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Albacore catch sampling – characterisation and sample design

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EXECUTIVE SUMMARY

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The New Zealand troll fishery catches the majority of the total removals of juveniles from the South Pacific albacore stock. Fish caught by longline throughout the South Pacific, including those caught by longline in New Zealand waters, are mainly larger sub-adult and adult fish. Continued monitoring of the catch composition of juvenile albacore in the New Zealand troll fishery is a critical input to the length-based regional stock assessment of the South Pacific albacore stock. Data from troll-caught albacore provided to the Western Central Pacific Fisheries Commission (WCPFC) are an important input in the South Pacific albacore stock assessment. Data from the port sampling programme have been provided to WCPFC since 1996−97.

A characterisation of the albacore tuna troll fishery in New Zealand waters was carried out before catch sampling started in 2015–16, and results of this were used to develop a sampling design that was representative of the fishery, spatially and temporally.

The albacore troll fishery takes place over the summer months from December to April and most fishing is on the west coast of New Zealand especially the west coast of the South Island (WCSI) in FMA 7. Characterisation focused on the most recent three years, 2012–13 to 2014–15, and also summarised earlier years (1996–97 to 2011–12).

Albacore have been sampled in the landing sheds of Licensed Fish Receivers for 18 years between 1996–97 and 2014–15 as part of the port sampling programme. We evaluated the temporal and spatial representativeness of the sampling relative to the fishery and found that it represented the fishery well.

The temporal and spatial distribution over the most recent three years provided a basis for ongoing sampling during the next three years, 2015–16 to 2017–18. The target coefficient of variation (CV) was 20%. We carried out simulations to investigate the effect on the CV of changing sample sizes and numbers of landings.

1. INTRODUCTION

Albacore tuna (*Thunnus alalunga*) caught in the New Zealand EEZ (Exclusive Economic Zone) are part of a single South Pacific Ocean stock that ranges from the equator to about 45° S. Female albacore mature at about 85 cm fork length (FL) and spawn in the austral summer from November to February in tropical and subtropical waters, between about 10° S and 20° S, west of 140° W (Murray 1994, Ramon & Bailey 1996, Murray et al. 1999).

Juvenile albacore recruit to surface fisheries in New Zealand coastal waters and in the vicinity of the subtropical convergence zone (STCZ) at about 2 years of age, at 45–50 cm FL. They then appear to gradually disperse north (Hampton & Fournier 2000) where they are caught by longline fleets. Longline fleets from Japan, Korea, China, and Taiwan, and domestic fleets of several Pacific Island countries, catch adult albacore throughout their range (OFP-SPC and the WCPFC Secretariat 2015). Fish caught by longline in the southern part of the region are smaller than those caught further north (Hampton & Fournier 2000). The New Zealand longline fishery catches adult and sub-adult albacore (Griggs et al. 2013).

There has been a troll fishery for juvenile albacore in New Zealand coastal waters since the 1960s, and in the central region of the STCZ since the mid-1980s (Murray 1994, Murray et al. 2000, Hampton & Fournier 2000). The New Zealand troll fishery is operated by domestic vessels mostly in New Zealand coastal waters, primarily off the west coast with Onehunga (Auckland), New Plymouth, Westport, and Greymouth being major landing ports.

The New Zealand albacore troll catch of 1796 t in 2007 was the lowest for nearly 20 years, mainly because of a reduction in active vessel numbers due to economic conditions. Catches have fluctuated since then, ranging between 1794 t and 3352 t between 2008 and 2012 (Williams & Terawasi 2012, Pilling et al. 2014). New Zealand troll catch was 2836 t in 2013 and 1937 t in 2014 (Anon. 2015a).

Troll vessels from the United States have fished for albacore in the South Pacific since 1986, in the STCZ, approximately 39–41° S, from 1000 n. miles east of New Zealand to waters off South America. Landings from these vessels fluctuated between 603 t and 2916 t between 1986–87 and 2003–04 (Childers & Coan 1996, Ito et al. 2005). In recent years, the United States troll fisheries for albacore have experienced a significant decline in participation. Between 2007 and 2013, the United States troll fleet catches have ranged between 151 t and 471 t (Pilling et al. 2014). The US troll catch in the South Pacific was 390 t in 2013, which declined to 263 t in 2014 (Anon. 2015b). Canadian landings in this fishery from its inception in 1987–88 to 2000–04 are estimated to have ranged from 134 to 351 t per season (Stocker & Shaw 2005), but since then have declined, and there have been no Canadian troll vessels in the South Pacific since 2007 (Anon. 2015c, Pilling et al. 2014). Up until 2007 there were also minor catches from the Cook Islands and French Polynesian fleets (Williams & Terawasi 2008), but these fleets have not been active in the troll fishery since then (Pilling et al. 2014), except for a 21 t catch in 2014 by a Cook Islands vessel (Anon. 2015d). With the decline in participation of other fleets since 2007, the New Zealand troll catch has made up approximately 90% of the South Pacific troll catch between 2008 and 2014 (Anon. 2015a, OFP-SPC and the WCPFC Secretariat 2015).

Labelle (1993) noted that STCZ albacore tend to be larger than those around New Zealand. Albacore sampled in the STCZ by the American fleet in 2003–04 had an average FL of 66 cm. Albacore reach sexual maturity at about 85 cm (Bailey 1991). Maturity studies carried out by Farley et al. (2012) show that 50% maturity was reached at 87 cm FL and 100% maturity was reached at 95 cm FL.

The size composition, sex ratio, and length-weight relationship of albacore caught by troll in New Zealand have previously been investigated by NIWA over 18 years (Griggs & Murray 2000, 2001a, b, Griggs 2002a, b, 2003a, b, 2004a, b, 2005a, b, 2008a, b, Griggs & Doonan 2010, Griggs et al. 2013, 2014). Fish sampled over these 18 years were mostly juveniles, ranging in size from 29 to 99 cm FL, with nearly all fish (99%) in the 47–80 cm range. A significant linear relationship was found between the logs of albacore FL and GW (greenweight). Griggs & Murray (2000) found that the sex ratio was not statistically different from 1:1.

Previous comparisons of temporal and spatial coverage of the troll fishery data by the catch sampling programme and Ministry for Primary Industries (MPI) observers have shown that observer data were not representative of the fishery because the observer coverage was not able to extend to enough vessels, and that port sampling is able to offer better representation of the fishery (Griggs et al. 2013, 2014). Troll vessel coverage by observers was discontinued for this reason.

Data from this albacore troll sampling programme are provided to Secretariat of the Pacific Community (SPC) for incorporation into the stock assessment of South Pacific albacore. The most recent assessments were described by Hoyle et al. (2012) and Harley et al. (2015). Continued monitoring of the catch composition of juvenile albacore in the New Zealand troll fishery is a critical input to the length-based regional stock assessment of the South Pacific albacore stock.

Due to the size-selectivity of trolling for smaller albacore, the New Zealand length data allow the assessment model to estimate the growth rates of small fish, and the last six years data are the only reliable source of this vital piece of information. These data provide the assessment with a clear growth signal, and more data will provide better certainty. The data provide some information about relative cohort strength from year to year, which also makes a contribution to the assessment.

This sampling programme increases the ability of the assessment to identify weak and strong year classes and to narrow down the causes of changes in catch rate. These data provide more accurate recruitment estimates for the model and improve the growth rate estimates allowing the model to pick up possible long-term growth rate changes with changes in the environment. These data also provide information on inter-cohort variation in size-at-age; at this stage more data are required as there are not enough data to identify what causes inter-cohort variation.

Albacore are currently managed outside the QMS. MPI is monitoring the status of albacore stocks in New Zealand's fisheries waters as part of New Zealand's contribution to the regional stock assessment. A stock assessment of albacore specifically for New Zealand fisheries waters is not currently possible as the proportion of the South Pacific stock that migrates through and/or resides in New Zealand fisheries waters is unknown, and likely to be a small portion of the stock. In the absence of a formal stock assessment for New Zealand fisheries waters, monitoring occurs through an annual catch sampling programme. Changes to the population structure, such as a pronounced reduction in catches of larger fish, or the absence of small fish are the types of signals that might indicate that the albacore stock is under pressure. A time-series of annual size structures will provide a means by which the Ministry can monitor the status of the albacore stock; and, possibly in the future, monitor the effects of management changes.

This research is necessary because:

- Annual length estimates from New Zealand are a critical data input into the regional assessment model;
- The project supports objectives in the albacore component of the Medium Term Research Plan for Highly Migratory Species; and
- This project also contributes to Business as Usual area 6 "Support environmental certification for the albacore fishery" of the "Annual Operational Plan for Highly Migratory Species Fisheries 2014/15".

The present project updates and extends previous analyses for three more years, thus increasing the port sampling time series to 21 years. It addresses the following objectives.

OVERALL OBJECTIVES:

1. To determine the length composition of the commercial catch of albacore (*Thunnus alalunga*) in New Zealand fisheries waters.

SPECIFIC OBJECTIVES:

1. To update the characterisation of the albacore fishery in New Zealand fisheries waters with the inclusion of data through the 2014−2015 fishing year.

2. To develop a sampling design to determine the representative length composition and length-weight relationships of the albacore fishery in New Zealand fisheries waters.

3. To conduct representative sampling to determine the length composition of albacore tuna during the 2015/16, 2016/17, and 2017/18 fishing years. The target coefficient of variation (CV) for the length composition is 20 % (mean weighted CV across all length classes).

This work is an extension to the sampling funded in 1996−97 and 1997–98 by the South Pacific Commission (SPC, now Secretariat of the Pacific Community), and 1998–99 to 2014–15 by the Ministry of Fisheries, now MPI.

This report covers Objectives 1 and 2 and the sample design developed here will be used for the sampling in Objective 3.

2. PART ONE – CHARACTERISATION OF THE FISHERY

2.1 METHODS

Specific Objective One:

To update the characterisation of the albacore fishery in New Zealand fisheries waters with the inclusion of data from the 2014−2015 fishing year.

2.1.1 Catch effort and sampling data

Spatial and temporal data recorded on Catch Effort Landing Return (CELR) forms from the albacore troll fishery were summarised, focusing on the three most recent years. Representativeness of the sampling strategy used previously was assessed.

Commercial troll catch effort data recorded by vessel personnel are recorded on CELR forms. These data were extracted from the *tuna* database (Wei 2007). Vessels record fishing positions daily on CELR forms, either as latitude and longitude or a Statistical Area. If a Statistical Area is recorded, a 'centroid' position is assigned in the *tuna* database (Wei 2007).

Fishers are required to record number of fish caught for the tuna species on CELR forms, but sometimes record weights instead, and these are separated when loading data to the tuna database (Wei, 2007). Catch weights were estimated from catch numbers by multiplying them by the average fish weight for each year which was determined by the albacore troll sampling programme. Where fishers recorded weight instead of fish number, these weights were divided by average weights to estimate catch numbers. Weights (instead of numbers) were recorded for 2.5% of CELR records where albacore catch was recorded during the most recent three years (2012−13 to 2014−15).

Shore based catch sampling of albacore began in 1996−97 and occurred each year for twelve consecutive years up to 2007−08. The 2008−09 year was not sampled. Sampling resumed in 2009−10 for six more years, up to 2014−15. In most years two ports were sampled, Onehunga (Auckland) and Greymouth. In some years fish were also sampled in New Plymouth. Because the fishery extends over the summer months, the 'albacore year' is from 1 July to 30 June, so 2014−15 is 1 July 2014 to 30 June 2015, with the majority of fishing in 2015.

The last characterisation of the troll fishery was carried out in MPI project ALB201201 (Griggs et al. 2014) which was based on the three previous years of sampling, 2009–10 to 2011–12 (summarised in Griggs et al. 2013).

This characterisation focuses on the 2012−13, 2013−14 and 2014−15 albacore fishing years. These are the three most recent years sampled by the shore based catch sampling programme under MPI projects ALB201201 (Griggs et al. 2014) and ALB201301 (Griggs & Large 2016).

2.1.2 GAM analysis on mean length

A generalized additive model (GAM) analysis was done to determine the variables that affect mean length in the catches as this determines sampling strata. Current strata are port and month. Data used were from the landing samples taken in the 2012−13, 2013−14 and 2014−15 years. The mean length from each landing sample was regressed against factors including year, month, port, latitude, longitude, vessel length, and vessel horsepower, with a cutoff of R^2 greater than 1%. Variables were selected step-wise according to the largest R^2 from the remaining candidates, with a variable accepted if significant (P-value ≤ 0.01).

Using the above step-wise order, the fits at each step were put into an ANOVA, and an F-test performed to determine the significance of the added variable at each step. The GAM analysis used the R functions 'gam' and' anova' in the R package 'mgcv' (R Development Core Team, 2010).

2.1.3 Representativeness of catch sampling

We summarised catch (CELR and sampling data) and effort (CELR data) by fishing year, using FMA to highlight the spatial characteristics of the fishery. We compared catch sampling (numbers of fish) to the CELR recorded catch.

To investigate the adequacy of sampling, the data were divided by month and into two latitude groups, north and south of 40.5° S latitude (30° S to 40.5° S and 40.5° S to 50° S), and comparison was made between catch sampling data and CELR data. We analysed the six most recent years individually, i.e., 2009−10, 2010−11, 2011−12, 2012−13, 2013−14 and 2014−15, and grouped the rest of the data into year groups as follows: 1996−97 to 2000−01, 2001−02 to 2004−05, and 2005–06 to 2007−08. Data were displayed using plots of distribution by latitude (0.1 degree bins) for each month. The number of vessels in the fishery and the number of albacore reported were examined as factors.

2.2 RESULTS

2.2.1 Catch effort and sampling data

The total albacore troll catch, in fish numbers and weight, for 1996−97 to 2014−15 is shown in Table 1 and Figure 1 (numbers of fish), along with effort as number of vessels and number of vessel days for each fishing year (Table 1, Figure 2).

Over this period the number of vessels operating in the fishery peaked at 314 in 2000−01, with 8137 vessel days (Table 1). Since 2005−06, fewer than 200 vessels have operated in the fishery, with the lowest number of vessels (120) in 2009−10. The number of vessels operating in 2012−13 was 153, 148 in 2013−14, and 128 vessels in 2014−15. The number of vessel days for the three years 2012−13 to 2014−15 was 4981, 4284 and 3945 (Table 1, Figure 2). Between 1996−97 and 2014−15, catches peaked in 2003−04, then declined until 2006−07, and have fluctuated since then (Table 1, Figure 1).

The number of fish sampled in each year and port is shown in Table 2 for the 18 years of catch sampling. Fishing positions of the commercial troll vessels and those sampled are shown in Figure 3. Almost all trolling was on the west coast of New Zealand with 95.3%, 93.4% and 92.9% of the catch (in numbers) for 2012−13, 2013−14 and 2014−15 (overall 94% for the three years) from the east coast, and most of that off the South Island. Positional accuracy is limited on CELR forms, and some of the positions in Figure 3 represent many points as they are shown as 'centroid' positions of Statistical Areas.

The number of vessels fishing by month and year by 0.1 degree latitude bins are shown for 2012−13 (Figure 4), 2013−14 (Figure 5) and 2014−15 (Figure 6). The highest vessel numbers were in January, February and March in all three years, and mainly in latitudes south of 40° S.

2.2.2 GAM analysis on mean length

The variables considered in the GAM analysis are listed in Table 3, the selection order of variables is shown in Table 4, and the F tests on the resultant cascade of models from the ANOVA are shown in Table 5. Fishing year, month, and latitude were statistically significant.

The GAM diagnostic plots are shown in Figure 7 and the pattern of the estimated effects are shown in Figure 8. The diagnostics look good and support normality of errors (linear pattern of points in the Q-Q plot) and constant variance (regular pattern of residuals above and below 0, lack of curvature).

The mean length varied with latitude, with an increased mean length south of 42º S, although there are wide confidence intervals so this trend is not conclusive. From December to January the mean length increased, followed by a decreased mean length through to April. The trend of catches of larger fish south of Greymouth, particularly from Statistical Areas 032 and 033 has been noted previously (Griggs et al 2013). Port of sampling was a minor effect.

2.2.3 Representativeness of catch sampling

Fishing effort in vessel days (Figure 9), and catch in numbers (Figure 10) are shown for CELR data by FMA for each fishing year from 1996–97 to 2014–15. Most of the effort and catch has occurred off the west coast of both islands (FMA 7, FMA 8 and FMA 9) with most fishing off the WCSI in FMA 7. Sampled landings show a similar trend with most of the fish from FMA 7 (Figure 11).

Catches in numbers of fish, expressed as percentages, are shown for CELR and sampling data by north (> 30º S and ≤ 40.5º S) and south (> 40.5º S and ≤ 50º S) latitude groups, and by year for 2009−10 to 2014−15, with groupings of years for earlier years (Table 6).

Sampling followed a similar pattern to that of the CELR data by latitude group in most years. Most of the catch came from the south latitude group as did the sampled catches. There was a trend of under sampling in the north latitude group between 2009−10 and 2012−13. These inconsistencies can be attributed to logistical difficulties collecting samples at the northern port. These issues have been addressed, resulting in more representative sampling in the north region in the most recent two years. In 2013−14, 37.1% of CELR data and 29.4% sample data was in the north latitude group, and in 2014−15, 36.8% of CELR data and 37.4% sample data was in the north latitude group (Table 6).

Catches in numbers of fish, expressed as percentages, are shown by month within each fishing year for each latitude group for 2012−13 to 2014−15 (Table 7), 2009−10 to 2011−12 (Table 8) and for the year groups 1996−97 to 2000−01, 2001−02 to 2004−05 and 2005−06 to 2007−08 (Table 9). Sampling in 2013−14 and 2014−15 was consistent with CELR catches by month and latitude group, capturing the trend of the majority of catch in the south in February and March and January's catch split between the north and south latitude groups

3. PART 2 – SAMPLE DESIGN

Specific objective 2

To develop a sampling design to determine the representative length composition and length-weight relationships of the albacore fishery in New Zealand fisheries waters.

3.1 BACKGROUND

The sample design is based on the characterisation of the fishery undertaken in Part 1 (Objective 1) of this report, focusing on the three most recent years. Sampling is to be representative of the albacore troll fishery, and the resulting length composition must have a coefficient of variation (CV) of no more than 20% (mean weighted CV across all length classes).

The representativeness of the current sampling strategy was assessed under Objective 1 in this report, and by Griggs & Large (2016) for the two most recent albacore fishing seasons (2013−14 and 2014−15). Other recent assessments were for 2012−13 (Griggs et al. 2014) and 2009–10 to 2011−12 (Griggs et al. 2013). The most recent characterisation was carried out by Griggs et al. (2013) and sample design was developed for sampling 2012−13 to 2014−15.

We firstly describe the sampling methodology that has been used for port sampling of albacore from 1996−97 to 2014−15 (hereafter referred to as 'the current sampling strategy').

3.1.1 Current sampling strategy

The original sample design was specified by SPC as 1000 fish sampled per month per port with a sub-sample of 100 fish weighed and measured each month from each port. This was revised by the HMS (Highly Migratory Species) Working Group to measure a number of fish each month proportional to the commercial catch, and to sample more landings, in order to increase representativeness. Proportional catch sampling began in 2009−10. Sampling should represent the fishery both spatially and temporarily, taking into account difference between areas and boats.

The current sampling strategy is as follows:

- two ports sampled, Auckland and Greymouth
- sampling from December to April
- fish selected at random from each vessel unloading
- the target number of fish sampled each month proportional to the catch
- target 100 fish per landing

100 fish sub-sampled for length and weight in each port, each month

3.1.2 Monthly sample targets and target coefficient of variation

Monthly sample targets for 2012−13 to 2014−15 were based on the monthly distribution of the catch during the previous three years (2009–10 to 2011–12). The targets and the numbers sampled each year and month during 2012–13 to 2014−15 are shown in Table 10. The number of fish, landings and vessels sampled by year, month and port, and the average number of fish sampled in each landing are shown in Table 11.

Mean weighted CVs (MWCVs) were calculated for each annual sample using the CALA (Catch-at-length and-age) package developed by NIWA (Francis et al. 2014) for the analysis of MWCVs across length classes. MWCVs of length frequency estimates were calculated with the port sampling data analysed in 1cm length classes. The MWCV was calculated as the average of the CVs for the individual length classes weighted by the proportion of fish in each class. CVs were calculated by bootstrapping with fish resampled within each landing and landings resampled within each month. The 1 cm resolution of the original data has been maintained because the purpose of the data is for inferring growth rate within a length-based age-structured model. The pooled MWCV for the length frequencies scaled to total catch numbers were below the 20% target for the three years sampled: 12.2% in 2012−13, 14.2% in 2013−14, and 15.1% in 2014−15.

3.2 METHODS

3.2.1 Evaluation of current sample design

In this study we evaluate the current sampling design and make appropriate revisions, based on the characterisation carried out under Objective 1 of this report.

3.2.2 Temporal and spatial distribution of catch

We based monthly sample targets for 2015–16 to 2017−18 on the proportion of catch each month during 2012−13 to 2014−15.

We summarised the temporal and spatial distribution of the catch over the most recent three years (2012−13, 2013−14 and 2014−15) to determine where sampling effort is best placed proportionally over time and space to achieve an annual sample representative of the catch in the three years 2015−16 to 2017−18.

3.2.3 Simulation to determine optimal sample size in relation to target CV

We ran simulations to assess the impact of changing the following on the CV:

- Number of landings sampled
- Number of fish in each landing
- Total number of fish sampled

Simulations were used to determine how CVs varied as sample sizes changed. The CALA package was used in a similar way as the bootstrap process to determine the MWCV for the annual sample. Calculations were repeated for a user-supplied range of sample sizes. We evaluated five annual sample sizes (5000, 4000, 3000, 2000 and 1000 fish).

A simulation exercise was then conducted to investigate the effect of sample size on CV, and thereby determine the optimum sample size. Simulations were carried out on each of the three sampled years from 2012−13 to 2014−15, for sample size combinations based on number of landings sampled per month and port (5, 10, 15, 20) and number of fish sampled per landing (50, 100, 150, 200). For each combination, CALA was used to simulate 1000 datasets, estimate a length frequency for each dataset and calculate the CV over the 1000 estimates.

3.3 RESULTS

3.3.1 Evaluation of current sample design

The results of comparisons made of catch and sampling in the characterisation of the fishery (Objective 1) showed that the sample design was good and that the sampling data was representative. Sampling two ports covered the spatial distribution well, with Auckland samples mainly from FMAs 8 and 9, and Greymouth samples mainly from FMA 7 and some from FMA 5 in some years. Sampling a large number of landings offered a good distribution throughout Statistical Areas of the west coast. The Auckland area was oversampled due to larger sample sizes.

During sampling in 2012−13, 2013−14 and 2014−15, approximately 200 fish were sampled per landing in Auckland, and around 100 fish per landing in Greymouth (Table 11). The average number of landings sampled in Auckland were 3, 6 and 6 landings per month for respectively, and in Greymouth 11, 10 and 10 landings per month for 2012−13, 2013−14 and 2014−15 respectively.

3.3.2 Temporal and spatial distribution of catch

The catch and the monthly proportions are shown in Table 12. The sample percentages were 8.7% in December, 31.8% in January, 32.6% in February, 19.5% in March, and 8.0% in April. Albacore catch by FMA and the percentage in each FMA is shown in Table 13. The largest percentage of the catch, 71.8% for the three-year total occurred in FMA 7 which is off the WCSI.

Catch percentages by month and FMA for the years 2012–13 to 2014–15 are shown in Table 14. The fishery started in the north on the East Coast in FMA 1 with a small albacore catch in November. The catch in December was predominantly in FMA 9 off the west coast of the North Island (WCNI), with small amounts in FMA 1, FMA 7 and FMA 8. The fishery moved southwards as the season progressed with January's catch split between FMA's 8 and 9 off the WCNI, and FMA 7 off the WCSI. From February onwards the majority of the catch was taken in FMA 7. Small catches in FMA 2 were seen later in the season, mainly in March.

3.3.3 Simulation to determine optimal sample size in relation to target CV

Monthly allocations of number of fish to sample each month for reducing total sample sizes (5000, 4000, 3000, 2000 and 1000 fish) are shown in Table 15, and the number of landings that would be sampled in each scenario are outlined in Table 16.

Simulation results show that the mean weighted CV reduced as more landings were sampled (for a given number of fish sampled in each landing), and the CV also reduced as more fish were sampled per landing (for a given number of landings sampled) (Table 17). The greatest reduction in CV was achieved by increasing the number of landings sampled rather than increasing the number of fish sampled per landing. The CV was reduced by half when the number of landings was increased from 5 to 20. The optimal sample size was 100 fish per landing. The biggest decrease in CV was seen between sample sizes of 50 and 100, while increasing to 150 and 200 fish per sample did not have a large effect on CV (Table 17).

When 5 landings were sampled per month and port, CV was over or close to the 20% target. When 10, 15 or 20 landings were sampled, the target CV was comfortably below the 20% target for all sample sizes (50, 100, 150 or 200) of fish per landing (Table 17).

The effect of reducing the total sample size on the number of landings can be seen in Table 16. With six port-month combinations to sample proportionately each year (Auckland in December and January, Greymouth from January to April), the number of landings to be sampled for each port-month combination dropped when the total annual sample sizes decreased.

When 5000 fish were proportionally allocated over the port-month combinations and 100 fish were sampled per landing, two of the port-months (Greymouth in February and March) had more than ten landings sampled, two port-months had eight landings sampled (Auckland and Greymouth in January), and two of the port-months had fewer than five landings sampled (Auckland in December and Greymouth in April) (Table 16). With this scenario (where there is the opportunity to sample at least 10 landings per port-month for the January to March peak of the season), simulation results suggest that the CV would be below the 20% target, but not lower than 15% (Table 17). If the total annual sample size was reduced to 4000 or less, only one port-month (February) would have ten or more landings sampled (Table 16), and with fewer than ten landings in most port-months (most would be closer to five), it is unlikely that the target CV of 20% would be met.

With a reduction of the total sample size below 5000 fish, the number of landings allocated to each port-month ceases to match the monthly percentage of annual catch required for proportional sampling (Table 15).

In conclusion, the ideal total sample size to achieve the target CV of 20% is 5000 fish proportionally allocated, with 100 fish sampled per landing.

3.3.4 New sample design

The new sample design (Table 18) will be used for the next three fishing seasons, 2015–16, 2016–17 and 2017–18.

Sampling will be carried out over the albacore troll fishery season, in two ports, Auckland and Greymouth. Sampling will begin in the north region in December, January sampling will be split between Auckland and Greymouth (so long as there are landings in both ports), and from February onwards sampling will be in Greymouth, until the end of the fishing season (typically April).

The target number of fish to be sampled in a landing will be 100 fish, in both ports, from fish selected at random, and 100 fish will be sub-sampled for both length and weight in each port each month. The total target number of fish is 5000 which will be sampled from about 50 landings.

The target number of fish sampled each month will be proportional to the catch, as shown in Table 18.

The number of fish sampled each month may be adapted to reflect any differences such as a late start to the season or changes in the timing of movements of fish from north to south.

4. DISCUSSION

A characterisation of the fishery was carried out to show the spatial and temporal distribution of the albacore troll fishery effort and catch during previous years, especially 2012−13 to 2014−15. Evaluation of the current sample design showed that the sampling represents the fishery well, both spatially and temporarily. There was some oversampling in the north due to different sample targets in Auckland. We address these issues with the new sample design. Monthly proportions of catches during 2012−13 to 2014−15 will be used for sampling during the 2015−16 to 2017−18 fishing seasons.

We carried out simulations that estimated the optimum total sample size to be 5000 to achieve a CV of less than 20%, and that reduction of the total annual sample size resulted in a higher CV and compromised representative allocation of landings per month.

Sampling needs to take into account differences between boats and between areas. To achieve this, and proportional sampling, and a CV below 20%, the new sample design targets 50 samples, proportionally spread over the summer months with 100 fish sampled per landing in both Auckland and Greymouth.

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Table 1: Total troll catch and effort recorded on CELR forms, 1996−97 to 2014−15.

ALB year	No. of fish	Weight (kg)	No. of vessels	Vessel days
1996−97	390 500	2 038 473	301	6 547
1997−98	573 300	2 992 704	298	7 822
1998−99	298 670	1 690 463	182	3 397
1999−00	566 247	2 672 202	269	7 004
2000−01	550 467	2 986 363	314	8 137
2001−02	555 510	2 826 972	306	7 843
2002−03	674 283	3 130 960	275	7 925
2003−04	568 179	3 167 817	245	6 422
2004−05	476 717	2 928 249	212	6 890
2005−06	393 427	2 183 331	183	4 278
2006−07	329 775	1 716 409	134	3 351
2007−08	436 442	2 018 381	153	4 451
2008−09	373 664	1 950 843	170	4 563
2009−10	325 928	1 720 897	120	3 169
2010−11	434 300	2 067 270	154	4 478
2011−12	435 736	2 169 966	155	4 768
2012−13	420 953	2 311 034	153	4 981
2013−14	340 183	1 598 861	148	4 284
2014−15	342 280	1 759 320	128	3 945

Table 2: Number of fish sampled each year and port from 1996−97 to 2014−15.

				Port
ALB year	Auckland	Greymouth	New Plymouth	All ports
1996−97	200	4 017		4 217
1997−98	982	2 996		3 978
1998−99	400	3 031		3 431
1999−00	949	3 013		3 962
2000−01	2 000	3 192		5 192
2001−02	1 400	3 770		5 170
2002−03	2 002	2 602	3 002	7 606
2003−04	1 821	2 666	998	5 485
2004−05	2 431	3 071		5 502
2005−06	1 600	3 070		4 670
2006−07	1 600	2 600		4 200
2007−08	400	4 164		4 564
2008−09				0
2009−10	600	3 585		4 185
2010−11	0	4 783		4 783
2011−12	400	4 700		5 100
2012−13	941	4 307		5 248
2013−14	2 041	3 774		5 815
2014−15	2 279	2 937		5 216
Total	22 046	62 278	4 000	88 324

Table 3: Variables considered in the GAM analysis.

Code	Variable
Mth	Calendar month
Lat	Latitude
alb_yr	Albacore fishing year (2014−15 is plotted as 2015)
Long	Longitude
overall.length.m	Overall length in m (the only length present for all vessels)
horse.power	Engine power of vessel (in horse power)
Port	Port the sample was taken in

Table 4: Order of variables as determined by step-wise procedure using the largest increase in R^2. See Table 3 for code descriptions. The selected variables are shown in blue.

	Variable	R-squared
First variable		
	mth	0.19
	alb.yr	0.22
	lat	0.09
	long	0.01
	port	0
	overall.length.m	0.06
	horse.power	0.01
Second variable		
	mth	0.39
	lat	0.31
	long	0.22
	port	0.22
	overall.length.m	0.3
	horse.power	0.22
Third variable		
	lat	0.5
	long	0.45
	port	0.4
	overall.length.m	0.39
	horse.power	0.4
Fourth variable		
	long	0.5
	port	0.5
	overall.length.m	0.5
	horse.power	0.5

Table 5: ANOVA and F-test results from the cascade of models on mean length (meanL, cm). See Table 3 for code descriptions. Cascade order determined from Table 4.

Model 1: meanL ~ 1
Model 2: meanL ~ alb.yr
Model 3: meanL ~ alb.yr + mth
Model 4: meanL ~ alb.yr + mth + s(lat)
Model 5: meanL ~ alb.yr + mth + s(lat) + s(horse.power)
Model 6: meanL ~ alb.yr + mth + s(lat) + s(horse.power) + s(long)
Model 7: meanL ~ alb.yr + mth + s(lat) + s(horse.power) + s(long) + s(overall.length.m)
Model 8: meanL ~ alb.yr + mth + s(lat) + s(horse.power) + s(long) + s(overall.length.m) + port

Model	Residual df	Residual Deviance	Df	Deviance	F	Pr(>F)	Signifiance code
1	133.0	1427.9	-	-	-	-	
2	131.0	1120.7	2.0	307.1	25.7	0.00	***
3	127.0	868.1	4.0	252.6	10.6	0.00	***
4	122.0	719.2	4.9	148.9	5.0	0.00	***
5	117.8	708.7	1.0	10.5	1.7	0.20	
6	119.7	703.8	1.3	4.9	0.6	0.47	
7	118.8	703.8	1.0	0.0	0.0	0.98	
8	118.2	706.4	0.6	-2.6	-	-	

Signifiance codes: *** , ≥0, <0.001; ** , ≥ 0.001, <0.01; * , ≥ 0.01, <0.05; . , ≥0.05, <0.01; blank, <0.05

Table 6: Comparison of CELR catch (numbers of fish) and sampled landings by fishing year (or group of fishing years) and latitude group from 1996−97 to 2014−15, expressed as percentages. Latitude group (30,40.5] is ≥ 30 and <40.5, etc.

	CELR data		Sample data	
	Latitude group		Latitude group	
	(30,40.5]	**(40.5,50]**	**(30,40.5]**	**(40.5,50]**
1996−97 to 2000−01	42.13	57.87	33.13	66.87
2001−02 to 2004−05	60.20	39.80	47.95	52.05
2005−06 to 2007−08	30.33	69.67	27.20	72.80
2009−10	33.11	66.89	9.56	90.44
2010−11	18.00	82.00	6.13	93.87
2011−12	12.35	87.65	5.85	94.15
2012−13	33.11	66.89	8.22	91.78
2013−14	37.13	62.87	29.36	70.64
2014−15	36.78	63.22	37.43	62.57

Table 7: Comparison of annual CELR catch numbers of fish and sample catch by month and latitude group for the 3 years sampled from 2012−13 to 2014−15, expressed as percentages. -, zero. Latitude group (30,40.5] is ≥ 30 and <40.5, etc.

	CELR data			Sample data		
	Latitude group			Latitude group		
2012−13	**(30,40.5]**	**(40.5,50]**	**Total**	**(30,40.5]**	**(40.5,50]**	**Total**
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	0.16	-	0.16	-	-	-
Dec	5.55	0.98	6.53	3.65	-	3.65
Jan	14.20	15.13	29.33	4.57	28.48	33.04
Feb	3.36	34.97	38.33	-	37.46	37.46
Mar	2.93	16.61	19.53	-	20.11	20.11
Apr	2.18	2.90	5.08	-	5.73	5.73
May	0.05	0.90	0.95	-	-	-
Jun	0.00	0.09	0.09	-	-	-
Total	33.11	66.89	100.00	8.22	91.78	100.00
2013−14	**(30,40.5]**	**(40.5,50]**	**Total**	**(30,40.5]**	**(40.5,50]**	**Total**
Sep	-	-	-	-	-	-
Oct	0.02	-	0.02	-	-	-
Nov	1.11	-	1.11	-	-	-
Dec	12.81	0.75	13.55	14.45	-	14.45
Jan	12.78	18.01	30.78	10.33	9.77	20.10
Feb	4.72	28.20	32.91	3.12	41.55	44.68
Mar	3.58	10.19	13.77	1.46	16.99	18.37
Apr	1.96	4.23	6.20	-	2.14	2.41
May	0.11	1.50	1.61	-	-	-
Jun	0.03	-	0.03	-	-	-
Total	37.13	62.87	100.00	29.36	70.64	100.00
2014−15	**(30,40.5]**	**(40.5,50]**	**Total**	**(30,40.5]**	**(40.5,50]**	**Total**
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	0.43	-	0.43	-	-	-
Dec	6.57	0.02	6.59	10.87	-	10.87
Jan	18.48	17.54	36.02	20.23	12.39	32.62
Feb	6.86	18.44	25.30	-	26.03	26.03
Mar	3.32	19.51	22.82	6.33	24.15	30.48
Apr	0.98	7.36	8.34	-	-	-
May	0.15	0.35	0.50	-	-	-
Jun	-	-	-	-	-	-
Total	36.78	63.22	100.00	37.43	62.57	100.00

Table 8: Comparison of annual CELR catch numbers of fish and sample catch by month and latitude group for the 3 years sampled from 2009−10 to 2011−12, expressed as percentages. -, zero. Latitude group (30,40.5] is ≥ 30 and <40.5, etc.

	CELR data			Sample data		
	Latitude group			Latitude group		
2009−10	**(30,40.5]**	**(40.5,50]**	**Total**	**(30,40.5]**	**(40.5,50]**	**Total**
Sep	<0.01	-	<0.01	-	-	-
Oct	-	-	-	-	-	-
Nov	0.02	-	0.02	-	-	-
Dec	5.39	-	5.39	-	-	-
Jan	22.21	6.04	28.25	9.56	-	9.56
Feb	2.55	26.80	29.35	-	50.74	50.74
Mar	0.72	24.15	24.87	-	32.11	32.11
Apr	1.29	9.49	10.78	-	7.59	7.59
May	0.93	0.41	1.34	-	-	-
Jun	-	-	-	-	-	-
Total	33.11	66.89	100.00	9.56	90.44	100.00
2010−11	**(30,40.5]**	**(40.5,50]**	**Total**	**(30,40.5]**	**(40.5,50]**	**Total**
Sep	-	-	-	-	-	-
Oct	0.10	-	0.10	-	-	-
Nov	0.22	0.03	0.25	-	-	-
Dec	7.43	0.03	7.47	-	-	-
Jan	7.49	24.57	32.06	4.78	25.20	29.98
Feb	0.89	35.57	36.46	-	44.46	44.46
Mar	1.22	18.86	20.08	-	19.78	19.78
Apr	0.65	2.90	3.55	1.35	4.43	5.78
May	<0.01	0.03	0.03	-	-	-
Jun	-	-	-	-	-	-
Total	18.00	82.00	100.00	6.13	93.87	100.00
2011−12	**(30,40.5]**	**(40.5,50]**	**Total**	**(30,40.5]**	**(40.5,50]**	**Total**
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	0.13	0.06	0.19	-	-	-
Dec	3.69	3.32	7.01	5.85	-	5.85
Jan	2.45	37.96	40.41	-	28.43	28.43
Feb	2.42	27.85	30.27	-	41.60	41.60
Mar	1.83	12.79	14.62	-	15.57	15.57
Apr	1.80	5.53	7.33	-	8.55	8.55
May	0.03	0.14	0.17	-	-	-
Jun	-	-	-	-	-	-
Total	12.35	87.65	100.00	5.85	94.15	100.00

Table 9: Comparison of annual CELR catch numbers of fish and sample catch by month and latitude group for the years 1996−97 to 2007−08 years expressed as percentages. - , zero. Latitude group (30,40.5] is ≥ 30 and <40.5, etc.

	CELR data			Sample data		
	Latitude group			Latitude group		
1996−97 to 2000−01	**(30,40.5]**	**(40.5,50]**	**Total**	**(30,40.5]**	**(40.5,50]**	**Total**
Sep	-	-	-	-	-	-
Oct	<0.01	-	<0.01	-	-	-
Nov	0.10	-	0.10	-	-	-
Dec	1.40	0.11	1.51	-	-	-
Jan	15.34	12.08	27.43	16.73	26.41	43.14
Feb	12.97	25.32	38.28	14.34	20.61	34.95
Mar	8.65	17.39	26.04	2.07	19.55	21.62
Apr	2.96	2.28	5.24	-	0.30	0.30
May	0.67	0.68	1.36	-	-	-
Jun	0.04	0.01	0.05	-	-	-
Total	42.13	57.87	100.00	33.13	66.87	100.00
2001−02 to 2004−05	**(30,40.5]**	**(40.5,50]**	**Total**	**(30,40.5]**	**(40.5,50]**	**Total**
Sep	-	-	-	-	-	-
Oct	<0.01	-	<0.01	-	-	-
Nov	0.12	-	0.12	-	-	-
Dec	5.27	0.05	5.32	2.61	-	2.61
Jan	25.72	7.46	33.18	21.59	12.31	33.90
Feb	12.46	15.52	27.98	14.71	18.09	32.81
Mar	10.00	13.63	23.64	9.04	17.05	26.08
Apr	5.87	3.07	8.94	-	4.59	4.59
May	0.75	0.06	0.81	-	-	-
Jun	<0.00	0.02	0.03	-	-	-
Total	60.20	39.80	100.00	47.95	52.05	100.00
2005−06 to 2007−08	**(30,40.5]**	**(40.5,50]**	**Total**	**(30,40.5]**	**(40.5,50]**	**Total**
Sep	-	-	-	-	-	-
Oct	<0.01	-	<0.01	-	-	-
Nov	0.04	-	0.04	-	-	-
Dec	4.27	0.01	4.28	-	-	-
Jan	13.24	13.13	26.36	17.96	8.30	26.25
Feb	4.90	33.68	38.58	6.94	29.57	36.51
Mar	4.15	19.55	23.70	2.31	23.15	25.46
Apr	3.08	3.20	6.28	-	11.78	11.78
May	0.65	0.10	0.75	-	-	-
Jun	<0.01	-	<0.01	-	-	-
Total	30.33	69.67	100.00	27.20	72.80	100.00

Table 10: Target number of fish to sample each month, and number sampled each year, month and port, 2012−13 to 2014−15, Auck, Auckland, Grey, Greymouth.

		2012−13			2013−14			2014−15		
Month	Target	Auck.	Grey.	Total	Auck.	Grey.	Total	Auck.	Grey.	Total
December	400	371		371	1 122		1 122	786		786
January	1 600	570	1 401	1 971	919	772	1 691	1 493	400	1 893
February	1 600		1 703	1 703		1 663	1 663		1 400	1 400
March	1 000		803	803		1 137	1 137		1 137	1 137
April	400		400	400		202	202			
Total	5 000	941	4 307	5 248	2 041	3 774	5 815	2 279	2 937	5 216

Table 11: Number of fish, landings and vessels sampled and average number of fish sampled each landing, by month and port for the years 2012−13 to 2014−15.

2012–13		**No. of fish**	**Landings**	**Vessels**	**Average no. of fish per landing**
Auckland	December	371	2	3	186
	January	570	3	3	190
Greymouth	January	1 401	14	9	100
	February	1 703	17	14	100
	March	803	8	7	80
	April	400	4	4	100
Total		5 248	48	31	

2013–14		**No. of fish**	**Landings**	**Vessels**	**Average no. of fish per landing**
Auckland	December	1 122	6	6	187
	January	919	5	5	184
Greymouth	January	772	8	6	96
	February	1 663	17	15	98
	March	1 137	12	11	98
	April	202	2	2	100
Total		5 815	50	33	

2014–15		**No. of fish**	**Landings**	**Vessels**	**Average no. of fish per landing**
Auckland	December	786	4	3	197
	January	1 493	8	8	186
Greymouth	January	400	4	4	100
	February	1 400	14	12	100
	March	1 137	12	9	95
Total		5 216	42	30	

Table 12: Annual CELR albacore catch (number of fish) by month (December to April) and monthly catch as percentage of the annual total for the years 2012−13 to 2014−15.

	Catch (number of fish)				% of annual catch			
	2012−13	2013−14	2014−15	3-year total	2012−13	2013−14	2014−15	3-year average
December	27 667	46 107	22 548	96 322	6.6	13.6	6.6	8.7
January	123 432	104 717	123 287	351 436	29.3	30.8	36.0	31.8
February	161 186	111 965	86 590	359 741	38.3	32.9	25.3	32.6
March	82 274	46 853	78 124	207 251	19.5	13.8	22.8	18.8
April	21 342	21 078	28 550	70 970	5.1	6.2	8.3	6.4
Other	5 052	9 463	3 181	17 696	1.2	2.8	0.9	1.6
Total	420 953	340 183	342 280	1 103 416				

Table 13: Annual CELR albacore catch (number of fish) by FMA (December to April) and FMA catch as percentage of the annual total for the years 2012−13 to 2014−15.

	Catch (number of fish)				% of annual catch			
	2012−13	2013−14	2014−15	3-year total	2012−13	2013−14	2014−15	3-year average
FMA 1	7 548	8 968	4 296	20 812	1.8	2.6	1.3	1.9
FMA 2	12 108	13 395	20 018	45 521	2.9	3.9	5.8	4.1
FMA 5	1 129	859	445	2433	0.3	0.3	0.1	0.2
FMA 7	320 470	242 976	228 424	791 870	76.1	71.4	66.7	71.8
FMA 8	41 558	28 184	46 640	116 382	9.9	8.3	13.6	10.5
FMA 9	37 584	45 581	42 374	125 539	8.9	13.4	12.4	11.4
Other	556	220	83	859	0.1	0.1	0	0.1
Total	420 953	340 183	342 280	1 103 416				

Table 14: Percentage of total annual CELR albacore catch (number of fish) in each month and FMA for the three years 2012−13, 2014−14 and 2014−15. Highest values (> 4%) are in bold.

2012−13	East Coast North Island		West Coast South Island		West Coast North Island	
	FMA 1	FMA 2	FMA 5	FMA 7	FMA 8	FMA 9
November	0.0	0.0	0.0	0.0	0.0	0.1
December	1.7	0.0	0.0	1.3	1.4	2.2
January	0.1	0.1	0.0	**17.0**	**5.7**	**6.3**
February	0.0	0.3	0.2	**35.9**	1.7	0.2
March	0.0	1.6	0.1	**16.8**	1.0	0.1
April	0.0	0.9	0.0	**4.1**	0.1	0.0
May	0.0	0.0	0.0	0.9	0.0	0.0
June	0.0	0.0	0.0	0.1	0.0	0.0

2013−14	East Coast North Island		West Coast South Island		West Coast North Island	
	FMA 1	FMA 2	FMA 5	FMA 7	FMA 8	FMA 9
November	1.0	0.0	0.0	0.0	0.0	0.1
December	0.7	0.1	0.0	2.0	2.2	**8.5**
January	0.4	0.1	0.0	**21.6**	**4.1**	**4.7**
February	0.3	0.1	0.2	**31.0**	1.3	0.1
March	0.2	2.0	0.1	**10.9**	0.5	0.1
April	0.1	0.1	0.0	**4.4**	0.1	0.0
May	0.0	0.0	0.0	1.5	0.0	0.0
June	0.0	0.0	0.0	0.0	0.0	0.0

2014−15	East Coast North Island		West Coast South Island		West Coast North Island	
	FMA 1	FMA 2	FMA 5	FMA 7	FMA 8	FMA 9
November	0.4	0.0	0.0	0.0	0.0	0.0
December	0.3	0.0	0.0	0.0	0.6	**5.7**
January	0.4	1.7	0.0	**19.2**	**8.3**	**6.4**
February	0.1	2.9	0.0	**19.2**	2.7	0.3
March	0.0	1.2	0.0	**20.3**	1.3	0.0
April	0.0	0.0	0.0	**7.6**	0.6	0.0
May	0.0	0.0	0.0	0.4	0.0	0.0
June	0.0	0.0	0.0	0.0	0.0	0.0

Table 15: Monthly sample targets for 2015−16 to 2017−18, with reduced total sample sizes. Targets are rounded to the nearest 100.

	% of annual catch	Proposed target sample size (number of fish)				
Total		**5000**	**4000**	**3000**	**2000**	**1000**
December	8.7	400	300	200	200	100
January	31.8	1 600	1 300	1 000	600	300
February	32.6	1 600	1 300	1 000	700	300
March	18.9	1 000	800	600	400	200
April	8.0	400	300	200	100	100

Table 16: Number of landings to sample at each port and month based on sample size allocations as set out in Table 15, with 100 fish sampled per landing.

Total sample size		**5000**	**4000**	**3000**	**2000**	**1000**
Port	Month	Number of landings to sample				
Auckland	December	4	3	2	2	1
	January	8	6	5	3	1
Greymouth	January	8	7	5	3	2
	February	16	13	10	7	3
	March	10	8	6	4	2
	April	4	3	2	1	1
Total		50	40	30	20	10

Table 17: Simulated mean weighted CV (percentage) for each combination of number of landings sampled per month and port (5, 10, 15, 20) and number of fish sampled (50, 100, 150, 200) per landing, for each sampled dataset from 2012−13 to 2014−15.

2012−13

No. fish	No. landings			
	5	10	15	20
50	21%	15%	12%	11%
100	17%	12%	10%	9%
150	16%	12%	9%	8%
200	16%	11%	9%	8%

2013−14

No. fish	No. landings			
	5	10	15	20
50	23%	16%	13%	12%
100	20%	14%	11%	10%
150	18%	13%	10%	9%
200	17%	12%	10%	9%

2014−15

No. fish	No. landings			
	5	10	15	20
50	25%	18%	14%	12%
100	21%	15%	12%	11%
150	20%	14%	11%	10%
200	19%	14%	11%	10%

Table 18: Monthly sample targets for 2015−16 to 2017−18, based on monthly catch proportions during 2012−13 to 2014−15.

Month	% of annual catch	Target number of landings to sample	Target number of fish to sample	Sampling port
December	8.7	4	400	Auckland
January	31.8	16	1 600	Auckland and Greymouth
February	32.6	16	1 600	Greymouth
March	18.9	10	1 000	Greymouth
April	8.0	4	400	Greymouth
Total		50	5 000	

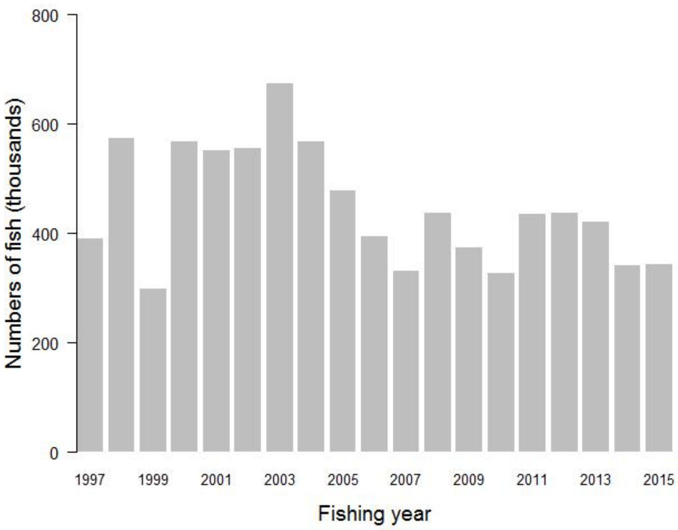
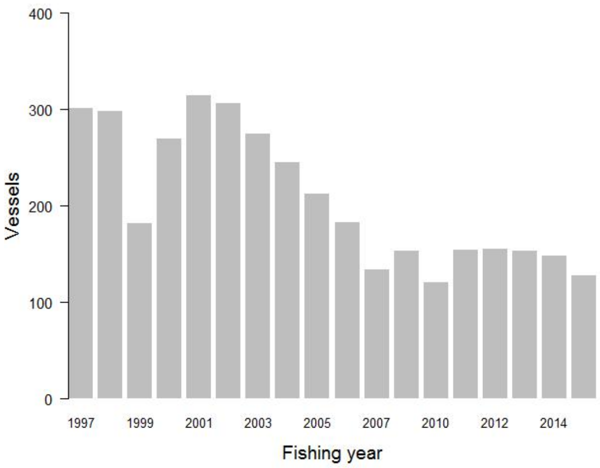


Figure 1: Albacore catch, numbers of fish (thousands) reported in CELR data, by fishing years 1996−97 (1997) to 2014−15 (2015).

(a) **(b)**



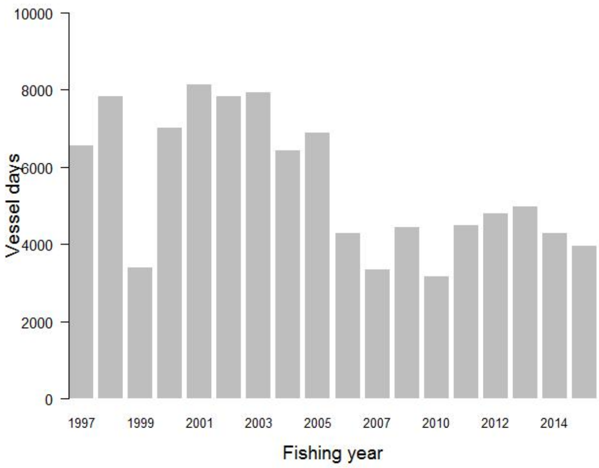


Figure 2: Effort, (a) number of vessels and (b) number of vessel days, reported in CELR data by fishing years 1997−2015 (2009 not included).

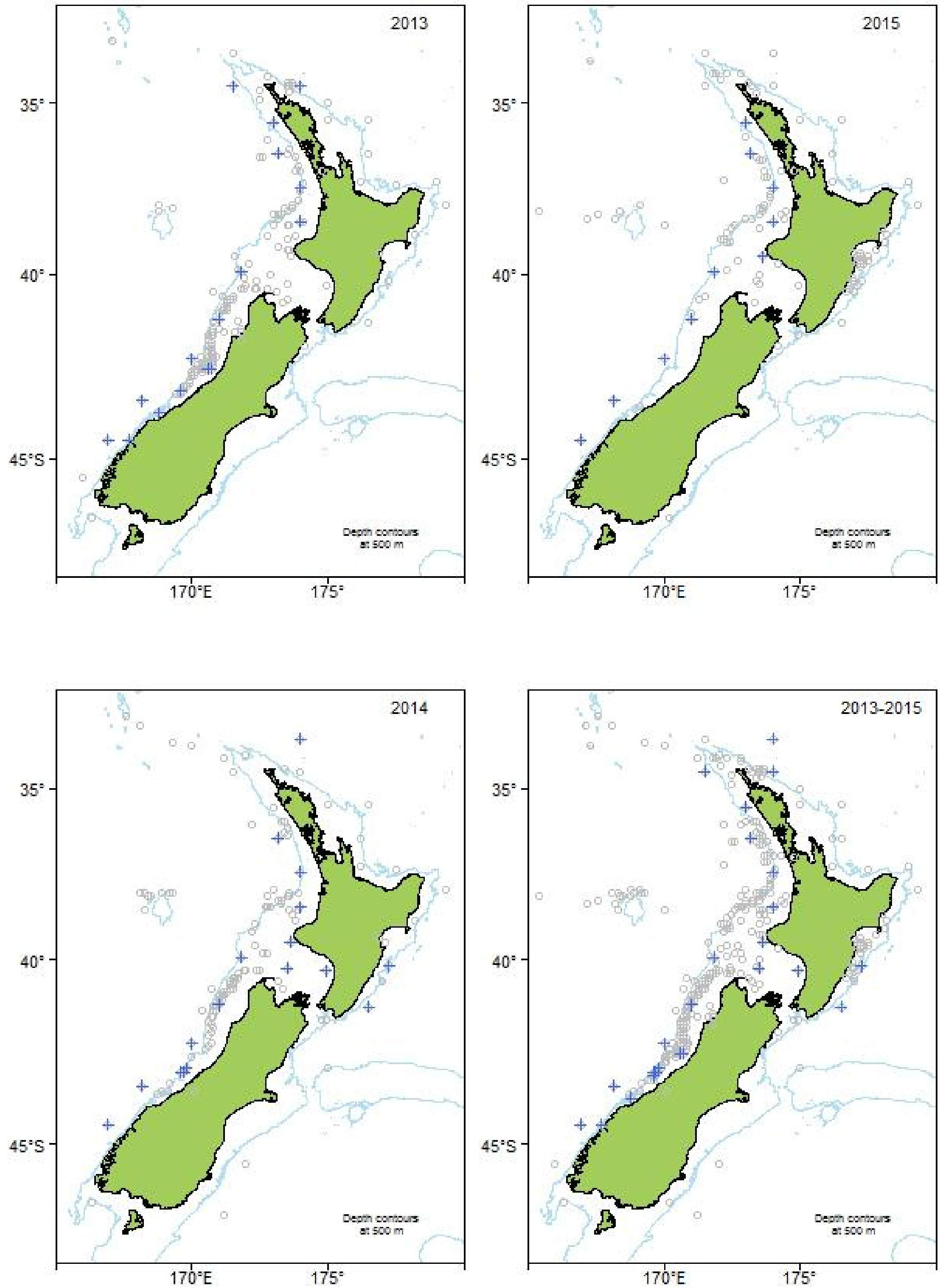


Figure 3: Positions of troll fishing from 2012−13 to 2014−15 recorded in CELR (grey) and catch sampling (blue) data for 2012−13 (2013), 2013−14 (2014), 2014−15 (2015), and all three years combined. The 500 m depth contour is shown in blue. Some data points are shown as the 'centroid' of a Statistical Area.

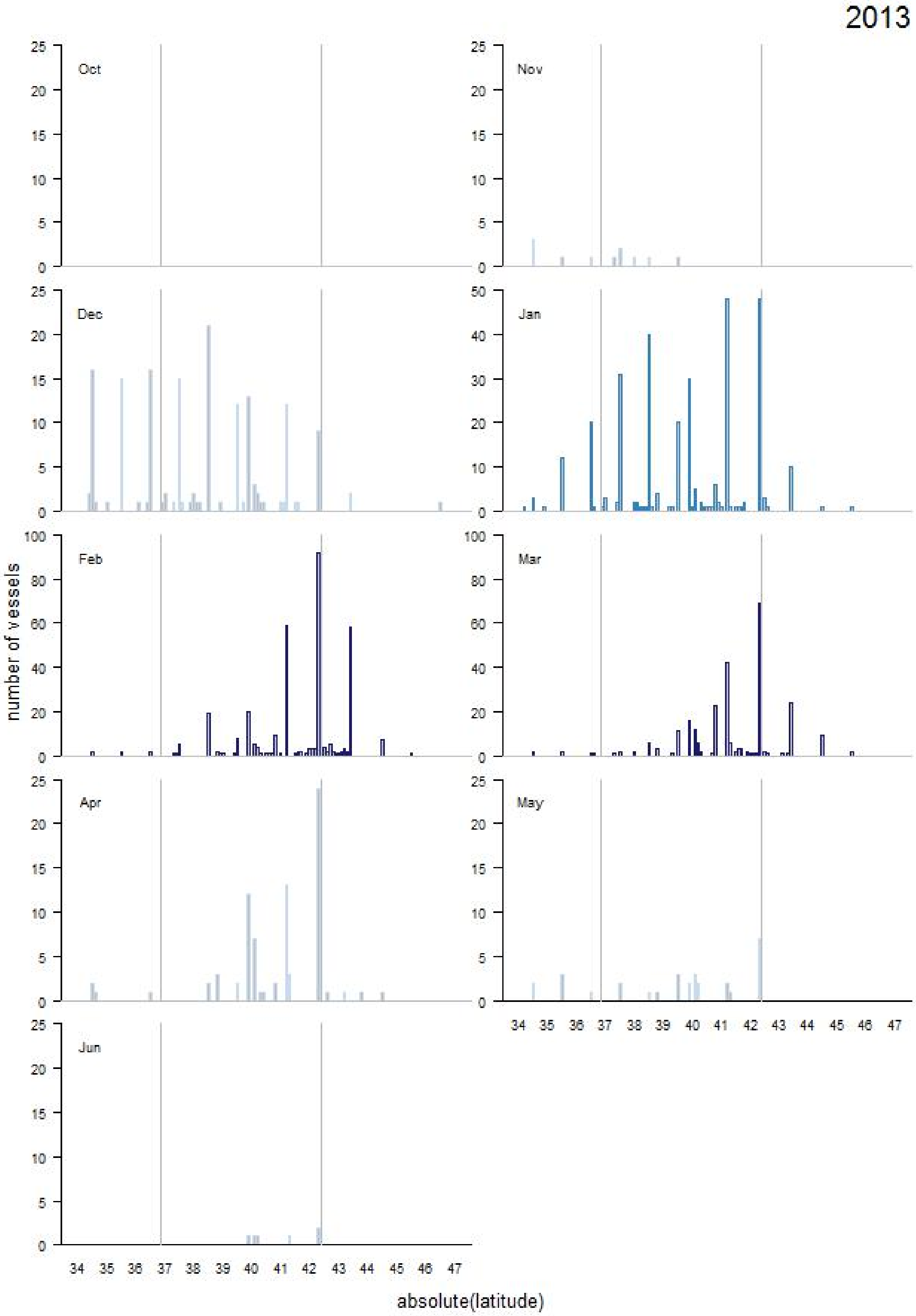


Figure 4: Number of vessels in CELR data by month and latitude (0.1 degree bins, absolute latitude where right side is more southerly) for 2012−13 (2013). Vertical grey lines mark Kaipara Harbour and Greymouth. Pale coloured bars are used for small sample sizes, where the y-axis scale is less than the scale used for dark bars representing more vessels. Three colours are shown representing y-axis scales of 25, 50, and 100.

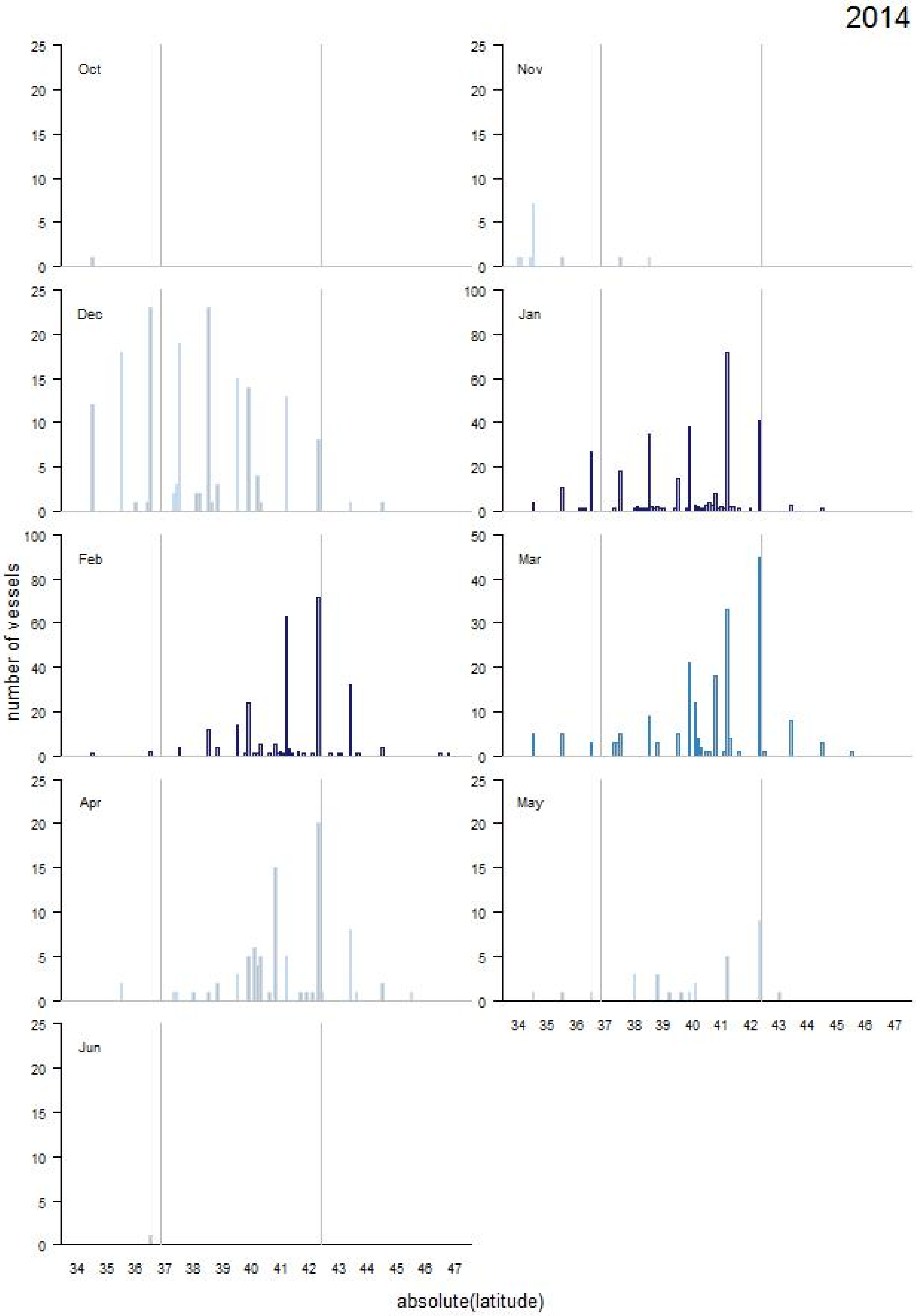


Figure 5: Number of vessels in CELR data by month and latitude (0.1 degree bins) for 2013−14 (2014). Vertical grey lines mark Kaipara Harbour and Greymouth. Pale coloured bars are used for small sample sizes, where the y-axis scale is less than the scale used for dark bars representing more vessels. Three colours are shown representing y-axis scales of 25, 50, and 100.

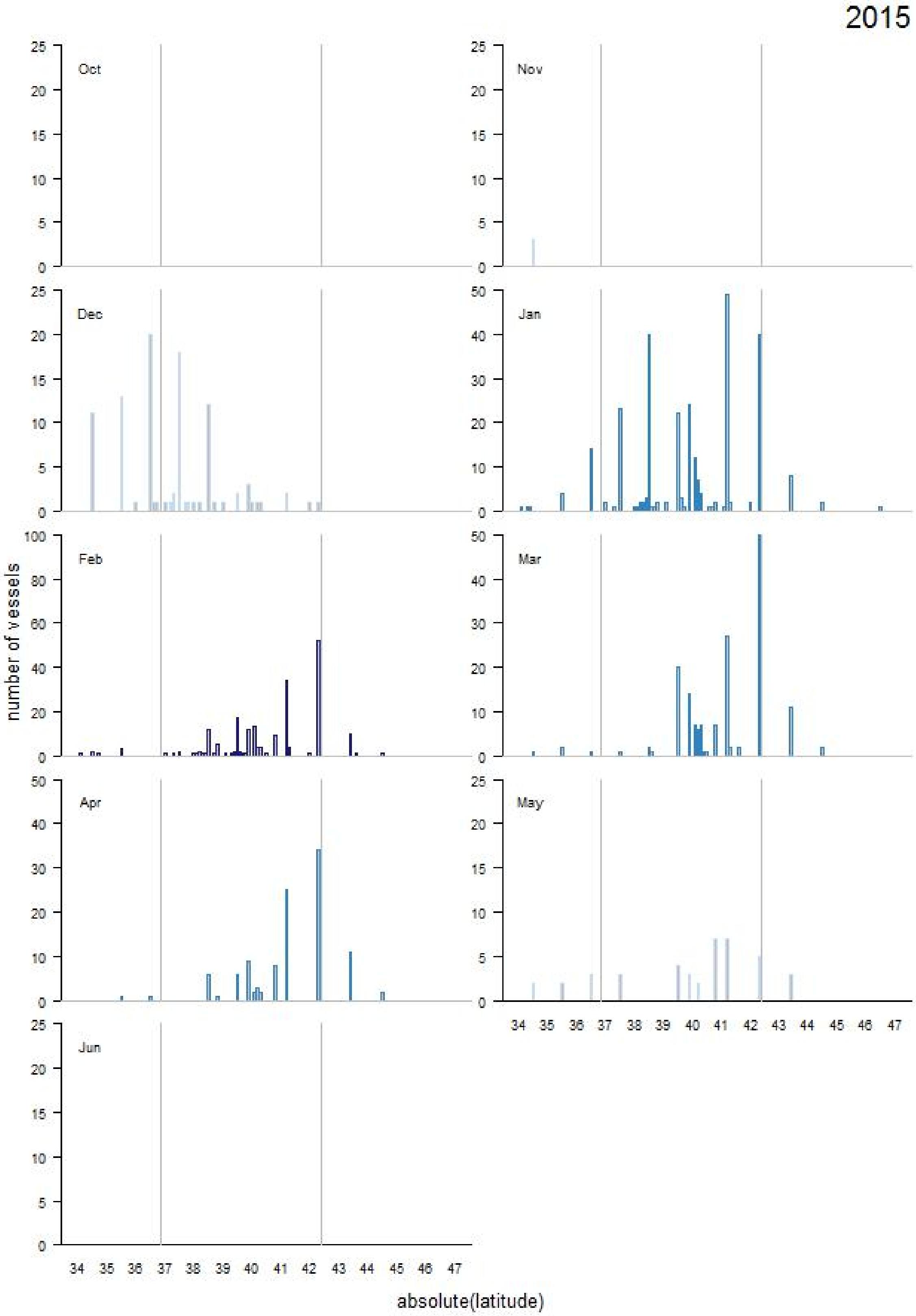


Figure 6: Number of vessels in CELR data by month and latitude (0.1 degree bins) for 2014−15 (2015). Vertical grey lines mark Kaipara Harbour and Greymouth. Pale coloured bars are used for small sample sizes, where the y-axis scale is less than the scale used for dark bars representing more vessels. Three colours are shown representing y-axis scales of 25, 50, and 100.

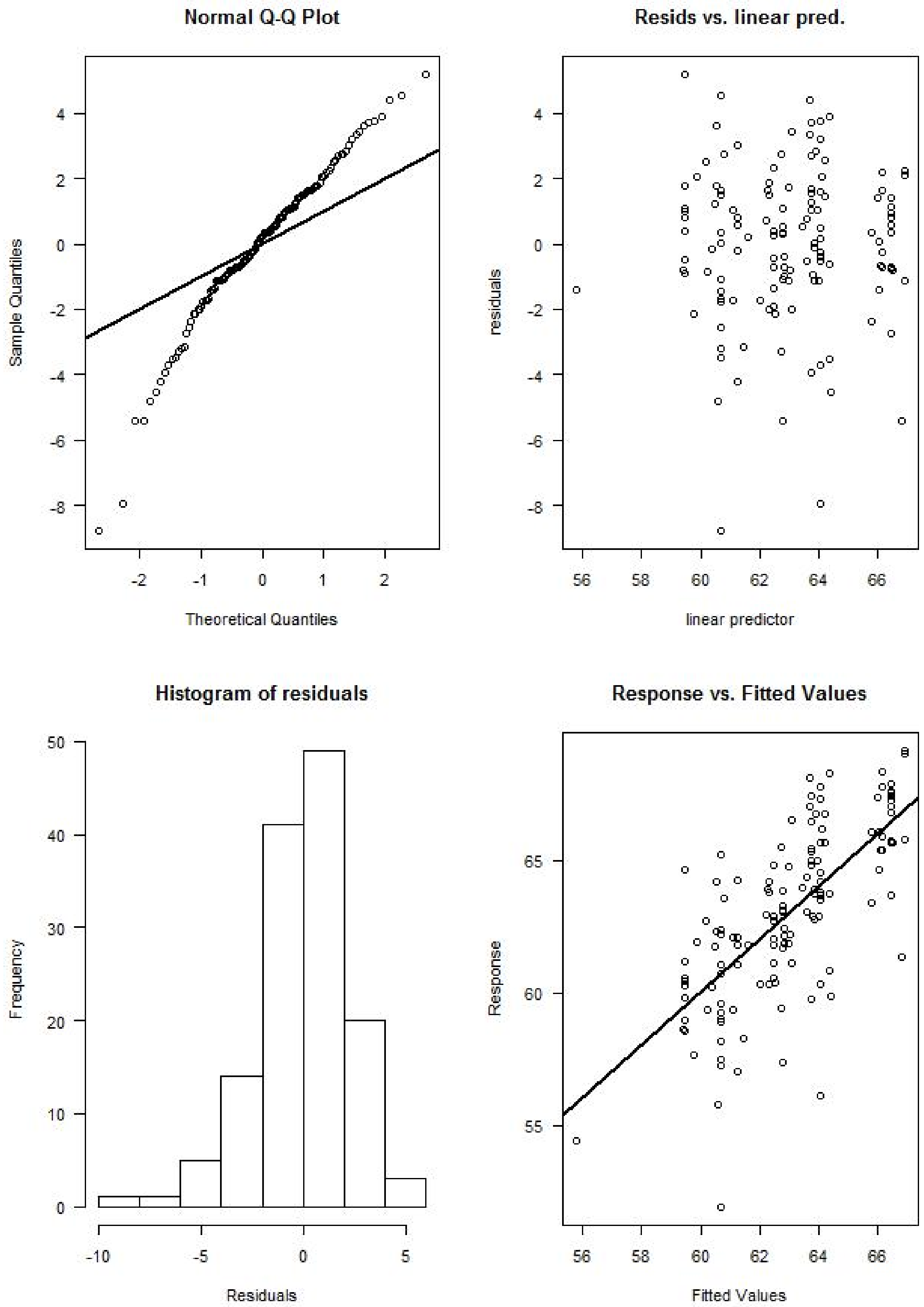


Figure 7: Diagnostics of the GAM regression on mean length from port sampling data.

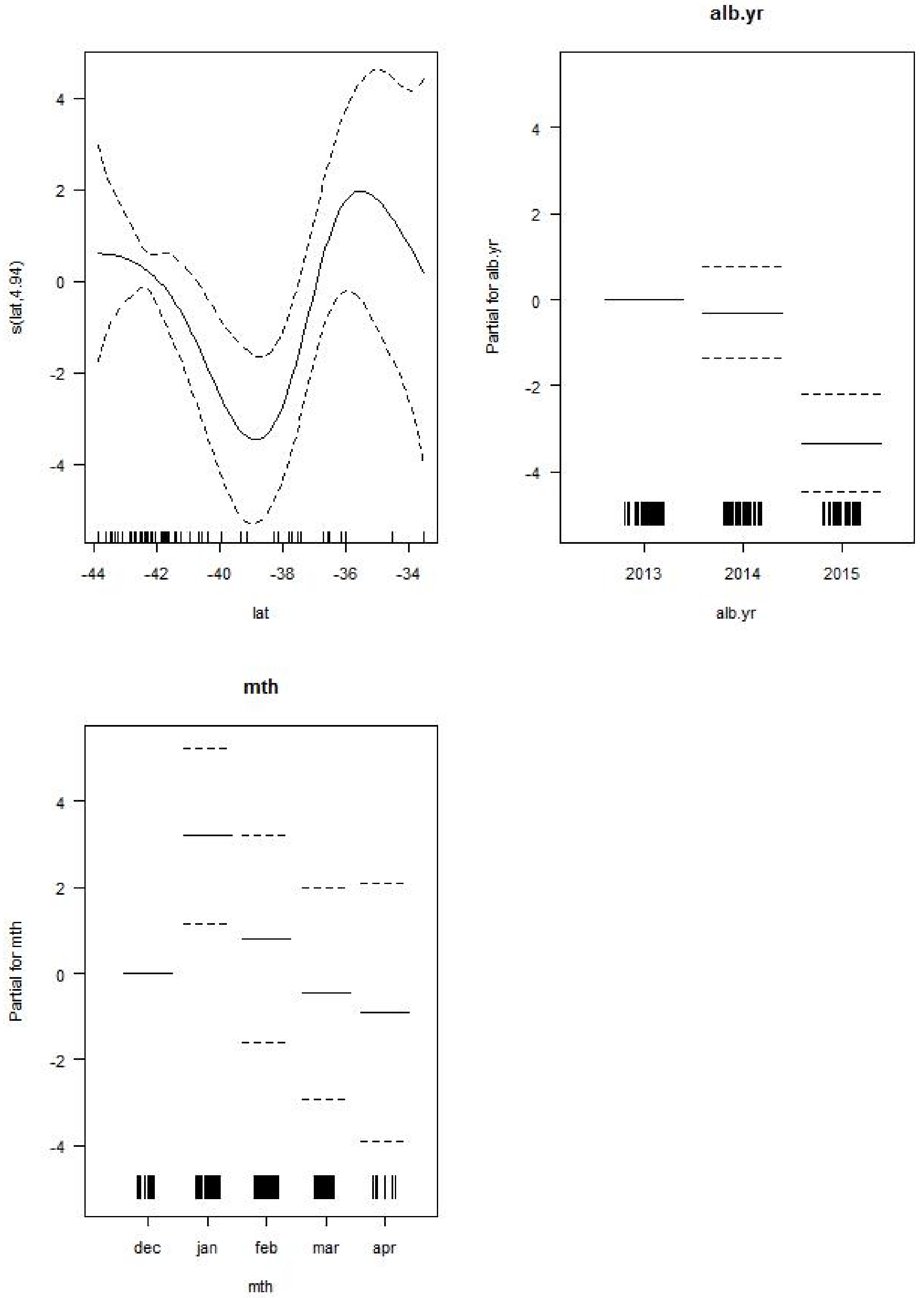


Figure 8: Effects of statistically significant factors in the GAM regression of length. The mean is the solid line, 95% confidence levels are the dotted lines, and marks at the bottom are the data used (jittered).

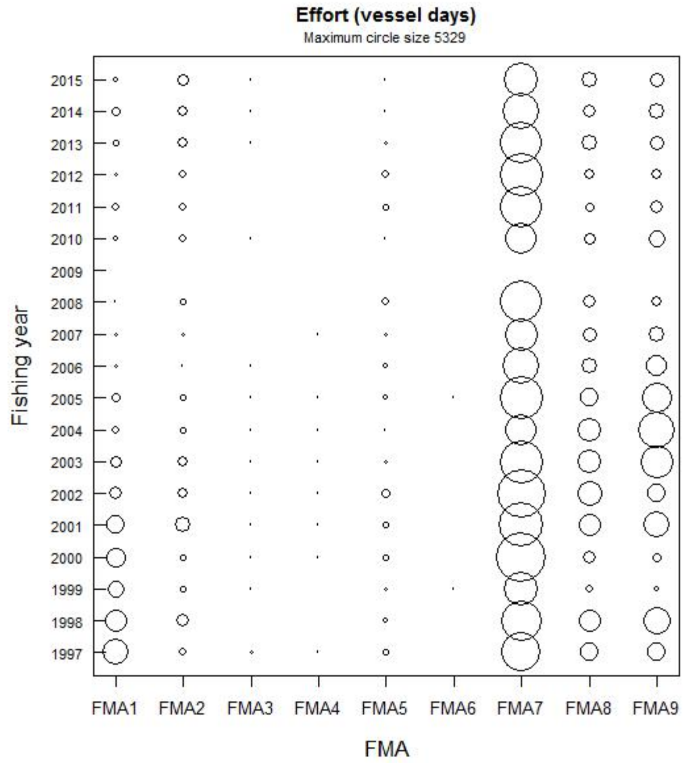


Figure 9: Annual pattern of effort (number of vessel days) reported in CELR data, by FMA. The area of the circles is proportional to the maximum value in each panel, indicated in the title.

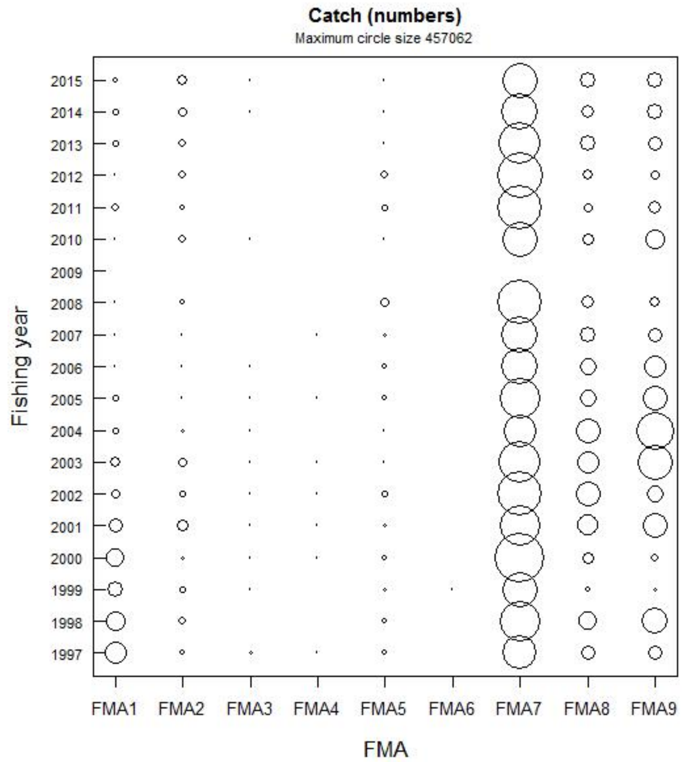


Figure 10: Annual pattern of albacore catch (numbers) reported in CELR data by FMA. The area of the circles is proportional to the maximum value in each panel, indicated in the title.

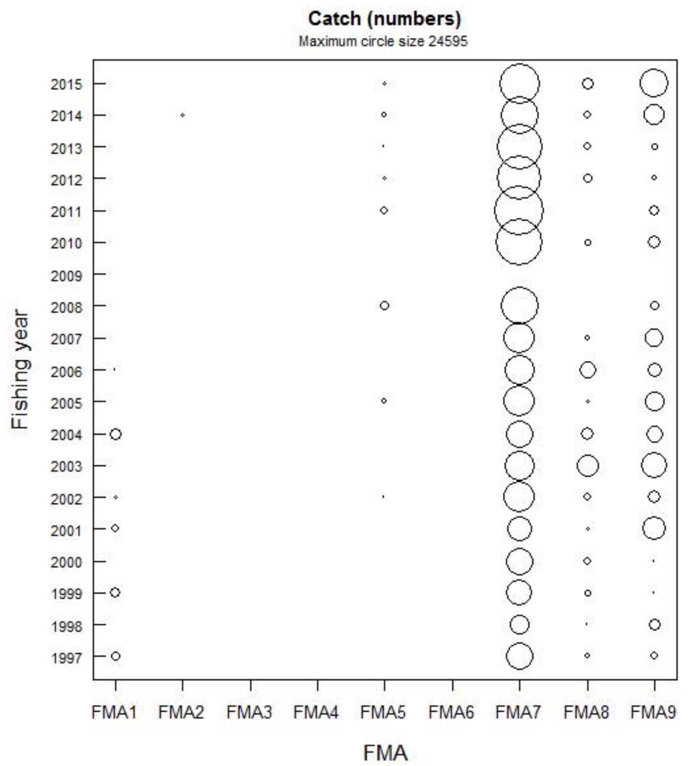


Figure 11: Annual pattern of albacore catch (numbers) reported in sampling data, by FMA. The area of the circles is proportional to the maximum value in each panel, indicated in the title.