Indices of albacore abundance from the west coast troll fishery, 1989–90 to 2007–08

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New Zealand Fisheries Assessment Report 2010/45
November 2010

Published by Ministry of Fisheries
Wellington
2010

ISSN 1175-1584 (print)
ISSN 1179-5352 (online)

Kendrick, T.H.; Bentley, N. (2010).
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New Zealand Fisheries Assessment Report 2010/45.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

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This study was contracted as Ministry of Fisheries project ALB2008/02 with the specific objective: "To update standardised CPUE for the west coast albacore troll fishery using data up to the end of the 2007/08 fishing year".

Albacore tuna caught in New Zealand waters are part of a single South Pacific Ocean stock that ranges from the equator to at least 49° S. Albacore are caught by trolling off the west coast of New Zealand during a narrow seasonal window (December to April) after which they become unavailable to that method. The fish taken in this fishery are small, comprising 2–3 cohorts of juvenile fish, and provide some of the only information on recruitment to the wider South Pacific stock.

The annual CPUE indices fluctuate around unity in a 3–4 year cycle, with small error bars around each point. Analyses repeated on independent subsets of core vessels yield annual indices that resemble each other closely, with little effect of standardisation. Within-year variance is small relative to the interannual variance in catch rates, reflecting the homogeneity of catch rates experienced across the fleet in any one year despite differences in fishing behaviour. The pattern of interannual variance appears not to be noise but a reasonably well determined signal of availability of these small albacore to the New Zealand troll fleet.

New Zealand is at the extreme range of albacore and the expansion /contraction of the small fish in the stock appears to be affected by climatic events outside the spatial and temporal scale of the New Zealand troll fishery. The El Niño/Southern Oscillation (ENSO) is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales, and the Multivariate ENSO Index (MEI) roughly coincides with the cyclical pattern of CPUE of troll-caught albacore in New Zealand waters.

The conclusion of this study is that CPUE of troll-caught albacore in New Zealand waters is unlikely to be a useful index of abundance, but is rather an index of availability of juvenile fish to New Zealand. There is probably no recruitment signal in these indices.

1 INTRODUCTION

1.1 The fishery

Two albacore stocks (North and South Pacific) are recognised in the Pacific Ocean. Albacore tuna caught in New Zealand waters are part of a single South Pacific Ocean stock that is distributed from the coast of Australia and archipelagic waters of Papua New Guinea eastward to the coast of South America and south of the equator to at least 49º S. The New Zealand catches represent about 10% of the total and are predominantly taken in summer by trolling, with most of the balance taken over winter by surface longline.

With the establishment of the Western and Central Pacific Fisheries Commission (WCPFC) in 2004, stock assessments of the South Pacific Ocean (SPO) stock of albacore tuna are now undertaken by the Oceanic Fisheries Programme of the Secretariat of the Pacific Community under contract to WCPFC. No assessment is possible for albacore within New Zealand fisheries waters as the proportion of the greater stock found within New Zealand fisheries waters is unknown and likely varies from year to year. Albacore taken by trolling are juveniles and provide some of the only information on recruitment to the wider South Pacific stock.

Albacore are currently outside the Quota Management System, but New Zealand, as a member of the WCPFC, has committed to not increasing the number of vessels actively fishing for South Pacific albacore in the Convention Area south of 20° S above "current" (2005) levels or "recent historical" (2000-2004) levels. (Conservation and Management Measure passed at the second annual meeting of the WCPFC).

The earliest known commercial catch of tuna in New Zealand waters (species unknown but probably skipjack tuna) was by trolling and was landed in Auckland in the year ending March 1943. Regular commercial catches of tuna, however, were not reported until 1961. Before 1973 the albacore troll fishery was centred off the North Island (Bay of Plenty to Napier and New Plymouth), with the first commercial catches off Greymouth and Westport (54% of the total catch) in 1973. These catches (species unknown but primarily albacore and skipjack with some southern bluefin and yellowfin tuna possible) are summarised in Figure 1.

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 variability, albacore landings have steadily increased since the start of commercial fishing in the 1960s. The average catch in the 1960s of 19 t, increased in the 1970s to 705 t, in the 1980s to 2256 t and in the 1990s averaged 4571 t. Catches peaked at more than 6700 t in 2002–03 due largely to the participation of two chartered longliners that exclusively targeted albacore (longline-caught albacore are more usually a bycatch of fishing for bigeye or southern bluefin tunas). Since then catches have declined to their lowest level since 1988 of less than 2100 t in 2007, with a subsequent increase in 2008 to nearer 3700 t (Table 1).

Albacore taken by trolling are small (averaging about 5 kg each) and are mainly caught off the west coast of New Zealand during a narrow seasonal window each year (December to April) after which they become unavailable to that method. Their subsequent movements are unknown, but they are considered unlikely to be the same fish that are taken by longline through the winter and which average about 10 kg each.

New Zealand has been undertaking annual catch sampling of the troll fishery since 1996–97 and while that programme is useful for evaluating relative strength of the three cohorts commonly present, it is less useful for estimating longer term trends in recruitment without reference to some measure of relative abundance. This was first attempted in 2005 under project TUN2002/03 which used data through to 2004 (Unwin et al. 2005).

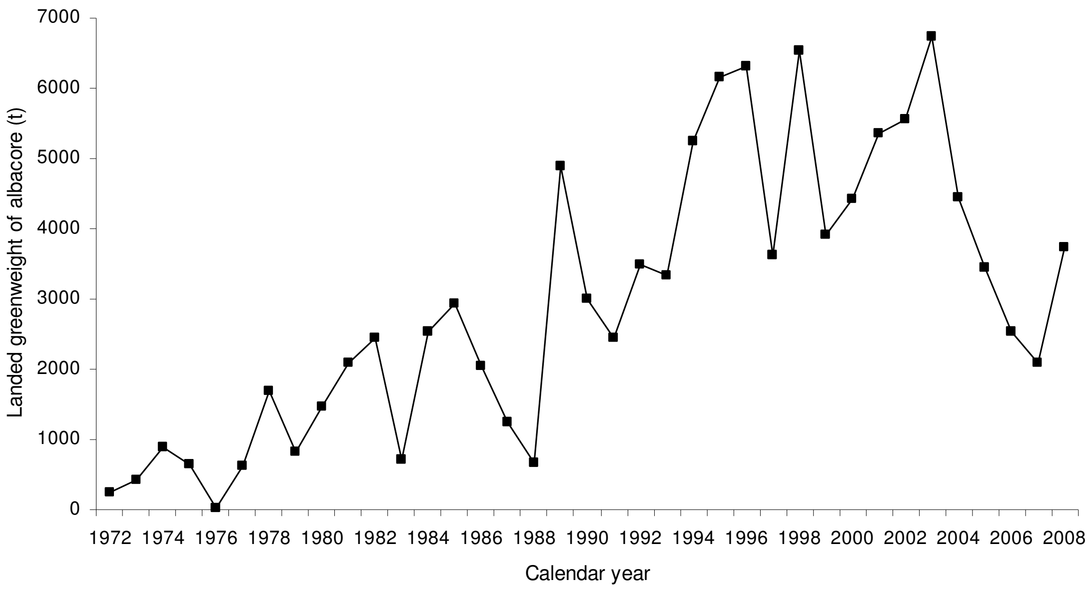

Figure 1: Catch of albacore (t) in New Zealand waters. (From MFish (2008), source: Lawson (2008)).

1.2 Previous work

The troll CPUE index from project TUN2002/03 (estimated using a negative binomial GLM and quasi Poisson GAM) was not accepted by the Highly Migratory Species Working Group as an index of abundance because the choice of potential explanatory variables was largely inappropriate, either due to the coarse scale at which catch effort data are captured on the CELR form type for trolling or for other reasons particular to the fishery such as its mode of operation concentrated in daylight hours and in one quarter of the year (January –March).

Sea Surface Temperature (SST and various derivatives thereof) obtained by remote sensing was considered most likely to have explanatory power, but were not available for the area off the west coast between 36 and 40^{o} S. This area accounted for 49% of the troll effort and effectively eliminated those data from the analysis. Quarter year was used as the temporal resolution in the previous study, but most troll effort occurs between January and March (Q2) and the other quarters are relatively unimportant. Longitude was important in that CPUE peaked between 170 and 172^{o} E, but this represents the difference between the west coast (main focus of troll activity) and the east coast which has always been relatively unimportant. Depth was offered and accepted into the model, but how that could be meaningfully associated with position at statistical area resolution is not clear. The measure of effort (number of hooks) used to calculate catch-per-unit-effort was also considered inappropriate.

While the above criticisms of the previous methods are valid and have been addressed wherever possible in this study, the resultant annual indices are similar and there is little effect of standardisation. This reflects the homogeneity of catch rates experienced across the fleet in any one year despite differences in fishing behaviour and is evidenced by the small within-year variance in catch rates relative to the interannual variance in catch rates.

Unwin et al. (2005) surmised that ocean agitation that determines the depth of the seasonal thermocline may influence the vertical availability of albacore to surface gears, with high agitation increasing thermocline depth, and making age 2 year albacore less available at the surface. They concluded that improved spatial resolution at which troll catch and effort data is recorded would be necessary to improve the utility of troll CPUE for an albacore assessment. However, this study highlights the lack of contrast in the data within any one year, and concludes that availability of juvenile albacore to this fishery is likely to depend on factors outside of the New Zealand EEZ including wider ecological effects that would be confounded with year effect in any standardised analysis of abundance.

2 DATA SOURCES AND METHODS

2.1 Data sources

Tuna fisheries catch and effort data have been collected by the Ministry of Fisheries since at least 1976 (Ministry of Agriculture and Fisheries at that time), but changes to data collection and processing mean that domestic fisheries catch and effort data are not currently available before 1989. CELR data are available beginning with the third quarter of 1989 (start of the 1989–90 fishing year).

Troll-caught albacore are estimated in numbers of fish on Catch Effort Landing Returns (CELRs) but the actual weight landed at the end of the trip is available from the bottom of the form and is verifiable from Monthly Harvest Returns (MHRs) that are required to be submitted by permit holders.

The characterisation was done on landed greenweight of albacore allocated to effort records proportionate to the estimated catch (in numbers of fish) using a variation of the Starr methodology (Starr 2007) that does not further amalgamate the data as reported. All troll catch and effort is reported on CELRs so that there is no need to combine data across formtype and therefore no need to further amalgamate data. Albacore are considered to belong to a single New Zealand stock and this reduces the complexity that is usually associated with the allocation of landed catch to effort in statistical areas that straddle more than one Fishstock.

The CPUE standardisation was done on estimated catch (numbers of fish), as is traditional for tuna, offered to the model as number of albacore per record (at the original CELR resolution). Almost all troll effort is targeted at albacore, so that records generally represented one vessel-day except when more than one Statistical Area was fished in the same day.

2.2 Methods used for grooming and collation of MFish catch and effort data

Catch and effort data were obtained from the MFish data base "*warehou*" using a two-part extract. The first part identified candidate trips by searching for all landings to Fishstock ALB 1 or which fished using troll gear between 01 October 1989 and 30 September 2008. Once trips that satisfied these criteria were identified, all effort and landing records associated with these trips were extracted. All statistical areas are valid for ALB 1. The total landed greenweight available from the bottom of the form and obtained in the "*warehou*" extract differs from the total landings of albacore reported in Ministry of Fisheries Science Group (2008) (which in the early years would have been derived from Licensed Fish Receiver Returns) especially in the early part of the time series. This is due to the relatively poorer error checking routines for catch effort data in those years.

Landings, estimated catch, and associated effort were all groomed separately before merging and the resultant annual total landed and estimated catches are compared in Figure 2 and Table 1. Estimated catch could be expected to overlay landed catch in Figure 1 perfectly (given the primary and secondary y-axis scales used) if all albacore were troll caught and weighed about 5 kg. The departure between the two series in the early 2000s reflects the increased proportion of longline catch of larger albacore during that period.

Outlier values in the landing data were identified by finding the trips with very high landings for albacore based on verified maximum values supplied by the Ministry of Fisheries Information Management Group. The effort data for these trips were then used to calculate the trip CPUE based on landings and the total estimated catch for the trip was calculated. Trips which had a ratio of landed to estimated catch which exceeded 4 and a CPUE which exceeded two times the 95th percentile of the trip CPUE distribution for the entire dataset were dropped entirely.

Table 1: The effect of grooming on the extract. Verified landed greenweight (t), landed greenweight from the bottom of the form as extracted from "*warehou*" database, landed greenweight after grooming (as used for the characterisation); as a percent of verified landings and as a percent of data available in the extract, estimated catch (thousands of fish) in the groomed dataset (as used for the CPUE analysis).

Fishing year	QMR reported catches (t)	Bottom of form (some edits)	Landed catch for analysis (t)	% analysis catch of landed catch	% analysis catch of QMR	Estimated catch in dataset (thousands fish)
89/90	3 144	2 051	1 991	97	63	481
90/91	2 451	2 296	2 215	96	90	470
91/92	3 434	4 876	354	7	10	700
92/93	3 323	1 715	1 262	74	38	571
93/94	5 315	4 546	1 220	27	23	997
94/95	6 195	4 551	3 900	86	63	1 065
95/96	6 316	5 583	4 836	87	77	877
96/97	3 728	4 168	3 996	96	107	517
97/98	6 525	6 711	6 152	92	94	815
98/99	3 727	3 852	3 731	97	100	405
99/00	4 697	4 918	4 681	95	100	679
00/01	5 509	5 500	5 364	98	97	617
01/02	5 531	5 817	5 680	98	103	622
02/03	6 300	6 583	6 432	98	102	798
03/04	4 969	5 246	5 062	97	102	774
04/05	3 501	3 622	3 581	99	102	518
05/06	2 627	2 799	2 774	99	106	437
06/07	2 069	2 210	2 185	99	106	385
07/08	3 631	3 887	3 737	96	103	687

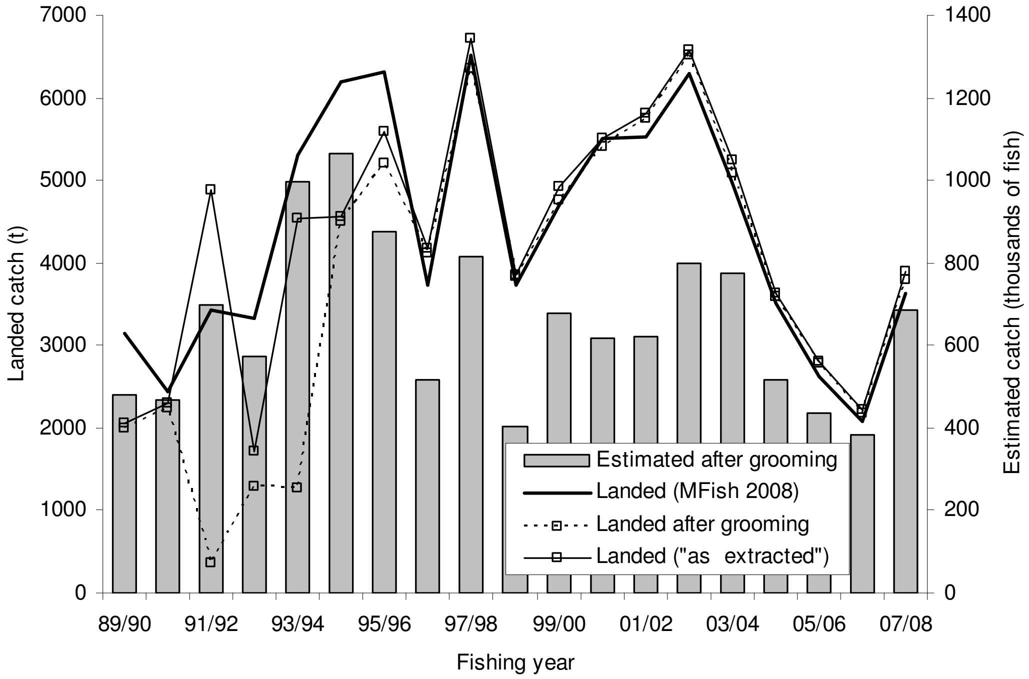

Figure 1: The effect of grooming on the extract. Verified landed greenweight (t); bold line, landed greenweight from the bottom of the form as extracted from "*warehou*" database, solid line, landed greenweight after grooming (broken line), estimated catch (thousands of fish) in the groomed dataset, Note: bars indexed on secondary axis.

Almost all albacore were landed green (whole) with a conversion factor of unity used to back-calculate greenweight from landed (processed weight) so that changes over time in conversion factors are not a concern for this species. Most albacore were landed to destination code L (landed to a Licensed Fish Receiver in New Zealand), but there were significant landings reported to destination code "R" meaning that they were retained on board for subsequent landing. These fish are not identifiable when subsequently landed and there is therefore a risk of double counting. When destination code "R" was used the entire trip was dropped with the loss of over 8600 t of albacore from the analysis dataset. The loss was most severe in the early 1990s but only affected the characterisation and was not reflected in the CPUE dataset which was based on estimated catch in numbers of fish. The shortfall apparent in landed catch when compared with the annual totals from LFRRs in those years (Figure 1) does suggest that there was in fact no double counting and that the landings coded to destination "R" could have been retained in the dataset.

Occasional outlier values (input errors) in the effort data were identified by comparison with empirical distributions derived from the effort variable (duration or number of sets), and where the values were in the extreme upper and lower tails of the distribution (a multiple of the 95th percentile value), they were replaced with the median value for the effort field for the affected vessel. Missing effort data were treated similarly. Missing values for statistical area, method, or target species within any trip were substituted with the predominant (most frequent) value for that field over all records for the trip. Trips with all fields missing for one of these descriptors were dropped entirely.

The allocation of landed catch to effort, performed for the characterisation section of the report, was done without further amalgamation of the data, by allocating the landed greenweight, declared at the end of the trip, to the effort events in the trip in proportion to the estimated catch. Where there were no estimated catches during the trip, the allocation was proportionate to the amount of effort. This method of using allocated landings retained more than 95% of landed ALB 1 for analysis in most years (the exceptions being 1991–92 and 1993–94 when there were several very high landings with the destination code "R", i.e. retained onboard). The allocated landed greenweights were then raised for each record in the dataset to represent, when summed, the QMR annual totals and used to describe the ALB 1 fisheries in the characterisation part of this study.

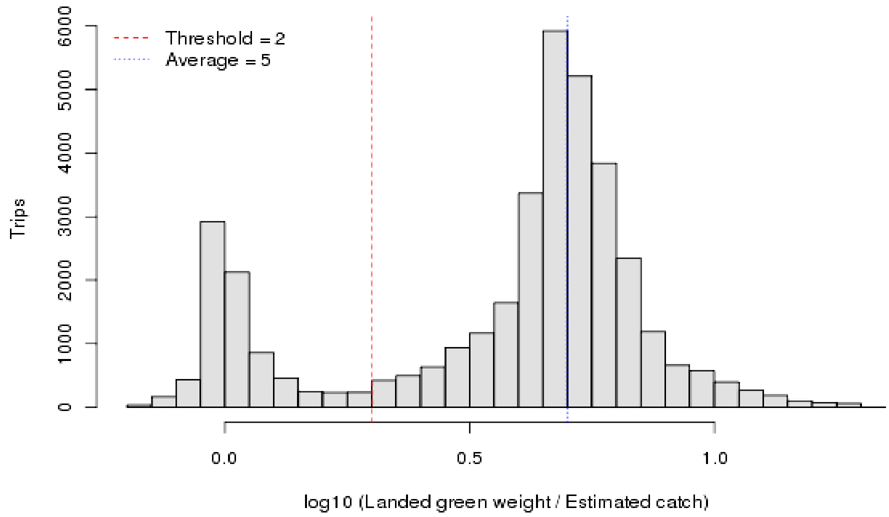

Figure 2: The distribution of values for log10 (landed weight / estimated catch) for individual fishing trips. Fish erroneously reported in weight are evident in this plot where they are centred on 0 (log10(1)). The dashed vertical line indicates the threshold below which a trip was deemed to have erroneously recorded estimated catch in weight rather than numbers.

For the CPUE standardisation part of this study, records for which any field had been corrected or replaced during grooming were dropped. Estimated catches were compared to the allocated landed greenweights for each trip to identify catches erroneously reported in weight (Figure 2). These records were converted back to numbers of fish using an assumed average weight of troll-caught albacore 5 kg. The data available for each trip included estimated (numbers of fish) and landed (greenweight) catch of albacore, total hours fished, total number of tows-sets-lines-hooks (depending on fishing method) fishing year, statistical area, target species, month of landing, and a unique vessel identifier.

2.3 Methods used for catch-per-unit-effort analysis

2.3.1 Definition of fisheries

The fishery in which juvenile albacore are monitored uses the troll method, is targeted at albacore, and operates in any statistical area off the west coast of either island. No restriction on month was used but most catch was taken during December to March in each fishing year.

2.3.2 Core fleet definitions

The data sets used for the standardised CPUE analyses were further restricted to those vessels that participated with some consistency in the defined fishery. Core vessels were selected on the basis of involvement by specifying two variables: the number of trips that determined a qualifying year, and the number of qualifying years that each vessel participated in the fishery.

The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of albacore. This selection process generally reduced the number of vessels in the dataset by about 70% while reducing the amount of landed albacore catch by about 20%. Note that the vessels thus selected are not necessarily the top vessels with respect to catching albacore.

2.3.3 Sea Surface Temperatures

The oceanographic data included in the analysis are from a Pacific Ocean Hindcast data set derived from a model-based ocean analysis system (NOAA NCEP EMC CMB Pacific). These data were available for each month from January 1980 to December 2008 and at a spatial resolution of one degree of latitude and 1.5 degrees of longitude. (http://iridl.ldeo.columbia.edu/SOURCES/.IGOSS/.nmc/.Reyn_SmithOIv2/.monthly/.dataset_documentation.html).

Sea Surface Temperature (SST) was collated at statistical area/month resolution for the whole time series. A mean monthly temperature based on a 10 year series (1990-1999) was also calculated for each statistical area, and the anomaly from those measures of normality was calculated for each area and month. These anomalies are effectively the SSTs with the strong seasonal pattern (highly correlated with month) removed. A pattern of colder and warmer than usual years is apparent when those monthly anomalies are averaged over a fishing year. The pattern is consistent across statistical areas, though the temperature range is generally greater and the minimum temperatures cooler the further south the statistical area. For clarity and contrast, only two areas are presented as examples (Figure 3). It is interesting to note that while El Niño events can generate an extreme water temperature response, the sign of that response relative to normal temperatures is not always predictable (Uddstrom & Oien 1999).

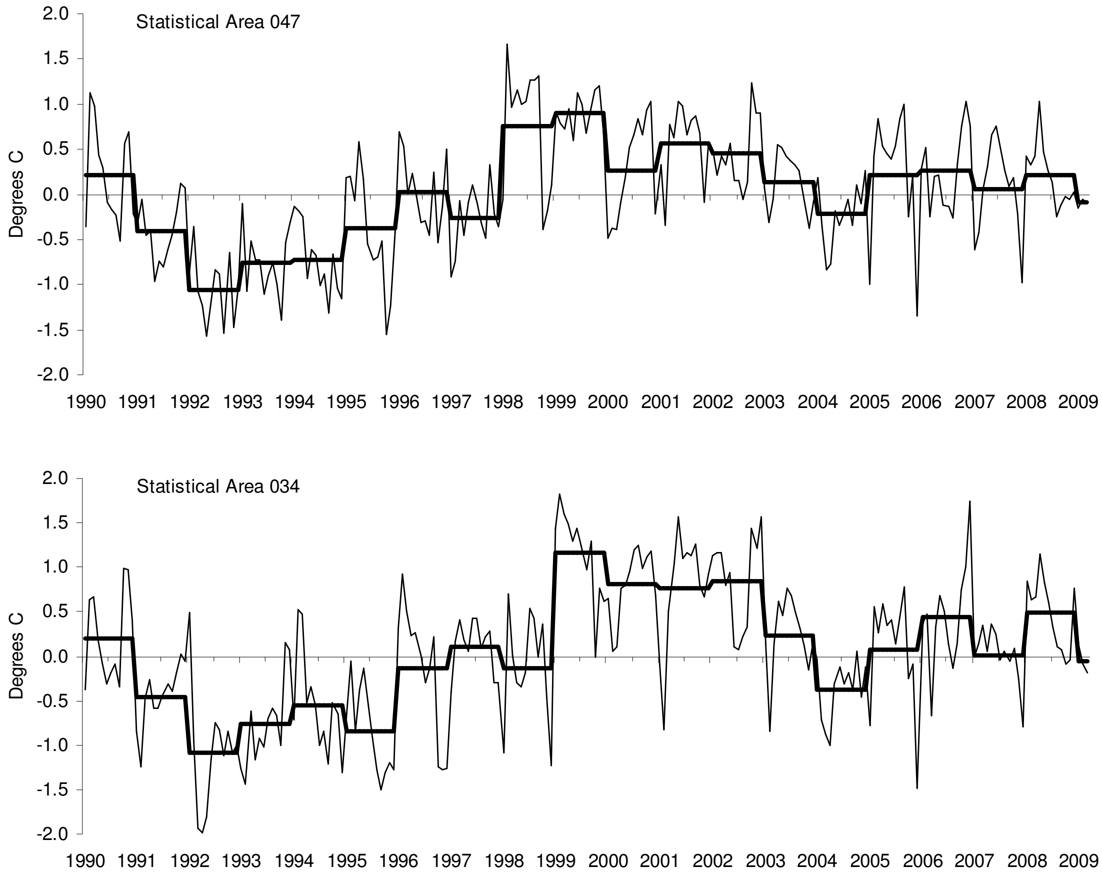

Figure 3: Monthly sea surface temperature anomalies (light line) relative to a ten year (monthly) average, and annual mean anomaly from ten year average (heavy line) for two selected statistical areas, 047 [Upper], and 034 [Lower].

2.3.4 Models

A lognormal linear model was fitted to successful landed catches of ALB 1, excluding zero catches. Catches were standardised for variance in the explanatory variables using a stepwise multiple regression procedure, selecting until the improvement in model R^2 was less than 0.01. The year effects were extracted as canonical coefficients (Francis 1999) so that confidence bounds could be calculated for each year.

The dependent variable for the lognormal models was the log of numbers of albacore per record where a record represented a vessel-day in most cases. The explanatory variables offered to the model were: *fishing year* (always forced as the first variable), and *month* (of catch), *Statistical Area (zone)*, and a unique *vessel* identifier. The logs of number of *vessel days* and *duration* were offered as alternative measures of effort to explain catch as a catch rate. Continuous effort variables were offered as third order polynomials. Environmental variables also offered as third order polynomials and included sea surface temperature (*SST*), *Monthly SST Anomaly*, and *Annual SST Anomaly*.

A month*area interaction term was also offered to attempt to account for the observed southerly drift of effort in this fishery during the season.

2.3.5 Statistical area zones

The spatial resolution of troll catch and effort data is determined by New Zealand Fisheries statistical area (Figure 4). For the CPUE standardisation statistical areas off the west coast were amalgamated into latitudinal bands (statistical area zones) to allow the model to account for the southerly drift of fish and fishers during the season as described in Table 2. This loses the longitudinal resolution in the data, but it is minimal (inshore/offshore), and of little interest as most activity occurs in the inshore statistical areas.

Unwin et al. (2005) found longitude was important in explaining variance in troll CPUE in that CPUE peaked between 170 and 172^{o} E, but that analysis was not confined to west coast areas, and that result describes the difference between the west coast (main focus of troll activity) and the relatively unimportant east coast.

Table 2: Statistical area groupings used to define the west coast troll fishery.

Statistical area (zone)	Statistical areas included
48	048, 104
47	047, 103
46	046, 102
45	045,
42	042, 101
41	041, 801, 701
36	036, 037, 038, 040, 703, 702
35	035, 704
34	034, 705
33	033, 706
32	032, 501
31	031, 030, 502
Other	East coast and other

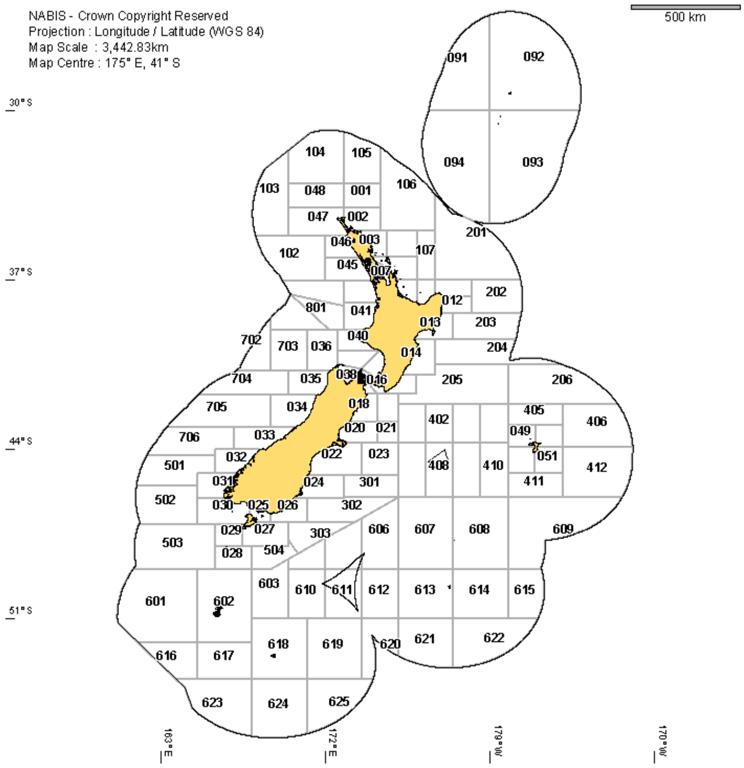

Figure 4: New Zealand fishery statistical areas used for spatial reporting of troll catch and effort.

3 RESULTS

3.1 Characterisation of the ALB 1 fisheries

Albacore are the second most important component of the domestic tuna catch (after skipjack), and are taken mostly by troll gear (54–96% annually since 1989–90) with most of the balance taken by surface longline (Table 3). Troll gear also takes a small amount of skipjack with occasional catches of other tuna species. Longline is mostly targeted at bigeye, and southern bluefin tunas and more recently swordfish, but the greatest part of the catch consists of albacore.

Following the development of domestic longlining in the early 1990s, the domestic tuna fleet operating in New Zealand fisheries waters peaked in 2001 and has subsequently declined. The rapid expansion, particularly in the late 1990s through to 2000, arose because tuna fisheries were among the few open access fisheries in New Zealand at that time. In 2002–03 a new longline fishery developed that exclusively targeted albacore and contributed to the peak in albacore catches that year (Kendrick 2006). It centred on two chartered (Philippine-flagged) vessels that have not returned since.

The two fishing methods operate quite differently from each other both seasonally and spatially, although many vessels fish both gear types, switching from troll to longline in time for the start of the bluefin tuna season in April–May (Figure 5). The longline fishery is widespread through New Zealand waters but catches most of its albacore in winter off the east coast of the North Island as a bycatch of the southern bluefin tuna fishery. The troll fishery is mainly a near-shore activity operating in summer months off the west coast of both islands (Figure 6). The size of fish also differs between methods with troll caught albacore averaging about 5 kg each and not considered likely to be the same cohort that are caught by longline later in the same year but which are usually about twice that size. The longline fishery is not considered in any further detail this study.

Table 3: Distribution of landed albacore by method and by fishing year for ALB 1 in tonnes and in percent of annual landings. Catches are raised to the annual QMR catch (Table 1). Percentages sum to 100 by year. SLL, surface longline.

Fishing	Landed catch (t)			Landed catch (%)		
year	Troll	SLL	Other	Troll	SLL	Other
89/90	3 030	68	46	96.4	2.2	1.5
90/91	2 361	43	48	96.3	1.7	2.0
91/92	2 379	831	225	69.3	24.2	6.5
92/93	2 602	663	58	78.3	19.9	1.8
93/94	3 286	1 959	71	61.8	36.9	1.3
94/95	5 450	713	33	88.0	11.5	0.5
95/96	5 244	989	83	83.0	15.7	1.3
96/97	2 739	953	36	73.5	25.6	1.0
97/98	4 973	1 527	25	76.2	23.4	0.4
98/99	2 028	1 686	13	54.4	45.2	0.3
99/00	3 307	1 365	25	70.4	29.1	0.5
00/01	3 455	2 040	13	62.7	37.0	0.2
01/02	3 294	2 232	7	59.5	40.3	0.1
02/03	4 145	2 162	11	65.6	34.2	0.2
03/04	4 097	853	18	82.5	17.2	0.4
04/05	3 009	481	11	86.0	13.7	0.3
05/06	2 203	418	6	83.9	15.9	0.2
06/07	1 783	280	6	86.2	13.5	0.3
07/08	3 415	201	15	94.1	5.5	0.4

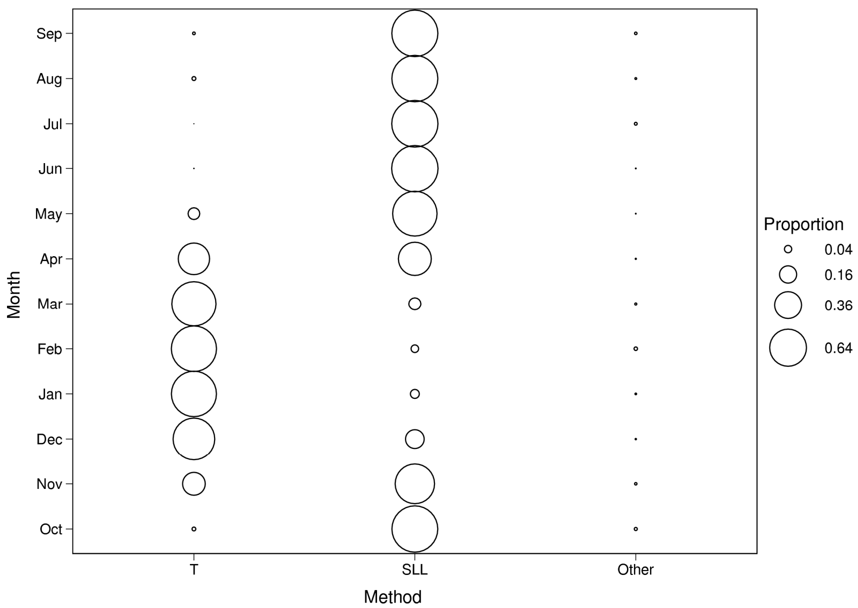

Figure 5: Seasonal distribution of landed albacore (proportion of landed weight) by fishing method, fishing years 1989–90 to 2007–08 combined.

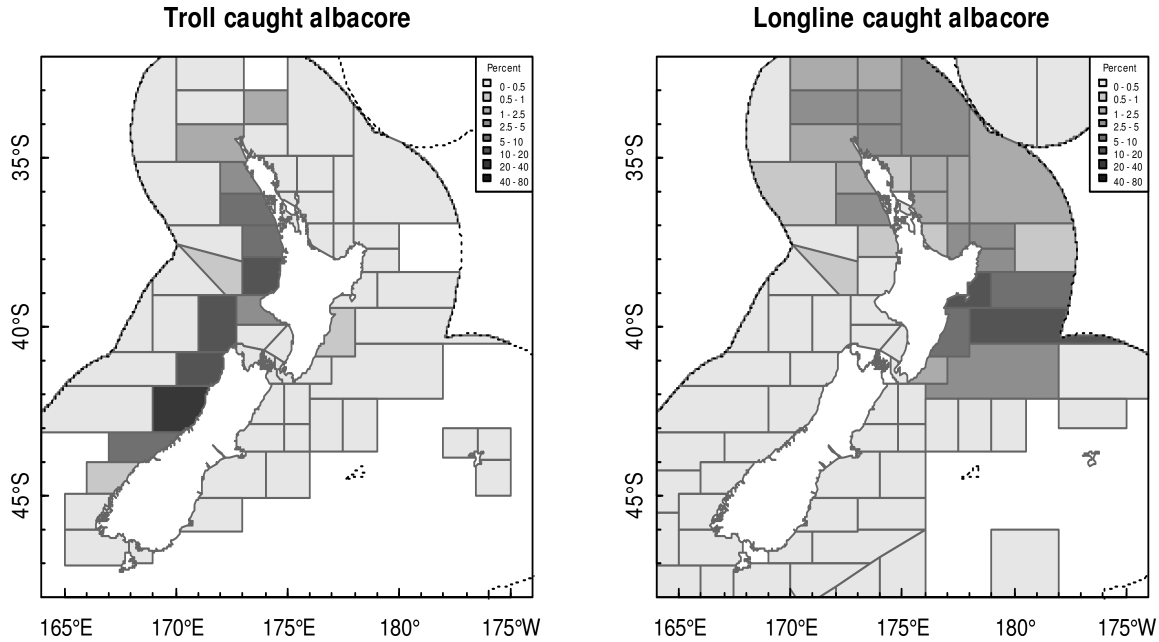

Figure 6: Recent spatial distribution of albacore catches (2000–01 to 2007–08) for the two main fishing methods (troll and surface longline) by statistical area. Percent of total number of fish for method. For statistical area labels see Figure 4.

3.2 Characterisation of the albacore troll fishery

The New Zealand tuna fleet is dominated numerically by about 170 (in 2008) domestically owned and operated vessels (mostly 15 to 25 m length) that fish for tunas using troll and longline gear, some of them switching between gear types by season or operating part of the year in non-tuna fisheries. There has been a significant reduction in the New Zealand tuna fleet since 2001 and most of the reduction has occurred in vessels smaller than 50 GRT (Anon 2009).

The numbers of vessels targeting albacore by troll for each fishing year is shown in Figure 7. The 2007–08 count of 148 troll vessels is just over 51% of the vessels fishing by this method in 2000–01 (288) and about 32% of the peak number of vessels operating in 1993–94 (455). These figures are from the groomed dataset and may be an underestimate in some years.

Troll catches peaked in the mid 1990s at over 5000 t and again in the early 2000s at nearer 4000 t (Table 3). Catches have declined each year since 2002 consistent with the decline in numbers of vessels operating in this fishery (Figure 7).

The troll fishery in New Zealand waters is almost entirely targeted at albacore (more than 99% in each year since 1989–90) (Figure 8, Table 4). Most of the catch in each year has been taken between January and March with some expansion into the first and third quarters of the fishing year in the mid 1990s and early 2000s (Figure 9).

Before 1973 the albacore troll fishery was centred off the North Island (Bay of Plenty to Napier and New Plymouth), with the first commercial catches off Greymouth and Westport (54% of the total catch) in 1973. In the 1990s there was considerable troll activity in east coast areas (primarily the Bay of Plenty) but that has since declined and the fishery is now focused on the inshore statistical areas off the west coast of both islands with the greatest catches in most years taken from Statistical Area 034 (Figure 10).

In 1998–90 and 1999–2000, the effort off the west coast was largely confined to the higher latitudes, south of about 40° S (Kendrick 2006), but since 2000–01, trolling has started in December and January as far north as 35° S, and then shifted south as summer weather conditions allow the fleet of small vessels to operate at higher latitudes off the exposed coast (Figure 11). In the third quarter there is an indication of some troll vessels returning northward while others switch gear to longline in time for the start of the southern bluefin fishery that takes place off the west coast of the South Island starting in May–June.

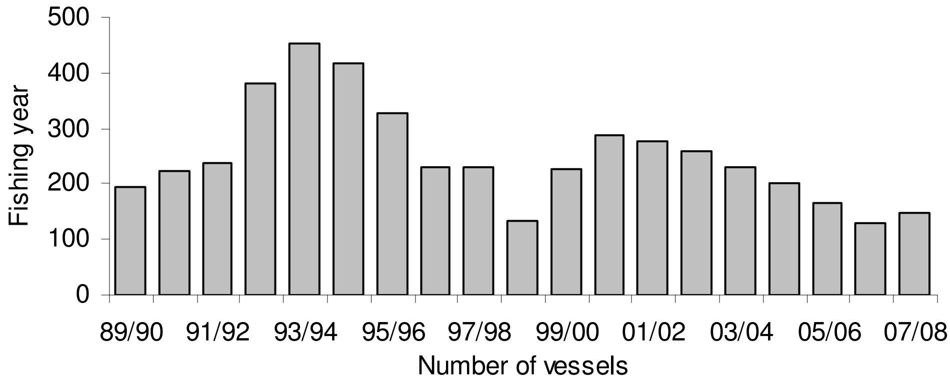

Figure 7: Number of vessels in the groomed dataset that used troll method and targeted albacore by fishing year.

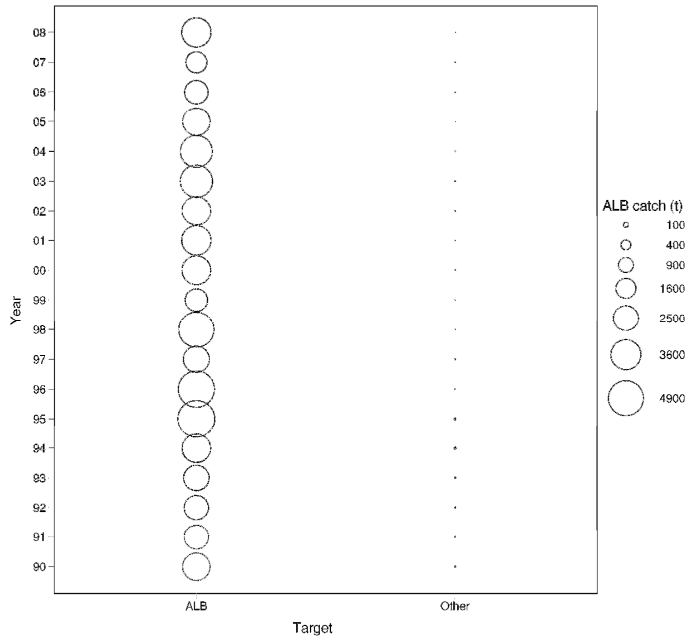

Figure 8: Distribution of troll caught albacore for ALB 1, by target species and fishing year. Circle areas are proportional to the catch totals for the troll method by year and are given in Table 4.

Table 4: Distribution of landed albacore for troll method by target species and fishing year in tonnes and in percent of annual landings; ALB, target species is albacore. Percentages sum to 100 by year.

Fishing	Landed catch (t)		Landed catch (%)	
year	ALB	Other	ALB	Other
89/90	3 021	8.7	99.7	0.3
90/91	2 358	2.6	99.9	0.1
91/92	2 374	5.0	99.8	0.2
92/93	2 595	6.8	99.7	0.3
93/94	3 263	22.9	99.3	0.7
94/95	5 436	13.8	99.7	0.3
95/96	5 241	3.4	99.9	0.1
96/97	2 736	2.5	99.9	0.1
97/98	4 972	1.3	100.0	0.0
98/99	2 027	0.6	100.0	0.0
99/00	3 305	2.1	99.9	0.1
00/01	3 454	1.0	100.0	0.0
01/02	3 292	1.7	99.9	0.1
02/03	4 142	2.9	99.9	0.1
03/04	4 096	0.9	100.0	0.0
04/05	3 009	0.1	100.0	0.0
05/06	2 203	0.4	100.0	0.0
06/07	1 783	0.4	100.0	0.0
07/08	3 415	0.1	100.0	0.0

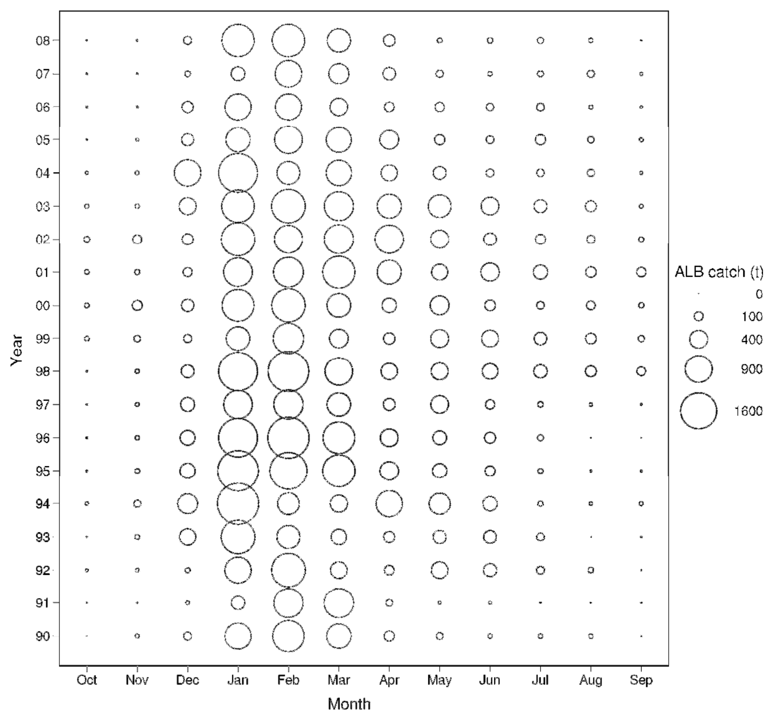

Figure 9: Distribution of targeted troll catch of albacore by month and fishing year.

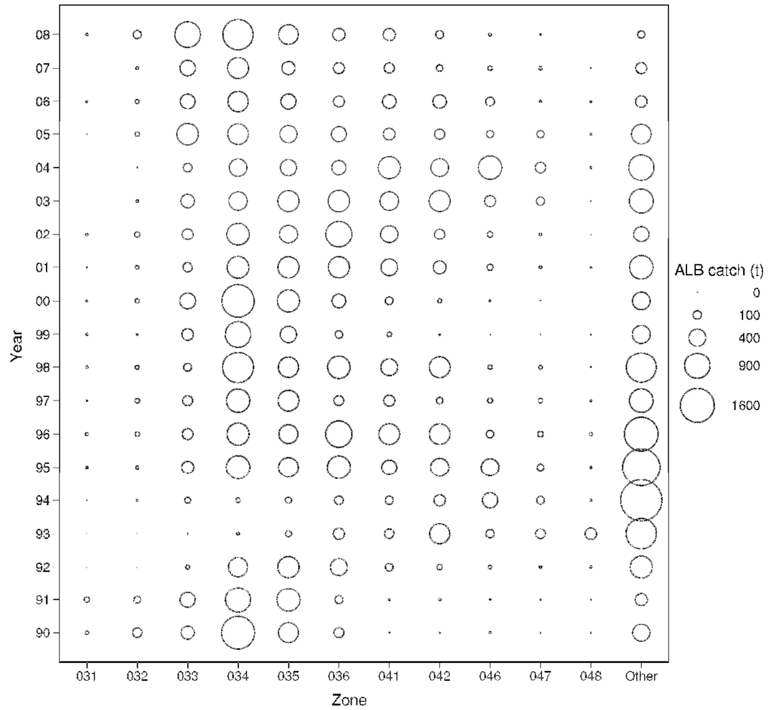

Figure 10: Distribution of targeted troll catch of albacore by statistical area (zone) and by fishing year. Circle areas are proportional to the annual catch totals for targeted troll given in Table 4.

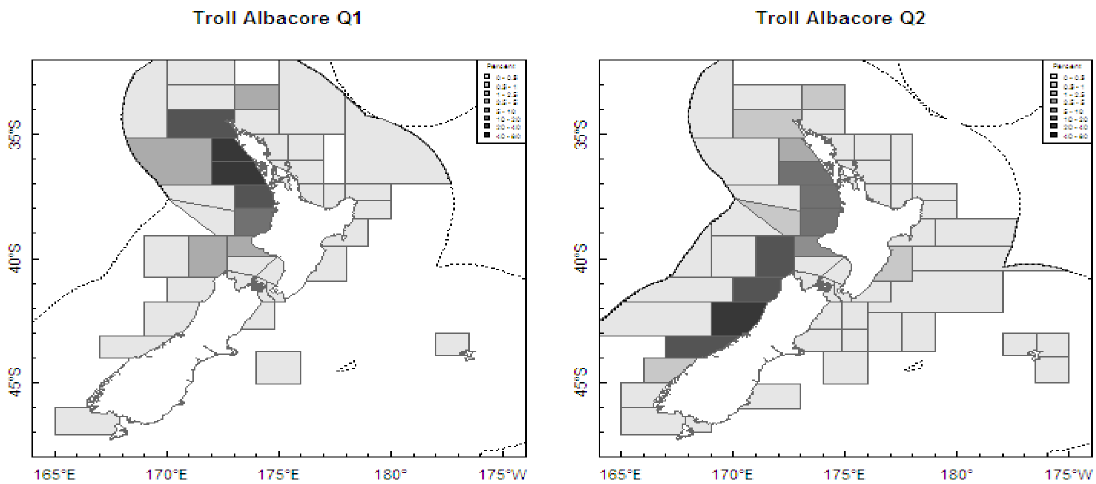

Figure 11: Spatial and seasonal distribution of recent troll catches of albacore (fishing years 2000–01 to 2007–08 combined), by year-quarter and statistical area. Percent of total troll catch. Q1, October – December; Q2, Jan–Mar; Q3, Apr–Jun; Q4, Jul–Sep. For statistical area labels see Figure 4.

3.2.1 Measures of effort for troll

The measures of effort for trolling include number of lines, number of hooks, vessel-day, and duration. Number of sets is not a variable collected for this method. The distribution of values for the number of lines (Figure 12) and number of hooks (Figure 13) used confirm that these data are contaminated with badly recorded effort. For example, there is a mode at 20 hooks (and at 25 lines) which is not feasible on boats of this size. Fishers are instructed to record the maximum number of (lines /hooks) in the water at one time, but it appears that they sometimes multiply this by an unknown factor.

The Highly Migratory Species Working Group (HMSWG) has, in the past, expressed a lack of confidence in these data and has also noted that number and experience of the crew (not recorded) is probably more important in determining the number of albacore landed than is the number of lines or hooks (N. Smith, MFish pers. comms). There is not thought to be much variation in rig among troll vessels, and it was recommended that vessel-day is used as the measure of effort for this method.

The distribution of duration fished (Figure 14) seems less prone to misunderstanding and more likely to reflect total hours trolled in a day.

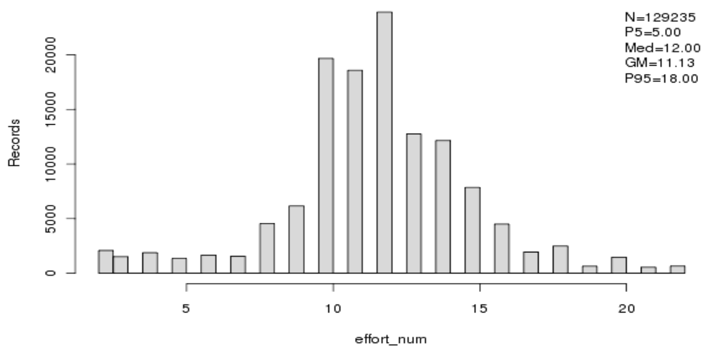

Figure 12: Distribution of effort 1 (maximum number of lines in the water at any time) for troll effort reported on CELRs .

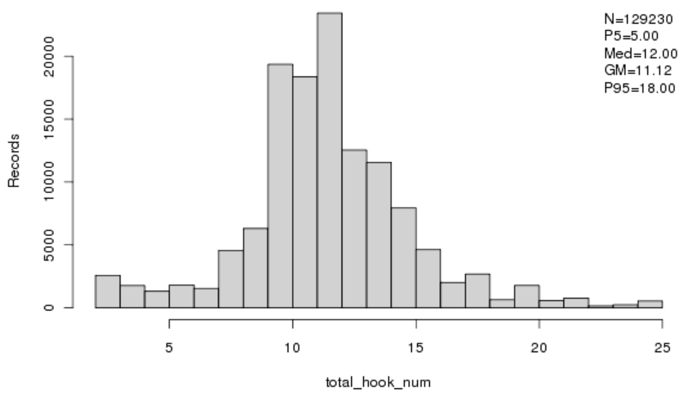

Figure 13: Distribution of effort 2 (maximum number of hooks in the water at any time) for troll effort reported on CELRs .

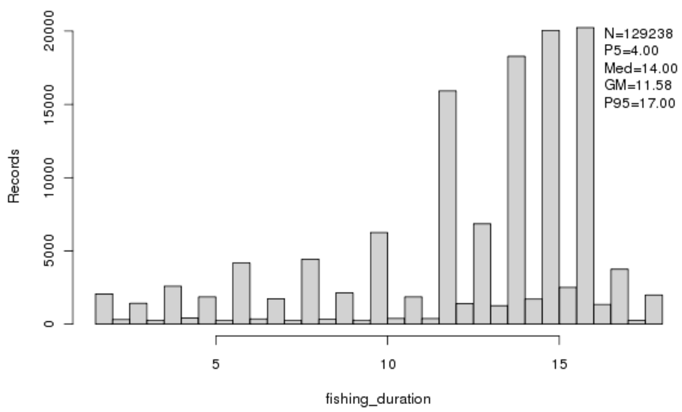

Figure 14: Distribution of duration of fishing for troll effort reported on CELRs.

3.2.2 Observer and other data

The albacore port sampling programme was established during the 1996–97 albacore fishing season. The first two years of sampling were funded through SPC, but the programme has been funded by the Ministry of Fisheries (costs recovered from industry) since 1998–99. Sampling typically occurs at three ports on the west coast of New Zealand, though only two ports were sampled in 2007 and 2008 due to the reduced distribution of fishing effort in those years. Sampling occurs during the austral summer (December–May).

Over the duration of the programme almost 58 000 albacore have been sampled for length (Figure 15). The length frequency data are provided to SPC annually and have been incorporated into the regional assessment for South Pacific albacore.

These multi-modal annual length frequency distributions reveal progressions of distinct modes associated with strong year classes. In 1999 a mode is evident in the length intervals 46–55 cm and dominates the catch length distribution in the following year. It remains evident in 2001 and 2002 as a large component of the broad mode in the large length classes, indicating this to be a strong cohort. The modal pattern in 1997 and high mean length may reflect the presence of a large cohort that dominated the fishery in 1995 (Unwin et al.2005).

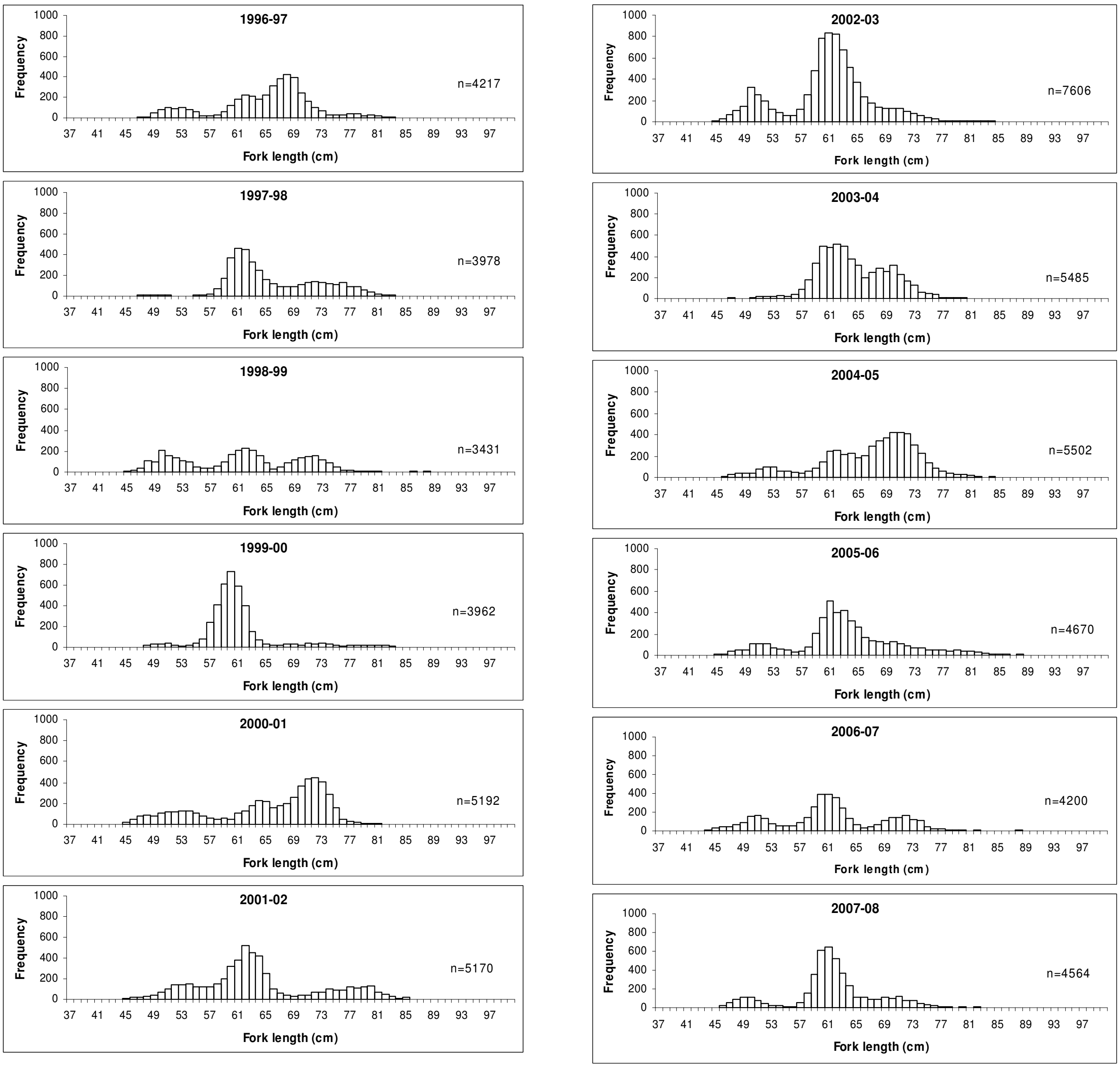

Figure 15: Size composition of albacore from shed sampling of the commercial troll fishery for 1996–97 to 2007–08 (reproduced from Griggs & Doonan (in press)).

In January 2008 when the data for this study were extracted, there existed four observed fishing trips (on four different vessels) for troll method in the Observer Database COD; one each in 1993, 1997, 2007 and 2008. The vessels were 15m, 16m, 28m and 36 m length with gross tonnages ranging from 35 to 127 t. The number of lines fished at any one time ranged from 6 to 14 lines (median 11) with presumably a single hook per line. Duration of fishing was not available.

3.3 Standardised CPUE

3.3.1 Core vessel selection and subsets

The number of vessels that have fished by troll for albacore is large (over 700), and a core fleet selection that required a minimum participation of at least five qualifying trips a year in at least four years accounted for about 80% of the landed catch but still resulted in a fleet of over 220 core vessels (Figure 16), too many to enter a model as individual levels of an explanatory variable in a standardised CPUE analysis. Raising the criteria to reduce the number of vessels tended to compromise coverage in the most recent years, therefore an alternative approach was taken of re-running the analysis on core vessels in batches. A high degree of correlation among the CPUE indices for each vessel subset would suggest that there is little noise in the overall CPUE index and that it is a good indicator of overall catch-per-unit-effort.

A batch of 40 core vessels that demonstrated good coverage and overlap in the time series was subset and is referred to as TROLL 1 (Figure 17). An alternative subset of 68 completely independent core vessels is referred to as TROLL 2 and their participation in the troll fishery is shown in Figure 18.

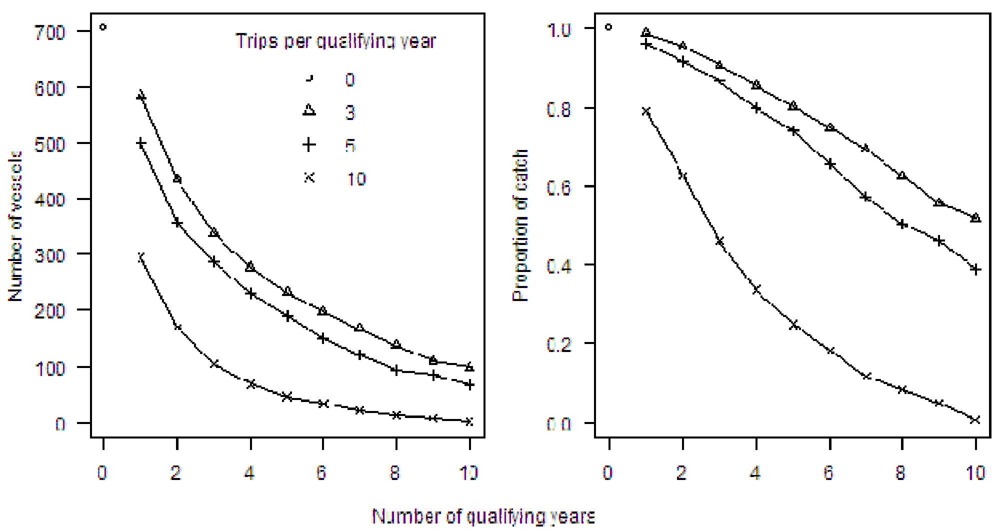

Figure 16: The number of vessels [top] and the proportion of estimated ALB 1 [bottom] retained in the ALB dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend.

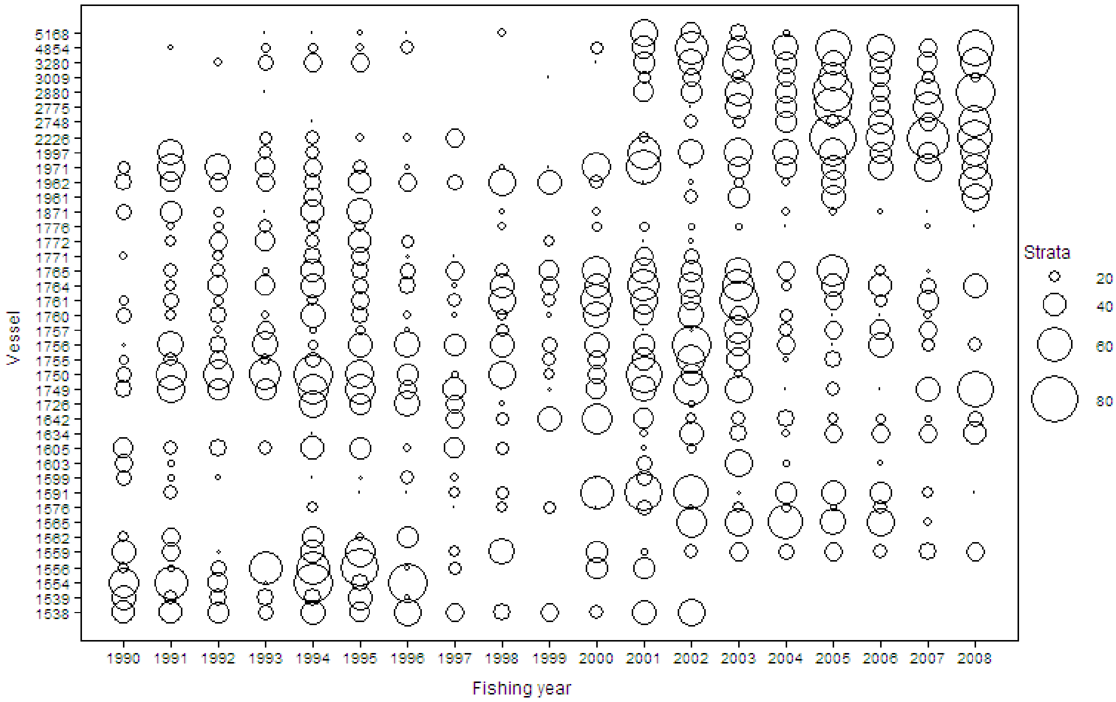

Figure 17: The participation of the TROLL 1 subset of core vessels (based on at least five qualifying trips per year in at least four years); Number of records for each vessel in each fishing year.

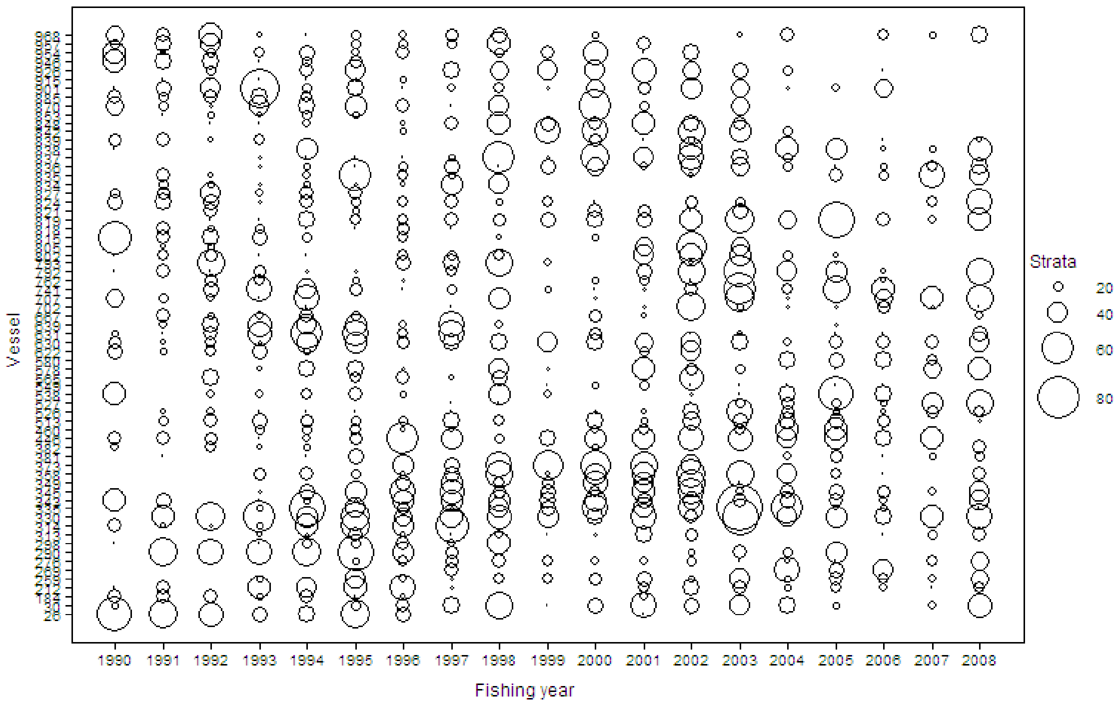

Figure 18: The participation of the TROLL 2 subset of core vessels (based on at least five qualifying trips per year in at least four years); Number of records for each vessel in each fishing year

3.3.2 Model selection

The parameterisation of the lognormal models for alternative vessel subsets was similar in that *duration of fishing* was the variable with the most explanatory power followed by *vessel ID*. *Month* was the third most important variable in both cases and entered TROLL 1 (Table 5) but not TROLL 2 (Table 6). The greater number of vessels (68 compared with 40) and the consequently greater degrees of freedom would probably account for that. Both models explained about 22% of the variance in catch rates as indicated by the R2 for the final model in bold, with the R. *Statistical area* (zone) did not enter either model and therefore the *month:area* interaction term could not be tested. *Sea Surface Temperature* (SST) and its two derivatives were not accepted into either model.

Table 5: Summary of the final lognormal model of the TROLL 1 core vessel subset. Independent variables are listed in the order of acceptance to the model. AIC, Akaike Information Criterion; R2, Proportion of deviance explained at each step and for the final model in bold; Final, whether or not the variable was included in the final model. Fishing year was forced as the first variable.

Term	DF	Deviance	AIC	R^2	Final
None	0	14 109	40 228	0.000	
Fishing year	19	13 500	39 638	0.043	*
Poly(log(duration), 3)	22	11 760	37 684	0.166	*
Vessel	61	11 114	36 958	0.212	*
Month	69	10 922	36 726	**0.226**	*
Statistical area zone	78	10 828	36 621	0.233	
Month:zone	121	10 620	36 432	0.247	
Poly(SST, 3)	124	10 577	36 380	0.250	
Poly(Monthly Anomaly, 3)	130	10 533	36 333	0.253	
Poly(Annual Anomaly, 3)	133	10 523	36 326	0.254	

Table 6: Summary of the final lognormal model of the TROLL 2 core vessel subset. Independent variables are listed in the order of acceptance to the model. AIC, Akaike Information Criterion; R2, Proportion of deviance explained at each step and for the final model in bold; Final, Whether or not the variable was included in the final model. Fishing year was forced as the first variable.

Term	DF	Deviance	AIC	R^2	Final
None	0	19 578	54 508	0.000	
Fishing year	19	18 800	53 773	0.040	*
poly(log(duration) 3)	22	16 110	50 844	0.177	*
Vessel	88	15 275	49 965	**0.220**	*
Month	96	15 088	49 746	0.229	
Statistical area zone	105	15 041	49 705	0.232	
Month:zone	150	14 776	49 457	0.245	
poly(Monthly Anomaly 3)	153	14 745	49 423	0.247	
poly(SST 3)	159	14 703	49 381	0.249	
poly(Annual Anomaly 3)	162	14 691	49 371	0.250	

3.3.3 Model fits

Diagnostic residual plots are presented for each model in Appendix A. For both models there is some departure from the lognormal assumption in the extreme tails of the distribution and some patterns in the residuals that are not adequately modelled.

Influence plots (Jiang & Bentley 2008) for each significant predictor variable in each model are presented in Appendix B. They describe the combined effect of the expected log catch rate at each level of the variable (model coefficients), and the distribution of the underlying data.

For both TROLL 1 (Figure B1) and TROLL 2 (Figure B4) there is a linear relationship between duration of fishing and predicted catch over the range in which most of the data occur with some complexity at the extremes where there are few observations. There has been a trend over most of the time series towards longer fishing duration and that has translated into increased observed CPUE. In TROLL 2 however, the trend reverses in the most recent four years so that overall the effect of duration for that subset of the core fleet is neutral.

For both TROLL 1 (Figure B2) and TROLL 2 (Figure B5) there is some contrast in performance between vessels and a tendency over time for the better performing vessels to be retained in the fishery so that the overall influence of vessel on observed CPUE has been to increase observed catch rates.

There is little difference in predicted catch with month for December through to March in TROLL 1, with lower catches predicted in November and in April coincident with declining effort (Figure B3). Catches in May and June are predicted to be considerably lower and in most years data are sparse for those months. A trend towards longer seasons with fishing extending into May has lowered observed annual CPUE overall although the magnitude of the effect is not great.

3.3.4 Trends in model year effects

The year effects from both models resemble each other closely despite the two analyses being based on independent subsets of core vessels. Each series varies around unity in a 3–4 year cycle with no overall trend up or down. The error bars around each point are small relative to the interannual variance and suggest that the pattern is not one of noise but a well determined index of availability of these fish to the troll fleet (Figure 19, Figure 20).

The effect of standardisation for both series is slight. The within-year variance is not great and there is not much potential for standardisation to change the interannual pattern in unstandardised CPUE.

The arithmetic mean CPUE based on all 700 troll vessels is very similar to that for each of the subsets TROLL 1 and TROLL 2, so that it is apparent that the pattern in the yearly effects reflects real interannual availability experienced across the fleet with only small differences able to be effected by the fishing behaviour of individual vessels.

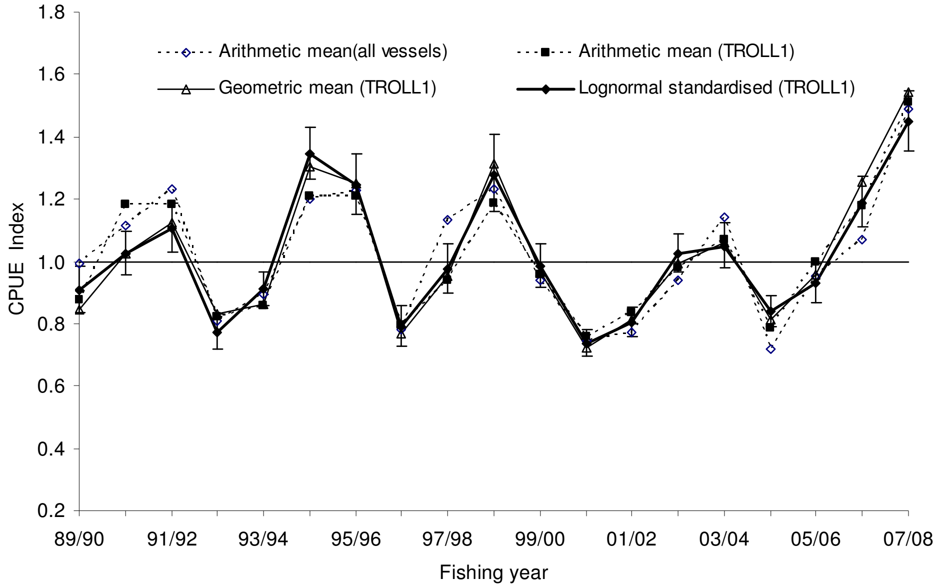

Figure 19: Effect of core vessel selection (vessel subset = TROLL 1) and standardisation on observed CPUE of troll-caught albacore in New Zealand waters. The core vessels comprise 220 vessels that completed a minimum of five troll trips per year in at least four years. TROLL 1 is a subset of 68 of those vessels.

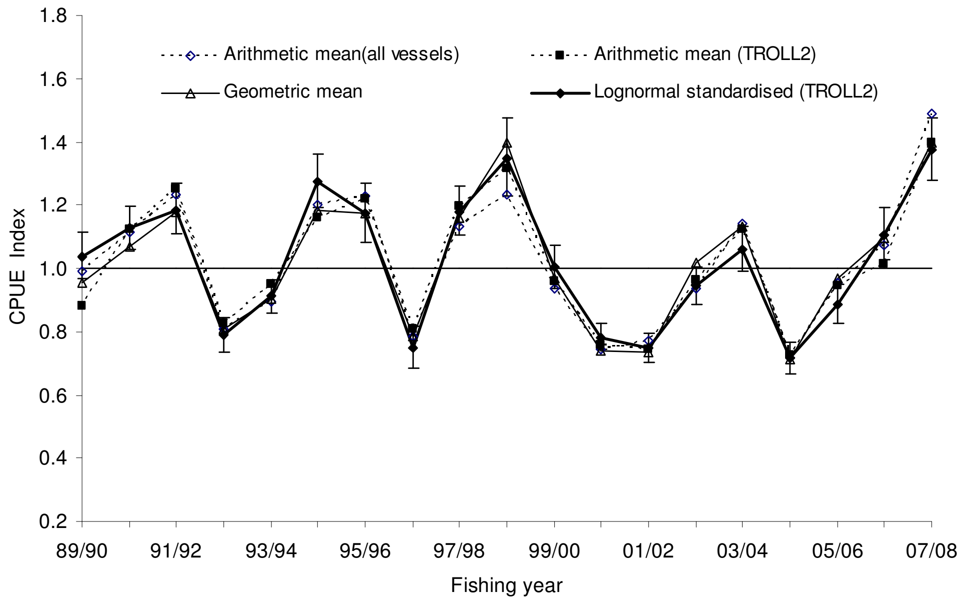

Figure 20: Effect of core vessel selection (vessel subset = TROLL 2) and standardisation on observed CPUE of troll-caught albacore in New Zealand waters. The core vessels comprise 220 vessels that completed a minimum of five troll trips per year in at least four years. TROLL 2 is a subset of 40 of those vessels.

3.4 Multivariate ENSO Index (MEI)

There is wide scale acceptance that large-scale climatic effects have an effect on the distribution and migration of albacore, and the El Niño/Southern Oscillation (ENSO) is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales. The mechanisms are many and various and can sometimes be conflicting. In the North Pacific El Nino events can create a northward and onshore extension of the range of albacore leading to them concentrating on the Californian coast. In the southwest Atlantic the availability of juvenile albacore to the nearshore fisheries of South Africa is reduced in El Niño years due to contraction of their range. Mechanisms associated with El Niño events that can retain or contract the range of highly migratory fish include deeper thermoclines that reduce their availability to surface methods and upwelling fronts that provide good foraging or through which they are reluctant to penetrate.

The Multivariate ENSO Index (MEI) attempts to monitor ENSO based on the six main observed variables over the tropical Pacific. These six variables are: sea-level pressure, zonal and meridional components of the surface wind, sea surface temperature, surface air temperature, and total cloudiness fraction of the sky http://www.cdc.noaa.gov/enso/index.html.

The MEI (sign reversed so that negative values correspond to warm El Niño events) is plotted for comparison with the standardised CPUE series for TROLL 1 and TROLL 2 in Figure 21.

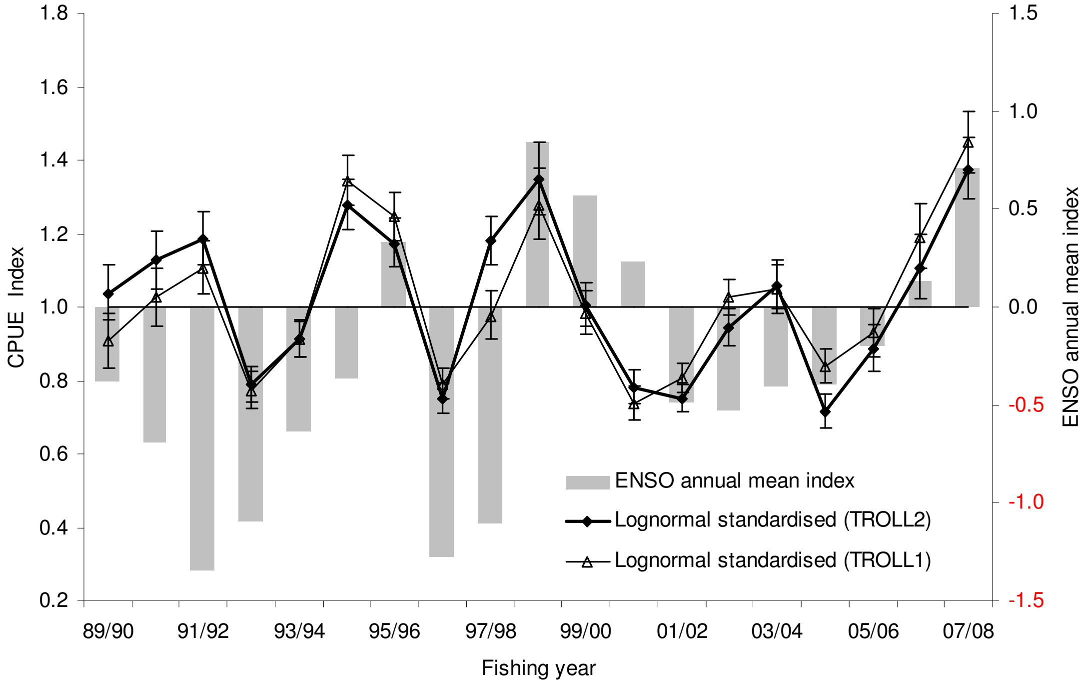

Figure 21: Comparison of annual indices of availability of troll-caught albacore in New Zealand waters (TROLL 1 and TROLL 2) with annual means of the Multivariate ENSO Index (MEI) an indicator of large climatic shifts affecting the South Pacific. Sign of ENSO index is reversed so that negative values indicate EL Niño events.

The negative MEI corresponds quite well with the changes in CPUE. For example, the sudden shifts in CPUE between 1995–96 and 1996–97 correspond with strong and sudden El Niño events. There is also a correspondence with directions of change in CPUE that happen over several consecutive years; such as the downward trend in CPUE from a peak in 1998–99 to a shallow El Niño in 2001–01 and the increases in CPUE over three consecutive years seen between 1992–93 to 1994–95, 1996–97 to 1998–99, and 2004–05 to 2007–08 that peak in La Niña or neutral years.

The availability of juvenile albacore to the troll fishery appears to correspond negatively with El Niño events and to respond positively and quite sensitively to any trend towards or away from that state. It is beyond the scope of this project to conjecture on the mechanism for the effect that ENSO events have on the availability of albacore to the nearshore troll fishery in New Zealand but the difference in the scale of variance within and between years suggests that it is likely to be related to the formation or depth of thermoclines, not necessarily within New Zealand waters as suggested by Unwin et al. (2005) but at a larger geographical and temporal scale than the catch effort data that we collect.

CPUE of troll caught albacore within New Zealand waters is unlikely to be index of abundance of the stock but rather an index of albacore availability in New Zealand.

3.5 Interpretation of shed sampled length frequencies

If CPUE of troll caught albacore does not index abundance but only the proportional availability of the juveniles to the nearshore waters of New Zealand, then it is unlikely to help extract additional information from the shed sampled length frequencies.

If the oceanographic structures indicated by the MEI that are responsible for contraction of the range of the stock were to act primarily or exclusively on one or more age classes, then it might indeed invalidate the existing value of that series in describing year strength. There is no indication that that is the case. By comparing the modal pattern in the catch in 1996–97, which was a strong El Niño year and one of unusually low CPUE, with the catch compositions in 1998–99 and 2007–08, strong La Niña years corresponding with peaks in CPUE, no strong dissimilarities are evident. All three cohorts are present in each of those years.

4 CONCLUSIONS

- The standardised annual CPUE indices fluctuate around unity in a 3–4 year cycle with small error bars around each point. This is not just a noisy signal, as the within year variance is small relative to the interannual fluctuations.
- The trend and precision of the annual indices is very similar when the analysis is repeated using a completely different subset of core vessels.
- The core vessels appear representative of the entire troll fleet regardless of experience (participation); the unstandardised CPUE for all troll vessels is little different from that for core vessels.
- Standardisation has very little effect on the unstandardised series. There is very little contrast in predicted CPUE among months and among statistical areas, indicating that either abundance is homogeneous when the fish are available or that fishers are able to track abundance almost perfectly.
- Local scale environmental effects were not accepted into the model, indicating that there is little contrast for the months and areas in which the fishery operates.
- Larger scale environmental effects appear to match many of the extreme shifts in availability and the effect may happen outside New Zealand waters and outside the troll season.

The Working Group recommended that: This is unlikely to be an index of abundance but rather an index of albacore availability in New Zealand. There is probably not a recruitment signal.

5 ACKNOWLEDGMENTS

This work was funded by the Ministry of Fisheries as project ALB2008-02. Thanks to members of the Highly Migratory Species Working Group, in particular, Paul Starr and Andrew Penney, for helpful suggestions. Thanks to Adam Langley for compiling the environmental data used.

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APPENDIX A: MODEL FITS

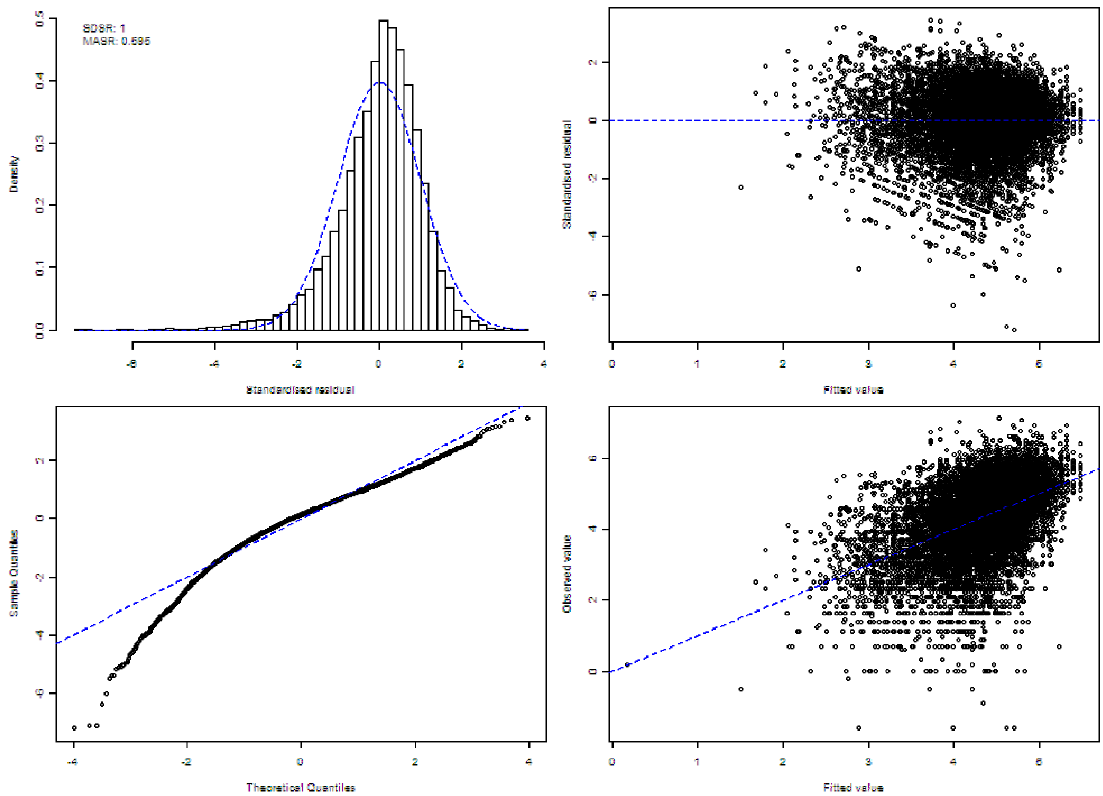

Figure A1: Plots of the fit of the standardised CPUE model to successful catches of albacore in the TROLL 1 vessel subset of the troll fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

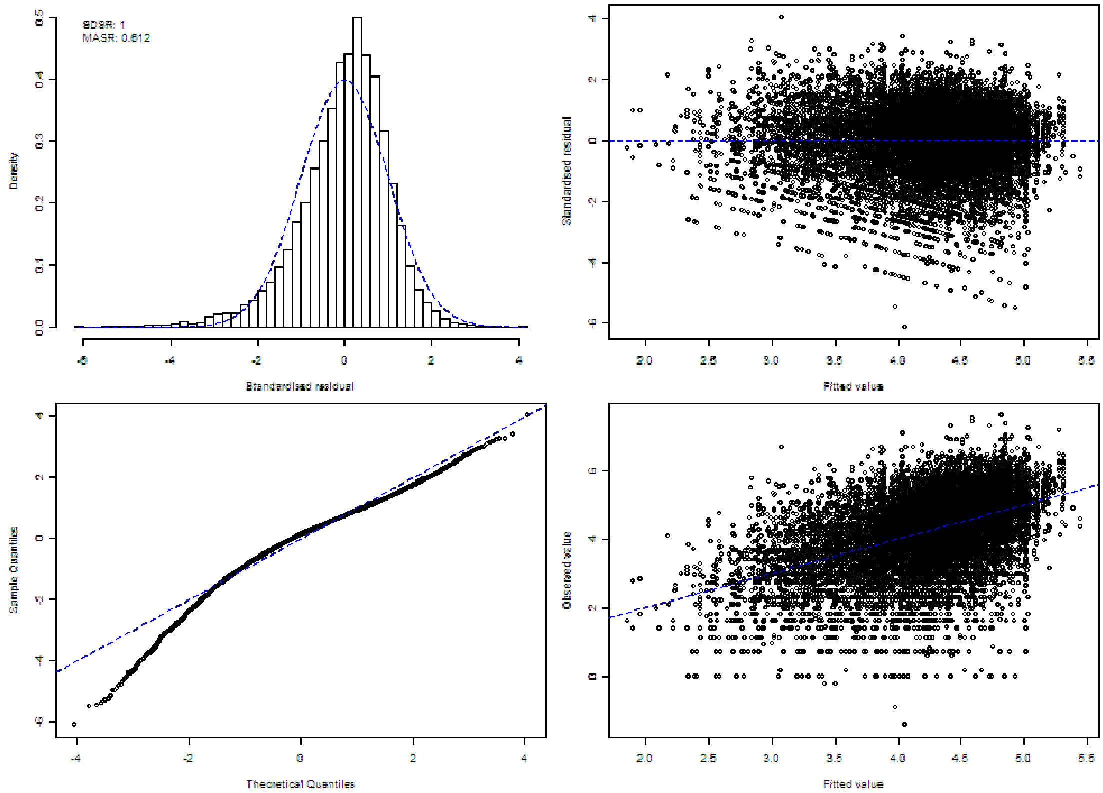

Figure A2: Plots of the fit of the standardised CPUE model to successful catches of albacore in the TROLL 2 vessel subset of the toll fishery. See Caption to Figure A1 for details.

APPENDIX B: MODEL TERM INFLUENCE PLOTS

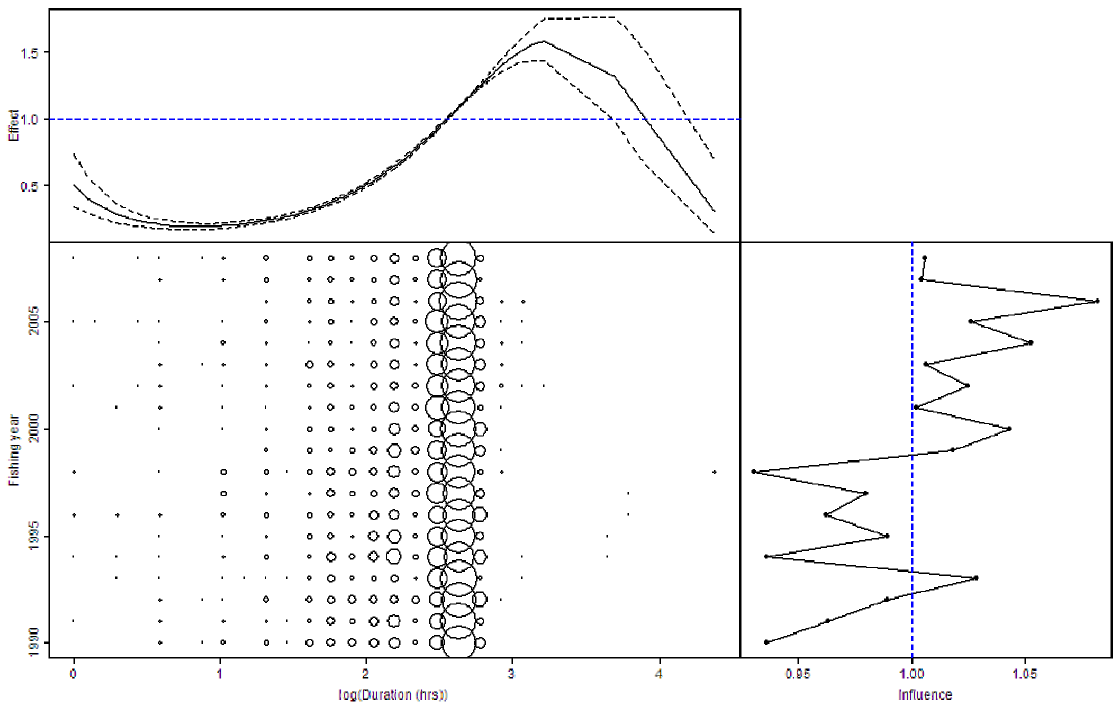

Figure B1: Effect and influence of log(duration) in the lognormal model of TROLL 1. Top: relative effect by level of variable. Bottom-left: relative distribution of variable by fishing year. Bottom-right: influence of variable on unstandardised CPUE by fishing year.

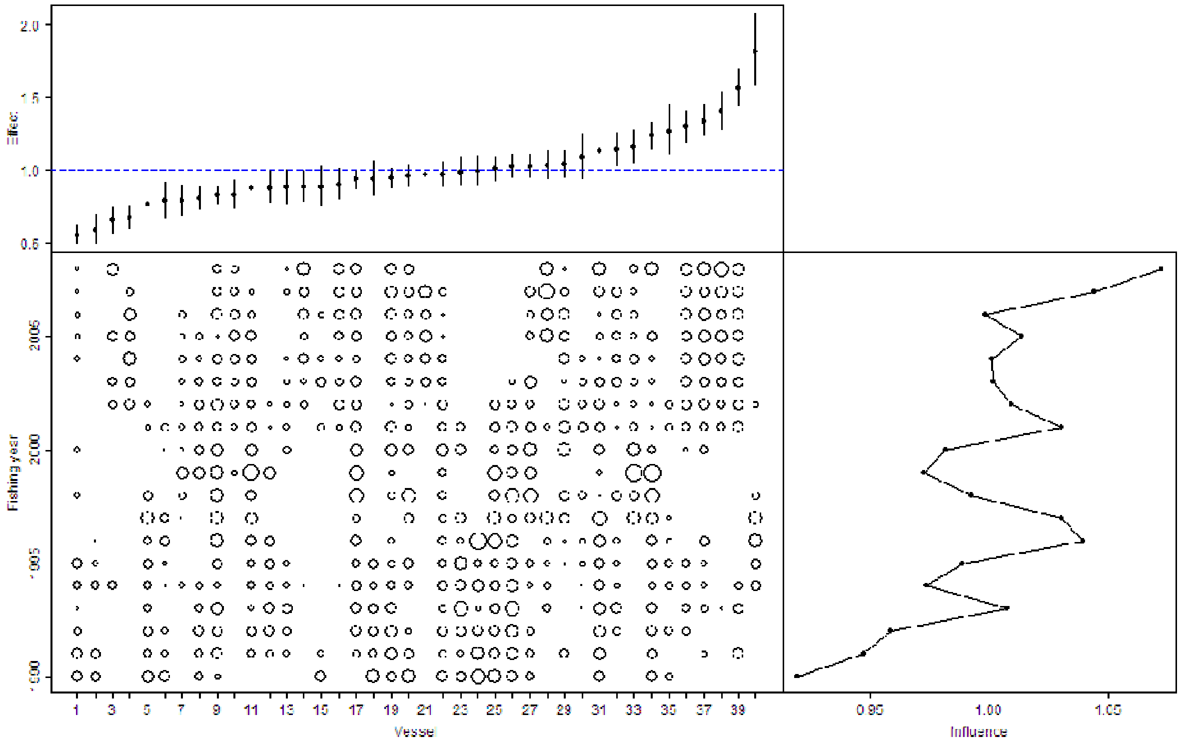

Figure B2: Effect and influence of vessel in the lognormal model TROLL 1. Top: relative effect by level of variable. Bottom-left: relative distribution of variable by fishing year. Bottom-right: influence of variable on unstandardised CPUE by fishing year.

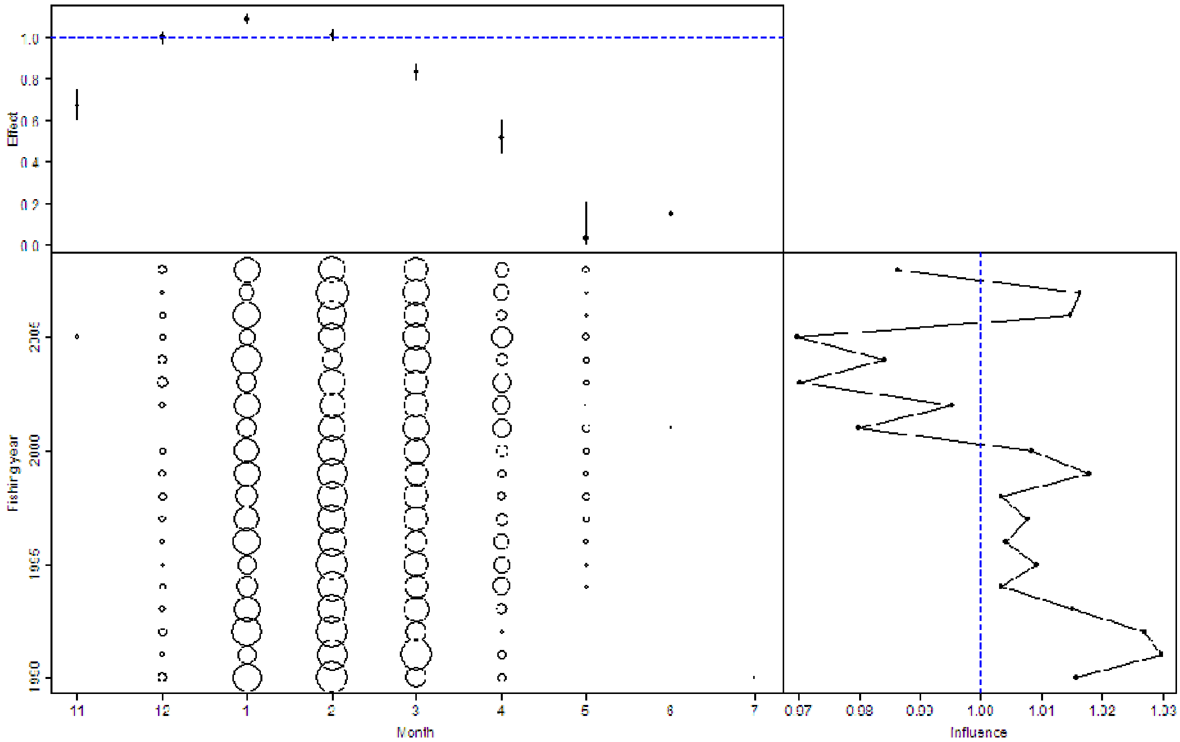

Figure B3: Effect and influence of month in the lognormal model TROLL 1. Top: relative effect by level of variable. Bottom-left: relative distribution of variable by fishing year. Bottom-right: influence of variable on unstandardised CPUE by fishing year.

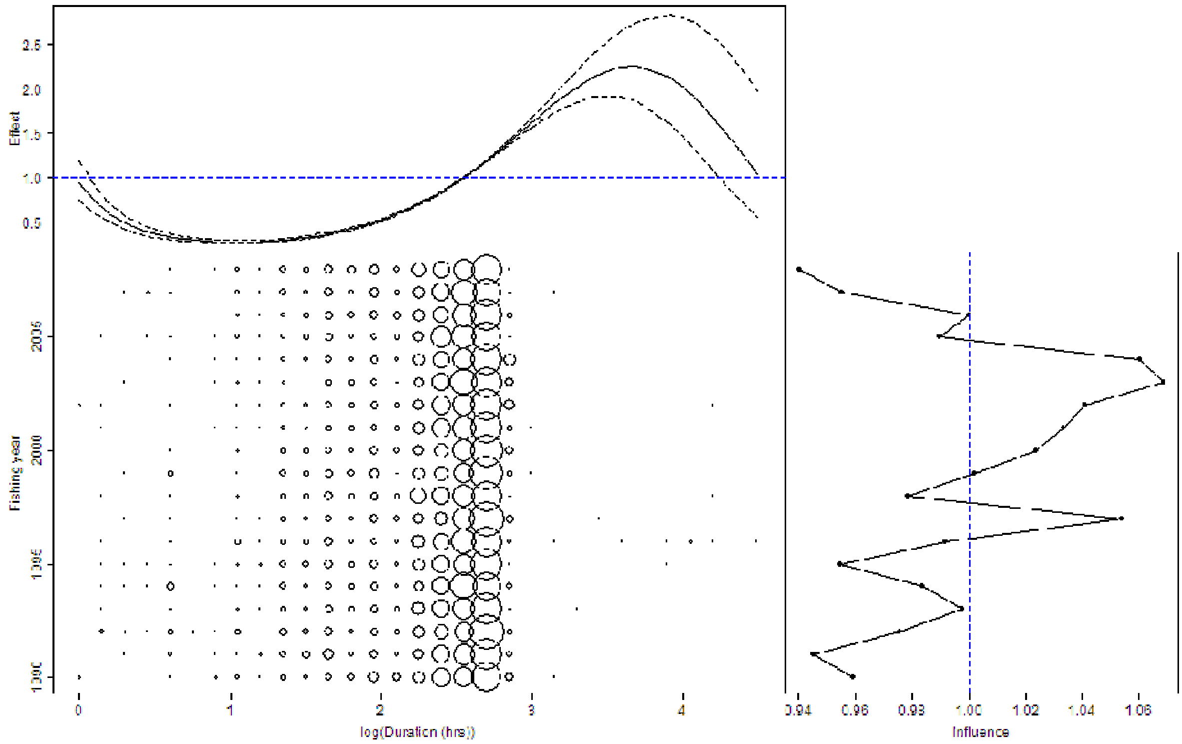

Figure B4: Effect and influence of log(duration) in the lognormal model TROLL 2. Top: relative effect by level of variable. Bottom-left: relative distribution of variable by fishing year. Bottom-right: influence of variable on unstandardised CPUE by fishing year.

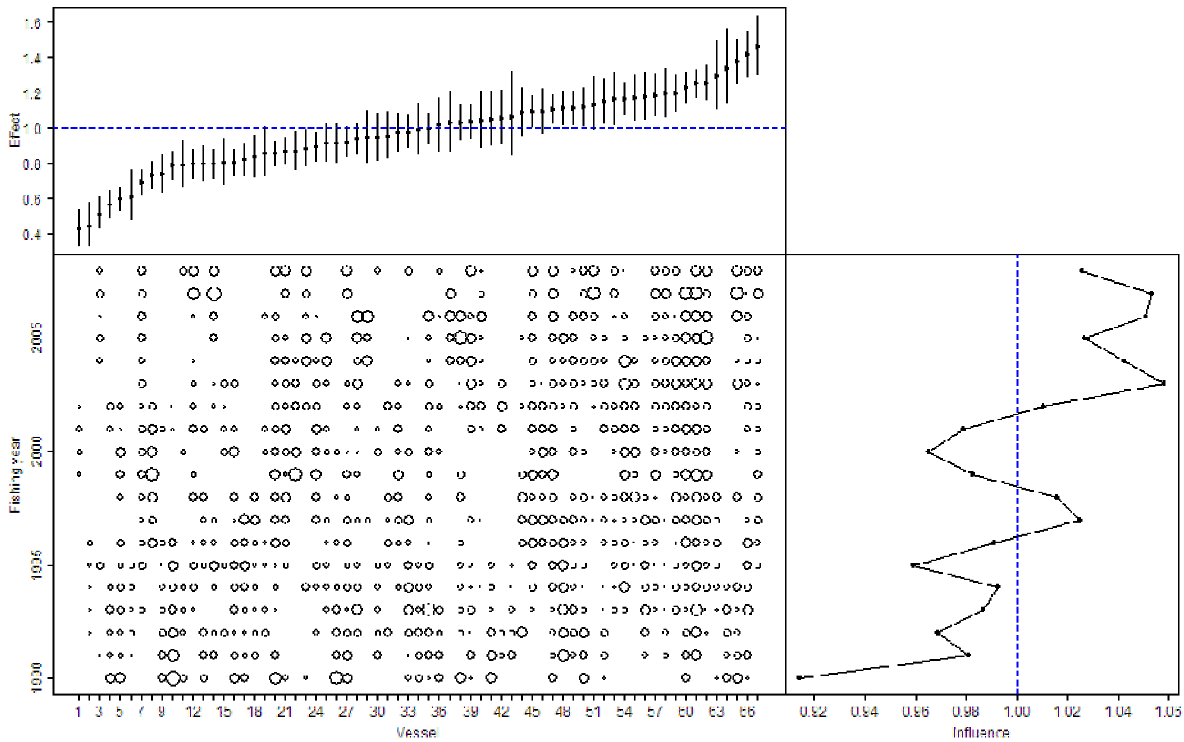

Figure B5: Effect and influence of vessel in the lognormal model TROLL 2. Top: relative effect by level of variable. Bottom-left: relative distribution of variable by fishing year. Bottom-right: influence of variable on unstandardised CPUE by fishing year.

APPENDIX C: DATA SUMMARIES

Table C1: Data summary for the fisheries defined for standardised CPUE analysis for core vessels; (Two independent subsets of qualifying core vessels based on a minimum of 5 tows per year for at least 4 years); TROLL 1 [upper] TROLL 2 [lower]. Number of trips percentage of records that recorded a zero catch of albacore number of core vessels total number of vessel-days total duration total estimated catch of ALB 1 (in thousands of fish) and the simple annual catch rate of ALB 1 (number of albacore/day).

Fishing year	Trips	% zero strata	Vessels	Vessel-days	Effort duration (hrs)	Catch (thousands fish)	TROLL 1 CPUE # /day
89/90	127	100	19	532	7 201	52	98
90/91	187	100	25	747	10 089	99	133
91/92	163	100	23	640	8 840	85	133
92/93	165	100	24	632	8 880	58	92
93/94	251	100	33	1 037	13 855	100	96
94/95	208	100	28	889	12 131	120	135
95/96	164	100	23	589	8 022	71	121
96/97	125	100	19	452	6 112	40	89
97/98	147	100	20	531	7 078	54	101
98/99	98	100	15	350	4 902	47	134
99/00	173	100	21	699	9 754	75	107
00/01	282	100	31	1 068	14 354	88	82
01/02	253	100	32	1 046	14 555	97	92
02/03	222	100	28	1 028	14 221	112	109
03/04	172	100	26	710	10 038	85	119
04/05	217	100	26	1 001	13 764	88	88
05/06	163	100	24	747	10 744	83	111
06/07	138	100	23	697	9 470	91	131
07/08	165	100	19	760	10 438	130	171

Fishing year	Trips	% zero strata	Vessels	vessel-days	Effort duration (hrs)	Catch (thousands fish)	TROLL 2 CPUE # /day
89/90	206	100	28	744	9 736	72	97
90/91	244	100	36	841	10 870	104	124
91/92	315	100	43	1 063	13 914	146	138
92/93	277	100	48	978	13 035	87	89
93/94	314	100	50	1 242	16 241	128	103
94/95	387	100	48	1 263	16 609	161	128
95/96	332	100	46	1 080	14 755	128	119
96/97	287	100	43	1 070	14 915	93	87
97/98	321	100	36	1 164	15 258	151	129
98/99	206	100	27	660	9 106	95	144
99/00	328	100	37	1 095	14 884	115	105
00/01	310	100	40	1 136	15 421	95	83
01/02	383	100	46	1 420	19 611	114	80
02/03	306	100	39	1 258	17 652	134	107
03/04	240	100	35	916	12 789	114	124
04/05	241	100	34	878	11 572	70	79
05/06	166	100	34	640	8 561	67	104
06/07	137	100	22	553	7 095	62	113
07/08	254	100	29	947	12 194	147	155

APPENDIX D: CPUE INDICES

Table D1: Relative year effects and 95% confidence intervals for the CPUE models fitted to the two independent subsets of core vessels ; TROLL 1 [upper] and TROLL 2 [lower] for ALB 1.

Fishing year	Arithmetic mean(all vessels)	Arithmetic mean	Geometric mean	Lognormal standardisation
89/90	0.991	0.880	0.849	0.944 (0.876-1.019)
90/91	1.115	1.189	1.029	1.076 (1.010-1.147)
91/92	1.232	1.188	1.126	1.164 (1.087-1.246)
92/93	0.808	0.823	0.831	0.783 (0.732-0.839)
93/94	0.894	0.860	0.867	0.934 (0.884-0.986)
94/95	1.201	1.215	1.310	1.325 (1.250-1.406)
95/96	1.227	1.178	1.208	1.198 (1.112-1.291)
96/97	0.783	0.809	0.789	0.779 (0.718-0.844)
97/98	1.132	0.952	0.963	1.041 (0.965-1.123)
98/99	1.234	1.198	1.326	1.303 (1.190-1.427)
99/00	0.938	0.961	0.966	0.950 (0.890-1.014)
00/01	0.745	0.741	0.715	0.713 (0.675-0.752)
01/02	0.772	0.828	0.801	0.779 (0.738-0.823)
02/03	0.938	0.974	0.983	1.004 (0.950-1.061)
03/04	1.140	1.070	1.060	1.023 (0.957-1.092)
04/05	0.717	0.790	0.824	0.823 (0.777-0.872)
05/06	0.954	0.994	0.959	0.885 (0.829-0.944)
06/07	1.072	1.171	1.250	1.180 (1.103-1.261)
07/08	1.489	1.526	1.555	1.480 (1.387-1.579)

Fishing year	Arithmetic mean(all vessels)	Arithmetic mean	Geometric mean	Lognormal standardisation
1990	0.991	0.886	0.956	1.079 (1.009-1.153)
1991	1.115	1.130	1.078	1.154 (1.085-1.228)
1992	1.232	1.258	1.179	1.260 (1.191-1.332)
1993	0.808	0.826	0.803	0.810 (0.764-0.858)
1994	0.894	0.941	0.899	0.928 (0.882-0.976)
1995	1.201	1.167	1.189	1.275 (1.212-1.340)
1996	1.227	1.141	1.113	1.137 (1.076-1.202)
1997	0.783	0.816	0.790	0.729 (0.690-0.770)
1998	1.132	1.185	1.168	1.183 (1.121-1.247)
1999	1.234	1.322	1.405	1.387 (1.295-1.485)
2000	0.938	0.964	0.969	0.985 (0.932-1.040)
2001	0.745	0.765	0.741	0.737 (0.698-0.777)
2002	0.772	0.735	0.733	0.696 (0.663-0.730)
2003	0.938	0.974	1.028	0.907 (0.863-0.955)
2004	1.140	1.133	1.135	1.034 (0.974-1.097)
2005	0.717	0.727	0.705	0.692 (0.651-0.735)
2006	0.954	0.947	0.970	0.924 (0.862-0.991)
2007	1.072	1.031	1.115	1.114 (1.033-1.202)
2008	1.489	1.413	1.417	1.451 (1.369-1.538)