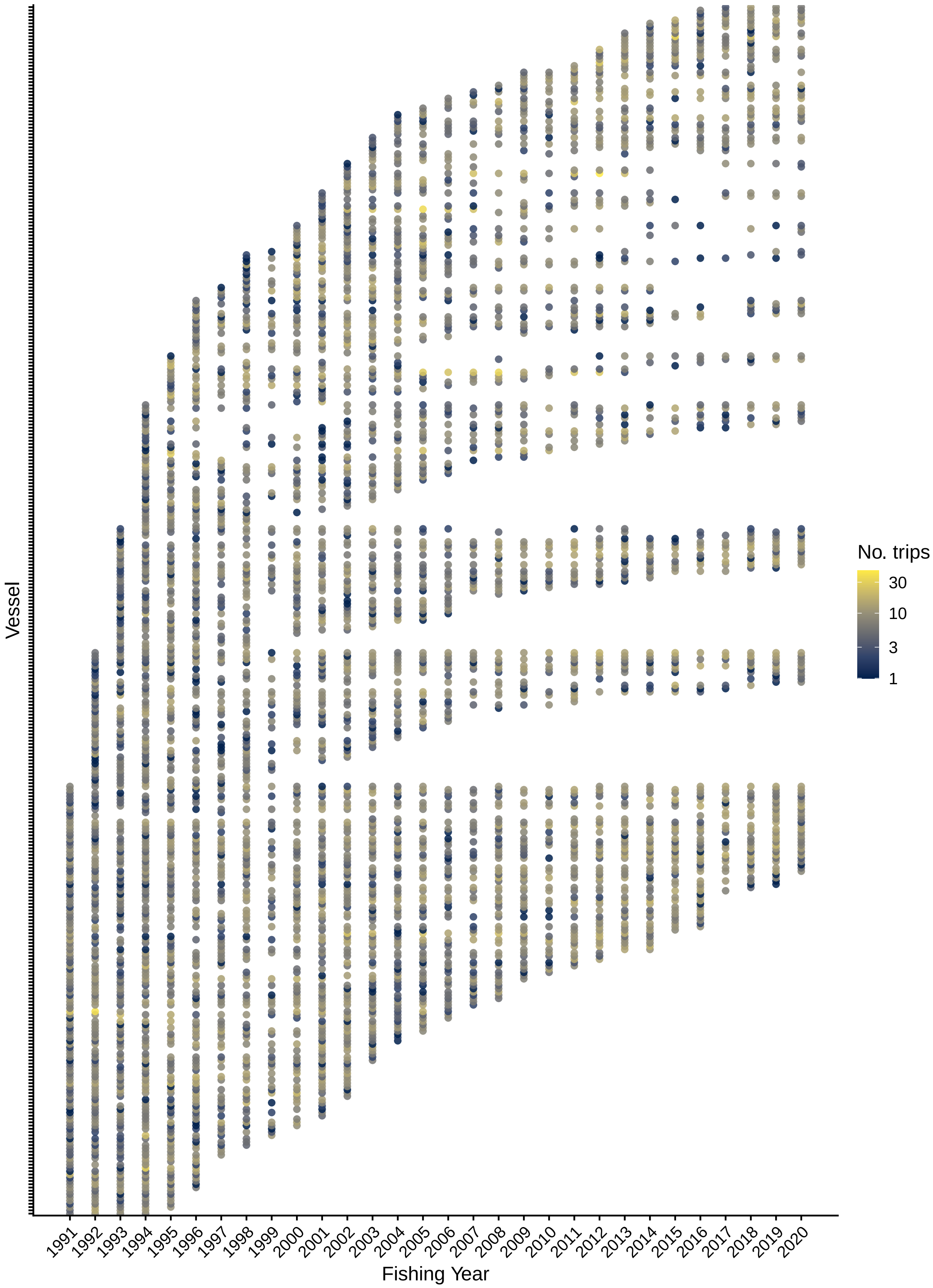

Figure A.16: Number of trips by fishing year for core vessels. The area of circles is proportional to the number of trips.

A.2.3 CPUE dataset summary

Table A.7: Summary of ALB 1 T CELR trip full data subset by fishing year after the data was checked for missing values and outliers were removed. Records represent a row in the dataset trip catch. Fishing years are labelled by the later calendar year e.g. 1990 = 1989/1990.

Fishing year	Vessels	Trips	Records	Effort (hrs)	Catch (t)
1991	132	860	860	39522.13	1729.37
1992	157	1090	1090	50558.10	2632.78
1993	181	1066	1066	51084.58	1811.57
1994	218	1602	1602	82392.30	3097.15
1995	204	1610	1610	71452.07	3681.06
1996	196	1479	1479	64429.18	3152.37
1997	164	1106	1106	52949.35	1809.48
1998	177	1362	1362	64497.98	3395.05
1999	104	665	665	30726.85	1480.26
2000	172	1372	1372	65018.22	2514.20
2001	201	1518	1518	78491.10	2538.35
2002	202	1584	1584	80288.27	2578.87
2003	189	1405	1405	83722.30	3239.05
2004	180	1209	1209	70828.13	3431.31
2005	158	1276	1276	75832.33	2517.86
2006	141	874	874	50306.27	1972.79
2007	105	684	684	40886.33	1766.58
2008	120	1026	1026	51181.17	3205.81
2009	120	921	921	52163.75	1693.35
2010	88	687	687	37420.32	1621.40
2011	112	997	997	53201.88	2818.19
2012	114	1068	1068	55437.82	2461.97
2013	117	1014	1014	58731.85	2424.00
2014	112	846	846	48820.02	2000.77
2015	88	799	799	46966.38	2219.87
2016	97	765	765	47245.18	1750.69
2017	74	611	611	42818.13	1639.63
2018	98	791	791	49127.67	2155.19
2019	93	818	818	51813.13	2129.99
2020	95	739	739	52851.34	2370.96

Table A.8: Summary of ALB 1 T CELR trip full total catch (t) subset by fishing year after the data was groomed by various filters. First row (Ungroomed data) shows catch before filters were applied. Subsequent rows below total catch display the percent of catch, and the total number of records.

Filter	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Ungroomed data	1994 (Percent: 100) (Records: 1107)	3323 (Percent: 100) (Records: 1496)	2526 (Percent: 100) (Records: 1715)	4380 (Percent: 100) (Records: 2462)	4971 (Percent: 100) (Records: 2488)	3919 (Percent: 100) (Records: 2003)	2295 (Percent: 100) (Records: 1524)	4275 (Percent: 100) (Records: 1805)	1544 (Percent: 100) (Records: 726)	2966 (Percent: 100) (Records: 1788)	2915 (Percent: 100) (Records: 2035)	3061 (Percent: 100) (Records: 1993)
Fishing duration is not NA	1992 (Percent: 100) (Records: 1102)	3316 (Percent: 100) (Records: 1490)	2510 (Percent: 100) (Records: 1697)	4335 (Percent: 100) (Records: 2433)	4858 (Percent: 100) (Records: 2417)	3790 (Percent: 100) (Records: 1910)	2122 (Percent: 92) (Records: 1424)	4167 (Percent: 100) (Records: 1744)	1510 (Percent: 100) (Records: 701)	2756 (Percent: 93) (Records: 1626)	2830 (Percent: 100) (Records: 1954)	2958 (Percent: 100) (Records: 1887)
Positive fishing duration	1992 (Percent: 100) (Records: 1102)	3316 (Percent: 100) (Records: 1490)	2510 (Percent: 100) (Records: 1697)	4335 (Percent: 100) (Records: 2433)	4858 (Percent: 100) (Records: 2417)	3790 (Percent: 100) (Records: 1910)	2122 (Percent: 92) (Records: 1424)	4167 (Percent: 100) (Records: 1744)	1510 (Percent: 100) (Records: 701)	2756 (Percent: 93) (Records: 1626)	2830 (Percent: 100) (Records: 1954)	2958 (Percent: 100) (Records: 1887)
Total fishing duration <180hrs	1987 (Percent: 100) (Records: 1101)	3157 (Percent: 100) (Records: 1484)	2278 (Percent: 90) (Records: 1682)	4021 (Percent: 92) (Records: 2413)	4797 (Percent: 100) (Records: 2411)	3634 (Percent: 93) (Records: 1899)	2076 (Percent: 90) (Records: 1419)	4037 (Percent: 94) (Records: 1736)	1510 (Percent: 100) (Records: 701)	2744 (Percent: 93) (Records: 1624)	2814 (Percent: 100) (Records: 1951)	2912 (Percent: 100) (Records: 1880)
Season Nov Apr	1987 (Percent: 100) (Records: 1099)	3157 (Percent: 100) (Records: 1482)	2274 (Percent: 90) (Records: 1669)	4011 (Percent: 92) (Records: 2392)	4770 (Percent: 100) (Records: 2374)	3632 (Percent: 93) (Records: 1889)	2072 (Percent: 90) (Records: 1407)	3990 (Percent: 93) (Records: 1701)	1509 (Percent: 100) (Records: 697)	2722 (Percent: 92) (Records: 1582)	2761 (Percent: 95) (Records: 1851)	2907 (Percent: 95) (Records: 1863)
Positive catch	1987 (Percent: 100) (Records: 1061)	3157 (Percent: 100) (Records: 1458)	2274 (Percent: 90) (Records: 1621)	4011 (Percent: 92) (Records: 2346)	4770 (Percent: 100) (Records: 2339)	3632 (Percent: 93) (Records: 1854)	2072 (Percent: 90) (Records: 1381)	3990 (Percent: 93) (Records: 1661)	1509 (Percent: 100) (Records: 690)	2722 (Percent: 92) (Records: 1570)	2761 (Percent: 95) (Records: 1803)	2907 (Percent: 95) (Records: 1825)
Core fleet selection	1729 (Percent: 87) (Records: 860)	2633 (Percent: 79) (Records: 1090)	1814 (Percent: 72) (Records: 1076)	3118 (Percent: 71) (Records: 1613)	3704 (Percent: 75) (Records: 1621)	3152 (Percent: 80) (Records: 1479)	1809 (Percent: 79) (Records: 1106)	3396 (Percent: 79) (Records: 1363)	1480 (Percent: 100) (Records: 665)	2522 (Percent: 85) (Records: 1381)	2538 (Percent: 87) (Records: 1518)	2583 (Percent: 84) (Records: 1589)

Filter	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Ungroomed data	3899 (Percent: 100) (Records: 1759)	4062 (Percent: 100) (Records: 1469)	2848 (Percent: 100) (Records: 1522)	2210 (Percent: 100) (Records: 1031)	1817 (Percent: 100) (Records: 751)	3437 (Percent: 100) (Records: 1207)	1776 (Percent: 100) (Records: 1024)	1720 (Percent: 100) (Records: 751)	2970 (Percent: 100) (Records: 1097)	2714 (Percent: 100) (Records: 1296)	2574 (Percent: 100) (Records: 1169)	2160 (Percent: 100) (Records: 968)
Fishing duration is not NA	3820 (Percent: 100) (Records: 1697)	4012 (Percent: 100) (Records: 1439)	2788 (Percent: 100) (Records: 1465)	2112 (Percent: 100) (Records: 966)	1811 (Percent: 100) (Records: 737)	3365 (Percent: 100) (Records: 1125)	1761 (Percent: 100) (Records: 1006)	1713 (Percent: 100) (Records: 742)	2948 (Percent: 100) (Records: 1059)	2627 (Percent: 100) (Records: 1208)	2541 (Percent: 100) (Records: 1127)	2099 (Percent: 100) (Records: 924)
Positive fishing duration	3820 (Percent: 100) (Records: 1697)	4012 (Percent: 100) (Records: 1439)	2788 (Percent: 100) (Records: 1465)	2112 (Percent: 100) (Records: 966)	1811 (Percent: 100) (Records: 737)	3365 (Percent: 100) (Records: 1125)	1761 (Percent: 100) (Records: 1006)	1713 (Percent: 100) (Records: 742)	2948 (Percent: 100) (Records: 1059)	2627 (Percent: 100) (Records: 1208)	2541 (Percent: 100) (Records: 1127)	2099 (Percent: 100) (Records: 924)
Total fishing duration <180hrs	3772 (Percent: 100) (Records: 1690)	3931 (Percent: 100) (Records: 1432)	2777 (Percent: 100) (Records: 1463)	2101 (Percent: 100) (Records: 964)	1811 (Percent: 100) (Records: 737)	3365 (Percent: 100) (Records: 1125)	1757 (Percent: 100) (Records: 1005)	1702 (Percent: 100) (Records: 740)	2917 (Percent: 100) (Records: 1056)	2627 (Percent: 100) (Records: 1208)	2541 (Percent: 100) (Records: 1127)	2085 (Percent: 100) (Records: 920)
Season Nov Apr	3737 (Percent: 100) (Records: 1658)	3920 (Percent: 100) (Records: 1419)	2766 (Percent: 100) (Records: 1449)	2082 (Percent: 94) (Records: 957)	1789 (Percent: 100) (Records: 721)	3359 (Percent: 100) (Records: 1108)	1756 (Percent: 100) (Records: 1002)	1675 (Percent: 100) (Records: 726)	2916 (Percent: 100) (Records: 1054)	2614 (Percent: 100) (Records: 1190)	2522 (Percent: 100) (Records: 1103)	2062 (Percent: 100) (Records: 895)
Positive catch	3737 (Percent: 100) (Records: 1622)	3920 (Percent: 100) (Records: 1379)	2766 (Percent: 100) (Records: 1407)	2082 (Percent: 94) (Records: 941)	1789 (Percent: 100) (Records: 701)	3359 (Percent: 100) (Records: 1098)	1756 (Percent: 100) (Records: 996)	1675 (Percent: 100) (Records: 712)	2916 (Percent: 100) (Records: 1049)	2614 (Percent: 100) (Records: 1179)	2522 (Percent: 100) (Records: 1075)	2062 (Percent: 100) (Records: 885)
Core fleet selection	3239 (Percent: 83) (Records: 1405)	3431 (Percent: 84) (Records: 1209)	2518 (Percent: 88) (Records: 1276)	1973 (Percent: 89) (Records: 874)	1767 (Percent: 100) (Records: 684)	3206 (Percent: 93) (Records: 1026)	1693 (Percent: 100) (Records: 921)	1621 (Percent: 94) (Records: 687)	2818 (Percent: 95) (Records: 997)	2462 (Percent: 91) (Records: 1068)	2424 (Percent: 94) (Records: 1014)	2001 (Percent: 93) (Records: 846)

Filter	2015	2016	2017	2018	2019	2020
Ungroomed data	2349 (Percent: 100) (Records: 882)	1905 (Percent: 100) (Records: 851)	1811 (Percent: 100) (Records: 702)	2300 (Percent: 100) (Records: 888)	2476 (Percent: 100) (Records: 986)	2851 (Percent: 100) (Records: 1051)
Fishing duration is not NA	2321 (Percent: 100) (Records: 863)	1872 (Percent: 100) (Records: 828)	1800 (Percent: 100) (Records: 690)	2280 (Percent: 100) (Records: 872)	2455 (Percent: 100) (Records: 963)	2851 (Percent: 100) (Records: 1051)
Positive fishing duration	2321 (Percent: 100) (Records: 863)	1872 (Percent: 100) (Records: 828)	1800 (Percent: 100) (Records: 690)	2280 (Percent: 100) (Records: 872)	2455 (Percent: 100) (Records: 963)	2850 (Percent: 100) (Records: 1048)
Total fishing duration <180hrs	2275 (Percent: 100) (Records: 858)	1872 (Percent: 100) (Records: 828)	1766 (Percent: 100) (Records: 687)	2262 (Percent: 100) (Records: 869)	2438 (Percent: 100) (Records: 960)	2828 (Percent: 100) (Records: 1034)
Season Nov Apr	2267 (Percent: 100) (Records: 836)	1830 (Percent: 100) (Records: 803)	1705 (Percent: 94) (Records: 660)	2260 (Percent: 100) (Records: 860)	2409 (Percent: 100) (Records: 932)	2818 (Percent: 100) (Records: 1006)
Positive catch	2267 (Percent: 100) (Records: 823)	1830 (Percent: 100) (Records: 787)	1705 (Percent: 94) (Records: 640)	2260 (Percent: 100) (Records: 846)	2409 (Percent: 100) (Records: 917)	2818 (Percent: 100) (Records: 950)
Core fleet selection	2220 (Percent: 94) (Records: 799)	1751 (Percent: 92) (Records: 765)	1640 (Percent: 91) (Records: 611)	2155 (Percent: 94) (Records: 791)	2130 (Percent: 86) (Records: 818)	2371 (Percent: 83) (Records: 739)

A.2.4 Gamma model diagnostics

Table A.9: Summary table for the gamma model. Model terms are listed in the order offered to the model. AIC: Akaike Information Criterion; *: Term included in final model.

Predictor	Df	AIC	% deviance	add % deviance	Included
intercept	1	556619.9	0.00	0.00	*
fyear	29	555500.0	3.11	3.11	*
vessel key	372	542209.0	30.98	34.09	*
modal stat area	20	541441.7	1.48	35.57	*
modal month	5	540463.6	1.77	37.33	*
ns(log(total fishing duration), 3)	3	527464.8	19.47	56.81	*
ns(SST, 3)	3	527353.4	0.15	56.95	*
ns(meiv2, 3)	3	527246.5	0.14	57.09	*
modal stat area:modal month	100	526945.8	0.59	57.68	*

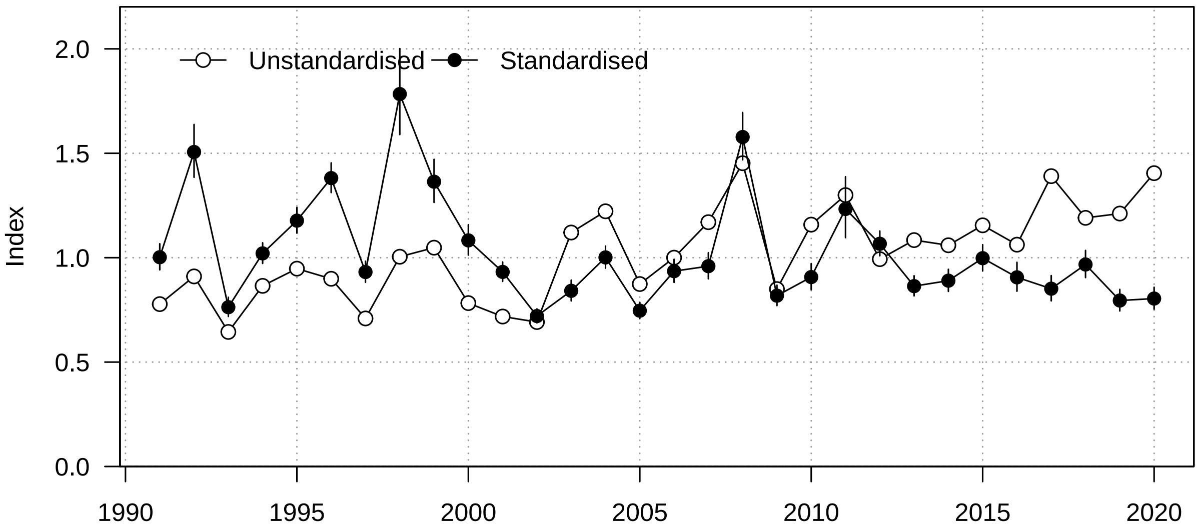

Figure A.17: Unstandardised (geometric mean; open circles) and standardised indices (black circles) for catch in the ALB 1 T CELR trip full dataset.

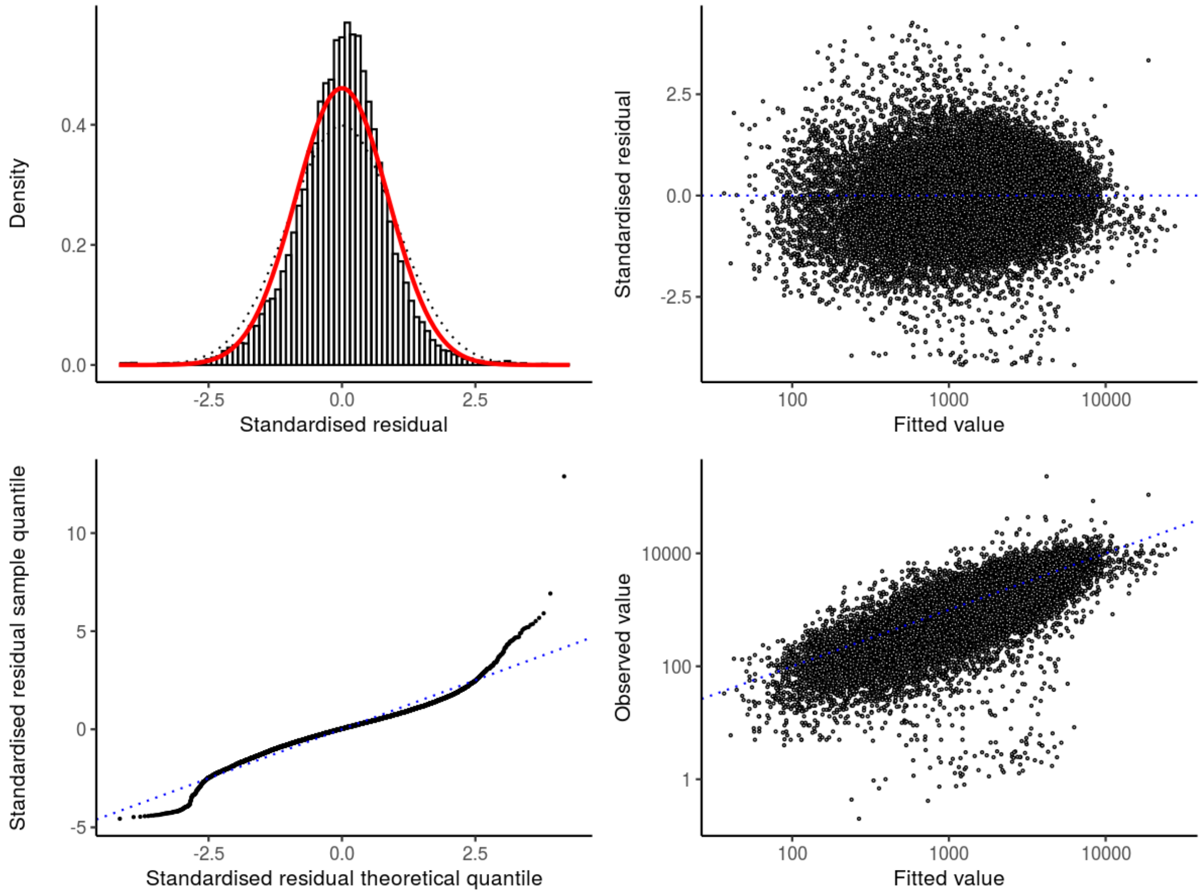

Figure A.18: Diagnostic plots for the gamma model for the ALB 1 T CELR trip full dataset.

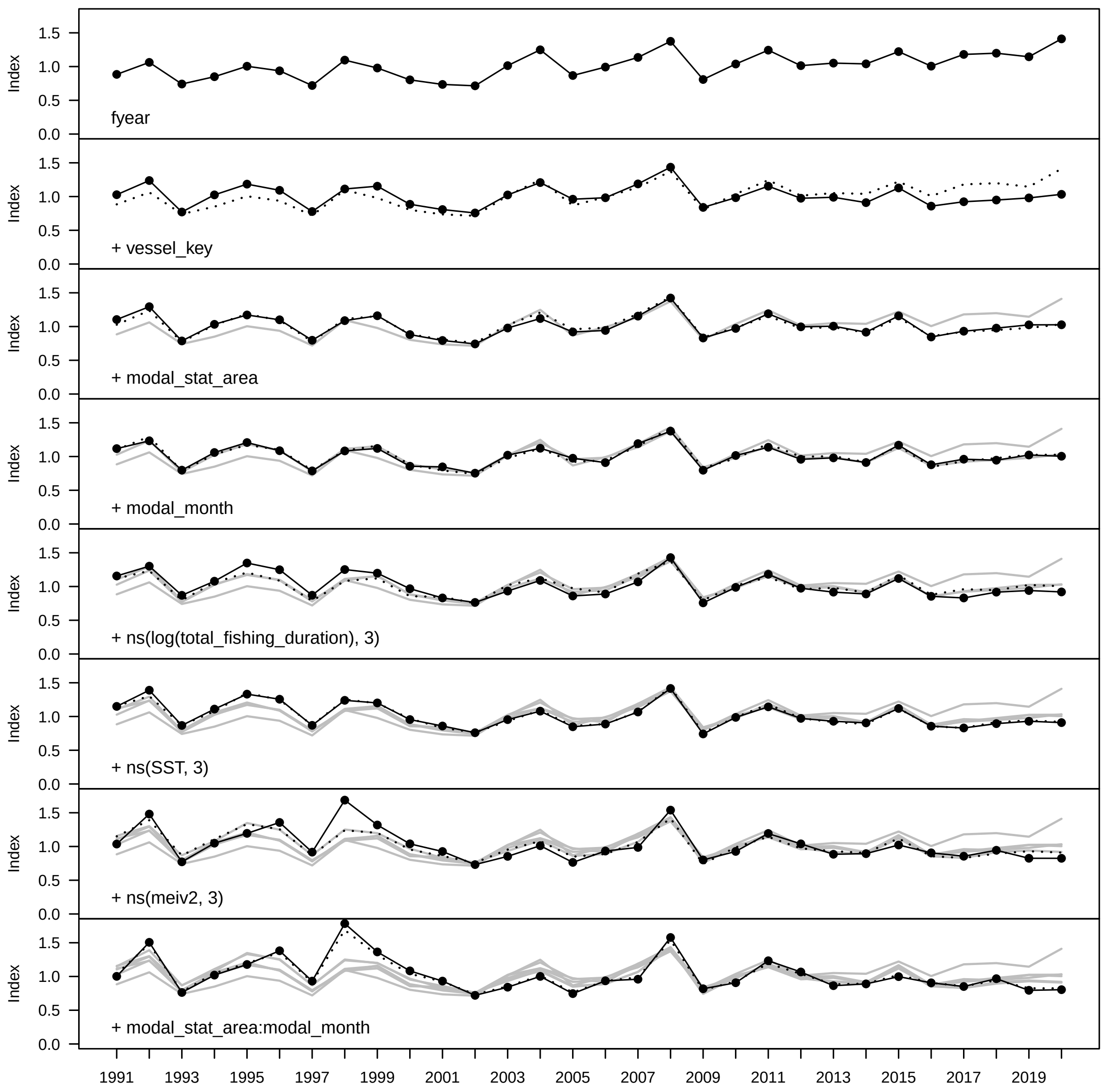

Figure A.19: Changes to the ALB 1 T CELR trip full index as terms are successively entered into the model

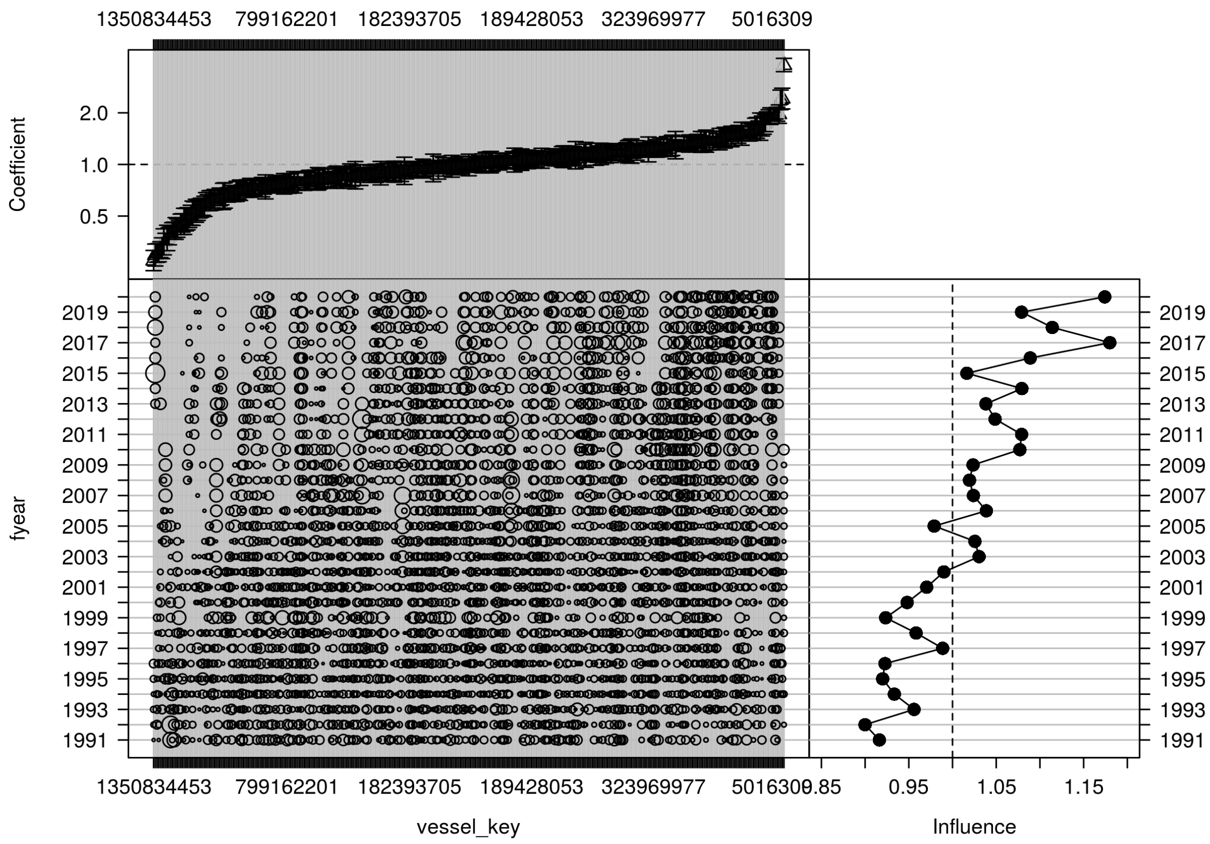

Figure A.20: CDI plot for vessel-key for the ALB 1 T CELR trip full catch-per-unit-effort dataset.

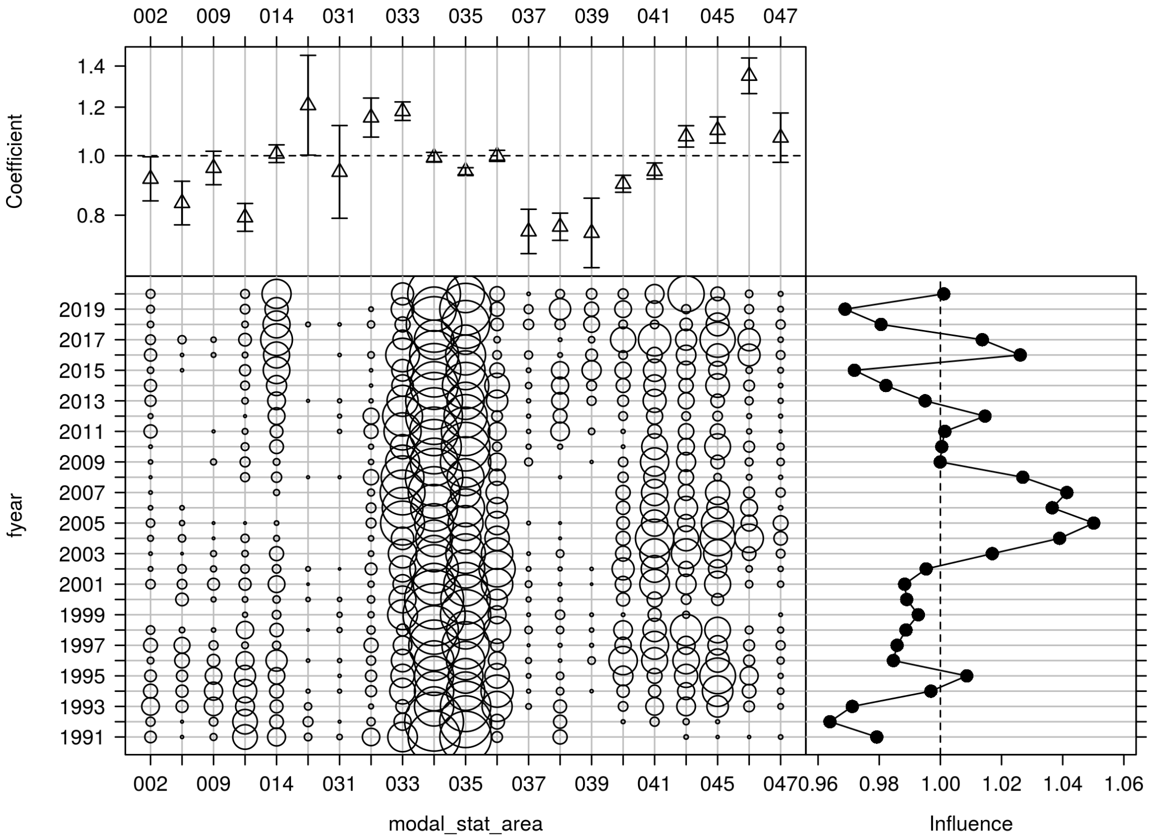

Figure A.21: CDI plot for modal-stat-area for the ALB 1 T CELR trip full catch-per-unit-effort dataset.

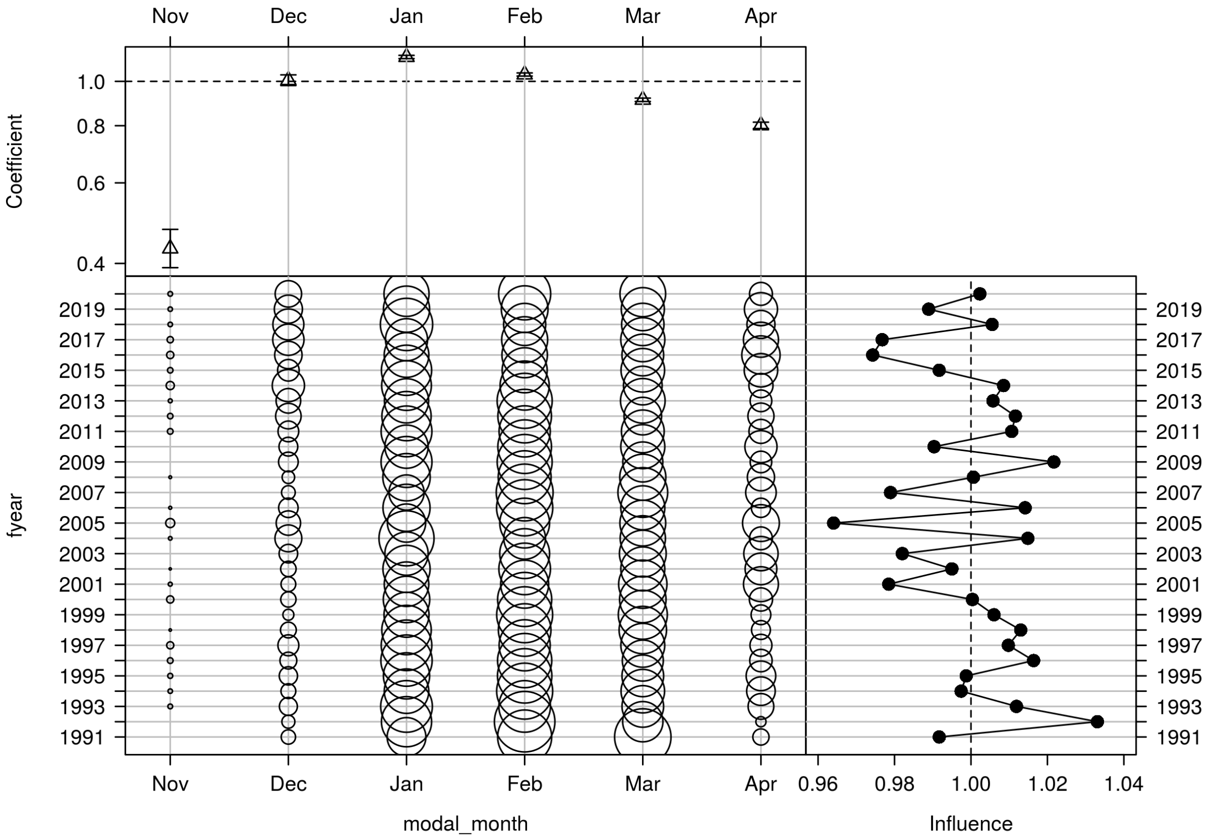

Figure A.22: CDI plot for modal-month for the ALB 1 T CELR trip full catch-per-unit-effort dataset.

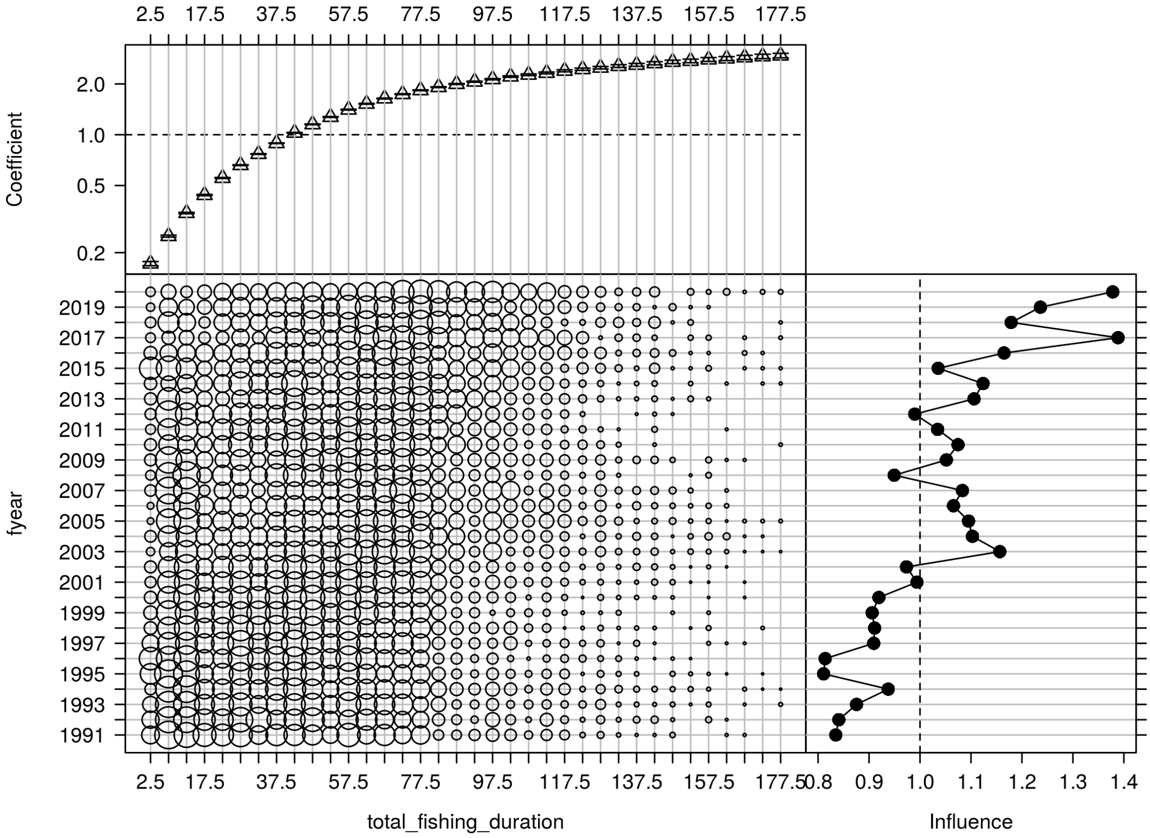

Figure A.23: CDI plot for log-total-fishing-duration for the ALB 1 T CELR trip full catch-per-unit-effort dataset.

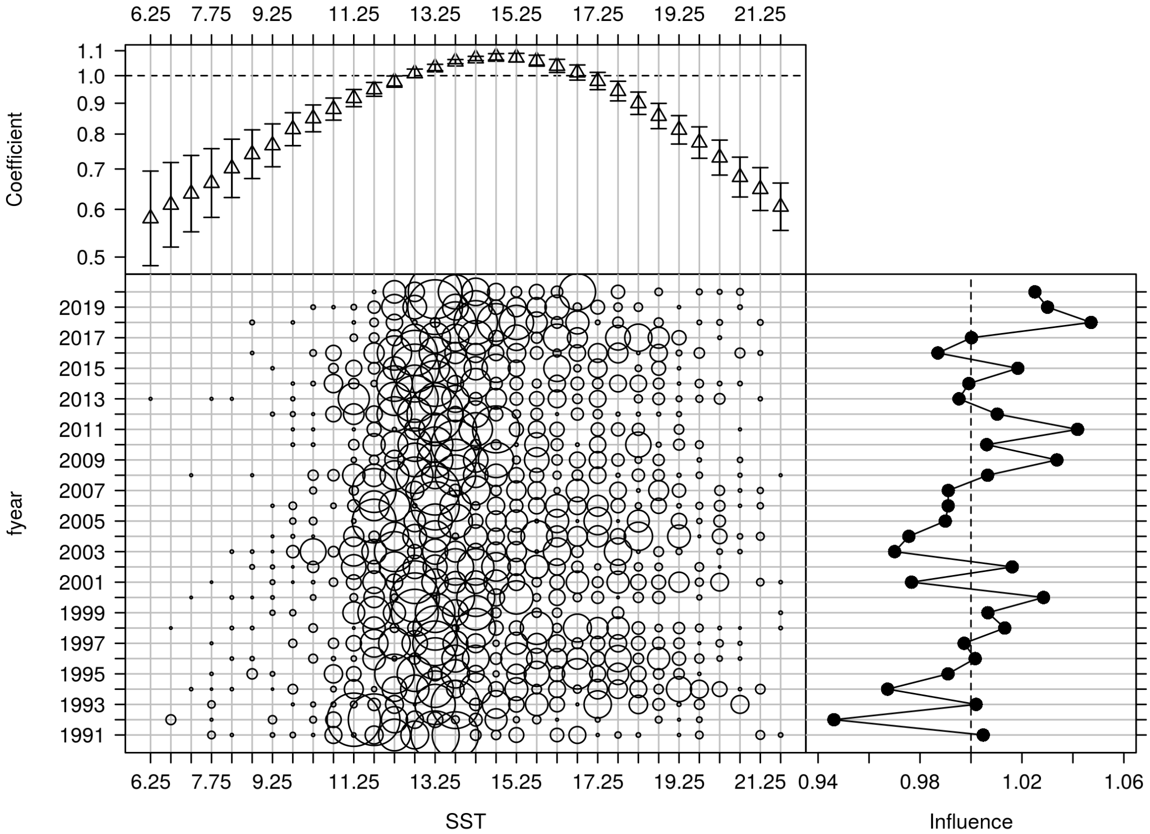

Figure A.24: CDI plot for for the ALB 1 T CELR trip full catch-per-unit-effort dataset.

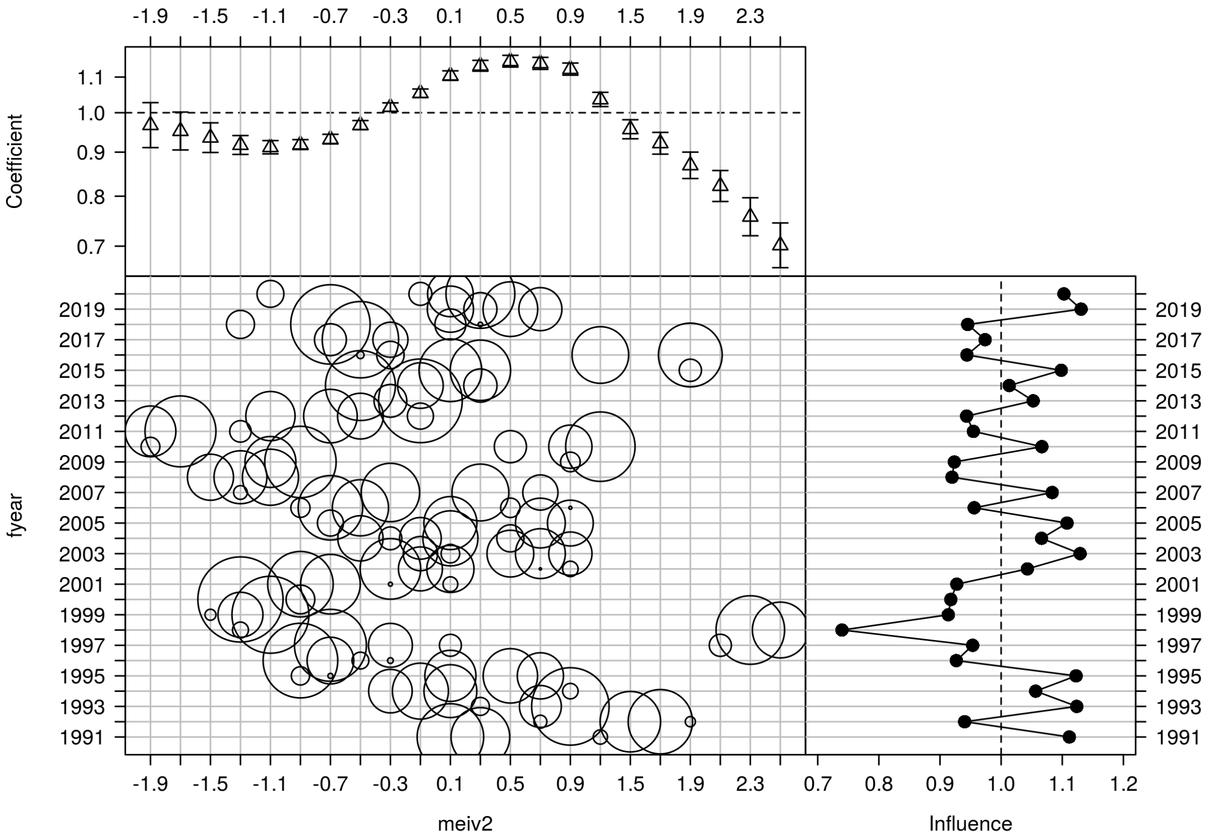

Figure A.25: CDI plot for meiv for the ALB 1 T CELR trip full catch-per-unit-effort dataset.

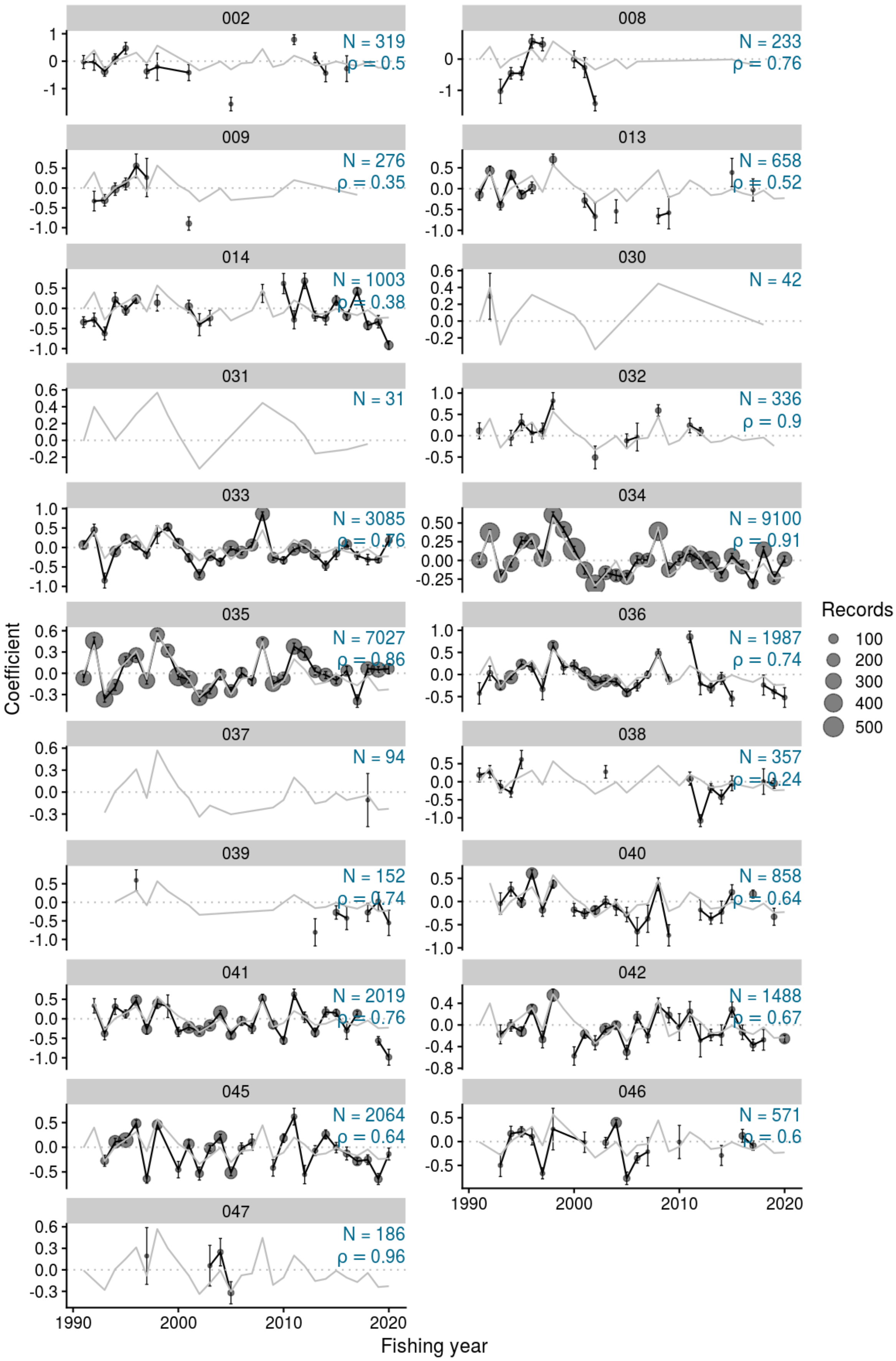

Figure A.26: Residual implied coefficients for area-year gamma model for the ALB 1 T CELR trip full dataset.

A.2.5 CPUE indices

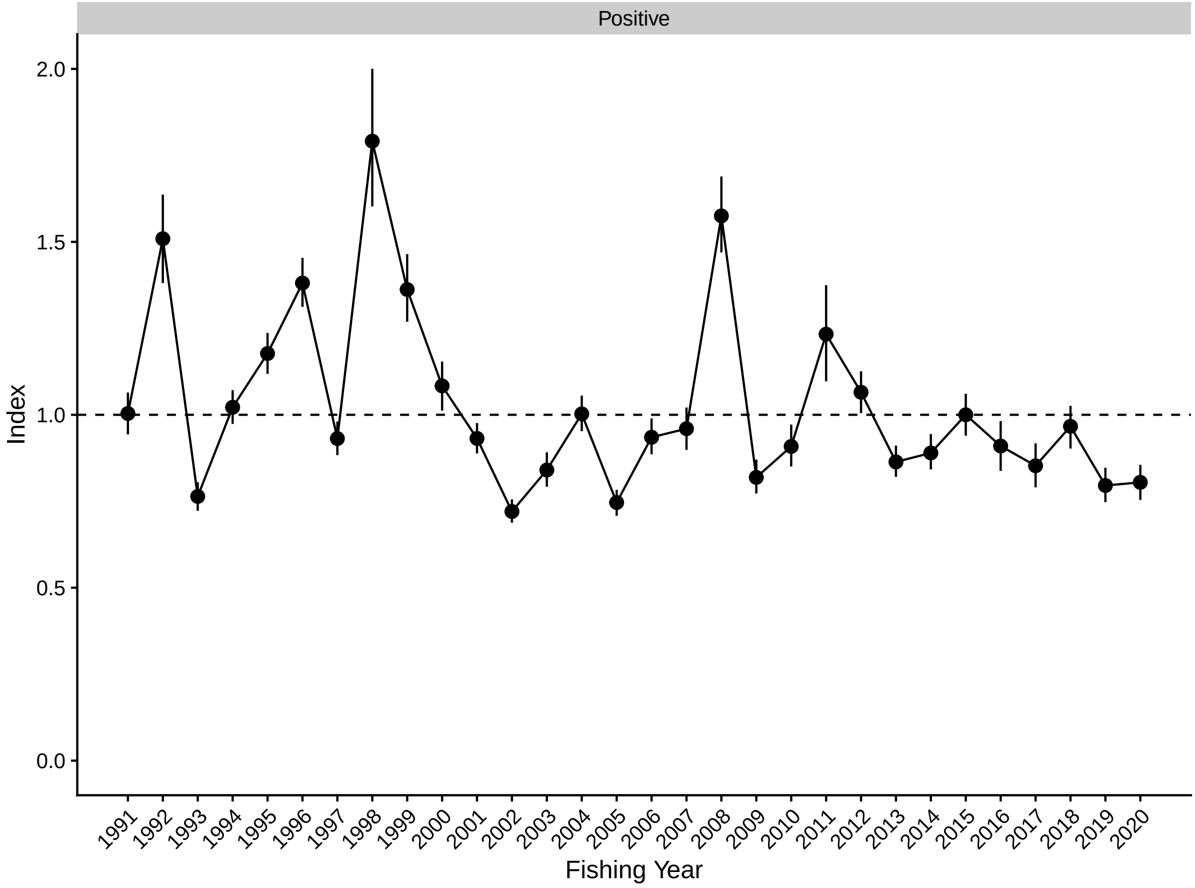

Figure A.27: Standardised indices and 95% confidence intervals for the ALB 1 T CELR trip full dataset.

A.2.6 Alternative distribution diagnostics for CPUE standardisation

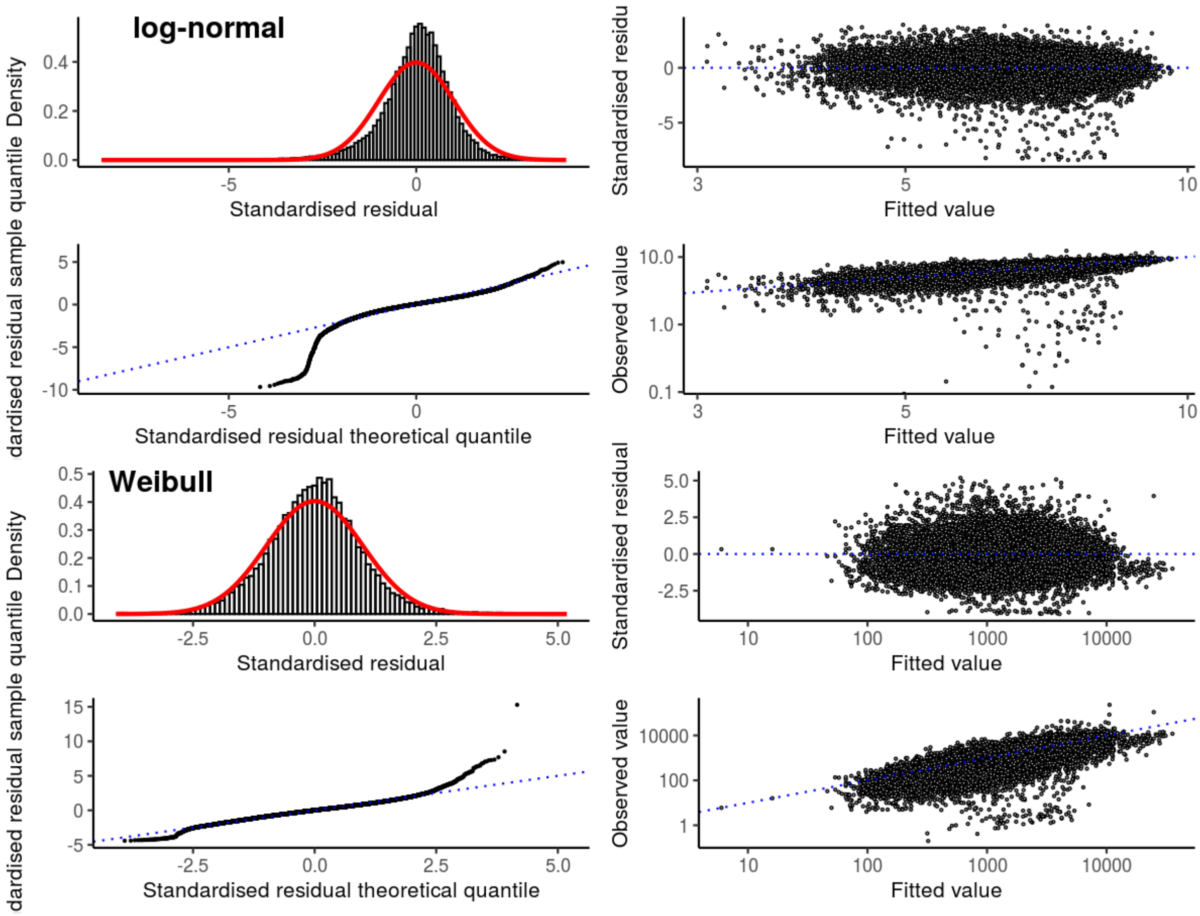

Figure A.28: Diagnostic plots for the log-normal and Weibull model for the ALB 1 T CELR trip full dataset.

Table A.10: Annual indices and standard errors for each model in ALB 1 T CELR trip full. Fishing years are labeled by the later calendar year e.g. 1996 = 1995/1996.

Fishing year	Positive	Positive SE
1991	1	0.031
1992	1.5	0.065
1993	0.76	0.021
1994	1	0.025
1995	1.2	0.03
1996	1.4	0.036
1997	0.93	0.025
1998	1.8	0.1
1999	1.4	0.05
2000	1.1	0.036
2001	0.93	0.022
2002	0.72	0.017
2003	0.84	0.025
2004	1	0.026
2005	0.75	0.019
2006	0.94	0.026
2007	0.96	0.031
2008	1.6	0.056
2009	0.82	0.025
2010	0.91	0.031
2011	1.2	0.071
2012	1.1	0.031
2013	0.86	0.023
2014	0.89	0.026
2015	1	0.031
2016	0.91	0.037
2017	0.85	0.032
2018	0.97	0.032
2019	0.8	0.025
2020	0.8	0.026

APPENDIX B: DATA GROOMING

Grooming of the statutory catch, effort and landings data followed the approach of Starr (2007), with a set of rules defined for each of the different types of data (Bentley 2012).

B.1 Landings

Table B.1: Grooming rules applied to landings data.

Rule	Effect	Description
LACFM	Fix	Replace missing conversion factors with the median over all years
LADAF	Flag	Landings where the landing date is in the future
LADAM	Flag	Landings where the landing date is missing
LADMR	Drop	Mandatory returns (e.g. sub-MLS)
LADTH	Drop	Retained (non-final) landings
LADTI	Flag	Invalid landing destination
LADTT	Flag	Vessel received transhippments
LADUP	Drop	Duplicate landings
LAFLA	Fix	Correct landings using a flatfish species code to FLA
LAGWI	Fix	Estimate missing greenweights
LAGWM	Drop	Missing greenweights that cannot be estimated
LAGWR	Flag	Check for out of range landings
LAHPB	Fix	Correct landings using a groper species code to HPB
LALNF	Flag	Unknown landing point
LASCD	Drop	Drop landings of secondary product states
LASCF	Fix	Correct some state codes
LASCI	Flag	Landings to invalid state code
LASEC	Fix	Landings to Crown or experimental stock codes
LATUN	Fix	Correct stock code for non-QMS tunas

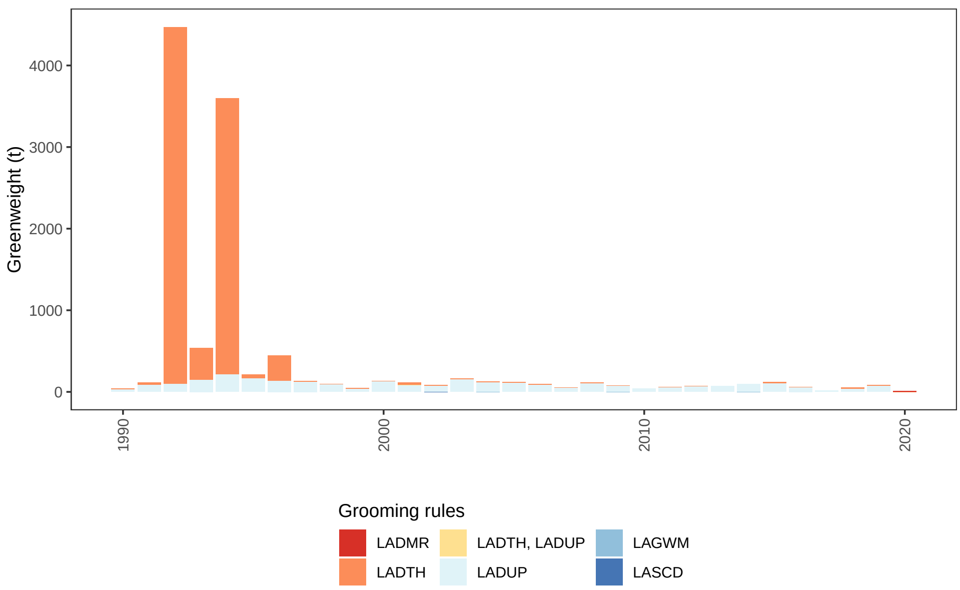

Figure B.1: The quantity of landings dropped, with the relevant grooming rules indicated.

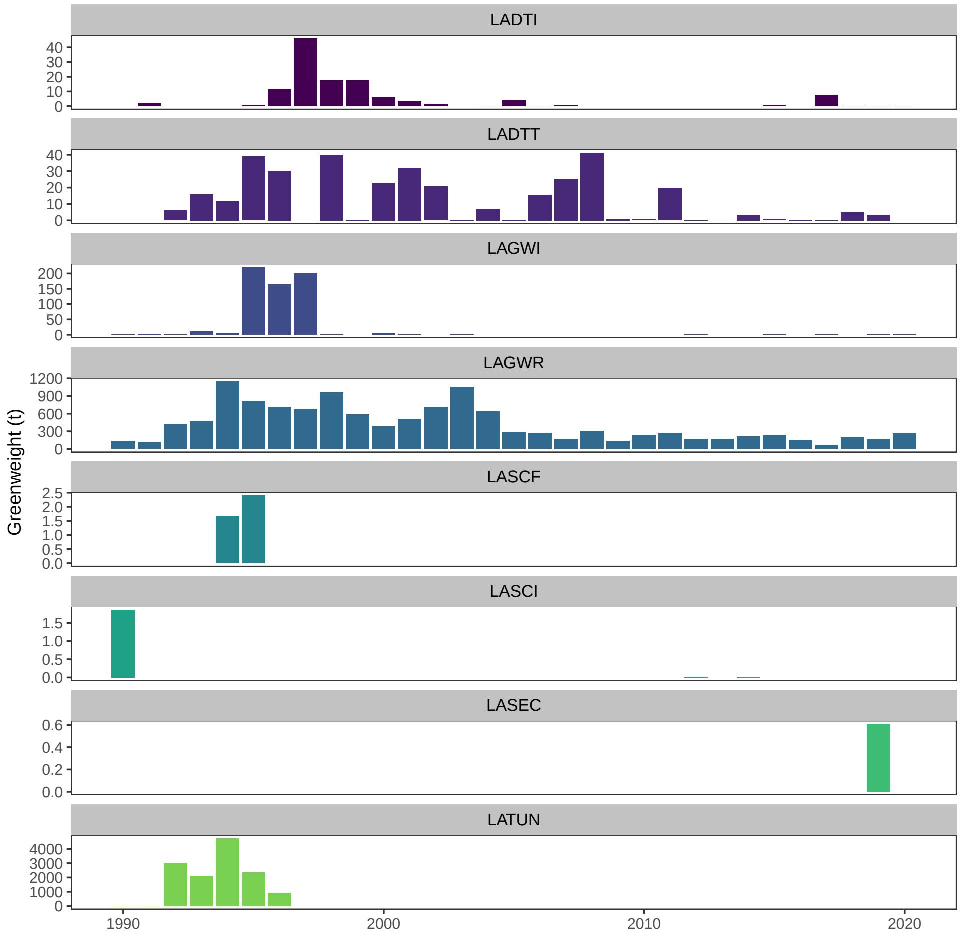

Figure B.2: The quantity of landings flagged or fixed by the grooming rules. Note that some landing events may be affected by multiple rules.

B.2 Effort

Table B.2: Grooming rules applied to effort data.

Rule	Effect	Description
DCFPM	Fix	Fill in missing method using other events on the same CELR form
DCFTS	Fix	Fill in missing target species using other events on the same CELR form
DCFAC	Fix	Fill in missing statistical area using other events on the same CELR form
FEPMN	Fix	Add PSH as a method code for certain vessels if method is null
FEPMI	Fix	Replace missing methods if there is only one method used on the trip (by form type)
FEPMM	Flag	Flag trips if any events have a missing method
FESAI	Fix	Substitude the modal statistical area from a trip for missing areas
FESAM	Flag	Flag events with missing statistical areas
FESAS	Fix	For BCO4 only correct RL statistical areas to general areas
FESAF	Flag	Flag non RLP events using RL statistical area codes
FESDF	Flag	Flag events in the future
FESDM	Flag	Flag events with missing start date/time
FETSE	Fix	Set target species to group code for HPB and FLA species
FETSW	Fix	Flag and set target species to null if target species is not a valid species code
FETSI	Fix	Replace missing target species with the modal value for a trip
FELLI	Fix	Replace lat/lon recorded as 999.9 with NULLs
FELLS	Fix	Set lat/lon to NULL where this conflicts with the reported statistical area
FEETN	Fix	Flag and fix some CP effort errors
FEEHN	Fix	Fix transposed effort numbers for lining methods on CELR forms
FEEMU	Fix	Fix SN mesh sizes recorded in inches
FEMEM	Flag	Flag events where the primary effort measure is missing
FEHDE	Flag	Flag records where the maximum daily effort is out of range
FEDBE	Fix	Transpose bottom and effort depths if reported effort depth > bottom depth

Table B.3: Grooming rules applied to estimated catch data.

Rule	Effect	Description
ESCWN	Fix	Correct cases where estimated catch is recorded in weight but number of fish is expected

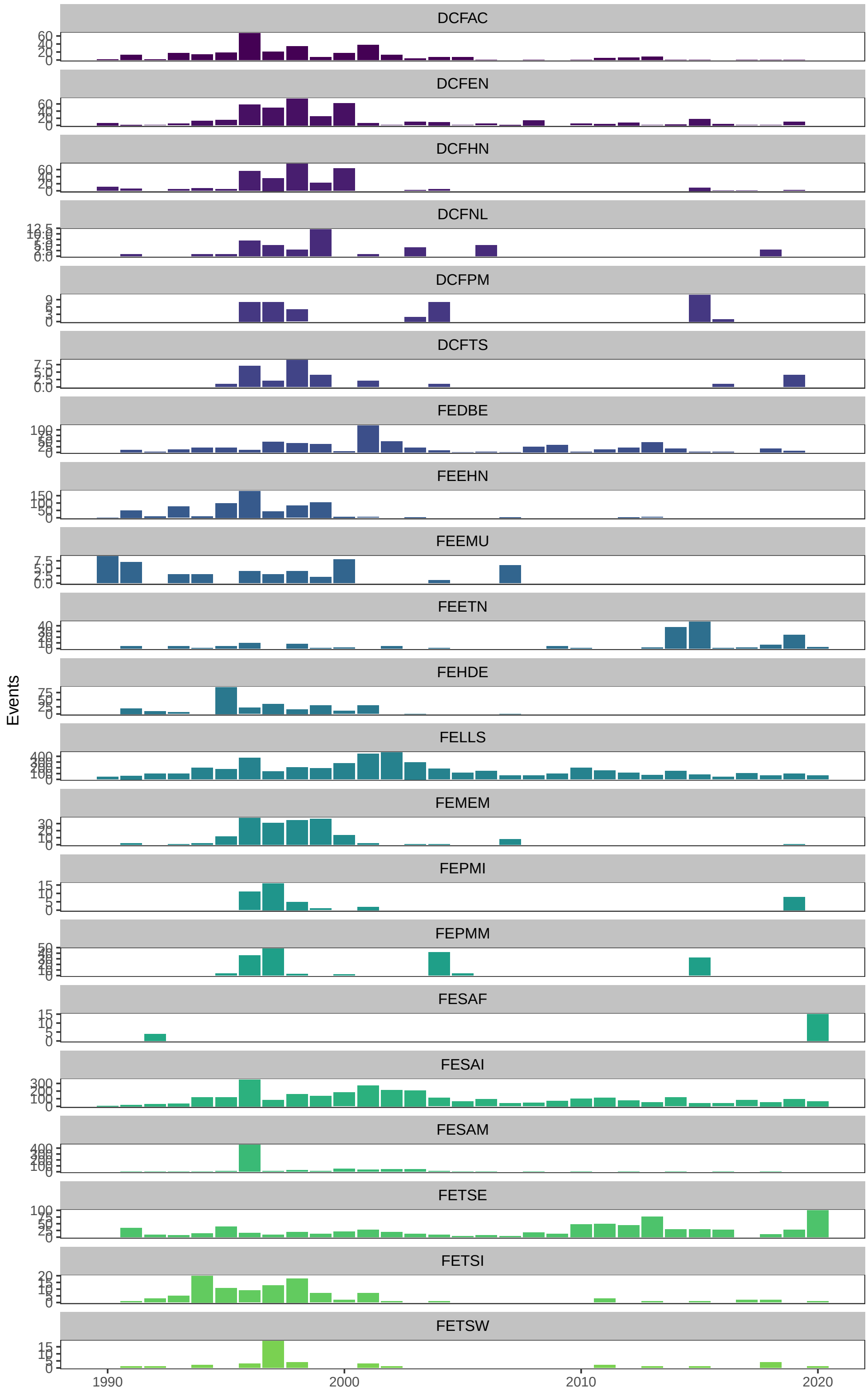

Figure B.3: The number of fishing events flagged or fixed by the grooming rules. Note that some events may be affected by multiple rules.

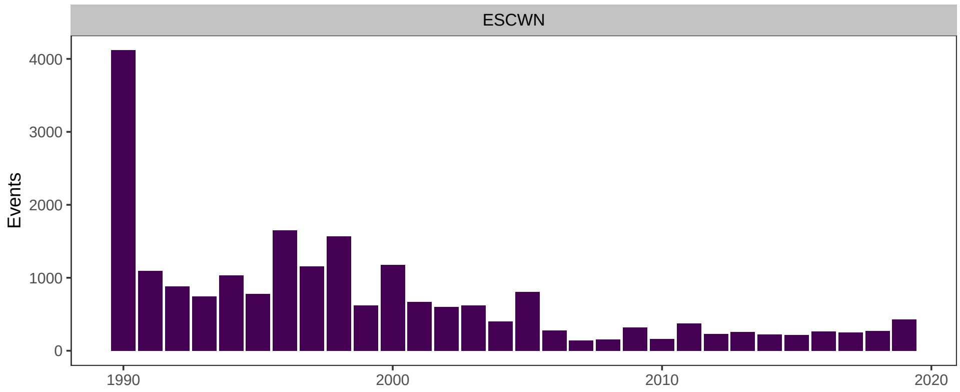

Figure B.4: The number of fishing events where the estimated catch of albacore was flagged or fixed by the grooming rules. Note that some events may be affected by multiple rules.

B.3 Grooming of catch numbers

For some species, and certain fishing methods and reporting forms, fishers have been instructed to report the estimated catch from a fishing event in numbers of fish instead of, or in addition to, the estimated catch weight. However, landings data for these species are usually reported in kilograms. The requirement to use different quantities for reporting the same fish in different parts of the reporting system has the potential to cause confusion. This is particularily relevant in cases where the Catch, Effort and Landing Return (CELR) form was in use, because the multi-purpose use of this form meant that the same fields had differing interpretations in different circumstances (i.e. depending on the species caught and method used).

In the case of albacore, calculation of the mean weight of fish from a trip (i.e. landed weight divided by estimated catch numbers) provides evidence that reporting errors have occured (Figure B.5): there is a mode of trips with a mean fish weight around 1 kg, in addition to a mode around 5 kg, whereas the lowest recorded weight of albacore in catch sampling data is around 1.5 kg (see, for example, Griggs 2008, Fig. 7). There are a smaller number of trips with unrealistically high mean weights (i.e. > 20 kg).

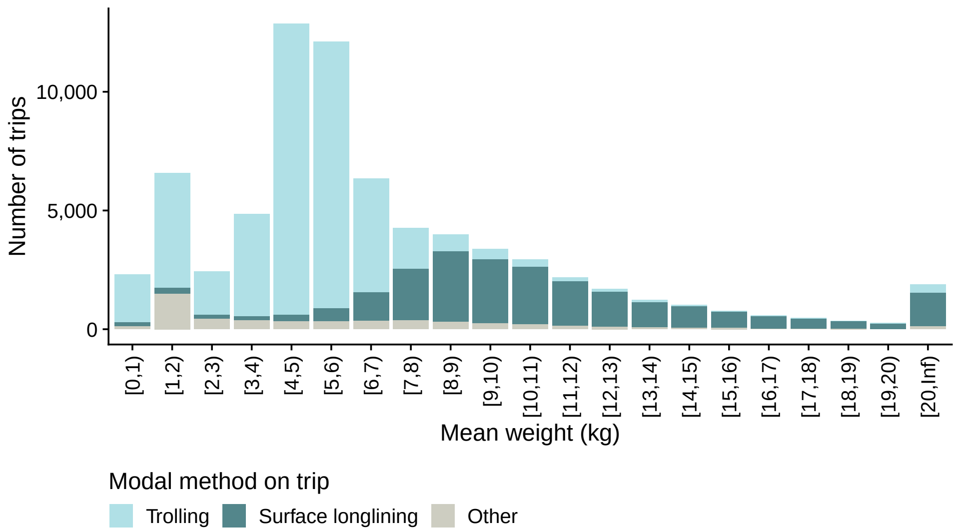

Figure B.5: Trip level mean weight of albacore by method, prior to the application of the ESCWN grooming rule.

Small mean weights from a trip are likely to arise from estimates being recorded in weight rather than numbers. In such cases, the calculated mean weight need not be exactly one because the fishers' estimated weights may differ somewhat from the weighed landed weight. A closer examination of the lower end of the distribution of mean weights (Figure B.6) suggests that a cut-off of 1.5 kg, based on the lowest weight recorded in catch sampling, will separate most of the trips with unreasonably low weights, although a somewhat higher threshold could be considered.

Trips with mean fish weights above and below the 1.5 kg threshold unsurprisingly have quite different relationships between estimated catch numbers and landed weights (Figure B.7). Although trips with a low mean fish weight have a wider distribution of estimated catch numbers, the distributions of landed weights and estimated numbers for the two classes of trip show considerable overlap (Figure B.8). As a result, the possibility that landed weights have been erroneously recorded in numbers, rather than estimated catches in weight, must also be considered.

Examining the relationship between catch (in numbers and weight) and catch rate (catch per day) demonstrates that trips with a mean fish weight below 1.5 kg tend to have higher catch rates in numbers than trips with larger mean fish weights, whilst that there is no clear grouping of catch rates when considered in terms of landed weight (Figure B.9). This provides strong evidence that low mean weights arise when estimated catches are recorded in weight (when numbers are expected) rather than landed weights erro-

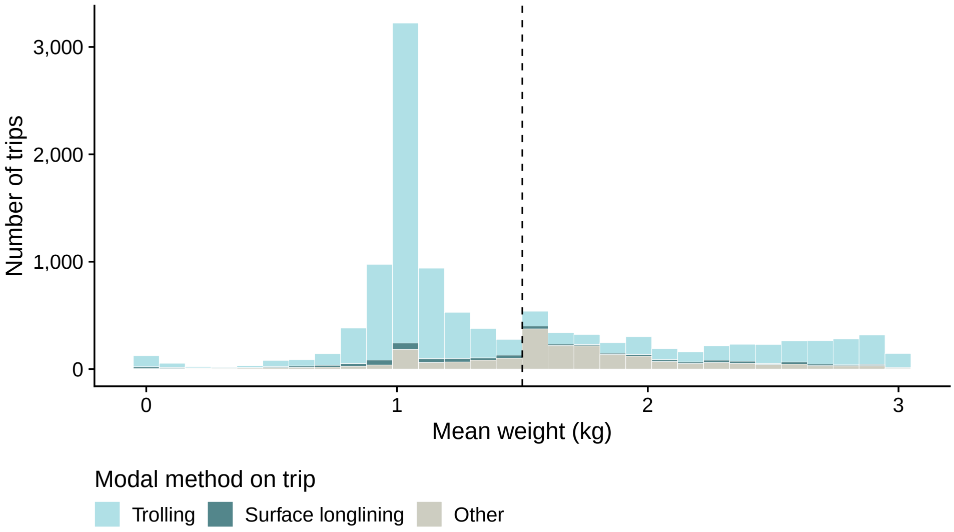

Figure B.6: Trip level mean weight of albacore by method, prior to the application of the ESCWN grooming rule, restricted to trips with a mean weight of less than 3kg.

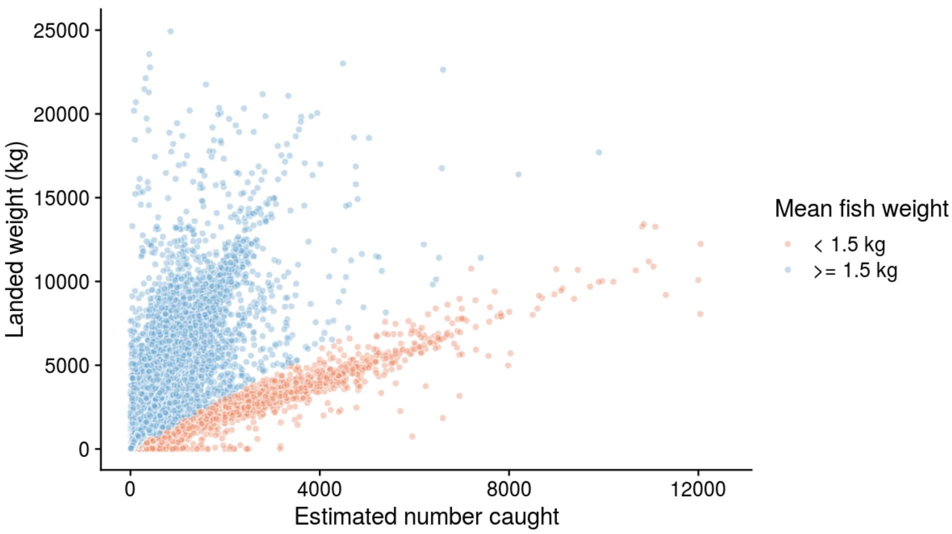

Figure B.7: The relationship between trip estimated catch numbers and landed weight of albacore, prior to the application of the ESCWN grooming rule.

neously recorded in numbers. This is consistent with the fact that landed weights are reported by both the fisher and Licensed Fish Receiver so should be less prone to error.

As a result, the grooming rule ESCWN corrects the estimated numbers for fishing events on trips with an implied mean fish weight less than 1.5 kg, where the estimated catch should be reported in numbers and where an estimated weight was not separately reported for the event. The recorded catch in numbers is divided by the mean fish weight for trips in the same fishing year and with the same modal fishing method, after excluding trips with a mean fish weight below the 1.5 kg threshold or exceeding 20 kg (Table B.4). This approach removes the mode of low mean fish weight trips in the groomed data (Figure B.10).

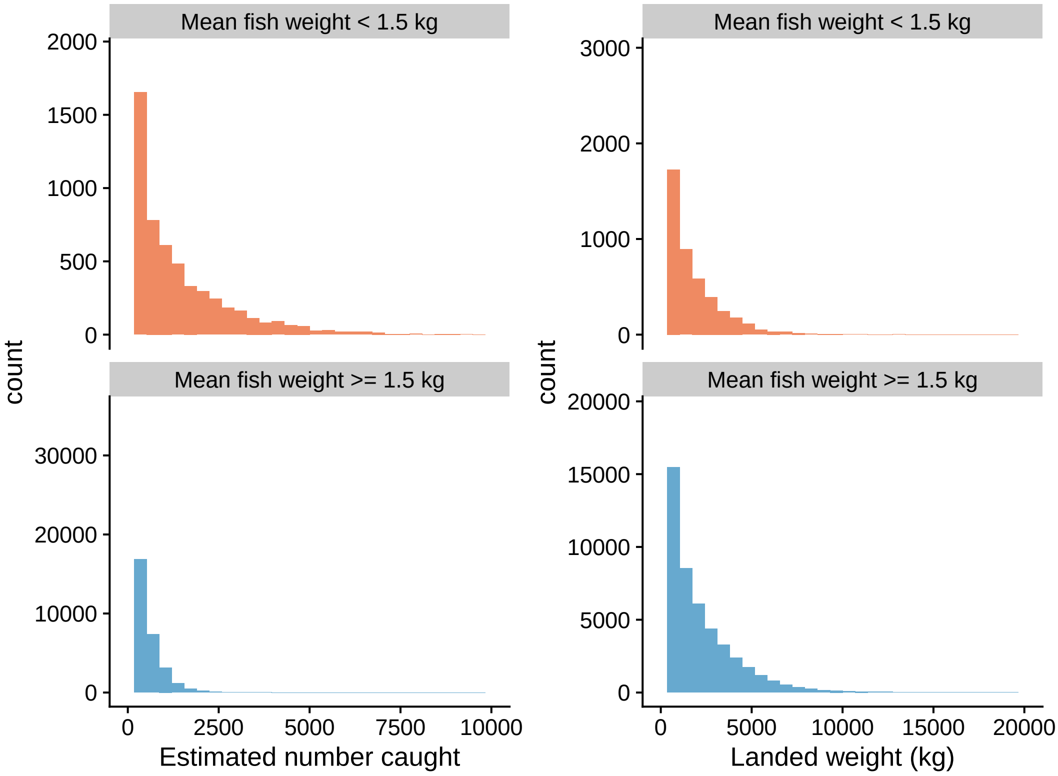

Figure B.8: The distributions of trip estimated catch numbers and landed weight of albacore, for trips with mean fish weights above and below 1.5 kg, prior to the application of the ESCWN grooming rule.

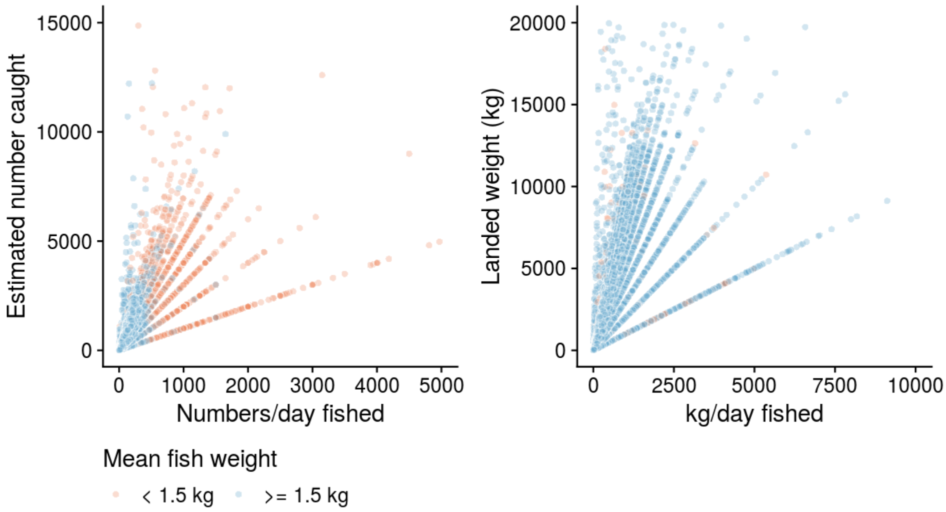

Figure B.9: The relationship between catch rate and catch in numbers and weight, for trips with mean fish weights above and below 1.5 kg, prior to the application of the ESCWN grooming rule.

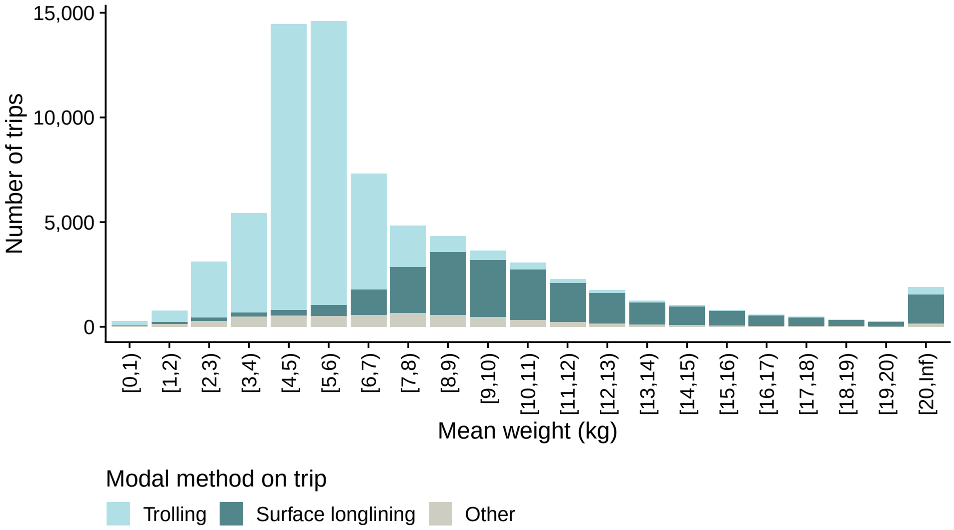

Figure B.10: Trip level mean weight of albacore by method, after application of the ESCWN grooming rule.

Table B.4: Mean fish weight (kg; total weight landed divided by estimated numbers landed) by fishing year and modal fishing method used on a trip, for the key methods catching albacore. Number of trips are indicated in parenthesis.

	Modal method on trip		
Fishing year	SLL	T	BLL
1990	1.86 (11)	2.81 (60)	
1991	4.42 (40)	4.60 (843)	3.90 (23)
1992	9.34 (92)	5.24 (1290)	5.09 (30)
1993	9.69 (177)	5.30 (1719)	4.63 (66)
1994	9.48 (365)	4.90 (2487)	4.18 (94)
1995	8.23 (618)	5.22 (2693)	3.95 (103)
1996	7.76 (608)	5.21 (1854)	6.39 (60)
1997	9.60 (515)	5.22 (1346)	5.68 (42)
1998	9.40 (897)	5.33 (1452)	2.54 (36)
1999	8.88 (1346)	4.73 (731)	5.97 (25)
2000	9.34 (1699)	4.75 (1609)	7.06 (23)
2001	8.92 (1993)	5.43 (1947)	4.18 (55)
2002	9.80 (2215)	5.25 (1893)	4.53 (27)
2003	9.06 (1627)	5.17 (1588)	4.42 (77)
2004	8.17 (1097)	5.41 (1339)	5.40 (36)
2005	9.88 (580)	5.87 (1307)	5.31 (61)
2006	10.76 (624)	5.36 (964)	5.44 (28)
2007	10.17 (434)	4.91 (706)	6.19 (42)
2008	10.53 (354)	5.21 (1147)	4.69 (41)
2009	9.27 (471)	4.49 (924)	3.85 (42)
2010	10.39 (486)	4.91 (698)	6.31 (31)
2011	9.02 (512)	4.57 (973)	4.81 (23)
2012	9.40 (484)	5.19 (1222)	4.78 (29)
2013	9.31 (440)	5.81 (1061)	6.07 (56)
2014	9.33 (365)	5.54 (920)	5.18 (36)
2015	9.08 (364)	5.69 (812)	4.22 (25)
2016	9.51 (462)	5.90 (789)	4.37 (21)
2017	9.79 (402)	6.26 (649)	6.28 (31)
2018	11.39 (437)	3.83 (833)	3.92 (24)
2019	10.89 (298)	4.79 (864)	4.27 (41)
2020	9.56 (321)	4.85 (1007)	4.71 (11)
2021	10.15 (137)	4.96 (1162)	5.50 (16)

APPENDIX C: MARKET SAMPLING DATA

C.1 Market length-frequency data

Table C.1: Market length frequency samples of albacore . From fishing years 1998-2008, 2010-2019

Area	Method	Sampled landings	Number of fish
FMA1	T	12	1707
FMA2	T	1	100
FMA5	T	1	100
FMA7	BLL	1	100
FMA7	BT	1	58
FMA7	SLL	2	260
FMA7	SN	1	200
FMA7	T	500	62635
FMA7	TL	1	85
FMA8	T	2	385
FMA9	T	128	23343

C.2 Length composition by area and method

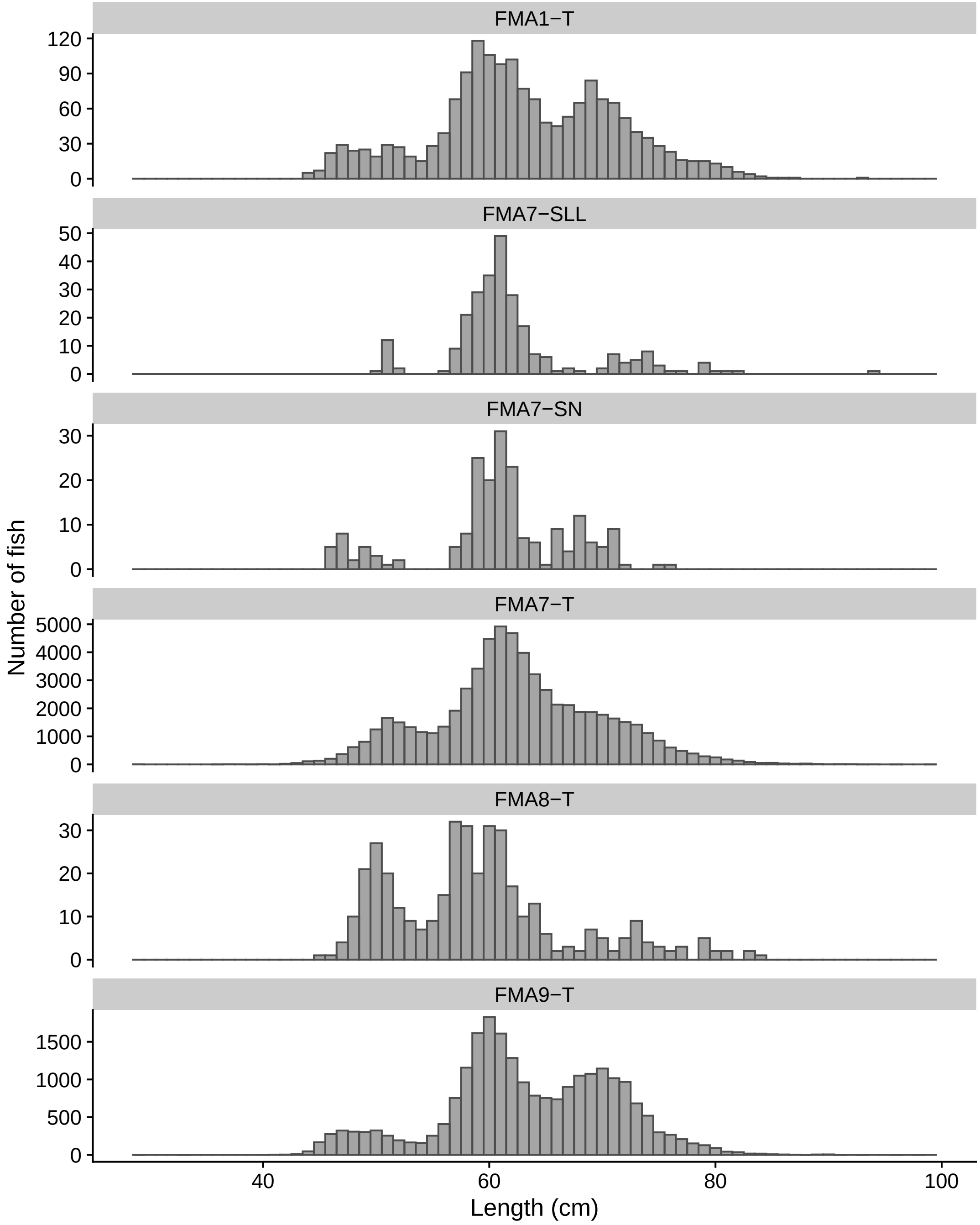

Figure C.1: Raw aggregate market sampling length-frequency distributions by area and method for albacore . From fishing years 1998-2008, 2010-2019

C.3 The trolling fishery

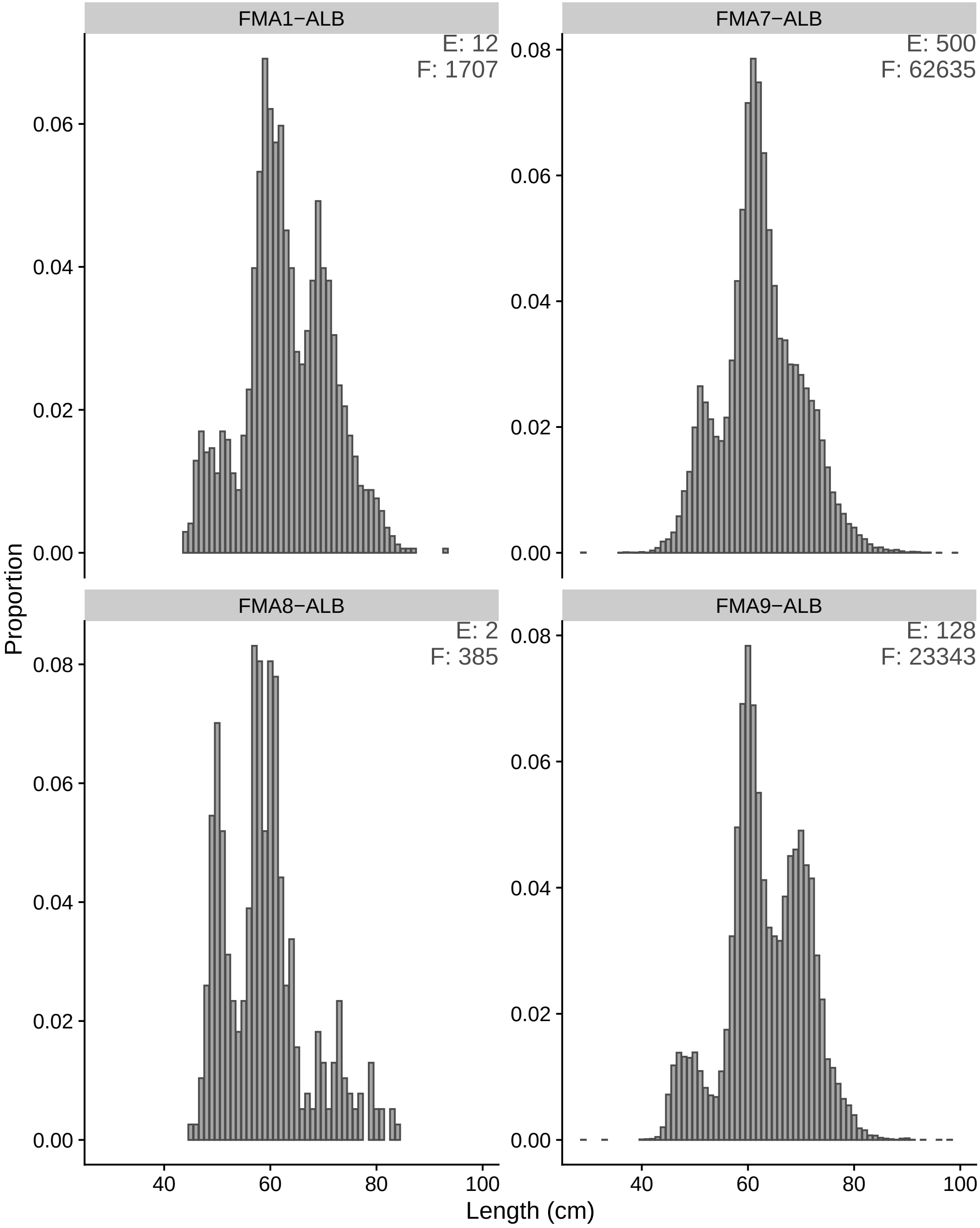

Figure C.2: Raw aggregate market sampling length-frequency distributions for albacore caught in the trolling fishery, by area and target species. From fishing years 1998-2008, 2010-2019

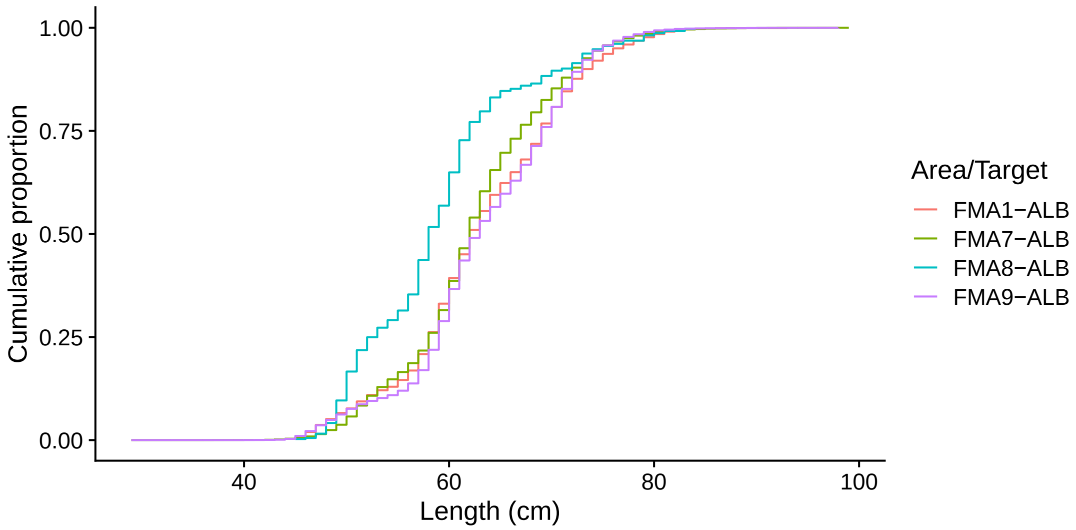

Figure C.3: Cumulative market sampling length-frequency distributions for albacore caught in the trolling fishery, by area and target species. From fishing years 1998-2008, 2010-2019

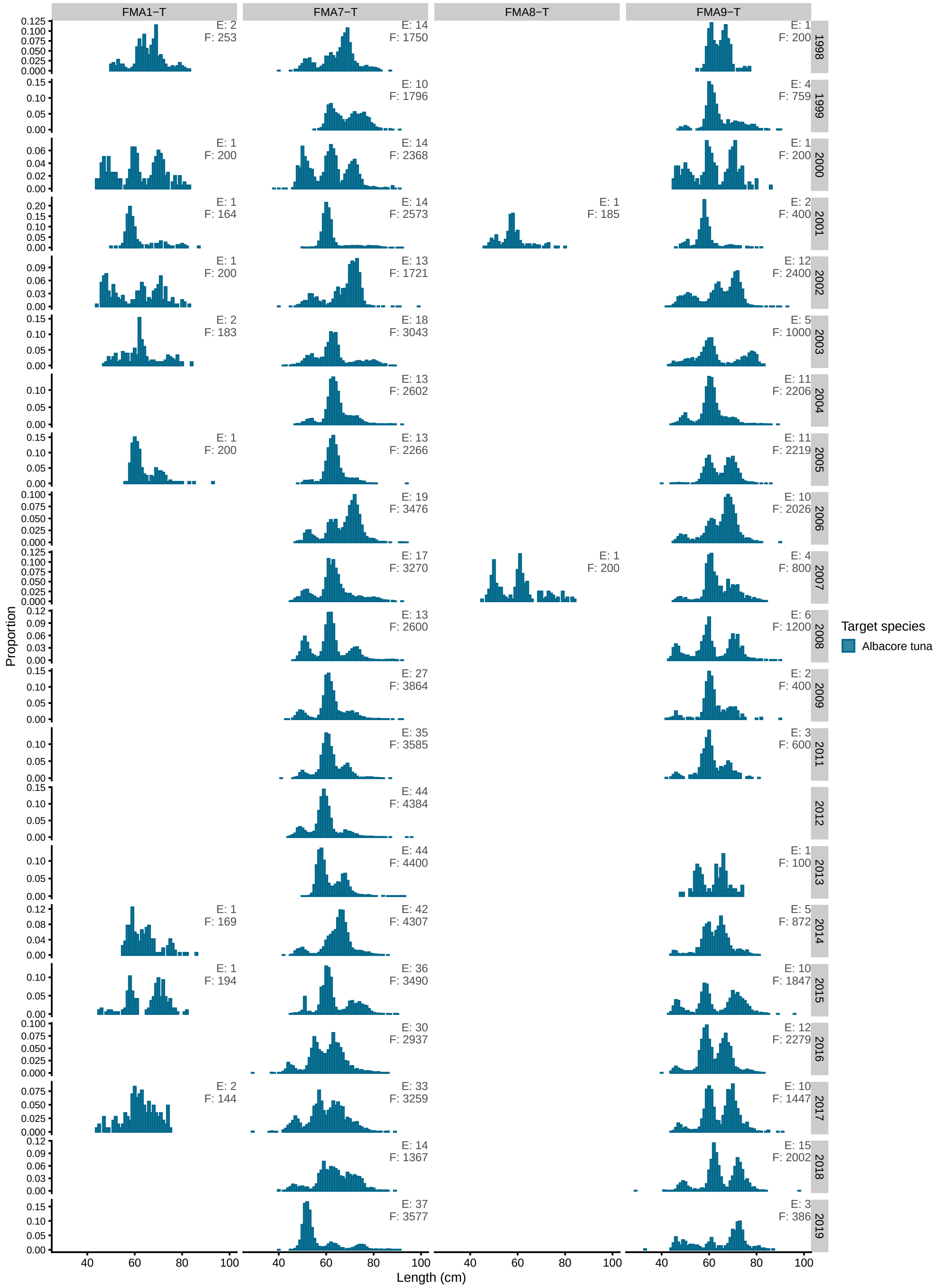

Figure C.4: Raw aggregate market sampling length-frequency distributions for albacore caught in the trolling fishery, by area, year, and target species.

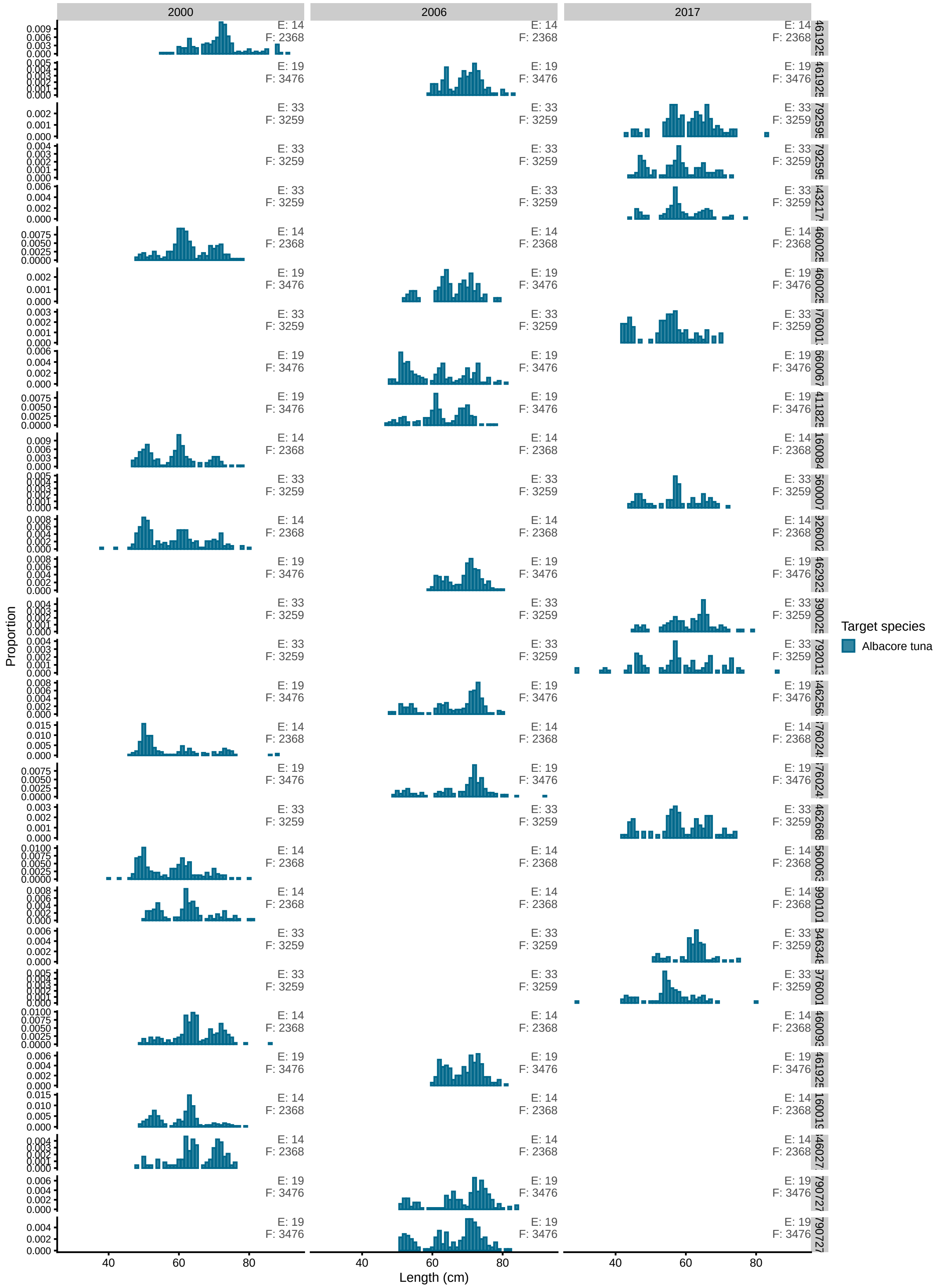

Figure C.5: Raw aggregate market sampling length-frequency distributions for albacore caught in the trolling fishery, by trip, and target species. For years 2000, 2006, and 2017 from FMA7 troll fishery.

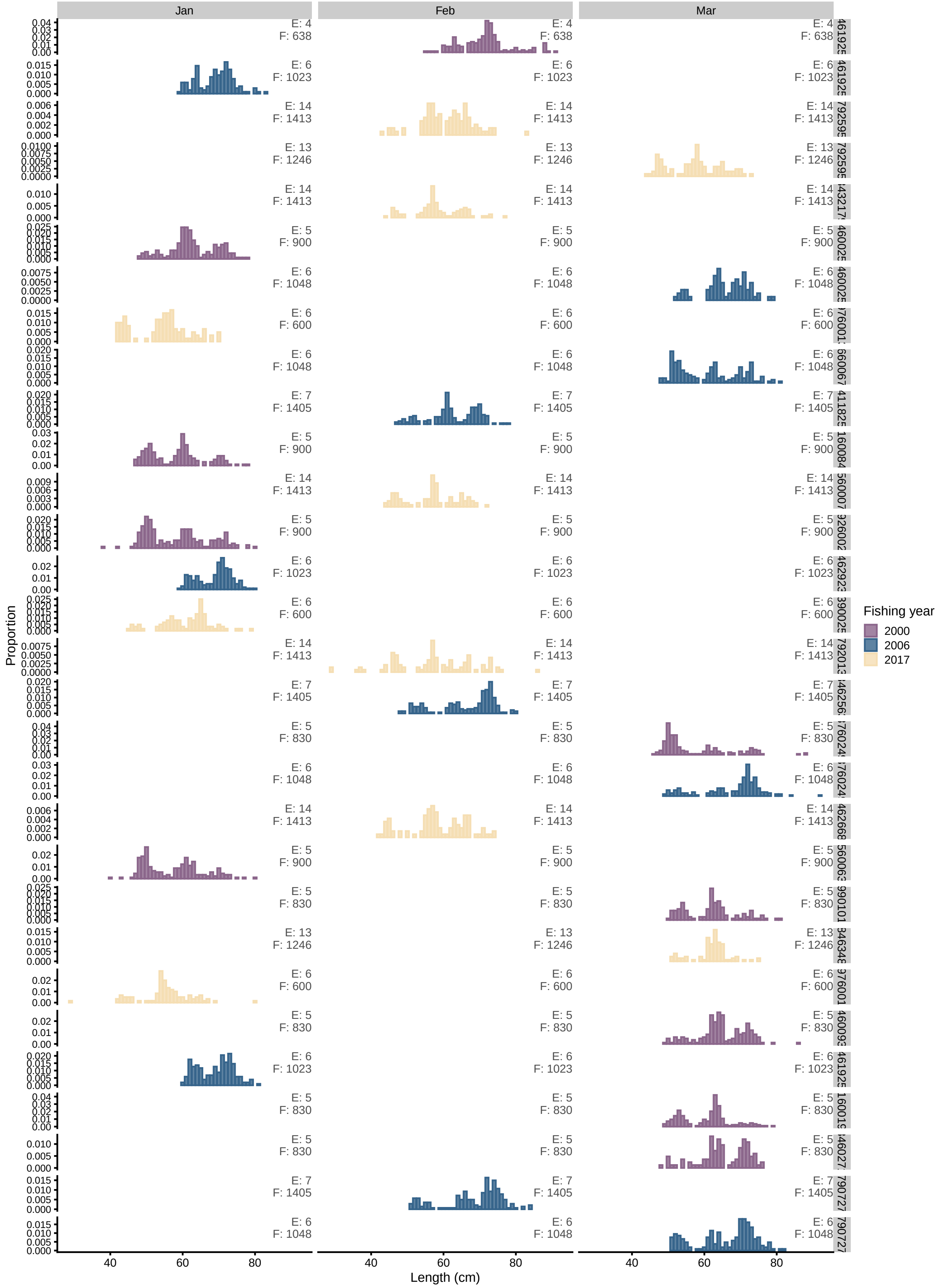

Figure C.6: Raw aggregate market sampling length-frequency distributions for albacore caught in the trolling fishery, by trip, and modal month fished. For years 2000, 2006, and 2017 from FMA7 troll fishery.

APPENDIX D: OBSERVER SAMPLING DATA

D.1 Observer length-frequency data

Table D.1: Observer length frequency samples, from fishing years 1991 to 2020

Area	Method	Sampled events	Number of fish
AKE	SLL	958	
AKW	SLL	281	
CEE	SLL	1390	
CET	SLL	2	5
CEW	SLL	6	203
CHA	SLL	1597	
KER	SLL	200	
SEC	SLL	1	1
SOU	SLL	944	
WANB	SLL	1	1
	SLL	13	655

D.2 Length composition by area and method

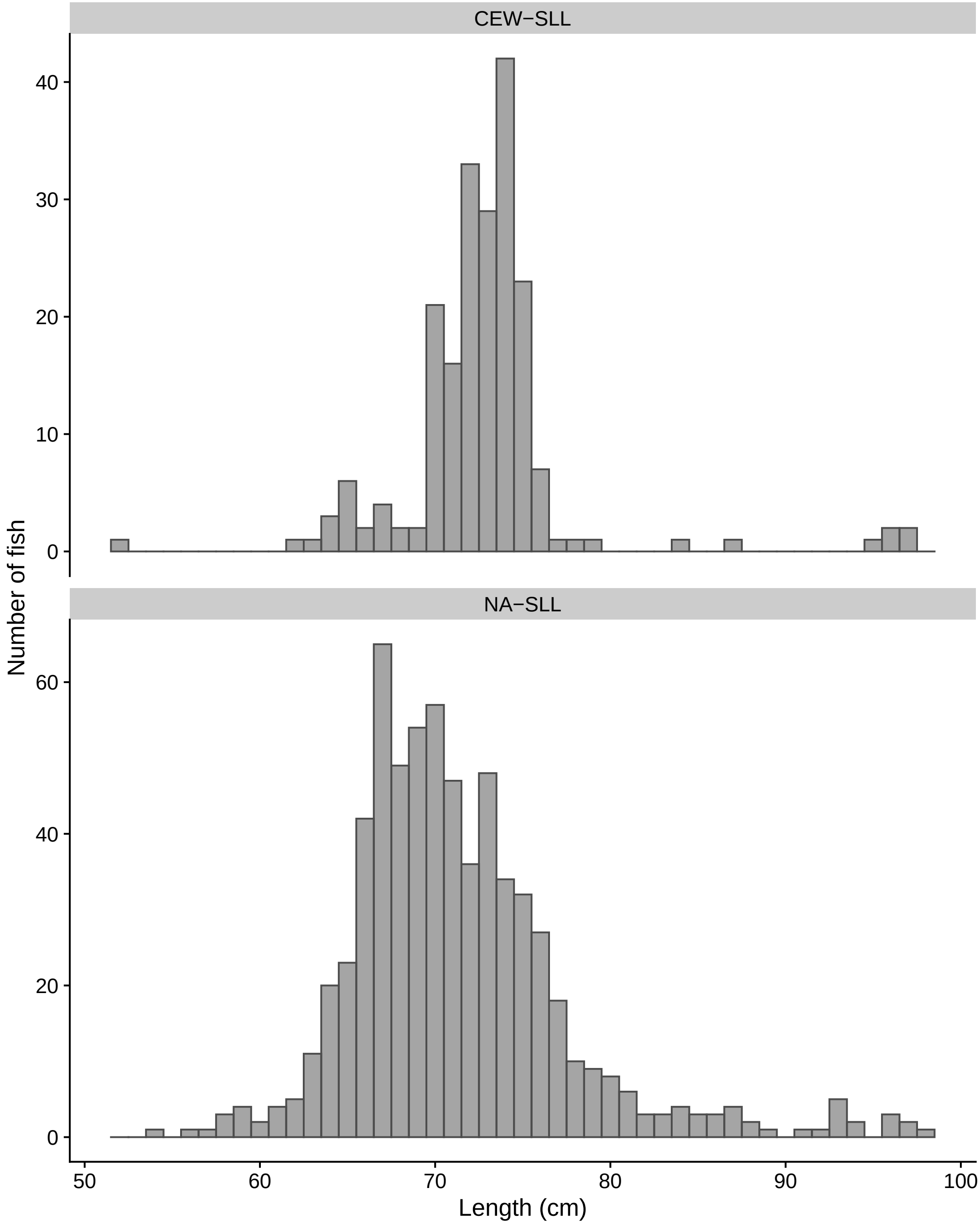

Figure D.1: Raw aggregate length-frequency distributions by area and method for albacore ,from fishing years 1991 to 2020.

D.3 The surface longlining fishery

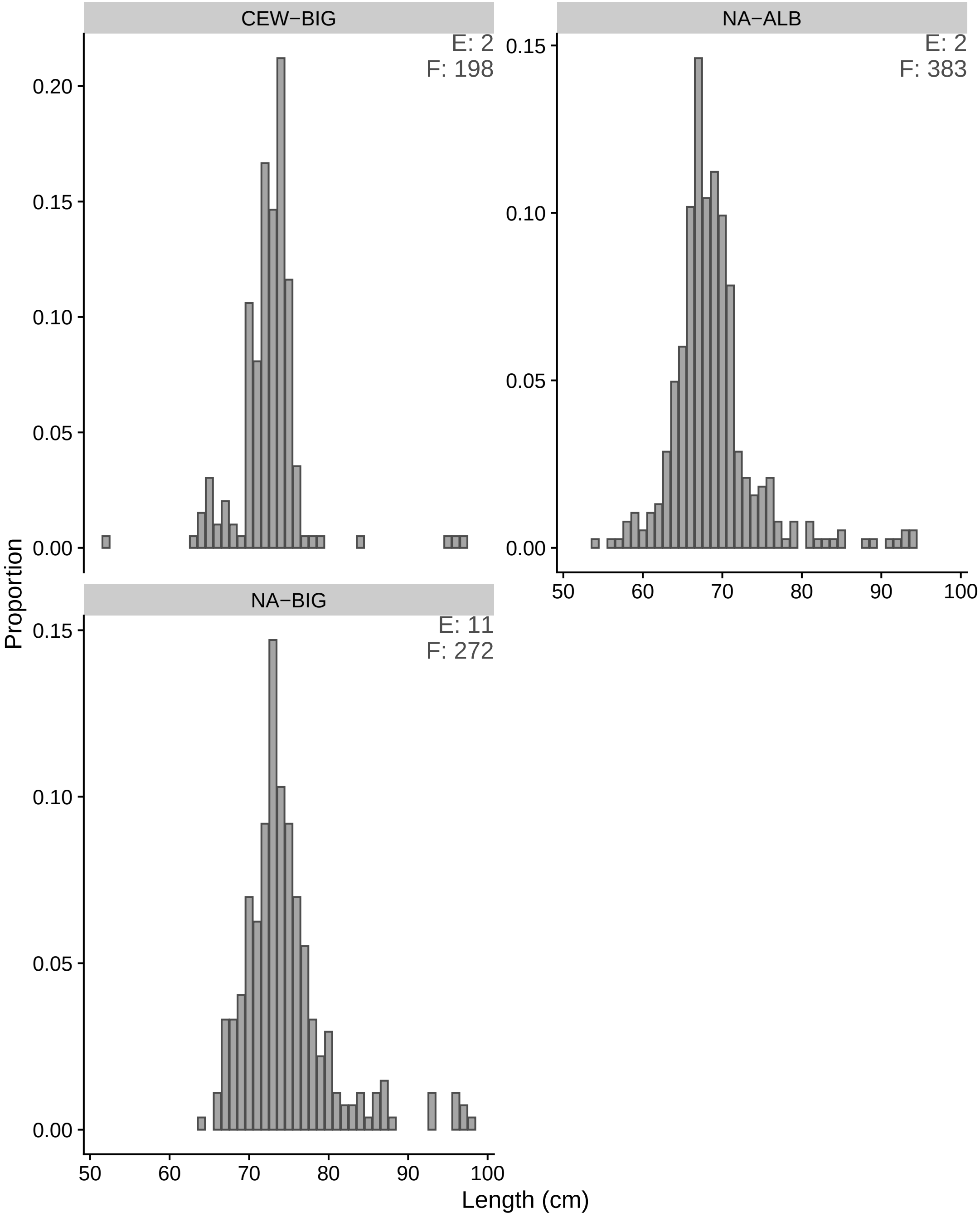

Figure D.2: Raw aggregate length-frequency distributions for albacore caught in the surface longlining fishery, by area and target species, from fishing years 1991 to 2020.

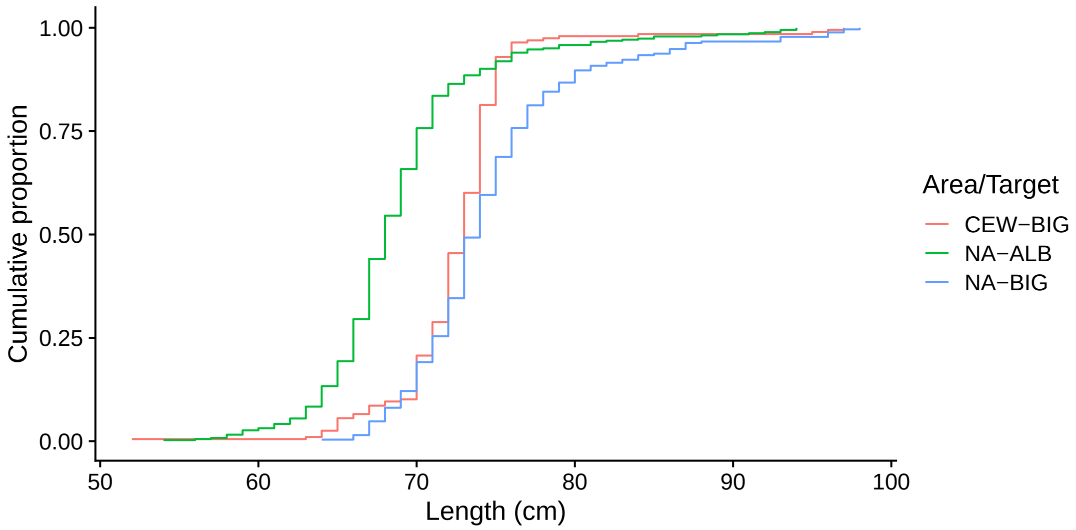

Figure D.3: Cumulative length-frequency distributions for albacore caught in the surface longlining fishery, by area and target species, from fishing years 1991 to 2020.

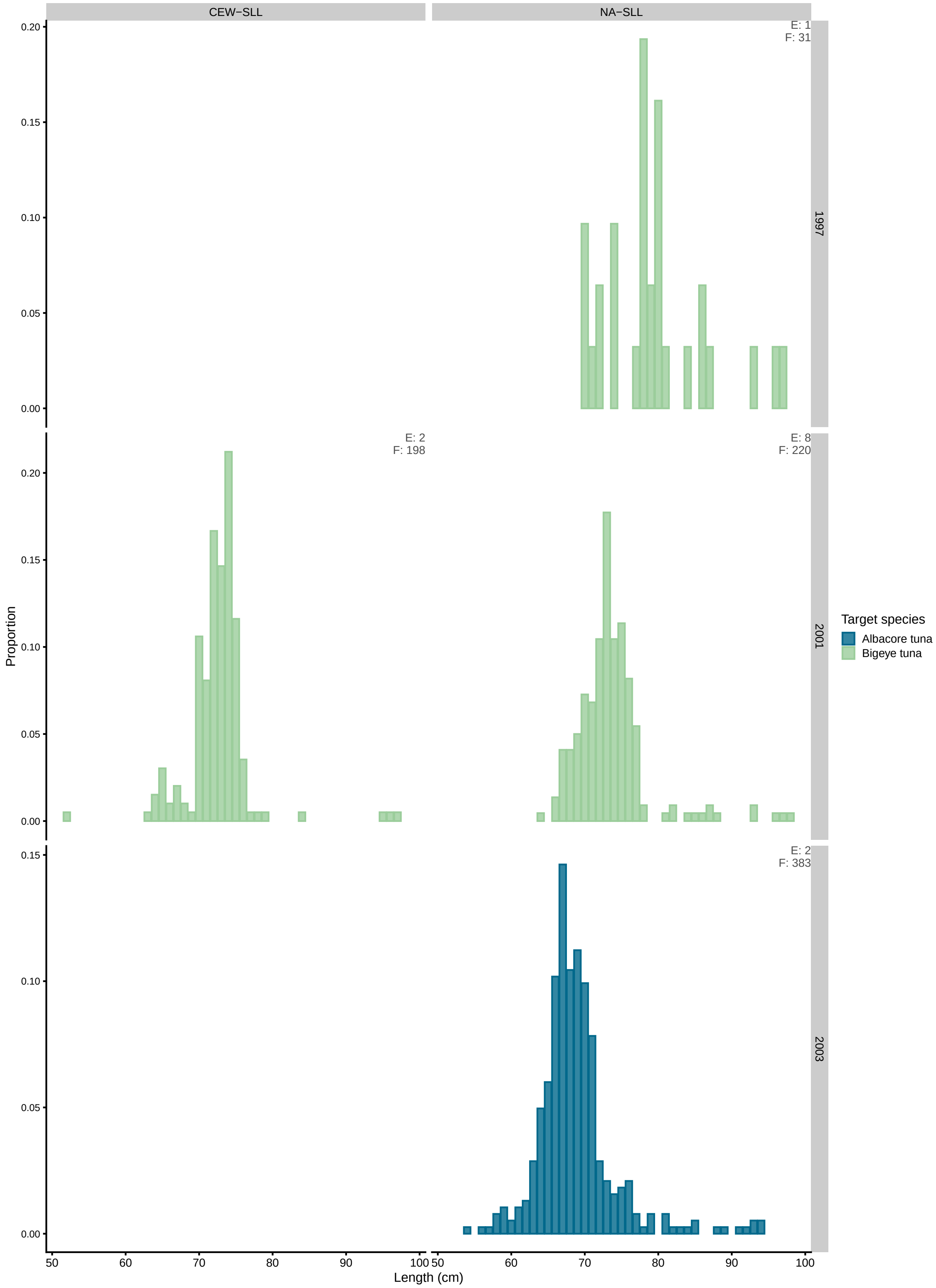

Figure D.4: Raw aggregate length-frequency distributions for albacore caught in the surface longlining fishery, by area, year, and target species.

APPENDIX E: ADDITIONAL CHARACTERISATION PLOTS

E.1 Catch distributions by method

E.1.1 The Trolling fishery

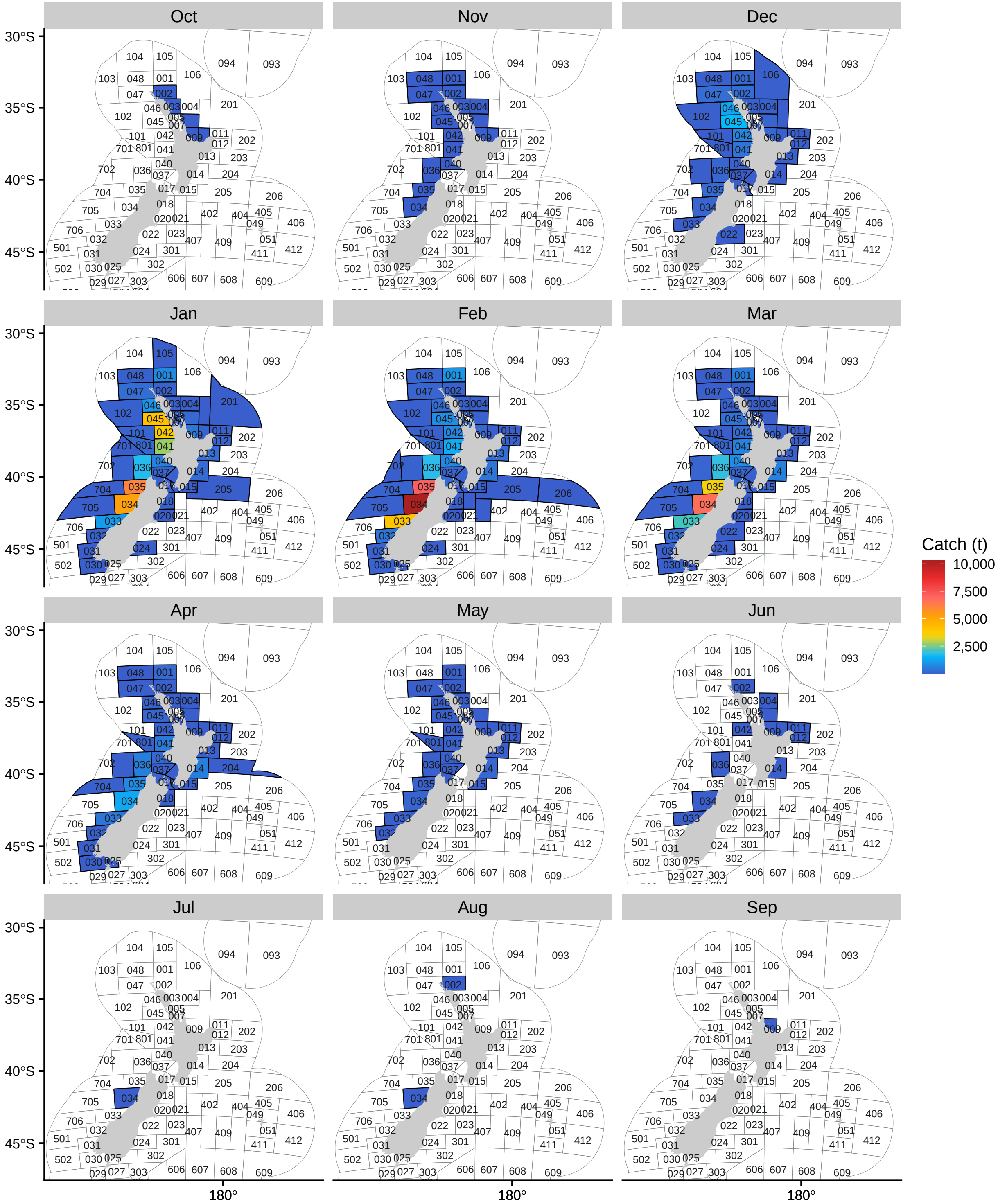

Figure E.1: Allocated landings (t) for the ALB 1 trolling fishery, aggregated by month and by statistical area. Statistical areas with data from less than three vessels or permit holders are omitted. From 1990 to 2020 .

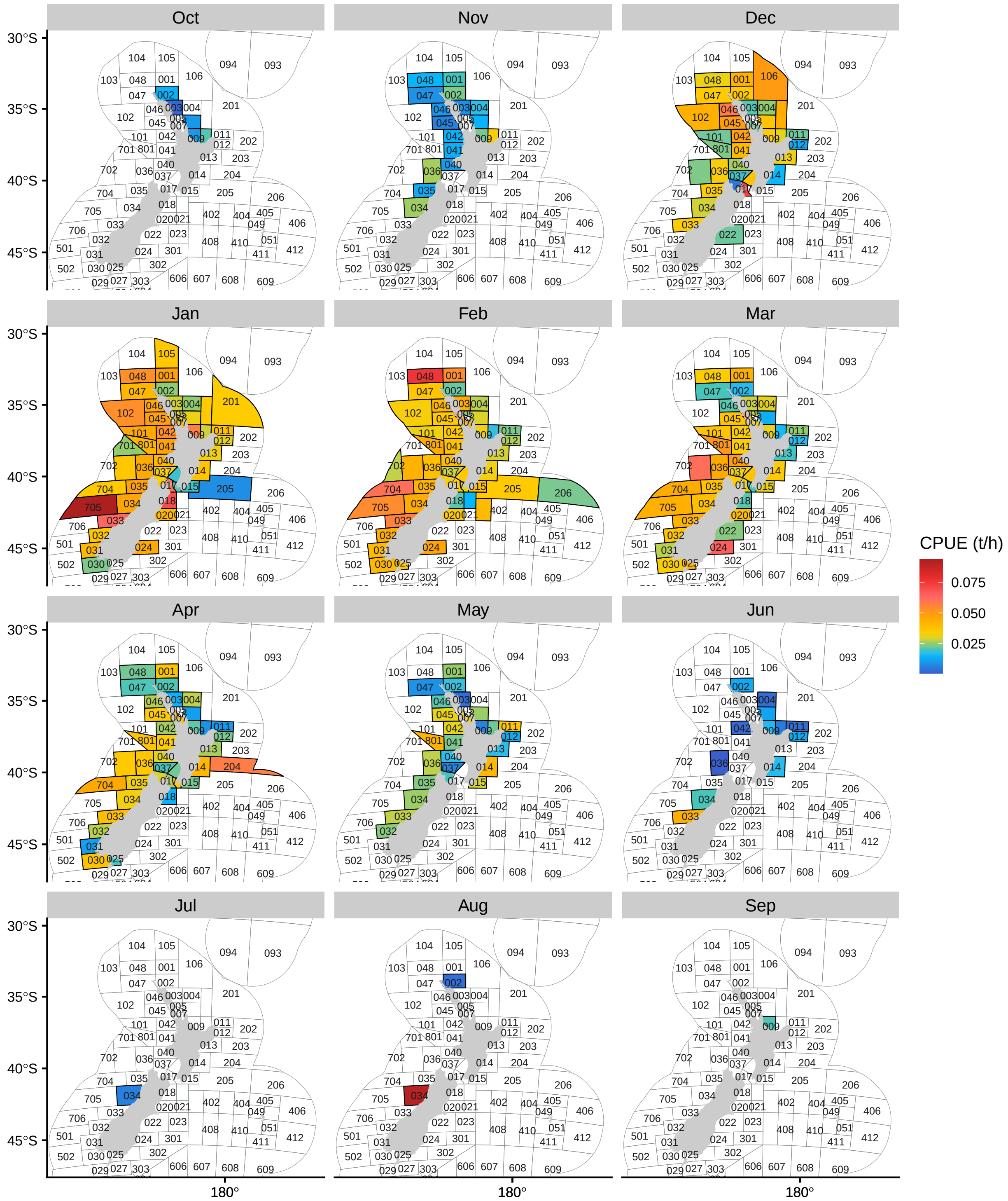

Figure E.2: Raw aggregate CPUE (t/h) for the ALB 1 trolling fishery, aggregated by month and by statistical area. Statistical areas with data from less than three vessels or permit holders are omitted. From 1990 to 2020 .

E.1.2 The Surface longlining fishery

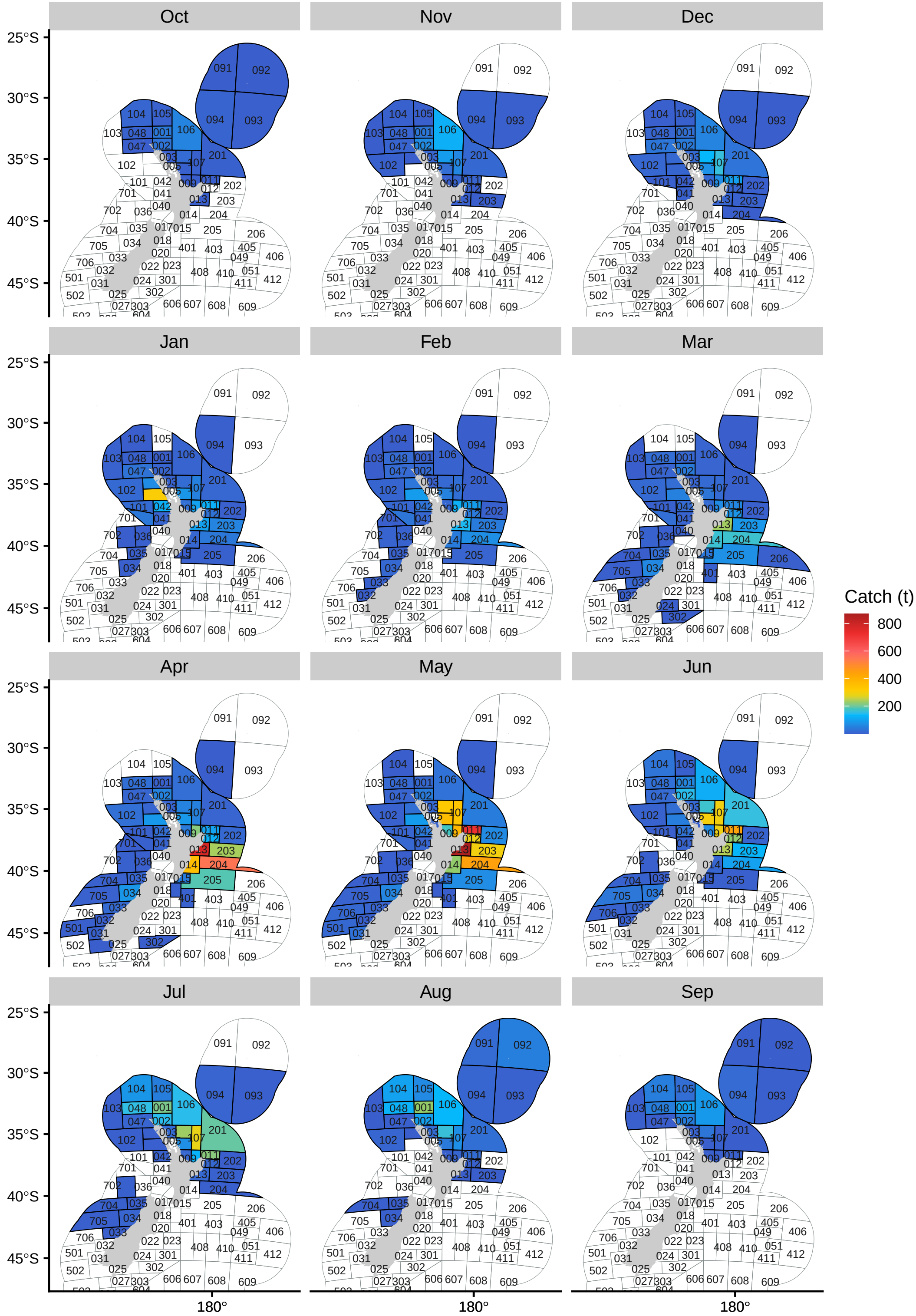

Figure E.3: Allocated landings (t) for the ALB 1 surface longlining fishery, aggregated by month and by statistical area. Statistical areas with data from less than three vessels or permit holders are omitted. From 1990 to 2020 .

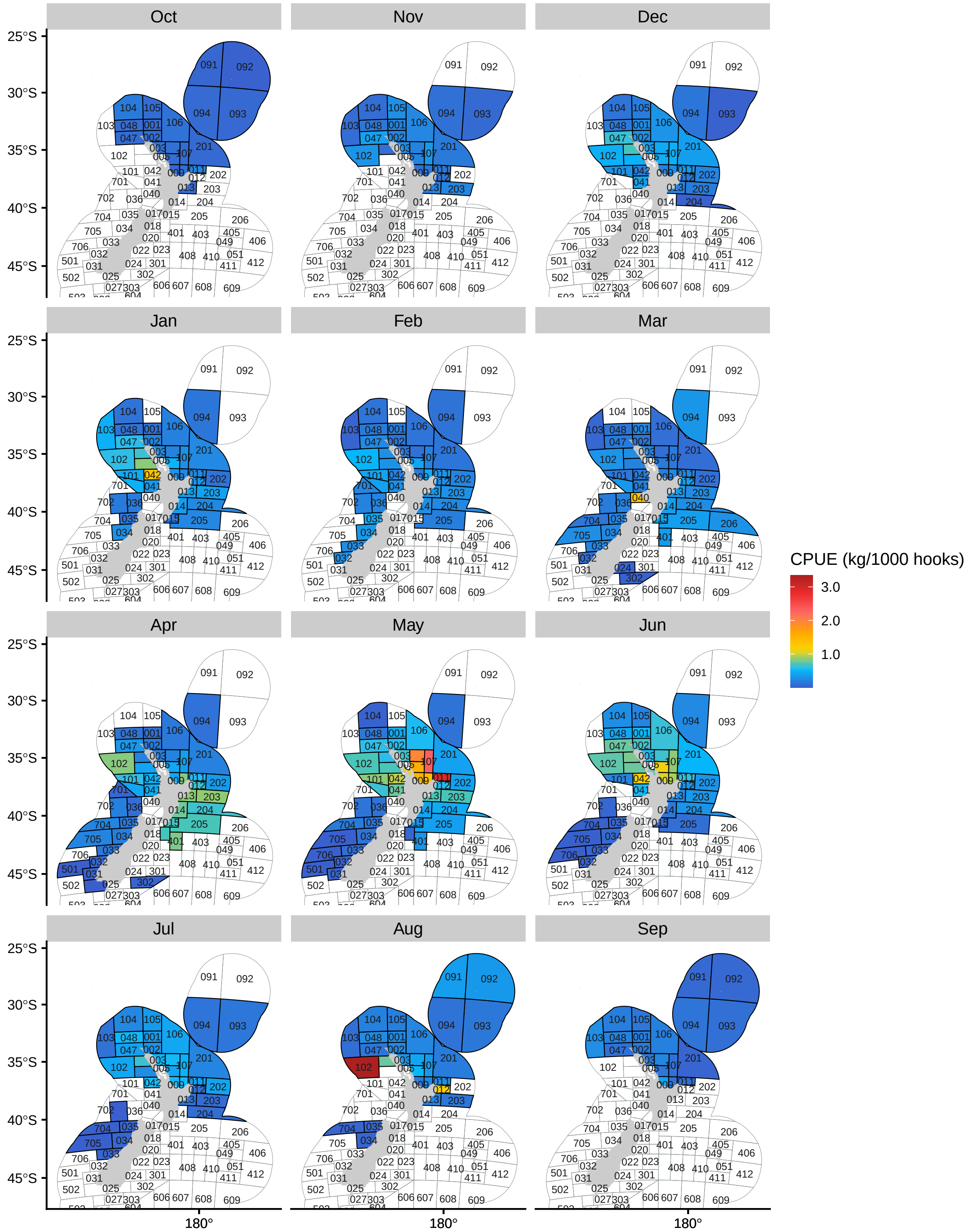

Figure E.4: Raw aggregate CPUE (kg/1000 hooks) for the ALB 1 surface longlining fishery, aggregated by month and by statistical area. Statistical areas with data from less than three vessels or permit holders are omitted. From 1990 to 2020 .

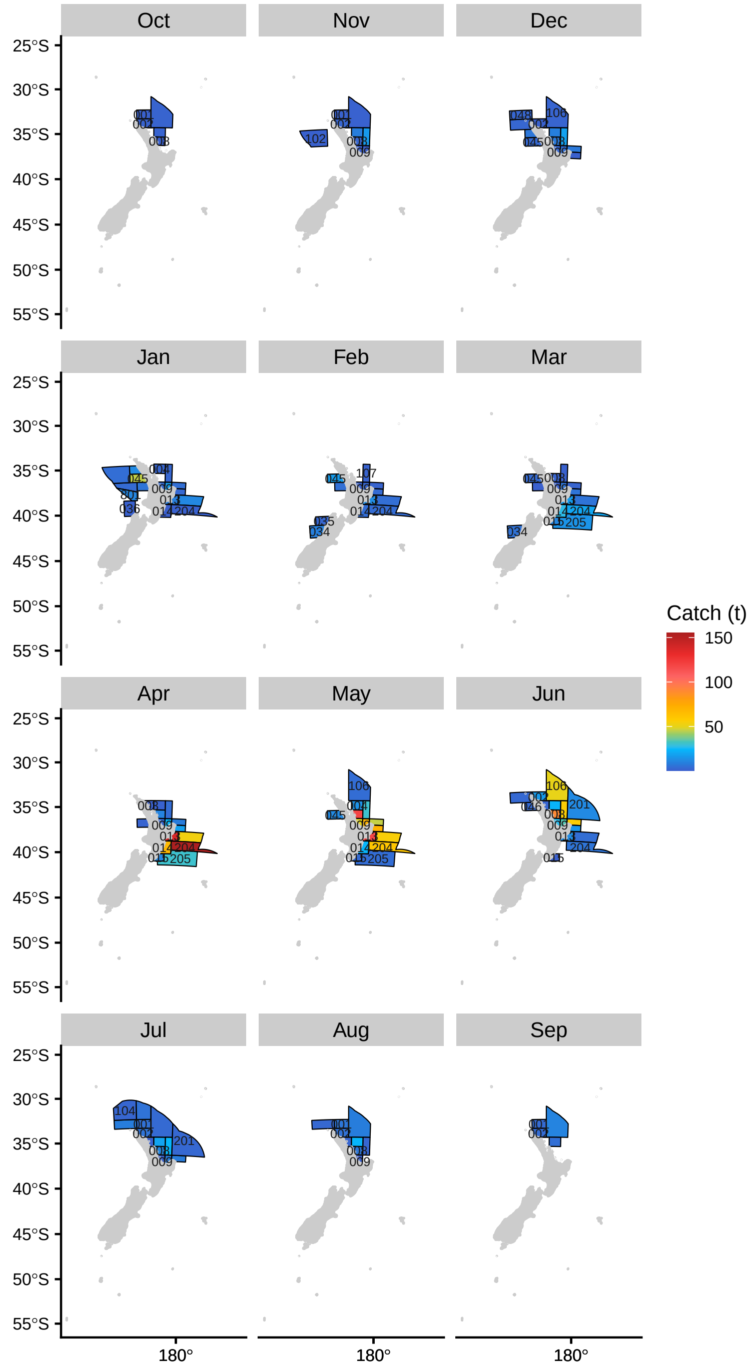

Figure E.5: Allocated ALB 1 landings (t) for the surface longlining fishery by key target species ALB aggregated by month and by statistical area. Statistical areas with data from less than three vessels or permit holders are omitted. From 1990 to 2020 .

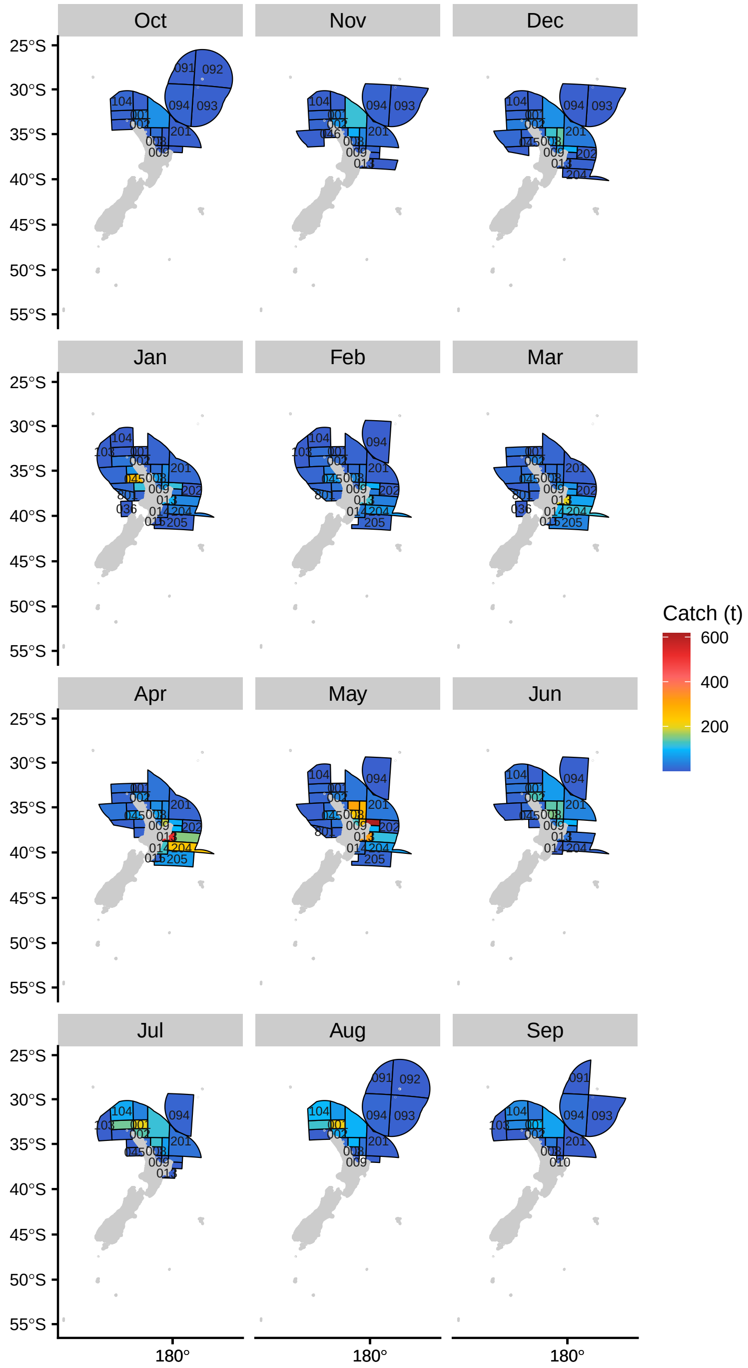

Figure E.6: Allocated ALB 1 landings (t) for the surface longlining fishery by key target species BIG aggregated by month and by statistical area. Statistical areas with data from less than three vessels or permit holders are omitted. From 1990 to 2020 .

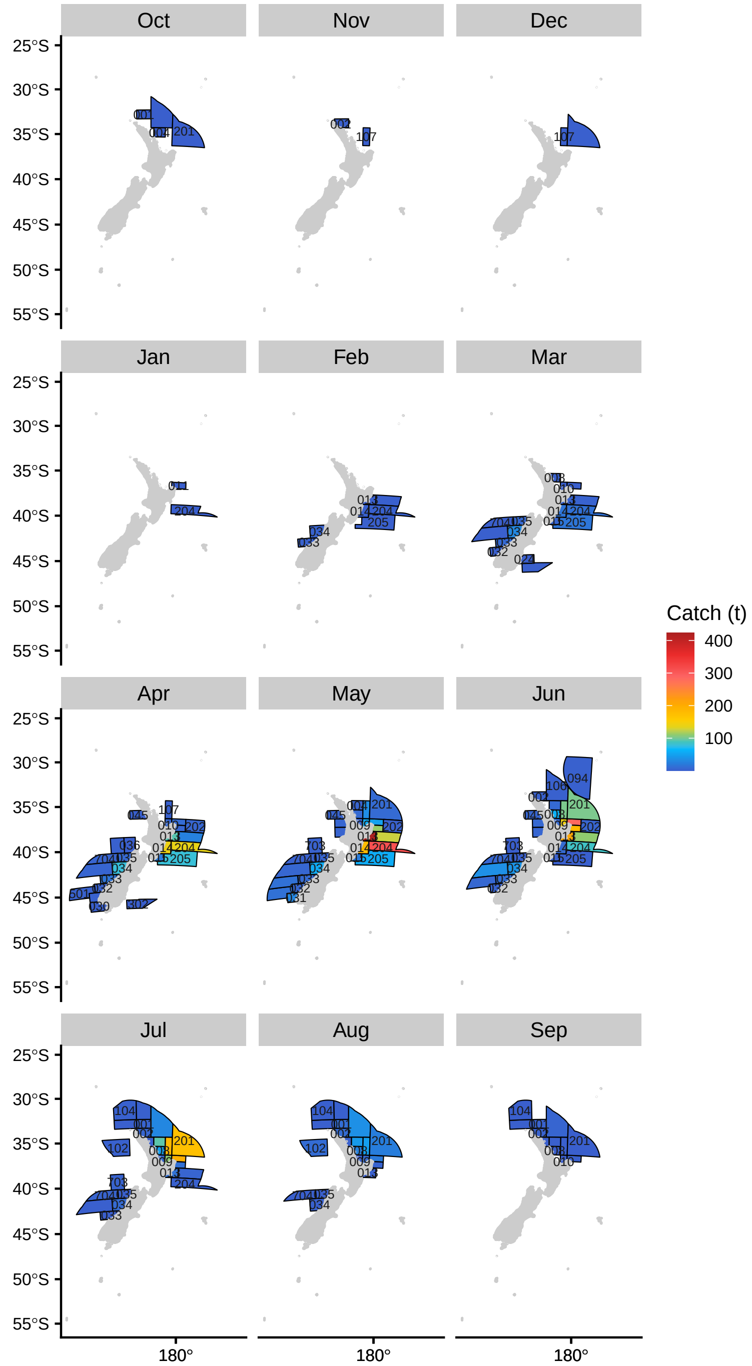

Figure E.7: Allocated ALB 1 landings (t) for the surface longlining fishery by key target species STN aggregated by month and by statistical area. Statistical areas with data from less than three vessels or permit holders are omitted. From 1990 to 2020 .

APPENDIX F: ADDITIONAL CHARACTERISATION TABLES

Table F.1: Landings by target species and fishing year, from 1990 to 2021, for the New Zealand surface longline fishery, for trips where the modal fishing method was surface longlining.

Fishing year	Albacore tuna	Bigeye tuna	Blue shark	Broadbill swordfish	Moonfish	Southern bluefin tuna	Yellowfin tuna	Other
1990	44.22	8.19		5.34	2.26	4.38	2.28	7.44
1991	38.63	17.08	0.16	13.61	5.59	34.43	4.44	44.79
1992	96.69	45.15	17.02	23.25	24.26	221.94	2.67	73.52
1993	274.73	39.35	30.06	53.20	42.01	179.82	2.33	118.38
1994	1172.75	71.72	337.54	94.30	90.95	267.94	31.39	154.12
1995	522.17	49.76	63.33	89.59	108.47	417.35	80.53	226.99
1996	835.41	76.78	54.71	155.80	106.40	124.95	165.52	216.02
1997	1026.70	97.13	57.92	225.06	116.60	312.26	133.60	210.63
1998	1470.27	312.73	44.84	470.32	222.13	278.98	85.78	219.81
1999	1691.31	356.08	73.21	854.63	258.12	425.18	153.03	320.73
2000	1381.25	440.86	47.43	821.92	293.24	349.18	89.80	253.13
2001	2043.38	455.26	74.08	919.21	341.31	349.93	114.09	468.22
2002	2399.49	283.47	181.74	883.28	325.82	461.97	60.63	533.16
2003	2283.73	191.92	250.53	619.28	221.14	399.28	42.97	466.31
2004	884.69	209.15	174.51	521.74	153.87	381.84	13.72	340.31
2005	497.51	159.22	350.10	316.49	103.12	253.05	30.04	238.48
2006	446.57	169.88	543.11	545.22	75.70	228.74	8.15	227.10
2007	294.31	195.15	486.59	761.50	69.79	229.49	18.54	176.66
2008	207.82	138.52	677.34	328.97	40.55	317.81	21.29	188.40
2009	414.83	234.32	771.03	386.40	78.47	413.58	4.85	213.63
2010	433.46	156.78	650.79	516.93	96.87	478.79	5.54	198.97
2011	315.21	180.08	738.96	706.70	113.21	553.49	2.41	252.67
2012	229.84	156.41	987.22	661.60	78.29	769.01	1.51	223.32
2013	296.76	111.00	701.49	750.58	80.65	725.65	0.43	216.83
2014	206.86	113.56	280.72	549.54	53.68	820.30	1.22	164.41
2015	149.68	80.38	582.56	699.41	30.75	909.49	13.98	195.10
2016	265.21	169.87	694.73	737.83	60.57	954.99	56.58	302.28
2017	211.52	104.54	603.71	470.41	54.73	914.16	6.84	181.58
2018	269.21	136.62	756.95	458.35	67.39	1002.90	22.03	233.37
2019	183.88	53.46	911.06	230.91	40.98	902.01	4.18	218.00
2020	178.97	58.61	728.95	187.18	50.69	953.41	8.57	267.41
2021	59.63	64.12	399.51	232.13	25.43	197.14	21.69	178.97

Table F.2: Total effort (no. hooks/1000) by target species and fishing year, from 1990 to 2021, for the New Zealand surface longline fishery, for trips where the modal fishing method was surface longlining. Dashed line indicates no effort recorded for target species in a particular year.

Fishing year	Albacore tuna	Bigeye tuna	Broadbill swordfish	Southern bluefin tuna	Other
1990	4	61	-	37	11
1991	24	890	20	11579	979
1992	40	745	43	8719	160
1993	14	691	-	4703	148
1994	70	1097	0	1345	169
1995	189	1187	1	2380	299
1996	176	1483	-	695	-
1997	134	1353	-	1624	184
1998	435	2256	0	1303	83
1999	535	4296	19	1892	147
2000	647	5837	3	1734	-
2001	494	7140	3	1903	283
2002	859	6970	-	2805	269
2003	1966	5113	-	3494	169
2004	463	3467	-	3192	211
2005	134	1643	150	1656	99
2006	59	1856	238	1488	37
2007	13	1505	188	1929	41
2008	-	953	119	1102	41
2009	7	1550	37	1477	14
2010	19	1222	124	1551	26
2011	13	1636	156	1333	18
2012	-	1283	182	1590	17
2013	6	988	313	1503	42
2014	3	726	190	1586	19
2015	-	373	447	1565	10
2016	20	622	443	1231	31
2017	3	495	321	1230	22
2018	-	569	386	1300	31
2019	3	435	153	1422	35
2020	4	381	130	1392	37
2021	4	253	253	470	11

APPENDIX G: GLOSSARY

Glossary of codes used for the effort and landings data.

Table G.1: Product state codes used in this report.

Code	Description
GRE	Green (or whole)
GUT	Gutted
HGU	Headed and gutted
HGF	Headed gutted and finned
DRE	Dressed
FIL	Fillets: skin-on
SKF	Fillets: skin-off
MEA	Fish meal
RLT	Tailed (rock lobster)
HGT	Headed gutted and tailed
GGO	Gilled and gutted tail on
GGT	Gilled and gutted tail off

Table G.2: Destination codes used in this report.

Code	Description
A	Returned, abandoned, or lost at sea
B	Taken or stored to use as bait for personal use
C	Disposed to Crown
D	Species not managed under QMS returned, abandoned, or lost at sea
E	Used for human consuption on board vessel
F	Landed under section 111 of Act
H	Loss of fish or fish product from holding container in water
J	Species subject to QMS returned, abandoned, or lost at sea
L	Conveyed or sold at time of landing
LR	Conveyed or sold at time of landing but not previously reported under landing code R
NP	Not provided
O	Converyed or transported on vessel leaving EEZ
QL	Transferred from holding to LFR
S	Seived by Fishery Officer under section 207 of Act
T	Transferred from vessel to another vessel
U	Taken or used as bait during trip
W	Sold under section 191(2) of Act
X	Species subject to QMS listed in schedule 6 and not spiny dogfish, and not blue shark, marko shark, or porbeagle shark returned dead or near dead, and not rock lobster returned, and returned to water, in accordance with requirements in Schedule 6 of Act
Z	Blue shark, marko shark, or porbeagle shark returned to water dead or near dead

Table G.3: Form type codes used in this report.

Code	Description
CEL	Catch Effort Landing return
ERS - Trawl	Electronic Reporting system trawl
ERS - Other Lining	Electronic Reporting system other lining

ERS - Tuna Lining	Electronic Reporting system Tuna-lining
TCP	Trawl Catch-Effort Processing return
TUN	Tuna return

Table G.4: Fishing method codes used in this report.

Code	Description
MW	Midwater trawl
TL	Trot lines
T	Trolling
SLL	Surface longlining

Table G.5: Species codes used in this report.

Code	Common name	Scientific name
SWO	Broadbill swordfish	*Xiphias gladius*
MOO	Moonfish	*Lampris guttatus*
ALB	Albacore tuna	*Thunnus alalunga*
BIG	Bigeye tuna	*Thunnus obesus*
STN	Southern bluefin tuna	*Thunnus maccoyii*
YFN	Yellowfin tuna	*Thunnus albacares*
SNA	Snapper	*Pagrus auratus*
BWS	Blue shark	*Prionace glauca*