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Albacore catch sampling – characterisation and sample design

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Griggs, L. Datta, S. (2019). Albacore catch sampling – characterisation and sample design.
New Zealand Fisheries Assessment Report 2019/36**. 54 p.**

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. Data from troll-caught albacore from this port sampling programme have been provided to the Western Central Pacific Fisheries Commission (WCPFC) for input into the South Pacific albacore stock assessment since 1996−97.

A characterisation of the albacore tuna troll fishery in New Zealand waters was carried out before catch sampling started in 2018–19, and the results of this were used to review and update the current sampling design to be representative of the fishery, spatially and temporally.

The albacore troll fishery takes place over the summer months from December to April and most fishing was on the west coast of New Zealand, especially the west coast of the South Island (WCSI) in FMA7. Characterisation focused on the most recent three years, 2015–16 to 2017–18, but earlier years (1996–97 to 2014–15) were also summarised.

Albacore have been sampled to determine the representative length composition and length-weight relationships of the fish in the landing sheds of Licensed Fish Receivers for 21 years between 1996–97 and 2017–18 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 of the fishery over the most recent years provided a basis for allocation of ongoing sampling by port and month which will be used for sampling during the next three years, 2018–19, 2019–20, and 2020–21. The target coefficient of variation (CV) for annual length distribution samples was 20%.

1. INTRODUCTION

Albacore tuna (*Thunnus alalunga*) caught in the New Zealand Exclusive Economic Zone (EEZ) 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 2017 (Williams & Terawasi 2012, Pilling et al. 2014, Anon 2018a). The New Zealand troll catch was 1969 t in 2016 and 1959 t in 2017 (Anon 2018a).

Troll vessels from the United States have fished for albacore in the South Pacific since 1986, in the STCZ, approximately 39–41º 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 declined to 145 t in 2016 and increased to 464 t in 2017 (Anon 2018b).

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. 2018c, 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. 2018d).

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 (OFP-SPC and the WCPFC Secretariat 2015).

Labelle (1993) noted that STCZ albacore tend to be larger than those around New Zealand. Albacore caught 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 is reached at 87 cm FL and 100% maturity is 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 21 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, Griggs & Large

2016, Griggs et al. 2018). Fish sampled over these 21 years were mostly juveniles, ranging in size from 29 to 99 cm FL, with nearly all fish (99%) in the 47–80 cm range (Griggs et al. 2018). A significant linear relationship was found between the logs of albacore FL and greenweight (GW). 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 observers from the Ministry's Scientific Observer Programme have shown that the observer data were not representative of the fishery because the observer coverage was not able to extend to enough vessels, and the port sampling was able to offer better representation of the fishery (Griggs et al. 2013, 2014). Troll vessel coverage by observers was discontinued in 2013 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), Harley et al. (2015) and Tremblay-Boyer et al. (2018). 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 troll for smaller albacore, the New Zealand length data provide the assessment with a clear signal, and more data will provide better certainty. The data provide some information about relative cohort strength from year to year.

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.

Albacore are currently managed outside the Quota Management System (QMS). Fisheries New Zealand 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 is 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. These data also form an important input into the Marine Stewardship Council (MSC) certification of the New Zealand albacore troll fishery.

This project also contributes to Key Focus Area 2 "Contribute to international processes through RFMOs" of the "Annual Operational Plan for Highly Migratory Species Fisheries 2017/18". The MSC has certified that the New Zealand troll fishery for albacore conforms to their Principles and Criteria for Sustainable Fishing. The New Zealand industry are currently preparing for the third MSC annual audit of the New Zealand albacore troll fishery.

The research in this report 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 Key Focus Area 2 "Contribute to international processes through RFMOs" of the "Annual Operational Plan for Highly Migratory Species Fisheries 2017/18".

The present project updates and extends previous analyses for three more years, thus increasing the port sampling time series to 24 years. It addresses the following objectives:

OVERALL OBJECTIVE:

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 2017−18 fishing year.

2. To review and revise, if necessary, the current 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 2018−19, 2019−20, and 2020−21 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 2017–18 by the Ministry of Fisheries, Ministry for Primary Industries, and now Fisheries New Zealand.

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 through the 2017−2018 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 as Statistical Area. If a Statistical Area is recorded, a 'centroid' latitude and longitude position is assigned in the *tuna* database (Wei 2007).

Fishers are required to record the 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 8.6% of CELR records where albacore catch was recorded during the most recent three years (2015−16 to 2017−18).

Shore based catch sampling of albacore began in 1996−97 and has occurred each year for twelve consecutive years up to 2007−08. The 2008−09 year was not sampled. Sampling resumed in 2009−10 for nine more years, up to 2017−18. 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 2017−18 is 1 July 2017 to 30 June 2018, with the majority of fishing in 2018.

The last characterisation of the troll fishery was carried out in MPI project ALB201501 (Griggs & Large, 2017) and this was based on the three previous years of sampling, 2012–13 to 2014–15 which were summarised by Griggs et al. (2014) and Griggs & Large (2016).

This characterisation focuses on the 2015−16, 2016−17 and 2017−18 albacore fishing years. These are the three most recent years sampled by the shore-based catch sampling programme under MPI project ALB201501 (Griggs et al. 2018).

2.1.2 GAM analysis on mean length

A generalized additive model (GAM) analysis was done to determine the variables that best predicted mean length in the catch samples, as these can then be used to determine sampling strata. Current sampling strata are port and month. Data used were from the landing samples taken in the 2015−16, 2016−17 and 2017−18 years. The mean length from each landing sample was regressed against factors including year, month, statistical area, port, vessel length, and vessel horsepower. Variables were selected step-wise according to R^2 from the remaining candidates, with a variable accepted if significant (F-test; P-value ≤ 0.01), with a cut-off for inclusion in the final model that each predictor should increase the R^2 by at least 1%

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 40.5º 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 nine most recent years individually, i.e., 2009−10, 2010−11, 2011−12, 2012−13, 2013−14, 2014−15, 2015−16, 2016−17 and 2017−18, and the rest 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 distributions by latitude (0.5 degree bins) for each month. Factors examined were: number of vessels in the fishery, troll duration, and number of albacore reported.

2.2 RESULTS

2.2.1 Catch effort and sampling data

The total albacore troll catch recorded on CELR forms, in fish numbers and weight, for 1996−97 to 2017−18 is shown in Table 1 and Figure 1 (numbers of fish), and effort as number of vessels and number of vessel days for each fishing year can be seen in Table 1 and Figure 2.

Between 1996−97 and 2017−18, catch numbers peaked in 2002−03, then declined until 2006−07, and fluctuated since then (Table 1, Figure 1). Catch numbers in 2015−16 and 2016−17 were lower than in the five previous years, and then increased in 2017–18, but catch weights have been similar over the past four years, from 2014−15 to 2017−18 (Table 1).

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, less than 200 vessels have operated in the fishery. The number of vessels dropped to 120 with 3169 vessel days in 2009–10, this being the lowest number of vessel days. Both the number of vessels and vessel days showed some increase over the next three years and fluctuated since then. In 2016−17 there were 98 vessels, the lowest number of vessels in the fishery since 1996–97 when the port sampling programme began. There were 130 vessels in the following year in 2017−18.

The number of fish sampled in each year and port is shown in Table 2 for 21 years of catch sampling. Fishing positions of the commercial troll vessels shown as Statistical Area density plots comparing albacore caught and sampled are shown in Figure 3 for 2015–16, 2016–17, and 2017–18. Almost all trolling was on the west coast of New Zealand with 93.7%, 86.5% and 93.7% of the catch (in numbers) for 2015−16, 2016−17 and 2017−18 respectively (overall 91.3% for the three years) from the west coast (a slight reduction from the 94% average over 2012–13 to 2014–15), and the majority of that was off the South Island.

The number of vessels fishing by year and month by 0.5 degree latitude bins are shown in Figure 4 for 2015–16 to 2017–18. The highest vessel numbers were in January, February, and March in all three years, mainly in latitudes south of 40° S in 2015–16 and 2017–18, while in 2016–17, most vessels were fishing north of 40° S from December to February and most were south of 40° S in March.

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-test on the resultant cascade of models from the ANOVA is shown in Table 5. In order of decreasing significance, explanatory variables included: statistical area, fishing year, month, and port of sampling.

The GAM diagnostic plots are shown in Figure 5. The diagnostics show that the residuals are approximately normally distributed, with a slight right skew (histogram of residuals), and correspondingly support normality of errors with a roughly linear pattern of points in the Q-Q plot, and a slight upwards skew on the right-hand side. The variance is approximately constant (residuals vs. linear predictor, regular pattern of residuals above and below 0, lack of curvature). The Q-Q plot shows that the estimated standard deviation is biased low, hence a steeper pattern of the residuals relative to the 1-1 standard for the normal distribution. This also causes a wider distribution of residuals (histogram plot) than expected.

The patterns of the estimated effects are shown in Figure 6. The mean length was most significantly associated with Statistical Area. To a lesser extent fishing year, month and port of sampling were explanatory variables for mean length, although these are considered secondary to the Statistical Area, with confidence intervals overlapping for both variables; in particular, month was highly correlated with Statistical Area, with sampling taking place mostly off the west coast of North Island in December and January, and this moved south through to April. There is no visible trend in month, in contrast to those observed at the last characterization (Griggs & Large 2017), where mean length increased from December to January and then decreased through to April. The length of vessel and horsepower were not significant influences on mean length.

2.2.3 Representativeness of catch sampling

Comparisons of fishing effort as troll duration by month and latitude are shown for CELR data and sampling data for 2015–16 to 2017–18 in Figure 7, and for catch in numbers of albacore in Figure 8. Based on a visual analysis of the data, the sampling followed fishery trends quite well.

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 in Table 6. These comparisons are shown by year and month for 2015–16 to 2017–18 (Table 7), 2012–13 to 2014–15 (Table 8), 2009–10 to 2011–12 (Table 9), and and for the year groups 1996−97 to 2000−01, 2001−02 to 2004−05 and 2005−06 to 2007−08 (Table 10).

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 due to logistic difficulties collecting samples at the northern port which have been addressed, resulting in more representative sampling in the north region in recent years. In the most recent three years the percentages of CELR data and sample data in the north latitude group were 39.8% and 23.0% (2015−16), 75.1% and 72.1% (2016–17), and 21.8% and 5.4% (2017–18) respectively (Table 7).

Sampling in 2015−16 was consistent with CELR catches by month and latitude group, capturing the trend seen in previous years of the majority of catch in the south in February and March and January's catch split between the north and south latitude groups. The trend was different in 2016–17 with most of the fishery in the north and sampling was adapted to follow the fishery. The season was short in the north in 2017–18, mostly confined to December, and December was under-sampled.

The percentage of catches (in numbers) are shown for CELR data by FMA and month for each fishing year from 1996–97 to 2017–18 in Figure 10. 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 in most years.

The trend was different in 2016–17 with greater numbers in FMA 8 and FMA 9. Sampled landings show a similar trend with most of the fish from FMA 7 including 2015–16 and 2017–18, and a good representation of FMA 7, FMA 8 and FMA 9 (Figure 9).

Annual Statistical Area density plots comparing albacore caught and sampled are shown in Figure 3 for 2015–16, 2016–17, and 2017–18, and plots by month are shown in Appendices 1, 2, and 3 for 2015–16, 2016–17, and 2017–18 respectively.

3. PART TWO – SAMPLE DESIGN

Specific objective 2

To review and revise, if necessary, the current 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 sampling design was based on the characterisation of the fishery undertaken in Part 1 (Objective 1) of this report, focusing on the three most recent years. Sampling was 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 et al. (2018) for 2015–16 to 2017–18. Other recent assessments were for 2013−14 and 2014−15 (Griggs & Large 2016), 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 & Large (2017) and the sampling design was developed for sampling 2015−16 to 2017−18. The assessment for this period was performed by Griggs et al. (2018).

We firstly describe the sampling methodology that has been used for port sampling of albacore from 1996−97 to 2017−18 (hereafter referred to as ‘the current sampling design’).

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 2015−16 to 2017−18 were based on the monthly distribution of the catch during the previous three years (2012–13 to 2014–15). The targets and the numbers sampled each year and month during 2015–16 to 2017−18 are shown in Table 11. 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 12.

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 1 cm 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 17.4% in 2015−16, 20.9% in 2016−17, and 16.2% in 2017−18, below the 20% target for the three years sampled, apart from 2016–17 (Griggs et al. 2018).

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 2018–19 to 2010–21 on the proportion of catch each month during recent years, focusing on 2015–16 to 2017−18.

We summarised the temporal and spatial distribution of the catch over the most recent three years (2015−16, 2016−17 and 2017−18) 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 2018−19 to 2020−21.

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 the sampling data were 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.

During sampling in 2015−16, 2016−17 and 2017−18, approximately 130 fish were sampled per landing in Auckland, and around 100 fish per landing in Greymouth (Table 12). The average number of landings sampled in each port were 5, 5 and 2 landings per month for 2015−16, 2016−17 and 2017−18 in Auckland, and in Greymouth the average number of landings sampled were 9, 3 and 10 landings per month for the three fishing years respectively.

3.3.2 Temporal and spatial distribution of catch

The catch and the monthly proportions are shown in Table 13. The average catch percentages over the three fishing years, 2015–16, 2016–17 and 2017–18, were: 11.4% in December; 32.6% in January; 26.7% in February; 19.6% in March; and 8.1% in April. Catch from other months made up 1.5% of the total.

Albacore catch by FMA and the percentage in each FMA is shown in Table 14. The largest percentage of the catch, 60.9% for the three-year total occurred in FMA 7 off the WCSI. In 2016–17 the catch in FMA 7 was much lower than in the 2015–16 and 2017–18 years, with only 25.4% of the catch from FMA 7, and greater amounts from FMA 9 and FMA 8 (Table 14).

Catch percentages by month and FMA are shown in Table 15, and this illustrates the differences in temporal and spatial distribution in the three years. In 2015–16, the December catch was mostly in the north from FMA 9, in January catches were split between northern FMAs 8 and 9 and WCSI in FMA 7, and most of the catch was from FMA 7 from February to May. This pattern was similar to that of previous years (Griggs & Large 2016, Griggs et al. 2018).

The fishing season was much different in 2016–17 when most of the fishery was off the west coast of the North Island (WCNI) from December to February. The fish moved south much later in the season than usual are were mostly caught off WCSI in February and March. Catches in FMA 2 were seen later in the season, mainly in April (Table 14).

In 2017–18 the fishery was very short in the north and mainly confined to December, and the majority of the fishery was in the south in FMA 7, with the strong peak of the season in January (Table 14).

3.3.3 New sample design

The new sample design will be used for the next three fishing seasons, 2018–19, 2019–20 and 2020–21.

The sample design used during 2015–16 to 2017–18 is shown in Table 16, and this was based on the proportions of albacore per month during the previous three years, 2012–13 to 2014–15.

The percentages of albacore catch in numbers by month during the last six years are shown in Table 17, and by month and FMA in Figure 10. The sample design would usually be based on the most recent three years, but we considered that these three years were too variable with the 2016–17 year in particular being too different from all other years. The pattern throughout most recent years was for early catch in the north in December continuing into January, which was split between north and south then the majority of the fishery off WCSI from then on. This trend throughout 2012–13 to 2014–15 was seen again in 2015–16, 2016–17 catches were mostly in the north, and 2017–18 had a very short season in the north and was dominated by catch in FMA 7 in January and lower catch in February than usual.

We considered two options, to base the sampling design for the next three years on the last three years (2015–16 to 2017–18), or to base it on the last six years (2012–13 to 2017–18), and these are shown in Table 18. We considered that Option 2 would be more appropriate, and this was endorsed by the HMS Working Group. This reflects higher recent catches in December increasing the target from 400 to 500, and lower catch in February recently which decreases the February target from 1600 to 1500. January, March and April remain the same.

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 19.

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 2017−18. Evaluation of the current sampling design showed that the sampling represents the fishery well, both spatially and temporally. The spatial and temporal distribution of most recent two fishing years were very different to earlier years, which is likely to be due to differences in sea surface temperatures.

In future, further work to improve estimation of standard deviation could be beneficial. An additional variable could be used in the GAM analysis to compensate for large variations in fishing patterns between fishing years, rather than using statistical area as an explanatory variable. One approach could be to assign a centroid for the peak of each fishing year (mid-February) and quantify fishing locations relative to this centroid (i.e. to account for years of high fishing around Auckland).

We summarised monthly proportions of catch in recent years as a basis for a revised sampling design for sampling during the 2018−19 to 2020−21 fishing seasons.

We considered that the most recent three years, 2015–16 to 2017–18 were very variable and in particular the 2016–17 year had a disproportionally high catch in the northern region compared with all other years in the port sampling programme. We considered that basing the sample design on these three years could therefore be biased and provided a second option based on the monthly catch proportions over the past six years, which we recommend, and this was endorsed by the HMS Working Group.

It was concluded by Griggs et al. (2018) that the proportion of albacore sampled followed the monthly catch distributions better than the target allocations, reflecting the ability of the samplers to respond to real time fishery trends.

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

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6. REFERENCES

Anon (2018a). New Zealand. Annual Report to the Commission – Part 1. Information on fisheries, research, and statistics, New Zealand. Western and Central Pacific Fisheries Commission Scientific Committee Fourteenth regular session, 8−16 August 2018, Busan, Republic of Korea, WCPFC-SC14-AR/CCM-16. 33 p.

Anon (2018b). United States of America. Annual Report to the Commission – Part 1. Information on fisheries, research, and statistics, United Sates of America. Western and Central Pacific Fisheries Commission Scientific Committee Fourteenth regular session, 8−16 August 2018, Busan, Republic of Korea, WCPFC-SC14-AR/CCM-27. 45 p.

Anon (2018c). Canada. Annual Report to the Commission – Part 1. Information on fisheries, research, and statistics, Canada. Western and Central Pacific Fisheries Commission Scientific Committee Fourteenth regular session, 8−16 August 2018, Busan, Republic of Korea, WCPFC-SC14-AR/CCM-02. 20 p.

Anon (2018d). Cook Islands. Annual Report to the Commission – Part 1. Information on fisheries, research, and statistics, Cook Islands. Western and Central Pacific Fisheries Commission Scientific Committee Fourteenth regular session, 8−16 August 2018, Busan, Republic of Korea, WCPFC-SC14-AR/CCM-04. 24 p.

Bailey, K. (1991). Observations on South Pacific albacore spawning as indicated by gonad indices. Fourth South Pacific albacore research (SPAR 4) workshop working paper No. 4. 8 p.

Childers, J.; Coan, A.L. (1996). U.S. South Pacific albacore fishery, 1986–1995. Sixth South Pacific albacore research (SPAR 6) workshop working paper No. 19. 22 p.

Farley, J.H.; Williams, A.J.; Davies, C.R.; Clear, N.P.; Everson, P.; Hoyle, S.D.; Nicol, S.J. (2012). Population biology of albacore tuna in the Australian region. CSIRO Marine and Atmospheric Research, FRDC Project; no. 2009/012 Final Report. 124 p.

Francis, R.I.C.C; Rasmussen, S; Fu, D.; Dunn, A. (2014). CALA: Catch-at-length and –age user manual, CALA v2.0-2014-08-25 (rev. 368) National Institute of Water & Atmospheric Research Ltd. Unpublished report held by NIWA library. 92 p.

Griggs, L. (2002a). Monitoring the length structure of commercial landings of albacore tuna during the 2001–02 fishing year. Final Research Report for Ministry of Fisheries Research Project TUN2001/02, Objective 1. December 2002. (Unpublished report held by Fisheries New Zealand, Wellington.)

Griggs, L. (2002b). Monitoring the length structure of commercial landings of albacore tuna during the 2001–02 fishing year. SCTB15 Working Paper ALB–5, 15th Meeting of the Standing Committee on Tuna and Billfish, Hawaii, 22–27 July 2002.

Griggs, L. (2003a). Monitoring the length structure of commercial landings of albacore tuna during the 2002–03 fishing year. Final Research Report for Ministry of Fisheries Research Project TUN2001/02, Objective 2. October 2003. (Unpublished report held by Fisheries New Zealand, Wellington.)

Griggs, L. (2003b). Monitoring the length structure of commercial landings of albacore tuna during the 2002–03 fishing year. SCTB16 Working Paper ALB–8, 16th Meeting of the Standing Committee on Tuna and Billfish, Mooloolaba, Australia, 9–16 July 2003.

Griggs, L. (2004a). Monitoring the length structure of commercial landings of albacore tuna during the 2003–04 fishing year. Final Research Report for Ministry of Fisheries Research Project ALB2003/01, Objective 1. October 2004. 17 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Griggs, L. (2004b). Monitoring the length structure of New Zealand commercial landings of albacore during the 2003–04 fishing year. SCTB17 Working Paper BIO–6, 17th Meeting of the Standing Committee on Tuna and Billfish, Majuro, Republic of the Marshall Islands, 9–18 August 2004.

Griggs, L. (2005a). Catch monitoring of the New Zealand albacore troll fishery. WCPFC–SC1 information paper SA IP–1, 1st meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Noumea, New Caledonia, 8–19 August 2005.

Griggs, L. (2005b). Monitoring the length structure of commercial landings of albacore (*Thunnus alalunga*) during the 2004–2005 fishing year. Final Research Report for Ministry of Fisheries Research Project ALB2003/01, Objective 2. November 2004. 21 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Griggs, L. (2008a). Monitoring the length structure of commercial landings of albacore (*Thunnus alalunga*) during the 2005–2006 fishing year. *New Zealand Fisheries Assessment Report 2008/15*. 20 p.

Griggs, L. (2008b). Monitoring the length structure of commercial landings of albacore (*Thunnus alalunga*) during the 2006–2007 fishing year. *New Zealand Fisheries Assessment Report 2008/50*. 23 p.

Griggs, L.; Doonan, I. (2010). Monitoring the length structure of commercial landings of albacore (*Thunnus alalunga*) during the 2007–2008 fishing year. *New Zealand Fisheries Assessment Report 2010/23*. 26 p.

Griggs, L.; Doonan, I. McGregor, V.; McKenzie, A. (2014). Monitoring the length structure of commercial landings of albacore (*Thunnus alalunga*) during the 2012−13 fishing year. *New Zealand Fisheries Assessment Report 2014/30*. 50 p.

Griggs, L.; Doonan, I. McKenzie, A.; Fu, D. (2013). Monitoring the length structure of commercial landings of albacore (*Thunnus alalunga*) during the 2009–10 to 2011−12 fishing year. *New Zealand Fisheries Assessment Report 2013/52*. 84 p.

Griggs, L.; Large, K, (2016). Albacore catch sampling during 2013−14 and 2014−15. *New Zealand Fisheries Assessment Report 2016/33*. 31 p.

Griggs, L.; Large, K, (2017). Albacore catch sampling – characterisation and sample design. *New Zealand Fisheries Assessment Report 2017/22*. 39 p.

Griggs, L.; Large, K.; Datta, S. (2018). Albacore catch sampling during 2015–16 to 2017–18. *New Zealand Fisheries Assessment Report* 2018/62. 58 p.

Griggs, L.; Murray, T. (2000). Determination of size composition, sex ratio, and length:weight relationships of albacore tuna during the 1998/99 fishing year from samples collected in the fish sheds. Final Research Report for Ministry of Fisheries Research Project TUN9801 Objective 4. 16 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Griggs, L.; Murray, T. (2001a). Monitoring the length structure of commercial landings of albacore tuna during the 2000–01 fishing year. Final Research Report for Ministry of Fisheries Research Project TUN2000/01. August 2001. (Unpublished report held by Fisheries New Zealand, Wellington.)

Griggs, L.; Murray, T. (2001b). Monitoring the length structure of commercial landings of albacore tuna during the 2000–01 fishing year. SCTB14 Working Paper ALB–3, 14th Meeting of the Standing Committee on Tuna and Billfish, New Caledonia, 9–16 August 2001.

Hampton, J.; Fournier, D. (2000). Update of MULTIFAN-CL based assessment of South Pacific albacore tuna. SCTB13 Working Paper, 13th Meeting of the Standing Committee on Tuna and Billfish, New Caledonia, 5–12 July 2000.

Harley, S.J.; Davies, N.; Tremblay-Boyer, L.; Hampton, J.; McKechnie, S. (2015). New Zealand. Stock assessment for south Pacific albacore tuna. Western and Central Pacific Fisheries Commission Scientific Committee Eleventh regular session, 5−13 August 2015, Pohnpei, Federated States of Micronesia, WCPFC-SC11-2015/SA-WP-06 Rev 1. 31 p.

Hoyle, S.; Hampton, J.; Davies, N. (2012). Stock Assessment of Albacore Tuna in the South Pacific Ocean. WCPFC-SC8 working paper SA-WP-04, 8th meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Busan, Republic of Korea, 7-15 August 2012.

Ito, R.; Hamm, D.; Coan, A.L.; Childers, J. (2005). Summary of U.S. fisheries for highly migratory species in the Western-Central Pacific, 2000–2004. WCPFC–SC1 working paper FR WP–17, 1st meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Noumea, New Caledonia, 8–19 August 2005.

Labelle, M. (1993). A review of the South Pacific albacore troll fishery 1985–1992. South Pacific Commission Tuna and Billfish Assessment Programme Technical Report No. 32. 25 p.

Murray, T. (1994). A review of the biology and fisheries for albacore *Thunnus alalunga*, in the South Pacific ocean. In Interactions of Pacific tuna fisheries. Edited by Shomura, S.; Majkowski, J.; Langi, S. (eds). *FAO Fisheries Technical Paper 336/2*: 188–206.

Murray, T.; Richardson, K.; Dean, H.; Griggs, L. (1999). New Zealand tuna fisheries with reference to stock status and swordfish bycatch. Final Research Report for Ministry of Fisheries Research Project TUN9701. June 1999. 126 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Murray, T.; Richardson, K.; Dean, H.; Griggs, L. (2000). National Tuna Fishery Report 2000 – New Zealand. SCTB13 Working Paper, 13th Meeting of the Standing Committee on Tuna and Billfish, New Caledonia, 5–12 July 2000.

OFP-SPC and the WCPFC Secretariat (2015). Trends in the south pacific albacore longline and troll fisheries. WCPFC-SC10 working paper WCPFC12-2015-14, 12th meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Kuta, Bali, Indonesia, 3–8 December 2015.

Pilling, M.P.; Harley, S.J.; Williams, P.; Hampton, J.; and the WCPFC Secretariat (2014). Trends in the South Pacific albacore longline and troll fisheries. WCPFC-SC10 working paper SA-WP-07, 10th meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Majuro, Republic of the Marshall Islands, 6–14 August 2014.

R Development Core Team (2010). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Ramon, D.; Bailey, K. (1996). Spawning seasonality in albacore, *Thunnus alalunga*, in the South Pacific Ocean. *Fishery Bulletin 94*: 725–733.

Stocker, M.; Shaw, W. (2005). Canadian albacore tuna fisheries in the north and south Pacific Ocean in 2004. WCPFC–SC1 working paper FR WP–4, 1st meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Noumea, New Caledonia, 8–19 August 2005.

Tremblay-Boyer, L.; Hampton, J.; McKechnie, S.; Pilling, G. (2018). Stock assessment of South Pacific albacore tuna. WCPFC-SC14 working paper SA-WP-05 Rev 2, 14th meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Busan, Republic of Korea, 8–16 August 2018.

Wei, F. (2007). Database Documentation: *tuna*. NIWA Fisheries Data Management Database Documentation Series. (Unpublished report held by NIWA library, Wellington.) 26 p.

Williams, P.; Terawasi, P. (2008). Overview of tuna fisheries in the western and central Pacific Ocean, including economic conditions – 2007. WCPFC-SC4 working paper GN WP-1, 4th meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Port Moresby, Papua New Guinea, 11–22 August 2008.

Williams, P.; Terawasi, P. (2012). Overview of tuna fisheries in the western and central Pacific Ocean, including economic conditions – 2011. WCPFC-SC8 working paper GN WP-1, 8th meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Busan, Republic of Korea, 7–15 August 2012.

Table 1: Total troll catch and effort recorded on CELR forms, 1996−97 to 2017−18.

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
2015–16	293 078	1 796 569	130	4 169
2016–17	280 281	1 762 970	98	3 688
2017–18	414 878	1 775 679	130	4 228

Table 2: Number of fish sampled each year and port from 1996−97 to 2017−18. -, not sampled.

ALB year	Port			
	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	-	-	-	-
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
2015–16	1 447	3 403	-	4 850
2016–17	2 386	1 193	-	3 579
2017–18	386	3 777	-	4 163
Total	**26 265**	**70 651**	**4 000**	**100 916**

Table 3: Variables considered in the GAM analysis.

Code	Variable
mth	Calendar month
alb_yr	Albacore fishing year (2015−16 is plotted as 2016)
stat.area	Statistical area
overall.length.m	Overall length in metres (the only length present for all vessels)
horse.power	Horse power
port	Port in which the sample was taken.

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

	Variable	R-squared
First variable		
	mth	0.21
	alb.yr	0.35
	stat.area	0.41
	port	0.24
	overall.length.m	0.10
	horse.power	0.02
Second variable		
	mth	0.49
	alb.yr	0.57
	port	0.41
	overall.length.m	0.42
	horse.power	0.42
Third variable		
	mth	0.61
	port	0.58
	overall.length.m	0.57
	horse.power	0.57
Fourth variable		
	port	0.62
	overall.length.m	0.61
	horse.power	0.61
Fifth variable		
	overall.length.m	0.62
	horse.power	0.62

Table 5: ANOVA and F-test results from the cascade of models on mean length (meanL, cm). See Table 2 for code descriptions. Cascade order determined from Table 3.

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

Model	Residual df	Residual Deviance	Df	Deviance	F	Pr(>F)	Signifiance code
1	116.0	3 009.82	-	-	-	-	
2	106.0	1 785.83	10	1 223.99	10.82	0.00	***
3	104.0	1 307.57	2.00	478.26	21.14	0.00	***
4	100.0	1 185.52	4.00	122.05	2.70	0.04	***
5	99.00	1 145.97	1.00	39.56	3.50	0.06	.
6	97.54	1 134.28	1.46	11.69	0.71	0.45	
7	95.83	1 089.75	1.70	44.53	2.31	0.11	.

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 2017−18, 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
2015–16	39.83	60.17	22.97	77.03
2016–17	75.10	24.90	72.13	27.87
2017–18	21.82	78.18	5.41	94.59

Table 7: Comparison of annual CELR catch numbers of fish and sample catch by month and latitude group for the 3 years sampled from 2015−16 to 2017−18, expressed as percentages. -, zero. Latitude group (30,40.5] is ≥ 30 and <40.5, etc.

	CELR data			Sample data		
	Latitude group			Latitude group		
2015−16	**(30,40.5]**	**(40.5,50]**	**Total**	**(30,40.5]**	**(40.5,50]**	**Total**
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	0.09	-	0.09	-	-	-
Dec	8.33	0.04	8.37	7.66	-	7.66
Jan	16.35	14.35	30.70	15.32	-	15.32
Feb	2.91	23.79	26.70	-	55.28	55.28
Mar	1.51	16.10	17.61	-	16.08	16.08
Apr	0.97	13.15	14.12	-	5.67	5.67
May	0.72	1.66	2.38	-	-	-
Jun	0.02	-	0.02	-	-	-
Total	30.92	69.08	100.00	22.97	77.03	100.00
2016−17	**(30,40.5]**	**(40.5,50]**	**Total**	**(30,40.5]**	**(40.5,50]**	**Total**
Jul	0.01	-	0.01	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	0.28	-	0.28	-	-	-
Dec	12.81	-	12.81	13.08	-	13.08
Jan	25.87	0.35	26.21	26.24	-	26.24
Feb	20.69	9.55	30.24	22.83	4.88	27.72
Mar	6.69	12.66	19.34	9.97	22.99	32.96
Apr	6.55	2.33	8.88	-	-	-
May	2.20	0.02	2.23	-	-	-
Jun	-	0.00	0.00	-	-	-
Total	75.10	24.90	100.00	72.13	27.87	100.00
2017−18	**(30,40.5]**	**(40.5,50]**	**Total**	**(30,40.5]**	**(40.5,50]**	**Total**
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	0.12	-	0.12	-	-	-
Dec	11.17	1.71	12.88	4.10	-	4.10
Jan	3.28	34.78	38.07	1.31	24.58	25.90
Feb	3.00	21.28	24.27	-	23.57	23.57
Mar	3.47	17.71	21.18	-	37.56	37.56
Apr	0.76	2.64	3.40	-	8.87	8.87
May	0.01	0.07	0.08	-	-	-
Jun	-	-	-	-	-	-
Total	21.82	78.18	100.00	5.41	94.59	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 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 9: 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 10: 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 11: Target number of fish to sample each month, and number sampled each year, month and port, 2015−16 to 2017−18.

		Sampled 2015–16		
	Target	Auckland	Greymouth	Total
December	400	554		554
January	1 600	893		893
February	1 600		2 157	2 157
March	1 000		1 046	1 046
April	400		200	200
Total	**5 000**	**1 447**	**3 403**	**4 850**

		Sampled 2016–17		
	Target	Auckland	Greymouth	Total
December	400	627		627
January	1 600	935		935
February	1 600	482	293	775
March	1 000	342	900	1 242
April	400			0
Total	**5 000**	**2 386**	**1 193**	**3 579**

		Sampled 2017–18		
	Target	Auckland	Greymouth	Total
December	400	256		256
January	1 600	130	1 010	1 140
February	1 600		1 068	1 068
March	1 000		1 299	1 299
April	400		400	400
Total	**5 000**	**386**	**3 777**	**4 163**

Table 12: Number of fish, landings and vessels sampled and average number of fish sampled each landing, by month and port for the years 2015−16 to 2017−18.

2015–16

Port	Month	No. of fish	No. of landings	No. of vessels	Average no. of fish per landing
Auckland	December	554	4	3	139
	January	893	6	5	149
Greymouth	February	2 157	22	19	98
	March	1 046	11	7	95
	April	200	2	2	100
2015–16	Total	4 850	45	29	

2016–17

Port	Month	No. of fish	No. of landings	No. of vessels	Average no. of fish per landing
Auckland	December	627	5	5	125
	January	935	7	7	134
	February	482	4	4	121
	March	342	2	2	171
Greymouth	February	293	3	3	98
	March	900	10	7	90
2016–17	Total	3 579	31	17	

2017–18

Port	Month	No. of fish	No. of landings	No. of vessels	Average no. of fish per landing
Auckland	December	256	2	1	128
	January	130	1	1	130
Greymouth	January	1 010	11	11	92
	February	1 068	11	10	97
	March	1 299	13	12	100
	April	400	4	4	100
2017–18	Total	4 163	42	28	

Table 13: Annual CELR albacore catch (number of fish) by month, and monthly catch as percentage of the annual total for the years 2015−16 to 2017−18.

	Catch (number of fish)				% of annual catch			
	2015−16	2016−17	2017−18	3-year total	2015−16	2016−17	2017−18	3-year average
December	23 725	35 910	53 167	112 802	8.1	12.8	12.8	11.4
January	90 862	73 469	158 084	322 416	31.0	26.2	38.1	32.6
February	78 186	84 757	101 307	264 249	26.7	30.2	24.4	26.7
March	51 722	54 218	87 469	193 409	17.6	19.3	21.1	19.6
April	41 312	24 872	14 037	80 222	14.1	8.9	3.4	8.1
Other	7 271	7 055	813	15 140	2.5	2.5	0.2	1.5
Total	293 078	280 281	414 878	988 238				

Table 14: Annual CELR albacore catch (number of fish) by FMA, and FMA catch as percentage of the annual total for the years 2015−16 to 2017−18.

	Catch (number of fish)				% of annual catch			
	2015−16	2016−17	2017−18	3-year total	2015−16	2016−17	2017−18	3-year average
FMA1	919	2 860	1 035	4 813	0.3	1.0	0.2	0.5
FMA2	15 920	34 907	24 841	75 669	5.4	12.5	6.0	7.7
FMA5	2 390	395	2 502	5 287	0.8	0.1	0.6	0.5
FMA7	200 737	71 193	330 155	602 085	68.5	25.4	79.6	60.9
FMA8	13 079	80 299	10 092	103 470	4.5	28.6	2.4	10.5
FMA9	56 071	90 627	43 661	190 360	19.1	32.3	10.5	19.3
Other	3 961	1	2 593	6 555	1.4	0.0	0.6	0.7
Total	293 078	280 281	414 878	988 238				

Table 15: Percentage of total annual CELR albacore catch (number of fish) in each month and FMA for the three years 2015−16, 2016−17 and 2017−18. Highest values (> 4%) are in bold.

2015−16	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	0.1	0	0	0	0	0
December	0.1	0.1	0	0	0.2	**7.6**
January	0	1.6	0	**14.9**	3.2	**10.8**
February	0	2.1	0.5	**22.8**	0.3	0.6
March	0	0.9	0.3	**15.5**	0.5	0.1
April	0.1	0.5	0	**13.2**	0.2	0.1
May	0	0.2	0	2.1	0	0
June	0	0	0	0	0	0

2016−17	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	0.2	0	0	0	0	0.1
December	0.5	0	0	0.1	0.1	**12.2**
January	0	0.6	0	0.4	**8.5**	**16.6**
February	0	0.8	0	**9.9**	**16.5**	3.0
March	0.3	2.3	0.1	**12.8**	3.5	0.4
April	0	**6.5**	0	2.2	0	0
May	0	2.2	0	0	0	0
June	0	0	0	0	0	0

2017−18	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
December	0.1	0	0	2.3	1.1	**9.2**
January	0.1	0.3	0.1	**35.5**	0.7	1.2
February	0	2.7	0.3	**20.9**	0.3	0
March	0	2.7	0.2	**18.0**	0.2	0
April	0	0.3	0	2.9	0.1	0
May	0	0	0	0.1	0	0
June	0	0	0	0	0	0

Table 16: Monthly sample targets for used for 2015−16 to 2017−18 sampling.

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	

Table 17: Proportions of albacore caught each month during 2012−13 to 2017−18 (December to April).

	2012–13	2013–14	2014–15	2015–16	2016–17	2017–18
December	6.7	13.9	6.6	8.3	13.1	12.8
January	29.7	31.7	36.4	31.8	26.9	38.2
February	38.8	33.9	25.5	27.4	31.0	24.5
March	19.8	14.2	23.0	18.1	19.8	21.1
April	5.1	6.4	8.4	14.5	9.1	3.4

Table 18: Monthly sample targets for 2018−19 to 2020−21, based on monthly catch proportions during 2015−16 to 2017−18 (Option 1) and 2012−13 to 2017−18 (Option 2) compared to the 2015−16 to 2017−18 targets (Current), all are rounded to the nearest hundred.

	Current	Option 1	Option 2
December	400	600	500
January	1 600	1 700	1 600
February	1 600	1 400	1 500
March	1 000	1 000	1 000
April	400	400	400
Total	5 000	5 100	5 000

Table 19: Monthly sample targets for 2018−19 to 2020−21, based on monthly catch proportions during 2012−13 to 2017−18.

Month	% of annual catch	Target number of landings to sample	Target number of fish to sample	Sampling port
December	10.2	5	500	Auckland
January	32.7	16	1 600	Auckland and Greymouth
February	30.3	15	1 500	Greymouth
March	19.5	10	1 000	Greymouth
April	7.3	4	400	Greymouth
Total		50	5 000	

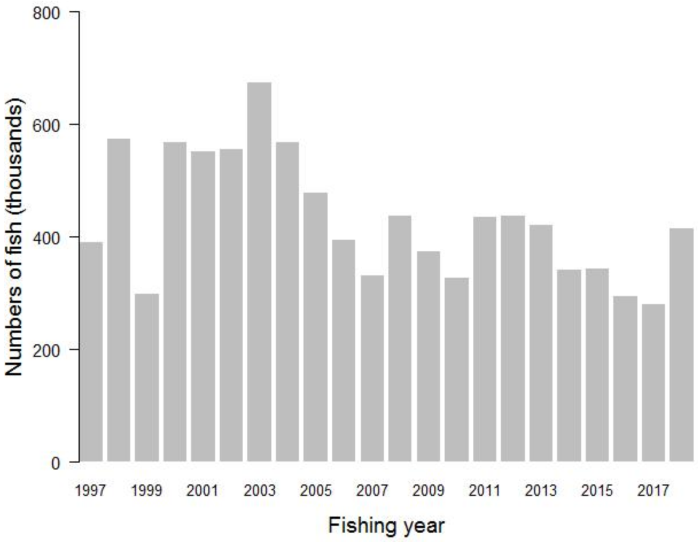
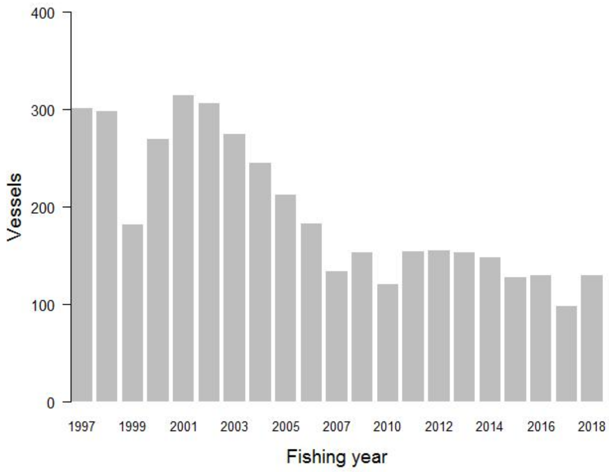


Figure 1: Albacore catch, numbers of fish (thousands) reported in CELR data, by fishing years 1996−97 (1997) to 2017−18 (2018).

(a)



(b)

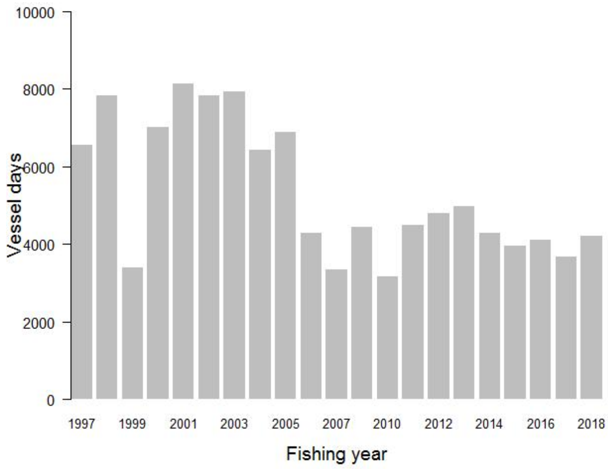


Figure 2: Effort, (a) number of vessels and (b) number of vessel days, reported in CELR data by fishing years 1997−2018 (2009 not sampled).

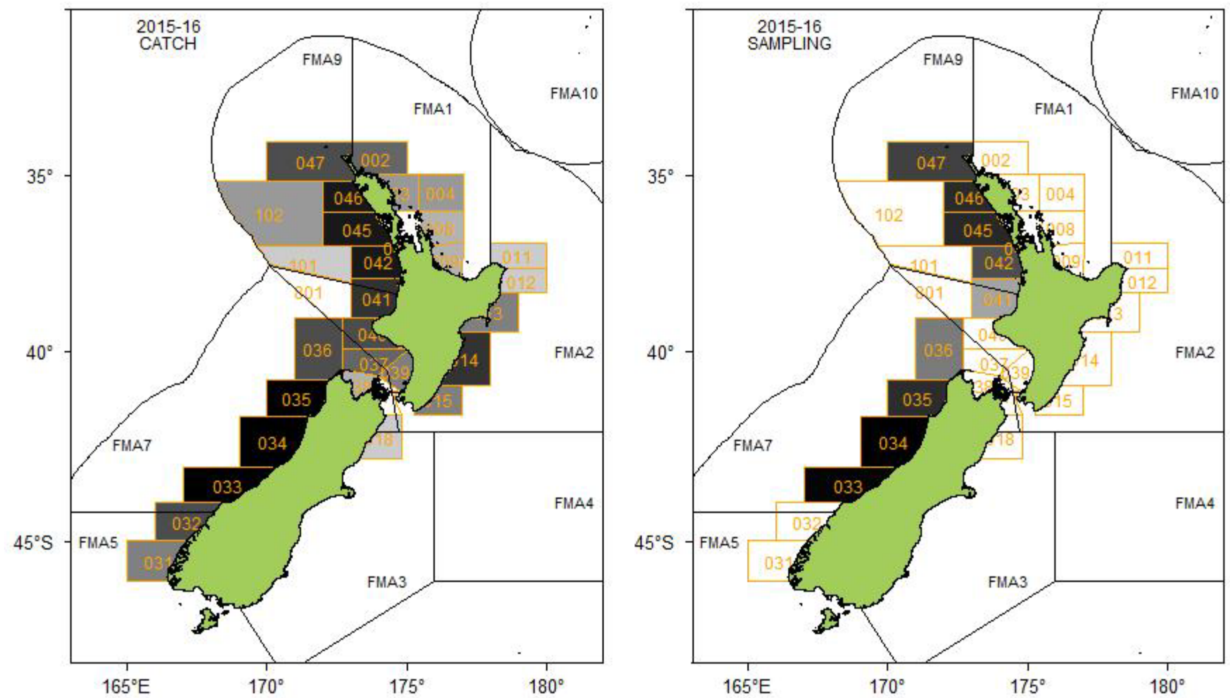


Figure 3: Annual statistical area density plots of albacore catch, fished (left) and sampled (right).
A logarithmic density scale was used (i.e. all catch numbers divided by the maximum catch in any one stat area) where 0=white and 1=black. Reproduced from Griggs et al. 2018.
2015−16.

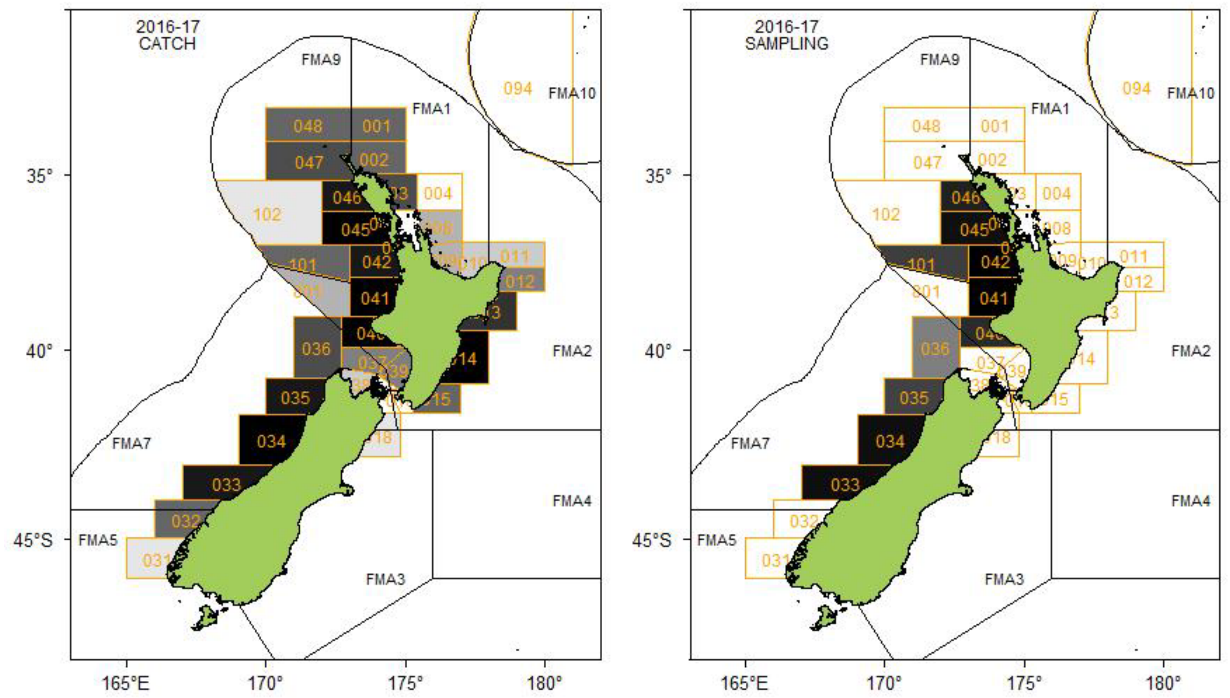


Figure 3 *continued*. 2016–17.

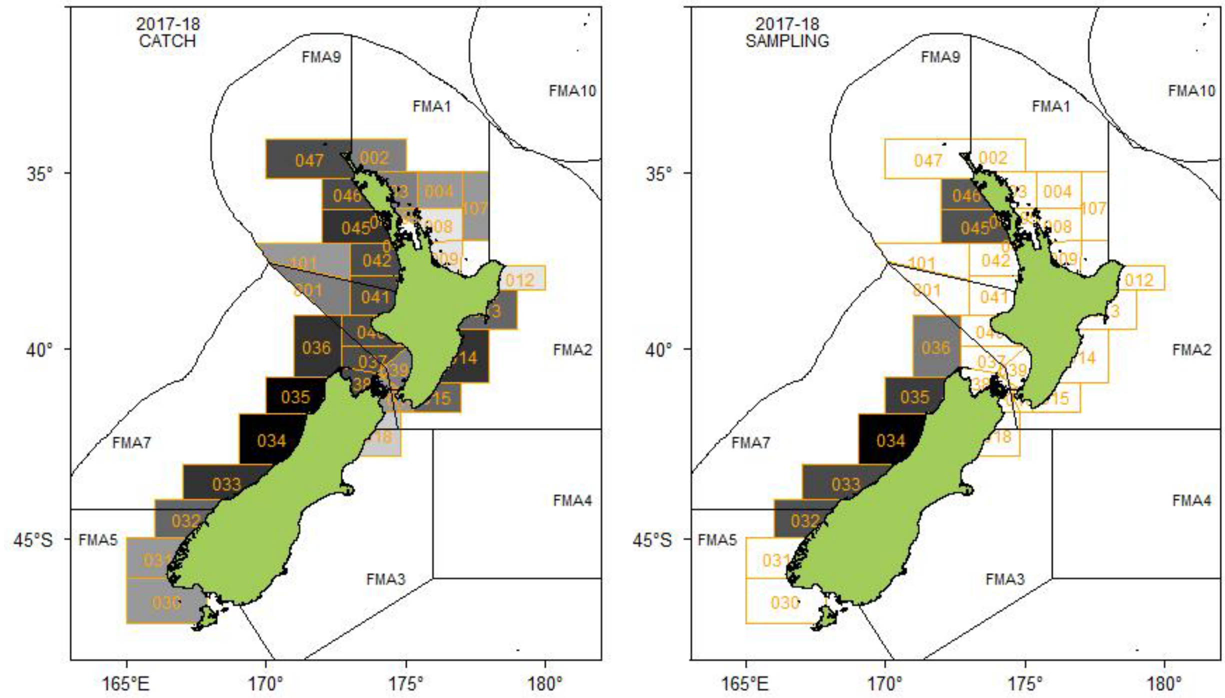


Figure 3 *continued*. 2017–18.

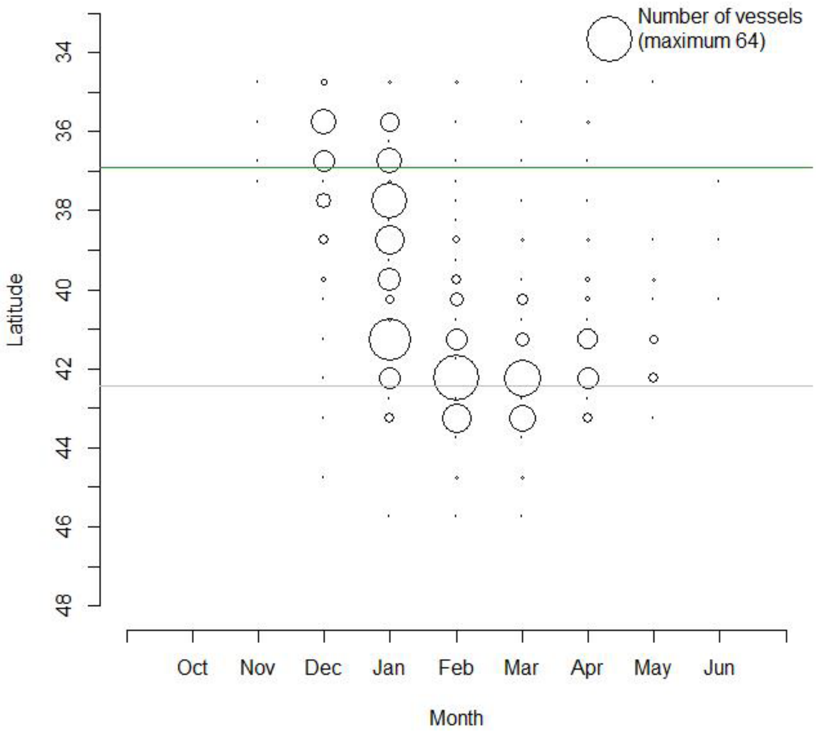


Figure 4: Number of vessels in CELR data by month and latitude (0.5 degree bins) for 2015−16. Horizontal lines mark Kaipara Harbour (green) and Greymouth (grey).

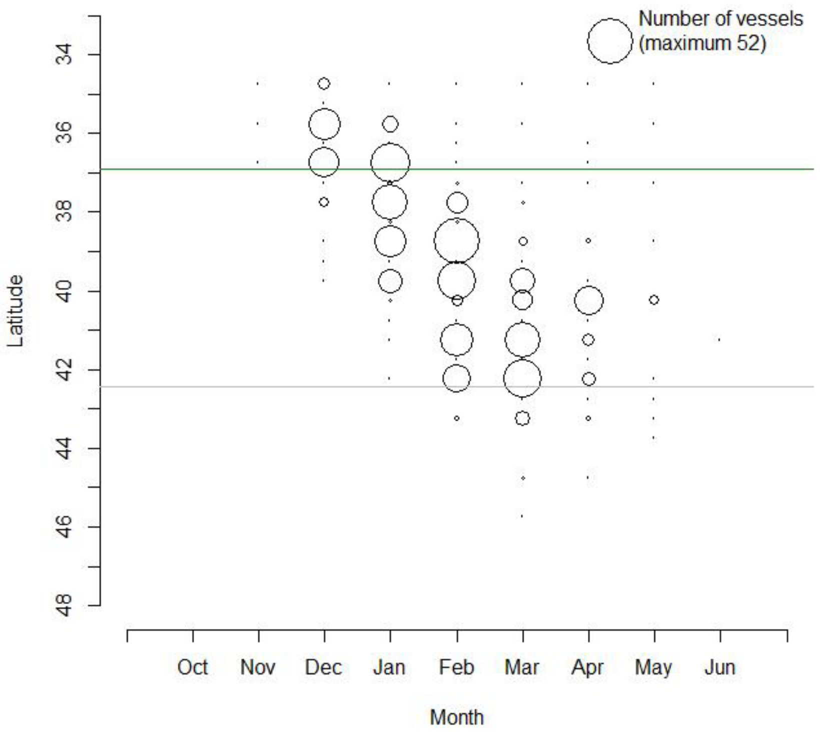


Figure 4 *continued*: 2016–17.

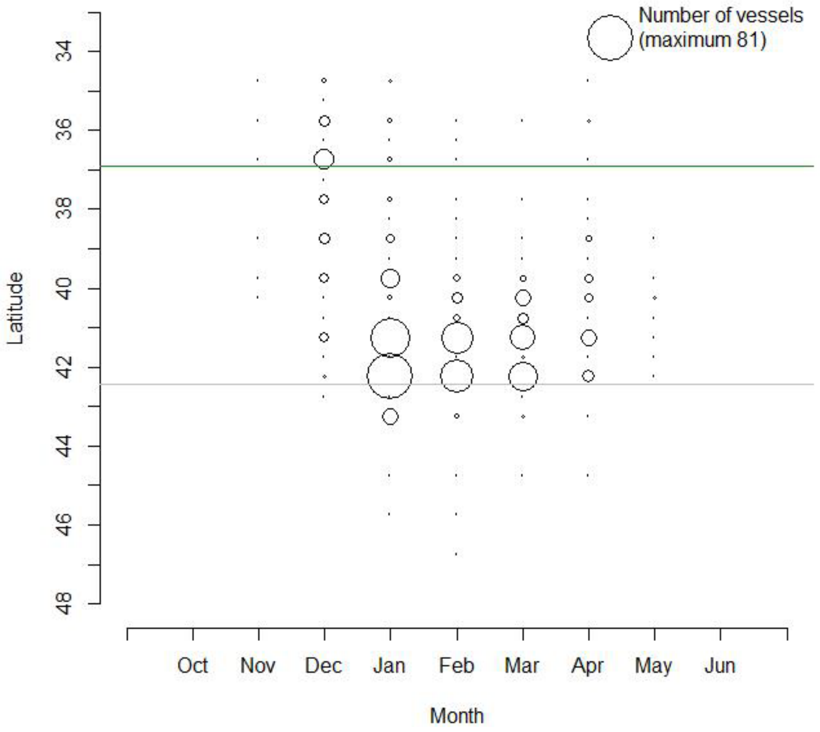


Figure 4 *continued*: 2017–18.

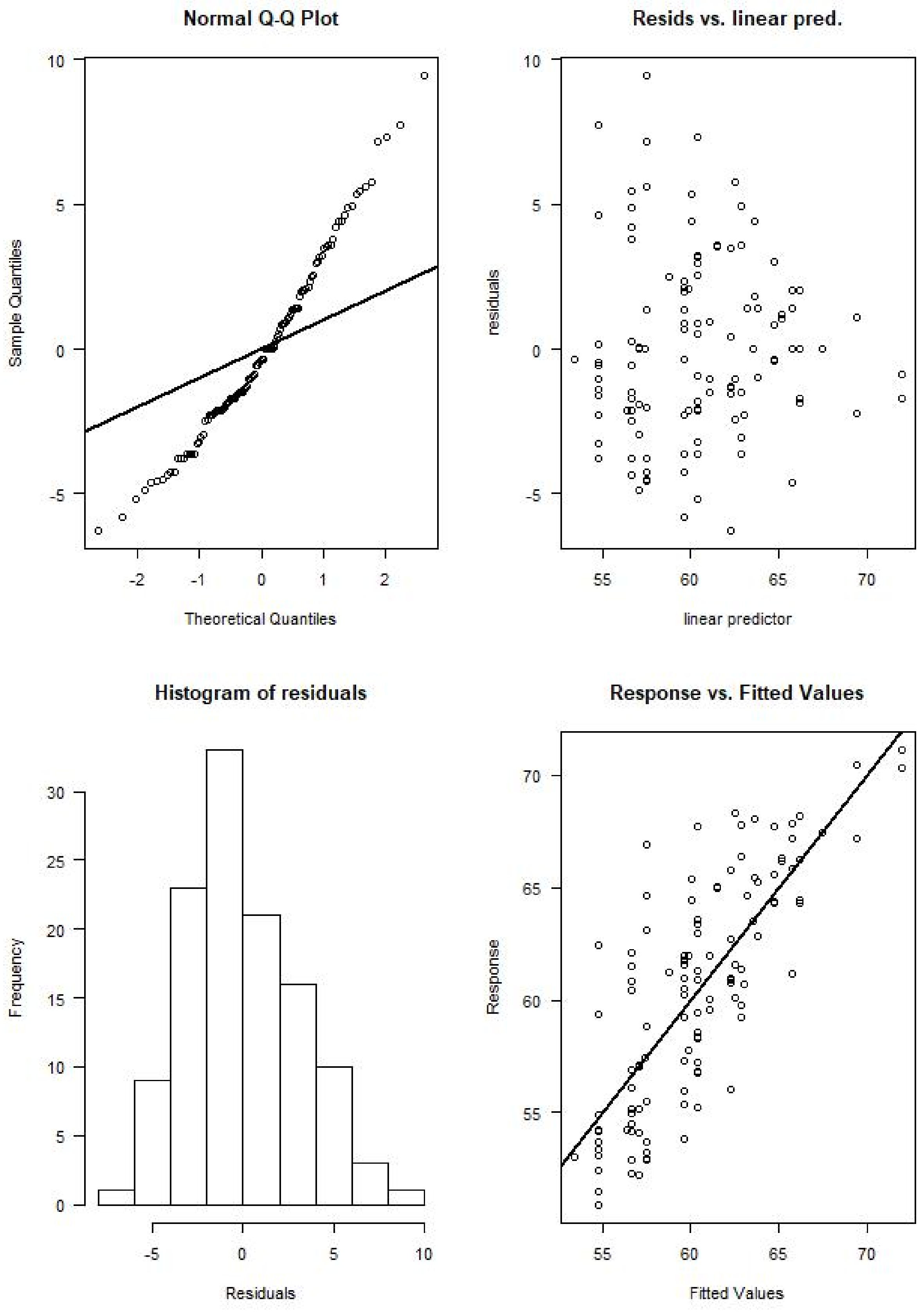


Figure 5: Diagnostics of the GAM regression on mean length from port sampling over the there-year period 2015–16 to 2017–18.

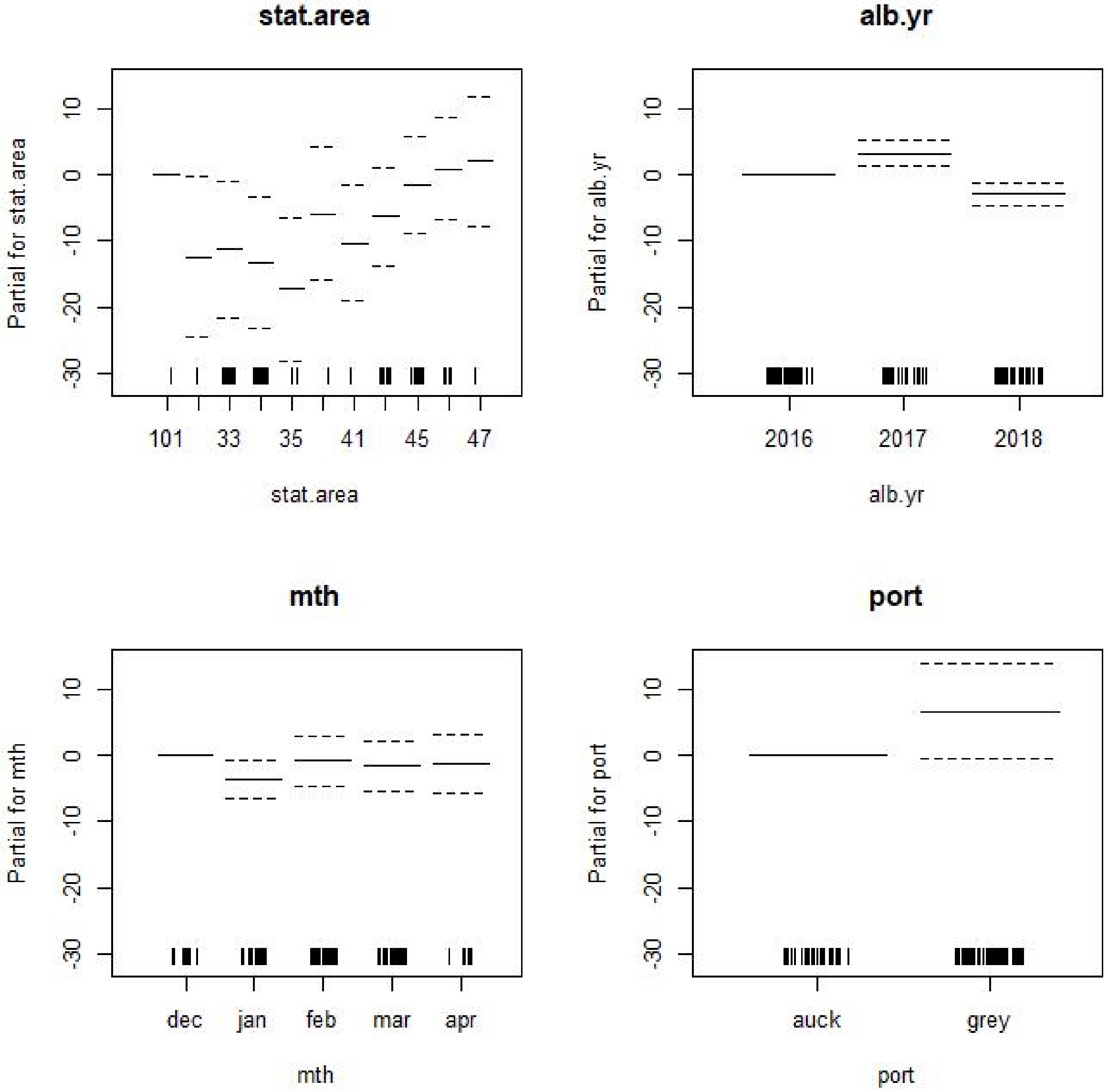
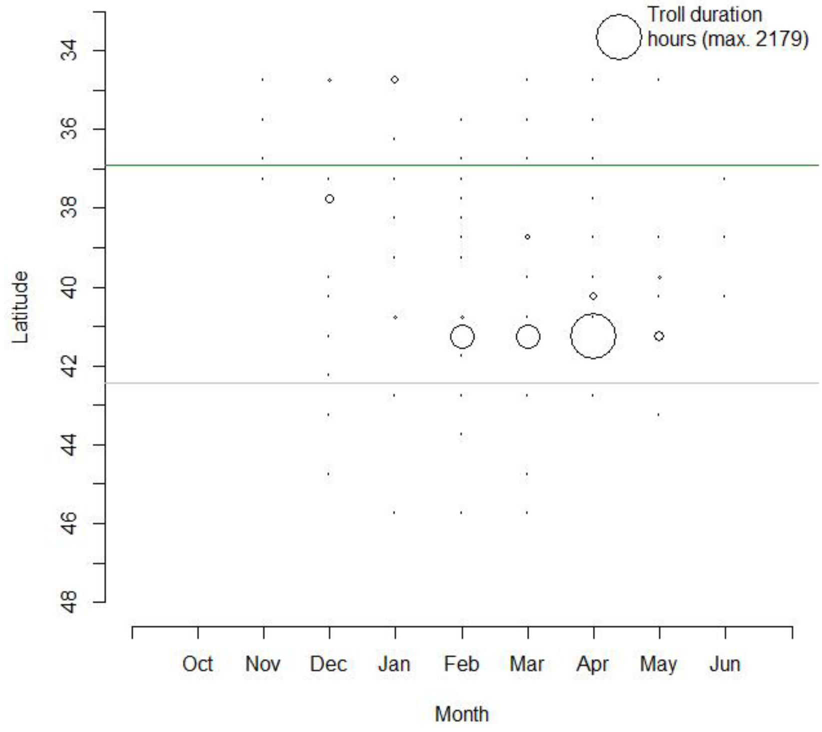


Figure 6: Effects of statistically significant factors in the GAM regression of length. The mean is the solid line, 95% confidence levels are the dotted lines, and marks at the bottom are the data used (jittered).

2015–16 CELR



2015–16 sampled

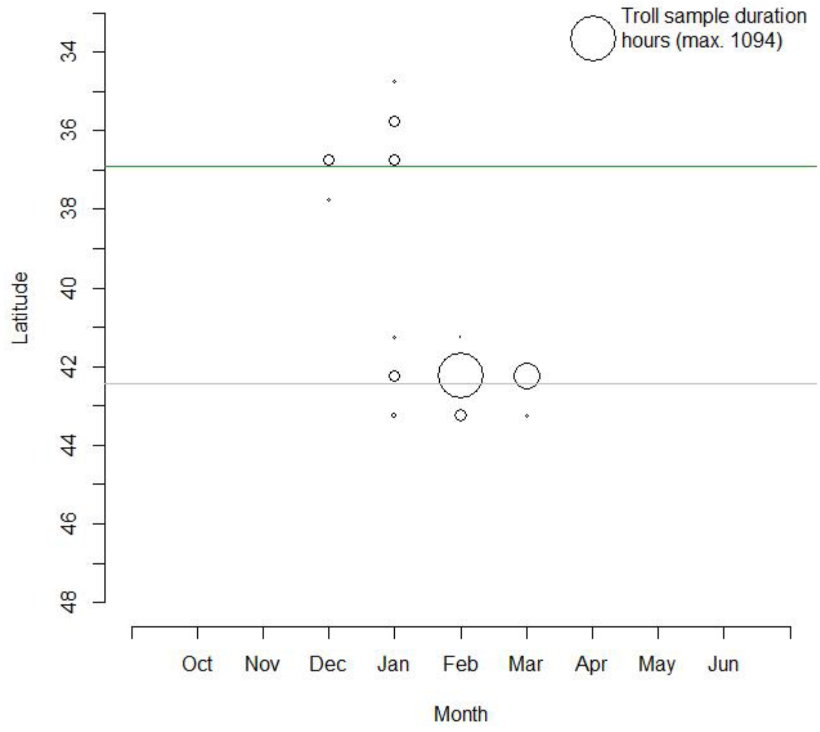
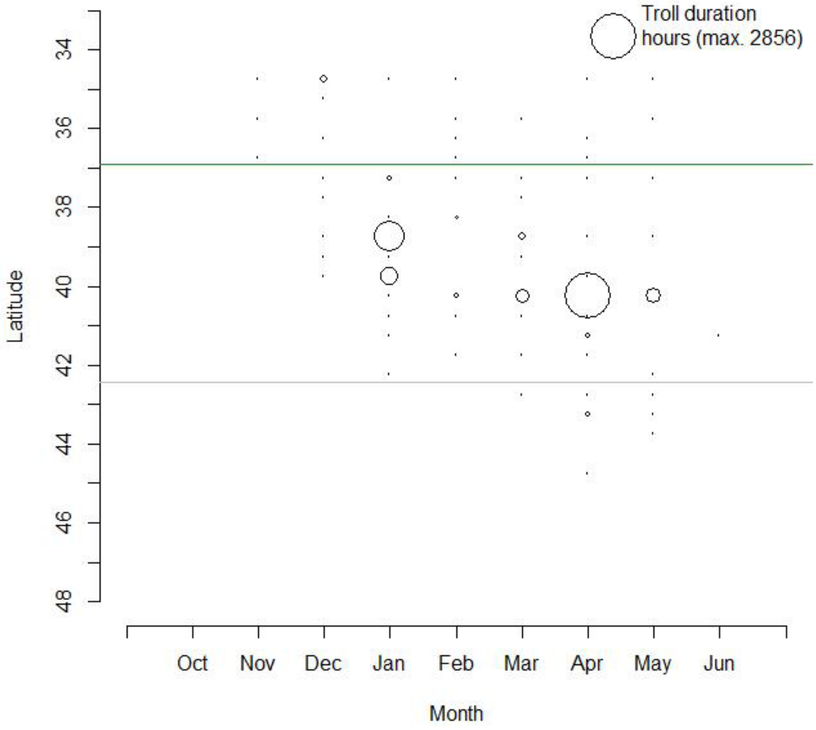


Figure 7: Troll duration (hours) in CELR data (top) and sample data (bottom) by month and latitude (0.5 degree bins) for 2015−16. Horizontal lines mark Kaipara Harbour (green) and Greymouth (grey).

2016–17 CELR



2016–17 sampled

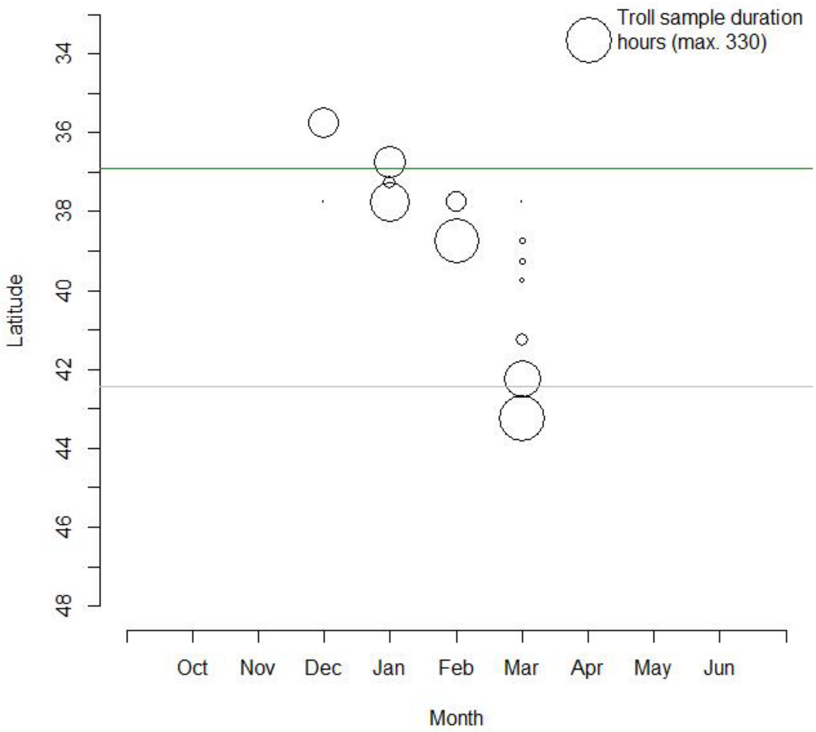
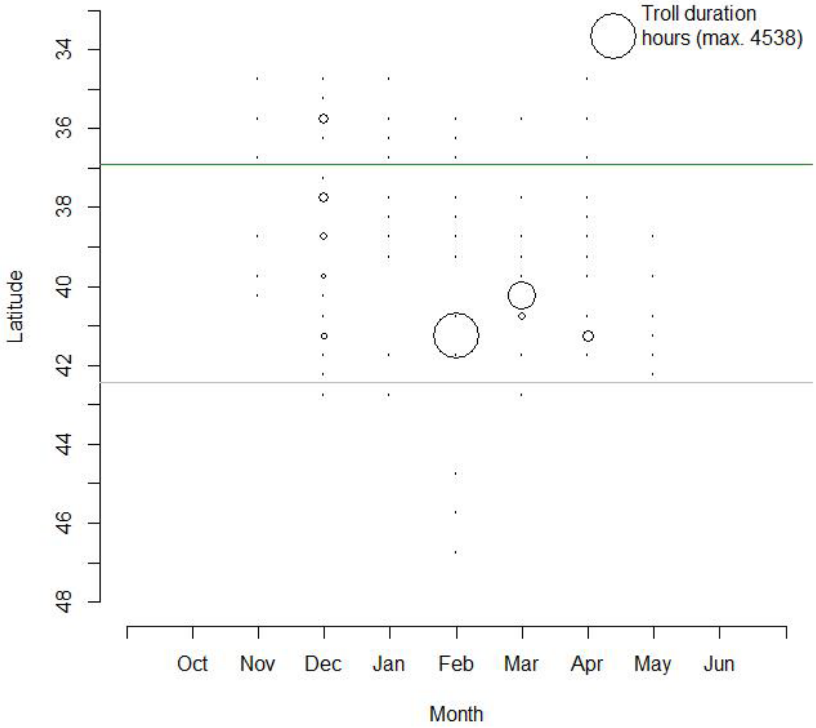


Figure 7 *continued*: 2016–17.

2017–18 CELR



2017–18 sampled

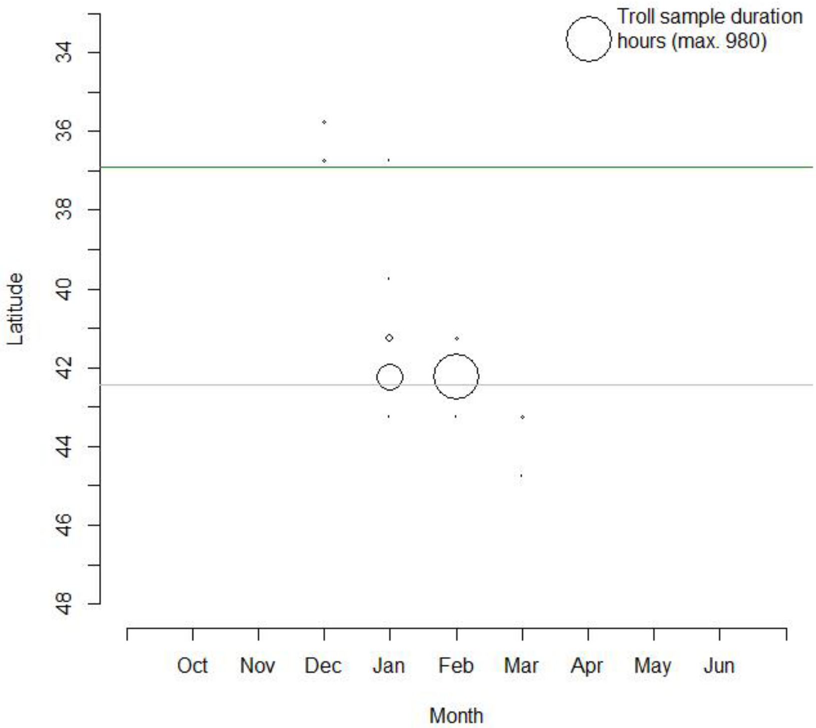
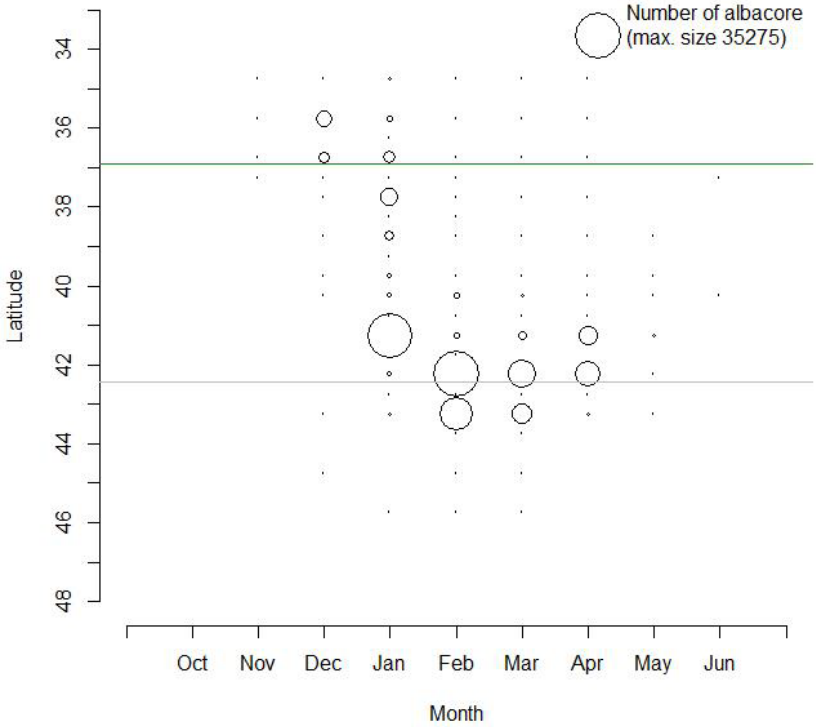


Figure 7 *continued*: 2017–18.

2015–16 CELR



2015–16 sampled

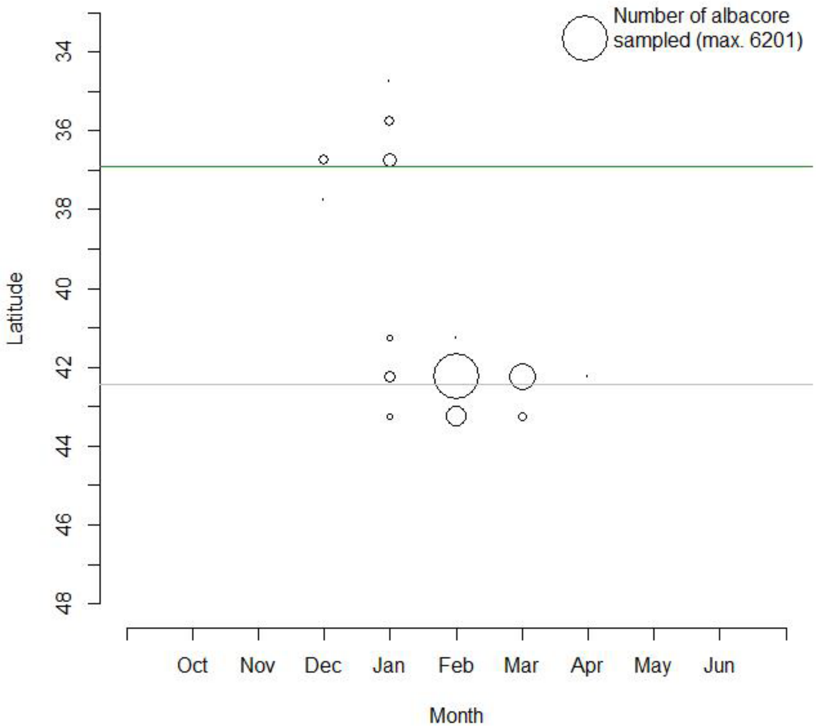
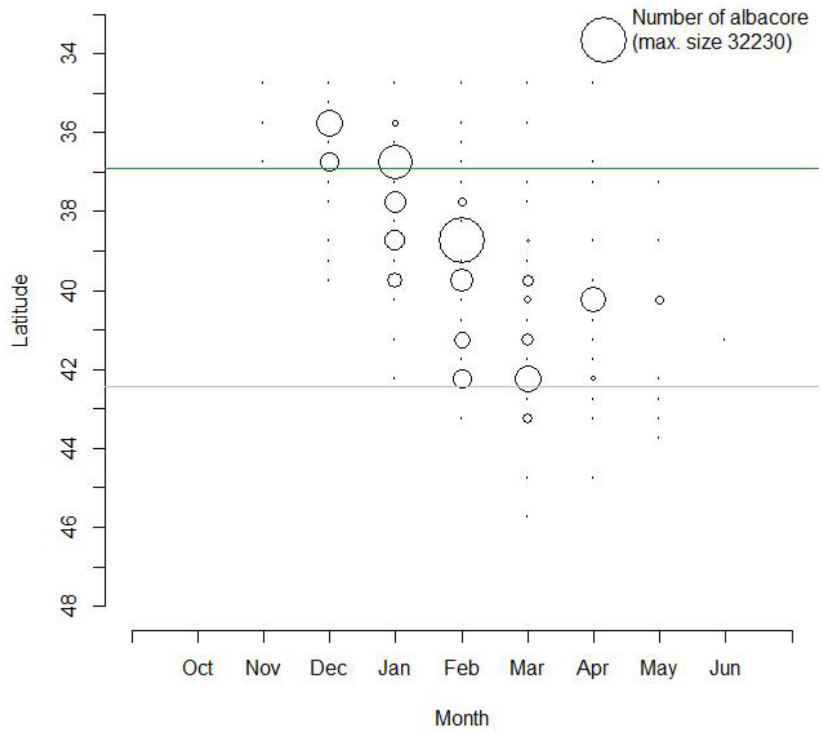


Figure 8: Number of albacore caught in CELR data (top) and sample data (bottom) by month and latitude (0.5 degree bins) for 2015−16. Horizontal lines mark Kaipara Harbour (green) and Greymouth (grey).

2016–17 CELR



2016–17 sampled

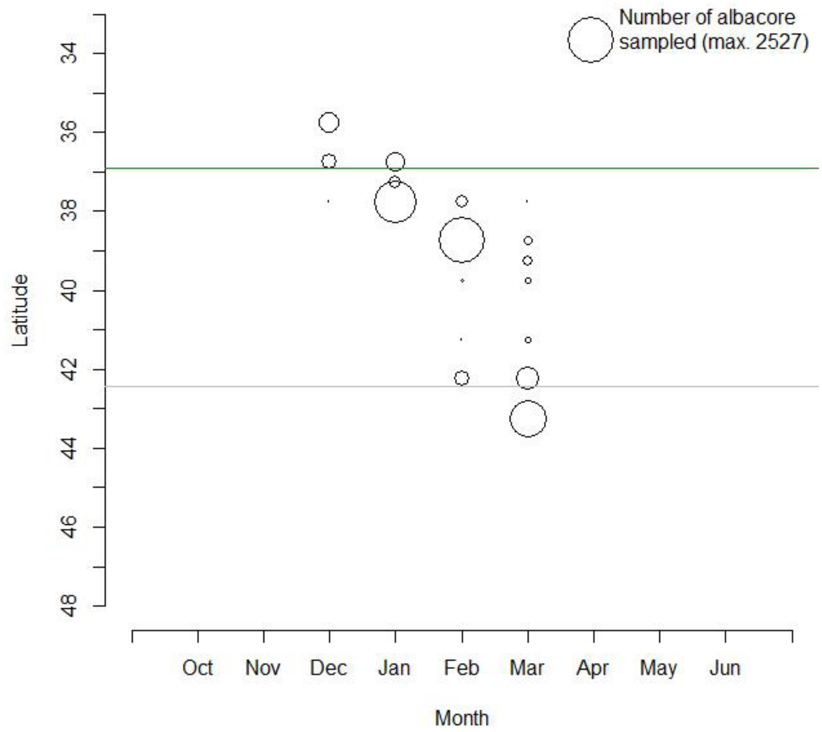
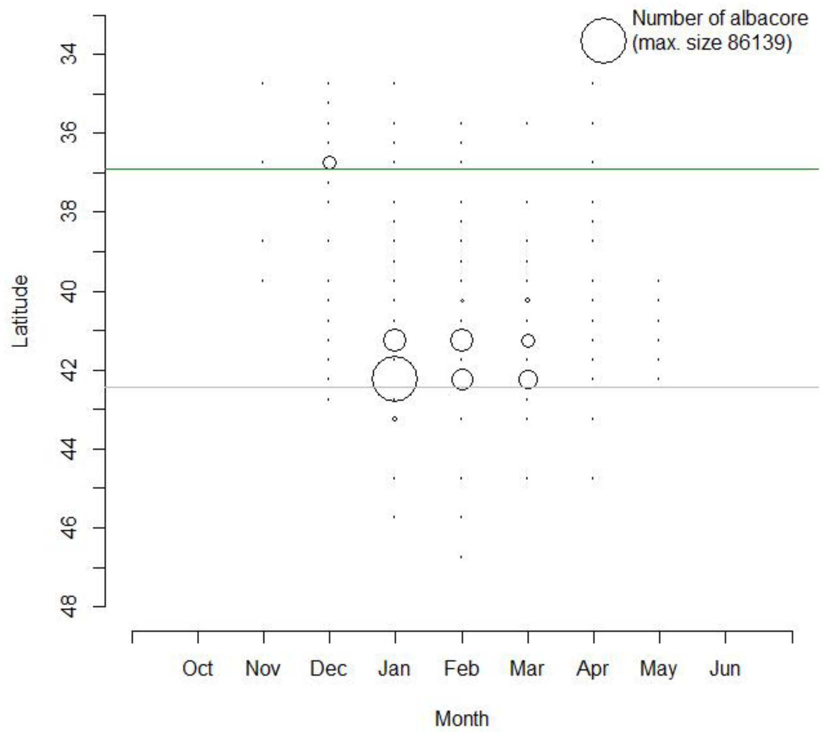


Figure 8 *continued*: 2016–17.

2017–18 CELR



2017–18 sampled

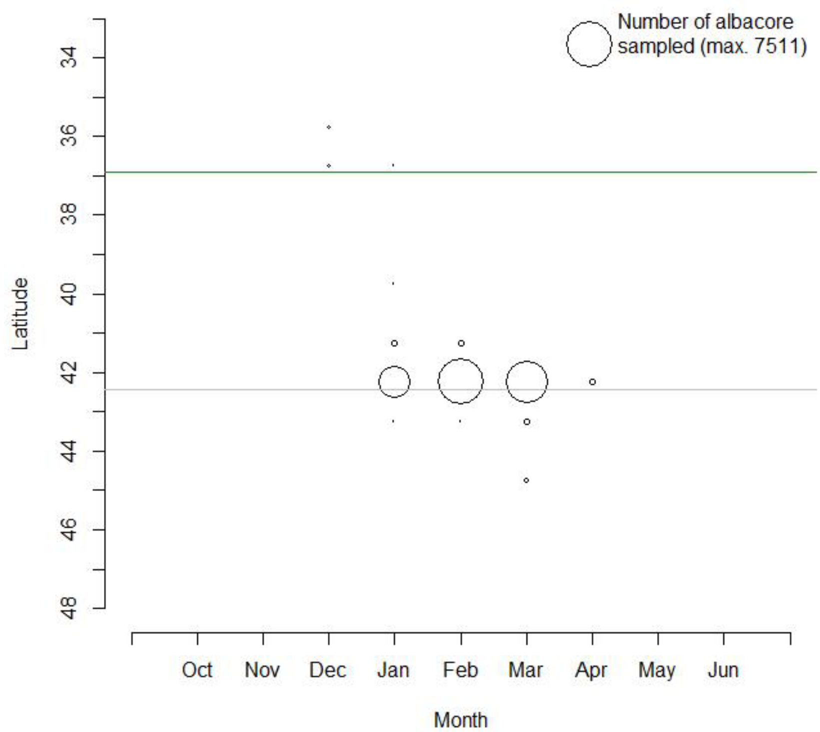
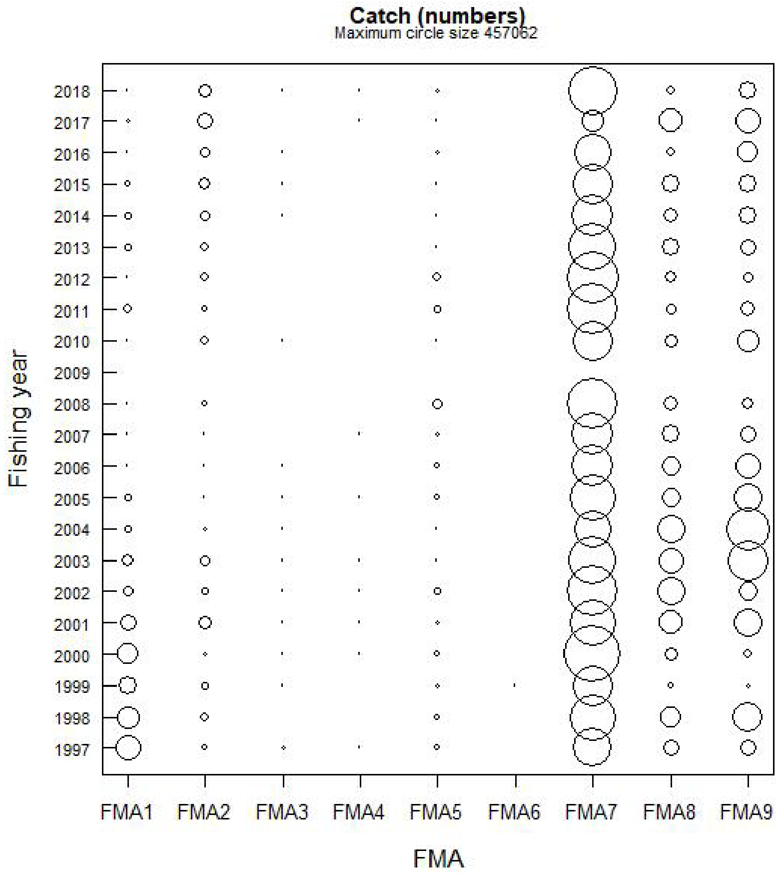


Figure 8 *continued*: 2017–18.



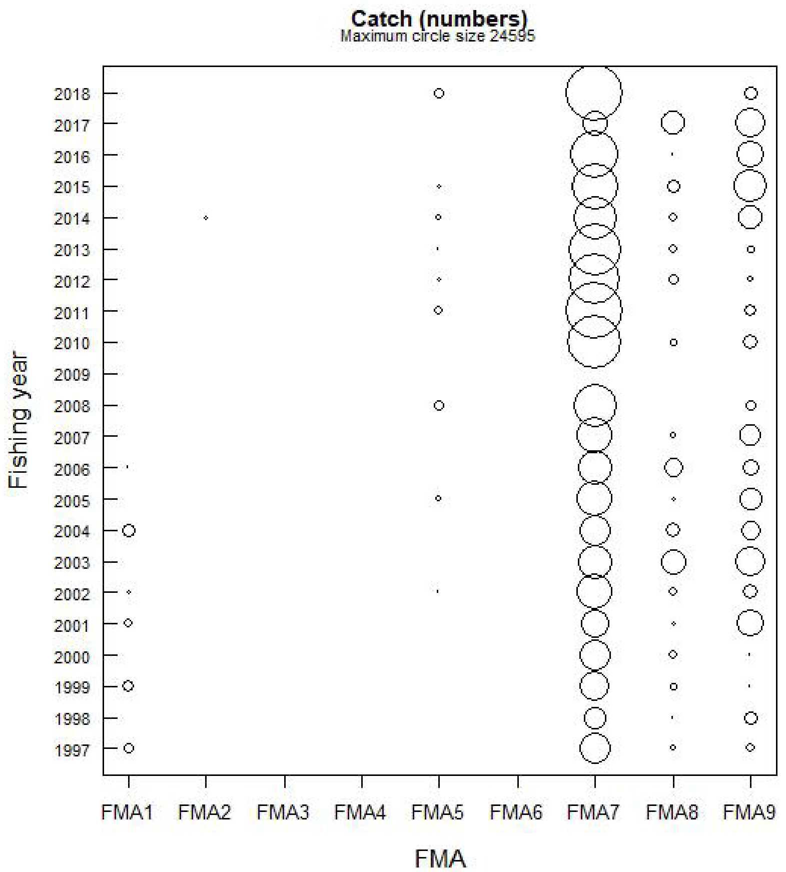
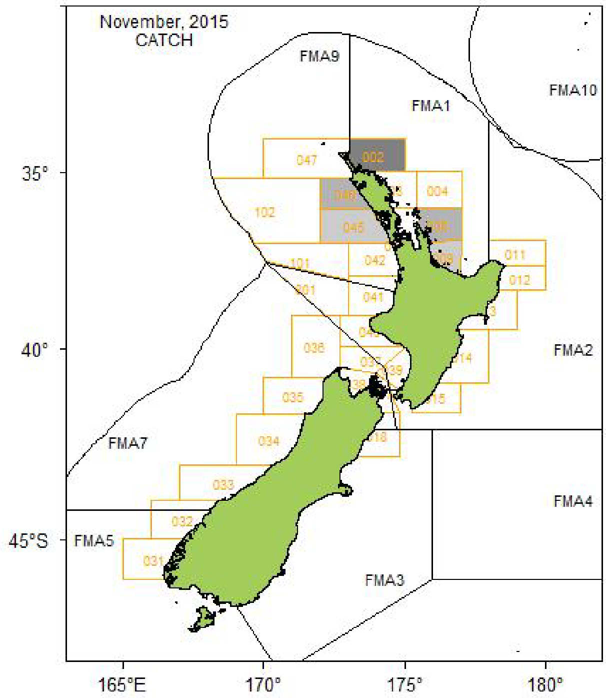


Figure 9: Annual pattern of albacore catch (numbers) reported in CELR data (top) and sampling data (bottom) by FMA. The area of the circles is proportional to the maximum value in each panel, indicated in the title.

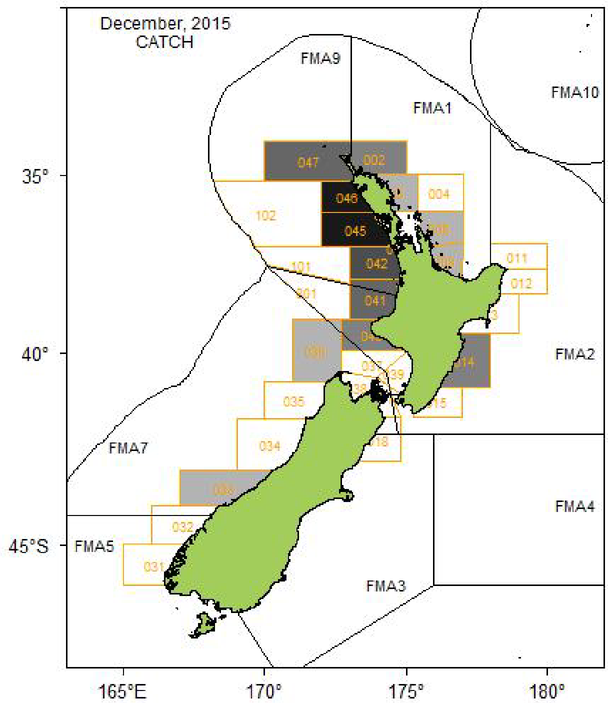
Figure 10: Percentage of albacore catch (numbers) reported in CELR data by month and FMA, 2012–13 to 2014–15 (left) and 2015–16 to 2017–18 (right).

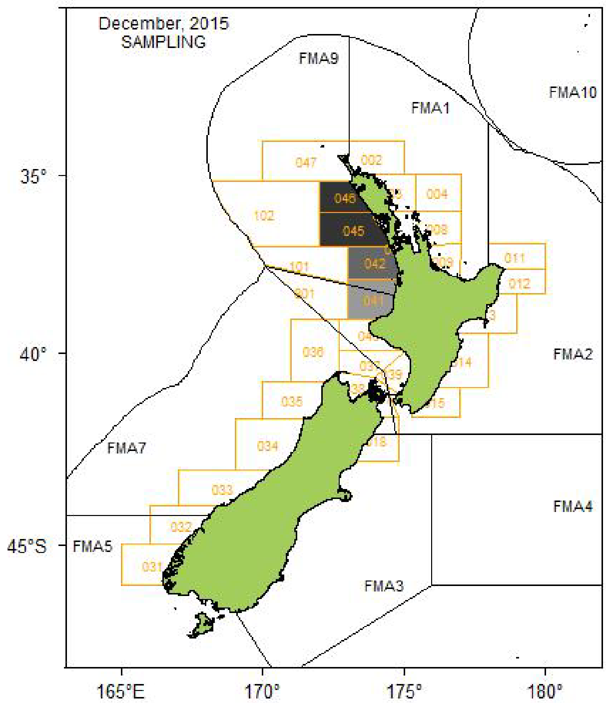
7. Appendix 1

Statistical area density plots of albacore catch, fished (left) and sampled (right) for 2015−16, by month. A logarithmic density scale was used (i.e. all catch numbers divided by the maximum catch in any one stat area) where 0=white and 1=black. Reproduced from Griggs et al. 2018.
November 2015.

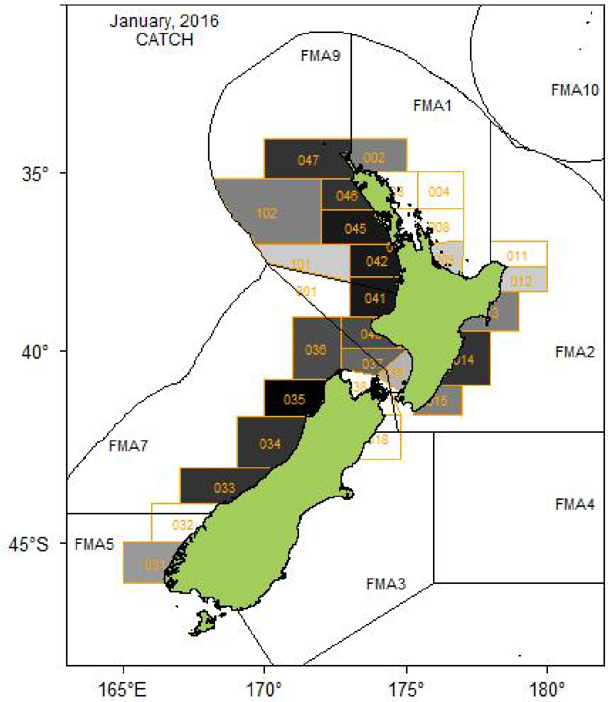


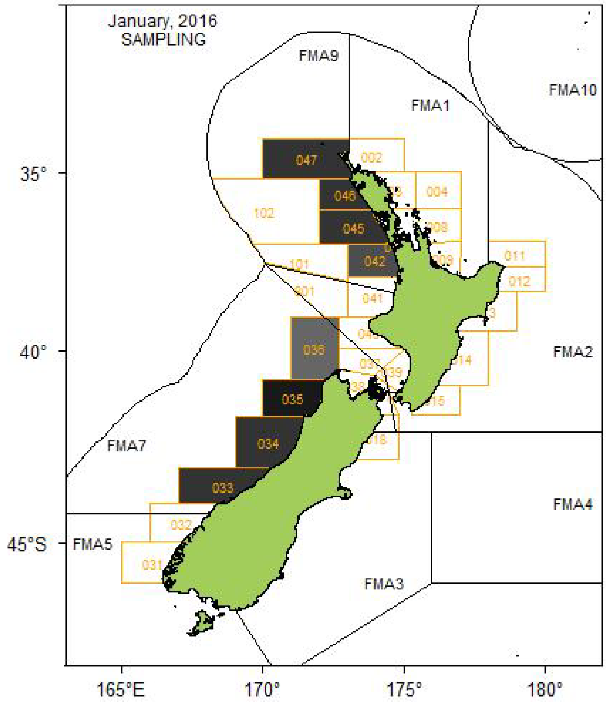
2015−16 *continued*. December 2015.



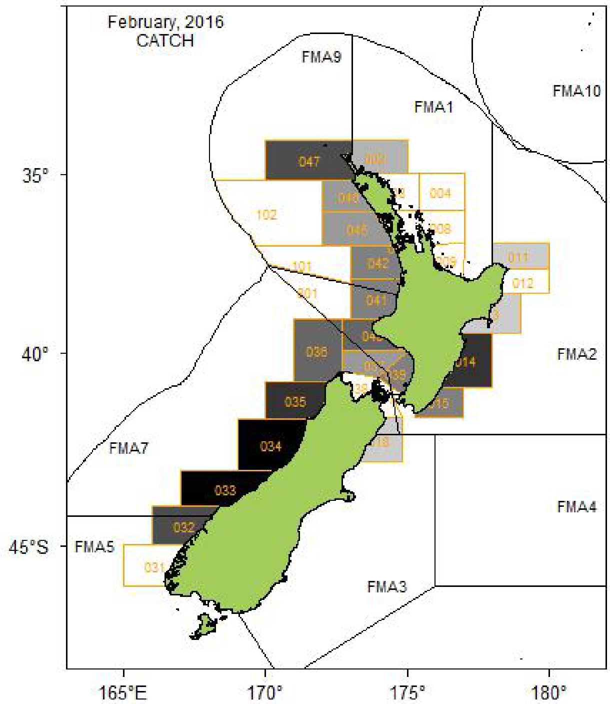


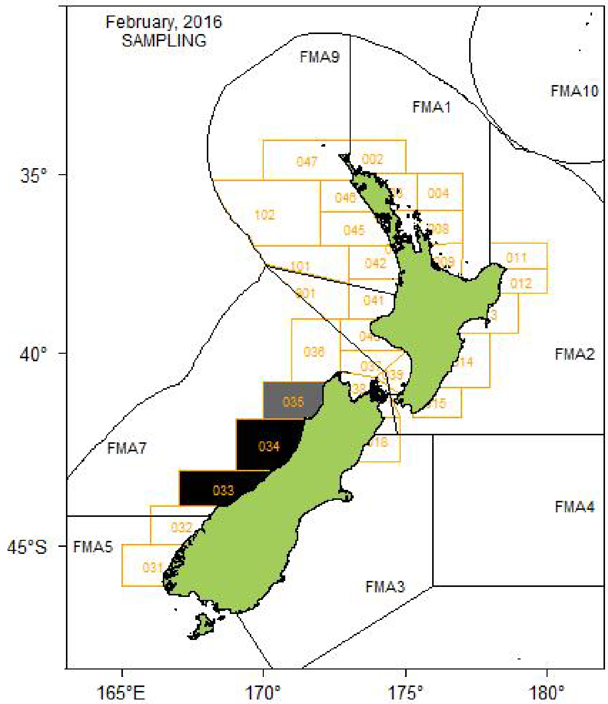
2015−16 *continued*. January 2016.



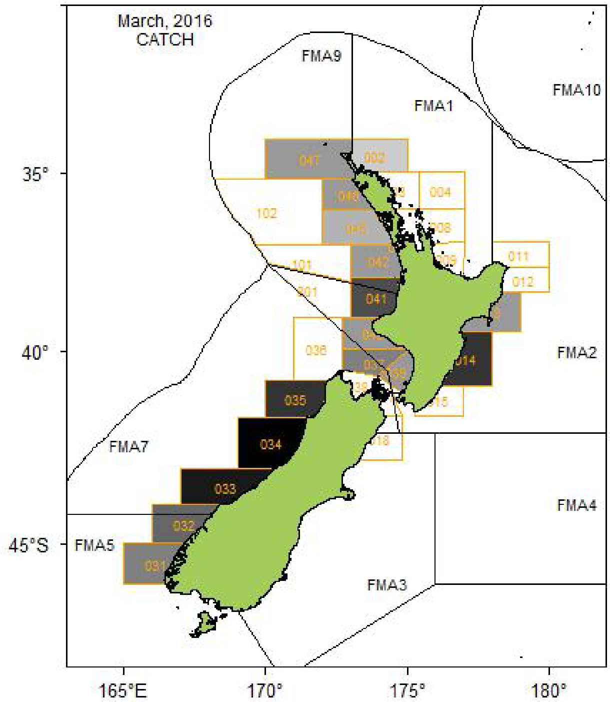


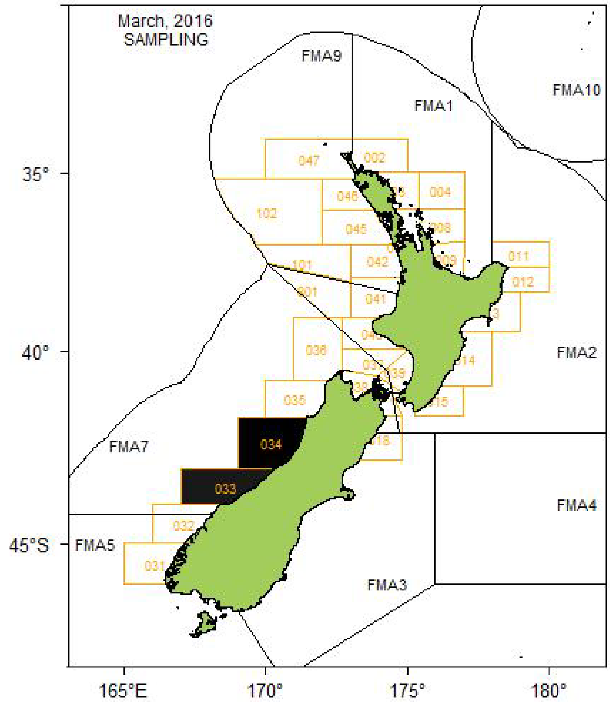
2015−16 *continued*. February 2016.



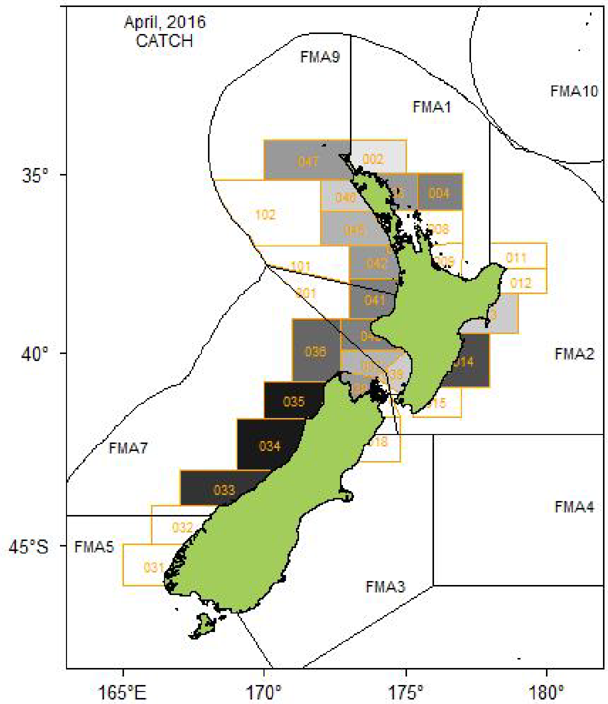


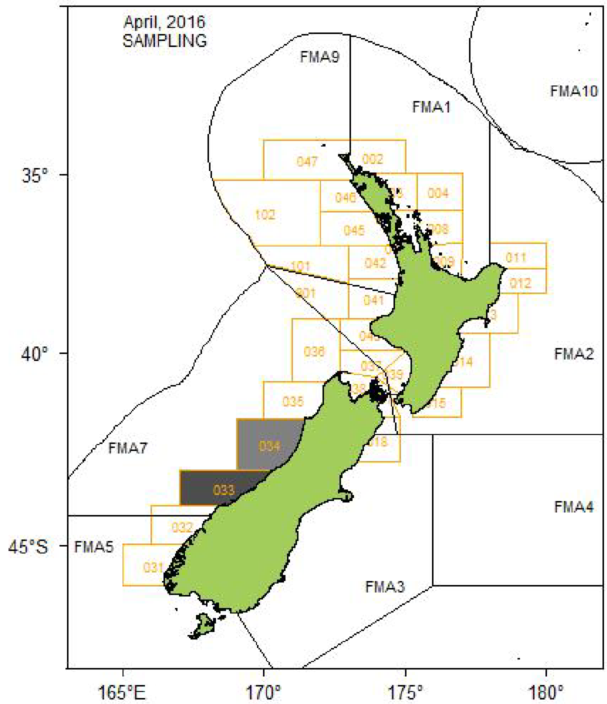
2015−16 *continued*. March 2016.



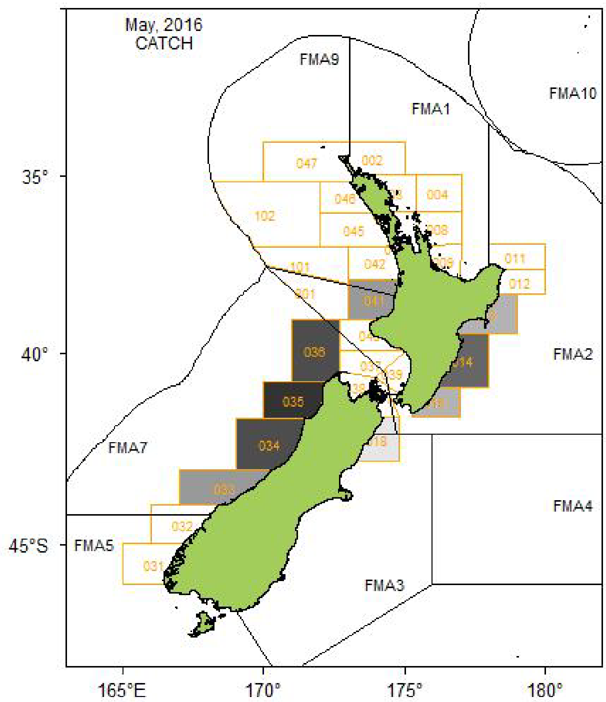


2015−16 *continued*. April 2016.

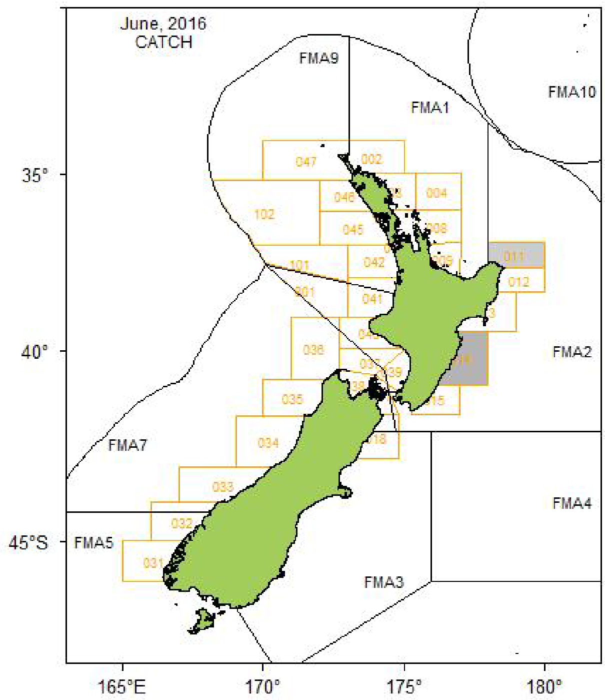




2015−16 *continued*. May 2016.

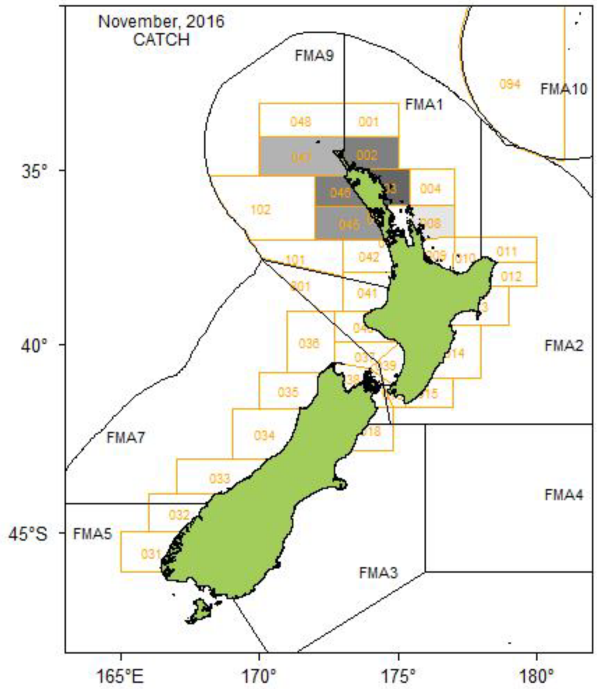


2015−16 *continued*. June 2016.

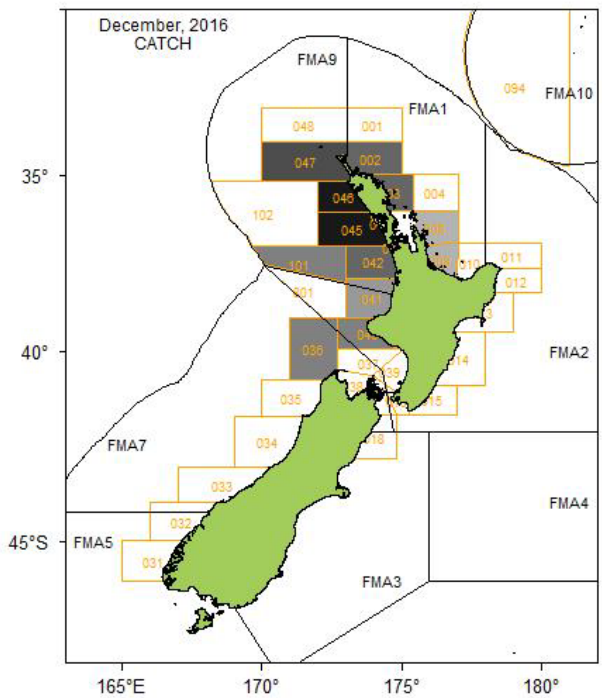


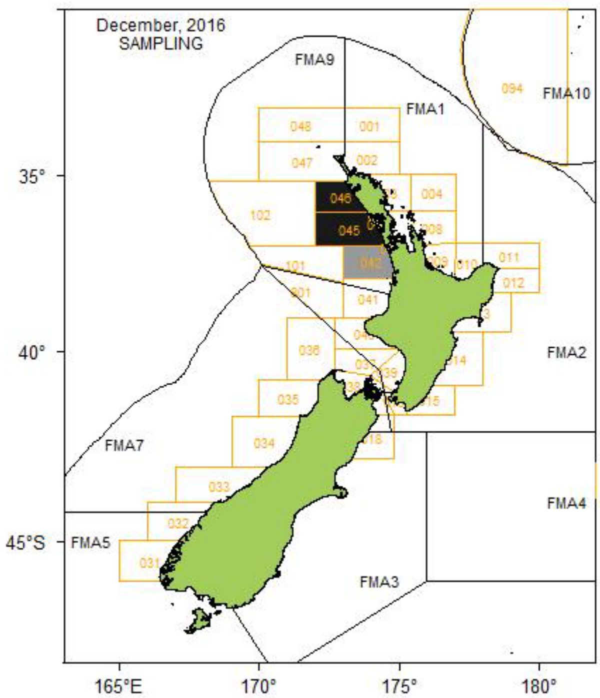
8. Appendix 2

Statistical area density plots of albacore catch, fished (left) and sampled (right) for 2016−17, by month. A logarithmic density scale was used (i.e. all catch numbers divided by the maximum catch in any one stat area) where 0=white and 1=black. Reproduced from Griggs et al. 2018.
November 2016.

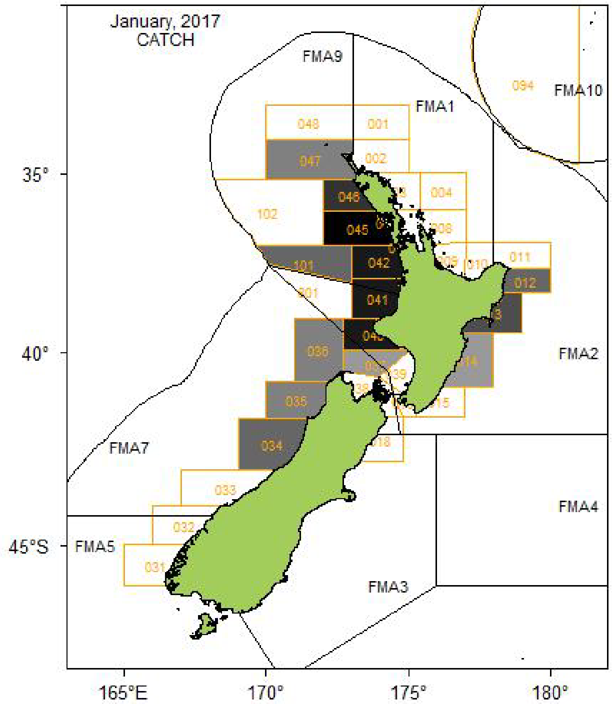


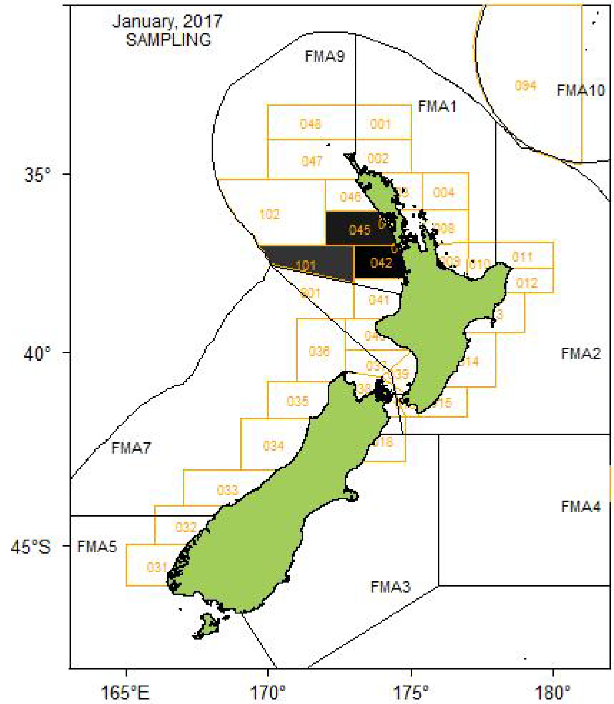
2016−17 *continued*. December 2016.



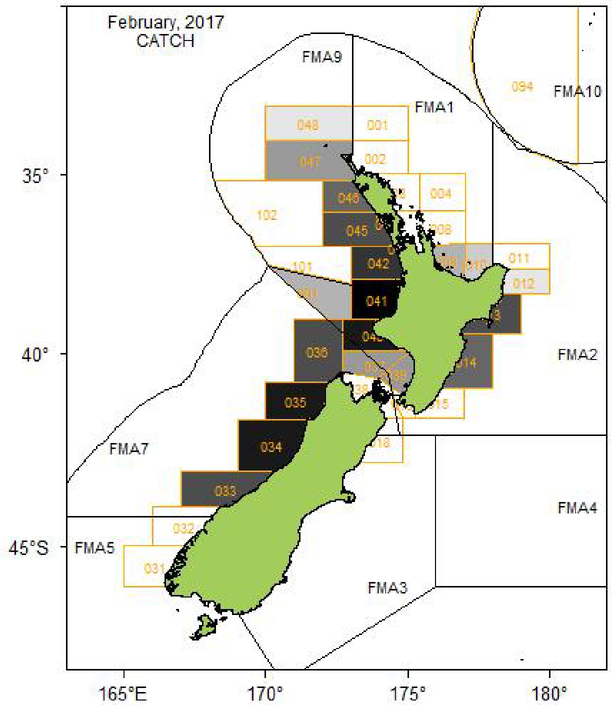


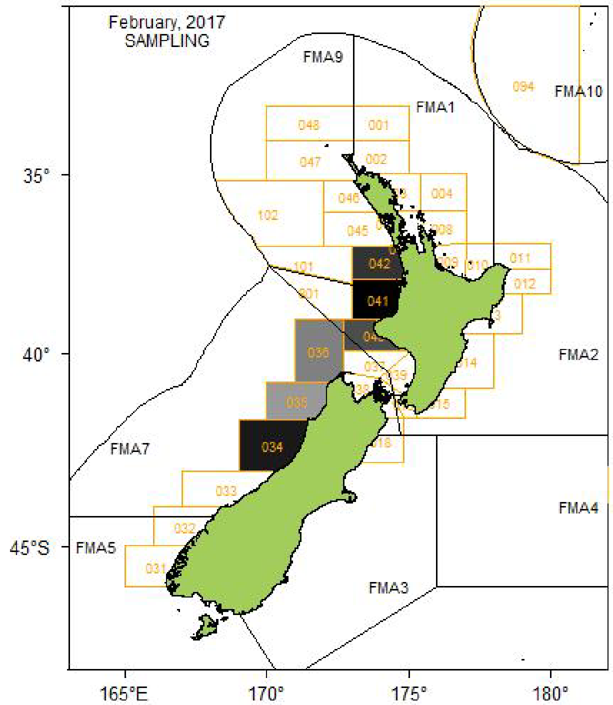
2016−17 *continued*. January 2017.



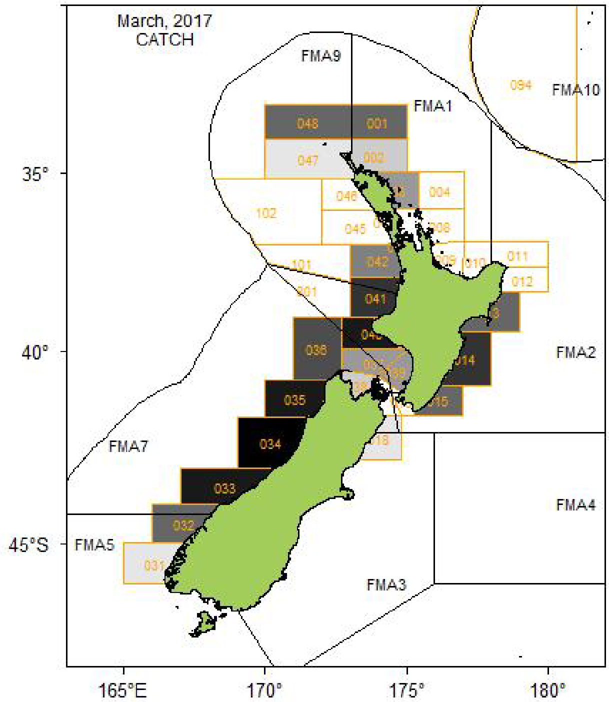


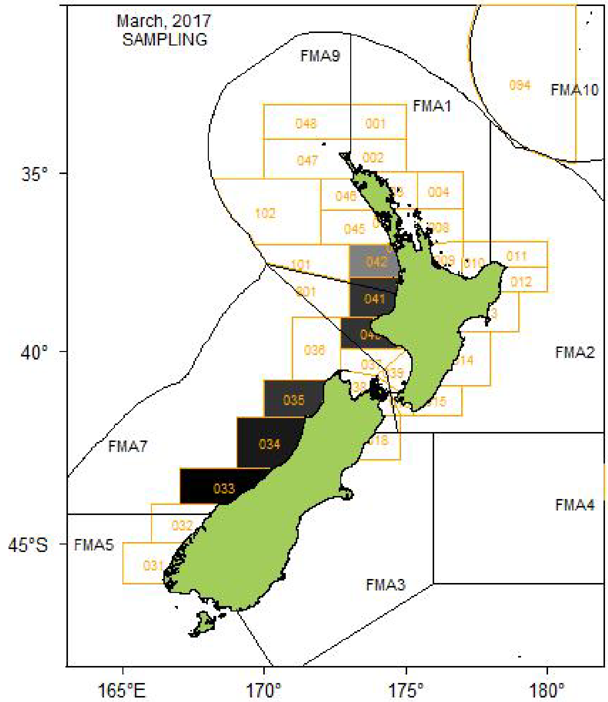
2016−17 *continued*. February 2017.



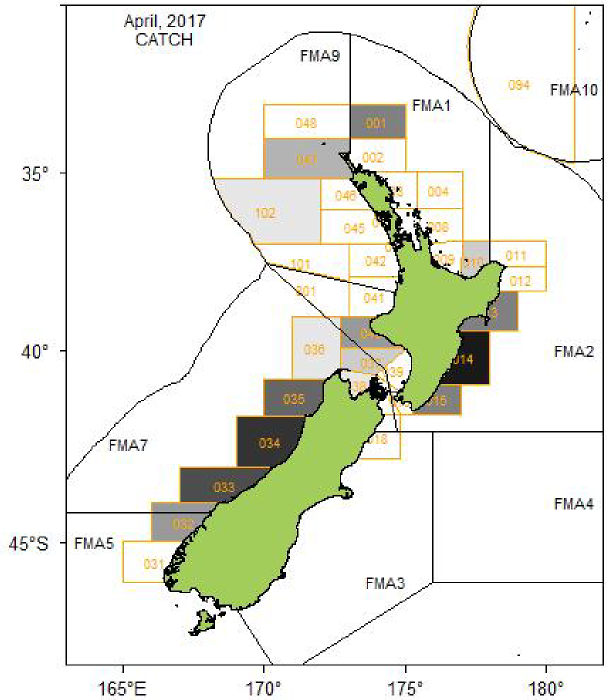


2016−17 *continued*. March 2017.

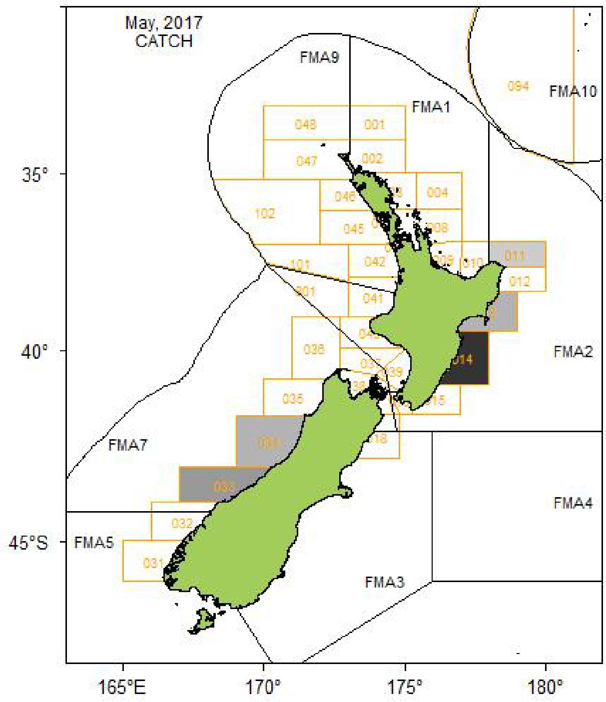




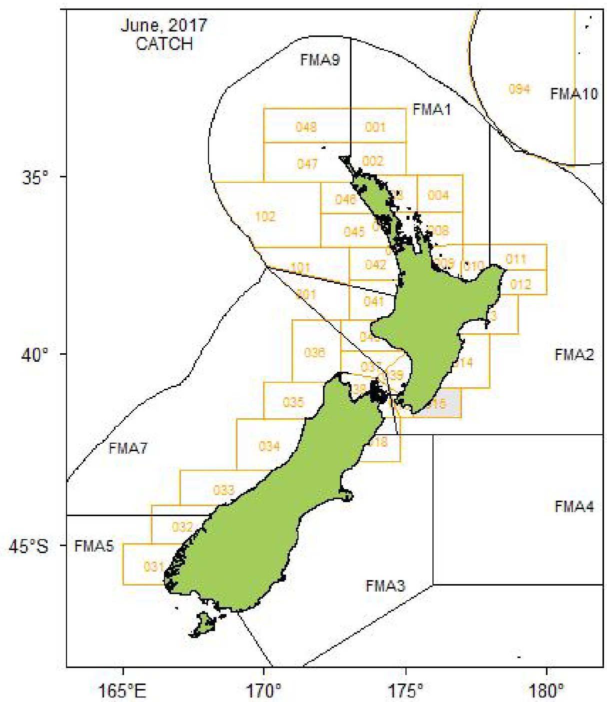
2016−17 *continued*. April 2017.



2016−17 *continued*. May 2017.

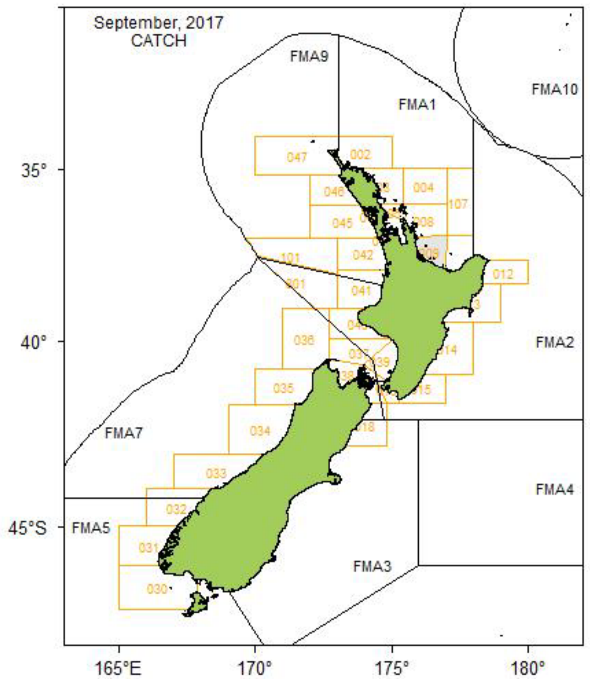


2016−17 *continued*. June 2017.

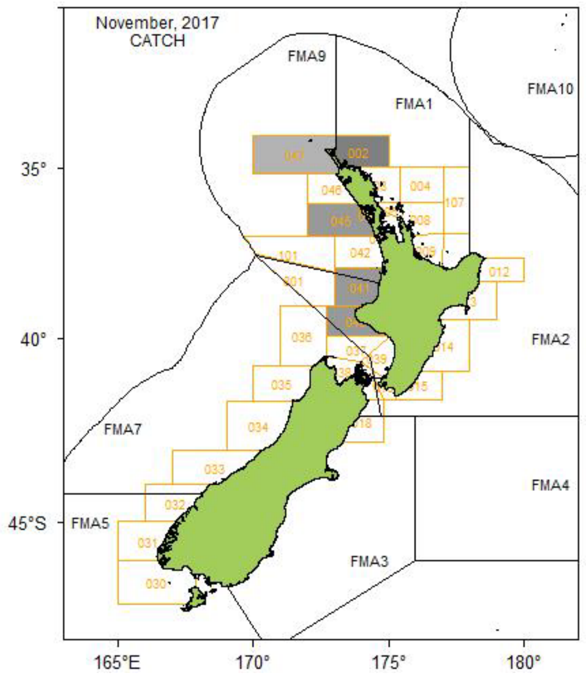


9. Appendix 3

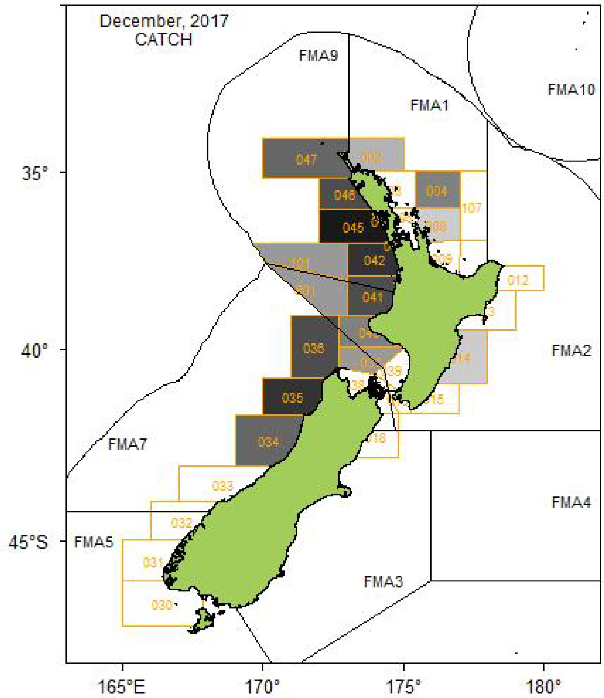
Statistical area density plots of albacore catch, fished (left) and sampled (right) for 2017−18, by month. A logarithmic density scale was used (i.e. all catch numbers divided by the maximum catch in any one stat area) where 0=white and 1=black. Reproduced from Griggs et al. 2018.
September 2017.

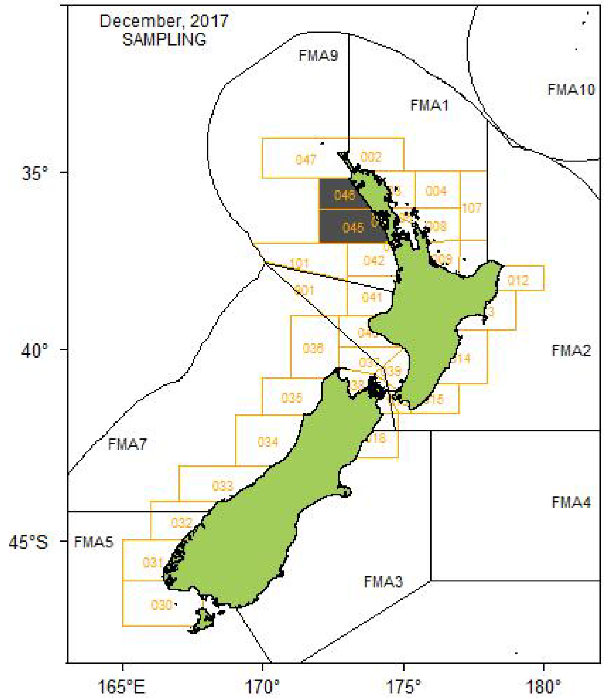


2017−18 *continued*. November 2017.

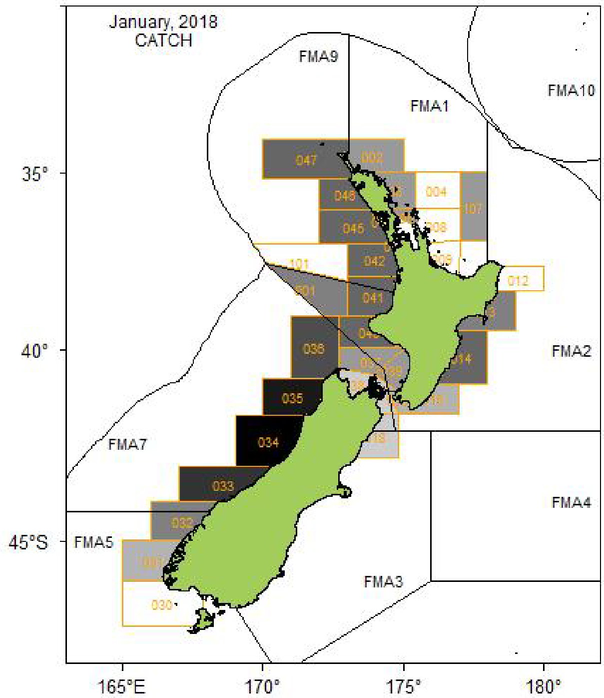


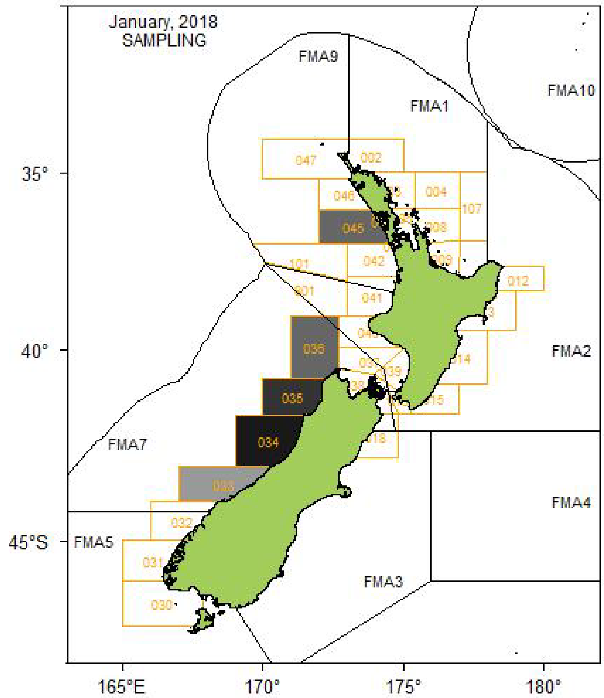
2017−18 *continued*. December 2017.



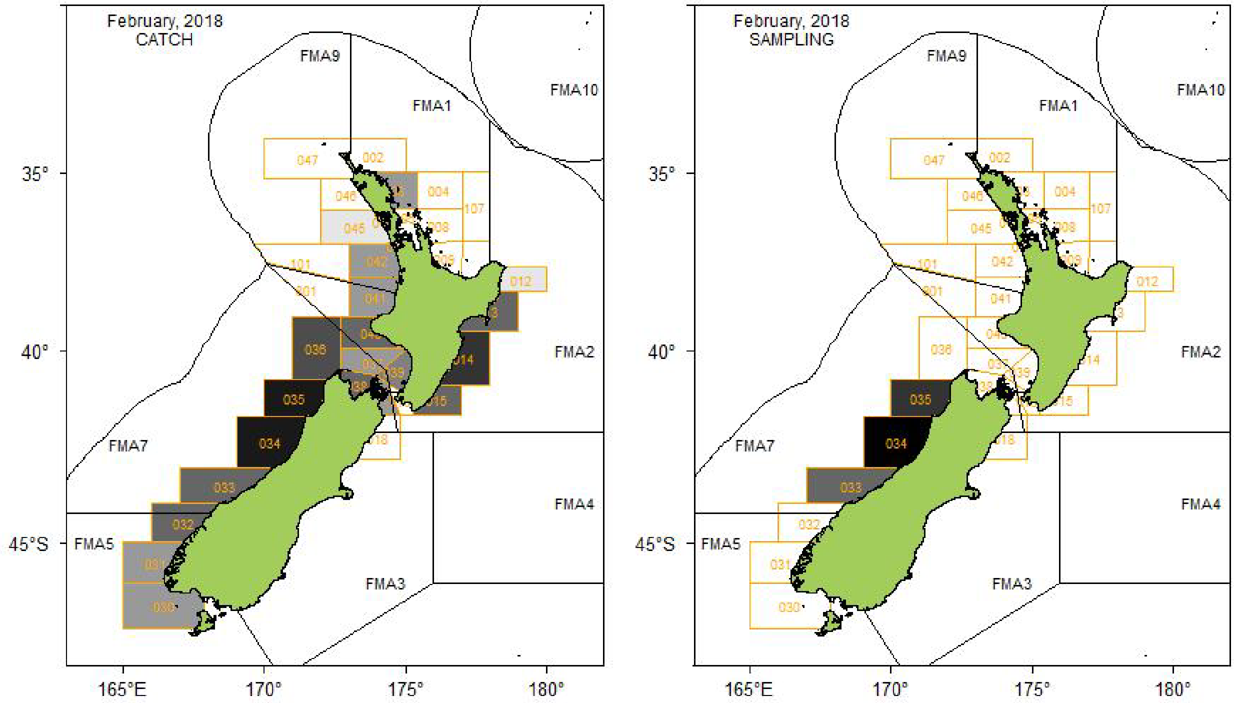


2017−18 *continued*. January 2018.

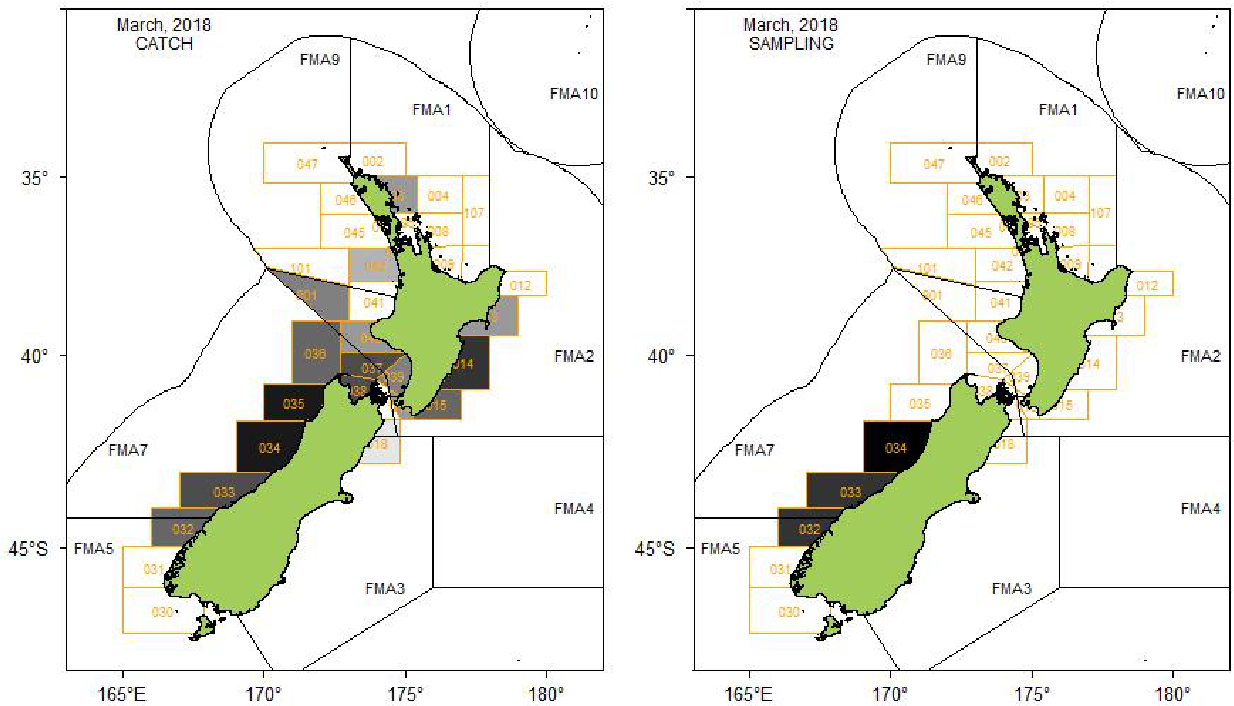




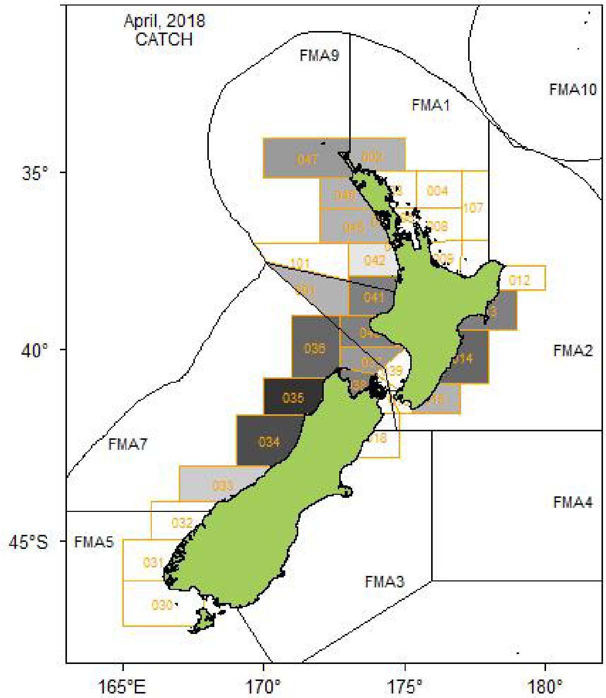
2017−18 *continued*. February 2018.

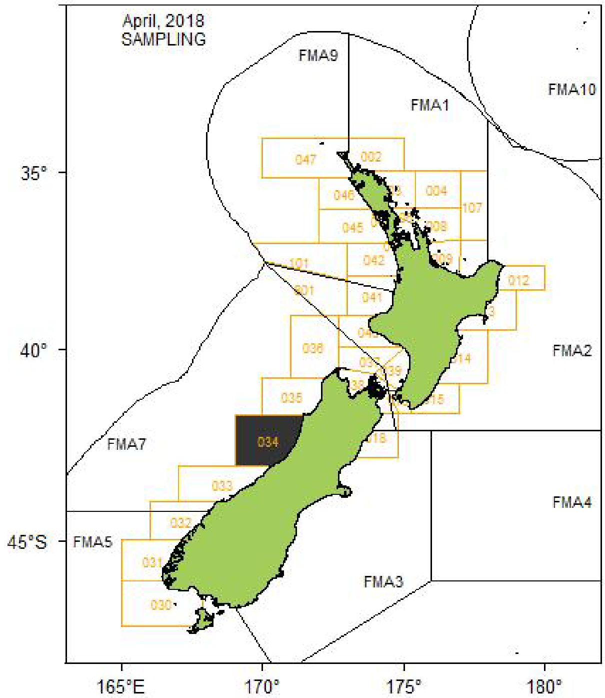


2017−18 *continued*. March 2018.



2017−18 *continued*. April 2018.





2017−18 *continued*. May 2018.