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Albacore catch sampling during 2015–16 to 2017–18

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EXECUTIVE SUMMARY

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Albacore caught by trolling during the 2015−16, 2016−17, and 2017−18 fishing seasons were sampled in fish sheds to determine the length frequency composition and length-weight relationship. Albacore were sampled from two ports, Auckland and Greymouth. Targets for sampling were based on the monthly distribution of the commercial catch during recent years. Fish were sampled from December 2015 to April 2016, December 2016 to March 2017 and December 2017 to April 2018.

During 2015−16, 4850 albacore were sampled from 45 landings and 29 vessels, and 532 fish were weighed. The number sampled in 2016−17 was 3579, from 31 landings and 17 vessels, with 1089 fish weighed. In 2017–18, 4163 fish were sampled from 42 landings and 28 vessels, with 661 weights recorded.

There were differences in the spatial and temporal distributions of catch and effort between the three years. The fishing season was much longer than usual in the northern region in 2016−17 with fewer fish caught in the southern region than usual, and in 2017–18 the season in the north was very short and the catch was dominated by small fish. Sampling represented the fishery well both temporally and spatially.

Albacore showed a multimodal length distribution with three to four modes visible in most samples in each year, month and port. Fish sampled during 2015−16 ranged in size from 29 to 91 cm, the median fork length (FL) was 62 cm and the mean FL was 61.6 cm. During 2016–17 the size range was between 29 and 98 cm, with a median FL of 64 cm and a mean FL of 64.4 cm. The length range of the fish sampled during 2017−18 was from 31 to 91 cm, the median FL was 53 cm and the mean FL was 57.1 cm. As albacore reach sexual maturity at about 85 cm almost all of these fish were juveniles. Length-weight relationships were determined, and length composition was scaled to the total catch, for each year.

Data from New Zealand troll caught albacore are an important input in the South Pacific albacore stock assessment. Data from the shed sampling programme have been provided to the Western Central Pacific Fisheries Commission (WCPFC) since 1996−97. The New Zealand troll fishery catches the majority of the total removals of juveniles from this stock and is one of only two target fisheries for juveniles. Failure to monitor size composition in this stock would appreciably increase the uncertainty of stock assessments.

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 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 coasts of the North Island and South Island 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 U.S. 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 (Anon2018b).

Canadian landings in this fishery from its inception in 1987–88 to 2003–04 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 contributions 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 sampled in the STCZ by the American fleet in 2003–04 had an average FL of 66 cm.

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 16 years were mostly juveniles, ranging in size from 29 to 99 cm FL, with nearly all fish (99%) in the 47–80 cm range.

Albacore reach sexual maturity at about 85 cm (Bailey 1991). Maturity studies carried out by Farley et al. (2012) show that 50% maturity reached at 87 cm FL and 100% maturity is reached at 95 cm FL. 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 MPI observers 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 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.

The present study updates and extends these previous analyses for three more years, 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 2017–18 by the Ministry of Fisheries, and Ministry for Primary Industries (now Fisheries New Zealand).

2. METHODS

2.1 Catch-effort data

Commercial troll catch-effort data recorded by vessel personnel are recorded on CELR (Catch Effort Landing Return) forms. These data were extracted from the *tuna* database (Wei 2007). Vessels recorded fishing positions daily on CELR forms, either as latitude and longitude or by statistical area. If a statistical area was recorded, a 'centroid' position for latitude and longitude was assigned in the *tuna* database (Wei 2007).

Fishers are required to record the number of fish caught for all tuna species reported on CELR forms, but sometimes recorded weights instead, and these records were identified when loading data to the tuna database (Wei 2007). Weights were apparently recorded for 8.1% of the 2015−16 to 2017−18 CELR troll records in which albacore catch was recorded. Where fishers recorded weight instead of fish number, the weights were divided by average weights (determined from the albacore troll sampling programme) to estimate catch numbers. Catch weights for other records were estimated from catch numbers by multiplying them by the average fish weight for each year.

The albacore troll fishery extends over the summer months, and the fishing year for albacore is from 1 July to 30 June, so 2015−16 is 1 July 2015 to 30 June 2016, with the majority of fishing occurring in 2016.

2.2 Catch sampling

Sampling targets for 2015−16, 2016−17, and 2017−18 were based on a recent characterisation and sample design carried out under Objectives 1 and 2 of this project, MPI project ALB201501 (Griggs & Large 2017). The sampling design was based on the spatial and temporal distribution of albacore during three previous years, 2012−13 to 2014−15 (Griggs et al. 2014, Griggs & Large 2016). This continued the trend for three years of sampling following each fishery characterisation (Griggs et al. 2013, 2014).

Analysis of the size composition of the fishery requires regular sampling through the season (December–April/May) and should take account of any differences among areas and boats. The original sampling design, as specified by the SPC, required fish to be sampled from at least five vessel unloadings, and selected at random from each unloading. At least 1000 FLs were to be recorded in each port, each month, and at least 100 of these fish were to be subsampled and individually weighed.

The sampling strategy was revised in 2009−10 by the HMS (Highly Migratory Species) Working Group to measure a number of fish each month that was proportional to the commercial catch each month, and to sample more landings, in order to increase the representativeness of the sampling data. In each landing, the aim was to sample 100 fish for length, and in each month to subsample 100 fish for individual weights.

Two ports, Auckland (Port Onehunga, on the west coast) and Greymouth, were sampled during the 2015−16, 2016−17, and 2017−18 troll fishing seasons. At each port, sampling was carried out on the premises of the Licenced Fish Receiver (LFR) before freezing or grading of the fish. The fish were kept on ice while on the vessel and frozen once they were discharged into the fish receivers. In Greymouth, fish were sampled by NIWA staff close to the wharf when the troll vessel unloaded its catch. In Auckland, fish were subsampled at the wharf and trucked to the LFR shed. Sampling was carried out by Sanford staff, who were trained by staff from Trident Systems. NIWA carried out audits to ensure that sampling was carried out correctly and to address any issues that arose. FL was measured to the whole centimetre, rounded down, and weight was recorded as GW to the nearest 0.1 kilogram.

The target number of fish to be sampled each month was 400 fish in December, 1600 fish in January and in February, 1000 fish in March and 400 fish in April (Griggs & Large 2017).

2.3 Size composition and length-weight relationships

Size composition and length-weight relationships for fish sampled during the 2015−16, 2016−17, and 2017−18 troll seasons are summarised and presented. Unscaled size frequency distributions were compiled by month and area. Linear regression parameters and their standard errors were derived, for the following equation:

$$\ln(GW) = b_0 + b_1 \times \ln(FL)$$

where b_0 and b_1 are the y-axis intercept and the slope of the line respectively.

The sampled catches were scaled to the total commercial catch using data from the troll fishery. The total catches of albacore by year and month as recorded by fishers on CELR forms were extracted from the *tuna* database for the 2015−16, 2016−17, and 2017−18 albacore fishing years.

Estimated scaled numbers-at-length were calculated for 2015−16, 2016−17, and 2017−18 using the "R" software (R Development Core Team 2010) '*Catch-at-age*', developed by NIWA (Bull & Dunn 2002). Sampled landings were matched with corresponding trips recorded on CELR forms to obtain the total catch of albacore in each landing. Samples were assigned to the capture FMA. Where fishing occurred in more than one FMA, the sample was assigned to the FMA with the most catch (by fish number). Samples were stratified by month and North-South area. The North area was defined as FMA areas 1, 2, 8, 9, and 10. The other samples were assigned to the South area.

Samples were scaled up by the total catch in the month within North-South area to give an overall scaled length frequency (LF). Some months were not sampled and the catches from these months were assigned to the nearest month that was sampled.

Coefficients of variation (CVs,) of the numbers-at-length were calculated (from the original data in 1 cm length classes) by bootstrapping with fish resampled within each landing and landings resampled within each month. Although the resulting CVs would be smaller if the size classes were aggregated, the finer resolution of the original data was maintained because the results are used for inferring growth rate within a length-based age-structured model, MULTIFAN-CL (Fournier et al. 1998). Mean weighted CVs (MWCVs) were calculated as the average of the CVs for the individual length classes weighted by the proportion of fish in each class, using the '*Catch.at.age*' software.

2.4 Representativeness of sampling

Sample data were compared with CELR data to assess their spatial and temporal representativeness in relation to the commercial catch. Comparisons were made by month, FMA and statistical area.

3. RESULTS

3.1 Total troll catch

The total New Zealand albacore troll catches by fishing year, in fish numbers and weights, for 1999–00 to 2017–18 are shown in Table 1 and a plot of fish numbers is shown in Figure 1. Over this period, the troll fishery peaked in 2002–03 and declined to 2006–07. Thereafter catches were relatively stable.

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.

3.2 Catch sampling

The numbers of fish sampled each year and port for the 21 years of albacore troll sampling are shown in Table 2. The target number of fish and the number sampled each year and month during 2015−16, 2016−17 and 2017−18 are shown in Table 3 and Figure 2. A summary of the number of fish, landings and vessels sampled, in each month and port during 2015−16, 2016−17, and 2017−18 is shown in Table 4.

During 2015–16, a total of 4850 fish were sampled, 1447 in Auckland and 3403 in Greymouth. Of 45 landings, 10 were sampled in Auckland, and 35 in Greymouth. There were 7 vessels sampled in Auckland during December and January, and 24 vessels were sampled in Greymouth between February and April. Six vessels were sampled more than once and two were sampled in both ports.

During 2016–17, a total of 3579 fish were sampled, 2386 in Auckland and 1193 in Greymouth. Of 31 landings, 18 were sampled in Auckland, and 13 in Greymouth. There were 13 vessels sampled in Auckland between December and March, and 8 vessels were sampled in Greymouth during February and March. Nine vessels were sampled more than once and four were sampled in both ports during the season.

During 2017–18, a total of 4163 fish were sampled, 386 in Auckland and 3777 in Greymouth. Of 42 landings, 3 were sampled in Auckland, and 39 in Greymouth. Two vessels were sampled in Auckland in December and January, and 26 vessels were sampled in Greymouth between January and April. Ten vessels were sampled more than once.

Weights were recorded for 532 fish during 2015−16, 1089 fish in 2016−17 and 661 in 2017−18. Two outliers were removed from the 2015−16 data, twelve from 2016−17 and one from 2017−18, leaving 530 1077, and 660 records for 2015−16, 2016−17, and 2017−18 respectively.

3.3 Size composition and length-weight relationships

Three to four length modes were visible each month during 2015−16 (Figure 3). Three modes can be seen in the Auckland samples with strong modes at 60 cm and 70 cm in December and January and a smaller mode at about 48 cm. Clear modes are seen at 47, 57 and 65 cm in the February Greymouth sample and there is a fourth mode at about 72 cm overlapping with the third mode. The March sample is similar to February with less well defined modes, and few fish were sampled in April but three small modes are still visible.

Three length-frequency modes were visible each month during 2016−17 (Figure 3). In December there is a very small mode at 47 cm, a larger mode at 61 cm and the largest mode at 72 cm. The January sample has clear modes at 49 cm, 62 cm and 72 cm and the second mode is the largest mode. In the Auckland February sample modes are at 50 cm, 62 cm and about 74 cm, and the March sample from Auckland is similar to that of February. Few fish were sampled in February in Greymouth but modes occur at about 50 cm, 61 cm and 74 cm. The March Greymouth sample has a mode of small fish at 46 cm, and overlapping second-third modes about 59 cm and 69 cm.

Three length-frequency modes were visible each month during 2017−18 (Figure 3). Few fish were sampled in Auckland in 2017−18. There are small modes at about 46 cm and 61 cm, and a larger mode at 72 cm in the December sample, and less distinct but similar modes from the small January sample from Auckland. All of the Greymouth samples have a very prominant mode of small fish and two smaller modes of larger fish. Modes in January are at 50 cm, 62 cm and about 73 cm, those in February are at 51 cm, 62 cm and 75 cm, the March modes occur at 52 cm, about 63 cm and 74-76 cm, and the April modes are at 52 cm, about 63 cm, and about 75 cm.

Small fish (less than 50 cm FL) were seen in all months each year and were particularly well represented in February-March 2017 and in Greymouth in 2018. Some large fish (longer than 75 cm) were also seen in all months.

Fish sampled during 2015−16 ranged in size from 29 to 91 cm, with nearly all fish (99%) in the 44–78 cm range, the median FL was 62 cm and the mean FL was 61.6 cm. During 2016–17 the size range was from 29 to 98 cm, with nearly all fish (99%) in the 45–80 cm range; the median FL was 64 cm and the mean FL was 64.4 cm. The length range of the fish sampled during 2017−18 was from 31 to 91 cm, with nearly all fish (99%) in the 31–81 cm range, the median FL was 53 cm and the mean FL was 57.1 cm (Table 5). Length frequency distributions with all months combined are shown in Figure 4. During the 21 years of sampling, FL of troll-caught albacore ranged from 29 to 99 cm, with nearly all of the fish (99%) in the 46–52 cm range; the median was 62 cm and the mean was 62.6 cm (Table 5).

The 21 year time series of annual unscaled length frequency distributions is shown in Figure 5. Three modes were visible in most months of the years sampled and modes tended to increase by about 1 cm each month during the sampling period. There was considerable variability in the distributions from year to year. The number of modes varied from two to four, with some years showing clearly defined modes and others overlapping (including 2014–15), and the proportion of fish in each mode varied from year to year. The 1999–00 sample featured a single dominant mode, while three equal sized modes were visible in 1988–89. Small fish (less than 55 cm) were well represented in some years especially 1998–99 and 2002–03, and lacking in other years, particularly 1997–98, 2003–04, and 2011−12. The greatest proportion of large fish (over 75 cm) was seen in the 2000–01 sample, while other years lacked large fish, especially 2007–08 to 2011–12. Large fish were well represented again in 2013–14. There is a very prominant mode of small fish in 2017−18, unique to that year.

A comparison of the troll length frequency distributions over all years combined, with those of albacore measured by observers on surface longline vessels is shown in Figure 6. The longline fishery catches larger adult and sub-adult fish than the troll fishery, which catches mostly juvenile fish.

Length and weight data have been recorded for 19 fishing years, 1998–99 to 2017–18. The length-weight relationships for troll sampled albacore are shown in Figure 7 for 2015−16, 2016−17, and 2017−18. A summary of the linear regression parameters and their standard errors is shown in Table 6.

The length frequencies scaled to the total catch numbers with bootstrapped 95% confidence intervals are shown in Figure 8 for 2015−16, 2016−17, and 2017−18. The pooled MWCV was 17.4% for 2015−16, 20.9% for 2016−17, and 16.2% for 2017−18, below the target CV of 20% except in 2016−17 which was slightly over 20%.

3.4 Representativeness of sampling

The number and percentage of days fished and sampled, by month are shown in Table 7 and Figure 9, and the number and percentage of albacore caught and sampled, by month can be seen in Table 8 and Figure 9.

Most fishing effort occurred from December to April (96.8% of the effort in 2015–16, 96.9% in 2016–17 and 98.8% in 2017–18) with the peak of the season from January to March (72.7% of the effort in 2015–16, 73.4% in 2016–17 and 78.3% in 2017–18). In all three years, monthly albacore catches were closely

aligned with fishing effort. In 2015–16 the peak catches of the season were in January and February and remained quite high while tapering downwards in March and April. February was the peak month in 2016–17, with high proportions in both January and March, while in 2017–18 the peak was in January, with high catches in both February and March (Figure 9).

The proportion of albacore sampled quite closely followed the monthly catch distribution. In 2016–17 the monthly sampling matched the actual catch (Figure 9) better than it matched the monthly targets (Figure 2).

The number and percentage of days fished and sampled, by FMA are shown in Table 9 and Figure 10, with number and percentage of albacore caught and sampled, by FMA in Table 10 and Figure 10. In 2015–16 and 2017–18, most troll fishing was in FMA 7 with some effort in west coast FMAs 8, and 9, and a small amount off the east coast in FMAs 1 and 2. Most of the catch was from FMA 7 and the majority of samples were from FMA 7 in these two years. The spatial distribution of effort and catches were different in 2016–17 with higher effort and catch in WCNI FMAs 8 and 9.

Catch by month and FMA is shown in Figure 11. In all three years, catches prior to December were very small and catches in December were predominantly in FMA 9. Differences between the three years were apparent from January onwards. In 2015–16, albacore catches continued in January on the WCNI mostly in FMA 9 with some catch in FMA 8. Fish had started to move south in January and the largest proportion of the catch in January 2016 was in FMA 7. Catches were predominantly WCSI in FMA 7 throughout March and April with some catch there in May (Figure 11).

The fishing season was significantly different in 2016–17 with the majority of the fishery remaining in the WCNI FMAs 8 and 9 throughout January and February and continuing into March. There was only a very small amount of albacore catch in FMA 7 in January, a significant amount in February, and March catches were predominantly in FMA 7. There was also some catch in FMA 2 especially in April (Figure 11). In contrast to the 2016–17 season, the 2017–18 season was very short in the north and catches in were predominantly in FMA 7 throughout January to April, with a strong peak of the season in January (Figure 11).

Statistical area density plots comparing albacore caught and sampled are shown in Figure 12 for 2015–16, Figure 13 for 2016–17, and Figure 14 for 2017–18. Plots by month are shown in Appendices 1, 2, and 3 for 2015–16, 2016–17, and 2017–18 respectively.

Most of the 2015–16 catch came from WCSI Statistical Areas 033, 034, and 035, and of the northern catch, most was from Areas 042, 045, and 046. Albacore catches in 2016–17 mostly came from WCNI Statistical Areas 040, 041, 042, 045, and 046, with most southern catch in Areas 033, 034, and 035. There was also a significant catch off the East Coast in Area 014. Most of the 2017–18 catch came from WCSI Statistical Areas 034 and 035. The small amount of northern catch was mostly in Area 045. Sampling followed the spatial and temporal distribution quite well in all three years (Appendices 1–3).

4. DISCUSSION

Catch sampling in landing sheds

Monthly distributions of the numbers of fish sampled during 2015−16 to 2017−18 adequately achieved the targets and represented the temporal and spatial coverage of the fishery well, especially during the season peak months of January to March. January was somewhat under-sampled, and March was over-sampled in 2016−17 and 2017−18. As 2016−17 was not a typical season, sampling was adapted to sample the fishery representatively, so more landings were sampled in the north in the early part of the season during December to February.

There was a lot of variation between the three fishing years covered in this project. The majority of the 2016–17 fishing season, from December to February was in the northern region. This predominance of the WCNI fishery had not occurred before during any of the years monitored by the albacore port sampling. The 2017–18 was in contrast to this with a very short season in the north and a strong season the south. The predominance of small fish in 2017−18 was also unusual. The total troll catch in terms of numbers of fish was high in 2017−18, but with their small size, the total troll catch weight for the season was similar to that of 2015−16 and 2016−17.

The proportion of albacore sampled closely followed the monthly catch distribution and matched the actual catch better than it matched the monthly targets, reflecting the ability of samplers to respond to real time fishery trends.

International use of troll data for stock assessment

Data from this albacore troll sampling programme are provided to SPC for incorporation into the stock assessment of South Pacific albacore. Recent assessments are 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.

The New Zealand troll data were specifically mentioned as informative data for the WCPFC South Pacific albacore stock assessment (Hoyle et al. 2012). Currently, the New Zealand troll size data provide essential information about growth rates of young fish. Hoyle et al. (2012) state "The data that provide by far the most information about growth rates is the New Zealand troll data, mostly sampled from 165–175°E, which is modelled at a monthly time step and demonstrates very clear and consistent growth modes."

The relative strength of different size modes in the same year provides information to the model about relative year class strength, i.e. relative recruitment. This information needs to be constantly updated and missing a year would result in losing precision.

SPC plans to use New Zealand troll size data to improve the assessment, and understanding of the albacore fishery by investigating variability in growth and recruitment timing among years (S. Brouwer, WCPFC, pers. comm.). Annual variation is seen, with fish growing faster or recruiting earlier in some years, but the level of variation has not been assessed or linked to covariates such as oceanographic variables. The time series of good quality data is still fairly short, so cutting back on sampling would make this work harder to do. Also, climate change may affect growth rates, which would change the productivity of the stock. This could have important implications to the fishery, but frequent sampling should enable the early detection of any changes to the fishery.

Recommendation

Accurate positional information in the troll fishery is limited by the use of CELR forms where most fishers record a statistical area rather than latitude and longitude. Fewer than 5% of forms have latitude and longitude recorded. Dependence on fishers' use of the appropriate CELR template causes confusion, especially about which species to record as weight and which to record as fish numbers. Consequently a mixture of fish number and fish weight are recorded for tuna species including albacore, when all should be recorded as fish numbers. Another limitation of CELR forms is the lack of provision for reporting bycatch and discards. Creation of a new custom troll form (similar to the TLCER form) would enable fishers to record bycatch, discards, accurate positional information, and both fish numbers and weight.

5. ACKNOWLEDGEMENTS

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The 1996–97 and 1997–98 troll data were sampled for the Secretariat of the Pacific Community. CELR data were extracted from the *tuna* database and the longline data collected by observers from the Fisheries New Zealand Observer Programme were extracted from the *cod* database.

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Table 1: Total troll catch recorded on CELR forms.

Year	Number of fish	Estimated Weight (kg)
1999–00	566 247	2 672 202
2000–01	550 467	2 986 363
2001–02	555 510	2 826 972
2002–03	674 283	3 130 960
2003–04	568 179	3 167 817
2004–05	476 717	2 928 249
2005–06	393 427	2 183 331
2006–07	329 775	1 716 409
2007–08	436 442	2 018 381
2008–09	373 664	1 950 843
2009–10	325 928	1 720 897
2010–11	434 300	2 067 270
2011–12	435 736	2 169 966
2012–13	420 953	2 311 034
2013–14	340 183	1 598 861
2014–15	342 280	1 759 320
2015–16	293 078	1 796 569
2016–17	280 281	1 762 970
2017–18	414 878	1 775 679

Table 2: Number of fish sampled for length each year by port from 1996−97 to 2017−18.

	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
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: Target number of fish to sample each month, and number sampled per month in each port and month during 2015–16, 2016–17, and 2017–18.

		Sampled 2015–16		
	Target	Auckland	Greymouth	Total
December	400	554		554
January	1600	893		893
February	1600		2 157	2 157
March	1000		1 046	1 046
April	400		200	200
Total		**1 447**	**3 403**	**4 850**

		Sampled 2016–17		
	Target	Auckland	Greymouth	Total
December	400	627		627
January	1600	935		935
February	1600	482	293	775
March	1000	342	900	1 242
April	400			0
Total		**2 386**	**1 193**	**3 579**

		Sampled 2017–18		
	Target	Auckland	Greymouth	Total
December	400	256		256
January	1600	130	1 010	1 140
February	1600		1 068	1 068
March	1000		1 299	1 299
April	400		400	400
Total		**386**	**3 777**	**4 163**

Table 4: Number of fish, landings and vessels sampled, in each month and port during 2015–16, 2016–17, and 2017–18.

2015–16

Port	Month	No. of fish	No. of landings	No. of vessels
Auckland	December	554	4	3
	January	893	6	5
Greymouth	February	2157	22	19
	March	1046	11	7
	April	200	2	2
2015–16	**Total**	**4850**	**45**	**29**

2016–17

Port	Month	No. of fish	No. of landings	No. of vessels
Auckland	December	627	5	5
	January	935	7	7
	February	482	4	4
	March	342	2	2
Greymouth	February	293	3	3
	March	900	10	7
2016–17	**Total**	**3579**	**31**	**17**

2017–18

Port	Month	No. of fish	No. of landings	No. of vessels
Auckland	December	256	2	1
	January	130	1	1
Greymouth	January	1 010	11	11
	February	1 068	11	10
	March	1 299	13	12
	April	400	4	4
2017–18	**Total**	**4 163**	**42**	**28**

Table 5: Summary of length frequency statistics for albacore sampled during 18 years of troll sampling, fork lengths in cm.

	n	Mean	Standard deviation	Min	1%	5%	Median	95%	99%	Max
1996–97	4 217	65	6.9	40	49	51	66	76	81	92
1997–98	3 978	66	6.7	45	51	59	64	78	81	91
1998–99	3 431	61.4	8.7	38	47	48	62	74	81	91
1999–00	3 962	61.1	5.6	39	49	55	60	74	81	94
2000–01	5 192	65.2	8.5	40	46	49	68	75	78	99
2001–02	5 170	63.6	8.6	42	47	51	62	80	83	89
2002–03	7 606	60.9	6.4	42	47	50	61	71	76	92
2003–04	5 485	64.3	5.1	40	52	58	63	73	76	94
2004–05	5 502	66.5	7.1	45	52	55	68	76	80	94
2005–06	4 670	63.3	7.5	45	50	52	63	78	83	92
2006–07	4 200	61.4	8.1	43	49	50	61	74	80	92
2007–08	4 564	61.6	6.4	42	49	51	61	73	77	92
2008–09	0									
2009–10	4 185	61.6	5.6	41	48	51	61	61	77	87
2010–11	4 783	59.3	6	44	46	49	59	59	76	96
2011–12	5 100	61.8	5.4	46	54	56	60	60	77	93
2012–13	5 248	64.1	6.3	42	47	50	65	74	78	86
2013–14	5 815	63.4	8.3	42	46	49	61	77	80	96
2014–15	5 216	61.1	7	29	44	47	61	71	78	86
2015–16	4 850	61.6	8	29	44	47	62	74	78	91
2016–17	3 579	64.4	8.1	29	45	49	64	76	80	98
2017–18	4 163	57.1	8.7	31	47	49	53	75	81	91
All troll	100 916	62.6	7.5	29	46	50	62	75	80	99

Table 6: Linear regression parameters for length-weight relationships.

	n	b_0	SE_{b0}	b_1	SE_{b1}	R^2
1998–99	317	-10.61	0.13	2.95	0.03	0.97
1999–00	397	-9.46	0.16	2.67	0.04	0.93
2000–01	599	-9.86	0.12	2.77	0.03	0.94
2000–02	606	-9.69	0.10	2.73	0.02	0.95
2002–03	709	-9.82	0.16	2.76	0.04	0.87
2003–04	598	-10.33	0.14	2.89	0.03	0.92
2004–05	400	-10.36	0.13	2.90	0.03	0.96
2005–06	600	-10.47	0.10	2.92	0.02	0.96
2006–07	598	-10.63	0.06	2.97	0.02	0.98
2007–08	574	-10.33	0.11	2.89	0.03	0.96
2009–10	500	-10.57	0.11	2.96	0.03	0.96
2010–11	386	-10.22	0.15	2.86	0.04	0.94
2011–12	498	-10.09	0.14	2.84	0.03	0.93
2012–13	673	-10.74	0.07	2.99	0.02	0.98
2013–14	1 068	-10.40	0.08	2.90	0.02	0.96
2014–15	851	-10.67	0.07	2.98	0.02	0.98
2015–16	530	-10.51	0.09	2.94	0.02	0.97
2016–17	1 077	-10.74	0.06	2.99	0.01	0.98
2017–18	660	-10.77	0.06	3.00	0.01	0.99
All troll	11 641	-10.42	0.02	2.91	0.01	0.96

Table 7: Number and percentage of days fished and sampled, by month

2015–16

		Days		% Days	
Year	Month	Fished	Sampled	Fished	Sampled
2015	November	15		0.4	
	December	366	22	8.8	8.5
2016	January	1135	72	27.2	27.8
	February	1097	100	26.3	38.6
	March	799	60	19.2	23.2
	April	637	5	15.3	1.9
	May	115		2.8	
	June	5		0.1	

2016–17

		Days		% Days	
Year	Month	Fished	Sampled	Fished	Sampled
2016	July	1		0.0	
	November	20		0.5	
	December	442	36	12.0	18.8
2017	January	818	44	22.2	23.0
	February	1030	48	27.9	25.1
	March	860	63	23.3	33.0
	April	423		11.5	
	May	93		2.5	
	June	1		0.0	

2017–18

		Days		% Days	
Year	Month	Fished	Sampled	Fished	Sampled
2017	September	2		0.0	
	November	22		0.5	
	December	561	11	13.3	4.8
2018	January	1364	55	32.3	23.9
	February	966	81	22.8	35.2
	March	983	72	23.2	31.3
	April	305	11	7.2	4.8
	May	25		0.6	

Table 8: Number and percentage of albacore caught and sampled, by month

2015–16

		No. of ALB		% ALB	
Year	Month	Fished	Sampled	Fished	Sampled
2015	November	277		0.1	
	December	23 725	554	8.1	11.4
2016	January	90 862	893	31.0	18.4
	February	78 186	2 157	26.7	44.5
	March	51 722	946	17.6	19.5
	April	41 312	300	14.1	6.2
	May	6 950		2.4	
	June	44		0.0	

2016–17

		No. of ALB		% ALB	
Year	Month	Fished	Sampled	Fished	Sampled
2016	July	17		0.0	
	November	798		0.3	
	December	35 910	627	12.8	17.5
2017	January	73 469	935	26.2	26.1
	February	84 757	775	30.2	21.7
	March	54 218	1 242	19.3	34.7
	April	24 872		8.9	
	May	6 239		2.2	
	June	1		0.0	

2017–18

		No. of ALB		% ALB	
Year	Month	Fished	Sampled	Fished	Sampled
2017	September	4		0.0	
	November	497		0.1	
	December	53 167	256	12.8	6.1
2018	January	158 084	1 140	38.1	27.4
	February	101 307	1 068	24.4	25.7
	March	87 469	1 299	21.1	31.2
	April	14 037	400	3.4	9.6
	May	312		0.1	

Table 9: Number and percentage of days fished and sampled, by FMA, Unk, unknown

2015–16

	Days		% Days	
FMA	Fished	Sampled	Fished	Sampled
FMA1	47		1.1	
FMA2	315		7.6	
FMA5	33		0.8	
FMA7	2674	195	64.1	75.3
FMA8	267	3	6.4	1.2
FMA9	772	61	18.5	23.6
Other	61		1.5	

2016–17

	Days		% Days	
FMA	Fished	Sampled	Fished	Sampled
FMA1	80		2.2	
FMA2	508		13.8	
FMA5	11		0.3	
FMA7	1 149	65	31.2	34.0
FMA8	833	33	22.6	17.3
FMA9	1 105	93	30.0	48.7
Other	2		0.1	

2017–18

	Days		% Days	
FMA	Fished	Sampled	Fished	Sampled
FMA1	30		0.7	
FMA2	512		12.1	
FMA5	28	4	0.7	1.7
FMA7	2 977	213	70.4	92.6
FMA8	170		4.0	
FMA9	489	13	11.6	5.7
Other	22		0.5	

Table 10: Number and percentage of albacore caught and sampled, by FMA, Unk, unknown

2015–16

	No. of ALB		% ALB	
FMA	Fished	Sampled	Fished	Sampled
FMA1	919		0.3	
FMA2	15 920		5.4	
FMA5	2 390		0.8	
FMA7	200 737	3 403	68.5	70.2
FMA8	13 079		4.5	
FMA9	56 071	1 447	19.1	29.8
Other	3 961		1.4	

2016–17

	No. of ALB		% ALB	
FMA	Fished	Sampled	Fished	Sampled
FMA1	2 860		1.0	
FMA2	34 907		12.5	
FMA5	395		0.1	
FMA7	71 193	1 093	25.4	30.5
FMA8	80 299	754	28.6	21.1
FMA9	90 627	1 732	32.3	48.4
Other	1		0.0	

2017–18

	No. of ALB		% ALB	
FMA	Fished	Sampled	Fished	Sampled
FMA1	1 035		0.2	
FMA2	24 841		6.0	
FMA5	2 502	100	0.6	2.4
FMA7	330 938	3 677	79.8	88.3
FMA8	10 092		2.4	
FMA9	43 661	386	10.5	9.3
Other	1 810		0.4	

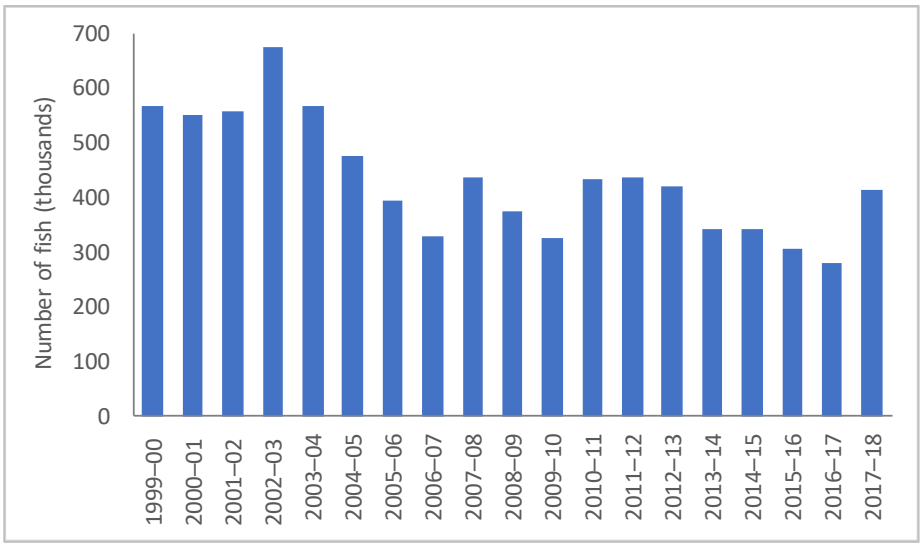


Figure 1: Total troll catch recorded on CELR forms.

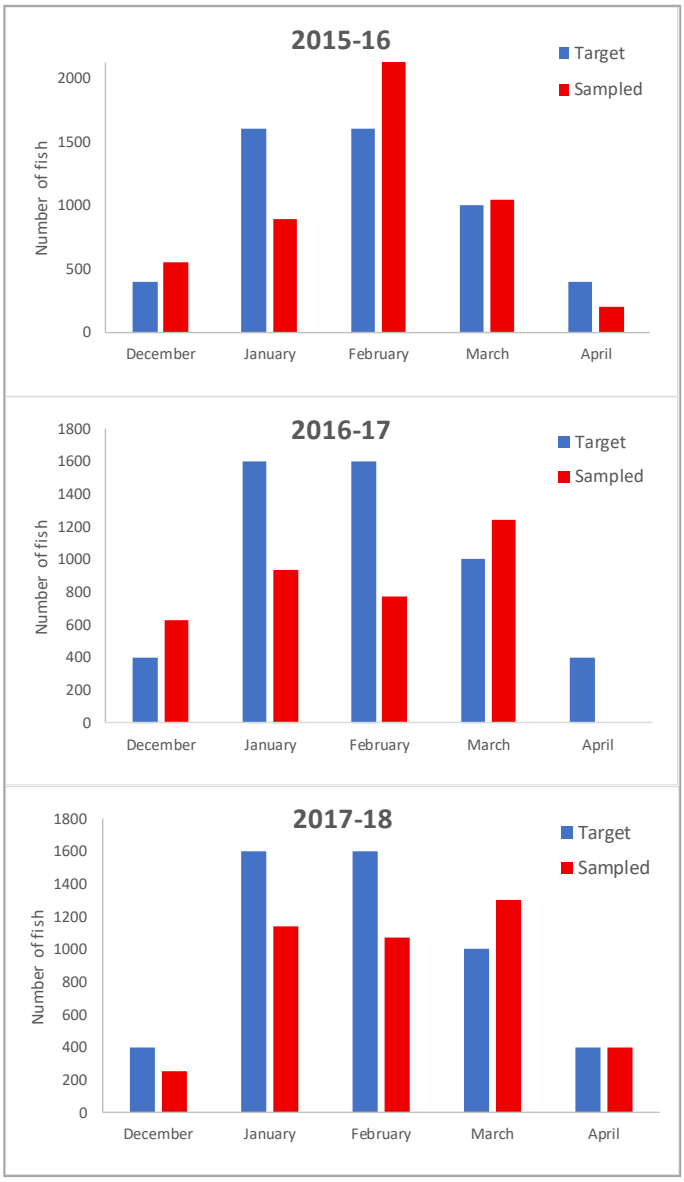


Figure 2: Target number of fish and number sampled each month during 2015–16, 2016–17, and 2017–18.

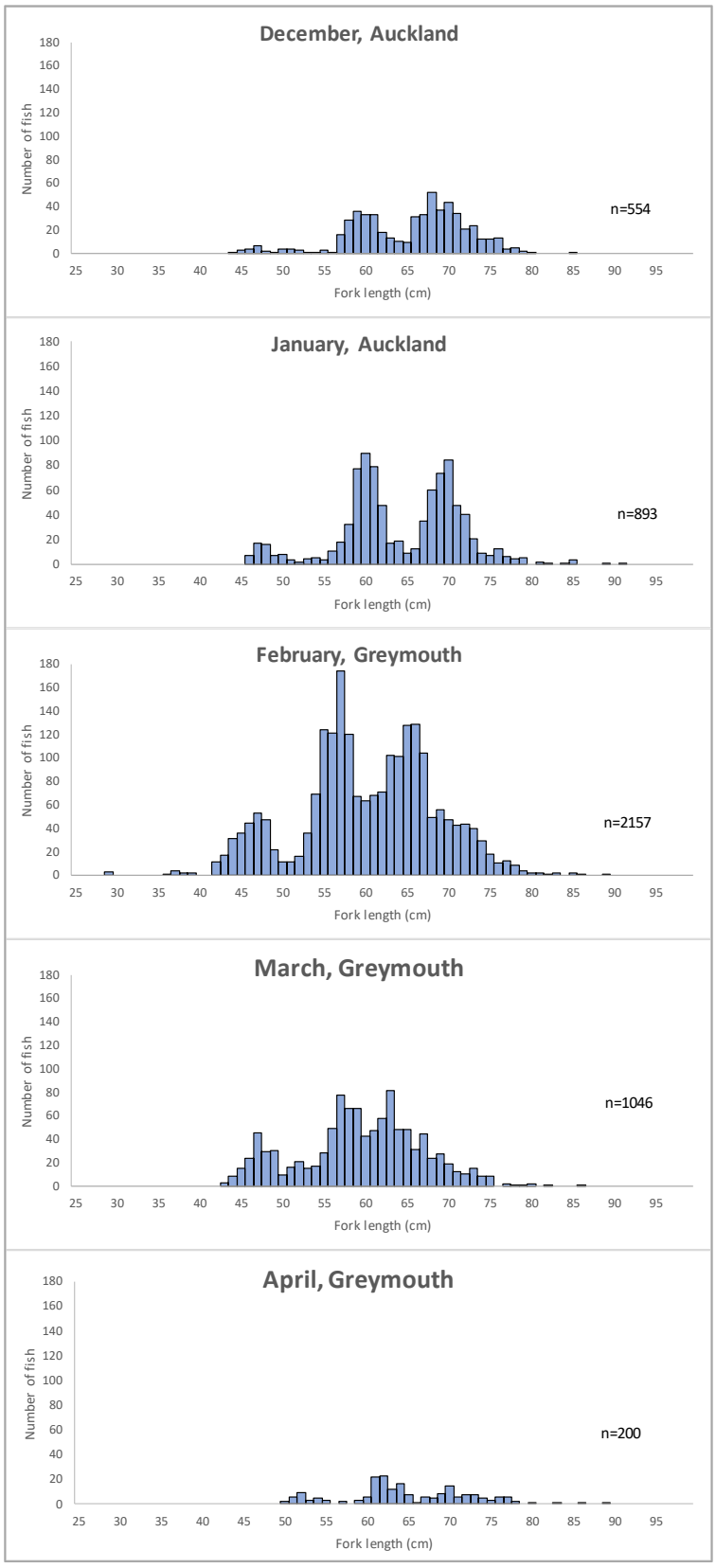


Figure 3: Albacore length frequency distributions, sampled from landings by troll vessels in Auckland and Greymouth during 2015–16.

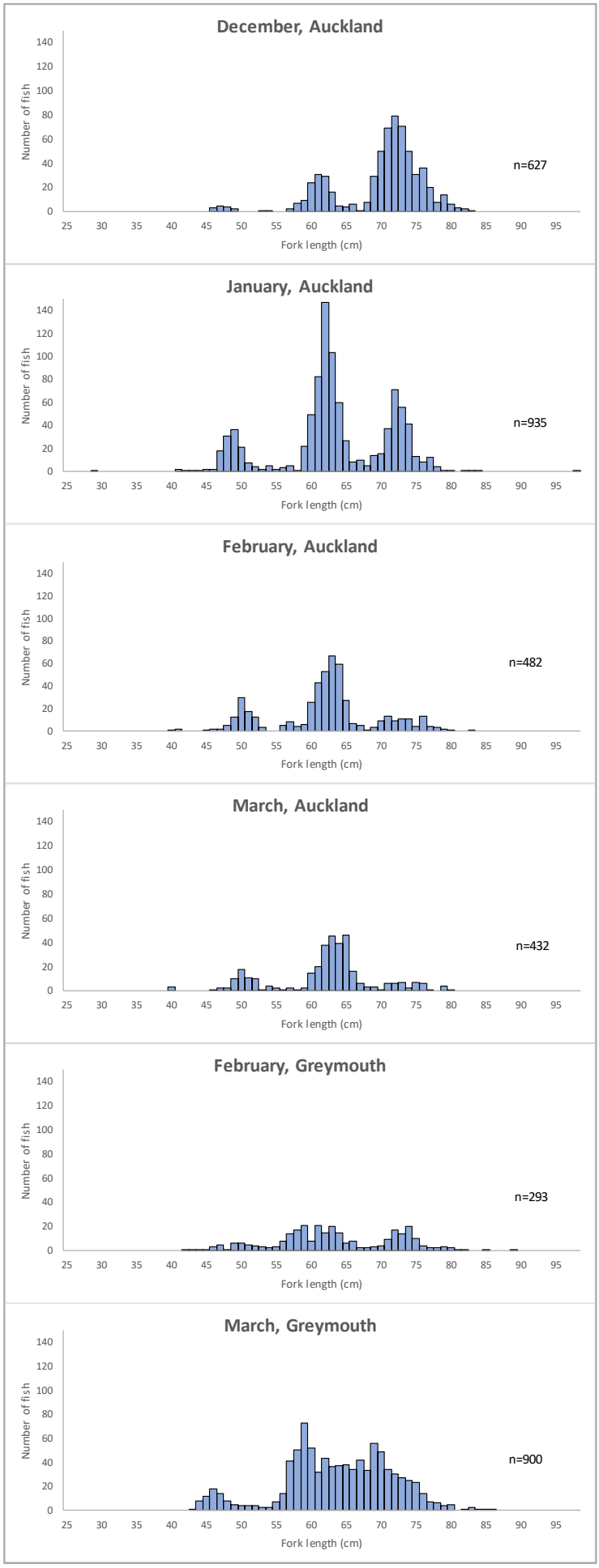


Figure 3 (continued): 2016–17.

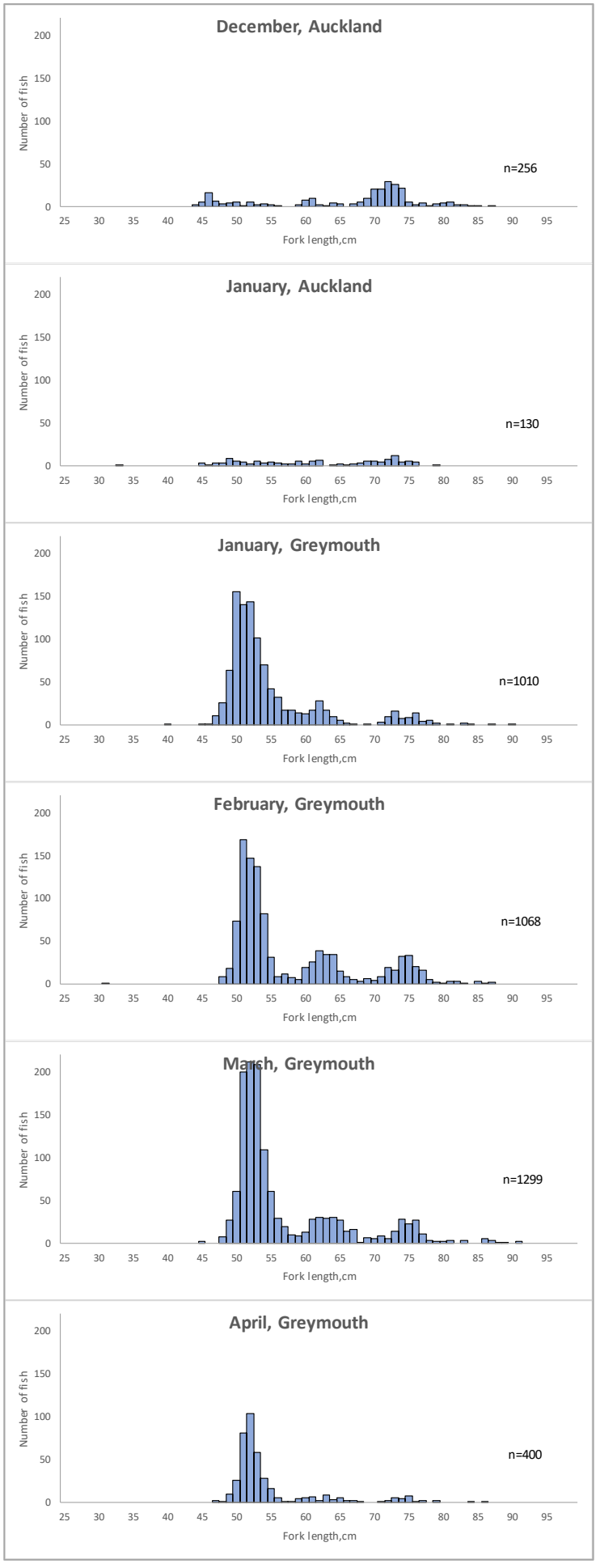


Figure 3 (continued): 2017−18.

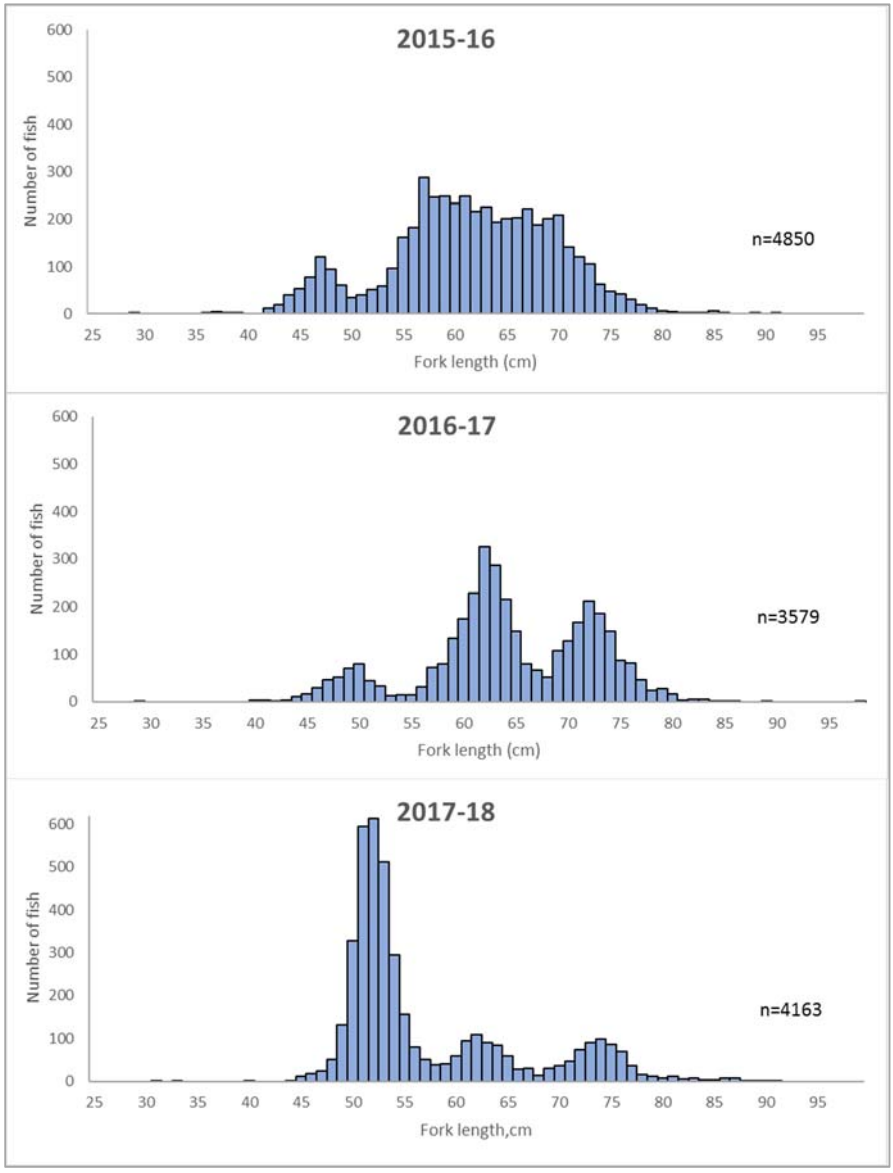


Figure 4: Albacore length frequency distributions, 2015−16, 2016−17, and 2017−18, all months combined.

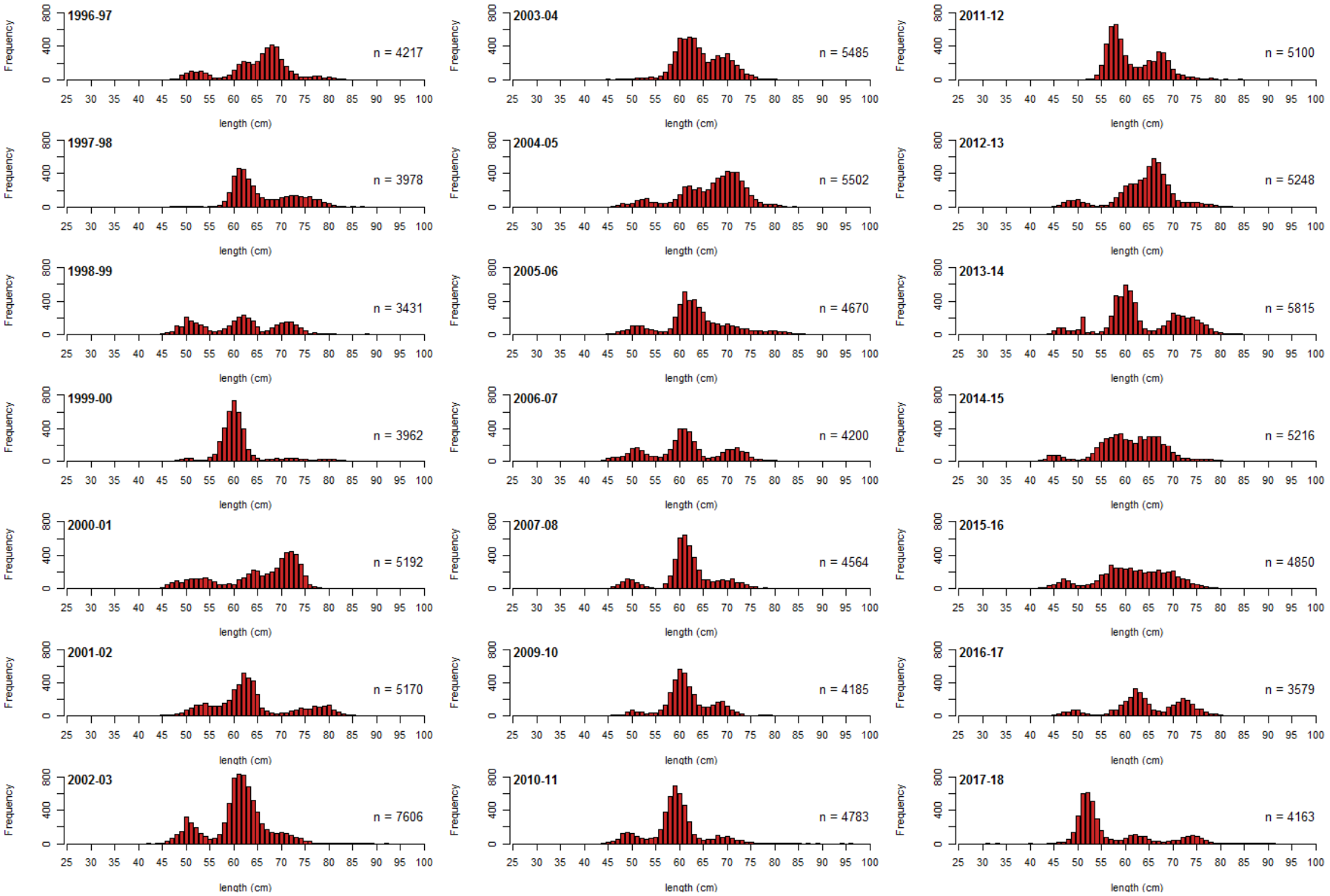


Figure 5: Albacore length frequency distributions for 21 years of sampled landings from troll vessels, 1996–97 to 2017–18.

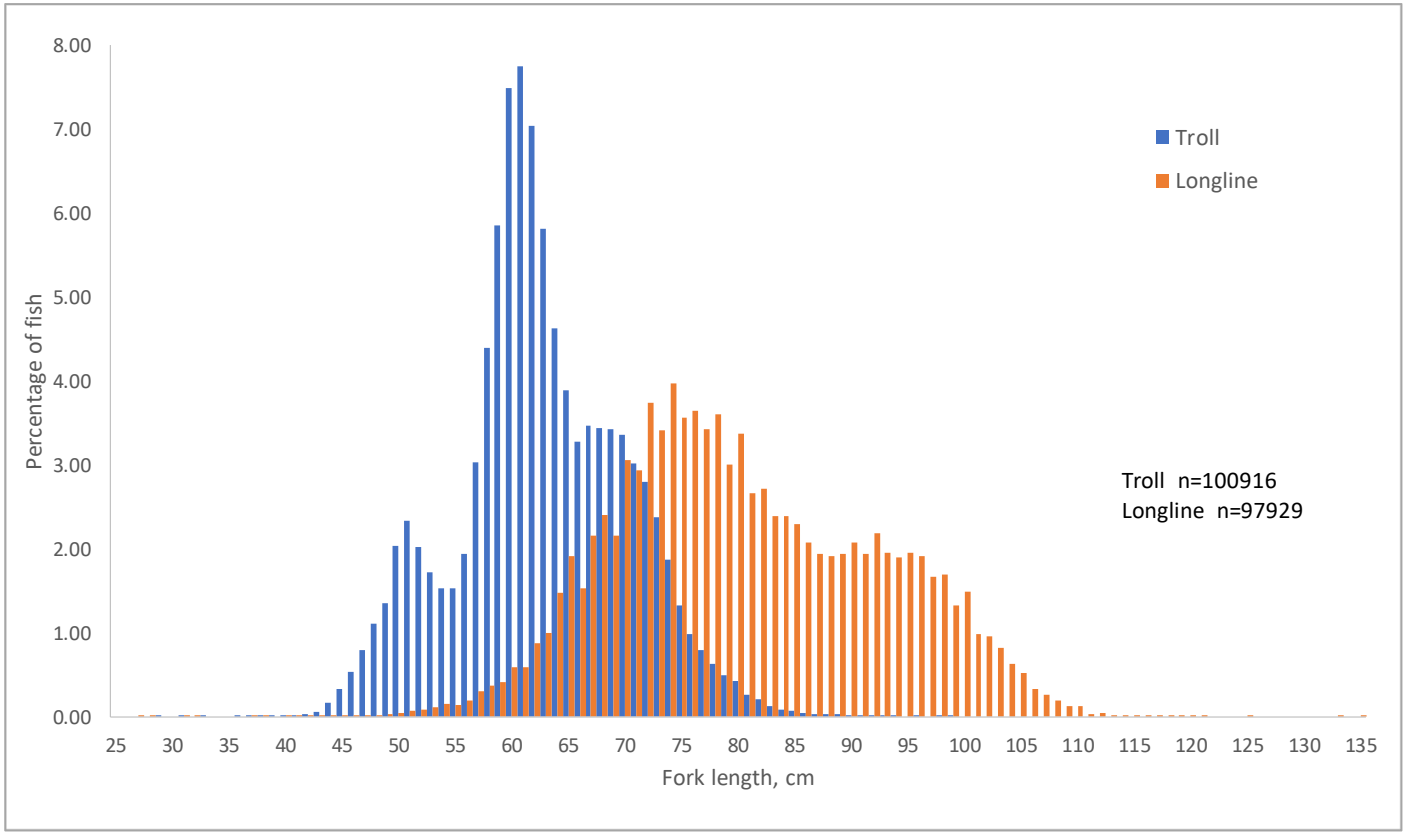


Figure 6: Length distribution of all troll sampled fish and all albacore measured by observers on longline vessels.

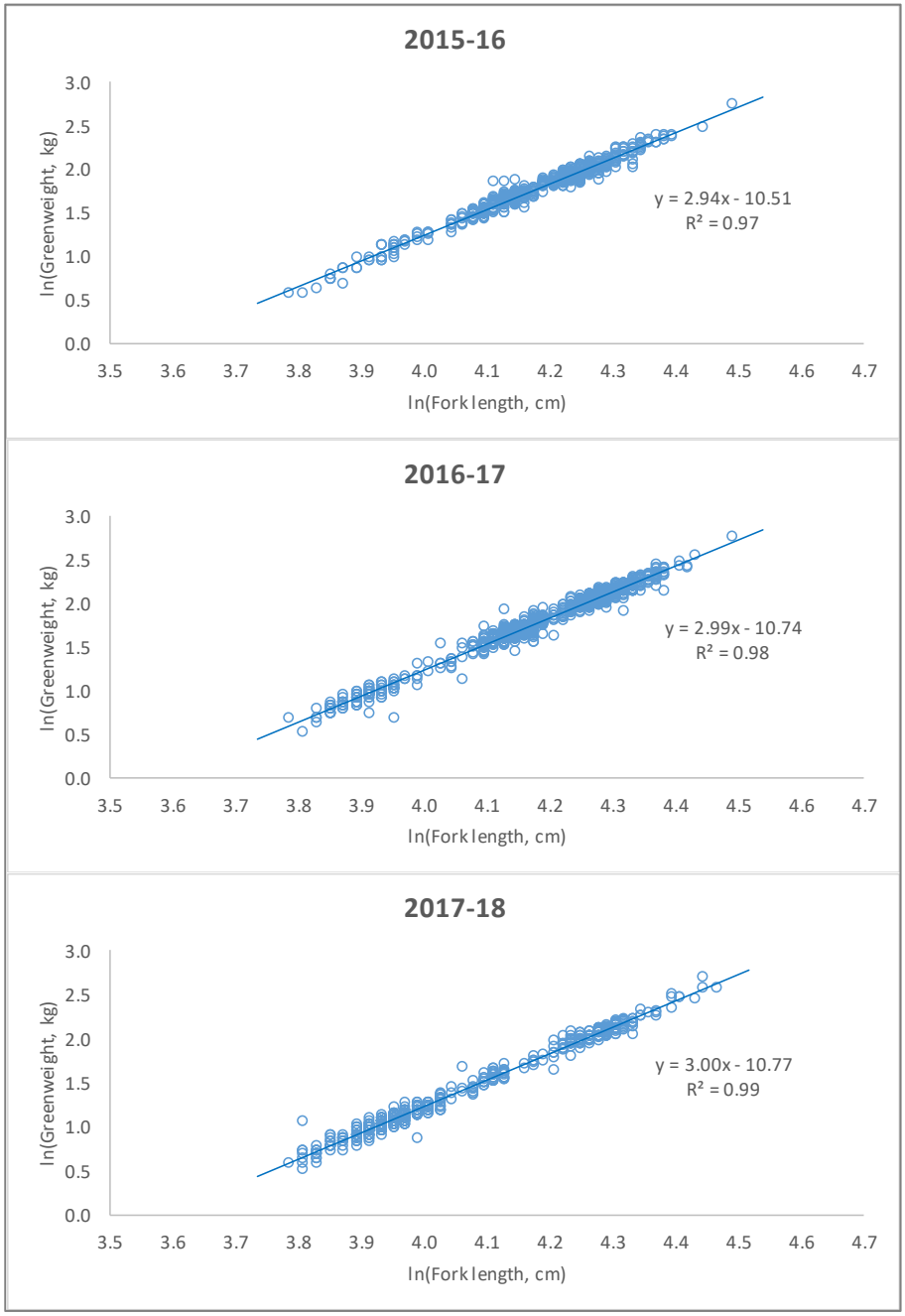


Figure 7: Length-weight relationship for troll caught albacore sampled from troll vessel landings, 2015−16, 2016−17, and 2017−18.

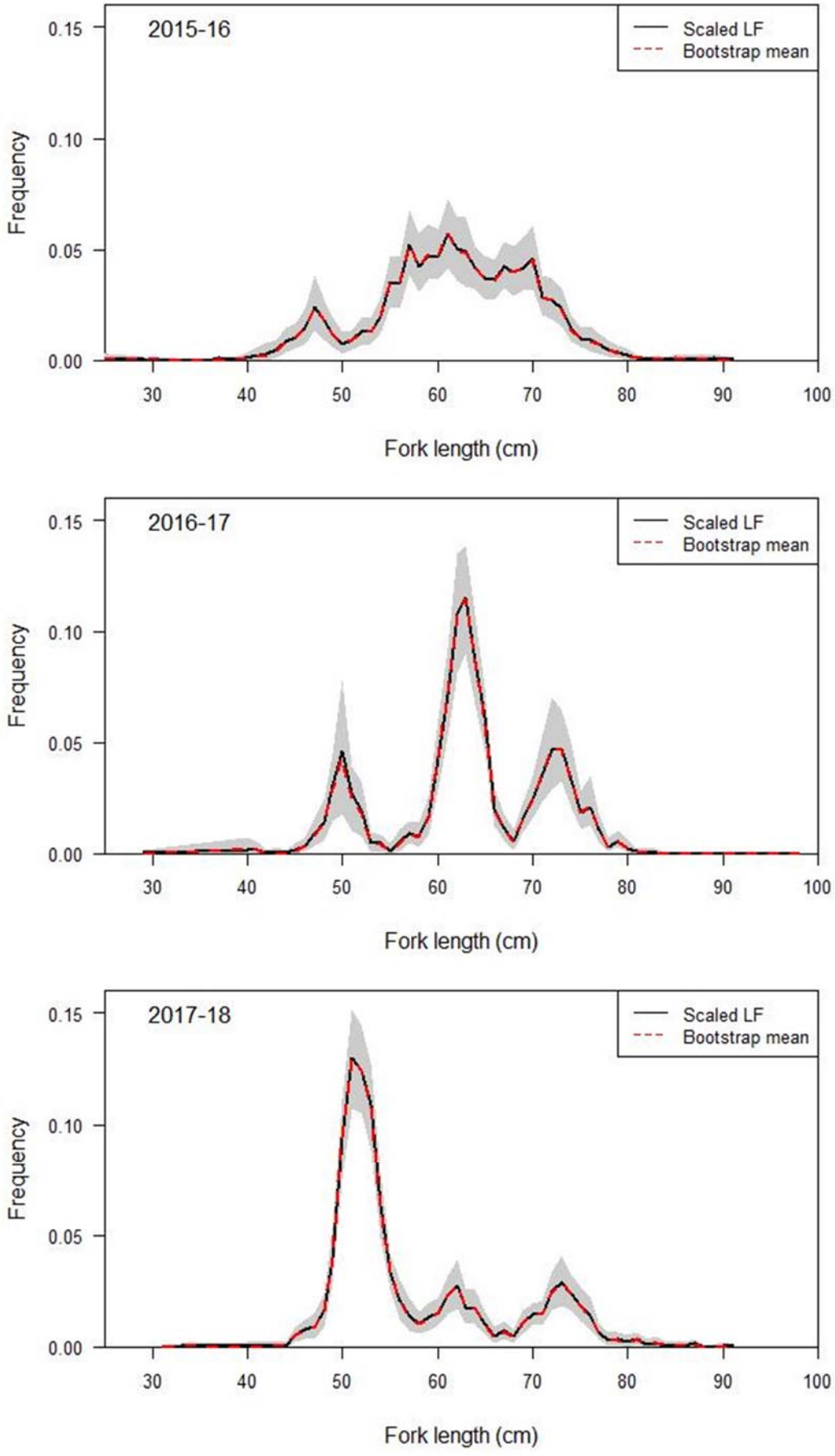


Figure 8: Albacore length frequency distributions, scaled to the total catch, 2015–16, 2016–17, and 2017–18. The scaled length frequency is shown by the solid black line, while the broken red line represents the bootstrapped median, and the grey region shows the bootstrapped 95% confidence interval.

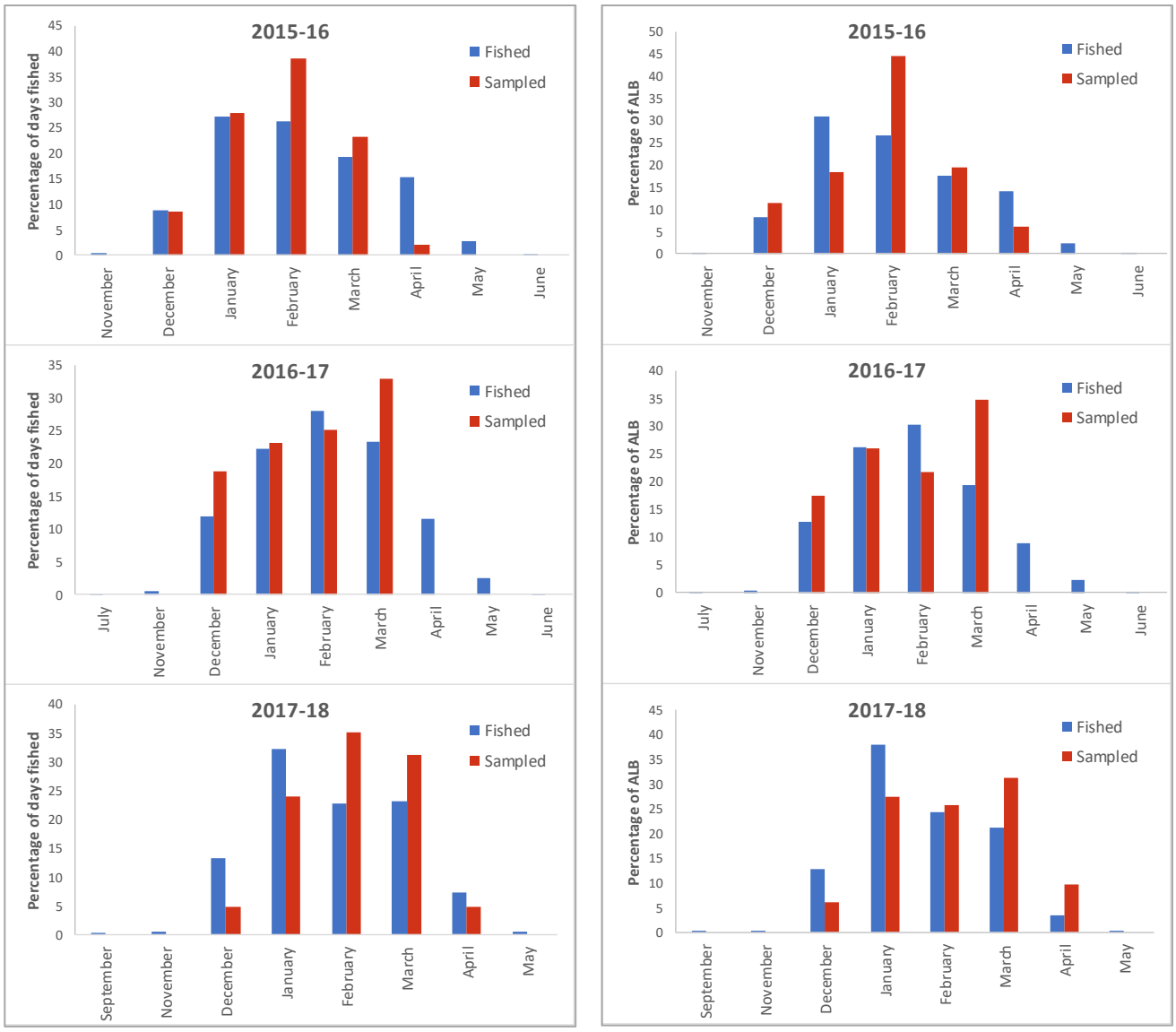


Figure 9: Percentage of days fished and sampled, by year and month (left) and percentage of albacore caught and sampled, by year and month (right).

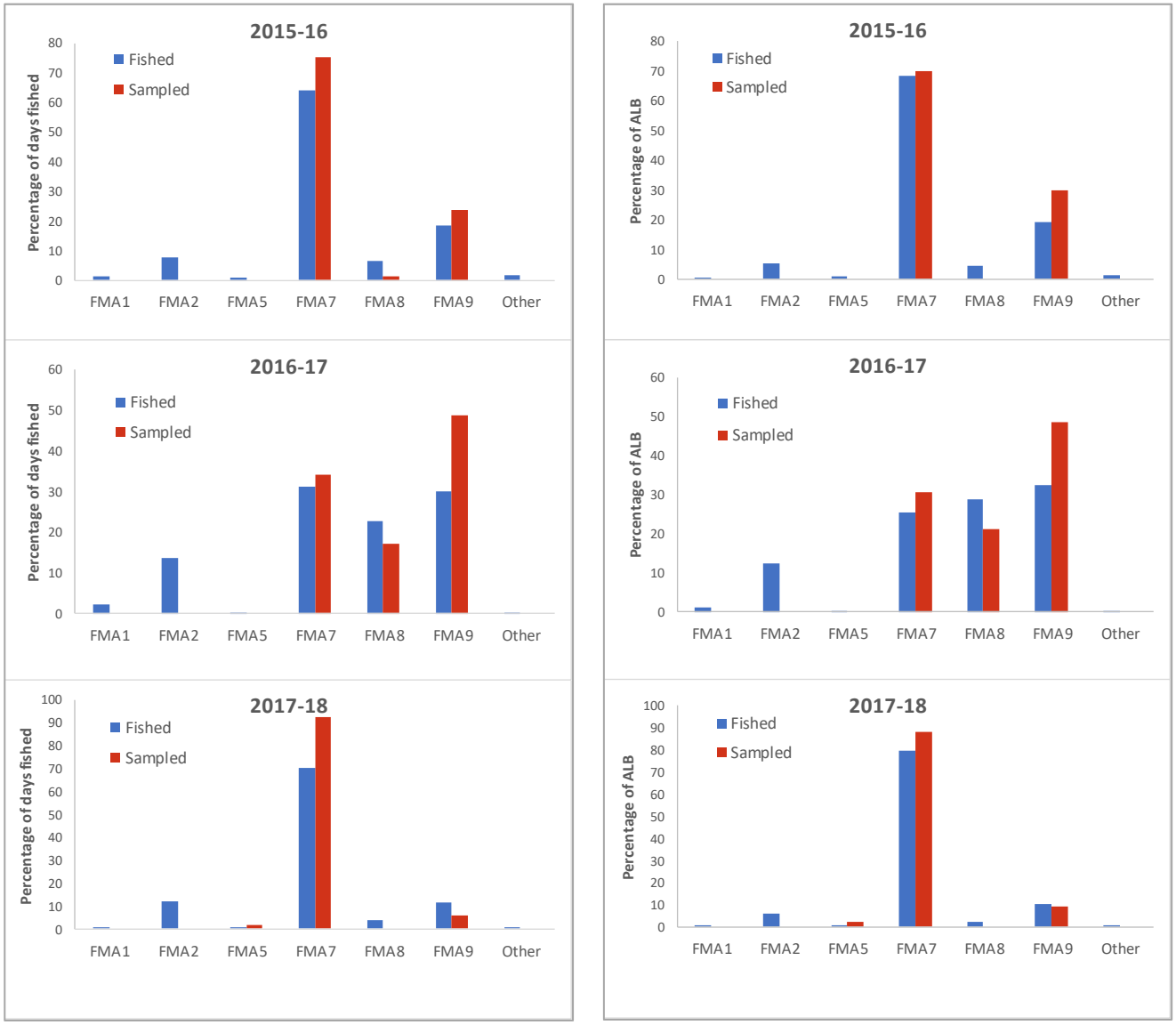


Figure 10: Percentage of days fished and sampled, by year and FMA (left) and percentage of albacore caught and sampled, by year and FMA (right).

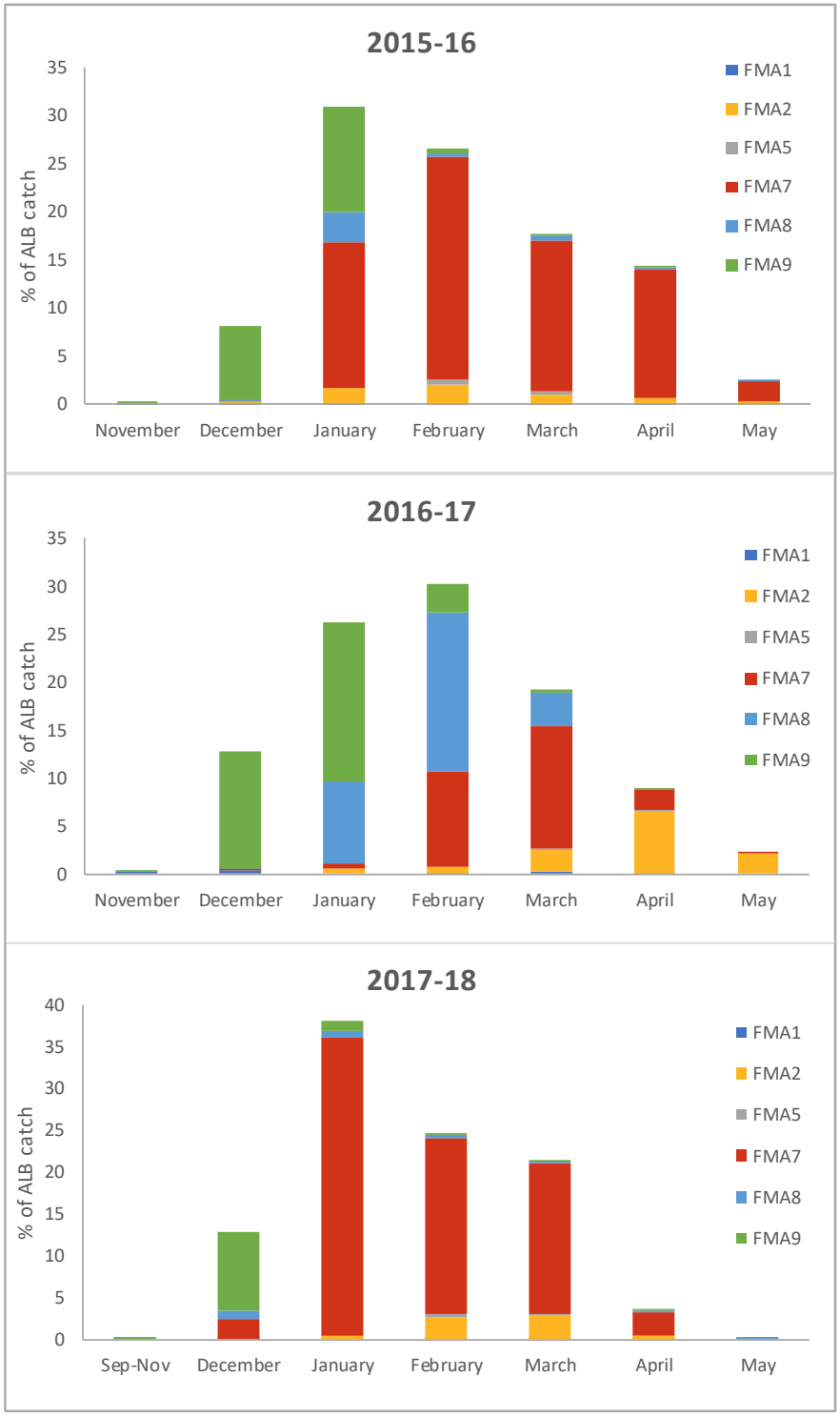


Figure 11: Proportion of catch by year, month and FMA.

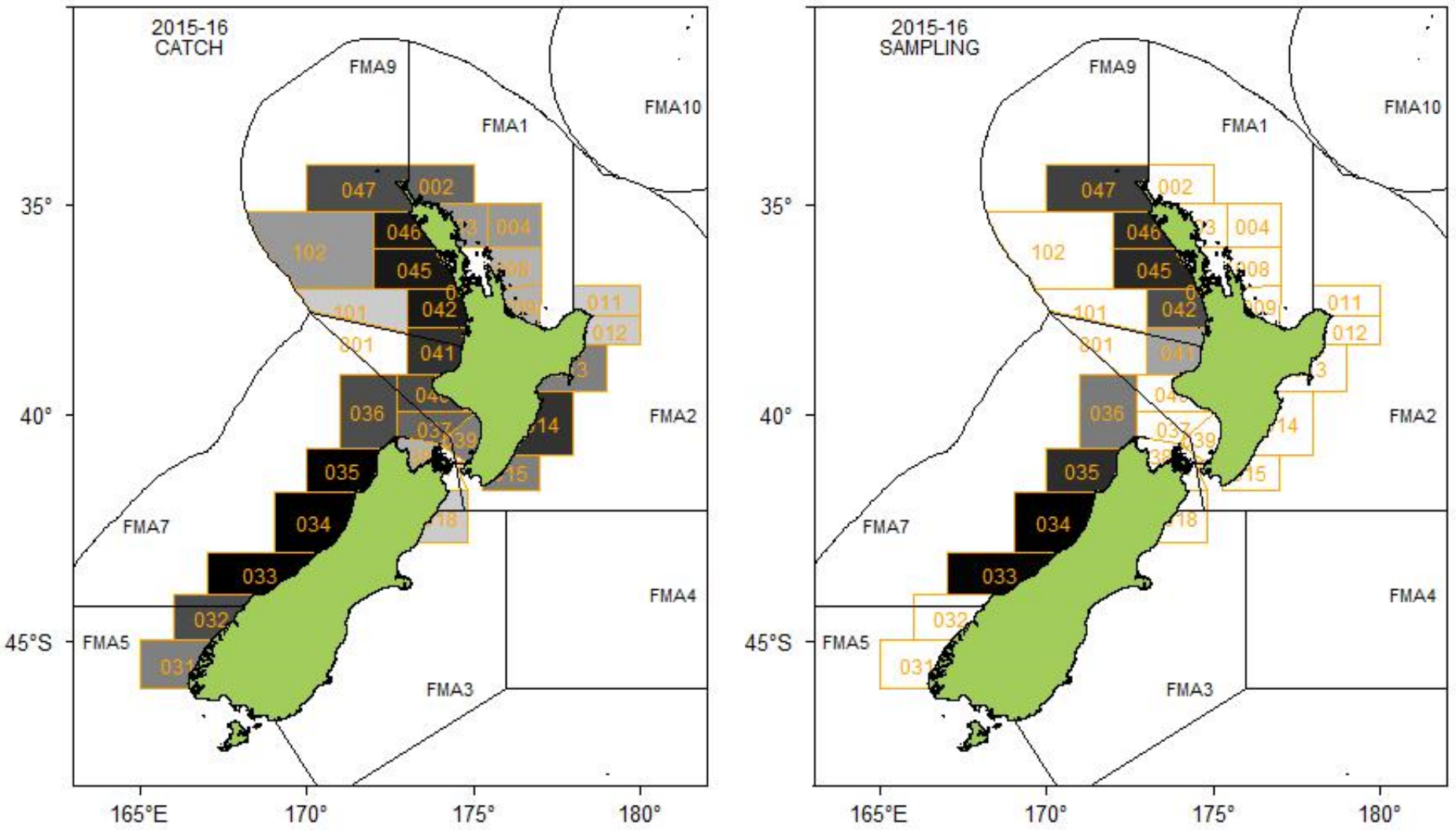


Figure 12: Statistical area density plots of albacore catch, fished (left) and sampled (right) for the 2015−16 year.
A logarithmic density scale was used (i.e. all catch numbers divided by the maximum catch in any one stat area) where 0=white and 1=black.

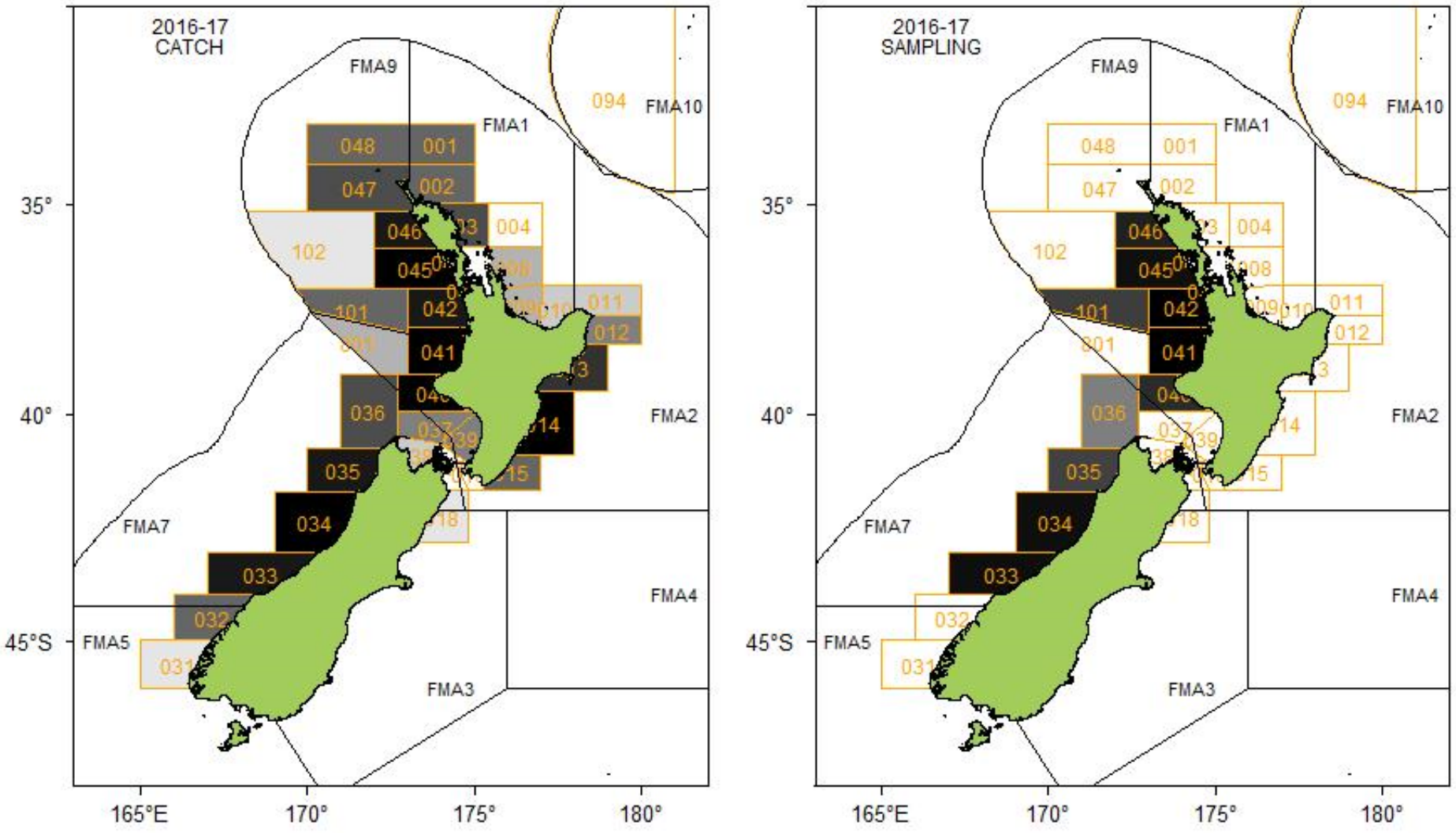


Figure 13: Statistical area density plots of albacore catch, fished (left) and sampled (right) for the 2016−17 year.
A logarithmic density scale was used (i.e. all catch numbers divided by the maximum catch in any one stat area) where 0=white and 1=black.where 0=white and 1=black.

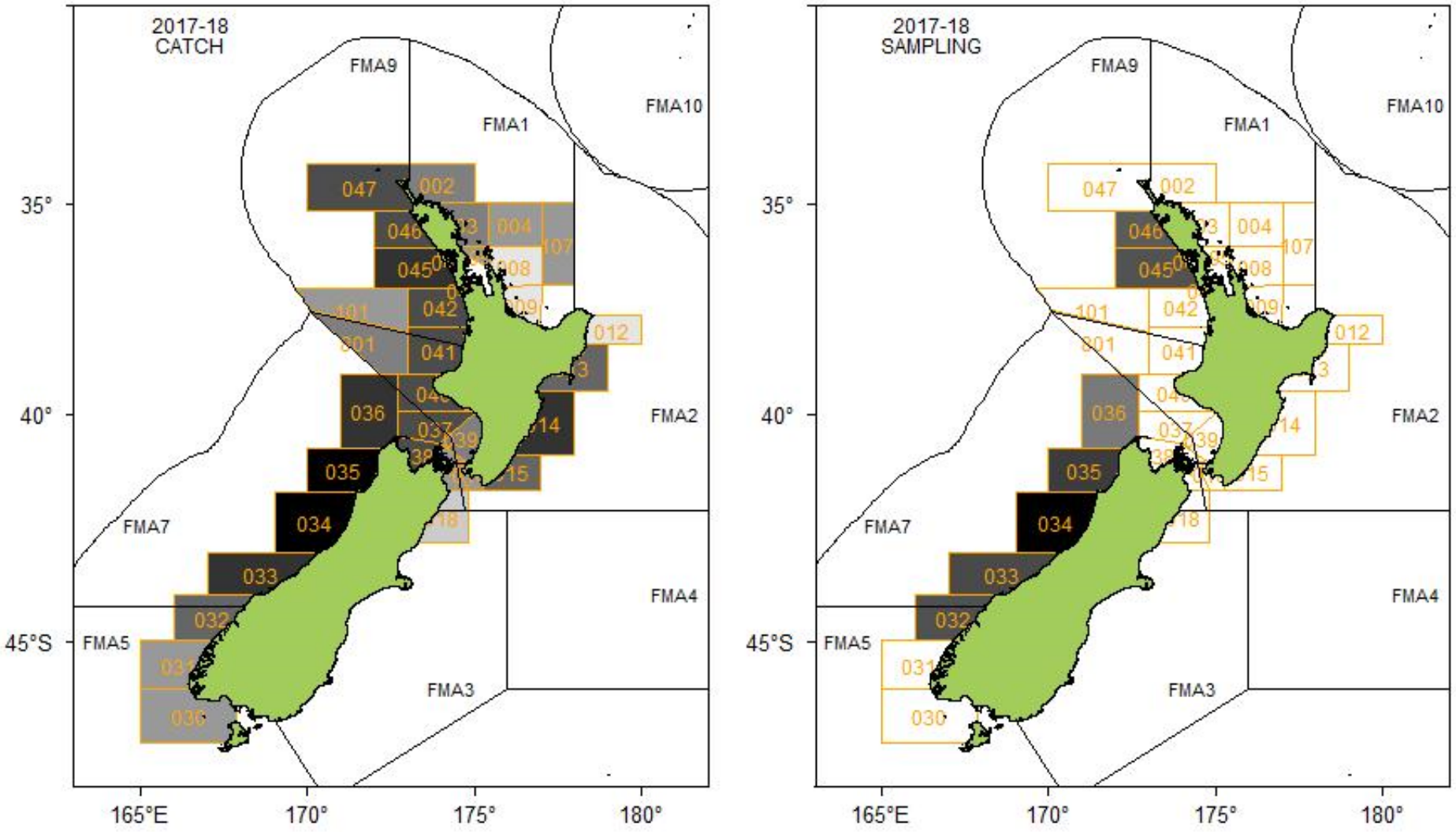
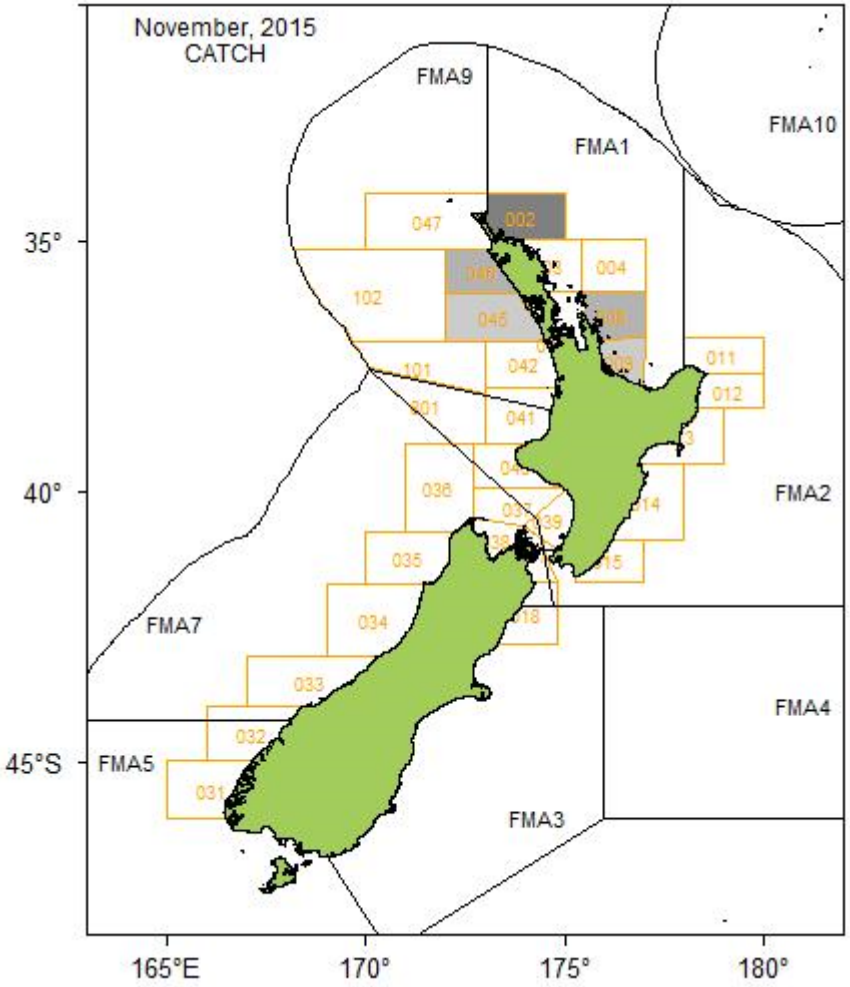


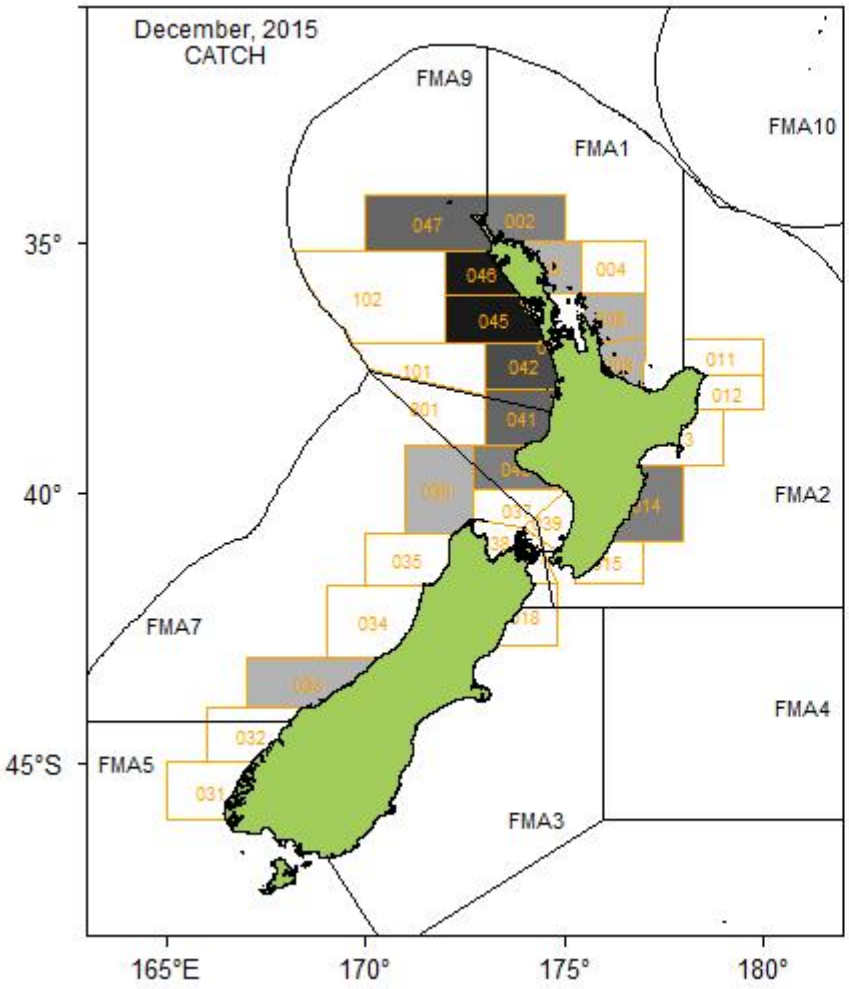
Figure 14: Statistical area density plots of albacore catch, fished (left) and sampled (right) for the 2017−18 year.
A logarithmic density scale was used (i.e. all catch numbers divided by the maximum catch in any one stat area) where 0=white and 1=black.

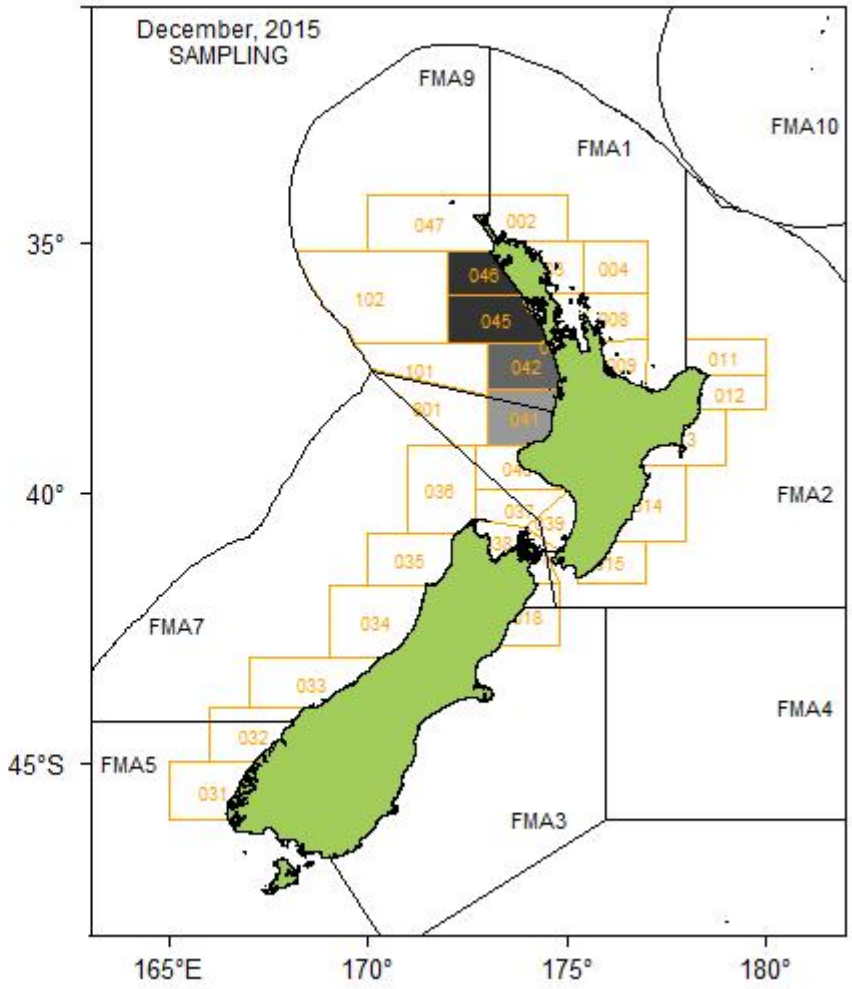
Appendix 1

Statistical area density plots of albacore catch, fished (left) and sampled (right) for the 2015−16 year, 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.
November 2015.

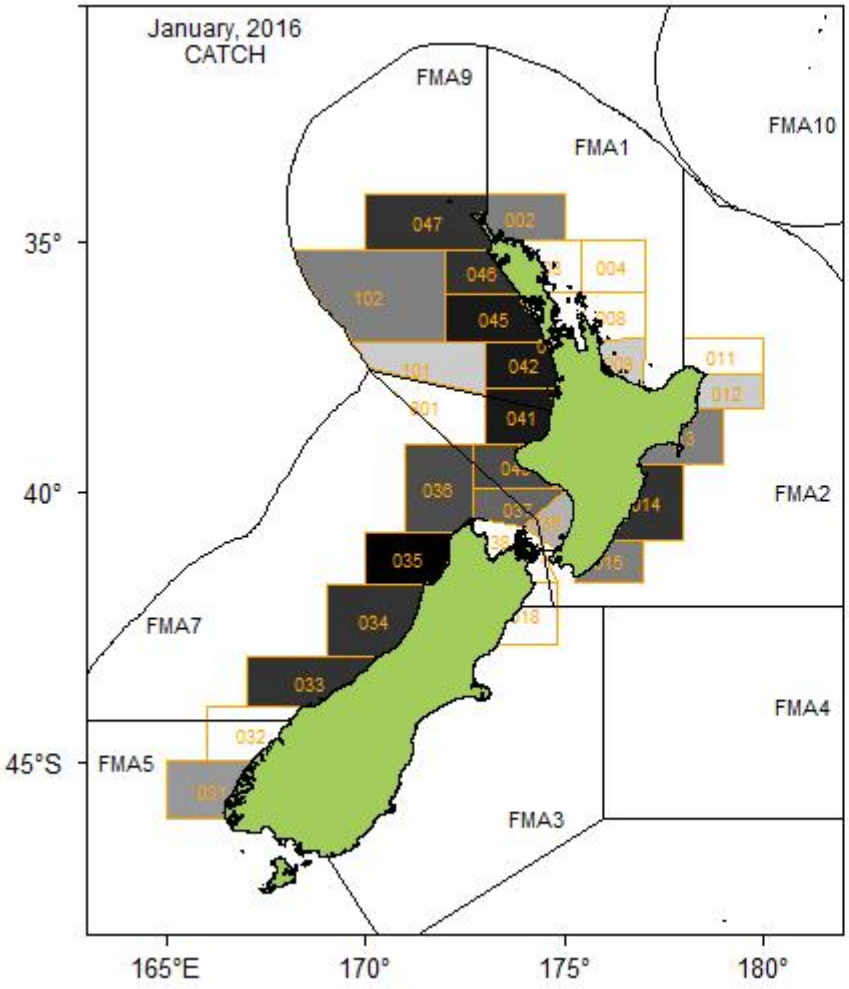


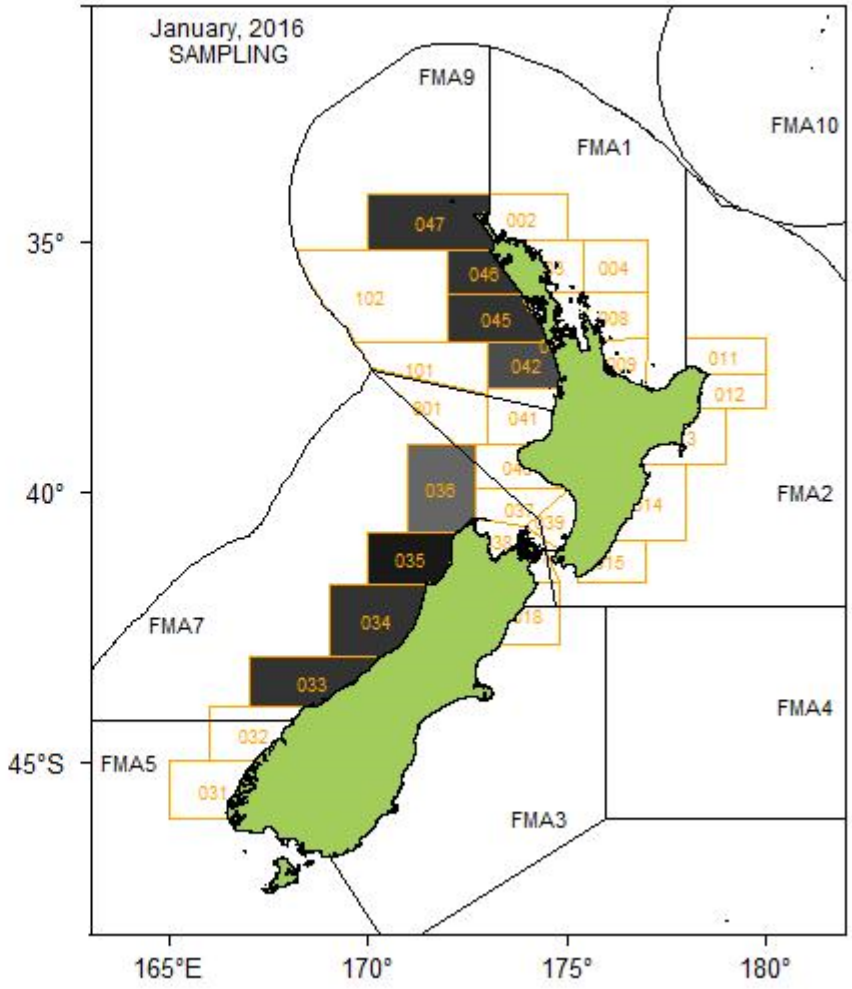
2015−16 *continued*. December 2015.



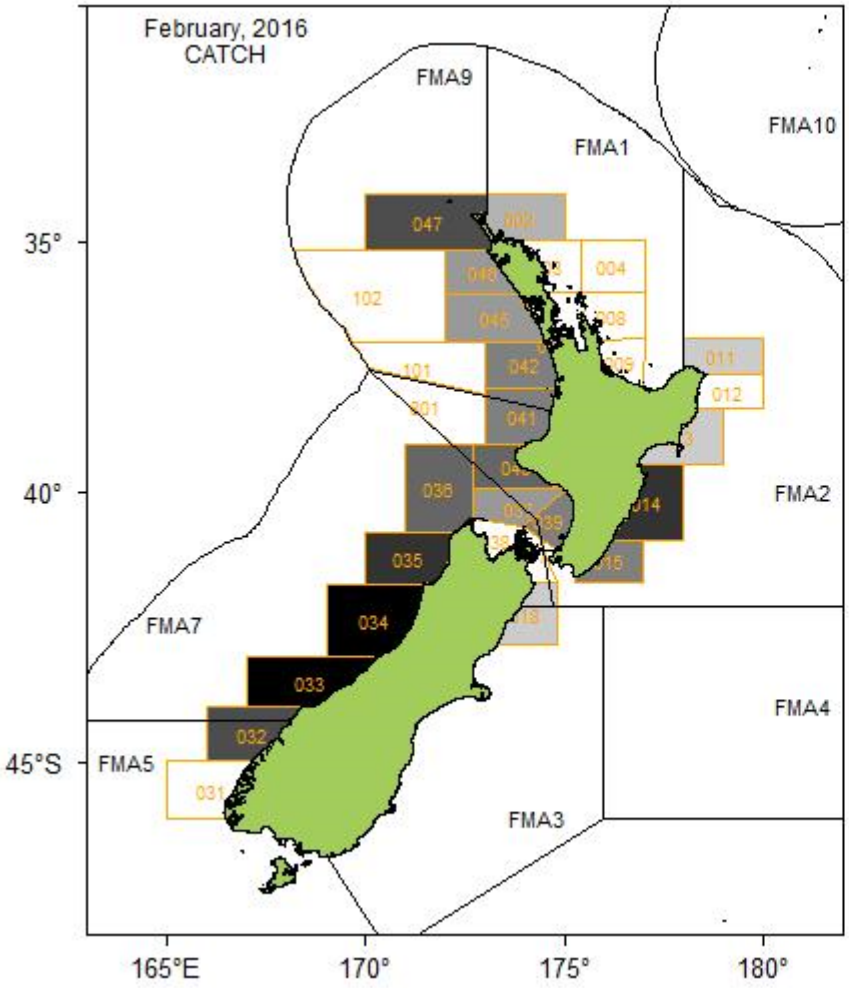


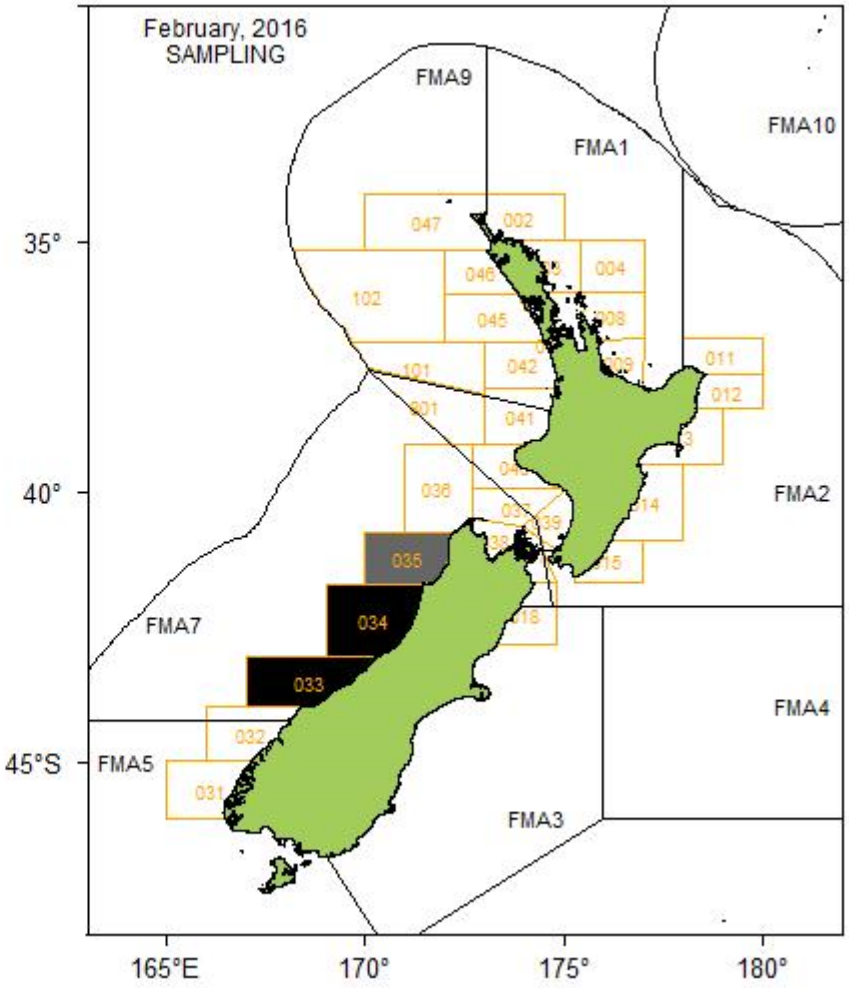
2015−16 *continued*. January 2016.



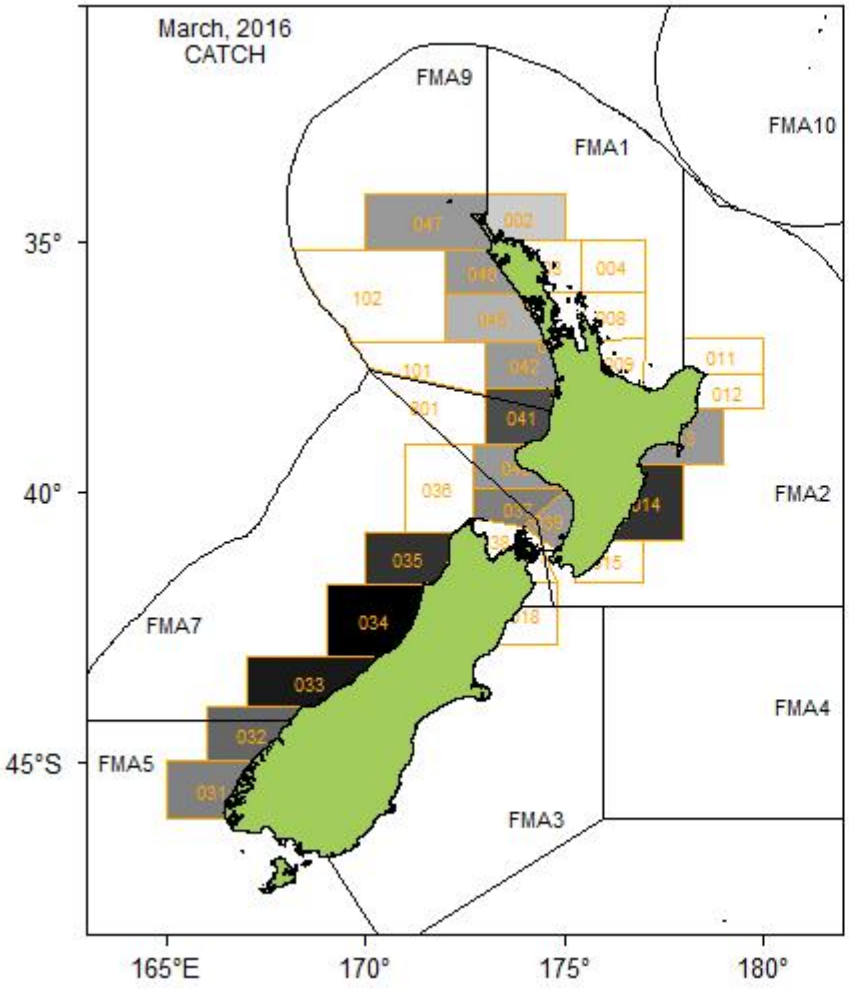


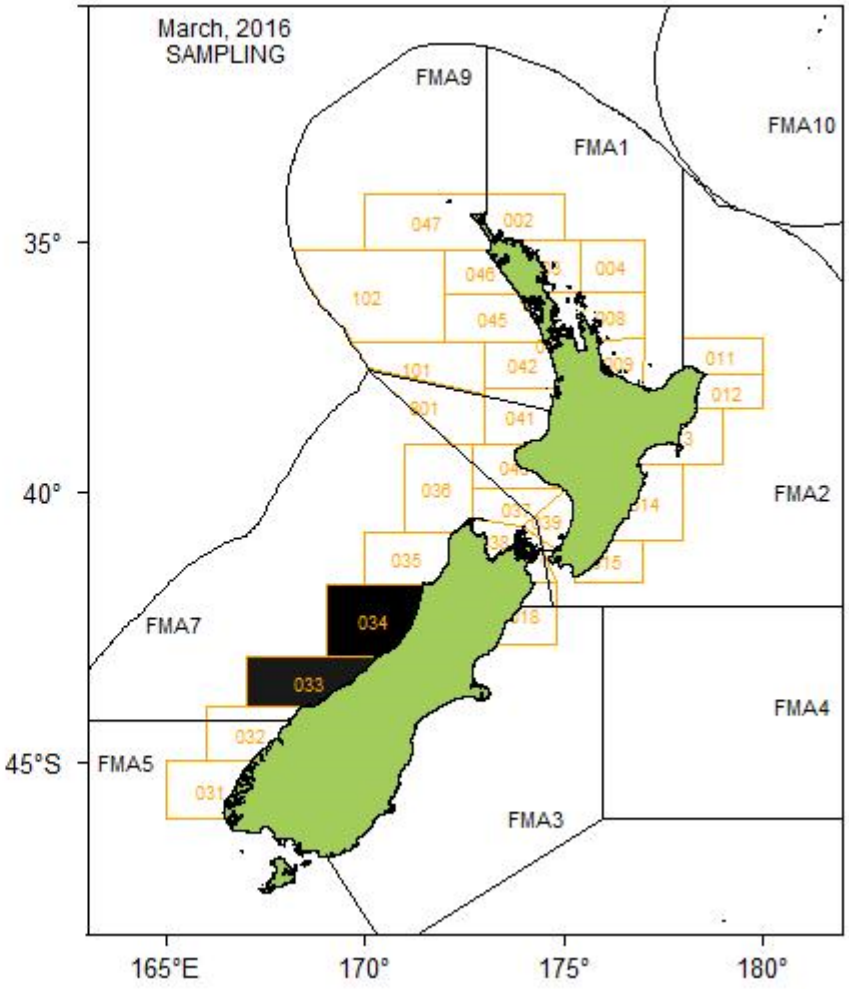
2015−16 *continued*. February 2016.



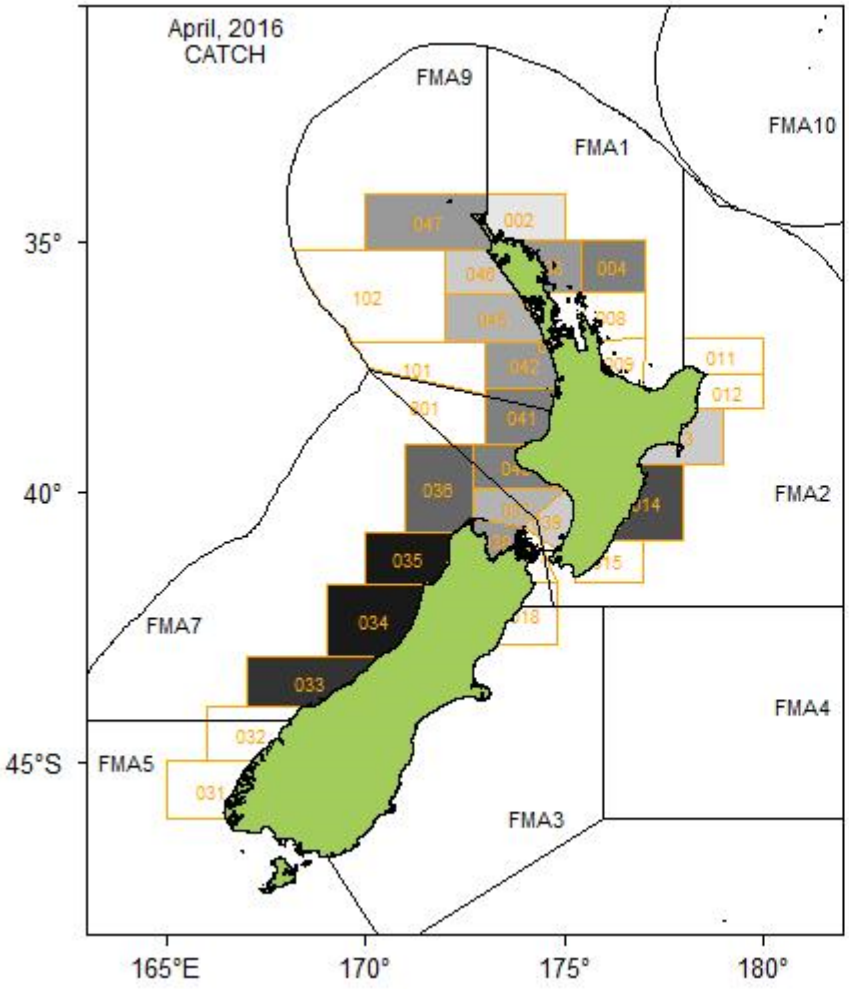


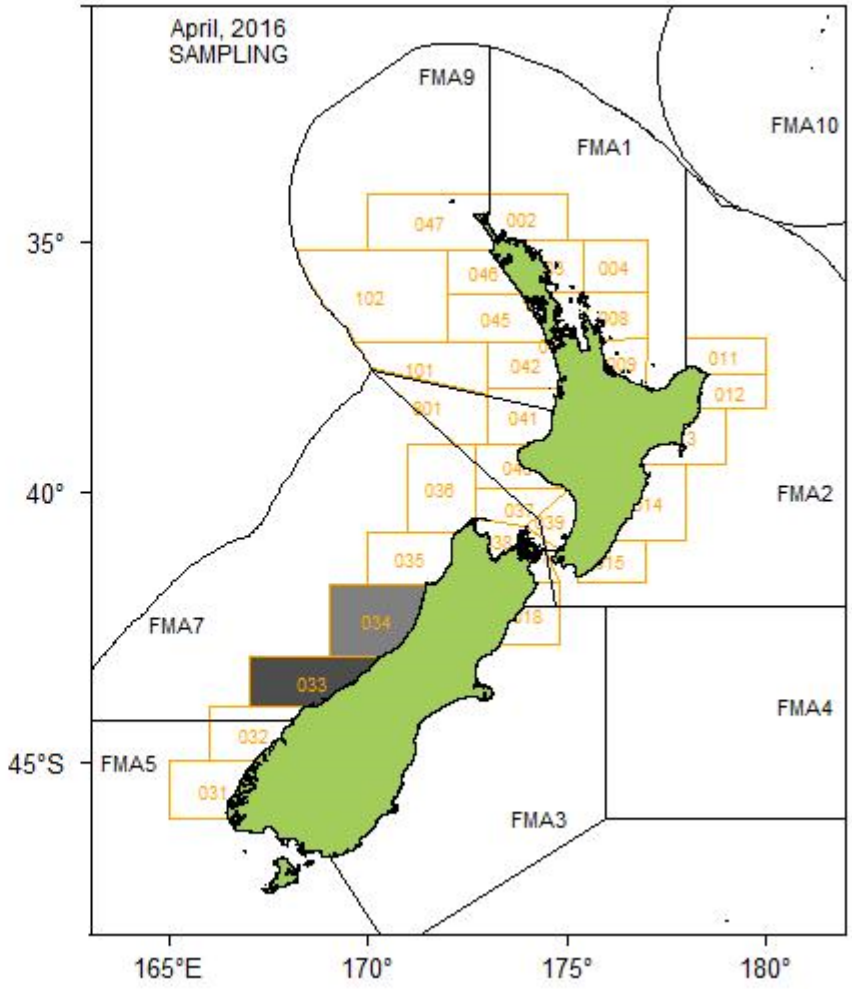
2015−16 *continued*. March 2016.



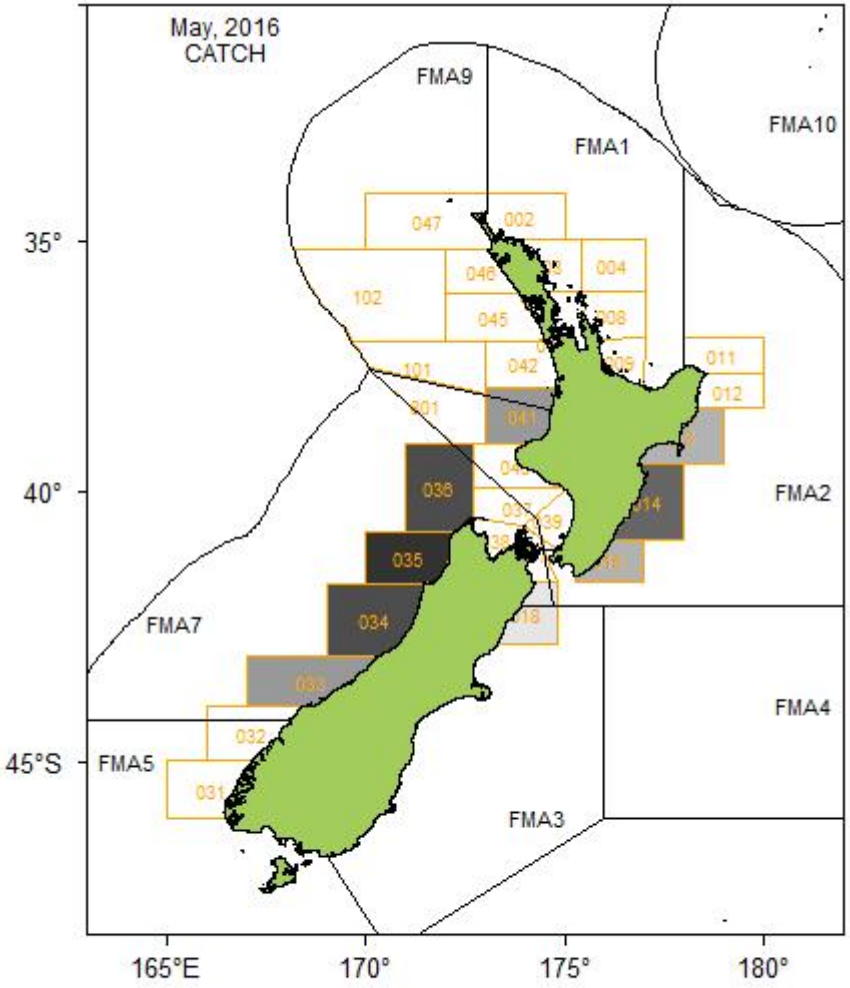


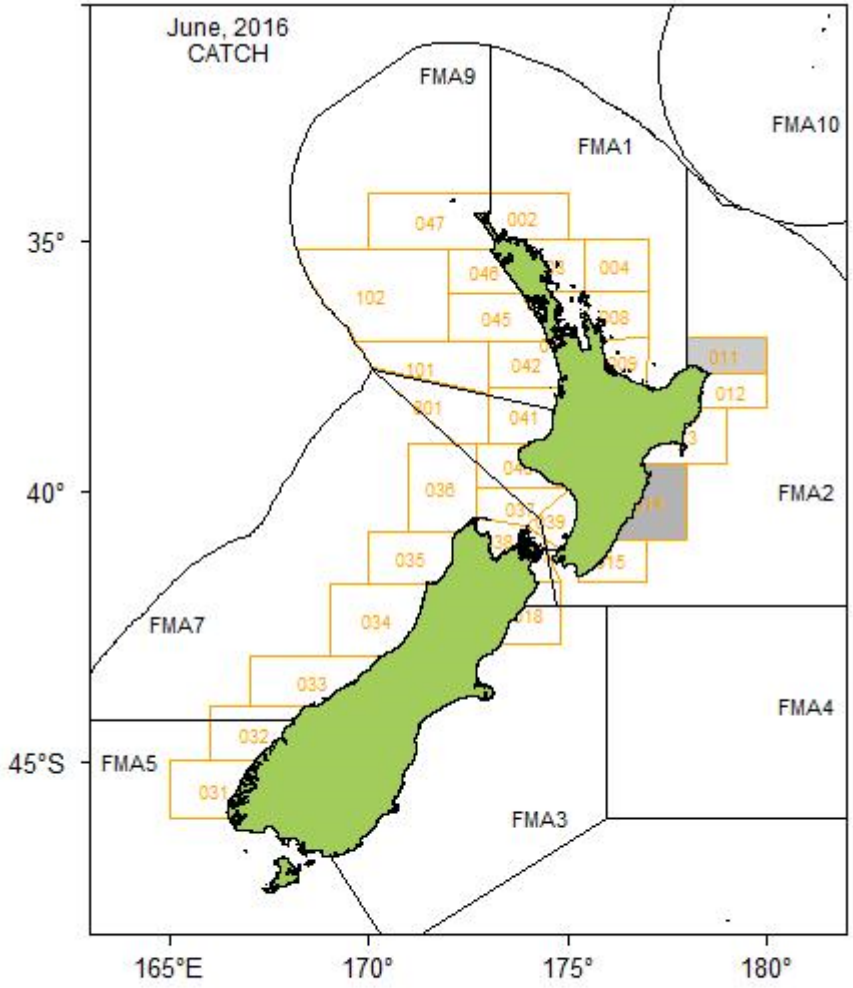
2015−16 *continued*. April 2016.





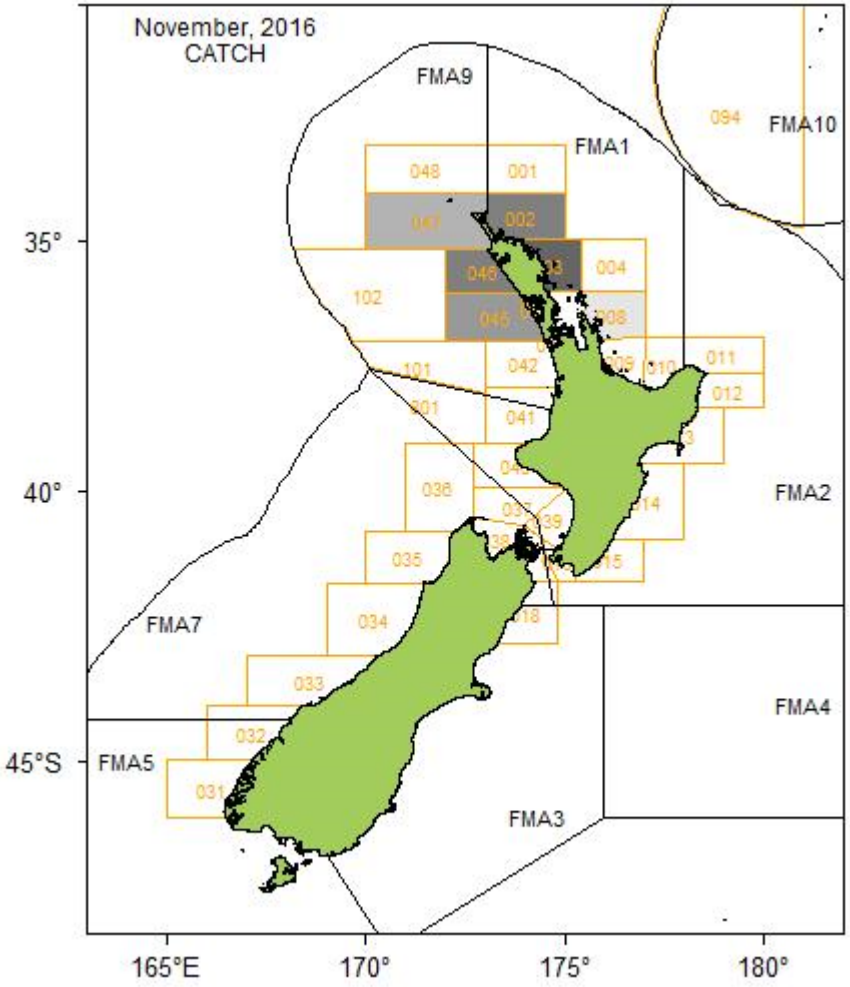
2015−16 *continued*. May and June 2016.



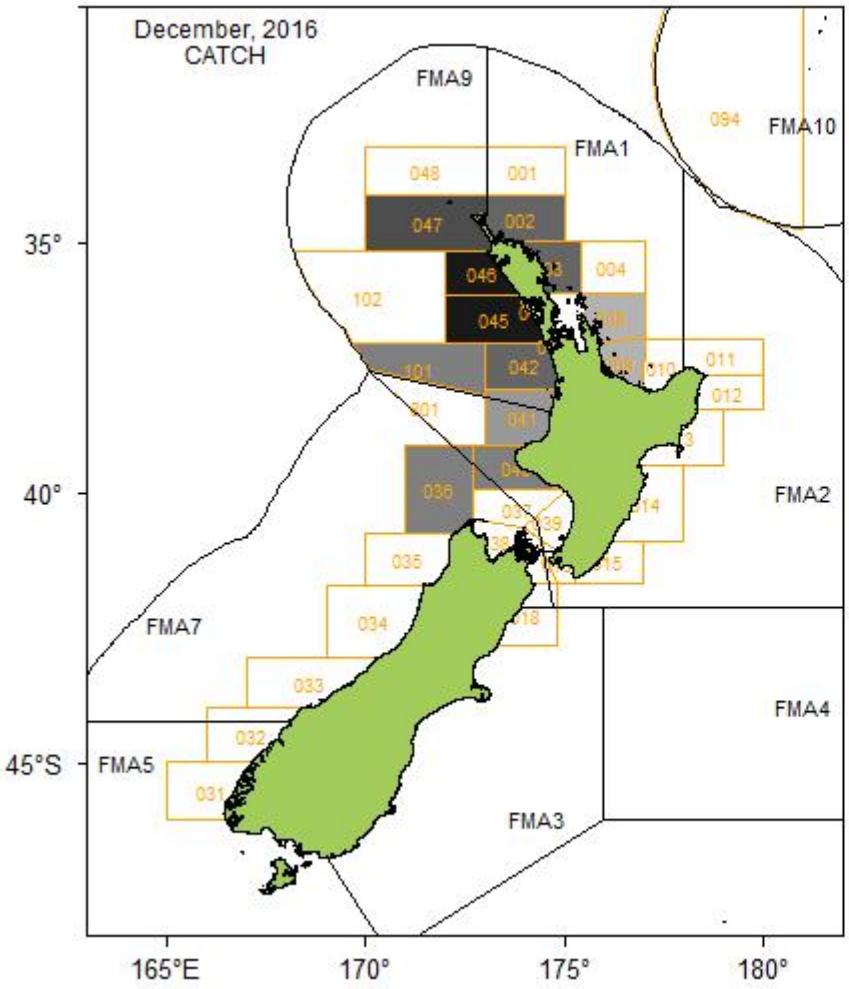


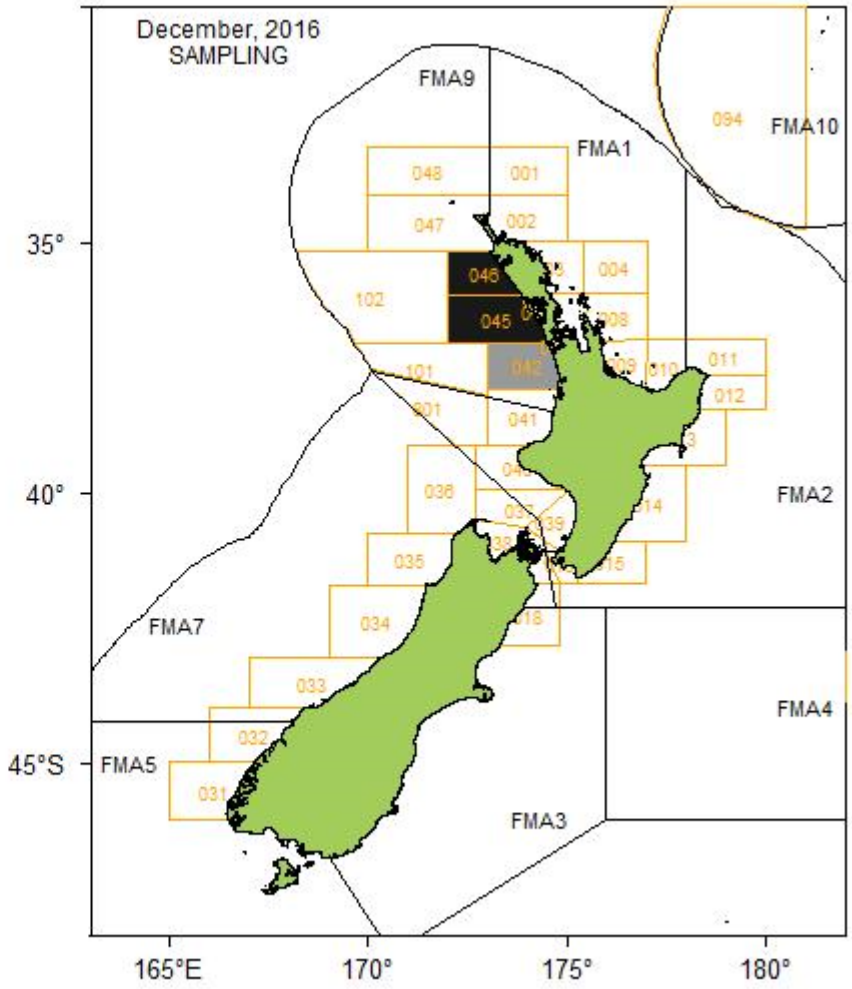
Appendix 2

Statistical area density plots of albacore catch, fished (left) and sampled (right) for the 2016−17 year, 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.
November 2016.

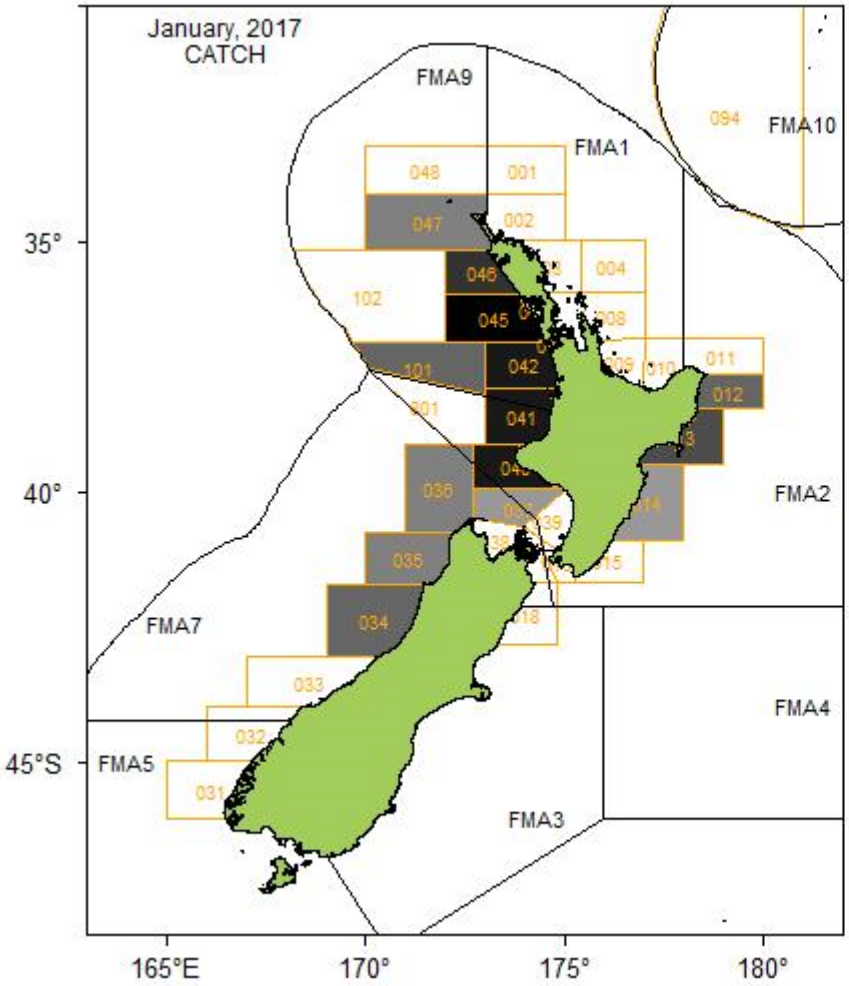


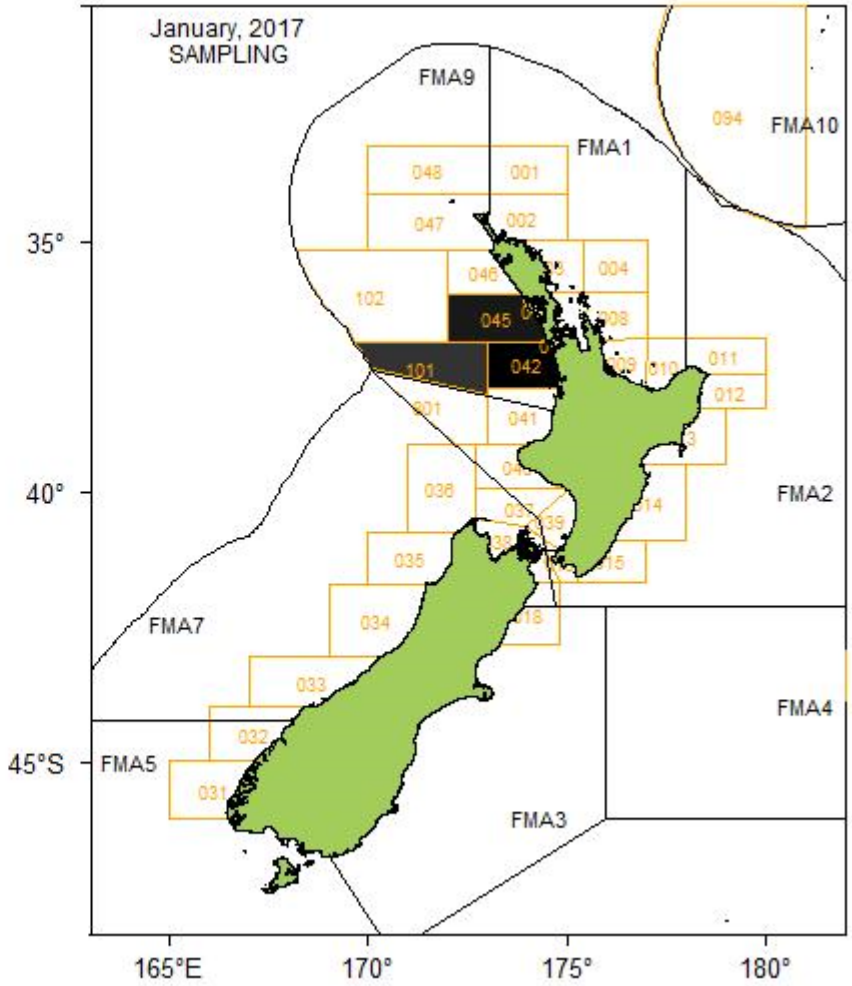
2016−17 *continued*. December 2016.



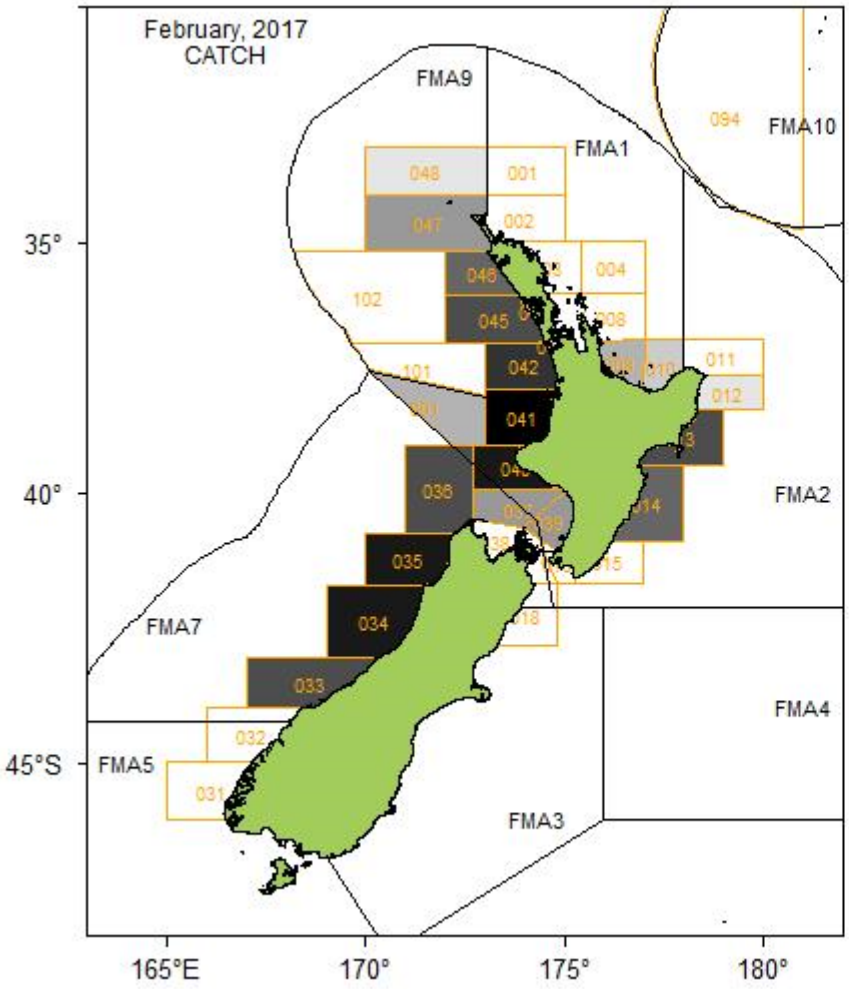


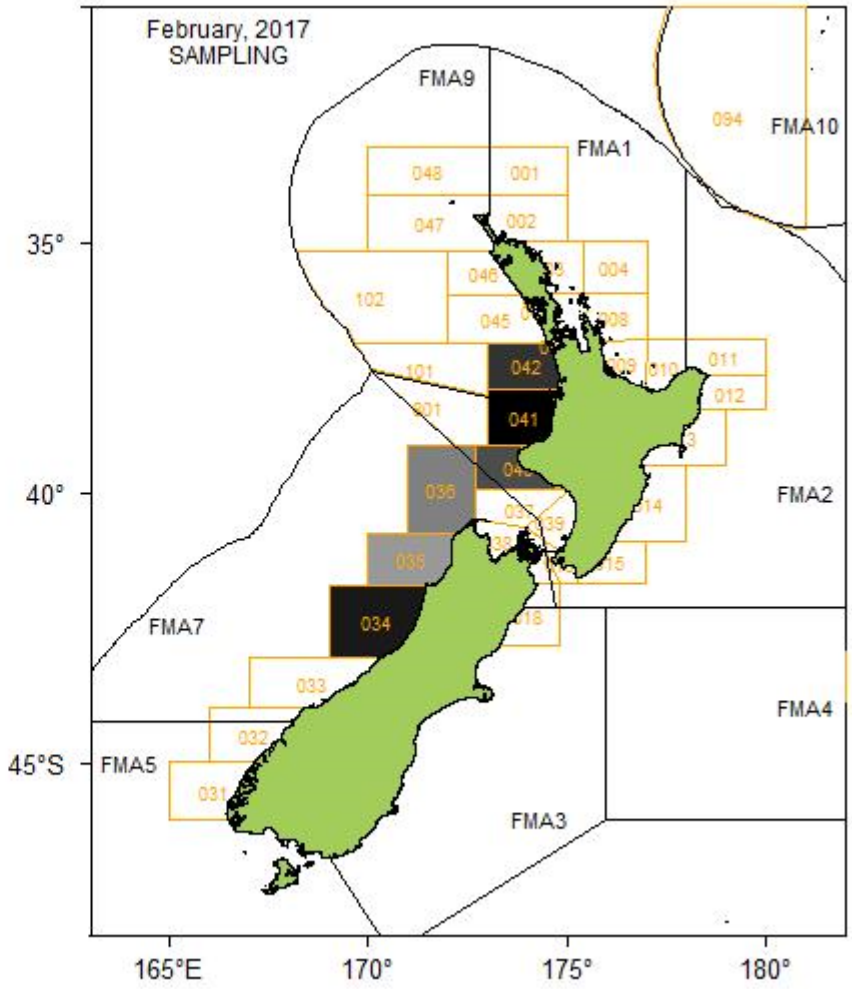
2016−17 *continued*. January 2017.



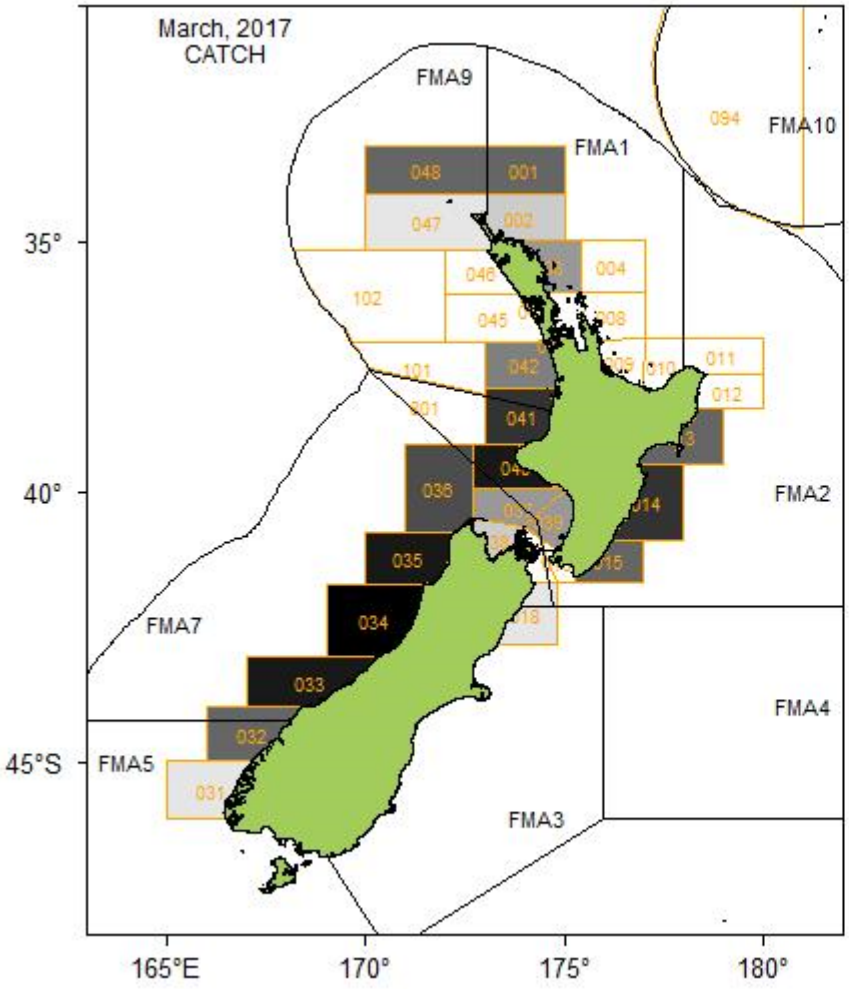


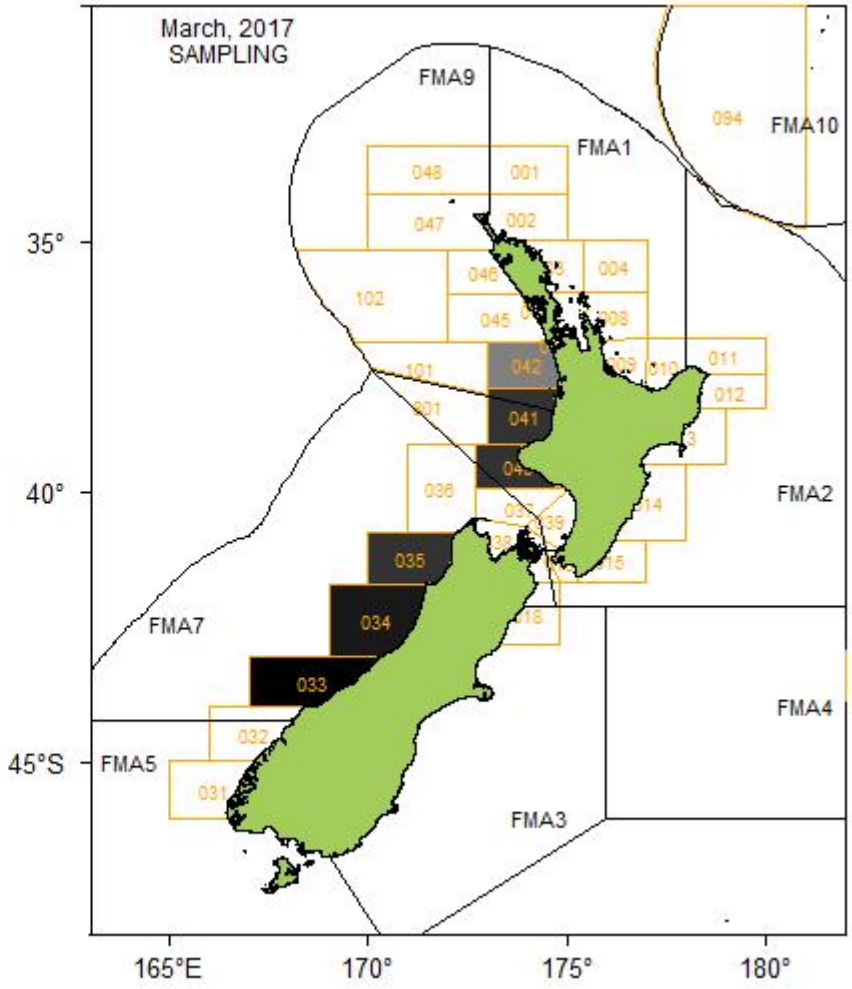
2016−17 *continued*. February 2017.



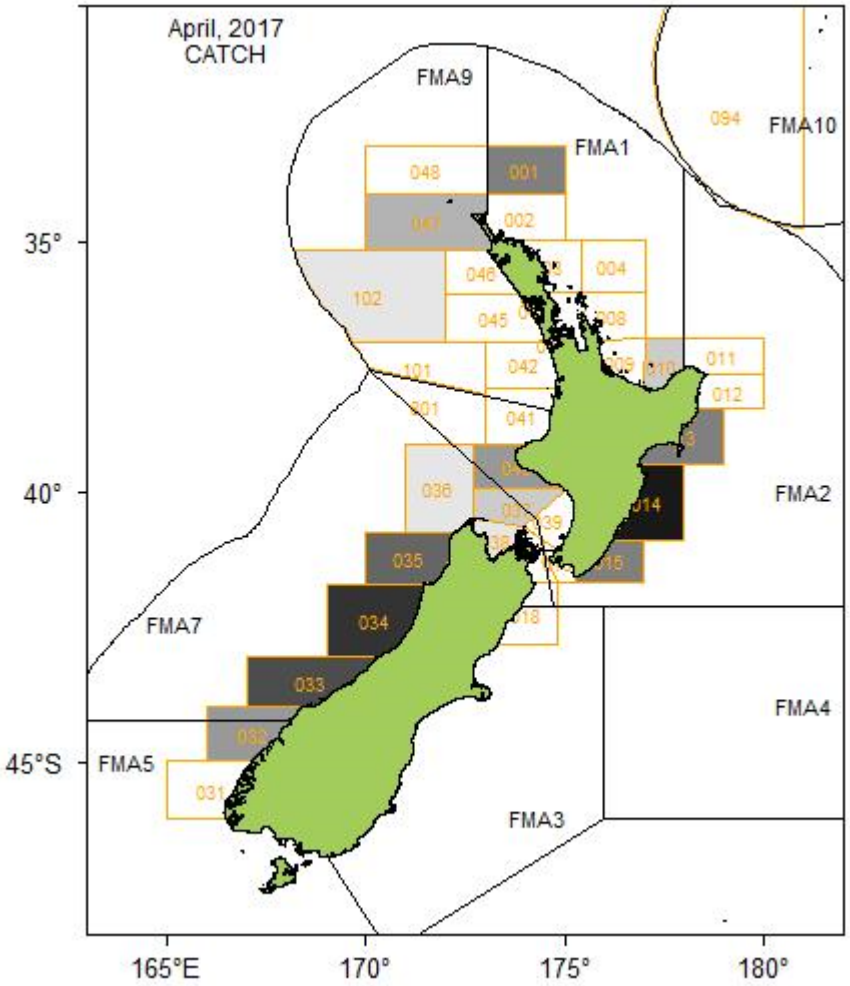


2016−17 *continued*. March 2017.

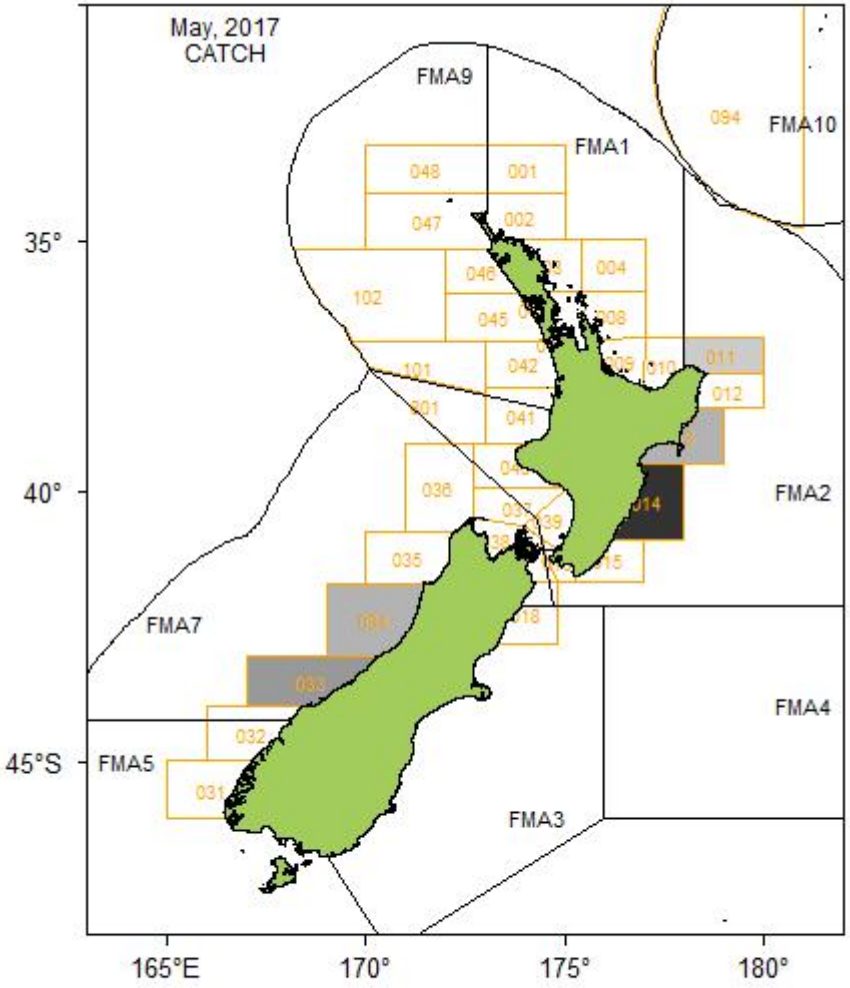


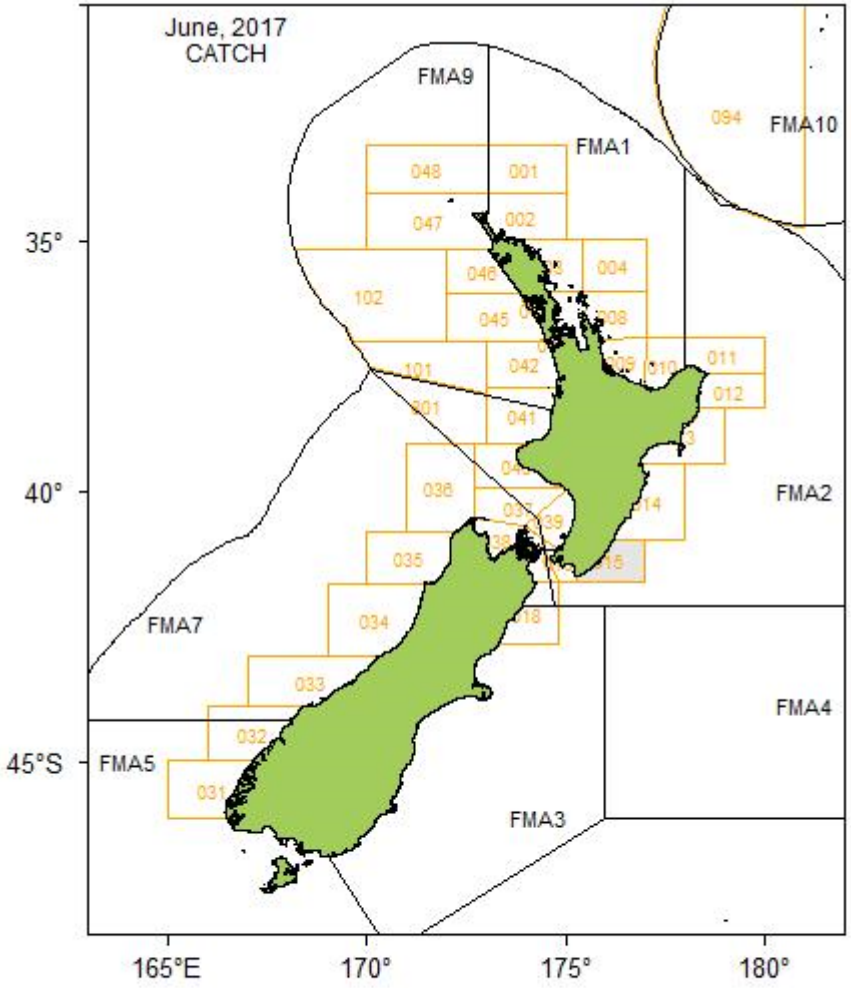


2016−17 *continued*. April 2017.



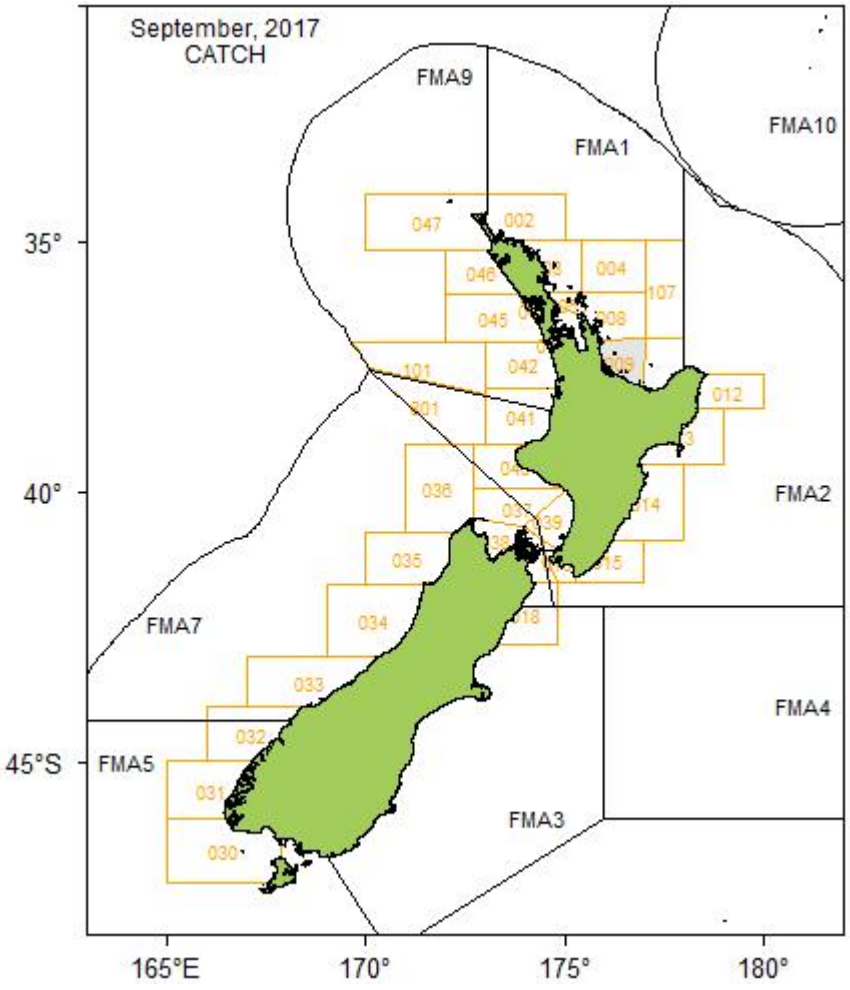
2016−17 *continued*. May and June 2017.

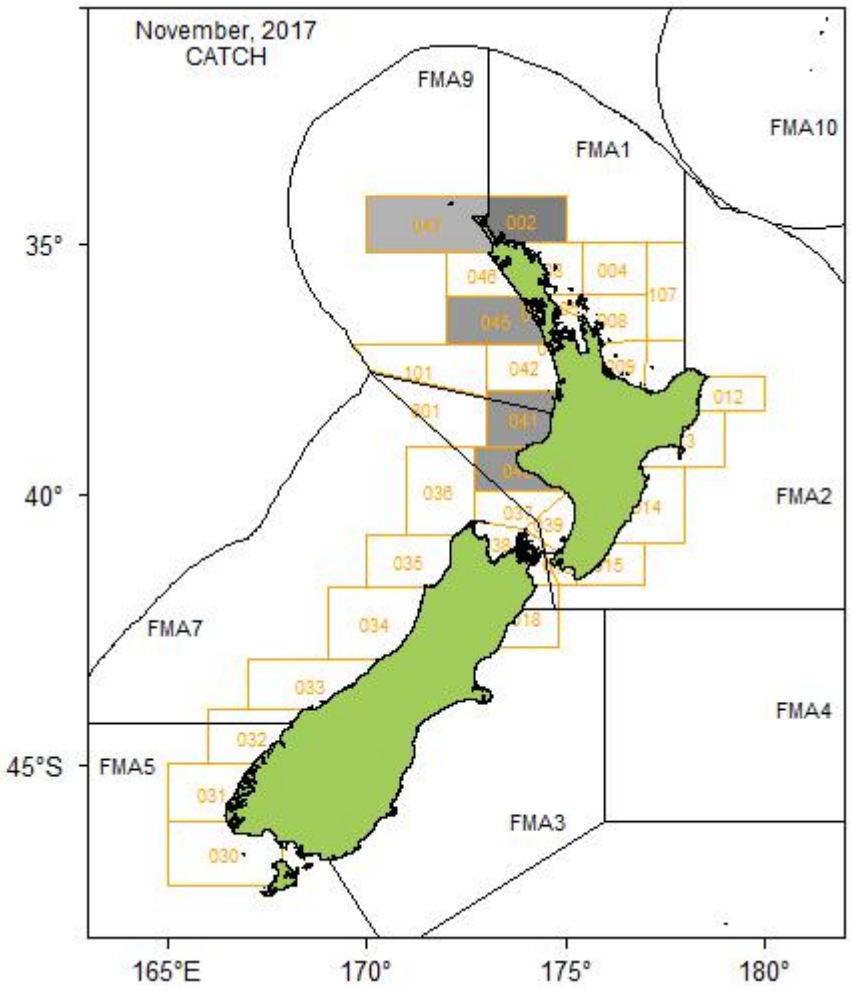




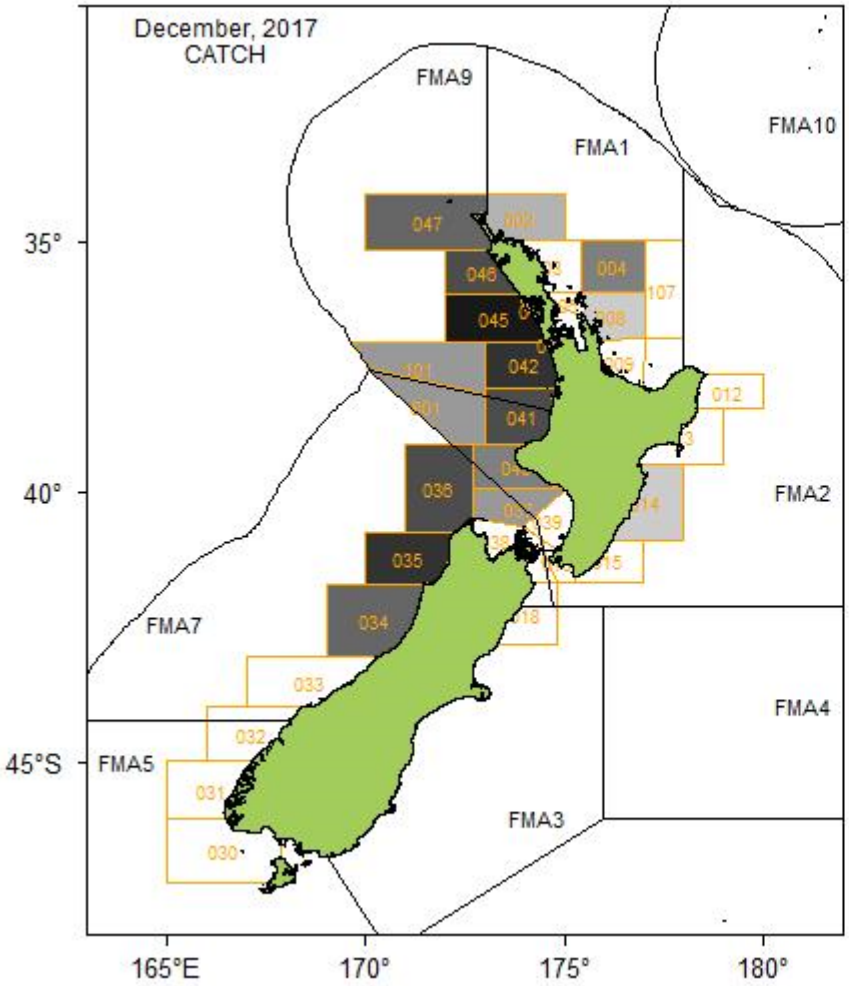
Appendix 3

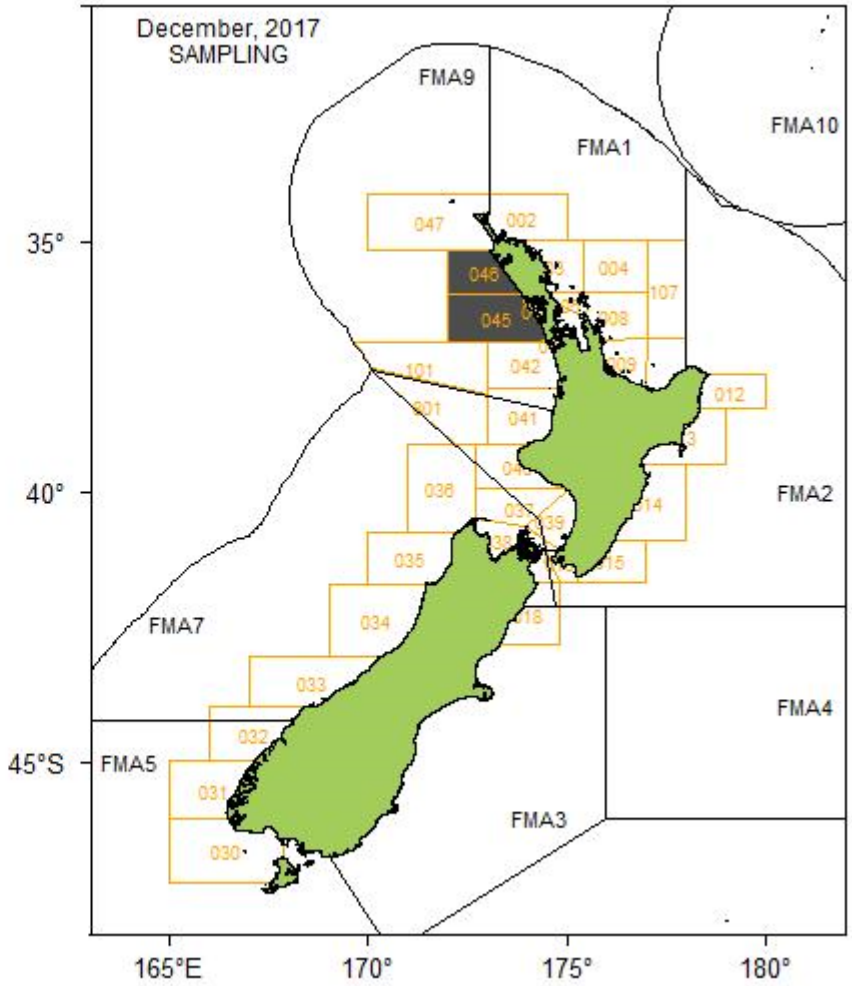
Statistical area density plots of albacore catch, fished (left) and sampled (right) for the 2017−18 year, by month.
A logarithmic density scale was used (i.e. all catch numbers divided by the maximum catch in any one stat area) where 0=white and 1=black.
September and November 2017



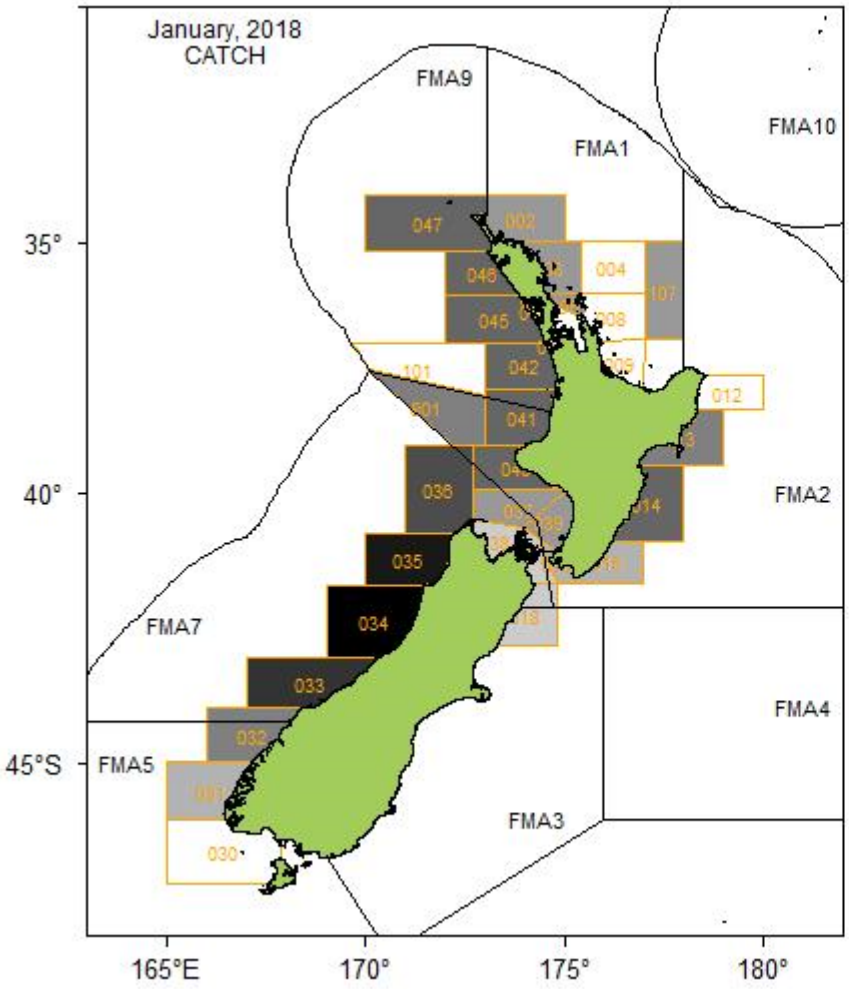


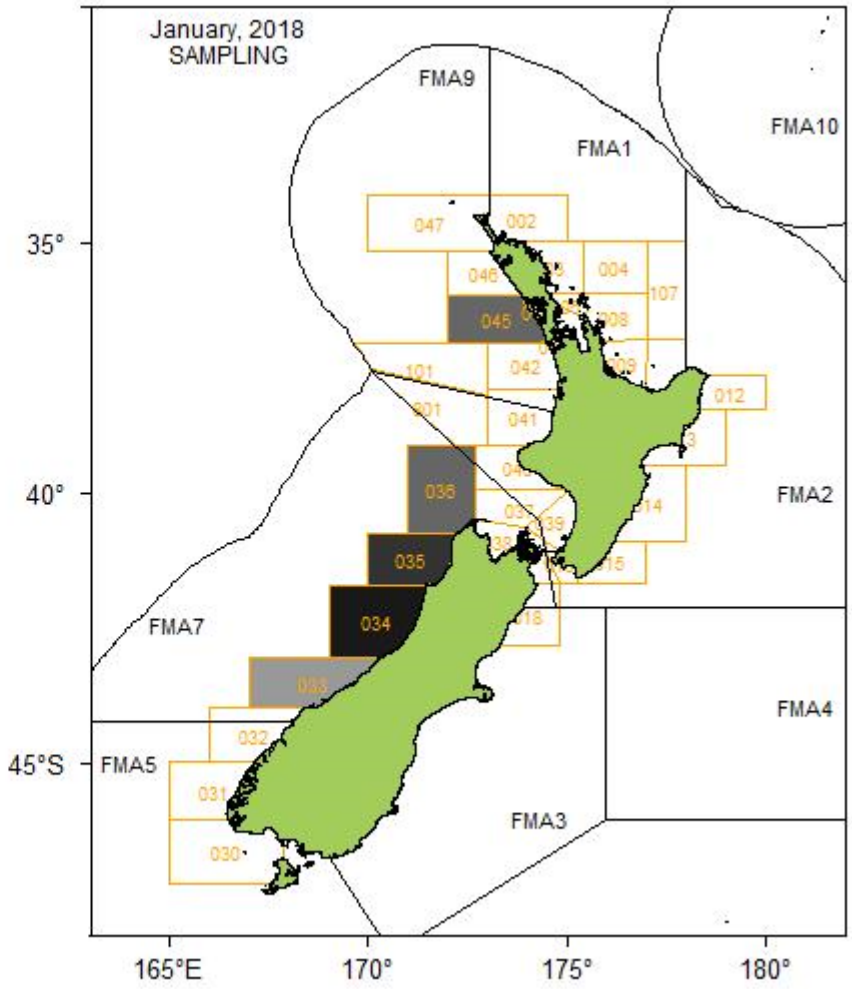
2017−18 *continued*. December 2017



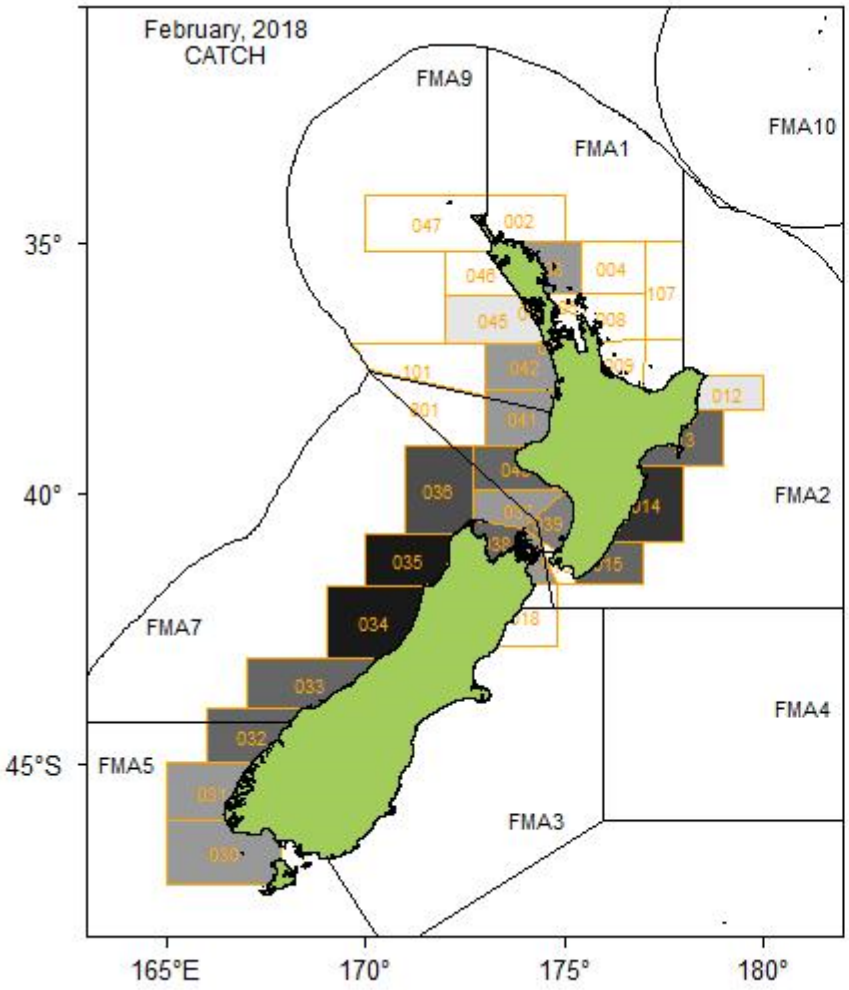


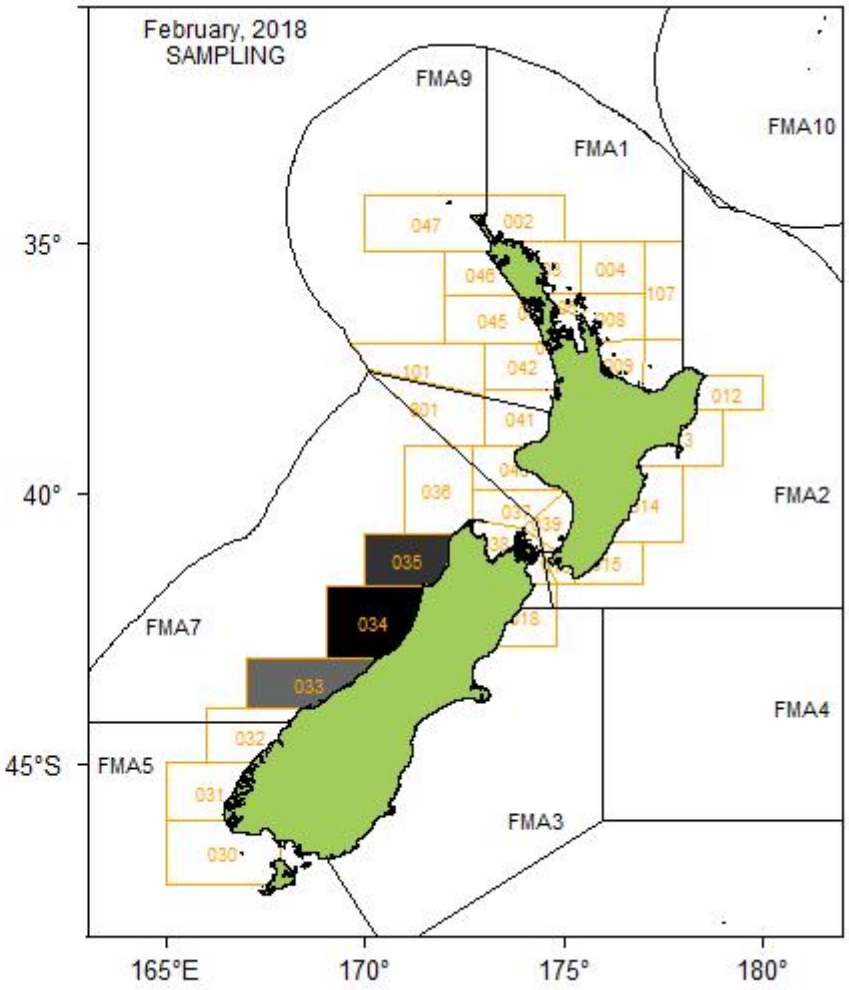
2017−18 *continued*. January 2018



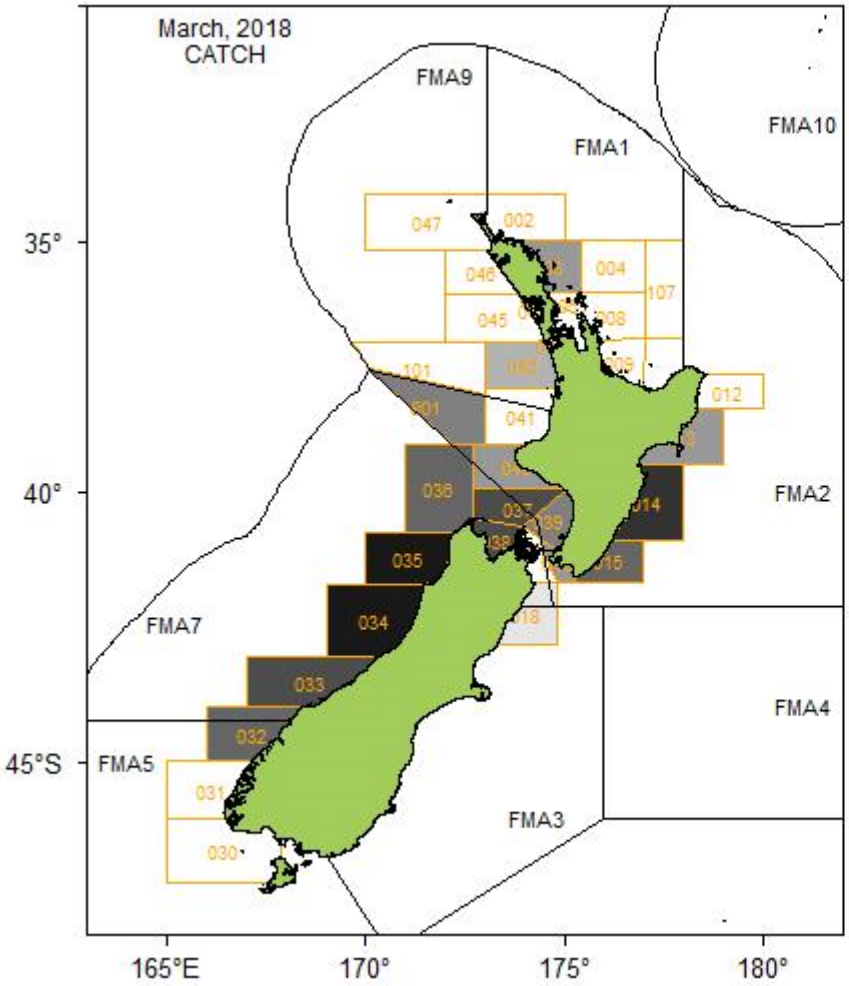


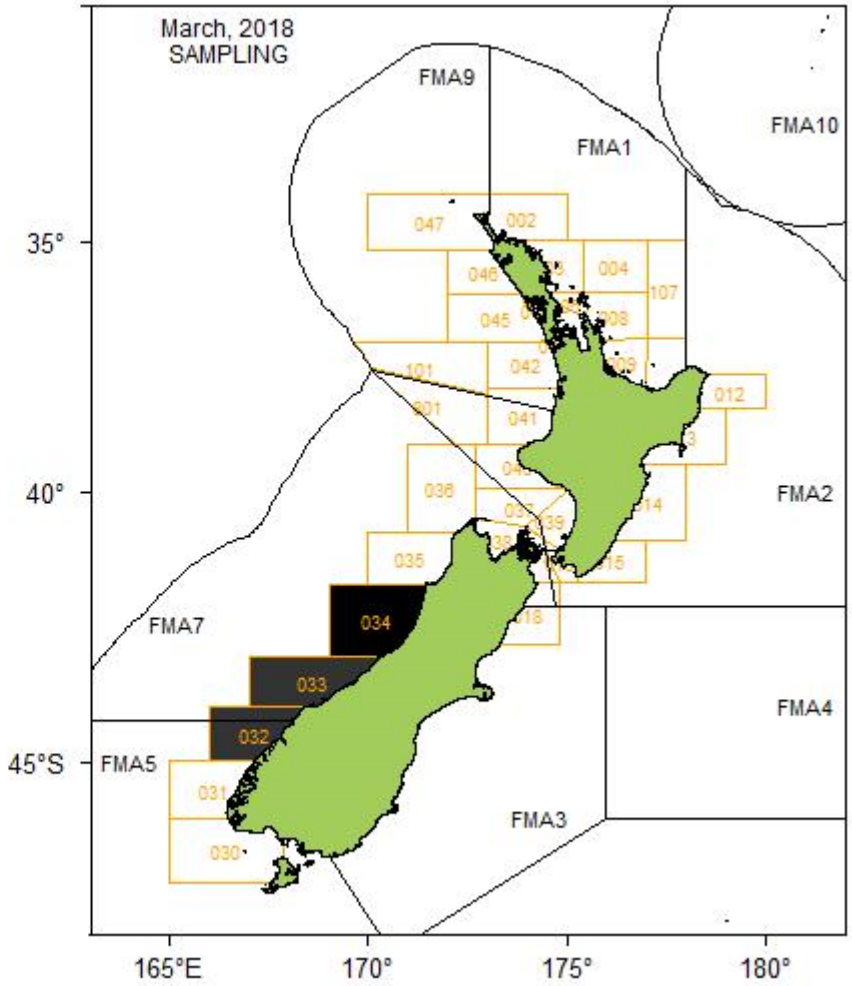
2017−18 *continued*. February 2018



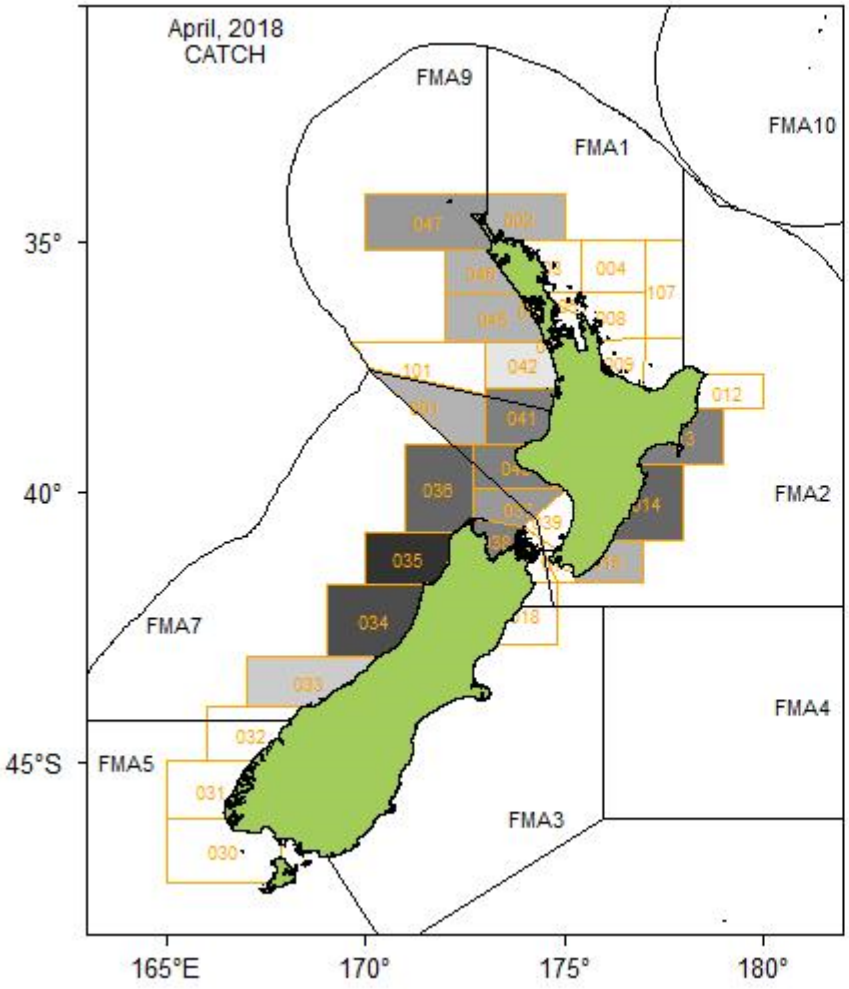


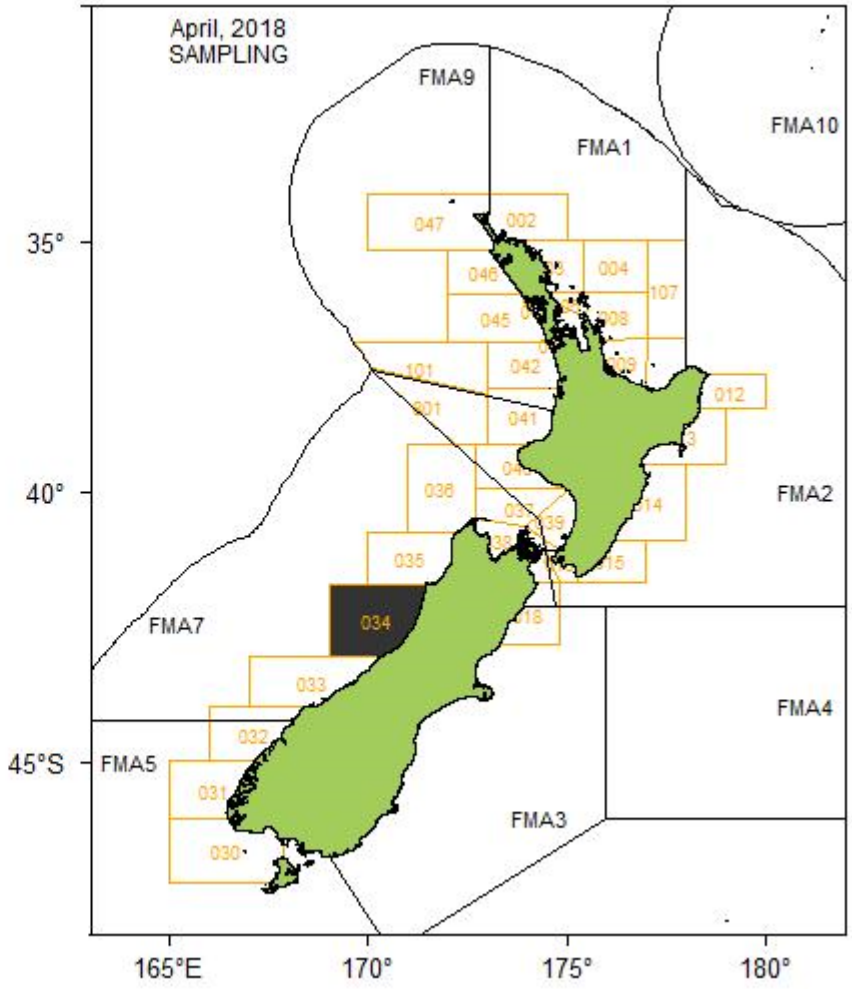
2017−18 *continued*. March 2018





2017−18 *continued*. April 2018





2017−18 *continued*. May 2018